GPU-Accelerated Transient Searches of LWA All-Sky Observations

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LWA
Long Wavelength Array

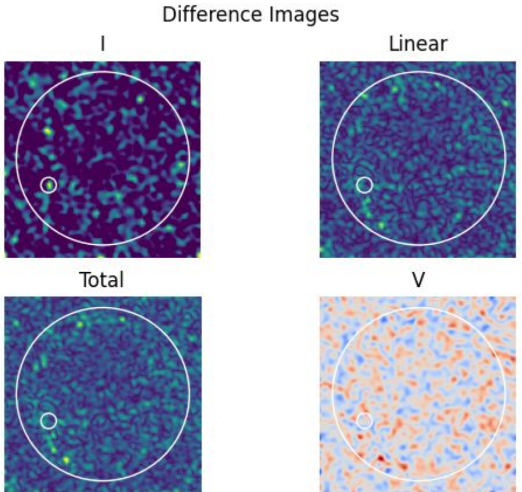
The Long Wavelength Array

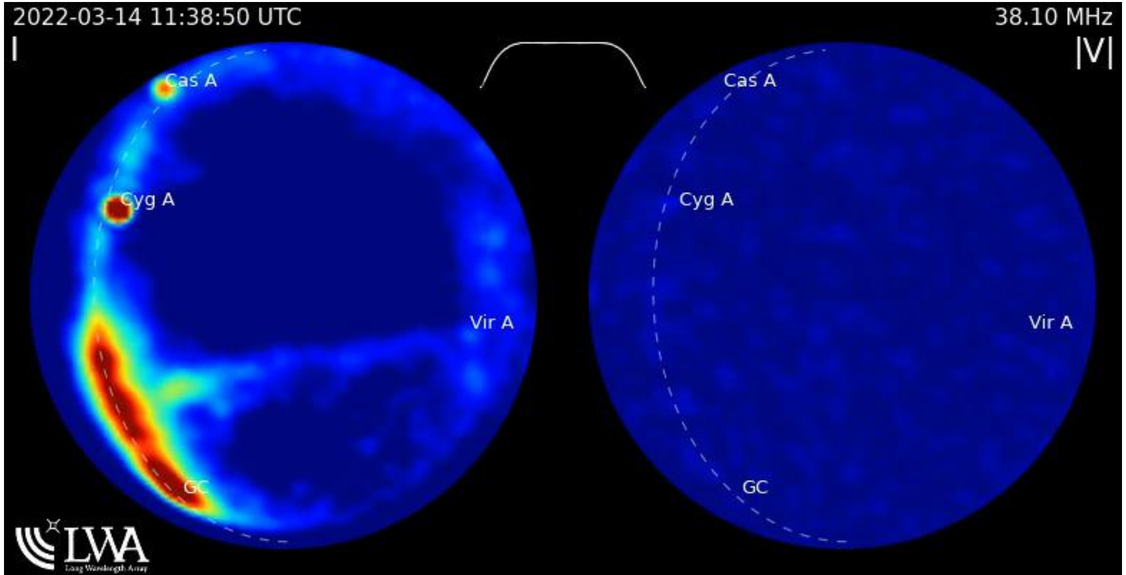
- LWA 1
- 256 Dipoles
- 10-80 MHz
- Multiple Modes
- TBN, 67 kHz of continuous bw

- LWA-SV
- 256 Dipoles
- 3-88 MHz
- Multiple Modes
- TBF, 19.8 MHz of continuous bw

