CO survey of ARCHEOPS cold cores

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Abstract. Density and velocity distribution of 13 molecular clouds have been derived from multi-isotopic multi-line CO observations. These observations are investigations of the initial conditions for star formation in cold molecular cloud cores. The targets were selected from the ARCHEOPS point sources (Désert et al. 1987). The ARCHEOPS balloon born submm-mm telescope located cold interstellar clouds with ∼ 12 arcmin angular resolution (Désert et al. 1987, Benoit et al. 2002). A sub-sample of 13 clouds have been mapped in $^{12}$CO(3-2), $^{13}$CO(2-1) and C$^{18}$O(2-1). The observations have been carried out with the KOSMA-3m telescope (Kramer et al. 2000) in February, 2009. The measuring’s pointing accuracy was around 10 arcsec. The calibration error was about 10-15%. The derived distribution of the gas column density indicated structured isolated molecular clouds with embedded cloud cores in 9 cases. Velocity gradient was found in 4 cases. The data set will be further used as input for Herschel target selection, observation and radiative transfer modelling.

1. Introduction
Dense region of the molecular clouds are the birthplaces of stars. They can be gravitational bounded cores or diffuse group of clumps. The local environment and interactions play a dominant role in the life of these clouds and affect the efficiency of star formation. An external influence changes the structure and shape of the parent molecular cloud. The line-shape and velocity-distribution inside the cloud provide us indirect information on the external influence. (Steinacker et al. 2005, de Vries et al. 2007, Horváth et al. 1995) It would be important to explore the interstellar medium, locate molecular cloud cores and derive their main parameters (temperature, and density inside the cloud) and examine the impact of external forces at barely known regions. Test object might be selected from a large area survey of cold galactic ISM, like the Archeops balloon-born experiment. Description of the instrument, the observational strategy and calibrations are presented F.-X. Désert et al. (2008). This is what we have done and this paper discusses the observation and analysis of CO measurement of cold galactic cores selected from the Archeops bright submillimetre point source catalog.

2. Target selection
A comparison of the Archeops bright point source-list to the Nagoya $^{13}$CO-survey by Yonekura et al.(1997) and Dobashi et al. (1994) were completed. A sub-sample of 13 cold cores were chosen which have low dust temperature and were associated with a $^{12}$CO or $^{13}$CO peak and preferably with extinction. (Kiss, 2009) The selected sources are: Arch103.97+10.93, ArchG106.88+05.29, ArchG108.11+02.75, ArchG108.80+01.40, ArchG110.26+02.46, ArchG115.83+03.97, ArchG115.92-01.62, ArchG117.33+03.14, ArchG120.67+04.02, ArchG121.76+00.22, ArchG124.54+02.09, ArchG127.69+02.65, ArchG128.93+04.35.
Figure 1. Calibrated spectra consist of the maximum intensity of the $^{13}$CO(2-1) [A], C$^{18}$O(2-1) [B], $^{12}$CO(3-2) [C] observation. Black lines represent the measured spectra, and grey lines the fitted Gaussian curves. There are velocity in km/s on the horizontal axis compared to the LSR, and brightness temperature in K on the vertical axis. A typical $^{12}$CO(3-2) line spectra from the "tail" is showed in [D].

Our analysis will be reviewed for one chosen cloud, the ArchG106.88+05.29 because there are the strongest $^{12}$CO (3-2) and $^{13}$CO (2-1) lines and we could detect strong C$^{18}$O (2-1) lines, too.

3. Observations

Multiisotropic, multilevel CO-observations have been carried out with the KOSMA-3m (Kramer et al., 1998) telescope between 6 and 14, February in 2009. The telescope is located at Gornergrat in Switzerland, and is maintained by the I. Physikalisches Institut (Cologne, Germany) and Radioastronomisches Institut, University of Bonn. The observed transitions were $^{12}$CO(3-2), $^{13}$CO(2-1) and C$^{18}$O(2-1) at 345.796, 220.399 and 219.560 GHz, respectively. The half power beamwidth of the telescope at these frequencies was 80, 120 and 120 arcsec. We used the OTF (on-the-fly) mode during the observation (Kramer et al. 2000). OFF positions were picked from the CO survey of Dame et.al. (Dame et al. 1987). The integration time per positions was 4 seconds, and the grid-size was 60 arcsec. At first the $^{12}$CO(3-2) and the $^{13}$CO(2-1) observation were done simultaneously, then having chosen the maximum position the C$^{18}$O(2-1) measurement was done to a smaller area, with a longer integration time. Our pointing sources were: Venus and Saturn. Our calibration sources were: DR21, Orion KL and W51A. The position error was about 10 arcsec and the calibration error was 10-15 %.

