（ショート）
ガンマ線バースト

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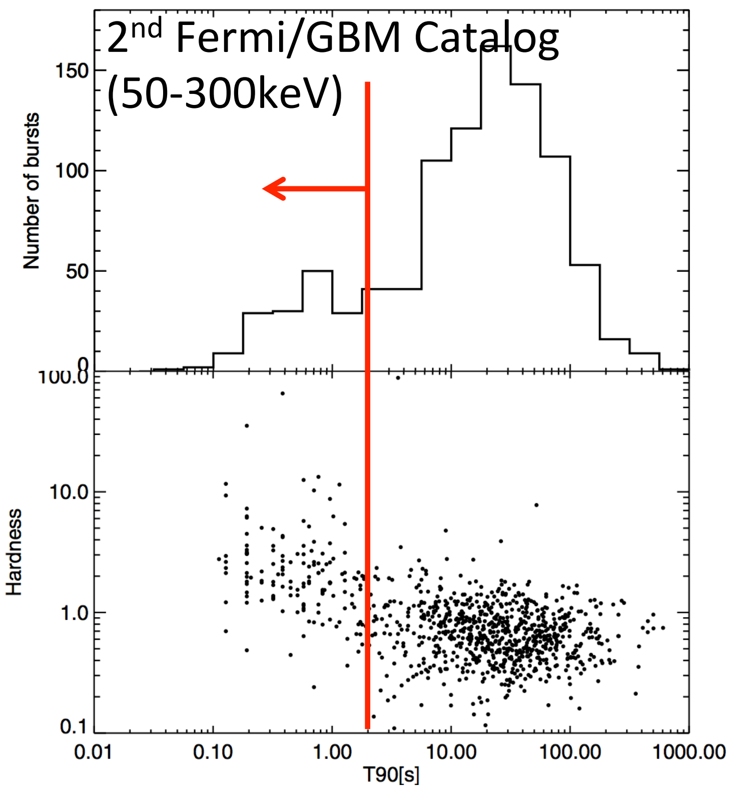
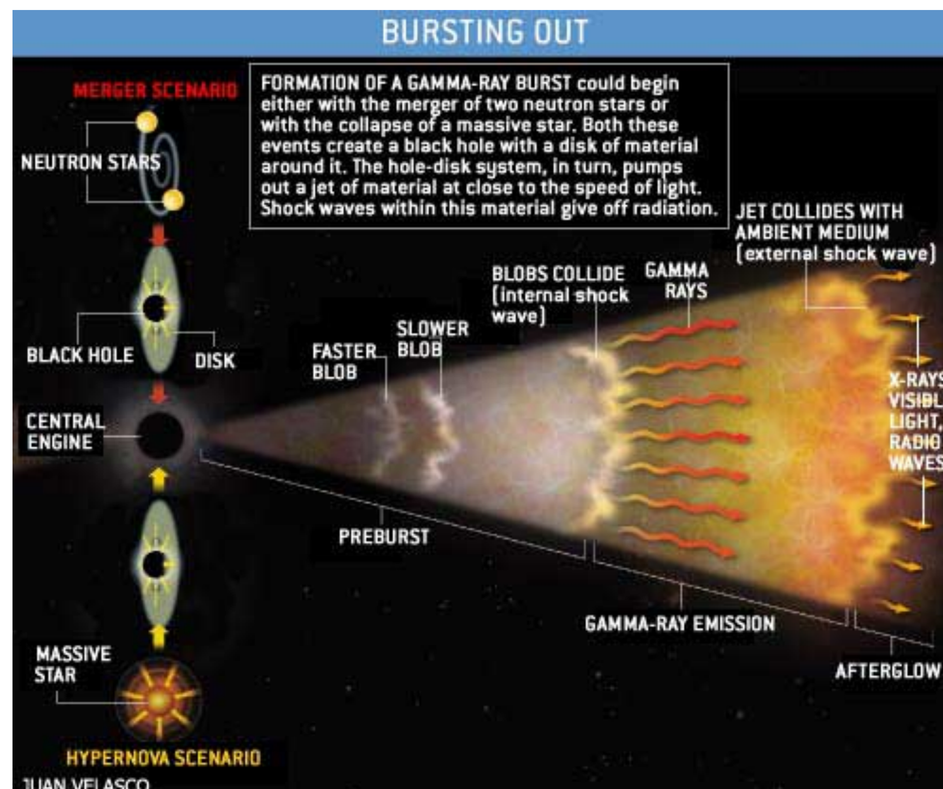
Contents

Contents

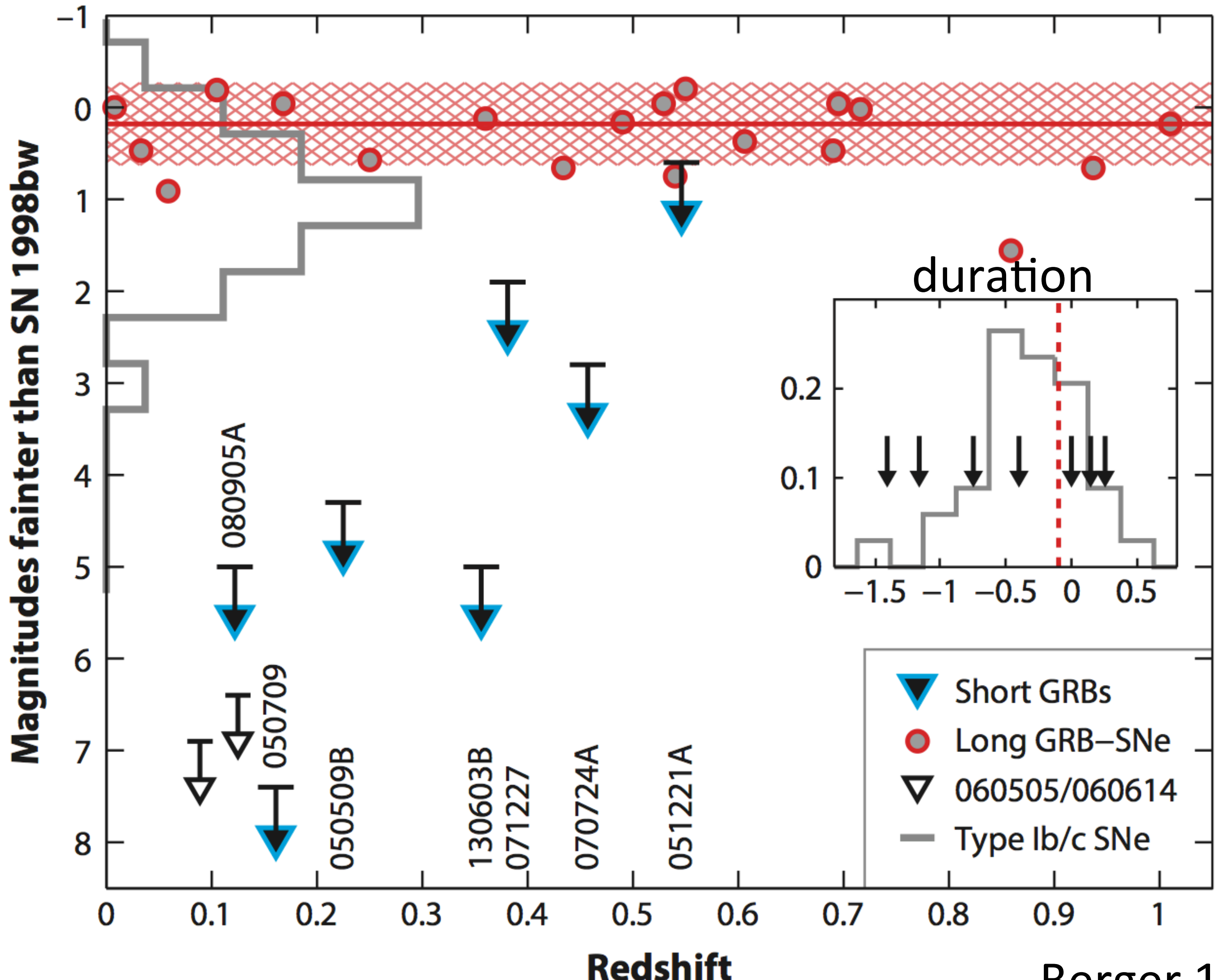
Short Gamma-Ray Bursts

- Total energy : ~10^{51} – 10^{53} erg (isotropic)
- Duration : ~10^{-2} – 2 sec
- Rate : ~10 Gpc^{-3} yr^{-1} (observed; Nakar+ 06)
- Jet-like outflow (opening angle ~5-10°; Fong+14)
- Afterglow ⇒ Jet-ISM interaction





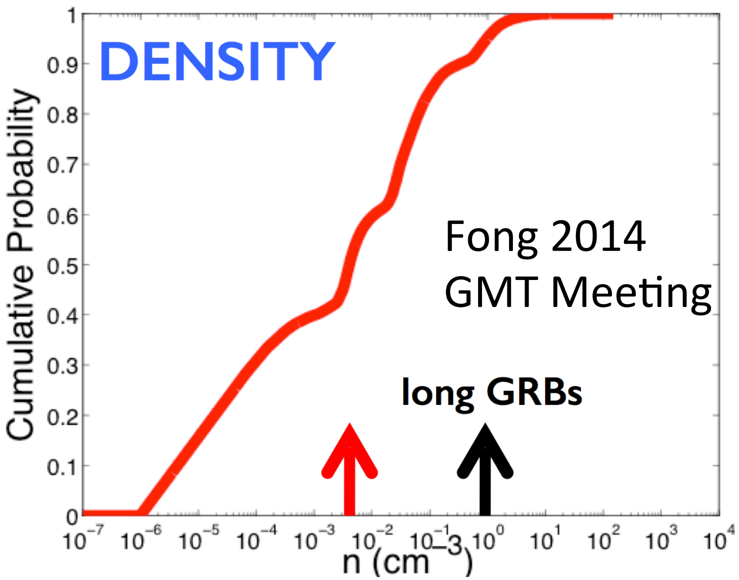
Lack of supernova association



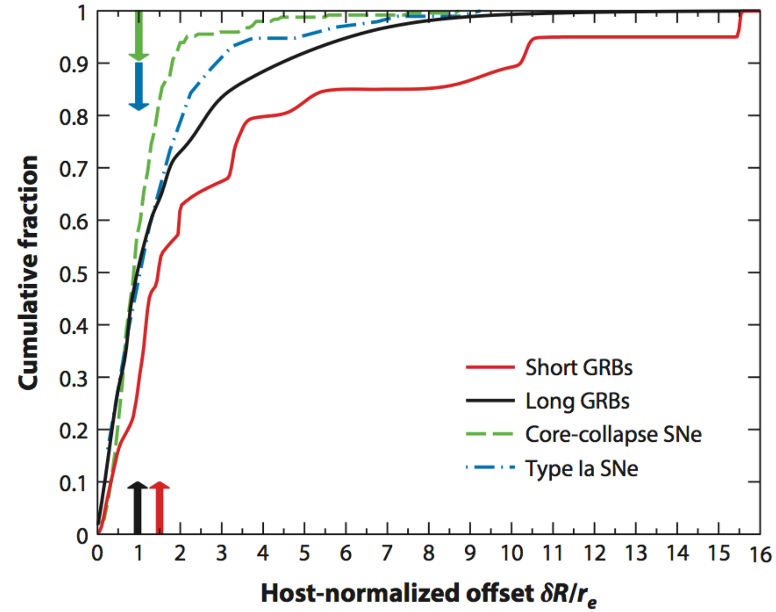
Berger 14

Environments

Circumburst density

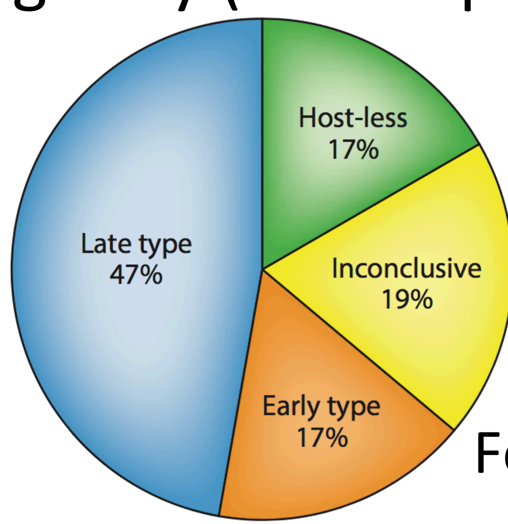


Offset distribution



Fong & Berger 13

Host galaxy (36 samples)

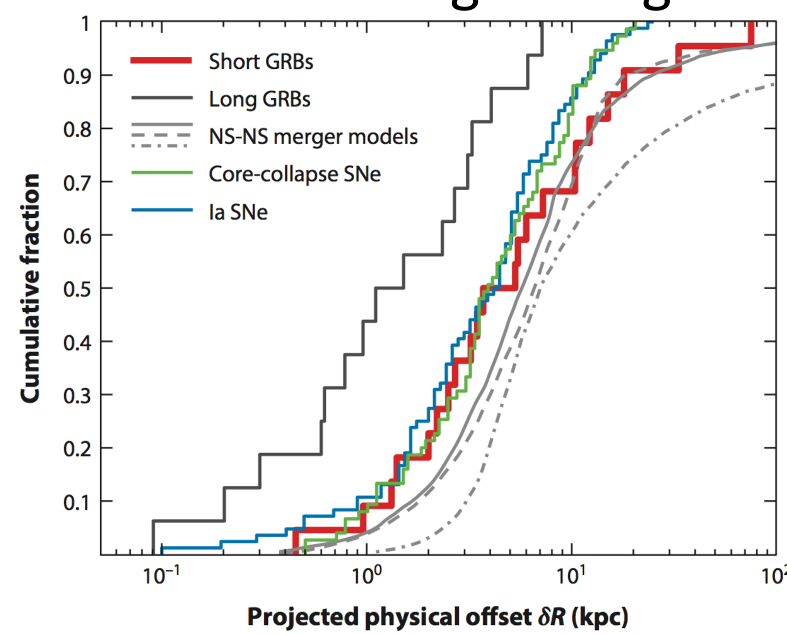


Fong+ 13

Compact binary merger (NS-NS, NS-BH)

- Energy ~10^{53} erg (Rotational and/or gravtational energies)
- Compact system (< 10^7 cm)
- Rate ~ 30 - 3000 $Gpc^{-3}yr^{-1}$ ⇔ ~ 10 $Gpc^{-3}yr^{-1}$ (observed)
- Lifetime ~ 0.1 – 10 Gyr
- Kick velocity ⇒ large offset
- No supernovae
- Macronovae

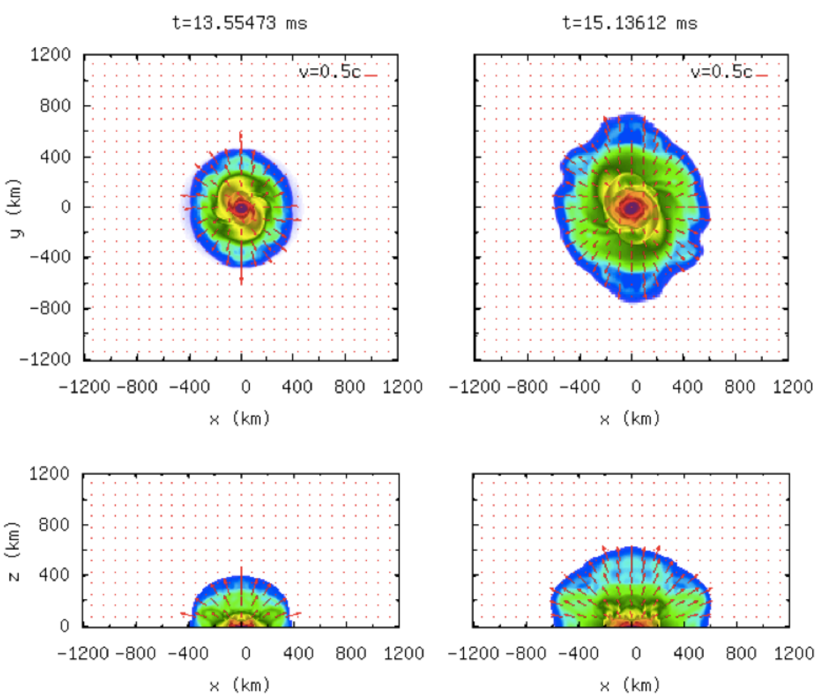
Fong & Berger 13



Contents

NS-NS merger ejecta

Hotokezaka+ 2013



Bound

Disk mass :

$$M_{\rm d} \sim 10^{-2} - 10^{-1} M_{\odot}$$

Unbound

Ejecta mass :

