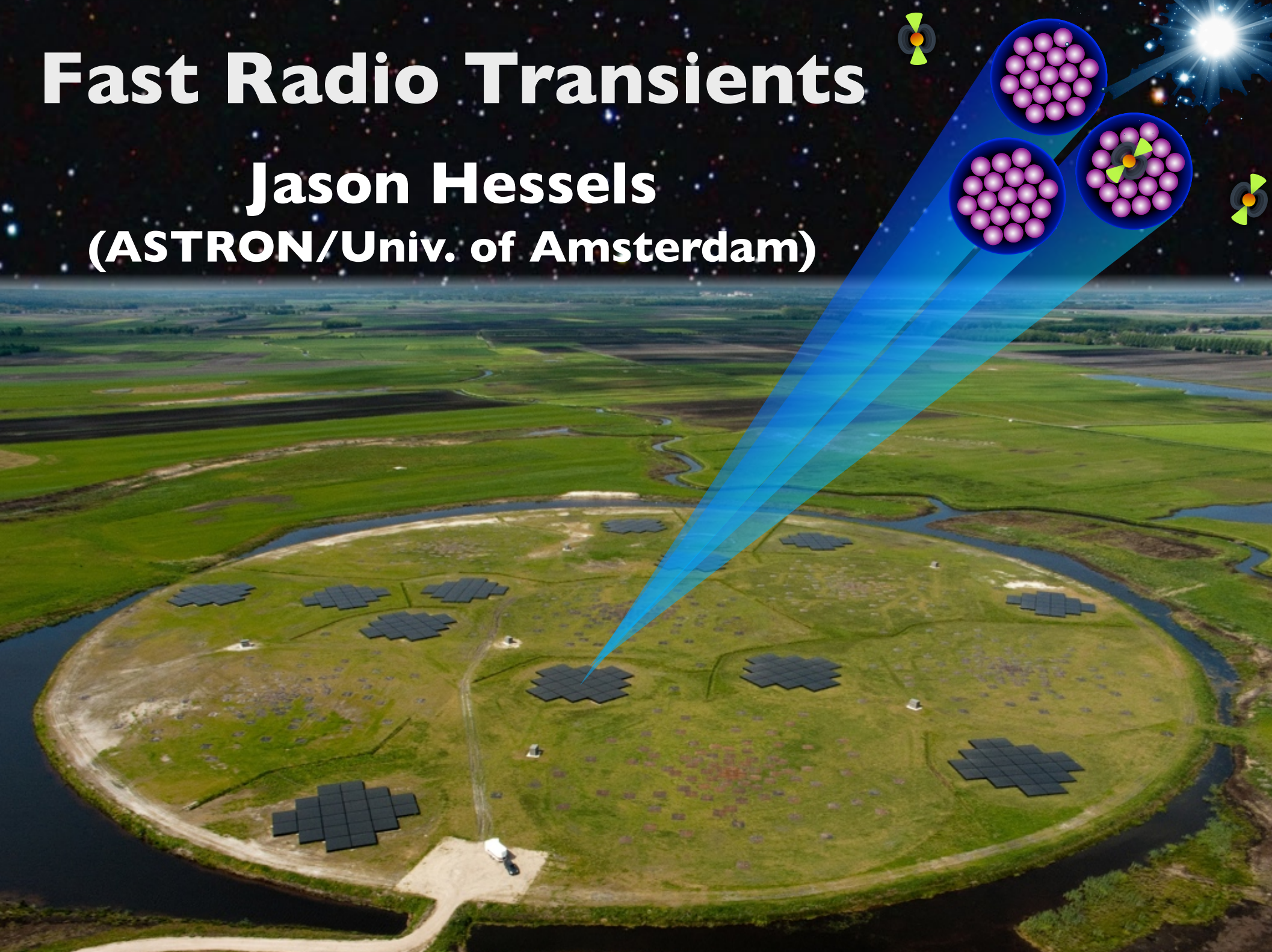
Fast Radio Transients

Jason Hessels
(ASTRON/Univ. of Amsterdam)



