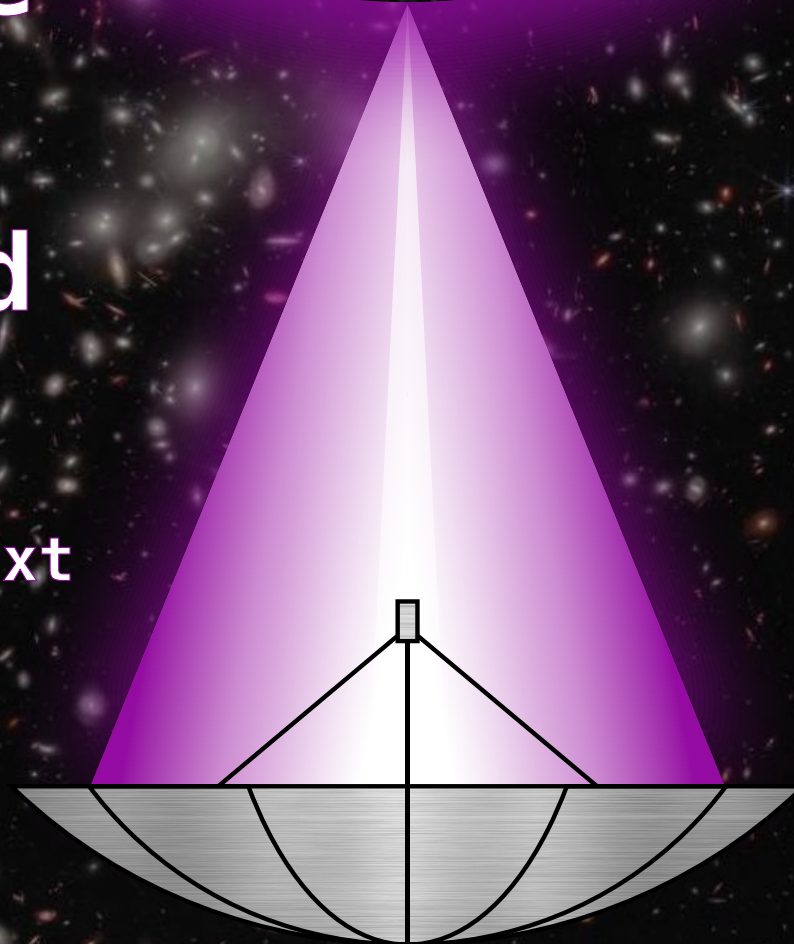
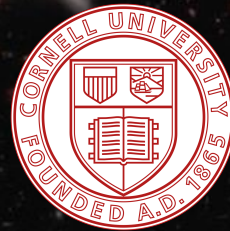


Where are all of the off-axis GRBs? A Late-Time Radio Campaign of Ic Broad Line Supernovae

Genevieve Schroeder
RAPID Response: Hot-wiring the Next
Generation of Time-Domain Science

March 27th, 2026

Email: gms279@cornell.edu



Where are all the off-axis long GRBs?



Where are all the off-axis long GRBs?



Off-axis GRBs and Where to Find Them

SNe Ic-bl (Many)

GRB-like Host

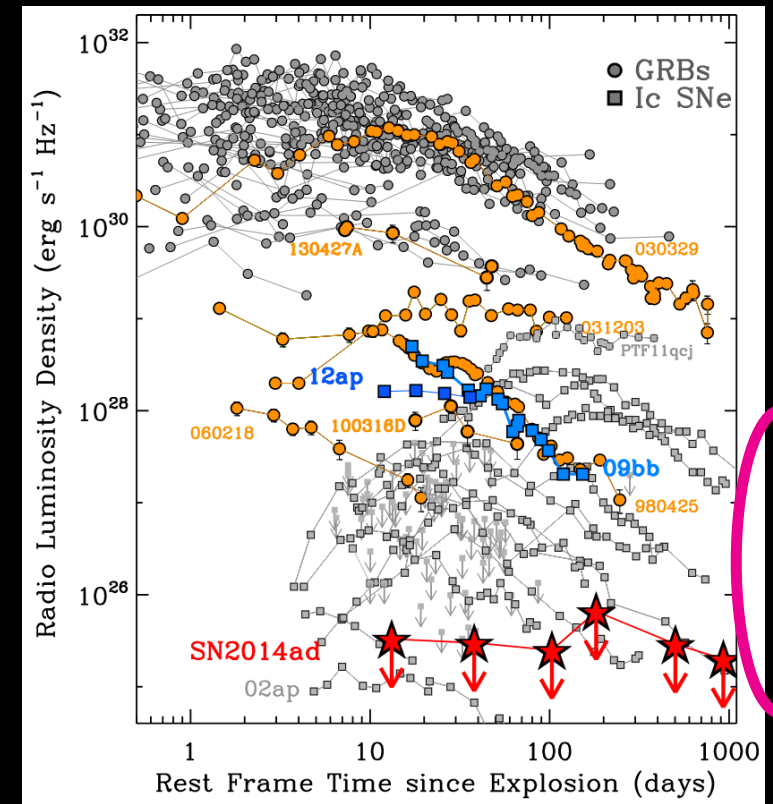
Well-spaced + Deep Radio

Radio Transient (Many)

