Formation of cold gas around superbubbles

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Image credit: ESA/PACS & SPIRE Consortium, S. Molinari, Hi-GAL Project

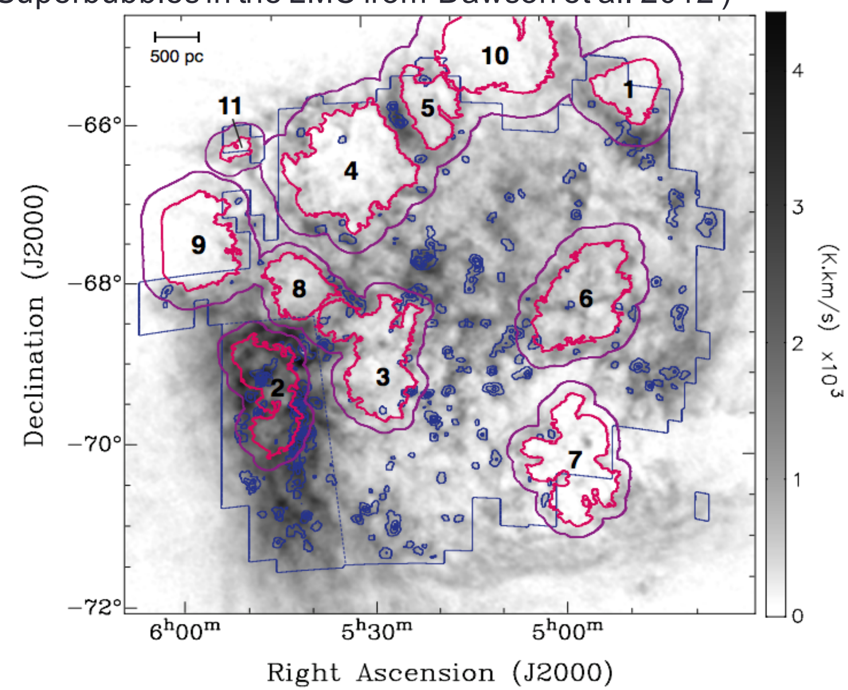
Superbubbles and Supershells

Superbubbles are large cavities of hot gas created by the combined wind and supernova feedback of several OB stars.

Supershells (Heiles 1979) are shocks of hundreds of parsecs size, usually associated with superbubbles.


(Image from Gemini. Violet corresponds to Hα)

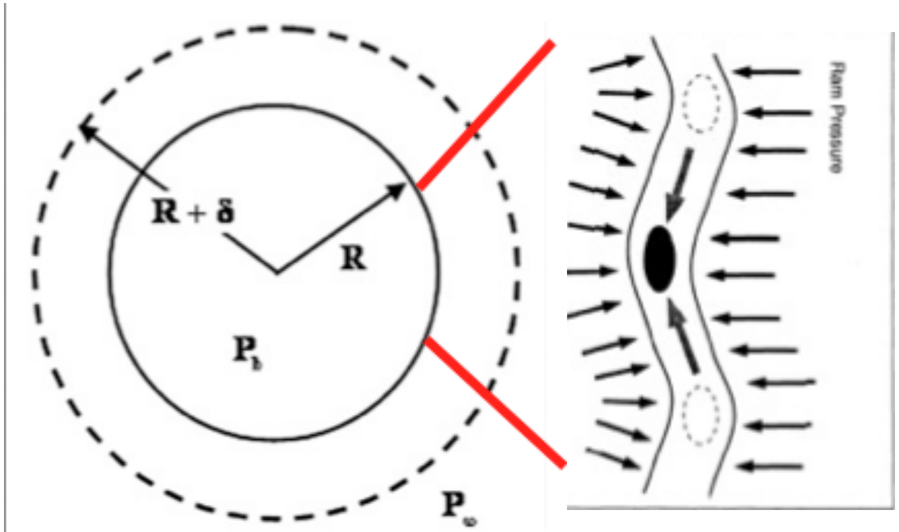
(Superbubbles in the LMC from Dawson et al. 2012)



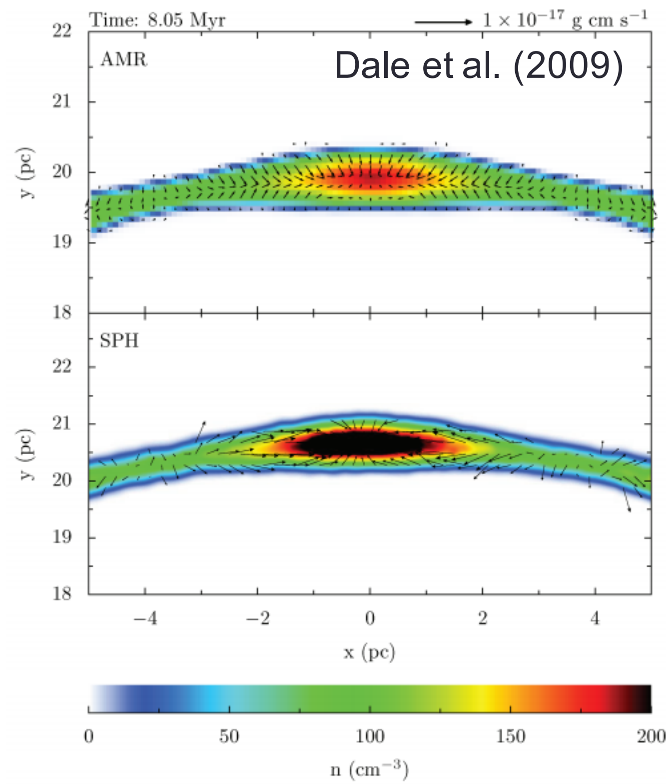
There is evidence of enhanced molecular gas content and young stars around them

Supershell fragmentation and molecular cloud formation

It is theorized that molecular gas forms around superbubbles due to the dynamical and/or gravitational instability of decelerating spherical shocks.



