Measuring BAOs in future SKA surveys

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*On behalf of the SKA Cosmology SWG
Baryon Acoustic Oscillations

• Coupled baryon-photon plasma in the early universe supports sound waves (speed = characteristic scale)

• This scale is left imprinted on the matter distribution after the baryons decouple from the photons
Baryon Acoustic Oscillations

- Coupled baryon-photon plasma in the early universe supports sound waves (speed = characteristic scale)
- This scale is left imprinted on the matter distribution after the baryons decouple from the photons
- Measurements of the galaxy clustering pattern allow us to recover it

→ Standard Ruler

Anderson et al. (2012)
Science with distance measures

- Measure BAO distance scale in radial + transverse directions (monopole and/or quadrupole)
  \[ \rightarrow \text{expansion rate and angular diameter distance} \]
Science with distance measures

- Measure BAO distance scale in radial + transverse directions (monopole and/or quadrupole)
  → expansion rate and angular diameter distance

- Probes dark energy, spatial curvature, energy content

- Useful low-redshift anchor for CMB measurements

Anderson et al. (2014)
Systematics

- BAO scale is remarkably robust to systematics
  → measuring only the *location* of a feature
- Non-linearities etc. induce ~0.2% shift in BAO scale (small, but needs to be accounted for)
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Reconstruction

- Galaxy distribution distorted by bulk flows on large scales
  → broadens the BAO peak
- Use observed density field + linear theory to “wind back” the distortion
BAO with the SKA

HI galaxy redshift survey

Measure redshifts for individually-detected galaxies (21cm line gives redshift)

✔ Tried-and-tested method in the optical
✔ Relatively “clean” in terms of foregrounds/systematics
✔ Phase 2 will cover **unprecedentedly large volume**

✗ Survey volume limited for Phase I sensitivity
✗ Mostly probes regimes that are already covered by optical surveys
BAO with the SKA

HI intensity mapping

No need to detect individual galaxies to access large scales → map the unresolved redshifted HI emission

✔ Very fast; no thresholding (“uses all the photons”)
✔ Can survey extremely large volumes
✔ Phase I competitive with large optical surveys!

✗ New method; relatively untested
✗ Potentially difficult foregrounds/systematics (Wolz, Santos)
✗ Phase I design sub-optimal; need autocorrelations
Forecasting

Combined Fisher forecasting formalism for IM and galaxy surveys  
*Bull, Ferreira, Patel, Santos (2014)*

Code publicly available at [gitorious.org/radio-fisher](http://gitorious.org/radio-fisher)

**Phase I**

- Galaxy survey: 10 million galaxies; 5,000 sq. deg.
- IM survey: 10,000 hours; 25,000 sq. deg.; autocorrelation mode

**Phase 2**

- Galaxy survey: 750 million galaxies; 30,000 sq. deg.
- IM survey: Dense aperture array? (e.g. MFAA)
Distance scale forecasts

Some data taken from Font-Ribera et al. (2014)
Distance scale forecasts

\[ \frac{\sigma_{D_V}}{D_V} \]

\( z \)

BOSS
SKA1 HI gal.
Distance scale forecasts

\[ \frac{\sigma_{D_V}}{D_V} \]

\[ \tilde{z} \]

- BOSS
- SKA1 HI gal.
- SKA1-MID B1 IM
- SKA1-MID B2 IM
- SKA1-SUR B1 IM
- SKA1-SUR B2 IM
Distance scale forecasts

\[ \frac{\sigma_{D_v}}{D_v} \]

- BOSS
- SKA1 HI gal.
- SKA1-MID B1 IM
- SKA1-MID B2 IM
- SKA1-SUR B1 IM
- SKA1-SUR B2 IM
- Euclid
- DESI

\[ z \]

0.00 0.05 0.10 0.15 0.20 0.25

0.00 0.01 0.02 0.03 0.04
Distance scale forecasts

![Graph showing distance scale forecasts with various datasets and error bars.](image-url)
Dark energy constraints
Dark energy constraints
Dark energy constraints
Summary

BAO: Precision cosmology probe for the SKA

SKA Phase 1

- IM survey competitive with DESI/Euclid!
- Need autocorrelations. IM technique not yet proven.

SKA Phase 2

- Best-in-class galaxy redshift survey
- Only LSST can compete in terms of volume probed
[EXTRA SLIDES]
Power spectrum

$\Delta P/P$

$k$ [Mpc$^{-1}$]
Including low-z BAO

Combined w. Planck + SKA1 gal.
### SKA specifications

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IM: autocorrelation vs. interferometry

The plot shows the relationship between $\kappa$ and $k_\perp$ [Mpc$^{-1}$] for 15m dishes. The graph compares the SD (red) and Int. (blue) regions of the correlation. The vertical dashed lines indicate the range of $k_\perp$ for 15m dishes.
~ BINGO

~ MeerKAT/ASKAP

~ SKA1

~ Euclid/LSST