Cosmic Magnetic Fields:
From Planets, to Stars and Galaxies
Proceedings IAU Symposium No. 259, 2008
K.G. Strassmeier, A.G. Kosovichev & J.E. Beckman, eds.

doi:10.1017/S1743921309030191

Local star formation triggered by SN shocks in magnetized diffuse neutral clouds

M. R. M. Leão[1], E. M. de Gouveia Dal Pino[1], D. Falceta-Gonçalves[2,3], C. Melioli[1,4] and F. G. Geraissate[1]

[1]Instituto de Astronomia e Geofísica - Universidade de São Paulo, Brazil
email: mrmleao@astro.iag.usp.br, dalpino@astro.iag.usp.br

[2]Núcleo de Astrofísica Teórica, Universidade Cruzeiro do Sul, Brazil

[3]Astronomy Department, University of Wisconsin, Madison, USA

[4]Dipartimento di Astronomia, Universitá di Bologna, Bologna, Italy

Abstract. Considering that the main source of turbulence in the ISM medium are the explosions of supernovae (SNe), we explore here the role of SN shock front interactions with clouds on the star formation triggering in presence and in absence of magnetic field.

Keywords. Stars: star formation — ISM: clouds – Supernova remnants.

We consider a supernova remnant (SNR) either in its adiabatic or in its radiative phase impacting with an initially homogeneous diffuse neutral cloud and show that it is possible to derive analytically a set of conditions that constrain a domain in the relevant parameter space where these interactions may lead to the formation of gravitationally unstable, collapsing structures.

One of these conditions determines the Jeans mass limit for the shocked cloud material due to the SNR impact. A second condition establishes that the shock front that propagates inside the cloud must have energy enough to sweep the entire cloud before stalling inside it due to radiative losses. In this way, the shock will be able to inject a maximum possible energy into the cloud material and compress it efficiently. A third condition establishes that the same shock front should not be too strong, otherwise it could destroy the cloud completely making the gas to disperse in the interstellar medium before becoming gravitationally unstable.

Using these conditions, we have built diagrams of the SNR radius, R_{SNR}, versus the initial cloud density, n_c. This work is an extension to previous study performed without considering magnetic fields (Melioli *et al.* 2006). The diagrams are also tested with fully 3-D MHD simulations involving a SNR and a self-gravitating cloud and we find that the numerical analysis is consistent with the results predicted by the diagrams, see Fig. (1).

The inclusion of a homogeneous magnetic field approximately perpendicular to the impact velocity of the SNR with an intensity $\sim 1\ \mu$G within the cloud results only a small shrinking of the star formation triggering zone in the diagram relative to that without magnetic field, a larger magnetic field ($\sim 10\ \mu$G) causes a significant shrinking, as expected. Though derived from simple analytical considerations these diagrams provide a useful tool for identifying sites where star formation could be triggered by the impact of a SN blast wave.

Applications of them to a few regions of our own galaxy have revealed that star formation in those sites could have been triggered by shock waves from SNRs for specific values of the initial neutral cloud density and the SNR radius. Finally, we have also evaluated the effective star formation efficiency for this sort of interaction.

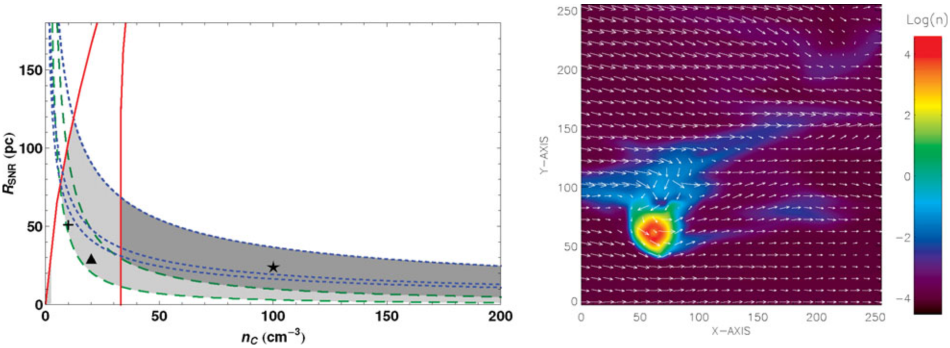

Figure 1. Left panel: Constraints on the SNR radius versus cloud density for a cloud with r_c = 10 pc. Dashed (green) line: upper limit for complete cloud destruction; solid (red) line: upper limit for the shocked cloud to reach the Jeans mass; dotted (blue) lines: upper limits for the shock front to travel into the cloud for different values of the cooling function $\Lambda(T_{sh})$. The shaded zones define the region where star formation can be induced by a SNR-cloud interaction. The light shaded zone defines the SF region domain for a cloud with $B_c = 0$ while the dark one defines the SF region domain for $B = 1\ \mu$G. The symbols in the panels indicate the initial conditions assumed for the clouds in numerical simulations. Right panel: Example of a colour-scale map of the mid-plane density distribution and magnetic field vectors for a simulated model with $n_c = 100$ cm^{-3}, $R_{SNR} = 25$ pc, and $B = 1\mu$G (the star in the left diagram) at time 2.5×10^6 yr. (Leão *et al.* 2008)

Conclusions

A uniform magnetic field (1 μG) plays some role over the Jeans constraint only, causing a drift of the allowed SF zone to higher cloud densities in the diagram when compared to the case with no magnetic field. When larger intensities of magnetic fields are considered ($5 - 10\ \mu$G), the shrinking of the allowed SF zone in the diagrams is much more significant.

The sfe for these SNR-cloud interactions is generally much smaller than the observed values in our own Galaxy (sfe $\sim 0.01 - 0.3$). This result is consistent with previous work in the literature and also suggests that the mechanism presently investigated, though very powerful to drive structure formation, supersonic turbulence and eventually, local star formation, does not seem to be sufficient to drive *global* star formation in normal star forming galaxies, not even when the magnetic field in the neutral clouds is neglected.

Acknowledgements

E.M.G.D.P., M.R.M.L., D.F.G. and F.G.G. acknowledge financial support from grants from the Brazilian Agencies FAPESP, CNPq and CAPES.

References

Falceta-Goncalves D., Lazarian A., & Kowal G. 2008, *ApJ* 679, 537

Kowal G. & Lazarian A. 2007, *ApJ* 666, L69

Leão, M. R. M., de Gouveia Dal Pino, E. M., Falceta-Gonalves, D., Melioli, C., & Geraissate, F. G., 2008, *MNRAS* accepted.

Melioli, C., de Gouveia Dal Pino, E. M., & Raga, A. 2005, *A&A* 443, 495

Melioli, C., de Gouveia Dal Pino, E. M., de la Reza, R., & Raga, A. 2006, *MNRAS* 373, 811

https://doi.org/10.1017/S1743921309030191 Published online by Cambridge University Press