V-FASTR: TRANSIENT DETECTION AT THE VLBA, AND IMPLICATIONS FOR THE SQUARE KILOMETRE ARRAY

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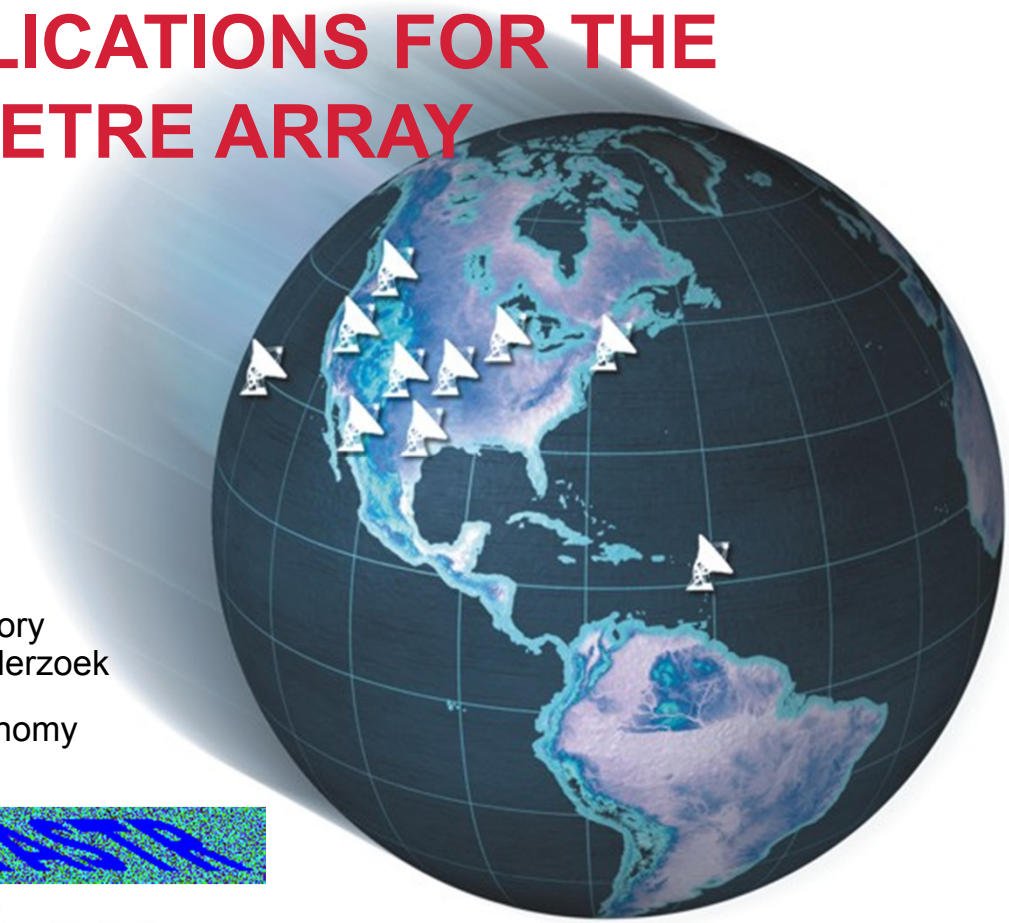

Image courtesy of NRAO/AUI

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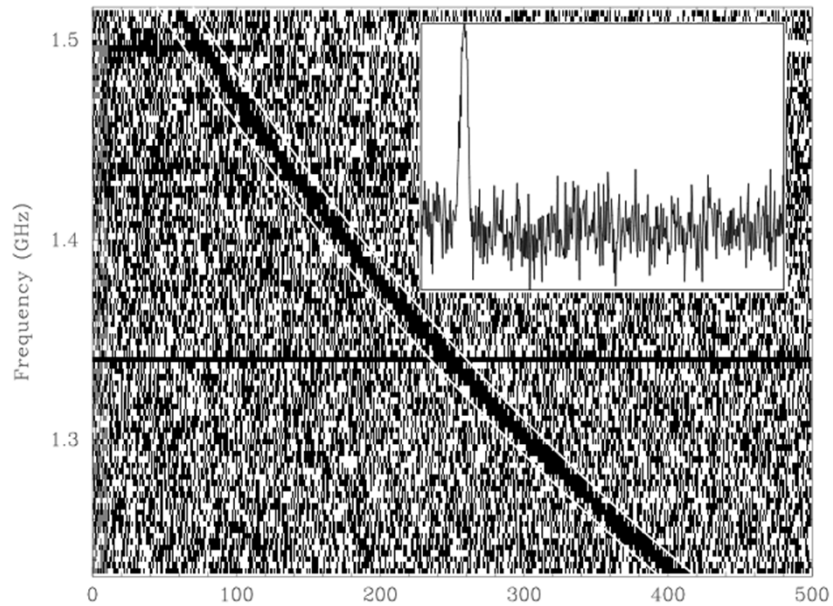
WHAT ARE FAST TRANSIENTS?

- **Short, non-periodic pulses**
  - Excellent probes of ISM, IGM via dispersion measure (DM) and rotation measure (RM)
- **Known sources**
  - Intermittent pulsars (RRATs)
  - Giant pulses
- **Exotic sources**
  - Black hole evaporation
  - ETI
- **Largely unexplored space**. New discoveries await!

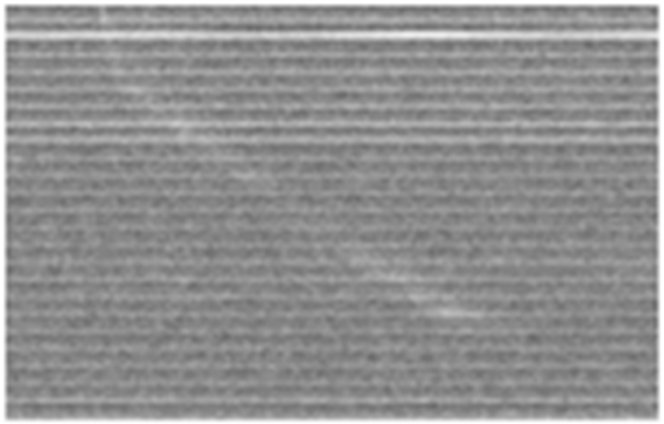


Lorimer et al 2007

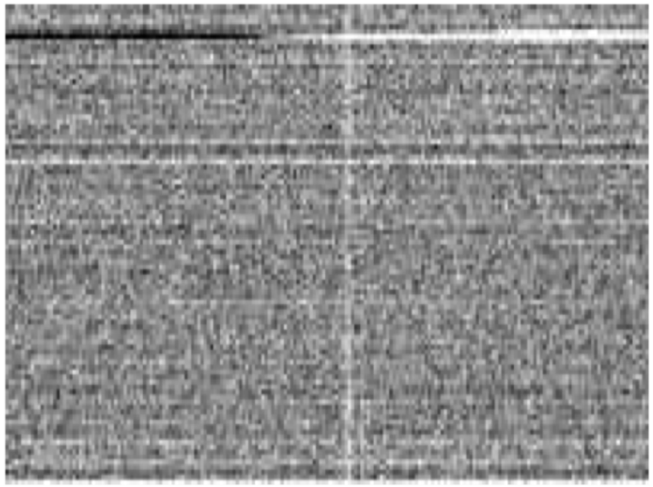
$\Delta t = 4.15\text{ms DM } (\nu_L^{-2} - \nu_H^{-2})$
Freq in GHz, DM in pc·cm^{-3}.
Detection requires "dedispersion"

