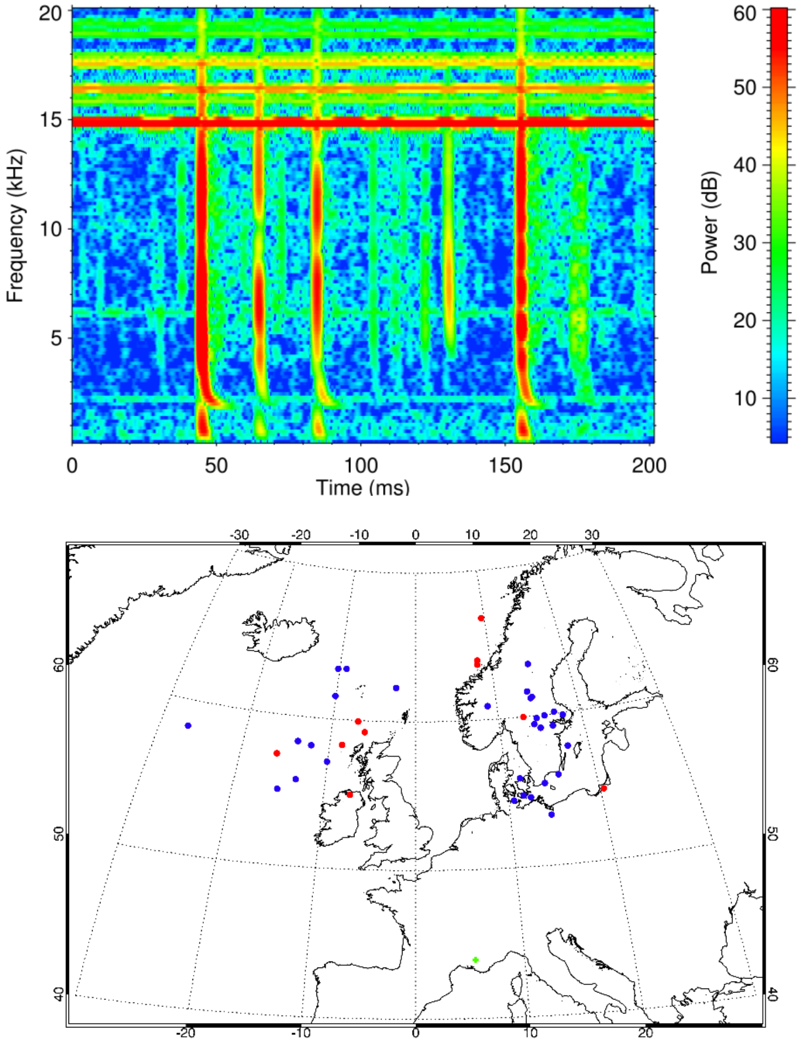
Results of the Department of Space Physics, Institute of Atmospheric Physics, Czech Academy of Sciences, published in 2017

1. Unusual Electromagnetic Signatures of European North Atlantic Winter Thunderstorms

We detected for the first time unusual daytime atmospherics with dispersion signatures originating from strong thunderstorms which occurred during winter months 2015 in the North Atlantic region. Using newly developed analysis techniques for 3-component electromagnetic measurements we were able to determine the source azimuth and to attribute these rare atmospherics to both positive and negative lightning strokes in northern Europe. We consistently found unusually large heights of the reflective ionospheric layer which were probably linked to low fluxes of solar X rays and which made the dayside subionospheric propagation possible. Although the atmospherics were linearly polarized, their dispersed parts exhibited left handed polarization, consistent with the anticipated continuous escape of the right-hand polarized power to the outer space in the form of whistlers.



