Crab Giant Pulses & Other Dispersed Transients

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on behalf of the LWA-1 Proposal Teams on CGPs, SDPs, and GRB Prompt Emission

May 12, 2011

mean subtraction

This spectrogram:
74.56 MHz, Tau A, 26 dipoles
1.86 MHz (W) x 102.7 s (H)
Pixels are 57 ms x 1.22 kHz
RMS Noise < 190 Jy / pixel
~ 09:00 local time, weekday

Things That Make m-λ Single Dispersed Pulses (SDPs)

- **Known: Pulsars**
  - **Crab Giant Pulses (CGPs)** (Popov *et al.* 2006; Bhat *et al.* 2007; LOFAR)
  - **Anomalously Intense Pulses (AIPs)** (Ulyanov *et al.* 2006; LOFAR)

- **Suspected:**
  - **GRB Prompt Emission** (Paesold & Benz 1998)
  - **Mergers of exotic compact objects** (Hansen & Lyutikov 2001)
  - **Expiration of primordial black holes (PBHs),** (Rees 1977; Blandford 1977)
  - **Topological phase transition of a PBH in the presence of an extra spatial dimension** (Kavic *et al.* 2008)
  - **Superconducting cosmic strings** (Vachaspati 2008)

- **Things not suspected**: Motivation for "source agnostic" search

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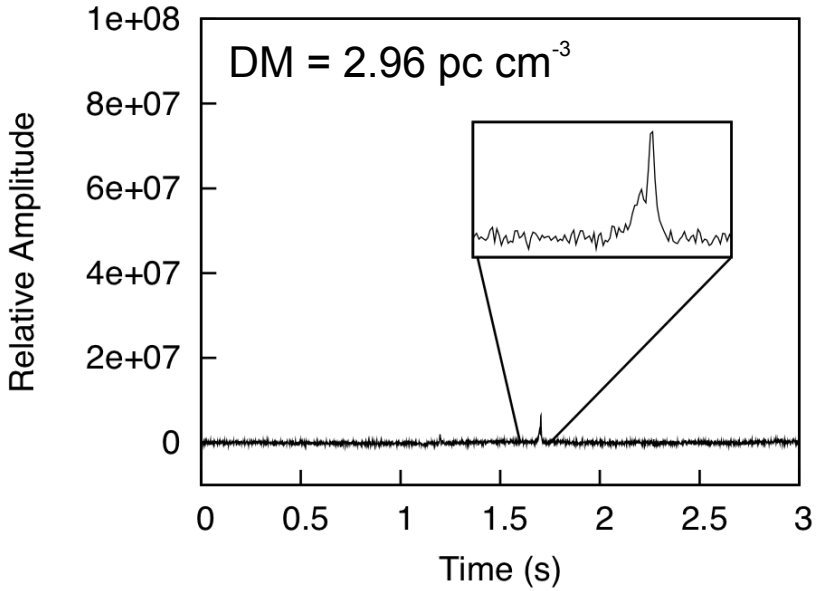
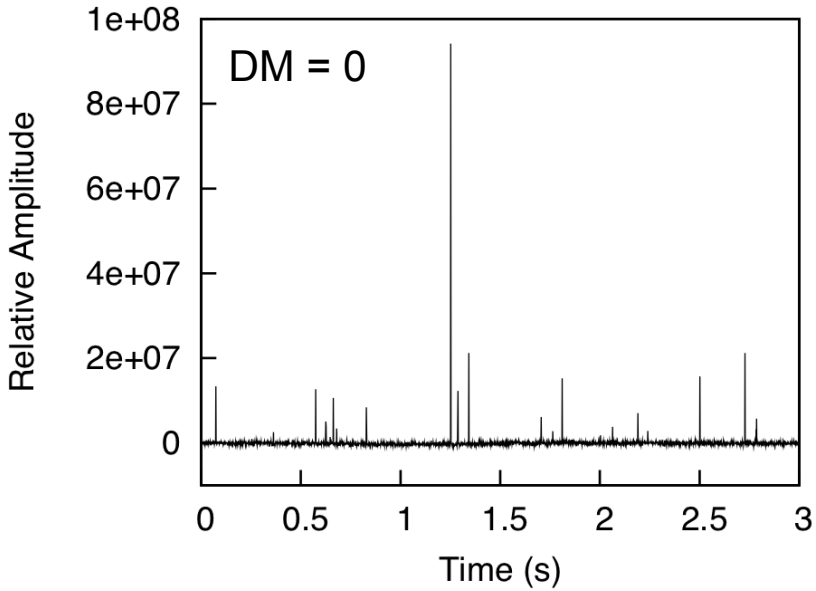
AIP Detected by LOFAR LBA





