コラプサーモデルにおける相対論的ジェットの伝搬

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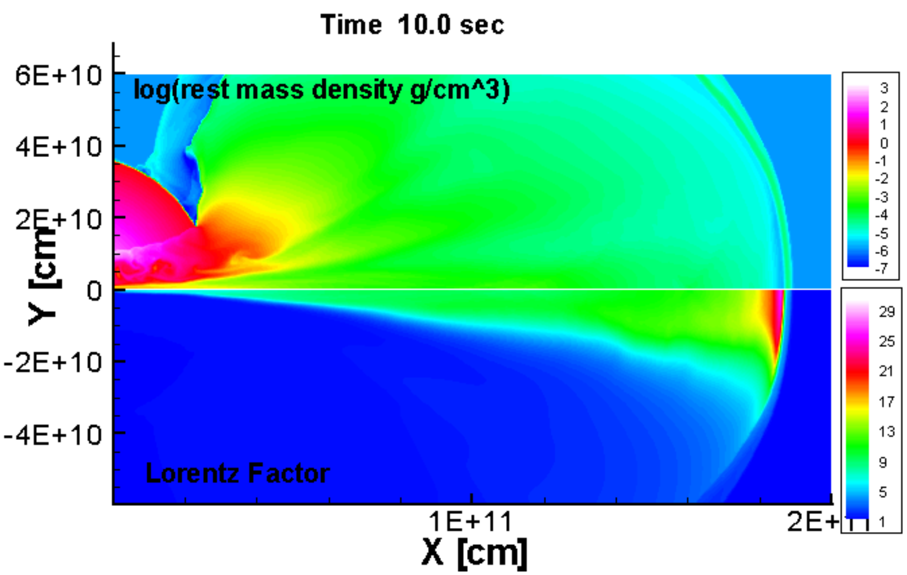

<u>Outline</u>

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Summary

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Introduction

Gamma-ray bursts(GRBs) are one of the brightest phenomena in the universe. $E\_iso \sim 10^{51-53}$ erg

- observed ~1000 events / year
- at cosmological distance
- two types by duration

  long burst longer than a few sec.

  short burst shorter than a few sec.
- Host galaxies are star forming galaxies (Bloom et al. 2002)
- Relativistic collimated flow = **Jet**

  (Γ ~a few hundred)

The central engine is not perfectly understood yet. But some observational evidences attract us the collapasrs model (a death of massive star).

