Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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Circumstellar chemistry of Si-C bearing molecules in the C-rich AGB star IRC+10216

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Abstract. Silicon carbide together with amorphous carbon are the main components of dust grains in the atmospheres of C-rich AGB stars. Small gaseous Si-C bearing molecules (such as SiC, SiCSi, and SiC_2) are efficiently formed close to the stellar photosphere. They likely condense onto dust seeds owing to their highly refractory nature at the lower temperatures (i.e., below about 2500 K) in the dust growth zone which extends a few stellar radii from the photosphere. Beyond this region, the abundances of Si-C bearing molecules are expected to decrease until they are eventually reformed in the outer shells of the circumstellar envelope, owing to the interaction between the gas and the interstellar UV radiation field. Our goal is to understand the time-dependent chemical evolution of Si-C bond carriers probed by molecular spectral line emission in the circumstellar envelope of IRC+10216 at millimeter wavelengths.

Keywords. stars: AGB & post-AGB, (stars:) circumstellar matter, stars: individual (IRC+10216).

1. Introduction

Dust formation and growth is far from being well understood because there are many unknowns in the formation pathways, the condensation sequences of refractory species, and the dependence on stellar and circumstellar properties. Dust grains in the atmospheres of C-rich AGB stars are mainly composed of silicon carbide and amorphous carbon (Savage & Mathis 1979, and references therein). Therefore, the study of gas phase carriers of Si-C bonds in the envelopes of C-rich stars is a promising approach for

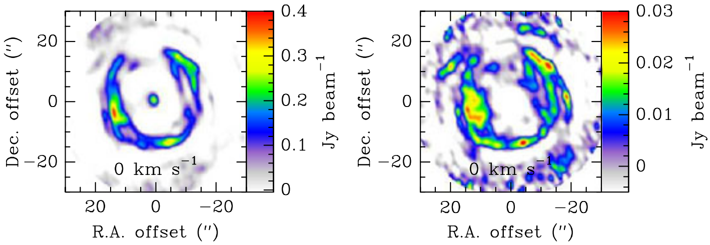

Figure 1. NOEMA maps of the SiC_2 $J_{Ka,Kc}$=$7_{0,7}$–$6_{0,6}$ (left) and the SiC Ω=2 J=4–3 e, f (right) emission lines toward IRC+10216 with v_{LSR}=$v - v_{sys}$ (v_{sys}=-26.5 km s^{-1}). The spectral resolution is $\Delta v \sim$4 km s^{-1}, and the spatial resolution is ∼2.″5.

shedding light on the formation of SiC dust. Here, we present our latest results derived from the analysis of single-dish (IRAM-30m) and interferometric data (SMA, NOEMA, and ALMA) of Si-C bearing, and other Si-bearing molecules in the circumstellar envelope of the prototypical AGB star IRC+10216.

2. Observations and analysis

We have carried out a comprehensive observational study of most of the Si-bearing molecules detected in the circumstellar envelope of IRC+10216. We have used ALMA, NOEMA, SMA, and the IRAM-30m telescope to observe several emission lines corresponding to SiC, SiC_2, SiCSi, SiS, and SiO. Calibration, reduction and merging standard procedures followed using CASA and GILDAS. The best spatial resolution achieved corresponds to the ALMA observations, with angular resolution as high as 0.″6.

Our analysis is based on radiative transfer analysis (MADEX, Cernicharo 2012) and chemical modelling of the molecules detected. The physical model of the CSE is essentially an updated revision of the models in Agúndez *et al.* (2012) and Cernicharo *et al.* (2013). Updated parameters are the kinetic temperature radial profile and mass-loss rate (Guélin *et al.* 2018). For more details about the chemical model see e.g. Velilla Prieto *et al.* (2015).

3. Results

SiC_2 and SiCSi are the main carriers of Si-C bonds in the innermost regions of the CSE with similar abundances in this zone ($\sim$10^{-7}). This result is consistent with predictions of thermodynamical equilibrium (Cernicharo *et al.* 2015). The lack of SiC emission arising from the innermost regions of the CSE might be evidence that SiC is condensed onto the dust grains as one of the main building blocks of dust grains in C-rich CSEs (Treffers & Cohen 1974). In the outermost parts of the CSE, SiC and SiC_2 are reincorporated into the gas phase at $r \sim 15''$ (see Fig. 1).

We have derived the radial profiles of the fractional abundances of SiO and SiS, which present oscillations that probably reflect the mass-loss episodicity of the star. On average, the fractional abundances estimated are f(SiO)$\sim$10^{-7} and f(SiS)$\sim$10^{-6}. The observations and analysis we have done pose strong evidences of a variable and episodic mass loss process acting on IRC+10216 creating dense shells with timescales of hundreds of years.

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