Activity Report 2015

Astronomical Institute / Academy of Sciences of the Czech Republic






BRIEF HISTORY OF THE INSTITUTE

The Astronomical Institute of the Academy of Sciences of the Czech Republic is one of the oldest scientific institutions in the country. It is the direct successor of the Observatory of the Jesuit College which was built in 1722 in the tower of the Clementinum in Prague. Later on, the institution of the "Mathematical Tower", which was in fact the observatory, was established in 1752. At that time meteorological observations began.

Since then the Observatory has undergone a number of changes, many of which have reflected professional, political and even societal reorganization. After Czechoslovakia gained its independence from the Austro-Hungarian Empire, the institute was renamed the "State Astronomical Observatory". In 1940, it was moved as such to an undistinguished apartment building in Vinohrady (Budečská Street) in Prague.

Long before that, in 1898, a private observatory owned by J. J. Frič was built in a small village Ondřejov, located 35 km south-east of Prague. This small observatory was donated to the state of Czechoslovakia, more specifically to Charles University in Prague, in 1928.

The site of the Ondřejov Observatry, at an elevation of 500 m in the relatively unpolluted environs of Prague, proved to be well chosen.

After the Czechoslovak Academy of Sciences was established in 1953, it was merged with the State Astronomical Observatory to create the Astronomical Institute, now belonging to the Academy of Sciences of the Czech Republic. In 1967 the largest Czech optical telescope withthe diameter of two metres was inaugurated in Ondřejov.

At the time of the division of the Federal Czechoslovak Republic into the Czech Republicand Slovak Republic in 1993, the Prague part of the Institute was moved to new premises in Prague-Spořilov. Currently, the Institute participates in ESO and ESA projects, as the Czech Republic became a member state of these organisations in 2007 and 2008, respectively.

Astronomical Institute
of the Czech Academy
of Sciences

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ACTIVITY REPORT
2015

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I

FOREWORD

Vladimír Karas, the Director of the Astronomical Institute.

Astronomical Institute of the Czech Academy of Sciences: history of astronomy from the medieval time keeping to modern scientific research

"*Astronomical Institute of the Czech Academy of Sciences is Public Research Institution engaged in professional scientific research in the fields of astronomy, astrophysics and space sciences, as well as in broad public outreach activities that have been pursued at the site of the Ondřejov observatory as well as in frequent educational events in the capital city of Prague and around the state. Our scientists lead projects and supervise in several doctoral programs that are accredited by Ministry of Education, Youth and Sports of the Czech Republic to teach university students to pursue original exploration in astronomy and astrophysics, theoretical physics, and plasma physics.*

The Institute is among the oldest scientific institutions in the country. It is the direct successor of the Observatory of the Jesuit College, located in the tower of the Clementinum in Prague, where scientific observations started in 1722. Visitors interested in history of science can tour one of the largest European building complexes occupying two hectares near the Charles Bridge. Astronomical Tower offers a beautiful view of the Old Town area just next to Johannes Kepler's house (currently a museum), along with the Baroque Library that still keeps the precious Vyšehrad Codex. In the Meridian Hall time keeping measurements were carried out till 19th century and two wall quadrants and unique instruments remain on display up to date.

Along a parallel line of history, in 1898, a private observatory owned by Josef Jan Frič was founded in Ondřejov village, 35 km southeast of Prague. In 1928 this small observatory was donated to the state and the Prague University, and then gradually expanded to its current state of the largest professional observatory in the country. The two establishments merged in 1953 within the State Astronomical Observatory to create the Astronomical Institute, since then belonging to the Academy of Sciences. Individual visitors and organized groups are welcome to visit the historical site of the Ondřejov observatory." – Vladimír Karas, the Director of the Astronomical Institute

The Institute today

Nowadays, the Institute emerges as a modern public organization involved in a rich set of international projects across Europe and worldwide. On the national level the Institute carries out the major part of research in astronomy and astrophysics in the Czech Republic. During the recent two decades the international collaboration of the Institute has been greatly expanded and it currently represents a significant part of its research activities, including the close cooperation with European Southern Observatory (ESO), European Space Agency (ESA), International Astronomical Union (IAU) and other important bodies where we are full members. The Institute represents the Czech astronomical community in the European professional journal of Astronomy and Astrophysics.

Centuries ago, astronomy was the first of classical sciences that had developed an observational basis to verify and, eventually, falsify our theories about the processes shaping the cosmic bodies and the Universe as a whole. To this end the development of highly sophisticated instrumentation has been crucial, as this allows astronomers to carry out precise observations and quantify and record results. However, along with the empirical approach, equally important has been the tight relationship with mathematics that provides the basis for deeper understanding of the origin and evolution of cosmic systems. Astronomy was the first to develop and employ procedures that are now routinely accepted by other branches of science as well as in engineering and technology.

Modern astronomy

Modern astronomy combines the cutting-edge technology of innovative engineering solutions for highly complex optical systems and space devices with the popular culture and citizen science, where the general public is engaged in research. The Institute contributes actively to all these roles especially through its international involvement in European Southern Observatory and European Space Agency, but also on the national level by cooperating with the Czech Astronomical Society and coordinating the Czech National Committee on Astronomy.

Through the involvement in ESO, the Czech Republic has joined the ambitious project of European Extremely Large Telescope (E-ELT). With a main mirror consisting of almost 800 segments, in total 39 meters across, the instrument will collect almost 15 times more light than any current telescope and it will be able to resolve 17 times sharper images than the Hubble Space Telescope. The shape of the mirror surface has to be extremely precise with roughness less than 10 nanometers. Once the construction of E-ELT is completed, it will have a major impact on our understanding of the Universe, including the most distant objects and the processes shaping the evolution of Cosmos. During all phases – the design, construction, operation, as well as data reduction and interpretation – astronomy requires highly trained professionals with deep knowledge, technical skills, and maximum dedication and enthusiasm.

Students of astronomy are trained in mathematical methods, theoretical and experimental physics, computing and informatics, as well as modern technology. They have to be; otherwise a continuous flood of discoveries would quickly fade away. However, discoveries in astronomy cannot be planned. In fact, nowhere in science any attempt of perfect planning of next steps has ever worked. Instead, serendipity is what defines future directions for those who are prepared to recognize newly emerging opportunities. The discovery of cosmic microwave background radiation is a clear-cut example of an incidental finding which shaped our view of the cosmic history by supporting the hypothesis of the Big Bang.

Understanding how Universe functions and evolves, what is our role in it, what will be the future of stars, of our Sun, and of the Solar System is clearly the main motivation for the endless effort of astronomers. It also motivates new generations to learn and creates an enormous interest of general public. But does the basic research in astronomy provide also some kind of direct benefit the society? In this context the issue of technical innovations and corporate spin-offs has become a fashionable topic of discussions. The Institute oversees the Czech largest involvement in ESA's scientific space mission of Solar Orbiter that has been currently in the intensive construction phase and scheduled for launch in 2018.

Astronomy for every day

Numerous practical applications of the „blue-sky" astronomy research exist and are very well known: Communication methods of today owe a lot to radio astronomy research that had started several decades ago and helped to develop techniques of transmitting, compressing, detecting and decoding weak signals. Besides other applications this laid basis to the modern wire-less technology.

Construction of ever bigger telescopes and ever more sensitive detectors is motivated by an unending hunt for photons from the most distant galaxies, quasars and other faint objects. Clearly this is useful and relevant in numerous other areas of technology development far away from astronomy. Astronomers realized the importance of charge-coupled devices (CCD) for imaging and these detectors are now present in all digital cameras. Likewise, active optics has been greatly improved in recent years in order to achieve amazingly sharp images and removing the degrading effect of atmosphere; the same technique is now employed in other areas of image processing.

X-ray astronomy has been pursued in order to reveal dense compact stars and black holes because the gas becomes enormously accelerated and heated by overwhelming gravitational attraction of these bodies, and so it radiates much of its energy in the form of high-energy radiation, X-rays and gamma-rays. However, the wavelength of this radiation is so short that ordinary telescopes that are suitable for much longer wavelengths of optical light cannot focus it. Astronomers have mastered techniques of X-ray imaging as well as high-dispersion studies of grating spectra. This knowledge is useful in variety of applications ranging from medicine to security.

One could continue endlessly discussing everyday applications of astronomical research. However, the few above-given examples should help us to understand that, indeed, basic research in astronomy creates valuable knowledge and experience.

Motivated by curiosity, fundamental research is equally useful as the search for solutions to specific problems: not only that the basic science provided foundations to all electronics including computers, transportation including rockets and satellites, communication technology including Internet, and so on, but even more importantly it creates deep cultural connections and gives us a broad perspective about Cosmos which surrounds us. Indeed, Heinrich Hertz did not discover electromagnetic waves with the aim of constructing radio; instead, it was the beauty of theoretical physics, which describes electromagnetism in terms of Maxwell's equations, that captivated him. Firm observational evidence in the form of data acquired by ground based telescopes and detectors on-board satellites are essential for the astronomical research, as well as the whole science, as without them the purely speculative research would quickly lose its directions.

At the Astronomical Institute we participate in the effort to reveal fundamental facts about our Universe and its diverse constituents including our Sun and billions of other suns in the Milky Way and distant galaxies, planets and small bodies of the Solar System, as well as enigmatic black holes and neutron stars. We do it because we recognize these topics as immensely important and also because we are confident that our research, like any other high-quality basic research, is equally useful for our society as the search for direct solutions to practical tasks of everyday life.

Participation in international projects

The Institute scientists have continued to collaborate in numerous ongoing international projects that are financed by the Czech Ministry of Education Youth and Sports, Czech Science Foundation, European Union and other bodies and agencies. Recently, two large-scale EU FP7 grants were successfully completed: ASTRONET, to establish a permanent mechanism for planning and coordination of European astronomy, and GLORIA (Global Robotic-telescopes Intelligent Array), to establish an open-access network of robotic telescopes in the world. While the former project reached its goals by formulating and publishing the Infrastructure Roadmap for European astronomy, the latter network clearly demonstrated that astronomy is an inspiring science that can involve many citizens starting from very early age of school children and continuing through high school and university students.

Recently, the Institute scientists have become increasingly involved in the activities of the Ondřejov ESO ARC: Atacama Large Millimiter/submillimeter Array Regional Center – ALMA, the largest ground-based interferometrical observatory located in Chilean desert.

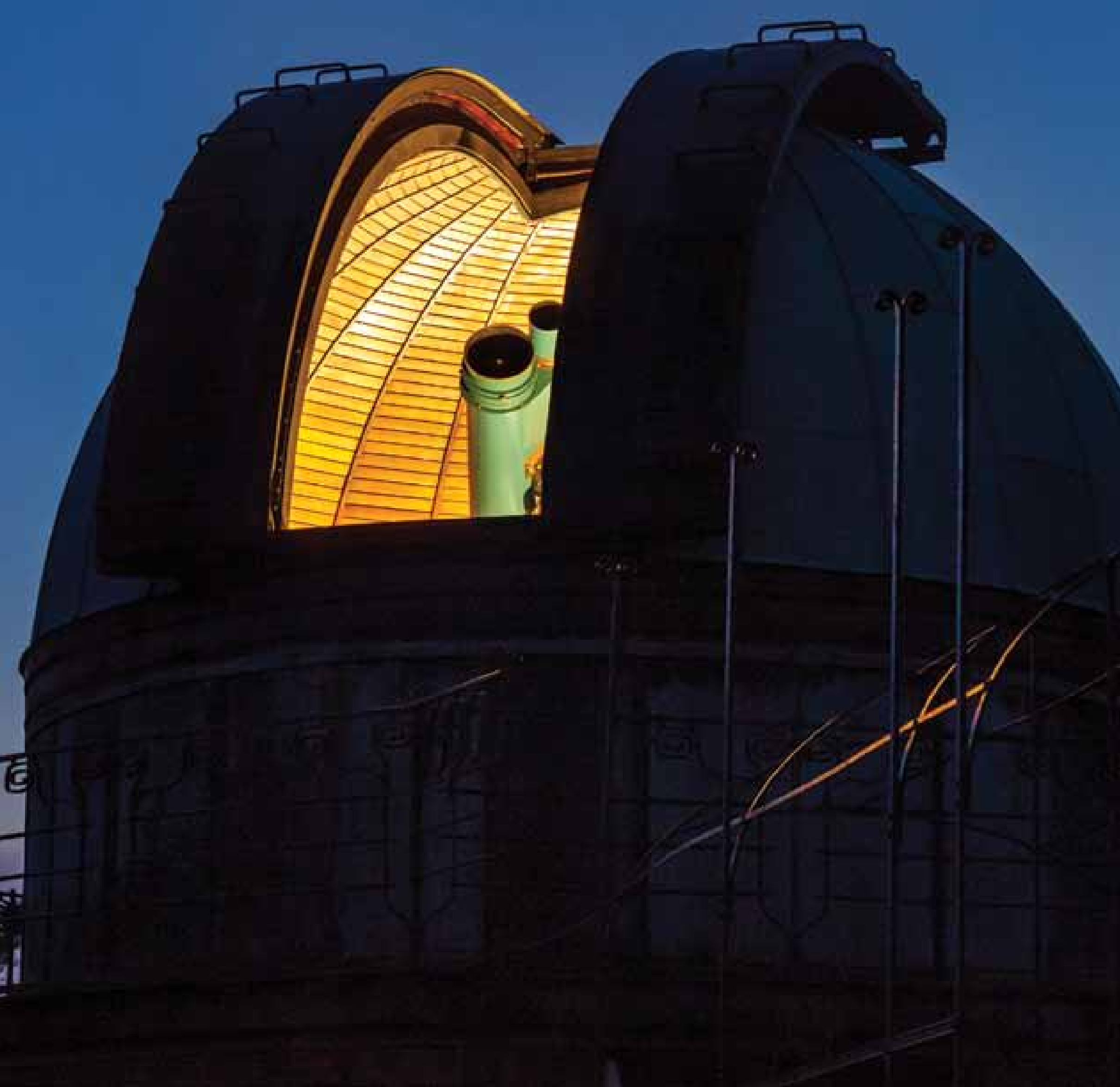
While celebrating its 125th anniversary in 2015, the Czech Academy of Sciences has recently formulated and implemented a visionary New Strategy ´AV21´. Astronomical Institute contributes to this ambitious endeavour in the area of Cosmic Risks (namely, studying near-Earth objects and exploring potentially dangerous asteroids) and Cosmic Weather (impact of Solar activity on life of individuals and the entire civilization of the Earth). We wish to work further toward expanding the astrophysics subjects to include more of our essential research areas, in particular, the technologically demanding Space Exploration, as well as the synergic overlap with astroparticle physics that appears so highly relevant to address fundamental open questions of today.

The headquarters of the Institute – Prague worksite.

CREDIT: BABAK TAFRESHI/ESO

ALMA Observatory in Chilean Atacama Desert.

II
STRUCTURE OF THE INSTITUTE



The research conducted at the Astronomical Institute covers a wide range of topics; from the immediate environment of the Earth to distant galaxies and black holes. The research activities are carried out in four scientific departments divided into working groups.

1. Solar Physics

1.1. Physics of Solar Flares and Prominences (numerical simulations of plasma processes and radiation transfer in flares and prominences, optical and UV spectral diagnostics, X-ray and radio observations)

1.2. Structure and Dynamics of the Solar Atmosphere (quiet and active regions, sunspots, granules and supergranules, interactions between plasma motions and magnetic field)

1.3. Heliosphere and Space Weather (magnetohydrodynamic numerical simulations of propagation and evolution of coronal mass ejections and other transient disturbances, solar activity monitoring and forecasting; image processing)

2. Stellar Physics

2.1. Physics of Hot Stars (theoretical and observational studies of binaries, early-type stars, Be and B[e] stars, white dwarfs, stellar winds, moving envelopes in general, and stellar pulsations)

2.2. Two-meter telescope group (operation, maintenance and development of the largest telescope in the Czech Republic)

2.3. High Energy Astrophysics (celestial X-ray and gamma-ray sources, cataclysmic variable stars, analyses of ground-based and satellite data, X-ray optics)

3. Interplanetary Matter

3.1. Meteor Physics (physical properties, chemical composition and spatial distribution of meteoroids, physical processes during meteoroid penetration into the atmosphere, meteor observations in optical region)

3.2. Asteroids (rotations, shapes, surface and bulk properties of near-Earth objects, binary asteroids, photometry and astrometry of asteroids)

4. Galaxies and Planetary Systems

4.1. Astrophysics of Galaxies (formation of star clusters and evolution of galaxies; comparison of radio, infrared, optical, and X-ray observations with analytical models and computer simulations of gravitational and hydrodynamic processes, kinematics and physical properties of AGN host galaxies)

4.2. Relativistic Astrophysics (active galactic nuclei and galactic black hole candidates; analysis, within the framework of general relativity, of high-energy X-rays; comparison with observations)

4.3. Planetary Systems (Earth rotation; Earth gravity field; resonances and dynamics of the asteroids, Kuiper belt and exoplanetary systems; creation of an astrometric star catalogue, motion of artificial satellites under the influence of gravitational and non-gravitational forces)

More details about the activities and recent results of the working groups are given in Chapter IV., the structure of the Institute is shown in Fig. 1.

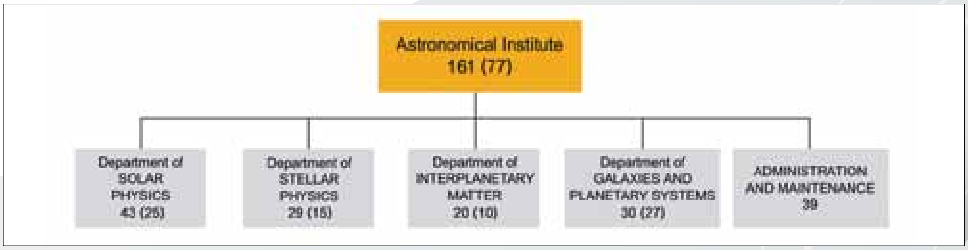


Fig. 1 – The structure of the Astronomical Institute of the Academy of Sciences of the Czech Republic. The total numbers of staff members in the Institute and in the departments are shown. Numbers of scientists are given in parentheses. Valid for the end of 2015.

Executive Staff, Contact Addresses

Director:
Prof. Vladimír Karas, DrSc / phone: (+420) 323 620 113 /
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Executive staff (2015). From left to right: D. Pivová, P. Spurný, M. Šlechta, J. Borovička, V. Karas, J. Palouš, P. Heinzel, M. Sobotka.

Council of the Institution

"Starting from 2007, Astronomical Institute, like the other institutes of the Academy of Sciences, gained new legal status of the so called public research institution. According to the law, the Council of the Institute, consisting from 5 internal and 4 external members, was elected at the beginning of 2012 for a period of 5 years. The Council organized a competition for the position of director of the institute. Other tasks of the Council include the determination of the main directions of research, approval of the budget

The Technical Assistance Section. From left: J. Nováková, J. Šticha, P. Navrátil, P. Ešner, S. Hauzar, J. Voláková, J. Schindler, V. Zámyslická and P. Vodrhánková.

The Personnel and Accounting Section. From left: J. Štichová, H. Hanušková, M. Chytrová, R. Plaček, Z. Ambrožová, I. Smolíková, J. Bečková, V. Kocourek, H. Kalibová and J. Kašpárek.

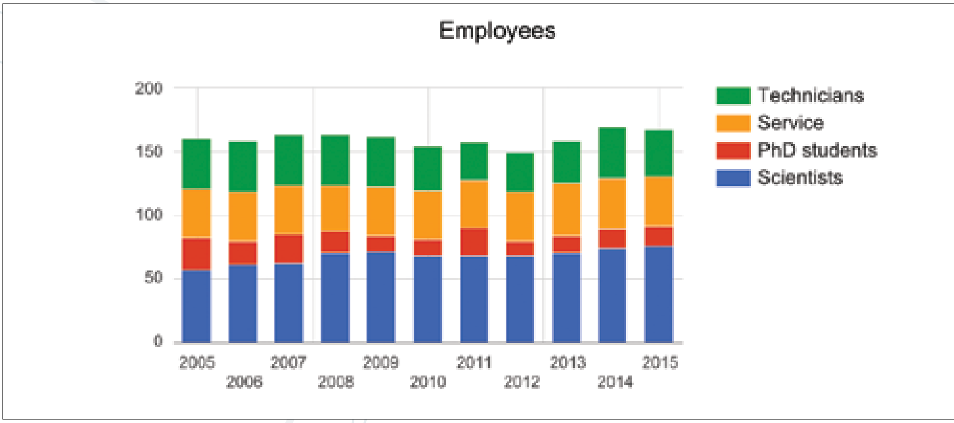


Fig. 4. Number of employees at the Institute since 2005 (some having part time-position).

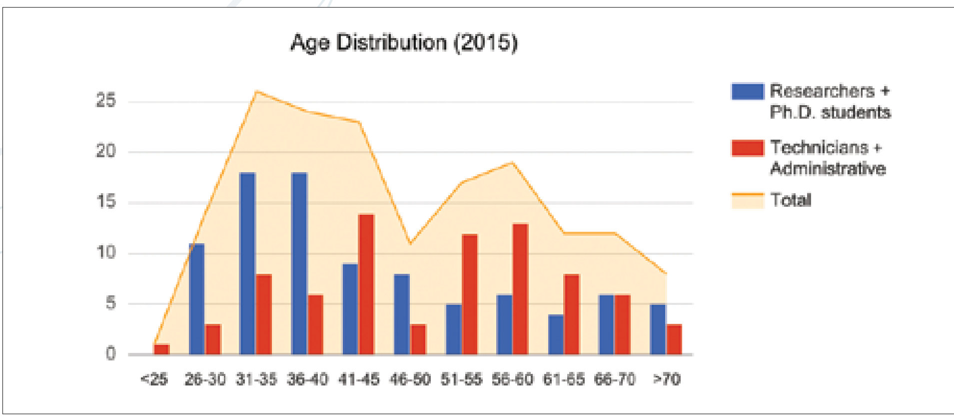


Fig. 5. Age distribution of all the employees and of those engaged in astronomical research.

of the institute, definition of internal rules, and approval of agreements between the institute and other organizations." – Jiří Borovička, chairman of the Council.

Personnel of the Council: J. Borovička – Chairman, B. Jungwiert – Vice-Chairman, P. Suchan – Secretary; M. Bárta, M. Bursa, P. Heinzel, D. Heyrovský (Charles University, Prague), V. Karas, M. Karlický, E. Marková (Czech Astronomical Society), M. Prouza (Institute of the Physics of the Academy of Sciences), L. Šubr (Charles University, Prague).

Infrastructure, Personnel and Funding

The Ondřejov Observatory represents a research campus with its own facilities such as a cafeteria, apartment houses etc. Housing for visitors is also available. The Prague part resides in a building at a campus together with two other institutes of the Academy of Sciences. Most of the Department of Galaxies and Planetary Systems reside in Prague.

The work of the scientific departments is supported by the library (Head librarian R. Svašková), computer-system and network manager (P. Ryšavý), mechanical workshop (J. Zeman), and administration and maintenance (R. Plaček). The administration and maintenance includes a finance section (Z. Ambrožová), personnel section (J. Štichová), accounting section (M. Chytrová), operations and supplies (H. Kalibová), maintenance (P. Ešner) and cafete-

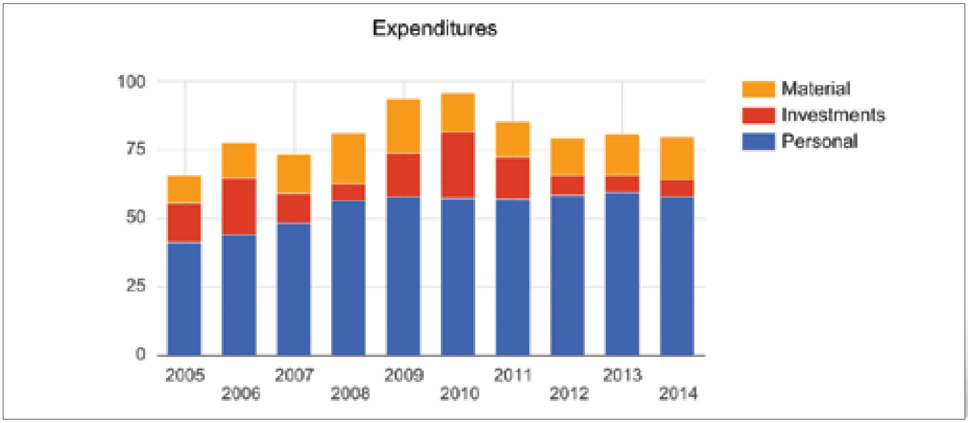
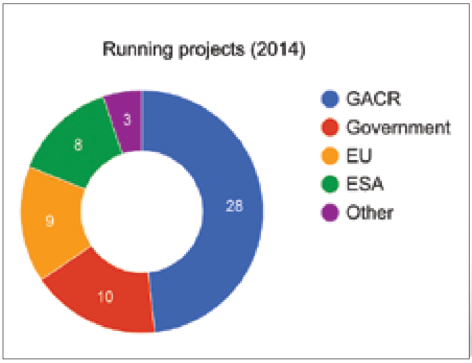


Fig. 6. Expenditures of the Institute since 2000 (in millions of Czech Crowns). Grants are not included.



The distribution of running projects in various international institutes in 2014.

ria (V. Zámyslická). The results of the work are popularized by public relation office (P. Suchan).

The total number of employees was 161 at the end of 2015, 41 of them were part-time employees. The number of scientists was 77 and there were 10 PhD students. The trend of the number of employees since 2005 is shown in Fig. 4. The age distribution is double-peaked, with one maximum around the age of 35 years (young scientists after the graduation and first PhD experience), the second peak is around 60 years (experienced scientists), which more or less reflects the age distribution of the Czech population.

Most of the Institute's funding comes from the Academy of Sciences. The amount of funding depends on the parliament-approved budget for the Academy of Sciences as well as on the regular international evaluation of the Institute organized by the Academy. Other sources of funding are grant agencies, ministries and other organizations supporting particular projects, including international ones. The expenditures since 2005 are shown in Fig. 6.

Mechanical Workshop

Head of the group: J. Zeman,
e-mail: jzeman@asu.cas.cz
Staff: J. Chytra, P. Vávra, V. Danda
Phone: (+420) 323 620 331

"Soon after the commencement of scientific activities at Ondřejov observatory, at the beginning of the 20th century, a mechanical workshop capable of providing basic development and repair of smaller instruments and equipment was established right in the grounds of the observatory." – Jiří Zeman, Head of the group.

The need to improve the working conditions and to increase the capacity of the workshop due to involvement in the construction of the 2-metre (now called „the Perek") telescope in the late 1950s and early 60' led to an enhancement of machining facilities, increase of the number of staff and the building of a new workshop where the DMW resides now.

In the past, staff of the workshop played a part in construction and manufacture of instruments not only for the scientific departments of the institute but also for observation sites abroad, for example on the island of Hvar in Croatia.

The group of Mechanical Workshop. From left: J. Chytra, J. Zeman (head), V. Danda, P. Vávra.

Currently, the DMW provides maintenance and repair of instruments at the institute. It is also involved in programs of scientific departments, participating in the development and manufacture of equipment for modern science. For example, the DMW colaborates with the Department of Interplanetary Matter on modernisation, expansion and digitalization of the Bolide Network, with the Solar Department on development of an experimental, fully robotic, solar telescope and with the Stellar Department on building of an Echelle spectrograph.

Library and Publishing

Head librarian – R. Svašková,

e-mail: bibl@asu.cas.cz

Staff: N. Karlická, e-mail: nada@asu.cas.cz; K. Soldánová, e-mail: katka@asu.cas.cz

Phone: (+420) 323 620 326

“The library’s main function consists in providing information resources and making them

The Library staff. From left: N. Karlická, R. Svašková, K. Soldánová.

available to all employees of the Institution and users from other organisations. The library also serves as a center providing information about astronomical and astrophysical literature for the entire Czech Republic." – Radka Svašková, Head Librarian.

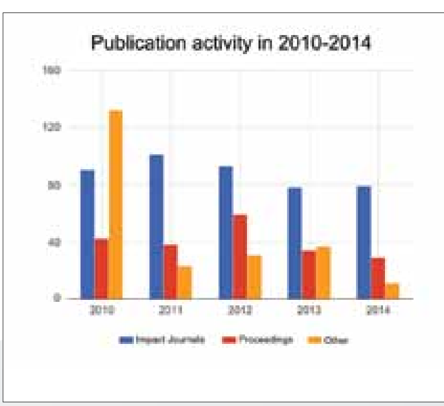
The history of the library goes back to the 18th century, books from this period are stored in a separate stock and are not only well preserved, but also benefit from a special care. The library's historical section contains 253 titles carefully described in a catalogue published in Scripta Astronomica No. 1. (1986) and No. 6. (1994). Twenty-two of the most endangered books from this section have already been completely restored. Total amount includes 82 600 items, including 15 000 books and 67 000 journal items (many of them are available in an unbroken line from the first volume).

Scientific literature is in the largest part represented by periodicals; the library has complete series of many fundamental astronomical journals. Some of these journals date since their first edition volumes and are now available online thanks to the Astronomical Institute's membeship of the National Consortium of Springer and Elsevier publishing houses.

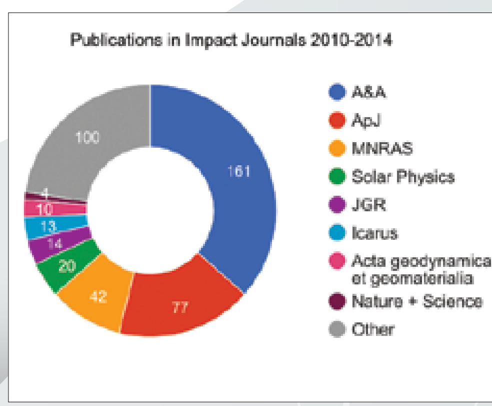
The library's monographs are located in a separate building that has been partly renovated in 2006 offering modern technical equipment and a comfortable and calm enviroment for studying. All users can access books catalogued in the world reknowned software Aleph compatible with the entire Academy.

Detailed information about services and facilities offered by the library is available on the website: istar.asu.cas.cz. The library accepts any request from its clients and obtains the requested articles and documents. In most cases the documents are not the originals, but copied or scanned versions.

The library also keeps connections with many other Astronomical Observatories all over the world and distributes all documents published by the Institute to 249 different locations as part of an international exchange. The Institute had been publishing the so called Bulletin of the Astronomical Institutes of Czechoslovakia until 1992 when this Bulletin became part of an European Journal: Astronomy and Astrophysics. This membership and participation now allows Czech researchers to publish their results in a top-level scientific journal with a high impact factor. Besides this journal, the Astronomical Institute published other non-periodical series such as Publications of the Astronomical Institute and the Scripta Astronomica.

