Science Drivers and Technical Requirements for Parkes High-Frequency Receiver

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Overview

- Science programs that *need* a Parkes high-frequency receiver.
- Technical requirements arising from science program.
- Some specific science projects in more detail :
  - VLBI parallax (Simon Ellingsen).
  - Polarization mapping (Ettore Carretti).
  - Ammonia mapping (Jim Jackson).

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What is proposed?

- A single package with two receivers covering 4-14 GHz and 12-30 GHz.
- Reuses existing amplifier designs and has less demanding feed requirements than a scaled 0.7-4 GHz feed.
- System temperatures ~30K in the lower band and 60-100K (on-sky) in the upper.

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Why is it needed?

- ***Sensitivity***: At frequencies < 16 GHz Parkes has a collecting area 1.4 times the 6x22m ATCA.
- ***Frequency coverage***: ATCA does no cover 12-16 GHz (methanol, OH, formaldehyde).
- ***VLBI***: The sensitivity of Parkes is critical for many VLBI observations.
- ***Simplicity***: Avoids many calibration and processing overheads of interferometry.

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Science drivers

- ***Masers***: searches and monitoring.
- ***Thermal lines***: (OH ; H_2CO ; NH_3 ; CH_3OH etc), often largely resolved by an interferometer.
- ***Magnetars***: or pulsars in directions with high dispersion.
- ***Polarization mapping***: High RM regions of MW need higher frequency observations.
- ***VLBI***: monitoring, parallax, ToO/NAPA response, intrinsically faint objects.

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Technical Implications (with a line/VLBI bias)

- 4 flexible IFs of bandwidth > 500 MHz (preferably 1 GHz or more) would let you* :
  - Simultaneously observe 4.7, 6.0 GHz OH, 4.8 GHz H_2CO, 6.7 and 12.2 GHz CH_3OH
  - Simultaneously observe multiple NH_3 inversion and rotational transitions, CH_3OH thermal and maser, plus H_2O maser, CCS, HC_3N and HC_5N.
  - Improved tropospheric calibration of VLBI observations (dependent on capabilities of rest of array).

* with appropriate samplers/recorders

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Issues with proposed system

- Not compatible with current or future geodetic VLBI receiver requirements.
  - 2-12 GHz lower band would allow current S/X, but the next generation geodesy will use 2-14 GHz systems.
  - Could better use be made of DSS43 time?
- Multi-pixel high frequency system has compelling science drivers and makes much more efficient use of telescope time.

Citation metrics – support or illumination?

We need to prioritize receiver upgrades based primarily on future potential and required capacity. Past usage statistics hide many inherent biases and are a highly biased metric.

The most highly cited Parkes papers since 2003 are predominantly pulsar and HI science.

Three of the top 10 Parkes papers from 2009 onwards are from the MMB.

Big surveys done with multi-pixel receivers, the gift that keeps on giving.

Conclusions

- A high-frequency broadband receiver would replace 6 existing receivers, many of which are far from state of the art => big incremental improvement in capability.
- RFI less of an issue above 4 GHz, existing RFI strategies would be sufficient.

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Accurate Distances through VLBI parallax

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VLBI Monitoring & Parallax

- With the current limitations on receiver changes at Parkes most frequencies > 4 GHz are available for only a small fraction of the year.
- This restriction is one of the major constraints in LBA scheduling and severely limits the ability of the LBA (at frequencies > 4 GHz) in
  - Monitoring objects which evolve on timescales < 6 months.
  - Parallax measurement
  - ToO/NAPA capability

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Size *does* Matter

- For spectral lines you can't increase sensitivity through greater bandwidth.
- For VLBI the coherence time (typically few-5 min) limits the integration time*.
- Baselines 25m antenna-Parkes are a factor of 2.5 more sensitive than between a pair of 25m antennae.
- As the only large aperture in the LBA, Parkes plays an important role (despite being slow and limited in elevation)

* You can extend this through phase referencing, but need a *suitable* phase reference source within a degree or two.

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Distances

- Trigonometric parallax is the “gold standard” for distance measurement beyond the solar system (no underlying assumptions about intrinsic brightness).
- To measure trigonometric parallaxes at kpc distances requires astrometry accurate to < 100μas
- VLBA observations of masers have been used to obtain accurate (~10%) distances to the Galactic Centre.
- Accurate distances are critical if you want to do real astrophysics for Galactic sources.

