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HaTr 4 — A Kinematical Study

Amy Tyndall

Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

D. Jones, M. Lloyd, T.J. O'Brien, D.L. Pollacco, D.L. Mitchell

HaTr 4 is a compact planetary nebula, known to contain a close binary central star. Using high spectral and spatial resolution position-velocity arrays in the emission lines of [O III] 5007Å, Hα and [N II] 6584Å, we show that the nebula comprises a bright waist with two faint, extended lobes and is oriented with its symmetry axis close to the plane of the sky.

The University of Manchester
Jodrell Bank Observatory

A. Tyndall, D. Jones, M. Lloyd, T. O'Brien, D.L. Pollacco, D. Mitchell

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Abstract

HaTr 4 is a compact planetary nebula known to contain a close binary central star. Using high spectral and spatial resolution position-velocity arrays in the emission lines of Hα, [NII] λ-6583.45 Å, and [OIII] λ-5006.84 Å, we show that the nebula comprises a bright waist with two faint, extended lobes and is oriented with its symmetry axis close to the plane of the sky.

1. HaTr 4

The central star of HaTr 4 is a photometric close-binary system with a period of 1.71 days (Bond & Livio, 1990). The nebula, discovered by Hartl & Tritton (1985), shows a highly bipolar 'butterfly' morphology, with twin lobes emanating from the central star system. However, it is believed that the visible nebulosity is in fact merely the waist of a much larger, fainter PN with lobes that project in the North-South direction and not the East-West direction as appears to be the case at first glance (de Marco, 2009).

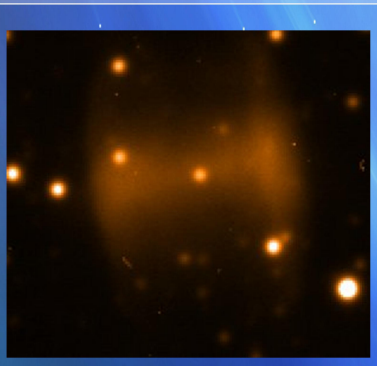

Figure 1 - Image of PN HaTr4

2. The Data

NTT

EMMI on the ESO-NTT (La Silla Observatory, Chile) was employed to acquire high-resolution longslit echelle spectroscopy of 4 slit positions in the Hα and [NII] λ6583.45 Å emission lines. The slit used was of length 330" and width 1" . The CCD was 2x2 binned, resulting in an angular resolution of 0.33" pixel^{-1} (3.8 kms^{-1} pixel^{-1}). Long spectral exposures of 1200s were taken for each slit position.

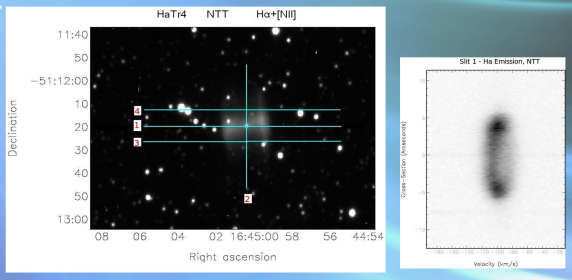

Figure 2 - Left image shows the 4 slit positions used on the NTT. Central image shows Hα emission from central slit position #1. Further is the corresponding [NII] λ6583.45 Å emission also from central slit position #1.

VLT

UVES on the VLT-UT2 (Paranal Observatory, Chile) was used with a slit of 30" x 0.6". No binning was employed, resulting in an angular resolution of 0.3" pixel^{-1}. In total, a further 2 slits were used to observe the nebula in Hα+[NII] λ6583.45 Å ,and 13 in [OIII] λ5006.84 Å .

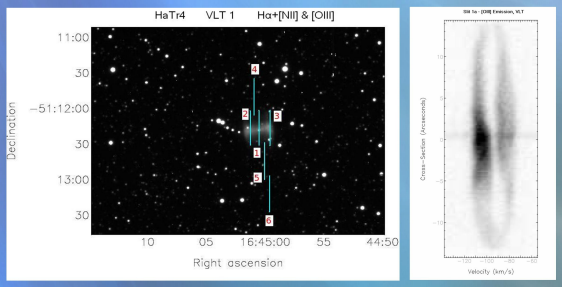

Figure 3 - Left image shows the 6 slit positions used on the VLT during the first night of observations. Right image shows [OIII] λ5006.84 Å emission from central slit position #1

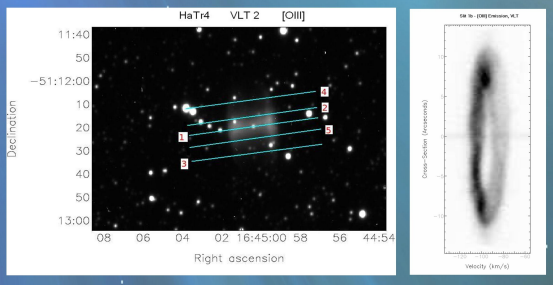

Figure 4 - Left image shows the 5 slit positions used on the VLT during the second night of observations. Right image shows [OIII] λ5006.84 Å emission from central slit position #1.

3. Analysis

The following results were acquired by analysing the [OIII] emission shown in Figure 3 and Figure 4.

By determining the velocity difference between the near- and far-sides of the nebula, its angular size and that the nebular symmetry axis approximately in the plane of the sky, it was possible to estimate a kinematical age for HaTr4. The kinematical age for HaTr4 was estimated to be of order 4000 years.

The inclination of the nebula (assumed to be 90° above) could be determined by assuming that the bright emission features on slit correspond to the near- and far.-sides of the nebula, and measuring their vertical off-set from one another. Using this method, the inclination of the nebula was determined to be approximately 85° (in good agreement with the assumption that the nebula lies in the plane of the sky).

4. Future Work

A 3D spatio-kinematic model of the nebular emission, consistent with both imaging and spectroscopy, is being developed using SHAPE (Steffen & Lopez, 2006) in order to characterise its morphology and velocity field of HaTr 4.

Using this model, it will be possible to fully constrain the nebular morphology and kinematics, which can then be compared to models of the central star system in order to ascertain what role the binary has played in the nebular evolution of HaTr 4.

References

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