FROM STAR AND PLANET FORMATION TO EARLY LIFE

PROGRAMME and ABSTRACTS

Published 22 April 2016

The conference constitutes the yearly meeting of the COST Action "Origins and Evolution of Life in the Universe" and the Nordic Network of Astrobiology, 25-28 April 2016, Vilnius, Lithuania
Scientific Organizing Committee

John Brucato (I)
Corinne Charbonnel (CH)
Elias Chatzitheodoridis (GR)
Veronique Dehant (B)
David Düner (S)
Jorge Gameiro (P)
Muriel Gargaud (F) [Chair of the Action Origins]
Wolf Geppert (S) [Vice-Chair of the Action Origins] [Co-Chair of the Conference]
Emmanuelle Javaux (B)
Zuzana Kanuchova (SK)
Terence Kee (UK)
Akos Kereszturi (H)
Purification Lopez Garcia (F)
Christophe Malaterre (CDN)
Nigel Mason (UK)
Olga Prieto-Balesteros (E)
Nuno Santos (P)
Ewa Szuszkiewicz (PL)
Gražina Tautvaišienė (LT) [Co-Chair of the Conference]

Local Organizing Committee

Arnas Drazdauskas
Žibutė Naimovičienė
Šarūnas Mikolaitis [Chair]
Gražina Tautvaišienė
Renata Ženovienė
Scientific Rationale

The meeting will cover a multitude of scientific subjects ranging from star and planet formation until the early evolution of life on Earth. It aims to bring together astronomers, physicists, chemists, geologists and biologists as well as academics and students from humanities to discuss the most important questions and newest findings in all related disciplines. Special sessions will be devoted to comets, meteorites, prebiotic chemistry and early life.

The meeting contains two types of sessions. The first three days will be devoted to plenary sessions with the following subjects:

- Physical and chemical processes under star and planet formation
- Formation of complex molecules in space, planetary and satellite atmospheres
- Before and after the Last Common Universal Ancestor: Early evolution of life
- Meteorites as probes for understanding the early solar system
- Comets and the early history of the solar system
- Geological conditions for prebiotic chemistry
- Early Universe, early Earth and the origin of life: Evolution of concepts in history and philosophy
- Borderline between chemistry and biology
- Scientific misconceptions: case studies in astrobiology

The last day of the conference will consist of parallel sessions, which allow detailed in-depth discussions of the following subjects:

- Physical and chemical processes under star and planet formation
- Formation of complex molecules in space, planetary and satellite atmospheres
- Before and after the Last Common Universal Ancestor: Early evolution of life
- Comets and meteorites: Composition, chemical processes and their role in the evolution of the solar system
- Early Universe, early Earth and the origin of life: Evolution of concepts in history and philosophy
PRACTICAL INFORMATION

CONFERENCE VENUE
The conference will be held in Vilnius, Lithuania at “ARTIS Centrum Hotels” which is just next door to the Presidential Palace and the Vilnius University.

CONFERENCE PLACE
Vilnius is the biggest city and the capital of Lithuania. It is a cosmopolitan city with diverse architecture located on the banks of Lithuania’s second longest river – Neris). The name of the city however originates from the Vilnia river, which is quite small in comparison. In 2009, Vilnius was the European Capital of Culture and is known for the architecture in its Old Town, declared a UNESCO World Heritage Site in 1994.

TRAVEL TO VILNIUS
The international airport in Vilnius (IATA code: VNO; http://www.vilnius-airport.lt/en/) is located just on the outskirts of the city. There are few options to get from the airport (Oro Uostas in Lithuanian) to the city.

By public transport (please visit the http://www.vilniustransport.lt/en/ webpage to check available routes and times)
To go to the conference venue from the airport there are two possibilities, bus 88 (less frequent but no change necessary) and bus 3G with change to bus 12 (every 15 minutes). The station is 50 m from the exit of the arrival section of Vilnius airport (slightly to the left).

By taxi
To avoid being cheated it is best to take a Vilnius airport approved taxi. Furthermore: Do only board taxis from the official Vilnius airport taxi rank outside the building. Normally a taxi ride should not cost you more than EUR 15,-.

CONTACTS
Wolf Geppert (+46-8-55378649) or mobile phone (+46-72-3691155)
Gražina Tautvaišienė (+370-618-49941)
lifeorigins2016@gmail.com
Above map provides a quick view at the area where the conference will be held, with the main points of interest marked (the conference venue, the Planetarium, and the closest bus stop you will arrive to if travelling by bus from the airport).

**Presentation format**
Invited lectures will be 30 minutes (+10 minutes of discussion) and plenary talks 25 minutes (+5 minutes discussion). Oral contributions will be selected from the abstracts and will be 15 minutes long (+5 minutes of discussion). The poster session will be held on the evening of Monday 25th April.
**PROGRAMME**

### Sunday April 24\(^{th}\), 2016

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00 - 19:00</td>
<td>Registration of participants at Artis Hotel</td>
</tr>
<tr>
<td>17:00 - 18:30</td>
<td>Public event at the Vilnius Planetarium</td>
</tr>
<tr>
<td>17:00 - 17:40</td>
<td>Comets: Relics of the Birth of our Solar System</td>
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<tr>
<td></td>
<td><em>Karen Meech, University of Hawaii, USA</em></td>
</tr>
<tr>
<td>17:40 - 17:45</td>
<td>Questions from the public</td>
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<tr>
<td>17:45 - 18:25</td>
<td>Rosetta - the Comet Chaser</td>
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<td></td>
<td><em>Martin Hilchenbach, MPI for Solar System Research, Germany</em></td>
</tr>
<tr>
<td>17:45 - 18:30</td>
<td>Questions from the public</td>
</tr>
<tr>
<td>18:30</td>
<td>Reception with wine and finger food at Artis Hotel</td>
</tr>
</tbody>
</table>

### Monday April 25\(^{th}\), 2016

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00 - 09:00</td>
<td>Registration</td>
</tr>
<tr>
<td>09:00 - 09:15</td>
<td>Welcome addresses and organizational matters</td>
</tr>
<tr>
<td></td>
<td><em>Muriel Gargaud, COST Action Chair, University of Bordeaux, FR</em></td>
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<tr>
<td></td>
<td><em>Wolf Geppert, Stockholm University, SE</em></td>
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<tr>
<td></td>
<td><em>Gražina Tautvaišienė, Vilnius University, LT</em></td>
</tr>
<tr>
<td>09:15 - 10:45</td>
<td>Session 1: Physical and chemical processes under star and planet</td>
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<td></td>
<td>formation (WG1)</td>
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<td></td>
<td><em>Chair: Ewa Szuszkiewicz, University of Szczecin, PL</em></td>
</tr>
<tr>
<td>09:15 - 09:45</td>
<td>The formation and evolution of planetary systems</td>
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<tr>
<td></td>
<td><em>Wilhelm Kley, University of Tübingen, DE</em></td>
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<tr>
<td>09:45 - 09:55</td>
<td>Discussion</td>
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<tr>
<td>09:55 - 10:15</td>
<td>Gas and Dust in Protoplanetary Disks</td>
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<td></td>
<td><em>Anne Dutrey, University of Bordeaux, FR</em></td>
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<tr>
<td>10:15 - 10:20</td>
<td>Discussion</td>
</tr>
<tr>
<td>10:20 - 10:40</td>
<td>Chemical evolution of star-forming regions</td>
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<td></td>
<td><em>Floris van der Tak, SRON, NL</em></td>
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<tr>
<td>10:40 - 10:45</td>
<td>Discussion</td>
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<tr>
<td>10:45 - 11:15</td>
<td>Coffee break</td>
</tr>
<tr>
<td>11:15 - 12:45</td>
<td>Session 2: Formation of complex molecules in space, planetary and</td>
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<td></td>
<td>satellite atmospheres</td>
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<tr>
<td></td>
<td><em>Chair: Wolf Geppert, Stockholm University, SE</em></td>
</tr>
<tr>
<td>11:15 - 11:45</td>
<td>The formation of complex molecules in space</td>
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<td></td>
<td><em>Tom Millar, Queen’s University Belfast, UK</em></td>
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<tr>
<td>11:45 - 11:55</td>
<td>Discussion</td>
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<tr>
<td>11:55 - 12:15</td>
<td>Gas phase chemistry and molecular complexity: how far do they go?</td>
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<td></td>
<td><em>Nadia Balucani, University of Perugia, IT</em></td>
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<tr>
<td>12:15 - 12:20</td>
<td>Discussion</td>
</tr>
<tr>
<td>12:20 - 14:00</td>
<td>Lunch break</td>
</tr>
</tbody>
</table>
14:00 - 15:30 | Session 3: Before and after the Last Common Universal Ancestor: Early evolution of Life  
Chair: Purificación López-García, Université Paris Sud, FR

14:00 - 14:30 | Molecular evolution before the domain ancestors: Indications for dramatic planetary changes during life’s early evolution  
Johann Peter Gogarten, University of Connecticut, US

14:30 - 14:40 | Discussion

14:40 - 15:00 | Energy and matter at the origin of life  
Nick Lane, UCL, UK

15:00 - 15:05 | Discussion

15:05 - 15:25 | Life as a dissipative structure; implications for the emergence of metabolism  
Wolfgang Nitschke, Université Aix-Marseille, FR

15:25 - 15:30 | Discussion

15:30 - 16:00 | Coffee break

16:00 - 17:30 | Session 4: Meteorites as probes for understanding the Early Solar System  
Chair: Akos Kereszturi, Konkoly Observatory, HU

16:00 - 16:30 | Introductory talk  
Henning Haack, University of Copenhagen, DK

16:30 - 16:40 | Discussion

16:40 - 17:00 | Pre-solar grains: the ingredients to make a solar system  
Ian Lyon, University of Manchester, UK

17:00 - 17:05 | Discussion

17:05 - 17:25 | Meteorites as probes for understanding the Early Solar System  
Zita Martins, Imperial College London, UK

17:25 - 17:30 | Discussion

17:30 - 20:00 | Dinner break

20:00 - 21:30 | Poster session

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**Tuesday April 26th, 2016**

09:00 - 10:30 | Session 5: Comets and the early history of the solar system  
Chair: Erik Vigren, Swedish Institute for Space Physics, SE

09:00 - 09:30 | Tracing early solar system history with comets: A compositional and dynamical perspective  
Karen Meech, University of Hawai‘i, USA

09:30 - 09:40 | Discussion

09:40 - 10:00 | New insights from ROSETTA into cometary dust  
Martin Hilchenbach, MPI for Solar System Research, DE

10:00 - 10:05 | Discussion

10:05 - 10:25 | Organic Molecules Identified by the Rosetta Lander Philae  
Uwe Meierhenrich, Université de Nice Sophia Antipolis, FR

10:25 - 10:30 | Discussion

10:30 - 11:00 | Coffee break
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Chair</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00 - 12:15</td>
<td>Session 6: Geological conditions for prebiotic chemistry</td>
<td>Emmanuelle Javaux, University of Liège, BE</td>
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<tr>
<td>11:00 - 11:30</td>
<td>The Hadean Earth vs. the Origin of Life</td>
<td>Stephen Mojzsis, University of Colorado, US</td>
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<tr>
<td>11:30 - 11:40</td>
<td>Discussion</td>
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<tr>
<td>11:40 - 12:10</td>
<td>Geochemical complexities as a setting for life’s origins</td>
<td>Robert Hazen, Carnegie Institute of Washington, US</td>
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<tr>
<td>12:10 - 12:15</td>
<td>Discussion</td>
<td></td>
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<tr>
<td>12:15 - 13:45</td>
<td>Lunch break</td>
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<tr>
<td>13:45 - 14:15</td>
<td>Some Twentieth-Century Ideas of Extraterrestrial Life and Physical Eschatology</td>
<td>Helge Kragh, University of Aarhus, DK</td>
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<tr>
<td>14:15 - 14:25</td>
<td>Discussion</td>
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<tr>
<td>14:25 - 14:55</td>
<td>The ghosts behind the molecules: the recent history of the attempts to understand the origin of life</td>
<td>Antonio Lazcano, National Autonomous University of Mexico, MX</td>
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<tr>
<td>14:55 - 15:00</td>
<td>Discussion</td>
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<tr>
<td>15:00 - 15:45</td>
<td>Coffee break</td>
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<tr>
<td>15:45 – 19:00</td>
<td>Management Committee Meeting of the COST Action TD1308</td>
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**Wednesday April 27th, 2016**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Chair</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>09:00 - 10:30</td>
<td>Session 8: Scientific misconceptions: case studies in astrobiology</td>
<td>Antonio Lazcano, National Autonomous University of Mexico, MX</td>
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<tr>
<td>09:00 - 09:20</td>
<td>Excitements and challenges in tracking the early traces of life</td>
<td>Emmanuelle Javaux, University of Liège, BE</td>
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<tr>
<td>09:20 - 09:25</td>
<td>Questions and ad-hoc discussion contributions</td>
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<tr>
<td>09:25 - 09:45</td>
<td>Tenacious misconceptions about biological evolution</td>
<td>Purificación López-García, Université Paris Sud, FR</td>
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<tr>
<td>09:45 - 09:50</td>
<td>Questions and ad-hoc discussion contributions</td>
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<tr>
<td>09:50 - 10:10</td>
<td>Misconceptions, Truths and Controversies: Is Origins of Life Research no Different from the Rest of Science?</td>
<td>Christophe Malaterre, UQAM, CA</td>
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<tr>
<td>10:10 - 10:15</td>
<td>Questions and ad-hoc discussion contributions</td>
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<tr>
<td>10:15 - 10:30</td>
<td>Open Discussion</td>
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<tr>
<td>10:30 - 11:00</td>
<td>Coffee break</td>
<td></td>
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<tr>
<td>11:00 - 12:05</td>
<td>Session 9: Borderline between chemistry and biology</td>
<td>John Brucato, Arcetri Observatory, IT</td>
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<tr>
<td>11:00 - 11:30</td>
<td>Transition between chemistry (non-life) and biology (life)</td>
<td>Sijbren Otto, University of Groningen, NL</td>
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<tr>
<td>11:30 - 11:40</td>
<td>Discussion</td>
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<tr>
<td>11:40 - 12:10</td>
<td>Chemical selection at the origins of life</td>
<td>Matthew Powner, UCL, UK</td>
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</table>
### Thursday April 28th, 2016

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>09:00 – 10:30</td>
<td>Parallel sessions</td>
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<tr>
<td>10:30 – 11:00</td>
<td>Coffee break</td>
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<tr>
<td>11:00 – 12:30</td>
<td>Parallel sessions</td>
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<tr>
<td>12:30 – 14:00</td>
<td>Lunch break</td>
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<tr>
<td>14:00 – 15:45</td>
<td>Parallel sessions</td>
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<td>15:45 – 16:15</td>
<td>Coffee break</td>
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<tr>
<td>16:15 – 17:45</td>
<td>Parallel sessions</td>
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<tr>
<td>17:45 – 19:00</td>
<td>Room for individual discussions of the individual WGs</td>
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</tbody>
</table>

### Detailed program for Thursday April 28th

#### Parallel sessions 09:00 – 10:30

- **09:00 - 10:30** Parallel Session P1: Protoplanetary disks and planet formation (WG1)  
  Aida Hall  
  *Chair:* Wilhelm Kley, University of Tübingen, DE

- **09:00 - 09:25** The variable circumstellar extinction in a protoplanetary disk with an embedded low-mass companion  
  Tatjana Demidova, Russian Academy of Sciences, RU

- **09:25 - 09:30** Discussion

- **09:30 - 09:55** From the chemistry in protoplanetary disk via the formation history of planets to the atmospheric composition  
  Christoph Mordasini, University of Berne, CH

- **09:55 - 10:00** Discussion

- **10:00 - 10:25** Stellar chemistry: hints for planet formation and structure  
  Nuno Santos, University of Porto, PT

- **10:25 - 10:30** Discussion

- **09:00 - 10:30** Parallel session P2: Basic chemical processes in astronomical environments (WG2)  
  Carmen Hall  
  *Chair:* Nadia Balucani, University of Perugia, IT

- **09:00 - 09:25** The Ortho-to-Para Ratio of NH$_2$ at Different Temperatures  
  Romane Le Gal, University of Virginia, US

- **09:25 - 09:30** Discussion
### Parallel sessions 11:00 – 12:30

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>11:00 - 11:35</td>
<td>The chemical heritage of planet-building material: new insights from ALMA and Rosetta</td>
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<td><em>Catherine Walsh, Leiden University, NL</em></td>
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<tr>
<td>11:35 - 11:45</td>
<td>Discussion</td>
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<tr>
<td>11:45 - 12:20</td>
<td>From chondrules to planets - tracking the recycling of solids in an evolving protoplanetary disk</td>
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<td><em>Martin Bizzarro, University of Copenhagen, DK</em></td>
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<tr>
<td>12:20 - 12:30</td>
<td>Discussion</td>
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<tr>
<td>11:00 - 12:30</td>
<td>Parallel Session P4: Formation of the building blocks of life (WG2)</td>
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<td><em>Chair: Yves Ellinger, University Pierre &amp; Marie Curie, FR</em></td>
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<td></td>
<td>Carmen Hall</td>
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<tr>
<td>11:00 - 11:25</td>
<td>State of the art electronic calculations and kinetic computations for formamide formation in cold interstellar clouds</td>
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<td><em>Dimitrios Skouteris, Scuola Normale Superiore, Pisa, IT</em></td>
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<tr>
<td>11:25 - 11:30</td>
<td>Discussion</td>
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</tbody>
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**09:30 - 09:55** The Role of Low-Energy Electrons in Astrochemistry: A Tale of Two Molecules
*Chris Arumainayagam, Wellesley College, US*

**09:55 - 10:00** Discussion

**10:00 - 10:25** Study of gas-phase ion molecular reactions at temperatures relevant to the atmosphere of Titan
*Ilia Zymak, J. Heyrovský Institute, CZ*

**10:25 - 10:30** Discussion

**09:00 - 10:30** Parallel session P3: Early Universe, early Earth and the origin of Life: Evolution of concepts in history and philosophy (WG3 + WG5)
*Mikado Hall*
*Chair: Christophe Malaterre, UQAM, Canada*

**09:00 - 09:25** C'est la Vie
*Kelly C. Smith, Clemson University, US*

**09:25 - 09:30** Discussion

**09:30 - 09:55** Biosphere complexity: A new approach towards a definition of life
*Thomas Böttcher, University of Konstanz, DE*

**09:55 - 10:00** Discussion

**10:00 - 10:25** Panspermia: a panoply of possibilities
*Clement Vidal, Vrije Universiteit Brussel, BE*

**10:25 - 10:30** Discussion

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**Parallel sessions 11:00 – 12:30**

**11:00 - 12:30** Parallel Session P1: Protoplanetary disks and planet formation (continued, WG1)
*Chair: Nuno Santos, University of Porto, PT*
*Aida Hall*

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**Parallel session P3: Early Universe, early Earth and the origin of Life: Evolution of concepts in history and philosophy (WG3 + WG5)**
*Mikado Hall*
*Chair: Christophe Malaterre, UQAM, Canada*