$$M_{\rm ej} \sim 10^{-4} - 10^{-2} M_{\odot}$$

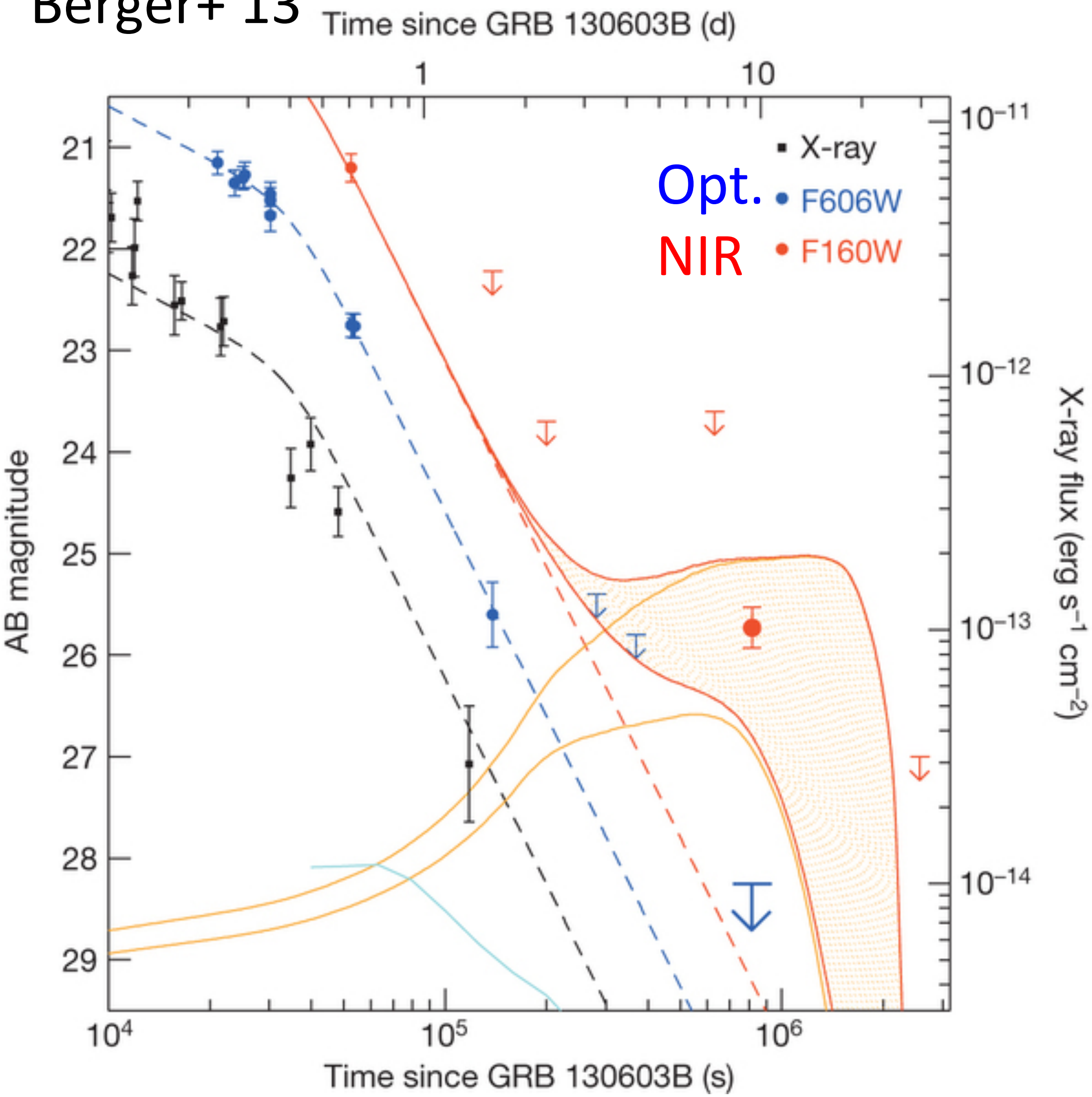
Ejecta velocity :

$$v_{\rm ej} \sim 0.1 - 0.3c$$

Nearly isotropic distribution

Macronova Candidate

Tanvir+ 13
Berger+ 13



t ~ 7 day

L_{NIR} ~ 10^{41}erg/s

T < 4000 K

(m_r-m_j ≥ 2.5)

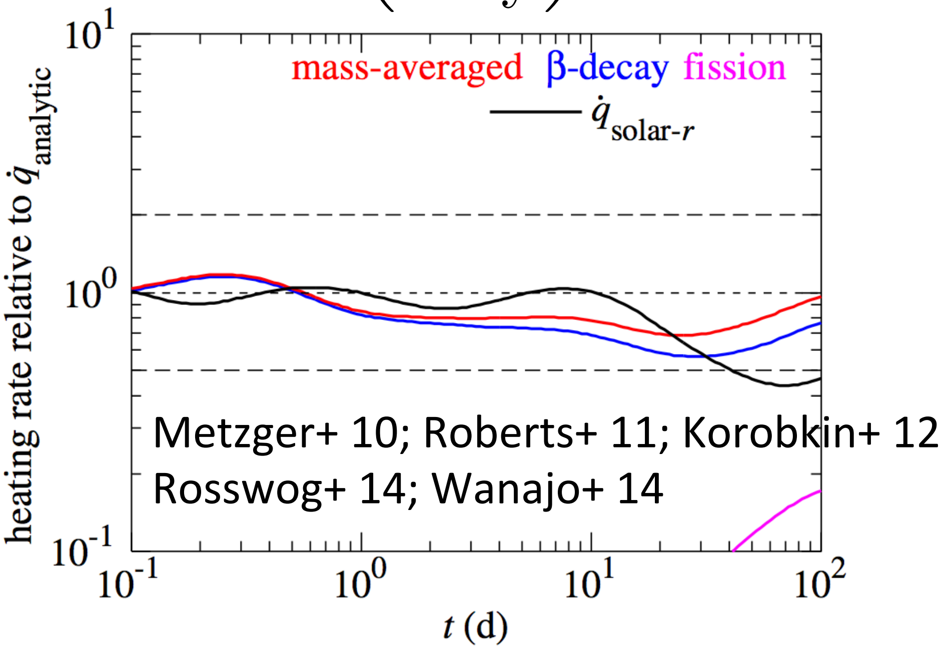
$$T \sim \left(\frac{L}{4\pi v_{\rm ej}^2 t^2 \sigma_{\rm SB}}\right)^{1/4}$$

$$\sim 3 \times 10^3 {\rm K} \left(\frac{v_{\rm ej}}{0.1c}\right)^{-1/2}$$

R-process model

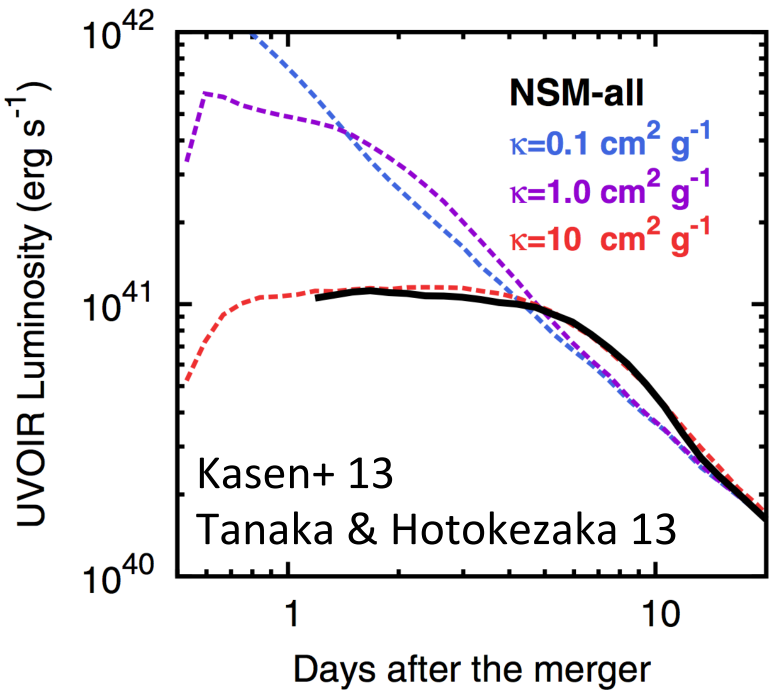
Nuclear heating rate

$$\dot{\epsilon} \sim 2 \times 10^{10} \left(\frac{t}{1\mathrm{day}}\right)^{-1.3} \mathrm{erg\ g^{-1} s^{-1}}$$



Opacity

$$\kappa \sim 10 \mathrm{cm^2\ g^{-1}}$$

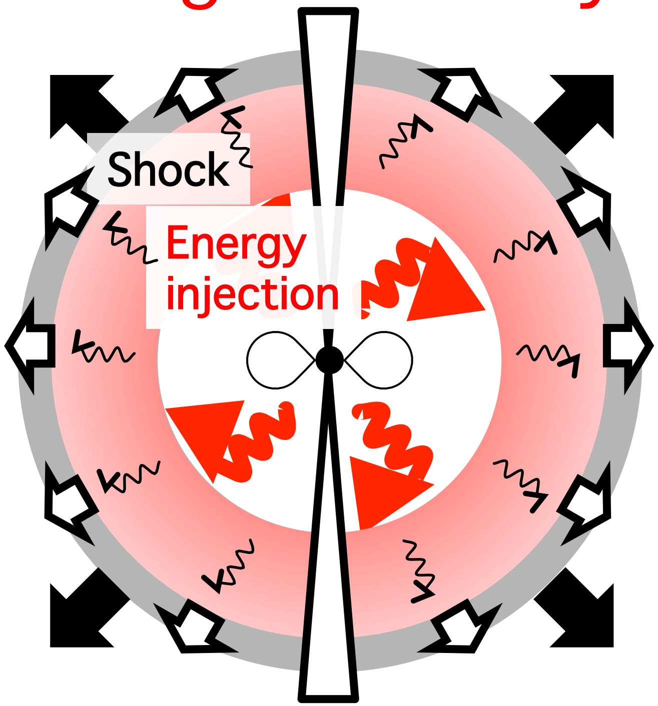


$$L \sim \dot{\epsilon} \times M_{\mathrm{ej}} \sim 10^{41}\ \mathrm{erg\ s^{-1}} \left(\frac{M_{\mathrm{ej}}}{0.03 M_\odot}\right)$$

$$t_{\mathrm{peak}} \sim 7\mathrm{day} \left(\frac{M_{\mathrm{ej}}}{0.03 M_\odot}\right)^{1/2} \times \left(\frac{\kappa}{10 \mathrm{cm^2 g^{-1}}}\right)^{1/2} \left(\frac{v_{\mathrm{ej}}}{0.1c}\right)^{-1/2}$$

Alternative models

Nuclear heating ⇒ Engine activity ?

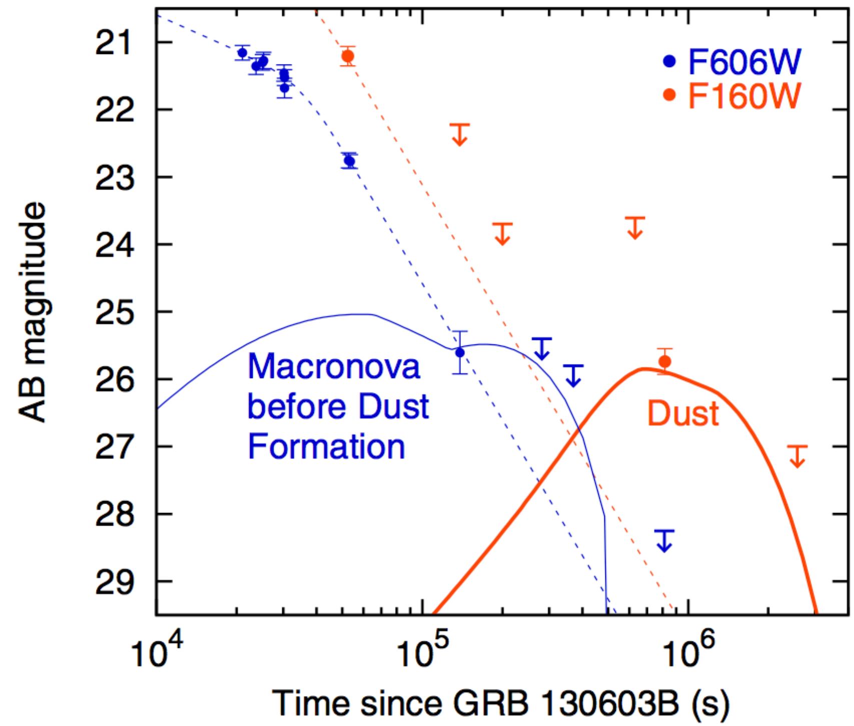


SK, Ioka & Takami 15

$$L \sim \frac{E_{\rm int}}{t}\left(\frac{t}{t_{\rm inj}}\right)^{-1}$$

$$\sim 10^{41}{\rm erg}\left(\frac{E_{\rm int}}{10^{51}{\rm erg}}\right)\left(\frac{t_{\rm inj}}{10^{2}{\rm s}}\right)\left(\frac{t}{7{\rm day}}\right)^{-2}$$

R-process elements ⇒ Dust ?



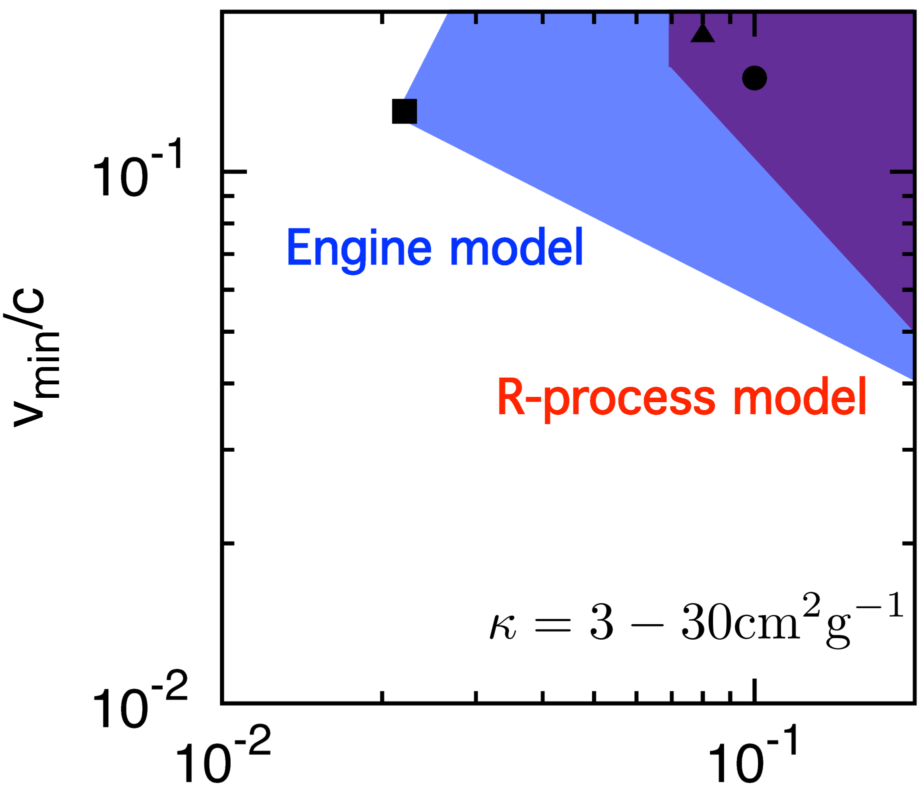
Takami, Nozawa & Ioka 14

$$\kappa_{\rm geo} = \frac{\pi r_{\rm dust}^2}{m_{\rm dust}} \sim \frac{\pi\left(N^{1/3} r_{\rm A}\right)^2}{N m_{\rm A}}$$

$$\sim 10^{6}\ {\rm cm^2 g^{-1}} N^{-1/3}$$

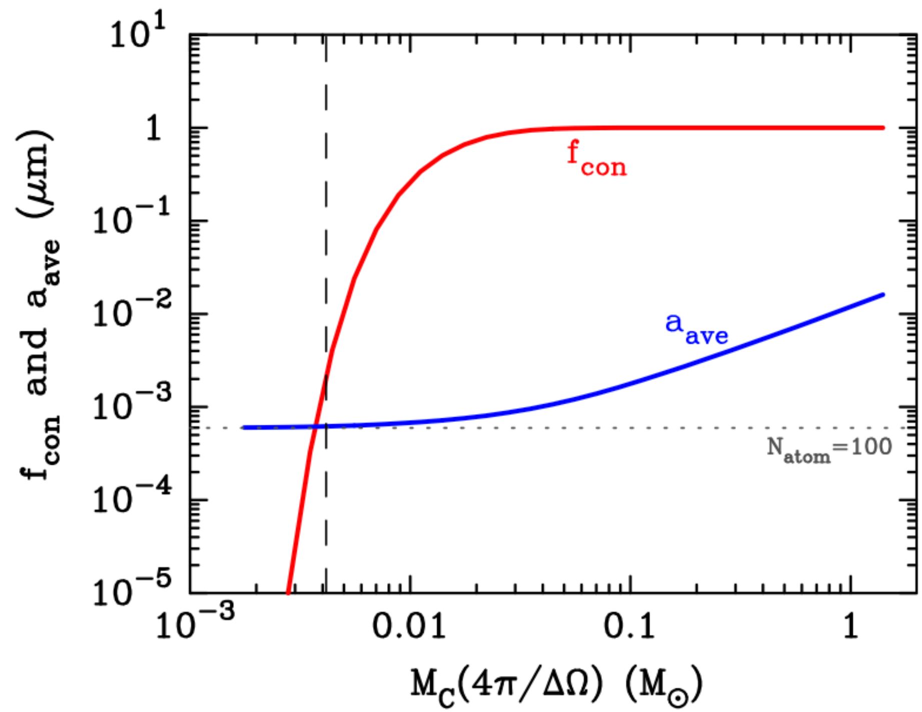
Alternative models

Nuclear heating
⇒ Engine activity ?



SK, Ioka & Takami 15

R-process elements
⇒ Dust ?



