Nobeyama CO Atlas of Nearby Spiral Galaxies

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ABSTRACT

We present the preliminary results of CO mapping survey of nearby spiral galaxies. The survey was performed by using the multi-beam receivers mounted on the Nobeyama 45-m telescope. The data are used to investigate distribution and kinematics of molecular gas in spiral galaxies.

1. INTRODUCTION

Since molecular gas is a key material for star formation, observations of the molecular gas in galaxies are essential to understand the formation mechanisms of molecular clouds and stars. CO surveys of spiral galaxies have been done so far to investigate distribution and kinematics of molecular gas. Observations performed with interferometers revealed detail structures of molecular gas, especially in the central regions of galaxies [1]. On the other hand, although single dish telescopes are of advantage to measure total flux, the observations by large single dish telescopes that can resolve large structures such as bars and arms have been limited [2]. This is because a lot of time is needed to map external galaxies with a single-beam receiver. The Nobeyama 45-m telescope is one of the telescopes that are suitable for such observations, since BEARS (the 25-Beam Array Receiver System: fig. 1) mounted on the 45-m telescope has a high performance for mapping observations. Therefore, we made a CO mapping survey of nearby spiral galaxies to investigate distribution and kinematics of molecular gas.

2. SAMPLE SELECTION

We selected sample galaxies according to the next selection criteria. (1) Morphological type in the RC3 [3] is in the range from Sa to Scd. (2) Distance is less than about 25 Mpc. (3) The isophotal axial ratio in the RC3 is larger than 0.7. This criterion corresponds to inclination angle of less than 78.5 deg. (4) Flux at 100 μm in IRAS Point Source Catalogue [5] is higher than about 10 Jy. (5) The morphology is not disturbed by interaction with other galaxies.

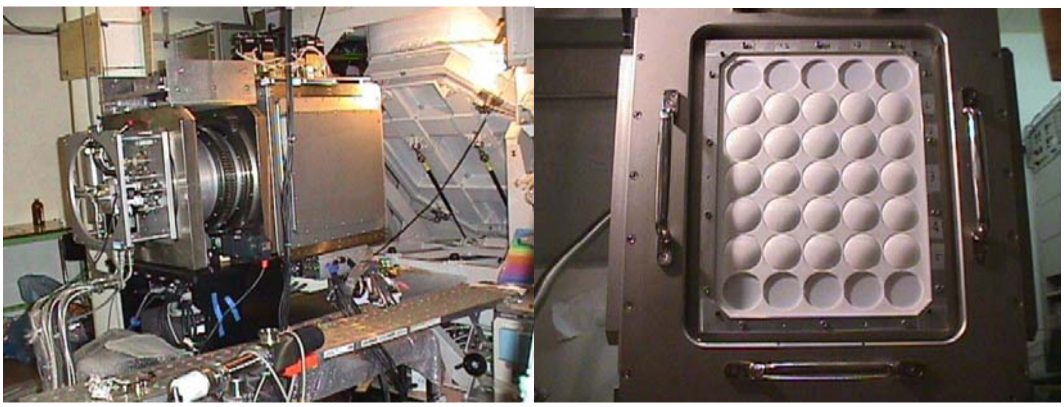

Fig. 1 Pictures of BEARS. Left) Rear view. Right) Front view.

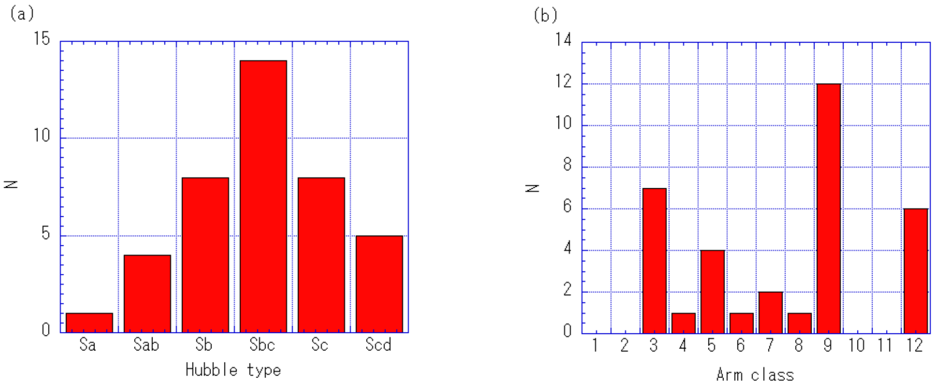

Fig. 2 (a) Distribution of Hubble type. (b) Distribution of arm class.