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**10:25 - 10:30** Discussion
<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
<th>Institution</th>
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</thead>
<tbody>
<tr>
<td>11:30 - 11:55</td>
<td>Synthesis of formamide and isocyanic acid after ion irradiation of frozen gas mixtures</td>
<td>Zuzana Kanuchova</td>
<td>Slovak Academy of Sciences, SK</td>
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<tr>
<td>11:55 - 12:00</td>
<td>Discussion</td>
<td></td>
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<tr>
<td>12:00 - 12:25</td>
<td>Formamide Prebiotic Plasma Chemistry Network in Reduction Atmospheres</td>
<td>Martin Ferus</td>
<td>J. Heyrovský Institute, CZ</td>
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<tr>
<td>12:25 - 12:30</td>
<td>Discussion</td>
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<tr>
<td>11:00 - 12:40</td>
<td>Parallel session P5: Before and after the Last Common Universal Ancestor: Early evolution of Life (WG3+ WG4)</td>
<td>Johann Peter Gogarten</td>
<td>University of Connecticut, US</td>
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<tr>
<td>11:00 - 11:20</td>
<td>Modeling the origins of cellular systems: How complex must our system be to observe cell-like behaviors?</td>
<td>Pierre-Alain Monnard</td>
<td>University of Southern Denmark, DK</td>
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<tr>
<td>11:20 - 11:25</td>
<td>Discussion</td>
<td></td>
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<tr>
<td>11:25 - 11:45</td>
<td>The last universal common ancestor: simple or complex?</td>
<td>David Moreira</td>
<td>Université Paris-Sud, FR</td>
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<tr>
<td>11:45 - 11:50</td>
<td>Discussion</td>
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<tr>
<td>11:50 - 12:10</td>
<td>Origin and evolution of aerobic processes</td>
<td>Céline Brochier</td>
<td>University of Lyon, FR</td>
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<tr>
<td>12:10 - 12:15</td>
<td>Discussion</td>
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<tr>
<td>12:15 - 12:35</td>
<td>The origin of eukaryotes is linked to the rooting of the Tree of Life... but the phylogenetic jury is still out</td>
<td>Richard Gouy</td>
<td>University of Liège, BE</td>
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<tr>
<td>12:35 - 12:40</td>
<td>Discussion</td>
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<tr>
<td>11:00 –12:00</td>
<td>Parallel session P3: Early Universe, early Earth and the origin of Life: Evolution of concepts in history and philosophy (WG5, continued)</td>
<td>Erik Persson</td>
<td>Lund University, SE</td>
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<td>11:25 - 11:30</td>
<td>Discussion</td>
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<td>11:55 - 12:00</td>
<td>Discussion</td>
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## Parallel sessions 14:00 – 15:30

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<th>Time</th>
<th>Session</th>
<th>Title</th>
<th>Chair/Institution</th>
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<tr>
<td>14:00 - 15:30</td>
<td>Parallel Session P1: Protoplanetary disks and planet formation</td>
<td>(continued, WG1)</td>
<td>Olga Prieto Balleteros, CAB, ES&lt;br&gt;Aida Hall</td>
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<tr>
<td>14:00 - 14:35</td>
<td>A comprehensive analysis of presolar SiC grains using NanoSIMS and Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS)</td>
<td>Alex Clarke, University of Manchester, UK</td>
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<td>14:35 - 14:45</td>
<td>Discussion</td>
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<td>14:45 - 15:20</td>
<td>Abundance trends with condensation temperature and terrestrial planet formation: The case of Zeta Reticuli</td>
<td>Vardan Adibekyan, Institute of Astrophysics and Space Sciences, PT</td>
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<tr>
<td>15:20 - 15:30</td>
<td>Discussion</td>
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<td>14:00 - 15:40</td>
<td>Parallel Session P4: Formation of the building blocks of life</td>
<td>(continued, WG2)</td>
<td>William Irvine, University of Massachusetts at Amherst, US&lt;br&gt;Carmen Hall</td>
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<tr>
<td>14:00 - 14:20</td>
<td>Follow the evolution of organic matter using laboratory experiments: from volatile organics to organic residues</td>
<td>Gregoire Danger, PIIM Marseille, FR</td>
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<td>14:20 - 14:25</td>
<td>Discussion</td>
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<td>14:25 - 14:45</td>
<td>Plausible Prebiotic Formation of Carbohydrates</td>
<td>Paul Clarke, University of York, UK</td>
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<td>14:45 - 14:50</td>
<td>Discussion</td>
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<td>14:50 - 15:10</td>
<td>About the abundance of prebiotic species: the energetic aspect</td>
<td>Yves Ellinger, University Pierre &amp; Marie Curie, FR</td>
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<td>15:10 - 15:15</td>
<td>Discussion</td>
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<td>15:35 –15:40</td>
<td>Discussion</td>
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<tr>
<td>14:00 - 15:15</td>
<td>Parallel Session P6: Life in extreme environments</td>
<td>(WG3 + WG4)</td>
<td>Anna Łosiak, Polish Academy of Sciences, PL&lt;br&gt;Mikado Hall</td>
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<td>14:00 - 14:20</td>
<td>Description and comparison of microbial communities and metagenomes in a subglacial lake under the Vatnajökull ice cap, East Skáftárkæl</td>
<td>Viggo Marteinson, MATIS, IS</td>
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<td>14:20 - 14:25</td>
<td>Discussion</td>
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<td>14:25 - 14:45</td>
<td>Life in Mars analogue sites: microbes adapted to extreme conditions in Iceland</td>
<td>Oddur Vilhelmsson, University of Akureyri, IS</td>
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<td>14:45 - 14:50</td>
<td>Discussion</td>
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</table>
14:50 - 15:10  Health hazards posed by ionizing radiation in manned space missions
BLEO
Franco Ferrari, University of Szczecin, PL
15:10 - 15:15  Discussion

Parallel sessions 16:15 – 17:45

16:15 - 17:45  Parallel session P7: Habitability (WG3 + WG4)
Chair: Yann Alibert, University of Berne, CH
Mikado Hall
16:15 - 16:40  Dissipative structures in the Universe: Super massive black holes and life
Andjelika Kovacevic, University of Belgrade, RS
16:40 - 16:45  Discussion
16:45 - 17:10  From stellar evolution to tidal interaction: impact on planetary habitability
Florian Gallet, University of Geneva, CH
17:10 - 17:15  Discussion
17:15 - 17:40  Water-rich planets: how habitable is a water layer deeper than on Earth?
Lena Noack, Royal Observatory of Belgium, BE
17:40 - 17:45  Discussion

16:15 - 17:45  Parallel Session P8: Comets and meteorites: Composition, chemical processes and their role in the evolution of the solar system (WG1 + WG2)
Chair: Martin Hilchenbach, MPI for Solar System Research, Germany
Aida Hall
16:15 - 16:40  First spectrally complete survey of cometary water emission at near IR wavelengths (0.9-2.5 ?m): C/2014 Q2 Lovejoy with TNG/GIANO spectrograph
Sara Faggi, Observatory of Arcetri, IT
16:40 - 16:45  Discussion
16:45 - 17:10  Prebiotic molecules in comets detected by Rosetta and their possible synthesis in the ice
Guillermo Muñoz Caro, Centro de Astrobiología, ES
17:10 - 17:15  Discussion
17:15 - 17:40  Ion chemistry in the innermost coma of comet 67P/Churyumov-Gerasimenko
Erik Vigren, Swedish Institute for Space Physics, SE
17:40 - 17:45  Discussion
17:45  Room for WG meetings
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<tr>
<td>09:00 - 10:30</td>
<td><strong>Internal meeting for COST Action TD1308</strong></td>
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<td><em>Chairs: M. Gargaud, W. Geppert</em></td>
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<td>10:30 – 11:00</td>
<td>Coffee break</td>
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<tr>
<td>11:00 - 12:00</td>
<td><strong>Internal meeting for COST Action TD1308</strong></td>
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<tr>
<td></td>
<td><em>Chairs: M. Gargaud, W. Geppert</em></td>
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<tr>
<td>12:00</td>
<td>Lunch, Departure of participants</td>
</tr>
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</table>
Invited and plenary speakers

Nadia Balucani  University of Perugia, Italy
Celine Brochier-Armanet  University of Lyon, France
Anne Dutrey  University of Bordeaux, France
Johann Peter Gogarten  University of Connecticut, USA
Henning Haack  University of Copenhagen, Denmark,
Robert Hazen  Carnegie Institution of Washington, USA
Martin Hilchenbach  MPI for Solar System Research, Germany
Emmanuelle Javaux  University of Liége, Belgium
Etienne Klein  CEA, France
Willy Kley  University of Tübingen, Germany
Helge Kragh  University of Copenhagen, Denmark
Antonio Lazcano  National Autonomous University of Mexico
Nick Lane  UCL, UK
Purificación López-García  Université Paris Sud, CNRS, Orsay, France
Ian Lyon  University of Manchester, UK
Christophe Malaterre  UQAM, Canada
Zita Martins  Imperial College, UK
Karen Meech  University of Hawai'i at Manoa, USA
Uwe Meierhenrich  Université de Nice Sophia Antipolis, France
Tom Millar  Queen's University Belfast, UK
Stephen Mojzsis  University of Colorado, USA
Christoph Mordasini  University of Bern, Switzerland
David Moreira  Université Paris Sud, France
Guillermo Muñoz Caro  Centro de Astrobiología, Spain,
Wolfgang Nitschke  Université Aix-Marseille, France
Sijbren Otto  University of Groningen, The Netherlands
Matthew Powner  UCL, UK
Floris van der Tak  University of Groningen, The Netherlands
Clement Vidal  Vrije Universiteit Brussel, Belgium
Erik Vigren  Swedish Institute for Space Physics
Catherine Walsh  Leiden University, The Netherlands
# LIST OF PARTICIPANTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
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<tbody>
<tr>
<td>Airo, Alessandro</td>
<td>Freie Universität Berlin</td>
<td>Germany</td>
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<tr>
<td>Alibert, Yann</td>
<td>University of Berne</td>
<td>Switzerland</td>
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<tr>
<td>Anderson, Isaac</td>
<td>University of Michigan</td>
<td>USA</td>
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<tr>
<td>Arnould, Jacques</td>
<td>CNES</td>
<td>France</td>
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<td>Adibekyan, Vardan</td>
<td>Institute of Astrophysics and Space Sciences</td>
<td>Portugal</td>
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<td>Arumainayagam, Chris</td>
<td>Wellesley University</td>
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<td>Arsenov, Nestor</td>
<td>LMU Munich</td>
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<td>Balucani, Nadia</td>
<td>University of Perugia</td>
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<td>Bagdonas, Vilius</td>
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<td>Benacchio, Leopoldo</td>
<td>INAF - Padova Astronomical Observatory</td>
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<td>Billings, Linda</td>
<td>National Institute of Aerospace</td>
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<td>University of Copenhagen</td>
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<td>Gameiro, Jorge Filipe</td>
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<td>MATIS, Iceland</td>
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Mason, Nigel  Open University  UK
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ten Kate, Inge Loes Utrecht University Netherlands
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Vilhelmsson, Oddur University of Akureyri Iceland
Walsh, Catherine Leiden University Netherlands
Žabka, Jan J. Heyrovsky Institute, Prague Czech Republic
Zapata, Davianys University Simon Bolivar Venezuela
Zdanavičius, Justas Vilnius University Lithuania
Ženovienė, Renata Vilnius University Lithuania
Zhu, Jane Wellesley College USA
Zymak, Ilia J. Heyrovsky Institute, Prague Czech Republic
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Meteorites as probes for understanding the Early Solar System  
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The formation and evolution of planetary systems

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The number of detected planetary systems has increased to about 1300 as of today. The surprising diversity of the newly discovered worlds required a revision of the standard theory of planet formation. In the talk I will discuss the main formation scenarios (sequential accretion vs. gravitational instability) in the context of the properties of the Solar System and observed sample of extrasolar planetary systems. The necessity of dynamical evolution of young planets in the disc will be emphasized and new results will be discussed.
Physical and chemical processes under star and planet formation
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In the early nineties, mm/submm arrays begun to routinely image gas and dust protoplanetary disks orbiting low-mass TTauri (similar to the young Sun) and young intermediate-mass stars. If the first images were strongly limited in sensitivity and angular resolution and did not allow observers to perform detailed comparisons with models. The advent of ALMA has drastically changed our view of these systems, allowing to constrain physical parameters such as the temperature, density of the turbulence. The most recent observations performed at high angular resolution also reveal that the geometry is more complex than that of a simple flaring disk, as usually assumed by most disk models. Several images show the presence of inner cavities and inhomogeneities in the gas and dust distributions.

In this talk, I will summarize our current understanding of the physical structure of disks as inferred from recent dust continuum maps and molecular spectro-imaging obtained at high angular resolution (< 0.5″) on a few prototypical objects such as TW Hydra, AB Auriga, GG Tau or DM Tau.
Chemical evolution of star-forming regions

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This talk reviews our current understanding of the physics and chemistry that occur in the birthplaces of new stars. After a glance at the lifecycle of gas in galaxies, I present the main stages of the formation of solar-type stars and their physical characteristics. The dominant chemical processes differ between each of these stages, and I will outline how the composition of star-forming matter can be used to better understand the formation of stars and planets.
The formation of complex molecules in space

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In this talk I will consider the chemistry of complex molecules in space, arbitrarily defined here as those containing 6 or more atoms, that is, some 60 of the near 190 molecules detected in interstellar and circumstellar media. These complex molecules include stable neutrals and radicals, anions and fullerenes. We know from observations that certain families of complex molecules, for example the polyynes, cyanopolyynes and their related ions, are formed in gas-phase reactions whereas others are most likely formed in the icy mantles of dust grains or in gas-phase chemistry following the evaporation of such mantles. I will describe the likely formation routes to these species, show that they may be used to probe the chemical history of the gas, discuss their potential as chemical clocks and their importance in instigating the formation of biological-related species.
Gas phase chemistry and molecular complexity: how far do they go?

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In the study of the origin of life, the main task for physical chemistry is to understand how the building blocks of biological molecules were formed in totally abiotic environments. The accumulation of organic molecules of increasing complexity, indeed, is believed to be an important step in the series of events that led from elementary particles to the emergence of life. But how massive organic synthesis could occur in primitive Earth, i.e. a water-dominated environment, is a matter of debate. Two alternative theories have been suggested so far: endogenous and exogenous synthesis. In the first theory, the synthesis of simple organic molecules having a strong prebiotic potential (simple prebiotic molecules SPMs, such as H2CO, HCN, HC3N, NH2CHO) occurred directly on our planet starting from simple parent molecules of the atmosphere, liquid water and various energy sources. Millers experiment was a milestone in this theory, but it was later recognized that the complexity of a planet cannot be reproduced in a single laboratory experiment. Some SPMs have been identified in the N2-dominated atmosphere of Titan (a massive moon of Saturn), which is believed to be reminiscent of the primitive terrestrial atmosphere. As such, the atmosphere of Titan represents a planetary scale laboratory for the comprehension of SPM formation in an environment close enough to primitive Earth and is the current frontier in the endogenous theory exploration. In the exogenous theory, SPMs came from space, the carriers being comets, asteroids and meteorites. The rationale behind this suggestion is that plenty of SPMs have been observed in interstellar clouds (ISCs), including star-forming regions, and in small bodies like comets, asteroids and meteorites. Therefore, the basic idea is that SPMs were formed in the solar nebula, preserved during the early phases of the Solar System formation in the body of comets/asteroids/meteorites and finally delivered to Earth by cometary and meteoritic falls. The fall of small bodies on Earth in the first period after the Solar System formation would bring water (as the isotopic D/H ratio of terrestrial water suggests) and the building blocks of biological molecules at the same time. In this contribution, the status of our knowledge on how SPMs can be formed in the gas phase, either in the primitive terrestrial atmosphere or in the cold nebula from which the Solar System originated, will be presented. Particular attention will be given to neutral-neutral reactions.
Horizontal Gene Transfer (HGT) has played an essential role in the spread of genetic and metabolic innovations between distantly related organisms. The further one moves back in time, the more likely it becomes that a gene transfer originated in lineage that went extinct since the transfer occurred (Fournier, Huang & Gogarten 2009). Because of HGT the most recent common ancestors of different molecules did not all coexist in the organismal most recent common ancestor, aka Last Universal Common Ancestor (LUCA). The molecular LUCA’s existed in different lineages and at different times (Zhaxybayeva & Gogarten 2004). Using the rooted ribosomal phylogeny (Fournier & Gogarten 2010) as a backbone, one can begin reconstruction of the reticulate history of genomes. Many other proteins, especially those that are part of the translation machinery, also place the root between the archaea and the bacteria (Woese et al. 2000, Zhaxybayeva, Lapierre & Gogarten 2005). Ancestral sequence reconstruction suggests that the ancestors of the bacterial and archaeal domains were extreme thermophiles, whereas the LUCA sequences reflect less thermophilic adaptations (Boussau et al. 2008, Fournier & Gogarten 2010, Galtier, Tourasse & Gouy 1999). These observations are compatible with a bottleneck that occurred at the time of the domain ancestors. Only organism that had previously adopted to higher temperatures survived through this bottleneck. This inference is also supported through the tree shape of molecular phylogenies (Gogarten-Boekels, Hilario & Gogarten 1995, Zhaxybayeva & Gogarten 2004). A candidate for the events causing this early bottleneck is the late heavy bombardment (Abramov & Mojzsis 2009), or the tail of the early heavy bombardment. This explanation implies that life is older than 3.8*10^9 years BP, and had adapted to different ecological niches on early Earth already when the last nearly sterilizing impacts hit the Earth.
Life as a Dissipative Structure; implications for the emergence of metabolism

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As noted by Erwin Schrödinger already back in the 1940s (Schrödinger 1948), traditional (i.e. equilibrium) thermodynamics has a problem with the notion of Life as an entity per se. The 2nd law of thermodynamics indeed requires that the extraordinary decrease in entropy represented by a living cell must be more than counterbalanced by an increase in entropy of the larger system it is part of. Life therefore crucially depends on the possibility to feed on free energy sources in the environment and is inconceivable in systems at thermodynamic equilibrium. Life’s present way to do so is Bioenergetics, that is, the multitude of free-energy converting systems observed in extant organisms. We consider that it is from the understanding of present day Bioenergetics that free-energy conversion at life’s emergence may be retrodicted and the basic common features of contemporary Bioenergetics will therefore be briefly summarized. While environmental disequilibria thus are necessary to reconcile the existence of life with traditional thermodynamics, in the framework of modern Far-from-Equilibrium-Thermodynamics remarkably they also provide the sufficient condition for life’s emergence. Many physical and chemical systems poised far from thermodynamic equilibrium indeed have been shown to generate (spatially and/or temporally) ordered (in a dynamical rather than a static sense) phenomena denoted Dissipative Structures. The emergence of Dissipative Structures occurs at thermodynamic instabilities when the systems free energy exceeds the threshold separating the so-called thermodynamic regime (close to equilibrium) from one of several stable states of generally lower symmetry than that of the system in the thermodynamic regime. The choice of a specific Dissipative Structure beyond the transition free energy is stochastic and a deterministic prediction of a systems path from the thermodynamic regime into the realm of Dissipative Structures therefore is impossible (for details, see Prigogine 1996) even if the ensemble of possible stable dissipative states can often be deduced (Cottrell 1979). However, we do know the eventual outcome of the evolutionary path of the free-energy converting system of life through innumerable thermodynamic instabilities generating ever more complicated Dissipative Structures: extant Bioenergetics. This allows us to deduce some of the choices life has made over its evolutionary history and in particular some of the more fundamental ones which must have been made already very early on, close to life’s ultimate emergence. Selected mechanisms underlying and/or arising from these choices will be discussed and a few fundamental engines (Branscomb & Russell 2013; Russell et al. 2013) involved in the respective conversions of free energy will be deduced from extant Bioenergetics. The types of primordial free-energy disequilibria likely having driven the emergence of life on planet Earth will be assessed and ramifications for life’s emergence in other settings will be discussed.

