



PROPOSAL COVER SHEET

V6.0

Cycle 10 Call for Proposals: LWA1 Radio Observatory

Submit to: lwa@unm.edu by 11:59 MDT Nov. 1, 2021

Project title: Continued Regular Monitoring of Pulsars with LWA1

Project Summary (please do not write beyond this space):

Since September 2015, we have been using LWA1 to monitor all pulsars known to be detectable by LWA1. At the time of this submission, this is 108 sources made up of 97 normal pulsars, 7 millisecond pulsars, and 4 sources detected through individual pulses. Reduced data products from these observations are stored in the LWA Pulsar Archive so that they are publicly available for anyone doing pulsar research. This data set is used for longterm timing of these pulsars, measurements of time variable interstellar medium effects, single pulse studies, flux measurements, study of the ionosphere, the detection of new phenomena such as potential echoes of the pulsar pulse from structures in the interstellar medium, and more. In addition to observing each pulsar at a cadence of 3-6 weeks, a subset of 12 bright pulsars that pass near the sun are monitored for 2 weeks centered on their closest passage to the sun. These observations are used to study the solar wind through its effects on the pulsar signal as well as to study the magnetic fields and electron density of coronal mass ejections.

Project Investigators:

	Name	Affiliation	Email
PI			
Co-I			
Co-I			
Co-I			
Co-I			
Co-I			

PI Contact Information

Mailing address:

Phone number:



Requested mode(s):

Backend(s) for each requested mode:

- ☒ LWA1 only
 ☒ DRX
 ☐ TBN
 ☐ TBW
 ☐ DR-Spec
☐ LWA-SV only
☐ DRX
☐ TBN
☐ TBF
☐ DR-Spec
☐ LWA1+SV Interferometer
☐ DRX

Observing Request Information (leave fields that do not apply to your setup empty):

LWA1 only time request:	hrs/beam:	4340	nr of beams:	2
LWA-SV only time request:	hrs/beam:		nr of beams:	
LWA1+SV interferometer time request:	hrs:		—	—
Repeated observations: length of each block (hrs):	Variable, 0.5 to 2 hours depending on pulsar brightness			
frequency of blocks (or when):	We use 2 beam hours per pulsar every 3 weeks			
Restrictions in observing time (time of day):	None			
Restrictions in observing time (time of year):	None			

Special requirements (e.g. external trigger, outrigger dipole – describe use):

Observational Details:

Please give center frequencies (ν_1 , ν_2) and corresponding bandwidth (BW) for each source. If more pointing positions are required, please attach a separate sheet with all details.

Source 1		Beam 1		Beam 2		Beam 3 (LWA1 only)		TBN	
Name		(MHz)		(MHz)		(MHz)		(MHz)	
RA (hh.h)	All	ν_1		ν_1	35.1	ν_1	64.5	ν_1	
Dec (dd.d)	>-48	B W		BW	19.6	BW	19.6	BW	
LST beg (hh.h)	All	ν_2		ν_2	49.8	ν_2	79.2	ν_2	
LST end (hh.h)	All	B W		BW	19.6	BW	19.6	BW	
Source 2		Beam 1		Beam 2		Beam 3		TBN	
Name		(MHz)		(MHz)		(MHz)		(MHz)	
RA (hh.h)		ν_1		ν_1		ν_1		ν_1	
Dec (dd.d)		BW		BW		BW		BW	
LST beg (hh.h)		ν_2		ν_2		ν_2		ν_2	
LST end (hh.h)		BW		BW		BW		BW	
Source 3		Beam 1		Beam 2		Beam 3		TBN	
Name		(MHz)		(MHz)		(MHz)		(MHz)	
RA (hh.h)		ν_1		ν_1		ν_1		ν_1	
Dec (dd.d)		BW		BW		BW		BW	
LST beg (hh.h)		ν_2		ν_2		ν_2		ν_2	
LST end (hh.h)		BW		BW		BW		BW	
Source 4		Beam 1		Beam 2		Beam 3		TBN	
Name		(MHz)		(MHz)		(MHz)		(MHz)	
RA		ν_1		ν_1		ν_1		ν_1	

(hh.h)									
Dec (dd.d)		BW		BW		BW		BW	
LST beg (hh.h)		v ₂		v ₂		v ₂		v ₂	
LST end (hh.h)		BW		BW		BW		BW	

