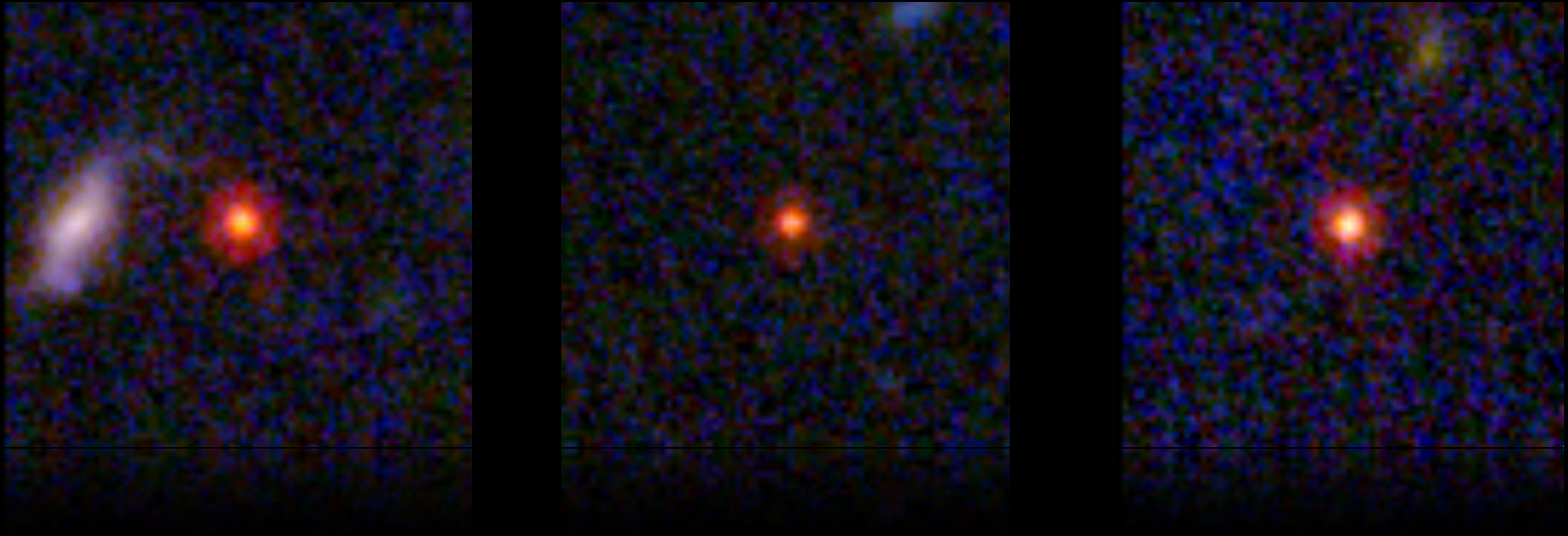
# Little Red Dots in the Roman Grism Era: Census and Black Hole Mass Constraints from Spectroscopic Variability

