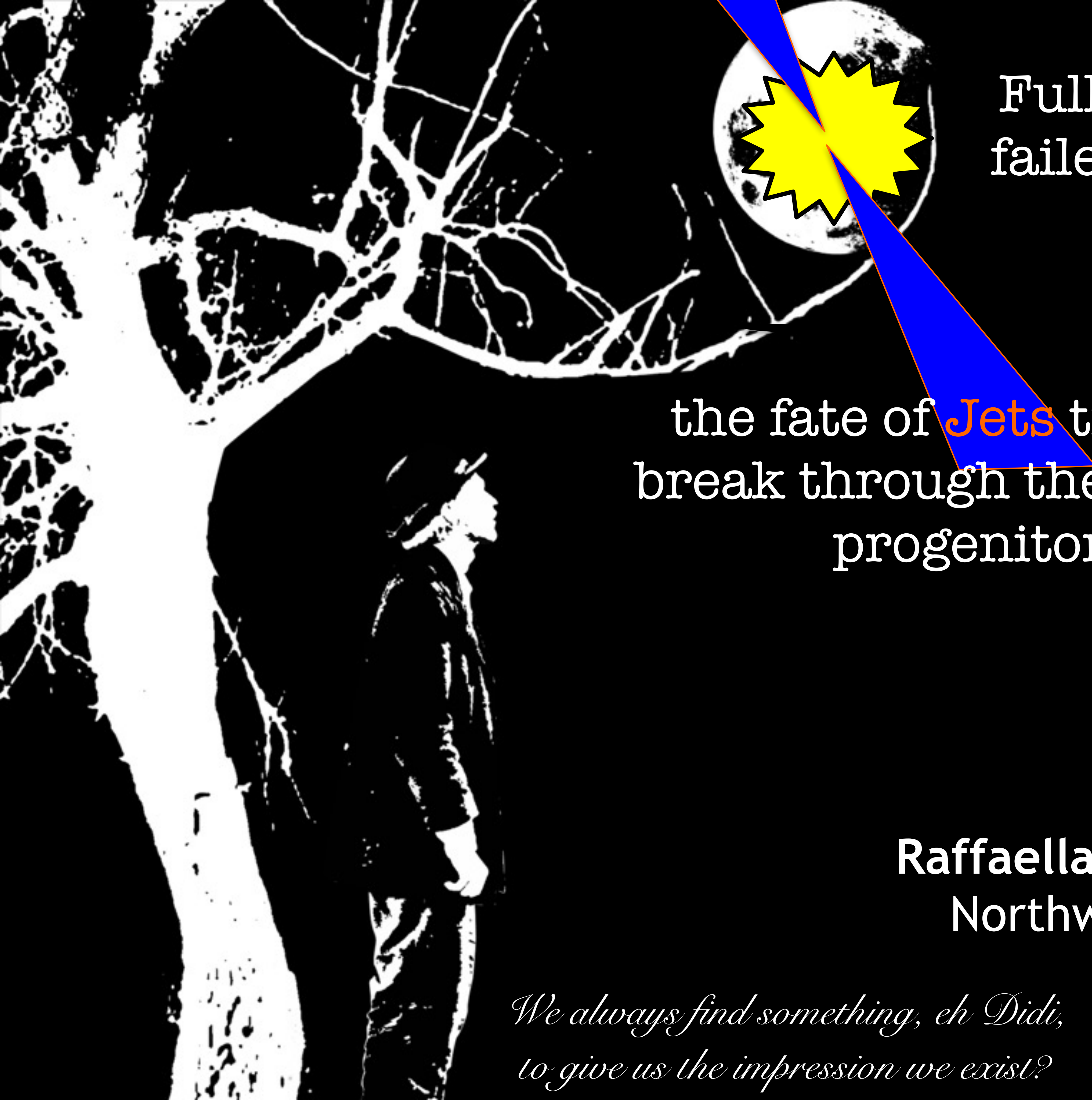
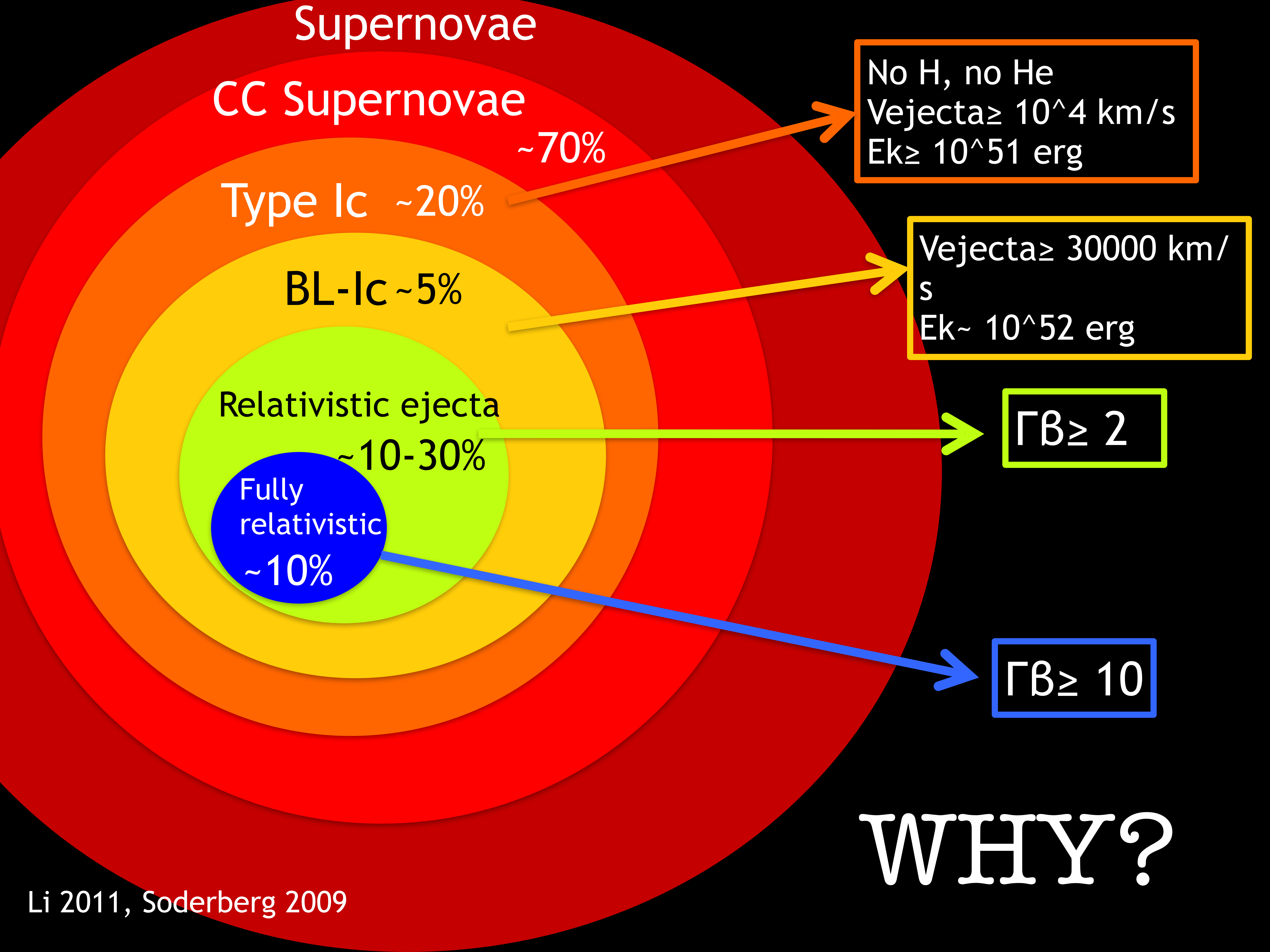


Fully successful, failed or barely failed:

the fate of Jets trying to break through their stellar progenitors

Raffaella Margutti
Northwestern

We always find something, eh Didi, to give us the impression we exist?


Supernovae
CC Supernovae
~70%
Type Ic ~20%
BL-Ic ~5%
Relativistic ejecta
~10-30%
Fully
relativistic
~10%
No H, no He
Vejecta≥ 10^4 km/s
Ek≥ 10^51 erg
Vejecta≥ 30000 km/
s
Ek~ 10^52 erg
Γβ≥ 2
Γβ≥ 10
WHY?
Li 2011, Soderberg 2009

1973

OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

On several occasions in the past we have searched the records of data from early *Vela* spacecraft for indications of gamma-ray fluxes near the times of appearance of supernovae. These searches proved uniformly fruitless. Specific predictions of gamma-ray emission during the initial stages of the development of supernovae have since been made by Colgate (1968). Also, more recent Vela spacecraft are equipped with

● ● ●

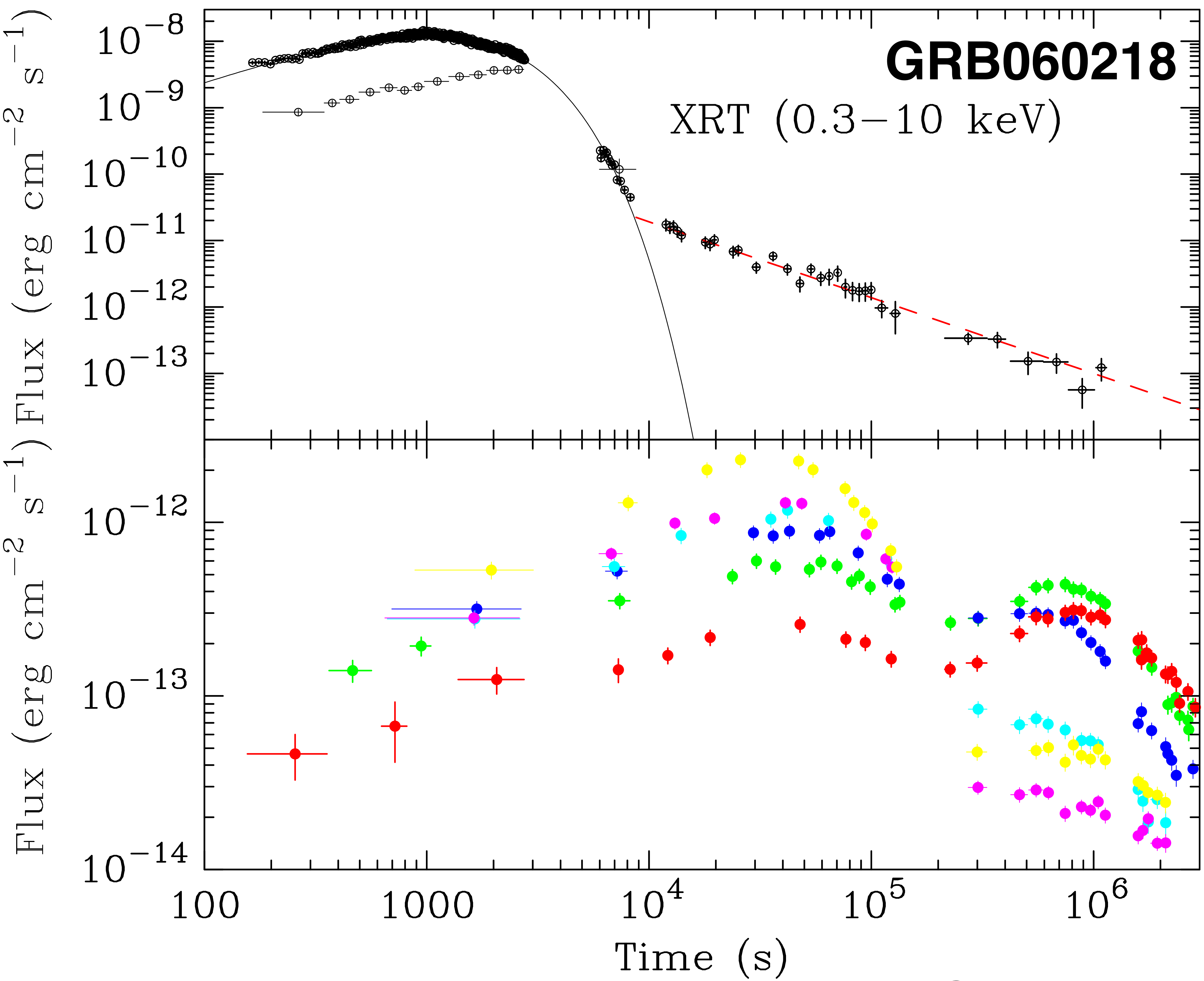
Thorne 1969). A source at a distance of 1 Mpc would need to emit $\sim 10^{46}$ ergs in the form of electromagnetic radiation between 0.2 and 1.5 MeV in order to produce the level of response observed here. Since this represents only a small fraction ($< 10^{-3}$) of the energy usually associated with supernovae, the energy observed is not inconsistent with a supernova as a source.

GAMMA-RAY BURSTERS AT COSMOLOGICAL DISTANCES

1986

BOHDAN PACZYŃSKI
Princeton University Observatory
Received 1986 May 12; accepted 1986 June 23

We propose that some, perhaps most, gamma-ray bursters are at cosmological distances, like quasars, with a redshift $z \approx 1$ or $z \approx 2$. This proposition requires a release of supernova-like energy of about 10^{51} ergs within less than 1 s, making gamma-ray bursters the brightest objects known in the universe, many orders of magnitude brighter than any quasars. This power must drive a highly relativistic outflow of electron-positron plasma and



Campana+2006

GAMMA-RAY BURSTS FROM STELLAR MASS ACCRETION DISKS AROUND BLACK HOLES[1]

S. E. Woosley

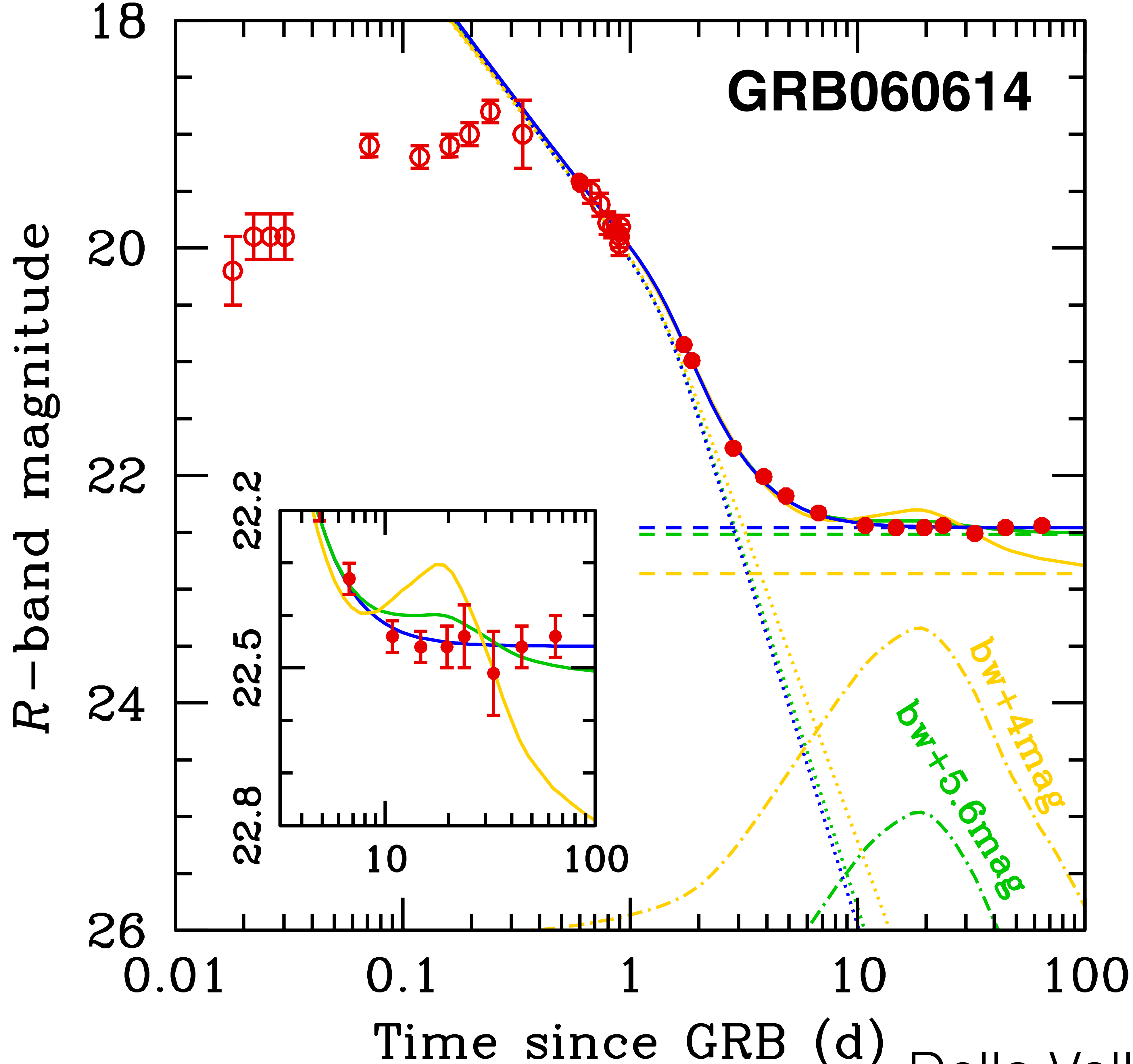
University of California Observatories/Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, Santa Cruz, CA 95064; and General Studies Group, Physics Department, Lawrence Livermore National Laboratory

Received 1992 June 22; accepted 1992 September 3

ABSTRACT

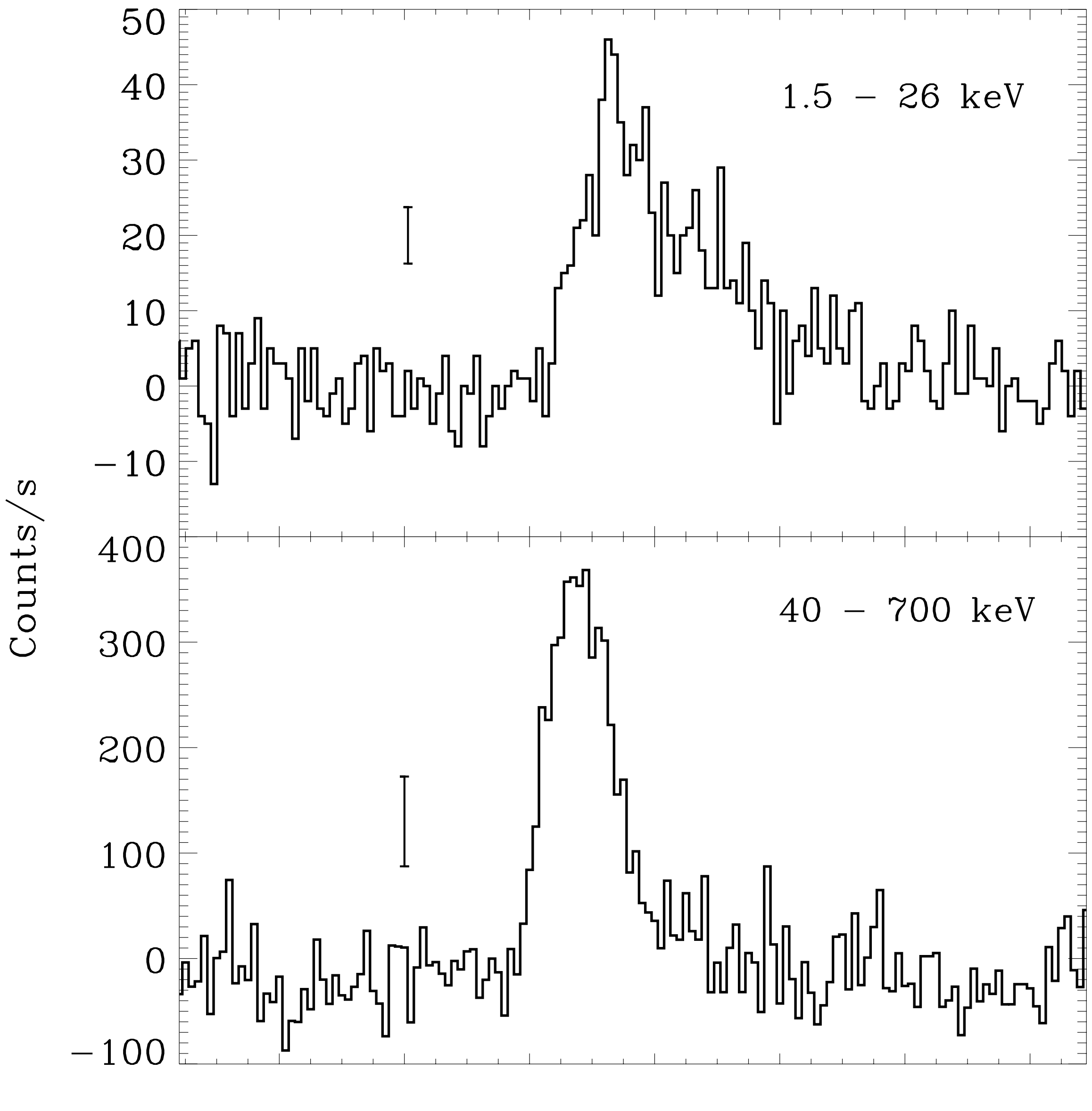
A cosmological model for gamma-ray bursts is explored in which the radiation is produced as a broadly beamed pair fireball along the rotation axis of an accreting black hole. The black hole may be a consequence of neutron star merger or neutron star–black hole merger, but for long complex bursts, it is more likely to come from the collapse of a single Wolf-Rayet star endowed with rotation ("failed" Type Ib supernova). The disk is geometrically thick and typically has a mass inside 100 km of several tenths of a solar mass. In the failed supernova case, the disk is fed for a longer period of time by the collapsing star. At its inner edge the disk is thick to its own neutrino emission and evolves on an viscous time scale of several seconds. In a region roughly 30 km across, interior to the accretion disk and along its axis of rotation, a pair fireball is generated by neutrino annihilation and electron-neutrino scattering which deposit approximately 10^{50} ergs s^{-1}. Electron scattering is more important in those cases where the baryonic contamination is high and the time scale for expansion increased. Extensive baryonic mass loss also occurs from the disk, and this may pose problems for production of a hard burst. Gamma-ray burst or not, this sort of event should occur in nature and should have an observable counterpart.