Takami, Nozawa & Ioka 14

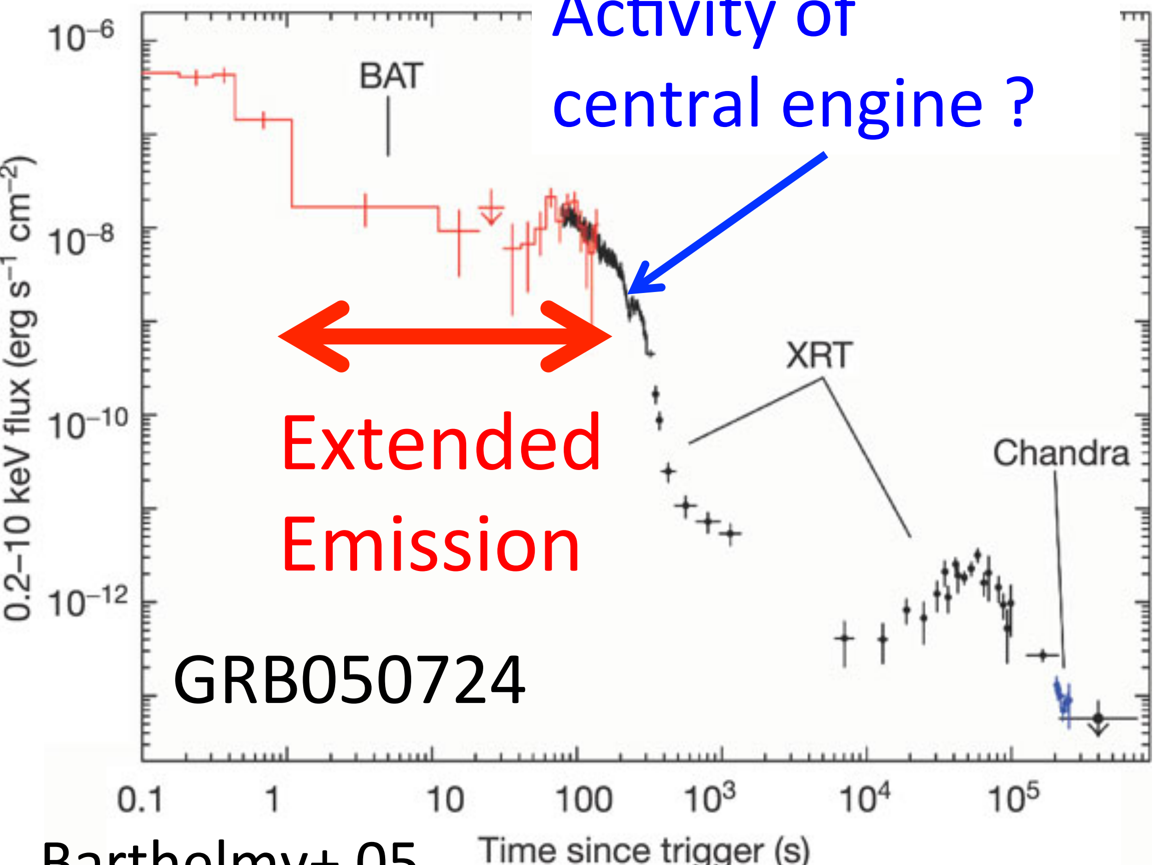
Ejecta mass : $M_{ej} \sim 10^{-2} M_\odot$
Ejecta velocity : $v_{ej} \sim 0.1 - 0.3c$

Contents

Extended emission

Extended emission : L ~ 10^{48}-10^{49} erg/s, T ~ 10^2 s

Too rapid decline.
Activity of
central engine ?



Barthelmy+ 05

cf. Prompt emission

L ~ 10^{50} - 10^{51} erg/s

T ~ 0.1 – 1 s

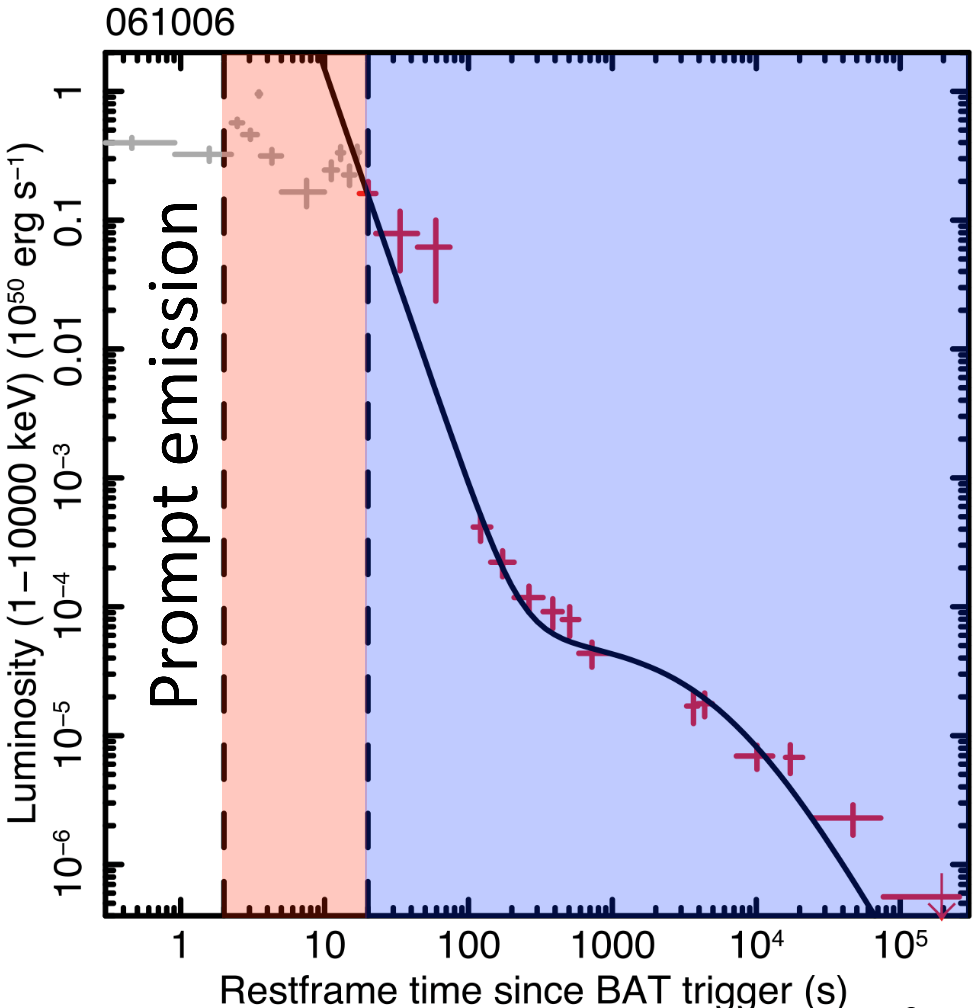
Total energy is comparable
~ 10^{50} - 10^{51} erg

Extended emissionを持つかどうかで明らかなHost galaxyの違いはない。(Fong+ 13)

Extended & plateau emissions

Extended emission : L ~ 10^{48}-10^{49} erg/s, T ~ 10^2 s

Plateau emission : L ~ 10^{46}-10^{47} erg/s, T ~ 10^3 – 10^4 s



Gompertz+ 13

cf. Prompt emission

L ~ 10^{50} - 10^{51} erg/s

T ~ 0.1 – 1 s

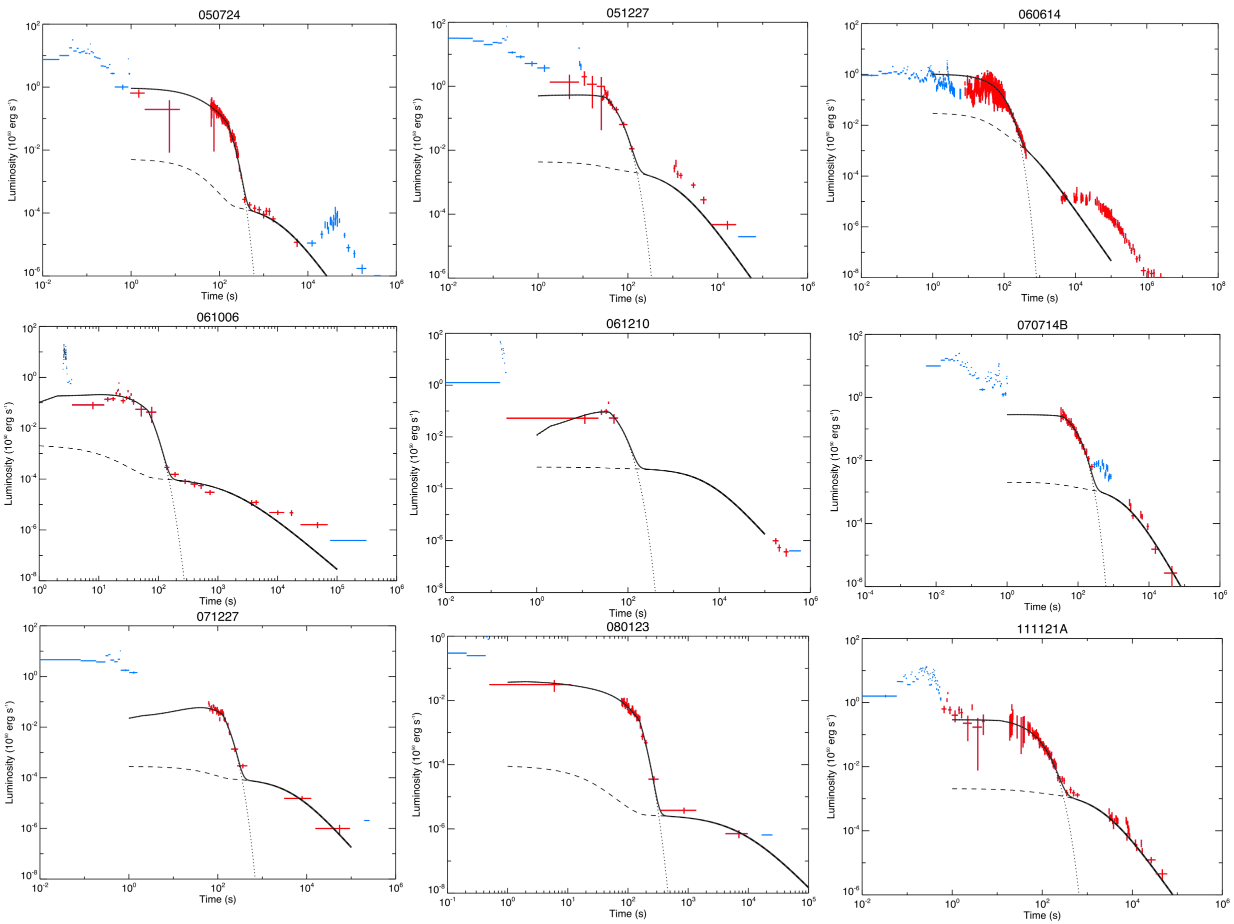
Total energy is comparable ~ 10^{50} - 10^{51} erg

Activity of central engine ~ 10^4 s ?

Extended & plateau emissions

Extended emission : L ~ 10^{48}-10^{49} erg/s, T ~ 10^2 s

Plateau emission : L ~ 10^{46}-10^{47} erg/s, T ~ 10^3 – 10^4 s



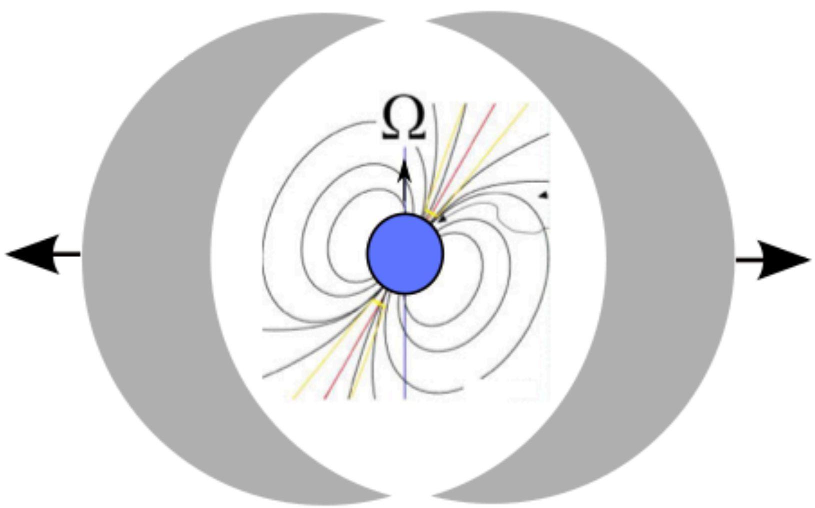
2 components ?

Gompertz+ 14

Neutron star model

$$\Omega_{\rm i} = 2\pi / P_{\rm i}$$

Long-lived NS (> 10^3 – 10^4 sec) with surface dipole magnetic field $B_s \sim 10^{15}$G and rotation period $P_i \sim 1$ ms



Metzger & Piro 14

$$L_{\rm sd} = \frac{1}{6c}\Omega_{\rm i}^2 \Psi_{\rm pc}^2$$

$$\sim 10^{49} \ {\rm erg \ s^{-1}} B_{\rm s,15}^2 P_{\rm i,-3}^{-4}$$

$$T_{\rm sd} \sim \frac{(1/2) I \Omega_{\rm i}^2}{L_{\rm sd}}$$

$$\sim 10^3 \ {\rm s} \ B_{\rm s,15}^{-2} P_{\rm i,-3}^2$$

Lifetime of a HMNS also determines the timescale of activity.

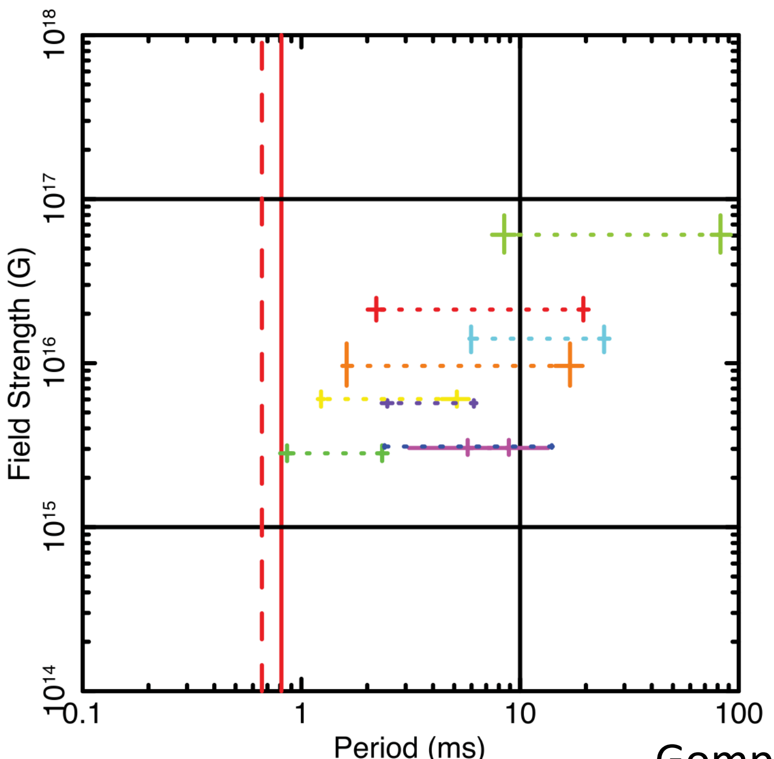
Neutron star model

$$\Omega_{\rm i} = 2\pi/P_{\rm i}$$

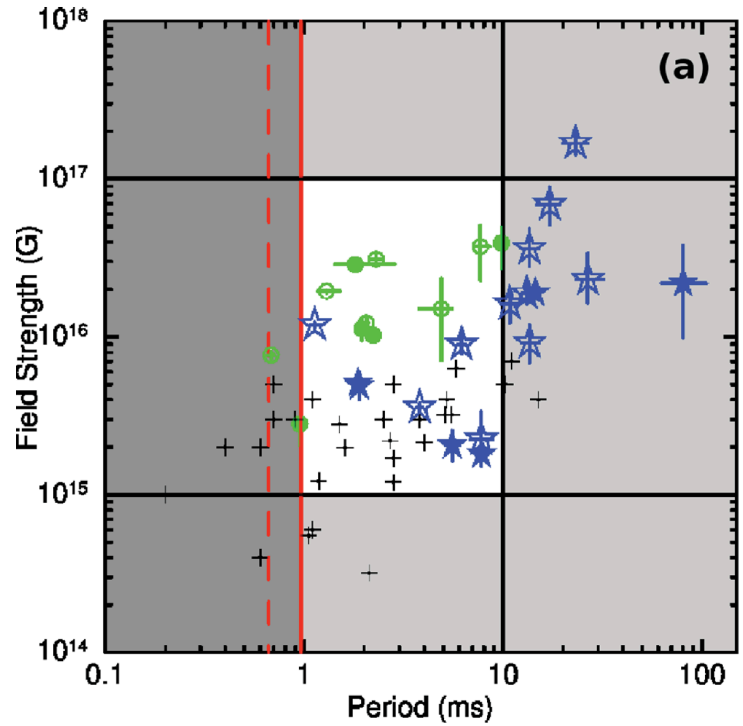
Long-lived NS (> 10^3 – 10^4 sec) with surface dipole magnetic field B_s ~ 10^{15}G and rotation period P_i ~ 1 ms

