

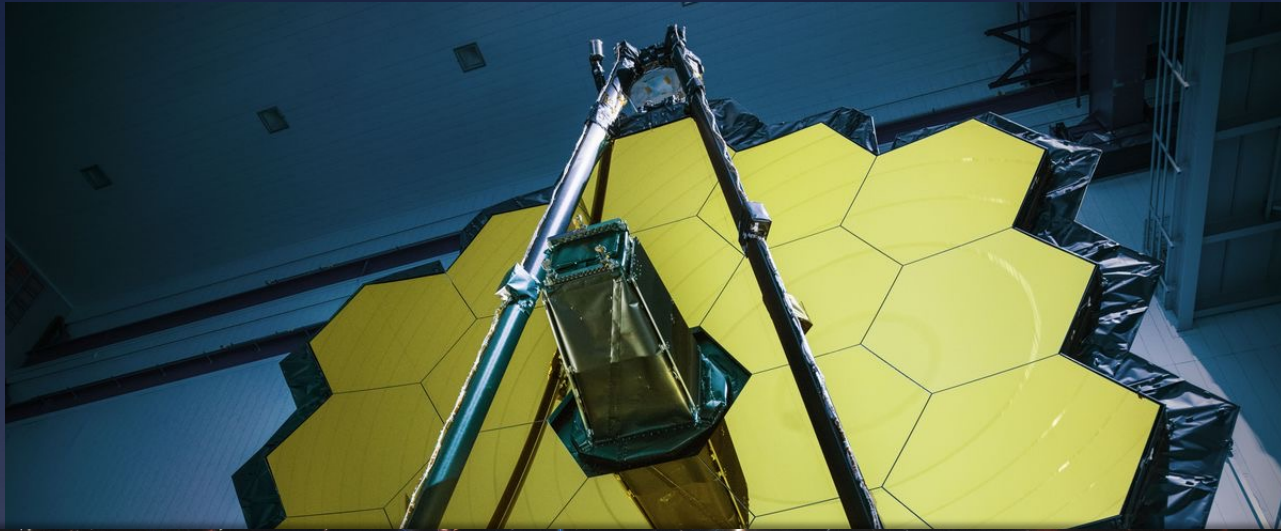
Little Red Dots and the Rise of Obscured AGN in the Early Universe

Dale Kocevski

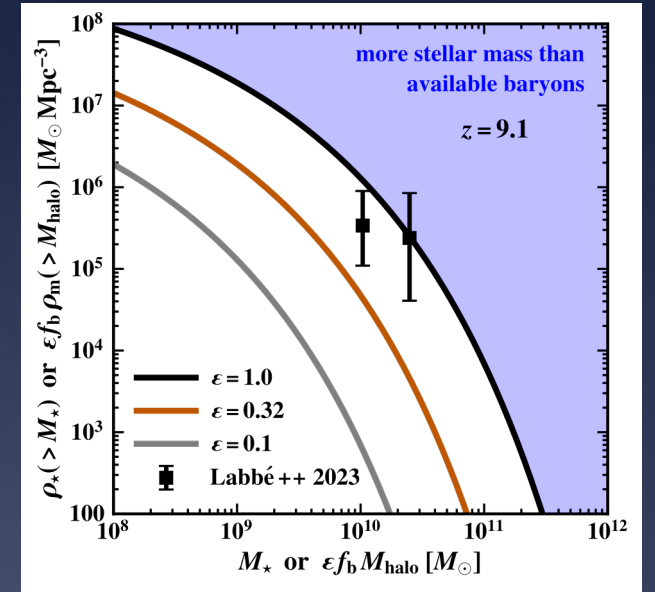
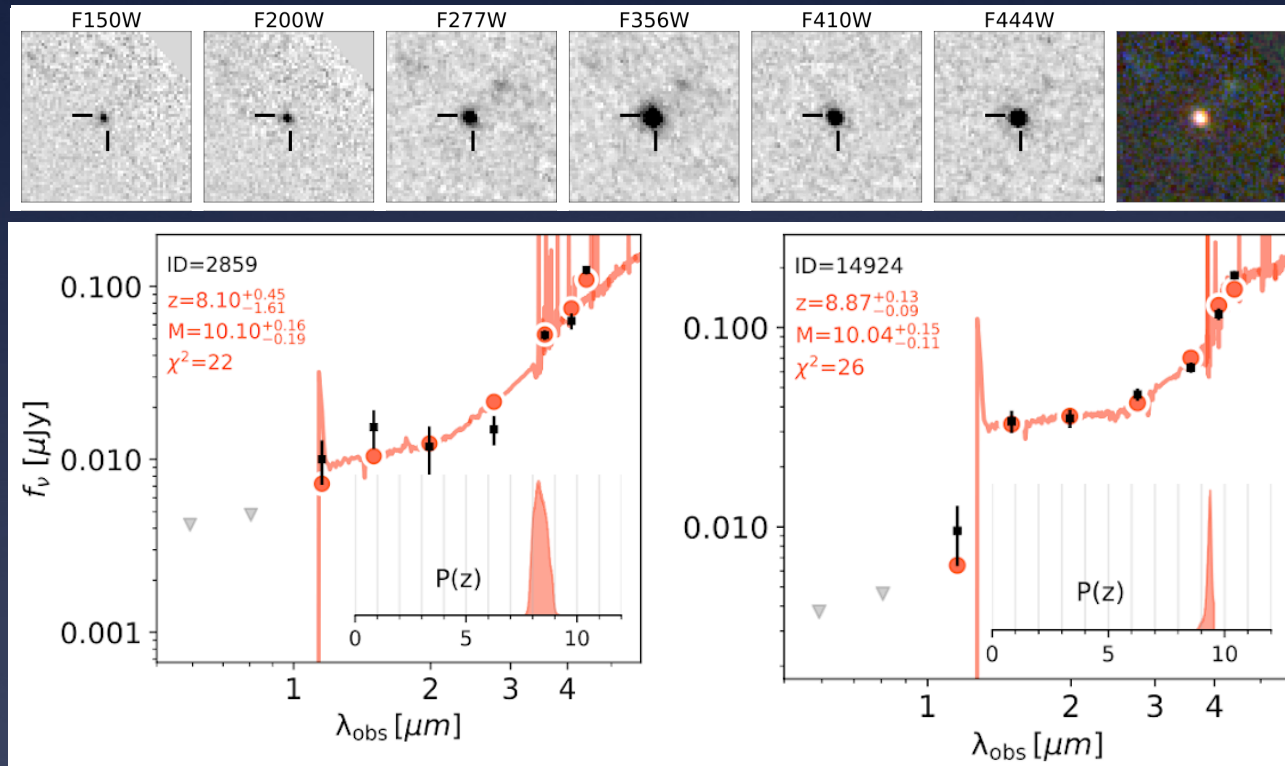
Colby College

Roman Workshop – July 2026

Insights on the Early Universe from JWST



Universe Breaking Galaxies



Boylan-Kolchin+23

* Labbe et al. (2023): Massive galaxies ($M > 10^{10} M_\odot$) found 700 Myr after the Big Bang ($z \sim 8$)

Universe Breaking Galaxies

NEWS

SPACE

Did the James Webb telescope 'break the universe'?

Astronomers are still figuring out how to interpret what JWST is telling them



BBC Sky at Night
MAGAZINE

Reviews ▼

Advice ▼

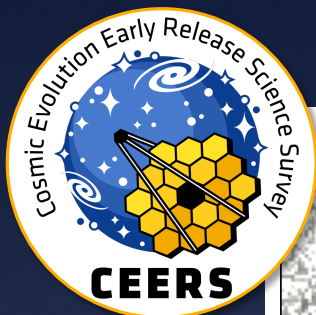
Science

Virtual Events ▼

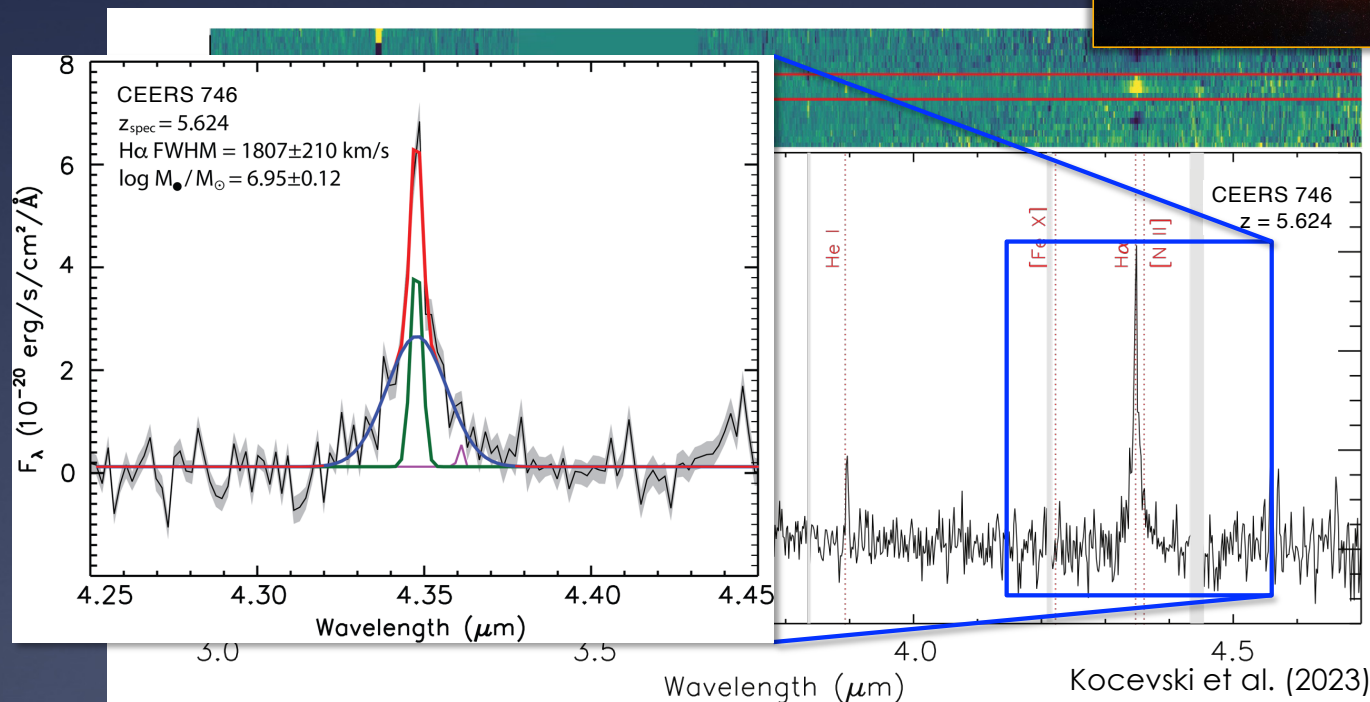
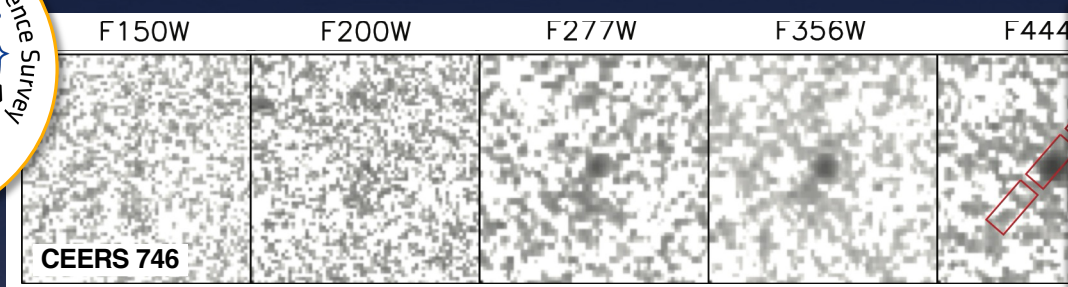
Astronomy news

What the Webb Telescope's 'Universe breaker' galaxies can tell us about the early cosmos

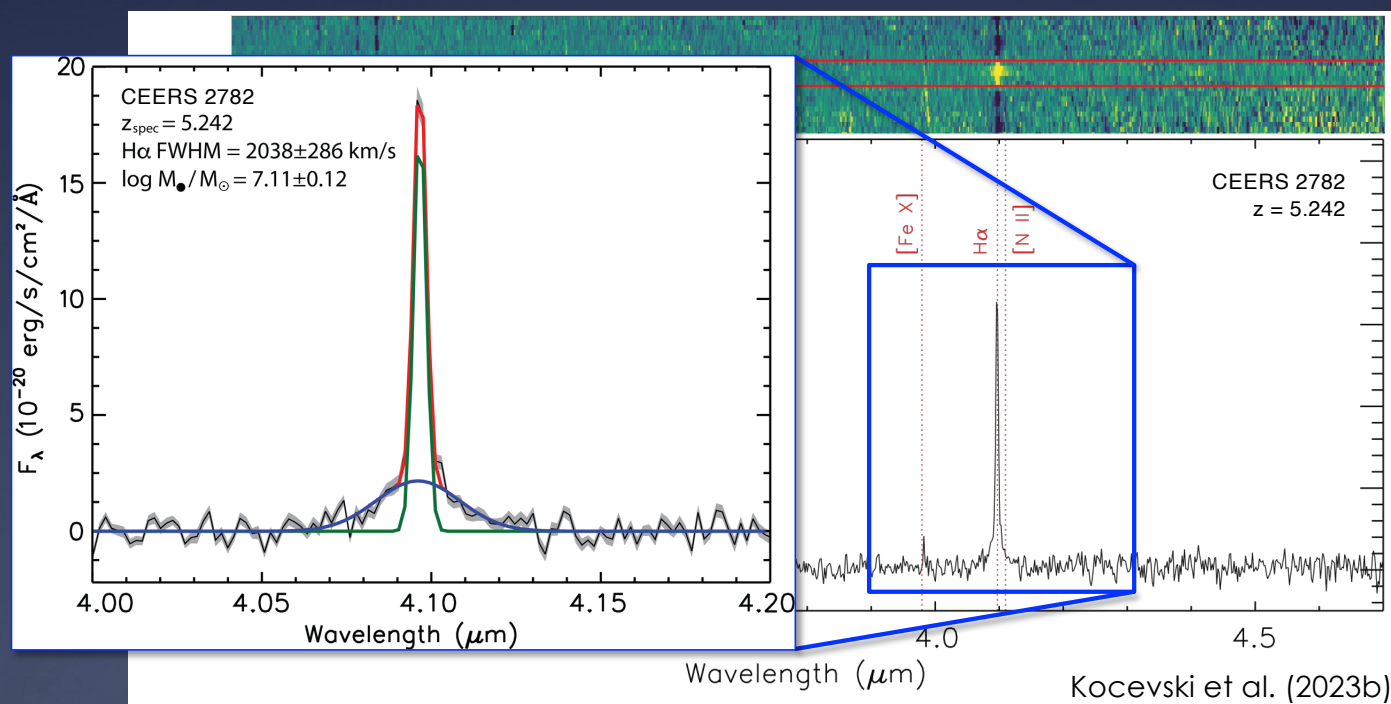
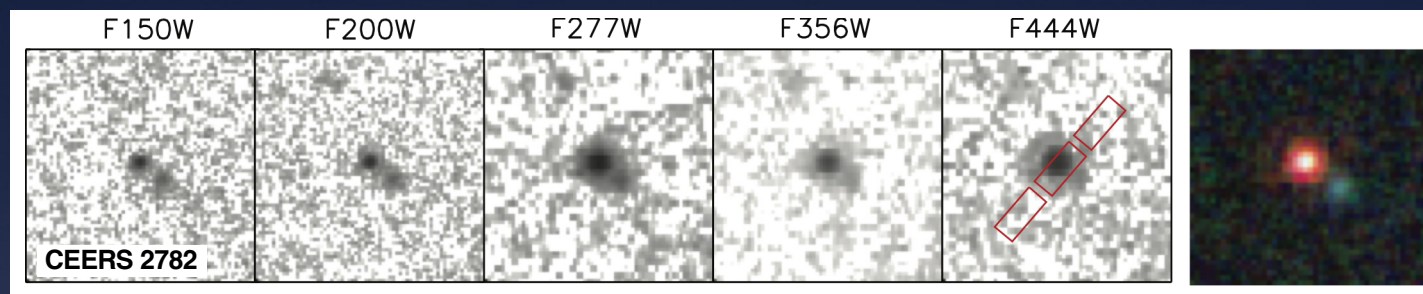
Researchers discovered 'Universe breakers' in JWST images, massive galaxies that existed way before current theories predicted



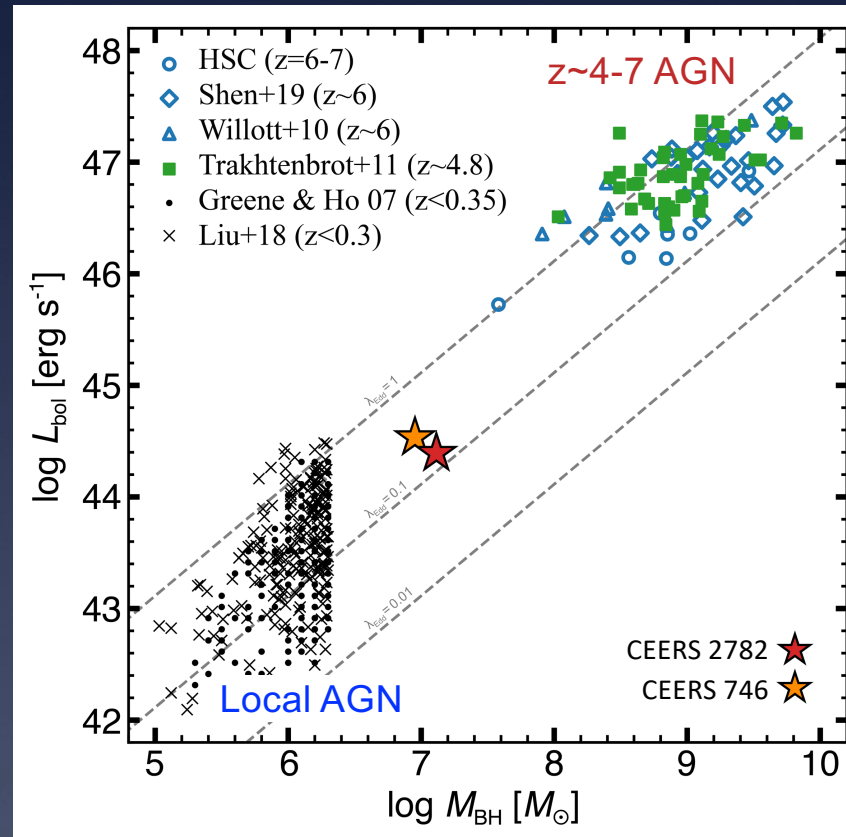
Hidden Little Monsters: Faint, Broad-line Emitters



Discovery of Faint, Broad-line AGN at $z > 5$



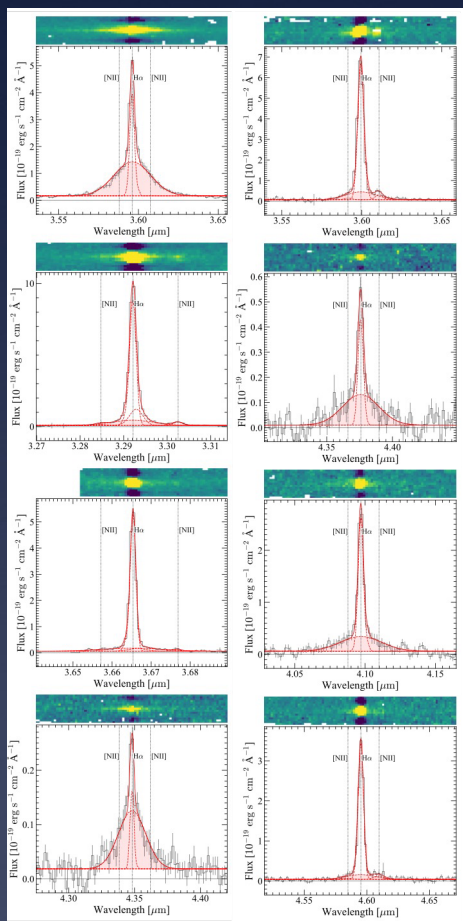
Hidden Little Monsters



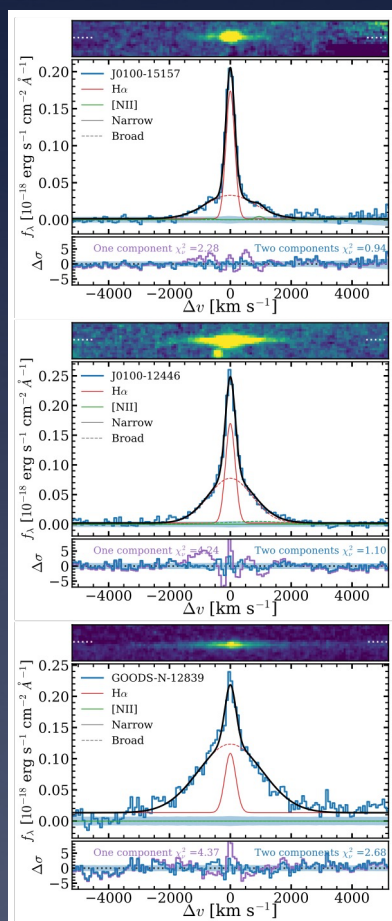
Kocevski et al. (2023)

- * CEERS Broad-line AGN 2-3 dex less massive than existing samples of $z > 6$ AGN. Least massive BH known in the early Universe.