TRANSIENT DETECTION CHALLENGES

- **Validation**
  - Atmospheric or terrestrial events may mimic dispersion profiles [Burke-Spolaor et al. 2011]
- **RFI**
  - Any momentary or time-variant change looks like an anomaly
- **Localization**
  - Important for interpreting a detected pulse
  - Challenging for single-dish studies
- **High data volumes**
  - milisecond-resolution data streams

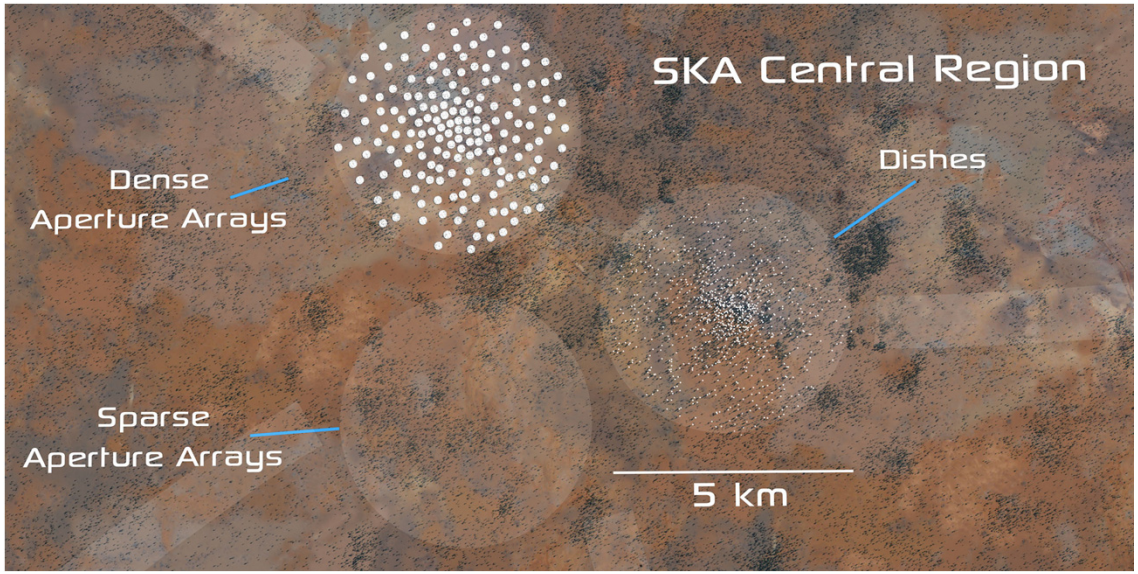


"Peryton" event - likely of terrestrial origin



Momentary RFI in Parkes Pulsar Survey

SOLUTION: CONTINENT-SCALE RADIO TELESCOPE



- **Good spatial resolution**
- **Geographic scale identifies local RFI**
- **General strategy**
  - Incoherent dedispersion of data streams in real-time
  - Real-time adaptive RFI excision, detection of candidate events
  - Copy snippets of raw data for candidates for post-processing

V-FASTR OVERVIEW

- **Real-time fast transient detector** on the Very Long Baseline Array (VLBA) using DiFX software correlator
- **Trailblazer for ASKAP CRAFT project**
- **Operates commensally on all VLBA Observations**
- **New technologies:**
  1. **Geographically-dispersed stations** exclude local interference
  2. **Adaptive self-calibration** of detection parameters
  3. **Automatic imaging** to validate and localize pulses

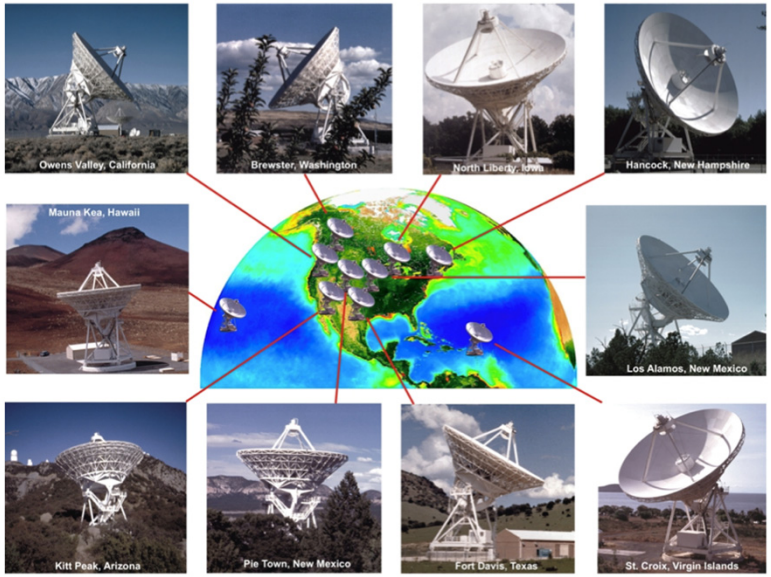
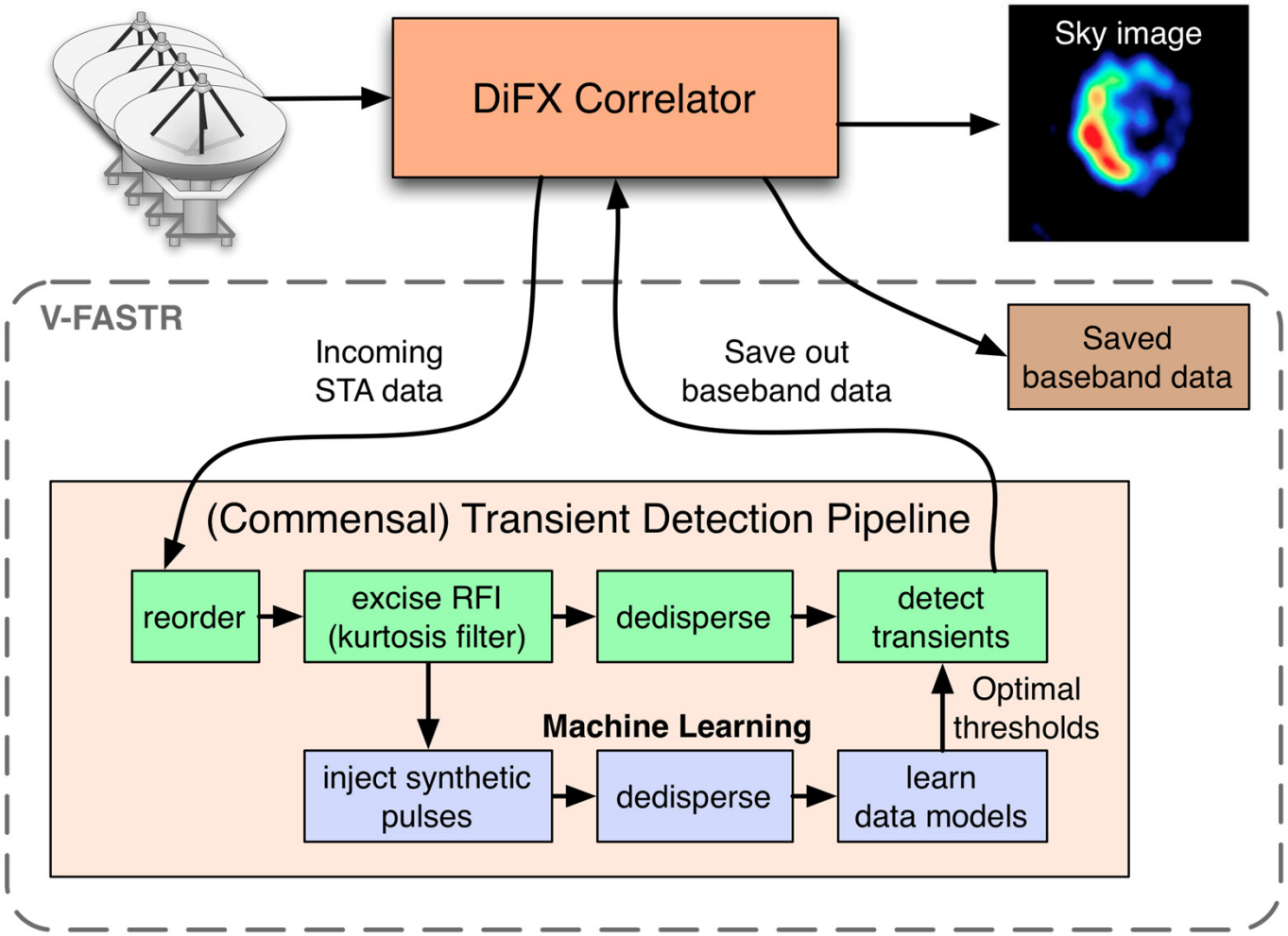


