# Supernovae with Tomo-e Gozen

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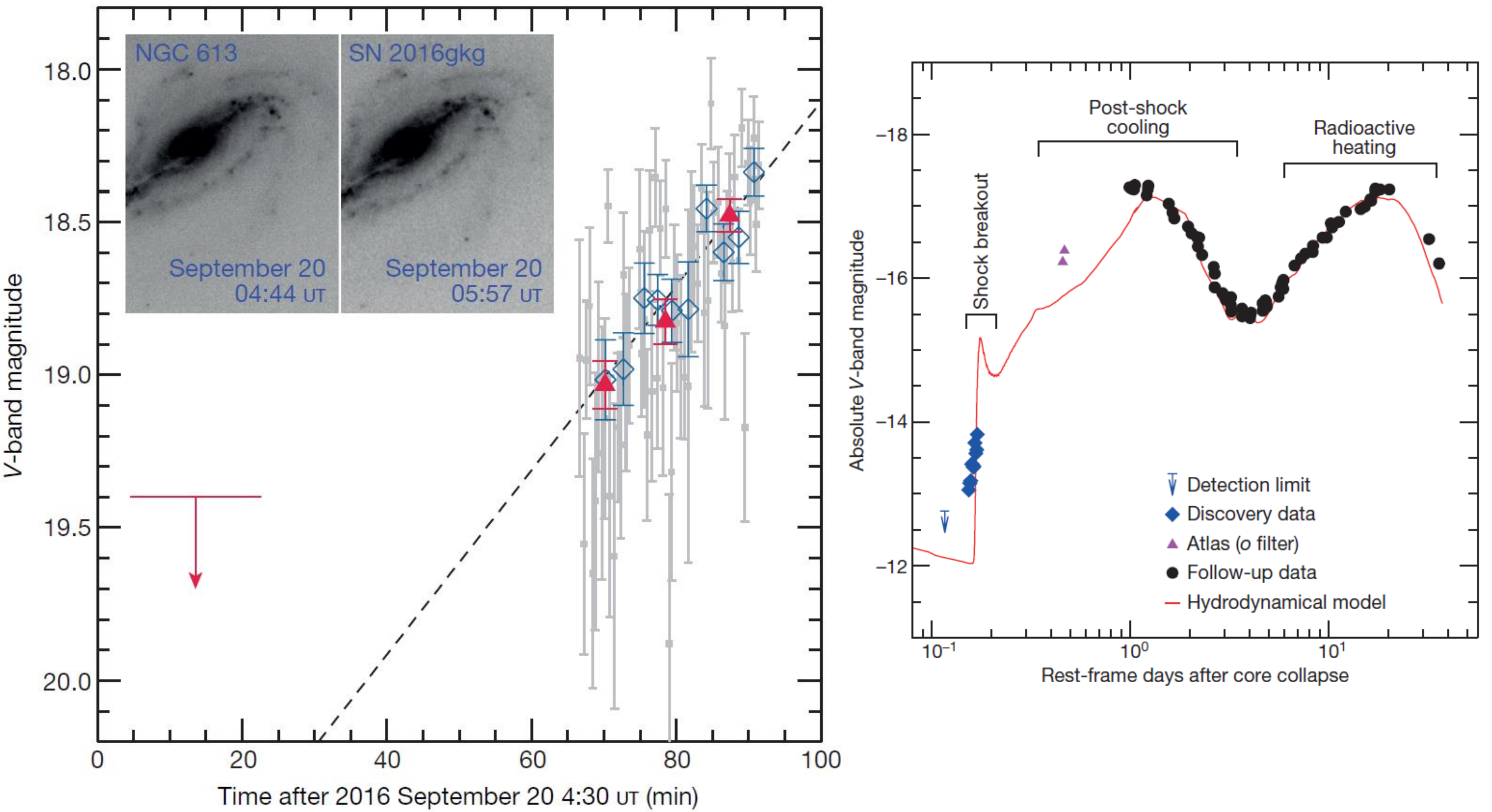
木曽シュミットシンポジウム2018

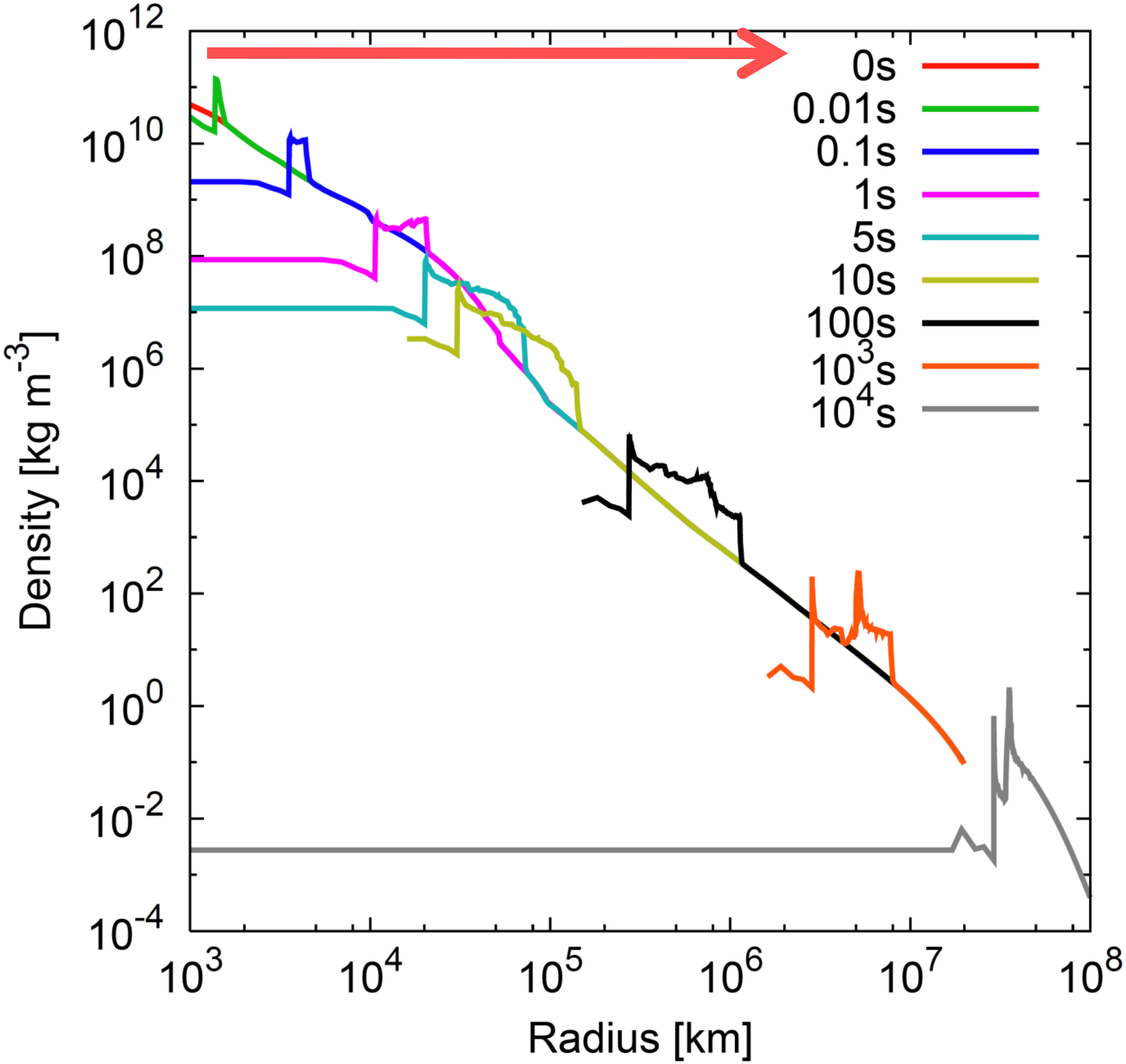
# Supernovae with Tomo-e Gozen

# SN IIb 2016gkg – shock breakout –




Bersten+18

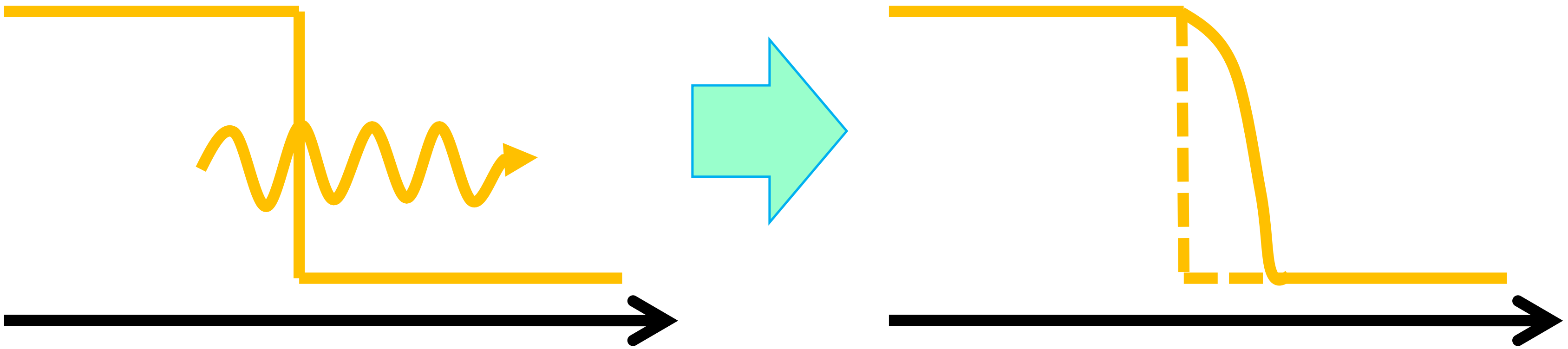
# What is the shock breakout?