We observed 35 galaxies including the data which have been already published. We added 5 galaxies which satisfy the criteria from [6] to our sample. Finally, the number of the sample galaxies is 40. Fig. 2 shows the distribution of Hubble type and arm class (AC) [7] of the sample galaxies. If we regard AC 1-4 as flocculent and AC 5-12 as grand design, 8 galaxies are flocculent, while 26 galaxies are grand design. 6 galaxies are unclassified. Numbers of barred (SB+SAB) and non-barred (SA) galaxies are 28 and 11, respectively. One galaxy is unclassified.

3. OBSERVATIONS

The SIS focal plane array BEARS (fig. 1), which consists of 25 beams, was used as receiver front-end [8]. The beam separation is ~41”. The digital spectrometers were used as receiver backend [9]. The total bandwidth and frequency resolution of the spectrometers are 512 MHz and 605 kHz, respectively, which correspond to 1331 km s^{-1} and 1.57 km s^{-1} at 115 GHz. Some of the data were obtained with S115Q which consists of 4 beams, before the operation of BEARS started. The beam separation of S115Q is 34”. For S115Q, Acousto-Optical Spectrometers (AOS) were used as backend. The total bandwidth and frequency resolution of AOS are 250 MHz and 250 kHz, which correspond to 650 km s^{-1} and 0.65 km s^{-1}, respectively. We smoothed the data to a velocity resolution of 5 km s^{-1} or 10 km s^{-1}.

The antenna temperature was obtained by chopper-wheel method correcting for atmospheric and antenna ohmic loss. The system temperatures during the observations were 500 K- 1000 K (SSB). The full half-power beam width (FWHM) was about 15" at 115 GHz. We converted T_a* into T_{mb} using the main beam efficiency of 0.4 (T_{mb}=T_a*/ η_{mb}). The telescope pointing was checked every 30 min - 1 hour by SiO maser. The pointing error was less than 7”. The grid spacing of the mapping is 11” for S115Q and 10.3” for BEARS.

4. PRELIMINARY RESULTS

We present some preliminary results in this section. Reference [10] shows that the difference of the scale lengths of the HI and H_2 in non-Virgo galaxies is much larger than in Virgo galaxies. Although [10] compared only radial distributions, our mapping data can be used for point by point comparisons. Fig. 3 shows the CO maps of galaxies in Virgo cluster [6][11]. References [6] and [11] discuss about the environmental effects on the molecular gas fraction in the galactic disks of the Virgo galaxies by comparing with the HI data. It was found that the relations between the molecular gas fraction and the surface density of total gas in some Virgo galaxies differ substantially from that seen in the field galaxies. Namely, some galaxies have extremely high molecular gas fraction in the galactic disk. This may be attributed to the fact that the diffuse HI gas was striped by ram pressure not only in the outer region where HI is dominant but also in the disk where H_2 is dominant, although the metallicity dependence of the molecular gas fraction has to be considered.

Fig. 4 shows the CO integrated intensity map of M83. The map shows the characteristic distribution of molecular gas often seen in barred spiral galaxies. That is, molecular gas concentrates on the center, the offset ridge along the bar, the bar end, and the spiral arms. Reference [11] shows that star formation efficiency (SFE) is lower in the offset ridge than the center, the bar end, and the spiral arms in 3 barred spiral galaxies in our sample. Furthermore, [11] derived pattern speed of the bar in the galaxies whose position angle of the major axis is close to the position angle of the bar using the method in [12]. Furthermore, the error of the derived pattern speed is estimated by numerical simulations.

Further analyses are under way. We will investigate following issues using the survey data.

- Difference of degree of concentration of molecular gas toward the center in various types of galaxies (bar/non-bar, AC, Hubble type).
- Dependence of molecular gas fraction on surface density of the total gas, UV radiation, and metallicity.
- Variation of SFE in a galaxy. Especially, relation with the strength of spiral arms or bars.