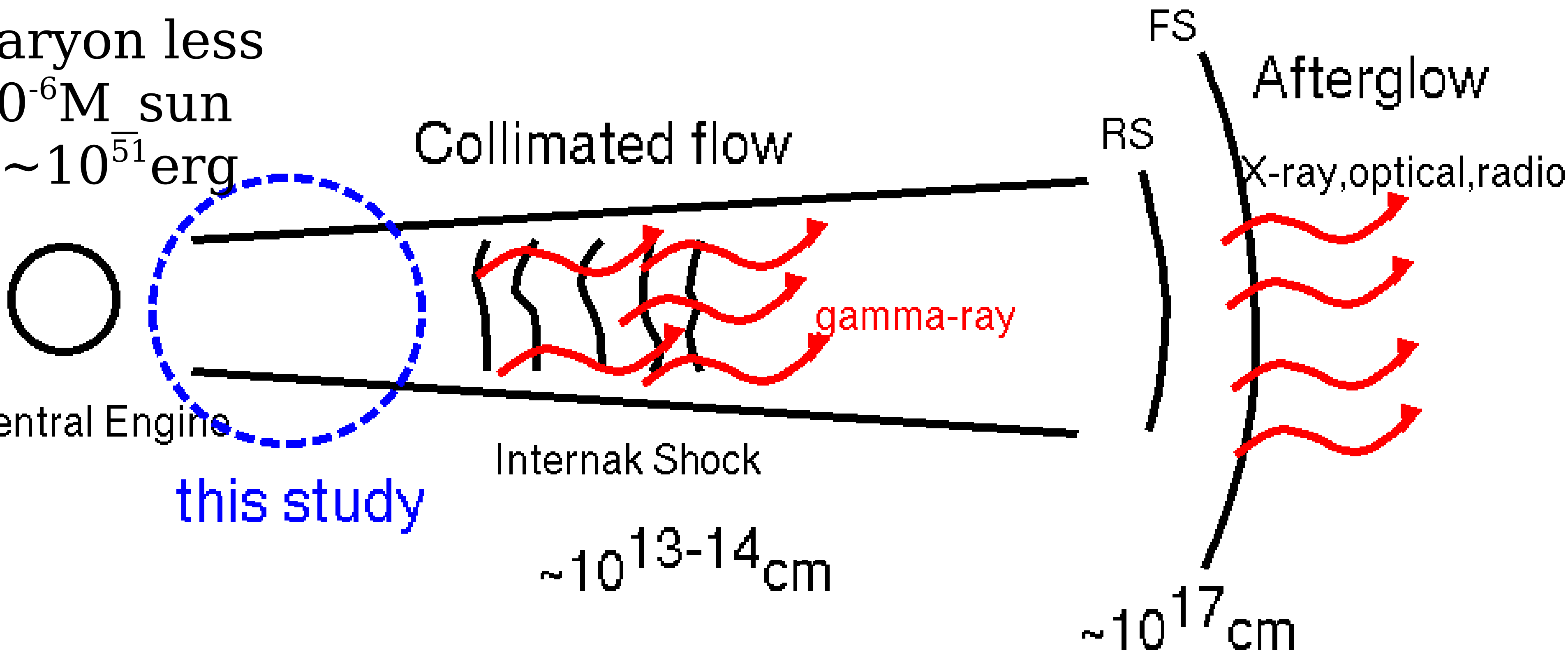
GRBs associated with SNe

GRB980425 and SN1998bw

GRB030329 and SN2003dh

GRBs : standard fireball & jet model

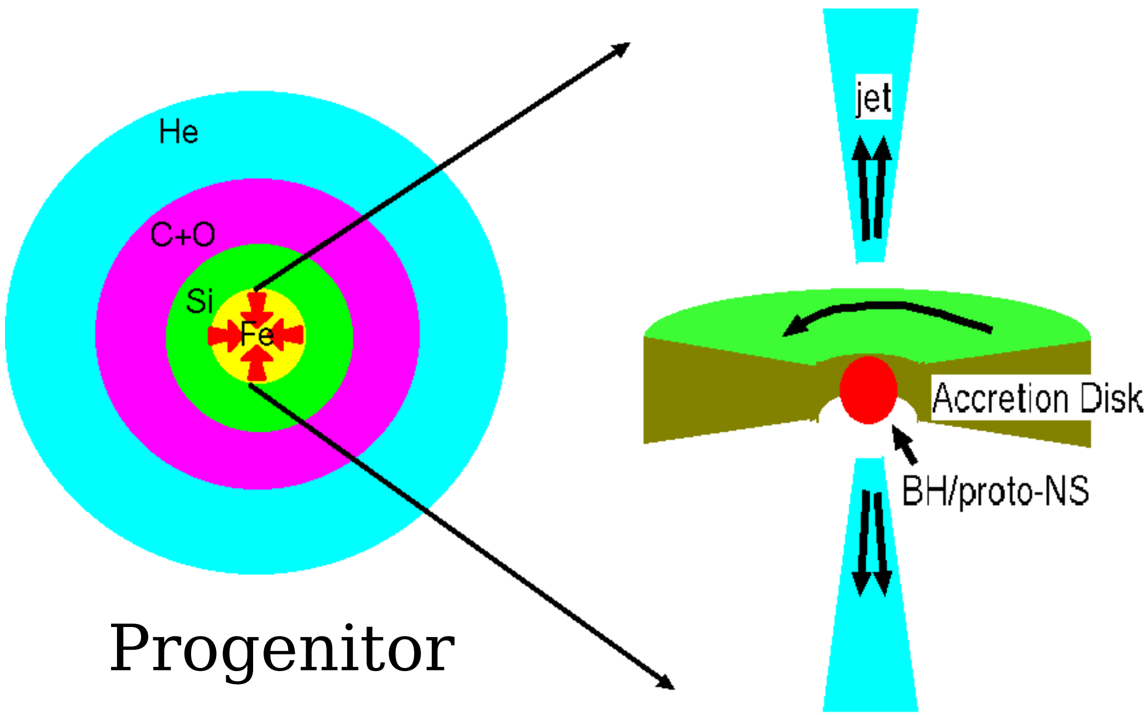
baryon less
10^{-6}M_sun
E~10^{51}erg



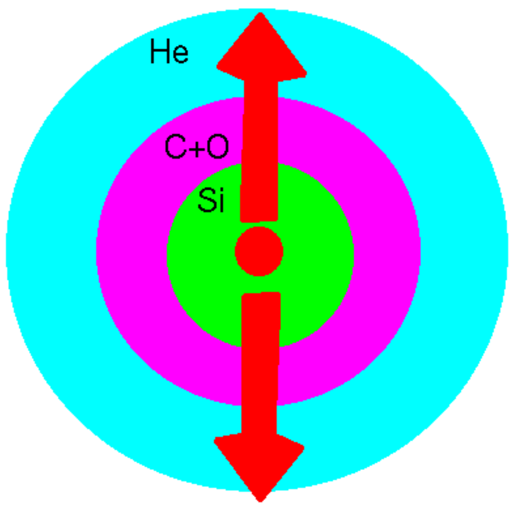
Gamma-rays : internal shocks
shell-shell collision
X-ray, optical radio : external shock

Central Engine Collapsar ?
Association GRB980425 and SN1998bw
GRB030329 and SN2003dh

Collapsar model (Wooseley 1993, MacFadyen et al. 1999)



accretion disk
about 10~20 secs



Fe core collapses and becomes BH/proto-NS
Outer layers begin to free-fall.

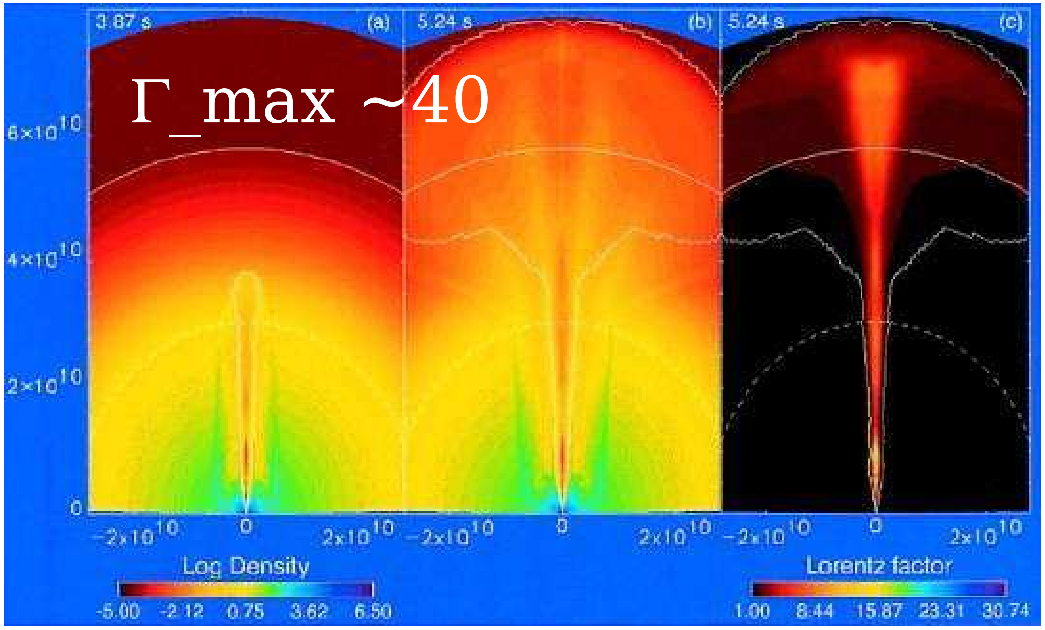
Due to rotation of the progenitor, accretion gas is expected to form an accretion disk