Radiation dominate after the shock wave and radiation are fully coupled with matter.

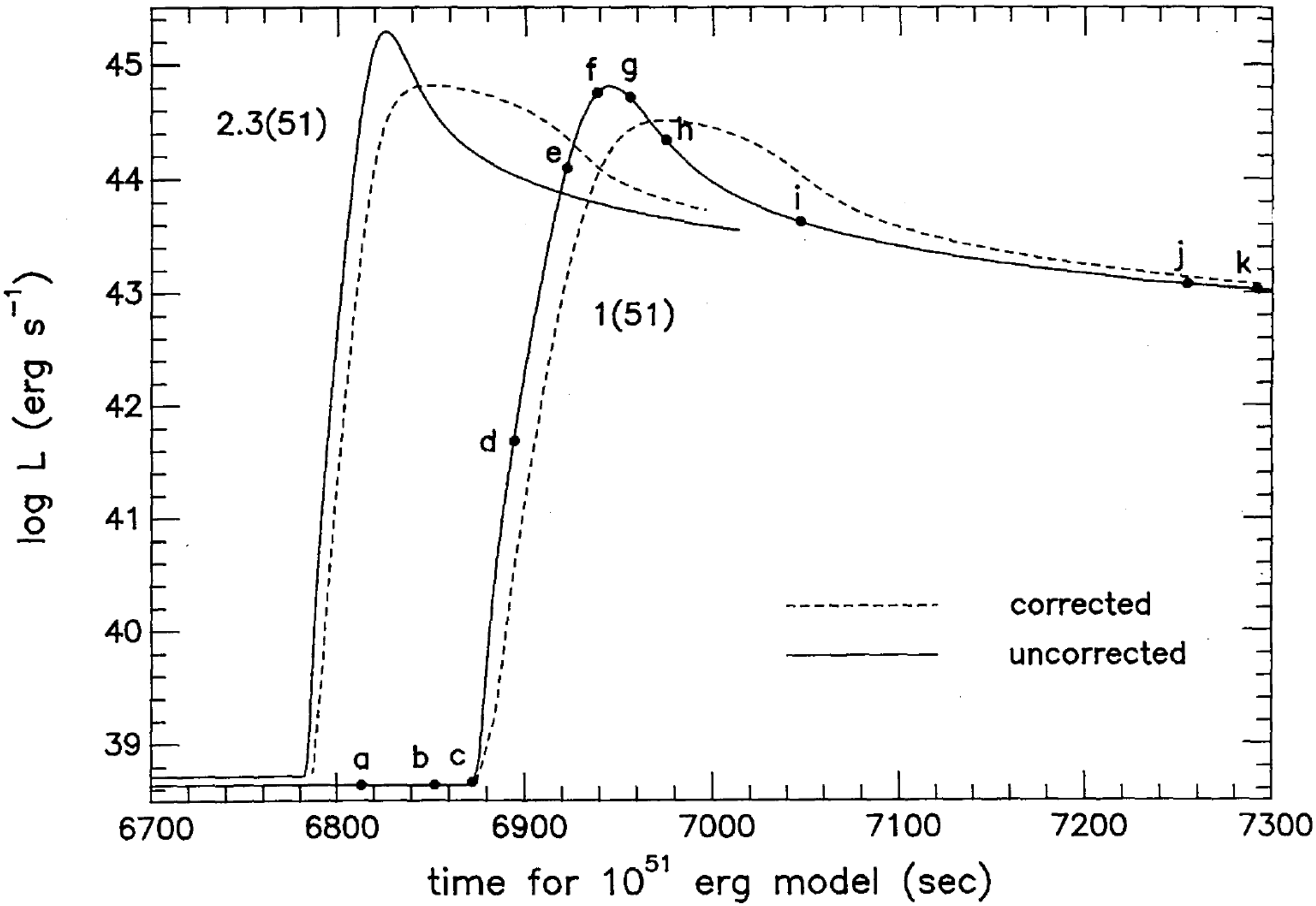
# When the shock wave approaches the stellar surface,

- Shock velocity: $v_{sh}$
- Diffusion velocity of radiation: $c/\tau$
- If $c/\tau > v_{sh}$ (typically, $\tau < c/v_{sh} \sim 10$),

