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Spatio-kinematic modelling of the double-shelled PN Abell 65

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Abell 65 is one of the few planetary nebulae known to contain a binary central star, and as such represents an opportunity to investigate the effect of binarity on nebula formation and evolution. Deep imaging and high-resolution echelle spectroscopy, in conjunction with spatio-kinematic modelling, reveal the bipolar nature of Abell 65 and importantly a nebular inclination consistent with that of the central binary, indicating that the binary may have played a dominant role in the shaping of the nebula. Furthermore, the data reveal the presence of two nebular shells, each with similar morphologies and inclinations, but not co-eval in nature (with the outer-shell being kinematically older).

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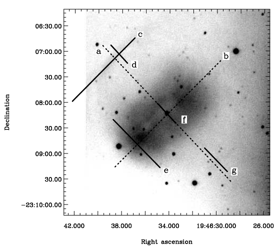
Abstract

Abell 65 is one of the few planetary nebulae known to contain a binary central star, and as such represents an opportunity to investigate the effect of binarity on nebula formation and evolution. Deep imaging and high-resolution echelle spectroscopy, in conjunction with spatio-kinematic modelling, reveal the bipolar nature of Abell 65 and importantly a nebular inclination consistent with that of the central binary, indicating that the binary may have played a dominant role in the shaping of the nebula. Furthermore, the data reveal the presence of two nebular shells, each with similar morphologies and inclinations, but not co-eval in nature (with the outer-shell being kinematically older).

1. Abell 65 and its central star

Based on deep-narrowband imagery, Bond and Livio (1990) describe A65 as an elliptical nebula, with a faint extended wisp to the northeast taken to be a sign of bubble penetration - indicating that the overall nebular symmetry axis is roughly perpendicular to the major axis of the bright elliptical emission. They also report a photometric period for the central star of ∼1 day. Walsh and Walton (1996) obtained deeper images of the nebula in [OIII]5007 Å, [NII]6584 Å and Hα, which clearly show the presence of an outer shell. A dark lane within the inner nebula suggests the presence of a hollow region. The 1 day period was confirmed spectroscopically, as well as photometrically, by Shimansky et al. (2009). Their modelling determined the central binary to be a hot sdO primary and an evolved secondary with an orbital inclination of $68 \pm 2°$. This system must have undergone a common envelope phase, the shedding of which is believed to play a major role in the shaping of planetary nebulae.

2. Observations

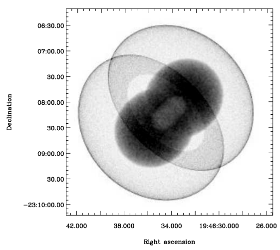


Using the Manchester Echelle Spectrometer on the 2.1m San Pedro Mártir telescope (Meaburn et al., 2003), two longslit spectra of the [OIII]5007 Å emission from A 65 were obtained with a 5' slit aligned roughly parallel and perpendicular to the long axis of the nebula (see image, slits a and b). Binning of 2×2 was employed, giving 0.62" pixel^{-1} in the spatial direction and a spectral resolution of ∼10 km s^{-1}. During the observations, the seeing did not exceed 2".

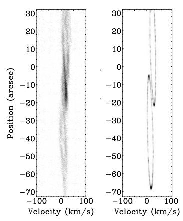
Twelve further longslit spectra were acquired with UVES at the VLT, using a 30" slit (Dekker et al., 2000). Several slits were positioned end-to-end such that longer slits could be produced (slits c, e and g). No binning was employed resulting in 0.19" pixel^{-1} in the spatial direction and a velocity resolution of ∼4 km s^{-1}. During the observations, the seeing did not exceed 1".

All observations were reduced using standard STARLINK routines.

3. Modelling



The [OIII]5007 Å emission from the nebula was modelled using SHAPE (Steffen & Lopez, 2006). The modelling assumes a Hubble-type flow for the nebular shell, but all other nebular parameters were allowed to vary freely (morphology, size, expansion velocity, etc.). The resulting images and PV arrays were compared by eye to the observations, until a best fit was established (for greater discussion of the method, see Jones et al. 2010). The best-fitting model comprises two bipolar shells, not kinematically co-eval in nature (with the outer shell being roughly twice the age of the inner), with symmetry axes inclined to the line of sight at ∼60°.



Shown on the left is an example of an observed and modelled PV array, in this case slit (c). As shown in the image in panel 2, slit (c) runs parallel to the nebular symmetry axis but through the edge of the outer shell crossing the wisp of emission remarked upon by Bond & Livio (1990). The velocity structure of this slit is typical of a bipolar nebula.

4. Discussion

The kinematics of the planetary nebula Abell 65 have been investigated and modelled. The nebula has a double-shelled structure inclined roughly perpendicular to that of the central binary, consistent with predictions of binary shaping (de Marco, 2009). The model, also, clearly shows that the bright central shell is not the waist of an extended bipolar structure as has previously been suggested.

References
- Bond & Livio 1990, ApJ, 335, 568
- Walsh & Walton 1996, A&A, 315, 253
- Shimansky et al. 2009, Astrophysical Bulletin, 64, 349
- Meaburn et al. 2003, RMxAA, 39, 185
- Dekker et al. 2000, SPIE vol. 4008, 534
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- Jones et al. 2010, MNRAS, 401, 405
- de Marco 2010, PASP, 121, 316

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