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

A. Hamie,[1,2]
[1]Paul Sabatier University, Toulouse, FRANCE (student)
[2]Linear Accelerator Laboratory, Orsay, FRANCE (intern)

25 April 2022

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

CONTENTS

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 that epoch, they had the size of the sound horizon and later expand as a function of 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 locate galaxies by their stars' light. Redshift measurements are performed by photometry or spectroscopy or both. Then, redshifts are converted to distances to extract statistical properties from the 3D galaxy distribution of surveyed volumes. Since the eighties, instruments and technics have been developed to improve precision, exposure time, number of analyzed objects per exposure, 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 resulting 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. Unfortunatelly, 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 extracted statistical properties. 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**