

Relativistic Jet Simulations in Gamma-Ray Bursts

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Gamma-Ray Bursts (GRBs)

✓ Extremely energetic gamma-ray flares

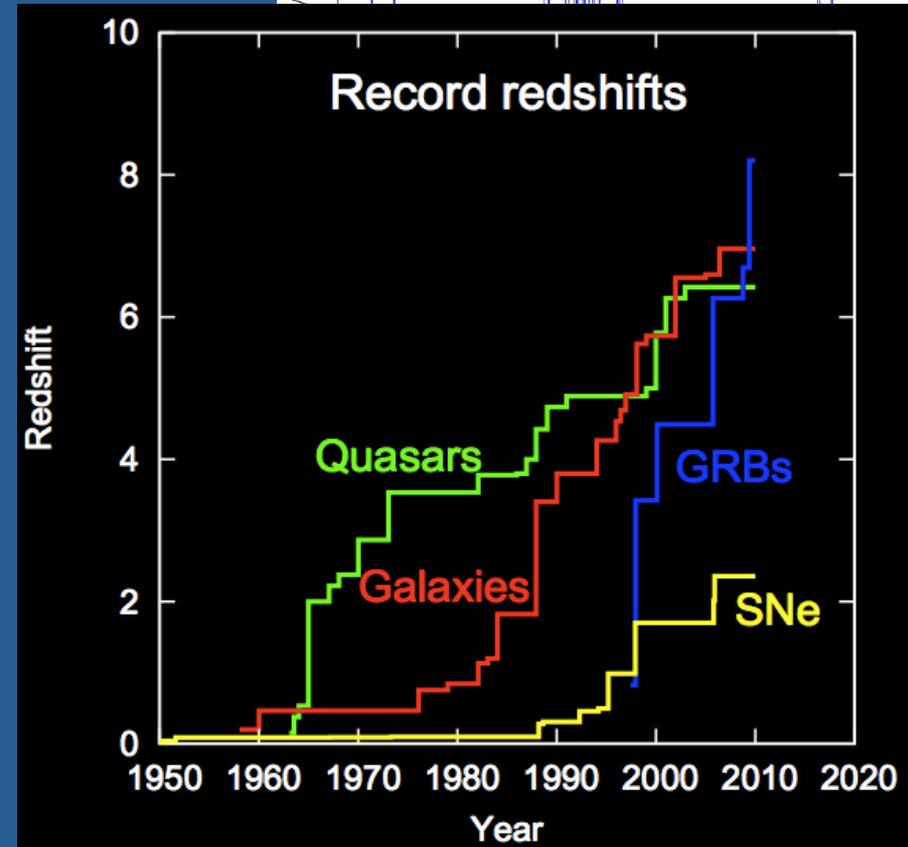
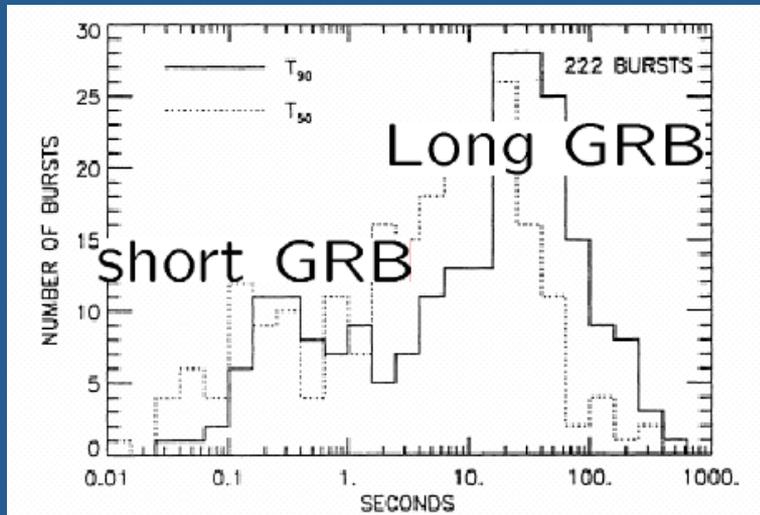
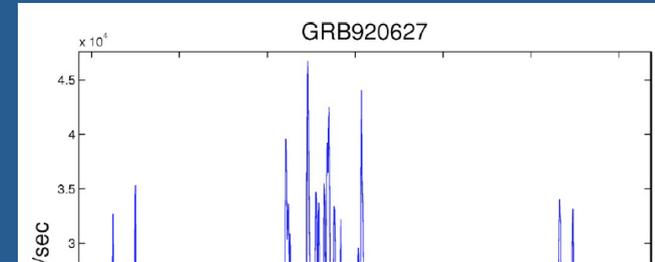
$$L \approx 10^{50-51} \text{ (erg / s)}$$

