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Detection of HCO$^+$ toward the planetary nebula K3-35

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Abstract. We report the first detection of HCO$^+$ (1–0) toward the young planetary nebula K3-35. This planetary nebula (PN) is particularly interesting because it is one ot the two PNe that exhibit water maser emission. The persistence of water molecules in this PN could be related with the presence of a massive molecular envelope responsible for shielding the water molecules against the ionizing radiation from the core of the star. We used the emission of HCO$^+$ to estimate the molecular mass in this PN which resulted in about 0.15 $M_\odot$ supporting that K3-35 is a very young PN. Also, from the HCO$^+$ column density and the ratio of molecular to ionized mass it can be observed that this molecule is present in significant amounts at a very early stage of the evolution of PNe.

Key words. Planetary Nebula – Stars: individual (K3-35) – Radio Lines:Stars: circumstelar matter

1. Introduction

The chemical composition of the molecular envelope that surrounds a young planetary nebula (PN) can reflect the recent history of the transition from the asymptotic giant branch (AGB) to the PN phase. When envelopes of AGB stars are oxygen-rich they are known to produce strong maser emission of OH, H_2O and SiO molecules, which appears stratified in the envelope, with the SiO masers located close to the stellar surface, water masers in about 10 - 100 AU, and OH masers farther away, up to 10^4 AU from the central star (Reid & Moran 1981; Chapman & Cohen 1986).

It is known that molecules that were present in the red giant envelope phase are progressively destroyed by the radiation of the core as the star evolves to the PN phase. In particular, water-vapor masers that are detected in the giant envelopes (Reid & Moran

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1981; Elitzur 1992; Habing 1996) and also in some proto-PNe (Likkel & Morris 1988; Marvel & Boboltz 1999; Gómez & Rodríguez 2002; Imai et al. 2002), are not expected to persist in the PN phase where the envelope begins to be ionized (Lewis 1989; Gómez et al. 1990). A simple calculation suggest that as the star begins the ionization of the surrounding envelope, entering in its PN phase, water molecules will be rapidly destroyed in a time scale of decades (Gómez et al. 1990). Thus, water masers are not expected in PNe, and only OH masers seem to persist for a considerable time (~ 1000 yr). Recently two PNe have been found to harbor water maser emission: K3-35 (Miranda et al. 2001) and IRAS 17347-3139 (de Gregorio-Monsalvo et al. 2004), suggesting that these objects are in a very particular stage of their evolution, where the physical and chemical conditions permit the existence of water molecules.

K3-35, is a young PN characterized by an S-shaped radio emission morphology with a clear point-symmetric structure (Aquist & Kwok 1989; Miranda et al. 2000: 2001). This PN evolved from an oxygen rich AGB star and the detected water-vapor masers are located at the center of the nebula in a torus-like structure with a radius of 85 AU (adopting a distance of ~5 kpc: Zhang 1995) and are also found at the surprisingly large distance of 5000 AU from the star, in the tips of the bipolar lobes (Miranda et al. 2001). Water masers are not supposed to be at such an enormous distance in an evolved star, where the physical conditions required to pump the water maser ($n_{H_2} \sim 10^8$ cm^{-3}, T$\gtrsim$ 600 K) are not expected to exist. Miranda et al. (2001) have proposed that the shocks driven by the bipolar jet could be creating the physical conditions necessary to pump the distant water-vapor masers. However, the presence and persistence of water molecules in these regions is still puzzling, probably related to some shielding mechanism due to the presence of high density molecular gas that protects water molecules against the ionizing radiation of the central star. Molecular gas has been detected toward K3-35, in particular, it was reported the presence of weak broad CO J=2–1 emission (Dayal & Bieging 1996), suggesting the presence of a neutral envelope. A full understanding of this shielding mechanism requires first the characterization of the physical conditions of the molecular gas around the planetary nebula together with detailed modeling studies. Any information about the chemestry and physical parameters of the gas in K3-35 is very important to understand the characteristics of such a particular object. In order to find some clues that might help to better understand this object, we undertook a survey for molecular emission having as a result the first detection of the HCO^+ (1–0) line emission toward this young planetary nebula.