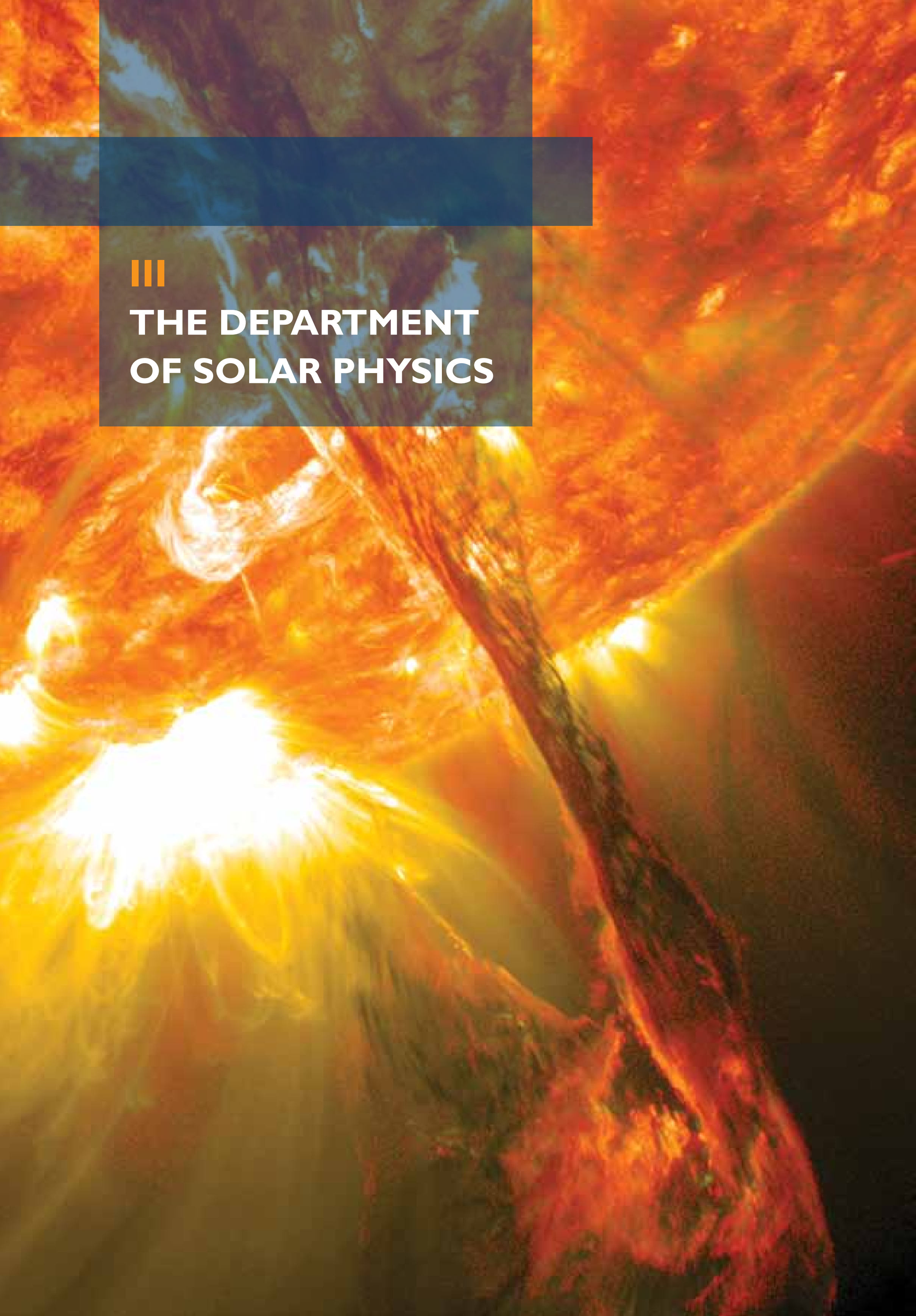


Number of Institute's publications over past four years.



Number of scientific papers published in different journals over past four years.

III
THE DEPARTMENT OF SOLAR PHYSICS



Head scientist – M. Sobotka. Deputy – M. Bárta.
Secretary: A. Chytrová,
Phone: (+420) 323 620 146,
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"The research of the Department of Solar Physics is focused to our nearest star, the Sun, particularly the active phenomena in the solar atmosphere. This includes solar flares as well as accompanying heliospheric effects, structure and evolution of solar active regions, prominences, sunspots, and the physics of solar corona and transition region. The research of the Solar Department can be characterized as a combination of solar observations in optical, radio, UV, and X-ray wavebands, analysis and interpretations of data, and theoretical research with extensive numerical modeling of the processes under study. The Department operates several instruments at the Ondřejov observatory – the solar patrol, the horizontal solar telescope with spectrograph HSFA2, three solar radio telescopes, and the robotic solar telescope SORT, which is under development. The Department is involved as a participant in two large international ground-based infrastructures – ALMA and GREGOR. The Department has three active working groups producing results with national and international impact." – Michal Sobotka, head of the Department of Solar Physics.

Physics of Solar Flares and Prominences working group

"The main results of this group concern the radiative transfer diagnostics of the solar atmosphere, flares and prominences, studies of magnetic reconnection and particle acceleration in solar flares, and the physics of solar corona and transition region. The members of the group are also engaged in space research activities and the ALMA Czech ARC node. The group is located in Ondřejov." – Marian Karlický, head of the group.

Personnel

The working group was headed by M. Karlický until November 2014, then by E. Dzifčáková. Research fellows: M. Bárta, A. Berlicki, B. Dabrowski, J. Dudík, E. Dzifčáková, F. Fárník, S. Gunár, P. Heinzel, M. Karlický, J. Kašparová, P. Kotrč, H. Meszárosová, D. Nickeler, P. Schwartz, J. Štěpán, A. Zemanová, W. Liu, and there have been several PhD students.

The Department of Solar Physics. From left: V. Snížek, P. Ambrož, K. Jiřička, P. Kotrč, D. Nickeler, H. Meszárosová, M. Karlický, A. Zemanová, J. Dudík, E. Dzifčáková, J. Leško, A. Chytrová, M. Klvaňa, J. Skála, P. Jelínek, M. Švanda, J. Štěpán, P. Heinzel, A. Berlicki, J. Jurčák, M. Sobotka.

Physics of Solar Flares and Prominences group. From left to right: V. Snížek, A. Berlicki, J. Leško, P. Kotrč, A. Zemanová, J. Dudík, E. Dzifčáková, D. Nickeler, H. Meszárosová, J. Skála, M. Karlický, P. Jelínek, K. Jiřička, P. Heinzel, and J. Štěpán.

Research results

Solar flares represent the most violent processes on the Sun, with great impact on the heliosphere and our planet. Total power of individual flares can be determined by detecting their continuum radiation and this was recently highlighted by the discovery of superflares on Sun-like stars. Heinzel & Avrett (2012, Solar Phys. 277, 31) made a review of the current knowledge about the most relevant optical continua and a prediction of the continuum emission of flares in mm/sub-mm radio domain, now covered by the ALMA interferometer.

Alfvén velocity and plasma beta are important parameters for modeling eruptive events, but they are difficult to obtain. Kotrč et al. (2013, Solar Phys. 284, 447) have shown a possible method to estimate these parameters through a comparison of observed and synthetic profiles of hydrogen lines. Along with other observables, the results indicate that the observed case of limb eruptive event is actually the initiation phase of a prominence eruption (Fig. 1).

The level of continuum emission from solar flares is directly related to the power of flares. Brightest emission is expected from the Balmer continuum, which is the hydrogen recombination continuum. In the study by Heinzel & Kle-

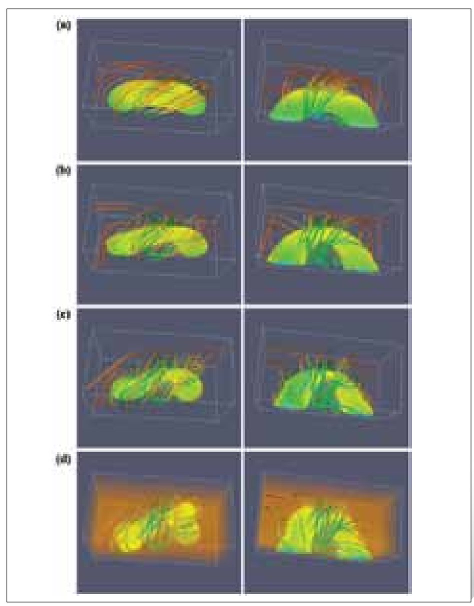


Fig. 1 – MHD model of the initial phase of a flux rope eruption. Colored lines represent magnetic field lines; the colors correspond to the local value of |B| (lower to higher values being coded from red to blue). The background color scale represents plasma density. Frames (a) – (d) were taken at different times. Top and side views are shown for each time.

int (2014, Astrophysical Journal 794, L23), the Balmer continuum was clearly detected for the first time from space, using the ultraviolet telescope and spectrograph IRIS (NASA). The result represents an important breakthrough in the flare physics with potential implications for space-weather studies.

Processes of magnetic reconnection and particle acceleration in flares were studied extensively, using numerical simulations as well as observations. Strong and localized electric currents and vortex flows, so called current-vortex sheets, are necessary to excite solar eruptions (flares and coronal mass ejections). A spontaneous current fragmentation caused by shear/vortex plasma flows was studied by Nickeler et al. (2013, Astronomy & Astrophysics 556, A61). It was found that strong current sheets imply strong vortex sheets and vice versa. The investigation of such current-vortex sheets is important to understand how solar eruptions are triggered by such fragmented sheets and how the solar atmosphere is heated. Nickeler et al. (2014, Astronomy & Astrophysics 569, A44) also studied the influence of a magnetic shear applied perpendicular to solar magnetic arcade structures, resulting in a formation of strongly filamented current sheets. The generated electric field parallel to the magnetic field is suitable to accelerate particles along the field lines and to heat the solar coronal plasma. The gained energies of the particles are comparable to observed values, emphasizing the importance of shear flows for particle acceleration in the solar corona. This work is an important new approach concerning the self-consistent connection between particle acceleration and MHD flows.

Intense beams of high energy particles generated in the corona are according to the standard flare model believed to transport the energy in flares downwards to the chromosphere. Varady et al. (2014, Astronomy & Astrophysics 563, A61) suggested alternative scenarios, where the non-thermal particles are re-accelerated during their transport from the coronal acceleration site to the thick-target region in the chromosphere. The important conclusion is that the re-acceleration of non-thermal electrons during their transport allows to reduce the demands on the efficiency of the primary coronal accelerator, on the electron fluxes transported from the corona downwards, and on the total number of accelerated coronal electrons during flares.

Karlický (2014, Research in Astronomy and Astrophysics 14, 753) summarizes new trends in studies of magnetic reconnection in solar flares. This review shows that plasmoids play a very important role in this primary flare process. Using the results of magnetohydrodynamic and particle-in-cell simulations, it is possible to describe how the plasmoids are formed, how they move and interact, and how a flare current sheet is fragmented into a cascade of plasmoids. Furthermore, it is shown that during the interactions of these plasmoids electrons are not only very efficiently accelerated and heated, but electromagnetic (radio) emission is also produced. Possible mechanisms for the triggering of magnetic reconnection are also explained. The relevant X-ray and radio signatures of these processes are then described and supporting EUV and white-light observations of plasmoids are added. The significance of all these processes for the fast magnetic reconnection and electron acceleration is outlined and their role in fusion experiments is briefly mentioned.

Radiative transfer methods are generally used to obtain physical parameters of solar atmosphere from spectral observations. The interpretation of linear and circular polarization of spectral lines is the only way to decipher the magnetization of the Sun and stars. Many spectral lines are formed under a very complicated physical conditions that require self-consistent calculation of the radiative transfer problem. A massively parallel 3D code PORTA was developed by Štěpán et al. (2013, Astronomy & Astrophysics 557, A143), making it possible to perform such calculations in full 3D space, with multilevel atoms, and taking into account the relevant

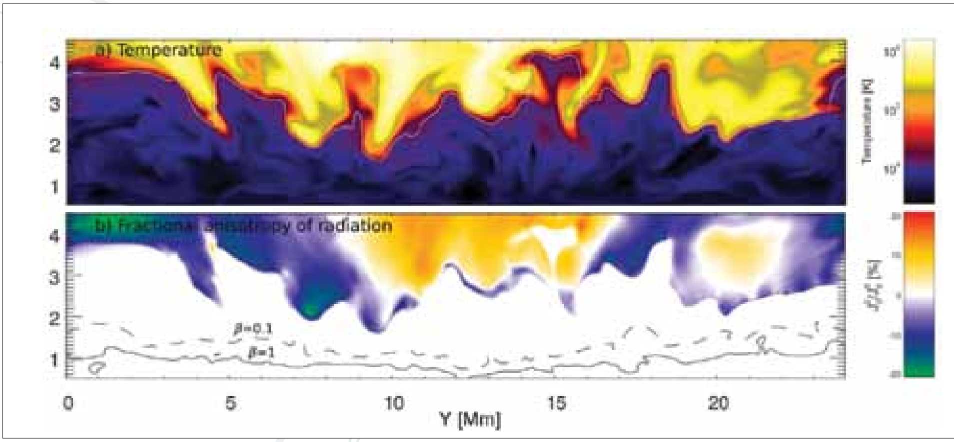


Fig. 2 – Example of three-dimensional radiative transfer calculation using the PORTA code. Upper panel shows the variation of plasma temperature in a vertical slice of the 3D MHD model atmosphere. The transition region appears in the red color, the corona in yellow, and the chromosphere in blue. Bottom panel shows the anisotropy of radiation in the core of the Lyman-alpha line.

physical ingredients of the polarized line formation (Fig. 2).

Fine structures of solar prominences were modelled by employing innovative combination of the magnetic field simulations, realistic prominence plasma description, and the multi-dimensional non-LTE radiative transfer modelling. Gunár et al. (2013, Astronomy & Astrophysics 551, A3) developed a unique iterative method for filling of the non-linear force-free field magnetic dips with hydrostatic prominence plasma that produces realistic 3D distributions of the prominence fine structure plasma. Gunár et al. (2014, Astronomy & Astrophysics 567, A123) used a complex 3D prominence magnetic field simulations and the multi-dimensional prominence fine structure and radiative transfer modelling to perform a detailed analysis of the June 22, 2010 prominence that has been extensively observed by multiple space-born and ground-based observatories.

Ellerman bombs are small-scale bright structures observed in the lower atmosphere. They play an important role in the chromospheric heating. Non-LTE radiative transfer models of Ellerman bombs were constructed by Berlicki & Heinzel (2014, Astronomy & Astrophysics 5567, A110) using simultaneously two spectral lines – Hα and Ca II H. They could be described by a "hot-spot" model, located close to the temperature minimum, with the temperature and/or density increase through a few hundred kilometers within the solar atmosphere.

The solar corona and transition region are outer parts of the solar atmosphere, where magnetic fields dominate the structure and motions of plasma, which is far from thermal equilibrium. The temperature rises by 2–4 orders of magnitude and mechanisms of this heating are not yet completely known. Dudík, Dzifčáková & Cirtain (2014, Astrophysical Journal 796, 20) calculated the 3D distribution of the area expansion factors in a potential magnetic field, extrapolated from the high-resolution Hinode/SOT magnetogram of the quiescent active region NOAA 11482. Loop-like structures characterized by locally lower values of the expansion factor are embedded in a smooth background. These loop-like flux tubes have squashed cross-sections and expand with height. The distribution of the expansion factors show an overall increase with height, allowing an active region core characterized by low values of the expansion factor to be distinguished. They argue that the structuring of the expansion factor can be a significant ingredient in producing the observed structuring of the solar corona.

The magnetically dominated plasma of the solar corona is an elastic and compressible medium, which can support propagation of various types of waves that are investigated in the context of coronal heating. Meszárosová et al. (2013, Solar Phys. 283, 473 pp.) have shown that fast magnetoacoustic waves can propagate also in a fan structure of magnetic field lines above the coronal magnetic null point. They estimated plasma parameters in observed radio sources and found them to be consistent with a presented scenario involving a magnetic null point. Further, 2D magnetohydrodynamic simulations were made (Meszárosová et al. 2014, Astrophysical Journal 788, 44 pp.), showing how propagating magnetoacoustic waves reflect basic physical parameters of their waveguides. Possibilities of detection of these waves in observations were studied.

A unique explanation of intriguing zebra patterns (Fig. 3) observed in radio emission of quite distinct astronomical objects, Sun and pulsars, was presented by Karlický (2013, Astronomy & Astrophysics 552, A90). It was shown that the waves with density variations modulate the radio continua generated by the plasma emission mechanism. Considering single magnetoacoustic waves in both the radio sources, solar zebra patterns as well as the zebras observed in the radio spectra of the Crab Nebula pulsar were successively modelled.

In the corona, the energy distribution of particles is far from the thermal (Maxwellian) one. The non-Maxwellian κ-distributions with an enhanced number of particles in the high-energy tail have been detected in the solar transition region and the solar wind and they can be present also in the corona. Dzifčáková & Dudík (2013, Astrophysical Journal Supplement 206, 9) used new atomic data for the calculation of ionization and recombination rates for the non-Maxwellian κ-distributions. The non-thermal rates allowed them to derive the ionization equilibria for the different κ-distributions and elements from H to Zn. The κ-distributions significantly influence both the ionization and recombination rates. They also widen and shift the ion abundance peaks. The updated ionization equilibrium calculations result in large changes for several ions, notably Fe VIII – Fe XIV. The results are compatible with the CHIANTI database.

Mackovjak, Dzifčáková & Dudík (2013, Astronomy & Astrophysics, 564, 130) investigated the influence of κ-distributions on the temperature structure of plasma represented by differential emission measure (DEM). They found that the DEM depends on the shape of the electron distribution. The DEMs of the active region cores show similar behavior with an increasing departure from the Maxwellian distribution, DEM peaks are typically shifted to higher temperatures and their shapes become more concave. The behavior of the quiet-Sun DEM distribution is different. It becomes progressively less multithermal with an indication of near-isothermal plasma for strongly non-Maxwellian distributions.

The members of the working group collaborate with research institutes in Brazil, France,

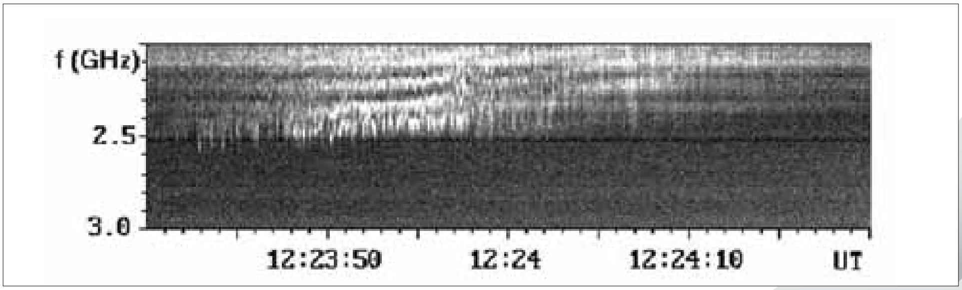


Fig. 3 – Zebra pattern observed during the 18 March 2003 event by the Ondřejov radio spectrograph.

Fig. 4 – Horizontal solar telescope with multi-channel slit spectrograph (HSFA2).

Structure and Dynamics of the Solar Atmosphere group. From left to right: M. Klvaňa, J. Jurčák, M. Sobotka, M. Švanda, P. Ambrož, and A. Chytrová.

Great Britain, Germany, Poland, Russia, Slovakia, Switzerland, and USA. The working group operates several ground-based solar telescopes at the Ondřejov Observatory:

HSFA2: The 0.5-m horizontal solar telescope (Fig. 4) equipped with a large multichannel slit spectrograph is used mostly for observations of flares and prominences in five spectral regions simultaneously: Ca II H, Hβ, Na I D and He I D3, Hα, and Ca II 854.2 nm, together with Hα slit-jaw images. At present, HSFA2 is fully computer-controlled and provides data on fast processes in solar flares and prominences (http://www.asu.cas.cz/~sos/). It is often utilized in coordinated campaigns with other European space and ground-based instruments. A new experiment for measurement of Balmer continuum changes in solar flares was installed at HSFA2 focal plane. Results based on the first successful observation were presented at the FLARES conference at Prague in 2014 and submitted for publication.

Radio telescopes: The radio flux and spectra of the Sun are observed daily with three instruments: a single-frequency 3 GHz receiver (RT3, 3-m dish), a 2.0–4.5 GHz radio spectrograph (RT4, 3-m dish), and a 0.8–2.0 GHz radio spectrograph (RT5, 10-m dish). Chosen time intervals with radio events are processed and archived – see http://www.asu.cas.cz/~radio/.

SORT: The 0.28-m solar robotic telescope was finished in 2015. It will provide a high-cadence detailed imaging of the solar chromosphere, particularly flares, in the Ca II H and Hα bands.

Structure and Dynamics of the Solar Atmosphere working group

"The main results of this group concern the physics of sunspots, particularly the penumbra, solar pores, small-scale magnetic structures, and the sub-photospheric convection. The members of the group are also engaged in ground-based instrumentation. The group is located in Ondřejov." – Michal Sobotka, head of the group.

Personnel:

The working group is headed by M. Sobotka. Research fellows: P. Ambrož, J. Jurčák, M. Klvaňa, M. Sobotka, and M. Švanda.

Research results:

Orphan penumbrae (Fig. 5) are structures visually resembling sunspot penumbrae, but are not connected to any umbra. The nature of strong gas flows that are observed in both types of penumbrae was studied by Jurčák et al. (2014, Astronomy & Astrophysics 564, A91). A simple magnetic field configuration of orphan penumbra allows to speculate that the fast flows are caused by the siphon flow mechanism. Based on the similarities between orphan and regular penumbrae, it was proposed that the Evershed flow is also a manifestation of the siphon flow.

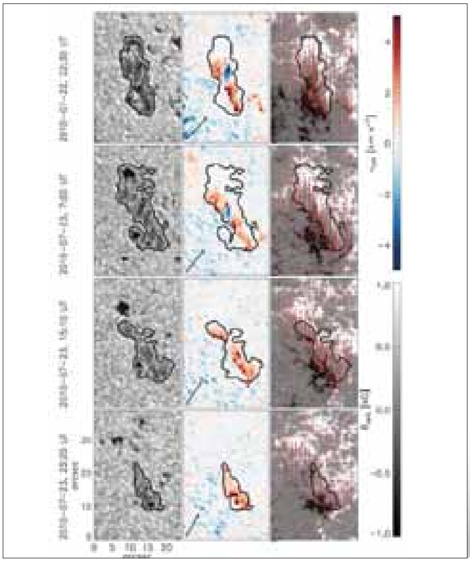


Fig. 5 – Temporal evolution of the orphan penumbra observed by HINODE/SOT in NOAA 11089. From left to right: continuum intensity, LOS velocity, and the vertical component of magnetic field with arrows indicating the strength and orientation of the horizontal component.

The processes of the formation of a sunspot penumbra are still not well understood. MHD simulations show that the critical inclination of magnetic field vector may trigger it. Jurčák et al. (2014, PASJ, 66S, 3J) studied the evolution of the magnetic field inclination on the forming umbra-penumbra boundary. Before the appearance of penumbral filaments, they observed an increase of magnetic field inclination, where the maximum inclination is co-temporal with the onset of penumbra formation (Fig. 6). In time, the penumbra filaments become longer and the penumbral bright grains protrude into the umbra, where the magnetic field is stronger and more vertical. Consequently, we observe a decrease in the magnetic field inclination at the boundary as the penumbra grows. They observationally confirmed that the penumbra formation is triggered by a critical value of the magnetic field inclination.

Solar pores are intermediate-size magnetic flux features (small spots) that emerge at the surface of the Sun. Despite the pores are lacking a penumbra, Sobotka et al. (2013, Astronomy & Astrophysics 560, A84) have proven that in the chromosphere, pores can be surrounded by a superpenumbra like developed sunspots. In addition to that, we addressed the important problem of chromospheric heating. We found that acoustic waves leaking up from the photosphere along the inclined magnetic field in a light bridge transfer enough energy flux to balance the radiative losses, so that the light-bridge chromosphere is heated by acoustic waves.

Magnetic bright points are the finest magnetic structures observed on solar surface. Their dynamics can play a crucial role in heating of higher layers of solar atmosphere. In collaboration with D. Utz (Austria) we investigated the magnetic field strength distribution of magnetic bright points (Utz et al. 2013, Astronomy &

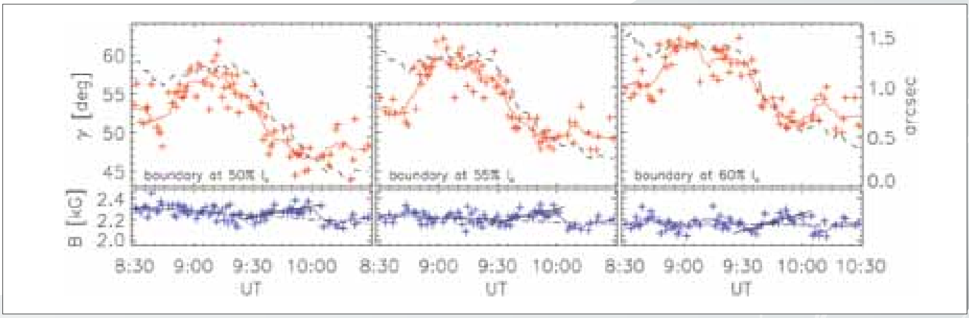


Fig. 6 – Temporal evolution of magnetic field inclination (red) and strength (blue) at the umbra-penumbra boundary segment. The values of magnetic field inclination γ and strength B smoothed over 10 minutes are shown by red and blue lines. The dashed black lines in the γ plots show the positions of the boundaries with time, where the axis on the right-hand side shows the span of the motions.

Astrophysics 554, A65). We used datasets from both active and quiet regions to investigate if the properties of magnetic bright points are sensitive to the surrounding activity. In all datasets, the obtained magnetic field strength distribution of magnetic bright points is similar and shows peaks around 1300 G. This agrees well with the theoretical prediction of the convective collapse model.

Convection and plasma motions in the upper layers of the solar convection zone are studied. Understanding the dynamics of plasmas and their coupling to the magnetic fields is very important in order to constrain models leading to an explanation of how and why the phenomena of solar activity (sunspots predominantly) form. Mostly large archives from the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory are used to study the topic.

We participated in development of a fully self-consistent analysis pipeline for time-distance helioseismology. The pipeline was tested and compared to the measurements from the surface (Švanda et al., 2013, Astrophysical Journal 771, 32) with the conclusion that the inferences from helioseismology match the surface measurements within the experimental error bars. The advantage of time-distance is to measure also the vertical component of the velocity vector. This allowed to estimate for instance the near-surface scale-height of density with a value close to the value predicted from the theoretical models. The improved method was used to assess the structure of the convection in the near-surface layers (Švanda et al., 2013, Astrophysical Journal 775, 7) down to a depth of 9 Mm. It was shown that the peak in the spatial power spectrum associated with supergranulation implying a large spatial extent of supergranule-like convection in depth.

Statistical surface properties of supergranules from HMI data were also studied (Roudier, Švanda et al., 2014, Astronomy & Astrophysics 567, A138). It was found that when using the watershed segmentation, the almost complete set of supergranules was obtained, statistical properties of which were comparable to the previous studies. Moreover, we studied a possibility of a dependence of the rotation and meridional speeds of supergranules on their sizes, as suggested by some authors. We did not find any significant deviations of proper motions of either small or large supergranules, thereby we do not support the possibility to use supergranules as tracers to learn about the solar rotation and meridional flow in depth.

A near-surface plasma flow in the vicinity of isolated symmetrical sunspots (the moat flow) was studied by Švanda et al. (2014, Astrophysical Journal 790, 135), using the local helioseis-

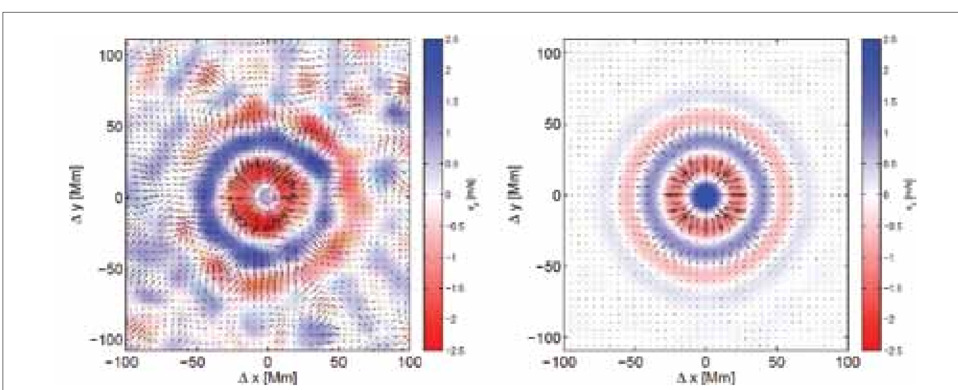


Fig. 7 – Comparison of vector flow around an average symmetric sunspot, marked by two concentric black circles, and an average supergranule. The horizontal velocity component is depicted by arrows, the vertical component by color coding. Major differences seen are the east-west asymmetry of the horizontal moat flow around the sunspot and the difference in the magnitude of the vertical velocity within the moat. The upflow ring at a distance of 38 Mm indicates the average location of neighboring supergranules.

mology technique. We found that it resembles the radial streaming in convective supergranules (Fig. 7). In the vicinity of sunspots, the flow is deformed due to the spot‘s proper motion, it is deflected backwards and to a downflow. This result contributes to our knowledge about the dynamics of sunspots – the most prominent phenomenon of solar activity.

The members of the working group collaborate with research institutions in Austria, France, Germany, Italy, Portugal, and Spain. Observational data come from large solar telescopes located in the Canary Islands observatories and from solar satellites SOHO and HINODE. The group is collaborating with leading German astrophysical institutes on the project GREGOR, a large solar telescope with a diameter of 1.5 m. The telescope was inaugurated on 21 May 2012 at Observatorio del Teide, Tenerife, Canary Islands. We took part in alignment and testing of post-focal instruments and in the "Early-Science" period of observations. Participation in the project, financed by the Czech Ministry of Education, Youth and Sports, allows us to share observing time on this unique instrument. The group collaborates with the Astronomical Observatory of the Coimbra University, Portugal, in the operation of the full-disc spectroheliograph, maintaining the software for data acquisition and processing since 2008. We upgraded this software in 2014. The daily observed spectroheliograms and Dopplergrams are available in the French solar data base BASS 2000.

Heliosphere and Space Weather working group

"The main results of this group concern the physics of the solar wind, including extended numerical simulations. The members of the group are also engaged in space research activities. The group is located in Prague." – Marek Vandas, head of the group.