✓ Cosmological Events

✓ Bimodal distributions

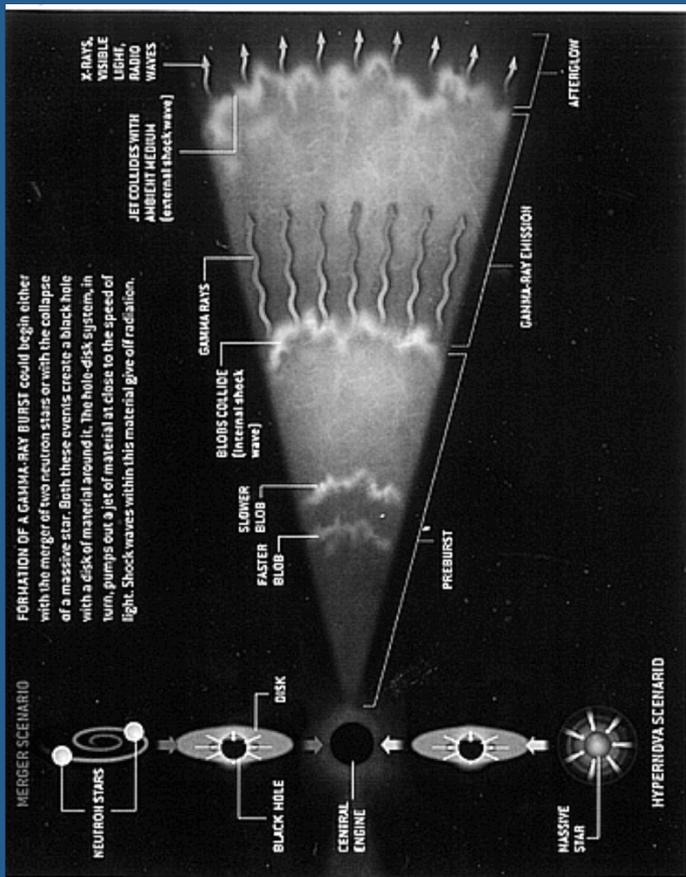
Short GRB, Long GRB

✓ Source of Gravitational Waves

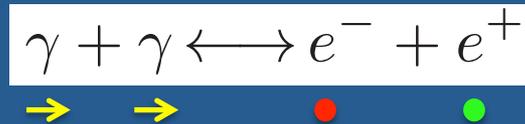


How GRBs can be produced?

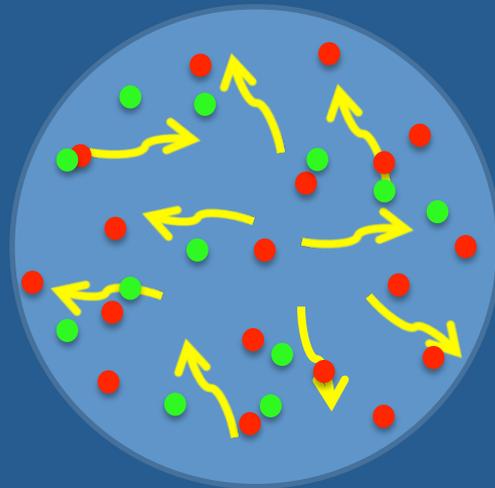
Gamma-rays must come from **Relativistic Jets**.
(collimated outflows with $v > 99.99\%c$)