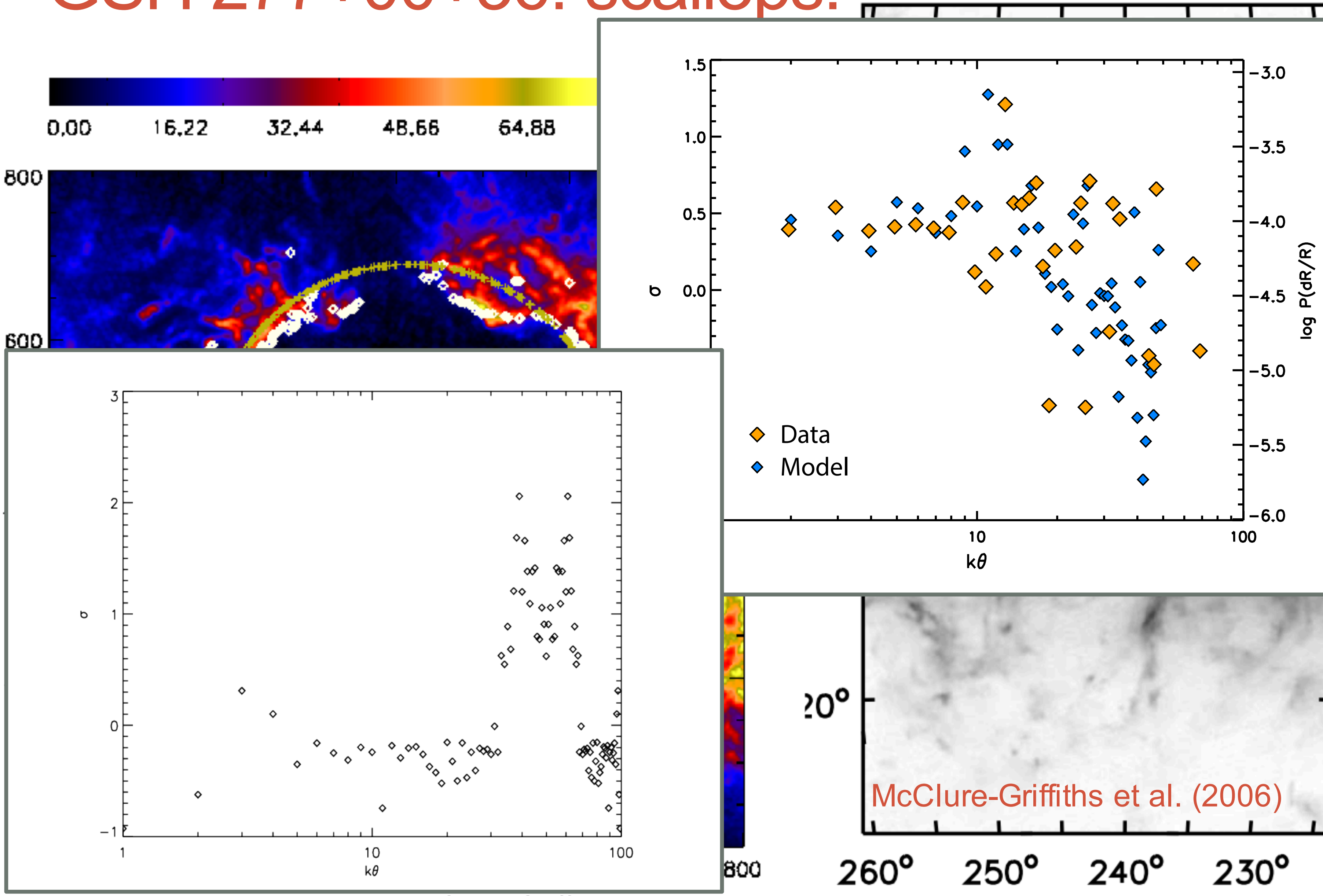
Dynamical Instability of the shell (Vishniac 1983) due to the different natures of the pressure on either side of the shock



"collect and collapse" model for star formation

Magnetic fields have so far only been considered in terms of their effect on the shock thickness, but so far not of their effect on the shell stability.

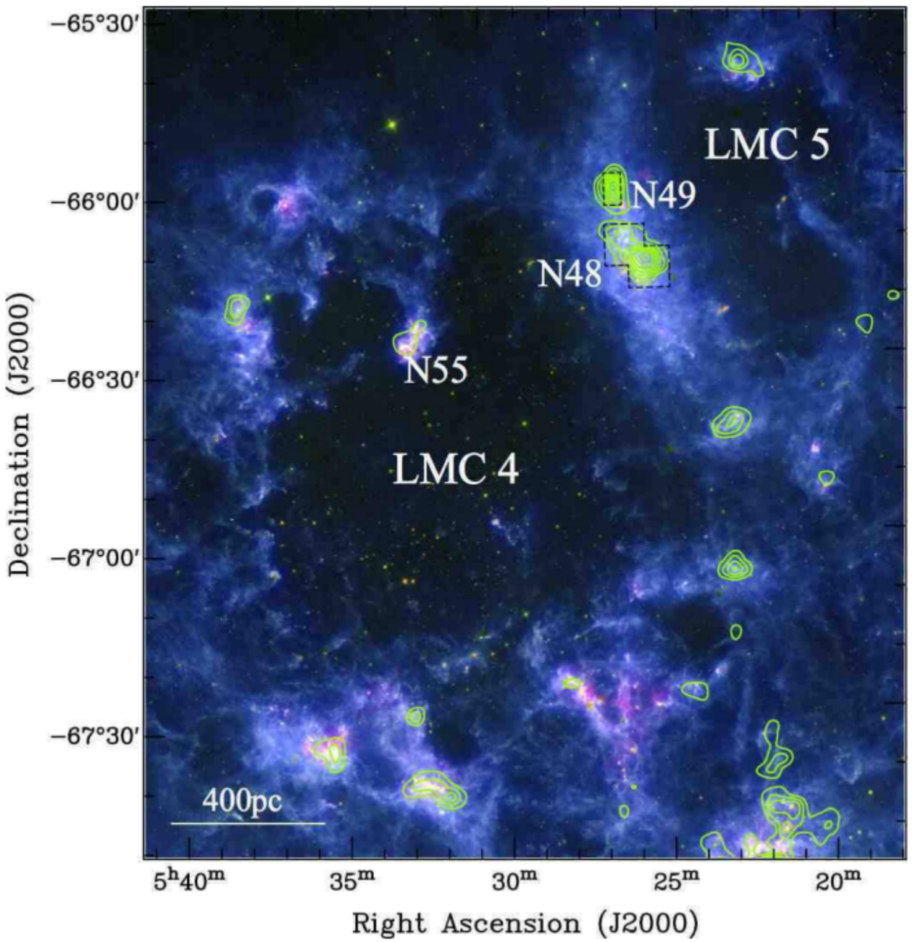
GSH 277+00+36: scallops!



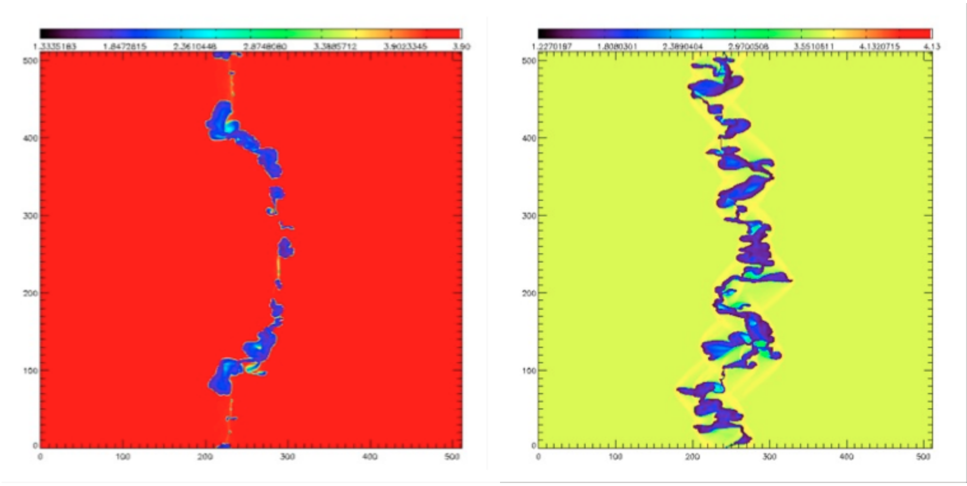
EN, Joanne Dawson, Naomi McClure-Griffiths, in prep.