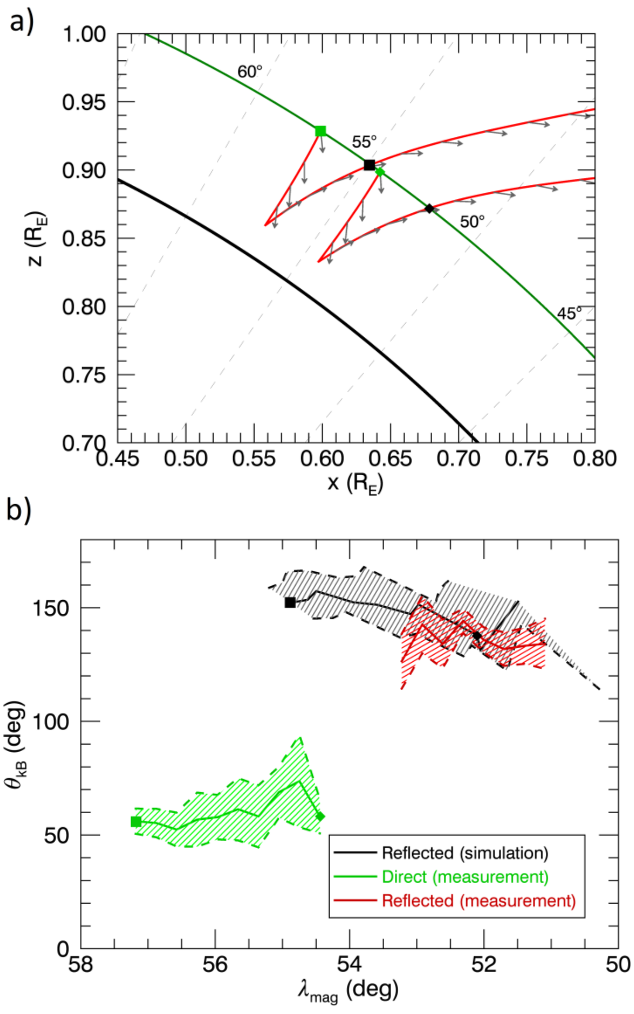
(top) Unusual daytime tweek which is pronounced enough to be suitable for further analysis (9 Jan 2015 at 11:31:41.6; (bottom) Locations of source lightning strokes. Red and blue dots represent positive and negative lightning strokes, respectively; a green cross shows the location of our VLF receiving station.

Reference:

Santolík, O., and **I. Kolmašová** (2017), Unusual Electromagnetic Signatures of European North Atlantic Winter Thunderstorms, Scientific Reports 7, 13948, doi:10.1038/s41598-017-13849-4.

2. Observation of ionospherically reflected quasiperiodic emissions by the DEMETER spacecraft

Quasiperiodic (QP) electromagnetic emissions are whistler mode waves at typical frequencies of a few kHz characterized by a periodic time modulation of their intensity. The DEMETER spacecraft observed events where the QP emissions exhibited a sudden change in the wave vector and Poynting vector directions. The change happened in a short interval of latitudes. We explained this behavior by ionospheric reflection and present a ray-tracing simulation which matched resulting wave vector directions. We also attempted to locate the source region of these emissions and concluded that they are most probably generated at the inner boundary of the plasmapause which also acted as a guide during the propagation of the QP emissions.



a) Detail of ionospheric reflection of simulated ray trajectories of whistler mode QP emissions. The thick black curve is the Earth's surface, and the green curve stands for the orbital altitude of the DEMETER satellite. The grey arrows represent the wave vector directions along the path with equidistant group time intervals of 0.01 s. The initial value of the magnetic latitude of depicted rays was 54.4 ° and 57.2°. (b) Dependence of the angular deviation of the wave vector from the local field *line on geomagnetic latitude for observed waves, together with simulated rays crossing the position of DEMETER. Green line connects the initial measured values for direct waves, red line connects the final measured values for reflected waves. Dashed green and red lines and filled areas represent the standard deviation. Black line shows the result of simulation of reflected rays, where the dashed black lines are results of simulation for averaged initial wave vector angle increased or decreased by the standard deviation. The ∼15 s gap between red and green areas represents the time interval where mixing of direct and reflected waves is most prominent and therefore cannot be used for comparison.*

Reference:

Hanzelka, M., O. Santolík, M. Hajoš, F. Němec, and M. Parrot (2017), Observation of ionospherically reflected quasiperiodic emissions by the DEMETER spacecraft, *Geophys. Res. Lett.*, *44*, 8721–8729, doi:10.1002/2017GL074883.

Related references:

Chen, L., **O. Santolík, M. Hajoš,** L. Zheng, Z. Zhima, R. Heelis, **M. Hanzelka**, R. B. Horne, and M. Parrot (2017), Source of the low-altitude hiss in the ionosphere, Geophys. Res. Lett., 44, 2060–2069, doi:10.1002/2016GL072181.

Nemec, F., K. Čížek, M. Parrot, **O. Santolik**, and J. Zahlava (2017), Line radiation events induced by very low frequency transmitters observed by the DEMETER spacecraft, J. Geophys. Res. Space Physics, 122, 7226–7239, doi:10.1002/2017JA024007.