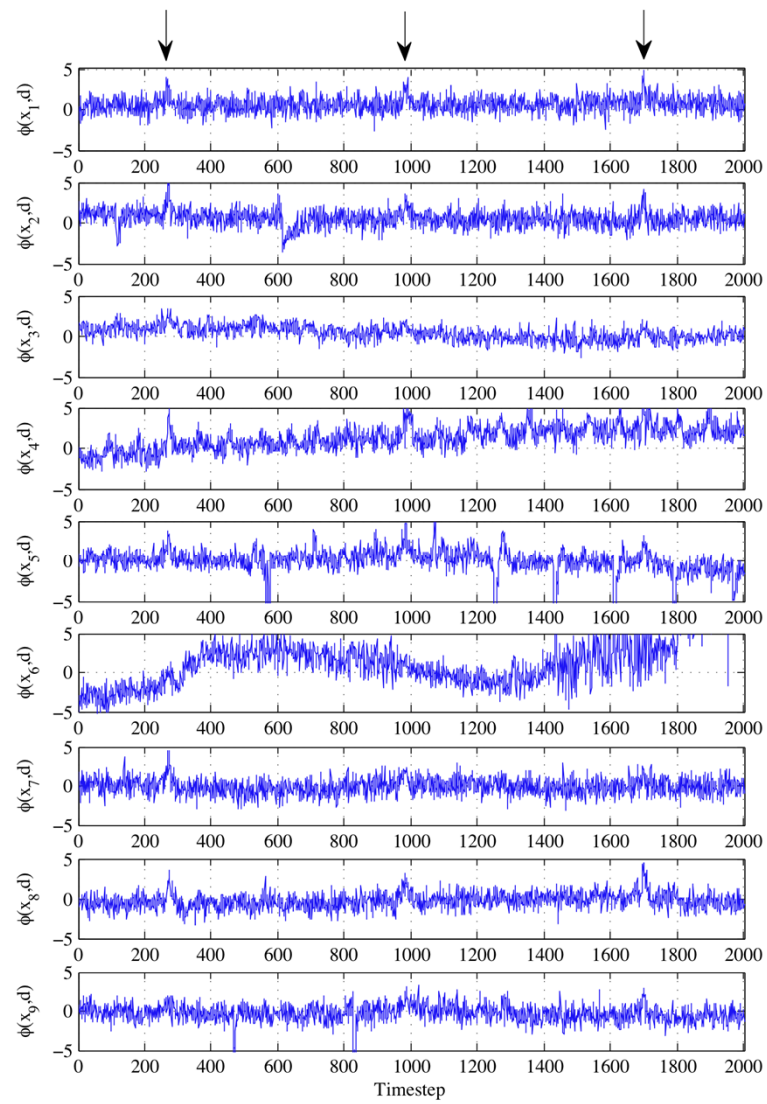
Image courtesy of NRAO/AUI and Earth image courtesy of the SeaWiFS Project NASA/GSFC and ORBIMAGE.

V-FASTR Pipeline



DATA QUALITY IS A PERENNIAL CHALLENGE

- **VLBA not designed for high time resolution**
- **Receiver performance varies over time**
  - Tsys changes based on station, sky position
  - Local RFI conditions are dynamic
  - One bad station can ruin an entire observation
  - Left: three pulses from B0329+54

