V-FASTR Commensal Observations and Real-time Classification Agent

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February 13, 2013

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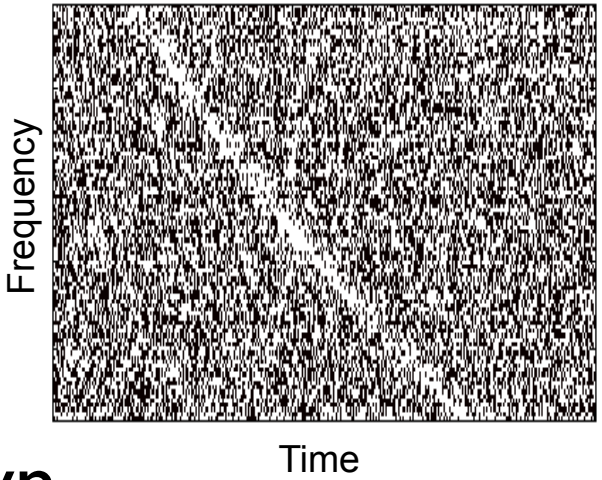
What's out there?

- Signals from known or hypothesized sources
  - Pulsars
  - Intermittent pulsars (RRATs)
  - Merging neutron stars
  - Evaporating black holes

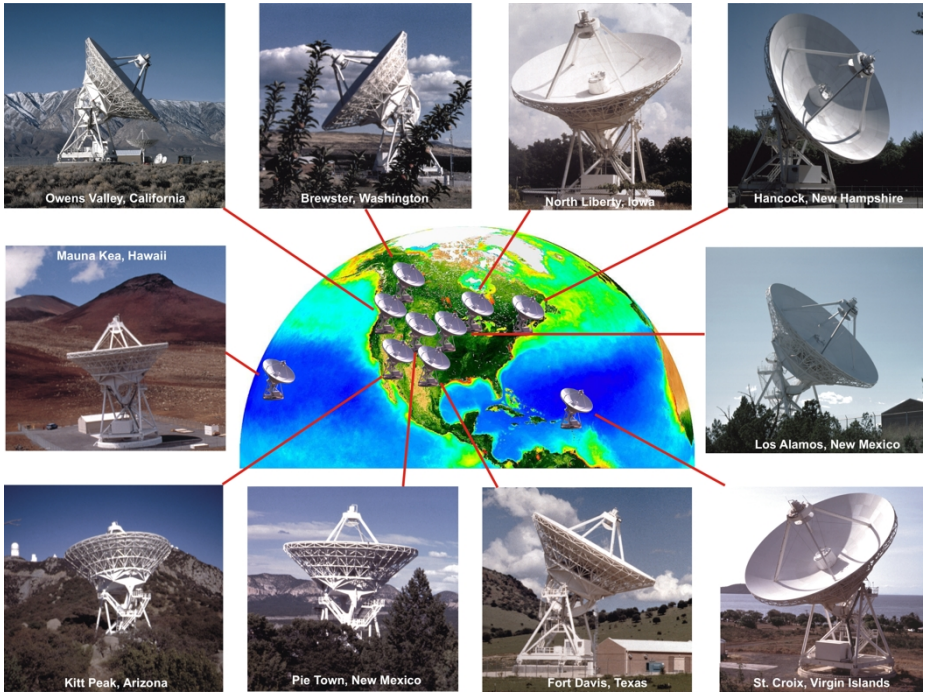
Pulsar J0742-2822
Parkes Beam 5 [Edwards et al., 2001]



- Signals from the unknown
  - Short-duration (~ms) transient signals: Largely unexplored space
- Signals are <u>dispersed</u> by the interstellar medium

V-FASTR's role

- VLBA:
  10 stations
  (25-m)
- 8600-km
  baseline
  - Milliarcsecond
    localization



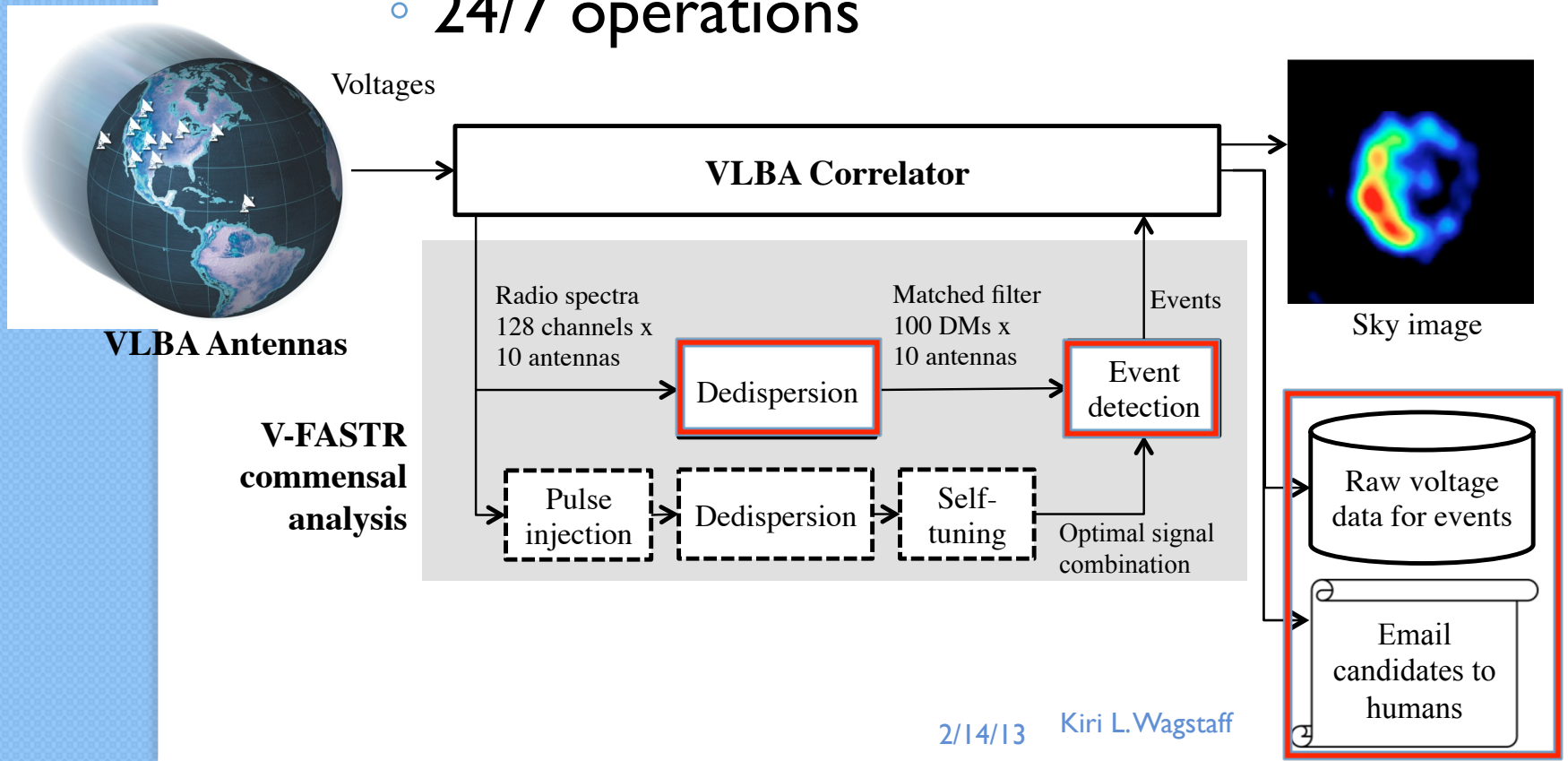
- V-FASTR: real-time commensal detection of fast transient signals
  - Commensal: analyze data as it is correlated; no control over pointing or parameters

In this talk:

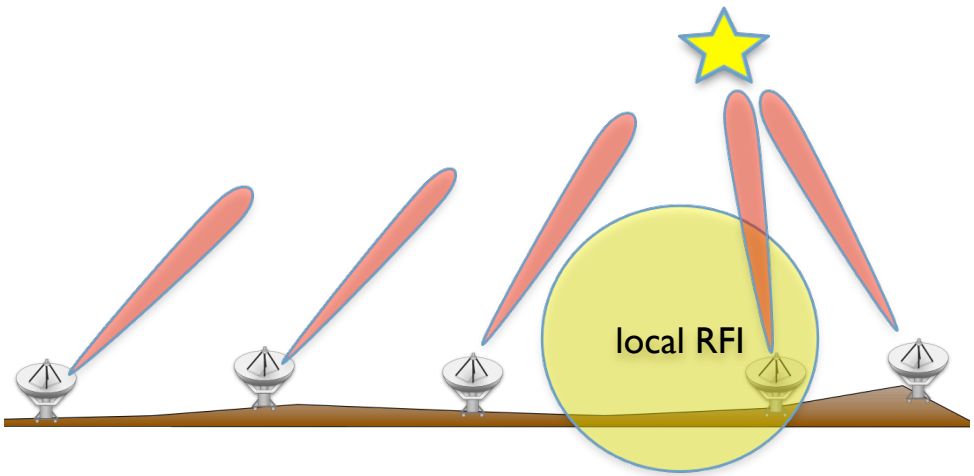
- How V-FASTR works
- Results to date
- New advance: V-FASTR tagging agent

V-FASTR Overview

- Goals:
  - Fast detection to save best candidates given limited buffer space
  - Minimal impact on VLBA system
  - 24/7 operations

