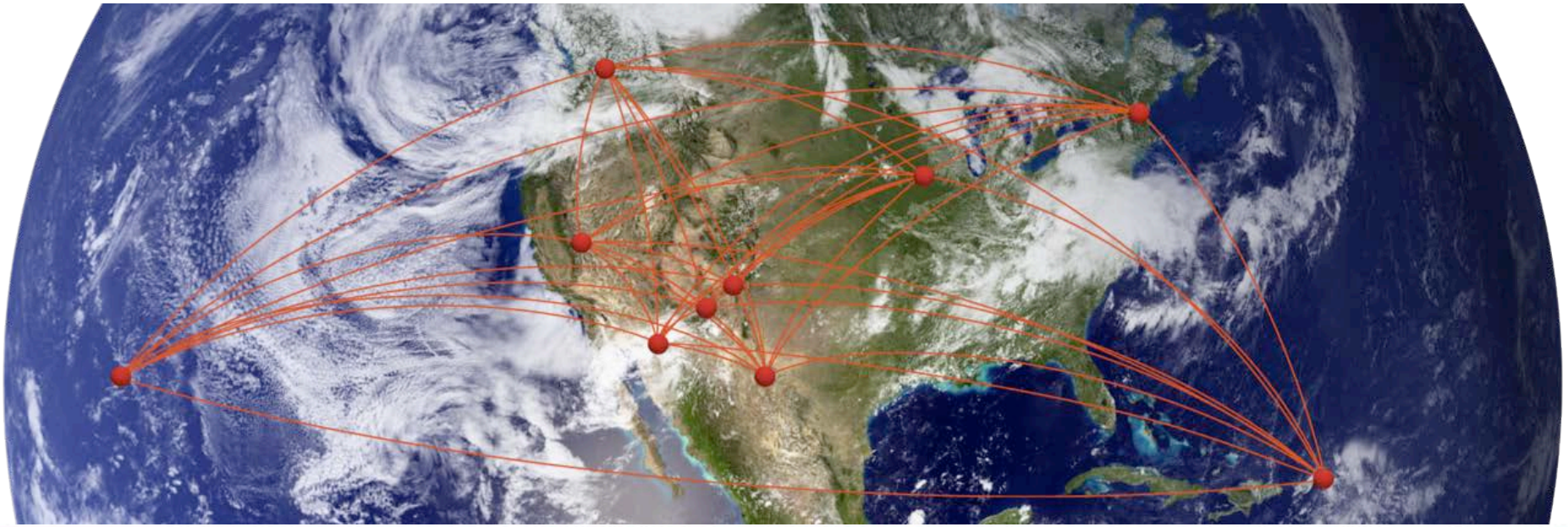
VLBA Status

TOG Jan 23, 2014



Walter Brisken

NRAO - Socorro

Atacama Large Millimeter/submillimeter Array

Karl G. Jansky Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array

VLBA after the Portfolio Review

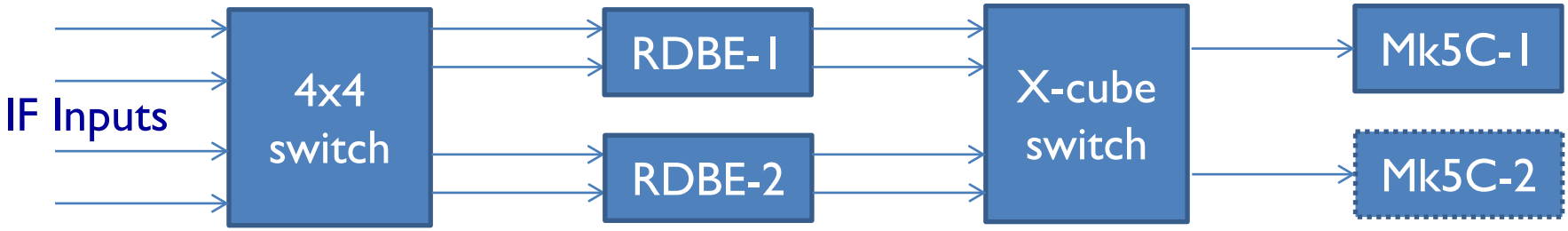
- NSF to "divest" much of NOAO-KP, GBT and VLBA
- In practice, NSF wants to be a minority partner (<=50%)
  - We're part way there already…
- We are cautiously optimistic about the VLBA's future
- Science partners contribute to VLBA operations
- USNO contract to measure UT1-UTC
  - Key parameter describing the spin phase of the Earth
  - Required to link celestial and terrestrial reference frames (e.g. GPS)
- Using our expertise to build receivers and correlators for others
- Developing other opportunities with NASA, US Navy, etc.

