Evaluating the E-Field Parallel Imaging Correlator (EPIC) with the Long Wavelength Array

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16 February 2023, 38th New Mexico Symposium

Long Wavelength Array (LWA)

- 256 dual-polarization dipole antennas
- Pseudo-randomly arranged array in 100m x 110m area
- Independent beams tunable over frequency range of 10-88 MHz
  - ~16 MHz effective bandwidth per tuning
- Beamformed digital receiver (DRX) outputs raw voltage time-series data

LWA station located on the Sevilleta National Wildlife Refuge (LWA-SV)

LWA-EPIC

- The E-Field Parallel Imaging Correlator (EPIC) is a direct imaging correlator for interferometer arrays
  (Thyagarajan et al. 2017)

- Images formed by convolution of gridding function with electric field distribution at each dipole

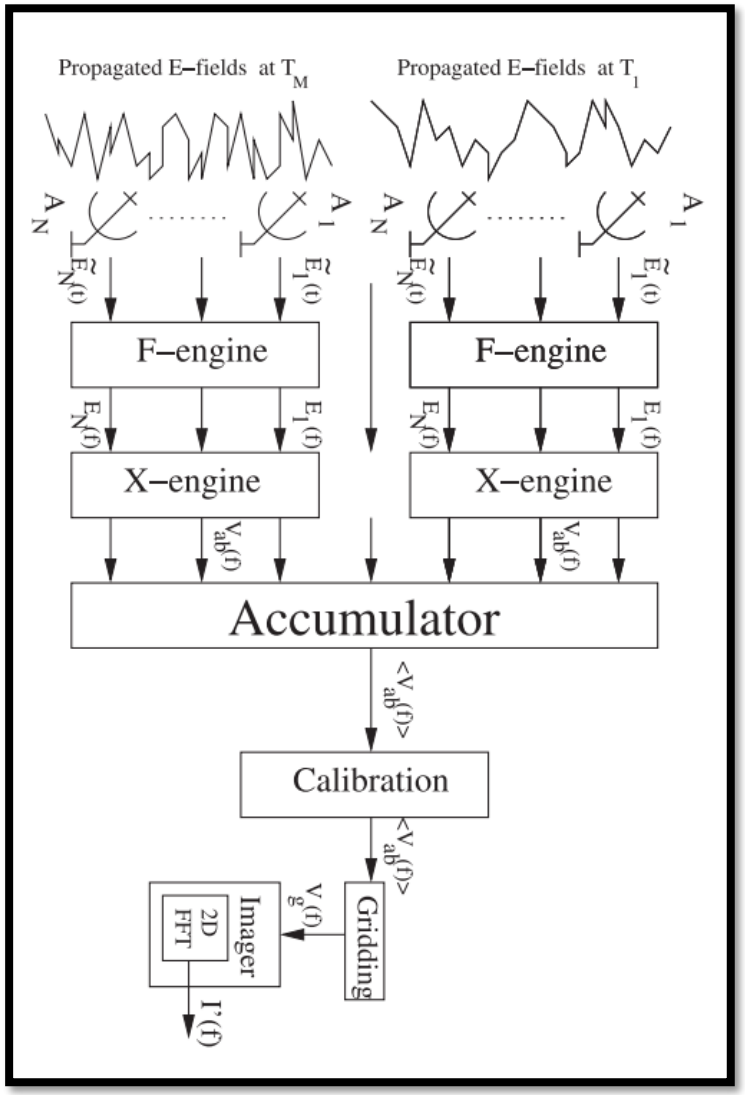
- Streaming output currently handled by Bifrost framework for GPU processing

LWA-EPIC

Standard FX-Correlator Schematic:

