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Probing Physics and Chemistry in Circumnuclear Torus with OH

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Abstract. We observed OH maser emission at 18cm in a circumnuclear torus surrounding the center of IRAS10173+0828 using the 7 telescopes of MERLIN, together with the Lovell antenna. IRAS10173+0828 is a distant super-luminous far-infrared galaxy. The OH maser emission is remarkably narrow (FWHP = 39km s^{-1}) for its strength, and the 1667 and 1665 MHz lines are well separated. The 1667 transition shows two distinct peaks displaced from one another by 100 km s^{-1}. Using our MERLIN observational results we probe the physics in the circumnuclear torus surrounding the center of IRAS10173+0828, obtain the kinematic properties of the torus, and study the central source.

1. Introduction

In January 2002 we observed line emission from OH masers in a region surrounding the center of IRAS10173+0828 using MERLIN. Powerful OH maser emission has been previously detected in the circumnuclear disk of Arp220, IIZw35, Mrk273, and IRAS17208-0014 by Lonsdale et al. (1998), Diamond et al. (1999), Yates et al.(2000), and Diamond et al.(1999), respectively. Previous VLBI observation and time series analysis of the spectra (Haschick, Bann & Peng 1994) suggests that the masers originate in a rotating torus surrounding a massive object (with a mass M of 1.5×10^7 $M_\odot$) at the center of the galaxy (Watson & Wallin 1994). IRAS10173+0828 is a distant super-luminous far-infrared galaxy (Mirabel & Sanders 1987). The OH maser emission is remarkably narrow (FWHP = 39 km s^{-1}) for its strength, and the 1667 and 1665 MHz lines are well separated. The 1667 MHz transition shows two distinct peaks separated by 100 km s^{-1}. Using our MERLIN observational results we probe the physics in the circumnuclear torus surrounding the center of IRAS10173+0828, obtain the kinematic properties of the torus, and study the central source.

2. Observations

We observed IRAS10173+0828 for 2×12 hrs on 24-25 Jan. 2002 using the 7 telescopes of MERLIN, (operated by the University of Manchester on behalf of PPARC), and including the Lovell antenna. The point-like quasar 0552+398 was used as the bandpass and flux calibration source. IRAS10173+0828 was observed by switching between two 4-MHz bands containing 128 frequency channels each. The bands were centered on 1588.5 and 1591.5 MHz. The total time on IRAS10173+0828 was 14.78 hr. In between each 4 min scan on IRAS10173+0828, the phase reference source 1015+057 was observed at 1590 MHz using a normal 16 MHz bandwidth, averaged to a single 14.5 MHz channel for data processing. 0552+398 was observed at all frequencies and configurations. All further processing was done in AIPS. The phase and amplitude of 0552+398 were calibrated and the data were used to derive tables of bandpass corrections for the both 4-MHz data sets. These data also showed that there were no instrumental phase changes associated with observing configuration or frequency changes. We self-calibrated the amplitude and phase of 1015+057 and applied these solutions and the bandpass corrections to the IRAS10173+0828. We then re-weighted the data from each antenna in proportion to its sensitivity. 1015+057 was observed at 10 18 27.8483, +05 30 29.936(J2000) and the pointing position of IRAS10173+0828 was 10 19 59.9, +08 13 34(J2000). The final absolute position accuracy of the components of IRAS10173 is 20 mas, plus a signal-to-noise-dependent relative error. We plotted the calibrated visibility amplitudes and phases of IRAS10173+0828 as a function of channel. We also converted the frequency axis to velocity. Using a line rest frequency of 1667.359 MHz, the velocity in channel 64 of the data set observed at 1588.5 MHz is v_{lsr}=14179.26 km s^{-1}. The data centered on 1588.5 MHz line showed a feature at the expected position of the 1667 MHz line but the data centered on 1591.5 MHz had a flat spectrum. We also Fourier transformed these continuum data without cleaning to give a one-channel dirty map, and similarly made a 128-channel dirty map of the data containing the line as well as continuum. We then subtracted the continuum map from each channel of line+continuum data. Finally we cleaned the resulting line-only data-cube, using a 200 mas FWHM circular restoring beam to make the maps easier to interpret visually. Note that the natural beam fitted to unweighted data is 286×171 mas; we checked that using a circular beam did not produce artifacts. The typical noise in a quite channel is σ_{rms} = 1 mJy beam^{-1}, rising to 2 mJy beam^{-1} in the brightest channel due to dynamic range limitations arising from the sparse coverage of the visibility plane.

3. Results

We detected a signal at $> 3\sigma$ in 19 velocity channels, out of 128 channels observed, and obtained the contour maps of OH maser in the 19 velocity channels. The physical parameters of the OH maser in the 19 velocity channels are shown in Table 1.

We find that the contour-maps of OH maser in some velocity channels extend to both east and west. The morphology of the contour is warped. This implies to us that the circumnuclear torus around the center of IRAS10173+0828 is warped. Using Yu's (1996) model we obtain from Table 1 that the mass of central black hole is $3\times10^{10}M_{\odot}$, that is, evidence of a massive black hole.

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Table 1. The physical parameters of OH maser in the 19 velocity channels*

CHAN No	VELOCITY (km/s)	RA_{offs} (mas)	error (mas)	Dec_{offs} (mas)	error (mas)	Peak (mJy/beam)
87	14050	4468	65	-195	67	5
88	14044	4457	68	-179	79	6
89	14039	4507	23	-127	25	14
90	14033	4482	19	-156	30	21
91	14028	4489	19	-153	21	27
92	14022	4482	19	-151	23	32
93	14016	4486	21	-169	25	29
94	14011	4493	19	-138	28	27
95	14005	4504	21	-155	27	22
96	13999	4489	28	-156	31	15
97	13994	4489	22	-208	28	14
98	13988	4504	35	-180	59	9
99	13983	4486	80	-130	74	7
100	13977	4464	41	-74	37	9
101	13971	4425	100	-144	79	5
102	13966	4529	69	-157	44	7
103	13960	4475	53	-66	68	7
104	13955	4511	45	-136	52	6
105	13949	4493	43	-100	53	6

*Reference position is RA(J2000)= 10 19 59.9, DEC(J2000)=08 13 34.0

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