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nanocosmos

GAS AND DUST FROM STARS TO THE LABORATORY: EXPLORING THE NANOCOSMOS

José Cernicharo, Christine Joblin, José Ángel Martín-Gago

Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

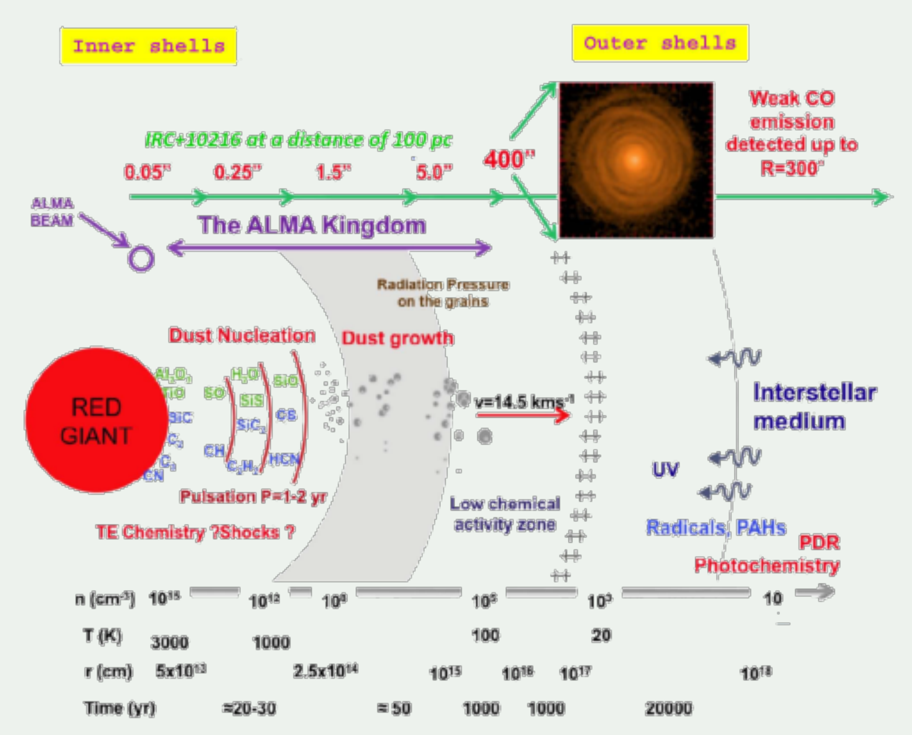
Institut de Recherche en Astrophysique et Planétologie - Université de Toulouse (UPS) & CNRS, France

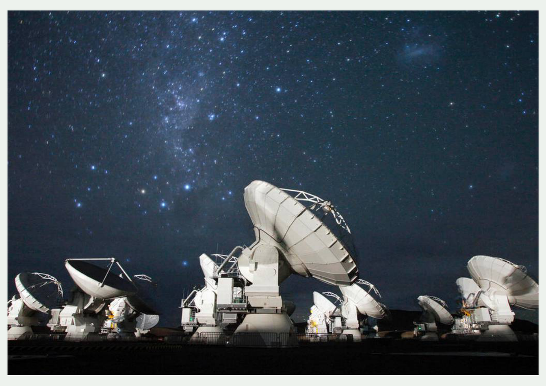
Presenter: Nick Cox (IRAP/CNRS, Toulouse)

Star death is the beginning of stardust

While cosmic molecules are formed under a large range of physical conditions, dust grains can only be efficiently formed in the innermost warm regions of evolved stars, mainly Asymptotic Giant Branch (AGB) stars, and in supernovae (SNe) explosions of more massive stars. SNe constitute the only possible sites for dust formation in the early Universe.

Dust formation scenario in AGBs can be simplified as a two-step process (see Fig. 1): formation of condensation seeds from the most refractory elements, followed by growth through condensation of refractory molecules at high temperature and other less refractory species at larger distances from the star. However many mysteries in this picture remain to be solved. A global picture of the dust and gas spatial distribution at subarsecond angular scales is still missing but major breakthroughs are expected thanks to the improved angular resolution of the new generation of instruments, e.g. ALMA & VLTI.



