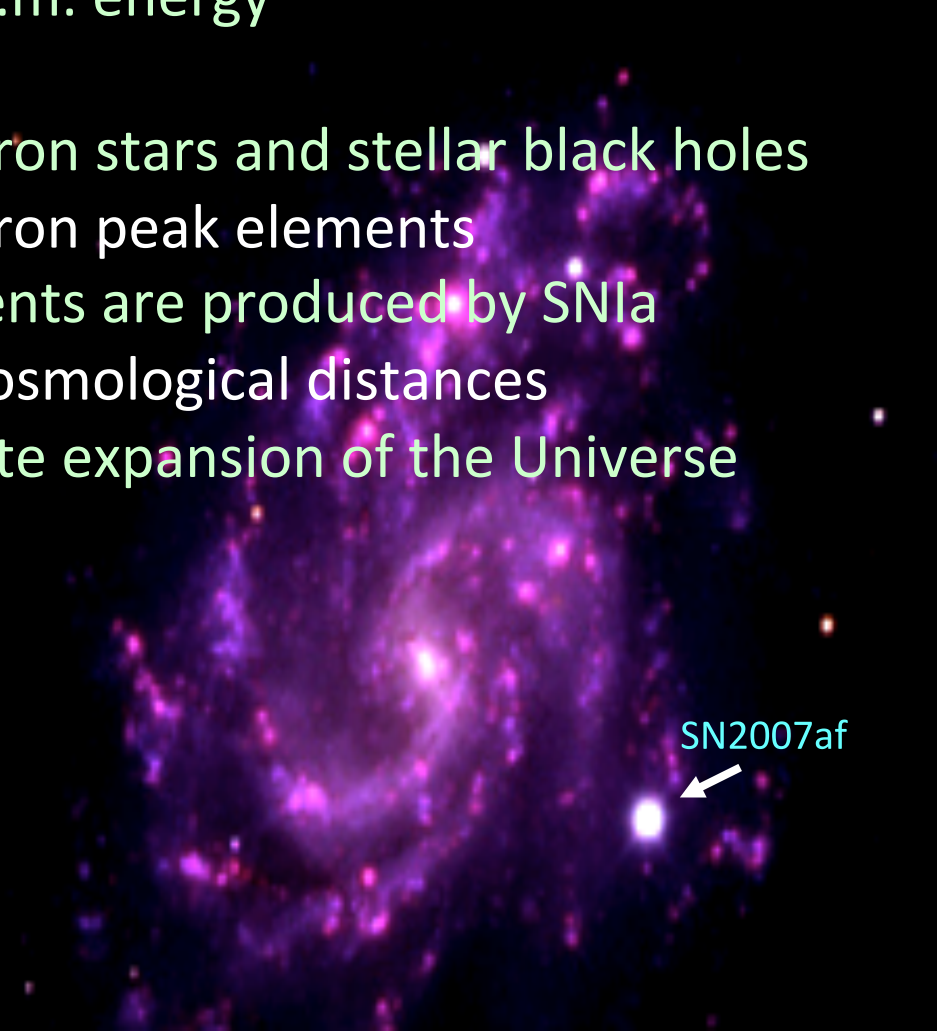
SNIa & CCSN

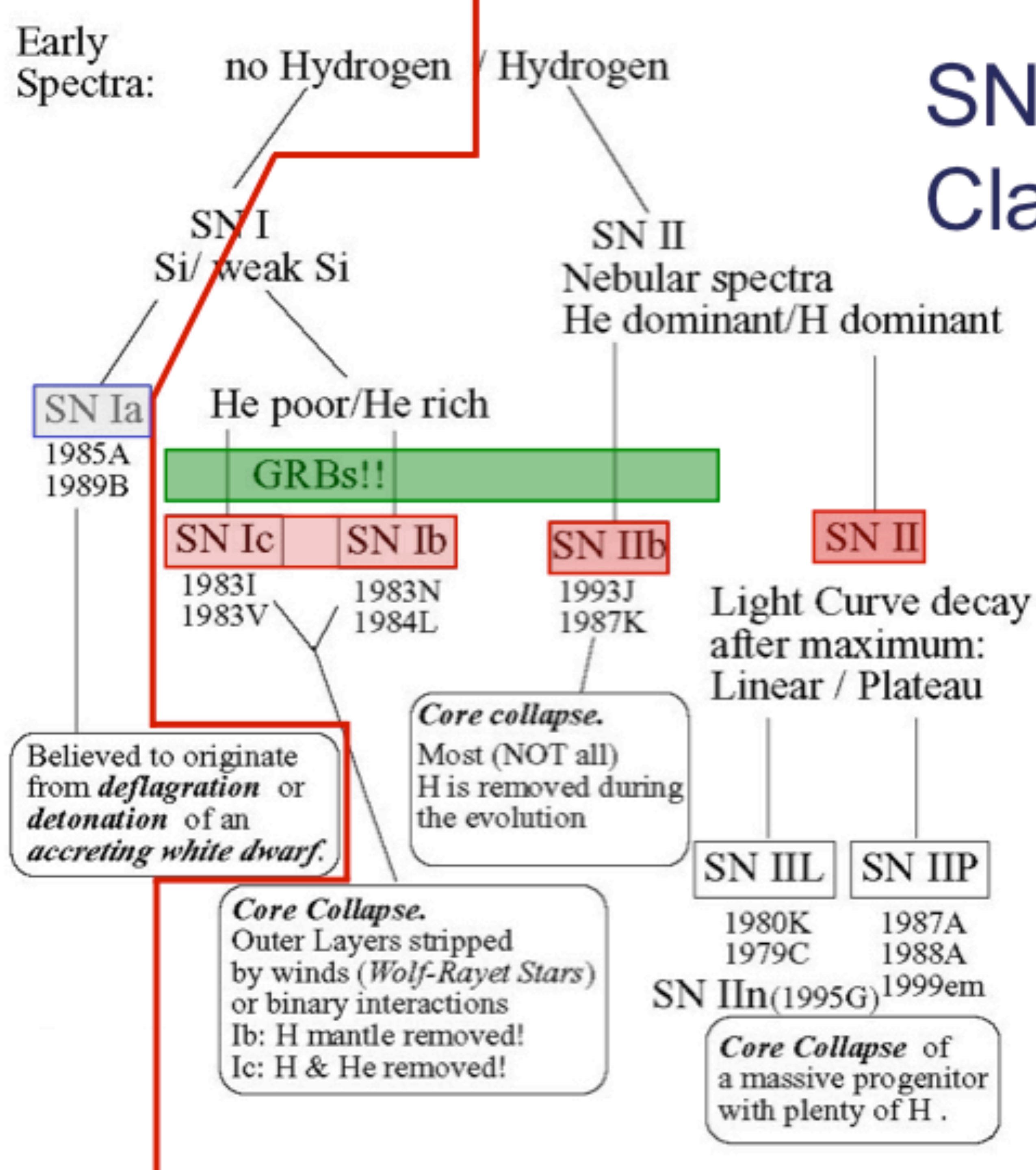
Munich, October 13th, 2017

Role of SN

- Huge amounts of energy involved in the explosion
  - ✓They inject 10^{51} ergs per event of kinetic energy
  - ✓They produce ~ 10^{49} ergs of e.m. energy
  - ✓ $L_{max} \sim 10^{10} L_o$
  - ✓They are at the origin of neutron stars and stellar black holes
- They are the major producers of iron peak elements
  - ✓ 50-60% of the Fe-peak elements are produced by SNIa
- They are well suited to provide cosmological distances
  - ✓ Discovery of the accelerate expansion of the Universe
  - ✓ Dark Energy EoS

