

# The Prototype All-Sky Imager

Jake Hartman (JPL)

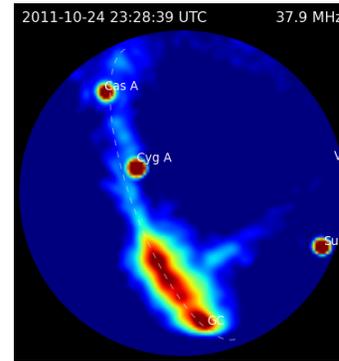


- ▶ **The PASI system**
  - Lightning
  - Transient monitoring
  - Results
  - Next steps



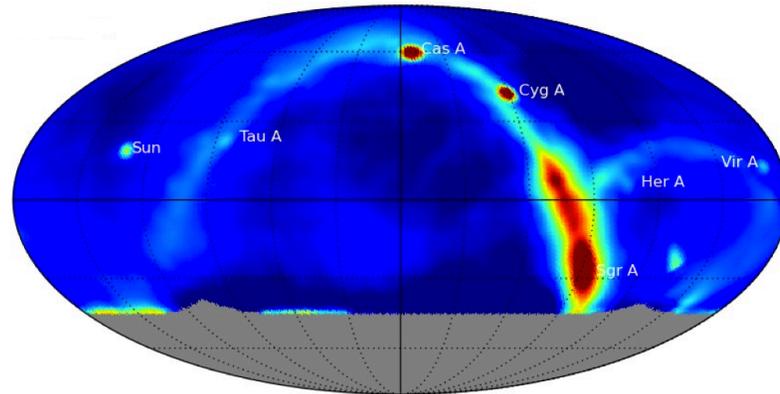
# The Prototype All-Sky Imager (PASI)

- Software correlator and imager in the LWA1's RFI shelter
- Receives a continuous 100 kSPS stream from all the dipoles
- Near-live imaging of the sky with up to 1 s cadence at 100% duty cycle, typically running 10–20 hr/day, covering  $3\pi$  sr



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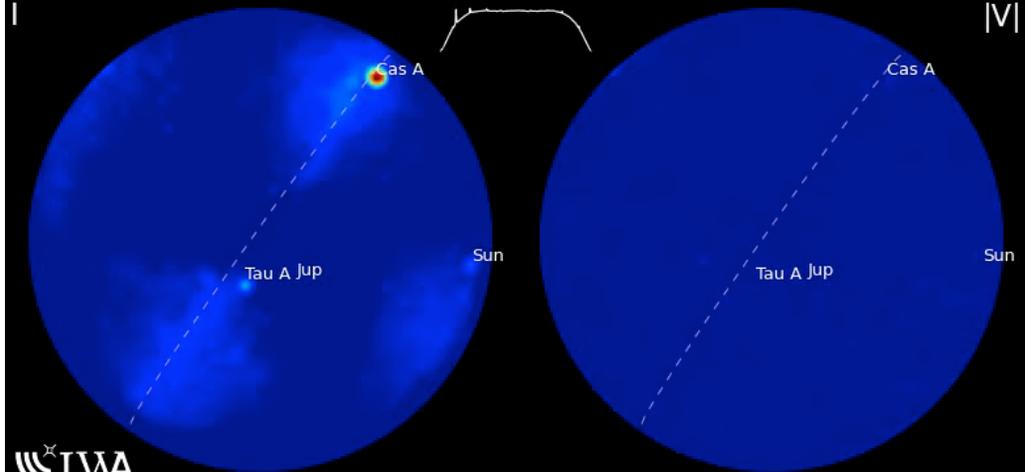
Dowell et al.,  
TBW sky survey