Proper Motion (VLBI)

Previous Work

- Many previous studies searching for late-rising afterglow following SNe
- Radio emission may be from: off-axis jet, CSM interaction, pulsar wind nebulae (VLBI is best way to distinguish)
- In Schroeder+2025 we observed a sample of SNe Ic-bl at later times than before (~10 years)

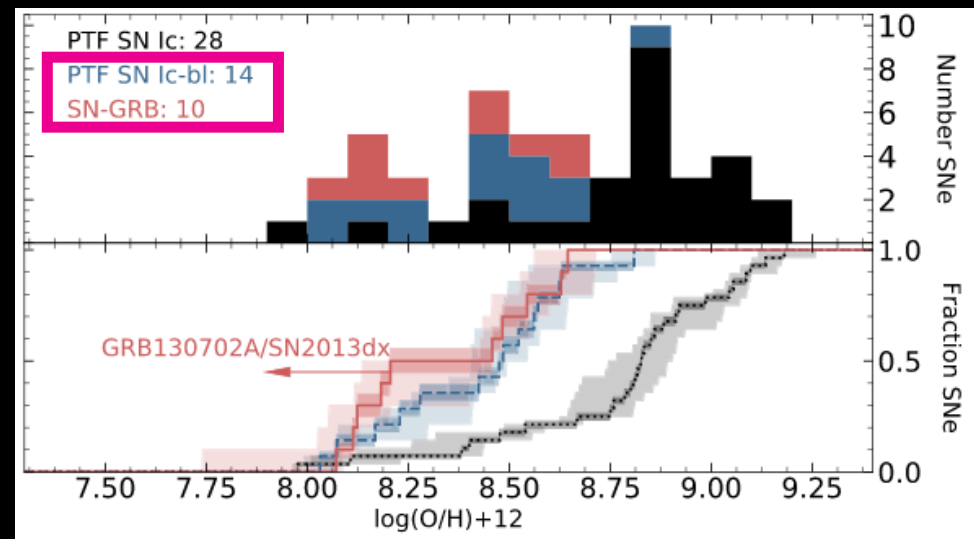


Marongiu+2019, see also Eftekhari+2021, Corsi+2016,2023, Berger+2003, Soderberg+2006