3. Chorus and radiation belts

Observations of whistler-mode chorus made by the THEMIS spacecraft inside the equatorial chorus source region often exhibit the following peculiar features. Two groups of chorus elements are visible simultaneously which are approaching the spacecraft from two different directions: either along or against the direction of the ambient magnetic field. Furthermore, both groups are slightly shifted in frequency with respect to each other and elements are of different intensities. We interpreted these features in the frame of the backward-wave oscillator theory by means of two exemplary events, yielding insight into the nonlinear generation mechanism and the specific source-observer geometry during the time of observation.

Reference:

Taubenschuss, U., A.G. Demekhov, and **O. Santolik**, Interpretation of whistler mode chorus observations with the backward wave oscillator model (2017), in Planetary Radio Emissions VIII, edited by G. Fischer, G. Mann, M. Panchenko, and P. Zarka, Austrian Academy of Sciences Press, Vienna, 233–242.

Related references:

Demekhov, A. G., J. Manninen, **O. Santolík**, and E. E. Titova (2017) Conjugate ground-spacecraft observations of VLF chorus elements, Geophys. Res. Lett 44, doi.org/10.1002/2017GL076139.

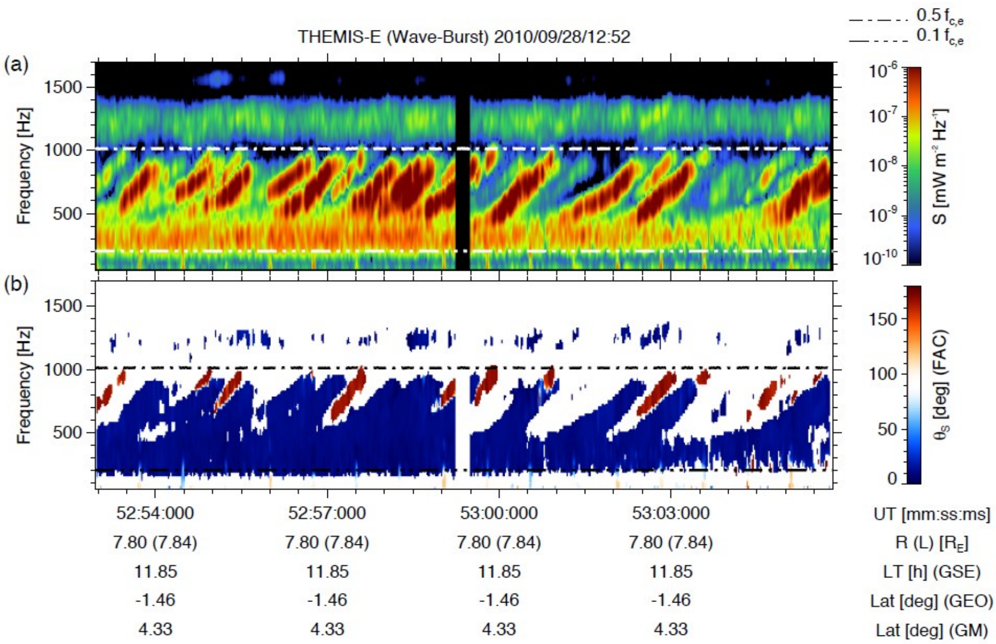
Breneman, A. W., A. Crew, J. Sample, D. Klumpar, A. Johnson, O. Agapitov, M. Shumko, D. L. Turner, **O. Santolik**, J. R. Wygant, C. A. Cattell, S. Thaller, B. Blake, H. Spence, C. A. Kletzing (2017). Observations directly linking relativistic electron microbursts to whistler mode chorus: Van Allen Probes and FIREBIRD II, Geophys. Res. Lett. 44, doi.org/10.1002/2017GL075001.

Demekhov, A. G., U. Taubenschuss, and **O. Santolík** (2017), Simulation of VLF chorus emissions in the magnetosphere and comparison with THEMIS spacecraft data, J. Geophys. Res. Space Physics, 122, 166-184, doi:10.1002/2016JA023057.

Ripoll, J.- F., **O. Santolík**, G. D. Reeves, W. S. Kurth, M. H. Denton, V. Loridan, S. A. Thaller, C. A. Kletzing, and D. L. Turner (2017), Effects of whistler mode hiss waves in March 2013, J. Geophys. Res. Space Physics, 122, 7433-7462, doi:10.1002/2017JA024139.

