Observing Transients with SKA Pathfinders

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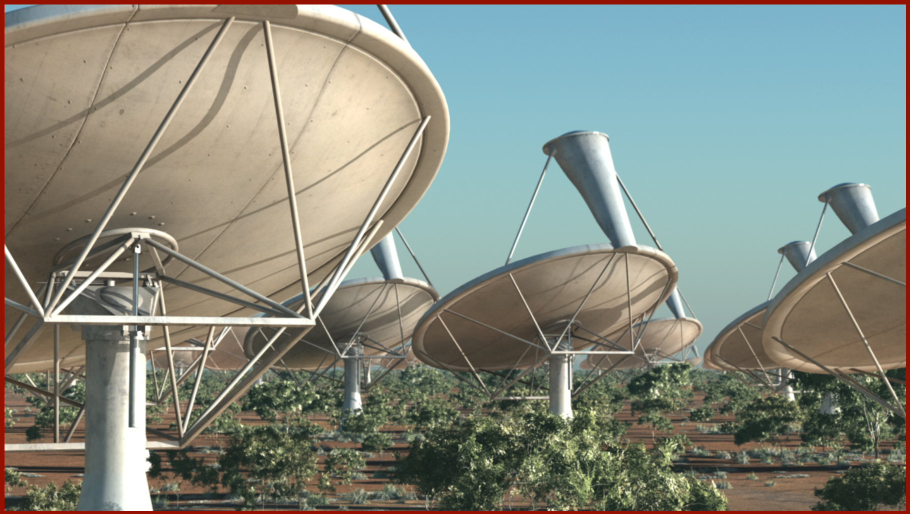
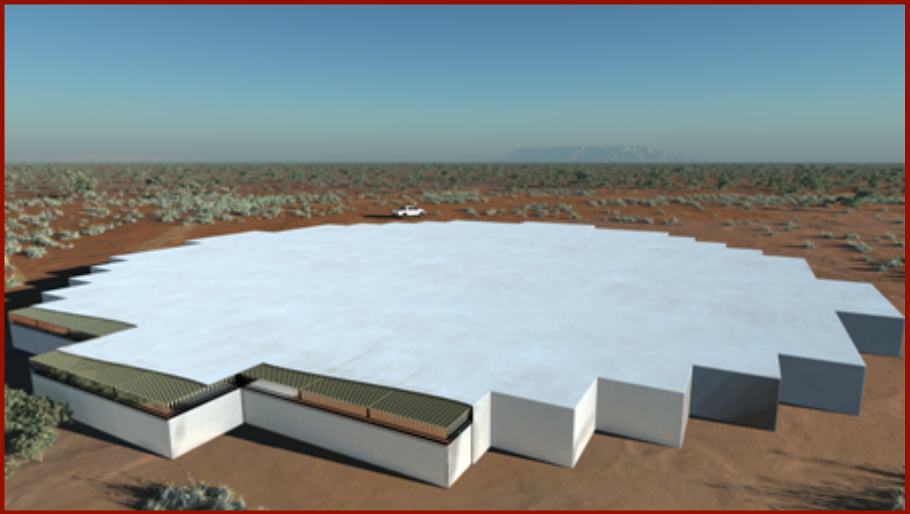
The Square Kilometre Array: The Future of Radio Astronomy

Three antenna technologies required to access full frequency range.



Aperture Array in Australia: 0.5–10 GHz



Dishes and Aperture Array in South Africa: 0.4–10 GHz

In the Meantime: Bright Prospects with SKA Pathfinders!

MeerKAT (South Africa)

Jansky VLA (USA)

LOFAR (Europe)

ASKAP (Australia)

Outline

- What do we know about the radio transient sky?
- How can we improve searches for radio transients?
- What successes do we expect from SKA pathfinders?
- How will SKA pathfinders improve our understanding of novae?

What do we know about the radio transient sky?

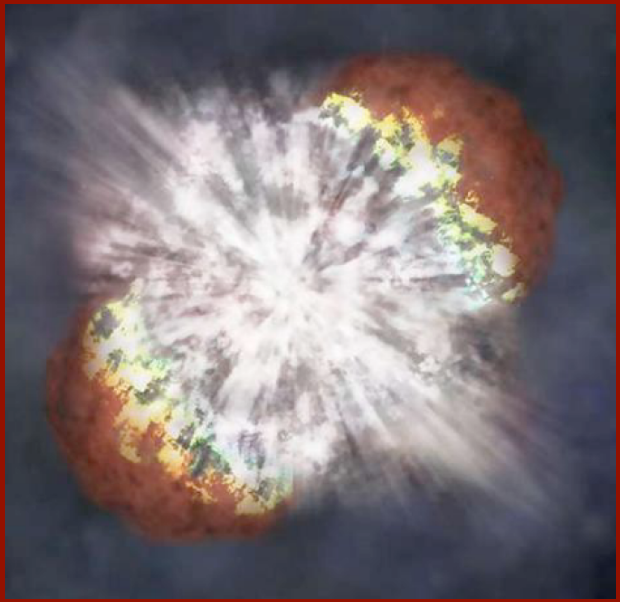
Three kinds of radio emission:

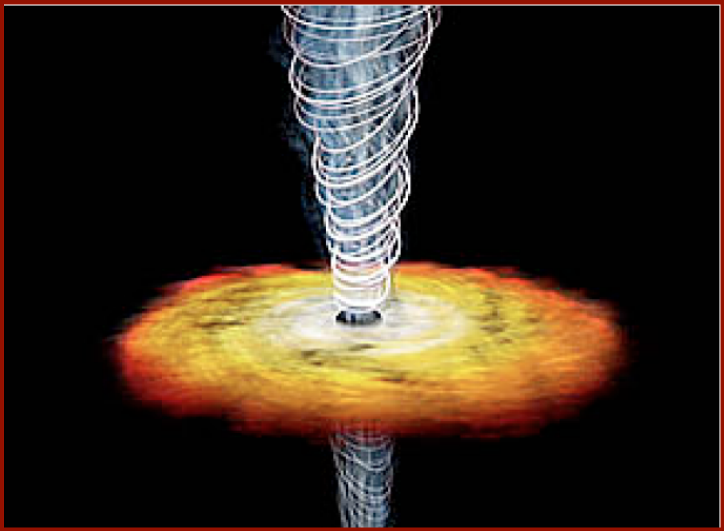
Synchrotron

Non-thermal coherent

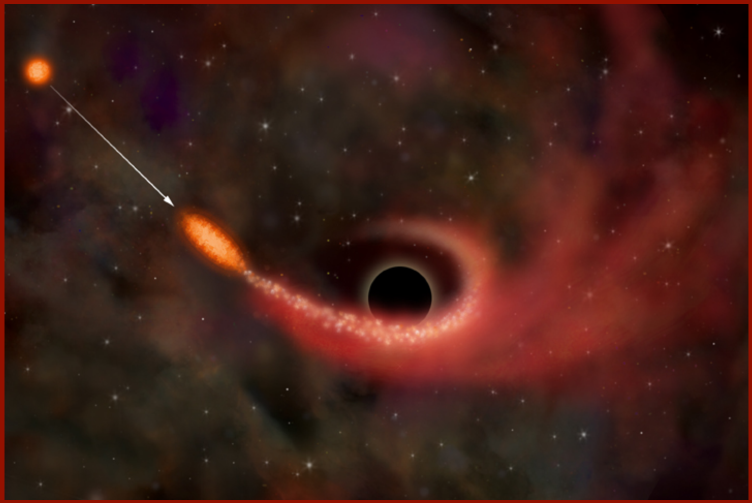
Thermal

Synchrotron emission traces shocks and jets.





- Gamma-ray bursts
- Supernovae
- X-ray binaries
- Tidal disruption events



(the majority of ‘slow’ radio transients)

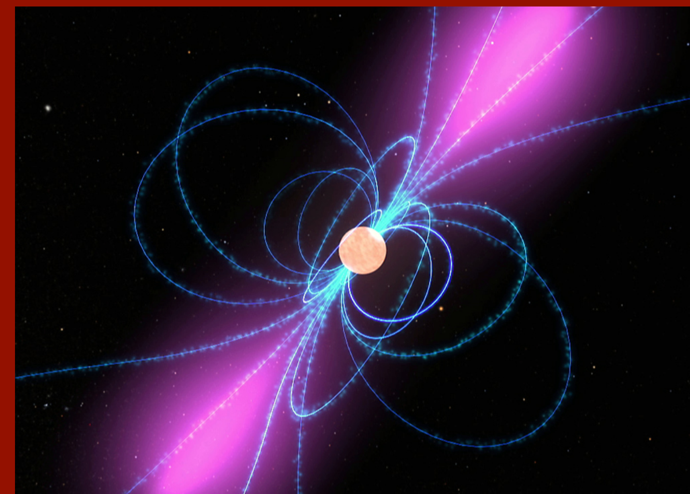
Three kinds of radio emission:

Synchrotron

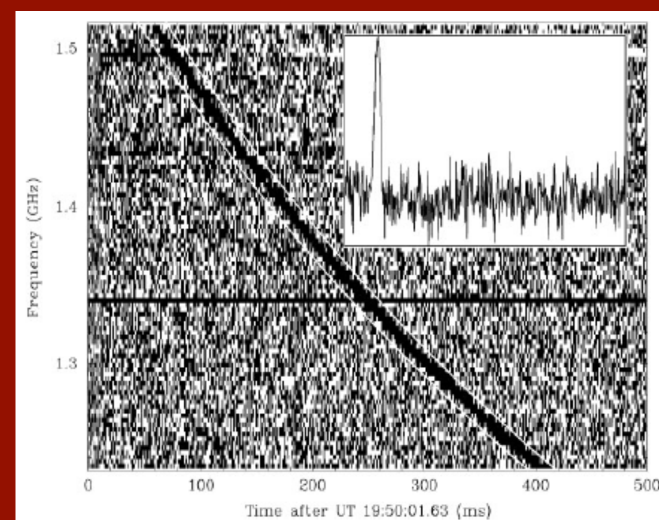
Non-thermal coherent

Thermal

'Fast' radio transients (<~ 1 sec duration)



- Pulsars
- Flare Stars
- Lorimer bursts ??



Lorimer et al. 2007

Different strategies used to study these--- but can be complementary with searches for 'slow' transients (>1 sec)

Three kinds of radio emission:

Synchrotron

Non-thermal coherent

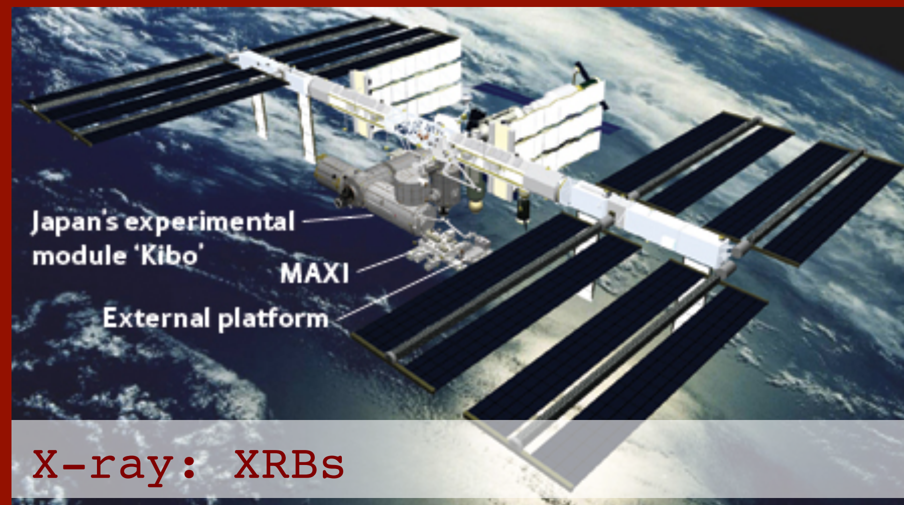
Thermal

Expanding H II regions

- Novae
- Symbiotic Stars

Radio transients aren't usually discovered in the radio.

gamma-ray: GRBs, novae(!)