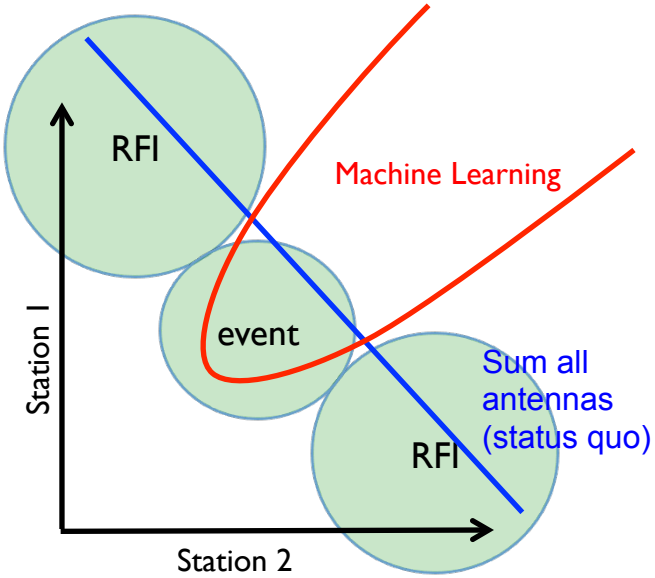


Robust Detection



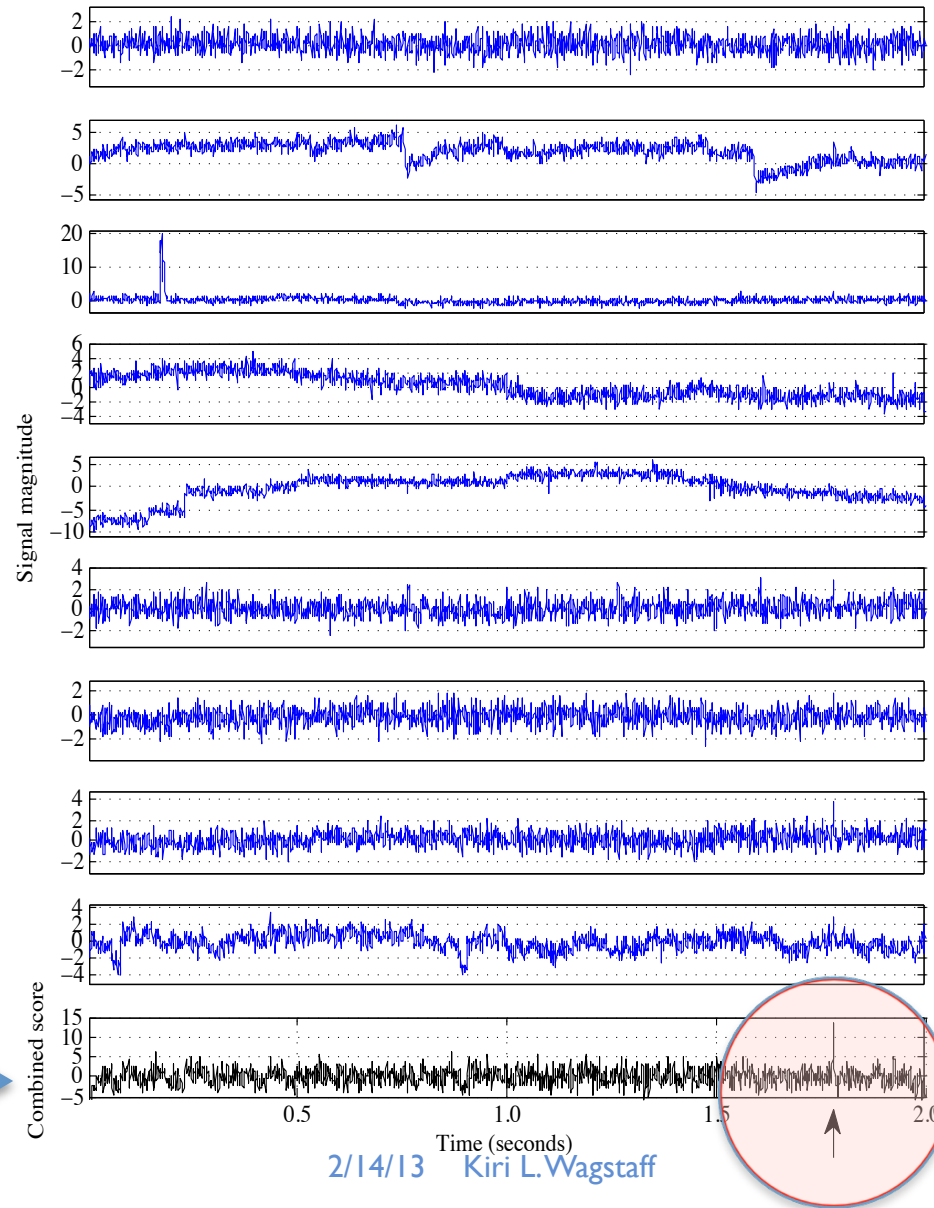
Leverage multiple stations to excise RFI

<u>Adaptive excision</u>:
Use machine learning to selectively include or exclude stations



Adaptive excision: example

Pulsar J1919+0021



Pulse detection

How to get this clean sum?

