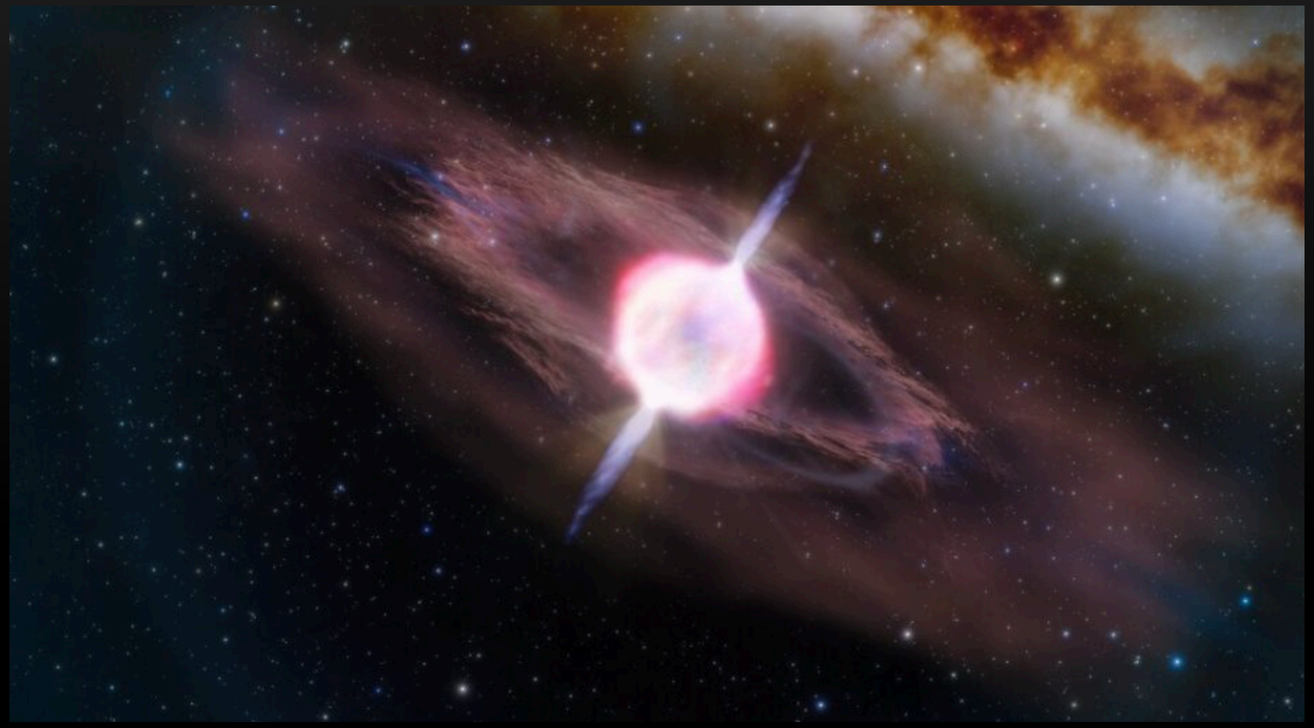
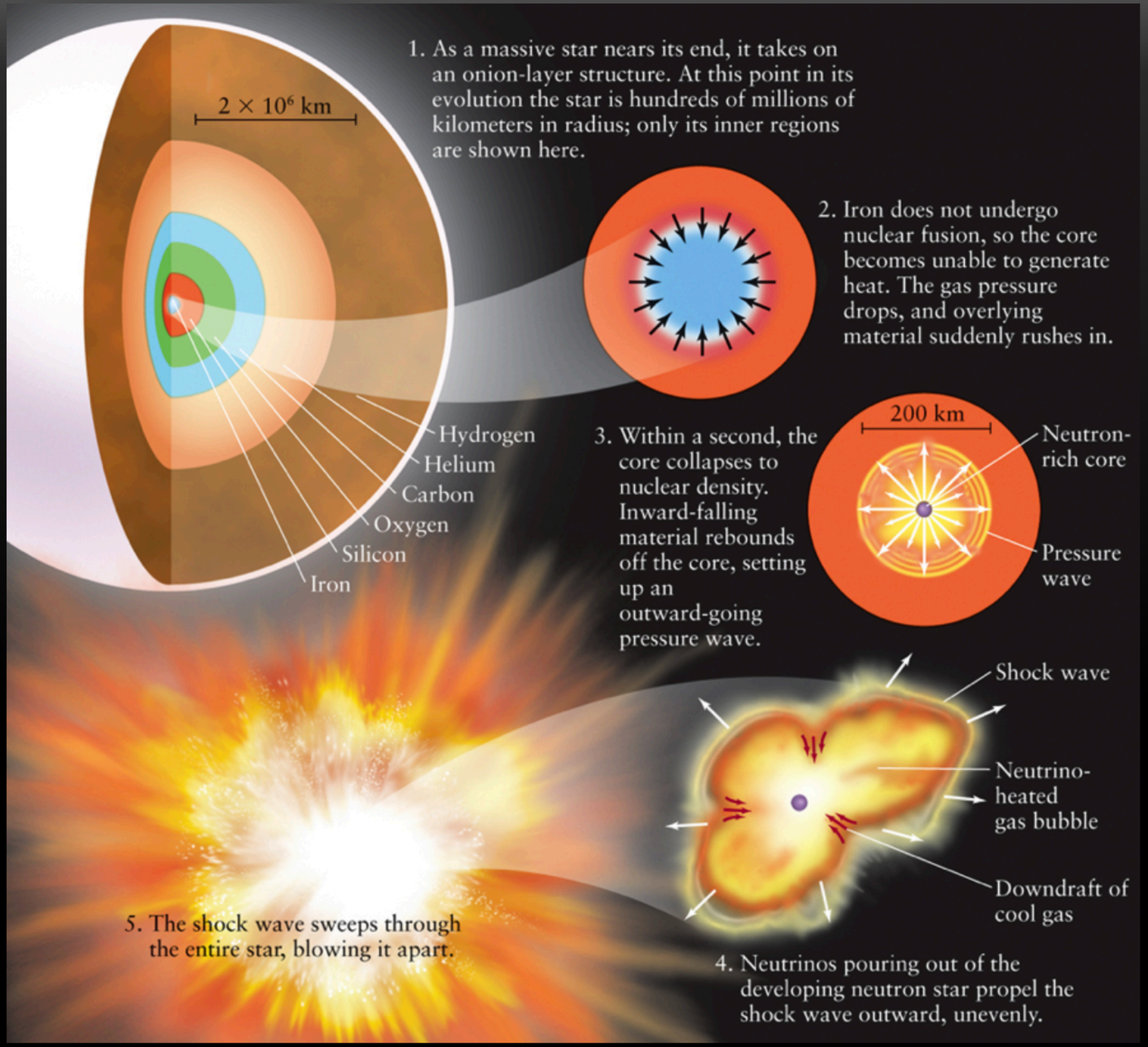
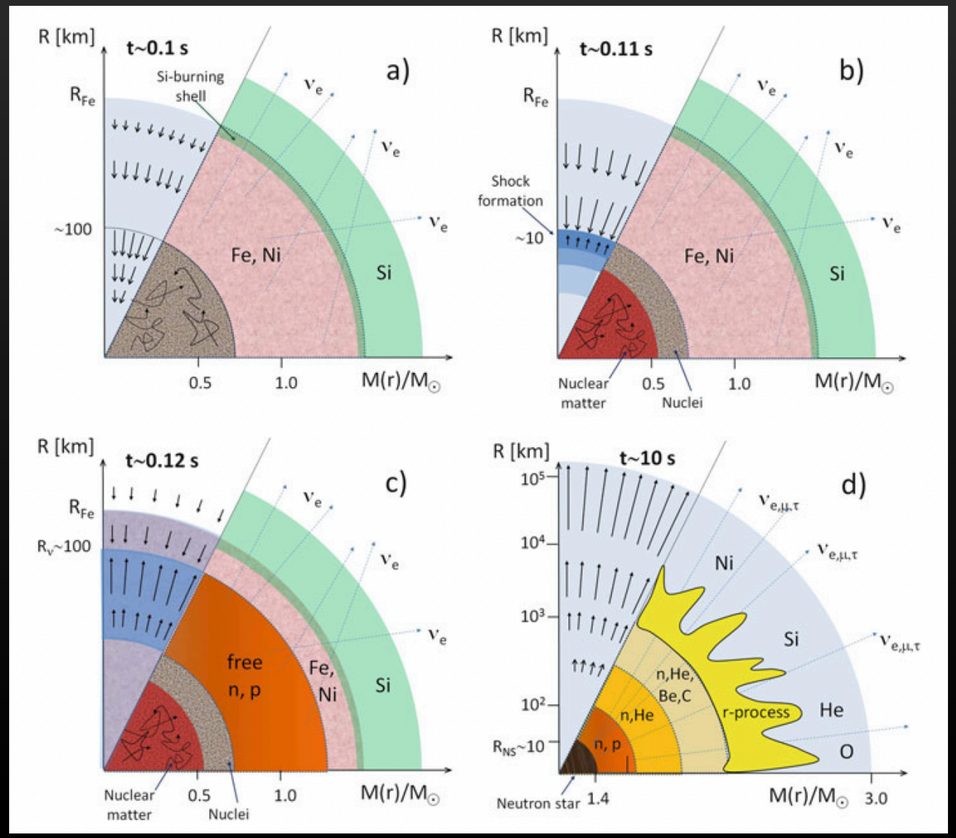
SIGNATURES OF COCOON IN GRB/SN



L. Izzo (INAF-OACN & DARK/NBI)

FEET - Bormio - February 27, 2024



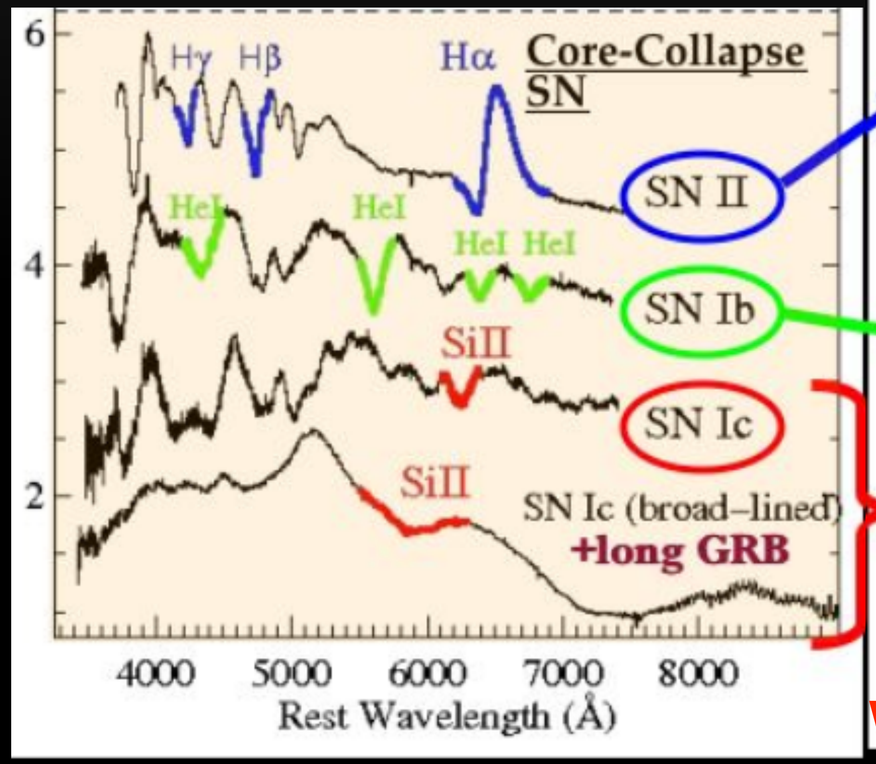


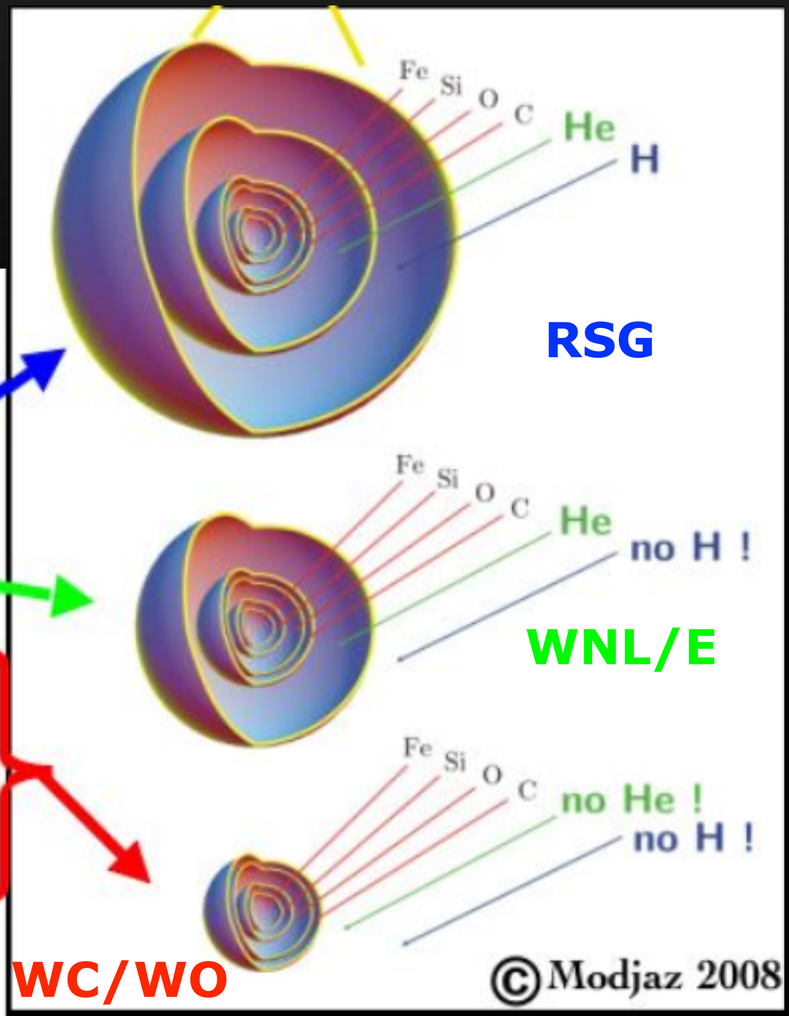
(courtesy Devor, Spurio)

