Kinematics of Selected Planck Galactic Cold Clumps

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We have completed a kinematical analysis of 184 selected Planck Galactic Cold Clumps (PGCC) [1] in order to understand better the stability of molecular clouds and the induced star formations. Most of our clumps are in the second quadrant of the Galaxy (Fig 1). For the investigation we used ^{12}CO, ^{13}CO, C^{18}O line observations which covered the 184 PGCCs fully or partially. The majority of the data were observed with the Osaka 1.85m telescope in Japan [2] and we also have some observations with the KOSMA 3m telescope, from Switzerland [3] and with the IRAM 30m telescope, Spain [4].

Based on 65 different size CO spectral maps (eg.: Fig 2A, 2B) we

- prepared 184 set of average spectra and found 249 line components
- calculated excitation temperatures and the optical depth
- gave velocity (***grad(v)***) and linewidth (***grad(Δv)***) gradients
- determined velocity and linewidth dispersions
- investigated the number of YSOs inside the clumps.

We also created larger scale velocity field maps (Fig 2C, 2D) and column density maps from Planck observations.

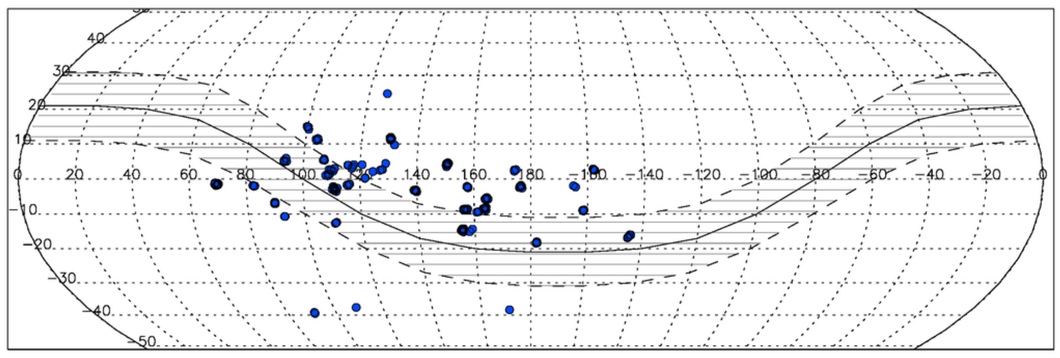


Fig 1: The 184 Planck GCC in the galactic sky with the respect of the Gould belt.

