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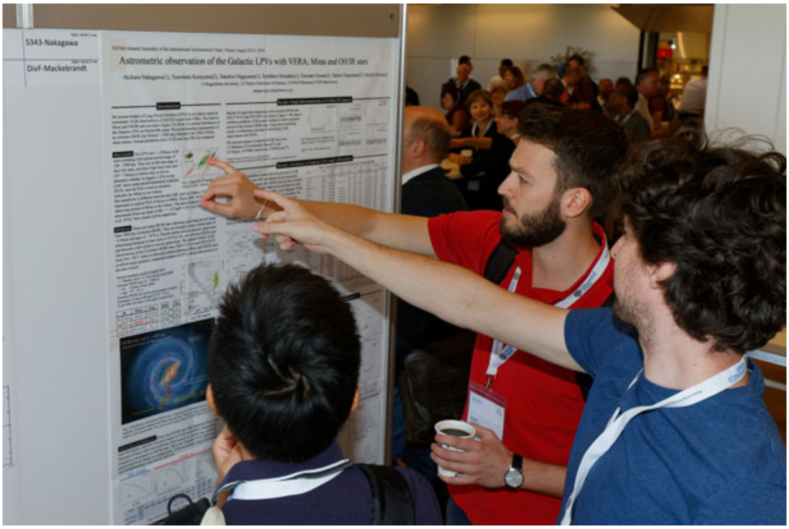

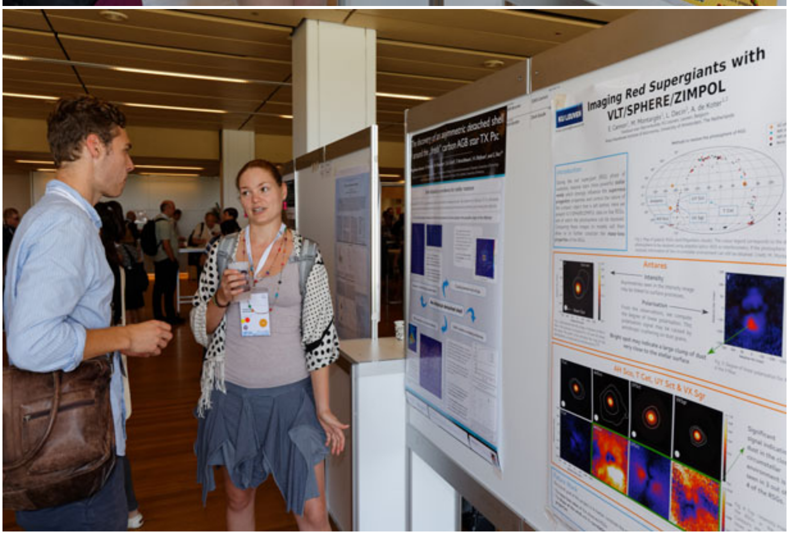

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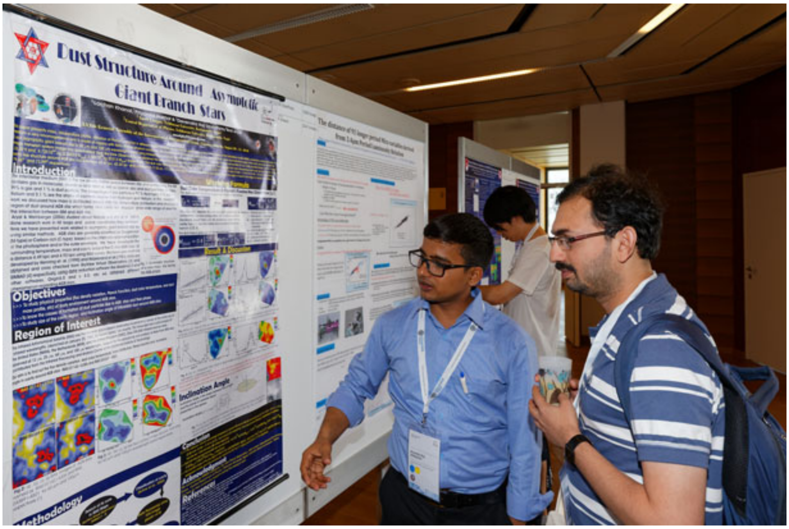

