# AstroChemical Newsletter #4

## February 2016

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# Abstracts

### CO and N2 desorption energies from water ice

**Edith C. Fayolle, Jodi Balfe, Ryan Loomis, Jennifer Bergner, Dawn M. Graninger, Mahesh Rajappan, Karin I. Öberg**

The relative desorption energies of CO and N2 are key to interpretations of observed interstellar CO and N2 abundance patterns, including the well-documented CO and N2H+ anti-correlations in disks, protostars and molecular cloud cores. Based on laboratory experiments on pure CO and N2 ice desorption, the difference between CO and N2 desorption energies is small; the N2-to-CO desorption energy ratio is 0.93±0.03. Interstellar ices are not pure, however, and in this study we explore the effect of water ice on the desorption energy ratio of the two molecules. We present temperature programmed desorption experiments of different coverages of 13CO and 15N2 on porous and compact amorphous water ices and, for reference, of pure ices. In all experiments, 15N2 desorption begins a few degrees before the onset of 13CO desorption. The 15N2 and 13CO energy barriers are 770 and 866 K for the pure ices, 1034-1143 K and 1155-1298 K for different sub-monolayer coverages on compact water ice, and 1435 and 1575 K for ~1 ML of ice on top of porous water ice. For all equivalent experiments, the N2-to-CO desorption energy ratio is consistently 0.9. Whenever CO and N2 ice reside in similar ice environments (e.g. experience a similar degree of interaction with water ice) their desorption temperatures should thus be within a few degrees of one another. A smaller N2-to-CO desorption energy ratio may be present in interstellar and circumstellar environments if the average CO ice molecules interacts more with water ice compared to the average N2 molecules.

ApJL, 2016, 816, L28
DOI: 10.3847/2041-8205/816/2/L28
Full-text URL: http://arxiv.org/abs/1512.06865

### UV photodesorption of methanol in pure and CO-rich ices: desorption rates of the intact molecule and of the photofragments

**M. Bertin, C. Romanzin, M. Doronin, L. Philippe, P. Jeseck, N. Litgerink, H. Linnartz, X. Michaut, J.-H. Fillion**

Wavelength-dependent photodesorption rates have been determined using synchrotron radiation for condensed pure and mixed methanol ice in the 7–14 eV range. The VUV photodesorption of intact methanol molecules from pure methanol ices is found to be of the order of 10−5 molecules/photon, that is two orders of magnitude below what is generally used in astrochemical models. This rate gets even lower (<10−6 molecules/photon) when the methanol is mixed with CO molecules in the ices.

This is consistent with a picture in which photodissociation and recombination processes are at the origin of intact methanol desorption from pure CH3OH ices. Such low rates are explained by the fact that the overall photodesorption process is dominated by the desorption of the photofragments CO, CH3, OH, H2CO, and CH3O/CH2OH, whose photodesorption rates are given in this study. Our results suggest that the role of the photodesorption as a mechanism to explain the observed gas phase abundances of methanol in cold media is probably overestimated. Nevertheless, the photodesorption of radicals from methanol-rich ices may stand at the origin of the gas phase presence of radicals such as CH3O, therefore, opening new gas phase chemical routes for the formation of complex molecules.

2016 The Astrophysical Journal Letters, 817, L12
DOI: 10.3847/2041-8205/817/2/L12
Full-text URL: http://arxiv.org/abs/1601.07027

## Low Temperature Formation of Nitrogen-substituted Polycyclic Aromatic Hydrocarbons (PANHs)—Barrierless Routes to Dihydro(iso)Quinolines

