



# 磁気流体流中の 星によって作られる衝撃波構造

Shuta Tanaka (Aoyama Gakuin U.)

on behalf of

TMT revolution

Tanaka, Matsumoto, Toma & Shoda

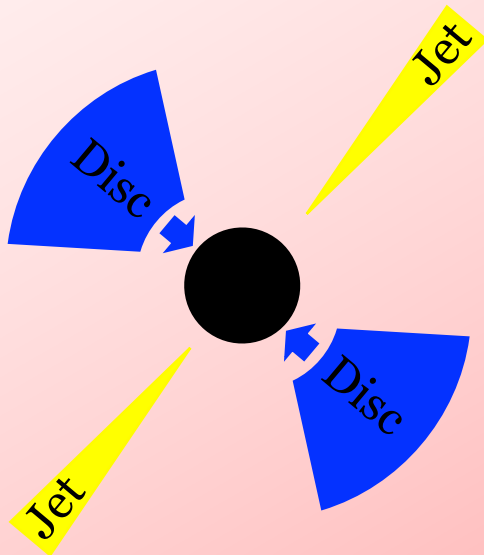
# Introduction



# Relativistic Jet

- Powered by NS or BH
- Relativistic plasma outflow
- High-energy (non-thermal) emission
- Bipolar jets from engine

Common astrophysical phenomena phenomena in AGN, microquasar & GRB



- Gravitational energy (inflow -> outflow)  
**Same as pulsar wind**
- Rotation powered?
- Role of magnetic field?
- How to accelerates to relativistic flow?
- How to collimate jets?

# Turbulence Acceleration

$$\langle \nabla_\mu (n u^\mu) \rangle = 0,$$

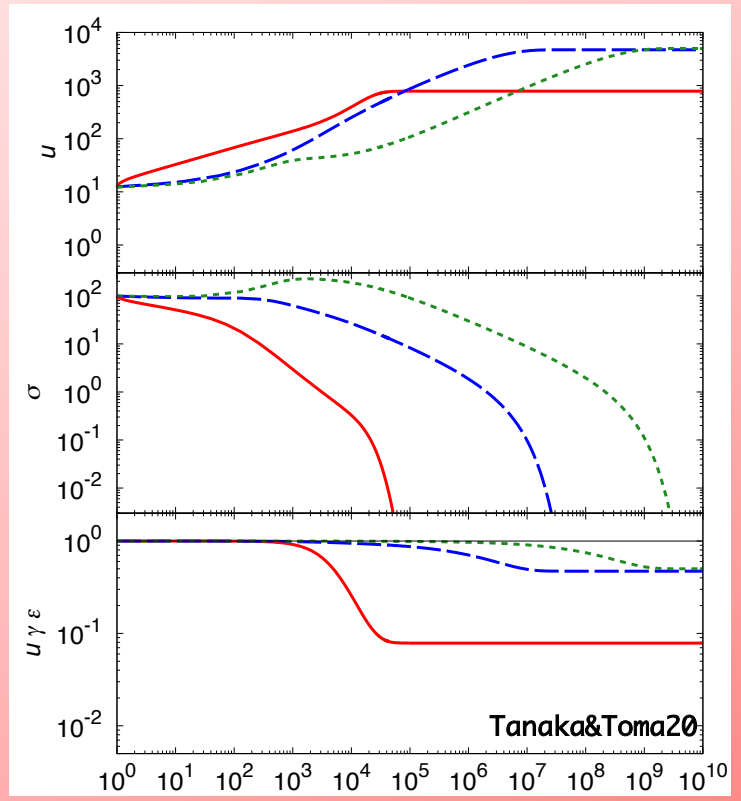
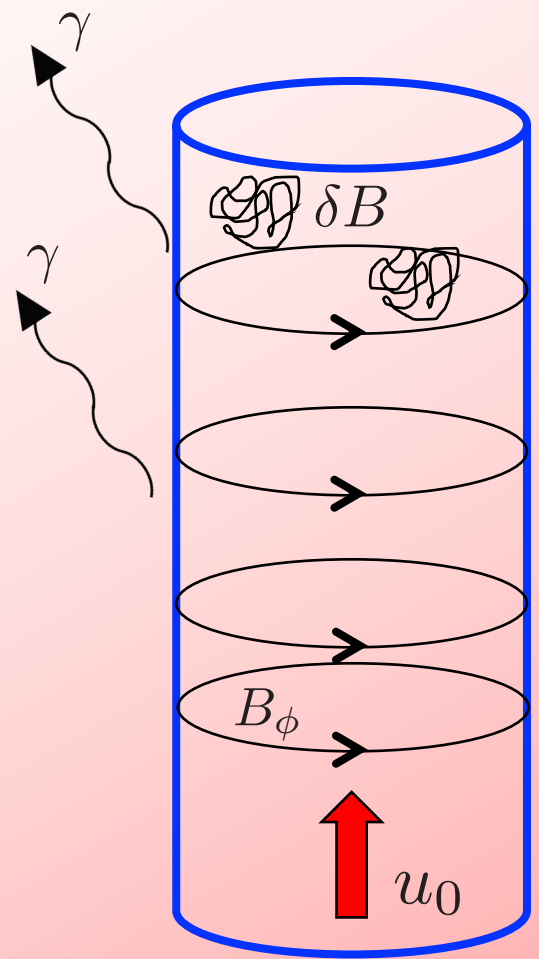
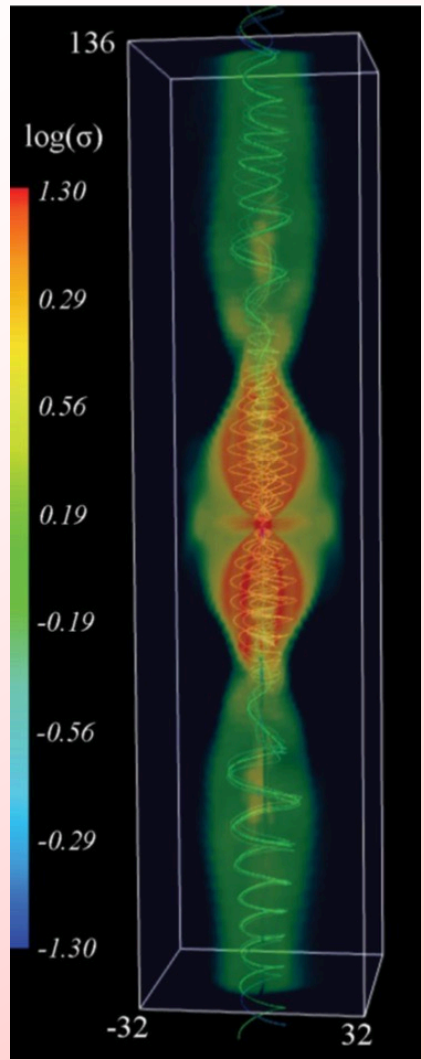
$$\langle \nabla_\mu T^{\mu t} \rangle = -\gamma \frac{\Lambda_{\text{rad}}}{c},$$

