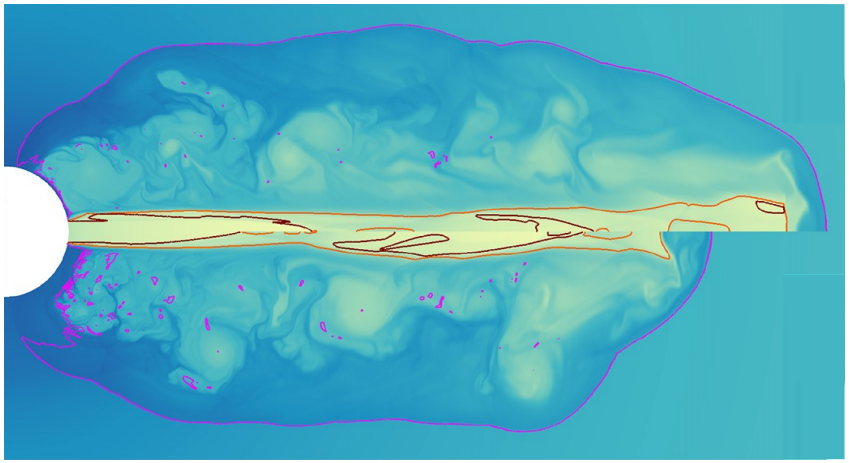
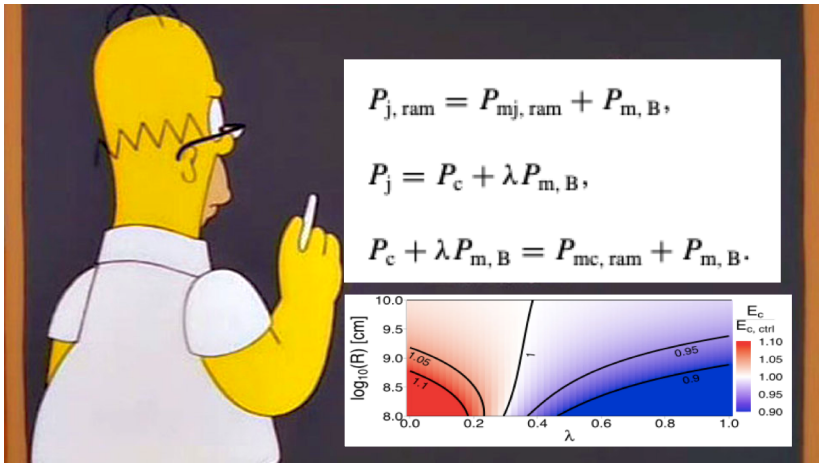
Magnetized medium effects in SGRBs





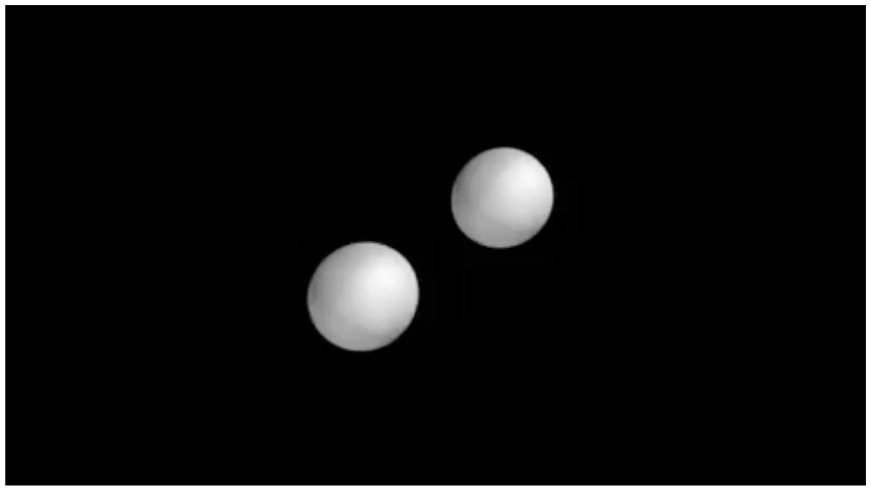
Diego López-Cámara (ICN-UNAM)

+ Leonardo **Garcia-Garcia** (IA-UNAM), Davide **Lazzati** (OSU)

(García-Garcia et al. 2023, 2024)

SGRBs (basics)…

(Ciolfi, et al. 2017)



Medium:

$\rho \sim 10^{10-14}\ g\ cm^{-3}$

$B \sim 10^{12-15}\ G$

(Paczynski 1986; Eichler et al. 1989; Ciolfi et al. 2017)

Jet:

$L_{iso} \sim 10^{49-52}\ \mathrm{erg\ s^{-1}}$

(Ghirlanda et al. 2009, Berger 2013)

$T_{90} < 2\ s$

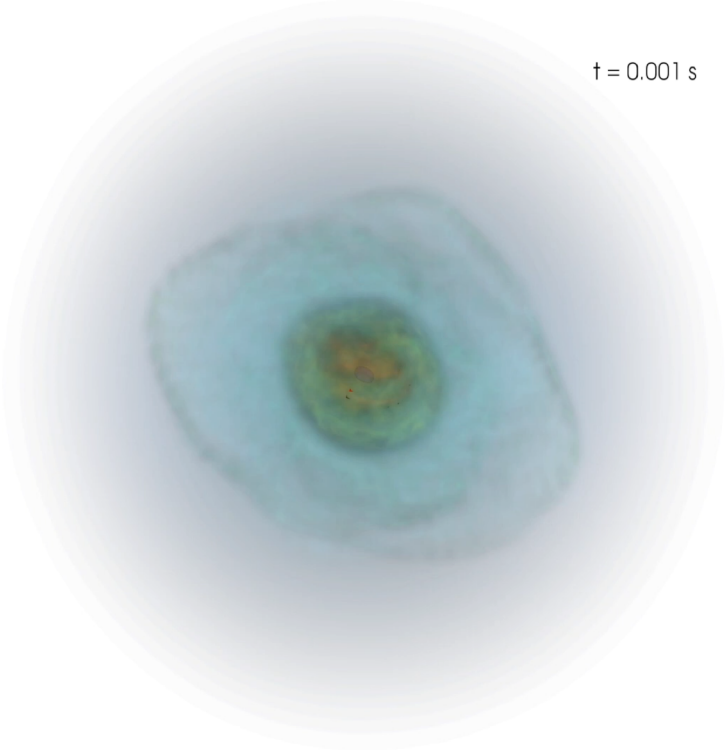
(Kouveliotou et. al. 1993)

