Wide-field Near-real-time Radio Transient Surveys

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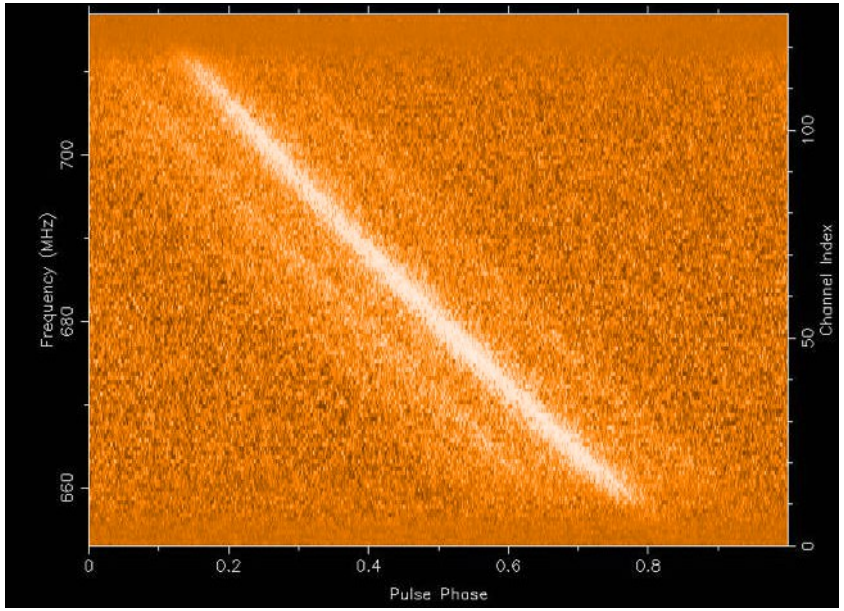
Radio Transients

Coherent

– Various flavors of coherent emission
– Variable on timescales of ns - minutes
– T_B as high as > 10^{38} K
– Typically discovered in time-series data

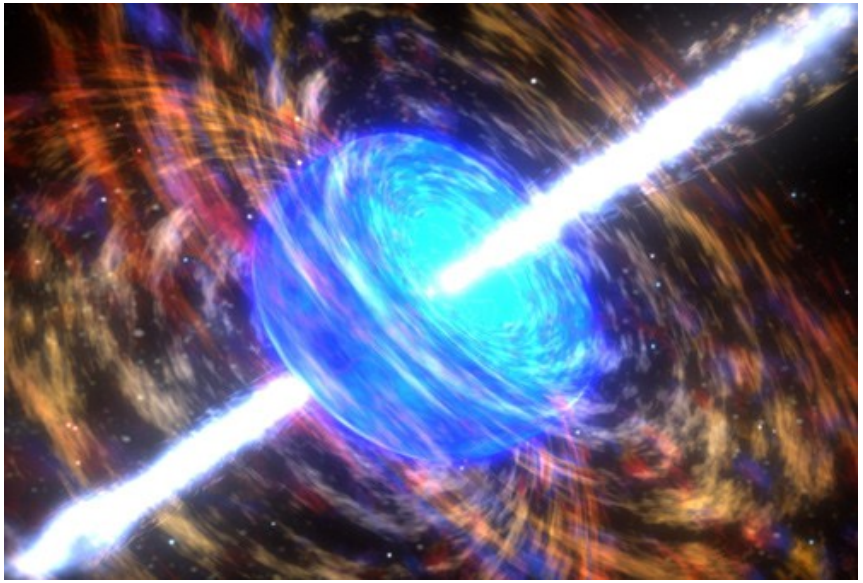


Examples

– Various classes of neutron stars
– Galactic Center Radio Transients
– Planets and Exoplanets
– Stellar bursts and pulsing BDs

Incoherent

– Typically synchrotron emission
– Variable on timescales of sec – years
– T_B < 10^{12} K
– Typically discovered in image data



Examples

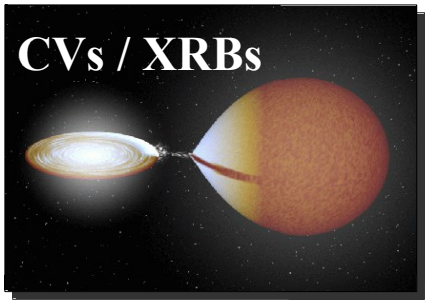
– AGN and Microquasar jets
– Supernovae & GRBs afterglows
– BH tidal disruption events (TDEs)
– Giant flares from magnetars

Credit: Gregg Hallinan

Slow Radio Transients

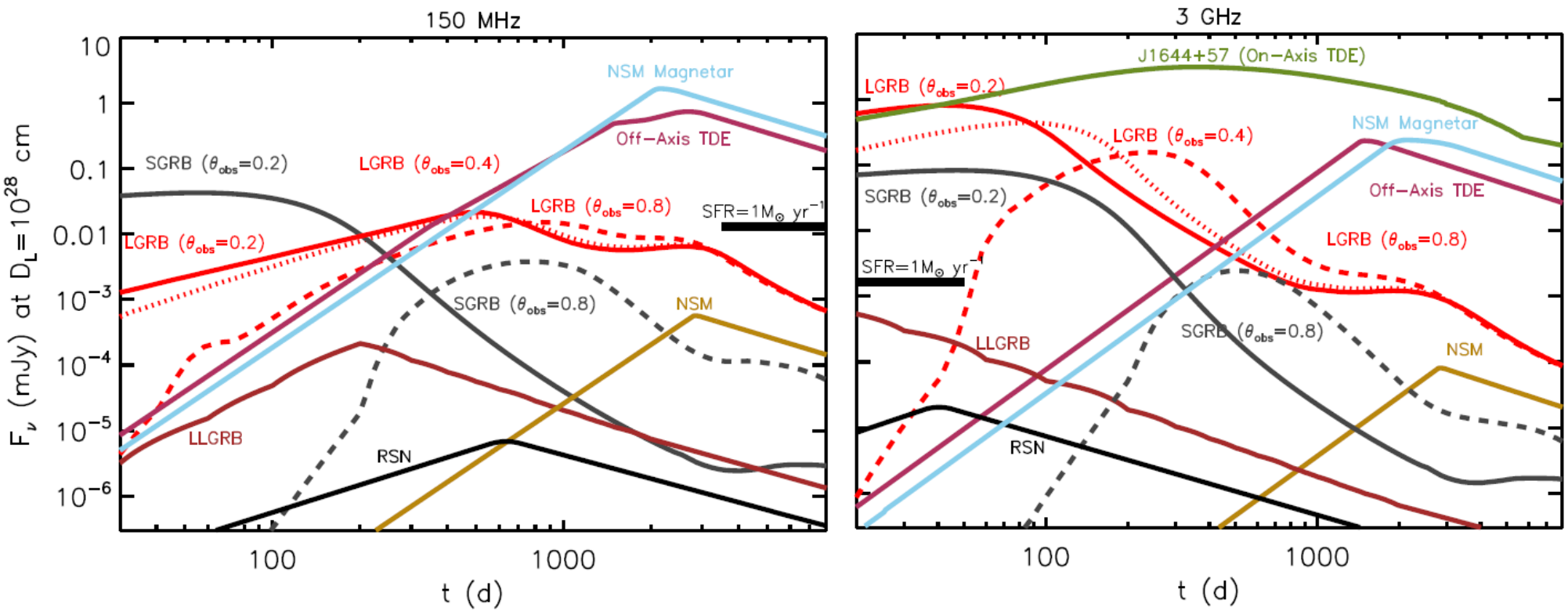
- Interaction of fast outflows with the surrounding medium
- Not affected by extinction, unlike optical surveys
- Often not narrowly beamed in contrast to high energies

> *"Given the typical jet opening angle of GRBs, for each burst pointing to the Earth there should be 700x more GRBs pointing in other directions."*
> – Ghirlanda et al. 2014



