High E flashes from Supernovae-Breakouts?

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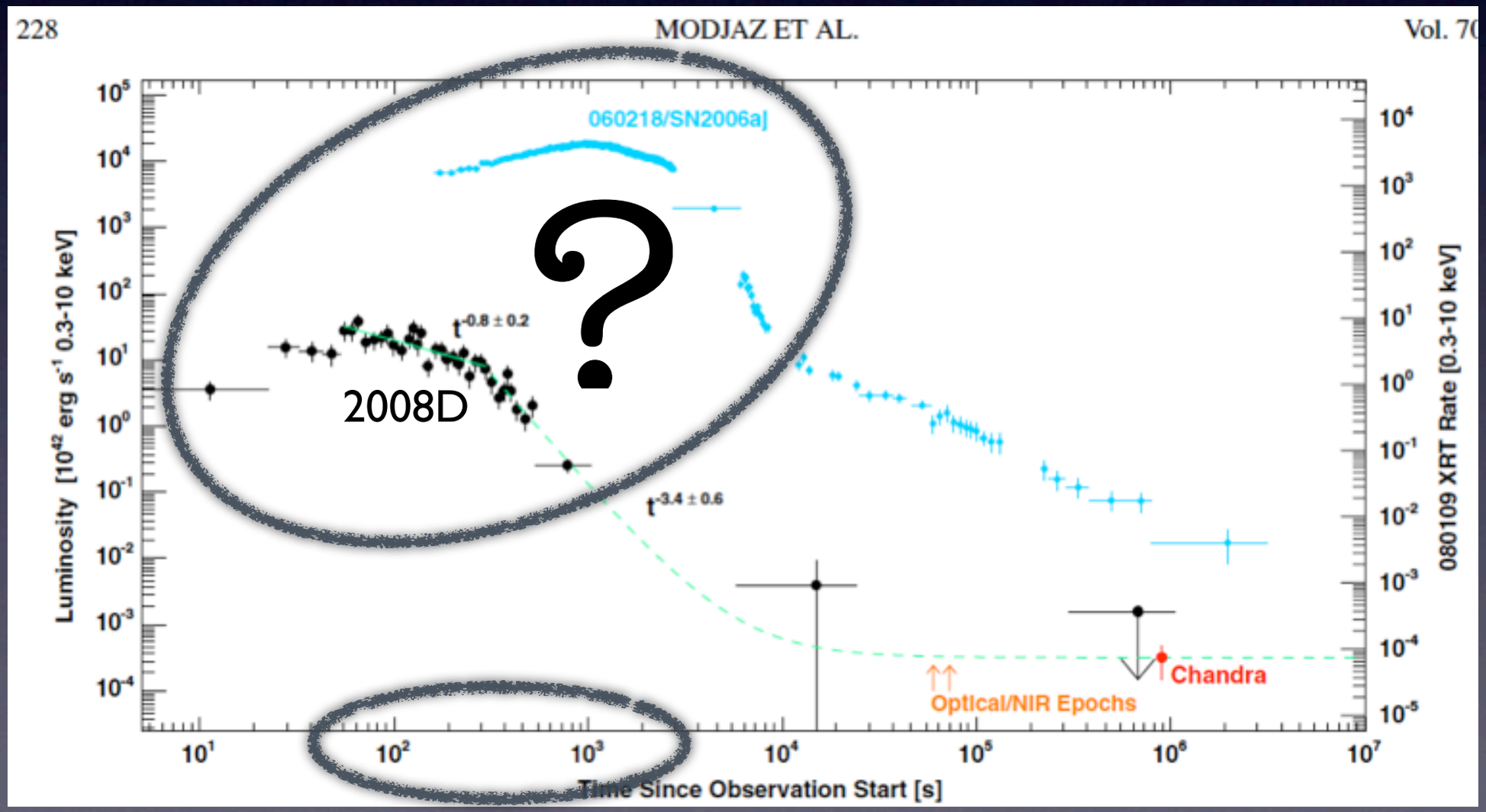


Observation: Some SNe observed with high-E flashes ("GRB"-SNe)

Theory: All SNe emit high-E flashes at breakout

[Colgate74, Falk 78, Klein&Chevalier 78]

Are these related?