Personnel

The working group is headed by M. Vandas. Research fellows: P. Hellinger, D. Herčík, S. Šimberová, Š. Štverák, P. Trávníček, M. Vandas, and there are several PhD students.

Research results

Proton thermal energetics represents one of the challenging problems of the solar wind physics. The earlier analysis of proton energetics in the fast solar wind (Hellinger et al. 2011, Journal of Geophysical Research 116, A09105), was extended to the slow solar wind. The proton

Heliosphere and Space Weather working group. From left to right: J. Laifr, M. Vandas, P. Hellinger, Š. Štverák, O. Šebek, M. Jílek.

parallel and perpendicular heating rates were determined and compared with those in the fast solar wind using Helios spacecraft in situ observations (Hellinger et al. 2013, Journal of Geophysical Research 119, 1351). The heating rates in the slow solar wind constrain possible heating processes. The necessary heating rates are comparable to estimated turbulent cascade rate, but it was shown that these estimates are based on questionable assumptions.

The proton temperature anisotropy in the solar wind exhibits apparent bounds compatible with theoretical instability constraints. Recent statistical analyses indicate that near these constraints, protons have enhanced temperatures and reduced collisionality. Hellinger & Trávníček (2014, Astrophysical Journal 784, L15) analyzed the WIND spacecraft data and showed that these results are a consequence of superposition of multiple correlations in the solar wind such as the yet unexplained correlation between the proton temperature and their bulk velocity.

Superposition of cylindrical and toroidal force-free magnetic fields were studied to model irregularities in magnetic structure of solar flux ropes or in interplanetary magnetic clouds. Local irregularity in the form of a compact toroid was added into a cylindrical linear force-free magnetic structure. The resulting configuration also was a linear force-free magnetic field. The effect of such modeling depends on aspect ratio of the compact toroid, its location and orientation, and on its magnetic field magnitude in comparison with that of the cylinder (Romashets and Vandas 2013, Solar Physics 284, 235).

Euler potentials have advantage that enable to study charged-particle motions with high accuracy. There are not many known analytic solutions for Euler potentials in magnetic systems. Vandas & Romashets (2014, Journal of Geophysical Research 119, 2579) constructed analytically Euler potentials of two current sheets of nonzero thickness parallel or antiparallel to each other and aligned with uniform ambient magnetic field and used them to investigate conditions for particle motion and trapping. The results can be applied to Birkeland currents in the Earth's auroral zone.

The asymmetric properties of the Hermean magnetosphere were studied using hybrid simulations (Herčík et al. 2013, Journal of Geophysical Research 118, 405). The asymmetry is explained as a result of kinetic processes at the bow shock layer that are convected through the magnetosheath. In particular, the properties of the magnetosheath are examined in order to identify source regions with significant mirror mode activity. Results are important for interpretation of MESSENGER in situ observations and for preparation of the upcoming BEPI-COLOMBO mission. This work results from active participation in the MESSENGER (NASA) and BEPI-COLOMBO (ESA, JAXA) spacecraft projects.

The group is also involved in image information processing. The art of image processing is a topic with boundaries well beyond astronomy. Astronomical image processing applies a variety of numerical methods to extract scientifically valuable information from the observed data. Applied sciences in this subject cover very broad area including pre-processing (data acquisition from the space and ground-based observation, standard data reduction, removing of noise components and random disturbances, raw and processed data archiving), modeling of image degradation, image fusion and reconstruction, statistical analysis of dynamical events, and pattern recognition. The recent result (Fig. 8) is a unique application of statistical moments in diagnostics of solar flares (Šimberová et al. 2014, Solar Physics 289, 193). New mathematical methods and algorithms are designed in cooperation with research groups

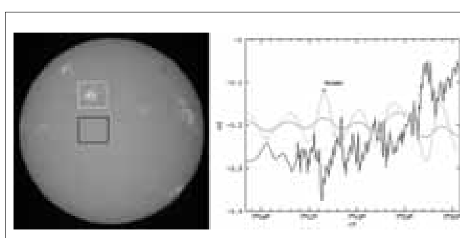


Fig. 8 – An automatic active-regions searching on the solar surface (left), significant and start time-point determination of the flare from the observed video sequence (right).

from the Institute of Information Theory and Automation of the ASCR.

The Solar Activity Monitoring and Forecasting unit, located in Ondřejov, provides regular solar observations in the white light and the Hα line. It uses three small full-disc refractors for drawings, white light, and Hα and two 20-cm refractors for imaging of active regions in the photosphere and Hα chromosphere (Fig. 10). The results, besides the use in the Team, are provided to the world net International Space Environment Service (ISES) as a part of the Regional warning Centre Prague (station No. 31516), and to the Solar influences Data Centre (SIDC) in Brussels. In addition to solar observations, the unit collects all the accessible data on the actual state of solar activity and regularly compiles and publishes daily and weekly solar-activity forecasts. The weekly activity forecasts are published every Thursday for approximately 50 Czech and international users (radio communications, radio amateurs, ISES, SIDC, and others). The daily solar activity forecasts are presented in the Czech Television as a part of the weather forecast. The solar-activity forecast, made in Ondřejov since 1978, is a national service and represents an integral part of the international space weather program. The observations can be found at the web site http://www.asu.cas.cz/~sunwatch/.

Space research activities of the Department of Solar Physics

The Department of Solar Physics currently participates in three space projects of European Space Agency (ESA): Solar Orbiter (Fig. 9), PROBA-3, and JUICE. The scientists, as members of several consortia, participate in the science goals definition and they are responsible namely for the development and manufacture of the following scientific instruments:

STIX: Low and high voltage power supply (PSU) for the STIX X-ray spectrometer-imager onboard the Solar Orbiter mission and its controlling flight software. The STIX consortium was established in 2006 with the Czech and Swiss active participation. Later on, the consortium was completed with participants from France, Germany, USA and Poland. The Department of Solar Physics participates in the definition of science goals of the project and develops the hardware in a special group of technicians in Brno, incorporated temporarily in the Department.

RPW: Low voltage power supply and power distribution unit for the RPW experi-

Fig. 9 – Artist's view of the Solar Orbiter spacecraft (image courtesy ESA).

Fig. 10 – Solar patrol with telescopes (up) and the control room with observers J. Leško and I. Macourková (down).

ment on the Solar Orbiter mission. The RPW consortium was formed as a response to the ESA announcement of opportunity for its M-class mission within the Cosmic Vision science program. Currently the consortium is led by CNES (France) and, besides ASU, it involves participants from Sweden, Austria, and USA. The RPW instrument's science goal is to provide in situ measurements in solar wind of both the electrostatic and electromagnetic fields and waves in a broad frequency range. Like in the previous (STIX) case, the hardware is developed by the group of technicians in Brno.

METIS: The participation in the METIS instrument onboard the Solar Orbiter mission has been proposed by the consortium (Italy, Czech Republic, France, Germany, USA) in response to the ESA's announcement of opportunity. The METIS design was aimed at performing off-limb and near-Sun coronagraphy, the task motivated by scientific questions of the origin and heating/acceleration of the solar wind streams, the origin, acceleration and transport of the solar energetic particles, and the transient ejection of coronal mass and its evolution in the inner heliosphere. The Department is responsible for manufacturing and delivering optical components: the primary and secondary telescope mirrors and the heat-rejection mirror. All these optical elements are now developed and will be manufactured in the Institute of Plasma Physics ASCR, the Research Centre for Special Optics and Optoelectronic Systems (TOPTEC) in Turnov. The Department will get scientific profit from the direct access to expected unique data received during observations with the instrument.

JUICE: Low voltage power supply and power distribution unit for the RPWI experiment on the JUICE mission to Jupiter (Fig. 11). The RPWI consortium was formed as a response to the ESA announcement of opportunity for its L-class mission within the Cosmic Vision science program. Currently the consortium is led by IRSU (Sweden) and, besides ASU, it involves participants from Austria and USA. The RPW instrument's science goal is to provide plasma and electromagnetic wave measurements in situ in the Jupiter's magnetosphere including close environment of several Jupiter's moons.

PROBA-3: The aim is the development, manufacturing, testing and delivery of the hardware components for the space coronagraph ASPIICS. The main goal of the mission is an in-orbit demonstration of formation-flying techniques and technologies and this will be implemented with a pair of small spacecrafts. The ASPIICS solar coronagraph will fully benefit from exploiting the formation-flight technique

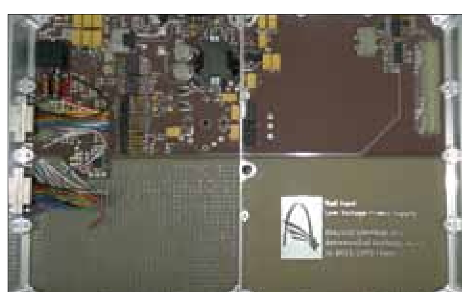


Fig. 11 – Current state of the preliminary engineering model of the power supply subsystem being developed at the Astronomical Institute for the RPWI experiment on the JUICE (ESA) mission.

to gain a unique access to the inner solar corona down to 1.04 solar radii over long periods of time under near-total solar eclipse conditions. The responsibility of the Department is to coordinate the development of the Front Door Assembly and the Primary Objective together with the Relay Optics done by national industrial partners – SERENUM, a.s. and TOPTEC center of the Institute of Plasma Physics ASCR. The original design of the Front Door Assembly (which constitutes the closing mechanism of the aperture of the optical telescope) was transferred from the Max-Planck Institute for Solar System Research in Göttingen, Germany to the national industrial partner SERENUM, a.s. Newly founded technological center TOPTEC of the Institute of Plasma Physics ASCR will develop and manufacture space--qualified optics.

Published Principal Results

We present abstract of the most interesting results of the last two years.

Proton thermal energetics in the solar wind: Helios reloaded

P. Hellinger, P. Trávníček, Š. Štverák, L. Matteini, M. Velli

Journal of Geophysical Research: Space Physics, 2013, Volume 118, Issue 4, p. 1351-1365

The proton thermal energetics in the slow solar wind between 0.3 and 1 AU is reinvestigated using the Helios 1 and 2 data, complementing a similar analysis for the fast solar wind [Hellinger et al., 2011]. The results for slow and fast solar winds are compared and discussed in the context of previous results. Protons need to be heated in the perpendicular direction with respect to the ambient magnetic field from 0.3 to 1 AU. In the parallel direction, protons need to be cooled at 0.3 AU, with a cooling rate comparable to the corresponding perpendicular heating rate; between 0.3 and 1 AU, the required cooling rate decreases until a transition to heating occurs: by 1 AU the protons require parallel heating, with a heating rate comparable to that required to sustain the perpendicular temperature. The heating/cooling rates (per unit volume) in the fast and slow solar winds are proportional to the ratio between the proton kinetic energy and the expansion time. On average, the protons need to be heated and the necessary heating rates are comparable to the energy cascade rate of the magnetohydrodynamic turbulence estimated from the stationary Kolmogorov-Yaglom law at 1 AU; however, in the expanding solar wind, the stationarity assumption for this law is questionable. The turbulent energy cascade may explain the average proton energetics (although the stationarity assumption needs to be justified) but the parallel cooling is likely related to microinstabilities connected with the structure of the proton velocity distribution function. This is supported by linear analysis based on observed data and by results of numerical simulations.

Tomography of Plasma Flows in the Upper Solar Convection Zone Using Time-Distance Inversion Combining Ridge and Phase-speed Filtering

M. Švanda

The Astrophysical Journal, 2013, Volume 775, Issue 1, article id. 7, 10 pp.

The consistency of time-distance inversions for horizontal components of the plasma flow on supergranular scales in the upper solar convection zone is checked by comparing the results derived using two k-omega filtering procedures – ridge filtering and phase-speed filtering – commonly used in time-distance helioseismology. I show that both approaches result in similar flow estimates when finite-frequency sensitivity kernels are used. I further demonstrate that the performance of the inversion improves (in terms of a simultaneously better averaging kernel and a lower noise level) when the two approaches are combined together in one inversion. Using the combined inversion, I invert for horizontal flows in the upper 10 Mm of the solar convection zone. The flows connected with supergranulation seem to be coherent only for the top ~5 Mm deeper down there is a hint of change of the convection scales toward structures larger than supergranules.

Hydrogen Balmer Continuum in Solar Flares Detected by the Interface Region Imaging Spectrograph (IRIS)

P. Heinzel, L. Kleint

The Astrophysical Journal Letters, 2014, Volume 794, Issue 2, article id. L23, 6 pp.

We present a novel observation of the white light flare (WLF) continuum, which was significantly enhanced during the X1 flare on 2014 March 29 (SOL2014-03-29T17:48). Data from the Interface Region Imaging Spectrograph (IRIS) in its near-UV channel show that at the peak of the continuum enhancement, the contrast at the quasi-continuum window above 2813 Å reached 100%-200% and can be even larger closer to Mg II lines. This is fully consistent with the hydrogen recombination Balmer-continuum emission, which follows an impulsive thermal and non-thermal ionization caused by the precipitation of electron beams through the chromosphere. However, a less probable photospheric continuum enhancement cannot be excluded. The light curves of the Balmer continuum have an impulsive character with a gradual fading, similar to those detected recently in the optical region on the Solar Optical Telescope on board Hinode. This observation represents a first Balmer-continuum detection from space far beyond the Balmer limit (3646 Å), eliminating seeing effects known to complicate the WLF detection. Moreover, we use a spectral window so far unexplored for flare studies, which provides the potential to study the Balmer continuum, as well as many metallic lines appearing in emission during flares. Combined with future ground-based observations of the continuum near the Balmer limit, we will be able to disentangle various scenarios of the WLF origin. IRIS observations also provide a critical quantitative measure of the energy radiated in the Balmer continuum, which constrains various models of the energy transport and deposit during flares.

Moat Flow System around Sunspots in Shallow Subsurface Layers

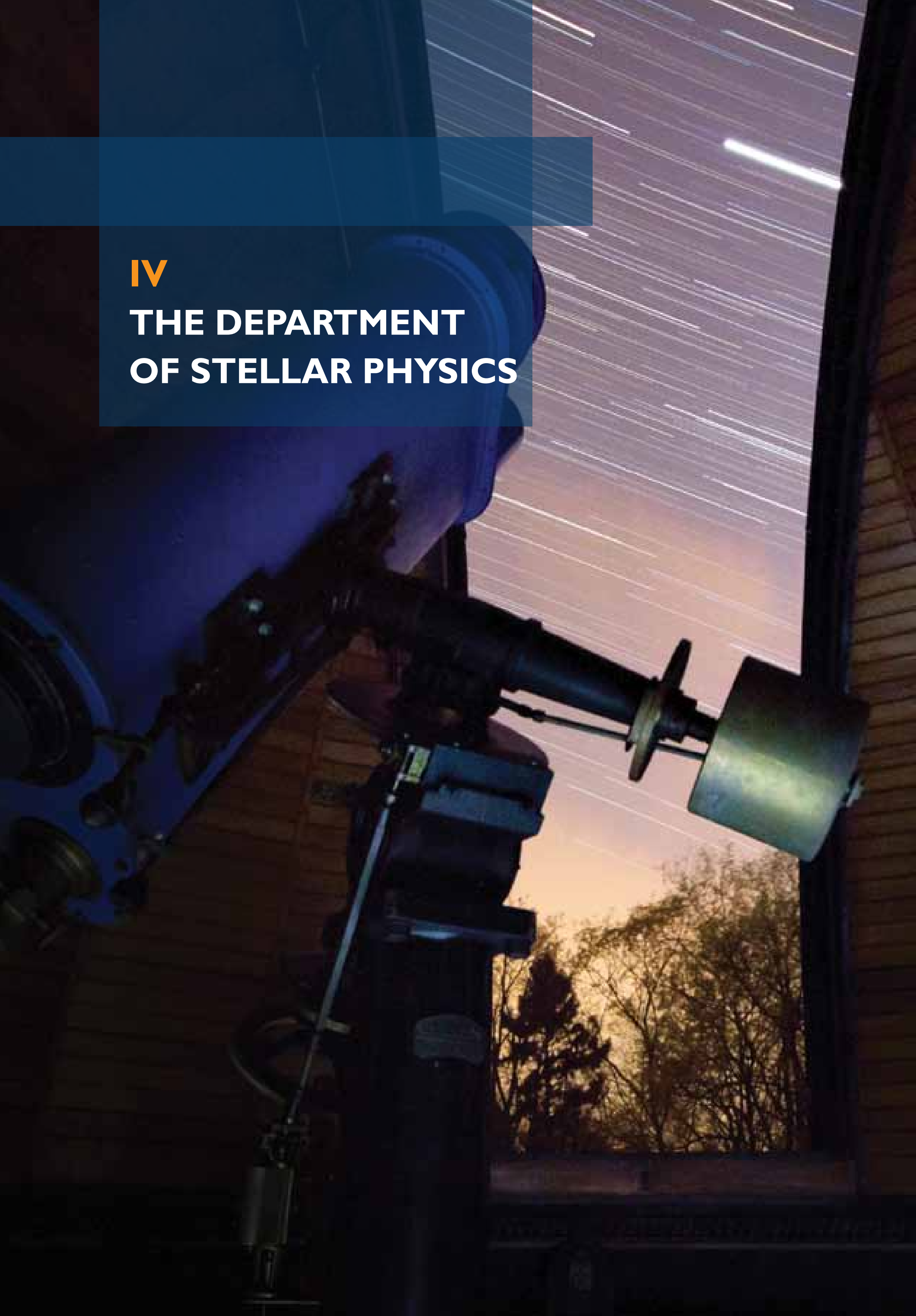
M. Švanda, M. Sobotka, T. Bárta

The Astrophysical Journal, 2014, Volume 790, Issue 2, article id. 135, 7 pp.

We investigate the subsurface moat flow system around McIntosh H-type symmetrical sunspots and compare it to the flow system within supergranular cells. Representatives of both types of flows are constructed by means of the statistical averaging of flow maps obtained by time-distance helioseismic inversions. We find that moat flows around H-type sunspots replace supergranular flows but there are two principal differences between the two phenomena: the moat flow is asymmetrical, probably due to the proper motion of sunspots with respect to the local frame of rest, while the flow in the supergranular cell is highly symmetrical. Furthermore, the whole moat is a downflow region, while the supergranule contains the upflow in the center, which turns into the downflow at about 60% of the cell radius from its center. We estimate that the mass downflow rate in the moat region is at least two times larger than the mass circulation rate within the supergranular cell.

Stony monolite of historical solstoce/equinox sun dial, located nearby the main building of the department.

IV
THE DEPARTMENT OF STELLAR PHYSICS



Head scientist – M. Šlechta. Deputy – M. Kraus.

Secretary: E. Kortusová,
Phone: (+420) 323 620 226,
E-mail: kortusova@asu.cas.cz

"Department of Stellar Physics is one of four departments of the Astronomical Institute. It is situated in Ondrejov. The department is divided into three working groups: the astrophysics of hot stars, the operation and development of Perek 2-m telescope and the high energy astrophysics group. The first two groups are closely involved with the Ondrejov 2-m telescope. The high energy astrophysics group requires other instrumentation described below." – Miroslav Šlechta, head of the Department of Stellar Physics.

Personnel

The working group is headed by J. Kubát. Research fellows: A. Hervé, P. Kabath, A. Kawka, P. Koubský, M. Kraus, G. Maravelias, M. Oksala, P. Škoda, B. Šurlan, S. Vennes, V. Votruba, and there have been several PhD students.

Research Results

Study of Be stars. About one fifth of all B-type stars in the Milky Way are Be stars - B type stars of luminosity class III, IV or V having one or more Balmer lines in emission at some time. Judging from results so far presented, Be stars can be understood as very rapidly rotating B stars, surrounded by a geometrically thin, gaseous, circumstellar disk which is excited by the UV radiation of the B star. Three scenarios have been proposed to explain the rapid rotation of the Be stars: (i.) Be stars are born as rapid rotators and are able to avoid spin-down during their further evolution. (ii.) They get spun up due to core contraction occuring when the hydrogen inside the core is exhausted. (iii.) They form due to close binary evolution.

Physics of Hot Stars Group and Two-meter Telescope Group (2015): From left bottom: J. Honsa, E. Kortusová, P. Škoda, J. Fuchs, L. Kotková, L. Řezba, M. Šlechta, P. Koubský, V. Votruba, A. Hervé, S. Vennes, M. Tlamicha, A. Kawka, J. Sloup, M. Kraus, S. Tomić.

Group of Hot stars

"The group's main area of research is studies of hot stars, although other research topics are pursued. The group consists of observers and theoreticians who collaborate on projects." – Jiří Kubát, head of the group.

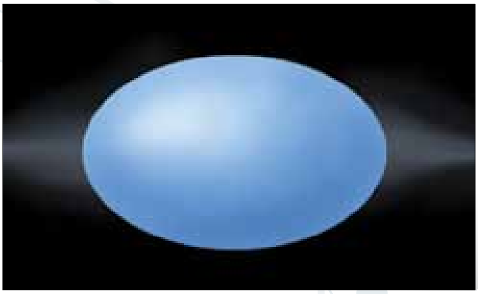


Fig. 1 – A graphic interpretation of star Achernar, one of the most known Be stars. On the equator level of star is geometrically thin, gaseous, circumstellar disk.

CREDIT: ESO

Fig. 2 – The Seagull Nebula is a roughly circular HII region centered on the Herbig Ae/Be-type star HD 53367.

Binarity has been proposed to be responsible for the origin of Be stars (see Fig. 1) by Kříž and Harmanec (1975). In that case, the disk would be an accretion disk. But statistical arguments on Be binarity continue to speak against it as a wide spread mechanism, since most Be stars do not belong to active mass transfer binaries with Roche lobe filling giants. Current binary scenarios discuss the Be stars not as components of close binaries where mass and angular momentum transfer occurs, but as remnants of close binaries after the mass and angular momentum transfer was completed (Berger and Gies 2001). The Roche lobe overflow of the original primary component can result in a rejuvenated, spun-up new primary that appears as a rapidly rotating Be star.

Calculation for case B of close binary evolution (Vanbeveren et al. 1998) for intermediate-mass main sequence stars let to the conclusion that up to 50 percent of all Be stars could have formed this way representing post mass exchange binaries (Pols et al. 1991). Therefore, many binary systems with evolved companions should exist which have not yet been discovered. According to Raguzova (2001), most of the evolved Be binary systems should have a white dwarf (WD) companion, about one fifth a helium star (sdO), and one tenth a neutron star (NS). Pols et al. (1991) predict that 80 percent of the evolved companions should be helium stars. Due to expected low masses for the companions it is difficult to detect them with currently used methods of radial velocities. Some Be stars with WD or NS companions are observed as Be/X-ray binaries where the X-rays originate during the mass accretion by the compact objects. The emission from the sdO companions should dominate in the XUV region.

For years, only one case of a Be + sdO binary - phi Per - has been known. The spectral signatures of the sdO in this system - lines of He II - were detected both in optical and UV regions (Poeckert 1981, Gies et al. 1998). Besides the He II lines, phi Per shows an additional feature that is inherent in a Be + sdO nature: single-peaked He I emission moving in anti-phase with the He II lines. Hummel and Štefl (2001) showed that this phenomenon is explicable, if it is assumed that a sector of the Be star disk is illuminated by the UV radiation from the hot secondary. This area becomes hotter and thus gives rise to the extra emission swaying from the red side of the helium absorption profile to the blue one and back. Similar features were found in 59 Cyg and in FY CMa, both systems confirmed as Be + sdO binaries, also called radiatively interacting binaries (RIB).

In 2010, we initiated a systematical search for the RIB objects using spectra from the 2-m telescope at Ondřejov and the 1.2-m telescope at DAO, Victoria, Canada (in robotic mode). The candidates for RIBs were selected from the archive of both telescopes which were complemented by new spectra. Three new RIBs were discovered: omicron Pup (Koubský et al. 2012), HD 161306 (Koubský et al. 2014), V 1165 Tau (in preparation). Thus, the number of known Be stars which were formed due to close binary evolution is growing, but it is still difficult to estimate the fraction of Be/compact object systems among all Be stars. This fraction depends on the assumed evolutionary model. Improved methods for an easier identification of evolved Be binaries with hot, compact companions are expected to lead to the detection of many such binaries in the future. This will allow us to assess the fraction of Be stars originating from the evolution of close binaries and, therefore, to test particular evolutionary models.

The temporal analysis of moving emission features of the He I lines can be used not only for deriving the period of a particular binary system, but also to probe the structure of the disk of a Be star and/or to monitor the variability of the compact source. Koubský et al. 2012, A&A, 545, A121, Koubský et al. 2014 A&A 567, A57.

The Perek 2-m telescope is an excellent tool for systematic monitoring of selected targets. However, our research is not purely restricted to data obtained with the 2-m telescope. Typically, we aim to obtain complementary data from instruments at other, large telescopes, such as the ESO Very Large Telescope at Paranal (see Fig. 3) in Chile and the GEMINI observatory on Hawaii, Kitt Peak National Observatory etc. These facilities provide spectroscopic and imaging data in different wavelength regimes (optical, infrared) that excellently complement our own data sets for a most complete analysis of individual stars, their winds and circumstellar environments.

Theoretical astrophysical studies nicely complement the observations conducted in our department. The aim is focused on the radiative magnetohydrodynamic modelling of stellar atmospheres and stellar wind. We also aspire to the better explain the phenomenon of accretion discs. This is interest of our colleague Jiří Kubát who closely cooperate with Jiří Krtička (Masaryk University, Brno, Czech republic) on this field.

Research on hot supergiants is one major research topic in the stellar department. In particular, we aim to improve our understanding of the origin, structure, and dynamics of the circumstellar material around evolved massive stars in short-lived transition phases such as the B[e] supergiants and the luminous blue variables (LBVs). In addition, we seek to unravel the triggering mechanism for the phases of enhanced mass-loss and mass eruptions in these stars. We also study their less violent counterparts, the classical B-type supergiants. We initiated an observing campaign to monitor a sample of Galactic B-type supergiants in different timescales. To achieve our goals, we perform both theoretical and observational investigations, combining optical observing facilities such as the Perek 2-m telescope at Ondřejov Observatory and the

CREDIT: PETR HORÁLEK/ESO

Fig. 3 – Panoramatic view of the ESO's Paranal observatory platform. Four domes with VLT telescopes are situated on right as the Milky Way sets before the dawn.

Fig. 4 – Michaela Kraus and her team discovered the SiO band emission from Galactic B[e] supergiants. This is an indication for a debris disk, i.e., a disk with dust particles and rocks. The figure depicts an artist's vision of a debris disk revolving a hot central object.

2.15m-telescope at CASLEO, Argentina, with infrared facilities provided by the ESO VLT and by GEMINI (North and South), to which we have access via our international collaborations.

We studied the structure and kinematics of the circumstellar material around evolved massive stars based on different tracers: The size and inclination of dusty disk regions were studied using interferometry (Cidale et al., 2012, Astronomy & Astrophysics, Volume 548, id.A72, 9 pp.). We analysed the shape of the [CaII] and CaII infrared triplet line profiles, which we discovered as valuable diagnostics, to trace the atomic gas parts of the circumstellar disks or rings (Aret et al., 2012, MNRAS, Volume 423, Issue 1, 10 pp.). In addition, we modeled the shape and strength of the CO band and the recently discovered SiO band emission (Kraus et. al., 2015, Astrophysical Journal, Volume 800, Issue 2, article id. L20, 5 pp.) to constrain the structure (density and temperature) and dynamics of the molecular disk parts. Our investigations revealed that emission of the [CaII] lines is only detectable from stars with dusty rings (see Fig. 4) or disks, i.e., stars with very dense circumstellar material, such as the B[e] supergiants, post-AGB stars, yellow hypergiants, and, occasionally, LBVs. Combining the results from all disk tracers, we also found that the material around B[e] supergiants cannot be located in a continuous outflowing disk. Instead, it is detached from the star and arranged in multiple, high-density rings or spiral arm like structures in Keplerian (or quasi-Keplerian) rotation. This, in turn, means that the material release must happen in several short and probably violent mass ejection events, similar to what is observed in LBVs. For one B[e] supergiant star we discovered the sudden appearance of CO band emission, and we conclude that this emitting material must result from a recent mass ejection event (Oksala et al., 2012, MNRAS, Letters, Volume 426, Issue 1, pp. L56-L60). Furthermore, our analysis of the molecular material in some B[e] supergiants in binary systems revealed that the accumulation of the material in circumbinary rings or spiral arms results from binary interaction processes (Kraus et al., 2013, Astronomy & Astrophysics, Volume 549, id.A28, 7 pp.).

We performed an infrared survey of a large number of evolved massive stars. This survey allowed us also to perform an abundance study, based on which we found that the B[e] supergiant phase occurs in the evolution of massive stars right after the main sequence rather than after the star has passed through the red supergiant phase. This is a surprising result, because this means that, despite many similarities, B[e] supergiants and LBVs are most probably not evolutionary linked but evolve from stars with different initial conditions (Oksala et al., 2013, Astronomy & Astrophysics, Volume 558, id.A17, 20 pp.). Moreover, we discovered criteria that allow us to unambiguously classify a star as either an LBV or a B[e] supergiant. Application of our infrared diagnostics to a sample of unclassified evolved massive stars resulted in the discovery of the first B[e] supergiants in the Andromeda galaxy (Kraus et. al., 2014, Astrophysical Journal, Volume 780, Issue 1, article id. L10, 5 pp.).

From our monitoring campaign of B-type supergiants, we discovered in the line profiles of HD 202850 a stable variation with a period of 1.6 h, which is much shorter than any theoretical predictions for stars in this evolutionary stage (Kraus et al., 2012, Astronomy & Astrophysics, Volume 542, id.L32, 4 pp.). We also analyzed a large set of optical spectroscopic data for 55 Cygni, which we classify as a new member of the alpha Cygni variables (Kraus et al., 2015, Astronomy & Astrophysics, Volume 581, id.S75, 22pp.). The observations were obtained with the Perek 2-m telescope at Ondřejov Observatory over a time interval of more than four years. From a period analysis, we identified 19 pulsation periods, ranging from 2.7 h to 22.5 days. These could be assigned mainly to p- and g-mode pulsations, while the longest period of 22.5 days is in agreement with a strange mode pulsation (see Fig. 5). In addition, from an analysis of the wind emission lines, in particular of Hα, we recognized time-variable mass-loss in this object, with a similar period of ~20 days, suggesting that the strange mode could trigger the time-variable mass-loss in this object.

Modelling of stellar atmospheres and winds with the collaboration with the Faculty of Science of Masaryk University in Brno has existed for about 15 years. This collaboration is led by Jiří Kubát in Ondřejov and Jiří Krtička in Brno. They published a large number of common scientific papers (mostly in Astronomy and Astrophysics) about theoretical modelling of stellar winds. The group involves people from both the stellar department of the Astronomical Institute and Faculty of Science and collaborates also with the Astrophysics group at the Potsdam University (Germany).

