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KINEMATICS OF THE PLANETARY NEBULA NGC 6781

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We report the radial velocity field of the ionized and molecular hydrogen gas in NGC 6781, obtained from scanning Fabry-Perot interferometer observations at the optical [N II] line and the near-infrared vibrationally excited line H_2 $S(1)$ 1–0 at 2.122 μm.

From its optical emission, NGC 6781 has been classified as a butterfly planetary nebula of middle type, with a high suspected inclination of the polar axis relative to the plane of the sky, which makes the object appear ring-shaped. An image of the nebula in the [N II] emission line reveals the presence of an extended and non spherical halo. The molecular emission is slightly larger than the diameter of the [N II] ring (Zuckerman & Gatley 1988). The observations for this work were carried out at the 2.1-m telescope of the Observatorio Astronómico Nacional at San Pedro Mártir, B.C. (México) using the UNAM scanning Fabry-Perot interferometers PUMA and PUMILA. General characteristics of the instrumental setup are given in Rosado et al. (1995) and Salas et al. (1999).

Figure 1 shows images of NGC 6781 corresponding to the emission of [N II] and H_2 at a heliocentric velocities of -66 and -46 km s^{-1}, respectively. Some of the integrated radial velocity profiles are shown. Due to the lower spectral resolution of the [N II] data, most of the profiles are single, except through the center, where velocity differences between the two components are maxima. In the case of the H_2 data, the emission at the center is too faint. When two velocity peaks are present, the heliocentric radial velocity of each component can be obtained by a Gaussian profile fitting. We have a work in progress to fit the kinematical data to a 3-D geometry. Up to now the best fitting is to take a double ellipsoidal shell, with an expansion velocity law proportional to the distance to the central star. The tilt of the polar axis respect to the line of sight is about 25°. In this scenario, expansion velocities for the nebula result on 10 km s^{-1} for the [N II] gas and 13 km s^{-1} for the molecular hydrogen at the equatorial region.

If the emission is due to shocks, as the ratio of the 2.248 μm $S(1)$ 2–1 to the 2.122 μm $S(1)$ 1–0 infrared lines suggests, we can estimate the density of the molecular hydrogen. In the model of Kwan (1977) the intensity of the $S(1)$ 1–0 emission line is calculated in terms of the shock velocity $V_{\rm s}$ and the pre-shock density n_0. The dependence is $n_0 \sim I_{S(1)\,1-0} \times {V_{\rm s}}^{-1.7}$. From the kinematical data, at the equator the expansion velocity of the shell is $V_{\rm sh}$ is 13 km s^{-1}, if we suppose a typical value of 5 km s^{-1} for the red giant wind, then the relative speed of the shock is 7 km s^{-1}. The average $S(1)$ 1–0 surface brightness is 10^{-4} erg cm^{-2} s^{-1} sr^{-1} and then the pre-shock density n_0 is 2.7×10^4 cm^{-3}. A morphological model and a density law are needed in order to calculate the total mass. If we assume a double ellipsoidal shape and a density law that decreases with the distance to the central star as r^{-2}, as in the case of NGC 2346 (Arias & Rosado 2000) then the estimated molecular mass is about 0.2 $M_\odot$. Ionized mass is 0.13 $M_\odot$.

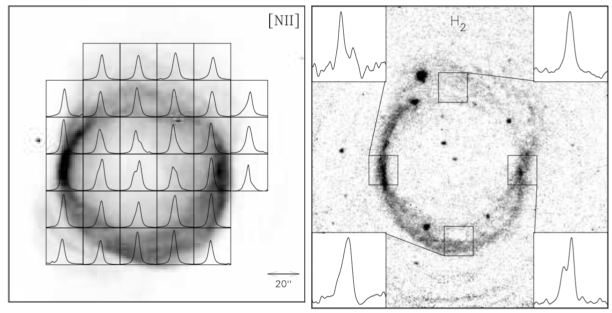

Fig. 1. Images of NGC 6781 corresponding to the emission of [N II] and H_2. Some of the integrated radial velocity profiles are shown.

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