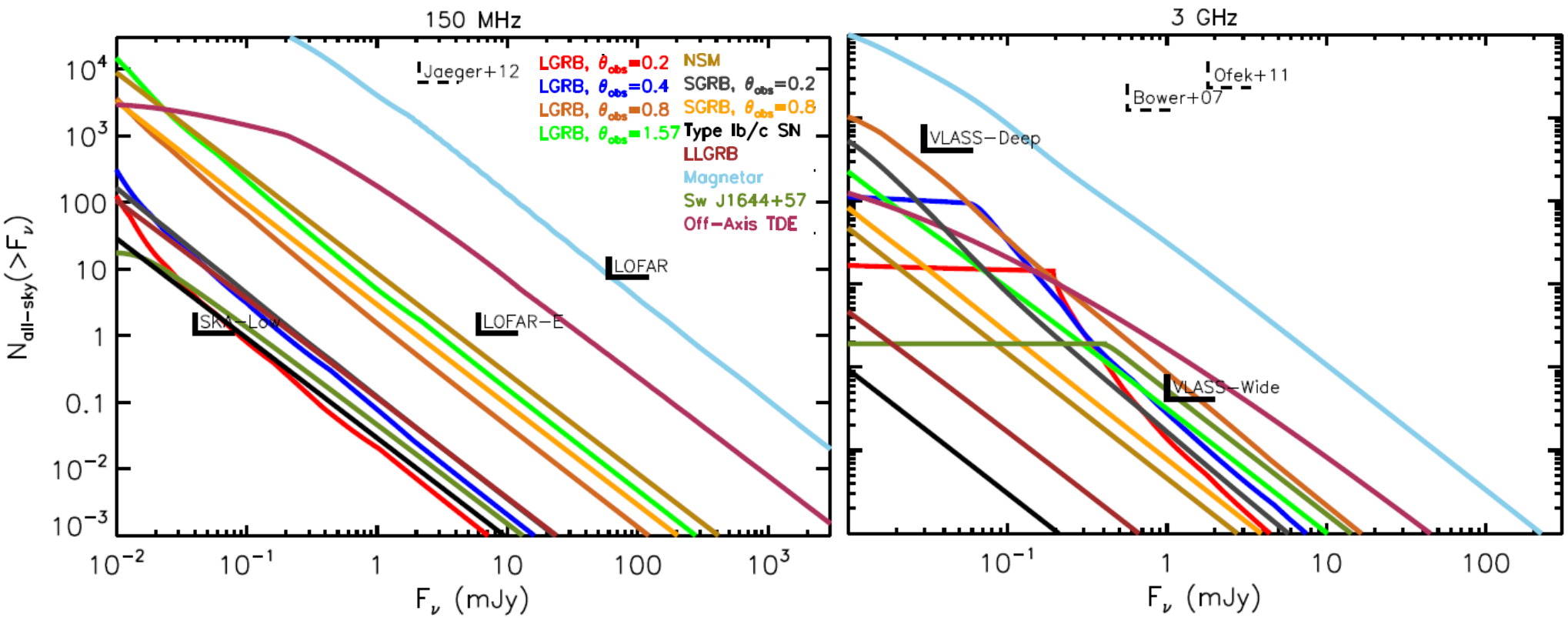
- Trace high energy particles arising in locations of high magnetic field

Extragalactic Incoherent Transients: Timescales



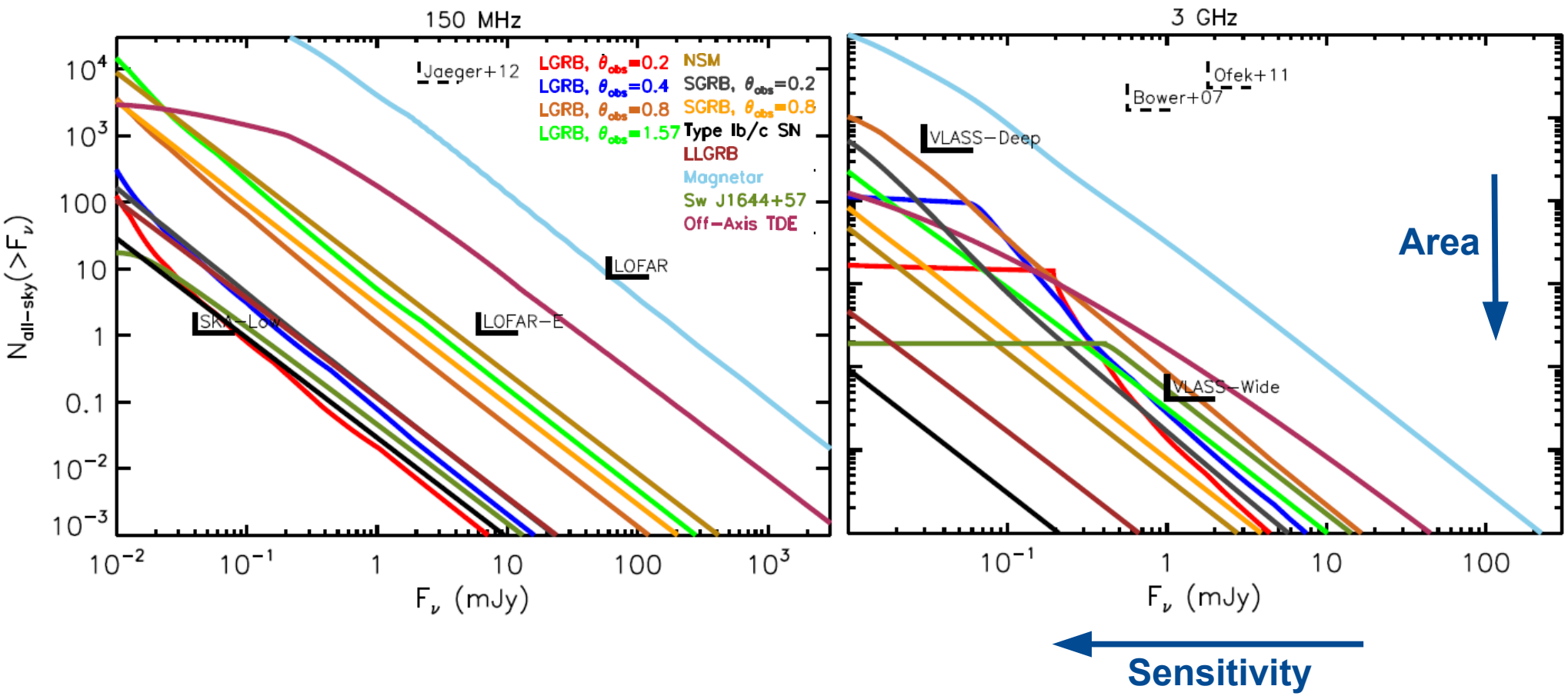
Metzger, Williams & Berger 2015

Extragalactic Incoherent Transients: Phase space



Metzger, Williams & Berger 2015

Extragalactic Incoherent Transients: Phase space



Metzger, Williams & Berger 2015

Most exciting transient discoveries

SKA mid (GHz):
Extragalactic explosions (days~months)

SKA low (MHz):
Galactic coherent transients (seconds~hours)

