Molecular hydrogen in NGC 6853

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Summary. We present subarcsecond (0\textquoteleft\textquoteleft 6) molecular hydrogen H$_2$ $\nu=1$\textgreater\textless\textasciitilde\textasciitilde 0 S(1) images of the planetary nebula NGC 6853. A mosaix of 11 fields of 4.2 x 4.2 arcminutes was covered, with a total area of 952 x 737 arcseconds. The central image reveals a rich structure in the form of cometary knots and filaments (often aligned towards the central star). The outer halo (0.54 pc) shows a more diffuse H$_2$ emission which indicates that the knots have most likely been formed by hydrodynamical plus photoionization processes rather than interaction with the interstellar medium. The line ratio H$_2$/Br\textgamma indicates that the excitation is due to shocks. The central star ionization flux sets the photoevaporation rate of the knots which ultimately determine their survival time and allows us to establish an upper limit for their densities.

Key words: planetary nebulae, molecular hydrogen

1 Introduction

Cometary knots are often found in nearby planetary nebulae (PNe) (e.g. [4]). Knots were often detected on recombination lines and molecular material such as CO and H$_2$. H$_2$ knots have recently been observed in NGC 7293 [5]. Soker [7] proposes that knots may have to be present before photoionization starts. However, some questions still remain as to how these knots are formed and how they survive the photoionization front. In order to study these issues, it is necessary to observe PNe with certain characteristics: we chose NGC 6853 because it is an ideal candidate for the study of molecular knots, as its distance is well-known from parallax [1], and therefore, its central parameters as well.
2 Observations

The data were obtained using the near infrared instrument LIRIS attached to the 4.2m WHT at the Observatorio Roque de Los Muchachos. The pixel scale is 0.25''/pix giving a FOV of 4.3x4.3 square arcmin. Images were obtained through the filters H$_2$ $\nu$=1–0 S(1) 2.122 microns, K-continuum (at 2.28 microns), and Br$\gamma$ (2.16 microns). A mosaic of 11 pointings was needed to cover the whole region occupied by the nebula (about 10x10 square arcmin). For each pointing a 300s exposure was taken "on target" plus and additional one of the same duration on a "nearby sky". In order to combine the mosaic, the geometrical distortion was corrected and an astrometric solution was computed for each pointing. The H$_2$ image presented here (see Figure 1) has been subtracted off the contribution from stars of the field, as located in the K-continuum image. A model PSF was subtracted for the identified stars using DAOPHOT2 routines. The seeing was 0''.6 as measured from field stars.

Fig. 1. H$_2$ $\nu$=1–0 S(1) 2.122 micron image of NGC 6833. N is up and E left. The size of the image is 952 x 737 arcseconds. The image is continuum subtracted, except in the NE corner.

3 Analysis of the knots

The knots are found at distances from the central star that vary from 0.008 to 0.35 pc, with typical sizes in the 310 to 723 AU range. No Br$\gamma$ emission could be
detected in the central part; however, it is possible to infer a lower limit of 20 for the \( \text{H}_2/\text{Br}^\gamma \) line ratios in the knots. This line ratio is typical for \( \text{H}_2 \) emission due to shock excitation [3, 2]. Line fluxes range from 0.9 to 4.5 \( \times 10^{-14} \text{ erg cm}^{-2} \text{ sr}^{-1} \), with peak values of 5.7 \( \text{ erg cm}^{-2} \text{ sr}^{-1} \). Most of the knots are concentrated on two cones (NE and SW) with the center at the central star (see Figure 2), and covering the central nebula (with a radius up to 0.35 pc). In the halo (between 0.35 and 0.54 pc), or AGB wind, the \( \text{H}_2 \) emission is more diffuse as the density of knots per square arcminute dramatically drops. This indicates that knots are the result of the interaction of the photoionization front with the inner shell, and not interaction with the interstellar medium.

![Graph](image)

**Fig. 2.** The \( \text{H}_2 \) emitting knots were identified as extended sources using the code Sextractor. Initially the sources were classified as stars or extended sources according to the stellar parameter provided by the code. All detections were cross-checked for non-counterparts in the continuum image (K-cont). The figure represents the spatial distribution of \( \text{H}_2 \) knots, restricted to the opening angles of the biconical structure (the largest knots are in black).

If we place the luminosity and effective temperature of the central star on the [6] evolutionary tracks, the star has been photoionizing for 36000 years. This compares well enough with dynamical ages from the central part (10000 years) and the outer part (76000 years). In order for the knots to survive the photoionization front, they
would need a minimum density of $0.4 \times 10^5$ cm$^{-3}$, which is consistent with densities found in knots and clumps ($1-10 \times 10^5$ cm$^{-3}$). As the star is declining its ionizing photons, most of the knots are expected to survive the photoionization front and populate the interstellar medium.

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**References**