$$L_{\rm sd} \sim 10^{49}~{\rm erg~s^{-1}} B_{\rm s,15}^2 P_{\rm i,-3}^{-4}$$

$$T_{\rm sd} \sim 10^3~{\rm s}~B_{\rm s,15}^{-2} P_{\rm i,-3}^{2}$$

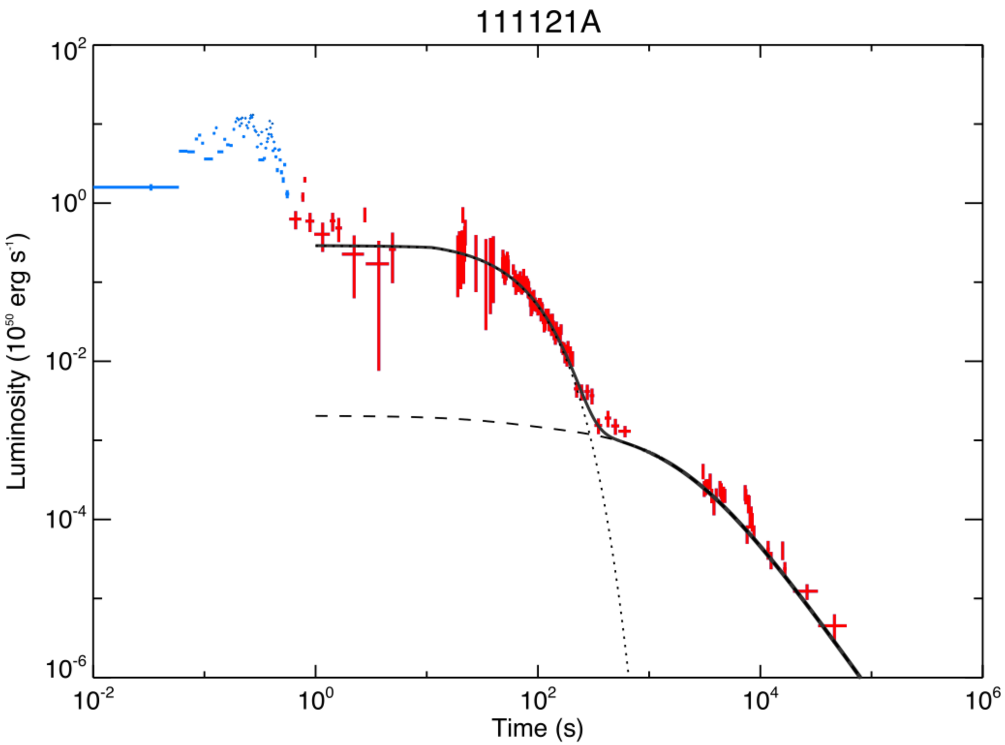


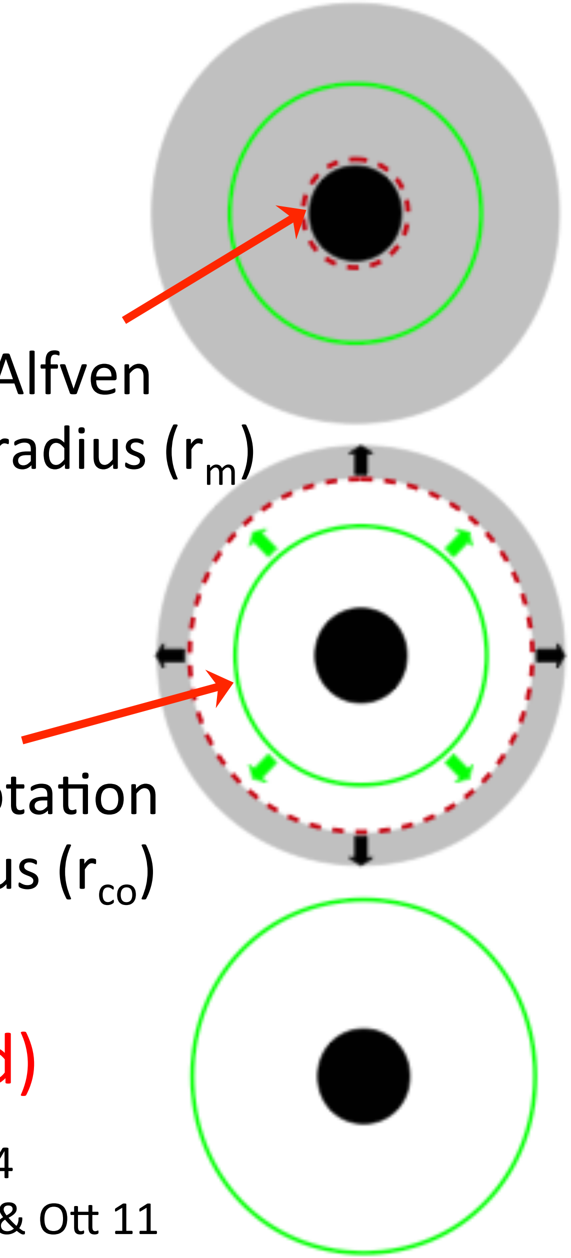
Gompertz+ 13



Rowlinson+ 13

Neutron star model





Two-phase model
Propeller ⇒ Ejector (pulsar wind)

Gompertz+ 14
See also Piro & Ott 11

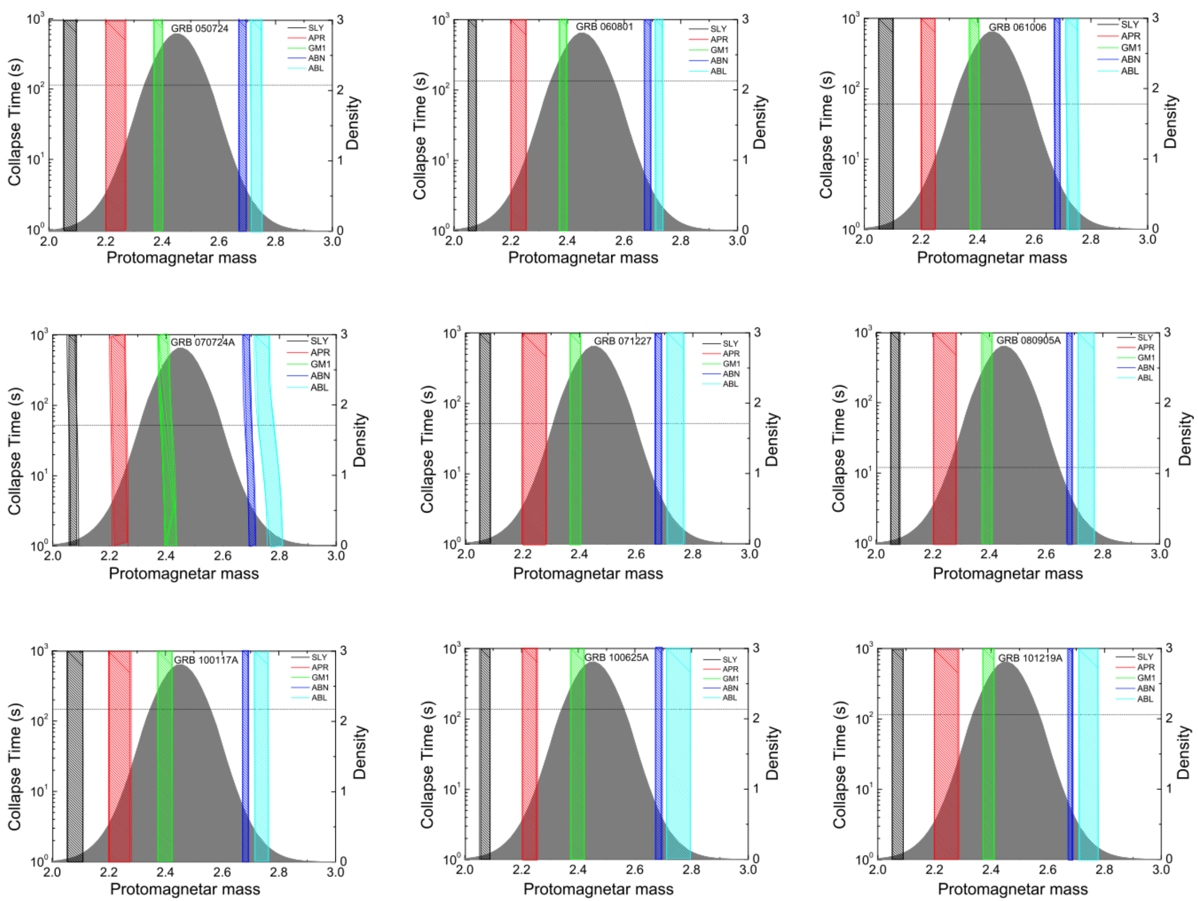
EoSに制限？

Lü+ 15

$$P(t) = P_0(1 + \frac{t}{\tau})^{1/2}$$

$$t_{\rm col} = \frac{\tau}{P_0^2}[(\frac{M_{\rm p} - M_{\rm TOV}}{\hat{\alpha} M_{\rm TOV}})^{2/\hat{\beta}} - P_0^2]$$

$$M_{\rm max} = M_{\rm TOV}(1 + \hat{\alpha} P^{\hat{\beta}})$$



光度曲線の急激な折れ曲がりをNSのCollapseと解釈することでNSの最大質量を制限。

Can only NS model explain the long activity ?

Lifetime of HMNS

Hotokezaka+ 13

$$\tau_{\rm wind},\ \ \tau_{\rm mri},\ \ \tau_{\rm cool} \ll 10^4{\rm s}$$

Alfven velocity

$$v_{\rm A} \sim \frac{B}{\sqrt{4\pi\rho}}$$

Angular momentum transport

- Magnetic winding effect

$$\tau_{\rm wind} \sim \frac{R}{v_{\rm A}} \sim 10^{-2}{\rm s}\ \rho_{15} B_{15}^{-1} R_6$$

Effective viscous parameter

$$\nu \sim \alpha \frac{c_{\rm s}^2}{\Omega}$$

- Magnetorotational instability (MRI)

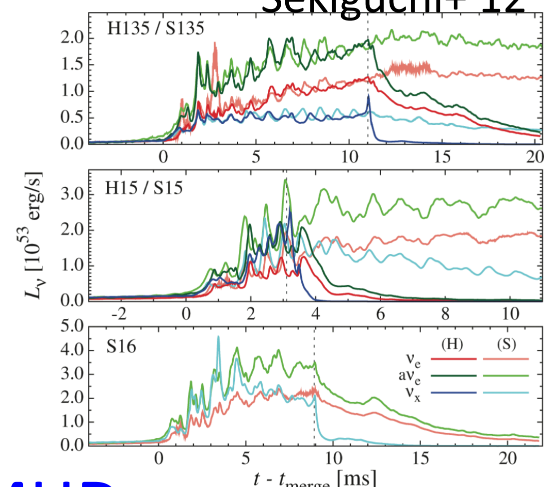
$$c_{\rm s} \sim 0.1c$$

$$\tau_{\rm mri} \sim \frac{R^2}{\nu} \sim 10^{-2}{\rm s}\ \alpha_{-2}^{-1} c_{{\rm s},-1}^{-2} R_6^2 \Omega_4$$

Neutrino cooling

$$\tau_{\rm cool} \lesssim \frac{M_{\rm NS}c^2}{L_\nu} \sim 1-10{\rm s}\ L_{\nu,53}^{-1}$$

Sekiguchi+ 12



Survival time of a HMNS increases in a RMHD.

Dionysopoulou+ 15

Lifetime of HMNS

Hotokezaka+ 13

$$\tau_{\rm wind},\ \ \tau_{\rm mri},\ \ \tau_{\rm cool} \ll 10^4{\rm s}$$

Angular momentum transport

- Magnetic winding effect

$$\tau_{\rm wind} \sim \frac{R}{v_{\rm A}} \sim 10^{-2}{\rm s}\ \rho_{15} B_{15}^{-1} R_6$$

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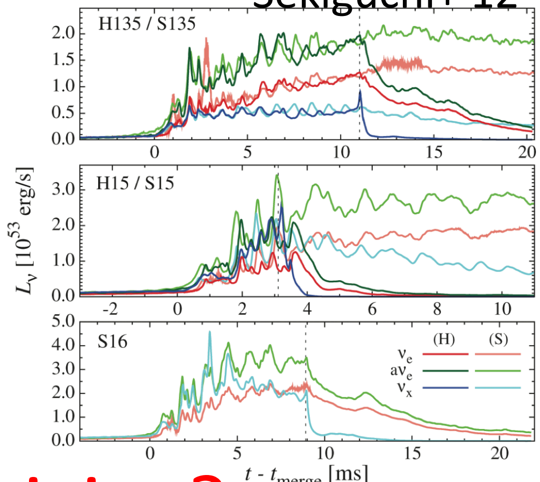

Can only NS model explain the long activity ?

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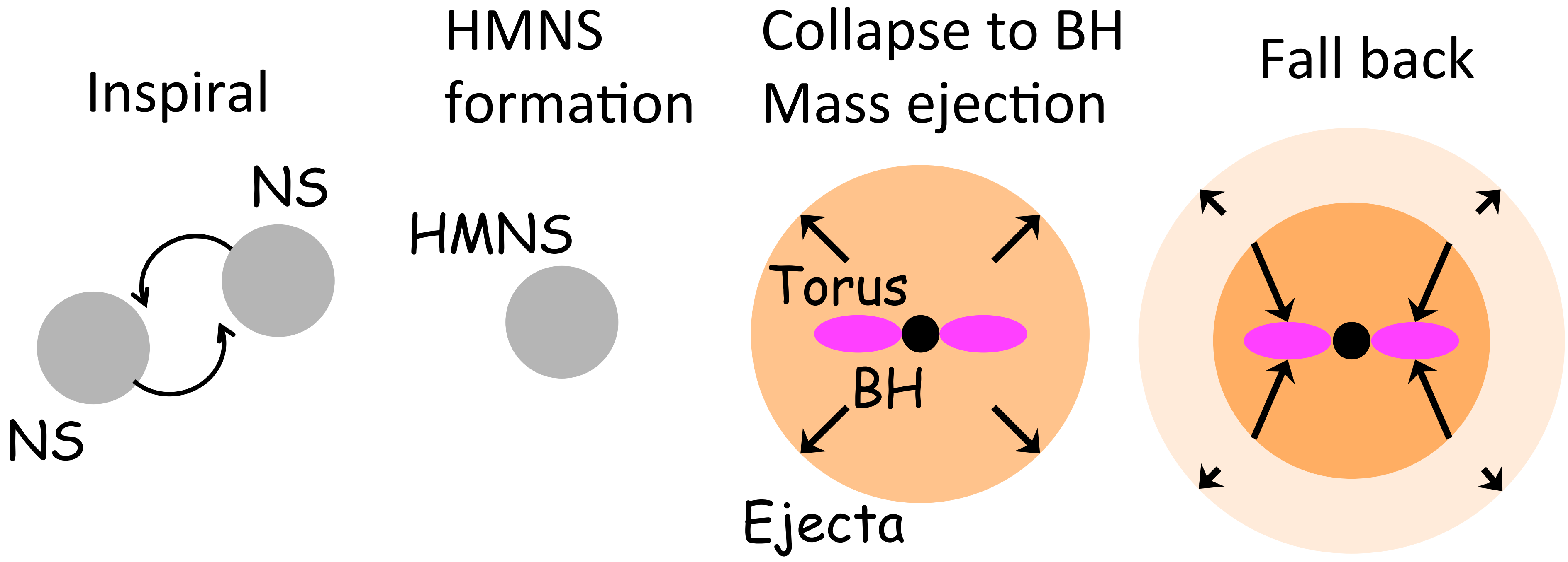
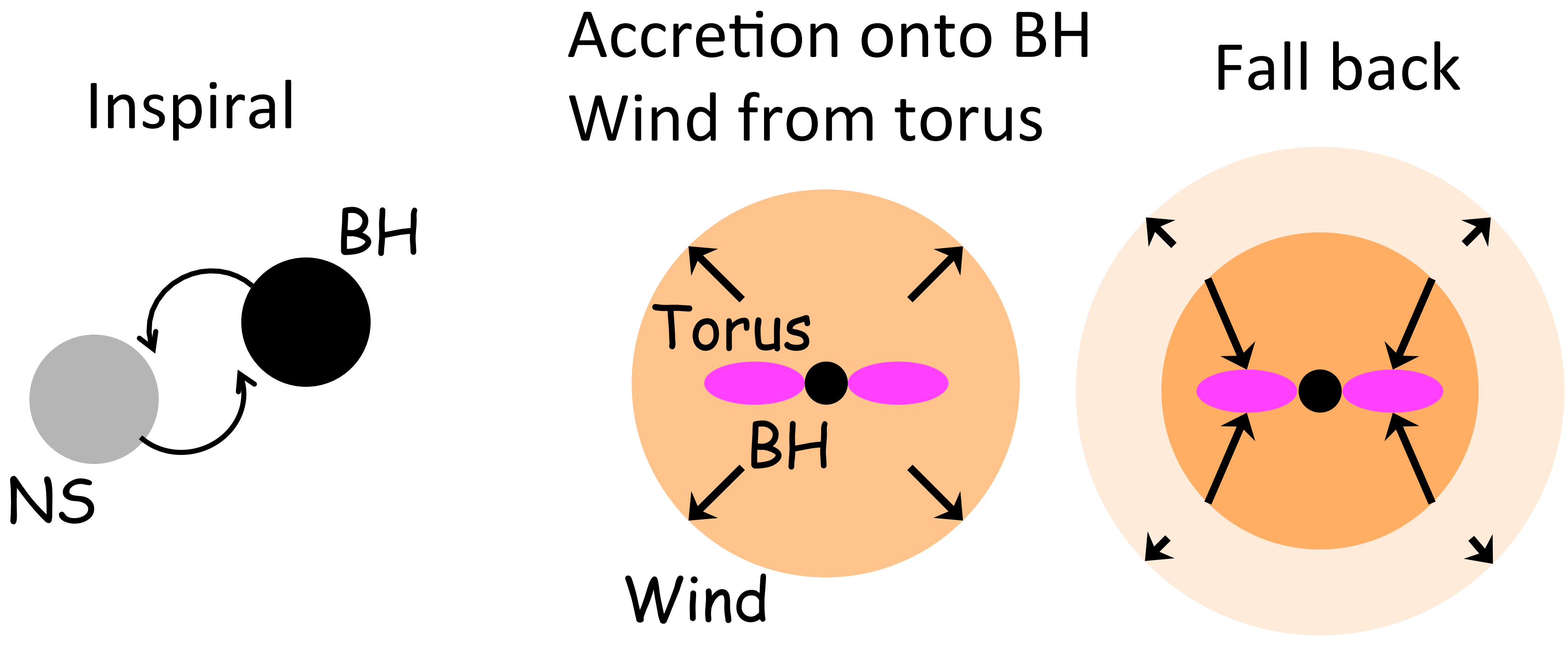
BH Scenario