For **Non-Relativistic** moving matter



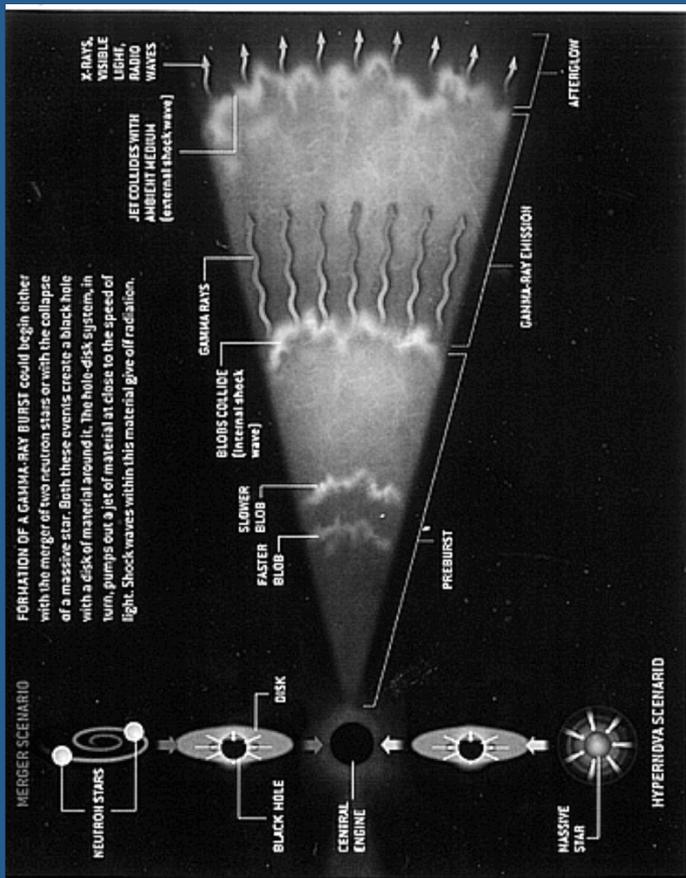
Electron-positron
pair creations



Thermal Emissions
(inconsistent with observations)

How GRBs can be produced?

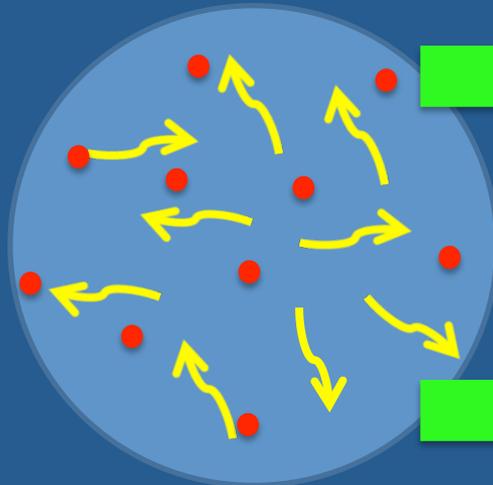
Gamma-rays must come from **Relativistic Jets**.
(collimated outflows with $v > 99.99\%c$)



