Laboratory Astrophysics: from Observations to Interpretation
Proceedings IAU Symposium No. 350, 2019
F. Salama & H. Linnartz, eds.
doi:10.1017/S174392131900646X

Low-temperature condensation of carbonaceous dust grains from PAHs

Lisseth Gavilan Marin[1], Salma Bejaoui[1], Gregory Gate[2], Michael Haggmark[2], Nathan Svadlenak[2], Mattanjah de Vries[2], Ella Sciamma-O'Brien[1] and Farid Salama[1]

[1]NASA Ames Research Center, Space Science & Astrobiology Division, Moffett Field, CA 94035, USA
email: lisseth.gavilanmarin@nasa.gov

[2]Department of Chemistry, University of California Santa Barbara, CA 93106, USA

Abstract. Interstellar carbon has been detected in both gas-phase molecules and solid particles. The goal of this study is to identify the link between these two phases of cosmic carbon. Here we report preliminary results on the low temperature formation of carbonaceous dust grains from gas-phase aromatic hydrocarbon precursors. This is done using the supersonic expansion of an argon jet seeded with aromatic molecules and exposed to an electrical discharge. We report experimental evidence of efficient carbon dust condensation from aromatic molecules including benzene and naphthalene. The molecular content of the solid grains is probed with laser desorption mass spectrometry. The mass spectra reveal a rich molecular composition including fragments of the parent molecule but also growth into larger molecular species.

Keywords. astrochemistry, molecular processes, plasmas, methods: laboratory, ISM: jets and outflows, ISM: molecules

1. Introduction

Carbon is ubiquitous in space and plays a key role in the evolution of the ISM and the formation of stars and planets. Yet the journey of carbon from large organic molecules to dust grains (or vice versa) still raises many open questions. Observations of infrared emission features between 3 to 20 μm (known as aromatic infrared bands, AIBs) towards diverse astronomical objects (HII regions, reflection nebulae, post-AGB stars) has informed laboratory research with spectroscopic constraints. Although the structure of the carriers is still not precisely determined, they have been attributed to aromatic molecular carriers, leading to two leading hypotheses: that the carriers consist of large molecules, mainly polycyclic aromatic hydrocarbons (PAHs, see review by Tielens (2008) and references therein) or that they consist of aromatic-aliphatic nanograins (e.g. Gavilan *et al.* 2017) and references therein). In this study we seek a link between these hypotheses, probing the molecular evolution of gas-phase PAH into solid carbon grains.

2. Methods

Laboratory analogs to interstellar dust are generally formed using combustion, plasma, and laser ablation, leading to samples spanning a wide variety of structures and aromatic/aliphatic ratios. Here we present the results of a study using the COsmic SImulation Chamber (COSmIC) experimental facility at NASA Ames (Salama *et al.* 2018). The COSmIC setup includes as Pulsed Discharge Nozzle (PDN) fed by a supersonic jet of argon seeded with organic molecules (Biennier *et al.* 2003). Here we present

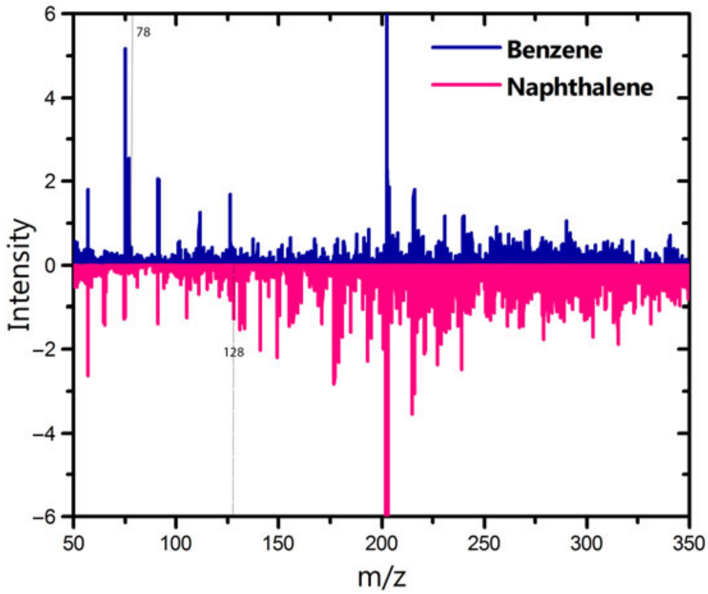

Figure 1. Laser-desorption mass spectra of carbonaceous grains prepared with benzene (78 amu) and naphthalene (128 amu), displaying peaks with S/N > 10 up to 350 amu.

the preliminary results for benzene and naphthalene. A 600 μs-long high voltage (-700 V) pulse generates a plasma discharge in the stream of the supersonic expansion where T (neutrals) = 150 to 200 K inside the PDN. Grains are collected in-situ onto substrates placed 7 cm away from the electrodes for a few hours. The precursor organic molecules are (polycyclic) aromatic hydrocarbons of increasing ring number. The samples are characterized ex-situ via laser desorption time-of-flight mass spectrometry (L2DI-TOFMS). In this technique, laser desorption at 1064 nm volatilizes low vapor pressure molecules from a surface into the gas phase. Jet cooled molecules are excited and photoionized, using an ArF excimer laser at 193 nm, and the ions are detected in a time-of-flight mass spectrometer (Meijer *et al.* 1990).

3. Results and astrophysical implications

Mass spectra of grains produced with single aromatic molecules reveal the rich molecular complexity within the grains condensed in the COSmIC chamber. We present a preliminary comparison of the spectra for grains prepared in experiments with benzene and naphthalene as the precursor aromatic (Fig. 1). Peaks with $S/N > 20$ exist in both cases at $m/z = 57$, 77, 203, 216, 231 and peaks with $S/N > 10$ are detected up to 350 amu. These are attributed to hydrocarbons with C_4 up to C_{18} atoms. We provide experimental evidence of efficient carbonaceous dust condensation from rotationally-cooled aromatic precursors. This result is applicable to the growth of carbon grains in circumstellar envelopes where molecular freeze-out is expected (Ziurys 2006).

Acknowledgment

The authors acknowledge support from the NASA SMD APRA program and travel grants to the IAU symposium 350. LGM is supported by a NASA postdoctoral program (NPP) fellowship. We thank Emmett Quigley (NASA ARC) and the de Vries team (UCSB) for technical support.

References

Biennier, L., Salama, F., Allamandola, L. J., *et al.* 2003, *J. Chem. Phys.*, 118, 7863
Gavilan, L., Le, K. C., Pino, T., *et al.* 2017, *A&A*, 607, A73
Meijer, G., de Vries, M. S., Hunziker, H. E., *et al.* 1990, *Applied Physics B*, 51, 395
Salama, F., Sciamma-O'Brien, E., Contreras, C. S., *et al.* 2018, Proceed. IAU Symposium 332, Vol. 13, 364. doi:10.1017/S1743921317011619
Sloan, G. C., Jura, M., Duley, W. W., *et al.* 2007, *ApJ*, 664, 1144
Tielens, A. G. G. M. 2008, *ARA&A*, 46, 289
Ziurys, L. M. 2006, *PNAS*, 103, 12274