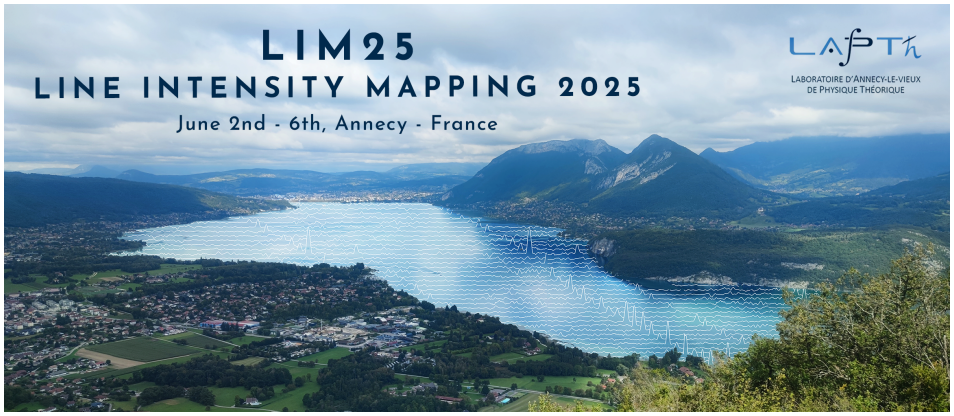
LIM25 - Annecy

lundi 2 juin 2025 - vendredi 6 juin 2025

Laboratoire d'Annecy de Physique Théorique (LAPTh)



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Opportunities in Optical/New Infrared Line Intensity Mapping

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Contributed Talks 10: LIM and Galaxy formation / 44

Harnessing the power of mm-wave intensity mapping to study early galaxy formation

Auteur: Guochao Sun[1]

Co-auteurs: Tzu-Ching Chang [2]; Claude-André Faucher-Giguère [1]; Steven Furlanetto [3]; Adam Lidz [4]; Tri Nguyen [1]; Bryan Scott [1]; Tjitske Starkenburg [1]

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Line intensity mapping (LIM) is an emerging technique in observational cosmology to spatially and spectrally map the aggregate line emission from large-scale structures, which promises to offer invaluable insights into physical processes that govern galaxy formation and evolution in the cosmological context. The mm-wave sky has been and will be surveyed by a number of LIM experiments such as CONCERTO, TIME, SPT-SLIM, FYST/CCAT-prime, and TIFUUN to study early galaxy formation and cosmic reionization. Novel simulation and analysis tools are thus needed to harness the full power of these LIM observations. I will discuss the development and applications of LIMFAST, a semi-numerical tool that builds on the 21cmFAST code for simulating a multitude of high-redshift LIM signals, including popular target lines like [CII] and [OIII] for mm-wave LIM experiments. I will first introduce how state-of-the-art models of galaxy formation in the early Universe are implemented in LIMFAST to realistically simulate the LIM signals. I will then present recent developments of a simulated-based inference framework that employs neural density estimation to learn key physical aspects of early galaxy formation, such as the star formation law and stellar feedback, from LIMFAST simulations of [CII] and [OIII] signals.

Contributed Talks 3: 21cm LIM, Analysis and Modeling / 45

Modeling Radio Recombination Line Contamination in 21cm Intensity Mapping

Auteur: Pip Petersen[1]

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Radio Recombination Lines (RRLs) are spectral lines produced through the transition between high principal quantum numbers (n > 150 in the context of this work). While RRL emission is individually weak at a single redshift (or over a narrow redshift band), intensity mapping integrates emission over

broad redshift ranges, allowing weak signals to compound. Additionally, multiple distinct RRLs at different redshifts can overlap with the 21cm observation band in frequency space, making them a potential contaminant in 21cm auto-power spectrum measurements. In this work, we develop an analytical model to assess the impact that large-scale RRL emission has on present and forthcoming post-reionization 21cm intensity mapping surveys. We find that both the RRL auto-power spectra and the 21cm-RRL cross-power spectra can introduce substantial contamination to the 21cm auto-power spectrum, with the effect enhanced for lines that fall close to the 21cm emission in physical space, and that this contamination can lead to BAO-like ringing in the cross-power spectrum. These preliminary results indicate the necessity of understanding the RRL contribution to observations and future analyses in this developing field.

Contributed Talks 5: CO LIM, Analysis and Modeling / **46**

Contributions of extragalactic emission lines to ground-based CMB observations

Auteur: José Luis Bernal[None]

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Similarly to the CIB, emission lines can be an appreciable source of extragalactic foreground anisotropies for CMB experiments. If bright enough, they may be a relevant component to account for in component separation, given their strong correlation with the CIB, and even extracted as signal from the CMB observations. Therefore, they may entail both a challenge and an opportunity for modelers and observers.

We focus on the CO rotational lines at redshifts $z \sim 0 - 6$, using an empirical parametrizations for the CO luminosities based on sub-mm observations. We find that at $\ell = 3000$ the amplitude of both CO autocorrelation and cross-correlation with the CIB could be detectable in an ACT-like experiment, especially when cross correlating different frequency bands. This implies that current observations can potentially be used to constrain the bright end of CO luminosity functions, which are difficult to probe with current sub-mm telescopes due to the small volumes they survey. We will discuss the significant implications in template-based searches for CMB secondaries, such as the kSZ, and potential strategies to isolate and measure the contribution from emission lines.

Contributed Talks 9: HEDTEX/CIBER/PRIMA / **47**

HETDEX: A Lyman-alpha Intensity Mapping Survey

Auteur: Maja Lujan Niemeyer[1]

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The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a spectroscopic galaxy survey mapping locations of one million Lyman-alpha-emitting galaxies (LAEs) at z~2-4. It also produces a huge 3D Lyman-alpha map that is ideal for intensity mapping. In this talk we present forecasts for intensity mapping with HETDEX using SIMPLE, a lognormal simulation framework. Because the complex radiative transfer of Lyman-alpha photons can cause RSD-like effects in galaxy clustering, we explore these effects in the context of Lyman-alpha intensity mapping.

Contributed Talks 16: LIM Analysis and Modeling / **48**

Computing the Power Spectrum Super Sample Covariance for LIM Surveys

Auteurs: José Luis Bernal[None]; Sefa Pamuk[1]

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The super sample covariance (SSC) appears in the form of a mode coupling for modes larger than the survey volume and modes inside the survey. Since typical line intensity mapping (LIM) surveys have limited sky coverage we believe that the contribution of the SSC to the covariance is non-negligable. We will present a mathematical framework to compute the theoretical SSC for the LIM power spectrum.

Contributed Talks 3: 21cm LIM, Analysis and Modeling / 49

21-cm LIM with MWA: The case of the missing channels

Auteurs: Akash Patwa[None]; Khandakar Md Asif Elahi[1]; Samir Choudhuri[None]; Shiv Sethi[None]; Shouvik Sarkar[None]; Somnath Bharadwaj[2]; Suman Chatterjee Chatterjee[3]

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The Murchison Widefield Array (MWA) is an excellent radio-interferometer for 21-cm line intensity mapping from the epoch of reionization (EoR). A major challenge in MWA data analysis is the periodic pattern of flagged channels in the visibility data, which leads to severe foreground contamination in the EoR window. We have developed a novel technique to mitigate this challenge, and realistic simulations show that our method can put reliable constraints on the 21-cm power spectrum even in the presence of periodically flagged channels. The key idea is that we first correlate the visibilities to estimate $C_\ell(\Delta\nu)$, and Fourier transform it to get the power spectrum $P(k_\perp, k_\parallel)$. $C_\ell(\Delta\nu)$ does not have a gap even when we have many frequency channels (ν) missing. We have put a significantly tight upper limit of $\Delta^2(k) < 934\,\mathrm{mk}^2$ at $k = 0.4\,\mathrm{Mpc}^{-1}$ for $z = 8$, with just 17 minutes of observation. Ongoing analysis of the entire 55 hours of the data indicates tighter constraints. We also see residual systematics due to limitations in our methods, and these necessitate further investigations.

Conntributed Talks 12: LIM and EoR / 50

The Dawn of Multi-Line Intensity Mapping

Auteur: Sarah Libanore[1]

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Line intensity mapping (LIM) offers a powerful way to explore uncharted regimes by capturing the cumulative photon flux from bright and faint sources. Among various applications, upcoming LIM surveys are expected to provide a unique view of the Epoch of Reionization and the Cosmic Dawn, when the first galaxies formed and neutral hydrogen still filled the intergalactic medium.

In this talk, I will present a self-consistent framework for modeling line cross-correlations and discuss its potential to constrain both cosmology and astrophysics. Recent developments are bringing us closer to the possibility of measuring such cross-correlation: HERA and LOFAR are setting upper limits on the 21-cm signal, while the launch of SPHEREx will soon enable observations of key emission lines. I will focus on the possibility of correlating the 21-cm signal and star-forming lines such as CII, OIII, Lyman-α. This correlation is expected to transition from positive at high redshift —when both signals are driven by high star formation regions —to negative as ionized bubbles form. This shift offers a powerful tool for constraining cosmological and astrophysical models through its sensitivity to the underlying matter power spectrum and star formation models. With new data in the coming years, multi-line intensity mapping will provide a powerful tool for constraining cosmological and astrophysical models, offering unprecedented insights into the Cosmic Dawn and the Epoch of Reionization.