References

On February 6th, 2016 at 22:07 the dark skies over Denmark turned bright, as the largest meteorite fall in Danish history was passing through the atmosphere toward the outskirts of Copenhagen. The fireball could be seen over most of Northern Europe. A picture taken from the Austrian alps at 900 km distance clearly tracks the fireball from a height of 90 km down to about 20 km, where the dark part of the flight commenced. The new Danish meteorite is a chondrite. Chondrites contain the oldest and most pristine materials from the birth of our Solar System. Chondrites contain particles that formed during the first 3 My after the Sun formed 4567.3 My ago. The particles seen in chondrites today originally formed in a disk orbiting our young star. Most of the material from the disk accreted to form planets but a small fraction ended up in asteroids. Some of the asteroids melted completely, shortly after they formed, but other asteroids have largely escaped geological processing. The primitive materials they formed from, have therefore survived intact for more than 4.5 Gy. Most of the larger particles in chondrites fall in two groups: Calcium Aluminum rich Inclusions (CAIs) and chondrules. Chondrules are, by far, the most common and have given name to the type of meteorites where you can find them. Chondrites are meteorites that contain mm-sized round particles known as chondrules. Chondrules formed in free orbit as preexisting solids were flash-melted to form droplets. The droplets solidified in free space and are therefore mainly found as perfect spheres. The chondrules contain small amounts of U that make it possible to date their formation. The have ages ranging from the age of the Solar System (4567.3 My) and up to 4564 My. CAIs, on the other hand, have condensed from a hot gas. Calcium and aluminum are highly refractory and are therefore the first elements to condense out of a hot gas. In contrast to the chondrules, all CAIs appear to have exactly the same age (4567.3 My). They likely formed close to the Sun during the earliest phases of our Solar System. They are the oldest dateable materials that we know of. Chondrites also contain finegrained material known as matrix. Unlike chondrules and CAIs the matrix have largely escaped thermal processing. Some types of chondrites, known as carbonaceous chondrites, contain large amounts of matrix which is rich in volatile components and organic compounds such as amino acids. These meteorites probably originate from asteroids far from the Sun where the temperatures were low enough that volatiles could condense out as solids and accrete as icy particles. Chondrites also contain evidence of short lived radioactive elements. The elements decayed away during the first few million years of the Solar Systems history but the decay products can be used to estimate their initial abundance. Since they have short halflives they must have formed in dying stars shortly before the Solar System formed. Their presence in the meteorites may therefore be used to constrain the types of stars that delivered material to our Solar System. Decay of the shortlived radioactive elements constituted a very significant heat source in the first planetary bodies to form in our Solar System. Asteroids that formed within 1 My after the CAIs contained enough of the shortlived radioactive isotope 26Al that they melted completely. The total melting allowed them to differentiate into a metallic core, a silicate mantle and a volcanic crust. Their interior structure therefore resembles that of our own planet, although they were much smaller. Later catastrophic collisions between asteroids have scattered fragments across the solar System. When the fragments fall on Earth in the form of meteorites they provide us with a unique opportunity to reconstruct the crucial phase from the birth of the Solar System to the time when the first larger bodies began to form.
Pre-solar grains: the ingredients to make a solar system

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Meteorites are composite materials that contain evidence of every phase of evolution of the solar system, ranging from atoms synthesized early in the history of the Universe to the formation of the planetary bodies that we see today. This presentation will look at the formation of condensates from giant stars, the seeding of these materials into the interstellar medium, the incorporation of these materials into the molecular cloud that collapsed to form the solar system to the formation of the first planetesimals in the early solar system. Surviving tracers of all the phases of evolution of solid material are found in meteorites which may be studied to discern stellar sources that supplied material to the nascent solar system, may have triggered the collapse of the molecular cloud that formed the solar system, contain evidence of the conditions in the interstellar medium and short lived radioisotopes that are extinct today but were heat sources in the early solar system and give a means of dating events in the early solar system.
Meteorites as probes for understanding the Early Solar System
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The Solar System is estimated to have been formed 4.6 billion years ago with the collapse of a dense cloud of interstellar gas and dust. These were incorporated in the solar nebula, and served as the building blocks from which future comets, asteroids and other planetary bodies may have originated. Meteorites are fragments from the asteroid belt known to contain extra-terrestrial molecules Cronin & Chang (1908); Martins & Sephton (1908), which formed by chemical reactions on the meteorite parent bodies, solar nebula or interstellar medium. By analyzing the organic inventory present in very primitive meteorites, we will be able to establish the chemical reactions and conditions of the early solar system. Carbonaceous chondrites are a primitive class of meteorites. They contain 3-5wt% organic carbon, present as insoluble organic matter (IOM) Cody & Alexander (2005), and as soluble organic compounds, including key compounds important in terrestrial biochemistry Cronin & Chang (1908); Martins & Sephton (1908). In this talk I will present the organic inventory of different carbonaceous meteorites. They contain soluble organic molecules with different abundances and distributions, which may reflect the extension of aqueous alteration and/or thermal metamorphism on the meteorite parent bodies. Data show that extensive aqueous alteration on the meteorite parent body may result on 1) the decomposition of -amino acids Botta et al. (2007); Martins et al. (2015); 2) synthesis of - and -amino acids Cronin & Chang (1908); Martins et al. (2015); Cooper & Cronin (1995); Glavin et al. (2006, 2010); and 3) higher relative abundances of alkylated polycyclic aromatic hydrocarbons (PAHs) Martins et al. (2015); Elsila et al. (2005). The abundances and distribution of the organic molecules present in primitive meteorites provide crucial information about the physical and chemical conditions of the early solar system.

References
Tracing early solar system history with comets:
A compositional and dynamical perspective

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During the earliest epochs of our solar systems formation, temperature gradients led to a variety of compositional and isotopic chemical gradients within the disk. This disk chemistry left its chemical fingerprints on the planetesimals that are today’s comets. Comet studies for decades have tried to understand the disk chemistry and formation location of comets through studies of their ices. The story is incomplete, however, without considering the dynamical movement of these small icy bodies as the giant planets formed. Recent dynamical models succeed in reproducing key characteristics of our current solar system; some of these models require significant migration of the giant planets, while others do not. These models provide different predictions on the presence of rocky inner solar system material expelled from the inner Solar System into the Oort cloud. This paper will discuss the chemical understanding in the context of recent space missions, and will discuss how new discoveries with the Pan-STARRS1 telescope may be the key to verifying the predictions of dynamical models. The Pan-STARRS1 telescope has been discovering many inactive and very low activity comets on long-period comet orbits. One of these has recently been discovered to be consistent with inner main belt rocky S-type material (Fig. 1). Furthermore, this object displays a very weak level of comet activity, five-six orders of magnitude less than typical ice-rich comets on similar orbits. This activity implies that this object has retained a tiny fraction of the water that is expected at its formation distance in the inner solar system, and this may offer new ideas about the relation between meteorites and their sources. We may be looking at fresh inner solar system Earth-forming material, ejected from, the inner solar system and preserved for billions of years in the Oort cloud.

Fig. 1. Reflectivity spectrum for Manx comet C/2014 S3 (PANSTARRS) obtained with the VLT 8m telescope on 2014 Nov. 18. Filter photometry from the CFHT on 2014 Oct. 22 and spectra of six S-type asteroids are also shown for comparison. All spectra are normalized to 1 at 0.65 µm.
New insights from ROSETTA into cometary dust

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The COmetary Secondary Ion Mass Analyser (COSIMA) is a dust particle composition analyzing instrument on board the ROSETTA spacecraft orbiting comet 67P/Churyumov-Gerasimenko since August 2014. COSIMA is collecting cometary particles on metal targets in the inner coma, identifies the collected particle on microscopic images and analyses their composition by secondary ion mass spectrometry. We will report on the findings of ROSETTA on the dust particles observed and collected in the inner coma of the comet within distances of 10 to 400 km.
Our understanding of the molecular origin of life is based on amino acids, ribose, and nucleobases that - after their selection by prebiotic processes - initiated the evolutionary assembly of catalytic and informational polymers, being proteins and ribonucleic acids. Following our previous amino acid identifications in the room-temperature residues of simulated precometary ices [1, 2] we have searched for a different family of molecules of potential prebiotic interest. Using multidimensional gas chromatography coupled to time-of-flight mass spectrometry, we have now detected ten aldehydes, including the sugar-related glycolaldehyde and glyceraldehyde in precometary ice analogues [3]. The two species are considered as key prebiotic intermediates in the first steps toward the synthesis of ribonucleotides in a planetary environment [4]. The detection of aldehydes in precometary ice analogues is coherent with our data received from the Rosetta mission [5] that successfully deposited the Philae lander on the nucleus of comet 67P/Churyumov-Gerasimenko in November 2014 [6]. The COSAC instrument, which is a GC-MS device specifically designed for the in situ characterization of chiral organic molecules, identified 16 organic species including aldehydes and N-bearing molecules in the cometary ice [7]. The complexity of cometary nucleus chemistry implies that early solar system chemistry fosters the formation of prebiotic material in noticeable concentrations.

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The physical chemical steps leading to life on Earth took place at a time when endogenous water/rock interactions were strongly influenced by exogenous effects (i.e. from impacts). There is no direct measure of the influx of extraterrestrial matter in the epoch of late accretion from approximately 4.45-3.80 Ga. It is within this time, however, that life likely emerged and some specific constraints on the thermodynamic regimes that modulated its emergence can now be made. Geochemical evidence shows the presence of a hydrosphere (Mojzsis et al., 2001) and evolved crust (Mojzsis et al., 2014; Roth et al., 2014) before about 4.38 Ga on Earth (Harrison, 2009), and ca. 4.43 Ga on Mars (Humayun et al., 2013; Nemchin et al., 2014). Hence, the necessary prerequisites for life: (i) liquid water, (ii) energy resources, (iii) organic building blocks, and (iv) adequate time for the abiotic chemistry to reach the biological singularity in a planetary milieu (cf. de Duve, 2005), existed a mere 100-150 Myr after the formation of the solar system. It makes sense to explore whether abundant extraterrestrial matter fed the planetary organic-chemical reactor that gave rise to life. Mass accumulated in the post-primary accretion timeframe subsequent to the Giant Impact (GI) event that formed the Moon at ca. 4.49 Ga (Jacobsen et al., 2014) in the postulated Late Veneer (LV) was (Bottke et al., 2010) was about 310^23 kg. Calculations suggest that the total mass of impactors to the Earth at the conclusion of the late heavy bombardment (LHB) often benchmarked with the formation of Orientale basin at ca. 3.80 Ga was 2.010^20 kg (Abramov et al., 2013). This is about 1500 less than the calculated mass of the LV (Walker, 2009); both the GI and LV erased surface rocks with the formation of magma oceans (Frank et al., 2016). With bulk average sulfur, carbon and phosphorus contents of CM, CI and EH chondrites (cf. Fitoussi and Bourdon, 2012) as a rough guide for a range of possible compositions of post-LV material delivered to Earth (Lodders and Fegley, 1998) and Mars (Abramov and Mojzsis, 2016), we can compute ranges for exogenous sources conservatively lead to the accumulation of the bio-essential elements: S (5.4-11.2x10^21g), C (7.8-69x10^20g) and P (1.9-4.2x10^20g). Taken at face value, the sources appear significant when compared to the cumulative mass delivered to the Moon, but the result for sulfur is still 1% of the total S inventory for all sediments and seawater at Earth's surface (Holland, 1984). Terrestrial sulfur sources that contributed to the origin of life were dominantly indigenous to Earth subsequent to primary accretion (Mojzsis, 2007). The quantities of carbon and phosphorus, on the other hand, were very large. Cumulative yields for late accretion shown above are equivalent to thousands of times the current C and P inventories of the biosphere. If such late accretion events commonly occur in young solar systems (e.g. Gaspar et al., 2009), bio-essential element augmentation from late planetary migrations of giant planets that perturb asteroids and comets into crossing orbits (Morbidelli, 2010) may be a shared feature in the formation of worlds thermodynamically primed for biopoesis.

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Geochemical complexities as a setting for life’s origins

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The origin of life occurred in a complex geochemical environment, characterized by significant chemical and thermal gradients, fluid fluxes, cycles, and interfaces. These aspects of the prebiotic world are critical to understanding life’s origins, as biochemical complexity emerges from geochemical complexity. Crystalline surfaces of common rock-forming minerals are likely to have played several important roles, including catalysis of key biomolecules; as interfaces for the selection, concentration and protection of those molecules; and as templates for the assembly of molecular structures. Thus mineral surfaces may have contributed centrally to the linked prebiotic problems of containment and organization by promoting the transition from a dilute primordial soup to highly order domains of molecules. Of special note is the combinatorial richness of geochemical niches on an Earth-like planet. Chemical events that might be unlikely on the time and spatial scales of a laboratory investigation may be deterministic at the scales of planets,
The ghosts behind the molecules: the recent history of the attempts to understand the origin of life

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The heterotrophic origin of life proposed by A. I. Oparin, J. B. S. Haldane and few others in the 1920s was part of a Darwinian framework that assumed that living organisms were the historical outcome of a gradual transformation of lifeless matter. This idea was strongly opposed by the geneticist H. J. Muller, who argued that single genes or DNA molecules represented primordial living systems. The debates that followed represent not only contrasting views of the nature of life itself, but also major ideological discussions that reached a surprising intensity in the years following the 1953 Miller-Urey experiment, which demonstrated the ease with which organic compounds could be synthesized under putative primitive reducing conditions. Following the Miller-Urey experiment attempts to understand the origin of life were shaped to a considerable extent by the development of molecular biology and, in socio-political terms, by the atmosphere created by Cold War tensions. Although as late as 1942 the possibility that bacteria were endowed with genetic material was held in doubt, the molecularization of biology led several scientists both in the USSR and in other European countries to acknowledge the key role that RNA molecules play in major biological processes and to discuss the idea that RNA could have preceded DNA as genetic material. This possibility was discussed by Belozersky, Haldane, Oparin and Lipmann, and in retrospect should be recognized as a pioneering attempt to put the developments in molecular biology within an evolutionary perspective. It was not until the late 1960s when the extraordinary intuition and deep understanding of Alex Rich, Carl Woese, Francis Crick and Leslie Orgel led to independent suggestions of what can be termed today the RNA World. Although this possibility has received strong support with the discovery of ribozymes, as of today there are many different definitions of what the RNA World.
Excitements and challenges in tracking the early traces of life

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Possible isotopic, biosedimentary, molecular and morphological traces of life suggest the early diversification of microbial communities in diverse environments. However, these traces may in some cases also be produced by abiotic processes or later contamination, leaving a controversy surrounding the earliest record of life on Earth. Before a microstructure can be accepted as a microfossil, a series of approaches need to be employed to prove its endogeneity, syngenicity, and biological origin, as well as to falsify an abiotic explanation for the observed morphologies or chemistries. These micro- to nano-scale analyses complement the macro-scale characterisation of the geological context, as the environmental conditions will determine the plausibility of ancient habitats and the conditions of fossilisation. Similar approaches are also applicable to the search for life in situ beyond Earth, such as the future Martian missions. Interpreting the paleobiology of unambiguous traces may also be challenging. Considerable debates still exist regarding the origins of the three domains of life (Archaea, Bacteria, Eucarya), their relationships and relative order of branching, as well as the evolution of cellular life before LUCA, and between FECA and LECA (first and last eukaryotic common ancestors). Molecular and ultrastructural analyzes provide insights on the evolution of crown groups of the 3 domains back to their respective last common ancestors, while the geological record may preserve both part of Earth and life history further back in time. Some of these early (Precambrian) biosignatures may be related to modern metabolisms or modern clades, but many cannot. However, regardless of taxonomy, the paleobiological record can provide direct evidence for extinct clades and/or for the minimum age of evolution of biological innovations. Examples will be presented to illustrate the challenges and excitements of studying the early traces of life.
Tenacious misconceptions about biological evolution

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Life and (biological) evolution are indissoluble. Evolution is the outcome of both, Darwinian processes implying reproduction with variation upon which natural selection acts, and drift. These processes are universal and underlie the biological diversity patterns that we see today. Understanding the mechanisms governing biological evolution leads to refuting some pervasive misconceptions on biological evolution. Among the most obstinate are the idea that complexity necessarily increases along evolution, that simple equals primitive or that bacteria and other unicellular organisms are less evolved than animals and plants. I will argue against these false assumptions, with specific examples. I will also comment on the limits of actualism (interpreting the past considering the present).
Misconceptions, Truths and Controversies: Is Origins of Life Research no Different from the Rest of Science?

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The growth of scientific knowledge is quite often shaped by numerous controversies among scientists about facts, methods or theories. Galileo argued against Ptolemy about the structure of the solar system. Newton and Descartes disagreed on the nature of light. Pasteur and Pouchet quarrelled over spontaneous generation. Einstein disagreed with Bohr and many others about the completeness of quantum mechanics. It would be surprising if a scientific field as speculative as origins of life research were to be devoid of any controversy. Indeed, numerous controversies do take place in origins of life research, ranging from debates about information-first versus metabolism-first scenarios, to disagreements about the importance of cellular membranes or even quarrels about the heterotrophic or autotrophic nature of early forms of life. An open question, however, is whether origins of life research is affected, not only by controversies, but also by specific misconceptions. Whereas scientific controversies can be defined as symmetrically organized debates between groups of scientists justified of their possessing the truth, misconceptions involve an asymmetry in that those holding the misconceptions often happen to be unaware of the existence of alternative justified beliefs that would render their own beliefs unjustified. In this contribution, I analyze the conceptual differences between scientific controversies and scientific misconceptions, and investigate the relevance of these concepts to specific debates in origins of life research.
Chemical Selection: High fidelity non-enzymatic syntheses of both nucleotides and amino acids are essential to elucidating the origin of life on Earth. We will demonstrate that a hybrid product of prebiotic amino acid and nucleotide syntheses, identified through system chemical analysis, is a missing link required for prebiotic amino acid and nucleotide selection. This missing link delivers unprecedented efficiency in selecting, organising, and directing the concomitant assembly of natural amino acids and nucleotides from complex mixtures.