[e.g. Kulkarni et. al. 98, Campana et. al. 06, Soderberg et. al. 08]

"GRB"-SNe: diverse, rare (except for 2008D)

SNe	z	FOV (deg^2)	log(V/Mpc^3)	log10(E/erg)	T(s)	
98bw	0.008	800	3.5	48	30	
03dh	0.17	5000	8.3	52.5	30	GRB
03lw	0.1	80	5.8	50	30	
06aj	0.03	4000	5.9	49.5	2000	
08D	0.006	0.16	-0.55	46	200	
10bh	0.06	4000	6.8	49.5	2000	

common: smooth light curve

late radio+X-rays: fast shocks, high CSM

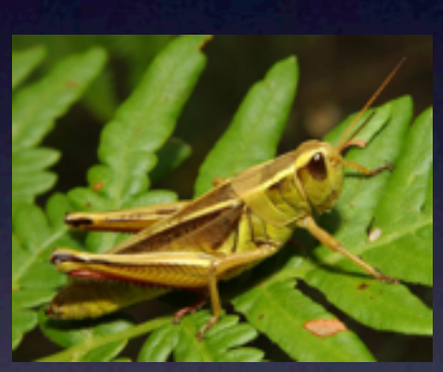
Note $10^{53} \neq 10^{48}$

GRB = Gamma Ray Burst

GEC = Grass Eating Creature

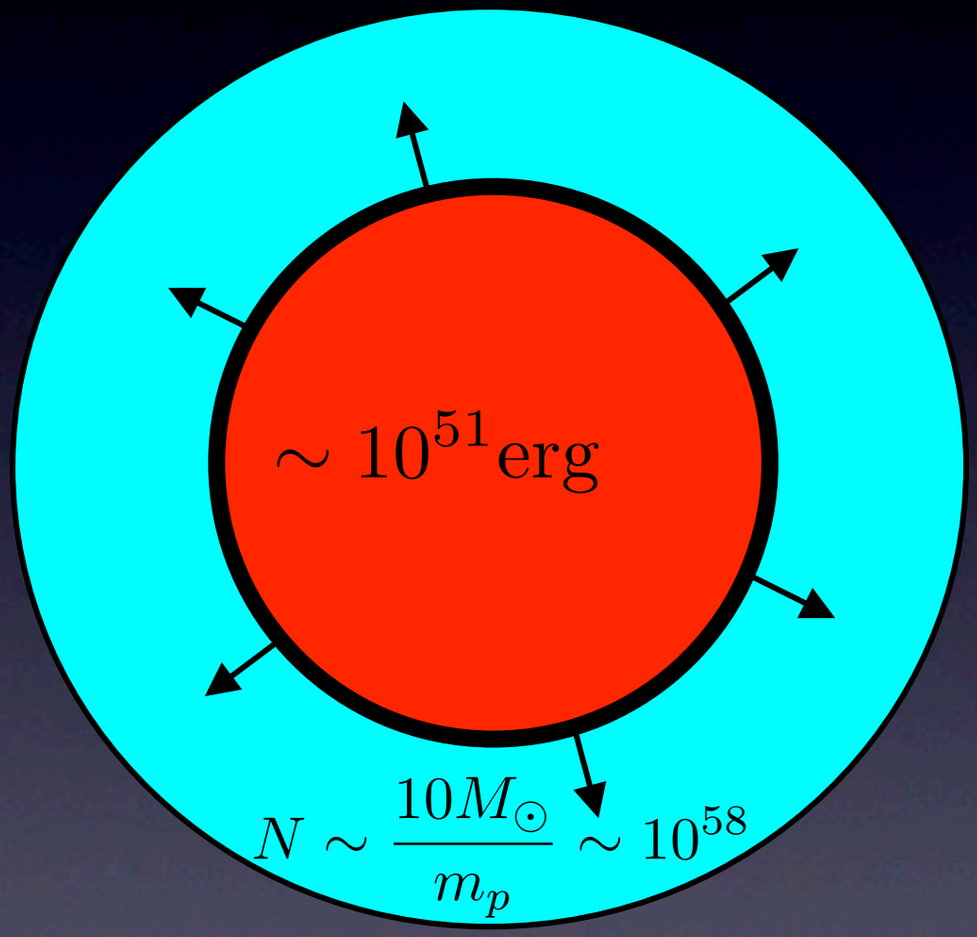
Cosmological GRB

03lw



98bw

Supernovae have good high E potential



Potential:

$$10^{51}\mathrm{erg},\ h\nu \sim \frac{E}{N} \sim 50\mathrm{keV}$$

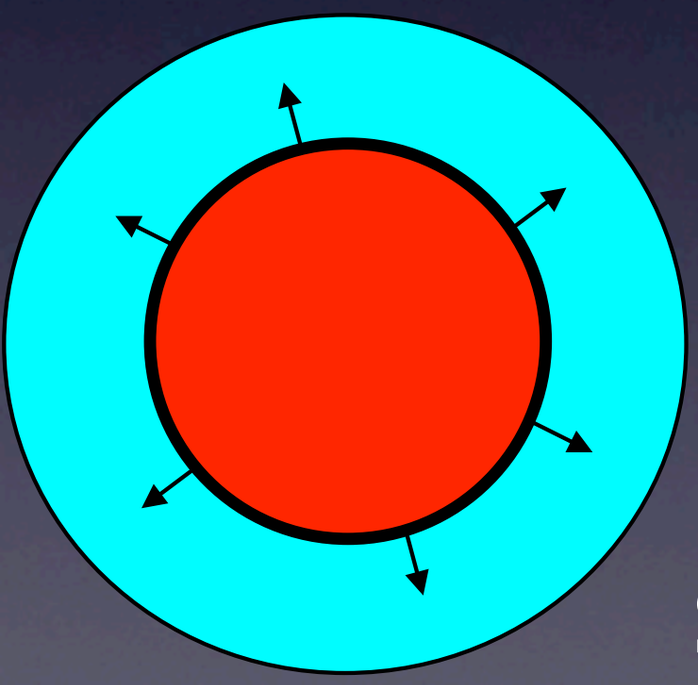
Get:

$$\lesssim 10^{50}\mathrm{erg},\ h\nu \sim \mathrm{eV}$$

Why SNe are not high E bursts?

