Finding extremely compact sources using the ASKAP VAST Survey

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* VAST is an international collaboration with over 70 members, led by Tara Murphy (The University of Sydney) and Shami Chatterjee (Cornell University). See http://www.physics.usyd.edu.au/sifa/vast for more information.

Abstract

VLBI observations of intraday variable (IDV) quasars found in the MASIV (Micro-Arcsecond Scintillation-Induced Variability) 5GHz VLA Survey of 500 flat-spectrum sources in the northern sky have shown that these sources are extremely compact, often unresolved, on milliarcsecond scales, and more core-dominated than their non-IDV counterparts.

VAST: an ASKAP Survey for Variables and Slow Transients, proposes to observe 10,000 square degrees of southern sky daily for 2 years in the VAST-Wide survey component. This is expected to reveal of order 30,000 compact sources brighter than 10 mJy showing refractive interstellar scintillation (the cause of centimetre-wavelength IDV) at the survey frequency of about 1.4 GHz. Many of these sources may be suitable astrometric calibrators for VLBI at higher frequencies.

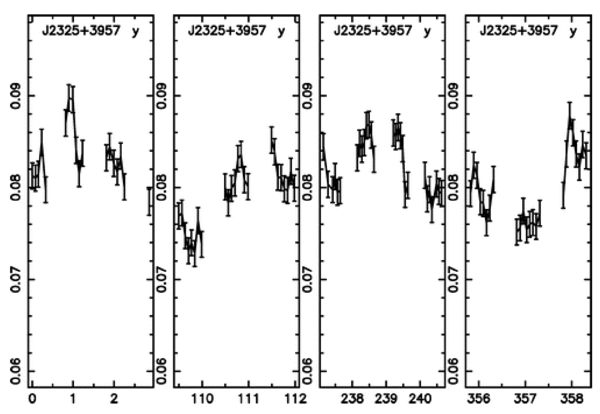
The MASIV VLA Survey

- VLA northern hemisphere survey of ~500 compact, flat-spectrum radio sources
- Initial survey: four observing sessions of 3 days each, spread at ~4 month intervals over the course of a year [1]
- Observed at 5 GHz with the VLA split into 5 subarrays
- Average source flux densities ≥ 0.1 Jy
- 443 unresolved sources in final analysis sample

Relevant results: [2]

- Over half of the sources showed intraday variability (IDV) in at least one epoch
- Clear Galactic dependence and correlation with Hα emission measure
  → IDV clearly linked to the interstellar medium: interstellar scintillation (ISS)
- Timescales detected in MASIV are hours to days
- RMS fractional variability 2-10% over 2 days

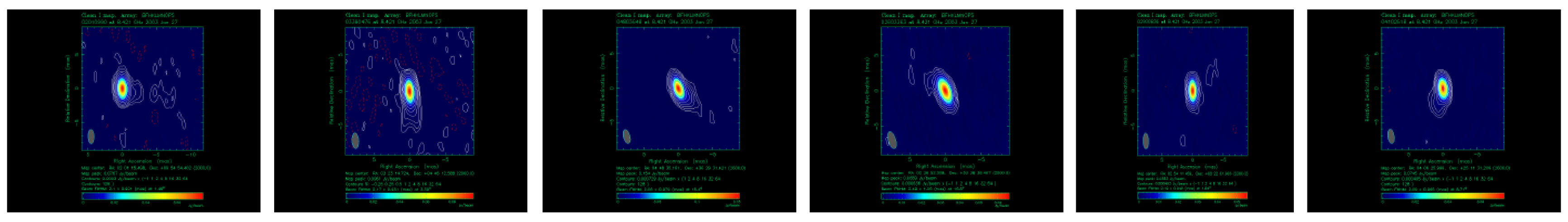
The VLA during the MASIV Survey



Example MASIV Survey data for a variable source

Results from VLBI follow-up of MASIV sources

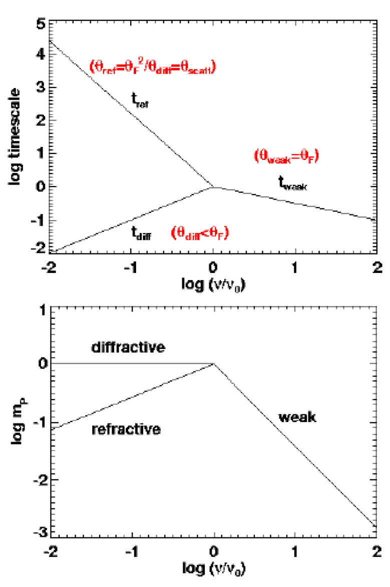
- [3],[4]: Scintillating sources are more core dominant than non-scintillating sources.
- The overall angular size of scintillating sources is significantly smaller than that of non-scintillators.
  - Implications: scintillators are likely to have less variable, milliarcsecond-scale core-jet structure than non-scintillators
    → Good candidates for ICRF and astrometric phase-referencing