Conntributed Talks 12: LIM and EoR / **51**

Detecting signature of helium reionization through line-intensity mapping

Auteur: Benedetta Spina[1]

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Helium reionization represents the most recent global transformation of the intergalactic medium, yet its main drivers and evolution remain poorly understood. Upcoming radio surveys aim to probe the Epoch of Reionization (EoR) using line-intensity mapping (LIM) techniques, with the most promising instruments being the Square Kilometre Array Phase 1 (SKA-1) MID, the Deep Synoptic Array 2000 (DSA-2000), and the Packed Ultra-wideband Mapping Array (PUMA). Similar to the 21 cm signal from neutral hydrogen (HI), singly ionized helium-3 can be mapped through its 3.46 cm emission line, which benefits from a higher spontaneous decay rate and a higher rest frequency (8.66 GHz) compared to HI.
We aim to determine the integration time required to detect the power spectrum of the 3.46 cm signal with radio surveys and to distinguish between different reionization models. To this end, we employ two suites of hydrodynamical simulations: one based on a standard late-reionization scenario (3
$lesssimz$
$lesssim5$) and another incorporating an alternative quasar luminosity function that leads to early reionization (5
$lesssimz$
$lesssim12$). We construct mock data cubes that account for various noise sources and compute the 3D power spectrum. Our results indicate that the 3.46 cm signal is strongly coupled to the cosmic microwave background (CMB) signal, making it challenging to disentangle the two and measure the power spectrum of the helium-3 brightness temperature alone. The integration time required to achieve a reasonable signal-to-noise ratio ranges from several months to years, depending on the instrument and redshift range. Unless combined with other observational probes, LIM techniques alone are unlikely to provide meaningful constraints on helium reionization in the near future.

Contributed Talks 6: ALMA/TIME/CCAT / **52**

Line Intensity Mapping with the ALMA Archive

Auteur: Christos Karoumpis[1]

[1] *University of Bonn*

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In anticipation of upcoming line-intensity mapping (LIM) experiments targeting CO and [CII] emission at z > 4, we have analyzed archival data from the Atacama Large Millimeter/submillimeter Array (ALMA) to place new constraints on CO(J_up = 3–6) line emission from galaxies at z = 1–5. Focusing on the well-studied COSMOS field, we take advantage of ALMA archival observations to probe the small, shot-noise-dominated scales of CO emission. By reanalyzing the archival data cubes within a LIM framework, we constrain the CO luminosity functions over cosmic time. These limits will not only refine our picture of molecular gas reservoirs in distant galaxies, but also pave the way for future high-redshift LIM studies in the COSMOS field, where CO lines from intermediate redshifts will serve as foregrounds. In this talk, I will outline our methodology, discuss the challenges of extracting faint signals from archival data, and present preliminary constraints that highlight the potential of using ALMA archives to probe molecular gas in the early universe.

Contributed Talks 2: MeerKLASS & SKA / 53

Hydrogen intensity mapping with MeerKAT: ongoing efforts

Auteur: Isabella Paola Carucci[1]

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In the radio band, we do LIM with the redshifted 21-cm radiation emitted by cosmic neutral hydrogen, HI. It is the most abundant baryonic component of the Universe, making it an ideal large-scale structure tracer, and it is the primary fuel of star formation, making it essential for understanding galaxy evolution. I'll focus on our current efforts to perform HI IM observations with the MeerKAT radio telescope. We tested our analysis pipeline by measuring the cross-correlation signal with an overlapping galaxy dataset; I'll describe those measurements and what they taught us. Results are encouraging and have instilled in us the confidence to pursue a direct detection of the HI cosmological signal, which I'll peer towards. In perspective, our ongoing work marks a milestone for the cosmology science case with the entire SKA Observatory (which the MeerKAT dishes will be part of in less than 5 years).

Contributed Talks 10: LIM and Galaxy formation / 54

Symbolic regression on chemical network for hydrodynamic simulations

Auteurs: Azadeh Moradinezhad[1]; Francisco Villaescusa-Navarro[2]; Zucheng GAO[3]

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The astrophysical uncertainty in line intensity mapping remains an obstacle to overcome. One of the promising solutions is to generate line intensity maps from hydrodynamic simulations (HD sims) with varied astrophysical properties. Running chemical network (CN) for gas particles in HD sims provides a realistic way to link the astrophysical properties with line luminosities. Given the gas properties, the CN iterates the thermal, chemical and radiative equilibrium equations until it converges, and then assign the luminosity of lines, such as [C II], CO, etc., based on the chemical abundance. However, running the CN is computationally demanding, while it does not explicitly show the connection between gas properties and line luminosities. In this work, we apply the symbolic regression on gas particles spanning a large parametric space. The obtained analytical expression helps us with not only speeding up generating of luminosity, but understanding the physics from astrophysical parameters to line luminosities.

Contributed Talks 11: LIM Analysis and Modeling / 55

Three-Dimensional Stacking as a LIM Statistic

Auteur: Delaney Dunne[1]

Co-auteurs: Kieran Cleary [1]; Patrick Breysse [2]; Dongwoo Chung [3]; Havard Tveit Ihle [4]; Jonas Lunde ; Hamsa Padmanabhan [5]; Nils-Ole Stutzer [4]

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LIM will rely heavily on joint analyses with traditional catalogs of galaxies to increase sensitivity, mitigate systematic errors, and study the coevolution of different tracers of galaxy formation and evolution. The joint analysis of choice has traditionally been cross-correlation, for its information content across a range of spatial scales, but other techniques can complement and extend cross-correlation results. In this talk, I will provide an in-depth view of one such technique –three-dimensional stacking. Especially in the current, early stage of the LIM field, the simplicity and robustness of stacking analyses have the potential to be extremely valuable. Using a multi-tracer simulation pipeline, I will demonstrate that the signal in a stacking analysis is dominated by clustering to a much greater extent than previously expected. I will also test various choices in the experimental design of both the LIM experiment and the galaxy catalog on which it is being stacked, and determine the optimal set-up for performing a stacking analysis.

Contributed Talks 13: Multiline/Multiwavelength Analysis / 56

A New Data-Driven Technique To Mitigate The Foregrounds Of Line Intensity Maps

Auteur: Hannah Fronenberg[1]

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Line intensity mapping (LIM) is an emerging observational technique for mapping the large-scale structure of the Universe across a broad redshift range. Multiple surveys targeting various spectral lines are now underway or soon to come online, aiming to make some of the first early statistical measurements. Despite this progress, foreground contamination remains a significant challenge for LIM across virtually all wavelengths, and many existing mitigation techniques have struggled to yield successful detections. In particular, astrophysical foregrounds with broad frequency structure pose a major obstacle. In this talk, we present a novel foreground mitigation scheme designed to remove broadband contaminants in LIM observations while accounting for instrumental response and systematic effects. Using a fully data-driven approach, we demonstrate that a trio of intra-dataset frequency-frequency cross-correlations enables an empirical estimate of the foreground power spectrum, which can then be subtracted from the data. As a case study, we simulate 21cm observations under various experimental configurations, such as single-dish instruments and radio interferometers, while incorporating systematic contaminants. We will showcase how one can achieve, under idealized conditions, percent-level signal residuals, demonstrating that nearly 4–5 orders of magnitude of foreground contamination can be removed in a single analysis step. We will also briefly comment on the limitations of this method and identify scenarios where the estimator is expected to break down.

Contributed Talks 13: Multiline/Multiwavelength Analysis / 57

Clues from Q –A null test designed for line intensity mapping cross-correlation studies

Auteur: Debanjan Sarkar[1]

Co-auteurs: Adrian Liu [1]; Ella Iles [1]

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In a future where multiple spectral lines have been mapped over the same cosmological volume, one can imagine not only performing cross-correlations to extract joint information between lines, but also as a tool for checking self-consistency of results. This can be particularly important given uncertain radiative transfer properties of various spectral lines that are only now beginning to be mapped, amongst other modelling concerns. In this talk, we illustrate how a combinations of cross power spectra can be used as a data-driven approach to verify the validity of linear biasing models, testing rather than assuming commonly used "first order"models for large scales.

Contributed Talks 5: CO LIM, Analysis and Modeling / 58

Creating Mock Maps for Line Intensity Mapping Experiments

Auteur: Doğa Tolgay[1]

Co-auteurs: Dongwoo Chung [2]; J. Richard Bond [1]; Norman Murray [1]

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Line Intensity Mapping (LIM) provides access to previously elusive data, facilitating statistical analysis. Many LIM experiments are currently in the pathfinder stage, and the absence of confirmed detections underscores the critical role of mock maps for exploring the correlations between line emissions and galaxy properties. Mock maps are created by painting the dark matter halos according to the response functions that utilize the relation between the observables in galaxies and the line luminosities. While the relation between observables and the line luminosities is very complex, statistical correlations can be established. In my presentation, I will elucidate the statistical relationship between line luminosity and inherent/derived observables for simulated FIRE (Feedback In Realistic Environment) galaxies, focusing on CO(1-0) to CO(8-7) lines at four different redshift regimes: z=0, 1, 2, and 3. The outputs of this work can be used to create mock maps and improve the pipeline of COMAP, EXCLAIM, mmIME-COPSS, CONCERTO, CCAT, AIM-CO, SPT-SLIM, and TIME experiments.

I will begin by introducing the FIRE simulations and post-processing methodology. Subsequently, I will elaborate on the evolution of CO luminosity from redshift three to the present day and compare it with available observations. Finally, I will examine the correlations between CO emission and galactic properties at different redshifts and explore the potential causal relationships they may suggest.

