Fast radio bursts and their multi wavelength follow-ups

Shivani Bhandari
Research plus postdoctoral fellow
CSIRO/ATNF

The era of collaborative multi-wavelength and multi-messenger astronomy: science and engineering
22-24 October 2019, Firenze (Italy)
Fast Radio Bursts
What do we know about FRBs?

• Bright (few to ~400 Jyms) millisecond duration pulses of coherent ($T_b > 10^{35}K$) emission
• Observed DMs > Galactic DMs
• Observed high DMs (~100 to 2600 pc/cc) correspond to high inferred redshifts.
• 50+ progenitor theories (frbtheorycat)
  ✴ Young magnetars
  ✴ Compact binary mergers

Lorimer+2007

Ravi+19
Cosmic Applications

Weighing the Ionised missing baryons

Credits: Illustris

First measurements of extragalactic magnetic fields

Independent measurement of the dark energy equation of state

Macquart+2015
How many FRBs?

90 FRBs (published)
FRB 121102
(Spitler et al 2016)

- 50+ published repeats
- Aperiodic and mostly clustered in time.
- Source flips between active and dormant state
- Sub-pulse drifting in the dynamic spectrum
- High rotation measure ~$10^5$ rad m$^{-2}$
- Concordance picture: A flaring magnetar embedded in a magnetised ion-electron wind nebula (Margalit and Metzger 2018)

(Gourdjiet+2019)
FRB121102 localisation

- Direct FRB localisation co-located with persistent radio source.
- Host galaxy is a star-forming dwarf at $z = 0.192$.

CHIME repeating FRBs
(The CHIME collaboration)
SURVEY FOR PULSARS AND EXTRA GALACTIC RADIO BURSTS

- Finding FRBs in real time
- Effecting multi-wavelength follow-ups
- Understanding the nature and origin of FRBs

Bhandari+2018
UTC START 2015-04-18-04:21:15
Source G233.2-03.3_s
PID P892
NE2001 DM 189.1684

**FRB Detections**

<table>
<thead>
<tr>
<th>SNR</th>
<th>Time</th>
<th>DM</th>
<th>Length</th>
<th>Beam</th>
<th>Known Source(s)</th>
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<td>774.723</td>
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</table>

**Beams Positions & Known Sources**

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<thead>
<tr>
<th>Beam</th>
<th>RA</th>
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<th>Gb</th>
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</tbody>
</table>

**Plots**

Superb mailing list
Superb@lists.pulsarastronomy.net
http://lists.pulsarastronomy.net/mailman/listinfo/superb_lists.pulsarastronomy.net

2 Attachments
Multi-wavelength synergies
Multi-wavelength follow-up campaign

Image credit: NASA.
Follow-up campaign

- FRB 151206
- FRB 151230
- FRB 160102

< a day 10 days ~ 3 months

- Radio
- Neutrino
- Optical
- X-ray
Any hints in radio follow-ups?

Observations

• **ATCA**
  – 42 pointing mosaics encompassing Parkes 15’ FWHM
  – C band 2 IFs - center freqs : 5.5 GHz and 7.5 GHz
  – Best RMS ~ 40 µJy/beam

• **GMRT**
  – L band - center freq : 1.4 GHz
  – Best RMS ~ 30 µJy/beam

• **VLA**
  – 7 pointing mosaics encompassing Parkes 15’ FWHM
  – C band - center freq : 5.9 GHz
  – Best RMS ~ 10 µJy/beam

Image credit: NRAO.
Any hints in radio images?

Significant variable sources in VLA images of FRB 151206 field

Significant variable source in ATCA image of FRB 160102 field
Does variability of sources lead to reliable host galaxy associations?

Not likely as the radio variability seen in FRB fields is consistent (within the uncertainties) with the variability in blind searches in literature.
Did FRBs repeat?

NO REPEATS in 14 hours

NO REPEATS in 16 hours

NO REPEATS in 11 hours

NO REPEATS in 48 hours
Optical follow-up results

- All variable sources attributed to
  - stellar variability
  - AGN variability
  - asteroids
- No optical afterglows/transients found to limiting magnitudes of
  - i-band ~ 25.0
  - r-band ~ 22.0
- Cadence range: minutes, days to weeks.

Credit: Gemini Observatory/AURA
X-ray follow-up

• Triggered for FRB 151230 and FRB 160102.
• FRB 151230
  • No sources detected above 3 sigma
  • limiting flux $\sim 1.9\times10^{-13}\ erg/cm^2/s$
• FRB 160102
  • No sources detected above 3 sigma
  • limiting flux $\sim 1.4\times10^{-13}\ erg/cm^2/s$
ANTARES

- ANTARES is a deep water neutrino detector.
- Aims to detect neutrino-induced muons (above 100 GeV) that produce Cherenkov light in the detector.
- Triggered at the time of FRB events to look for neutrino counterparts.
- No neutrino event was detected in correlation with FRB events.
Localisation with Parkes

14' positional uncertainty

Parkes beam overlaid on DECAM image.

Credits: Igor Andreoni
The Australian SKA Pathfinder (ASKAP)

- 36 antennas, each 12m in diameter.
- Frequency coverage: 700 MHz to 1.8 GHz
- 300 MHz instantaneous bandwidth
- 36 independent beams
- 30 square degree field-of-view at 1.4 GHz
- 6 km maximum baseline
The Commensal Real-Time ASKAP Fast Transients (CRAFT)
The dispersion–brightness relation for fast radio bursts from a wide-field survey

R. M. Shannon, J.-P. Macquart, [...] C. J. Riseley

Nature 562, 386–390 (2018) | Download Citation

—Wide (exposure: 5.1e5 deg\(^2\) hr) and shallow (26 Jy ms) Fly’s eye survey
—20 FRBs detected
—Bright FRBs exist (34 - 420 Jy ms)
—Lower DM sample than detected by Parkes (114-991 pc cm\(^{-3}\))
—No evidence for repetition in self-followup.
The high-fluence bursts are the nearby analogues to the more distant events.
ASKAP Fly’s eye FRBs

10’ localisation

Shannon+2018
FRBs and Interferometry

Credits: NRAO
Find an FRB real-time

Localise using interferometry

Do amazing Science

FRB signal

FRB host galaxy

CRAFT candidates

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<td>S/N</td>
<td>21.08</td>
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<tr>
<td>DM</td>
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</table>

Single flash traced to its host galaxy

pp. 546 & 565

FAST RADIO BURST

Wildfire smoke in the stratosphere

p. 587

Stone Age humans at high altitude

pp. 541 & 583

$15

9 AUGUST 2019

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nature astronomy

Bursting with potential
Lorimer Burst
First sample of FRBs
Real-time FRB
Repeating FRB
UTMOST
Multi-wavelength campaign
CHIME FRBs

Perytons
Arecibo detection
GBT, Faraday rotation
Bright FRBs
Localisation repeater
ASKAP FRB population
Single burst localisation

Lorimer+07, Burke-Spolaor+11, Thornton+13, Spitler+14, Petroff+15, Spitler+16, Ravi+16, Caleb+17, Farah+18, Chatterjee+17, Bhandari+18, Shannon+18, CHIME+19, Bannister+19, Ravi+19
Thank you

CSIRO Space and Astronomy Science
Dr. Shivani Bhandari
Research Plus Postdoctoral Fellow
E: shivani.bhandari@csiro.au

More about ASKAP FRBs
See Stuart Ryder’s talk