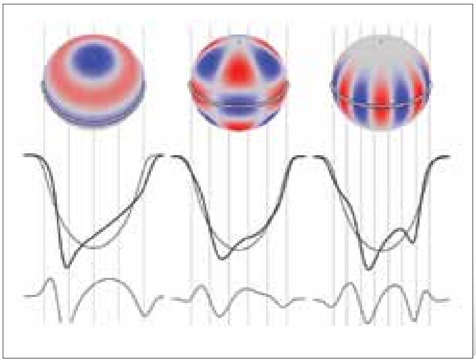


Fig. 5 – Illustration of the influence of stellar pulsations on the observable spectral line profile. The pulsation modes are shown on the top in blue (moving towards us) and red (moving away from us), the impact on the line profile is shown in the middle, and the difference between line profiles of pulsating and non-pulsating stars are shown in the bottom panels.

The most important property of massive, hot stars is their mass outflow expelled via stellar winds. Hot star wind mass-loss rates depend on the abundance of individual elements. This dependence is usually accounted for assuming scaled solar chemical composition. The rotational mixing in evolving stars brings CNO-processed material to the stellar surface, increases the abundance of nitrogen at the expense of carbon and oxygen, which potentially influences the mass-loss rates. We studied the influence of the modified chemical composition resulting from the rotational mixing on the wind parameters, particularly the wind mass-loss rates. We use our non-local thermodynamic equilibrium wind code (Krtička & Kubát, 2010, Astronomy & Astrophysics 519, A50) to predict the wind structure and compare the calculated wind mass-loss rate for the case of scaled solar chemical composition and the composition affected by the CNO cycle. For some parameters, the mass-loss rates are changed

(Krtička & Kubát, 2014, Astronomy & Astrophysics 567, A63).

Recent studies of O-type stars demonstrated that discrepant mass-loss rates are obtained when different diagnostic methods are employed. Wind inhomogeneity (i.e. "clumping") may be the main cause for this discrepancy. To estimate more reliable mass-loss rates of massive, hot stars we developed a Monte Carlo radiative transfer code with a full 3-D description of clumping (Šurlan et al., 2012, Astronomy and Astrophysics 541, A37), and investigated how the properties of clumping affect the derived mass-loss rates. Combining optical observations with the Ondřejov 2-m Perek telescope, satellite ultraviolet observations, and highly sophisticated 3-D radiative transfer calculations showed that wind clumping resolves the previously reported discrepancy between H and P v mass loss diagnostics. There is no need to artificially reduce the mass-loss rates, nor to assume a sub-solar phosphorus abundance or an extremely high clumping factor. These results contribute to a better determination of the mass-loss rates of massive, hot stars (Šurlan et al., 2013, Astronomy & Astrophysics 559, A130).

CREDIT: ESA, NASA

Fig. 6 – Artistic impression of a white dwarf with its size compared to the Earth.

We continued our spectroscopic investigation of high-proper motion white dwarfs (Fig. 6) that were selected from the New Luyten Two Tenths (NLTT) catalogue. Our work included the spectropolarimetric survey of cool white dwarfs using the FORS spectrograph attached to the VLT at the European Southern Observatory (ESO). This led to the discovery of a number of new magnetic white dwarfs, including the first close double degenerate system comprised of a magnetic white dwarf and a non-magnetic white dwarf companion offering clues for the origin of magnetic fields in compact objects (Kawka & Vennes 2012, MNRAS, 425, 1394).

Our spectroscopic survey also revealed several new polluted hydrogen-rich (DAZ) white dwarfs (Kawka & Vennes 2011, A&A, 532, A7; Kawka & Vennes, 2012, A&A, 538, A13; Vennes & Kawka 2013, ApJ, 779, 70), which were targets for follow-up observations with the X-shooter spectrograph attach to the VLT at the ESO. These high signal-to-noise and high-resolution spectra enabled us to study the white dwarf atmospheric parameters including detailed abundance patterns. These stars participated in the demise of planetary systems, and studies of their abundance patterns enable us to determine the accretion source (planet, comet, asteroid). Our studies of these cool DAZ white dwarfs have shown that a higher incidence of magnetism is present in this class of objects when compared to the general population of white dwarfs (Kawka & Vennes, 2014, MNRAS, 439, L90). This higher incidence suggests that planets/asteroids orbiting the progenitor star of the white dwarf plays a role in the formation of magnetic fields in white dwarf stars. Our X-shooter observations also uncovered a double degenerate system that includes the first carbon-polluted (DQ) white dwarf showing traces of nitrogen (Vennes & Kawka 2012, ApJ Letters, 745, L12; Vennes et. al., 2012, ApJ Letters, 756, L5). The discovery of such a system is important to our understanding of the phases of evolution, during the red giant stage and beyond.

We have also conducted a survey of ultra-violet bright objects selected from the Galaxy Evolution Explorer (GALEX) all-sky survey (Vennes, Kawka, Nemeth, 2011, MNRAS, 410, 2095). This resulted in the discovery of several bright hot subdwarfs suitable for detailed follow-up studies and of the rare oxygen-polluted white dwarf GALEX J1931+0117 (Vennes, Kawka & Nemeth 2010, MNRAS, 404, L40; Vennes, Kawka & Nemeth, 2011, MNRAS, 413, 2545). The hot subdwarfs (sdB, sdO) were analysed for their atmospheric parameters (effective temperature, surface gravity, helium abundance: Nemeth, Kawka, Vennes, 2012, MNRAS, 427, 2180). Since binarity is instrumental in the formation of hot subdwarf stars many of our stars were targeted for radial velocity measurements. Our radial velocity survey resulted in a binary fraction of about 40% (Kawka et al., 2015, MNRAS, 450, 3514). This survey also enabled us to discover the shortest period sdB plus white dwarf binary which a prime candidate progenitor for a Type Ia supernova (Vennes et al., 2012, ApJ, 759, L25).

All detailed analyses of the white dwarfs and hot subdwarfs were performed using our own state-of-the-art model atmosphere codes.

Group of operation and development of Perek 2-m telescope

"Perek 2-m telescope is a national facility for Czech astronomers. It is named after the astronomer Lubos Perek, born in 1919, who supervised the construction of the telescope and was leading the stellar department in the first years. The diameter of the primary mirror is 2-m and it was the ninth largest telescope in the world in 1967 when the telescope was inaugurated. The telescope is used for stellar spectroscopy and operates in the coude focus where the effective focal length is 64m with the effective focal ratio 1:32." – Miroslav Šlechta, head of the group.

Personnel

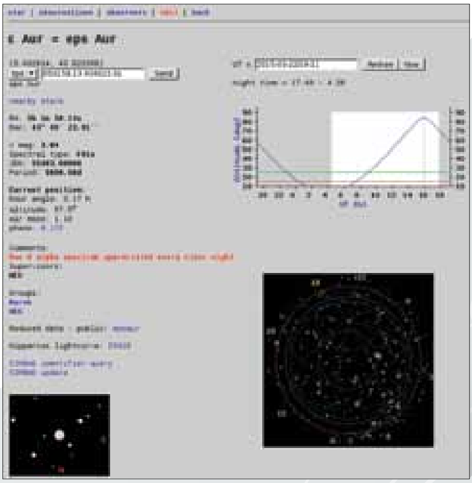
The working group is headed by M. Šlechta. Staff: L. Kotková, J. Fuchs, J. Sloup, L. Řezba, J. Honsa, M. Tlamicha.

About the telescope

The 2-m Perek telescope is the principal instrument of the stellar department. It is primarily used for the medium dispersion spectroscopy. Our spectrographs are installed in coude focus – effective focal length 63.5m.

Mostly, we use a single order slit spectrograph. It operates in the first and second spectral orders. In the first order the individual spectrum covers approximately 470 an-

The Perek 2-m telescope is the primary instrument in the Ondřejov observatory.



Example of the web-application (by Lenka Kotková) for the support of astronomer. Upper left: characteristics of the star. Upper right: altitude of the star (grey are – astronomical night, white area – astronomical day). Lower left: field of view of the finding telescope (16 arc min in diameter). Lower right: position of the star on the sky (small white circle).

gstroms and is available in interval from about 5000 up to 9000 angstroms. The second order is available in interval approximately 3700 up to 5000 angstroms. The resolving power is about 13000 around H-alpha.

Another available instrument is the echelle spectrograph OES (Ondřejov Echelle Spectrograph). The dispersion elements are grating and prism. It is used in range about 4000 up to 8000 angstroms. The resolving power is 55000 around H-alpha and depicts 112 angstroms in the order of H-alpha.

We provide some useful support to improve comfort of the observation: meteorological station (air pressure, triple point, wind – speed and direction – rainfall, etc.). Also the cloud cover is monitored using the full-sky fish eye camera. An automatic warning is sent when the humidity exceeds the limit value of 90%. The astronomer can plan the observing strategy using an extensive database of observed stars. The database automatically displays the position of the target on the sky, the current altitude (indicating whether the target is currently accessible for the telescope) and also its altitude for the following 24 hours (to help plan the observing strategy), list of reduced spectra of the target and a lot of other useful information about the selected target.

The group of High Energy Astrophysics (2015): From left: V. Šimon, J. Štrobl, V. Hudcová, M. Jelínek, R. Hudec.

About the team

The team is responsible for the reliable operation of the Perek telescope. All supporting tools are optimized so as to satisfy the requests of astronomers. These tools are entirely prepared by the local working group. Lenka Kotková prepared the database of monitored objects and their visibility, list of raw and reduced spectra, etc. Jan Fuchs prepared the observational user-interface for local and remote control of the telescope. The electric and/or electronic tools are controlled by Jan Fuchs and Luděk Řezba.

Remote observing is available to astronomers. For security reasons, our IT expert (Jan Fuchs) has to give the astronomer's computer (i.e., individual IP address) permission to access the telescope/instrument computers. During the night only one IP address (i.e. only one „outside" computer) can access the observational interface. This permission is automatically canceled the next day at noon UT. Of course, the remote astronomer also has all of the support data (meteorological station, slit camera and full-sky camera) at the disposal. For the remote control permission, the astronomer is required to know the telescope and has to spend some nights in Ondřejov personally.

Reconstruction and service works

The technical team realized and organized several significant service works or upgrades in the last years. These include:

- driving electronics of the 2 m Perek telescope (2007),
- driving electronics of the spectrograph (2010),
- New CCD chip EEV 42-10 BX – Pylon Excelon 2048x512 and the new driving user interface developed by Jan Fuchs (2013),
- service works on the dome shutter (2012)
- service of the mechanism of the opening/closing the shutter,
- service works on the 24 trucks of the dome (2014–) - step by step service of trucks on which the dome moves.

Group of High Energy Astrophysics

"High-energy astrophysics (HEA) is a perspective science branch and represents a modern and rapidly developing area of recent astrophysics which requires specific approaches. The HEA group in the Institute participates in space projects based on extended international collaborations. The related publication activity is on a high level and includes publications in journals with an impact factor. The scientific activity and output of the HEA group is internationally recognized with numerous collaborations and presentations in international conferences. The group, founded in 1990, is recently small but has numerous external collaborators and students." – René Hudec, head of the group.

Personnel

The working group is headed by R. Hudec. Staff: V. Šimon, J. Štrobl, C. Polášek, V. Hudcová. Several PhD students have been part of the group as well.

Research

The main research fields of the HEA group are: the study of gamma-ray bursts (GRBs), search for GRB optical counterparts, investigations of activity of celestial X-ray and gamma-ray sources, multispectral analyses, design and development of space and ground based instruments (robotic telescopes). Part of this research is investigation of afterglows of GRBs. The study concentrates on the analy-


CREDIT: NASA

Fig. 7 – Artistic impression of the NASA's mission SWIFT observing strong X-ray burst.

sis of the comprehensive properties of these events, the observed relation of the afterglow and the underlying supernova, and the implications for the environment in their host galaxies. The team made population studies of optical afterglows and obtained thus direct information about the environment of these GRBs. These studies also enabled to separate the contribution of synchrotron emission of a relativistic jet and thermal emission of the underlying supernova using commonly available observing methods.

The HEA group also studies the long-term activity of the astrophysical high-energy sources located in our Galaxy. It concentrates on the systems that contain a mass-accreting compact object like low-mass X-ray binaries, cataclysmic variables and supersoft X-ray sources. The research of the HEA group concentrates on the analysis of the long-term activity in the X-ray and optical regions. The team also investigates the dependence of the observed characteristics of these objects (and their activity) and their physical parameters. For investigating the activity in the X-ray band, this HEA group mainly uses data provided by the monitors on board satellites (in particular NASA RXTE and Swift – see Fig. 7). The group conducts time series analysis of the long-term variations and investigates the X-ray hardness ratios in various X-ray bands. It provides interpretations of the activity and the responsible physical mechanisms. It analyses the X-ray observations of the long-term activity of the X-ray transients and persistent X-ray sources, for example the neutron-star system KS 1731-260 which underwent peculiar repetitive changes of its accretion disk during transition from its very long main outburst (Šimon, 2010, Astronomy & Astrophysics, 513, A71). This study enabled to place this activity in the context of the systems with the mass accreting compact object. These analyses also show the importance of monitoring of the sky in the X-ray region.

Our specialty recognized worldwide is the study of archival photographic images, both direct and spectral, and we participate active-

The 0,25-m BART telescope of the GLORIA project located in one of the domes of the Institute.

ly in the rescue of valuable old observations stored in the archives of various observatories on glass photographic plates and negatives.We use these archival data to monitor the long-term behaviour of high-energy radiation sources and can thus follow and interpret their physical nature.This enables us to study the activity of such sources on very long time scales (at least several decades back to the past; e.g. Šimon, 2014, New Astronomy, 33, 44 pp., and Hudec, 2011, Astronomical Plate Archives and Binary Blazars Studies, Journal of Astrophysics and Astronomy, Volume 32, id. 91). These analyses also confirm the scientific importance of astronomical plate archives for astrophysics. They enable us to study the evolution of astrophysical objects during very extended time segments, in some cases even of the order of 100 years. Since many such optical counterparts display very strong activity which even undergoes large changes of its properties with time, such archival plates prove to yield very important information about the past activity which cannot be obtained by any other means. The new, before unknow, 1910 giant flare of supermassive BH candidate OJ287 found and investigated by us on HCO archival plates can serve as an example (Hudec et al., 2013, Astronomy and Astrophysics, Volume 559, id.A20). This research field is perspective because monitoring of a large sample of high-energy systems is needed to shed more light on the parameters of the state transitions (including the relation of these events to the state of the long-term activity) both of a given object and a group. The investigations included low dispersive spectral plates as well, which proved to serve as excellent tool for ESA Gaia satellite studies and simulations (Hudec and Hudec, 2011, Journal of Physics CS, Volume 328, id.012018).

The HEA group built and operates its own two robotic telescopes (D 0.5-m telescope, D50, and a D 0.25-m called BART), both with CCD detectors (e.g. Nekola, Hudec, Jelinek et al., 2010, Experimental Astronomy, Volume 28, id.79). They are used for photometry of optical emission of high-energy radiation sources, with emphasis on rapid follow up of celestial GRBs, specifically the observations of early phases of their optical afterglows in collaboration with the NASA satellite Swift. In this framework, it obtained CCD observations of the afterglow of GRB 090726 and pro-

D50 Ondřejov robotic telescope has been included within the GLORIA network

vided a physical interpretation (Šimon et al., 2010, Astronomy & Astrophysics, 510, id.A49). This analysis also proved the efficiency of this ground-based segment of satellite observing. The HEA group participated in a large international collaboration that provided observations of the afterglow of the unique gamma-ray source SWIFT J1955+2614 by a large network of ground-based monitoring telescopes and a very deep image of the quiescent source after the outburst using a D 10-m Spanish telescope (Šimon et al., 2012, MNRAS, 422/2, 981).The group also participates in interpreting the data. This included a discussion of the emission mechanisms and similarities between synchrotron emission of J1955, proved to be located in our Galaxy, and the optical afterglows of the extragalactic gamma-ray bursts. The HEA group also analysed the data from the instrument UVOT onboard the NASA satellite Swift for investigating the optical afterglow of GRB 060218 (Šimon et al., 2010, Astronomy & Astrophysics, 523, id.A56). This team investigated the time evolution of this afterglow, and searched for the common properties of this unique event and other long GRBs. Nowadays; both robotic telescopes are included in the first worldwide network of robotic telescopes with free access, developed with our participation (EU project GLORIA).

Besides observing optical afterglows of GRBs, the D50 instrument observes optical emission of selected high-energy sources. It is able to obtain series of images, which can be repeated for many nights and investigate the phenomena of the long-term activity of such sources. The group analyses these data and provides their physical interpretation. For example, it studied the activity of the cataclysmic variable V795 Her and showed how the tidal force is important in affecting the thermal-viscous instability of the accretion disk (Šimon et al., 2012, Astronomy & Astrophysics, 2012, 540, A15). This study has a general importance because it shows that the tidal heating like the one operating in V795 Her can also largely influence the state of the accretion disks in other systems (the so--called permanent superhumpers).

In this research, the HEA group has very rich experience in international cooperation, and collaborates e.g. with teams at the Dr. Remeis Bamberg Observatory of Erlangen University, Wurzburg University, Pennsylvania State University, IAA Granada, University College Dublin, MPE Garching, NASA GSFC, NASA MSFC, ESA, INAF Roma, INAF Bologna, University of Boulder, Colorado, USNO Flagstaff AZ, University of Utah Logan, Sonneberg Observatory, Hamburg Observatory, and many others. Also collaboration with Czech Institutions is extensive (Czech Technical University in Prague, Institute of Chemical technology, etc.). The HEA group uses data e.g. from satellites INTEGRAL, Swift, Fermi, RHESSI, RXTE, and simultaneously acquires data from optical telescopes, and so it can study the high-energy objects in a wide range of wavelengths. It also participates in the design and development of new innovative space experiments with an emphasis on X-ray optics, telescopes, and monitors, and participates in proposals for new space missions in the X- and gamma-ray astrophysics such as ATHENA, LOFT, THESEUS, LOBSTER etc. (e.g. Hudec, R. et al.: Czech Contribution to LOFT, Acta Polytechnica, Volume 53, id.30 (2013). The group regularly organizes international conferences and workshops (AXRO, ASTROPLATE and IBWS), and participates in the organization of large international conferences such as SPIE Europe, Frascati workshop on Multispectral behaviour of cosmic high-energy sources, and international conferences on Frontier objects in astrophysics.

Published Principal Results

We present abstract of the most interesting results of the last two years.

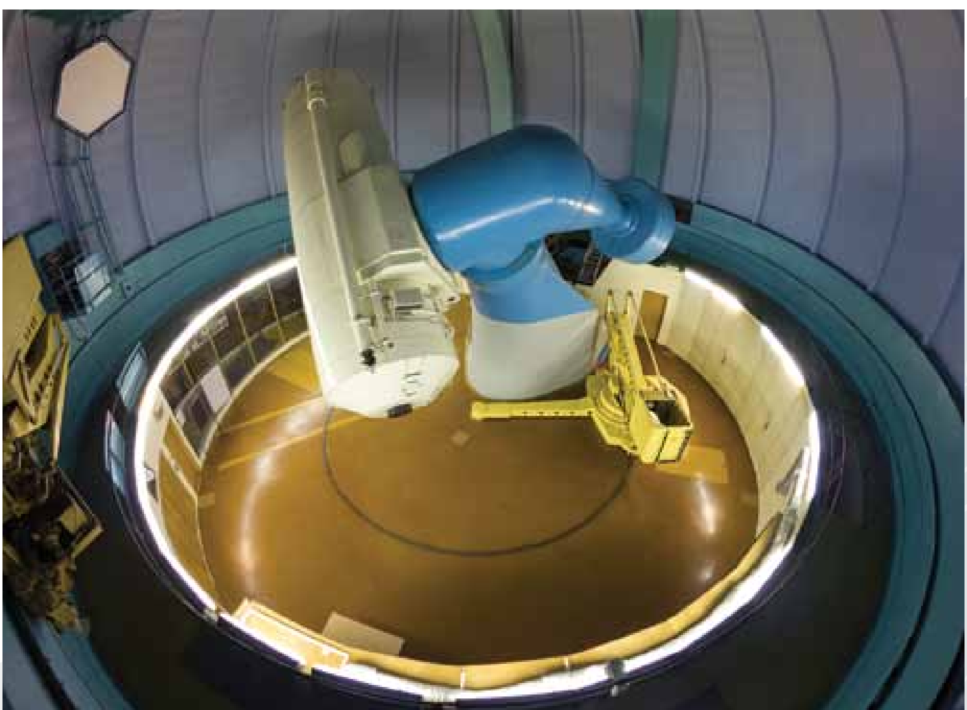
Probing the ejecta of evolved massive stars in transition. A VLT/SINFONI K-band survey
M. E. Oksala, M. Kraus, L. S. Cidale, M. F. Muratore, M. Borges Fernandes
Astronomy & Astrophysics, 2013, Volume 558, id.A17, 20 pp.

Massive evolved stars in transition phases, such as luminous blue variables (LBVs), B[e] supergiants (B[e]SGs), and yellow hypergiants (YHGs), are not well understood, and yet crucial steps in determining accurate stellar and galactic evolution models. The circumstellar environments of these stars reveal their mass--loss history, identifying clues to both their individual evolutionary status and the connection between objects of different phases. Here we present a survey of 25 such evolved massive stars (16 B[e]SGs, 6 LBVs, 2 YHGs, and 1 Peculiar Oe star), observed in the K-band with the Spectrograph for INtegral Field Observation in the Near-Infrared (SINFONI; R = 4500) on the ESO VLT UT4 8 m telescope. The sample can be split into two categories based on spectral morphology: one group includes all of the B[e]SGs, the Peculiar Oe star, and two of the LBVs, while the other includes the YHGs and the rest of the LBVs. The difference in LBV spectral appearance is due to some objects being in a quiescent phase and some objects being in an active or outburst phase. CO emission features are found in 13 of our targets, with first time detections for MWC 137, LHA 120-S 35, and LHA 115-S 65. From model fits to the CO band heads, the emitting regions appear to be detached from the stellar surface. Each star with ^{12}CO features also shows ^{13}CO emission, signaling an evolved nature. Based on the level of ^{13}C enrichment, we conclude that many of the B[e]SGs are likely in a pre-Red Supergiant phase of their evolution. There appears to be a lower luminosity limit of log $L/L_{\&SUN}$; = 5.0 below which CO is not detected. The lack of CO features in several high luminosity B[e]SGs and variability in others suggests that they may in fact be LBV candidates, strengthening the connection between these two very similar transition phases.

New binaries among UV-selected, hot subdwarf stars and population properties

A. Kawka, S. Vennes, S. O'Toole, P. Nemeth, D. Burton, E. Kotze, D. A. H. Buckley
MNRAS, 2015, 435, pp. 3514-3548

Hot subdwarf stars are core helium burning stars with thin hydrogen envelopes, and their common origin is closely linked to binarity. Using several telescopes from around the world, including ESO facilities, we have conducted a survey of 38 objects and measured the orbital parameters of seven new close binaries comprising a hot subdwarf primary and with orbital periods ranging from 0.17 to 3 days. Combining our results with those of other such surveys we have conducted a population study showing that the secondary mass distribution is dual peaked with the lower mass peak represented by cool low mass main-sequence stars and the higher mass peak being comprised of white dwarf stars.



Wide-angle view in the upper deck of the dome with Perek 2-m telescope, the largest instrument of the Ondřejov observatory. Credit: Petr Horálek.

V

THE DEPARTMENT OF INTERPLANETARY MATTER

Head scientist – P. Spurný. Deputy – P. Pravec.
Secretary: H. Zichová,
Phone: (+420) 323 620 160,
E-mail: hana.zichova@asu.cas.cz
"Attention of the department is devoted to the study of the interactions of interplanetary bodies of different sizes with the Earth's atmosphere and on physical studies of asteroids in the Solar system. The Department consists of two working groups: The Group of Meteor Physics and the Asteroid Group." – Pavel Spurný, head of the Department of Interplanetary Matter.

Meteor Physics Group

"The Group of Meteor Physics observes meteors in the optical region, analyses observed data by own methods and procedures (continuously improved) and performs theoretical interpretations of the observations. The basic observational system is the European Fireball Network (EN) which was established in former Czechoslovakia in 1963 and it is the longest continuously operational fireball network on the world. Faint meteors are observed by video techniques." – Jiří Borovička, head of the group.

Personnel

The working group was headed by J. Borovička. Research fellows: D. Čapek, P. Koten, P. Pecina, P. Spurný, R. Štork, L. Shrbený, V. Vojáček. Assistants: J. Boček, Z. Karas, J. Keclíková, L. Kopřivová, L. Smolíková, J. Starý, H. Zichová.

Ondřejov is the center of the European Fireball Network and all its activity is coordinated by our group. As of the end of 2014, the network consists of 11 stations in Czech Republic, 14 stations in Germany and 2 in Slovakia and Austria. In scope of this experiment we closely cooperate with colleagues from Comenius University in Bratislava operating 4 video all-sky systems in Slovakia and with several amateur groups active in the Netherlands, Poland, Slovenia, Croatia, Austria and Hungary. All Czech stations have been equipped with sophisticated instruments for optical observation of fireballs, the Autonomous Fireball Observatory (AFO) and, in the last three years, also the Digital Autonomous Fireball Observatory (DAFO). We significantly participated on development of these modern and fully automated instruments. They significantly increased efficiency

Department of Interplanetary Matter. From left to right: R. Štork, P. Pecina, P. Koten, P. Pravec, H. Zichová, D. Čapek, L. Smolíková, P. Kušnirák, V. Vojáček, K. Hornoch, J. Keclíková, J. Boček, J. Starý, J. Borovička, P. Spurný, L. Shrbený.

Meteor Physics Group. From left to right: D. Čapek, J. Boček, P. Koten, J. Borovička, P. Pecina, H. Zichová, L. Smolíková, J. Starý, P. Spurný, V. Vojáček, R. Štork, J. Keclíková, L. Shrbený.

of our observations and complexness and precision of the acquired data. Fireball spectra are simultaneously photographed at the Ondřejov Observatory.

"We also participate in the project of the Desert Fireball Network (DFN) in Australia equipped with AFO. Sensitive television cameras are used in the double station video observation program for observation of faint meteors and their spectra during the activity of interesting meteor showers. Similarly as in the case of fireball cameras we started modernization of the video observations of meteors. We developed new automatic video cameras MAIA (Meteor Automatic Imager and Analyzer). The cameras are located on two sites separated by 90 km (Ondřejov and Kunžak) and regularly carry out automatic double station observations. The observational data are used to study physical processes during the penetration of meteoroids into planetary atmospheres, including ablation, deceleration, radiation, and meteoroid fragmentation. The physical properties and chemical composition of different types of meteoroids, their origin and distribution in the solar system and their relation to comets, asteroids and meteorites are being determined. Theoretical calculations of the processes affecting meteoroids in interplanetary space (thermal destruction, changes of rotation) are also being performed." – Pavel Spurný, the researcher of the group.

The Group of Meteor Physics is a world-leading group in observations of bright bolides and interpretation of bolide data. In the recent years, we specialized on the instrumentally observed meteorite falls. The scientific value of the data increases when both bolide and the corresponding meteorites can be analyzed. The number of instrumentally observed meteorite falls rapidly increased in the recent years thanks also to our observations and/or computations.

Research Results

Using improved methods Spurný, Haloda, Borovička et al. (2014, Astronomy & Astrophysics 570, A39) performed a new analysis of the Benešov bolide of May 7, 1991 (Fig. 1). A revised atmospheric trajectory and a new impact location were obtained. This allowed us to recover four highly-weathered meteorites with a total mass of 12g exactly in the predicted area. For the first time a meteorite was found so long (20 years) after the bolide observation. Even more interestingly, the meteorites contain three different mineralogical types. The Benešov meteoroid and its parent asteroid were thus significantly heterogeneous.

The Ondřejov team did the most important part of this work. All records which we

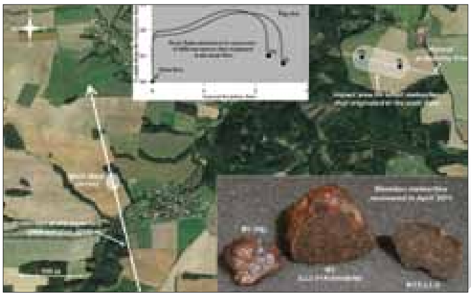


Fig. 1 – Projection of the terminal part of the atmospheric trajectory of the Benešov bolide, dark flight and corresponding impact area for small meteorites originated in the main flare, and Benešov meteorites found in 2011.

analyzed were taken by our cameras. We also did all measurements and computations which led to the revised atmospheric trajectory and determination of the new impact location.

Another interesting bolide brought meteorite in Slovakia and had been analyzed by Borovička et al. (2013, Meteoritics and Planetary Science, 48, 1757-1779). The Košice meteorite fall occurred in Slovakia on February 28, 2010. Bad weather prevented direct imaging of the fireball by dedicated meteor cameras. Fortunately, three surveillance video cameras in Hungary recorded, at least partly, the event. These records allowed us to reconstruct the trajectory and velocity of the fireball and recover the meteorites. In addition, the fireball light curve was recorded by camera radiometers through the clouds. New method of modeling atmospheric fragmentation of bolides was also described and applied to the Košice fall. We took into account macroscopic fragments as well as dust formed during the fragmentation. The dust was allowed to be released either immediately or gradually. Most of the Košice meteoroid was found to be quite weak in comparison with other ordinary chondrites. The orbit was characterized by large aphelion distance, almost approaching the orbit of Jupiter.

Probably the most discussed event in the decade, meteorite fall over Chelyabinsk, Russia, on 15th February 2013 (Fig. 2), had been analyzed and studied by Borovička, Spurný et al. (2013, Nature, 503, 235-237). The impact of an asteroid near Chelyabinsk, Russia, in February 2013 was the largest collision with cosmic body since 1908. It caused significant damage and worldwide attention. In the work the atmospheric trajectory and velocity was determined from casual video records. Atmospheric fragmentation was described in detail with inferences about the internal structure of the body. Heliocentric orbit was determined and it was suggested that the impactor originated from larger asteroid 86039.

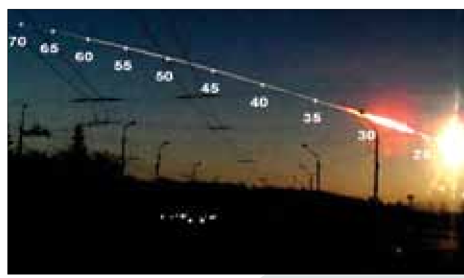


Fig. 2 – Video frame of the Chelyabinsk bolide and its trail taken by A. Ivanov in Kamensk-Uralskyi with height marks added according to our trajectory computation (heights above sea level in km).

