Relativistic Gas Dynamics & Turbulence

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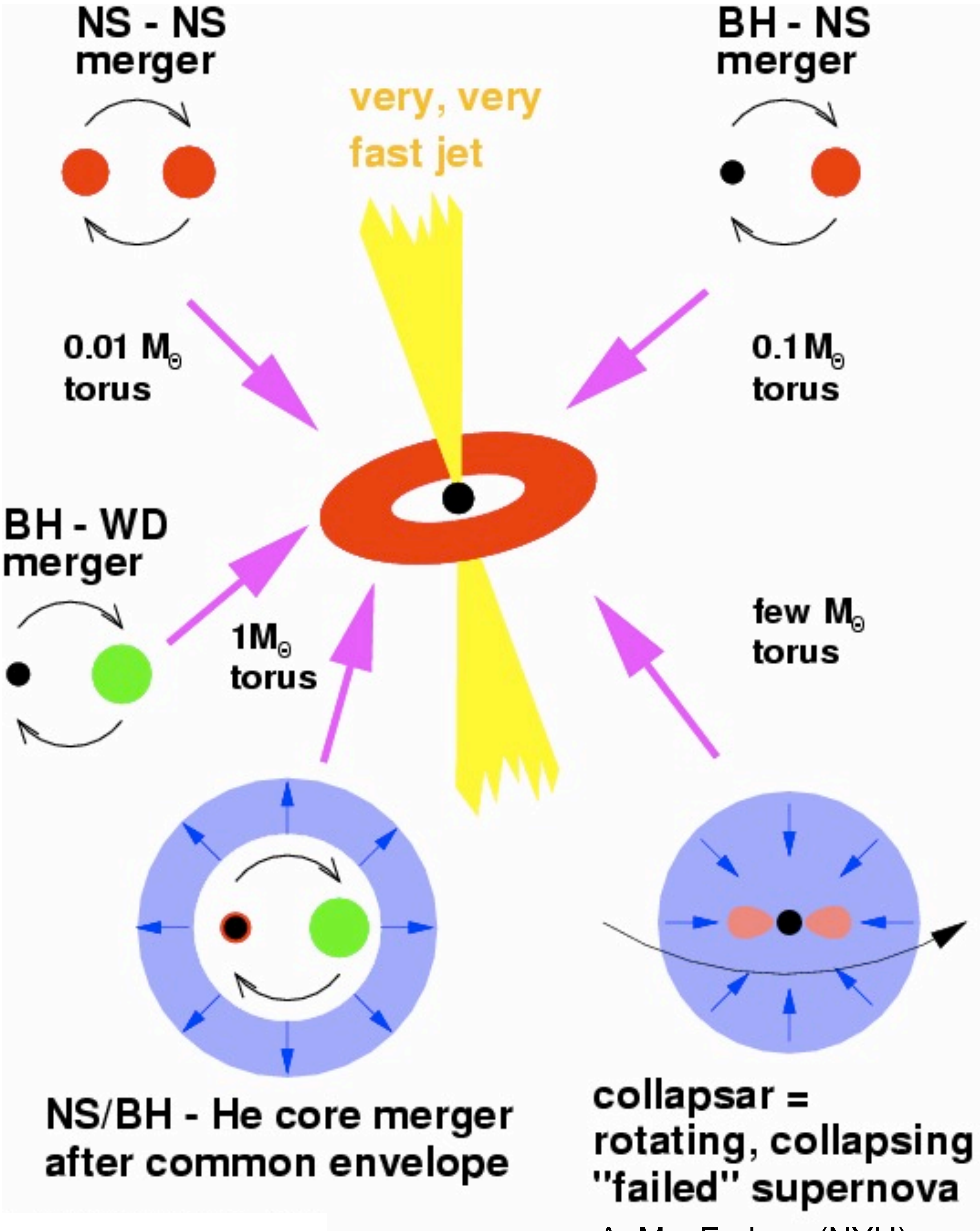
w/ Paul Duffel, Jonathan Zrake & Hendrik van Eerten

The Future

- Training for Students!!!
- Robust Codes
- High-Order Codes
- Novel Approaches
- Data for Observers

Hyper-accreting black hole or ms magnetar



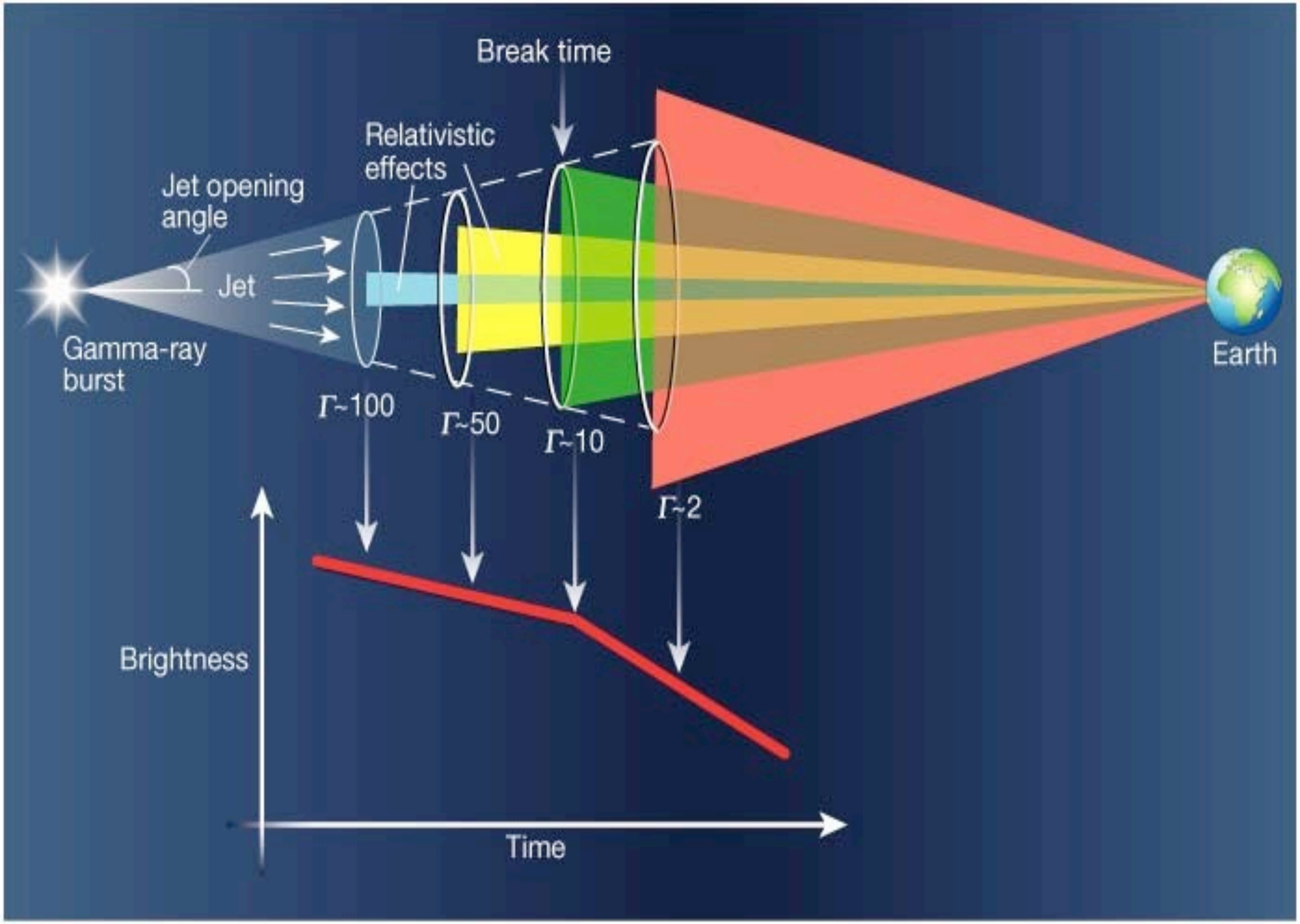
GRB photons are made far away from engine.

Can't observe engine directly with light. (neutrinos, gravitational waves?)

Electromagnetic process or neutrino annihilation to tap power of central compact object.

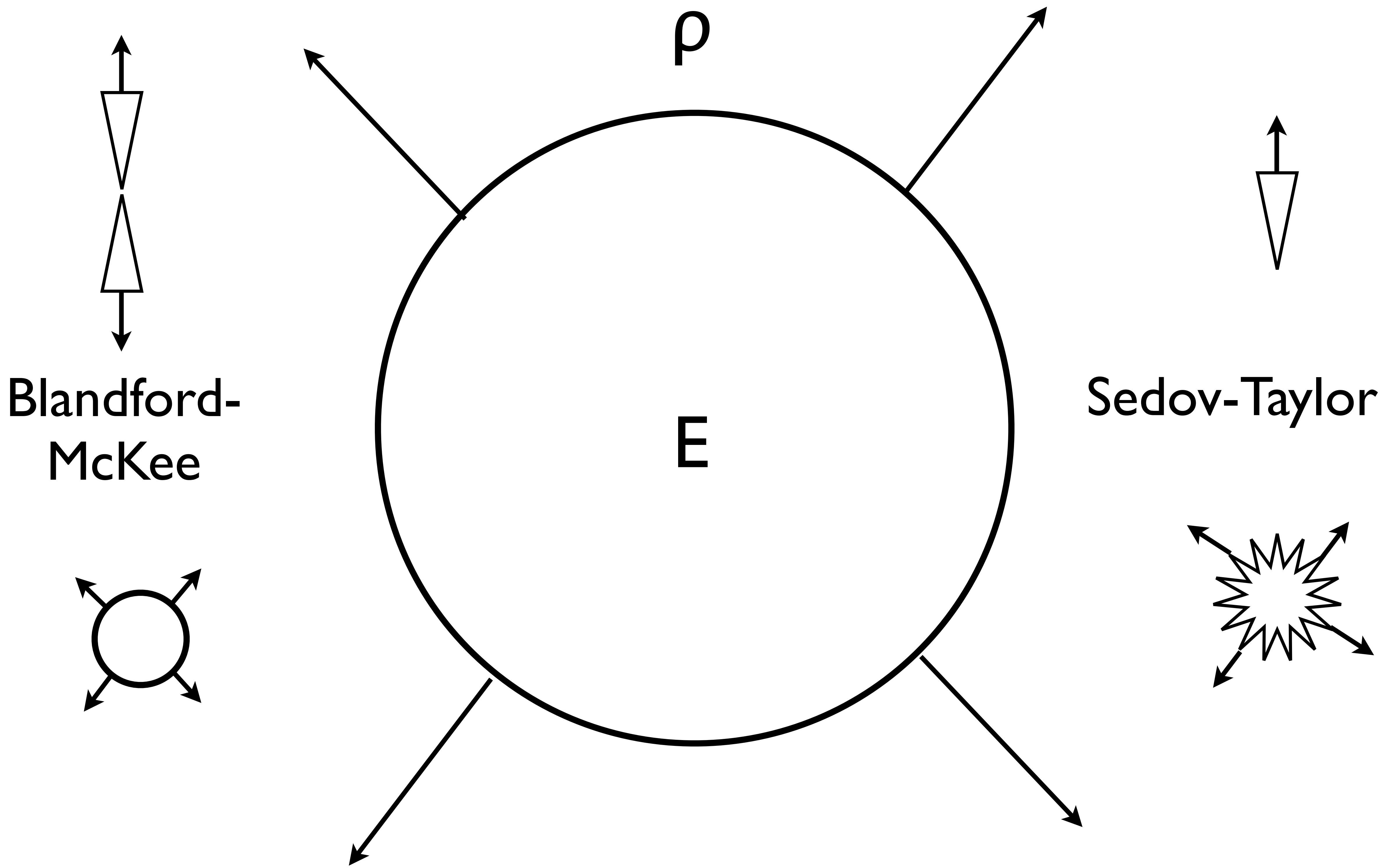
AstroComputing, SDSC

GAMMA RAY BURST AFTERGLOWS



Need $\varepsilon_B \sim 0.001$ for synchrotron

Spherical Attractor

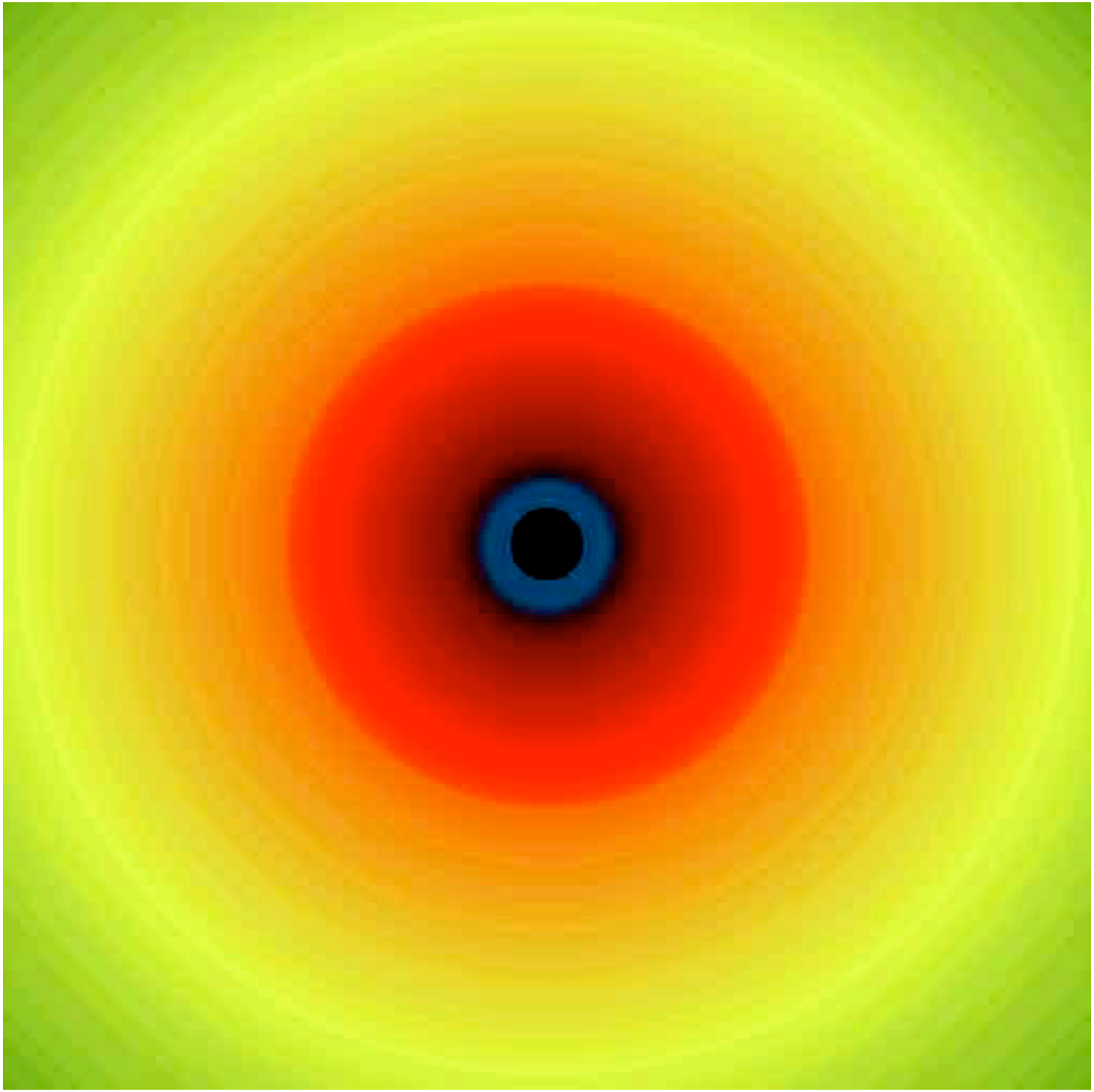


RAM: 5th order accuracy WENO w/ AMR

Method	N	L1 Error	Convergence Rate
F-WENO-RK5	80	1.87e-3	
	160	1.17e-4	4.0
	320	1.30e-5	3.2
	640	6.82e-7	4.3
	1280	2.54e-8	4.7
	2560	8.01e-10	5.0
	5120	2.40e-11	5.1
U-PPM-RK4	80	1.10e-2	
	160	2.56e-3	2.1
	320	5.74e-4	2.2
	640	1.34e-4	2.1
	1280	3.10e-5	2.1
	2560	7.33e-6	2.1
	5120	1.82e-6	2.1