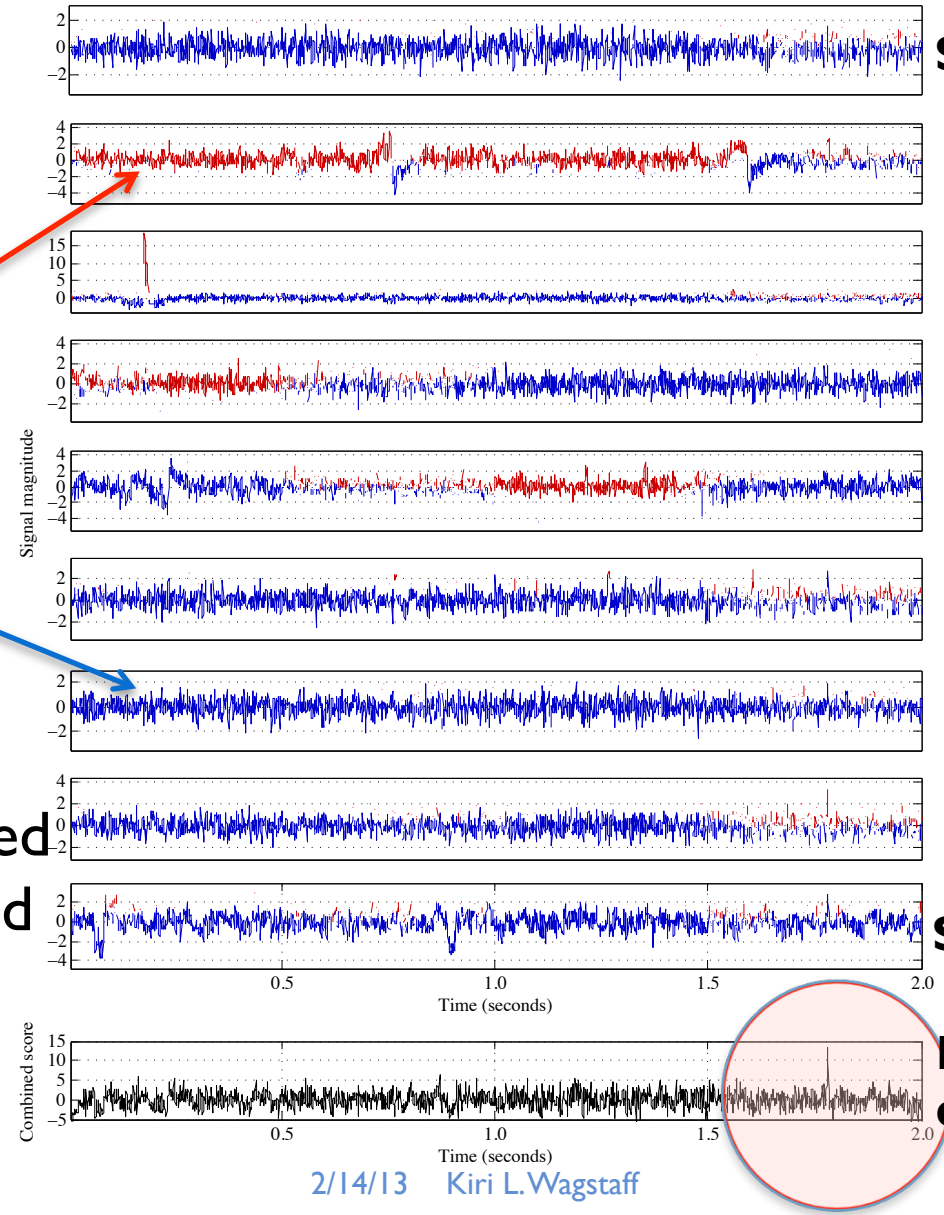
Adaptive excision: example

Pulsar J1919+0021

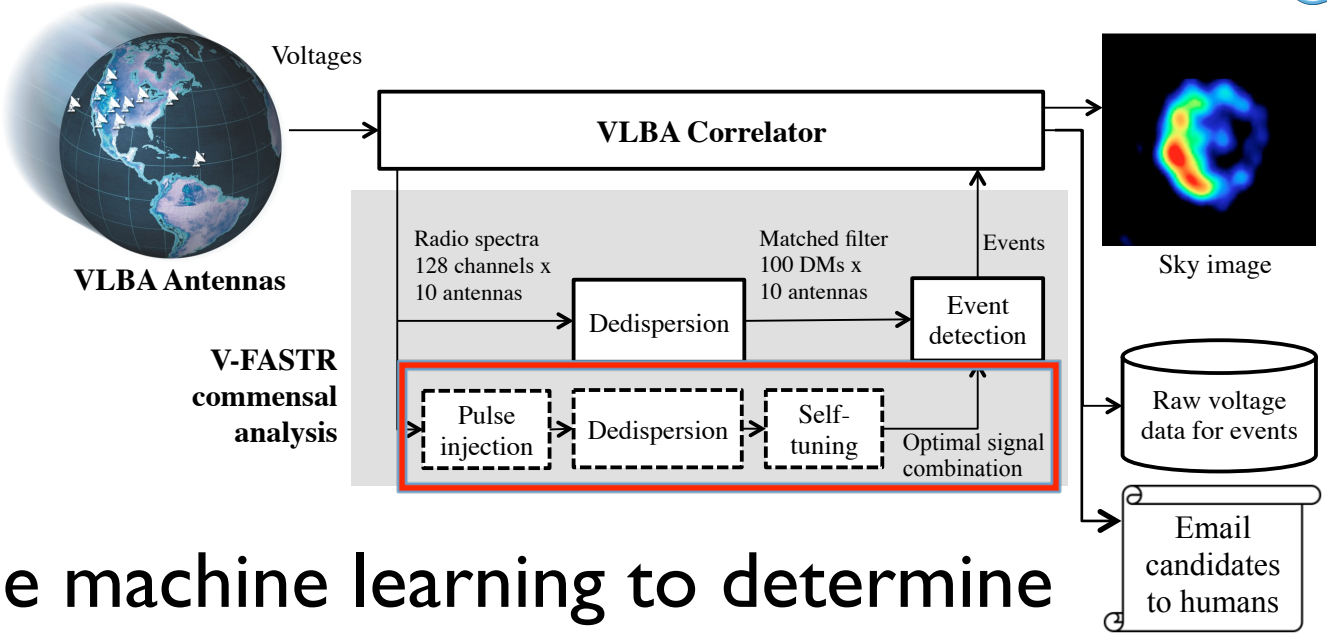
Selected for excision

Contributing to sum

Here, data is detrended and adaptively excised



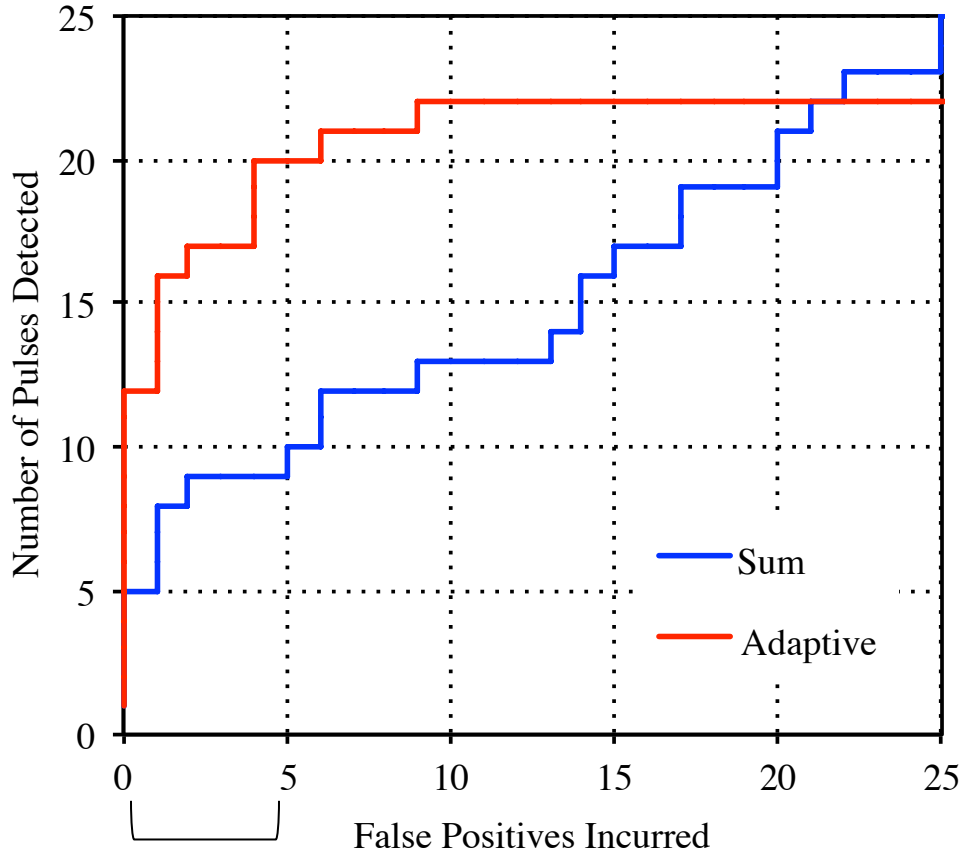
Adaptive excision: method



- Use machine learning to determine how many stations to ignore
  - Inject synthetic pulses into recently collected data with known SNR, DM
  - Determine how many stations to excise so that the synthetic pulses can be recovered
  - Re-train every 10,000 time steps (20 seconds)

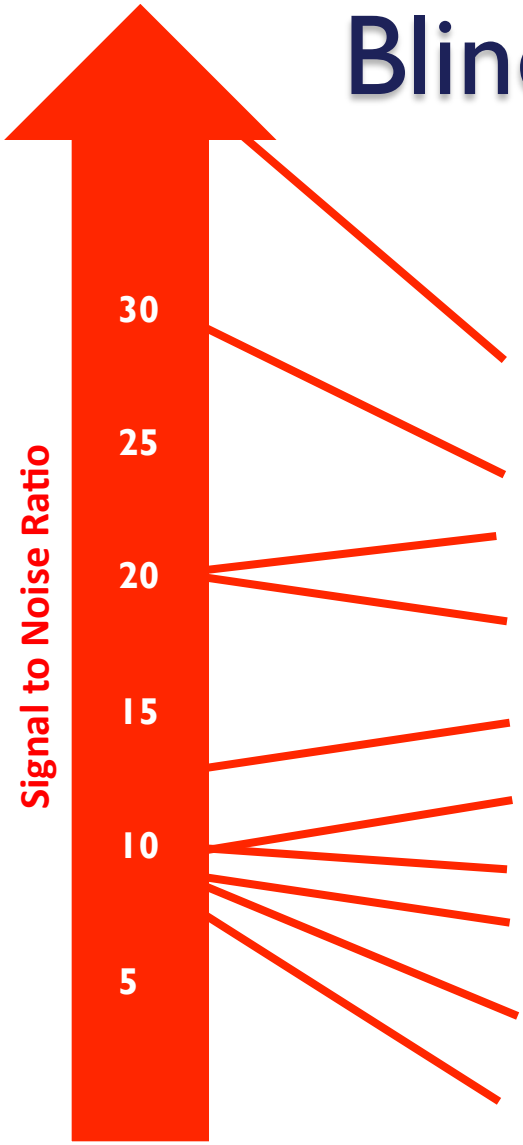
Adaptive excision: performance

- Pulse detection for a single representative pulsar observation



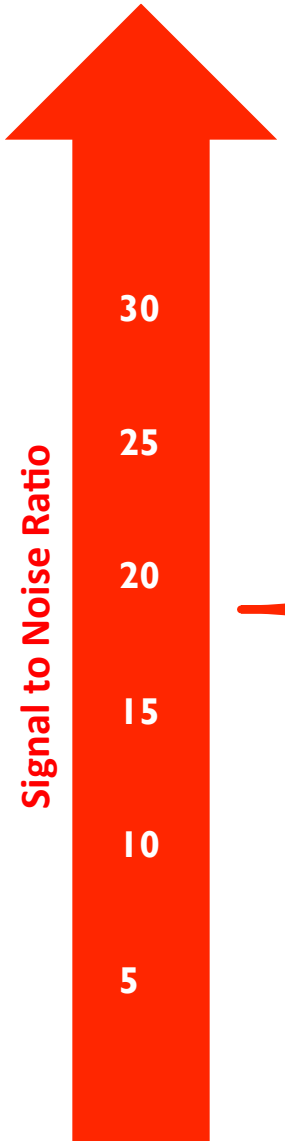
Relevant performance range

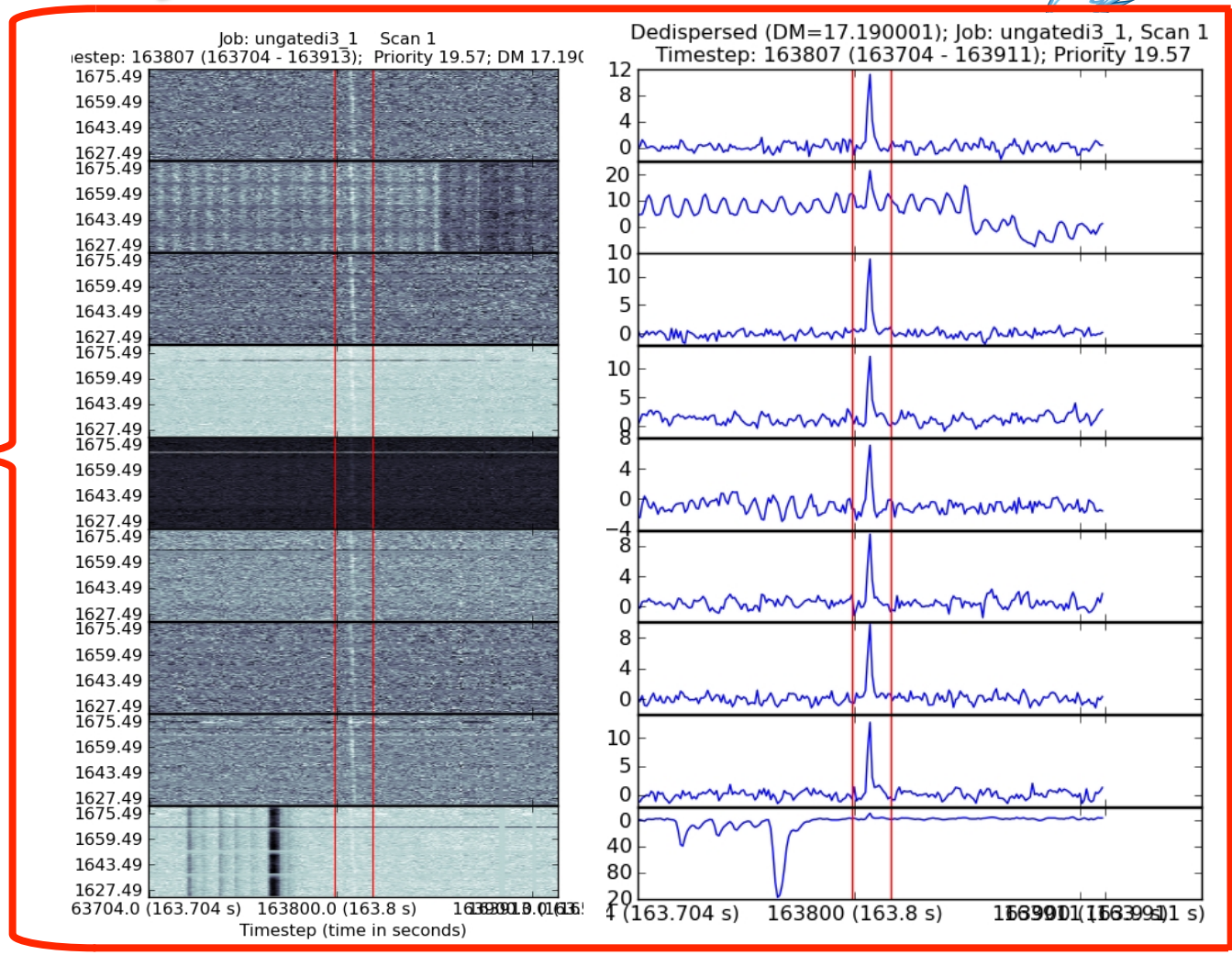
Blind pulsar detections

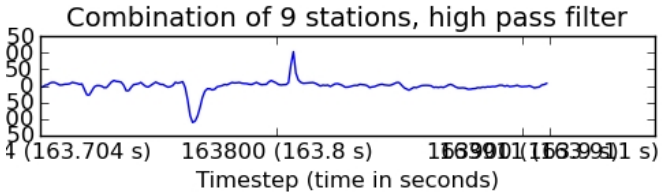


Pulsar name	Max SNR	DM	Typical on-pulse flux density (Jy)
J0332+5434	>50	26	14.0
J2113+2574	29	25	0.06
J1136+1551	20	5	1.0
J0826+2637	19	20	0.5
J1935+1616	12	158	1.0
J1645-0317	10	36	0.5
J0157+6212	10	30	0.14
J1919+0021	9	90	0.05
J0147+5922	9	40	0.13
J0953+0755	8	3	2.0

