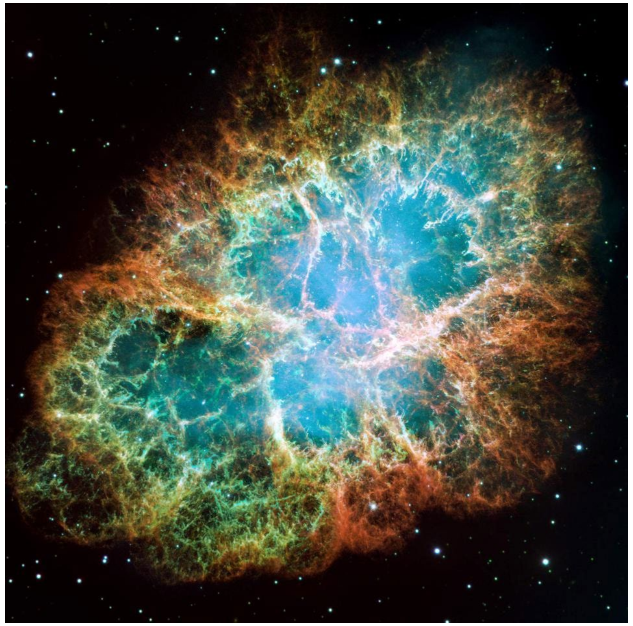
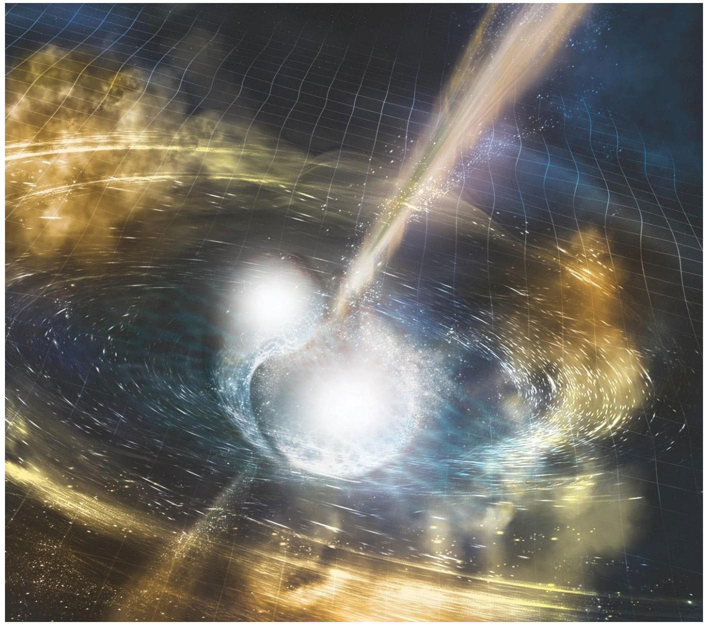
CMB-S4 Summer Collaboration Meeting

The cm-wavelength Transient Sky…

and Lessons for the Systematic Exploration of the mm Sky

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Caltech

Central thesis…

The cm transient sky is rich*

Systematic exploration of the mm transient sky will be rich

Systematic exploration of the mm transient sky will be complementary

The prospects for serendipitous discovery are high

*Timescales of seconds to years

Extragalactic radio transients almost exclusively trace synchrotron emission from shocks…

Excellent means to diagnose relativistic outflows; sensitive to a wider range of energies than the gamma-ray regime

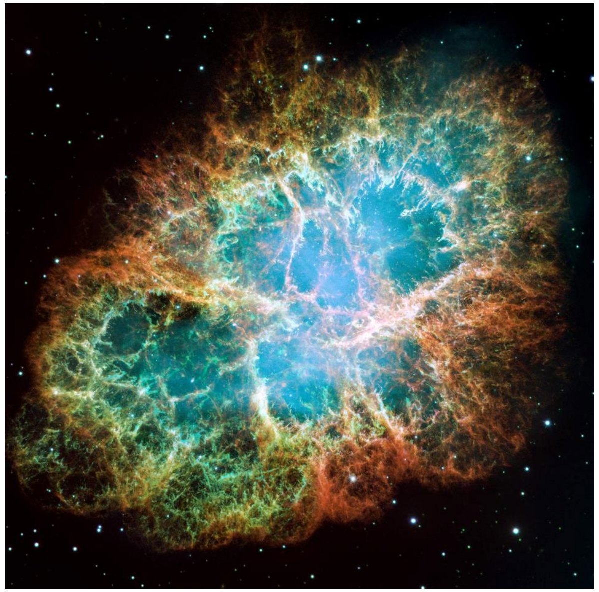
Very sensitive to dense interaction

Largely unaffected by dust obscuration

Accretion

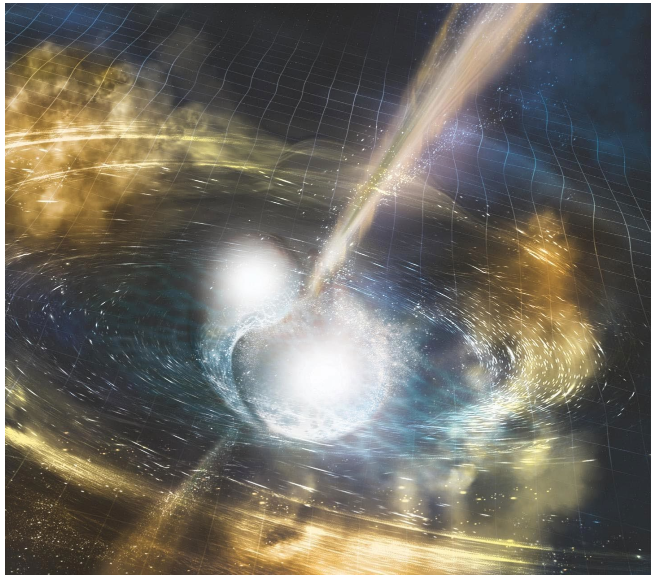
Active Galactic Nuclei (AGN)
Tidal Disruption Events (TDEs)

Core collapse
(young stellar populations)



Supernovae
Long GRBs
Magnetar plerions

Mergers
(old stellar populations)