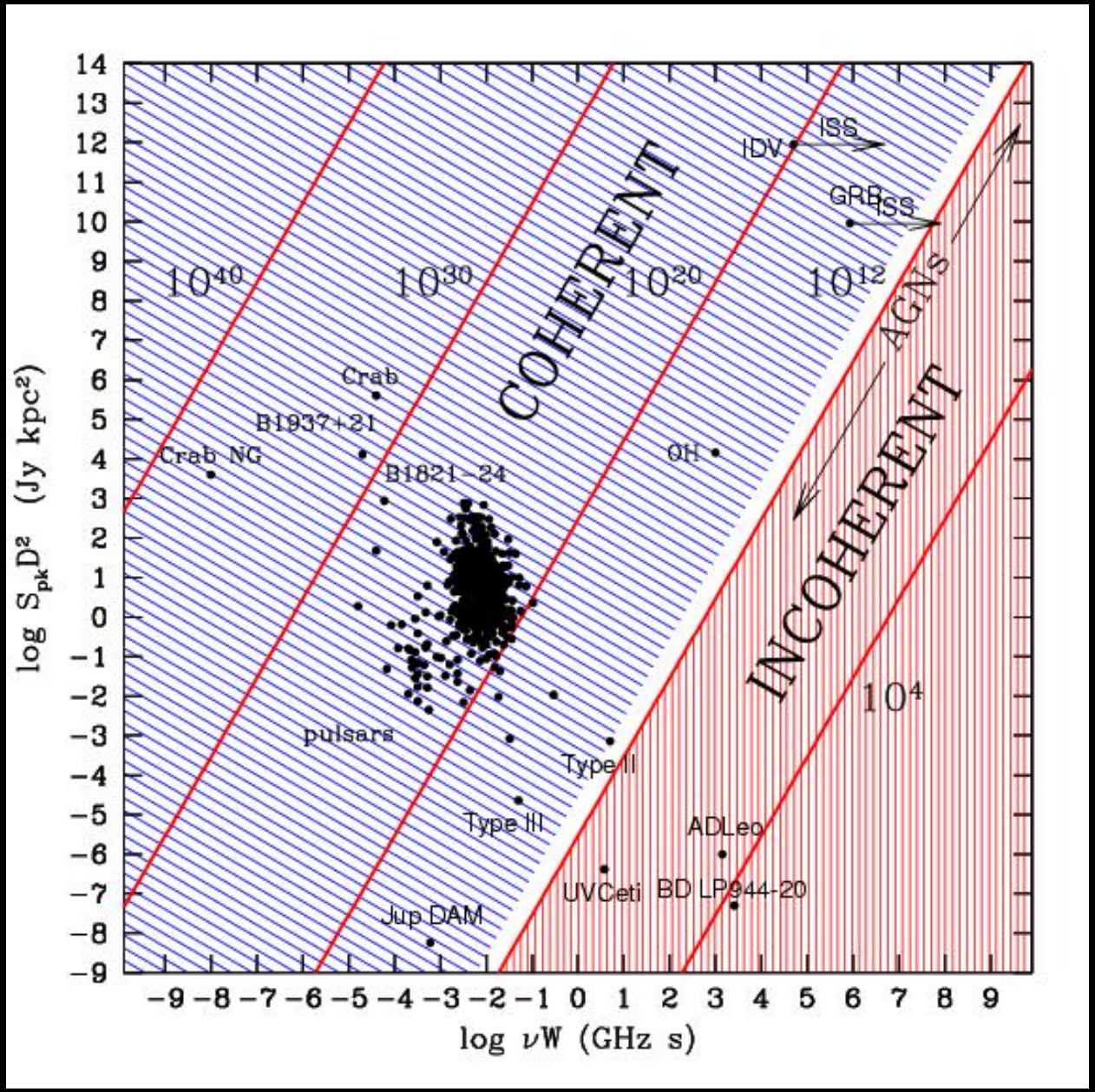
Will discuss

- 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

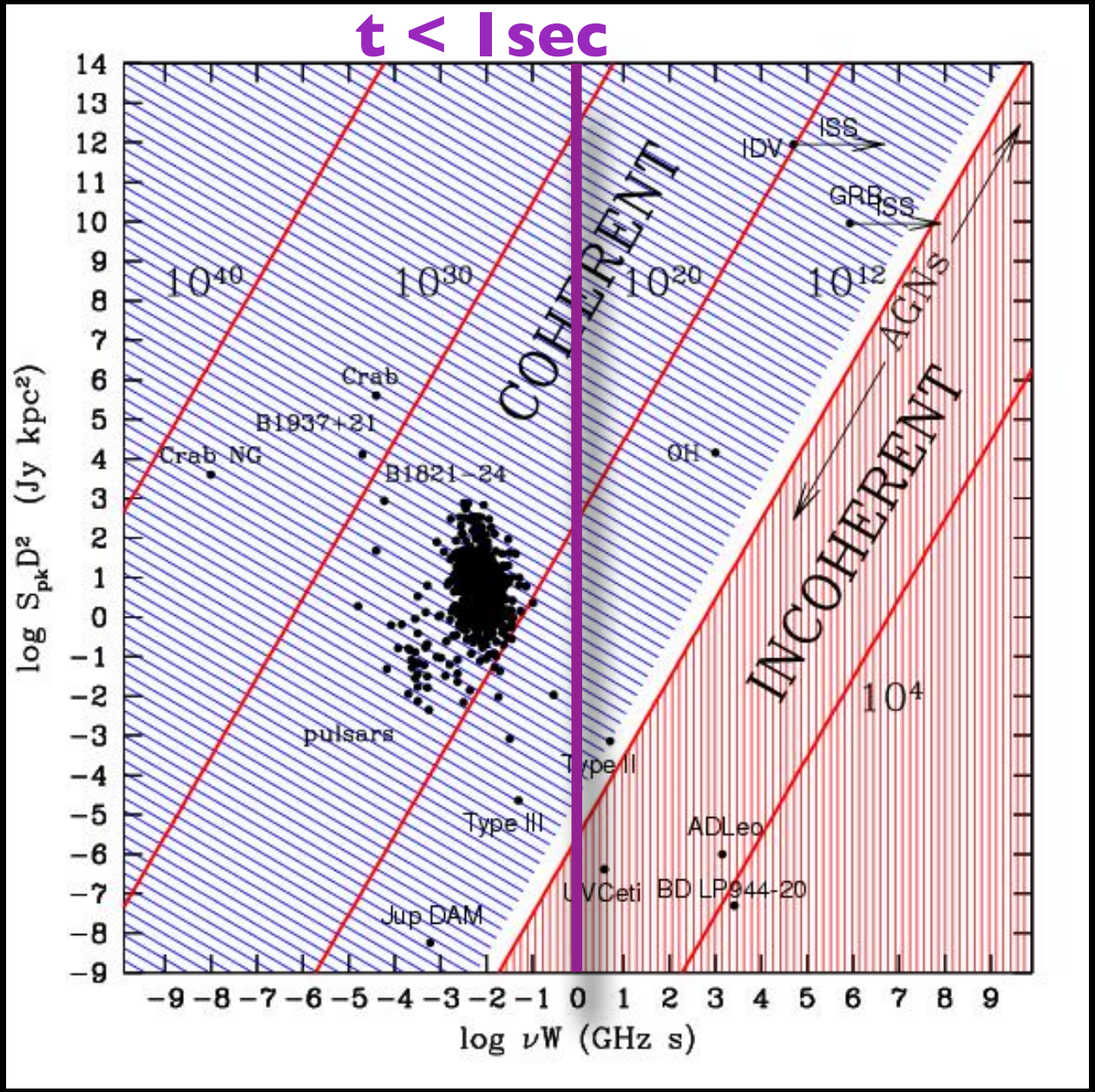


Cordes et al. 2004

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

Large portions of phase space empty and unexplored!

Transient Parameter Space



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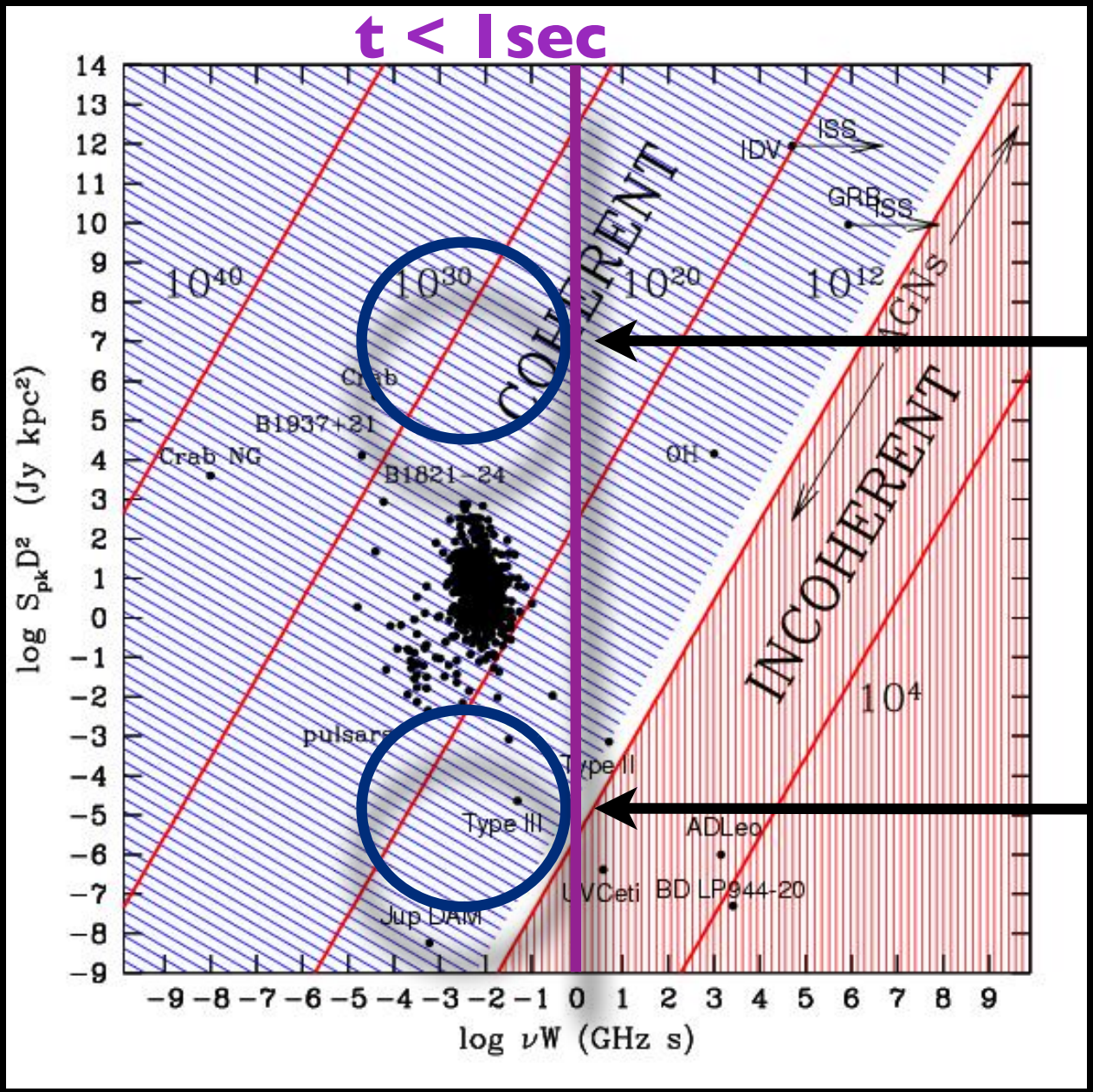
Transient Parameter Space