$\Gamma_0 \sim 5\ (\Gamma_\infty \sim 400)$

(Piran 1999, Ghirlanda et al. 2018)

$\theta_j \sim 5^\circ - 15^\circ$

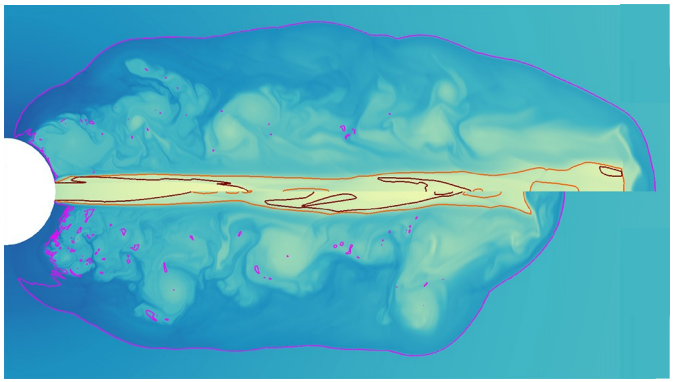
(Fong et al. 2015)



(Lazzati, et al. 2017)

B_m in SGRBs (sims)…

Propagation of a SGRB-jet through a $\rho \uparrow\uparrow$ and $B \uparrow\uparrow$ media



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **519,** 4454–4460 (2023) https://doi.org/10.1093/mnras/stad023
Advance Access publication 2023 January 06

Dynamics of a relativistic jet through magnetized media

Leonardo García-García [1]★ Diego López-Cámara [2]★ and Davide Lazzati [3]

[1] *Instituto de Astronomía, Universidad Nacional Autónoma de México, 04510 Ciudad de México, CDMX, México*
[2] *Instituto de Astronomía, Cátedras CONACyT – Universidad Nacional Autónoma de México, AP 70-264, CDMX 04510, México*
[3] *Department of Physics, Oregon State University, 301 Weniger Hall, Corvallis, OR 97331, USA*

Magnetized medium (static)

Relativistic and collimated jet (non magnetized)

2.5 RMHD simulations

B_m in SGRBs (sims setup)…

Medium:

$\rho \propto R^{-3}$

$B \propto R^{-1.5}$

(Ciolfi et al. 2017-ish)

Jet:

$L_j \sim 10^{50}\ erg\ s^{-1}$

$\Gamma_0 = 5$

$\theta_j = 10^{\circ}$

$d_{co} = 200\ km$

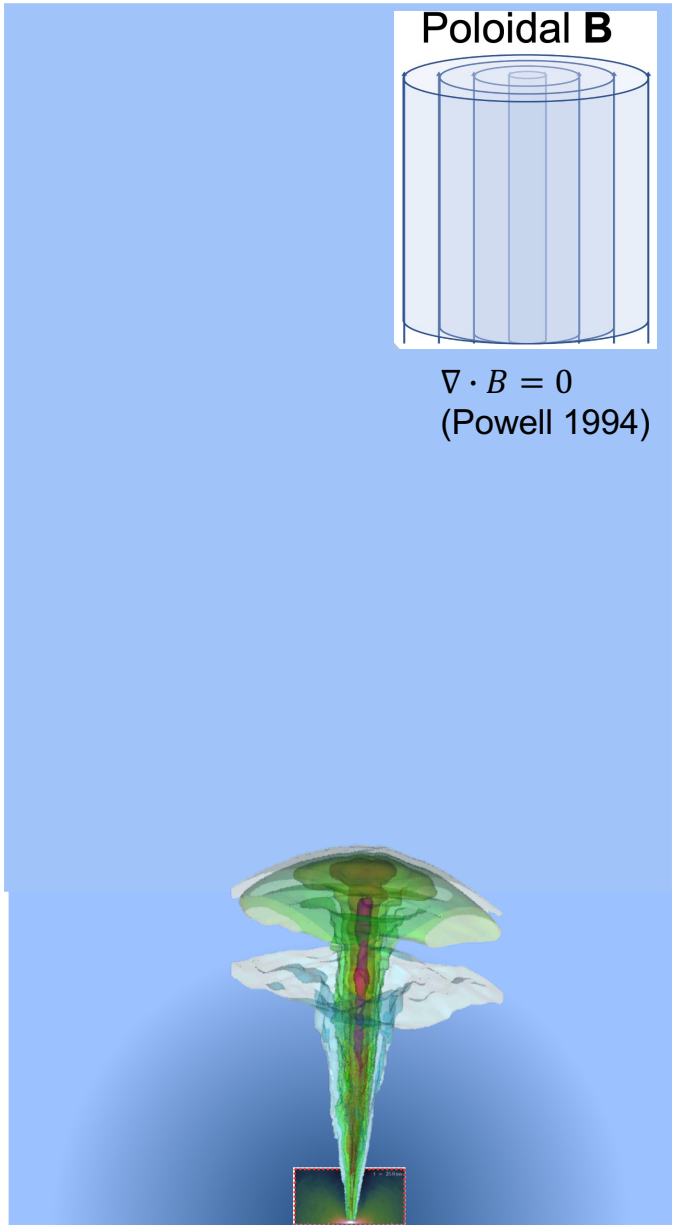
PLUTO code

(Migone et al 2007)

(12 RMHD models)