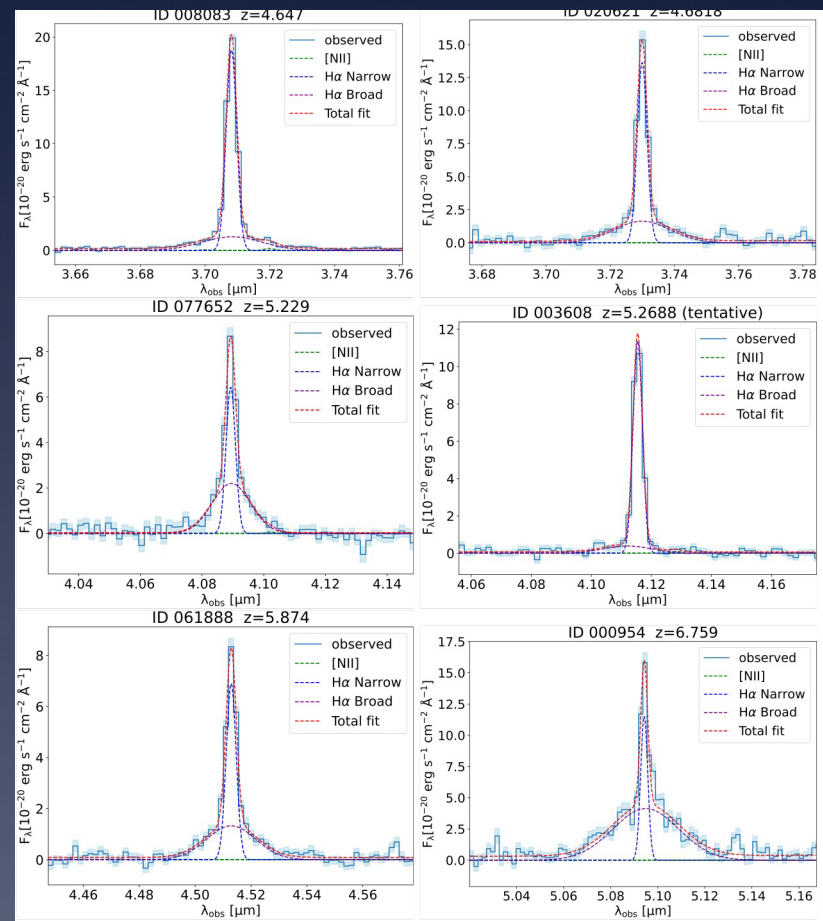
A Large Population of Faint Broad-Line AGN at $z > 4$



Harikane+23

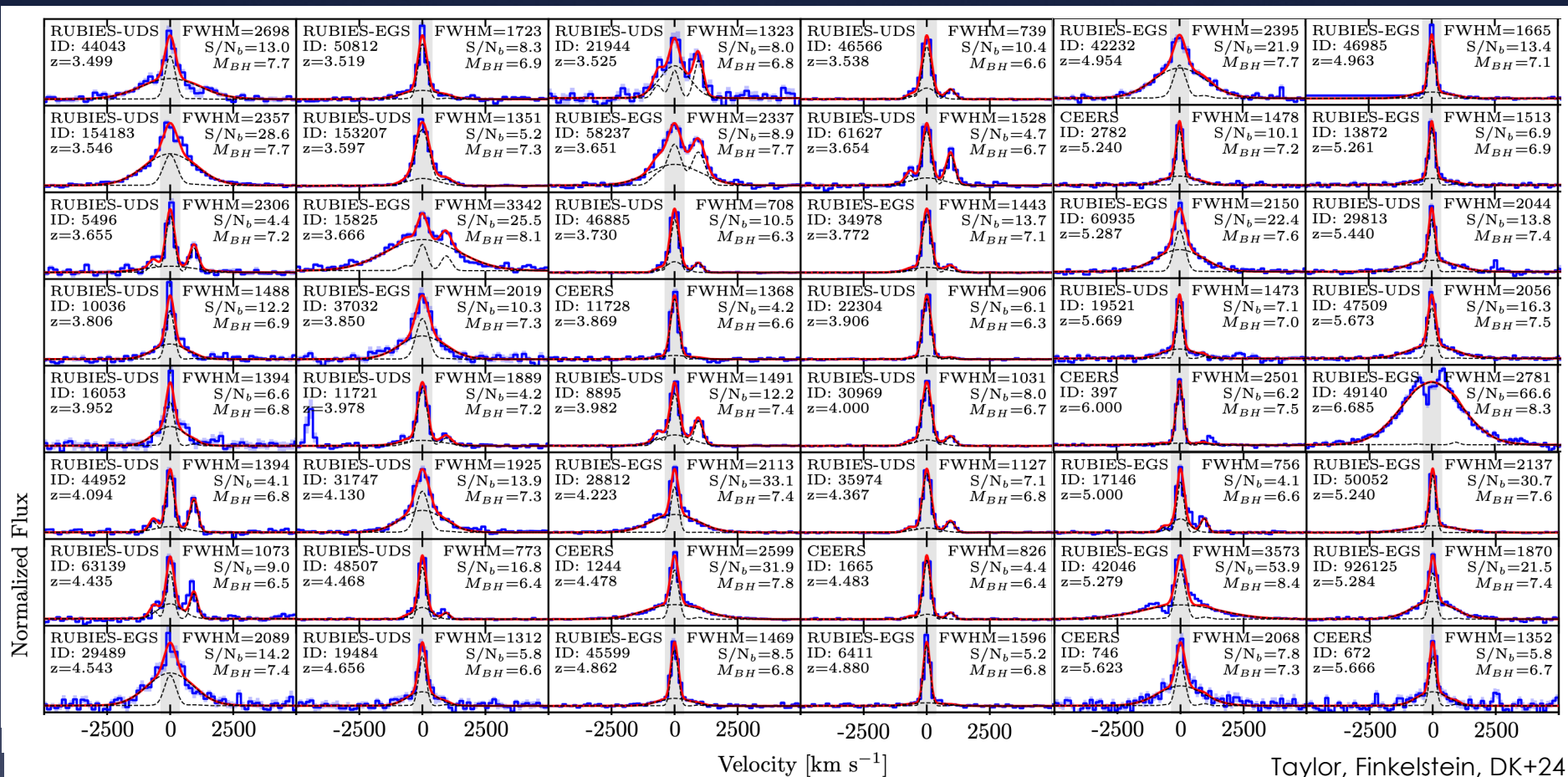


Matthee+23



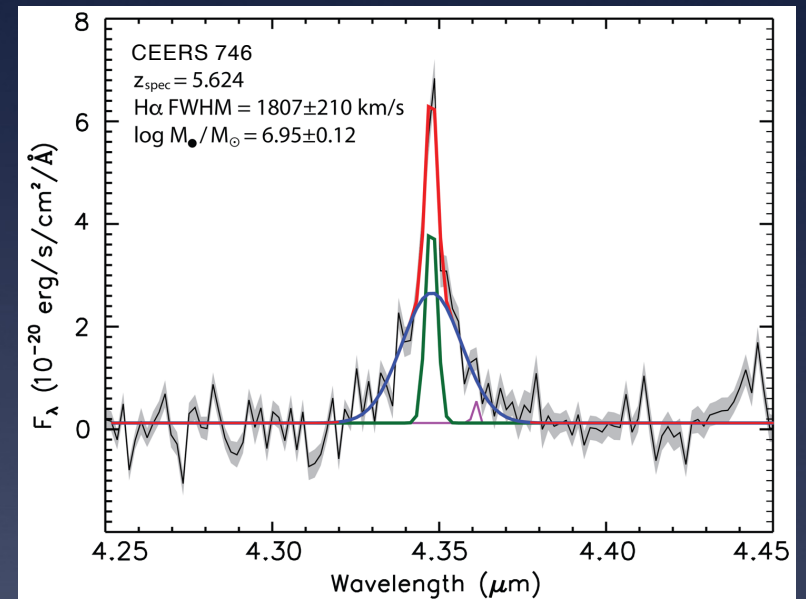
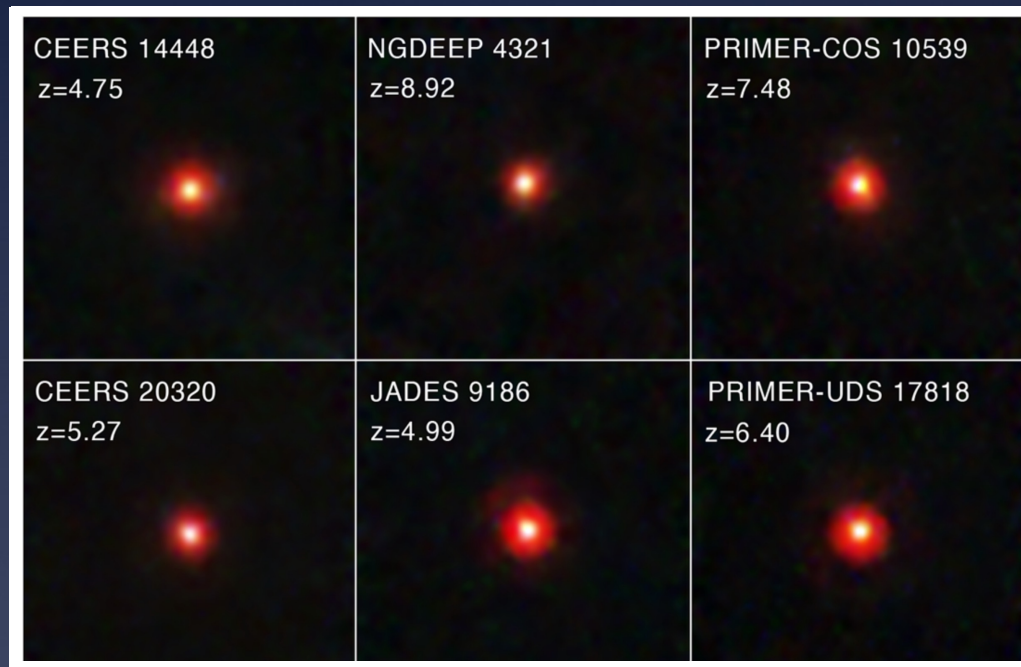
Maiolino+23

A Large Population of Faint Broad-Line AGN at $z > 4$



* 62 broad-line AGN identified in CEERS+PRIMER-UDS fields at $4 < z < 7$ using RUBIES dataset.

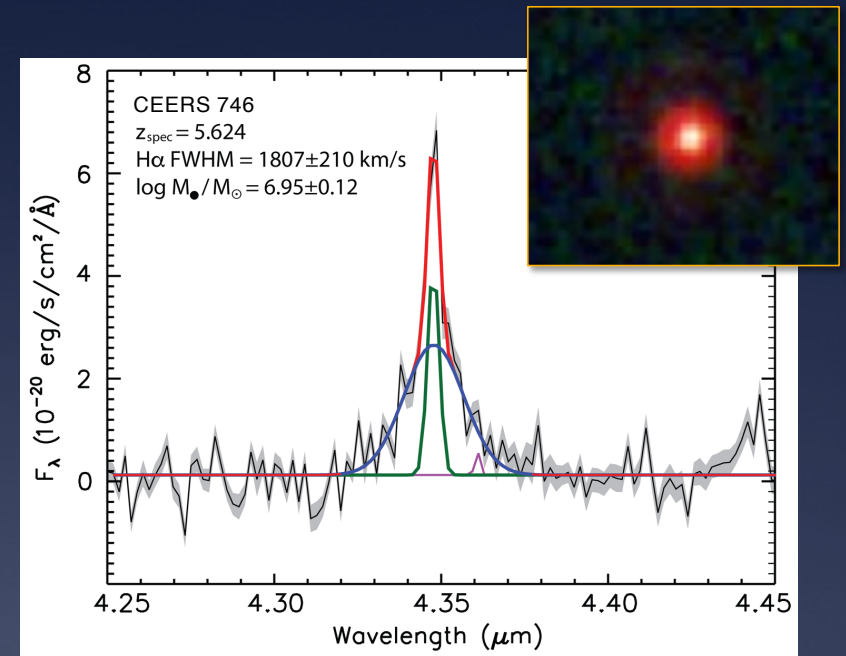
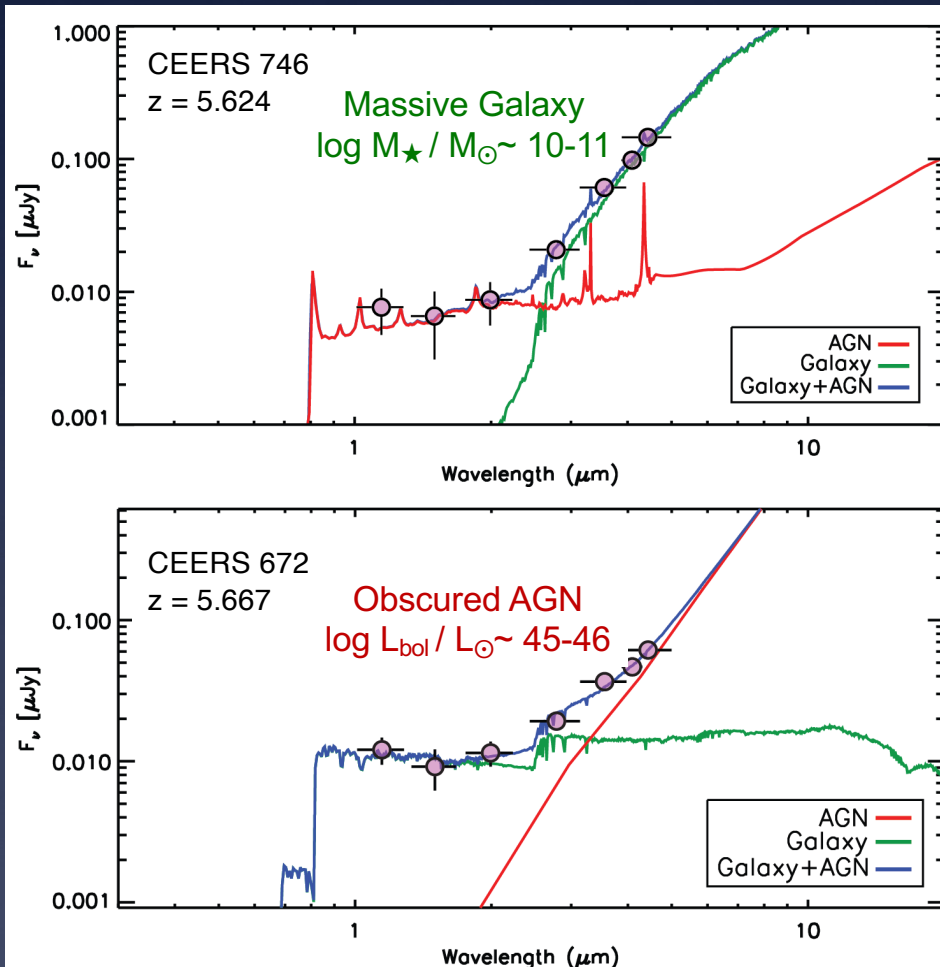
Little Red Dots: Massive Galaxies or Obscured AGN?



Kocevski+23

- * Origin of V-shaped SED debated since the detection of first broad-line LRD
- * Make up 20-30% of broad-line sources identified by JWST at $z > 5$.

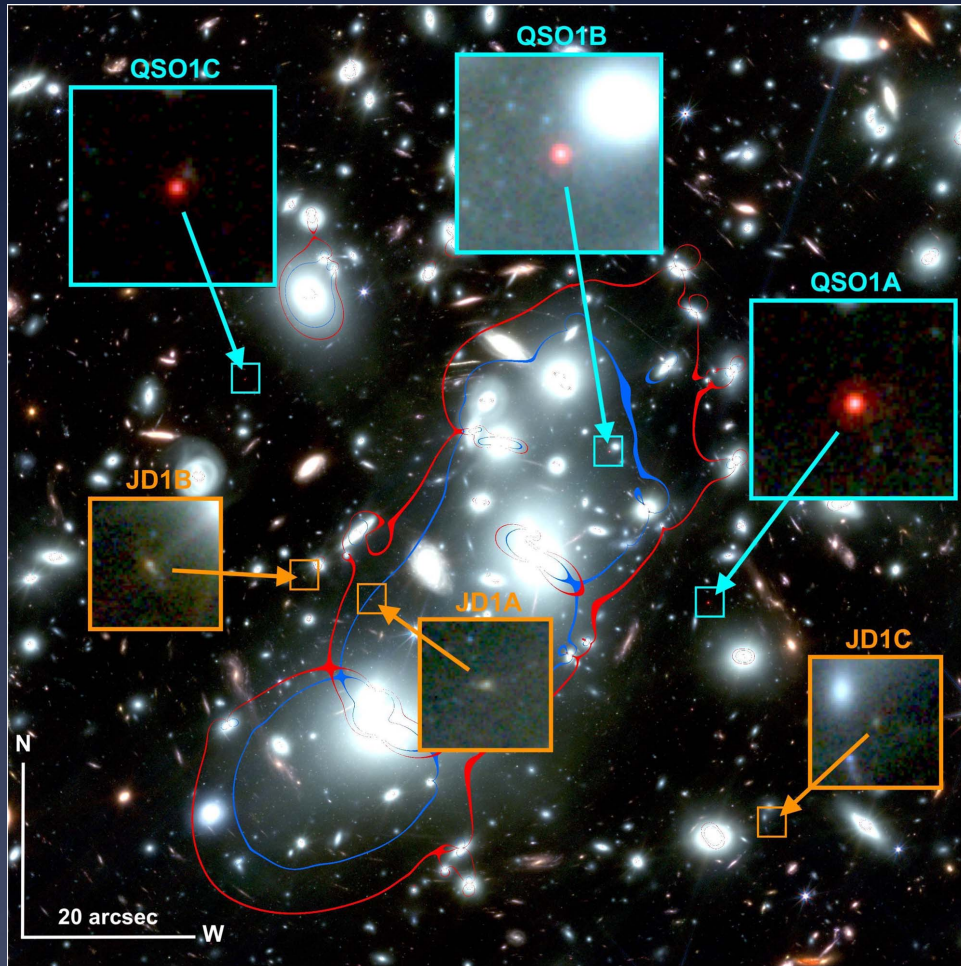
Little Red Dots: Massive Galaxies or Obscured AGN?



