Fast Radio Bursts

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Neutron Stars: A brainstorming workshop @NCRA-TIFR, Pune

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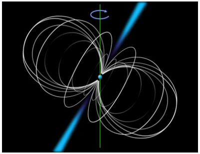
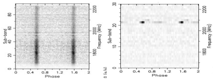
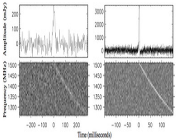
Finding pulsars



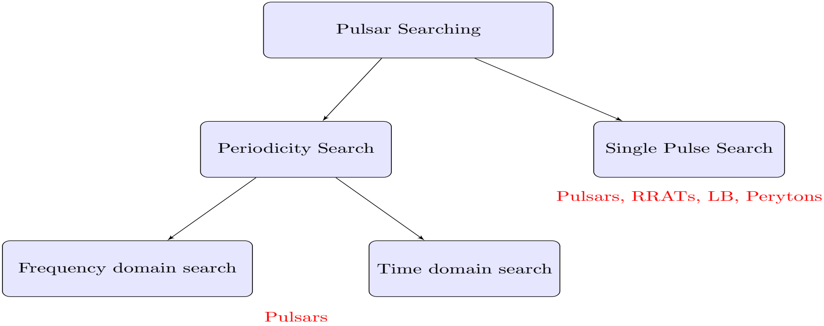
1. Periodic signal



2. Emission over the entire bandwidth (almost).
3. non-zero DM



4. $\Delta t \propto \frac{DM}{f^2}$
5. Point source – only in one beam (or one or two adjacent beams with reduced S/N) in case of a multi-beam receiver.



Pulsar Searching

Periodicity Search

Single Pulse Search

Pulsars, RRATs, LB, Perytons

Frequency domain search

Time domain search

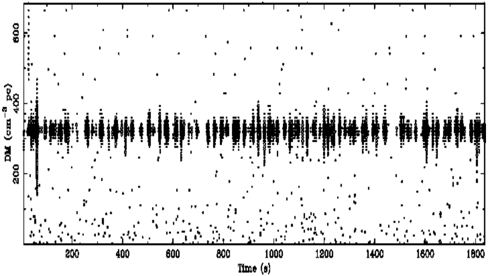
Pulsars

Motivation for single pulse search

Existance of nulling pulsars were known. Periodicity searches are supposed to fail if duration of null is sufficiently long during the time of observation

Can be applied to other non-periodic/quasi-periodic radio signals:

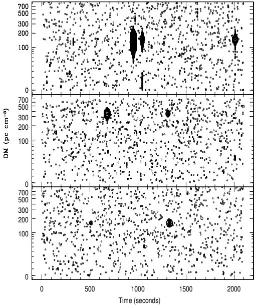
Single Pulse Search: PSR J1157-6224 (in PMPS data)



Algorithm derived as McLaughlin's Ph.D thesis project:

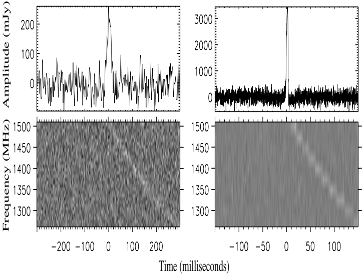
Cordes & McLaughlin; 2003, ApJ, 596, 1142.

Single Pulse Search: RRATs



RRATs J1317-5759, J1443-60, J1826-14

RRATs J1443-60, J1819-1458

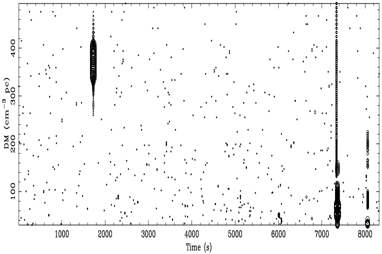


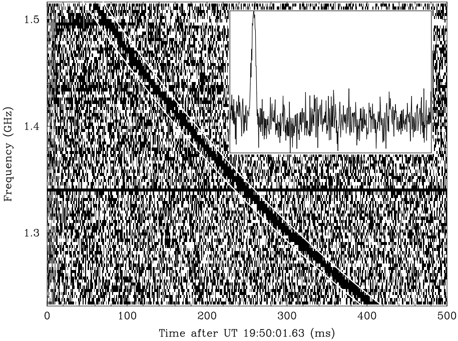
McLaughlin *et al.*; 2006, Nature, 439, 817: **R**otating **R**adio **T**ransients