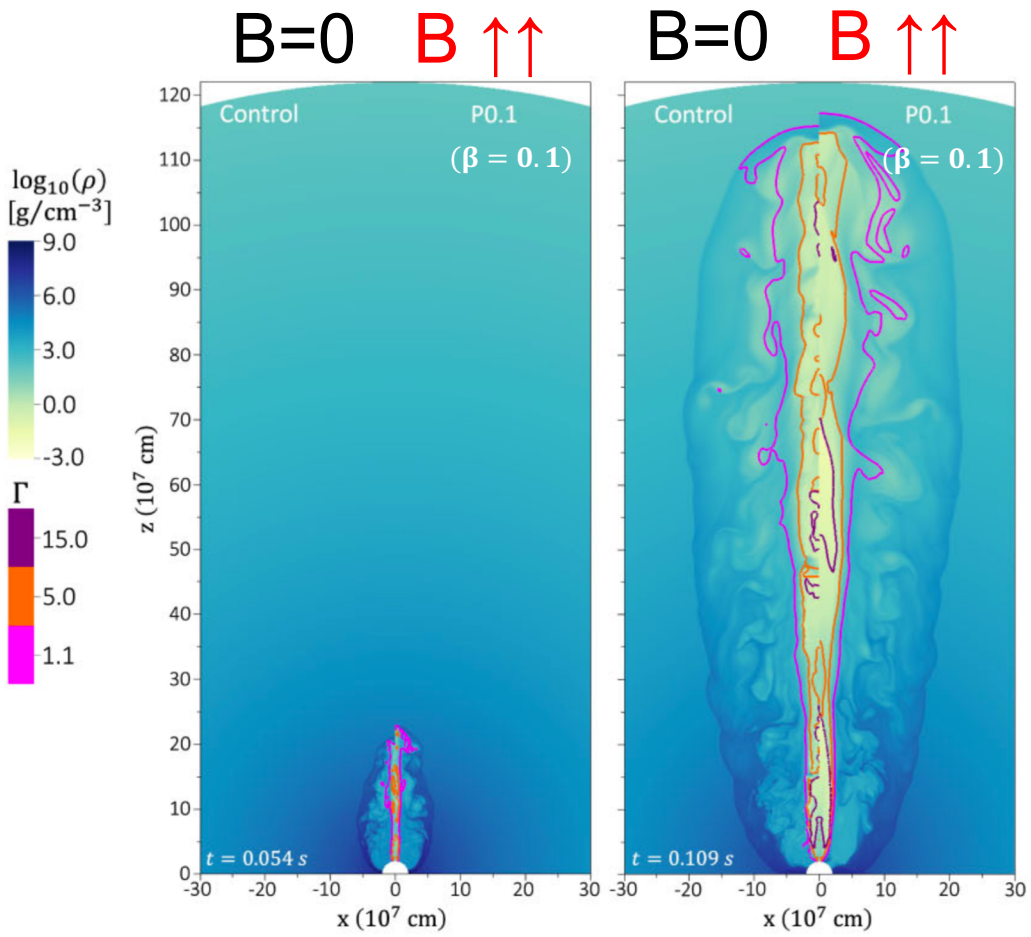
$(\beta = P_g/P_B)$

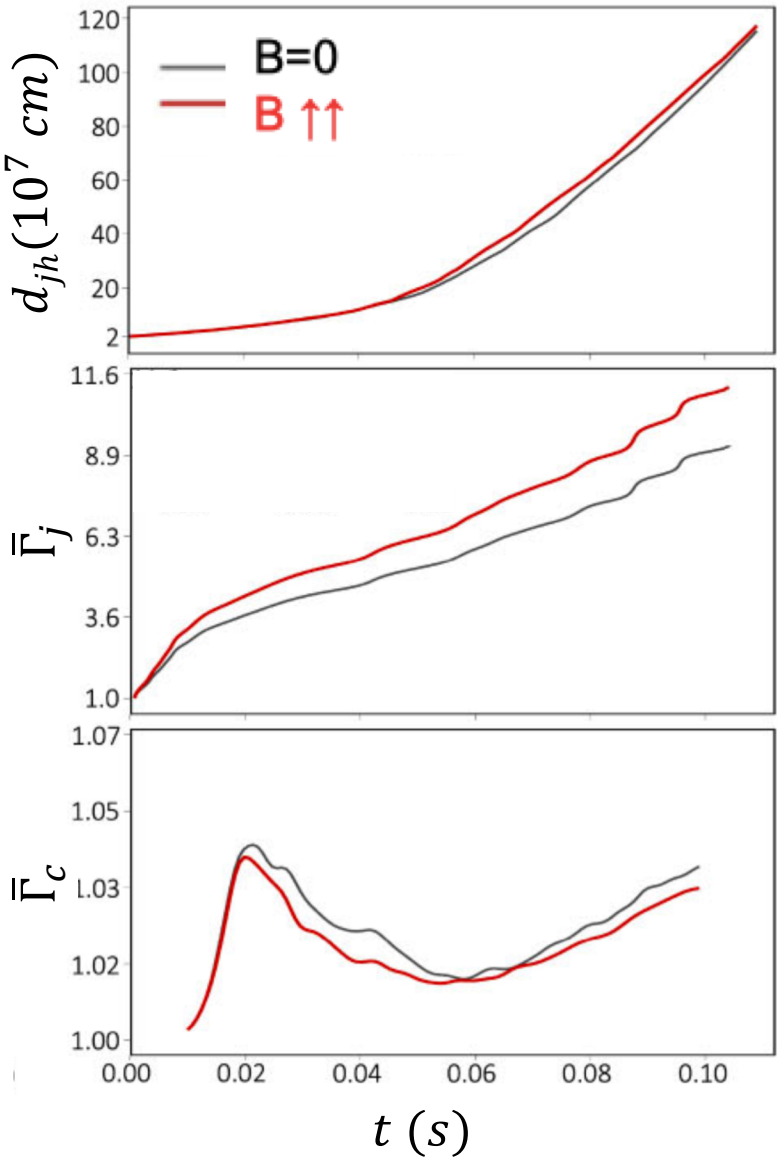
Name	β_m	Resolution
Control	∞	LR, MR, SR, and HR
P0.1	0.1	SR
P0.5	0.5	SR
P1.0	1.0	SR
P5.0	5.0	SR
P20	10	SR
P25	25	SR
P50	50	SR
P75	75	SR
P100	100	SR
P500	500	SR
P1e4	10^4	SR



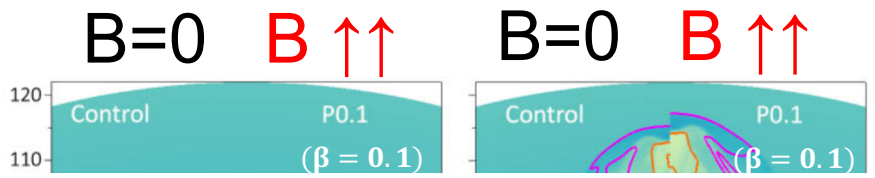
$\nabla \cdot B = 0$
(Powell 1994)