Glycolysis: Phosphoenol pyruvate (PEP) is biology's highest energy phosphate and has a central role in metabolic pathways, including glycolysis and gluconeogenesis, the shikimic acid pathway, carbon fixation in plants, phosphoryl-transfer in bacteria and entry into ketogenesis and the citric acid cycle. A high-yielding chemoselective prebiotic synthesis of PEP in water will be demonstrated from the same chemical feedstocks used to synthesise nucleotides and amino acids. Furthermore, the derivation of each of the intermediates of the glycolysis pathway will be elaborated through simple modification of one chemical system.
The variable circumstellar extinction in a protoplanetary disk with an embedded low-mass companion

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The presence of an unseen protoplanet has to impact on the matter distribution and illumination condition of the circumstellar disk. The large-scale inhomogeneities of matter can be produced by periodic perturbations of the protoplanetary disk by the protoplanet. Such structures can effect on the circumstellar extinction and propagation of the star radiation to an observer. We consider the influence of the low-mass companion embedded in extended protoplanetary disk on the brightness curve of the central star. The hydrodynamic flows produced by the motion of the companion are simulated using our modification of GADGET-2 code. The column density of the circumstellar dust on the line between the star and an observer as a function of the phase of the orbital period is calculated. We intersect the disk matter in a number of directions to estimate effect of the disk orientation on the light curves. It allows us to explore the contribution of the different parts of the disk to the extinction of the star luminosity. The calculation show the periodic variation of the column density of the matter can originate in the common disk and the circumstellar disk of the central star. The results of the simulation are applied to explain the brightness curves of UX Ori stars, which circumstellar disks are observed almost edge-on.
Despite the enormous increase in observational data on extrasolar planets in the past two decades, many aspects of their formation are still not well understood to date. In particular, the origins of the oldest known class of exoplanets, the hot Jupiters, is still not clear. A new approach to disentangle different formation mechanisms might be offered by an observational technique that has recently seen a lot of progress, which is the spectroscopy of planetary atmospheres. This is because the spectrum represent a window into the atmospheric composition of a planet. In my talk I will show how it might be possible to find the traces of the chemistry in protoplanetary disk via the planetary formation history in the spectrum of an (exo)planet, based on the results of a planet formation and evolution model and assumptions about the refractive and volatile composition of the planetary building blocks like planetesimals and comets. In particular, different migration mechanisms might lead to distinct imprints, which is very important from a planet formation point of view. To this end we simulate the physical and chemical processes during a planet’s formation using a global planet formation model, tracing the material abundances in the accreted material. We then consider the planet’s subsequent evolution, evolving the radius, internal, and atmospheric structure to an age of several Gyrs when (exo)planets are typically observed. Using an atmospheric radiative transfer and chemistry model we finally calculate the spectrum of the planets at this age. With this, we can study differences in the spectra resulting from, e.g., different carbon to oxygen ratios due to different migration histories. We find that a formation inside the water ice line can lead to a strong imprint, but only if the building blocks in the inner protoplanetary disk contain refractory carbon grains in significant quantities. It is then discussed whether these imprints can be observed with current and future instruments, and which steps need to be taken in the theoretical models to better understand the link between formation and spectra.
Stellar chemistry: hints for planet formation and structure

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Planets form as an outcome of the star formation process. It is thus with no surprise that understanding the stars, their properties, and their chemical abundances, provides fundamental clues to understand planet formation and composition. In this talk I will start by reviewing some of the most recent works on the relation between stellar properties and the occurrence of planetary systems. A focus will be given to the information provided by the study of chemical abundances. The link between stellar properties and the architecture/composition of the planetary systems will then be explored.
The chemical heritage of planet-building material: new insights from ALMA and Rosetta

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Protoplanetary disks are the birth sites of planetary systems. Gas and ice chemistry during protoplanetary disk formation and evolution ultimately determines the composition of planet- and comet-building material, the study of which is important for gaining insight into our origins. In recent years, our understanding of the chemical composition and structure of nearby disks has advanced significantly. The Atacama Large Millimeter/Submillimeter Array (ALMA) has revealed the dust and gas structure of disks at (sub)mm wavelengths with unparalleled resolution, approaching size scales commensurate with that of our own solar system (< 50 AU). In addition, the Rosetta mission is measuring the composition of comet 67P/C-G in situ with unprecedented accuracy. The cometary material is likely representative of that in the natal protoplanetary disk around the young sun. I will discuss the chemistry which occurs in protoplanetary disks and its importance in determining the composition of the planet- and comet-building material. I will discuss the results of protoplanetary disk chemical models in light of recent ALMA results which probe the cooler outer disk, and I will also describe the potential formation routes and observability of so-called "complex organic molecules", species that are considered to be the precursors of prebiotic molecules, such as amino acids. I will discuss how transformational results from the Rosetta mission are shedding new light on the heritage of comet-building material.
From chondrules to planets tracking the recycling of solids in an evolving protoplanetary disk

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The most abundant constituent of chondrites are chondrules, mm-sized spherules formed by transient heating events. High-resolution uranium-corrected Pb-Pb dates indicate that chondrule formation started contemporaneously with the Solar System first solids, CAIs, and lasted 3 Myr (Connelly et al. 2012). Further, numerical simulations show that the main growth of asteroids results from gas-drag-assisted accretion of chondrules, leading to the formation of planetary embryos <3 Myr (Johansen et al. 2015). Thus, chondrules dominate the precursor material of most asteroids and, by extension, inner Solar System planets.

We report U-corrected Pb-Pb ages and 54Cr/52Cr compositions (54Cr) of individual chondrules from the pristine ordinary chondrite NWA5697 (L3.10) to better understand the history and nature of the material that accreted to form the inner Solar System planets. A total of 13 chondrules, including 8 with measured 238U/235U, record Pb-Pb ages ranging from 4567.6±0.5 to 4563.6±0.5 Myr. These chondrules record 54Cr values typical of inner Solar System asteroids and planets, namely ranging from -90 to +25 ppm relative to Earth. Collectively, these data require that genetically-unrelated chondrules formed in different regions of the inner disk and were thereafter transported to the accretion region of the NWA5697 parent body. Moreover, the 3 Myr age variability recorded by chondrules from the same parent body entails storage and recycling of chondrules via multiple chondrule forming-events. It is well established that the chondrule-forming process increases the U/Pb ratio via Pb devolatization. Therefore, continuous recycling of chondrules will lead to a secular increase in the U/Pb ratio of younger chondrules and, thus, more evolved initial Pb isotope compositions with time. Our data reveals a linear relationship between the chondrule ages and initial Pb compositions with younger chondrules systematically recording more evolved compositions. These observations suggest that recycling and, hence, outward transport of chondrules is intrinsically linked to the chondrule forming process. If chondrule accretion is the main growth mechanism leading to planetary embryos, our data imply that the precursor material to the inner Solar System planets was effectively devolatized. Thus, Earth’s volatile inventory must reflect a post accretion feature, perhaps through late delivery of volatile-rich bodies.

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A comprehensive analysis of presolar SiC grains using NanoSIMS and Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS)

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Presolar grains are micron-sized dust grains which condensed from the gases surrounding dying stars. They are identified by their highly anomalous isotope ratios (relative to solar compositions) which vary by several orders of magnitude, and are only explained by stellar nucleosynthesis. Presolar silicon carbide (SiC) grains are the best studied, with over 10,000 individual grains having been analysed (Hynes & Gyngard, 2009). However, nearly all of these grains were extracted from their host meteorite with the use of harsh acids. These acids have been shown to damage grain surfaces (Stephan et al., 1997; Henkel et al., 2007), and may remove any implanted material (Verchovsky et al., 2001; Lyon et al., 2007) or grain coatings (Bernatowicz et al., 2003) which are present. A gentle separation method was developed (Tizard et al., 2005) which extracts presolar SiC grains without the use of potentially damaging chemicals. This study aims to analyse gently separated, in-situ and acid residue presolar SiC grains. Each grain will be comprehensively analysed in order to determine any elemental or isotopic heterogeneity within the grain, as well as to assess the effects of each extraction method on the grains. Presolar SiC grains were identified by mapping each sample for C, N and Si, and selecting grains with anomalous isotopic compositions. Each grain was analysed on the NanoSIMS 50L to determine the \(^{13}\text{C}/^{12}\text{C}, {^{15}\text{N}}/{^{14}\text{N}}\) and \(\delta^{28,30}\text{Si}\) ratios. Following this, each grain will be depth profiled using a Time-of-Flight Secondary Ion Mass Spectrometer, in order to identify any variations in elemental and isotopic composition within the grains. At the present time, 71 presolar SiC grains have been identified from 2 acid residues and 2 in-situ samples. Of these, 65 are mainstream grains- that is, they are part of a group which make up around 90% of all presolar SiC grains. The remaining 6 are AB grains, which are 3% of presolar SiC grains. Within each grain, the C and Si isotope ratios are almost homogeneous, whereas some variations are seen in N isotopes. Across all 71 grains, there are large variations in C, Si and N isotope ratios. \(^{12}\text{C}/^{13}\text{C}\) varied between +5.67 and +133, \(^{14}\text{N}/^{15}\text{N}\) from +35.5 to +5357, \(\delta^{28}\text{Si}\) ratios were between -269 and +225 %, and \(\delta^{30}\text{Si}\) ranged from -121 to +120 %. These early results of acid residue and in-situ presolar SiC grains are promising, and further work with the TOF-SIMS will identify any heterogeneity in other elements and isotopes within each grain. In addition, gently separated presolar SiC grains will soon be analysed with both the TOF-SIMS and NanoSIMS, completing the sample set, allowing comparisons to be made between the three sample types.

References


Abundance trends with condensation temperature and terrestrial planet formation: The case of ζ Reticuli

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Fig. 1. Differential abundances ($ζ^2_{\text{Ret}}$ − $ζ^1_{\text{Ret}}$) against condensation temperature. The abundance are derived for the the combined spectra and spectra that was used in Saffe et al. (2016). The black dashed line represents the trend when all the elements are used for the linear regression and the red line is the result of the linear regression when only elements with $T_c > 900$K are used.

References


During the last decade astronomers have been trying to search for chemical signatures of terrestrial planet formation in the atmospheres of the hosting stars. Several studies suggested that the chemical abundance trend with the condensation temperature, $T_c$, is a signature of rocky planet formation. In particular, it was suggested, that the Sun shows a "peculiar" chemical abundances because of the presence of the terrestrial planets in our solar-system. However, rocky material accretion or the trap of rocky materials in terrestrial planets is not the only explanation for the chemical 'peculiarity' of the Sun, and other Sun-like stars with planets. In this talk I propose to make a very brief review of this topic, and present our last results for a particular case of Zeta Reticuli binary system: A very interesting and well-known system (in science fiction and ufology known as the world of Grey Aliens, or Reticulans) where one of the components hosts an exo-Kuiper belt. These results are product of a research project that was supported by this, COST Action TD1308 through STSM grant. I believe that this conference is the most suitable place, and best opportunity to present my results to the large scientific community that this meeting is going to host.
The Ortho-to-Para Ratio of NH$_2$ at Different Temperatures

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Thanks to recent Herschel results, the ortho-to-para ratio (OPR) of NH$_2$ has been estimated towards the following high-mass star-forming regions: W31C (G10.60.4), W49N (G43.20.1), W51 (G49.50.4), and G34.3+0.1. Depending on the position observed along the line-of-sight, the OPR was found to lie either slightly below the high temperature limit of three (in the range 2.2-2.9) or above ($\sim$ 3.5 and two lower limits of $> 4.2$ and $> 5.0$). Though lower values than the statistical limit are strictly forbidden in thermodynamical equilibrium, variations of the OPR, both below and above the strict limit, can be explained by astrochemical models taking into account nuclear-spin gas-phase chemistry. For temperatures below 50 K, the thermal OPR of H$_2$ is $< 10^{-1}$, far lower than the “normal” value of three, which corresponds to the ratio of the spin statistical weights. In such a para-enriched H$_2$ gas, our astrochemical models can account for the “anomalously low” observed NH$_2$-OPR values by considering nuclear spin gas-phase chemistry. Values larger than three may be explained by assuming that the thermalization processes of NH$_2$ can occur, increasing the OPR with the decreasing temperature. In order to use these mechanisms, we include the H-transfer reaction NH$_2$ + H in our models. This reaction has been shown to proceed without a barrier, meaning that the H-transfer will be efficient in the temperature range of interest. Our models suggest that values below three arise in regions with temperatures $\geq$ 20 – 25 K, depending on time, and values above three at lower temperatures.

References

The Role of Low-Energy (≤ 20 eV) Electrons in Astrochemistry: A Tale of Two Molecules

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In the interstellar medium, UV photolysis of ice mantles encasing dust grains is thought to be the mechanism that drives the synthesis of “complex” molecules. The source of this reaction-initiating UV light is assumed to be local because externally-sourced UV radiation cannot pass through the ice-containing dark, dense molecular clouds. Externally sourced cosmic rays ($E_{\text{max}} \approx 10^{20}$ eV), in addition to producing UV light within these clouds, also produce large numbers of low-energy (≤ 20 eV) secondary electrons. The goal of our studies is to understand the low-energy electron-induced processes that occur when high-energy cosmic rays interact with interstellar ices. Using electron stimulated desorption (ESD), post-irradiation temperature-programmed desorption (TPD), and infrared reflection absorption spectroscopy (IRAS), we have investigated the radiolysis initiated by electrons in condensed methanol and ammonia at $\approx 90$ K under ultrahigh vacuum ($1 \times 10^{-9}$ Torr) conditions. We have identified fifteen low-energy (≤ 20 eV) electron-induced methanol radiolysis products, many of which have been previously identified as being formed by methanol UV photolysis in the interstellar medium. We have also found evidence for the electron-induced formation from ammonia of hydrazine ($N_2H_4$), diazene ($N_2H_2$), cyclotriazane/triazene ($N_3H_3$) and triazane ($N_3H_5$). We have investigated the reaction yields’ dependence on film thickness, irradiation time, incident current, electron energy, and metal substrate. These results provide a basis from which we can begin to understand the mechanisms by which methanol and ammonia can form more complex species in cosmic ices. Studies such as ours may ultimately help us better understand the initial stages of the genesis of life.

Fig. 1. Image shows how cosmic rays produce low-energy electron when interacting with extraterrestrial ices
Study of gas-phase ion molecular reactions at temperatures relevant to the atmosphere of Titan
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Theoretical models of the chemical kinetics of the ionosphere of Saturn’s moon, Titan, are highly dependent on the precision of the rates of the reactions of ambient ions with hydrocarbon molecules at relevant temperatures. To provide kinetics data closer to the required temperature, the newly built VT-SIFT instrument includes a novel temperature variable flow tube and temperature regulation system was used to study temperature dependence of \( \text{CH}_3^+ + \text{O}_2 \) and \( \text{N}_2^+ + \text{CH}_4 \) reactions over the temperature range 245−305 K (see fig. 1 and fig. 2). The \( \text{CH}_3^+ + \text{O}_2 \) reaction proceeds thus:

1a) \[ \text{CH}_3^+ + \text{O}_2 + \text{He} \rightarrow \text{CH}_3\text{O}_2^+ + \text{He} \]

1b) \[ \text{CH}_3^+ + \text{O}_2 \rightarrow \text{HCO}^+ + \text{H}_2\text{O} \]

The association channel (1a) is considered to be the most relevant channel for interstellar chemistry and was studied previously using the original SIFT instrument (Adams and Smith 1981). The exothermic binary channel (1b) becomes dominant at low number densities of neutrals. The measured rate constant for this channel \( k_{1b} = (4.7 \pm 0.9) \times 10^{-11} \text{ cm}^3 \text{s}^{-1} \) at 302 ± 1 K, see fig. 1, in agreement with a previous ICR measurement (Huntress 1977). These results are used to estimate the absolute error of rate coefficient measurements using this new VT-SIFT instrument by comparison with published data (Huntress 1977). The apparent small decrease of \( k \) at the lower temperature to of 248 ± 5 K (fig. 1) is not statistically significant. The reaction of the \( \text{N}_2^+ \) ions with methane has two exothermic bimolecular channels:

2a) \[ \text{N}_2^+ + \text{CH}_4 \rightarrow \text{CH}_3^+ + \text{H} \]

2b) \[ \text{N}_2^+ + \text{CH}_4 \rightarrow \text{CH}_2^+ + \text{H}_2 \]

Channel (2a) is very dominant (>90% of the total products; Tichy et. al. 1979). The temperature dependence of the formation of the \( \text{CH}_3^+ \) ions was explored (the minor \( \text{CH}_2^+ \) channel neglected) and the results are shown in fig. 2.

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Fig. 1. Preliminary measurements of the CH$_3^+$ + O$_2$ reaction rate coefficient in the temperature range 245 – 305 K (red squares) compared to a previous ICR measurement ostensibly at 297 K (blue circle).

Fig. 2. Measurements of the signal ratio of CH$_3^+$ ions, $N_{CH_3^+}(T)$, to $N_{N_2^+}(T)$, in the N$_2^+$ reaction with CH$_4$ over the temperature range 240 – 310 K at a constant CH$_4$ flow rate.
There is an increasing need to come to a consensus about what living systems are and are not. We are launching an intensive search for life beyond Earth and disagreement over the proper concept of life has already created sharp debate concerning the interpretation key experiments. And developments in synthetic biology and computer science are forcing researchers to ask whether the systems they create embody the minimal characteristics of living systems. In recent years, two ends of the continuum have dominated the debate. On one end are those who view definition as the specification of necessary and sufficient conditions, an approach ill suited to biological categories. On the other end are those who define life in terms of what can be easily tested or observed rather than what matters theoretically. As a result, thoughtful commentators tend to either call for a radical pluralism with respect to definitions of life or become pessimistic about the possibility of defining life at all. Yet both conclusions are premature and instead I propose an account of life similar to the phylogenetic concept of species developed by Mishler and Brandon. If we first identify an evolutionary "essence" of life, we can allow for a plurality of specifications of this more general category depending on factors like researcher interest. It is thus possible to hold on to the ideal of life as a natural kind while allowing that there is merit to more than one approach to the problem.
Biosphere complexity: A new approach towards a definition of life

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Defining life has, despite numerous attempts, remained an elusive scientific endeavour. The challenge is deeply rooted in the heterogeneous appearance and characteristics of biological entities and the variety of semantic meanings of the term life. It is here aimed to define life in context of its origins and the search for life in the Universe. I will argue that apart from semantic problems with the term life, a scientific definition can be only achieved if life is considered the property of a biosphere capable of evolution and not an individual cell or organism. This property is results from the interaction of mostly non-autonomous, interdependent units combining molecular complexity and information complexity. A mathematical basis for a universal complexity scale is given that allows quantifying structural and information complexity of corresponding biogenic units. This definition aims to provide a framework for correlating and comparing developmental stages of potential biospheres in the Universe and early steps of evolution on Earth. By its quantitative nature, defining life by biosphere complexity is compatible with gradual scenario at the emergence of life from a prebiotic world and also may help investigating the origins of life on Earth. This novel approach provides an alternative solution to defining life that can be of operational value for astrobiology, prebiotic chemistry, and evolutionary biology.
Panspermia: a Panoply of Possibilities

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We propose a framework to structure panspermia theories, i.e. the claim that biological material can transit in space, before entering nondestructively into planets. Once considered marginal, recent developments in astrobiology now support some crucial steps of such scenarios. There are various versions of the theory, from radio-panspermia, pseudo-panspermia, lithopanspermia, to directed panspermia. They are more or less plausible, more or less controversial.

We attempt at a wide exploration of possible scenarios through the examination of key issues: What entities could be diffused? Complex organic compounds, protozoa, bacteria, viroids, viruses, or others? How far could they travel? Through interplanetary, interstellar, intergalactic or universal distances? How would the transfer work? Via radiative pressure on the bare biological material, via rocks, comets, interstellar gas or a galactic dynamics? How often could the process happen? Did it happen just once since the origin of Earth, thus suggesting an alternative theory of the origin of life on Earth, or could it be a continuous input of biological material, like Fred Hoyle and Chandra Wickramasinghe proposed? We present a Drake-like equation to evaluate the different factors needed for panspermia to occur.

An intentional, directed panspermia led by extraterrestrial intelligence requires a different conceptual treatment. We use Orgel and Crick’s principle of cosmic reversibility, which says that if we are capable of doing X in the future, then, given that the time was available, another extraterrestrial civilization might well have done X already. The principle allows two perspectives to enrich each other, first, imagining how we could colonize space, and imagining how extraterrestrials could do it. The key issues for directed panspermia concern motivation (why seed?), strategy (what to seed?), engineering (how to send the seeds?), and navigation (how to reach the destination?). We propose an original test for directed panspermia.

Exploring the large range of possible panspermia theories invites us to seriously envision a living cosmos. Such a broad view on cosmic life may help us to better understand our origins and to more wisely shape our far future (Arrhenius & Borns 1908; Crick & Orgel 1973; Nicholson 2009; Wickramasinghe 2015).

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Astrobiology in culture: NASAs current interests

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Astrobiology is a productive means of stimulating and sustaining scholarly and public dialogue on the intersections of science and culture. This paper will report on NASA’s current interests and activities at these intersections, addressing how and why NASA Astrobiology has decided to pursue specific projects. The goals of NASA-sponsored astrobiology research raise fundamental philosophical, ethical, and theological questions. Thus NASA Astrobiology has a history of encouraging dialogue among scientists and others on these questions. NASA's Astrobiology Program funds trans-disciplinary research into the origin, evolution, distribution, and future of life in the universe. Astrobiology also involves studies in the humanities and social sciences, which focus especially on the future of life, including the key question of how the discovery of extraterrestrial life might affect human civilization. The mid-1990s brought the establishment of an expanded Astrobiology Program at NASA and the publication of claims of fossil evidence of past life in a martian meteorite fragment. In the face of growing scientific, political, and public interest in the possibility of extraterrestrial life, the NASA Astrobiology Program focused some of its attention on social, ethical, and philosophical questions relating to the discovery of extraterrestrial life, funding efforts to introduce astrobiology to the broader scientific community and to public audiences. The Program cosponsored workshops organized by the American Association for the Advancement of Sciences Dialogue on Science, Ethics, and Religion program on the philosophical, ethical, and theological implications of astrobiology, held in 2003-2004. Astrobiology "roadmaps" of 1998, 2003, and 2008 articulated four principles fundamental to implementation of NASA's Astrobiology Program, including the principle that the astrobiology community recognizes a broad interest in its work, especially in areas such as the search for extraterrestrial life, achieving a deeper understanding of life, the potential to engineer new life forms adapted to live on other worlds, the broader implications of discovering life beyond Earth, and envisioning the future of human life on Earth and in space.