AMR
jet
+wind

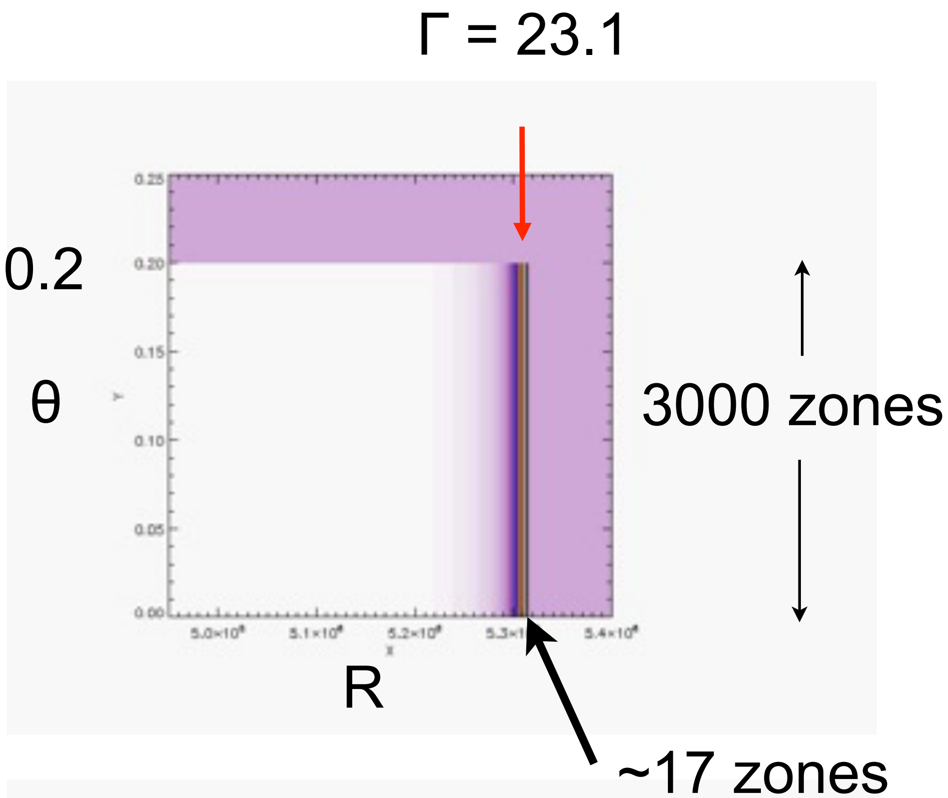
AM&Zhang
(2009)

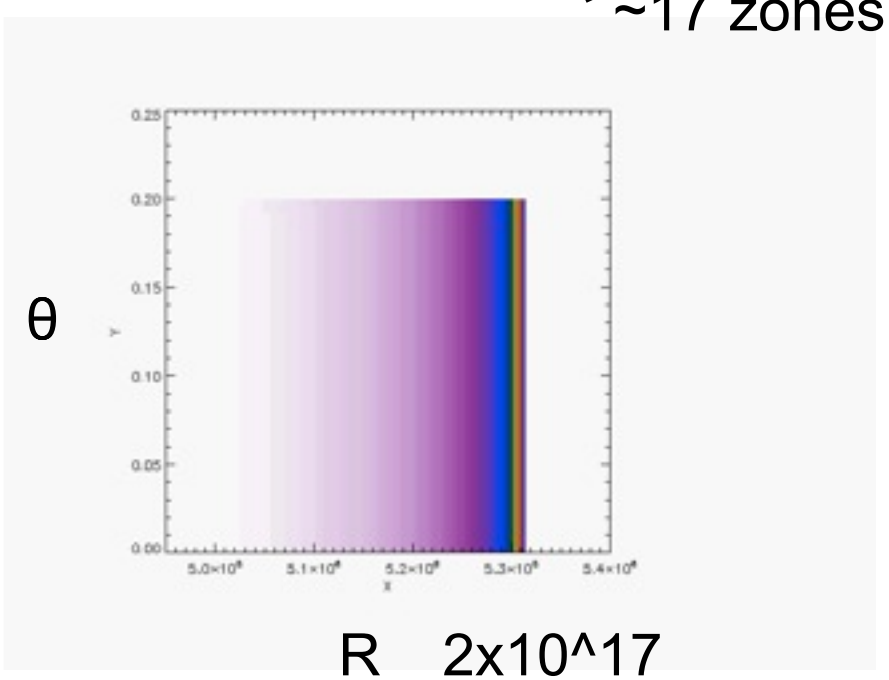


AMR
jet
+wind

AM&Zhang
(2009)

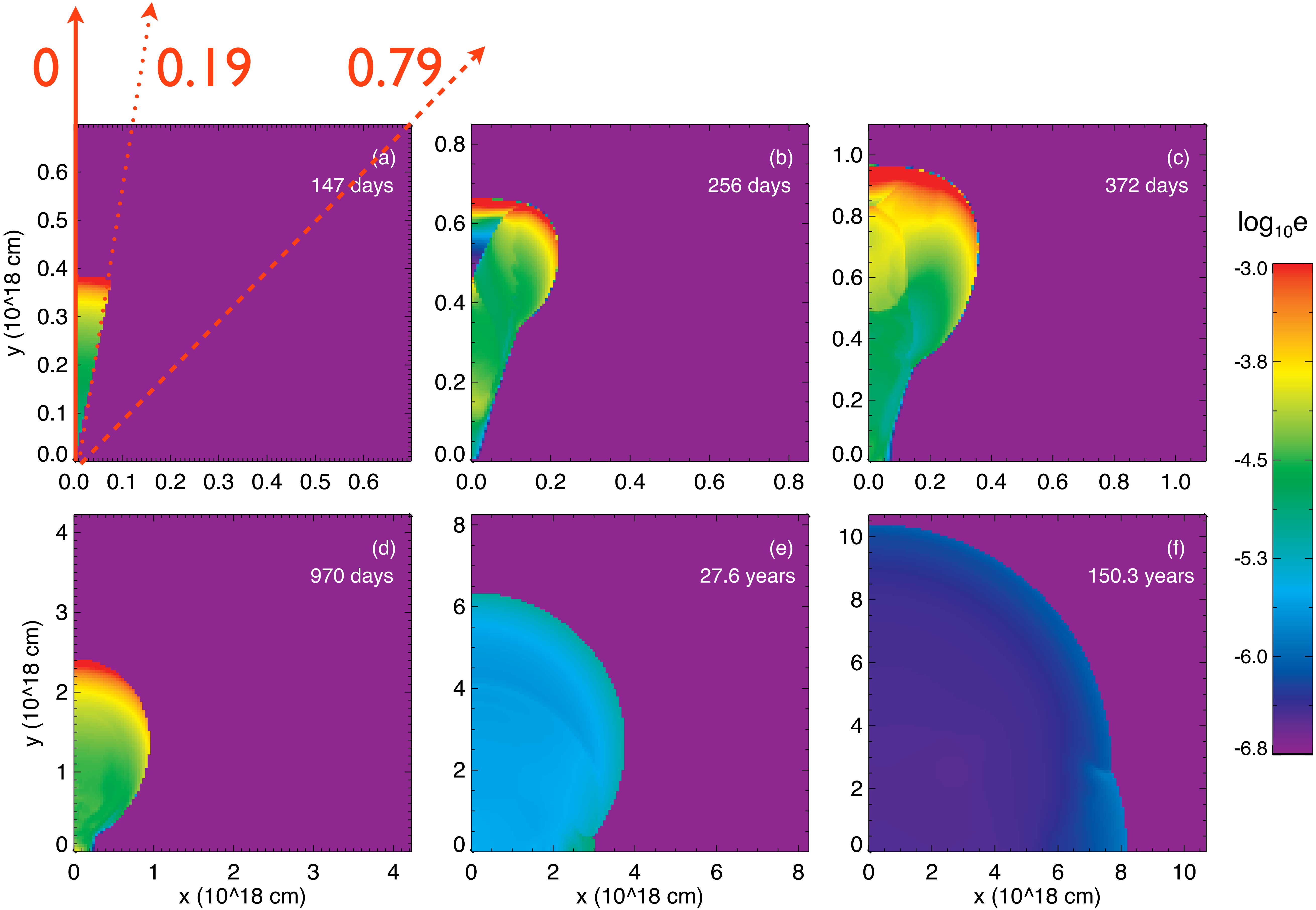
AG Jet Initial Conditions





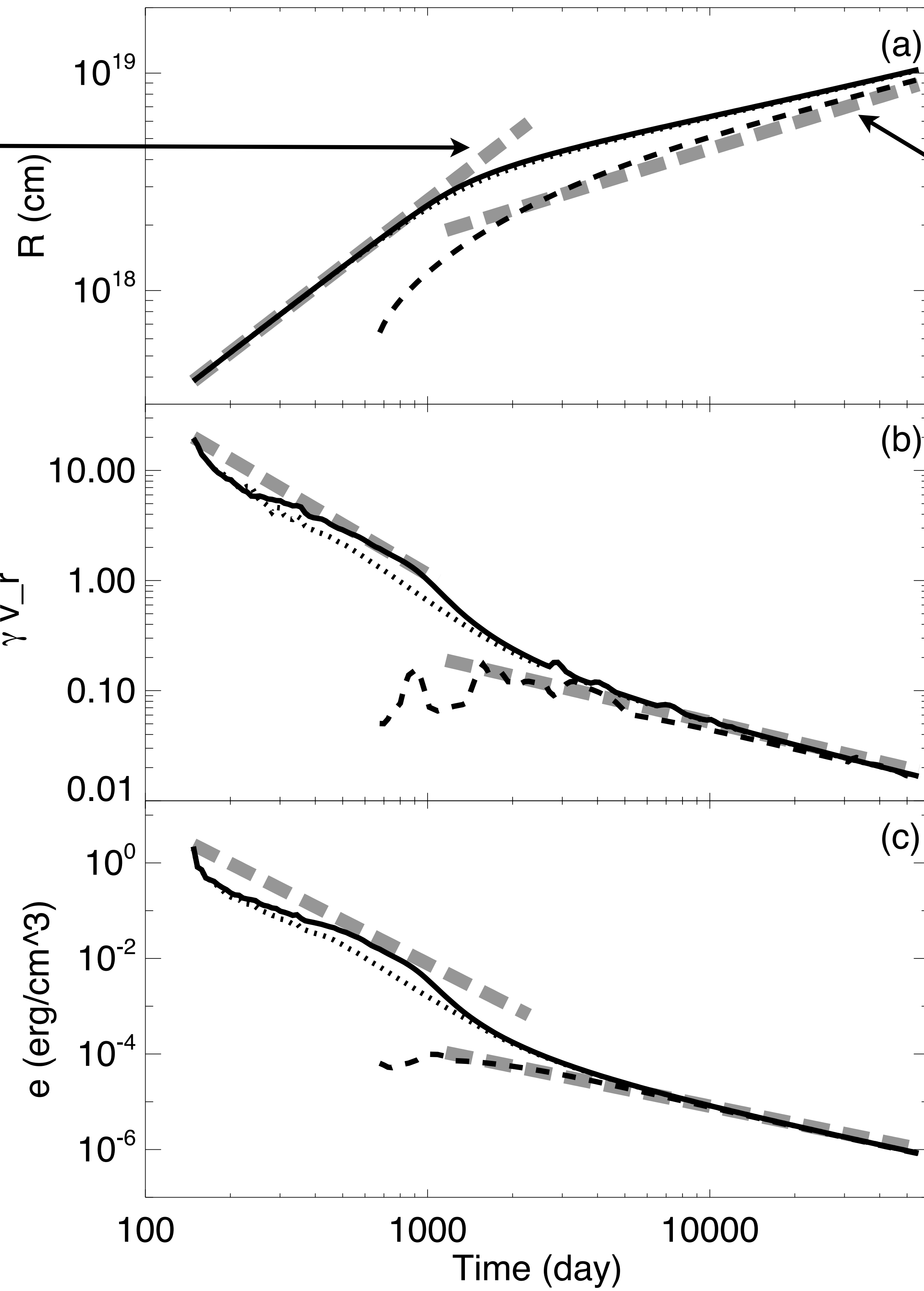
- Blandford-McKee
- E_{iso} = 1e53 erg
- n_o = $1cm^{-3}$
- Γ = 23.1
- Θ_{jet} = 0.2

- Spherical Coords
- 16 levels of AMR
- R_o = 1.59e17 cm
- R/ΔR = 196608
- 4e10 zone equiv.