$$-\langle u_\nu \nabla_\mu T_{\text{FL}}^{\mu\nu} \rangle = \frac{\delta b^2/2}{\tau_{\text{diss}}} - \frac{\Lambda_{\text{rad}}}{c},$$

$$\frac{1}{2} \langle \bar{b}_\mu e^{\mu\nu\alpha\beta} \nabla_\nu F_{\alpha\beta} \rangle = -\frac{\bar{b}^2/2}{\tau_{\text{conv}}},$$

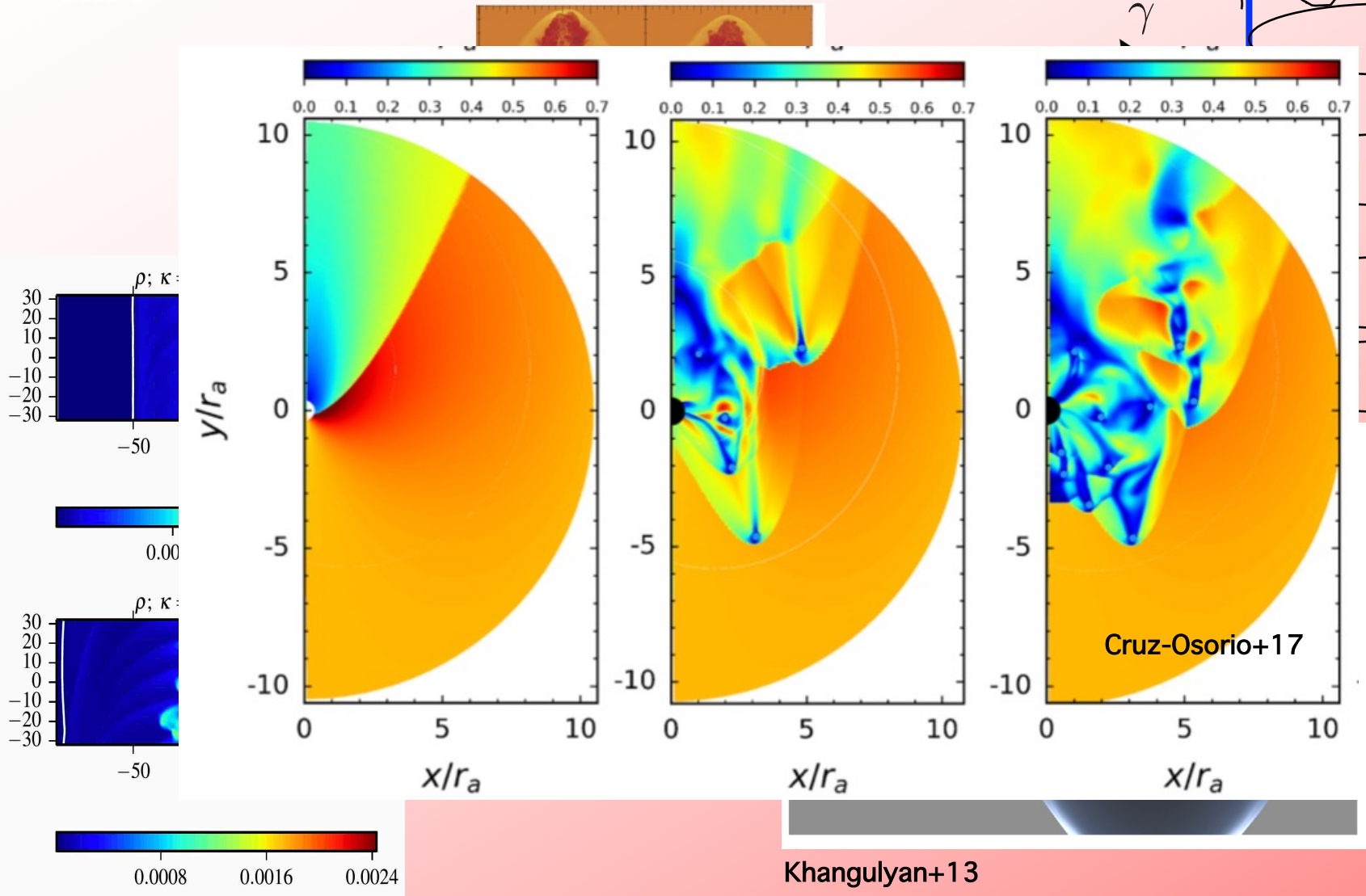
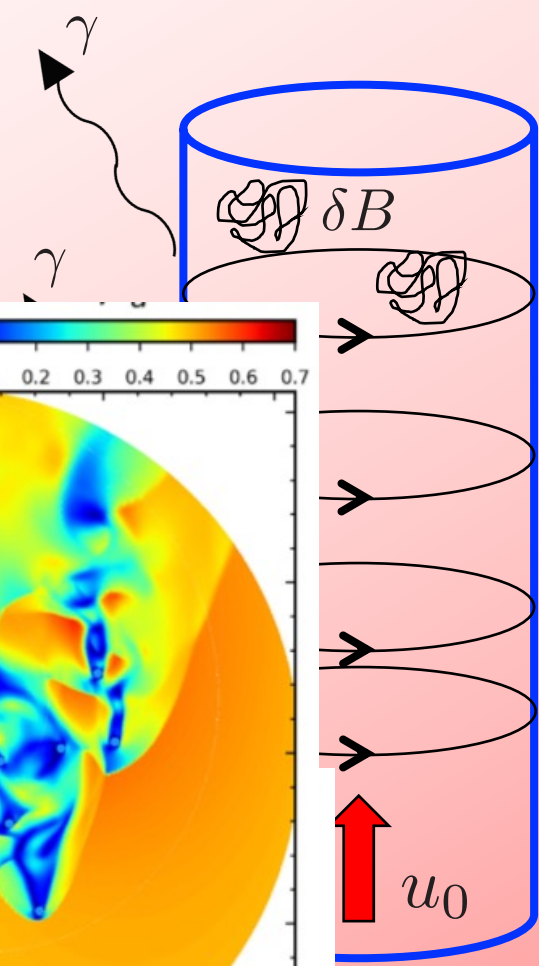
$$\frac{1}{2} \langle \delta b_\mu e^{\mu\nu\alpha\beta} \nabla_\nu F_{\alpha\beta} \rangle = \frac{\bar{b}^2/2}{\tau_{\text{conv}}} - \frac{\delta b^2/2}{\tau_{\text{diss}}}.$$

Bromberg&Tchekhovskoy16



Tanaka&Toma20

# Turbulence Formation?



Cruz-Osorio+17

Khagulyan+13

Porth&Komissarov15

**Numerical Study**

*Preliminary*

# Set Up – 2D Rel. MHD

## デカルト座標

松本仁くんのスライド

### 乱流加速の計算設定

$$\Gamma = \frac{4}{3}$$
$$\rho_{\text{jet}} = 1$$
$$\sigma_{\text{jet}} = 1$$
$$\beta_{\text{jet}} = 0.4$$
$$\frac{P_{\text{jet}}}{\rho_{\text{jet}}} = \frac{\beta_{\text{jet}} \sigma_{\text{jet}}}{2 - \frac{\Gamma}{\Gamma-1} \beta_{\text{jet}} \sigma_{\text{jet}}} = 1$$