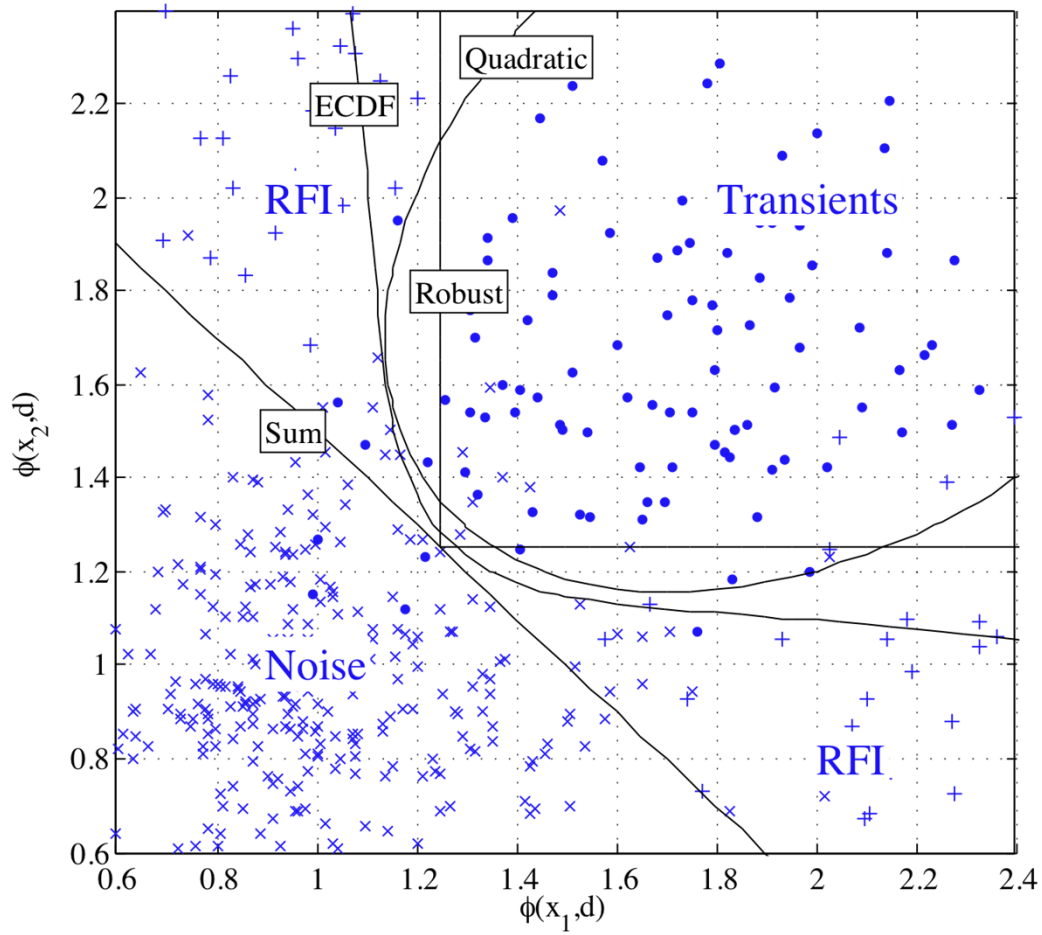


MULTI-STATION DETECTION ALGORITHMS

Sum $$\max_{DM} \frac{1}{A} \sum_{a=1}^{A} S_a(DM)$$

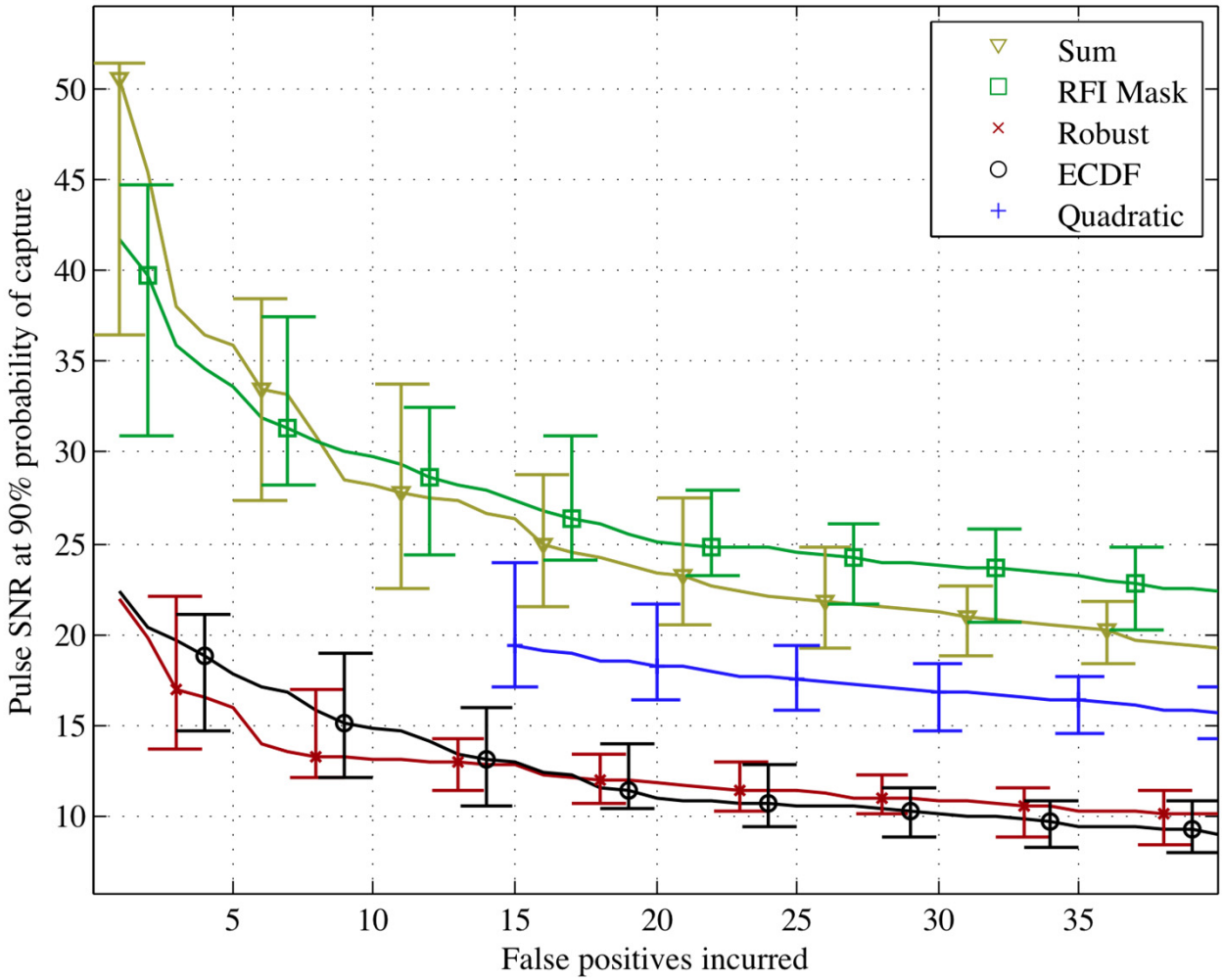
Robust $$\max_{DM} \frac{1}{A} \sum_{a=1}^{A-1} S_a(DM)$$

ECDF $$\max_{DM} \frac{1}{A} \sum_{a=1}^{A} P(X \leq S_a(DM))$$



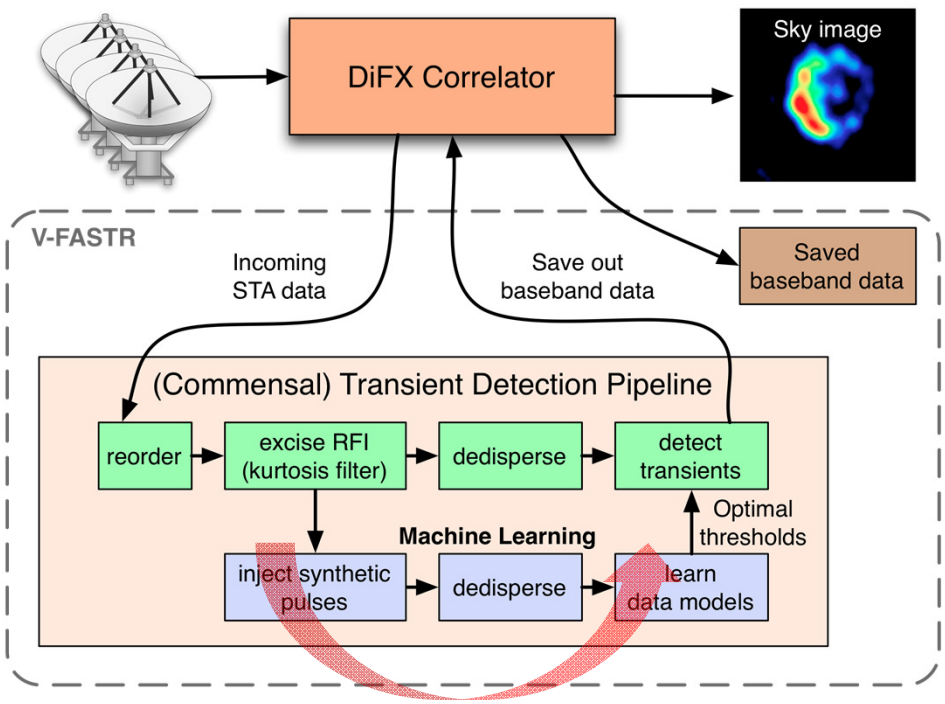
[Thompson et al., *Apj* 2011]