By now, the astrobiology community has widely recognized the importance of thinking about science in its cultural context. The latest iteration of the astrobiology roadmap now called a science plan does not specifically identify a need to address social, cultural, ethical, and theological issues relating to the study of the origins of life and the search for evidence of extraterrestrial life because the community has embraced this endeavor as part of its ongoing work. NASA Astrobiology is contributing funding for two major initiatives that examine astrobiology in culture: the Baruch S. Blumberg NASA/Library of Congress Chair in Astrobiology and the Center of Theological Inquiry's (CTI's) 2015-2017 study-in-residence project, "Inquiry on the Societal Implications of Astrobiology". The Blumberg Chair was created to support scholars interested in the intersection of the sciences and humanities. The Chair for 2015-16 is Nathaniel Comfort, historian of science at Johns Hopkins University. CTI is an independent academic institution for interdisciplinary research on global concerns with an international visiting scholar program in Princeton, NJ. Its astrobiology project is intended to refresh and expand scholarly and public dialogue on this subject, which is of growing interest due to the discovery of thousands of extrasolar planets and the ongoing search for potentially habitable environments in our solar system and beyond. Astrobiologists will participate in this program as "visitors", spending a week at a time at CTI to meet with scholars selected for the inquiry. CTI has obtained a $1.7 million grant from the Templeton Foundation to expand the inquiry, providing more fellowships for resident scholars in both years, allowing additional participants to join symposia with

1 For information on other DOSER events on life in the universe, see: http://www.aaas.org/page/physics-cosmos-events.
NASA research scientists, and enabling CTI to launch a three-year outreach program to share the results of this inquiry with global leaders in interdisciplinary studies, religious thought, and the public understanding of science and society.

References

State of the art electronic calculations and kinetic computations for formamide formation in cold interstellar clouds

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Formamide (HCONH\(_2\)) is a molecule which can be found in both comets and interstellar clouds and, moreover, whose potential as a precursor of life has been well noted in the literature (see Saladino (2012)). Consequently, identifying viable chemical passages for its formation is a question of the highest importance. In this work, all product channels originating from the OH\(^+\)CH\(_2\)NH and NH\(_2\)\(^+\)HCHO reaction schemes (eventually leading to the formation of formamide) have been investigated through state of the art electronic computations (see Barone (2015)). Kinetic computations have been carried out using capture theory and the RRKM method, taking into account dynamical effects such as anharmonicity and the presence of hindered rotations as well as quantum effects such as tunnelling and quantum reflection (through a semiclassical approach). Resolution of the resulting master equation furnishes branching ratios and rate constants for all possible product channels.

References

Synthesis of formamide and isocyanic acid after ion irradiation of frozen gas mixtures

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Among the complex organic molecules observed in the gas phase of pre- and proto-stellar objects and in cometary comae, formamide and isocyanic acid are particularly intriguing because of their possible role in prebiotic chemistry. An open debate concerns their formation route and, in particular, if they are formed by chemical reactions in the gas phase and/or on the grains surface. In the latter case it is important to understand the role of energetic processing in forming them from simpler frozen molecular species. Here we present new laboratory experiments showing that the formation of both formamide and isocyanic acid can be induced by energetic processing of astrophysical ice analogues. Ice mixtures (H2O:CH4:N2, H2O:CH4:NH3, and CH3OH:N2) have been processed by energetic (30–200 keV) ions (H+ or He+) and FTIR spectroscopy allowed a quantitative measure of the amount of HNCO and NH2HCO produced. The experimental results show that energetic processing can quantitatively reproduce the amount of formamide observed in cometary comae and in many circumstellar regions. HNCO is also formed, but additional formation mechanisms have to be taken into account to explain the abundances obtained from astronomical observations. We suggest that energetic processing of ices is the main mechanism to produce formamide. Once formed, this molecule is injected in the gas phase after icy grain mantles desorption.

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Formamide Prebiotic Plasma Chemistry Network
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Formamide-based chemistry is currently broadly discussed hypothetic scenario for the origin of biomolecules. Besides the traditional HCN or reduction atmospheres-based concepts of biomolecules synthesis, the current results show that formamide molecule can play not only the role of a parent compound but it is also a substrate or intermediate in a series of complicated reaction chains leading from inorganic mixtures to broad palette of biomolecules, e.g. all the canonical nucleic bases of the genetic code, ribose and other sugars, aminoacids or fatty acids. During the past decade, comets, HCN hydrolysis, interstellar space, reduction atmospheres, ammonium-formate dehydration etc.; have been identified as direct sources or environments for chemical synthesis of formamide. However, in most cases, the exact chemistry of such systems is not well explored experimentally or theoretically. Moreover, the plausibility and relation to prebiotic environment is also questioned. In the current study, we employed a wide range of experimental methods to explore formamide chemistry in system, where this molecule does not directly play a role of a starting substrate, but it is a suspected intermediate of reactions leading from simple prebiotic mixtures to biomolecules. The results are compared with experiments with formamide. The chemistry is mapped by Marco A. Saitta and Fabio Petrucci from Université Pierre et Marie Curie - Sorbonne using unique Quantum Monte Carlo (QMC) methods. We have focused our effort on two environments relevant to prebiotic chemistry: a) transformation of atmosphere exposed to a shock wave of extraterrestrial body impact plasma (Early and Late Heavy Bombardment in our solar system during evolution and stabilization of orbits), b) transformations of atmosphere in electrical discharges (lighting in heavy clouds of dust, vapors and other aerosols from impact, volcanic activity and evaporation in early atmosphere) In our study, we have demonstrated plausibility of formamide and biomolecules (nucleic bases and glycine) synthesis from simple reduction atmospheres of carbon monoxide, ammonia and water in thermal shock wave induced by high power laser and upon electric field. Formamide plays a role of an intermediate, which quickly enters subsequent reaction chains leading to synthesis of biomolecules, particularly canonical RNA nucleic bases and glycine. In subsequent experiments we have also demonstrated that purine and pyridine bases are upon electric field in a glow discharge nitrogen plasma mutually transformed in series of reactions starting again with dissociation to simple mixture of reduction gases.
Follow the evolution of organic matter using laboratory experiments: from volatile organics to organic residues.

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A living organism arranges a set of chemical processes to maintain a non-equilibrium state by exchanging matter and energy with its environment, as well as to reproduce and evolve. A large set of molecules and a given environment therefore interact to sustain a living organism. The living cannot exist and grow without chemical processes, whereas a chemical reaction can take place without the necessity of living. Chemistry can be considered as “universal.” However, clues that the emergence of life is a common and inevitable phenomenon in our Galaxy have not yet been provided. Currently, the known life forms resides only on the Earth. To determine if other planetary systems could undergo a similar evolution, it seems important to trace the fate of organic matter. This will help to understand what chemical processes could be established, in which environments and from which sources of matter and energy. The knowledge of this chemical evolution will provide clues about the possibility of finding other environments that may lead to the emergence of biosystems. In this context, this contribution will focus on laboratory experiments concerning UV irradiation and warming of astrophysical ice analogs. We will determine in which extent these experiments provide information on the chemical reactivity occurring during the formation of a planetary system as well as on the organic matter composition of interplanetary objects. We will particularly discuss about the formation and detection of volatile organic compounds (Abou Mrad et al. 2014, 2016) and on the composition of refractory residue (Danger et al. 2013, 2015) formed during the ice processing.

References

How did life begin? This is one of the greatest unanswered questions in science. In order to answer this question it is necessary to understand how Life's building blocks were formed. Whilst much work has focused on the formation of amino acids, relatively little has addressed the formation of sugars. Whilst amino acids themselves are inefficient at catalysing aldol reactions in water, we have shown that amino acids esters and amino nitriles can. Tetroses and 2-deoxy pentoses can be selectively formed through catalysis by amino acid ester or amino nitriles from acetaldehyde, glyceraldehyde and glycolaldehyde in pH 6 and pH 7 phosphate buffer and unbuffered water. We have also demonstrated a link between natural L-amino acids derivatives and their ability to catalyse the formation of natural D-sugars.

A related question is; how did the first cell-like structures, capable of catalysing reactions, arise? Hydrogels share many of the same properties as cells, allowing molecules to diffuse in and out whilst at the same time providing protection for the contents inside. We have designed a prebiotically plausible dipeptide hydrogelators and shown that they have the capability to catalyse the formation of simple sugars.

This lecture will provide full details of our studies to date, include the prebiotic formation of 2-deoxy-D-ribose.
About the abundance of prebiotic species: the energetic aspect

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Among the complex organic molecules (COMs) detected in the past thirty years, a significant number of prebiotic species has been identified under the form of two or more isomers. The interpretation of their relative abundances is still an open issue. More recently, the results of an observational search for gas phase urea, \((\text{NH}_2)_2\text{CO}\), have been reported (Remijan et al. 2014). In spite of strong presumptions, whether it is urea or another species (for example an isomer) seems to remain a pending question. This would be a detection follows previous observations of peptide bond containing molecules and identifications of numerous amino acids in meteorites (Botta et al. 2002; Martins & Sephton 2009). Here, we consider whether the relative stabilities of the corresponding isomers that can possibly be formed with the same set of atoms might be a determining factor in their detection. We address also the issue of why the relative abundance of aminoacids of the same family is so different from one type of chondrite to another. The question was first addressed by means of quantum density functional theory (DFT) simulations. The hybrid B3LYP functional was used throughout. The geometries of all species part of this survey were fully optimized and verified to be real minima by vibrational analysis. When necessary, the lowest isomers found this way were reconsidered in higher level simulations to derive more accurate energy differences. Urea and thio-urea are the most stable compounds in their respective families (Fourré et al. 2016) It is consistent with previous calculations that showed unambiguously that the peptide bond is the most stable arrangement that can be formed in the case of molecules of \(\text{CH}_2\text{n}+\text{NO}\) generic formula (Lattelais et al. 2011). We have also computed the stability of all the conformers of every isomer of the glycine, alanine, and amino butyric acid families, considering the protonated, ionized, anionic and zwitterionic forms in addition to the neutral species. With 2 carbon atoms, neutral glycine, \(\text{NH}_2\text{CH}_2\text{COOH}\), is not the most stable compound. It is consistent with its non observation, which does not mean that this molecule is not present in the ISM. With 3 carbon atoms, neither \(\alpha\)-alanine, \(\text{NH}_2\text{CH}(\text{CH}_3)\text{COOH}\), nor \(\beta\)-alanine, \(\text{NH}_2\text{CH}_2\text{CH}_2\text{COOH}\), is the most stable isomer in the neutral form. When protonated, \(\beta\)-ala is the most stable isomer with \(\alpha\)-ala close by, whereas the reverse situation is found in the zwitterionic forms. The case of butyric amino acids isomers will also be presented. This body of simulations underlines the interest of the minimum energy criterion as a tool for the primary search of target molecules (Lattelais et al. 2009). Strong correlations have been found between the relative abundances deduced from the analysis of the carbonaceous material and the type of chondrite for protonated and zwitterionic aminoacid isomers.

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Inspecting the Role of Serpentinite-hosted Hydrothermal Minerals in Prebiotic Processes: Binding of Nucleic Acids Components to Brucite

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The passage from geochemistry to biochemistry probably resulted from the combination of multiple complex phenomena between organic and inorganic systems, and studying how organic molecules interact with minerals may be a step forward in resolving unsolved questions about the origin of life (Hazen 2006; Fornaro et al. 2013). Submarine serpentinite-hosted hydrothermal vents draw particular interest as plausible locations for the origin of life, since the disequilbria and strong redox gradients established by mixing the hot and highly reducing hydrothermal fluids with the overlying cold seawater may provide the energy necessary for the synthesis of key prebiotic molecules (Martin et al. 2008; Braakman 2013). In this geochemical context, we focused on the adsorption properties of magnesium hydroxide, named brucite (Mg(OH)₂), which is a product of the serpentinization process, with the aim of evaluating potential roles that serpentinite-hosted hydrothermal minerals play in concentrating and selecting fundamental prebiotic molecules such as nucleic acids components from dilute aqueous environments, and potentially in catalyzing the formation of more complex species in plausible prebiotic conditions (Estrada et al. 2015). In particular, the thermodynamics of adsorption of nucleic acids components on brucite has been investigated first experimentally, determining the equilibrium adsorption isotherms at room temperature. Then, a rigorous and quantitative thermodynamic characterization of the adsorption data has been provided by using of the computer code GEOSURF (Sahai & Sverjensky 1998), based on the extended triple-layer model (ETLM) for predicting surface speciation as a function of environmental conditions as well as the stoichiometry and equilibrium constants. The results indicate that brucite is able to selectively adsorb nucleic acid components from dilute aqueous environments. Moreover, the surfaces of this mineral are able to induce well-defined orientations of the molecules through specific molecule-mineral interactions, suggesting a role in assisting prebiotic self-organization.

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Modeling the origins of cellular systems: How complex must our system be to observe cell-like behaviors?

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To understand how living cells could emerge from inanimate matter, many designs of minimal self-replicating chemical systems, also called protocell, have been proposed based on the self-assembly and self-organization of molecules, i.e., from the bottom up.

An often proposed, operative definition of protocell postulates that functional protocells can only be obtained when three interconnected components are present in a single chemical system, a compartment, a catalytic network and an information system. Through the intertwined functions of their components, these protocells would be able to exhibit emergent properties that are the hallmarks of living cells (capacity of self-maintenance, self-replication and potential to evolve).

However, this definition does not precisely describe component features, e.g., molecular composition, functional complexity or evolution capacity. We will reflect on two challenges in protocell design (the complexity of reaction networks and the nature/function of the information component) using examples of protocell designs, we and other researchers have recently developed, highlighting influences from the geochemical environment.
The last common ancestor of all living beings: simple or complex?

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All living beings on Earth share a number of biological features that strongly advocate for the fact that they descend from a single common ancestor, as Darwin already proposed more than one century ago. Nevertheless, the specific characteristics of that common ancestor have been hotly debated. Initially, it was believed that the ancestor would have been an extremely simple organism (a "progenote" in Woese’s terms). However, the increasing availability of complete genome sequences and the use of sophisticated phylogenomic tools to analyze them have lead to elaborate a much more complex image of the last common ancestor. I will present data that support this view, including evidence for the presence of a lipid membrane, a DNA genome, as well as replication, transcription and translation machineries. Thus, the last common ancestor was probably similar to many simple contemporary prokaryotic cells, which suggests that several cellular features have remained stable during huge evolutionary times and that simplification may have been an evolutionary mechanism as common as complexification during Life’s history.
The origin of eukaryotes is linked to the rooting of the Tree of Life... but the phylogenetic jury is still out

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The origin of the eukaryotes remains one of the most contentious puzzles in evolution. In the late 1970s, C. Woese discovered Archaea and put an end to the dichotomous view of Life (eukaryote vs prokaryote). Since Woese's revolution, the Tree of Life (ToL) has been divided into three domains (Bacteria, Archaea and Eukaryota), yet with unclear relationships. Rooting the ToL then became a problem. Indeed, the question of the origin of eukaryotes is directly related to the location of this root, which also affects the nature of the Last Universal Common Ancestor (LUCA). Several scenarios might explain the origin of the eukaryotic cell: (a) the three domains have an independent origin and directly stemmed from the primordial soup; (b) the three domains stemmed from a simple LUCA, and their evolution proceeded by increasing complexity in eukaryotes; (c) the three domains stemmed from a complex LUCA, and their evolution proceeded by simplification in prokaryotes; (d) eukaryotes originated from a fusion event between an archaeon and a bacterium, the latter being the mitochondrion and their other properties evolving after this event; (e) eukaryotes originated from a fusion event between an archaeon and a bacterium, the result being a proto-eukaryote not yet equipped with a mitochondrion. During the last 15 years, technical advances in phylogenetic methods have relocated many simple organisms higher in the ToL, which means that they are actually secondary simplified. However, even the best evolutionary models are not yet able to address difficult phylogenetic issues, whether at shallow depth or at deep evolutionary times. This raises a fundamental question: does simple always mean ancestral? For the time being, the commonly accepted bacterial root for the ToL (in scenario (b)) is still unproven, so that the current consensus can be traced back to the prejudice of Aristotle's Great Chain of Beings, in which simple organisms are ancestors of more complex life forms. Indeed, during early evolution, there might have been many independently arising lineages, both before and along LUCA, none of them having left extant descendants. The major bottlenecks that occurred as a result of catastrophic events in Earth's history (e.g., meteorite impacts or snowball Earth periods) might explain why we only have three domains of Life nowadays. Furthermore, extant lineages coalesce to a LUCA that was not necessarily simple and located at the base of the ToL. Instead, it probably lived much later and was more complex than generally acknowledged.

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Description and comparison of microbial communities and metagenomes in a subglacial lake under the Vatnajökull ice cap, East Skaftárketill

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The subglacial lakes in Vatnajökull host endemic communities of microorganisms adapted to cold, dark, and nutrient-poor waters (Gaidos et al., 2009; Marteinsson et al., 2013). Here, we present new insights on the subglacial microbial communities of Vatnajökull based on molecular data generated from samples of two subglacial lakes, a subglacial flood, and a lake that was formerly subglacial but is now partly exposed. The populations of the major taxa in the two subglacial lakes are indistinguishable (>99% 16S rRNA sequence identity), despite separation by 6 kilometers and an ice divide; the Sulfuricurvum-like taxon is ubiquitous in our samples. We propose that much of the glacial bed of Vatnajökull is connected by an aquifer in the underlying permeable basalt, and that these subglacial lakes are colonized by members of a subterranean microbiome that are adapted to ambient conditions and energy sources. Our hypothesis of a "deep" source is supported by growth of thermophiles in enrichments from lake samples. Metagenomes from samples collected at the bottom (A3) of the eastern Skaftárketill lake, from the whole water column (Bmix) in the lake and from a mixture of enrichment cultures (4C) (Enr) were sequenced by Illumina and analysed for functional and taxonomy composition. Around 4.106 reads were obtained for each sample with an average length of 107 bp. A functional analysis of the metagenomes was initiated by performing whole metagenome assemblies using SPAdes and CLC AssemblyCell. Contigs were then processed through MG-RAST and detected KEGG Orthologs (KOs) were used as reference to recruit the raw reads. The analyses showed virus-associated genes in 7% of the total reads in the lake but not in enrichments and 6,3% of all 16S rDNA miTAGs belonged to archaeal sequences. This was not observed previously by using amplified 454TAGs. The sample from the bottom of the lake contained mainly genes associated with anaerobic metabolism such as nitrate reductase, a gene lacking in the sub–surface sample. It encompassed mainly three species together recruited (as best hit) 51,7% of the total reads: Sulfurospirillum deleyianum, Sulfuricurvum kuijense and Sulfurimonas denitrificans, all associated with sulfidic environment. In the sub-surface sample, 17 genera recruit at least 50% of the reads, revealing a more complex microbial assemblage than at the bottom of the lake. Genetic distance analysis of environmental sequences showed that about 50% of the reads do not match to a reference sequence with identity equal to or higher than 93% of identity, revealing an important, yet uncharacterized biodiversity. The enrichment sample was both functionally and taxonomically different from the lake samples. In order to confirm the community structure of the eastern Skaftárketill lake, rDNA fragments from the metagenome were assemble and manually curated. Several complete sequences were obtained and used as reference for a miTAG recruitment approach (Logares et al., 2014). These analyses confirmed the presence of the main bacterial taxa detected by Marteinsson et al. (2013). However, the assembled rDNA genes revealed a low abundance of taxonomic lineages without close relatives in public reference datasets (SILVA) such as the Caldiserica phylum (best hit in NR around 84% identity for the complete 16S/23S), the recently described Saccharibacteria phylum (91-94% identity; Brown et al., 2015) and various Bacteroidetes (distance ranging from 84 to 94% identity). Part of this distance can be explained by an unequal representation of the global biodiversity in 16S rDNA reference datasets with regards to 23S rDNA. Interestingly, metagenomic reads with close hits in the archaeal domain (Euryarchaeota and Thaumarcheota) were detected in the bottom sample (A3) and the enrichment samples. However no complete
sequence could be assembled for this domain since all the reads detected fell within a specific 100-150 bp-long region of reference archaeal 16S. Curiously, all of these reads seem to stop at specific locations of the 16S gene. The subglacial lakes in Vatnajökull are plausible analogues to past or present environments on Mars and ice satellites of the outer Solar System.