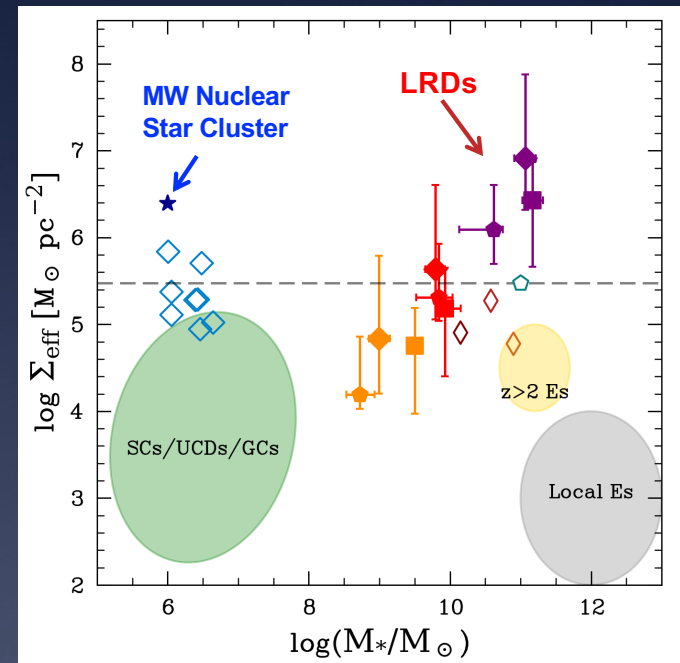
Kocevski+23

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LRDs are Extremely Compact



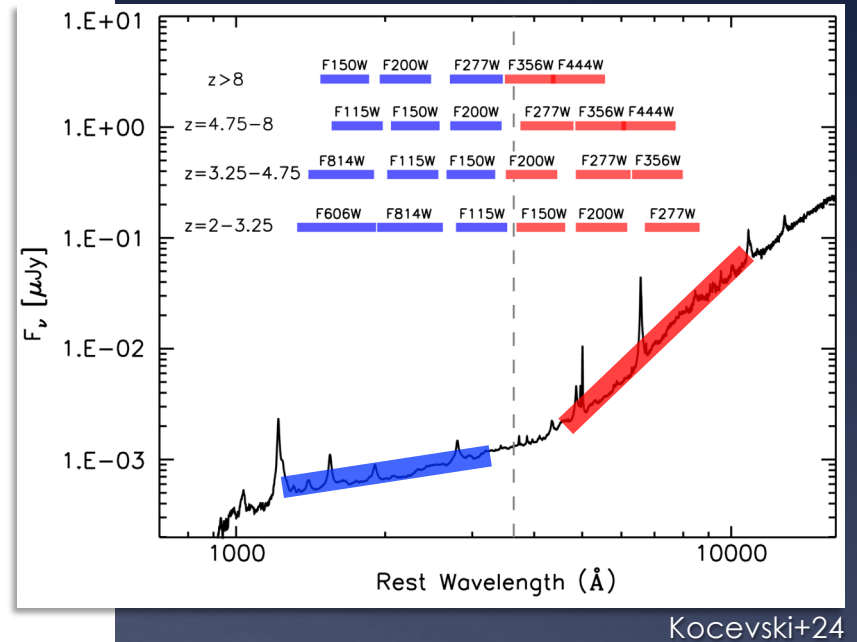
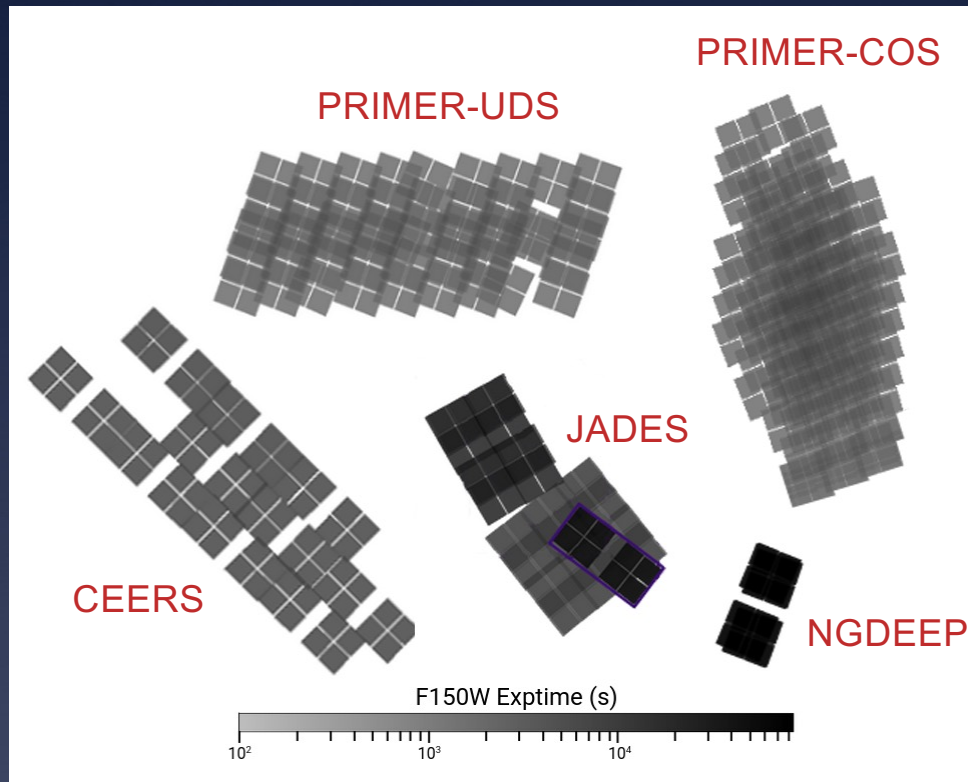
Furtak+23



Baggen+24

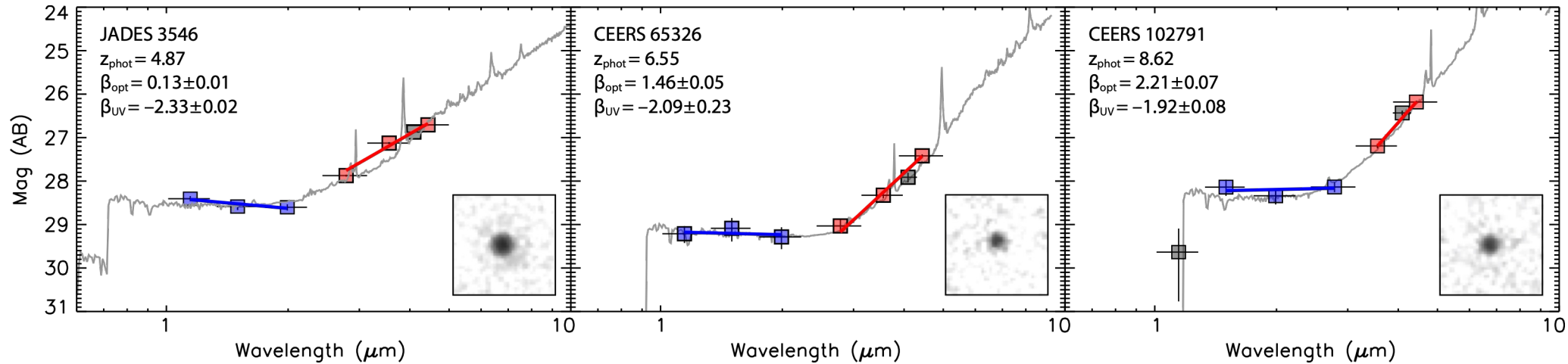
- * Triply lensed LRD in Abell 2744 constrains size to $R_e < 35$ pc (Furtak+24). Stellar mass of $\sim 10^{10} M_\odot$ implies stellar density over 10x of globular clusters.

A Census of Little Red Dots at $z > 2$



- * LRDs can be identified photometrically using rest-frame UV and optical continuum slopes. Extends search to wider redshifts vs color selection.

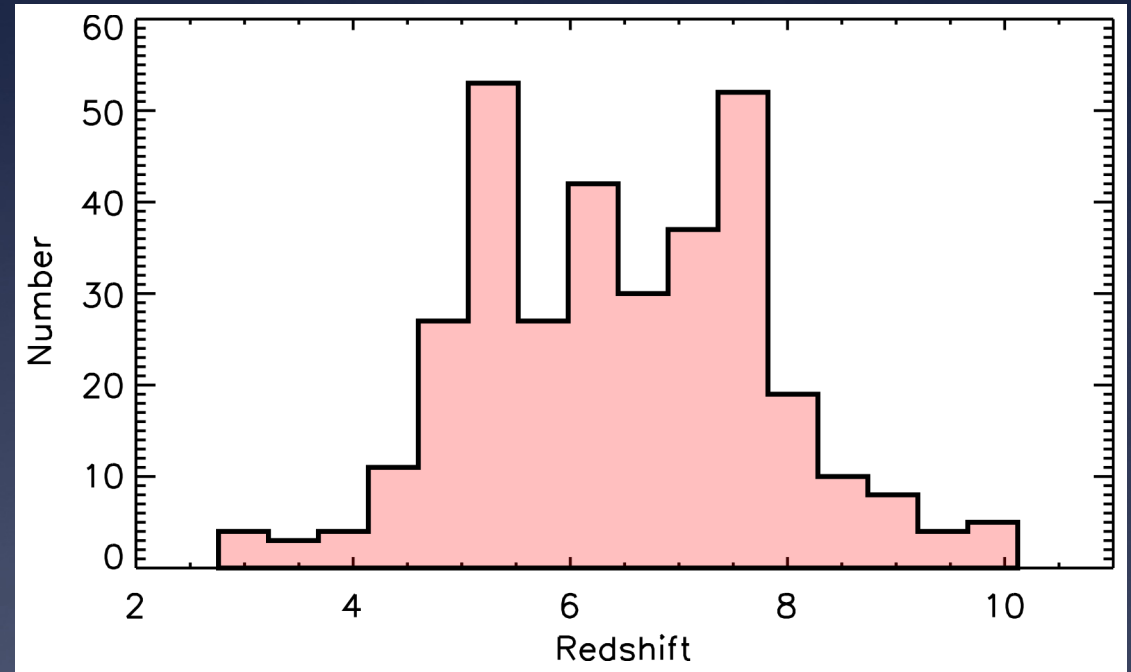
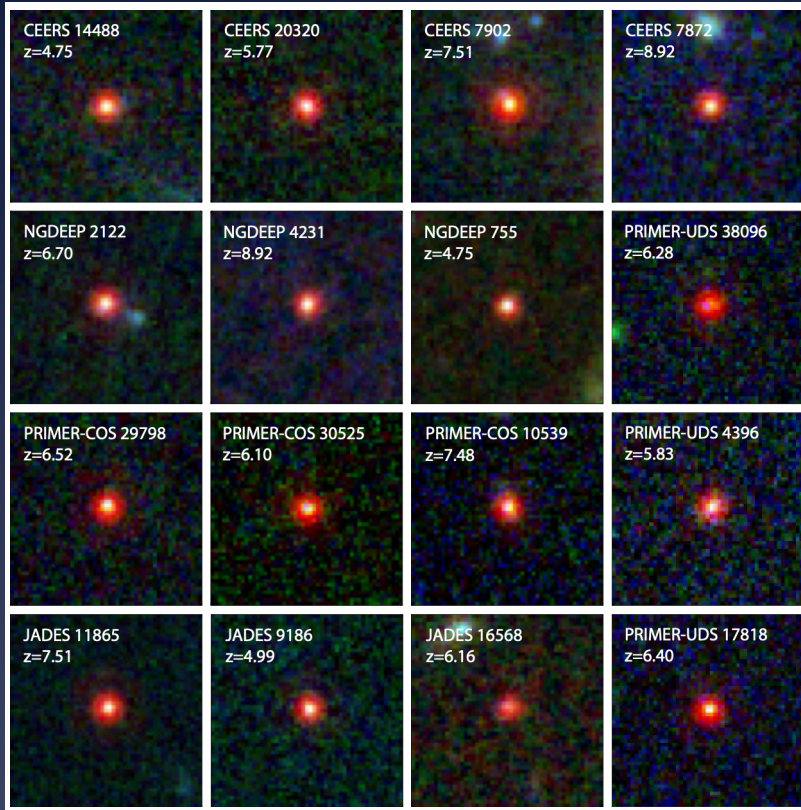
A Census of Little Red Dots at $z > 2$



Kocevski+25

- * LRDs selected using rest-frame UV and optical continuum slope. Measured for all sources at $z > 2$.
- * Fields: CEERS, JADES, NGDEEP, UNCOVER, PRIMER COS & UDS
- * Final sample includes 341 candidate faint, red AGN.

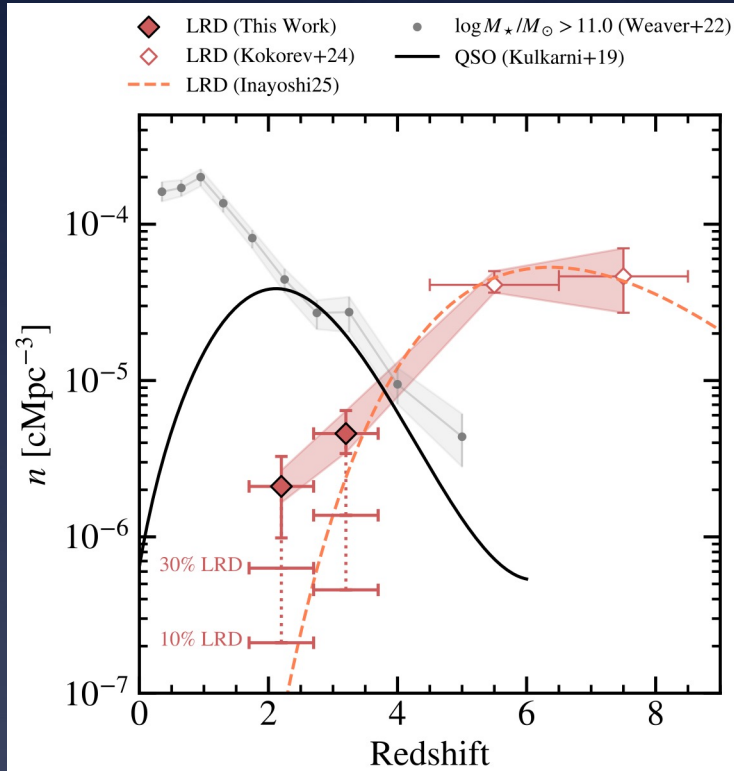
The Rise of LRDs at $z > 4$



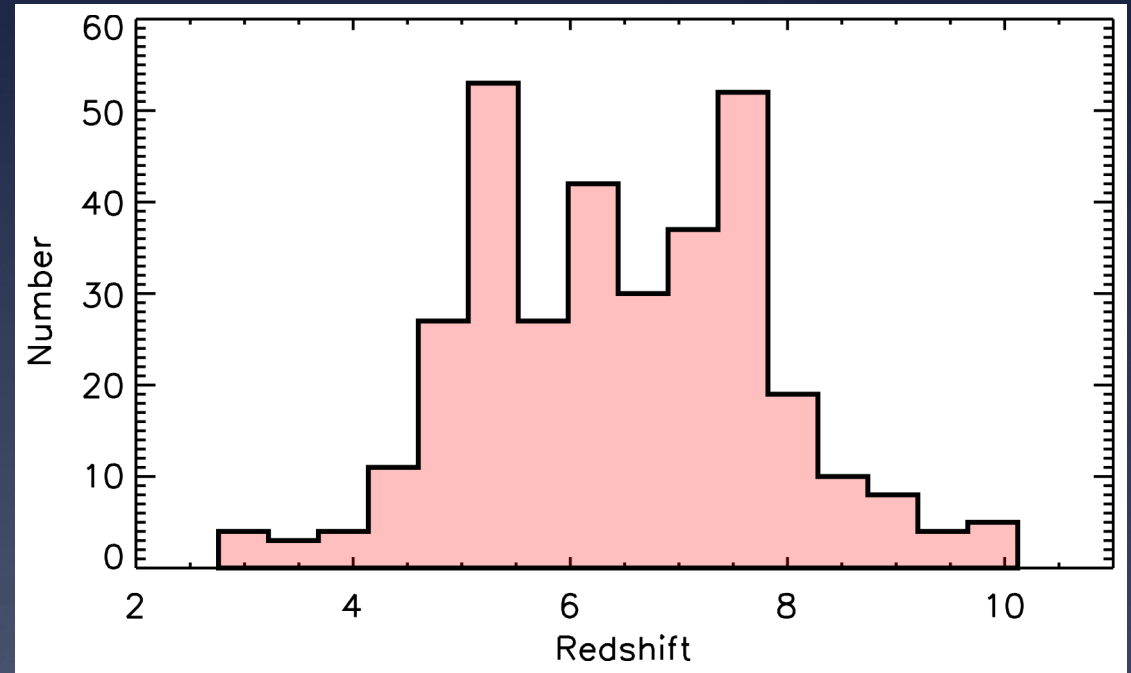
Kocevski+24

- * LRDs appear to **emerge in large numbers at $z \sim 4$** and peak at $z \sim 6.5$
- * Lower redshift analogs exist, but number density drops dramatically at $z < 4$ (see Ma+25, Bisigello+25 and Lin+25)

The Rise of LRDs at $z > 4$



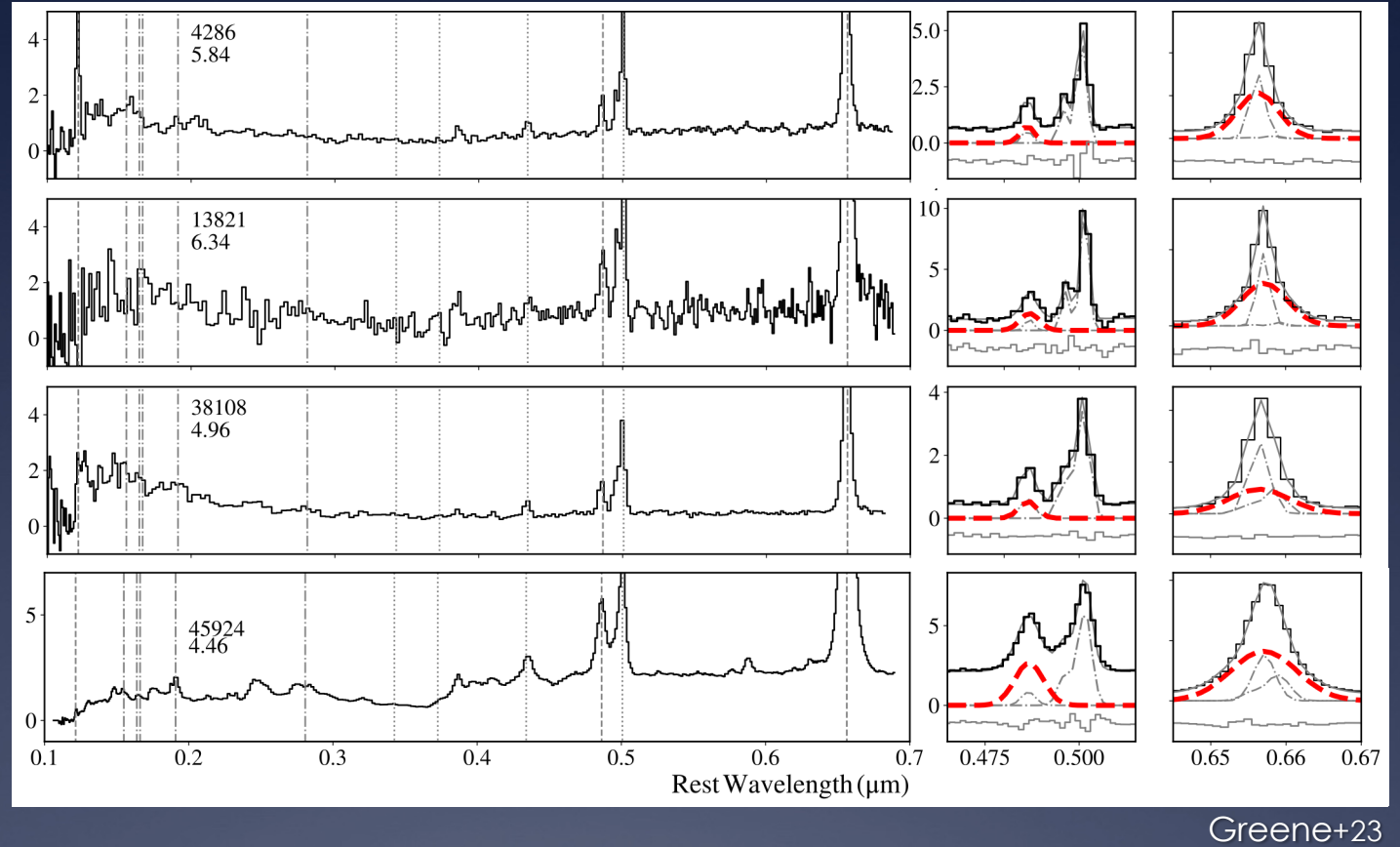
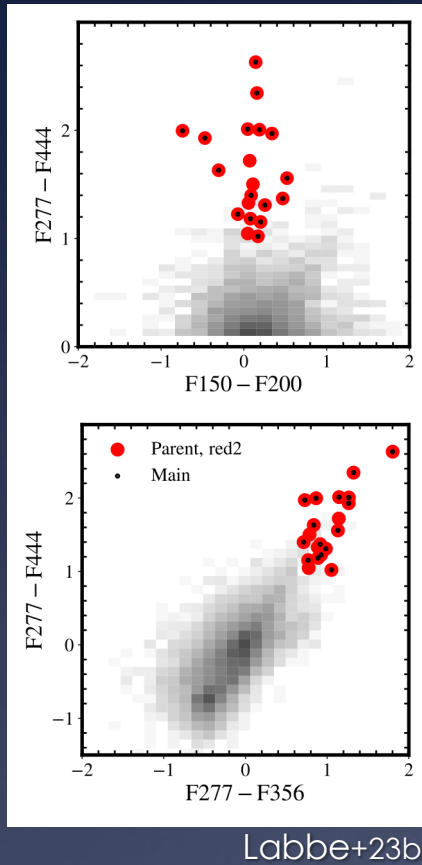
Ma+25



Kocevski+24

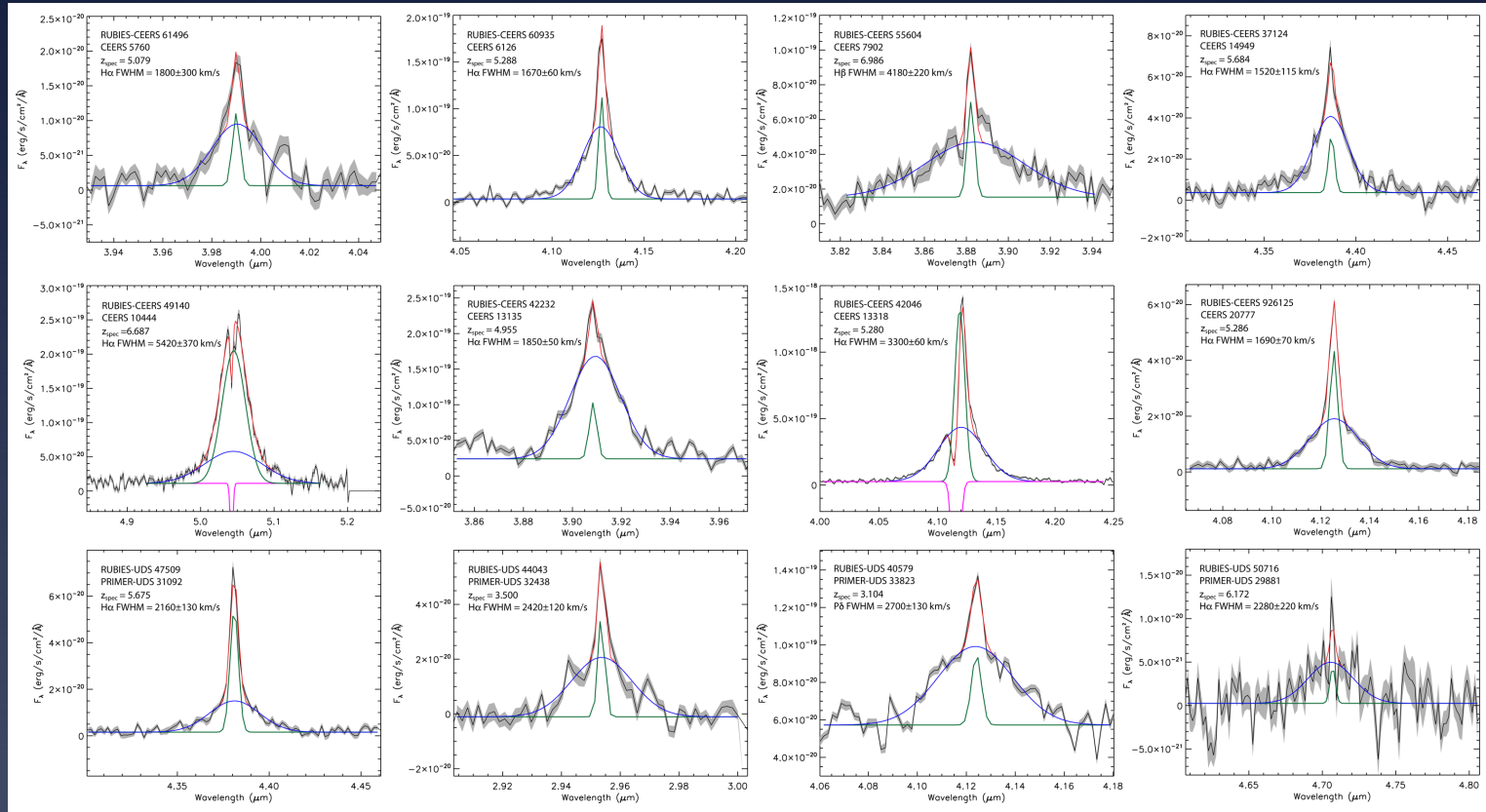
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Confirmed Broad-Line Detections



* UNCOVER PRISM spectroscopy confirms 2/3 of reddest LRDs have broad lines.