B_m in SGRBs (sims results I)…

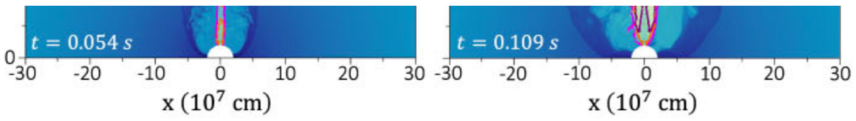


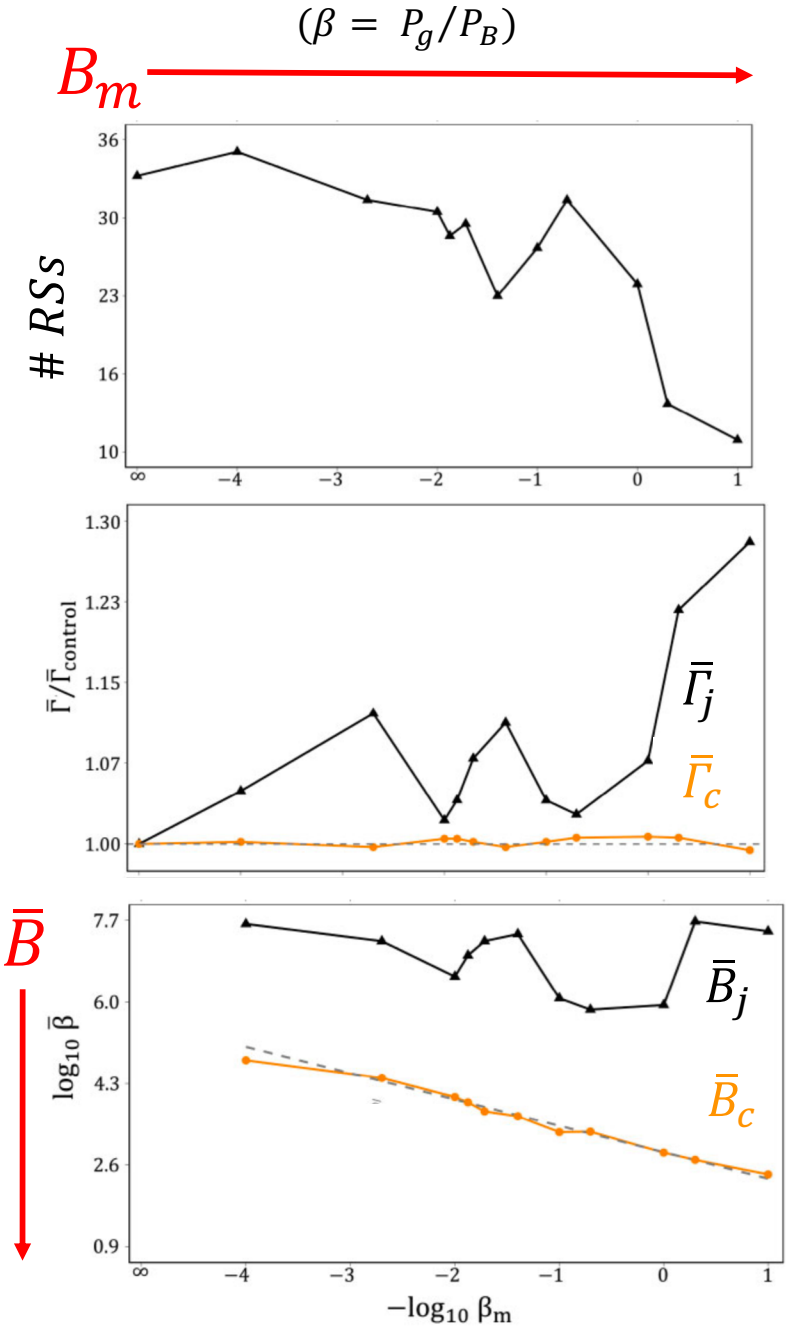


B_m in SGRBs (sims results II)…



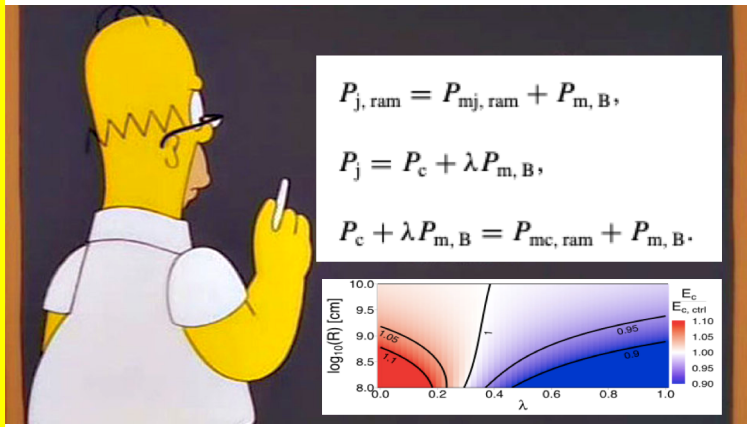
Name	β_m	Resolution
Control	∞	LR, MR, SR, and HR
P0.1	0.1	SR
P0.5	0.5	SR
P1.0	1.0	SR
P5.0	5.0	SR
P20	10	SR
P25	25	SR
P50	50	SR
P75	75	SR
P100	100	SR
P500	500	SR
P1e4	10^4	SR





B_m in SGRBs (analytic)…

Propagation of a SGRB-jet through a $\rho \uparrow\uparrow$ and $B \uparrow\uparrow$ media



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **531,** 2903–2911 (2024) https://doi.org/10.1093/mnras/stae1348
Advance Access publication 2024 May 27

A semi-analytical model for the propagation of a relativistic jet in a magnetized medium

Leonardo García-García [1]★ Diego López-Cámara [2] and Davide Lazzati [3]
[1]*Instituto de Astronomía, Universidad Nacional Autónoma de México, 04510, Ciudad de México, CDMX, México*
[2]*Investigador por México, CONAHCyT – Universidad Nacional Autónoma de México, Instituto de Astronomía, AP 70-264, CDMX 04510, México*
[3]*Department of Physics, Oregon State University, 301 Weniger Hall, Corvallis, OR 97331, USA*