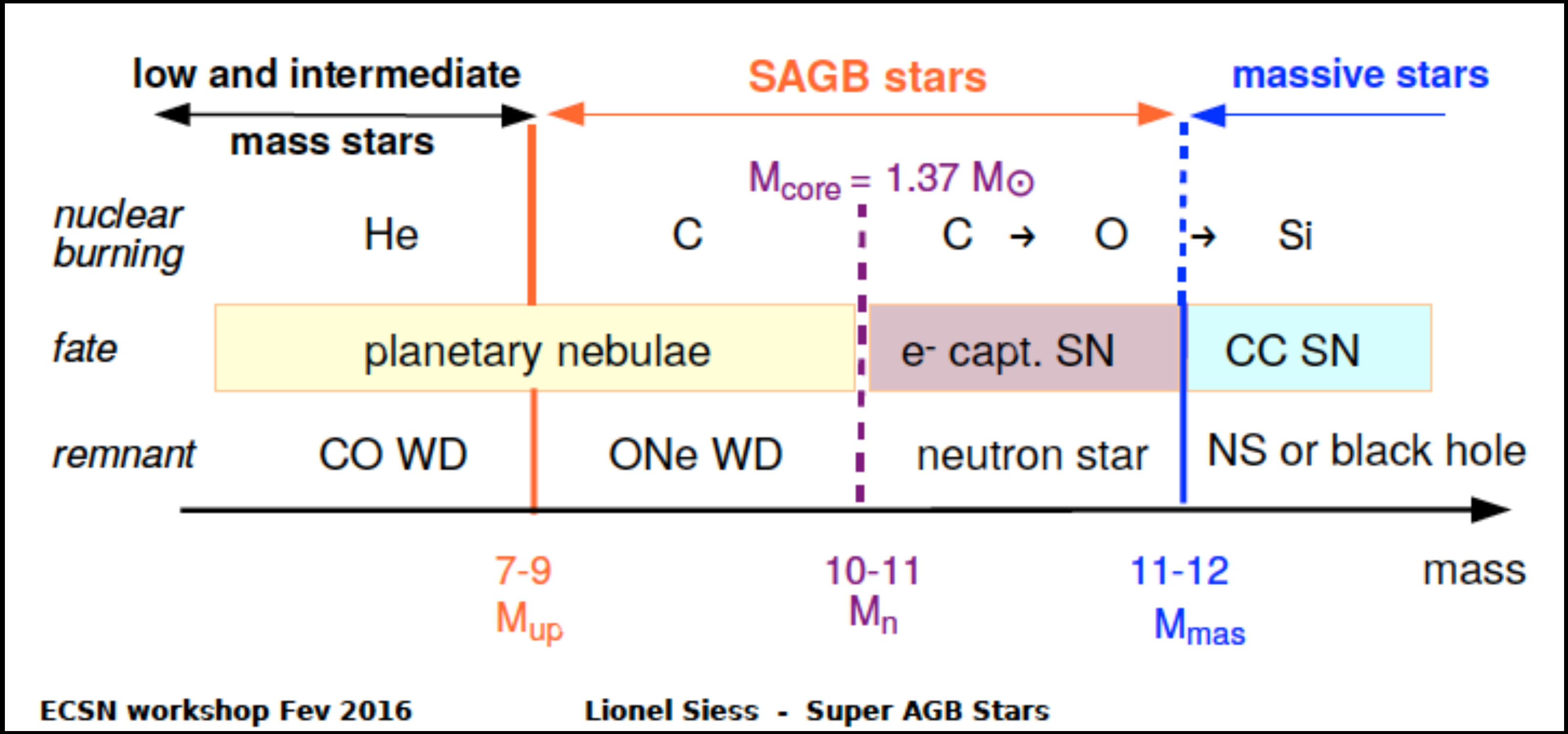


SN Classification



From B. Leibundgut

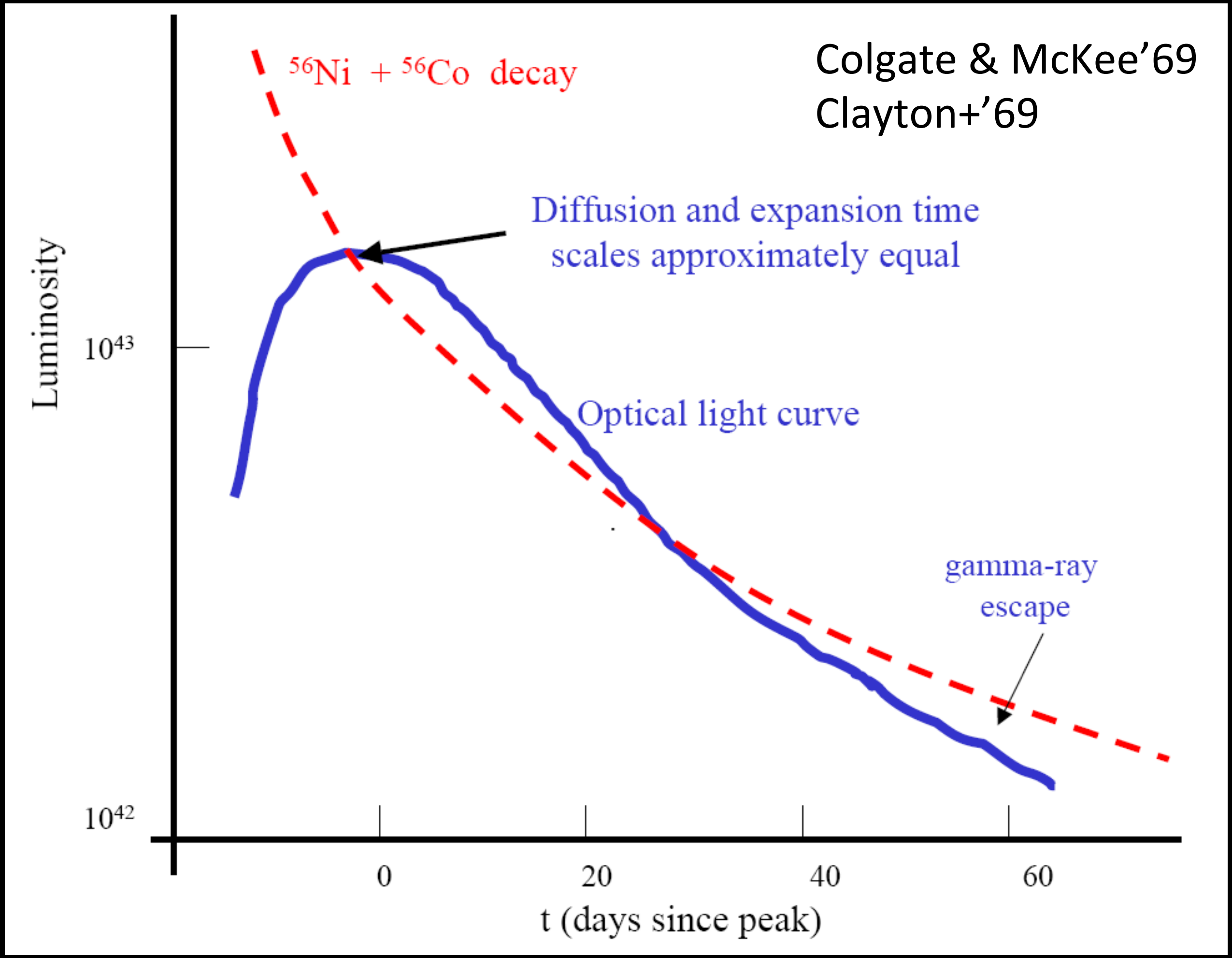
Explosions related to e.d. cores in single/binary stars



The fate of these cores depends on the rate at which the front injects energy and e-captures on ashes remove energy

- He cores always explode
- C/O cores can explode or collapse
- Hybrid C/O-O/Ne can explode or collapse
- O/Ne cores collapse, explode?
- Fe cores always collapse

SNIa are caused by the thermonuclear explosion of a C/O white dwarf near the Chandrasekhar's mass in a close binary system



Gehrels et al 1987
Ambwani & Sutherland 1988
Burrows & The, 1991
The et al 1993
Ruiz-Lapuente et al 1993
Hoflich et al 1994
Kumagai & Nomoto 1995
Woosley & Timmes 1997
Gómez-Gomar et al 1998
Summa et al 2013

(from S. Woosley ppt)

