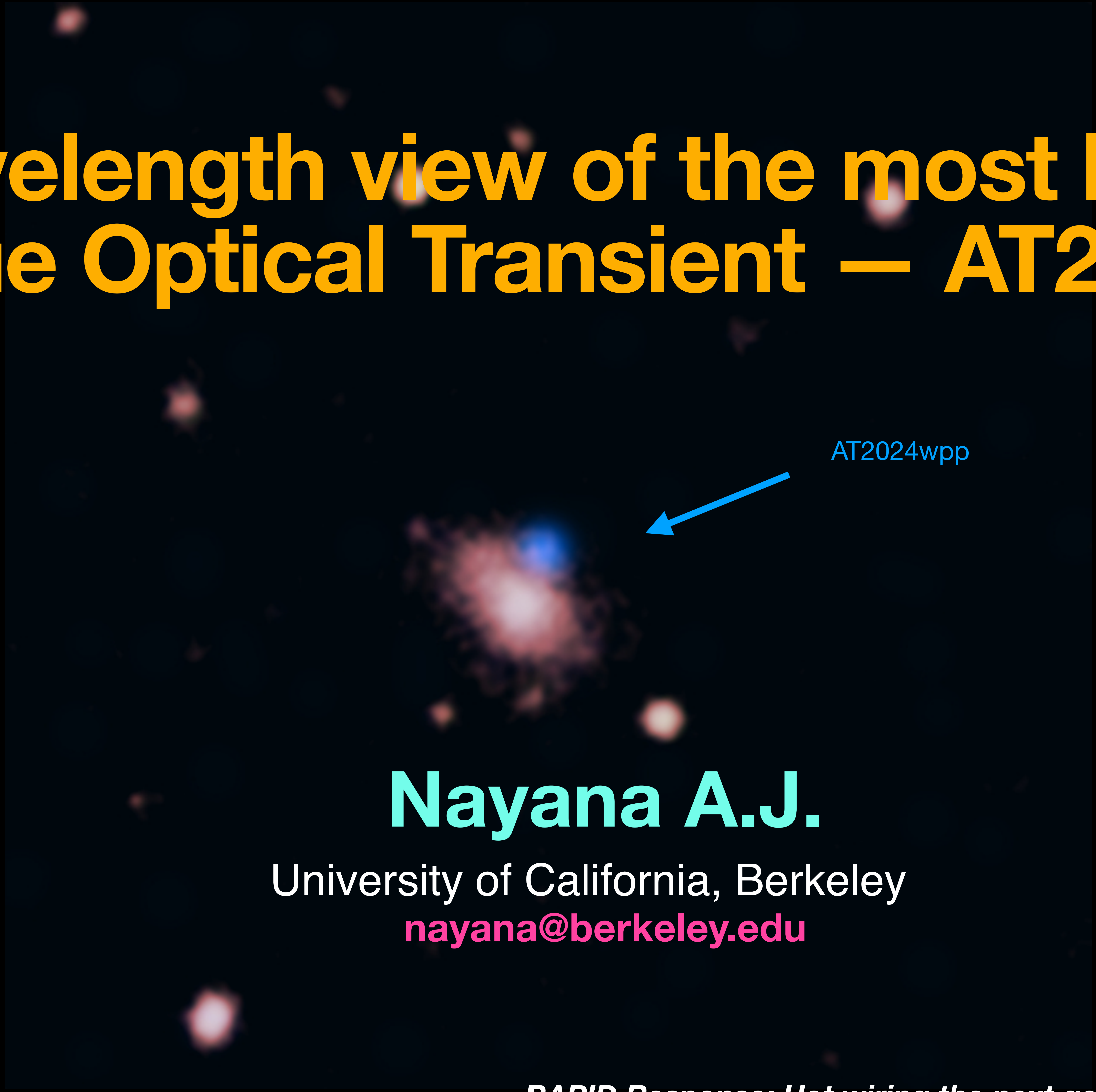
Multiwavelength view of the most luminous Fast Blue Optical Transient — AT2024wpp



Nayana A.J.

University of California, Berkeley

nayana@berkeley.edu

Raffaella Margutti
Ryan Chornock
Natalie LeBaron
Olivia Aspegren

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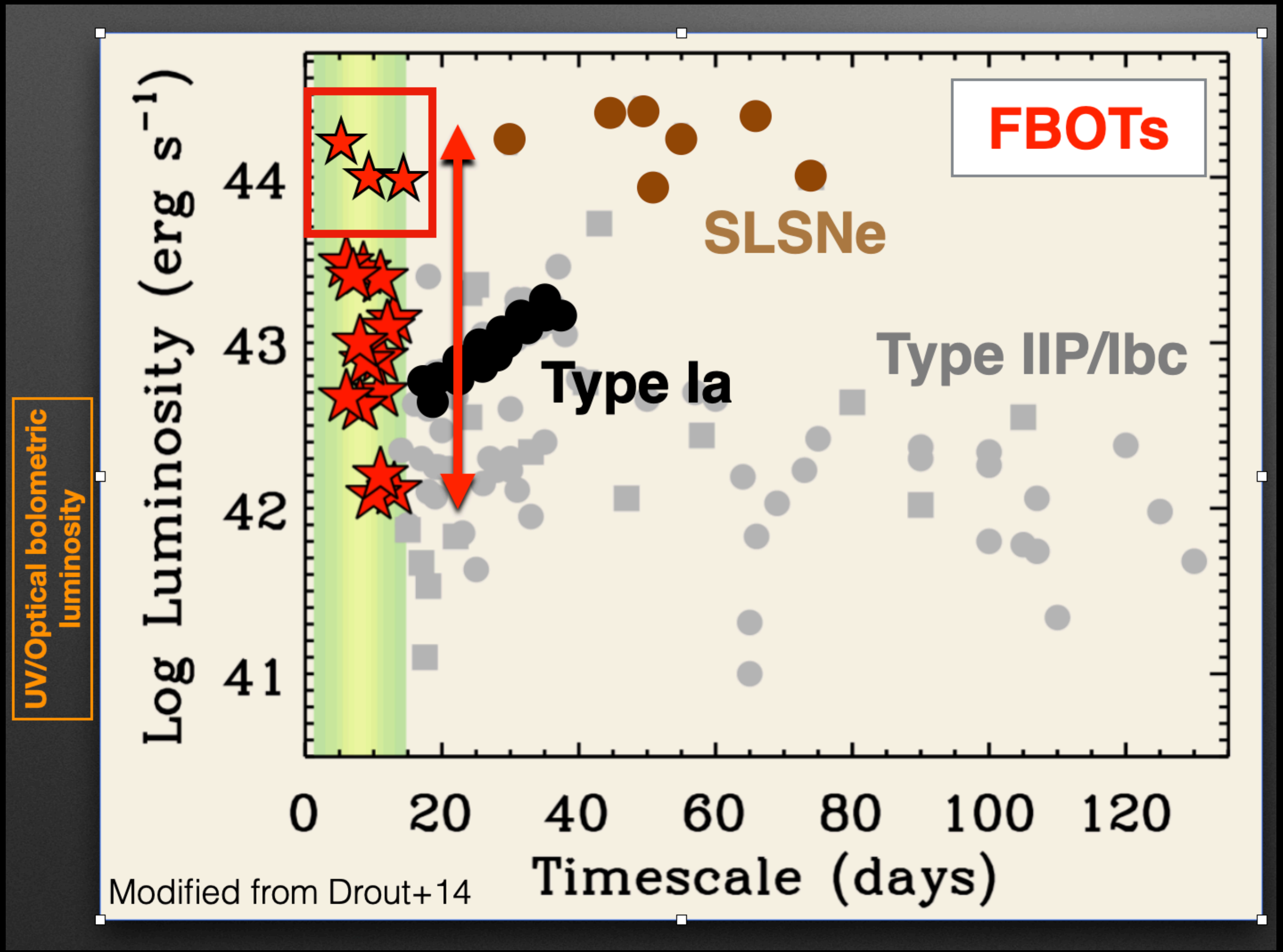
RAPID Response: Hot wiring the next generation of time-domain science