**Dorian S. N. Parker, Tao Yang, Beni B. Dangi, Ralf. I. Kaiser, Partha P. Bera, and Timothy J. Lee**

Meteorites contain bio-relevant molecules such as vitamins and nucleobases, which consist of aromatic structures with embedded nitrogen atoms. Questions remain over the chemical mechanisms responsible for the formation of nitrogen-substituted polycyclic aromatic hydrocarbons (PANHs) in extraterrestrial environments. By exploiting single collision conditions, we show that a radical mediated bimolecular collision between pyridyl radicals and 1,3-butadiene in the gas phase forms nitrogen-substituted polycyclic aromatic hydrocarbons (PANHs) 1,4-dihydroquinoline and to a minor amount 1,4-dihydroisoquinoline. The reaction proceeds through the formation of a van der Waals complex, which circumnavigates the entrance barrier implying it can operate at very low kinetic energy and therefore at low temperatures of 10 K as present in cold molecular clouds such as TMC-1. The discovery of facile de facto barrierless exoergic reaction mechanisms leading to PANH formation could play an important role in providing a population of aromatic structures upon which further photo-processing of ice condensates could occur to form nucleobases.

ApJ, 815, 115, 2015
DOI: 10.1088/0004-637X/815/2/115
Full-text URL: http://iopscience.iop.org/article/10.1088/0004-637X/815/2/115/meta

## Water and acetaldehyde in HH212: The first hot corino in Orion

**C. Codella, C. Ceccarelli, S. Cabrit, F. Gueth, L. Podio, R. Bachiller, F. Fontani, A. Gusdorf, B. Lefloch, S. Leurini, M. Tafalla**

Aims: Using the unprecedented combination of high resolution and sensitivity offered by ALMA, we aim to investigate whether and how hot corinos, circumstellar disks, and ejected gas are related in young solar-mass protostars. Methods: We observed CH3CHO and deuterated water (HDO) high-excitation (Eu up to 335 K) lines towards the Sun-like protostar HH212--MM1. Results: For the first time, we have obtained images of CH3CHO and HDO emission in the inner about 100 AU of HH212. The multifrequency line analysis allows us to contrain the density (> 10^7 cm^-3), temperature (about 100 K), and CH3CHO abundance (about 0.2-2 x 10^-9) of the

emitting region. The HDO profile is asymmetric at low velocities (< 2 km s^-1 from Vsys). If the HDO line is optically thick, this points to an extremely small (about 20--40 AU) and dense (> 10^9 cm^-3) emitting region. Conclusions: We report the first detection of a hot corino in Orion. The HDO asymmetric profile indicates a contribution of outflowing gas from the compact central region, possibly associated with a dense disk wind.

A&A, 2016, 586, L3
DOI: 10.1051/0004-6361/201527424
Full-text URL: http://arxiv.org/abs/1601.00539

## Spontaneous polarization of solid CO on water ices and some astrophysical implications

**Alexander Rosu-Finsen, Jérôme Lasne, Andrew Cassidy, Martin R. S. McCoustra and David Field**

Reflection absorption infrared spectroscopy (RAIRS) is used to show that when 20 monolayer (ML) films of solid CO are laid down on solid water substrates at 20 to 24 K, the films polarize spontaneously. CO films were prepared on three types of water ice: porous amorphous solid water (CO-pASW), crystalline water (CO-CSW) and compact amorphous solid water (CO-cASW) with corresponding fields of 3.76 (0.15) E7 V/m for CO-pASW, 2.87 (0.15) E7 V/m for CO-CSW and 1.98 (0.15) E7 V/m for CO-cASW. For comparison, CO laid down on SiO2 yields 3.8 (0.15) E7 V/m. Our results are of relevance to an understanding of the chemistry and physics of dense star-forming regions in the interstellar medium, in which dust particles become coated with solid CO on a layer of cASW. The polarization charge which accumulates on the CO surface acts as a catalyst for the removal of electrons and ions from the medium and may account for the low degree of ionization observed in these regions, a feature which is an important factor for the rate of star formation.