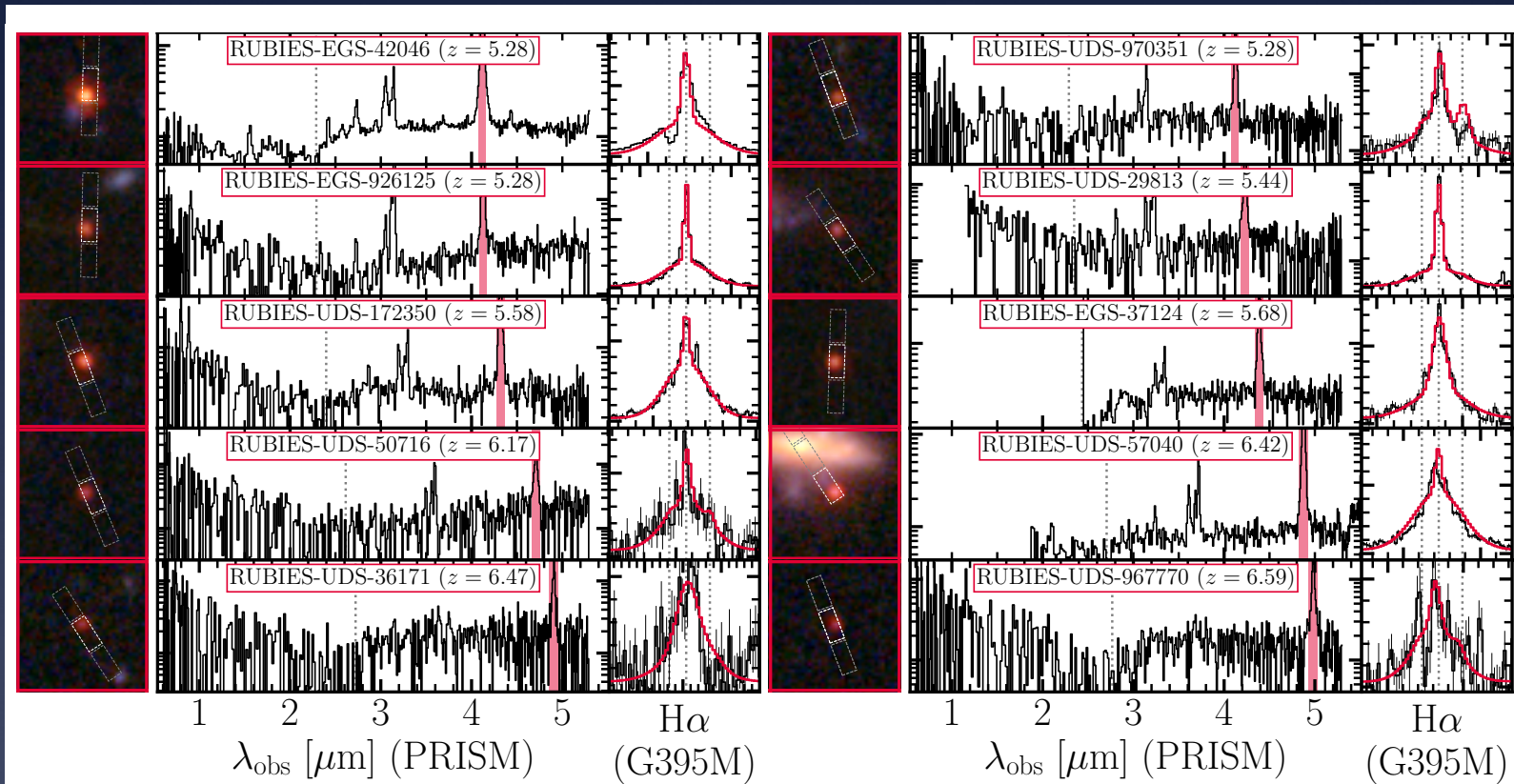
Confirmed Broad-Line Detections



Kocevski+25

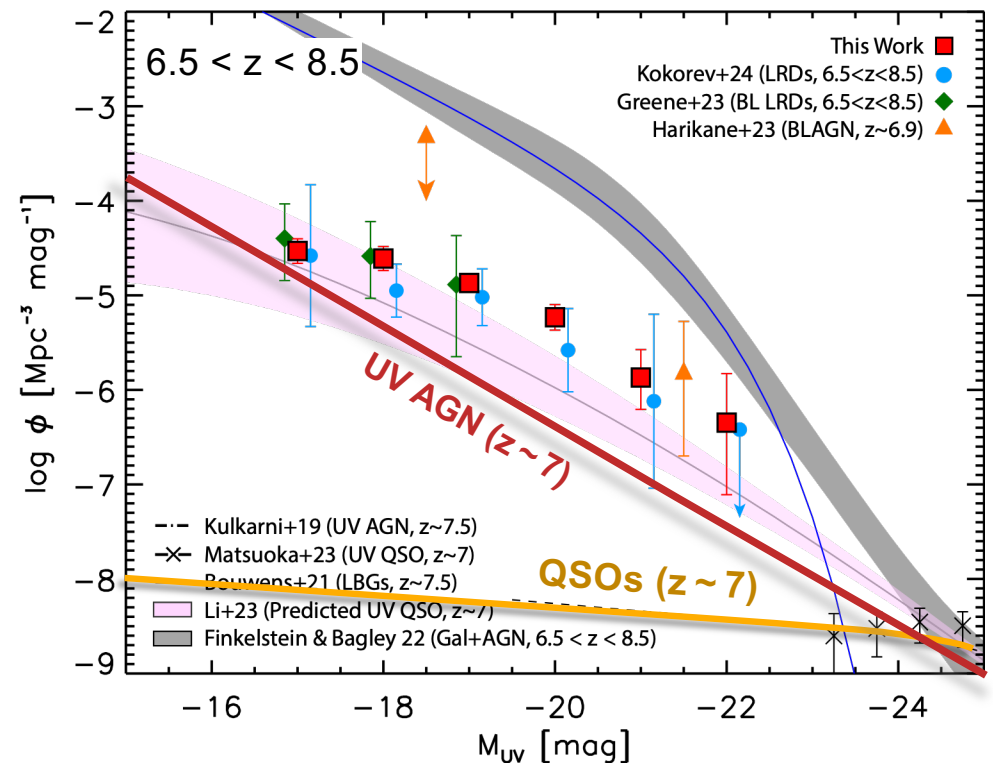
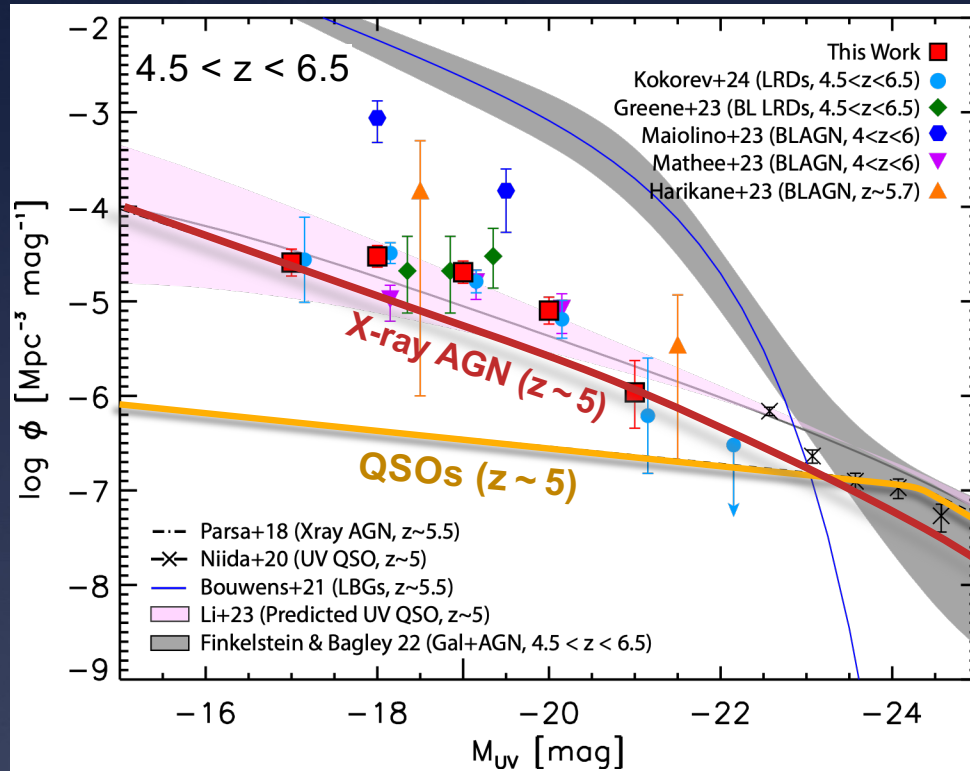
- * NIRSpect G395M spect from the RUBIES survey of 24 LRDs in our sample confirms that 70-80% show broad-line emission (1400-4200 km/s).

Confirmed Broad-Line Detections



* **Hviding+25:** All point sources with V-shaped continua have broad lines

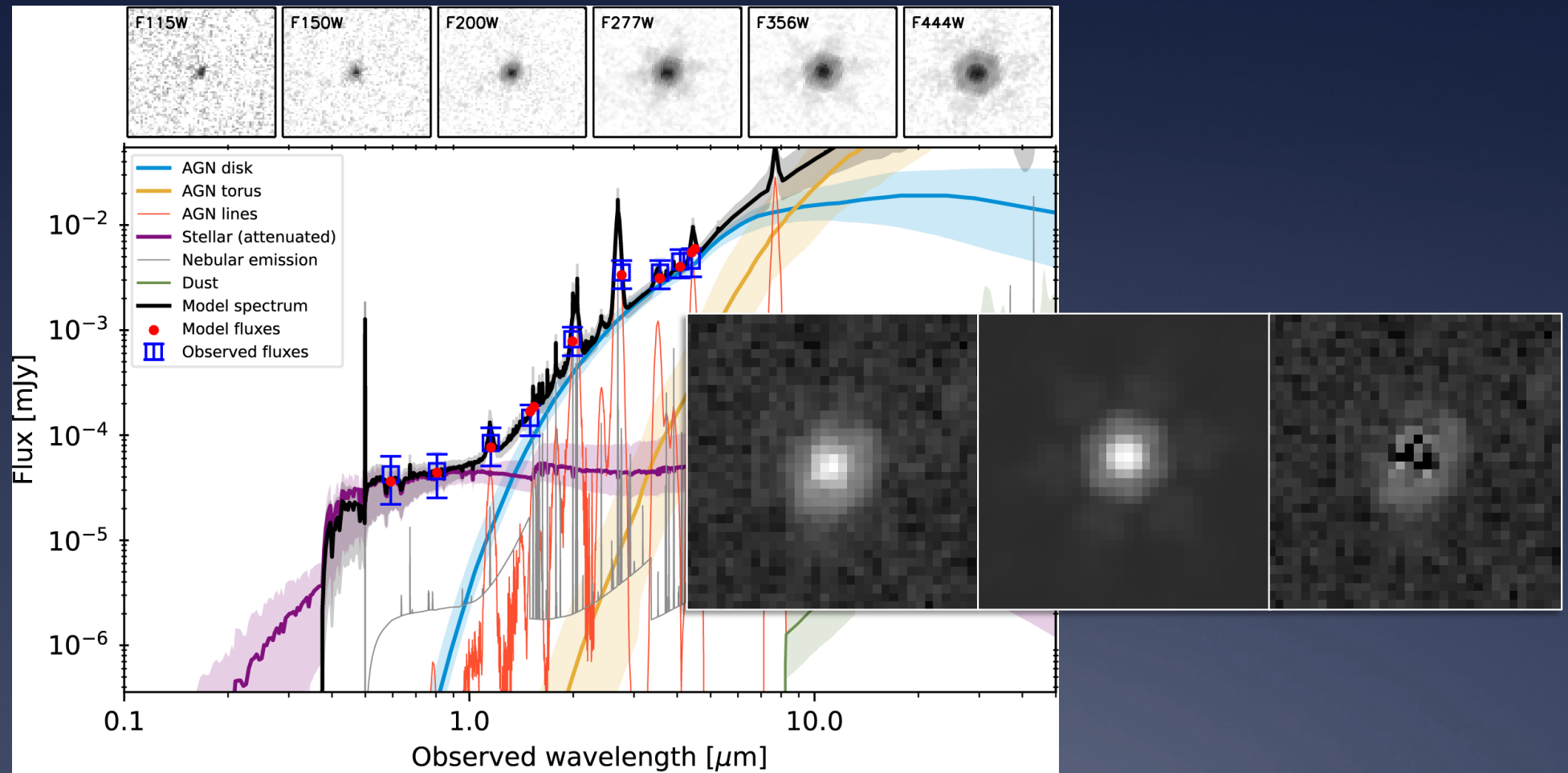
Rest-UV Luminosity Function of LRDs



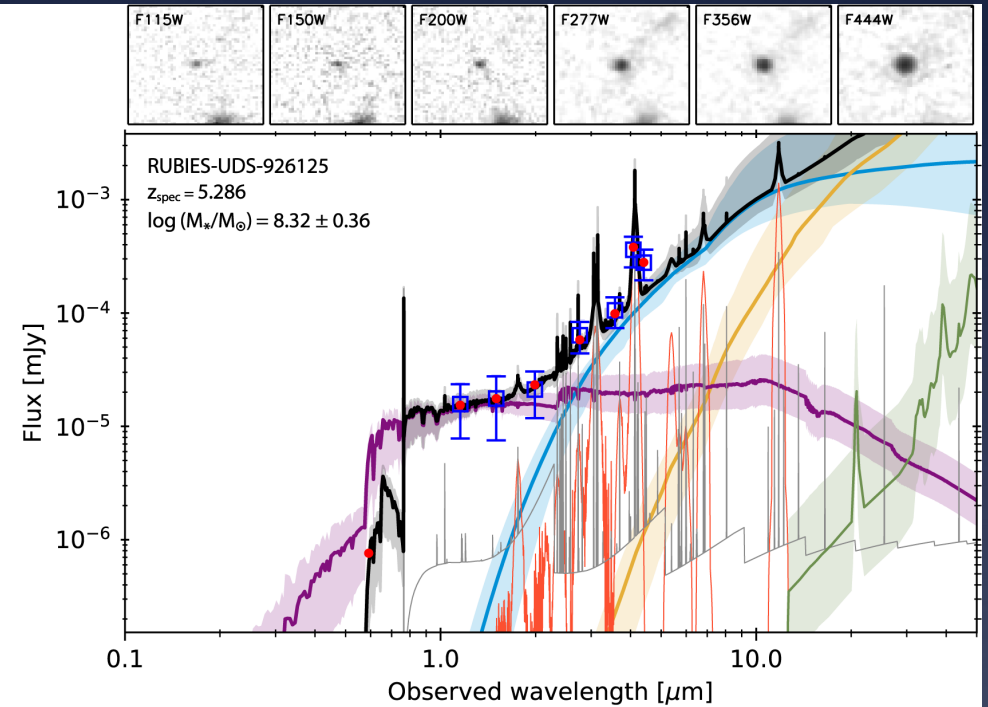
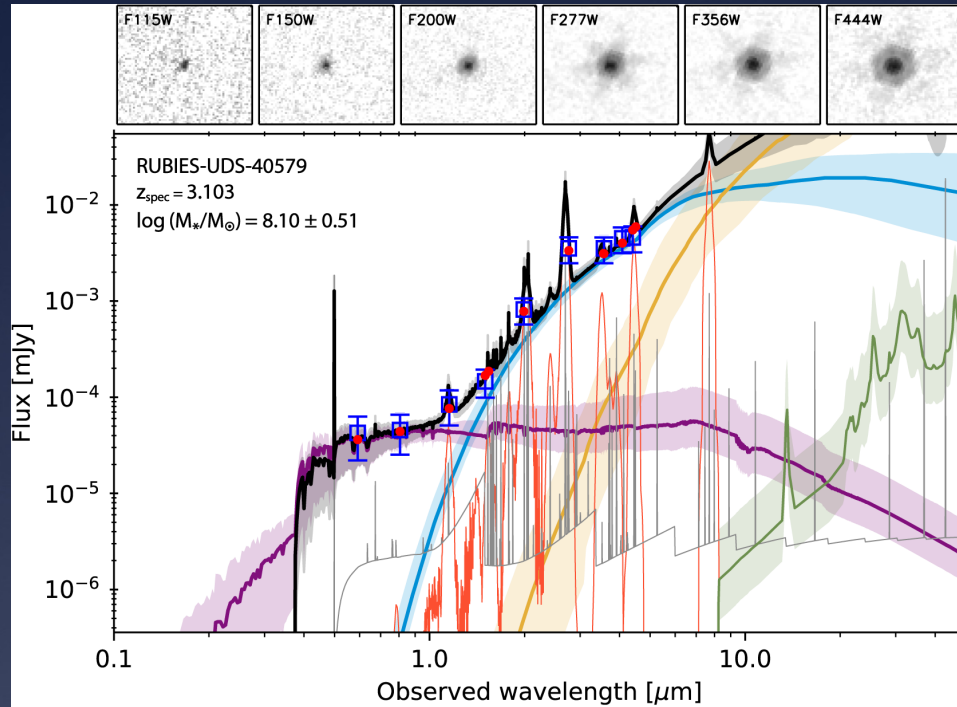
Kocevski+25

- * Number density 10x above extrapolations of bright quasars at $z \sim 5$. Roughly 1 dex above X-ray and UV-selected AGN. See also Kokorev+24.