Inspiral
NS
NS
HMNS
formation
HMNS
Collapse to BH
Mass ejection
Torus
BH
Ejecta
Fall back

BH Scenario



Inspiral
BH
NS
Accretion onto BH
Wind from torus
Torus
BH
Wind
Fall back

Energy sources

- Rotation:

$$\sim 10^{53} \left(\frac{M_{\rm BH}}{3M_\odot} \right) \ {\rm erg} \qquad (a/M_{\rm BH} = 0.5)$$

- Torus gravitational energy:

$$\sim 10^{53} \left(\frac{M_{\rm d}}{10^{-1} M_\odot} \right) \ {\rm erg}$$

- Ejecta kinetic energy:

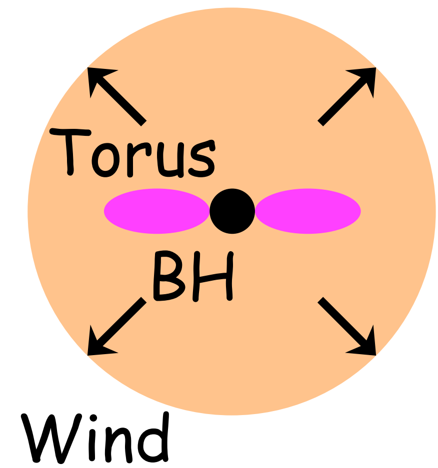
$$\sim 10^{51} \left(\frac{M_{\rm ej}}{10^{-2} M_\odot} \right) \left(\frac{v_{\rm ej}}{0.3c} \right)^2 \ {\rm erg}$$

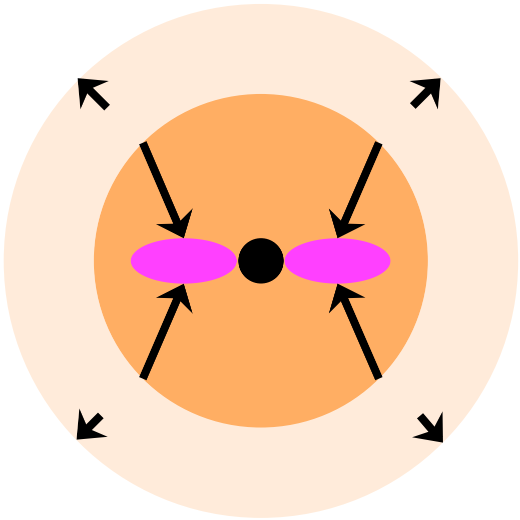
- Radioactivity:

$$\sim 10^{49} \left(\frac{\epsilon}{10^{-3}} \right) \left(\frac{M_{\rm ej}}{10^{-2} M_\odot} \right) \ {\rm erg}$$

- Magnetic field:

$$\sim 10^{48} \left(\frac{B}{10^{15} {\rm G}} \right)^2 \ {\rm erg}$$





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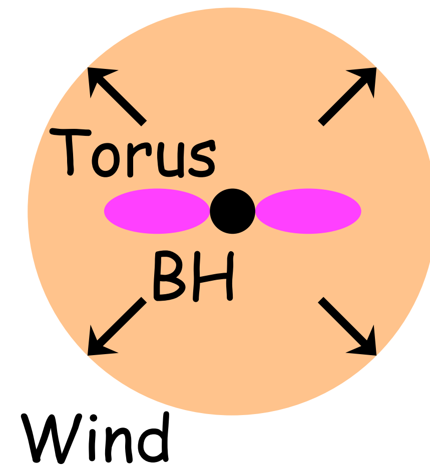

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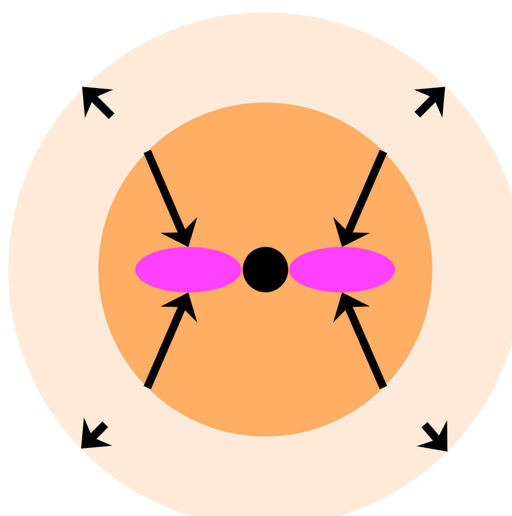


Timescale in BH case

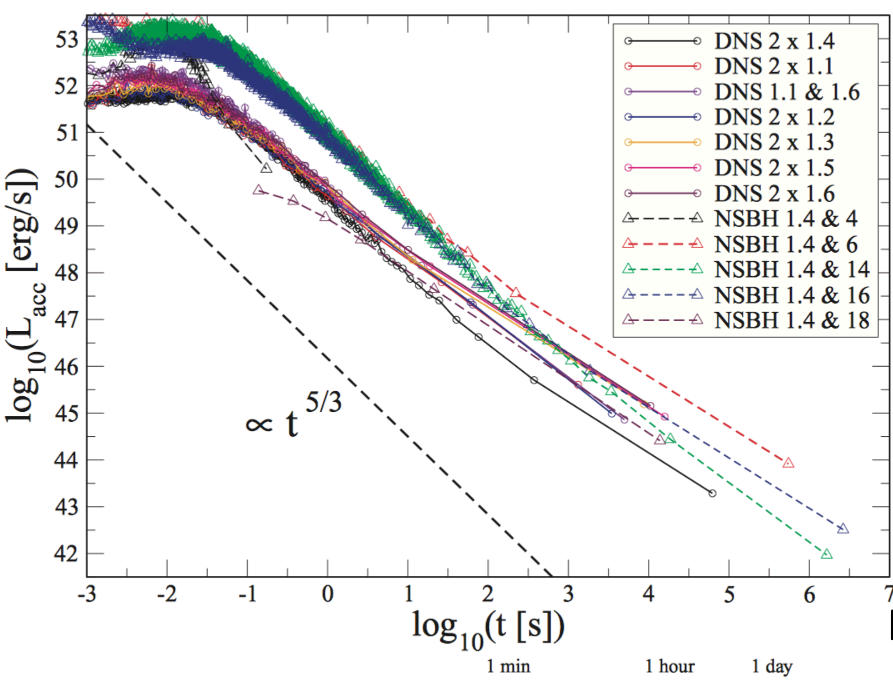
Free fall time

$$t_{\rm ff} = \frac{1}{\sqrt{G\rho}} \sim 10^{-4}{\rm s}\ M_{0.5}^{-1/2} r_6^{3/2}$$

$r_{\rm d}$: 円盤半径
H: スケールハイト

Accretion time

$$t_{\rm acc} \sim \frac{t_{\rm ff}}{\alpha}\left(\frac{r_{\rm d}}{H}\right)^2 \sim 10\ {\rm s}\ \alpha_{-2}^{-1} M_{0.5}^{-1/2} r_{\rm d,7}^{3/2} \left(\frac{H}{r_{\rm d}}\right)_{-1}^{-2}$$



Rosswog 07

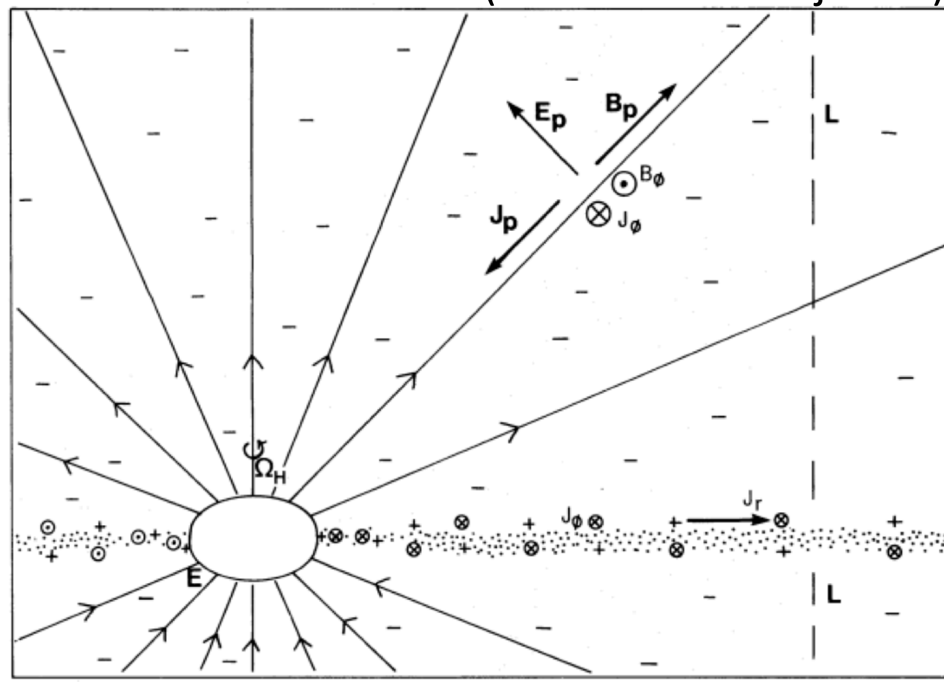
$T > 10^2$ sec では、光度が降着率で決まるとするとプラトーのような構造は期待できない。

重力エネルギーの解放で難しければ、BHの回転エネルギーしかない。

Blandford-Znajek process

Jetのエネルギー源 ⇒ BHの回転エネルギー

(Blandford & Znajek 77)



Poynting Flux

$$P_{\rm BZ} \sim \frac{\kappa}{4\pi c}\Omega_{\rm h}^2\Psi^2 f(\Omega_{\rm h})$$

κ = (6π)$^{-1}$ for split monopole.

Ψが一定であれば、
質量降着率に依存しない

ホライズンでの角速度

$$\Omega_{\rm h} = ac/2r_{\rm h}$$

磁気フラックス

$$\Psi = \frac{1}{2}\int_\theta\int_\phi |B^r|\sqrt{-g}d\theta d\phi$$

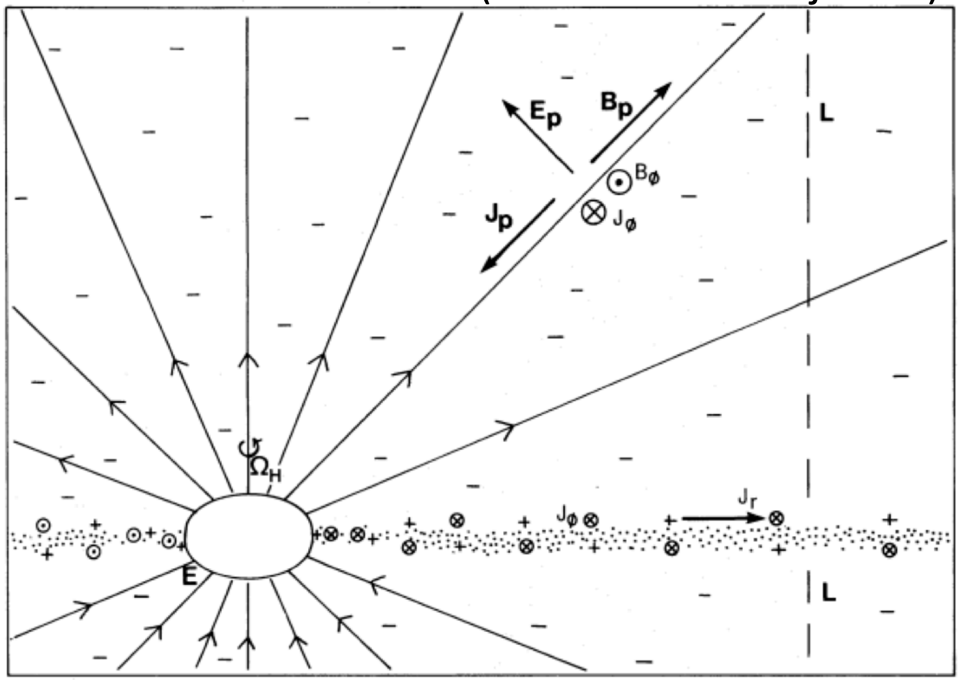
$$a = Jc/GM \quad r_{\rm h} = r_{\rm g}\left(1+\sqrt{1-a^2}\right) \quad r_{\rm g} = 2GM/c^2$$

$$f \approx 1 + 1.38(\Omega_{\rm h} r_{\rm g}/c)^2 - 9.2(\Omega_{\rm h} r_{\rm g}/c)^4$$ Tchekhovskoy+ 10

Blandford-Znajek process

Jetのエネルギー源 ⇒ BHの回転エネルギー

(Blandford & Znajek 77)



Poynting Flux

$$P_{\rm BZ} \sim \frac{\kappa}{4\pi c}\Omega_{\rm h}^2\Psi^2 f(\Omega_{\rm h})$$

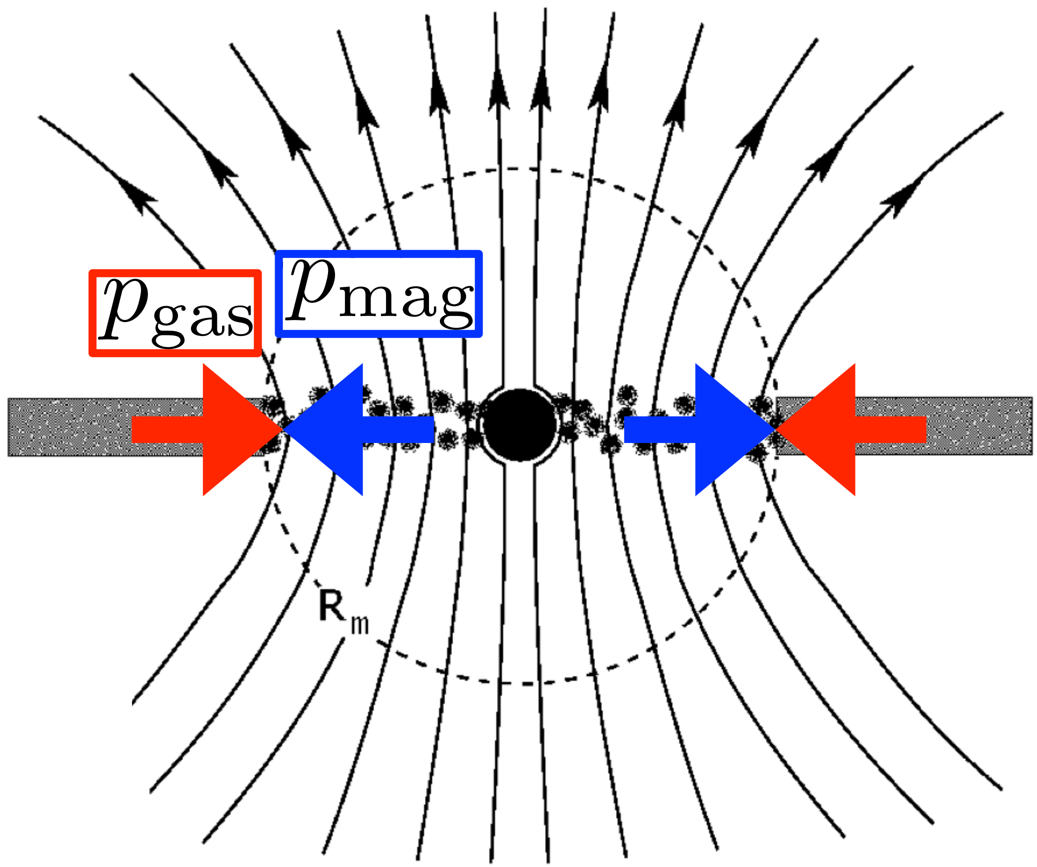
$\kappa = (6\pi)^{-1}$ for split monopole.