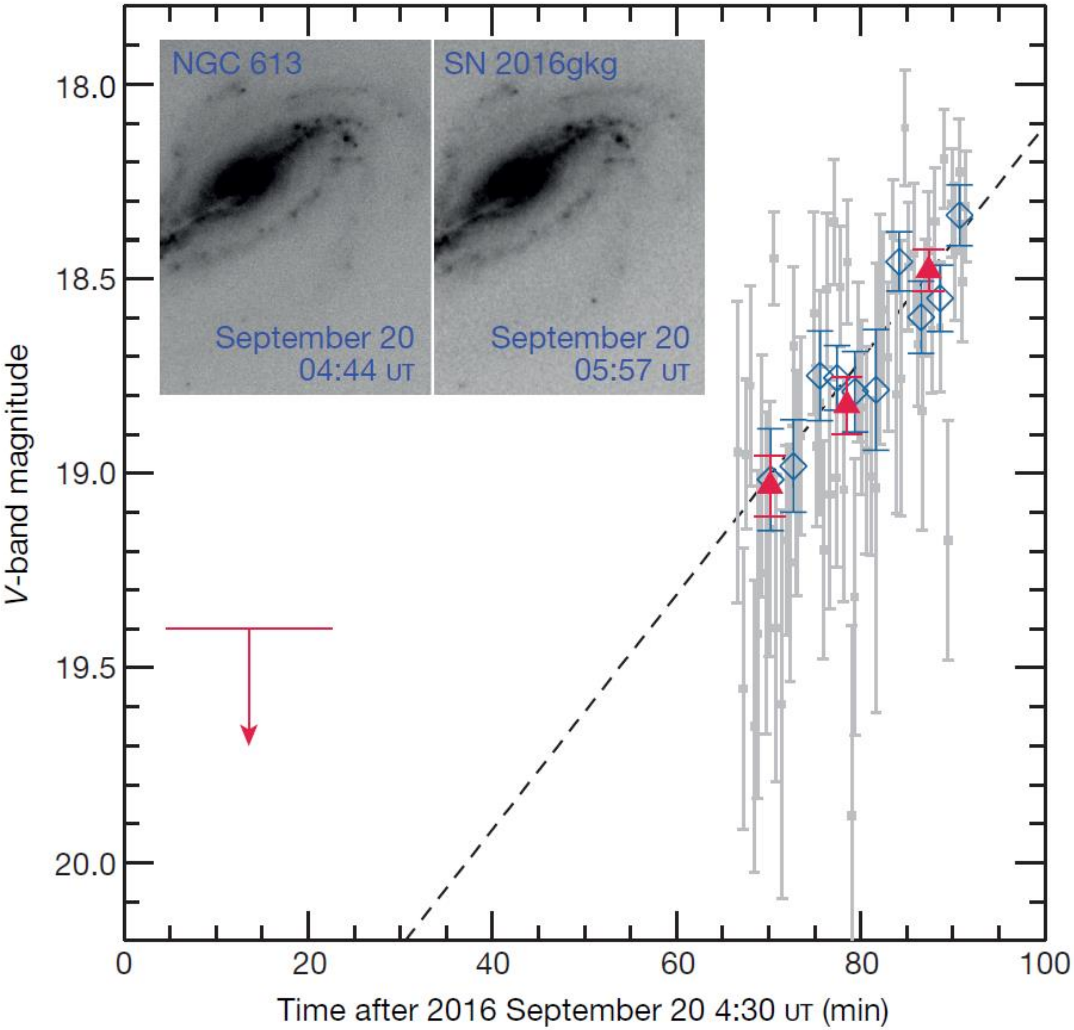


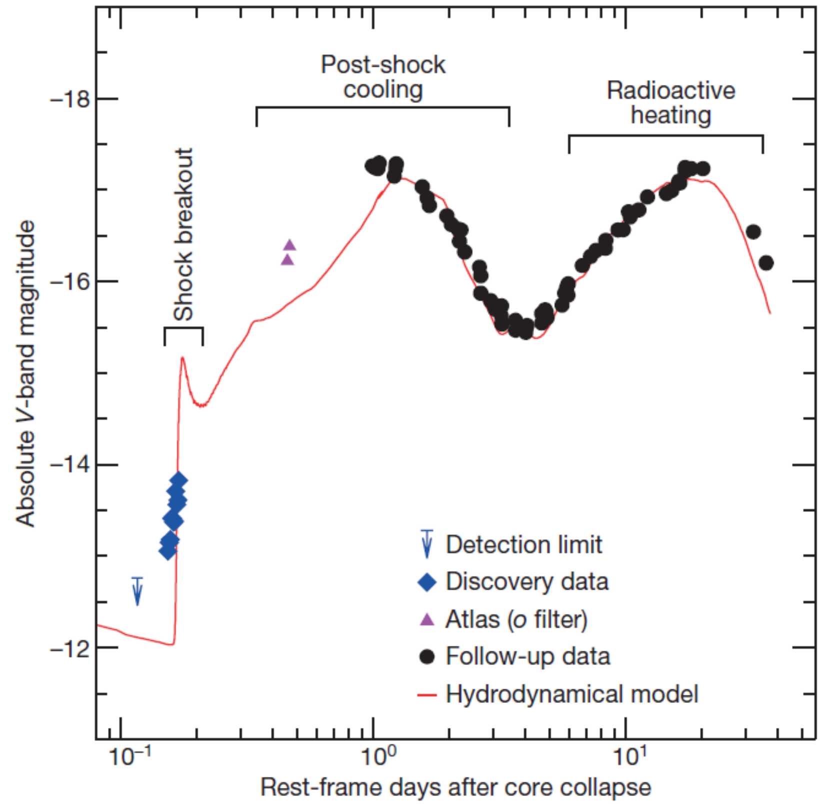
- Radiation partially affects matter and vice versa.
- Radiation hydrodynamics and >=2 temperatures are required.

# Shock Breakout
(Ensman & Burrows 92)



# SN IIb 2016gkg – shock breakout –

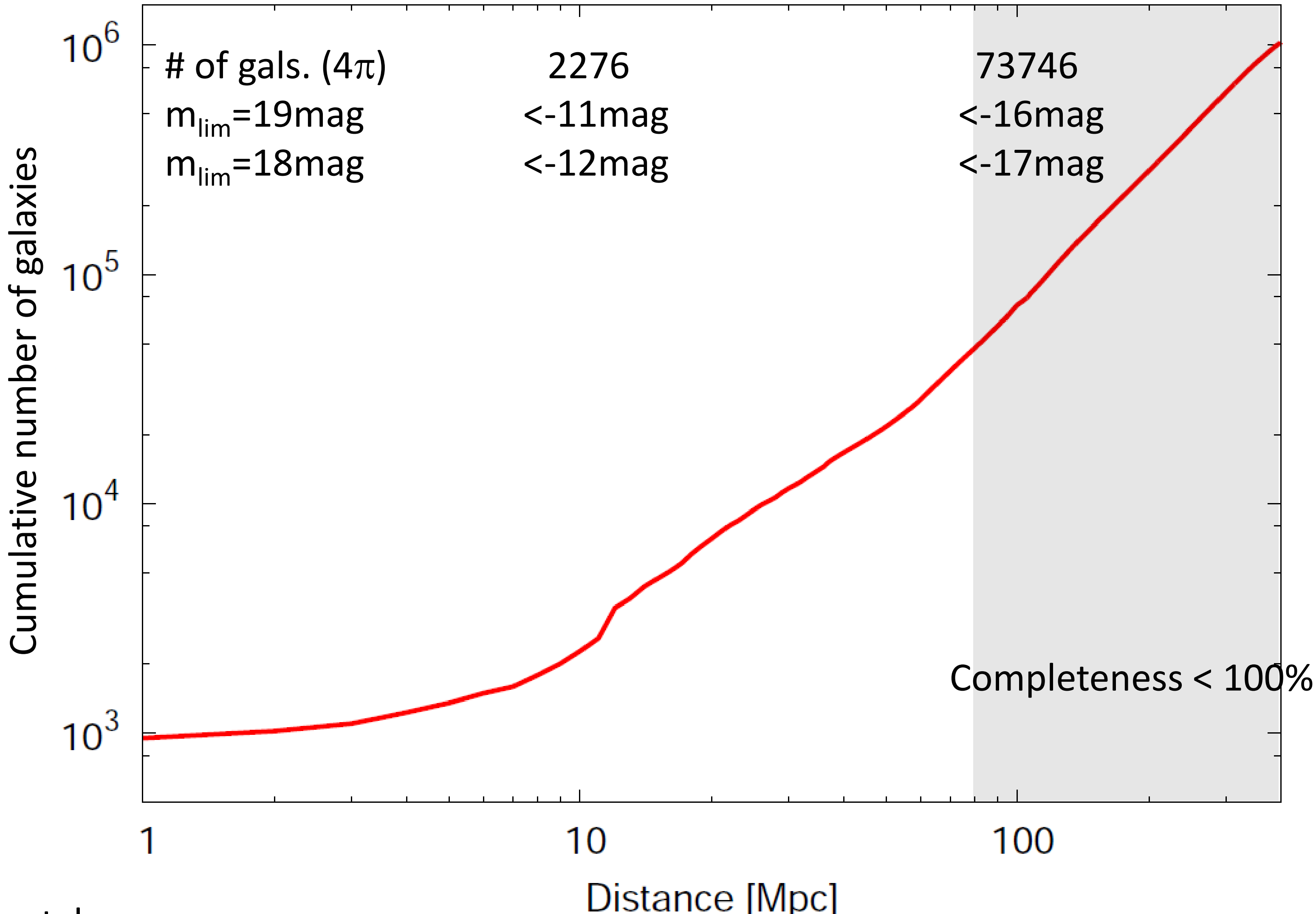



"The chance probability of this discovery is of the order of $10^{-6}$ assuming a duration of 1 h and one supernova per century per galaxy."

Bersten+18

# How many nearby galaxies?




GLADE catalog

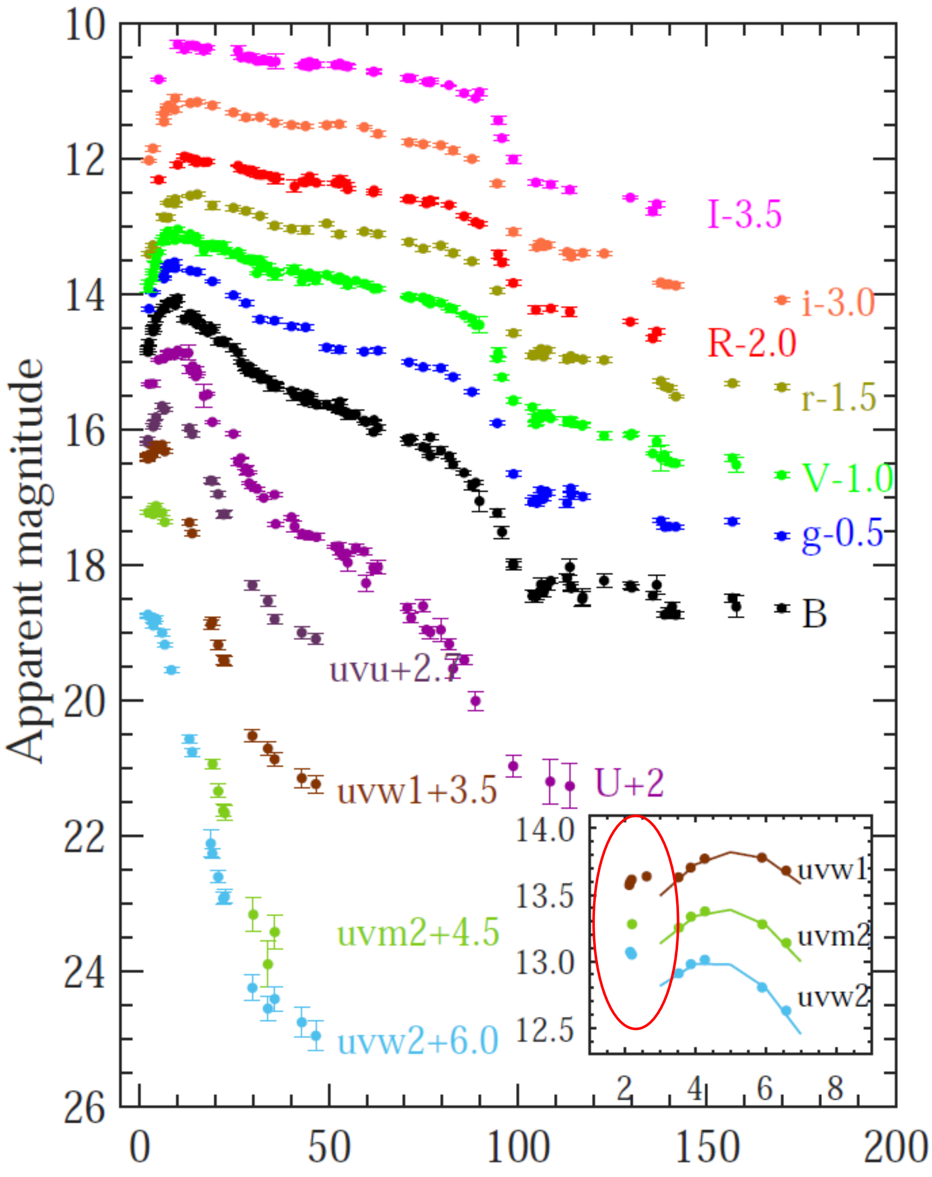
# Shock breakout of SN2016gkg
# $M_{peak}$~ -15mag, $\tau$~1hr