Free-fall time scale
$\sim 1/\mathrm{sqrt}(\rho G)$

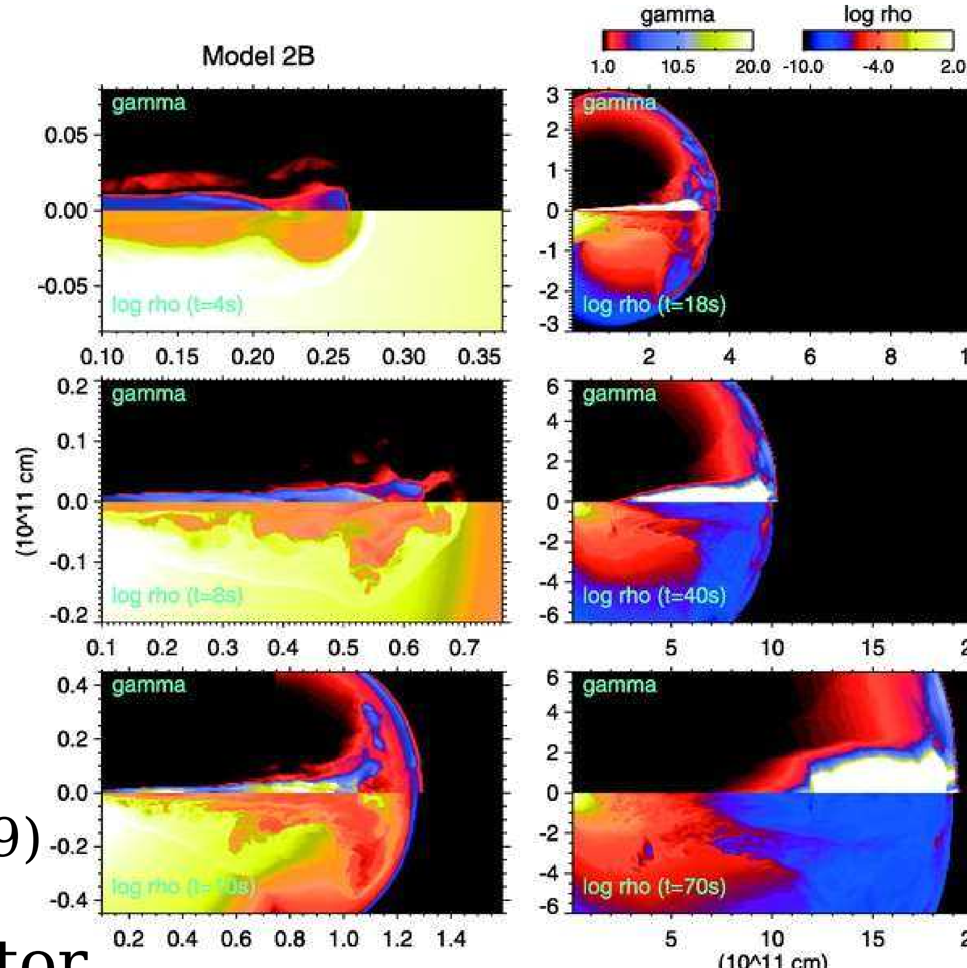
MHD and/or another effect form bipolar jets.

This jet should propagate in the progenitor !

Two types of approaches by ReHD:
thermal energy deposition & injected jet



Aloy et al. (ApJL 2000)
(thermal energy deposition)
Relativistic version : MacFadyen (1999)



Zhang et al. (a jet injected)

An emerging jet from the center should propagate in the progenitor and erupt to ISM.

What type of jets should be formed in the center of collapsing star ? (Our main purpose of this study)