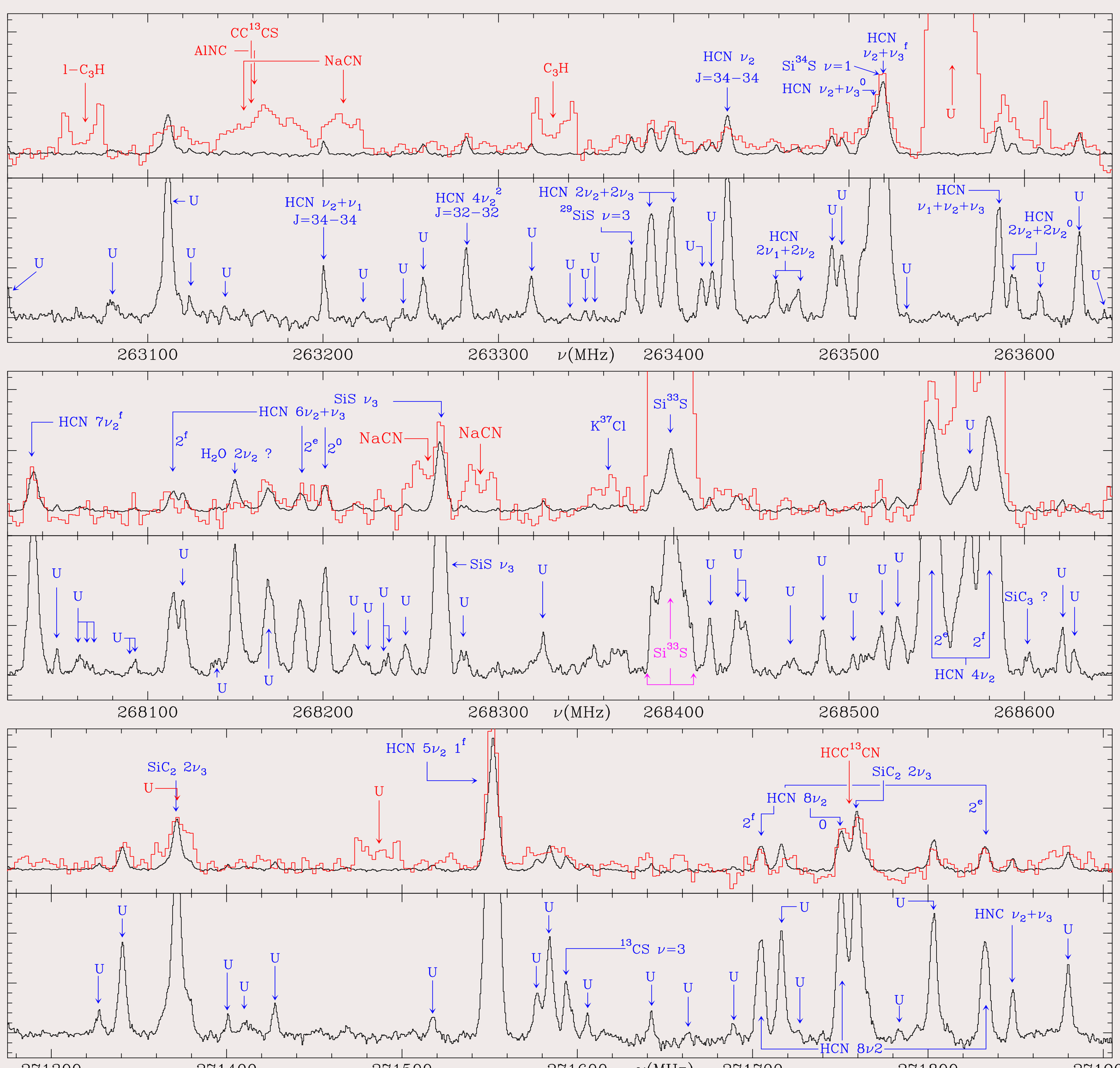


In C-rich AGBs, carbonaceous grains (SiC grains, hydrogenated amorphous carbons) are formed, whereas in O-rich AGBs silicates and other oxides are formed. In PPNe/PNe, carbonaceous grains are processed from a more aromatic character. Large polycyclic aromatic hydrocarbons (PAHs) that carry the 3.3-12 µm emission features are observed in interstellar and circumstellar UV-irradiated regions.

Stellar **dust is processed**, altering its physical & chemical properties, by UV photons, energetic particles, and shocks during the later stages of stellar evolution, the protoplanetary (PPN) and planetary nebula (PN) stages, and when it is injected and transported in the different phases of the interstellar medium.

First ALMA observations

Narrow U lines in the minifrequency spectral survey of IRC+10216.