Requirements

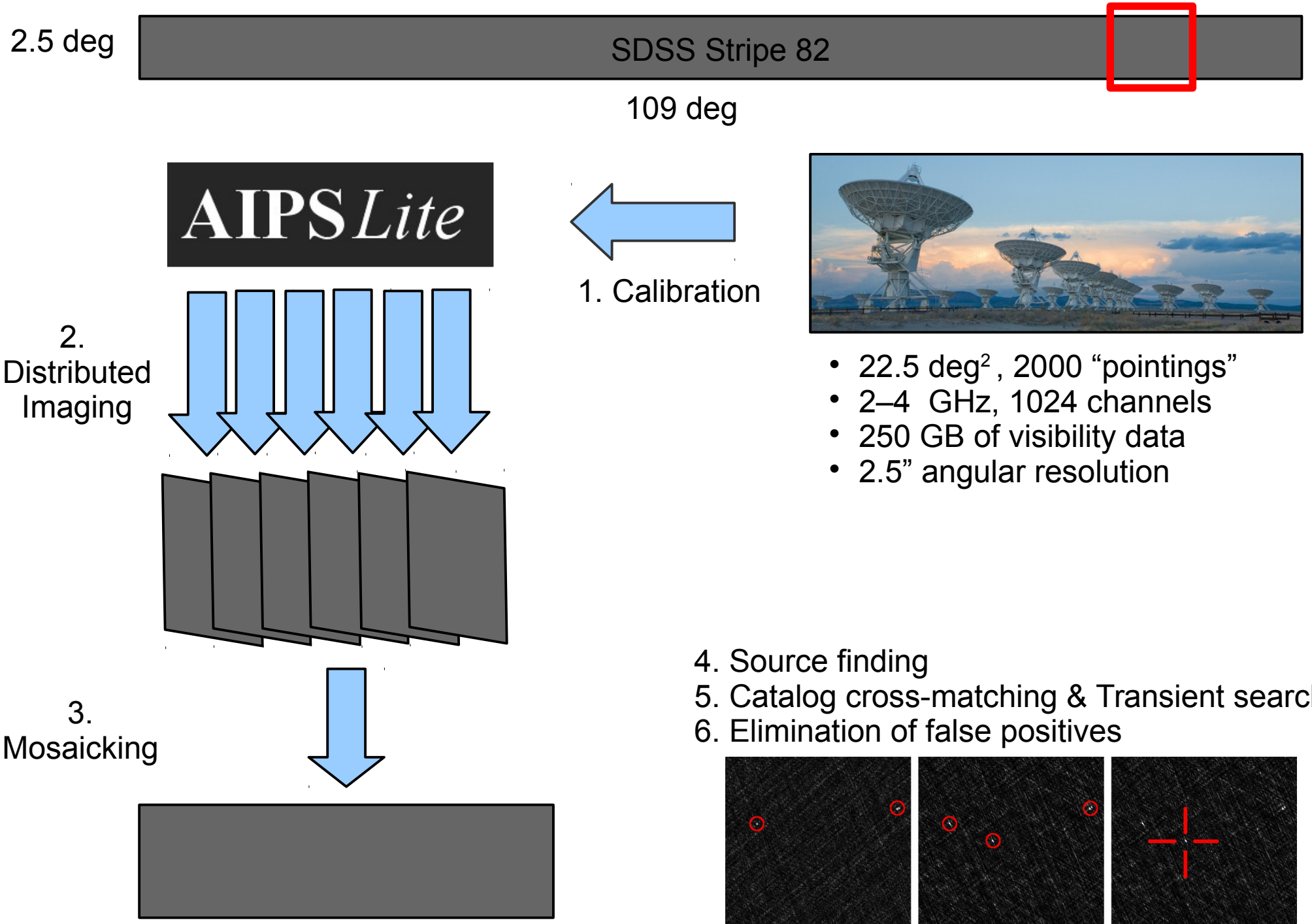
1. Wide area to maximize probability of finding transients
2. Arcsec resolution to get good localization
3. Repeated observations for good sampling of light curves
4. Minimal lag between observations and discovery

Challenges

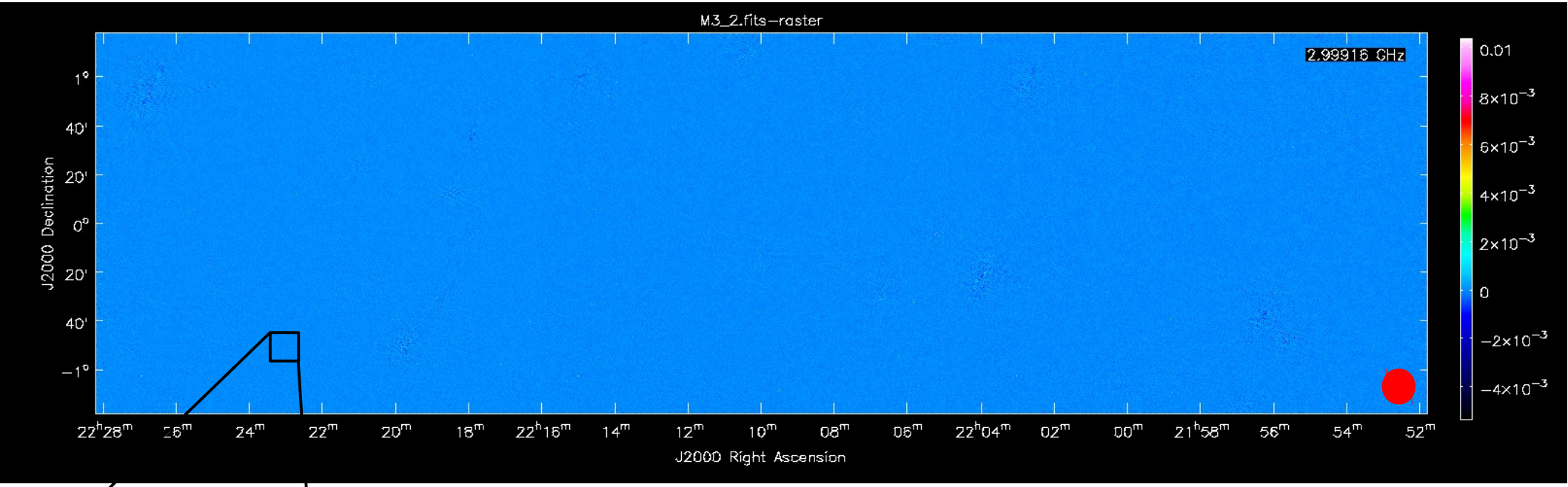
SKA mid:
- Small fields of view

SKA low:
- Ionosphere
- Direction-dependent calibration

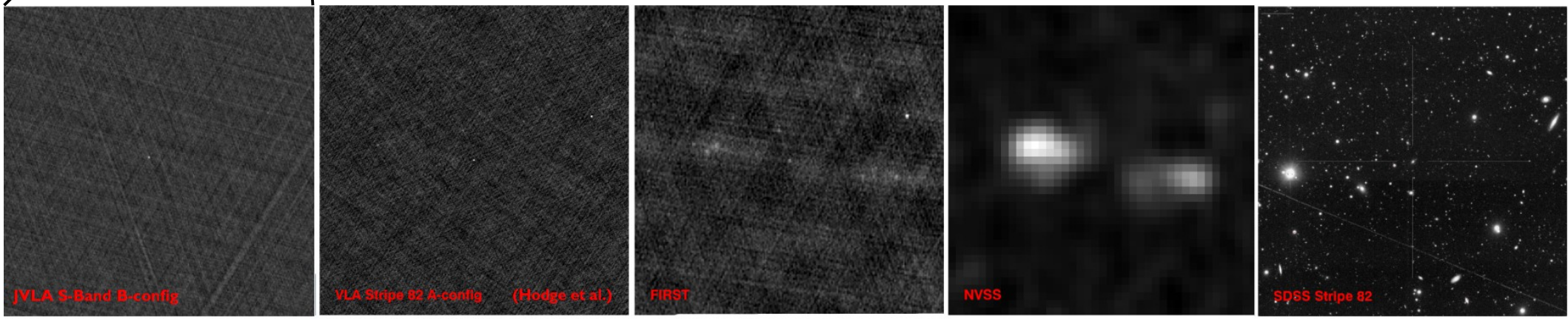
The Caltech-NRAO Stripe 82 Survey (CNSS)


2.5 deg
SDSS Stripe 82
109 deg
AIPS Lite
1. Calibration
2. Distributed Imaging
3. Mosaicking
• 22.5 deg^2 , 2000 “pointings”
• 2–4 GHz, 1024 channels
• 250 GB of visibility data
• 2.5” angular resolution
4. Source finding
5. Catalog cross-matching & Transient search
6. Elimination of false positives