  - But… resources are expected to remain extremely thin

Legacy system and Mark5A

- No more scientific observations with Mark5A or analog BBC system
- Mark5A units remain at 2 VLBA sites for final wideband / legacy comparison testing
  - E.g., relative delay through the two systems
- 4 BBCs and samplers remain in use for pointing measurements
- Mark5A and analog BBC system remain in use at the GBT for RadioAstron use
  - This is driven by eTransfer needs
  - Effort is underway to transition this as well

Upgraded (wideband) backend electronics



- 4 IFs from antenna (512 MHz centered on 768 MHz)
- 4x4 switch: fully general IF switch (any output can be attached to any input)
- RDBE
  - DDC personality: 1-4 channels, 1-128 MHz/channel, VDIF or Mark5B
  - PFB personality: 16 channels, 32 MHz/channel, Mark5B only
  - 2x DDC for 8 channels; 512 MHz max total bandwidth; VDIF only
- X-cube switch
  - Fully general 10 Gbps switch; burst mode; some local storage
- Mark5C
  - 2nd unit only at PT and MK (for USNO UT1-UTC observing)

GBT+VLBA wideband system + Mark5C

- Fully installed at all 10 VLBA sites and GBT
- Currently restricted to 2-bit samples and 2^n baseband channels
- Polyphase FilterBank (PFB) mode
  - 16 channels @ 32 MHz BW from 1 or 2 IFs
  - Coarse tuning: 32 MHz steps
  - 2048 Mbps only
- Digital Down-Converter (DDC) mode
  - 1, 2, 4 or 8 channels @ 1-128 MHz BW from 1-4 IFs
    - All channels must have same BW
    - 64 MHz max bandwidth when using 8 channels
  - Fine tuning: 15.625 kHz steps, not commensurate with 10 kHz
    - Least common multiple tuning step is 250 kHz
  - 4-2048 Mbps data rate

VLBI at the VLA

- 1 Mark5C recorder fed directly by WIDAR correlator
  - Comparable flexibility to the RDBE DDC mode
  - Multi-thread VDIF output only
- Currently 4 baseband channels, 1-128 MHz BW each, is offered
- 8 baseband channels, 1-64 MHz is being commissioned
- Single subarray only. Full phased "Y27" is the only phasing mode supported at this time.

Mark5C

- Using Haystack's DRS (version 0.9.19-1) for all scientific observing
- Using Conduant's SDK 9.2 with firmware update (ver 16.37) for large drive support
  - No compatibility problems for drives <= 2 TB seen
  - I strongly recommend updating the firmware!
- At 2 Gbps we see some packet loss (about 1 in 10^5 or so)
  - Happens as a result of packet jitter when packets go through X-cube switch
  - Upcoming fix to address this (see Chet's talk)

Ultra-rapid response capability

- Respond to triggers quickly
  - < 15 minutes from trigger to observing demonstrated
- Requires PI software to be running at VLBA operations
  - Receives external trigger
  - Formulates observing script (sched input)
  - Emails script and instructions to operator
- Currently limited to non-observing periods
  - About 30% of time is available for such observations
  - Preemptive mode may be possible for highly ranked projects
- One project using this mode now
  - Search for prompt GRB emission (K. Bannister)

Resident Shared Risk Observing Program

- Observers visit to Socorro to develop new capabilities!
- Based on the EVLA RSRO program
  - But a bit more flexible in scope
- Past examples:
  - Mark4 output format from DiFX (David Gordon)
  - Multi-phase-center amplitude calibration in AIPS (Enno Middelberg)
  - Ultra-rapid response (Keith Bannister)
- Technically oriented people especially welcome!

Developments (FY13 and FY14)

- FY2013 (Oct 1, 2012 to Sep 30, 2013)
  - Completed the Sensitivity Upgrade
  - Digital down-converter commissioned for spectroscopy
  - Implemented a rapid-response capability
  - Developing a new synthesizer for versatile tuning
  - First fringes to LMT
- FY2014 (Oct 1, 2013 to Sep 30, 2013)
  - Stabilize and document existing capabilities
    - Attenuator setting and timing issues
  - New sched release (any day now)
  - Improved operator GUI
  - Continue retiring VME station computer (if time permits)
  - Support wider range of VLA observing modes (if time permits)

More info

- VLBA Observational Status Summary
  - http://www.vlba.nrao.edu/astro/obsstatus/current/
  - (For information regarding VLBA capabilities)
- Call for Proposals
  - https://science.nrao.edu/enews/6.7/
  - (For information regarding Feb 3 2014 proposal deadline)

Questions?

