Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
Proceedings IAU Symposium No. 343, 2019
F. Kerschbaum, M. Groenewegen & H. Olofsson, eds.

doi:10.1017/S1743921318007871

Abundance Estimates in Carbon Star Envelopes

S. Massalkhi, M. Agúndez and J. Cernicharo

Molecular Astrophysics Group, IFF, CSIC, C/ Serrano 123, E-28006, Madrid, Spain

Abstract. The synthesis of dust grains mostly takes place in the circumstellar envelopes (CSEs) of asymptotic giant branch (AGB) stars. What are the precursor seeds of condensation nuclei and how do these particles evolve toward the micrometer sized grains that populate the interstellar medium? These are key questions of the NANOCOSMOS project. In this study, we carried out an observational study to constrain what the main gas-phase precursors of dust in C-rich AGB stars are.

Keywords. astrochemistry, (stars:) circumstellar matter, AGB and post-AGB

1. Introduction

During the late stages of their evolution, AGB stars experience significant mass loss, which results in extended CSEs. These environments are efficient factories of molecules and dust grains and their chemical nature depends to a large extent on the C/O elemental abundance ratio at the stellar surface. Although much has been advanced recently, there is still much to understand about how dust grains form, what their main gas-phase seeds are and what is their role in the formation of dust around AGB stars. To investigate this, we carried out observations with the IRAM 30m telescope of 25 C-rich AGB stars of diverse mass-loss rates to search for emission of SiC_2, SiO, SiS and CS in the λ 2 mm band. We aim to model their emission and determine their abundances in each source to provide a global view of how abundant they are in CSEs around C-rich AGB stars.

2. Abundance Estimate

We adopted a common physical scenario consisting of a spherically symmetric envelope of gas and dust expanding with a constant velocity and mass-loss rate around a central AGB star. The spherical envelope is described by the radial profile of various physical quantities, such as the gas density, the kinetic temperature of the gas, the dust temperature, the expansion velocity, and the microturbulence velocity. We also consider a dusty component of the envelope. We performed non-LTE excitation and radiative transfer calculations to model the line emission of the molecules, based on the multi-shell LVG (Large Velocity Gradient) method. The circumstellar envelope is divided into a number of concentric shells, each of them with a characteristic set of physical properties, and statistical equilibrium equations are solved in each of them. In each shell, the contribution of the background radiation field (cosmic microwave background, stellar radiation, and thermal emission from surrounding dust) is included. We consider that the molecules are formed close to the star with a given fractional abundance, which remains constant across the envelope up to the outer regions, where they are photodissociated by the ambient ultraviolet radiation field of the local interstellar medium. To model the emission lines and determine the abundance, we varied the initial fractional abundance relative to H_2 of the molecule, f_0, until the calculated line profiles matched the observed ones. We choose as best-fit model the one which results in the best overall agreement

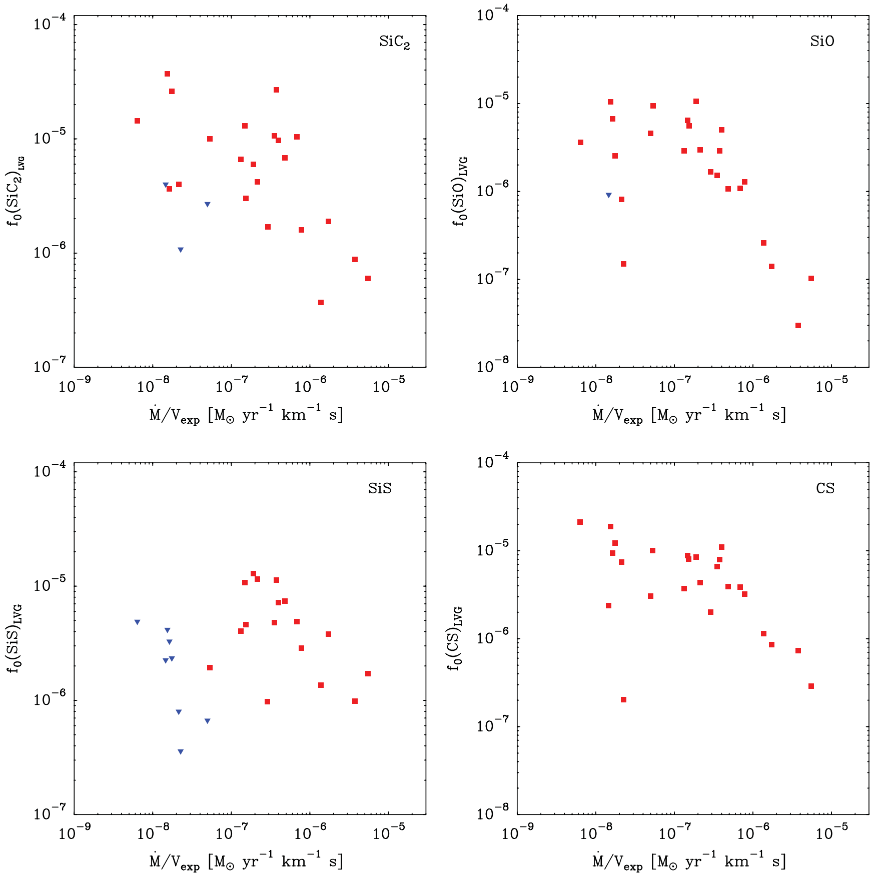

Figure 1. Fractional abundances relative to H_2 for SiC_2, SiO, SiS, and CS are plotted as a function of density measure ($\dot{M}/V_{\rm exp}$). Upper limits for the non-detections are denoted with downward triangles.

between calculated and observed line profiles for the entire set of lines observed. In those cases in which no lines are detected, we derive upper limits to the abundance by choosing the maximum abundance that results in line intensities compatible with the noise level of the observations.

3. Results

The fractional abundance of SiC_2 shows an interesting trend with the density in the envelope, evaluated through the quantity $\dot{M}/V_{\rm exp}$. As shown in Fig. 1, SiC_2 becomes less abundant as the density in the envelope increases. Our interpretation is that the SiC_2 molecules deplete from the gas phase to incorporate into solid dust grains, a process that is favored at higher densities owing to the higher rate at which collisions between particles occur. The ring molecule SiC_2 thus emerges as a very likely gas-phase precursor in the process of formation of SiC dust in envelopes around C-rich AGB stars (Massalkhi *et al.* 2018). We note a similar trend for SiO and CS, which we interpret as evidence of efficient adsorption of SiO and CS onto dust grains. In contrast to these results, SiS does not show any clear trend, suggesting that it is less likely to adsorb onto dust grains than SiC_2, SiO and CS (Massalkhi *et al.*, in prep.).

Reference

Massalkhi, S., Agúndez, M., Cernicharo, J., *et al.* 2018, *A&A*, 611, A29

https://doi.org/10.1017/S1743921318007871 Published online by Cambridge University Press