Orville subsystem

$\mathcal{O}(N^2)$

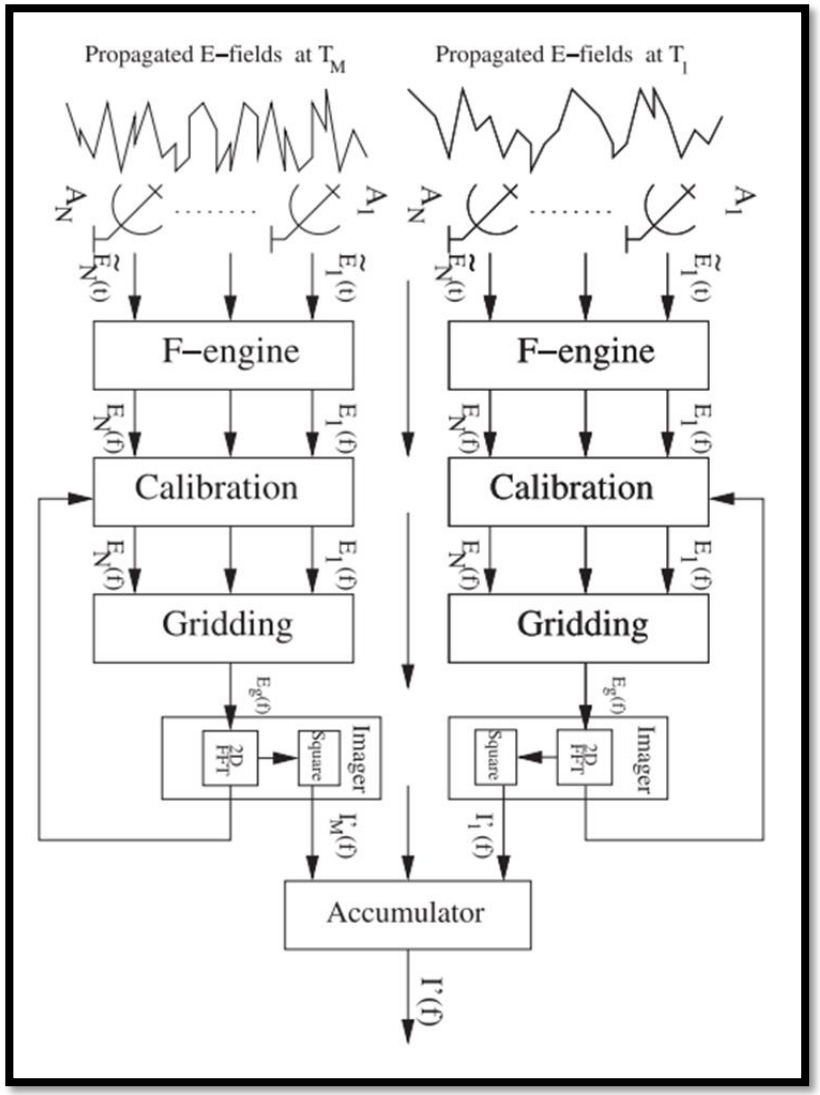


Thyagarajan et al. 2017

EPIC Correlator Schematic:

EPIC subsystem

$\mathcal{O}(N \log N)$



LWA-EPIC parameter space

- All-sky coverage
- Real-time observing, commensal with other LWA modes

- Custom time resolution from milliseconds up to hours
- Designed for continuous operation
- Blind Transient Search ready