Supershell interactions

Fujii et al. (2014) colliding shells in the LMC

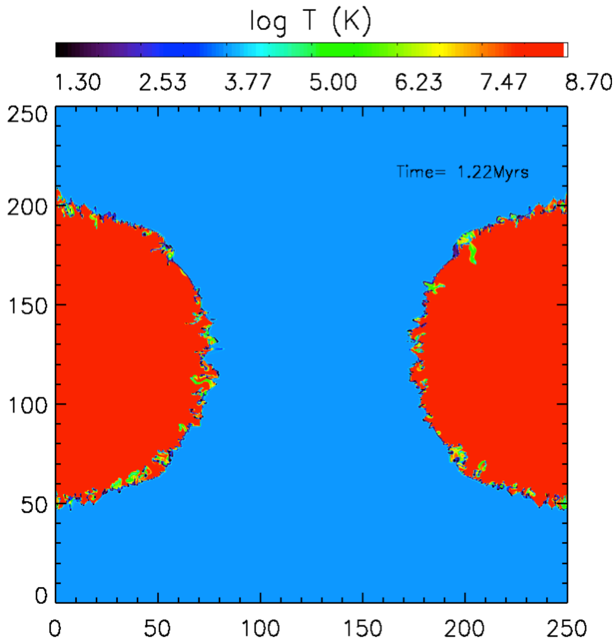


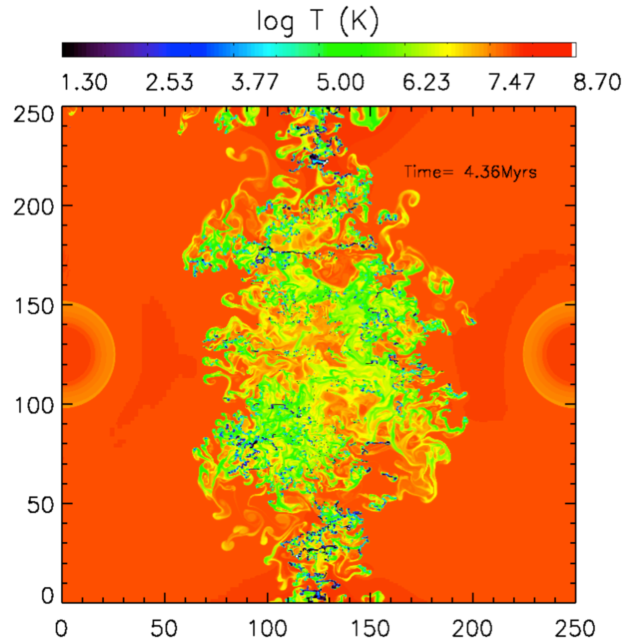
Whenever supershells are observed to interact, there is either an enhanced molecular gas content or young stars at the collision interface.
Does this mean that supershell collisions trigger an additional instability?

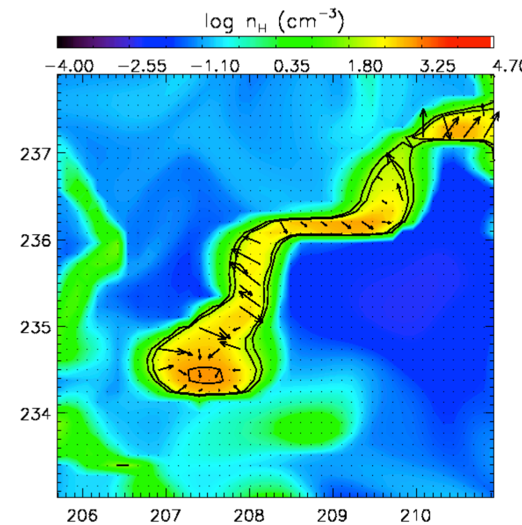


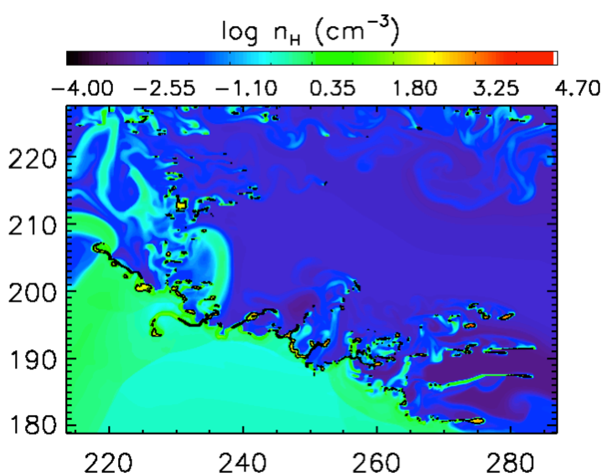
2D models of supershell collisions (E.N. +2011)

2D simulations of OB associations comprising 50 stars each



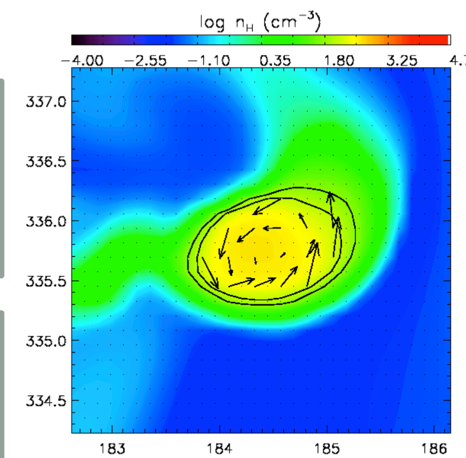






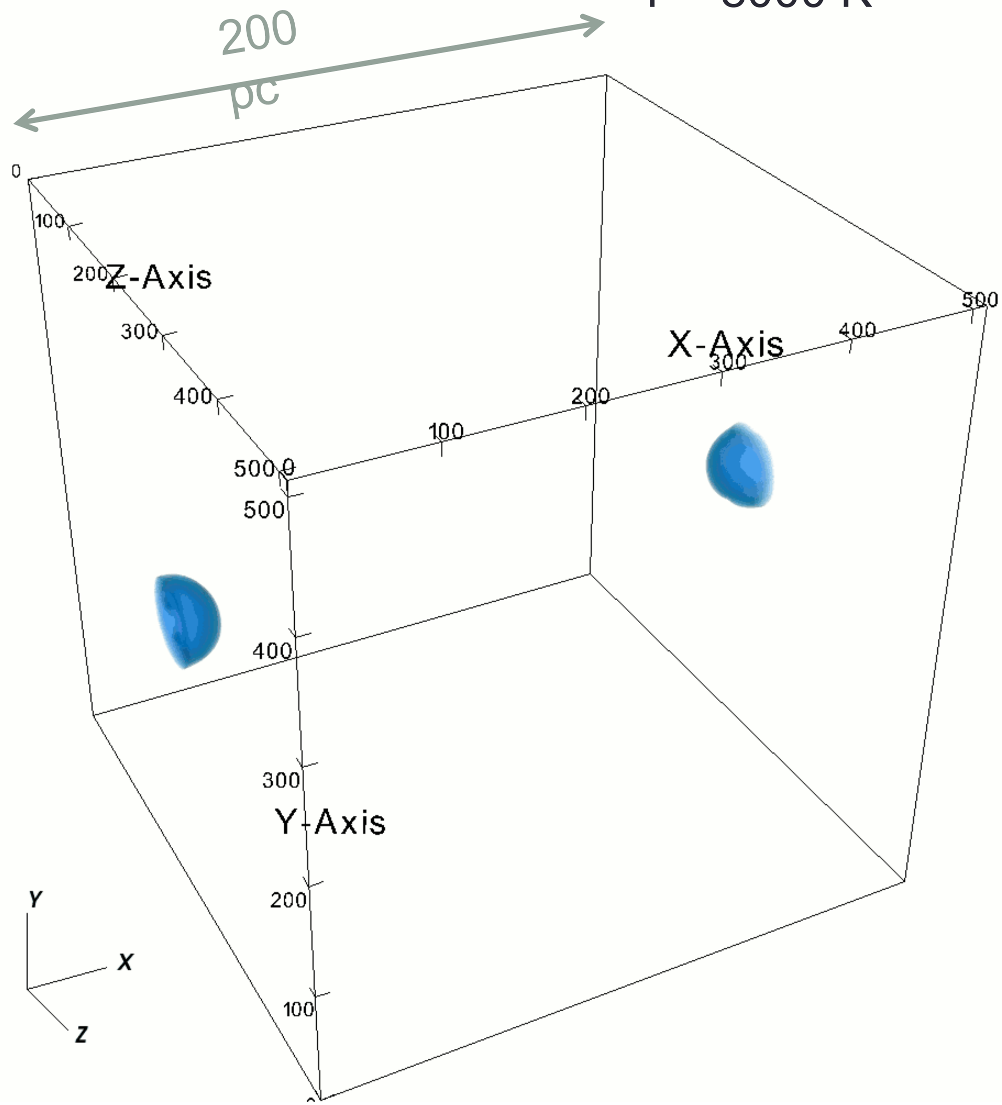
Feedback regions positioned 500 pc apart in a warm, turbulent insterstellar medium

