The 23rd Rudolf Brdička Memorial Lecture

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Superfluid Helium Nanodroplets: Very Cold and Extremely Gentle

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Superfluid Helium Nanodroplets: Very Cold and Extremely Gentle

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The extraordinary phenomenon of superfluidity first found in liquid helium below 2.17 K has confounded theoreticians ever since its discovery in 1938 by Kapitza in Moscow and Allen and Miesener in Cambridge (UK). Today molecular beams of helium clusters ranging in size from a few atoms up to nanodroplets with as many as 1010 – 1012 atoms formed in free jet expansions provide new opportunities to explore and utilize superfluidity at the microscopic level. The sharp phonon wings found in the spectra of embedded chromophores confirmed that the droplets, which are cooled evaporatively in vacuum to 0.37 K, are indeed superfluid. Then the free rotations seen previously in highly resolved infra-red chromophore spectra, not found previously in any liquid, could also be attributed to superfluidity1. More recent spectroscopic studies indicate that even chromophores with only about 8 attached He atoms exhibit related superfluid effects2. Another surprising manifestation of superfluidity is the observation that electronically excited Ag atoms are ejected from droplets without friction as long as their velocities are less than the limit predicted by Landau in 19473. Quantum vortices, another hallmark of superfluidity, have been indirectly identified inside huge droplets4, where they organize metal atoms into long metal nanowires. These and other experiments make superfluid helium nanodroplets by far the coldest and gentlest of all cryomatices with remarkable properties.

Present day experiments are directed at extending the spectroscopies to large organic and biomolecules, to exploring the unique structures of cryo-organised clusters and their chemical reactions. The demonstration of laser alignment5in the cold droplets and femto-second pulse-probe experiments open up new avenues for dynamical studies. Also the first successful electron diffraction experiments6 and X-ray diffraction experiments carried out at SLAC on individual pure and doped droplets7 point the way towards many new exciting areas of research in physics, chemical physics and chemistry.

(1) Toennies, J. P.; Vilesov, A. F. Angew Chem Int Edit 2004, 43, 2622.

(2) McKellar, A. R. W.; Xu, Y. J.; Jager, W. J Phys Chem A 2007, 111, 7329.

(3) Brauer, N. B.; Smolarek, S.; Loginov, E.; Mateo, D.; Hernando, A.; Pi, M.; Barranco, M.; Buma, W. J.; Drabbels, M. to be published 2013.

(4) Gomez, L. F.; Loginov, E.; Vilesov, A. F. Phys Rev Lett 2012, 108.

(5) Pentlehner, D.; Nielsen, J. H.; Slenczka, A.; Molmer, K.; Stapelfeldt, H. Phys Rev Lett 2013, 110, 093002.

(6) Zhang, J.; He, Y.; Freund, W. M.; Han, F.; Chen, L.; Harthcock, C.; Kong, W. Phys Rev Lett 2012, submitted.

(7) Vilesov, A. F., Private communication.

BRDIČKA LECTURES

1. ***(1991)*** *Edgar **HEILBRONNER** (Eidgenossische Technische Hochschule, Zürich)*
"**The old Hűckel formalism**"

2. ***(1992)*** *Kamil **KLIER** (Lehigh University, Bethlehem, Pennsylvania)*
"**Physical chemistry in two dimensions**"

3. ***(1993)*** *Joshua **JORTNER** (Tel Aviv University, Tel Aviv)*
"**Clusters – a bridge between molecular and condensed matter chemical physics"**

4. ***(1994)*** *David J. **SCHIFFRIN** (The University of Liverpool)*
"**Electrochemistry in two-dimensional systems**"

5. ***(1995)*** *Josef **MICHL** (University of Colorado, Boulder, Colorado)*
"**Molecular kit for new materials**"

6. ***(1996)*** *Gerhard **ERTL** (Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin)*
"**Self-organization in surface reactions**"

7. ***(1997)*** *Roger **PARSONS** (University of Southampton)*
"**Electrochemistry in the last 50 years: from Tafel plotting to scanning tunnelling**"

8. ***(1998)*** *G. Barney **ELLISON** (JILA and University of Colorado, Boulder, Colorado)*
"**The chemical physics of organic reactive intermediates in combustion and atmospheric processes**"

9. ***(1999)*** *Henry F. **SCHAEFER III** (University of Georgia, Athens, Georgia)*
"**The third age of quantum chemistry**"

10. ***(2000)*** *Alexis T. **BELL** (University of California and Lawrence Berkeley Laboratory, Berkeley, California)*
"**Progress towards the molecular design of catalysts –lessons learned from experiments and theory**"

11. ***(2001)*** *Mario J. **MOLINA** (Massachusetts Institute of Technology, Cambridge, Massachusetts)*
"**The Antarctic ozone hole**"

12. ***(2002)*** *Jean-Marie **LEHN** (Université Louis Pasteur, Strasbourg a Collége de France, Paris)*
"**Selforganization of supramolecular nanodevices**"

13. ***(2003)*** *Helmut **SCHWARZ** (Technische Universität Berlin)*
"**Elementary processes in catalysis: looking at and learning from** "**naked**" **transition ion**"

14. ***(2004)*** *Rudolph A. **MARCUS** (California Institute of Technology, Pasadena)*
"Strange isotope effects in stratospheric ozone and in the earliest minerals in the solar system"

15. ***(2005)*** *Avelino **CORMA** (Instituto de Tecnología Química, Valencia)*
" **Supramolecular Entities Based on Molecular Sieves for Catalysis and Synthesis of New Materials**"

16. ***(2006)*** *Paul **CRUTZEN** (Max Planck Institute for Chemistry, Mainz):*
"Atmospheric Chemistry and Climate in the ´Anthropocene´"

17. ***(2007)*** *Harry B. **GRAY** (California Institute of Technology, Pasadena**)***
"The Currents of Life: Electron Flow through Metalloproteins"

18. ***(2008)*** *Michael **GRÄTZEL** (Ecole Polytechnique Fédérale de Lausanne)*
"**Mesoscopic Electrodes for Generation and Storage of Electric Power from Sunlight"**

19. ***(2009)*** *Gabor. A. **SAMORJAI** (Department of Chemistry and Lawrence Berkeley Natkional laboratory, University of California, Berkeley)*
"Molecular Foundations of Heterogeneous Catalysis"

20. ***(2010)*** *Pavel **HOBZA** (Institute of Organic Chemistry and Biochemistry of the AS CR)*
"Noncovalent Interactions and their Role in Chemistry and Biochemistry"

21. ***(2011)*** Klaus ***MÜLLEN*** (Max-Planck Institute, Mainz, Germany)
"Carbon Materials and Graphenes"

22. ***(2012)*** *Enrico **GRATTON** (University of California, Irvine)*
"Nanoimaging technique with high time and spatial resolution: Mechanisms of translocation through the nuclear pore complex"

Rudolf BRDIČKA
(1906-1970)

Professor of physical chemistry at Charles University, founding member of the Czechoslovak Academy of Sciences, founder and first director of the Institute of Physical Chemistry of the Czechoslovak Academy of Sciences.

An outstanding electrochemist renowned in particular by his pioneering work on kinetic polarographic current and on applications of polarography in medicine. A brilliant university teacher, author of an internationally recognized textbook of physical chemistry. He has crucial merits for development of modern physical chemistry in this country.

To commemorate his work and personality, the Institute of Physical Chemistry of the Academy of Sciences of the Czech Republic has organized since 1991 annually a festive R. Brdička Lecture. Invited speakers have been eminent scientists active in some field relating to the research currently pursued in the Institute.