Neutron star mergers
Short GRBs
Magnetar plerions

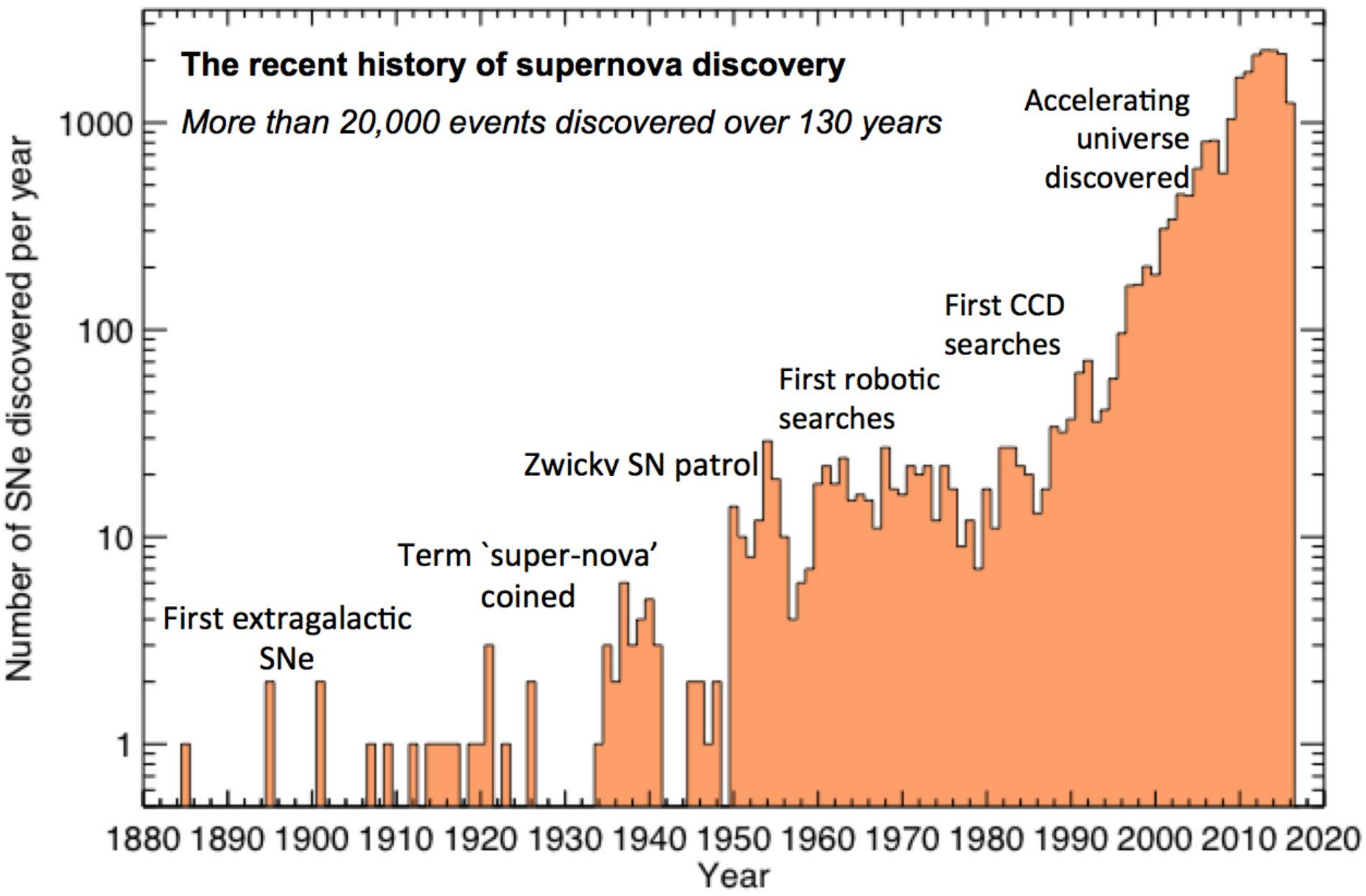
Galactic: Extrasolar Space Weather

The activity and space weather of a star impacts the atmospheric evolution of exoplanets
(Talks by Meredith MacGregor and Rachel Osten)

Traces bulk plasma motion; electron energy – complementary to flare emission in optical/UV/X-rays

A diversity of coherent and incoherent phenomena Crosley & Osten 2018; Villadsen & Hallinan 2019; MacGregor et al. 2021
)

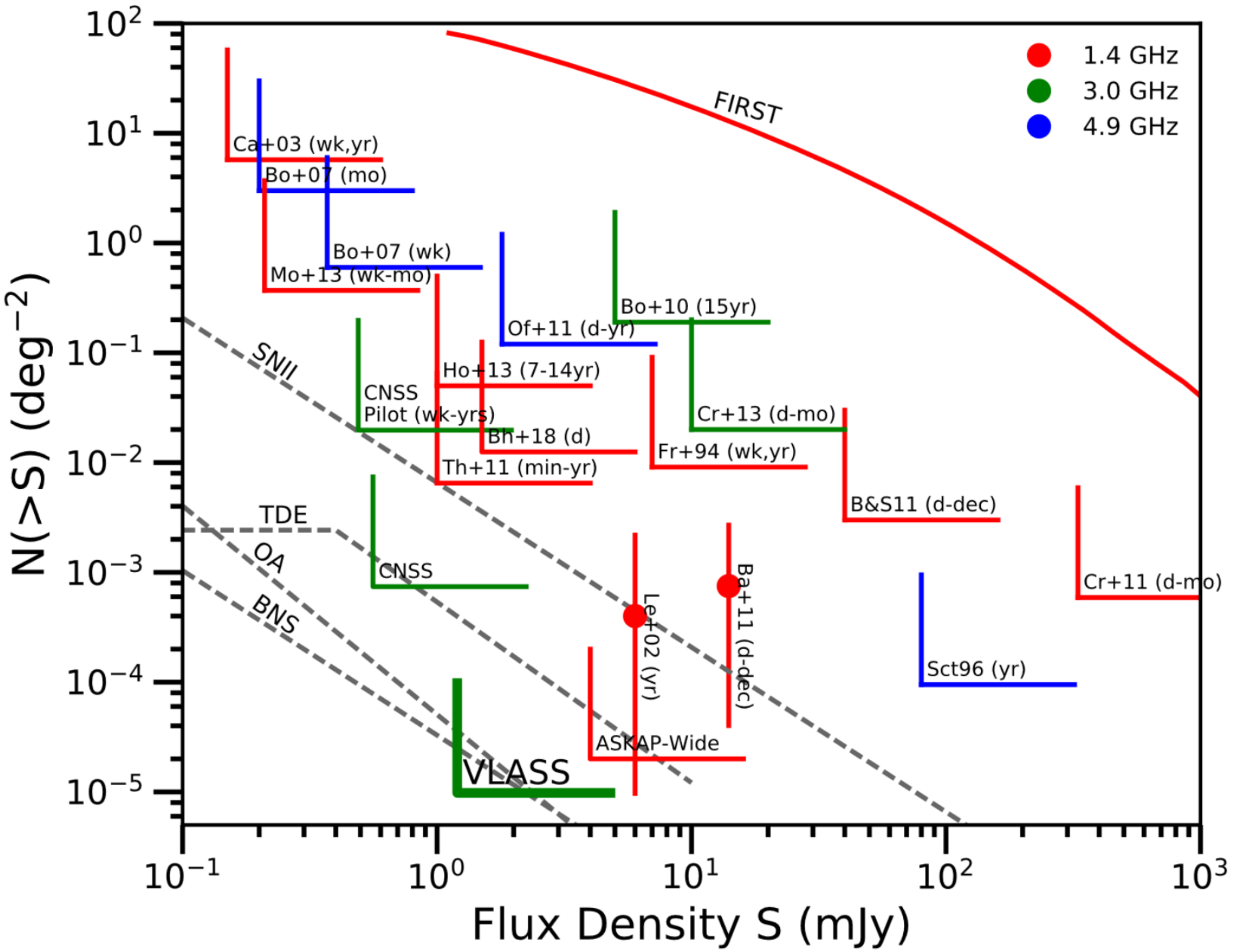
Synoptic radio transient surveys lag optical and higher energy surveys by decades