Contributed Talks 11: LIM Analysis and Modeling / 59

Understanding the LIM Galaxy Power Spectrum: The Role of Shot Noise, Satellite Galaxies, and Secondary Bias

Auteurs: Kana Moriwaki[1]; Rui Lan Jun[1]; Sownak Bose[2]; Tom Theuns[2]

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We present a physically motivated model for the power spectrum of galaxies weighted by their star formation rates, decomposing it into a 1-halo and 2-halo term while incorporating key effects such as nonlinear bias, scale-dependent shot noise and halo exclusion. Our model reproduces the LIM TNG power spectrum to within a few percent across all scales. We find that omitting satellite galaxies leads to an underestimation of both the large-scale bias and the mean intensity by approximately 30% at z~1.5.
Additionally, we investigate the impact of secondary bias, revealing systematic errors of ~5% in the 2-halo term and ~10% in the 1-halo term. These results highlight the importance of accurately modelling galaxy-halo connections and halo-scale effects to extract optimal information from LIM surveys.

Contributed Talks 3: 21cm LIM, Analysis and Modeling / 60

Results from CHIME

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(placeholder for interesting results)

Contributed Talks 4: COMAP / 61

Simulating systematics in COMAP

Auteur: Leah Hansen[1]

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In this talk we present a physically motivated signal simulation of the most central systematics in the COMAP telescope. While the Season 2 COMAP results provided the strongest constraints on cosmological CO line emission to date, 75% of the data were cut due to systematic errors. Properly understanding, and subsequently mitigating, the systematics are crucial in order to recover the lost data. This is an important step towards obtaining the first COMAP detection. The most significant systematics modeled are a detailed time-varying ground pickup model and a standing wave model. The systematics are simulated at the TOD level, and propagated through the COMAP data analysis pipeline. We present time-domain, map-domain and power spectra analysis of the simulated signal systematics before and after the pipeline filtering.

Contributed Talks 6: ALMA/TIME/CCAT / 62

CCAT: Submillimeter Line Intensity Mapping of [CII] and CO with FYST

Auteur: Jonathan Clarke[1]

Co-auteurs: Ankur Dev [2]; Rodrigo Freundt [3]; Christos Karoumpis [4]; Thomas Nikola [3]; Tejas Oak [5]; Yoko Okada [6]; Dominik Riechers [7]; Gordon Stacey [3]; Wider CCAT Collaboration

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The components of FYST (the Fred Young Submm Telescope) are arriving in Chile at the time of writing (March 2025) and the assembly of the observatory is anticipated to finish in the second half of 2025. In early 2026 we expect first light with Prime-Cam, a modular receiver for FYST, with the EoR-Spec (Epoch of Reionization Spectrometer) instrument module being deployed later that year, setting the table for initial line intensity mapping observations and the Deep Spectroscopic Survey (DSS) in early 2027. It is important to make accurate forecasts for the first stages of the [CII] LIM observation in the 210-420GHz range. These predictions include the [CII] signal at redshifts between 3.5 and 8, expected CO interloper signal at lower redshift, and atmospheric noise. They also inform how well the aforementioned noise sources can be removed from the signal. We present results from the latest simulations, including the impact of masking and cross-correlation techniques in recovering [CII] signal. We also show possible synergies for CO observations with other instruments. In addition, we present the updated status of the telescope and instrument, for the initial observation period and shortly thereafter.

Contributed Talks 13: Multiline/Multiwavelength Analysis / 63

There and back again: Recovering autospectra information from crosscorrelation measurements

Auteur: Elizabeth Mc Bride[1]

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Intensity mapping experiments will soon have surveyed large swathes of the sky, providing information about the underlying matter distribution of our early Universe. The resulting maps can be used to recover statistical information, such as the power spectrum, about the measured spectral lines (for example, H i, [C ii], and [O iii]). However precise power spectrum measurements, such as the 21 cm autocorrelation, continue to be challenged by the presence of bright foregrounds and non-trivial systematics. By cross-correlating different data sets, it may be possible to mitigate the effects of both foreground uncertainty and uncorrelated instrumental systematics. Beyond their own merit, cross-correlations could also be used to recover autocorrelation information, and such a technique has been proposed in the literature for recovering the 21 cm power spectrum. Generalizing this result, I will present a statistical framework for combining multiple cross-correlation signals in order to infer information about the corresponding autocorrelations. I do this first within the least squares estimator framework, and show how one can derive the previously proposed technique, along with

several alternative estimators. I also investigate the posterior distribution of recovered autocorrelation and associated model parameters. I will show that, for certain noise regimes and cosmological signal modelling assumptions, this procedure is effective at recovering autospectra from a set of cross-correlations. Finally, I will showcase this new framework in the context of several near-future line intensity mapping experiments.

Contributed Talks 16: LIM Analysis and Modeling / 64

CCAT EoR-Spec: Observation planning from commissioning to the full deep spectroscopic survey

Auteur: Yoko Okada[1]

Co-auteurs: Ankur Dev ; Dominik Riechers ; Gordon Stacey ; Jonathan Clarke ; Thomas Nikola

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In this talk, we present the current status of the observation planning for the CCAT (Cerro Chajnantor Atacama Telescope) EoR-Spec (Epoch of Reionization Spectrometer). EoR-Spec is one of the Prime-Cam modules of Fred Young Submillimeter Telescope (FYST) operated by the CCAT Observatory. It covers the frequency range between 210 to 420 GHz and uses a cryogenic scanning Fabry-Perot Interferometer with a resolving power of ~100 as its spectral device. EoR-Spec will be installed in Prime-Cam during the second year of CCAT operation. The primary science goal of the EoR-Spec is the investigation of the evolution of the ionizing sources during and post EoR. This is accomplished by a deep spectroscopic survey (DSS) of the E-COSMOS and E-CDFS fields in [CII] via the line intensity mapping method, covering the redshift between 3.5 to 8. We performed coverage simulation of DSS with various scanning patterns and parameters and investigated the mapping efficiency and homogeneity. We will also present the calibration strategy, as well as plans for commissioning and the early science phase.

Contributed Talks 10: LIM and Galaxy formation / 65

SLICK-LIM: A Physically-Motivated, AI-Assisted Framework for Forecasting Molecular Line Intensity Mapping Experiments

Auteur: Karolina Garcia[1]

Co-auteur: TIM Collaboration

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Accurately interpreting Line Intensity Mapping (LIM) across a broad range of redshifts requires methods that complement traditional empirical relations, which may not fully capture the complexity of astrophysical processes. Cosmological hydrodynamical simulations coupled with Photodissociation Region (PDR) modeling and machine learning techniques provide physically motivated predictions at scalable simulation volumes with manageable computational costs. Building upon these efforts, I've been leading the development of SLICK-LIM, a forecasting framework built on the Scalable Line

Intensity Computation Kit (SLICK), designed to efficiently generate realistic predictions for CO, [CI], and [CII] emission lines in large volumes. Applying SLICK-LIM to leading cosmological simulations —SIMBA, IllustrisTNG, and CAMELS—I will present forecasts for upcoming LIM experiments and explore how variations in key astrophysical and cosmological parameters impact the predicted line intensity power spectrum. Finally, I'll present ongoing efforts to develop the data reduction pipeline and associated astrophysical modeling for the Terahertz Intensity Mapper (TIM).

Contributed Talks 14: LIM and Cosmology / 66

Constraining the [CII] Luminosity Function and the nature of Dark Matter with the LIM power spectrum

Auteur: Elena Marcuzzo[1]

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Forthcoming measurements of the LIM power spectrum (PS) are expected to set valuable constraints on several astrophysical and cosmological quantities. We present two forecasts for the FYST Deep Spectroscopic Survey (DSS) at z⊠3.6 and also make predictions for future wider and/or more sensitive surveys.
The first study targets the [CII] luminosity function (LF), which is still highly uncertain due to the limitations of current observations. Our Bayesian analysis shows that the DSS should be able to constrain the clustering and shot-noise components of the PS –which provide information on the moments of the LF –with a signal-to-noise ratio of ~3 or higher, depending on the actual underlying LF. By jointly fitting the PS and the LF (from ALPINE data) we directly constrain Schechter-function parameters. We find that the normalisation and the break are precisely and accurately measured while the faint-end slope remains highly uncertain (unless α approaches -2). Notably, increasing the survey sensitivity by a factor of $\sqrt{10}$ at fixed sky coverage yields greater improvement than covering a 10x larger area at fixed sensitivity.
The second study extends our approach to probing the nature of dark matter (DM). We consider cold and warm thermal relics and set constraints on their mass. Our results show that, in a CDM universe, warm candidates with masses below 1–3 keV can be ruled out, depending on the survey area and the underlying [CII] LF.

Contributed Talks 5: CO LIM, Analysis and Modeling / 67

Joint component separation for multi-tracer mm-wave intensity mapping

Auteur: Carlos Sierra[1]

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The constraining power of upcoming line intensity mapping surveys will be limited by the presence of bright foregrounds and line interlopers. In this work, we implement a CMB-style multi-component separation framework to isolate emission lines of interest by considering correlations between all sources. Working in the context of CO mapping, we model and jointly fit all relevant mm-wave signals—CO and [CII] line emissions, diffuse Galactic emissions, the CMB and SZ effects, and the cosmic infrared background—within a single power spectrum likelihood that incorporates

the multi-frequency covariance of these signals. We highlight the significant cross-power information provided by external galaxy surveys to break degeneracies. By preserving the full statistical content of both the intensity mapping and galaxy datasets, we show that this approach leads to an enhanced recovery of the CO power spectrum.