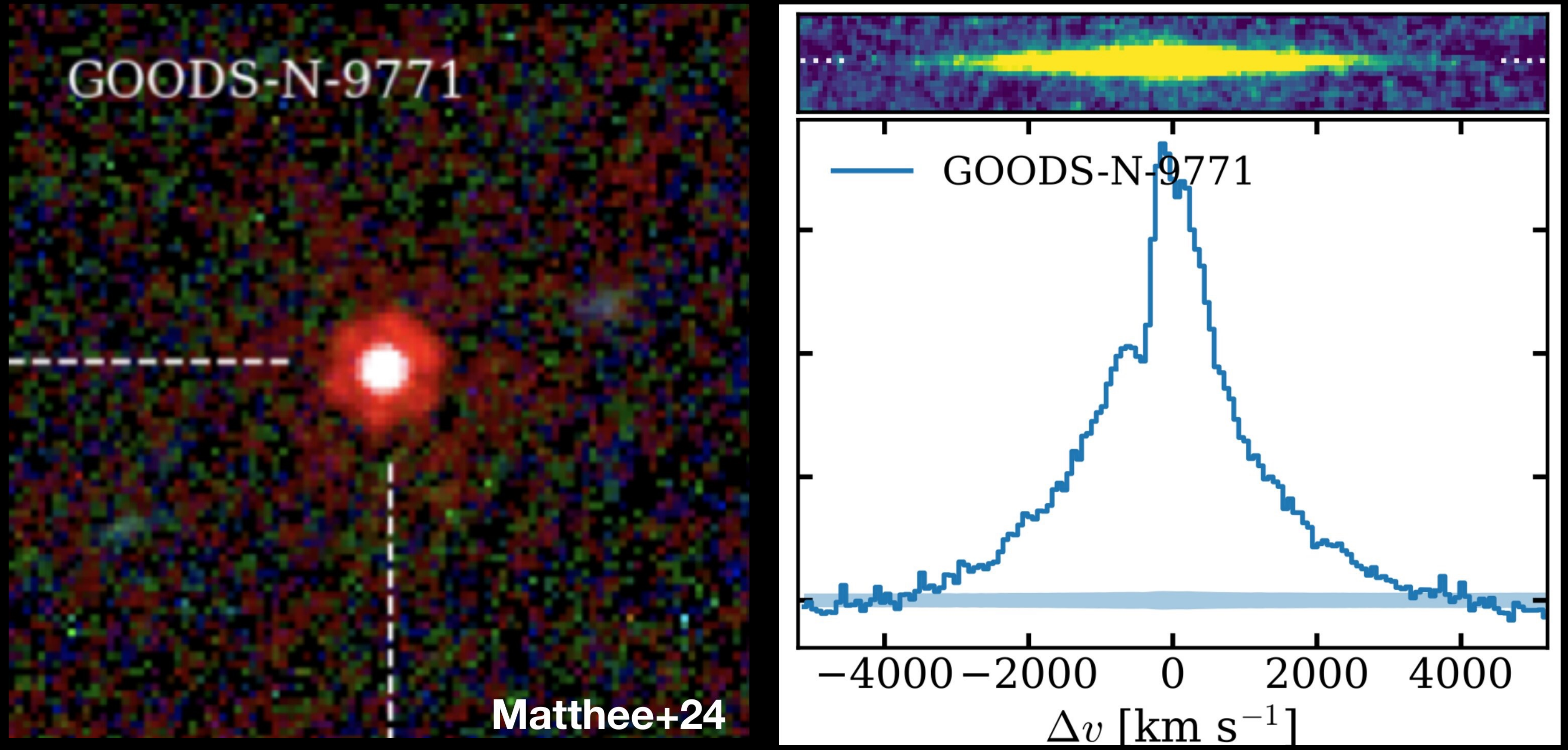


**Zhaoran Liu (MIT)**

with Rohan P. Naidu, Amy Secunda, Jenny E. Greene, Jorryt Matthee, John Chisholm, Anna de Graaff, Luke Robbins, Jacqueline Antwi-Danso, Gabriel Brammer, Wendy Q. Sun, Anna-Christina Eilers, Seiji Fujimoto, Lukas J. Furtak, Erin Kara, Vasily Kokorev, Danilo Marchesini, Pascal A. Oesch, Justin D. R. Pierel, Xuejian Shen, Robert A. Simcoe, Alberto Torralba, Mark Vogelsberger

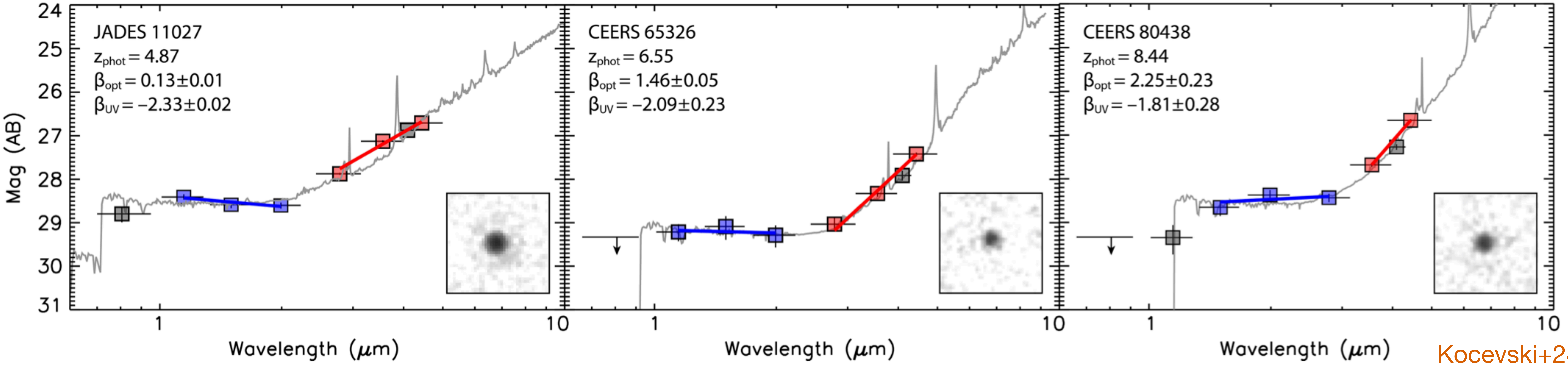
# Little Red Dots: compact, red, broad-line — and puzzling