Number of supernovae discovered per year
(Stritzinger & Moriya 2018)

- Radio has played a key role in **follow-up** of transients

- Systematic searches open up a window on new populations



- Transient detection ∝ survey speed
- survey speed ∝ FoV x $(A_{eff}/T_{sys})^2$
- **Cadence is very important!**

- **Past:** Caltech-NRAO Stripe 82 Survey (CNSS)
- **Current:** VLA Sky Survey (VLASS)
- **Future:** SKA; DSA-2000

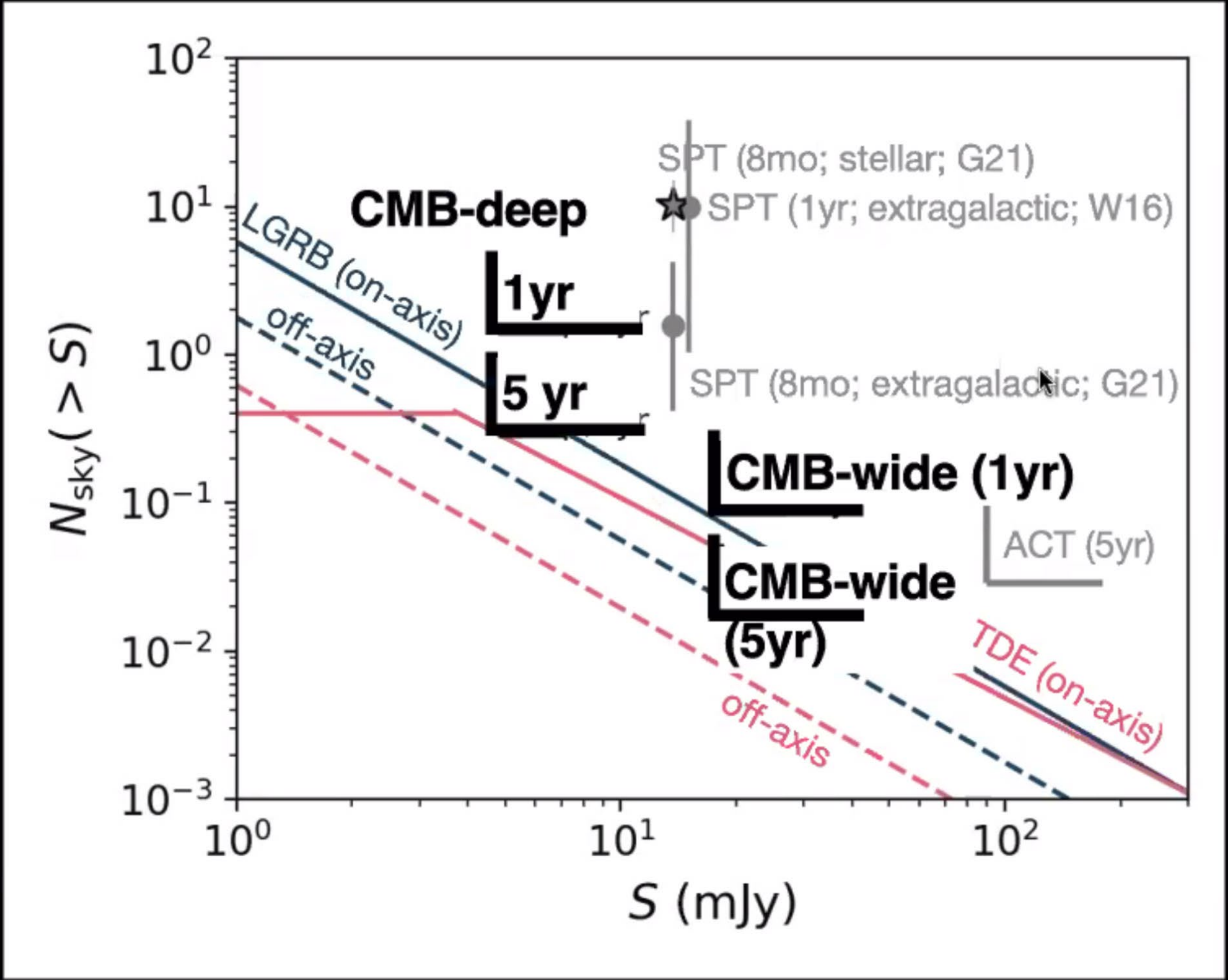
Lacy et al. 2020

CMB-S4 capabilities

More sensitive + wider area

Wide survey (Chile):
half-sky at ~daily cadence
~18 mJy (6σ) in 1 week

3% sky: deep survey (Pole)
~5 mJy (6σ) in 1 week



Slide from Anna Ho: Intro plenary

Advantages mm vs cm

cm:
Survey speed is easier!

mm:

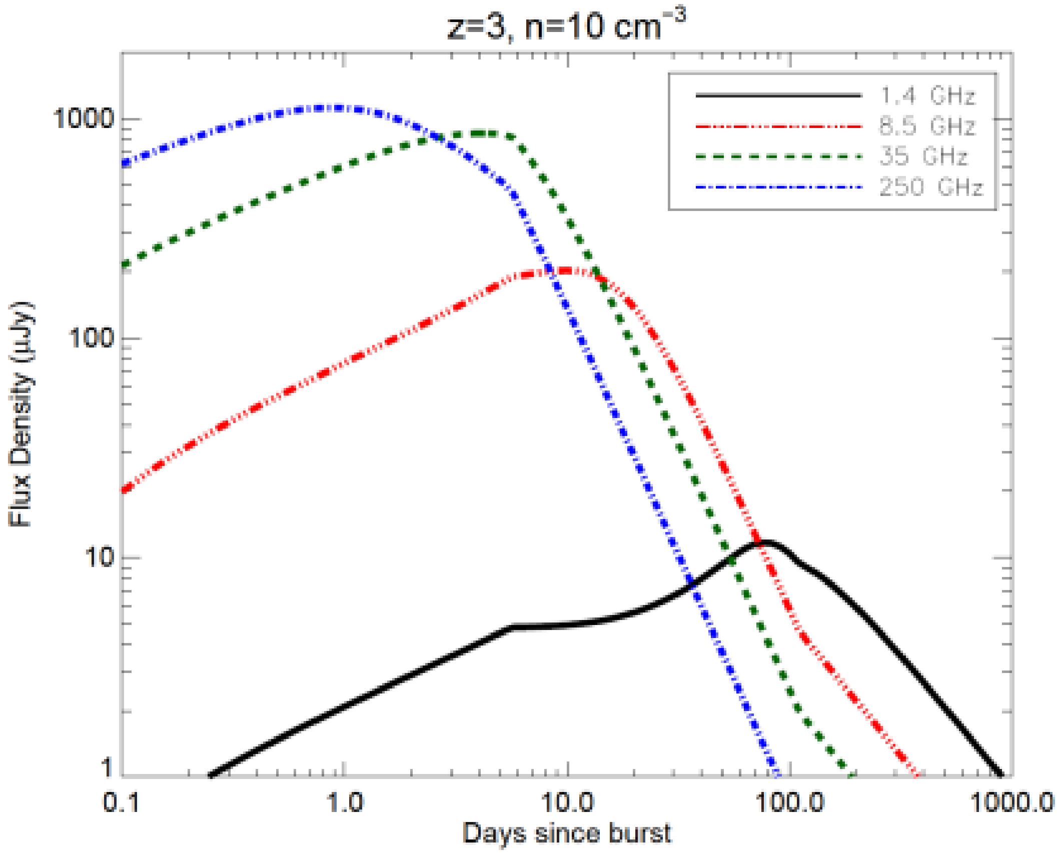
Synchrotron sources often brighter and peak earlier, e.g., GRBs (Antonio Ugarte-Postigo's talk)

Largely unobscured by free-free absorption

Unaffected by propagation effects

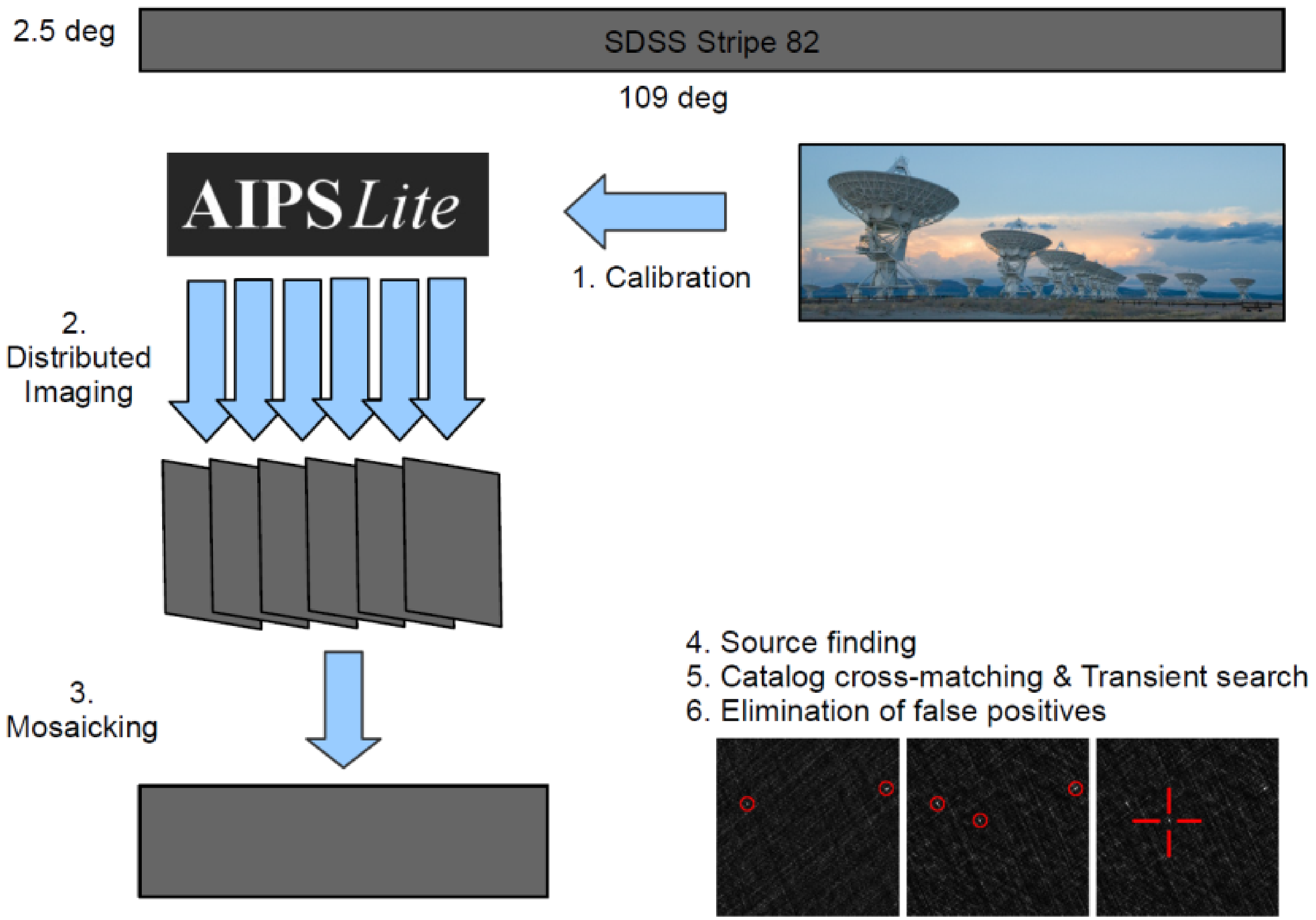
Sensitive to distinct components, e.g. reverse shock – Tanmoy Lasker's talk