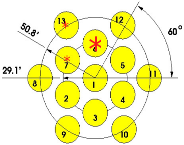
90 RRATS: http://astro.phys.wvu.edu/rratalog/

Single Pulse Search: Lorimer Burst

S_{1400}	30 ± 10 Jy,
RA, *DEC*	$01:18:06, \ -75:12:19$ (survey of Magellanic clouds; 24-August-2001)
l, *b*	$300.653075, \ -41.80$
W	5 ms
DM	$375 \ \mathrm{cm}^{-3}\mathrm{pc}$
d	1 Gpc ($z \sim 0.3$) [NE2001 for Galactic electron density + guess value [($\sim 100 \ \mathrm{cm}^{-3}\mathrm{pc}$) of DM contribution from a host galaxy + models for intergalactic electron plasma]



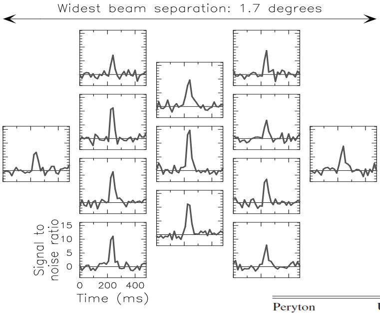


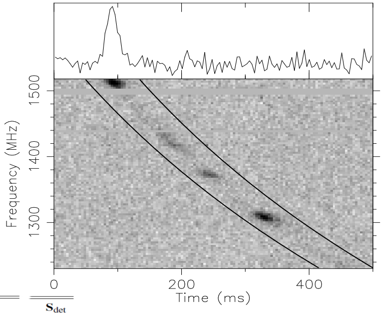


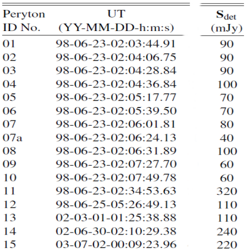
Lorimer, Bailes, McLaughlin, Narkevic, Crawford; 2007, Science, 318, 777.

Single Pulse Search: Perytons

Burke-Spolaor, Bailes, Ekers, Macquart, Crawford; 2011, ApJ, 727, 18.

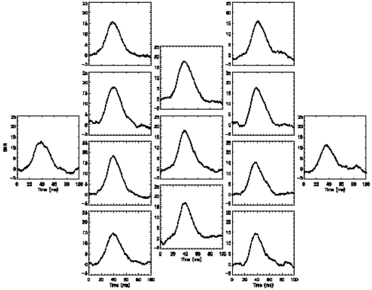


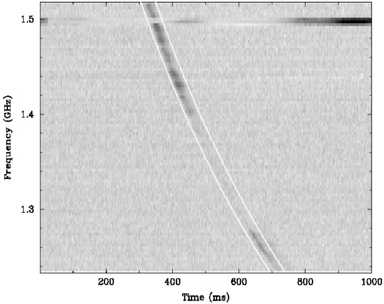




Peryton ID No.	UT (YY-MM-DD-h:m:s)	S_{det} (mJy)
01	98-06-23-02:03:44.91	90
02	98-06-23-02:04:06.75	90
03	98-06-23-02:04:28.84	90
04	98-06-23-02:04:36.84	100
05	98-06-23-02:05:17.77	70
06	98-06-23-02:05:39.50	70
07	98-06-23-02:06:01.81	80
07a	98-06-23-02:06:24.13	40
08	98-06-23-02:06:31.89	100
09	98-06-23-02:07:27.70	60
10	98-06-23-02:07:49.78	60
11	98-06-23-02:34:53.63	320
12	98-06-25-05:26:49.13	110
13	02-03-01-01:25:38.88	110
14	02-06-30-02:10:29.38	240
15	03-07-02-00:09:23.96	220

