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VLTI/MIDI OBSERVATIONS OF THE CIRCUMSTELLAR SHELL OF AN AGB STAR: W HYDRAE

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Abstract. W Hydrae is a prototype AGB star with a dusty circumstellar shell. The shell is marginally resolved at ground-based subarcsecond resolution; the unresolved dust condensation radius is expected to be of order $30 - 50$ mas. Since the dusty circumstellar shell is brightest in the mid-IR, the high spatial resolution required at mid-infrared wavelengths can currently only be achieved by using MIDI on the VLTI. We therefore outline a possible observing programme for the VLTI, using MIDI at 10μm. In a single night of short-baseline VLTI observations with two Auxiliary Telescopes, we can achieve sufficient (u, v) plane coverage to resolve the shell geometry of W Hya, which will provide strong constraints on the mass loss processes in late-type stars. We expect to either obtain an estimate of the dust condensation temperature, or evidence for interrupted mass loss.

1 W Hya as a prototype late-type star for mass-loss studies

W Hydrae (W Hya) is an Asymptotic Giant Branch (AGB) star with a dusty circumstellar shell. As many other AGB stars, W Hya is a Long Period Variable of Semiregular (SR) type, and a likely precursor of a Planetary Nebula (see e.g. Habing 1990 for a review).

Recent diffraction limited observations at 9.8, 11.7 and 18.0 μm obtained with the Mid-InfraRed Array Camera 3 (MIRAC3; Hoffmann et al. 1998) mounted at the 3.0m NASA Infrared Telescope Facility (IRTF) show a partialy resolved, possibly asymmetric envelope at sub-arcsecond resolution (Marengo et al. 2000).

The dynamical evolution of AGB circumstellar envelopes is largely controlled by the dust component, which provides the momentum coupling between the stellar radiation and the outflowing wind (*dust driven* mass loss). Resolving the

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circumstellar shell of W Hya will therefore provide strong constraints on the mass loss processes in late-type stars. If we could measure the inner radius of the shell, we would either obtain an estimate of the dust condensation temperature, or evidence for interrupted mass loss. Finally, the degree of asymmetry in the dusty shell will allow us to explore the issue of asymmetric mass loss and thus provide clues for the formation processes of asymmetric Planetary Nebulae.

2 The need for VLTI: choice of instrument and configuration

The key parameter to constrain the dust formation processes in the W Hya system is the dust condensation radius of its circumstellar shell. Radiative transfer models predict this quantity to be of the order of a few stellar radii, or $2-3$ A.U. (Ivezić & Elitzur 1997). With an Hipparcos distance of 8.73 mas (Perryman et al. 1997), we should thus expect a minimum inner radius of the W Hya dusty envelope of $\sim 35-50$ mas, which can only be measured by using interferometry.

In addition, due to thermal dust emission and strong silicate dust features around 9.8 μm, the dusty circumstellar shell is brightest at mid-infrared wavelengths. The combination of these properties, i.e., the high spatial resolution required at mid-infrared wavelengths, can currently only be achieved by using the MID-infrared Interferometric instrument (MIDI; Mariotti 1998) at 10 μm, at the focus of the Very Large Telescope Interferometer (VLTI). The simultaneous use of multiple MIDI channels in the N band will allow us to fit radiative transfer visibilities, in order to obtain robust estimates of the temperature and density distribution of the circumstellar shell.

Since MIDI's design only allows the use of two delay lines, the choice of baseline is critical for the coverage of the (u,v) plane. Given the source's brightness ($N \sim -4.8$; Neugebauer, Sargent & Westphal 1971), this project can easily be done using the Auxiliary Telescopes (ATs). Thanks to the brightness of the object and its position in the sky (δ(J2000)$= -28°22'03.5''$), this project only requires a single night to obtain good coverage of the (u,v) plane, cf. Fig. 1a. A single short baseline of 64m (AT positions C1 and G2) will allow us to resolve the shell geometry to a sufficient accuracy.

3 Data analysis strategy and expected quality of the results

In order to estimate the expected sensitivity of the VLTI fringes, we used the "Astronomical Software to PRepare Optical interferometry observations" (ASPRO) package, an interferometric observing preparation tool developed at the J.M. Mariotti Center of the University of Grenoble (France).

We modeled W Hya as a superposition of a point source and a truncated exponential disk, which is expected to be sufficiently close to reality to base our observing and analysis strategy on. If the (u,v) coverage shown in Fig. 1a can be achieved, assuming $\sim 5\%$ on-source observations, the expected visibility amplitude $V(u,v)$ of the model star with circumstellar disk is that of Fig. 1b. Our source is

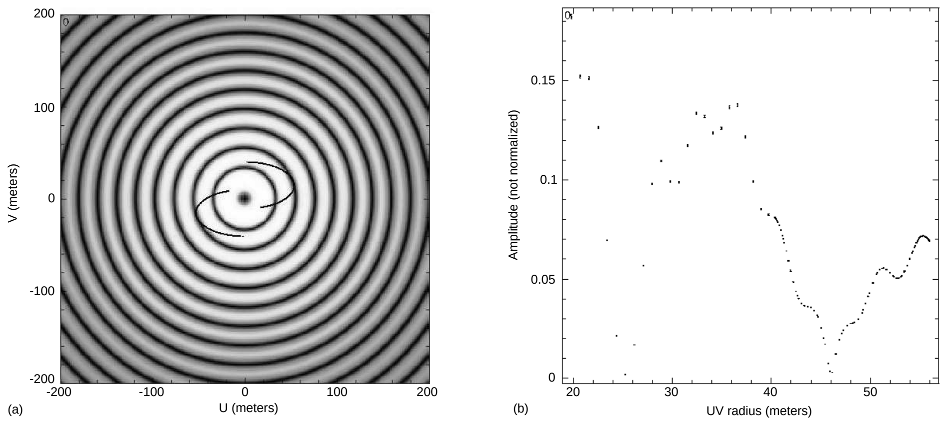

Fig. 1. *(a)* Expected VLTI (u, v) coverage of W Hya for a one-night observing run in June (solid curves), superposed on the first derivative of the visibility amplitude to the (u, v) radius. Light areas indicate steep slopes of the visibility amplitude. *(b)* Visibility amplitude as as function of (u, v) radius for the input model of panel *(a)*, consisting of a point source and a truncated exponential disk. A sampling rate corresponding to $\sim 5\%$ on-source observing time has been assumed.

clearly sufficiently bright to allow us to determine the shell parameters, including the radial dependence of the temperature, density and the shell geometry, by fitting model visibilities associated with various radiative transfer models of the source to the observed visibility amplitude. We emphasize the need for good (u, v) coverage once more, as this will ultimately determine how well we can obtain an estimate of the shell geometry.

References

Habing H.J., 1990, in Mennessier M.O., Omont A., eds., From Miras to Planetary Nebulae: Which Path for Stellar Evolution? Editions Frontières, Gif-sur-Yvette, p. 16

Hoffmann W.F., et al., 1998, Proc. SPIE, 3354, 647

Ivezić Ž., Elitzur M., 1997, MNRAS, 287, 799

Mariotti J.-M. et al., 1998, Proc. SPIE, 3350, 800

Marengo M., et al., 2000, in Kastner J.H., Soker N., Rappaport S., eds., ASP Conf. Ser. Vol. 199, Asymmetrical Planetary Nebulae II: From Origins to Microstructures. Astron. Soc. Pac., San Francisco, p. 91

Neugebauer G., Sargent W.L.W., Westphal J.A., 1971, PASP, 83, 305

Perryman M.A.C., et al., 1997, A&A, 323, 49L