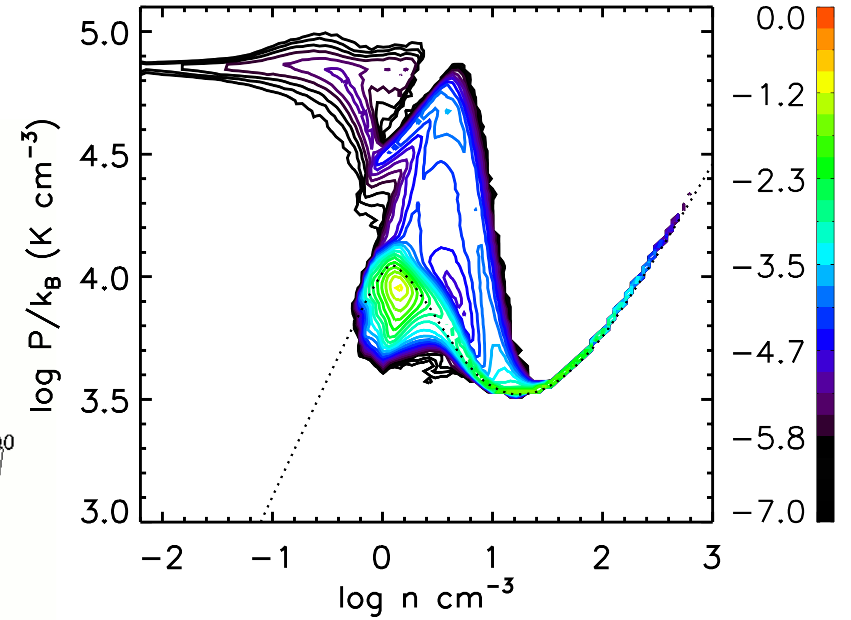
Internal structure of the clouds is resolved: rotating, turbulent or quiescent clouds

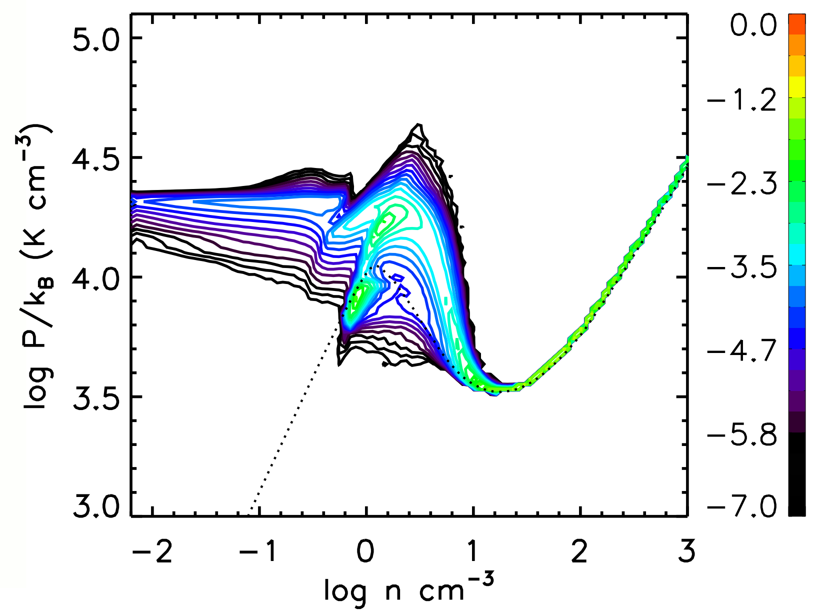


Numerical simulation of two colliding supershells, hydrodynamical case

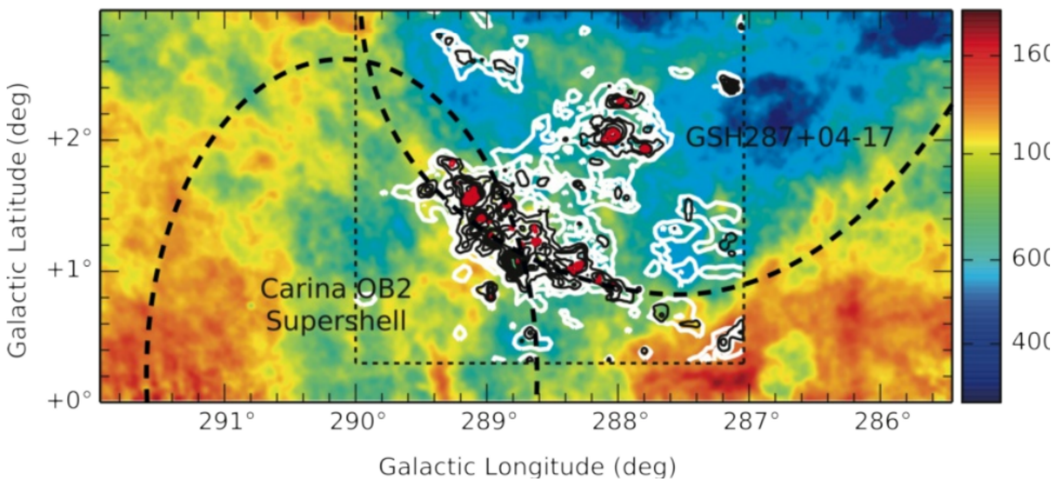
$n_0 = 500\ \mathrm{cm}^{-3}$
Ms = 1
T = 8000 K