Fast Blue Optical Transients (FBOTs)

- Rapid timescales (t_{rise} < 10 days)
- Peak Luminosities > 10^{44} erg/s
- Blue colors
- Featureless spectra
- In tension with traditional SN models



Drout+ 2014, Pursiainen+ 2018, Ho+ 2019, Margutti+ 2019

Luminous FBOTs (LFBOTs)

- Rare subclass with extreme luminosities $(L_{\mathrm{pk}} \gtrsim 10^{43}\ \mathrm{erg/s})$
- Bright X-ray and Radio Emission
- Intrinsically rare $< 0.1\,\%$ CCSNe rate
- Prominent examples: **AT2018cow, CSS161010, AT2022tsd**
- Progenitor models: (i) Engine-driven models

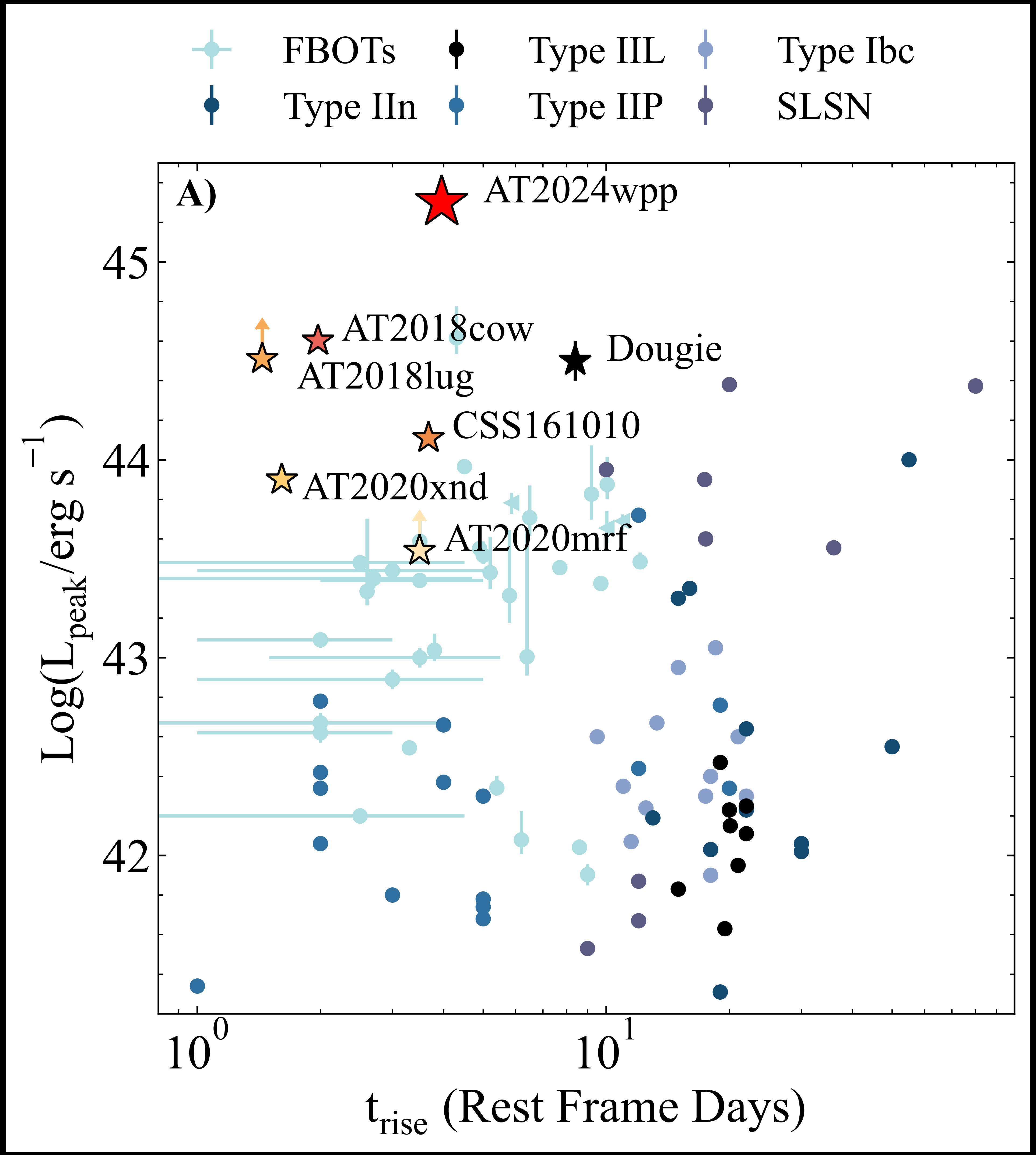
  (ii) CSM interaction models

Only 7 LFBOTs with detailed multiwavelength observations

Ho+ 2019, 2020, 2022, 2023, Margutti+ 2019, Coppejans+ 2020, Yao+ 2022, Bright+ 2022, Chrimes+ 2024, Sevilla+ 2026

AT2024wpp

- Brightest LFBOT to date
- Lpk ~ $(2 - 4) \times 10^{45}$ erg/s
- Distance 411 Mpc
- UVOIR observations (first 100 days)
- X-ray and radio observations (first 280 days)



(Perley+ 2026, Omad+ 2026, Liu+ 2026)

(LeBaron+ 2026)

AT2024wpp—UVOIR properties

- UV-optical spectrum is a thermal continuum
- At peak T > 30,000 K and maintains a high temperature (> 20,000 K)
- $t_{\rm rise} = 4\,{\rm days}$ $M_{\rm ej} < (1-2)\,M_{\odot}$
- Radiated energy in the first 45 days $> 10^{51}\,{\rm erg}$
- Featureless spectra till ~ 35 days, and then shows faint H and He features
- NIR excess at t ~ 30 days

  (i) Reprocessing by pre-existing dust
  (ii) Free-free opacity effects $(\rho_0 \sim 7 \times 10^{-16}\,{\rm g\,cm^{-3}\,at\,R_0} \sim 10^{16}\,{\rm cm})$

(LeBaron+ 2026)

