AstroChemical Newsletter #77

April 2022

You can access the full abstracts by clicking the paper titles. Submit your abstracts before the 25th of each month for inclusion in the following newsletter.

Abstracts

The prebiotic molecular inventory of Serpens SMM1: II. The building blocks of peptide chains

Niels F.W. Ligterink, Aida Ahmadi, Bijaya. Luitel, Audrey Coutens, Hannah Calcutt, Łukasz Tychoniec, Harold Linnartz, Jes K. Jørgensen, Robin T. Garrod, Jordy Bouwman

This work aims to constrain the abundances of interstellar amides, by searching for this group of prebiotic molecules in the intermediate-mass protostar Serpens SMM1-a. ALMA observations are conducted toward Serpens SMM1. A spectrum is extracted toward the SMM1-a position and analyzed with the CASSIS line analysis software for the presence of characteristic rotational lines of a number of amides and other molecules. NH2CHO, NH2CHO ν12=1, NH132CHO, CH3C(O)NH2 ν=0,1, CH2DOH, CH3CHO, and CH3C(O)CH3 are securely detected, while trans-NHDCHO, NH2CDO, CH3NHCHO ν=0,1, CH3COOH, and HOCH2CHO are tentatively identified. The results of this work are compared with detections presented in the literature. A uniform CH3C(O)NH2/NH2CHO ratio is found for a group of interstellar sources with vast physical differences. A similar ratio is seen for CH3NHCHO, based on a smaller data sample. The D/H ratio of NH2CHO is about 1--3% and is close to values found in the low-mass source IRAS 16293-2422B. The formation of CH3C(O)NH2 and NH2CHO is likely linked. Formation of these molecules on grain surfaces during the dark cloud stage is a likely scenario. The high D/H ratio of NH2CHO is also seen as an indication that these molecules are formed on icy dust grains. As a direct consequence, amides are expected to be present in the most pristine material from which planetary systems form, thus providing a reservoir of prebiotic material.

Accepted for publication in ACS space and earth chemistry
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Full-text URL: https://arxiv.org/abs/2202.09640

The chemical nature of Orion protostars: Are ORANGES different from PEACHES? ORANGES II.

M. Bouvier, C. Ceccarelli, A. López-Sepulcre, N. Sakai, S. Yamamoto and Y.-L. Yang

Understanding the chemical past of our Sun and how life appeared on Earth is no mean feat. The best strategy we can adopt is to study newborn stars located in an environment similar to the one in which our Sun was born and assess their chemical content. In particular, hot corinos are prime targets since recent studies showed correlations between interstellar Complex Organic Molecules (iCOMs) abundances from hot corinos and comets. The ORion ALMA New GEneration Survey (ORANGES) aims to

assess the number of hot corinos in the closest and best analogue to our Sun's birth environment, the OMC-2/3 filament. In this context, we investigated the chemical nature of 19 solar-mass protostars and found that 26% of our sample sources shows warm methanol emission indicative of hot corinos. Compared to the Perseus low-mass star-forming region, where the PErseus ALMA CHEmistry Survey (PEACHES) detected ~60% of hot corinos, the latter seem to be relatively scarce in the OMC-2/3 filament. While this suggests that the chemical nature of protostars in Orion and Perseus is different, improved statistics are needed in order to consolidate this result. If the two regions are truly different, this would indicate that the environment is likely playing a role in shaping the chemical composition of protostars.

