Stellar bubbles dynamics in the presence of cosmic ray

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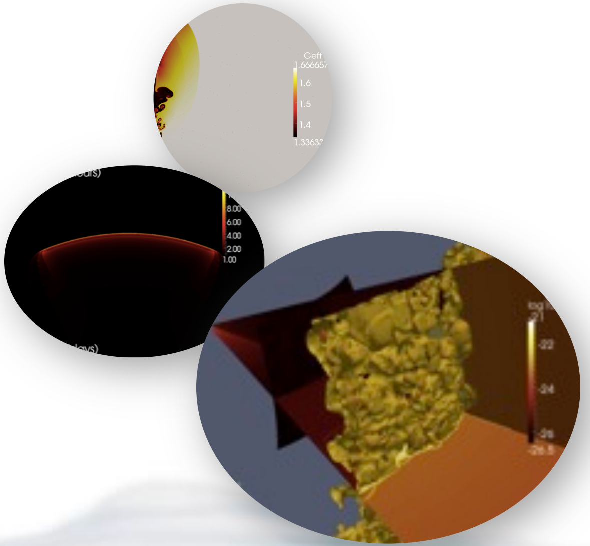


A. J. van Marle
- APC

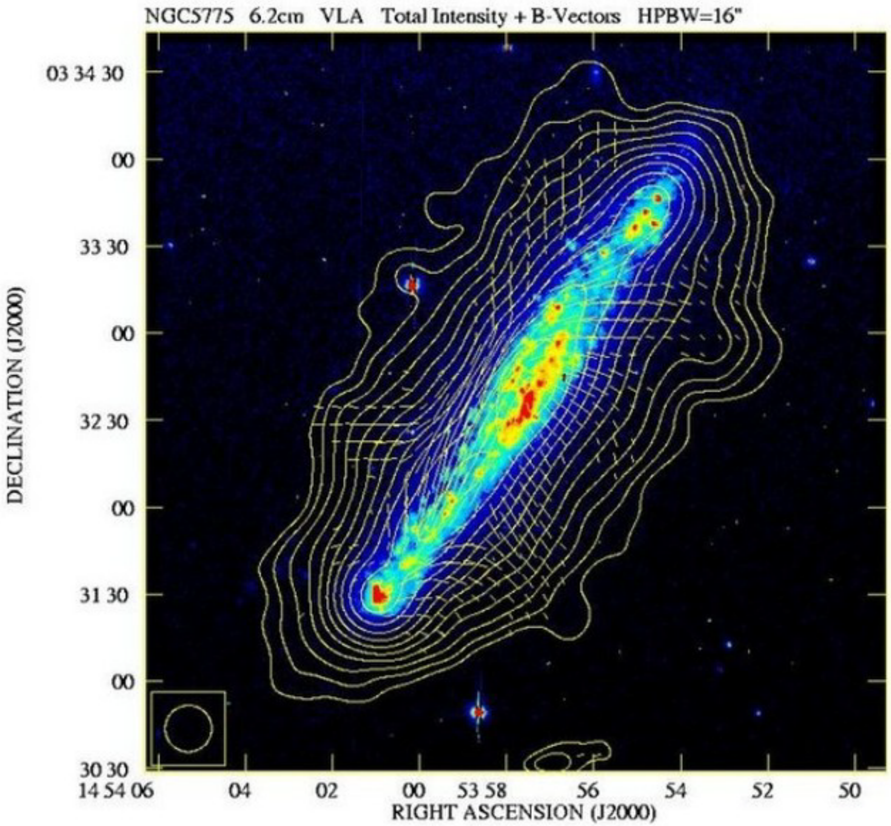
A. Marcowith
- L'Université de Montpellier

