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


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] 5007 Å, Hα and [N II] 6584 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.
HaTr 4 - A Kinematical Study

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 (Hα λ6563.45 Å, and [OIII] λ5006.84 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 7.1 days (Bond & Linsky, 1998). The nebula was discovered by Bond & Trimble (1986), shows a highly bipolar, double-loop morphology, with two lobes emanating from the central star system. It is believed that the emission is due to fast-moving, high-velocity winds from the two stars. The nebula is symmetric, with one lobe visible on the north-south axis and the other on the east-west axis, which appears to be the case at first glance (McClure, 2004).

Figure 1: Image of PN HaTr 4.

2. The Data

NIT

Echelle on the ESO-NIT (La Silla Observatory, Chile) was used to acquire long-exposure echelle spectroscopy of 157 positions in the Hα and [NII] λλ6583.45 Å emission lines. The slit was 2" wide, resulting in an angular resolution of 0.3" pixel⁻¹ (3.8 km/s pixel⁻¹). Long-slit exposures of 1200s were taken for each slit position.

Figure 2: Left image shows the slit positions used on the NIT. Central image shows the emission lines to spread all over the slit. Right image shows the corresponding emission line spectra as the central position is moved.

VLTI

LWES on the VLTI UT2 (Paranal Observatory, Chile) was used with a slit of 0.5" x 0.5". No binning was employed, resulting in a spatial resolution of 0.3" pixel⁻¹. In total, 365 slits were used to observe the nebula in Hα+[NII] λλ6583.45 Å and 13 in [OIII] λ5006.84 Å.

Figure 3: Left image shows the slit positions used on the VLTI. Central image shows the red shift of some emission groups. Right image shows the emission from central slit position.

3. Analysis

The following results were acquired by analyzing the [OIII] emission shown in Figure 2 and Figure 4.

By determining the velocity difference between the near and far sides of the nebula, its angular size, and that the nebula is approximately in the plane of the sky, it was possible to measure a kinematical age for HaTr 4. The kinematical age for HaTr 4 was estimated to be less than 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 side and far side of the nebula, and measuring their vertical offset from one another. Using this method, the inclination of the nebula was determined to be approximately 90° in agreement with the assumption that the nebula lies in the plane of the sky.

Figure 4: Image of PN HaTr 4.

4. Future Work

A 2D spatio-kinematic model of the nebula was constructed using SPHIRE (Steinmetz & Lopez, 2006) in order to characterize its morphology and velocity field of HaTr 4.

Using this model, it will be possible to fully constrain the nebula's 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 nebula's evolution of HaTr 4.