Hartley, D. P., C. A. Kletzing, W. S. Kurth, G. B. Hospodarsky, S. R. Bounds, T. F. Averkamp, J. W. Bonnell, **O. Santolik,** and J. R. Wygant (2017), An improved sheath impedance model for the Van Allen Probes EFW instrument: Effects of the spin axis antenna, J. Geophys. Res. Space Physics, 122, 4420-4429, doi:10.1002/2016JA023597.

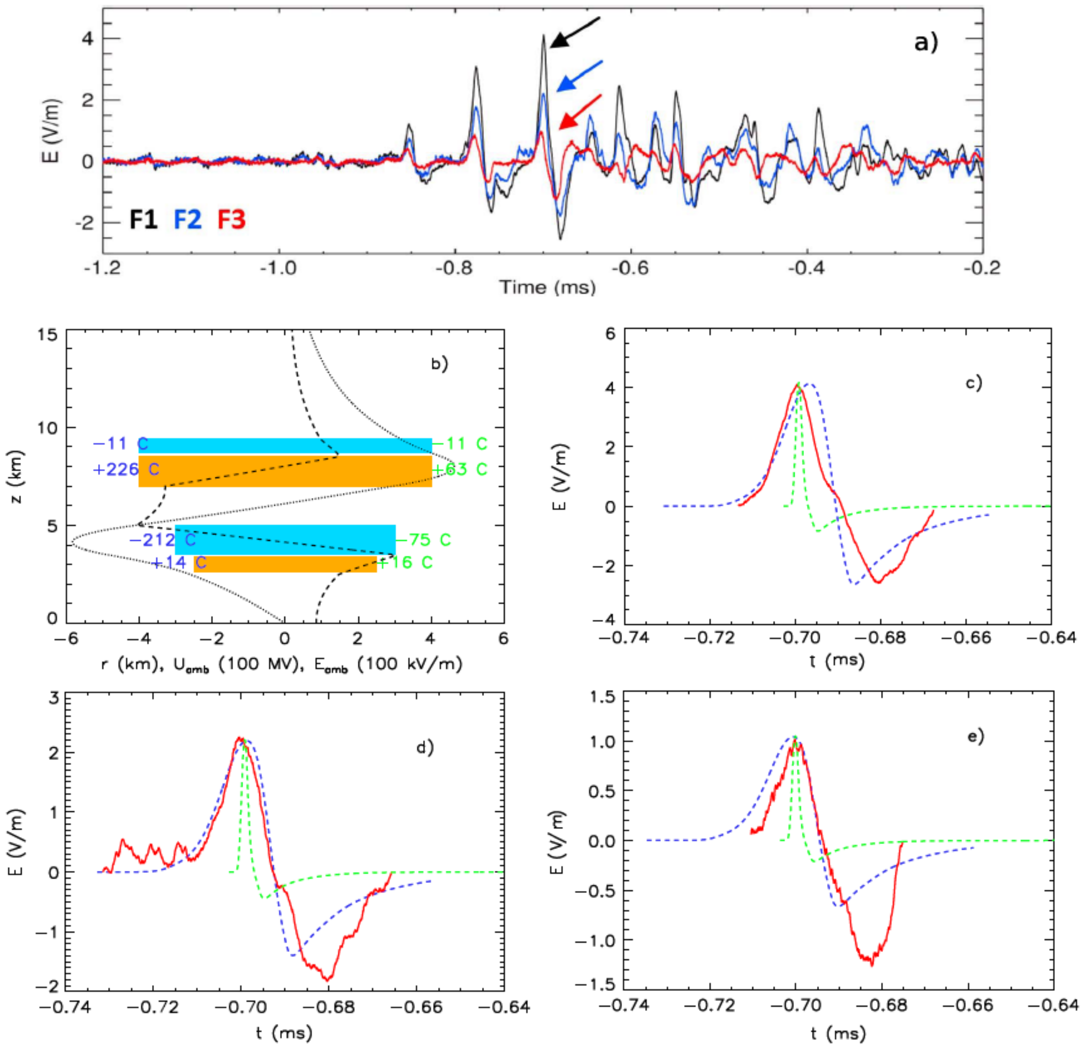
Turner, D. L., Lee, J. H., Claudepierre, S. G., Fennell, J. F., Blake, J. B., Jaynes, A. N., ..., **Santolik, O.** (2017). Examining coherency scales, substructure, and propagation of whistler mode chorus elements with Magnetospheric Multiscale (MMS). Journal of Geophysical Research: Space Physics, 122, 11, doi:10.1002/2017JA024474.