Outline of the talk

Motivations

Cosmic Ray fluid description

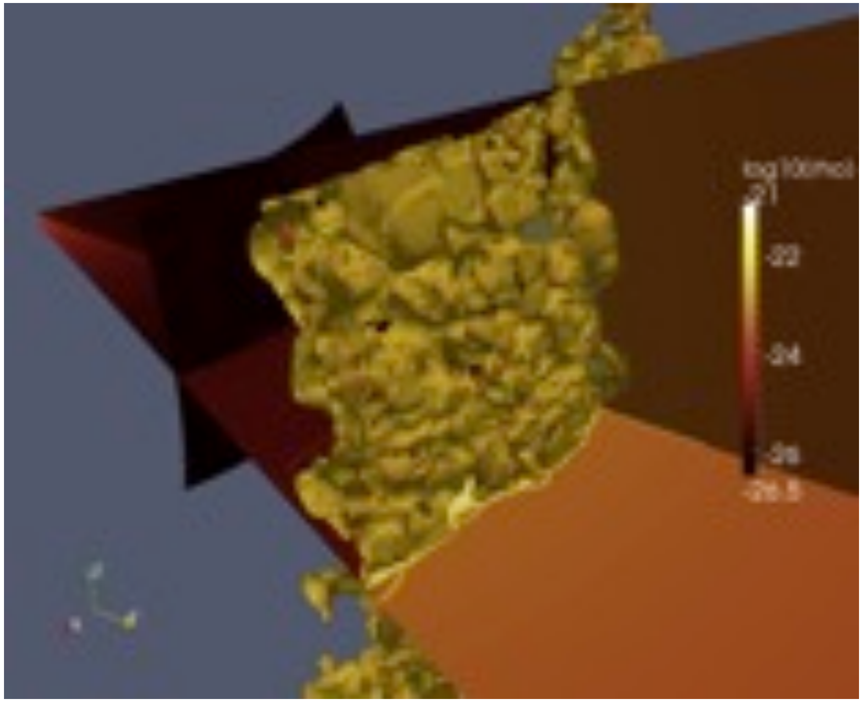
CR effect on stellar bubble

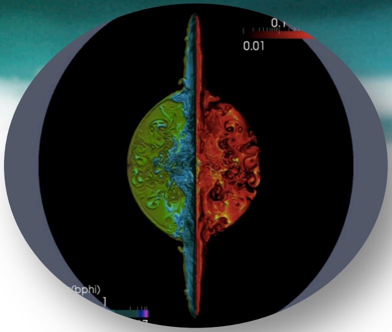


Introduction – Cosmic Ray- Circumstellar medium

Subject to strong interaction gas-cosmic ray

- Wind-ISM interaction
- Cosmic Rays energy reservoir
- Cosmic Rays induce anisotropic pressure.





Two-fluid implementation of Cosmic Ray

Cosmic ray in ISM and fluid description

- Cosmic Ray R are mostly generate by SN, with 10% of the thermal SN energy (Ackermann 2013)
- Cosmic Ray has same energy as magnetic fields and turbulence (Ferriere 2001)
- Inefficient cooling
- Coupling CRs-gas is indirect via magnetic fields
- CRs diffuse along the magnetic fields

Super wind in M82
(NASA/JPL-Caltech/STScl/CXC/UfoA)

Fluid description of Cosmic ray

- Momentum transfer through pressure gradient
- Heat gas at : v grad (Pressure of CR)
- Diffusion along the magnetic field (is 3/5 X 10^{28} cm^2/s at energies around 1GeV (Strong et al. 2007))
- Cosmic ray is described by relativistic equation of state (Γ=4/3)

Two-fluid description

$\partial\rho/\partial t + \nabla\rho v = 0,$

$\partial\rho v/\partial t + \nabla\cdot(\rho vv + p_{tot}) = 0,$

$\partial e_{tot}/\partial t + \nabla\cdot[(e_{tot} + p_{tot})v] = \nabla\cdot(D\nabla(e_{cr})),$

$\partial e_{cr}/\partial t + \nabla\cdot[(e_{cr} + p_{cr})v] = v\cdot\nabla p_{cr} + \nabla\cdot(D\nabla e_{cr}).$