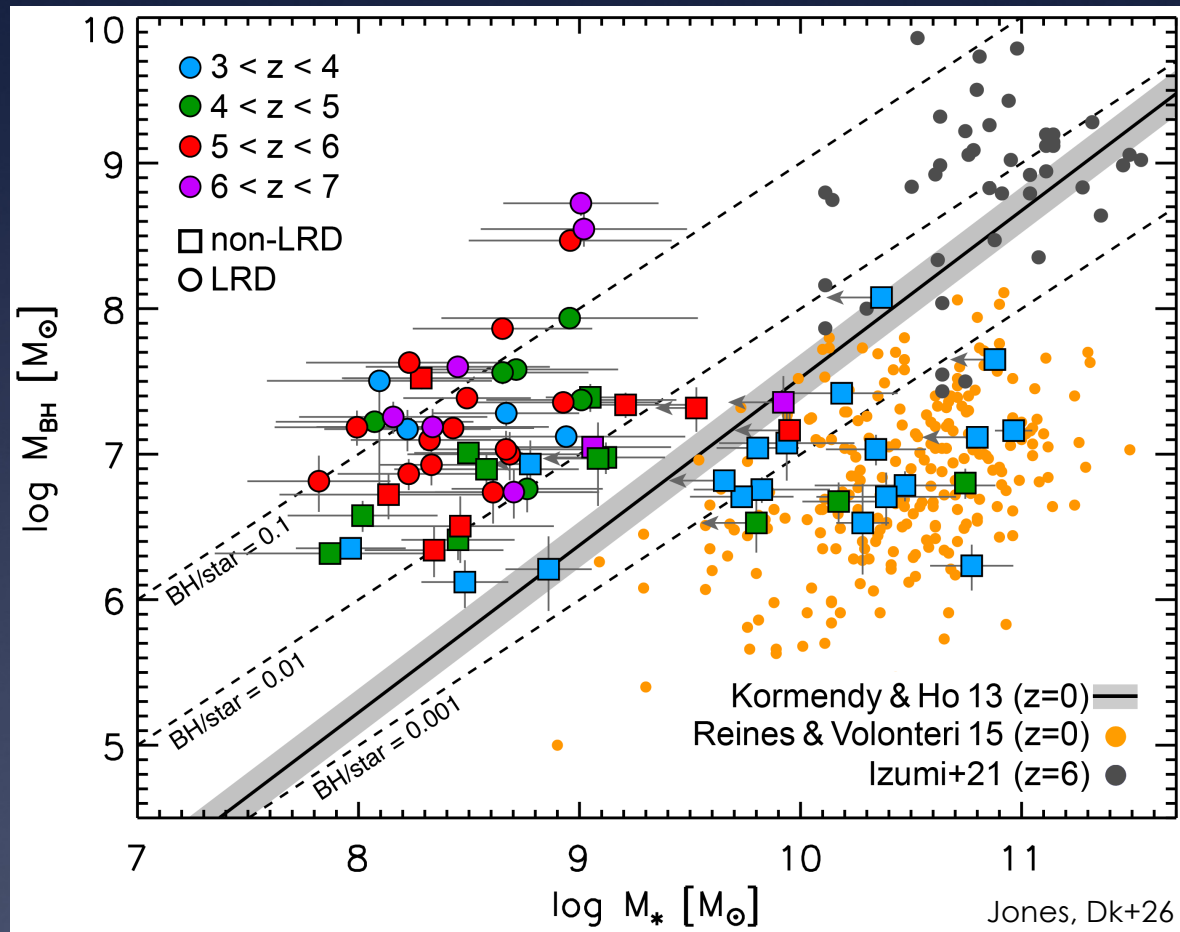
Estimating Host Masses for LRDs



Estimating Host Masses for LRDs

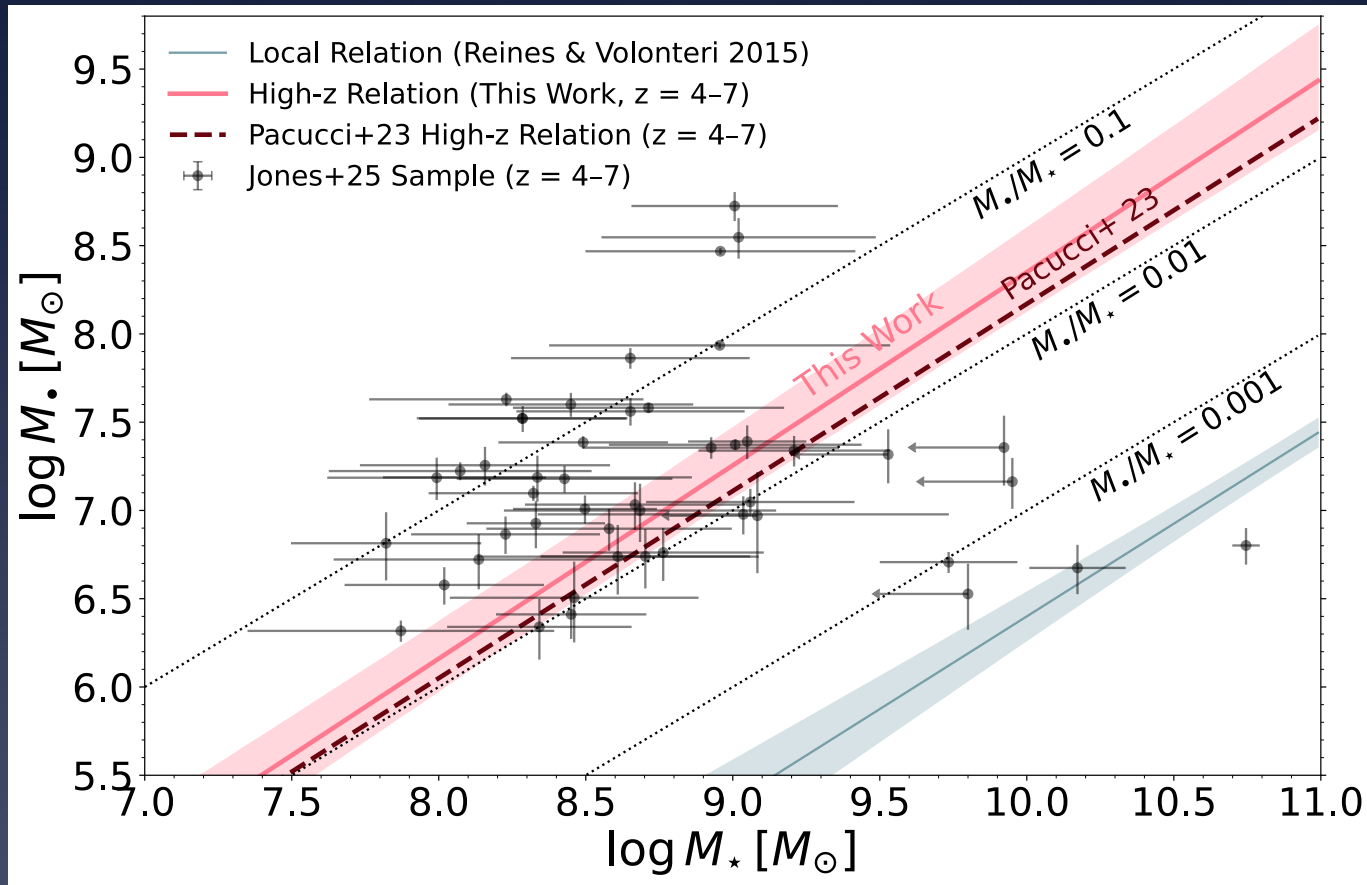


Black Hole vs Galaxy Mass



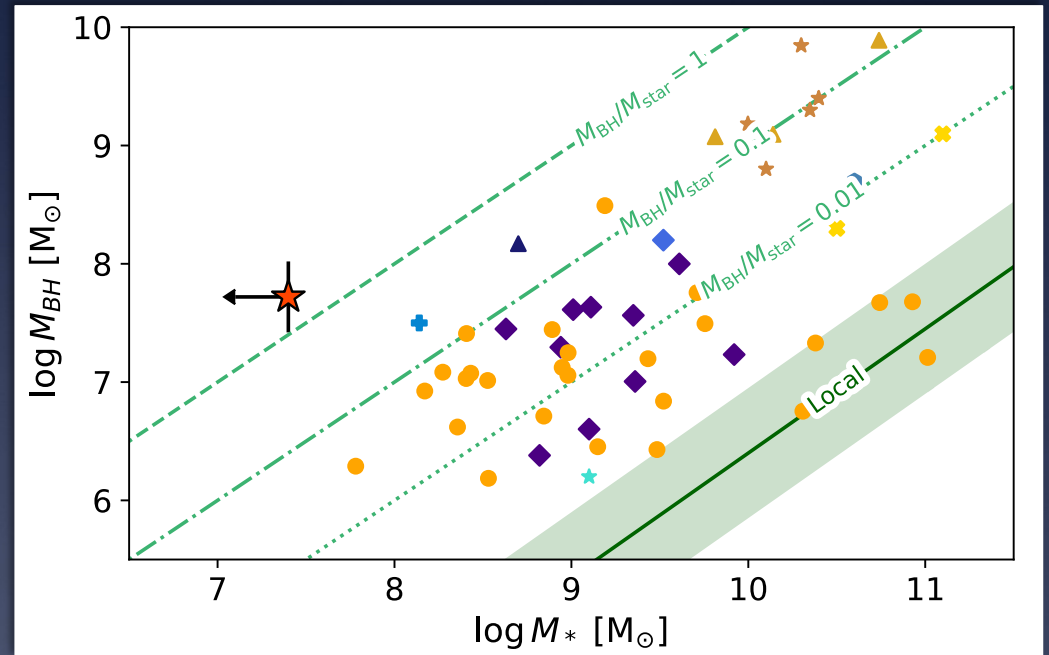
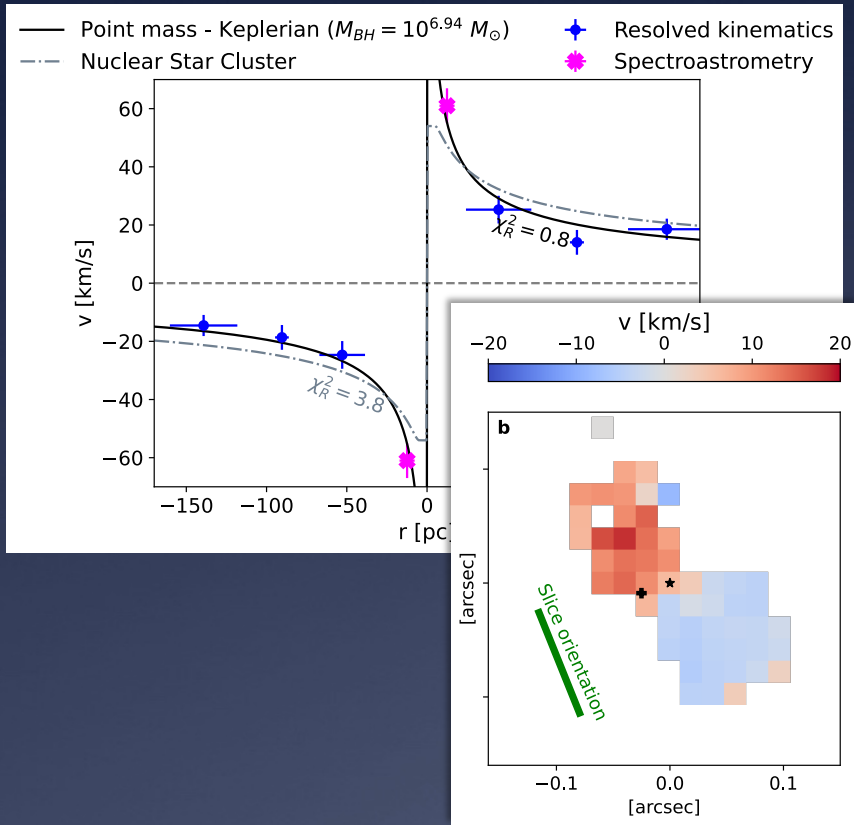
* Host masses scatter above local relationship, favoring **overmassive** BH scenario.

Evidence for Over-massive BH in LRDs



- * Using forward modeling approach of Pacucci+24, we find that LRDs at $4 < z < 7$ deviate from local scaling relationship at $>3\sigma$ (Jones, DK+25)

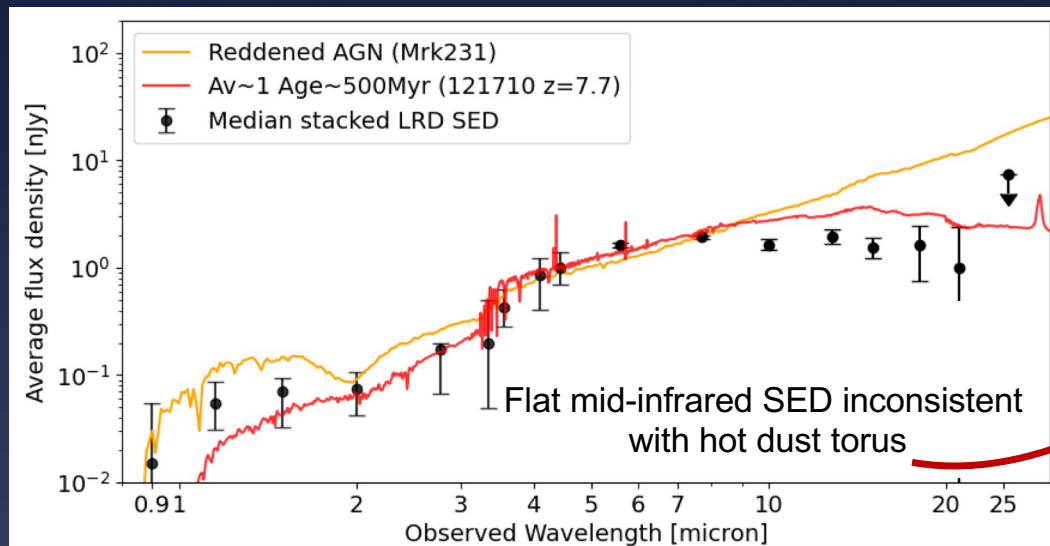
Direct Measurement of BH Mass in an LRD at $z=7.04$



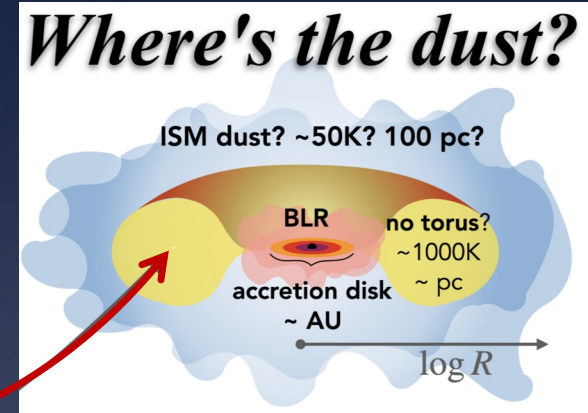
Juodžbalis+25

* Naked BHs: dynamical mass measurement finds low stellar mass components.

Are LRDs Really Powered by AGN?

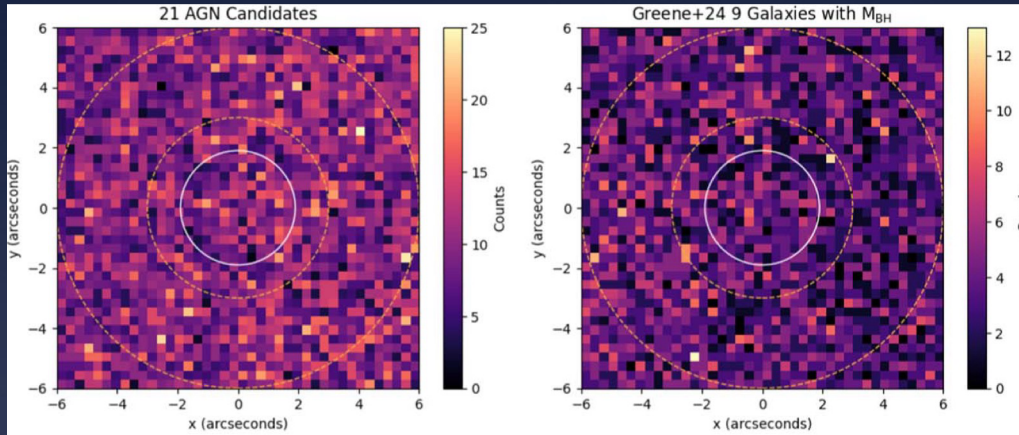


Williams+23

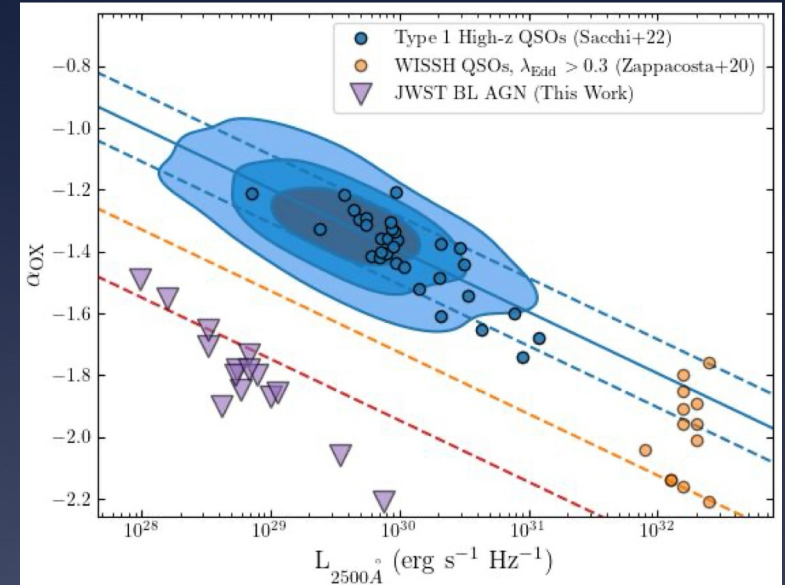


- * **Lack of mid-infrared detection** is inconsistent with the presence of a hot dust torus. (Williams+23, Perez-Gonzalez+24, Akins+24, Leung+24).
- * LRDs deviate from **X-ray** to optical relationships by 5σ (Maiolino+24, Lambrides+24).
- * Several LRDs identified with apparent **stellar breaks** (Wang+24).
 - * Are broad-lines due to gas dynamics in dense, massive galaxies (Baggen+24)?

Are LRDs Really Powered by AGN?



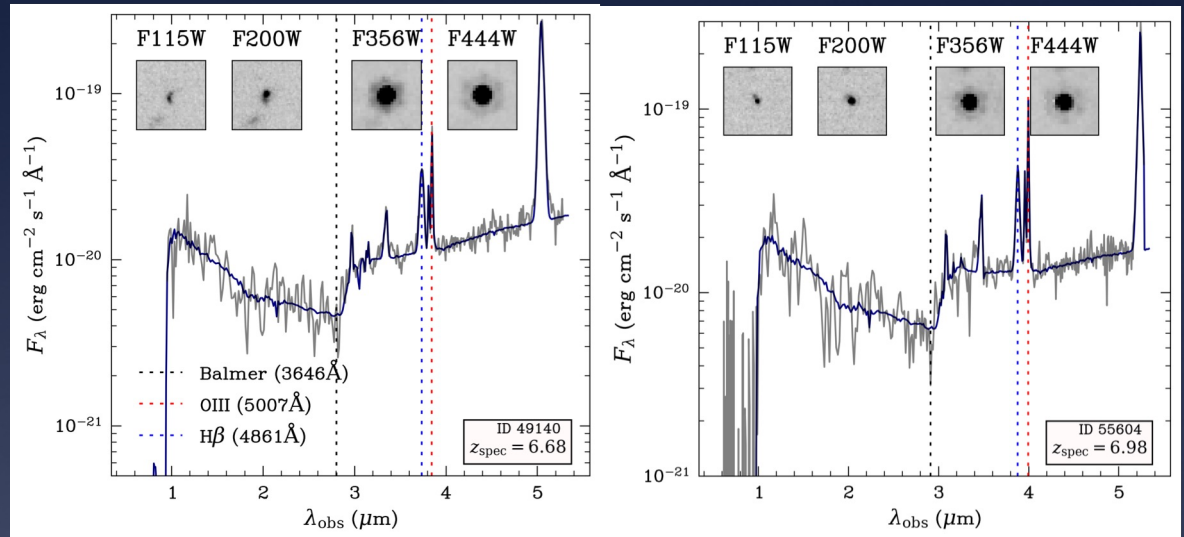
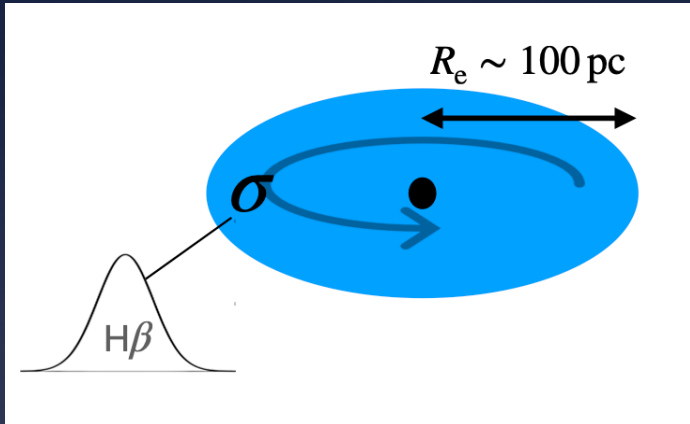
Ananna+24