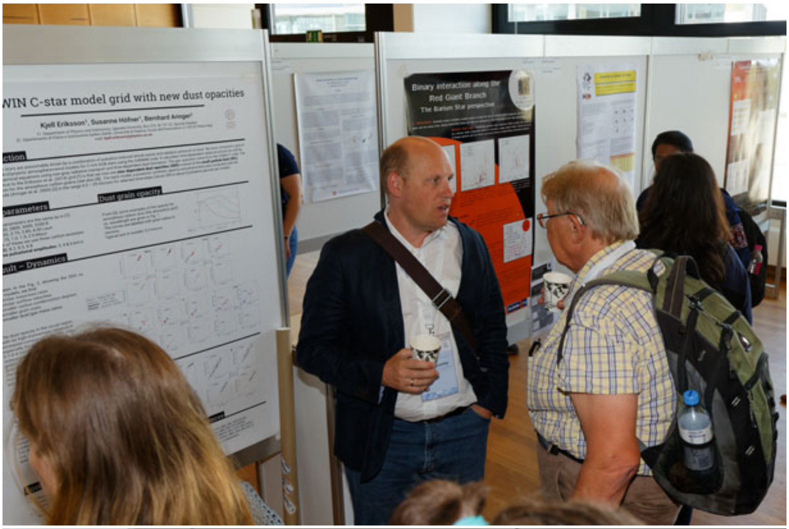

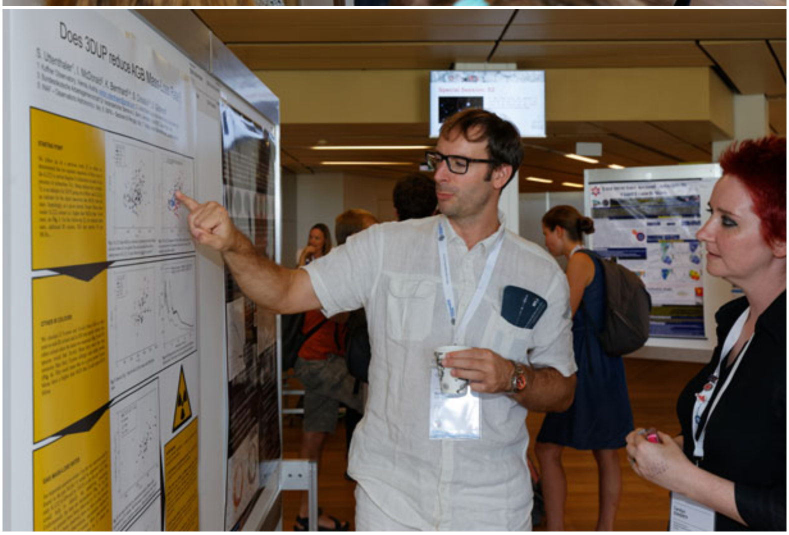

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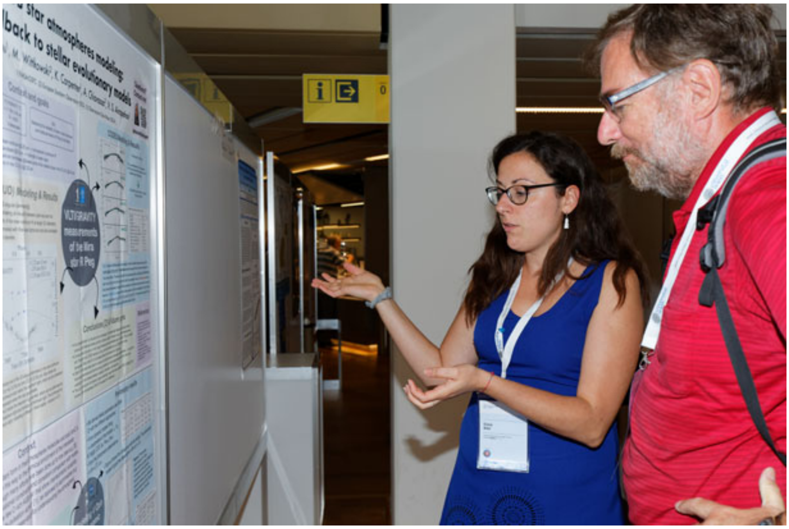