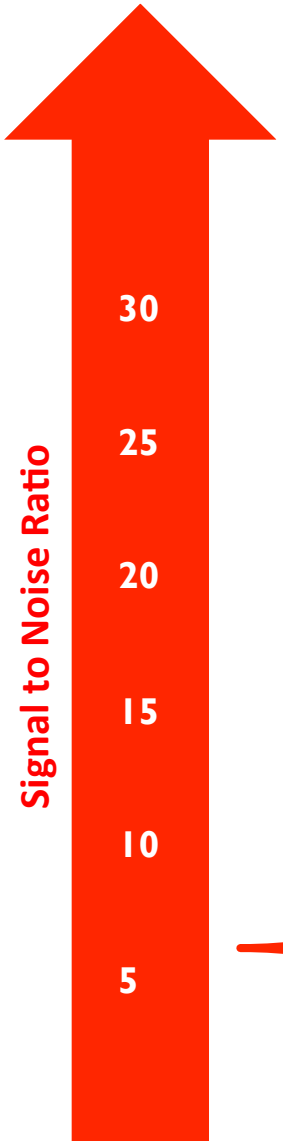
PSR J0826+2637: DM: 17, SNR: 19

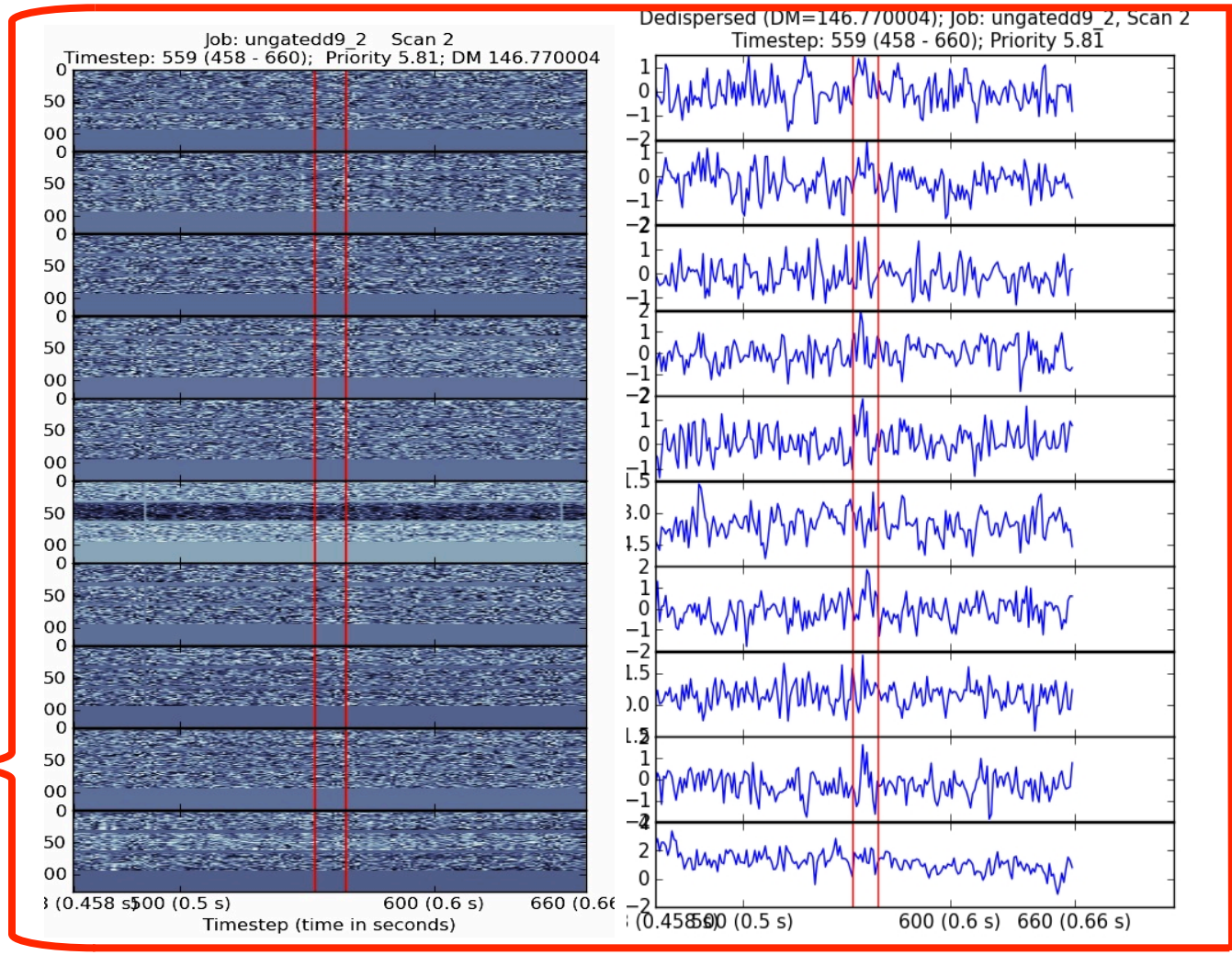


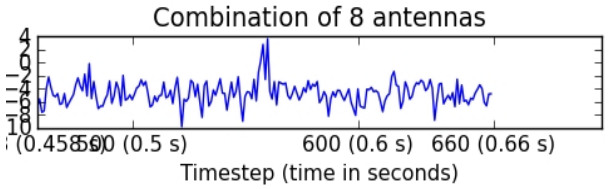




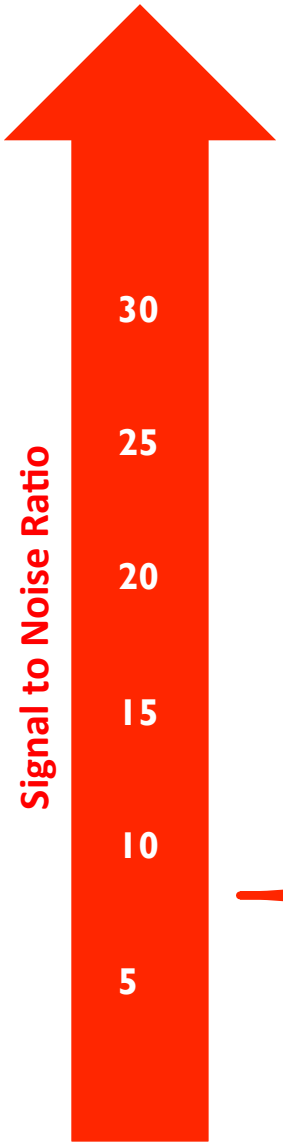
PSR J1935+1616: DM: 146, SNR: 6

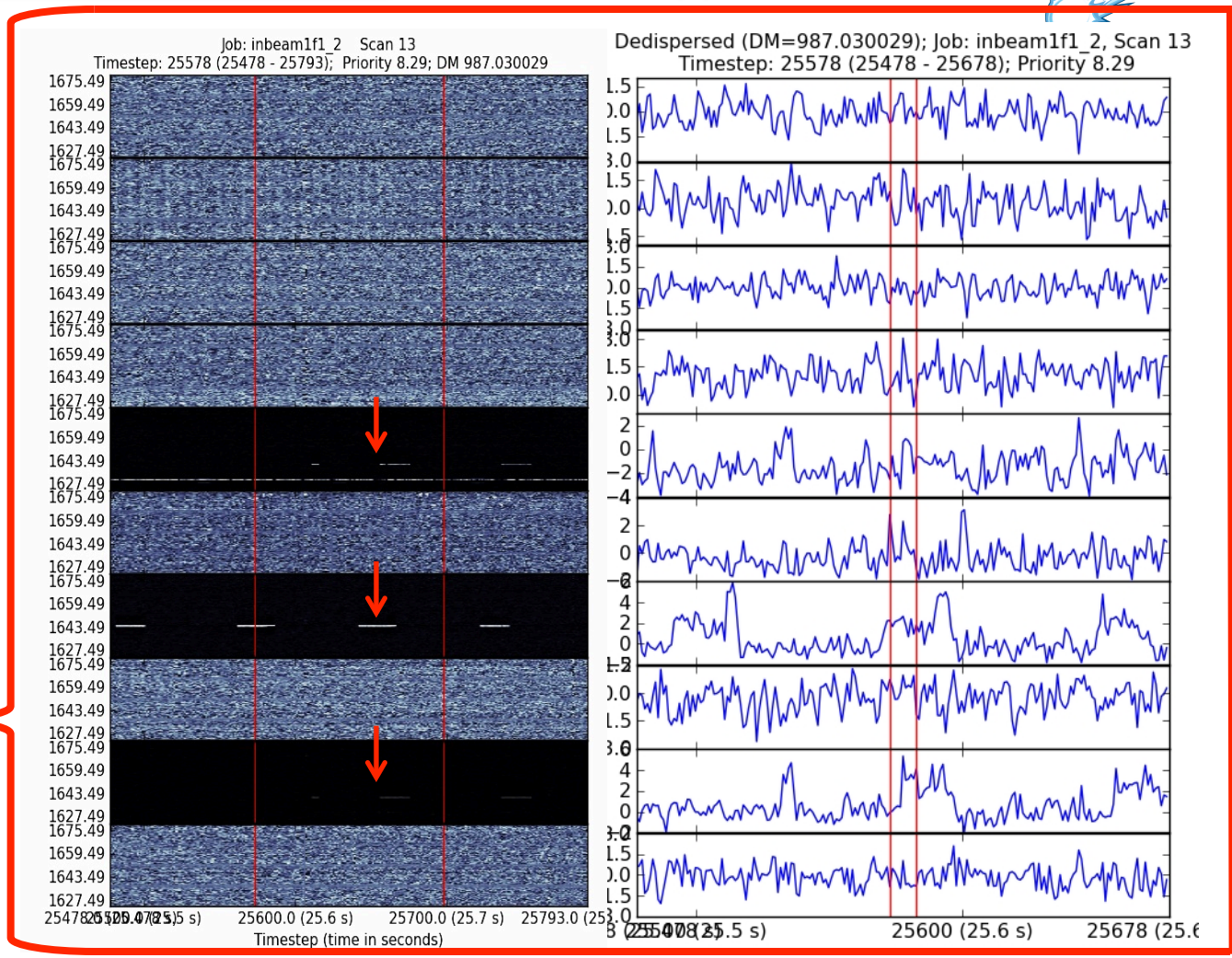


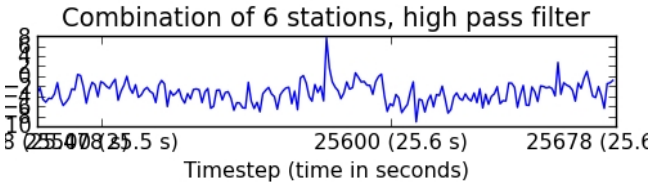




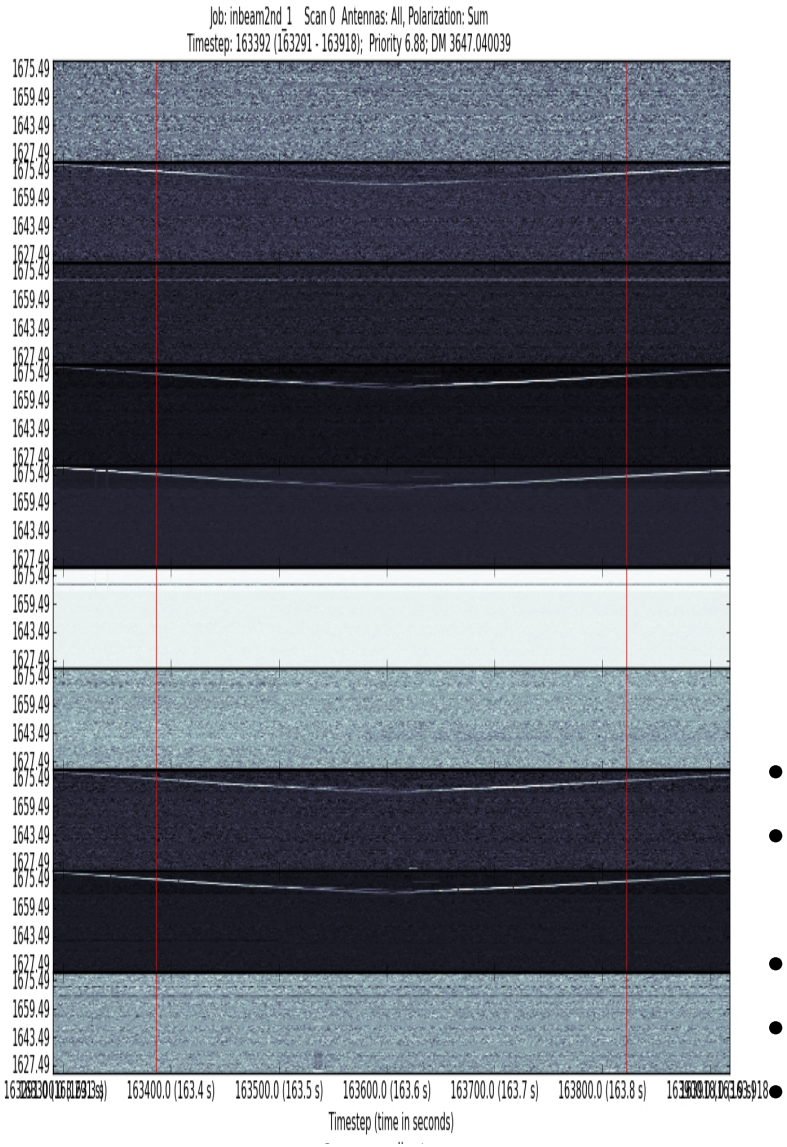
