The University of Manchester
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The Morphologies and Kinematics of Planetary Nebulae with Close-Binary Central Stars

PPARC
Particle Physics and Astronomy Research Council

The role of close-binary stars in PN evolution

It has been proposed by Soker (2000) that close-binary central stars are required to form the most collimated planetary nebulae (PNe), e.g. M2-9 (Fig.1). Mass transfer in the binary system is thought to produce an accretion disk around the more compact stellar component and subsequently jets will be launched along the polar axis of the binary, which create elongated, narrow lobes.

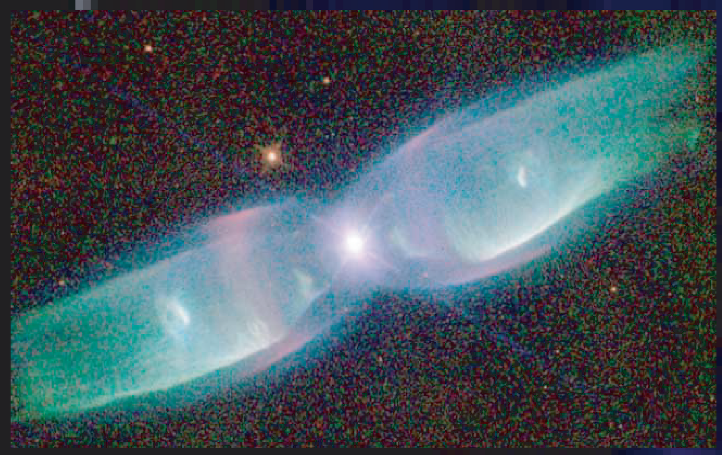

Figure 1: The collimated PN M2-9

A programme is currently underway to study the morphologies and kinematics of PNe with confirmed close-binary central stars. Three of the observed PNe have eclipsing binaries; these objects are important because their physical parameters can be determined in a model independent way. The properties of these PNe can be used to study the role of close-binary central stars on PN evolution.

Observations

Longslit line profiles of northern sky targets were obtained in June 2004 with the Manchester Echelle Spectrometer combined with the 2.1-m San Pedro Martir telescope (SPM-MES).

Southern sky targets were observed in 2005 using UCLES combined with the 3.9-m Anglo-Australian telescope (Fig. 2), and the EMMI spectrograph combined with the 3.58-m ESO New Technology Telescope in La Silla.

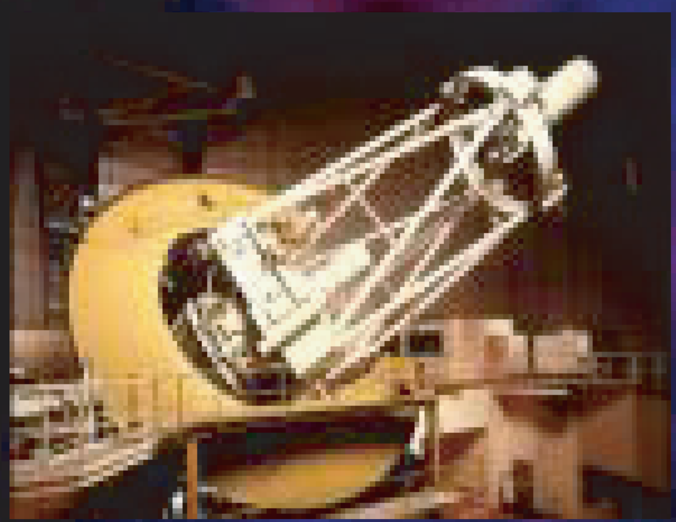

Figure 2: The 3.9-m Anglo-Australian telescope

Test case (1): Abell 63

UU Sge is the central star of Abell 63 and is almost totally eclipsing at an inclination of 87.5°. Its physical parameters have been derived with unprecedented accuracy. Abell 63 provides an ideal opportunity to test the hypothesis that the nebula has the same inclination as the central binary system.

A deep Hα+[NII] image of Abell 63 is shown in Fig. 3. Abell 63 has a bright nebular shell and from this, faint, well-confined extensions lead to end-caps, giving the overall impression of a tube with a waist.