For **High-Relativistic** moving matter

$$\gamma + \gamma \leftrightarrow e^- + e^+$$

~~Electron-positron pair creations~~



Fluid velocity

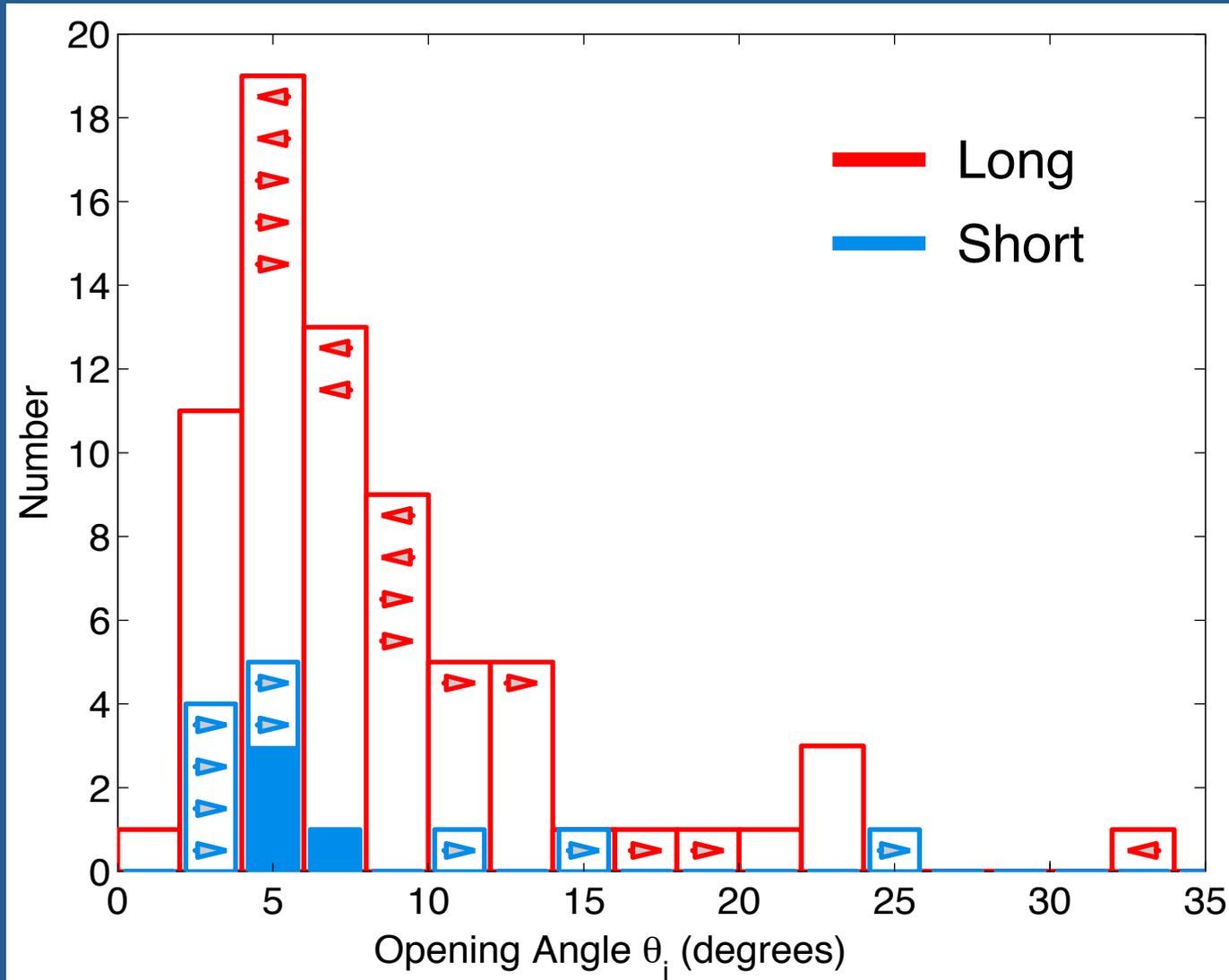