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Life in Mars analogue sites: microbes adapted to extreme conditions in Iceland

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The cold deserts, lava fields, and caves of Iceland’s highlands have been suggested as suitable analogue sites in which to model potential martian microbial biotopes and test instruments scheduled for martian exploration. Although barren, the sites are far from sterile, being home to a multitude of autochthonous and allochthonous bacteria, archaea and fungi. While the likelihood of extant microbial life on the surface of Mars can at best be considered remote, the subsurface may hold somewhat greater promise. The basaltic subsurface environments in Iceland would appear to offer suitable analogues. In our studies on microbial populations within barren Icelandic habitats, we have isolated a number of heterotrophic bacteria, many of which display facultative chemolithotrophy and may thus contribute to local biogeochemical processes. Among habitats of astrobiological interest that we have investigated in recent years include biofilms on lava tube cave walls, surface communities in barren basaltic desert sand environments, and geothermally-impacted subsurface groundwater. Successfully isolated and cultivated taxa include close relatives of many commonly encountered environmental bacteria, such as various members of the Actinobacteria, Alphaproteobacteria, Betaproteobacteria, Gammaproteobacteria, Cytophagia, Sphingobacteria, Deinococci, and Firmicutes, some of which are known to exhibit tolerance to extremes of temperature, radiation, and water availability. Two disparate subsurface environments will be discussed in particular: a lava tube cave and a geothermal aquifer accidentally exposed during an ongoing tunneling project. Both habitats yielded diverse culturable bacteria, many of which have demonstrable chemolithotrophic potential and may be of biogeochemical importance. Among isolated biogeochemically relevant bacteria from these environments are several Paenibacillus isolates with bioweathering potential, oligotrophic Patulibacter, Schlegelella, Collimonas, Dietzia, Aeromicrobium, and Kribbella spp., and more. The possible adaptive and survival strategies of these bacteria will be discussed, as will be their potential bioweathering roles in basaltic subsurface environments.
Health hazards posed by ionizing radiation in manned space missions BLEO

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Ionizing radiation poses a serious threat to manned space missions outside the magnetosphere of the Earth. In this talk missions to the Moon, Mars and Near-Earth Objects will be considered. The results of a research aimed to characterize the doses of ionizing radiation that could be absorbed during missions of this type and their effects will be presented. Recommendations to mitigate the hazards to human health due to energetic particle irradiation and galactic cosmic rays beyond low earth orbit/BLEO will be proposed.
Dissipative structures in the Universe: Super massive black holes and life

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In the Universe, density, thermal, pressure and chemical gradients create far from equilibrium dissipative structures: galaxies, black holes, stars, convection cells, whirlpools, hurricanes as well as life itself. These spontaneously emerged structures cause the destruction of the gradients which gave birth to them. For example, simple inspection of physical parameters related to Earth, Venus and Mars shows that it is the Earth with the highest entropy generation rate, probably it is not coincidental with its being inhabited. Also, earth lifeforms take in high-grade energy at low entropy, and degrade it into high-entropy, low-grade energy. Here we review the contribution of supermassive black holes (SMBH) to the overall entropy in the Universe and attempt to describe their influence on life constrains.

As a result of our monitoring campaign of Active Galactic Nuclei(AGN), we determined SMBH masses in the centers of 2 type 1 AGN: Arp102B (Shapovalova et al. 2013), 3C390.3 (Shapovalova et al. (2001)), and QSO binary black hole candidate E1821+643 (Shapovalova et al 2016). Using calculated masses of these objects, and three parametric Shechter function as a model of SMBH mass function in observable Universe, we were able to estimate SMBH entropy densities and entropies of such objects.

Assuming that single SMBHs inhabit almost all of the 10^{11} galaxies cores in the visible Universe, and that information (entropy) content of single SMBH is 1.7 × 10^{95} (average value of information content of Arp102B and 3C390.3), we estimate that total entropy contribution of SMBHs is ~ 2 × 10^{106}.

This value is smaller than holographic bound of the Universe indicating that dissipative processes and presumably life can going on. This emphasize need of more refined life-searching strategy, which could be a shift from ‘follow the water and/or oxygen’ to ‘follow the free energy and entropy’.

Astrobiology– Black hole physics – Methods: data analysis

References
From stellar evolution to tidal interaction: impact on planetary habitability

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With the ever-growing number of detected and confirmed exoplanets, the probability to find a planet that looks like the Earth increases every year. While it is clear that being in the habitable zone does not imply being habitable, a systematic study of the evolution of the habitable zone as well as the evolution of the planetary orbital motion is required to account for their dependence upon stellar parameters.

While stellar rotation plays a crucial role in stellar structure evolution, stellar activity, and star-planet interaction through tidal perturbation, it is usually not included in such analysis.

In this presentation, I will present, for the first time, the results of the impact of rotating stellar models (using the STAREVOL code) on both habitable zone and tidal dissipation evolution around and inside low-mass stars.
Water is necessary for the origin and survival of life as we know it. In the search for life-friendly worlds, water-rich planets therefore are obvious candidates and have attracted increasing attention in recent years. The surface $\text{H}_2\text{O}$ layer on such planets (containing a liquid water ocean and possibly high-pressure ice below a specific depth) could potentially be hundreds of kilometers deep depending on the water content and the evolution of the proto-atmosphere. We study possible constraints for the habitability of deep water layers and introduce a new habitability classification relevant for water-rich planets (from Mars-size to super-Earth-size planets). A new ocean model has been developed that is coupled to a thermal evolution model of the mantle and core. Our interior structure model takes into account depth-dependent thermodynamic properties of high-pressure water and the possible formation of high-pressure ice. We find that heat flowing out of the silicate mantle can melt an ice layer from below (in some cases episodically), depending mainly on the thickness of the ocean-ice shell, the mass of the planet, the surface temperature and the interior parameters (e.g. radioactive mantle heat sources). The high pressure at the bottom of deep water-ice layers could also impede volcanism at the water-mantle boundary for both stagnant lid and plate tectonics silicate shells. We conclude that water-rich planets with a deep ocean, a large planet mass, a high average density or a low surface temperature are likely less habitable than planets with an Earth-like ocean.
First spectrally complete survey of cometary water emission at near IR wavelengths (0.9-2.5 µm): C/2014 Q2 Lovejoy with TNG/GIANO spectrograph.


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Comets are the most pristine bodies of Solar System and water is the most abundant constituent of cometary ice. Its production rate is used to quantify cometary activity and the measurements of ortho-para ratio can clarify the nature and meaning of the spin temperature in the cosmic context. Last February 2015, we acquired the first comprehensive high resolution spectral survey of comet C/2014 Q2 Lovejoy in the 0.9-2.5 µm range, by observing with GIANO - the near-IR spectrograph on TNG (the Italian Telescopio Nazionale Galileo in La Palma, Canary Islands, ES). We detected emissions of radical CN, water (H₂O), and many undefined emission features. We quantified the water production rate by comparing the calibrated line fluxes with the NASA Goddard full non resonance fluorescence cascade model for H₂O. The production rate of ortho and para water provide an estimation of ortho to para ratio consistent with statistical equilibrium (3:0), but the confidence limits are not small enough to enable a critical test of the nuclear spin temperature in this comet. Until now, high-resolution spectroscopy in the infrared (2.7 - 5 µm) has been a powerful tool to quantify molecular abundances in cometary comae. Today the expansion to the near-IR region (0.9-2.5 µm) will extend this capability to new band systems. Our observations open a new pathway for cometary science in the near-infrared spectral range (0.9-2.5 µm) and establish the feasibility of astrobiology-related scientific investigations with future high resolution IR spectrographs on 30-m class telescopes, e.g., the HIRES spectrograph on the E-ELT telescope.
Prebiotic molecules in comets detected by Rosetta and their possible synthesis in the ice

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The presence of organic matter in comets that might have contributed to the origin of life on earth was proposed in various pioneering works (e.g., Chamberlin & Chamberlin 1908, Oró 1961, Greenberg 1993). The formation of relatively complex molecules in pre-cometary icy dust grains, that include organic species of prebiotic interest, was simulated experimentally under vacuum by photon (UV and X-rays) and cosmic-ray (protons, electrons, heavier nuclei) irradiation of ice mixtures containing H₂O, CO, CO₂, CH₃OH, and NH₃. There was, however, a large gap between the bountiful number of complex species detected in these experiments and the reduced set of molecules inferred from cometary observations. The ESA-Rosetta mission has contributed very significantly to fill this gap with the detection of desorbing molecules from the comet nucleus using the ROSINA mass spectrometer and the chemical analysis of the dust during landing by the Ptolemy and COSAC instruments. These findings will be interpreted after comparison to the available laboratory data on ice irradiation, and the possible formation routes will be discussed. The temperature programmed desorption (TPD) of a complex ice mixture in the laboratory also aids to interpret the data collected by ROSINA during the first cometary approach.

References
Ion chemistry in the innermost coma of comet 67P/Churyumov-Gerasimenko

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Comets are remnants from the formation of the solar system ~4.6 billion years ago. Studies of comets can therefore teach us about chemistry and physical conditions in the protoplanetary nebula. Moreover, during the late heavy bombardment, ~4.1-3.8 billion years ago, comets delivered water and other key volatiles to the Earth. The ESA Rosetta mission, launched in 2004, reached within 100 km from comet 67P/Churyumov-Gerasimenko in August 2014 at a heliocentric distance of ~3.6 astronomical units (AU). Since then it has followed the comet closely (at distances typically of a few tens to a few hundreds km), accompanying it through the perihelion passage in August 2015 (at 1.25 AU) and beyond. A varying activity level and changes in the relative abundances of molecules in the coma have been observed not only with changing distance to the sun, but also with respect to the spacecraft position in the comet frame. The main focus of this contribution is on the ionization balance and the ion chemistry within the innermost coma of 67P. A clear correlation between the ambient neutral number density and the electron number density was observed early in the escort phase, and with the relative abundance of electrons with respect to the neutrals indicative of an innermost ionosphere largely controlled by photoionization, electron impact ionization and outward radial transport. Closer to perihelion, model-observation comparisons suggest (as anticipated) an enhanced influence of ion-electron dissociative recombination on the ionization balance. I will also make the point that for a relatively weakly outgassing comet, such as 67P, the build up of molecules from chemical reactions in the coma is rather inefficient. This implies that molecules observed in the coma easily can be assigned as parent molecules sublimated from the surface and/or near surface layers of the cometary nucleus. Reported relative abundances of a series of molecules observed in the coma of 67P will be compared with observations from other cometary comae and interstellar clouds.
POSTERS
Plasma Chemistry in Reduction Atmospheres

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We have demonstrated plausibility of formamide and biomolecules synthesis from simple reduction atmospheres of ammonia, carbon monoxide, water and formaldehyde or methanol upon inert molecular nitrogen atmosphere. In an impact plasma simulation at temperatures of 4500 K, formamide, nucleic bases and glycine are formed from simple reduction atmosphere in presence of catalytic material montmorillonite. In electric field, all the mentioned biomolecules together with formamide have been formed without any presence of catalytic material. In the chemistry of reduction atmospheres, formamide is not a parent molecule of these reactive radical species. It plays a role of intermediate, which quickly enters subsequent reaction chains leading to synthesis of biomolecules, particularly canonical RNA nucleic bases and glycine. Finally, purine and pyridine bases can be upon electric field in glow discharge nitrogen plasma mutually transformed in series of reactions starting with dissociation to simple mixture of reduction gases hydrogen cyanide, ammonia, carbon monoxide nad water and subsequent reaction with the parent substrate. In all the cases, experimental and theoretical results show that formamide plays role of an intermediate molecule presented in very low concentrations.
Dissociative Charge Transfer of Interstellar Dimethyl Ether and Methyl Formate in collisions with He+. Experimental and theoretical study

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Ion-molecule reactions play an important role in the chemistry of planetary ionospheres and interstellar molecular clouds. Helium ions are found in the interplanetary space and have also been detected in Titan’s magnetosphere and in the Earth’s polar cusp region (Melo et al., 2006). For this reason, studies on collisions of molecules with He⁺ are of fundamental importance for modeling planetary and cometary atmospheres, but especially the interstellar medium (Bene & Bacchus-Montabonel, 2014). In the experiment that we report, dissociative charge transfer reactions are carried out with the smallest organic O-containing molecules: dimethyl ether (CH₃OCH₃), DME, and methyl formate (HCOOCH₃), MF. The former molecule (DME) is particularly important in hot cores (Schwell et al., 2012), while the latter (MF) is another important specie observed by radioastronomy in hot cores and it is very abundant in star forming regions (Schwell et al., 2012). These molecules play both a key role in understanding the origin of life, because they lead to the synthesis of bio-polymers (Occhiogrosso et al., 2011). For this reason, they immediately evoke great interest and several models were developed to explain why and how these molecules are formed and destroyed in space (Jaber et al., 2014). Furthermore, recent observations show the presence of these molecules in regions where the dust temperature is less than 30 K: pre-stellar cores (Vastel et al., 2014) and cold envelopes of low-mass protostars (Jaber et al., 2014). A new model proposes that gas-phase reactions, triggered by the non-thermal desorption of methanol from the outer shell of the cold core, where the temperature is circa 10 K, give the major contribution to DME and MF formation in cold regions (Balucani et al., 2015). However, to expand this model it is necessary to consider also the decomposition reactions. Therefore, experimental results about the reactions of He⁺ with dimethyl ether and methyl formate are of crucial importance, because they represent the most important fragmentation channel of these molecules.

We have investigated these reactions by using the home-built Guided-Ion Beam Mass Spectrometer (GIB-MS) apparatus. Absolute cross sections and product branching ratios have been measured as a function of the collision energy in the hyperthermal energy range (i.e. from about 0.5 to 7 eV). In addition, charge transfer processes and the fragmentation dynamics have been studied with theoretical methods for the system DME-He⁺.

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Diagnostics Of Dc Gliding Discharge Fed By CH₄-N₂ And Admixtures For The Mimic Of Titans Atmosphere

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This work extends our previous experimental studies of the chemistry of Titans atmosphere by atmospheric glow discharge. The exploration of Titan atmosphere was initiated by the exciting results of the Cassini-Huygens mission and obtained results increased the interest about prebiotic atmospheres. Titan is the largest moon in Saturn's lunar system and it has been a subject of interest to astronomers, planetary scientists as well as chemists because its atmospheric conditions are thought to have resembled to those conditions on the Earth several billion years ago. Many organic compounds as hydrocarbons and nitriles were confirmed in its atmosphere. Our laboratory experiments shown that various complex compounds can be formed, for example the higher hydrocarbons, nitriles or even amino acids.

This contribution presents the results obtained by Fourier Transform Infra Red spectroscopy (FTIR) of the discharge exhaust gas. An atmospheric pressure DC glow discharge was created between two stainless steel electrodes separated by a 2 mm gap. The electrode system used the standard configuration of the gliding arc discharge but due to the low applied power as well as low gas velocity the discharge is not moving along the electrodes. The discharge was operated with an applied voltage of 400 V and current in range 15 mA to 40 mA in pure nitrogen enriched by 1–5 % of CH₄ at the total flow rate of 100 sccm and H₂O vapour admixture (2 %). Flow rates of all gases through the reactor were regulated using mass flow controllers (Bronkhorst). There was connected bottle gas washing with the high purity water just before the entrance to the analyzer. The exhaust gas was analysed in-situ by FTIR spectroscopy using IR cell with total length of 15 cm. Collected FTIR spectra were analysed and was found that hydrogen cyanide (HCN) was the most abundant product at wavenumbers of 720 cm⁻¹. Ammonia (NH₃) was identified at 966 cm⁻¹. The other major products were acetylene (C₂H₂) as well as carbon monoxide (CO) and water (H₂O). These products were recognized in all gas mixtures. H₂O is supposed to be imported from meteoritic fluxes in the atmosphere. Its photodissociation into H and OH, followed by the reaction between OH and CH₃ radical could be the source of atmospheric CO and CO₂.
Carbon to nitrogen ratio in stars of open clusters

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Stellar chemical composition study is one of the important fields of astrobiology. Recent spectroscopic studies showed that stars hosting planets are significantly more metal-rich than those without planets. One of the possible interpretation of this fact is the so-called ”self-enrichment” scenario. It is believed that the origin of overabundance of metals is related to the accretion of rocky planetesimal materials on to the star. A relevant method to check this possibility is to study abundances of volatile elements (e.g., C, N, O, S).

Using a Gaia-ESO survey sample of high-resolution UVES spectra we have determined the C/N ratio for red giant branch stars in a sample of open clusters. We compare our results with recently developed stellar evolution models which take into account various mixing scenarios.
Optical emission spectroscopy of atmospheric glow discharge generated in nitrogen-methane gaseous mixtures

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This work extends our previous investigation of nitrogen-methane (N\(_2\)-CH\(_4\)) atmospheric glow discharge for simulation chemical processes in Titans or early Earth prebiotic atmospheres. We present results obtained by optical emission spectroscopic (OES) observations. The theory of the evolution of life is based on the possibility of the synthesis of organic compounds by abiotic processes from inorganic species. Possible energy sources for these processes include UV radiation, electric discharges, shock waves, radioactivity, cosmic rays, solar wind, volcanoes or hydrothermal vents (Janda et al. (2008)). Sixty years ago, the Miller-Urey experiment showed that many biologically important organic compounds, including sugars and amino acids, could be formed by methane, hydrogen, ammonia and water to spark discharge. They detected products like HCN, aldehydes, ketones and the ammonia in liquid water (Miller (1953)). This work is focused on experiments with water (H\(_2\)O) addition to the atmospheric glow discharge fed by N\(_2\)-CH\(_4\) mixture and diagnostic of this discharge by OES. The electrode system used the standard configuration of the gliding arc discharge but due to the low applied power as well as low gas velocity the discharge is not moving along the electrodes. The discharge was operated at an applied voltage of 400 V and discharge current in range 15 to 40 mA in pure nitrogen enriched by 1–5\% of CH\(_4\) (both gases having quoted purity of 99.995\%) with admixture of 2\% of H\(_2\)O at the total flow rate of 100 sccm. Flow rates of all gases through the reactor were regulated using mass flow controllers (MKS, Flow Measurement & Control Products). The optical spectra in the range of 250-700 nm were measured by JobinYvon spectrometer TRIAX 550 with the 1200 grooves per mm grating coupled with a multichannel detector. The emitted light was led to the monochromator entrance slit by a multimode quartz optical fibre mounted to the quartz window on reactor wall. All experiments were done at room temperature. The spectra belonging to various bands of CN violet and C\(_2\) spectral systems were recorded as well as spectral bands of OH and very weak NH bands. Also the 2nd positive and 1st negative nitrogen spectral systems were recorded. Rotational temperature will be calculated from obtained data depending on the experimental conditions.

