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VLA OBSERVATIONS AT 7 MM OF THE PLANETARY NEBULA IC 4997

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RESUMEN

Presentamos observaciones de alta resolución angular (0.1″) hechas con el VLA a 7 mm hacia la nebulosa planetaria con morfología bipolar IC 4997. Se detectó una estructura central brillante, posiblemente relacionada con el núcleo interno reportado por Miranda y Torrelles (1998) y se discute la posibilidad de que esta detección esté relacionada con emisión de polvo. Usando observaciones a otras frecuencias tomadas con resolución angular similar se obtuvo el índice espectral.

ABSTRACT

We present high angular resolution (0.1″) VLA observations at 7 mm wavelength towards the planetary nebula with bipolar morphology IC 4997. We detect a compact central structure possibly associated with the inner core reported by Miranda & Torrelles (1998) and discuss whether or not this detection is related to dust emission. The spectral index of the central region has also been derived using observations at other frequencies made with similar angular resolution.

Key Words: **PLANETARY NEBULAE: INDIVIDUAL (IC 4997)**

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1. INTRODUCTION

During the last decade a new aspect of planetary nebulae (PNe) has come to light through the discovery of highly collimated, high-velocity outflows in these objects (e.g., Miranda & Solf 1992; López et al. 1993; Balick et al. 1994; Manchado et al. 1996; Sahai & Trauger 1998). The existence of this kind of structure was not expected in PNe given that the conditions to form jets do not seem to be present in these evolved stars and the origin of these asymmetries in PNe remains as an open question. IC 4997 (PK 58-10.1, IRAS 20178+1634) is a double-shell PN which exhibits jet-like components (Miranda, Torrelles & Eiroa 1996; Miranda & Torrelles 1998, hereinafter MT98). This young and compact PN (adopted distance ~ 2.5 kpc, Cahn, Kaler, & Stanghellini 1992), shows photometric and spectral variability of the nebular emission gas (Menzel, Aller, & Hebb 1941; Aller & Liller 1966; Feibelman et al. 1979; Ferland 1982; Feibelman et al. 1992; Arkhipova et al. 1994; Hyung et al. 1994; Miranda et al. 1996), H I in absorption (Altschuler et al. 1986), broad Hα wings (Miranda et al. 1996) and a large dust content (Pottasch et al. 1984; Lenzuni, Natta, & Panagia 1989). OH 1667 MHz maser emission was tentatively detected towards IC 4997 (Tamura & Kazes 1989), but not confirmed by Tamura et al. (1990), although they cannot exclude the possibility of time variability. The presence of these various emissions makes this a very interesting and peculiar object. In this work we present observations at 7 mm toward IC 4997 with the goal of learning more details about the origin of collimated outflows in PNe and how they may be formed.

2. OBSERVATIONS

The 7-mm (43 GHz) continuum observations of IC 4997 were made during 1999 December 11 using the Very Large Array (VLA) of the NRAO[4] in the B configuration. The observations were made with 16 antennae distributed along the array and using the fast switching mode. The synthesized beam for maps made with the task IMAGR of AIPS, setting the robust parameter of Briggs (1995) to 5, is $0.18\times0.16''$ at P.A. $= -32°$.

3. RESULTS AND DISCUSSION

Figure 1 shows the 7 mm map of IC 4997. We detect a bright inner core and several weak components distributed along the major axis, possibly related to the bipolar structure of the nebula. The total flux density at 7 mm is very high, approximately 1.5 times larger than that at 2 and 3.6 cm (Miranda et al. 2002), whereas the 2–3.6 cm spectrum is flat, suggesting optically thin free-free emission (MT98). There are two possible scenarios to explain the relatively large 7 mm flux. One is the presence of warm

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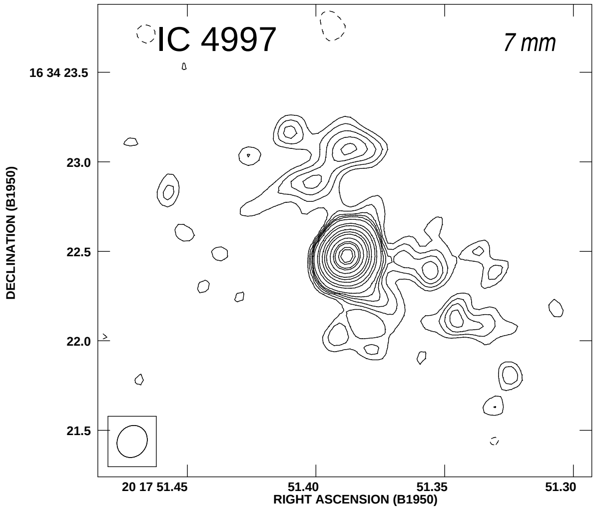