Phys. Chem. Chem. Phys., 2016, Advance Article
DOI: 10.1039/C5CP07049J
Full-text URL:
http://pubs.rsc.org/en/content/articlelanding/2016/cp/c5cp07049j#!divAbstract

## Molecular formation along the atmospheric mass loss of HD 209458 b and similar Hot Jupiters

**R. Pinotti, H. M. Boechat-Roberty**

The chemistry along the mass loss of Hot Jupiter' s is generally considered to be simple, consisting mainly of atoms, prevented from forming more complex species by the intense radiation field from their host stars. In order to probe the region where the temperature is low (T < 2000 K), we developed a 1D chemical and photochemical reaction model of the atmospheric mass loss of HD 209458 b, involving 56 species, including carbon chain and oxygen bearing ones, interacting through 566 reactions. The simulation results indicate that simple molecules like OH+, H2O+ and H3O+ are formed inside the region, considering that residual H2 survives in the exosphere, a possibility indicated by recent observational work. The molecules are formed and destroyed within a radial distance of less than 10^7 km, but the estimated integrated column density of OH+, a potential tracer of H2, is high enough to allow detection, which, once achieved, would indicate a revision of chemical models of the upper atmosphere of Hot Jupiters. For low density Hot Jupiters receiving less intense XUV radiation from their host stars than HD 209458 b, molecular species could conceivably

be formed with a higher total column density.

Planetary and Space Science, In Press
DOI: 10.1016/j.pss.2015.12.010
Full-text URL: http://arxiv.org/abs/1601.00821

## Direct measurement of desorption and diffusion energies of O and N atoms physisorbed on amorphous surfaces

**M. Minissale, E. Congiu, F. Dulieu**

Context. Physisorbed atoms on the surface of interstellar dust grains play a central role in solid state astrochemistry. Their surface reactivity is one source of the observed molecular complexity in space. In experimental astrophysics, the high reactivity of atoms also constitutes an obstacle to measuring two of the fundamental properties in surface physics, namely desorption and diffusion energies, and so far direct measurements are non-existent for O and N atoms. Aims. We investigated the diffusion and desorption processes of O and N atoms on cold surfaces in order to give boundary conditions to astrochemical models. Methods. Here we propose a new technique for directly measuring the N- and O-atom mass signals. Including the experimental results in a simple model allows us to almost directly derive the desorption and diffusion barriers of N atoms on amorphous solid water ice (ASW) and O atoms on ASW and oxidized graphite. Results. We find a strong constraint on the values of desorption and thermal diffusion energy barriers. The measured barriers for O atoms are consistent with recent independent estimations and prove to be much higher than previously believed ( Edes = 1410(-160+290); Edif = 990 (-360+530) K on ASW). As for oxygen atoms, we propose that the combination Edes − Edif = 1320–750 K is a sensible choice among the possible pairs of solutions. Also, we managed to measure the desorption and diffusion energy of N atoms for the first time (Edes = 720(-80+160); Edif = 525(-200+260) K on ASW) in the thermal hopping regime and propose that the combination Edes-Edif = 720–400 K can be reasonably adopted in models. The value of Edif for N atoms is slightly lower than previously suggested, which implies that the N chemistry on dust grains might be richer.

A&A 585, A146 (2016)
DOI: 10.1051/0004-6361/201526702
Full-text URL: http://www.aanda.org/articles/aa/abs/2016/01/aa26702-15/aa26702-15.html

## Merged-beams Reaction Studies of O + H3+

**N. de Ruette, K. A. Miller, A. P. O'Connor, X. Urbain, C. F. Buzard, S. Vissapragada, and D. W. Savin**

We have measured the reaction of O + H3+ forming OH+ and H2O+. This is believed to be one of the key gas-phase astrochemical processes initiating the formation of water molecules in dense molecular clouds. For this work, we have used a novel merged fast-beams apparatus that overlaps a beam of H3+ onto a beam of ground-term neutral O. Here, we present cross-section data for forming OH+ and H2O+ at relative energies from ≈3.5 meV to ≈15.5 and 0.13 eV, respectively. Measurements were performed for statistically populated O(^3P) in the ground term reacting with hot H3+ (with an internal temperature of ~2500–3000 K). From these data, we have derived rate coefficients for translational temperatures from ≈27 K to ~1E5 K for the formation of OH+ and ~1E3 K for the formation of H2O+. In order to convert these results to a thermal rate coefficient suitable for astrochemistry, we have added the

