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CO Twin Peaks and Centrally Concentrated H_2 Emission at the Center of the cD Seyfert Galaxy NGC 1275

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We report interferometric observations of 2.6 mm CO and a spectroscopy of 2 μm H_2 emission in NGC 1275. The CO emission shows a non-axisymmetric distribution in $r \leq 10$ kpc and a ring-like structure with *twin peaks* at $r \approx 1.4$ kpc. On the other hand, the H_2 emission is concentrated within $r \leq 340$ pc and its velocity-resolved line profile is fitted by a Gaussian with FWHM ≈ 250 km s^{-1}. All these molecular structures are well explained by a non-axisymmetric potential whose existence is implied by our data. Similarities with NGC 1068 propose the importance of non-axisymmetric potential in a process of AGN formation.

Introduction

Studies of spatial and velocity structures of circumnuclear molecular gas are essential for understanding the gas transportation mechanism in the process of AGN formation. We made high resolution observations of CO J = 1-0 and H_2 v = 1-0 S(1) emission at the center of Seyfert galaxy NGC 1275. NGC 1275 (3C84, Perseus A) is a cD galaxy located at the center of Perseus cluster. The optical heliocentric velocity is 5260 km s^{-1} (de Vaucouleurs et al. 1991). For $H_0 = 75$ km s^{-1} Mpc^{-1}, the distance to NGC 1275 is 70 Mpc^{-1} and $1''$ corresponds to 340 pc. The position of the nucleus is R.A. (1950) = $03^{\rm h}\ 16^{\rm m}\ 29^{\rm s}\!.569$, Dec. (1950) = $41^\circ\ 19'\ 51''\!.94$.

Observations

The CO J = 1-0 emission was observed with the Nobeyama Millimeter Array on 1993 December 21 – 25 and 1994 February 9 –12. We used SIS receivers (Sunada, Kawabe, & Inatani 1993) tuned to a center frequency of 113.2786 GHz. The system noise temperature in SSB was $\sim$ 800 K at the zenith. A velocity resolution of the FFT spectro-correlator FX (Chikada et al. 1987) is 0.84 km s^{-1}. Phases were self-calibrated using the strong continuum component at the nucleus of NGC 1275. The

2.122 μm H_2 v = 1-0 S(1) emission was observed at the 3.0-m Infrared Telescope Facility (IRTF) on 1992 August 23. The Cryogenic Echelle Spectrograph, CSHELL, (Tokunaga et al. 1990) was used with a velocity resolution of 30 km s^{-1}. The detector is a NICMOS-3 array (256 × 256 pixels, 1 – 2.5 μm HgCdTe, $0.''25$/pixel, 7.5 km s^{-1} /pixel). A $2''$ × $30''$ slit was placed along the east–west direction at the nucleus.

CO Ring, Twin Peaks, and Concentration of H_2 Emission

Figure 1 presents velocity channel maps of the CO emission. The CO emission from $r \leq 30''$ (10 kpc) shows non-axisymmetric distribution; 80 % of the total flux arises from the west side of the nucleus (c.f., a velocity integrated map in Inoue et al. 1995). In the central $10''$ (3 kpc), two strong peaks (Peak 1 and Peak 2) and an arc-shaped region (Figure 1(d)) are seen at $r \approx 1.4$ kpc, and their velocities are blue-shifted at Peak 1 and red-shifted at Peak 2 with respect to the velocity at the position of the nucleus (5320 km s^{-1}). These data indicate an existence of a rotating (partial) ring. The estimated rotation velocity of the ring is 210 km s^{-1} for a circular rotation, assuming an inclination angle of 45°. The molecular mass confined in the ring is approximately 6×10^9 $M_\odot$. Since this mass is much larger than 10 % of the dynamical mass, the molecular gas in the ring is considered to be gravitationally unstable (Shlosman, Frank, & Begelman 1989).