The most important part was the determination of trajectory and velocity from non-scientific records. That work was done entirely by our team. The method was invented here, the software was prepared and the measurements were done. Our team computed the fragmentation, the interpretation of the atmospheric behavior and the properties and landing points of individual fragments.

A very bright Perseid fireball on 12th August 2012, recorded by different instruments operated by Ondřejov team and photographer Horálek, had been analyzed by Spurný et al. (2014, Astronomy & Astrophysics, A64, 6 pp.). This is the highest meteor ever observed that does not belong to the Leonid shower. Its atmospheric trajectory and orbit belong to the most precise and reliable ever obtained for Perseid meteor. Its video spectrum is the highest spectrum of a meteor ever obtained. For the first time we proved that only atmospheric emissions of O, N and N2 were present above 130 km. This work was done entirely by the team.

"Studies of meteor showers is one of our main programs too. We regularly observe annual meteor showers with video techniques. The pupose is not only to infer the activity profile but also to study physical properties and spectra of meteoroid from various parent bodies or to search for possible new showers." – Pavel Koten, the researcher of the group.

The fireball networks provide data on large shower meteoroids and occasionally capture unexpected activity of some showers, as was the case of September Epsilon Perseids in 2013 and Kappa Cygnids in 2014. In some cases the video and photographic data can be combined leading to very complex analyses of individual fireballs (see the Perseid with exceptional beginning height above 170 km).

We studied the possible meteoroid stream associated with the Příbram and Neuschwanstein meteorites (Koten et al., 2014, Icarus. vol. 239, pp. 244-252). The trajectories and orbits of video meteors were analysed to determine whether such stream may contain also small particles. An orbital evolution model was applied on cloned particles to investigate possible connection. It was tested if such small sample of the orbits is similar by chance or if the stream is real. We found that is impossible to prove the existence of faint meteor shower connected with the stream. This work represents cooperation between Czech and French astronomers and connection of both experimental and theoretical approaches in study of the meteor showers. All the experimental data were obtained within the double-station observational program in the Czech Republic. The data were analyzed using the tools of the Czech part of the team. The French scientists contributed with the modeling of the orbital evolution of the meteoroids, since they are experts in this field of meteor astronomy.

A Draconid meteor shower outburst in 2011 was observed from on board two scientific aircraft deployed above Northern Europe on 8th October 2011. The activity profile was measured using a set of photographic and video cameras. The results show (Koten et al., 2014, Earth, Moon and Planets, vol. 112, p. 15-31), that the main peak of the activity occurred around 20:15 ± 0:0.5 UT which is consistent with the model prediction. The corrected hourly rates reached a value of almost 350. The brighter meteors peaked about 15–20 min earlier than the dimmer ones. This difference can be explained by different directions of the ejection of the meteoroids from the parent comet. One of the instruments was even able to detect meteors connected with the material ejected from the parent comet before 1900 and thus confirmed the prediction of the model, although it was based on uncertain pre-1900 cometary data. Another small peak of the activity, which was caused by material ejected during the 1926 perihelion passage of the parent comet, was detected around 21:10 UT. The mass distribution index determined using the narrow field-of-view video camera was 2.0 ± 0.1. This work shows that the observation of meteor outbursts can constrain the orbital elements, outgassing activity and existence of jets at the surface of a comet.

The structure of small cometary meteoroids and the process of their ablation in the atmosphere are still not well understood. Borovička et al. (2014, Earth, Moon, and Planets, Volume 113, p. 15-31) analyzed complex data on 8 Draconid meteors, which represent the most fragile meteoroids known. We have combined spectroscopy (Fig. 3), photometry, dynamics and morphology of the meteors to study the properties of 1 – 3 cm sized meteoroids. Some meteors had smooth and flat light curves without any flares, high decelerations, and the release of most sodium in the first half of their trajectories. All these features can be explained by the complete and quick disintegration of the meteoroids into small grains. Other meteors had low deceleration, exhibited flares at relatively low heights 84–83 km and sodium was present along the whole trajectories. Our analysis suggests that their bulk density was similar to the meteoroids of the previous group and their fragmentation started at similar heights. The main difference was that the grain release was much slower and not from the whole body. This work, which was done entirely by our team, demonstrated that various textures with various resistances to atmospheric fragmentation exist among Draconid meteoroids and even within single meteoroids.

The rotation of meteoroids after the ejection from comets has not been studied until Čapek started to work on that (2014, A&A 568, A39). He developed a sophisticated numerical model that describes the rotation of irregularly shaped meteoroids due to action of a gas escaping from the nucleus of a parent comet. Meteoroid shapes were approximated by digitized shapes derived from distinct sets of different terrestrial rock samples. Simple relationship was derived for median of spin frequencies f (Hz) as a function of meteoroid size D (m) and ejection velocity v_{ej} (ms^{-1}) as $f = (2\text{-}5)\times10^{-3}\ v_{ej}\ D^{-0.88}$. The dependence of the median of spin frequencies on meteoroid density and on the physical properties of cometary nucleus is hidden in the value of v_{ej}. The distribution of spin frequencies is roughly normal on the log scale. It is relatively wide with more than 95% of values inside the interval (0.1, 10) times f Most of meteoroids are non-principal axis rotators. The median of mean angle between angular momentum vector and spin axes is approximately 12°. Angular momentum vectors are not distributed randomly in space, but are concentrated it the perpendicular directions with respect to the gas flow.

Borovička was invited to be lead author of a chapter in the book Asteroids IV of the University of Arizona Press (2015, arXiv: 1502.03307) by the editors. He selected Spurný and Brown from Canada as co-authors. The chapter is a review of the current knowledge of properties of small (1 – 20 m) asteroids based on the observation of fireballs and, in particular, the instrumentally observed meteorite falls. The observation techniques and methods of data analysis are also reviewed.

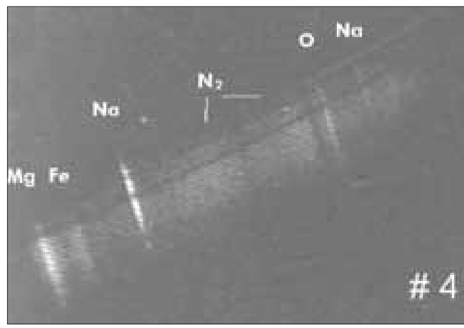


Fig. 3 – The spectrum of one of the studied Draconid meteors (co-added video frames) showing clearly the shift of the Na emission to higher altitudes.

Most of the chapter was written by our team members. P. Brown contributed some special techniques (infrasound), described some individual events (carbonaceous meteorite falls, Carancas) and the influx section.

Asteroids Group

"The Asteroids group focuses on physical studies of asteroids in the Solar system. We study non--gravitational processes in small asteroids, binary systems and paired asteroids, and asteroids in excited (non-principal) rotation states. We also observe so-called Near-Earth Asteroids (NEAs) and their source regions. NEAs are a part of the asteroid population that represents an impact hazard for the Earth. Precise astrometry allows to determine the orbits of NEAs and therefore to calculate their potential risk for the Earth. There is a number of observatories across the

world which collaborate with us on the project. Our two main observational instruments are the 1.54-m Danish telescopes at the European Southern Observatory, La Silla, Chile which we use since 2012 and the 0.65-m telescope at Ondřejov. The observations on the 1.5-m telescope at La Silla are run within our collaborative project with the Danish colleagues at the Niels Bohr Institute, Copenhagen University. The collaboration with the other observatories across the world provides us with data from a number of their instruments that allow us to get a substantially more thorough understanding of the studied objects." – Petr Pravec, head of the group.

Asteroids Group. From left to right: P. Scheirich, T. Henych, K. Hornoch, P. Pravec, P. Kušnirák, A. Galád.

Personnel

The working group was headed by P. Pravec. Research fellows: P. Scheirich, A. Galád, T. Henych. Assistants: P. Kušnirák, K. Hornoch.

Research results

We studied absolute magnitudes and albedos of asteroids (Pravec et al., 2012, Icarus 221, 365-387). Two of the key physical quantities of asteroids are their absolute magnitudes and albedos and their knowledge is needed in about any study of asteroids (see Fig. 4). Thus we analyzed our precise photometric observations that we obtained for 583 main-belt and near-Earth asteroids with the Ondřejov 0.65-m and the Table Mountain Observatory 0.6-m telescope since 1978 to 2011. With our precise data, we studied an accuracy of asteroidal absolute magnitudes published in the catalogs MPCORB, AstDyS and JPL Horizons. We found that the data in the catalogs are systematically biased for asteroids with absolute magnitudes H > 10 (corresponding to asteroid diameter D ≤ 30 km), and especially above H ~ 12 (D ≤ 10 km). As a result of the catalog data bias, asteroid albedos derived from thermal infrared observations made by the Wide-field Infrared Survey Explorer (WISE) spacecraft were severely biased; for small asteroids, the WISE albedos were overesti-

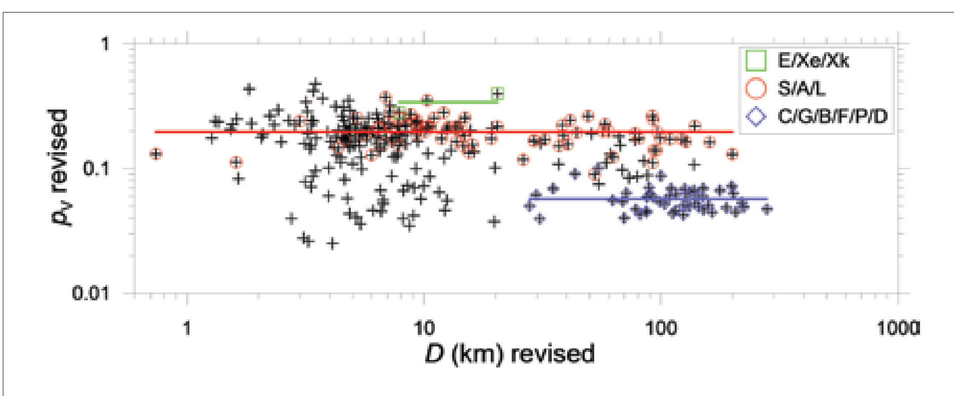


Fig. 4 – Asteroids of different compositions have different albedos. The primitive types (C and similar) are dark, scattering only about 6% of incoming sunlight, but the diferentiated (rocky; S and similar types) asteroids are lighter with geometric albedos about 0.20.

mated by as much as 50% on average. We derived corrected albedos for the asteroids in our sample and we found that a trend of the mean WISE albedo estimates increasing and from collaborating stations in Europe, North and South America and Australia. We derived parameters of the binary asteroids. We found that the binary orbits are not

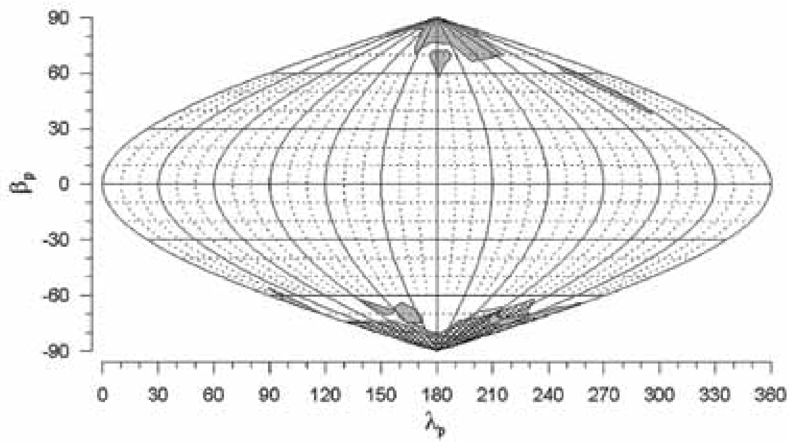


Fig. 5 – Poles of binary asteroids concentrate around both the North and South Pole of the ecliptic. This anisotropy is explained as a result of the spin axis evolution under the influence of the non-gravitational thermal effect called YORP.

with asteroid size decreasing from D ~ 30 down to ~5 km for S-type asteroids found by Mainzer et al. (2011) was largely due to the systematic bias in the MPCORB absolute magnitudes that they used. We showed that albedos of S-type asteroids actually do not change with asteroid size, and we derived the unbiased mean albedos for S/A/L and C/G/B/F/P/D asteroids. These results are important for many fields of studies of asteroids, and for our studies of asteroid evolutionary processes in particular, as our accurate, non-biased data are needed for correct physical interpretations.

We also studied 18 binary asteroids, that we discovered during 2005-2011, especially their properties and constraints on evolutionary processes (Pravec et al., 2012, Icarus, 218, 125-143). We used the technique of time-resolved photometry. The data were taken with the Ondřejov 0.65-m telescope oriented randomly. We analyzed the data including simulations of observational selection effects and we found that the binary orbital poles concentrate within 30 deg from the poles of the ecliptic. We proposed two explanations for the concentration, both being due to an action of the thermal YORP effect on asteroids. The effect is a result of the torque of infrared photons emitted from asteroid's irregular surface. This effect, besides spinning up the asteroid up to the critical frequency, also moves its pole to the up- or downright position. The findings extend our knowledge on how the YORP effect acts on asteroids (see Fig. 5). This non-catastrophic evolutionary mechanism is a key process that re-shapes the asteroid population.

The Ondřejov team took a part of the photometric observations of the asteroid binaries and we collected observations taken from several collaborating stations in the world. We modeled the data and derived parameters of the binary systems. We run simulations of the photometric survey, described observational biases present in the data and derived the distribution of orbital poles of the asteroid systems.

Henych & Pravec continued in the study of the effects of subcatastrophic impacts of small asteroids (2013, MNRAS, 432, p. 1623-1631). They simulated collisions between asteroids of various physical and material parameters. They found that tumbling is photometrically detectable for the rotational axis misalignment angle ß ≥15 deg. They also found that subcatastrophic collisions are a plausible cause of non-principal axis rotation for small slowly rotating asteroids. The determining parameter is the ratio of the projectile orbital angular momentum to the target rotational angular momentum, and we derived a relation between this ratio and the angle ß. Then they compared the limiting energy for the onset of tumbling with the shattering energy. Slowly rotating asteroids of diameter ≥100 m can be rotationally excited by collisions with energies below the shattering limit.

We also analyzed a spin state of asteroid (99942) Apophis (see Fig. 6). As known, this asteroid possesses a small risk of impacting Earth in 2068 and a knowledge of its spin state is important for improving modeling of its orbit and refining its impact probability estimate. We measured (Pravec et al, 2014, Icarus, 233, 48-60) it extensively with the 1.54-m telescope at La Silla observatory and a few collaborating stations. We analyzed the obtained data and we found that the asteroid is in a state of non-principal axis rotation (i.e., free precession, also called tumbling). Our results indicate a slightly increased probability of the asteroid's impact on 2068 April 12, but it is still very small; our follow-up paper with detailed modeling of the Apophis' orbit and analysis of the impact probability by Farnocchia et al. (2015) is in press. We also looked at Apophis in a context of the population of slowly tumbling asteroids, estimated their rotational damping times and discussed possible spin excitation mechanisms. We found that tumblers predominate among slowly rotating asteroids with damping times ≥ 0.2 Gyr. Our results suggest that there are actually two or more asteroid spin evolution mechanisms in play, or that the factor of μQ (the rigidity times the quality factor) decreases with decreasing asteroid size. These findings have important implications for our understanding of properties and evolutionary processes working in near-Earth asteroids.

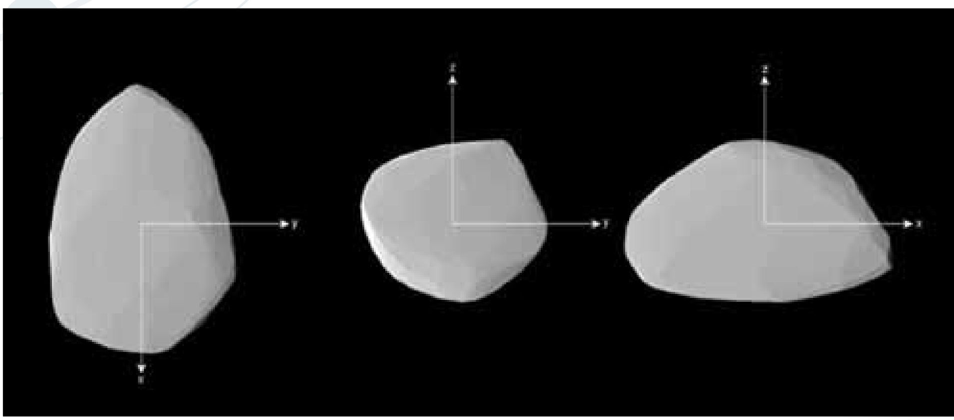


Fig. 6 – Shape model of the potentially hazardous, asteroid (99942) Apophis.

Our team obtained the most abundant data for Apophis, with the 1.54-m telescope on La Silla and the 0.65-m telescope in

Ondřejov. Then we analyzed and modeled the data using methods we developed, with contribution by our colleague Ďurech. We applied the theories of asteroid de-excitation in interpretation of the results. The expertise of our team, both on the photometric observations and on the modeling and theoretical interpretation front, was crucial for the work. A thorough collaboration with a few other teams of experts in the world was also a key to this success.

Published Principal Results

We present abstract of the most interesting results of the last two years.

The trajectory, structure and origin of the Chelyabinsk asteroidal impactor

J. Borovička, P. Spurný, P. Brown, P. Wiegert, P. Kalenda, D. Clark, L. Shrbený
Nature 503, p. 235-237 (2013)

Earth is continuously colliding with fragments of asteroids and comets of various sizes. The largest encounter in historical times occurred over the Tunguska river in Siberia in 1908, producing an airburst of energy equivalent to 5-15 megatons of trinitrotoluene (1 kiloton of trinitrotoluene represents an energy of 4.185×10^{12} joules). Until recently, the next most energetic airburst events occurred over Indonesia in 2009 and near the Marshall Islands in 1994, both with energies of several tens of kilotons. Here we report an analysis of selected video records of the Chelyabinsk superbolide of 15 February 2013, with energy equivalent to 500 kilotons of trinitrotoluene, and details of its atmospheric passage. We found that its orbit was similar to the orbit of the two-kilometre-diameter asteroid 86039 (1999 NC43), to a degree of statistical significance sufficient to suggest that the two were once part of the same object. The bulk strength--the ability to resist breakage--of the Chelyabinsk asteroid, of about one megapascal, was similar to that of smaller meteoroids and corresponds to a heavily fractured single stone. The asteroid broke into small pieces between the altitudes of 45 and 30 kilometres, preventing more-serious damage on the ground. The total mass of surviving fragments larger than 100 grams was lower than expected.

Reanalysis of the Benesov bolide and recovery of polymict breccia meteorites - old mystery solved after 20 years

P. Spurný, J. Haloda, J. Borovička, L. Shrbený, P. Halodová
Astronomy & Astrophysics, 2014, Volume 570, id.A39, 14 pp.

The main motivation for this work was to explain and solve the old mystery connected with the detailed instrumental observation of the Benešov superbolide on 7 May 1991 over the central part of the Czech Republic. Detailed analyses of this undoubted meteorite fall were published in several papers, and this is one of the best documented bolides (at least of the superbolide category) ever observed. However, despite high-quality data, favorable trajectory, relatively large terminal mass, and especially great efforts and many attempts, no meteorite was found in the weeks and years after the fall. Here we solve and explain this old mystery. In spring 2011, just before the twentieth anniversary of this extraordinary case, we remeasured all available all-sky records and reanalyzed the data. We used slightly different methods and new approaches, which we gradually developed to analyze several recent instrumentally observed meteorite falls (Morávka, Neuschwanstein, Jesenice, Bunburra Rockhole, Mason Gully, and Košice). We assembled a new consistent picture of the Benešov event, which resulted in a slightly revised impact location and suggested a new strategy that might lead to a recovery of Benešov meteorites after 20 years. The reality completely confirmed all our assumptions and surpassed our expectations. We found four small highly weathered fragments irregular in form and completely without fusion crust with a total mass of 11.63 g (1.54 g (H5), 7.72 g (with achondritic clast), 1.99 g, 0.38 g (all LL3.5)). They were recovered exactly in the predicted impact area for corresponding masses, namely within 40 m from the highest probability line. Although all fragments are very small and their weathering grade is high (W3 for all pieces), their interior was preserved enough for reliable analysis (except for the smallest one). The meteorite is classified as a polymict breccia containing three recognized lithologies with different texture, chemical, and mineralogical composition. This result is pioneering in many aspects. We proved that in some special cases it is still possible to predict and find meteorites a long time after the fall. The most important result, however, is the heterogeneity of the recovered meteorites. This case clearly shows that larger meteoroids can be compositionally very complicated bodies. We discovered that the Benešov meteoroid consisted of at least three different types of material – LL3.5, H5, and primitive achondrite. This case also implies that it is very useful to study as many fragments as possible from one fall because there can be significant differences among them.

Instrumentally documented meteorite falls: two recent cases and statistics from all falls

P. Spurný

Proceedings of the International Astronomical Union, 10, pp 69-79 (2015)

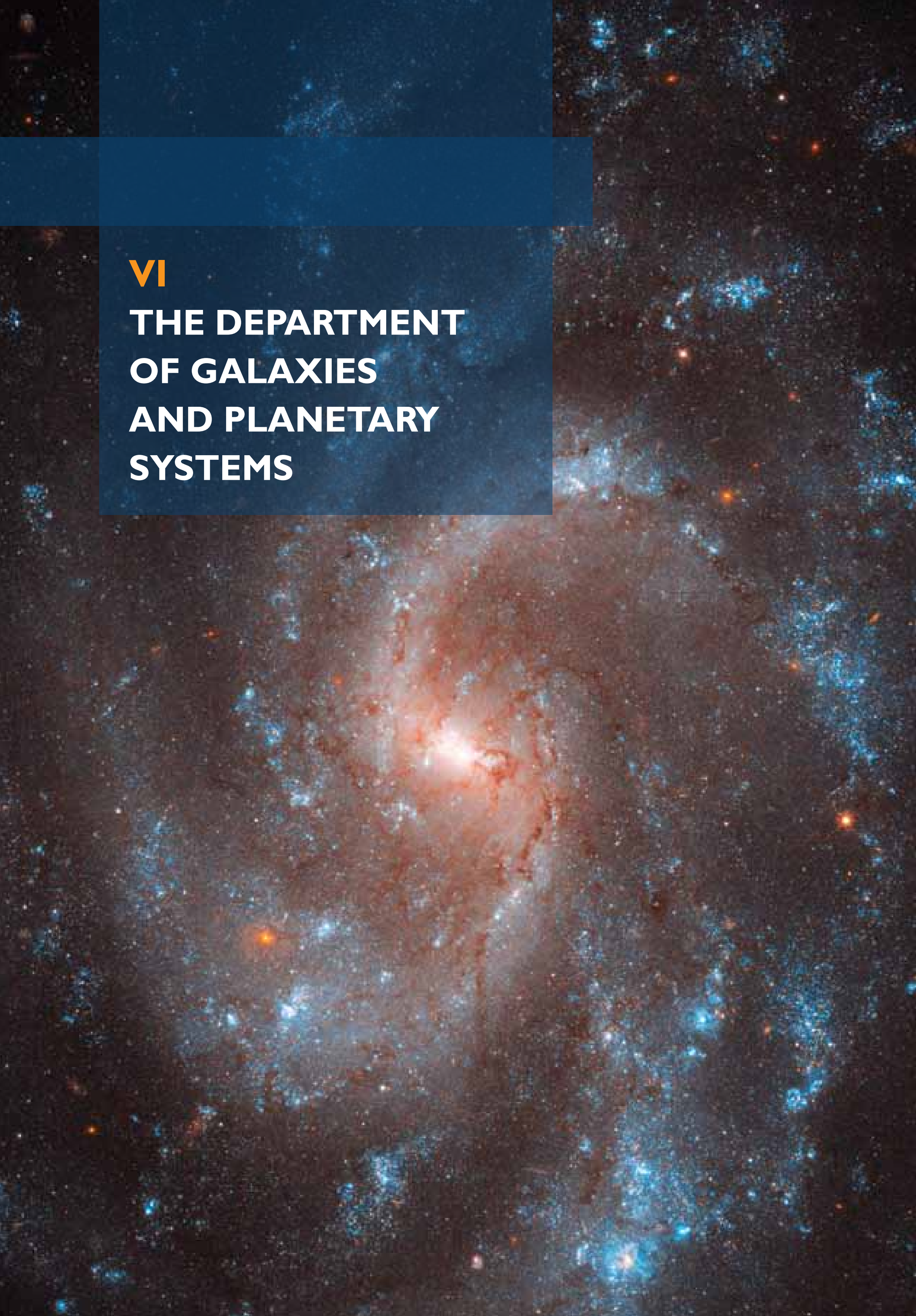
Very successful observation of the Žďár nad Sázavou (shortly Žďár) meteorite fall on 9th December 2014 (Spurný 2015) was a direct result of more than two years of intensive modernization of the Czech part of the European fireball network (EN). This modernization consisted in development of the new digital autonomous fireball observatories (DAFO), which were gradually installed alongside the older "analog" (using photographic films) autonomous all-sky system (AFO) on all Czech stations. Luckily this modernization was finished by deployment of the DAFO on the last station of our network just a few hours before the bolide! The fall of the meteorite was captured photographically and photoelectrically by 10 cameras at 7 Czech stations of the EN at 16:16:45 UT. Thanks to immediate availability of digital images very precise data on atmospheric trajectory, heliocentric orbit, luminosity, dynamics, fragmentation history and probable impact area were quickly determined (see images on page 59). The first small meteorite (6g) was found on 20 December 2014. Two more meteorites 39 g and 42 g were found on 12 January and 2 May 2015. All three meteorites were found during dedicated search and all were recovered exactly in the predicted location for given mass. The meteorites were classified as the L3.9 ordinary chondrite, which means, that it is a very primitive material. Žďár is then the lowest metamorphosed L chondrite among all 24 known instrumentally documented falls and thanks to the high quality and large number of available instrumental records this case belongs to the best ever described meteorite falls.

Fireball camera snapshot of bolide Žďár nad Sázavou from December 9th, 2014.

Dedicated search for meteorites in the predicted impact area.

One of the recovered meteorites captured in its original position.

VI
THE DEPARTMENT OF GALAXIES AND PLANETARY SYSTEMS



Head scientist – J. Palouš. Deputy – C. Ron.
Secretary: M. Bečvářová,
Phone: (+420) 226 258 400,
E-mail: marcela.becvarova@asu.cas.cz

"Research of the team focuses in the areas of star formation and stellar clusters, evolution of galaxies in groups and clusters, super-massive black holes in the center of the Milky Way and central parts of active galaxies. Another active theme is Earth's rotation and its gravity field, and precise astrometry. There are three working groups in the department." – Jan Palouš, head of the Department of Galaxies and Planetary Systems.

Physics of Galaxies Working Group

"The mission of the group is to study star formation, to explore physical processes in young massive stellar clusters, and to discuss the evolution of galaxies in groups and clusters. Radio, infrared, optical, and X-ray observations are compared to analytical models and computer simulations of gravitational and MHD processes." – Jan Palouš, head of the group

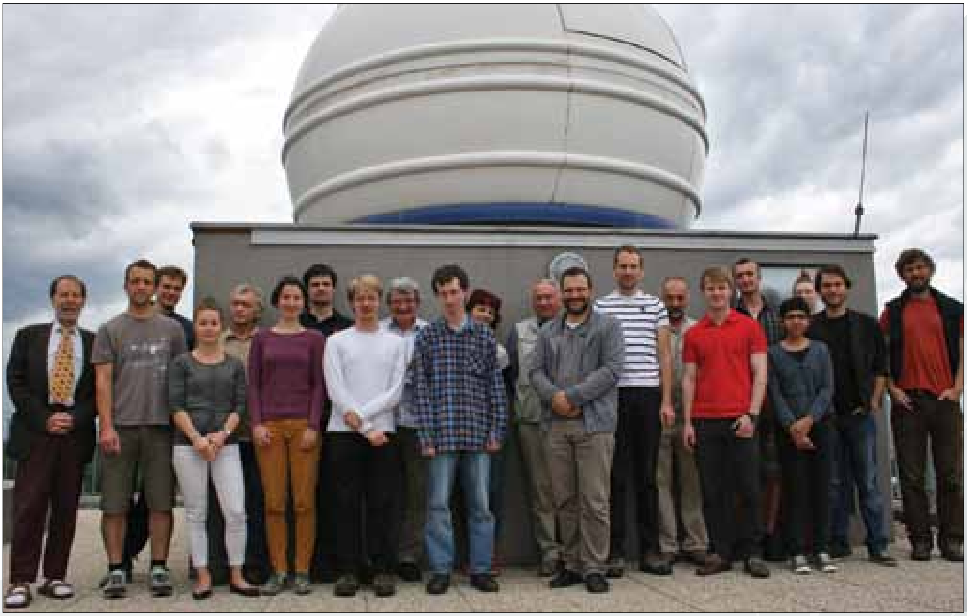
Personnel

The working group is headed by J. Palouš. Research fellows: S. Ehlerová, P. Jáchym, B. Jungwiert and R. Wünsch. Post-doctorate fellows: I. Ebrová, I. Orlitová, R. Taylor, and there are several PhD students.

Research results

Interstellar medium in galaxies, including our own Milky Way, is full of different structures. Many of them, namely HI shells and IR bubbles, are thought to be created by the energy released by massive stars. This release leads to an expanding shock wave, which propagates through the interstellar medium and sweeps it to denser walls encircling less dense interiors. In younger stages of the evolution, the walls are detectable by their infrared (IR) emission, while in later stages the best medium for observations is the neutral hydrogen (HI).

We performed multi-wavelength studies of several IR bubbles: N094, N115, N131 (see Fig. 1), where we compared the distribution of the heated gas (IR emission) with the dense molecular gas (CO) and the neutral hydro-



Department of Galaxies and Planetary Systems. From left to right: Z. Šíma, O. Kopáček, P. Jáchym, I. Tužinská, P. Hadrava, T. Jeřábková, R. Wünsch, R. Taylor, J. Palouš, F. Dinnbier, M. Bečvářová, J. Vondrák, M. Dovčiak, M. Bursa, C. Ron, J. Čechura, J. Hamerský, D. Kunneriath, I. Ebrová, F. Marin, J. Horák.

Physics of Galaxies Group. From left to right: P. Jáchym, T. Jeřábková, J. Palouš, F. Dinnbier, I. Ebrová, R. Wünsch, R. Taylor.

gen (HI). Finding CO and HI which belong to the structure enables us to estimate distances – and consequently dimensions – of bubbles, that are otherwise unavailable. One IR bubble, N107, was intensively studied and numerically simulated (Fig. 2 – Sidorin et al, 2014). Since IR bubbles are usually young, their progenitors, i.e. young stars producing the energy, should still exist. We tried to locate them and compare their properties with our predictions based on observations of IR bubbles.

