HIGH-DENSITY-AND-TEMPERATURE CIRCUMNUCLEAR MOLECULAR TORUS IN M51

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1. Introduction

It is very important to know the physical conditions of circumnuclear molecular gas in order to understand the nature of Active Galactic Nuclei (AGN), since the circumnuclear molecular gas in active galaxies might be directly affected by or is affecting the activity of nucleus. To investigate the physical conditions of the molecular clouds in detail, multi-line observations with millimeter arrays are essential.

2. Results and Discussion

In order to investigate the physical properties of circumnuclear molecular gas in active nucleus, we have observed the central region of M51 in ^{13}CO (1-0) line with Nobeyama Millimeter Array (NMA) and compared with the ^{12}CO (1-0) and HCN (1-0) data by Kohno *et al.*(1996) (see Figure 1). The ^{13}CO emission distributes along a pair of inner spiral arms as ^{12}CO, and is deficient at the very center of the galaxy in contrast with the centrally peaked HCN image. At this central 4 arcsec ($\sim$ 200 pc) region, we found that HCN (1-0) integrated intensity is 3 times or more larger than ^{13}CO (1-0) intensity, in spite of much larger abundance of ^{13}CO molecule than that of HCN. On the other hand, the HCN/^{13}CO intensity ratio in the outer region (i.e. the spiral-arm region) is only $\sim 0.5 - 0.6$. From the calculation

Y. Sofue (ed.), The Central Regions of the Galaxy and Galaxies, 237-238.

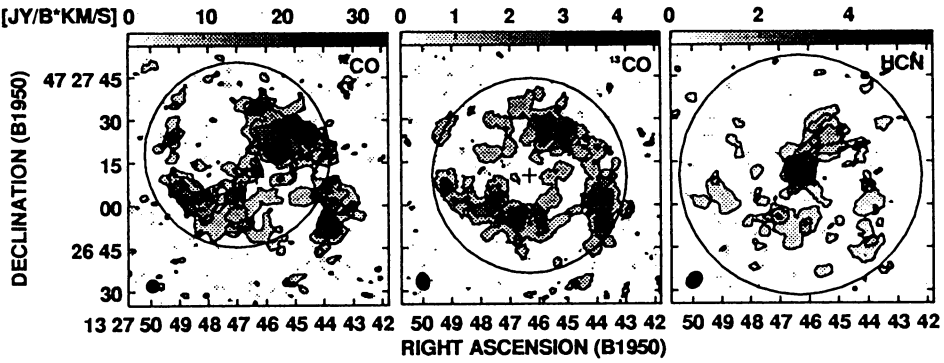

Figure 1. Integrated intensity maps of ^{12}CO, ^{13}CO, and HCN lines of the central region of M51. The field of view of each map is indicated with a circle. The cross of each map marks the 6 cm continuum emission peak. Synthesized beam is shown at the bottom-left corner of each map. The gray scale is shown at the top of each map. The contour levels are $1.5, 3, 4.5, \cdots, 9\sigma$. ^{12}CO and HCN maps were taken by Kohno *et al.*(1996).

based on the Large-Velocity-Gradient (LVG) approximation, we found that the observed high HCN (1-0)/^{13}CO (1-0) intensity ratio of > 3 suggests molecular gas in this region is dense ($n(H_2) \sim 10^{5\pm1}$ cm^{-3}) *and* warm ($T_{kin} > 100$ K), even if HCN abundance, ^{13}CO abundance, and velocity gradient are normal.

By search of previously published ^{13}CO (1-0) and HCN (1-0) data, we found that high HCN (1-0)/^{13}CO (1-0) ratio (>1) is observed in the central region of Seyfert galaxy NGC 1068 and strong nuclear starburst galaxy M82, where nuclear jet and/or burst of star-formation might severely affect the molecular gas. On the other hand, the HCN (1-0)/^{13}CO (1-0) ratio in the central region of IC 342 and Milky Way, and the spiral-arm region of M51, where the star-forming activity is lower than strong starburst nucleus, are less than unity. Our density and temperature estimations using the HCN (1-0)/^{13}CO (1-0) ratios of the nuclear regions of NGC 1068 and M82, are consistent with the estimations of other groups (Tacconi *et al.*, 1994; Wild *et al.*, 1992) which using high-J emission lines. These results suggest that the HCN/^{13}CO intensity ratio traces high density *and* high temperature conditions.

References

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