- 16723 galaxies at <40Mpc ($M_{peak}$)
- 9449 galaxies at <25Mpc ($M_{peak}$ + 1mag)
- Tomo-e can cover 5000deg$^2$/~3hr (1/8 of all sky)

- 2000 (1200) galaxies at <40 (25)Mpc/~3hr
- $10^6$ galaxies = 500 (850) times "~3hr observations"
- 170 (280) clear nights = ~2-3yrs

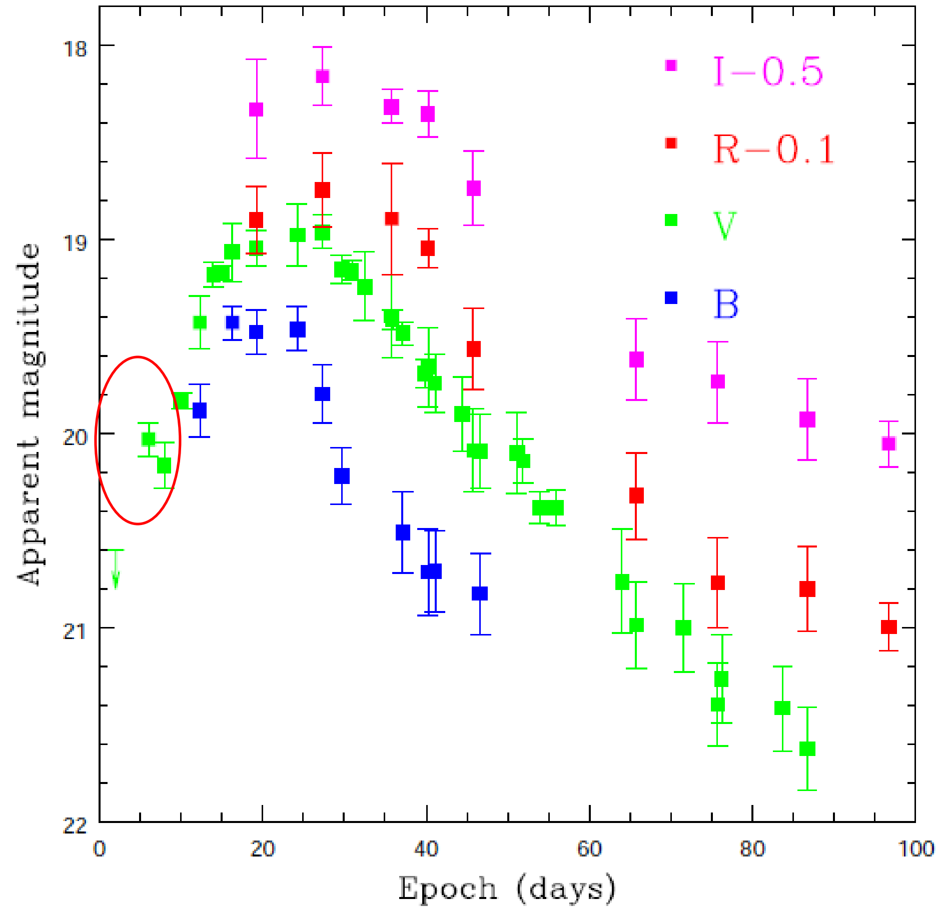
- But we cannot put 2 LC points during the shock breakout.

# Type IIP SN2016X




Huang+18

# Type Ic LSQ14efd

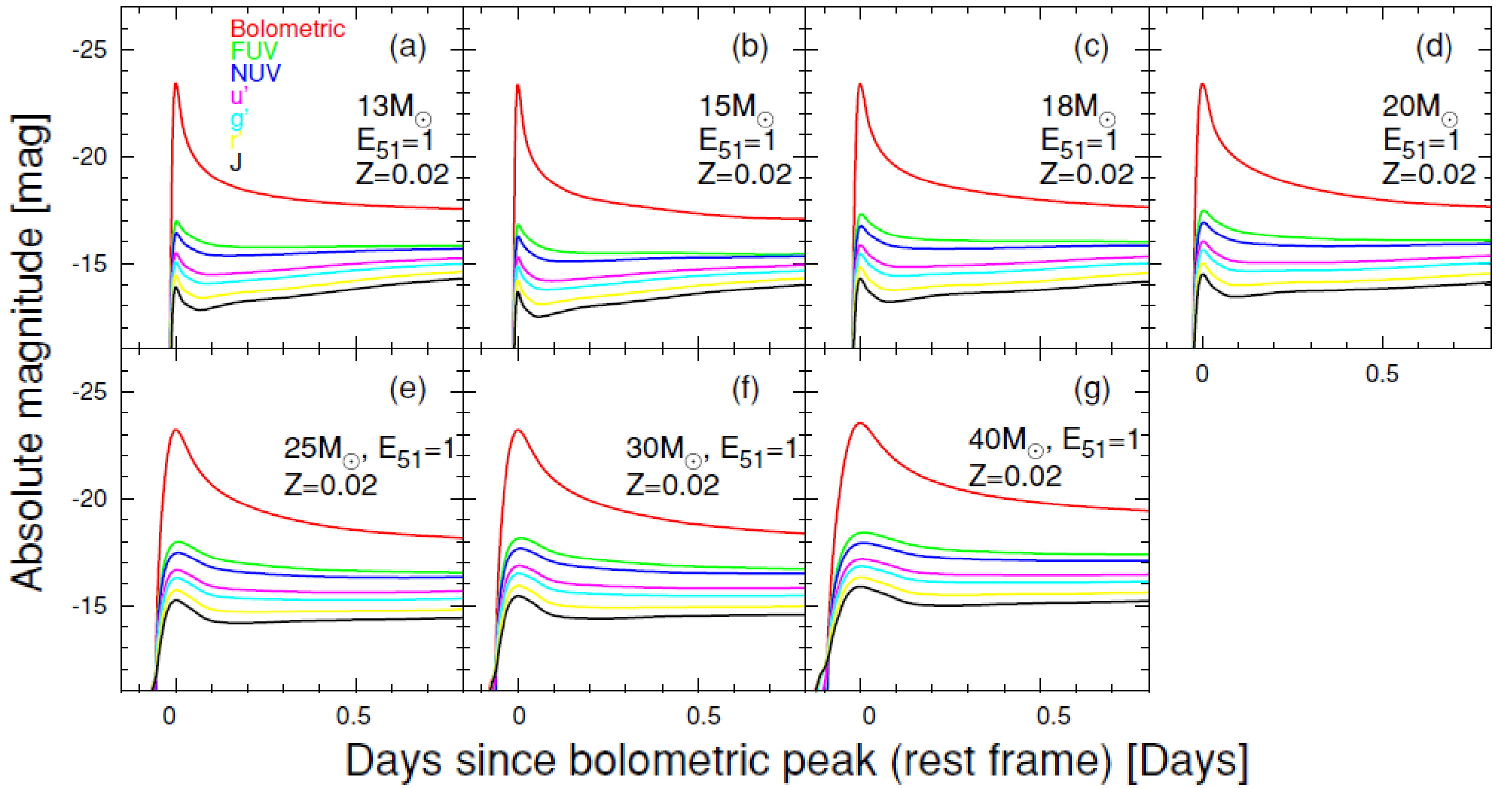



We may increase the cadence after we detect several SNe immediately after the explosion (Tomo-e SN survey II?).

