

Searching for Single Dispersed Pulses with LWA1 DRX Beams

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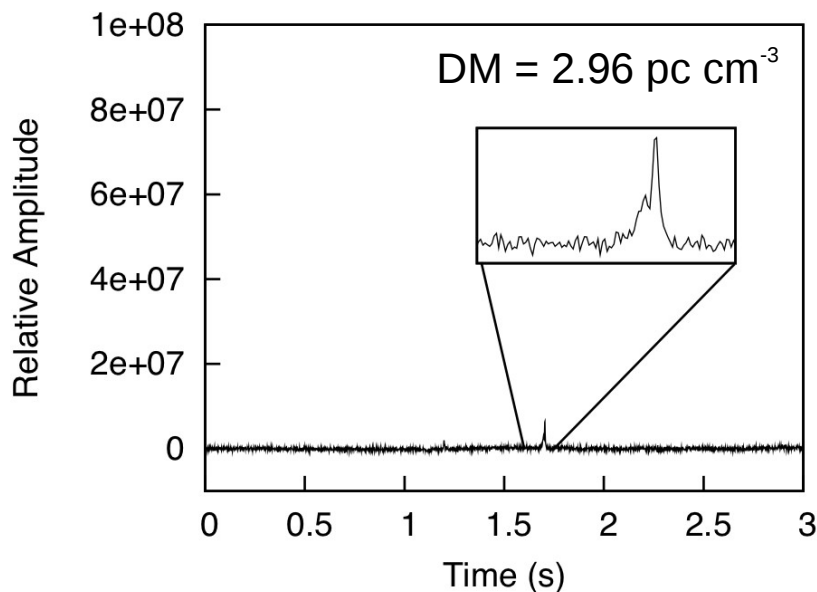
Things That Make m- λ Single Dispersed Pulses (SDPs)

- **Known: Pulsars**
 - **Crab giant pulses (CGPs)** (Popov *et al.* 2006; Bhat *et al.* 2007; LOFAR)
 - **Anomalously-intense pulses (AIPs)** (Ulyanov *et al.* 2006; LOFAR)
 - **RRATs** (McLaughlin 2006)
- **Suspected:**
 - **Giant flares from magnetars** (Gaensler *et al.* 2005; Taylor & Granot 2006)
 - **Expiration of primordial black holes (PBHs)**, (Rees 1977; Blandford 1977)
 - **Prompt emission from GRBs** (Paesold & Benz 1998)
 - **Prompt emission from supernovae** (Colgate 1975)
 - **Mergers of exotic compact objects** (Hansen & Lyutikov 2001)
 - **Cusping superconducting cosmic strings** (Vachaspati 2008)
- **Things not suspected:** Motivation for “source agnostic” search

SDP Projects Underway at LWA1

- CFP1 CGP campaign (160 hrs, 24% done)
 - Almost all of data taken so far is pre-April 2012 and thus diminished value for CGPs due to pointing error)
- CFP1 SDP campaign (80 hrs, 60% done)
 - Also a lot of mis-pointed data, but less important here...
- CFP1 GCN-Triggered GRB campaign (80 hrs, < 1% done)
 - Awaiting necessary modifications to MCS
- LIU's Cat-2 observing program
- CFP2 Proposals
- N.B.: Data from many DRX-mode projects can be mined for SDPs