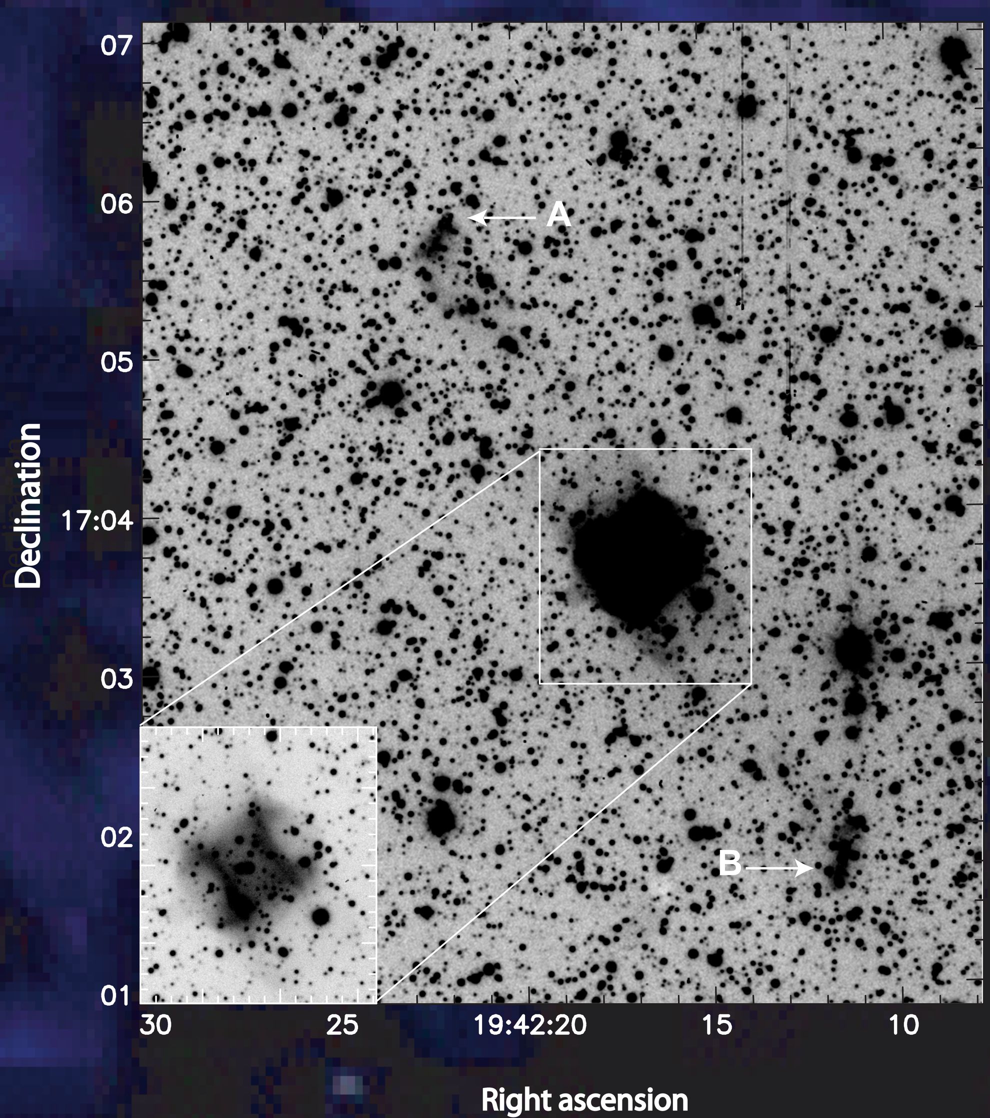

Figure 3: An Hα+[NII] image of Abell 63. The end-caps are labelled A and B

Fig. 4a (left) shows an image of the central nebular shell of Abell 63 with slit positions 1, 3 and 9 drawn on, and the corresponding longslit spectra (right). The spectra are consistent with viewing a radially-expanding hollow tube in cross-section. The kinematic ages of the nebular shell and the extended lobes are found to be consistent at 12,900 years, suggesting they were both formed during the same event. The kinematical age is consistent with theoretical evolutionary tracks for AGB remnants (Schoenberner 1981).