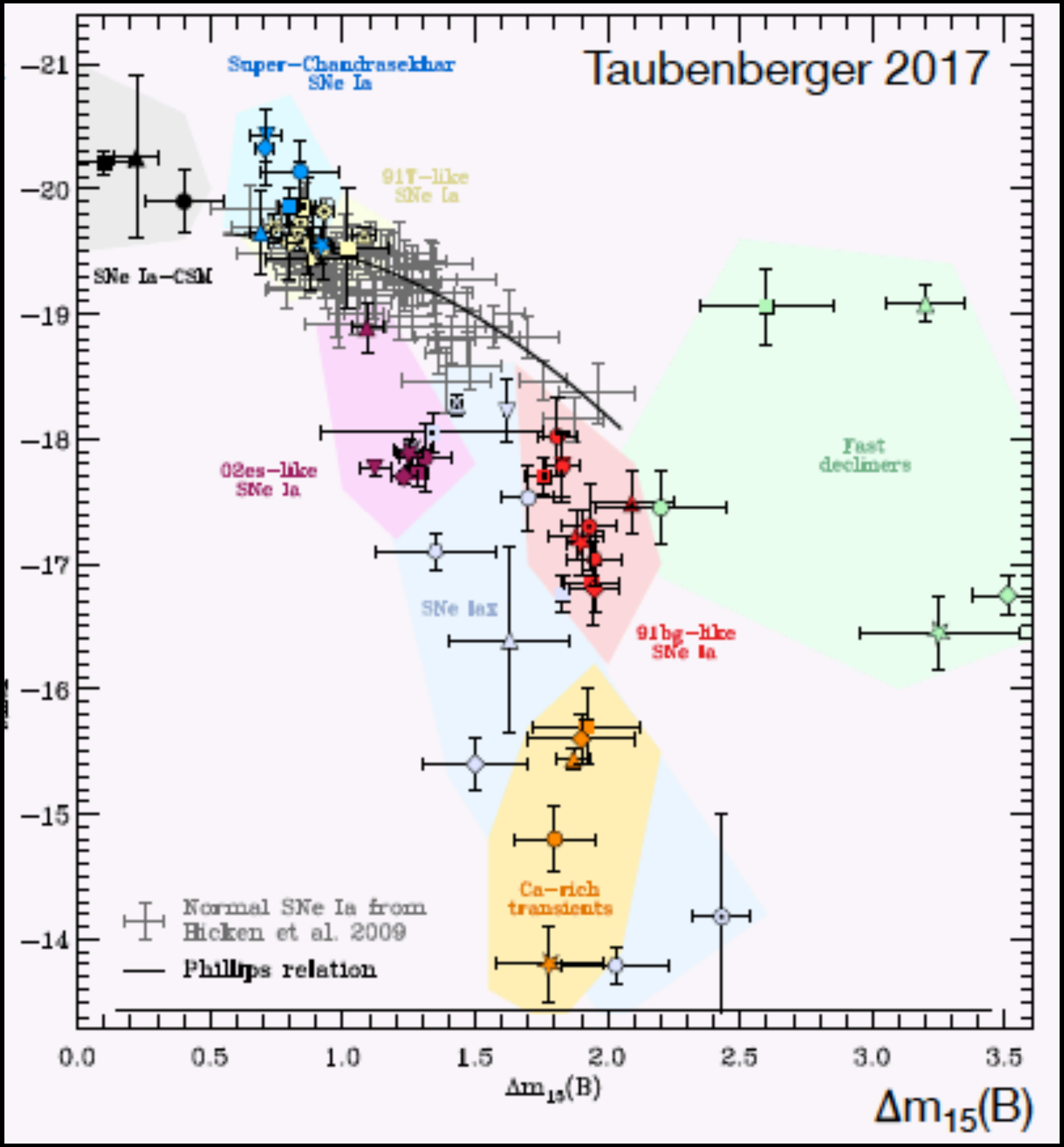
The necessary condition to use γ – rays as a diagnostic tool is to detect them!

Comptel/CGRO

SN1991T (Lichti+'94, Morris+'97)
 Detection
SN1998bu (Georgii+'01)
 Upper limit

Integral

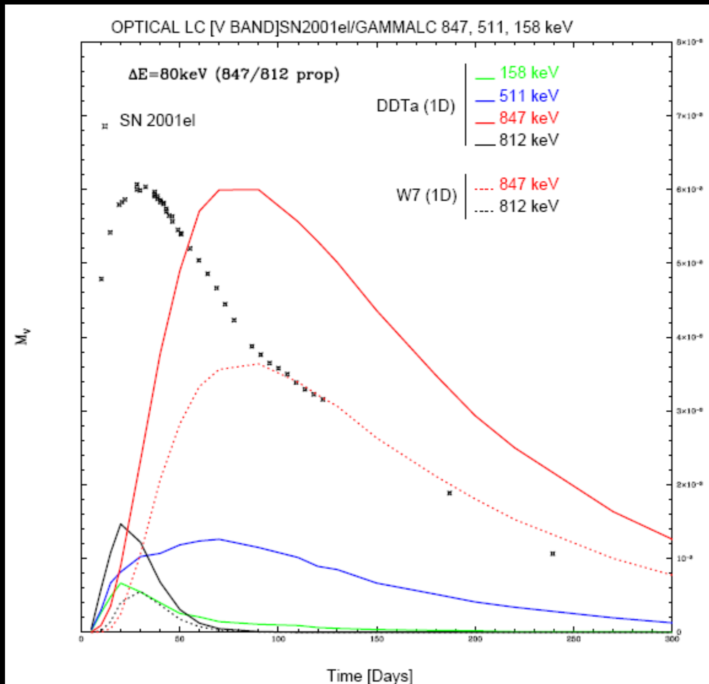
SN2011fe (Isern+'13) Upper limit
SN2014J Detection!
 (Churazov+'14,15
 Diehl+'14,15
 Isern+'16)