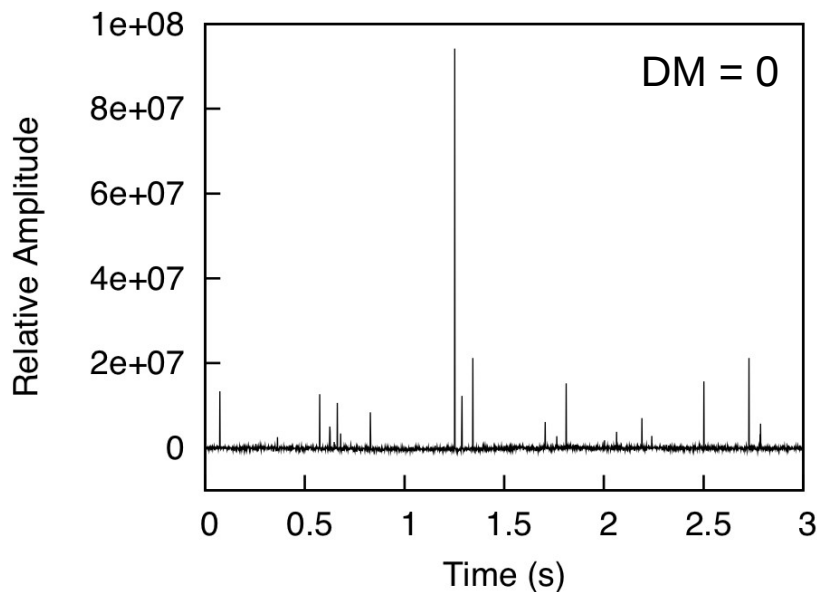
An AIP Detection Reported by LOFAR



PSR B0950+08

$P = 0.253 \text{ s}$