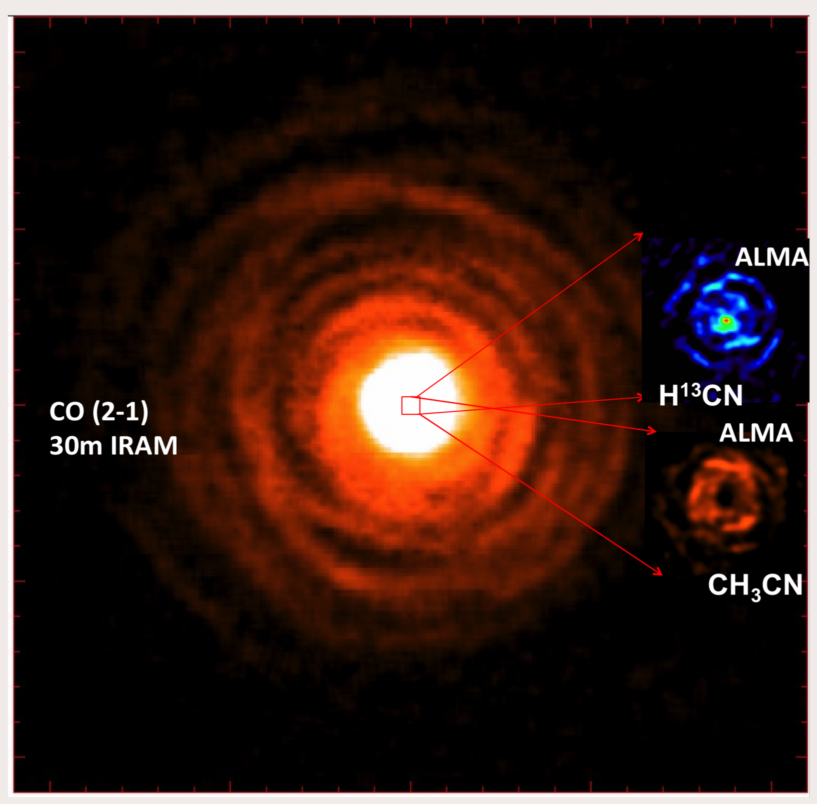


Hundreds of previously undetected narrow unidentified U-lines are observed in ALMA spectra (black) of IRC +10 216 compared to previous IRAM 30m data (red)!

All these U-lines arise in a region very close to the photosphere (within 0.6").

Hence, the carriers of these features are certainly playing an important role in the dust growth process.

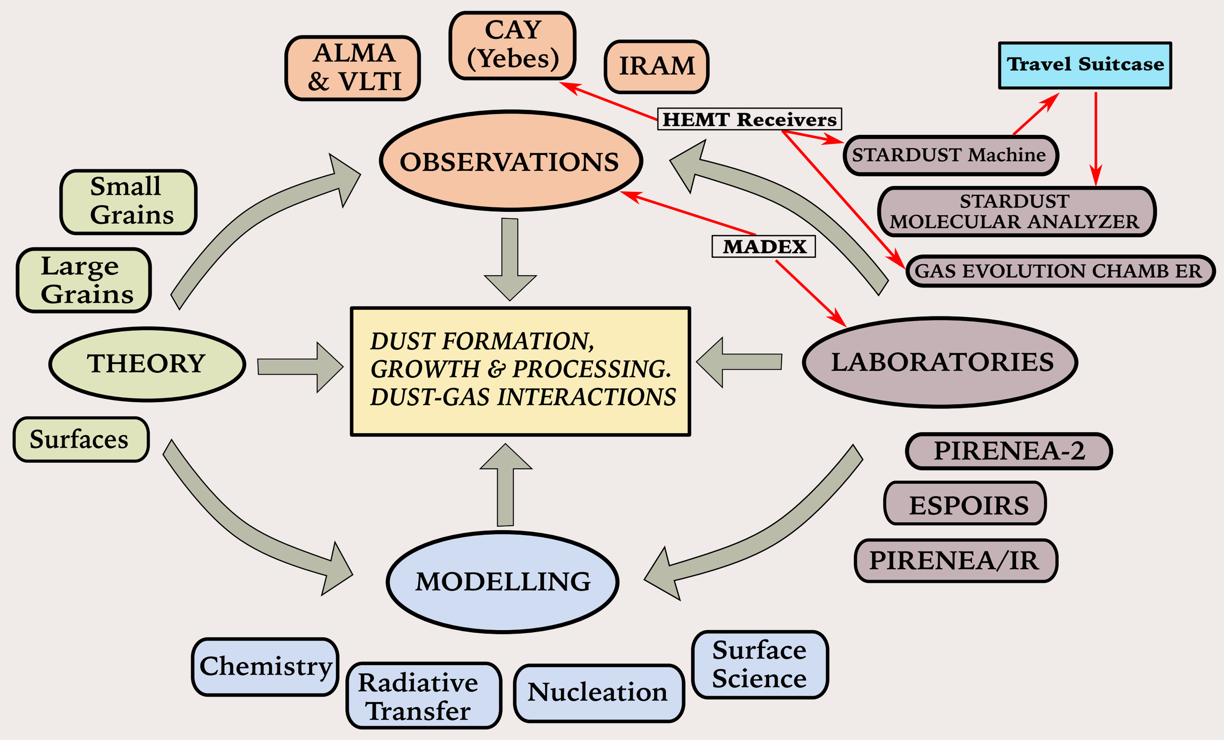
The chemistry, dust formation and the spatial distribution of matter in IRC+10216