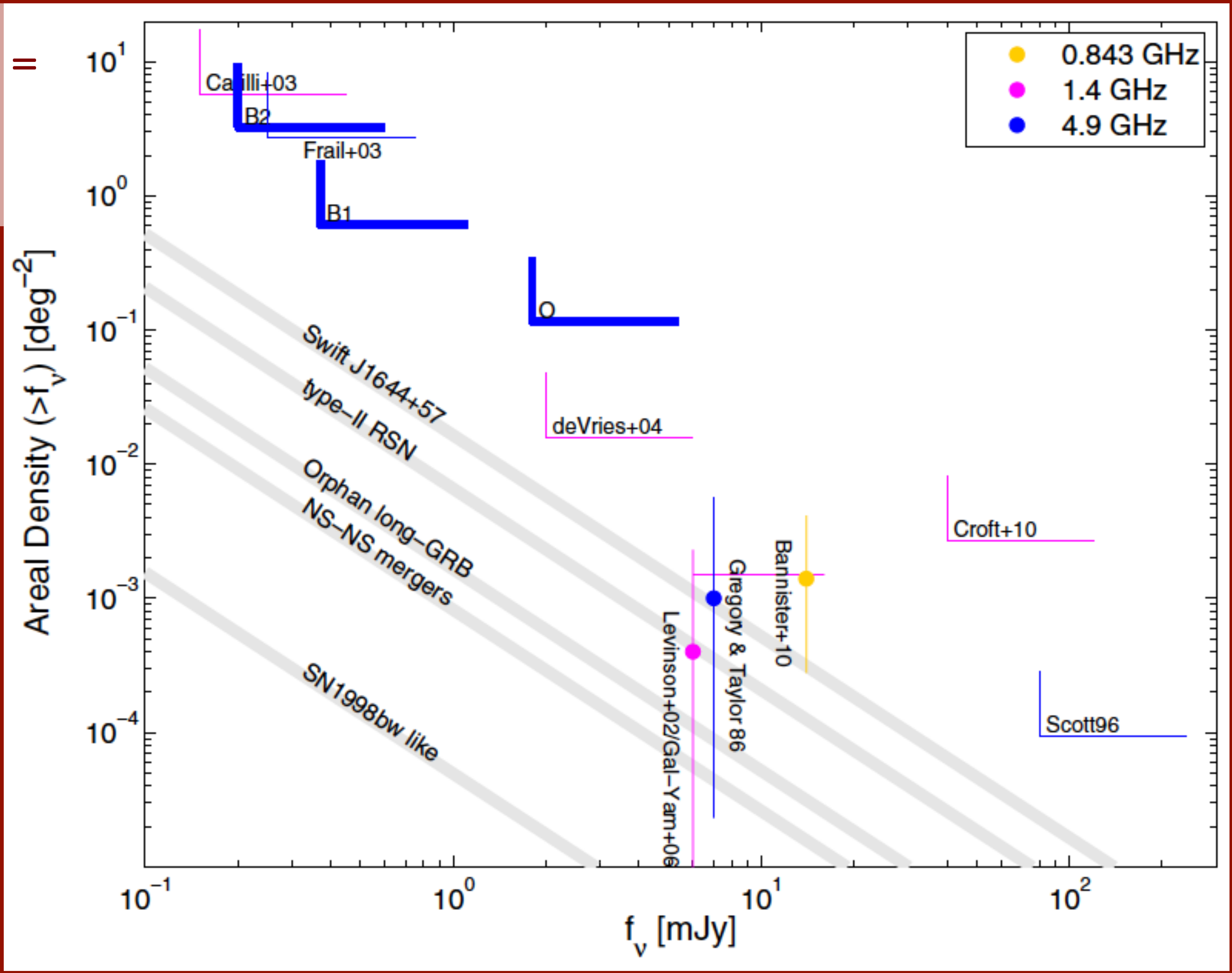


X-ray: XRBs

Optical: Supernovae, Novae

We are on the cusp of discovering slow radio transients through blind searches.

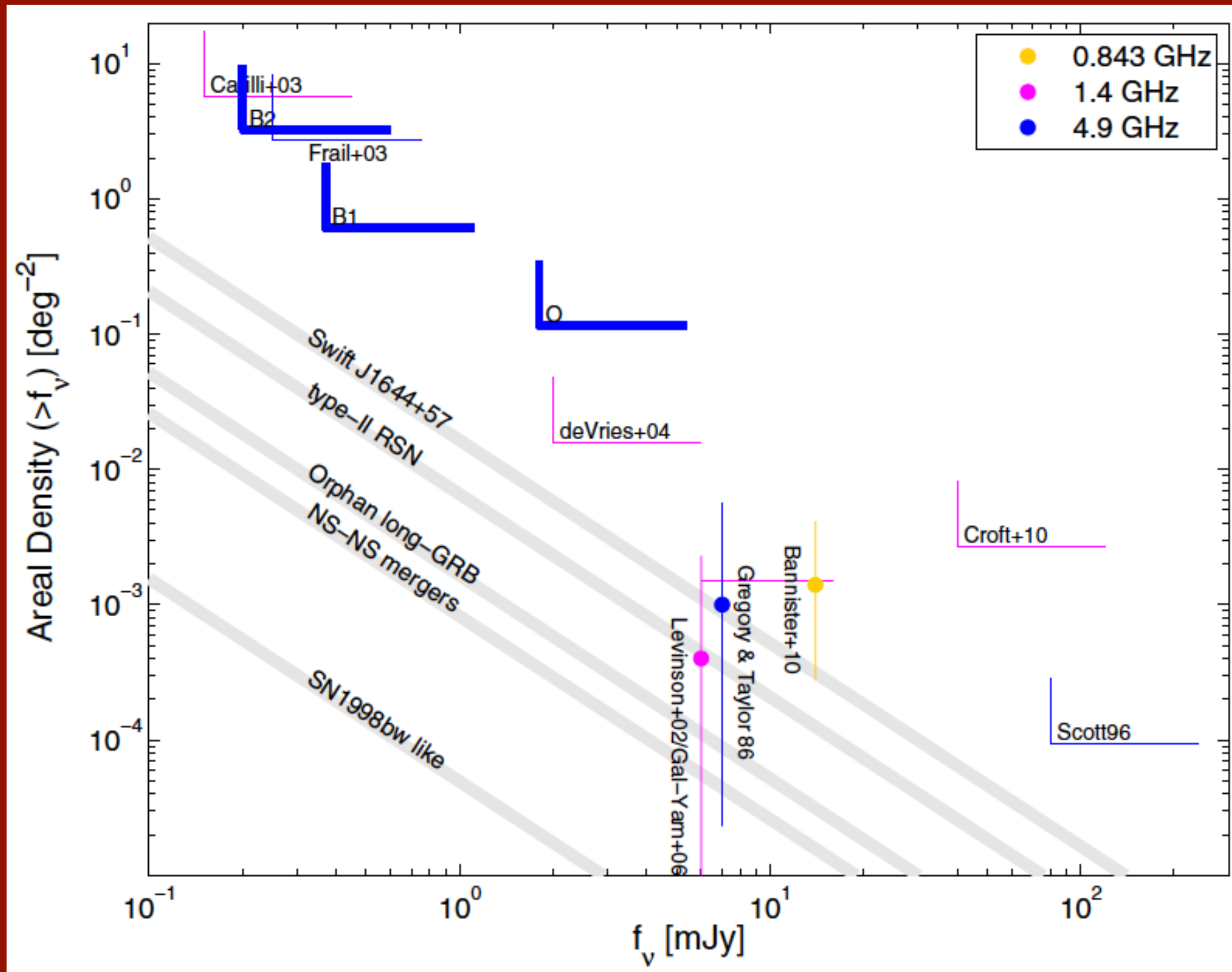
$$\frac{1}{\text{Survey Area}} = \frac{1}{(N_{epochs}-1) * \text{Field Area}}$$



Frail et al. 2012

How can we improve searches for radio transients?

How can we improve searches for radio transients?

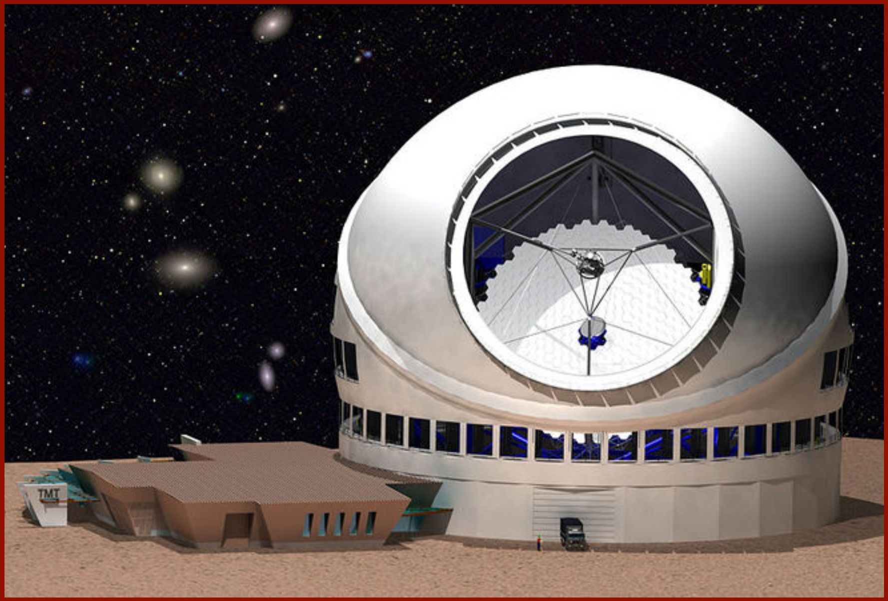


More survey area

More sensitivity

Frail et al. 2012

Improving Searches for Radio Transients: More Sensitivity



Ground-based optical:

$$\frac{S}{N} \propto \sqrt{A}$$

Radio:

$$\frac{S}{N} \propto A$$

Improving Searches for Radio Transients: Better Computers

100 MHz → 8 GHz bandwidth

factor of ~9.5 in S/N!

Arrays with many elements are possible to correlate.

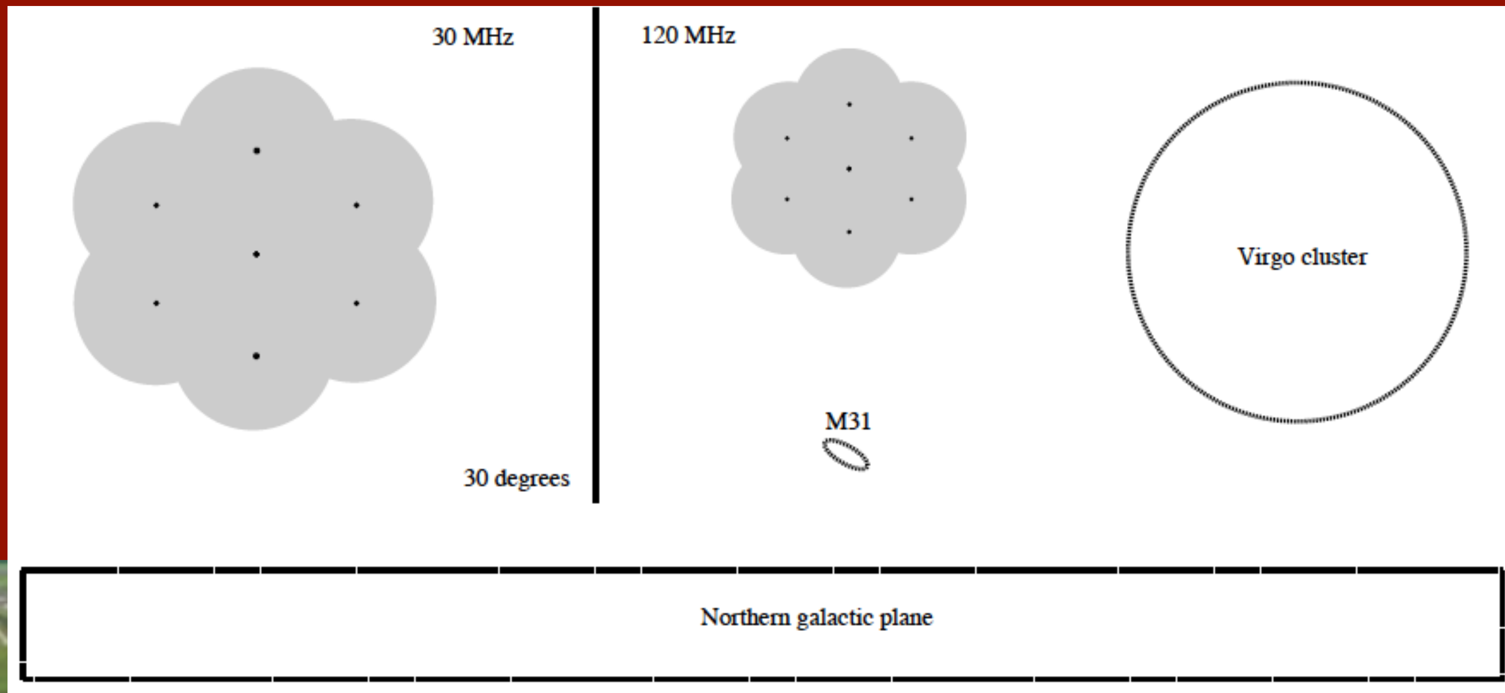
Improving Searches for Radio Transients: More Survey Area

$$\mathrm{FOV} \approx \frac{\lambda}{D_{\mathrm{dish}}}$$

Large N—small D arrays

Phased arrays of receivers give a FOV of 30 sq. deg. on ASKAP.