PSR B0950+08
P = 0.253 s
DM = 2.96 pc cm^{-3}

(One of 6 pulsars currently known to produce meter-wavelength AIPs)

Stappers *et al.* (2011), astro-ph/1104.1577

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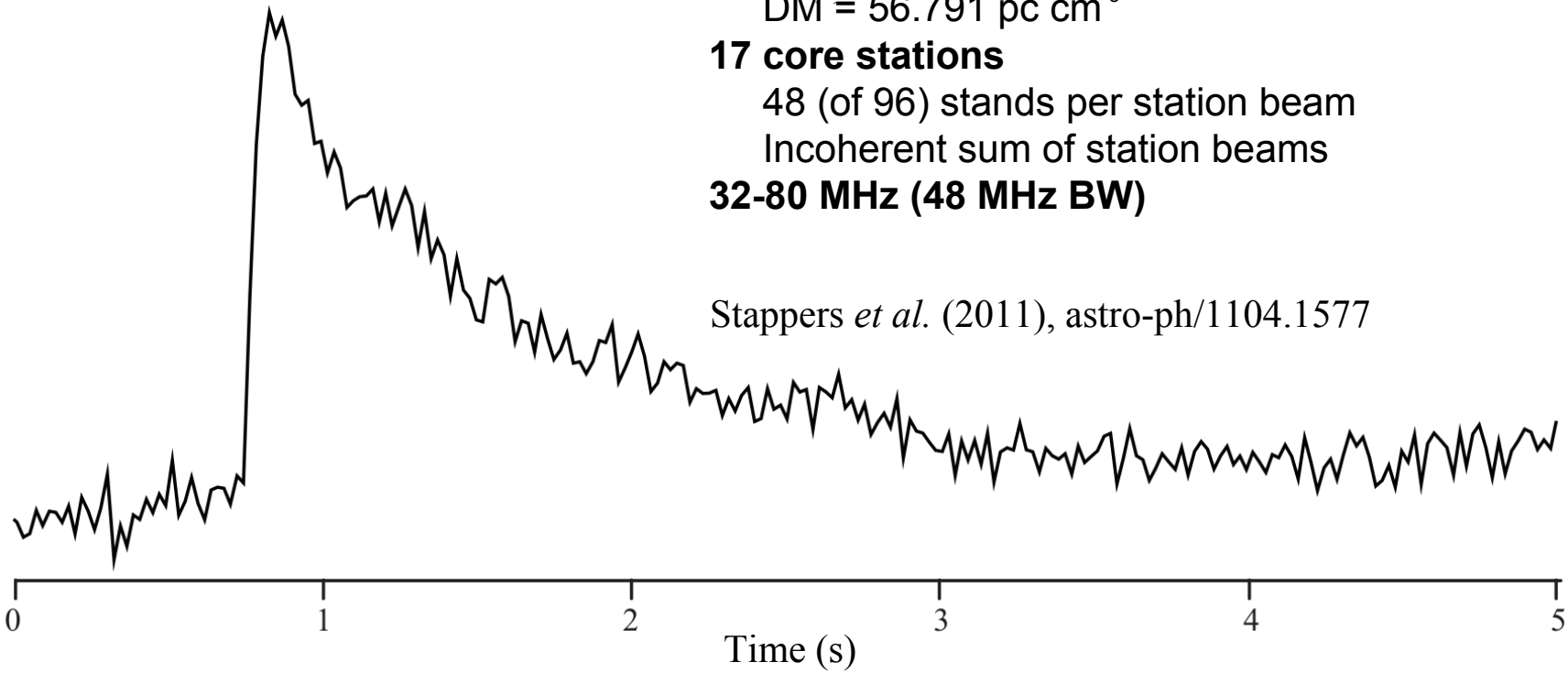
CGP Detected by LOFAR LBA