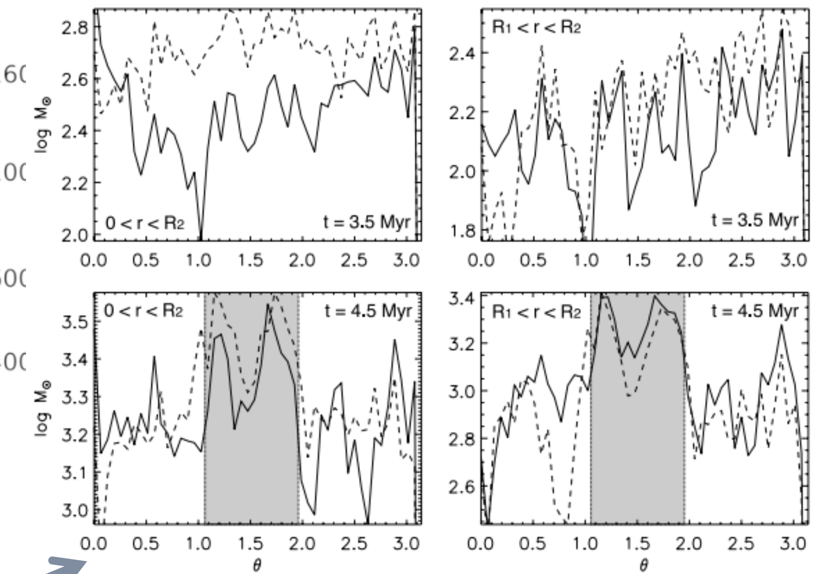




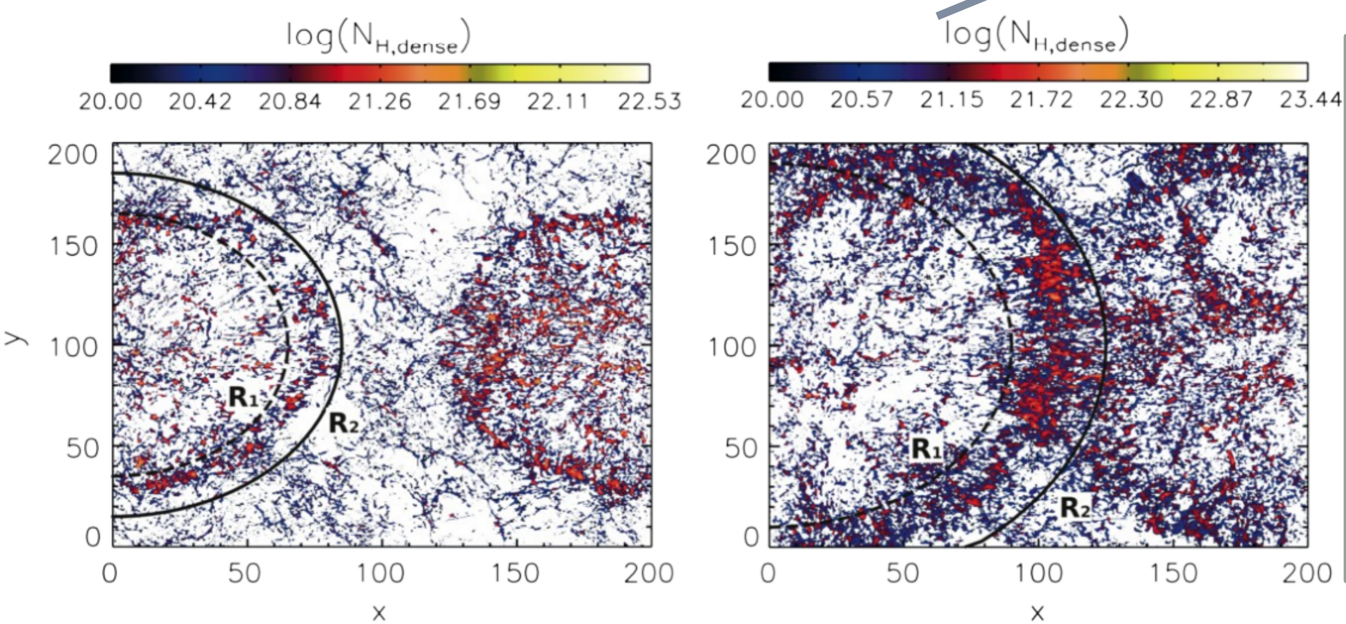


Interacting shells: Observations meet simulations





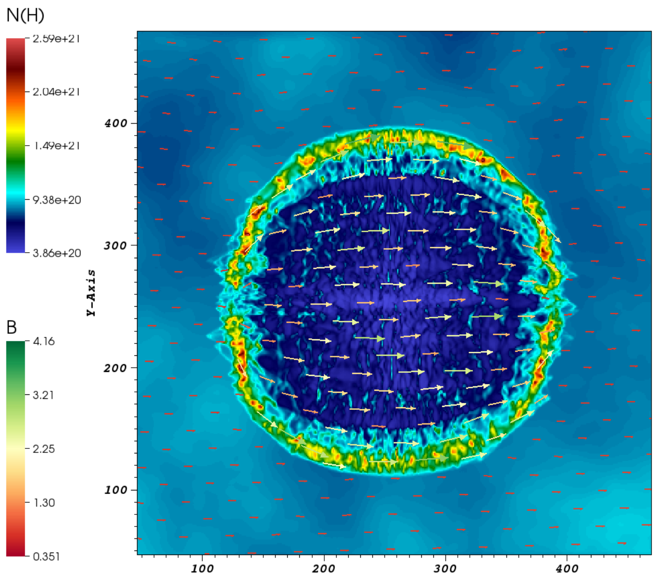
Dawson, E.N. et al. (2015)



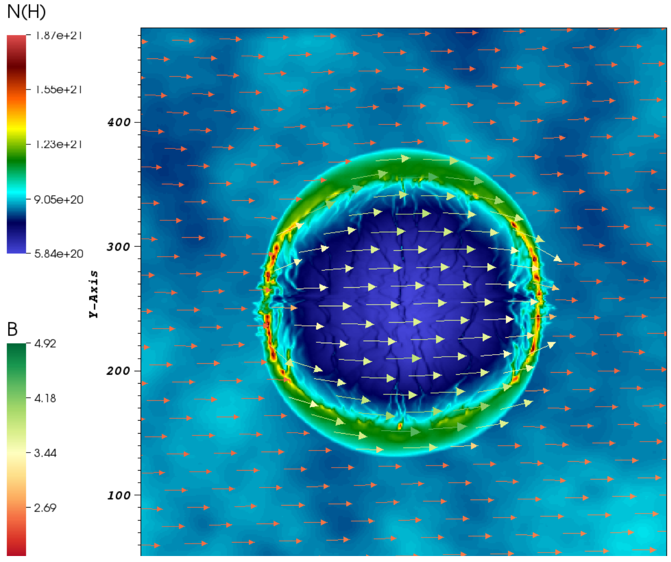
Comparison between hydro simulations and observations of a GMC between two Galactic supershells:

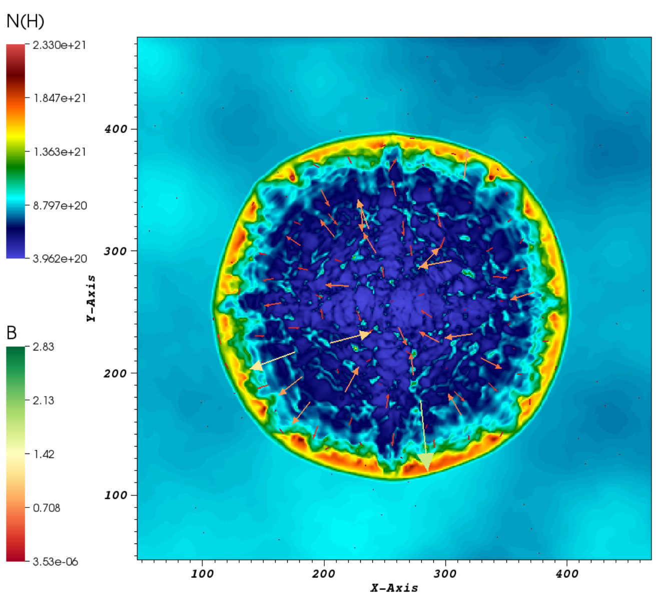
No additional dense gas due to the shell collision!

