SF2A 2018
P. Di Matteo, F. Billebaud, F. Herpin, N. Lagarde, J.-B. Marquette, A. Robin, O. Venot (eds)

VELOCITY GRADIENTS OF GIANT MOLECULAR CLOUDS AT GALACTIC SCALES

S. Khoperskov[1,2] and E. Vasiliev[3,4]

Abstract. We explore the effect of galactic evolution on the rotation of giant molecular clouds (GMCs) in isolated magnetized galaxy simulation. In this model, without prominent structures, we have extracted about 1000 isolated clouds. The properties (mass, size, velocity dispersion) and scaling relations of these clouds consistent with that found for the Milky Way and nearby galaxies. By making an analysis of the velocity field of each isolated GMC we found that clouds itself has a substantial linear velocity gradient – ranging from 0.01 to 0.1 km s^{-1} pc^{-1} which is a function of galactocentric distance.

Keywords: Galaxies, star formation, ISM, clouds

1 Introduction

The knowledge of initial conditions and physical processes driving the conversion of interstellar gas into stars is fundamental to the understanding of galactic evolution. Molecular clouds play a key role in this process, in particular in those that are still actively forming stars. During the last decade, great efforts have been made to explore the properties of GMCs in galaxy-scale simulations (e.g., Dobbs et al. 2006, 2011, 2015; Baba et al. 2017). However, one of the missing points in understanding of the GMCs evolution is their rotation and angular momentum. Previous observational studies, have found that the cloud exhibits a velocity gradients across atomic and molecular clouds and clumps (e.g., Rosolowsky et al. 2003). This regular velocity pattern is interpreted as rotation of the GMCs. Molecular cloud cores have modest velocity gradients $0.4 - 3$ $kms^{-1}pc^{-1}$ and the cloud cores do not appear to be supported by rotation (Goodman et al. 1993). Imara et al. (2011) measured a linear velocity gradients of 0.05 $kms^{-1}pc^{-1}$ for GMCs in M 33. Braine et al. (2018) have shown that molecular clouds rotate in M 33. In this work, we further evaluate the effects of global galactic disc dynamics on the giant molecular clouds physical parameters. We perform analyses on the resolved clouds to gain insight into the origin of their kinematics.

2 Results

To investigate the properties of molecular clouds and their intrinsic velocity gradients in magnetized spiral galaxies we have conducted a galaxy evolution experiment using our three-dimensional code Khoperskov et al. (2014). The code has been successfully passed the standard tests for magnetic gas dynamics and has been already utilized for several galactic-scale simulations (Khoperskov & Bertin 2015; Khoperskov et al. 2016; Khoperskov & Khrapov 2018). We take into account major processes governing the formation of giant molecular clouds: self-gravity, magnetic field, and tabulated molecular line cooling and heating models (Khoperskov et al. 2013).

Global galactic disk evolution is driven by self-gravity, thermal instability and small-scale perturbations and so on. The cumulative action of these processes lead to the fragmentation of the gaseous disk and formation of small-scale isolated clumps – clouds, which may collide and merge each other. Such picture has been described in details in numerous papers (e.g., Tasker 2011; Dobbs et al. 2011; Renaud et al. 2013; Fujimoto et al. 2014).

[1] GEPI, Observatoire de Paris, PSL Research University, CNRS, Place Jules Janssen, F-92195 Meudon Cedex, France
[2] Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya st., 48, 119017 Moscow, Russia
[3] Southern Federal University, Stachki Ave. 194, Rostov-on-Don, 344090 Russia
[4] Special Astrophysical Observatory of Russian Academy of Sciences, Nizhnii Arkhyz, Karachaevo-Cherkesskaya Republic, 369167 Russia

© Société Francaise d'Astronomie et d'Astrophysique (SF2A) 2018

We identify clouds from the simulation, as connected regions above a threshold density of 100 cm^{-3}. Following Rosolowsky et al. (2003) we fit the 2D map of velocity along the line of sight for a cloud as: $v_{\rm los} = v_{\rm sys} + a_x(x - x_0) + a_y(y - y_0)$, where v_{sys} is the mean LOS velocity, x_0 and y_0 are the coordinates of a cloud center, a_x, a_y are the velocity gradients along axes x and y, respectively. This procedure has been applied for each cloud. Figure 1 presents the results of the fitting procedure for a typical cloud in our simulation and also statistics for the best-fit gradients.