Lambrides+24

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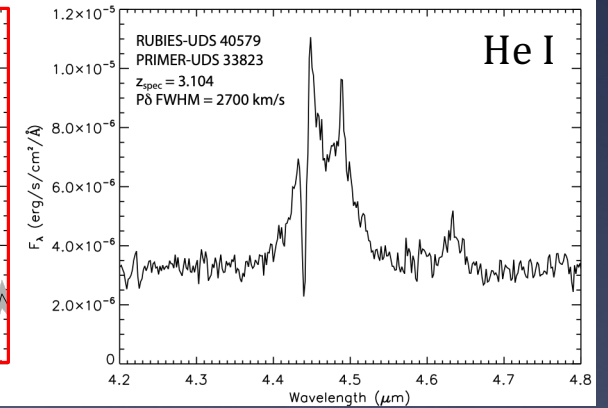
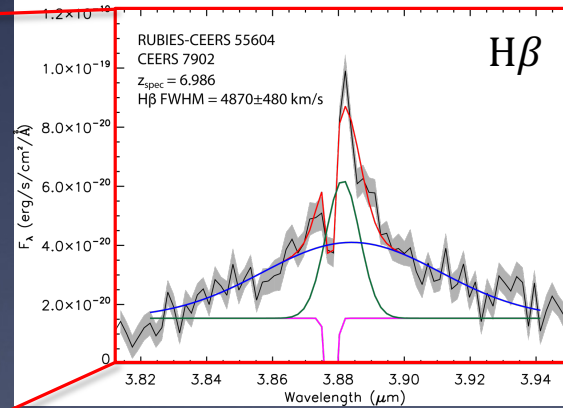
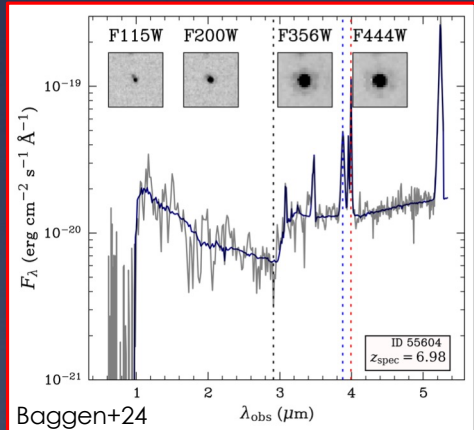
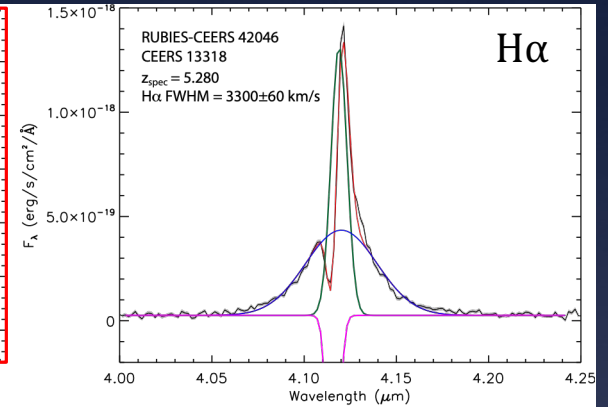
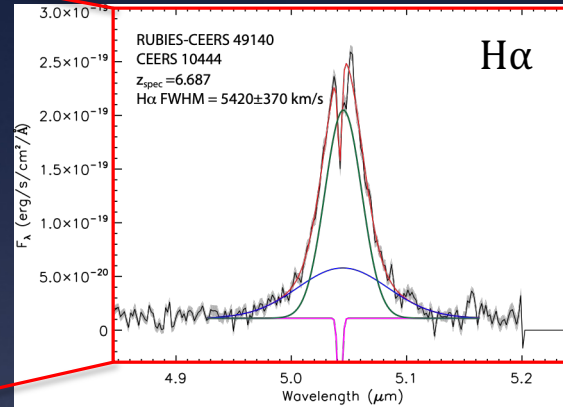
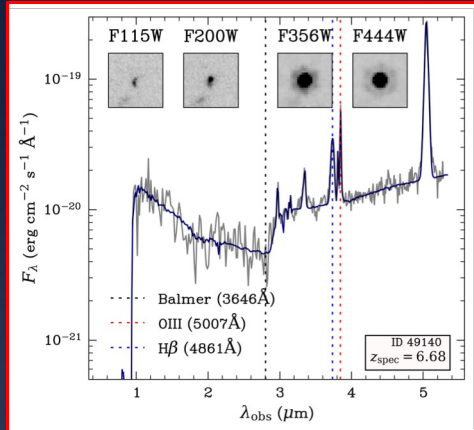
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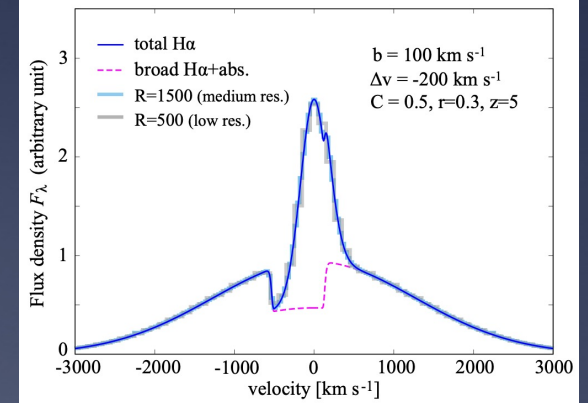
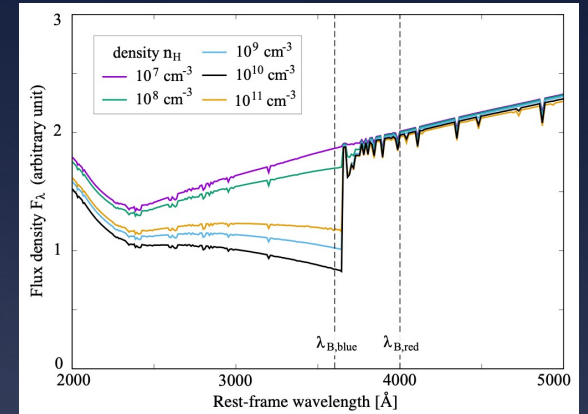
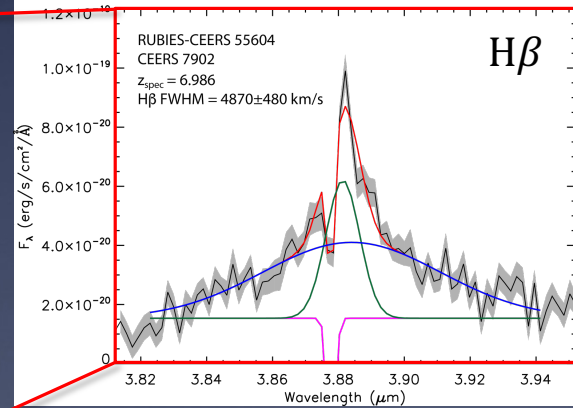
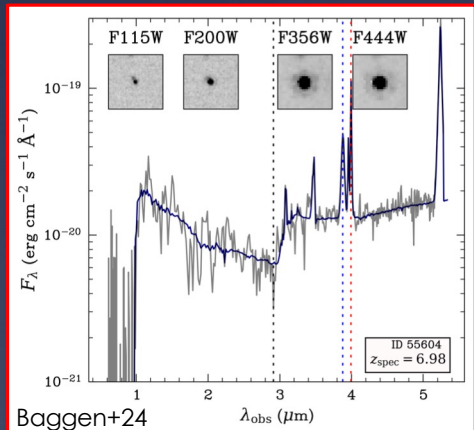
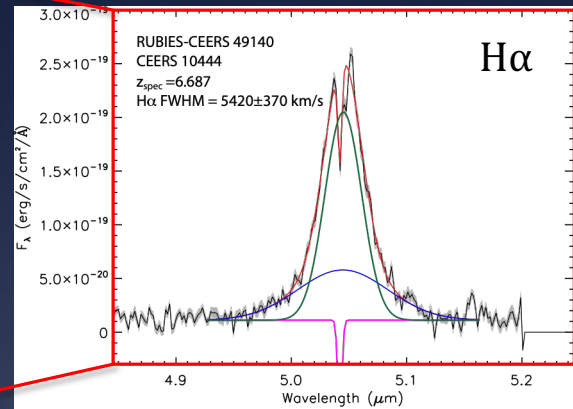
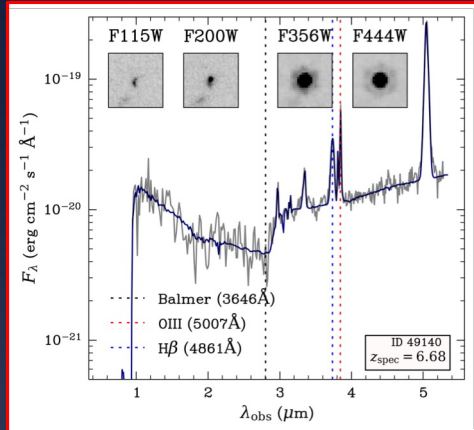
Balmer Absorption or Stellar Breaks?



* Balmer break LRDs also show **Balmer absorption** in their emission lines, which may mimic a stellar break (Inayoshi & Maiolino 24)

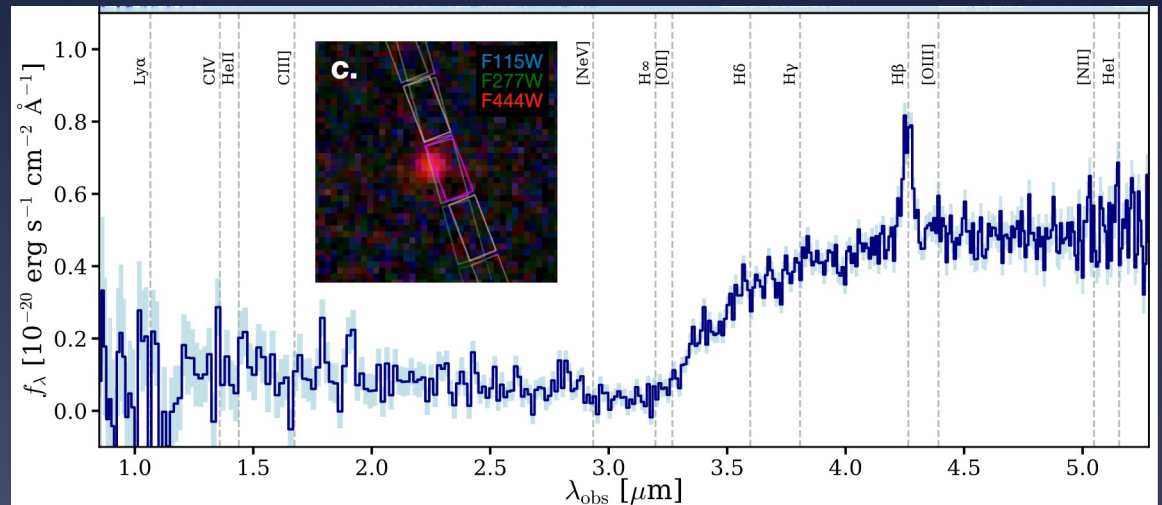
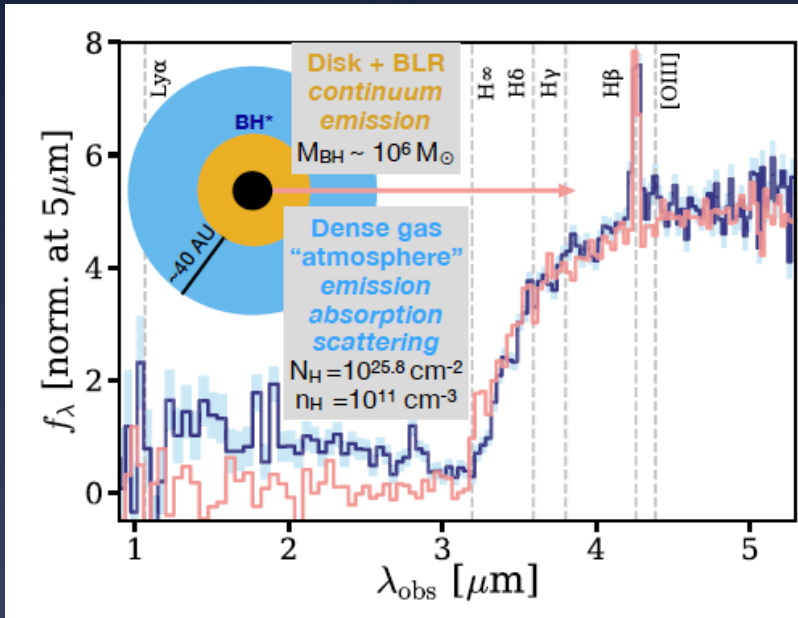
Kocevski+25

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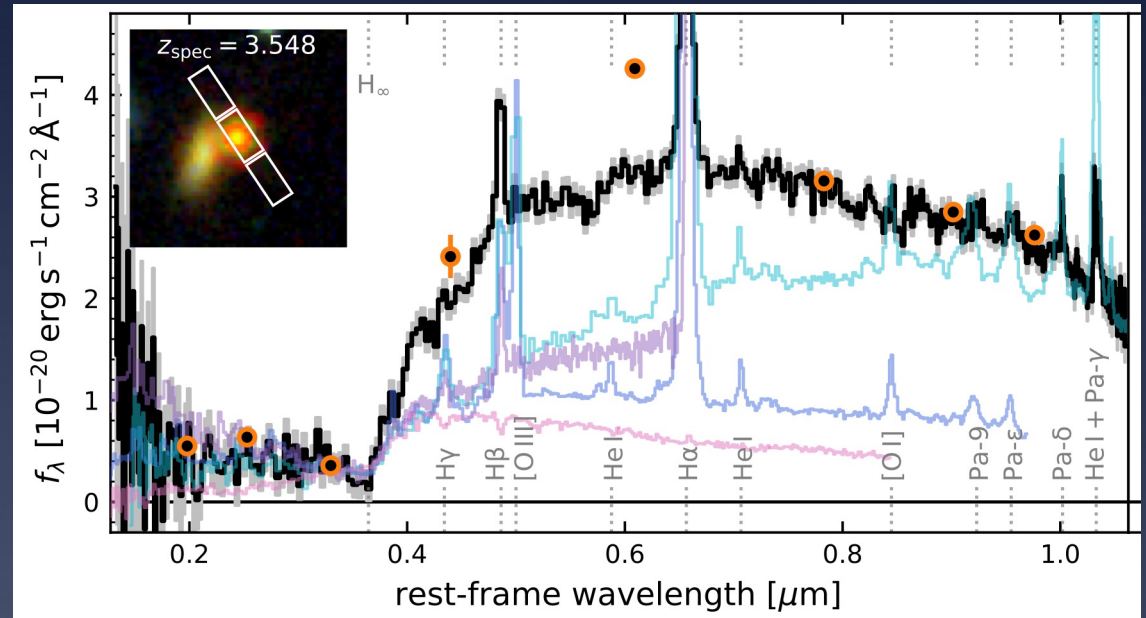
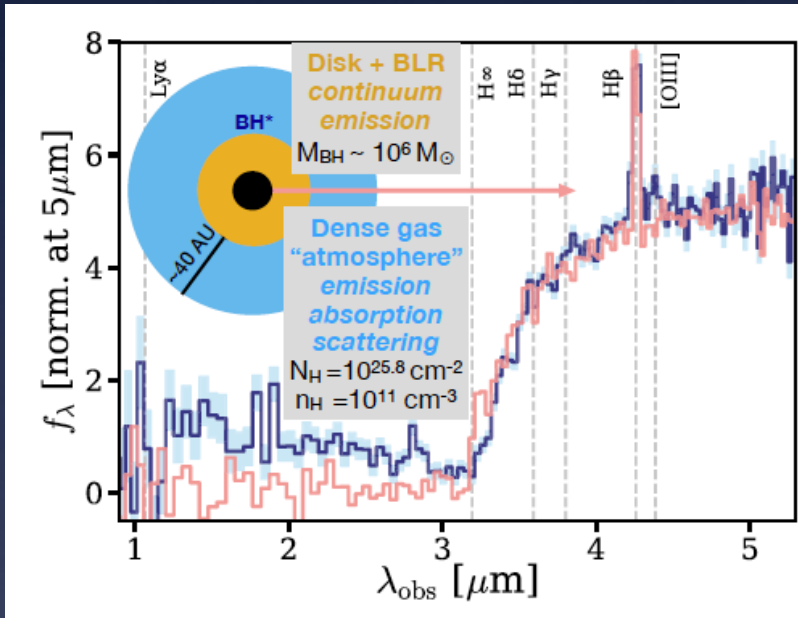
A Family of Heavily Gas Enshrouded LRDs



Naidu+25

- * A population of LRDs with extreme Balmer breaks identified (de Graaf+25, Naidu+25, Taylor+25). Appear to be **gas enshrouded** instead of dust reddened.

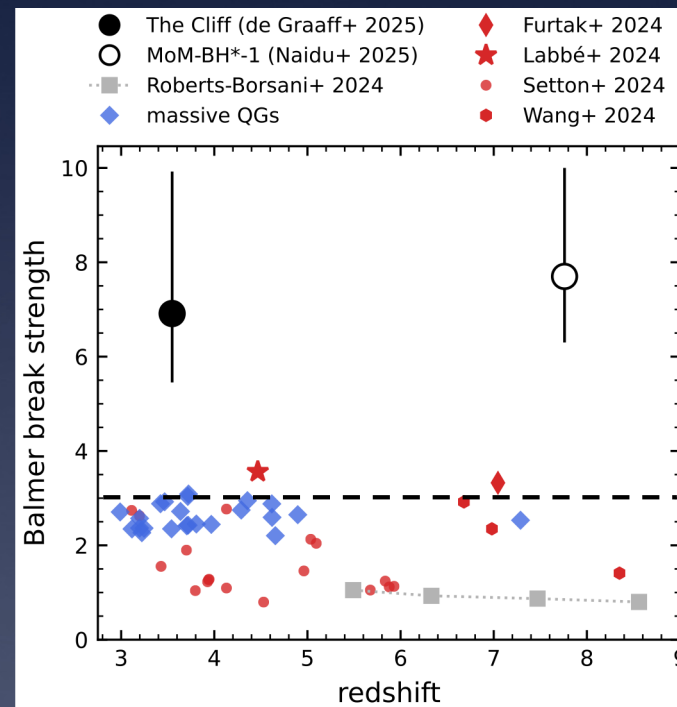
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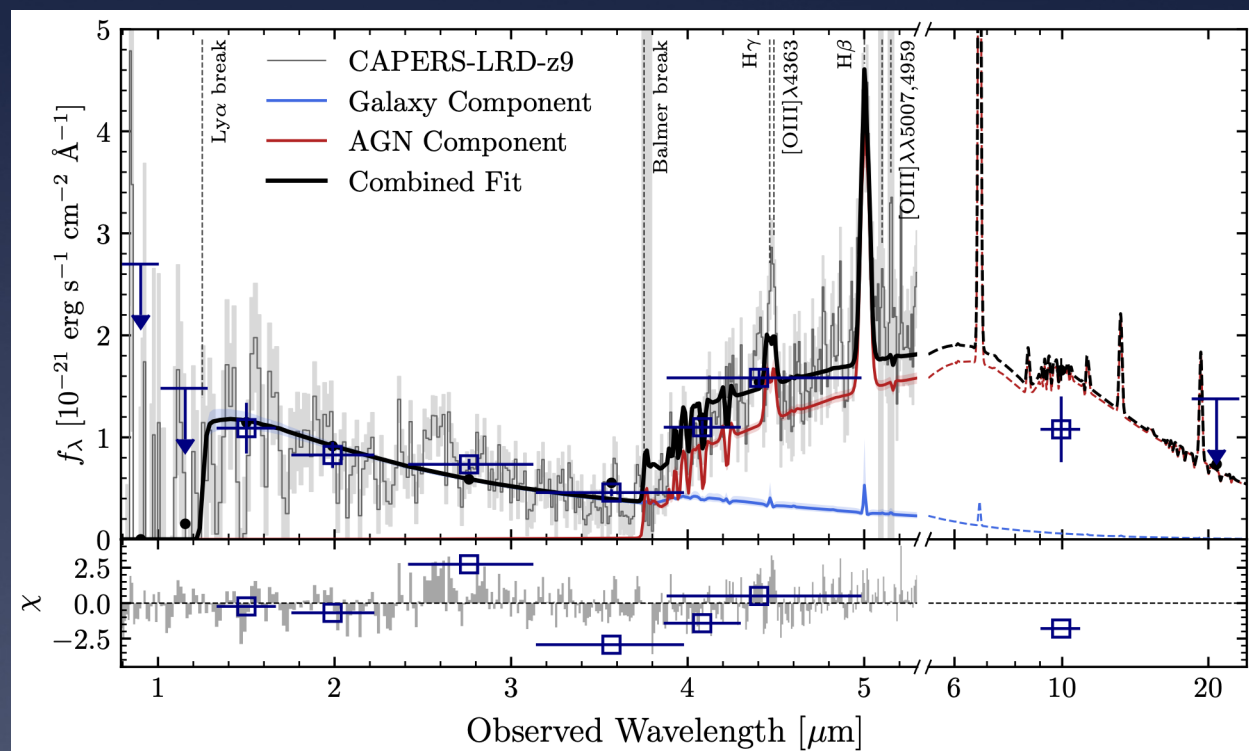
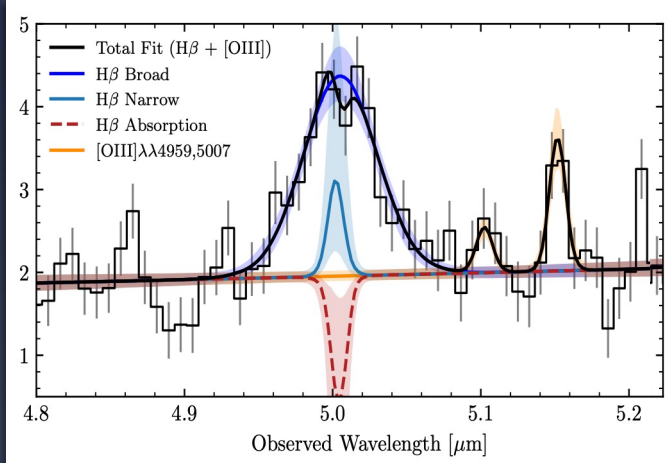
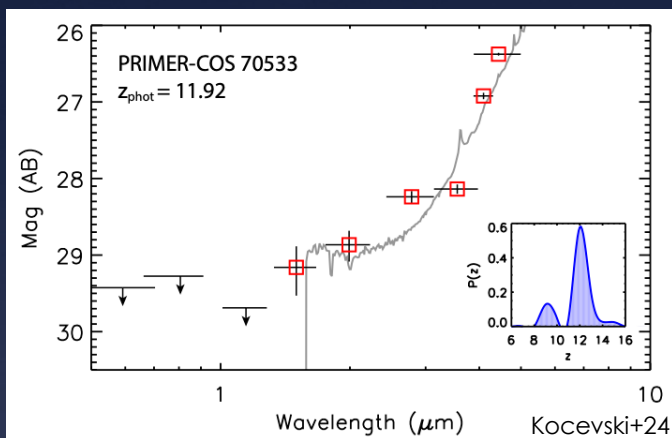
A Family of Heavily Gas Enshrouded LRDs