X-ray observations

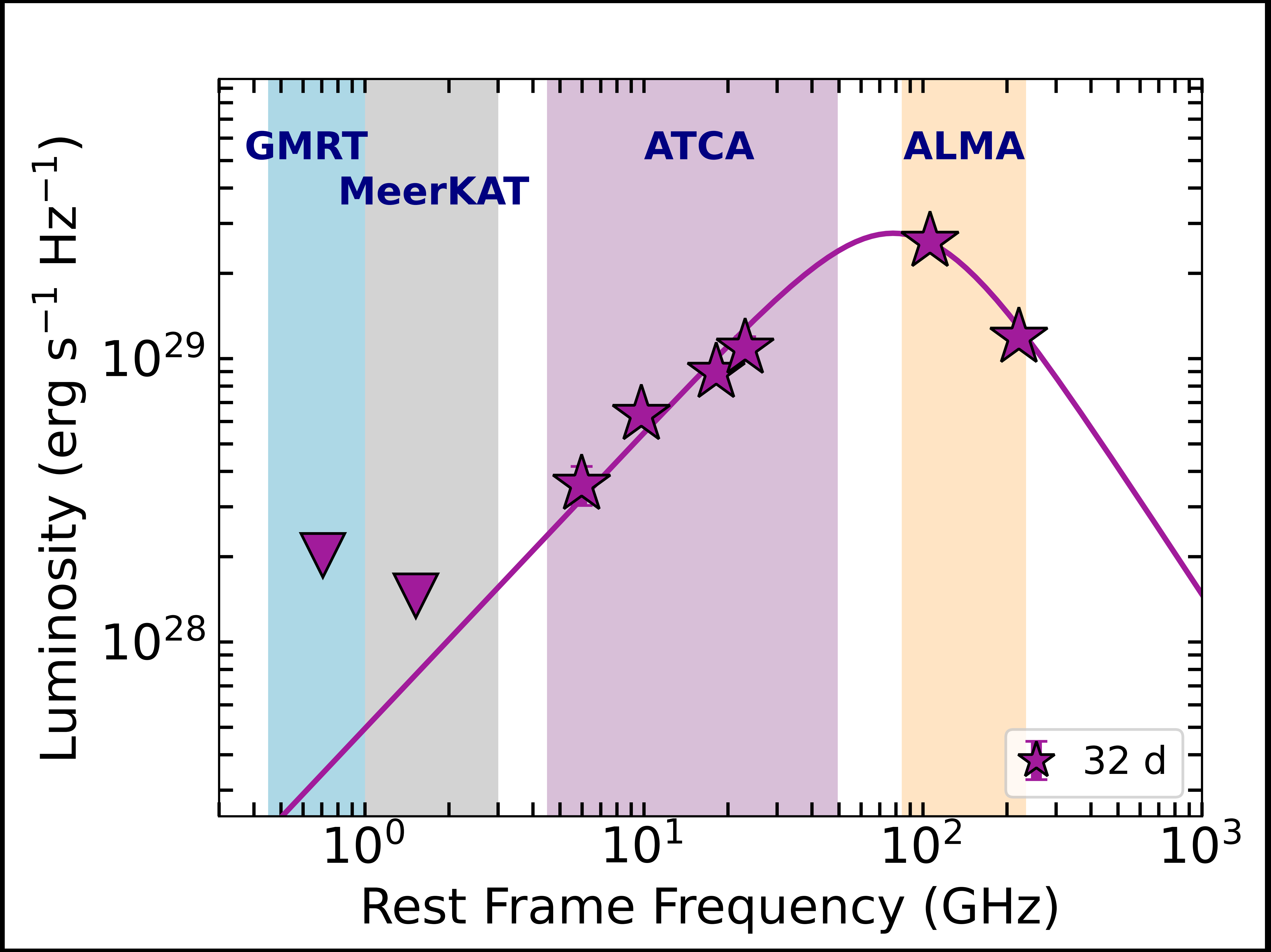
- Swift XRT (0.3–10 keV) $\delta t \approx 2 - 119$ days —> light curve
- Chandra (0.3–10 keV) $\delta t \approx 18 - 75$ days (4 epochs)
- XMM-Newton (0.2–12 keV) $\delta t \approx 18 - 75$ days (3 epochs)
- NuSTAR (3–79 keV) $\delta t \approx 6 - 75$ days (5 epochs)

X-ray observations covering 0.3—79 keV at multiple epochs (t ~ 2–119 days)

(Nayana+ 2025)

Radio observations

- GMRT (0.25–1.4 GHz)
- MeerKAT (1–1.5 GHz)
- ATCA (5–33 GHz)
- ALMA (100-200 GHz)

