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GMCs in Galactic scale simulations

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Abstract. Using 3D gas dynamics simulations we investigate physical properties of molecular clouds in disk galaxies. We argue that in our models molecular clouds are formed due to joint influence of self-gravity, cloud collisions and other feedback processes occurring in the Galactic disc. We analyse physical properties of the simulated clouds and find that the synthetic statistical distributions are close to those observed in the nearby galaxies. We analyse how Kennicutt-Schmidt relation behaves on sub-galactic scales and we find a spatial scale at which the relation has a breakdown.

1. Introduction

Giant molecular clouds (GMCs) are considered as an essential part of the interstellar medium. In disk galaxies they are mostly concentrated in spiral arms and give a birth for the majority of Galactic stellar clusters. Generally speaking their physical properties and evolution govern the star formation history of a parent galaxy. In this paper, we study the properties of molecular clouds by using high-resolution galactic-scale simulation.

To simulate the galaxy evolution, we use our numerical code based on the unsplit TVD MUSCL scheme for ideal MHD flows (Khoperskov et al. 2014). The spatial resolution in our simulations of gas dynamics is 6 pc. Such a high resolution allows us to follow the evolution of molecular clouds on the background of large scale gaseous structures and study physical properties of individual molecular clouds (see Fig. 1 left). In our models molecular clouds are combined into hierarchical structures and agglomerations with sizes of 100 pc and greater (see also Dobbs et al. 2006). They are mostly formed in spiral arms and are believed to be short-lived structures with typical timescale $\sim 10^7$ yrs (see also, e.g. Dobbs et al. 2008; Fujimoto et al. 2016).

2. Results

The number of clouds extracted in our models depends on the choice of hydrogen column density threshold value. For the fiducial value of 1.9×10^{21} cm^{-2} we extract $\approx 10^3$ isolated clouds. The physical parameters of these clouds are enclosed in following ranges: mass is varied in the range $10^4 - 10^7 M_\odot$, size is within 3 – 100 pc, one-dimensional velocity dispersion is in the range 0.1 – 10 km s^{-1}, mean surface density is within 60 – $300 M_\odot$ pc^{-2}. These parameters depend slightly on the Galactic morphology (see details in Khoperskov et al. 2016). Using UV flux as

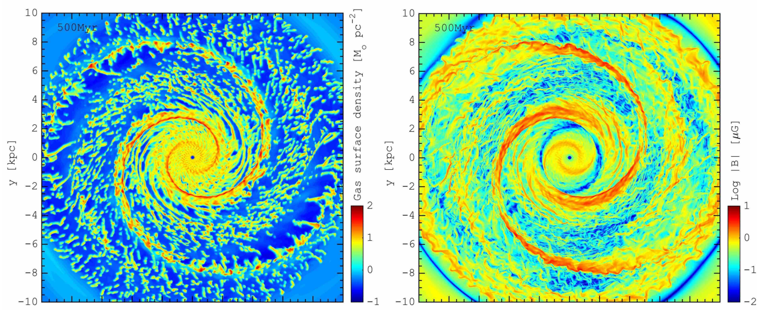

Fig. 1. The gas surface density (left) and magnetic field strength (right) in log-scale at $t = 500$ Myr in model with dominant two-armed grand design spiral pattern. Rotation is clockwise.

SFR calibrator we find a systematic offset between the surface star formation rate ($\Sigma_{\rm SFR,UV}$) and surface gas density (Σ_{gas}) on scales larger than molecular cloud sizes. Averaging over different spatial scales we find (a) no dependence between $\Sigma_{\rm SFR,UV}$ and $\Sigma_{\rm gas}$ below $\sim$ 50 pc; (b) a transition range within $\sim$ 50 – 120 pc, where a some dependence is appeared and the power-law index in the relation increases from 0 to 1 – 1.8; (c) a coincidence the $\Sigma_{\rm SFR,UV} - \Sigma_{\rm gas}$ dependence obtained in our simulations on scales larger than $\sim$ 120 pc (Khoperskov & Vasiliev 2017) with that established empirically (Schmidt 1959; Kennicutt 1998).

The magnetic field mainly follows the gas distribution: a global two-arm shape is easily detected, but on small scales it demonstrates smoother distribution in comparison with gaseous one (see Fig. 1). The latter can be seen just behind the spiral arms, where the magnetic field has a cirrus structure. We note that the gas morphology on large scales in a disk galaxy with magnetic fields looks similar to that in models without it. However the amount of isolated clouds in the disk is reduced if the magnetic field strength increases, that is in a good agreement with the previous studies (Shetty & Ostriker 2006; Dobbs & Price 2008). This influence is more remarkable for smaller molecular clouds, which are disappeared for higher magnetic strength (Khoperskov & Khrapov 2017).

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