9 degrees



0.8 Gpix image from a single observing block



Cutouts compiled by Steve Myers

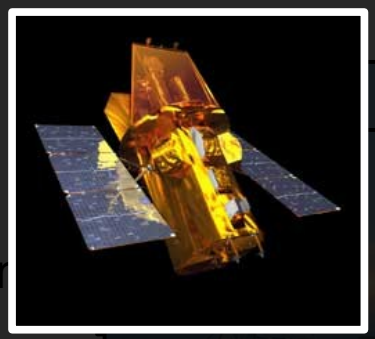
2.5 deg

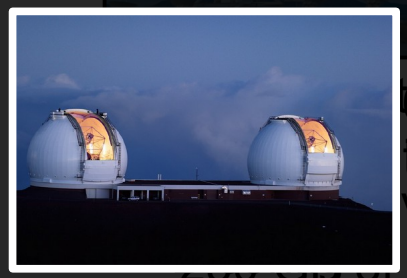
SDSS Stripe 82

109 deg

AIPS Lite

1. Calibration





SDSSIII

Distr

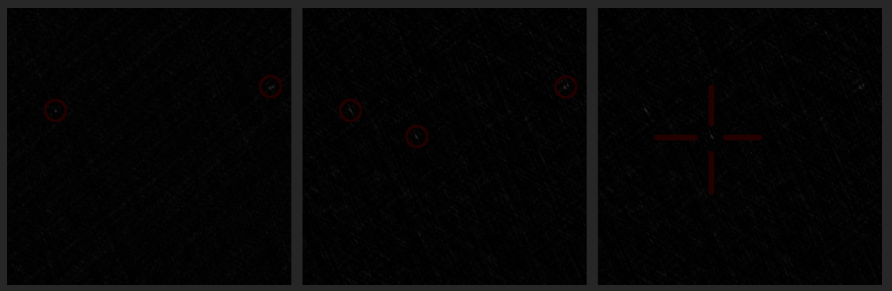
Ima

4. S

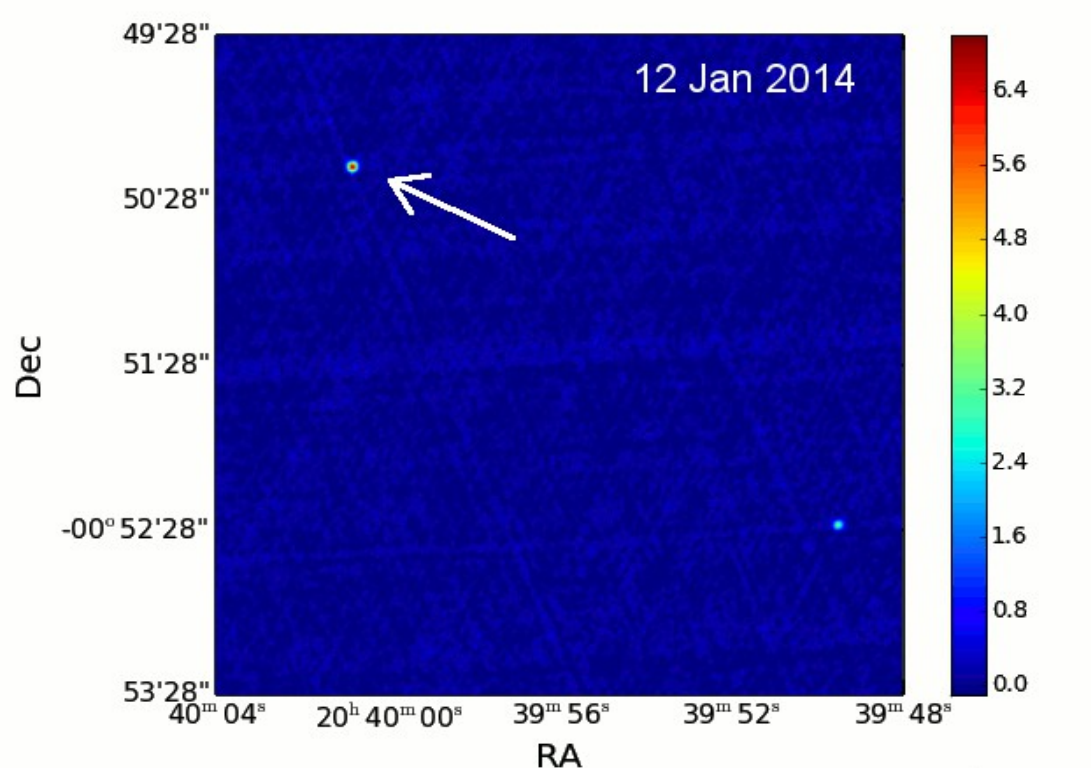
5. C

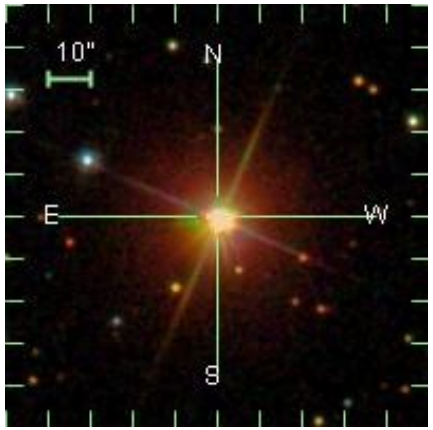
6. Elimination of false positives

Mosaicking

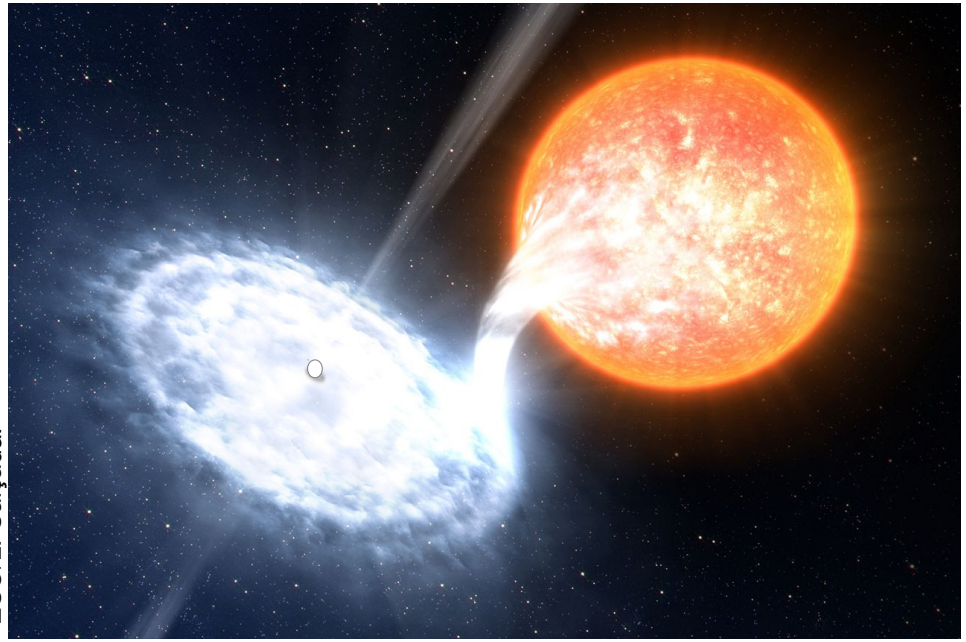


1. AE Aqr: Cataclysmic Variable



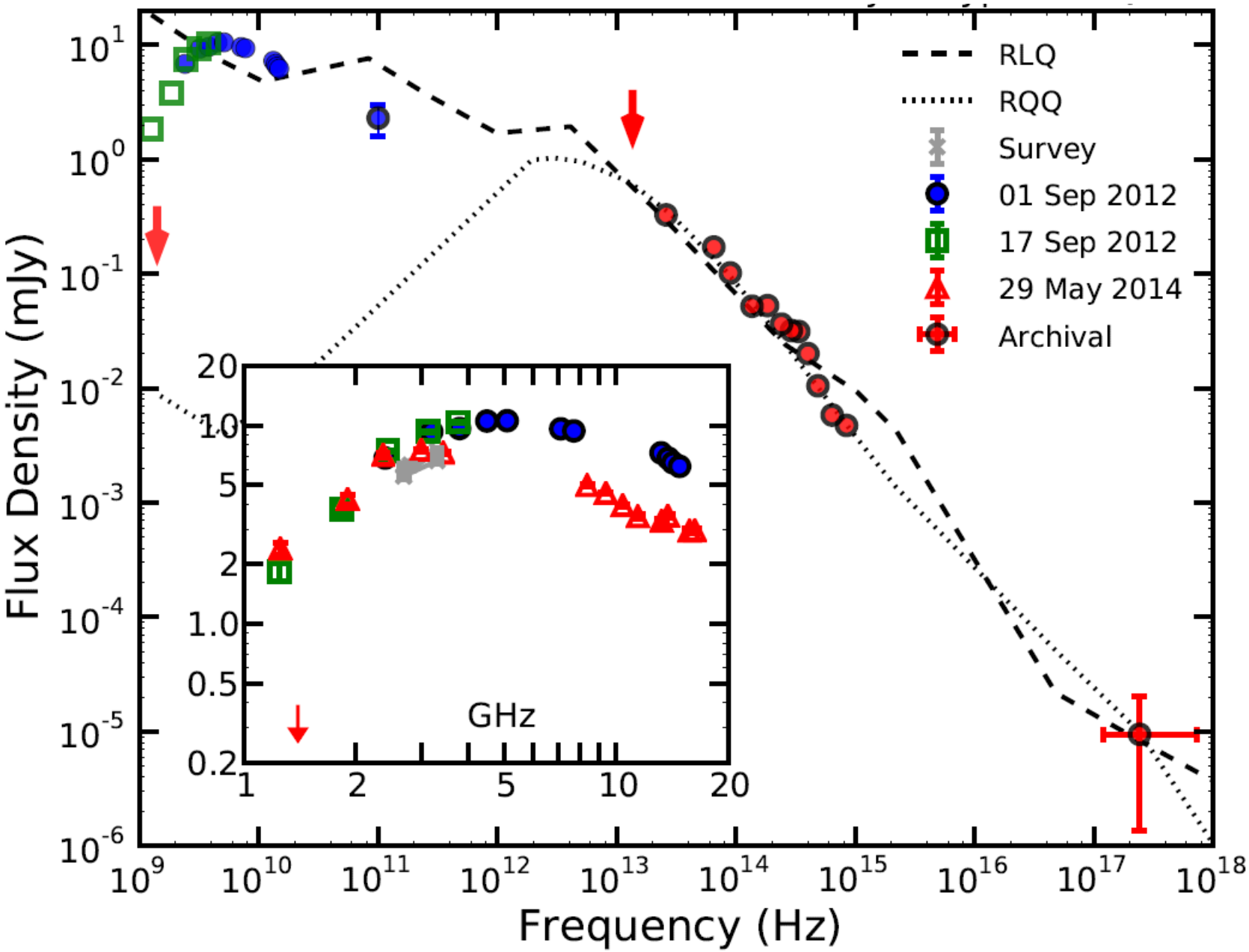


WD + K4V
d = 86 pc
T = 10 hr
P = 33 s



ESO/L. Calçada.