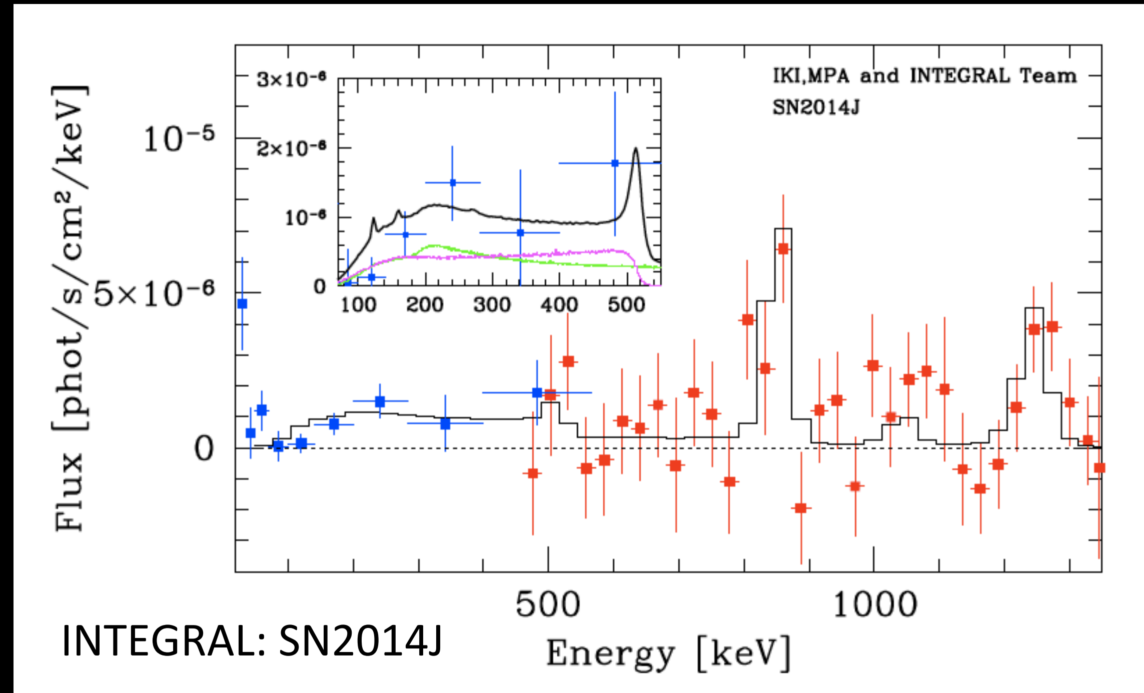


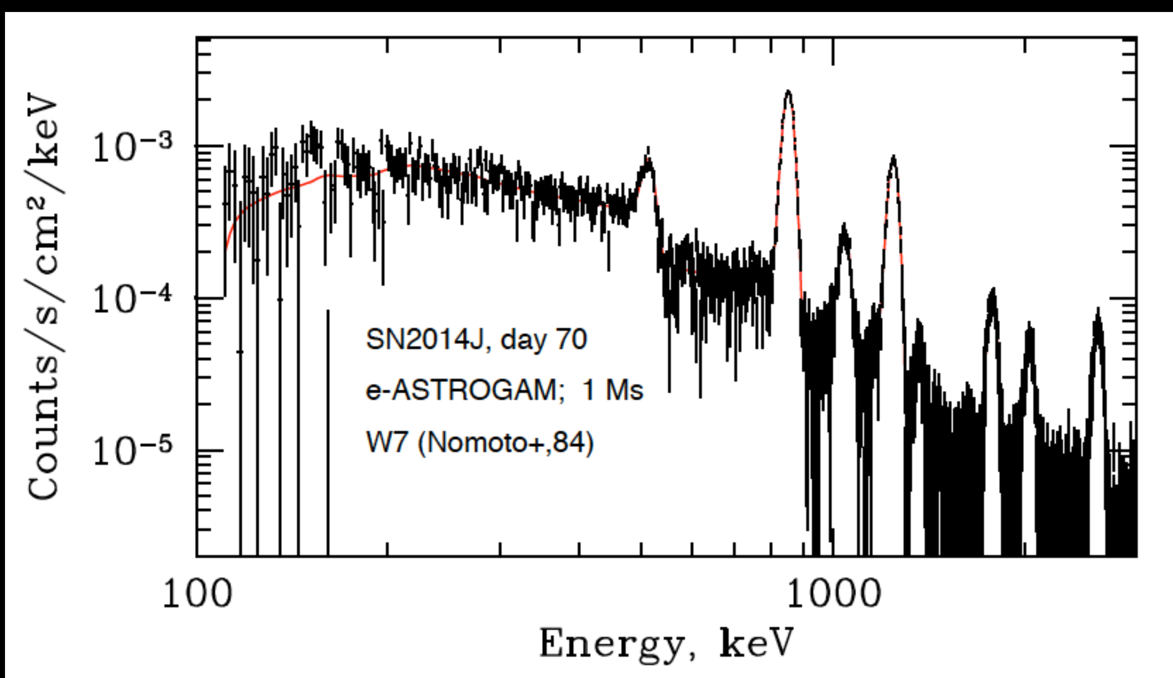
Need to callibrate the Phillips relationship
Different scenarios & explosion mechanisms can coexist
Each scenario/explosion has the own gamma signature

Scenarios

- Single degenerate scenario (Whelan & Iben'73, Nomoto'82, Han & Podsialowski'04)
- Double degenerate scenario (webbink'84, Iben & Tutukov'84
- Sub-Chandrasekhar scenario (Woosley & Weaver'94,Livne & Arnet'95, Shen et al'13)
- WD-WD collision scenario (Kushnir et al'13)
- Core degenerate scenario (Livio & Riess'03, Kashi & Soaker'11, Soker'11)





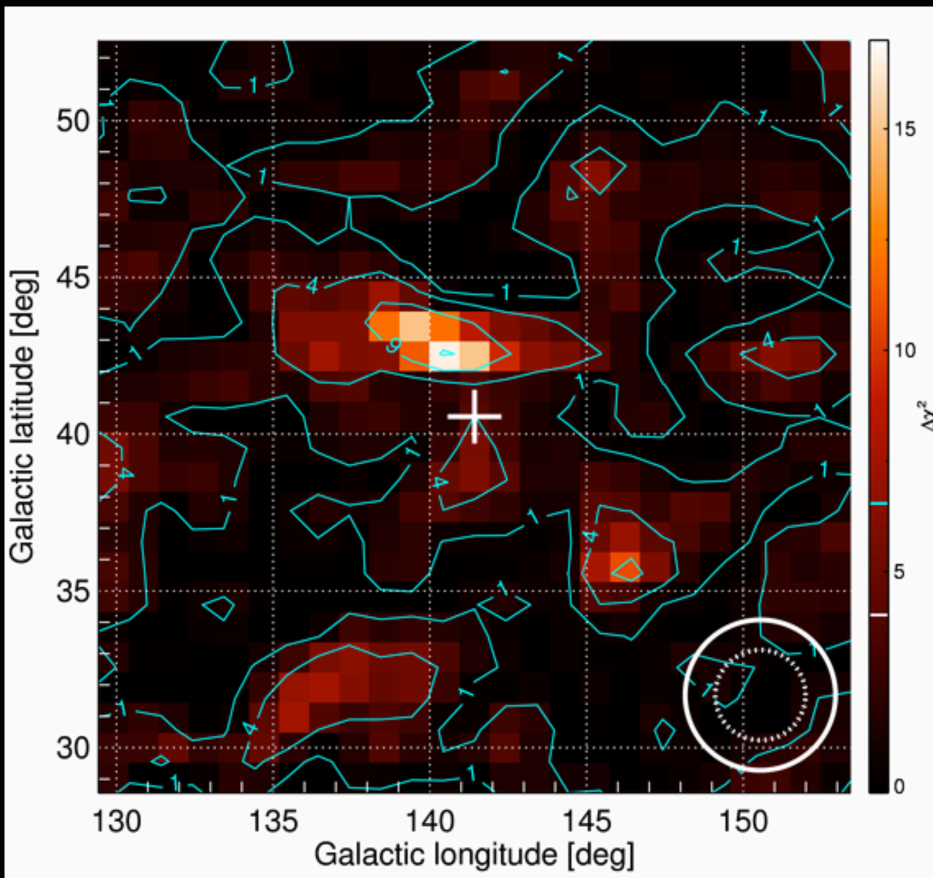


^{56}Co lines

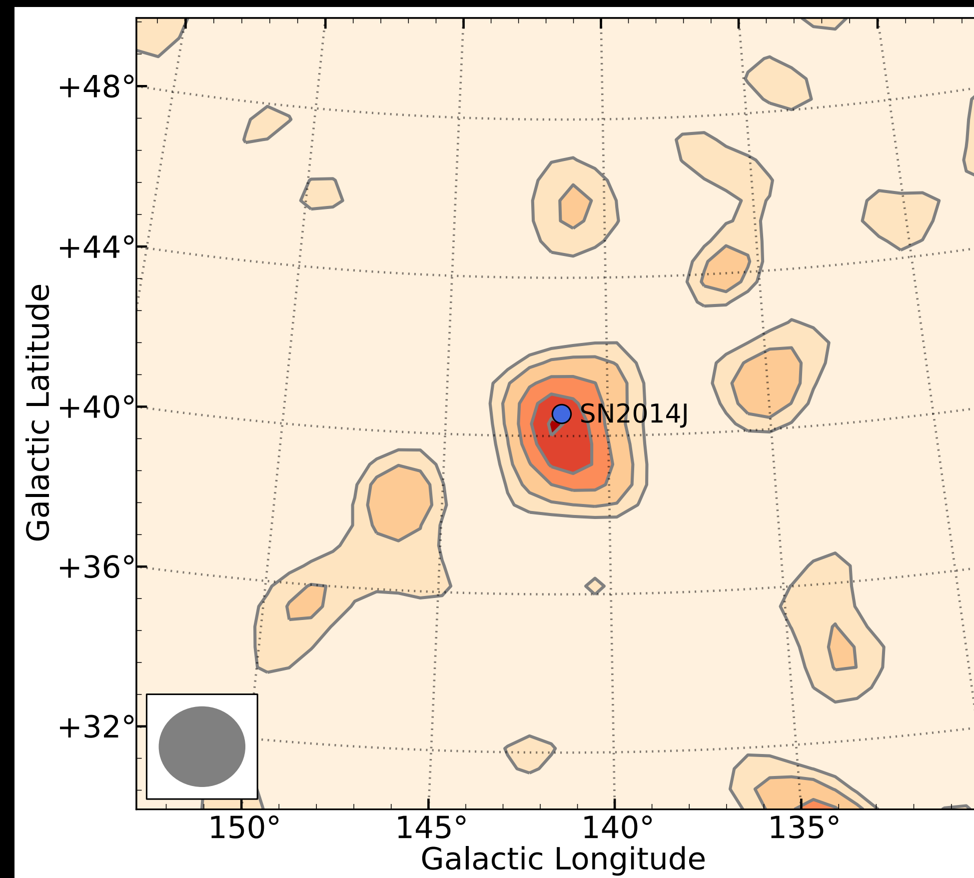
eASTROGAM:
Detection of 56Co lines up to 35 Mpc (10 σ/ 1Ms)