A single bubble in a magnetic field: “weak” (β~10) vs “strong” (β~1) field

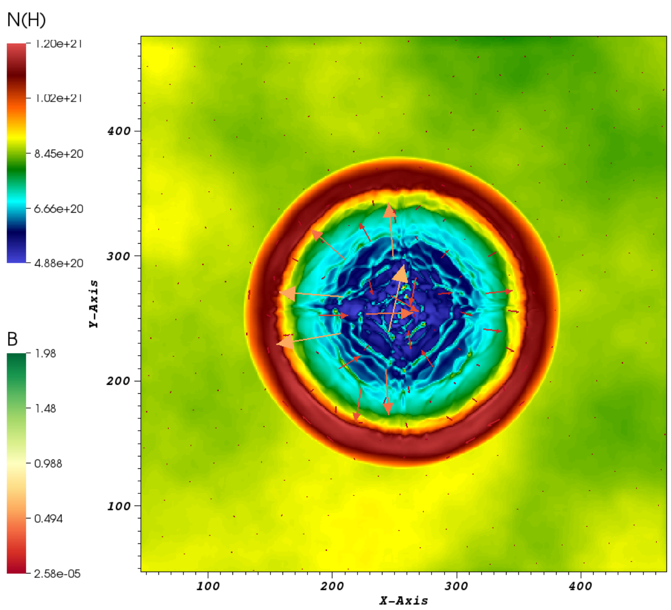


Increasing the magnetic field strength broadens the shell perpendicular to the mean field direction.



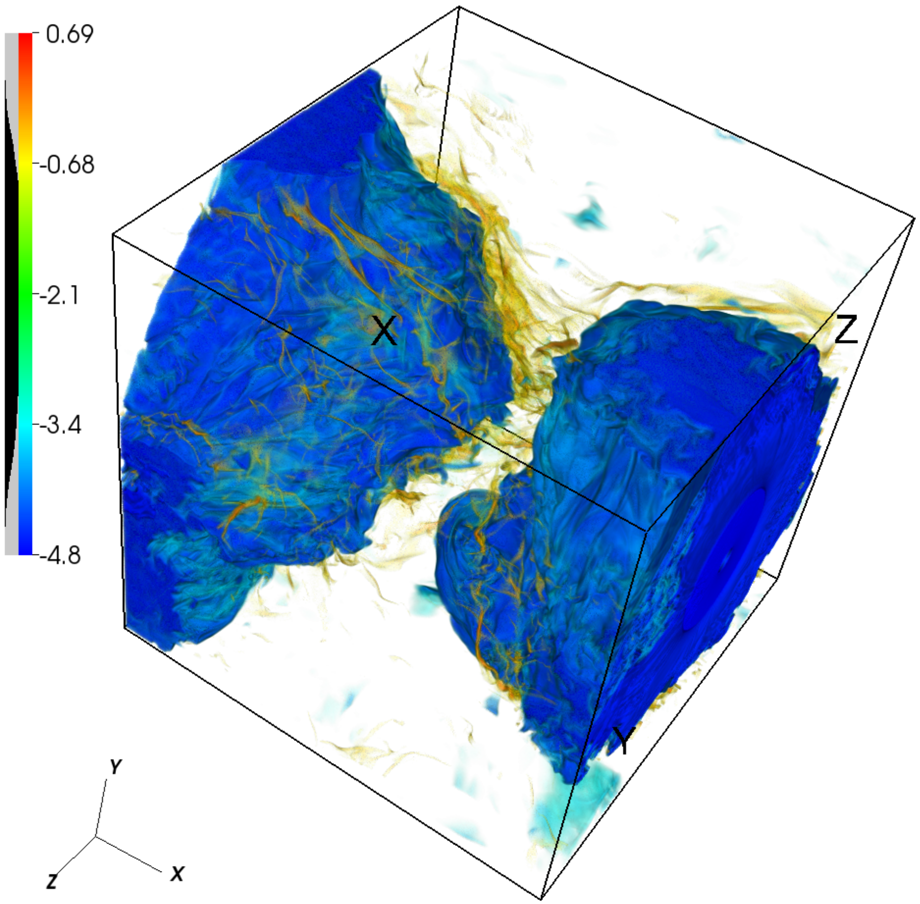


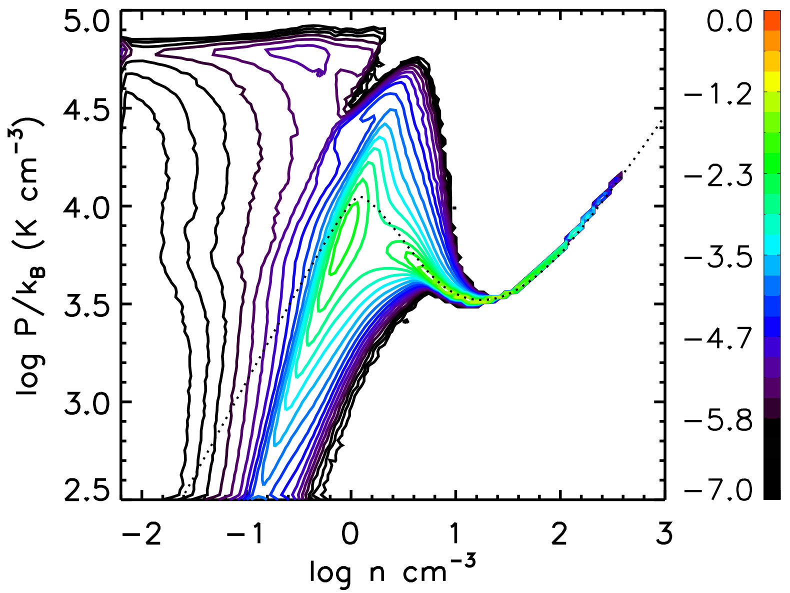
It also causes more filamentary fragments to form on the shock surface

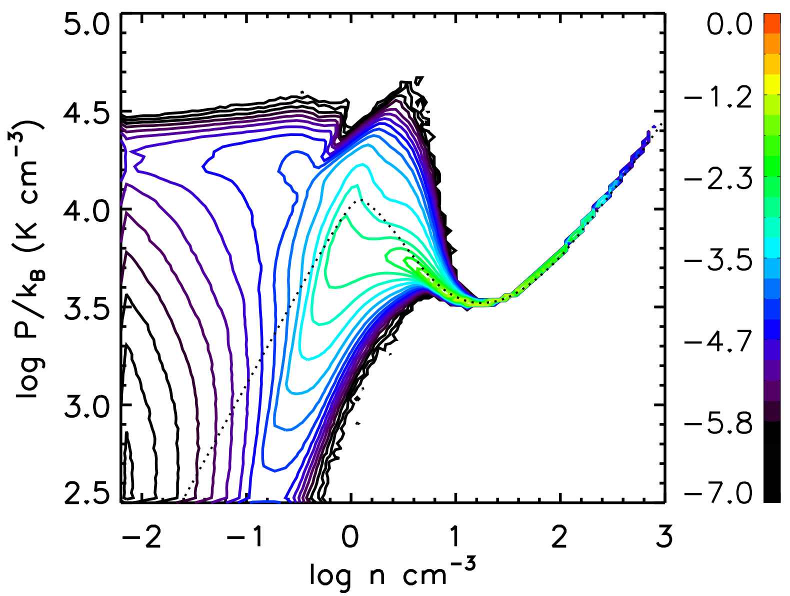


MHD case with mean field parallel to the collision axis

Magnetic field initiated with a 5μG strength, oriented along x.