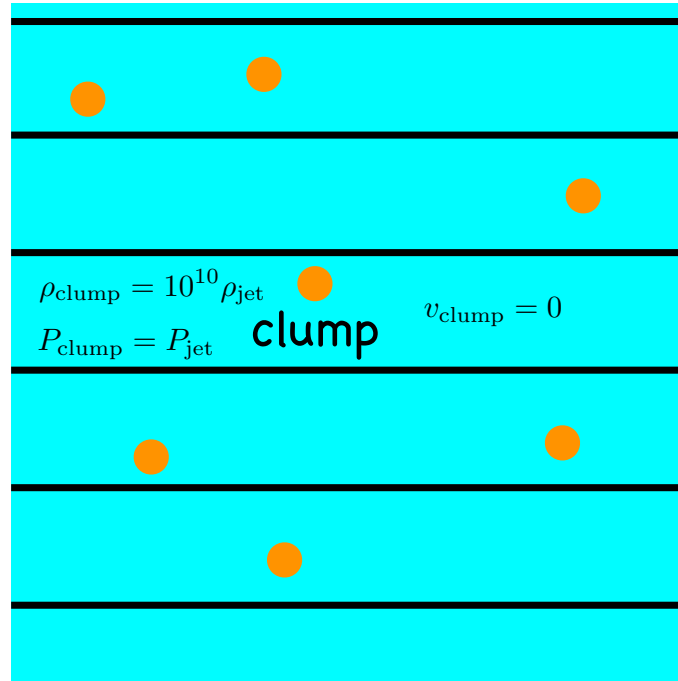
$> 0$

↓

$$\beta_{\text{jet}} \sigma_{\text{jet}} < 0.5$$

periodic

free condition



$N_x = N_z = 400$

$$b_x = \sqrt{\frac{2P_{\text{jet}}}{\beta_{\text{jet}}}} \sim 2.236$$

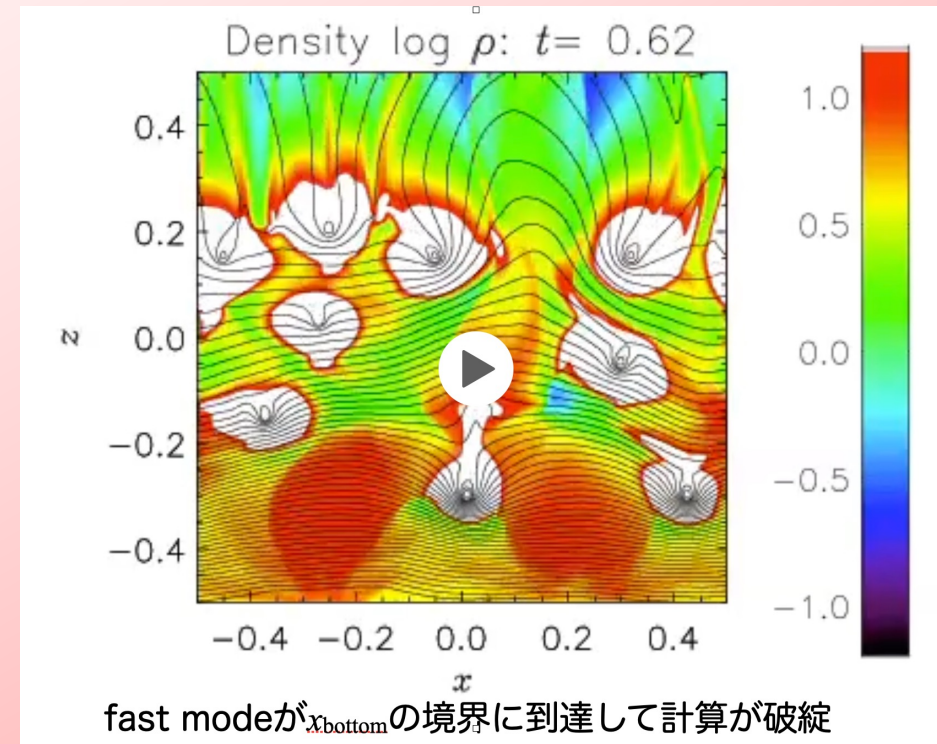
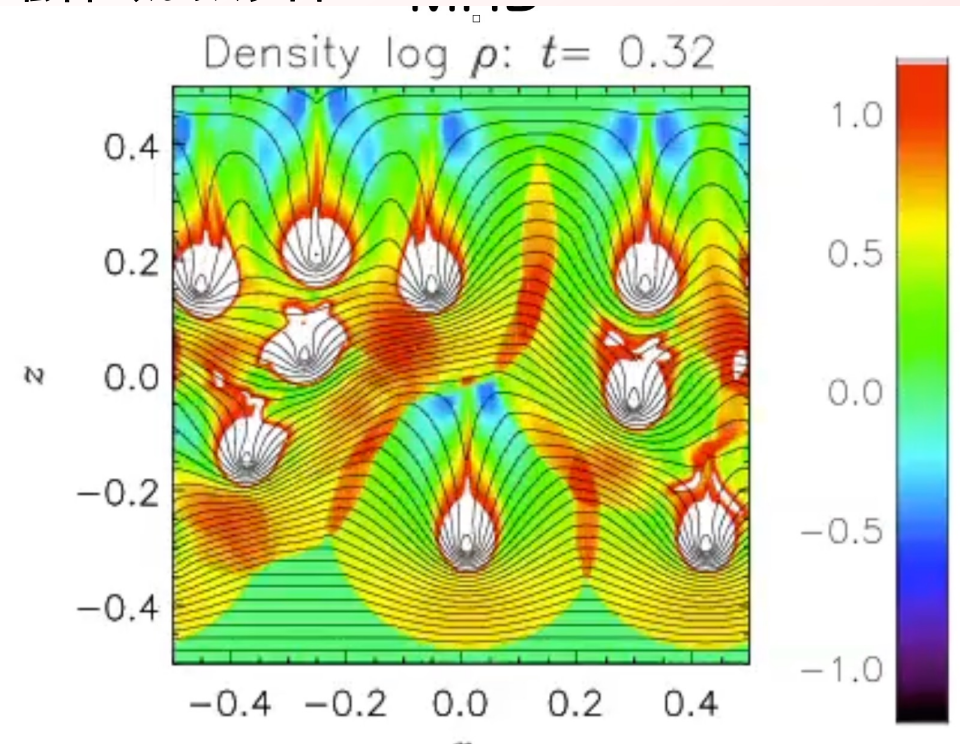
periodic