Back-up slides follow

Key Capabilities of the VLBA

- Ten 25-m antennas working from 0.3 to 90 GHz
- Baselines up to 8600 km
- Highest resolution imaging in astronomy (0.1 mas)
- Best astrometric telescope in existence
  - ±10 uas accuracy, *i.e.*, 10% parallax distances at 10 kpc
- Fast response to transient phenomena
- Flexible scheduling
- VLBA used alone or as part of a global array (e.g., HSA)

Science Status. Breakdown

- We typically get ~55 new proposals per semester
- A large fraction of time on schedule is existing projects
- New and existing programs in 2013B
  - 53% astrometry
  - 36% imaging
  - 11% other (surveys, photometry, absorption, etc.)

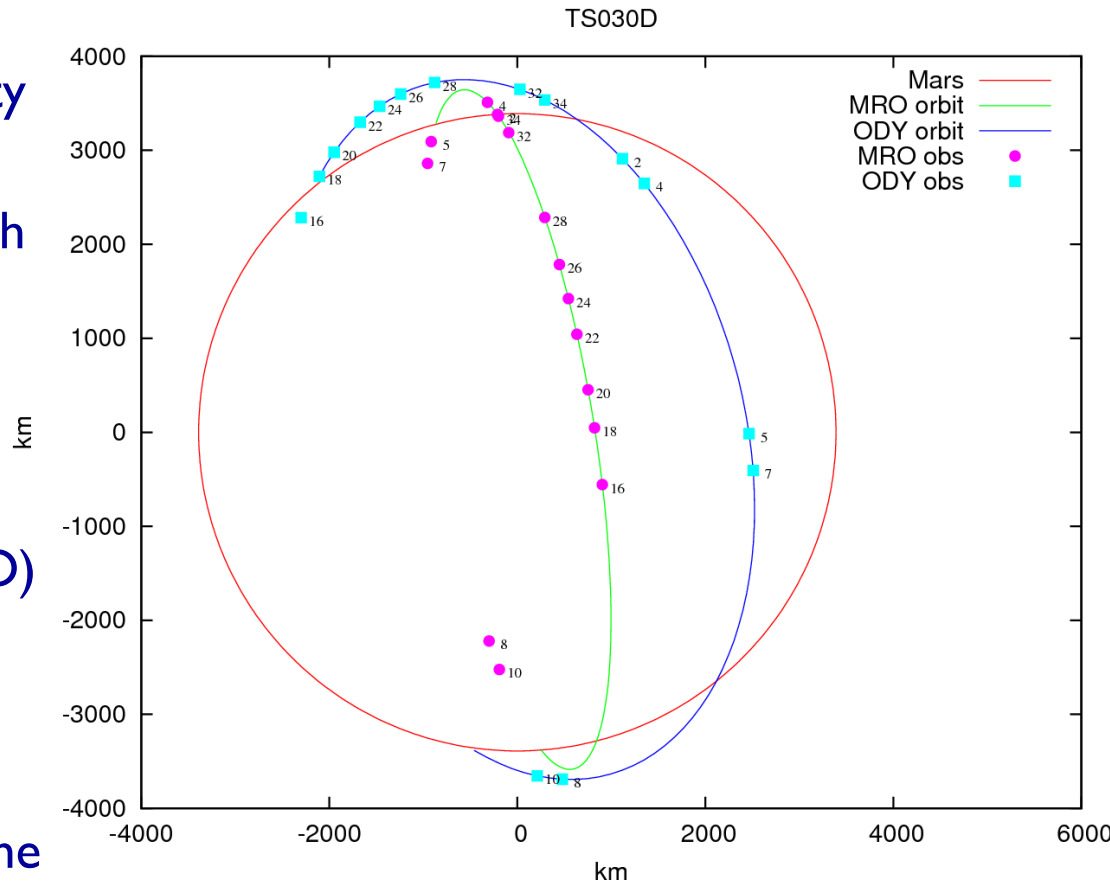
  - 46% are extragalactic
  - 51% is galactic
    - Big departure compared to "classic" VLBI!