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Full-text URL: https://arxiv.org/abs/2202.13835

Ionise hard: interstellar PO+ detection

Víctor M. Rivilla, Juan García de la Concepción, Izaskun Jiménez-Serra, Jesús Martín-Pintado, Laura Colzi, Belén Tercero, Andrés Megías, Álvaro López-Gallifa, Antonio Martínez-Henares, Sara Massalkhi, Sergio Martín, Shaoshan Zeng, Pablo De Vicente, Fernando Rico-Villas, Miguel A. Requena-Torres, Giuliana Cosentino

We report the first detection of the phosphorus monoxide ion (PO+) in the interstellar medium. Our unbiased and very sensitive spectral survey towards the G+0.693−0.027 molecular cloud covers four different rotational transitions of this molecule, two of which (J=1−0 and J=2−1) appear free of contamination from other species. The fit performed, assuming Local Thermodynamic Equilibrium conditions, yields a column density of N=(6.0±0.7)e11 cm−2. The resulting molecular abundance with respect to molecular hydrogen is 4.5e−12. The column density of PO+ normalised by the cosmic abundance of P is larger than those of NO+ and SO+, normalised by N and S, by factors of 3.6 and 2.3, respectively. The N(PO+)/N(PO) ratio is 0.12±0.03, more than one order of magnitude higher than those of N(SO+)/N(SO) and N(NO+)/N(NO). These results indicate that P is more efficiently ionised in the ISM than N and S. We have performed new chemical models that confirm that the PO+ abundance is strongly enhanced in shocked regions with high values of cosmic-ray ionisation rates (1e-15 − 1e-14 s−1), as occurs in the G+0.693−0.027 molecular cloud. The shocks sputter the interstellar icy grain mantles, releasing into the gas phase most of their P content, mainly in the form of PH3, which is converted into atomic P, and then ionised efficiently by cosmic rays, forming P+. Further reactions with O2 and OH produce PO+. The cosmic-ray ionisation of PO might also contribute significantly, which would explain the high N(PO+)/N(PO) observed. The relatively high gas-phase abundance of PO+ with respect to other P-bearing species stresses the relevance of this species in the interstellar chemistry of P.

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Absolute measurements of state-to-state rotational energy transfer between CO and H2 at interstellar temperatures

Hamza Labiad, Martin Fournier, Laura A. Mertens, Alexandre Faure, David Carty, Thierry Stoecklin, Piotr Jankowski, Krzysztof Szalewicz, Sébastien D. Le Picard, and Ian R. Sims

Experimental measurements and theoretical calculations of state-to-state rate

coefficients for rotational energy transfer of CO in collision with H2 are reported at the very low temperatures prevailing in dense interstellar clouds (5–20 K). Detailed agreement between quantum state-selected experiments performed in cold supersonic flows using time-resolved infrared–vacuum-ultraviolet double-resonance spectroscopy and close-coupling quantum scattering calculations confirms the validity of the calculations for collisions between the two most abundant molecules in the interstellar medium.

Physical Review A 105, L020802 (2022)
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Mid-IR and VUV spectroscopic characterisation of thermally processed and electron irradiated CO2 astrophysical ice analogues

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The astrochemistry of CO2 ice analogues has been a topic of intensive investigation due to the prevalence of CO2 throughout the interstellar medium and the Solar System, as well as the possibility of it acting as a carbon feedstock for the synthesis of larger, more complex organic molecules. In order to accurately discern the physico-chemical processes in which CO2 plays a role, it is necessary to have laboratory-generated spectra to compare against observational data acquired by ground- and space-based telescopes. A key factor which is known to influence the appearance of such spectra is temperature, especially when the spectra are acquired in the infrared and ultraviolet. In this present study, we describe the results of a systematic investigation looking into: (i) the influence of thermal annealing on the mid-IR and VUV absorption spectra of pure, unirradiated CO2 astrophysical ice analogues prepared at various temperatures, and (ii) the influence of temperature on the chemical products of electron irradiation of similar ices. Our results indicate that both mid-IR and VUV spectra of pure CO2 ices are sensitive to the structural and chemical changes induced by thermal annealing. Furthermore, using mid-IR spectroscopy, we have successfully identified the production of radiolytic daughter molecules as a result of 1 keV electron irradiation and the influence of temperature over this chemistry. Such results are directly applicable to studies on the chemistry of interstellar ices, comets, and icy lunar objects and may also be useful as reference data for forthcoming observational missions.