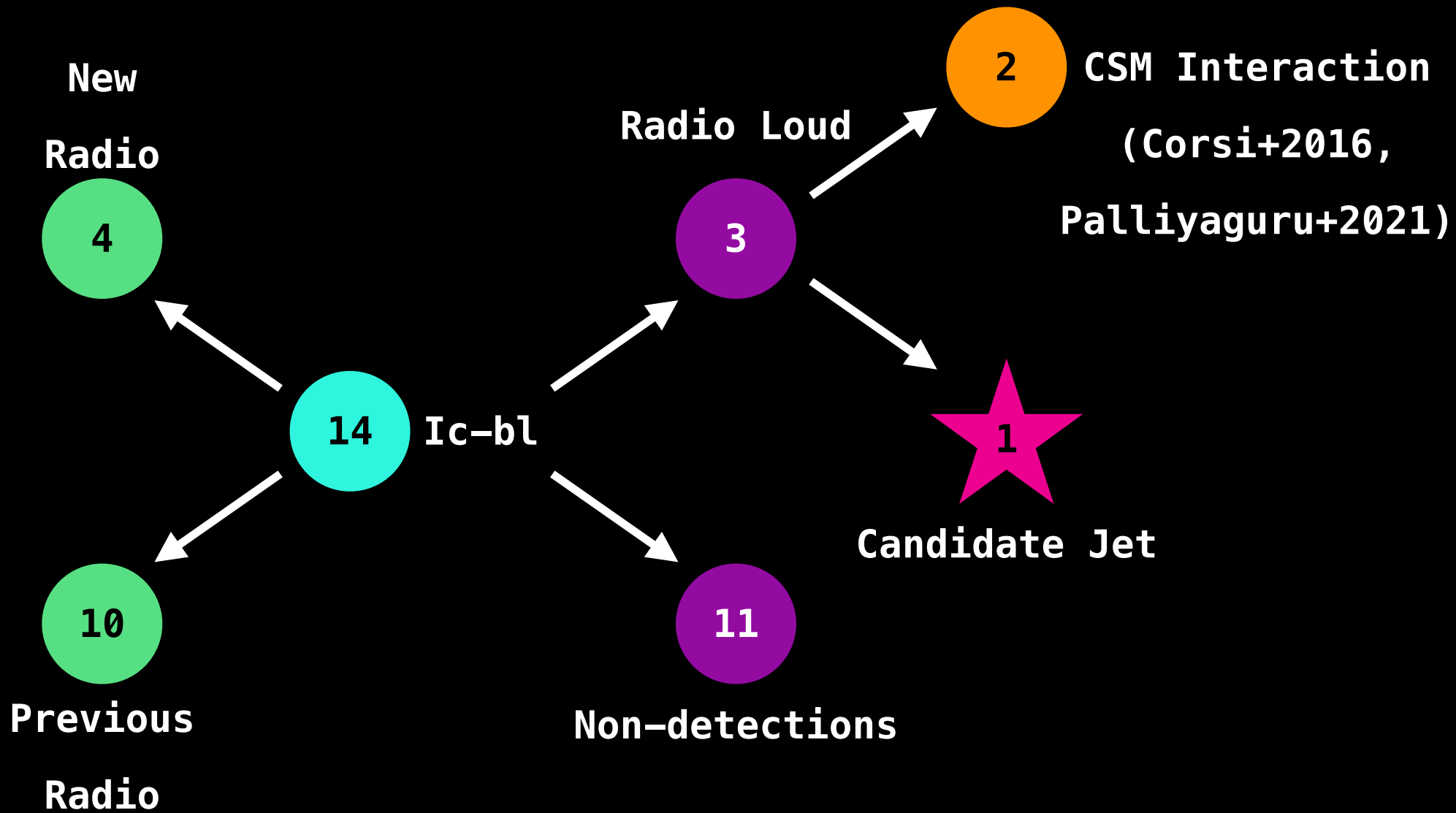
My Sample

Palomar Transient Factory ($0.0150 < z < 0.1580$)

- Modjaz+2020 compared the host galaxy properties of 14 SNe Ic-bl, 28 Ic SNe, and 10 GRB-SN ($z < 0.3$)
- SNe Ic-bl and GRB-SN had indistinguishable host properties
- These Ic-bl offer a great sample to search for off-axis jets