Improving Survey Area: Beam Forming at LOFAR



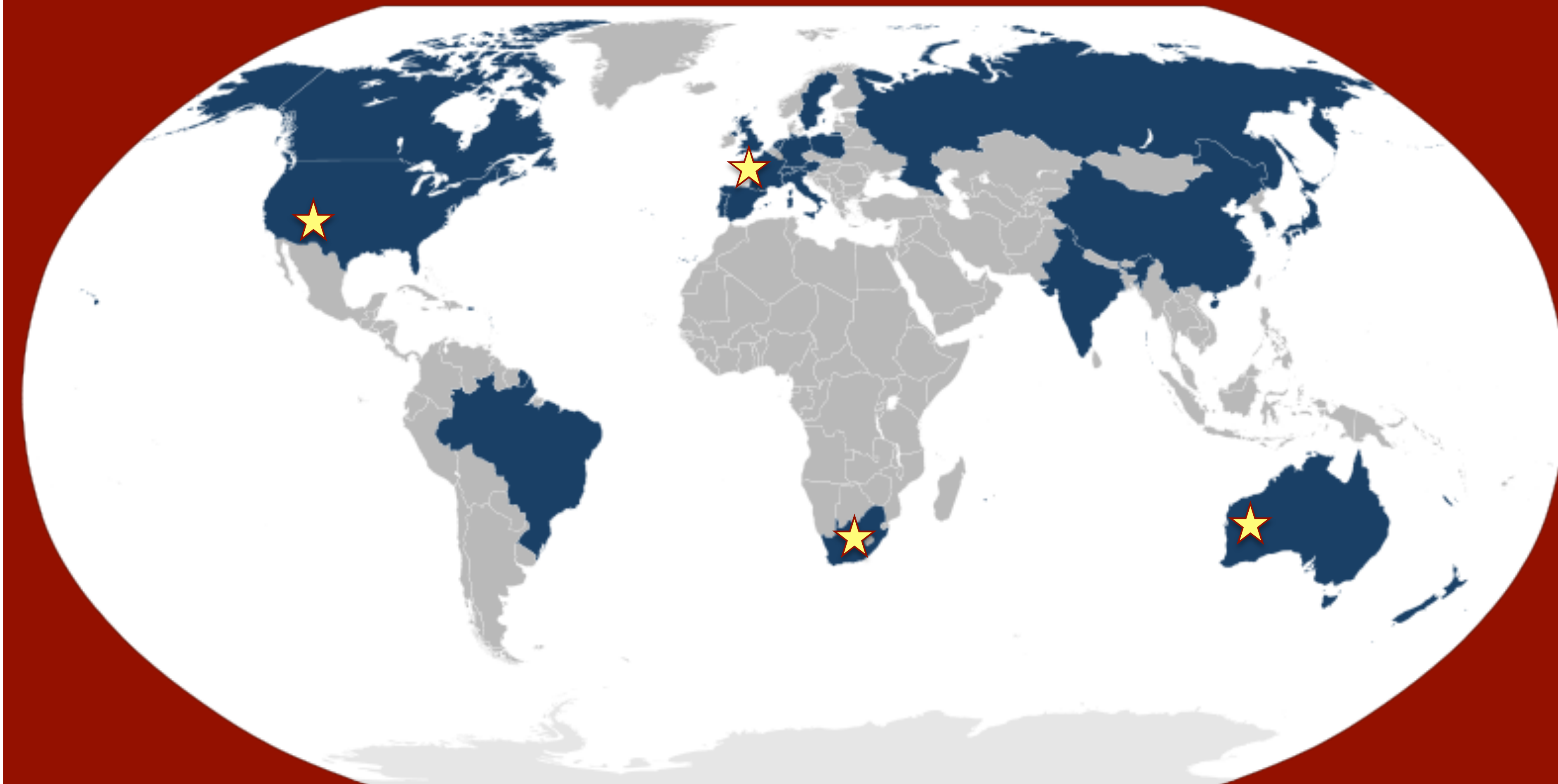
8 simultaneous beams, each of:

90 sq deg (30–80 MHz)

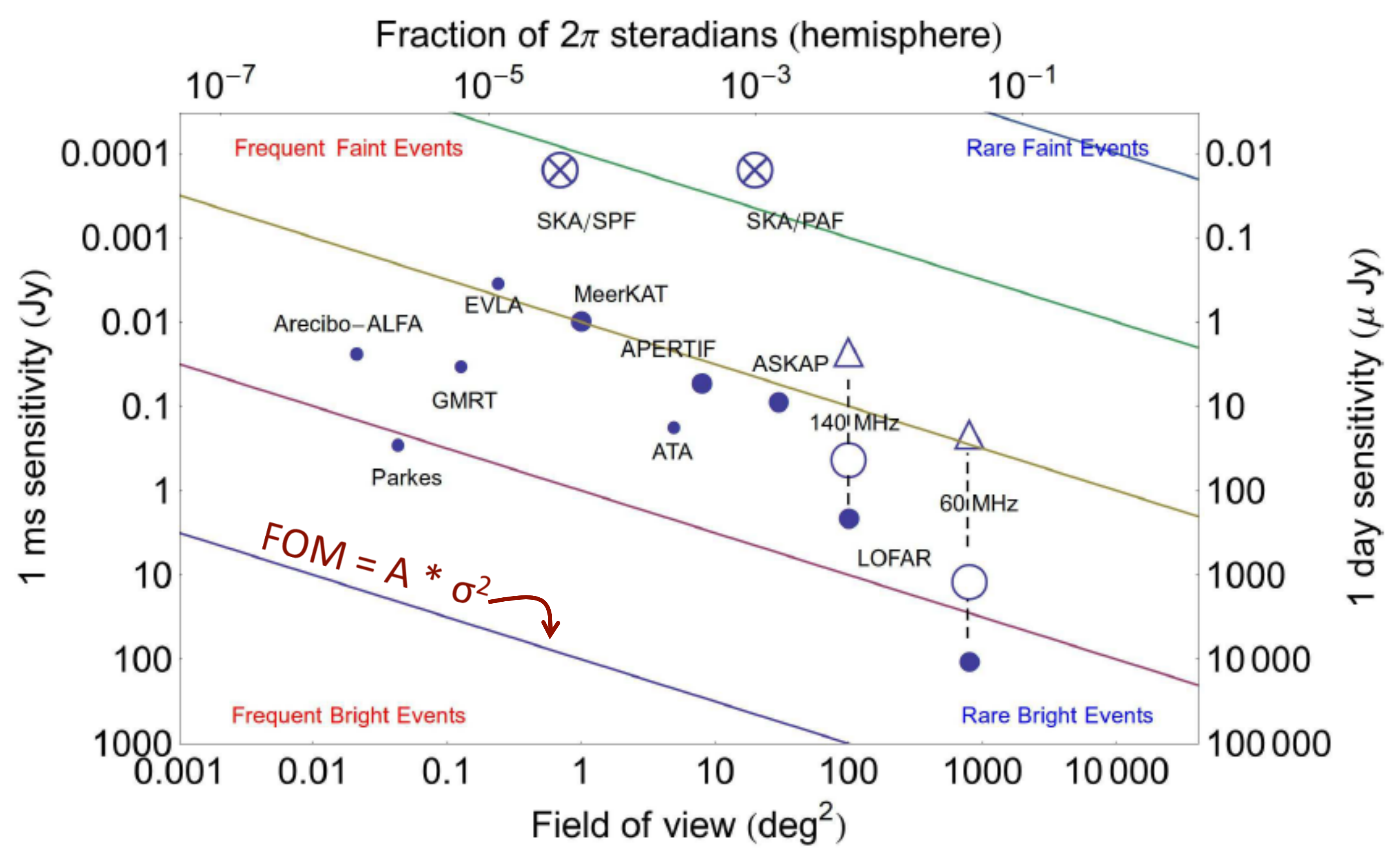
25 sq deg (120–240 MHz)

Tackling the transient sky with SKA pathfinders

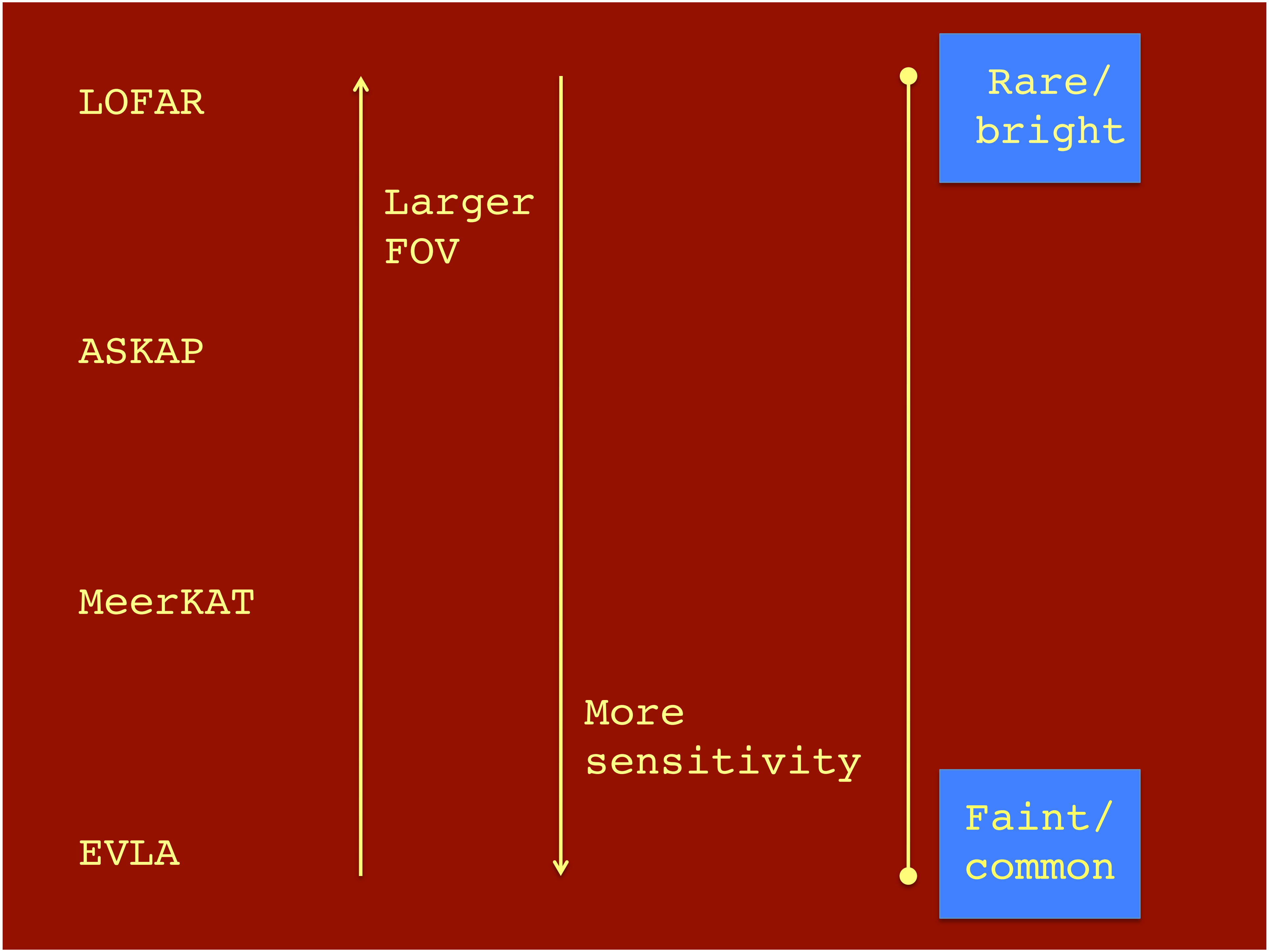
SKA pathfinders are nicely divided between north and south.

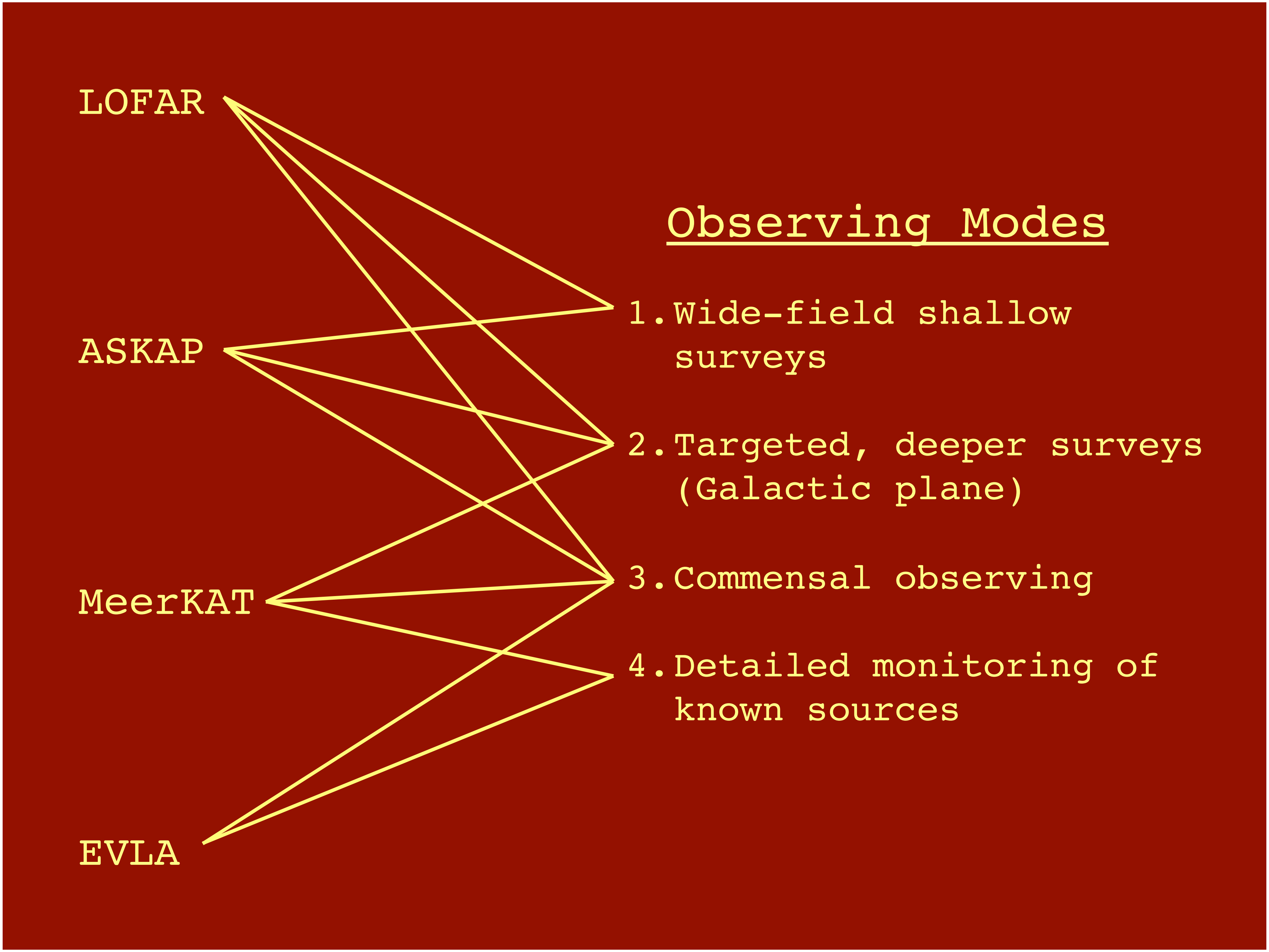


SKA pathfinders all have roughly the same figure of merit for transient searches.