2. VTC 2330-00: Rebirth of AGN jet



Mooley et al. 2016

The GMRT 150 MHz Stripe 82 Transient Survey (G1STS)

G1STS

2.5 deg

SDSS Stripe 82

109 deg

- 100 deg^2
- 20” resolution

Standard Calibration Procedure

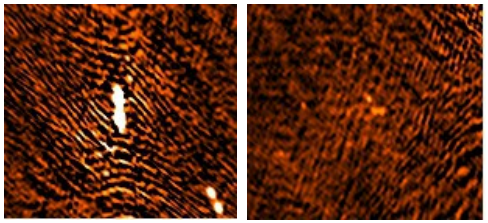
- Derive complex gains
- Apply to target
- RFI flag target

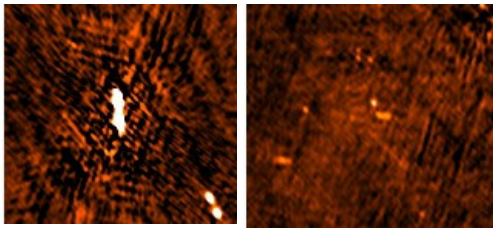
Self Calibration Procedure

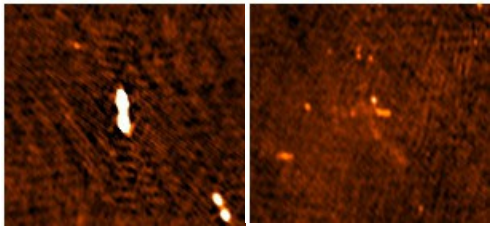
- Widefield imaging
- Self calibration

SPAM Calibration Procedure

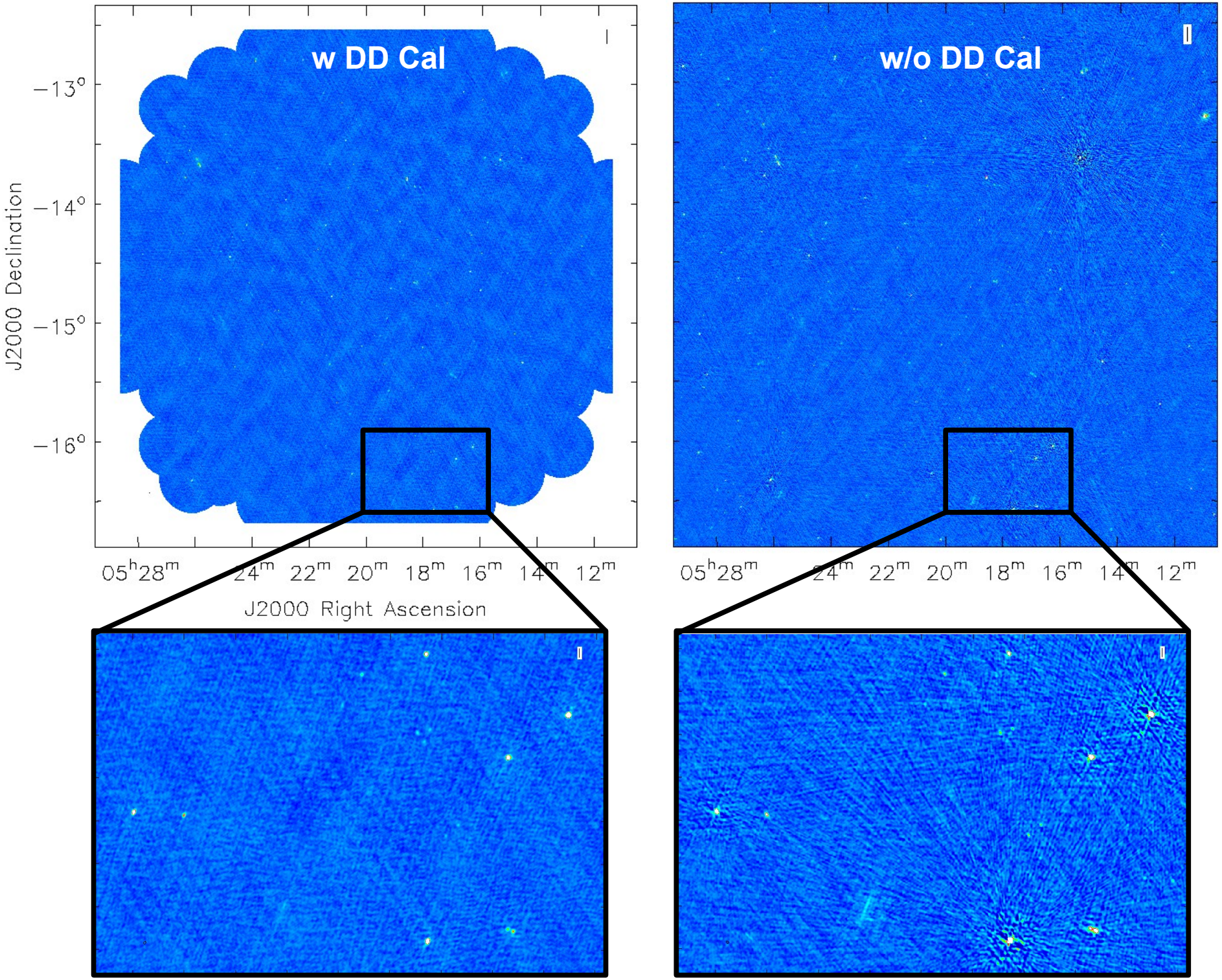
- Derive phase errors (peeling)
- Fit phase screen
- DD calib + imaging