Contributed Talks 8: SPHEREx / 68

Intensity Mapping with SPHEREx Deep-Field Near-Infrared Maps at 102 Wavelengths

Auteur: Shuang-Shuang Chen[1]

Co-auteurs: Ari Cukierman [1]; Asantha Cooray [2]; Chi Nguyen [1]; Darren Dowell [3]; Giulia Murgia [1]; Howard Hui [1]; Jae Hwan Kang [1]; Jamie Bock [1]; Jordan Mirocha [3]; Mary Minasyan [1]; Michael Zemcov [4]; Olivier Doré [5]; Phil Korngut [1]; Tzu-Ching Chang [3]; Yun-Ting Cheng [1]

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I will present the SPHEREx map-making pipeline, a key component of our effort in intensity mapping. SPHEREx is an all-sky near-infrared spectral survey that was launched in early March. One of its three main science goals is to explore the origin and evolution of galaxies and probe the epoch of reionization (EoR) through a deep survey mapping large-scale structure. SPHEREx will produce two deep-field spectral mosaic maps, each covering ~100 deg^2 in 102 wavelengths near the north and south ecliptic poles, with high sensitivity ideal for studying the extragalactic background light (EBL). The EBL maps contain total galactic light production, including faint and diffuse sources such as unresolved low-redshift galaxies, intra-halo light (IHL), and sources from EoR. Joint analysis of auto- and cross-channel power spectra enables component separation, providing constraints at different angular scales. The amplitude of the linear clustering signal traces the cosmic star formation history. In addition, cross-correlation with galaxy surveys enables redshift tomography, as EBL emission correlates only with galaxies at the same redshift. By leveraging SPHEREx's 3D line intensity cubes, we can conduct multi-line intensity mapping and probe galaxy evolution with high signal-to-noise. Our map-making pipeline processes exposure images to mosaic maps and computes power spectra. We remove zodiacal and Galactic foregrounds, calibrate instrumental effects, and validate our analysis by propagating simulated observations through the pipeline. I will present the current status of SPHEREx intensity mapping with our deep-field maps across 102 wavelength bands. Additionally, we can generate maps in other regions of the sky for different science objectives.

Contributed Talks 4: COMAP / 69

Reionization Cross-Correlations with COMAP-Wide

Auteur: Patrick Breysse[1]

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I will introduce COMAP-Wide, an extension to the ongoing CO Mapping Array Project. Currently, COMAP is operating an autocorrelation-focused CO intensity mapping survey targeting ~12 square degrees of total sky area. COMAP-Wide aims to complement this deep survey with a wide-area, cross-correlation-focused measurement of ~400 square degrees. The primary target of COMAP-Wide will be a cross-correlation between the CO(2-1) rotational line and reionization-era 21 cm measurements from the LOFAR interferometer, with a long-term goal of measuring the size of EoR bubbles. In this talk, I will describe the COMAP-Wide survey and discuss it's ability to constrain the CO and HI signals from the EoR. I will also briefly summarize possibilities for lower-redshift cross-correlations.

Contributed Talks 9: HEDTEX/CIBER/PRIMA / 70

PAH Intensity Mapping with SPHEREx and PRIMA

Auteur: Yun Ting Cheng[None]

Auteur correspondant ycheng3@caltech.edu

Polycyclic aromatic hydrocarbons (PAHs) produce some of the most prominent emission features in the infrared spectra of galaxies. PAHs play a crucial role in the thermal balance and chemistry of the ISM and serve as a good tracers of star formation activity and dust abundance. Ongoing and planned upcoming missions such as SPHEREx and PRIMA will enable the study of multiple PAH features in galaxies across cosmic time. An intensity mapping approach offers a powerful means to probe the aggregate PAH emission from all galaxies, providing complementary information to individual source detection. However, since PAH features are broad spectral structures that can be resolved across multiple spectral channels in a typical lLIM observation, the standard LIM formalism must be adapted for PAH intensity mapping. In this work, we develop a framework that fully accounts for the spectral convolution between PAH features and observed filters in the intensity mapping context. Using this framework, we forecast the sensitivity of SPHEREx and PRIMA in detecting PAH intensity as a function of redshift.

Contributed Talks 14: LIM and Cosmology / 71

Constraining primordial non-gaussianity in the WebSky2.0 line-intensity mock maps

Auteur: Nathan Carlson[1]

Co-auteurs: Dongwoo Chung [2]; J. Richard Bond [3]

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Upcoming LIM surveys require extensive modelling to effectively separate faint signals from foregrounds. The WebSky mock maps are one such model, consisting of simulated sky maps that are statistically analogous to LIM observations. WebSky maps have been used extensively to study the cosmic microwave background (CMB), and the new WebSky2.0 simulations deliver the resolution and modelling updates to make mock maps for upcoming LIM observatories that will deliver new insights into cosmology. WebSky2.0 mocks are fast and efficient and can be generated for universes with beyond-the-standard-model cosmologies such as primordial non-Gaussianity (PNG), allowing us to directly test theoretical cosmology against observational LIM data. Of particular interest are primordial intermittent non-gaussianities (PINGs), a general class of non-Gaussianity that is produced in multi-field inflation models and may not be easily observed using conventional tests of PNG. We demonstrate that PINGs can be constrained using the WebSky2.0 LIM mocks for the CCAT

and COMAP observatories, and propose PINGs as a potential science case for upcoming LIM surveys.

Contributed Talks 4: COMAP / **72**

The COMAP power spectrum methodology towards a future CO detection

Auteur: Nils-Ole Stutzer[1]

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In this talk, we will present the state-of-the-art COMAP power spectrum methodology, discuss key lessons learned since the COMAP Season 2 release, and mention some advantages of a joint COMAP-Pathfinder and COMAP-Wide analysis. The COMAP power spectrum methodology relies on cross-correlating maps made by specific configurations of detectors and elevations, each with largely independent associated detector- or elevation-specific systematic effects. This yields a CO estimator that is both sensitive and robust against systematic effects. Furthermore, the methodology can easily be adapted to other experiments and incorporated into any existing or future end-to-end cosmological data analysis pipeline. This will be especially important in the coming years when integrating down towards the first CO LIM detections and jointly analyzing data sets like those of the COMAP-Pathfinder, COMAP-Wide, and others. As the sensitivity of COMAP is approaching that needed to detect a signal at the level of our fiducial model, we will consider how to balance the sensitivity and robustness against systematic effects. We will also show some correlations in $(k_\perp, k_\parallel)$-space not yet accounted for, and how we can use our power spectrum methodology to investigate the origin and morphology of systematic effects in $(k_\perp, k_\parallel)$-space.

Contributed Talks 11: LIM Analysis and Modeling / **73**

Understanding the extended [CII] halo and its implications for LIM with cosmological zoomed simulations

Auteur: Lunjun Liu[1]

Co-auteurs: Guochao Sun [2]; Andreas Faisst [3]; Claude-André Faucher-Giguère [2]; Adam Lidz [4]

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Several ALMA programs have shown the ubiquity of extended [CII] halos in high-redshift galaxies. Not only can such extended structures potentially affect the [CII] line intensity mapping (LIM) signal, but they also provide a unique avenue to understand the formation and evolution of high-z galaxies, whose supernova-driven outflows may eject [CII]-emitting gas from star-forming regions out to ~10kpc scale. To understand the physical origin and time evolution of the extended [CII] emission, we leverage 3D dust radiative transfer and photoionization simulations to produce synthetic observations of the galaxy-scale [CII] emission for a large sample of simulated galaxies from the Feedback in Realistic Environments (FIRE) project. With spatially resolved interstellar medium, these cosmological zoomed simulations enable detailed investigations to (1) differentiate the contributions to the extended [CII] emission from satellite galaxies versus galactic outflows, and (2) characterize the

strength and variability of the extended [CII] emission and how it connects to the scatter of galaxy-scale [CII] luminosity. In this talk, I will discuss the comparison between our simulated profiles of [CII] emission and observations, along with the impact of this extended emission on the high-z [CII] LIM signal.

Contributed Talks 2: MeerKLASS & SKA / **74**

Unveiling the HI auto-power spectrum with MeerKAT

Auteur: Matilde Barberi Squarotti[1]

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Neutral hydrogen (HI) intensity mapping is emerging as a revolutionary probe of the Large Scale Structure of the Universe and the MeerKLASS collaboration (MeerKAT Large Area Synoptic Survey) is currently running precursor analyses aiming to test the single-dish technique for mapping the cosmological 21cm signal using MeerKAT data. This signal, originating from the line emission at 1420MHz of HI permeating the cosmic web, is extremely weak compared to astrophysical contaminants, making foreground removal one of the major challenges to tackle.
I will present the analysis of 2021 MeerKAT L-band data, focusing on foreground cleaning strategies and, most notably, on the implementation of internal cross-correlations to mitigate noise and systematics. This technique enabled the first-ever detection of the cosmological HI signal at large scales that didn't require an external spectroscopic galaxy datasets for cross-detection. The results obtained show robustness against a variety of consistency tests performed and agreement with previous constraints coming from the cross-correlation of previous MeerKAT data and WiggleZ galaxies.