star is very opaque

$$\tau \sim 10^7 R_{13}^{-2}$$



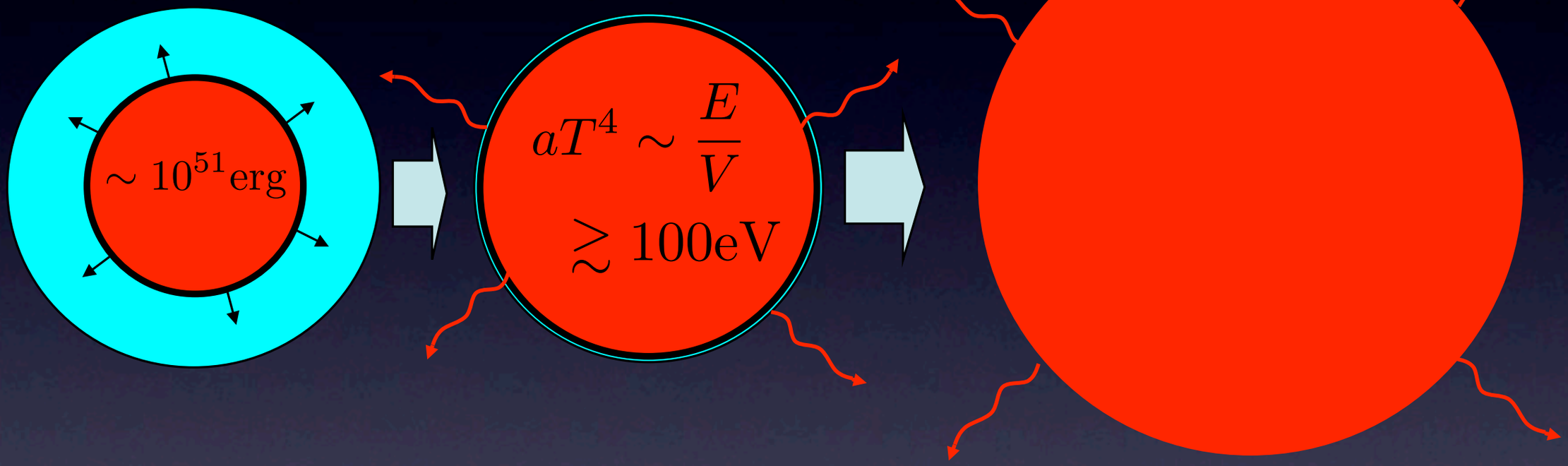
1. Too many photons

Radiation mediated shock- too efficient

2. Adiabatic Loss

Star needs to expand to release radiation

Breakout-beat adiabatic losses



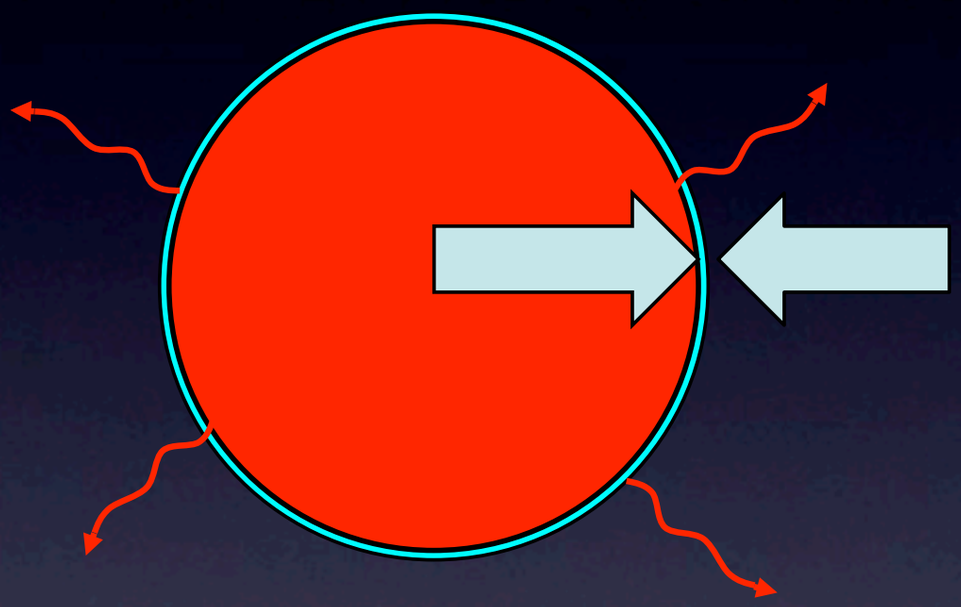
Dark

Breakout
X-rays