Voyager 1. Where are you?

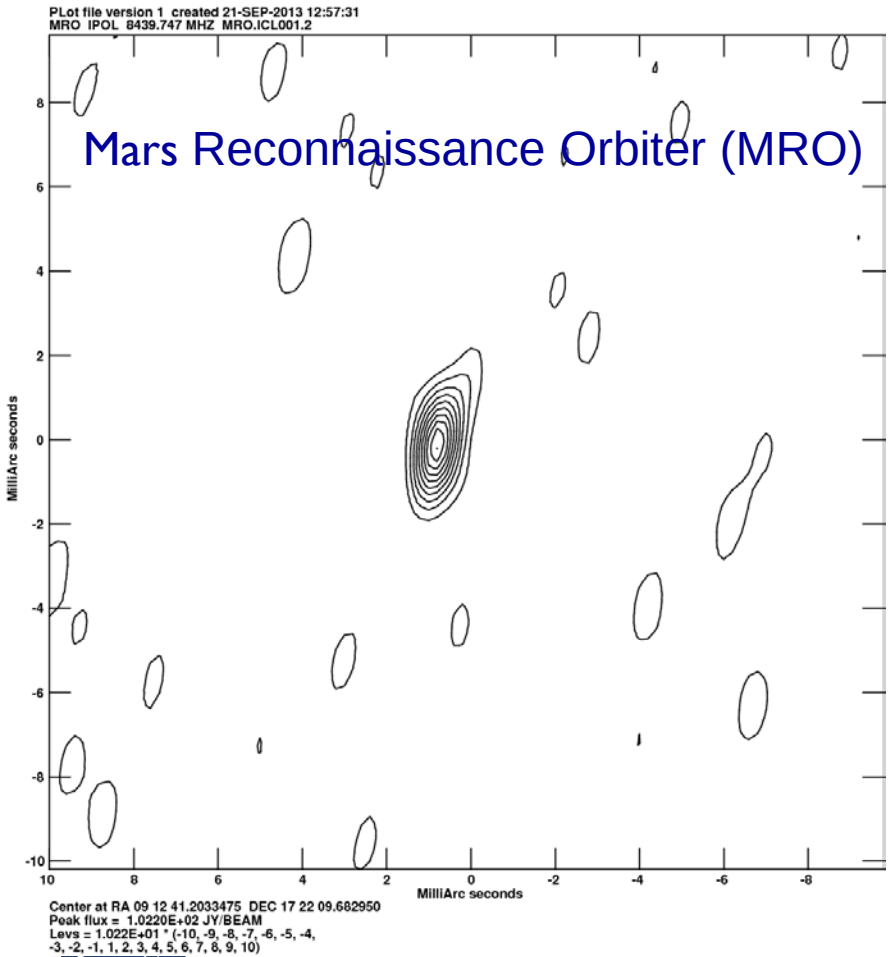
- Observed in narrow-band mode
  - eTransfer to Socorro for corr.
  - 2 observations: Feb and July '13
- Voyager 1 was 0.6" off ephemeris
  - And increasing!
  - VLBA noted in NASA press conf.