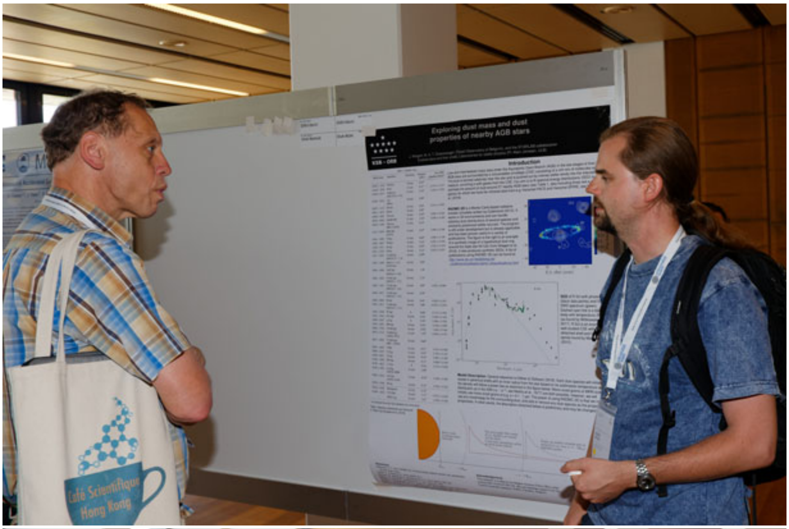

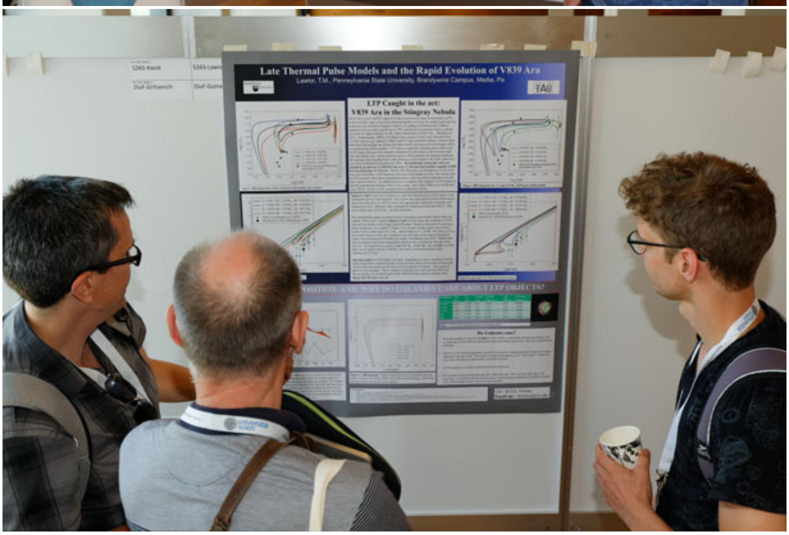

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M 1–92 revisited: the chemistry of a common envelope nebula?

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Abstract. We report on new molecular-line observations of the bipolar pre-planetary nebula M 1–92. The new IRAM 30 m MRT and NOEMA data shows the presence of shock induced chemistry in the nebula. From the derived [^{17}O]/[^{18}O] ratio, we suggest that the sudden mass loss event responsible for the formation of the nebula 1200 yr ago may also have resulted in the premature end of the AGB phase of the central star.

Keywords. stars: AGB and post-AGB, stars: evolution, stars: individual (M 1–92)

1. Introduction

M 1-92 is a $5'' \times 11''$ bipolar pre-planetary nebula with a 18,000 K (Sánchez-Contreras *et al.* 2008) central star and 10^4 $L_\odot$ at a distance of 2.5 kpc (Cohen & Kuhi 1977). The nebula is a bi-lobed structure divided by an equatorial flat disk, where most of the material is molecular gas, $\sim$ 0.9 $M_\odot$ (Bujarrabal *et al.* 1998a). ^{13}CO maps show that the nebula is dominated by a linear velocity gradient, most likely resulting from a sudden (common-envelope like) event occurred 1200 yr ago (Alcolea *et al.* 2007). Optical spectroscopy reveals the presence of a fast ionized wind very close to the star ($V_{\rm exp}$ up to 750 km s^{-1}; Sánchez-Contreras *et al.* 2008). Hα, H_2, OI, NII, OIII, SII are detected from compact knots located in the middle of the two lobes, revealing the existence of shocks along the symmetry axis, but amounting to just 10^{-3} $M_\odot$ (Bujarrabal *et al.* 1998b).