# The Prototype All-Sky Imager (PASI)

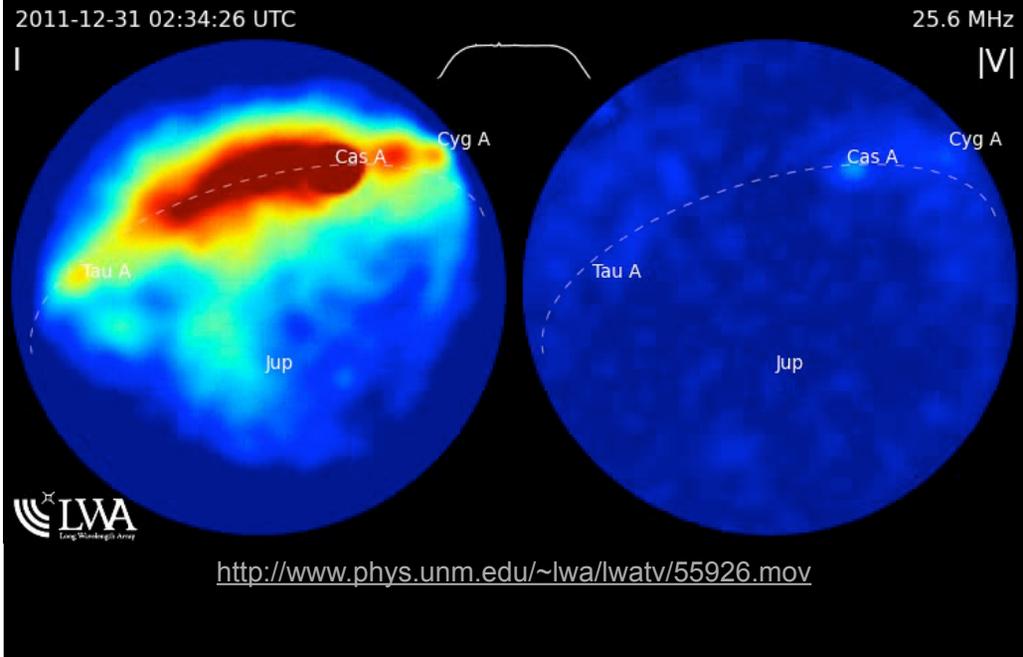
2013-03-30 00:00:05 UTC

52.00 MHz



<http://www.phys.unm.edu/~lwa/lwatv/56381.mov>

# The Prototype All-Sky Imager (PASI)



http://lwa.unm.edu/live

**LWA TV ... live!**

These images show the sky above the first LWA station. They update every few seconds, and they're typically about 30 seconds old. If the image isn't updating right now, it means we're probably working on the telescope or taking spectra rather than images.

Each image shows the full sky, down to the horizon at the image's edge. Depending on the current operating mode of the LWA's Prototype 40-Sky Imager experiment, there may be one or two images. If there is one, it shows the total intensity -- the power coming from each point on the sky. If there are two, the left will show the total intensity, and the right will show the intensity of circularly polarized radio waves.

At the upper left you can see the average time of the data that went into the image (given in UTC, which is basically the same as Greenwich Mean Time). There is no time gap between the images: we are imaging sky in real time with a 100% duty cycle. At the upper right is the central frequency of the image. In the center is a 100 kHz bandwidth spectrum from a single antenna and polarization; the images are produced from the middle 75 kHz.

Finally, we've labeled the brightest objects in the sky:

Finally, we've labeled the brightest objects in the sky:

- Cas A -- a supernova remnant
- W A -- a prominent elliptical galaxy also known as M87
- Tau A -- the Crab Nebula, a supernova remnant
- Cyg A -- a bright radio galaxy
- Jup -- Jupiter, which only can be seen when it is bursting
- Sun -- the Sun, which can become so bright that it wipes out everything else in the image!
- Dashed line -- the plane of our galaxy
- CC -- the center of our galaxy.

Of course, there will sometimes be points in our image other than these labeled ones! Most of these are due to radio frequency interference (RFI): radio emitters from sources other than the sky. The sky will sometimes be wiped out by bright RFI, particularly at low frequencies and during the day. However, some blips just may be something new: flares from the Sun, flares or intergalactic radio counterparts to gamma-ray bursts, or something totally new and unexpected. Our computers will be monitoring these movies to let us know when something unusual pops up!

**Reruns**

Every day, we make a movie showing 24 hours of the sky, compressed down to about 10 minutes of video. Each movie starts at around sunset at the LWA.

To view a video, click the date that you'd like in the calendar. LWA TV only came online recently, so most of the early dates don't have videos. Days with videos have their dates in red and are clickable.