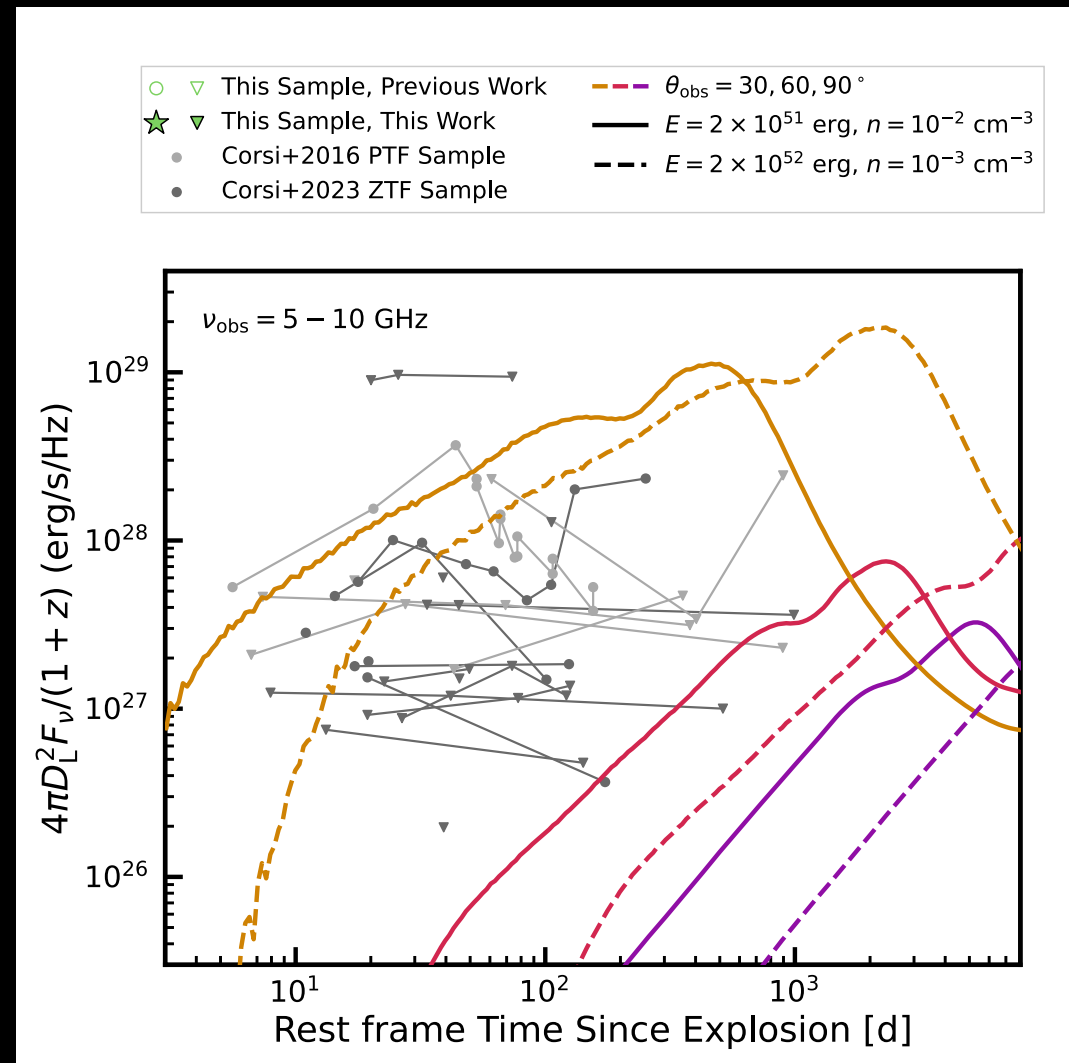


Modjaz+2020



Off-axis Models From FIREFLY (Dastidar & Duffell 2024)

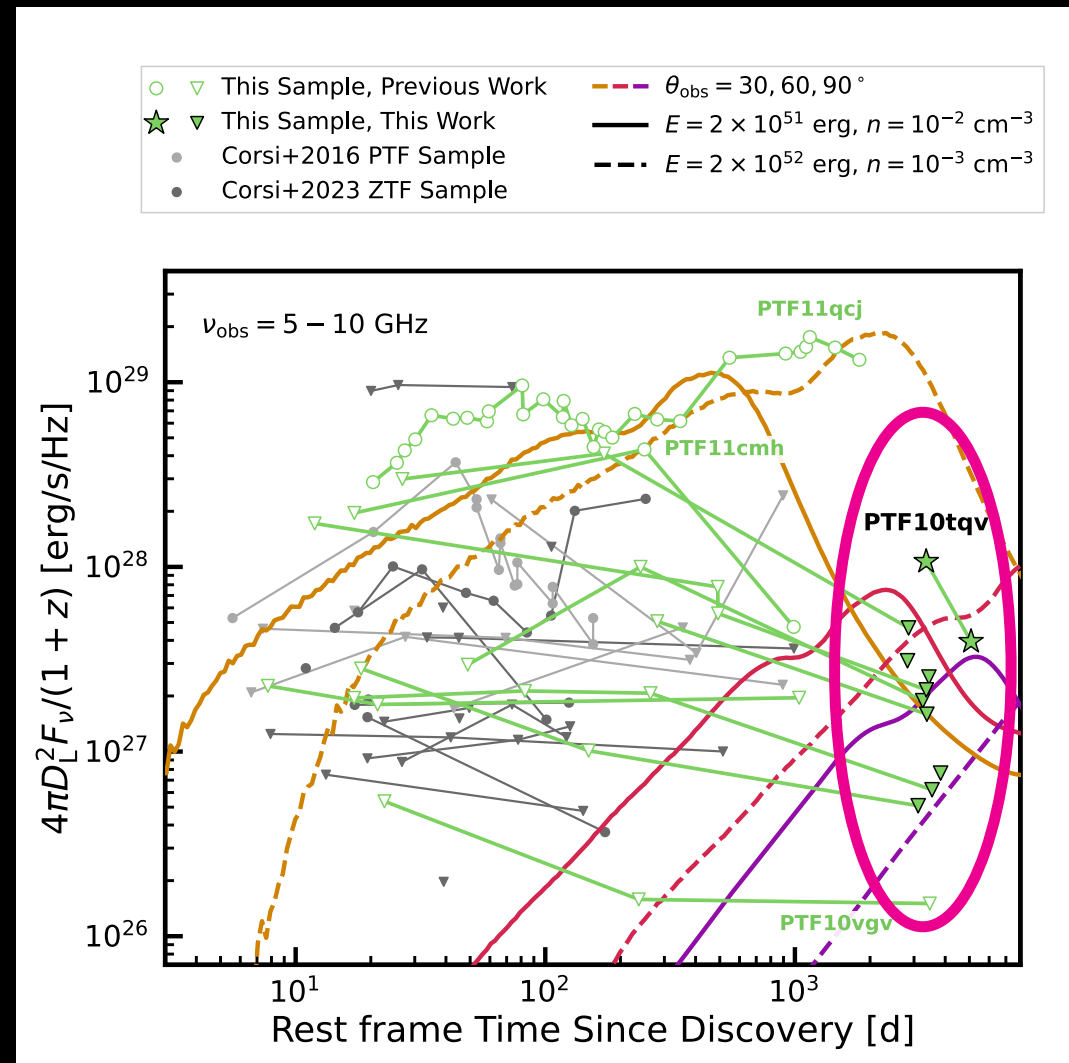
- The late time observations are able to probe off-axis models of $\theta_{\text{obs}} \gtrsim 60^\circ$
- Our candidate jet is more luminous than our non-detections
- What models are consistent with our observations?