PULSAR B0329+54 OBSERVATION

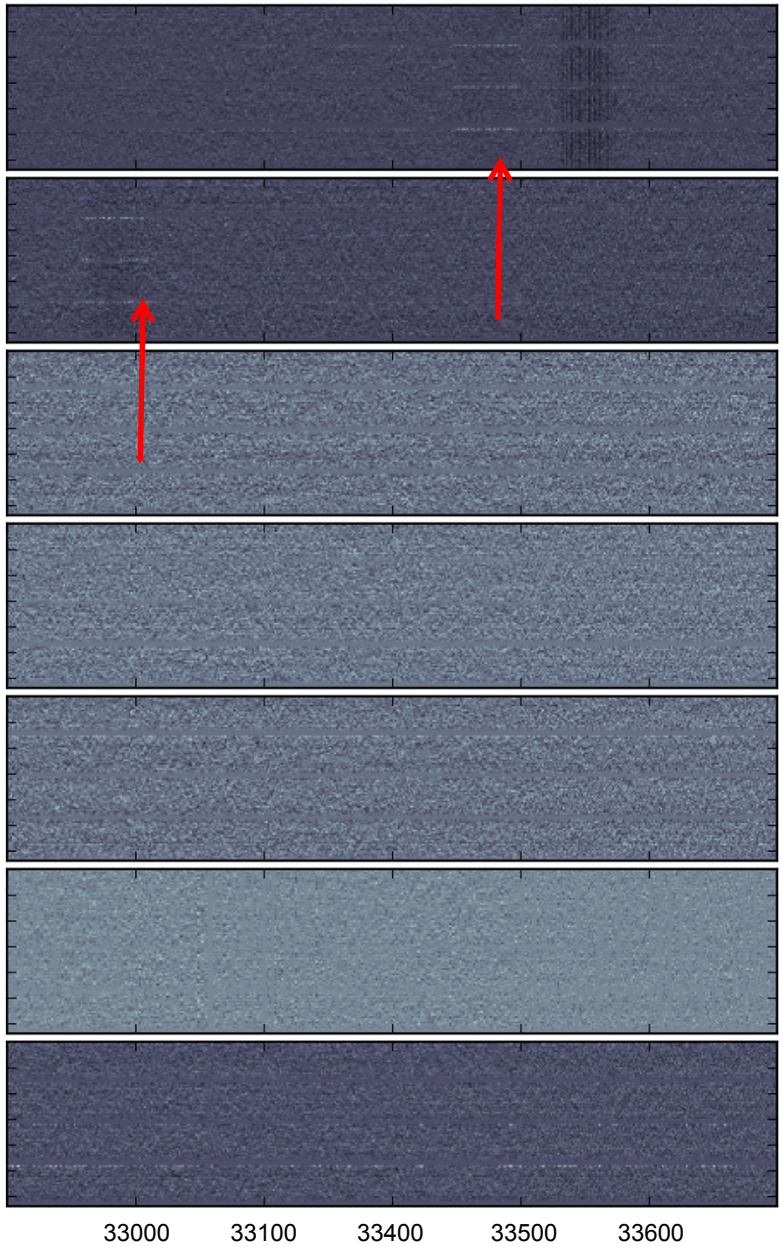


ADAPTIVE REAL TIME SELF-CALIBRATION

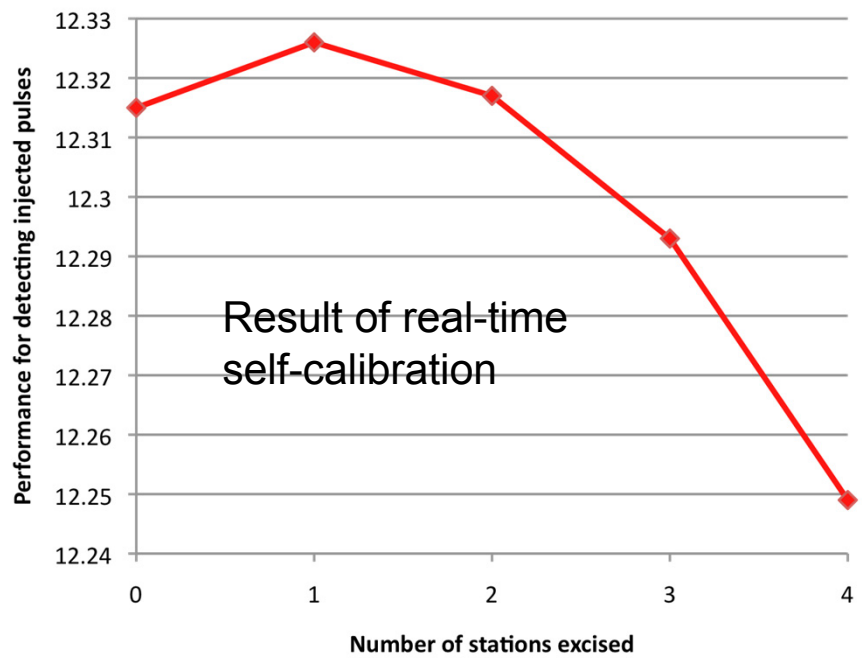
- **Many parameters must be tuned per observation**
- **Example: how many stations to excise?**
  - Too many loses sensitivity
  - Too few risks RFI
- **Test in real-time on a parallel data stream**
  - Inject synthetic transient pulses at known intervals
  - Optimize parameters to retrieve them



