The structure and motions of the Milky Way & Local Group

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Overview

• Science:
  – Astrometry and Very Long Baseline Interferometry.
  – The structure of the Milky Way.
  – Motion of the Local Group and “near-field” cosmology.

• Technical
  – Is VLBI part of SKA phase 1?.... Yes!
  – Assumptions and likely practical limitations
Astronomy vs. Astrophysics

- What is the difference between astronomy and astrophysics?
Astrometry with VLBI

• With the ATCA absolute positions are accurate to around 0.4” and relative positions to around 0.05”.

• VLBI gives intrinsic resolution around 3 orders of magnitude greater.

• State of the art VLBI astrometry at centimetre wavelengths can achieve absolute accuracies of 0.000005” (5 μas).

• If we were to take a football and place it on the Moon that would have an angular size of ~150 μas.
At the distance of the moon an angular size of 5 μas corresponds to a linear scale of < 1 mm.

5 μas - That is smaller than a bee’s endophallus!
Structure of the Milky Way

• Objects in the Milky Way are nearby:
  – Great for sensitivity and resolution.
  – But uncertainties in distance are a major issue.
• With VLBI accurate distances have been measured to more than 100 star formation regions.
• The first trigonometric parallax to a southern star formation has recently been measured (Krishnan et al. 2015, ApJ in press; arXiv:1503.05917).
• A concerted effort is required to “catch-up” to the north prior to SKA1-MID coming online.
Structure of the Milky Way

Trigonometric parallax of G339.88-1.26


Studies of the Milky Way and Local Group
Structure of the Milky Way

Spiral arm structure of the Milky Way from trigonometric parallax.

\[ R_0 = 8.34 \pm 0.16 \text{ kpc} \]
\[ \Theta_0 = 240 \pm 8 \text{ kms}^{-1} \]

Not just star formation!

• The major uncertainty in the tests of GR from the Hulse-Taylor binary pulsar are due to Galactic motion.
  – Improved Galactic motion parameters result in a factor of 3 reduction in the uncertainty of the orbital decay measurement.

• The distance to the Pleiades is important for stellar evolution. Recent VLBI parallax distances (Melis et al. 2014, Sci, 345, 1029) are 10% higher than Hipparcos.
Motion of the Local Group

- Are the Magellanic Clouds on their first passage of the Milky Way?
- The Magellanic Clouds and other local group members provide a unique opportunity for studying hierarchical structure formation.
- VLBI can measure the proper motion of objects in the Magellanic Clouds to an accuracy of better than 50 μas/year.
- With SKA1-mid sensitivity we will be able to detect around 100 objects in the MC and much better measure the CoM motions.
VLBI and the SKA

• The first science from an ASKAP antenna was VLBI (Tzioumis et al. 2010).
• Also the first science from the Warkworth 30m antenna (Petrov et al. 2015, PASP in press; arXiv:1502.06802).
• VLBI requirements are modest:
  – A correlator mode to “tie” the array.
  – A suitable time/frequency standard (e.g. H-maser).
  – A recorder.
SKA1-MID VLBI Astrometry

- It currently takes 1 day of array time (over 1 year) to measure a parallax (incl. calibration overheads).
- With SKA1-MID this drops to 4 hrs per source (after re-baselining).
- With this integration time you also get improved astrometric accuracy because in-beam phase calibration becomes practical.
- It will be possible to do tomography of nearby spiral arms with SKA1-MID (1% distance at 2 kpc):
  - Complementary to magnetism and HI studies.
Studies of the Milky Way and Local Group

Yaragadee

Katherine

VLBI Telescopes in Australia

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SKA1-MID and VLBI

• Hartbeesthoek regularly participates in LBA observations, but limited mutual visibility and a lack of intermediate baselines Australia-Africa provide challenges.
• With SKA1-MID in South Africa we will see similar issues. Establishing intermediate sites as part of AVN developments would enhance science capabilities.
• SKA1-MID will open up the possibility of in-beam phase referencing at 5 cm wavelength for some sources and at SKA2 sensitivity it will be possible for all sources.
Conclusions

- VLBI between SKA1-MID (or parts of it) and the LBA will provide opportunities for early SKA science.
- East-west baselines are important for parallax measurements.
- Our knowledge of the scale and structure of the Milky Way impacts a broad range of astrophysics.
- Having SKA antennas at remote sites in Africa and beyond will maximise the science return from VLBI with the SKA.