必要な要素

1. 磁場の強さ (ポロイダル)
2. 磁場のスケール ($\gg r_g$)
3. 磁気フラックスの維持

磁気フラックスの維持

ガス圧などでBHを貫く磁気フラックスを維持

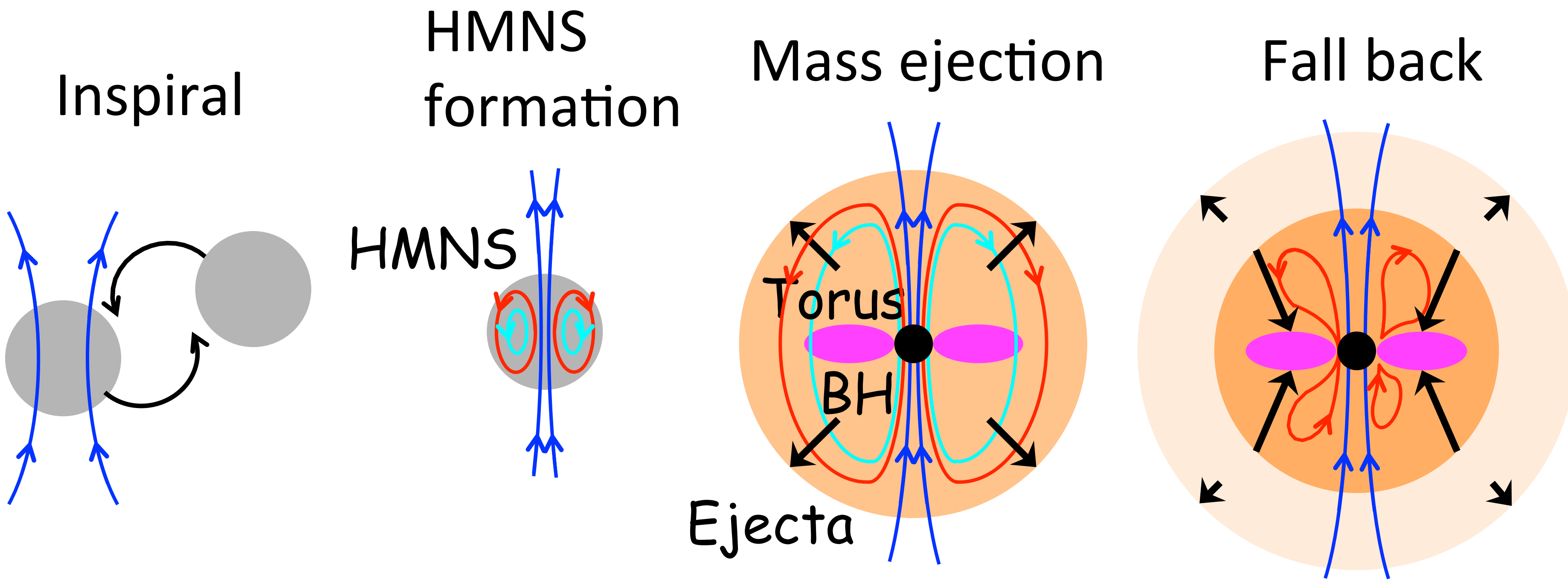


Narayan+ 03

$P_{gas} < P_{mag}$ なら磁場が広がる → 磁気フラックスが下がる

⇒ 降着率の進化がエネルギー供給時間を決める。

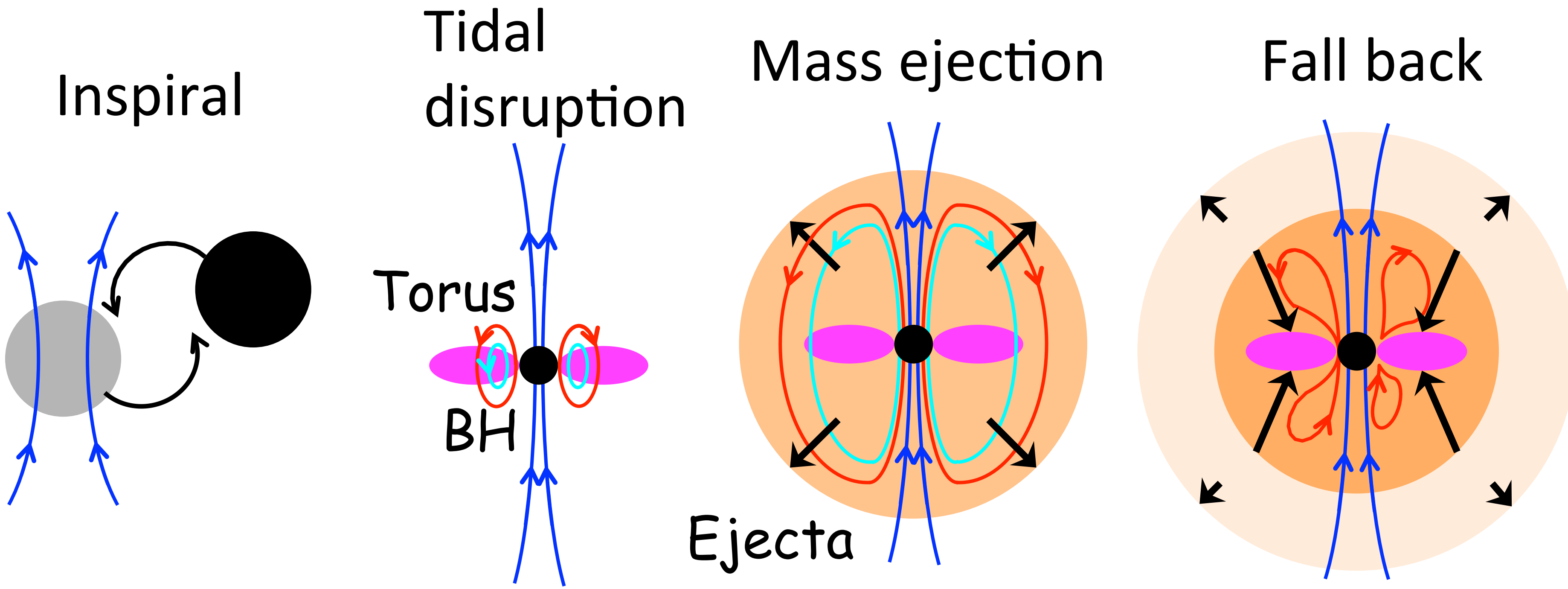
BH Scenario



B_{NS}~10^{12}G B-amplification B-expansion B-reconnection

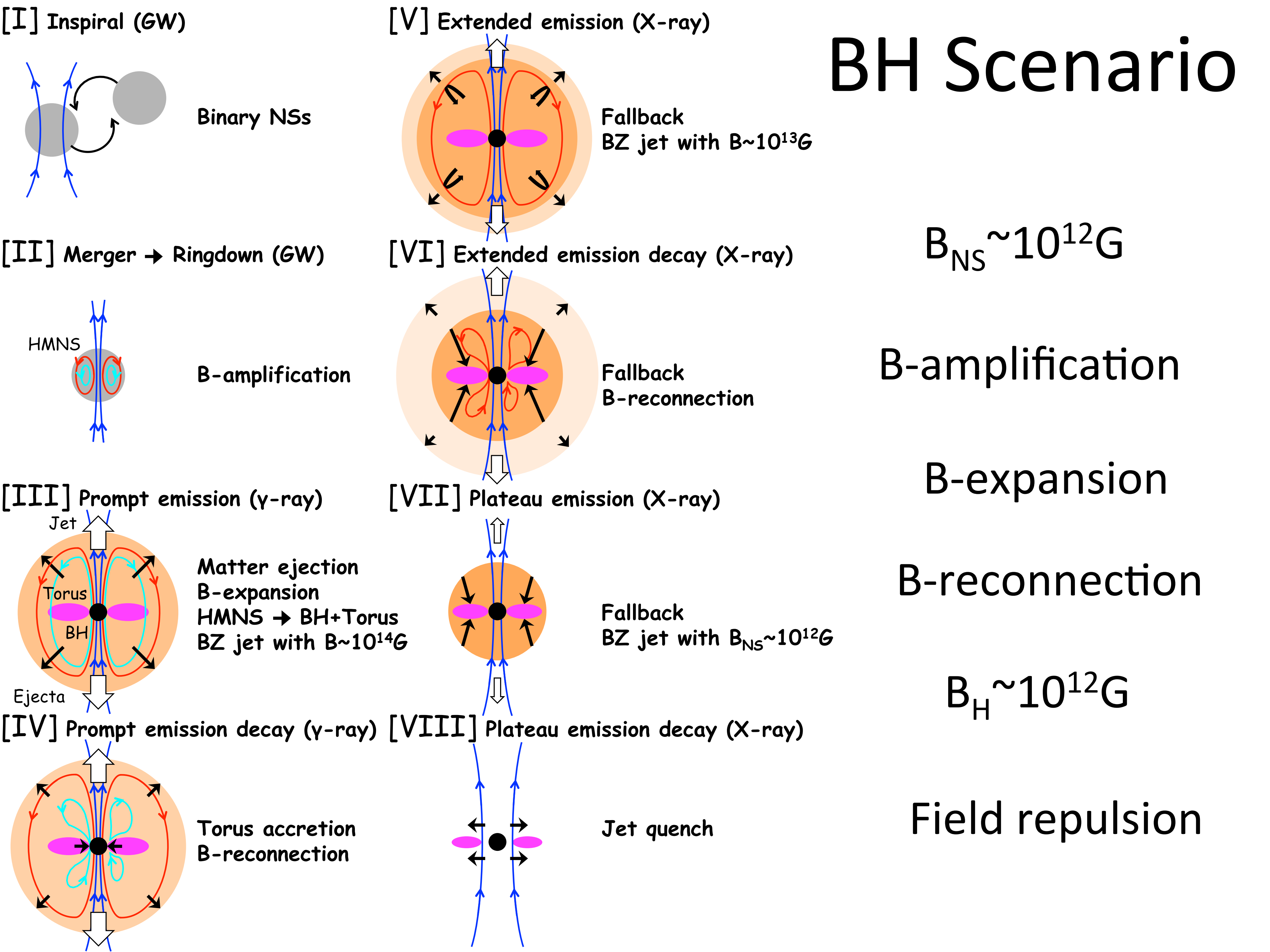
1. 磁場の強さ (ポロイダル)
2. 磁場のスケール (>> r_g)
3. 磁気フラックスの維持

BH Scenario

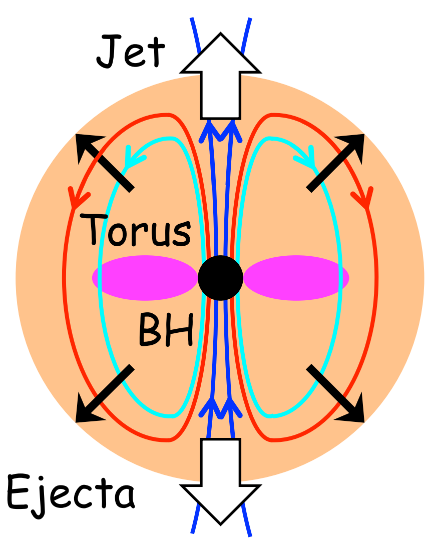


B_{NS}~10^{12}G　B-amplification　B-expansion　B-reconnection

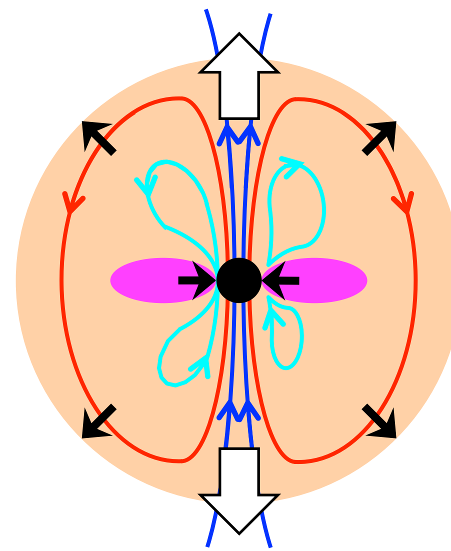
1. 磁場の強さ (ポロイダル)
2. 磁場のスケール (>> r_g)
3. 磁気フラックスの維持


BH Scenario
[I] Inspiral (GW)
Binary NSs
[II] Merger → Ringdown (GW)
HMNS
B-amplification
[III] Prompt emission (γ-ray)
Jet
Torus
BH
Ejecta
Matter ejection
B-expansion
HMNS → BH+Torus
BZ jet with B~10^14G
[IV] Prompt emission decay (γ-ray)
Torus accretion
B-reconnection
[V] Extended emission (X-ray)
Fallback
BZ jet with B~10^13G
[VI] Extended emission decay (X-ray)
Fallback
B-reconnection
[VII] Plateau emission (X-ray)
Fallback
BZ jet with B_NS~10^12G
[VIII] Plateau emission decay (X-ray)
Jet quench
B_NS~10^12G
B-amplification
B-expansion
B-reconnection
B_H~10^12G
Field repulsion

Prompt emission



Matter ejection
B-expansion
HMNS → BH+Torus
BZ jet with B~10^{14}G



Torus accretion
B-reconnection

$a_* = Jc/GM^2 \sim 0.7$ (Shibata & Taniguchi 06)

Radiative efficiency $\eta \sim 0.1$

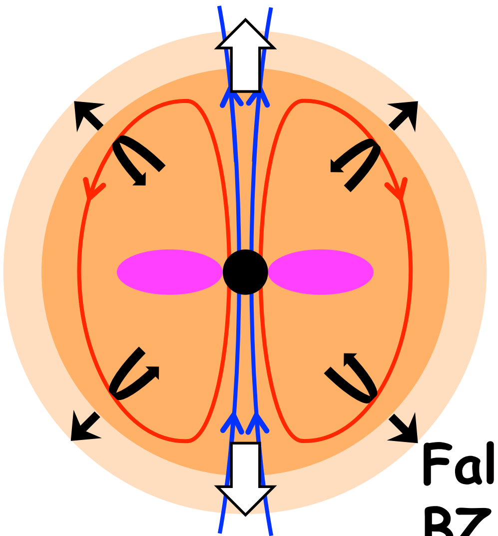
Covering factor $(\Delta\Omega) \sim 10^{-3}$

BZ Power

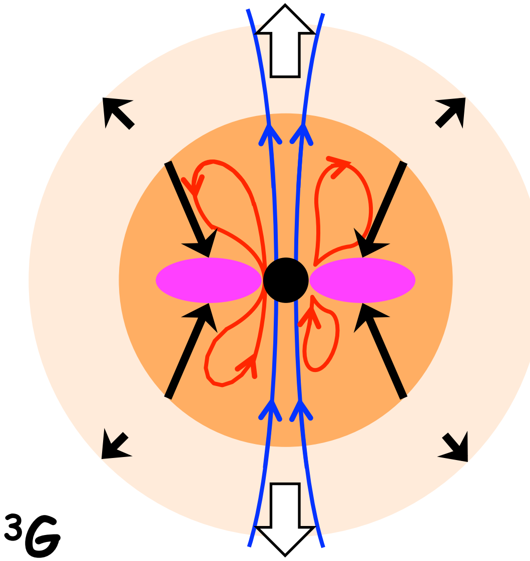
$$L_{\rm BZ} \sim 2.0 \times 10^{48}\ {\rm erg\ s^{-1}} a_{*,0.7}^2 B_{\rm h,14}^2$$

$$L \sim 2.0 \times 10^{50}\ {\rm erg\ s^{-1}} \eta_{-1} (\Delta\Omega_{-3})^{-1} a_{*,0.7}^2 B_{\rm h,14}^2$$

Extended emission



Fallback
BZ jet with B~10^{13}G



Fallback
B-reconnection

$a_* = Jc/GM^2 \sim 0.7$ (Shibata & Taniguchi 06)

Radiative efficiency $\eta \sim 0.1$

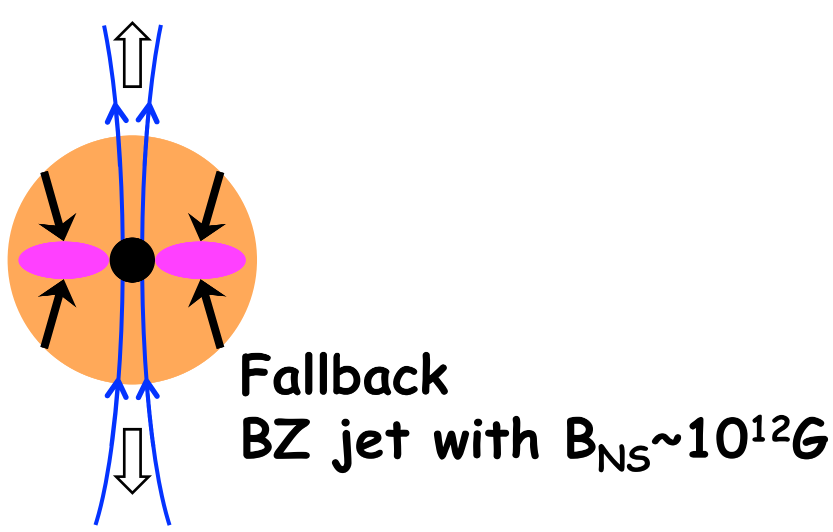
Covering factor $(\Delta\Omega) \sim 10^{-3}$

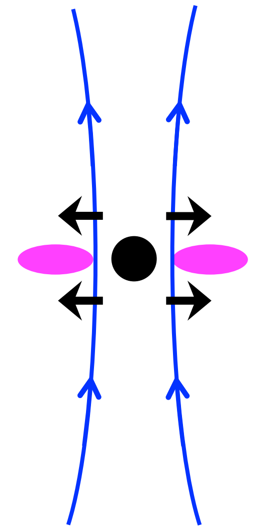
BZ Power

$$L_{\rm BZ} \sim 2.0 \times 10^{46}\ {\rm erg\ s}^{-1} a_{*,0.7}^2 B_{\rm h,13}^2$$

$$L \sim 2.0 \times 10^{48}\ {\rm erg\ s}^{-1} \eta_{-1} (\Delta\Omega_{-3})^{-1} a_{*,0.7}^2 B_{\rm h,13}^2$$

Plateau emission





$a_* = Jc/GM^2 \sim 0.7$ (Shibata & Taniguchi 06)

Radiative efficiency $\eta \sim 0.1$

Covering factor $(\Delta\Omega) \sim 10^{-3}$

BZ Power

$$L_{\rm BZ} \sim 2.0 \times 10^{44}\ {\rm erg\ s^{-1}} a_{*,0.7}^2 B_{\rm h,12}^2$$

$$L \sim 2.0 \times 10^{46}\ {\rm erg\ s^{-1}} \eta_{-1} (\Delta\Omega_{-3})^{-1} a_{*,0.7}^2 B_{\rm h,12}^2$$

Plateau emission

Pressure balance

$$p_{\rm gas} = \frac{GM\Sigma}{r^2}$$

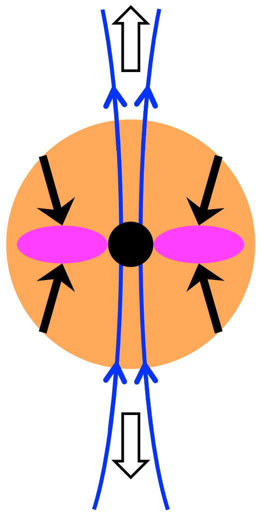
$$p_{\rm mag} = \frac{B^2}{8\pi}$$

$$\Sigma = \frac{\dot{M}}{2\pi r \epsilon v_{\rm ff}}$$

$$v_{\rm ff} \sim \sqrt{\frac{GM}{r}}$$

$$\epsilon \sim 0.01$$

(Tchekhovskoy+ 11)