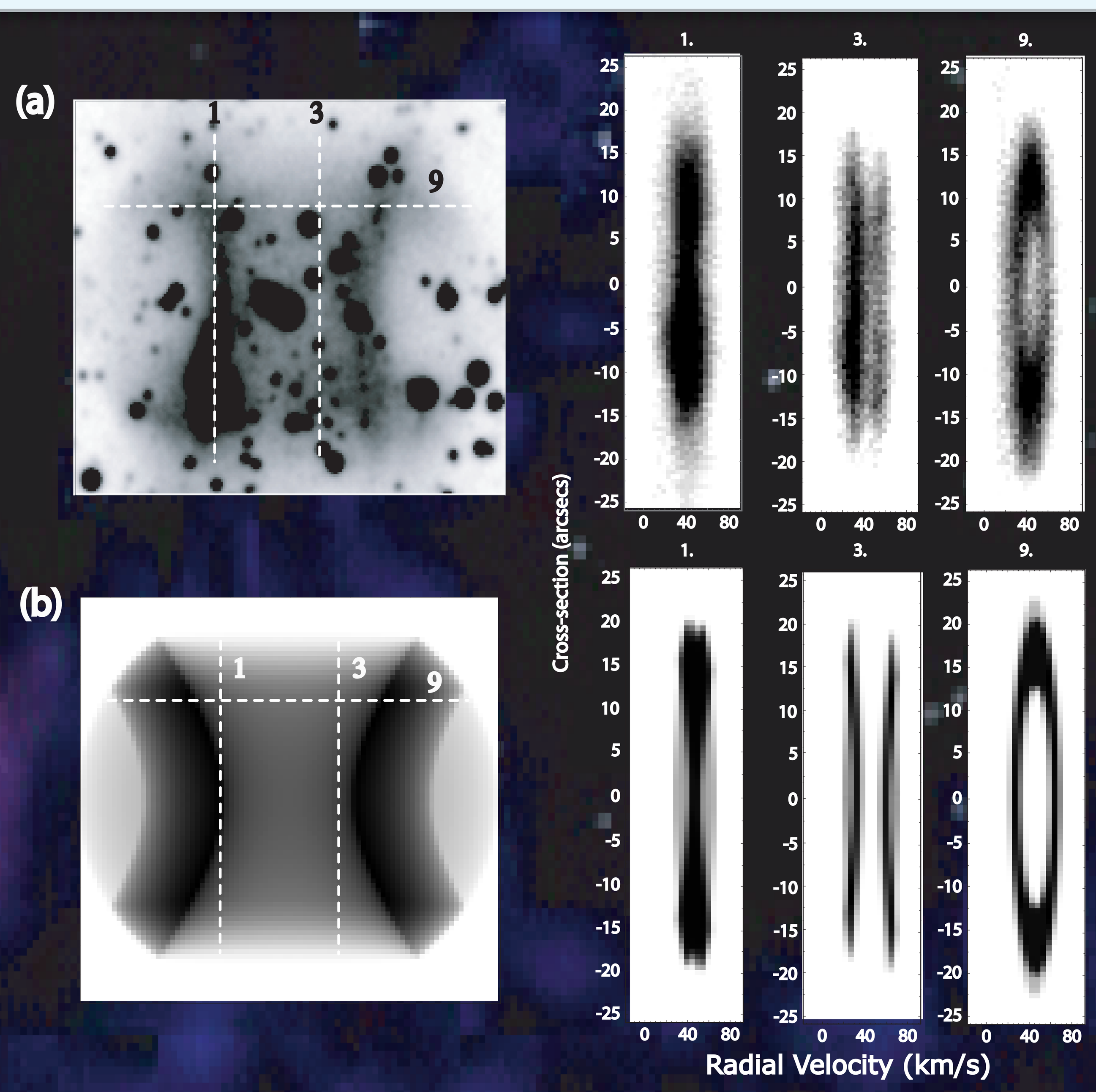

Figure 4a (left): A deep image of the central nebular shell of Abell 63 with three slit positions drawn on; (right) longslit spectra from the marked slit positions.

Figure 4b (left): Image of a morphological-kinematical model of Abell 63; (right) synthetic longslit spectra from slit positions drawn on model.

A 3-D morphological-kinematical model has been developed that is consistent with the large-scale velocity features of Abell 63. The nebula shell has been modelled by a hyperbolic function, wherby the velocity increases uniformly with distance from the centre. A 2-D image of the model is shown in Fig. 4b (left). Synthetic spectra were extracted from the datacube coinciding with slit positions 1, 3 and 9 and are shown in Fig. 4b (right). The model was tested with a range of inclinations and it was found that the synthetic spectra most closely resembled the observed longslit spectra when the model inclination matched that of the central binary system. This is the first proof that a planetary nebula is ejected with the same inclination as the binary system.

