Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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AGB star atmospheres modeling as feedback to stellar evolutionary and galaxy models

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Abstract. The chemical enrichment of the Universe is considerably affected by the contribution of cool evolved stars. We studied the O-rich star R Peg and the C-rich star V Oph, using respectively the VLTI/GRAVITY and VLTI/MIDI instruments. We interpret the data using grids of 1-D and 3-D dynamic model atmospheres.

Keywords. AGB and post-AGB – atmospheres – mass-loss – stars: carbon – circumstellar matter – techniques: interferometric – techniques: high angular resolution –

1. Introduction

Toward the end of their lives, stars on the Asymptotic Giant Branch (AGB) produce in their atmospheres heavy chemical elements, molecules, and dust. Their mass loss produced by stellar winds will place this material into the interstellar medium. Even though many efforts have been carried out to-date (see e.g. Hron 1998), we still lack observational constraints and a consistent comparison with models, to retrieve fundamental information on this evolutionary stage. Ground-based interferometric measurements with high-angular resolution instruments from VLTI, such as GRAVITY and MIDI, can help to test dynamical models describing the behavior of the outer AGB atmospheres at various spatial scales.

2. Overview, observations, and goals

We present two separate projects. The first one consists of monitoring the photosphere and extended atmosphere of the O-rich AGB star R Peg with VLTI/GRAVITY, and studying its molecular composition using 1-D and 3-D model atmospheres. This work has been already published by Wittkowski *et al.* (2018). Hence, we focus here on the second ongoing project: modeling the C-rich star V Oph, observed with VLTI/MIDI in the N-band by Ohnaka *et al.* (2007), using 1-D dynamic model atmospheres. V Oph is indeed one of the few C-rich AGB stars showing interferometric variability in the N-band, probably related to its pulsation activity, and for this reason is a particularly interesting case-study for understanding the atmospheric dynamics in these type of stars. In this ongoing work we aim to: (1) better understand the physical processes responsible for molecule and dust formation close to the star; (2) verify if the extended molecular and dust layers can be explained by dust-driven winds triggered by large-amplitude stellar pulsation alone, or if some other contributing mechanism is required.

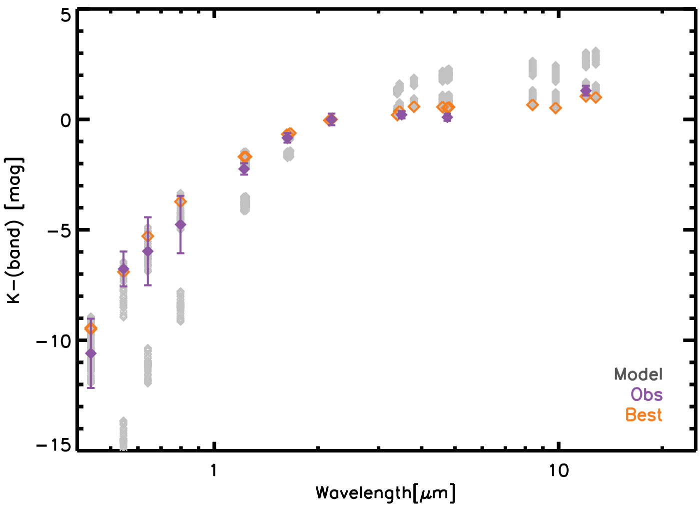

Figure 1. Photometric observations of V Oph. Observations (purple circles) are compared to the synthetic photometry derived from the dynamic models (gray diamonds). Orange diamonds show the best fitting time-steps of the star.

3. Preliminary results

We compare V Oph photometric data from the literature, and interferometric MIDI observations, with a grid of 1-D dynamic model atmospheres for C-rich stars by Eriksson *et al.* (2014) (based on Höfner *et al.* 2003, 2016), as similarly done by Rau *et al.* (2015, 2016, 2017). We derive the atmospheric stratifications and fundamental stellar parameters, and provide constraints for dynamic atmospheres, the mass loss process for carbon stars, and stellar evolutionary models. Figure 1 shows that the grid of C-rich stars dynamic model atmospheres fits the photometric data well at all wavelengths ($\chi^2 = 1.51$). We refer to a future paper (Rau *et al.* in prep.) for details on this analysis.

4. Future plans

Further investigation is upcoming concerning the fit to the interferometric data. We also need further studies to interpret how the reflection and dissipation of Alfv*é*n waves (see also Airapetian *et al.* 2010) could explain the interferometric variability of V Oph. Radiative transfer modeling studies with RADMC3D, will deepen our knowledge on the causes of interferometric variability, and on the dust stratification around the star. Our team is planning to observe V Oph also with the second generation VLTI instrument in the *LM*- and *N*-bands: MATISSE. These observations will help to disentangle the interferometric variability, if due to pulsation as speculated by Ohnaka *et al.* (2007), or to yet unobserved surface structures.

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