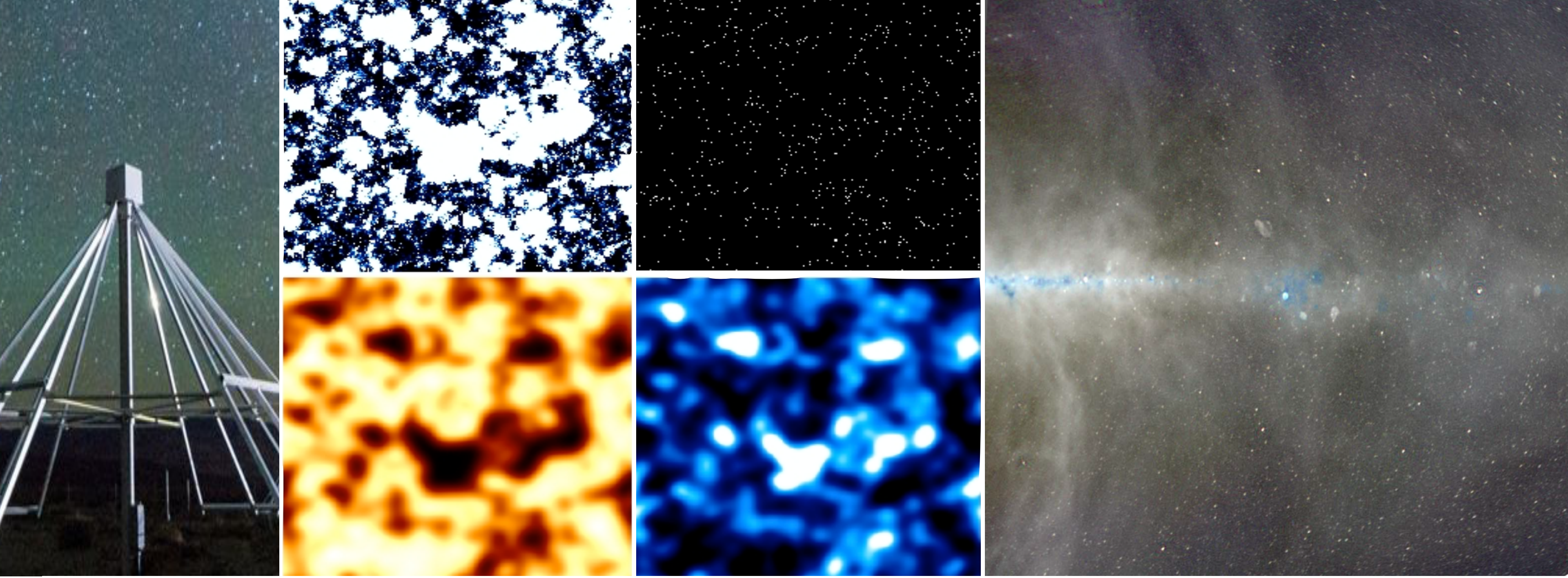

Virtual Research Presentation Conference

Intensity Mapping Data Analysis

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Tutorial Introduction

Abstract

The recently developed technique of intensity mapping uses the integrated emission from spectral lines in galaxies to track the growth and evolution of cosmic structure. The essential idea is that instead of trying to detect line emission from individual galaxies, one measures the total line emission from a number of galaxies within the defined volume comprising a spectral-spatial pixel. Fluctuations from pixel to pixel trace large-scale structure, and the evolution with redshift is revealed as a function of receiver frequency. We are developing data analysis tools, along with accompanying end-to-end simulations to test the pipeline and calculate transfer functions necessary for the measurement. Building such simulation tools to enable this calculation is our first objective. Second, we develop the data analysis pipeline, focusing on the map-making, component separation, and power spectrum estimation aspects, which build on new analysis techniques and modules we have developed.

Problem Description

a) While there have been early intensity mapping efforts (e.g., Chang et al. 2010; Cheng et al. 2018), these have provided primarily upper limits and several challenges remain for a full exploitation of this technique. This requires a large number of fast simulations appropriate for the emission lines during the EoR, which is currently lacking in the field.

b) **Caltech-JPL is the leading institution with strong involvement in most IM experiments.** Much of the current intensity mapping work is ground-based and key experiments are led by Caltech campus with JPL participation.