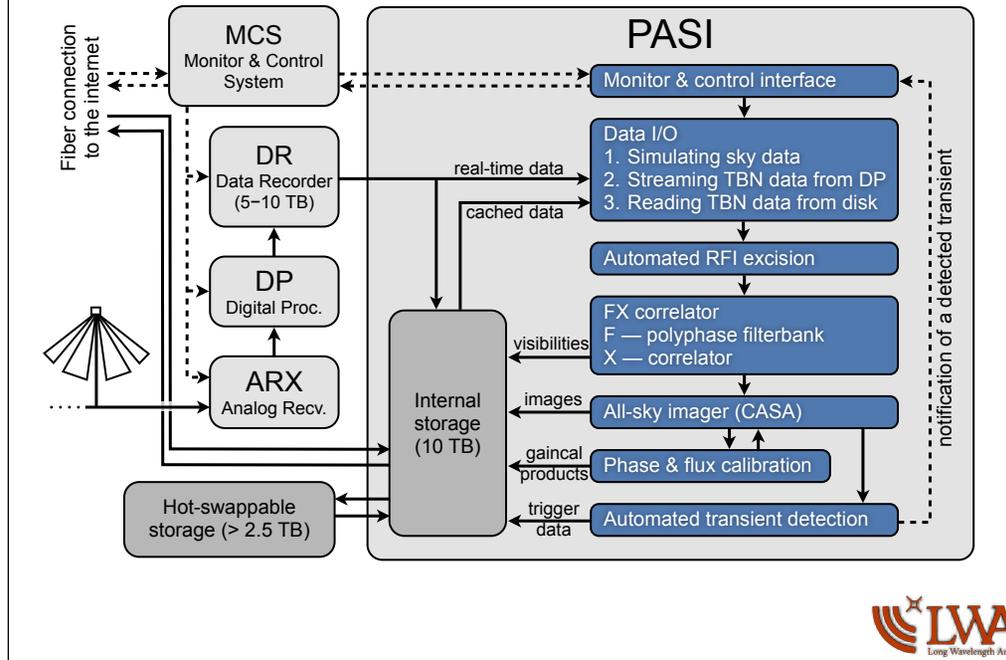
Each day's movie may be as much as 100 MB.

2011 December						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
27	28	29	30	1	2	3
5989	5989	5994	5989	5994	5989	5988
4	5	6	7	8	9	10
5989	5990	5991	5992	5993	5994	5995
11	12	13	14	15	16	17
5996	5987	5998	5999	5990	5991	5992
18	19	20	21	22	23	24
5993	5994	5995	5996	5997	5998	5999
25	26	27	28	29	30	31
5990	5991	5992	5993	5994	5995	5996
1	2	3	4	5	6	7
5997	5998	5999	5990	5991	5992	5993

Logos for JPL, The University of New Mexico, and other partners are visible at the bottom of the page.

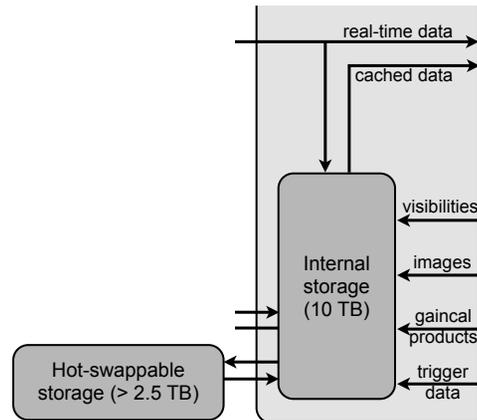


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Internal storage provides look-back time for all levels of data products