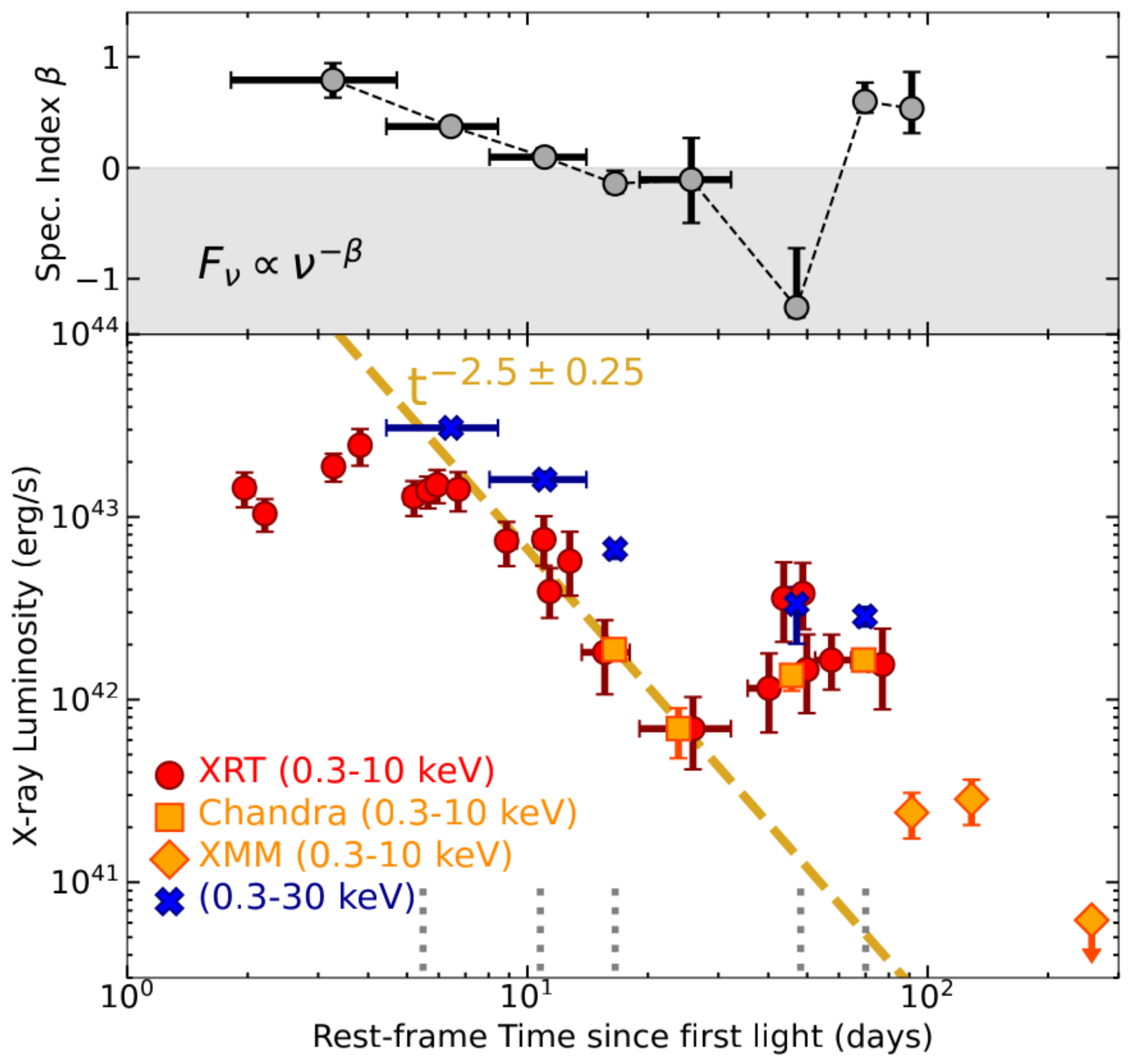


Radio spectra covering 0.25—200 GHz at multiple epochs (19–175 days)

(Nayana+ 2025)

X-ray spectral and temporal evolution

- Luminous, roughly constant emission in the first 7 days.
- Phase of rapid ($t^{-2.5}$) decline until 30 days.
- A major rebrightening from 35 days, peaking at ~50 days.
- Initially, a soft spectrum ($F_\nu \propto \nu^{-0.80}$) that gradually hardens with time.
- Extreme spectral hardening ($F_\nu \propto \nu^{1.25}$) at 50 days.

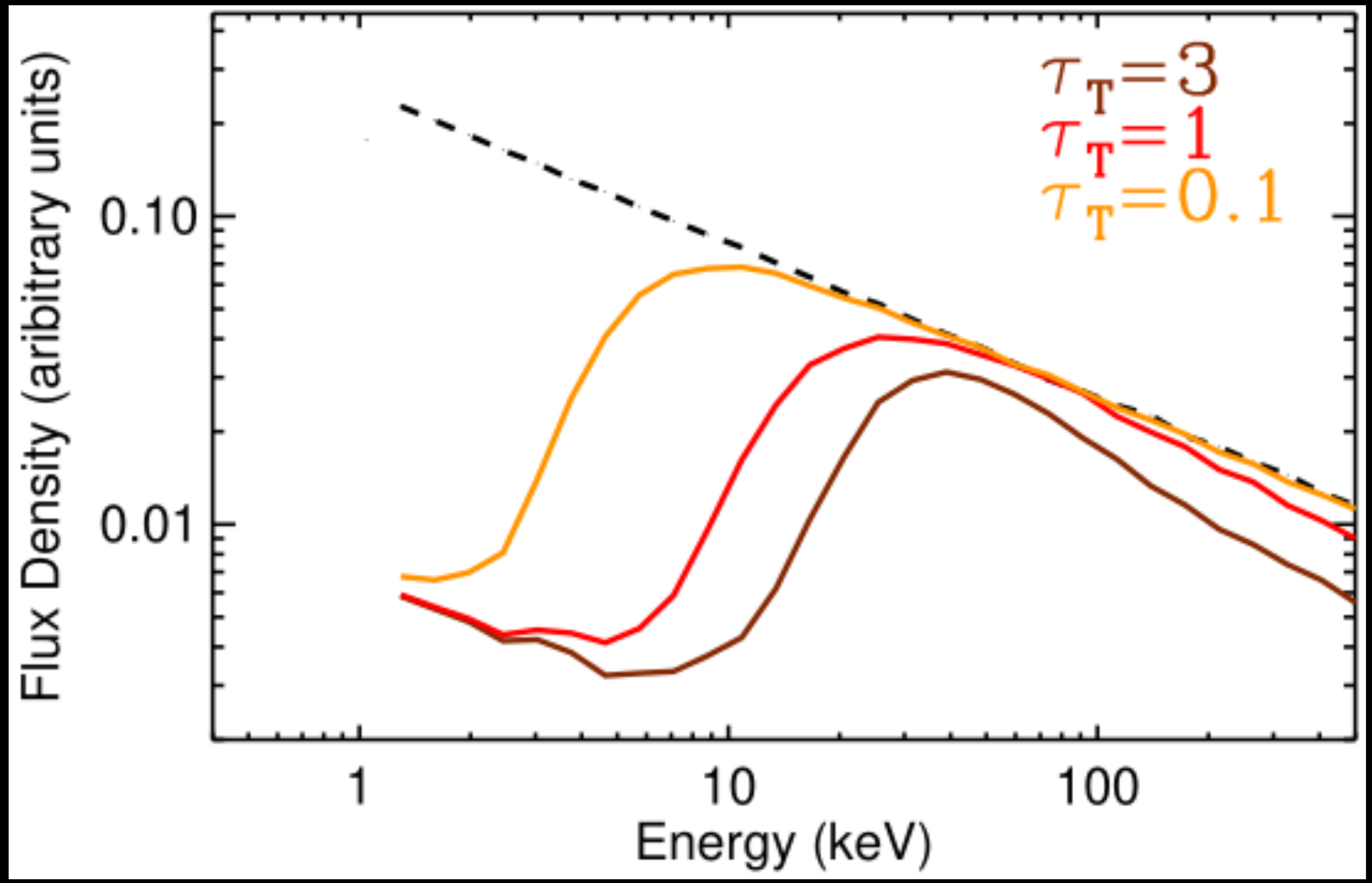


Nayana+ 2025

Physical Implication

(A transient Compton hump)

- Transmission of radiation from a high-energy source through ejecta with variable optical depth to photoelectric absorption and Compton scattering.
- Hard spectrum — incompatible with fast cooling of non-thermal electrons