Barbarino+17

# Shock breakout of Type IIP SNe

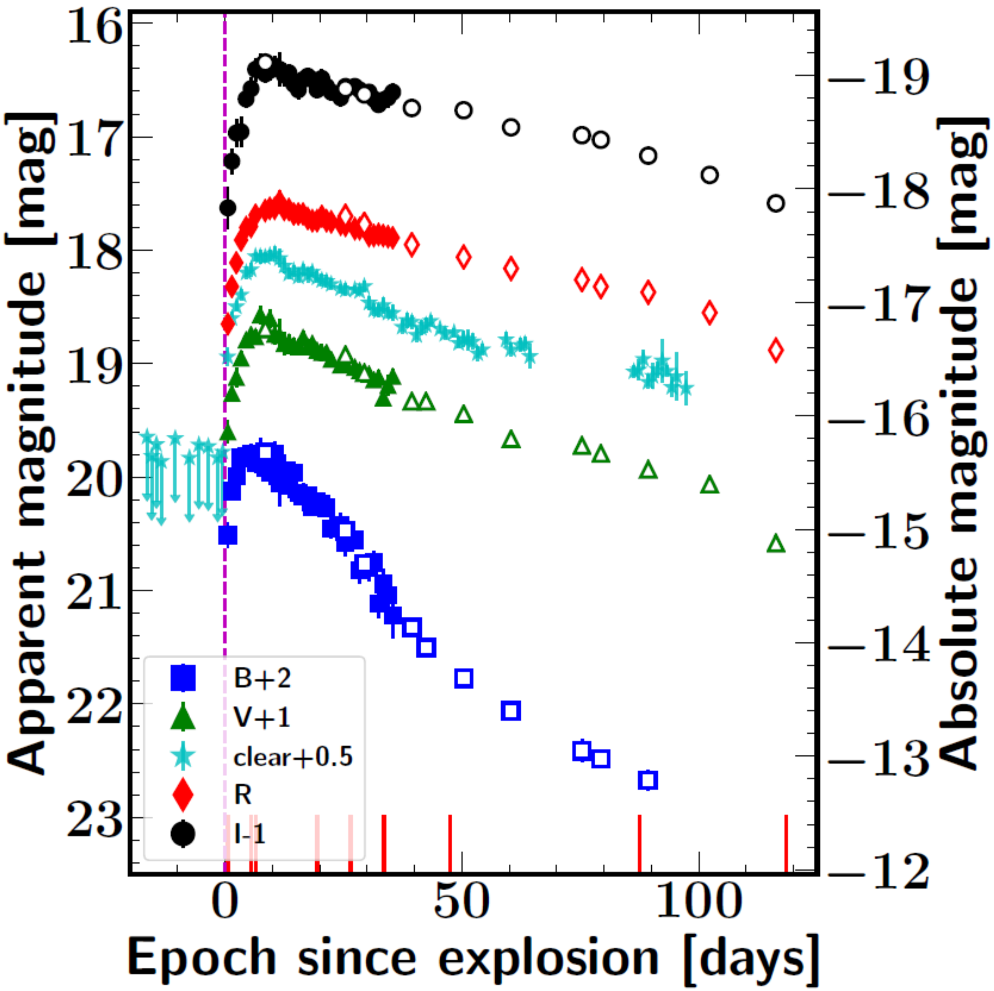
# $M_{peak}$~ -15- -16mag, τ~1-4hr

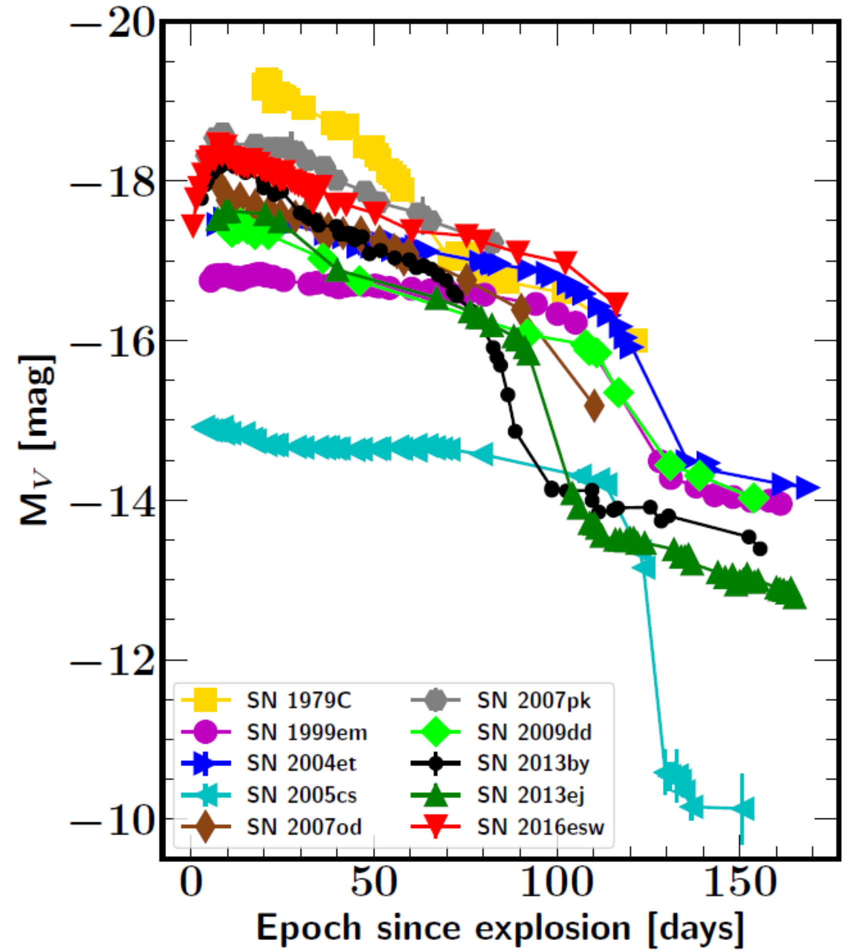



- It would be easier by a factor of several than SN2016gkg, in terms of brightness and duration.
- 1mag brighter (x2) and 4 times longer (x4)

# Type IIP SN 2016esw

## observed within the 1st day after the explosion




de Jaeger+18

# Rapid rise of Type IIP SNe $M_{peak}$~-17- -18mag, $\tau$~5days

- 436444 galaxies at <250Mpc ($m_{lim}$=19mag) but the GLADE catalog is incomplete

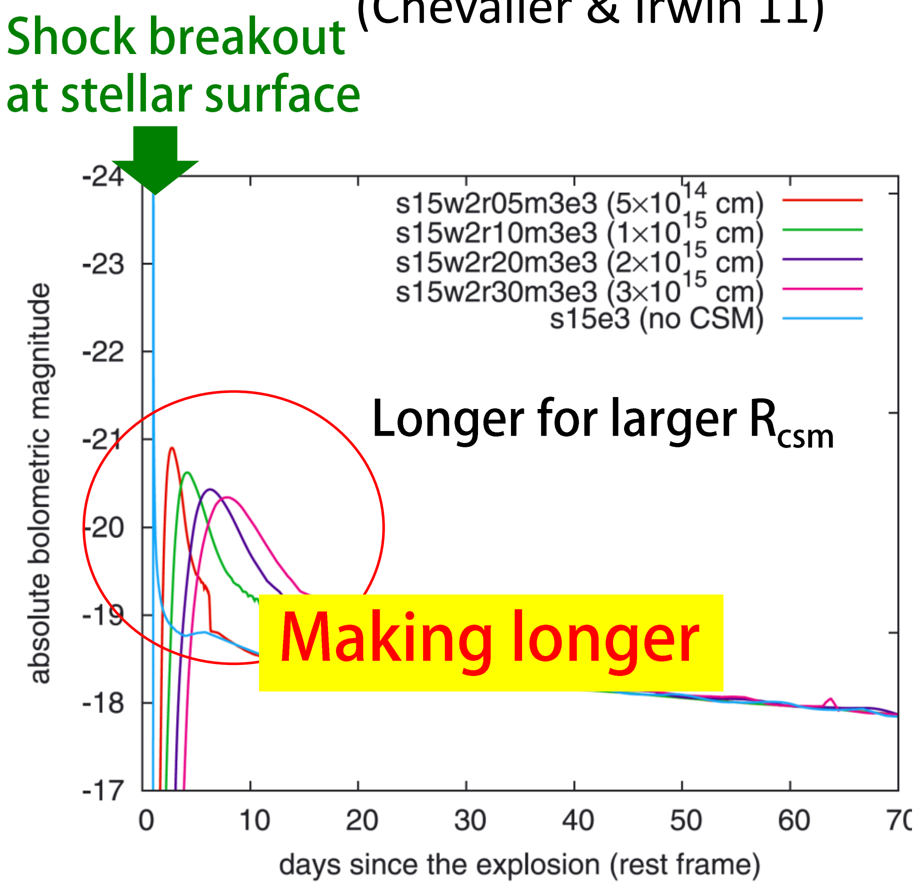
- Assuming $10^{-6}$SN/day/$Mpc^3$ and 10hr obs./day
  - 3SNe/night (V=8x$10^6$$Mpc^3$, $M_{peak}$)
  - 0.2SNe/night (V=5x$10^5$$Mpc^3$, $M_{peak}$+1mag)
  - 0.05SNe/night (V=1.4x$10^5$$Mpc^3$, $M_{peak}$+2mag)