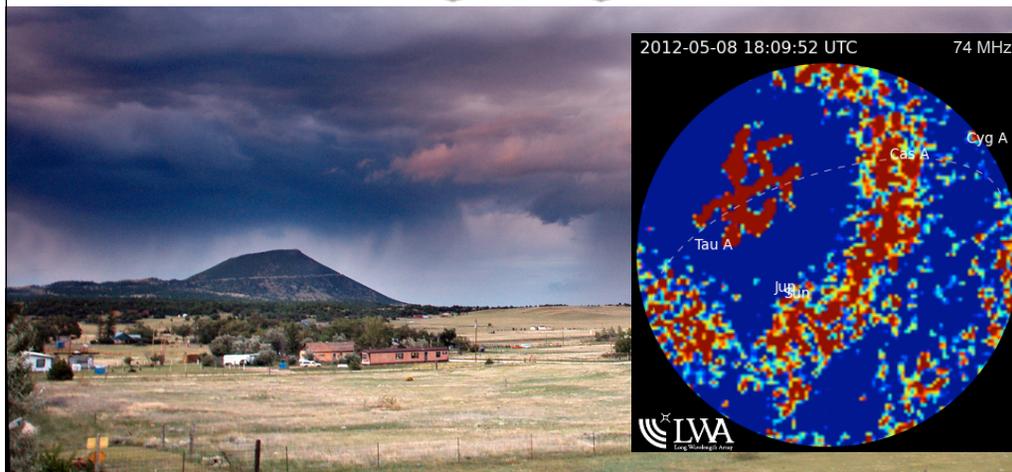


- 10–20 hours for raw data — not yet implemented
- > 30 days for visibilities with 1 s time resolution
- images kept forever
- detection candidates kept forever

- The PASI system
- ▶ **Lightning**
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# Lightning!



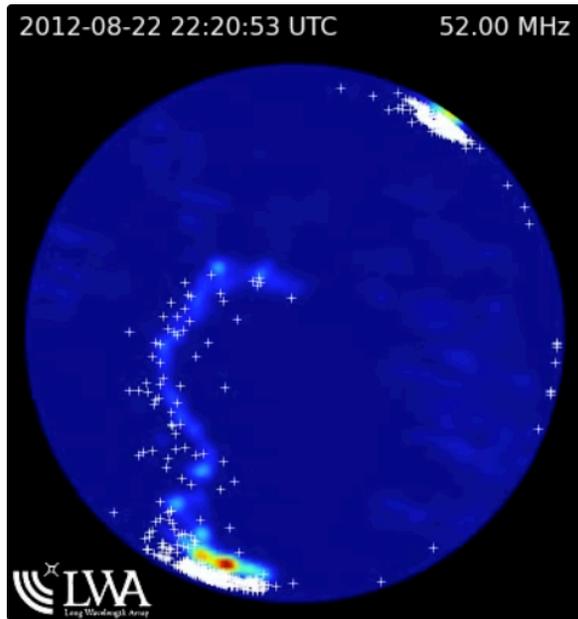
## LWA1 lightning observation mode

When lightning is present near the LWA1:

- Set TBN to 85 MHz and reduce the gain
- Record the raw data to disk on DR5
- Post-process with 5 ms (current) to 50  $\mu$ s (anticipated) time resolution
- Compare results from NMT / Langmuir Lab's instrumentation, especially the Lightning Mapping Array