2022, Journal of Molecular Spectroscopy, 385, 111599
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The two hot corinos of the SVS13-A protostellar binary system: counterposed siblings

E. Bianchi, A. López-Sepulcre, C. Ceccarelli, C. Codella, L. Podio, M. bouvier, J. Enrique-Romero

We present ALMA high-angular resolution (~ 50 au) observations of the Class I binary system SVS13-A. We report images of SVS13-A in numerous interstellar complex organic molecules: CH3OH, 13CH3OH, CH3CHO, CH3OCH3, and NH2CHO. Two hot corinos at different velocities are imaged in VLA4A (Vsys= +7.7 km s-1) and VLA4B

(Vsys= +8.5 km s-1). From a non-LTE analysis of methanol lines we derive a gas density of 3e8 cm-3, and gas temperatures of 140 K and 170 K for VLA4A and VLA4B, respectively. For the other species the column densities are derived from a LTE analysis. Formamide, which is the only N-bearing species detected in our observations, is more prominent around VLA4A, while dimethyl ether, methanol and acetaldehyde are associated with both VLA4A and VLA4B. We derive in the two hot corinos abundance ratios of ~ 1 for CH3OH, 13CH3OH, and CH3OCH3, ~ 2 for CH3CHO, and ~ 4 for NH2CHO. The present dataset supports a chemical segregation between the different species inside the binary system. The emerging picture is that of an onion-like structure of the two SVS13-A hot corinos, caused by the different binding energies of the species, also supported by ad hoc quantum chemistry calculations. In addition, the comparison between molecular and dust maps suggests that the interstellar complex organic molecules emission originates from slow shocks produced by accretion streamers impacting the VLA4A and VLA4B disks and enriching the gas-phase component.

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Multiply charged naphthalene and its C10H8 isomers: bonding, spectroscopy and implications in AGN environments

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Naphthalene (C10H8) is the simplest polycyclic aromatic hydrocarbon (PAH) and an important component in a series of astrochemical reactions involving hydrocarbons. Its molecular charge state affects the stability of its isomeric structures, which is specially relevant in ionised astrophysical environments. We thus perform an extensive computational search for low-energy molecular structures of neutral, singly, and multiply charged naphthalene and its isomers with charge states +q = 0-4 and investigate their geometric properties and bonding situations. We find that isomerisation reactions should be frequent for higher charged states and that open chains dominate their low-energy structures. We compute both the scaled-harmonic and anharmonic infrared spectra of selected low-energy species and provide the calculated scaling factors for the naphthalene neutral, cation, and dication global minima. All simulated spectra reproduce satisfactorily the experimental data and, thus, are adequate for aiding observations. Moreover, the potential presence of these species in the emission spectra of the circumnuclear regions of active galactic nuclei (AGNs), with high energetic X-ray photon fluxes, is explored using the experimental value of the naphthalene photodissociation cross-section, sigma_{ph-d}, to determine its half-life, t_{1/2}, at a photon energy of 2.5 keV in a set of relevant sources. Finally, we show that the computed IR bands of the triply and quadruply charged species are able to reproduce some features of the selected AGN sources.

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Detection of the S(1) Rotational Line of H2 toward IRC+10216: A Simultaneous Measurement of Mass-Loss Rate and CO Abundance

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We report the first detection of the S(1) pure rotational line of ortho-H2 at 17.04 um in an asymptotic giant branch star, using observations of IRC+10216 with the Echelon-cross-echelle Spectrograph (EXES) mounted on the Stratospheric Observatory for Infrared Astronomy (SOFIA). This line, which was observed in a very high sensitivity spectrum (RMS noise ~0.04% of the continuum), was detected in the wing of a strong telluric line and displayed a P Cygni profile. The spectral ranges around the frequencies of the S(5) and S(7) ortho-H2 transitions were observed as well but no feature was detected in spectra with sensitivities of 0.12% and 0.09% regarding the continuum emission, respectively. We used a radiation transfer code to model these three lines and derived a mass-loss rate of 2.43(0.21)E-05 M_sun/yr without using the CO abundance. The comparison of this rate with previous estimates derived from CO observations suggests that the CO abundance relative to H2 is 6.7(1.4)E-04. From this quantity and previously reported molecular abundances, we estimate the O/H and C/H ratios to be 3.3(0.7)E-04 and >5.2(0.9)E-04, respectively. The C/O ratio is >1.5(0.4). The absence of the S(5) and S(7) lines of ortho-H2 in our observations can be explained by the opacity of hot dust within 5R* from the center of the star. We estimate the intensity of the S(0) and S(2) lines of para-H2 to be ~0.1% and 0.2% of the continuum, respectively, which are below the detection limit of EXES.