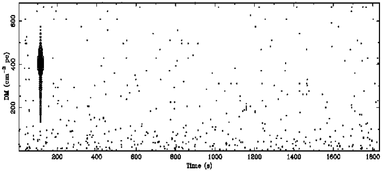
Single Pulse Search: Perytons





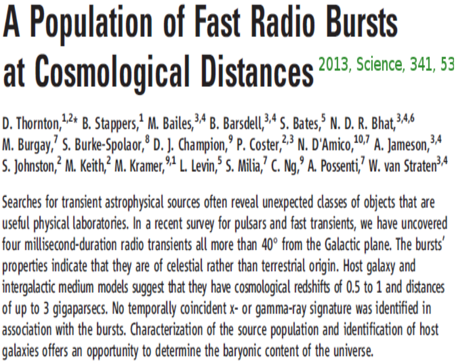
S_{1400}	0.6 to 0.7 Jy (4 perytons)
RA, *DEC*	13, -47 to 16, -63 (PMPS – $\lvert b\rvert < 5^\circ$ and $260^\circ(-105^\circ) < l < 50^\circ$)
l, b	334, 03 to 306, -0.4
W	23 *to* 31 ms
DM	350 to 421 $\mathrm{cm^{-3}pc}$
d	7, 6, 7 and 9 kpc (if celestial) [NE2001 for Galactic electron density]

3, 12 (two) Augusts 1998, 15 September 2003
All sunny days at Parkes!!



Bagchi, Nieves, McLaughlin; 2012, MNRAS, 425, 2501.

Single Pulse Search: Fast Radio Bursts

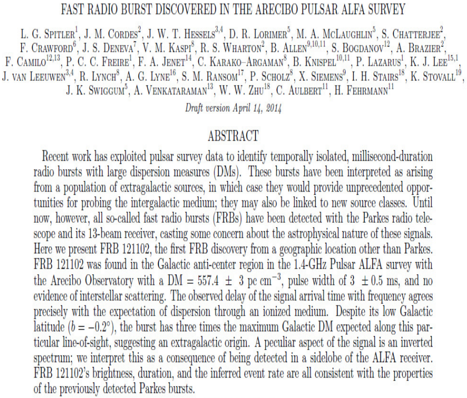


A Population of Fast Radio Bursts at Cosmological Distances

2013, Science, 341, 53

D. Thornton,[1,2]* B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6]
M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4]
S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7] W. van Straten[3,4]

Searches for transient astrophysical sources often reveal unexpected classes of objects that are useful physical laboratories. In a recent survey for pulsars and fast transients, we have uncovered four millisecond-duration radio transients all more than 40° from the Galactic plane. The bursts' properties indicate that they are of celestial rather than terrestrial origin. Host galaxy and intergalactic medium models suggest that they have cosmological redshifts of 0.5 to 1 and distances of up to 3 gigaparsecs. No temporally coincident x- or gamma-ray signature was identified in association with the bursts. Characterization of the source population and identification of host galaxies offers an opportunity to determine the baryonic content of the universe.



FAST RADIO BURST DISCOVERED IN THE ARECIBO PULSAR ALFA SURVEY

L. G. Spitler[1], J. M. Cordes[2], J. W. T. Hessels[3,4], D. R. Lorimer[5], M. A. McLaughlin[5], S. Chatterjee[2],
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F. Camilo[12,13], P. C. C. Freire[1], F. A. Jenet[14], C. Karako–Argaman[8], B. Knispel[10,11], P. Lazarus[1], K. J. Lee[15,1],
J. van Leeuwen[3,4], R. Lynch[8], A. G. Lyne[16], S. M. Ransom[17], P. Scholz[8], X. Siemens[9], I. H. Stairs[18], K. Stovall[19],
J. K. Swiggum[5], A. Venkataraman[13], W. W. Zhu[18], C. Aulbert[11], H. Fehrmann[11]