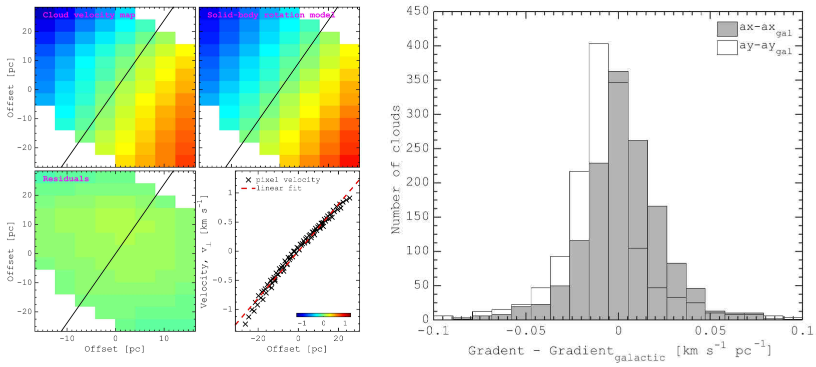

Fig. 1. Left: The examples of the fitting procedure for four clouds extracted in simulation. Upper left panel demonstrates the velocity map inside a cloud. Top right panel presents the best fit solid body rotation model. Bottom left panel is the velocity residuals between two velocity maps depicted in upper panels. The rotation axis obtained for the solid-body model is shown by solid line in the panels. In lower right panel the dependence of the gas velocities in each pixel of the velocity map (upper left panel) on the distance from the rotation axis (solid line) is shown by crosses. The dashed red line corresponds to the solid-body rotation fit. **Right:** Histogram of cloud velocity gradients for the entire sample corrected for galaxy rotation.

Observed median gradients value is roughly 0.03 kms^{-1}pc^{-1} which yields a rotation period of 250 Myr which is much longer than free-fall time and life-time of typical molecular clouds. Such characteristics are in a good agreement with recent observational study Braine et al. (2018).

The research is carried out using the equipment of the shared research facilities of HPC computing resources at Lomonosov Moscow State University supported by the project RFMEFI62117X0011. The work is supported by RFBR according to the research project 16-32-60043. EOV is thankful for support from the Russian Scientific Foundation (grant 14-50-00043).

References

Baba, J., Morokuma-Matsui, K., & Saitoh, T. R. 2017, MNRAS, 464, 246

Braine, J., Rosolowsky, E., Gratier, P., Corbelli, E., & Schuster, K.-F. 2018, A&A, 612, A51

Dobbs, C. L., Bonnell, I. A., & Pringle, J. E. 2006, MNRAS, 371, 1663

Dobbs, C. L., Burkert, A., & Pringle, J. E. 2011, MNRAS, 413, 2935

Dobbs, C. L., Pringle, J. E., & Duarte-Cabral, A. 2015, MNRAS, 446, 3608

Fujimoto, Y., Tasker, E. J., Wakayama, M., & Habe, A. 2014, MNRAS, 439, 936

Goodman, A. A., Benson, P. J., Fuller, G. A., & Myers, P. C. 1993, ApJ, 406, 528

Imara, N., Bigiel, F., & Blitz, L. 2011, ApJ, 732, 79

Khoperskov, S. A. & Bertin, G. 2015, MNRAS, 451, 2889

Khoperskov, S. A. & Khrapov, S. S. 2018, Astronomy and Astrophysics, 609, A104

Khoperskov, S. A., Vasiliev, E. O., Khoperskov, A. V., & Lubimov, V. N. 2014, Journal of Physics Conference Series, 510, 012011

Khoperskov, S. A., Vasiliev, E. O., Ladeyschikov, D. A., Sobolev, A. M., & Khoperskov, A. V. 2016, MNRAS, 455, 1782

Khoperskov, S. A., Vasiliev, E. O., Sobolev, A. M., & Khoperskov, A. V. 2013, MNRAS, 428, 2311

Renaud, F., Bournaud, F., Emsellem, E., et al. 2013, MNRAS, 436, 1836

Rosolowsky, E., Engargiola, G., Plambeck, R., & Blitz, L. 2003, ApJ, 599, 258

Tasker, E. J. 2011, ApJ, 730, 11