False alarm: DM: 987(!), SNR: 8



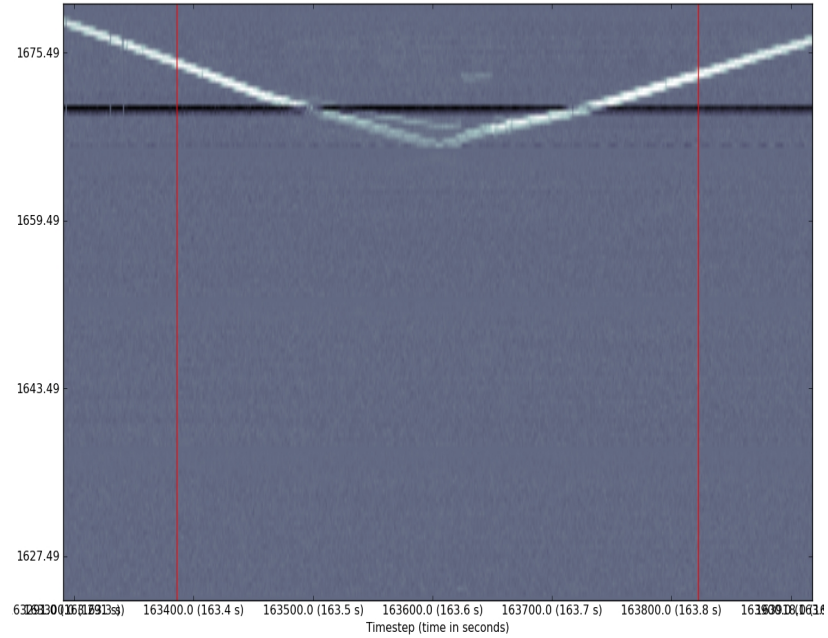




Mystery: "V-chirp"



Summed across stations:



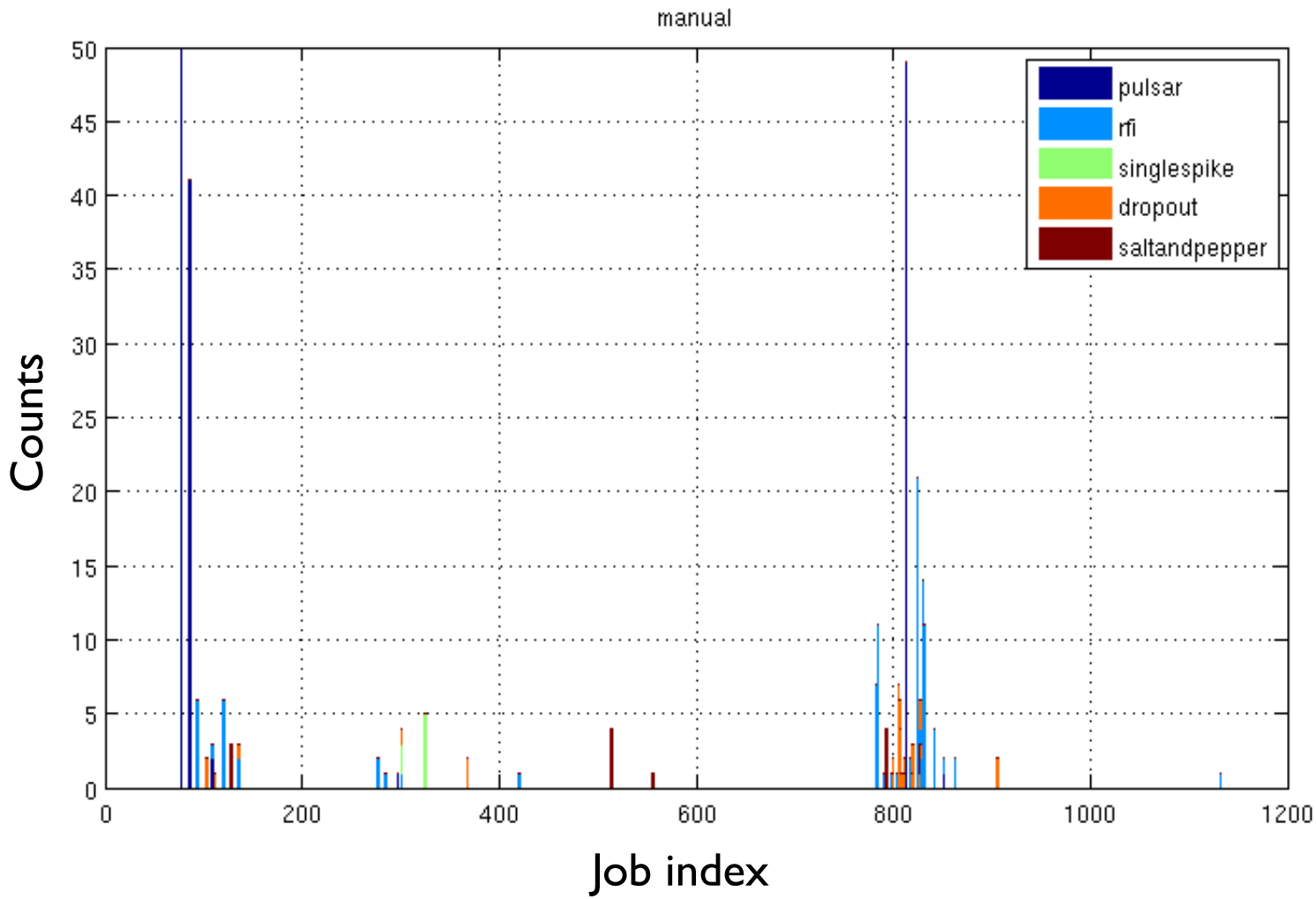
- 5 examples in 4 months
- Not VLBA artifact
  - Similar signals seen by GBT, 350 MHz
- Not local RFI (multi-station)
- Not lunar echo (some high declinations)
- Not radiosonde (at least 1200 km alt.)
- Satellite?