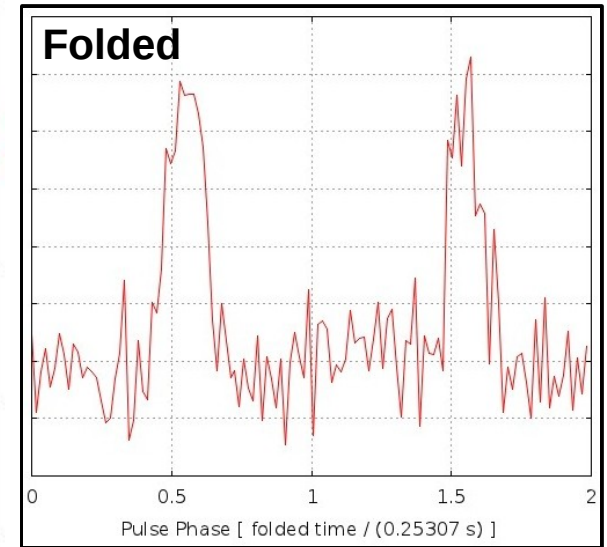
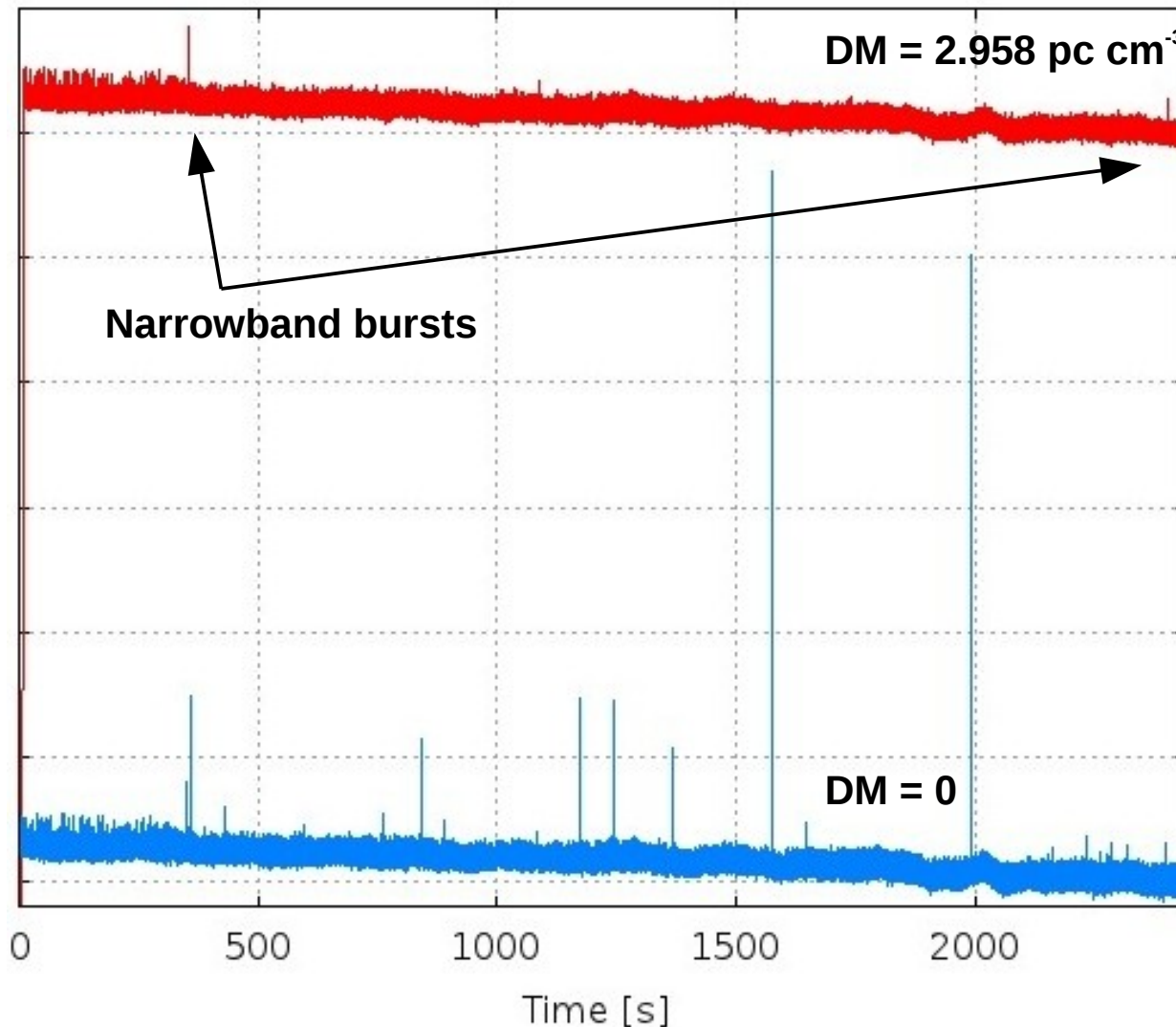
$DM = 2.96 \text{ pc cm}^{-3}$



