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# H 2–12, A MISIDENTIFIED PLANETARY NEBULA IN KEPLER SNR

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RESUMEN

Presentamos imágenes de banda angosta y espectros echelle de rendija larga de H 2–12. Esta nebulosa ha sido clasificada como una nebulosa planetaria. Sin embargo, los datos presentados aquí muestran que este objeto es en realidad parte de los nudos y filamentos más brillantes localizados en la parte occidental de la remanente de supernova de Kepler. Por lo tanto, la clasificación de H 2–12 como una nebulosa planetaria debe ser considerada como errónea.

ABSTRACT

Narrow-band direct images and long-slit, echelle spectra are presented for H 2–12. This nebula has been classified as a true planetary nebula. However, the data presented here shows that this object is actually part of the brightest knots and filaments located on the western side of Kepler's supernova remnant. Therefore, H 2–12 must be noted as a misclassified planetary nebula.

*Key Words:* **HYDRODYNAMICS — ISM: INDIVIDUAL (H 2–12) — ISM: JETS AND OUTFLOWS — ISM: PLANETARY NEBULAE — ISM: SUPERNOVA REMNANTS**

## 1. INTRODUCTION

H 2–12 was discovered by Guillermo Haro with the Tonantzintla Schmidt camera through objective prism observations (Haro 1952). The object was included in the Perek & Kohoutek (1967) catalogue of galactic planetary nebulae (PK 4+6 1) but Bond (1976) and Kohoutek (1978) describe it as the brightest knot in the nebular remnant of Kepler's supernova. Probably as a consequence of these works Acker et al. (1987) list it as a misclassified planetary nebula (PN). However, later on Acker et al. (1992) include it again as a true or probable PN in the ESO-Strasbourg Catalogue of galactic PNe (PNG 004.5+06.8). H 2–12 is not included in the list of misclassified PNe published by Kohoutek at later dates (1994;1997).

We have studied H 2–12 as part of an observing program of PNe with high [N II]/H$\alpha$ and [S II]/H$\alpha$ emission line ratios (Riesgo-Tirado & López 2002). H 2–12 is among the objects in that sample with the highest line ratios, with values [N II]/H$\alpha$ = 2.89 and [S II]/H$\alpha$ = 0.90 similar to those expected from shock excited nebulae, e.g., supernova remnants.

Here we present deep narrow-band imagery in relevant emission lines and long-slit echelle spectra from several positions across the nebula. These observations confirm that this nebula is not a true planetary nebula but rather part of the bright knots and filaments located in the western side of Kepler's supernova remnant.

## 2. OBSERVATIONS AND RESULTS

Both images and spectra were obtained at the f/7.9, 2.12 m telescope of the Observatorio Astronómico Nacional in San Pedro Mártir. The narrow-band images were obtained with the MEXMAN filter wheel on 2000 June 27. The images of H 2–12 in the light of [O III] ($\lambda_c$ 5009 Å, 52 Å HPBW), H$\alpha$ ($\lambda_c$ 6565 Å, 11 Å HPBW), [N II] ($\lambda_c$ 6585 Å, 10 Å HPBW) and [S II] ($\lambda_c$ 6726 Å, 54 Å HPBW) are shown in Figure 1. Exposure times were 1800 s for each image. A SITE CCD with 1024 × 1024, 24 $\mu$m ($\equiv 0\farcs3$) square pixels was the detector. The images were reduced by standard techniques removing bias and cosmic rays; they were trimmed and divided by their corresponding flatfields. Seeing varied between 1–$1\farcs5$ during these observations. The images in Fig. 1 cover a $1\farcm4 \times 1\farcm4$ area centered on H 2–12.