0
0.19
0.79
(a)
147 days
(b)
256 days
(c)
372 days
(d)
970 days
(e)
27.6 years
(f)
150.3 years
$\log_{10}e$
-3.0
-3.8
-4.5
-5.3
-6.0
-6.8
y (10^18 cm)
x (10^18 cm)

Blandford-McKee

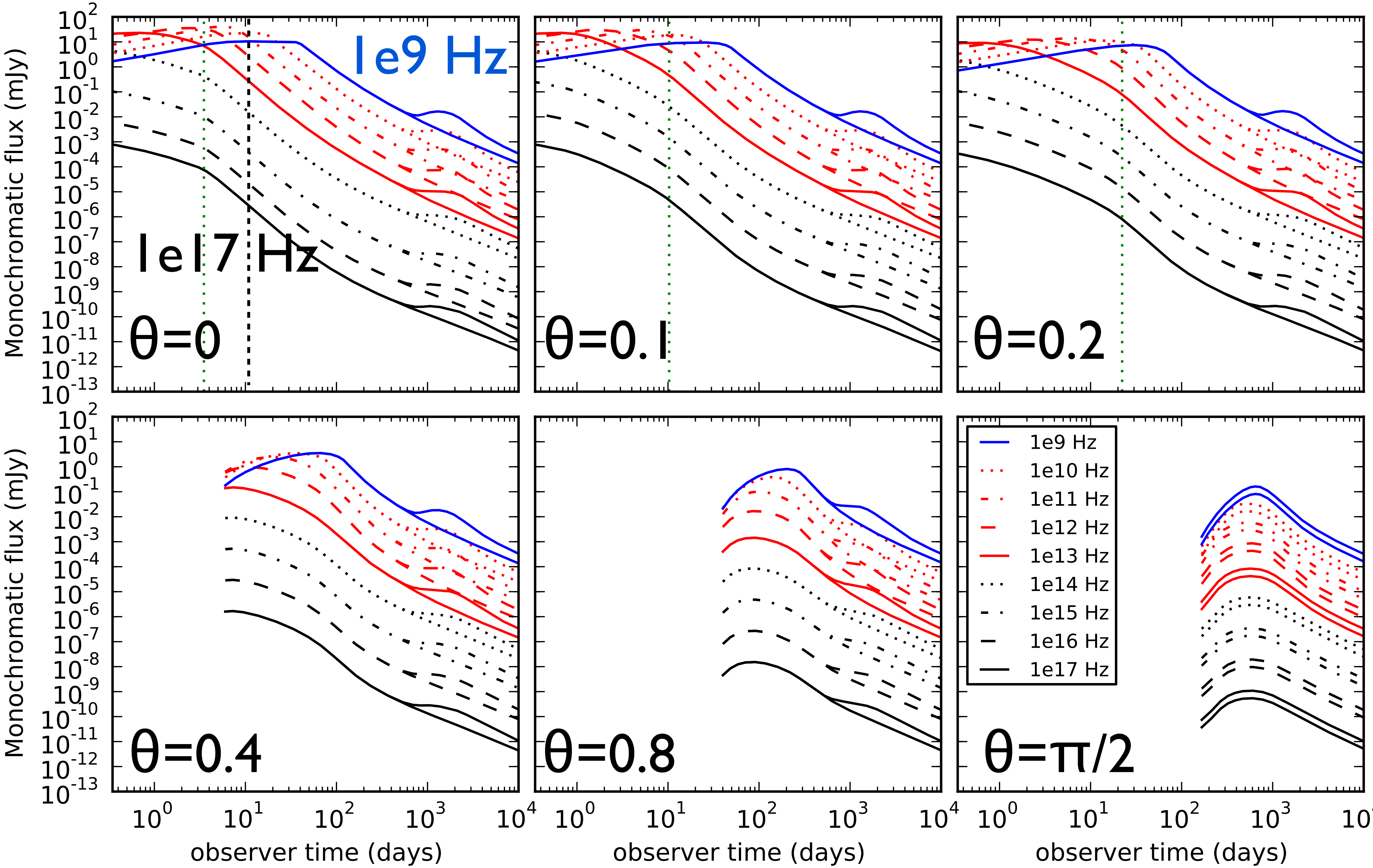


Sedov

θ = 0,0.19,π/4

Off-Axis Light Curves

van Eerten, Zhang & AM (ApJ, 2010)

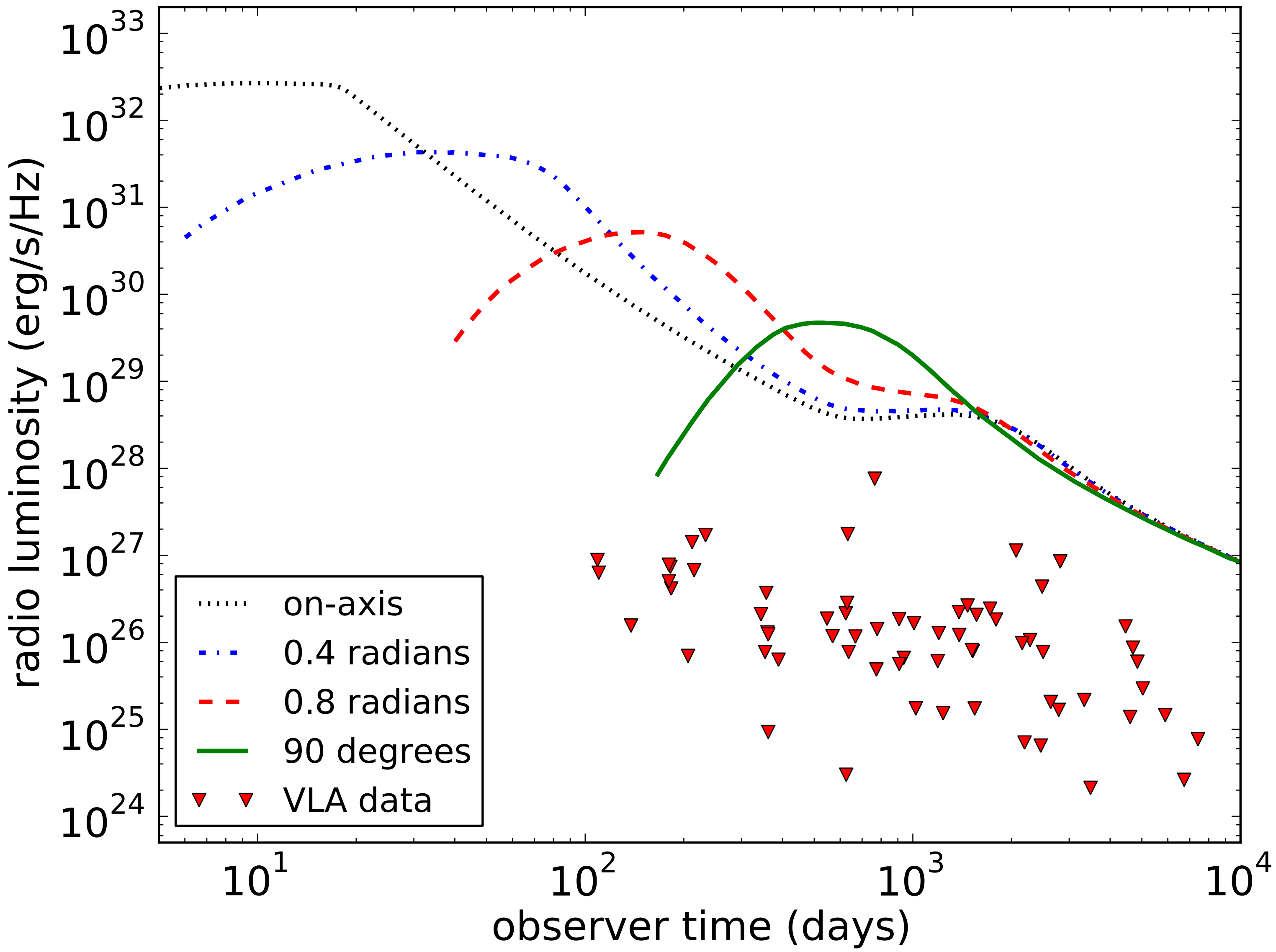


Poster 3.05

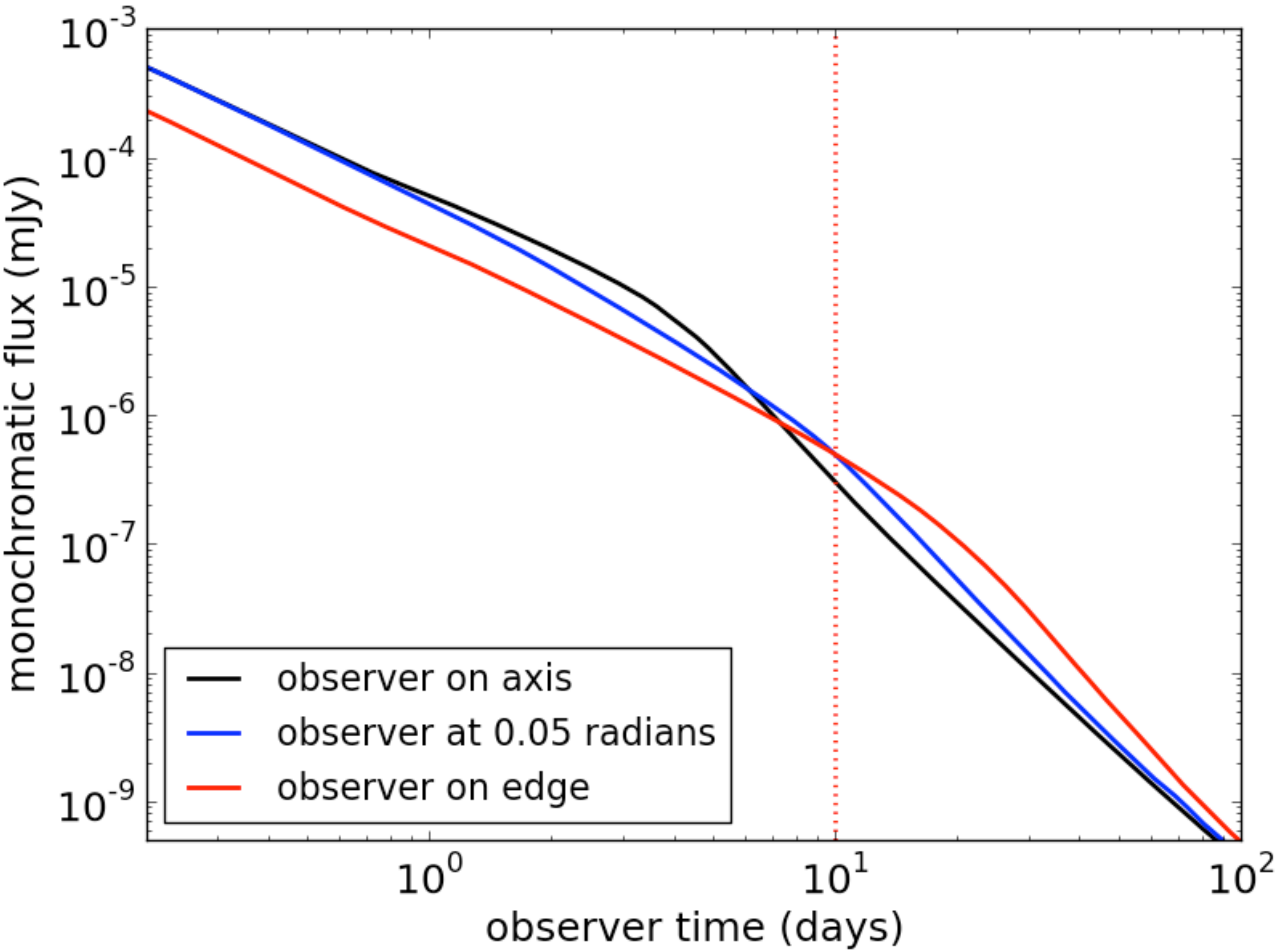
http://cosmo.nyu.edu/afterglowlibrary/

Supported by NASA 09-ATP-0190

SN-GRB

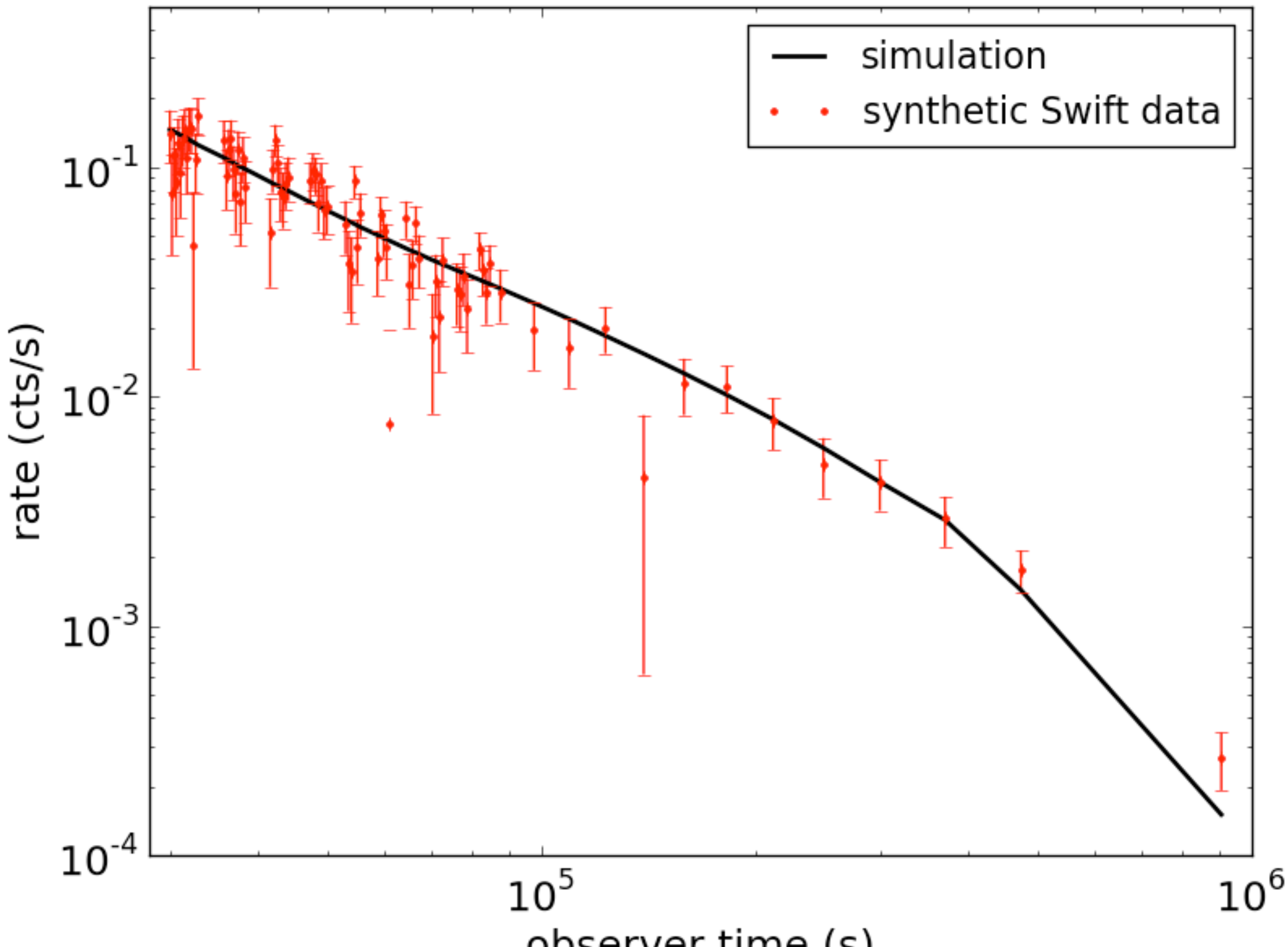


radio luminosity (erg/s/Hz)
observer time (days)
on-axis
0.4 radians
0.8 radians
90 degrees
VLA data
10^{33}
10^{32}
10^{31}
10^{30}
10^{29}
10^{28}
10^{27}
10^{26}
10^{25}
10^{24}
10^{1}
10^{2}
10^{3}
10^{4}