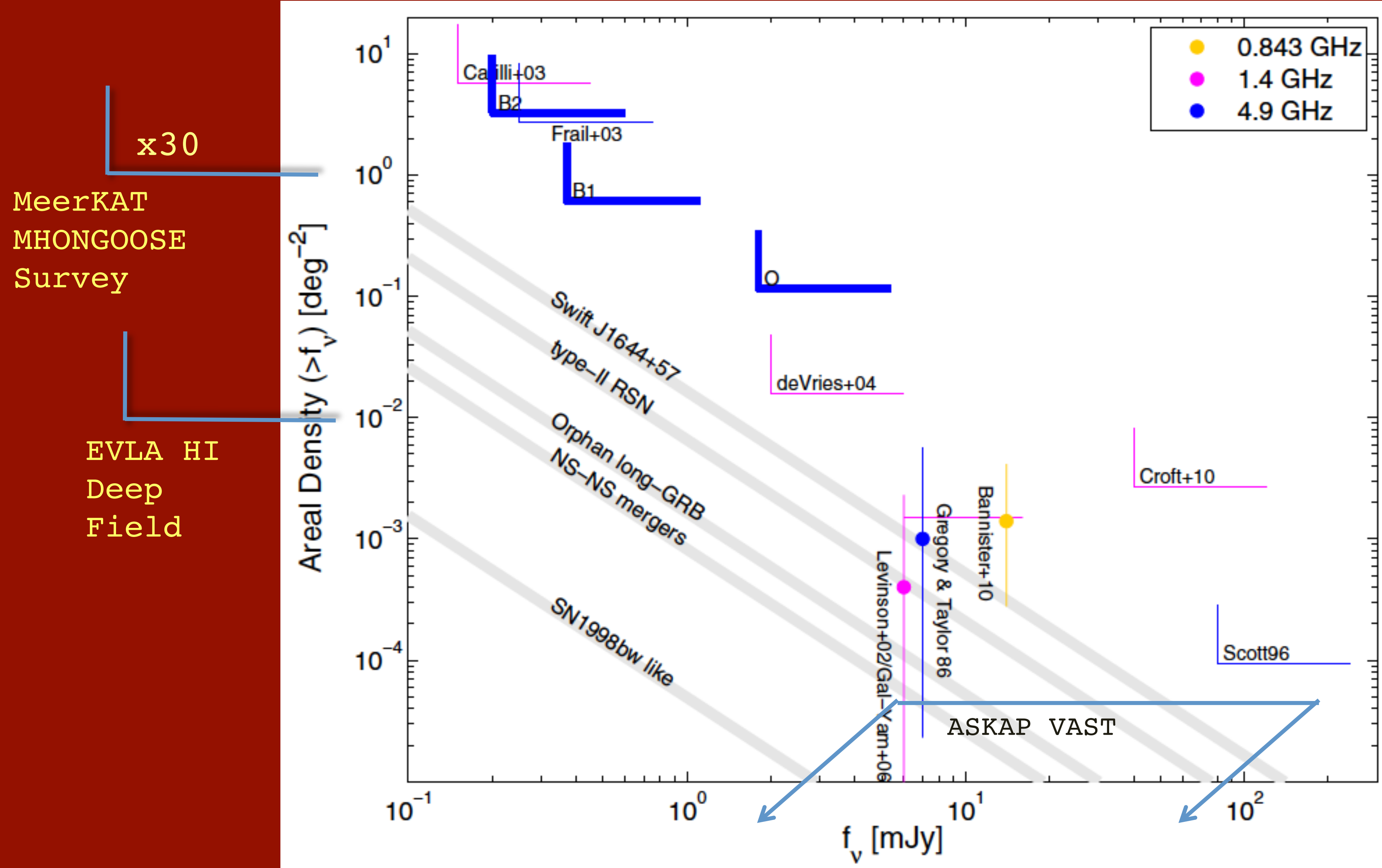


Fender et al. 2011

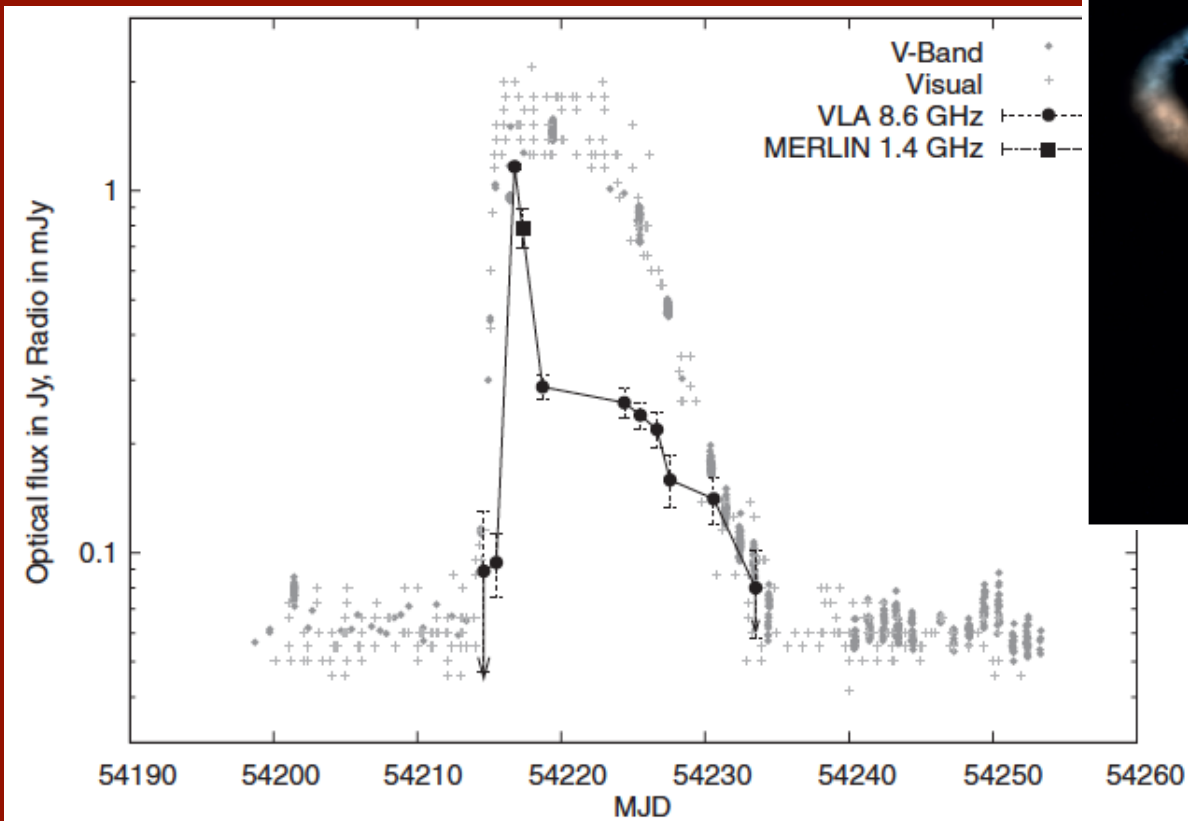

LOFAR
ASKAP
MeerKAT
EVLA
Larger FOV
More sensitivity
Rare/ bright
Faint/ common

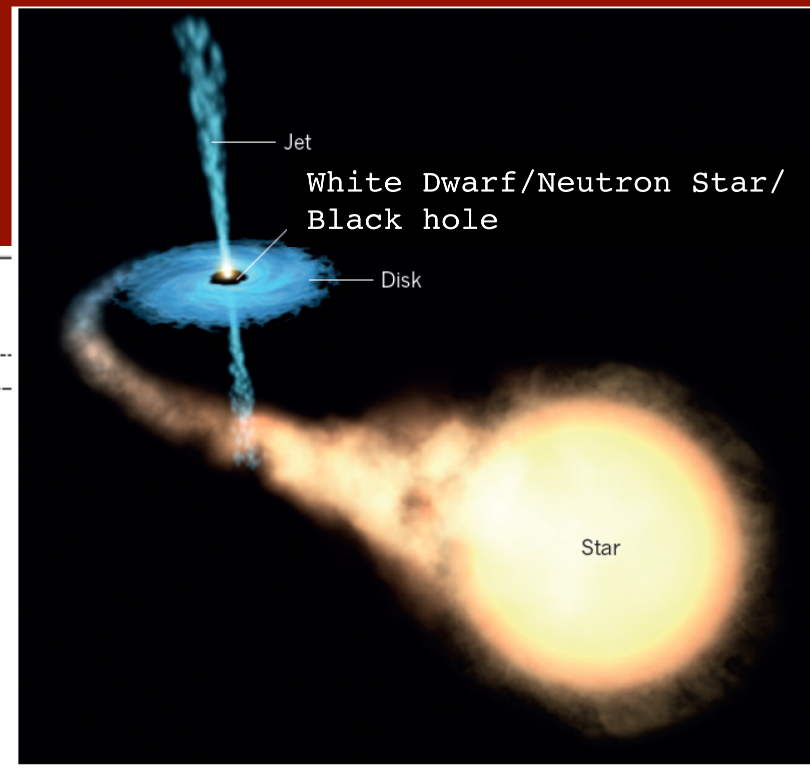

LOFAR
ASKAP
MeerKAT
EVLA
Observing Modes
1. Wide-field shallow surveys
2. Targeted, deeper surveys (Galactic plane)
3. Commensal observing
4. Detailed monitoring of known sources

SKA Pathfinders will thoroughly probe radio transient parameter space.



The Joys of Commensal Observing: Accreting Binaries with MeerKAT

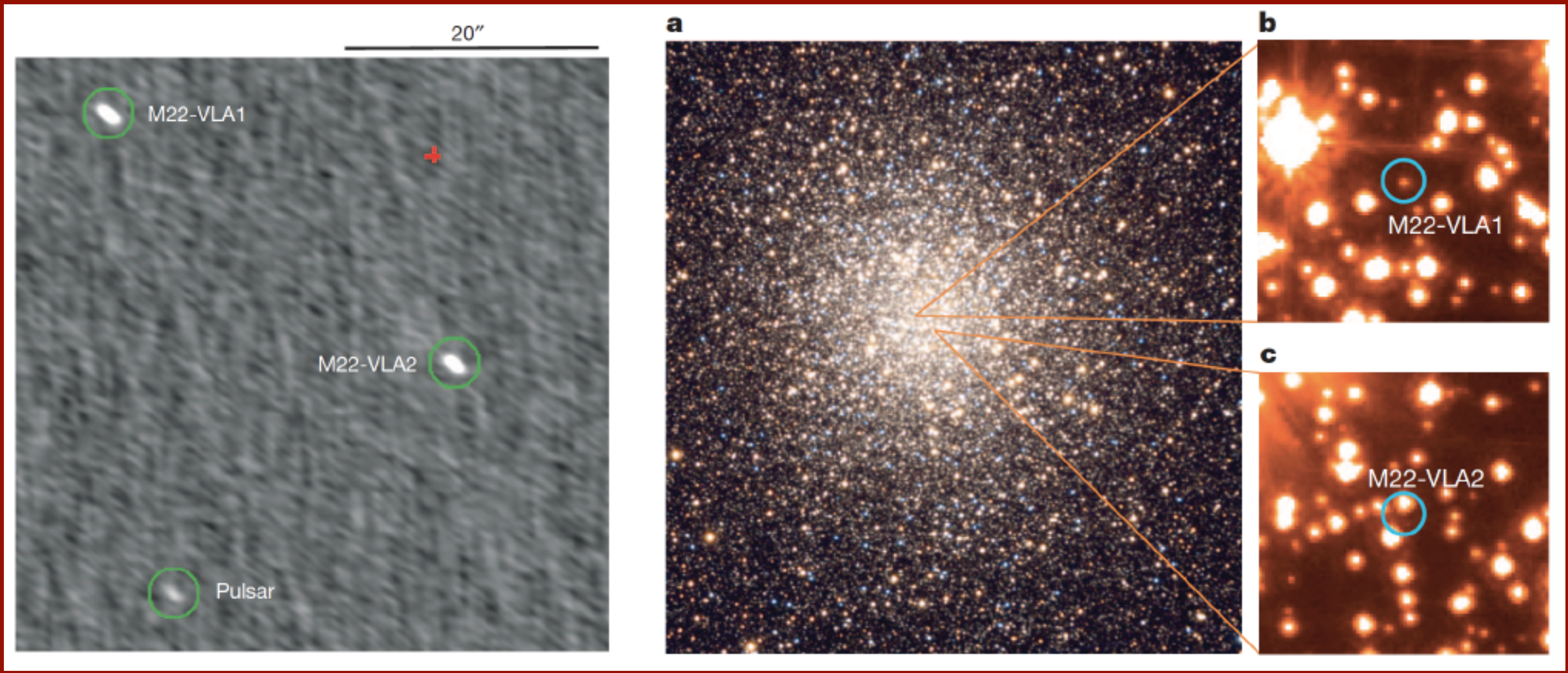




Radio jet from a dwarf nova in SS Cyg

(Kording, Rupen, et al. 2008)