PSR B0531+21
P = 0.033 s
DM = 56.791 pc cm^{-3}
17 core stations
48 (of 96) stands per station beam
Incoherent sum of station beams
32-80 MHz (48 MHz BW)

Stappers *et al.* (2011), astro-ph/1104.1577



LWA-1, for comparison:
~30% greater sensitivity (258 stands, coherently combined)
But also, each stand is strongly sky-noise dominated (better per-stand sensitivity)
Up to ~78 MHz BW (possible with 3 beams)
Sees B0531+21 transit at Z=12° (vs. 31°) (higher dipole gain)

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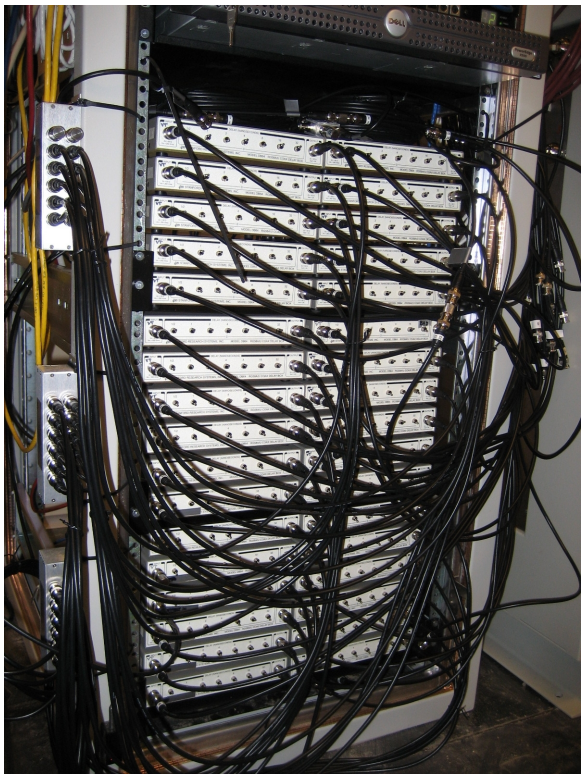
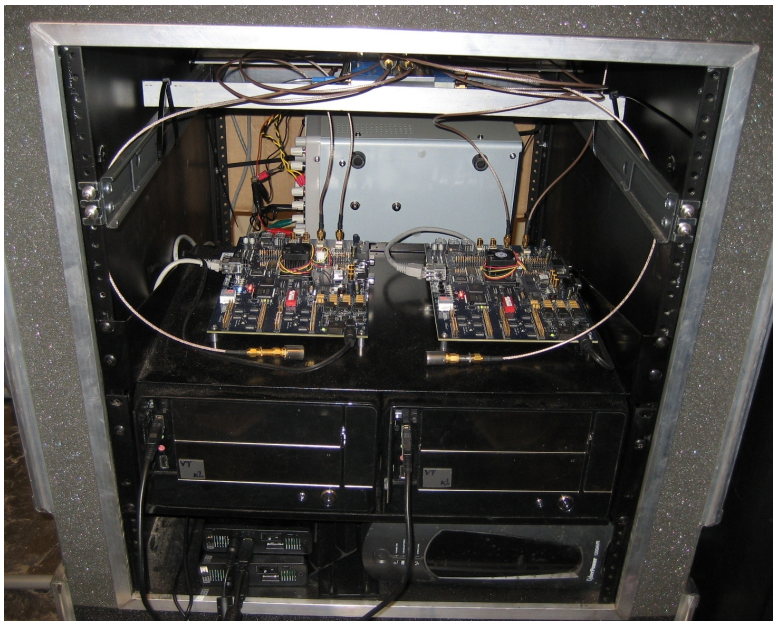
LWA1 "S60" System

