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

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ABSTRACT

Context. As a category of 21 cm cosmology, the promising Intensity Mapping (IM) technique uses radio interferometry to constraint Dark Energy via Baryon Acoustic Oscillations (BAO) detection. IM is under development, five pathfinder interferometers are built to study its viability, resolve technical challenges, and determine the shape of future dedicated interferometers.
Aims. This work aims to prove the required sensitivity to detect faint and close HI clumps with the pathfinder Tianlai. These faint clumps are embedded in 10^4 brighter foreground and intstruments noise, their detection represents a proof of concept for BAO's detection with future IM large interferometers.
Methods. We simulated the operation of Tianlai around the North Celestial Pole (NCP) using the map-making software `JSkyMap`. We developed a pipeline involving a sources finder, a multi-frequency foreground subtraction method, and post-processing applying the finder on large samples of observation strategies sky maps. The required sensitivity is proved by detections statistics.
Results. Using simulations of operations of the central seven-dish of Tianlai with a gaussian instruments noise having $1mK$ standard deviation. 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 (mJy) requires a total exposure time of six months around the NCP region.

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

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1 INTRODUCTION

Currently, the main source of cosmological information is redshift surveys that trace galaxies' distribution by their stars' light emission in optical and IR wavelengths. 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 the surveyed volume. Nowadays, flagship optical/IR experiments such as Euclid, LSST, and DESI aim to increase surveyed volumes up to $z = 3$ and will produce an unprecedented amount of data. On the other hand, possible updates of the ΛCDM model, for instance constraining the universe's expansion history, require larger volumes of surveys. In this context, the development of new high finish mechanical and electrical technology in Radio Interferometry, particularly digitalization at Gigahertz frequencies, has emerged a new technique named Intensity Mapping (IM), able to quadruple the surveyed volume up to $z = 6$. Such volume allows studying the equation of state through the accelerated era and a large interval of the pre-accelerated era Cosmic Visions 21 cm Collaboration et al. (2018). Similarly, it produces a larger number of linear modes and allows constraining inflationary relics and non-gaussian correlation in primordial statistical properties. Furthermore, it introduces a new tracer to available cross-correlations below $z = 2$.

IM consists of mapping the intensity of the 21-cm spin-flip line of atomic hydrogen in the sky using a drift scan. Instead of locating galaxies by their stars' light, IM maps their atomic hydrogen reservoir. Therefore, It uses a limited angular resolution sufficient to measure the collective emission of galaxies outlining LSS without the need for resolving individual objects. Thus, IM uses sensitivity and resolution adapted to cosmological scale making it a practical and cost-effective surveying technique to be proposed as a part of the post-optical cosmology era. At present, IM is in the R&D phase and it is not yet been considered a competitor for optical surveys. Many pathfinder experiments were built or scheduled to address IM technical challenges such as Tianlai, CHIME, HIRAX, BINGO. Other general-purpose experiments such as LOFAR and SKA-low will offer valuable experiences in terms of calibration and data management. An example of future large interferometers dedicated to IM is PUMA described in Slosar et al. (2019). Up to this time, IM signals were measured in cross-correlations with optical catalogs using mostly large single dishes telescopes. The first proof of concept was obtained from a non-dedicated instrument