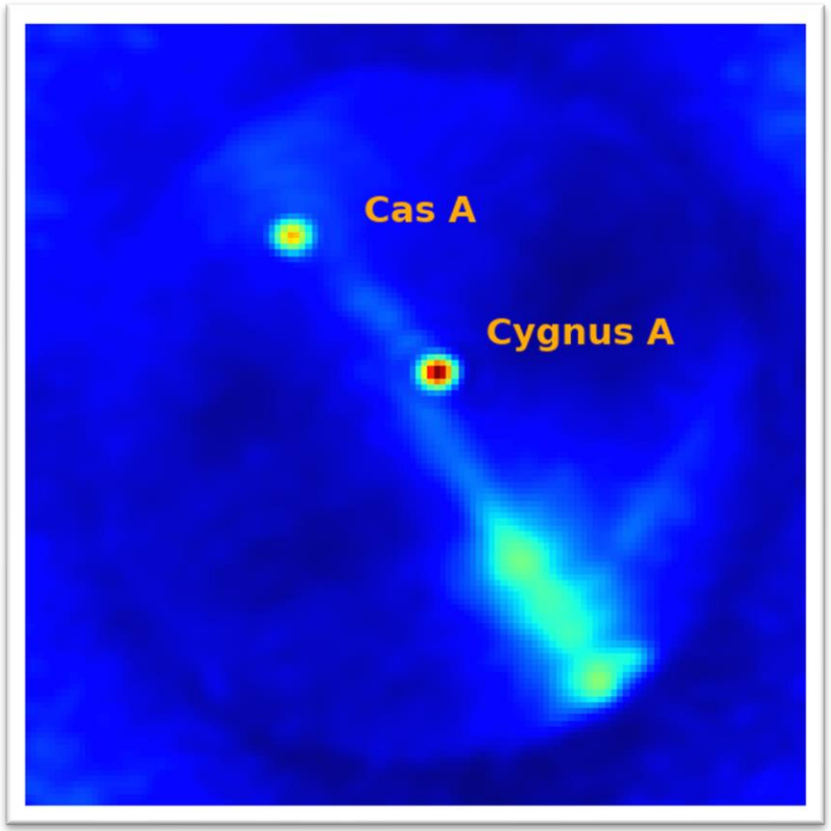
EPIC Evaluation Observations

1. All-sky imaging fidelity and demonstration increased parameter space accessible using EPIC

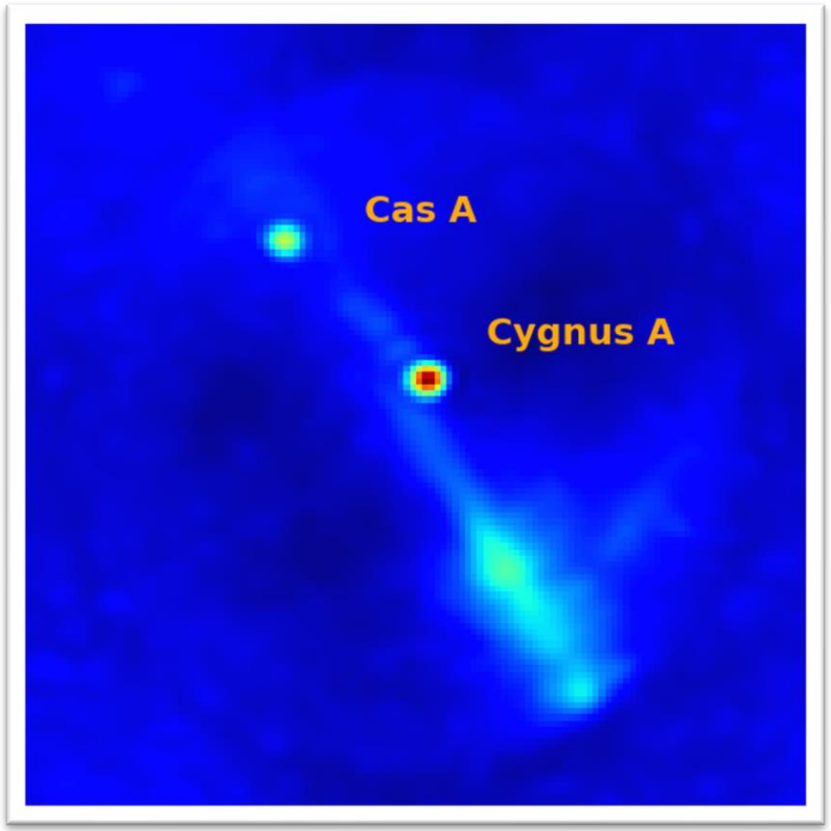
2. Matched observations of Crab Pulsar for dispersed pulse recovery
   - Beamed observations at 46.0 MHz and 49.3 MHz

Imaging Comparison

Orville (Standard FX Corr.)