Complementary:
growing evidence for dense shells around the sites of supernovae
cm and mm sensitive to shells at different distances



Chandra & Frail 2012

Caltech-NRAO Stripe-82 Survey



- 300 square degrees; 3 epochs to 70 μJy

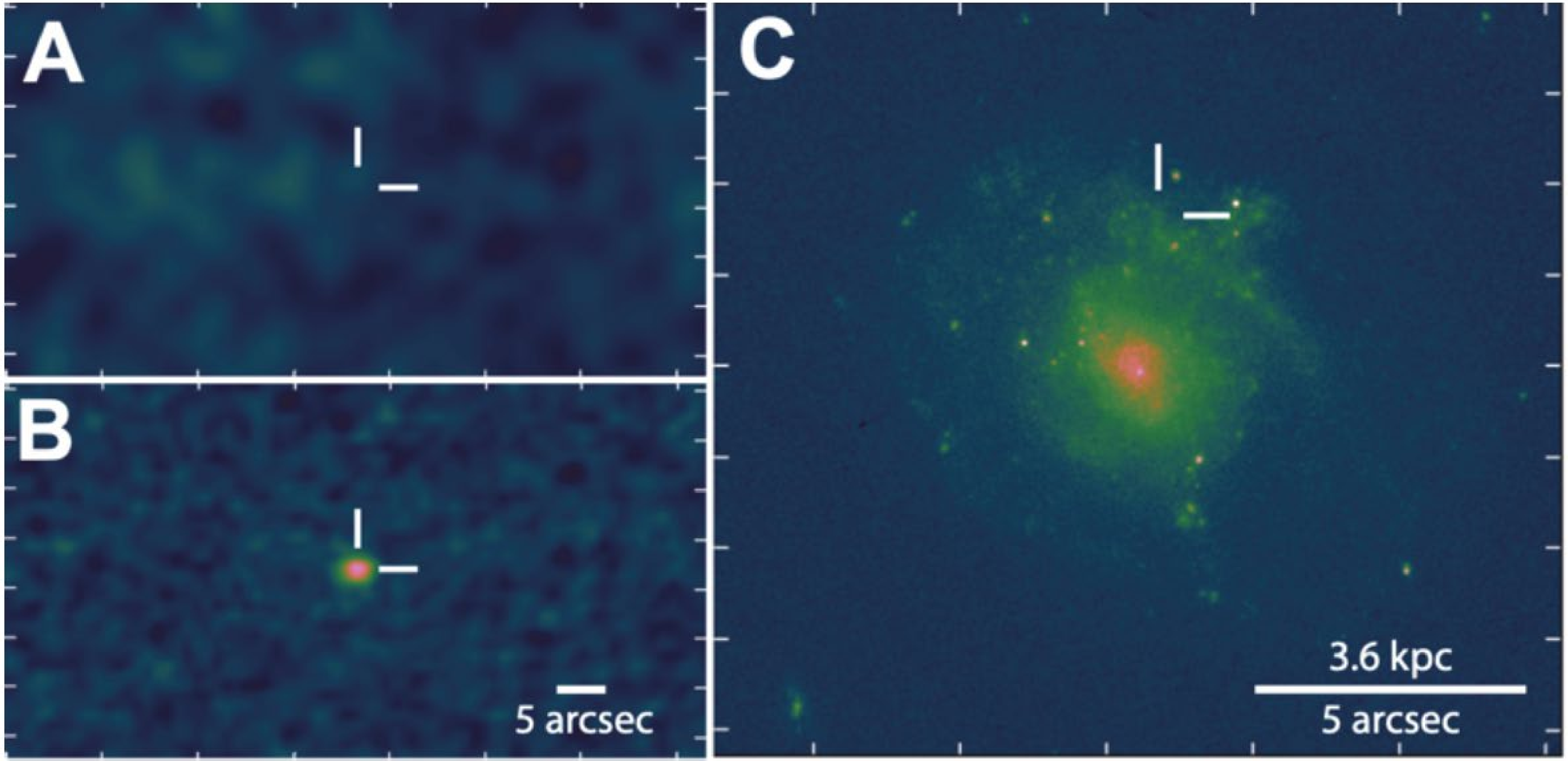
- Extreme AGN variability, stellar flares (Mooley et al. 2016)

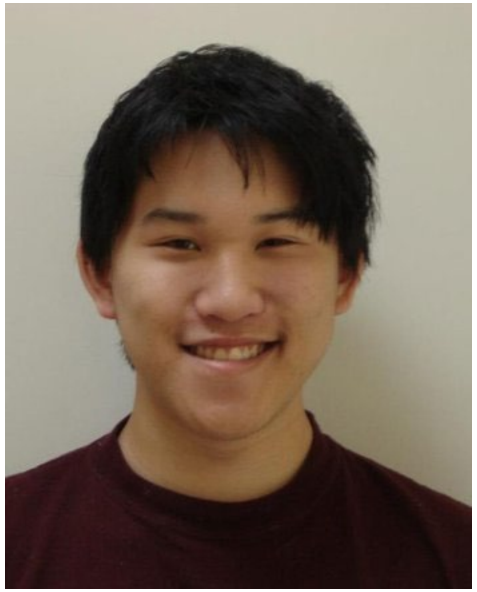
- The first radio discovered TDE, CNSS J0019+00 - (Anderson et al. 2019)

The VLA Sky Survey (VLASS)

- 34,000 deg^2
- 3 epochs over 7 years
- 140 μJy rms noise per epoch (2-4 GHz)
- Currently 50% completed!
- **1200 radio transients in Epoch 2.1 vs Epoch 1.1**
  - *Best candidate for an orphan GRB (Law et al. 2019; Mooley et al. 2021)*
  - *A growing sample of radio-discovered TDEs (Ravi et al. 2021; Somalwar et al. in prep)*
  - *Quasars transitioning from radio-quiet to radio-loud on decade timescales (Nyland et al. 2020)*
  - *Luminous afterglows to historical supernovae (Stroh et al. 2021)*
  - *A merger-driven core collapse supernova (Dong et al. 2021)*

