Fast Radio Transients

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Will discuss

- Single-pulse searches
- Pulsar “giant” pulses
- The “Lorimer” Burst
- RRATs (rotating radio transients)
- Perytons
- FRBs (fast radio bursts)
Won’t discuss

• (exo)Planets
• Flare stars
• Solar burts
Transient Parameter Space

Large portions of phase space empty and unexplored!

$(W_\nu)^2 \propto SD^2/T$

Cordes et al. 2004
Large portions of phase space empty and unexplored!
Transient Parameter Space

Cordes et al. 2004

Large FoV for rare, bright events

Large instantaneous sensitivity for weak source classes

Cordes et al. 2004
What are we missing?

Gamma-ray burst from BATSE (Burst and Transient Source Experiment) on CGRO

- These are observed a few times a week.
- For radio fast transients, we’re scratching the surface of 10,000 events per day.
Propagation Effects

\[ I(t) = g_r g_d S(t) \ast h_{DM}(t) \ast h_d(t) \ast h_{Rx}(t) + N(t) \]

Observed signal ➔ Emitted signal

Scattering

Dispersion

Frequency ➔ Time

Frequency ➔ Time
Galactic Dispersion

Contour of constant dispersion measure (NE2001 model; Cordes & Lazio)
Pulsar Searching

- RFI Excision
- Dedispersion
- Single Pulse Search
- FFT Search
- Cand Sifting
Pulsar Searching

Dispersion measure trial

Zoom 3x

20 ms
The Lorimer Burst

Lorimer et al. 2006, *Science*

- Spectral index $-4^{+/-1}$, Dispersion and Pulse Broadening (Komolgarov)
- $\text{DM} > \text{expected from Galaxy}$.
- No observed repeats.
- Hundreds per day per sky.
The Thornton Bursts
a.k.a. Fast Radio Bursts (FRBs)
Thornton et al. 2013, Science

- FRB 110220.
- DM = 944 pc/cc
- z ~ 0.8?
- Shows expected dispersive delay and scatter-broadening.
- 10,000 /sky/day?!
Terminology

**RRATs** (e.g. McLaughlin et al. 2006)
- Sporadically pulsing pulsars.
- DM implies Galactic distance.
- Repeating (in general).

**Perytons** (e.g. Burke-Spolaor et al 2011)
- Appear to be near-field (terrestrial/atmospheric).
- Narrow DM range $\sim 350$pc/cc.
- “Kinked” delay with time.
- “Patchy spectra”.
Terminology

**Giant Pulse** (e.g. Hankins et al. 2004)

- Sporadic exceptionally bright pulsar pulses.
- Narrower than normal pulses.
- May come from different emission region.
- Crab and PSR B1937+21 are famous examples.

**FRBs** (e.g. Thornton et al. 2013)

- Term generally used when DM > maximum Galactic value.
- Follow dispersive delay.
- Non-repeating (we think!).
- Could be extra-Galactic.
Where do these signals come from?

- Merging Black Holes
- Supernovae
- Magnetars
- Evaporating Black Holes
- Super-giant Pulses
- Gamma-ray Bursts
- SETI
- Flare stars
- Pernicious RFI
- Atmospheric effects
- A well-coordinated hoax
- "Blitzars"
- We are here

Pulsars
Gamma-ray Bursts
Flare stars
Pulsars
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Spoiler alert: We don’t know.
Why Interesting

If at least some FRBs are extragalactic:

• Origin in a cataclysmic event (study extreme physics).
• Complement to grav. wave events?
• Probe intergalactic medium. Missing baryon problem (McQuinn 2013; Deng & Zhang 2014). Also map intergalactic magnetic fields.
• Use as cosmic rulers. Measure dark energy equation-of-state parameter “w” at z>2 (Zhou et al. 2014).

Need an “FRB factory” capable of detecting and localizing 1000s of these.
How to make progress

• Real-time detection and signal buffering.
• Localization.
• Get polarimetry.
• Detect at other frequencies.
• Detect at other observatories.
• Characterize the “zoo” of fast radio signals (including RFI, different frequency sweeps etc.)
• SKA I has the potential to be the premier FRB factory
ARTEMIS

Real-time pulsar and transient searches

Karastergiou
DRAGNET

GPU Cluster

Raw data
1 - 72 stations

100 Fields-of-view
Offline processing
10hr / week observing

Sub-arrays
80x400 Fields-of-view

Realtime processing
Observe 24/7
Localize events
PALFA FRB

Spitler, Cordes, Hessels, Lorimer, McLaughlin, Chatterjee,...
Parkes (HTRU) has found ~12, one every 200hrs of observing.
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In Summary

• FRBs are a burgeoning class of transient signal with the potential for high-impact science.

• The field is still in its infancy, and there are many unknowns (rate, spectrum, origin(s)).

• Regardless, current (e.g. LOFAR) and upcoming (SKA) facilities can make a major impact on exploring the fast transient parameter space.