HI shells are usually older than IR bubbles and often they are also more energetic. We made a catalogue of HI shells in the Milky Way based on the Leiden/Argentina/Bonn (LAB) all-sky HI survey (Ehlerová & Palouš, 2013, Astronomy&Astrophysics, 550, 23). We used an automated search routine, which was first used in the previous paper (Ehlerová & Palouš, 2005, Astronomy&Astrophysics, 437, 101). Now it was improved and applied to an all-sky survey. The advantage of using the automated search is the uniformity of results. We identified 333 shells in the Milky Way. We also obtained the Hα spectrum of one of the largest galactic HI supershells, GS242-0+37, to test, if its walls or interior are (partially) ionized, i.e. if it still powered by massive stars.

Fig. 1 – Multiwavelength image of the infrared bubble N115: the infrared emission (red), the parent CO cloud (green) and the neighbouring HI (blue).

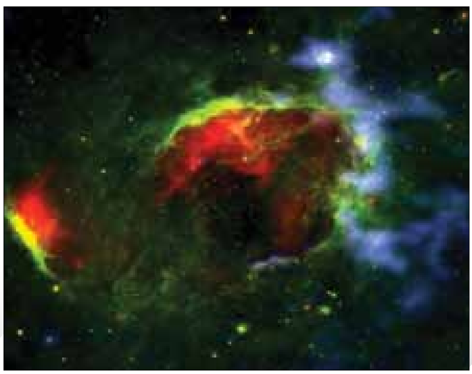


Fig. 2 – N107: bubble in the Galactic plane (Sidorin et al. 2014, Astronomy&Astrophysics, 565, 6).

A long studied topic in the group is the gravitational fragmentation of HI shells. We analyzed the fragmented wall of the Carina Flare Supershell (Wünsch et al, 2012, Astronomy&Astrophysics, 539, 116) and we performed new MHD numerical simulations.

Another objects of the interest are young massive stellar clusters (Super Star Clusters – SSC). They present large numbers of massive stars all of which lose substantial fractions of their mass in stellar winds and supernova explosions. Chevalier & Clegg (1985, Nature, 317, 44) – CC85 – proposed a model of SSC winds, where the mechanical energy of individual stellar winds and supernovae (SNe) is thermalized in random collisions causing the reinserted gas to heat up to large temperatures (~107 K). This produces a large overpressure able to drive a stationary cluster wind. The radiative and other energy losses are neglected in CC85's adiabatic model, given the low cooling rates expected from gas at such high temperatures. However, the adiabatic model becomes inadequate for massive and compact SSCs (Silich et al. 2004, Astrophysical Journal, 610,226): as soon as the cluster mass approaches a critical value, cooling becomes important and the CC85 model no longer applies. Tenorio-Tagle et al. (2007, Astrophysical Journal, 658, 1196), Wünsch et al. (2007, Astronomy&Astrophysics, 471, 579; 2008, Astrophysical Journal, 683, 683) and Palouš et al. (2010, AUS, 266, 41; 2011, AUS, 270, 267) proposed a new model in which clusters evolve in the bimodal hydrodynamical regime only a fraction of the inserted gas leaves the cluster as a wind (see Fig. 3).

In Palouš et al. (2013, Astrophysical Journal, 772, 128), we have generalized the model to use the radial distribution given by the Schuster profile and studied how the results depend on its steepness. There is solid observational and theoretical evidence that dust produced by supernovae can survive passage through the reverse shock and get into the hot medium where it may contribute to cooling. Since the cooling function is an essential input into the cluster wind model, we study the influence of the dust cooling in Tenorio-Tagle et al. (2013, Astrophysical Journal, 778, 159). Another important process that has to be taken into account to predict the mass of the second stellar generation is the ionization of surfaces of dense clumps by the EUV radiation of massive stars of the first generation. We have developed an analytical model and estimated time after which the clumps start to self-shield themselves and cool below 10^4 K (Palouš et al., 2014, Astrophysical Journal, 792, 105). In Silich et al. (2010a, Astrophysical Journal, 711, 25), we predict that massive young galaxies with high star formation rates similar to those detected as SCUBA sources are likely to accumulate the mass in their interiors leading to a fast interstellar matter enrichment, as observed in high redshift quasars. Nuclear star clusters, that typically include supermassive black holes, have been studied in Silich et al. (2010b, AUS, 267, 324) and Hueyotl-Zahuantitla et al. (2010, Astrophysical Journal, 716, 324; 2013, Astrophysical Journal, 766, 92). We show, using radiation-hydrodynamic simulations including AGN X-ray heating, that a filamentary/clumpy structure is formed in the inner part of the cluster.

Using millimeter telescopes ESO APEX and IRAM 30m we searched for cold, molecular gas in tails of ram pressure stripped (RPS) galaxies in galaxy clusters (see Fig. 4). The removal of star-forming interstellar matter (ISM) reservoir from orbiting galaxies by ram pressure of intra-cluster medium (ICM) is a powerful mechanism that can cause sudden quenching of star formation (SF) and make the cluster late-type stav forming galaxies migrate through the "green valley" of the galaxy color-magnitude diagram, towards passively evolving, gas-poor S0 and Sa types. The stripped ISM forms one-sided, "cometary" tails extending from the galaxies.

With the IRAM 30m telescope we further discovered abundant molecular gas along the 50 kpc long RPS tail of the Coma cluster galaxy D100. Our observations suggest (Jáchym et al., 2013, Astronomy&Astrophysics, 556, 99; Jáchym et al., 2014, Astrophysical Journal, 792, 11), that in massive clusters, compression of stripped gas by the surrounding ICM that determines the temperature and density dis-

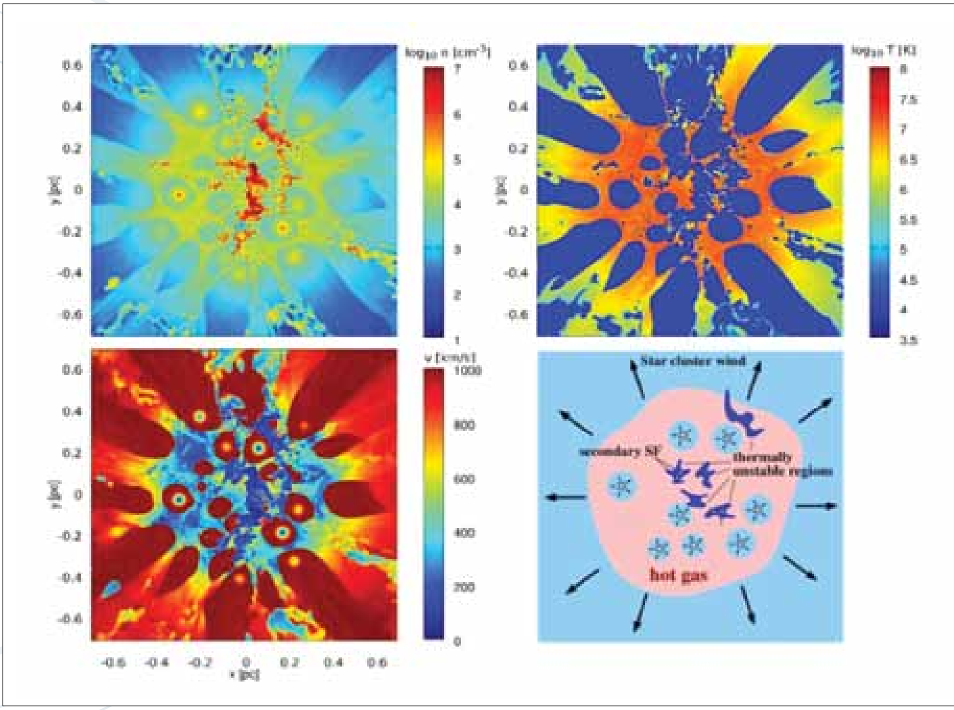


Fig. 3 – Model of the cluster in the bimodal regime. The sketch on the bottom right panel shows how dense clumps are formed in the central cluster region by the thermal instability of the hot gas. At the same time, the cluster wind emerges close to the border of the cluster. The other panels show a snapshot from our 3D hydrodynamic simulation: logarithm of the particle density (top left); logarithm of temperature (top right); and the wind velocity (bottom left).

tribution of gas in the tail, is efficient in producing observable levels of both hot and cold gas phases. In the less massive Virgo cluster, we searched for molecular gas in the prominent star-forming tail of the dwarf galaxy IC3418, but we reached only sensitive upper limits, and moreover our deep Chandra observations did not reveal any soft X-ray emission. Recently, our project was accepted for observations with the millimeter interferometer ALMA.

We focused on using stellar shells in so-called shell galaxies as tools to constrain their gravitational potential. Shells are faint arc-like features, mostly formed as tidal caustics through an accretion of a dwarf galaxy along an almost radial trajectory. They are kinematical density waves propagating from the center of the host galaxy. In the first phase, we developed, under the λ-CDM paradigm, a new method to constrain the dark matter distribution around elliptical galaxies. This is very important since shells occur predominantly in ellipticals where it is more complicated to infer the dark matter profile than in disk galaxies. The method (Jílková et al., 2010, ASPC 423, 243; Ebrová et al. 2012, Astronomy & Astrophysics 545, 33; Ebrová, 2013, PhD thesis, arxiv:1312.1643) builds on our prediction of a quadruple-peak line-of-sight velocity profile; it relies on relating the four peaks to the gravitational potential. In the second phase, we embarked upon using shell galaxies to test the Modified Newtonian Dynamics (MOND), as alternative to the dark matter hypothesis solving the missing mass problem. In Bílek et al. (2013, Astronomy & Astrophysics, 559, 110), we used our newly developed shell identification method (1) to show that the shell distribution in the galaxy is well compatible with MOND, (2) to derive the age of the shell system and (3) to confirm the earlier expectations that the accreted galaxy has to make a few oscillations before it gets finally dissolved.

We developed a code for performing the shell identification method automatically. We used it in Bílek et al. (2014a, Astronomy & Astrophysics, 566, 151) to predict that if MOND works, then a new shell in NGC 3923 must exist at the distance of around 200 kpc from the center. This provides a strong test of MOND. CFHT 3.6-m telescope accepted our proposal under the international Opticon Access Program and will try to find the shell observations in 2015. In Bílek et al. 2014b (accepted to Astronomy & Astrophysics, arXiv:1412.6556) we showed what we would measure by the above method of Ebrová et al. if MOND is correct. Related developments on shell galaxies and MOND, namely a prediction of a counterpart of the Tully-Fisher relation, are given in Bílek et al. 2014C (2015, Can. J. of Phys., vol. 93, pp. 203-212). All the above research on shell galaxies was carried out fully at our institute with a strong participation of 6 PhD students; 3 PhD theses devoted to the topic (1 defended, 2 underway with defenses planned for 2015); 2 undergraduate students started their master theses on this topic in 2014.

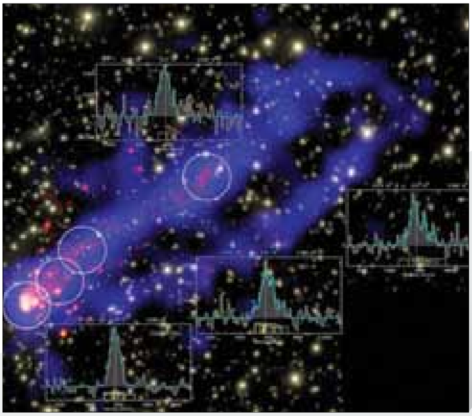


Fig. 4 – APEX CO(2-1) spectra in the ram pressure stripped Norma cluster galaxy ESO137-001.

Lyman-α Reference Sample survey (LARS) was very interesting topic of our study last years. We have recently started using the Lyman-α line of hydrogen for studying nearby galaxies, in collaboration with Geneva Observatory, Stockholm University and other European and American institutions (see Hayes et al., 2013, Astrophysical Journal 765, L27; Hayes et al., 2014, Astrophysical Journal 782, 6; Pardy et al., 2014, Astrophysical Journal 794, 101; Östlin et al., 2014, Astrophysical Journal 797, 11). Lyman-α is the dominant tool for distant galaxy searches, thanks to its brightness. At the same time, Lyman-α resonantly scatters on the interstellar and intergalactic gas and dust, which makes the observational signatures complex. Therefore, we study in detail the mechanisms of Lyman-α transfer and escape from galaxies in the local Universe, using the most advanced astronomical facilities such as the Hubble Space Telescope, the Very Large Telescope (VLT), and the Very Large Array (VLA). In particular, we are in charge of the Lyman-α spectroscopic data interpretation with the use of numerical radiation transfer codes. HST spectroscopy demonstrates that in order to escape from the galaxy without being absorbed, Lyman-α must either scatter to large distances in dust-poor environment, or make use of gas outflows or low-density holes in a clumpy medium.

Our involvement in CALIFA, Calar Alto Legacy Integral Field spectroscopy Area survey (CALIFA – 3D spectrograph mounted at the Calar Alto 3.5-m telescope), builds on our previous experience with integral-field spectroscopy and spatially resolved studies of conditions in the central kiloparsec of both active and quiescent galaxies (Krips et al., 2011, Astrophysical Journel 736, 37; Oh et al., 2013, Astrophysical Journal 767, 117). Nearly 600 galaxies have been observed during 2010-2014, so far resulting in public releases of science quality datacubes for 200 galaxies in two spectral resolution setups. Our team members participate at both the general tasks – the survey design, sample selection/characterization, data release (Sánchez et al., 2012, Astronomy & Astrophysics 538, 8; Husemann, 2013, Astronomy & Astrophysics 549, 87; Walcher et al., 2014, Astronomy & Astrophysics 569, 1) – as well as on specific galaxy evolution studies using CALIFA data with the emphasis on relation between stellar mass, stellar metallicity and gas metallicity. Three PhD students supervised at our institute have participated in CALIFA survey effort.

Relativistic Astrophysics Working Group

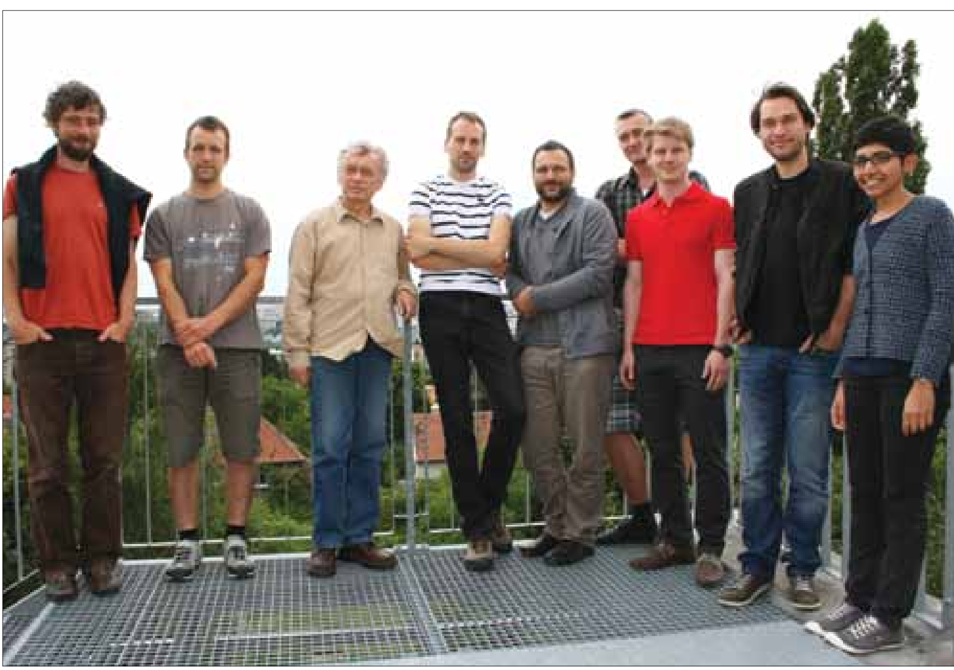
"The mission of the group is to explore physical processes near accreting stellar-mass black holes in binary systems and super-massive black holes in active galactic nuclei, as well as the Milky Way's under-luminous core by theoretical approaches, numerical modeling, and data interpretation. In collaboration with our partners abroad, both archival and newly obtained data are employed – X-ray, near-infrared, optical, and sub-millimeter." –Vladimír Karas, the head of the group.

Personnel

The working group was headed by V. Karas. Research fellows: M. Bursa, M. Dovčiak, P. Hadrava, and J. Horák. Post-doctorate fellows: J. Čechura, O. Kopáček, D. Kunneriath, F. Marin, J. Svoboda, and A. Trova. We had several PhD students too.

Research results

The research focus of the group has concentrated on probing the vicinity of compact objects via a wide spectrum of observational techniques, numerical codes and analytical approaches: By studying stellar-mass black holes and compact stars we explore their interaction with the cosmic environment. We aim to understand matter under extreme conditions, including gravitationally collapsed bodies, and to explore the nature of space-time. By studying supermassive black holes, their role as active emitters allows detection in the distant Universe, thereby probing an epoch of several hundred million years after the Big Bang, as well as the more quiescent



Relativistic Astrophysics Group. From left to right: J. Horák, O. Kopáček, P. Hadrava, M. Bursa, M. Dovčiak, J. Hamerský, J. Čechura, F. Marin, D. Kunneriath.

period of nearby galaxies and the Milky Way. The innermost regions around black holes can be well studied by the X-ray spectroscopy. A relativistically broadened iron line has been reported in spectra of AGN and X-ray binaries. This feature has appeared to be transient in some sources (e.g., an active galaxy 4U 1344-60, J. Svoboda et al., 2012, Astronomy & Astrophysics, 545, 148). The exact shape of the line profile is scientifically valuable information because it allows us to measure the black hole spin and inspect the geometrical and physical properties of the accretion flow. The black hole spin and inclination define the extreme energy shifts of radiation (Karas & Sochora 2010, Astrophysical Journal, 725, 1507; Sochora et al. 2011, MNRAS, 418, 276). The accretion-flow geometry influences the radial emissivity. Svoboda et al. 2012 (Astronomy & Astrophysics, 545, 106) have been able

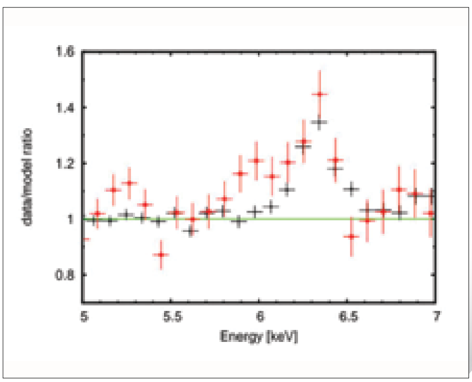


Fig. 5 – Iron line in X-ray spectra of 4U 1344-60 observed by XMM-Newton (2001, red) and Suzaku (2011, black). Figure from Svoboda et al. (2012).

to reproduce steep gradients of the emissivity profiles by a concentrated X-ray source close to the black hole, a radially-stratified ionization of the disc, and the limb-brightening (see Fig. 5).

Dovčiak and Marin follow a Monte Carlo approach to produce near-infrared to X-ray spectro-polarimetry predictions to be compared with observations of accretion discs around supermassive black holes (collaboration with Univ. Strasbourg and Roma Tre; Marin & Dovčiak 2015, Astronomy & Astrophysics, 573, 60). Taking into account heat advection and non-Keplerian rotation, Bursa has investigated slim disc models in with regard to spin estimates (collaboration with MIT/CfA Cambridge and CAMK Warsaw; Sadowski et al. 2011, Astronomy & Astrophysics, 527, 17). The group has provided observational and theoretical studies of angular emissivity in strongly curved gravitational fields, and analyzed its effect on the resulting spectrum originating from discs. Such a complementarity is ensured by a close collaboration between the members of the group.

The X-ray spectral modeling suit of routines named KY has been continuously maintained and developed for the community. Since its early definition (Karas et al. 1992), particular features of the KY approach are the dual step of pre-computing the GR light rays that can be used a posteriori within the widely known (publicly available) spectral fitting package XSPEC as well as a stand-alone application for timing and polarization. New models fit the observed data with a particular physical model of the system, e.g. with a relativistically broadened iron line model (KYNRLPLI) and with a reprocessed disc emission (KYREFLIONX) in the lamp-post geometry (Dovčiak et al. 2014, arXiv:1412.8627).

Not every compact object is found in a state of high accretion rate. The nearest supermassive black hole to us, Sgr A*, is situated at the very center of our Milky Way galaxy where its faint luminosity is explained by low accretion and only episodic flares (see Fig. 6). Its proximity and complex environment make Sgr A* an ideal astrophysical laboratory. Marin and Karas have modeled the reprocessed X-ray signal emerging from reflection nebulae in the Galactic center (Marin et al. 2014; MNRAS, 441, 3170). These provide strong observational constraints for future polarimetric missions, showing that the morphology of the scattering region can be explored, thus revealing the history of the source. Its recent activity is interpreted by multiple accretion events of gaseous clouds onto the central black hole

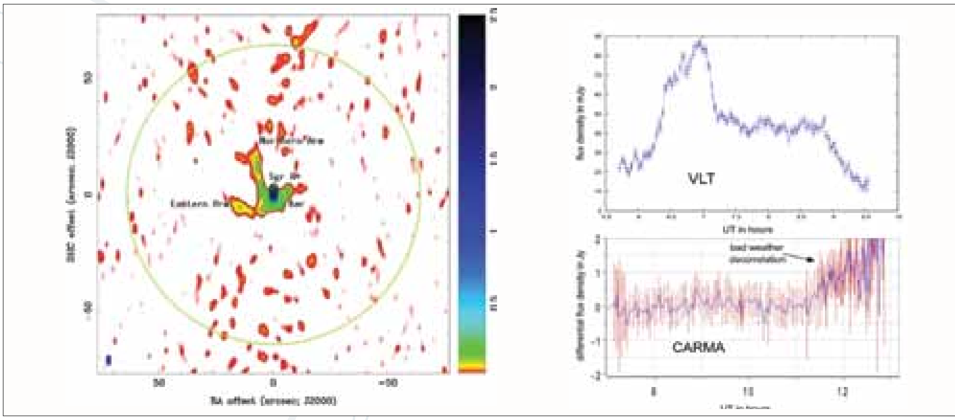


Fig. 6 – Left panel: the Minispiral in the center of the Milky Way, as seen by CARMA at 3 mm. Right panel: Simultaneous coverage of 3.8 μm Galactic center NIR flare and the corresponding 3 mm CARMA light curve (Kunneriath et al. 2010, 2012).

(Czerny et al. 2013, Astronomy & Astrophysics, 555, 97; Kunneriath et al. 2014, IAUS 303, 228).

Trova and Karas explore various aspects of self-gravity of fluid discs and its impact on hydrodynamical simulations (collaboration with Univ. Bordeaux in France; Trova et al. 2014, Astronomy & Astrophysics, 563, 132). This work is done in collaboration with groups at Silesian University in Opava and Charles University in Prague. Deep in the potential well of ergosphere, new physical effects occur. Hamerský and Karas work on the formation of magnetized fluid tori (Hamerský & Karas 2013, Astronomy & Astrophysics, 555, 32), while Kopáček studies acceleration of electrically charged matter by reconnection near black holes (Kopáček & Karas 2014, Astrophysical Journal, 787, 117). Such theoretical works include the effects of collimation and the transition from regular to chaotic motion (Kopáček 2011, PhD Thesis). Horák and collaborators have developed a general-relativistic scheme for the corotation-instability mechanism that operates in accretion discs. They show that this is a generic feature of general relativity (Horák et al. 2012, PASJ, 64, 76; 2013, MNRAS 434, 276).

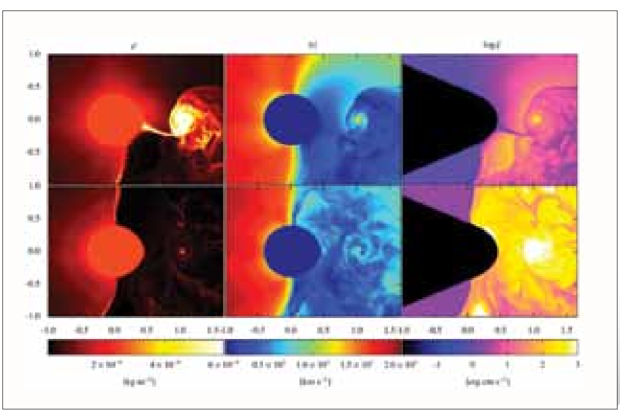


Fig. 7 – Radiation-hydrodynamical simulation of a stellar wind in the equatorial plane of Cygnus X-1, including effects of the X-ray ionization. F rom Čechura & Hadrava (2014).

A code for three-dimensional time-dependent radiation hydrodynamic simulations of stellar winds in interacting binaries has been developed to improve models of high-mass X-ray binaries and to explore the properties of circumstellar matter (Čechura & Hadrava 2014, arXiv:1412.3924 – see Fig. 7). Other codes by Hadrava continue to be updated by the author and widely used by the community: FOTEL for solving radial-velocity and light-curves, and KOREL for disentangling the spectra of multiple stars. These turned out very successful tools for the determination of pulsation velocities from observed spectra of Cepheids, and the Baade-Wesselink calibration of the primary distance markers.

Planetary Systems Working Group

"The mission of the group is the research in dynamics of Earth rotation, its gravity field, orbital analysis of space missions, and astrometry with Zeiss Photographic Zenith Tube in Ondřejov." – Cyril Ron, the head of the group.

Personnel

The working group was headed by C. Ron: Research fellows: A. Bezděk, J. Klokočník, Z. Šíma, J. Vondrák and post-doctorate fellow J. Sebera.

Research results

Orbital resonances played an important role in the past gravity field determination and evaluation (Klokočník et al., 2013, Surv. Geoph., 34, 43) and the GOCE's fine orbit tuning can be considered as a new application of resonant phenomena analyses to orbits of Earth's artificial satellites, see Fig 8. Gravity disturbance, the Marussi tensor, invariants of the gravity field, their certain ratio and other functions of the geopotential were computed based on the harmonic coefficients of the global gravitational field model EGM 2008 (newly also EIGEN 6C4). It is suggested that morphotectonic and landform patterns with very conspicuous combinations of significantly high positive or negative values of the radial derivatives in the Marussi tensor are under the strong influence of rapid and/or intensive geomorphic processes. These geophysical signatures reflect the regional dynamics of the Earth surface evolution. Based on the observed data, covering several years, we obtained an average annual continental hydrology signal, where the main geographical areas with important hydrological variations are evident, see Fig. 9. Currently the GNSS-based gravity field solutions are a topical theme in space geodesy. The results were published in (Bezděk et al., 2014, Adv. Space Res., 53, 412).

Space accelerometers are important devices for measuring the non-gravitational forces acting on Earth satellites, such as the atmospheric drag, radiation pressures, direct and Earth-reflected solar radiation and terrestrial infrared radiation, and the forces due to satellite thrusters. It is important to measure non-gravitational forces in order to improve the knowledge of their natural causes, this is especially true for atmospheric drag, and to reduce them as a perturbing signal in the precise orbit determination procedures, as is the case of recent gravity field dedicated missions (CHAMP, GRACE, GOCE). The problem with space accelerometers is that due to their ultra-high sensitivity they cannot be calibrated on the ground. Nowadays, their calibration is more a scientific problem rather than an engineering one.

Planetary Systems Group: Left image (from left to right): Z. Šíma, J. Vondrák, M. Bečvářová, C. Ron. Right image: J. Klokočník and A. Bezděk.

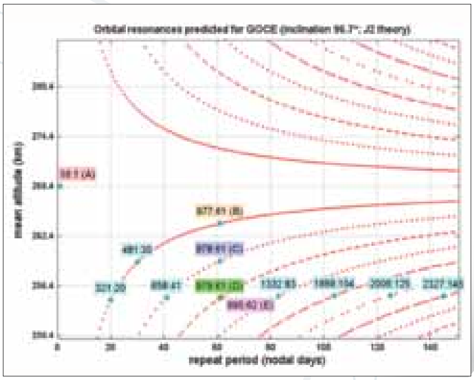


Fig. 8 – Resonant evolution graph for GOCE and orbits suggested or selected for its gradiometry measurements. The x-axis shows the number of Earth's revolutions, the mean altitude of the satellite is on the y-axis. Choice of the repeat cycle was driven by the desire to optimize the spatial coverage for the GOCE gradiometer (Klokočník et al. 2013).

This is the reason why European Space Agency launched a call to scientific teams for a calibration of space accelerometers carried aboard each of three satellites in the mission Swarm. We developed an original method of calibration based on comparison of the measured accelerometer readouts with a calibration standard derived from precise GPS orbits (Bezděk, 2010, J. Geodyn. 50, 410).

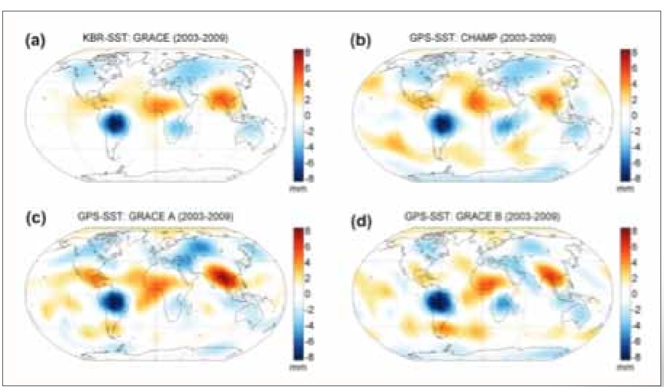


Fig. 9 – Average seasonal geopotential variations Computed from a) GRACE, and from GPS positions of GHAMP and GRACE A/B satellites (Bezděk et al., 20M).

Our calibration proposal was accepted by ESA. The three Swarm satellites were successfully put in orbit in November 2013 and the accelerometer data have been available early in 2014. Together with other teams invited by ESA we try to solve problems so that the data could be finally released to scientific users. In 2014 we contributed at all three meetings of ESA Swarm calibration/validation teams. Our attention has also been drawn to particular algorithms for processing satellite and terrestrial gravity data. In (Sebera et al., 2012, J. Geod., 86, 713) the computation of the associated Legendre functions of the second kind was optimized up to degree of several thousand. The resulting procedures allow us to use spheroidal basis functions for flattened bodies that have many applications in planetary science.

Sebera et al. (2013, J. Geod., 87, 223) have been investigating alternative relationships for the Cartesian derivatives of the spherical harmonic series. Although these formulas are known from the sixties, they are not widely used in gravity field modelling. We tested their capabilities in the spherical harmonic analysis of the scattered and heterogeneous input data (acceleration vector, gravitational gradients) and we found these are systematically faster when compared with our previous implementation. The routines are now being used in the acceleration approach mentioned above (Bezděk et al., 2014, Adv. Space Res., 53, 412).