Fallback

BZ jet with B_{NS}~10^{12}G

Confinement timescale

Plateau emission

Pressure balance

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$$p_{\rm mag} = \frac{B^2}{8\pi}$$

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$$v_{\rm ff} \sim \sqrt{\frac{GM}{r}}$$

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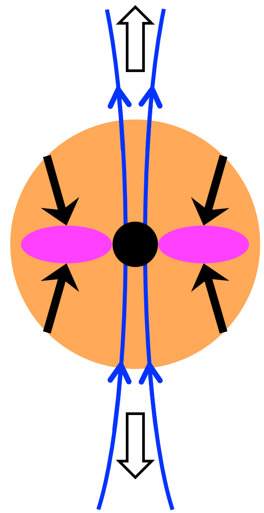
(Tchekhovskoy+ 11)



Accretion rate

$$\dot{M} = \frac{2}{3}\frac{M_{\rm d}}{t_0}\left(\frac{t}{t_0}\right)^{-5/3}$$

$$t_0 \sim 2\pi\sqrt{\frac{R_{\rm NS}^3}{GM_{\rm NS}}} \sim 3.3\times10^{-4}{\rm s}$$

Fallback
BZ jet with B_{NS}~10^{12}G

Confinement timescale

Plateau emission

Pressure balance

$$p_{\rm gas} = \frac{GM\Sigma}{r^2}$$

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$$v_{\rm ff} \sim \sqrt{\frac{GM}{r}}$$

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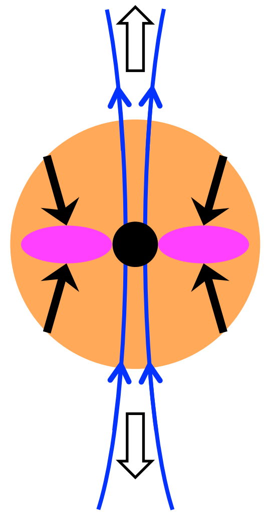


Fallback
BZ jet with B_{NS}~10^{12}G

Accretion rate

$$\dot{M} = \frac{2}{3}\frac{M_{\rm d}}{t_0}\left(\frac{t}{t_0}\right)^{-5/3}$$

$$t_0 \sim 2\pi\sqrt{\frac{R_{\rm NS}^3}{GM_{\rm NS}}} \sim 3.3\times 10^{-4}{\rm s}$$

Confinement timescale $(r = r_{\rm g} = 2GM/c^2)$

$$T = \left(\frac{16\pi}{9}\right)^{3/10} t_0^{2/5}\left(\frac{r_{\rm g}}{c}\right)^{3/5}\left(\frac{M_{\rm d}c^2}{\epsilon B_{\rm H}^2 r_{\rm g}^3}\right)^{3/5}$$

$$\sim 1.4\times 10^4{\rm s}\ \epsilon_{-2}^{-3/5} M_{{\rm d},-1}^{3/5} M_{0.5}^{-6/5} B_{{\rm H},12}^{-6/5}$$

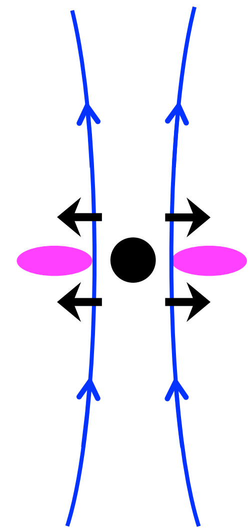
Plateau emission decay

ホライズンの中に閉じ込められなくなって以降の進化

Magnetic field

$$B_{\rm h} \propto r_{\rm m}^{-2}$$

円盤の内縁より内側の
磁場は一様とする。



Pressure

$$p_{\rm gas} \propto r_{\rm m}^{-5/2} t^{-5/3} \quad \Rightarrow \quad B_{\rm h} \propto t^{-20/9}$$

$$p_{\rm mag} \propto B_{\rm h}^2$$

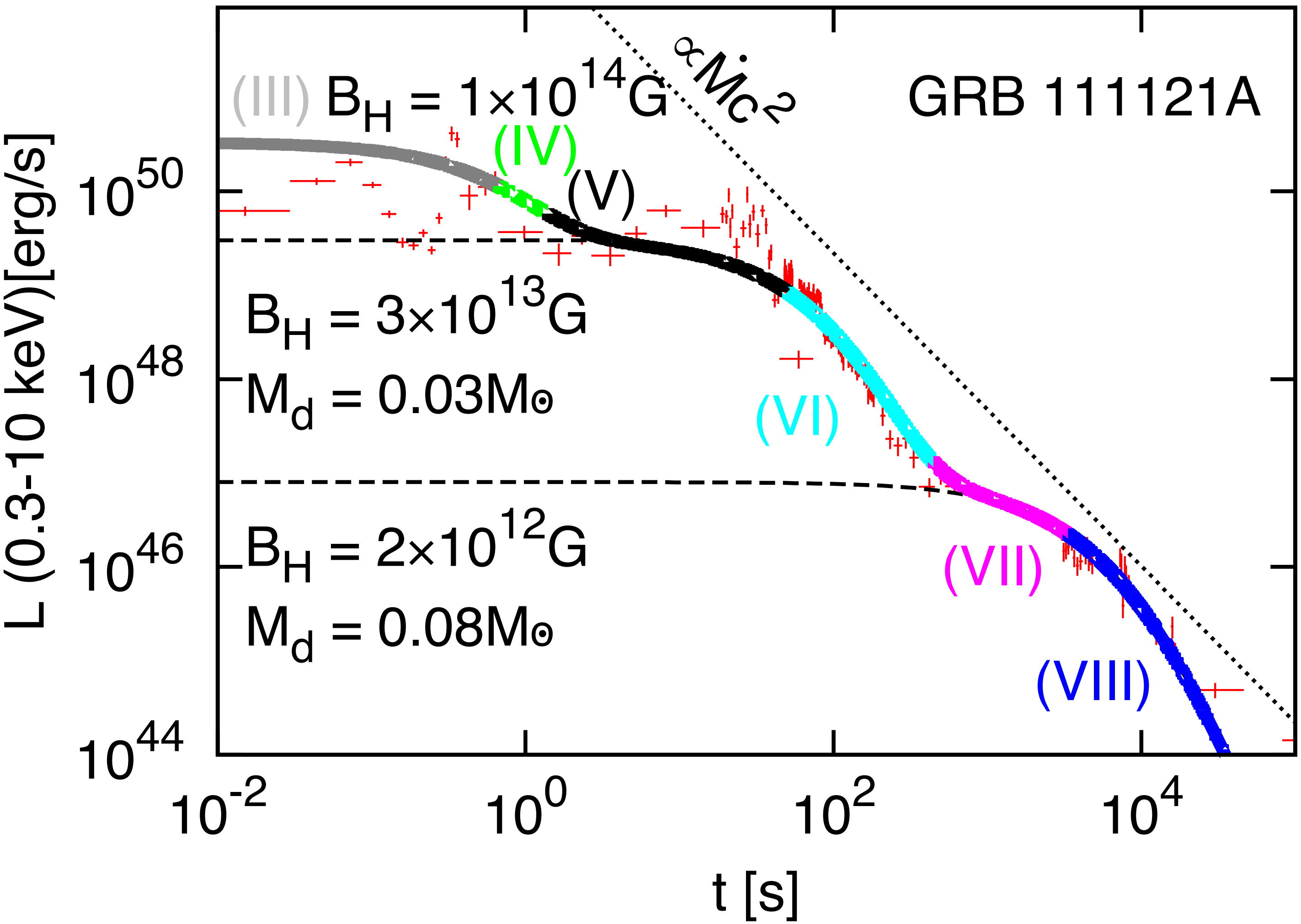
Luminosity evolution

$$L_{\rm BZ} \propto \left(1 + \frac{t}{T}\right)^{-40/9}$$

(スピンダウンは無視)

Light curve

(Preliminary)



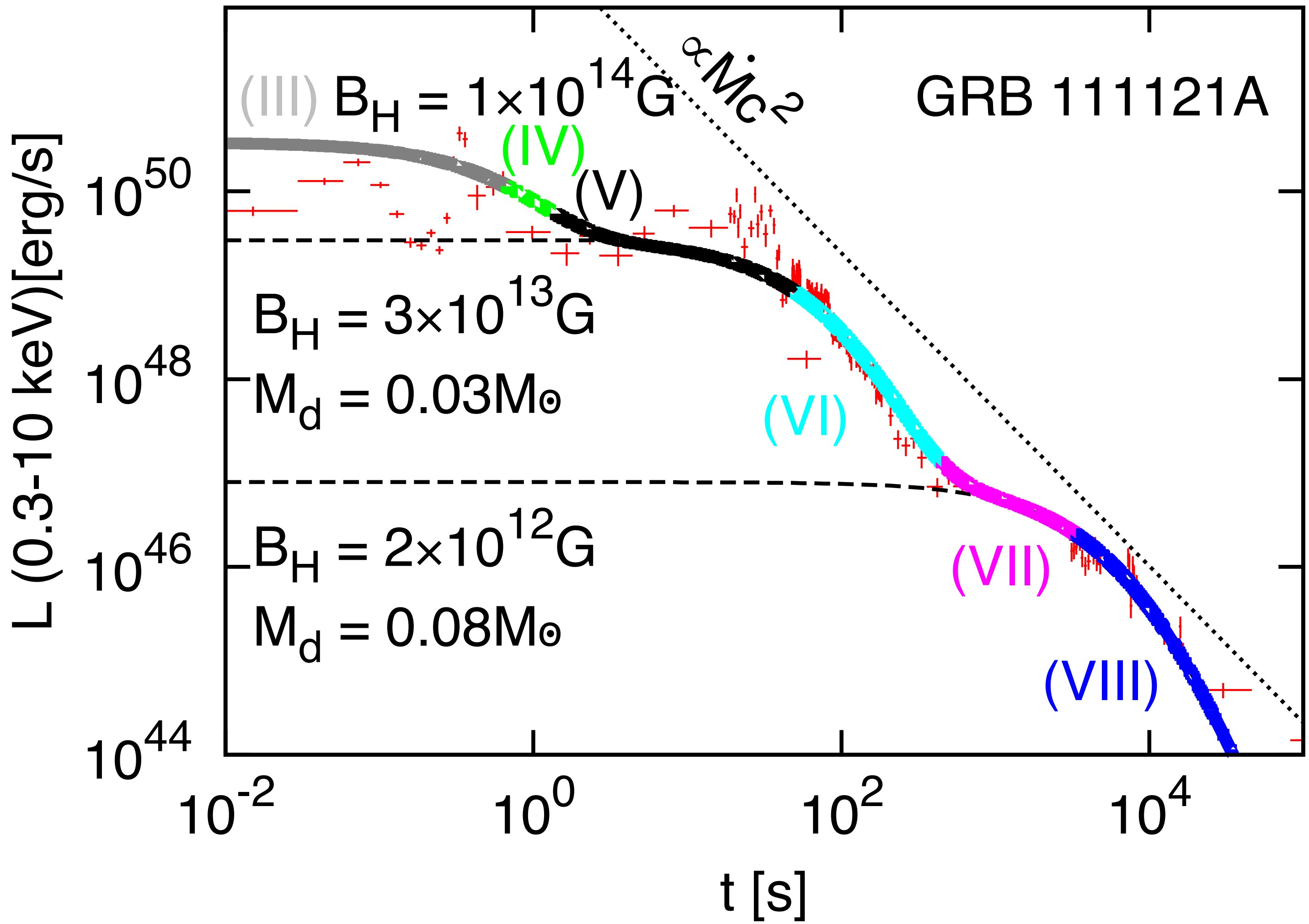
$$L \sim L_0 \left(1 + \frac{t}{T}\right)^{-40/9}$$

$$L_0 \sim 2.0 \times 10^{46}\ \mathrm{erg\ s^{-1}}\ \eta_{-1}(\Delta\Omega_{-3})^{-1} a_{*,0.7}^2 B_{\mathrm{h},12}^2$$

$$T \sim 1.4 \times 10^4 \mathrm{s}\ \epsilon_{-2}^{-3/5} M_{\mathrm{d},-1}^{3/5} M_{0.5}^{-6/5} B_{\mathrm{h},12}^{-6/5}$$

Light curve

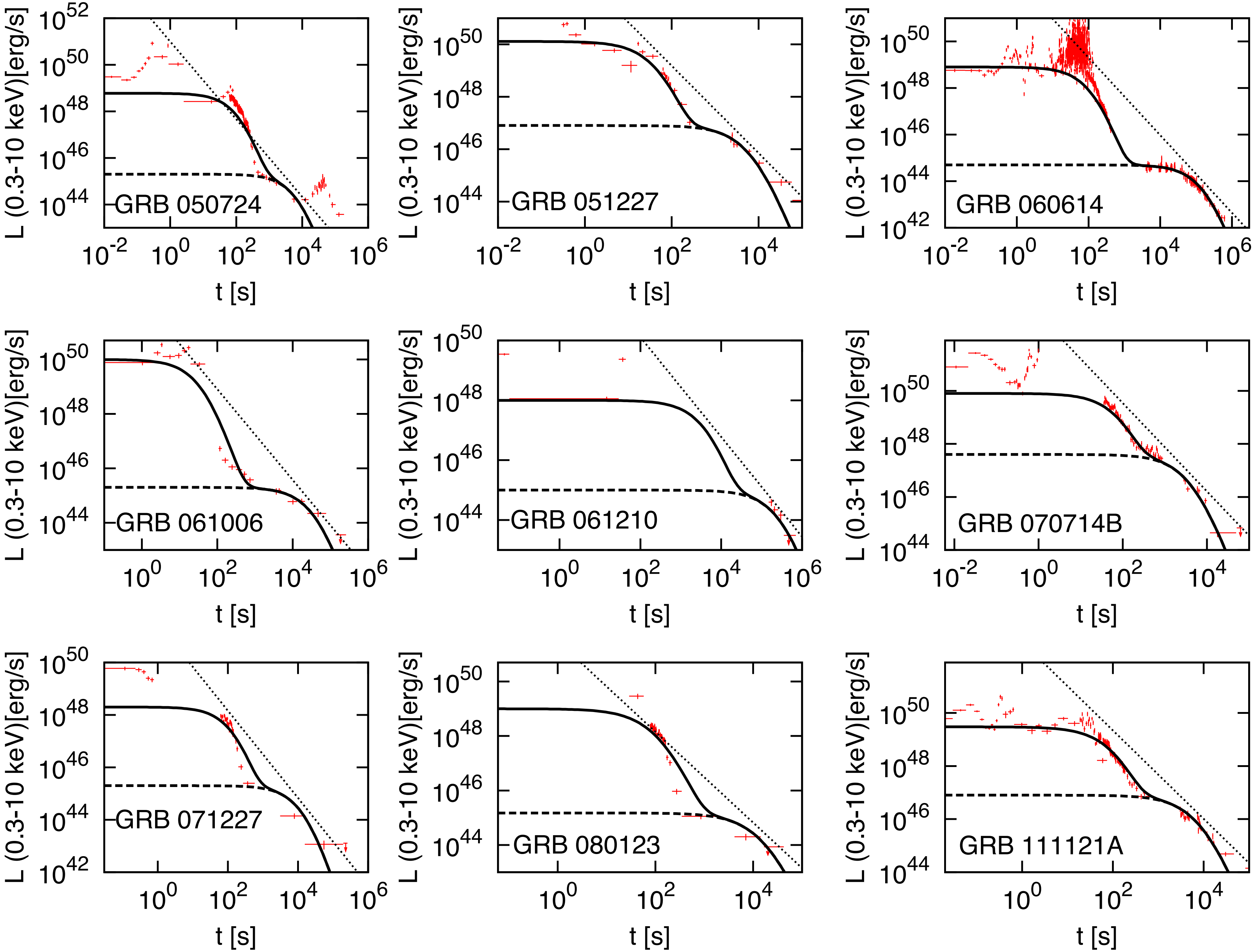
(Preliminary)



$$B_{\rm h} \sim 1.8 \times 10^{12}{\rm G}\ \eta_{-1}^{-1/2}(\Delta\Omega_{-3})^{1/2} a_{*,0.7}^{-1} L_{47}^{1/2}$$

