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MyCn18 – The Engraved Hourglass Nebula

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Abstract. The structure and kinematics of MyCn 18 are reviewed and new VLT infra-red images are presented, revealing strong, spatially extended emission from the highly ionised core of this nebula and also the existence of a possible binary companion.

1. Introduction and Review

The beautiful and intriguing Engraved Hourglass planetary nebula caught the public imagination with the publication of the narrowband WFPC2 images of Sahai et al. (1999). The first detailed study of this object was by Corradi & Schwarz (1993), who compared it to the post-symbiotic nebulae He2-104 and BI Cru, based on morphological similarities, but noted that there was no direct evidence for a central symbiotic object. They found that the characteristic speeds of the nebular gas were $\sim \pm 25$ kms^{-1}, much lower than the ± 100 kms^{-1} seen in the other two objects and also noted that MyCn 18 has a double humped infra-red spectral energy distribution, again indicating that it is a true PN rather than a symbiotic nebula. The distance to MyCn 18 is uncertain; hereafter we follow Corradi & Schwarz and adopt a distance of 2.4 kpc, which gives a size of ~ 0.22 pc for the projected long axis dimension.

Bryce et al. (1997) presented high spectral and spatial resolution longslit spectra which revealed high speed (up to 500 kms^{-1}) knots of emission which lie roughly along the main axis but outside the main hourglass shell. O'Connor et al. (2000) presented a more detailed study of these knots. Their position-velocity arrays show that the knots follow a Hubble-like law, but they do not extrapolate back to the nebular centre. The kinematical age of the rings of the hourglass was calculated to be $t = 2400$ yrs, based on a $5''$ diameter and $v_{\rm exp} \sim 24$ kms^{-1}. For the fastest knot, $r_{\rm obs}/v_{\rm obs} \sim 1250$ yrs. O'Connor et al. (2000) speculated that the origin of these knots may lie in a nova-like process.

The WFPC2 images (Sahai et al. 1999) reveal a wealth of structural detail. The main hourglass has bright rims with a faint, radial, filamentary structure and etched rings around the hourglass lobes. There is a small, faint, inner hourglass, together with a bright ring $\sim 1.8 \times 1.4''$ (Ring 1) with a local minimum in emission at its centre and a smaller ring (Ring 2), seen most clearly in the high ionisation image. The central star is offset to the south-west of the geometric centres of these features, and this offset cannot be explained by a high proper motion through the ISM as the nebular structures all retain a high degree of axial symmetry. Several scenarios for asymmetric mass ejection of the AGB circumstellar envelope were considered and Sahai et al. favour some type of binary central system and note that the symbiotic nebulae He2-104 and R Aqu, (known binary central stars), also show an inner and outer hourglass. They calculated the total nebular mass to be $\sim 0.02 - 0.1$ M$_\odot$ and the mass in the fast knots to be $\sim 10^{-5}$ M$_\odot$, equivalent to the mass lost in a typical nova explosion. The central star was calculated to have a magnitude of $m_{\rm v} = 14.9$, and Sahai et al. concluded that it is probably surrounded by hot dust as the expected K-band flux (derived assuming $T_{\rm eff} = 51\,000$ K) is much less than the observed value of 0.033 Jy (Whitelock, 1985). Sahai et al. considered various formation processes. Interacting stellar winds models can generate an hourglass shape for equator to pole density ratios ≥ 10 but cannot account for the complex inner structures. Garcia-Segura et al. (1999) have generated an hourglass shape numerically from a single, rapidly rotating star. Sahai & Traugher (1998) proposed that a round circumstellar envelope would be later shaped by the effect of a fast (100 km s^{-1}) collimated outflow. We see evidence for just such an outflow in the fast knots of MyCn18.

Dayal et al. (2000) presented a spatio-kinematic model, constrained by the HST images and the spectra from Corradi & Schwarz (1993). They derived electron densities of $\sim 10^4$ cm^{-3} in the central region, falling to 1350 cm^{-3} in the lobes. The radial velocity field increases with latitude and dynamical timescales are 1000 yrs at the waist, 2500 yrs in the lobes. They find that the hourglass nebula is density bounded except in the region close to the waist of the nebula and the lobes are almost hollow shells, having about 0.013 M$_\odot$ in the lobe walls but only 0.006 M$_\odot$ within the lobes.