2. Observations

From February 22 to March 12 2003 we made a survey for molecular lines toward K3-35 using the 20-m telescope of Onsala Space Observatory[1] , this survey included the following molecules: SiO, HCO^+, $H^{13}CO^+$, HNC, HCN, HC_5N, HC_3N, CS, CN, CH_3OH and ^{13}CO. The antenna aperture efficiency at 86 GHz, which is the band correspondient for the HCO^+ transition, is 0.50, giving a ratio of flux density to antenna temperature 22 Jy/K. The beamwidth of the antenna is about 44″.

3. Results and Discussion

Weak HCO^+ (1–0) emission was detected with the 20-m Onsala telescope. Figure 1 shows the continuum substracted spectrum smoothed to a resolution of 5.4 km s^{-1} and the fitted gaussian curve, the *rms* noise of the spectrum is of 0.003 K. The peak of the emission line is centered at 29 ± 5 km s^{-1} and has a FWHM of 25 ± 6 km s^{-1}, in agreement with the CO J=2–1 broad emission detected by Dayal & Bieging (1996) suggesting that the HCO^+ emission is associated with the nebula. The signal-to-noise ratio (S/N) for the HCO^+ (1–0) is about 4 and the integral intensity is 6.6 ± 1.2 Jy km s^{-1}. Assuming that the emission is opthically thin and adopting an abundance of

[1] Onsala Space Observatory at Chalmers University of Technology is the Swedish National Facility for Radio Astronomy

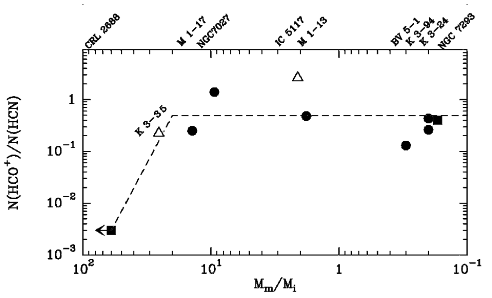

Fig. 2. Abundance of HCO^+ relative to HCN as a function of $M_{mol}/M_{HII}\sim$ 25. All points but K3-35 are from Josselin & Bachiller (2003)

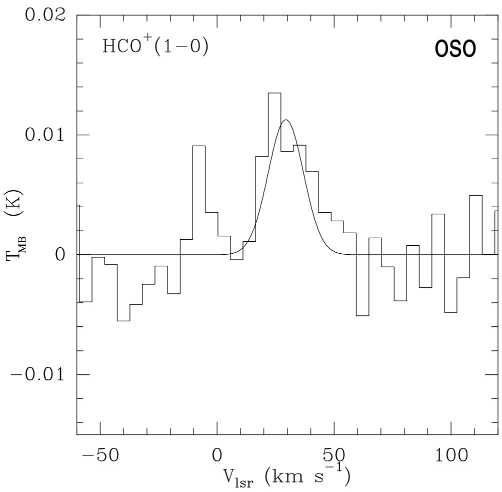

Fig. 1. Onsala telescope HCO^+ (1–0) spectrum. The rms noise in the off-line channels is 0.003 K, the peak of the emission line is ~ 0.012 K and is centered at 29 ± 5 km s^{-1} and the FWHM is of 25 ± 6 km s^{-1}.

$N(HCO^+)/N(H_2)\sim 7\times10^{-8}$ (Sánchez Contreras & Sahai 2004) and a rotational temperature $T_{rot}\sim$ 120 K (Dayal & Bieging 1996), we have estimated a molecular mass for the K3-35 envelope of about 0.15 $M_\odot$. If the line is not opthically thin, this would be a lower limit for the molecular mass. Using the emission of the radio-continuum at 3.6 cm we have also calculated the ionized mass giving a ratio of molecular to ionized mass of $M_{mol}/M_{HII}\sim$ 25. This value is slightly greater than those obtained by Josselin & Bachiller (2003) for compact PNe, this fact corresponds to a younger evolutive stage for K3-35. In Figure 2 it is shown the position of K3-35 in the evolutive diagram presented by Josselin & Bachiller (2003). From this result it is corroborated that the abundace of HCO^+ with respect to HCN increases rapidly in young planetary nebulae to persist in the more evolved ones and supports that K3-35 is a very young planetary nebula.

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