results together for both exit channels and scaled the summed data on statistically populated oxygen to thermally populated oxygen. For this we have used theory as a guide, thereby accounting for the temperature dependence of the O fine-structure levels. Our results are in good agreement with two independent flowing afterglow measurements at a temperature of ≈300 K, and with a corresponding level of H3+ internal excitation. This good agreement suggests that the internal excitation of the H3+ does not play a significant role in this reaction. The Langevin rate coefficient is in reasonable agreement with the experimental results at 10 K but a factor of ~2 larger at 300 K. The two published classical trajectory studies using quantum-mechanical potential energy surfaces lie a factor of ~1.5 above our experimental results over this 10–300 K range.

Astrophys. J. 816, 31 (2016)
DOI: 10.3847/0004-637X/816/1/31
Full-text URL: http://arxiv.org/abs/1508.07882

## Efficient ortho-para conversion of H2 on interstellar grain surfaces

**E. Bron, F. Le Petit, and J. Le Bourlot**

Context: Fast surface conversion between ortho- and para-H2 has been observed in laboratory studies, and this mechanism has been proposed to play a role in the control of the ortho-para ratio in the interstellar medium. Observations of rotational lines of H2 in Photo-Dissociation Regions (PDRs) have indeed found significantly lower ortho-para ratios than expected at equilibrium. The mechanisms controlling the balance of the ortho-para ratio in the interstellar medium thus remain incompletely understood, while this ratio can affect the thermodynamical properties of the gas (equation of state, cooling function). Aims: We aim to build an accurate model of ortho-para conversion on dust surfaces based on the most recent experimental and theoretical results, and to validate it by comparison to observations of H2 rotational lines in PDRs. Methods: We propose a statistical model of ortho-para conversion on dust grains with fluctuating dust temperatures, based on a master equation approach. This computation is then coupled to full PDR models and compared to PDR observations. Results: We show that the observations of rotational H2 lines indicate a high conversion efficiency on dust grains, and that this high efficiency can be accounted for if taking dust temperature fluctuations into account with our statistical model of surface conversion. Simpler models neglecting the dust temperature fluctuations do not reach the high efficiency deduced from the observations. Moreover, this high efficiency induced by dust temperature fluctuations is quite insensitive to the values of microphysical parameters of the model. Conclusions: Ortho-para conversion on grains is thus an efficient mechanism in most astrophysical conditions that can play a significant role in controlling the ortho-para ratio.

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Full-text URL: http://arxiv.org/abs/1601.04356

## Efficient electron-promoted desorption of benzene from water ice surfaces

**D. Marchione, J. D. Thrower, M. R. S. McCoustra**

Desorption of benzene (C6H6) from solid water surfaces [compact amorphous solid water (c-ASW) and crystalline ice (CI)] during irradiation of ultrathin solid films with low

energy (250–300 eV) electrons has been investigated. The observed desorption behaviour is complex but typically two desorption components, with particularly large cross-sections, were present in the observed signal. A fast component, with a cross-section up to 10^–15 cm2, is attributed to desorption of isolated C6H6 molecules that are hydrogen-bonded to small clusters of water (H2O) molecules on the solid water surface. A slower component, with a cross-section of ca. 10^−17 cm2, is attributed mainly to desorption from larger C6H6 islands on the solid water surface. Possible desorption mechanisms are proposed and astrophysical implications are discussed.