- 1SNe with rapid rise over 2mag / 20 clear nights (~2months)

# Origin of rapid rising

- Wind shock breakout

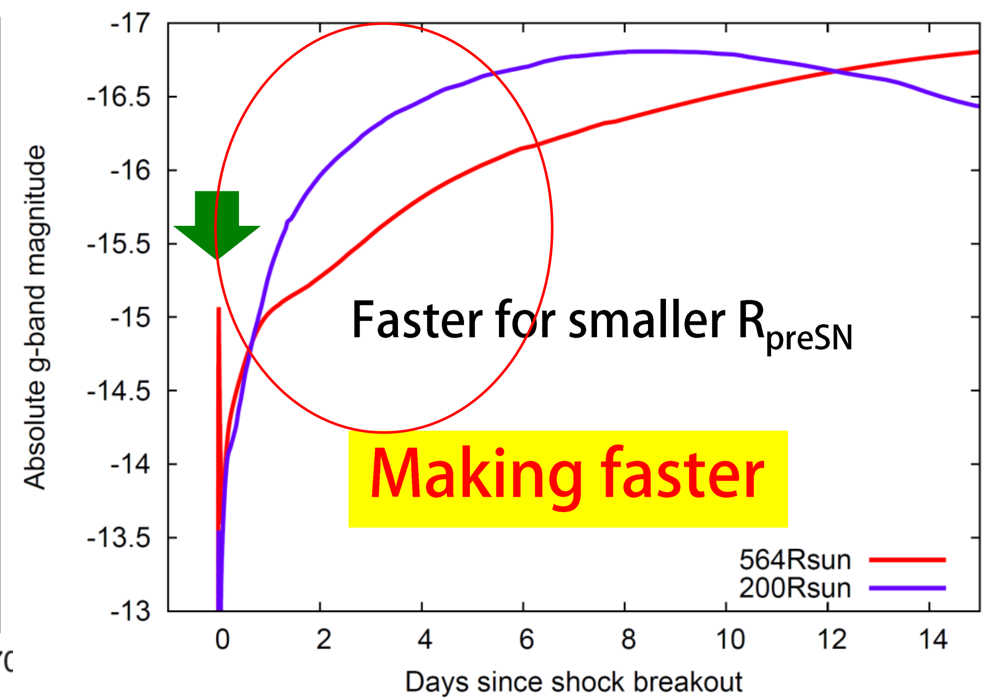
(Chevalier & Irwin 11)




Moriya, NT+11

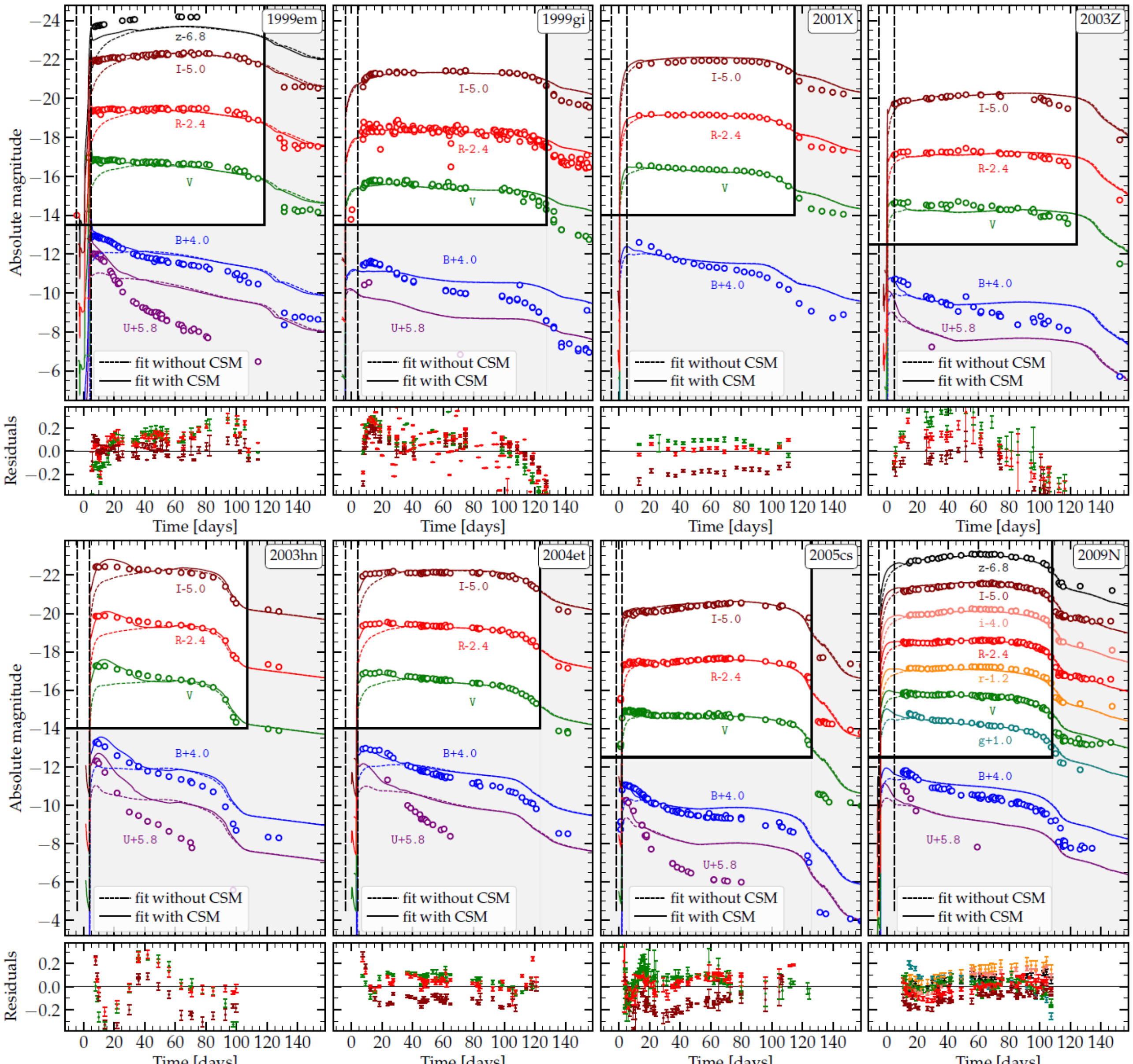
- Cooling envelope

(Nakar & Sari 10; Rabinak & Waxman 11; Shussman+16; Sapir & Waxman 16)