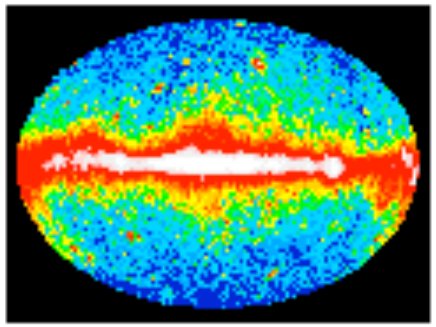


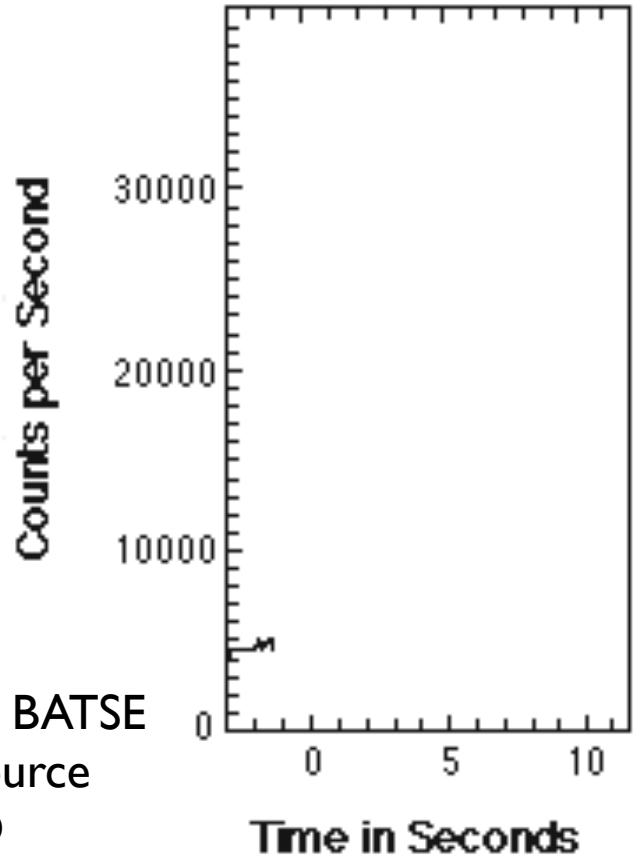
Large FoV for rare, bright events

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.

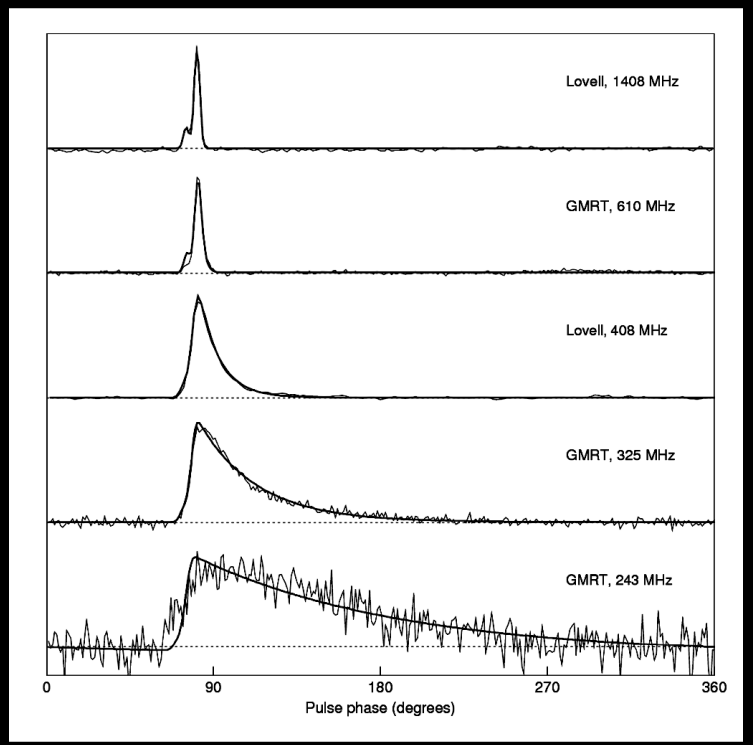
Propagation Effects

Observed signal →

$$I(t) = g_r g_d S(t) * h_{\mathrm{DM}}(t) * h_d(t) * h_{\mathrm{Rx}}(t) + N(t)$$

