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THE FORMATION AND EVOLUTION OF DENSE FILAMENTS AND RIDGES

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Abstract. We confront two rather different star forming filaments: The Musca filament which forms isolated low-mass stars and the DR21 ridge which forms massive star clusters. Both regions are observed with several spectral lines, using the APEX, NANTEN2, IRAM 30m and SOFIA telescopes, that trace the gas from the ambient cloud into the dense filament/ridge. For both regions we find that the large scale kinematics are most likely explained by bending of the magnetic field which drives continuous inflow to the formed filament. For the DR21 ridge, it is additionally found that gravitational collapse takes over at a distance of ∼1-2 pc from the ridge. The bending of the magnetic field in both sources would be the result of a large scale collision that initiates star formation in both regions.

Keywords: ISM kinematics, star formation, magnetic field, ISM structure

1 Introduction

Herschel observations highlighted that the majority of low-mass stars form in dense filaments (e.g. André et al. 2010), while the majority of high-mass stars form in the hubs where such filaments converge, in very massive filaments, so-called ridges, and in galactic bones (e.g. Jackson et al. 2010; Hill et al. 2011). The origin and evolution of these dense filaments is thus essential to understand the initial conditions of star formation. A comparison of low- and high-mass star forming filaments is also particularly interesting to understand how cores can overcome the typical Jeans mass such that high-mass stars can form. To address these questions, we studied the Musca filament, a prototype filament that can form low-mass stars, and the DR21 ridge which forms several clusters of massive stars. Both regions are presented in Fig. 1.

2 Asymmetric inflow driven by bending of the magnetic field

APEX observations show velocity gradients in $C^{18}O$(2-1) over the Musca filament, see Fig. 1, that are directly linked to the ambient cloud kinematics. This mass inflow fits with mid-J CO observations towards the filament that can be explained by filament accretion shocks that form the dense gas in the filament (Bonne et al. 2020b). The large-scale ^{12}CO(1-0) kinematics show that all the ambient gas of the Musca filament is blueshifted with respect to the filament and forms a 'V′-shape perpendicular to the filament, see Fig. 1. This velocity profile and more systematic kinematic asymmetries in Chamaeleon-Musca (Bonne et al. 2020a), suggest that star formation in Chamaeleon-Musca was initiated by a 50 pc scale HI cloud collision. This collision bends the magnetic field, as described in Inoue et al. (2018), that drives the inflow to the Musca filament.
For the DR21 ridge it was found that the ridge is gravitationally collapsing (Schneider et al. 2010). In the new larger maps, a V-shape is observed in the PV diagrams perpendicular to the ridge, similar to Musca, which becomes increasingly clear in tracers of the lower density ambient cloud such as [CII], see Fig. 1. In the

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denser gas tracers, the dynamics start to show indications of rapid gravitational acceleration at r $\sim$ 1 pc. As gravitational collapse of the cloud requires to pass through the bended magnetic field lines, this bending might play a substantial role in counterbalancing pure gravitational acceleration.

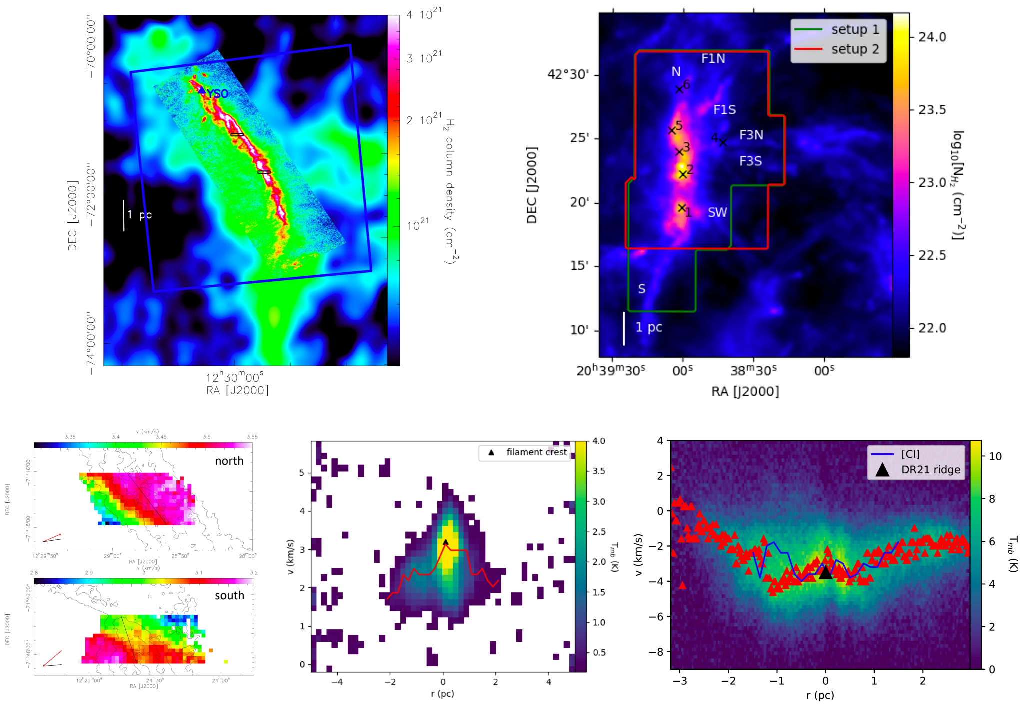

Fig. 1. Top left The column density map of the Musca filament with the NANTEN 2 (blue) and APEX (black) map size. **Top right** The same for the DR21 ridge with the IRAM 30m map sizes. **Bottom Left**: $C^{18}O$(2-1) velocity fields at two locations over the Musca filament (outlined by the contours). **Bottom middle**: The ^{12}CO(1-0) PV diagram perpendicular to the Musca filament. The red line follows the maximal intensity as a function of the radius. **Bottom right**: The same for the DR21 ridge constructed from [CII] observations from the FEEDBACK Legacy survey with the SOFIA telescope (Schneider et al. 2020).

3 Conclusions

The formation of the Musca filament and DR21 ridge appears to be triggered by a similar mechanism with an important dynamic role for the magnetic field in the mass collection on the filament. In the DR21 cloud, gravity becomes increasingly dominant at pc scales compared to Musca where gravity only takes over at $\sim$0.1 pc scale. This pc scale gravitational instability in the DR21 cloud increases the mass provision to centers of collapse where massive stars, orders of magnitude above the typical Jeans mass, can form.

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References

André, P., Men’shchikov, A., Bontemps, S., et al. 2010, A&A, 518, L102

Bonne, L., Bontemps, S., Schneider, N., et al. 2020a, A&A, 644, A27

Bonne, L., Schneider, N., Bontemps, S., et al. 2020b, A&A, 641, A17

Hill, T., Motte, F., Didelon, P., et al. 2011, A&A, 533, A94

Inoue, T., Hennebelle, P., Fukui, Y., et al. 2018, PASJ, 70, S53

Jackson, J. M., Finn, S. C., Chambers, E. T., Rathborne, J. M., & Simon, R. 2010, ApJ, 719, L185

Schneider, N., Csengeri, T., Bontemps, S., et al. 2010, A&A, 520, A49

Schneider, N., Simon, R., Guevara, C., et al. 2020, PASP, 132, 104301