In Figure 2, we compared the central 3 kpc region of the CO map with that of an optical image taken by HST. We found a morphological correlation between the CO peaks and dark lanes on the optical image: One dark lane appears to extend southward from the position of Peak 1, while another dark lane stretches northward from the position of Peak 2. In other words, Peak 1 and Peak 2 are located where the two dark lanes intersect the molecular ring. This morphology of the CO peaks is exactly similar to that of *twin peaks* near inner Lindblad resonances (ILRs) in barred galaxies (Kenney et al. 1992).

In contrast to the CO distribution, the H_2 emission is concentrated within $r \leq 1''$ (340 pc). The spatial distribution is not resolved with our $2''$ slit. The velocity-resolved H_2 profile is fitted by a Gaussian with a FWHM of 250 km s^{-1} (Inoue et al. 1995). No indication of rotation is found along the east-west direction.

Interpretation

The morphology and kinematics of the central molecular gas are well explained by a non-axisymmetric potential whose existence is implied by the non-axisymmetric gas structure in $r \leq 10$ kpc and the presence of *twin peaks* on the ring at $r \approx 1.4$ kpc. Model calculations show that the gas ring forms at ILR with a presence of inner Lindblad resonances (e.g., Combes & Gerin 1985). Our discovery of *twin peaks* on the ring supports this hypothesis. If the instability of the ring causes infalls of the gas to the nucleus (e.g., Shlosman, Frank, & Begelman 1989), the observed concentration of H_2 emission is probably the result of such accretion. The line width of the Gaussian-like H_2 profile indicates a turbulent kinematics (with a speed ~ 100 km s^{-1}) in $r \leq$ 340 pc. This turbulence is probably caused by collisions between the molecular clouds fallen from the unstable ring or flown by nuclear winds. The shocks by such cloud-cloud collisions can explain the thermal excitation of the H_2 emission (Kawara & Taniguchi 1993). It is noteworthy that the size, rotation velocity, and mass of the molecular ring, and the distribution and velocity width of the H_2 emission, are all consistent with those of NGC 1068. Since NGC 1068 has the IR bar (Scoville et al. 1991) and our data are also suggestive of a non-axisymmetric potential in NGC 1275, the role of the non-axisymmetric potential is considered to be important in the process of AGN fueling.

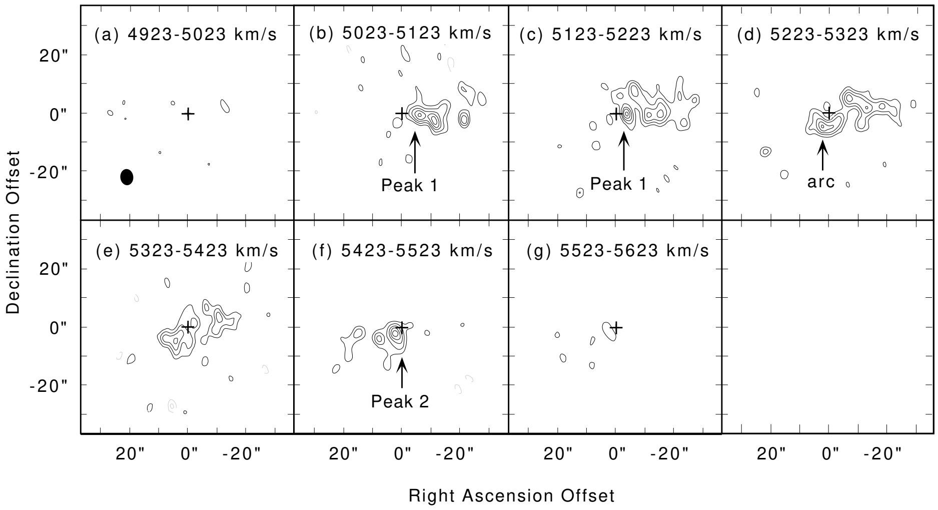

Figure 1: Velocity channel maps of the CO emission. The beam size is $5.''1 \times 3.''6$ with a position angle of 5.6° (illustrated at the left bottom corner of Figure 1 (a)). The noise level at the position of the nucleus is 39 mJ beam^{-1}, while at the other positions in the map is 19 mJy beam^{-1}. The contour interval is 19 mJy beam^{-1}. The lowest absolute level is 38 mJy beam^{-1}.