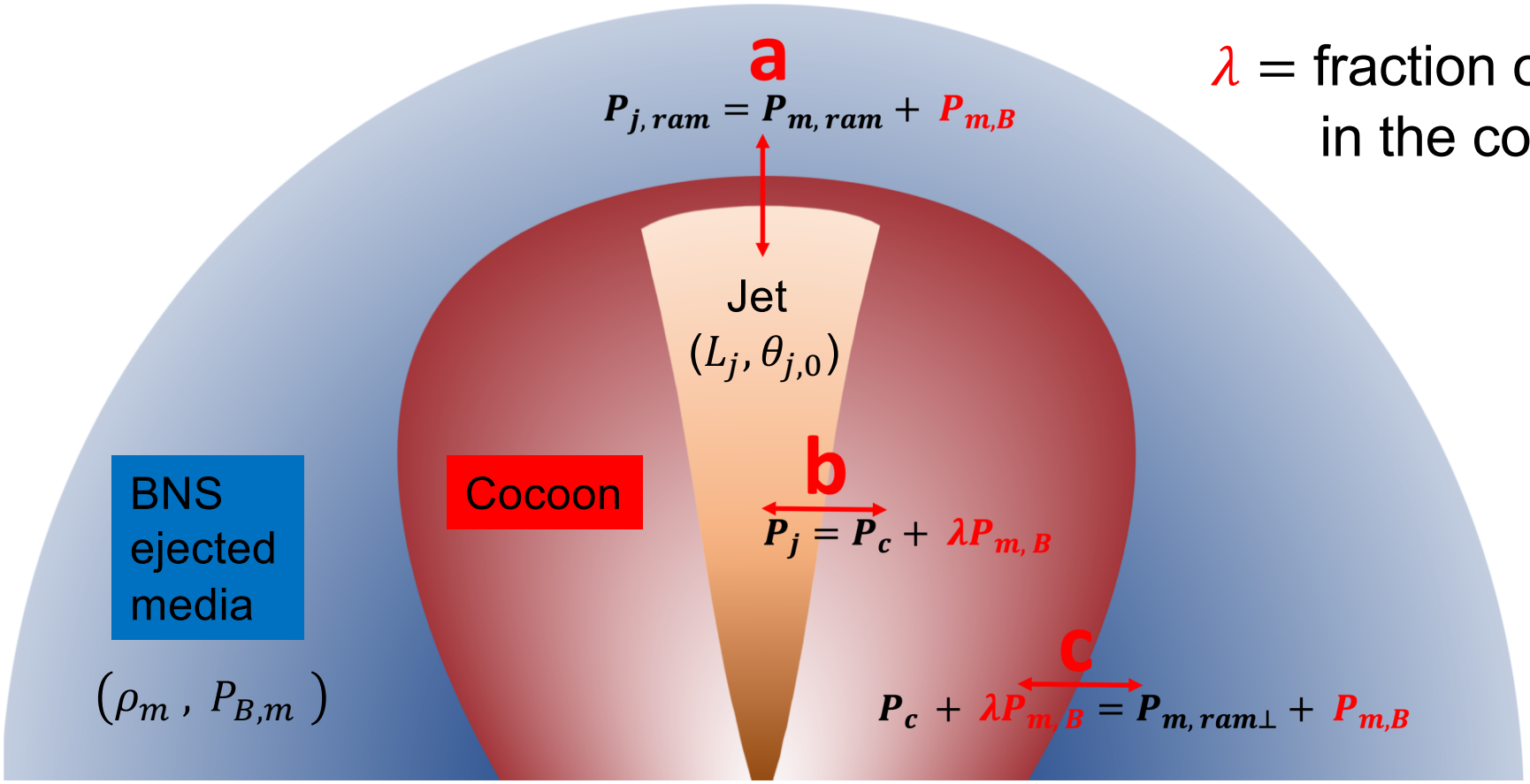
Based on Lazzati & Perna (2019): SGRB though a non-B medium.

Based on pressure balances between: jet, cocoon, and medium.

Static medium with a poloidal B field.

B_m in SGRBs (analytic setup)…

v_{jh} , θ_j , θ_c , E_c ?



λ = fraction of $P_{m,B}$ in the cocoon

$\rho_m \propto r^{-n}$

(we use $n = 3$)

$B_m \propto r^{-q}$

(we use $q = 1.5$)

(static)

B_m in SGRBs (analytic results I)…

$$v_{jh}\ ,\ \theta_j\ ,\ \theta_c\ ,\ E_c\ ?$$

$$v_{jh} = c\left(\frac{1-\sqrt{1-\left(1-\frac{\rho_m c^3 r^2 \Omega_j}{L_j}\right)\left(1-\frac{P_{m,B}\Omega_j c}{L_j}\right)}}{1-\frac{\rho_m c^3 r^2 \Omega_j}{L_j}}\right) \qquad \text{with } P_{B,m}=\frac{B^2}{8\pi}$$

$$\theta_j = acos\left(1-\frac{3\pi P'_B L_j sin^2\theta_{j,in}}{4c\left[2L_j\rho_m v_{jh}+3\lambda\pi r^2 P_{m,B}P'_B\right]}\right)$$

$$\theta_c = acos\left(1-\frac{\pi P'_B}{2\rho_m v_{jh}^2}\right) \qquad \text{with } P'_B = P_{m,B}(1-\lambda)+\left[\left(P_{m,B}(1-\lambda)\right)^2+\frac{4\rho_m L_j v_{jh}}{3\pi r^2}\right]^{1/2}$$