Even with adaptive excision, many candidates to review per day

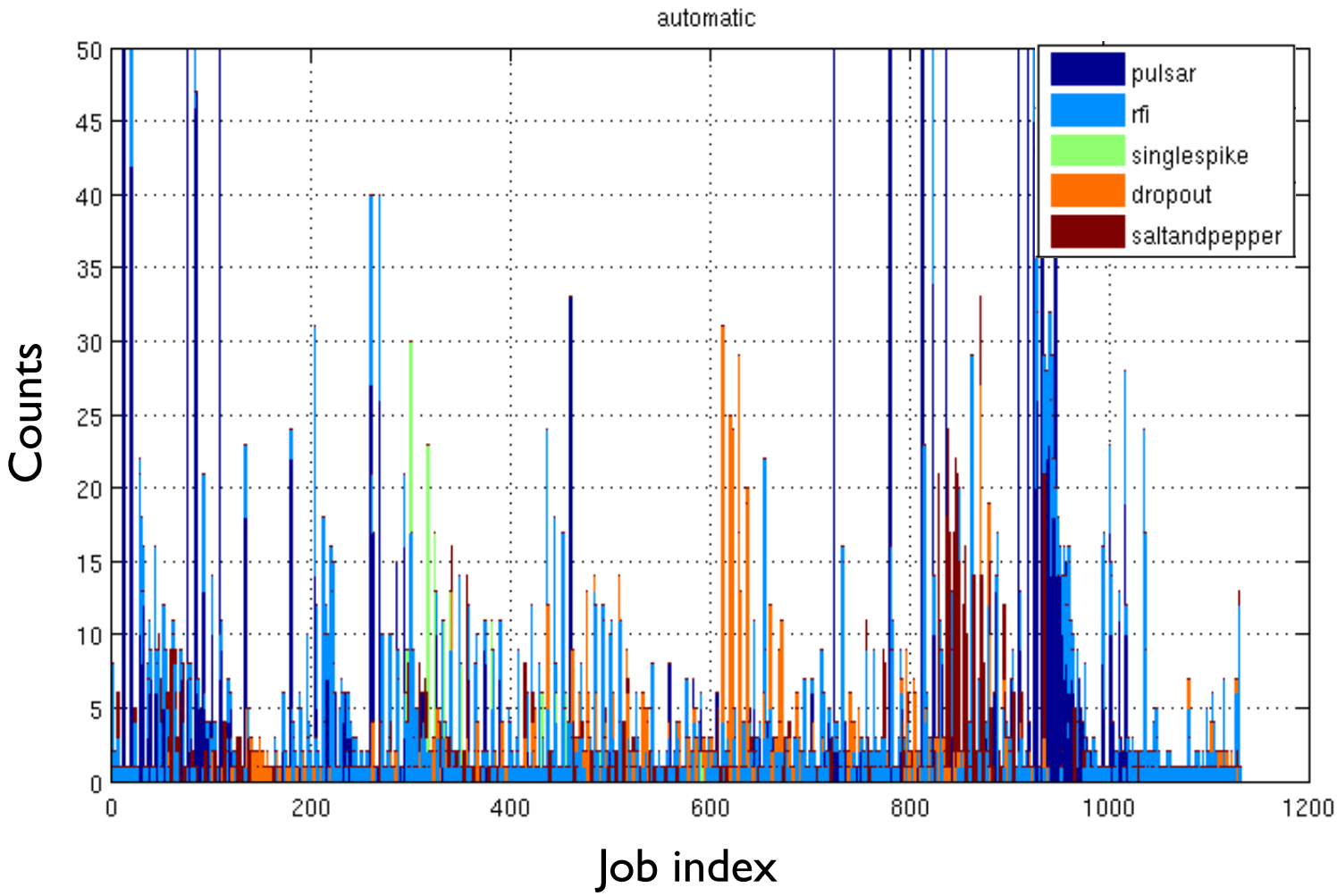
- Can we automate some of this?

- ML Tagging Agent
  - Learn properties of different event types to classify new ones
  - Method: Bayes Net (probabilistic model)
  - Features
    - Asymmetry: power before event vs. after
    - Magnitude: power within event vs. outside
    - Variance in power during pulse
    - Dropouts: number of zeroed timesteps

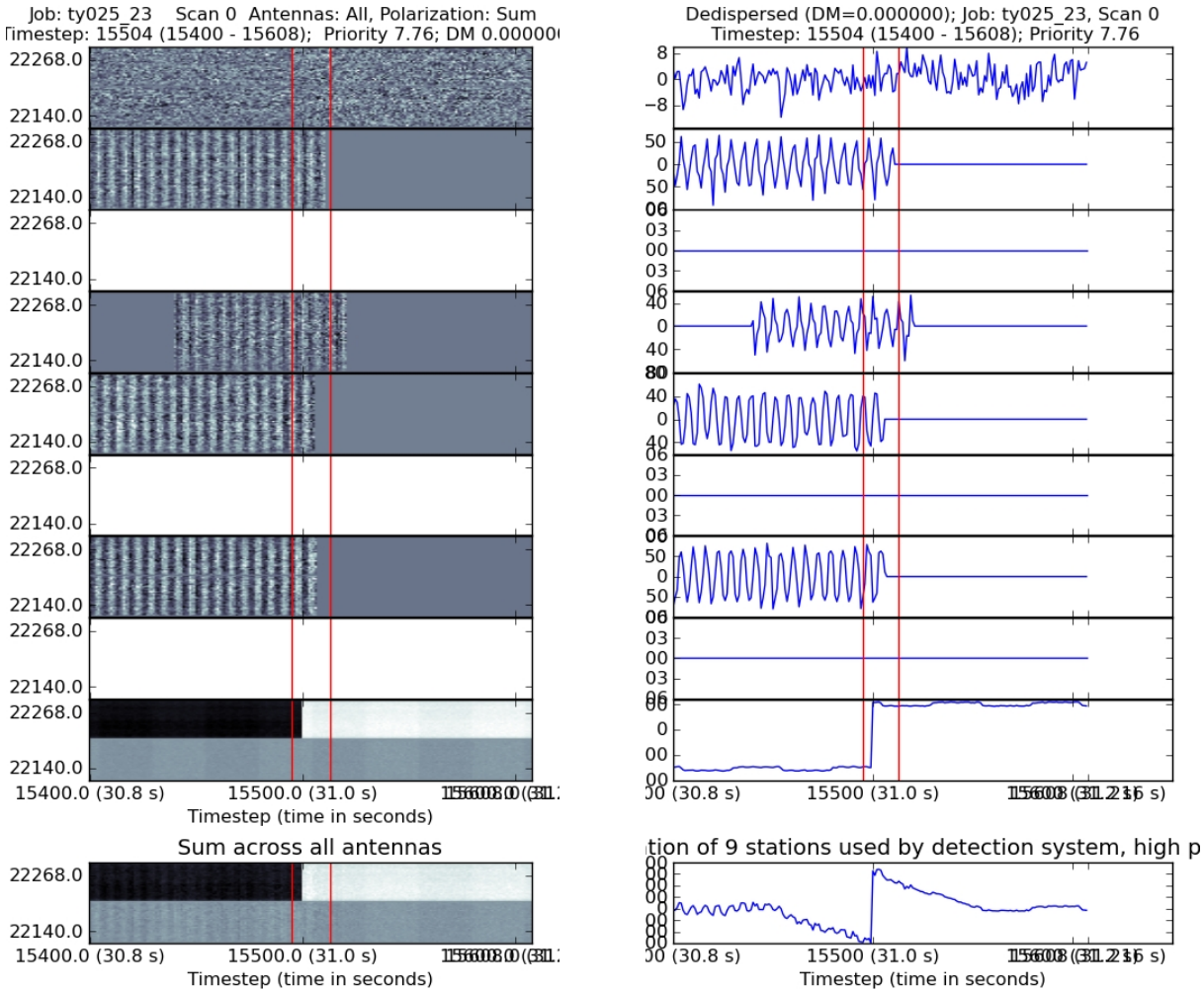
Training data (manually labeled)



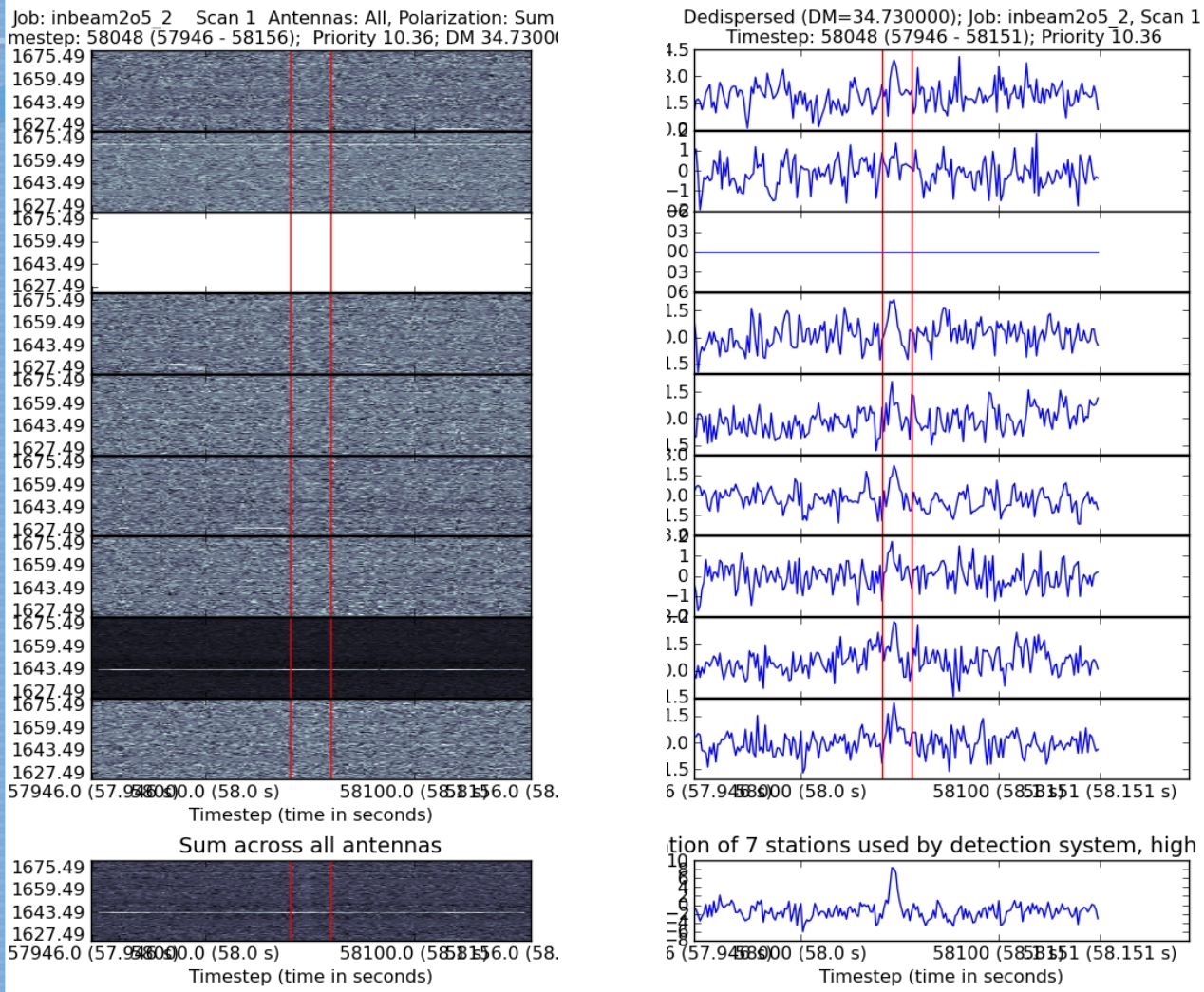
Tagging Agent's output



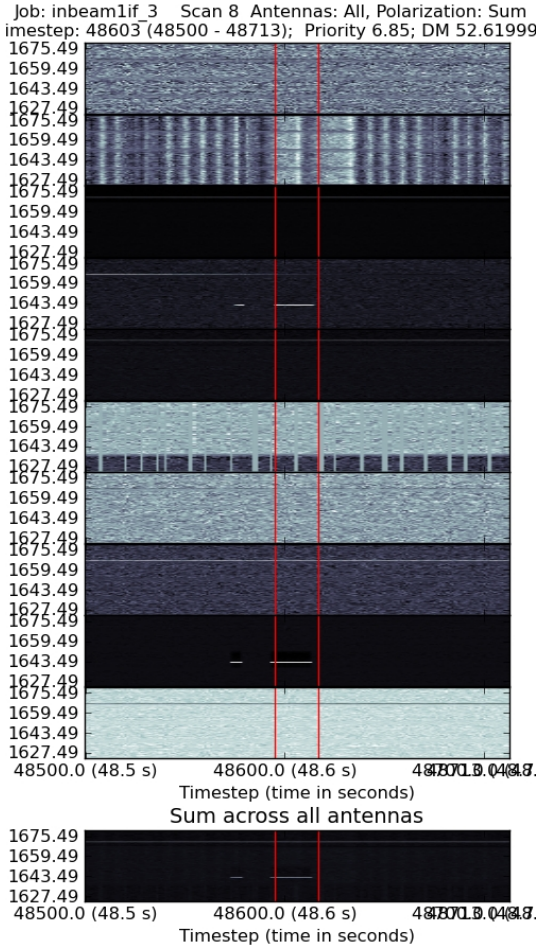
Tagging Agent: "data dropout"