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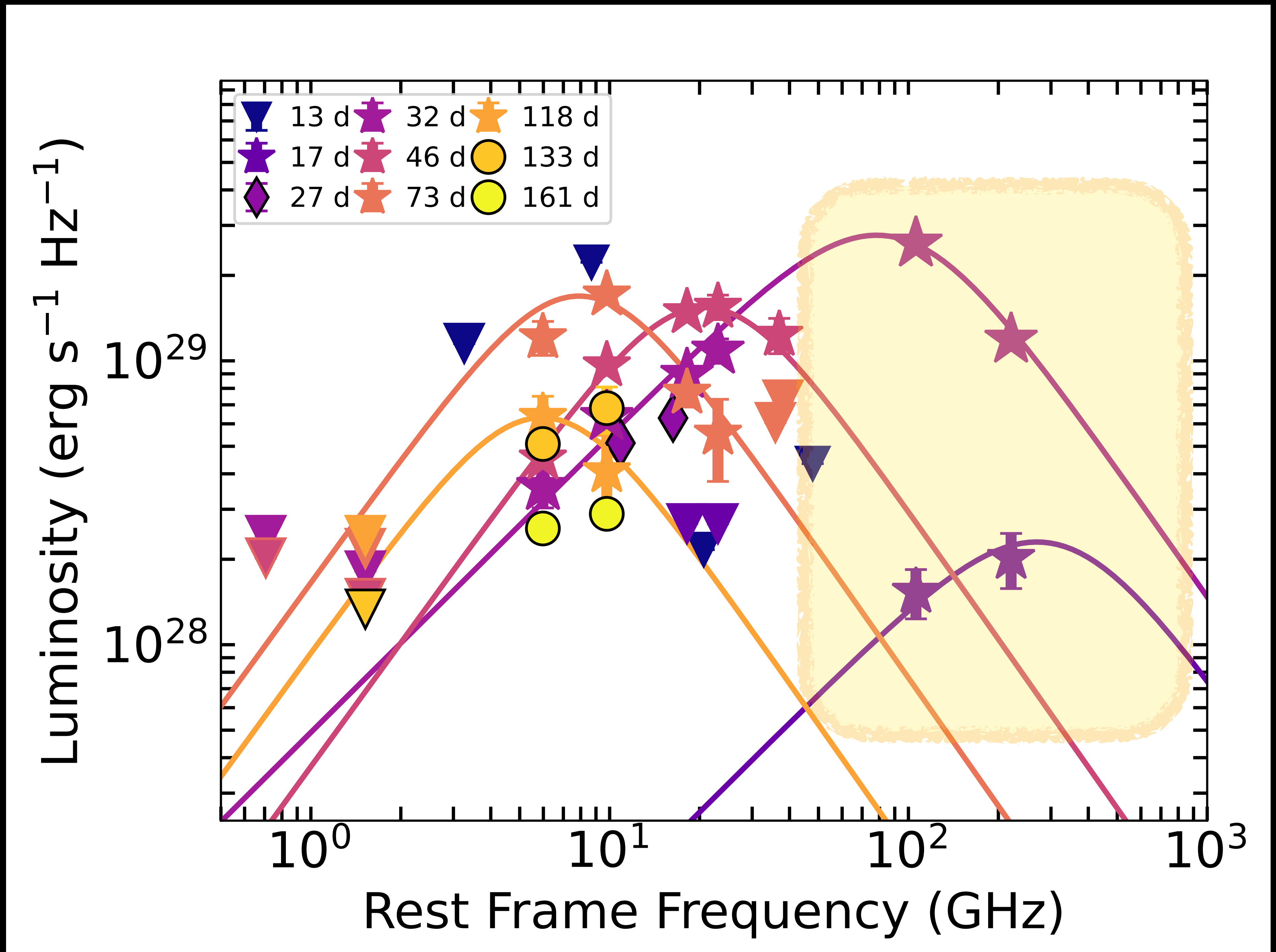
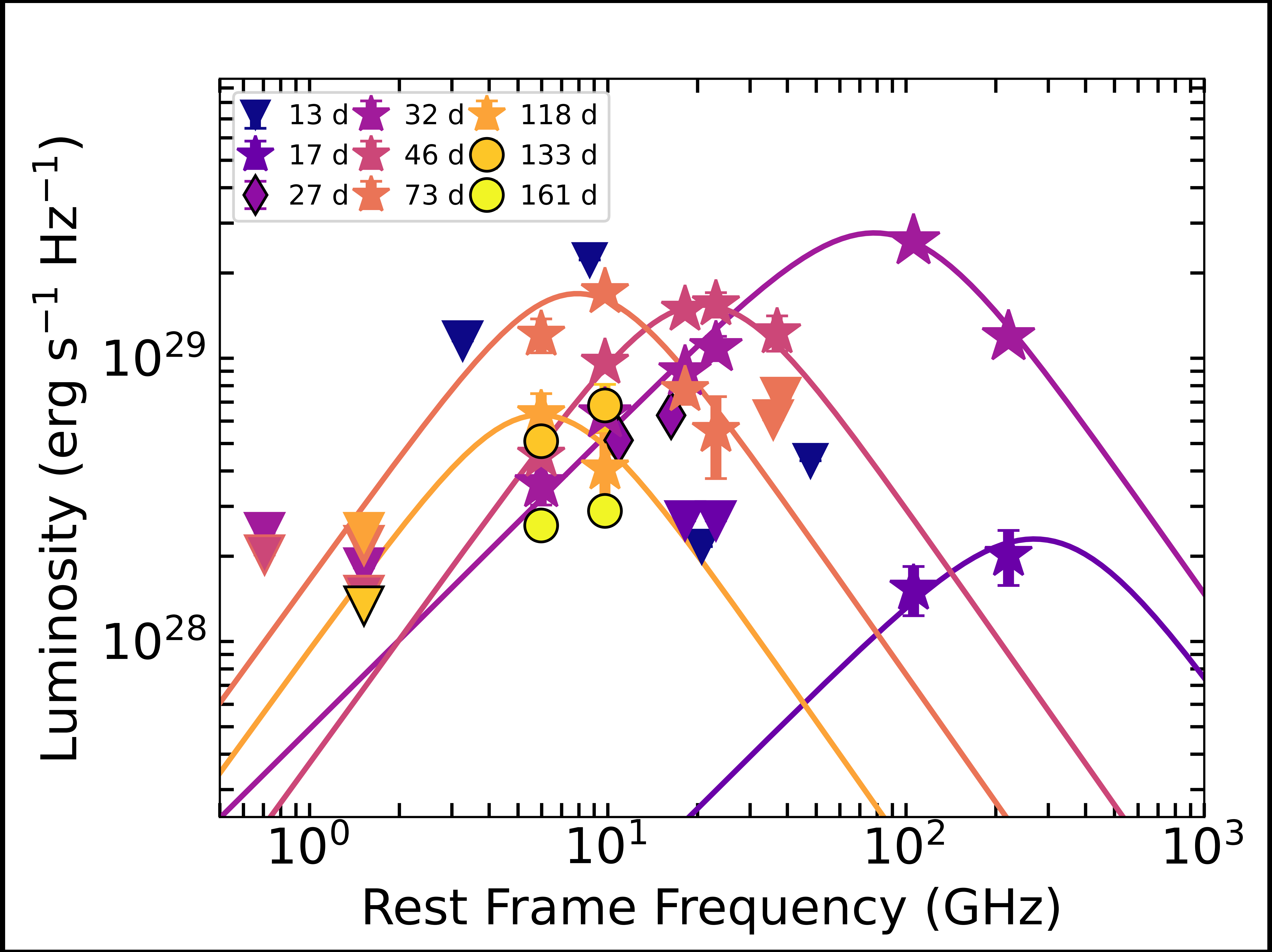
Radio spectral evolution

- Extremely rapid rise of the mm emission
- Spectral inversion at t > 118 days
- Rapidly growing $R_{\rm sh} \propto t^{3.12\pm0.12}$
- $\Gamma\beta c \approx$ 0.07—0.4 c at t ~ 32—73 days
- Shock energies ~ (0.7—33) $\times 10^{48}$ ergs