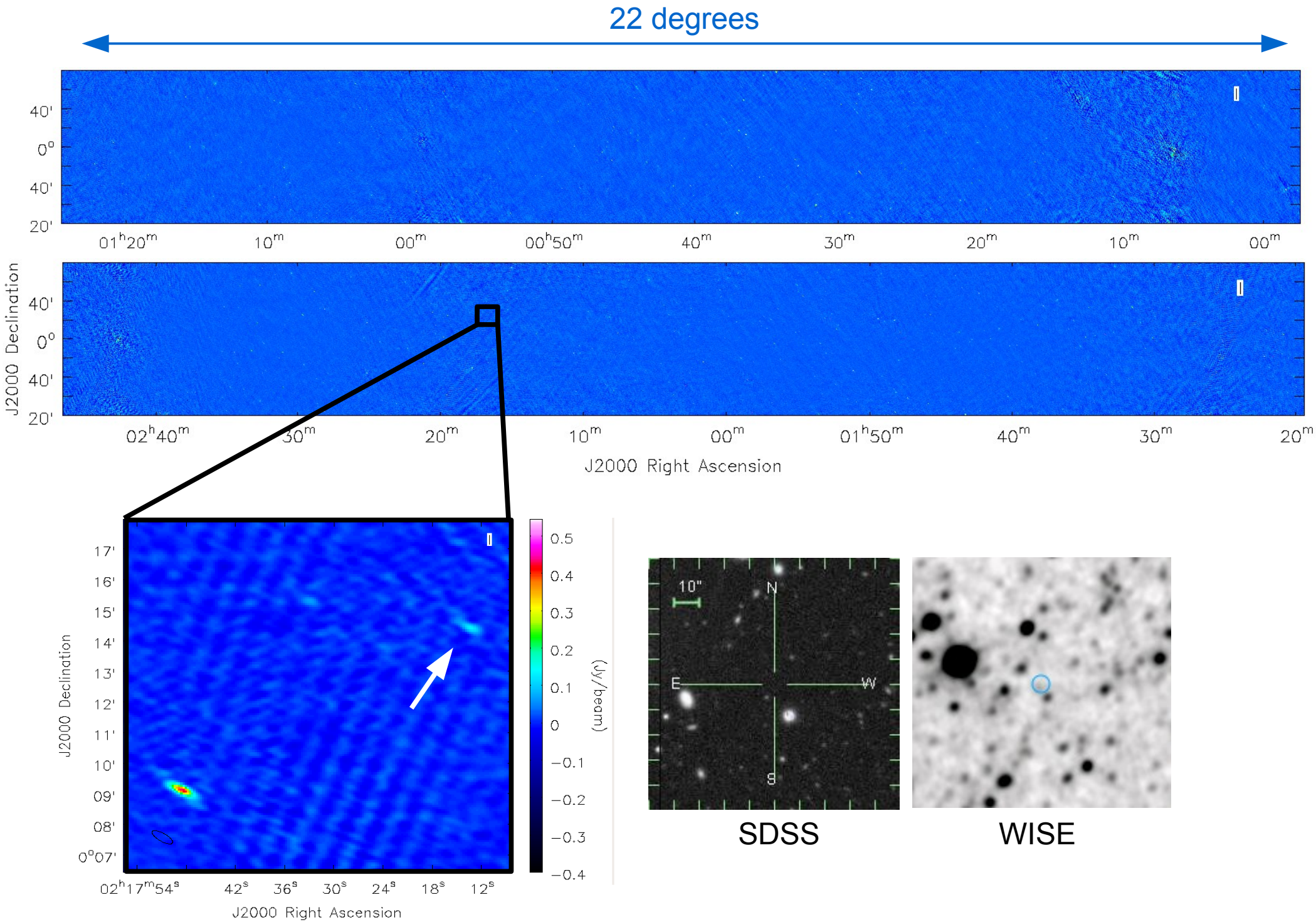




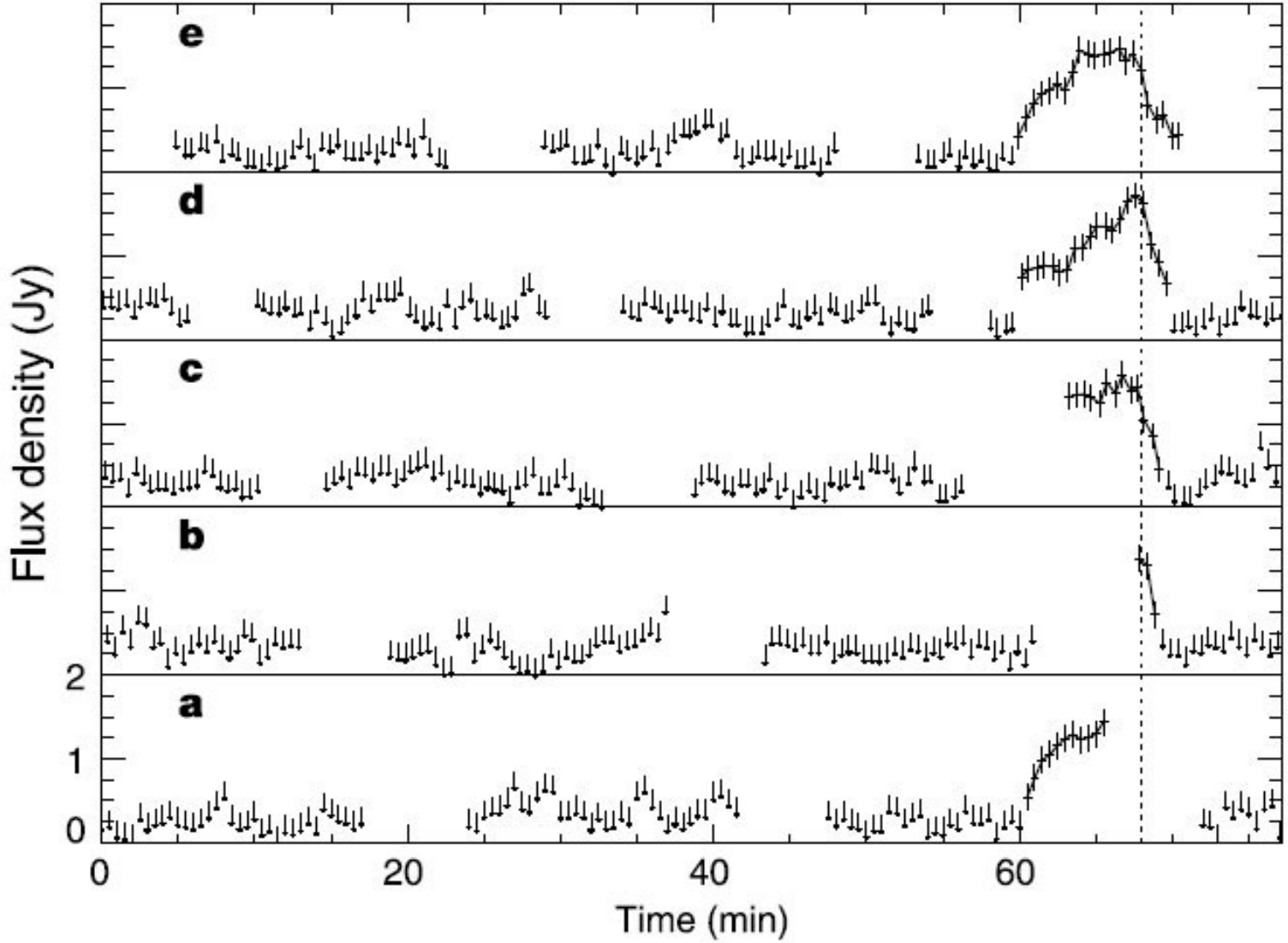


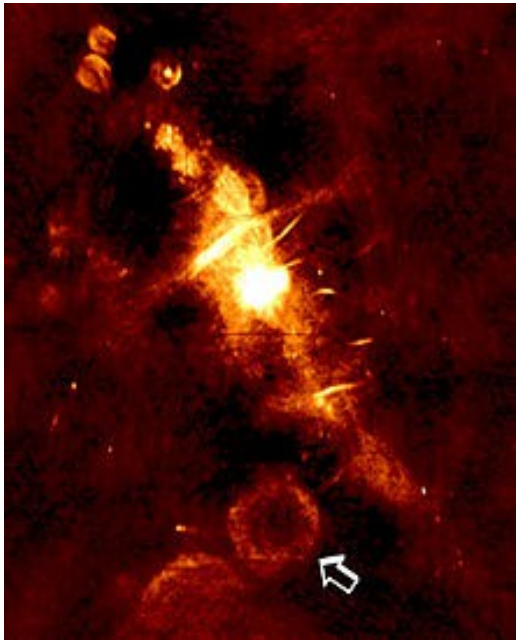
Intema et al. 2009


w DD Cal
w/o DD Cal
−13°
−14°
−15°
−16°
J2000 Declination
05h28m
24m
22m
20m
18m
16m
14m
12m
J2000 Right Ascension


22 degrees
40'
0°
40'
20'
01h20m
10m
00m
00h50m
40m
30m
20m
10m
00m
J2000 Declination
40'
0°
40'
20'
02h40m
30m
20m
10m
00m
01h50m
40m
30m
20m
J2000 Right Ascension
17'
16'
15'
14'
13'
12'
11'
10'
09'
08'
0°07'
J2000 Declination
02h17m54s
42s
36s
30s
24s
18s
12s
J2000 Right Ascension