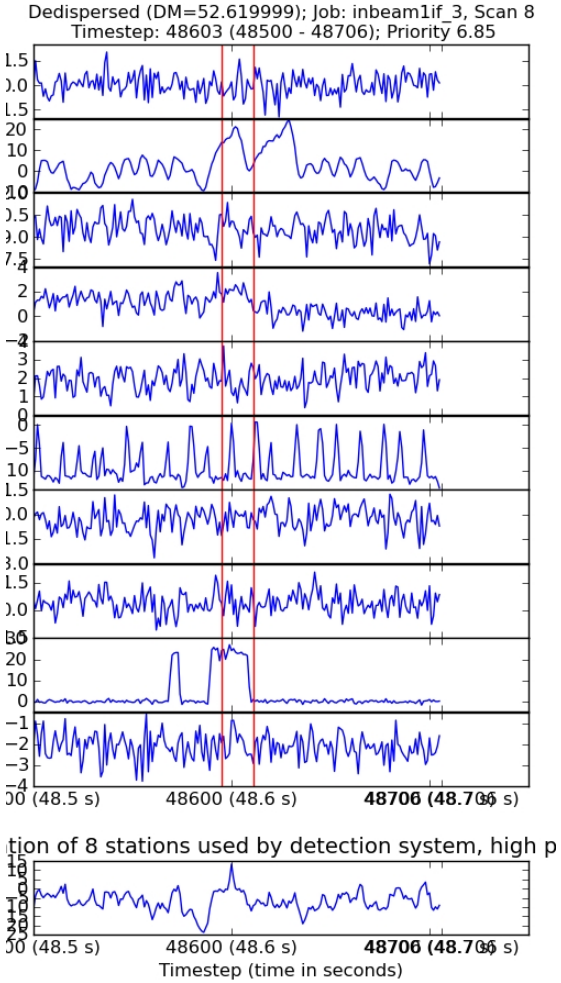


Tagging Agent: "interesting / pulsar"

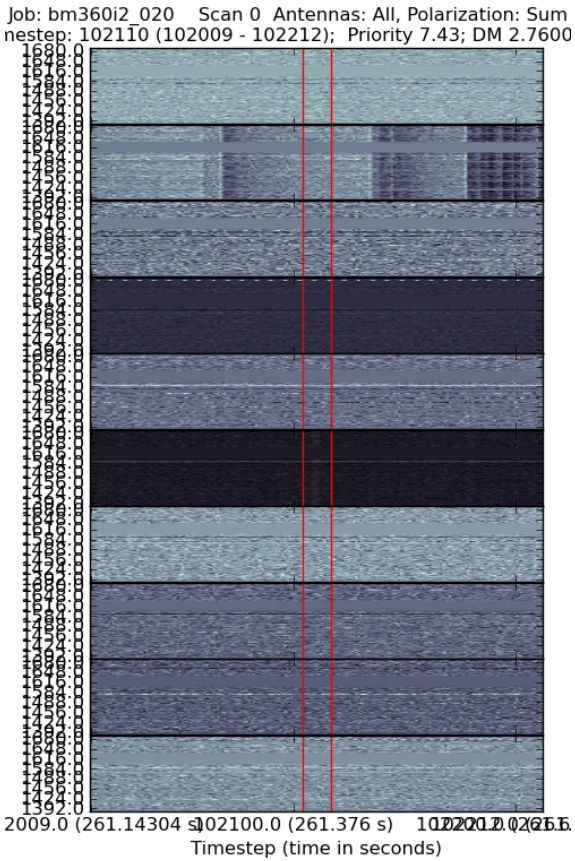


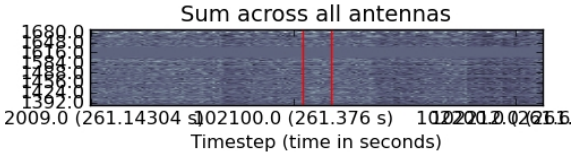
Tagging Agent: "RFI"

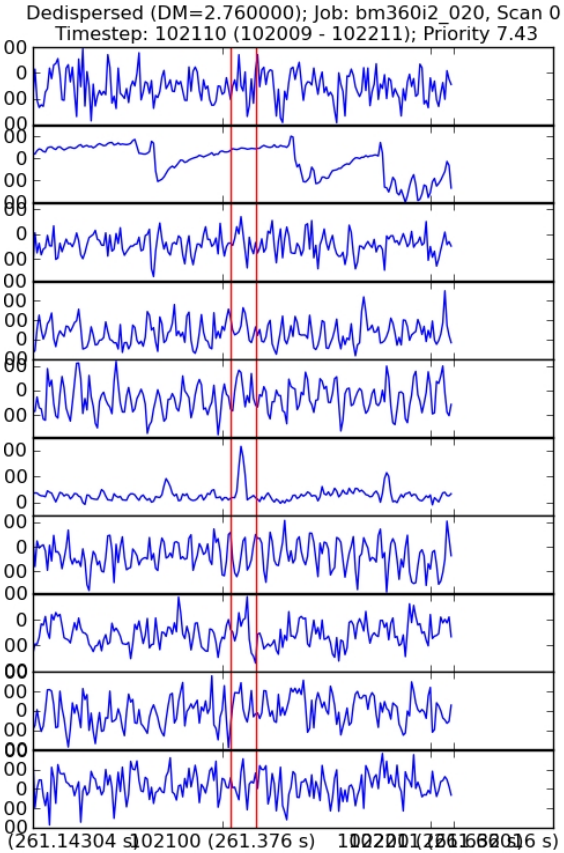


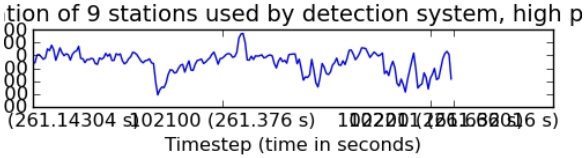


Tagging Agent: “interesting / pulsar”









Evaluation: Confusion matrix for training set

Overall accuracy: 90%

Automatic \ Human	Pulsar	RFI	Single-spike	Drop-out	Salt & Pepper
Pulsar	160	25	0	0	0
RFI	3	75	0	0	0
Singlespike	1	0	7	1	0
Dropout	0	2	0	31	0
Salt & Pepper	0	0	0	0	16

Especially good performance given that V-FASTR does no folding or periodicity analysis

V-FASTR Notifications

V-FASTR: 73 candidates in inbeam1ie_1 (Walter to review). — V-FASTR Notifications

From: **David Thompson (VLBA transient) <dthompso@aoc.nrao.edu>** Hide
Subject: V-FASTR: 73 candidates in inbeam1ie_1 (Walter to review).
Date: December 30, 2012 9:44:54 PM PST
To: David R (388E) Thompson <David.R.Thompson@jpl.nasa.gov>, RandallWayth Wayth <r.wayth@curtin.edu.au>, Adam Deller <deller@astron.nl> and 11 more...

Walter is responsible for reviewing and archiving.

View all detections:
http://ska-dc.jpl.nasa.gov/vfastr/goto/tns_inbeam1ie_1 ← Click

Job summary:
Freq min: 1627.49 MHz
Freq max: 1675.49 MHz
Estimated DM granularity for 2ms integrations: 44.5573

Num active antennas: 10
Detections:

priority	DM	scan	time_start-time_end	pointing
35.64	17.2	1	272985-273004	J1136+1551PT
20.51	17.2	32	113990-114010	J1136+1551PT
19.95	17.2	26	97809-97838	J1136+1551PT
17.48	3051.7	12	83839-83841	J1257-1027PT
16.51	17.2	3	203926-203944	J1136+1551PT
14.86	17.2	1	305046-305056	J1136+1551PT
14.61	17.2	28	170119-170147	J1136+1551PT
14.39	17.2	9	1570-1574	J1136+1551PT
13.75	17.2	24	294150-294160	J1136+1551PT
13.53	17.2	5	50580-50587	J1136+1551PT
13.37	17.2	3	158782-158806	J1136+1551PT
12.81	52.6	26	279530-279570	J1136+1551PT
12.59	17.2	5	184782-184789	J1136+1551PT
12.38	17.2	32	150818-150828	J1136+1551PT
12.26	70.9	28	269896-269901	J1136+1551PT
11.93	34.7	28	47774-47785	J1136+1551PT

V-FASTR Web Portal

VFASTR Data Portal | VFASTR Data Portal | VFASTR Data Portal

ska-dc.jpl.nasa.gov/vfastr/review-job/c0a638ae-d60b-4ad1-ba8f-4a43...

