Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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Zooming into the complex dusty envelopes of C-rich AGB stars

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Abstract. Recent advances in high-angular resolution instruments (VLT and VLTI, ALMA) have enabled us to delve deep into the circumstellar envelopes of AGB stars from the optical to the sub-mm wavelengths, thus allowing us to study in detail the gas and dust formation zones (e.g., their geometry, chemistry and kinematics). This work focuses on four (4) C-rich AGB stars observed with a high-angular resolution technique in the near-infrared: a multi-wavelength tomographic study of the dusty layers of the circumstellar envelopes of these C-rich stars, i.e. the variations in the morphology and temperature distribution.

Keywords. techniques: high angular resolution, techniques: interferometric, stars: AGB and post-AGB, infrared: stars

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Our sample is composed of four C-rich AGB stars (namely R For, R Scl, R Lep and II Lup) selected for showing secondary periods known as "obscuration events" (Whitelock *et al.* 2006). Such events may be related to the orbital motion of a companion, and they have been found thus far only in C-rich AGB stars. All four targets were observed in the near-infrared using an aperture masking technique on the VLT which essentially converts a single-dish 8-m telescope into an interferometer (SAM/NACO; Tuthill *et al.* 2010). We report here on our preliminary results.

Aperture masking is proven to be an excellent tool in detecting companion stars. However, no such detection was found in R For, R Scl and R Lep data (a companion may have been detected in II Lup, Lykou *et al.* 2018). If such companions exist then they may be fainter than the SAM/NACO detection limit, or they are wider binaries and therefore the companion is located outside the field-of-view. Here, the dusty envelopes (pseudo-continuum) do not present morphological asymmetries, with the exception of II Lup in K, L and M (Lykou *et al.* 2018) and possibly R For in H (Lykou *et al.*, in prep.). The angular sizes of the dusty envelopes were derived from the azimuthally-averaged visibility data after fitting circular Gaussian functions (Fig. 1), and they are only indicative of the true scale of the circumstellar envelopes.

An attempt to estimate envelope temperatures was made using the relation of Bedding *et al.* (1997), the angular sizes derived from this work, and the bolometric magnitudes from the P–L relation of Whitelock *et al.* (2006) and the *Gaia* DR2 distances. We find that the envelope temperature of R Lep and R Scl is decreasing with increasing wavelength with values ranging from 1700 to 1000 K, which is expected taking into account that cooler layers of the envelope are probed at longer wavelengths. However, the envelope of R For appears to be much cooler in J. The difference in sizes compared to literature data (Fig. 1), and the apparent variation of the envelope radii and temperatures with wavelength, can be explained as:
(a) a true signature of dynamic variations within the envelope with pulsation phase and wavelength observed, or

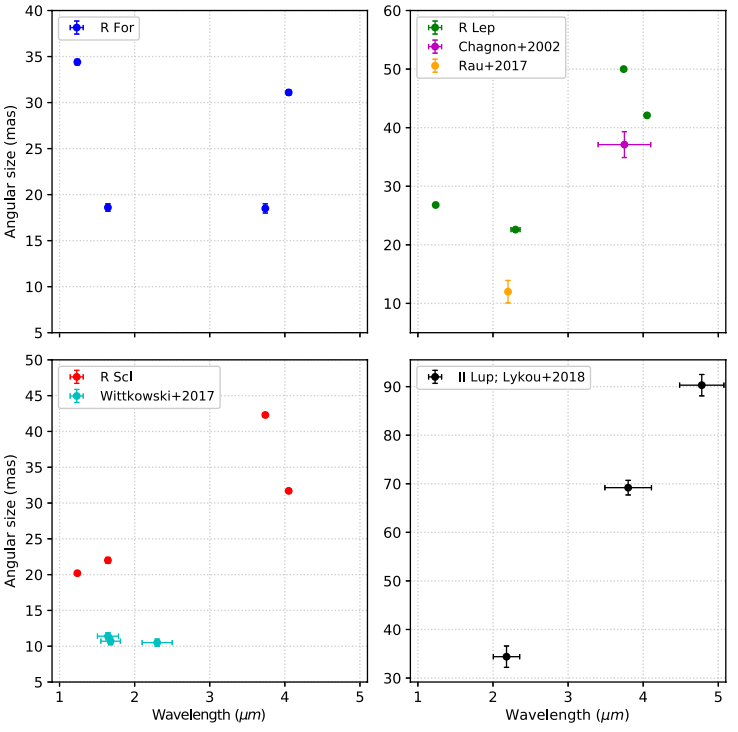

Figure 1. The angular sizes of the four AGB stars compared to literature values (Chagnon *et al.* 2002, Lykou *et al.* 2018, Rau *et al.* 2017, Wittkowski *et al.* 2017). Horizontal errorbars correspond to the filter bandwidths.

(b) a limiting case of detecting circumstellar envelopes with this technique, where the actual envelopes are smaller than the SAM/NACO detection limit.

Aperture masking is a time-effective technique when searching for temporal variations in the circumstellar envelopes of AGB stars. The technique can work in synergy with current spectro-interferometric instruments, such as GRAVITY and MATISSE on the VLTI, as it offers shorter baselines in similar wavelength ranges that can fill the gap between small (≤ 10 mas; VLTI) and intermediate spatial scales (20–400 mas; SAM). We intend to explore such a combination of techniques in the near future to achieve a better understanding on the variability of these four sources.

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