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THE ^{13}CO OUTER GALAXY SURVEY OF TRAO USING MULTIBEAM ARRAY RECEIVER SYSTEM

YOUNGUNG LEE, B. G. KIM, J. H. JUNG, H. G. KIM, I. S. YIM, K. D. KIM, H. W. KANG, AND J. H. CHOI
Korea Astronomy and Space Science Institute, Daejeon 305-348, Korea
E-mail:yulee@kasi.re.kr
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ABSTRACT

A survey project of TRAO with the fifteen beam array receiver system is presented. A multibeam array receiver system has been purchased from FCRAO, and is being installed on TRAO 14m telescope. The target region of the survey is from $l = 120° \sim 137°, b = -1° \sim +1°$, and velocity resolution would be 1 km/sec after smoothing from the original resolution of 0.64 km s^{-1} in the transition of $J = 1-0$ of ^{13}CO . The survey region is a part of the ^{12}CO Outer Galaxy Survey(OGS), and would be an extension of the Bell Laboratories ^{13}CO Galactic Plane Survey. By combining with the existing ^{12}CO database of the Outer Galaxy Survey, we will derive physical properties of identified molecular clouds and will conduct and statistical analysis of the Outer Galalxy molecular clouds. Reduction process and analysis methods will be introduced.

Key words : ISM : molecular lines - ISM : survey - objects : molecular clouds

I. INTRODUCTION

Molecular clouds are known to be located on the inner part of spiral arms. Several statistical studies of the molecular clouds in survey data have led to significant results on the kinematics of disk structure, locations and extent of spiral arms, and the mass and size spectra of the molecular clouds. These analyses were based on a simple methodology for recognizing molecular clouds in survey data.

However, these studies had been based mostly on ^{12}CO survey. In the Outer Galaxy, especially, there had been a couple of survey in ^{12}CO ($J = 1 - 0$), such as MINI survey (Dame et al. 2001), which covered entire Galactic Plane on 9′ grid. and the Outer Galaxy Survey by Heyer et al (1998) with much higher spatial resolution smaller than an arcminute. High resolution data are ideal for studies of cloud morphology, the cloud size distribution, the internal kinematics of clouds, and their distribution.

In order to study physical properties of molecular clouds in the Outer Galaxy, we are planning a large–scale ^{13}CO $J = 1 - 0$ (110.2GHz) survey using the Taeduk Radio Astronomy Observatory (TRAO) 14m telescope and a fifteen–beam receiver system, which is being installed. In this proceeding, we will present the mapping plan of the Galactic Plane in ^{13}CO 1-0 spectra. In fact, emission of ^{13}CO is optically thin comparing with ^{12}CO line, and its abundance is $\sim 1/50$, much smaller than that of ^{12}CO . Moreover, it is ubiquitously spreaded over the Galactic Plane. Thus, the data obtained in the ^{13}CO emission line with a large spatial coverage and a high resolution can be used to quantitatively study the molecular material near young stellar objects, since the more optically thin emission traces dense regions where star formation takes place.

Corresponding Author: Y. Lee

II. OBSERVATION PLAN

The TRAO 14 m telescope is located within the Daeduk Science Town in Daejeon City, Republic of Korea, which has been operating since 1987. Recently, an old 15-beam array receiver system had been purchased from Five College Radio Astronomy Observatory(FCRAO). After solving the long-standing problem of backend specification, we are now installing the revived array receiver system on the 14 m telescope. As one of key science projects in TRAO, we selected the Galactic Plane Survey in ^{13}CO $J = 1 - 0$ in the second quadrant, which is the region observed by Heyer et al. (1998), know as the Outer Galaxy Survey (OGS) in ^{12}CO $J = 1 - 0$. Beamsize of 14 m telescope at ^{13}CO $J = 1-0$ is about 50″, and the grid of mapping is also 50″, thus the survey would be an exact beam-sampling mode. Comparing grid and beamsize with other major surveys of molecular clouds in the Galactic Plane, it would be by far higher resolution except the Galactic Ring Survey (Jackson et al. 2006)

We have a new correlator system with four different bands and resolution, which are 31KHz × 386 ch, 63KHz × 396ch, 234.4KHz × 427ch, 859.4KHz × 465ch. In this survey, we will use 234.4KHz × 427ch, which has a velocity resolution of 0.638 km s^{-1} in ^{13}CO $J = 1-0$, and covering 272 km s^{-1} velocity span. The final velocity resolution can be chosen properly, such as 1 km s^{-1}. We will set the rms noise temperature level of $\sim$ 0.1 K per channel.