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

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

No B0950+08 AIPs Seen at LWA1 (Yet)



PSR B0950+08
120225_0500_B1_NS
39.4 MHz Center x 19.6 MSPS
Pointing Error in Effect
No RFI Mitigation

A Crab GP Detection Reported by LOFAR

PSR B0531+21

$P = 0.033 \text{ s}$

$DM = 56.791 \text{ pc cm}^{-3}$

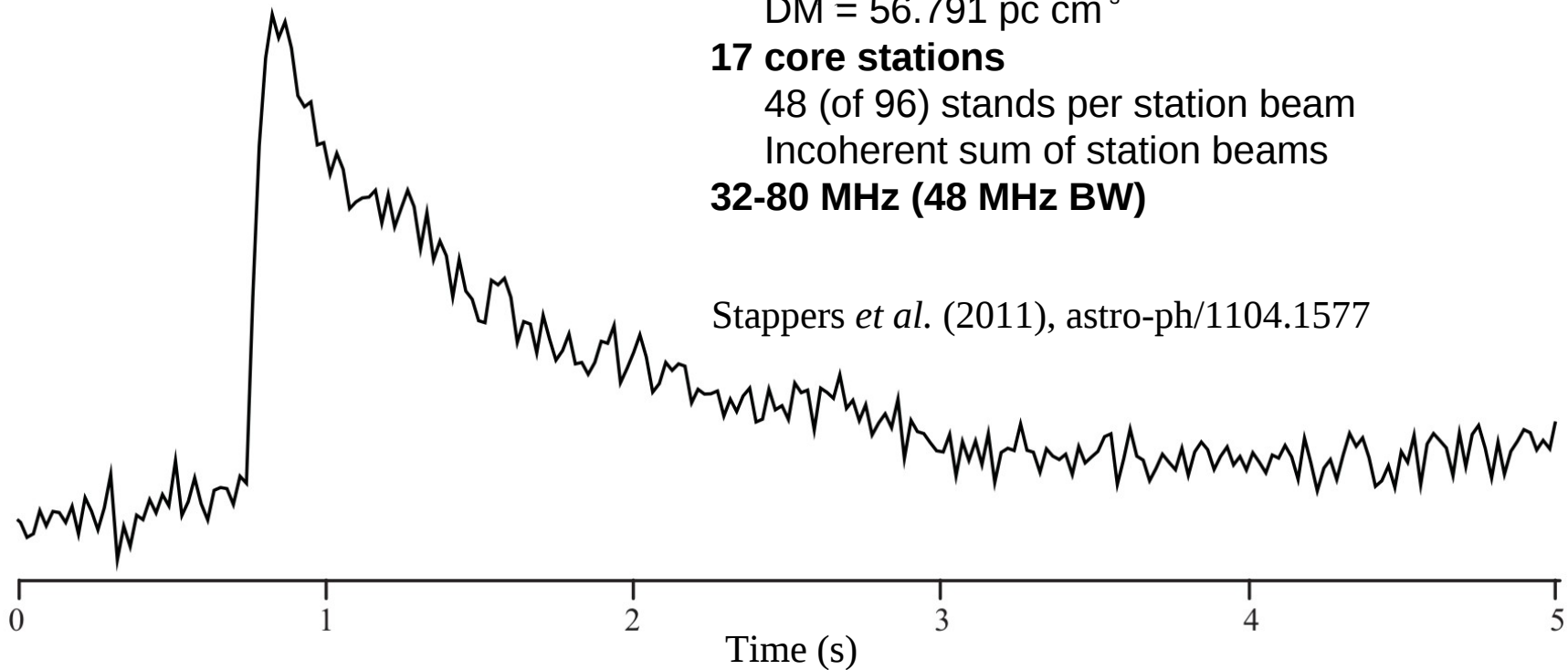
17 core stations

48 (of 96) stands per station beam

Incoherent sum of station beams

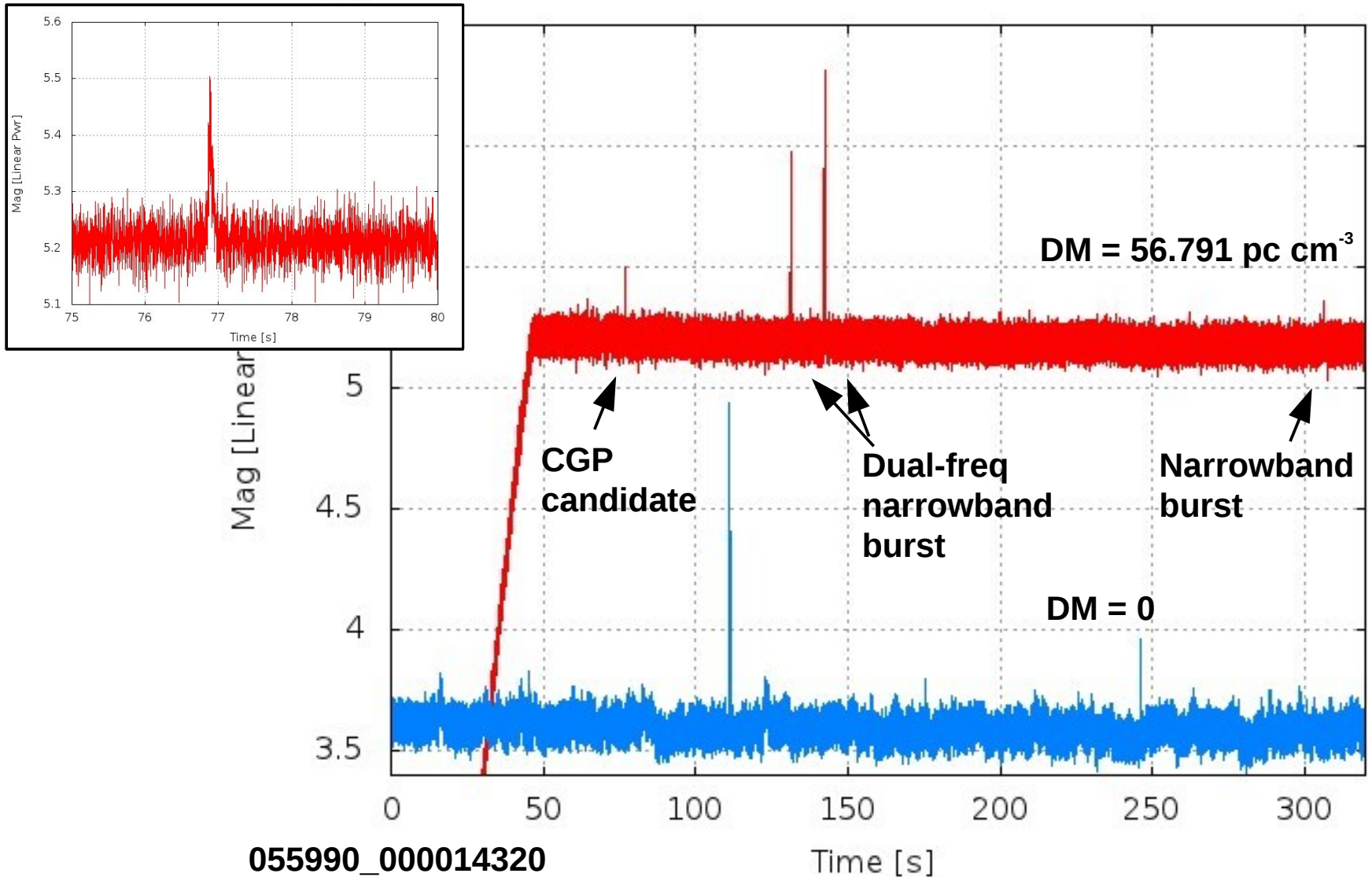
32-80 MHz (48 MHz BW)

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



LWA1 should have roughly equal sensitivity *in this case* (LWA Memo 185)

