Contribution ID: **54** Type: **Poster**

The abundance of SiC2 in Carbon Star Envelopes

Monday 11 June 2018 10:48 (1 minute)

During the late stages of their evolution, asymptotic giant branch (AGB) stars experience significant mass loss processes, which result in extended circumstellar envelopes (CSEs). These environments are efficient factories of molecules and dust grains. The main paradigm for the dust formation process involves a first step in which condensation nuclei of nanometer size are formed from some gas-phase precursor seeds of highly refractory character and a second step in which the nuclei grow to micrometer sizes by accretion and coagulation as the material is pushed out by the stellar wind. The chemical nature of the molecules and dust grains formed 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 are dust grains formed and which are the main gas-phase seeds. This is the main driver of the ERC Synergy Project NANOCOSMOS.

Silicon carbide (SiC) dust grains, which are detected through a band at 11.3 micron, are exclusively found in the envelopes around C-type (C/O>1) AGB stars (Treffers & Cohen 1974). Here, we explore what the main precursor seeds of SiC dust grains are. Only three gas-phase molecules containing the Si-C bond have been observed in C-rich envelopes around AGB stars. The ring molecule SiC₂ has been observed towards a few AGB and post-AGB stars (Thaddeus et al 1984; Bachiller et al. 1997; Zhang et al. 2009a,b), while SiC and Si₂C have only been observed in the C star envelope IRC +10216 (Cernicharo et al. 1989, 2015). Much of the knowledge about the role of these three molecules as seeds of SiC dust grains comes from the study of IRC +10216, as in this source SiC₂ has been thoroughly identified across the mm and sub-mm ranges with ground based radio telescopes and with the Herschel Space Telescope (Lucas et al. 1995; Cernicharo et al. 2010; Velilla Prieto et al. 2015). The scenario emerged from these studies suggests that only SiC₂ and Si₂C are present in the inner circumstellar layers of IRC +10216, while SiC is probably a photodissociation product of these molecules, and thus it is restricted to the outer envelope. This scenario indicates that SiC₂ and Si₂C are likely the main gas-phase seeds to form SiC dust grains.

To explore the role of gas-phase SiC₂ molecules on the formation of silicon carbide dust, we have used the IRAM 30m telescope to observe SiC₂ in a wide sample of C-rich AGB stars. The observations have been interpreted carrying out non-LTE excitation and radiative transfer calculations to estimate the fractional abundance of SiC₂ in the CSEs. The behavior of the abundance of SiC₂ as a function of the envelope density indicates that this gas-phase molecule does indeed play an important role as seed of silicon carbide dust.

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Session Classification: Poster Presentations

Track Classification: What is dust?