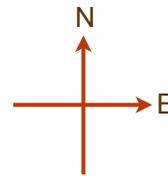


# Fast imaging of lightning

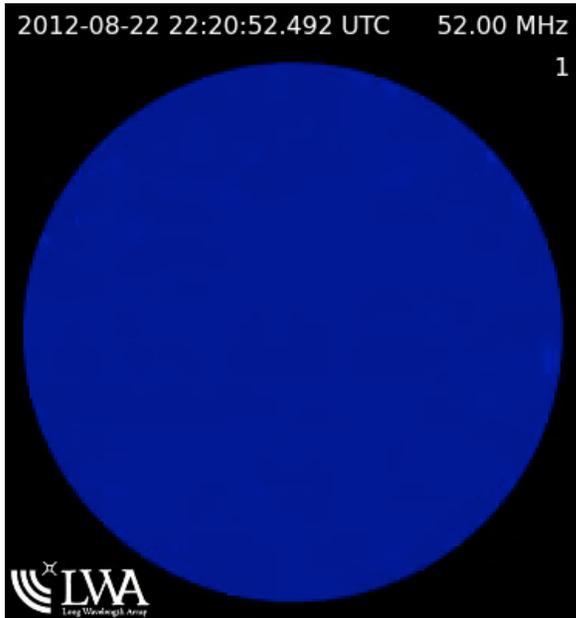


Intra-cloud discharge,  
traveling from SSW  
horizon to overhead

5 s integration

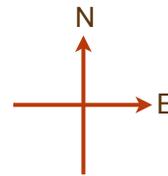


# Fast imaging of lightning

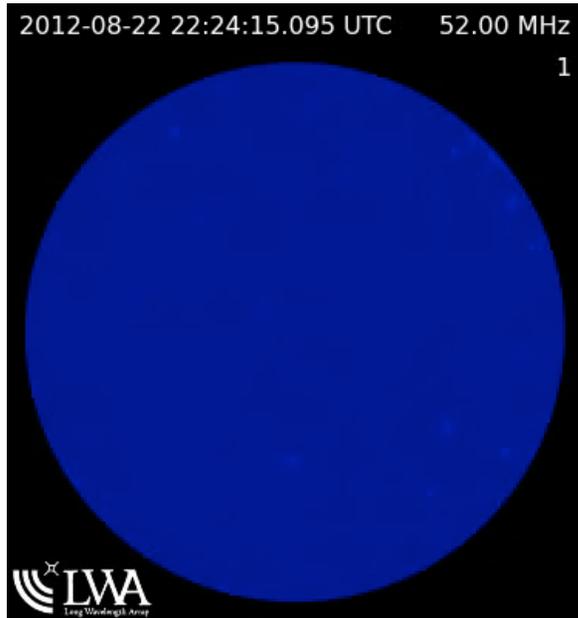


Intra-cloud discharge,  
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5 ms integrations

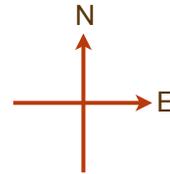


# Fast imaging of lightning

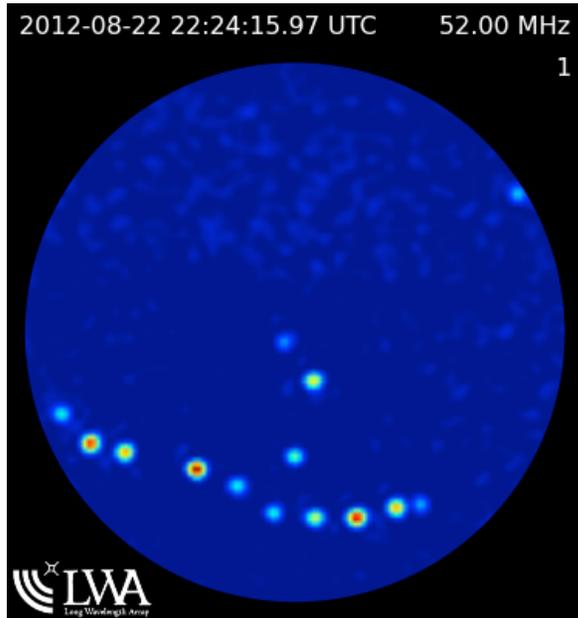


Intra-cloud discharge,  
initiating overhead,  
branching, then traveling  
to the horizons

5 ms integrations

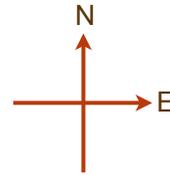


# Fast imaging of lightning



Intra-cloud discharge,  
initiating overhead,  
branching, then traveling  
to the horizons

30 ms integration



The PASI system  
Lightning  
▶ **Transient monitoring**  
Results  
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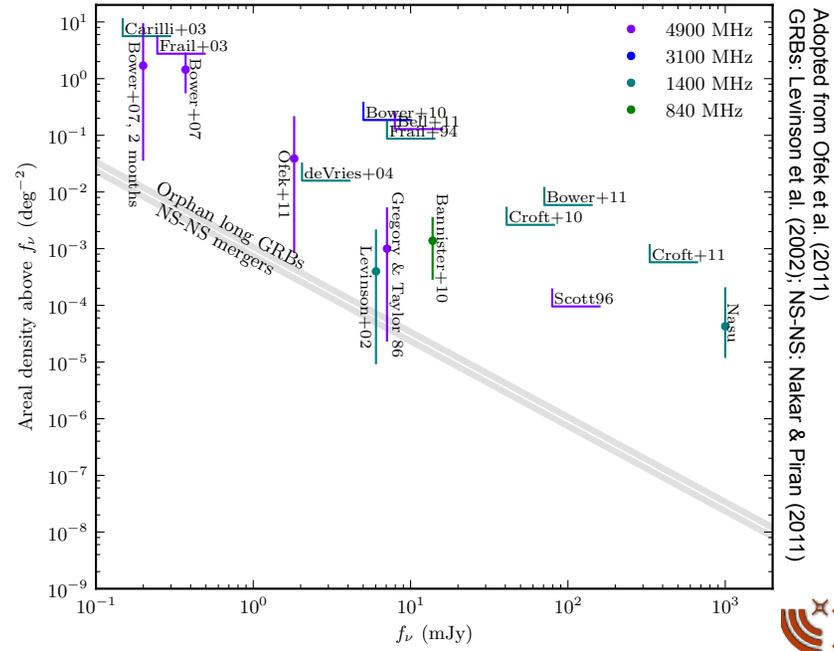