Fig. 1. Contour 7 mm radio continuum map of the inner region of IC 4997; beam size $0.18 \times 0.16''$ at P.A. $= -32°$. Contour levels are -3, 3, 4, 5, 6, 7, 9, 15, 20, 30, 40, 50, 70, 90, 100, 120, and 130 times 0.25 mJy/beam, the rms noise of the map.

dust, since dust emission rises rapidly with increasing frequency. However, from a simple calculation assuming similar dust properties to those found in protoplanetary disks (Beckwith et al. 1990), an unfeasibly large dust mass ($\sim$10 $M_{\odot}$) is required to account for the 7 mm flux. Another possibility to explain the increasing emission with frequency is that the 7 mm emission arises from optically thick free-free emission.

As a preliminary analysis we apply a free-free core-halo model consisting of two regions: An inner shell with high electron density (2×10^6 cm^{-3}), optically thick ($\sim 10^3$ at 1 GHz) and with a small angular size ($\sim 0.08''$) and an extended outer shell ($\sim 2.5''$), moderately optically thick (0.78 at 1 GHz), and with an electron density of $\sim 1 \times 10^4$ cm^{-3}. All these parameters are consistent with previous observations (MT98; Hyung et al. 1994; Lee & Hyung 2000).

However, dust emission cannot be entirely discounted since the 7 mm emission could be a combination of free-free emission plus dust. In fact, spectral indices $\alpha \geq 3$ ($S_\nu \sim \nu^\alpha$) are obtained toward the core of the nebula in the 2 cm–7 mm wavelength range, suggesting the presence of dust in this inner region. Observations at higher frequencies would certainly help to confirm these results.

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REFERENCES

Aller, L. H., & Liller, W. 1966, MNRAS, 132, 337
Altschuler, D., Schneider, S. E., Giovanardi, C., & Silvergate, P. R. 1986, ApJ, 305, L85
Arkhipova, V. P., Kostyakova, E. B., & Noskova, R. I. 1994, PAZh, 20, 122
Balick, B., Perinotto, M., Maccioni, A., Terzian, Y., & Hajian, A. 1994, ApJ, 424, 800
Beckwith, S. V. W., Sargent, A. I., Chini, R. S., & Guesten, R. 1990, AJ, 99, 924
Briggs, D. 1995, Ph.D. thesis, New Mexico Institute of Mining and Technology.
Cahn, J. H., Kaler, J. B., & Stanghellini, L. 1992, A&AS, 94, 399
Feibelman, W. A., Hobbs, R. W., McCracken, C. W., & Brown, L. H. 1979, ApJ, 231, 111
Feibelman, W. A., Aller, L. H., & Hyung, S. 1992, PASP, 104, 339
Ferland, G. J. 1982, MNRAS, 188, 669
Hyung, S., Aller, L. H., & Feibelman, W. A. 1994, ApJS, 93, 465
Lee, H. & Hyung, S. 2000, ApJ, 530, L49
Lenzuni, P., Natta, A., & Panagia, N. 1989, ApJ, 345, 306
López, J. A., Palmer, J., & Meaburn, J. 1993, ApJ, 415, L135
Manchado, A., Stanghellini, L., & Guerrero, M. A. 1996, ApJ, 466, L95
Menzel, D. H., Aller, L. H., & Hebb, M. H. 1941, ApJ, 93, 230
Miranda, L. F., & Solf, J., 1992, A&A, 260, 397
Miranda, L. F., & Torrelles, J. M. 1998, ApJ, 496, 274 (MT98)
Miranda, L. F., Torrelles, J. M., & Eiroa, C. 1996, ApJ, 461, L111
Miranda, L.F., et al. 2001, in preparation.
Pottasch, S. R., et al. 1984, A&A, 138, 10
Sahai, R., & Trauger, J. T. 1998, AJ, 116, 1357
Tamura, S., & Kazes, I. 1989, in IAU Symp 131, Planetary Nebulae, ed. S. Torres-Peimbert (Dordrecht: Kluwer), 209
Tamura, S., Kazes, I., & Shibata, K. M. 1990, A&A, 232, 195

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