



Workshop on Spectral Diagnostics to Explore the Cosmic Dawn with *JWST*

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The Institute hosted a science workshop on *Spectral Diagnostics to Explore the Cosmic Dawn with JWST*, from July 31–August 02, 2017. With the upcoming launch of *Webb*, and the recent advances in observational and theoretical work to predict and interpret the spectra of first galaxies, it was timely to hold a workshop on this topic at the Institute. Spectroscopy with *Webb* will be a powerful tool for probing the physics of first galaxies and the processes that regulate galaxy evolution. Emission and absorption lines will offer important diagnostics of the galaxy chemical composition, star-formation rates, feedback mechanisms, stellar populations, and escape of ionizing radiation. Theoretical studies have made significant advances in modeling the feedback and outflows in galaxies, radiative transfer in the IGM at early epochs, and have predictions for what we may be able to observe with *Webb*. The aim of the organizing committee was to bring together expert observers and theorists to discuss the spectral diagnostics and efficient strategies to maximize *Webb* science for exploring high-redshift galaxies. This would also provide opportunities to forge new collaborations.

The scientific program consisted of 17 invited talks, 24 contributed talks, and 14 electronic posters. There were about 70 participants registered for the workshop. The topics included the observed properties of galaxies at cosmic dawn, the Lyman continuum and ionizing budget in the reionization era, spectral properties of cosmic noon ($z = 1.5\text{--}3$) galaxies, and extreme emission-line galaxies across redshifts. There were talks on the Lyman-alpha escape from galaxies, feedback and outflows from starbursts and active galactic nuclei (AGNs), and emission-line diagnostics. The sessions also covered theoretical models of the first galaxies and AGNs with emphasis on predictions for *Webb*. There were dedicated sessions to discuss the ingredients required for modeling spectra of high redshift galaxies, and role of dust and chemical enrichment at early epochs.

The presentations at the workshop highlighted new spectral diagnostics using the rest-frame UV and optical emission lines that can take advantage of the wavelengths accessible for *Webb*

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spectroscopy of galaxies at $z > 7$. There are specific UV emission-line ratios being identified that can be used to produce a "BPT-diagram" [named for Baldwin, Phillips, and Terlevich, who developed the method] to distinguish the contributions from AGNs, starbursts, and shocks. Extreme emission line galaxies at low and intermediate redshifts for which these emission lines are currently accessible, serve as good local analogs to calibrate the spectral diagnostics for studying galaxies in the reionization epoch. They also offer insights into the ingredients that are required to model the ionizing spectrum of low-metallicity systems; for example, the need for including the evolution of stellar binaries in interpreting spectra was emphasized. The review talks on evolution of massive stars focused on the role of stellar winds as a function of metallicity, common envelope evolution of binaries, and the challenges involved in reproducing the observed spectral features with current stellar population models.

The identification of sources of reionization and the ionizing budget is a key science topic that the *Webb* telescope will address. However, the high fraction of neutral hydrogen in the IGM at $z > 7$ would make it difficult to detect the UV ionizing continuum directly. The workshop had talks which discussed how to use indirect probes to identify galaxies that facilitate the escape of ionizing galaxies, and calibrate them to derive the escape fraction of ionizing radiation. The analysis of Lyman-alpha profiles and how they help to constrain the geometry, neutral hydrogen column density, and IGM topology were discussed. The recent results from spectroscopy of strong-lensing cluster fields were presented, which offer a first glimpse of the spectral features that will be observed for the low-luminosity galaxies at high redshifts using the *Webb*. Theoretical models and hydrodynamic simulations were discussed with regard to nature of the first galaxies, black holes, and pop III stars. The presentations also featured mock *Webb* observations, and predictions for UV luminosity function and strengths of the spectral features that will be observed with *Webb*.

The *Webb* proposal planning tools session on the last day of the workshop included a detailed presentation of the Near-Infrared Spectrograph (NIRSpec) micro-shutter array (MSA) planning tool, followed by parallel sessions for the demo of *JWST* Exposure Time Calculator, and Astronomer's Proposal Tool. The workshop concluded with the *Webb* data analysis tools session, which introduced participants to the new spectroscopy analysis and visualizations tools that are being developed for *Webb*.

We received positive feedback on the spectral diagnostics workshop from the participants, who conveyed that this was a great opportunity to present their recent results and discuss new projects to be done with *Webb*. Thanks to the event coordinator Flory Hill, and Thomas Marufu, Calvin Tullos for technical support, and all the SOC members (Harry Ferguson, Claus Leitherer, Janice Lee, Alaina Henry, Jennifer Lotz, Gabe Brammer, Iva Momcheva, Nor Pirzkal, and Jason Tumlinson) for the successful organization of the workshop.



Fig. 1: Group photo of participants of the Workshop on Spectral Diagnostics to Explore the Cosmic Dawn with *JWST*.

[Links to workshop event](#)

[Links to posters](#)

[Link to webcasts](#)