Subject headings: accretion, accretion disks — black hole physics — gamma rays: bursts — stars: evolution — supernovae: general

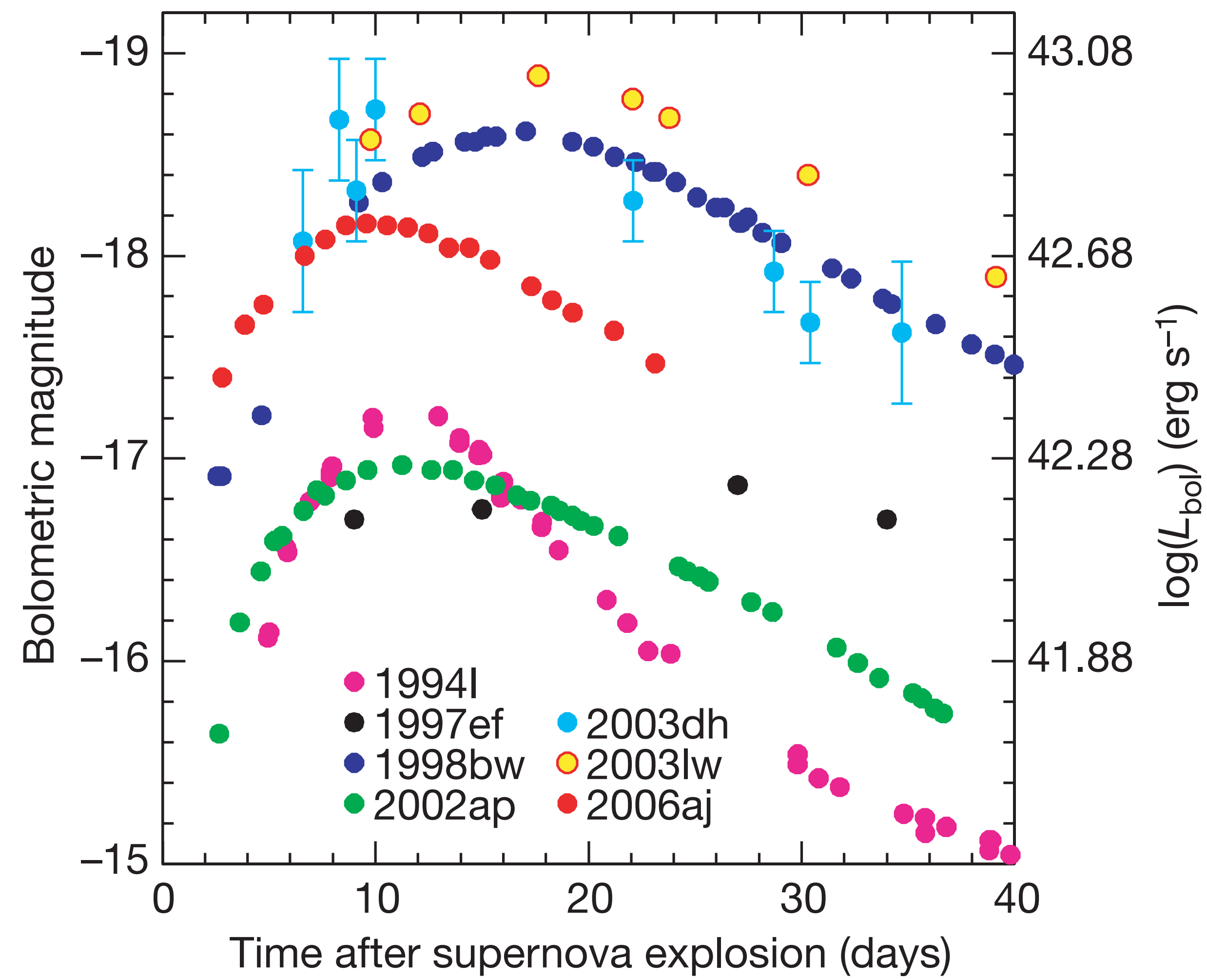


Della Valle+2006

GRB980425

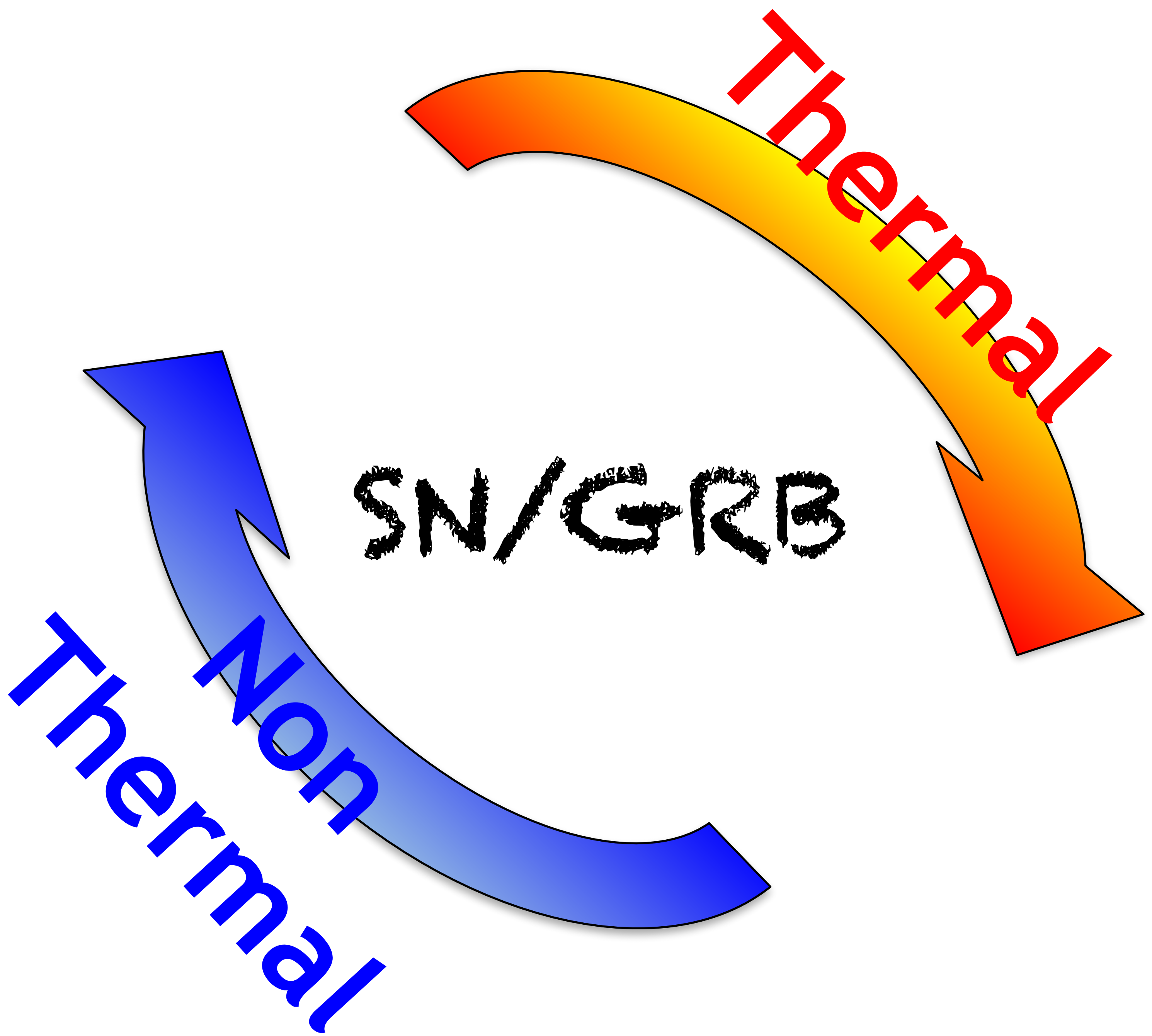


Pian+1999

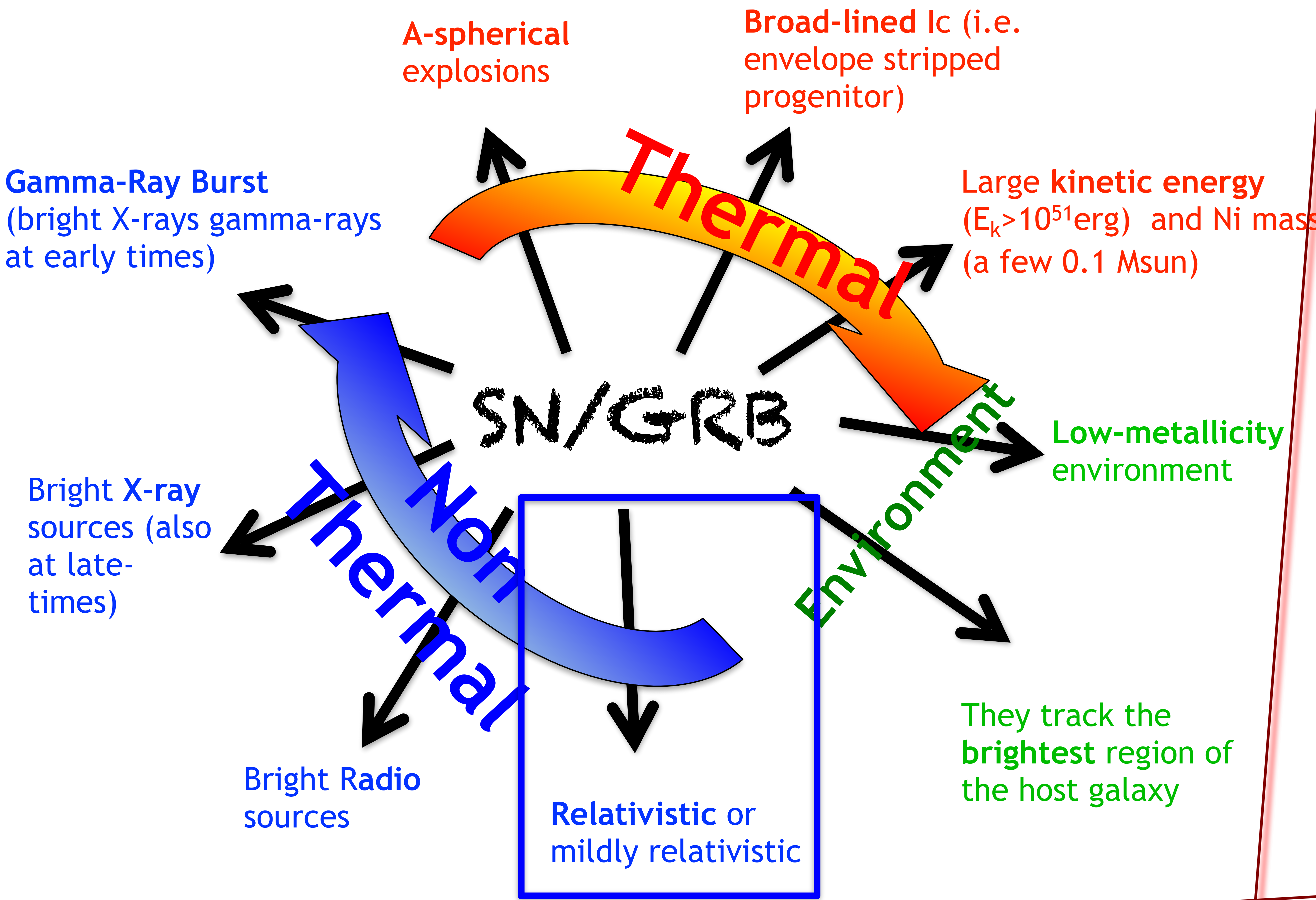


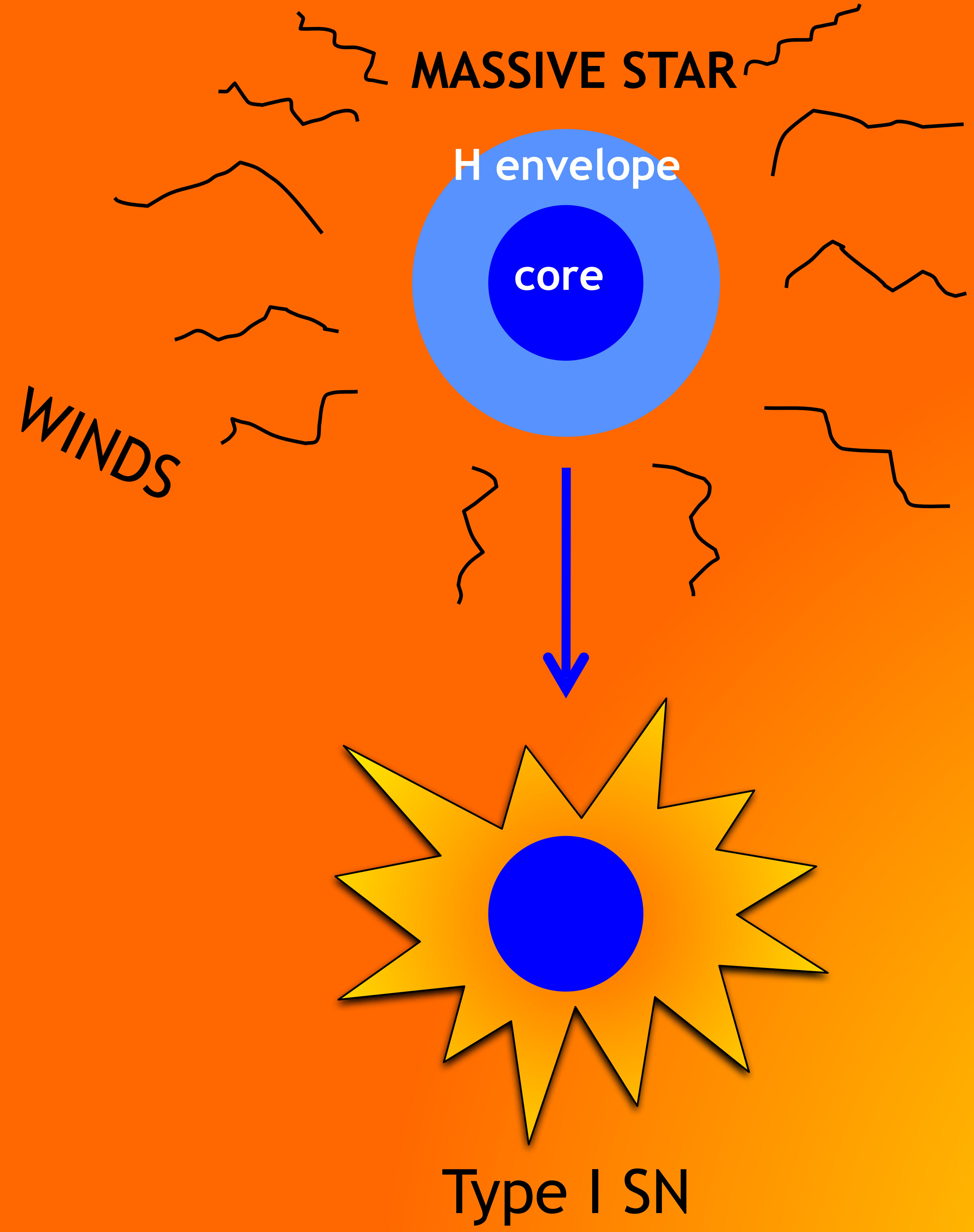
Pian+2006

GRB171205A (d=160 Mpc!)

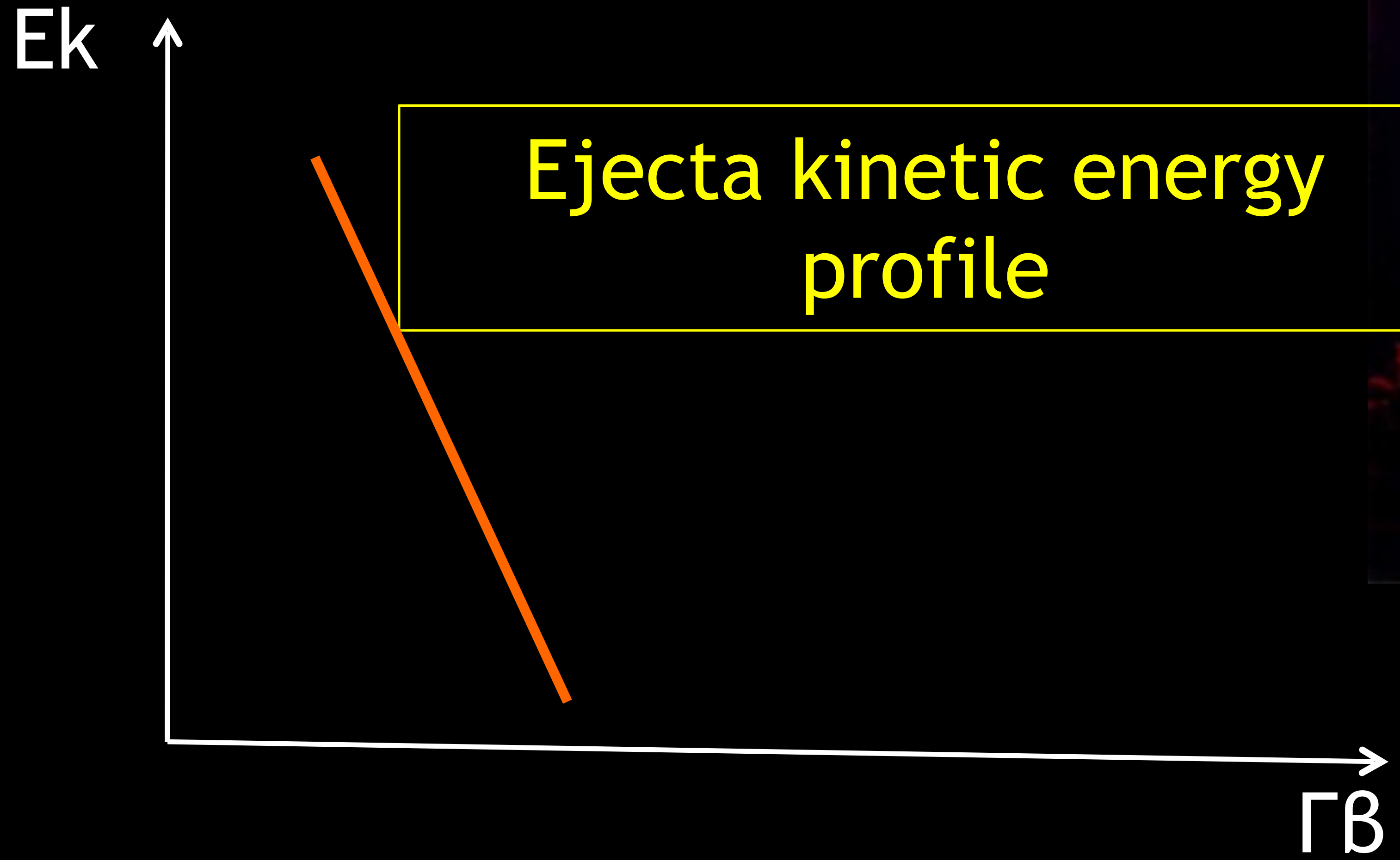


Hjorth & Bloom 2012, Barniol-Duran +, Berger +, Bromberg +, Campana +, Cano+, Chakraborti+, Chornock +, Clocchiatti+, Corsi+, Della Valle+, Guetta +, Kulkarni+, Lazzati+, Mc Fadyen+, Malesani +, Mazzali +, Maeda+, Modjaz+, Morsony+, Nakar+, Pian +, Sanders +, Soderberg +, Valenti+

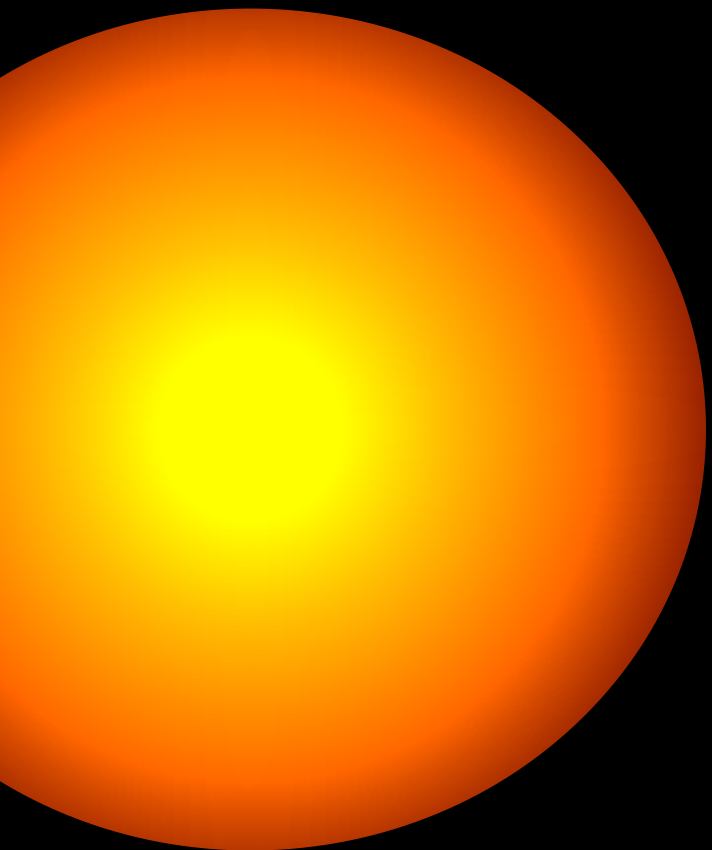

A-spherical explosions
Broad-lined Ic (i.e. envelope stripped progenitor)
Thermal
Gamma-Ray Burst (bright X-rays gamma-rays at early times)
Large kinetic energy (E_k>10^{51}erg) and Ni mass (a few 0.1 Msun)
SN/GRB
Low-metallicity environment
Environment
Bright X-ray sources (also at late-times)
Non Thermal
They track the brightest region of the host galaxy
Bright Radio sources
Relativistic or mildly relativistic