↑ Emitted signal

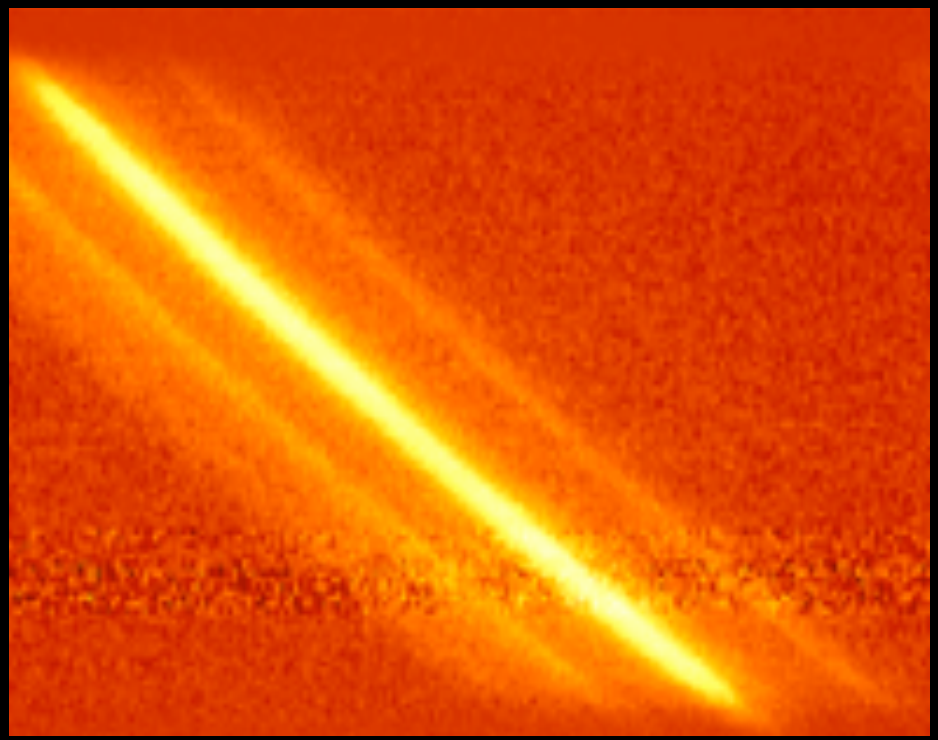
Scattering



Frequency ↑

Time →

Dispersion



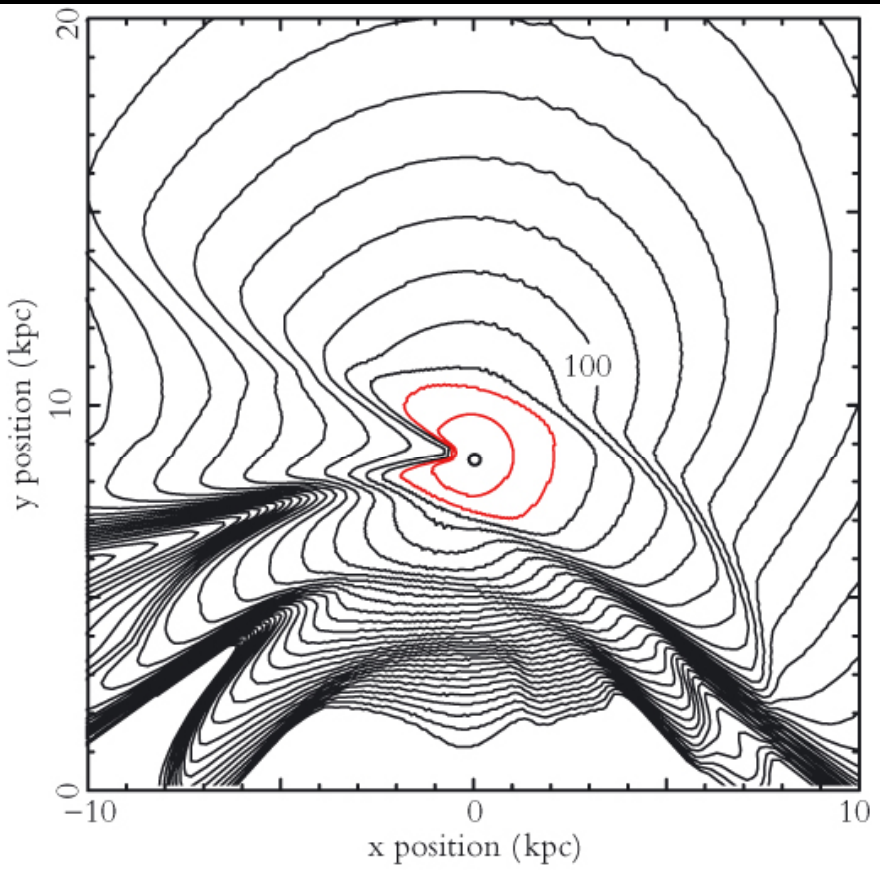
Frequency ↑

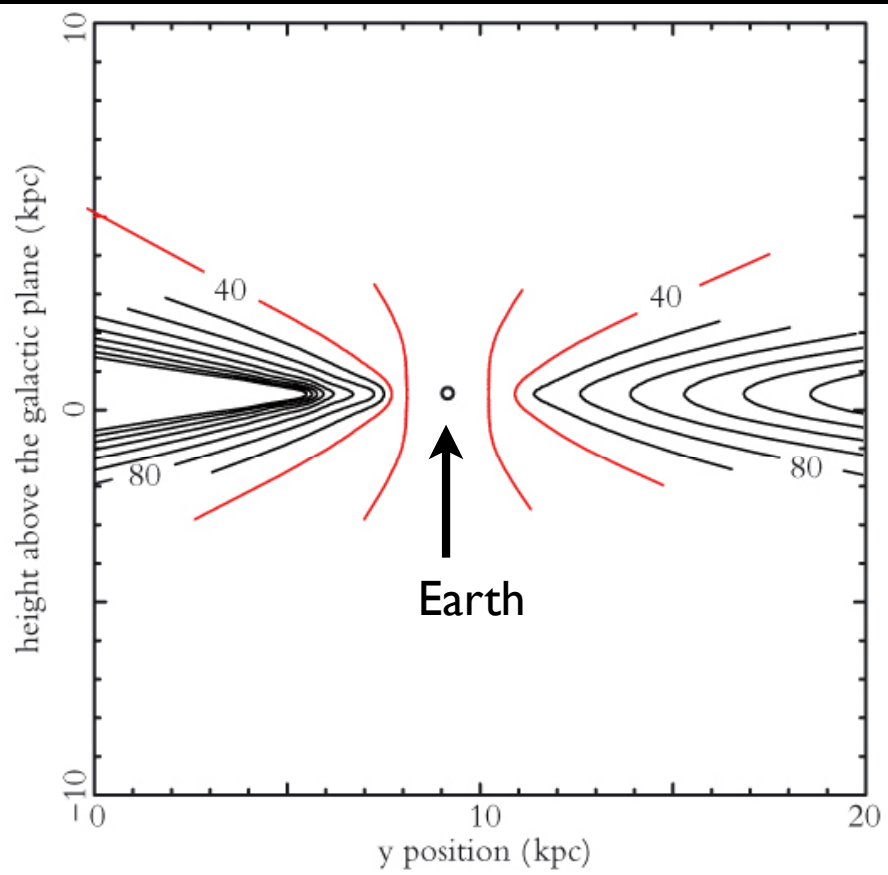
Time →

Galactic Dispersion

Galaxy top-down

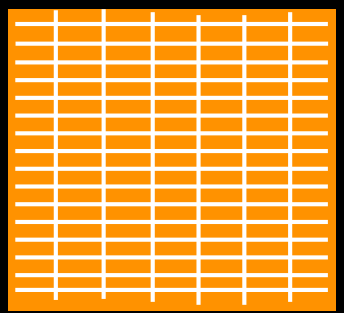
Along Galactic plane



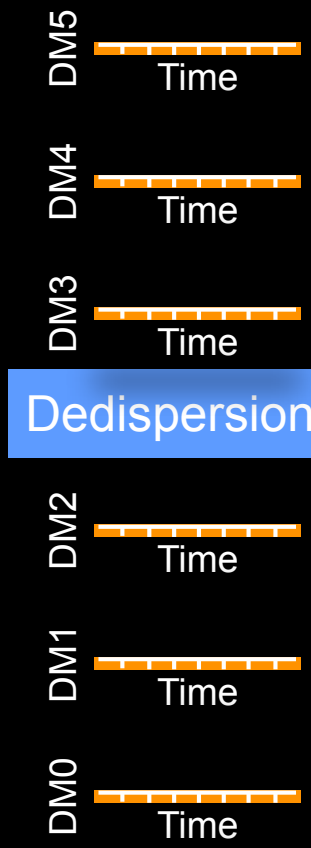


- Contours of constant dispersion measure (NE2001 model; Cordes & Lazio)