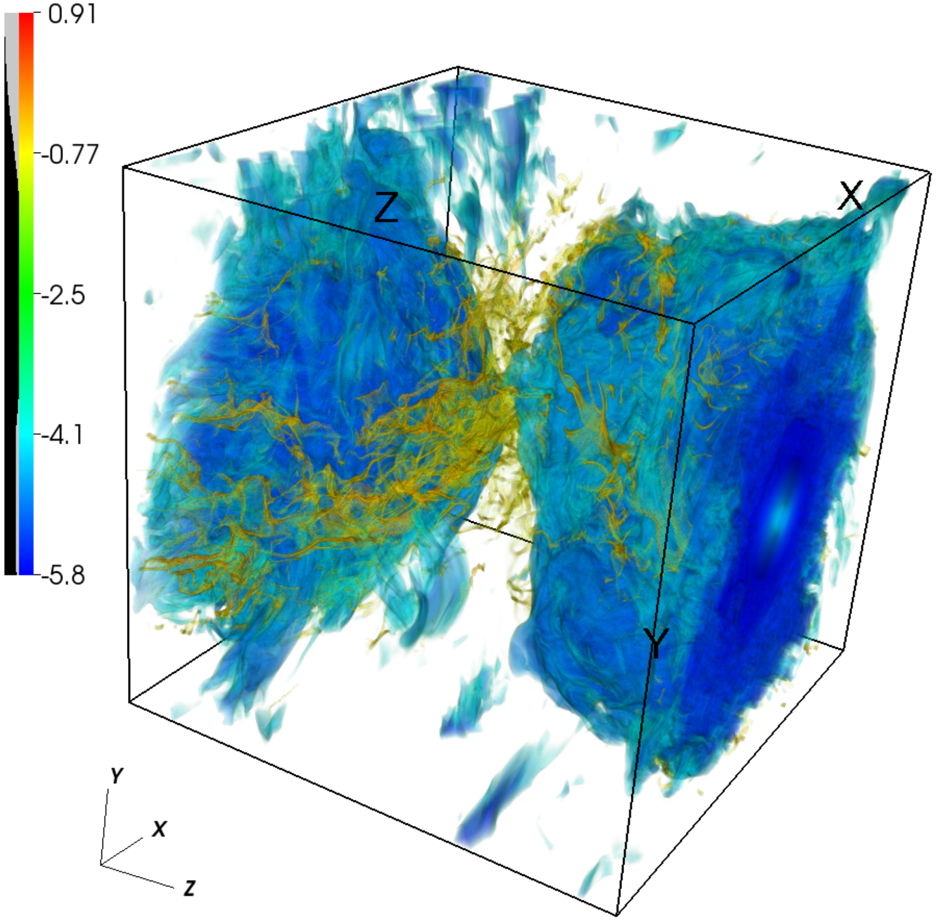


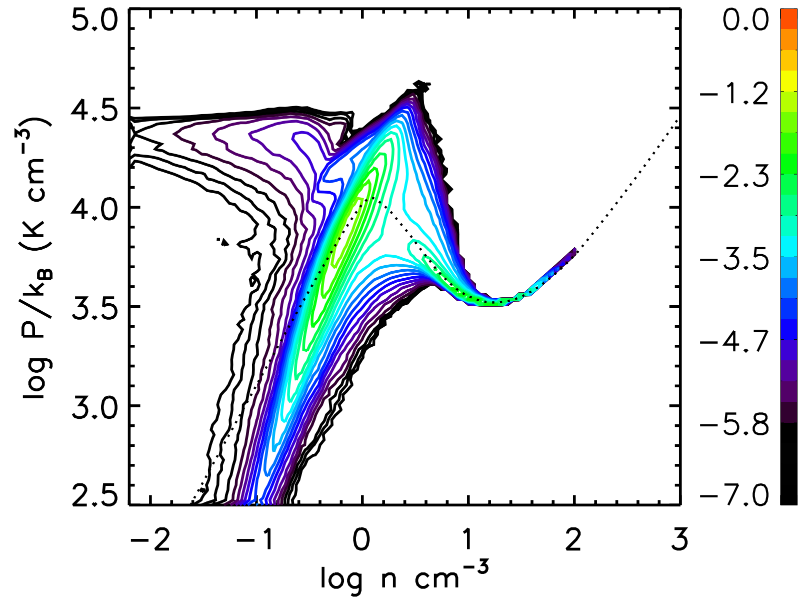


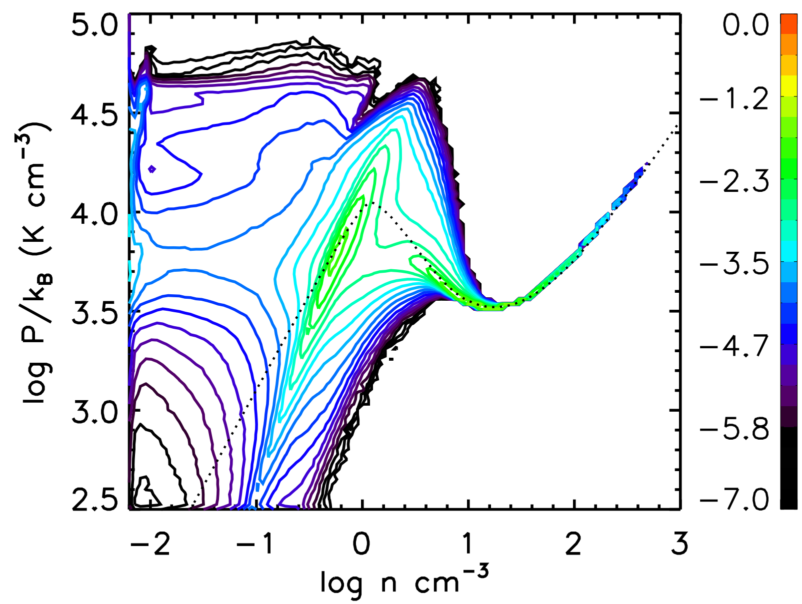


MHD case with mean field perpendicular to the collision axis

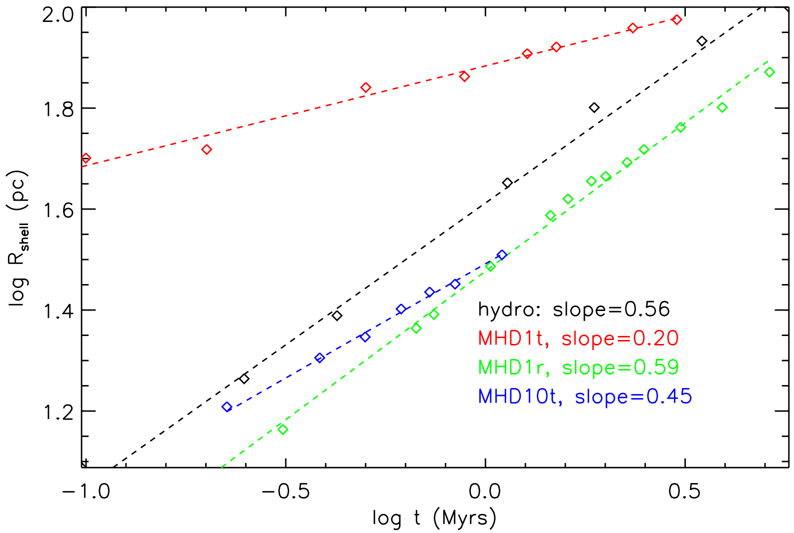
Magnetic field initiated with a 5μG strength, oriented along y.