MASSIVE STAR
H envelope
core
WINDS
Type I SN

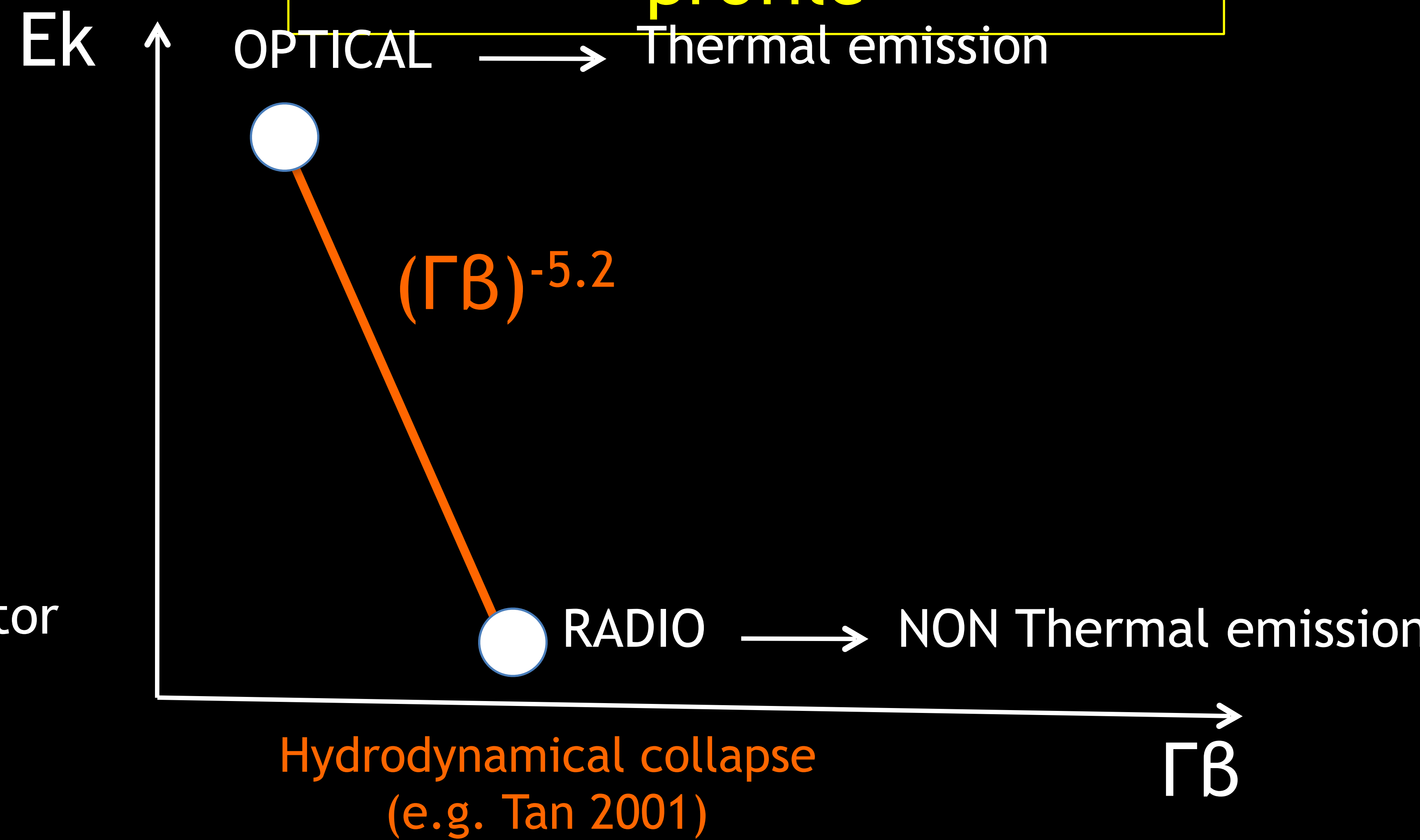
Ejecta kinetic energy profile

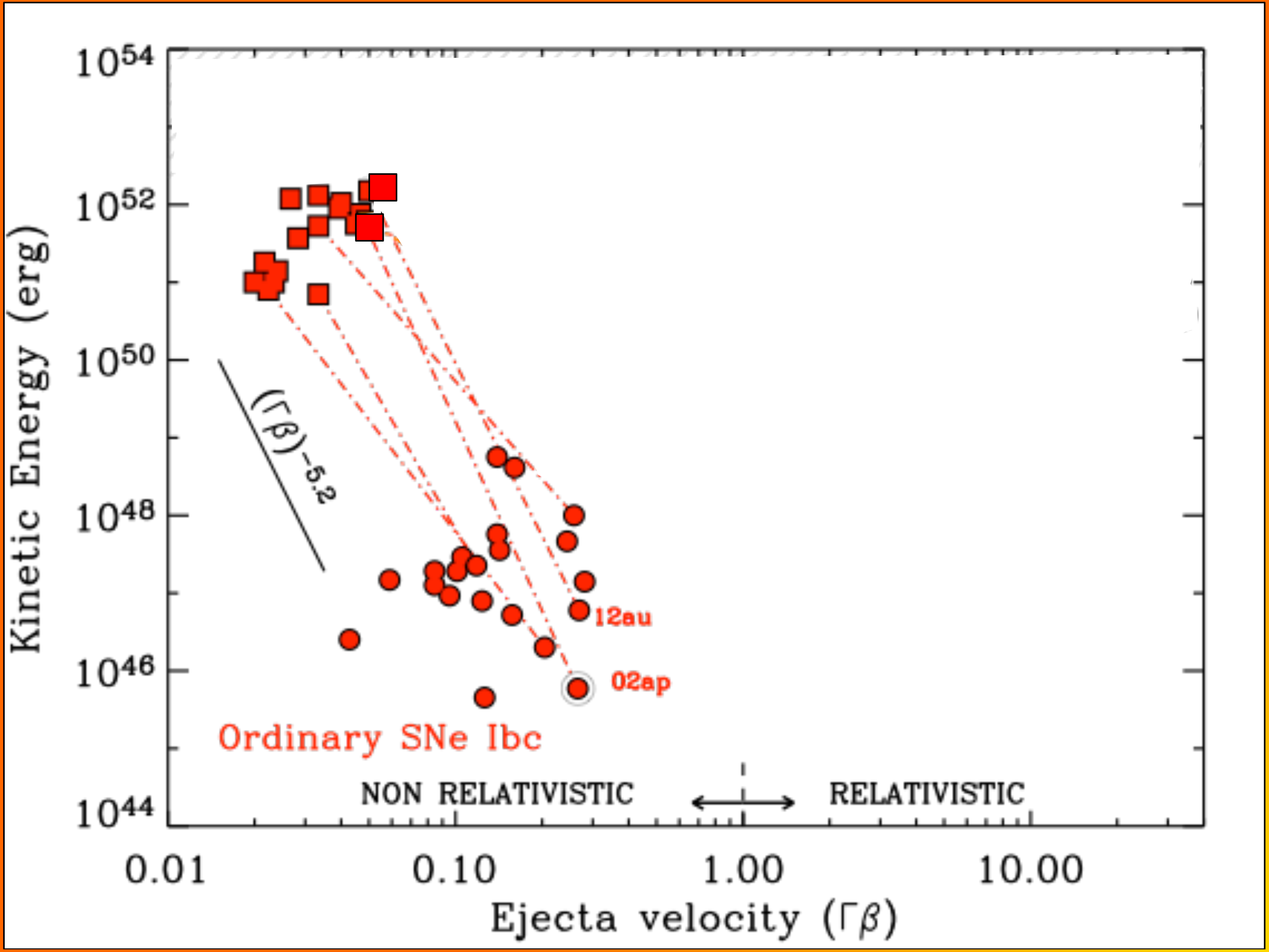


Ejecta kinetic energy profile



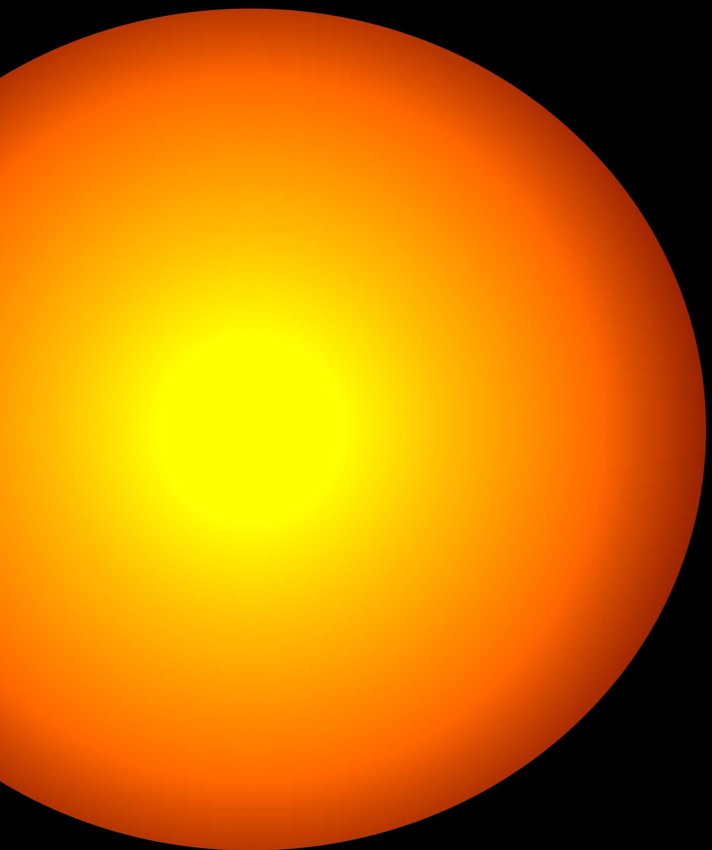
Hydrogen-stripped progenitor
Core-collapse



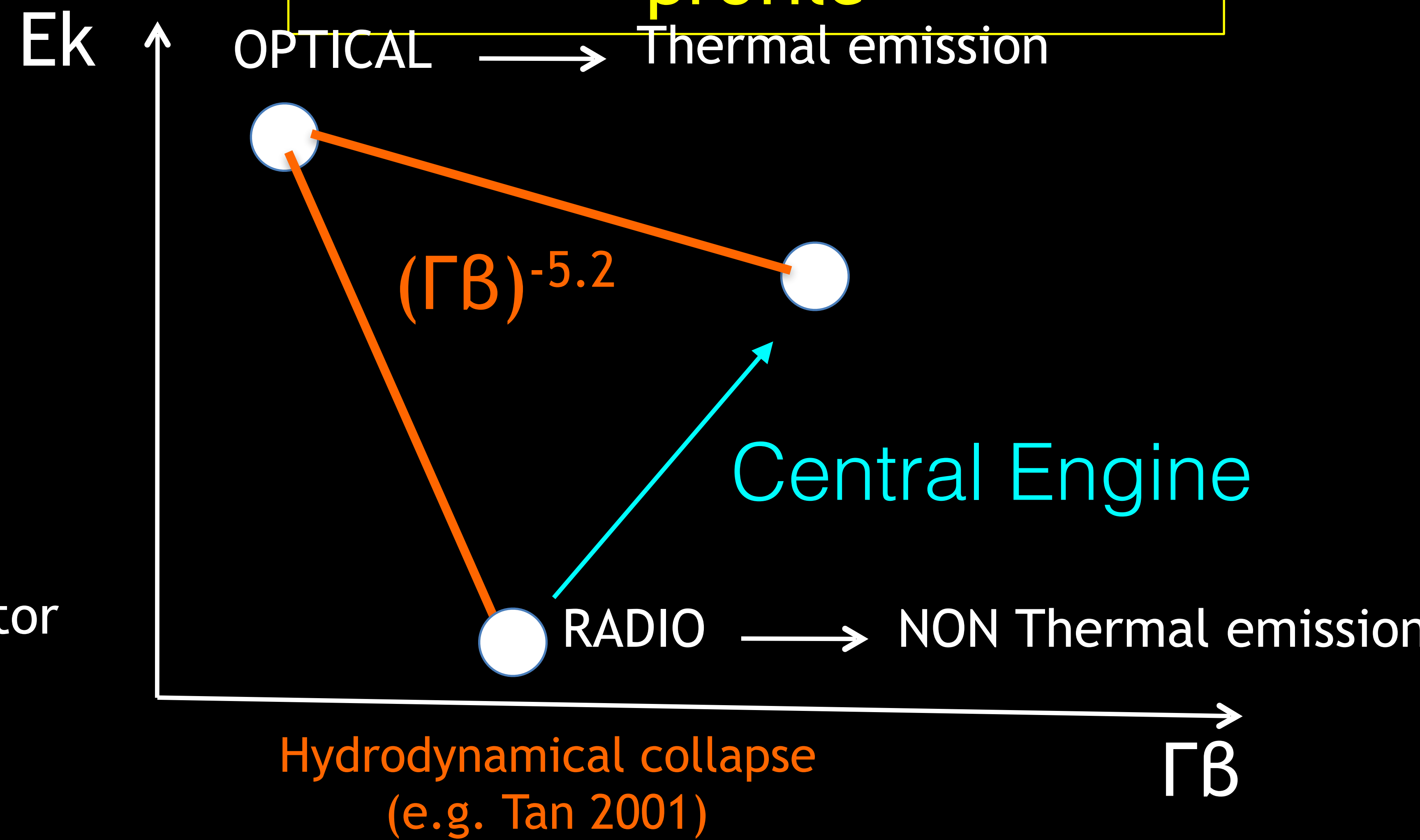


Margutti +13, +14; Kamble +13; Soderberg +06, +10

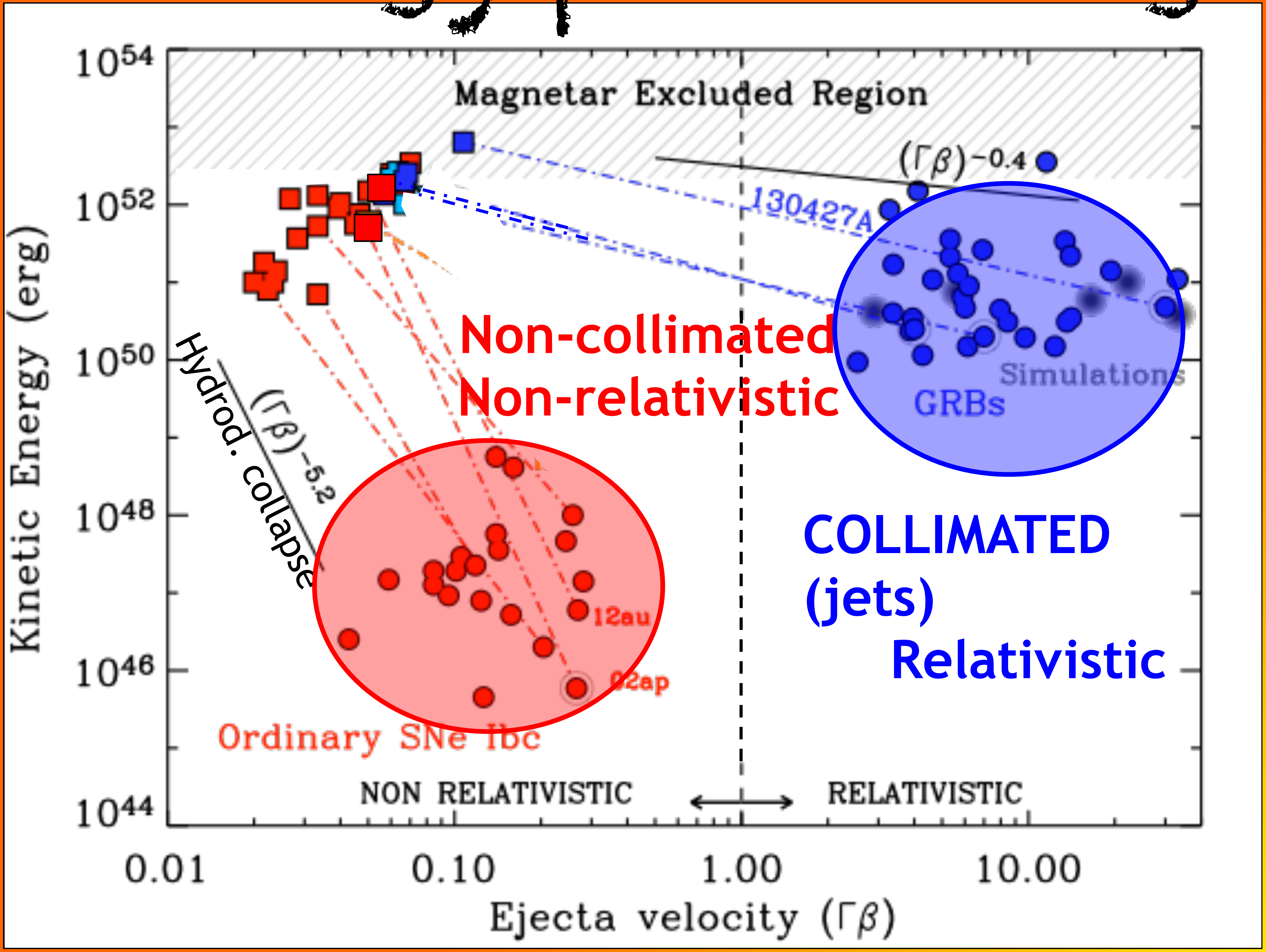
Ejecta kinetic energy profile



Hydrogen-stripped progenitor
Core-collapse



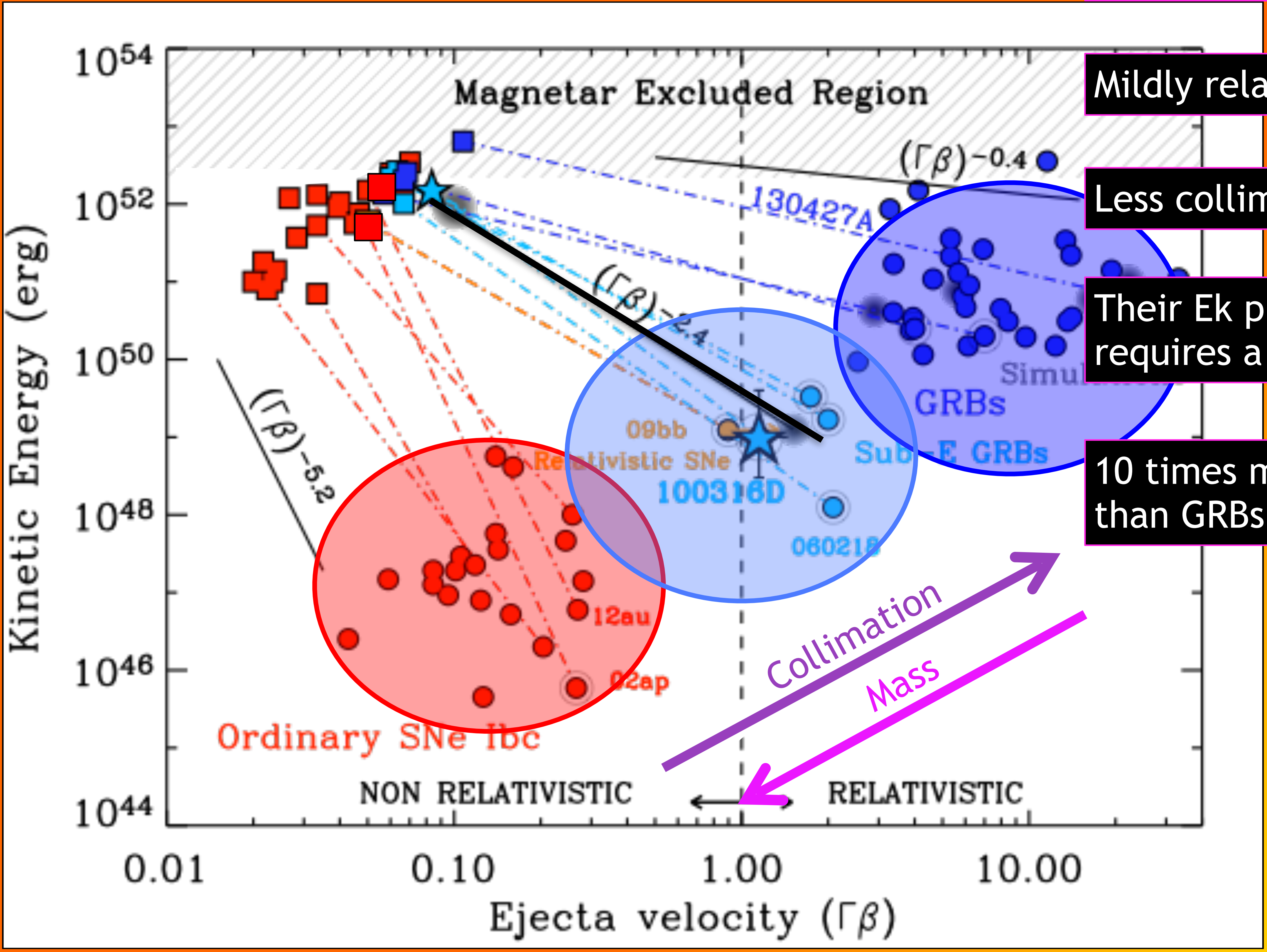
Energy partitioning



Take-away list:

1. Energy partitioning

-->Continuum



Less energetic than GRBs (local universe)