Initial Condition

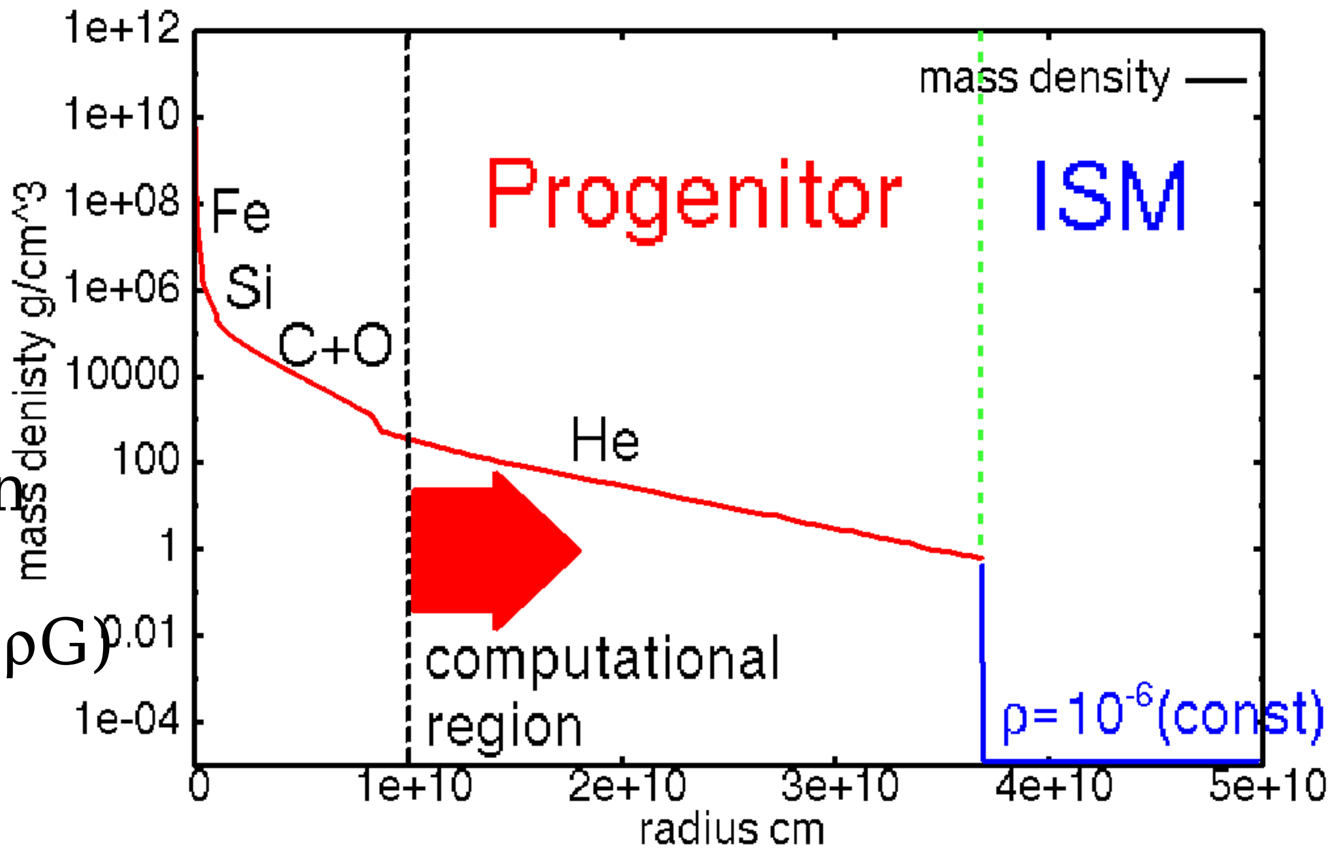
Core collapse SNe

1. Fe core collapses and forms a BH or proto-neutron star (1~3 M_sun)

2. Outer layers begin to free-fall time scale ~1/sqrt(ρG)

3. An accretion disk is formed.

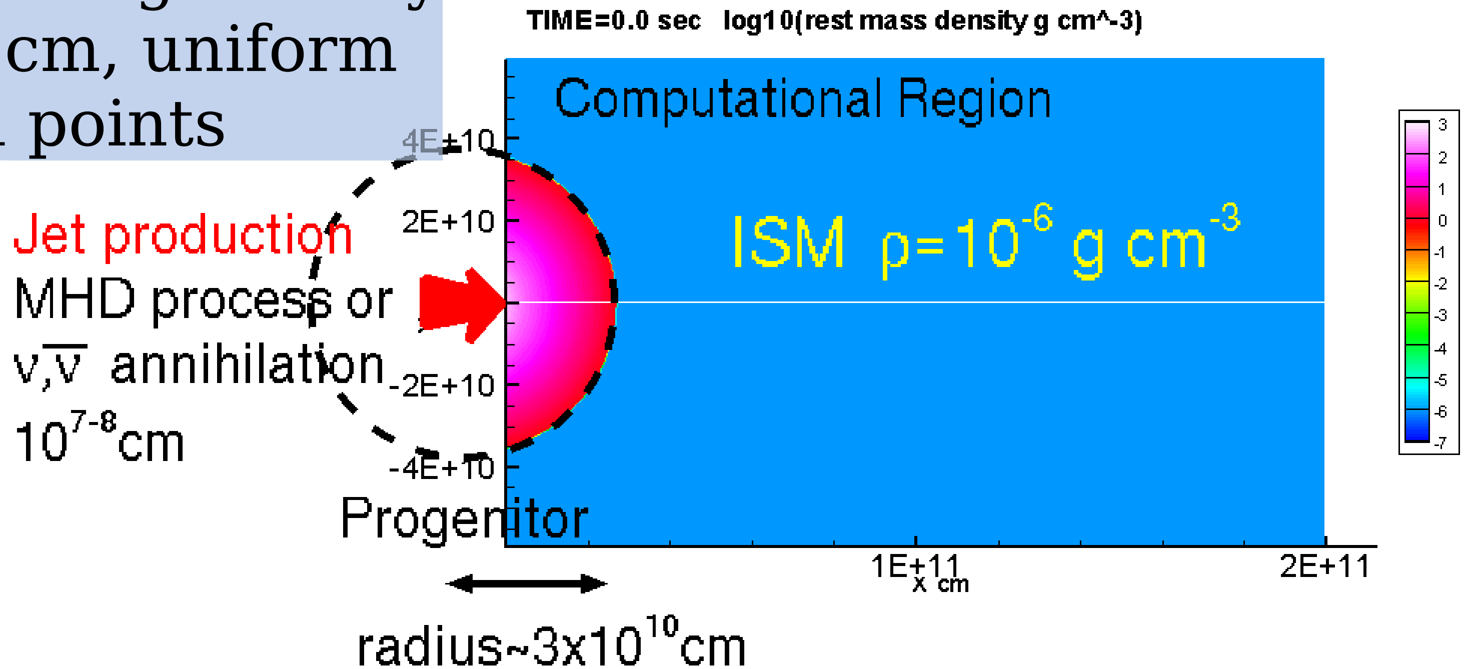
4. A jet is formed by MHD and/or another effects



Progenitor Hashimoto et al. (1997)
40M_sun at main sequence
16M_sun presupernova

Initial Condition cont.