*JWST's unexpected new population: compact red objects at $z \approx 4$–$7$ that look like accreting black holes, yet fail many standard AGN test*



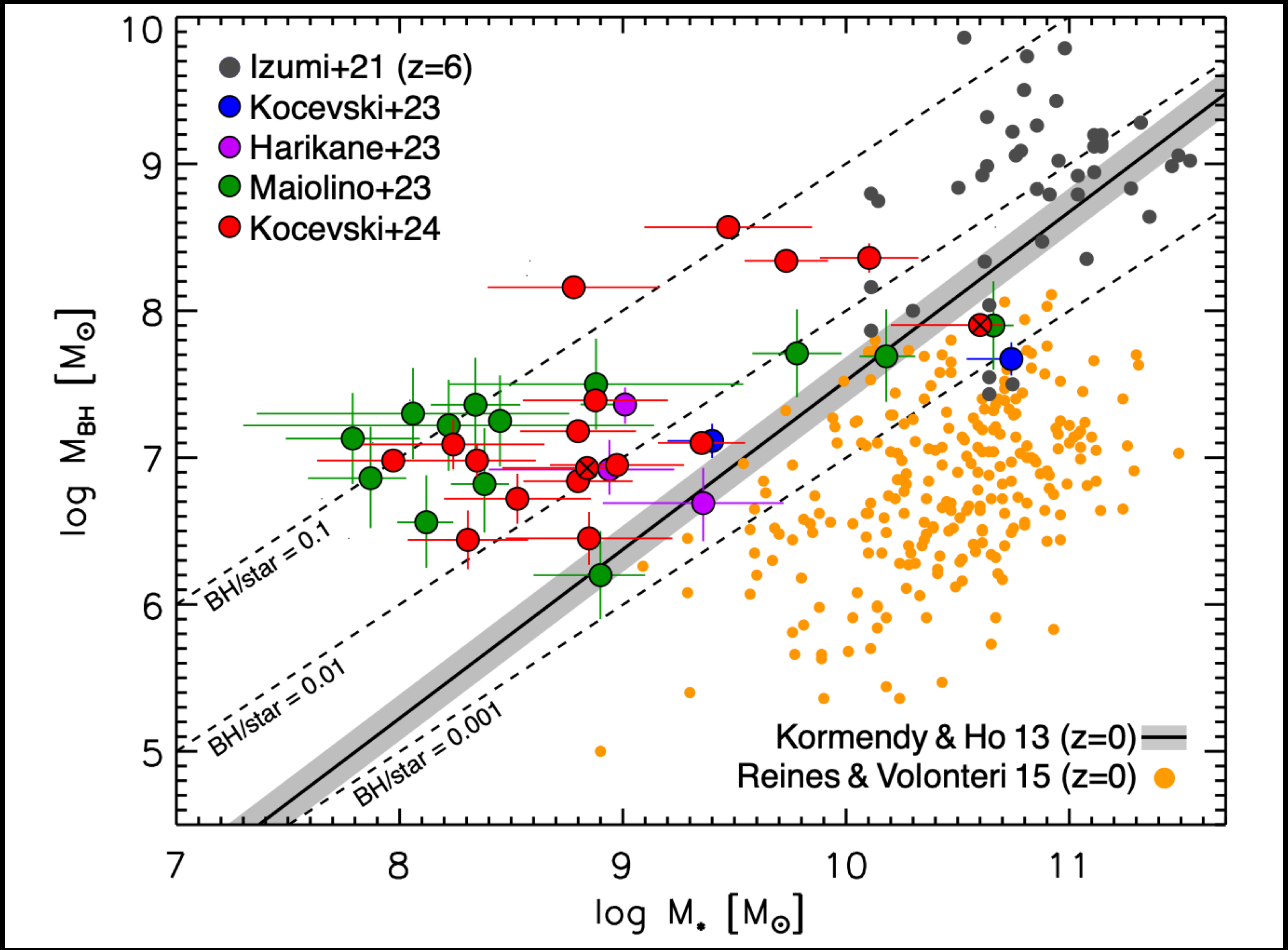

*GOODS-N-9771 (Matthee+24): broad Hα, FWHM ≈ 2000 km/s*

- Red + compact + broad Balmer lines (Matthee+24, Kokorev+24, Akins+24)
- X-ray faint: 10–100× below Type 1 AGN (Yue+24, Maiolino+24)
- Little hot and cold dust (Williams+24, Akins+24, Xiao+25)
- ~100× more abundant than the quasar LF at $z > 5$ (Greene+24, Kocevski+24)
- V-shape SED breaking at the Balmer limit; strong Balmer breaks (Setton+24, de Graaff+25, Naidu+25)