Possible Scenarios



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Order of magnitude rise in mm component in 2 weeks

Apparent

Off-axis models

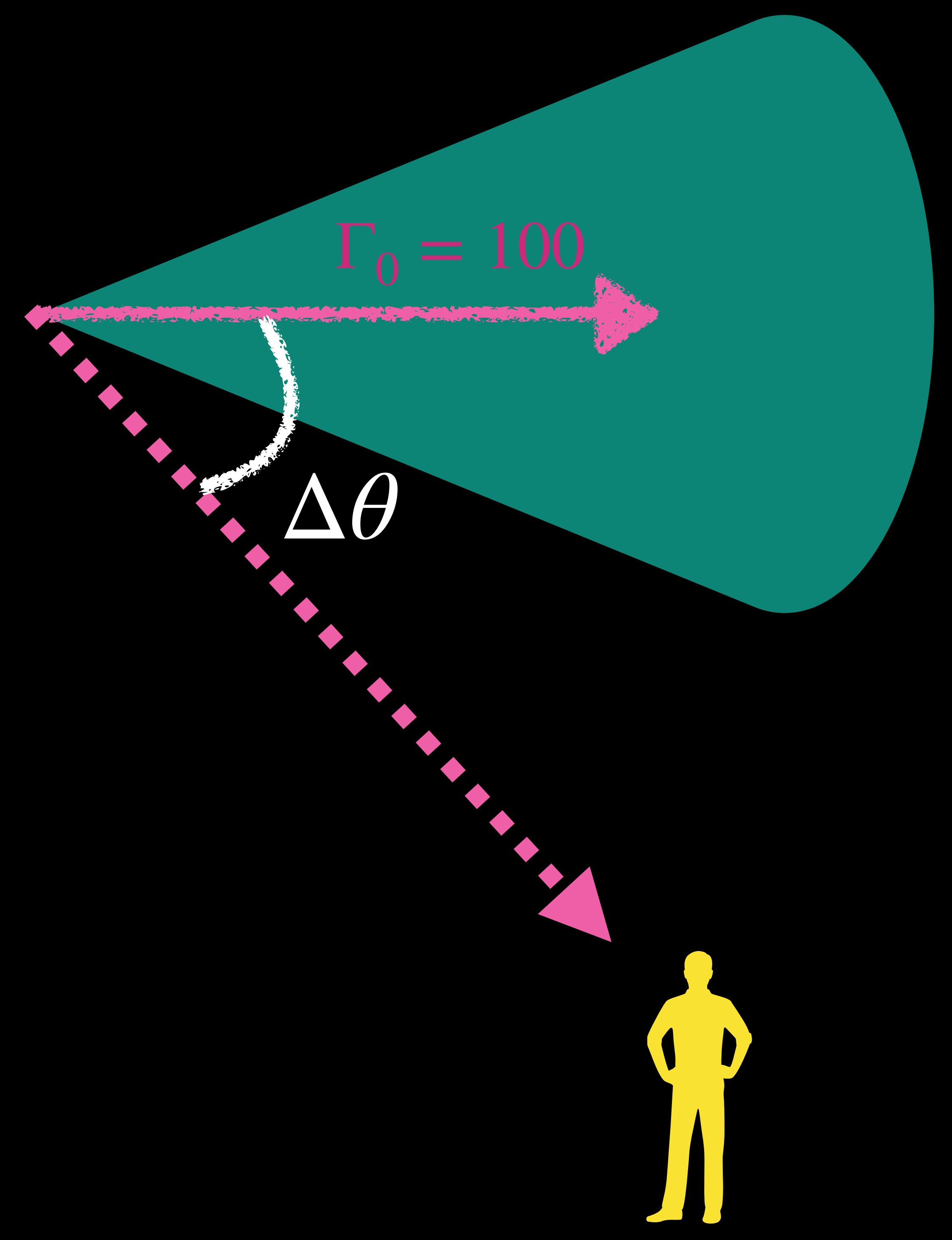
Real

Cooling effects

Shock propagating in dense medium

Shock deceleration time scale

$$R_{\rm dec} = \left[\frac{3E_{\rm K,iso}}{4\pi n m_{\rm p} c^2 \beta_0^2 \Gamma_0^2}\right]^{1/3}$$