Finally, an alterntive way to work with gravitational data in a mass-free space was investigated in (Sebera et al., 2014, Surv. Geoph. 35, 941). The purpose was to downward continue satellite gravity data from the GOCE mission without using spherical harmonics. For this purpose, we suggested a two-step iterative procedure based on the Poisson integral equation, which allows to shift (or interpolate) gravity data in space to prevent dramatic noise amplification.

The nutation model IAU2000 is very close to the real motion of Earth's spin axis in space, so the celestial pole offsets measured by VLBI (deviations of the observed pole position from the model) are very small, typically smaller than 1 mas. However, some periodic terms can still be detected in the residuals, partly coming from the still possible deviations of the adopted model from reality, partly because of the presence of free variations that are unpredictable and thus not included in the model. They are due to the fact that the Earth's outer fluid core and inner solid core can rotate around the axes that are not coincident with the spin axis of the mantle. The possible additional excitation due to geophysical fluids (atmosphere, ocean and hydrology on continents) can be derived from their angular momentum functions that are publicly available with sub-diurnal resolution in 6-hour intervals. We studied the effects of the geophysical fluids and geomagnetic field on the spin axis using the integration of broad-band Liouville equations and have found the significant correlation between integrated and observed pole offsets in the interval 1989-present (Vondrák and Ron, 2014, Acta Geodyn. Geomater, 11, 193). We also analyzed the long-term variations of the Earth's rotation starting with decade variations (Chapanov et al., 2010, IAU Symp. 264, 407) and proceeded towards centennial (Ron et al., 2012, Acta Geodyn. Geomater, 9, 259) up to millennial ones (Chapanov et al., 2015, Acta Geodyn. Geomater, 12, 259).

Published Principal Results

We present abstract of the most interesting results of the last two years.

Corotation resonance and overstable oscillations in black hole accretion discs: general relativistic calculations

J. Horák, Dong Lai

Monthly Notices of the Royal Astronomical Society, 2013, Volume 434, Issue 4, p. 2761-2771

We study the dynamics of spiral waves and oscillation modes in relativistic rotating discs around black holes. Generalizing the Newtonian theory, we show that wave absorption can take place at the corotation resonance, where the pattern frequency of the wave matches the background disc rotation rate. We derive the general relativistic expression for the disc vortensity (vorticity divided by surface density), which governs the behaviour of density perturbation near corotation. Depending on the gradient of the generalized disc vortensity, corotational wave absorption can lead to the amplification or damping of the spiral wave. We apply our general theory of relativistic wave dynamics to calculate the non-axisymmetric inertial-acoustic modes (also called p modes) trapped in the innermost region of a black hole accretion disc. Because general relativity changes the profiles of the radial epicyclic frequency and disc vortensity near the inner disc edge close to the black hole, these p modes can become overstable under appropriate conditions. We present the numerical results of the frequencies and growth rates of p modes for various black hole spin and model disc parameters (the surface density profile and sound speed), and discuss their implications for understanding the enigmatic high-frequency quasi-periodic oscillations observed in black hole X-ray binaries.

On the Onset of Secondary Stellar Generations in Giant Star-forming Regions and Massive Star Clusters

J. Palouš, R. Wünsch, G. Tenorio-Tagle

Astrophysical Journal, 2014, 792, 105-113

Here we consider the strong evolution experienced by the matter reinserted by massive stars, both in giant star-forming regions driven by a constant star formation rate and in massive and coeval superstar clusters. In both cases we take into consideration the changes induced by stellar evolution on the number of massive stars, the number of ionizing photons, and the integrated mechanical luminosity of the star-forming regions. The latter is at all times compared with the critical luminosity that defines, for a given size, the lower mechanical luminosity limit above which the matter reinserted via strong winds and supernova explosions suffers frequent and recurrent thermal instabilities that reduce its temperature and pressure and inhibit its exit as part of a global wind. Instead, the unstable reinserted matter is compressed by the pervasive hot gas, and photoionization maintains its temperature at $T \sim 10^4$ K. As the evolution proceeds, more unstable matter accumulates and the unstable clumps grow in size. Here we evaluate the possible self-shielding of thermally unstable clumps against the UV radiation field. Self-shielding allows for a further compression of the reinserted matter, which rapidly develops a high-density neutral core able to absorb in its outer skin the incoming UV radiation. Under such conditions the cold ($T \sim 10$ K) neutral cores soon surpass the Jeans limit and become gravitationally unstable, creating a new stellar generation with the matter reinserted by former massive stars. We present the results of several calculations of this positive star formation feedback scenario promoted by strong radiative cooling and mass loading.

Prospects of 3D mapping of the Galactic Centre clouds with X-ray polarimetry

F. Marin, V. Karas, D. Kunneriath, F. Muleri
Monthly Notices of the Royal Astronomical Society, 2014, Volume 441, Issue 4, p. 3170-3176

Despite past panchromatic observations of the innermost part of the Milky Way, the overall structure of the Galactic Centre (GC) remains enigmatic in terms of geometry. In this paper, we aim to show how polarimetry can probe the three-dimensional position of the molecular material in the central ~100 pc of the GC. We investigate a model where the central supermassive black hole Sgr A* is radiatively coupled to a fragmented circumnuclear disc (CND), an elliptical twisted ring representative of the central molecular zone (CMZ), and the two main, bright molecular clouds Sgr B2 and Sgr C. 8-35 keV integrated polarization mapping reveals that Sgr B2 and Sgr C, situated at the two sides of the CMZ, present the highest polarization degrees (66.5 and 47.8 per cent, respectively), both associated with a polarization position angle psi = 90° (normal to the scattering plane). The CND shows a lower polarization degree, 1.0 per cent with psi = –20.5°, tracing the inclination of the CND with respect to the Galactic plane. The CMZ polarization is spatially variable. We also consider a range of spatial locations for Sgr A* and the reprocessing media, and investigate how the modelled three-dimensional geometry influences the resulting GC polarization. The two reflection nebulae are found to always produce high polarization degrees (>>10 per cent). We show that a 500 ks observation with a broad-band polarimeter could constrain the location and the morphology of the scattering material with respect to the emitting source, revealing the past activity of Sgr A*.

Very Large Telescope (VLT) of the ESO's Paranal Observatory pointing the Laser Guideed Star.

CREDIT: PETR HORÁLEK/ESO

VII
INVOLVEMENT IN INTERNATIONAL SCIENTIFIC ORGANIZATIONS

A strong aspect of the Institute performance is its extensive international collaboration. Regardless of the difficulties in establishing international contacts before 1989, the Institute is now internationally recognized as a leading research organization in the field of Astronomy and Astrophysics. Since the General Assembly of the International Astronomical Union (IAU) in Prague in 2006, the Institute organizes numerous international meetings and symposia. While Prof. Jan Palouš continues to serve as IAU Vice-President, preparations have just started for the forthcoming European Week of Astronomy and Space Science as a major event to be held in Prague 2017.

In 2008 the Czech Republic became a regular member of the European Space Agency (ESA). This membership was a successful ending of long-lasting negotiations with ESA representatives and preparation on the Czech side. During that preparatory period scientists of the Institute have been helping with organizational matters related to space research. Since then the Institute plays a visible role in the space research in the Czech Republic which helps us to build long term strategic partnerships between Industry and Academia. The Institute continues to have representatives in the national Board for Space Activities, in the Board of Directors and Supervisory Board of the Czech Space Office, in the Czech PRODEX Board, in the Board of Space Activities of the Czech Academy of Sciences and in the Coordination Board of the Minister of Transportation. The ESA membership has opened new broad possibilities especially in the field of space-related sciences.

Observations from above the Earth atmosphere have had a crucial importance for astronomy and astrophysics since the very beginning of the Space Age. Therefore the Astronomical Institute has been involved in many space projects. For example, a new type of micro-accelerometer was developed and placed aboard the US Space Shuttle

Examples of ESA projects at the Institute, ongoing or finishing till the end of 2015

Project name	PI	Period
Solar Orbiter - METIS (coronograph): Czech contribution: main M1 and M2 mirrors	A. Berlicki	2011–2018
Solar Orbiter - STIX (Spectrometer Telescope for Imaging X-Rays): Czech contribution: Power Supply design, development and manufacture	F. Fárník	2011–2018
PROBA-3: Hardware contribution to ASPIICS conograph onboard PROBA-3 mission-Phase B and Phases C, D	S. Gunár	2011–2016
RPWI Instrumentation for JUICE Mission: Definition and Development	P. Hellinger	2011–2017
Solar Orbiter-RPW (Radio and Plasma Waves Instrument): Czech contribution: Power Supply Unit design, development and manufacture	P. Hellinger	2011–2018
L-DEPP-Definition: Lunar Dust Environment and Plasma Package for Lunar Exploration	P. Hellinger	2011–2015
PROBA 2: DSLP Operations on Board - Raw Data Processing and Archiving	Š. Štverák	2011–2015
BepiColombo: Kinetic processes in the solar wind, Mercury`s magnetosheath and magnetosphere	P. Trávníček	2008–2015

Atlantis, and a hard X-ray spectrometer was launched on the US Air Force satellite MTI where it successfully observed during three years. Micro-accelerometer know--how was transferred and that enabled companies to receive contracts with ESA-ASTRIUM, and to manufacture micro-accelerometers for three ESA satellites SWARM launched in 2013.

In 2011 ESA approved the Solar Orbiter (M2-class mission by ESA) and the work on phases C/D of the satellite construction started. We have participated in three international consortia to build the scientific payload instruments METI S (UV coronagraph), STIX (hard X-ray telescope) and RPW (in situ radio plasma-wave detector). The launch is expected in 2018. Also the formation flight project Proba-3, with a large externally occulting coronograph, is on track entering the production phase. The Institute scientists continue with their involvement in Gaia, GOCE, XMM and other ongoing projects of ESA. Recently the CLASP polarimetry mission of JAXA and NASA space agencies was approved, with the Institute's participation.
Many of our results came from observations made by the telescopes at European Southern Observatory sites. The Czech Republic is a member of ESO since 2007, which allows to the scientists of the Astronomical institute to use the instruments at La Silla Observatory, Paranal observatory or participate on the ALMA project. The following table shows some of our observational projects performed by ESO instruments.
The Institute takes an active role also in promoting all aspects of ESO membership

An examples of approved observation programs for 2013-2015 in which scientists of our institute took part.

Project name	Telescope	Scientists
Nature of variable SgrA* X-ray and polarized NIR flares: Probing the accretion stream and source variability during the passage of DSO/G2.	UT4-Yepun/ NACO APEX/LABOCA APEX/SABOCA	M. Bursa, M. Dovčiak, V. Karas, D. Kunneriath
Differential L'-band spectroscopy of the Dusty S-cluster Object (DSO/G2) approaching SgrA*.	UT4-Yepun/ NACO	M. Dovčiak, V. Karas, D. Kunneriath
Multiple stellar systems as a key to understand period variations and magnetic activity cycles	2.2/ FEROS	P. Zasche, M. Brož, P. Mayer, M. Wolf
Photospheric signature of accreted material onto cool, old white dwarfs.	UT2-Kueyen/ XSHOOTER	A. Kawka, S. Vennes
The 3-D Structure and Kinematics of Small Magellanic Cloud by Disentangling of Stellar and Interstellar Spectra	UT2/ FLAMES	P. Hadrava, S. Ehlerová, R. Klement, J. Palouš, A. Růžička, S. Štefl
Properties of rare double degenerates: A new class of nitrogen-polluted DQ white dwarfs?	UT3/ XSHOTER	S. Vennes, A. Kawka
Probing physical conditions in the molecular gas in the wake of the galaxy ESO137-001	APEX/ SHeFI	P. Jáchym
Submillimetre observations with LABOCA and SABOCA: a key to constrain clumping and determine precise mass-loss rates in massive stars	APEX/ LABOCA	J. Kubát, B. Šurlan, M. E. Oksala, J. Krtička, M. Kraus
Studying the structure and kinematics of disks around evolved massive stars using SiO band head emission	UT1/CRIRES	M. Kraus, M. E. Oksala

in the Czech Republic, scientific as well as industrial. To this end a dedicated www.eso-cz.cz website is supported. In 2014, ESO hosted an industry event for Czech businesses at its Headquarters in Garching, where the meeting representatives of interested Czech companies and institutions were offered information about ESO, given an introduction to the E-ELT and presented potential opportunities that are available to take part in its industrial activities.

The European ARC (ALMA Regional Centre) has been formed as a coordinated distributed network of seven nodes, which are part of the support system for the ALMA (Atacama Large Millimeter/submillimeter Array) telescope. One of the nodes is hosted at the Astronomical Institute of Academy of Sciences in Ondrejov. The Czech node provides services namely in ALMA-related research in solar physics and laboratory millimeter spectroscopy. In these areas it serves the ALMA user community in the Czech Republic and the entire region of Central and Eastern Europe. In the solar research with ALMA this expertise is unique even at the European scale. Partly it serves also international community from Brazil and Chile (ALMA location). The services provided to the users range from help with proposal preparation (Phase I), negotiation of technical details of the project with the observatory (Phase II), data reduction and imaging (QA2) up to help with data analysis and interpretation. At the same moment the Czech node helps with further development of ALMA in commissioning of the new solar observing mode. In fulfilling its tasks the Czech node is closely collaborating with ESO, partner nodes in Europe, ARCs at NRAO and NAOJ, Joint ALMA Observatory (JAO) and also with academic institutions in the Czech Republic. The Institute proposed a new ALMA-CZ Research Infrastructure at 2014, and it is currently at a promising stage of negotiations for funding.

CREDIT: ESO

ALMA, an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA construction and operations are led on behalf of Europe by ESO. ESO has established one of European ALMA Regional Centres in Ondřejov. Following the recent proposal by the Institute, the Czech node of the European ARC has been included in the updated Roadmap of Research Infrastructures in the Czech Republic.

The Institute have also obtained a long--term access to the 1.54-m Danish telescope located at ESO La Silla Observatory in Chile. We run two long-term photometric projects at the telescope: the NEOSource project and the Gaia Support project. The

NEOSource project is run by the Interplanetary Matter Department and it is focused on physical studies of near-Earth asteroids and their source regions in the main asteroid belt. The Gaia Support project is run by the Stellar Department and it is focused on objects used to calibrate the observations. The 1.54-m telescope is also cooperating in the international network Gaia Science Alerts to perform follow-up observations of peculiar sources detected by the satellite.

The European Fireball Network (EN) was established in former Czechoslovakia in 1963 and its current updated version represents the longest continuously operational fireball network in the World. The center of EN is located in Ondřejov and the Institute coordinates all its activity. At present it consists of eleven stations in Czech Republic, fourteen stations in Germany and two in Slovakia and Austria. Within the scope of this experiment we closely cooperate with our colleagues in Comenius University in Bratislava, who operate four video all-sky systems in Slovakia, and with several amateur groups active in the Netherlands, Poland, Slovenia, Croatia, Austria and Hungary. Recently, all Czech stations have been equipped with the very sophisticated instrument for optical observation of fireballs, the Autonomous Fireball Observatory (AFO). In the last three years the new instrument for fireball photography, the Digital Autonomous Fireball Observatory (DAFO) has been developed and gradually installed at all Czech stations. These modern and fully automated instruments significantly increase the efficiency of our observations and precision of the acquired data. Fireball spectra are simultaneously photographed at the Ondřejov Observatory. We also participate in the project of the Desert Fireball Network (DFN) in Australia equipped with AFO, and we analyze data from this remote experiment. We have continued to use the double station (Ondřejov–Kunžak base) video observations of faint meteors. Our goal in this research has been not only to monitor the activity of known meteor showers but also to look for unexpected events. In case of predicted outbursts or enhanced activity we promptly adjust our observational program. For this purpose we use an automatic double station MAIA cameras as well as original manual video cameras.

PHOTO: PETR HORÁLEK

The dome with 1,54-m Danish telescope at La Silla site of ESO.

Teams of the Institute at the Ondřejov site as well as abroad pursue other important programs. These include an active involvement in the recently established EAST (European Association for Solar Observations). Organization as well as an active participation in large solar projects GREGOR, the largest European solar telescope, where the Institute takes part under a bilateral agreement with the Leibniz Institute for Astrophysics. This has opened an opportunity for the Czech solar community to obtained the leading-edge data. The 1.5-m solar reflector, located at Observatorio del Teide, Tenerife, was developed and built under the leadership of the Kiepenheuer Institute for Solar Physics in Freiburg with the Leibniz Institute for Astrophysics Potsdam, the Institute for Astrophysics Göttingen, and the Max Planck Institute for Solar System Research in Göttingen as German partners and with the Instituto de Astrofísica de Canarias and the Astronomical Institute of the Czech Academy of Sciences as international partners. The telescope is designed for observations of the solar photosphere and chromosphere in the visible and near infrared and equipped with a high-order adaptive optics. It was inaugurated in 2012 and has started in early 2014 its "Early Science" phase with access restricted to the GREGOR partners. At this moment, there are three post-focus instruments: the broad-band imager, the GREGOR Fabry-Perot interferometer (GFPI), and the grating infrared spectrograph (GRIS). Members of the Solar Department took part in the installation and alignment of GFPI since 2011 and in three campaigns of Early Science observations.

The Institute has been active in the ASTRONET network to shape the influential Roadmap for the future directions of Astronomy research in Europe, its planned infrastructures and personnel aspects. Furthermore, special projects cover joint research work of the Institute astronomers with the U.S. scientists (e.g. the scientific participation in Space Research performed within NASA programs or a continued research done jointly with collaborators at Massachusetts Institute of Technology or the Smithsonian Center for Astrophysics). More recently a promising opportunity has emerged within the Czech Academy and Chinese Academy of Sciences mutual cooperation scheme, and we actively pursue this path. There are even more types of international collaboration of the Institute and some are in progress individually by the researchers themselves as well as by the working groups of the Institute (see Chapter IX.).

The largest European solar telescope GREGOR with a 1.5 m primary mirror.

VIII
WHO YOU CAN MEET IN THE INSTITUTE?

1. List of Scientific Staff

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Department of Stellar Physics

Department of Galaxies and Planetary Systems

Department of Interplanetary Matter

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Solar magnetic and velocity fields, solar differential rotation and meridional circulation. Dynamic properties of the solar convection zone and of the solar atmosphere. Structure of the solar corona, models of the coronal magnetic field and their temporal variations.

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Numerical MHD modeling of solar flares and prominences (solar-flare reconnection, current-sheet dynamics, energy cascades in magnetic reconnection, MHS equilibria in prominences), multi-scale modeling of space-plasma processes. Solar radiophysics (plasma wave dynamics, micro-instabilities, radio emission theory, interpretation of radio bursts). High-performance computing.

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Solar atmosphere and active events: flares, prominences, Ellerman bombs, chromospheric structures; NLTE modeling of the solar atmosphere in flares, prominences and other chromospheric structures.

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Celestial mechanics, orbital dynamics of low earth artificial satellites, modeling of Earth gravity field, kinematic orbits, orbital resonances, atmospheric drag, models of thermospheric density, use of satellite microaccelerometric data.

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Missing mass problem, dark matter, modified gravity, galaxy evolution and interactions, galaxy photometry.

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Non-gravitational effects on small solar system bodies (Yarkovsky and YORP effect), thermal stress and rotation of meteoroids.

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Galaxies with fine structures, shell galaxies, dwarf spheroidal galaxies in the Local Group, cluster galaxies - galactic kinematics, dynamical friction, dark matter distribution in galaxies, mergers of galaxies, tidal interactions (N-body simulations, test-particle simulations, analytical and semi-analytical calculations, cosmological context).

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Interstellar medium, HI shells and supershells (automatic detection algorithm, statistical studie of shells in the Milky Way, numerical simulations), star formation.

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Active events in the solar atmosphere. Non--LTE radiative transfer: multi-level problems, partial frequency redistribution, 2D-transfer. Structure and dynamics of the chromosphere and flares, physics of isolated plasma structures. Time-dependent non-LTE problems in radiation hydrodynamics, energy balance, heating mechanisms. Spectral diagnostics and analysis with semi-empirical models.

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Relativistic astrophysics of compact sources, oscillation of relativistic fluid tori, variability and polarization of X-rays from compact objects.

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Particle-In-Cell simulations of space plasmas and development of PIC code for simulations of dusty plasmas.

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Computer engineering support for projects in satellite/space astronomy, in high energy astrophysics, and related fields such as robotic telescopes and analyses of archival data. ESA INTEGRAL OMC ISOC pointing software and operations. Related citizen science and involvement of schools and scholars.

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High energy astrophysics with emphasis on multi-spectral analyses and eruptive processes in cosmic plasma. Gamma ray bursts, galactic and extragalactic X-ray and gamma-ray sources. Searches for counterparts at optical wavelength. Analyses of evolution and emission mechanisms. Design and development and design of X-ray optics and X-ray telescopes for space as well as laboratory applications.

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research scientist
Solar flares: non-LTE radiative transfer, analysis of optical and hard X-ray spectra.

Adéla Kawka
(kawka@sunstel.asu.cas.cz)
research scientist
Evolution, atmospheric properties of white dwarfs, and their distribution within our Galaxy, close binary systems: their evolution, orbital parameters and atmospheric properties of the components stars. Spectroscopic and photometric observations in the optical and ultraviolet of white dwarfs and close binaries.

Jaroslav Klokočník
(jklokocn@asu.cas.cz)
research scientist emeritus
Satellite dynamics, orbit determination from observations, gravity field of the Earth, orbital resonances, navigation for applied satellites, satellite (crossover) altimetry, tests of accuracy of gravity field models, gradiometry.

Miroslav Klvaňa
(mklvana@asu.cas.cz)
research scientist
Magnetic and velocity fields in solar active regions and quiet photosphere (observations, interpretation, and modeling), instrumentation, data processing.

Ondřej Kopáček
(kopacek@ig.cas.cz)
postdoctorand
Dynamics of charged particles in the vicinity of magnetized compact objects, deterministic chaos in relativistic systems, magnetospheres of accreting black hole systems.

Pavel Koten
(koten@asu.cas.cz)
research scientist
Photometry, light curves and physical structure of faint video meteors, models of meteoroids, double station observations of meteors, trajectory computation, image processing of video meteors, automation of the observati-

on and data processing, meteor streams identification.

Lenka Kotková

(lenka@asu.cas.cz)
research engineer
CCD spectroscopy and photometry, telescope operation, data acquisition, reduction and analyses, development and maintaining of various databases.

Pavel Kotrč

(pkotrc@asu.cas.cz)
research scientist
Solar atmosphere, flares, surges, prominences, coronal loops, spectral observation and analysis, diagnostics of solar activity phenomena, solar corona, eclipses of the Sun, instrumentation.

Pavel Koubský

(koubsky@sunstel.asu.cas.cz)
research scientist emeritus
Early-type stars, close binaries, Be stars, astronomical techniques.

Michaela Kraus

(kraus@sunstel.asu.cas.cz)
research scientist
Winds and circumstellar disks of hot stars; Be and B[e] stars; ionization structure calculations in distorted winds; modeling forbidden emission lines from winds and disks, and the spectral energy distribution of flat, flared and outflowing dusty disks; evolution of massive stars and evolutionary connections between their evolved phases.

Jiří Kubát

(kubat@sunstel.asu.cas.cz)
senior research scientist
Radiative transfer, theory of stellar atmospheres, calculation of model stellar atmospheres, line profiles, NLTE physics, dynamics of stellar winds.

Brankica Kubátová

(brankica.kubatova@asu.cas.cz)
postdoctorand
Theory of radiative transfer and stellar atmospheres of hot stars; Studying effect of wind inhomogeneities (i.e. clumping) on wind model predictions; Monte-Carlo simulations; Modeling of stellar spectra and determination of stellar and wind parameters.

Devaky Kunneriath

(devaky@ig.cas.cz)
postdoctorand
Galactic center science: flare modelling of Sgr A*, ISM, modelling of Galactic structure, radio interferometry and IR observations.

Peter Kušnirák

(peter@asu.cas.cz)
research engineer
Photometry of asteroids. Observations at D65 and DK154 telescopes. Processing and analysis of obtained and incoming photometry data for main-belt, NEAs and binary asteroids.

Grigorios Maravelias

(grigorios.maravelias@asu.cas.cz)
postdoctorand
Circumstellar environment of hot stars; evolution of massive stars; High-Mass X-ray binaries; stellar populations in our Galaxy and Local Group.

Frederic Marin

(frederic.marin@asu.cas.cz)
postdoctorand
Broadband (near IR, optical, UV, X-ray) spectropolarimetric simulations of high energy sources: Galactic center, active galactic nuclei, gamma ray binaries. Convener of the Galactic center group for the ESA's pre-selected project XIPE.

Hana Meszárosová

(hana@asu.cas.cz)
research scientist
Solar flares, radio radiation, data analysis, statistical methods. Impulsively generated magnetoacoustic waves in the solar coronal loops and analysis of radio and X-rays data.

Dieter Nickeler

(nickeler@asu.cas.cz)
research associate
Stationary ideal and non-ideal MHD flows of large scale stellar winds (astrospheres/heliosphere) and solar flows, solutions of nonlinear

MHD equations, theory of magnetic reconnection and magnetic topology.

Ivana Orlitová

(ivana@sirrah.troja.mff.cuni.cz)
postdoctorand
Narrow-line regions of active galaxies, kinematics and excitation of gas.

Jan Palouš

(palous@ig.cas.cz)
senior research scientist
Dynamics and evolution of galaxies; star formation, winds and mass recycling; shells, super--shells and filaments; gas stripping, formation of star clusters; gravitational instability.

Radek Peřestý

(peresty@asu.cas.cz)
research engineer
Microgravity environment, accelerometry, non--gravitational forces, artificial satellite dynamics.

Cyril Polášek

(polasek@asu.cas.cz)
research engineer
High-energy astrophysics, data reductions, optics, testing and development of innovative X--ray and optical CCD telescopes of apertures.

Petr Pravec

(ppravec@asu.cas.cz)
senior research scientist
Physical properties of asteroids, photometry and astrometry of asteroids and comets, discoveries, recoveries and follow-up of both new and old poorly observed asteroids.

Simone Recchi

(simone.recchi@asu.cas.cz)
postdoctorand
Chemodynamical simulations. Formation and evolution of star clusters. Multiple stellar populations in globular clusters. Initial mass function.

Cyril Ron

(ron@ig.cas.cz)
research scientist
Astrometry, PZT observations and their analysis, Earth orientation parameters (EOP) from optical astrometry and combination of the EOP series derived from different techniques, geophysical excitations of the Earth rotation.

Josef Sebera

(josef.sebera@fsv.cvut.cz)
postdoctorand
Earth's gravity field determination by terrestrial and space techniques (satellite altimetry/gradiometry).

Lukáš Shrbený

(shrbeny@asu.cas.cz)
postdoctorand
Physics of bright photographic meteors, measurements of all-sky images.

Petr Scheirich

(petr.scheirich@centrum.cz)
postdoctorand
Modeling of binary and tumbling asteroids from photometric data.

Pavol Schwartz

(schwartz@asu.cas.cz)
research associate
Non-LTE study of the solar filaments and prominences, EUV spectroscopy of small-scale chromospheric structures, reduction of the data from SoHO/CDS and SoHO/SUMER spectrographs and from instruments of Hinode satelite.

Michal Sobotka

(msobotka@asu.cas.cz)
senior research scientist
Sunspots, fine structure and velocity fields in solar photosphere, high spatial resolution photometry and spectroscopy, image processing, time-series analysis, instrumentation.

Vjačeslav Sochora

(sochora@astro.cas.cz)
research engineer
Radiation processes in strong gravity and their applications to active galactic nuclei and Galactic black holes.

Pavel Spurný

(spurny@asu.cas.cz)

senior research scientist

Physics of meteor flight in the atmosphere, computations of meteor orbits and trajectories, prediction of meteorites impact positions, radiation of meteors at very high altitudes, reduction methods for determination of meteor trajectories, high resolution light curves of fireballs from AFO radiometers, double station television observations of meteors.

Jiří Svoboda

(jiri.svoboda@asu.cas.cz)

postdoctorand

Effects of strong gravitational field acting on radiation near compact objects, X-ray spectroscopy.

Ondřej Šebek

(ondrej.sebek@asu.cas.cz)

PhD student

Plasma interactions at satellites of outer planets, kinetic effects, numerical (hybrid) modeling and data analysis.

Stanislava Šimberová

(ssimbero@asu.cas.cz)

research associate

Digital image processing in astronomy and astrophysics; pattern recognition - image fusion, contextual classification, feature selection, classifier performance, filtration. Image enhancement and restoration - multispectral image analysis and reconstruction, texture synthesis, geometric transformation, probabilistic relaxation, multichannel blind deconvolution.

Vojtěch Šimon

(simon@asu.cas.cz)

research scientist

High energy astrophysics. Long-term activity and eruptive processes of accreting compact objects; relations of the character of orbital modulation to the long-term activity. Afterglows of gamma-ray bursts (GRBs), supernova - GRB connections, implications for the environment in the host galaxies of GRBs. CCD photometry, data analysis and evaluation.

Petr Škoda

(skoda@sunstel.asu.cas.cz)

research scientist

CCD spectroscopy, data acquisition and reduction, telescope instrumentation, computational astrophysics, astronomical databases and archives and the Virtual Observatory.

Miroslav Šlechta

(slechta@sunstel.asu.cas.cz)

research associate

Observational and computational astronomy, CCD data acquisition and reduction. History of natural sciences and astronomy.

Jiří Štěpán

(stepan@asu.cas.cz)

research scientist

Non-LTE polarized radiative transfer, atomic processes, chromospheric magnetic fields, solar flares, software development.

Rostislav Štork

(stork@asu.cas.cz)

research associate

TV observation of faint meteors.

Jan Štrobl

(strobl@asu.cas.cz)

research engineer

Cataclysmic variable stars – multispectral analysis, high-energy X-ray & gamma-ray sources data analysis, CCD sky monitors and related data analyses and interpretations.

Štěpán Štverák

(stverak@ig.cas.cz)

postdoctorand

Non-thermal properties of particle distributions in space plasmas, H/W development of plasma diagnostic tools (Langmuir probes), numerical modeling and data analysis, simulations of collisionless plasmas.

Michal Švanda

(michal@astronomie.cz)

research scientist

Inversion methods for local helioseismology, travel-time measurements, velocity and magnetic fields in solar photosphere, large-volume data processing.

Adam Tichý

(adamtichy@sunstel.asu.cas.cz)
PhD student
Stellar atmosphere modelling, especially radiation in stellar winds. Statistical thermodynamics used in stellar atmospheres.