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The Central 1000 au of a Pre-stellar Core Revealed with ALMA. II. Almost Complete Freeze-out

Paola Caselli, Jaime E. Pineda, Olli Sipilä, Bo Zhao, Elena Redaelli, Silvia Spezzano, Maria José Maureira, Felipe Alves, Luca Bizzocchi, Tyler L. Bourke, Ana Chacón-Tanarro, Rachel Friesen, Daniele Galli, Jorma Harju, Izaskun Jiménez-Serra, Eric Keto, Zhi-Yun Li, Marco Padovani, Anika Schmiedeke, Mario Tafalla, Charlotte Vastel

Pre-stellar cores represent the initial conditions in the process of star and planet formation. Their low temperatures (<10 K) allow the formation of thick icy dust mantles, which will be partially preserved in the future protoplanetary disks, ultimately affecting the chemical composition of planetary systems. Previous observations have shown that carbon- and oxygen-bearing species, in particular CO, are heavily depleted in pre-stellar cores due to the efficient molecular freeze-out onto the surface of cold dust grains. However, N-bearing species such as NH3 and, in particular, its deuterated isotopologues, appear to maintain high abundances where CO molecules are mainly in solid phase. Thanks to ALMA, we present here the first clear observational evidence of NH2D freeze-out toward the L1544 pre-stellar core, suggestive of the presence of a "complete-depletion zone" within a ~1800 au radius, in agreement with astrochemical pre-stellar core model predictions. Our state-of-the-art chemical model coupled with a non-LTE radiative transfer code demonstrates that NH2D becomes mainly incorporated in icy mantles in the central 2000 au and starts freezing-out already at ~7000 au. Radiative transfer effects within the pre-stellar core cause the NH2D(1_11-1_01) emission to appear centrally concentrated, with a flattened distribution within the central ~3000 au, unlike the 1.3 mm dust continuum emission which shows a clear peak within the central ~1800 au. This prevented NH2D freeze-out to be detected in previous observations, where the central 1000 au cannot be spatially resolved.

The Astrophysical Journal, in press

Full-text URL: https://arxiv.org/abs/2202.13374

SOFIA/GREAT observations of OD and OH rotational lines towards high-mass star forming regions

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Only recently, OD, the deuterated isotopolog of hydroxyl, OH, has become accessible in the interstellar medium; spectral lines from both species have been observed in the supra-Terahertz and far infrared regime. Here we study rotational lines of OD and OH towards 13 Galactic high-mass star forming regions, with the aim to constrain the OD abundance and infer the deuterium fractionation of OH in their molecular envelopes. We used the Stratospheric Observatory for Infrared Astronomy (SOFIA) to observe the 2Π3/2 J=5/2−3/2 ground-state transition of OD at 1.3 THz (215 µm) and the rotationally excited OH line at 1.84 THz (163 µm). We also used published high-spectral-resolution SOFIA data of the OH ground-state transition at 2.51 THz (119.3 µm). Our results show that absorption from the 2Π3/2 OD J=5/2−3/2 ground-state transition is prevalent in the dense clumps surrounding active sites of high-mass star formation. We performed detailed radiative transfer modelling to investigate the OD abundance profile in the inner envelope for a large fraction of our sample. Our modelling suggests that part of the absorption arises from the denser inner parts, while the bulk of it as seen with SOFIA originates in the outer, cold layers of the envelope for which our constraints on the molecular abundance suggest a strong enhancement in deuterium fractionation. We find a weak negative correlation between the OD abundance and the bolometric luminosity to mass ratio, an evolutionary indicator, suggesting a slow decrease of OD abundance with time. A comparison with HDO shows a similarly high deuterium fractionation for the two species in the cold envelopes, which is of the order of 0.48% for the best-studied source, G34.26+0.15. Our results are consistent with chemical models that favour rapid exchange reactions to form OD in the dense cold gas.

