Multidisciplinary Astrochemistry School

Centro de Astrobiología
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Author:

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Title of the poster:

Tracing the thermal and chemical history of interstellar ices

Abstract:

Simple ices form on the surfaces of dust grains in the very early stages of star formation. During stellar evolution their structure and composition can be severely modified by protostellar heating where species can segregate and even sublimate from the grain surface. Key to understanding these processes are thermal and chemical traces, ices with absorption bands that are sensitive to their local environment. Carbon monoxide (CO) and carbon dioxide (CO_2) in particular have proven to be valuable tracers of ice composition and ice heating events. They are found in high abundance in the solid state towards many protostellar sources and have multiple absorption bands in the near- and mid-infrared. One hindrance however is the fact that the strong ice absorption bands of CO and CO_2 suffer from grain shape and size effects that can alter the regular appearance of the absorption feature. In the case of CO_2 an alternative tracer is the weaker $^{13}CO_2$ isotopologue band that also shows intriguing variations depending on the line of sight. Now with the exquisite sensitivity and high resolution of the JWST this weaker band has become accessible at high S/N, allowing us to study its profile in greater detail than ever before. Combined with high resolution laboratory data, we are now well equipped to analyze the ice profiles of CO and CO_2 and their isotopologues and determine isotope ratios. This will give us a better understanding of the physicochemical processes that take place during stellar evolution.

Author:

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Observatorio Astronómico Nacional (OAN, IGN)

Title of the poster:

Sulfur molecules in protoplanetary discs

Abstract:

Although sulfur is one of the key elements for life, the chemistry of this element is poorly understood in interstellar environments, and the location of the main reservoirs remains unknown. To shed more light on this issue, we used the IRAM 30 m telescope to collect spectra for 21 young stellar objects. We have employed the GILDAS/CLASS software to reduce and analyze these spectra, finding clear evidences of CS, H_2CO and H_2S emission lines for a significant part of the sample. In addition, weaker emission lines corresponding to other molecules have been measured.

Author:

Carlos del Burgo Olivares

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Title of the poster:

MOSS: An Interstellar Chamber to Mimic Organic Synthesis in Space

Abstract:

We present the incipient MOSS (Mimicking Organic Synthesis in Space), designed for the formation and processing of ice mantles in interstellar and circumstellar medium conditions. MOSS is a high-vacuum setup with a base pressure below P = $1x10^{-7}$ mbar where a sample holder at the end of a cold finger reaches a temperature of about 87 K by means or an open-cycle liquid N_2 cooling system. A substrate, typically composed of a Mid-IR transmitting material (KRS5, MgF2 or CaF_2), is placed on it where the ice layer is deposited. The ices are processed with UV radiation from a D_2 lamp. The sample is subsequently slowly heated to room temperature, resulting in a residue containing the most refractory products of the photonic and thermal processing. This residue will be analysed outside the chamber by IR spectroscopy, to know the main functional groups of the molecules it contains, and by GC-MS, to separate the products and know their relative amounts.

Author:

AntoineEspagnet

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Title of the poster:

Modeling the Chemistry of Solar-type Protostars

Abstract:

More and more large spectral surveys are carried out in the radio/submm/mm range to characterize the molecular composition of star-forming regions. As chemical compositions can differ from one source to another, it is important to study the origin of these differences.

Some YSOs (Young Stellar Objects) exhibit luminosity bursts triggered by episodic accretion. The sudden rise in temperature caused by the luminosity burst can sublimate some of the molecules frozen on the dust grains. The release of new molecules into the gas phase and the increase in temperature could probably affect the long-term evolution of the chemical environment. But the impact of luminosity bursts on the chemistry of protostellar systems has not been studied thoroughly. In this study, we model the impact of single luminosity bursts on the chemical composition of solar-type protostars, from the hot inner region of the envelope (hot corino) to the cold outer region. The analysis of these results will allow us to identify chemical tracers of past luminosity bursts, which will be compared to observational studies.

Author:

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Title of the poster:

Multi-scale study of sulfur chemistry in hot corinos

Abstract:

Studying the sulfur chemistry in young protostars is key to understand the origin and delivery of this element to our own planet. This work focuses on analysing the spectral lines of sulfur bearing species of the ECHOS project sample of Class 0 protostars. These protostars are complex systems with different components: cold envelope (R~10000 au), hot core (R~100 au) y bipolar outflow (high-velocity gas), and with different physical and kinematic contitions. The combination of data from single-dish spectra (IRAM-30m, Yebes-40m) and interferometric data from NOEMA and ALMA, will allow us to study the chemical variations between the different components, as well as within the same component.