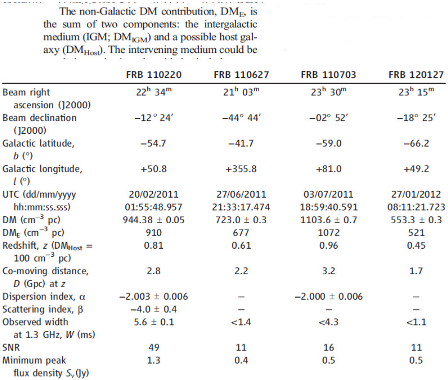
Draft version April 14, 2014

ABSTRACT

Recent work has exploited pulsar survey data to identify temporally isolated, millisecond-duration radio bursts with large dispersion measures (DMs). These bursts have been interpreted as arising from a population of extragalactic sources, in which case they would provide unprecedented opportunities for probing the intergalactic medium; they may also be linked to new source classes. Until now, however, all so-called fast radio bursts (FRBs) have been detected with the Parkes radio telescope and its 13-beam receiver, casting some concern about the astrophysical nature of these signals. Here we present FRB 121102, the first FRB discovery from a geographic location other than Parkes. FRB 121102 was found in the Galactic anti-center region in the 1.4-GHz Pulsar ALFA survey with the Arecibo Observatory with a DM = 557.4 ± 3 pc cm^{-3}, pulse width of 3 ± 0.5 ms, and no evidence of interstellar scattering. The observed delay of the signal arrival time with frequency agrees precisely with the expectation of dispersion through an ionized medium. Despite its low Galactic latitude ($b = -0.2°$), the burst has three times the maximum Galactic DM expected along this particular line-of-sight, suggesting an extragalactic origin. A peculiar aspect of the signal is an inverted spectrum; we interpret this as a consequence of being detected in a sidelobe of the ALFA receiver. FRB 121102's brightness, duration, and the inferred event rate are all consistent with the properties of the previously detected Parkes bursts.

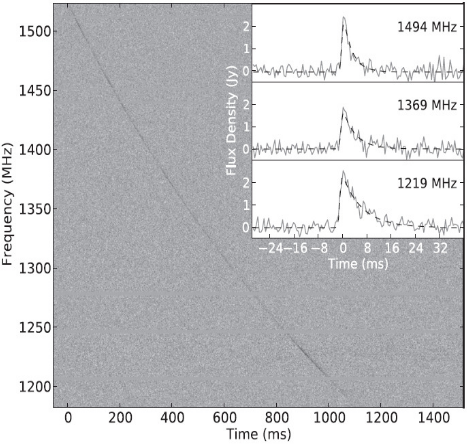
2014, ApJ, 790, 9

Single Pulse Search: Fast Radio Bursts at Parkes

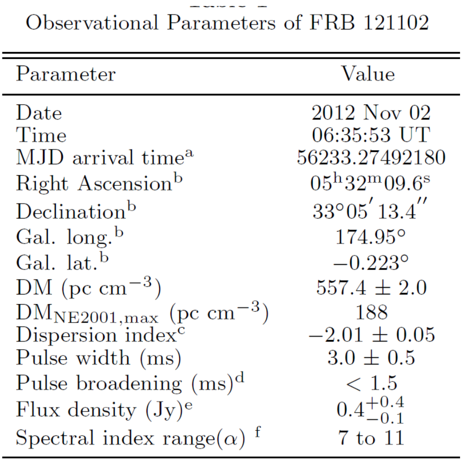


The non-Galactic DM contribution, DM_E, is the sum of two components: the intergalactic medium (IGM; DM_{IGM}) and a possible host galaxy (DM_{Host}). The intervening medium could be

	FRB 110220	FRB 110627	FRB 110703	FRB 120127
Beam right ascension (J2000)	$22^h\ 34^m$	$21^h\ 03^m$	$23^h\ 30^m$	$23^h\ 15^m$
Beam declination (J2000)	−12° 24′	−44° 44′	−02° 52′	−18° 25′
Galactic latitude, b (°)	−54.7	−41.7	−59.0	−66.2
Galactic longitude, l (°)	+50.8	+355.8	+81.0	+49.2
UTC (dd/mm/yyyy hh:mm:ss.sss)	20/02/2011 01:55:48.957	27/06/2011 21:33:17.474	03/07/2011 18:59:40.591	27/01/2012 08:11:21.723
DM (cm^{-3} pc)	944.38 ± 0.05	723.0 ± 0.3	1103.6 ± 0.7	553.3 ± 0.3
DM_E (cm^{-3} pc)	910	677	1072	521
Redshift, z (DM_{Host} = 100 cm^{-3} pc)	0.81	0.61	0.96	0.45
Co-moving distance, D (Gpc) at z	2.8	2.2	3.2	1.7
Dispersion index, α	−2.003 ± 0.006	–	−2.000 ± 0.006	–
Scattering index, β	−4.0 ± 0.4	–	–	–
Observed width at 1.3 GHz, W (ms)	5.6 ± 0.1	<1.4	<4.3	<1.1
SNR	49	11	16	11
Minimum peak flux density S_ν (Jy)	1.3	0.4	0.5	0.5