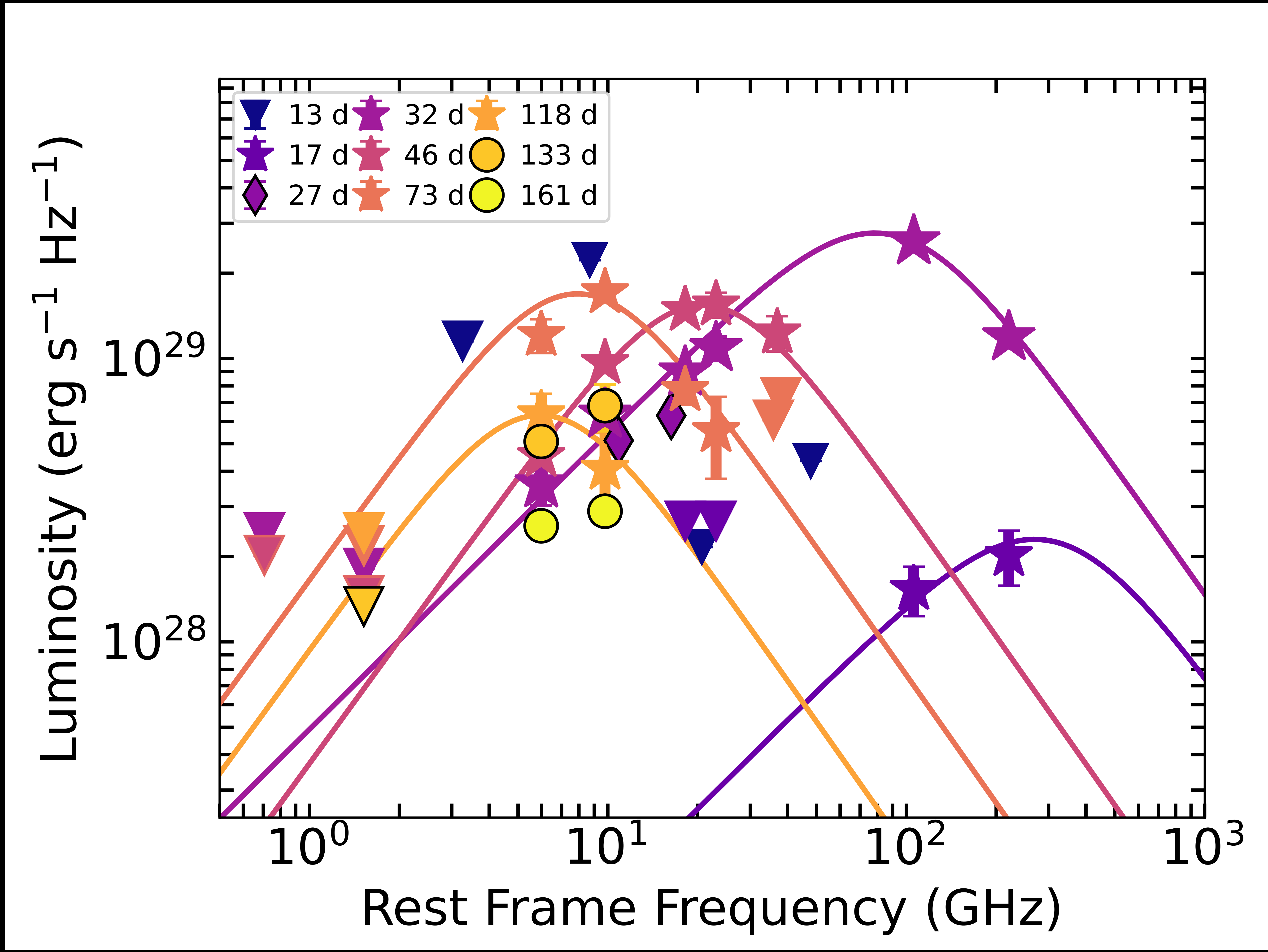


$$t_{\rm dec} = \frac{R_{\rm dec}}{2c\beta_0^2\Gamma_0^2}$$

$$t_{\rm pk} = t_{\rm dec}(\Gamma_0 \Delta\theta)^2 < 1\,{\rm day}$$

$$t_{\rm pk} \approx 30\,{\rm days}$$

Possible Scenarios



Apparent

~~Off-axis models~~

Real

~~Cooling effects~~

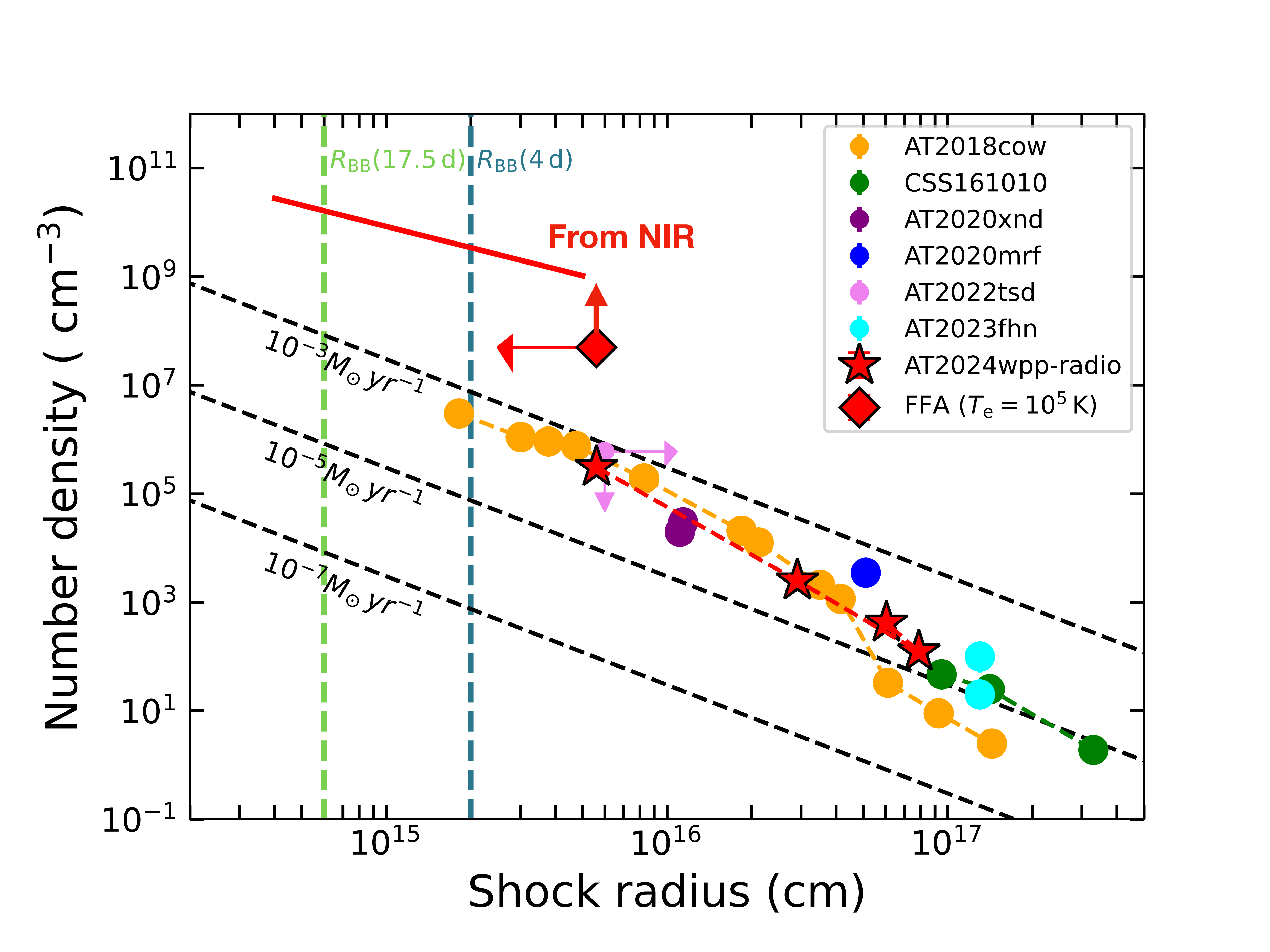
Shock propagating in dense medium

$$\Delta F = e^{-\tau_{\rm FFA}} \longrightarrow \tau_{\rm FFA} \propto \int_{R1}^{R2} n^2 dr$$

Nayana+ 2025

Density profile

- Strikingly similar density profiles $\rho_{\mathrm{CSM}} \propto r^{-3}$
- Similar evolutionary phases that set up these environments?
- Relatively flat density profile at $R<10^{16}$ cm
- Complementary results from NIR



