Shock evolution and energy dissipation of magnetized blast waves (邦題：磁場優勢ジェットが織り成す相対論的爆風)

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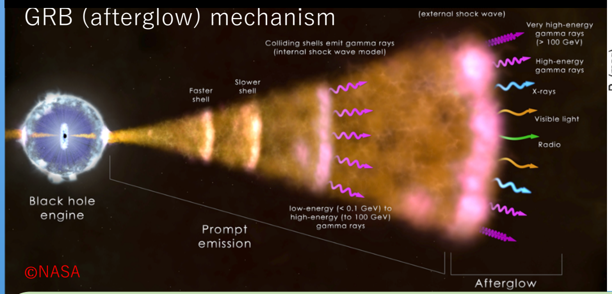
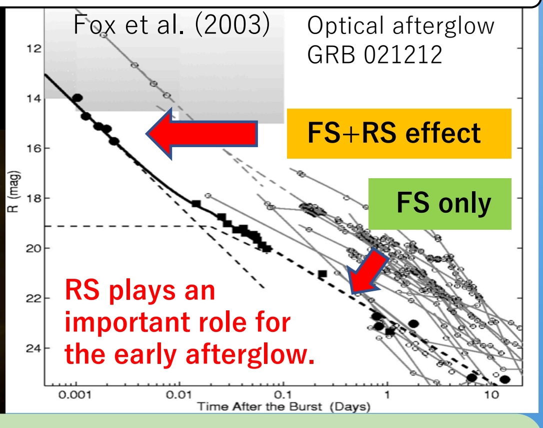
Topic : Relativistic Magneto-Hydrodynamic Simulation on Jet – ISM interaction

Shocks propagate into two directions :
・Forward shock (FS) : go into ISM
・Reverse shock (RS) : back into Jet

GRB (afterglow) mechanism





About Problem : The effect of magnetic field on RS property is less well understood.
Previous Research : Only weakly magnetized blast waves are simulated (Giannios et. al 2008).
My Research Point : Can the initial jet energy dissipate even for highly magnetized jet?
This is the first SRMHD simulation in the world for highly magnetized blast waves !!!

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Basic equations (1D spherical symmetry)

・$\frac{\partial \rho\gamma}{\partial t}+\frac{1}{r^2}\frac{\partial}{\partial r}r^2(\rho\gamma v_r)=0$: Mass
・$\frac{\partial \tau}{\partial t}+\frac{1}{r^2}\frac{\partial}{\partial r}r^2(w\gamma^2 v_r-\rho\gamma v_r)=0$: Energy
・$\frac{\partial S}{\partial t}+\frac{1}{r^2}\frac{\partial}{\partial r}r^2(w\gamma^2 v_r^2+p)=\frac{2p}{r}$: Momentum
・$\frac{\partial B_\theta}{\partial t}+\frac{1}{r}\frac{\partial}{\partial r}r(B_\theta v_r)=0$: Induction

$\tau=w\gamma^2-p-\rho\gamma$: total energy density
$w=\varepsilon+p_g+2p_m$: magnetic enthalpy
$\rho, p_g, p_m, \varepsilon$ are defined at the comoving frame

・The heat ratio (Mignone et. al 2004)

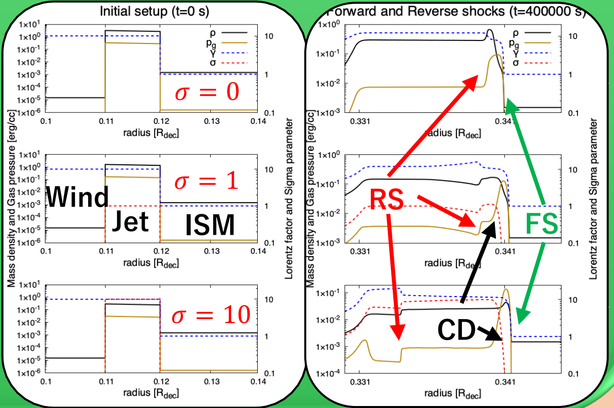
$$\gamma_c=1+\frac{\varepsilon+\rho}{3\varepsilon}$$

・The definition of decelerated radius

$$E_{ini}^{jet}=\frac{4\pi}{3}R_{dec}^3 n_{ISM}\gamma^2 m_p c^2$$

・**Sigma parameter : $\sigma=\frac{B_\theta^2}{4\pi(\varepsilon+p_g)\gamma^2}=\frac{B\ energy}{K\ energy}$**

Code : 1D sphere symmetrical SRMHD
・2^{nd} order MUSCL-TVD (minmod flux limiter)
・2^{nd} order Runge-Kutta
・Local Lax-Friedrichs (or CENTRAL scheme)
・500,000 static grids ← due to high sigma, γ
・MPI parallelized (1000 cores, 1 day)



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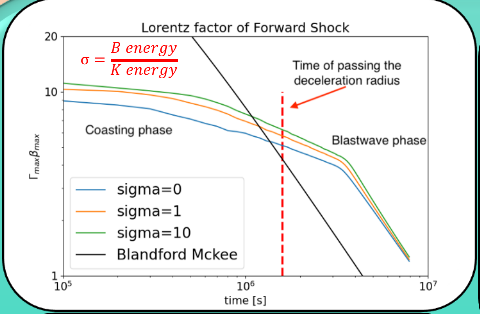

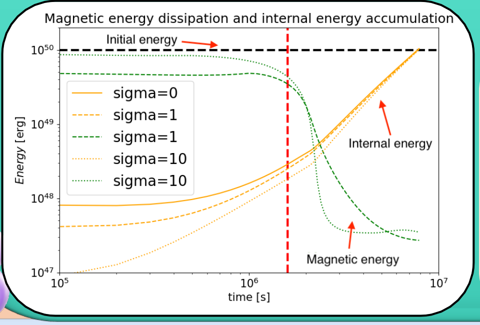

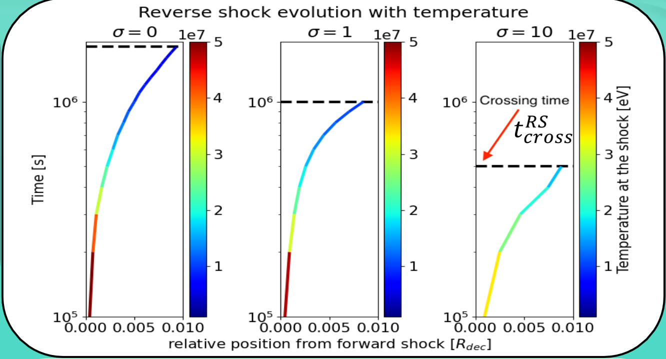

Key features from these results
・FS seems independent of initial sigma value.
・FS is asymptotic to Blandford Mckee phase.
・RS crossing time shorten as sigma increases.
・RS temperature goes down as it propagates.
・Magnetic energy is converted to kinetic one.
・Kinetic energy dissipates to be internal one.

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Q1. Does magnetization affect shock behavior?

・RS crossing time is significantly affected as σ : large → t_{cross}^{RS} : small.
・FS indeed depends only weakly on initial magnetization sigma value.

$\sigma=\frac{B\ energy}{K\ energy}$

Q2. Can initial jet energy dissipate to internal one?

・Magnetic energy is dissipated to kinetic one after passing deceleration radius.
・Kinetic energy is fully dissipated to internal energy by RS and FS (dominated).

Problem and Future work

・Find exact reason why magnetic energy suddenly drops for magnetized jet.
・Introduce an adaptive mesh refinement (AMR) to achieve ultra high resolution.