Searching for CGPs in LWA1 Data



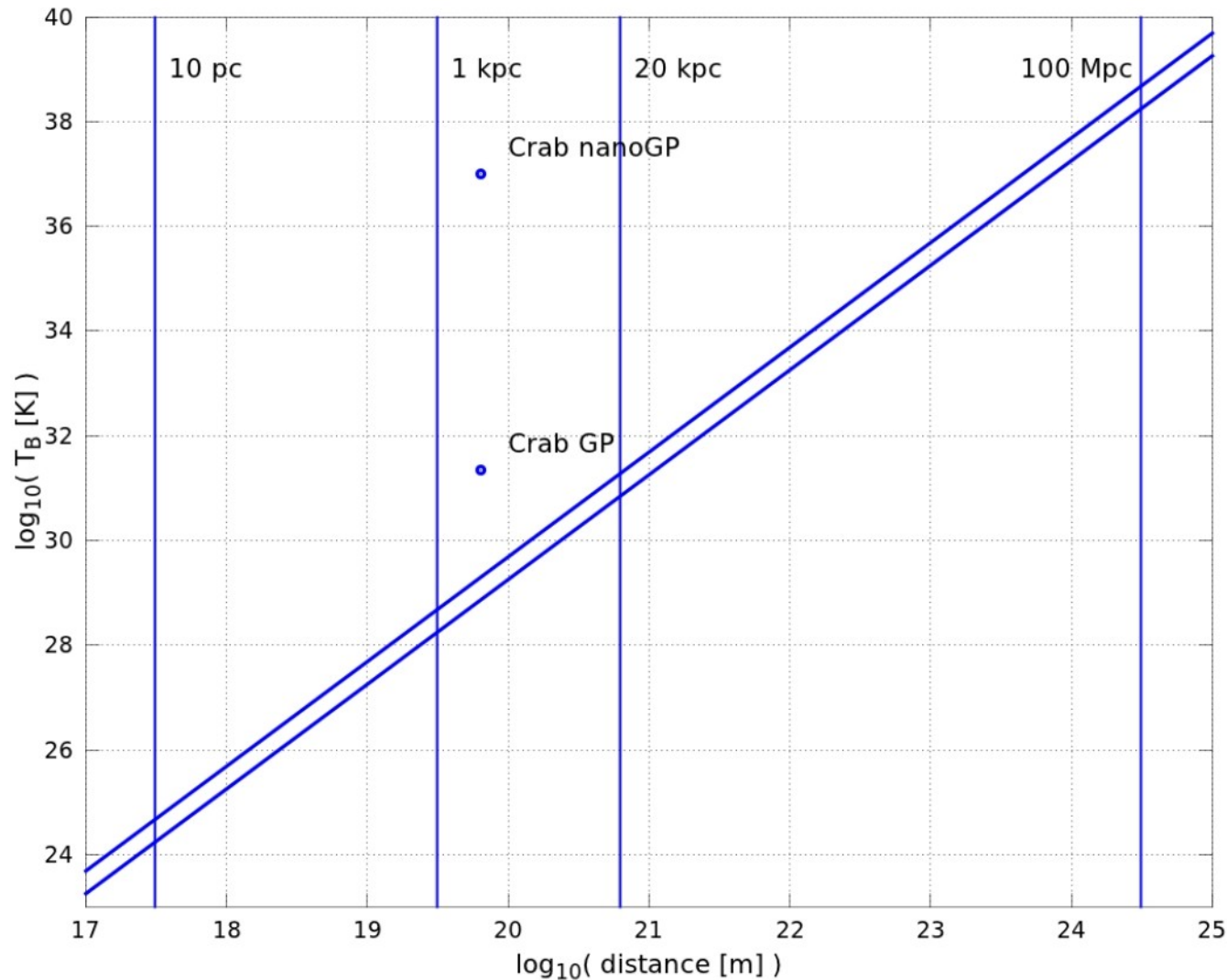
055990_000014320

59.0 MHz Center x 19.6 MSPS

Pointing Error in Effect

No RFI Mitigation

LWA1 SDP Sensitivity



GPs detectable throughout the galaxy
(Assuming DM is “reasonable”)

NanoGPs detectable to ~10 Mpc

Figure 4: Survey pulse sensitivity in terms of the apparent brightness temperature $T_B \approx (2c^2 S / (\pi k \nu^2)) (d/l)^2$, where S is flux density, and d and l are the distance and diameter of the source, respectively (Katz *et al.* 2003). Here we assume $l = 100$ km, $\Delta\tau = 1$ ms, and the upper and lower curves are 74 MHz and 38 MHz, respectively. It should be noted that dedispersion is required (and provided) to reliably achieve this sensitivity for d greater than a few pc.