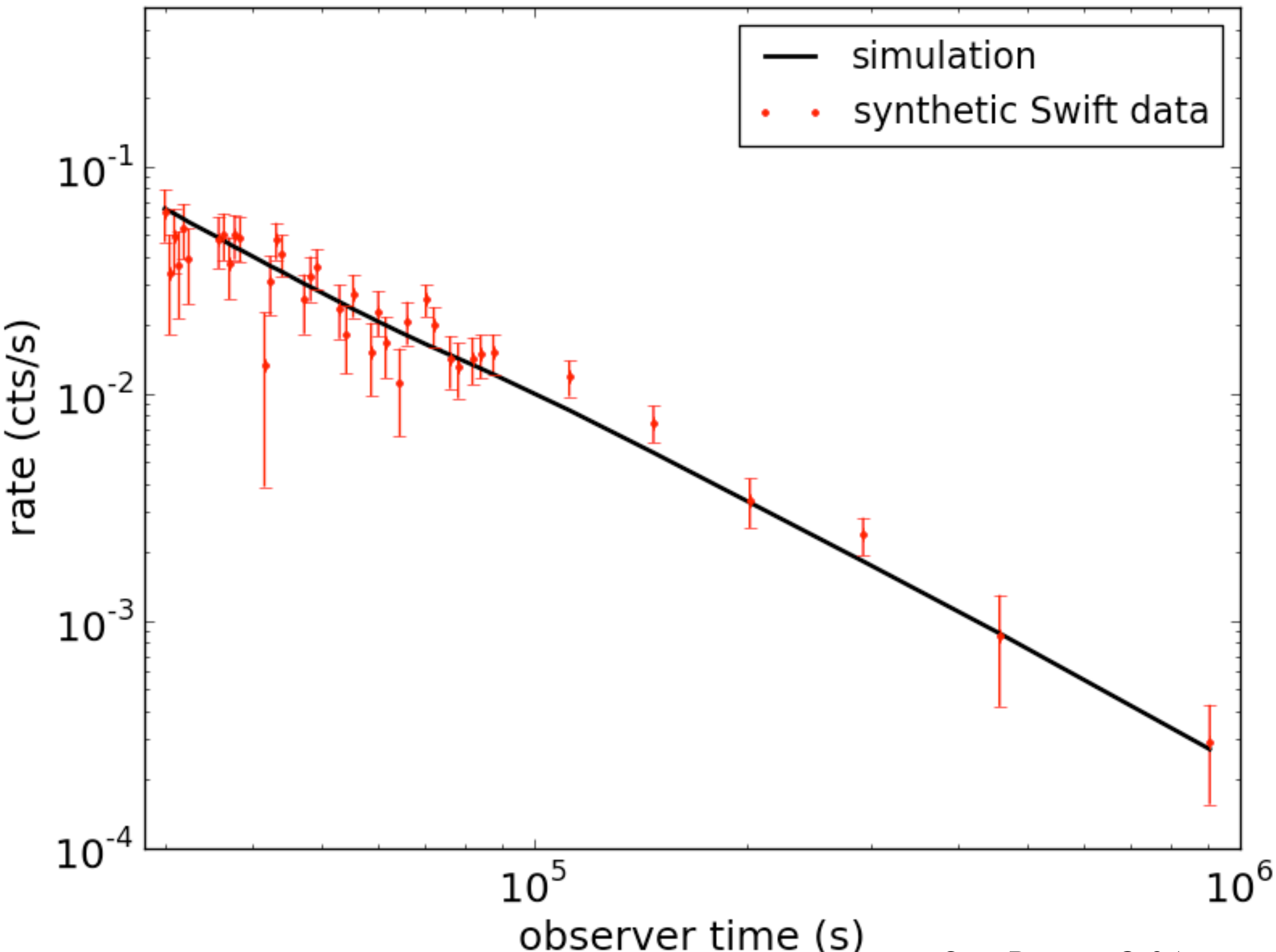
See Poster 3.06

On Axis



See Poster 3.06

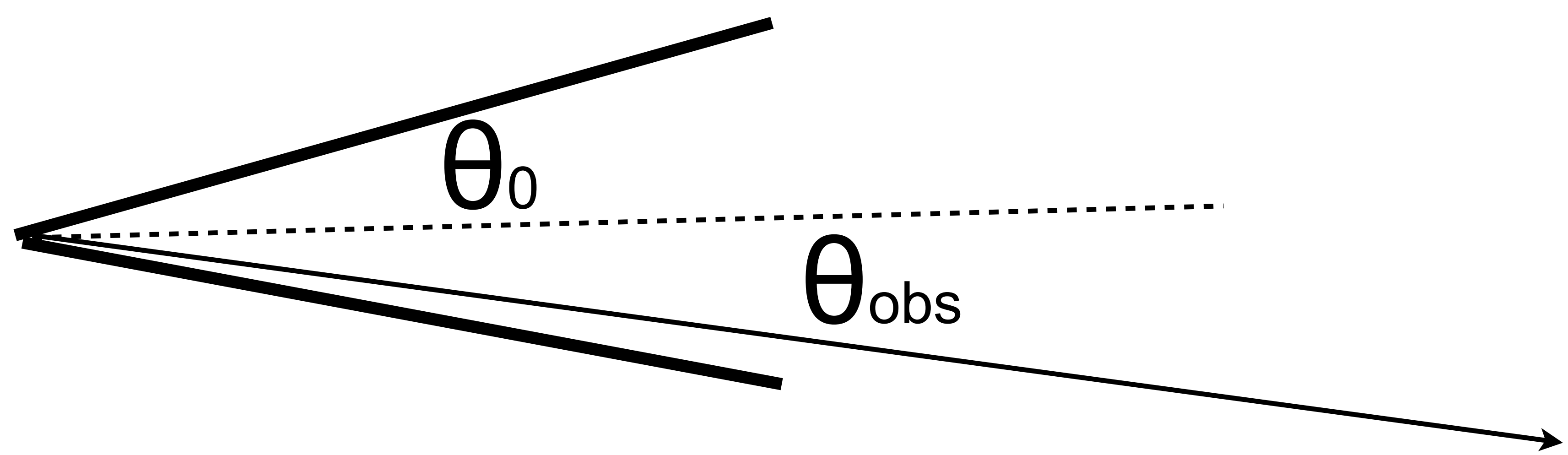
On Edge



See Poster 3.06

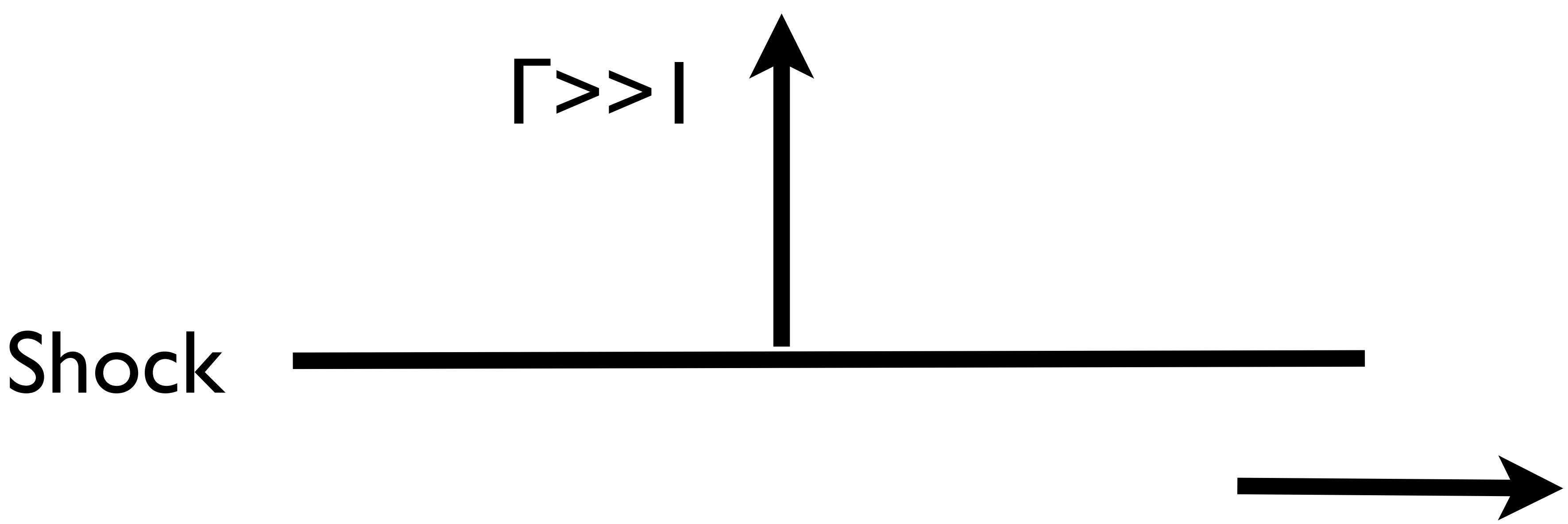
Estimated Jet Break Time for Off-Axis Observer

$$t_j = 3.5(1+z)E_{iso,53}^{1/3} n_1^{-1/3} \left(\frac{\theta_0 + \theta_{obs}}{0.2}\right)^{8/3} \text{ days},$$