SN types and progenitors

Type Ic-SNe

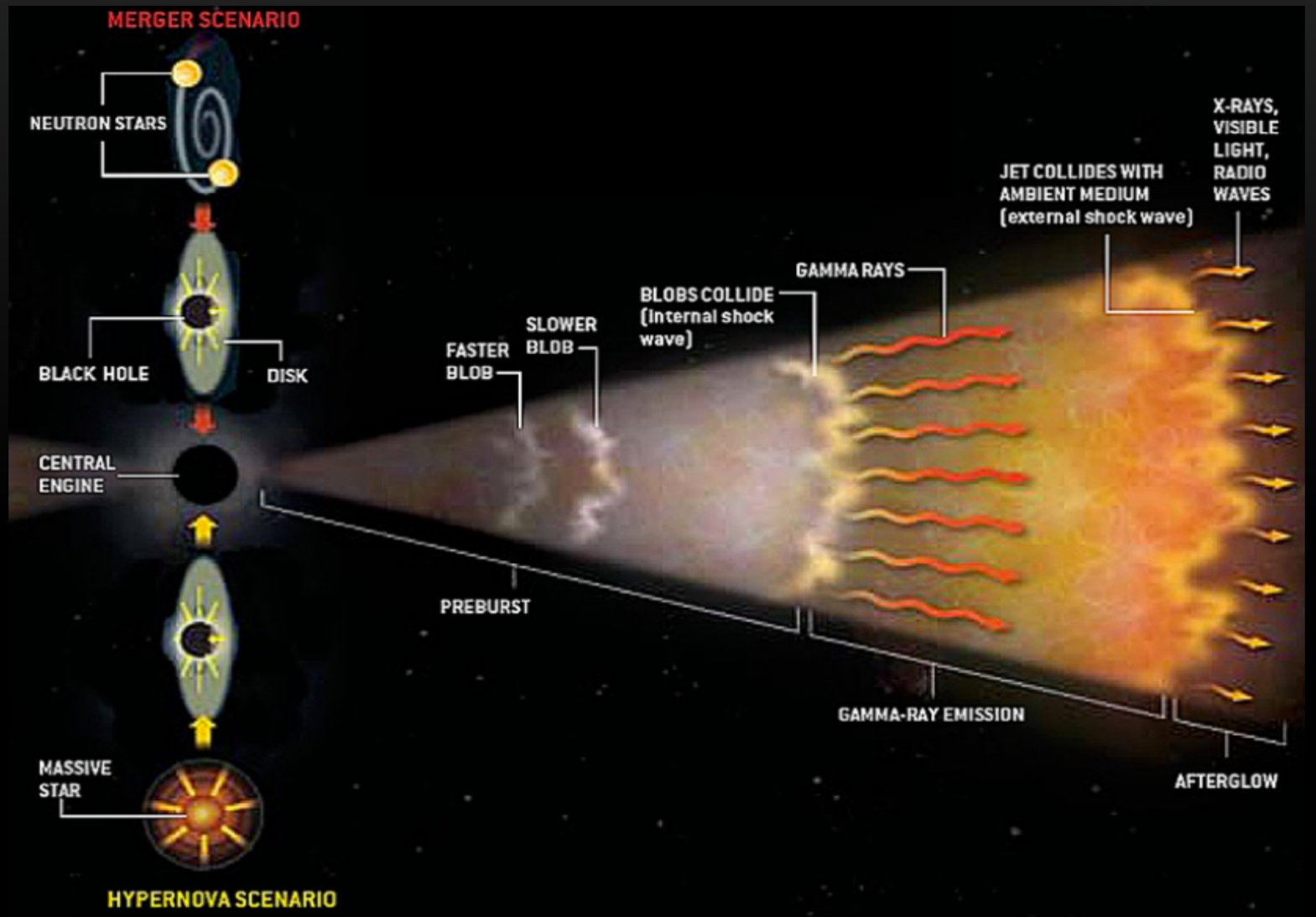
CC SNe from H- and He-stripped progenitors





(courtesy Modjaz)

Gamma-ray bursts



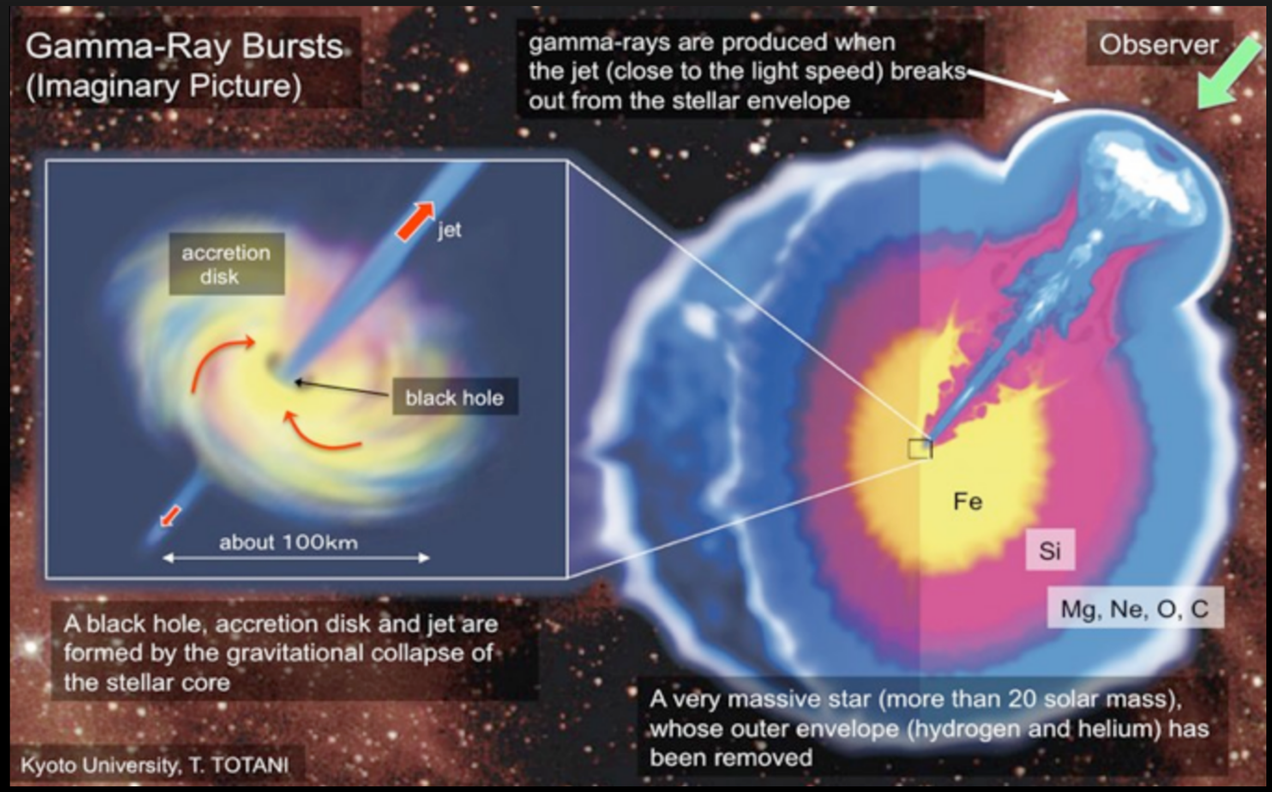
GRB-SN connection

Fast-rotating Fe core => central engine

Low metallicity:

- weak stellar winds (low L losses)
- efficient chemical mixing
- homogeneous evolution

(type Ic events without losing large mass)



(Maeder & Meynet 2001)

(courtesy Totani)

The jet cocoon

See Nakar talk

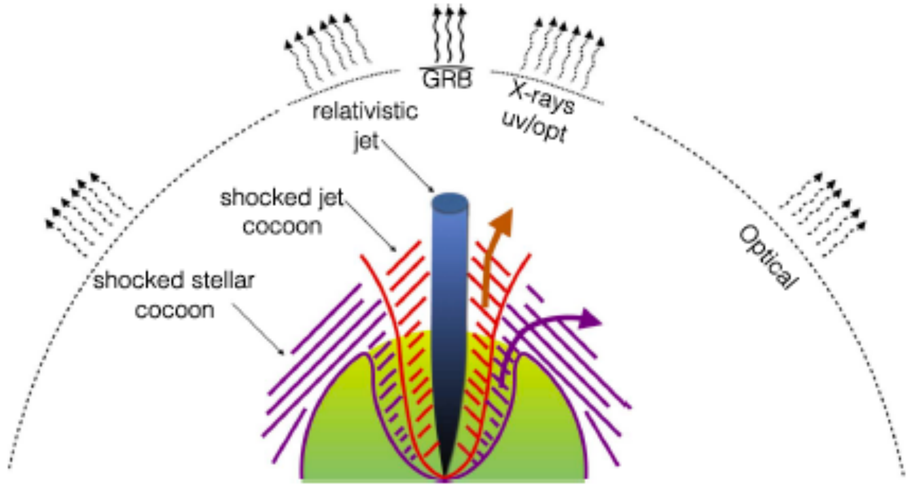
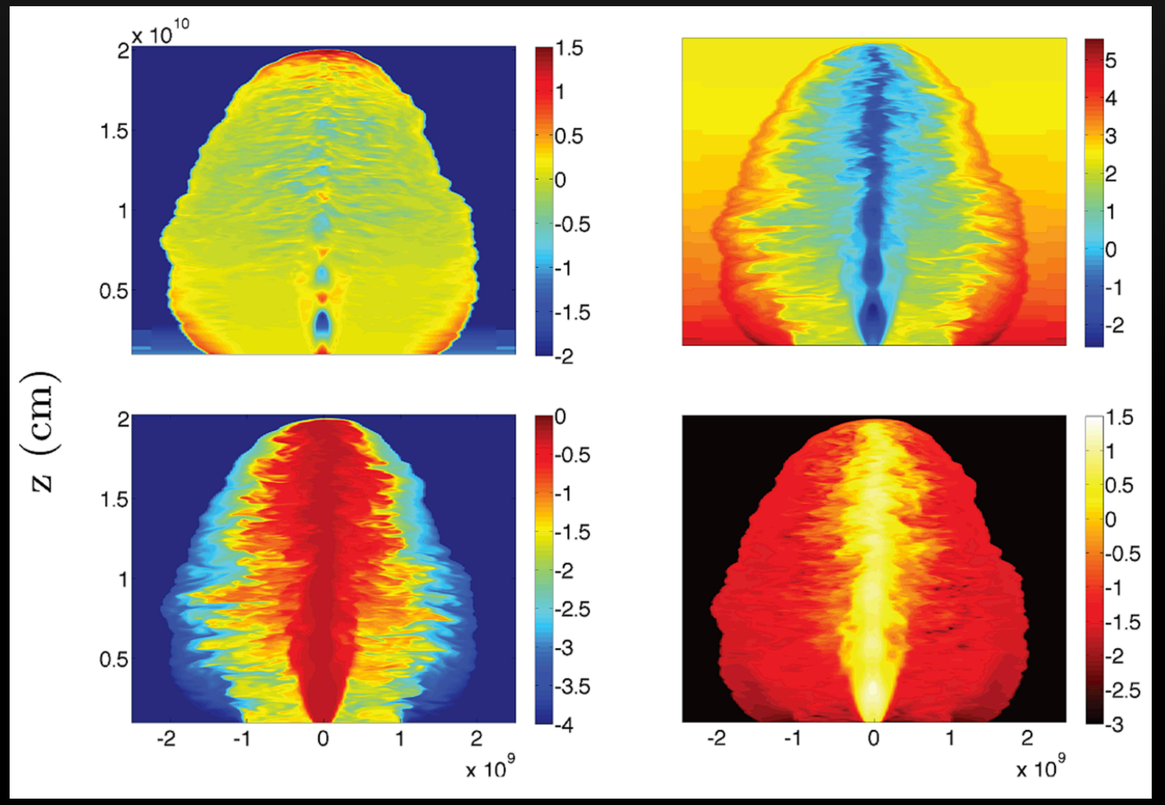
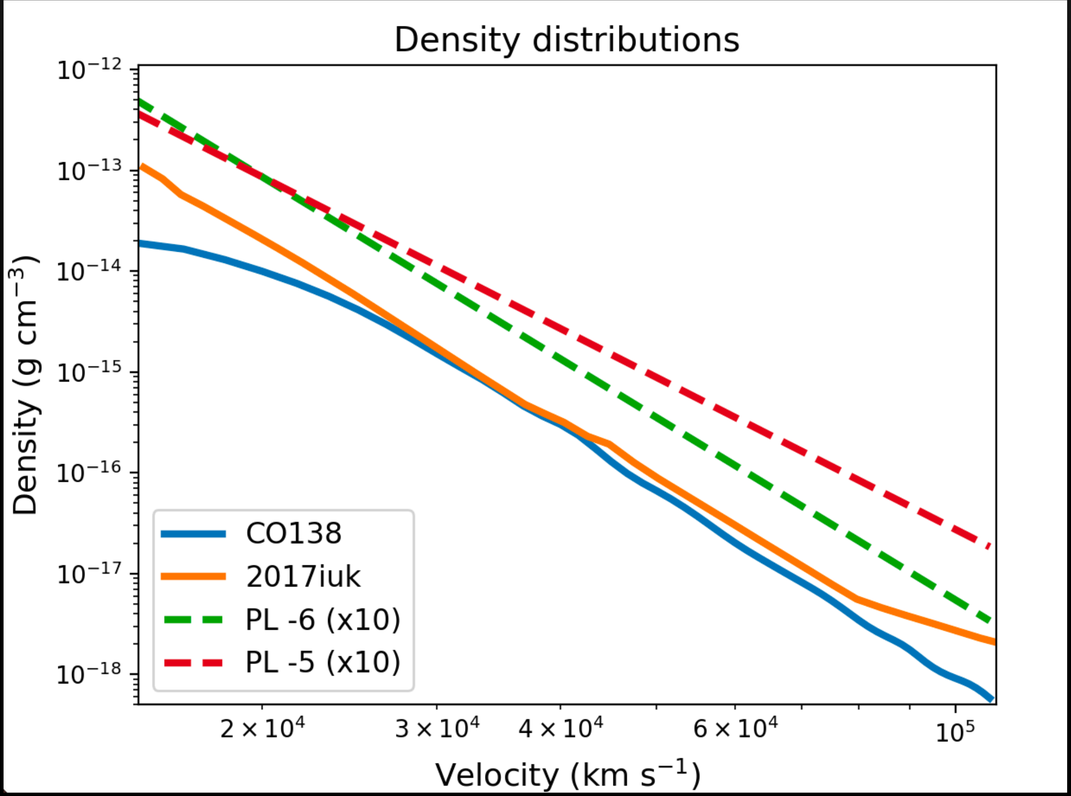