Fluid velocity

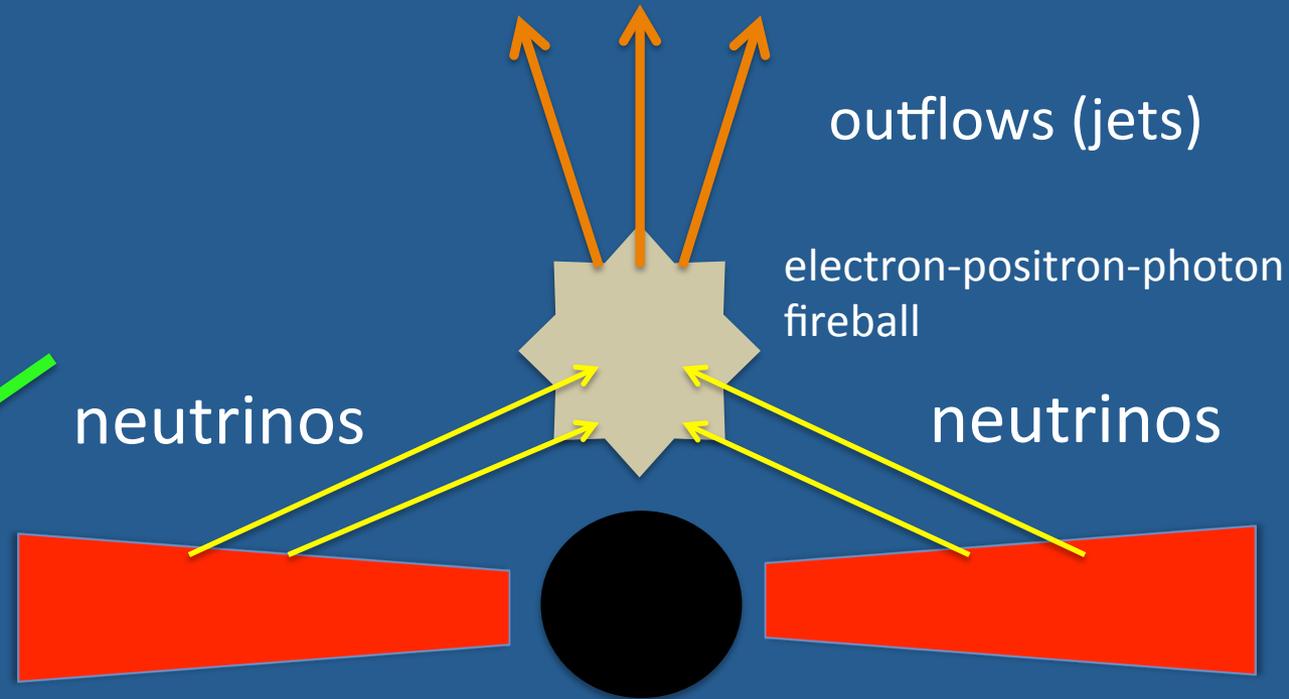
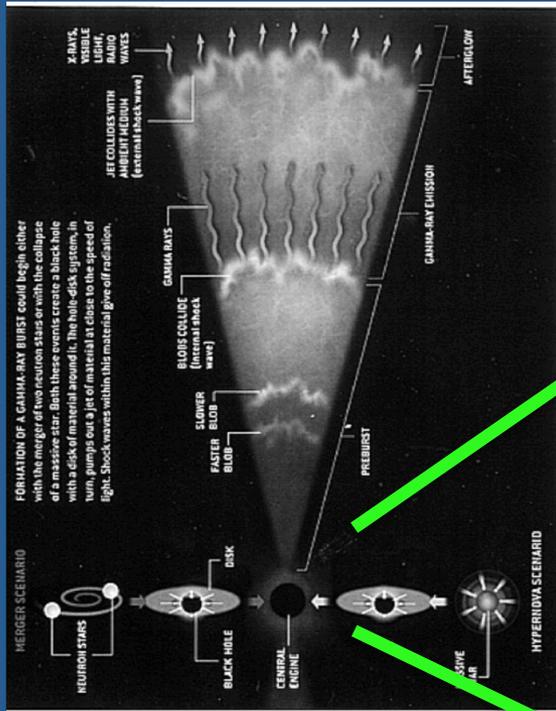
Non-Thermal gamma-rays
(Consistent with observations)

