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The dark lane of the planetary nebula NGC 6302

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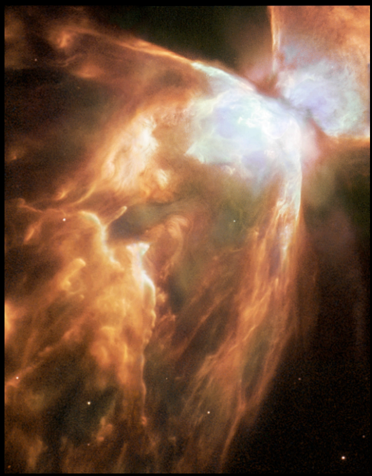

Summery

The butterfly-shaped planetary nebula, NGC 6302, shows a unique, dense equatorial dark lane, which is presumably a dusty disc. We trace the structure of this disc using Hubble Space Telescope (HST) Hα and NII images, Very Large Telescope (VLT) L- and M-band images at 0.4-arcsec resolution, and a JCMT 450 micron image. Extinction maps are derived from these images. Within the disc, the extinction is $A_{H\alpha}$=5-7 mag. The 450 micron map shows a north-south elongated central core, tracing the massive dust disc, and extended emission from dust in the bipolar flows. A fit to the SED yields the disc dust mass of 0.03 M_{sun}. The innermost region shows an ionized shell. The orientation of the polar axis shows a marked change between shell, disc and inner and outer outflow. The structures are well described by the warped-disc model of Icke (2003). An infrared source is found close to the expected location of the central star.

Warped disk in NGC 6302

This bipolar nebula shows disc traces by an high extinction.
The outflows close to the disc are traced by a strong edge. These features are exactly predicted by the hydrodynamic model by Icke (2003; Fig 3).

The extinction is estimated from Hα and 6cm continuous emission. The highest extinction is recorded by A(Hα)=6 mag.

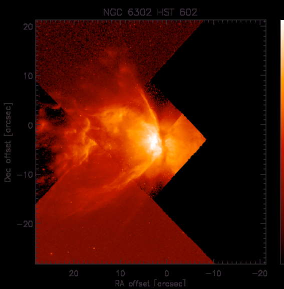

Fig. 1

The HST WFPC2 image in the F656N band (6564 Angstrom). The scale is log $I\nu$ in Jy arcsec^{-2}. The image is dominated by the Hα line.

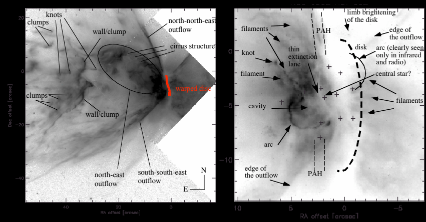

Fig. 2 Schematic view of NGC 6302. Outer region (left) and the central region (right)

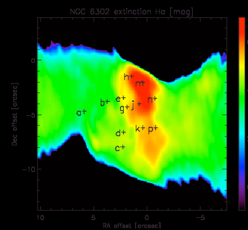

Fig. 4 Extinction map derived from Hα and 6cm ($A_{H\alpha}$).

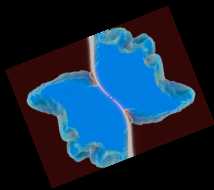

Fig 3. Warped disc calculated by the hydrodynamic model (Icke 2003)

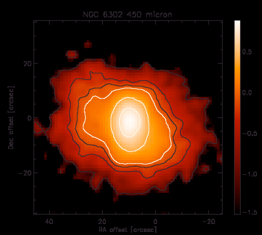

Fig 5. The SCUBA/JCMT 450 micron image in log Iν in Jy per beam.