Contrinbuted Talks 7: EXCLAIM/TIM/TIFUUN/SPTSLIM / **75**

Simulating line intensity mapping observations with TIFUUN on ASTE

Auteur: Kanako Narita[1]

Co-auteurs: Bunyo Hatsukade [2]; Kana Moriwaki [3]; Kotaro Kohno [3]

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Recent observations by the James Webb Space Telescope have discovered numerous high-redshift galaxies, suggesting that galaxies may have evolved from an earlier stage of the Universe than expected. Exploring when heavy elements like carbon began to accumulate in the universe is an essential question in astronomy. Line intensity mapping (LIM) at millimeter to sub-millimeter wavelengths provides a comprehensive understanding of high-redshift galaxies, including both bright and faint ones, and their carbon contents by detecting signals from C+, C0, and CO. The Terahertz Integral Field Unit with Universal Nanotechnology (TIFUUN)[1], which leverages the integrated superconducting spectrograph technology demonstrated by DESHIMA [2][3][4], will provide a new capability for the sub/mm-LIM when deployed at the Atacama Sub-millimeter Telescope Experiment (ASTE).
In this research, we investigate the constraining power of TIFUUN on ASTE, when TIFUUN is equipped with two integral field units (IFUs) optimized for LIM. We assume provisional survey specifications of $\sigma \approx 1$ mJy/beam and R = 500 at Band 1 (124-180 GHz with the angular resolution of 48

arcsec) and Band 2 (248-301 GHz with the angular resolution of 27 arcsec) over an area of 1 deg^2, and use mock observational data generated from the Illustris-TNG simulation. We find that more than 100 individual sources of [CII] at z ~6 could be detected at a significance of 5σ or greater, allowing us to constrain the [CII] luminosity function at the brightest end. Contributions from faint galaxies will be detected through power spectrum; however, it is necessary to remove bright foreground CO line galaxies. In this presentation, I will discuss foreground removal and its implications for the detectability of the [CII] power spectrum at z~6 using TIFUUN on ASTE. Specifically, I will explore an approach that combines multiple techniques, including a masking method based on a galaxy catalog and a cross-correlation analysis leveraging the detection of multiple emission lines, to effectively mitigate foreground contamination.

[1] Nishimura, Y., et al. 2025, LTD2025
[2] Endo, A., et al. 2019, Nature Astronomy, **3**, 989
[3] Taniguchi, A., et al. 2022, Journal of Low Temperature Physics, **209**, 278
[4] Endo, A., et al. 2025, LTD2025

Contributed Talks 14: LIM and Cosmology / **76**

Large Scale Structure analysis using line intensity mapping

Auteur: Yuka Yamada[1]

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With upcoming wide-field line intensity mapping(LIM) projects such as SPHEREx and SKA, it is expected that LIM will capture the large-scale structure of the universe and provide complementary constraints on cosmological models alongside existing galaxy surveys. To perform cosmological analyses using LIM, it is necessary to generate mock observational data covering cosmological volume under multiple cosmological models and compare them with real observations.

Currently, the most effective approach for producing large mocks is to assume calculate dark matter distribution using N-body simulations and pre-process the line intensity using empirical relations. However, N-body simulations scale with the square of the number of particles (N^2), making it challenging to generate thousands of realizations required for cosmological analysis.

This study aims to construct mock observational data suitable for cosmological analysis using quasi-N-body simulations, which scale with NlogN in computational cost. By comparing the results with mock observations generated from hydrodynamic simulations and conventional N-body simulations, we evaluate and refine this approach.

Contributed Talks 6: ALMA/TIME/CCAT / **77**

Spectral Datacube Cleaning for CCAT Deep Spectroscopic Survey

Auteur: Ankur Dev[1]

Co-auteurs: Christos Karoumpis [2]; Dongwoo Chung [3]; Frank Bertoldi [4]; Gordon Stacey [3]; Jonathan Clarke [5]; Kaustuv Basu [4]; Tejas Oak [4]; Thomas Nikola [3]; Yoko Okada [6]

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The Epoch of Reionization Spectrometer (EoR-Spec) on the Fred Young Submillimeter Telescope (FYST) will conduct a Line Intensity Mapping (LIM) survey in the frequency range from 210 to 420 GHz, targeting the [CII] emission across redshifts 3.5 to 8.0. EoR-Spec observations are affected by atmospheric noise, correlated signals and systematics that impact power spectrum measurement. To understand these effects, we conduct end-to-end simulations that incorporate instrumental factors such as focal plane configuration, spectral channels, detector and beam properties, scan patterns, and atmospheric conditions. We evaluate how low-frequency 1/f noise affects different k-modes in the [CII] power spectrum.

We simulate EoR-Spec observations at the Cerro Chajnantor site using the Time-Ordered Astrophysics Scalable Tools (TOAST) framework, accounting for weather variations and spectrometer frequencies. To mitigate correlated 1/f noise, we apply techniques such as common-mode removal and Principal Component Analysis (PCA) to construct cleaned datacubes and sky maps. We analyze the cleaned mock spectral datacube to assess the impact of the processing pipeline on the 3D power spectrum. These simulations help in developing data processing strategies for first-light observations with the EoR-Spec instrument.

Contributed Talks 1: CHIME & CHORD / 78

Progress towards measuring the HI auto power spectrum with CHIME

Auteur: Arnab Chakraborty[1]

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The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a drift-scan radio interferometer located at the Dominion Radio Astrophysical Observatory (DRAO) in Penticton, British Columbia, Canada. CHIME, operating between 400 and 800 MHz, will map the redshifted 21-cm emission of neutral hydrogen between redshifts z = 0.8 − 2.5 across the northern sky. The 21cm line is a tracer of the large-scale structure of matter, whose statistics encode a well-understood standard ruler, the baryon acoustic oscillation scale. By detecting and tracking the evolution of this scale with redshift, CHIME aims to constrain the expansion history of the Universe over this crucial redshift epoch when the overall energy density of the Universe is expected to have become dominated by dark energy. However, measuring the cosmological 21-cm signal is challenging due to bright astrophysical foregrounds, which are about 4-5 orders of magnitude brighter than the cosmological HI signal, coupled with chromatic instrument response and also emission from terrestrial sources. I will discuss methodologies developed to address these issues and the improvements made in the data processing to measure the cosmological 21-cm signal in auto-correlation. I will show the first results of the auto power spectrum using CHIME data.

Contributed Talks 15: LIM Analysis and Modeling / 79

SKA-Euclid Synergies of post-Reionization Universe: 21cm - galaxy cross bispectrum

Auteur: Leon Noble[1]

Co-auteurs: Suman Majumdar [1]; Matteo Viel [2]; Fabio Fontanot [3]; Gabriella De Lucia [3]; Marta Spinelli [4]

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The Square Kilometer Array (SKA-Mid) will map the post-reionization Universe, using the 21cm line emitted by the neutral Hydrogen (HI) with accuracy and detail that was never possible. The SKA-Mid will first make the statistical detection of the 21cm signal via power spectrum measurements, and the inference of astrophysics of the galaxies and Cosmology will follow with these detections. The power spectrum, by definition, measures the amplitude of the signal fluctuations at different scales and only completely characterizes the statistical properties of a signal, which is a Gaussian random field. However, due to the gravitational instability, the redshifted 21cm signal from the post-EoR will be highly non-Gaussian. Additionally, the signal will contain the imprints of the primordial non-Gaussianity. Thus, to quantify the non-Gaussianity in the 21cm signal, one has to consider higher-order statistics such as the bispectrum. However, residual foreground and systematics associated with the instrument will hinder a high signal-to-noise ratio detection of the 21cm auto bispectrum with fewer observational hours. One way to boost the signal-to-noise ratio is to do a cross-correlation measurement with galaxy redshift surveys. Additionally, these cross-correlations have the potential to provide improved constraints on the Cosmological parameters. In this talk, we will discuss the prospects of 21cm - galaxy cross-bispectrum with SKA-Mid and Euclid. We will show the forecast on the detectability of the 21cm-galaxy cross bispectrum for all the unique k-triangles using state-of-the-art HI and foreground simulations. Additionally, we will discuss the nature of this cross-bispectrum and its ability to constrain dark matter models and cosmological parameters. These analyses highlight the potential of combining 21cm observations with complementary datasets in this era of precision Cosmology.

Contributed Talks 4: COMAP / 80

COMAP data analysis: Lessons learned and future plans

Auteur: Jonas Lunde[None]

Auteur correspondant j.g.s.lunde@astro.uio.no

This talk reflects on the present and future of data analysis techniques in line intensity mapping, with examples from COMAP. COMAP continues to integrate down and will soon achieve a sensitivity consistent with the level of our fiducial models, but proper handling of systematics and a robust data model will be vital in this effort. The Season 2 COMAP results utilized PCA filtering in order to remove standing wave systematics in the data, and we reflect on our experience with this, and other filtering techniques. We talk about the complications around PCA and PCA-like non-linear filtering, what biases they induce in our estimates, and how this can be mitigated. One potential solution, heavily employed in the CMB field, is to perform global and join analysis over many or all parameters by sampling and marginalizing, which provides more robust and unbiased estimators.