Mildly relativistic

Less collimated than GRBs

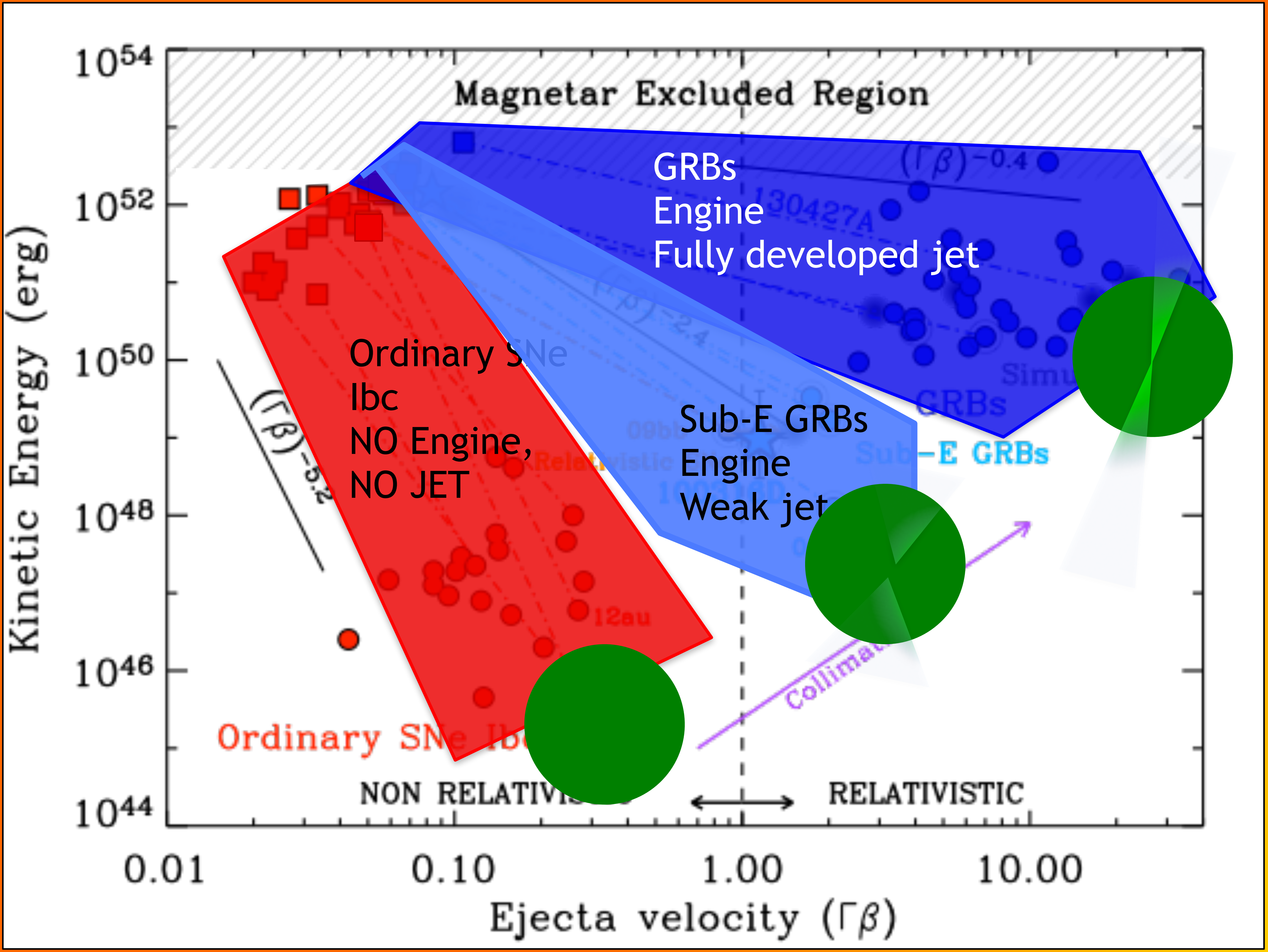
Their Ek profile still requires a CE

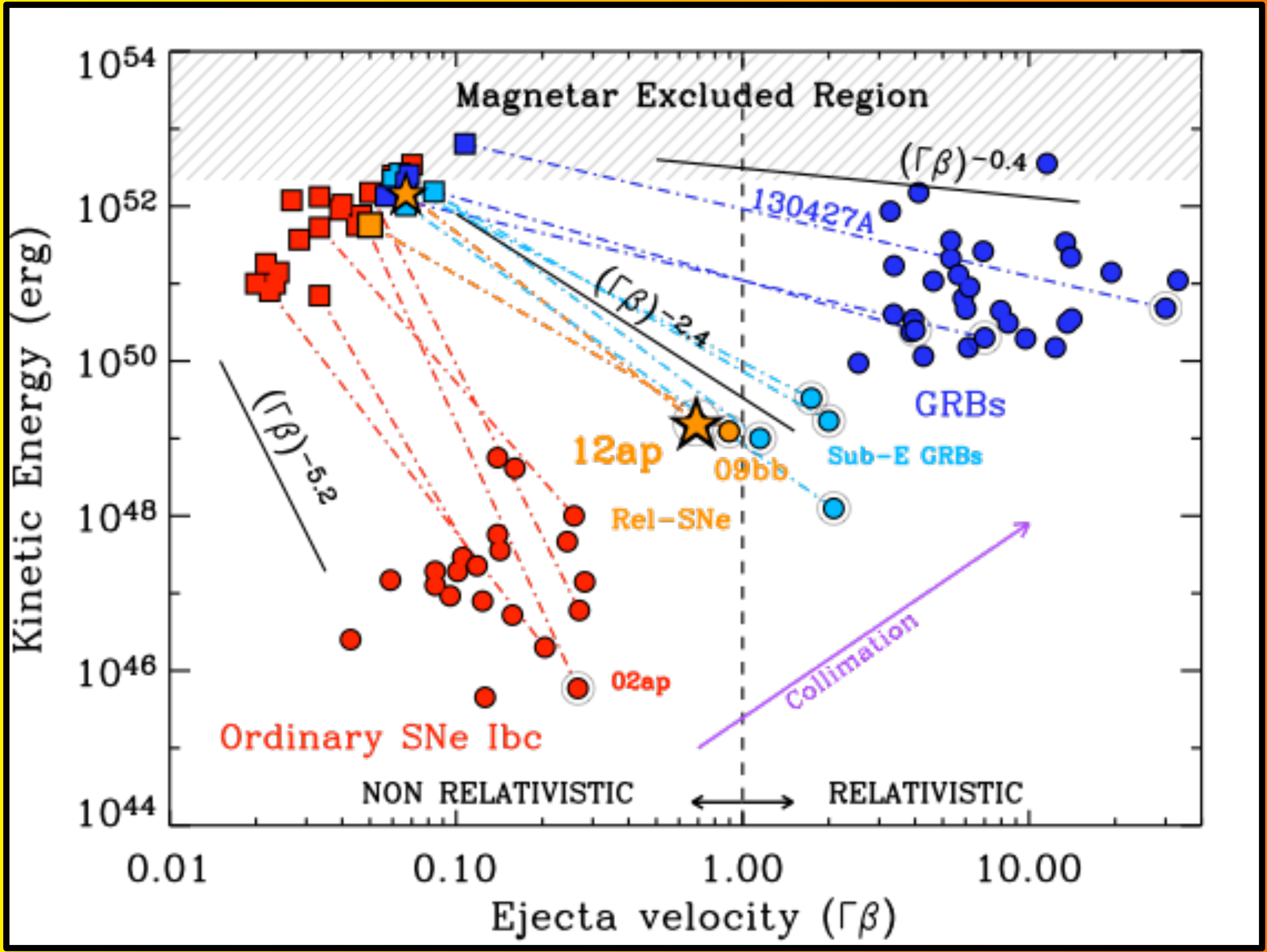
10 times more common than GRBs

Take-away list:

1. Energy partitioning
2. Continuum of stellar Explosions

The big picture: H-stripped explosions

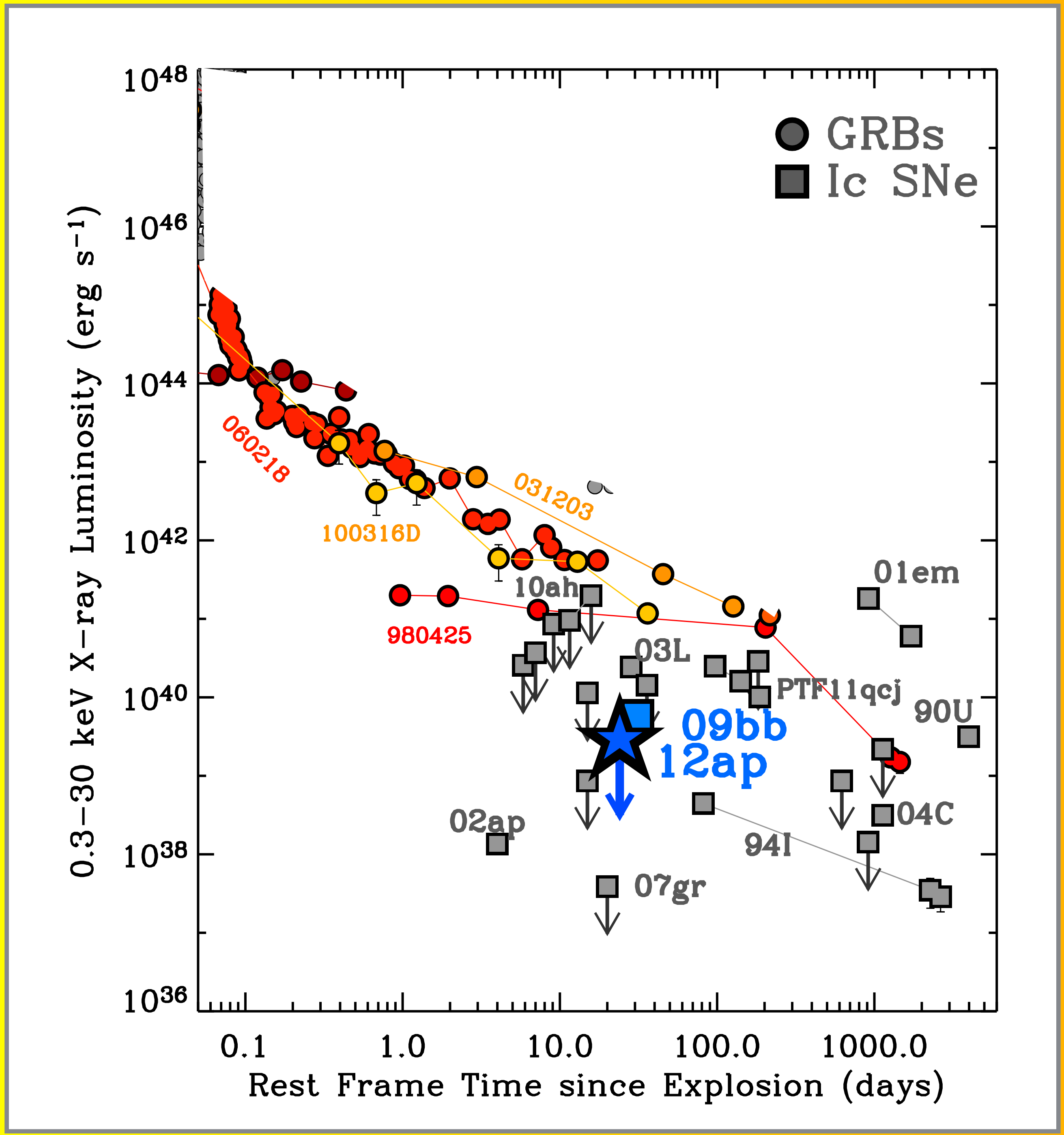


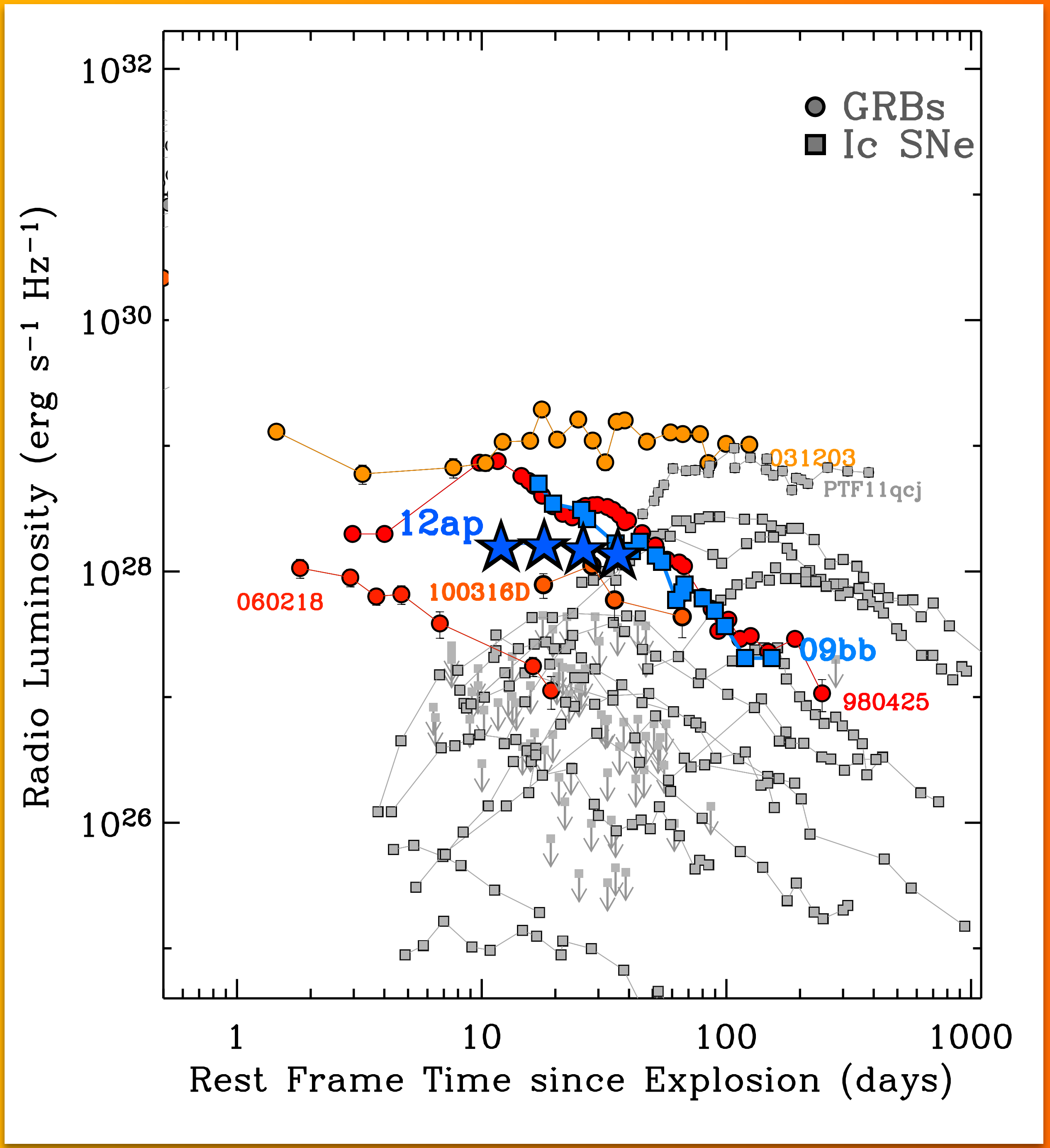


Margutti +14b

X-rays

Radio

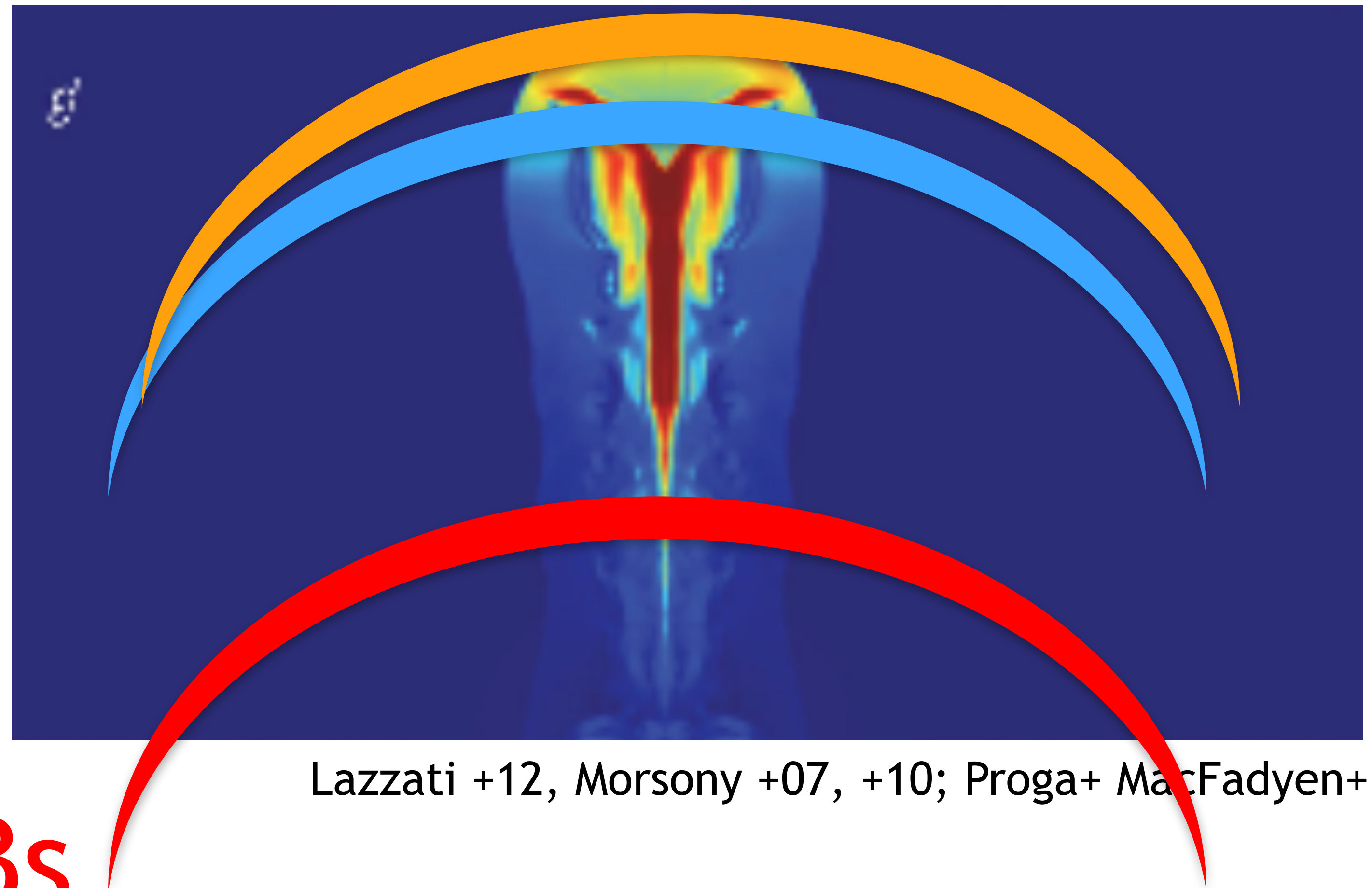




Margutti+14

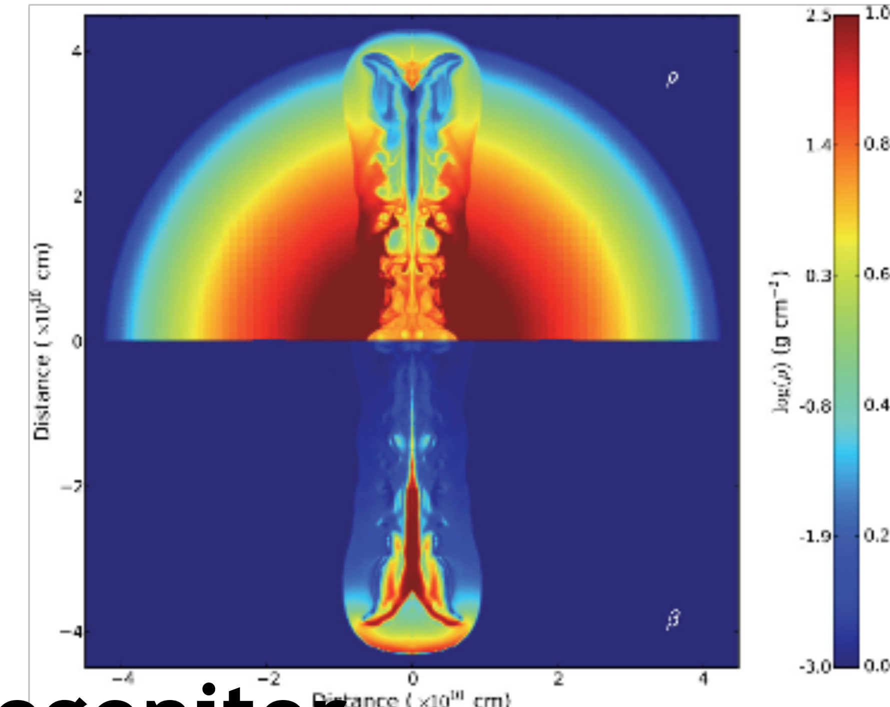
Take-away list:

1. Energy partitioning
2. Continuum of stellar Explosions
3. Sub-E GRBs and Rel-SNe are INTRINSICALLY different classes of engine-driven explosions (>100 times fainter in the X-rays and gamma-rays)



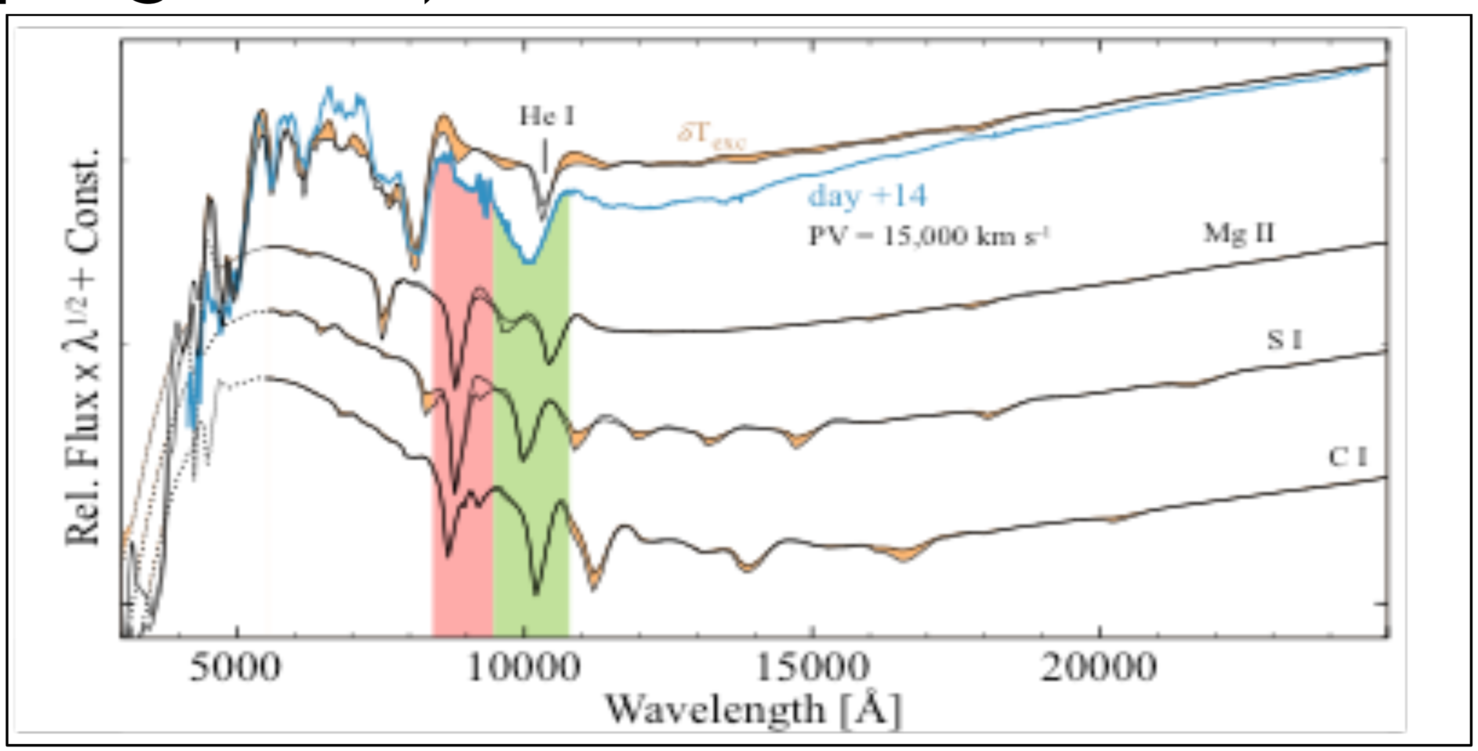
Lazzati +12, Morsony +07, +10; Proga+ MacFadyen+

Why a jet fails to breakout?