After the observation the necessary calibration steps were done on the spot using the GILDAS data analysis package following the (Kramer et al. 2000).

4. Analysis

Calibrated sample-spectra are shown in the Figure 1. The lines from the $^{13}$CO (2-1) and C$^{18}$O (2-1) observations are mainly Gaussian (just like the sample-spectra) but in the core the $^{12}$CO (3-2) line spectra have a prominent wing in the blue side which suggests a presence of outflow from an embedded YSO (see Fig. 1C). However, if we look to the tail and not to the core of the cloud we can get a different characteristic. Figure 2. shows the distribution of the three different CO-isotopomers. To follow the way of the definition of the core-size written in Wu
et al. (2000), an ellipse was fitted to the half maximum contour of the 13CO-intensity (Figure 3.) In this case the core is compact and spherical. After the basic calibration steps we can determine the brightness temperature from the spectra. Following the description of Wilson et al. (2008), the excitation temperature, the optical depth and the column densities are countable. The 12CO excitation temperature of Arch106.88 is 21 K, and varied between 5 and 20 K for the other clouds of the sample. The column density to the 13CO molecule has been also derived and we estimated the column density of the H2-molecule as well. The ratio between H2 and 13CO is N(H2)=7.89×10^5 N(13CO) taken from Beuther et al.(2000). All of these parameters are represented in the Table 1.

Arch106.88 has a head-tail shape so we studied the velocity-gradient in its axis of symmetry. These axis were shown in the Figure 2. We found a very weak velocity gradient in the 12CO-lines, but in the 13CO line the effect is not detectable. Figure 4. shows the line velocities along the two axis, from the [−3′.5, 4′.5] to grad A, and from the [−4′.5, 4′.5] offset coordinate (grad B) as an initial position. The distribution of linewidth (FWHM) was also checked and is shown in Fig. 4.

5. Results
- We detected 12CO (3-2) and 13CO (2-1) in all 13 selected cold Archeops clouds.
- C18O (2-1) was also detected in five of the clouds.
- Clouds structure and density distribution were obtained. We found a compact cloud core in 9 cases, and a diffuse structure in 4 cases.
- The sizes of the cores were estimated.
- The excitation temperature and the column densities of H2 molecule were determined in the core position of each cloud.
- Velocity gradient was found in 4 cases.
Figure 4. The velocity (left) and linewidth-gradient (right) along the two axis from the $^{12}$CO-observation. There are distances on the vertical axis in the unit of pc, and there is a velocity and a linewidth on the horizontal axis. Both units are km/s. The equation of the fitted line are showed on the left corner of the diagram.

| Name          | Offset coordinate | a/b | PA [deg] | $T_{ex}$ [K] | N(H$_2$) [$\times 10^{21}$cm$^{-2}$] | Distance [pc] |
|---------------|-------------------|-----|----------|--------------|-------------------------------------|--------------|
| ArchG106.88+05.29 | -2'.1 : 6'.3       | 3'.3| 0.70     | 25           | 21.0                                | 11.8         | 910          |

Table 1. The name of the source (1), central position of the ellipse in offset coordinate (2), the major axis of the fitted ellipse (3), the ratio of the minor and major axis (4), the position angle (the different from east) (5), the exciting temperature of the $^{12}$CO (6), the column density of H$_2$ (7), and the estimated distance of the cloud from (Yonekura et al. 1997)(8).

The data will be further used as input for Herschel target selection, observation and radiative transfer modelling.

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References

Benoit A, Ade P, Amblard A, Ansari R, Aubourg E, Bartlett J, Bernard J-P, Bhatia R S, Blanchard A, et al 2002 *ApJ* 17 101
Beuther H, Kramer C, Deiss B and Stutzki J 2000 *A& A* 362 1109
Désert F-X, Macas-Prez J F, Mayet F, Giardino G, Renault C, Aumont J, Benoit A, Bernard J-Ph, Ponthieu N, et al. 2008 *A& A* 481 411
Dobashi K, Bernard J-Ph, Yonekura Y and Fukui Y 1994 *ApJS* 95 419
Horváth A and Tóth L V 1995 *Ap& SS* 233 169
Kiss Z., private communication
Kramer C, Beuther H, Simon R, Stutzki J and Winnewisser G 2000 *ASPC* 217 194
Steinacker J, Bacmann A, Henning Th, Klessen R and Stickel M 2005 *A& A* 434 167
de Vries C H, Narayanan G and Snell R L 2007 *IAUS* 237 409
Wilson T L, 2008 The Tools of Radioastronomy
Wu Y, Yan H, Wang J, Wu J, Zhao Y, Lei C, Sun J and Wang L 2000 *ASPC* 217 96
Yonekura Y, Dobashi K, Mizuno A, Ogawa H and Fukui Y 1997 *ApJS* 110 21