The curious case of VT1210+4956



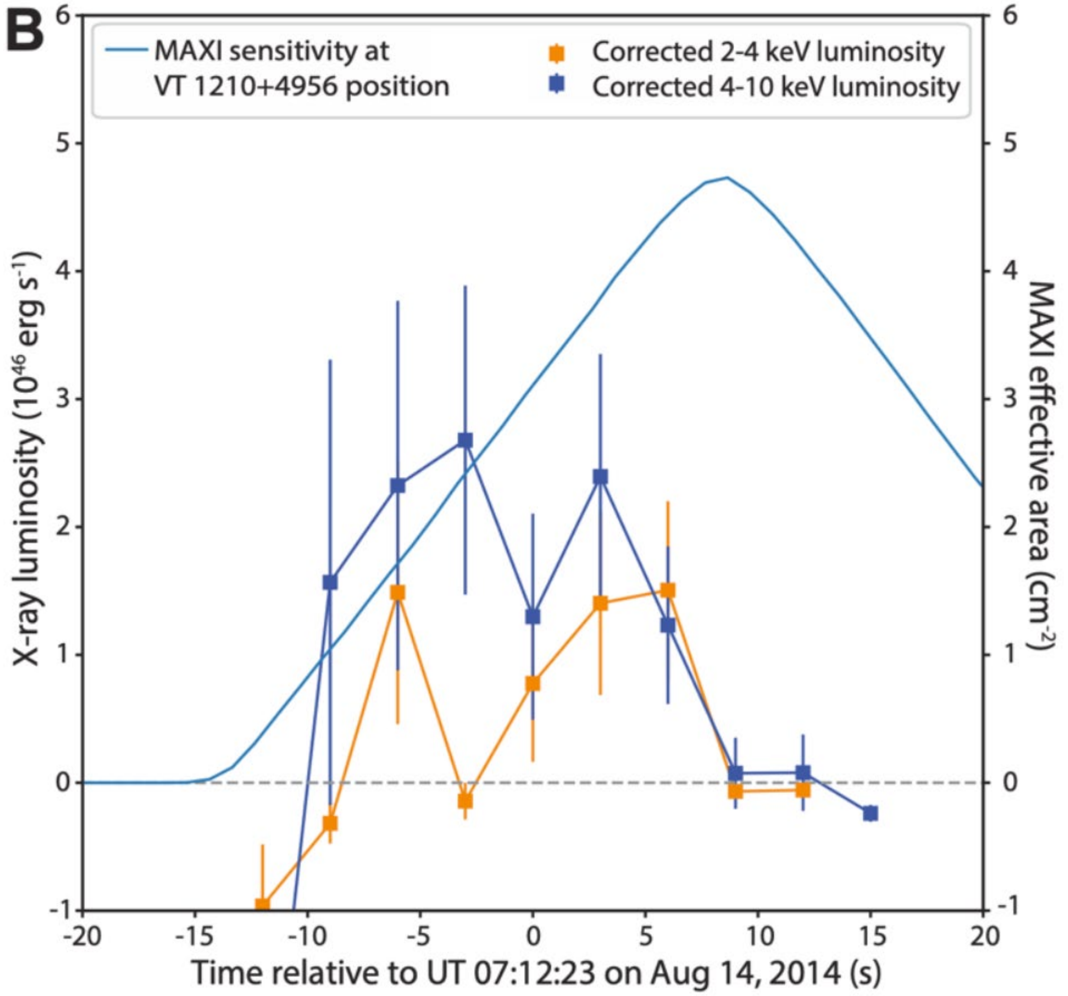


Thesis work of Dillon Dong

- Absent from FIRST; a few mJy in VLASS
- Extremely luminous, $>10^{29}$ erg s^{-1} Hz^{-1}
- Residing on a galaxy at 149 Mpc

The curious case of VT1210+4956

- Radio transients , $>10^{29}$ erg s^{-1} Hz^{-1} usually associated with relativistic transients
- Association found with MAXI GRB 140814A
- Properties imply a jet