González-Gaitán, NT+15

# Wind shock breakout
# SN IIP with dense CSM



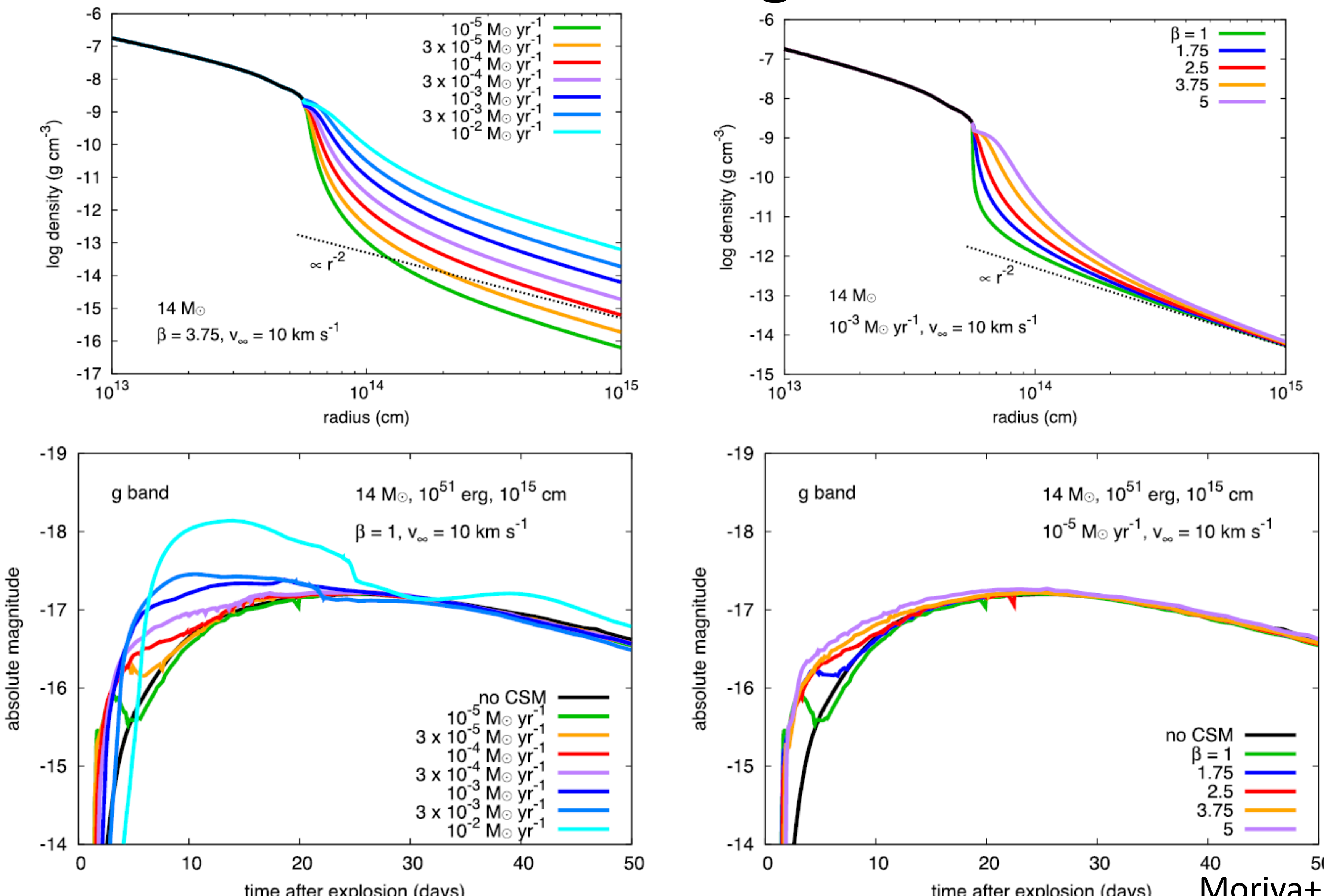

E = (0.1-1.3)x$10^{51}$ erg,
$M_{CSM}$ = 0.18-0.83$M_\odot$
for 70% of the SNe

SNe IIP with dense CSM will not have the shock breakouts at the stellar surface.

We may need to reduce the expected number of shock breakouts by a factor of 1/3.

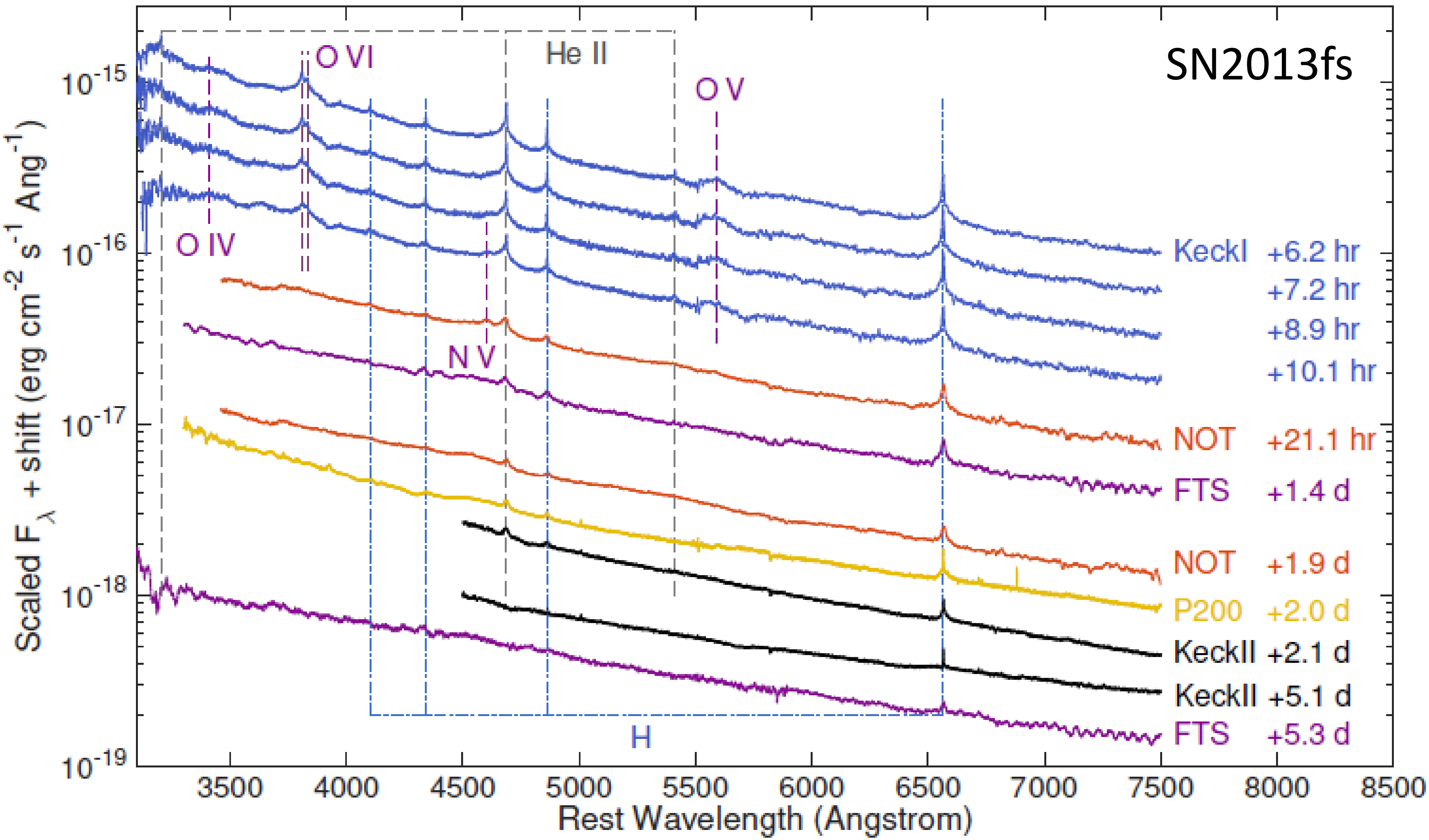
Morozova+17

# Wind shock breakout
# SN IIP with accerelating dense CSM




Moriya+18

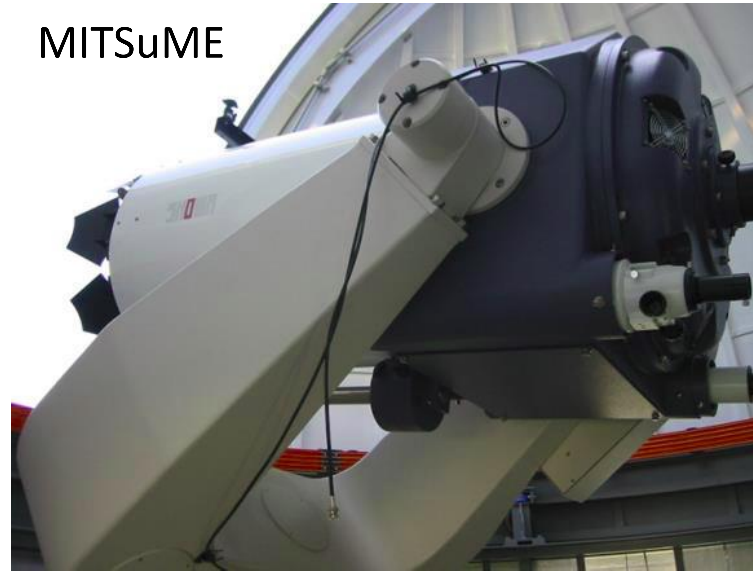
# SN2013fs –firm evidence of dense CSM-



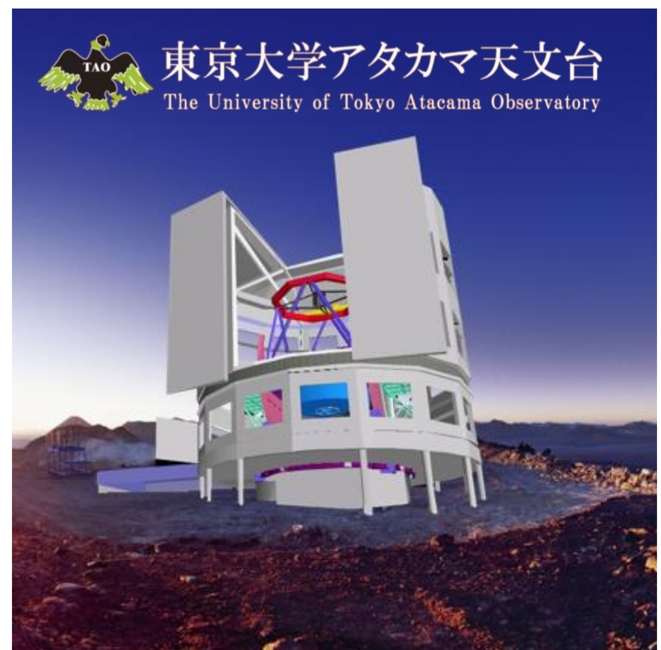

Yaron+17

Rapid follow-up obs. is important!