2D axisymmetric geometry
dx=dy = 1.E8 cm, uniform
600x2000 grid points



Relativistic hydrodynamic Eq.
P=(γ-1) ρ ε γ = 4 / 3 (const)
Godunov type code
Marquina's flux formula
2nd order accuracy in space
Mizuta et al.(2004)

$$\frac{\partial(\rho\Gamma)}{\partial t} + \frac{1}{r}\frac{\partial r(\rho\Gamma v_r)}{\partial r} + \frac{\partial(\rho\Gamma v_z)}{\partial z} = 0$$

$$\frac{\partial(\rho h\Gamma^2 v_r)}{\partial t} + \frac{1}{r}\frac{\partial r(\rho h\Gamma v_r^2 + p)}{\partial r} + \frac{\partial(\rho h\Gamma^2 v_r v_z)}{\partial z} = \frac{p}{r}$$

$$\frac{\partial(\rho h\Gamma^2 v_z)}{\partial t} + \frac{1}{r}\frac{\partial r(\rho h\Gamma^2 v_r v_z)}{\partial r} + \frac{\partial(\rho h\Gamma^2 v_z^2 + p)}{\partial z} = 0$$

$$\frac{\partial(\rho h\Gamma^2 - p)}{\partial t} + \frac{1}{r}\frac{\partial r(\rho h\Gamma^2 v_r)}{\partial r} + \frac{\partial(\rho h\Gamma^2 v_z)}{\partial z} = 0$$

Injected Jet Condition

Fixed parameters

- $dE/dt = 1.0 \times 10^{50}$ erg / sec,
  where $E = E_{kin} + E_{th} + E_{rest}$
  follow 10secs
  $E\_tot = 1.0 \times 10^{51}$ erg
- $R\_b = 8.0 \times 10^{8}$ cm

$\Gamma_{max} \sim \Gamma (1 + \varepsilon / c^2)$
free expansion

cf .SNe
v~sqrt(E / M),
where $E = E_{kin} + E_{th}$

We vary Γ, and ε / c^2 of the jet

Dense ⟷ Dilute

ε/c^2 \ Γ	1 (v=0.3c)	5 (v~0.97c)
0.1	progenitor	progenitor/ISM
1	progenitor	progenitor/ISM
5	progenitor	progenitor/ISM
10		progenitor/ISM

↕ Dilute

ε / c^2 >~ 1 relativistic temperature

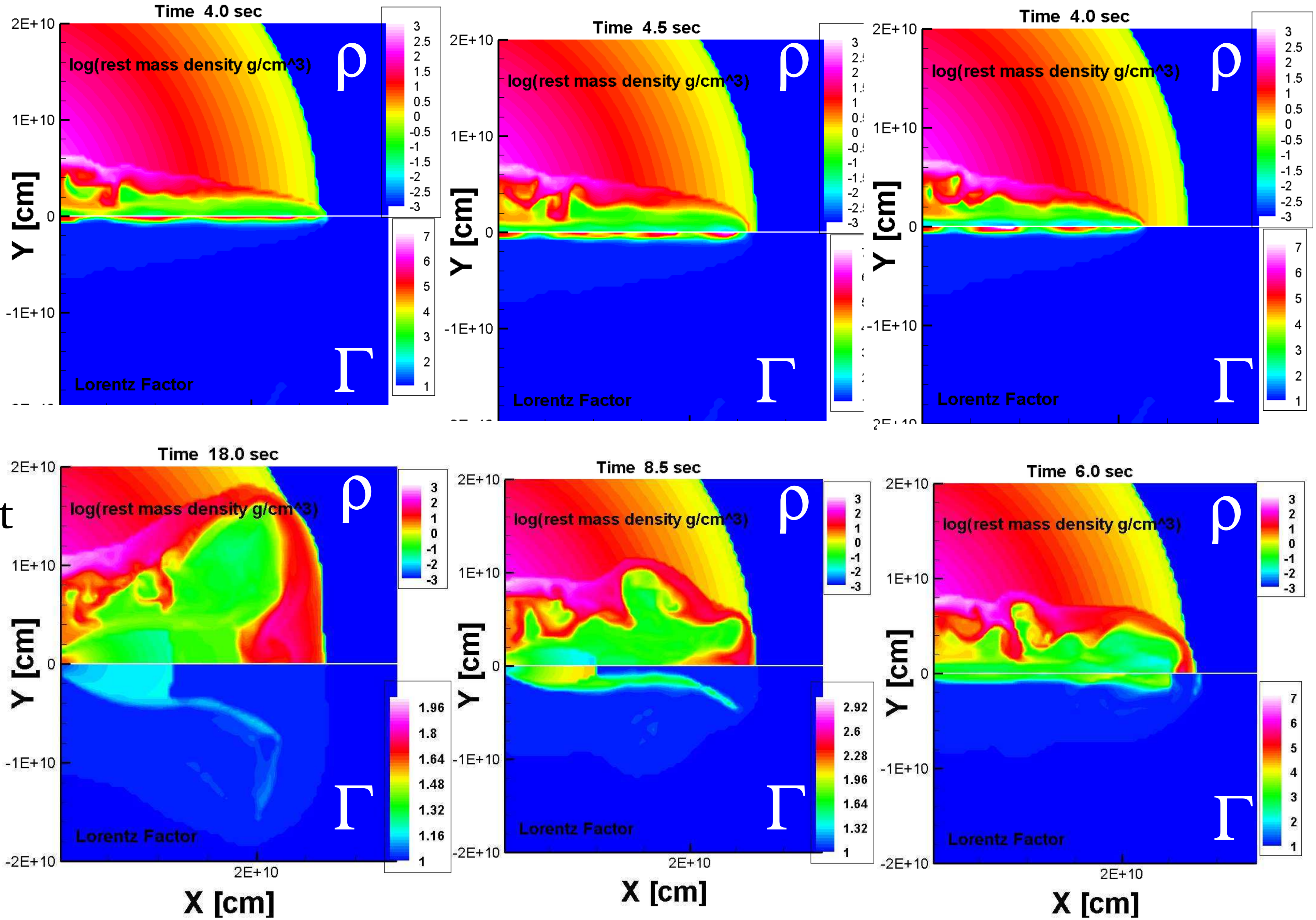
Γ : bulk Lorentz factor
ε : specific internal energy