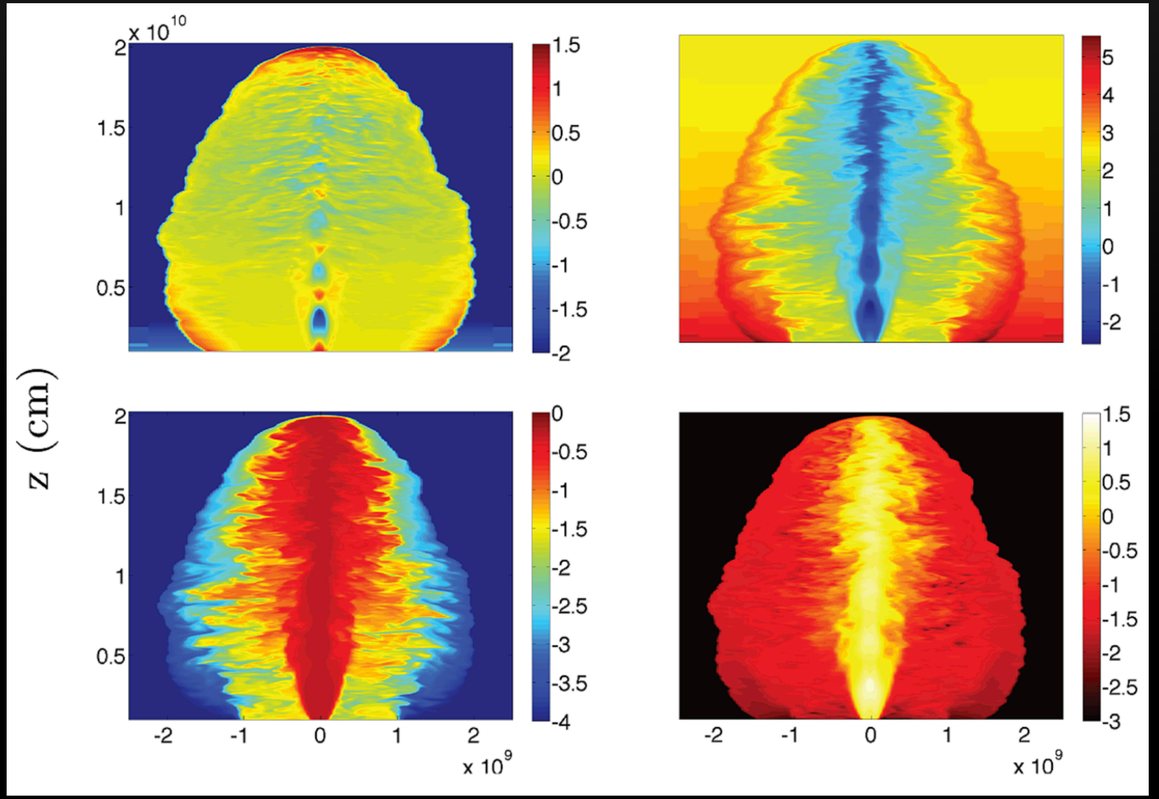
Figure 1. Schematic description of the Collapsar's jet and the cocoon. The cocoon is composed of two components: an inner "shocked jet cocoon" and an outer "shocked stellar cocoon." The jet cocoon is more dilute and hence it expands after breakout to faster, possibly relativistic, velocities. Also shown are the different emission components and their angular extent. A typical opening angle of the relativistic cocoon components (if exist) is ~0.5 rad. The stellar cocoon is sub-relativistic. As it gets out of the star it engulfs the star and its emission is practically isotropic.



(Nakar & Piran 2017, Harrison+ 2017)

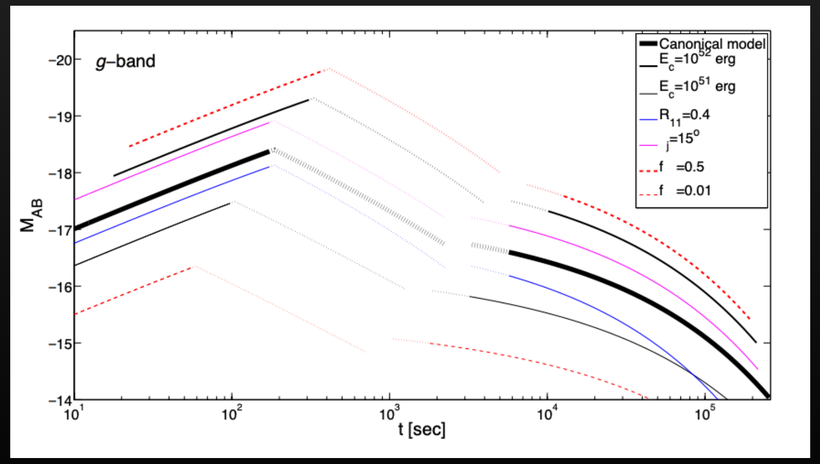
The jet cocoon

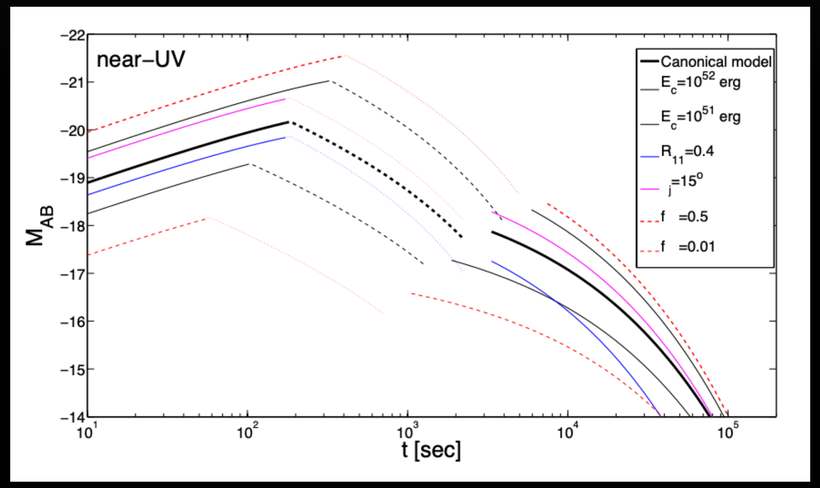




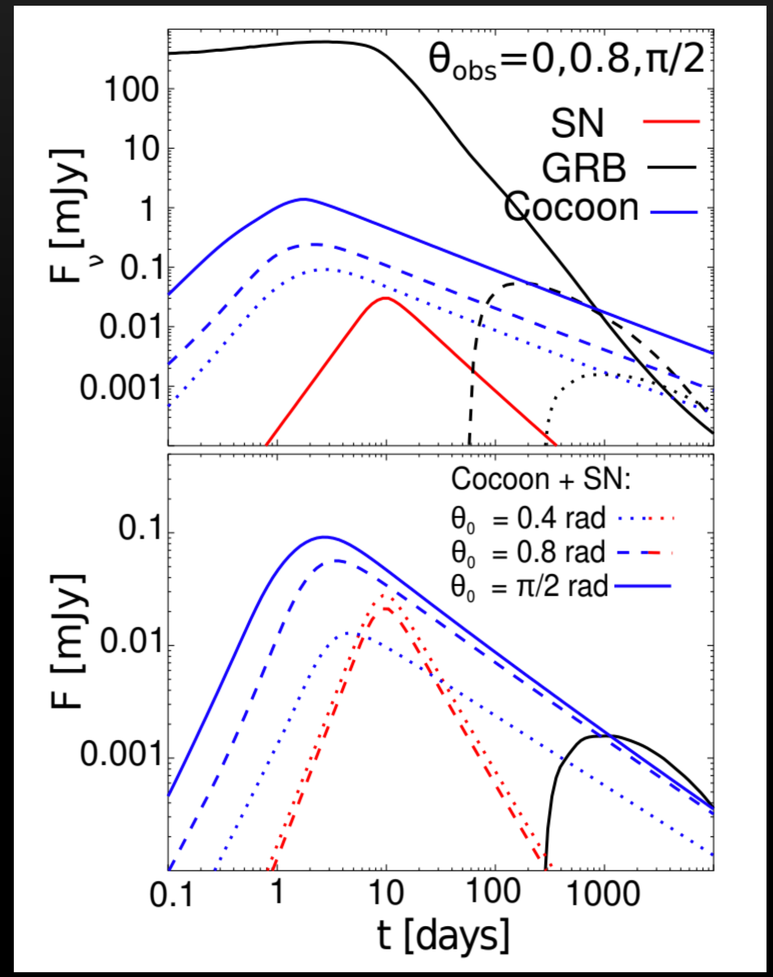
(Iwamoto+ 1999, LI+2019, Maeda+2023, Harrison+ 2017)