(top) Poynting flux and (bottom) polar angle for chorus emission observed by THEMIS-A on October 29, 2008. The dashed-dotted line marks half of the local electron cyclotron frequency. Orbital coordinates of the spacecraft are given at the bottom.

4. A model of preliminary breakdown pulse peak currents and their relation to the observed electric-field pulses

Preliminary breakdown pulses (PBPs) occur in the initial phase of lightning. We designed a realistic model for their description to investigate relation between PBP peak currents and PBP electric field amplitudes, and their relation to the return stroke (RS) peak currents. We demonstrated that the PBP peak currents can reach 200 kA, and can be comparable or higher than the corresponding RS peak currents. For a typical PBP electric field waveform PBP peak currents were approximately proportional to the electric field amplitudes. We showed that the PBP bipolar overshoot depends primarily on the characteristic time of the line conductivity increase. The magnitude of the charge centers was demonstrated to be very large in order to model the observed PBPs with amplitudes up to 32 V/m at 100 km. Such energetic current pulses might be capable to produce elves or terrestrial gamma-ray flashes.



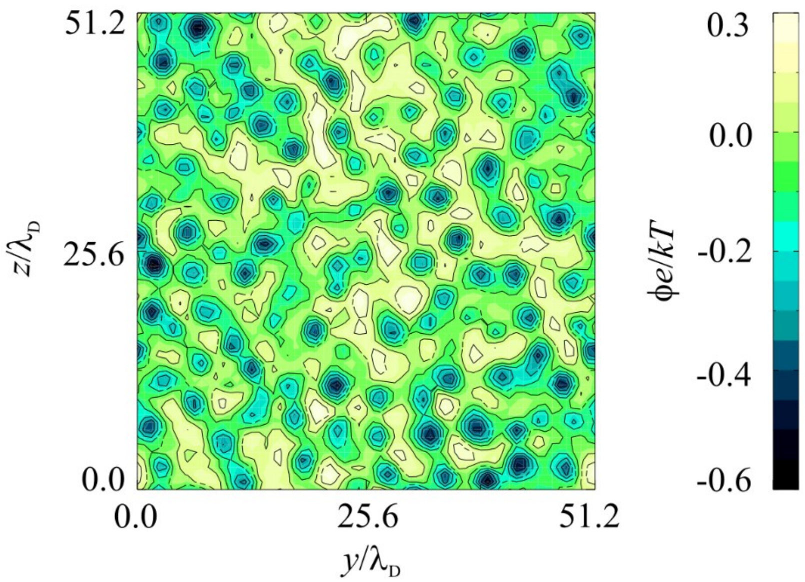
a) Example of the pulse-train measured at the distance of 306.1 km (F1), 415.8 km (F2), and 562.9 km (F3) from a lightning RS location. b) Charge structure inside a simulated thundercloud plotted with (dotted line) ambient potential and (dashed line) ambient electric field. c)-e) Measured (solid red line) and simulated (dashed lines) PBPs at three different distances corresponding to lines F1-F3 from a). Blue dashed line shows the simulated PBP, which are compared with observations (red line). Green dashed line is obtained by the same model with different parameters .

Reference:

Kaspar P., O. Santolik, **I. Kolmasova**, and T. Farges (2017), A model of preliminary breakdown pulse peak currents and their relation to the observed electric-field pulses, Geophys. Res. Lett., 43, 596-603, doi:10.1002/2016GL071483.

5. Numerical heating of electrons in particle-in-cell simulations of fully magnetized plasmas

We analyzed the role of spatial resolution of the electron gyroradius in electrostatic particle-in-cell (PIC) simulations. We demonstrated that resolving the gyroradius was crucial for simulations of strongly magnetized plasmas and that nonresolving it resulted in substantial anisotropic heating of electrons. The numerical heating was suppressed by the higher-order weighting to the grid, but it could not be avoided. We discussed possible mechanisms behind this numerical heating. The study was carried out with a fully three dimensional electrostatic PIC code with an external magnetic and electric fields.



The evolution of filamentary structures along magnetic field. Both axes are normalized to the Debye length λD.

Reference:
M. Horký, W. J. Miloch, and V. A. Delong (2017), Numerical heating of electrons in particle-in-cell simulations of fully magnetized plasmas, *Phys. Rev.* E 95, 043302.

