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The asymmetric nebula M 3–15

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We present *HST* images and VLT/UVES spectra of a nebula surrounding a [WC 5] central star. The data reveal a complex morphology of the object showing of a number of rings and wings with several velocity components, best interpreted in terms of a binary interactions.

The asymmetric planetary nebula M 3-15

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M 3-15 (PN G 006.8+04.1) has a [WC 5] central star

It is assumed to belong to the Galactic Bulge.

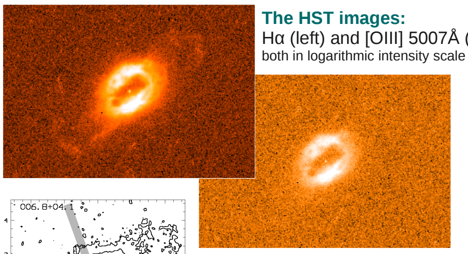
Recently a dual dust chemistry was found in its spectra (Perea-Calderon et al., 2009).

This planetary nebula like most of [WC]-type nebulae shows a turbulent velocity component in addition to a constant expansion velocity (Gesicki et al. 1998).

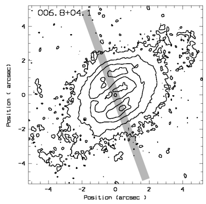
Gesicki et al. (1998) discussing M 3-15 concluded that ``the assumed very high turbulence may only be an approximation to a more complicated situation with strong velocity variations in radial direction".

We obtained HST images and VLT/UVES spectra of this object and found in the data a very intriguing velocity pattern.

This velocity seems to be unique and also the central star belongs to scarcely populated [WC 5] class (actually more common in the Galactic Bulge than in the disk) therefore the results shouldn't be generalized.



The HST images:
Hα (left) and [OIII] 5007Å (below)
both in logarithmic intensity scale

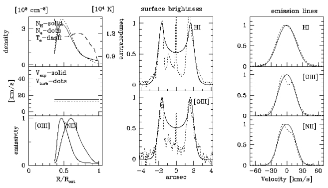


The contour plot of the Hα image
with intensities (0.5,2,10,30,50) adopted to show all nebular structures and with spectrograph slit indicated

Photoionization modelling of the nebula

The Torun codes (photoionization and kinematics in spherical symmetry) have been applied to fit the data. The density was adopted to reproduce the cross-sections of images.

The averaged emission profiles were fitted with a constant velocity of 15 km/s with additional turbulent component of comparable value.



The figure shows the radial distributions of density, velocity and emissivity of the spherical model (left panels), the surface brightness profiles fitted to the image cross-sections (centre) and the emission line profiles fitted to the averaged along the slit observed profiles.

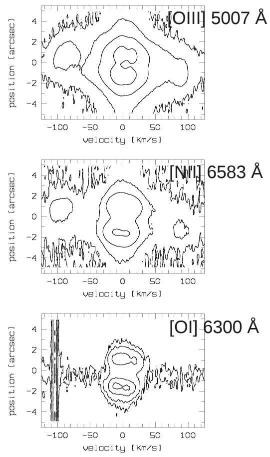
Our modelling shows that the emission line strengths are quite well fitted for stellar temperatures ranging between 70-90 kK. The higher temperatures resulted in stronger HeII 4686Å line, but we noticed that in our UVES spectra there is no trace of the nebular component to this line. This favours the stellar temperature values lower than derived by van Hoof & Van de Steene (1999).

The low ionization/excitation lines indicate the presence of the ionization front.

The ionized mass should be as high as 0.5 M_{SUN} to reproduce the flux in Hβ line.

The emission lines shown in the P-V plots

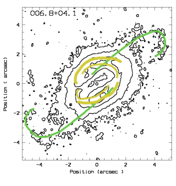
(contours 1,10,100,1000 for [OIII] and [NII], 2,5,20,40 for [OI])



Remarkable are the high velocity components (at approximately ±85 km/s) already noticed by Pena et al. (2001), they are seen nearly at the same spatial position as the main emissions.

The main components of the emission lines show splitting in the upper and lower parts of the slit which means that both the northern and southern fragments of the ring consist of ejecta moving in opposite directions.

Nebular rings and wings



M 3-15 is probably composed of a number of arches (wings), moving with different velocities and non-coplanar.

The main nebular body is nearly empty in its centre so it cannot be an ellipsoid or barrel seen with limb enhancement, this has to be a ring-like structure.

It cannot be a single ring seen in projection because this wouldn't result in the observed line splitting, there should be more components.

Looking at the HST image one can identify a number of concentric, fragmented rings, very schematically marked with yellowish lines.

If we would like to identify the weak and fast component with **the faint outer wings** (both in VLT spectra and in HST image are at the level of about 1% of maximum intensity) - the structure should follow approximately the green line.

The outer wings are about 3 times larger than the inner structures while their velocity is 6 times higher – they might be younger.

Conclusions:

The very high turbulence deduced earlier appears now to be a superposition of a number of wings moving with different speed and in different directions. We warn against generalization since there exists another highly turbulent (18 km/s) planetary nebula NGC 1501 with WC4/OVI central star, which appears to be quite regular turbulent bubble (Sabbadin et al. 2000).

There is (yet) no direct evidence of binarity of the central star however we point that:
• the multitude of rings and wings can be interpreted via binary interactions
• the dual dust chemistry might be explained by a disk in a binary or spiralling of a low-mass body into an AGB star
• [WR]-type central star can be a result of a binary merger

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