2022 Astronomy & Astrophysics 658, A193
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Full-text URL: https://arxiv.org/abs/2201.00635

Rotational spectroscopy of isotopic oxirane, c-C2H4O

Holger S. P. Müller, Jean-Claude Guillemin, Frank Lewen, Stephan Schlemmer

We studied the rotational spectrum of oxirane in a sample of natural isotopic composition in selected regions between 158 GHz and 1093 GHz. Investigations of the isotopologs with one 13C or one 18O were the primary focus in order to facilitate searches for them in space. We also examined the main isotopic species mainly to look into the performance of Watson's A and S reductions both in an oblate and in a prolate representation. Even though oxirane is a rather asymmetric oblate rotor, the A reduction in the IIII representation did not yield a satisfactory fit, as was observed frequently earlier for other molecules. The other three combinations yielded satisfactory fits of similar quality among each other; the A reduction in the Ir representation required two parameters less than both S reduction fits.

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Full-text URL: https://arxiv.org/abs/2201.09266

Uniform Supersonic Flows in Chemical Physics: Chemistry Close to Absolute Zero Studied Using the CRESU Method

B.R. Rowe, A. Canosa and D.E. Heard (editors)

Radioastronomy has painted an extraordinary picture of the Galactic interstellar medium, which displays an amazing organization and structuring of matter from very hot ultra-diluted media to very cold denser milieus considered as the cradles of stars. In these latter environments, the discovery of a chemical diversity of molecules, including those associated with precursors to life itself, immediately brought to light the question of the mechanisms leading to their formation and persistence at temperatures as low as 10 K. The chemical networks developed to understand telescope observations required a great deal of physical and chemical parameters relevant to interstellar conditions, particularly at very low temperatures. These included the rate coefficients of thousands of gas phase chemical reactions. Such data were missing in the 1970s, when the very first molecular discoveries were made. Then, in the early eighties, it was realised that uniform supersonic flows were ideal chemical reactors to study reaction kinetics at interstellar temperatures. Uniform Supersonic Flows in Chemical Physics reviews 40 years of use of such reactors, the so-called CRESU machines, focusing on major breakthroughs brought to chemical physics, physical chemistry, astrophysics and astrochemistry by the various experiments carried out with such apparatuses. The wealth of kinetic data at very low temperatures provided new targets for the predictions of theory, with new theoretical methods being developed to explain observed behaviour. The first two chapters describe the physical context of reaction kinetics at very low temperatures and the requirements needed to run optimally such uniform supersonic flows, together with an historical perspective. Chapters 3 to 9 describe the various families of chemical processes that have been explored within the CRESU technique, highlighting major advances and offering an exhaustive up-to-date bibliography. Chapters 10 and 11 show how these experimental results have helped in improving the ideas in quantum chemistry and interstellar modelling. The book concludes with an overview of potential perspectives and new routes to be explored.