Pulsar Searching

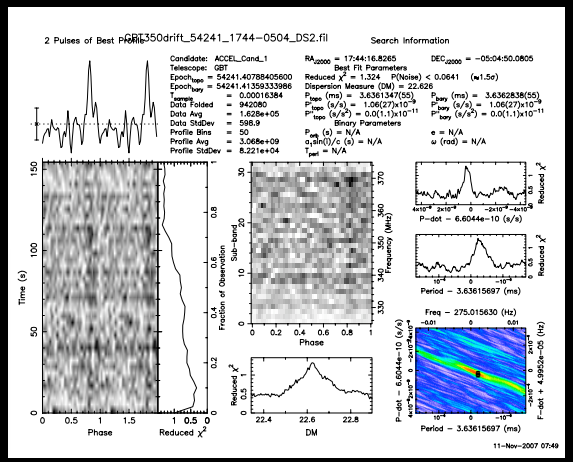


RFI Excision



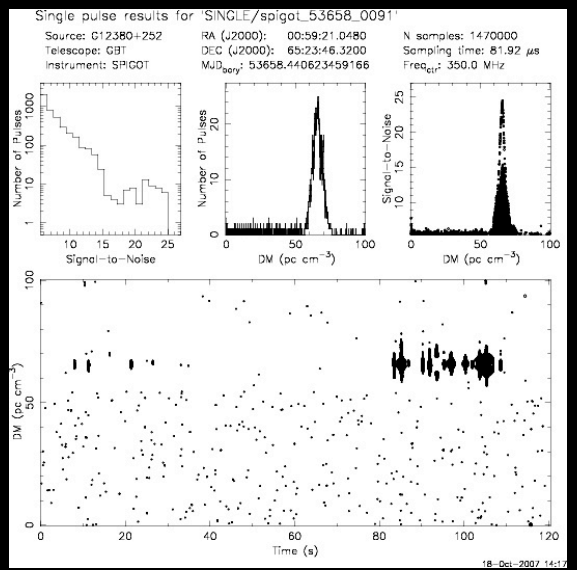
Dedispersion

FFT Search



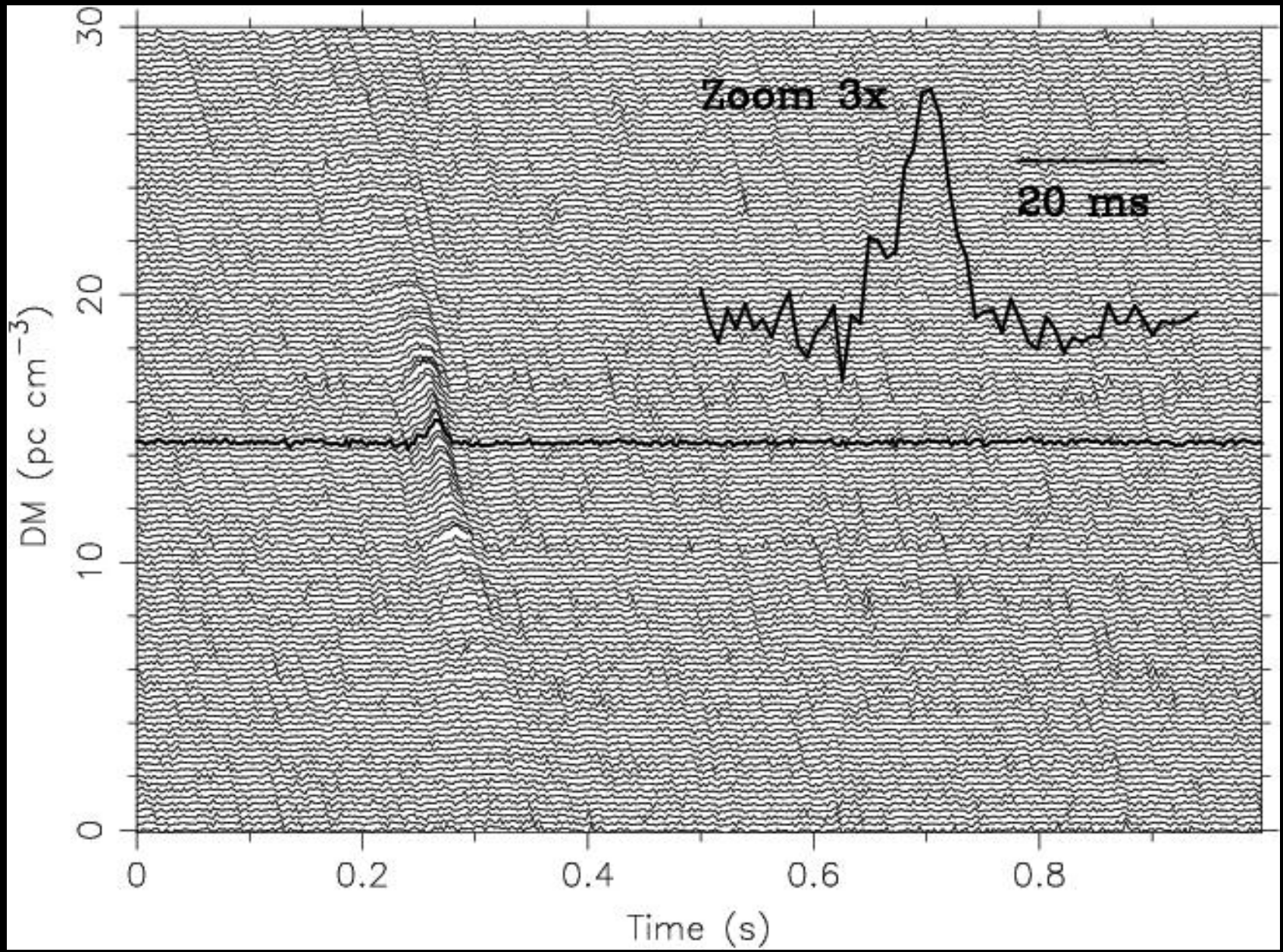
Cand Sifting

Single Pulse Search



Cand Sifting

Pulsar Searching

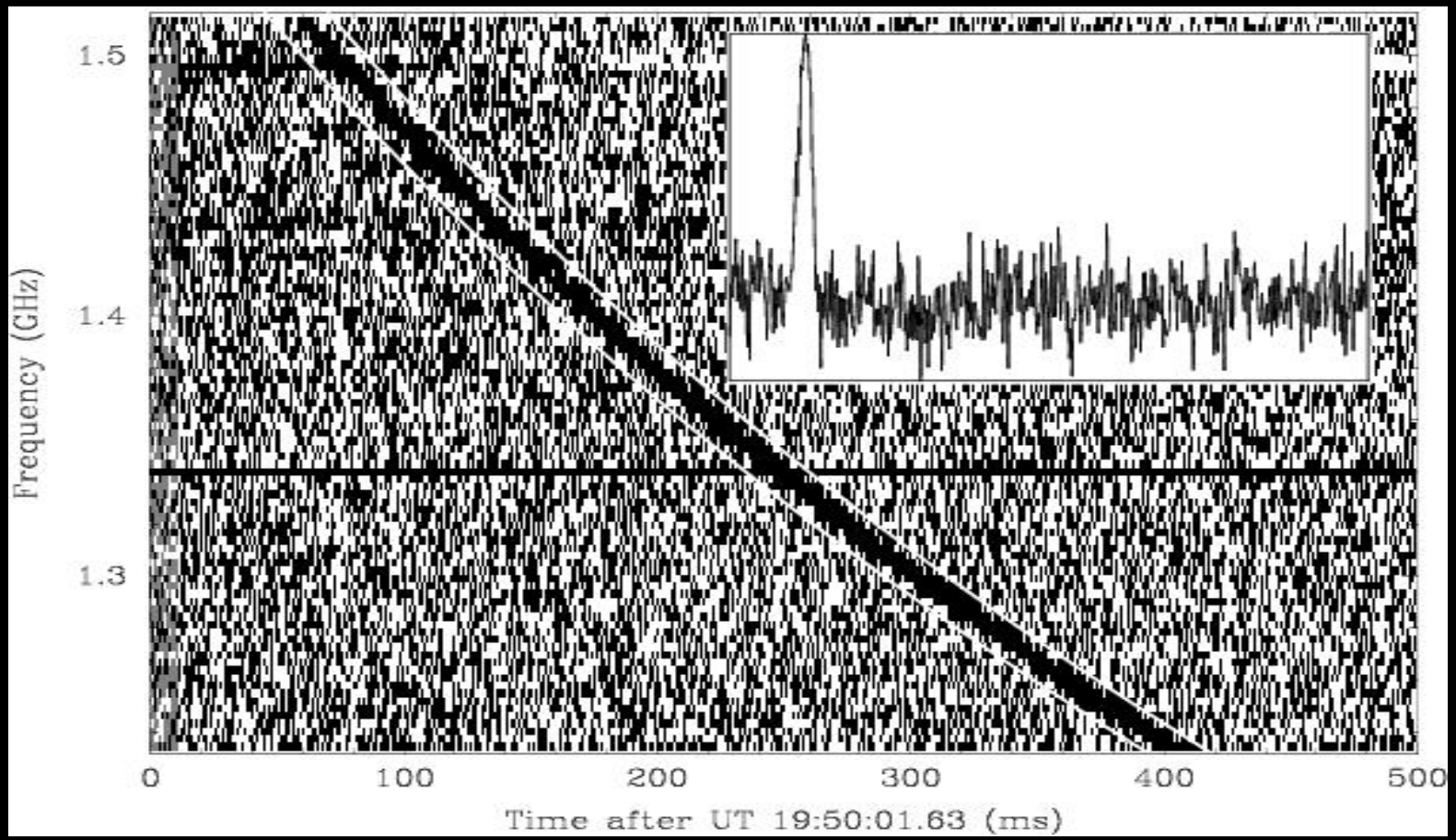


Dispersion measure trial →

Time →

The Lorimer Burst

Lorimer et al. 2006, *Science*

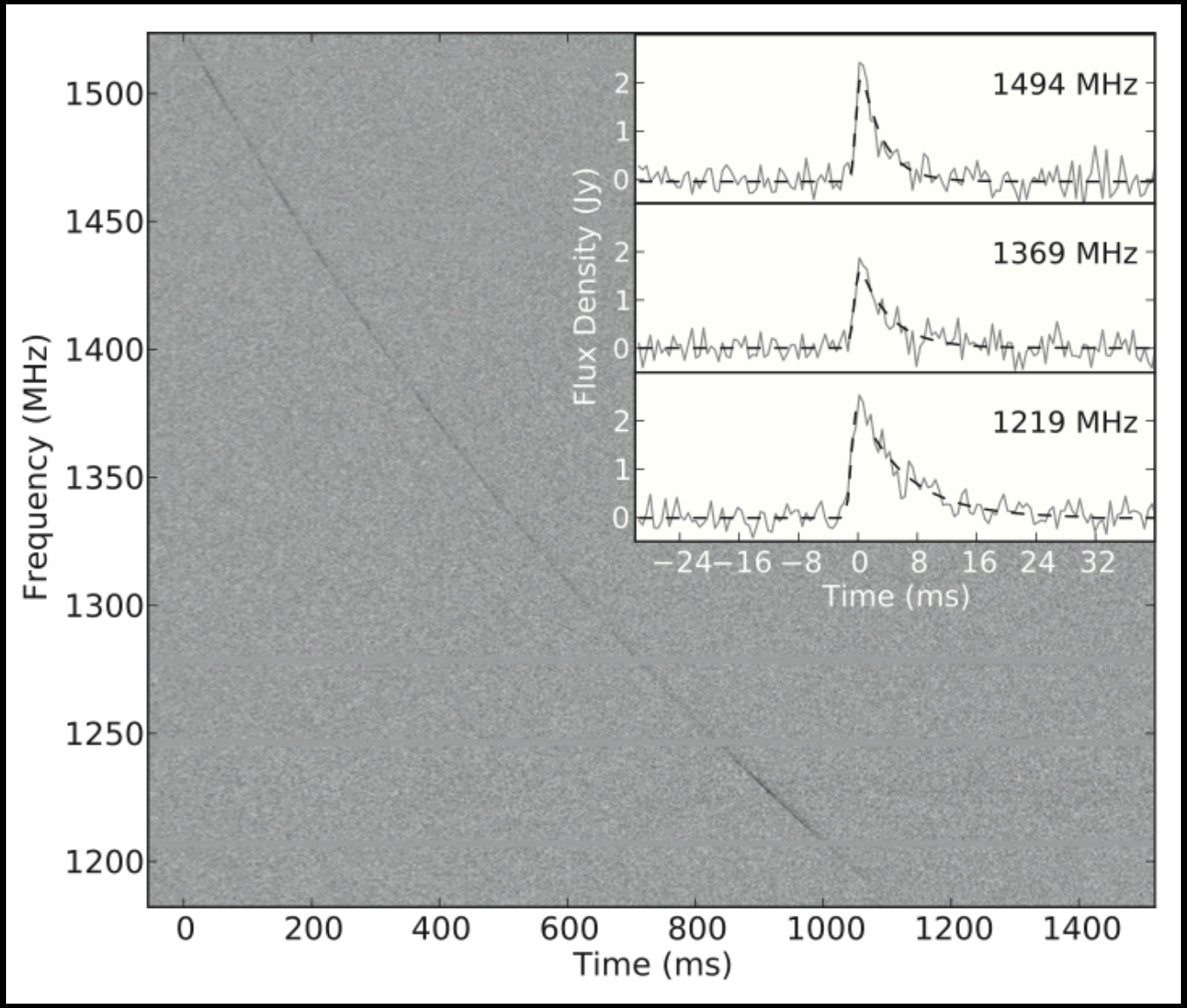


- DM > expected from Galaxy.
- No observed repeats.
- Hundreds per day per sky.