Sanja Tomić

(sanja.tomic@asu.cas.cz)
PhD student
Spectroscopic observations of B supergiants, analysis of spectroscopic time-series using asteroseismic tools, identification of pulsation periods, role of pulsations in triggering stellar mass loss, influence of pulsations on spectral appearance of evolved massive stars.

Pavel Trávníček

(trav@alenka.ufa.cas.cz)
research scientist
Kinetic simulations (hybrid/Vlasov codes) of collisionless plasmas, kinetic processes in the interaction between plasma flows and planets and moons, temperature anisotropy driven instabilities in the solar wind and Earth's magnetosheath, shocks in collisionless plasmas.

Audrey Trova

(audrey.trova@asu.cas.cz)
postdoctorand
Theory of self-gravitating fluid discs and tori, including effects of small electric charge.

Marek Vandas

(vandas@asu.cas.cz)
senior research scientist
Magnetohydrodynamic simulations of interplanetary disturbances, acceleration of electrons by shock waves, magnetic clouds in the solar wind.

Michal Varady

(varady@asu.cas.cz)
research associate
Solar flares and coronal loops. Numerical modeling of their hydrodynamics, electromagnetic emission, transfer and dissipation of energy of high energy particle beams in solar atmosphere, modeling of solar flares combined with radiative transfer. EUV and soft X-ray observations and diagnostics of high energy particle beams.

Stephane Vennes

(vennes@sunstel.asu.cas.cz)
senior research scientist
Stellar evolution, white dwarfs, evolved binaries; Computational astrophysics, radiative transfer and convective transport in stellar atmospheres, diffusion, stellar opacities; Data analysis, spectroscopic and photometric surveys and databases, stellar parameters.

Vlastimil Vojáček

(vojacek@asu.cas.cz)
PhD student
Photometry, light curves, physical structure, trajectory computation and image processing of faint video meteors. Spectroscopy and physics of meteor flight in atmosphere.

Jan Vondrák

(vondrak@ig.cas.cz)
research scientist emeritus
Reference frames, Earth rotation and its interaction with geophysical excitations, polar motion, precession-nutation, astrometry, ephemeris astronomy.

Viktor Votruba

(votruba@sunstel.asu.cas.cz)
research scientist
Radiation hydrodynamics, theory of radiatively driven stellar winds from hot stars, multicomponent stellar wind, numerical simulations, various type of instabilities in stellar wind, nonlinear dynamics.

Jan Vraštil

(jan.vrastil@asu.cas.cz)
PhD student
Rotation of asteroids, gravitational and non-gravitational effects, photometry of asteroids and variable stars.

Richard Wünsch

(richard.wunsch@matfyz.cz)
research scientist
Radiation-hydrodynamic simulations, self-gravity, grid-based codes; interstellar matter, star formation, expanding shells and supershells; planet formation, protoplanetary discs, layered discs; super star clusters, thermal instability.

Michal Zamazal

(michal.zamazal@asu.cas.cz)
research engineer
Solar Orbiter STIX and RPW power supply circuits design, simulation documentation, testsand measurements. It also includes design and realization of the bench setup and hardware including special tools and electronic instruments for the power supplies testing.

Alena Zemanová

(kulinova@asu.cas.cz)
research associate
Solar flares, spectroscopic diagnostics - soft X-ray spectra, diagnostics of the non-thermal distributions in the corona and the transition region, data processing (satellite and groundbased), participating on the developemnent of Solar Optical Robotic Telescope.

6.2 Personal Awards

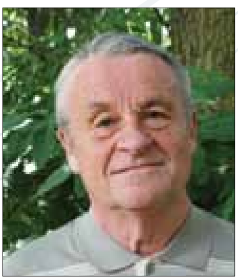
Following employees of the Institute received individual awards in 2013–2015:

Miroslav Bárta received the Academy of Sciences Award for excellent scientific results in his research of the solar eruptions (2013).

Jiří Borovička received the Kopal lecture granted by the Czech Astronomical Society for the significant results in the field of interplanetary matter (2014).

Jaroslav Dudík was awarded the Premium of Otto Wichterle from Academy of Sciences of the Czech Republic for studying the solar corona (2014).

Petr Heinzel was awarded the Honorary Medal of Ernst Mach of Academy of Sciences of the Czech Republic for his mertis in the physics of the Sun (2015).



Marián Karlický received the Academy of Sciences Award and the František Nušl Award of the Czech Astronomical Society for significant scientific results in his research of the solar physics (2013).

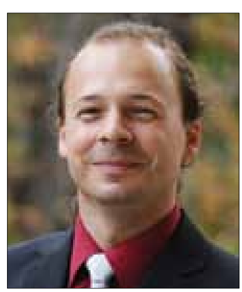
Frederic Marin received Jan Frič Award from the Institute for his work in study of active galaxy cores (2014).

Jan Palouš was awarded the Medal of the Academy of Sciences of the Czech Republic (2014) and the František Nušl Award of the Czech Astronomical Society (2015) for his mertis in the physical sciences.

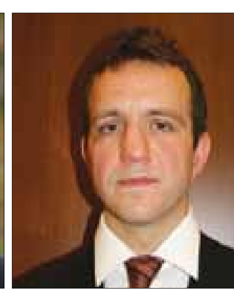
Petr Pravec recieved the Kopal lecture granted by the Czech Astronomical Society for the significant results in the field of interplanetary matter (2015).

Jiří Svoboda received Jan Frič Award from the Institute for his work in cosmology and study of the black holes (2013).

Jiří Štěpán was awarded the Premium of Otto Wichterle from Academy of Sciences of the Czech Republic for studying electromagnetic radiation (2013).



Michal Švanda received the Academy of Sciences Award for young researchers for research of new helioseismic methods (2014).



Ondřej Kopáček recieved Jan Frič Award from the Institute for his work in study of black hole magnetospheres (2015).

6.3. Supervision of PhD Theses

On the basis of an agreement with the Faculty of Mathematics and Physics of Charles University, Prague, the Astronomical Institute participates in the undergraduate study programs of Astronomy and Astrophysics and on Plasma Physics. The Institute, along with the Faculty, is also responsible for PhD-study program on Theoretical Physics, Astronomy and Astrophysics. Students of some other universities (including Masaryk University, Brno) are also supervised by researchers from the Astronomical Institute.

PhD Theses Supervised by Researchers of the Institute

Almáši M. (Masaryk University, Brno), supervisor S. Ehlerová.

Bartošková K. (Masaryk University, Brno), supervisor B. Jungwiert.

Bílek M. (Charles University, Prague), supervisor B. Jungwiert.

Čechura J. (Charles University, Prague), supervisor P. Hadrava.

Dinnbier F. (Charles University, Prague), supervisor R. Wünsch.

Doležalová B. (Masaryk University, Brno), supervisor J. Kubát.

Dvořáková Š. (Masaryk University, Brno), supervisor P. Koubský.

Ebrová I. (Charles University, Prague), supervisor B. Jungwiert.

Fišák J. (Masaryk University, Brno), supervisor J. Kubát.

Hamerský J. (Charles University, Prague), supervisor V. Karas.

Henych T. (Masaryk University, Brno), supervisor P. Pravec.

Herčík D. (Czech Technical University, Prague), supervisor P. Trávníček.

Janák Z. (Masaryk University, Brno), supervisor V. Votruba.

Janeková L. (Masaryk University, Brno), supervisor B. Jungwiert.

Jeřábková T. (Masaryk University, Brno), supervisor V. Votruba.

Jílek M. (Technical Unieversity, Prague), supervisor P. Trávníček.

Křížek M. (Charles University, Prague), supervisor B. Jungwiert.

Laifr J. (Czech Technical University, Prague), supervisor P. Trávníček.

Mackovjak S. (Comenius University, Bratislava, Slovakia), supervisor E. Dzifčáková.

Matěchová L. (Masaryk University, Brno), supervisor V. Votruba

Muratore M. F. (University of La Plata, Argentina), supervisor M. Kraus.

Okleštěk J. (Masaryk University, Brno), supervisor J. Koubský.

Skála J. (J. E. Purkyně University, Ústí nad Labem), supervisor M. Bárta.
Skála P. (Czech Technical University, Prague), supersivor R. Hudec.

Sidorin V. (Charles University, Prague), supervisor J. Palouš.

Sochora V. (Charles University, Prague), supervisor V. Karas.

Šebek O. (Czech Technical University, Prague), supervisor P. Trávníček.

Šejnová K. (Masaryk University, Brno), supervisor V. Votruba.

Tichý A. (Masaryk University, Brno), supervisor J. Kubát.

Tomič S. (Charles University, Prague), supervisor M. Kraus.

Vážný J. (Masaryk University, Brno), supervisor P. Škoda.

Vojáček V. (Charles University, Prague), supervisor J. Borovička.

Zychová L. (Masaryk University, Brno), supervisor S. Ehlerová.

PhD Theses successfuly defended under the scientific supervision by researchers of the Astronomical Institute

Čechura J.: Physics of X-ray Binaries

(2014, Charles University, Prague; supervisor P. Hadrava)

Abstract: We present a novel observation interpreting method for the high-mass X-ray binaries (HMXBs) based on a combination of spectroscopic data and numerical results of a radiation hydrodynamic model of stellar wind in HMXBs. By using an indirect imaging method of Doppler tomography, we calculate synthetic tomograms of a predicted emission in Low/Hard and High/Soft X-ray states and compare them with tomograms produced using phase-resolved optical spectra of Cygnus X-1, a prototype of HMXBs. The emis- sions of HMXBs are determined by the local conditions within the circumstellar medium - namely by local density, temperature, and ionization parameter. These quantities are computed by the radiation hydrodynamic code and strongly depend on the X-ray state of such systems. By increasing intensity of an X-ray emission produced by the compact companion in the HMXB-model, we achieved a complete redistribution of the circumstel- lar medium in the vicinity of the modelled system. These changes (which simulate the transitions between two major spectral states) are also apparent in the synthetic Doppler tomograms which are in a good agreement with the observational data.

Ebrová I.: Shell galaxies: kinematical signature of shells, satellite galaxy disruption and dynamical friction

(2013, Charles University, Prague; supervisor B. Jungwiert)

Abstract: Stellar shells observed in many giant elliptical and lenticular as well as a few spiral and dwarf galaxies presumably result from radial minor mergers of galaxies. We show that the line-of-sight velocity distribution of the shells has a quadruple-peaked shape. We found simple analytical expressions that connect the positions of the four peaks of the line profile with the mass distribution of the galaxy, namely, the circular velocity at the given shell radius and the propagation velocity of the shell. The analytical expressions were applied to a test-particle simulation of a radial minor merger, and the potential of the simulated host galaxy was successfully recovered. Shell kinematics can thus become an independent tool to determine the content and distribution of dark matter in shell galaxies up to ~100 kpc from the center of the host galaxy. Moreover we investigate the dynamical friction and gradual disruption of the cannibalized galaxy during the shell formation in the framework of a simulation with test particles. The coupling of both effects can considerably redistribute positions and luminosities of shells. Neglecting them can lead to significant errors in attempts to date the merger in observed shell galaxies.

Hamerský J.: Astrophysical processes near a galactic centre

(2015, Charles University, Prague; supervisor V. Karas)

Abstract: An accretion torus is an important astrophysical phenomenon which is believed to account for various features of mass inflow and release of radiation on diverse scales near stellar-mass as well as supermassive black holes. When the stationary torus is perturbed it starts to oscillate and once some part of the torus overflows the closed equipotential surface, defined by the stationary solution, this material is accreted or ejected. These oscillations reveal both spacetime properties and the intrinsic characteristics of the torus model. We study the oscillation and accretion properties of geometrically thick accretion tori using general relativistic magnetohydrodynamic simulations. We discuss the impact of the presence of the large scale magnetic field and the profile of the specific angular momentum on the oscillation properties and on the accretion flow motion.

Henych T.: Excitation of asteroid rotations through impacts

(2013, Masaryk University, Brno; supervisor P. Pravec)

Abstract: Most asteroids are found to be in principal axis rotation states. There is, however, a group of asteroids, called tumblers, which are in an excited state of rotation, i.e., freely precessing. This is indicated by their complex, two-periodic, lightcurves and also by radar measurements of the first confirmed and also the best described tumbler, 4179 Toutatis. A damping of the excited rotation is rather fast in most asteroids which explains why we observe most of them in a basic rotation state. A question arises on how were the asteroids excited. There are two major mechanisms to explain this, collisions and a torque related to Yarkovsky–O'-Keefe–Radzievskii–Paddack (YORP) effect. In the thesis we describe an analytical model we constructed to verify the plausibility of the collisional mechanism of the excitation of asteroid rotation. The main features of the model are the scaling laws used for calculation of the impact crater dimensions and the angular momentum transfer efficiency based on laboratory impact experiments. After the collision, a rotational lightcurve is generated for the simulated asteroid and we judge if the tumbling is detectable by the standard photometric analysis. We found that large subcatastrophic collisions are a plausible mechanism to excite rotations of small slowly rotating asteroids. The rotational axis misalignment is used as a measure of tumbling magnitude. Tumbling begins to be detectable for the misalignment angle larger than ~15 degrees with high accuracy data. We also found that the result of a collision can be simply described by the ratio of the orbital angular momentum (mainly carried by the projectile) and the rotational angular momentum of the target. We derived a relation between this ratio and the rotational axis misalignment. In addition, we compared the specific impact energy of the collision to the threshold energy which would already cause a serious damage to the asteroid. We found that asteroids as small as ~ 100 m can have excited rotation by collision without being damaged. Finally, we discuss our results and describe further work to be done to understand the processes that excite asteroid rotations.

Herčík D.: Planetary investigation by global numerical simulations: Study of Hermean environment

(2014, Czech Technical University, Prague; supervisor P. Trávníček)

Abstract: The thesis is based on the data analysis of hybrid numerical simulations of solar wind interaction with the Hermean magnetosphere. The main aim is to provide a global picture of the resulting magnetosphere, its structure, features, and highlight some processes within. Magnetosphere of Mercury is smaller than the terrestrial one, however, it seems to exhibit similar features and behaviour. Different scale (temporal and spatial) plays role in the enhancement of significance of kinetic effects on the processes as well as on the global magnetospheric structure. Hybrid simulations are suitable for kinetic effects study as the proton kinetics is implemented into the code. Six simulations, varying in the orientation of the Interplanetary Magnetic Field (IMF), are analysed and compared. It shows a large influence of the IMF orientation on the magnetospheric structure. The comparison of these simulations is provided within the thesis. Via summarization of the Earth's magnetospheric features in the first part, the comparison with observed results is given.

Mackovjak Š.: Diagnostics of the non-Maxwellian distributions in the solar corona and transition region

(2014, Comenius University, Bratislava, Slovakia; supervisor E. Dzifčáková)

Abstract: The non-Maxwellian κ-distributions have been detected in various space plasmas, including solar wind. However, no evidence of their presence in the solar corona has been found yet. The PhD thesis is focused on diagnostics of κ-distributions of electrons in the solar corona and transition region using spectroscopic data. The diagnostic methods were proposed by Dzifčáková and Kulinová (2010) for spectral lines of iron ions. These methods are in PhD

thesis extended using lines of other ions. Lines suitable for diagnostics of κ, as well as density and temperature were selected. A specialized observation for the Hinode/EIS instrument were prepared and carried out. This dataset is analyzed and diagnosed parameters of coronal plasma are presented and discussed. The diagnosed results shown that the investigated plasma is unlikely to be Maxwellian. The differential emission measure (DEM) of different solar regions were investigated and the in uence of κ-distribution to the DEM were shown. For lower κ, the peaks of the DEMs are typically shifted to higher temperatures and the DEMs themselves become more wider. The PhD thesis provides straightforward analysis from theoretical diagnostic method to application on obtained data. The presented results challenge the traditional Maxwellian analysis of coronal observations. The PhD Thesis Report offers a short introduction to the κ-distributions and the summary of the most important results of the the PhD thesis.

Sochora V.: Astrophysical processes near compact objects: studying extremal energy shifts from accretion rings

(2013, Charles University, Prague; supervisor V. Karas)

Abstract: The X-ray emission from inner regions of an accretion disk around black holes provides wealth of information about matter in extreme conditions. A spectral profile of radiation from a narrow circular ring has a characteristic double-horn profile. Red and blue peaks of the profile are close to the extremal values of the energy shift. We describe a useful approach to calculate the extremal energy shifts in the regime of strong gravity. We discuss if the radial structure of the disk emission could be reconstructed using extremal energy shifts of the individual rings. For this purpose, we simulate artificial data from a bright active galactic nucleus and show that the required sensitivity and energy resolution can be reached with the proposed LOFT mission.

6.4. Participation in Editorial and Advisory Boards

V. Bumba: honorary member of the Editorial Board of Solar Physics.

M. Dovčiak: member of the Advisory board for Cosmic Research at MEYS.

P. Hadrava: vice-president of the Editorial board of CAS (until 2013); member of the Editorial board of "Dějiny vědy a techniky" (History of Sciences and technology).

P. Heinzel: member of the Editorial Board of Solar Physics.

V. Karas: member of the Advisory Board for Classical and Quantum Gravity.

M. Karlický: member of the Editorial Board of Solar Physics; member of the Editorial Board of Contributions of the Astronomical Observatory Skalnaté Pleso.

J. Kleczek: honorary member of the Editorial Board of Solar Physics.

P. Kotrč: member of the Editorial Board of Central European Astrophysical Bulletin.

J. Kubát: member of the Editorial Board of Astronomy & Astrophysics; member of Editorial advisory board of the Bulgarian Astronomical Journal.

C. Ron: member of the Editorial board of the Romanian Astronomical Journal and of their Geoinformatics FCE CTU.

J. Vondrák: member of the Editorial Board of Contributions of the Astronomical Observatory Skalnaté Pleso; member of the Editorial Board of Serbian Astronomical Journal; member of the Editorial Board of Astropis.

6.5 Scientific Staff Involved in International Organizations

The following scientists employed at the Astronomical Institute are (or were) members of the International Astronomical Union in last two years:
P. Ambrož, M. Bárta, J. Borovička, V. Bumba, M. Bursa, D. Čapek, M. Dovčiak, E. Dzifčáková, S. Ehlerová, F. Fárník, S. Gunár, P. Hadrava, P. Heinzel, J. Horák, R. Hudec, P. Jáchym, B. Jungwiert, J. Jurčák, P. Kabath, V. Karas, M. Karlický, J. Kašparová, A. Kawka, J. Kleczek, J. Klokočník, M. Klvaňa, D. Korčáková, P. Koten, P. Kotrč, P. Koubský, M. Kraus, J. Kubát, H. Mészárosová, D. Nickeler, J. Palouš, P. Pecina, L. Perek, P. Pravec, C. Ron, L. Shrbený, P. Scheirich, P. Schwartz, M. Sobotka, P. Spurný, Z. Šíma, V. Šimon, P. Škoda, M. Šlechta, J. Štěpán, M. Švanda, M. Vandas, S. Vennes, J. Vondrák, V. Votruba, R. Wünsch

Involvement of scientists from the Institute in other important international organizations

Committee on Space Research (COSPAR), European Astronomical Society (EAS), American Astronomical Society (AAS), Royal Astronomical Society (RAS), European Geophysical Union (EGU), American Geophysical Union (AGU), International Association of Geodesy (IAG) and the International Union of Geodesy and Geophysics (IUGG), European Association for Solar Telescopes (EAST), Council of Research Institute for Geodesy, Topography, and Cartography (CRIGTC), European Space Agency (ESA), Czech National Astronomical Committee of International Astronomical Union (CNAC IAU), European Solar Physics (ESPD), Community of European Solar Radio Astronomers (CESTRA), Joint Organization for Solar Observations (JOSO), Committee on Radio Astronomy Frequencies (CRAF), International Union of Radio Science (URSI), International Association for Pattern Recognition (IAPR), Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), Czech and Slovak Pattern Recognition Society (CSPRS), European Southern Observatory (ESO), National Aeronautics and Space Administration (NASA) etc. The involvement in these and other organizations is given in the following list of activities of individuals.

P. Ambrož: member of Czech National Committee of SCOSTEP.
M. Bárta: board member of CESTRA, member of Czech National Committee of SCOSTEP and member of team of Czech node of ESO/EU ALMA Regional Center.
R. Brajša: member of team of Czech node of ESO/EU ALMA Regional Center.
J. Borovička: vice-president of the Commission Meteors, Meteorites, and Interplanetary Dust of the IAU and member of EAS.
V. Bumba: member of EAS.
M. Dovčiak: member of XMM-Newton AO-13 panel for reviewing the ESA's XMM-Newton observational proposals; co-chair of the science working group for the ESA's Athena mission (launch in 2028).
F. Fárník: member of Science program Committee of ESA; member of Czech National Committee of COSPAR.
P. Hadrava: member of CHAMA (Commission for History of Ancient and Medieval Astronomy IUHPS), Comisssion C19 Astrophysics IUPAP IUPAP, ASTRONET and ELTSRC.
P. Heinzel: member of Czech Committee PRODEX and the Science Program Committee of ESA, Czech National Astronomical Committee of IAU, Czech National Committee of COSPAR; member of EAS.

R. Hudec: Member of AAAS and SPIE.
K. Jiřička: national representative member of URSI and European Science Foundation of CRAF; member of Committee on Radio Astronomy Frequencies (CRAF) of the European Science Foundation (ESF).
B. Jungwiert: member of AAS and EAS.
V. Karas: member and Chairman of the Time Allocation Committee Panel for ESA's XMM-Newton and a member of the Evaluation Panel for European Research Council's Starting Grants; member of RAS, The International Society on General Relativity and Gravitation, American Astronomical Society.
M. Karlický: member of Czech National Astronomical Committee of IAU and co--leader of team of Czech node of ESO/EU ALMA Regional Center; member of the Executive committee of WISER (World Institute for Space Environment Research, University of Adelaide). Co-leader of WISER Research Working Group on Sun/Heliosphere.
A. Kawka: member of Observing Programmes Committee for the ESO and representative member of the Users Committee for the ESO, chair of the Czech time the ESO/MPG 2.2-m telescope at La Silla in Chile; member of the Astronomical Society of Australia (MASA); representative member of the ESO User Committee.
J. Klokočník: member of COSPAR, IAG/IUGG, EGU, AGU.
P. Koten: member of Task Group on Meteor Shower Nomenclature of Commission Meteors, Meteorites and Interplanetary Dust of the IAU.
P. Kotrč: national representative member of JOSO.
M. Kraus: member of the German Physical Society (DPG); member of the German Astronomical Society (AG).
H. Mészárosová: member of Advisory Group Space of EU: Horizon 2020; member of the European Physics Society (EPS); representative member of the European Solar Physics Division (ESPD).
D. Nickeler: member of the German Astronomical Society (AG).
J. Palouš: vice-president of the IAU and member of the scientific board of the Centre de Données Stellaires; member of RAS; member of Royal Society of Edinburgh.
L. Perek: associate member of the Royal Astronomical Society since 1970; member of the Deutsche Akademie der Naturforscher Leopoldina since 1975; member of the International Institute of Space Law since 1977, member of its Board of Directors 1996-2006; member of the International Academy of Astronautics since 1977; advisor to its President 2002-2006; honorary member of the Academie Nationale de l'Air et de l'Espace, Toulouse, since 1994, and member of EAS.
P. Pravec: member of the Organizing Committee of Commission Positions & Motions of Minor Planets, Comets & Satellites and a member of panel C of the Observing Proposal Committee of the ESO; member of the Division of Planetary Sciences of the AAS and member of the Spaceguard Foundation.
C. Ron: member of the CRIGTC. Council of Research Institute for Geodesy, Topography, and Cartography.
M. Sobotka: national representative member of EAST.
Z. Šíma: since 1995 member of the International Geoid Service, Special Working Group of the GSFC/DMA and member of Special Commission SC3 – Fundamental Astrogeodetic Constants of the IAG/IUGG; Inter-Commission Committee on Planetary Geodesy of IAG/IUGG; also member of Scientific Instrument Society.

Member of Società Astronomica Italiana.
S. Šimberová: national representative member of IAPR-TC13 and president of CSPRS.
P. Trávníček: member of AGU.
M. Vandas: since 2000 member of COSPAR Scientific Commission D (Space Plasmas in the Solar System, including Planetary Magnetospheres) to IAU Liaison, since 2002 member and since 2008 secretary of the National Committee of SCOSTEP.
S. Vennes: representative member of the Scientific Technical Committee for the ESO; consultant for NASA proposal selection committees and Fellow of the Astronomical Society of Australia (FASA).
J. Vondrák: member of the Organizing Committee of IAU Commission 4 – Ephemerides.
V. Votruba: member of technical team in the GAIA satellite wide international.
P. Koubský: member of technical team in the GAIA satellite wide international.

6.6 Visitors of the Institute

Each year we host number of scholars, postdocs and students from all over the world who came to spend their time working with colleagues at our Institute. Here we present the list of scientists who visited us in 2013–2014:

Name	Country	Days
Abe S.	Japan	3
Alemán T.	Spain	13
Altyntsev A. T.	Russia	20
Andersen J.	Denmark	7
Andre P.	France	4
Andreani P.	Germany	4
Anzer U.	Germany	14
Araudo A.	Argentina	7
Aret A.	Estonia	27
Barunina I.	Russia	9
Berežnoj A.	Russia	106
Bisbas T.	England	6
Borkar A.	Germany	8
Brajša R.	Croatia	4
Bucha B.	Slovakia	11
Calderón P.	Chile	8
Cidale L.	Argentina	16
Clark P.	Germany	6
Colas F.	France	4
Comeron F.	Chile	4
Czerny B.	Poland	10

Name	Country	Days
Čapanov J.	Bulgaria	14
Dadhich N.	India	3
Dale J.	Germany	70
Demleiner M.	Germany	3
Dinčič J.	Serbia	19
Done Ch.	England	9
Du J.	China	7
Dudík J.	England	11
Eckort A.	Germany	4
Egal A.	France	4
Elmegreen B. G.	USA	5
Elshaer A. S. A. E.	Egypt	14
Epitropakis A.	Greece	19
Eppelbaum L. V.	Izrael	7
Fernandes M. B.	Brazil	8
Fukui Y.	Japan	5
Geng L.	China	7
Gilles M.	France	6
Girichidis P.	Germany	8
Gömöry P.	Slovakia	17
Gonzáles M. S.	Mexiko	12

Name	Country	Days
Goosmann R.	France	6
Granada A.	Swiss	5
Gunár S.	England	4
Guttenbrunner S.	Austria	5
Haid S.	Germany	7
Hamann W.R.	Germany	4
Hamedivafa H.	Iran	14
Hameury J.M.	France	8
Chapanov J.	Bulgaria	15
Ilič N.	Serbia	20
Iliev L.	Bulgaria	29
Ivanov E.	Russia	23
Janjes A.	Serbia	20
Jejčič S.	Slovenia	30
Jílková L.	Netherlands	4
Juany J.	China	30
Kabáth P.	Chile	12
Kahraman F.	Poland	12
Karssen G.	Germany	19
Kartashova A.	Russia	15
Kashapova L.	Russia	14
Khorrami Z.	France	14
Köppen J.	France	63
Kornoš L.	Slovakia	2
Kostič P.	Serbia	19
Kroupa P.	Germany	5
Kupriyanova E.	Russia	9
Kuprjakov J.	Russia	287
Kuznětsov A.	Russia	30
Kuznetsov S.	Russia	8
Kylafis N.	Greece	22
Kyung Kwon M.	France	4
Lai D.	USA	7
Laing R.	Germany	2
Leedjarv L.	Estonia	7
Lemmerer B.	Austria	13
Li S.	China	7
Lindflab O.	Sweden	5

Name	Country	Days
Liu D.	China	7
Liu F.	China	7
Liu W.	USA	4
Mackovjak Š.	Slovakia	27
Mačeta D.	Serbia	7
Marin F.	France	82
Matlovič P.	Slovakia	5
Matt G.	Italy	4
Maximov V.A.	Russia	9
Meshalkina N.S.	Russia	60
Morgachev A.	Russia	15
Mozgova A.	Ukraine	9
Muračov A.	Russia	8
Muratore M.F.	Argentina	105
Muratova N.	Russia	15
Naletto G.	Italy	2
Nastala J.	Poland	5
Niemczura E.	Poland	39
Oksala M.	France	5
Olsson E.	Sweden	34
Olsson E.	Sweden	7
Onič D.	Serbia	5
Orlitová I.	Swiss	3
Papadakis I.	Greece	3
Parsa M.	Germany	6
Peissker F.	Germany	14
Petrovič J.	Serbia	19
Piantschitsch I.	Austria	13
Pirkovič I.	Serbia	19
Radosavljevič I.	Serbia	20
Radovič V.	Serbia	9
Radziszewski K.	Poland	10
Ragan S.	Germany	6
Remillard R.	USA	6
Rosen A.	USA	8
Rozanska A.	Swiss	19
Rudawska R.	Slovakia	2
Rybák J.	Slovakia	18

Name	Country	Days
Sharikov S.	Mexiko	19
Shenar T.	Germany	12
Shum C. K.	USA	4
Schaerer D.	Swiss	2
Schmieder B.	France	50
Sijie Y.	China	7
Silich S.	Mexiko	13
Smiljanič S.	Serbia	20
Smith R.	Chile	8
Stankovic M.	Serbia	19
Su C.	China	7
Susino R.	Italy	3
Sych R.	Russia	16
Tagle T. G.	Mexiko	37
Tan B.	China	78
Tan Ch.	China	29
Taylor R.	USA	4
Testi L.	Germany	2
Tomič S.	Serbia	14
Tóth J.	Slovakia	8
Trova A.	France	59
Tsap Y.	Russia	8
Uttley P.	Netherlands	2
Utz D.	Austria	16
Vallverdú R. E.	Argentina	31
Vaubaillon J.	France	
Velovič V.	Serbia	19
Vieira R. S.	Brazil	5
Wade G.	Kanada	5
Walch S.	Germany	12
Wang W.	China	7
Weigelt M.	Luxembourg	3
Whitworth A.	England	16
Yan Y.	China	7
Yan Zhen	China	14
Yu W.	China	10
Yu Wenfei	China	12
Zapior M.	Poland	20

Name	Country	Days
Zeid I.	Egypt	14
Zhang W.	China	27
Zhang Y.	China	30
Zhdanov D.	Russia	6
Zwaan M.	Germany	4
Žiňon-Muňoz C.	Spain	5

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Photos: Archive of the Institute, NASA, ESO, ESA, Vlastimil Vojáček, Petr Horálek

Front Page: A bright bolide Žd'ár nad Sázavou captured on December 9th, 2014 by a camera at Červená hora station of the European Fireball Network. The -15 absolute magnitude bolide was observed by thousands of eyewitnesses over large part of central Europe and two small fresh meteorite fragments were soon located during dedicated search within 100m of the predicted location for given mass thanks to very precise records of its atmospheric trajectory.

Graphics and Layout: Martina Zoubková

Tisk: Novatisk a.s.