## Exploring new transient phase space

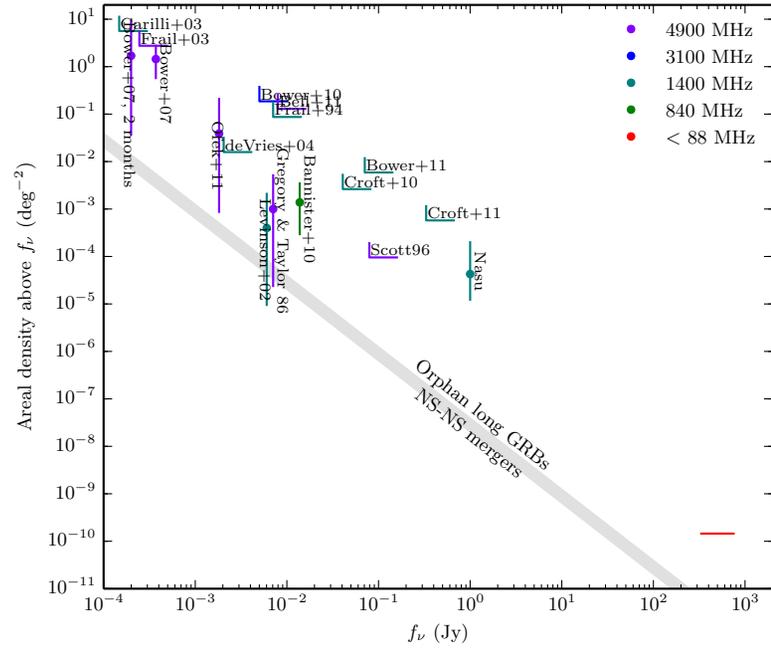
- Low frequency, full Stokes
- Large field of view: 10,000 deg<sup>2</sup> per image
- Cadence: 1–5 s integrations, 100% duty cycle
- Uptime: ~12 hr good data per day  
(currently limited by TBN / beamformer conflicts)
- Duration: ~6000 hr data and counting
- Noise limit from image differencing: ~100 Jy rms



# Exploring new transient phase space



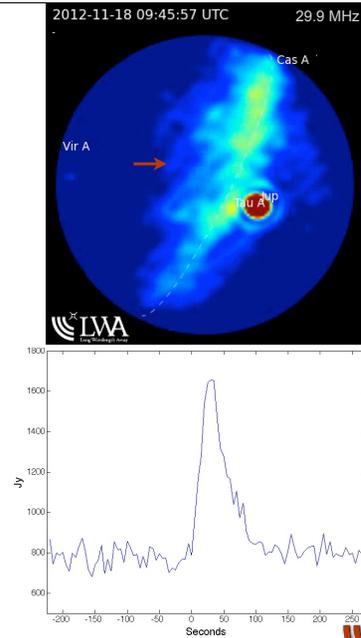
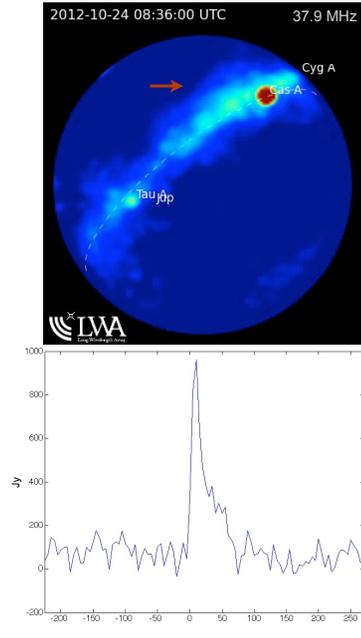
# Exploring new transient phase space