The Joys of Commensal Observing: Globular Clusters with MeerKAT



Discover black holes in globular clusters and study their variability

Strader, Chomiuk et al. 2012

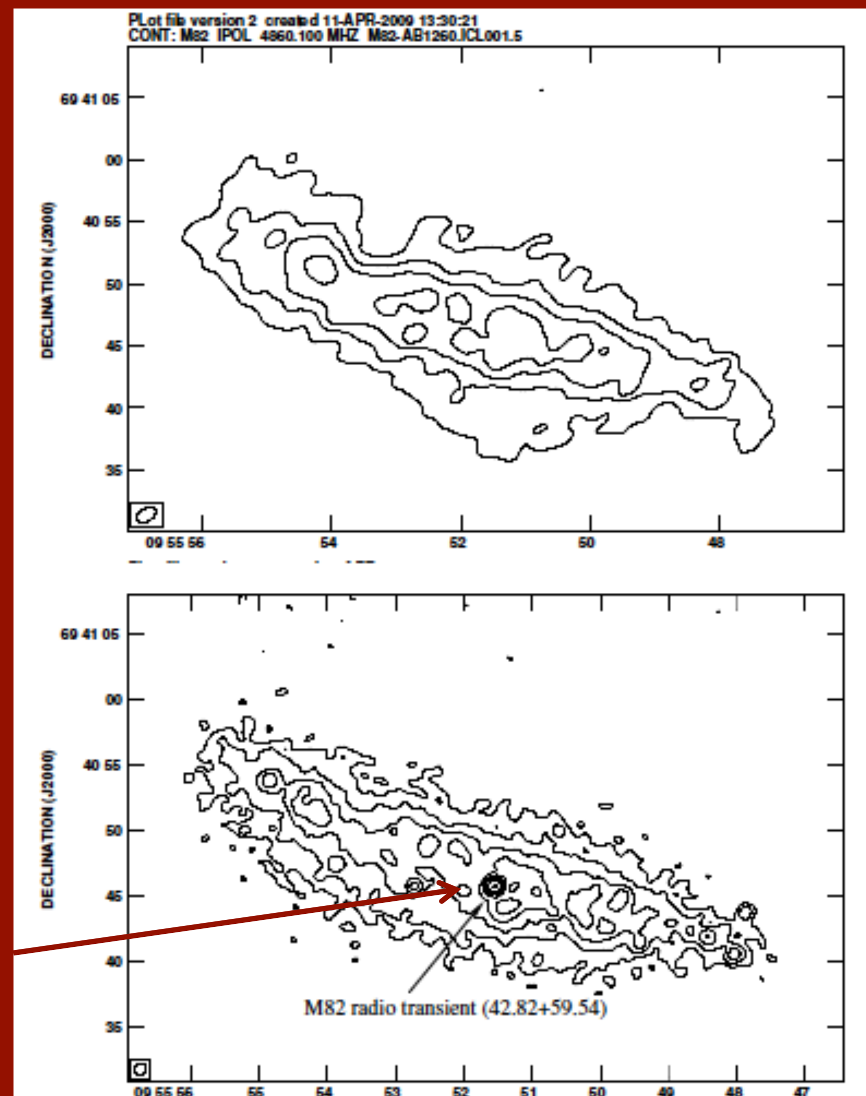
How many SNe are we missing due to dust extinction?

Could be half!
(Horiuchi et al. 2011)

Search nearby
(< 100 Mpc) starburst
galaxies for SNe over
several years.

Great fit for ASKAP.

SN 2008iz in M82



(Brunthaler et al. 2009)

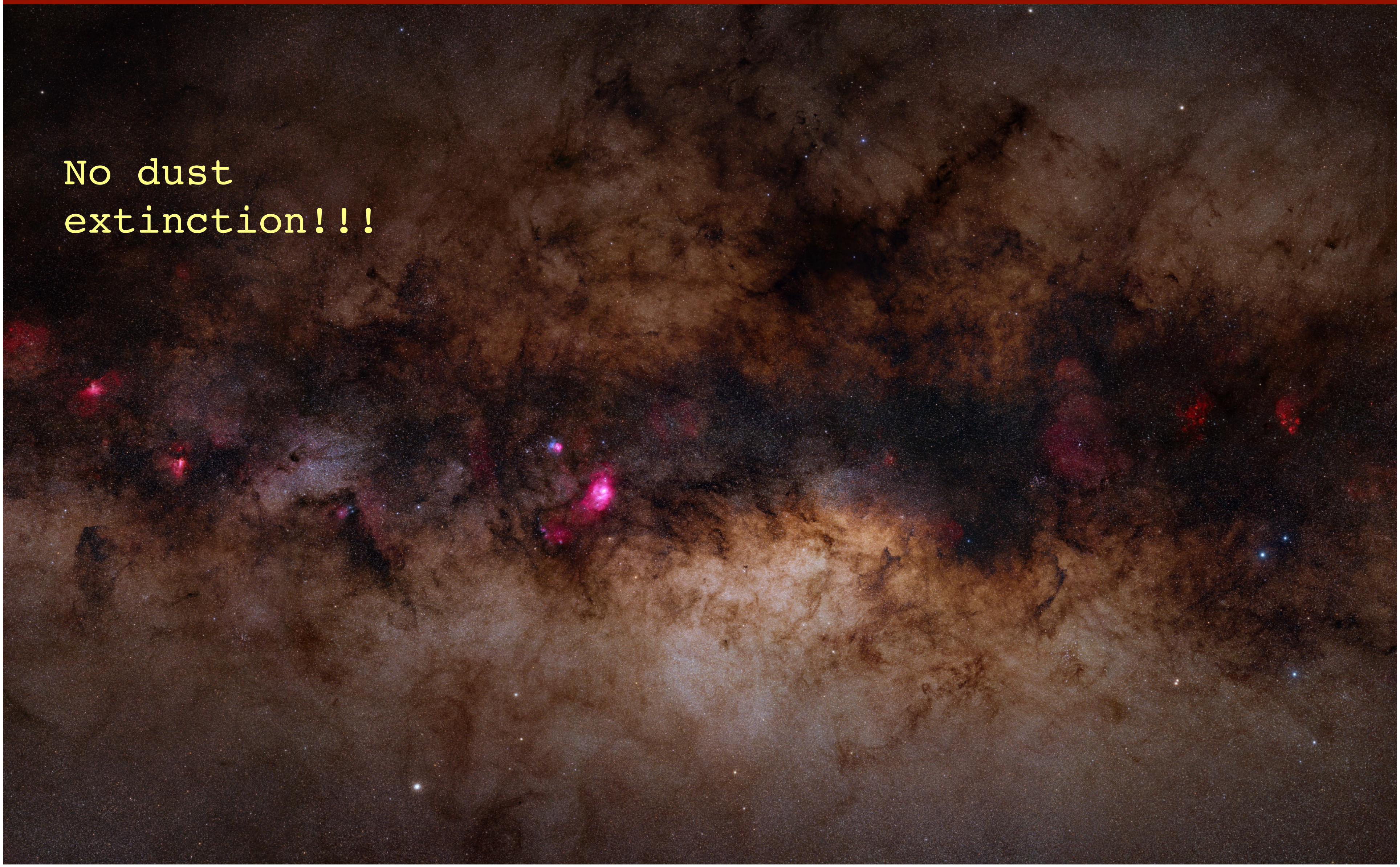
Novae and the Next Generation of Radio Facilities

That's nice, but...
what can
SKA pathfinders
do for me?

SKA Pathfinders will survey the Galactic Plane in the time domain.

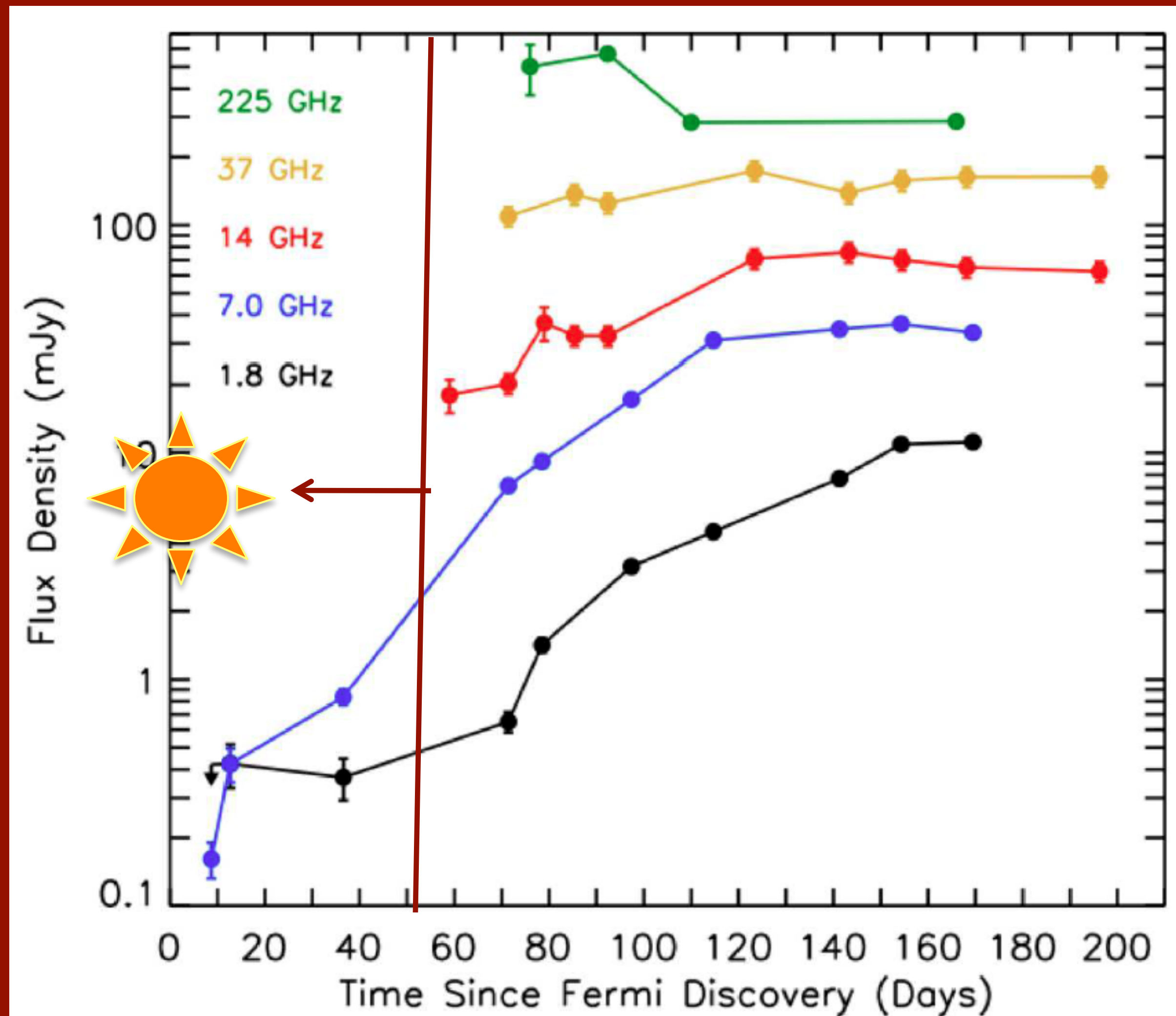
- Commensal observations with MeerGAL survey (3300 h with MeerKAT)
- Galactic Bulge survey with MeerKAT (4 visits per year)
- VAST Galactic with ASKAP (surveys Galactic plane weekly)
- Northern Galactic plane survey with LOFAR

Galactic Radio Surveys will be awesome for novae.



Galactic Radio Surveys will be awesome for novae.