During the propagation in the progenitor

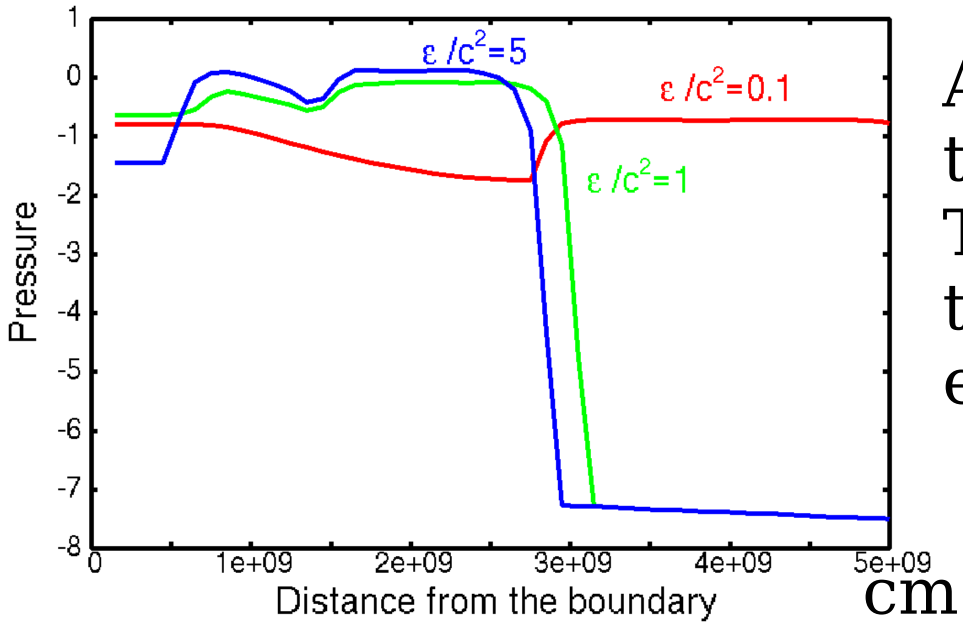
ε_jet/c²=0.1 | ε_jet/c²=1 | ε_jet/c²=5

Γ_jet =5

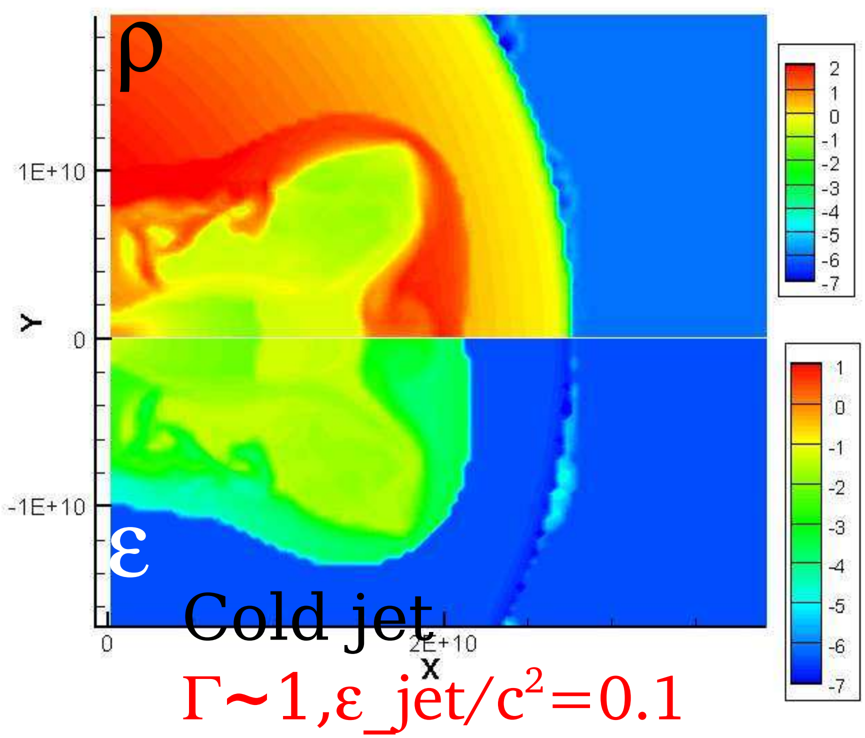
Γ_jet ~1 (v= 0.3c)