relativistic flow

$$\gamma_{\text{jet}} = 3 \quad v_{\text{jet}}/c = 0.9428$$

# Set Up – 2D Rel. MHD

松本仁くんのスライド



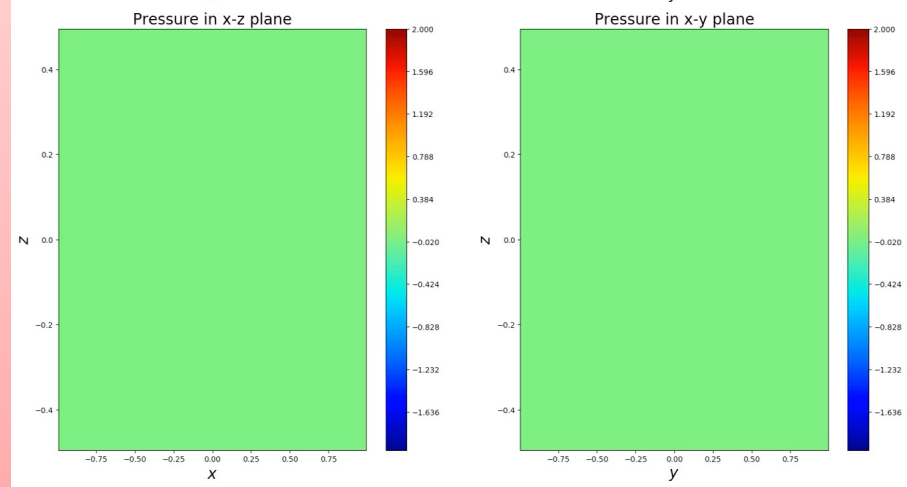
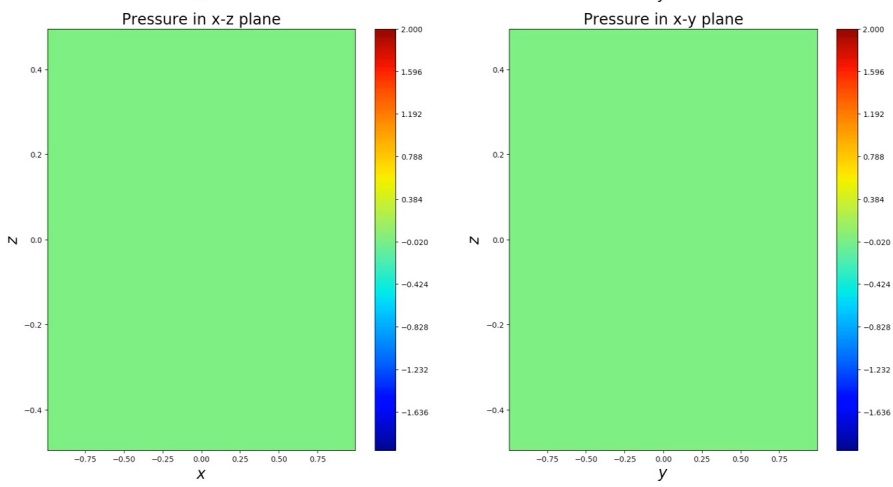
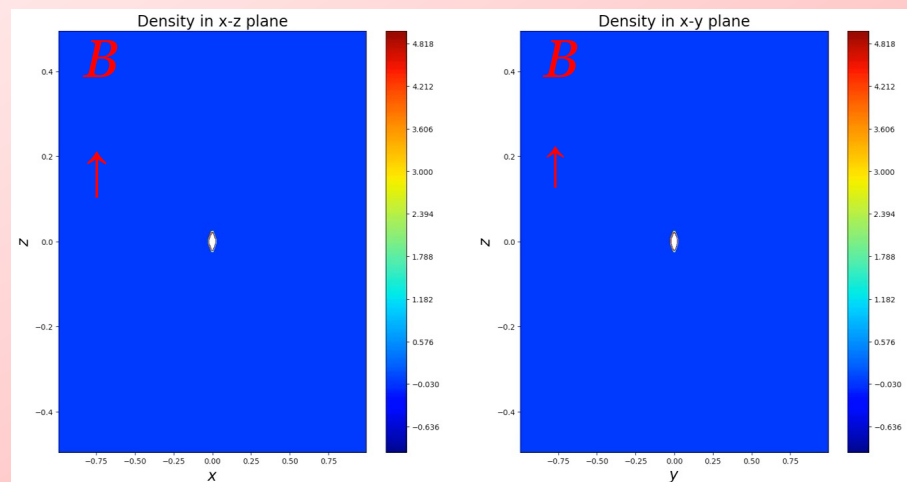
