

Slide #1

Hi everyone, thank you for the opportunity to speak here today. In this talk, I will be taking us on an exciting journey to the edge of the observable Universe.

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As a brief introduction, here is a cartoon illustration of what we predicted to see prior to the launch of JWST...

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And here is what we actually saw... A surprising overabundance of luminous galaxies at high redshifts.

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Fundamentally, my research tries to answer the question of: "Why?" Why are there so many luminous galaxies in the early Universe?

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To answer this question, I am studying one very special galaxy, JADES-GS-z14-0 at redshift 14.18, which is the second most distant galaxy currently known...

This galaxy represents the best archetype for the early galaxy formation that has been observed by JWST. It is extremely luminous; remarkably red; spatially extended, which suggests minimal contributions from an AGN; and surprisingly massive only a few hundred million years after the Big Bang.

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Late last year, we obtained the deepest spectroscopy ever acquired by MIRI at roughly 34 hours of exposure time. And this represents only two-thirds of the final data set! Here are the most notable things we see in the spectrum - a strong detection of the [OIII] doublet around 7.5 microns, even stronger than expected from the imaging data; a strong detection of the hydrogen recombination line H α around 10 microns, but this line is weaker than expected; and a strong detection of the rest-frame optical continuum between 5 and 7 microns, with tentative evidence for a Balmer continuum break. If confirmed, a Balmer break would indicate a significant population of old stars.

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So what did we learn from these observations? On the y-axis, I am showing the H α line luminosity while on the x-axis, I am showing the UV continuum

luminosity. Green and grey points represent galaxies beyond redshift 3. Purple diamonds represent three luminous galaxies beyond redshift 10 that have MIRI spectroscopy. Finally, the blue star represents JADES-GS-z14-0.

H α is often used as a proxy for the recent star-formation rate, as indicated by the twin y-axis on the right side of the figure. JADES-GS-z14-0 is forming roughly ten solar masses per year in stars, which is smaller than previously inferred from the SED fitting; this is telling us something about the burstiness of the star-formation history for this galaxy.

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Here is a similar figure as the one shown on the previous slide, but now with the ionizing photon production efficiency shown on the y-axis. The value that we measure for JADES-GS-z14-0 is similar to the canonical value that we observe locally, which is shown by the grey shaded region. It is somewhat lower than typical values measured for galaxies beyond redshift 3 and much lower than the stellar population maximum, which is shown by the black line.

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This figure shows different emission line ratios on the x- and y-axes. The O32 index is on the y-axis and is often used as a proxy for the ionization parameter, while the R3 and R23 indices on the x-axes are often used as a proxy for the gas-phase metallicity. These emission line ratios indicate extreme ionization conditions and metallicities consistent with roughly 10% solar.

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However, when you use the emission line ratios shown on the previous slide to infer physical properties, you are only using two or three of the emission lines that we have observations for. We can instead use detailed photoionization modeling to infer physical properties, as demonstrated by this figure. If you fit all of the emission lines shown in the upper right panel, we instead infer metallicities consistent with roughly 50% solar, and possibly up to 100% solar, less than 300 million years after the Big Bang.

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Finally, here is preliminary work showing the mass-metallicity relation predicted by a few different sets of simulations. Our inferred value for JADES-GS-z14-0 is an extreme outlier when compared to the theoretical predictions...

The high metallicities are suggesting little ejective feedback, which is telling us something about elevated star-formation efficiencies at high redshifts. This is

supported by ongoing work with detailed chemical evolution modeling. Thus, for JADES-GS-z14-0, we are observing rapid formation with little or no feedback.

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I will conclude by leaving you all with the brief summary of my talk. We recently obtained the deepest spectroscopy ever acquired by MIRI for JADES-GS-z14-0. These data reveal extreme ionization conditions and rapid metal enrichment less than 300 Myr after the Big Bang. We find evidence for bursty star-formation histories and increased star-formation efficiencies. If these conditions are common among distant galaxies, then this is a preliminary answer to why we are observing an overabundance of luminous galaxies in the early Universe. Finally, I argue that MIRI is the future for understanding the first stars and galaxies!