The spatial distribution of each molecule is a key parameter to understand the role of each molecular species in the formation and growth of dust grains. From the largest to the smallest scales chemistry will dominate the extent of each species. In particular, the spatial distribution of matter as traced by CO, HCN, and other species will permit to track the role of the different chemical processes, from condensation on the grains to pure gas phase photochemical processes.

Beyond the current frontiers

The aim of NANOCOSMOS is to understand the physical and chemical processes leading to the formation of cosmic dust. Astronomical observations and computer modeling by themselves cannot provide a full description of dust formation & processing and its interaction with gas-phase species. The original approach of NANOCOSMOS is to combine astronomical observations at high angular resolution and sensitivity, with modelling supported by top-level laboratory simulations.

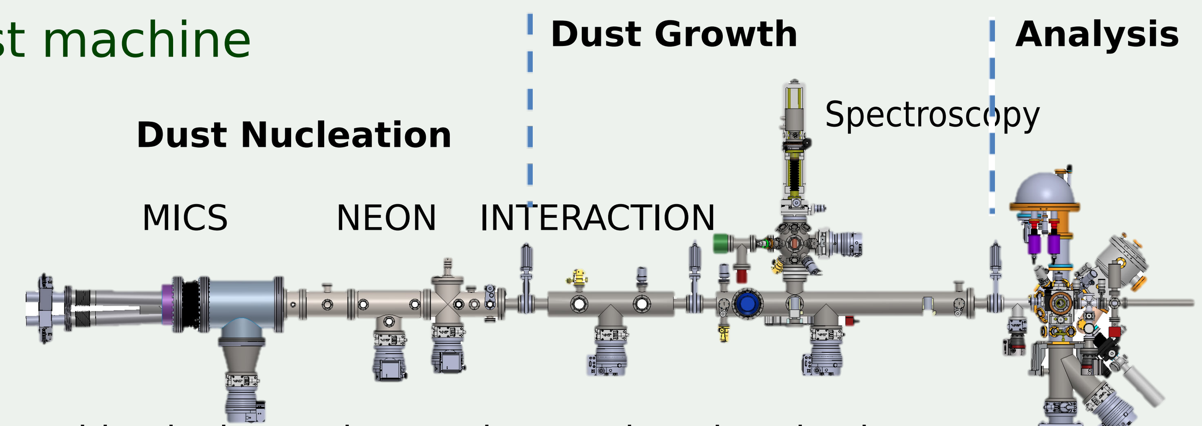


Several **simulation chambers** will be built to study the molecular precursors of dust grains, dust growth (gas-grain interactions), processing, and spectroscopy. In addition, **microwave HEMT receivers** will be developed to be installed at the 40m IGN radiotelescope for a systematic line survey of 200+ evolved stars, as well as to be used for spectroscopic measurements in simulation chambers.

The project lies on a **synergetic approach** between astronomers, vacuum and microwave engineers, molecular and plasma physicists, surface scientists, including both experimentalists and theoreticians, which is the key to provide a cutting-edge view of cosmic dust.