The jet cocoon



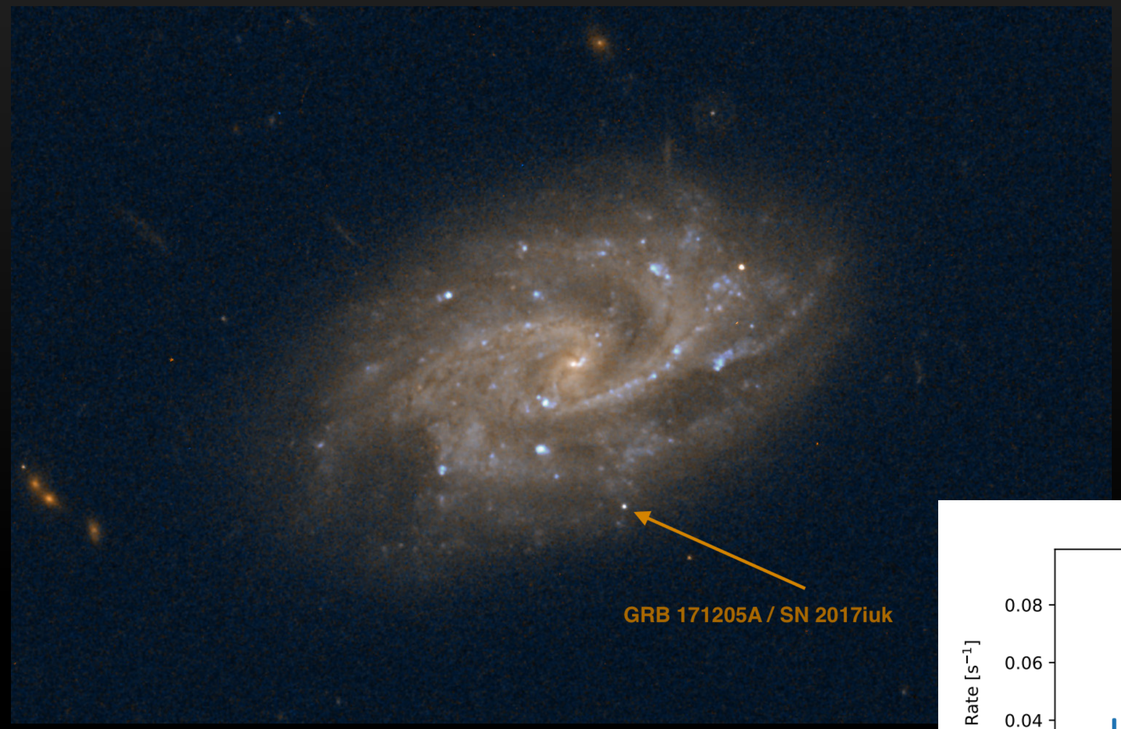


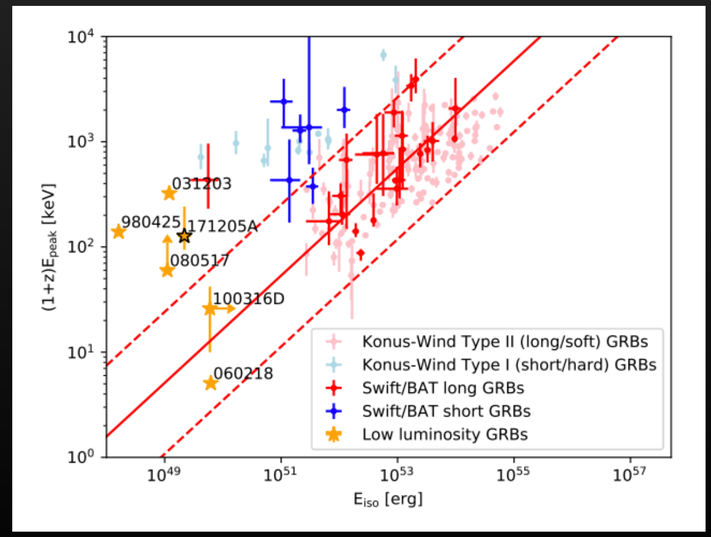
(Nakar & Piran 2017, De Colle+ 2021)

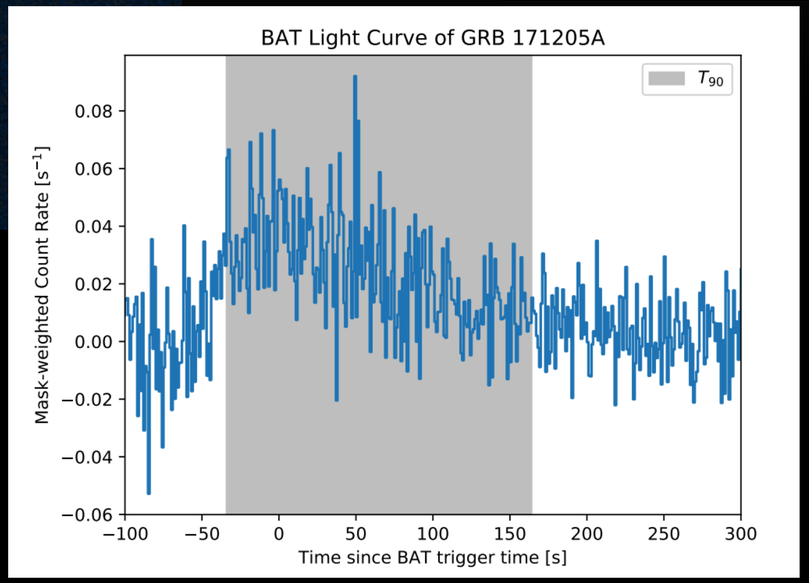


See also Chandra talk

GRB 171205A/SN 2017iuk







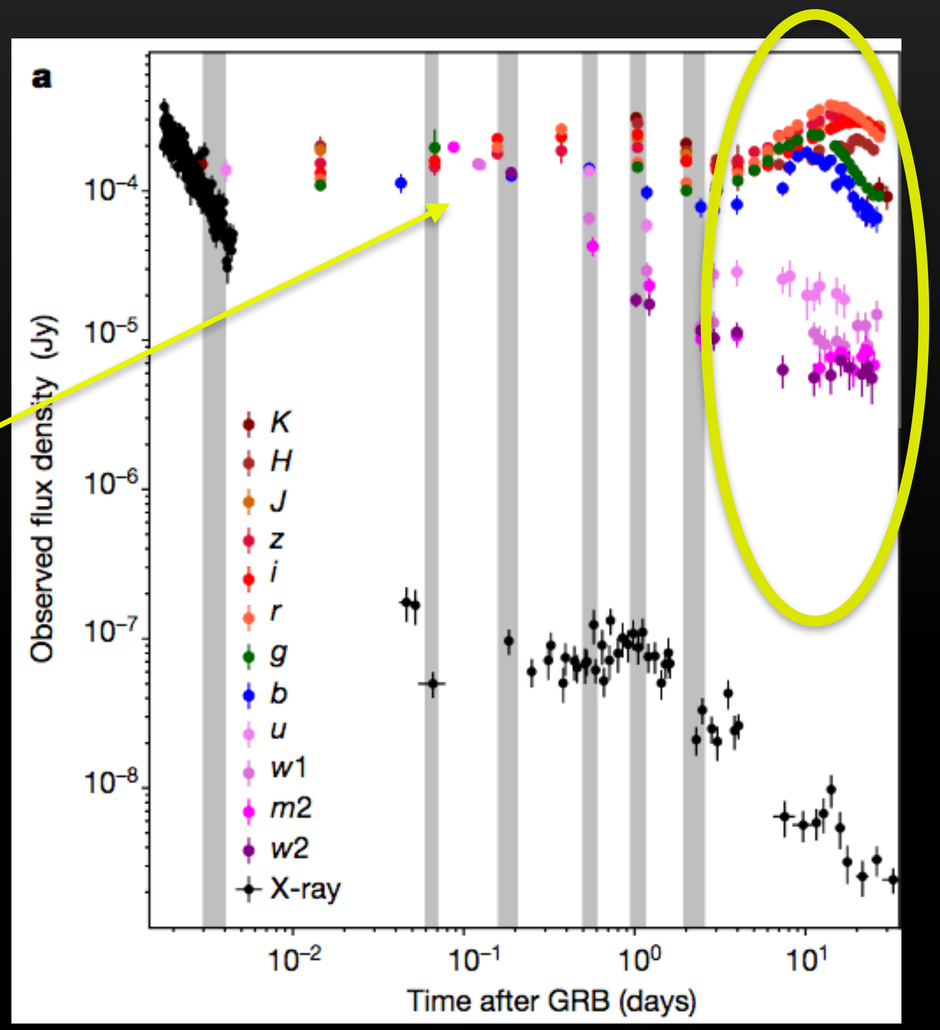
(LI+ 2019, D'Elia+ 2018)

GRB 171205A/SN 2017iuk

rapid decay in the X-ray afterglow emission

> very faint afterglow

anomalous behaviour in the first day at UV-optical freqs



multi-wavelength photometric & spectroscopic campaign (Swift, VLT, GTC, GROND, PST2, OSN, GOTO, ...)

(LI+ 2019)