- GBT-HIM (21 cm, PI Chang, JPL), COMAP (CO, PI Cleary, CIT), TIME ([CII], PI Bock/Crites, CIT/JPL/Toronto), LWA (21 cm, PI Hallinan, CIT), SPHEREx (Ha/Lya, PI Bock, PS Doré, CIT/JPL)

c) **Mission possibilities** run the spectrum from Explorer-class missions that might focus on the CO lines not observable from the ground, to probe-class missions. For example,

- **SPHEREx** (MIDEX, Phase B, PI Bock) has an important IM component (PS Doré, Co-I Chang)
- **Cosmic Dawn Intensity Mapper** (CDIM) Probe study (PI Cooray, Study Scientist Chang, Co-I Doré) proposes multi-line IM of the Epoch of Reionization.
- **FARSIDE** Probe study (PI Burns, Co-PI Hallinan, Co-I Chang) has a 21cm Dark Ages component.
- **CHIC** 21cm Cosmic Dawn concept under study (MO; PI Chang, Co-I's Doré and Seiffert).
- **GEP** Galaxy Evolution Probe study (PI: J. Glenn) is investigating the IM science case.

Methodology

The two main goals of our task are:

1. **Build a semi-numerical simulation tool** appropriate for emission lines in the IM regime during cosmic reionization, based on the state-of-the-art code 21CMFAST (Mesinger et al. 2011) that focuses only on 21cm emission.

2. **Extend and employ a state-of-the-art spherical harmonic analysis tool** for drift-scan interferometric data from the LWA-OVRO to update the 21cm power spectrum limit at z=18.

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Results

LIMFAST : a semi-numerical simulation tool for computing line emission from galaxies at high redshift. We have created the main body of the code and are currently extending its capabilities.

Highlights:

- **Fast** simulations enabling various **reionization scenarios**.
- Modeling of **multiple emission lines**; Lya, Ha, Hb, [OII], [OIII], [NII], [CII], CO, 21cm, etc.
- Coverage of **large cosmic volumes** extending out to linear regimes.

Core structure and accomplishments:

- 21cmFAST simulation provides the distribution of matter and radiation background during reionization.
- Inclusion of analytical models of galaxy and star formation that provide the radiation sources at z = 5 - 25.
- Implementation of radiative transfer treatments to obtain emission maps for a large number of emission lines.
- Implementation of power-spectrum calculations for analysis of emission maps.

Results

Probing Cosmic Dawn with LWA-OVRO : The LWA-OVRO is an interferometric array of 288 dual-polarization dipoles channelizing at 24 kHz in the 27–85 MHz band ($50<z<16$ for HI). Eastwood et al 2018, 2019 developed a full *m*-mode map making and power spectrum pipeline to produce existing constraints on Cosmic Dawn with 28 hrs of data at 78 MHz. We are now updating the pipeline and using it to analyze a new dataset of **138 hour, full-band** data.

Highlights:

- **Deep, full-band** foreground maps.
- **High spectral resolution** that could enable study of radio recombination lines
- Potential **new limits on the 21cm power spectrum at Cosmic Dawn** (overlapping with EDGES, Bowman et al 2018).

Core structure and accomplishments:

- Completed confirmation of existing limit using the Eastwood et al 2019 *m*-mode pipeline and data.
- Identified several possibilities for pipeline optimization including ionospheric modeling and smooth-spectrum signal priors.
- Begun development of improved pipeline and processing of 138 hour dataset towards an improved 21 cm power spectrum limit at Cosmic Dawn.

Publications and References

Publications

[A] Mas-Ribas, Ll. & Chang, T. C., Physical Review D, Volume 101, Issue 8, article id.083032, 2020.

[B] Cheng, Yun-Ting, Chang, Tzu-Ching, Bock, James J., "Phase-Space Spectral Line De-confusion in Intensity Mapping", 2020, to appear in ApJ, arXiv:2005.05341

References

[1] Chang, T.-C., et al., 2010, Nature, 466, 463

[2] Cheng et al, 2018, ApJ, 868, 26

[3] Mesinger et al., Monthly Notices of the Royal Astronomical Society, Volume 411, Issue 2, pp. 955-972. 2011

[4] Eastwood, M. et al. 2018, AJ, 156. 32