← Max Stellar Break

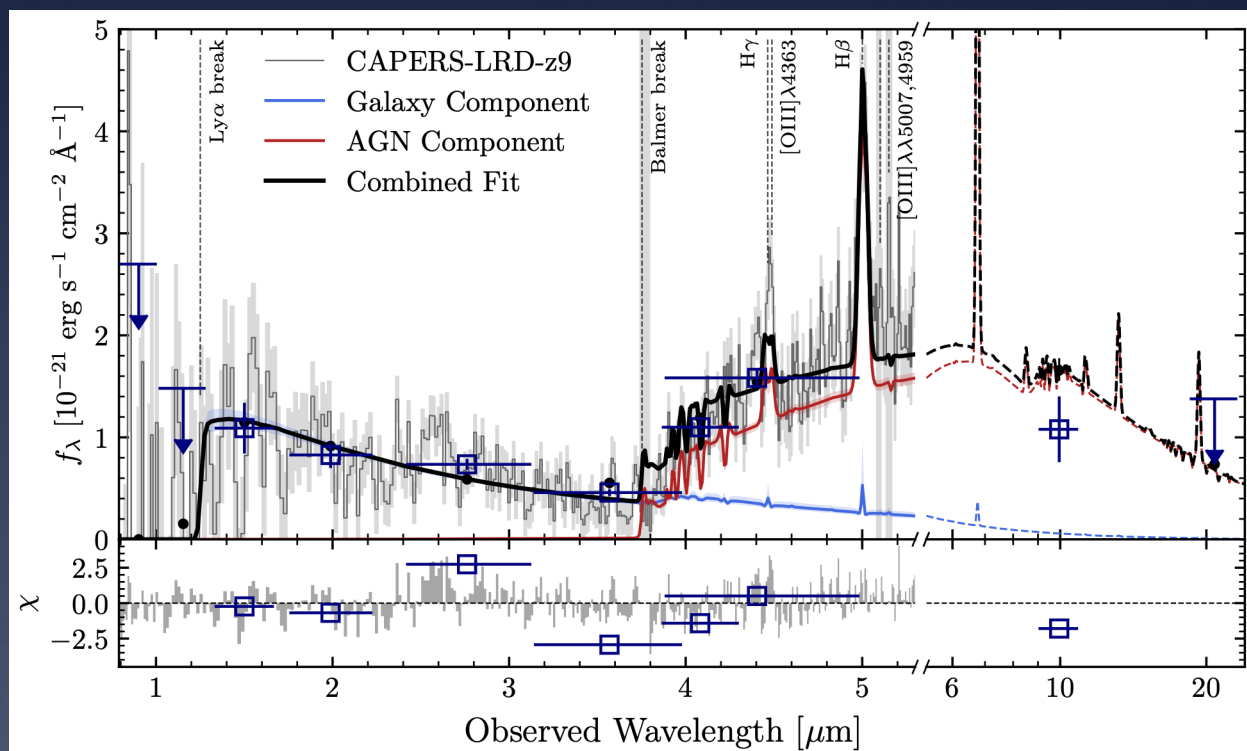
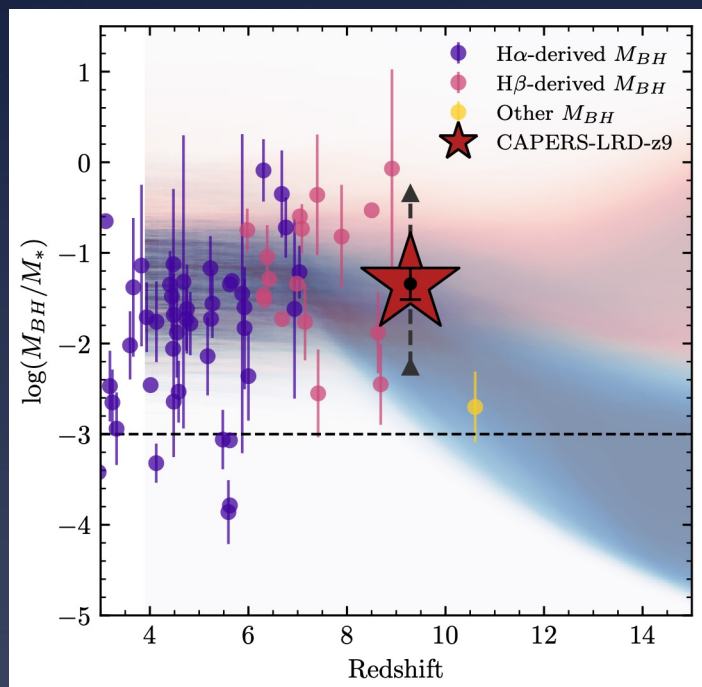
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CAPERS-LRD-z9: A Gas Enshrouded LRD at $z=9.3$

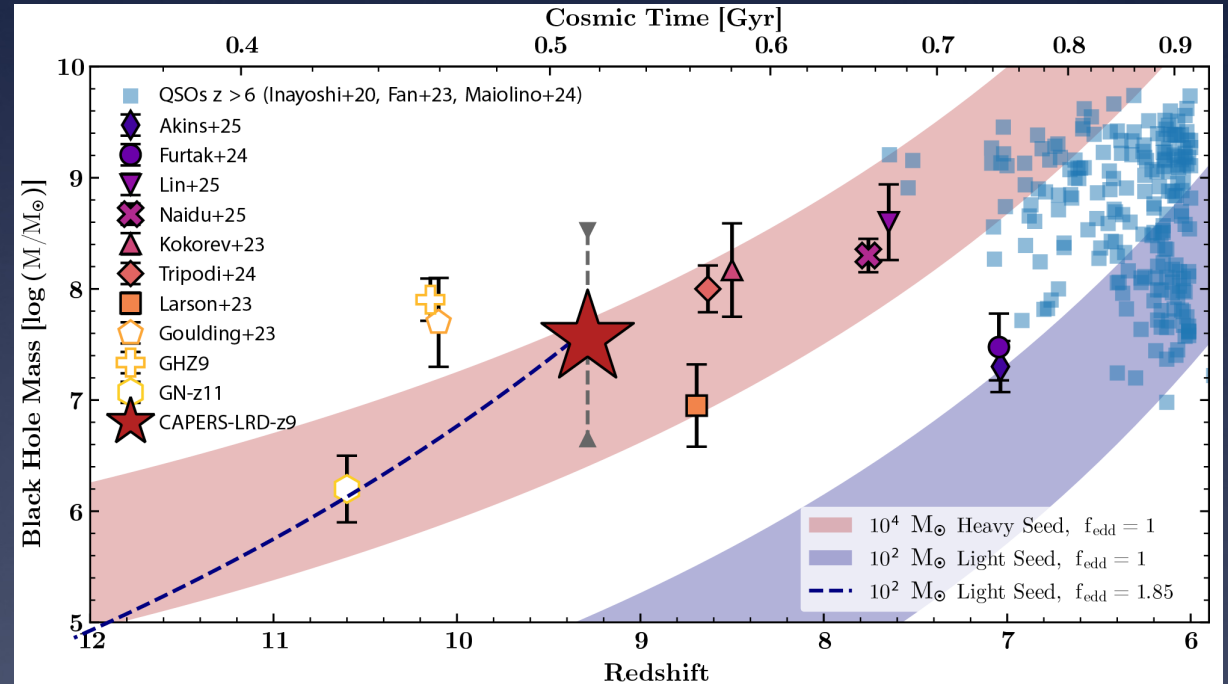
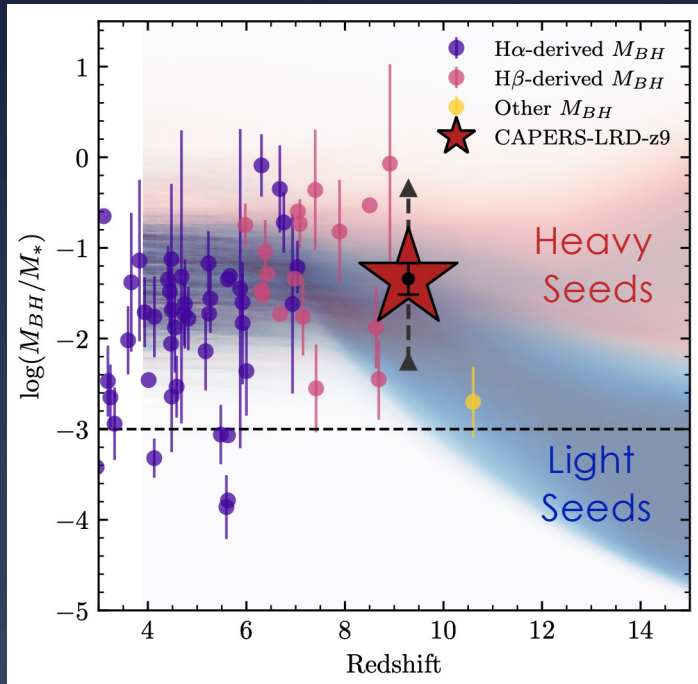


Taylor, Kokorev, DK+25

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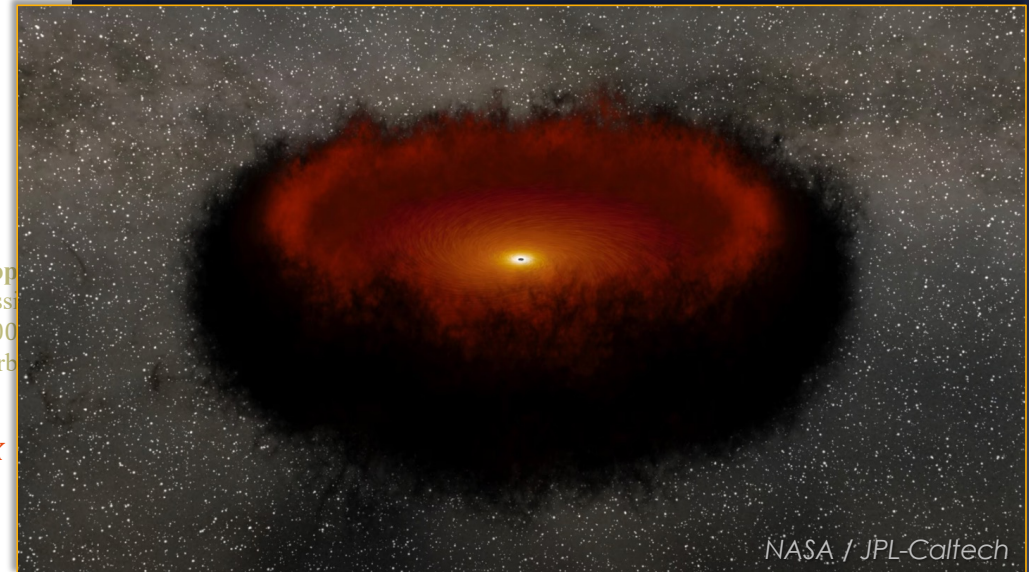
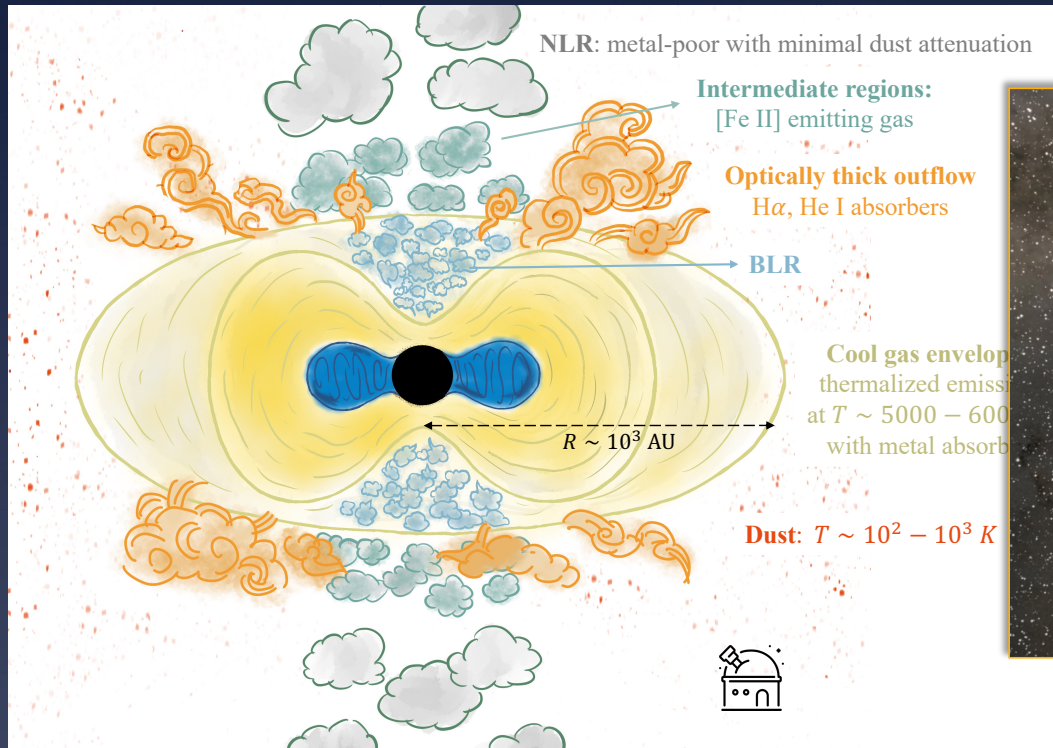
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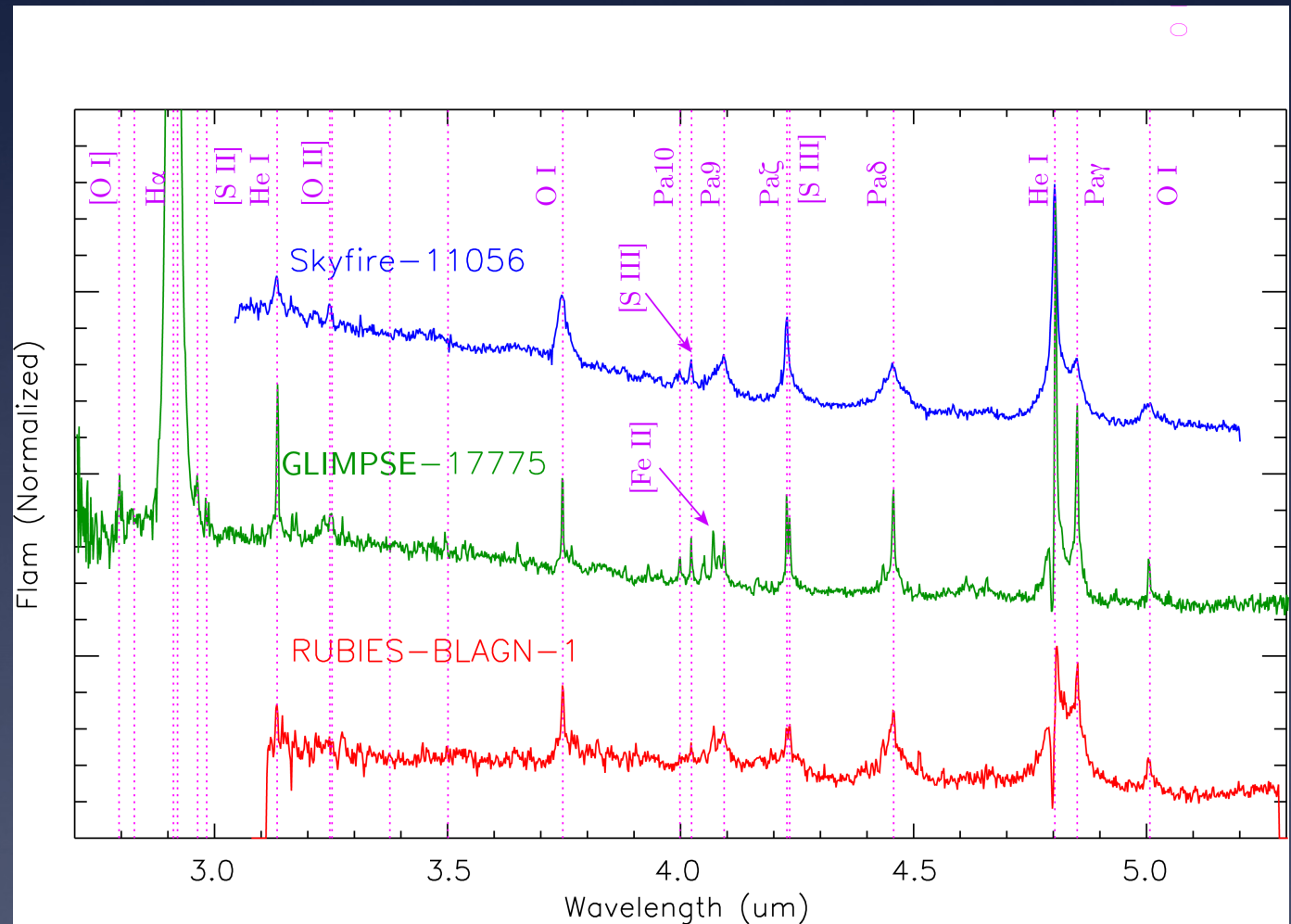
- * An overmassive black hole at $z=9$ requires a high initial seed mass or sustained super-Eddington growth. Favors heavy seed scenario.