Contributed Talks 1: CHIME & CHORD / 83

Framework for the physical interpretation of HI power spectrum measurement with CHIME

Auteur: Albin Joseph[1]

[1] *Arizona State University*

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Mapping the distribution of neutral hydrogen through its 21 cm emission line provides a powerful cosmological probe for studying large-scale structures. The Canadian Hydrogen Intensity Mapping Experiment (CHIME), a drift-scan radio interferometer located in British Columbia, Canada, maps this redshifted 21cm HI emission across the frequency bandwidth of 400-800 MHz. In this talk, I will present an analysis framework for interpreting HI power spectrum measurements from CHIME. I will discuss our methodological approach for extracting cosmological and astrophysical parameters, addressing parameter constraints and degeneracies. I will outline the critical challenges for robust parameter extraction, particularly the effects of instrumental response and foreground contamination. Additionally, I will present a comparative analysis placing CHIME's capabilities in context with other 21 cm experiments, highlighting the complementary nature of different observational strategies.

Contributed Talks 8: SPHEREx / **84**

Mock skies for SPHEREx auto- and cross-correlation analyses

Auteur: Jordan Mirocha[1]

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SPHEREx, NASA's latest space telescope (launched March 11th, 2025!), will soon begin its survey of the entire sky in 102 near-infrared spectral channels. Intensity mapping – including auto- and cross-spectrum analyses – will be focused on a 100 deg^2 deep field centered on the north ecliptic pole, but shallower maps will exist over the whole sky enabling cross-correlations with surveys operating anywhere on Earth. In support of pipeline validation and the eventual interpretation of our measurements, we have developed a custom framework for generating mock extragalactic skies, including the continuum and line emission from central galaxies (star-forming and quiescent), their satellites, and diffuse intrahalo light across all of cosmic history. I will introduce our approach to modeling these various components, present basic predictions including comparisons to a lighter weight halo model, and discuss how these mocks can be used to prepare for cross-correlations between SPHEREx and other intensity mapping experiments in the next few years.

Contrinbuted Talks 7: EXCLAIM/TIM/TIFUUN/SPTSLIM / **85**

The Terahertz Intensity Mapper: CII Line Intensity Mapping at Cosmic Noon

Auteur: Ryan Keenan[1]

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The Terahertz Intensity Mapper (TIM) is a NASA far-infrared balloon mission that will conduct a line intensity mapping survey of the [CII] 157um line during the peak and wind down of cosmic star formation. The redshift range of our survey - 0.5<z<1.7 - corresponds to the expected peak in the mean [CII] intensity, and provides abundant opportunities for cross-correlation with extensive existing and planned multi-wavelength surveys. I will provide an overview of the TIM instrument, our progress in preparing for flight in the 2026-2027 austral summer, and our expected scientific results. TIM will achieve sufficient sensitivity to differentiate between a wide range of models for the [CII] auto-power spectrum. Further, by targeting GOODS-S and the Euclid Deep Field Fornax, TIM can detect even the most pessimistic models for [CII] with a signal to noise ratio of 15 or greater in cross-correlation with NIR spectroscopic surveys. This will allow TIM to constrain the mean [CII] intensity in multiple redshift bins around cosmic noon, providing an independent accounting of the cosmic star formation history.

Contributed Talks 1: CHIME & CHORD / 86

CHORD: The Canadian Hydrogen Observatory and Radio-transient Detector

Auteur: Simon Foreman[1]

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The Canadian Hydrogen Observatory and Radio-transient Detector (CHORD) is an interferometric radio telescope optimized for 21cm cosmology, radio transients, and Milky Way science. CHORD is currently under construction at the Dominion Radio Astrophysical Observatory in Western Canada, and will leverage the technical and scientific successes of its sibling experiment, the Canadian Hydrogen Intensity Mapping Experiment (CHIME), while incorporating numerous advances in instrumental design. In this talk, I will present CHORD's defining properties, construction status, and science goals, with a focus on intensity mapping and other spectral-line science.

Contributed Talks 1: CHIME & CHORD / 87

Connecting LIM & matter at high z with the CMB lensing-21cm bispectrum: prospects from CHIME

Auteur: Tristan Pinsonneault-Marotte[1]

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The 21cm line of neutral Hydrogen (HI) is an excellent tracer of the large-scale structure (LSS) of matter, with the potential to map most of the observable Universe. Its use as a cosmological probe has so far been hampered by the difficulty of separating the 21cm signal from the overwhelmingly bright radio foregrounds, along with the challenges of instrumental calibration and contamination from terrestrial sources. Cross-correlations with external datasets have emerged as an effective way to mitigate these issues. Leveraging the constraining power of multiple tracers can also provide a handle on systematics and break parameter degeneracies in an era when surveys of LSS are quickly becoming more plentiful and varied. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is one of only a few experiments to have reported cross-correlation detections of 21cm already, and analysis efforts continue to be focused on extracting cosmological information from years of observations. In this talk, I will make the case for a cross-correlation of 21cm observations with measurements of CMB lensing and present methods under development to pursue this idea with CHIME. Although the lensing convergence is sensitive to an integral of the LSS along the line-of-sight to the CMB – precisely the long-wavelength modes that are most degenerate with the 21cm foregrounds – non-linear gravitational evolution is expected to couple small-scale clustering measurable with HI to large-scale density fluctuations that are traced by lensing. It may be possible to detect this correlation by constructing an estimator targeting squeezed configurations of the bispectrum.

Contributed Talks 1: CHIME & CHORD / 88

Simulation framework for HI power spectrum measurement with CHIME

Auteur: Shabbir Isak Shaikh[1]

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HI intensity mapping offers a unique window to map the distribution of matter by tracing the distribution of neutral hydrogen. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) aims to measure the clustering of HI through its 21cm emission at redshifts 0.8 to 2.5. In this talk, I will present a simulation framework for modeling and interpreting CHIME HI power spectrum measurement. I will discuss the methods to simulate the HI signal corresponding to CHIME frequency channels accurately and incorporate instrumental effects into power spectrum modeling. These simulations play a crucial role in validating our analysis pipeline and improving the reliability of the cosmological measurements.

Contributed Talks 6: ALMA/TIME/CCAT / 89

The Tomographic Ionised-carbon Mapping Experiment (TIME): 2025 status update

Auteur: Dongwoo Chung[1]

Co-auteurs: Abigail Crites [1]; Anthony Turner [2]; Asantha Cooray [3]; Audrey Dunn [4]; Ben Vaughan [1]; Chao-Te Li [5]; Clifford Frez [2]; Dan Marrone [6]; Dang Pham [7]; Eli Wolochow [4]; Evan Mayer [6]; Fionna Hufford [4]; Ian Lowe [6]; Ibrahim Shehzad [1]; Isaac Trumper [6]; Jamie Bock [2]; Jason Sun [8]; Jonathon Hunacek [2]; Kenny Lau [2]; Matt Bradford [2]; Michael Zemcov [4]; Nick Emerson [6]; Ryan Keenan [9]; Samantha Berek [7]; Selina Yang [1]; Shwetha Prakash [1]; Sukhman Singh [1]; Tashun Wei [5]; Tess Case-Cortez [4]; Tzu-Ching Chang [2]; Victoria Butler [1]; Yun-Ting Cheng [2]

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TIME is a 200-300 GHz grating analogue spectrometer with a TES focal plane, operating from the Arizona Radio Observatory on Kitt Peak, Arizona. The degree-wide linear field of view, spanned by 16 dual-polarisation feeds with instantaneous spectrometry, makes TIME an excellent pathfinder for mm-wave line-intensity mapping. This talk will provide a general status update on how we continue to meet challenges in instrumentation and analysis, as we target an operations restart in winter 2025-26. The TIME team continues to view the experiment as a key testing ground for techniques to characterise and remove hyperspectral correlated noise and systematics, in a way that will interact closely with other LIM experiments, including some with direct personnel overlap (COMAP, CCAT/EoR-Spec).

Conntributed Talks 12: LIM and EoR / 91

21-cm x Galaxies during the Epoch of Reionization: Prospect for Detection with Current and Future Radio and Optical Surveys

Auteur: Kai-Feng Chen[1]

Co-auteur: Jacqueline Hewitt [1]

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Over the past decade, large radio experiments have set ever more stringent upper limits on the 21-cm power spectrum during the Epoch of Reionization. With increased sensitivity from current and planned future surveys, we are moving fast towards detecting the 21-cm auto power spectrum. However, with the complexities of systematic effects in low-frequency instruments, validating a potential detection remains a foremost challenge. Cross-correlation between 21-cm and other biased tracers at the same redshift provides an excellent method for such a validation while introducing additional cosmological and astrophysical constraints. In this talk, I will discuss our recent efforts to create foreground-filtered 21-cm image cubes around bright Ly-alpha emitters with the Hydrogen Epoch of Reionization Array. Stacking these 21-cm image cubes provides one of the quickest ways to detect a cross-correlation signal. I will discuss forecasts from applying our imaging pipeline on mock observations obtained from the THESAN radiation-magneto-hydrodynamic simulations. Our results are an important step towards combining 21-cm experiments with current and future high-redshift galaxy surveys such as the Lyman Alpha Galaxies in the Epoch of Reionization survey, the Reionization EXplorer, and the Nancy Grace Roman Space Telescope.

Contributed Talks 9: HEDTEX/CIBER/PRIMA / 92

Systematic characterization for intensity-galaxy cross-correlations: A case study for the Cosmic Infrared Background Experiment

Auteurs: Grigory Heaton[1]; Richard Feder[2]

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Cross-correlation between galaxy redshifts and cosmic infrared background (CIB) anisotropies can offer further insight on the source of observed fluctuations as a function of redshift in the three-dimensional structure of the universe. However, such cross-correlations are sensitive to redshift tracer catalog non-uniformity, which can be significant in certain limits and without mitigation. In this presentation we focus on characterizing tracer non-uniformity, using controlled mocks as well as catalogs from Legacy Survey, unWISE, and HSC. This work is part of an ongoing cross-correlation analysis utilizing near-infrared imaging from the 4th flight of the Cosmic Infrared Background ExploRer (CIBER), and lays the groundwork for future cross-correlations with SPHEREx and other intensity mapping experiments.