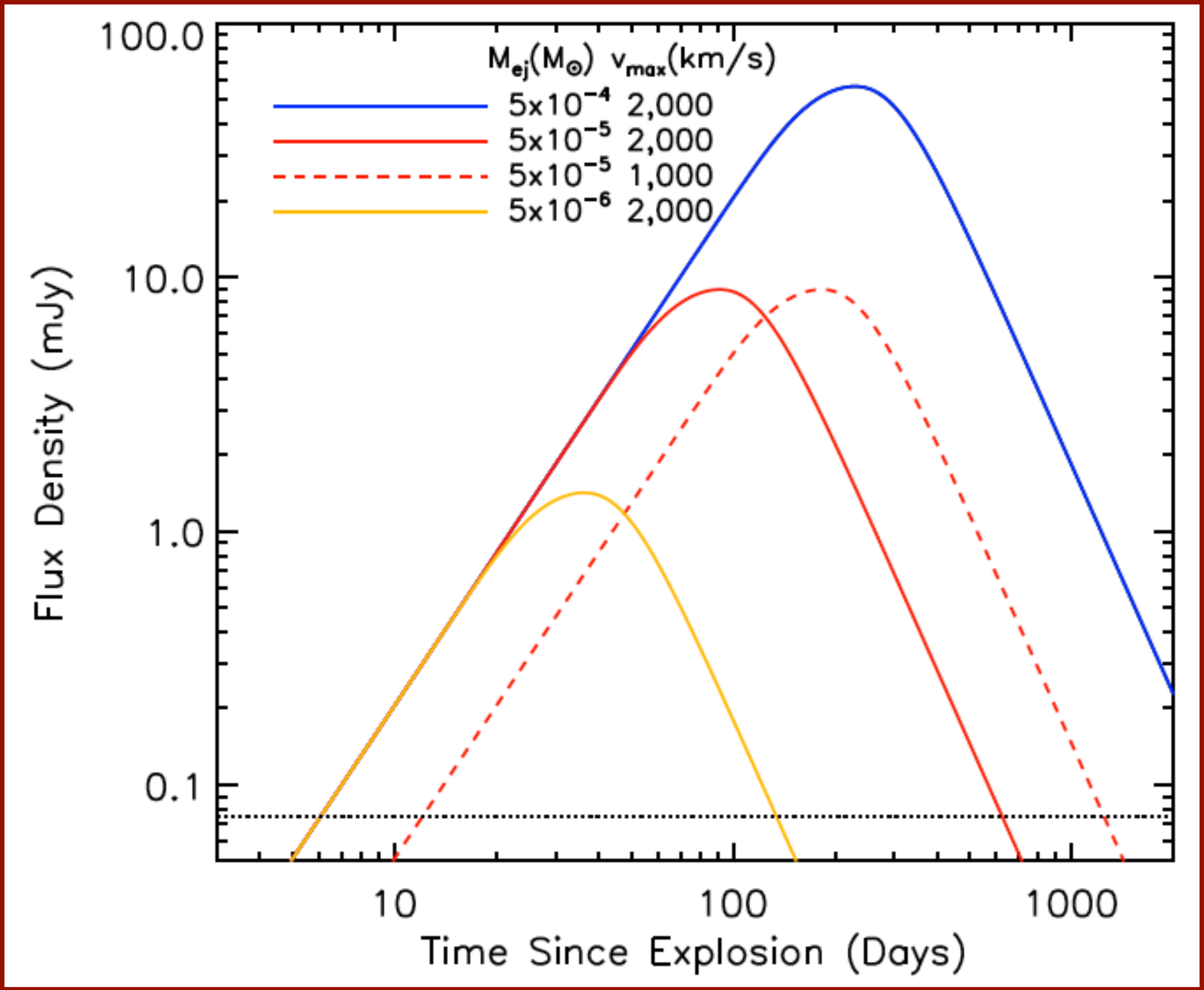
- No dust extinction!!!
- Can observe during the day.



Mon 2012

Galactic Radio Surveys will be awesome for novae.

- No dust extinction!!!
- Can observe during the day.
- Luminosity scales with ejecta mass.



Radio surveys will provide a fresh understanding of the Milky Way's nova population

- No dust extinction!!!
- Can observe during the day.
- Luminosity scales with ejecta mass.

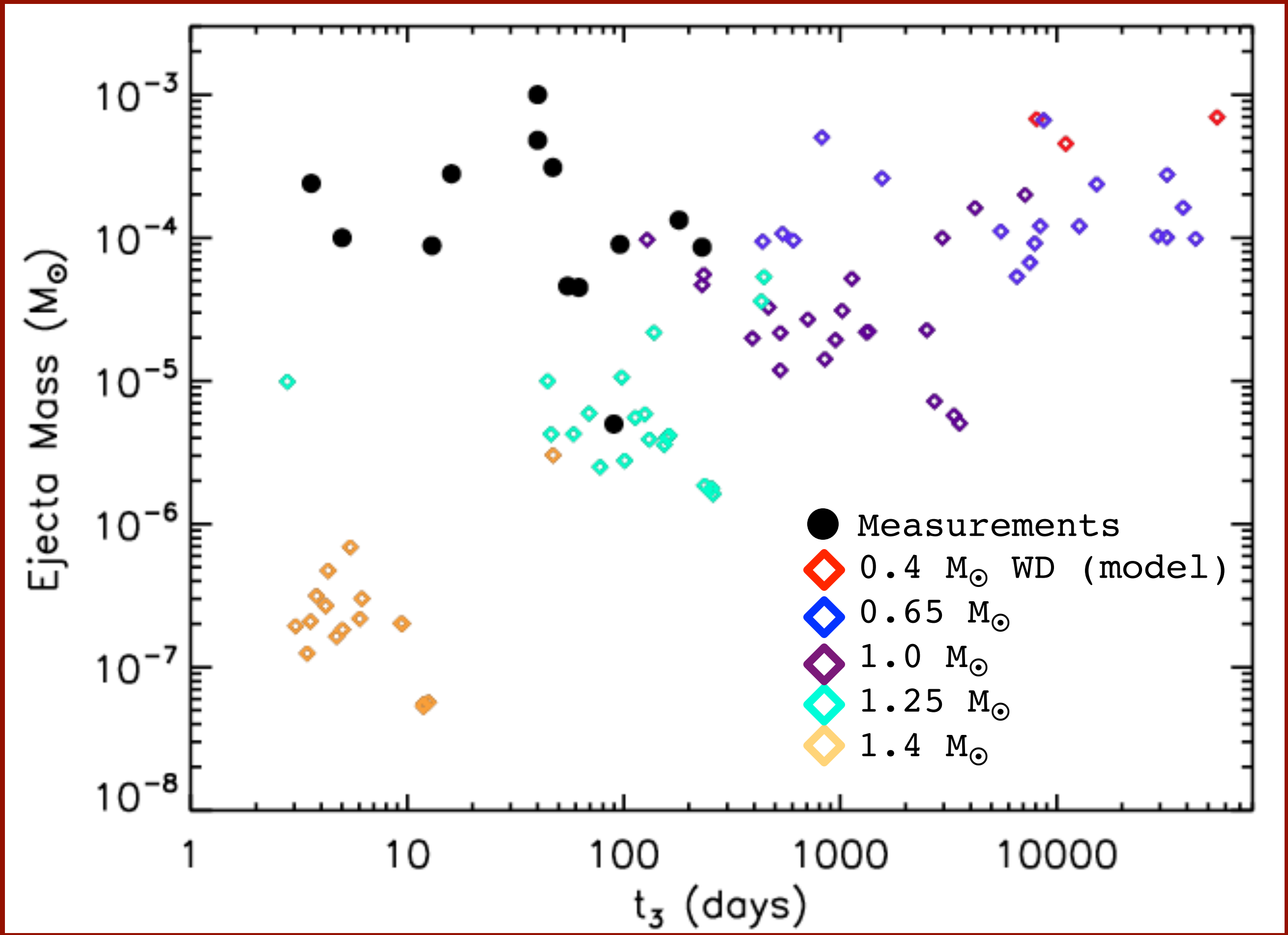
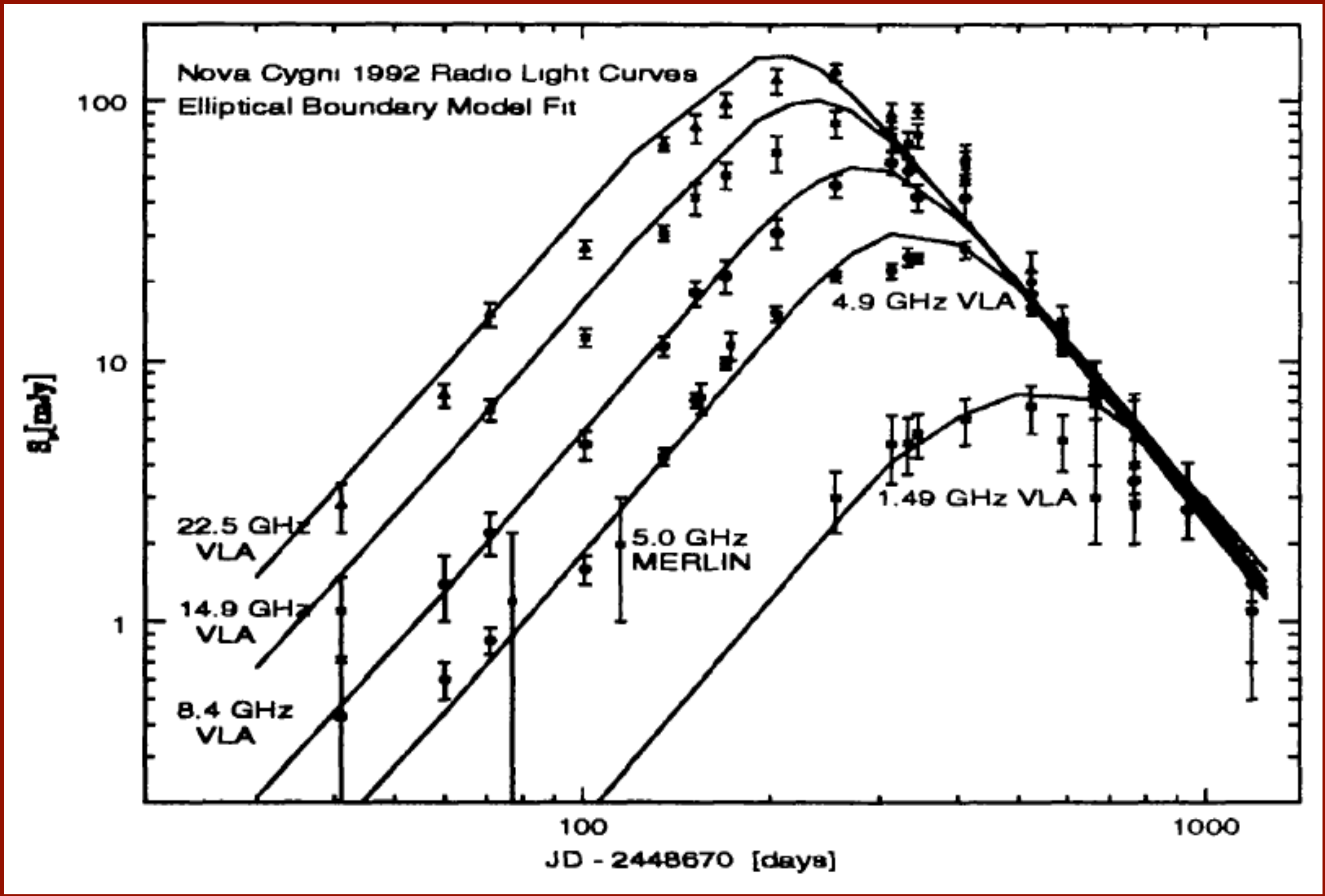


Figure from Roy et al. 2013, BASI review
Data from Seaquist & Bode 2008 and E-Nova Project
Models from Yaron et al. 2005

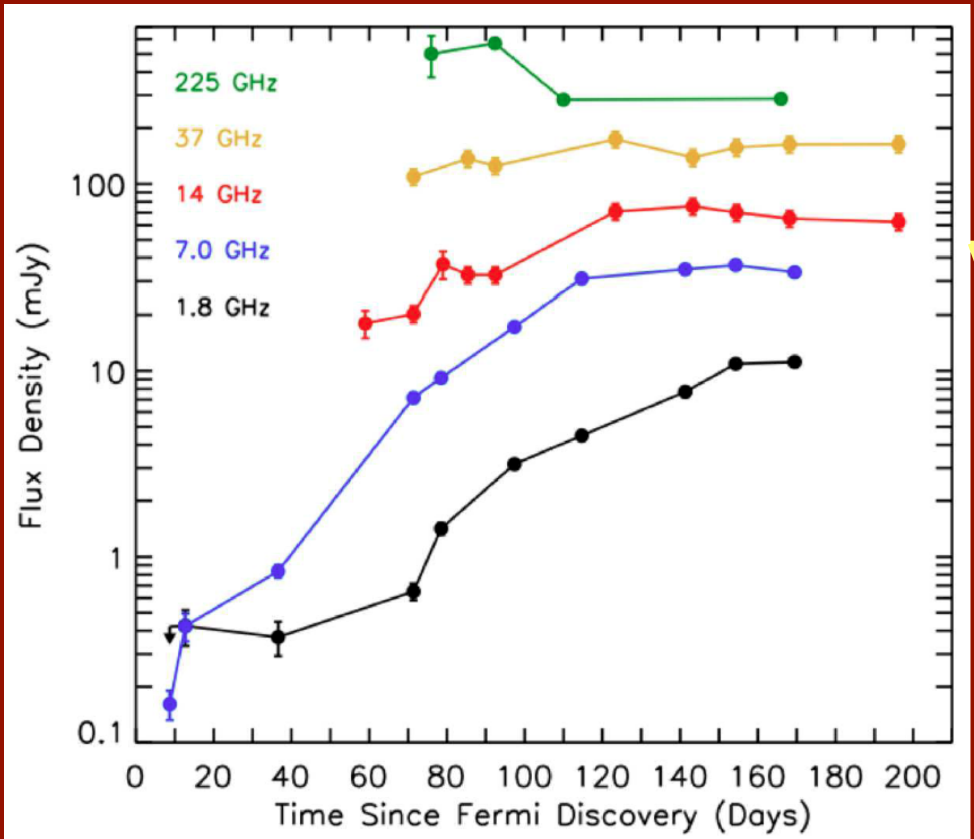
Ideally (for novae), Galactic transient searches would not be too low frequency.



Hjellming 1996

Will we detect radio novae in other galaxies?