Schroeder+2025

Off-axis Models From FIREFLY (Dastidar & Duffell 2024)

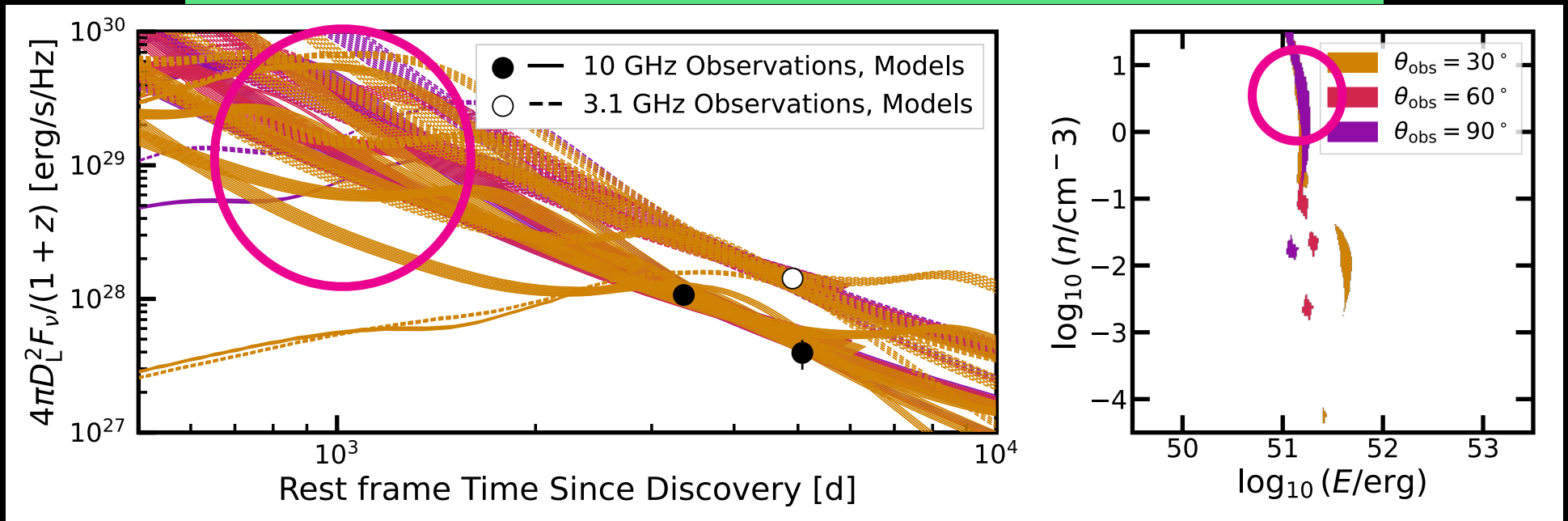
- The late time observations are able to probe off-axis models of $\theta_{\text{obs}} \gtrsim 60^\circ$
- Our candidate jet is more luminous than our non-detections
- What models are consistent with our observations?



Schroeder+2025

Candidate Jet: PTF10tqv

$$E \approx 10^{51} - 10^{52} \text{ erg}$$



Schroeder+2025

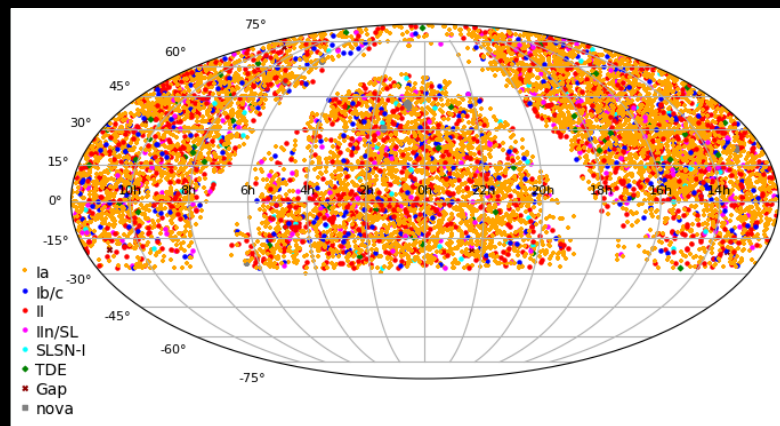
Off-axis GRBs and Where to Find Them

	PTF Sample
SNe Ic-bl (Many)	14 😐
GRB-like Host	14 😄
Well-spaced + Deep Radio	10 😐
Radio Transient (Many)	1 😞
Proper Motion (VLBI)	0 😭

So... where are they?