The Prototype All-Sky Imager (PASI) at LWA-1

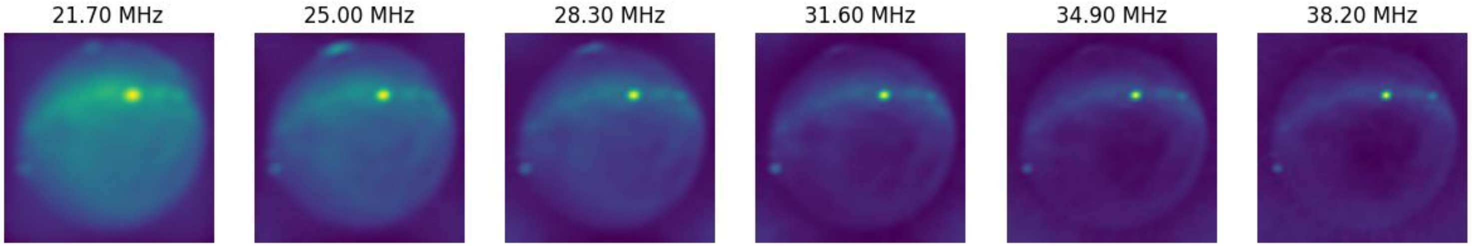
- Uses TBN data
- Images over 1/3 of the sky every 5 seconds
- Data going back to March of 2012
- Daily movies published on LWA-TV (https://leo.phys.unm.edu/~lwa/lwatv.html)
- Used to detect MRAs, place limits on GRB prompt emission, study Ionospheric Phenomena





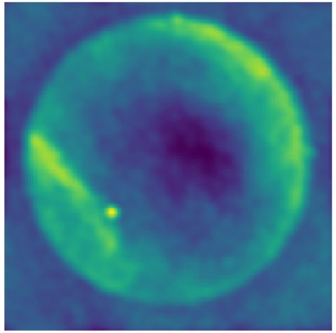
The Orville Wideband Imager at LWA-SV

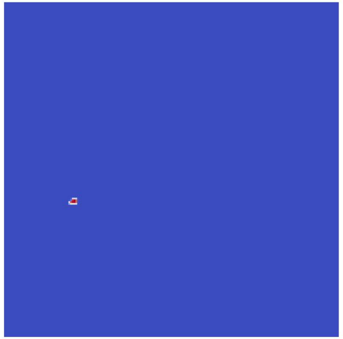
- Uses TBF data (19.8 MHz of bandwidth)
- 198 channels (100 kHz bandwidth), averaged down to 6 channels
- Archival data going back to May 2020
  - LASI narrowband images going back to May 2016
- Follows LWA-SV tuning
  - A 19.8 MHz window between 1 and 91 MHz
  - Usually between 20 and 50 MHz

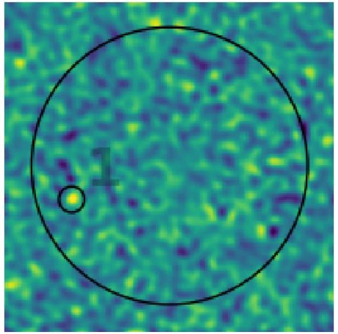


Procedure

- Archival, simultaneous Orville and PASI data
- Reject frequencies below 20 MHz
- Make difference images
- Flux correct from bright A-team sources
  - Archival data is not flux calibrated
- Measure RMS noise
- Group pixels into source islands
- Perform QC







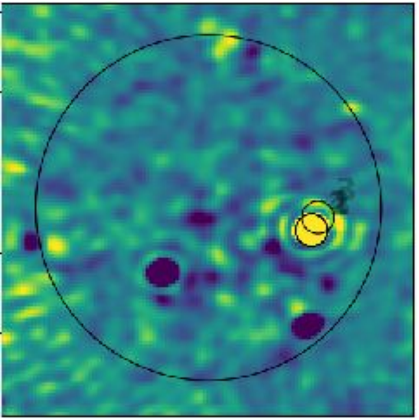
Complications

- Big Data
  - About 1.1 Gigabytes per hour for the past 4.5 years
  - GPU Computing via Bifrost's Map (Cranmer et al. 2017)
- Mask A-team
- Sidelobes
  - Dynamic Range cut
- Anticoincidence
  - Scintillation
  - Airplanes
  - Local RFI