Observed opening angles of GRBs

(Berger 2013, Fong et al. 2013)



What is the **origin** of GRBs??



Long GRB: Death of Massive Stars

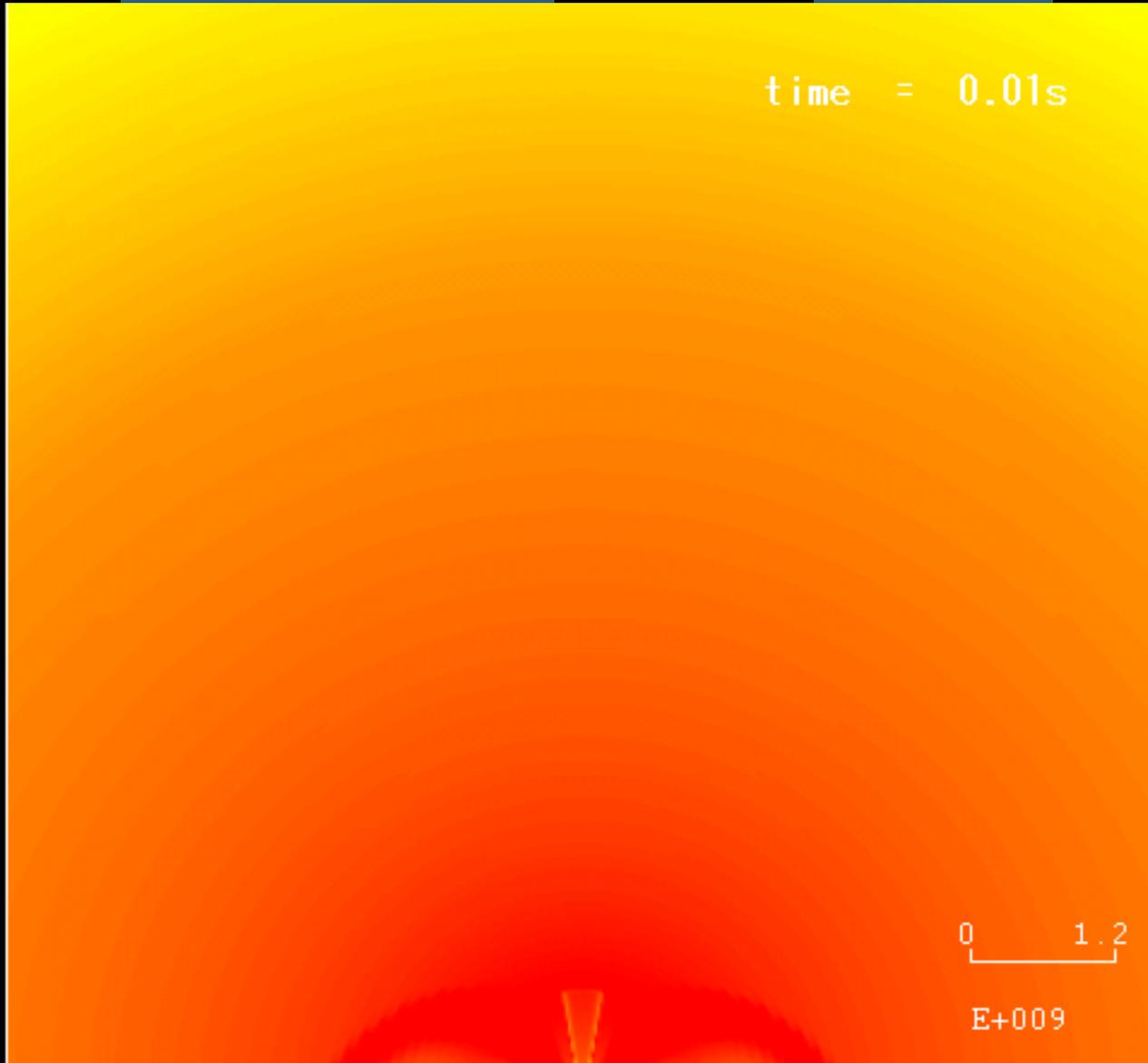
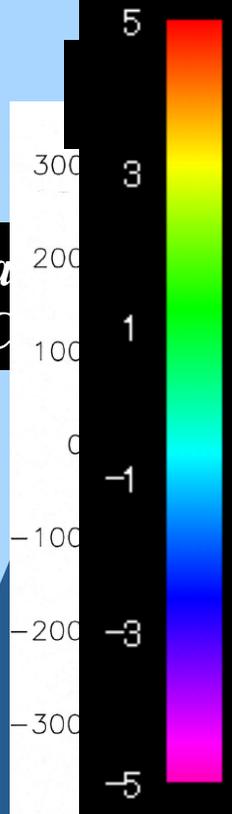
Short GRB: Mergers of double compact Stars