References


Recent studies suggest that planets around stars in open clusters are as common as they are around isolated stars. By analysing the abundances of CNO elements that are key to life as we know it, we can better understand what is needed for planet formation. Open clusters give us an opportunity to analyse the stars with better accuracy. Analysis of a number of stars that are roughly at the same distance from us, the same age, and chemical composition provides us with information about the primordial cloud from which the cluster originated. Abundance determinations of CNO elements can help us to better understand the internal processes in evolving stars. Observations have shown that after a star enters the red giant branch (RGB), due to internal mixing processes there is a change in the abundances of these elements in stellar atmospheres. The standard evolution models predicts only one dredge-up event at RGB. However, studies have shown that in low mass stars ($< 2 \, M_\odot$) there are extra mixing mechanisms responsible for bringing the core-processed material to the surface. The new proposed mechanisms involve thermohaline- and rotation-induced mixing which happen later on RGB. The alteration of $^{12}\text{C}/^{13}\text{C}$ ratio in stellar atmospheres is the main indicator of mixing processes happening in the interior of a star. We present new results of CNO and $^{12}\text{C}/^{13}\text{C}$ isotopic ratio investigations in RGB stars of 7 open clusters. We compare our results with previous studies and recently developed stellar evolution models which take into account thermohaline- and rotation-induced mixing.
Cognitive Computing and Astrobiology
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Astrobiology is an interdisciplinary science, connecting results from e.g. biology, astrophysics, and geology. It is difficult for an individual researcher to have deep knowledge in all related disciplines, and to keep up with all research knowledge that is published all the time. Cognitive computing is a system that learn at scale, reason with purpose and interact with humans naturally. Cognitive computing systems can be used to effectively access even unstructured large databases, such as in molecular biology, mineralogy, planetary science, and exoplanets to retrieve relevant information with natural language inquiries. Some examples of using cognitive computing for astrobiological information retrieval are presented.
Origin of eukaryotes is one of the central transitions during the early life; without eukaryotes there would be no multicellular life. In particular, the scalable energy production by mitochondria and efficient recombination by sex are important for large and complex organisms. Origin of eukaryotes was for long time a very controversial subject, and many open questions still exist.

According to the most accepted view, the complex archaeon host similar to recently found lokiarchaeon took mitochondrion as endosymbiont which resulted in a large influx of bacterial genes to the host genome. This would explain bacterial type metabolic routes, lipids and introns. The archaean hosts cytoskeletal and membrane remodeling systems are related to the origin of endomembrane systems, nucleus and the cell division machinery. The mechanisms behind signaling and RNA interference are likely to have their roots on both prokaryotic domains, RNAi also in phages. The chromosomal structure and meiosis are least well explained and both autogenous and viral origins are suggested. On the other hand, the alternative 'eukaryotes early' view suggests that some eukaryotic features would have derived directly from the earliest stages of life, though it is now commonly accepted that the last common ancestor of modern eukaryotes (LECA) was a complex cell with nearly all typical eukaryotic properties that probably lived relatively late.

Structure is more conserved than the sequence and can retain evolutionary information already lost from the sequence. How can a large number of eukaryote specific structure superfamilies exists with no obvious relatives among prokaryotes, if most eukaryote specific biological processes have prokaryotic roots? Are these proteins at the heart of eukaryote specific processes, or additional elements that finalize the elements inherited from prokaryotes? Where they present already at LECA, or did they developed later to separate lineages? Where these structural superfamilies come from?

We have classified SCOP structural superfamilies from the Superfamily-database according to the taxonomic and functional groups. As expected, the eukaryote specific superfamilies have particularly much of regulation-related, and little of metabolism related functions. Eukaryote specific superfamilies present in wide variety of lineages (probably from LECA) are enriched with information related and intracellular processes, while extracellular processes are particularly common in superfamilies present only in single lineages, mainly in opisthokonta. However confirming exactly how these superfamilies relate to the eukaryote specific processes and their possibly prokaryotic roots will require more detailed analyses and this work is now ongoing.

In future we will extend our analysis to the more distant past and approach the properties of LUCA by analyzing protein superfamilies.
Micro-Laser Induced Breakdown Spectroscopy (LIBS) to analyze and characterize and classify iron meteorites

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Based on the potential and viability of Laser-Induced Breakdown Spectroscopy (LIBS) for its deployment on robotic vehicles scheduled for planetary exploration missions, a LIBS system was installed on the mobile NASA Mars Science Laboratory (MSL) rover in 2004. This important application recognized the LIBS community efforts in the past decade and provided a great impulse for further development of LIBS use for collecting planetary geological data. In particular, the next rover missions Exomars 2018 and future space missions have promoted a series of studies of the minute quantities of meteorites and planetary-analogue rock samples that will be returned, thus making it crucial to develop non-invasive or semi-invasive diagnostic analytical methods to study these materials. As a result of the extensive research activity conducted over the past two decades in the development, advancement and application of LIBS, several reviews were published on the multiple applications of LIBS to various materials (Hahn and Omenetto, 2012) and a few very recent ones have focused on geomaterials (Harmon et al., 2013; Hark and Harmon, 2014; Qiao et al., 2014; Senesi, 2014). The genetic classification of iron meteorites is based on structural and compositional properties of magmatic iron originated from the crystallization of a metal melt, primitive chondrite, products of partial melting and impact events (Chabot et al., 2007). Iron meteorites are grouped into 12 main classes of distinct compositional ranges which indicate that each group was derived from a separate parent body. There are also numerous ungrouped and grouplets of iron meteorites with distinct compositional characteristics, which suggest derivation from 90 to 100 different bodies. The objective of this study was to apply an innovative approach of the LIBS technique coupled with optical microscopy (micro-LIBS) to the quantitative analysis and characterization of an iron meteorite directly from the thin petrographic section in atmospheric air, also in comparison to the corresponding quantitative LIBS analytical data obtained on the whole meteorite sample. The Calibration Free (CF) method was used for the quantification, allowing to perform LIBS elemental analysis without the use of standard samples (Ciucci et al., 1999). Quantitative LIBS analysis data were compared to the corresponding ones obtained by traditional analytical methods, such as ICP-MS, EDS-SEM, that are generally applied for the analysis of meteorites. Micro-LIBS technique allowed to analyze by optical microscopy grains on thin section. Thus the technique was shown to be useful for the analysis of the chemical composition in relation to micro-structures of iron meteorites.

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The structures in circumbinary planetesimal disks

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Young stars both single and multiple at the initial phases of the evolution pass the stage of accretion of matter from the remnants of the circumstellar envelope, which is a protoplanetary disk. Eventually the gas-dust disk loses a gas component, and dust particles stick together and grow up in sizes settling down to the disk plane. By the time, when most of the gas leaves the disk, the planetesimals (kilometer-sized) are formed, of which later protoplanets are generated. Therefore, the structural inhomogeneity, which indicate the presence of massive bodies in the disk, can be observed. We investigate the formation of structures in the planetesimal disk of binaries with an embedded circumbinary planet. The motion of the planetesimals around the binary are treated in the framework of a restricted planar four-body problem “binary–planet–planetesimal”: the planet perturbs the motion of the planetesimal, but not the motion of the binary, the planetesimal does not perturb the motions of the planet and the binary. Our numerical experiments show that the shape of the generated structures depends essentially on the configuration and system parameters. If we consider the binary without planets the single-arm spiral appears in the disk. It can be destroyed if the planet is embedded in the circumbinary disk. The planet around a binary or a single star forms a ring-shaped structure along its orbit, however, the dynamics of planetesimals in the rings is different for cases of the binary and single star. The existence of structural features in the planetesimal disk may indicate the presence of massive bodies in it, or the binarity of the object. Type of inhomogeneity allows indirectly to judge about the system configuration.
On the probability of seeding exoplanets

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The first meteorite particle of potentially extragalactic origin has recently been observed. The peculiar velocity of neither galaxies nor their ejecta can exceed 1% of the speed of light. Therefore, such objects could only originate from within the galaxy clusters. Since our Galaxy is not a member of any cluster, the matter exchange could probably only take place inside a volume not exceeding that of the Local Group of Galaxies. Such particles could disseminate organic molecules across great distances and, possibly, seed habitable exoworlds. In this study we address the probability of these rare events.

We investigate the probability of the interstellar and intergalactic meteorite particles reaching exoplanets from three different databases, and of these planets being in the circumstellar habitable zones (HZ).

In order to properly address this problem, we calculated the probabilities of these unrelated events; we adopted and adjusted the model of directed panspermia in order to calculate the probability of such a particle reaching the target. In order to calculate the probability of an exoplanet from a certain database being in the HZ, we calculated the HZ boundaries of their host stars and derived the continuous probability distribution for any planet in any of the three databases. We coupled the two unrelated probabilities, using optimized coupling formula, in order to estimate the probability of both events happening at the same time.

The coupled probability of the two events are highest, in all three databases, for the planets orbiting host stars 1.4-1.6 solar masses. However, it was found that entries from the Exoplanet Orbit Database have the largest value of coupled probability (0.4) being in the habitable zone and seeded by an intergalactic meteorite particle. As for the catalogue of the Extrasolar Planets Encyclopaedia and NASA Exoplanet Archive databases, these values are 0.2 and 0.3, respectively.

The probabilities of these events are low, which was expected. Even so, these events are not improbable and such problems should be further investigated. The future improvements and expansions on the three databases will help improve the accuracy of such estimations.

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The elemental distribution of life building species in the Galactic discs

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It is well known, that carbon, nitrogen and oxygen are important building blocks of life. Thus, we study the distribution and relationship between radial, vertical Galactic distances and carbon, nitrogen, oxygen and alpha-element abundances of FGK stars in the Galactic disc. We use a Gaia–ESO survey sample of high-resolution UVES spectra. We tag thin and thick disc populations using alpha-element abundance-to-iron ratios to study radial and vertical abundance distributions of these identified populations and derive radial and vertical CNO abundance gradients.
On the origin of Na, K, and others in Europa exosphere

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At a time when Europa is considered as a plausible habitat for the development of an early form of life, spatial missions in preparation, ESA JUICE et NASA Europa Clipper, with launchings in 2022 and 2025, are aimed at probing the internal structure and exosphere of this moon of Jupiter. Of particular concern is the origin of neutral sodium and potassium atoms detected in Europa exosphere (together with magnesium though in smaller abundance), since these atoms are known to be crucial for building the necessary bricks of prebiotic species. Contrary to the usual hypothesis that they are issued from the contamination produced by the intense volcanism of Io nearby, these volatile elements could originate directly from the icy shield of Europa (Cipriani et al. 2008; Leblanc et al. 2002, 2005; Johnson et al. 2002). Nevertheless their origin and history are still confused.

Europa is supposed to hide an internal ocean under tenths of kilometers of water ices (Hand et al. 2006). It is assumed that in its early history, the satellite was constituted by a rocky kernel surrounded with a global ocean, which could have acquired metallic elements as ions by direct contact of water with the rocky internal shield. Then, as Europa progressively cooled down, layers of ices formed under pressure between the kernel and the ocean as well as on the surface. The icy layers would have kept trapped the sodium and potassium initially dissolved in the internal ocean, allowing their future progression to the surface and identification in the exosphere of the satellite. We propose to check this scenario by means of quantum chemistry simulations.

Computational chemistry models based on first principle periodic density functional theory (DFT) have shown to be well adapted to the description of compact ice and capable to describe the trapping and neutralization of the initial ions in the ice matrix (Ellinger et al. 2015) while convection models could explain how Na and K trapped in the icy matrix have been driven to the surface of Europa carried by hot ices raising up (Pappalardo et al. 1998) and finally ripped off by a sputtering mechanism.

The process proposed here showing how the positive ions become neutral when progressing toward the surface of the ice crust can be applied to all the elements considered, alkali metals like Na and K, as well as to Mg and probably to Ca, their respective abundances depending essentially of their solubility and chemical capabilities to blend with water ices.

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Molecular dynamics study of collision-induced chemistry in cosmic ices

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Collision of low-energy cosmic rays in the form of neutral or charged atoms on the icy mantles of grains in the interstellar medium can trigger chemical reactions producing more complex molecules. Molecular dynamics with density functional theory was used to model the dependence of this process on ice morphology and other factors.
Complex and deuterated species in molecular cloud L379

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The molecular cloud L379 is a region of star formation situated at the distance of 2 kpc from the Sun. The region has a complex structure and consists of several cores. Here we present a detailed astrochemical study of one of the cores in the region, L379IRS1, paying special attention to complex and deuterated species. Basing on the spectral survey presented in Kalenski 2006 and adopting the structure of the object from Kelly & Macdonald (1996), we replicate the chemical evolution of the region and define its chemical age.

The reported study was funded by RFBR according to the research project No. 16-02-00834 A.
Nowadays living systems are not able to directly use the energy from external physical sources, like Sun or hydrothermal vents. The species that are dependent on such sources (photoautotroph and thermophile microorganisms, plants) must transform the energy into the more convenient form. In biology, it exclusively means the creation of electrochemical gradients by active and/or passive transport of ions through the lipid membrane. Subsequently, the energy from e.g. proton gradients is used to synthesis of ATP, the biological energy storage molecule. It is generally accepted that such ATP synthesis already existed in the LUCA, forasmuch as the proton pumping ATPases are found in all present day living organisms. Hence, it is very probable that also the systems on the border of autocatalytic chemistry and evolvable biology (let’s call them the chevol systems) in the early history of Earth, obeyed the same principle. In fact, except the chemolithotrophy, there were no other usable sources of energy. Therefore we can suspect that the early chevol forms also used the energy from the Sun to form proton gradients, which results in accumulation of energy. And due to Schrodinger’s theorem that “order makes order”, it could be the proverbial spark to launch the cascade of reactions, which could form the basis of protometabolism. A number of archea species use single transmembrane protein bacteriorhodopsin to generate proton gradients. Thus archea proton pumping mechanism can serve as a superior model for chevol proton transport. However, the capability to form proton gradients obeys the strict physical laws and is not limitless. With the increase of proton gradient, there also increases the probability of the reverse reaction resulting in equilibrium - “death” of chevol system. Therefore, with the help of proton gradients simulations, we discuss the parameters of the chevol protons transport machinery (proton count rates, numbers, and sizes of photon-driven pumps), in regard to the sustainable energy accumulation. We found that one photon-driven pump, in our lipid vesicle model system with radius 100 nm and count rate of seven protons per second, can establish the transmembrane potential almost equal to the current bacteriorhodopsin system (0.2 V).
Dark clouds in the vicinity of the emission nebula Sh2-205

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Results of CCD photometry in the seven-colour Vilnius system for 922 stars down to \( V = 1617 \) mag and for 302 stars down to 19.5 mag are used to investigate the interstellar extinction in a 1.5 square degree area in the direction of the P7 and P8 clumps of the dark cloud TGU H942 in the vicinity of the emission nebula Sh2-205. In addition, we also use 662 red clump giants identified combining the 2MASS and WISE infrared surveys. The resulting extinction versus distance plots are compared with the Dame et al. (2001) results of the distribution and radial velocities of CO clouds, as well as with dust maps in different passbands of the IRAS and WISE orbiting observatories. A possible distance of the front edge of the nearest cloud layer at \( 130 \pm 10 \) pc is found. Probably, this dust layer covers all the investigated area giving the extinction up to 1.8 mag in some directions. The second rise of the extinction seems to be present at 500-600 pc. Within this layer the clumps P7 and P8 of the dust cloud TGU H942, the Sh2-205 emission nebula and the infrared cluster FSR 655 can be located. In the direction of these clouds, we identified 88 young stellar objects and a new infrared cluster.
Spectroscopic Study of \( n \)-Propyl Cyanide
and Astronomical Detection of its Vibrationally Excited States

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We have recorded laboratory rotational spectra of \( n \)-propyl cyanide (\( n \)-PrCN) at frequencies up to 500 GHz and are presently carrying out a comprehensive analysis on the ground state and several vibrational states for both the gauche and anti conformers of this species. Work is in progress and is currently concentrating on the 36 to 70 GHz and 89 to 127 GHz regions. Rotational constants were already available for the first four lowest vibrational states (Hirota, 1962), facilitating the laboratory analysis, but from a too limited data set to give the accuracy required for useful predictions for astronomical purposes. Extensive data is already available for the ground state and is summarised in Belloche et al. (2009).

Ground-State, \( n \)-PrCN has previously been detected (Belloche et al., 2009) in the star-forming Sagittarius molecular cloud (specifically in the Northern Sgr B2(N) hot molecular core). The quantum-leap in sensitivity and spatial resolution of the new Atacama Large Millimetre Array (ALMA) affords the possibility of detecting many more new species in the interstellar medium. Some lines of vibrationally excited \( n \)-PrCN, both gauche and anti, have been identified in ALMA data we obtained for Sgr B2(N) between 84.0 and 114.4 GHz in its Early Science Cycles 0 and 1.

We will give some examples, both of the laboratory spectra under analysis and of the astrophysical detection. The ultimate goal of this work is to contribute to the understanding of the chemical processes and physical conditions that lead to the build-up of molecular complexity in star and planet forming regions.

References

Dust - molecular dark cloud LDN183 in Serpens

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Molecular cloud LDN 183 is part of interconnected complex of clouds which also include dark clouds LDN 169 and LDN 134. The cloud is situated at b = +37 deg above the Galactic plane at a distance 100 pc and is one of the closest molecular clouds to the Sun.

The study is based on CCD photometry in the Vilnius seven-color system. CCD exposures for 174 stars down to V 14 mag were obtained with the Maksutov-type 35/51 cm telescope of the Moltai Observatory in Lithuania, and for 232 stars down to 20.5 mag with the 1.8 m V ATT telescope of the Vatican Observatory on Mt. Graham, Arizona. Using photometric parameters, two-dimensional spectral types, interstellar extinctions and distances for most of the stars are determined.

116 red clump giants were identified by combining the results of infrared photometry from the 2MASS and WISE surveys. New identified red clump giants and stars with Vilnius photometry were used in the interstellar extinction run with distance investigation.

The results of the study are compared to the works other authors, not only in optical but also in IR and Radio wavelengths.
Photometric Investigation of the Star-forming region NGC 2264

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Young star clusters, especially with ages less than a few million years, are a direct result of star formation processes since they are associated with star-forming regions. An extensive surveys of young open star clusters are crucial for understanding the formation of stars and planets. Young and massive open clusters in giant molecular clouds (GMCs) are relatively rare within the nearest kiloparsec. NGC 2264 in the Monoceros constellation at a distance of about 0.8 kpc from the Sun is one of them. In the present contribution we investigate six areas in the direction of the central and northern parts of this cluster. The study is based on photometric classification of stars in spectral and luminosity classes using CCD photometry in the Vilnius seven-color system done with the 1 m telescope of the US Naval Observatory at Flagstaff, Arizona, and the 1.8 m VATT telescope of the Vatican Observatory on Mt. Graham, Arizona. Additionally, for investigation of interstellar extinction towards NGC 2264, we use several hundreds of red clump giants (RCGs), identified by combining the selected two-color diagrams of the infrared 2MASS, WISE and Spitzer surveys.
The presence of liquid water is a key requirement for life as we know it. Despite modern Mars being dry and cold, geological evidences suggest that liquid water was present on the surface of Mars in the past and we know that water ice is still present in the Martian subsurface.

It is hypothesised that if an Earth-like type of life ever appeared on Mars, it was able to shelter underground when the surface conditions became deleterious.