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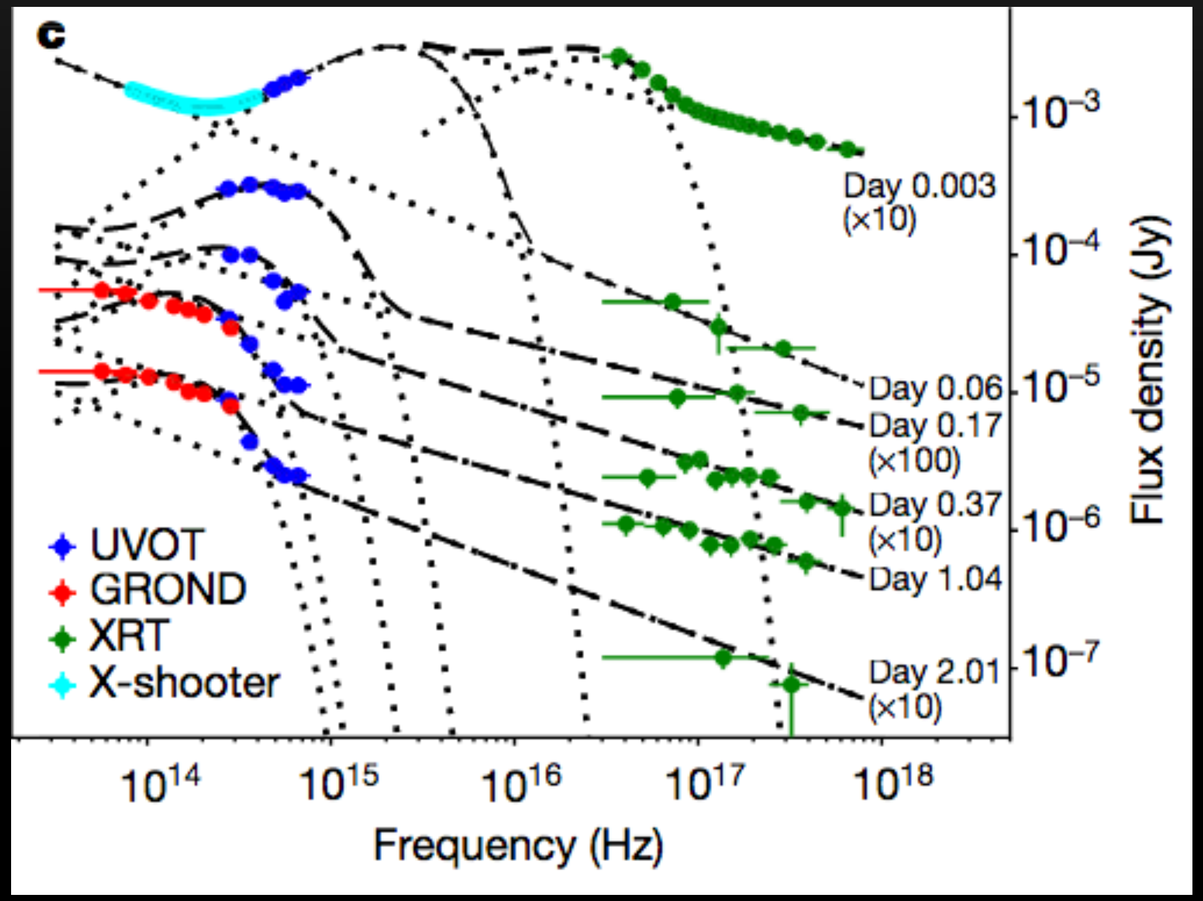
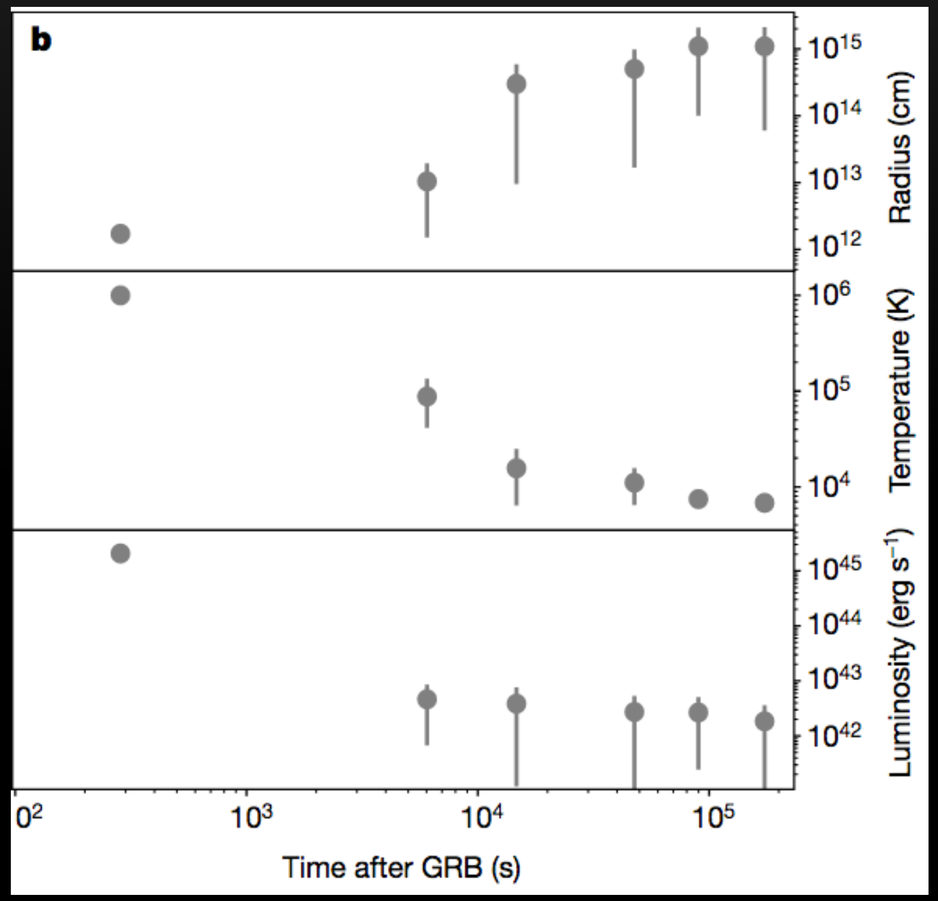
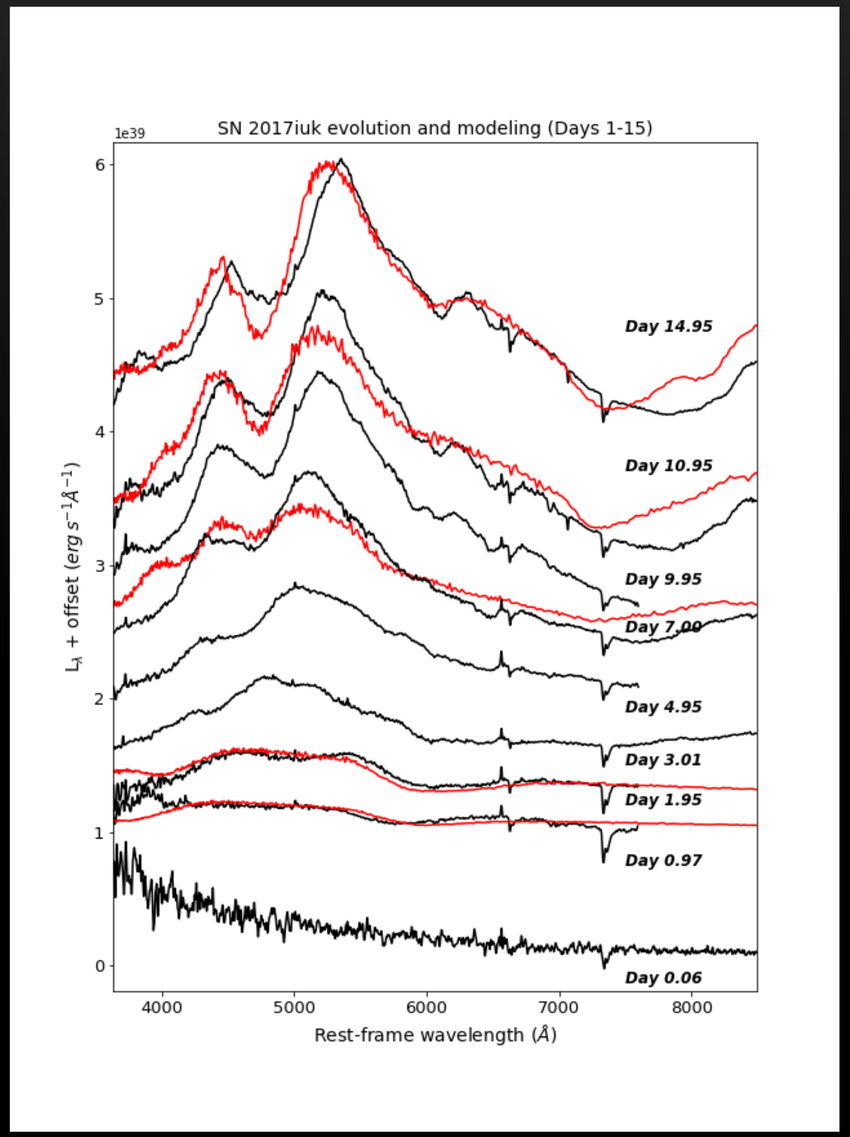
from near-IR to X-rays





GRB 171205A/SN 2017iuk

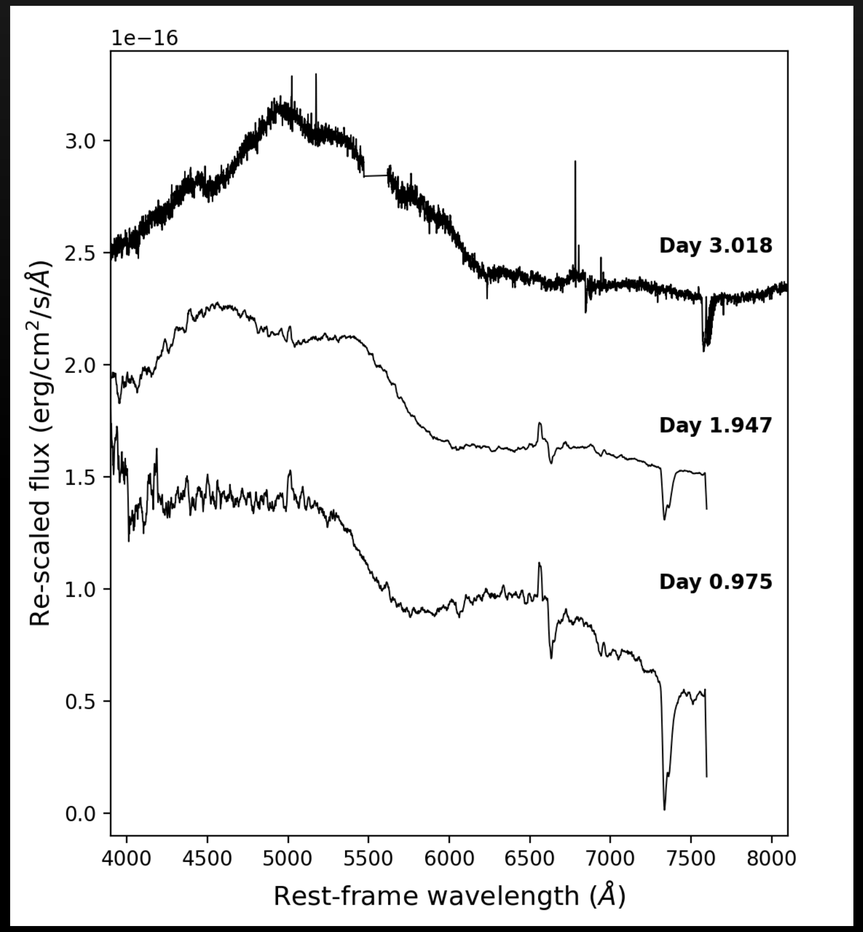


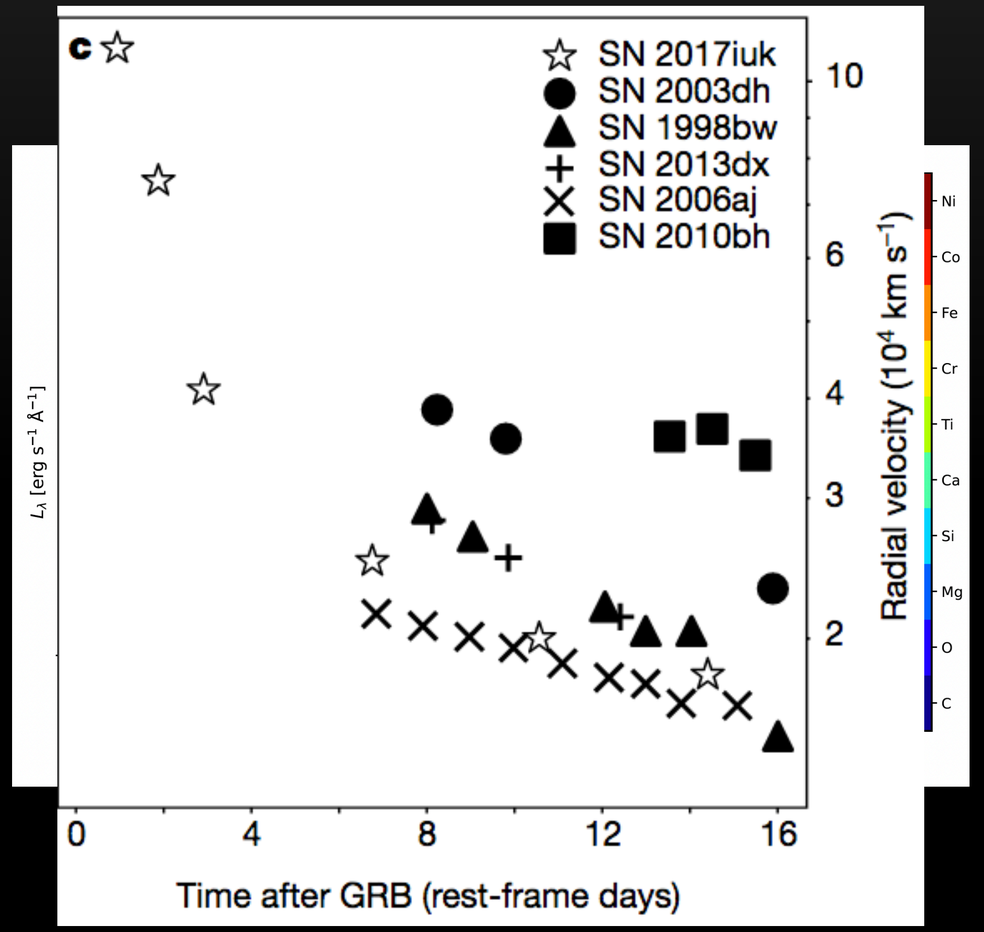
~Daily Spectroscopy monitoring

2017 12 05	0.0625	08:56:18	X-shooter	1x600
2017 12 06	0.975	06:44:42	OSIRIS	2x600
2017 12 07	1.947	06:05:03	OSIRIS	2x600
2017 12 09	3.018	07:46:23	X-shooter	2x400
2017 12 09	3.943	05:58:28	OSIRIS	5x600
2017 12 10	4.954	06:14:12	OSIRIS	3x600
2017 12 12	7.005	07:24:06	X-shooter	2x400
2017 12 13	7.982	06:54:38	FORS	1x600
2017 12 14	8.905	05:03:45	OSIRIS	3x600
2017 12 15	9.947	06:05:03	OSIRIS	3x600
2017 12 16	10.952	06:11:45	OSIRIS	2x400+2x400
2017 12 18	12.973	06:41:08	OSIRIS	2x300+2x600
2017 12 20	14.936	05:48:39	OSIRIS	2x300+2x500

GRB 171205A/SN 2017iuk

Very early spectra - modeling





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Spectral synthesis model (TARDIS code)

TARDIS !
Exploring supernovae made easy

- CO138 model (1998bw)