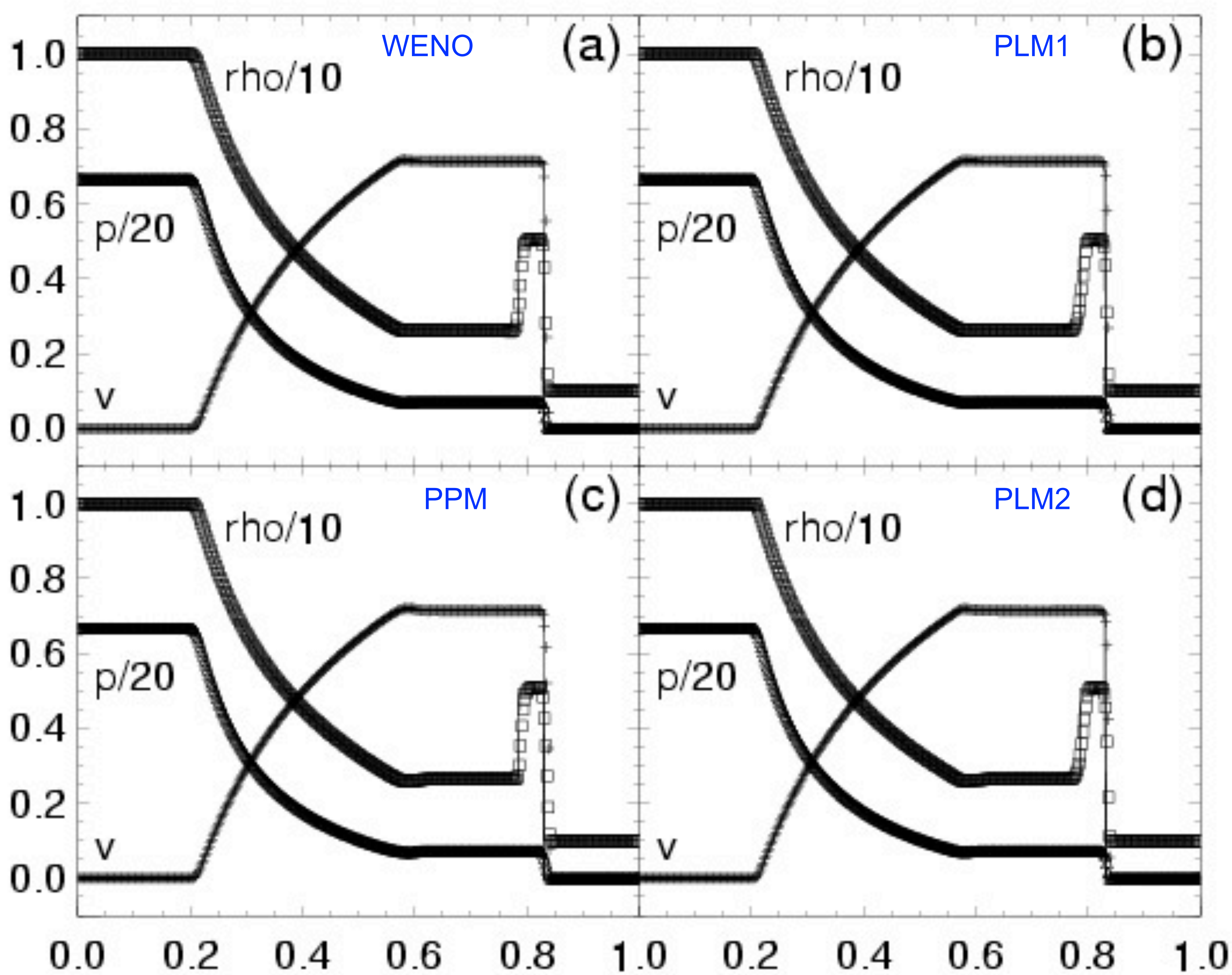


A. MacFadyen (NYU)

Lateral Expansion



Shock Tube Test



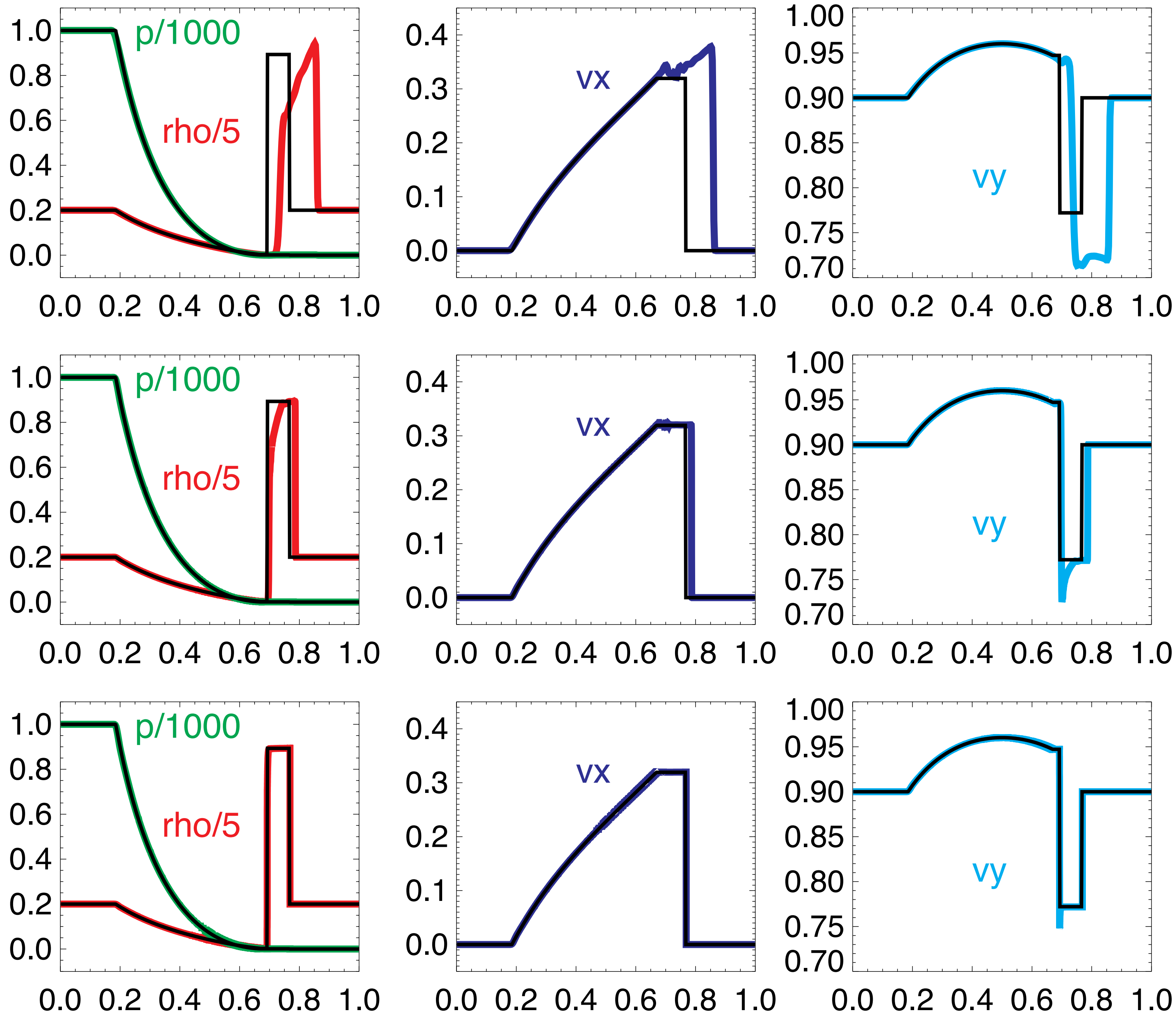
Shear Flow Resolution

AMR

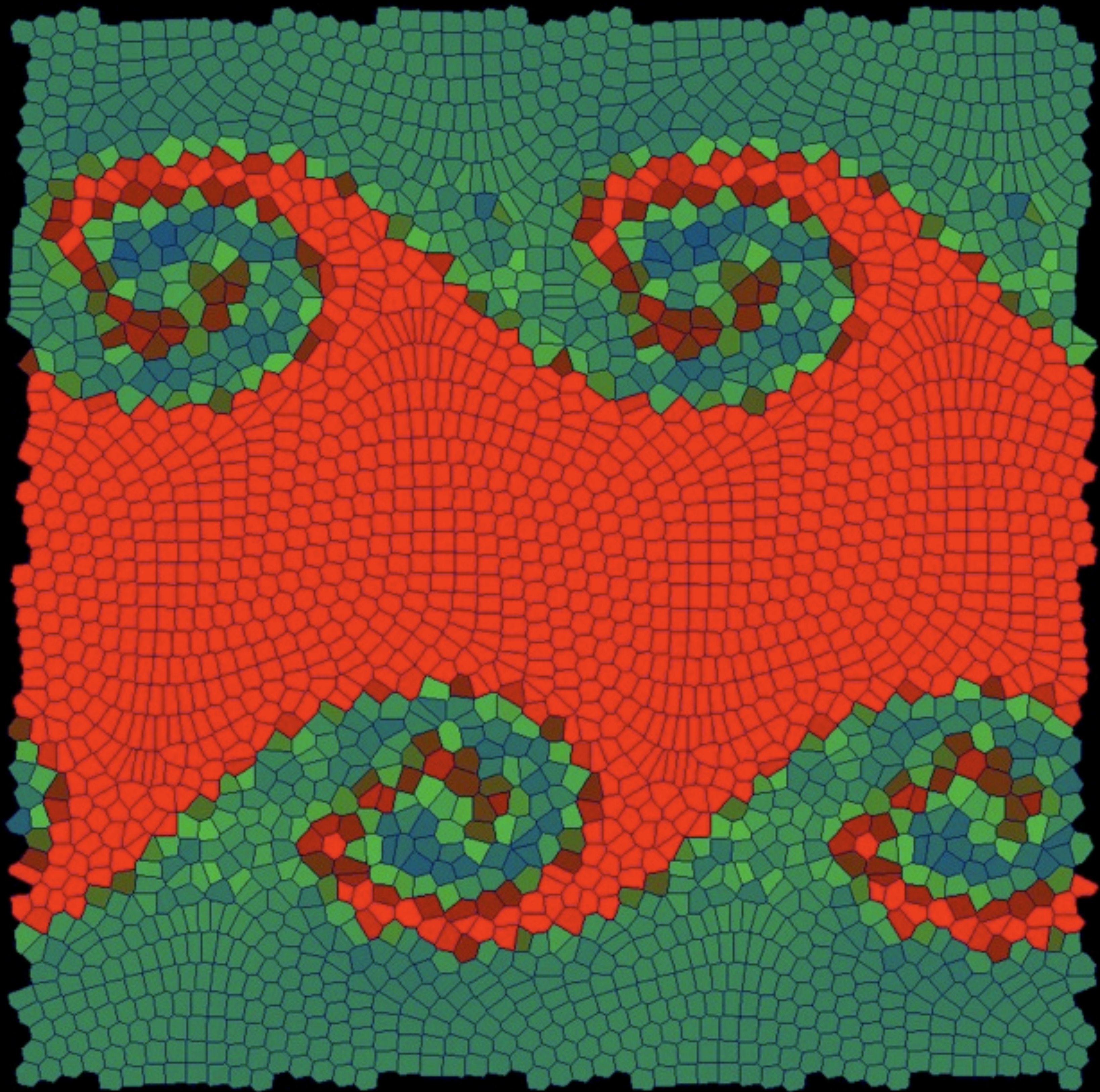
2 levels — 400