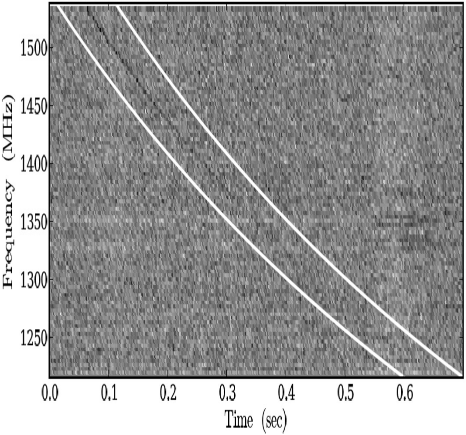


Single Pulse Search: Fast Radio Bursts at Arecibo



Observational Parameters of FRB 121102

Parameter	Value
Date	2012 Nov 02
Time	06:35:53 UT
MJD arrival time[a]	56233.27492180
Right Ascension[b]	$05^h32^m09.6^s$
Declination[b]	$33^\circ 05' 13.4''$
Gal. long.[b]	174.95°
Gal. lat.[b]	−0.223°
DM (pc cm^{-3})	557.4 ± 2.0
$DM_{NE2001,max}$ (pc cm^{-3})	188
Dispersion index[c]	-2.01 ± 0.05
Pulse width (ms)	3.0 ± 0.5
Pulse broadening (ms)[d]	< 1.5
Flux density (Jy)[e]	$0.4^{+0.4}_{-0.1}$
Spectral index range(α) [f]	7 to 11



Fast Radio Burst/Perytons ... hypotheses

1. arXiv:1410.4323 [pdf, ps, other]

Axion Stars and Fast Radio Bursts
A. Iwazaki
Comments: 4 pages, no figure

4. arXiv:1409.5516 [pdf, ps, other]

Implications of fast radio bursts for superconducting cosmic strings
Yun-Wei Yu, Kwong-Sang Cheng, Gary Shiu, Henry Tye
Comments: 10 pages, 1 figure, accepted for publication in JCAP

36. arXiv:1307.1409 [pdf, other]

Fast radio bursts: the last sign of supramassive neutron stars
Heino Falcke (1 and 2 and 3), Luciano Rezzolla (4 and 5) ((1) Radboud University Nijmegen, (2) Frankfurt)
Comments: Astronomy & Astrophysics, in press - 6 pages, 1 figure, revised after referee comments, slightly expande abridged
Journal-ref: A&A 562, A137 (2014)

5. arXiv:1409.4031 [pdf, other]

Fast Radio Bursts and White Hole Signals
Aurélien Barrau, Carlo Rovelli, Francesca Vidotto
Comments: 5 pages

7. arXiv:1408.1333 [pdf, ps, other]

Radio emissions from pulsar companions : a refutable explanation for galactic transients and fast radio bursts
Fabrice Mottez (LUTH), Philippe Zarka (LESIA)

23. arXiv:1401.6674 [pdf, ps, other]

A model for fast extragalactic radio bursts
Yuri Lyubarsky
Comments: 5 pages

33. arXiv:1307.7708 [pdf, ps, other]

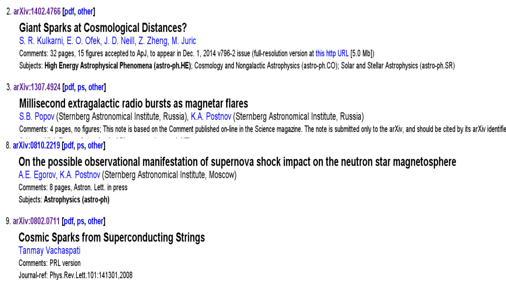
Cosmological Fast Radio Bursts from Binary White Dwarf Merge
Kazumi Kashiyama, Kunihito Ioka, Peter Mészáros
Comments: 5 pages, 1 figure, published in ApJL (submitted on 07/29/2013)
Journal-ref: The Astrophysical Journal 776 L39 (2013)

29. arXiv:1310.4893 [pdf, ps, other]

A possible connection between Fast Radio Bursts and Gamma-Ray Bursts
Bing Zhang (UNLV)
Comments: ApJL, in press. Title shortened following the suggestion of ApJL. A discussion on possible detection of FRBs following GRBs by Bannister et al. (2012, ApJ, 757, 38) is added

