Dusty discs around evolved stars

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Abstract

We present the discovery of dusty, edge-on discs around stars at different late-type evolutionary stages, Menzel 3, M2-9 and Sakurai’s Object. All three objects have been observed at high-angular resolution with MIDI on the Very Large Telescope Interferometer (VLTI). Characterising the dusty discs in the core of these nebulae and at different evolutionary stages, provides invaluable constraints on the processes that lead to these massive nebulae, which is one of the main scopes of this project. The analysis of each disc have been explored with the means of radiative transfer modeling.

What we’re looking for

Intermediate mass stars (1-8 M\(_{\odot}\)) undergo extreme mass loss during the late stages of their evolution. The mechanisms that dominate those stellar outflows are responsible for the shaping of the ejecta. The ejected material seems to depart from spherical symmetry during the late Asymptotic Giant Branch (AGB) stage, when it evolves into asymmetrical structures. These stars are giant factories of dust and heavy elements. Depending on their abundances during the AGB stage, they are either Oxygen-rich or Carbon-rich stars. In return, O-rich or C-rich dust (created in the atmospheres of AGBs) indicates the evolution phase at which is was ejected from the star. Complex phenomena perturb the mass-ejection in the late stages of stellar evolution: stellar magnetic fields, fast rotation or binarity are often involved, with the latter playing a more efficient role that needs to be confirmed. Such mechanisms can lead to the creation of a circumstellar, dusty disc. The compact and dense dusty cores in the centre of the nebula can be studied by means of infrared interferometry.

Infrared Interferometry

A planetary nebula (PN) is the ejected, ionised envelope of an evolved star. The star usually remains in the centre of the nebula and may be surrounded by a dusty disc. The PN may expand up to 0.1pc, while the disc may be 10–100AU, thus about 10\(^3\) smaller than the observed nebula. The ability of optical telescopes to detect these objects is very limited, while interferometers are quite suitable for the job. We have used the MIDI instrument with 3 of the 8.2m Unit Telescopes, which gave us a resolution \(\approx 0.01\) arcsec in the mid-infrared (N-band, 8-13.5 \(\mu\)m). We obtained six sets of spectrally dispersed visibilities for Menzel 3, four for M2-9 and six for Sakurai’s Object (Fig.3).

The Discs

Dusty discs observed by the VLTI around the central sources of nebulae, are the remnants of mechanisms that shape the gaseous ejecta into bipolar/multipolar nebulae. Our sample consists of three different stages of evolved stars, namely a bipolar planetary nebula (Menzel 3), a symbiotic star (M2-9) and a very-late-thermal-pulse object (Sakurai’s Object) allowing us to compare and assess the evolution of those dusty structures throughout the final stages of stellar evolution. For each of the three cases, we have detected a dusty disc around the central ionising source in the mid-infrared with VLTI. Their intrinsic geometric and physical properties have been determined with the use of radiative transfer modelling (MC3D, Wolf 2003) and these are presented in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Menzel 3</th>
<th>M2-9</th>
<th>V4334 Sgr</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R_{\text{in}}-R_{\text{out}}) (AU)</td>
<td>9 - 500</td>
<td>15 - 900</td>
<td>25 - 500</td>
</tr>
<tr>
<td>Distance (pc)</td>
<td>1.4</td>
<td>1.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Luminosity (L(_{\odot}))</td>
<td>30,000</td>
<td>60,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Temperature (K)</td>
<td>5,000</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Height at 10AU (AU)</td>
<td>~17 AU</td>
<td>~36 AU</td>
<td>~47 AU</td>
</tr>
</tbody>
</table>

**Conclusions**

- Dusty structures (discs/intips) are found in different stages of late stellar evolution: from AGBs as VYs, to PNe as M2-9 (Lykke et al. in prep.) and Menzel 3 (Chesneau et al. 2007) to VLTP events as Sakurai’s Object (Chesneau et al. 2009).
- The origin of discs is clearly linked to mass loss, as it is seen in the evolving disc of M2-9. Disks remain stable for long periods of time after the cease of mass loss (e.g. Menzel 3). In both cases the dust mass within the discs is 1% of that residing in the lobes.
- We summarise that masses parameters remain present past the planetary nebula phase, as seen in Sakurai’s Object. If binarity is the main shaping agent, then it seems that the angular momentum vector is stable for longer timescales.

References

3. Evans et al. 2006, AANRAS, 373, L75
10. Zijlstra 2007, BAoA Astronomy, 16, 79