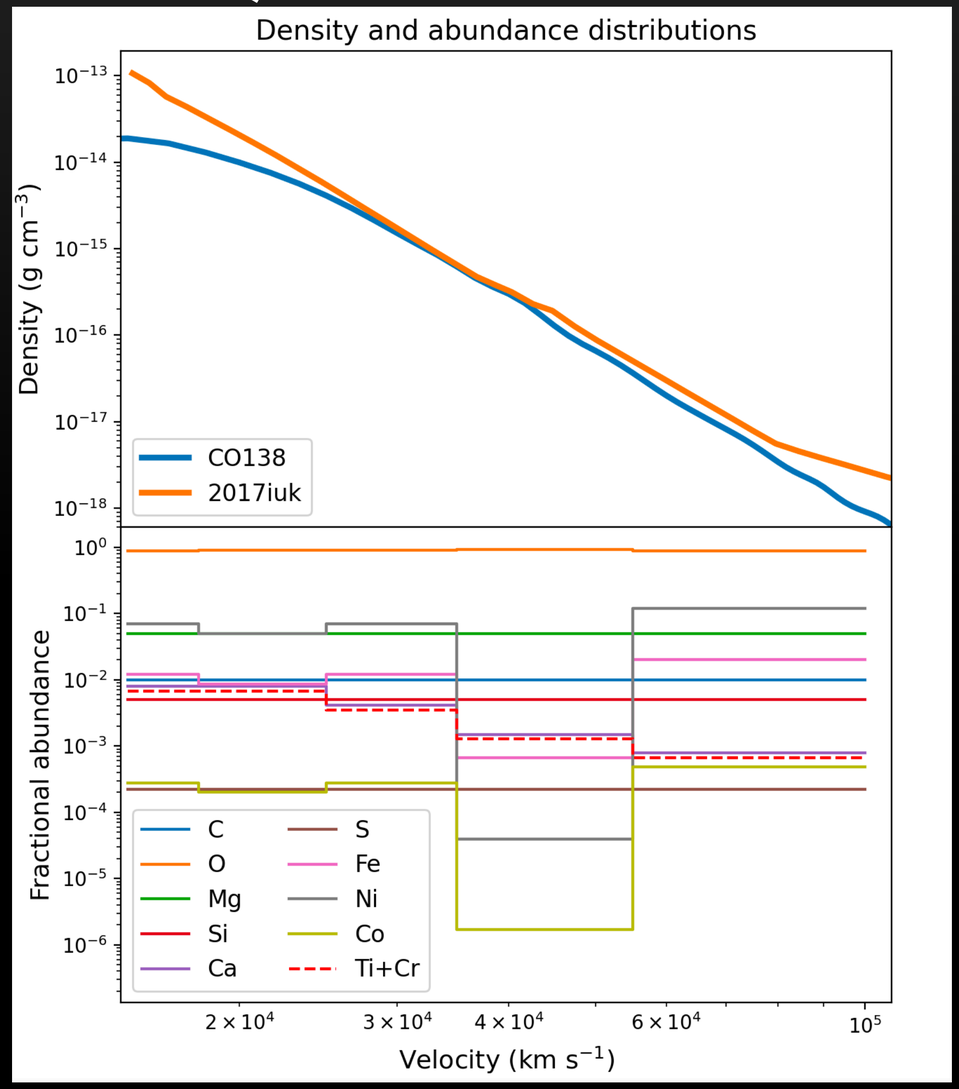
+

- flat distribution at high velocities

M_{cocoon} ~ 0.13 MSun — E_{kin} ~ 10^{52} erg

M_{ejecta} ~ 2.9 MSun

(Kerzendorf & Sim 2014, Iwamoto+ 1998, Maeda+ 2002, LI+ 2019)

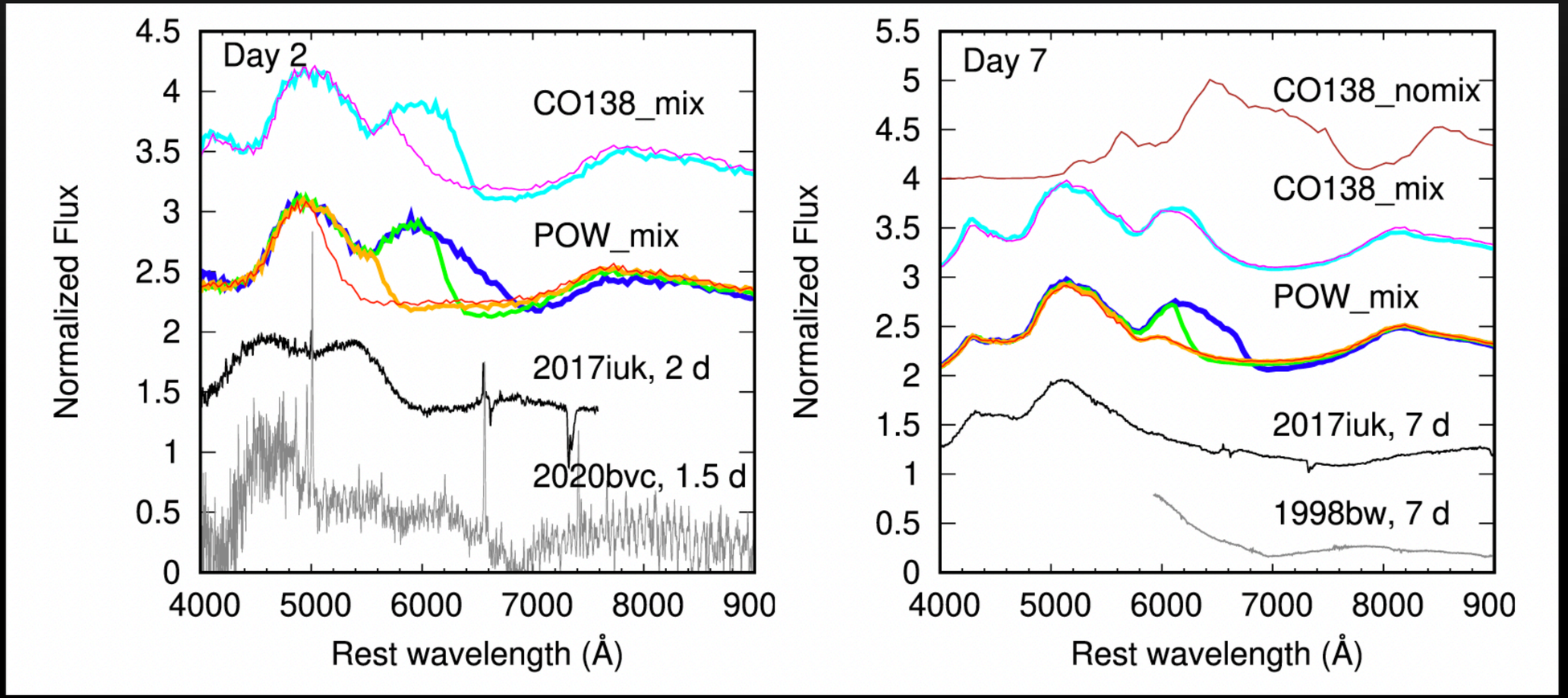


GRB 171205A/SN 2017iuk

Check with other density model configurations

80,000 km/s
100,000 km/s

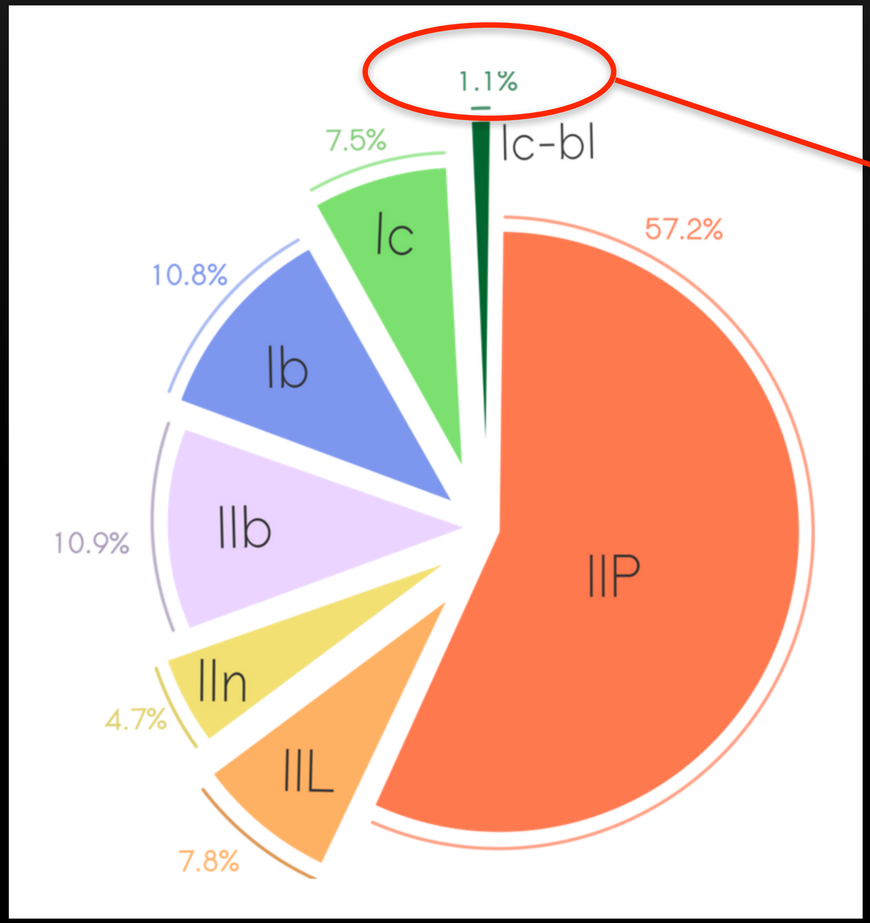
60,000 km/s
80,000 km/s
100,000 km/s
120,000 km/s



(Maeda+ 2023)

Ic BL SNe w/o GRBs

Relative number of CC-SNe



~10% of Ic-BL SNe are "apparently" associated with a GRB

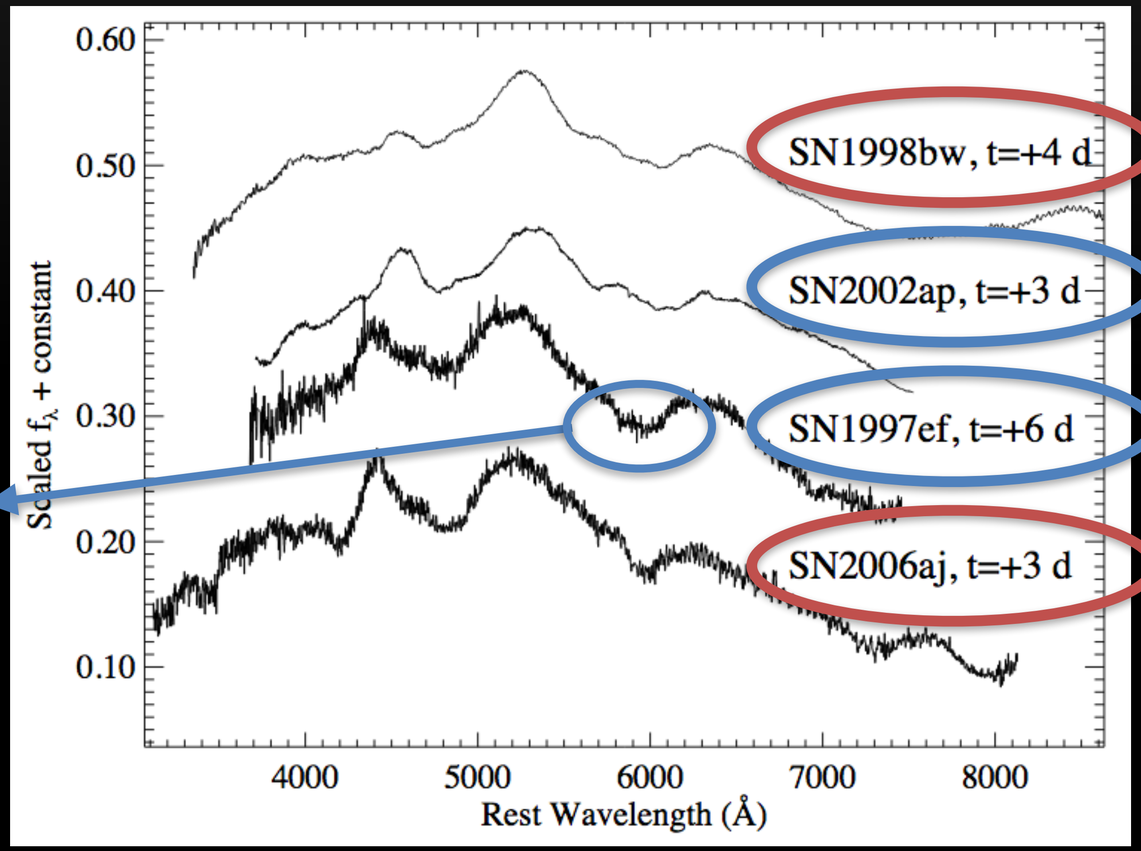
What about the remaining 90%?