$$E_c = L_j\left(t-\frac{r_{jh}}{c}\right)$$

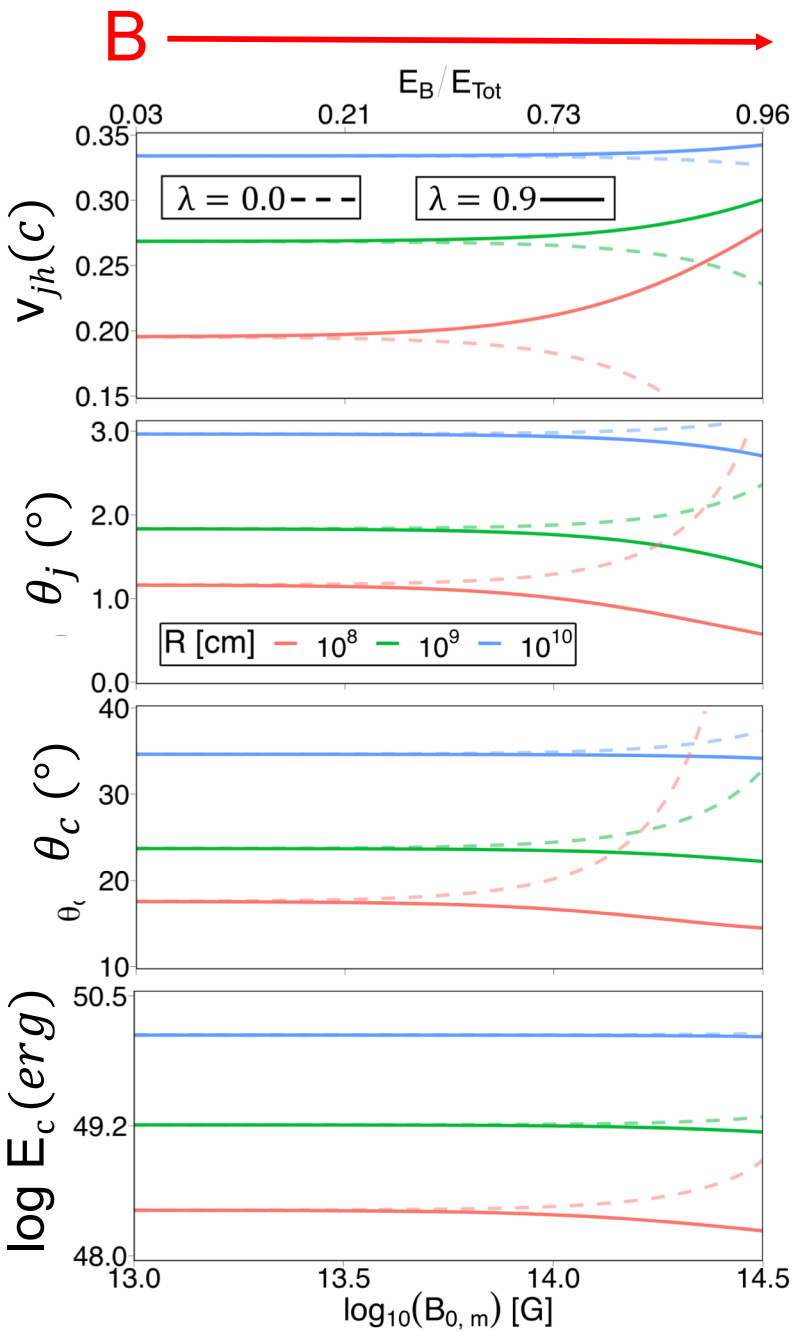
B_m in SGRBs (analytic results II)…

$$v_{jh} = v_{jh}(B, \lambda)$$

$$\theta_j = \theta_j(B, \lambda)$$

$$\theta_c = \theta_c(B, \lambda)$$

$$E_c = E_c(B, \lambda)$$



Medium

(Ciolfi et al. 2017-ish, GG23)

$$\rho_m \propto R^{-3}$$

$$B_m \propto R^{-1.5}$$

Jet

(SGRB-ish, GG23)

$$L_j = 10^{50}\ erg\ s^{-1}$$

$$\Gamma_j \sim 5$$

$$\theta_j \sim 10^{\circ}$$

B_m in SGRBs (analytic results II)…

(more…)

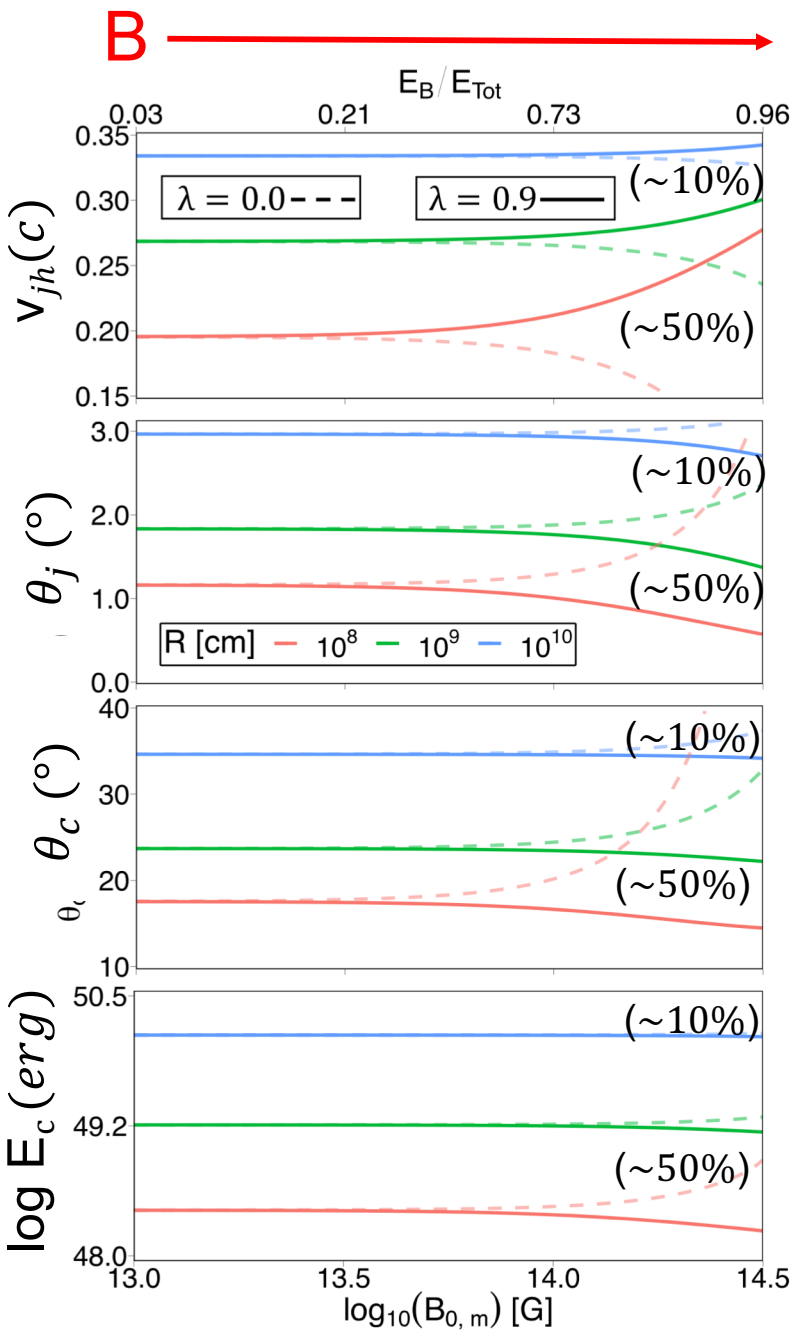
What λ?