UV-optical

See talk by I. Rabinak

Breakout -Expectations



$R = 10^{13}\mathrm{cm}$

$v = 10^{9}\mathrm{cm/s}$

$\rho = 10^{-9}\mathrm{gr/cm^3}$

$$\tau = \frac{c}{v}$$

$$E \sim Mv^2 \sim 10^{47}\mathrm{erg} \qquad \propto R^2 v$$

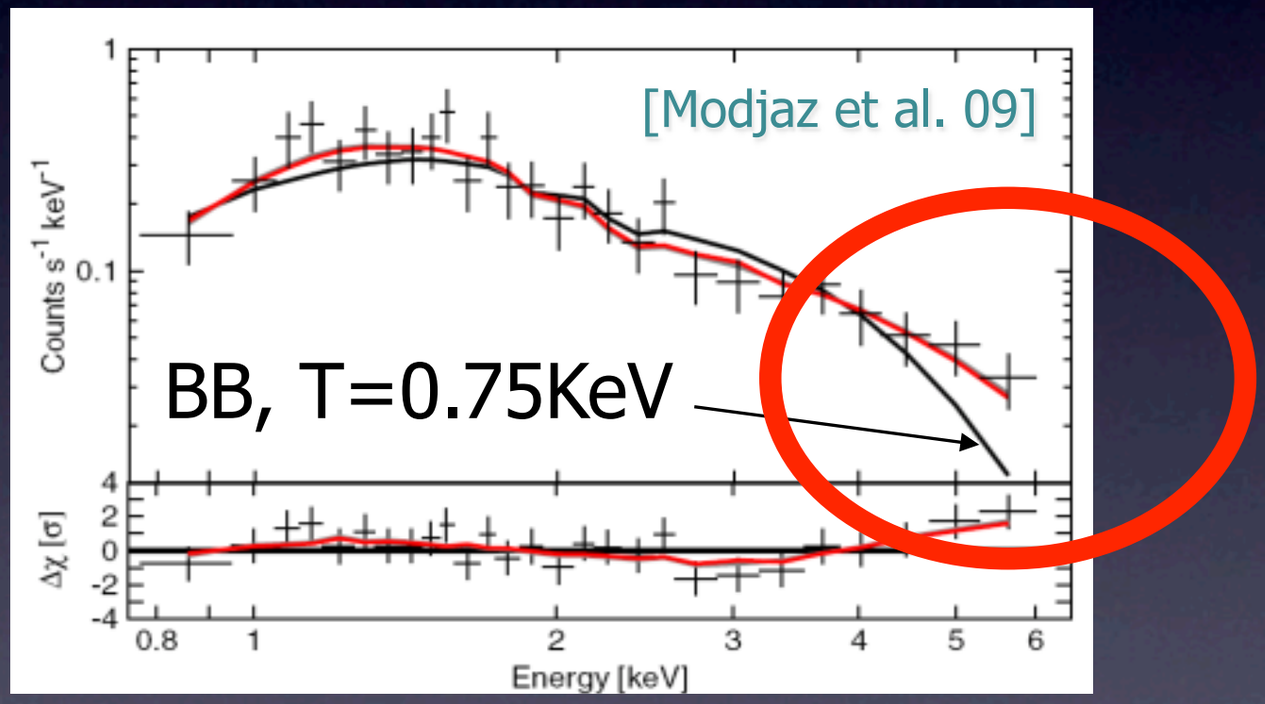
$$t \sim \frac{R}{c} \sim 300s \qquad \propto R$$