Objectives of SDP Campaigns

- **Detections (of course)**
- **With or without detections, set usefully-tight limits**
- **Rate (events $\text{pc}^{-3} \text{yr}^{-1}$) as a function of**
 - **Wavelength**
 - **Pulse width**
 - **Energy (Jy s)**
- **Rate-volume limits that can plausibly be achieved by LWA1 are sufficient to impacts fundamental theory in some cases**

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
- Check for associations in GW, optical, γ -ray, etc.
 - Positive associations suggest possible progenitors
- Pulse profile contains information about ISM

SDP Work Plan

- **Confirm instrument & procedures are in order by reliably detecting:**
 - **Periodic emission from “easy” pulsars (Thanks Paul & Kevin!)**
 - **AIPs (Not there yet...)**
 - **CGPs (Not there yet...)**
- **Use above test cases to tune automated SDP processing (Loa)**
- **Port Loa to HPC clusters:**
 - **ATHENA** (<http://www.arc.vt.edu/resources/hpc/athena.php>)
 - **PROMETHEUS** (purpose-built cluster, see next slide)
- **Going forward:**
 - **Process mammoth backlog of data (liberate storage)**
 - **Implement UNM-VT NLR data path for future observations**
 - **Implement Loa pipeline in shelter (quasi-commensal observing)**
- **ALTES Campaign (deep survey; see later slide)**

PROMETHEUS



Computing GPU

nVidia Tesla C2075

- 448 Cores @ 1.15 GHz
- 6GiB ECC GDDR5 @ 1.5 GHz
- 515/1030 Gflops (double, single)
- PCIe x16 (Gen 2)

System CPU

Intel Core i7-3930

- 6 cores + Hyper-threading -> 12 logical cores
- 3.2 GHz clock (3.8 GHz turbo)
- 4-ch. memory controller (up to 51.2 GiB/s)
- Core-to-Core PCIe fabric for IPC
- 10 PCIe ports

Computing FPGA

Xilinx ML605 Evaluation Kit (Virtex 6)

- 2 GiB DDR3 (6.4 GiB/s)
- 1.8 MiB On-chip Block Ram
- 241K Logic Cells
- 10/100/1000 Mb Ethernet
- PCIe x4/x8 (Gen 2/Gen1)

System RAM

G.SKILL Ripjaws Z Series 32GB

- 240-pin DDR3
- 1.8 GHz
- 8 x 4 GiB

Network Interface

Chelsio T440-CR

- 4x SFP+ ports (Aggregation / Failover)
- 10Gb/port
- LRO, LSO, TCP Chimney
- iSCSI, FCoE, iWarp, RDMA offloading
- PCIe x8 (Gen 2)

Miscellaneous

- 1 TB system HDD
- 2 - GbE ports
- 2 - eSATA ports (+SPM)
- 6 - USB 3.0 ports
- 10 - USB 2.0 ports
- Bluetooth / WiFi

Rendering / Alt. Computing GPU

MSI N580GTX Twin Frozr II (nVidia GTX 580)

- 512 Cores @ 772 MHz
- 1.5GiB ECC GDDR5 @ 2.0 GHz
- 1581 Gflops (single)
- PCIe x16 (Gen 2)

**Heterogenous
HPC cluster**

**Each node
(shown left)
has:**

- Core i7-3930
+ 32GB RAM
- Vertex-6 FPGA
- GPU

**Total 4 nodes
~8 Tflop/s**

**100% point-point
interconnects
Over 10GbE**

**Now undergoing
integration,
commissioning,
software
development**

ALTES

- 520 beam-hour “source-agnostic” survey
- Thorough search of DM from [1,10] to [350,800] pc cm⁻³
- Time resolution limited only by scatter broadening by the ISM
- Two 64 MHz beams ~4 Jy ($\tau=1s$, 5σ), 4-30 deg FOV
 - “Track” beam (cold out-of-plane, Galactic center/inner plane, galactic plane close to zenith), preferably with pulsar
 - “Patrol” Beam on 30 minute repeating schedule:
 - 20 min fixed @ zenith
 - 5 min on bright pulsar
 - 4 min all-sky continuum pulse survey, from Z=0 to Z=65 deg
 - Beam pointing diagnostic (map)
 - All-sky full-freq coverage, albeit at low duty cycle
 - 1 min at NCP
- RFI anticoincidence using omni horizon beam (vertical collinear array)
- Data analysis requires ~5 million CPU-hours

Thanks!