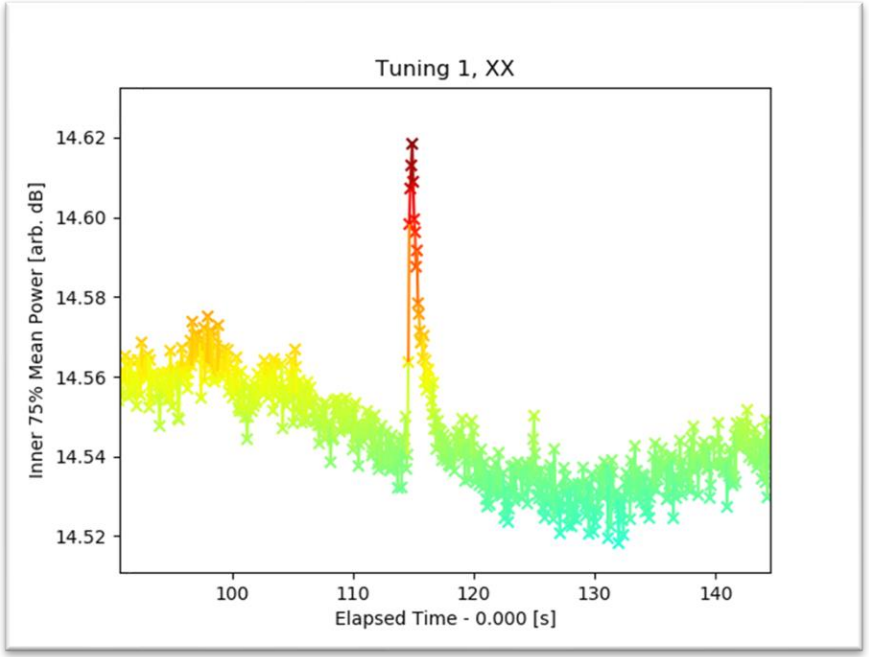


EPIC

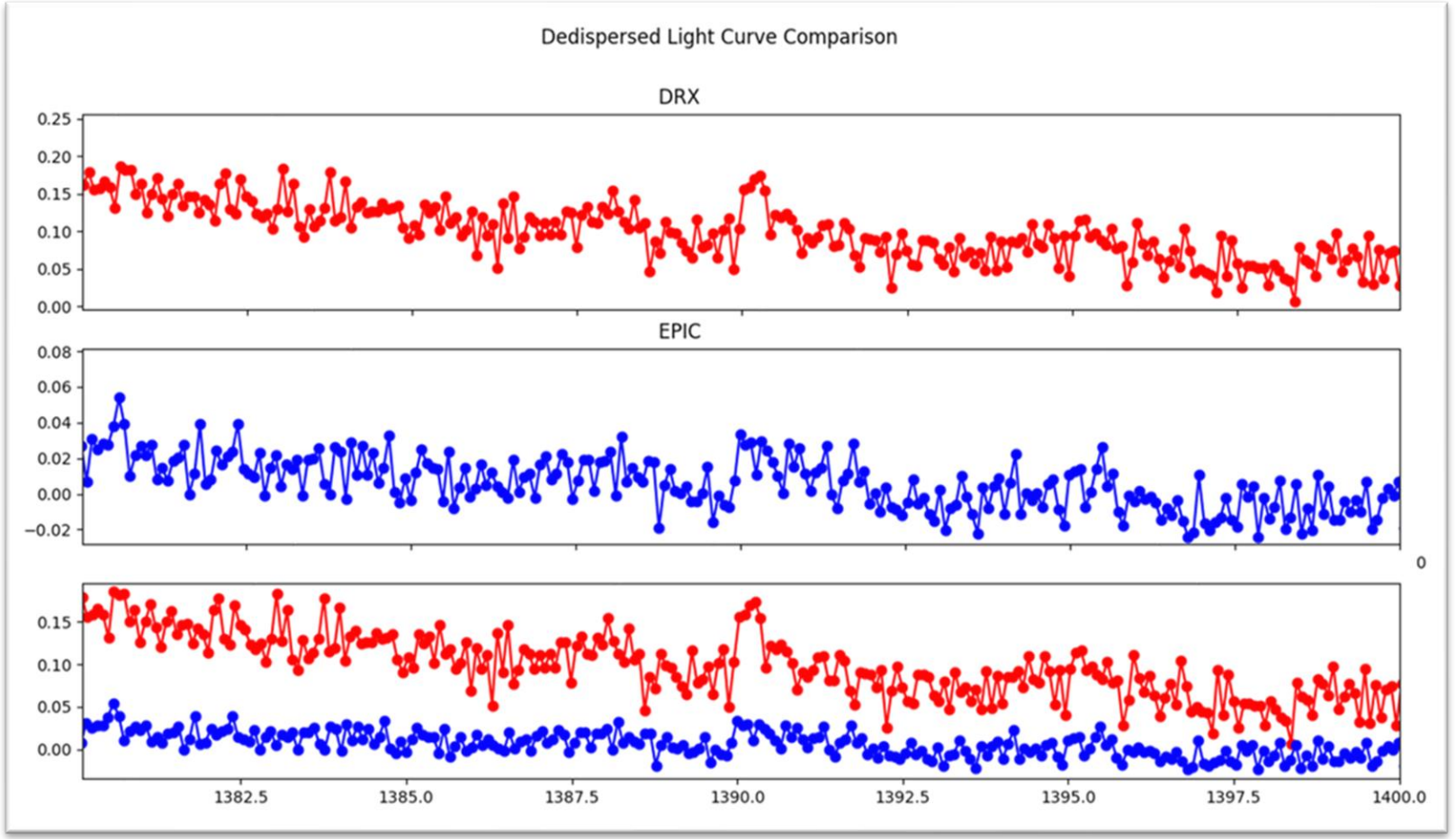


Commensal Observations from Dec. 16th 2022 - 21:45:14 (UTC), t = 5 seconds, 128 sq. pixels, BW = 100kHz

LWA-EPIC Crab Tests

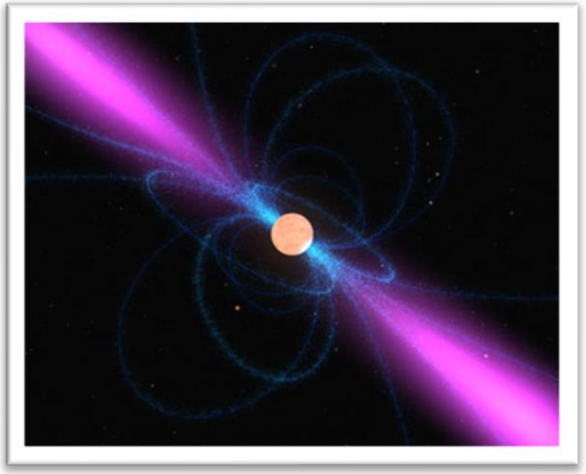


Full Spectrum DRX



Reduced bandwidth to match EPIC

Potential Applications & More



Pulsars &
Pulsar Timing studies

Fast Radio Bursts (FRBs)

Stellar Flares and
Exoplanet Radio Emission

Continuous monitoring of any number of LWA user defined sources

Future Work:

- Continue to improve the EPIC framework operating at LWA-SV
- Create unit tests for further installations of the EPIC system

References

- LWA EPIC github (https://github.com/epic-astronomy/LWA_EPIC)
- LWA Memo series (https://leo.phys.unm.edu/~lwa/memos/)
- Thyagarajan et al 2017 MNRAS 461-1
- Kent et al 2019 (arXiv:1909.03973)
- Eftekhari et al 2016 (arXiv:1607.08612)
- Images:

LWA Collaboration for Telescope Images

Astronomy.com (https://astronomy.com/news/2020/03/hunting-aurorae-astronomers-find-an-exoplanet-using-a-new-approach)

MIT News (https://news.mit.edu/2022/astronomers-detect-radio-heartbeat-billions-light-years-earth-0713)

NASA Pulsar (https://www.nasa.gov/mission_pages/GLAST/multimedia/pulsar_stills.html)

UCSC News (https://news.ucsc.edu/2011/10/crab-pulsar.html)

Current Limitations to subsystem

- Balancing GPU load is the biggest constraint on what parameter space is observable
- This means balancing:
  - Image Size for Nyquist Sampling
  - Total bandwidth
  - Channel size
  - Time resolution
  - Switch throughput for writing data as fast as it is processed