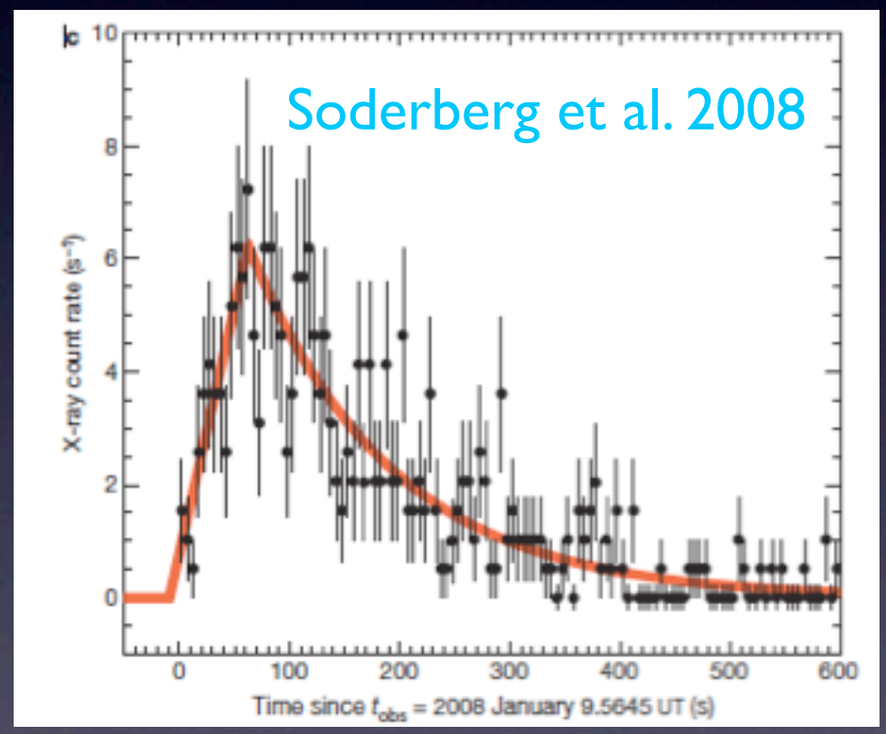
$$aT^4 \sim \rho v^2 \quad T \sim 70eV \qquad \propto v^{1/2}\rho^{1/4}$$

Ibc SN2008D-XRF080109

$E \sim 2 \times 10^{46}\mathrm{erg}$ $t \sim 200\mathrm{s}$ $R \sim 3 \times 10^{12}\mathrm{cm}$ $\surd$

Main challenge: hard spectrum





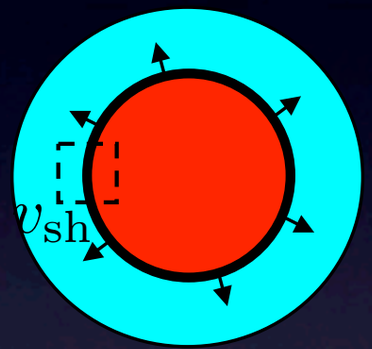
Clue: high velocity (v>0.25c) from radio+X-ray afterglow