#SNIa ~10 in 3 years

SN2014J early emission



Emission of ^{56}Ni (158 & 812 keV) mapped onto the position of SN2014J (cross). (Diehl+'14)

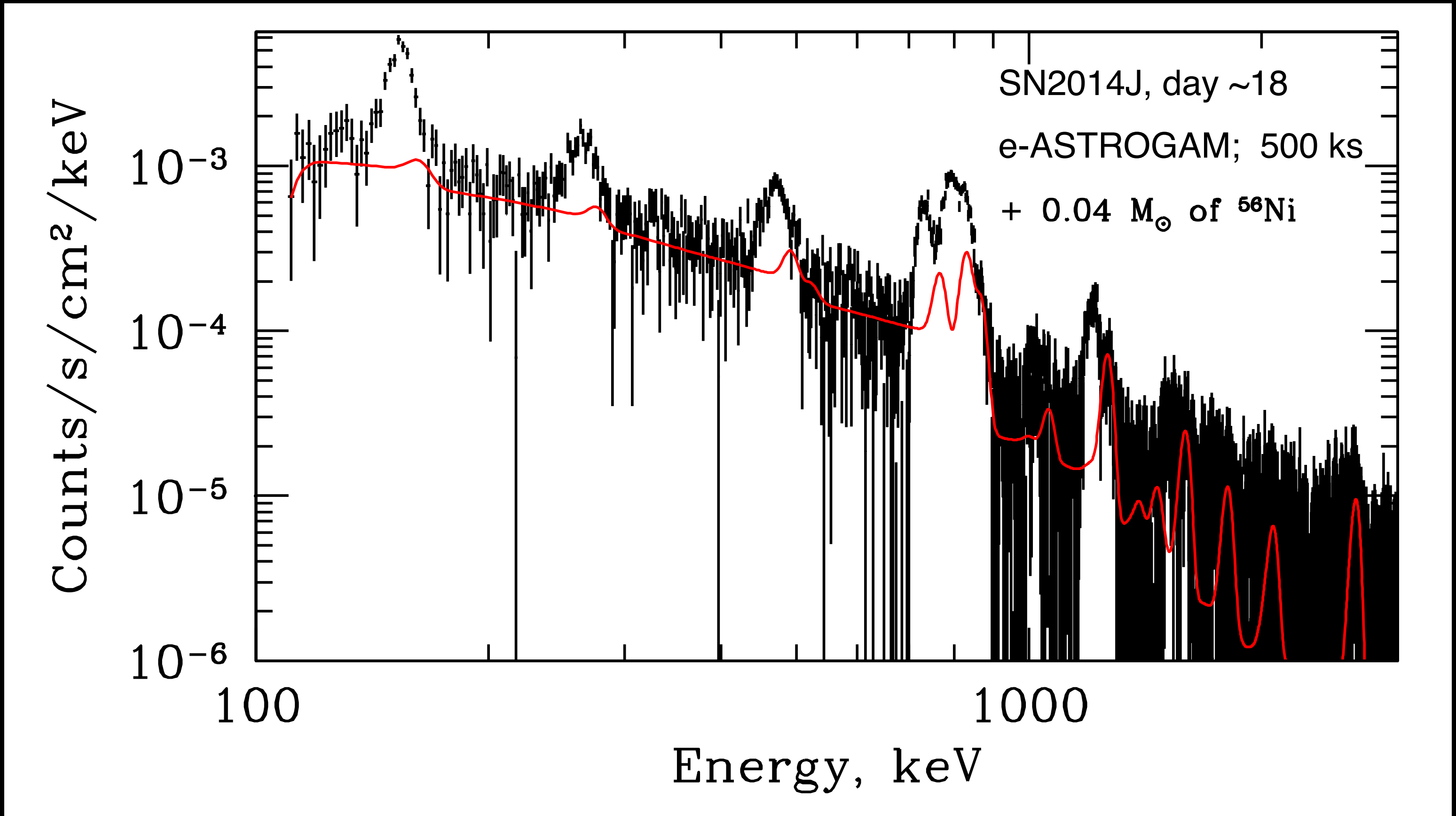


145-165 band/ 16-35 days a.e.
Excess in the SN2014J position
5σ (Isern+'16)

Despite the two teams disagree in the details, the excess is real and probably caused by the presence of ^{56}Ni in the outer layers

#Two issues: detached blobs from the interior or He ignition (subCH) → More precise data are needed!

eASTROGAM could detect the presence of 2e-3 Mo of Ni



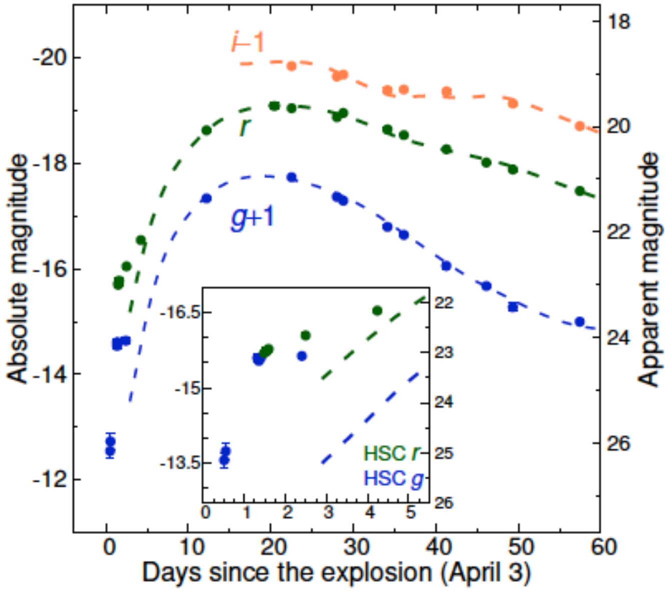


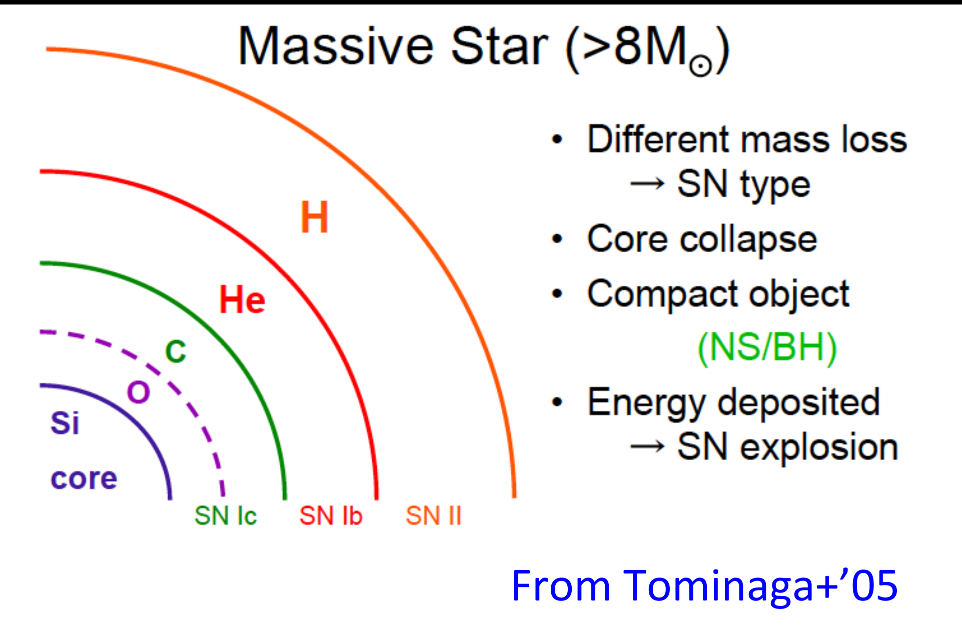
Figure 1: The multi-band light curve of MUSSES1604D. Photometry in *g*, *r* and *i* bands (observer-frame) are in the AB system. Error bars denote 1-σ uncertainties. Dashed lines are best-fitting light curves derived from the non-early photometry (t $\gtrsim$ 12 days) with SALT2[16]. The explosion epoch is estimated by adopting a classical t^2 fireball model for the early-flash phase (see Methods). The inset zooms in on the early-phase multi-band light curve by Subaru/HSC, which shows that the brightening in *g*-band "paused" after the second-night observation.