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
(Jy/beam)
10"
N
E
W
S
SDSS
WISE

GCRT J1745-3009

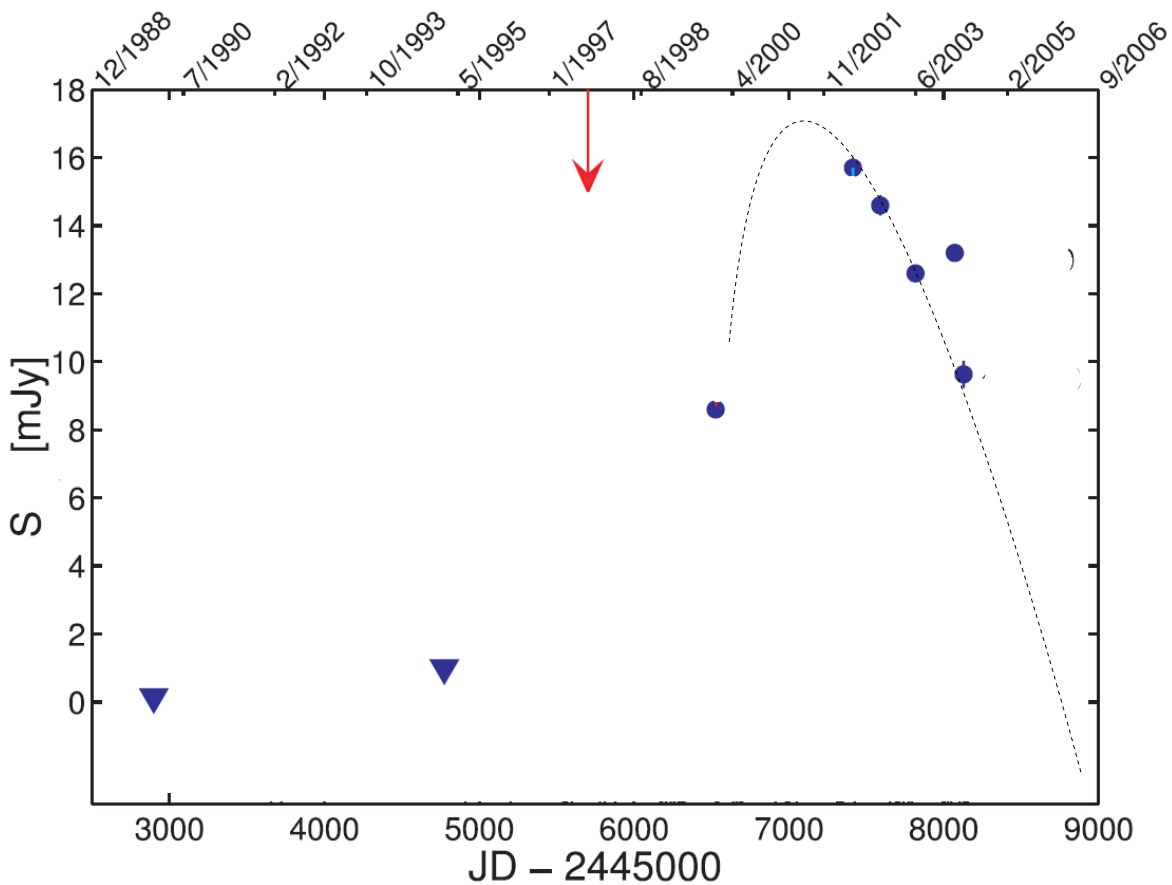




d>77pc: Coherent

Hyman et al. 2005

Supernova VLA 121550.2+130654



Levinson et al. 2002, Gal-Yam et al. 2006

ThunderKAT **VLA Sky Survey** **uGMRT**


Summary

– Consider on-the-fly mapping for SKA mid

– Fast calibration, imaging, and source-finding are key

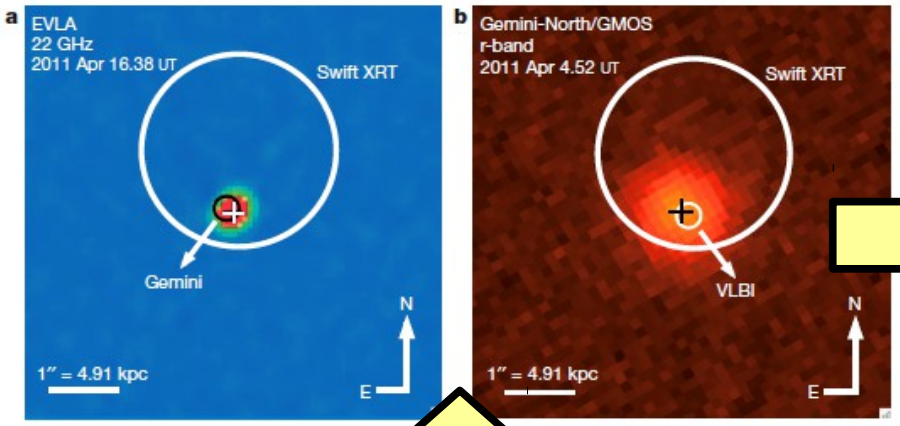
– GHz sky best for extragalactic synchrotron transients (days~months)
– MHz sky best for Galactic coherent transients (seconds~hours)