$v_{jh} = v_{jh}(B, \lambda)$

$\theta_j = \theta_j(B, \lambda)$

$\theta_c = \theta_c(B, \lambda)$

$E_c = E_c(B, \lambda)$



$\lambda = 0.9 + B_m \Rightarrow v_{jh} \uparrow$

$\lambda = 0.0 + B_m \Rightarrow v_{jh} \downarrow$

$\lambda = 0.9 + B_m \Rightarrow \theta_j \downarrow$

$\lambda = 0.0 + B_m \Rightarrow \theta_j \uparrow$

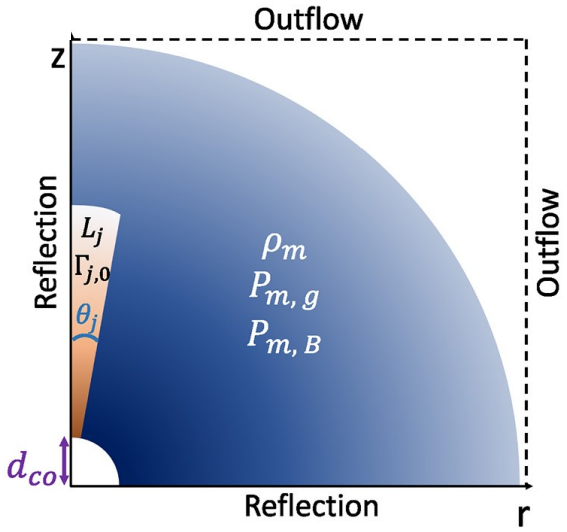
$\lambda = 0.9 + B_m \Rightarrow \theta_c \downarrow$

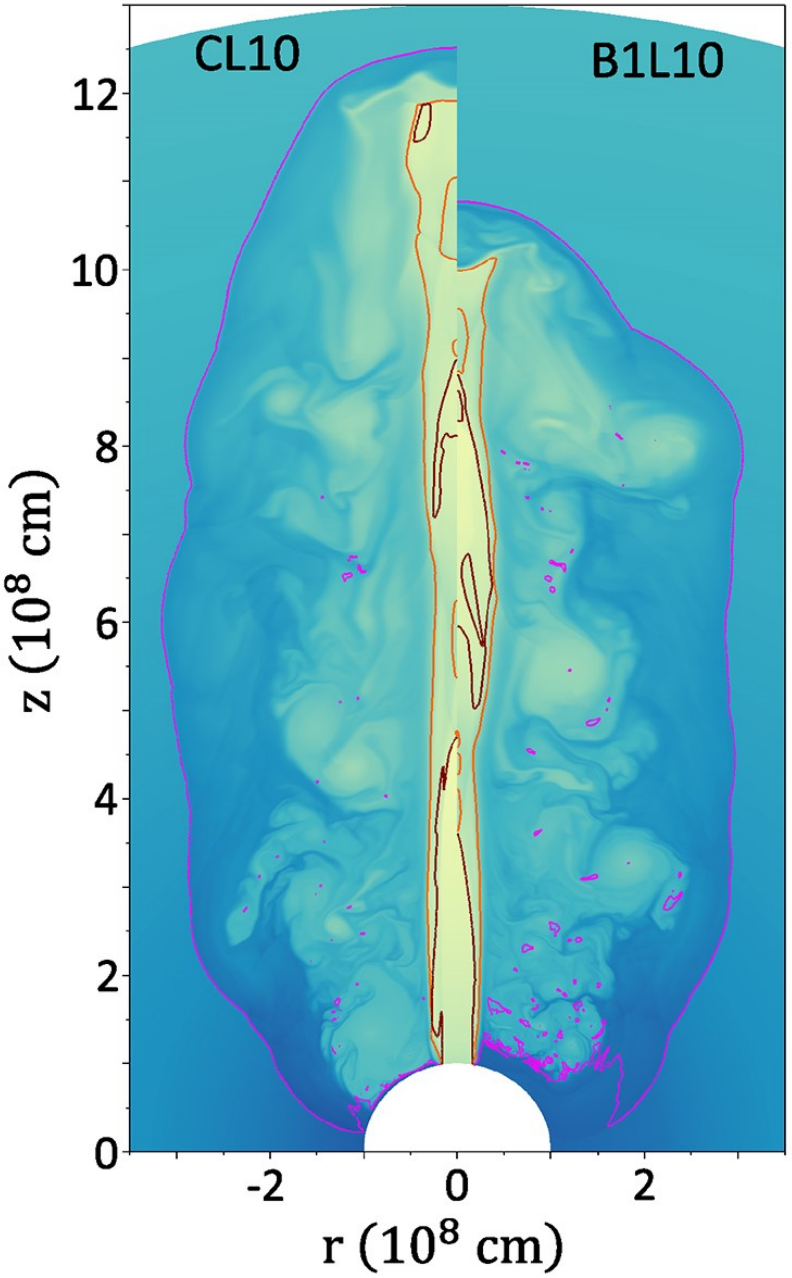
$\lambda = 0.0 + B_m \Rightarrow \theta_c \uparrow$

$\lambda = 0.9 + B_m \Rightarrow E_c \downarrow$

$\lambda = 0.0 + B_m \Rightarrow E_c \uparrow$

B_m in SGRBs (analytic results IV)…





2D RHD simulations.

Pluto RMHD code (Mignone et al. 2012).