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(Sub-)millimeter-wave spectroscopy of gauche-propanal

Oliver Zingsheim, Holger S. P. Müller, Luis Bonah, Frank Lewen, Sven Thorwirth, Stephan Schlemmer

A detailed analysis of (sub-)millimeter-wave spectra of the vibrational ground state (v=0) combined with the energetically lowest excited vibrational state (v24=1; aldehyde torsion) of gauche-propanal (g-C2H5CHO) up to 500 GHz is presented. Both vibrational states, υ=0 and v24=1, are treated with tunneling rotation interactions between their two respective tunneling states, which originate from two stable degenerate gauche-conformers; left- and right-handed configurations separated by a small potential barrier. Thanks to double-modulation double-resonance (DM-DR) measurements, important but weak c-type transitions connecting the tunneling states could be unambiguously assigned. In addition, Coriolis interaction as well as Fermi resonance between the two vibrational states needed to be taken into account to derive fits with experimental accuracy using Pickett's SPFIT program in a reduced axis system (RAS). Based on the rotational analysis, the fundamental vibrational frequency nu24 of gauche-propanal is redetermined to 68.75037(30) cm−1.

J. Mol. Spectrosc. 384 (2022) Art. No. 111565
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Full-text URL: https://arxiv.org/abs/2112.04945

CHEMOUT: CHEMical complexity in star-forming regions of the OUTer Galaxy. I. Organic molecules and tracers of star-formation activity

F. Fontani, L. Colzi, L. Bizzocchi, V.M. Rivilla, D. Elia, M.T. Beltran, P. Caselli, L. Magrini, A. Sanchez-Monge, L. Testi, D. Romano

The outer Galaxy is an environment with metallicity lower than the Solar one. Because of this, the formation and survival of molecules in star-forming regions located in the inner and outer Galaxy is expected to be different. To gain understanding on how chemistry changes throughout the Milky Way, it is crucial to observe outer Galaxy star-forming regions to constrain models adapted for lower metallicity environments. In this paper we present a new observational project: chemical complexity in star-forming regions of the outer Galaxy (CHEMOUT). The goal is to unveil the chemical composition in 35 dense molecular clouds associated with star-forming regions of the outer Galaxy through observations obtained with the IRAM 30m telescope. In this first paper, we present the sample, and report the detection at 3~mm of simple organic species HCO+, H13CO+, HCN, c-C3H2, HCO, C4H, and HCS+, of the complex hydrocarbon CH3CCH, and of SiO, CCS and SO. From c-C3H2, we estimate new kinematic heliocentric and Galactocentric distances based on an updated rotation curve of the Galaxy. The detection of the molecular tracers does not seem to have a clear dependence on the Galactocentric distance. We also analyse the HCO+ line profiles. We find high velocity wings in ~71% of the targets, and their occurrence does not depend on the Galactocentric distance. Our results, confirmed by a statistical analysis, show that the presence of organic molecules and tracers of protostellar activity is ubiquitous in the low-metallicity environment of the outer Galaxy. Based on this, and on the additional evidence that small, terrestrial planets are omnipresent in the Galaxy, we support previous claims that the definition of Galactic Habitable Zone should be rediscussed in view of the ubiquitous capacity of the interstellar medium to form organic molecules.

A&A, in press
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Full-text URL: https://arxiv.org/abs/2203.00719

Announcements

The lifecycle of cosmic PAHs - symposium, Aarhus University, DK, 5-9 Sept 2022

Registration is now open for the “The lifecycle of cosmic PAHs" symposium, at Aarhus University, Denmark from 5th-9th September 2022.
Abstract submission for contributed talks and posters closes on 2nd May 2022.
For more information please visit the symposium webpage
https://conferences.au.dk/cosmicpah2022/
Polycyclic Aromatic Hydrocarbons (PAHs) are ubiquitous in space where they play a key role in the heating of interstellar gas via the photoelectric effect, in setting the ionization balance of the interstellar medium (ISM) and potentially also as catalysts for formation of interstellar molecular complexity and as a component of interstellar organic material and dust. PAHs are identified as carriers of the aromatic infrared bands (AIBs) and are

observed in a diverse range of interstellar environments. Yet, their lifecycle in interstellar space is still not well understood.
The aim of this symposium is to bring observational astronomers, theorists and experimentalists working on PAH observations, formation, fragmentation, photo-physics, spectroscopy, surface science and chemistry together to shed light on the lifecycle of cosmic PAHs and to explore the future opportunities for PAH research provided by novel theoretical and experimental methods and future observational missions with focus on JWST and ELT. This is the third installment in a series of meetings on interstellar polycyclic aromatic hydrocarbons (PAHs) with previous meetings held in Toulouse in 2010 and in Noordwijk in 2016.

