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Detecting faint HI clumps with Tianlai as a proof for Intensity Mapping

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ABSTRACT

Context. Intensity Mapping (IM) as a category of 21 cm cosmology uses radio interferometry to constraint Dark Energy (DE) via Baryon Acoustic Oscillations (BAO) analysis. IM is under development, five pathfinder interferometers are built to study its viability and resolve technical challenges. These pathfinders will determine the shape of future IM dedicated interferometers.
Aims. This work aims to prove the required sensitivity to detect faint and close HI clumps with the pathfinder Tianlai. These clumps have mK amplitudes and their detection represents a proof of concept for BAO's detection with future IM large interferometers.
Methods. We simulated the operation of Tianlai using the map-making software JSkyMap. We developed a pipeline that involves sources finding, multi-channel foreground subtraction, and processing of large samples of simulated observation strategies sky maps. Thus, the required sensitivity is proved by detections statistics.
Results. Using simulations of operations of the central seven-dish of Tianlai with 1 mK of instruments noise. We detected with an efficiency of 70 % clumps having an S/N=1.5 and with a negligible false detection rate.
Conclusion. Detecting nearby faint HI clumps with an amplitude in the order of mK requires a total exposure time of six months.

Key words: 21-cm cosmology, HI clumps, source finders, map-making artifacts

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1 INTRODUCTION

The universe's expansion has shifted from power law to an exponential function of cosmic time. While Dark Energy (DE) represents the ΛCDM interpretation of this acceleration, alternative theories use modifications of General Relativity. An observational cosmology method for constraining the expansion history consists of tracing Baryon Acoustic Oscillations (BAO) in the matter density field.

BAO represents the baryonic remnants of frozen oscillating overdensities in the baryons-photons fluid at photons decoupling time. At this epoch, they had the size of the sound horizon and later expand with cosmic time. Therefore, they manifested as an abundance of a given scale in the statistical properties of cosmological surveys. Thus, tracing BAO through redshifts gives indications of variations in the expansion rate.

BAO are often traced by visible matter distribution in optical/IR redshift surveys. These surveys observe stars' light inside galaxies. Redshift measurements are performed by photometry or involving photometric targeting followed by a spectroscopic measure. Then, redshift is converted to distance in order to make maps of surveyed volumes and extract statistical properties. Since the eighties, instruments and technics have been developed to improve precision, exposure time, number of analyzed objects per exposure, the field of view, and maximal measured redshift. Thus, the volume below $z = 2$ which includes the beginning of the acceleration epoch benefits from the cumulated data from many surveys that gave high precision measurements. A better constraining for DE or any other potential modified gravity theories during the pre-acceleration epoch requires at least the same level of precision for higher redshift. This is not guaranteed with such surveys above $z = 2$. Galaxies become fainter and surveys often use quasars as direct tracers or map neutral hydrogen on their line of sight with the Ly-α line. The rarety of these objects deteriorates the construction of the power spectrum. So, here is the need for new experiments that improve surveyed samples above $z = 2$. Currently, flagship optical/IR experiments such as Euclid, LSST, and DESI aim to increase surveyed volumes above $z = 3$ and will produce an unprecedented amount of data. In parallel, other non-optical techniques are under development.

The development of new high finish mechanical and electrical technology in Radio Interferometry, particularly digitalization at Gigahertz frequencies, has emerged the Intensity Mapping (IM) technique. IM aims at surveying volumes up to $z = 6$. **Such data**