2. New observations

We have performed a full frequency scan of M 1–92 in the 3, 2, and 1.3 mm bands using the IRAM 30 m MRT, detecting for the first time $C^{18}O$, $C^{17}O$, HCO^+, $H^{13}CO^+$, HCN, $H^{13}CN$, CN, HNC, N_2H^+, SiO, SO, ^{34}SO, SO_2, $^{34}SO_2$, SH_2, $^{34}SH_2$, CS, NS and SO^+. Line profiles are of three kinds. CO and isotopologues show very similar broad profiles, –48 to +48 km s^{-1}, originating from the whole molecular nebula. Si– and S–bearing molecules only show emission from the central velocities, –20 to +20 km s^{-1}, suggesting that they arise from the equatorial component dividing the two lobes. Finally, HCO^+, HCN, HNC, N_2H^+, and CN show a triple peaked shape, only expected if the emission comes from the equator and tips of the nebula, but not from the lobe walls.

We have also conducted radio-interferometric observations, 8 GHz-wide, centered at 160, 176, 223, and 239 GHz, using the IRAM NOEMA interferometer, with resolutions of $0\farcs6$–$0\farcs8$ and 2.5–3.5 km s^{-1}. We covered ^{13}CO, $C^{18}O$, $C^{17}O$, HCO^+, $H^{13}CO^+$, HCN,

$H^{13}CN$, and CN 2–1 lines, and several transitions of SO, SO_2, and SO^+. The maps confirmed the expected location of the different emissions according to their profile shapes, but with some surprises. S-bearing species trace two components, the outer parts of the equatorial disk and a very compact one close to the star. This compact component is more prominent in higher excitation lines, and shows a very low velocity dispersion of $5\,\mathrm{km\,s^{-1}}$. As expected, HCO^+, HCN, and CN are detected in the outer parts of the equatorial structure and at both axial tips. However, HCO^+ and HCN are also detected in the middle of the two lobes, at $\pm\,2''\!.5$ from the central star, just ahead of the compact knots seen in optical forbidden lines, a region devoid of CO. This component shows a large velocity dispersion, up to $60\,\mathrm{km\,s^{-1}}$, and a lower kinematic age of 600 yr. All this suggest that these species are the result of a shock-induced non-equilibrium chemistry.

3. Results

Combining 30 m MRT single-dish data and the maps obtained with NOEMA, we estimate excitation and abundances for several species in M 1–92, using rotational diagrams in the optically thin approximation. We divide the molecular line emission in two bins, the line core with $V_{\rm exp} \leqslant 20\,\mathrm{km\,s^{-1}}$, and the line wings with $V_{\rm exp}$ between 20 and $50\,\mathrm{km\,s^{-1}}$. All species show low excitation temperatures, $\sim$10–15 K, in agreement with previous results (Bujarrabal *et al.* 1998a); only SO_2 shows a component with $T_{\rm exc} \approx 30$ K or higher. For a $[^{13}CO/H_2]$ ratio of 10^{-5}, we derive a total mass of $0.9\,M_\odot$. For the low velocity emission we derive abundances (relative to H_2) of 6 and $4\cdot10^{-8}$ for SO_2 and SO, and 7 and $3\cdot10^{-9}$ for HCO^+ and HCN, respectively. For the shocked regions detected in HCN and HCO^+ we cannot derive relative abundances since ^{13}CO is not co-spatial, but HCN shows twice the abundance of HCO^+, contrarily to what happens in the equatorial parts of the nebula. The SO_2 warm component must arise from the central compact component detected in the NOEMA maps.

From the $C^{17}O$ and $C^{18}O$ J=1–0 and 2–1 observations, we derive a $[C^{17}O]/[C^{18}O]$ abundance ratio of 1.62. Since no important fractionation effects are expected, we conclude that the $[^{17}O]/[^{18}O]$ isotopic ratio is 1.6. This ratio is constant along the AGB evolution, and it can be used to determine the initial mass of the star (de Nutte *et al.* 2017). A value of 1.6 gives an initial mass of 1.7 $M_\odot$ (values above 4–5 $M_\odot$ are excluded because they imply a much faster post-AGB evolution Gesicki *et al.* 2014). For a $1.7\,M_\odot$ initial mass, it is expected that the 3rd Dredge-Up results in the formation of a C-rich star. However, M 1–92 is O-rich (OH masers, strong SO and SO_2 lines, low $[^{12}C]/[^{13}C]$ ratio). One way to solve this apparent contradiction is assuming that the sudden $0.9\,M_\odot$ mass ejection that resulted in the formation of the nebula 1200 yr ago, prematurely ended the AGB evolution of the star, before it turned into C-rich.

Acknowledgements

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