Path Forward to Finding Them

- ZTF Bright Transient Survey (Fremling+2020, Perley+2020)
- Flux limited, unbiased, spectroscopically classified
- Well understood sample of Ic-bls at low redshift (~ 90 to date, $\langle z \rangle = 0.04$)

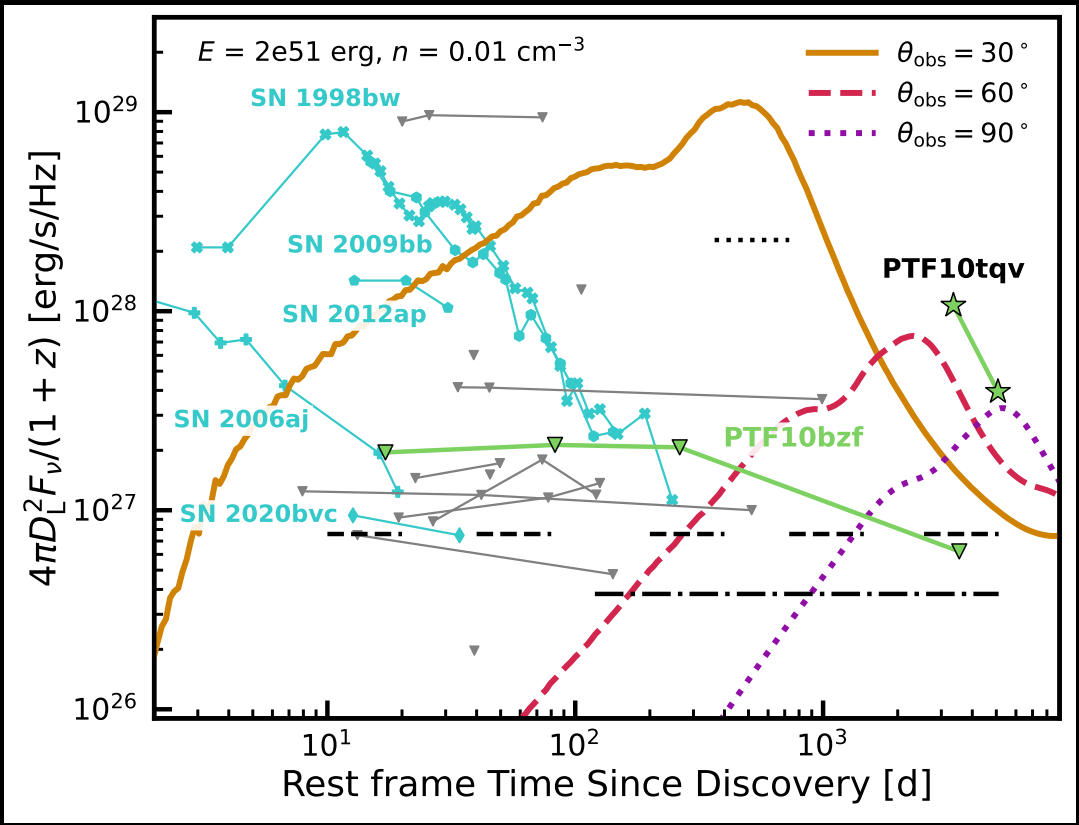


sites.astro.caltech.edu

So... where are they?

Path Forward to Finding Them

- ▼ Corsi+2023 ZTF Sample
- 20 μJy @ 10 GHz (5σ , 1hr VLA), $z = 0.04$
- 600 μJy @ 3 GHz (5σ , VLASS), $z = 0.04$
- .-.- 10 μJy @ 1.4 GHz (5σ , DSA-2000), $z = 0.04$