Example Cloud at l=107.0 b=+5.5

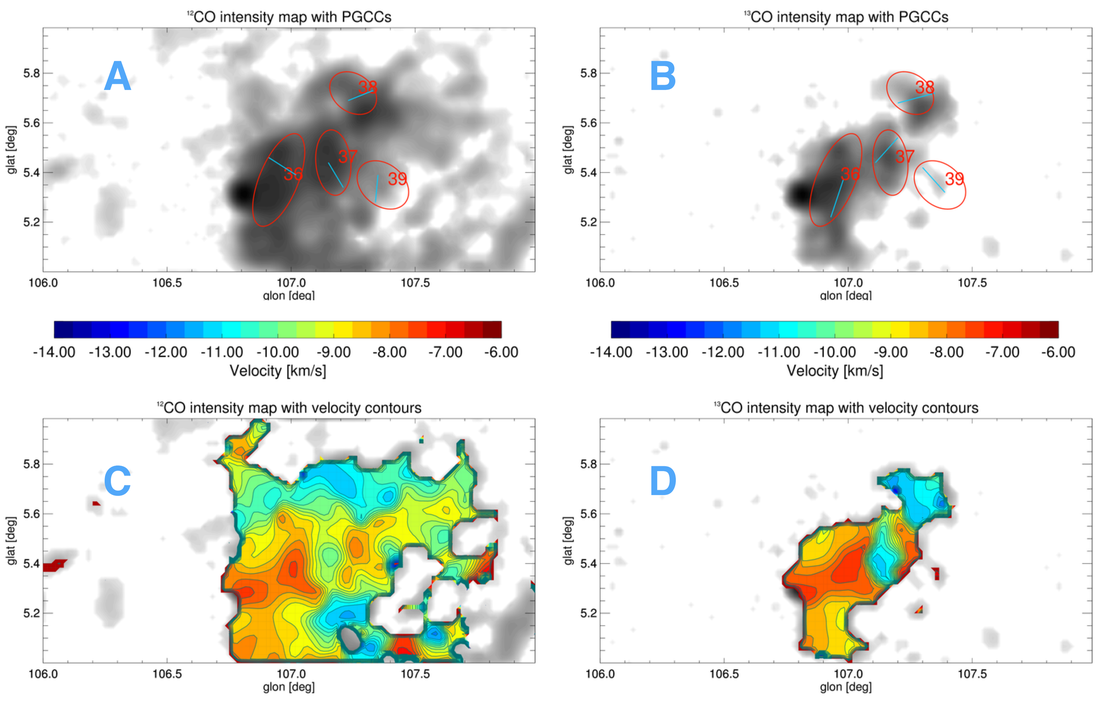


Fig 2: ^{12}CO (A) and ^{13}CO (B) intensity maps with the PGCCs on it. The blue lines shows the positions, lengths and directions of the gradient lines within the clumps. (C, D) shows the ^{12}CO and ^{13}CO velocity field contours on the intensity maps.

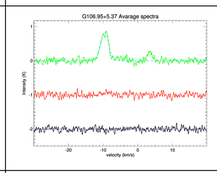
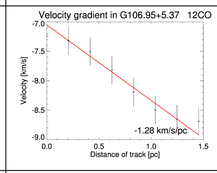
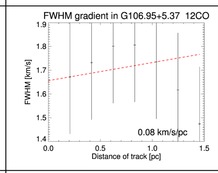
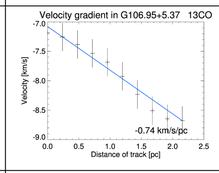
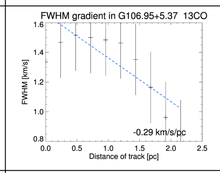
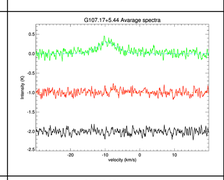
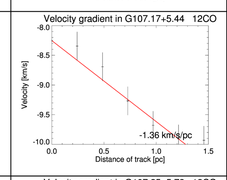
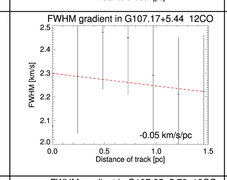
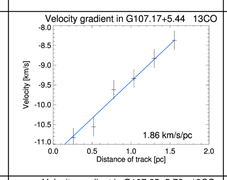
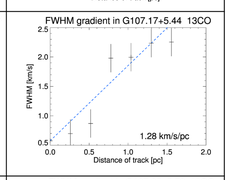
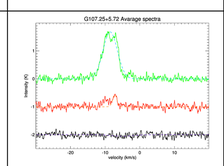
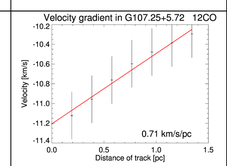
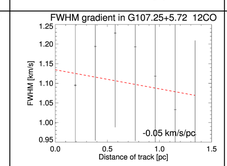
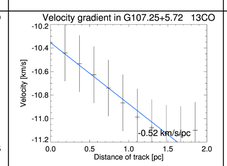
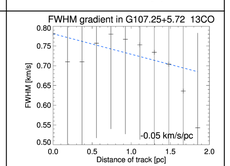
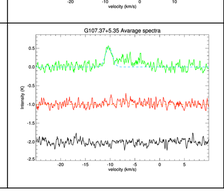
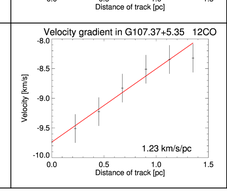
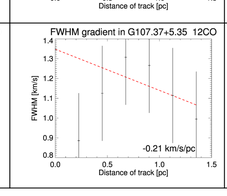
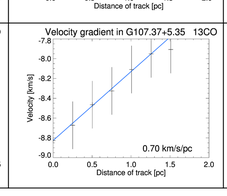
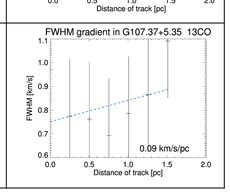
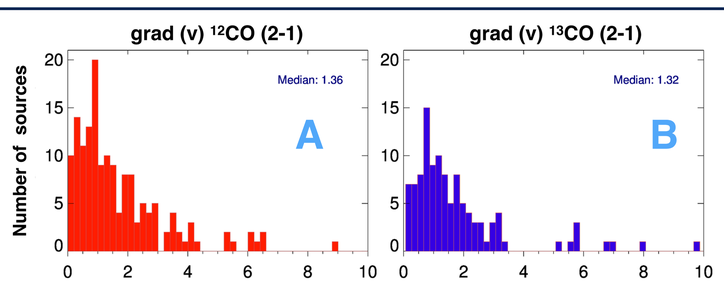
	Average Spectra	grad(v)^{12}CO	grad(Δv)^{12}CO	grad(v)^{13}CO	grad(Δv)^{13}CO
36					
37					
38					
39					