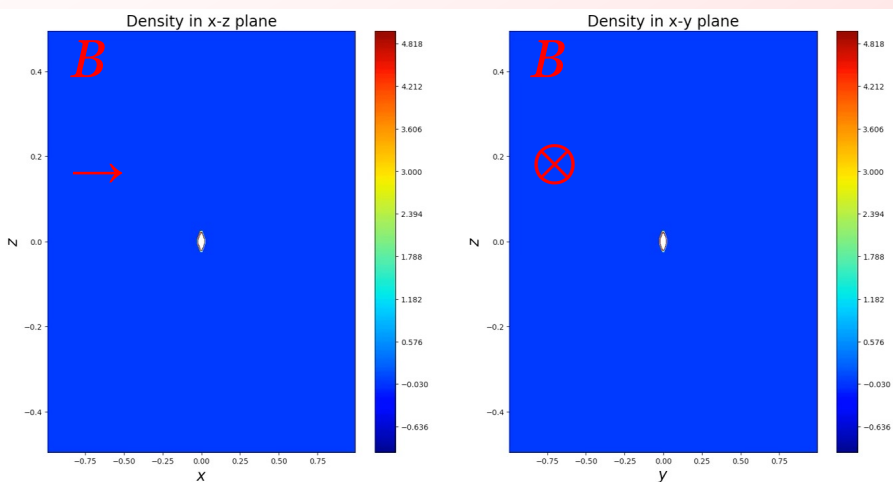
一つにして詳しく調べる



3D:  $\sigma_{\text{jet}} = 0.1, \beta_{\text{jet}} = 4, \Gamma_{\text{jet}} = 3$

$\Phi_B = \pi/2$

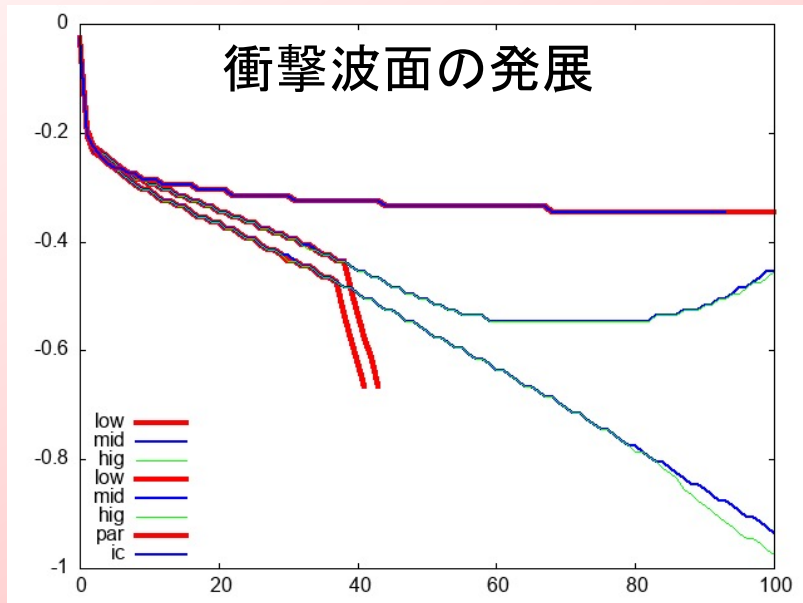
$\Phi_B = 0$



# Blob $\rightarrow$ Pole

次元性の効果?

