Dust shell and central star of the planetary nebula NGC 6537

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1. Summary

A certain fraction of planetary nebulae (PNe) shows bipolar shapes. The central stars of PNe have experienced a large mass loss at the end of the AGB phase. The interaction of the slow AGB winds with fast PN wind may cause a bipolar wind. However, we have not yet studied the morphology of AGB wind.

Bipolar PNe may have higher progenitor mass (Kastner et al. 1996, ApJ 462, 777). NGC 6537 is known to be nitrogen and helium over-abundant (Peimbert 1978), which is the characteristic of type I PN, which probably have high main sequence mass (5-8 M_{sun}). However, the central star of NGC 6537 had not been detected before.

Here, we report the first detection of the central star. Using the multi-band photometry and constrains from the dynamical age of the nebula, we derive a temperature in the range of 1.5-2.5x10^5 K, a luminosity ~10^3 L_{sun}, and a core mass Mc=0.7-0.9 M_{sun}. The progenitor mass is probably M_i=3-7M_{sun}.

The extinction map shows a largely symmetric, and compact dust structure. This shell is most likely a shell, and traces the high mass-loss at the end of AGB phase. The dynamical age shows that this shell and bipolar outflow were formed almost simultaneously.

2. Observations

A K-band image of NGC 6537 was obtained with the Adaptive Optics system, NAOS-CONICA on the Very Large Telescope (VLT) on the 6th of March. The approximate spatial resolution is 0.22'' (RA direction) and 0.16'' (Dec direction).

Optical HST images were taken on the 12th of September 1997 with Wide Field Planetary Camera 2 (WFPC2). The pixel scale is 0.1'' per pixel.

2.1 Central Star

We clearly find an isolated central star in the K-band and three optical images. We show images of the K-band and HST F631N (6372 Angstrom) in Figure 1 and 2 (the location of the central star is indicated).

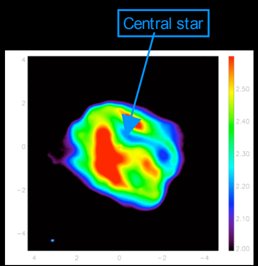

Fig 1. K-band image of the central region of NGC 6537

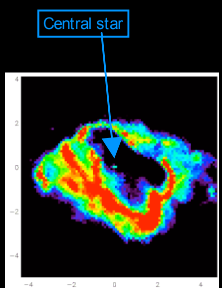

Fig 2. HST F631 image of the central region

2.2 Extinction map

The extinction map is estimated from the HST Hα (F656N) and Hβ (F487N) images. We assumed the electron temperature of 15000 K, and the electron density of 1x10^4 cm^{-3} (Pottasch et al. 2000b A&A 363, 767). The Hα and Hβ ratio of 2.79 (case B) is used (Storey and Hummer 1995, MNRAS 272, 63),

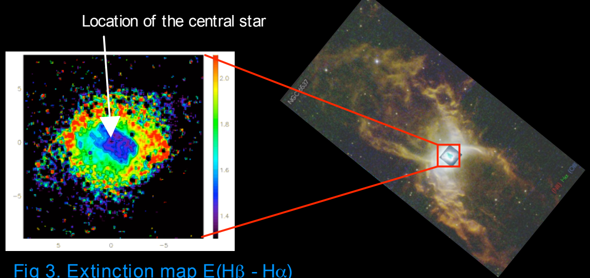

Fig 3. Extinction map E(Hβ - Hα)

Figure 3 clearly shows that the extinction is not uniform, showing that extinction is mostly circumstellar origin as well. The extinction is distributed in a 'ring-like' structure.

The central star is located at the centre of this ring, but not at the centre of arcs with ionised gas.

3. Discussion

3.1 Luminosity of the Central Star

We estimate the luminosity of the central star using our photometric data and estimated temperature (Figure 4).

Initially, we fit the photometric data with the T_{bb}=500 000 K black body, the distance of D_0=2.4 kpc, and the stellar radius of r_0=1.16x10^{-2} R_{sun} (Pottasch 2000a). With these parameters (case Ia), the fit is within the uncertainties for optical fluxes, but not suitable to the K-band flux.

For the next step, we scale the blackbody by a factor of α^2, i.e., solid angle $\Omega \sim \pi (\alpha\, r_0/D_0)^2$ is a factor of α^2 larger. The lowest flux range within the uncertainty is fitted with α=1.16 (case Ib), and the highest flux range is found at α=1.438 (case Ic). Luminosity is calculated with two possibilities for each case: the scaling factor is adopted to the distance, or to the radius. We also vary the Tbb according to our Tz, and Casassus et al (2000)'s estimate of 150,000 K (case IIIa and IIIb).

Table 1 Fitting parameters to the magnitudes, and resultant luminosities

	T_{bb} [K]	α	L_{star} [L_{sun}]
Case Ia	500 000	1.00	7.5x10^3
Case Ib	500 000	1.16	(7.5-10.1)x10^3
Case Ic	500 000	1.38	(7.5-14.4)x10^3
Case II	150 000	2.64	61-426
Case IIIa	340 000	1.41	(1.6-3.2)x10^3
Case IIIb	340 000	1.68	(1.6-4.5)x10^3

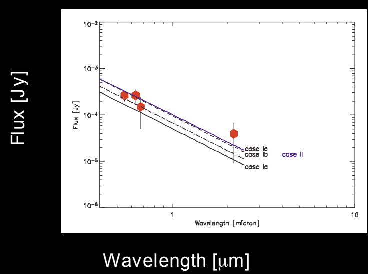

Fig 4. Fluxes and their uncertainties of the central star, and blackbody fits

3.3 Evolutionary Stage of the Central Star

The estimated range of the luminosity, L_{star}, and the effective temperature, T_{eff} (assuming T_{eff}=T_{bb}) is plotted on the HR diagramme (Figure 5). The evolutionary track for solar abundance (Bloecker 1995, A&A 299, 755) is compared. The The central star could have entered the cooling track.

The L_{star} and T_{eff} are within the evolutionary tracks for the star with core mass of 0.7-0.8 M_{sun} and with zero age main sequence mass M_{ZAMS}=3-7 M_{sun}, supporting that the initial mass of this bipolar nebula is relatively high mass.

The dynamical age derived from the size of inner shell and a wind speed of 16 km s^{-1}, at a distance of 1.2 kpc is about 1400 years. The bipolar lobes have velocities of =350 km s-1. This gives an essentially the same age. This dynamical age excludes a central star of 500 000 K.

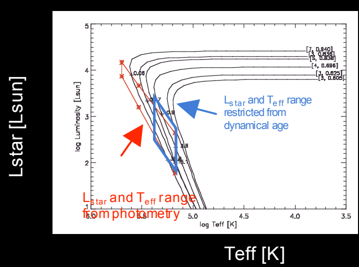

Fig 5. Range of luminosity and effective temperature (red line) of the central star. Evolutionary tracks (Bloecker 1995) are plotted [M_{ZAMS}, $M_{core\,mass}$]

3.3 Dust shell

The morphology of dust shell is circularly symmetric, and either a torus or a spherical shell (with some holes for bipolar outflow). There is no evidence for a disk.

This dust shell should be a remnant of AGB mass-loss, and estimated mass is about 0.2Msun. The density is estimated to be higher than 3x10^4 cm^{-3}, which is sufficiently high enough to resist against PN wind, and the shell could keep the original shape which were ejected during AGB phase.