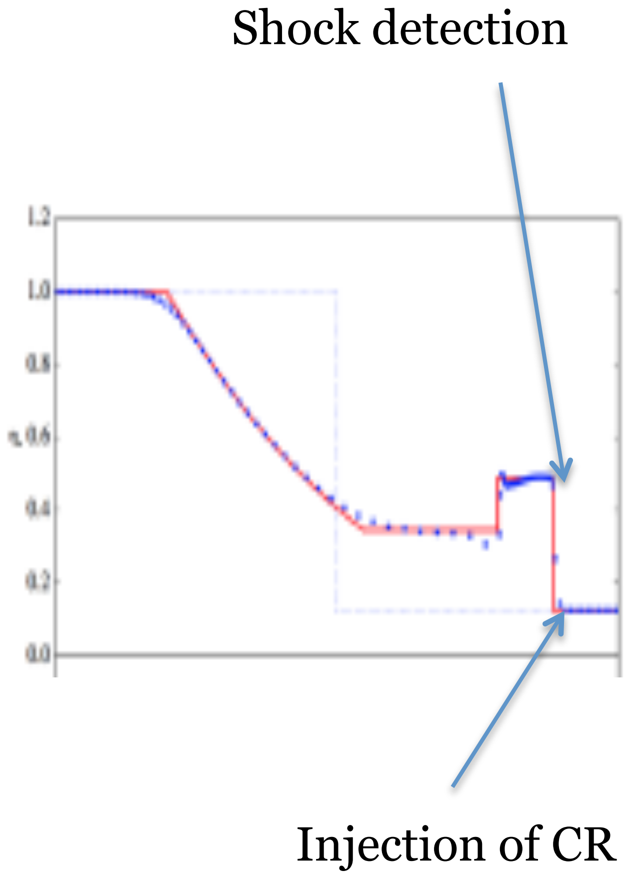
Hanasz & Lesch 2003

- ρ : *gas density*
- v :*gas speed*
- $p_{tot} = p_{gas} + p_{cr}$: *total pressure*
- p_{cr}: *cosmic ray pressure*
- e_{cr}: *cosmic ray energy.*

Implementation for choc CR injection

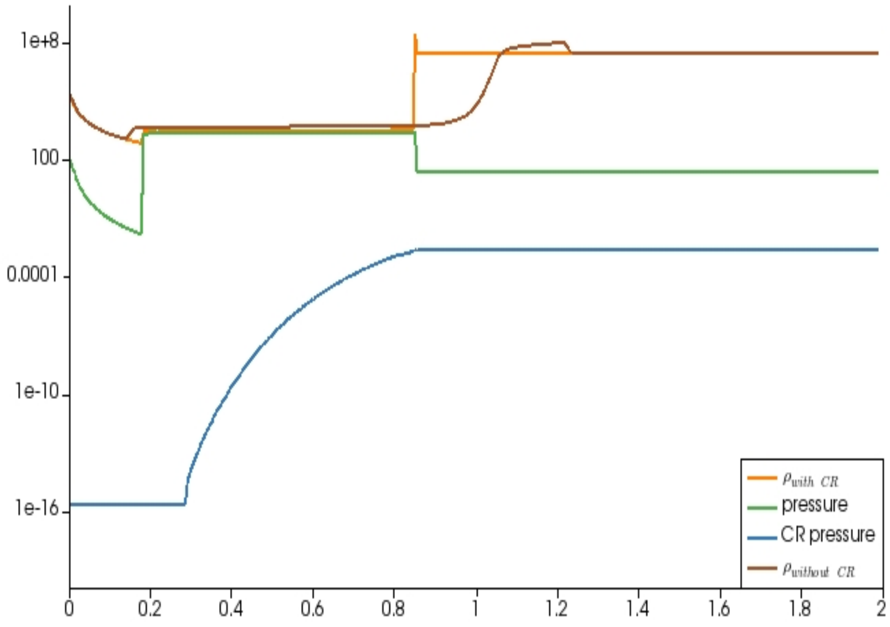
Case: CR are injected at the chocs

- Fraction of the thermal energy realised at the choc is transferred to Cosmic Ray pressure
- Injection region scale of order of CR diffusion distance around choc
- CR injected mainly in low-cooling shocks.