Examples of milliarcsecond-scale structure of scintillating sources, from VLBA observations (see Ojha et al. 2004)

Frequency dependence of interstellar scintillation (ISS)

- Scintillation behaviour changes from 5 GHz to 1.4 GHz [5],[6]
- At 5 GHz (MASIV): typically weak scattering (strong scattering at low Galactic latitudes)
- At 1.4 GHz (VAST): strong scattering – refractive ISS (RISS)
- Timescales of RISS are expected to be ~10x longer at 1.4 GHz cf 5 GHz (for transition frequency ν_0 between weak and strong scattering of a few GHz)
  → **VAST will see RISS on timescales of weeks to months** (days for very nearby scattering screens)
- Point source modulation index (RMS fractional variability) at 1.4 GHz may be reduced by a factor ~2 cf 5 GHz (but depends on compact fraction, angular size and transition frequency)
- RISS at 1.4 GHz implies component angular sizes typically of order 0.1 mas



Frequency dependence of ISS timescale (upper panel) and modulation index (lower panel)

Artist's impression of ASKAP at the MRO. Credit: Swinburne Astronomy Productions.

The Australian Square Kilometre Array Pathfinder is a next-generation radio telescope currently under construction in Western Australia, led by CSIRO ATNF.

ASKAP specifications:

- ASKAP will comprise an array of 36 antennas each 12m in diameter
- System temperature design goal of 35K
- Frequency range 0.7 to 1.8 GHz, instantaneous bandwidth 300 MHz
- Phased array feed technology: 30 independent beams, each of 1 sq deg, yielding **30 square degrees field of view** at 1.4 GHz
- Maximum baseline ~6km
- Full cross-correlation of all antennas
- In the first 5 years of observations (anticipated starting in 2013), at least 75% of time will be devoted to large surveys
- After an open international competition, ten major surveys have been selected to proceed to a design study phase.

ASKAP "BETA" phase

- The Boolardy Engineering Test Array will consist of six antennas operating at the Murchison Radio-astronomy Observatory (MRO) by 2011. Full ASKAP field-of-view, but lower sensitivity as only 1/6 ASKAP collecting area.
- BETA is potentially useful for large-area sky monitoring surveys for relatively bright sources

VAST: An ASKAP Survey for Variables and Slow Transients

- VAST is one of the ASKAP Survey Science Projects now beginning a design study
- VAST aims to:
  - discover and investigate variable and transient ("slow" = >5s) phenomena, e.g. flare stars, intermittent pulsars, X-ray binaries, magnetars, extreme scattering events, intra-day variables, radio supernovae and "orphan" afterglows of gamma ray bursts.
  - probe unexplored regions of phase space to search for new classes of radio transient sources.
- Proposed Wide, Deep and Galactic plane surveys
- VAST-Wide survey component:
  - **10,000 square degrees** (400 pointings)
  - Observe for 6 hours per day, **every day for 2 years**
  - Total time requested 4380 hours
  - 40 seconds per pointing plus overheads, **RMS sensitivity 0.5 mJy/beam**

Implications for finding compact sources in the VAST Survey

- Only the most compact, core-dominated sources exhibit ISS
- Expect ~3 compact, flat-spectrum sources per square degree with S>10 mJy at 1.4 GHz [7],[8]
- Many of these would be expected to show refractive interstellar scintillation (RISS) at 1.4 GHz, implying angular sizes typically no larger than ~0.1 mas
- Expect the 1.4 GHz scintillators to be even more compact at higher frequencies where astrometry is ideally performed
- VAST should be able to reliably detect variations down to less than a few % in sources with total flux density ≥ 0.1 Jy (and larger variations in weaker sources)
- **The VAST Survey will find:**
  - **thousands of good candidate astrometric calibrators in the southern hemisphere**
  - **potential phase-reference calibrators in the vicinity of any transients detected, for rapid VLBI follow-up, e.g. to measure proper motions of Galactic transients and pin down their origin**

References

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