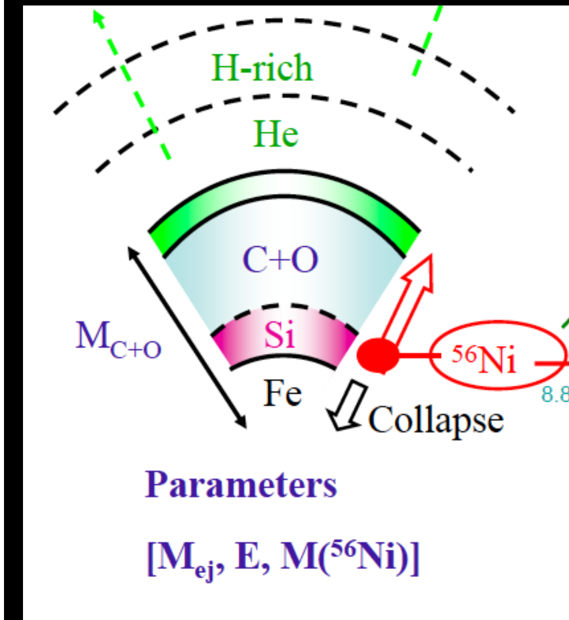
Exemple: SN2016jhr displays a bump in the early light curve. Several possible origins: SubCH, interaction CSM...

^{56}Ni lines would provide unambiguos information about the origin

The proof that subCh (He ignited SNIa) really exist would be a major achievement: annihilation line, frequency of SNIa, chemical evolution...

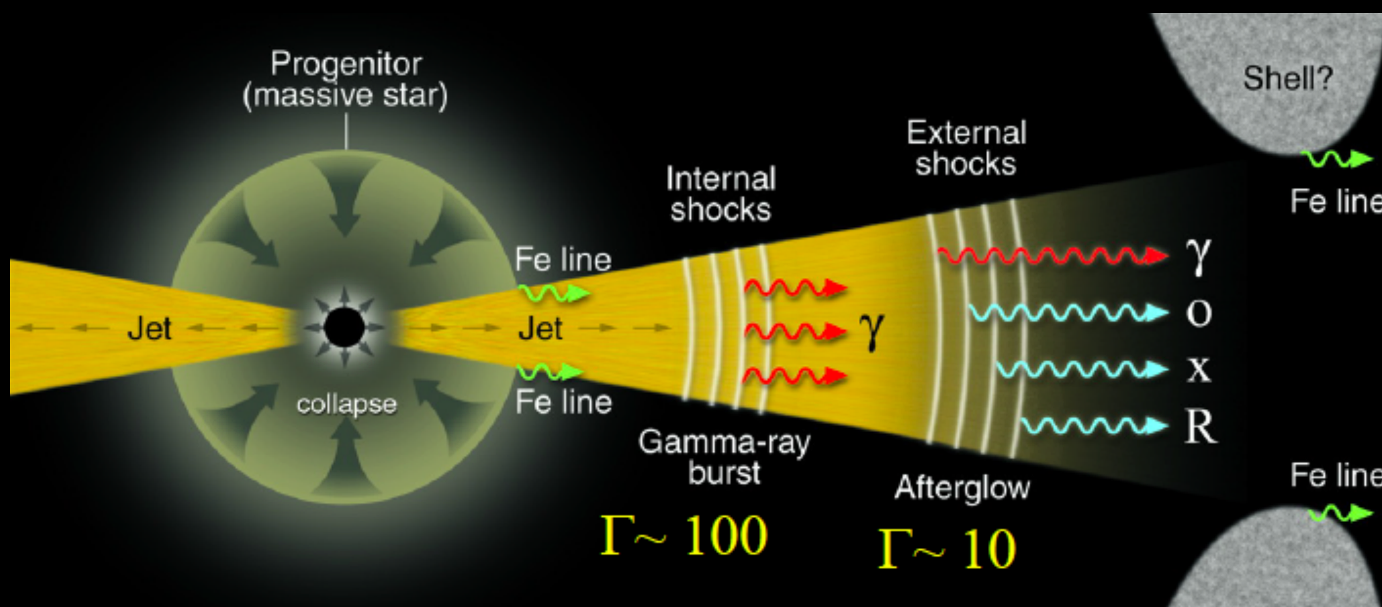
Core Collapse Supernovae



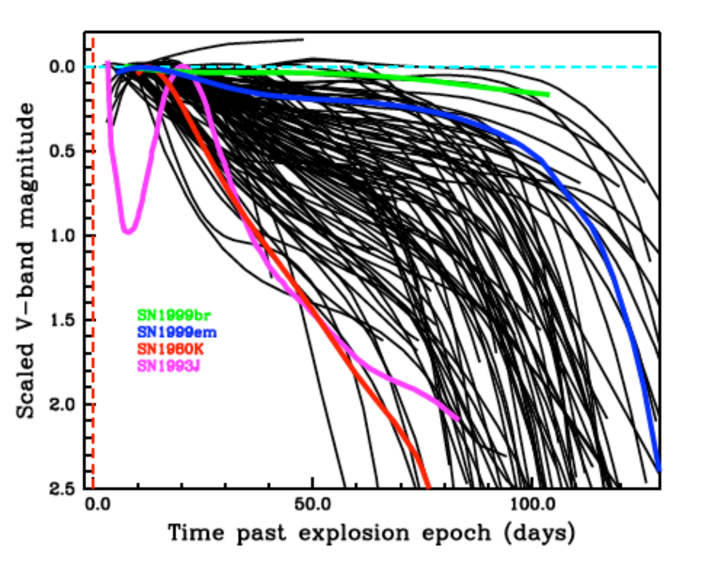


$M_{ms}/M_\odot$	$M_{C+O}/M_\odot$
~ 40	13.8
~ 35	11.0
~ 22	5.0

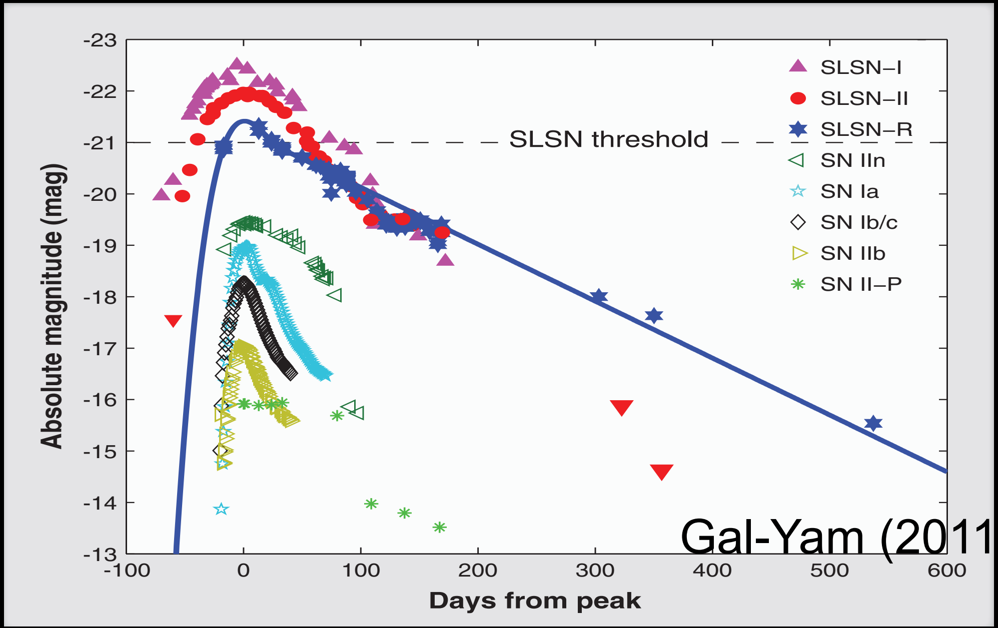
GRBs



SNIIP, SNIIL, 87A-like



Light curve with a large variety of shapes caused by the different envelopes
$M_{56} \sim 10^{-6} - 10^{-1}$ Mo
Sensitivity strongly depends on the width of the line
30-70 times more sensitive than INTEGRAL @ 847 keV



Superluminous supernovae
Pair instability
Circumstellar interaction
Massive winds.
#...