Author:

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Institution:

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Title of the poster:

Experimental characterizing of porous particles with photopolarimetry

Abstract:

Investigating the properties of cosmic dust is crucial for advancing our understanding of the interstellar medium and the initial stages of planetary systems. These studies also offer valuable data for comparing against theoretical models and simulations. Presently, one of the most fascinating aspects of cosmic dust is its porosity, which varies in both size and density of pores on the surfaces of dust grains. Variations in porosity result in differences in light scattering when other properties remain constant. Therefore, examining porosity is vital for enhancing our knowledge of light scattering phenomena. Our research methodology involves measuring the light reflected from surfaces with specifically characterized porosities to isolate the impact of this property. We direct a laser beam onto the flat surfaces of cylinders made from cosmic dust analogs and measure the scattered light across an angular range from 90 to 177 degrees using the IAA apparatus at the CoDuLab, as detailed by Mu et al. (2010). Our experimental setup is designed to measure all elements of the Mueller Matrix, providing a comprehensive analysis of how porosity influences light scattering.

Author:

Pau Grèbol-Tomàs

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Title of the poster:

Nanoindentation of Lunar Basalts: Mechanical Properties of the Northwest Africa (NWA) 12008 Meteorite

Abstract:

A good knowledge of the mechanical properties of lunar meteorite samples and their analogs may be particularly relevant to design future lunar space missions (e.g. Artemis). Moreover, a proper classification of extraterrestrial materials is key when devising maneuvers where physical contact processes are crucial, especially for in-situ resource utilization (ISRU) and even impact-hazard defense missions (e.g. DART).

In this work, we tackle the study of meteorite mechanical properties using nanoindentation. This quasi-nondestructive and powerful technique is still quite uncommon for mechanical studies of extraterrestrial samples. We have evaluated the hardness, Young modulus, and elastic and plastic works of different minerals of NWA 12008, a highly-shocked lunar basalt.

Our preliminary results show that there may be intrinsic differences between the mechanical properties of former Earth minerals and their lunar counterparts, specially for olivine. We hypothesize that this remarkable behavior may be attributed to a high porosity of this achondrite. The different behaviors arise several questions about their formation environments: how different were primordial Earth and primordial Moon? What were their physical and chemical particularities? How does asteroidal impact change lunar mechanical properties?

Author:

Claudio Hernández-Vera

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Pontificia Universidad Católica de Chile

Title of the poster:

Constraining the icy origin of H_2CO in HD 163296

Abstract:

Protoplanetary disks are considered a material reservoir for planetary assembly. Hence, resolving the spatial distribution of complex organic molecules (COMs) in protoplanetary disks is crucial in estimating the potential habitability of other worlds. Unfortunately, a significant portion of the organic inventory is thought to be locked on the surface of dust grains, mostly the O-bearing COMs. In this case, smaller but brighter tracers like formaldehyde (H_2CO) can be used. H_2CO is a small organic molecule considered a precursor of O-bearing COMs on the icy surfaces of dust grains, but gas-phase reactions can also form it. Since the specific contribution of each mechanism is poorly constrained, determining the dominant formation pathway of H_2CO is necessary for setting up its potential as a tracer of the cold reservoir in protoplanetary disks. In this context, we resolved several H_2CO lines toward the bright protoplanetary disk HD 163296 with ALMA. We determined the excitation conditions of H_2CO as a function of disk radius and put constraints on the height of H_2CO emission to get clues about its formation. We expect to complement our results with the DECO ALMA large program sample of 80 protoplanetary disks to obtain representative statistics of H_2CO formation.

Author:

Seonjae Lee

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Seoul National University

Title of the poster:

Chemical Modelling of HCN/HNC Ratio in Different Environments

Abstract:

Hydrogen cyanide (HCN) and Hydrogen isocyanide (HNC) are isomers that have similar chemical properties. However HNC can be reduced into other molecules with reactions with atomic hydrogen (H) and atomic oxygen (O), resulting in the variation of the HCN/HNC abundance ratio. The reaction rates differ by gas temperature, resulting in different abundance ratios in different environments. The barrier energies of these reactions are in dispute.

In this work, we calculated the HCN/HNC abundance ratio in different physical/chemical environments, using the chemical code PURE-C. The abundance ratio seen in many observations are reproduced in models with low barrier energies, contrary to quantum calculations reported before. We examine the effects of timescale, temperature, UV radiation, cosmic ray ionization, and gas density on the abundance ratio. One-point simulations of protoplanetary disk midplane in an accretion burst were performed. Finally, we analyze the HCN/HNC ring of a protoplanetary disk, V883 Ori using our model.