Contributed Talks 8: SPHEREx / 93

SPHEREx Instrument Performance and Early In-Orbit Results

Auteur: Howard Hui[1]

Co-auteur: SPHEREx Collaboration

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The Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer (SPHEREx) is a NASA Medium Explorer mission designed to carry out the first all-sky spectral survey in the near-infrared (0.75–5 μm) with spectral resolutions ranging from R ~ 41 to 135.
In this talk, we present an overview of SPHEREx's instrument performance, drawing from the first 40 days of in-orbit commissioning and calibration. We will discuss detector behavior, optical performance, spectral calibration, and system stability. In addition, we will share early SPHEREx observations, and we will outline the structure of SPHEREx data products and describe how the community can leverage them for line intensity mapping analyses.

Contributed Talks 2: MeerKLASS & SKA / 94

Pursuing Large-Scale Structure Measurement with MeerKLASS

Auteur: Wenkai Hu[1]

Co-auteur: Mario Santos [1]

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HI intensity mapping is a promising technique for overcoming telescope sensitivity limits by capturing the large-scale distribution of HI, which is essential for studying the large-scale structures. Significant progress has been made in detecting the HI cross-correlation power spectrum using intensity mapping survey utilizing MeerKAT's L-band receiver, and there is a good prospect of detecting the HI auto power spectrum in the near future. MeerKLASS, launched in late 2022, has accumulated over 400 hours of observations across approximately 2,000 deg² and aims to cover over 10,000 deg² within next four years, will address this challenge by employing HI intensity mapping with MeerKAT's UHF-band receiver in single-dish mode, enabling the study of large-scale HI power spectra at higher redshifts and enhancing our knowledge of cosmic structure formation. Despite its advantages, single-dish mode is not the primary observing mode of MeerKAT, introducing instrumental and observational challenges that are negligible in standard interferometric imaging. These include 1/f noise, systematics from receiver gain variations, beam effects, and atmospheric fluctuations, necessitating the development of a dedicated data reduction pipeline.
This presentation highlights our efforts in processing MeerKAT UHF intensity mapping data from MeerKLASS. I will introduce the MeerKLASS calibration pipeline, MuSEEK (Multi-dish Signal Extraction and Emission Kartographer), designed to mitigate systematic errors, radio frequency interference (RFI), bandpass variations, and flux calibration issues, ensuring precise large-scale HI measurements. I will also present the latest calibration and map-making results, demonstrating our ability to extract scientifically meaningful HI signals. Additionally, I will assess the noise performance of MeerKLASS, focusing on 1/f noise characterization and mitigation strategies. Finally, key advancements in MeerKLASS will be highlighted, emphasizing its impact on HI cosmology and intensity mapping techniques.

Contrinbuted Talks 7: EXCLAIM/TIM/TIFUUN/SPTSLIM / 95

First On-Sky Data from SPT-SLIM : a Mm-wave Line-Intensity Mapping Spectrometer at the South Pole

Auteurs: Jessica Zebrowski[None]; SPT-SLIM Collaboration[None]

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The South Pole Telescope Shirokoff Line Intensity Mapper (SPT-SLIM) is an experiment to demonstrate the use of superconducting on-chip spectrometers for millimeter-wave line intensity mapping.

SPT-SLIM is optimized to detect redshifted carbon monoxide (CO) line emission from high-redshift (0.5 < z < 2) galaxies in the 2 mm atmospheric window as a pathfinder for future high-redshift LIM cosmology experiments. The instrument achieved first light during its deployment in the 2024-2025 austral summer and successfully completed a two-week observing campaign. In this talk, I will present an overview of the SPT-SLIM instrument design and describe its commissioning and Y1 performance. I will share early results from the initial observing run and discuss the prospects for a longer survey with upgraded instrumentation during the 2025-2026 austral summer.

Keynote 2: LIM with CO and COMAP / **96**

LIM with CO and COMAP

Auteur: Kieran Cleary[1]

[1] *California Institute of Technology*

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Carbon monoxide is one of the main targets for line intensity mapping, offering the potential to trace the dense gas history of the universe during the Epoch of Galaxy Assembly, and the galactic sources of ionization at the Epoch of Reionization. We review the features of CO emission that make it attractive for this purpose, discuss the current and future experimental landscape and in particular, describe the current status and next phases of the CO Mapping Array Project.

Contrinbuted Talks 7: EXCLAIM/TIM/TIFUUN/SPTSLIM / **98**

The EXperiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM): status and forecasts

Auteur: Peter Timbie[1]

[1] *University of Wisconsin*

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EXCLAIM is a balloon-borne cryogenic telescope that will use the line intensity mapping technique to survey the spectrum of diffuse emission from both the Milky Way and the cosmic web to probe star formation, the interstellar medium, and galaxy evolution across cosmic time. EXCLAIM's primary extragalactic science survey will map 305 deg2 with angular resolution 4 arcmin in the SDSS Stripe 82 field. Its focal plane includes 6 on-chip spectrometers based on kinetic inductance detectors. The spectrometers have spectral resolving power R = 512 over the frequency range = 420 - 540 GHz and target emission of the [CII] line over redshifts 2.5 < < 3.5 and several CO lines for < 1. The spectral resolving power and cryogenic telescope allow the survey to access dark windows in the spectrum of emission from the upper atmosphere. Cross-correlation with galaxy redshift catalogs isolates line emission from the large-scale structure at target redshifts. I will discuss the status of the hardware development, mission planning, the data analysis pipeline, and sensitivity forecasts.

Contributed Talks 15: LIM Analysis and Modeling / **99**

Joint Bayesian calibration and map-making for intensity mapping experiments

Auteur: Zheng Zhang[1]

Co-auteurs: Mario Santos ; Phil Bull [1]

[1] *University of Manchester*

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This work presents a framework for joint calibration and map-making using Gibbs sampling. Instead of conditioning on a fixed noise level, our data model employs multiplicative noise as a direct application of the radiometer equation, accurately capturing the coupling between noise level and system temperature. To enable unbiased and fast estimation of gain and system temperature, we develop an iterative GLS sampling method. Absolute flux calibration can be achieved either with external sources or internally using known signal injections, such as noise diodes. To handle correlated noise, we introduce a proper $1/f$ noise model that avoids spurious periodic correlations in the time domain caused by the conventional assumption of diagonal DFT noise covariance. Furthermore, we implement this workflow in an efficient software package, leveraging the Levinson algorithm to reduce the computational complexity of noise parameter sampling to O(N^2), ensuring good scalability. Although this workflow is demonstrated for auto-correlation measurements, the strategies and techniques can also be applied to cross-correlation measurements by ignoring the correlated noise but taking an extra multiplicative gain in the data model.

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CO interloper mitigation with spectral line deconfusion method for FYST [CII] LIM experiment

Auteur: Tejas Oak[1]

Co-auteurs: Ankur Dev [2]; Christos Karoumpis [3]; Dominik Riechers [4]; Frank Bertoldi [1]; Jonathan Clarke [5]; Kaustuv Basu [1]

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The Fred Young Submillimeter Telescope (FYST) is a state of the art telescope under construction at the Chilean plateau of Cerro Chajnantor. FYST will perform the line intensity mapping experiments targeting the [CII] (158 μm) fine-structure line, which is one of the most abundant cooling lines in the star forming regions of the universe. The most challenging aspect related to [CII] LIM is mitigating the interloper contamination. The CO rotational lines emitted by galaxies at intermediate redshifts end up in the same observing frequency as the targeted [CII] signal; making its separation more difficult.
Recent studies examine the use of conceptually simple masking techniques to address this issue; but they report its diminishing effectiveness at lower frequencies, as well as an increased uncertainty due to survey volume loss (M Van Cuyck et al., 2023, Karoumpis et al., 2024). In this work, we explore the application of the phase-space spectral line deconfusion method (Cheng et al., 2020) as an interloper mitigation strategy for the FYST. This approach works by fitting CO spectral line templates to the intensity map, iteratively converging at a sparse distribution of line emitting sources. We assess the performance of this method in reconstructing the [CII] power spectrum based on the CO and [CII] mock tomographies generated using IllustrisTNG simulation We find that the method performs well, especially at low frequencies (high redshifts) where other approaches are less effective.

Contributed Talks 15: LIM Analysis and Modeling / 103

Optimal Techniques for Analyzing Line Intensity Mapping Data

Auteur: Anirban Roy[1]

[1] *New York University*

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Line intensity mapping (LIM) has emerged as a powerful tool in astrophysics, leveraging statistical analysis of integrated spectral line emissions originating from distant star-forming galaxies. This talk will review key methods for LIM data analysis, including power spectrum and voxel intensity distribution techniques, to constrain cosmological and astrophysical parameters. I will also explore advanced field-level inference techniques using machine learning, emphasizing its potential to improve data interpretation. The strengths and limitations of these approaches will be discussed, particularly their applications in cross-correlation studies with tracers like galaxy surveys and 21cm signals. This overview aims to provide insights into optimizing LIM data analysis for current and next-generation experiments.