Mon 2012

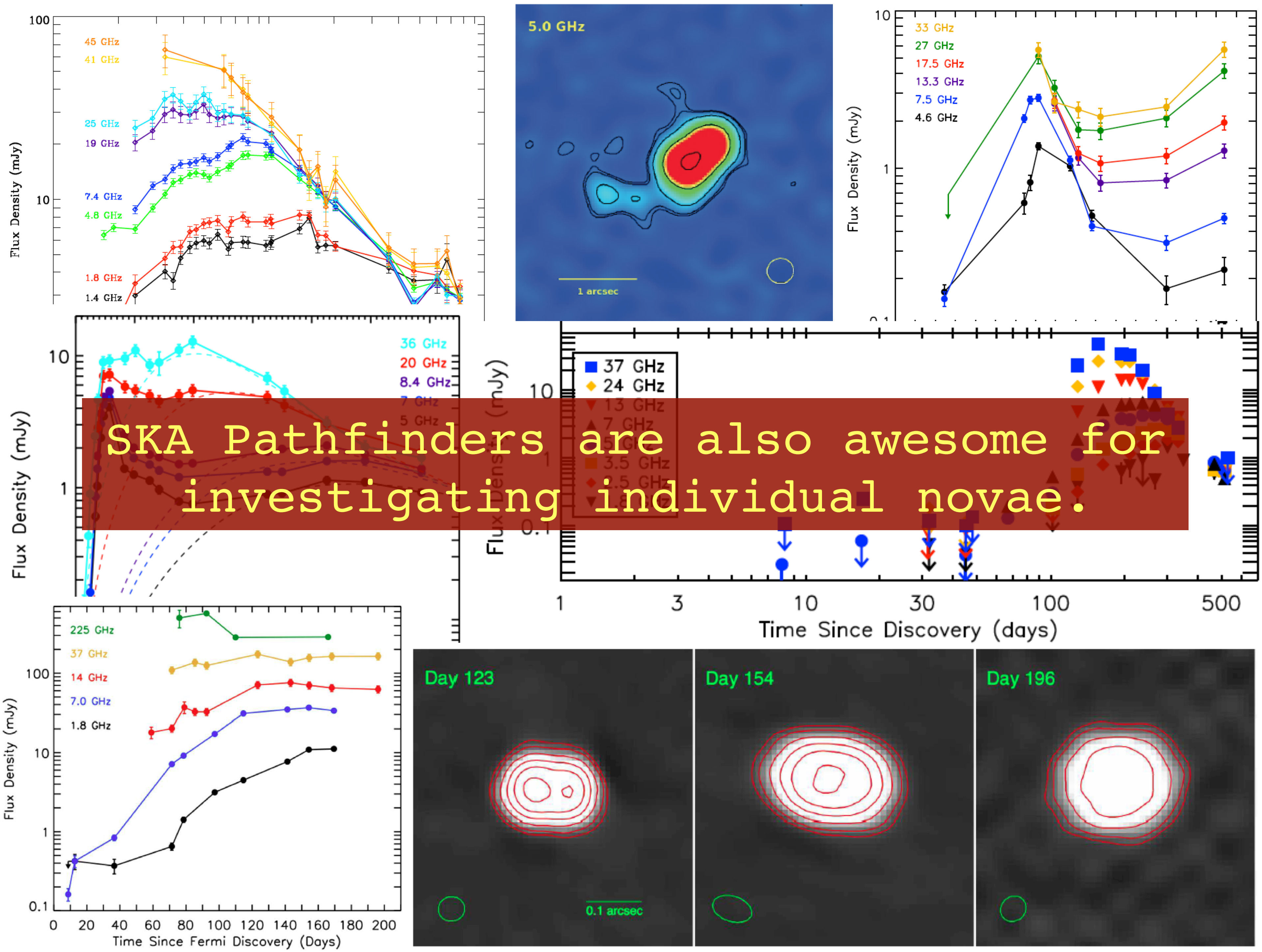


~0.25 mJy at Magellanic Clouds (10 GHz)

~0.5 μJy at M31

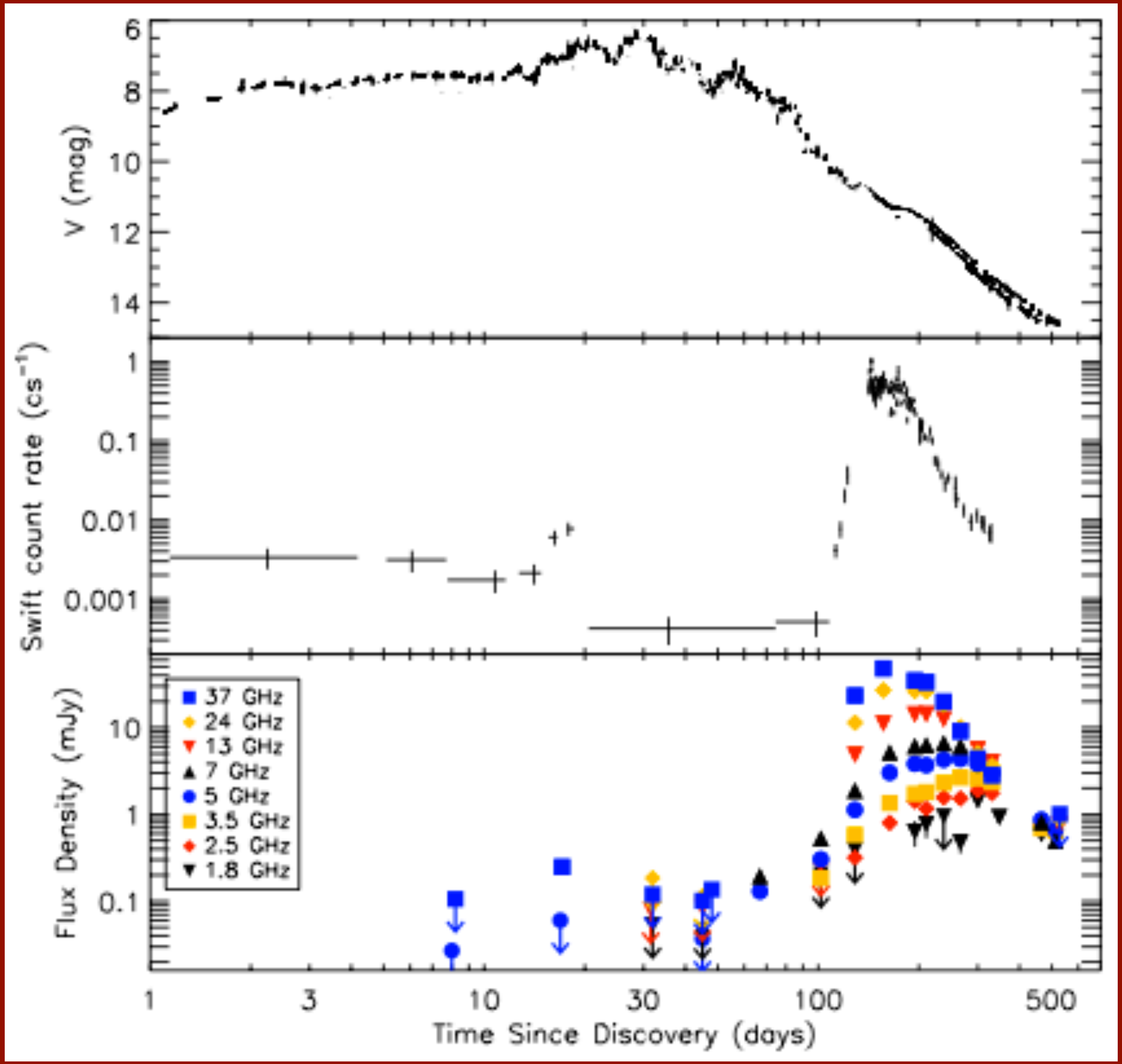
Not in the north! (well, maybe w/SKA)

Maybe in the SMC/LMC with MeerKAT.

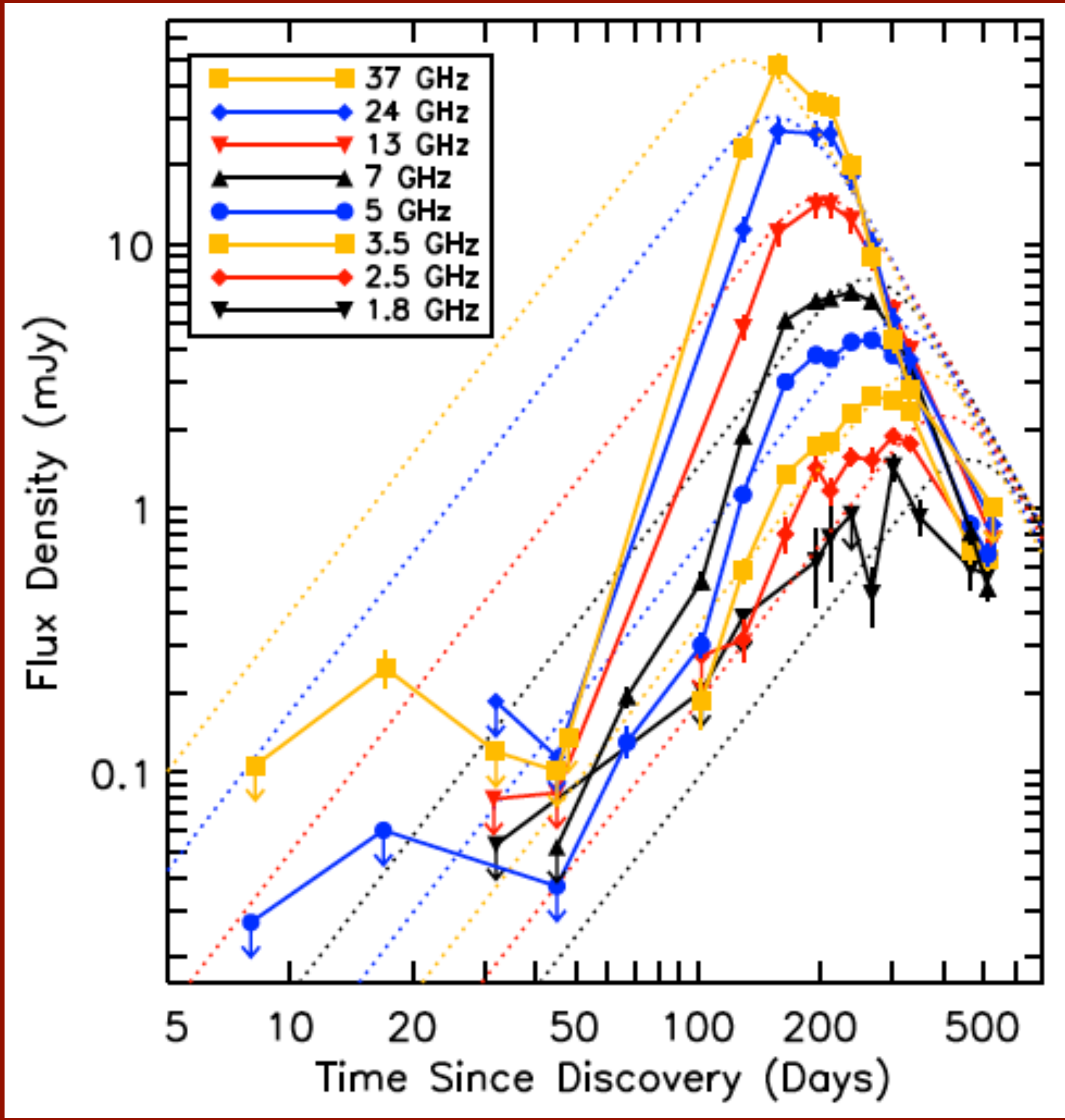


SKA Pathfinders are also awesome for investigating individual novae.