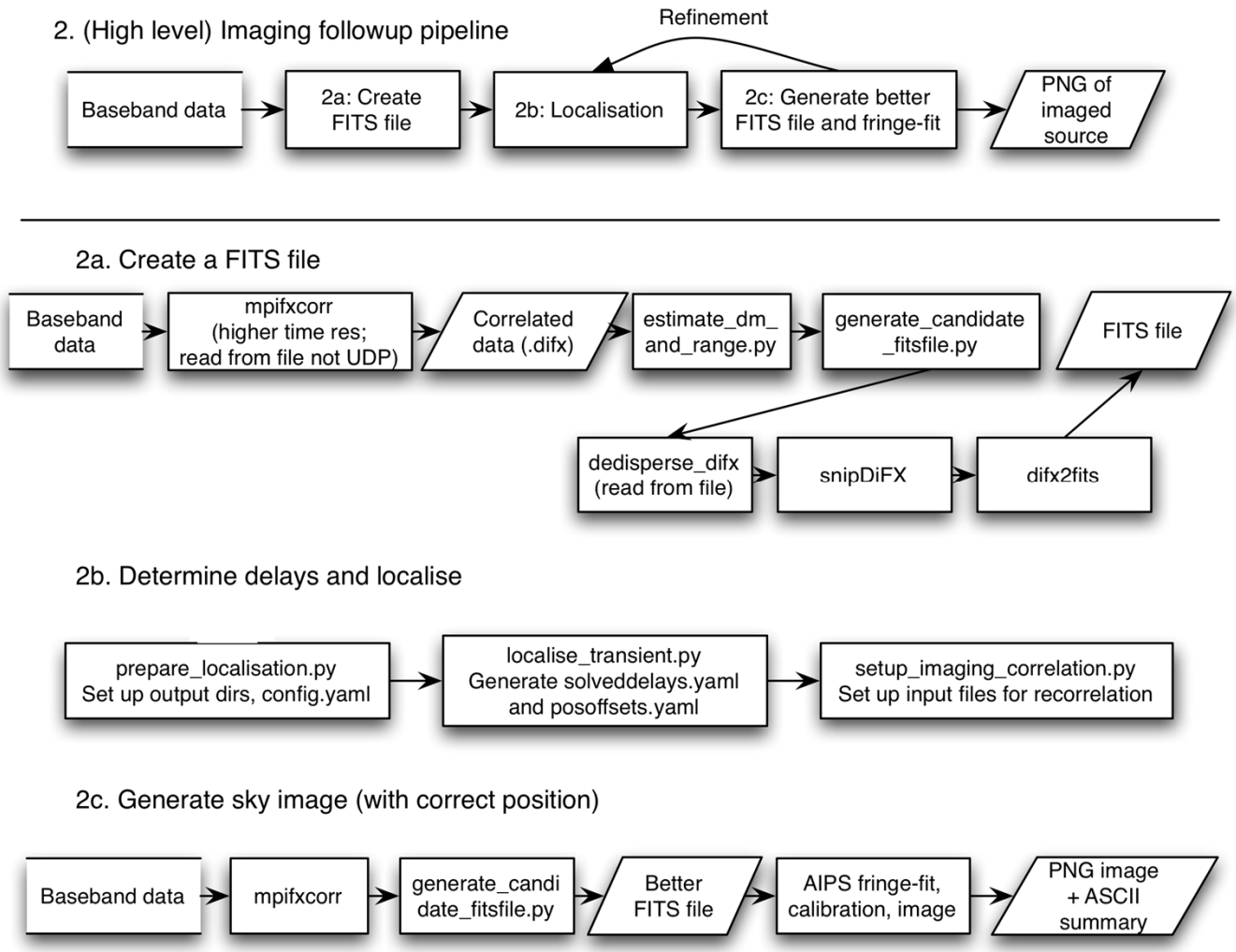
EXAMPLE



- L-band observation correlated on June 26, 2011
- Some stations exhibit channelized RFI (filterbank power data shown here for 7 stations)

