A PAF for Parkes

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Outline

Technical Overview assumptions

Science Goals:
- HI cosmic web
- HI intensity mapping
- Fast Radio Bursts
- Technical Advantages on other science:
  - Standing wave mitigation
  - OH / HI deep integrations
  - Stray radiation suppression
A Phased Array Feed for Parkes

700 - 1800 MHz

• Loose ~100 MHz around 900 MHz

Tsys ~ 50-60 K

efficiency ~ 0.8

FoV ~ 2.2 deg²

Raw comparison in survey speed with MB: FoV x \( (A_e/T_{sys})^2 \):

• 1.25x MB
Diffuse HI mapping

Galaxies require fresh fuel for their continued star formation
Simulations predict lots of gas at \( N_H \sim 10^{17} \text{ cm}^{-2} \)
Possible to find IGM with sensitive HI observations
Diffuse HI mapping

How much low column density HI is connecting galaxies?

- M31-M33 connection (Braun & Thilker 2005)
- Resolved into low $N_H$ clumps with GBT (Wolfe et al 2013)
  - 50% of mass in clumps and the rest unresolved
HI Intensity Mapping

3D view of HI fluctuations and measurement of $w$

- Emission from many galaxies blended to create an intensity field
- Measure power spectrum of HI
  - $\text{rms}$ fluctuations larger for smaller beam, smaller frequency width

Battye et al (2013)
HI Intensity Mapping

Chang et al (2010) GBT

\[ \Omega_{\text{HI}} = 5.5 \pm 1.5 \times 10^{-4} \]

\(<z> = 0.8\)

\(\Omega_{\text{HI}}\)
HI Stacking/Intensity Mapping

A metric for survey speed is:

$$SS = \text{FoV} \times \Delta \nu \times (\frac{A_e}{T_{\text{sys}}})^2$$

Improvement over current MB plus HIPSR, and...

- Access to higher redshift
- Significant potential gains in systematics
  - Improved bandpass
  - Cleaner beams

<table>
<thead>
<tr>
<th></th>
<th>FoV 1.4 GHz (deg²)</th>
<th>Δν (MHz)</th>
<th>A_e (m²)</th>
<th>T (K)</th>
<th>SS_1.4/SS_MB</th>
<th>SS_700</th>
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<tbody>
<tr>
<td>MB_{current}</td>
<td>0.8</td>
<td>64</td>
<td>2250</td>
<td>28</td>
<td>1</td>
<td>-</td>
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<td>MB_{HIPSR}</td>
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<td>220</td>
<td>2250</td>
<td>28</td>
<td>3.4</td>
<td>-</td>
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<tr>
<td>PAF_{384}</td>
<td>2.2</td>
<td>384</td>
<td>2573</td>
<td>50</td>
<td>6</td>
<td>2.9</td>
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<tr>
<td>PAF_{600}</td>
<td>2.2</td>
<td>600</td>
<td>2573</td>
<td>50</td>
<td>9.4</td>
<td>4.5</td>
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</tbody>
</table>

Modified from Meyer ATUC 2012 talk
Fast Radio Bursts

Strong (>1 Jy) Millisecond bursts (Lorimer+07, Thornton+13)

- Estimate ($0.2 < z < 1$)
- Event rate of $\sim 1.0 \times 10^4$ events sky$^{-1}$ day$^{-1}$

Fully sample the focal plane for better localisation

- MB one-off localisation full beam $\sim 30'$
- PAF one-off localisation FWHM/S-N
  - For S/N of 10 that’s 1.5’!
Technical Advantages

PAF can significantly reduce standing waves

- Parkes affected by well-known 5 MHz standing wave
- Work with PAF on WSRT shows removal of standing wave
  - Estimate down by a factor x1000! (Oosterloo et al 2010)
  - Probably not quite as good for Parkes
Technical Advantages: Nicer Beams

Kalberla et al. (2010)
A PAF should allow us to form nice beams for deep, low stray radiation, HI integrations

• Compete with GBT
Doing good things— even better

**Diffuse HI:**
- extended frequency range
- improved bandpass, better beams
- possibilities for improved RFI rejection

**OH:**
- Enable fast mapping, not currently possible with MB
- Better bandpass

**Polarization mapping**
- New frequency window
- Potentially excellent polarization performance (over smaller field of view?)

**Searching for transients:**
- Comparable mapping speed to MB
- Broader bandwidth
- Better localisation
Why a PAF on Parkes is a good thing: I

Extend HI science to higher redshifts
• PAF frequency range 700 - 1800 MHz allows us to push below current MB redshift range to z=1
• Potential for sophisticated RFI rejection

Diffuse HI mapping:
• Modest gain/break even in survey mapping but:
  • Enormous potential improvement in spectral baselines
  • Improved beamshapes

Fast Radio Bursts
• Ability to improve localisation by factor of ~10 over MB
• Sky coverage is similar to MB, frequency coverage larger

Cosmic rays
Why a PAF on Parkes is a good thing: II

Better understanding of PAFs

• Improve our understanding of beam-forming
• How good can they be?!
• How to deal with RFI in an increasing RFI environment

Demonstrate viability for FAST?

• FAST will be a 500m single dish, imagine a PAF!
# PAF minimum requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Coverage</td>
<td>700 - 1800 MHz</td>
</tr>
<tr>
<td>Instantaneous Bandwidth</td>
<td>380 - 600 MHz</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>&lt;1 kHz over narrow range(s); 5 kHz</td>
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<tr>
<td>Tsys</td>
<td>50 K</td>
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</table>

**SKA1 PAF would be even better**
Build a PAF - Just Do It!