Effect of ISM CR pressure

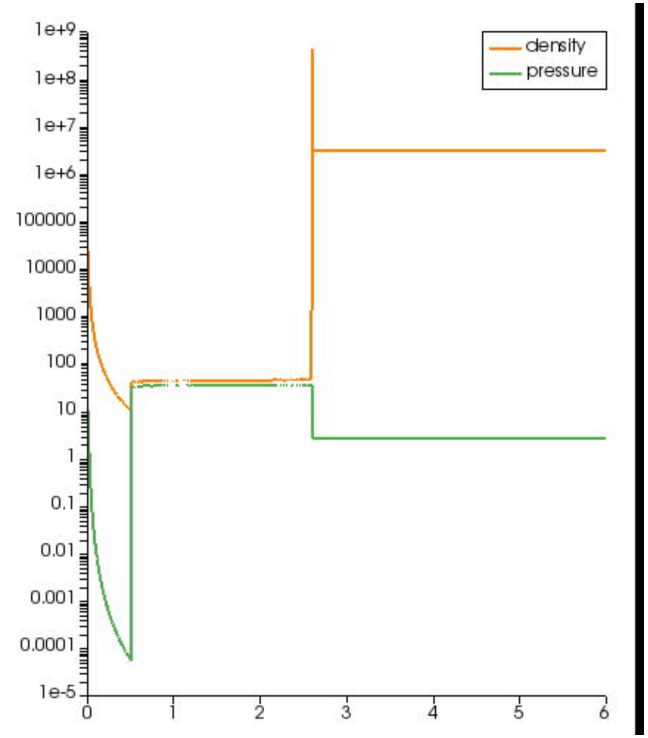
- Decelerate the shock propagation
- Decrease cooling of the shocked ISM



Effect of CR on shocks (without cooling)

Low injection of CR and shocks doesn't effect

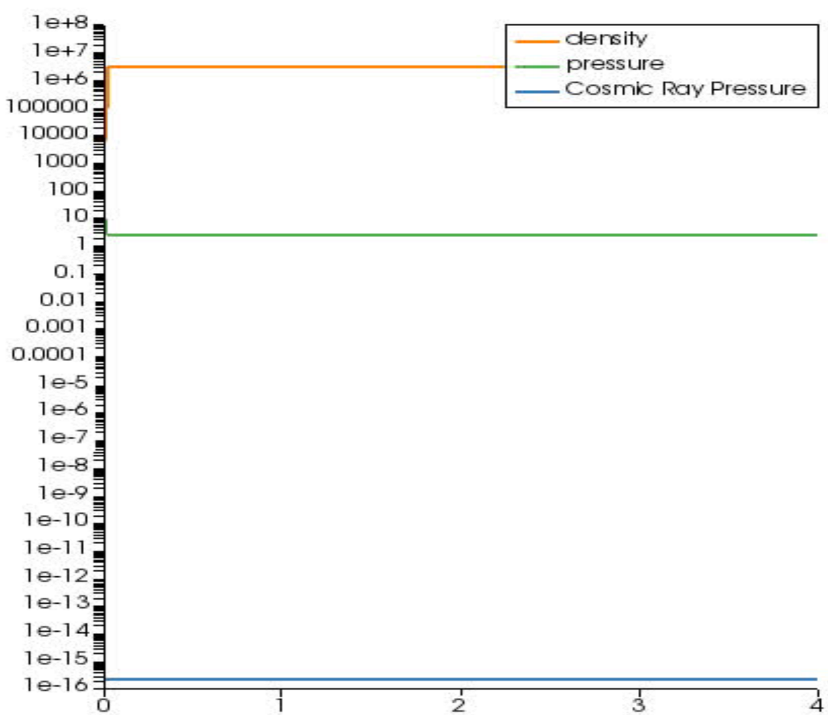
Increase of CR injection at shocks induce a compression of the shock

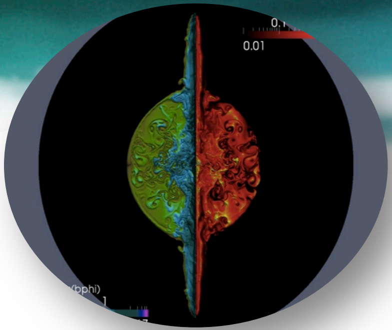


Effect of CR on shocks (with cooling)

The injection of CR at shocks

- Decrease in gas temperature at the shock
- Competition bewteen CR and gas cooling





Circumstellar medium of massive star

- CR limit the bubble size.
- WORK IN PROGRESS