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Astrometry & Zenith Angle

- Accurate astrometry requires the target sources to be at zenith angles $Z < 50^{\circ}$.
- This is because the uncertainty in the zenith delay σ_τ produces an error in the source-calibrator path difference

$$\Delta l = \sigma_\tau \sec Z \tan Z \Delta Z$$

- This means that for the Galactic longitude range ~260 – 360 parallax measurements can only be made with the LBA

Methanol maser VLB
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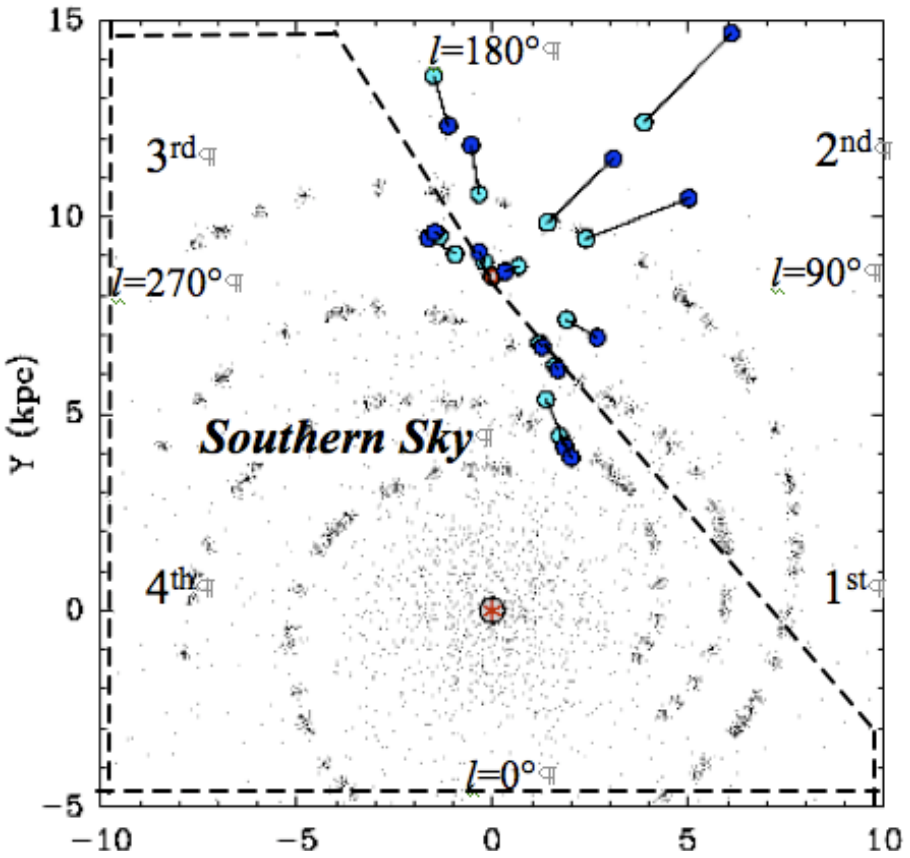
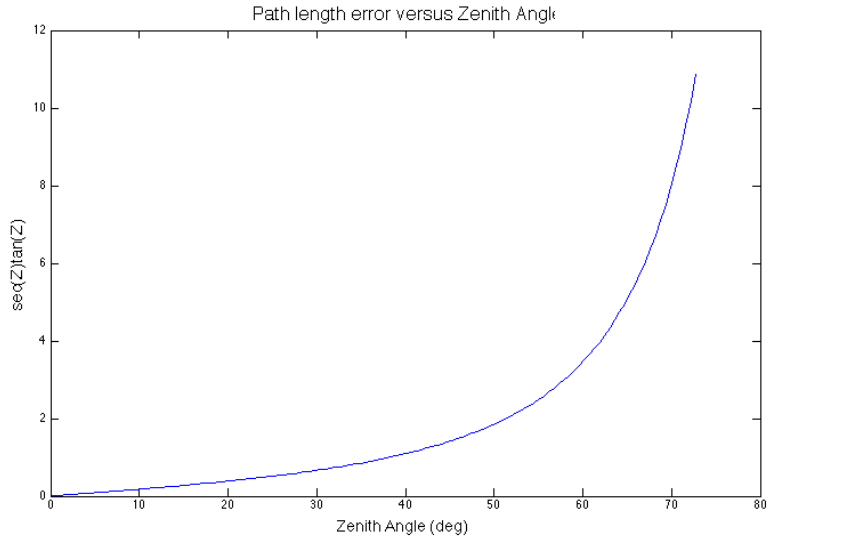
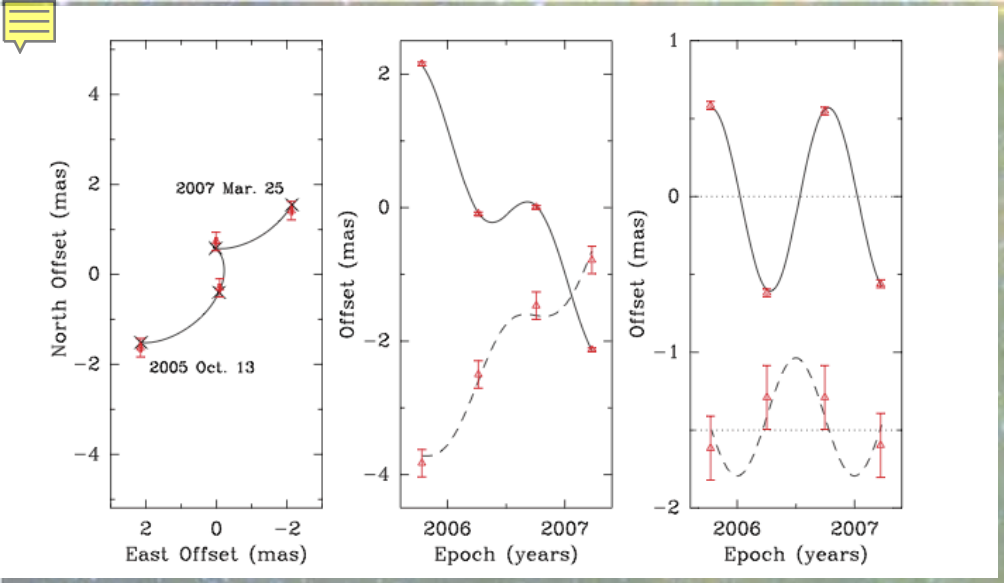