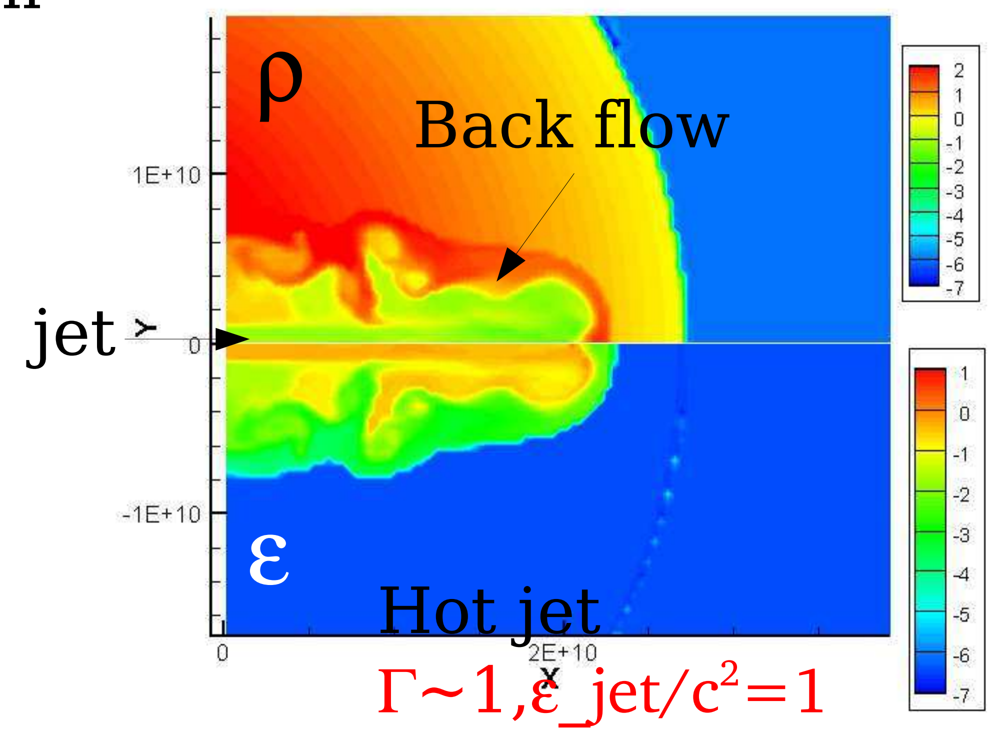


A hot jet can drive progenitor gas effectively

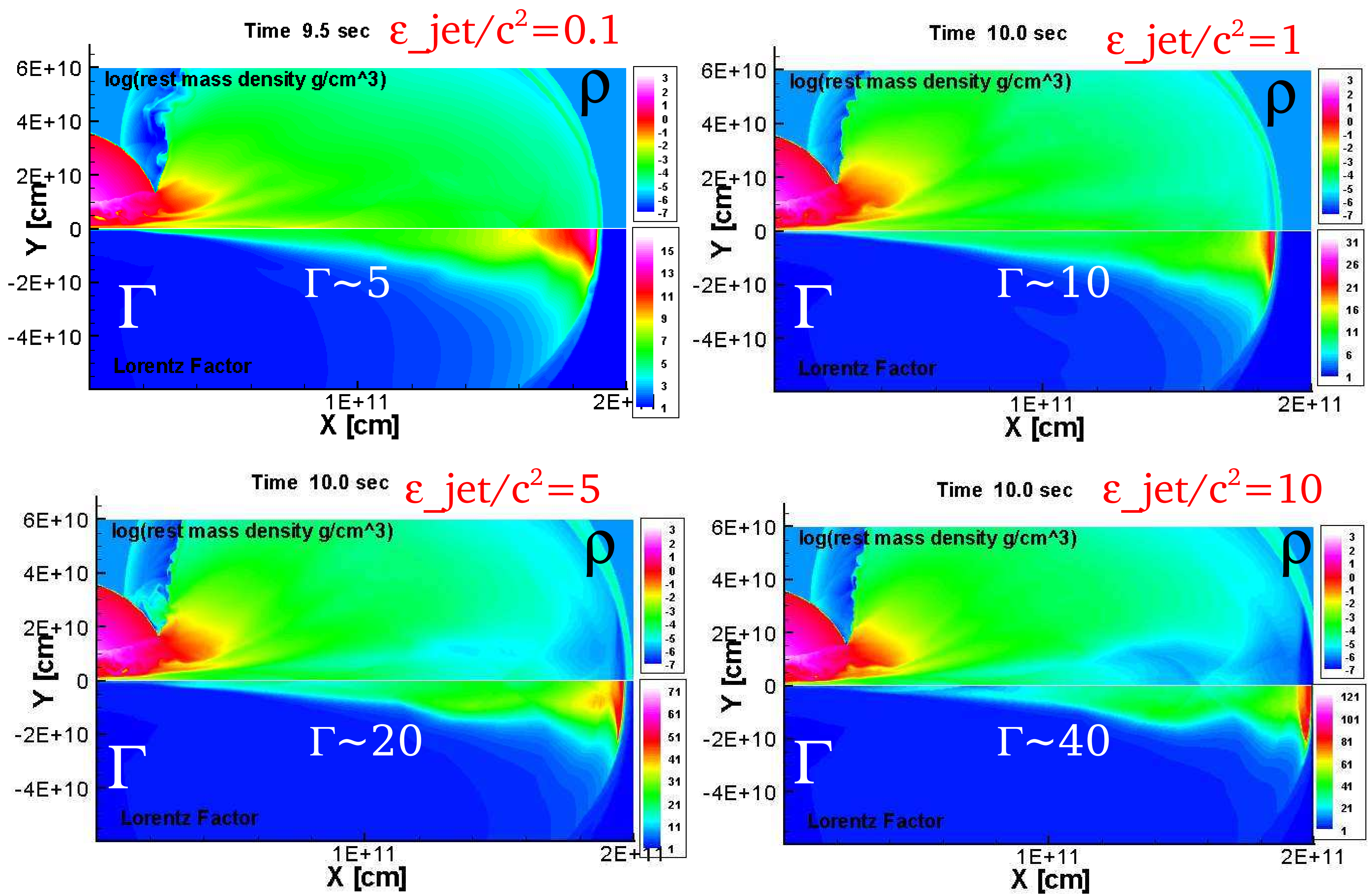


As the internal energy increases, the pressure also increases. Then the plasma can expand to the propagation direction effectively.

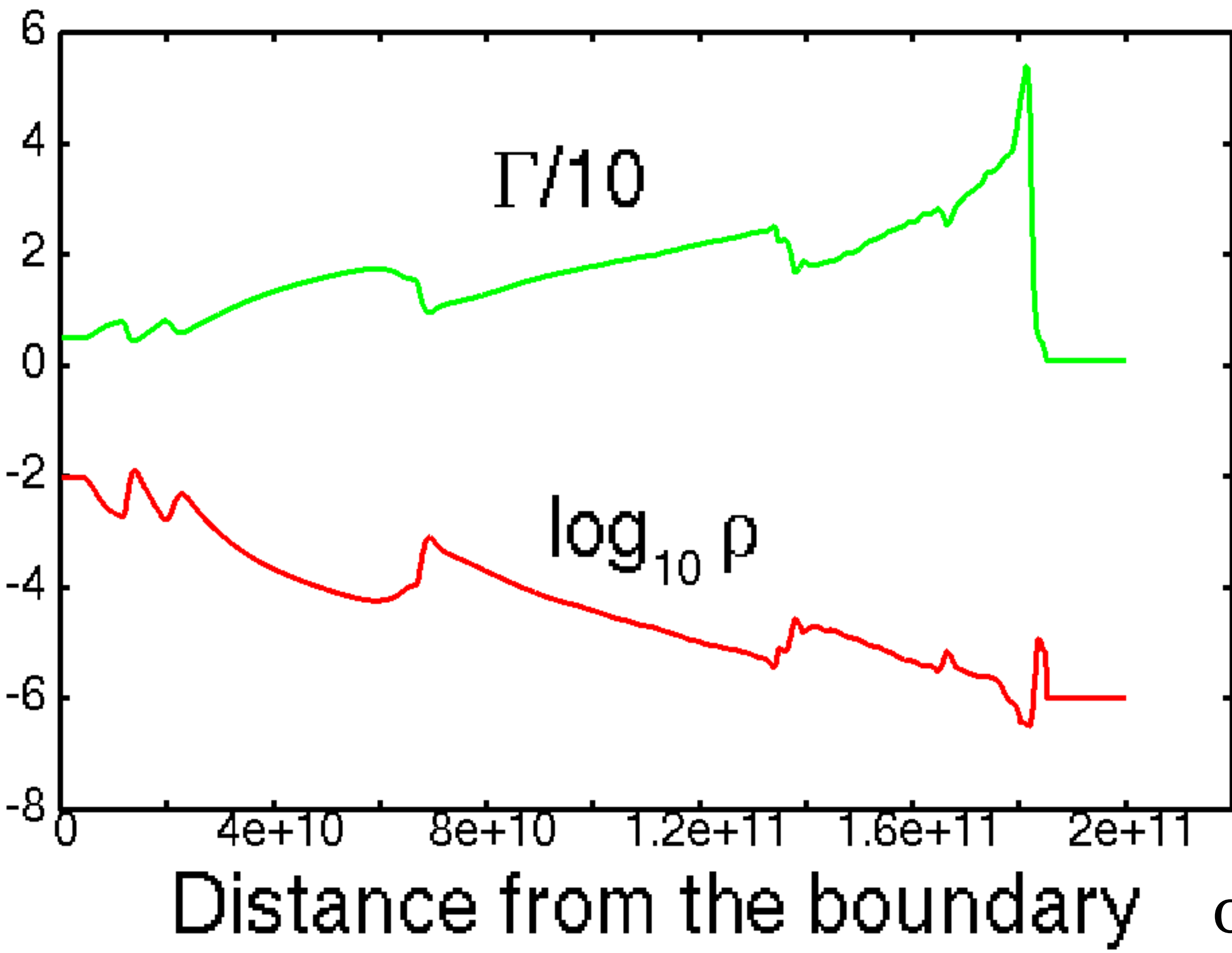




After eruption from the progenitor (Γ=5)



Internal structure of the jet



cm

During the propagation in the progenitor, internal structure appears (oblique shocks).

Is this the origin of the valiability of the prompt emission ?

$\Gamma=5, \ \ \varepsilon/c^2=5$

Summary

In the progenitor

- During the propagation in the progenitor, the jet is so-called `light jet'.
  (=>internal structure : origin of variability ?)
- A hot jet is preferred to collimate for the non-relativistic jet.

After the eruption

- After the eruption of the progenitor, a thermal expansion occurs.
- Relativistic flow remains along the propagation direction.
- Maximum Lorentz factor is good agreement with simple relation $\Gamma (1+\varepsilon /c^2)$

Future work

- More wide range parameter space should be studied
- Observational discussion may be possible.
  (Precursor, nucleosynthesis)