An H$\alpha$ image was also obtained with the same instrument on 2000 June 29. This image, shown in

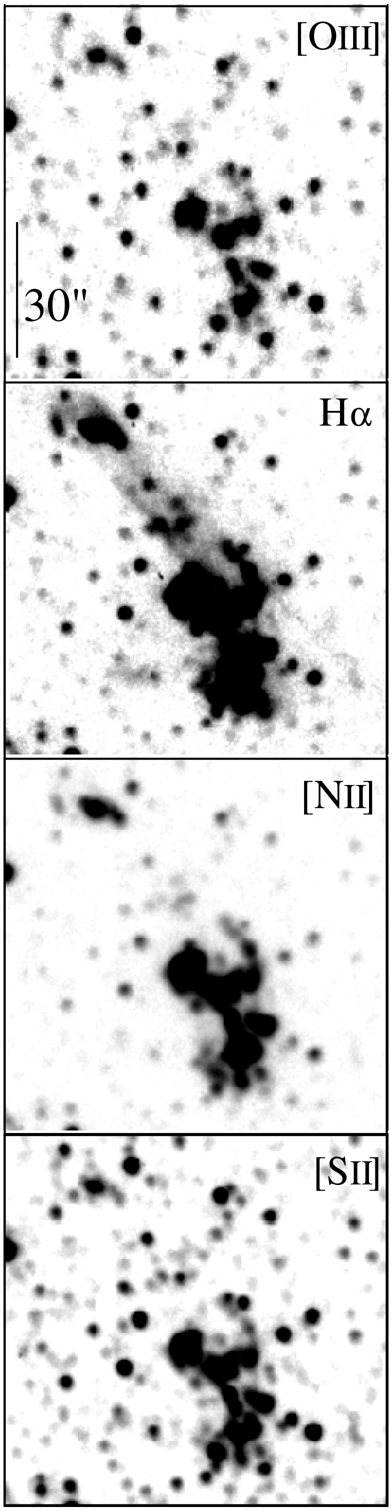


Fig. 1. A mosaic of logarithmic negative images centered on H 2–12. It covers an area of 1.′4 × 1.′4.

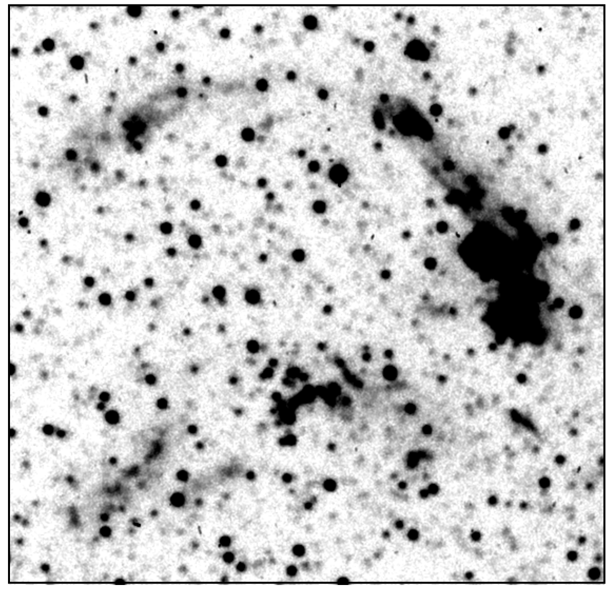

Fig. 2. Logarithmic Hα image of H 2–12 covering an area of 2.′8 × 2.′8. North is upward and East is to the left side.

logarithmic representation in Figure 2, covers a 2.′8 × 2.′8 area and shows clearly the remarkable large scale structure in the neighborhood of H 2–12.

The long-slit echelle spectra were obtained with the Manchester Echelle Spectrometer at SPM (Meaburn et al. 1984; Meaburn et al. 2003). This spectrometer has no cross-dispersion. A filter of 90 Å bandwidth was used to isolate the 87th order containing the Hα + [N II] 6548, 6584 emission lines. We used the same SITE CCD described above. Two times binning was employed in both spatial and spectral dimensions. Consequently, 512 increments, each 0.′′60 long, gave a total projected slit length of 5.′12 on the sky. The spectra were calibrated to ±1.0 km s$^{-1}$ accuracy against a Th/Ar arc lamp. The spectral resolution was 10 km s$^{-1}$. The slit was oriented E – W. A set of seven slit positions was obtained across the main body of the nebula. Integration times of 1800 s duration were obtained for all the slit positions, each followed by a calibration spectrum. The location of the slit positions are indicated in Figure 3 over a logartithmic Hα image of H 2–12. The corresponding [N II] 6584 line profiles extracted from these regions are shown in the same figure.