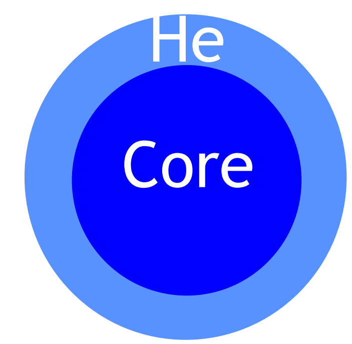


Shorter engine life-time
(same progenitor)

Larger progenitor
(same engine life-time)



Milisavljevic, RM +14

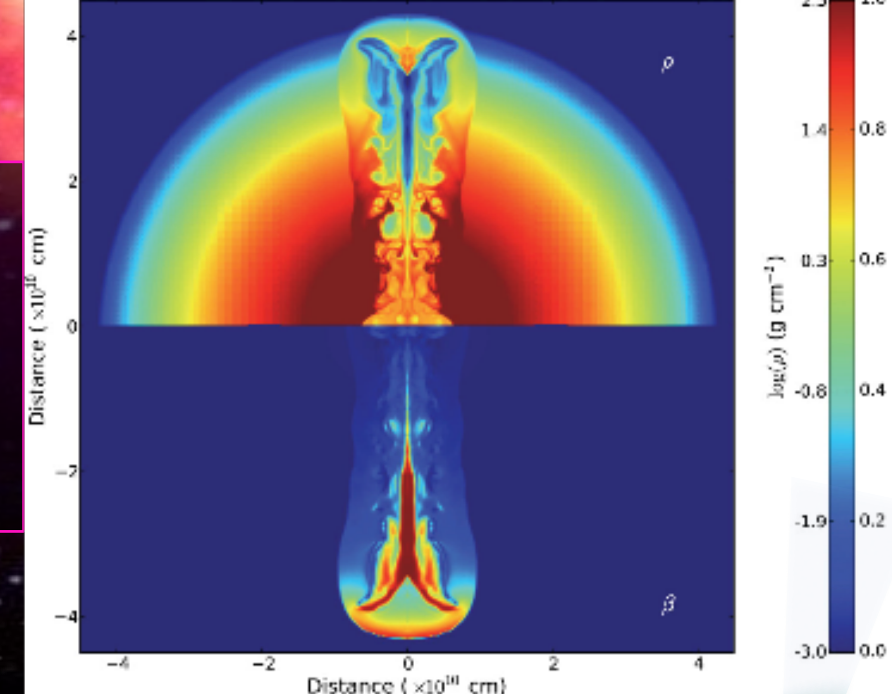


CENTRAL ENGINES DIE YOUNG IN RELATIVISTIC SUPERNOVAE: THE CASE OF SN 2012AP

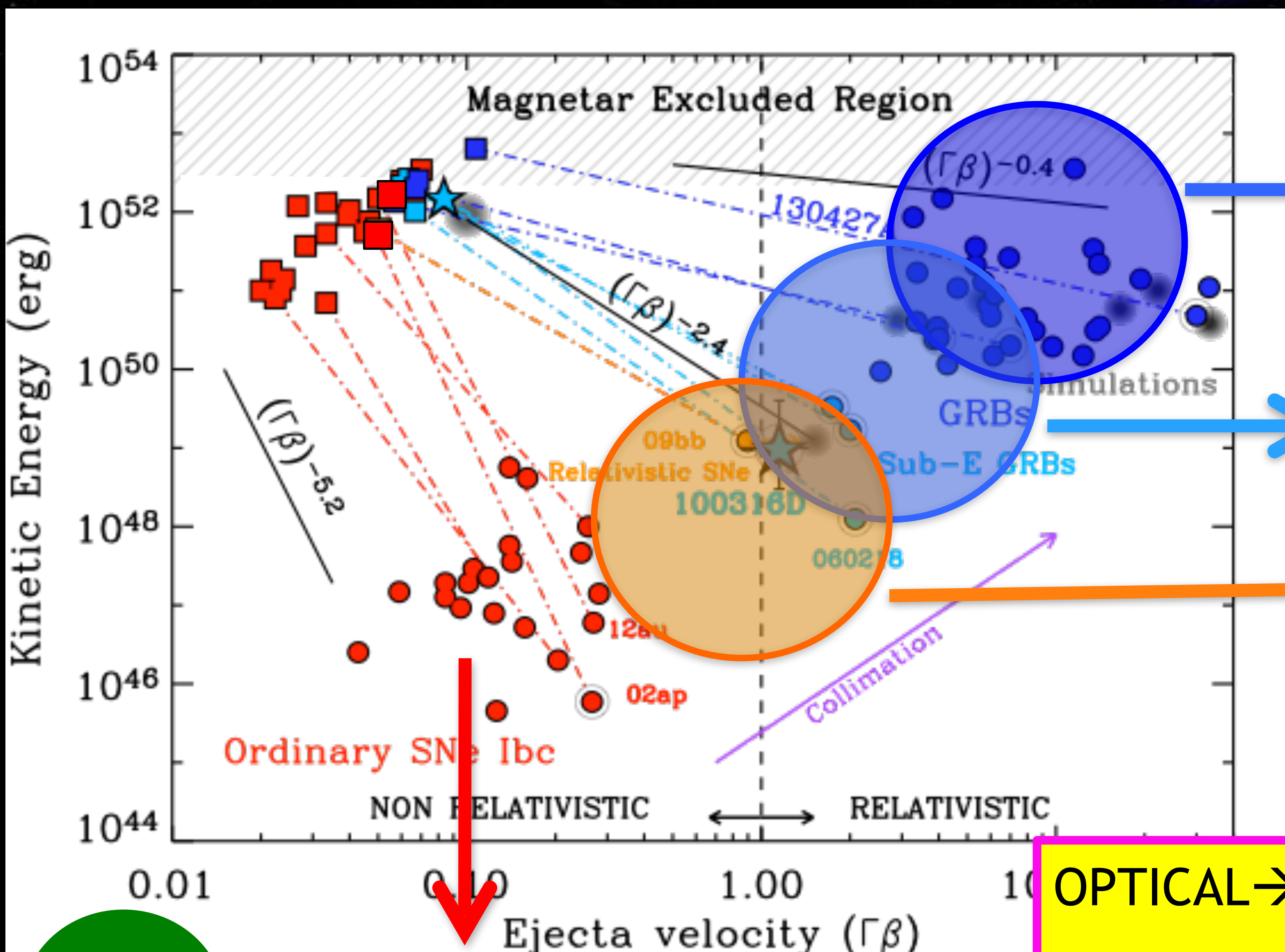
R. MARGUTTI[1], D. MILISAVLJEVIC[1], A. M. SODERBERG[1], C. GUIDORZI[2], B. J. MORSONY[3], N. SANDERS[1], S. CHAKRABORTI[1], A. RAY[5], A. KAMBLE[1], M. DROUT[1], J. PARRENT[1], A. ZAUDERER[1], L. CHOMIUK[4]

Draft version February 12, 2014

The ~~Zoo~~ Bestiary of engine-driven explosion



Lazzati +12, Morsony +07, +10



Fully successful jet break out

Barely successful jet break out

Barely failed jet break out

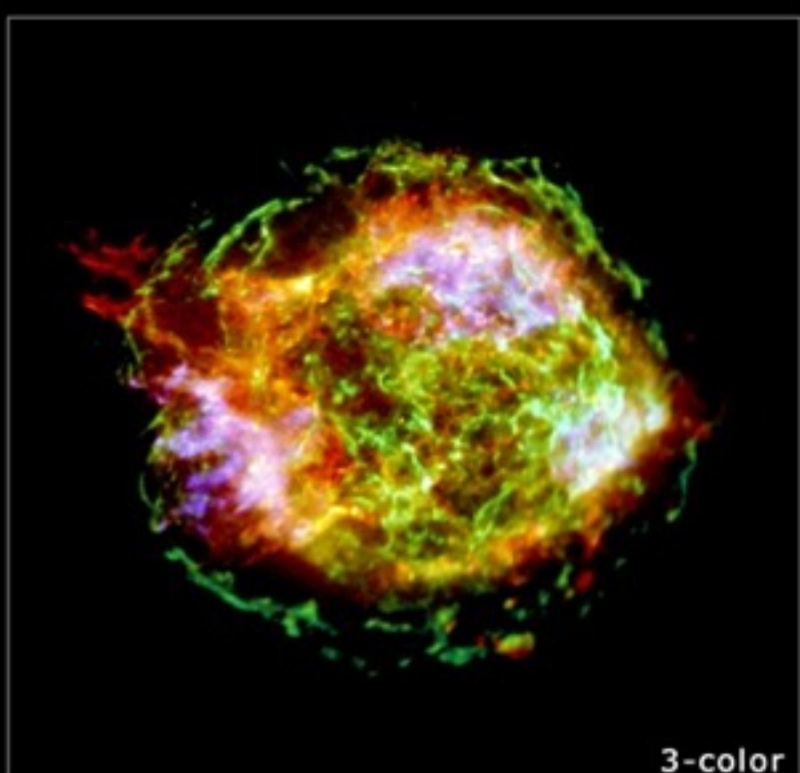
Consistent with hydrodynamical explosion (No need for a jet/eng

OPTICAL→ (phot) energetic of the explosion
(spec) composition + environment
RADIO→ Engine vs. no engine
X-rays→ Jet breakout vs. no breakout

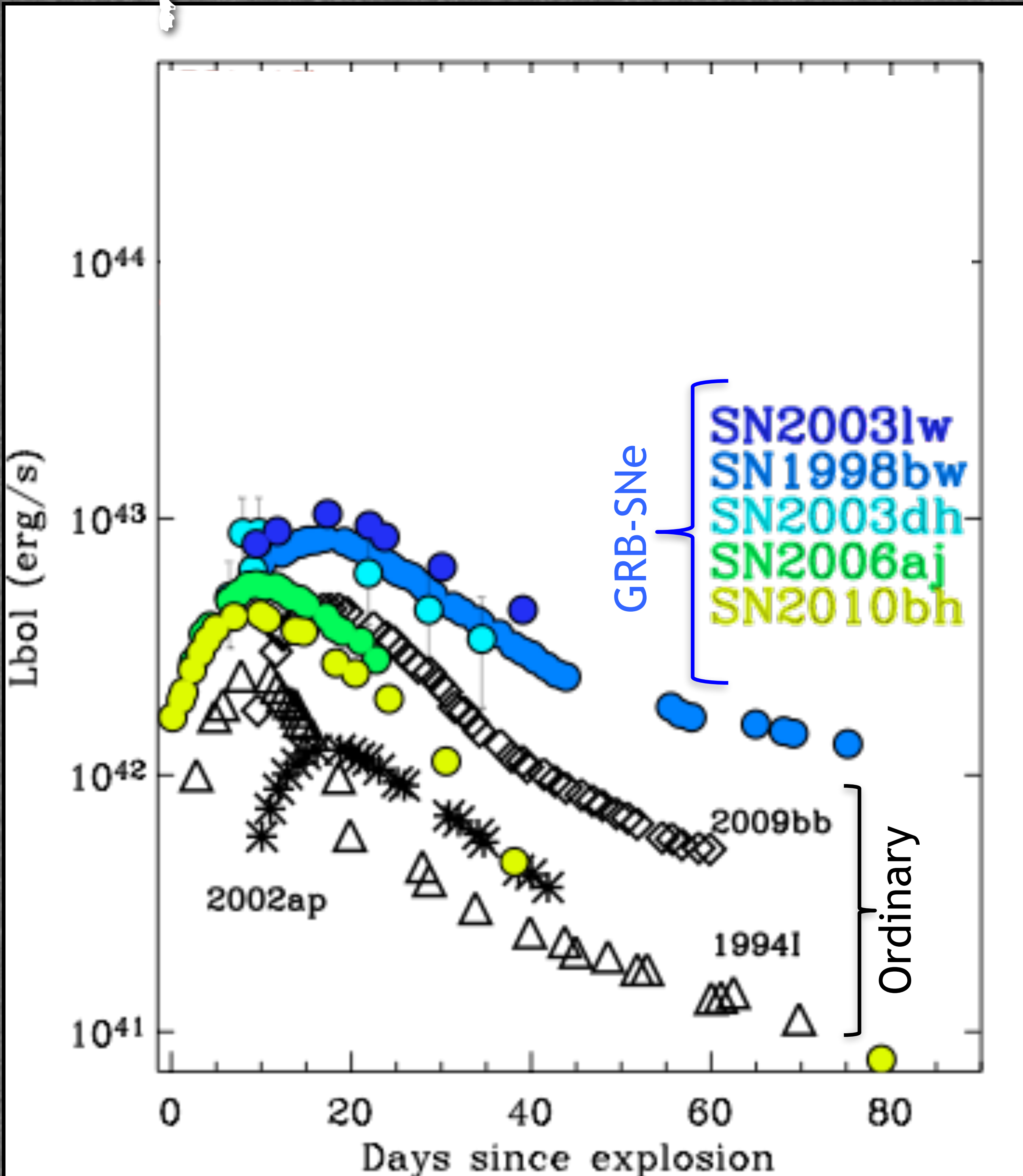
Jets might be ubiquitous…

Cas A

Milisavljevic +13



Super-Luminous SNe



Margutti et al., 2017

E_{rad}= 10^{51} erg

E_K= 10^{52} erg

What Source of Energy powers SLSNe ?

ENERGY SOURCE- SUPERLUMINOUS

What powers SLSNe?

Interaction

E.g. Chevalier 2011
Pan & Loeb 2013

^{56}Ni

Gal-Yam 2009

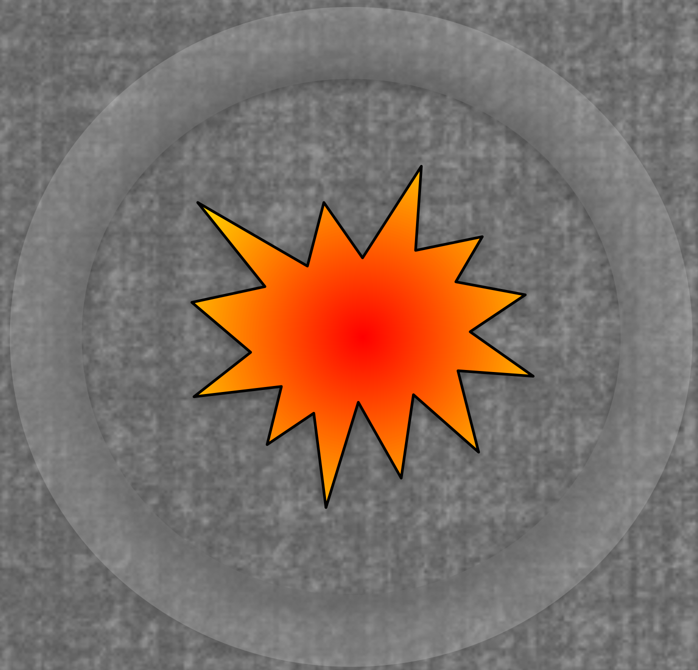
Magnetar

Kasen & Bildsten 2010
Woosley 2010

What powers SLSNe?

Interaction

E.g. Chevalier 2011
Pan & Loeb 2013



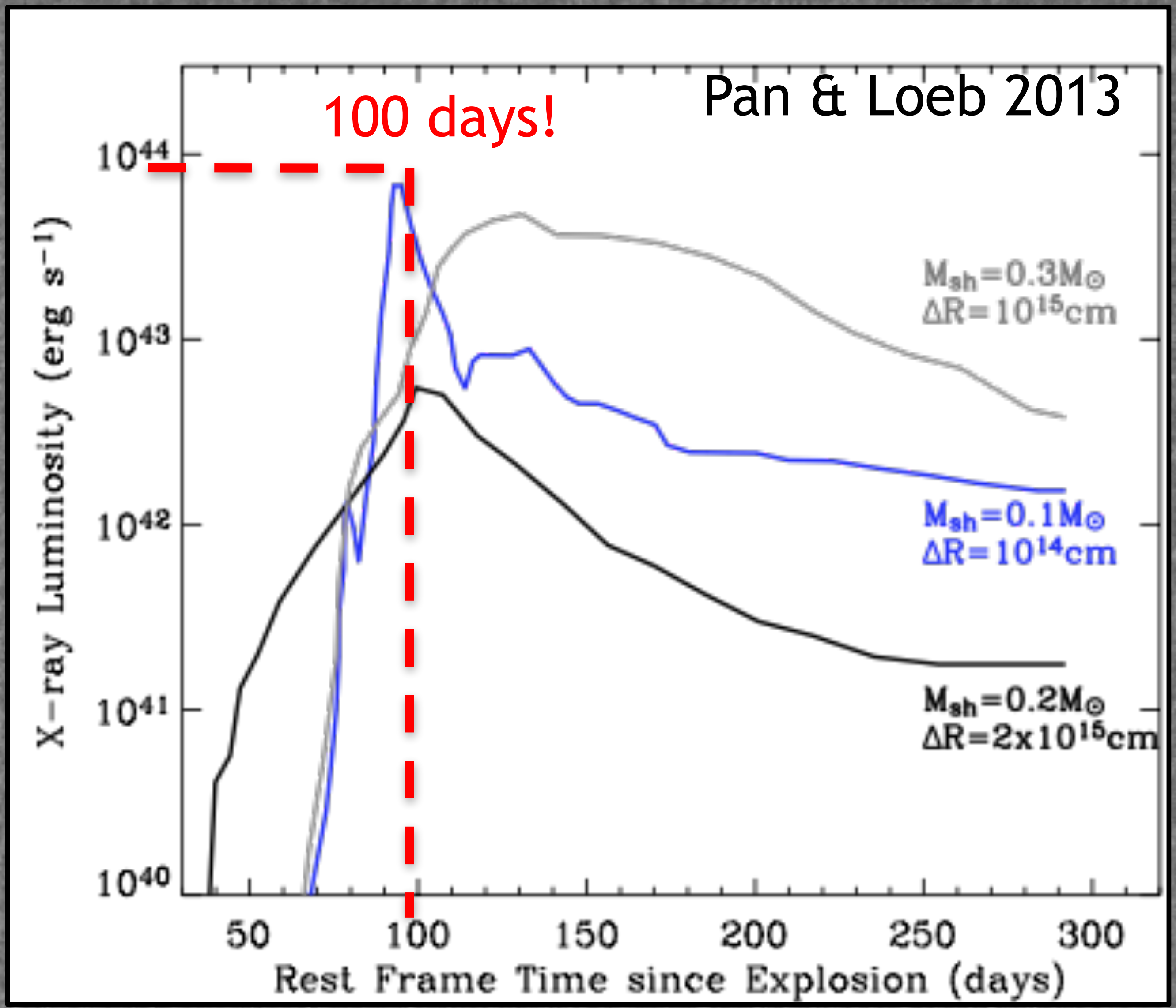
Increased
Efficiency

^{56}Ni

Gal-Yam 2009

Magnetar

Kasen & Bildsten 2010
Woosley 2010



What powers SLSNe?

Interaction
E.g. Chevalier 2011
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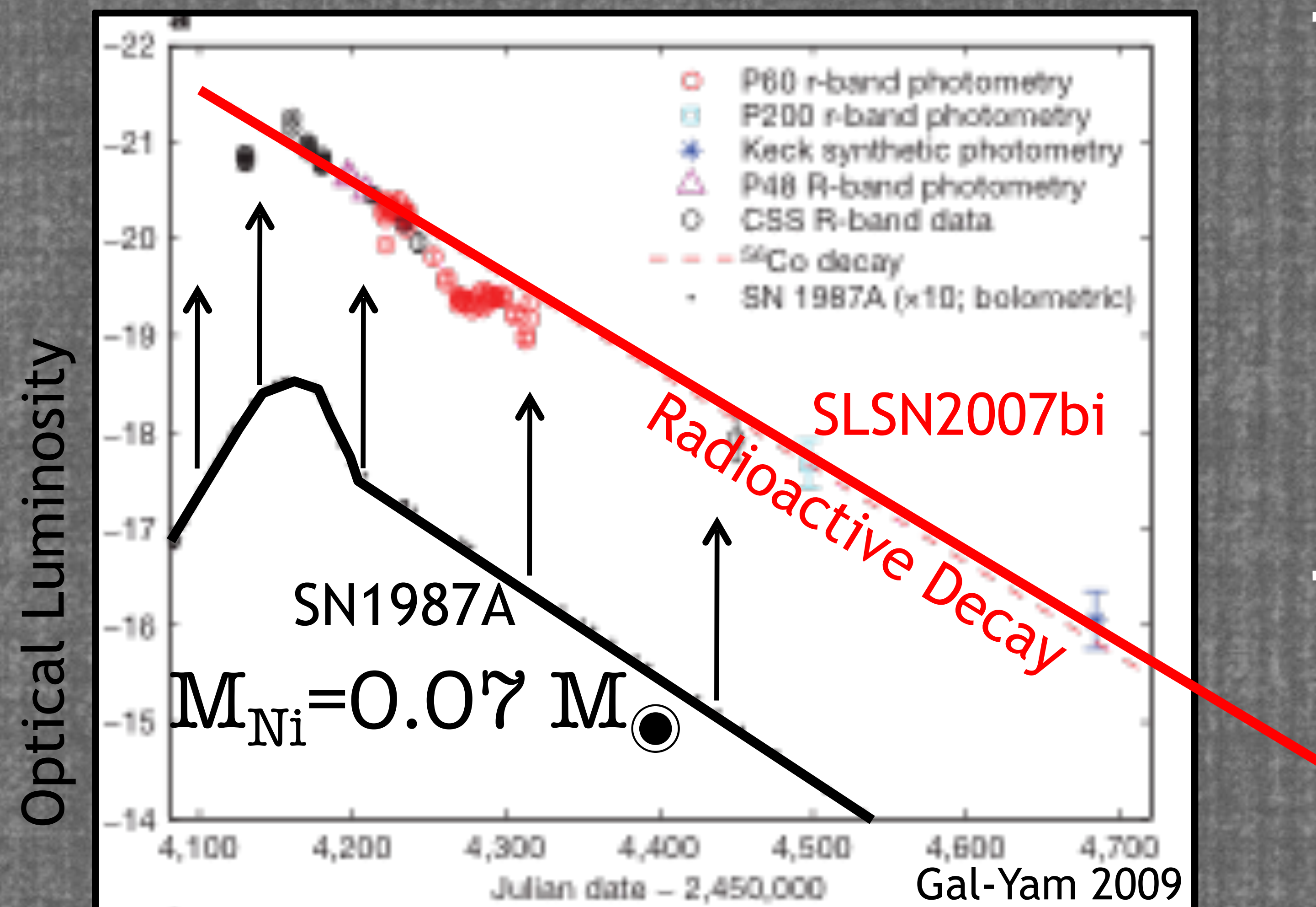