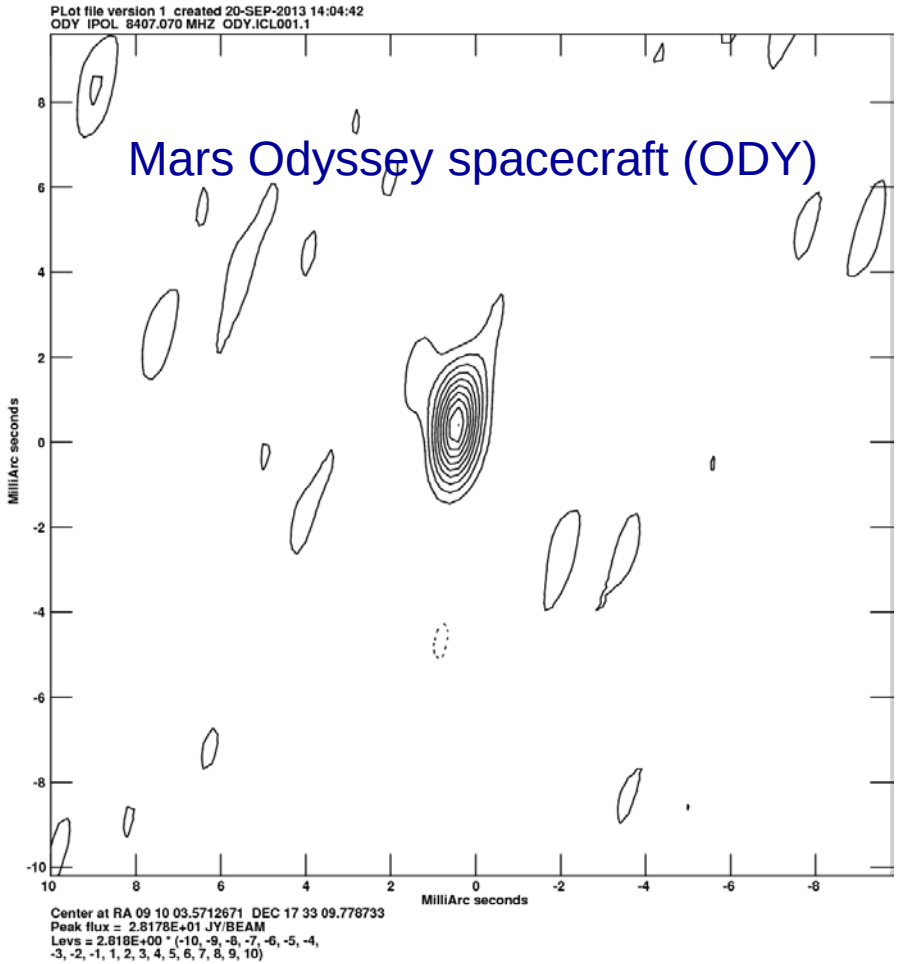
Spacecraft Tracking Demonstration

- Demonstrate the VLBA's ability to provide high precision coordinates for spacecraft with low latency
  - 0.2 mas = 1 nanoradian
  - Target latency < 3 hrs
- Tests target the Mars Reconnaissance Orbiter (MRO) and Mars Odyssey (ODY) spacecraft.
- The two spacecraft are <5 arcsec apart and fall in the same VLBA field of view



Preliminary single-scan images





Coordinates are milliarcseconds relative to ephemeris position. 1mas =1 mile

V-FASTR: VLBA Fast Transient project

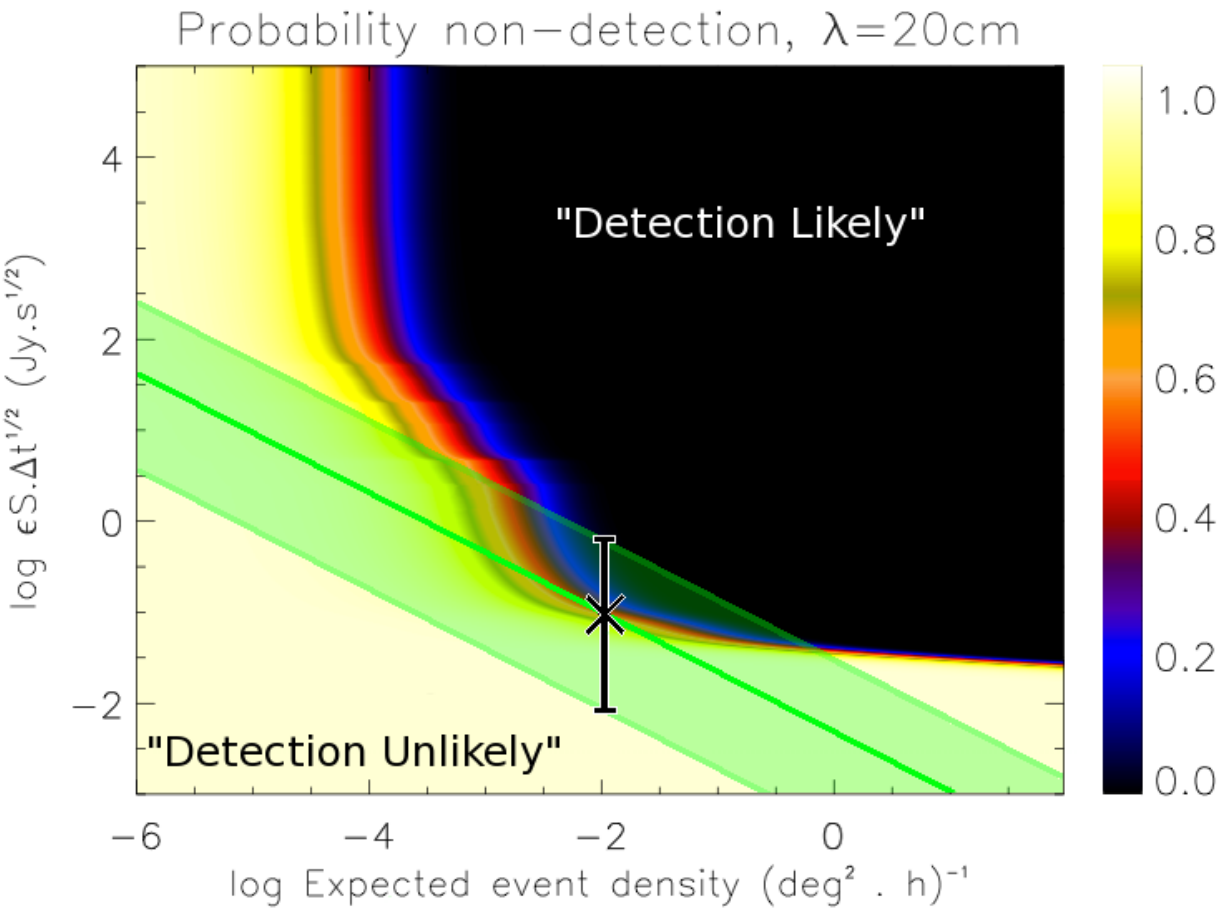
- Commensal search for Fast Radio Bursts (FRBs)
- Looks for coincidence between multiple well-separated antennas
- Basic data flow
  - Peel spectrometer data out of DiFX after fringe rotation
  - Incoherent dedispersion
  - Pulse detection
- Machine learning techniques applied
  - Decision tree classification
  - Robust estimators
  - Synthetic pulse injection / detection
- Strong candidate events' baseband data copied for later processing