5 levels — 3200

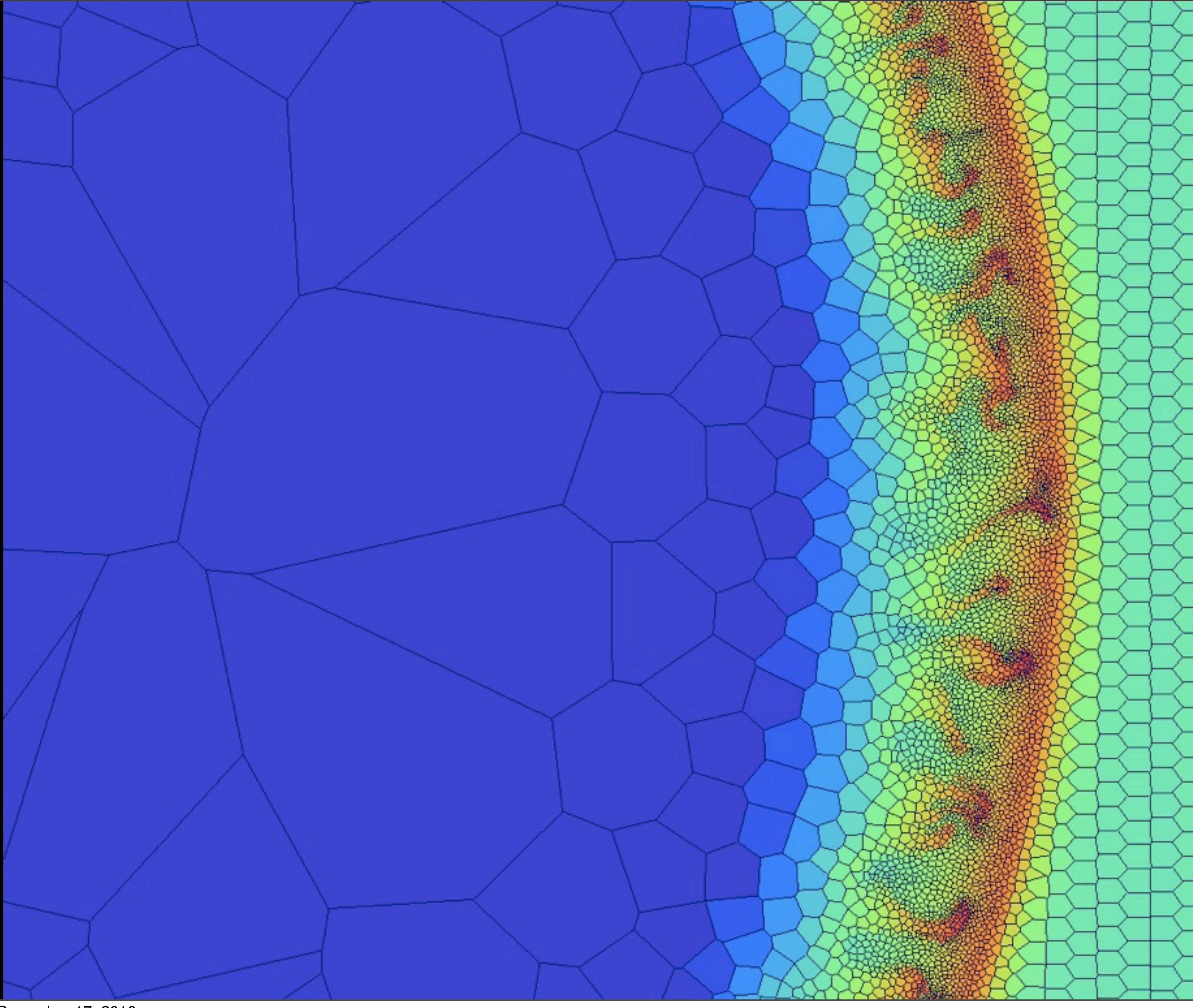
9 levels — 51200

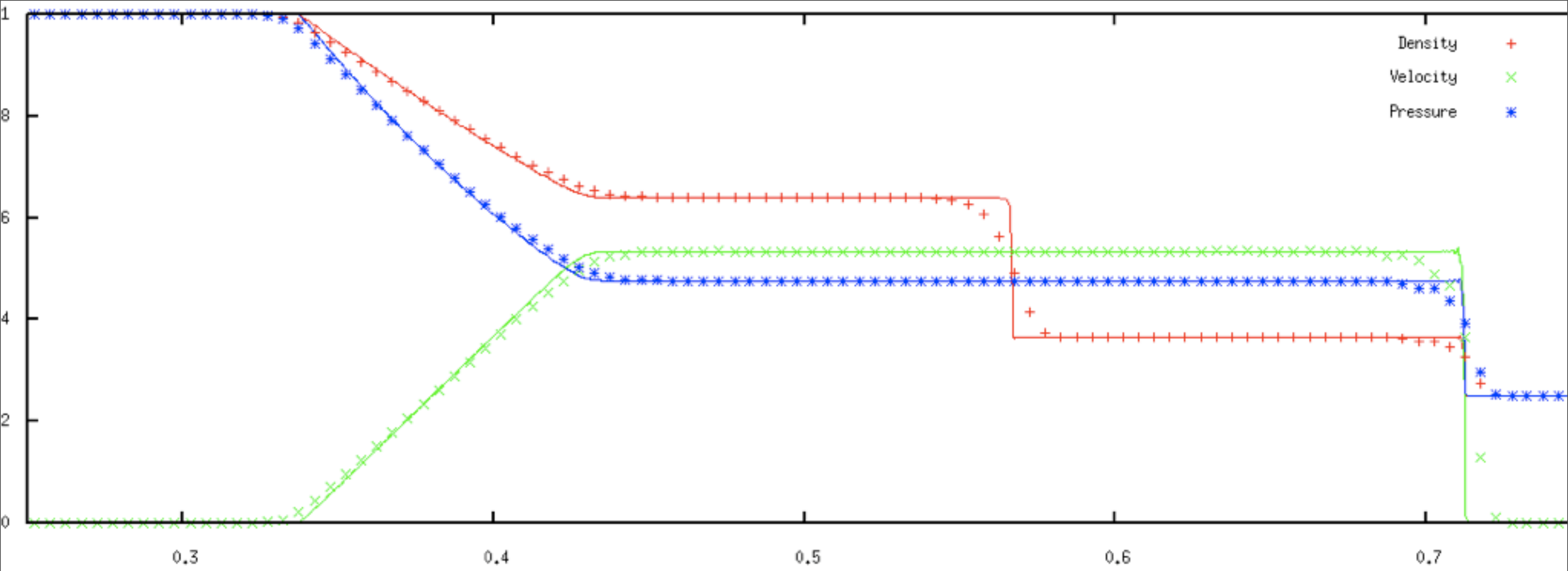


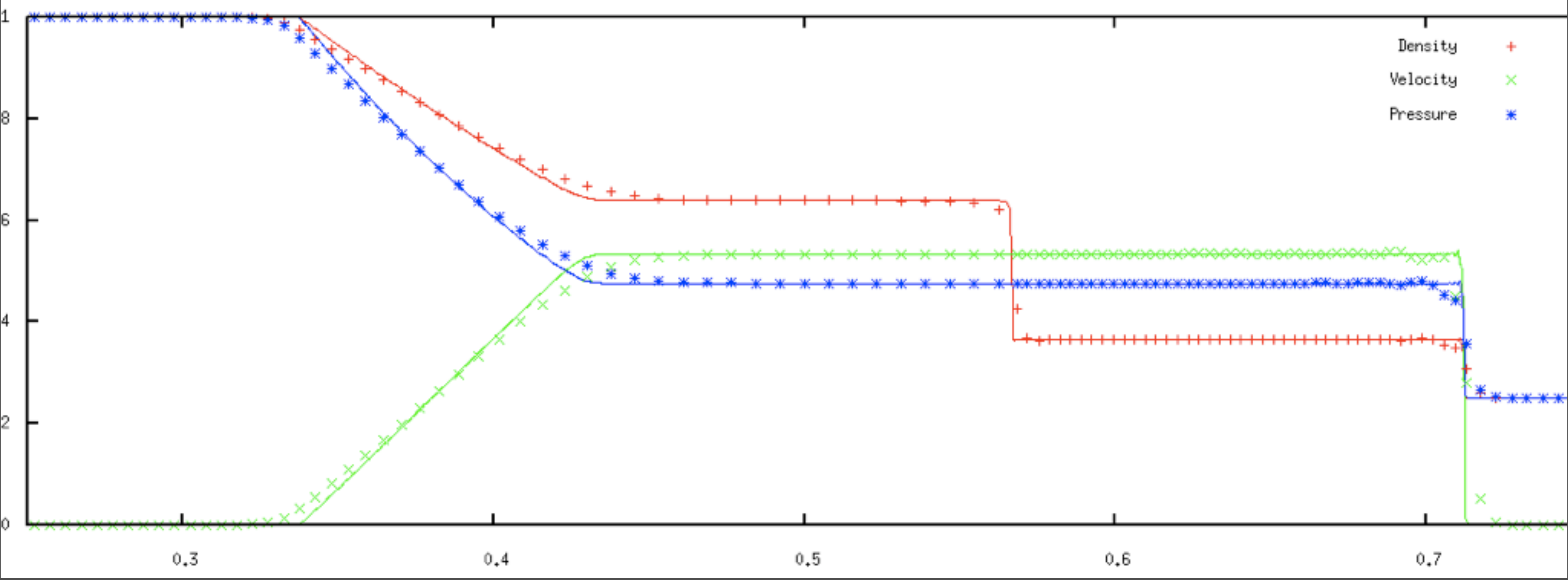
Tess



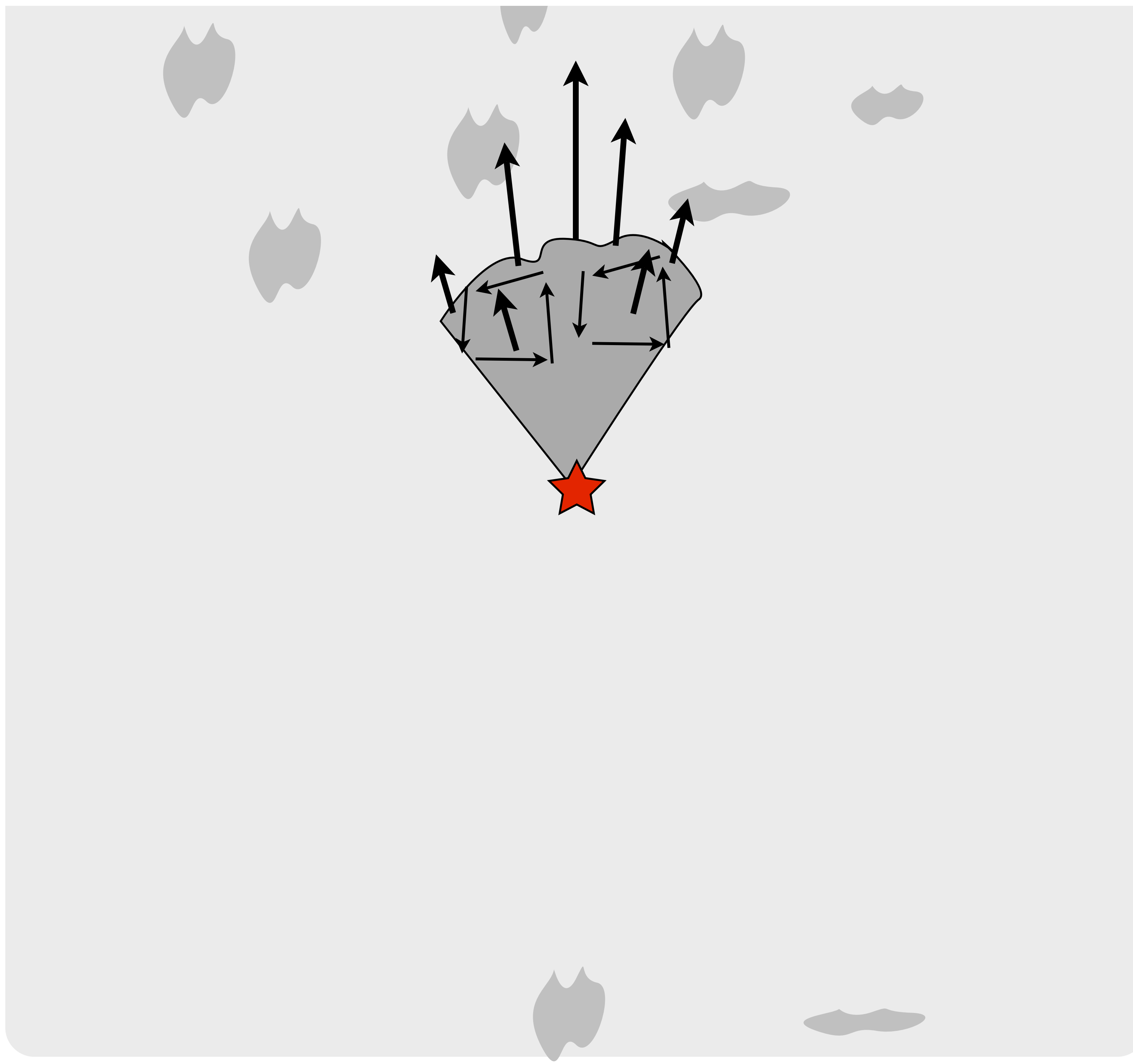
Duffel & MacFadyen (2010)