Physical Chemistry Chemical Physics (PCCP), 2016, 18, 4026-4034
DOI: 10.1039/C5CP06537B
Full-text URL:
http://pubs.rsc.org/en/content/articlelanding/2016/cp/c5cp06537b#!divAbstract

## Interstellar Hydrides

**M. Gerin, D.A. Neufeld, J.R. Goicoechea**

Interstellar hydrides -- that is, molecules containing a single heavy element atom with one or more hydrogen atoms -- were among the first molecules detected outside the solar system. They lie at the root of interstellar chemistry, being among the first species to form in initially-atomic gas, along with molecular hydrogen and its associated ions. Because the chemical pathways leading to the formation of interstellar hydrides are relatively simple, the analysis of the observed abundances is relatively straightforward and provides key information about the environments where hydrides are found. Recent years have seen rapid progress in our understanding of interstellar hydrides, thanks largely to far-IR and submillimeter observations performed with the Herschel Space Observatory. In this review, we will discuss observations of interstellar hydrides, along with the advanced modeling approaches that have been used to interpret them, and the unique information that has thereby been obtained.

Accepted for publication in Annual Review of Astronomy and Astrophysics 2016, Vol. 54.
Full-text URL: http://arxiv.org/abs/1601.02985

## Structure and Stability of Neutral and Positively Charged Hydrogenated Carbon Clusters: a Novel Method for Structure and Fragmentation Analysis

**Juan Pablo Sánchez, Néstor Fabián Aguirre, Sergio Díaz-Tendero, Fernando Martín and Manuel Alcamí**

In this work we present a systematic theoretical study of neutral and positively charged hydrogenated carbon clusters (CnHmq+ with n=1-5,m=1-4 and q=0-3). A large number of isomers and spin states (1490 in total) has been investigated. For all of them we have optimized the geometry and computed the vibrational frequencies at the B3LYP/6-311++G(3df,2dp) level of theory; more accurate values of the electronic energy have been obtained at the CCSD(T)/6-311++G(3df,2dp) level over the geometry previously obtained. From these simulations we have evaluated several properties such as relative energies between isomers, adiabatic and vertical ionization potentials, and dissociation energies of several fragmentation channels. From the large amount of data obtained some statistically meaningful conclusions can be obtained from the energy distribution of the different isomers and structures. A new analysis technique is also proposed to evaluate a large number of fragmentation channels in a wide energy range allowing to easily obtain a general picture of the fragmentation behavior of this kind of

clusters.

J. Phys. Chem. A , (Accepted)
DOI: 10.1021/acs.jpca.5b10143
Full-text URL: http://pubs.acs.org/doi/pdf/10.1021/acs.jpca.5b10143

# Announcements

## Half a Decade of ALMA: Cosmic Dawns Transformed. International ALMA Meeting to be held September 20 - 23, 2016 in Indian Wells, CA, USA

The sensitivity and spectral grasp of the Atacama Large Millimeter/submillimeter Array (ALMA) have revolutionized the study of youngest structures in the Universe, from galaxy formation through the formation of stars and planets. ALMA has produced over 300 refereed papers with over 3000 citations at its four-year mark, reporting impressive and scientifically compelling results as the most sensitive and highest resolution mm/submm interferometer in the world. One aim of the four day conference is to highlight recent ALMA results at the threshold of its fifth year of operation. Another goal is to bring together researchers from around the world to motivate collaborations for ALMAs Cycle 5. Science topics will include all fields of astronomy, from cosmology and galaxies in the distant universe, nearby galaxies and the Galactic Center, ISM and star formation in our own galaxy, astrochemistry, circumstellar disks, exoplanets, solar system, stellar evolution and the Sun. The conference will feature invited and contributed talks as well as poster sessions. Young researchers and students are particularly encouraged to attend the meeting. http://tinyurl.com/z63hlt7