- 磁場
- 速度場
- Poleの向き

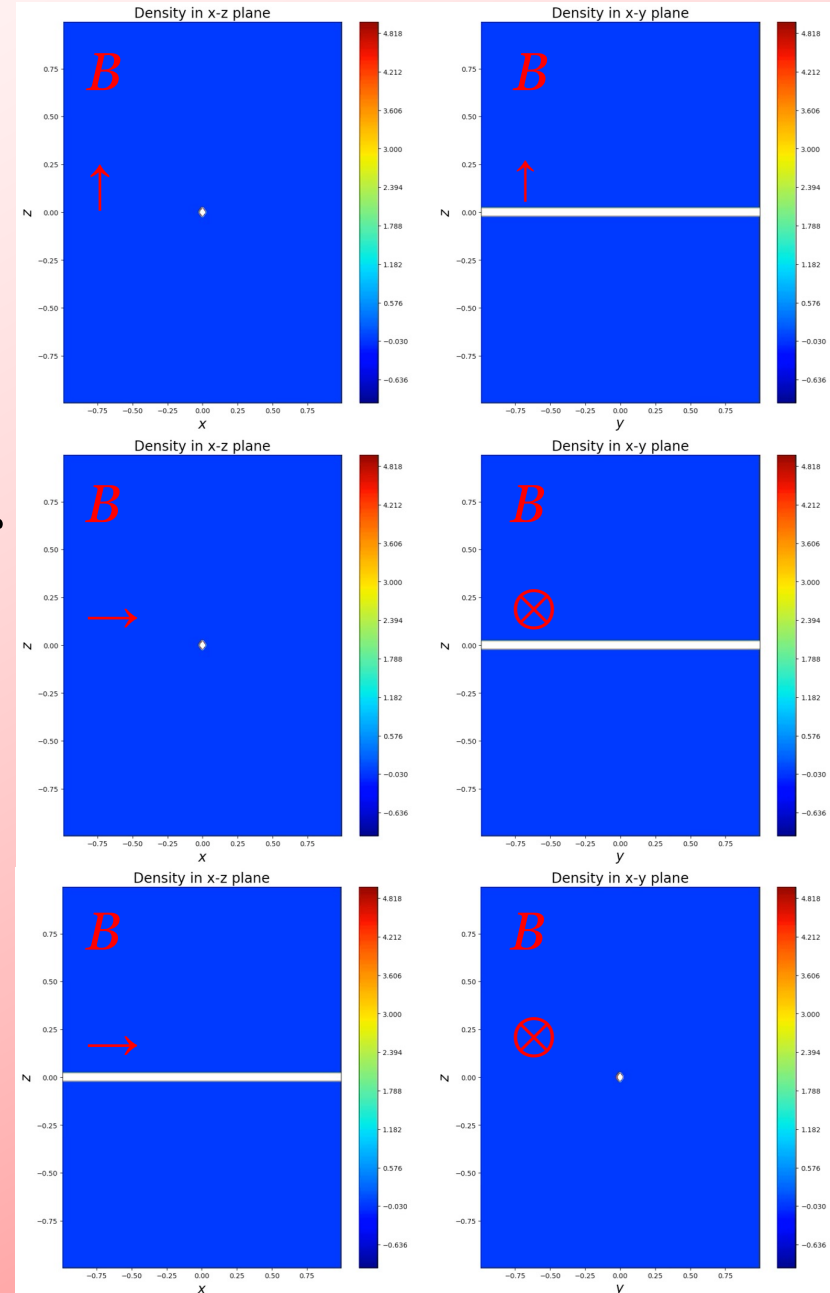


parallel

undular

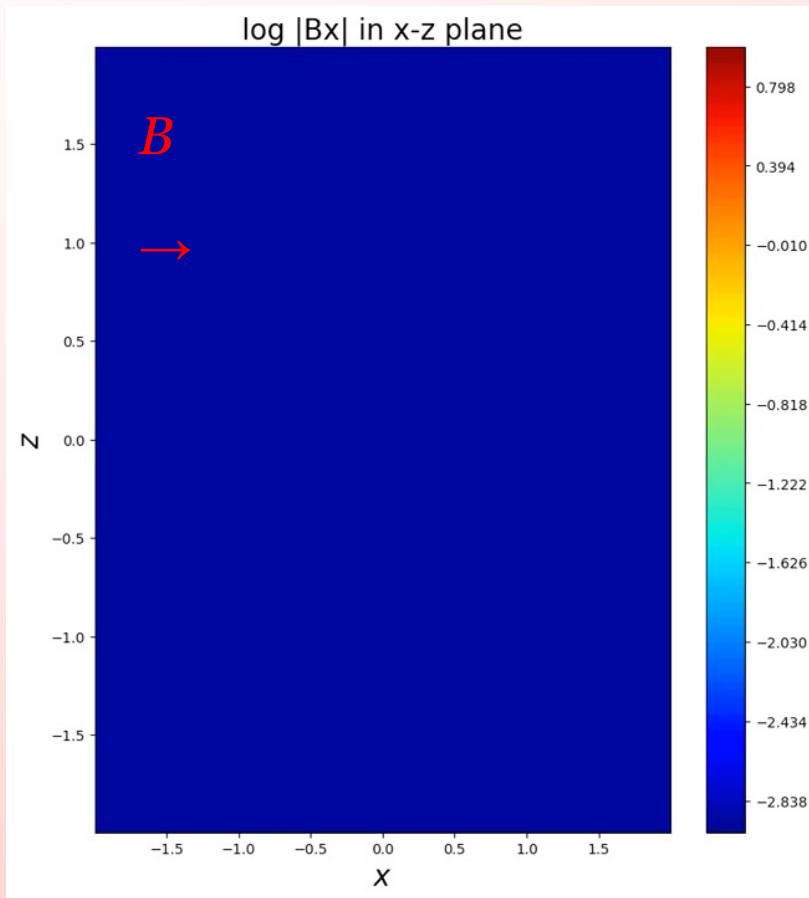
inter-  
change

$\rho$

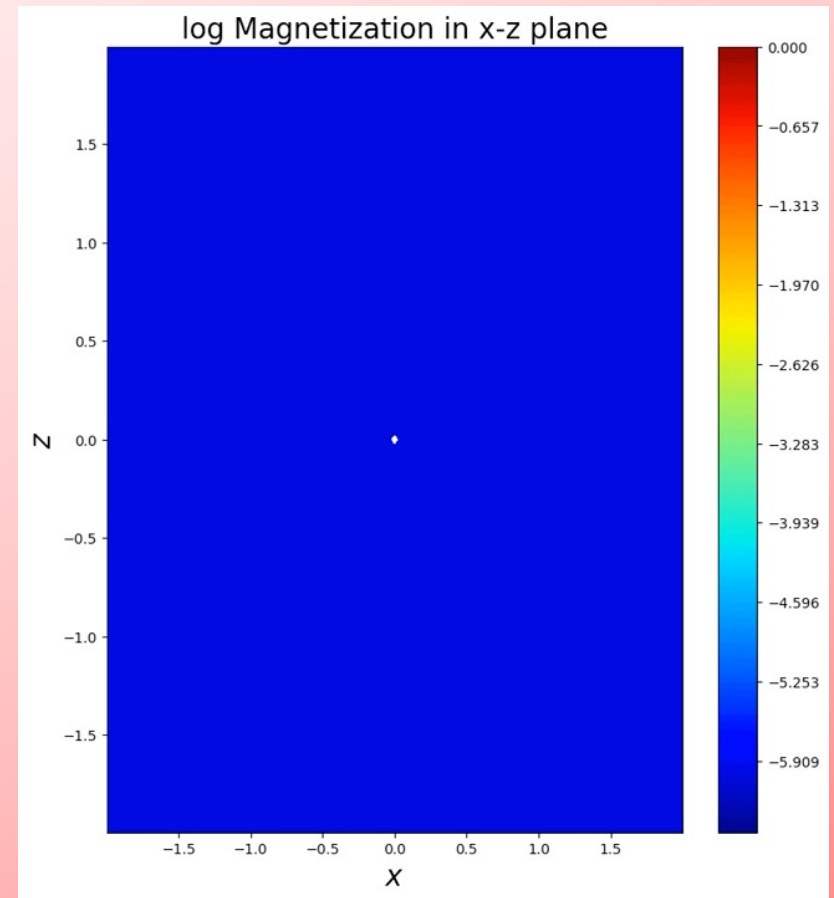


$$\sigma_{\text{jet}} = 10^{-6}, \beta_{\text{jet}} = 10^3, \Gamma_{\text{jet}} - 1 = 10^{-1}$$

$B_x$



$\sigma$



# Summary

- 超音速流に乱流を起こしたかった。
  - Numerical studyでBlobを置くのは最善ではないかも.
- 2D shock tube problem
- Gamma-ray binaryやLaboratory Experiments?