Adopted from Ofek et al. (2011)  
GRBs: Levinson et al. (2002), NS-NS: Nakar & Piran (2011)



# Unidentified FRED transients

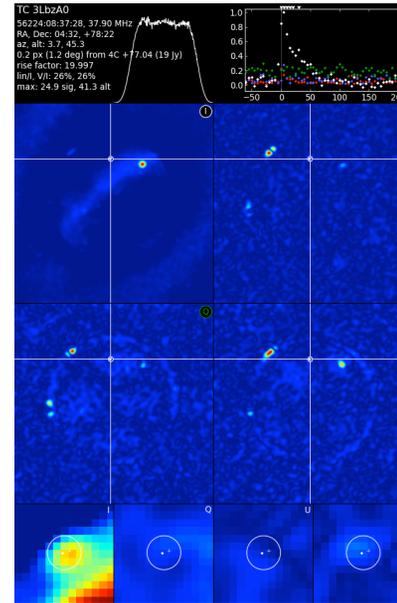


Obenberger, Hartman, Taylor, et al. (in prep.)

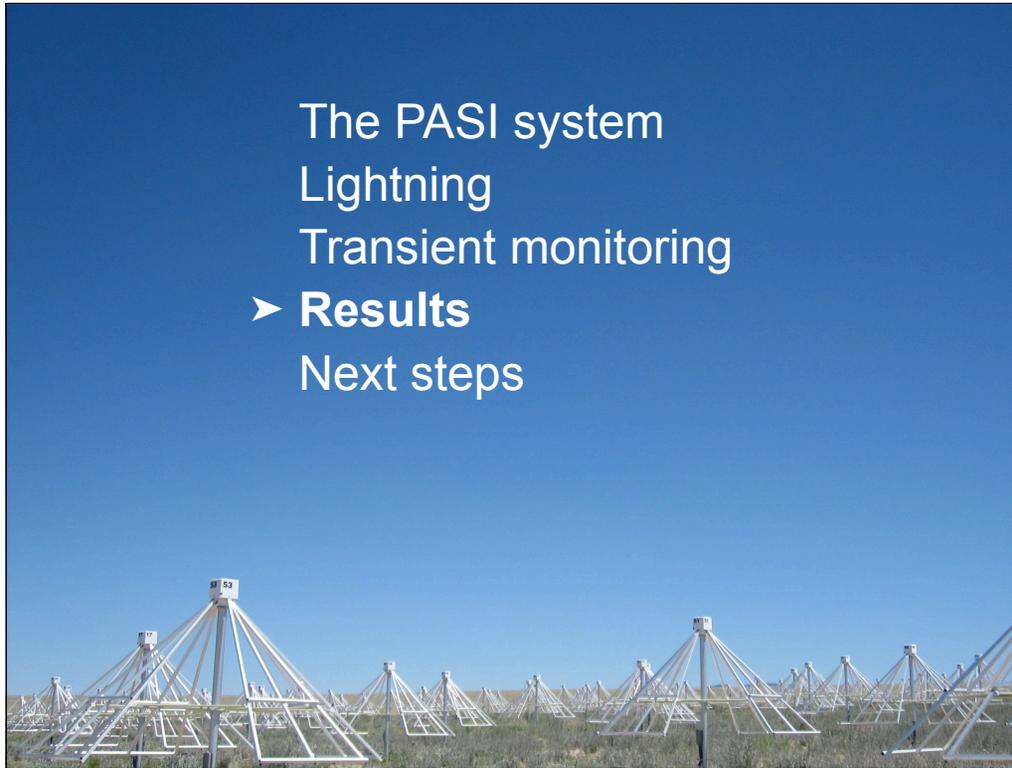


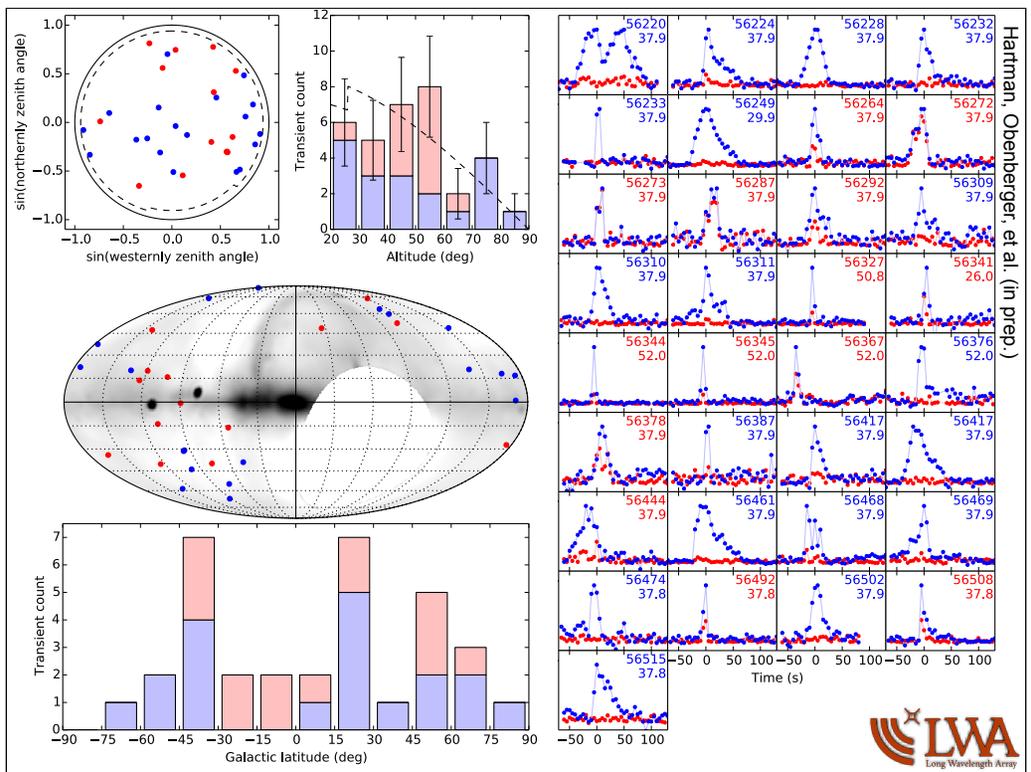
## Detection strategy

- Confusion: 100 Jy/beam at 38 MHz
- Image differencing in Stokes I and V
- Detect large rises  
( $> 5 \sigma$  off G. plane;  $> 7 \sigma$  on it)
- Remove transient candidate if:
  - below  $20^\circ$ – $25^\circ$  altitude
  - obvious RFI in the spectrum
  - *any* associated linear polarization
  - close to  $>30$  Jy VLSS sources
  - vis data reveal it's not broadband
  - moving across the sky!
- 300 days searched,  