Invited speakers include:
Kathrin Altwegg, University of Bern; José Ángel Martín Gago, CSIC; Partha P. Bera, NASA Ames Research Center; Christiaan Boersma, NASA Ames Research Center; Sandra Brünken, Radboud University; Wybren Jan Buma, Universiteit van Amsterdam; Jan Cami, University of Western Ontario; Ewen K. Campbell, University of Edinburgh; Jeremy Chastenet, University of California San Diego; Leen Decin, Univesity of Leuven; Francois Dulieu, Université de Cergy-Pontoise; Michael Duncan, University of Georgia; M. Samy El-Shall, Virginia Commonwealth University; Christine Joblin, Université Toulouse III - Paul Sabatier; Rocco Martinazzo, Università degli Studi di Milano; Stefanie N. Milam, NASA Goddard Space Flight Center; Giacomo Mulas, INAF; Conor A. Nixon, NASA Goddard Space Flight Center; Jos Oomens, Radboud University; Melanie Schnell, Christian-Albrechts-Universität zu Kiel; Alan Tokunaga, University of Hawaii; Henning Zettergren, Stockholm University; Xander Tielens, Leiden University.

Scientific Organising Committee: Liv Hornekær; Els Peeters; Olivier Berné; Xander Tielens; Annemieke Petrignani. Local Organising Committee: Andrew Cassidy; John Thrower; Rijutha Jaganathan; Gabi Wenzel; Karin Vittrup; Liv Hornekær.

Postdoctoral Position in Experimental Molecular Astrophysics

The Columbia Astrophysics Laboratory (CAL) invites applications for a Postdoctoral Research Scientist (PdRS) to perform laboratory studies of dissociative recombination for key molecular ions that are used to probe the properties of diffuse clouds in the interstellar medium. The experiments will be performed on the Cryogenic Storage Ring (CSR), which is located at the Max Planck Institute for Nuclear Physics (MPIK) in Heidelberg, Germany. The successful candidate will based in Heidelberg, Germany, and will provide the day-to-day leadership for the CAL-MPIK collaboration, headed by Dr. Daniel Wolf Savin at CAL and Dr. Oldřich Novotný at MPIK.
The appointment is initially for one year, with the possibility of renewal for up to two additional years; this is contingent upon the availability of funds and mutual satisfaction. The successful candidate will have a Ph.D. or the equivalent degree in Physics, Chemistry, Astrophysics, or a related field, with an emphasis in molecular physics. Desired laboratory skills include operation of particle detectors and related electronics, analog and digital signal processing, data reduction and multidimensional data analysis, and statistical and systematic error propagation. Desired computer skills include programming (ROOT, C++, LabView, Python), 3D CAD (SolidEdge), Linux OS, and Windows OS.
The successful candidate will have a strong background in at least some of the areas listed above, a proven research ability, and evidence of future research potential. The candidate is expected to be able to work well independently and cooperatively with a team and to communicate the results of his/her research both orally and in writing. Demonstrated written and oral communication skills are highly desirable. Questions regarding this position can be addressed to Dr. Savin at dws26@columbia.edu.

Applicants should submit a cover letter, curriculum vitae (including a list of publications) and statement of past research. In addition, they should arrange to have three letters of reference sent directly by the writers to Dr. Savin. Applications will be considered only after all of the requested material has been received. Applications and letters should be submitted by email to dws26@columbia.edu. Screening of applicants will begin immediately and will continue until the position has been filled.
Columbia is an Equal Opportunity Employer/Disability/Veteran Employer. CAL values a diverse workforce and culture of inclusion, which are keys to attracting and engaging the brightest minds to further our record of scientific excellence and groundbreaking innovations. Applications from women, minorities, and other underrepresented groups are strongly encouraged.