$4M_\odot < {}^{56}Ni < 7M_\odot$

X-rays from shock interaction with an ordinary medium → Super-Luminous X-rays are *not* a natural expectation

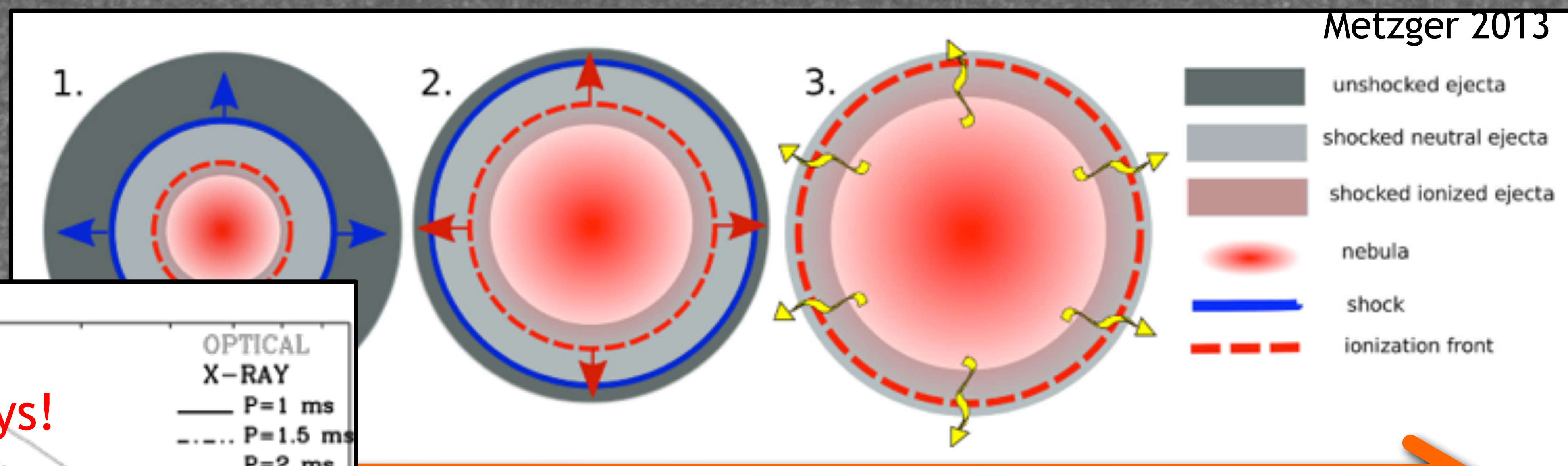
Late-time optical observations (MMTCam)

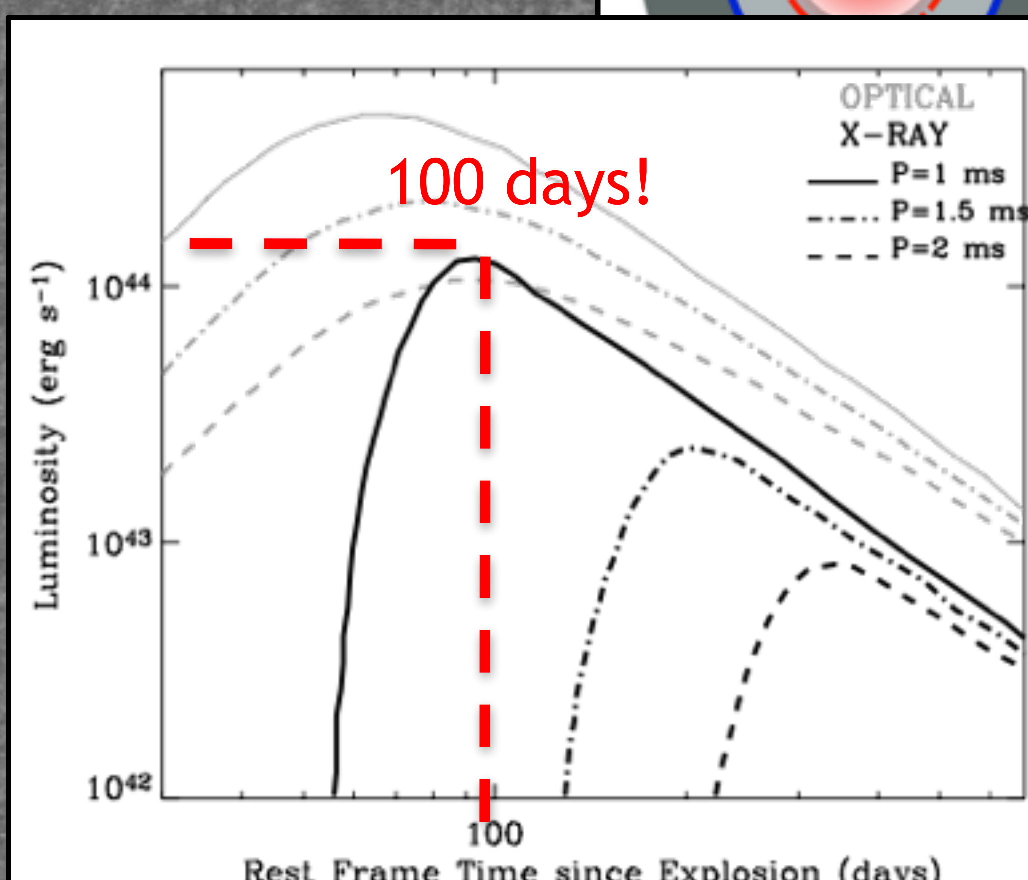
What powers SLSNe?

Interaction
E.g. Chevalier 2011
Pan & Loeb 2013

^{56}Ni
Gal-Yam 2009

Magnetar
Kasen & Bildsten 2010
Woosley 2010





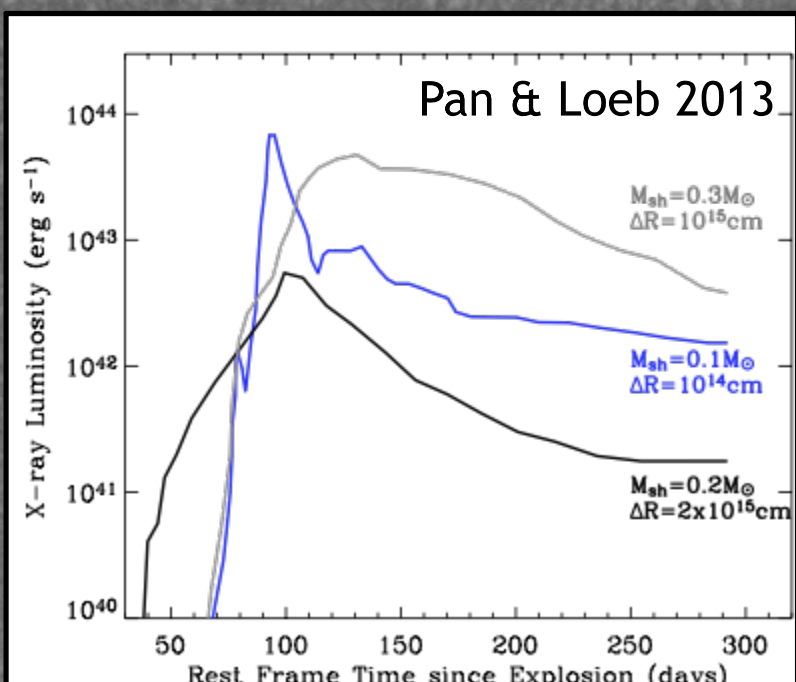
TIME

"The problem is completely specified by the properties of the pulsar and of the ejecta"
Metzger 2013

What powers SLSNe?

Interaction

E.g. Chevalier 2011
Pan & Loeb 2013

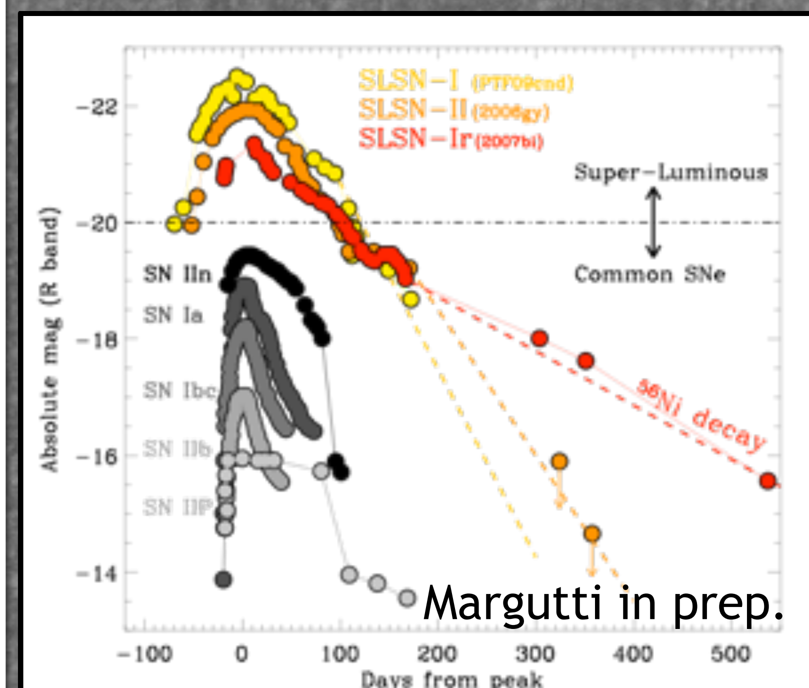


X-rays

Increased Efficiency

^{56}Ni

E. g. Gal-Yam 2009
(Pair Instability Explosions)

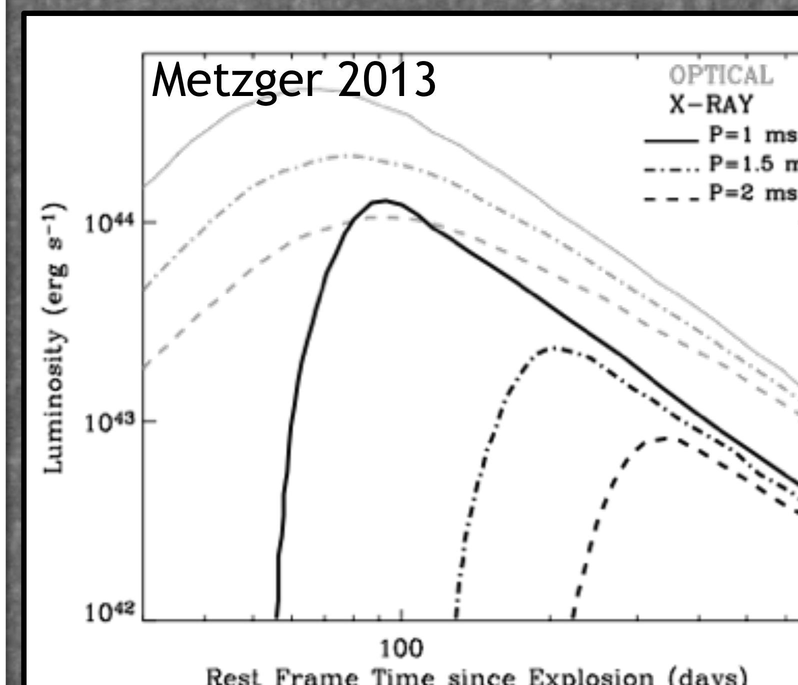


Optical

More “Ordinary Fuel”

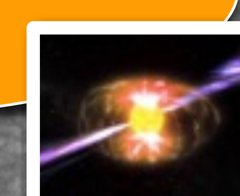
Magnetar

E.g. Kasen & Bildsten 2010
Woosley 2010

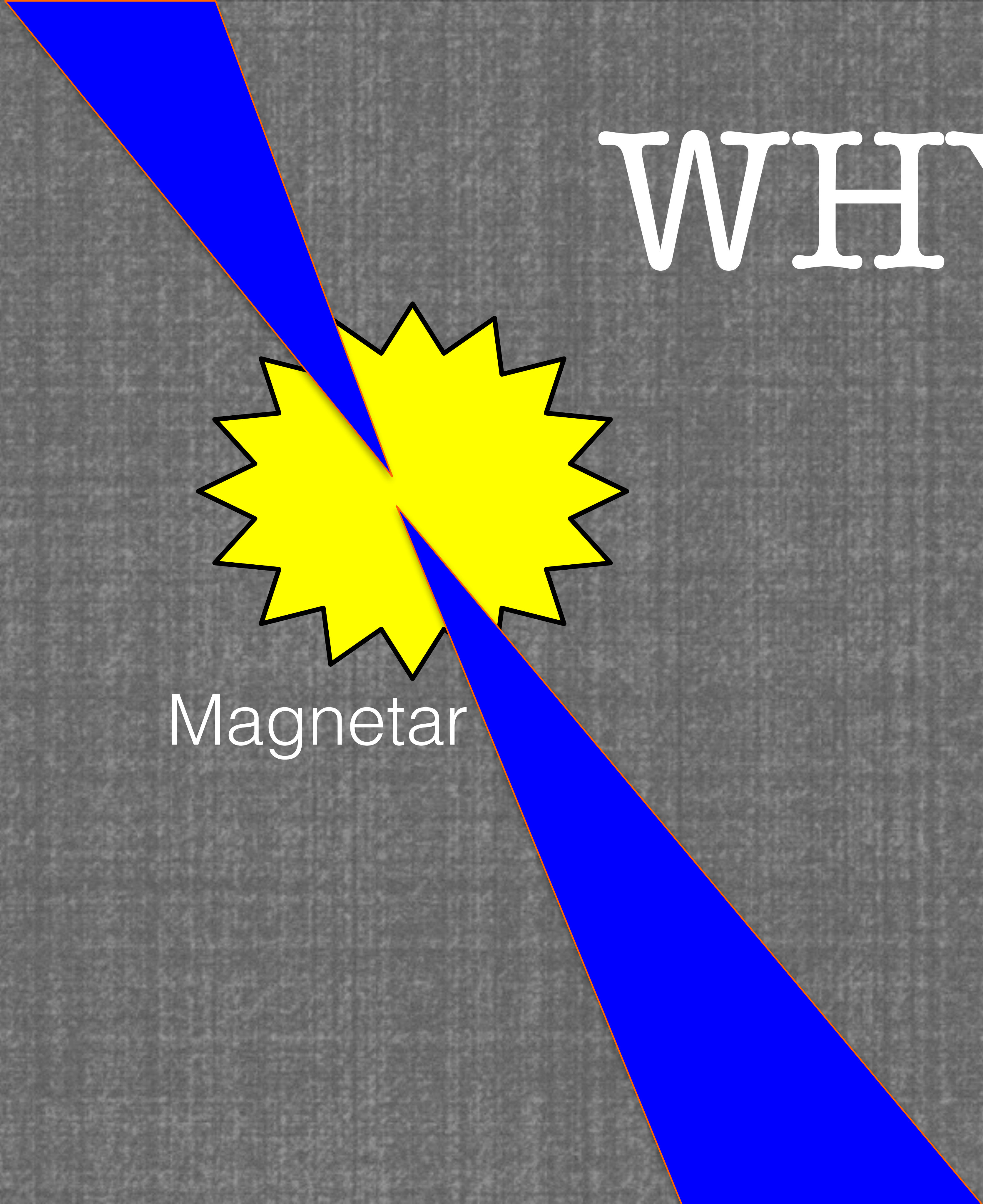


X-rays+Optical

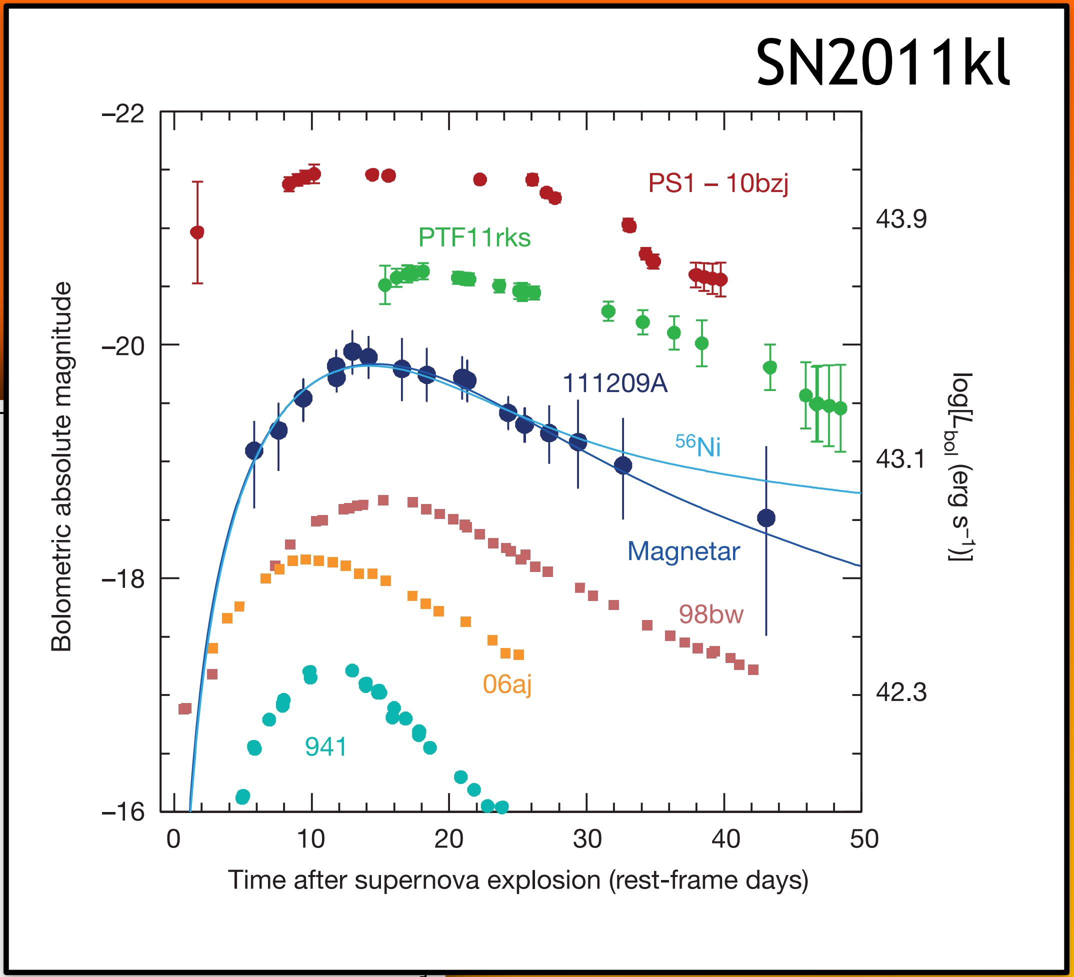
Extra Energy Source



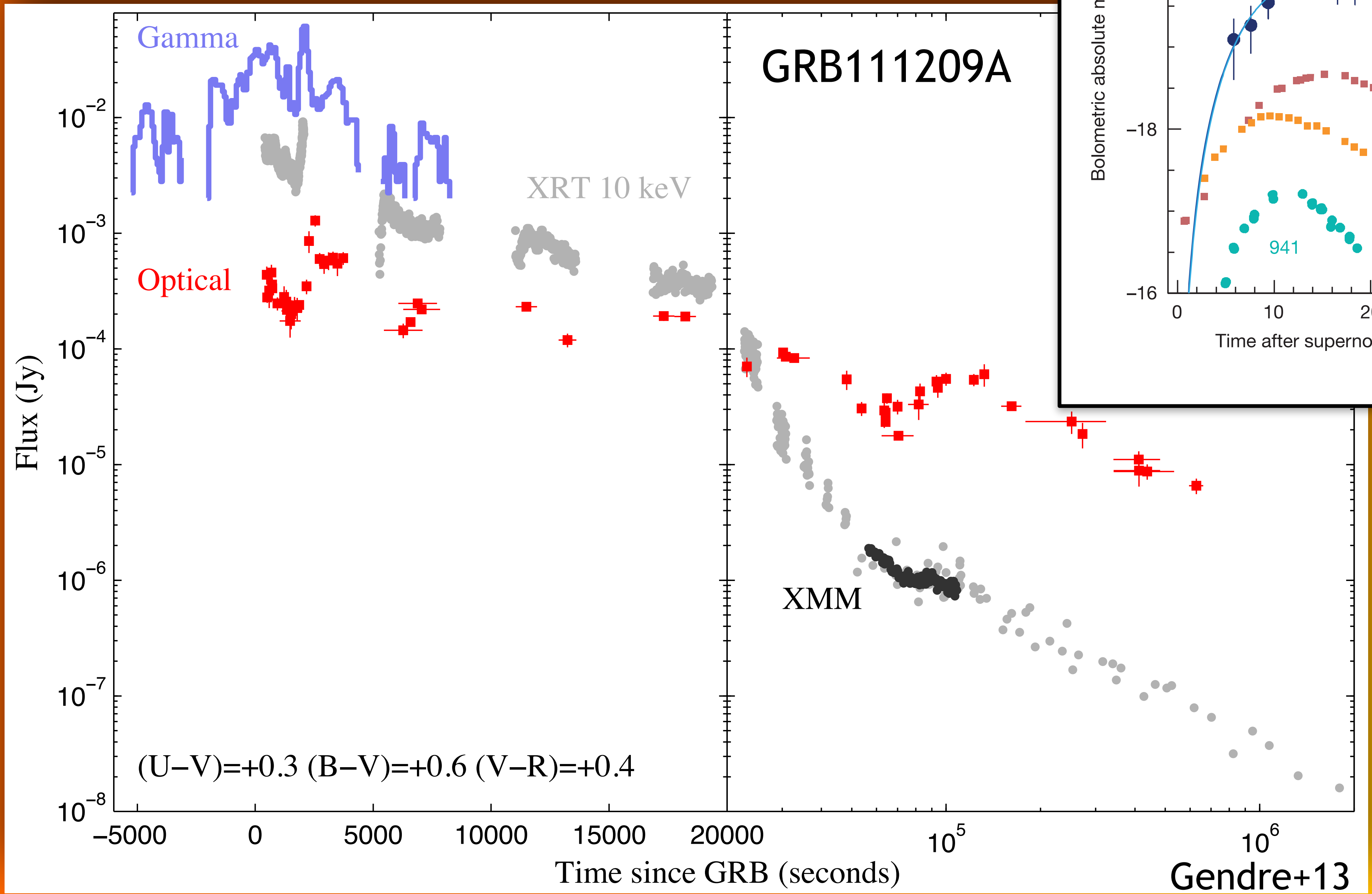
WHY?