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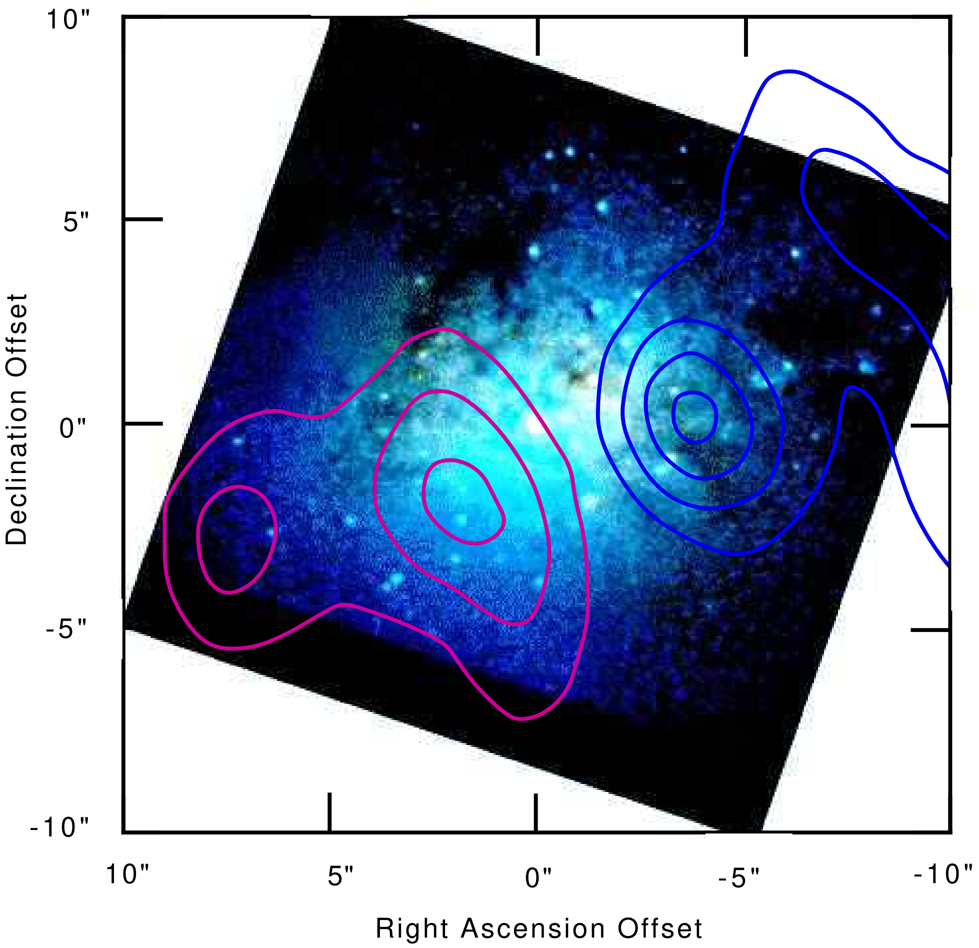

Figure 2: Comparison with an optical image. Color image: The optical image taken by HST (distributed by the Space Telescope Science Institute; c.f., Holtzman et al. 1992). Contours: Velocity integrated CO maps (west: 5070 – 5270 km s^{-1}, east: 5370 – 5570 km s^{-1}). The contour level starts from 52 mJy $beam^{-1}$ with an interval of 20 mJy $beam^{-1}$.

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