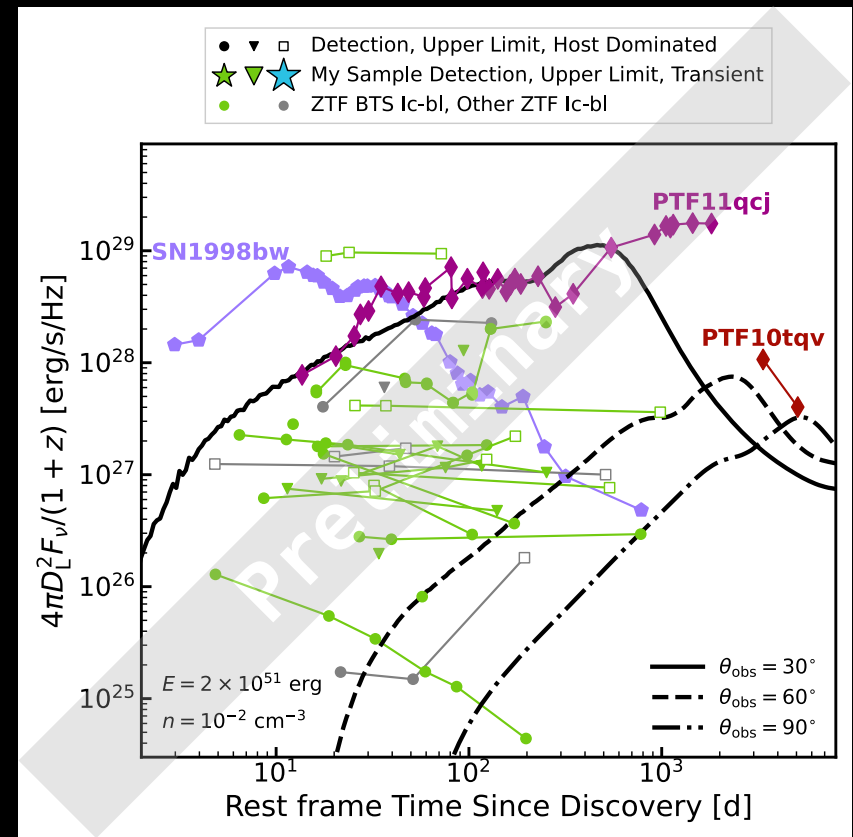


Schroeder+2025

Observing 80 SNe Ic-bl with VLA

1–8 years post discovery

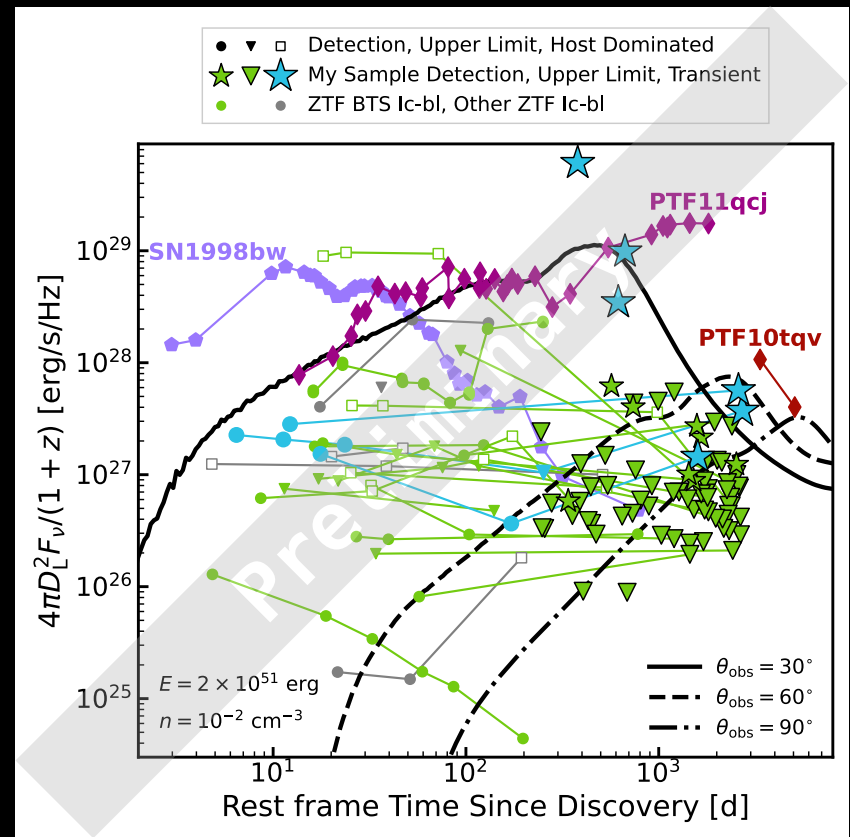
- ~71 hr in 26A, A-config
- So Far: 76 Observed & Imaged (only 20 observed before)



Schroeder+ in prep.

Observing 80 SNe Ic-bl with VLA 1–8 years post discovery

- ~71 hr in 26A, A-config
- So Far: 76 Observed & Imaged (only 20 observed before)
- 14 Radio Sources, 6 confirmed transients
- Three luminous ($\gtrsim 10^{28}$ erg/s/Hz) and young ($\lesssim 2$ years)
- Analysis and Follow-up Ongoing



Schroeder+ in prep.