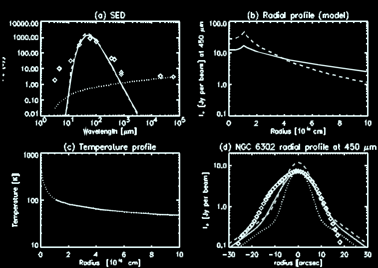

Fig. 6 (a) The SED of NGC 6302 (diamonds) and model fits with two different radial profiles (solid line $\rho=\rho_0(r/r_0)^{-1}$;dashed line $\rho=\rho_0(r/r_0)^{-2}$). (b) Model radial profile at 450 micron. (c) Temperature distribution (d) Comparison of the theoretical radial profile for density distributions.

Far-infrared emission from the disc

NGC6302 was observed with SCUBA/JCMT on 15th April 1998. The bema size is about 7 and 13 arcsec at 450 and 850 micron, respectively. At 450 and 850 micron, NGC 6302 was resolved (image at 850 micron is not shown). A large amount of far-infrared excess is detected near the centre of nebula. This excess supposed to be thermal emission from dust grains in the disc.

We model the SED using radiative transfer code (Nomura 2002; Nomura and Millar 2004). A detached dust shell is assumed with a inner and an outer radius, R_{in} and R_{out}. Two different radial distributions of dust grains are used: $r=r_0(r/r_0)^{-1}$ and $r=r_0(r/r_0)^{-2}$. The distance is taken as 1kpc and the luminosity as 2436 L_{sun} (obtained from IRAS data). The SED is fitted reasonably well with the model parameters $R_{in}=1\times10^{16}$ cm and $R_{out}=1\times10^{17}$ cm, and a dust mass of 0.03 M_{sun}. This suggests gas mass of 3 M_{sun} if gas-to-dust ratio is 100.The dust temperature ranges between 50 and 100 K.
Below 12 micron, the observed flux is much higher than the model fit, showing that a dust component with a much higher temperature must be present.

Central star or hot ionised gas?

A compact infrared source is present near the centre of symmetry of the PN. It has no counter part at Ha image, suggesting high optical depth or non-ionised gas. The flux of compact source using 0.4-arcse aperture photometry is 10.6, 11.4, and 13.8 in magnitudes in M_NB, NB_4.07, and NB_3.21,
The IR photometry, for a temperature of 1.0×10^5 K (Ashley and Hyland 1988) gives a luminosity $L=4.8\times10^4$ L_{sun}.This luminosity would be consistent with the evolutionary track for stars with initial mass of 5 M_{sun} (Vassiliadis and Wood 1993). But if the temperature is higher (Ashley and Hyland 1988), the resultant luminosity increases dramatically. In addition, the extinction should not be ignored which has not been calculated in the estimate above. The luminosity could be even higher. This suggests that infrared source is unlikely to be a central star itself, but could be ionised gas associated with the central star.

We have obtained L-band spectra of NGC 6302 with ISAAC. Across the central bob, we detect hydrogen recombination lines and a 3.94 micron emission line, while the other regions along the slit do not show a 3.94 micron line at all. There is a clear difference in the spectra towards the central objects. 3.94 micron line is identified as [SiX] by Cassasus et al. (2005), although it could be [FeII] line which is of photometric origin in O-type stars (Lenorzer et al. 2002). The nature of this central object is an open question.

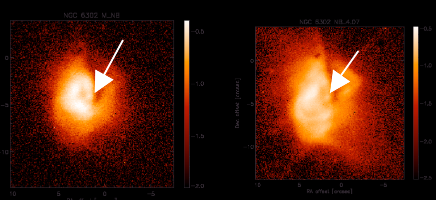

Fig 7. M_NB (left) image and NB_4.07 image (right). Possible central star is indicated by arrows.

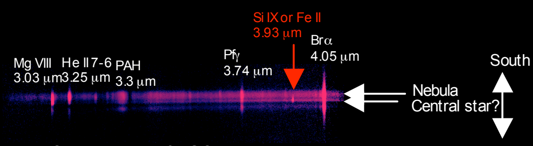

Fig 8. Spectral image of NGC 6302 in the central region