In addition, too big for WR, UV+optical Rabinak et. al. 2011

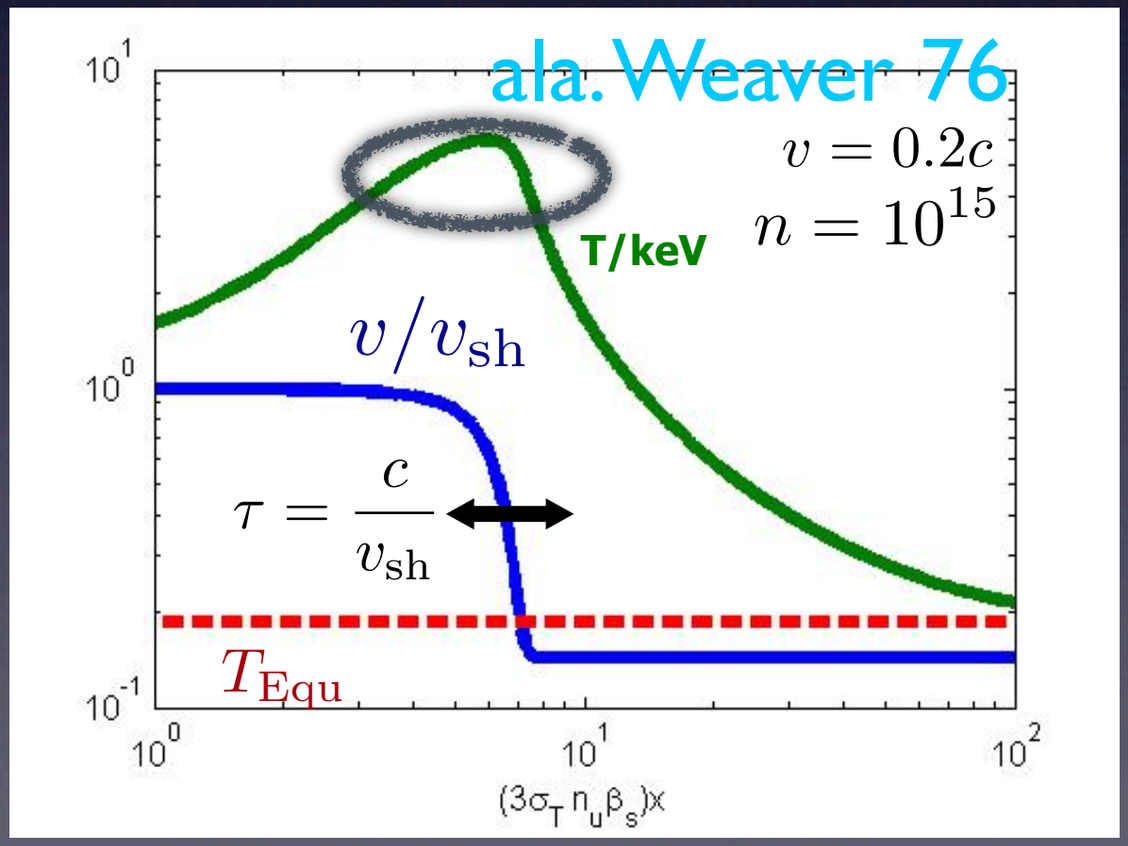
Fast breakout- less photons- high T

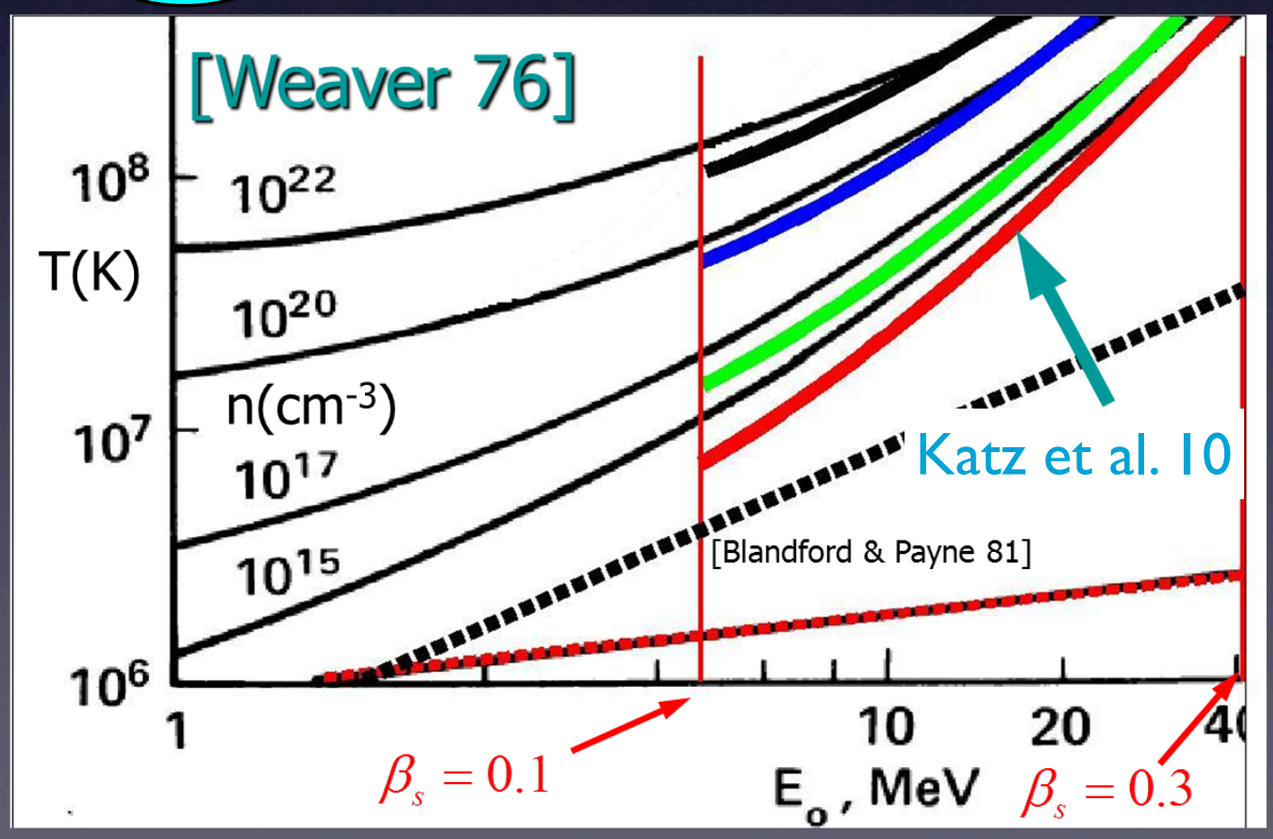
Katz et. al. 10 Nakar&Sari 10

Steady state shock



$v \gtrsim 0.1c$





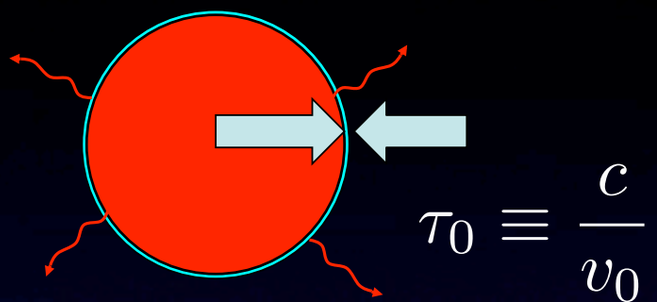
Compton Scattering, Bremsstrahlung

$T \propto v^8 \log$

Breakout Details Universal

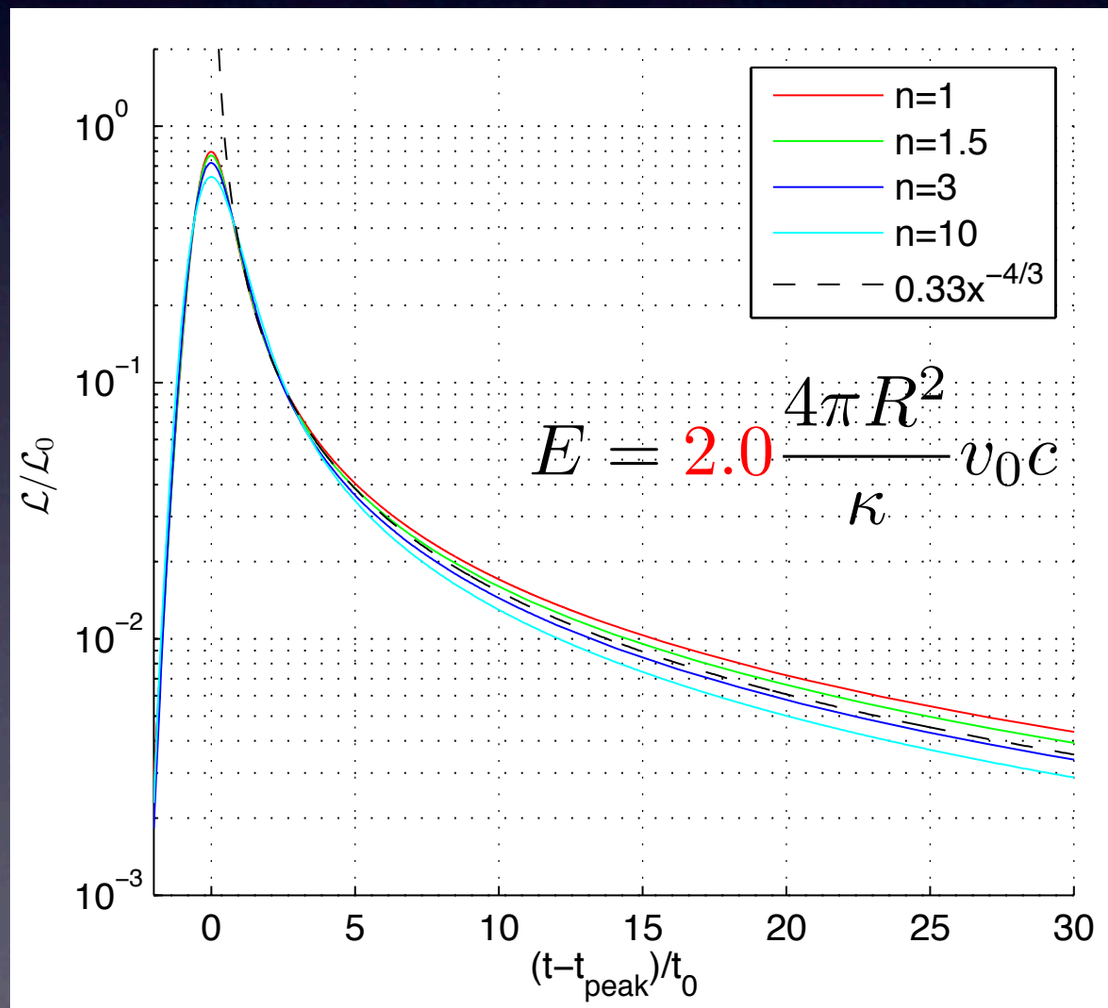
Sapir et. al. 11 Katz et. al. 11

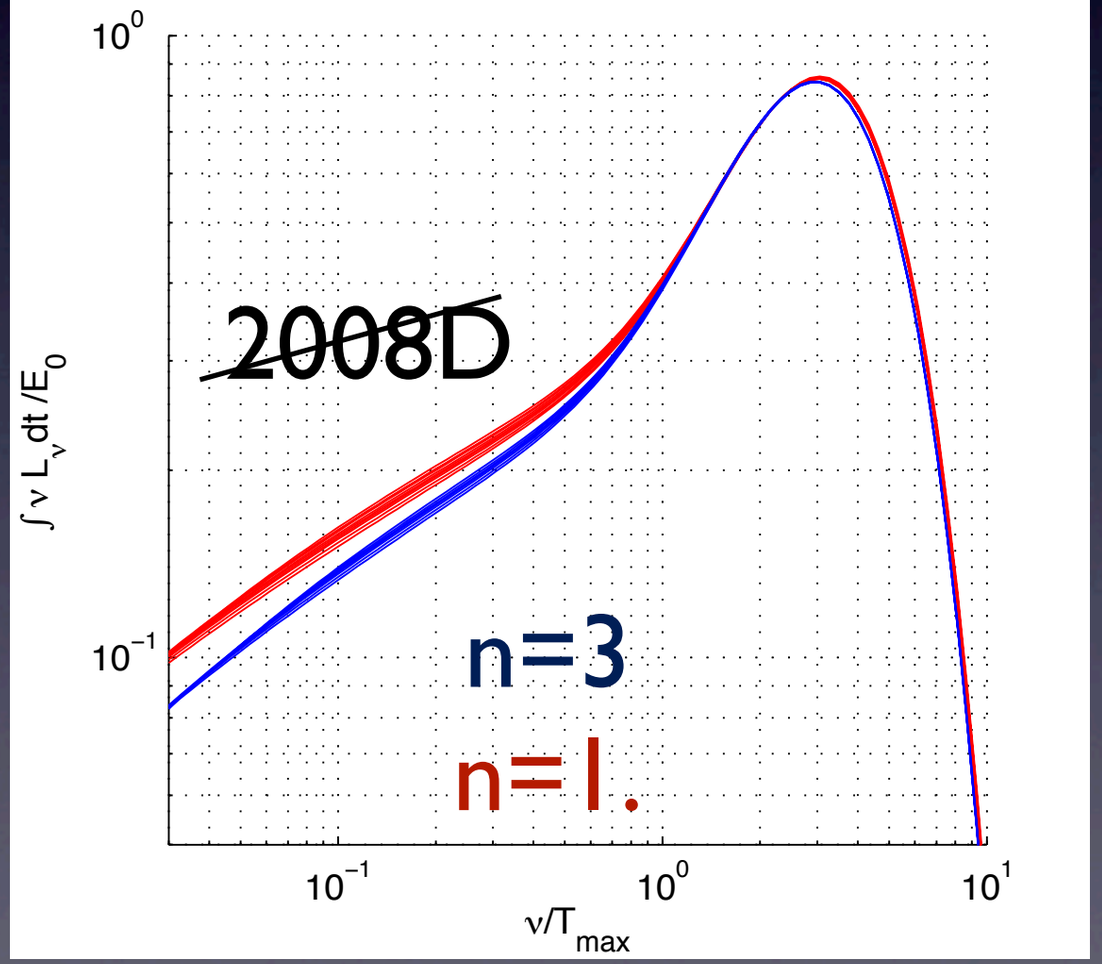
$$\rho \propto (R-r)^n$$



$$\tau_0 \equiv \frac{c}{v_0}$$

v_0, ρ_0, κ, n





Breakout work

	Steady State	Order of Mag	Full star Particular	General Breakout
Slow	$aT^4 = \frac{18}{7}\rho v^2$	e.g. Matzner&Mckee99 Campana et. al. 06 Nakar&Sari 10	e.g. Klein&Chevalier78 Ensman&Burrows92 Tominaga et. al. 09	Lasher&Chan 79 Sapir et. al. 10 Katz et. al. 10