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Title of the poster:

Modeling of the High-velocity Jet Powered by the Massive Star MWC 349A

Abstract:

Jets and disk winds arise from materials with excess angular momentum ejected from the accretion disk in forming stars. The launching mechanism and their impact within the innermost gas of these objects remains vastly unknown. MWC349A is a massive star with a circumstellar disk in Keplerian rotation and an ionized wind launched from the disk surface. ALMA observations of hydrogen radio recombination lines (RRLs) masers from this system provide a detailed picture of its ionized environment. The analysis of the unresolved H30α and H26α RRL emission with the 3D non-LTE radiative transfer model MORELI reveals an ionized jet with a velocity of 250 km/s launched from the disk and engulfed within the ionized wind. Our model shows that the jet is poorly collimated and slightly misaligned with respect to the disk rotation axis. We present additional ALMA observations of the H26α maser in the most extended configuration with a resolution of 0.02 that resolves the RRL emission for the first time. The resolved emission is in agreement with the model developed to fit the unresolved emission. Our results show the potential of RRL masers as powerful probes of the innermost ionized regions and the high-velocity jets from massive stars.

Author:

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Title of the poster:

The missing sulfur problem: the H_2S and OCS cases

Abstract:

H_2S and OCS are formed efficiently in the surface of interstellar grains, as complex organic molecules do, which are the precursors of life. The study of H_2S and OCS chemistry is important to determine which reactions are produced in grains′ surfaces and the efficiency of the different processes to release these molecules to the gas phase. We study the chemistry of these molecules using high spatial resolution observation from the NOEMA interferometer of a sample of 24 protostars from the Perseus cloud, located in regions with different star formation activity. The comparison between these objects allows us to investigate the influence of the environment in the formation of these species. In addition, we present new detections of D_2S in Class 0 protostars. Results show that sulfur grain surface molecules reveal hotter and/or more dynamic regions near the cores of young protostars, thus providing valuable information on the dynamical evolution in these early stage of the formation of low and intermediate-mass stars.

Author:

Wiebke Riedel

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Title of the poster:

Forming methanol by nondiffusive processes

Abstract:

Complex organic molecules (COMs) form in a lukewarm temperature regime (30-100K) during a gradual warm-up phase of the molecular clouds, when grain surface radicals become more mobile. However, multiple COMs have recently been discovered in the gas phase of pre-stellar cores at low temperatures (<15K), questioning the warm scenario as the sole formation process and making it necessary to explore nondiffusive reaction mechanisms. Pre-stellar cores are ideal for studying nondiffusive processes, as heavy precursors of COMs are immobile on the dust grains due to the low temperatures. In these physical conditions, deuteration is enhanced, providing valuable additional information on chemical pathways.

We added several nondiffusive reaction mechanisms Eley-Rideal reactions, photodissociation-induced reactions and three-body reactions into a gas-grain chemical code (Sipilä+2015a, Sipilä+2019b) which includes deuterium chemistry. Our first tests target the simplest of O-bearing COMs - methanol and its singly deuterated isotopologue. We performed a 1D-model of the pre-stellar core L1544, which is one of the best studied objects of its kind.

We find that the Eley-Rideal mechanism has the largest effect among the explored mechanisms, increasing the column density by an order of magnitude to a level which is in good agreement with observations, but simultaneously suppressing deuteration.

Author:

Marten Scheuck

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Title of the poster:

Asymmetries in the innermost regions of circumstellar disks

Abstract:

In order to further constrain planet formation we study the innermost regions of circumstellar disks (r<10 au), the composition and structure of these regions plays an important part in the formation of planetary systems.

Many of these disks show, in addition to gaps and rings, asymmetric structures that are, as of yet, not well understood and often located between 0.1 to 10 au. We aim to understand their spatial and spectral structure with high angular resolution (resolving sub-au size structures) using the VLTI/MATISSE instrument in the mid-infrared range by characterising the chemical makeup of the disks using the spectral line information that describes the dust species appearing in them. Using the VLTI/MATISSE interferometric data in conjunction with VLTI/PIONIER and VLTI/GRAVITY data we apply an analytical modelling approach deducing a best fit model using Bayesian statistics. We are interested in the disks around bright Young Stellar Objects (YSOs), located a few hundred parsec away, with our main focus being the Herbig Ae/Be stars, but also T Tauri stars, and debris disks. With the results of these modelling we hope to gain more in depth knowledge on the role these innermost disks play in planet formation.