## NAASC Workshop on Molecular Gas in Galactic Environments

We are delighted to announce a Call for Abstracts for the 2016 NAASC Workshop on Molecular Gas in Galactic Environments to be held April 4 – 7, 2016, in Charlottesville, VA. https://science.nrao.edu/science/meetings/2016/molecular-gas-in-galactic-environments/home ALMA’s line sensitivity and spectral grasp has resulted in the identification and imaging of more than forty molecules outside the Milky Way. The workshop focuses on the character of the molecular gas in the varied environments in which these molecules are found beyond our Galaxy. This international conference will bring together ALMA, VLA and GBT users and potential users of other upcoming facilities, such as ngVLA, JWST, and TMT to consider what capabilities or upgrades to these instruments might facilitate the study of extragalactic molecules most. Major Topics of Discussion Include: • Exploring the relationship between molecular distributions and physical processes in those galaxies • Investigating the roles of molecular variation in extreme metallicity environments • Examining the existence and cause of isotopic gradients within galaxies • Scrutinizing variations in molecular excitation, both rotational and vibrational • Seeking evidence for and causes of molecular abundance gradients • Identifying molecules useful as probes of nuclear infall and outflow • Determining the prospects of molecules as probes of black hole masses. Confirmed Invited Speakers: • Francesco Costagliola • Nanase Harada • Christian Henkel • Leslie Hunt • Takuma Izumi • Adam Leroy • Sergio Martin • Gergö Popping • Dominik Riechers • Nick Scoville • Jean Turner This 4-day NAASC workshop will consist of a number of invited talks to guide the discussions of relevant questions to be addressed. Contributed abstracts will be solicited, and the SOC will select a subset for oral presentations, with the rest accepted as posters. Registration will include workshop materials, daily breakfast, breaks, and a welcome reception. An optional conference dinner will also be available. Submissions by students and early-career

researchers are especially encouraged. To promote their attendance, students are offered a discounted registration rate and a free double-occupancy room in the conference hotel for the duration of the conference. Abstract submission is now available via the conference website – the deadline is February 7th. Registration will open the week of January 11, and Early Bird registration rates will be available until the abstract deadline https://science.nrao.edu/science/meetings/2016/molecular-gas-in-galactic-environments/home We look forward to seeing everyone in Charlottesville in April!

## Leiden/ESA Astrophysics Programme for Summer Students (LEAPS)

The Leiden Observatory and the European Space Agency invite applications for the Leiden/ESA Astrophysics Programme for Summer Students (LEAPS). LEAPS is a highly competitive programme for students with a keen interest in astronomy, astrophysics, solar physics, and planetary sciences to perform a 10-12 week summer research project in collaboration with a research scientist from Leiden Observatory or ESA. The programme is open to all students not currently studying for a Ph.D., but who are enthusiastic about pursuing research in the space sciences. Students at the senior-undergraduate or masters level, in particular, are encouraged to apply. Projects will begin approximately 1st June 2016 and end by mid to late August 2016. In 2015 the programme had 22 successful candidates. We expect to make a similar number of appointments this year, depending on interest and the number of available projects which are suited to the applicants' research interest and skills. The list of proposed projects, and the instructions for the application are available at http://www.strw.leidenuniv.nl/summerstudents/ The deadline for applications is February 6, 2016.

## The ISM-SPP Olympian School of Astrophysics 2016

Paralia Katerini, Mt Olympus, Greece. 3-7 October 2016. http://school2016.olympiancfa.org/ The School focuses on the physics and chemistry of the galactic and extragalactic interstellar medium including star formation, and on astrochemistry from photoionized to photodissociation and molecular regions. The scope of the school is to gather young researchers particularly PhD students and early career scientists to discuss about theoretical and numerical aspects of the general field of the interstellar medium, in a pleasant area located next to the sea and at the foot of world’s famous Mt. Olympus. Topics include: • Physics and Dynamics of the Interstellar Medium (galactic, extragalactic) • Astrochemistry (photoionization, photodissociation, molecular regions) • Hydrodynamics (instabilities, turbulence, magnetic fields) • Star formation (from low-mass to high-mass stars, triggered and non-triggered) • Hydrodynamical simulations and the comparison with observations Invited key speakers: • Robi Banerjee (University of Hamburg, Germany) • Andreas Burkert (Ludwig-Maximilians Universitat Munchen, Germany) • Kalliopi Dasyra (National and Kapodistrian University of Athens, Greece) • Simon Glover (University of Heidelberg, Germany) • Peter Schilke (University of Cologne, Germany) • Kostas Tassis (University of Crete, Greece) For further information please visit the link: http://school2016.olympiancfa.org/