UL-GRBs and SLSNe-I

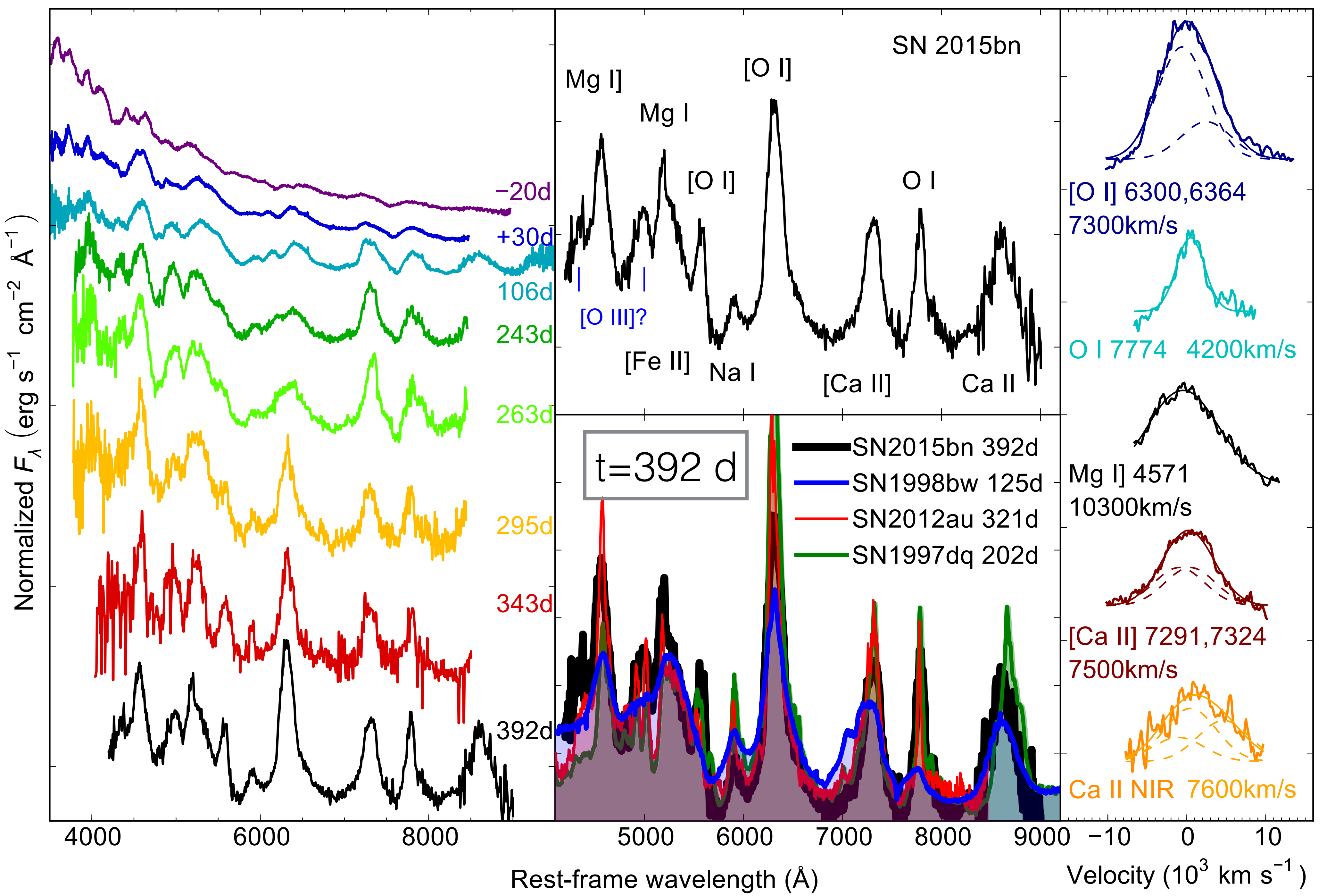


Greiner+15



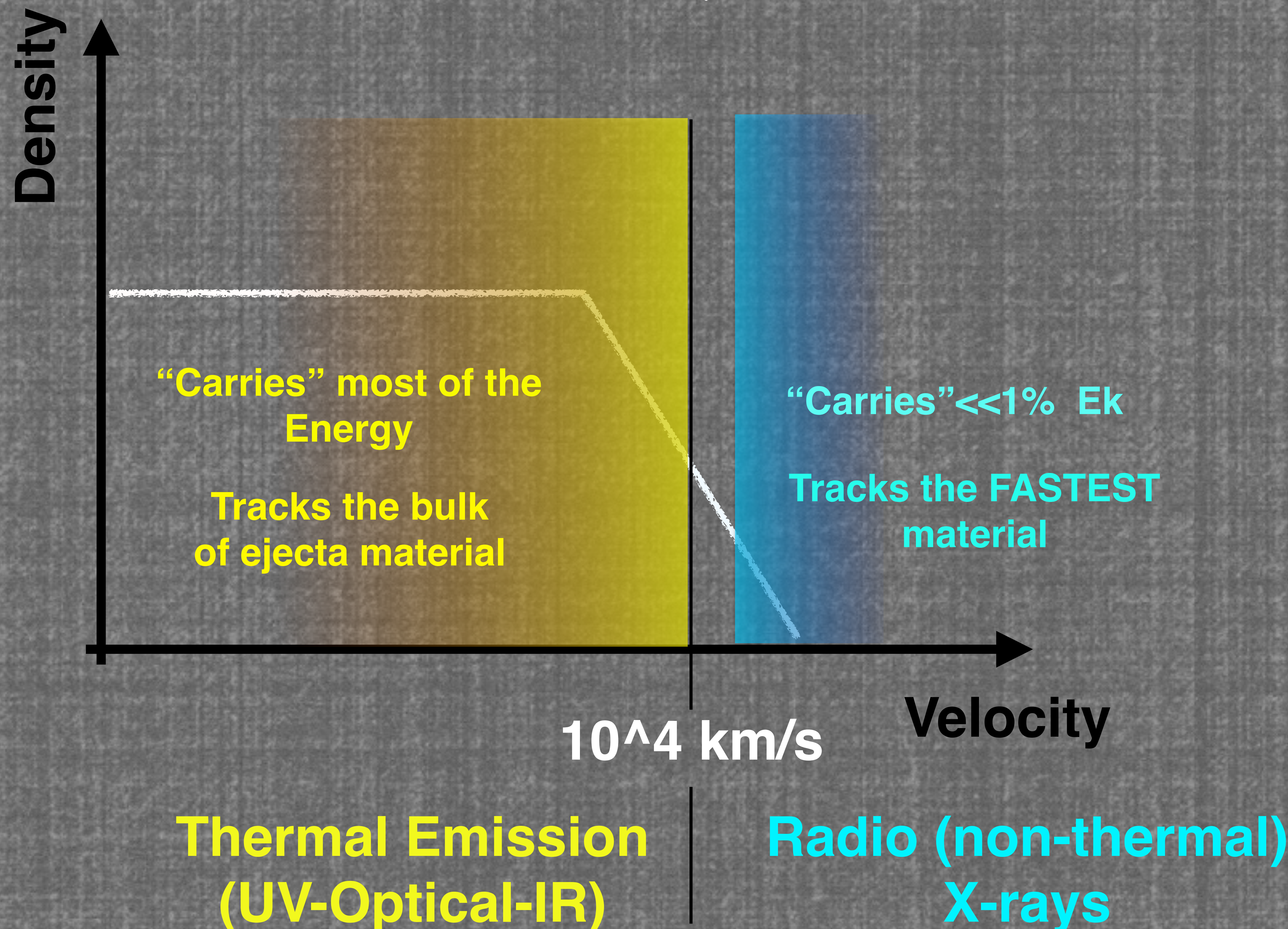
Gendre+13

Similarity of SLSN2015bn to "Hypernovae" at late times

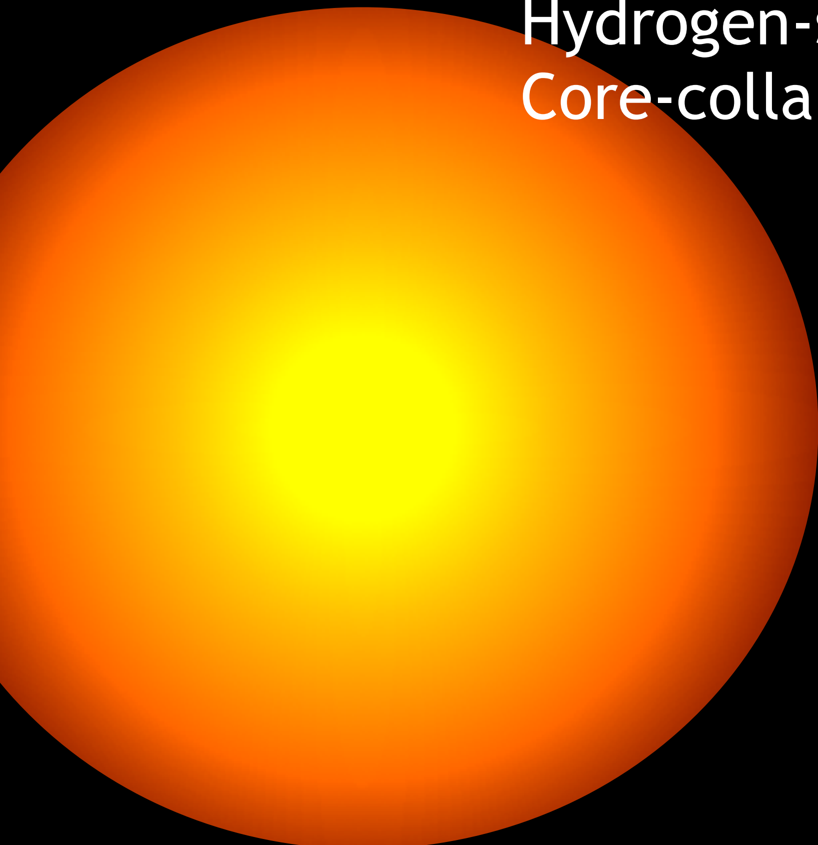


Nicholl+2016

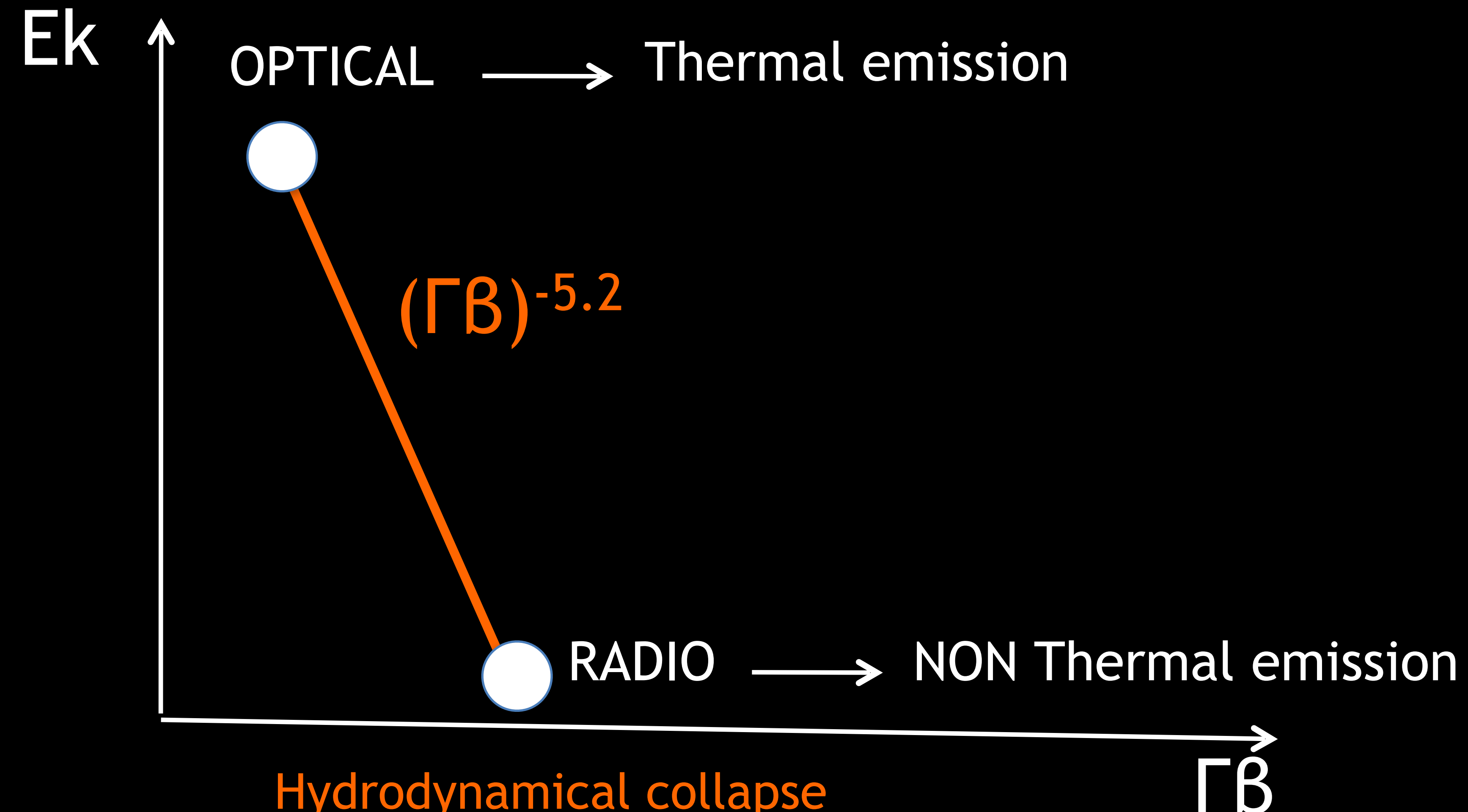
SN Ejecta profile



Hydrogen-stripped progenitor
Core-collapse

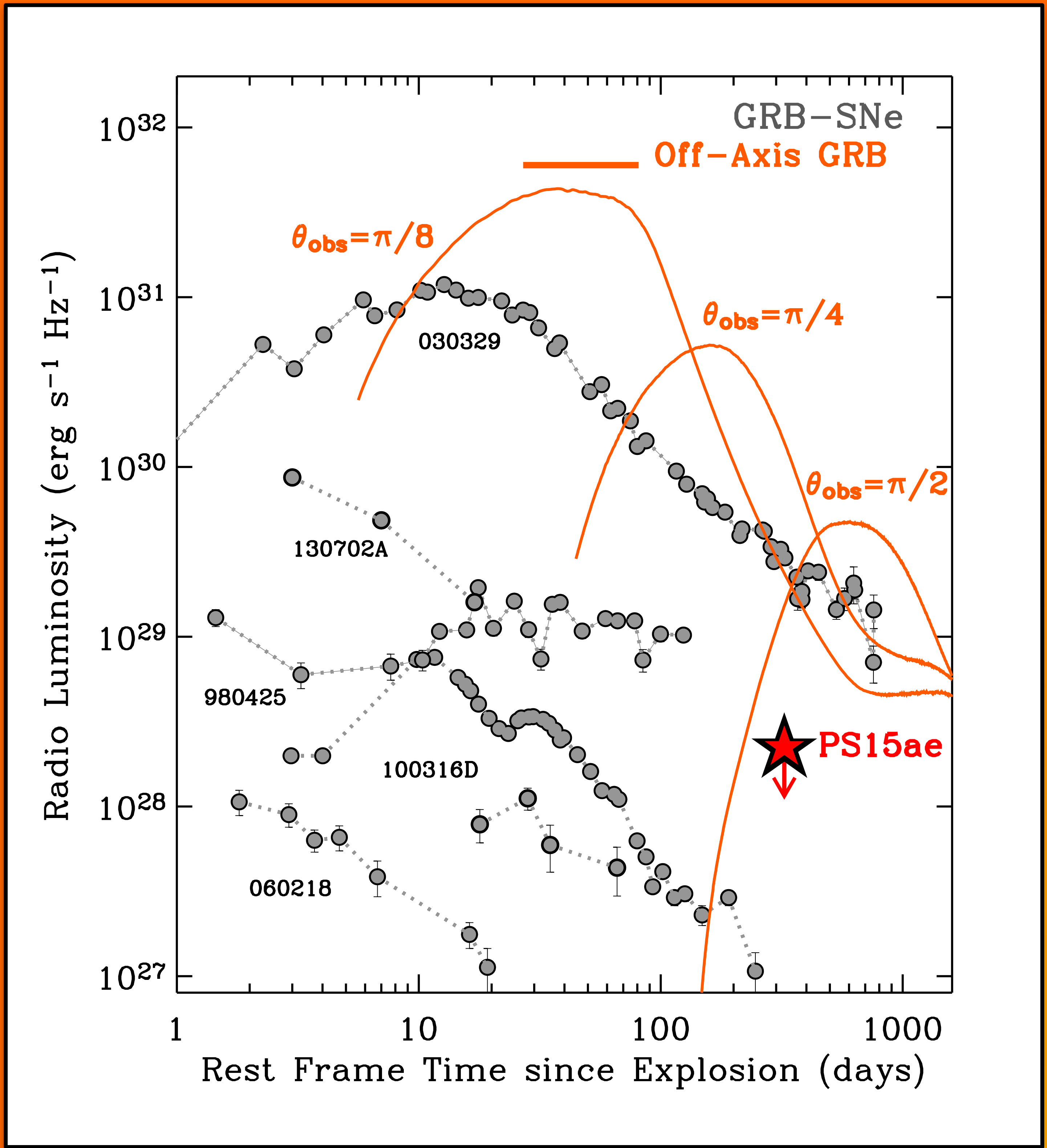


Ejecta kinetic energy profile



Hydrodynamical collapse
(e.g. Tan 2001)