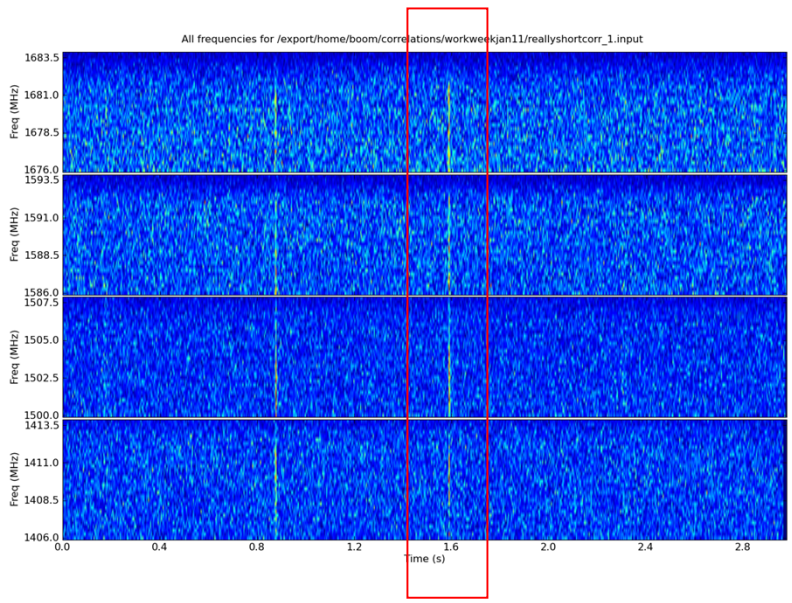


SINGLE-PULSE IMAGING

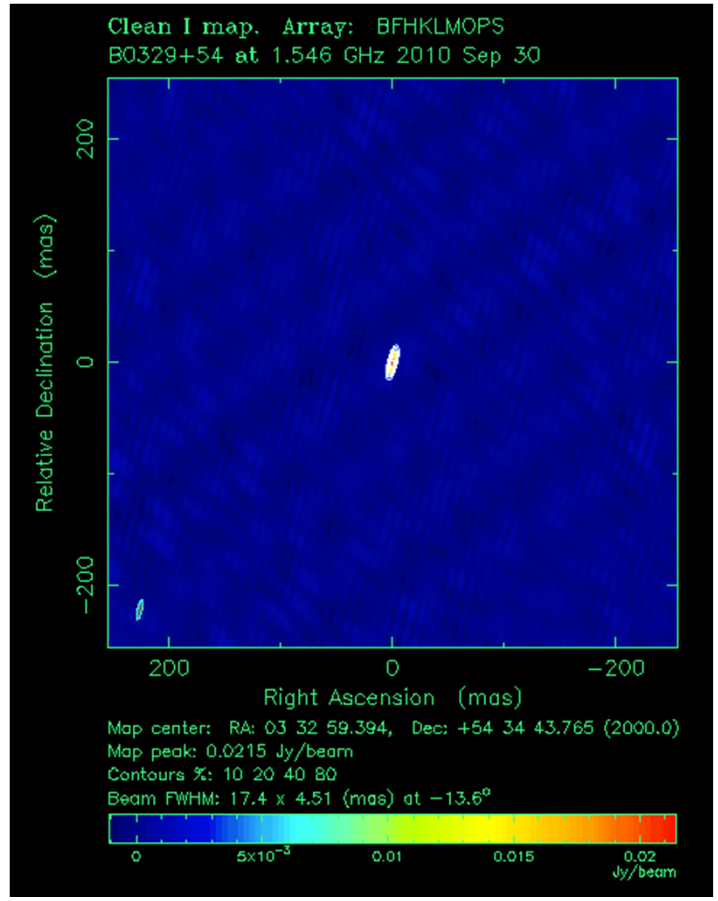


SINGLE-PULSE IMAGING

- Imaging of B0329+54 from a single pulse, no external calibration



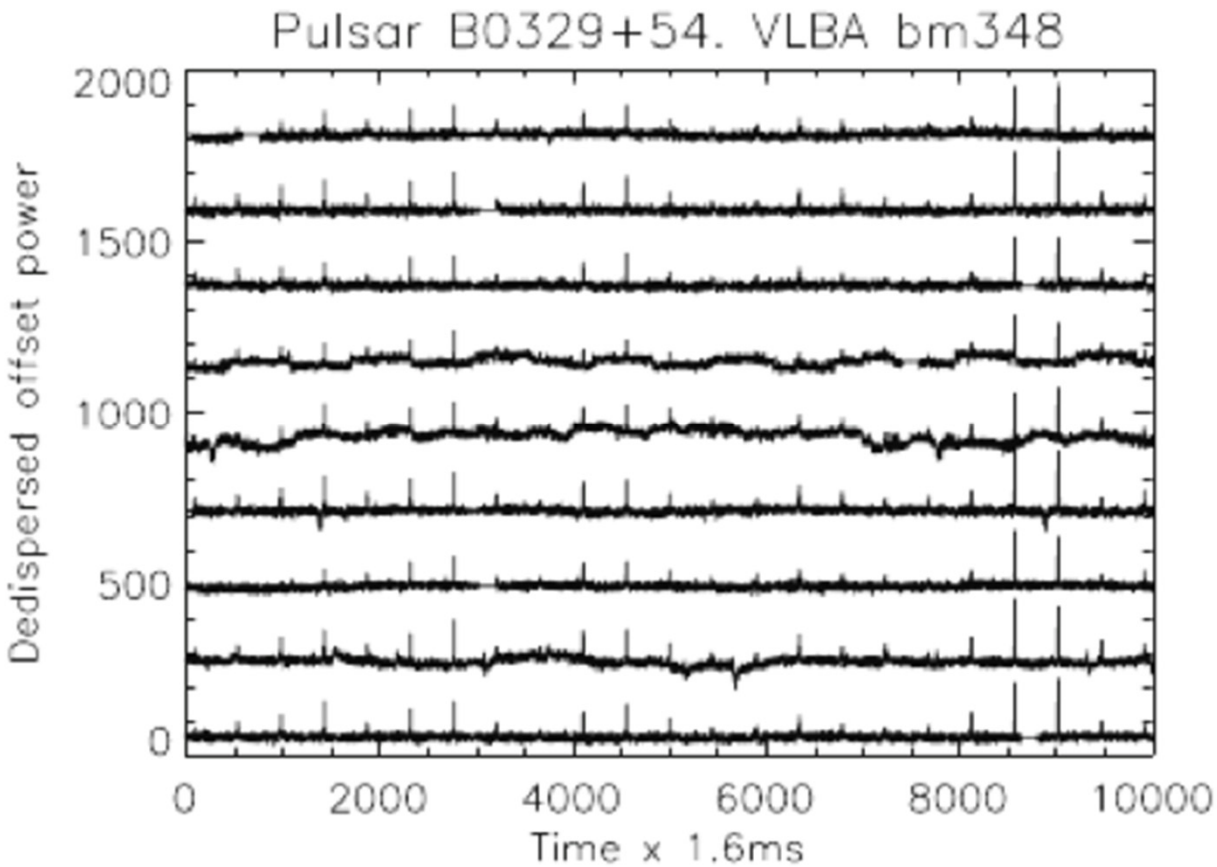
Post-correlation dedispersed



Cleaned image from ~5ms data

INITIAL V-FASTR RESULTS

- Single pulse detections of B0329+54 and the Crab



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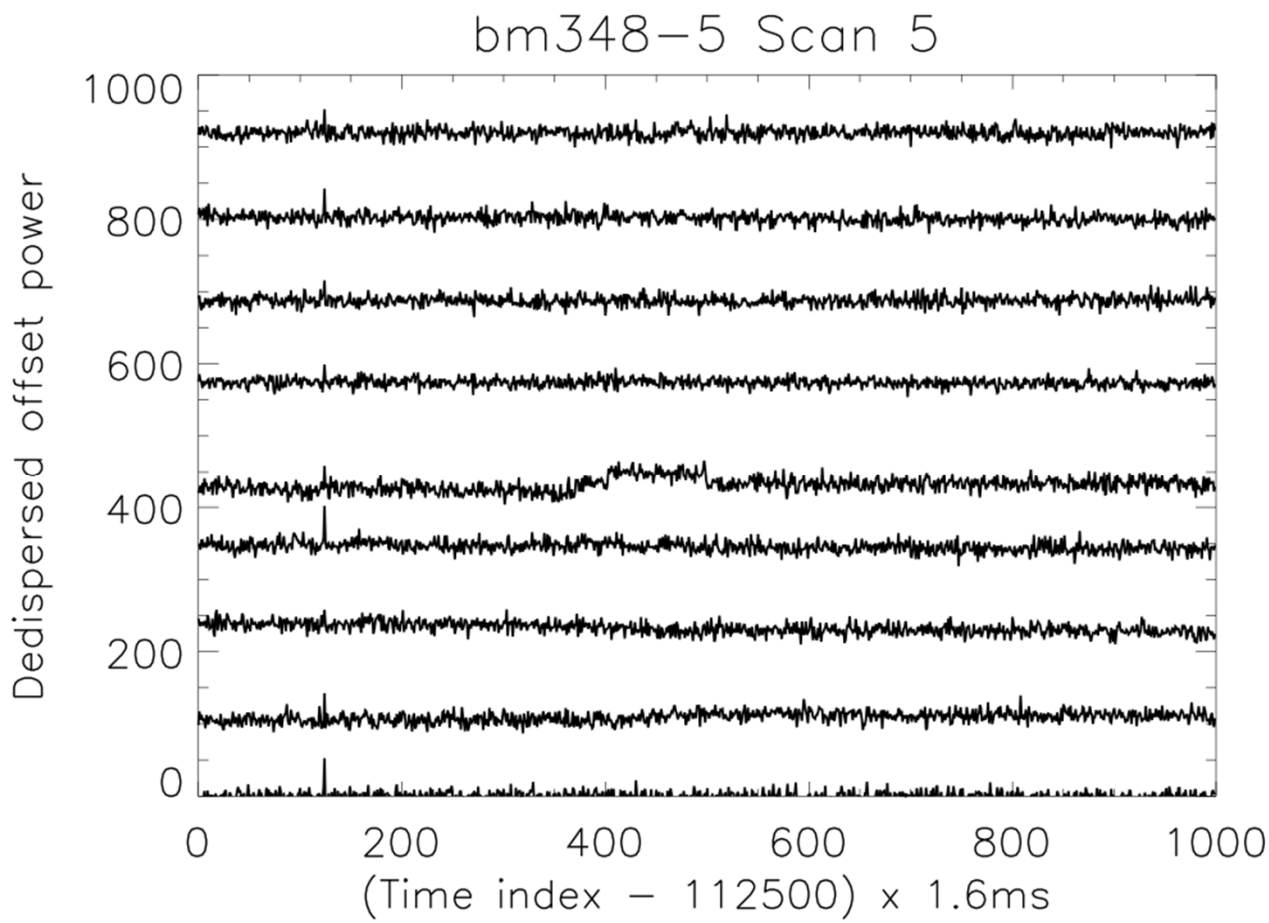