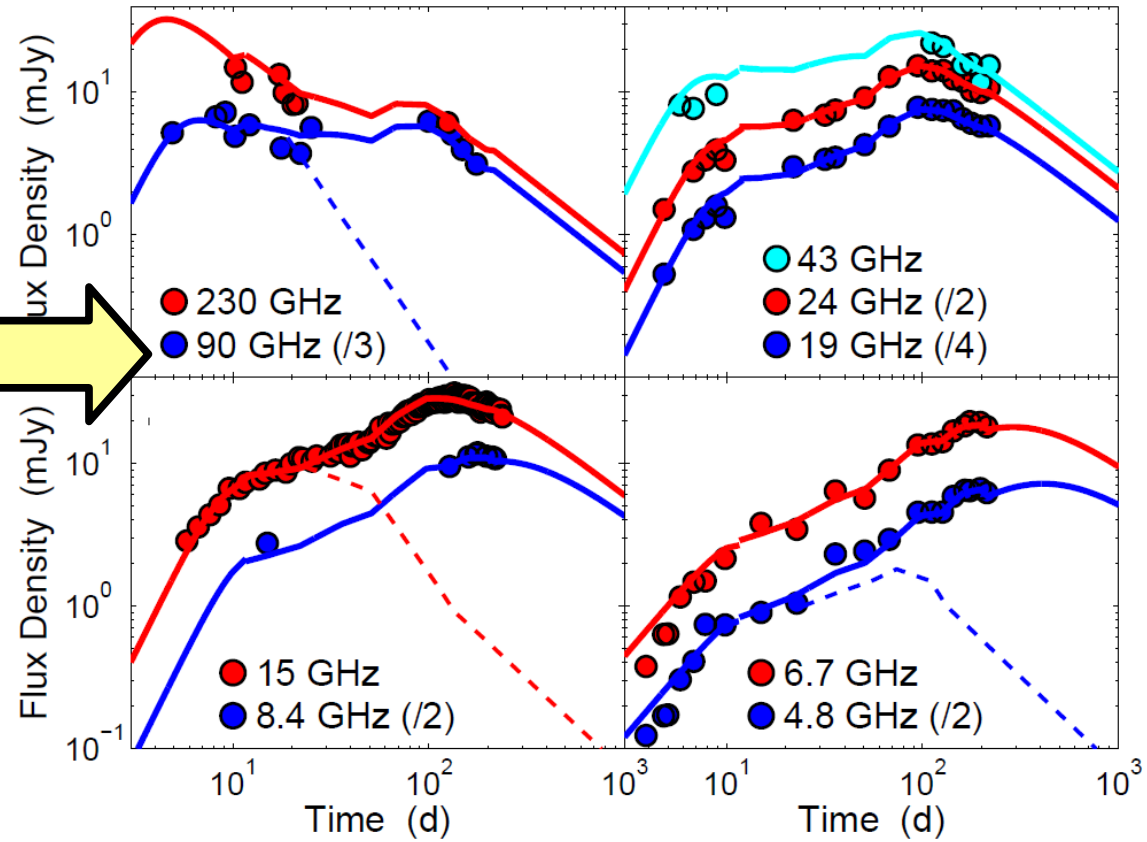
– Optimize the quality of calibration/imaging and the lag between observations and discovery

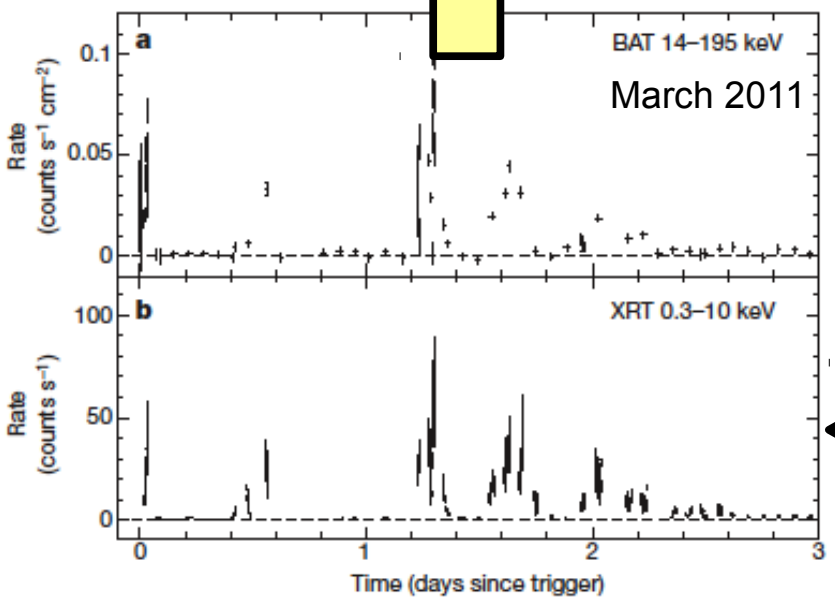
– ThunderKAT (MeerKAT), VLASS (JVLA) and uGMRT will be testbeds

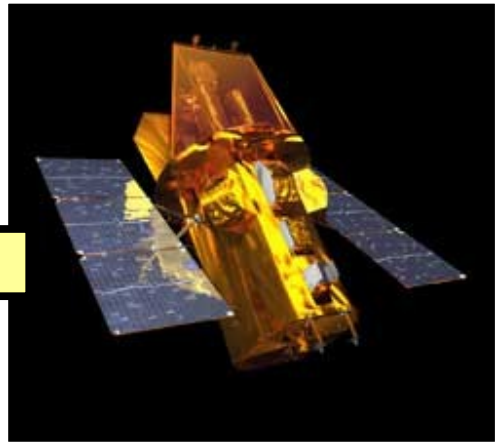


Swift J1644+57





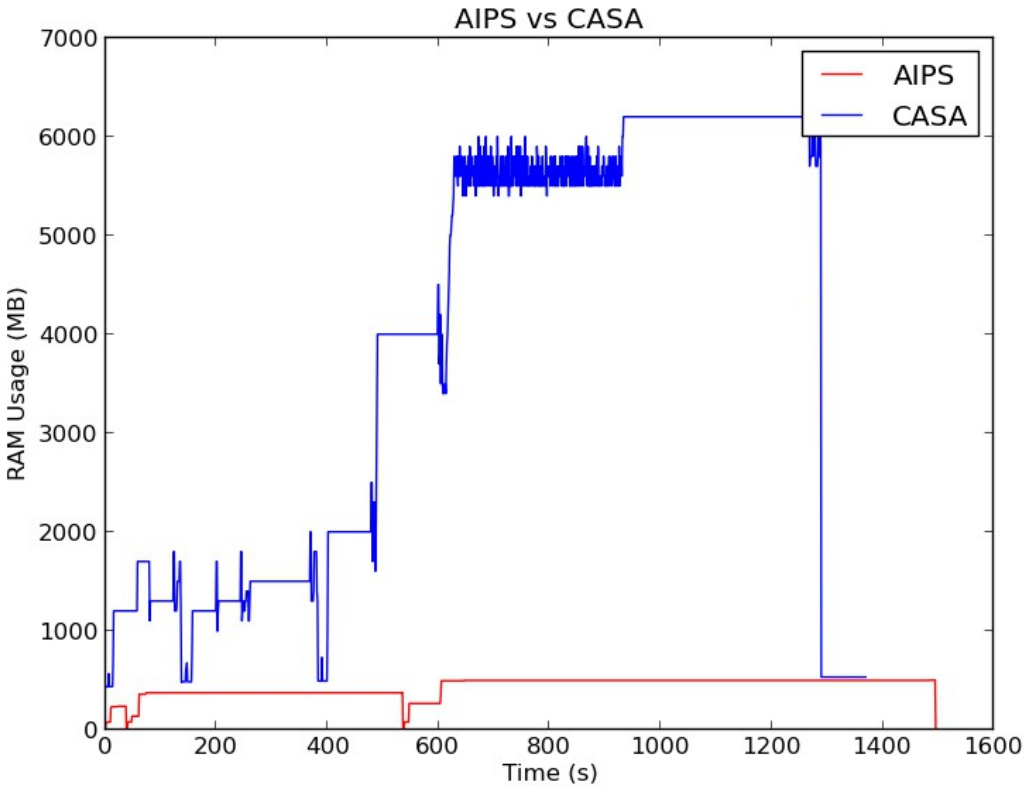




Burrows et al. 2011, Zauderer et al. 2011 (Nature), Levan et al. 2011 (Science), Berger et al. 2012

Software Choice

- AIPS, CASA, other?
- Speed / Memory
- 5 – 10 x RAM
- 1 – 3 x 10 x Speed



Credit: Stephen Bourke