(courtesy Stevance)

Ic BL SNe w/o GRBs

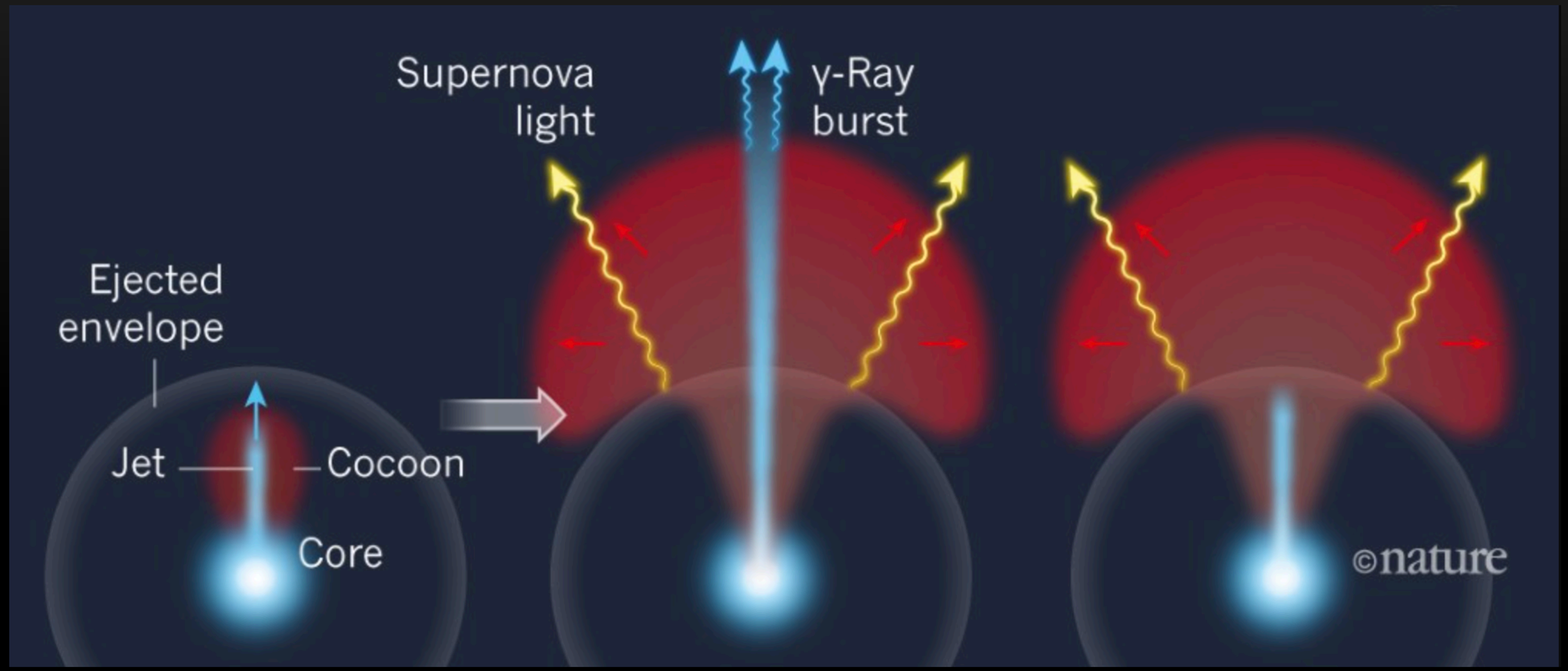
GRB-SN are Ic-BL SNe, but not all type Ic-BL SNe are associated with a GRB => no relativistic jet emission

V_{ej} ~ 25,000 kms



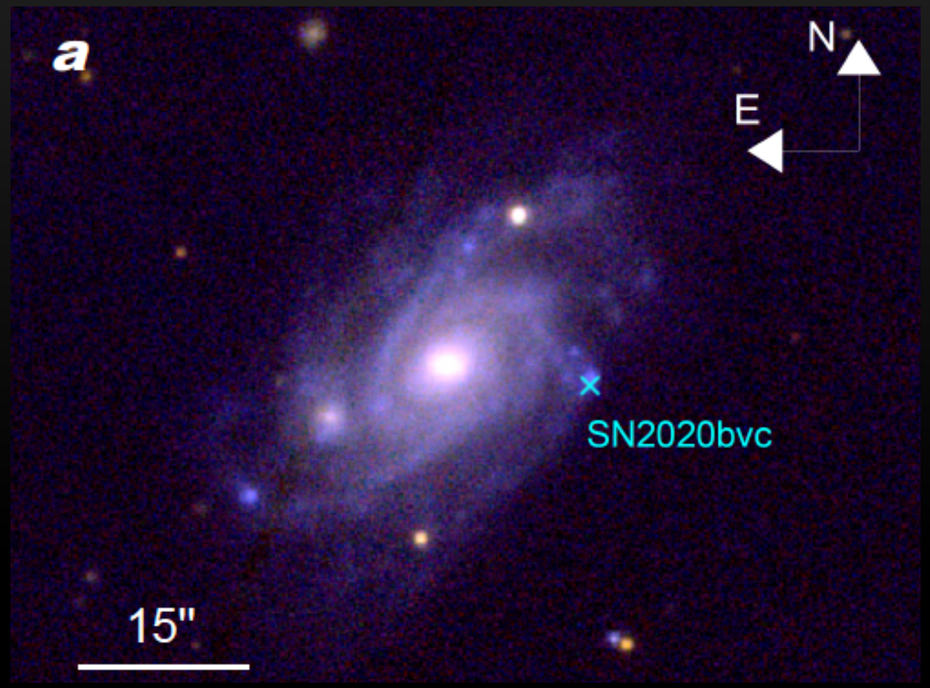
(Mazzali+ 2000)

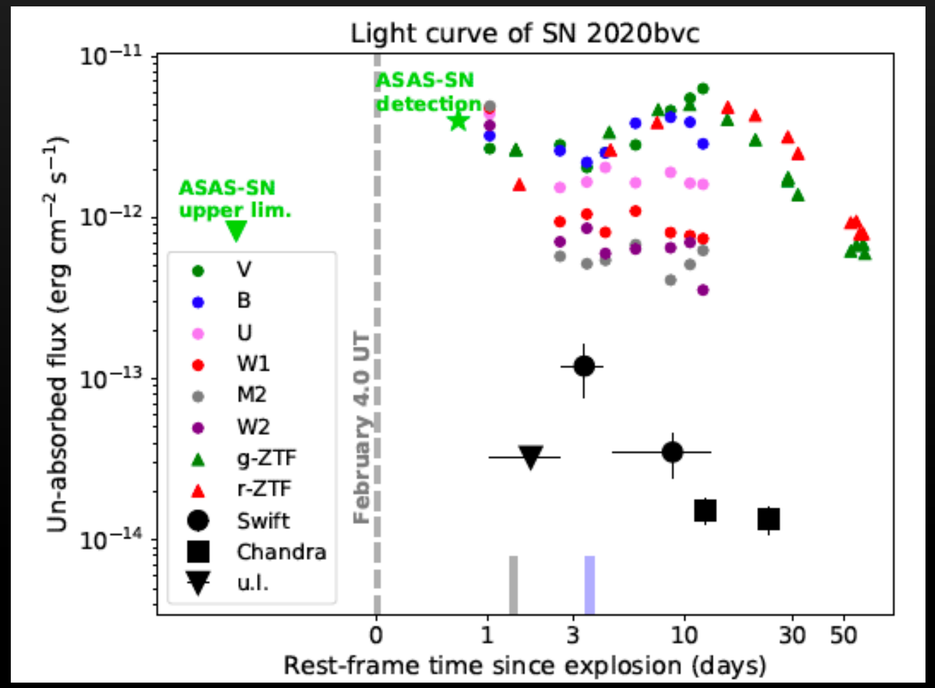
Ic BL SNe w/o GRBs



(Nakar 2019)

SN 2020bvc

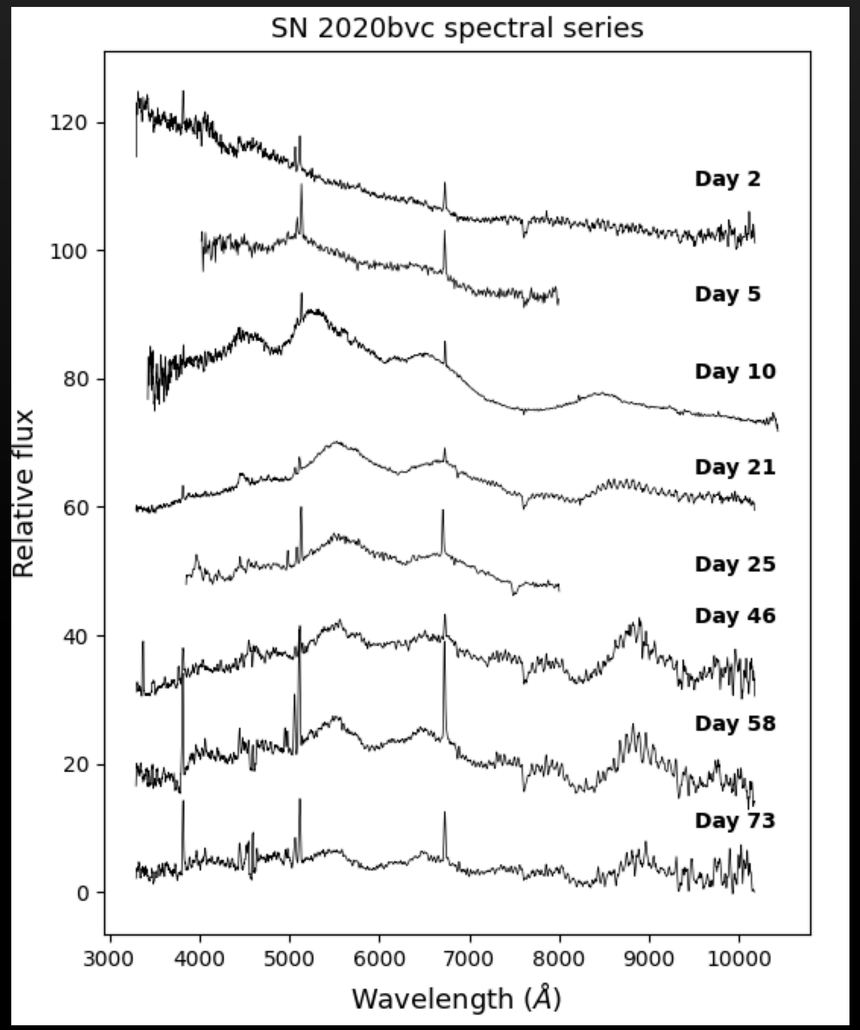


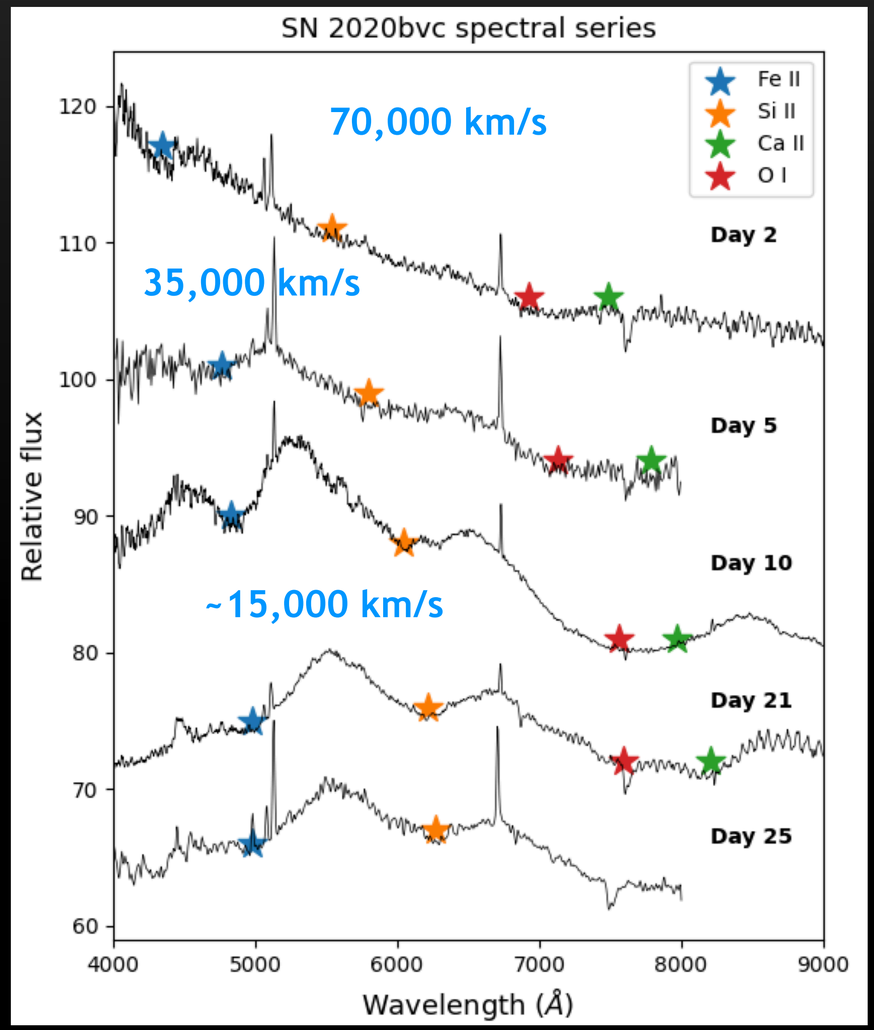


type-Ic BL SN @ z = 0.025235

(LI+ 2020, Ho+ 2020)