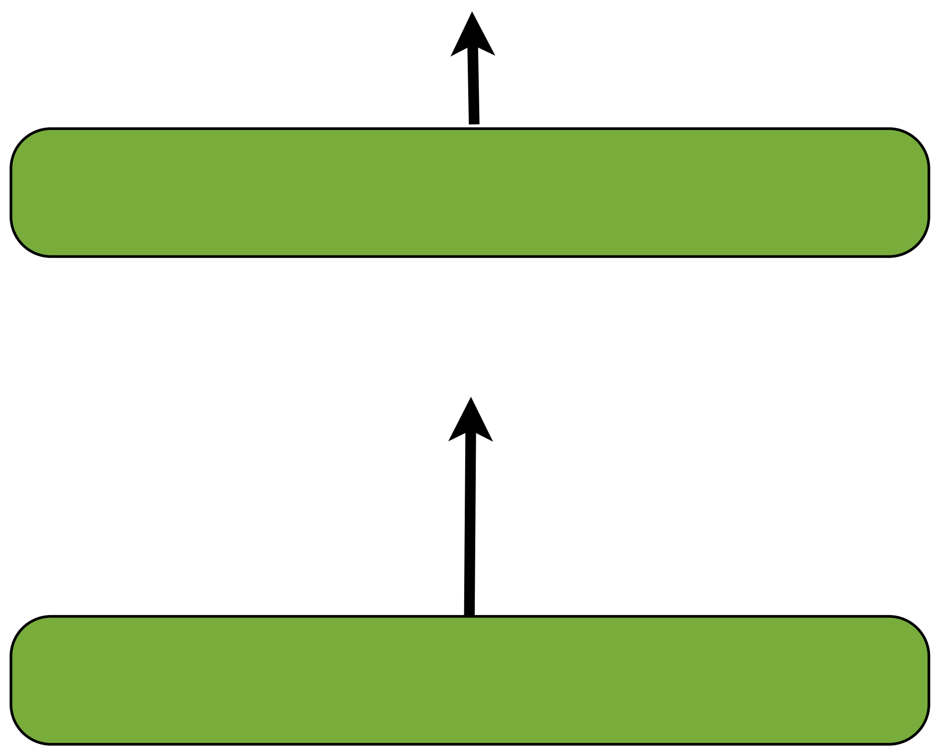

Density
Velocity
Pressure
0.3
0.4
0.5
0.6
0.7


Density
Velocity
Pressure
0.3
0.4
0.5
0.6
0.7

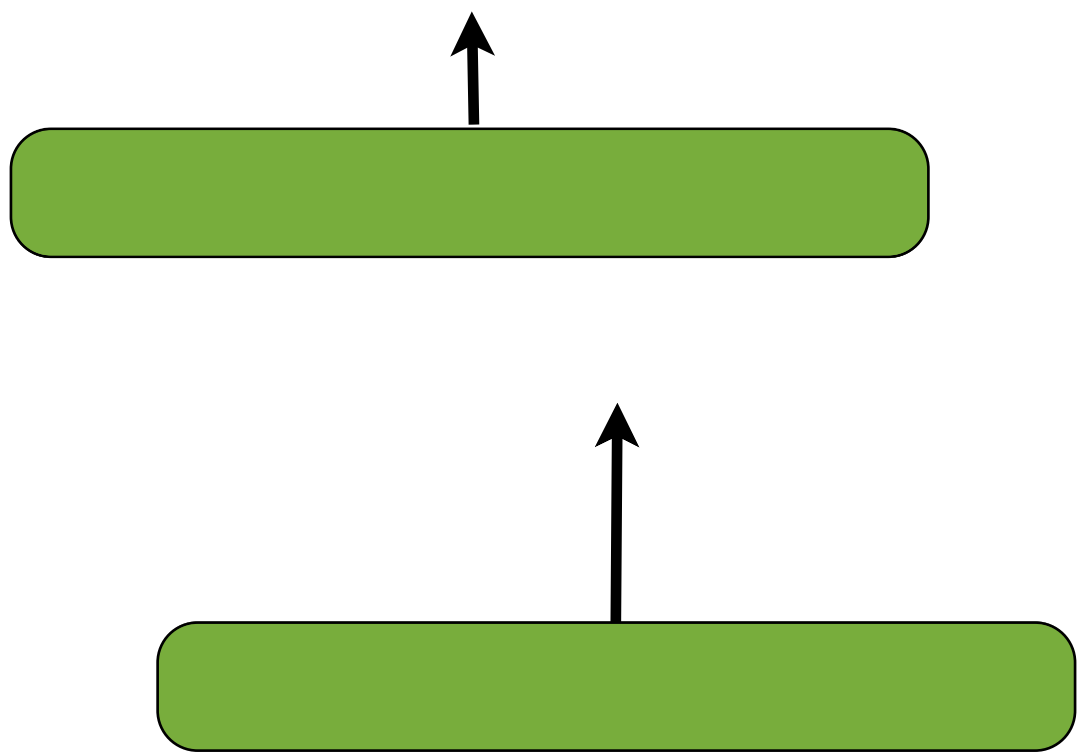
Jet & Clumps



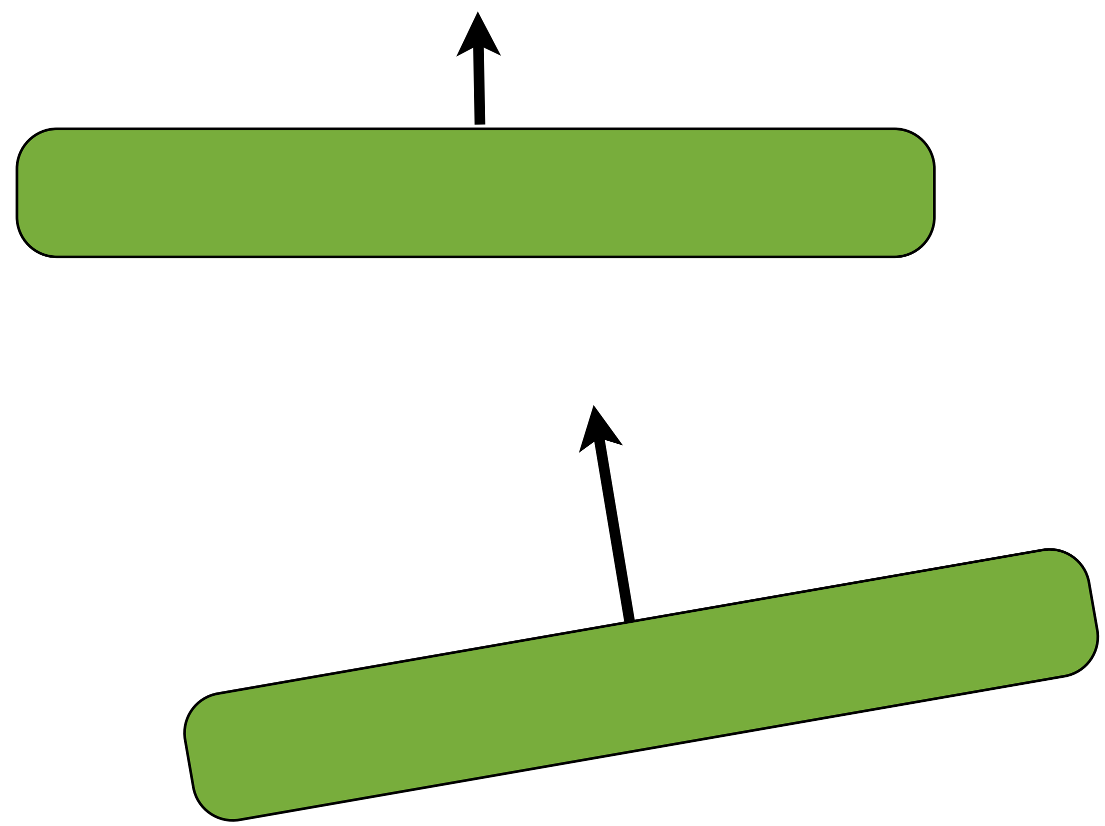
Flying Pancakes



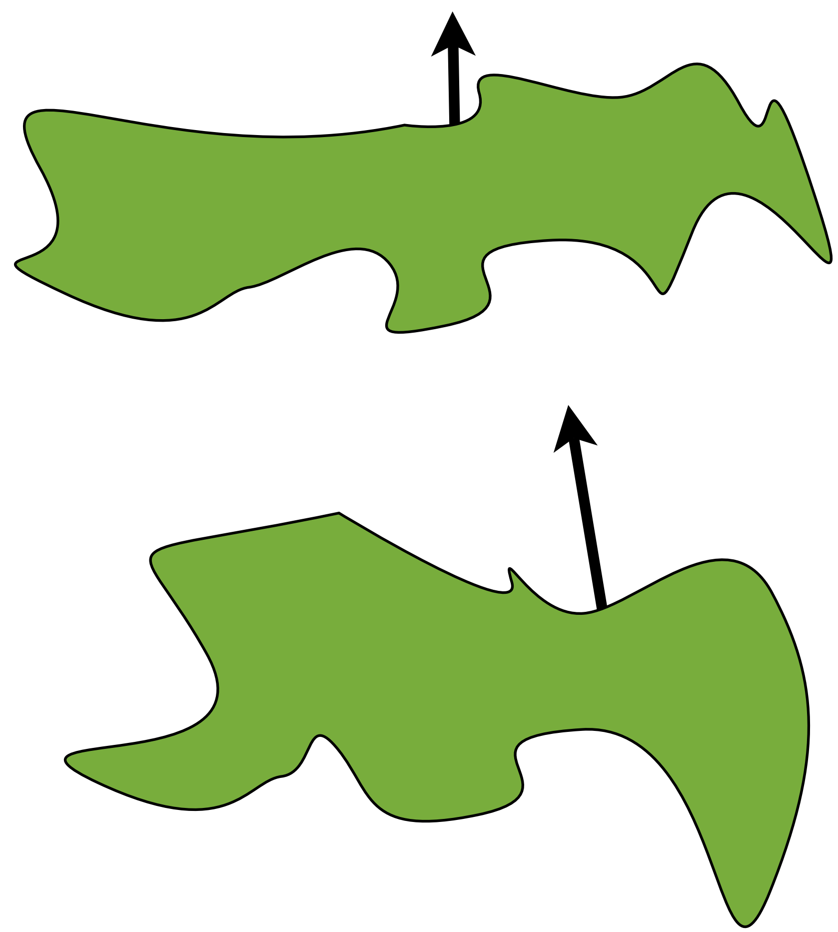
Misaligned



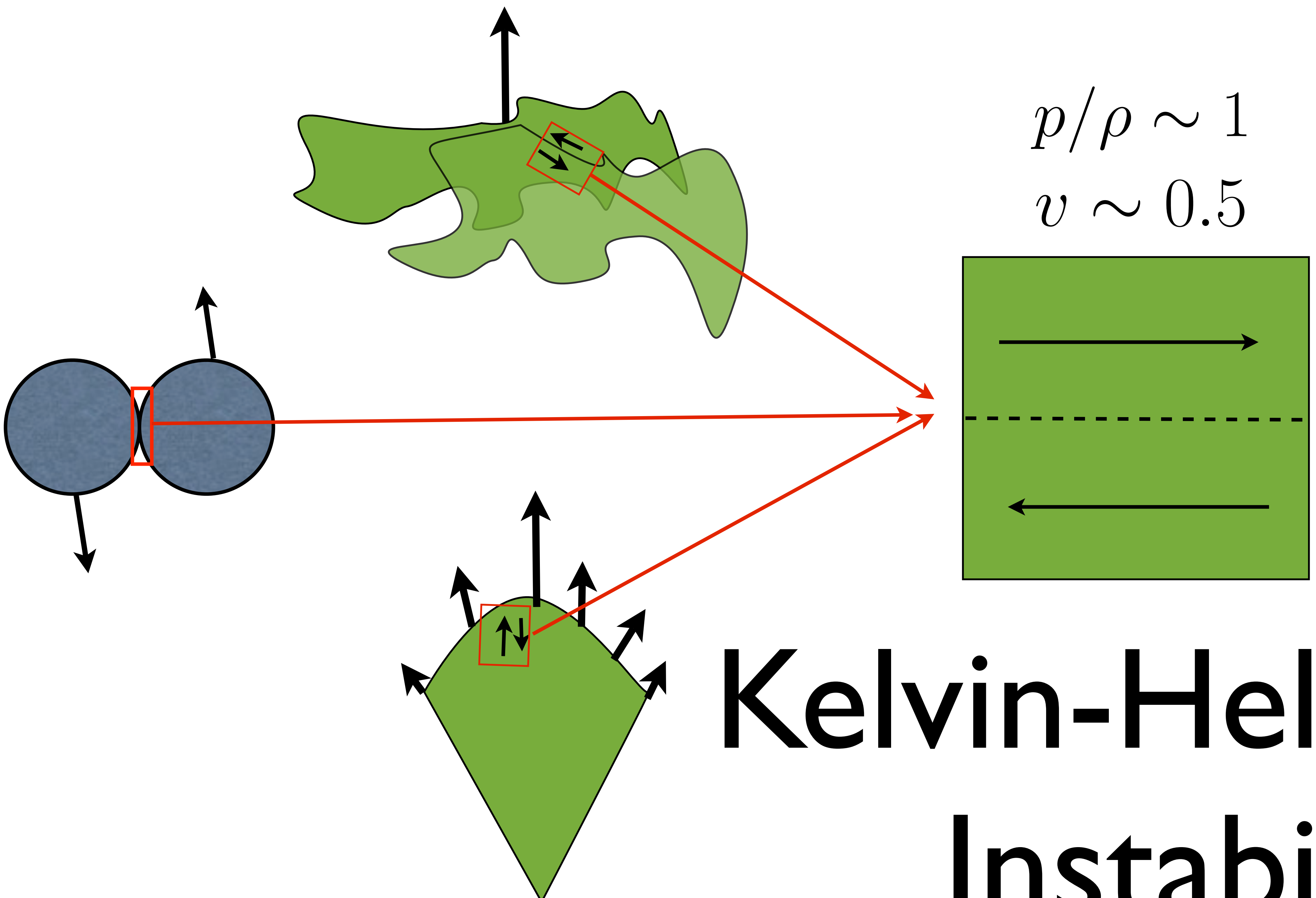
Oblique



Colliding Clumps



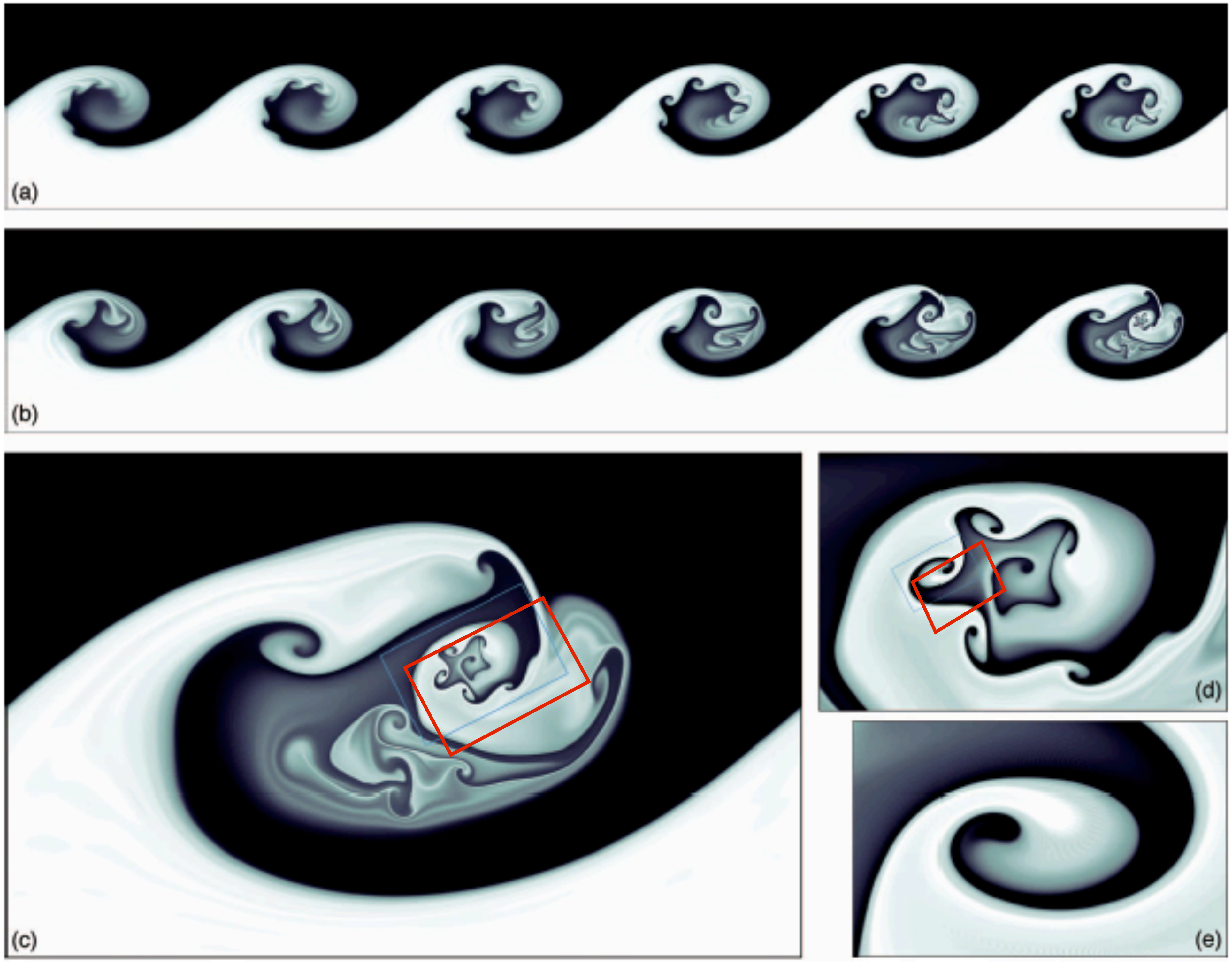
Shear Patches



Kelvin-Helmholtz Instability