## 3. DISCUSSION

### 3.1. *Morphology*

At first glance, H 2–12 resembles a knotty, bipolar PN. However, its morphology is highly peculiar, even for PNe with complex structures (e.g., López 2000). Only Pe 1–17 bears some resemblance to this curious object (Guerrero, Vázquez, & López 1999) among the PNe known to the authors.

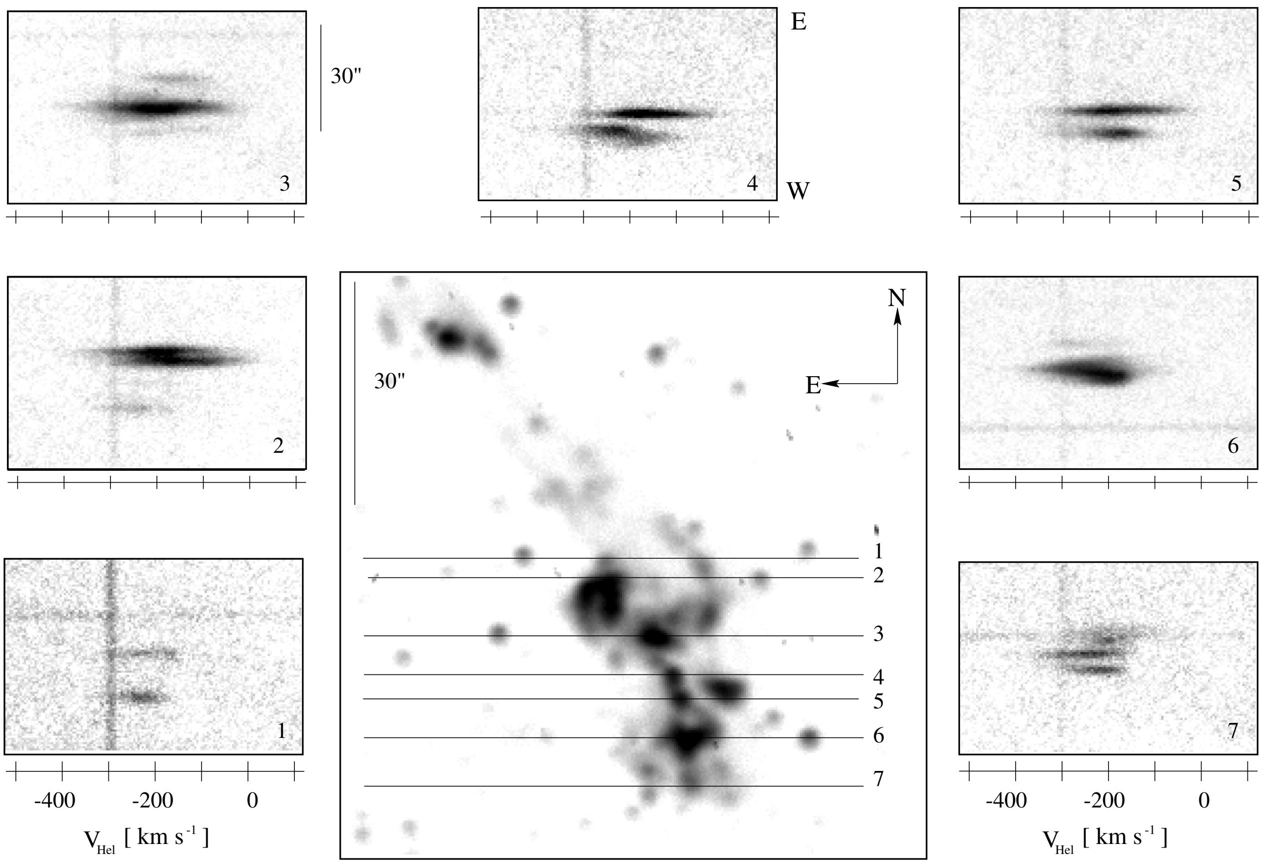


Fig. 3. Set of seven long-slit echelle spectra obtained across H 2–12. Slit positions are indicated over a logarithmic Hα image. All slits are oriented E–W. The [N II] $\lambda_c$ 6585 Å line profiles extracted from these slit positions are shown as position-velocity diagrams.

