Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
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The carbon star R Sculptoris sheds its skin

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Abstract. We describe near-IR H-band VLTI-PIONIER aperture synthesis images of the carbon AGB star R Sculptoris with an angular resolution of 2.5 mas. The data show a stellar disc of diameter $\sim$ 9 mas exhibiting a complex substructure including one dominant bright spot with a peak intensity of 40% to 60% above the average intensity. We interpret the complex structure as caused by giant convection cells, resulting in large-scale shock fronts, and their effects on clumpy molecule and dust formation seen against the photosphere at distances of 2–3 stellar radii. Moreover, we derive fundamental parameters of R Scl, which match evolutionary tracks of initial mass 1.5 ± 0.5 $M_\odot$. Our visibility data are best fit by a dynamic model without a wind, which may point to problems with current wind models at low mass-loss rates.

1. Introduction

Mass loss becomes increasingly important during the AGB phase, both for the stellar evolution, and for the return of material to the interstellar medium. Some carbon-rich AGB stars are known to exhibit a clumpiness of their circumstellar environment (e.g., Weigelt *et al.* 1998). R Scl is a carbon-rich semi-regular pulsating AGB star with a period of 370 days at a distance of 370 ± 100 pc. ALMA observations in CO revealed a spiral structure, indicating the presence of a previously unknown companion (Maercker *et al.* 2012).

The near-IR imaging results of the stellar disc presented here are based on Wittkowski *et al.* (2017). Further descriptions of our results are available in an ESO blog† and an ESO picture of the week‡.

2. Observations and results

We obtained VLTI-PIONIER data of R Scl at three spectral channels in the near-IR H-band with baselines between 11 m and 140 m, providing an angular resolution of 2.5 mas. We reconstructed images with the `IRBis` package (Hofmann *et al.* 2014), using a best-fit model as a start image, a flat prior, and smoothness as regularisation. We investigated different start images, regularisations, priors, and image reconstruction packages, and obtained very similar reconstructions in all cases. The resulting images (1.68 μm example in Fig. 1) show a complex structure within the stellar disc, including a dominant bright spot with a peak intensity of 40-60% above the average intensity.

We interpret the features in our images as dust clumps at radii of 2–3 R_{star} seen against the photosphere. Such dust clumps may be caused by giant convection cells resulting in large-scale shock fronts and leading to clumpy molecule and dust formation, as modeled by Freytag & Höfner (2008) and Freytag *et al.* (2017).

We compared the VLTI-PIONIER, and VLTI-AMBER, data to a grid of dynamic atmosphere and wind models by Eriksson *et al.* (2014). We obtained a best fit with

† Available at http://www.eso.org/public/blog/how-stars-die/
‡ Available at http://www.eso.org/public/images/potw1807a/

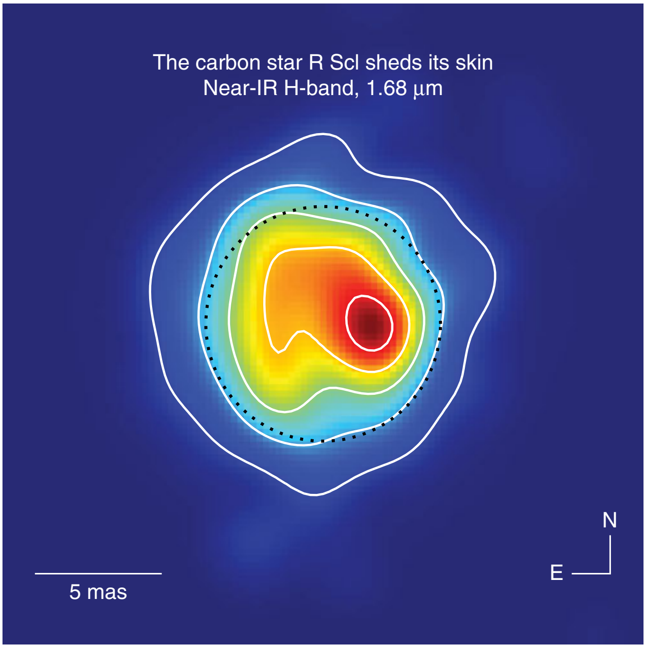

Figure 1. Image of R Scl at 1.68 μm, reconstructed with the `IRBis` package. The estimated Rosseland angular diameter is indicated by the dashed black circle. Contours are drawn at levels of 0.9, 0.7, 0.5, 0.3, 0.1. From Wittkowski *et al.* (2017).

a model without a wind, which may point to problems with current wind models at low mass-loss rates. We estimated an angular Rosseland diameter of 8.9 ± 0.3 mas, and derived further fundamental parameters of R Scl, which match evolutionary tracks (Lagarde *et al.* 2012, Marigo *et al.* 2013) of initial mass $1.5 \pm 0.5\,M_{\odot}$.

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