SLSNe-I and off-axis GRBs



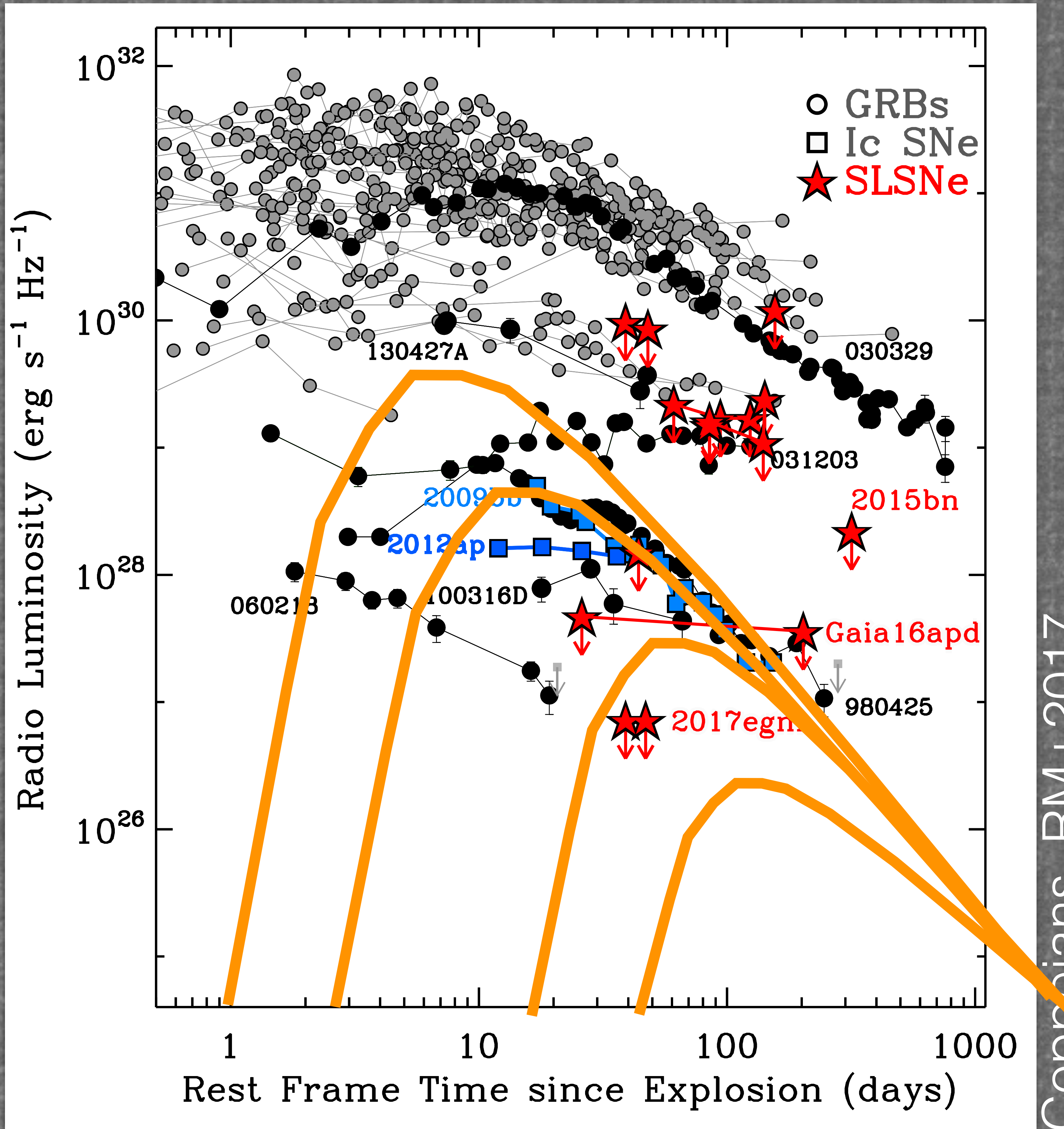
Nicholl+16

Eiso= 1d53 erg

n= 1 cm-3

Theta_jet= 10 deg

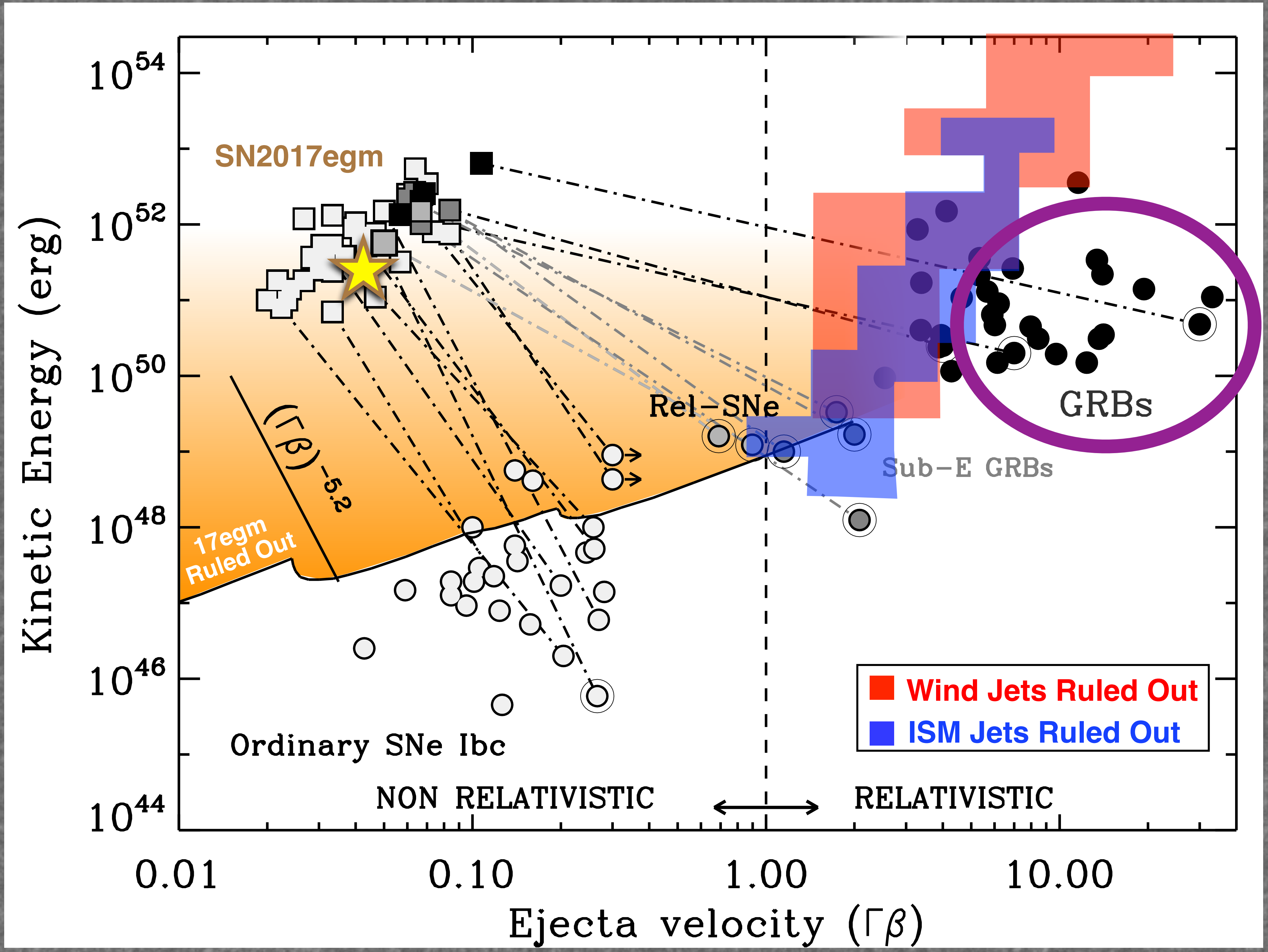
SLSN-I Radio Campaign



Coppejans, RM+2017

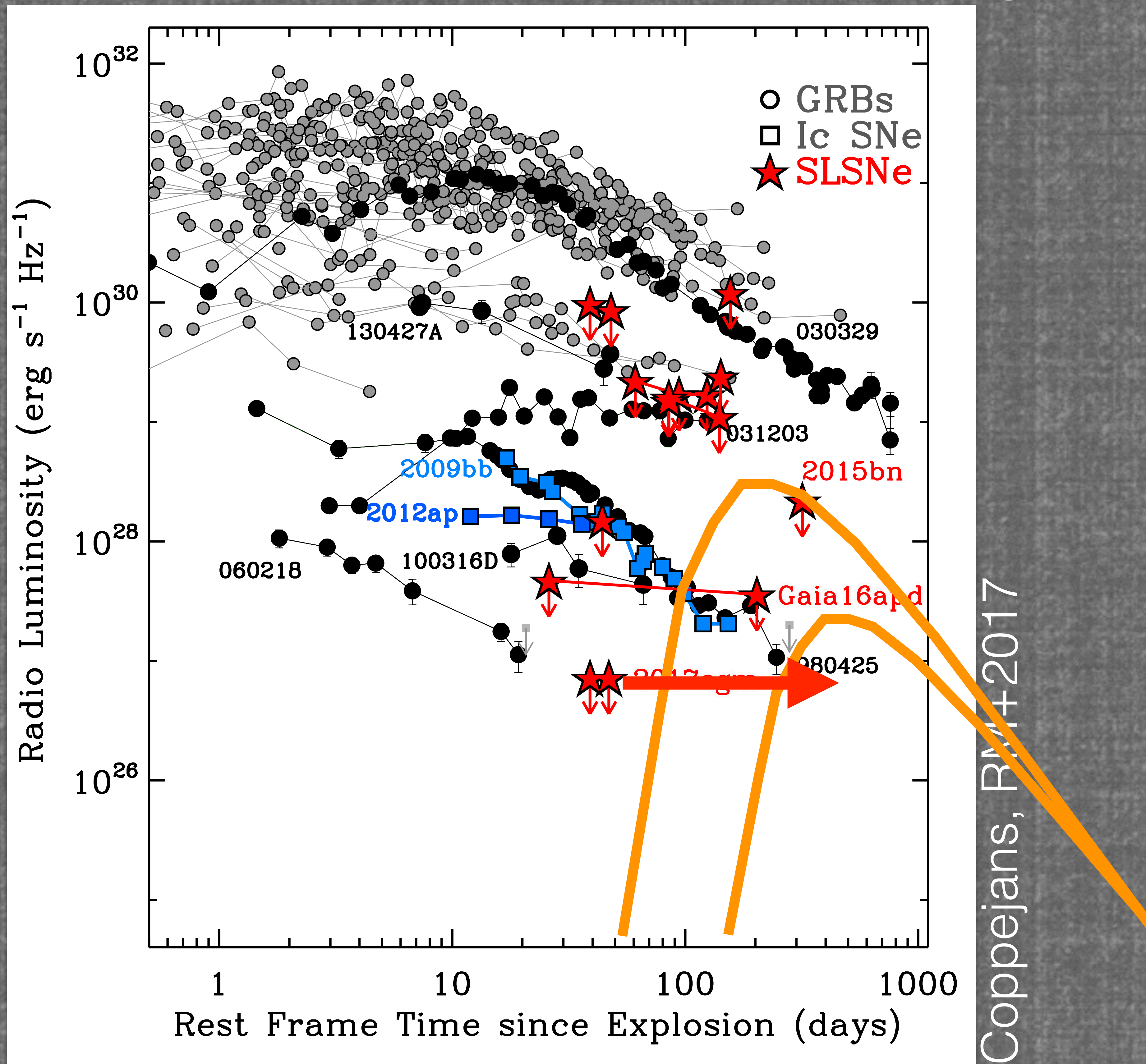
Ek
Density
epsilon_e
epsilon_B

Ruled Out (for every obs. angle): Ek>5d50 erg in Mdot>1d-4 Msun/yr



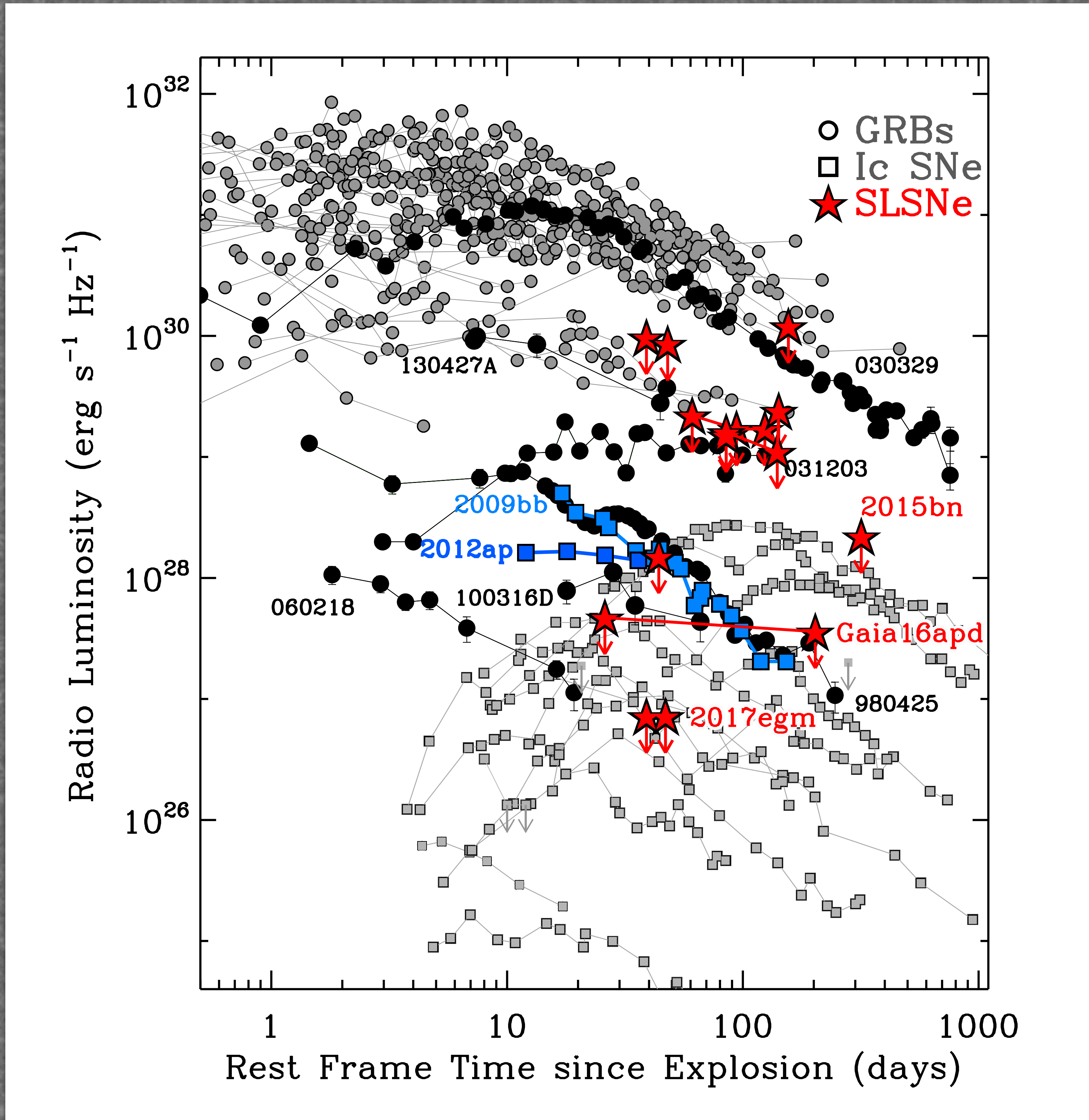
Coppejans, RM+2017

SLSN-I Radio Campaign



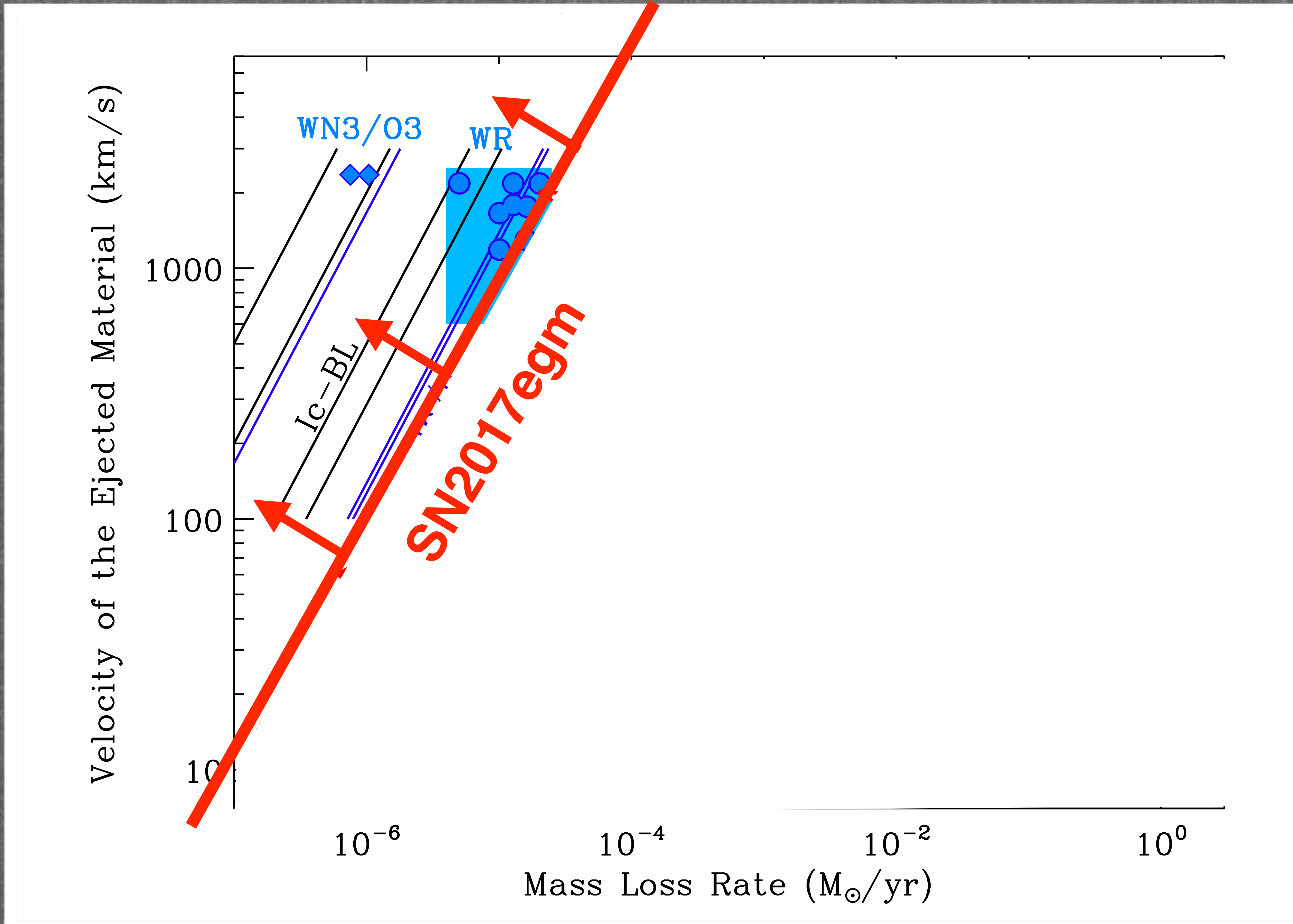
Coppejans, RM+2017

SLSN-I Radio Campaign

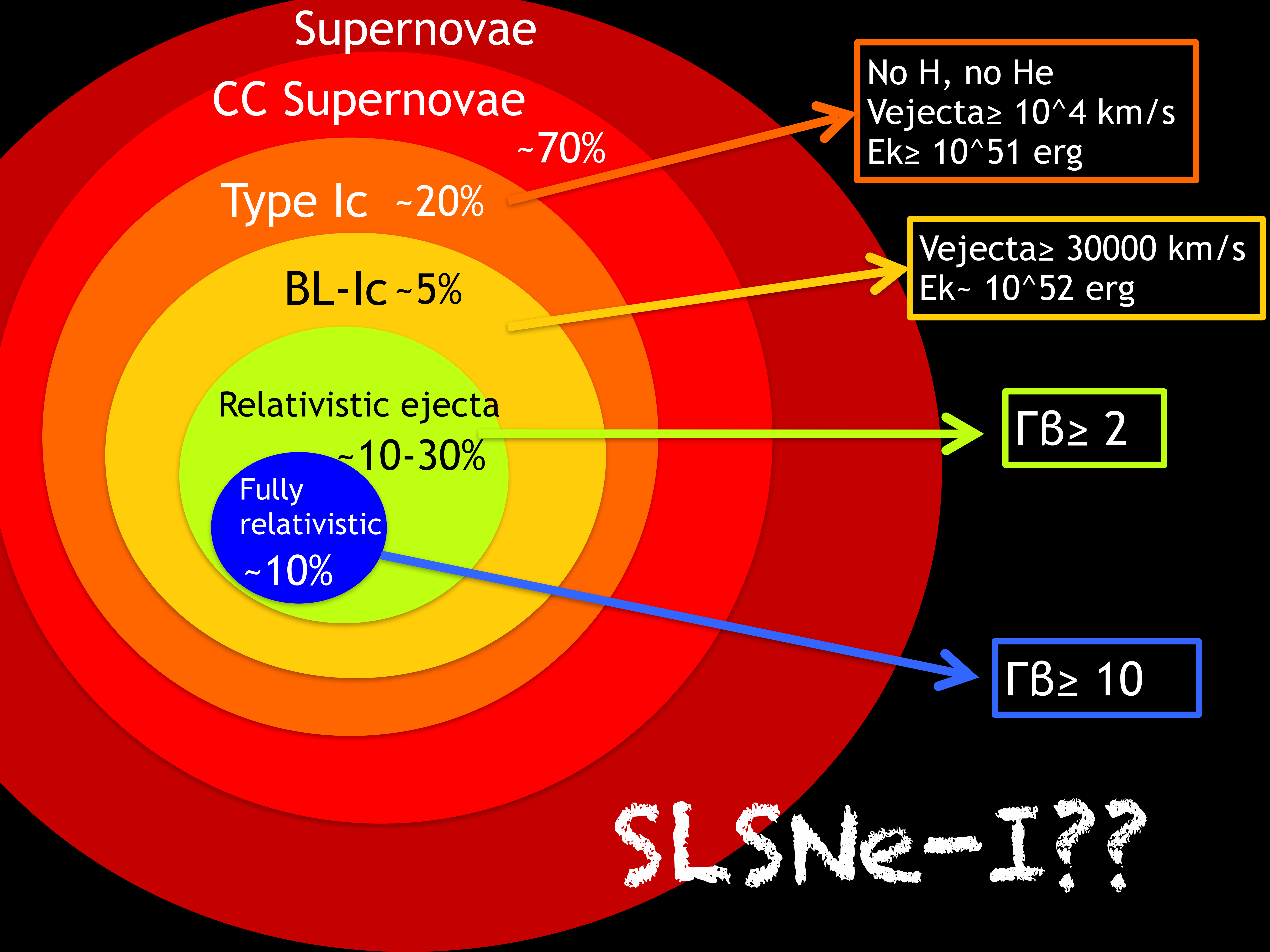


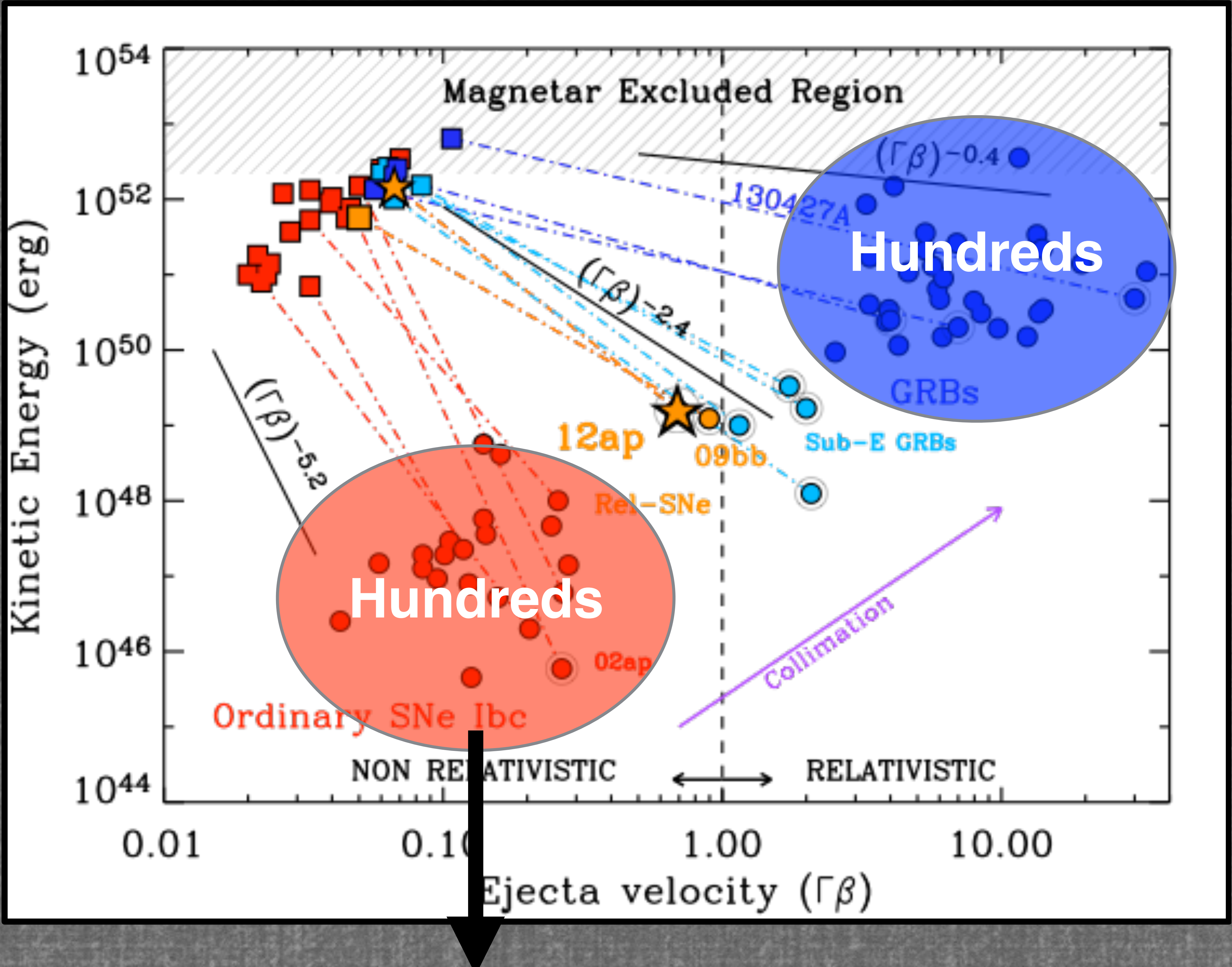
Coppejans, RM+2017

The mass-loss plane:



Margutti+2017


Supernovae
CC Supernovae
~70%
Type Ic ~20%
BL-Ic ~5%
Relativistic ejecta
~10-30%
Fully
relativistic
~10%
No H, no He
Vejecta≥ 10^4 km/s
Ek≥ 10^51 erg
Vejecta≥ 30000 km/s
Ek~ 10^52 erg
Γβ≥ 2
Γβ≥ 10
SLSNe-I??



https://sne.space/