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 ~350pc/cc.
- "Kinked" delay with time.
- "Patchy spectra".

Terminology

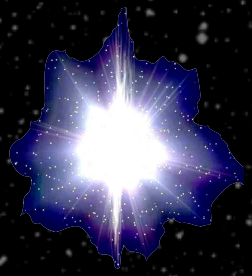
Giant Pulse (e.g. Hankins et al. 2004)

- 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.

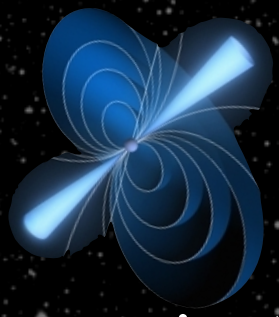
Merging
Black Holes



Supernovae

Magnetars

Evaporating
Black Holes



Super-giant
Pulses

extra-Galactic

Gamma-ray
Bursts

Galactic

Flare stars

SETI

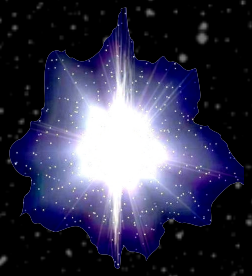
Pernicious RFI
Atmospheric effects
A well-coordinated hoax

We are here

Pulsars

“Blitzars”

Merging
Black Holes



Supernovae

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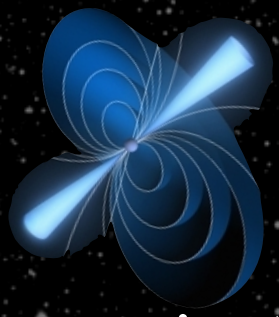


Super-giant
Pulses

Where do these signals come from?

Gamma-ray
Bursts

SETI

Flare stars

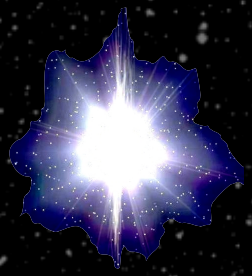
Pernicious RFI
Atmospheric effects
A well-coordinated hoax

We are here

Pulsars

“Blitzars”

Merging
Black Holes



Supernovae

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Evaporating
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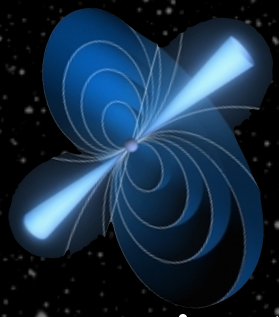


Super-giant
Pulses

Gamma-ray
Bursts

Spoiler alert:
We don't know.

SETI

Flare stars

Pernicious RFI
Atmospheric effects
A well-coordinated hoax

We are here

Pulsars

"Blitzars"

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).

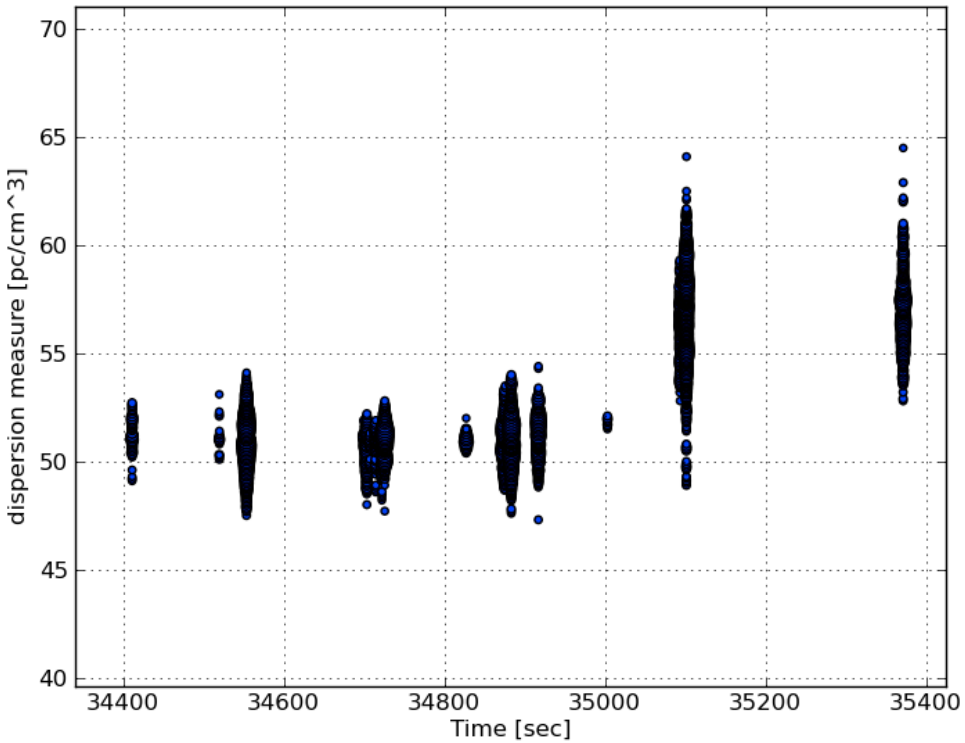
Need an "FRB factory" capable of detecting and localizing 1000s of these.

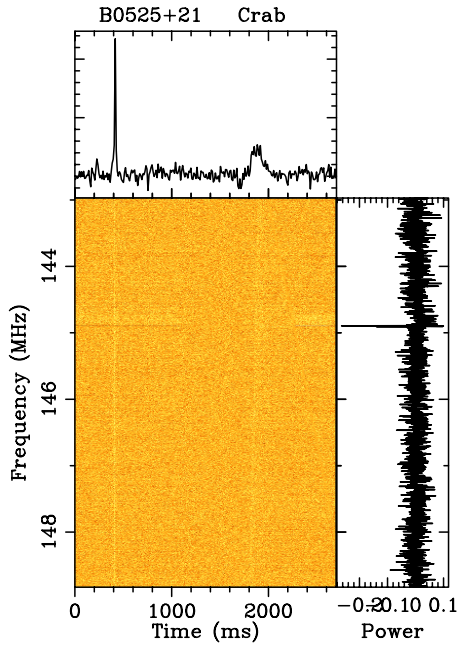
How to make progress

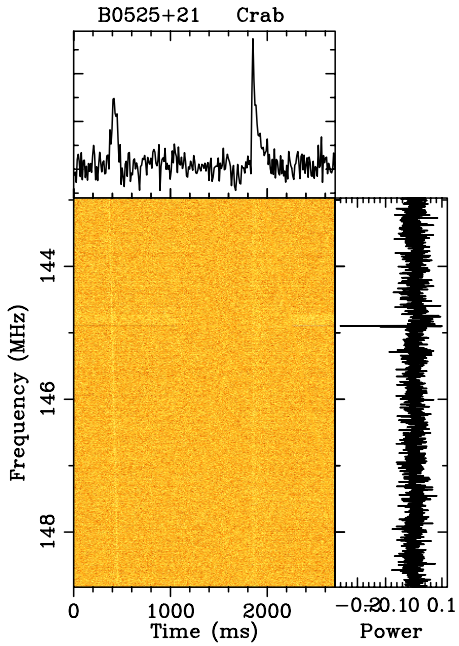
- Real-time detection and signal buffering.
- Localization.
- Get polarimetry.
- Detect at other frequencies.
- Detect at other observatories.
- Characterize the "zoo" of fast radio signals (including RFI, different frequency sweeps etc.)
- **SKA1 has the potential to be *the premier* FRB factory**