VLBA versus the LBA

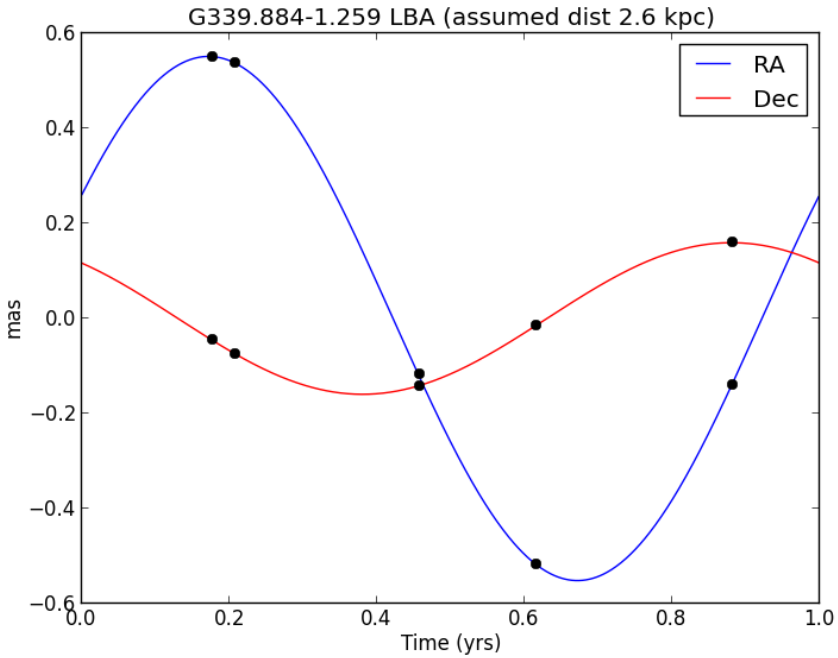
The VLBA has a number of advantages over the LBA for parallax :



Parallax in G232.6+1.0 (Reid et al. 2009a)

- ✓ Homogeneous antennas and receiver/IF system.
- ✓ More antennas and longer baselines.
- ✓ Flexible scheduling.
- ✓ More flexible IF system allows more accurate tropospheric calibration.

Sampling of LBA parallax observations of G339.884-1.259



Parkes High Frequen
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Conclusion

- I have been involved with two papers in the last 6 months where a VLBA parallax measurement has been critical for a robust astrophysical analysis of star formation processes probed by MMB-related data.
- Current lack of flexibility in Parkes high frequency receivers means opportunities for high-impact science are being missed, or partially compromised.

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