Table 1: Clump index (in our list), average spectra (green: ^{12}CO, red: ^{13}CO, black: C^{18}O), ^{12}CO *grad(v)*, ^{12}CO *grad(Δv)*, ^{13}CO *grad(v)* and ^{13}CO *grad(Δv)* of the four clumps inside the example cloud. The values of the gradients are in the right corner of the plots. (Gradient-determining algorithm was optimized to the velocity, therefore the fit of the *grad(Δv)* can be incorrect.)



Statistical analysis

The median value of the *abs(grad(v))* in our sample is around ***1.3 km/s/pc***, which seems to be CO line (ie density) independent. (Fig 4A, 4B) The Spearman's rank correlation of the position angles of the gradient lines considering different CO isotopomers is 0.54.

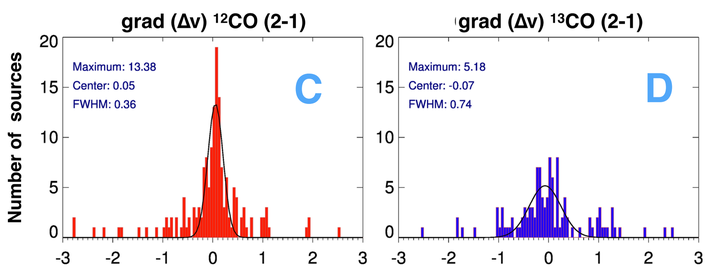
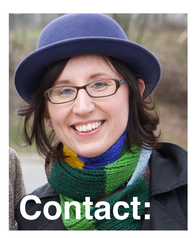


Fig 4: Histogram plot of ^{12}CO and ^{13}CO *grad(v)* [A, B] and *grad(Δv)* [C, D]. We fit Gaussian profile to the *grad(Δv)* data.

We investigated the correlation of the *grad(v)* and *grad(Δv)*, and call their correlation POSITIVE while increasing *grad(v)* leads increasing *grad(Δv)*, and NEGATIVE if the change of *grad(v)* and *grad(Δv)* are inverse. The two type of linewidth behaviors occur nearly equal probability, so the default assumption is that the data is drawn from populations with the same true variance. (Fig 4C, 4D)

References:
[1] Planck Collaboration XXVIII. (2015) arXiv 1502.01599P
[2] Nishimura, A., Tokuda, K., Kimura, K., et al. (2015) ApJS, 216, 18
[3] Kramer, C. et.al (2000) ASPC Vol.217 p.194
[4] http://www.iram-institute.org/

Acknowledgements:
"Based on observations carried out with the IRAM 30m Telescope. IRAM is supported by INSU/CNRS (France), MPG (Germany),IGN (Spain), KOSMA 3m Telescope operated by the I. Physikalisches Institut, Universität zu Köln, and the Radioastronomisches Institut, University of Bonn and the 1.85m Telescope at NRO operated by Osaka Prefecture University, together with Tokyo Gakugei University "
We would like to thank Kazuhiro Dobashi, Toshikazu Onishi and Atsushi Nishimura the high-quality observations. We also thank Mika Juvela the valuable comments on this work.



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