34. arXiv:1307.4985 [pdf, ps, other]

Cosmological Fast Radio Bursts from Binary Neutron Star Mergers
Tomonori Totani (Univ. of Tokyo)
Comments: 4 pages, no figure. Matches the published version in PASJ. References added. This is an open access paper at the PASJ website this http URL
Journal-ref: Pub. Astron. Soc. Jpn. 65, L12 (2013)



2. arXiv:1402.4766 [pdf, other]

Giant Sparks at Cosmological Distances?
S. R. Kulkarni, E. O. Ofek, J. D. Neill, Z. Zheng, M. Juric
Comments: 32 pages, 15 figures accepted to ApJ, to appear in Dec. 1, 2014 v796-2 issue (full-resolution version at this http URL [5.0 Mb])
Subjects: **High Energy Astrophysical Phenomena (astro-ph.HE)**; Cosmology and Nongalactic Astrophysics (astro-ph.CO); Solar and Stellar Astrophysics (astro-ph.SR)

3. arXiv:1307.4924 [pdf, ps, other]

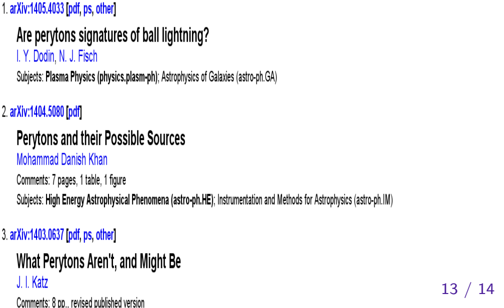
Millisecond extragalactic radio bursts as magnetar flares
S.B. Popov (Sternberg Astronomical Institute, Russia), K.A. Postnov (Sternberg Astronomical Institute, Russia)
Comments: 4 pages, no figures; This note is based on the Comment published on-line in the Science magazine. The note is submitted only to the arXiv, and should be cited by its arXiv identifie

8. arXiv:0810.2219 [pdf, ps, other]

On the possible observational manifestation of supernova shock impact on the neutron star magnetosphere
A.E. Egorov, K.A. Postnov (Sternberg Astronomical Institute, Moscow)
Comments: 8 pages, Astron. Lett. in press
Subjects: **Astrophysics (astro-ph)**

9. arXiv:0802.0711 [pdf, ps, other]

Cosmic Sparks from Superconducting Strings
Tanmay Vachaspati
Comments: PRL version
Journal-ref: Phys.Rev.Lett.101:141301,2008



1. arXiv:1405.4033 [pdf, ps, other]

Are perytons signatures of ball lightning?
I. Y. Dodin, N. J. Fisch
Subjects: **Plasma Physics (physics.plasm-ph)**; Astrophysics of Galaxies (astro-ph.GA)

2. arXiv:1404.5080 [pdf]

Perytons and their Possible Sources
Mohammad Danish Khan
Comments: 7 pages, 1 table, 1 figure
Subjects: **High Energy Astrophysical Phenomena (astro-ph.HE)**; Instrumentation and Methods for Astrophysics (astro-ph.IM)

3. arXiv:1403.0637 [pdf, ps, other]

What Perytons Aren't, and Might Be
J. I. Katz
Comments: 8 pp., revised published version

Possibility of detections of FRBs using SKA/GMRT

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 206:2 (22pp), 2013 May
doi:10.1088/0067-0049/206/1/2

DETECTION OF FAST TRANSIENTS WITH RADIO INTERFEROMETRIC ARRAYS

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[5] School of Physics, University of Melbourne, Victoria 3010, Australia
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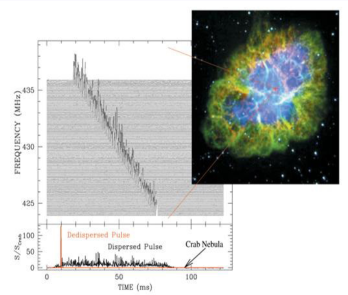
ABSTRACT