Time Delay Analog Beamformer
~30 dipoles
Switch-selectable 0.5 ns delay resolution



Digitizers / Digital Receivers / Data Acquisition
4 ea. 12-bit x 120-MSPS A/Ds on
2 Altera Stratix II FPGA evaluation boards
Up to 11.4 h continuous recording to PC



S_{min} < 200 Jy (5σ, 1 s, 1.86 MHz, Z=12°)
Accumulated time-on-sky: 366 h continuous
+ 506 h low duty cycle

Ellingson, Liu & Craig (2011), LWA Memo 176.

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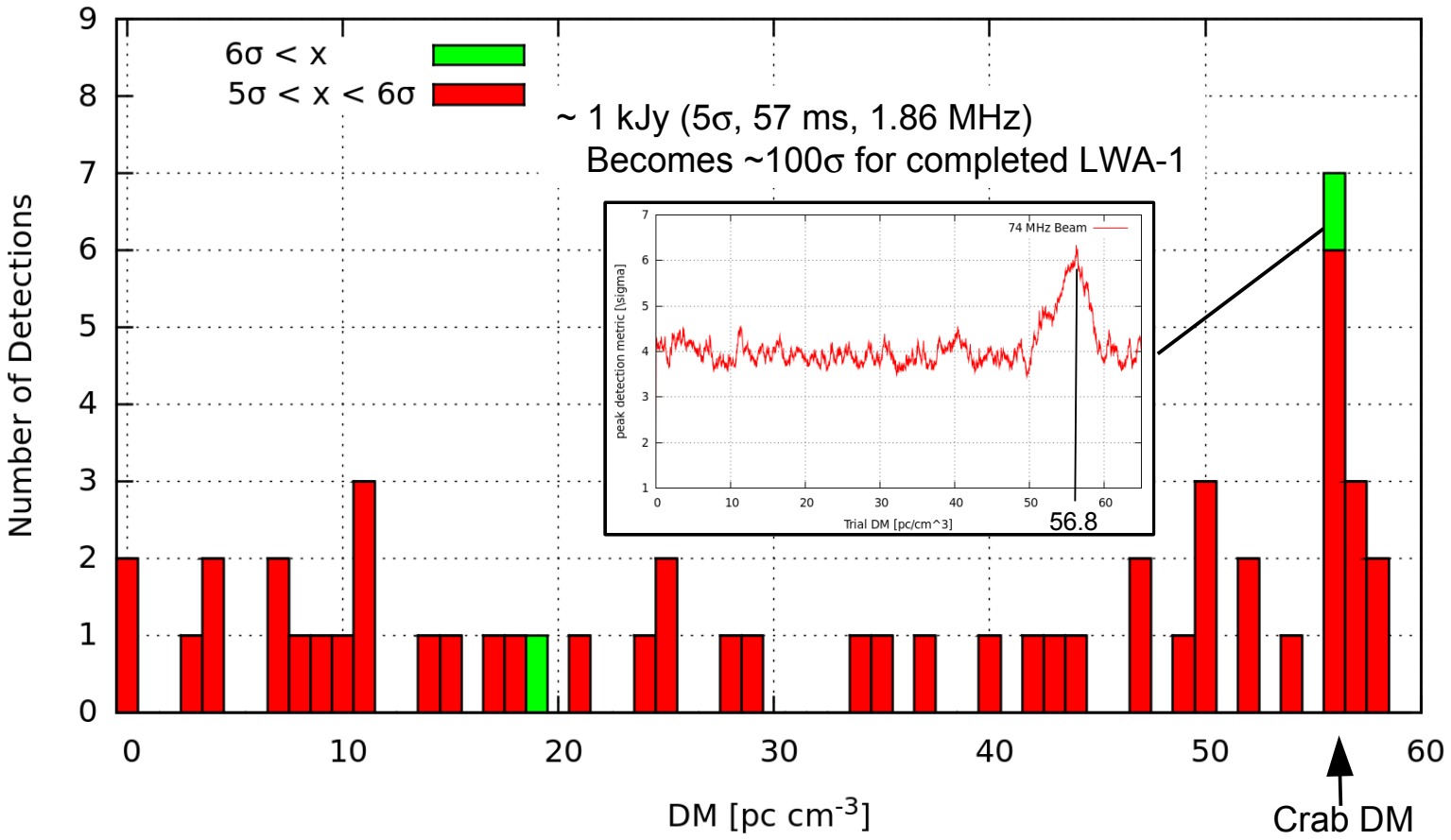
First Glimpses of Crab Giant Pulses