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SuperSpec on the horizon: On-Chip Prototyping for MUSCAT and LIM simulations at the LMT

Auteur correspondant jair.vega@inaoe.edu.mx

Keynote 8: Current and Future Technologies for Line Intensity Mapping / 107

Technologies and Instrumentation for Line Intensity Mapping

Auteur: Kirit Karkare[1]

[1] *Boston University*

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As the Line Intensity Mapping (LIM) field moves from upper limits to first detections to detailed characterization of the signal, increasingly sensitive, specialized instruments will need to be deployed. Technological advances—whether in spectrometer architecture, detector sensitivity, readout, signal processing, or instrument modeling—will enable the next generation of experiments. I will present an overview of the technologies used by LIM instruments over a wide range of wavelengths. Based on the sensitivity required for next-generation science goals, I will discuss promising avenues for improvement and how future LIM experiments might be configured.

Contributed Talks 16: LIM Analysis and Modeling / 110

CCAT EoR-Spec: Observation planning from commissioning to the full deep spectroscopic survey

Contributed Talks 2: MeerKLASS & SKA / 111

Neutral hydrogen intensity mapping in the era of the SKA Observatory

Auteur: Stefano Camera[1]

[1] *University of Turin*

Auteur correspondant stefano.camera@unito.it

In this talk, I shall review the prospects for neutral hydrogen (HI) intensity mapping with the SKA Observatory (SKAO). HI intensity mapping will be highly complementary to traditional cosmological probes such as galaxy clustering and weak lensing, allowing us to test the foundations of our concordance cosmological model - an especially timely endeavour, in the view of the newest results but the Dark Energy Spectroscopic Instrument. Moreover, HI intensity mapping with the SKAO has the potential to open new windows on the understanding of inflation and gravity on cosmological scales, alone and in synergy with cosmological surveys at other wavelengths.

Keynote 6: The Epoch of Reionization with 21 cm Intensity Mapping, an overview of the current status / 112

The Epoch of Reionization and Cosmic Dawn with the redshifted 21 cm radiation.

Auteur: Saleem Zaroubi[None]

Auteur correspondant saleem@astro.rug.nl

In this talk, I will present the current observational and theoretical status of the HI line intensity mapping of the EoR and Cosmic Dawn. In particular, I will discuss the recent upper limits results on the 21 cm power spectrum at the redshift range 8-11, from the LOFAR EoR and HERA projects. I will also present the prospects of the field for the coming few years.

Keynote 1: Data Analysis Challenges in Line Intensity Mapping: a HERA Perspective / 113

Data Analysis Challenges in Line Intensity Mapping: a HERA Perspective

Auteur: Steven MURRAY[1]

[1] *Scuola Normale Superiore di Pisa*

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The incredible potential of 21cm line intensity mapping as a probe of early structure formation, stellar and galactic evolution, the thermal history of the IGM and cosmology have been understood since the late 1990's. Nevertheless, despite recent breakthroughs at low redshifts, and ever-tightening limits at high redshift, this potential has not been realized as fully as might have been expected twenty years ago. The fundamental reason for this is a nasty conjunction of spectrally-structured instrumental systematics and extremely bright foregrounds, whose joint properties are still not understood at the high precision required to separate them from the 21cm signal. In this talk, I will review some of these systematics, and recent developments in analysis techniques designed to overcome them, giving a sense for where current observational efforts stand. I will exemplify these issues by concentrating on recent improvements by the HERA collaboration, whose unique strategy have thus far yielded the most stringent upper limits on the pre-reionization 21cm power spectrum. In doing so, I will

cover topics of relevance for all experiments, including inpainting of flagged data, mutual coupling, gain calibration and the modelling of systematic residuals for propagation towards astrophysical inference.

Contributed Talks 14: LIM and Cosmology / 114

The dawn of cosmic dawn cosmology

Auteur: Ely Kovetz[1]

[1] *Ben-Gurion University*

Motivated by the opportunities for synergy between cosmic dawn line-intensity mapping and complementary observables such as the cosmic microwave background radiation and the ultraviolet luminosity functions of high-redshift galaxies, we will demonstrate new simulation and data-analysis pipelines that consistently combine these different sources of information and meet runtime requirements to enable Bayesian parameter inference. Using these tools, we will present the strongest bounds to date on ultralight dark matter in the 10^{-25}-10^{-23} eV mass window and on a range of models in which dark matter has velocity-dependent interactions with baryons.

Keynote 5: How can we learn about the physics of galaxy formation from LIM? / 115

How can we learn about the physics of galaxy formation from LIM?

Auteur: Rachel Somerville[None]

Auteur correspondant rsomerville@flatironinstitute.org

The large scale clustering of all luminous tracers in the Universe is governed by a combination of cosmological structure formation and baryonic processes, which are intertwined in a non-linear and poorly understood manner. Although processes such as star formation and black hole feedback occur on scales of less than a parsec, it is known that they can impact potential LIM signals even on relatively large scales of 10's of Mpc, making modeling them extremely challenging. I will discuss recent progress in developing physics-based models for forecasting and interpreting multi-tracer LIM results using multi-scale simulations, semi-analytic modeling, and machine learning.

Contributed Talks 8: SPHEREx / 116

SPHEREx Begins Mapping the Universe

Auteur correspondant olivier.dore@caltech.edu

Conntributed Talks 12: LIM and EoR / 118

Unveiling the EoR with LIM and 21cm-galaxy synergies

Auteur: Caroline Heneka[None]

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Cross-correlating 21cm intensity maps from the SKA with galaxy surveys and other line-intensity mapping (LIM) tracers is a powerful strategy to study the Epoch of Reionization (EoR). Galaxy surveys —using Lyman-alpha, OIII, or H-alpha emitters identified through dropout techniques, grism, or spectroscopic observations —offer precise redshifts and have been shown, through mock and analytical studies within the SKA EoR science working group, to be highly promising for early detections. I will present updated signal-to-noise forecasts across different survey strategies (wide-shallow vs. deep-narrow) and instruments such as Subaru/HSC/PFS, MOONS, and the Roman Space Telescope. Complementarily, LIM of UV to infrared lines traces diffuse ionised and dusty media, offering new insights when cross-correlated with 21cm maps. I will present LIM advancements and updated prospects for cross-correlation with SKA-low measurements, focusing promising lines such as Lyman-alpha and infrared dust tracers such as PAHs. Together, these approaches offer a multifaceted view of reionization, informing models of IGM morphology, ionizing sources, and cosmology.

Contributed Talks 10: LIM and Galaxy formation / 119

HYACINTH: HYdrogen And Carbon chemistry in the INTerstellar medium in Hydro simulations

Auteur: Cristiano Porciani[1]

[1] *University of Bonn*

Understanding the cold/molecular gas content of galaxies requires modelling processes spanning a wide range of spatial and time scales—from cosmic accretion to interstellar chemistry. We present results from the MARIGOLD simulations, which incorporate our new sub-grid model HYACINTH (Hydrogen and Carbon chemistry in the Interstellar medium in Hydro simulations) into the RAMSES code. HYACINTH enables on-the-fly tracking of H_2, CO, C, and C^+ in large-scale cosmological simulations. Our results match current constraints on the cosmic H_2 density and highlight a significant contribution from low-mass galaxies that may be missed by current observations. We also explore the [C II] fine-structure line as a molecular gas tracer, finding that its correlation with molecular gas strengthens over time. In the context of line-intensity mapping, we extract the halo occupation properties of [C II] emitters in our simulations to inform models of large-scale [C II] fluctuations. These findings demonstrate the value of simulations in interpreting observations and uncovering the cold/molecular gas reservoir that fuels star formation across cosmic time.

Contributed Talks 3: 21cm LIM, Analysis and Modeling / 120

Designing Achromatic Beams with Interferometry

Auteur: Albert Stebbins[1]

[1] *Fermilab*

A well known problem in astronomical spectroscopy of confused sources comes from achromaticity (the wavelength dependence) of the spatial beams of the spectrograph. This achromaticity aliases spatial structure into spectral structure. One cannot completely separate spatial from spectral because of achromaticity. It is shown that if one has multiple overlapping beams one can synthesize beams which have much less achromaticity than the originals, allowing one to greatly reduce the uncertainty in the spectra of individual sources. A formalism for optimally synthesizing beams is presented. Since intensity mapping by definition is looking at confused sources this formalism should have wide applicability in this field.

Contributed Talks 16: LIM Analysis and Modeling / 121

NoInterNet: separating line interloper contributions in the angular power spectrum

Auteur: Marina Cagliari[1]

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In line intensity mapping, multiple emission lines are observed within a given frequency band. The brightest line is typically considered the target line, while the others act as interloper lines. This leads to maps that combine contributions from structures at different redshifts. A similar challenge arises in modern slitless spectroscopic surveys, where an emission line may be misclassified, resulting in incorrect redshift measurements for determined objects. In this work, I adapt a machine learning-based approach, originally developed to remove interloper contamination from the galaxy power spectrum, to the cleaning of angular power spectra from intensity maps. Using a set of simulated maps with varying interloper contributions built from a lightcone that covers SPHEREx frequencies, I consider three emission lines: Hα as the target line, and [OII] and [OIII] as interlopers. I train a neural network to disentangle the contributions of the three lines from the observed angular power spectrum and recover the interloper fraction quantified by an amplitude rescaling factor. I test the algorithm varying the input information, using auto- and cross-power spectra in different channels, and increasing the stochastic noise in the maps. This study demonstrates the potential of machine learning for cleaning interloper-contaminated angular power spectra in line intensity mapping surveys.