The first radio maps of MyCn18 were published by Bains et al. (2002), who presented maps at four frequencies obtained with the Australia Telescope Compact Array. These again show that the emission is strongly core dominated but in the higher resolution maps the emission also traces the hourglass lobes. In the 8640 MHz image the radio peak is offset to the west of the geometric nebular centre, following the offset of the central star in the optical images. The measured brightness temperatures (< 2000 K) are low, presumably an effect produced by beam dilution of a clumpy nebula in addition to the nebula not being particularly optically thck. Spectral index maps show the core to be more optically thick than the lobes at the lower frequencies.

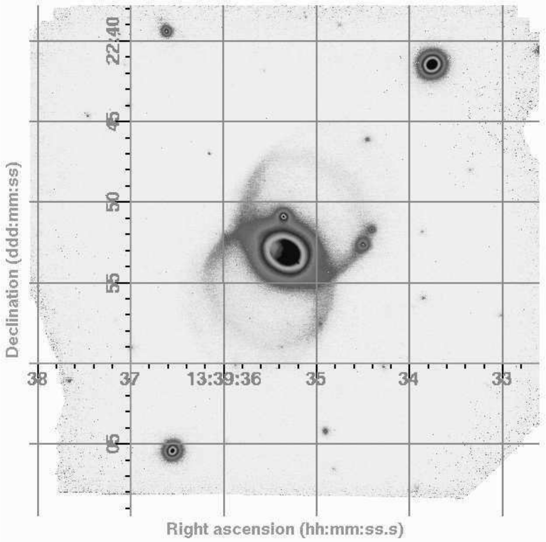

Figure 1. Ks band VLT image of MyCn 18 showing faint, diffuse emission from the lobes and strong emission from the central region.

2. New, Infra-red Observations of MyCn 18

In May 2003, we observed MyCn 18 in the infra-red using NACO on the VLT, the adaptive optics providing a resolution of $< 0.1''$. A preliminary Ks-band image is shown in Fig. 1. There is faint emission tracing the hourglass lobes and much stronger emission from the core, which follows the same double ring structure observed by Sahai et al. (1999). We also obtained narrowband images through a molecular hydrogen filter. A preliminary image is presented in Fig. 2a, which shows a thin ring of emission from the hourglass waist. This is probably line emission, as it is clearly different in structure from the diffuse continuum emission. The central region is shown in Fig. 2b, here Rings 1 and 2 can be seen, but we note that most of this emission is probably continuum. The N-S extensions from the star are filter ghosts, however there may be an extended feature to the west of the central star. Of particular interest is the discovery of a star to the south-west of the central star, just outside Ring 1, on the minor axis of the nebula. It is tantalising to speculate that this star is part of the MyCn 18 system and may thus have played a role in its shaping and evolution.

3. Conclusions

We are currently analysing the new VLT infra-red images, which may well reveal the first detection of molecular emission lines from this object and, perhaps more importantly may contain direct evidence for a binary central system. If this is the case then we have the enticing prospect of being able to determine in great detail the evolutionary history of this PN. The prospect of shaping as a result

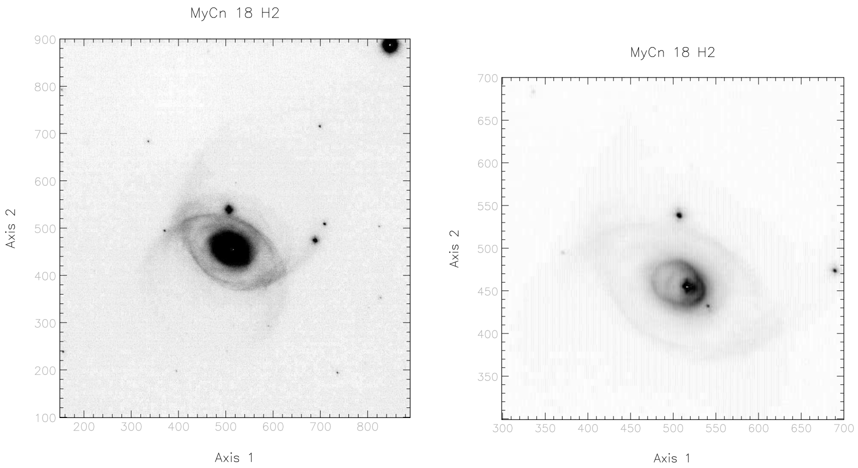

Figure 2. The narrowband images (not continuum subtracted), showing line emission coincident with the waist of the hourglass. The second panel is an enlargement of the central region, showing emission coincident with Rings 1 and 2 as well as the potential companion star.

of binary interactions has been a recurring theme of this conference. Numerical simulations are well advanced but to date, concrete observational evidence is sadly lacking. For this reason, MyCn 18 is proving to be not just a beautiful object but potentially an extremely important one for the wider understanding of PN evolution.

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