- **74.56 MHz; ~16 h with B0531+21 within the S60 (26-dipole) beam FWHM**
- **Manual inspection of 103-s spectrograms for RFI; ~40% rejected**
- **Incoherent dedispersion, 0.03 < DM < 60.00, ΔDM=0.03 pc cm^{-3}**
- **57 ms rectangular matched filter, sorted into 1 pc cm^{-3} bins**

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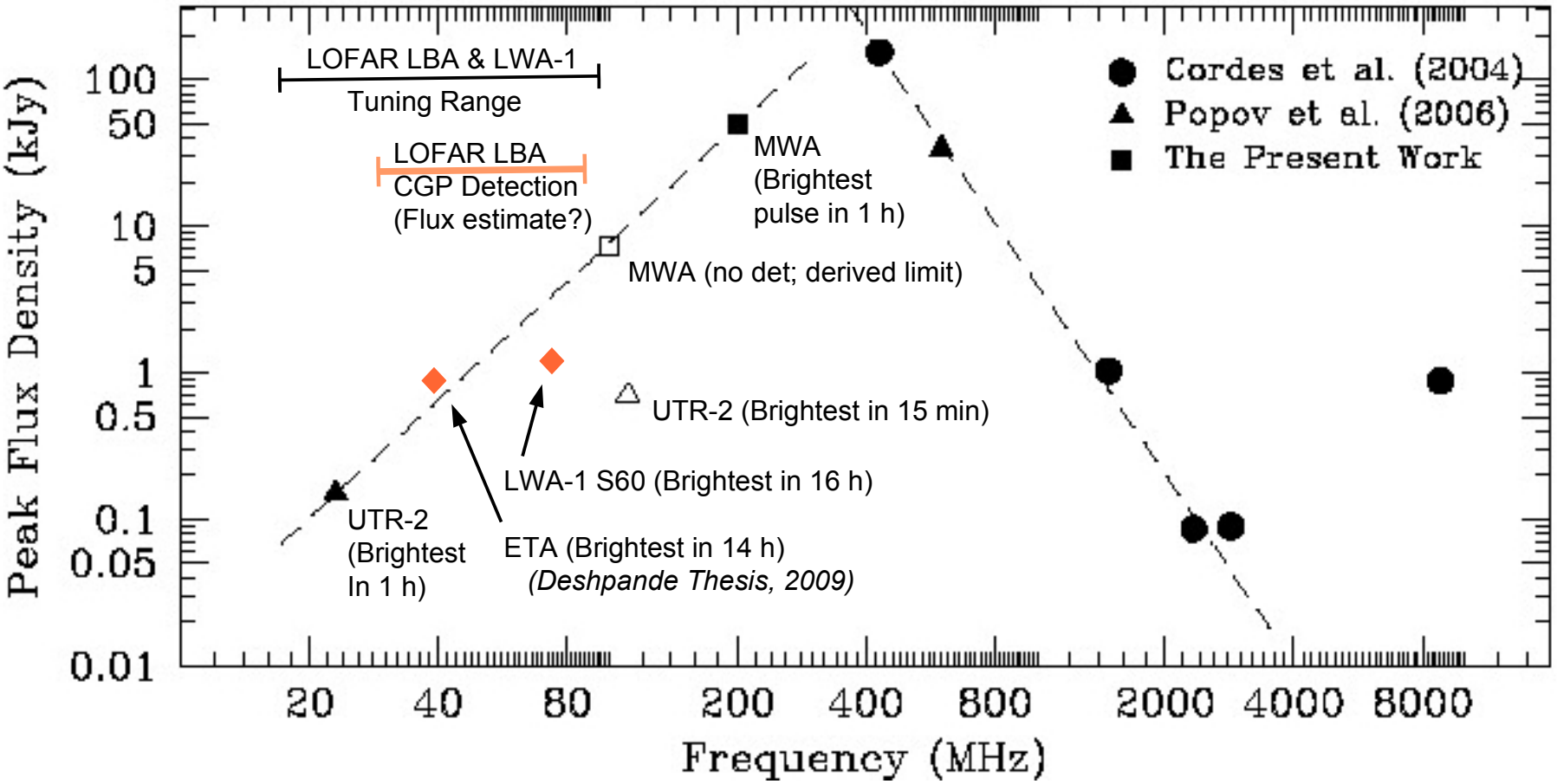
Crab Giant Pulses – Spectrum