200 days remaining



- The PASI system
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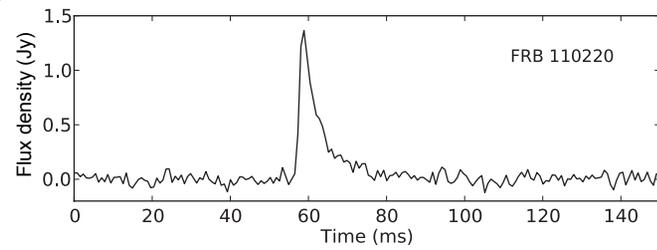


Hartman, Oberberger, et al. (in prep.)



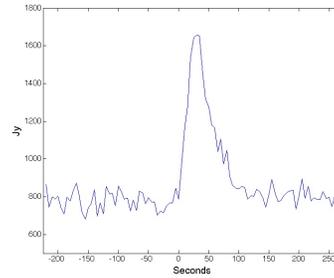
# Fast Radio Bursts?

Parkes Radio Telescope



Thornton et al. (2013)

LWA1



LWA1 / Parkes:  
 $10^{-1.5}$  in frequency  
 $10^4$  in time  
 $10^3$  in flux density



## Next steps

Soon:

- Process 200 days of more data
- Further verification that these are real
- Measure or limit DMs from visibility data
- Flux calibration, self-calibration
- Check associations with nearby stars

Over the next ~year:

- Search beamformed data:  
detectable in Steve's SDP project?
- Trigger beamformed observations
- More / better data: OVRO and Sevilleta