Optical, X-ray, Radio Evolution of T Pyx

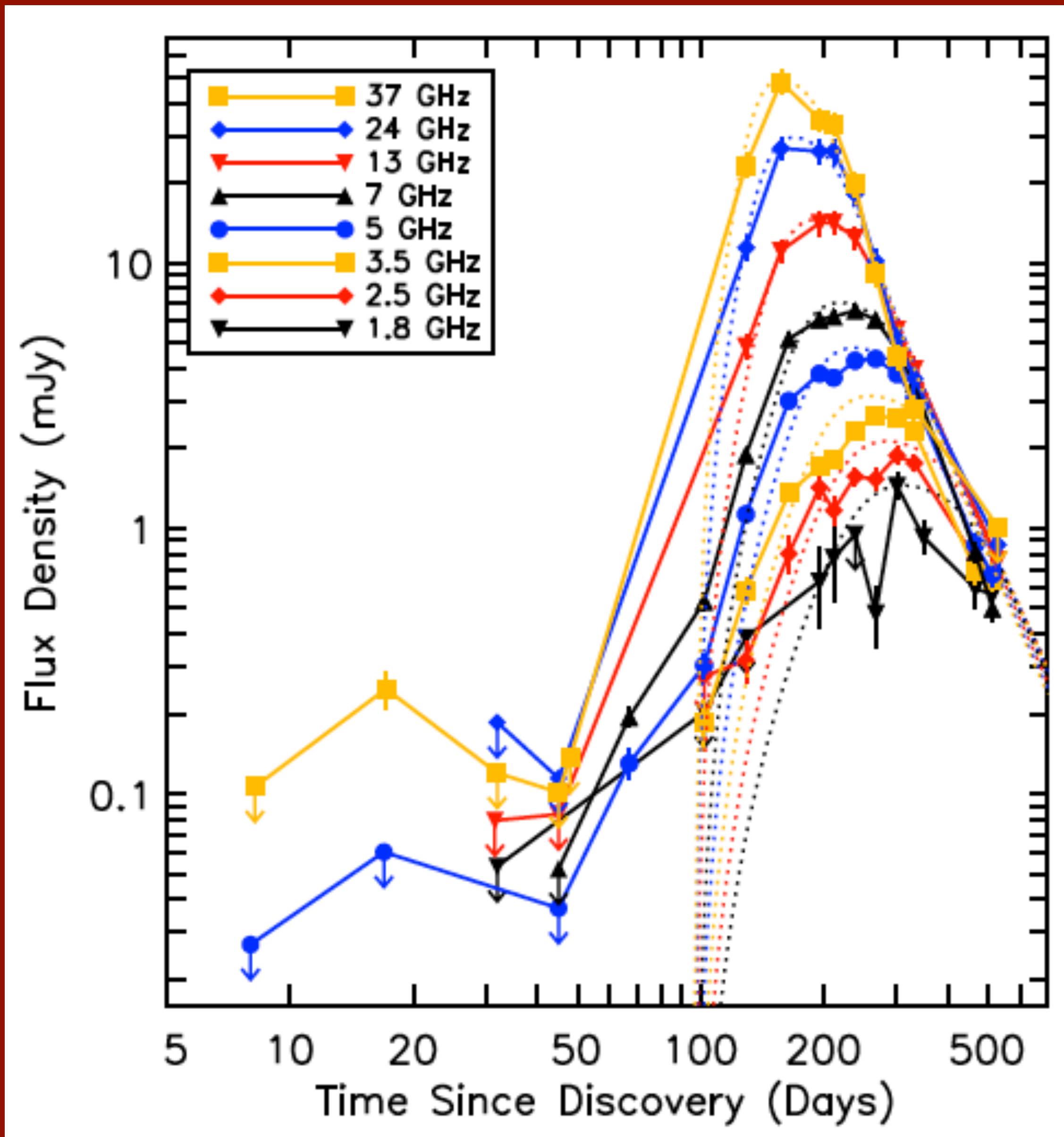


T Pyx gets radio bright...belatedly



Nelson et al. 2012 arXiv 1211.3112

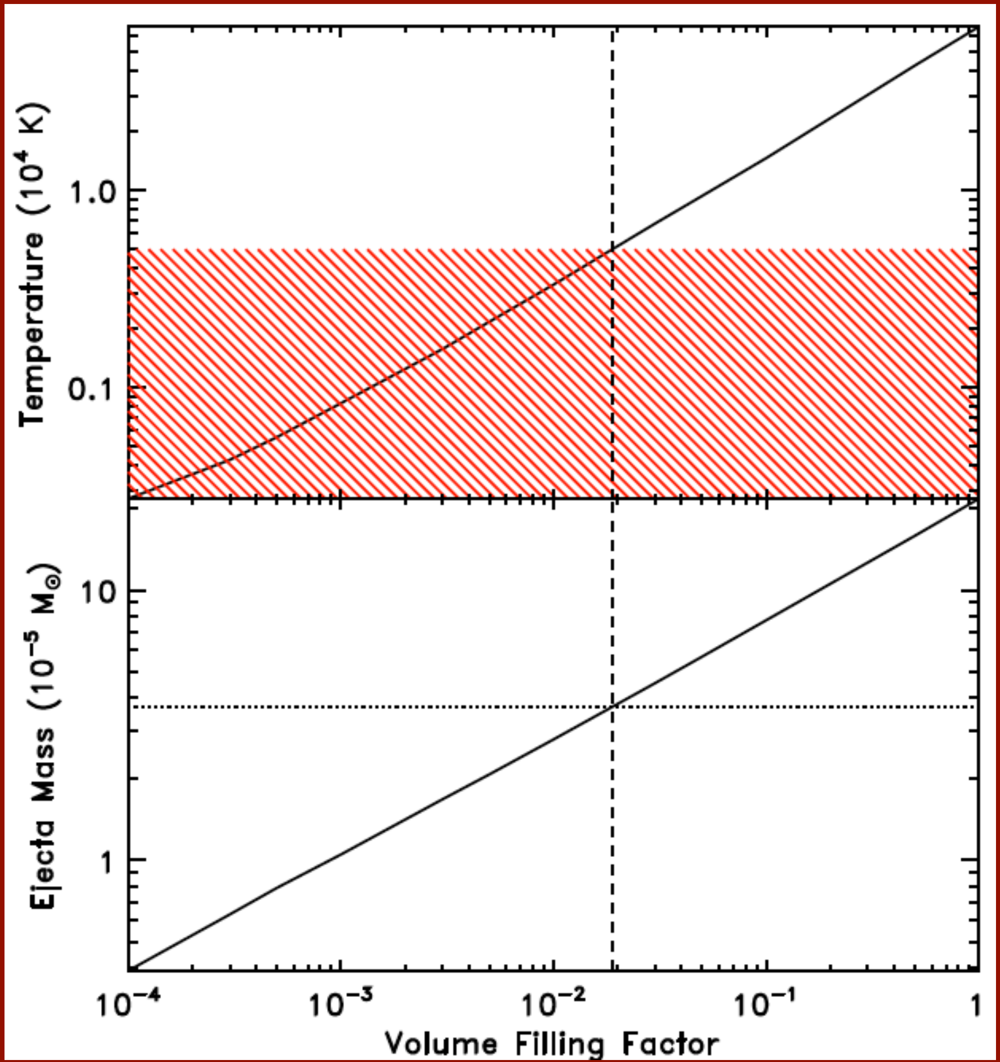
T Pyx had a massive, delayed ejection

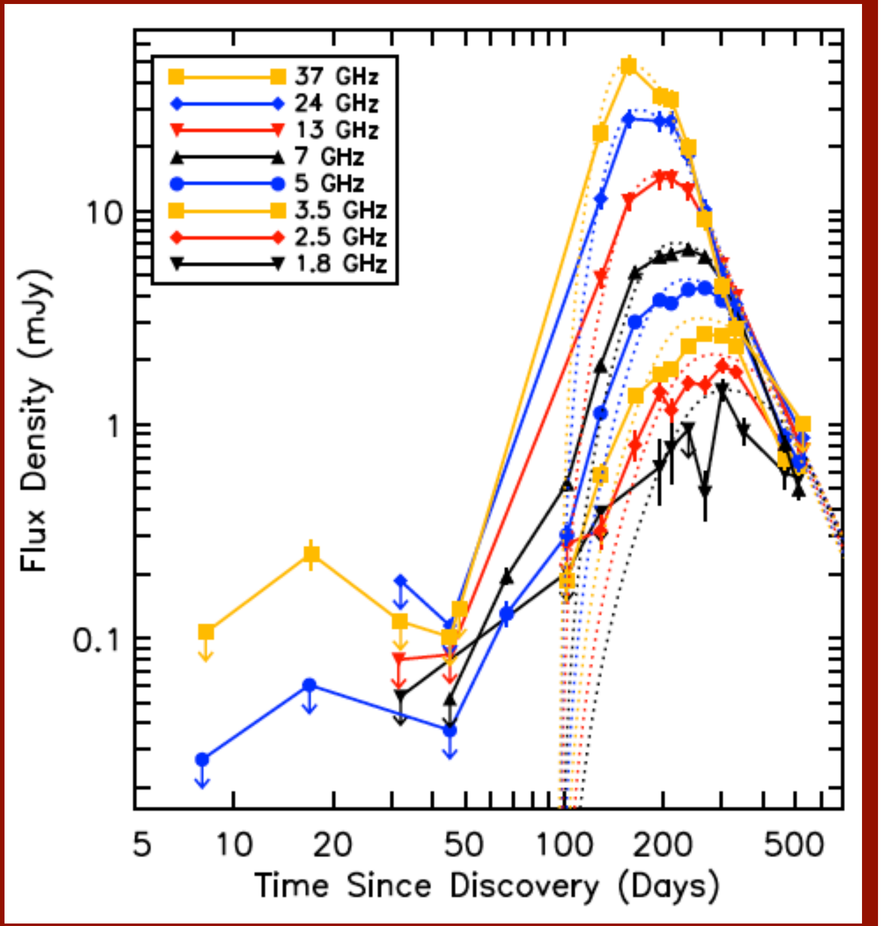


3×10^{-4} $M_{\odot}$ expelled 2–3 months after the beginning of optical rise.

Nelson et al. 2012 arXiv 1211.3112

Ejecta mass can decrease if clumpy.

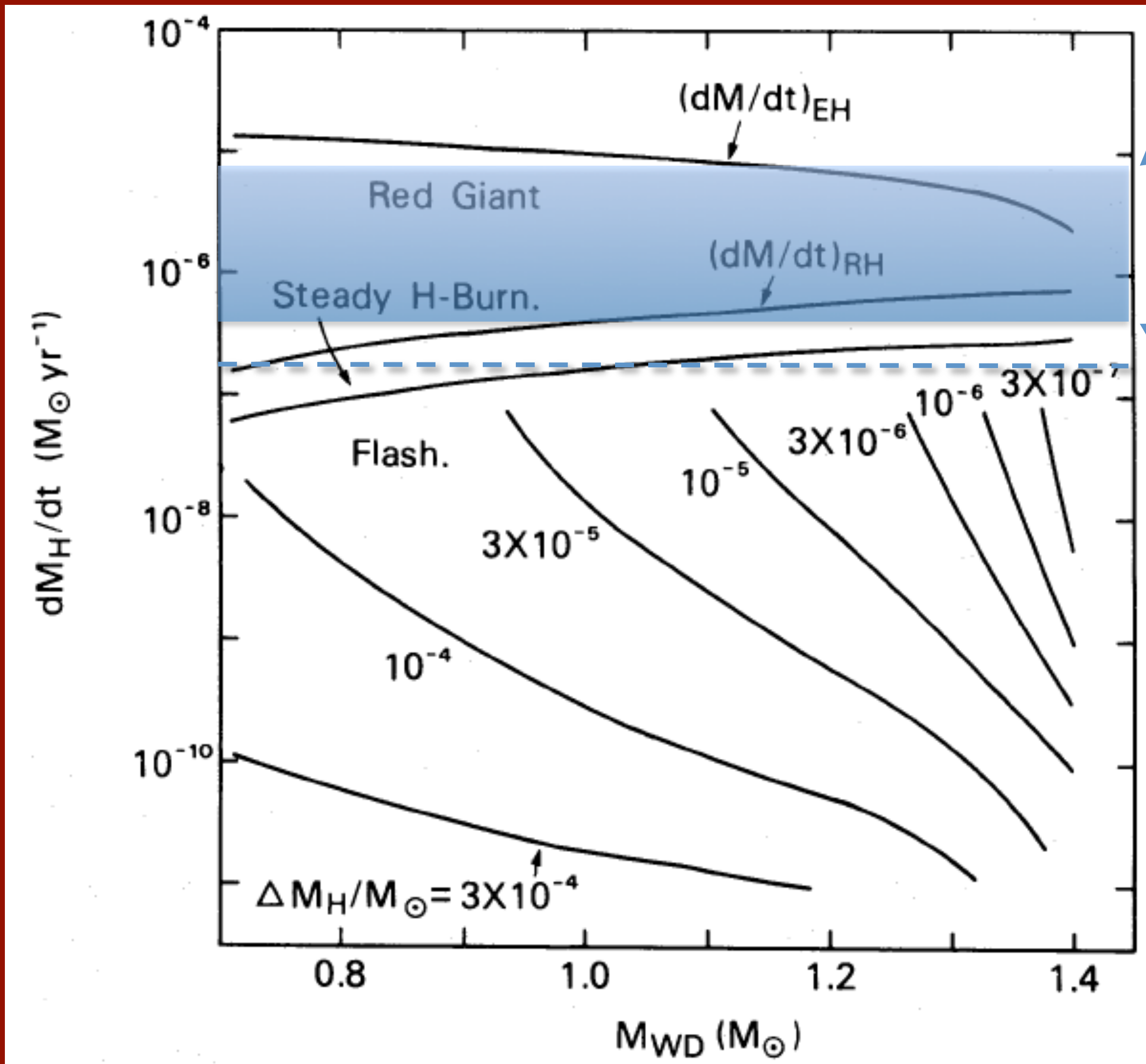




Nelson et al. 2012 arXiv 1211.3112

Ejected mass can be as low as 2×10^{-5} $M_\odot$

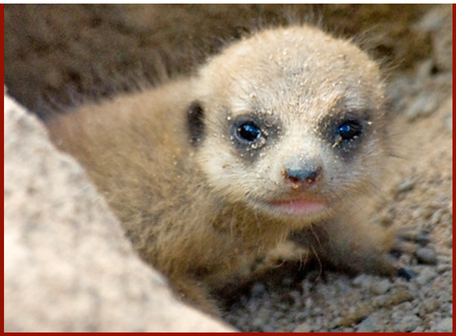
T Pyx's accretion rate barely makes sense for a nova.



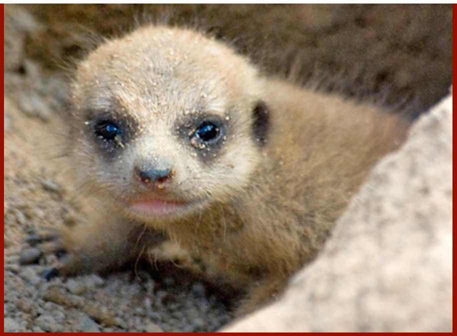
$\frac{3 \times 10^{-4}\ M_\odot}{44\ yr}$

$\frac{2 \times 10^{-5}\ M_\odot}{44\ yr}$

Nomoto 1982



In Conclusion



- We are living in a Golden Age for radio astronomy *and* survey astronomy---
it's a good time to be studying novae!

- We are on the cusp of understanding the radio transient sky---SKA pathfinders will crack open this discovery space.

- Time-domain Galactic radio surveys will provide a fresh view of the Milky Way's nova population.

- SKA pathfinders will provide fundamentally important data on individual novae:
e.g., a massive and delayed ejection from T Pyx.