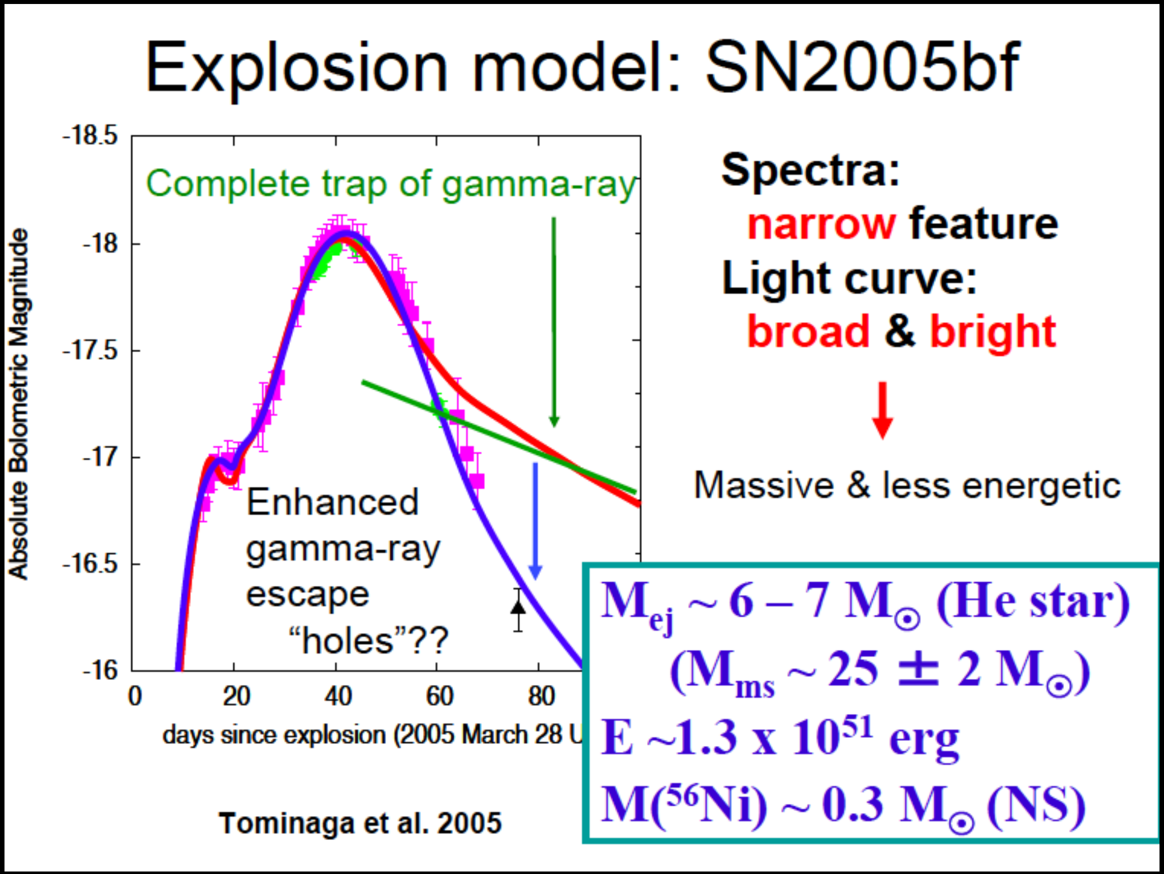
In all cases detection of ^{56}Ni would be crucial

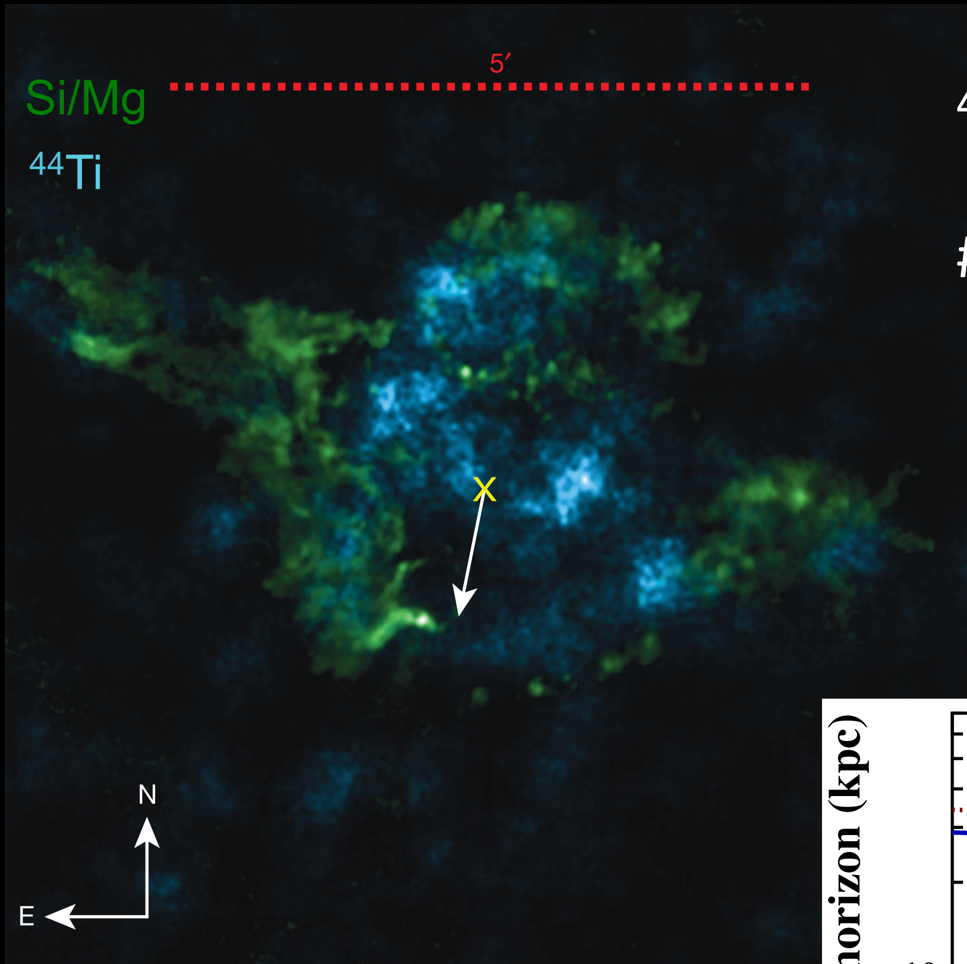
The mass of Ni depends on the initial mass

Name	$M_{ej}/M_\odot$	$M_{ms}/M_\odot$	$E/10^{51}$erg	$M(^{56}Ni)/M_\odot$
1998bw	10	40	50	0.4
1997ef	8	30-35	15	0.15
2002ap	4	20-25	4	0.08
1994I	1	13-15	1	0.07

The velocity of NS and the association to GRB suggest non spherical events → Holes, jets,..

