Astronomy with Millimeter and Submillimeter Wave Interferometry
ASP Conference Series, Vol. 59, 1994
M. Ishiguro and Wm. J. Welch (eds.)

CO(3-2) Observations of IRAS F10214+4724 at NMA

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ABSTRACT We have observed CO(J=3-2) emission of the z=2.286 galaxy IRAS F10214+4724 using the Nobeyama Millimeter Array.

INTRODUCTION

Formation and evolution of galaxies are among the most important and fascinating problems in astronomy. To approach the problem observationally, one must inevitably observe galaxies at high-redshifts. Such high-redshift galaxies are favorable especially for millimeter-wave radio astronomers, because of the number of bright molecular and atomic lines (eg. CO and CI) redshifted into atmospheric windows in millimeter wavelength. The extremely luminous galaxy IRAS F10214+4724 at $z \sim 2.3$ [1] is the first such object, ie. molecular line emission at high redshift[2]. To investigate this galaxy in detail, we made aperture synthesis observations of CO(J=3-2) line. We found that the molecular gas, $M(H_2)=10^{11.5\pm0.5}M_\odot$, is associated with the optical object and its extent is small. A review of this galaxy by Kawabe with a summary of observations in various wavelengths is elsewhere in this volume.

OBSERVATION and RESULTS

Observations were made during Jan.-May 1992 at NMA in three array configurations. The results from one configuration data have already been published [3,4]. The CO(3-2) emission is detected at the position of the optically identified object (Fig.1). A beam deconvolved size of the emission is 3"(=12 kpc; q_0=0.5 and H_0 =100 km/s/Mpc) in diameter. The CO(3-2) line luminosity is 6×10^7 $L_\odot$, which is 500 times larger than that of our Galaxy observed by COBE[5].

DISCUSSION

For this luminous galaxy, the main concerns are (1) what is the energy source of its huge infrared luminosity $L_{IR}=10^{14}L_\odot$, starburst or AGN, and (2) whether it is a primeval galaxy or a dust enshrouded quasar or something else. Observations of molecular line emission with an interferometer can answer these questions in termes of the quantity and distribution of molecular gas, which is the raw material of star formation.

Estimation of molecular gas mass is, however, not easy for this extreme

https://doi.org/10.1017/S025292110002008X Published online by Cambridge University Press

galaxy from CO(3-2) data. One simple way is to assume that the molecular gas mass is proportional to the CO(3-2) luminosity and make a comparison with the Galaxy; it gives $M(H_2) = 1\times10^{12}M_\odot$. This value may be an upper limit since CO emissivity is proportional to $T_R/n_{H2}^{1/2}$ and the higher dust temperature (80K[6]) of IRAS F10214+4724 compared with the Galaxy indicates that CO radiation temperature is also high. The other method for estimation of molecular gas mass is to apply the Galactic CO(1-0)-H_2 conversion factor corrected by assumed T and n_{H2} to IRAS F10214+4724. This method gives $M(H_2)=3\times10^{11}M_\odot$ for T and n_{H2} as in the Galaxy and $M(H_2)= 1\times10^{11}M_\odot$ for T=50K and $n_{H2}=10^{3.5}cm^{-3}$ as in starburst galaxies. Consequently, a crude estimate of mass of molecular gas in IRAS F10214+4724 is $\log M(H_2)/M_\odot = 11.5\pm0.5$.

Distribution of molecular gas is simple at our resolution; the molecular gas mentioned above is confined to the typical size of galaxies, less than 12kpc in diameter. One concern is that our CO(3-2) observations give a half linewidth, about 200km/s, and 1/4 flux compared to the first observation[2] of CO(3-2) emission at the NRAO 12m telescope. Observations at IRAM 30m[7] and NRO 45m[8] have confirmed our narrower linewidth. The discrepancy could be explained by complex distribution of molecular gas, but it is not yet settled. We do not find any other significant emission in our maps.

From our observations, a large mass of molecular gas is found to be confined in the typical size of a galaxy, 12 kpc. Thus, it is natural to expect that there is active star formation in this galaxy. If the star formation powers the galaxy, molecular gas will be consumed within $\sim10^7$ years, ie. starburst. On the other hand, it is worth noting that the mass to luminosity ratio of IRAS F10214 +4724 ($\log L_{IR}/M(H_2) = 3.0$) is 10 times as high as the highest $L_{IR}/M(H_2)$ value of luminous infrared galaxies and active starforming regions in our Galaxy[9][10]. Thus, the huge infrared luminosity of IRAS F10214+4724 can not be explained by a simple scale-up of active star formation seen in our neighborhood. The energy source of this galaxy is therefore an AGN or unusually active and efficient star formation, or both.

SUMMARY

We made aperture synthesis observations of CO(J=3-2) emission from the extremely luminous galaxy IRAS F10214+4724 (z=2.286) using the Nobeyama Millimeter Array. We found that a large amount of molecular gas $M(H_2)=10^{11.5\pm0.5}M_\odot$ is concentrated in a galactic scale, <12kpc in diameter, of IRAS F10214+4724. Since the luminosity-to-gas mass ratio is very high, $L_{IR}/M(H_2)=10^{2.5\pm0.5}L_\odot/M_\odot$, the origin of the luminosity will be either an AGN or starburst in unusually high efficiency, or both. If star formation is the dominant energy source, it may be a starburst event at an early stage of galactic evolution which makes a substantial part of stars in the galaxy.

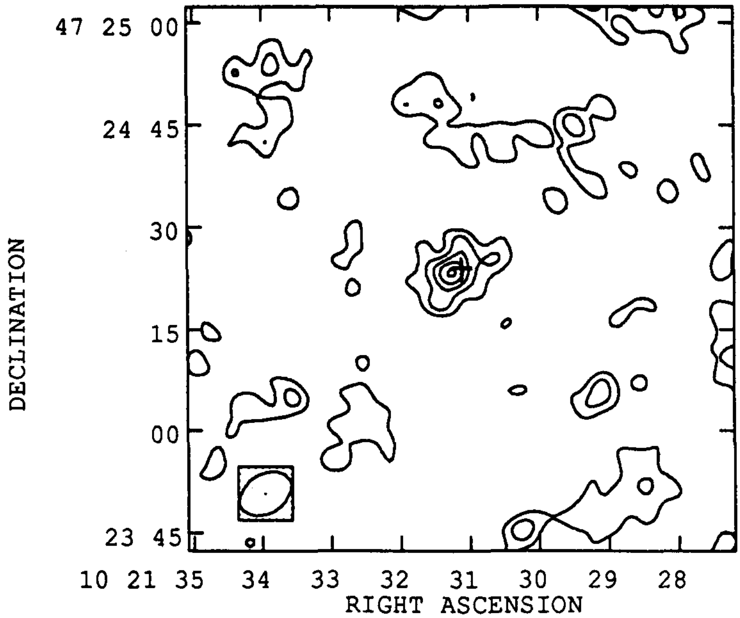

Figure 1. CO(3-2) image of IRAS F10214+4724 with 8"×6" resolution. Contour interval is 5mJy/beam ≈1.2σ (rms noise is determined from maps of line-free channels.), negative and zero contours are omitted. Cross marks the position of the optical galaxy (R.A.=10h21m31.12s dec.=+47°24'23.9" (1950)).

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