6. Space weather

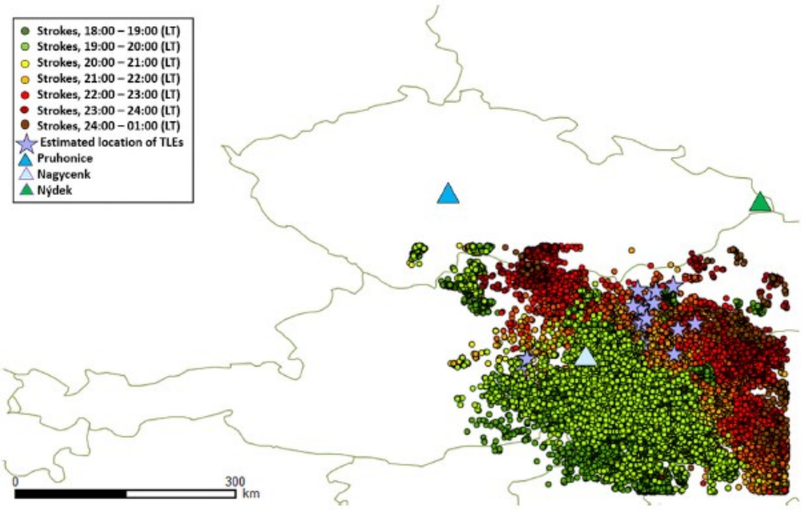
Reference:

C. Möstl, A. Isavnin, P. D. Boakes, E. K. J. Kilpua, J. A. Davies, R. A. Harrison, D. Barnes, **V. Krupar**, J. P. Eastwood, S. W. Good, R. J. Forsyth, V. Bothmer,M. A. Reiss ,T. Amerstorfer, R. M. Winslow, B. J.

Anderson, L. C. Philpott, L. Rodriguez, A. P. Rouillard, P. Gallagher, T. Nieves-Chinchilla, and T. L. Zhang (2017), Modeling observations of solar coronal mass ejections with heliospheric imagers verified with the Heliophysics System Observatory, Space Weather, 15, 955–970, doi:10.1002/2017SW001614.
Miteva, R., S. W. Samwel, and **V. Krupar** (2017), Solar energetic particles and radio burst emission, J. Space Weather Space Clim. 2017, 7, A37, doi.org/10.1051/swsc/2017035.

7. Transient luminous events

Optical recordings of transient luminous events (station Nydek, observer M. Popek) were used for a study of an influence of thunderstorm activity on the ionospheric sporadic E-layer and for an analysis of orbital fragmentation of a larger meteorite from the Perseid cluster.



Geographic locations of lightning strokes from 2014. 07. 30. 18:00 to 2014. 07. 31. 01:00, LT. The locations of the observed sprites are shown with stars. Stations at Pruhonice, Nagycenk, and Nydek are indicated by the blue, light-blue and green triangles, respectively

Reference:

Barta, V., Ch. Haldoupis, G. Satori, D. Buresova, J. Chum, M. Pozoga,K. A. Berenyi, J. Bor, **M. Popek**, A. Kis, P. Bencze (2017), Searching for effects caused by thunderstorms in midlatitude sporadic E layers, Journal of Atmospheric and Solar-Terrestrial Physics 161, 150–159.

Related reference:

Koten, P. D. Capek, P. Spurný, J. Vaubaillon, **M. Popek**, and L. Shrbeny (2017), September Epsilon Perseid cluster as a result of orbital fragmentation, Astronomy & Astrophysics, Vol. 600, doi.org/10.1051/0004-6361/201630246.

Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences in 2017

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3. Michajlo Hajoš, research scientist
4. Miroslav Hanzelka, MSc student, 20% FTE
5. Miroslav Horký, postdoctoral associate, 20% FTE until March 31, 100% FTE since April 1
6. Petr Kašpar, postdoctoral associate
7. Vratislav Krupař, research scientist, 100% FTE until April 30, 50% FTE since May 1
8. Oksana Krupařová, research scientist, 100% FTE until April 30, 75% FTE since May 1
9. Radek Lán, research engineer
10. Jan Lukačevič, research engineer, 60% FTE since July 1
11. Martin Pauer, research engineer, 20% FTE
12. David Píša, research scientist
13. Martin Popek, TLE observer, 25% FTE
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16. Ulrich Taubenschuss, research scientist
17. Alexander Tomori, PhD student, 50% FTE
18. Hana Špačková (née Zemanová), PhD student, 50% FTE