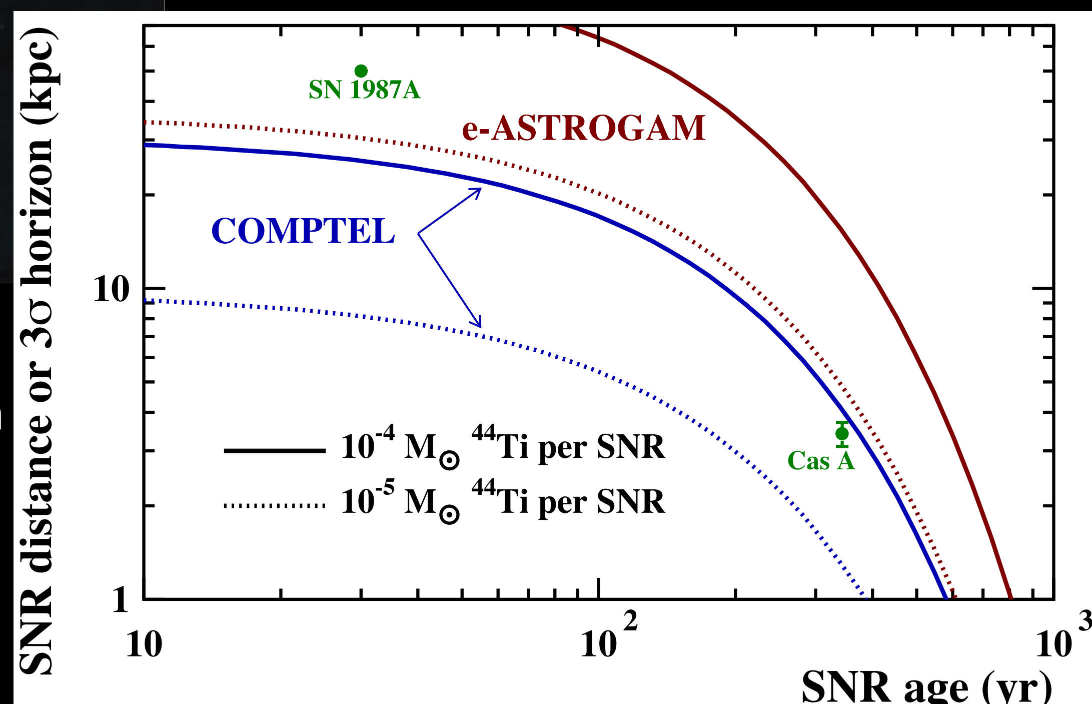
The detection of ^{56}Ni-^{56}Co would provide basic information as proved in the case of SN1987A !





^{44}Ti in Cas A (NuSTAR)

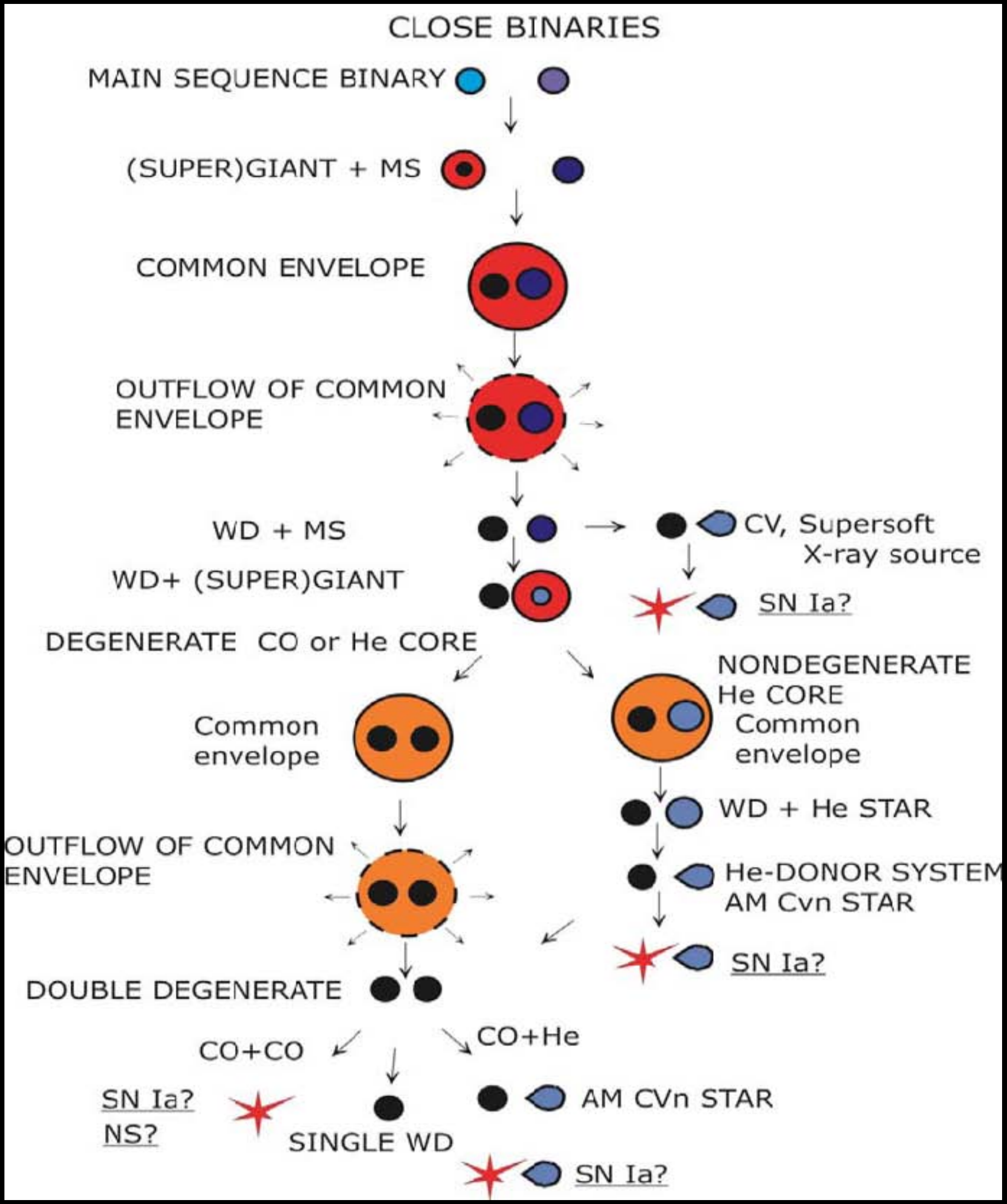
Distributed in knots in the inner region → Convective instability (Grefenstette+' 14,17)

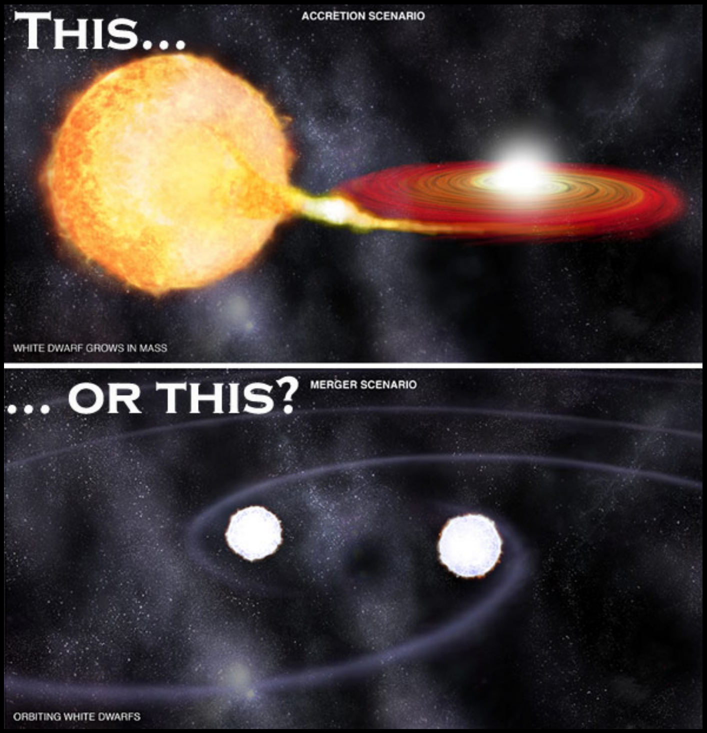


eASTROGAM would allow detection of 44Ti in most of young remnants (< 500 yrs) of the Milky Way.

SNR87A and the youngest in LMC

Scenarios leading to a SNIa





Accreted matter:
H, He or C+O

Everything able to explode eventually do it!
At a first glance both scenarios SD & DD can coexist!