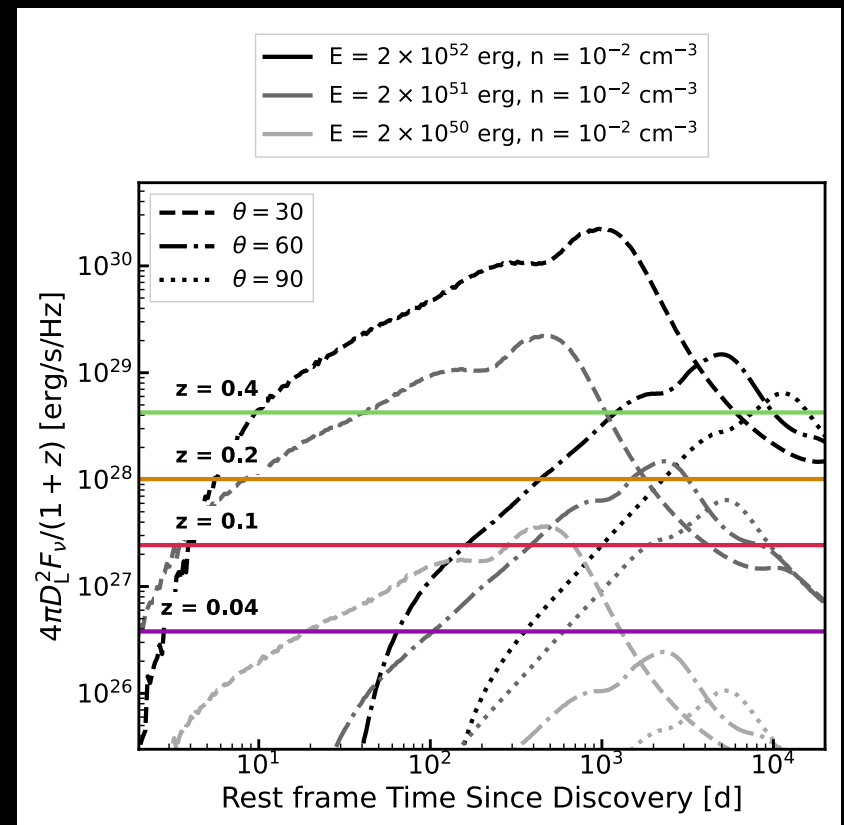
Off-axis GRBs and Where to Find Them

	PTF Sample	ZTF BTS Sample
SNe Ic-bl (Many)	14 😐	80+ 😄
GRB-like Host	14 😄	?
Well-spaced + Deep Radio	10 😐	80+(w/ VLASS) 😊
Radio Transient (Many)	1 😞	6+ 😄
Proper Motion (VLBI)	0 😭	? (Observe 3+)

The Future of Detection

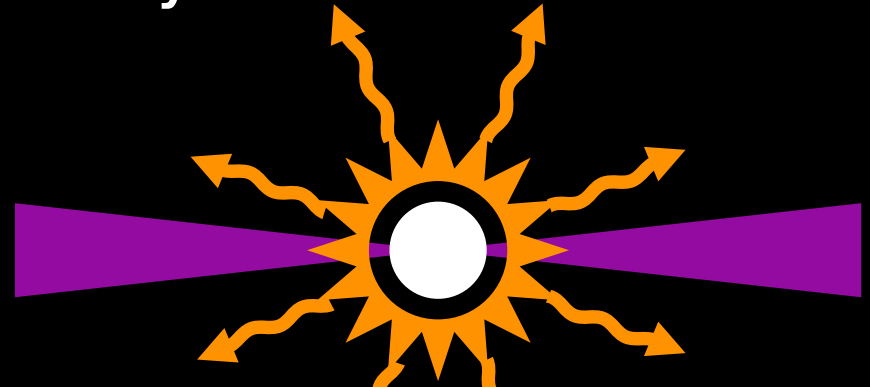
LSST/Roman + DSA

- DSA can detect off-axis GRBs in SNe Ic-bl for $z \lesssim 0.2$ if:
 - high energy ($\gtrsim 10^{51}$ erg)
 - high density ($\gtrsim 10^{-2} \text{ cm}^{-3}$)
 - not far off axis ($\lesssim 30^\circ$)
- $\sim 10\text{--}100$ s $z \lesssim 0.2$ off-axis GRBs/year in DSA
- Biggest challenge: actually classifying Ic-bl



Conclusions + Questions

- We have a PTF candidate off-axis jet, planned VLBI observations will help confirm the source of emission
- The ZTF BTS Ic-bl sample harbors at least 6 more candidates (further observations required)
- What will classification of SNe Ic-bl look like in the future? How can we connect optically discovered SNe with radio surveys like the DSA?



Thank You!

Email: gms279@cornell.edu

[arXiv:2507.15928](https://arxiv.org/abs/2507.15928)