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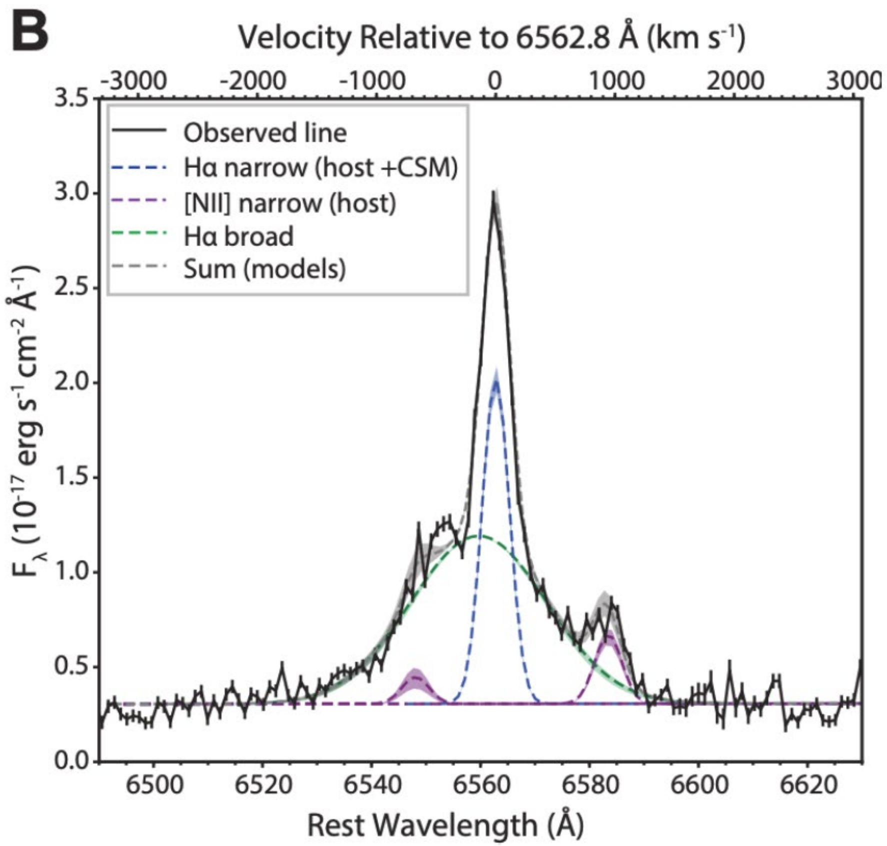
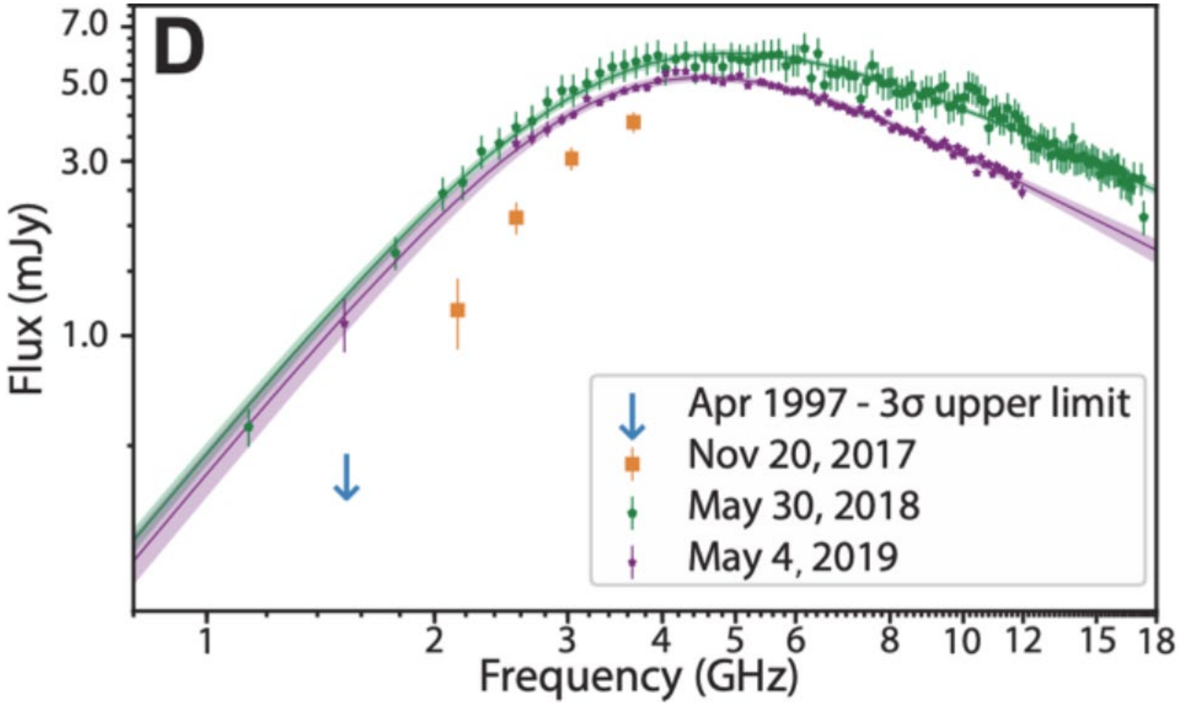
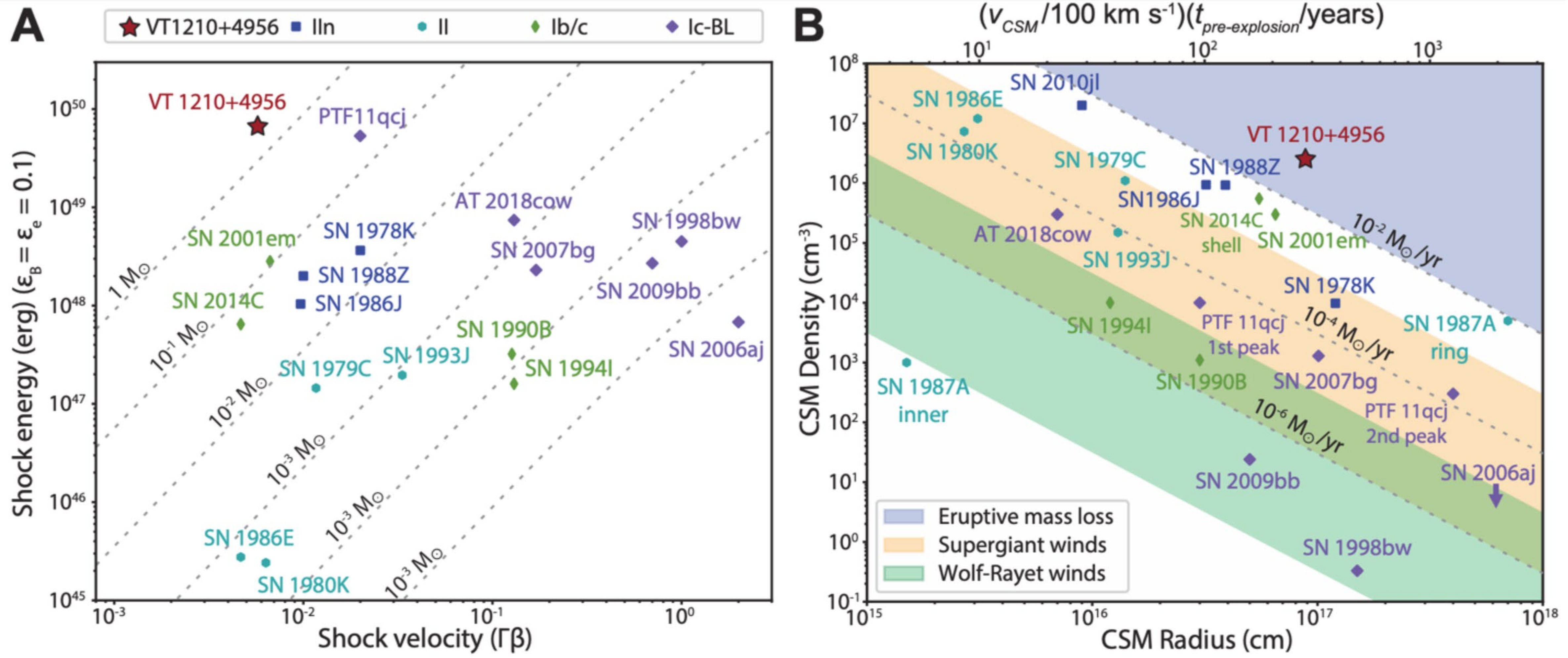