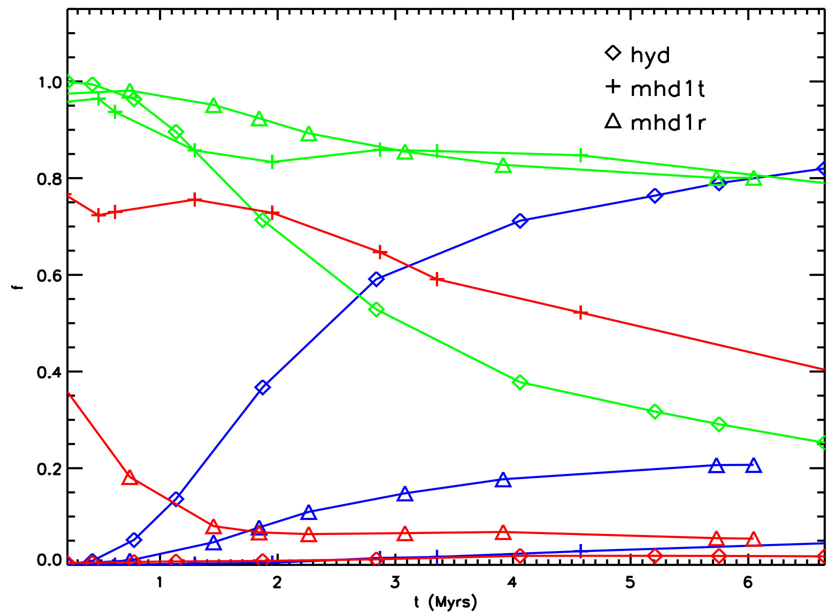
Expansion laws and gas phases



(Analytic wind similarity solution: $R \sim t^{0.6}$)

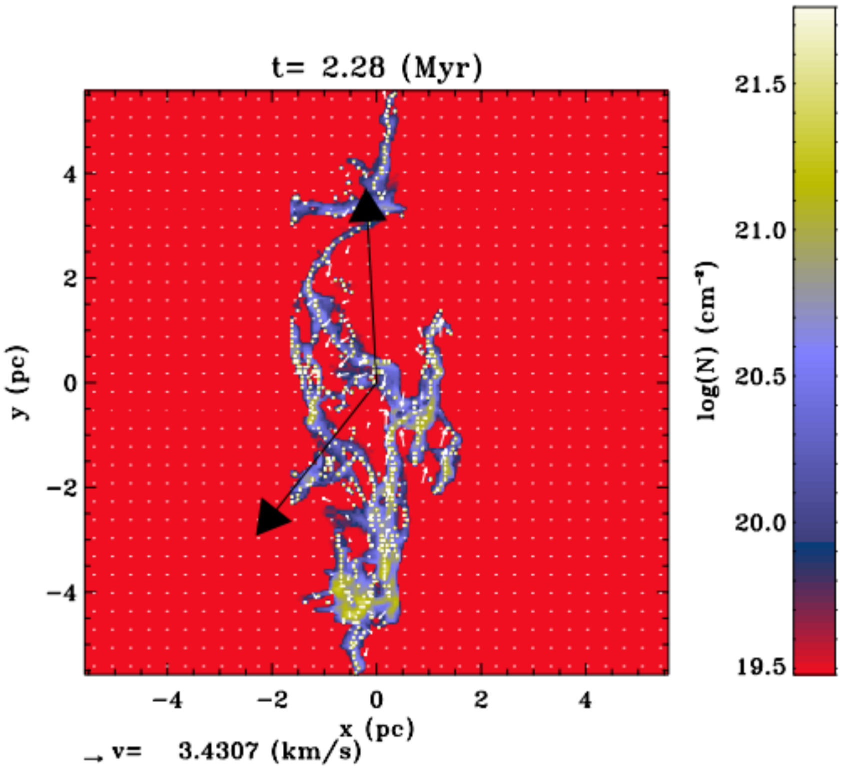
A magnetic field oriented along the collision axis doesn't alter the expansion law with respect to the hydro case.

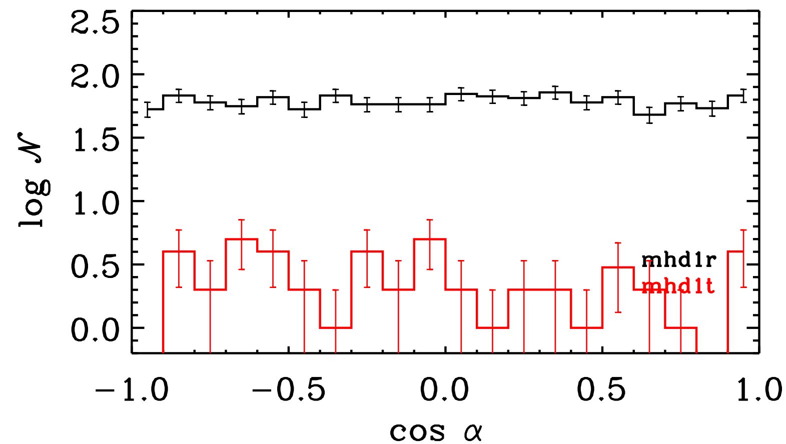
However, the formation of dense gas is greatly affected, as well as the momentum carried by each phase.

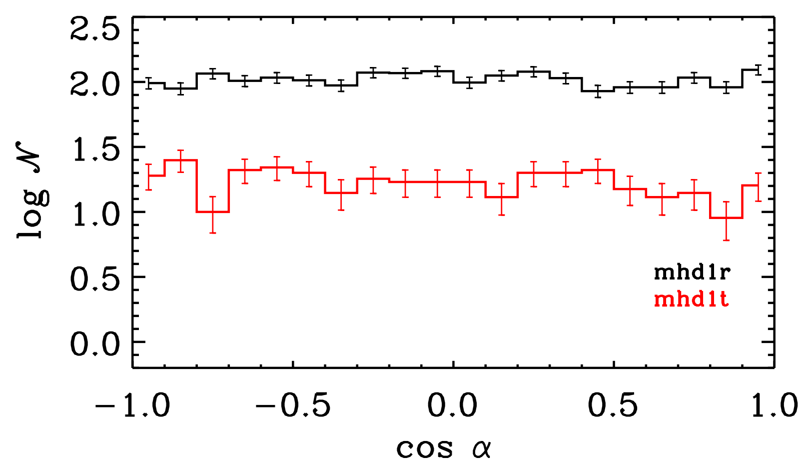


Locating filaments in 3D simulations

1. Put a threshold in density to select densest locations
2. Apply a friends-of-friends algorithm to identify filaments
3. Solve for the eigenvectors of the inertia matrix to find the filament's principal directions
4. Find the local centers of mass along the longest axis and calculate local properties







Conclusions

- Cold dense clouds form naturally around expanding supershells due to a combination of fluid instabilities

- However, even when we use self-gravity, we cannot form the observed additional dense gas at supershell interaction regions. In fact, pre-existing dense gas gets heated and evaporated.

- Even a weak magnetic field opposing the bubble expansion affects the expansion law of the superbubbles, the amount of dense gas formed and the morphology of the cold clouds.

- In hydro simulations most of the wind momentum is transferred to the cold gas. In MHD simulations the momentum is carried principally by the warm gas.