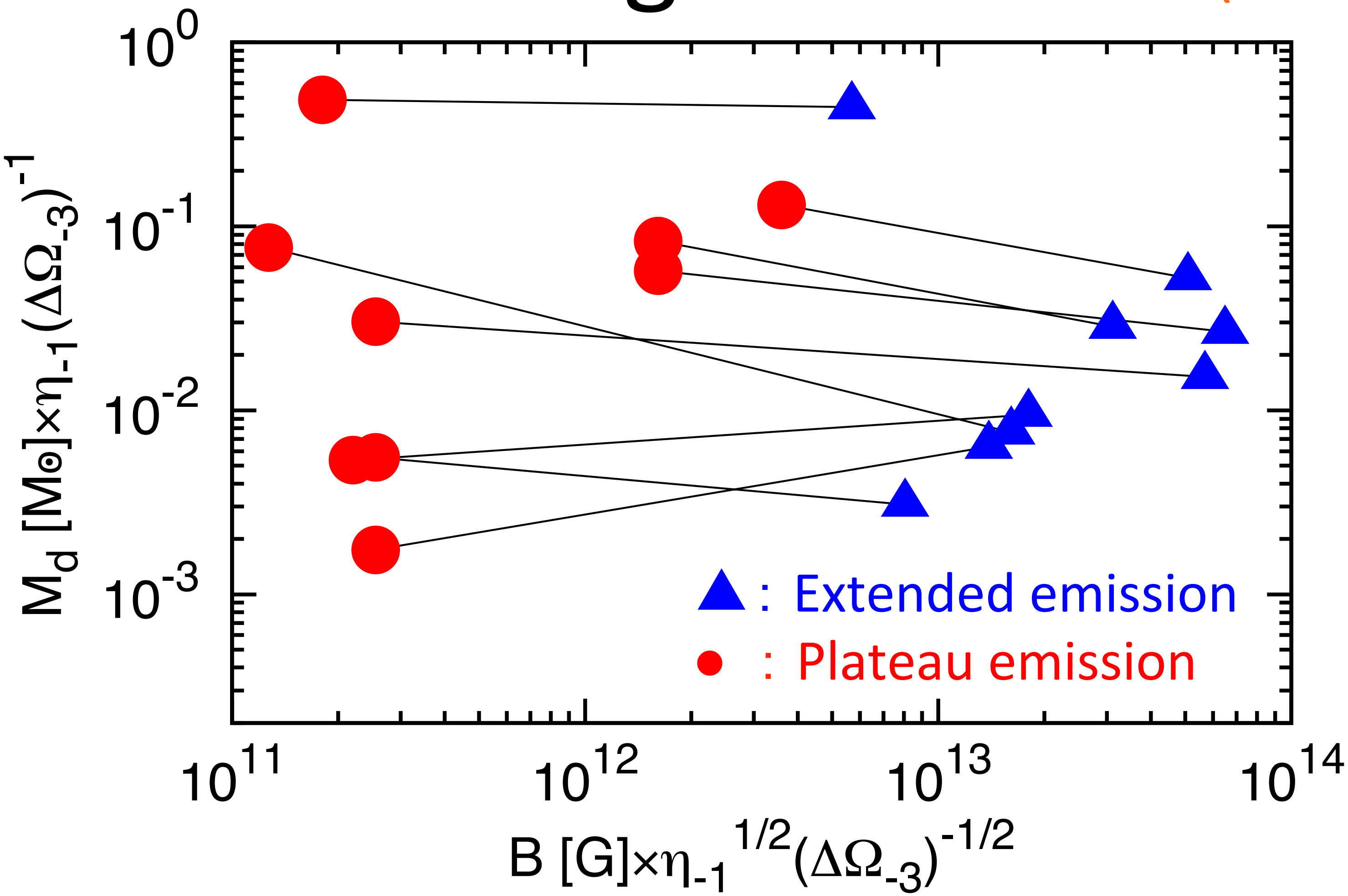
$$M_{\rm d} \sim 0.10 M_{\odot}\ \eta_{-1}^{-1}(\Delta\Omega_{-3}) a_{*,0.7}^{-2} \epsilon_{-2} M_{0.5}^{2} L_{47} T_{4}^{5/3}$$

Fitting results (Preliminary)



Fitting results

(Preliminary)



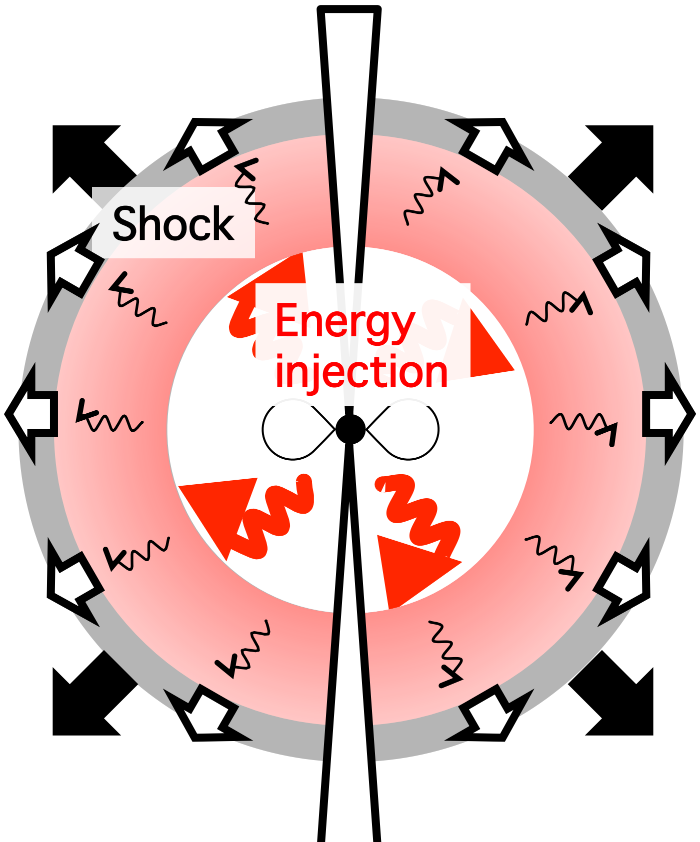
磁場: $10^{11}\mathrm{G} \lesssim B \lesssim 10^{13}\mathrm{G}$ $10^{13}\mathrm{G} \lesssim B \lesssim 10^{14}\mathrm{G}$

円盤質量: $10^{-3} M_\odot \lesssim M_\mathrm{d} \lesssim 10^{-1} M_\odot$

Heated ejecta

Shock heating

$$L_{\rm th} \sim \frac{E_{\rm int}}{t}\left(\frac{t}{t_{\rm inj}}\right)^{-1} \sim \underline{E_{\rm int}t_{\rm inj}}t^{-2}$$



同じ量のエネルギー注入でも、後から注入したほうが光度が大きくなる。

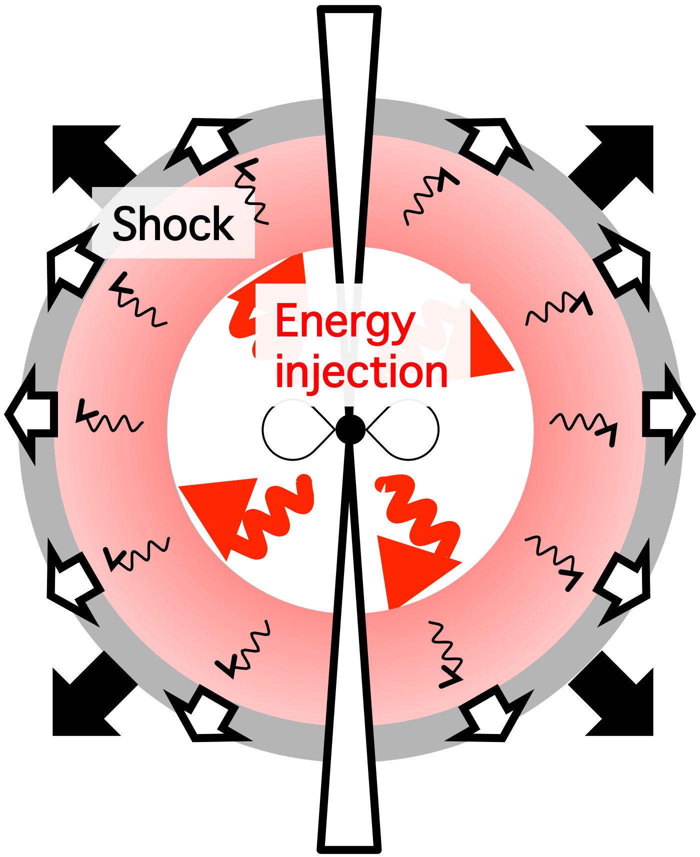
活動期間が長いほど、加熱された物質からの放射に反映されやすい。

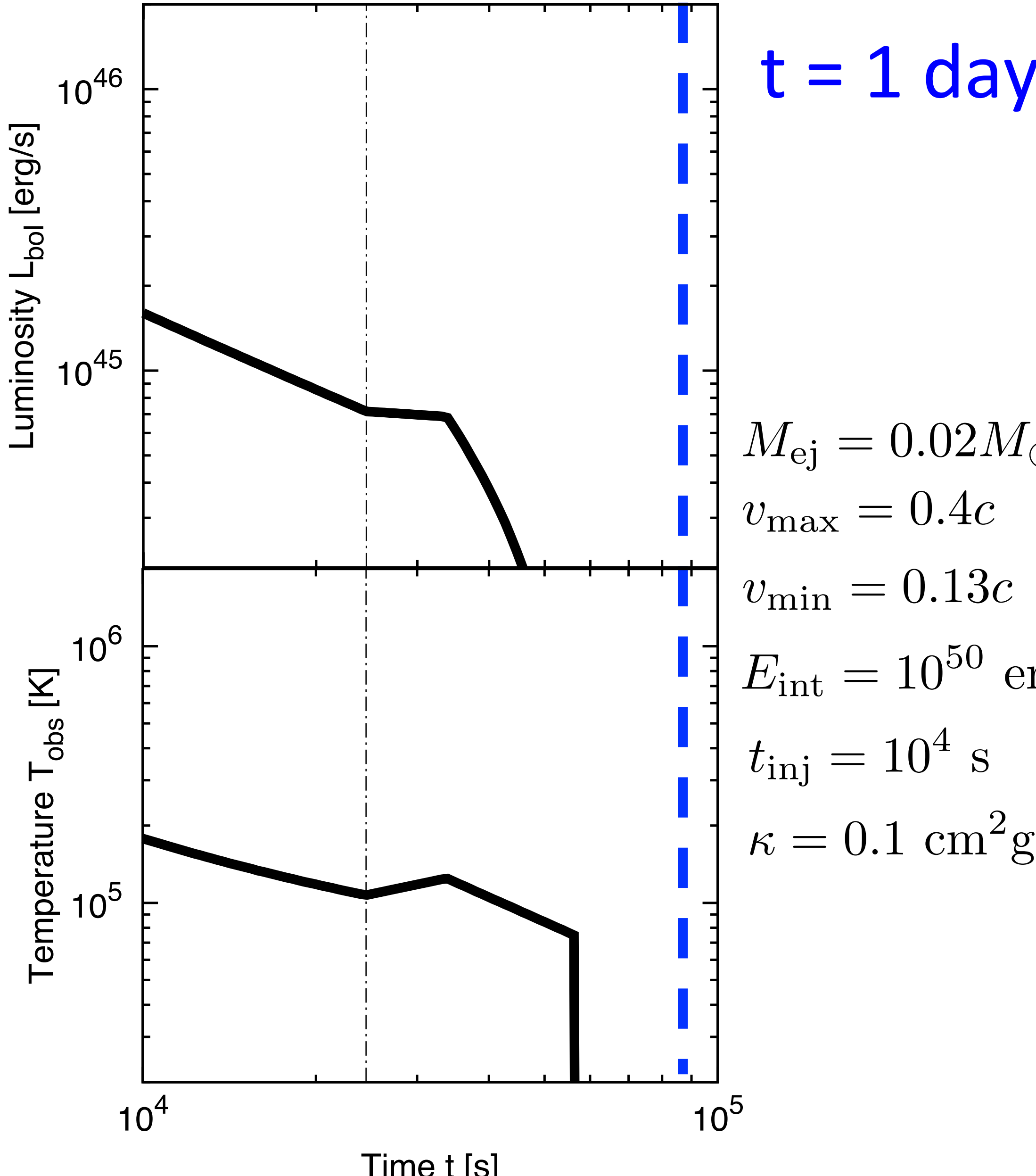
Heated ejecta (Preliminary)

$L \sim 10^{45}$ erg s^{-1}

$T \sim 10^5$K

$t \sim 10^4 - 10^5$ s





$M_{ej} = 0.02 M_\odot$

$v_{max} = 0.4c$

$v_{min} = 0.13c$

$E_{int} = 10^{50}$ erg

$t_{inj} = 10^4$ s

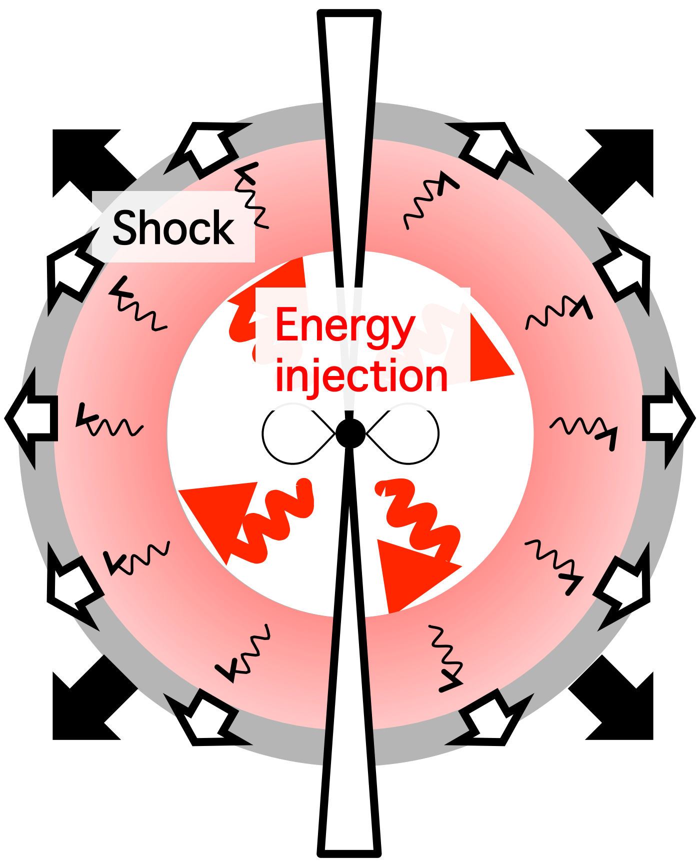
$\kappa = 0.1$ cm^{2}g^{-1}

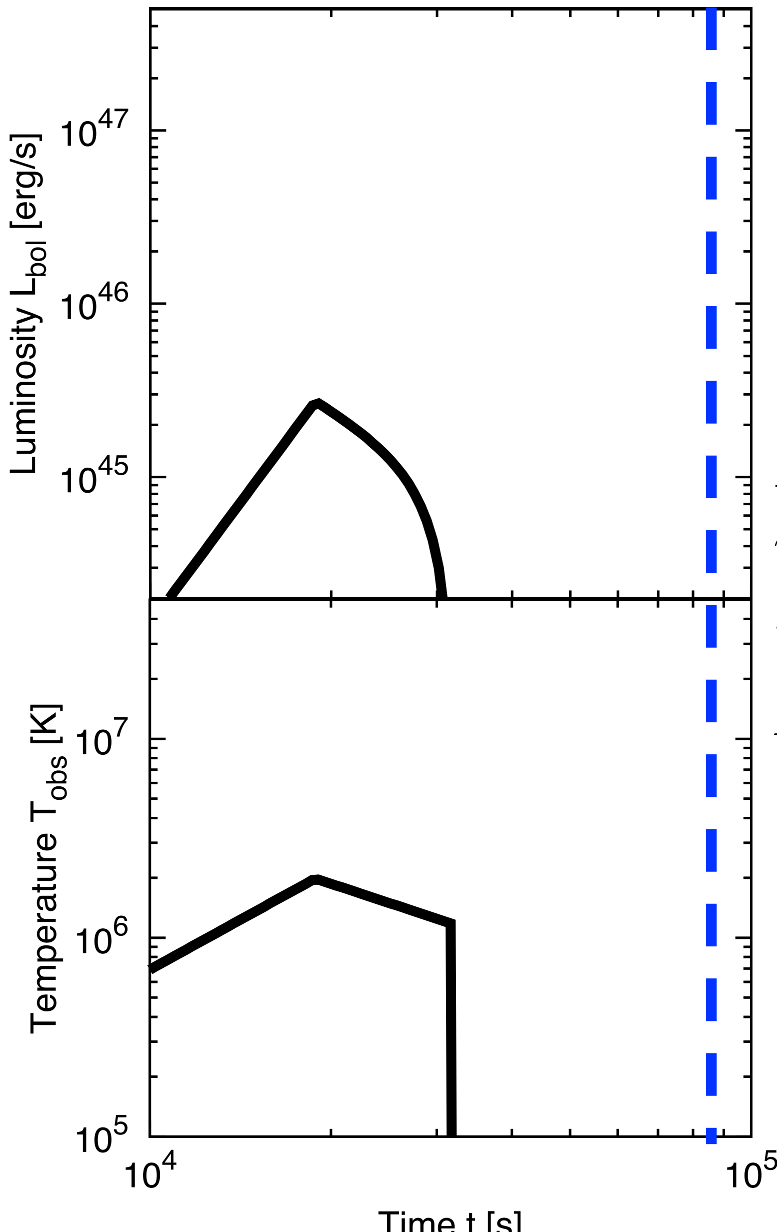
Heated ejecta (Preliminary)

$L \sim 10^{45} - 10^{46}$ erg s^{-1}

$T \sim 0.1 - 1$ keV

$t \sim 10^4 - 10^5$ s





t = 1 day

$M_{ej} = 10^{-3} M_\odot$

$v_{max} = 0.4c$

$v_{min} = 10^{-2}c$

$E_{int} = 10^{50}$ erg

$t_{inj} = 10^4$ s

$\kappa = 0.1$ cm^{2}g^{-1}

Summary

- short GRBの中心エンジンは ~10^4 sの活動期間を持つことが示唆されている。
- 長期間放射に対して、中心エンジンがBHの場合かつBZ機構の枠組みでモデルを構築。
- 中性子星が合体前に持つ磁場と合体後のfallbackで、光度とタイムスケールを説明することが可能。観測へのフィットから得られる磁場と円盤質量は ~10^{12}G, ~0.1$M_{\odot}$の範囲。
- もし合体後に放出される物質の加熱に使われる場合は、ほぼ等方的に最大 ~10^{45} erg s^{-1} 程度で数時間X線 - UVで光る可能性がある。