Bhat *et al.* (2007), *ApJ,* 665, 618.



- **Challenging due to large pulse magnitude variation, possibility of spectral index variation, difficulty of flux calibration (varying dipole antenna temp; bright & complex sky)...**

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Future of SDP Observing at LWA-1

- Confirm instrument & procedures are in order by reliably detecting:
  - Periodic emission from “easy” pulsars
  - AIPs
  - CGPs

- Conduct CGP campaign (approved for 160 hrs over 10 months)

- Conduct SDP campaign (approved for 160 hrs over 11 months)
  - Data from CGP campaign can be reused here
  - Data from pulsar campaign also possibly useful here – depends on how far that data is reduced

- Conduct GCN-Triggered GRB campaign (80 hrs over 10 months)
  - Requires MCS enhancements

SDP Search Scheme (for Unknown Sources)

- Four tunings (2 beams), spanning 20-80 MHz, pointing to zenith
  - High frequencies: Sources remain in beam for about 15 min, accommodating DMs up to ~1000 pc cm^{-3}
  - Low frequencies: Sources remain in beam for about 40 min, accommodating DMs up to ~100 pc cm^{-3}

- Simultaneously, four identical tunings (other 2 beams) tracking an easy "reference" pulsar. Reasons:
  - Independent sanity check
  - RFI anti-coincidence
  - Second independent FOV from which the source cannot drift (thus, DM limited only by session length)
  - More time on pulsars

Interpreting SDP Detections

- Dispersion measure gives a rough idea of distance to source
- Spectrum indicates Lorentz factor in fireball scenarios
- Scatter broadening likely obscures source pulse width, so:
  - hard to bound emission volume, so
  - hard to estimate brightness temperature
  - Simultaneous multi-frequency observations needed to improve
- Check for associations in GW, optical, γ-ray, etc.
  - Positive associations suggest possible progenitors
- Pulse profile contains information about ISM

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Objectives of SDP & Triggered-GRB Campaigns

- **Detections (of course)**

- **Non-detections set new rate-volume limits**
  - **This alone impacts fundamental physical theories in some cases**
  - **Planned LWA-1 observations should result in data sufficient to improve existing limits by many orders of magnitude.**

- **Establishing reasonably-tight limits is hard; we should learn to do this better**
  - **Rigorous characterization of rate (events pc^{-3} yr^{-1}) is as a function of wavelength, pulse width, and energy (Jy s):**
    Large parameter space
  - **Dealing with instrument- and procedure-induced biases**
  - **Dealing with RFI (the primary impediment to efficient automation of searches...)**

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Thanks!