Next-generation radio arrays, including the Square Kilometre Array (SKA) and its pathfinders, will open up new avenues for exciting transient science at radio wavelengths. Their innovative designs, comprising a large number of small elements, pose several challenges in digital processing and optimal observing strategies. The Giant Metrewave Radio Telescope (GMRT) presents an excellent test-bed for developing and validating suitable observing modes and strategies for transient experiments with future arrays. Here we describe the first phase of the ongoing development of a transient detection system for GMRT that is planned to eventually function in a commensal mode with other observing programs. It capitalizes on the GMRT's interferometric and sub-array capabilities, and the versatility of a new software backend. We outline considerations in the plan and design of transient exploration programs with interferometric arrays, and describe a pilot survey that was undertaken to aid in the development of algorithms and associated analysis software. This survey was conducted at 325 and 610 MHz, and covered 360 deg^2 of the sky with short dwell times. It provides large volumes of real data that can be used to test the efficacies of various algorithms and observing strategies applicable for transient detection. We present examples that illustrate the methodologies of detecting short-duration transients, including the use of sub-arrays for higher resilience to spurious events of terrestrial origin, localization of candidate events via imaging, and the use of a phased array for improved signal detection and confirmation. In addition to demonstrating applications of interferometric arrays for fast transient exploration, our efforts mark important steps in the roadmap toward SKA-era science.

Key words: instrumentation: interferometers – methods: observational – pulsars: individual (J1752-2806) – techniques: interferometric

Dispersion Measure (*DM*) ◂ Return



$$v_g = c\left[1-\left(\frac{f_p}{f}\right)^2\right]^{1/2},\ f_p = \sqrt{\frac{e^2 n_e}{\pi m_e}}$$

$$f\uparrow\ \Rightarrow v_g\uparrow\ \Rightarrow t_{travel}\left(=\frac{\int_0^d dx}{v_g}\right)\downarrow,$$

$$\Delta t = \frac{e^2}{2\pi m_e c}\left(\frac{1}{f^2_{\rm up}}-\frac{1}{f^2_{\rm low}}\right)\int_0^d n_e(RA, DEC, x)dx = \mathcal{D}\left(\frac{1}{f^2_{\rm up}}-\frac{1}{f^2_{\rm low}}\right) DM.$$

$\mathcal{D} = \frac{e^2}{2\pi m_e c} = 4.18\times 10^3\ \mathrm{MHz}^2\ \mathrm{pc}^{-1}\ \mathrm{cm}^3\ \mathrm{s}$; $DM = \int_0^d n_e(RA, DEC, x)dx$ in $\mathrm{pc}\ \mathrm{cm}^{-3}$

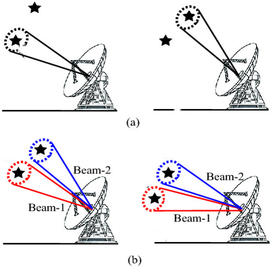
We get good signal only when guessed *DM* is close to actual *DM*.

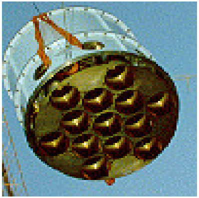
$d \neq 0$ means $DM \neq 0$

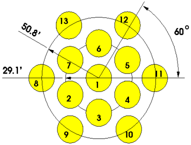
Multibeam

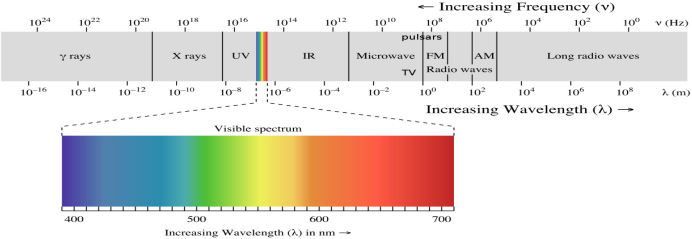
◂ Return

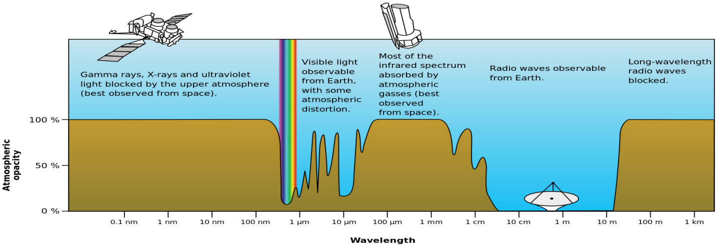
Parkes Multibeam:











(above 6 GHz and below 1 MHz is blocked)