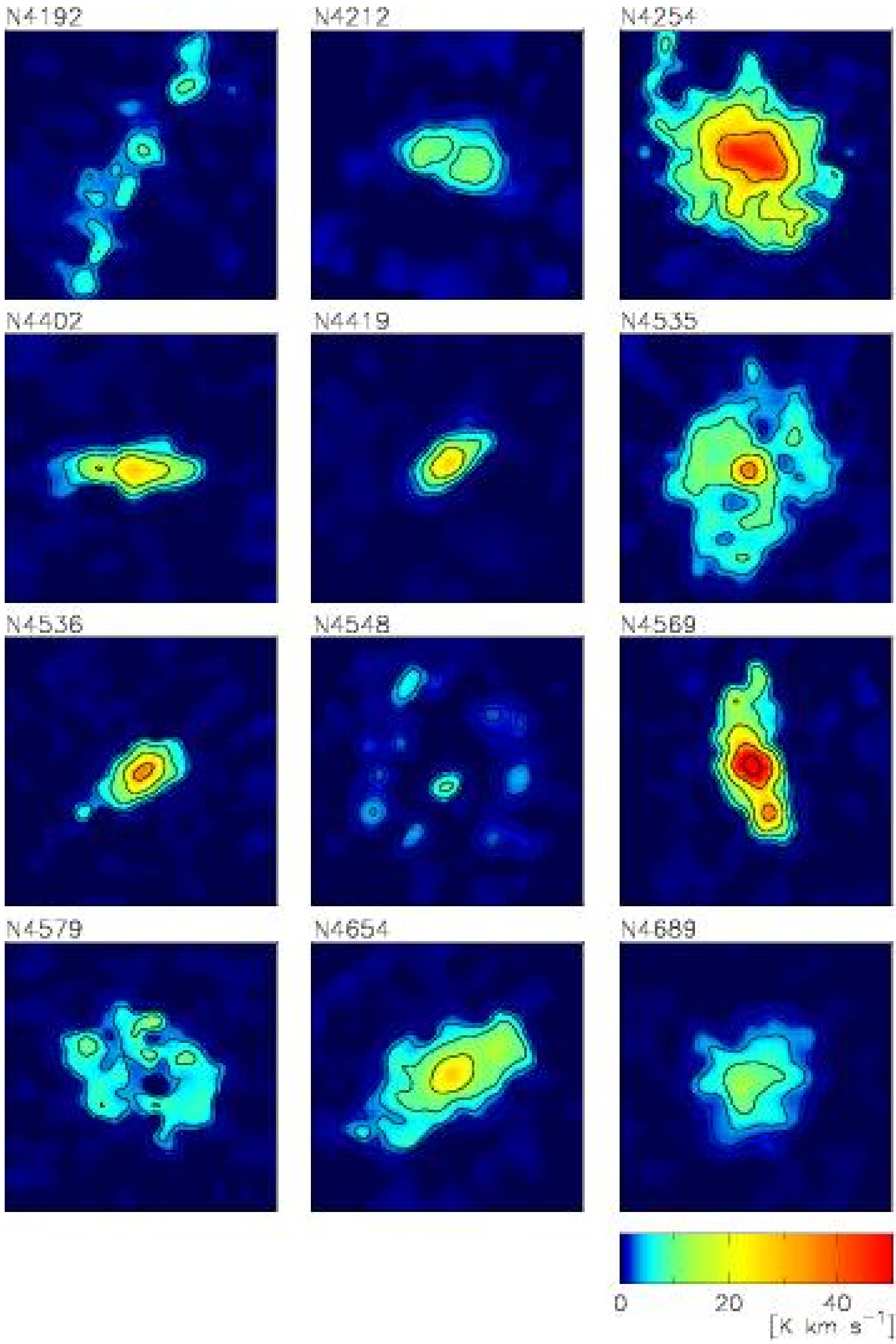

Fig. 3 CO integrated intensity maps of galaxies in Virgo cluster.

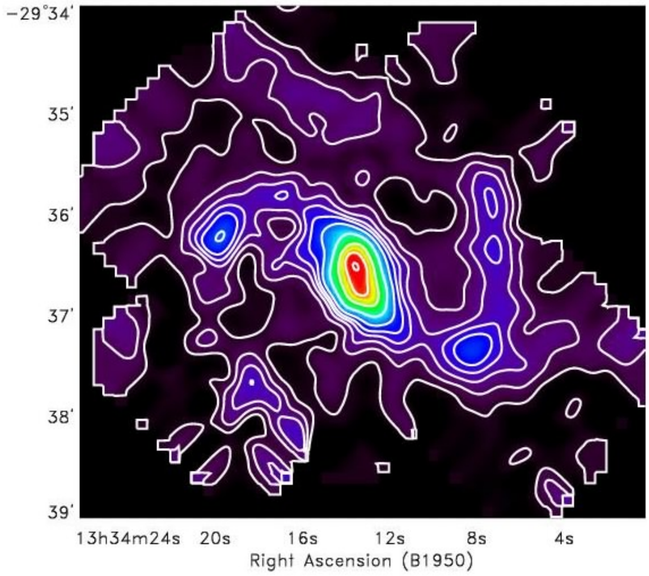

Fig. 4 CO integrated intensity map of M83.

5. SUMMARY

We made CO mapping survey of 40 nearby spiral galaxies using Nobeyama 45-m telescope. The data is useful for investigations of distribution and kinematics of molecular gas in spiral galaxies. Especially, since the 45-m telescope can resolve the bar and the spiral arms in the sample galaxies, it is expected that the data can be used to investigate molecular cloud formation and star formation in these structures by comparing the distribution of the molecular gas to those of atomic gas and star formation.

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