The original OGS covers the Galactic area $102°.5 <$

$l < 141°.5$, $-3° < b < 5°.4$, and the velocity range -152 km s^{-1} $< V_{\rm LSR} <$ 40 km s^{-1} , at 45″ spatial resolution sampled every 0.81 km s^{-1}. The first initial target region would be $120° < l < 137°$, $-1° < b < 1°$, covering about 34 square degrees. The expected system noise temperature at 110.2 GHz would be about 400 K.

III. THE OUTER GALAXY

Most of the molecular clouds do exist in the arm, and massive cloud seldom exist between the arms. Carey et al. (1995) reported in their second quadrant survey of molecular clouds that the interarm population is very small comparing to arm components, and is dominated by smaller clouds. This fact can be similarly applied to the Outer Galaxy. In addition, most of the mass of molecular gas in spiral arm is contained in the GMC's.

Early study of spiral arms (Cohen et al. 1980) showed that the Local arm is the lane of ^{12}CO clouds lying approximately in the velocity interval from 0 km s^{-1} to -20 km s^{-1}, and the Perseus arm in the parallel line at -40 km s^{-1} to -60 km s^{-1} along the Galactic Plane from $l = 105°$ to $l = 130°$. Recently, Heyer et al. (1998) presented the Local ($-20 < V_{LSR} <$ +4 km s^{-1}) and Perseus arm ($-61 < V_{LSR} < -33$ km s^{-1}) velocity intervals based on their OGS data.

For molecular clouds in the Outer Galaxy, their kinetic distances can be determined without any ambiguity. The kinetic distances of the clouds were estimated with a flat rotation curve of $R_0 = 8.0$ kpc and $\Theta_0 = 220$ km s^{-1}. This is one of the biggest advantage of studying the Outer Galaxy molecular clouds. All the physical parameters can be derived once the unambiguous distances are determined.

IV. REDUCTION AND ANALYSIS

When one starts to deal with a huge database from the telescope, he/she will find that the classical reduction method would not be a good idea, which is mostly based on manual mode, reducing one-by-one, though one may run a limited batch job for a stack of spectra. For a small number of spectra, manual mode may be good enough as one may conduct the reduction process very carefully. However, if the number of spectra becomes larger, for example, more than a few thousands, one may not be able to conduct a consistent reduction job from the first to the last, though one may be getting used to the reduction process itself. Human error factors (tiredness, and gradual generosity) grow bigger as the process goes on. Eventually, the reduction process may loose its consistency.

A brief explanation of the fast reduction process for the will be addressed, as a detailed reduction process of large database was reported in other paper (Lee tel al. 2001). Each section of the cube data can be displayed on a two-dimensional image displayer at once, saoimage (ds9) or ximtool, when using IRAF. In *SPA* one may see the line profile of each spectrum, including the bad baseline(s) and bad pixel(s). The transformation of spectra to image can allow us to recognize the patterns of the baselines, bad pixels, and the quality of data. Within IRAF the obtained spectra can be transformed to IRAF data format or FITS format, and this can be handles as a 3-dimensional image. Image displaying and recognizing the patterns are the major merits of this method. Another merit is displaying the composite spectra of any image section up to a few hundred spectra at once. However, *fcrao* package does not include statistics and ripple pattern subtraction routines, thus the efficiency of data reduction is not enough to handle a large amount of spectra. In fact, there are several hundreds of reduction tasks within IRAF which can be manipulated for the more efficient reduction process, including 'imhistogram (or phistogram)' and 'imstatistics'. These two tasks are excellent for the statistics of the whole image or partial image section.

When a cube data is successfully reduced and constructed, the next step would be an analyzing it and deducting several physical parameters. For survey data, the first thing would be identifying process of individual clouds efficiently. This process was also presented in Lee, Jung and Kim(1997).

The cloud identification code can be applied to analyze the structure of giant molecular cloud. By applying several threshold temperatures to the target cloud, we may be able to see the hierarchical tree structure in detail, and the estimated physical parameters of subclouds can be statistically analyzed.

By combinging with the existing ^{12}CO database of OGS, and using the analysis code, we will derive physical properties of identified molecular clouds and will conduct and statistical analysis of the Outer Galalxy molecular clouds.

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