JPL | Work projects | To Read | MLIS | To Watch | To Learn | To blog | New car

V-FASTR Data Portal

JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | SCIENCE & TECHNOLOGY

Home → Job: tns_inbeam1ie_1 → Review

Job: tns_inbeam1ie_1

There are 37 scans and 90 events in this job. **Unassigned** *is responsible for review.* ■ *Reviewed*

List of Events By Scan Number:

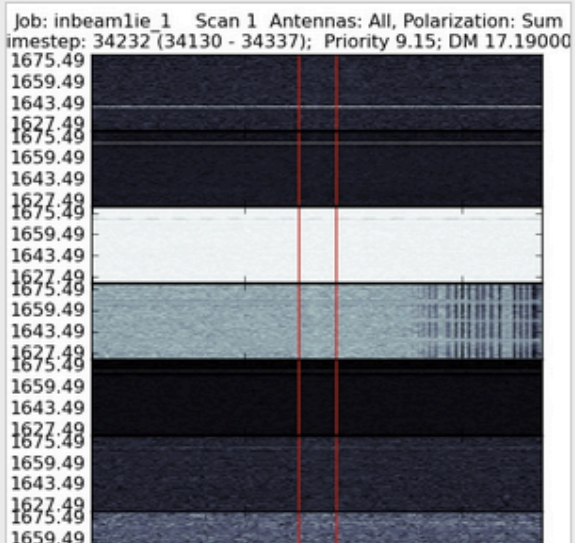
Scan 0 (No events) View Scan Metadata

Scan 1 View Scan Metadata

Event 1 - *Start time*: 12:44:02, *Priority*: 9.153, *Median DM*: 17.190

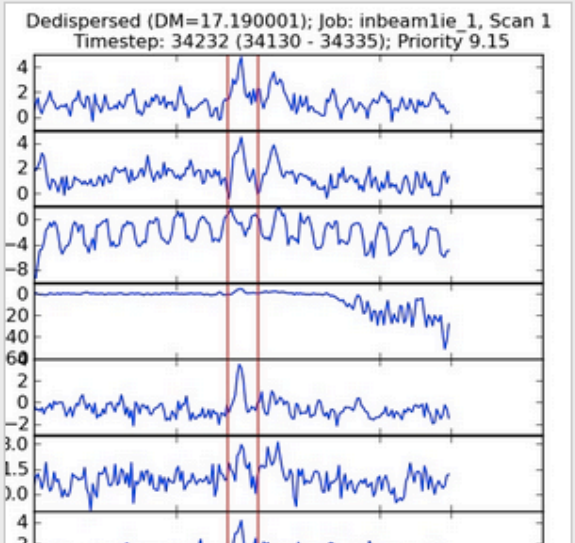
Detection Imagery

view zoomed sum across antennas | view fullsize

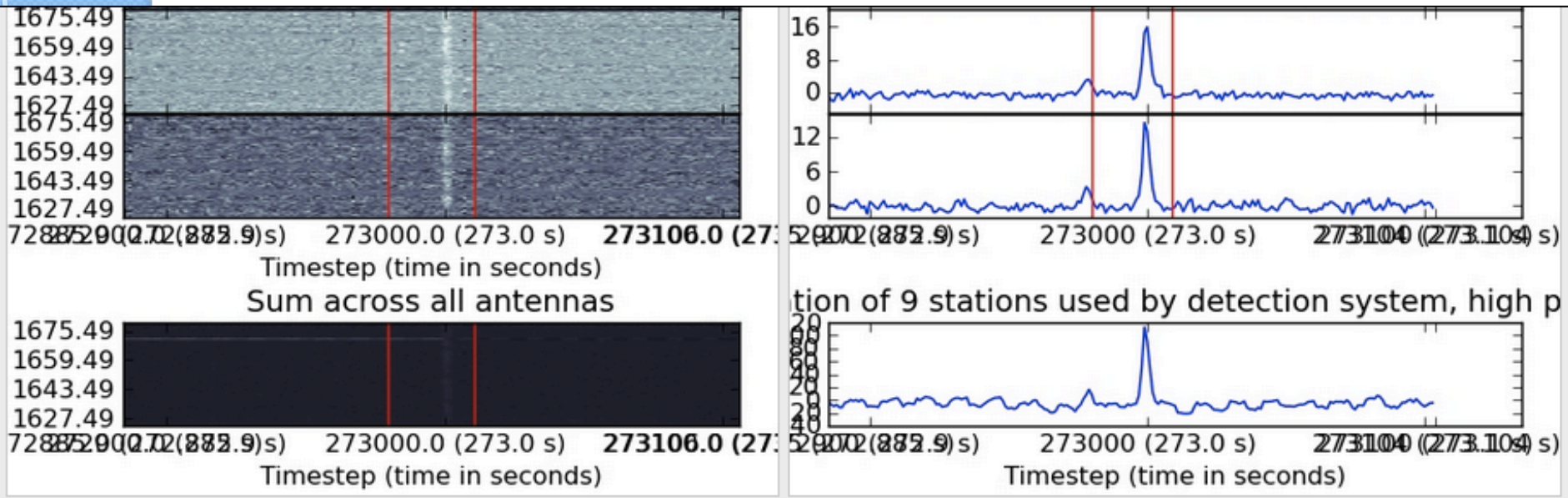


Dedispersion Imagery

view fullsize



Web portal tagging interface



Event Tags

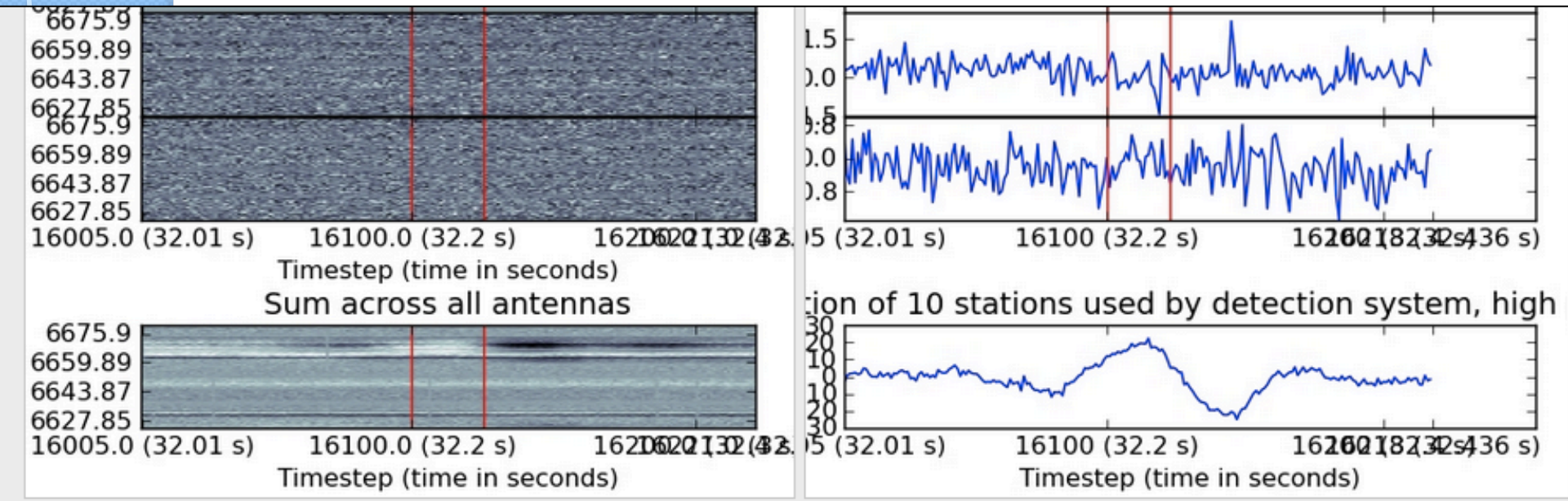
Human generated tags look like this, whereas machine generated tags look like this. Hover over a tag with your mouse to see details.

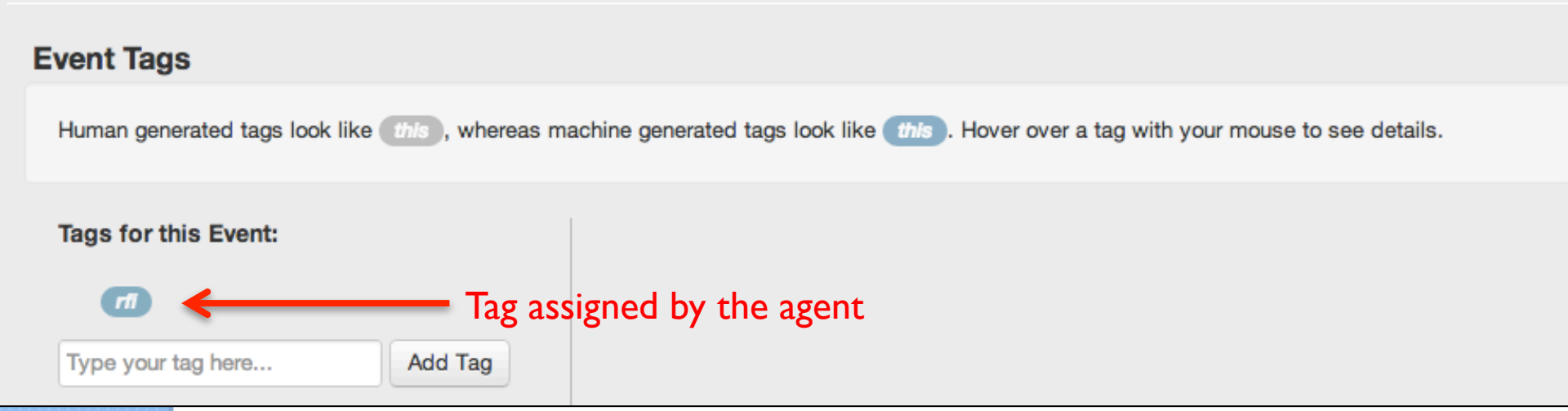
Tags for this Event:

pulsar ← Tag assigned by the agent

Type your tag here... Add Tag

Web portal tagging interface





Tag assigned by the agent

Summary

- V-FASTR: longest-running commensal transient detection system (since July 2011)
  - First search >2 GHz
- Blind pulsar detections: validation
- Machine learning enables
  - Robust excision
  - Auto-tagging of event types
    - 90% reliability now
    - Training set grows daily
- Future: further streamline review process and notifications (event RSS feeds?)

- Contact: `kiri.wagstaff@jpl.nasa.gov`

Further reading

- "V-FASTR: The VLBA Fast Radio Transients Experiment," Wayth et al., ApJ 735(2), 2011
- "Detection of fast radio transients with multiple stations: A case study using the Very Long Baseline Array," Thompson et al., ApJ 735(2), 2011
- "Limits on the event rates of fast radio transients from the V-FASTR experiment," Wayth et al., ApJ 753(2), 2012
- "A framework for interpreting fast radio transients search experiments: application to the V-FASTR experiment," Trott et al., ApJ 2013
- "Real-time adaptive event detection in astronomical data streams: Lessons from the VLBA," Thompson et al., IEEE Intelligent Systems, to appear