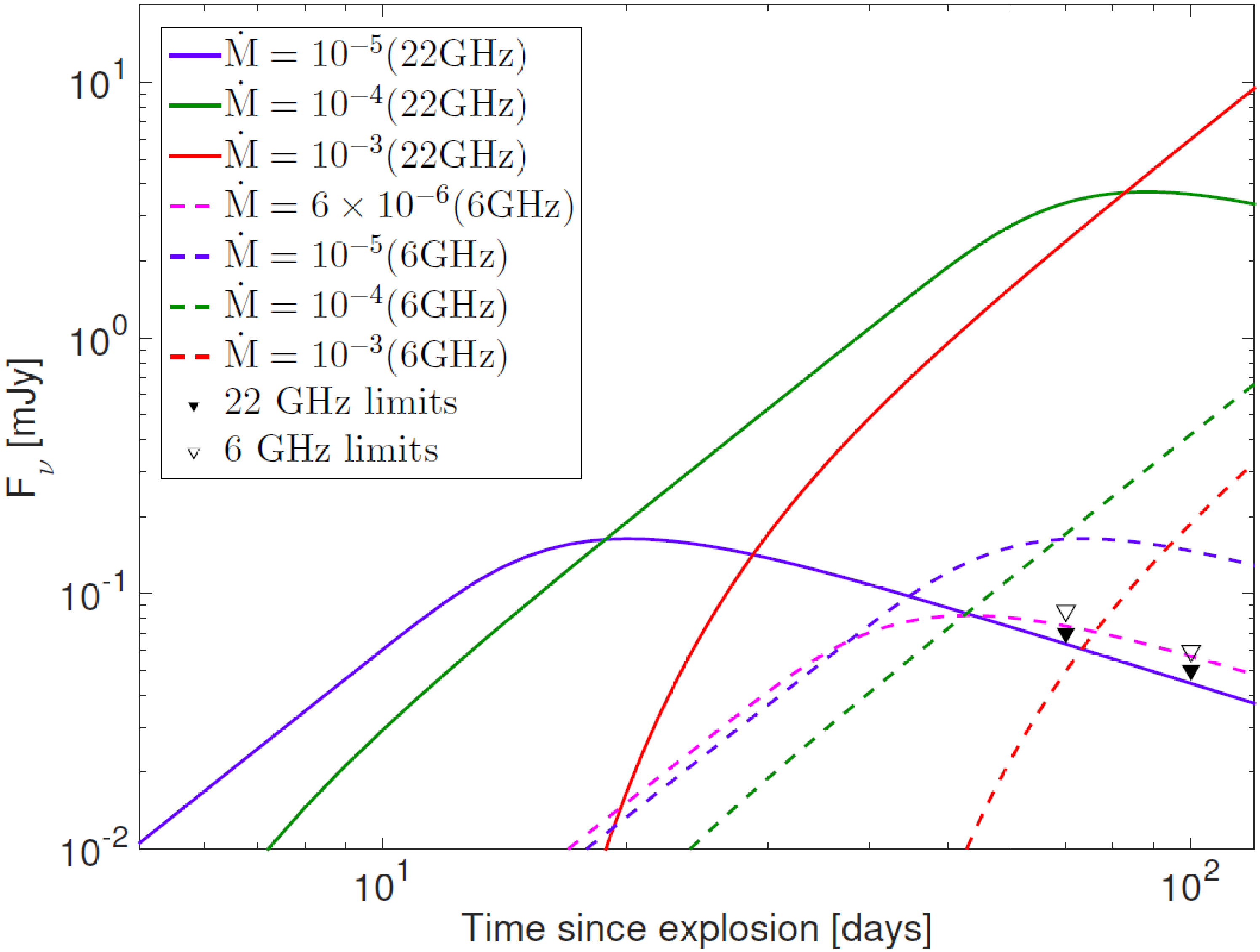
# Follow-up observations



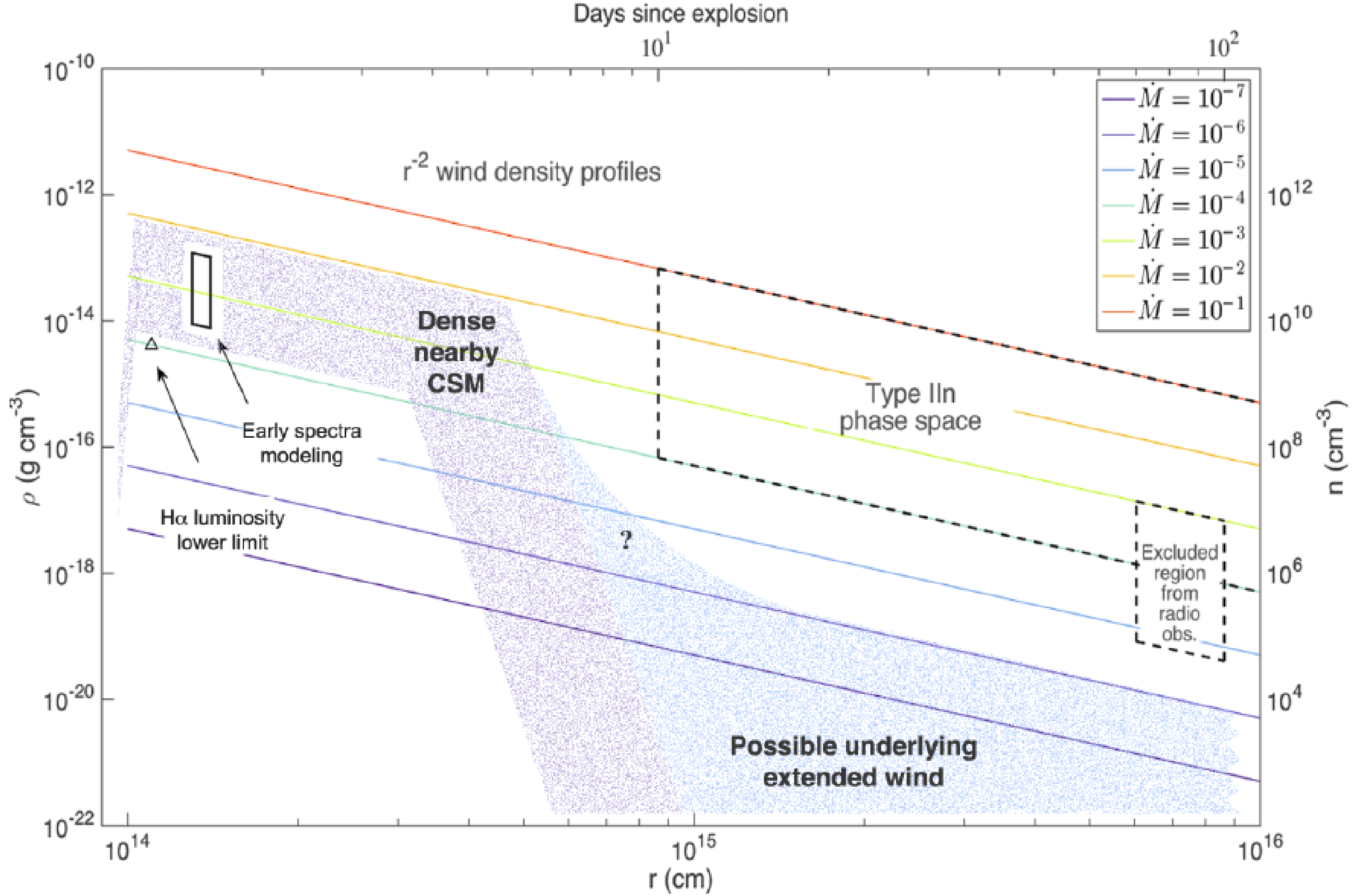


# SN2013fs -strict upper limit in radio-




Yaron+17

# SN2013fs -structure of CSM wind-




Yaron+17

Variable mass loss rate at the end of presupernova evolution?

# Summary

- Tomo-e SN survey will detect rising part of shock breakout (~1SN/2-3yrs) and shock breakout of SNe IIP (~1SN/1yr).
- We may increase the cadence later to capture the evolution of the shock breakout.

- Secure targets are the rapid rising of SNe IIP (~1SN/2months).
- Immediate and continuous follow-up observations are quite important. Tomo-e SN survey and follow-up obs. will reveal the fate of the massive stars.