The purpose of this work is to study biomarkers in an environment on Earth that experiences similar conditions as on Mars (intense solar irradiation, cold temperatures, extreme thermal fluctuations, unstable liquid water). The Chilean Altiplano, more particularly the volcano Sairecabur, has been chosen for that purpose and compared with the nearby Atacama desert, dryest place in the world and used since the 1970s as a Martian analogue by NASA. Soil samples were collected in May 2015 near and on the volcano (between 4300 and 5300 m) and in the desert (2400 m).

It is postulated that, at high altitude, most of the microbiota, and the biomolecules they produce, will be found just above the subsurface ice layer, where liquid water is available. For this reason, a high-resolution depth-analysis of the soil was planned and samples were collected every 2 cm down to 21 cm deep, along with environmental parameters.

The samples are currently analysed for their organic content.
Cassini CAPS-ELS spectrometer revealed the presence of large negative ions in the ionosphere of Titan (Coates et al. 2007). Recently, a mechanism has been proposed for the possible formation of these ions, in which the cyanoacetylene, HC$_3$N, played a key role (Zabka et al. 2012). Chemical ionization technique (NCI and APCI-) were used successfully to prepare model complex (HC$_3$N)$_x$·C$_2$N$^-$ anions in the gas phase. The reaction itself and CID experiments were studied using a Waters Quattro Premier TM tandem quadrupole mass spectrometer operating in negative ion mode and VG ZAB2-SEQ mass spectrometer. CID mass spectra of these anions, as well as their ion molecule reactions with HC$_3$N support the previously proposed reaction scheme (Zabka et al. 2012, Zabka et al. 2014). Quantum chemistry calculations revealed details of the ion structures, energetics and reaction mechanisms. High-energy CID spectra of (HC$_3$N)$_x$·C$_2$N$^-$ anions showed a complexity of ionic and neutral products that can be expected to be formed by the high-energy ion precipitation observed at Titan (Cravens et al. 2008).

Presented experiments show that in spite of its low abundance in Titan atmosphere (Vuitton et al. 2009), the cyanoacetylene is probably one of the most important species in the ionospheric chemistry of Titan.

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Fig. 1. Pressure dependent mass spectra of reactions of C$_x$N$^-$ anions ($x = 3, 5, 7, 9$) with HC$_3$N.
The sporulation hypothesis: why Bacteria has a greater rate diversification than Archaea

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In this issue we propose an explanation for the gap of the rates of speciation between Archaea and Bacteria. Life on Earth has been characterized by unicellular prokaryotes in its first phases. The only two prokaryotic domains currently known, are Archaea and Bacteria and therefore they represent the most ancient known forms of life. These two domains have had a remarkable success since they colonized, with a huge number of species, all the habitats on the biosphere including the extreme ones that are out of reach for any other living kingdom. Nevertheless, the known biodiversity and the number of species of Archaea are much lesser than the Bacteria ones. Indeed Catalogue of Life¹ lists about 10,000 accepted bacterial species (and between 10⁷ and 10⁹ different predicted species, (Curtis et al. 2002; Dykhuisen 1998) in 52 phyla (Rappé & Giovannoni 2003) while only 400 for Archaea in 18 (Hugenholtz 2002) phyla. We know that in the animal kingdom, the acquisition of a greater capability of mobility increases the probability of colonization of new habitats. For instance, the ability to fly increased in large extent the speciation rate of insects, birds and chiropters that are richer in species than their sister clades lacking flight. In this issue, we try to explain the gap between the rates of speciation of Archaea and Bacteria proposing the sporulation hypothesis. Thanks to the acquisition of sporulation, Bacteria could and can easily disperse, resist to severe conditions and colonize new habitats. The relationship between expansion and the origin of species is a fundamental question of evolutionary biology and can help us to understand the first steps of the first forms of life.

Keywords: Bacteria – Archaea – diversification – early life – sporulation

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¹ http://www.catalogueoflife.org
Mars analogues for space exploration (MASE project)

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Is life out there? In order to assess the habitability of Mars, which is (or has been) the most Earth-like planet in our Solar System, the first step is to investigate microorganisms thriving in terrestrial biotops with Mars similar conditions (0.13% O2 in the atmosphere, low nutrients, low temperatures, high salinity and oxidising compounds, acidity) and comparable multi-stresses. The MASE (Mars analogues for space exploration) consortium is a team of researchers from all over Europe, combining a broad spectrum of interdisciplinary expertise. Five major sampling sites (dedicated campaigns: cold sulfur springs in Germany, potash mine in England, cold acidic lake in Iceland; samples already available: Rio Tinto in Spain, permafrost samples from Svalbard) were chosen with the major goal to cultivate and characterize novel anaerobic microorganisms which are specifically adapted to harsh conditions. Samples from these different Mars analogue areas on Earth were collected and anaerobic microorganisms adapted to these extreme conditions are being isolated. These new strains will be subjected to mars-relevant environmental stress factors alone and in combination in the laboratory under controlled conditions, e.g. radiation, high salt concentrations, low water activity, oxidising compounds. The aim is to understand how combined environmental stresses affect the habitability of a number of Mars analogue environments on Earth, specifically for anaerobic organisms and to find out, if these organisms are also able to survive under Martian conditions. Crucial to assessing the habitability of any environmental system is a detailed understanding of the geological, physiochemical and biological context in which the environment is set. One of the key outcomes of MASE is a comparison and synthesis of just such a collection of context data from a varied set of Mars analogue sites. The future experiments in the MASE project aim at the identification of the underlying cellular and molecular mechanisms and the comparison to other new isolates from Mars analogue environments on Earth.
CNO abundances in giants of the multiple-population globular cluster NGC 1851

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Globular clusters might be the first places in which extra-terrestrial life was formed in our Galaxy. The clusters date back to the early life of the Milky Way – nearly 10 billion years ago. Some of them have several populations of stars with a slightly different chemical composition. An origin of such differences is widely debated nowadays. We investigated the globular cluster NGC 1851 which has two distinct subgiant branches. We determined CNO and Fe abundances for a sample of up to 45 NGC 1851 giants. High-resolution spectra were obtained with the ESO VLT UVES spectrograph in the framework of the Gaia-ESO Survey. The stars in our sample can be separated into two groups with a difference of 0.1 dex in the mean metallicity, 0.3 dex in the mean C/N, and no significant difference in the mean values of C+N+O. We provide interpretations of these and other results of the study.
Interstellar extinction in the direction to the young open cluster IC 4996

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The open cluster IC 4996 (RA (J2000) = 20h16m30s, DEC (J2000) = +37°38') is found in the center of the Cygnus OB1 association in a region of Cygnus. It could be an active star formation zone since there are lots of young star clusters, massive and young O-B type stars associated with ionized hydrogen (HII) areas. This area holds probably the densest molecular cloud in the Galaxy. Near the Cyg-X cloud complex, the OB2 association is well examined while OB1 and OB9 are not. There is suspicion that open cluster IC 4996 might be the part of OB1 association. Age of association should be somewhere around 7.5 Myr while distance is in the range of 1.25 – 1.83 kpc (Reipurth & Schneider 2008). That fits quiet well with the average of estimates determined by various researchers. Interstellar reddening Av in the cluster area is somewhere between 1.96 mag (Alfaro et al. 1985) and 2.04 mag (Vansevicius & Petrauskas 1989), in other hand, some authors states that the reddening in this cluster area is differential. The distance to this cluster is mentioned in a few papers and the estimates are between 1.5 and 2.4 kpc. There exist several works devoted to stellar studies in the field of this cluster, but only a few photometric studies have been published. It is worth to mention that there are only two photometric studies made in this field using CCD cameras. We present new results obtained with VATT telescope (15' x 15' field) in Vilnius seven-color photometric system. The reddening and distances to the stars in the field were acquired after two dimensional classification were made.

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An experimental and modelling study of geochemical bio-signatures for life on early Mars

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In this study, we used a combination of experimental microbiology and thermochemical modelling techniques to identify potential geochemical bio-signatures for life on early Mars. The heterotrophic bacterium, Burkholderia sp. strain B_33, was grown in a minimal growth medium with basalt as the sole nutrient source. No growth was detected without the basalt. During exponential growth, the pH decreased rapidly from pH 7.0 to 3.6 and then gradually increased to a steady-state of equilibrium of between 6.8 and 7.1. Microbial growth coincided with an increase of key elements in the growth medium (Si, K, Ca, Mg and Fe). To distinguish between biologically-induced and abiotic weathering products, and to understand the difference in alteration conditions between both, we used thermochemical modelling (code CHIM-XPT, M. H. Reed, University of Oregon). We modelled the dissolution of the basalt in very dilute brine at 25 °C, 1 bar; the pH was buffered by the mineral dissolution and precipitation reactions. In the model we assumed complete dissolution of the rock into solution. Preliminary results suggested that at the water to rock ratio of 1/107 zeolite, hematite, chlorite, kaolinite and apatite formed abiotically. The biotic weathering processes were modelled by varying the alteration conditions within the model, for example pH. Preliminary studies for a basaltic system, have suggested that microbial mediated dissolution of basalt would result in 'simpler' secondary alterations, consisting of Fe-hydroxide and kaolinite, under conditions where the abiotic system would form chlorite in addition to Fe-hydroxide and kaolinite. The results from this study demonstrate that, by using an experimental and theoretical approach, it is possible to identify secondary alteration minerals that could potentially be used to distinguish between abiotic and biotic weathering processes on early Mars. This work is crucial for interpreting data from past, present and future life detection missions to Mars.
Overview on spectroscopic observations of exoplanetary atmospheres

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The present poster is summarizing my undergraduate final thesis, completed in 2015. The aim is to provide the reader with an overview on the spectroscopic research of exoplanetary atmospheres, which is today’s avant-garde in the field of exoplanets.

The four most used and important spectroscopic observational methods are presented here (direct imaging, primary eclipse (transits), secondary eclipse and phase curve observations), followed by a comparison of the results of the most impactful studies achieved in the field.

Currently the transiting (primary eclipse) observational method is used for the majority of gained exoatmospheric spectra, followed by the method of direct imaging. About two dozens of exoplanets have been successfully investigated, predominantly hot jupiters, remarkably frequent HD 189733b and HD 209458b. Nonetheless spectra of a few super-Earths, have also been obtained, among them GJ 1214b. The first detected substances in exoplanetary atmospheres are H2, H2O, CO, CO2, CH4 and Na.

Spectroscopic observations of exoplanetary atmospheres are already a fact, however interpretations of the observations are controversial and ambiguous, since some of the detected substances can be explained by cloud effects, too. The next generation space (JWST) and ground (30m-) telescopes will continue the work. The focus will be put on transit spectrum observations, since given the technology of the next years this technique can take larger steps towards the investigation of potential Earth 2.0.

Fig. 1. Phase curves of HAT-P-2b for different wavelengths after correction of the data. The upper phase curves at 3.6 and 4.5µm show a record of a whole orbital period, while the lowest phase curve contains only data from the primary eclipse to the next secondary one. The best fits are overplotted in red, the dashed line signals the stellar flux, the 0 point on the abscissa corresponds to the shortest distance between star and planet, the periapse (taken from Lewis et al. (2013)).
Fig. 2. The directly observed spectra of the four exoplanets HR 8799b, c, d and e are displayed from the top left to the bottom right. The flux $f_1$ is plotted as a function of the wavelength, along the abscissa, spanning a range from 1000 to 1800nm. In each of the boxes is plotted the spectrum of the respective exoplanet (with error bars) and a spectrum of a reference body. In the upper right corner of the HR 8799c box are shown some wavelength ranges where the investigated molecules show their features, from left to right NH3, C2H2, CO2 and CH4 (taken from Oppenheimer et al. (2013)).

Fig. 3. The upper diagram shows data points from different observation projects of the super-Earth GJ 1214b and models for solar-like and pure H2O atmosphere. The lower shows a zoom-in on the records from the HST by Kreidberg et al. (2014) and the curves for other model atmospheres. The data points do not agree with any of the plotted models (taken from (Kreidberg et al., 2014)).
Complex and deuterated species in molecular cloud L379

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The molecular cloud L379 is a region of star formation situated at the distance of 2 kpc from the Sun. The region has a complex structure and consists of several cores. Here we present a detailed astrochemical study of one of the cores in the region, L379IRS1, paying special attention to complex and deuterated species. Basing on the spectral survey presented in Kalenskii & Shchurov (2016) and adopting the structure of the object from Kelly & Macdonald (1996), we replicate the chemical evolution of the region and define its chemical age.

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Trace-element composition of Late Glacial sediments of Lithuania: ICP-MS study

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When a large ET object hits the Earth, small particles resulted from the impact (both from the impactor and from the targeted material) can travel in the atmosphere for thousands of kilometers before they finally get deposited (Bunch et al., 2008; Artemieva & Morgan, 2011). If the impact occurred over N. America, the dominating west winds (Isarin and Renssen, 1999; Brauer et al., 2008) could have delivered the impact-related microparticles as far east as Europe. Lithuania could be an important place in determining the eastern boundary of the Late Pleistocene ET material occurrence. We are applying here geochemical analyses of sediments across four Late-Glacial lake sequences from Lithuania in order to decipher the trace element distribution. This way, the presence of anomalous (in particular, ET-related) components in the sediments can be detected. Concentrations of trace elements in four Late Pleistocene lake sediment sequences across Lithuania (Dengtiltis, Krokšlys, Lopaiciški-2 and Ula-2 sites) were studied using ICP-MS. Most studied sequences are lithologically inhomogeneous and are characterized by uneven distribution of trace-elements across the sequences. Conducted geochronological modeling suggests that the studied parts of sedimentary sequences deposited during a time period from Blling to Younger Dryas. Such elements as Cr, Cu, Eu, La, Ni, Zn, Zr, and platinum group elements were used for constraints. According to geochemical characteristics, material for sediments of the Dengtilis and Krokšlys sequences was delivered from the same or very similar source, whereas such material for sediments of the Ula-2 and Lopaiciški-2 sites was delivered from different sources. Changes in geochemical characteristics of the sediments are mostly due to the changes in lithology and conditions of sediment deposition. However, some geochemical features are consistent with the presence of extraterrestrial material in at least two horizons separated by app. 2,000 years, and resulted from two separated events. The younger horizon is detected for all studied sequence and corresponds to the age of ca. 11.0-11.5 ka BP. Its geochemical features are suggested to be resulted from a local meteorite impact/bolide explosion tentatively related to the Velnio Duobs meteorite crater. The older horizon detected only for the Ula-2 sequence corresponds to the age of ca. 13.5 ka and is due to the bolide airburst. There is also suggestively meteoritic material in sediments dated as ca. 12.9 ka BP. The presence of volcanic materials related to the volcanic activity in the French Massif Central (a volcano of ca. 15.3 ka BP), and Laacher See volcano in Germany (12.88 ka BP) are suggested for some sedimentary layers of the studied sequences. We also suggest, that sediments from the Lopaiciški-2 drilling site contain minute amounts of volcanic and meteoritic materials at the levels just above that corresponding to the age of 12,900 162 cal BP. The volcanic material from this site can be related to the eruption of the Laacher See volcano (12.88 ka BP). On the other hand, so far we cannot unequivocally confirm or disconfirm whether meteoritic material in the Lopaiciški-2 sediments existing at the same stratigraphic level as the Laacher See volcanic material is related to the pre-YD ET event suggested by Firestone et al. (2007). The applied geochemical methodology, if confirmed by further research on additional sequences, could potentially be used as an additional tool for correlation between different Late Pleistocene records for a period during which radiocarbon dating still contains uncertainties.

References


The evidence for the astronomical forcing of phytoplankton and conodont diversity and abundance in the Wenlock (Silurian)

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The fossil record, it is known, is the only direct source of information on the past biotic change as well as its connection to the changes in terrestrial and cosmic environments. In the past several decades there was constant growth in recognition that quasiperiodic changes in the Earth’s orbital parameters (eccentricity, obliquity and precession) were major players in modulating environmental change in the Mesozoic and especially the Cenozoic eras. The Paleozoic era of the Phanerozoic eon and the earlier times, received significantly less attention from the point of view of dynamic cyclostratigraphy and the study of so called Milankovitch cycles.

In this contribution we present evidence from the study of the sedimentary successions of the Silurian period from two deep cores (Ledai-179 and Viduklė-61), that at least two groups of ancient organisms, namely conodonts and phytoplankton (acritarchs and green algae) experienced cyclic changes that can be explained as caused by the periodic variations in Earth’s orbital eccentricity. The studied time interval spans the middle and the upper parts of the Wenlock epoch - a time of significant geobiological perturbations in climate and oceanography. Long-term cycles observed in phytoplankton assemblages from the Viduklė-61 core section in their estimated duration are similar to 400 Ka long eccentricity cycles. On the other hand several conodont paleoecological parameters (abundance, diversity and evenness) experienced statistically significant fluctuations which period length is close to that of modern ≈100 Ka short eccentricity cycles. These cyclicities are major components of recent past periodic climate changes during the Quaternary period, which is dominated by cold climates. Similarly the studied time interval experienced significant climate cooling episode which could be a reason for the increased susceptibility of Earth’s system to the periodic astronomical perturbations.
Record of Precambrian to Cambrian life in the Mizarai impact crater lake

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Mizarai impact crater is located in Southern Lithuania, near the resort Druskininkai. It is regularly rounded depression, 6 km in diameter, 500 m deep, while the impact breccias layer is up to 2000 m thick. The type of impactorasteroid is not known. The cosmogenic origin of the crater is confirmed by set of indices used for the recognition of such structures: rounded negative gravity anomaly, planar deformation structures (PDF) of at least three systems, in quartz and feldspar crystals, isotropisation of minerals with formation of lechatelierite and maskelinite; kink bands in biotite; shatter cones, glassy rocks, various kinds of breccias including suevite. The crater is characterized by four boreholes two of them (Mizarai-344 and Lazdijai-29) have been drilled in the very centre of crater on the central uplift, and the other two boreholes (1422 and Druskininkai-270) where drilled in the marginal part of the crater.

The crater is filled up by sedimentary sequence composed by clastic rocks ranging from conglomerate, to sandstones, siltstones and clays. The layering is rhythmic. The sequence is not dated geochronologically. Based on the rare acritarch fossils the age could vary from the Ediacaran to the Cambrian. The crater is covered by Triassic, Cretaceous and Quaternary rocks. Based on paleogeographic reconstructions this sequence was formed in the local lake in the continental environment. A’ In the drillcores of both boreholes in the central part of the crater the black coloured cerrogenous material located on the layering surfaces of the siltstone was been discovered. In the borehole Lazdijai-29 they appear in the interval 407-427 m (from the surface), and in Mizarai-344 on the similar depth 432,6 m. Thus in both boreholes they appear on the same or very close stratigraphic level, and might be coeval. This stratigraphic level is in the lower part of the sedimentary section which foot starts on the depth of 525 (Mizarai-344) and 512 m (Lazdijai-29). There is to indications, that the stratigraphic level the fossils appear is in lower part of the sedimentary fill of the crater, which means, that it was colonized soon after the impact. The study of these objects using SEM revealed complicated morphological structures of these materials forming circles with the diameter of ≈250 microns, film fragments or plates with regular embayments. Raman spectroscopy performed by dr. G. Niaura proved that the patches are composed by amorphous carbon, possibly representing material of organic origin.

The morphological features suggest affinities of the material with problematic late Precambrian algae or so called vendotenids. The rounded circles in the organic mats, based on their morphology and the size, could be attributed to the remains of conceptacles of red or brown algae. More detailed investigation showed even more complicated micro-structures in form of films resembling bacterial mats, filaments, rosettes (≈200 micron in diameter) similar to Archean coccoids microfossils of few microns in size. These features are morphologically compatible (similar) to the structures regarded as possibly organogenic found in the Archean rocks in Australian and South African cratons and those observed in some meteorites of the type of carbonaceous chondrites (Murchison, Efremovka, Orgueil) and Martian meteorite Nakhla. Thus the asteroid impact created space for the development and also the preservation of the late Precambrian to early Cambrian lake ecosystem.