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A large bubble around the AGB star R Dor detected in the UV

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ABSTRACT

Many asymptotic giant branch (AGB) and supergiant stars exhibit extended detached shells in the far-infrared, resembling rings or arcs. These structures have long been interpreted as the bow shock formed in the interface between the stellar wind and the interstellar medium (ISM), the astrosphere. To date, only a few AGB stars have been observed showing an extended shell in the ultraviolet (UV): the cometary tail drifting away from *o* Ceti, and a bubble around IRC+10216, CIT6, and U Hya. This paper describes a search of UV extended shells around AGB stars using archival *Galaxy Evolution Explorer* (*GALEX*) far-UV images. After inspecting visually 282 *GALEX* images, we identified the fourth discovery of a UV bubble around the AGB star R Dor. The bubble is seen as a 26 arcmin × 29 arcmin ring, corresponding to an actual diameter of 0.41 × 0.46 parsec^2. The mass of the thin UV bubble is estimated to be $\simeq$0.003 M$_\odot$. The morphological asymmetry (less than ∼20 per cent) and brightness variations of this shell are uncorrelated with the stellar proper motion and thus they can rather be ascribed to inhomogeneities in the ISM. Archival *Infrared Astronomical Satellite* 60 and 100 μm images reveal that the bubble is filled with cold (i.e. $\lesssim$32 K) dust. All UV bubbles known to date are limited to be within a distance $\lesssim$350 pc and at high Galactic latitudes ($|b| \gtrsim 35^\circ$), which suggests that their detection is hampered in most cases by the strong UV interstellar extinction.

Key words: ISM: bubbles – ultraviolet: ISM – stars: AGB and post-AGB – circumstellar matter – mass-loss.

1 INTRODUCTION

The first large-scale structure detected in the ultraviolet (UV) associated with the mass-loss of an asymptotic giant branch (AGB) star was found around *o* Cet (Martin et al. 2007). Images obtained by the *Galaxy Evolution Explorer* (*GALEX*) observatory showed an arc-like structure opposed to a long cometary tail extending up to 2° from the star (Martin et al. 2007). The arc and the tail are both aligned with the direction of the large stellar proper motion, 225.8 mas yr^{-1} (*HIPPARCOS*; Turon et al. 1993). Actually, the arc seen in *o* Cet (and detached shells in other AGB stars) can be detected over a wide range of wavelengths, from radio wavelengths to UV, and is formed by the shock between the stellar wind and the local interstellar medium (ISM) or gas previously expelled from the star (Libert et al. 2007; Cox et al. 2012). The infrared (IR) radiation emitted by arcs and shells is thermal, after grains are heated by the passage of a shock wave (Cox et al. 2012), whereas the UV emission is probably composed of emission lines of various atomic species. Although the morphology of these structures generally resembles an arc, the fermata symbol or a shell, *o* Cet is the only case known to date where a *drifting or cometary tail* is seen trailing behind the star as it moves at large speed (Knapp et al. 2003; Wareing et al. 2007).

Radio and IR observations of AGB stars have revealed a large number of detached shells (often reaching several arc minutes in size) formed by the shock between the stellar wind and the local ISM (Libert et al. 2007; Cox et al. 2012; Brunner et al. 2019; Mečina et al. 2020). However, after *o* Cet, only three additional detached shells were eventually detected at UV wavelengths to date: IRC+10216 (Sahai & Chronopoulos 2010), CIT 6 (Sahai & Mack-Crane 2014), and U Hya (Sanchez et al. 2015). Differently from *o* Cet, all these shells are approximately round, and hereafter they will be called 'bubbles'. In all these cases, the AGB star is located near the centre of the expanding bubble, which follows the proper motion of the star.

This paper reports the fourth discovery of a newly found UV bubble around an AGB star. In Section 2, we describe the sample of AGB stars examined and some characteristics of these images; Section 3 gives a general description of R Dor and its close circumstellar environment; Section 4 describes the bubble around R Dor, both in the UV and IR; in Section 5, we discuss the factors that play a role in the *detection* of UV shells, as well as those that contribute to their *formation and endurance*; and in Section 6, we present our conclusions.

2 A SEARCH FOR UV STRUCTURES AROUND NEARBY AGB STARS

The *GALEX* satellite (Morrissey et al. 2005) constitutes the main data base for this research because it covered large portions of the sky in the near- and far-UV bands. The target sample was composed of: (1) all regular Miras listed in the *general catalogue of variable stars* (GCVS5.1; Samus et al. 2017); (2) the list of nearby semiregular stars, compiled by Glass & van Leeuwen (2007); and (3) the list of AGB and supergiant stars showing bow shocks and detached shells, detected in the far-IR by Cox et al. (2012). After cross-correlating these lists with the *GALEX* data base, we were left with a total of 282 stars observed by *GALEX* in at least one band. Eventually, we inspected visually each image in search of circumstellar features. As

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