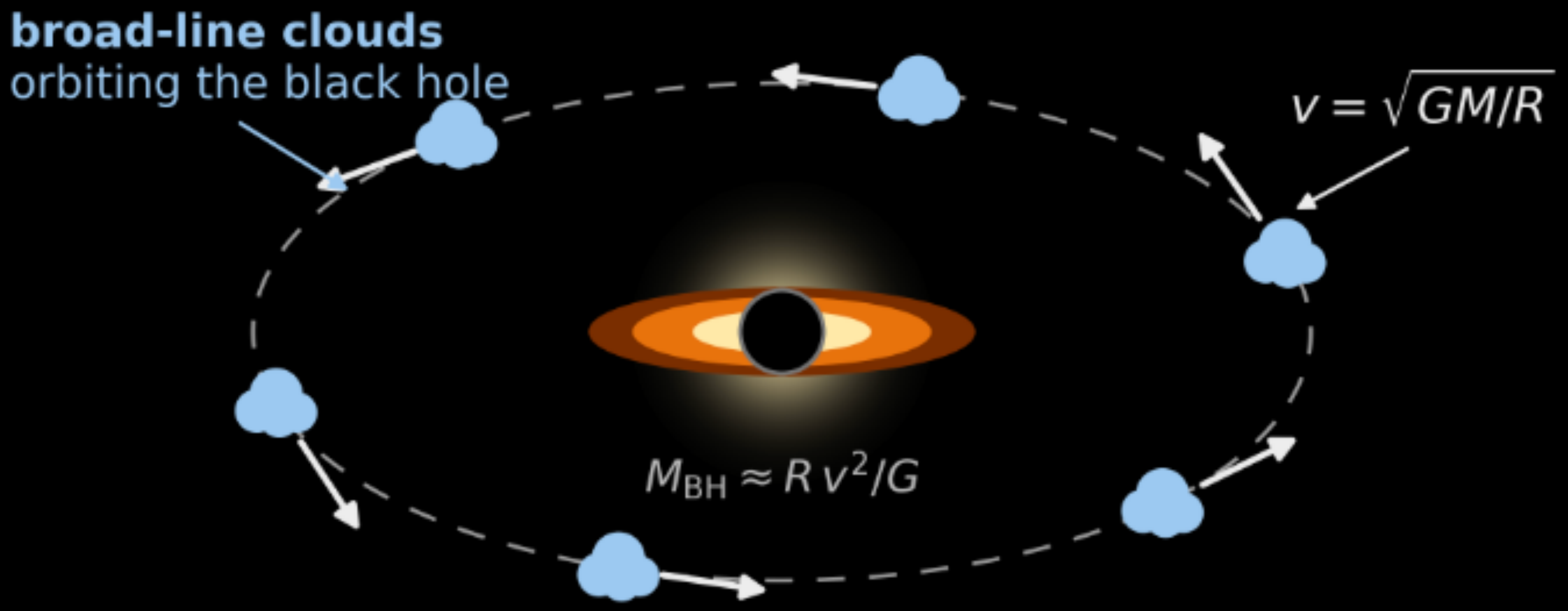

Kocevski+24

# They look like impossibly massive black holes

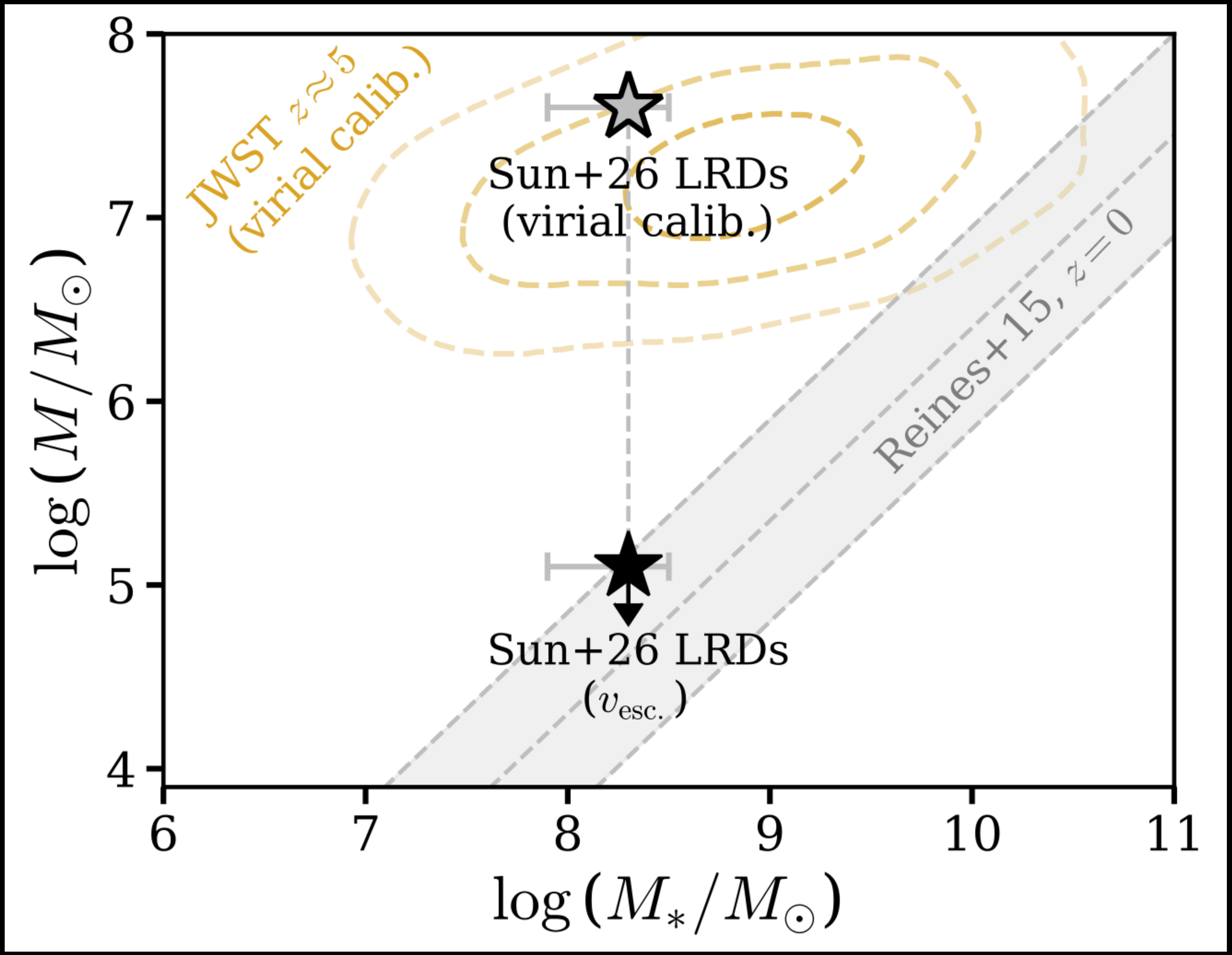



Jones, Kocevski+24

- Host galaxy stellar masses only ~$10^7$–$10^8$ $M_\odot$ (Matthee+25, Lin+26)
- Virial BH masses from broad Hα: $M_{bh}$ ~ $10^7$–$10^8$ $M_\odot$ (Maiolino+23, Harikane+23, Kocevski+24)
- $M_{bh} / M_\star$ ~ 0.01-0.1 vs. local scaling relation: $M_{bh} / M_\odot$ ~ 0.001