ARTEMIS

Real-time pulsar and transient searches







Karastergiou

LOFAR

Raw data
1 - 72
stations

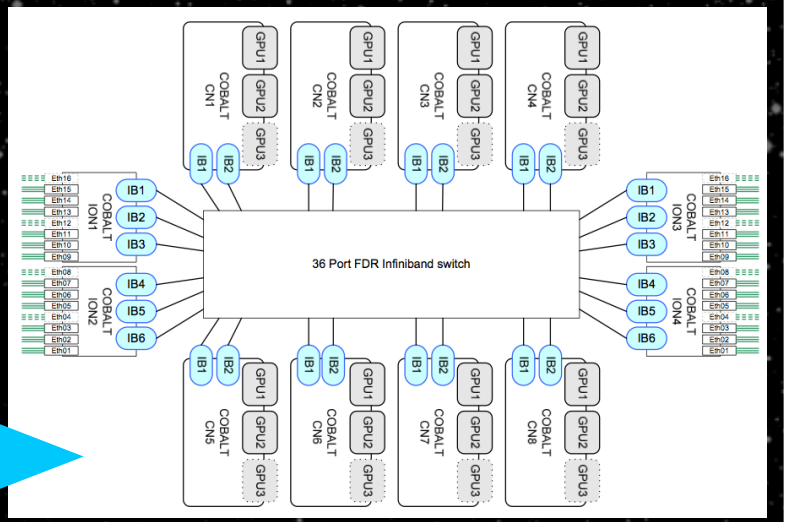
100 Fields-of-view

Offline processing

10hr / week
observing

DRAGNET

GPU Cluster



Sub-arraying

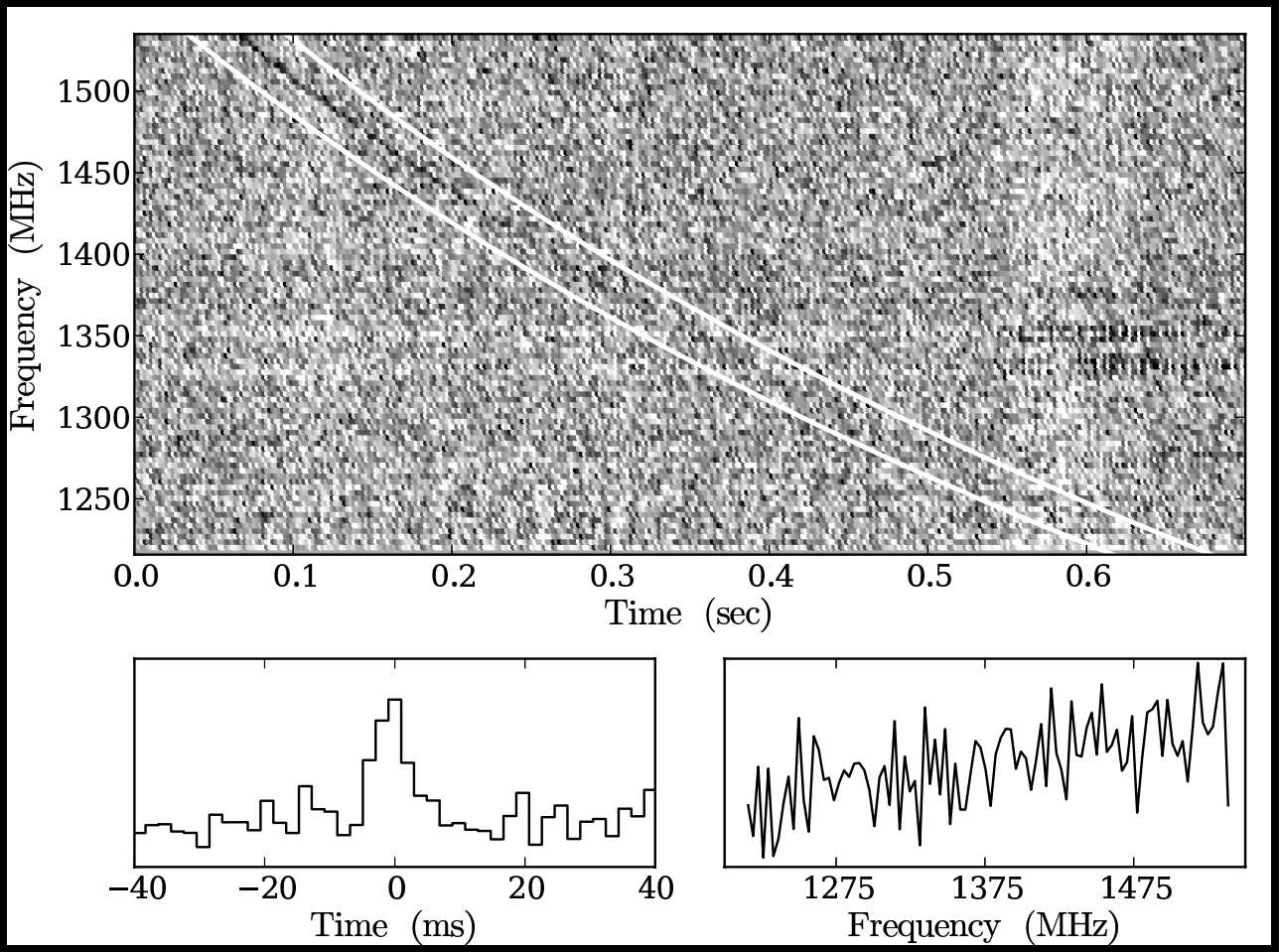
80x400 Fields-of-view

Realtime processing

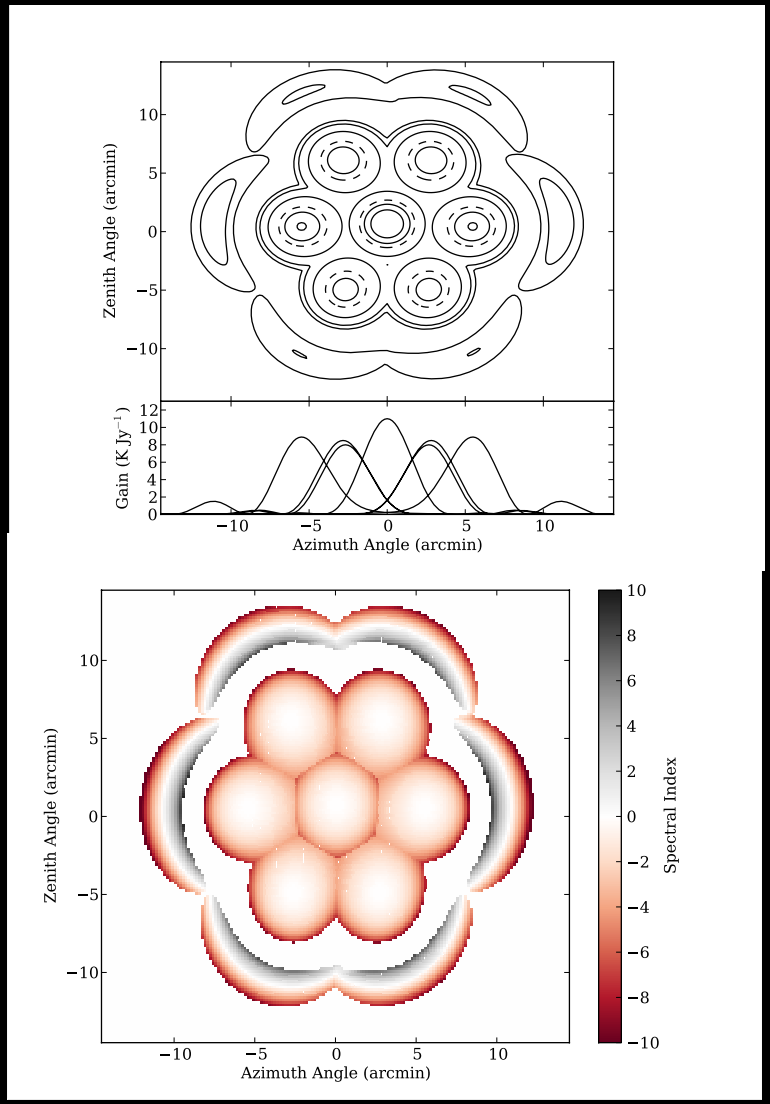
Observe 24/7

Localize events

PALFA FRB