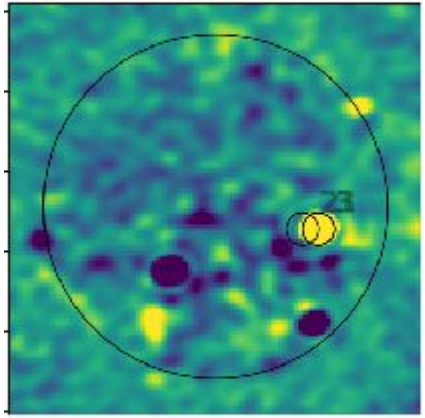
An interesting test case

Orville blind detections

28.3 MHz

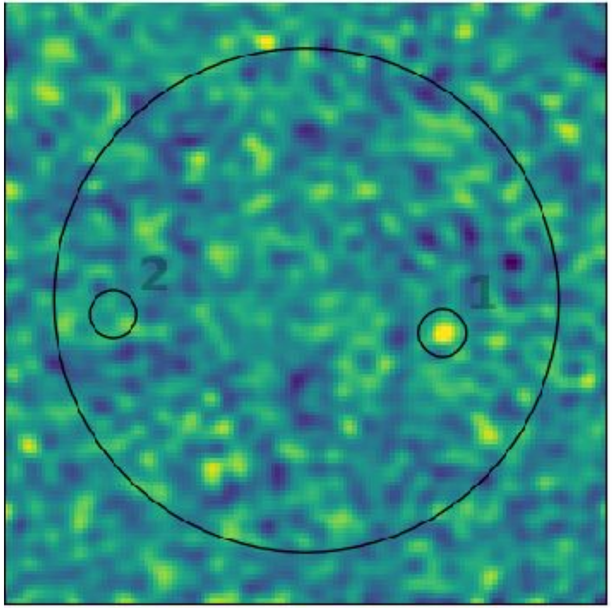


31.6 MHz



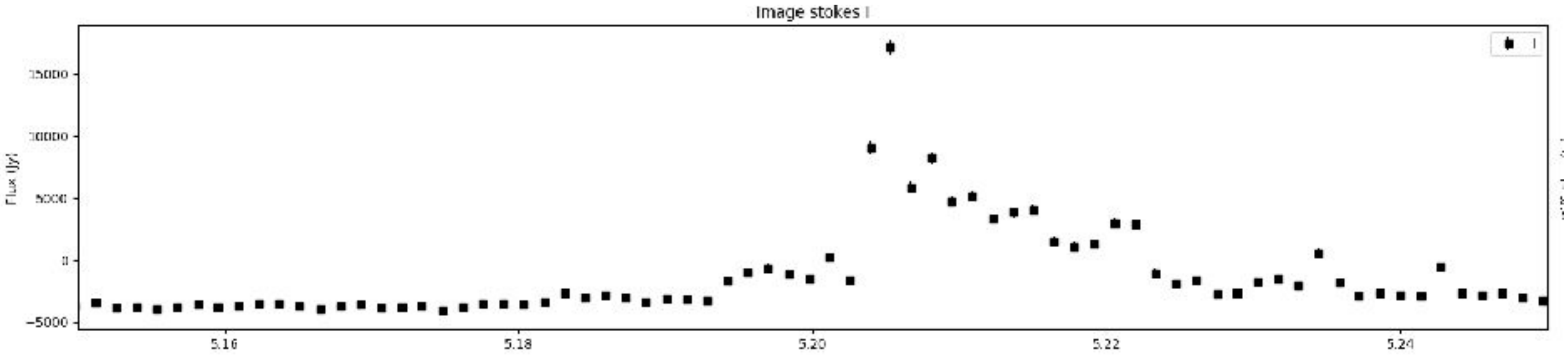
PASI blind detection

38.1 MHz

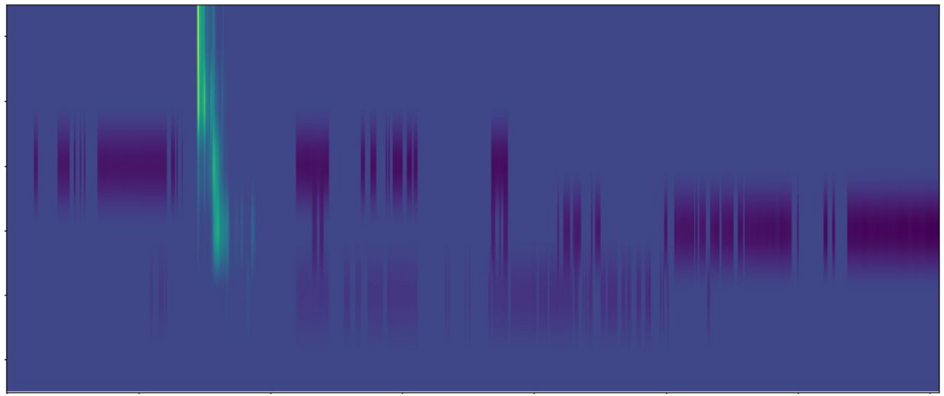


An interesting test case

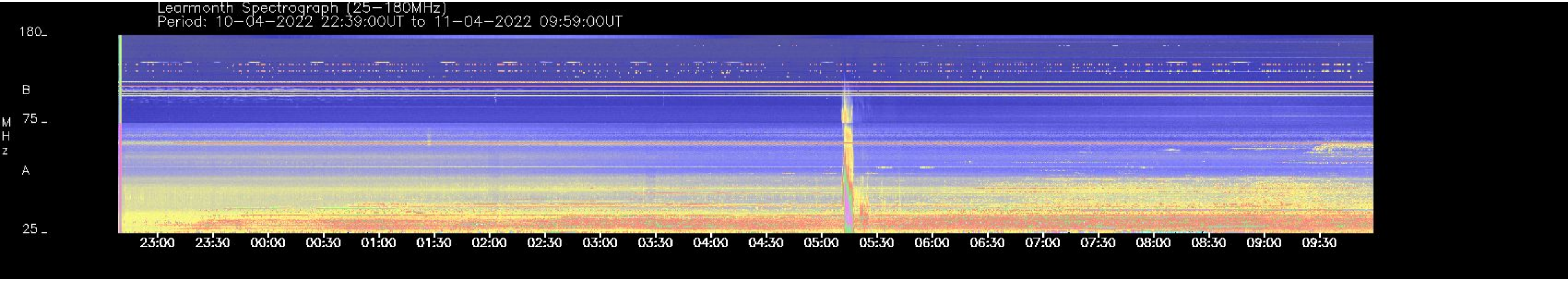
PASI



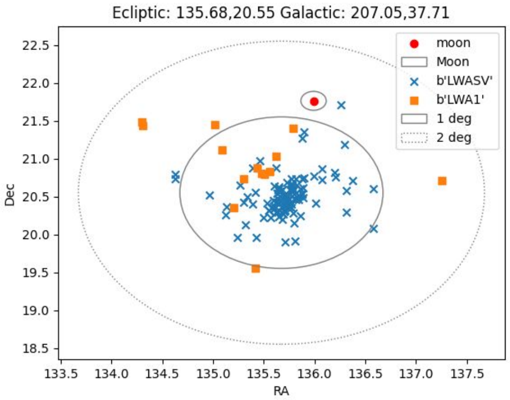
Orville



Alas, it's the sun



From the Australian Space Weather Forecasting Centre



via the Moon

Summary

- About 4.5 years of Orville All-sky images
- Transient searches
  - Difference imaging
  - Flux calibration
  - Flagging problem images
  - GPU computing
- Anticoincidence w/ PASI
  - Reject airplanes and scintillating sources
- Detected the sun reflecting off the moon
  - Shows the methodology should work
- Searches and development ongoing

Complications: Big Data

- 6 frequency channels ⨉ 4 stokes parameters ⨉ 721 images ⨉ 128 pixels ⨉ 128 pixels ≈ 283.5 million pixels per hour
  - or about 1.1 Gigabytes per hour for the past 4.5 years
- Solution: parallelization
- GPU computing
  - Map from the Bifrost stream processing framework (Cranmer et al. 2017)
- 1 hr of data in a couple of minutes using very modest hardware

Complications: A-team/ bright sources

- The sun
- Jupiter
- Virgo A
- Tau A
- Hercules A
- Cassiopeia A
- Cygnus A

- All very bright and scintillating
- Mask off a circular region around the source

Complications: Other problem sources

- Horizon RFI is common
  - Choose sources above ~30 degrees or so elevation
  - Dynamic Range cut
- Bright sources cause sidelobes
  - Make a dynamic range cut
  - keep if interesting transient
- Known scintillating sources appear transient
  - Check against 3C and VLSSr
  - Anticoincidence between stations
- Airplanes and meteor reflections show up in the middle of the image
  - Anticoincidence
  - Frequency and polarization properties?

Using anticoincidence to reject scintillation

- Requires accurate positions
  - Works best towards the center of FOV
- Rejects most meteors
  - Unfortunately rejects MRAs
  - Slight chance of alignment
- Greatly reduces number of sources
- Requires both stations to be taking data