Author:

Katerina Slavicinska

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Leiden Observatory

Title of the poster:

Investigating chemical inheritance versus reset during star formation via deuterated water ice detected with JWST

Abstract:

Water-rich ices that form on interstellar dust grains in prestellar cores are thought to be potential birthplaces and reservoirs of many complex organic molecules (COMs). However, due to the powerful physical processes that occur throughout star and planet formation, it is uncertain how much of this primordial water ice is preserved (i.e., inherited) versus how much is destroyed and reformed (i.e., reset) before it can be accreted into planetary bodies. The similarity of cometary HDO/H_2O ratios to gas-phase HDO/H_2O ratios measured interferometrically in the hot inner regions of clustered low-mass protostars suggests that cometary ices are largely inherited from the prestellar stage with little chemical alteration, but it is still a matter of debate whether gas-phase chemical abundances reflect the composition of sublimated protostellar ices or if they are strongly affected by gas-phase chemistry. To resolve this debate, ice deuterium abundances must be probed directly, which is now possible with the unprecedented sensitivity of the James Webb Space Telescope (JWST). In this work, we present HDO/H_2O ice ratios derived from JWST protostellar spectra and compare them to gas-phase HDO/H_2O ratios measured towards protostellar objects in various evolutionary stages to determine if primordial COM-rich interstellar ices are preserved throughout star formation.

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Title of the poster:

A systematic FTIR and VUV investigation of ion, electron, and thermal processing of ethanolamine ices

Abstract:

Ethanolamine (EtA) is a crucial component of cell membranes, recently detected in the interstellar medium (ISM) by Rivilla et al. 2021. The endurance and resilience of EtA under ISM conditions remain unproven. We exposed pure EtA and H_2O:EtA mixed ices to various energetic mechanisms in controlled lab conditions. FTIR and VUV spectra were collected during electron and He+ ion irradiation at 20 K. Products like H_2O, CO, CO_2, OCN-, HNCO, NH_3, C_2H_5OH, and CH_3CHO were identified.

Electron irradiation destroyed 29.3% of pure EtA ice and 7.98% of EtA in mixed ice, while He+ ions destroyed almost all EtA in a water environment (99.6%). These differences align with ions deeper penetration in thicker ices. EtA mixed in water ice proved more stable than its pure form. H_2O:EtA mixed ice in KBOs would degrade within 910 years, while in cold dense clouds, its half-life would be 1.7×10^7 years, indicating greater stability. This research sheds light on EtA′s behavior under ISM conditions, crucial for understanding its role in the origins of life.

Author:

Ann Mary Wilson

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Title of the poster:

Radiolysis of pure Interstellar ice analogues using electrons

Abstract:

Star formation in the interstellar medium (ISM) takes place in regions of low temperature and high density, called dense clouds. These cold conditions lead to the formation of icy mantles on dust grains, made by the condensation of molecules such as water, methane, and ethanol. The irradiation of these species using electrons and UV photons is a subject of much research as such reactions take place in dense clouds.

Irradiation of pure methane, water, ethanol, and the mixtures of these species using electrons was performed at an extremely low temperature (8 K) and high vacuum pressure simulating the conditions of ISM, to find a formation pathway for Dimethyl ether which has been observed towards various star formation regions. The irradiated ices were probed using Vacuum ultraviolet (VUV) light produced by the synchrotron light source, ASTRID 2 at ISA, Centre for Storage Ring Facilities, Aarhus. In addition, the VUV photo absorption spectra of various ices will provide necessary reference spectra to aid the analysis of data obtained by the JUICE and other observational space missions.

Author:

Enyi Zhu

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Title of the poster:

L_X/L_bol distribution of field M dwarfs and its influence on planet habitability

Abstract:

Searching for habitable planets around M dwarfs has drawn increasing attention due to their good detectability. However, the strong UV and X-ray flares of some M dwarfs might cause severe atmospheric escape of the planet and prohibit the emergence of life. The goal of this master thesis is thus to establish the distribution of fractional X-ray luminosity, L_X/L_bol, of field M dwarfs and characterize their influence on planets in the habitable zone.

The unbiased X-ray sample of my thesis reaches 85% completeness for M dwarfs earlier than M6 (mass>0.1 Mʘ) up to 10 pc from the Sun. The final cumulative distribution of L_X/L_bol of field M dwarfs shows that although half of them are more X-ray luminous than typical K and G stars, 68.5% to 97% of them have biological effective irradiance (UV irradiation that are harmful to DNAs) smaller than prebiotic Earth value. As prebiotic chemistry already took place at that time on Earth, the UV irradiation of M dwarfs is actually not harmful for prebiotic life on the majority of planets.