## Summer Astrochemical School "ASTROCHEMISTRY: FROM SPACE TO EARTH"

SUMMER SCHOOL, Grenoble (France), 29/8-9/9 2016 “ASTROCHEMISTRY: FROM SPACE TO EARTH" AIMS OF THE SCHOOL Astrochemistry is the field that studies how interstellar atoms combine into molecules, in the gas phase and on the surfaces of the interstellar grains. It is the interplay between these two processes that leads to the rich

chemistry observed in space, at galactic and extragalactic scales. To extract all the information from the astronomical observations of molecules and exploit them at the best is, however, a truly multidisciplinary endeavor. It requires complementary approaches (observations, modeling, laboratory, theory) to be combined with accurate knowledge in several fields: astrophysics, chemistry, atomic and molecular physics, solid state physics. This implies different communities to work together and to learn to understand each other, whose languages are often very different. The school aims to offer a series of courses on all the above interdisciplinary aspects of Astrochemistry, from the basic concepts to the state-of-the-art research in each of them. The scope is to train PhD students and young researchers of the different communities that make up Astrochemistry and foster the collaboration/networking among them. PROGRAM The school is organized in two weeks of lectures complemented with extensive “hands-on” activities, where students will have the occasion to apply the concepts to real cases. The program of the school comprises lectures on: Methods of detection and analysis of interstellar molecules; Basics of radiative transfer and astrochemical modeling; Interstellar chemistry and star formation; Basics on astrochemical processes; Methods for theoretical chemistry applied to gas phase and solid state interstellar chemistry; Basics of laboratory experiments for astrochemistry and spectroscopy; Proposal and applications writing. Confirmed teachers: Prof. S. Althorpe (University of Cambridge), Prof. V. Barone (Scuola Normale Superiore, Pisa), Prof. E. Bergin (University of Michigan), Prof. J. Black (Chalmers University of Technology, Onsala), Dr. H. Cuppens (Radboud University, Nijmegen), Dr. E. Dartois (Institut d’Astrophysique Spatiale, Paris), Prof. L. Dore (Università di Bologna), Prof. F. Dulieu (LERMA, Paris), Dr. P. Hily-Blant (IPAG, Grenoble), Prof. M-E. Palumbo (Osservatorio di Catania, Catania), Prof. I. Sims (Université de Rennes) and Prof. S. Viti (University College of London). PRATICAL INFORMATION The school will be held at IPAG in Grenoble (France), during the period 29/8-9/9 2016. The students will be lodged in the student residence of the Université Grenoble Alpes. The participation will be restricted to about 30 students, divided in about three equal groups with background in astronomy, theoretical and experimental chemistry, respectively. APPLICATIONS Applications should be sent to Cecilia.Ceccarelli@obs.ujf-grenoble.fr and Pierre.Hily-Blant@obs.ujf-grenoble.fr and should contain: Name, Affiliation, Grade (PhD or Post-Doc) 1 page CV Brief letter of motivation Recommendation letter(s) Requested financial support: yes/not The deadline for the application submission is the 15 April 2016. A financial support to European students is possible. Information on the selected students will be provided by 30 April. More detailed information can be found in the website: http://astrochem2016.sciencesconf.org/ SOC: C.Ceccarelli (chair), G.Nyman (co-chair), N. Balucani, A.Bergeat, S.Jerosimic, D.Talbi, P.Theulé LOC: P.Hily-Blant (chair), B.Bishop, C.Favre, C.Kahane, B.Lefloch, A.Faure The School is co-organized by the Institut de Planétologie de Grenoble (IPAG), the EU COST Action CM1401, and the French National Project PCMI.