1 Introduction

Detection of pulsed emission from neutron stars has been one of the main science areas of the first station of the LWA and has been the subject of $\sim 25\%$ of the LWA publications to date. They have also been the subject of multiple UNM undergraduate research theses and make up at least some portion of the research areas for multiple current UNM graduate students (see Section 2 for more details on the science being performed with these observations). Additionally, there is a Pulsar Club at the University of Virginia consisting of ~ 10 students using LWA1 pulsar observations in order to learn about radio astronomy and pulsars. Most of the data used for these publications and theses have resulted from an ongoing program to monitor all of the pulsars and rotating radio transients (RRATs) known to be detectable by the LWA1 station. The monitoring program began in earnest in September of 2015 and has grown to consist of 108 sources. These sources consist of 97 normal pulsars, 7 millisecond pulsars (MSPs; here defined using spin period < 20 ms), and 4 sources that are detected only through individual pulses (the Crab pulsar and 3 RRATs). The sky distribution of these 108 sources is shown in Figure 1. The results from the ongoing monitoring program consist of multiple reduced data products from the observation that can be used to perform all typical pulsar analyses including, pulsar timing, analysis of single pulse properties, flux measurements, etc and are stored in the publicly available LWA Pulsar Archive¹. The data reduction is performed using routines included in the Pulsar extension of the LWA Software Library (LSL; Dowell et al. 2012) as well as standard pulsar reduction software.

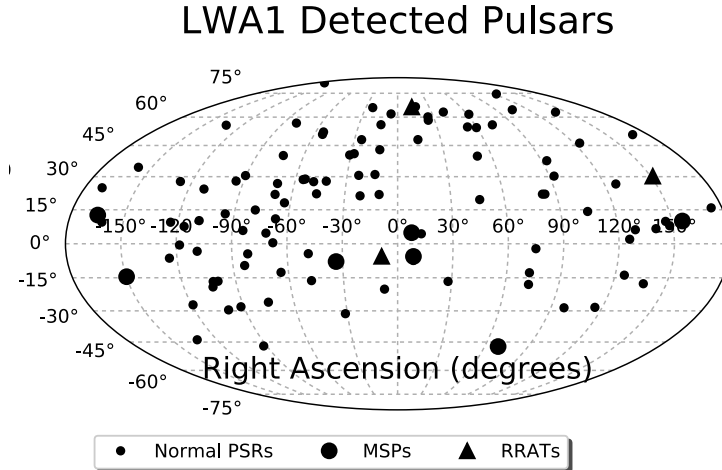


Figure 1: The sky distribution of the pulsars being monitored with LWA1. The pulsars that are detectable at low frequencies are typically nearby due to more distant pulsars being strongly affected by the interstellar medium. As a result, the detectable pulsars are distributed over the whole sky with a smaller preference for the Galactic plane than seen in the higher frequency detected population.

For Cycle 10, we request a total of 4340 beam-hours to continue monitoring pulsars with LWA1. This request consists of 3604 beam-hours to continue monitoring the current set of pulsars. This requires 106 (there are two pulsar pairs that can be observed as single pointings: B2016+28/B2020+28 and B0525+21/B0531+21) pairs of beams observed 17 times per year. We request another 336 beam-hours to take daily observations for 14 subsequent days of sessions (2 beams) for 12 pulsars as they pass near the sun. We also request 400 beam-hours for

¹<http://lwa10g.alliance.unm.edu/PulsarArchive>

testing additional pulsars identified from the known set or newly discovered pulsars plus monitoring timing assuming some of these additional pulsars are added to the long-term monitoring program. The observations requested here, other than the targeted observations as pulsar pass near the sun, can be superseded by observations from other projects and can be managed as a filler project, as it has been for many years. These observations will be observed in the same mode as past pulsar monitoring. We will observe each pulsar using 2 beams in order to span the full split bandwidth mode of LWA1 with tunings set at 35.1, 49.8, 64.5, and 79.2 MHz. These frequencies have been chosen such that they can be combined afterward into a single observation spanning the full frequency range.

2 Low Frequency Pulsar Observations

Low frequency pulsar observations are providing new insights into the distribution of electrons in the interstellar medium (Krishnakumar et al., 2017, Bansal et al., 2019), measurements of high precision rotation measures and other pulsar polarization properties (Noutsos et al. 2015, Dike et al., 2020), constraints on ionospheric electron density and magnetic field models (Malins et al., 2018), constraints on densities and magnetic field strengths of coronal mass ejections (Howard et al., 2016), and studies of pulsar emission through spectral turnovers (Stovall et al., 2015, Bilous et al., 2016).