Fast	Weaver 76, Katz et. al. 10	Katz et. al 10 Nakar&Sari 10		Sapir et. al. 11
Relativistic	Levinson &Bromberg 08 Katz et. al. 10 Budnik et. al. 10	Nakar&Sari 11 Bromberg et. al. 11 98bw,06aj,03lw,10bh? some GRBs??		?

winds (e.g. Arcavi et al. 11, Chevalier&Irwin 11, Morya&Tominaga11, Svirsky et. al. 12)

asymmetry (e.g. talk by A. Suzuki)

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Collisionless shock (leading to hard emission)?

Star? [e.g. Klein&Chevalier78]

No, radiation succsesfully accelerates the matter ahead of the shock

[Lasher&Chan79, Epstein81]

Wind?

Unavoidable!, radiation fails [Katz et. al. 11]

$$v_{\max} \propto \frac{E_\gamma}{r^2} \quad E_\gamma \lesssim M v^2 \propto r$$

at breakout- $v_{\max} \sim v$

later- $v_{\max} < v$!

Wind breakout (PTF09UJ?, Ultra Lumious IIn?)-> can approach full potential!

Katz et. al 11, Chevalier&Irwin 12, Svirsky et al. 12

$$E_\gamma \to 10^{51}\mathrm{erg} \qquad h\nu \to 50\mathrm{keV}$$

Collisionless shock @ $\tau > 1$

- Efficient Bremstrahlung
- Efficient (Coulomb) electron heating
- Proton acceleration-> Significant neutrino emission
- Too deep stops X-rays Chevalier&Irwin 12, Svirsky et al. 12

Conclusions

- High E SNe breakouts- must exist, key to measure SNe progenitors. Details: universal robust
- 2008D? Likely breakouts. High E: 1. v>0.1, no time to make photons. Details: fail. Wind? Asymmetry (see talk by A. Suzuki)?
- Wind - Must form collisionless shock. Possible $10^{51}\mathrm{erg}$ in hard X-rays
- 98bw, 06aj... relativistic breakouts? -> next talk by Udi Nakar