Only the $P_{m.B}$ and not its geometry

B_m in SGRBs (analytic results V)…

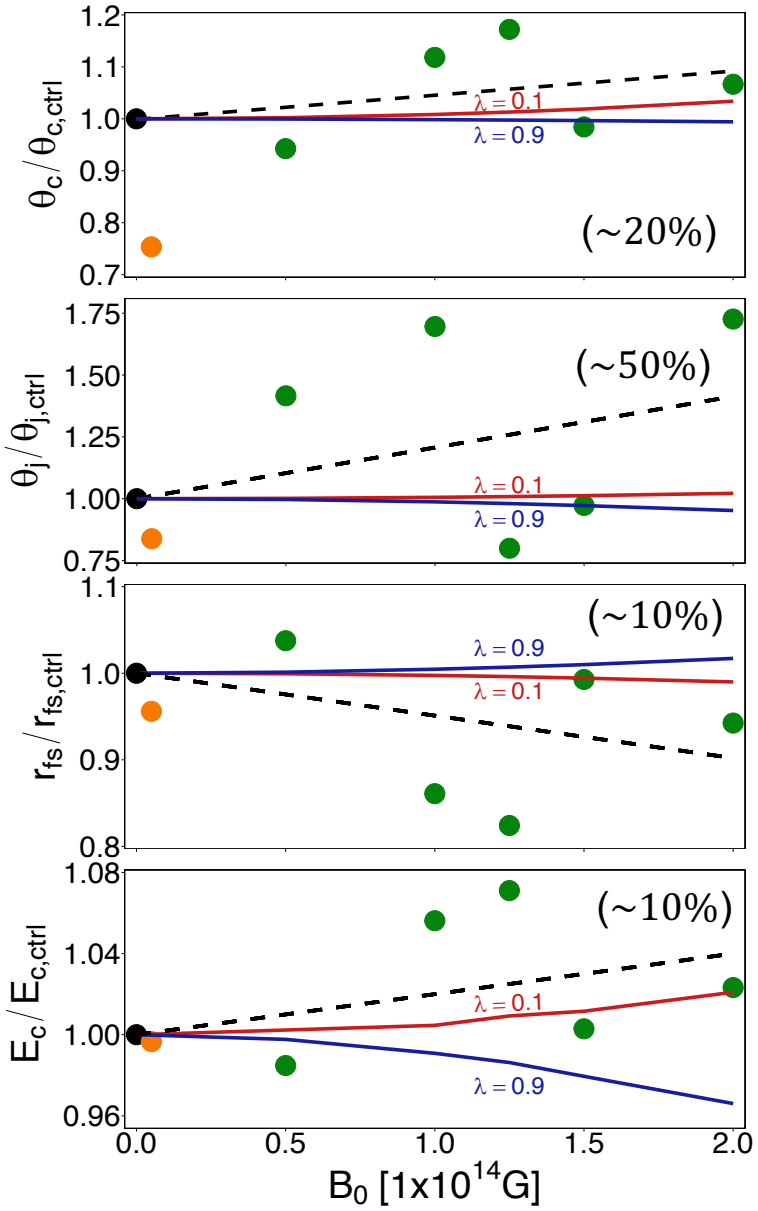
Simulations: dots

Trend-line: black dashed

Analytic: red/blue line

$\lambda \sim 0.1$

Extra:
GG2023 with poloidal $\boldsymbol{B}$ shows good agreement with our results.



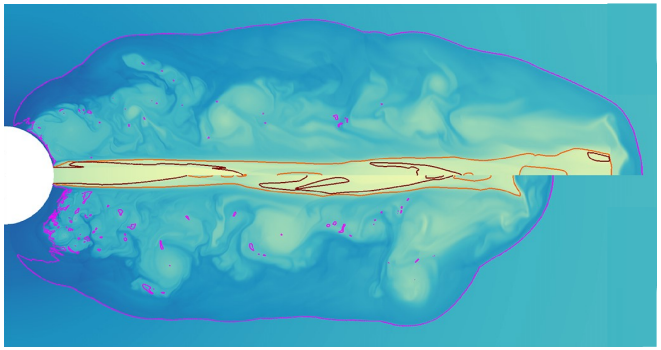
Sims trendline:
$\uparrow B_m \Rightarrow \theta_c \uparrow$

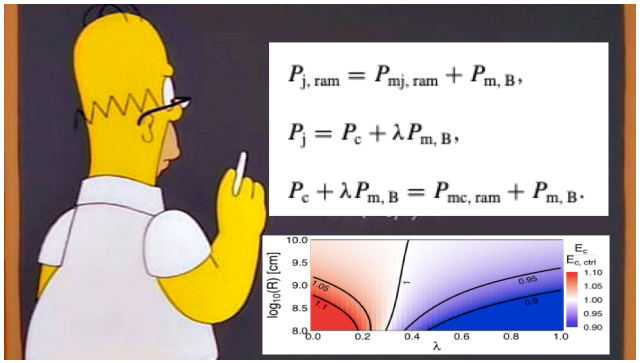
Sims trendline:
$\uparrow B_m \Rightarrow \theta_j \uparrow$

Sims trendline:
$\uparrow B_m \Rightarrow RSs \downarrow$

Sims trendline:
$\uparrow B_m \Rightarrow E_c \uparrow$

Summary…

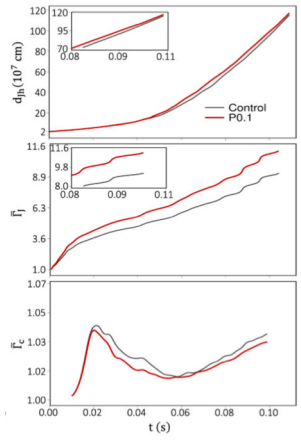


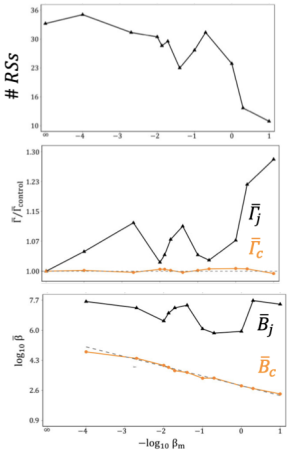


2.5D RMHD simulations:

B_m affects the SGRB

Recollimation shocks diminish

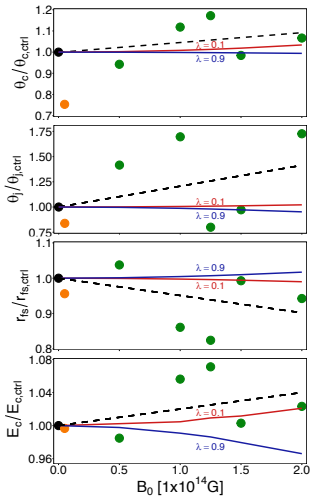


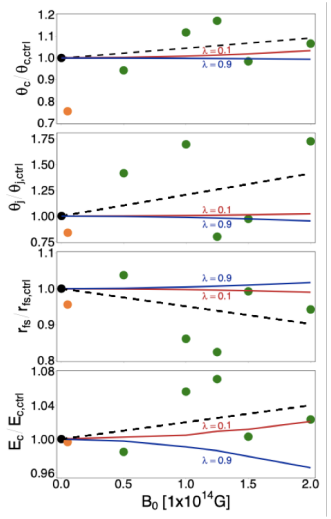


Analytic model:

B_m and λ affect the SGRB

$\lambda \sim 0.1$





Thanks

Gracias

(see you here again in X years?)