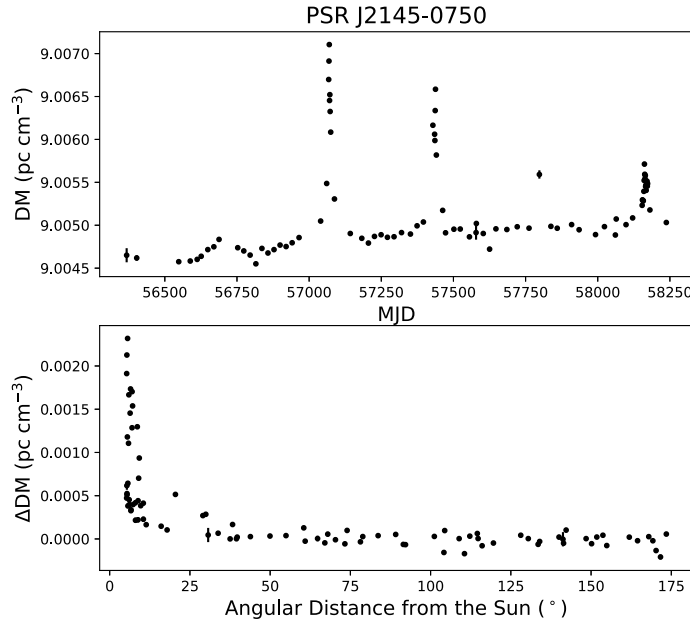


Figure 2: Top: The time variable dispersion measures for the MSP J2145-0750 showing a clear periodic cusp as the pulsar passes near the sun. This cusp is due to extra dispersion from the solar wind. Bottom: The change in dispersion measure as a function of solar elongation angle.

One area of scientific interest for long-term monitoring at low frequencies is the possibility of improving the datasets of ongoing pulsar timing array (PTA) experiments (like NANOGrav) which are attempting to detect nanohertz gravitational waves from supermassive blackhole binaries by timing high quality MSPs. One of the largest sources of error for PTAs is the time variable effects of the interstellar medium. These effects are greatest and therefore are most easily measured at the lowest frequencies. Low frequency observations of pulsars in general are improving

this understanding and has the potential to directly correct for it in MSPs that are observed by low frequency instruments and these PTAs. Low frequency pulsar observations may be able to directly contribute to PTA efforts by measuring the additional dispersion from the solar wind (Tiburzi & Verbiest, 2018, Kumar et al., in review). Additionally, these measurements could improve the existing models of solar wind used in PTAs or other solar wind applications. Figure 2 demonstrates the strong effect at low frequencies of the solar wind on the dispersion measure of the MSP J2145-0750. We are requesting time to continue monitoring 12 bright pulsars that pass within 10° of the sun. These observations consist of 14 consecutive days centered on the pulsars time of smallest solar elongation.

In addition to the general topics mentioned above, observations of specific pulsars that are bright at low frequencies have resulted in an increased understanding of pulsar emission and, in some cases the discovery of new phenomena. These include studies of mode switching pulsars like the very steep spectrum PSR B0943+10 (Bilous et al. 2014, Bilous et al. 2018) which has recently been observed simultaneously by LWA1/Arecibo/LOFAR and XMM-Newton to characterize the mode switching in X-rays (Mereghetti et al., 2016). Another is PSR B0823+26 which though previously believed to be a nulling pulsar, has been shown that the nulling states is actually a quiet emission mode (Sobey et al., 2015). Another example is an anomalous state seen in PSR B0919+06 where when examined at the level of individual pulses, the pulsed emission at frequencies above 300 MHz will move slightly forward in pulse phase for 5-10 rotations. Recent observations have shown that at frequencies below about 200 MHz, these states are observed to not be shifts in pulse phase but rather appear as nulls (Shaifullah et al., 2018). Another new phenomenon is pulse components that steadily drift over hundreds of days that have been observed in PSRs B2217+47 (Michilli et al. 2018) and B1508+55 (Osłowski et al., in prep., Bansal et al., 2019.). The cause of these drifts is currently unclear, but Michilli et al. (2018) proposed that they are echoes of the pulsar’s main pulse from structures in the interstellar medium. **All of the pulsars mentioned above, as well as others with interesting characteristics are included in the set of pulsars being monitored by LWA1.**

References

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