Experimental set-up development

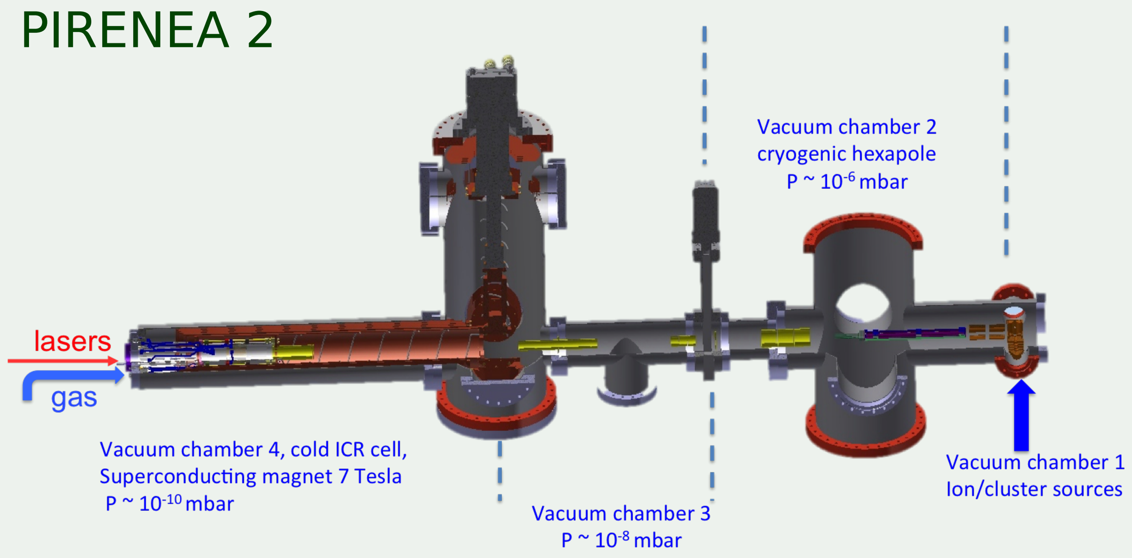
Stardust machine



Stardust machine is devoted to produce and analyze in-situ highly-controlled analogs of the cosmic-dust in a versatile ultra-high-vacuum experiment. In this environment we will mimic the nucleation of the aggregates and the interaction they may experience with the circumstellar gases.

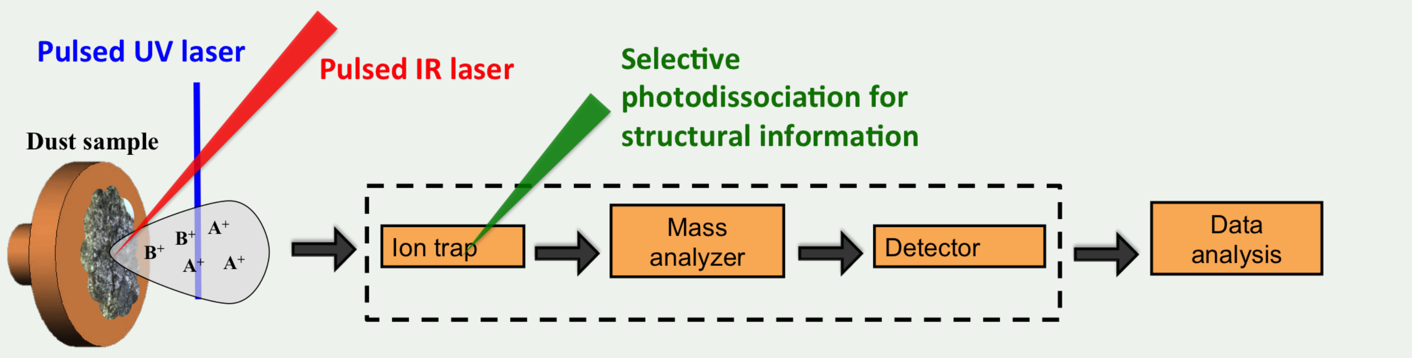
MICS: Nanoparticle fabrication using a Multiple Ion Cluster Source in UHV
NEON: Neutrals from Ions Chamber, particle separator
INTERACTION: Interaction of the generated nanoparticles with injected gas
Spectroscopy: In-flight analysis via UV and micro-wave spectroscopy
Analysis: In-situ stardust particle analysis (XPS-TDS), processing and collection. Collected species can be transferred into other setups by a vacuum suitcase.

PIRENEA 2



The design of PIRENEA 2 is optimized to study the physical and chemical properties of PAHs and nanograins of astrophysical interest including UV processing and reactivity in isolated conditions to be compared to surface science experiments.

AROMA: Stardust molecular analyzer



This Nanocosmos set-up is dedicated to the analysis of the molecular content of the cosmic dust analogues that are produced in the different reactors (cold plasma reactors and Stardust machine).

The interdisciplinary team

Teams at CNRS / Université de Toulouse 3	Main institutes in Spain
* Milieu Interstellaire, Cycle de la Matière, Astro-Chimie at IRAP * Interactions Ions-Matière at LCAR-IRSAMC * Matériaux et Procédés Plasmas at LAPLACE * Modélisation, agrégats, dynamique at LCPQ-IRSAMC	* Instituto de Cienca de Materiales de Madrid (CSIC) * OAN and Centro Tecnológico de Yebes (IGN) * Universidad de Valladolid (spectroscopy) * Universidad de Castilla la Mancha (chemistry)