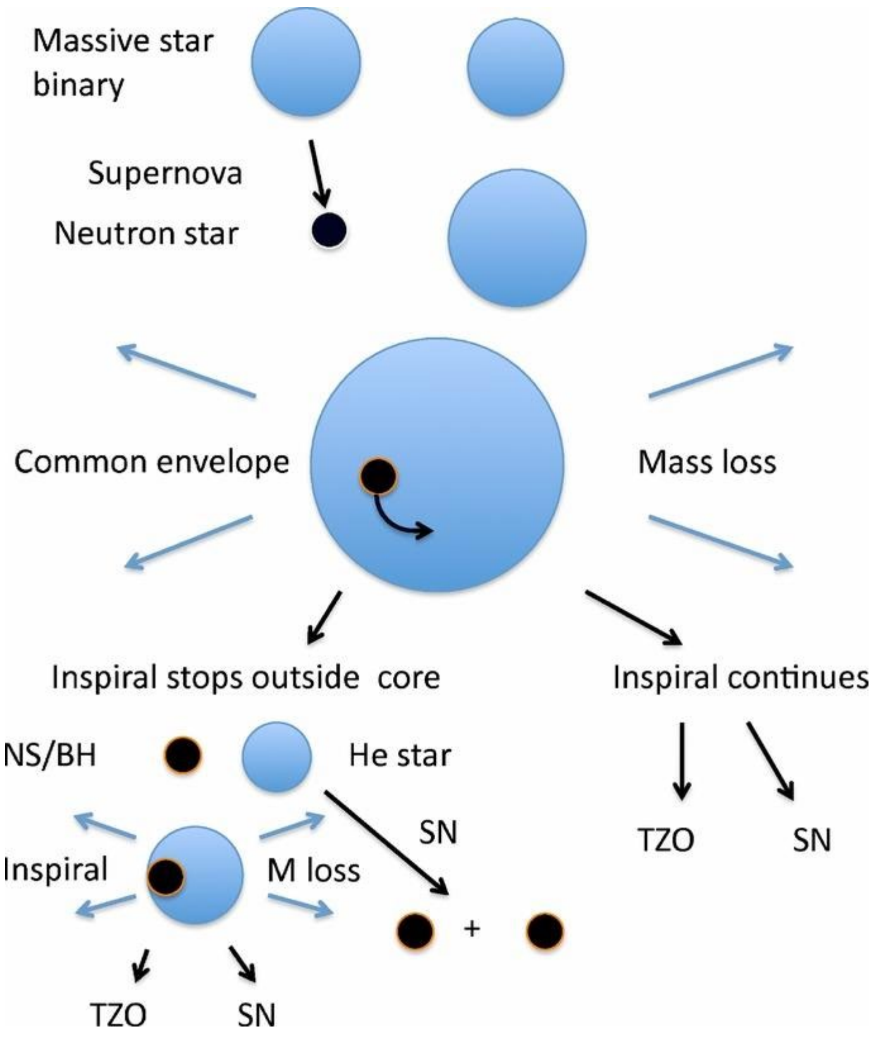


- Radio and optical follow-up data confirm a **slow-moving** shock (~1340 km/s)
- Size of 10^{17} cm

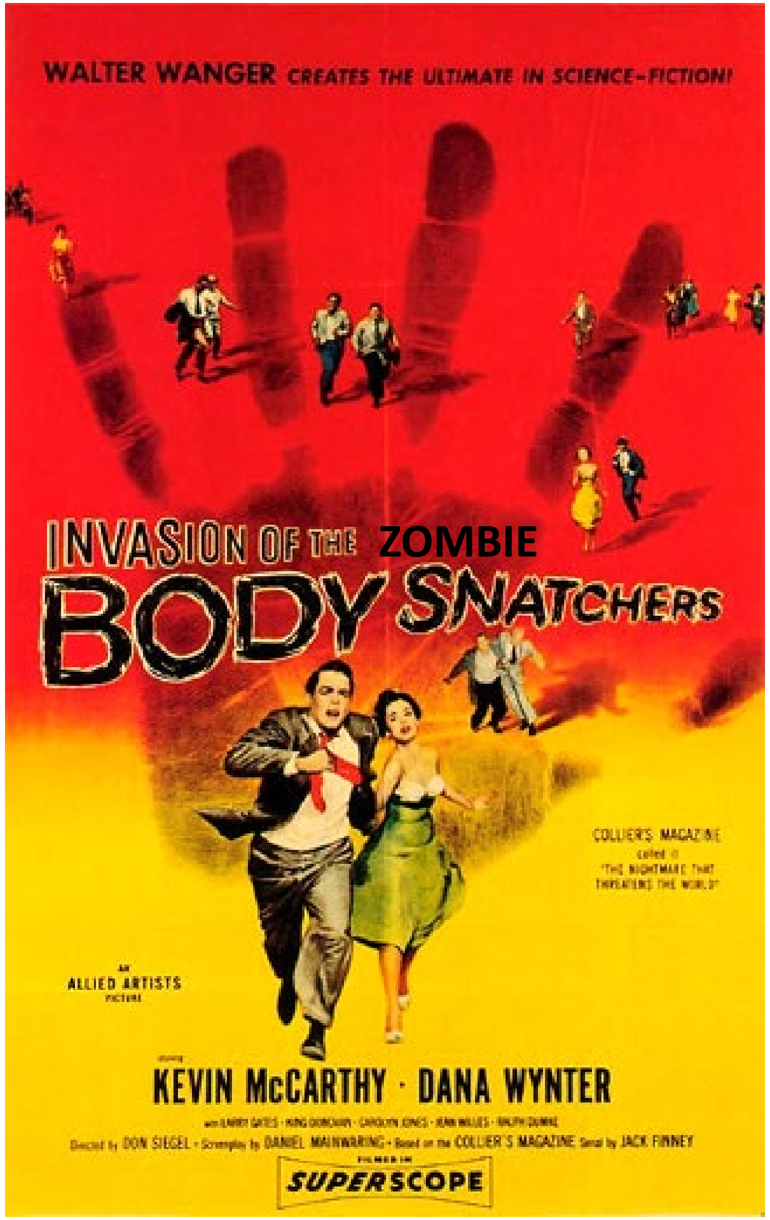
The curious case of VT1210+4956



- The corresponding supernova ejecta hit a shell of >1 solar mass at 10^{17} cm
- Requires eruptive mass loss centuries prior to explosion – binary interaction favored



Chevalier et al. 2012



Dong et al. 2021, Science

Chase the expected; expect the unexpected

There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.

Prioritize the transient science unique to CMB-S4;
high probability of the serendipitous

Transients that look innocuous at other wavelengths – e.g. AT2018cow (Ho et al. 2019)

Discovered at mm wavelengths - Incredibly energetic mm stellar flares (e.g. Guns et al. 2021)

Localization is essential! [ALMA, NOEMA, SMA, SPRITE]
Multi-wavelength archival data is important
Triggered follow-up is important (e.g. broadband radio spectra) - propose triggered programs in advance
Polarization is useful

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