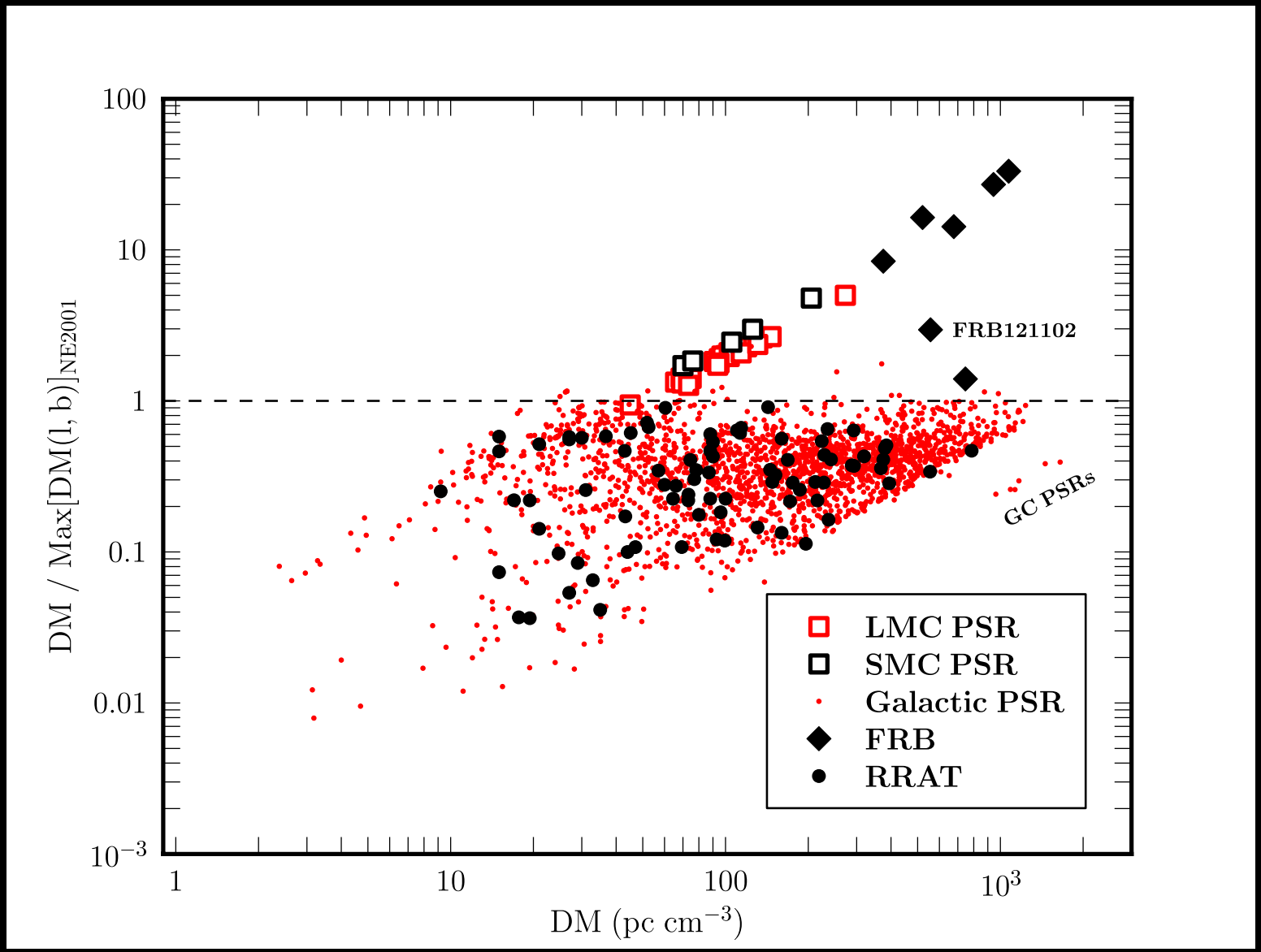
Spitler



Cordes & Chatterjee

Spitler, Cordes, Hessels, Lorimer, McLaughlin, Chatterjee,...

Detections (out of date)



Cordes

Parkes (HTRU) has found ~12, one every 200hrs of observing

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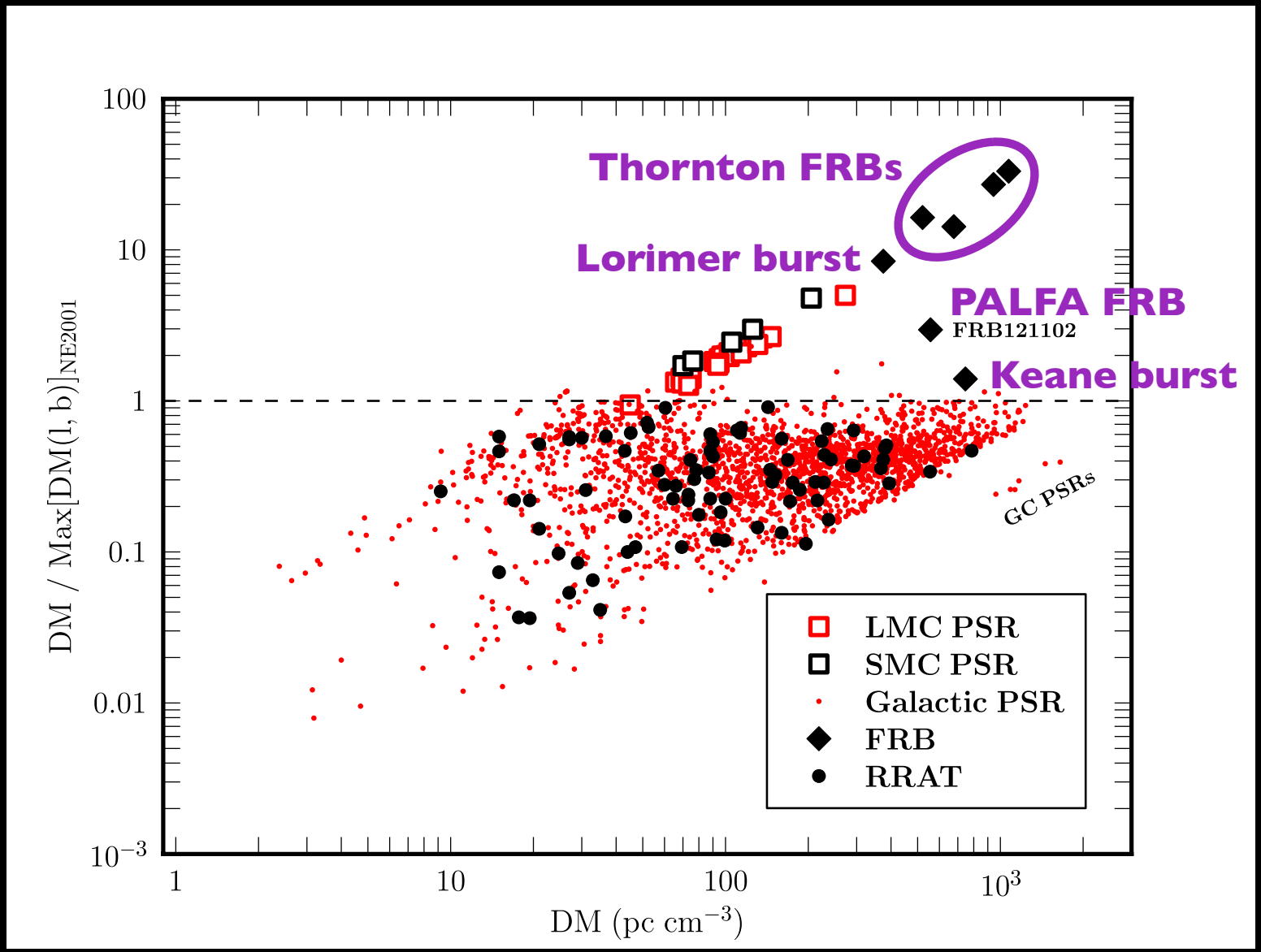

Cordes

Parkes (HTRU) has found ~12, one every 200hrs of observing

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.