V-FASTR: Strengths / weaknesses

- Strengths
  - Well established / well understood system at this point
  - Hundreds of hours per year of commensal observing at L-band
  - Geographic isolation of antennas
  - **Localization** of bursts to <1" if detected
  - Searches over 30 MHz to 90 GHz; targets likely hosts
- Weaknesses
  - Relatively low sensitivity (limited bandwidth)
    - But very close to sensitivity of reported events
  - Time delay between observing and detection

Overall: strong contender for first experiment to localize a burst!

V-FASTR: Sensitivity



S. Spolaor Priv. Com

480hrs at 20-cm
at 256 Mb/s (mostly)

Expected rate will very much depend on the burst population's width and DM distributions.

2Gbps V-FASTR threshold : 0.92 Jy

One event every 2 weeks

NRAO

Desired upgrades

- Improved delay model
  - Goal: improved astrometry, perhaps to the 3 microarcsecond level
  - Migrate to Calc 11
  - Make use of improved weather and tide models
  - Improve antenna metrology (temp sensors, tilt meters, …)
  - Outfit remaining antennas with GPS receivers
- Bandwidth expansion
  - Burst mode (might be implemented easily via X-cube switch)
  - New recorders and media
  - IF upgrade (required for > 1 GHz/pol bandwidth; quite expensive!)
  - Improved receivers/down-converters
    - One possible end-point: EVLA receiver suite + W-band

Desired upgrades (2)

- Ka-band receivers
  - With X-band dual-band capability
  - Desired for astrometry/geodesy
- Upgraded Q-band (40-50 GHz)
  - Better LNAs to reduce Trec
  - Wider tuning range
  - Dual IF-pair option for wide spanned bandwidth
- VLBI support in CASA
  - Joint NRAO/Haystack proposal being reviewed now

Desired upgrades (3)

- Fiber links to antennas: orders of magnitude to go!
  - Currently 1.4 Mbps
  - 10 Mbps would allow some rapid correlation science
    - Routine near-real-time fringes tests could become common
  - 100 Mbps would allow some experiments to bypass disk shipment
  - 1 Gbps would allow no more disk shipment (at today's data rates)
    - Estimated to cost about $2M/year (minus some cost savings)
    - Would enable different operating model for the VLBA
  - 10 Gbps would enable new science
    - Start to reconsider 2-bit sampling here
  - 100 Gbps would max out cm-wavelength receivers
    - Completely merge operations with the VLA?

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