Long GRB: Collapsar Model

Woosley 1993

Rapidly rotating
mas

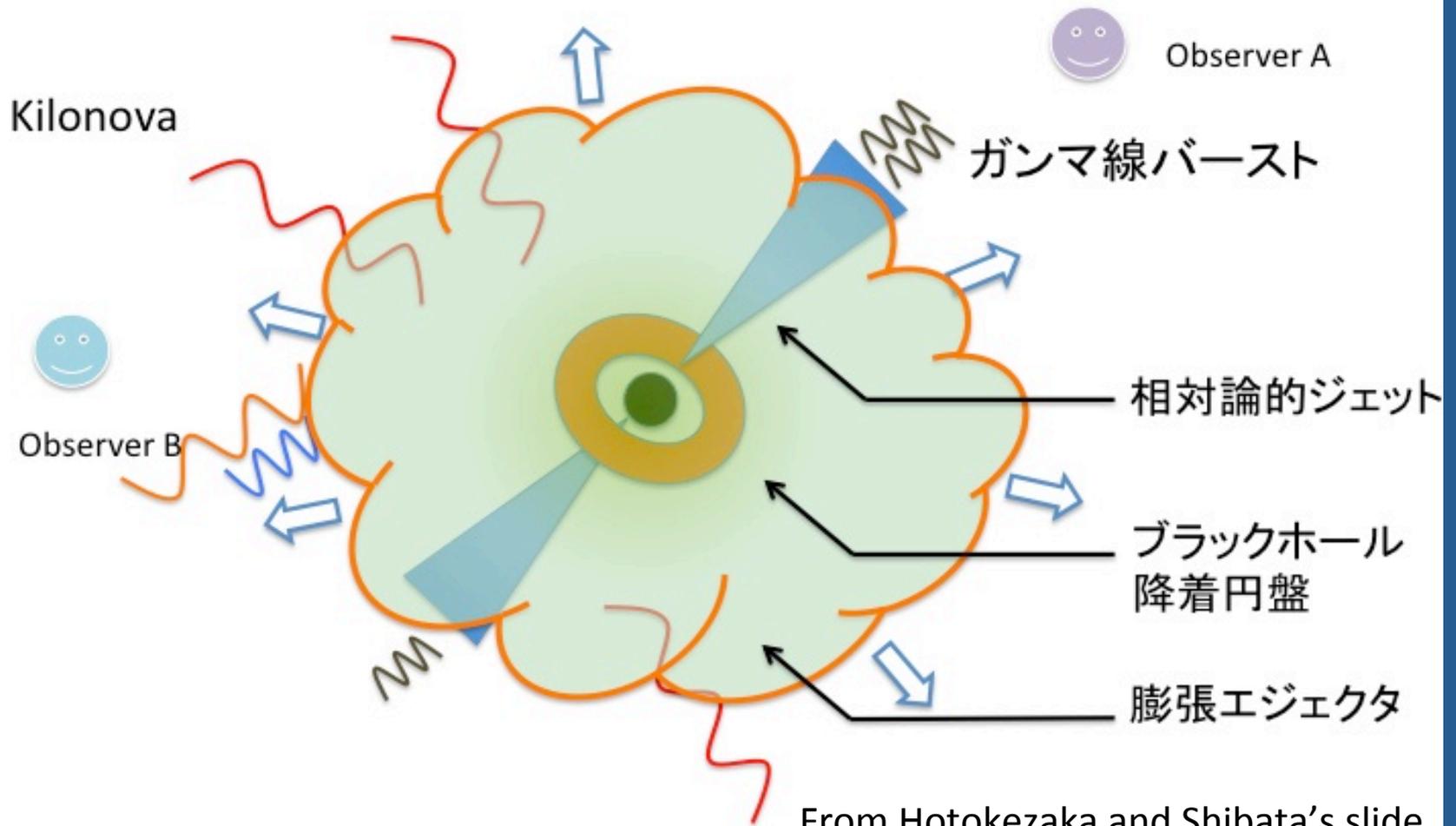
Gravitational
Collapse



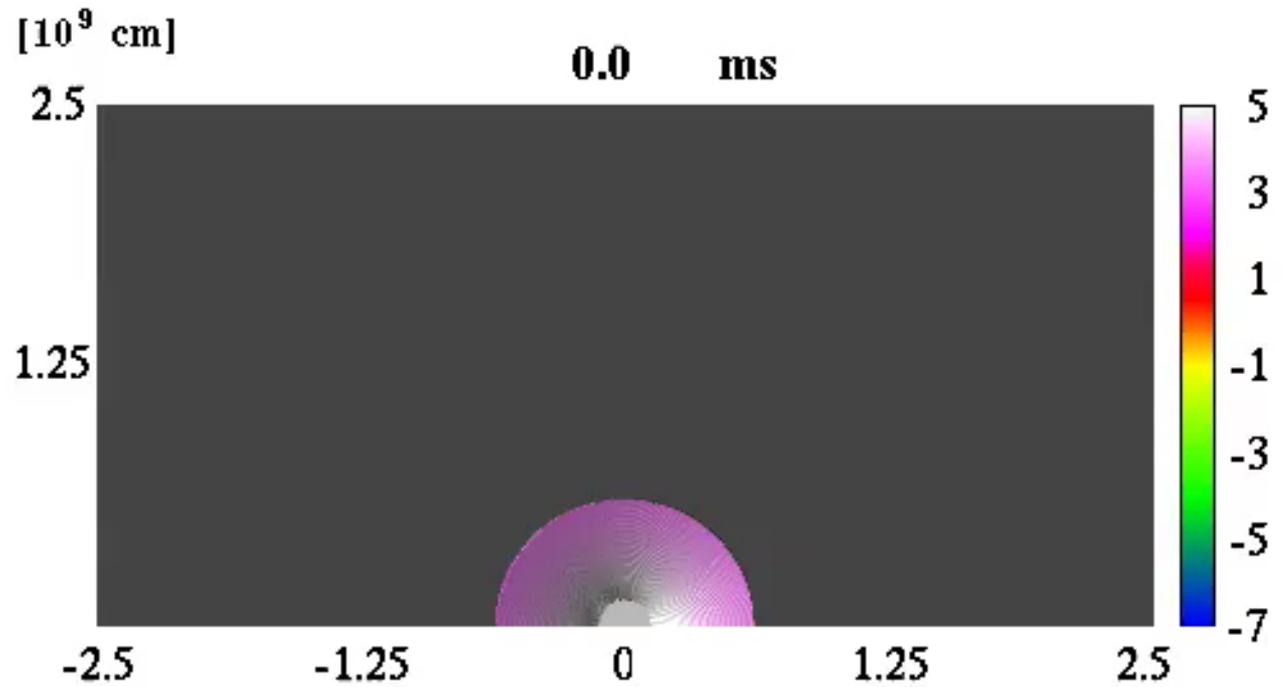
e

Jet

連星中性子星合体後の様子(想像図)