SN 2020bvc





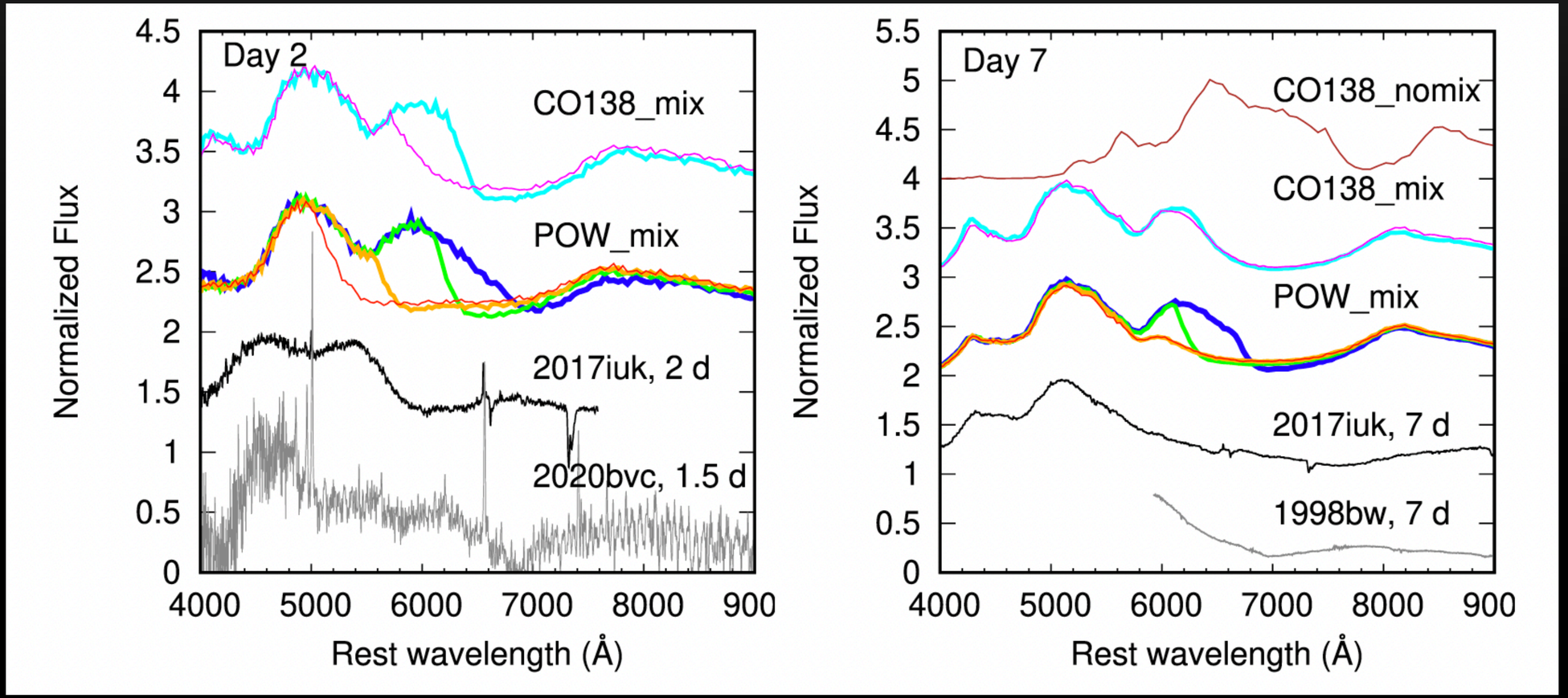
(TBS)

SN 2020bvc

Check again with density model configurations

80,000 km/s
100,000 km/s

60,000 km/s
80,000 km/s
100,000 km/s
120,000 km/s



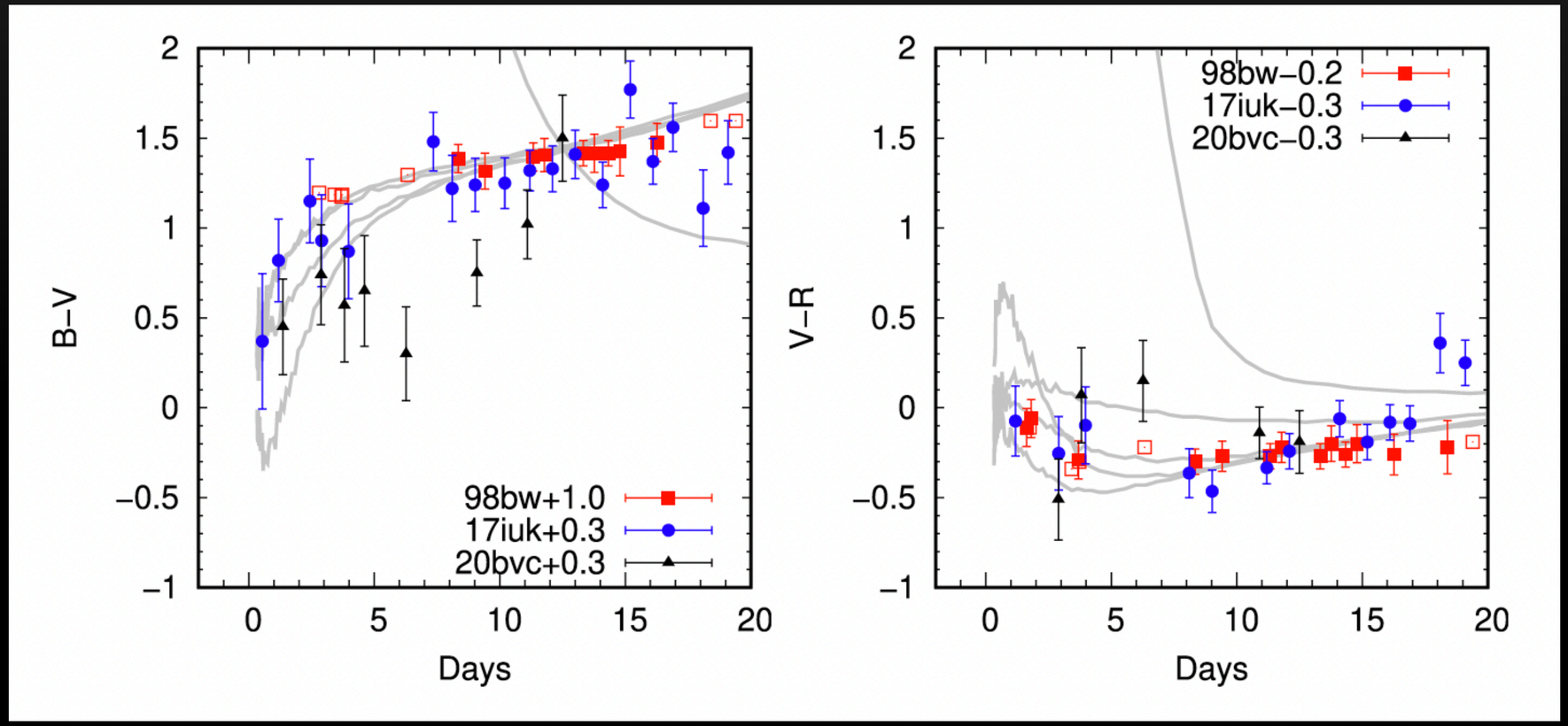
(Maeda+ 2023)

GRB 171205A/SN 2017iuk

Photometric behavior

80,000 km/s
100,000 km/s

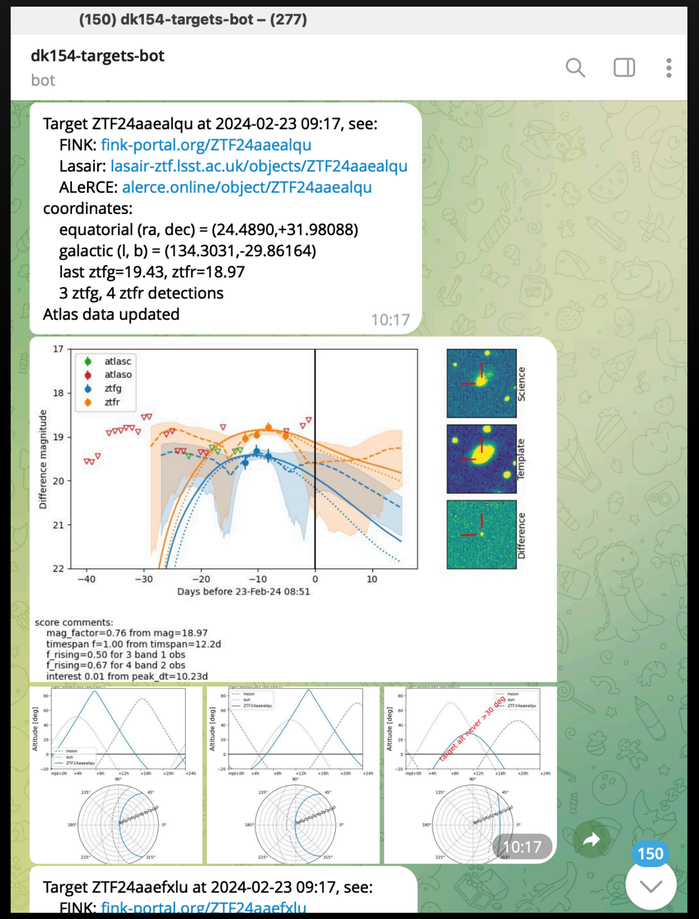
60,000 km/s
80,000 km/s
100,000 km/s
120,000 km/s



(Maeda+ 2023)

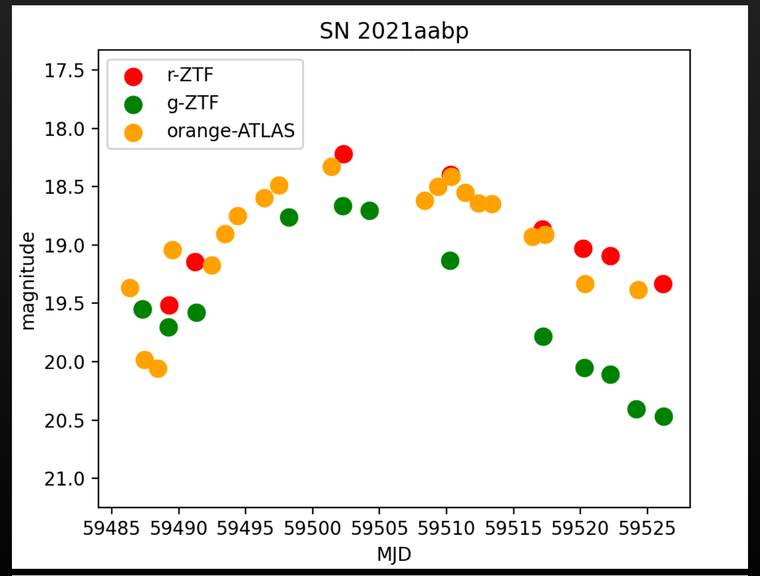
Photometric candidates

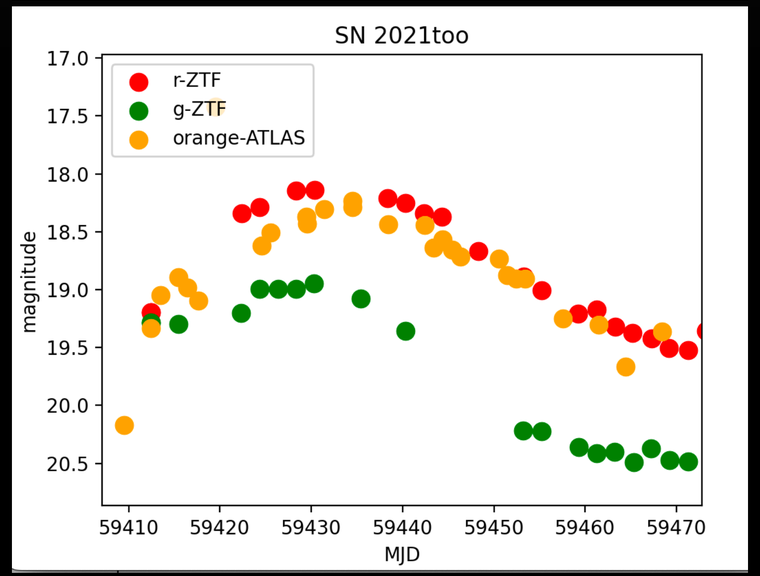
Automatic procedure for the ID of candidates



Early color evolution from brokers

Immediate activation of spec facilities (DK154, SOXS, NOT, etc.)





Summary

Jet-driven SNe give rise to jet-cocoon stellar shocked emission @ UV-optical

High-velocity broad absorptions in very early spectra

Synthesis modeling points out to:
- flat, high densities at $v_{exp} > 50{,}000$ km/s
- enhanced IME and Fe-peak abundances due to shock nucleosynthesis

GRB-less Ic-BL SNe could be engine-driven choked-jet explosions

Smoking gun: neutrinos? GWs? High-energy?

Thanks!