The main body of H 2–12 is formed by a group of distinct knots that follow an elongated and curved morphology. These knots are bright in low and high excitation species (see Fig. 1). An additional puzzling structure, apparent in the Hα image, is a long filament that seems to emerge from the northern section of the knotty structure (not from the center of the bright nebula) and extends towards the north-east. On a larger scale, (see Fig. 2) this filament is noted to be very extended and remarkably bent towards the north-east, as if defining the perimeter of a circular structure or cavity which can hardly be identified with a collimated outflow. No counter-part on the other side of the nebula is apparent. Furthermore, a detailed inspection of the images does not reveal a likely candidate as the core of the putative planetary nebula.

### 3.2. *Kinematics*

The line profiles from the knots of H 2–12 are very unusual, even for PNe with high-velocity outflows (e.g., López et al. 1997; López 2002). No global, diffuse, emission is detected over H 2–12, only localized emission from the knots (see Fig. 3). The kinematics of each individual knot are characterized by narrow velocity spikes covering a range of $\sim$ 400 km s$^{-1}$ (V$_{hel}\sim$ 0 to $-400$ km s$^{-1}$). The emission located at nearly $-300$ km s$^{-1}$ along the slit in the PV diagrams in Fig. 3 corresponds to airglow.

The line profiles in H 2–12 are somewhat similar to the [O III] velocity spikes identified in Abell 30 and Abell 78 by Meaburn et al. (1996; 1998), though at much lower speeds which originate from the interaction of the stellar wind with dense clumps. However, if H 2–12 is interpreted as a bipolar PN, the line profiles from these knots do not correspond to a bipolar outflow. Furthermore, there are no signs in the outflow of any kind of symmetry with respect to the center of the nebula, nor in any other sense, even considering extreme tilts with respect to the line of sight. Only in the extreme slit positions 1 and 7 the material seems to be predominantly blueshifted, with values between V$_{hel}\sim$ $-350$ to $-150$ km s$^{-1}$. Thus, the whole knotty structure of H 2–12 is observed to move nearly with a common high velocity pattern, as would be expected from an extended shocked region.

The peculiar line profiles in H 2–12 with their high speeds and highly localized emission regions, the lack of any apparent expanding symmetry, the odd overall morphology, the high [N II]/H$\alpha$ and [S II]/H$\alpha$ line ratios and the bright [O III] emission are more akin to those expected from collisionally excited shocked regions.

## 4. THE NATURE OF H 2–12

The unusual characteristics of H 2–12, not corresponding to a PN, prompted us to explore its nature beyond the realm of planetary nabulae, finding that Bond (1976) had already identified H 2–12 with V843 Oph, Kepler's SNR. Furthermore a number of papers in the field of SNR (e.g., Van den Bergh & Pritchet (1991); Blair, Long, & Vancura (1991) have studied H 2–12 as a well known part of Kepler's SNR; however, this connection had gone unnoticed in the PN field, e.g., the ESO-Strasbourg catalogue and the lists of misidentified PNe by Kohoutek.

The anomalous morphology, line ratios, and peculiar, localized, high velocity line profiles are thus understood as having originated in the remnant environment where the dense knots that form H 2–12 are now behaving as radiative shocked regions, expanding and cooling after the passage of the SNR blast. This interpretation is supported by the combined X-ray (Chandra), optical (*HST*) and infrared (Spitzer) images of the Kepler supernova remnant, recently released in http://chandra.harvard.edu/photo/2004/kepler/.

The unsual line ratios of H 2–12 found in our survey of PNe motivated this investigation. It is concluded that H 2–12 corresponds to the brightest, knotty structure on the western edge of Kepler's SNR and should then be noted as a misclassified PN.

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