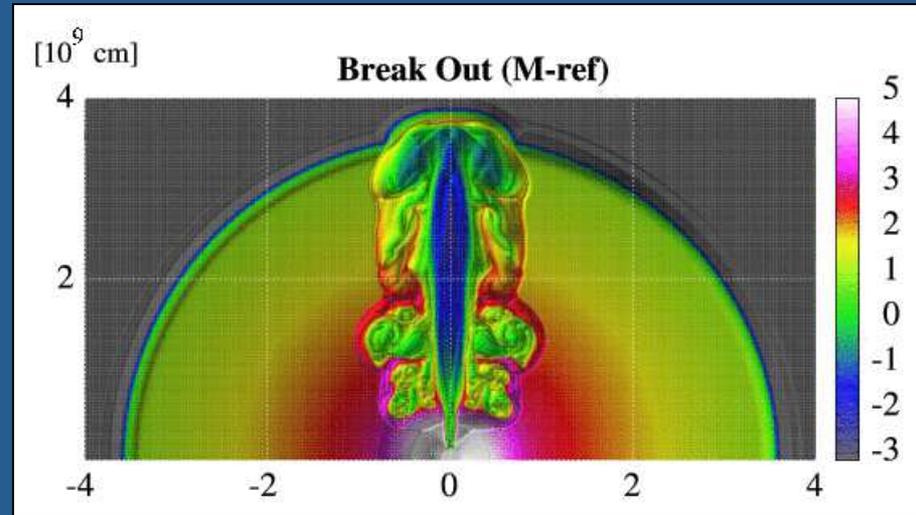
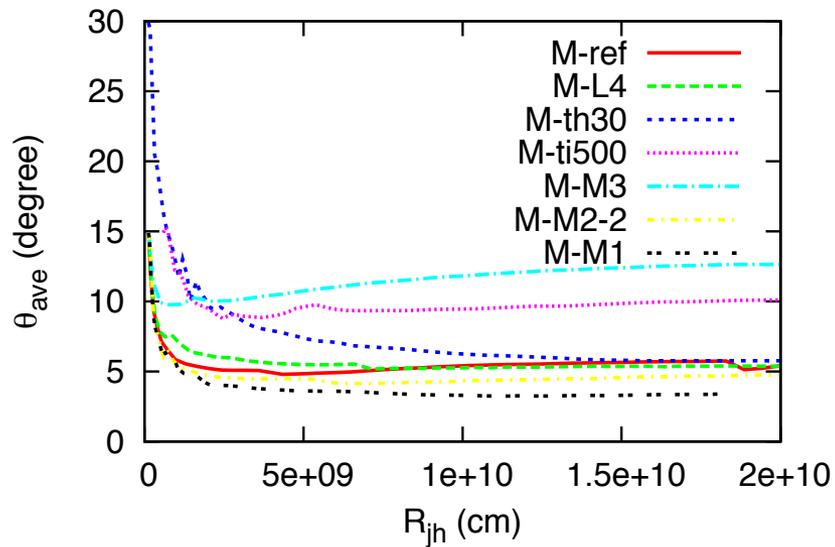
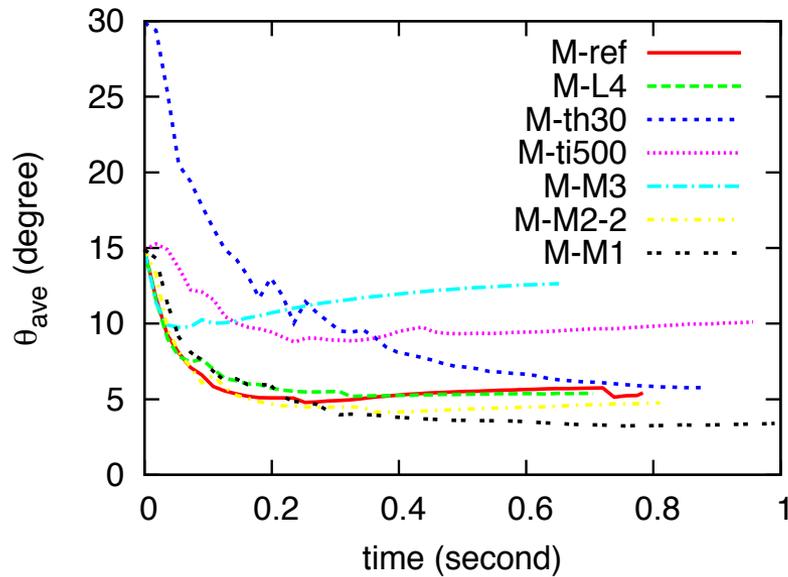


Animation by
Sekiguchi & Nagakura



$M=0.01M_{\text{sun}}$,
 $L=2.e50 \text{ erg/s}$,
 $\Theta=15^\circ$

Success of Jet Collimations



$$\theta_{ave}(t) \equiv \frac{\int_{r_{esc}}^{R_{jh}} \theta_{op}(t, r) dr}{R_{jh}(t) - r_{esc}},$$

Summary

1. GRBs are very high energy events with (probably) two populations
- 2 Relativistic Jets are mandatory for producing GRBs
3. Long GRBs are supposed to originate from the death of massive stars
4. Short GRBs, on the other hand, may come from compact binary mergers
5. We demonstrated the jet breakout and collimation due to the interaction with matter by relativistic hydrodynamical simulations