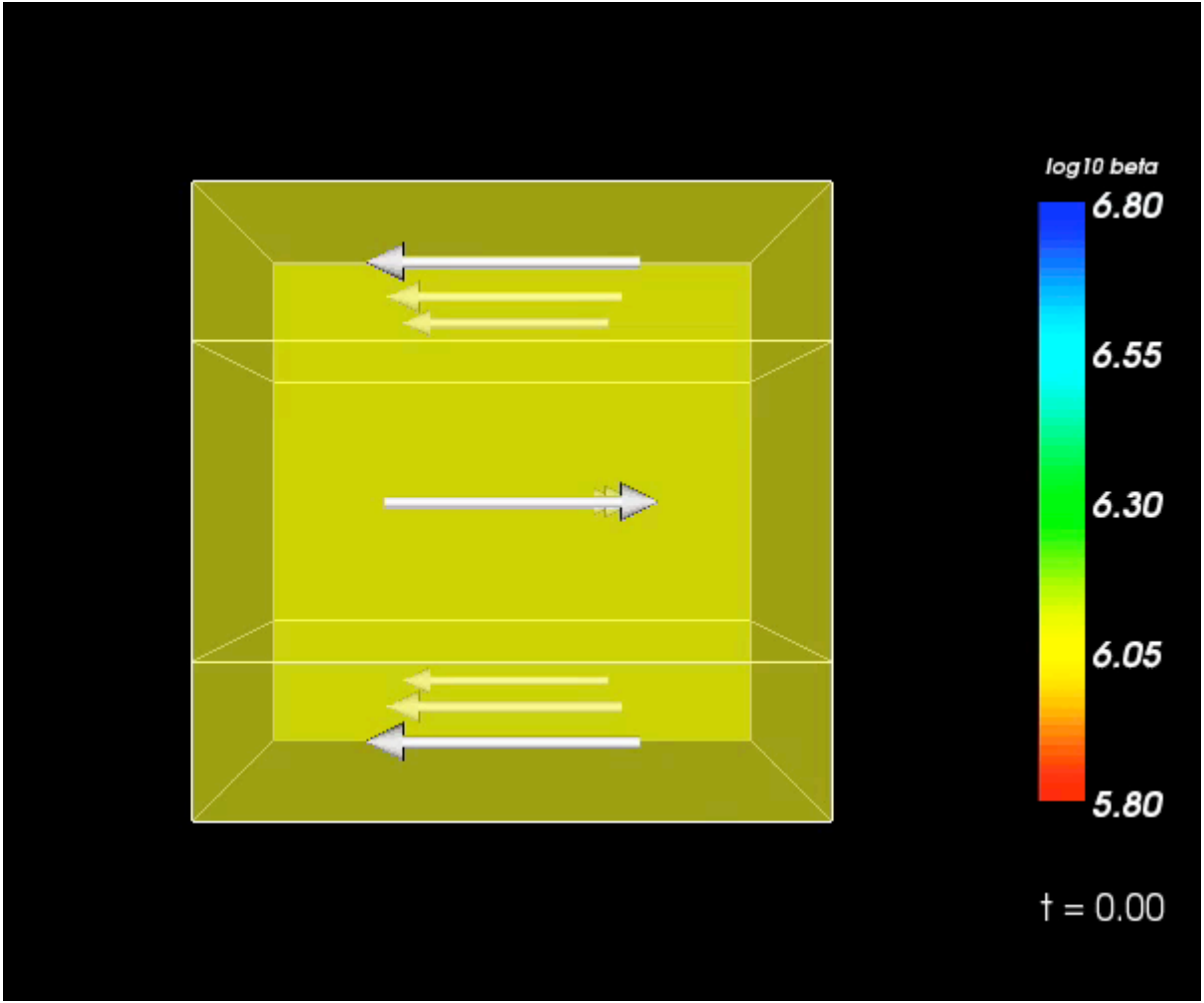
Kelvin Helmholtz Clouds

Big Whirls Have Little Whirls

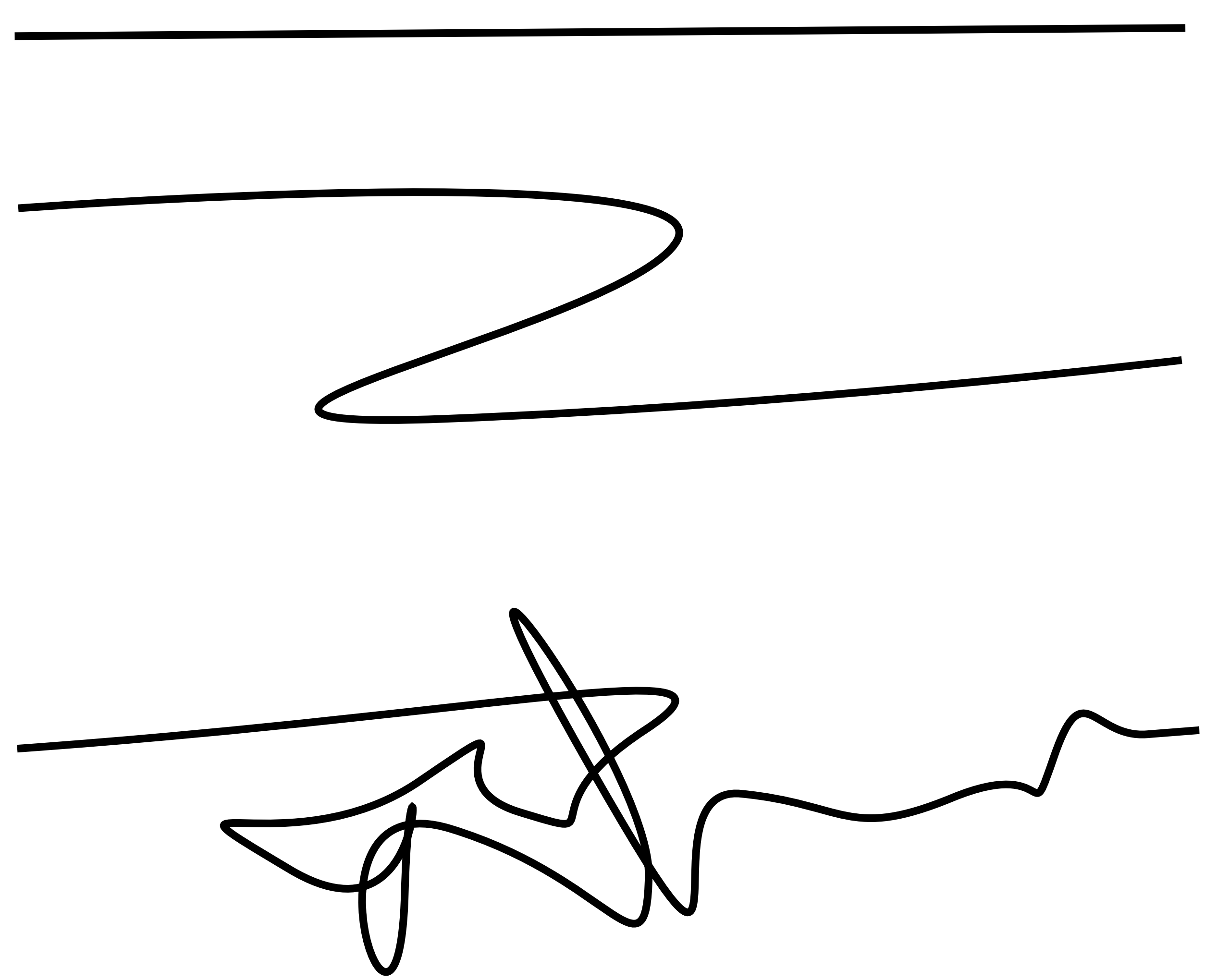


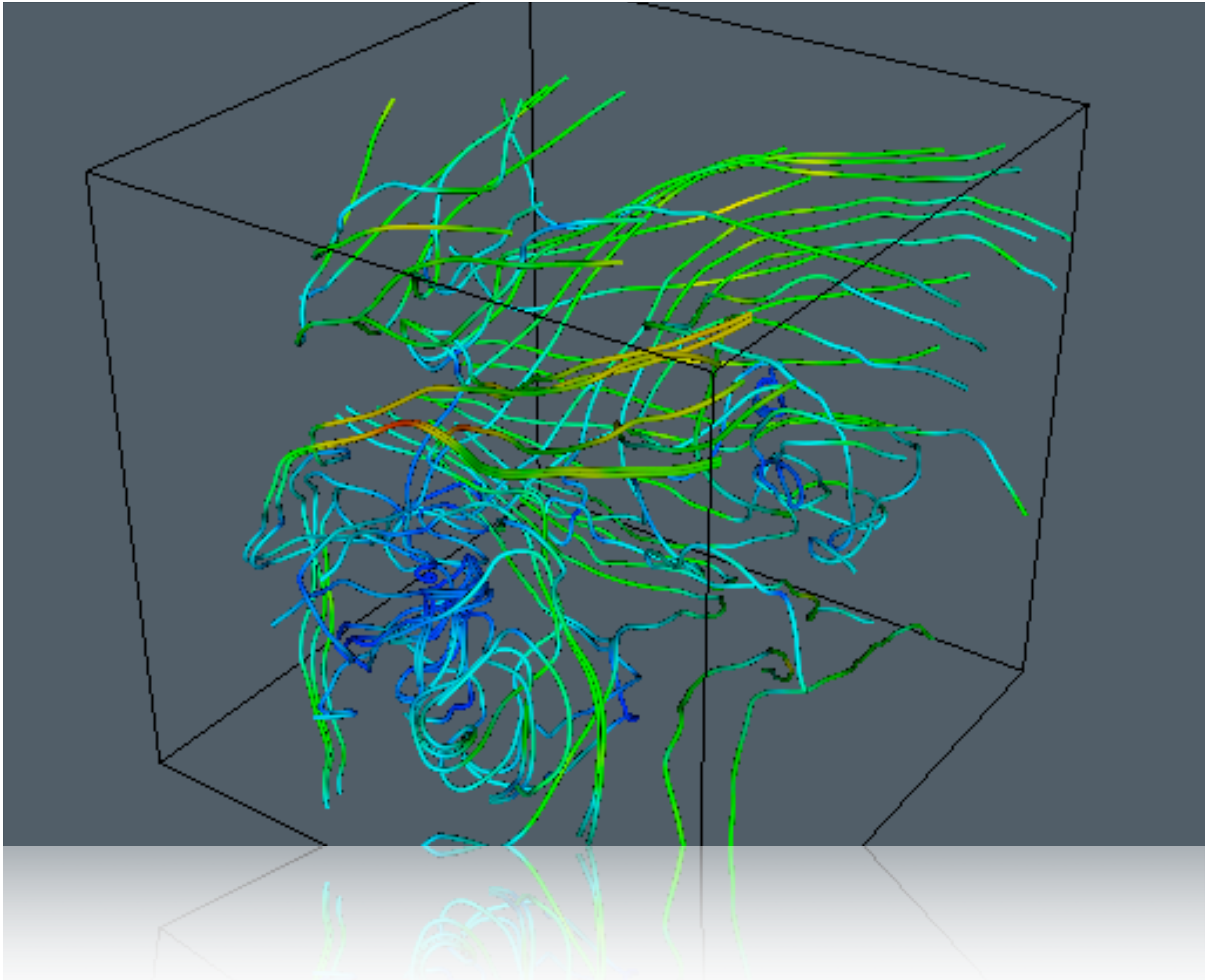
Joly et al (2008)

KH: 1024^3 Rel. MHD

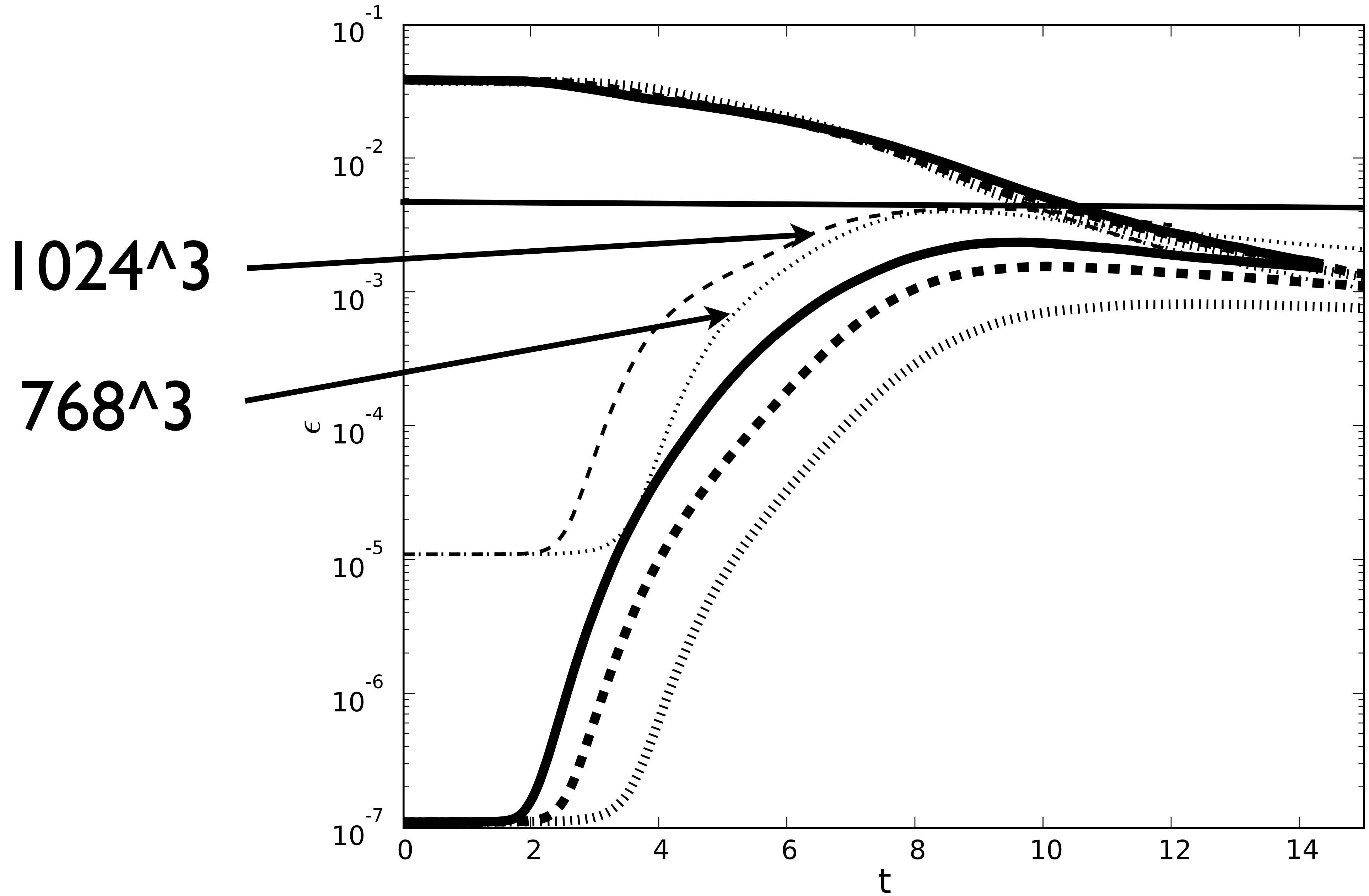


Twisting and Folding



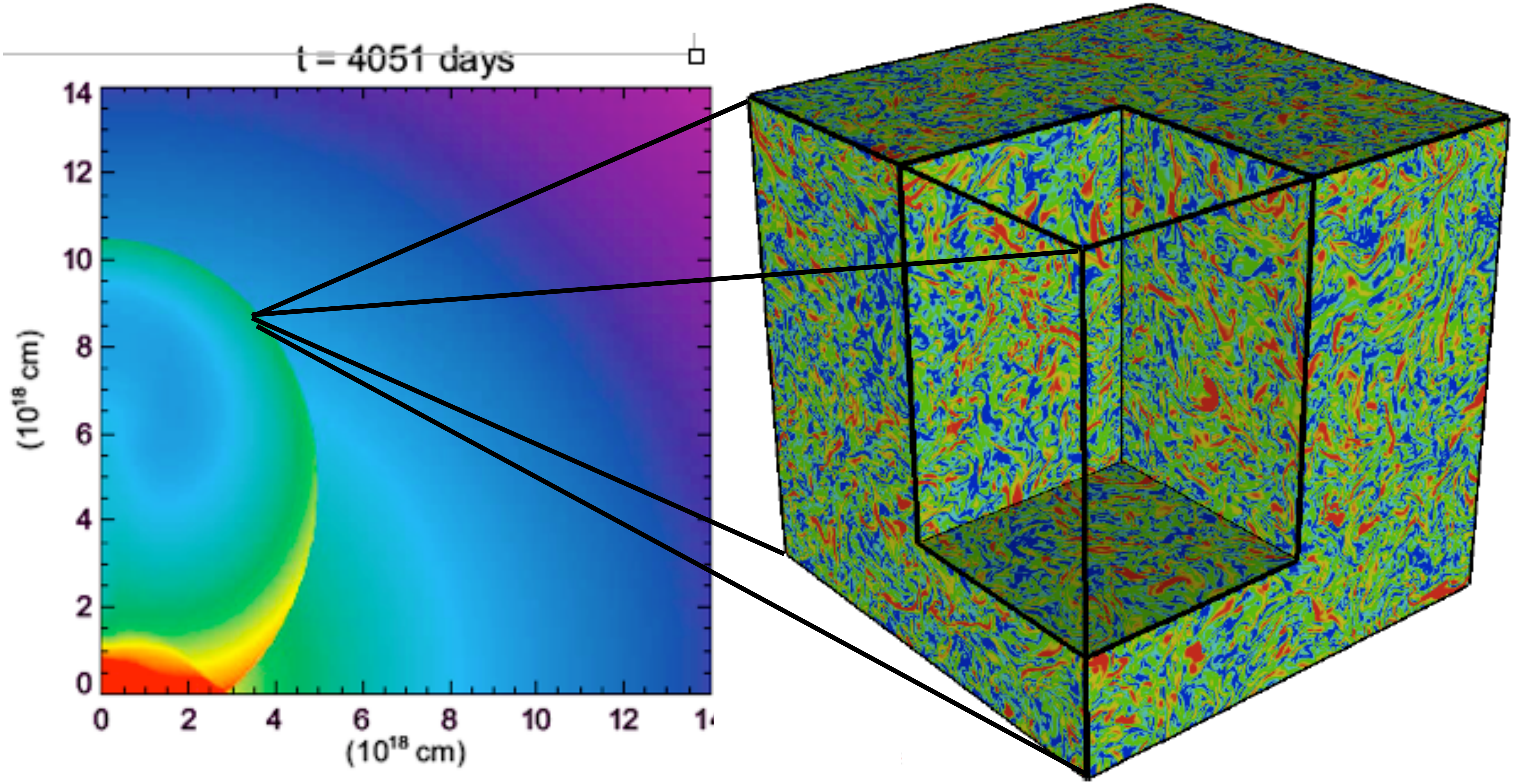


Magnetic Energy Saturation



$$\epsilon_B = 5 \times 10^{-3}$$

$\varepsilon_B = 0.005$



Zhang, AM&Wang, ApJL (2009)

$$T^{\mu\nu} = (P + \rho)u^{\mu}u^{\nu} + Pg^{\mu\nu}$$