Test case (2): Sp1

Sp1 is unique amongst the known sample of PNe with close-binary central stars because it appears as an almost perfect ring on the sky (Fig. 5a); this is characteristic of viewing a hollow spherical nebula in cross-section. Such a morphology is not expected amongst PNe with close-binary nuclei and contradicts current theories of nebular shaping. Bond & Livio (1990) proposed that we are actually viewing a bipolar nebula pole-on. This interpretation is supported by the nested ring structure of Sp1. We have obtained longslit spectra to determine which model is correct. Fig. 5b shows an Hα spectrum from a slit positioned N-S along Sp1. The spectrum exhibits 3 distinct velocity components, which are expected from viewing a bipolar nebula end-on.

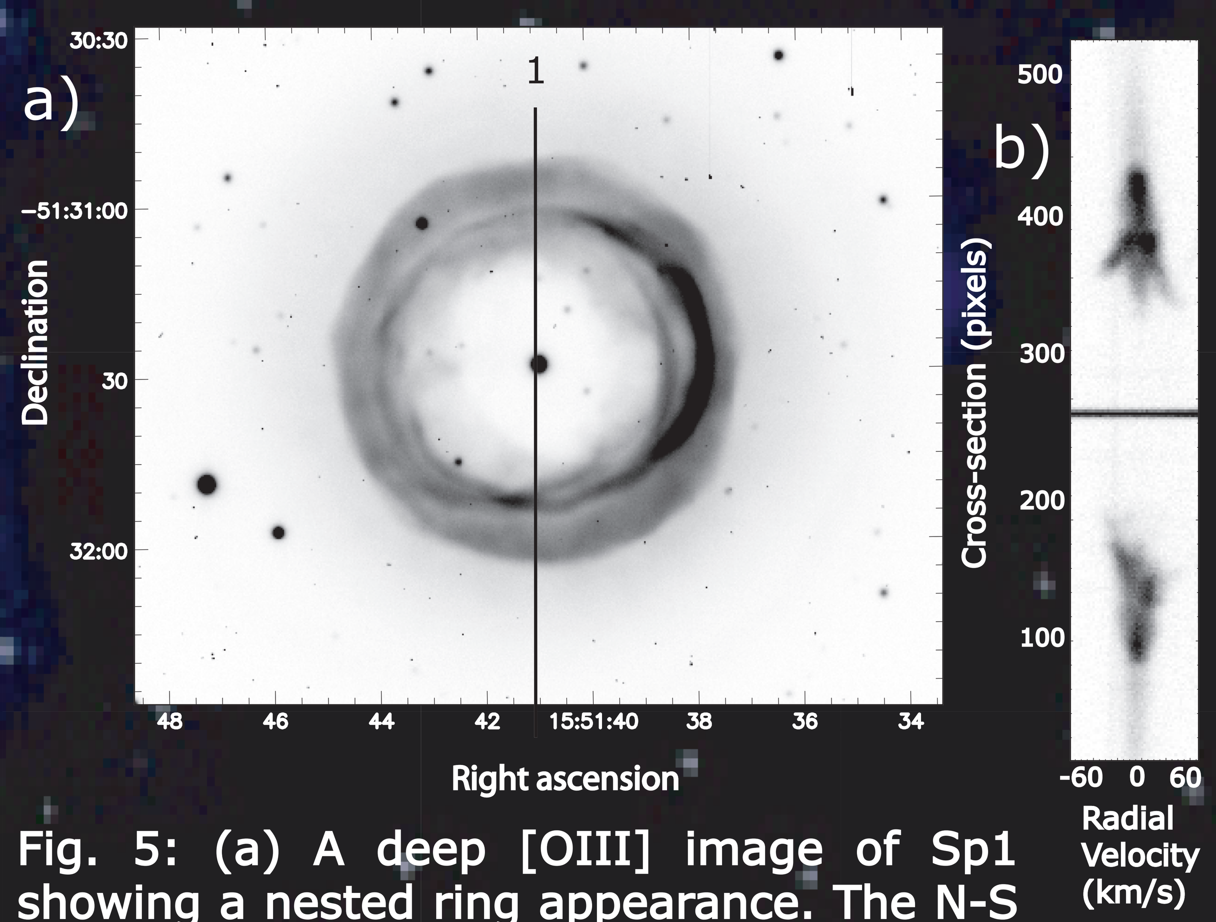

Fig. 5: (a) A deep [OIII] image of Sp1 showing a nested ring appearance. The N-S slit position is drawn on. (b) An Hα longslit spectrum from the N-S slit.

Soker, N. & Rappaport, S., 2000, ApJ, 538, 241
Schoenberner, D., 1981, A&A, 103, 119
Bond, H.E. & Livio, M., 1990, ApJ, 355, 568