Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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The Maser-emitting Structure and Time Variability of the SiS Lines $J = 14 - 13$ and $15 - 14$ in IRC + 10216

J. P. Fonfría[1], M. Fernández-López[2], J. R. Pardo[1], M. Agúndez[1], C. Sánchez Contreras[3], L. Velilla-Prieto[1], J. Cernicharo[1], M. Santander-García[4], G. Quintana-Lacaci[1], A. Castro-Carrizo[5] and S. Curiel[6]

[1]Molecular Astrophysics Group, Instituto de Física Fundamental, CSIC, C/ Serrano, 123, 28006, Madrid (Spain)
email: jpablo.fonfria@csic.es

[2]Instituto Argentino de Radioastronomía, CCT-La Plata (CONICET), C.C.5, 1894, Villa Elisa (Argentina)

[3]Department of Astrophysics, Astrobiology Center (CSIC-INTA), Postal address: ESAC campus, P.O. Box 78, E-28691, Villanueva de la Cañada, Madrid (Spain)

[4]Observatorio Astronómico Nacional, OAN-IGN, Alfonso XII, 3, E-28014, Madrid (Spain)

[5]Institut de Radioastronomie Millimétrique, 300 Rue de la Piscine, 38406 Saint-Martin d'Hères (France)

[6]Departamento de Astrofísica Teórica, Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510, Mexico City (Mexico)

Abstract. AGB stars are important contributors of processed matter to the ISM. However, the physical and chemical mechanisms involved in its ejection are still poorly known. This process is expected to have remarkable effects in the innermost envelope, where the dust grains are formed, the gas is accelerated, the chemistry is active, and the radiative excitation becomes important. A good tracer of this region in C-rich stars is SiS, an abundant refractory molecule that can display maser lines, very sensitive to changes in the physical conditions. We present high angular resolution interferometer observations (HPBW $\gtrsim 0''.25$) of the $v = 0$ $J = 14 - 13$ and $15 - 14$ SiS maser lines towards the archetypal AGB star IRC+10216, carried out with CARMA and ALMA to explore the inner $1''$ region around the central star. We also present an ambitious monitoring of these lines along one single pulsation period carried out with the IRAM 30 m telescope.

Keywords. line: profiles, masers, radiative transfer, techniques: high angular resolution, techniques: interferometric, (stars:) circumstellar matter, stars: individual (IRC+10216)

1. SiS Maser emission and Spatial distribution

The SiS $J = 14 - 13$ and $15 - 14$ maser lines were observed toward the AGB star IRC+10216 with CARMA and ALMA (Fonfría *et al.* 2014; Cernicharo *et al.* 2013) with high spectral and angular resolutions (Fig. 1, upper left). SiS$(14 - 13)$ was modelled with the code developed by Fonfría *et al.* (2014). We assumed the spherically symmetric physical and chemical conditions for SiS derived by Fonfría *et al.* (2015) but allowing the rotational temperature, $T_{\rm rot}$, to be asymmetric if necessary. $T_{\rm rot}$ was varied only where needed to reproduce all the velocity-channel maps. It was chosen to be negative to describe population inversion only if there was no other way to reproduce the emission.

We found that the observed brightness distribution, comprising two bright spots, an extended component, and a bipolar structure, cannot be explained neither by thermal

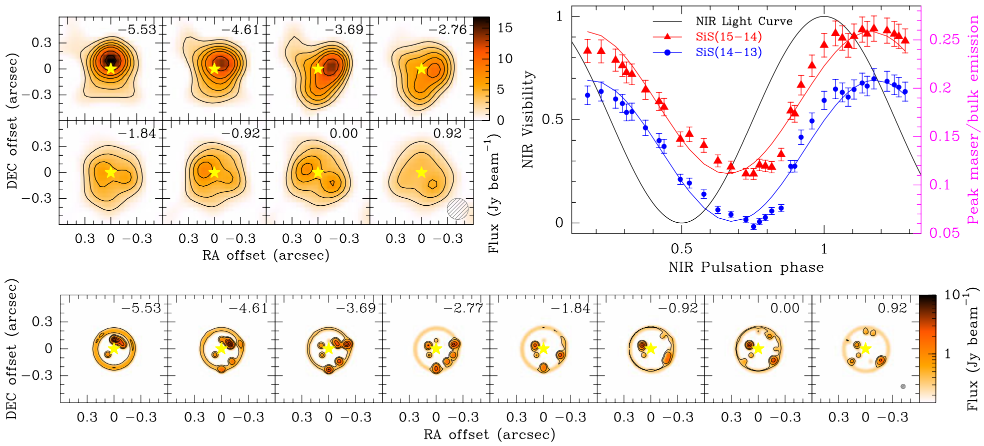

Figure 1. Several CARMA SiS(14 − 13) velocity-channel maps (HPBW $\simeq 0''.25$; *upper left*), synthetic emission in logarithmic scale (HPBW $= 0''.05$; *lower*), and time dependence of ratio of the strongest maser peak and the bulk emission in the same velocity interval (*upper right*).

emission nor by flux calibration errors, and maser emission is needed. The maser emission can be reproduced with a set of compact maser spots in an extended structure modelled as a shell (Fig. 1, lower). A large fraction of the total emission has a maser nature (75%). About 40% of the maser emission comes from the compact spots, mainly from the brightest ones located to the NW of the star, and 60% from the extended component.

2. Time Variability

We also monitored the SiS lines $J = 14-13$ and $15-14$ throughout a whole pulsation period with a sampling time of 16 days (Pardo *et al.* 2018). Some of the narrow maser components of these lines show evident time variations following the NIR light-curve of the star. Other spectral components display a milder time variability. The comparison of these SiS lines with thermally excited lines of other molecules suggests that the extended maser emission also varies over time. The time dependence of the ratio of the strongest maser peak and the bulk emission is offset by $\simeq 0.2$ pulsation periods with respect to the NIR light-curve (measured 10 years ago; Fig. 1, upper right), which could indicate a recent variation of the NIR light-curve or unexpected excitation effects.

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