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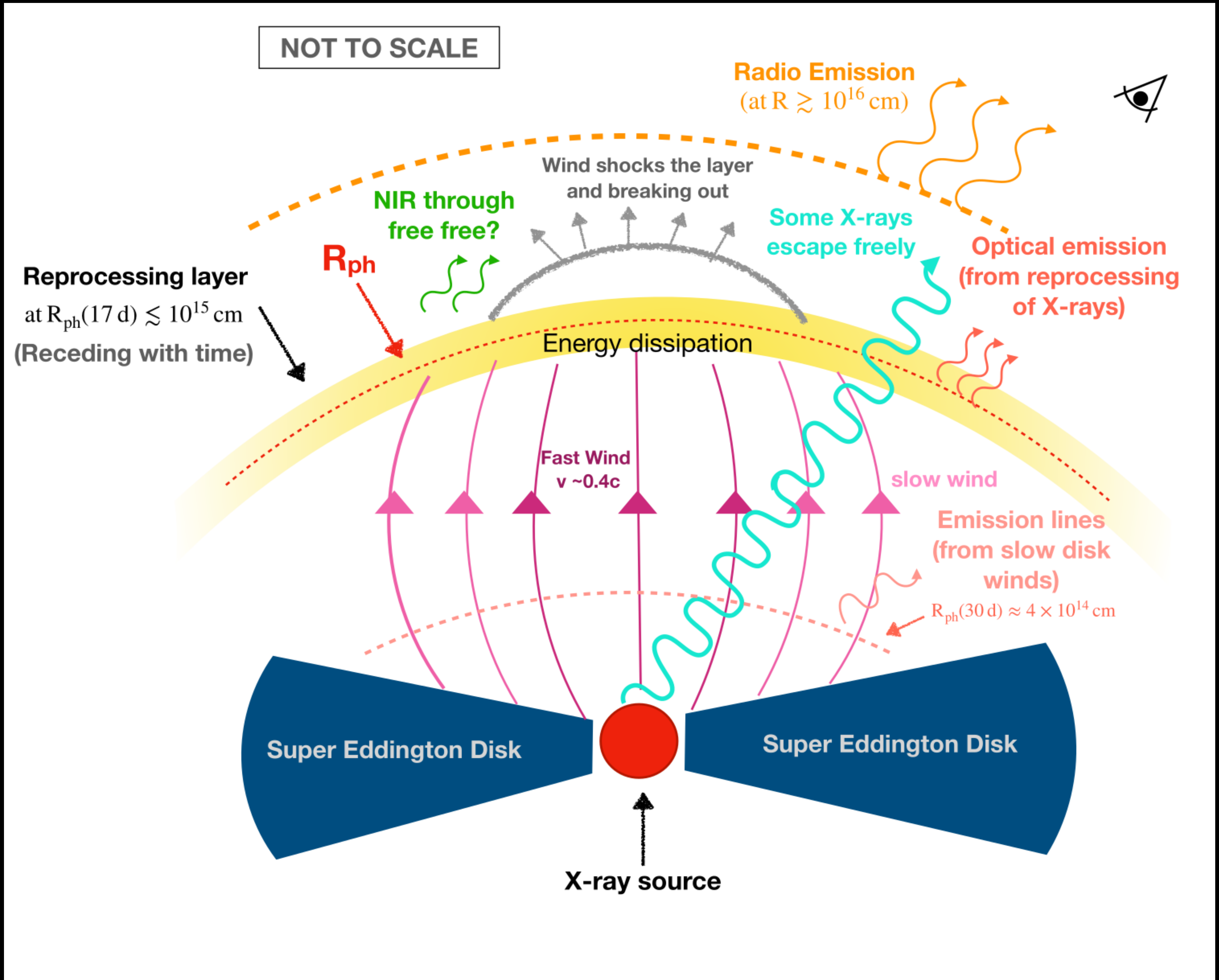
Comprehensive Physical Picture



Motivated by
Metzger+ 2022
and Tsuna+ 2025

Nayana+ 2025
LeBaron+ 2026

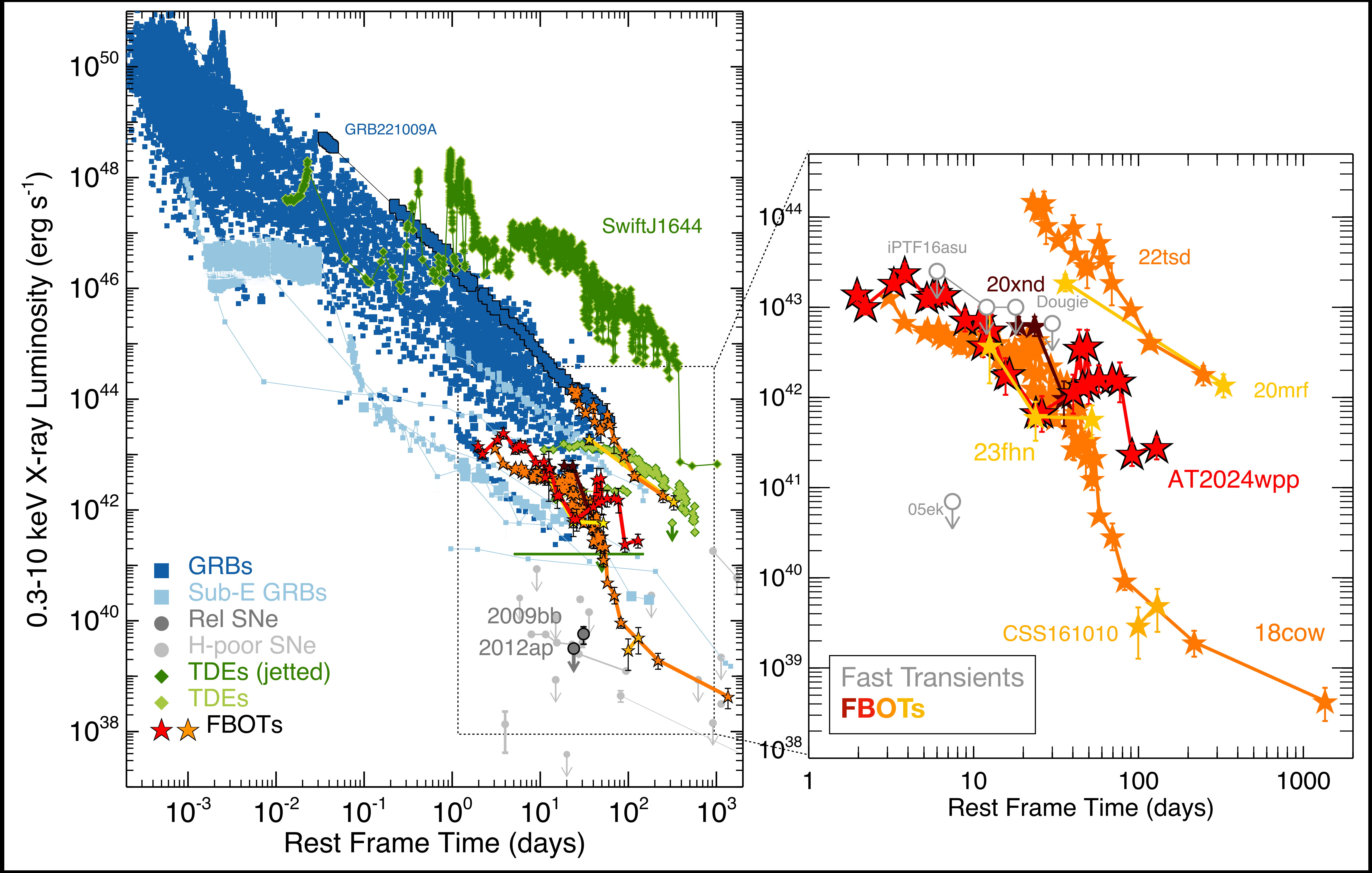
Discussion points

- Coordinated multi-wavelength observations are essential to understand explosion mechanisms and environments
- Prioritization of targets —multiwavelength resources are limited
- Fast response (preferably automated trigger responses) to facilitate early multi-wavelength follow-up
- Facility-level coordination is crucial:
    - Soft+hard X-ray observations
    - Sub-GHz to mm band radio monitoring
- Early-time mm-band observations remain largely unexplored — critical for constraining immediate environments

Thank you!

Backup slides

AT2024wpp and other LFBOTs in X-ray bands



AT2024wpp and other LFBOTs in radio bands