Gas Enshrouded LRDs Across Cosmic Time

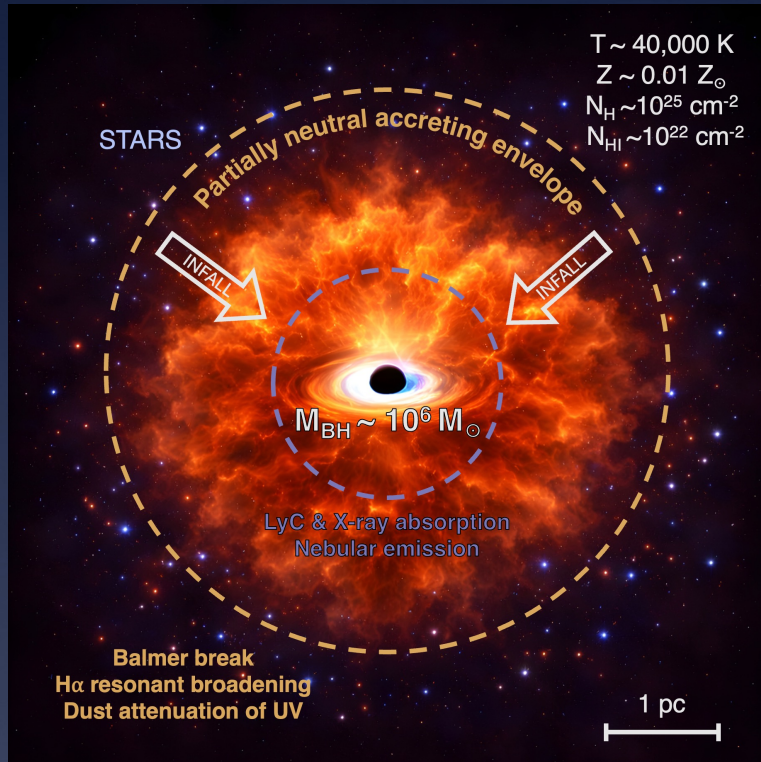


Spectral Signatures of Dense Obscuring Gas

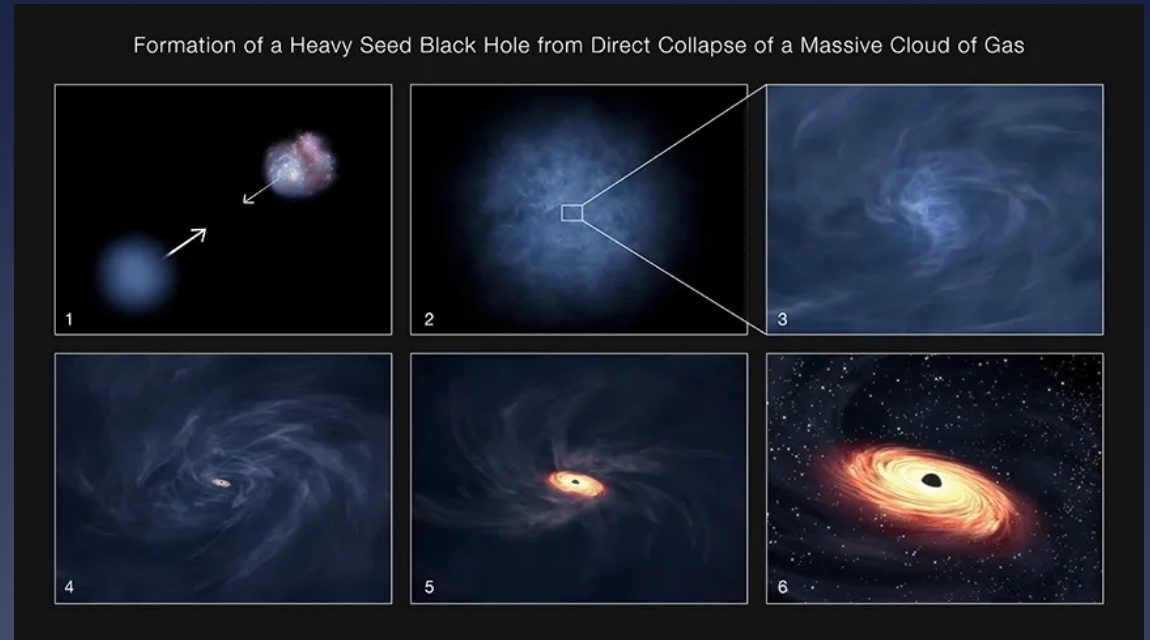
- * He I $\lambda 7065$ and $\lambda 10830$
 - * Highly sensitive to density
 - * Collisionally-enhanced
- * Fe Emission Line Forest
 - * Requires $L\alpha$ pumping
- * O I $\lambda 8446 - \lambda 11290$
 - * Bowen-fluorescent
 - * Requires $L\beta$ pumping
- * Exponential line profiles
 - * Thompson scattering in a dense ionized gas.
 - * $n_e > 10^8 \text{ cm}^{-3}$



LRDs as Early Episodes of Black Hole Growth



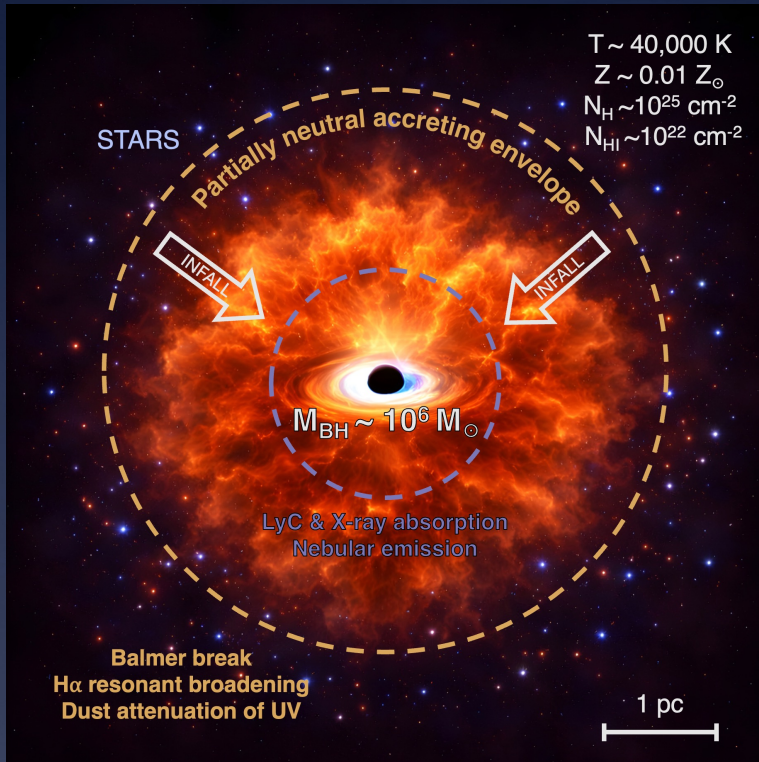
Pacucci+26



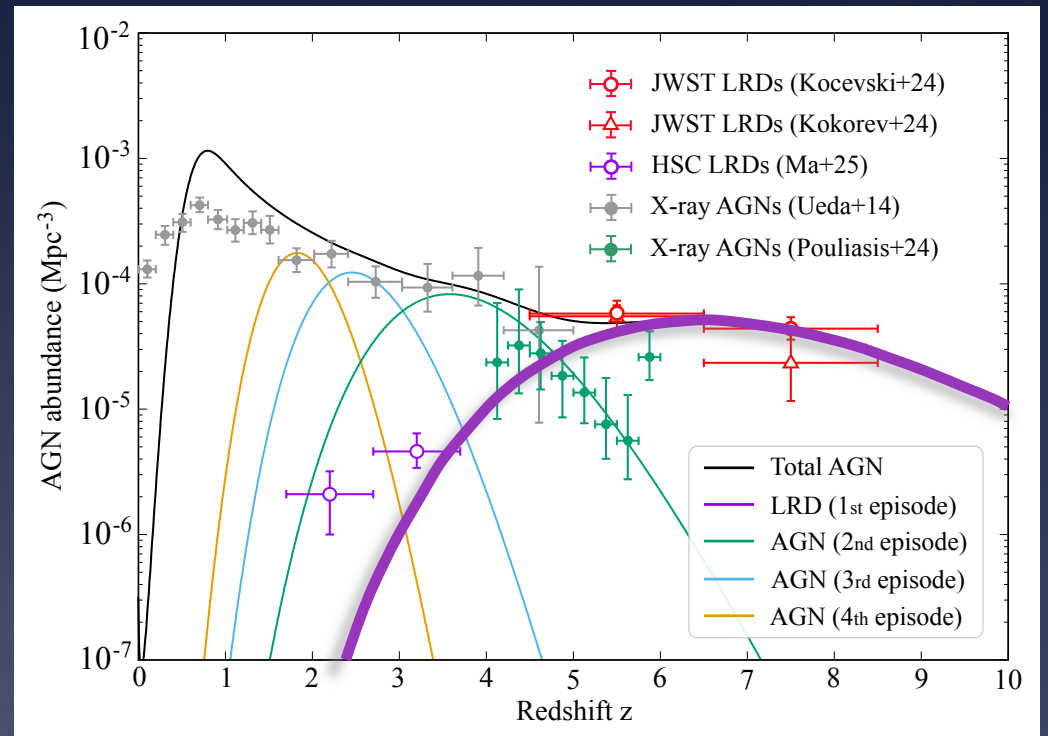
NASA/STScI/Leah Hustak

- * Accretion episode following **direct collapse BH seed** formation (Cenci+25, Pacucci+26, Begelman+26).
- * **Initial accretion episodes** associated with newly formed seed BHs (Inayoshi+24).

LRDs as Early Episodes of Black Hole Growth



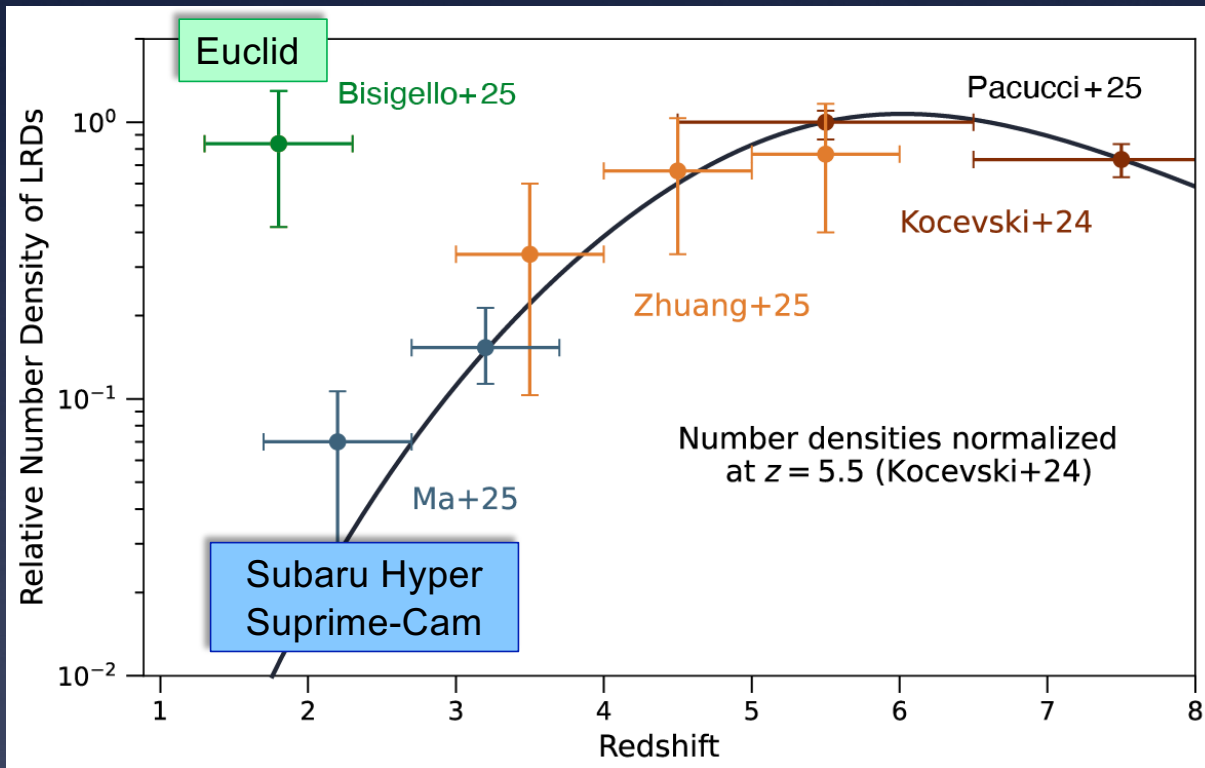
Pacucci+26



Inayoshi 25

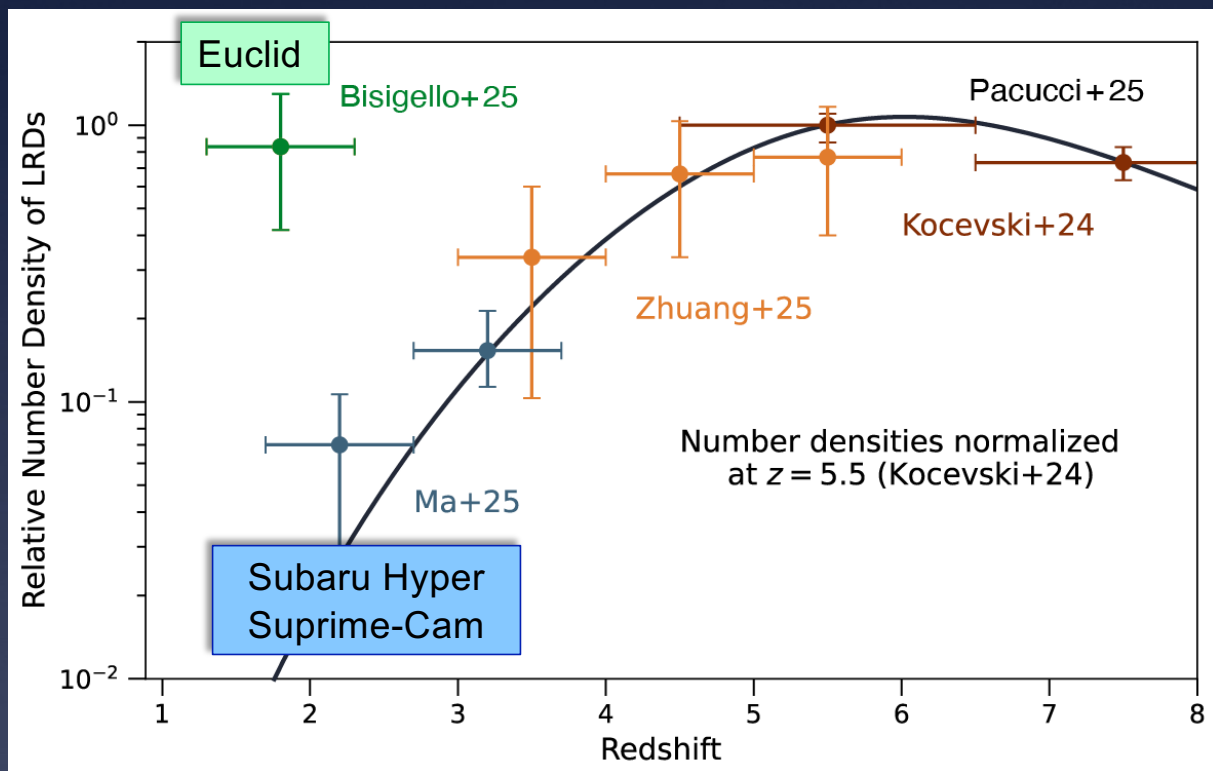
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LRDs as Early Episodes of Black Hole Growth

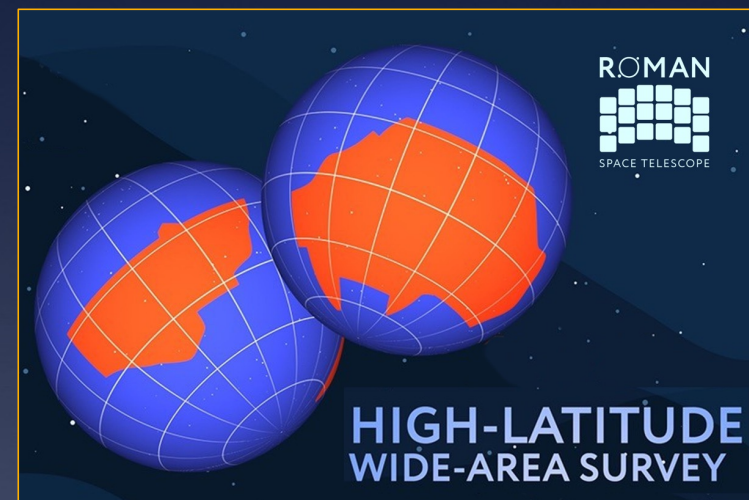


Adapted from Pacucci+25

Constraining the Low-z Abundance of LRDs with Roman

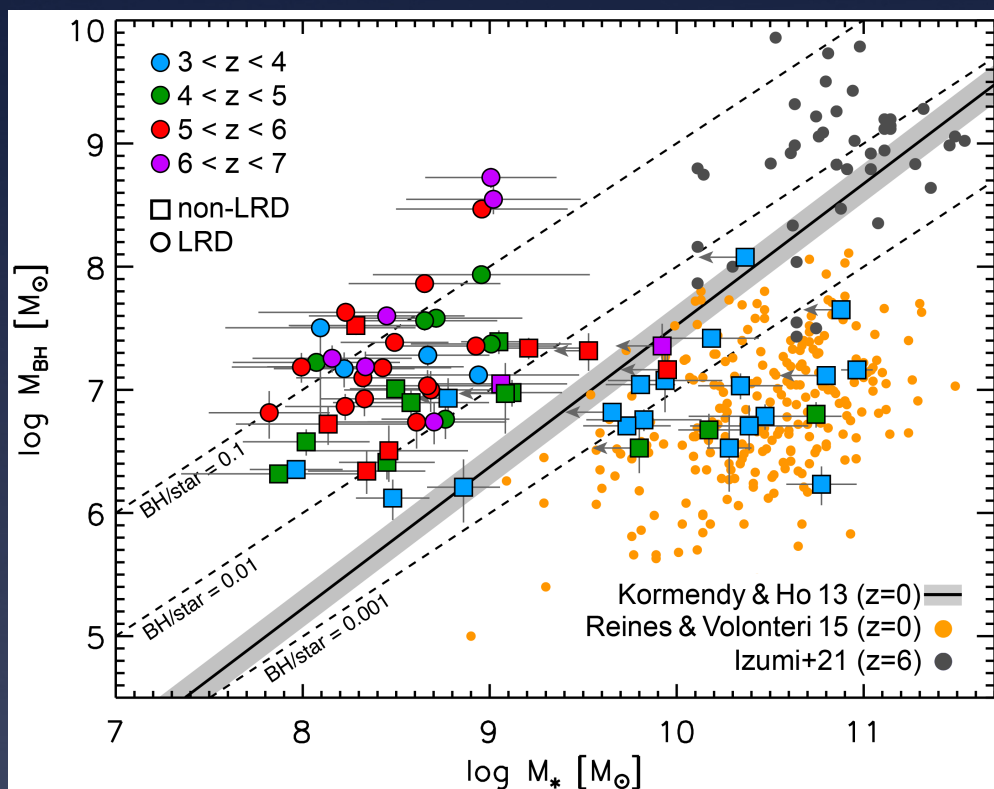


Adapted from Pacucci+25

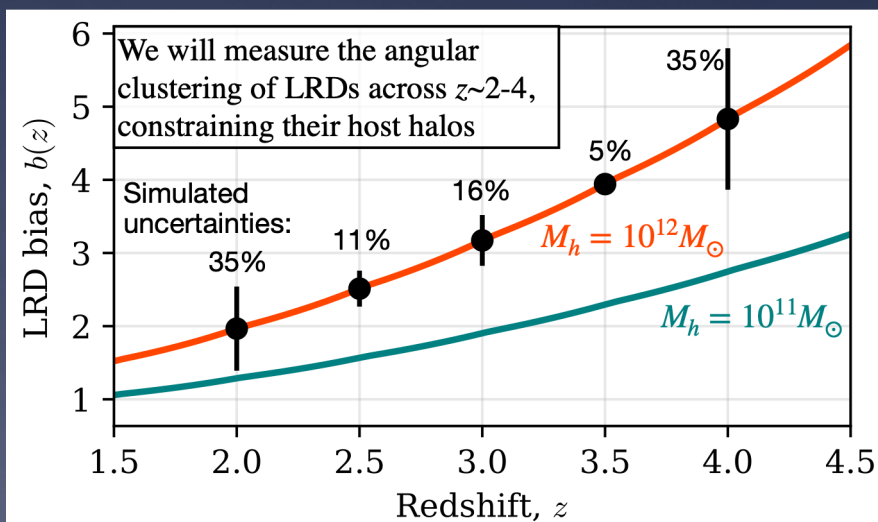
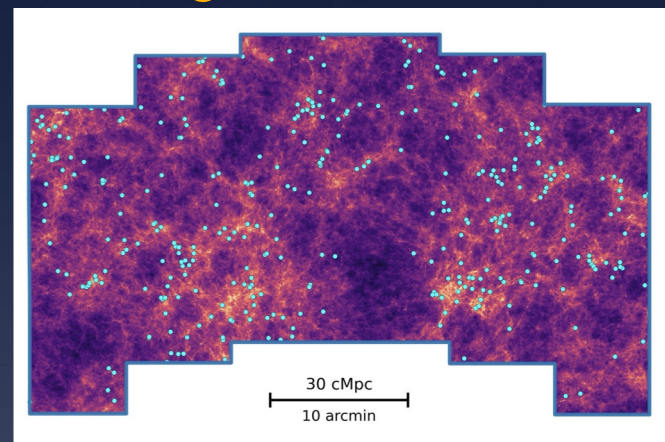


- * Roman HLWAS Deep Tier
 - * 19 deg² with 6 filters
 - * 40x larger than JWST legacy fields
- * Will provide between 1,000 – 10,000 LRDs based on current estimates.

Constraining LRD Host Masses via Clustering with Roman



Jones, Dk + 26



Courtesy S. Finkelstein

Summary

- * High number density of red, compact objects with UV excess and broad emission lines at $z \sim 5-6$.
- * Family of extreme LRDs suggest gas absorption may explain their red colors instead of dust extinction.
- * Likely gas-enshrouded, infant BHs growing at super-Eddington rates.
- * Roman observations will provide key measurements of LRDs at low- z :
 - * UV luminosity function at $z=2$ to constrain redshift evolution.
 - * Measure host masses via clustering