SUMMARY

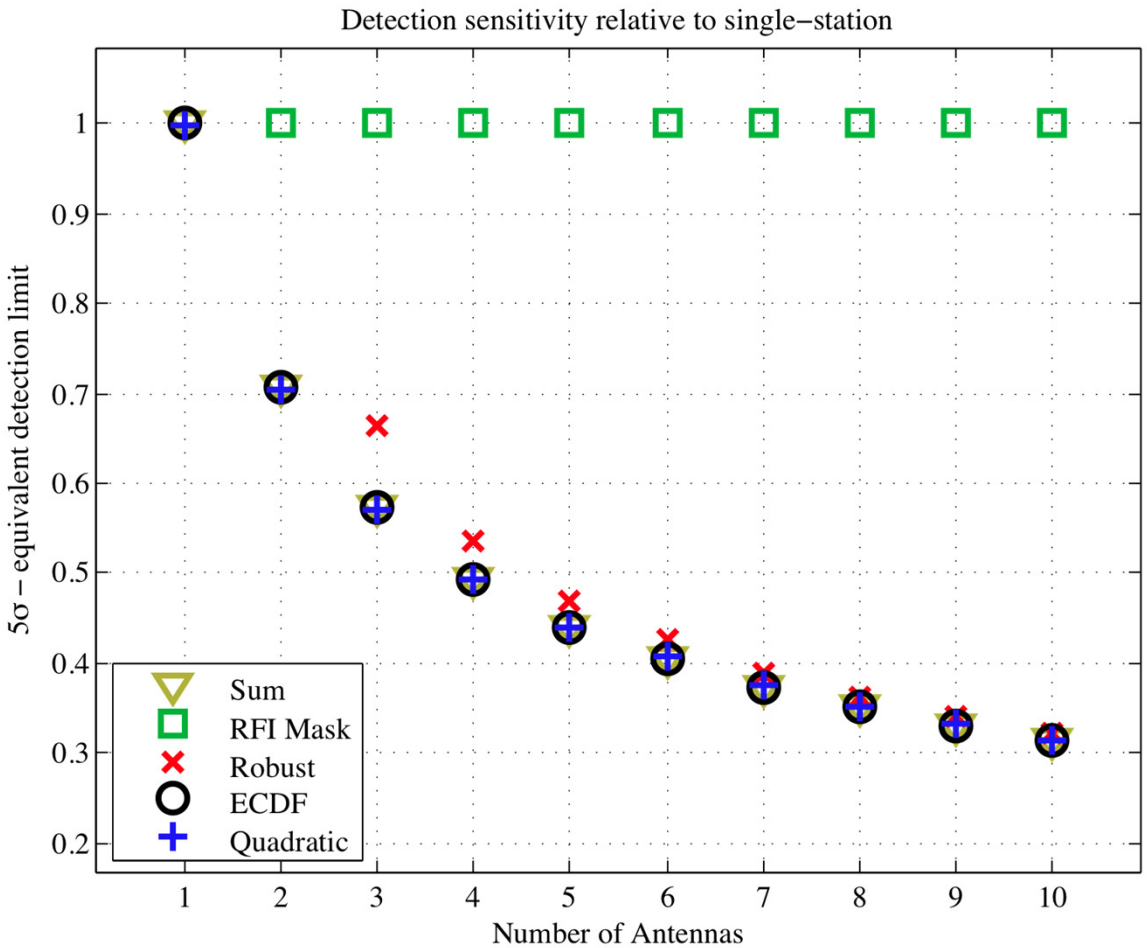
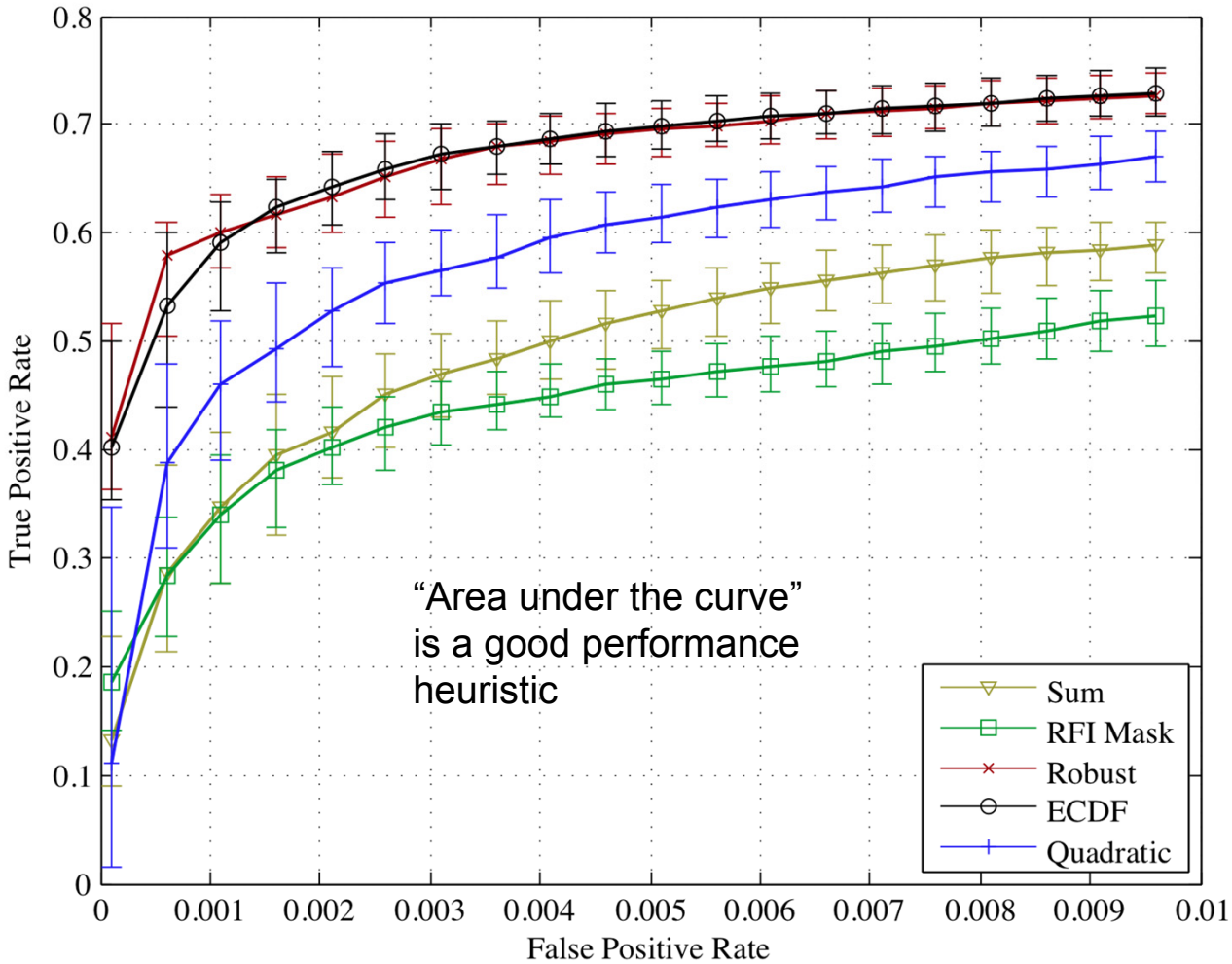
- **Continent-scale arrays hold special advantages for transient detection**
- **Adaptive and automatic systems will be important for commensal operation on large arrays**

THANKS

Sarah Burke-Spolaor, Dayton Jones, Peter Hall, the ASKAP/CRAFT team, The National Radio Astronomy Observatory, Robert Preston, Joe Lazio

BACKUP SLIDES

SENSITIVITY ANALYSIS FOR MULTIPLE-STATION CONFIGURATIONS



Detection performance ROC Curve for Pulsar B0329+54 observation