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Galaxy redshift survey in neutral hydrogen with FAST

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The feasibility of a large-scale survey via the 21cm emission from neutral hydrogen utilising the Chinese Five-hundred metre Aperture Spherical Telescope (FAST) is investigated. It is found to be a powerful instrument, with an estimated 10^7 galaxies found in around 2 years with an average redshift of 0.15 if a focal plane array is employed with 100 independent beams. FAST also lends itself well to constraining cosmological parameters such as Γ and n_s; 5% and 7% respectively independent of CMB measurements. When combined with simulated PLANCK data one can expect w to be constrained to within 5% of -1. FAST compares favourably with the pathfinder missions for the Square Kilometer Aray (SKA), finding only a factor two less galaxies than the 10% SKA, but crucially probing the local universe, while the precursor SKA's find galaxies with a higher mean redshift thereby being both competitive with and complimentary to the 10% SKA. The 1% SKA is expected to be far outclassed by FAST.

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1. Introduction

A significant source of information for constraining cosmological parameters to date has come from large scale galaxy surveys, the largest of which utilising optical techniques, such as the 2dF-GRS[1] and SDSS[2] teams. Outside of the optical region, surveys have been performed using the 21cm emission from neutral hydrogen (HI) as a tracer of the galaxies allowing for a spectroscopic galaxy redshift survey [1]. This is a challenging technique, requiring both faster survey speeds as well as lower noise levels to probe higher redshifts, a combination that can only be meet with costly improvements in collecting area and field-of-view (FoV). The current state-of-the-art is a shallow all-sky survey; the combined HIPASS [2] and HIJASS [3] survey, which has found $\sim 10^4$ galaxies. There is however just such a technology development programme underway, with its goal of the SKA[3], with collecting area $\sim 10^6\,\mathrm{m}^2$ and a FoV much greater than $1\,\mathrm{deg}^2$, the SKA may detect $\sim 10^9$ galaxies. There also exists a Chinese based telescope that has great potential for HI surveys which will come online prior to the SKA (~ 2020). Called the Five-hundred-metre Aperture Spherical Telescope (FAST), it will be an Arecibo-like telescope with a significantly larger aperture ($\sim 500\,\mathrm{m}$) and FoV [4].

2. Five-hundred-metre Aperture Spherical Telescope (FAST)

The FAST telescope has secured all funding needed and at completion ($\sim 2012-2013$) will be the largest single dish telescope in the world. The expected specifications of the telescope [4] relevant to our discussion here are:

- $A_{\mathrm{eff}} = 50000\,\mathrm{m}^2$, with efficiency of 70%.
- At 21cm wavelength the beam width (FWHM) is $\theta \approx 3$ arcmin.
- The maximum observable zenith angle is of order 40° hence the amount of sky accessible to the telescope is $\approx 20000\,\mathrm{deg}^2$.
- Operates a focal plane array at 1.4 GHz with n_{B} instantaneous beams, each with $T_{\mathrm{sys}} = 25\,\mathrm{K}$ (hence $A_{\mathrm{eff}}/T_{\mathrm{sys}} \approx 2000\,\mathrm{m}^2\,\mathrm{K}^{-1}$ per beam) and dual polarization capability.

For an in-depth analysis of the methodology please refer to the publication this article is based on [5].

3. Galaxy Survey

The fiducial 19 beam FAST, observing for 120 s on a field (denoted by t_{obs}), and completing a full-sky observation in 2 years, will discover $\sim 3 \times 10^6$ at a signal-to-noise, S/N, of 4. By contrast, the proposed FAST utilising 100 beams will find 10^7 galaxies in the same timescale, with $t_{\mathrm{obs}} = 600\,\mathrm{s}$.

[1]2dF homepage: www.aao.gov.au/2dF
[2]SDSS homepage: www.sdss.org
[3]SKA homepage: www.skatelescope.org/documents

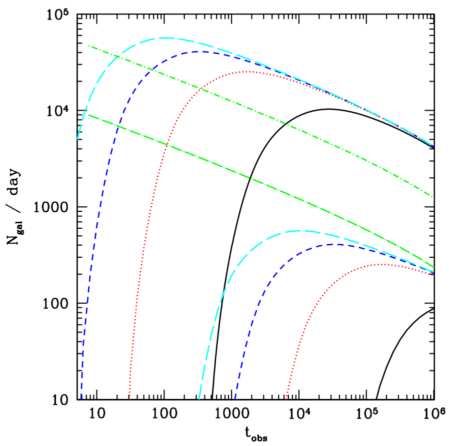

Figure 1: Predicted number of galaxies for a day of observing as a function of observation time per pointing. The straight green curves indicate FAST with 100 beams (upper, dotted-short-dash) and 19 beams (lower, dotted-long-dash) respectively. The upper sloped curves correspond to the 10% SKA with varying resolutions (in arcsec); 24 (cyan, large-dash), 18 (blue, short-dash), 12 (red, dot) and 6 (black, solid). The lower curves are for the case of the 1% SKA with the lines equating to the same resolutions as before.

4. FAST and the 10% SKA

FAST compares favourably with the proposed SKA pathfinder missions, the so-called 1% and 10% versions. For this comparison it has been assumed that the specifications of the SKA pathfinders differ only from FAST by having a larger Field-of-View, $\Omega_{\rm FoV} = 1\,{\rm deg}^2$, and effective area, $A_{\rm eff} = 70000\,{\rm m}^2$; $7000\,{\rm m}^2$, 10% SKA and 1% SKA respectively. Also a more stringent $S/N = 6$ has been selected. For the SKA pathfinders a range of potential resolutions are considered; $24, 18, 12, 6$ arcsec. As a result of this improved angular resolution there are a greater number of galaxies resolved out than in the case of FAST, and hence the bias for longer observation times per pointing that will probe deeper in redshift and therefore find objects that are within the beam. In Figure 1 it is clearly demonstrated that FAST with 100 beams is comparable to the 10% SKA in terms of maximum number counts, while both versions of FAST are far superior to the 1% SKA.

References

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