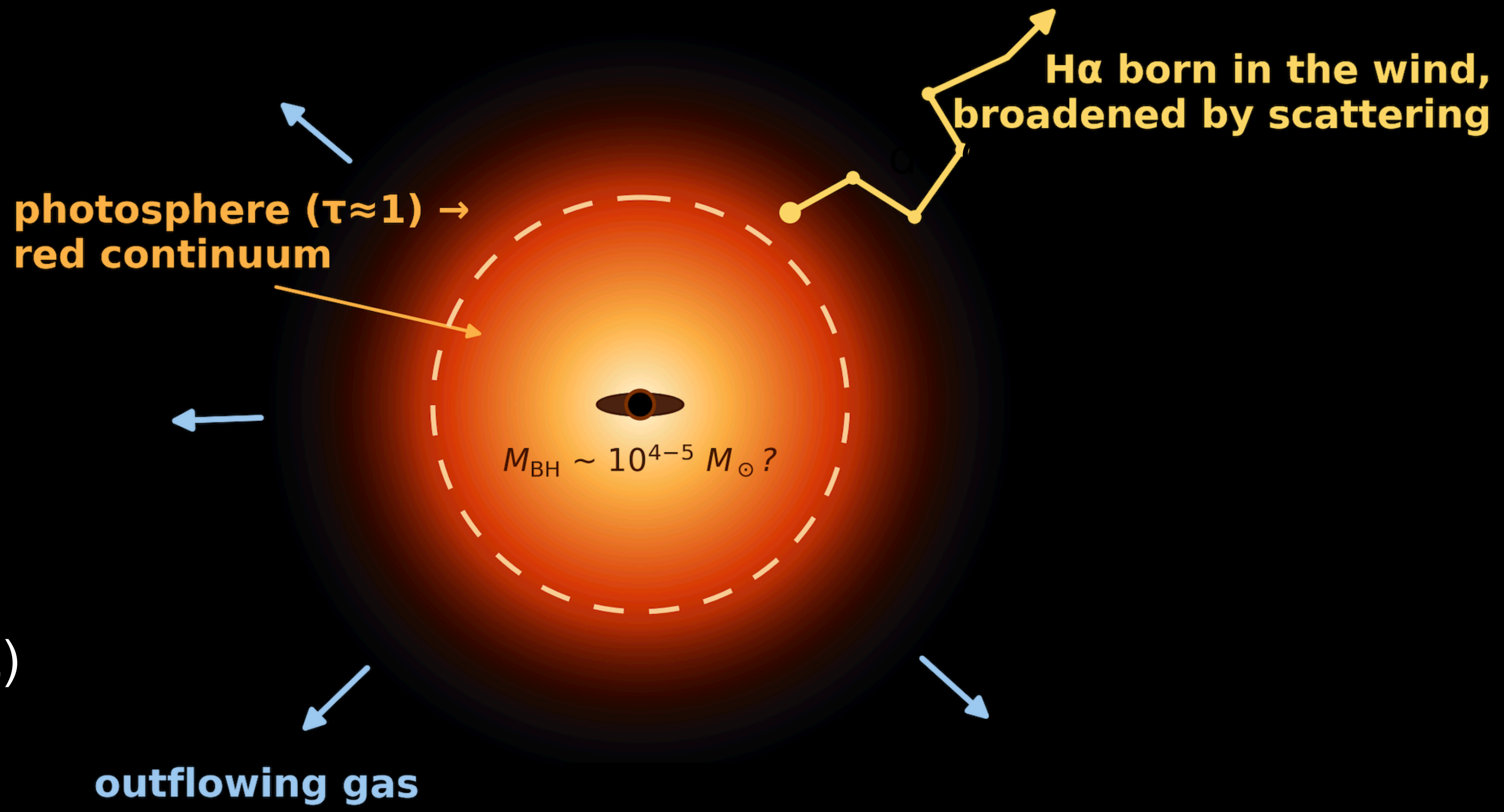


# But we don't even know their black hole masses




Naidu+26 (incl. ZL)

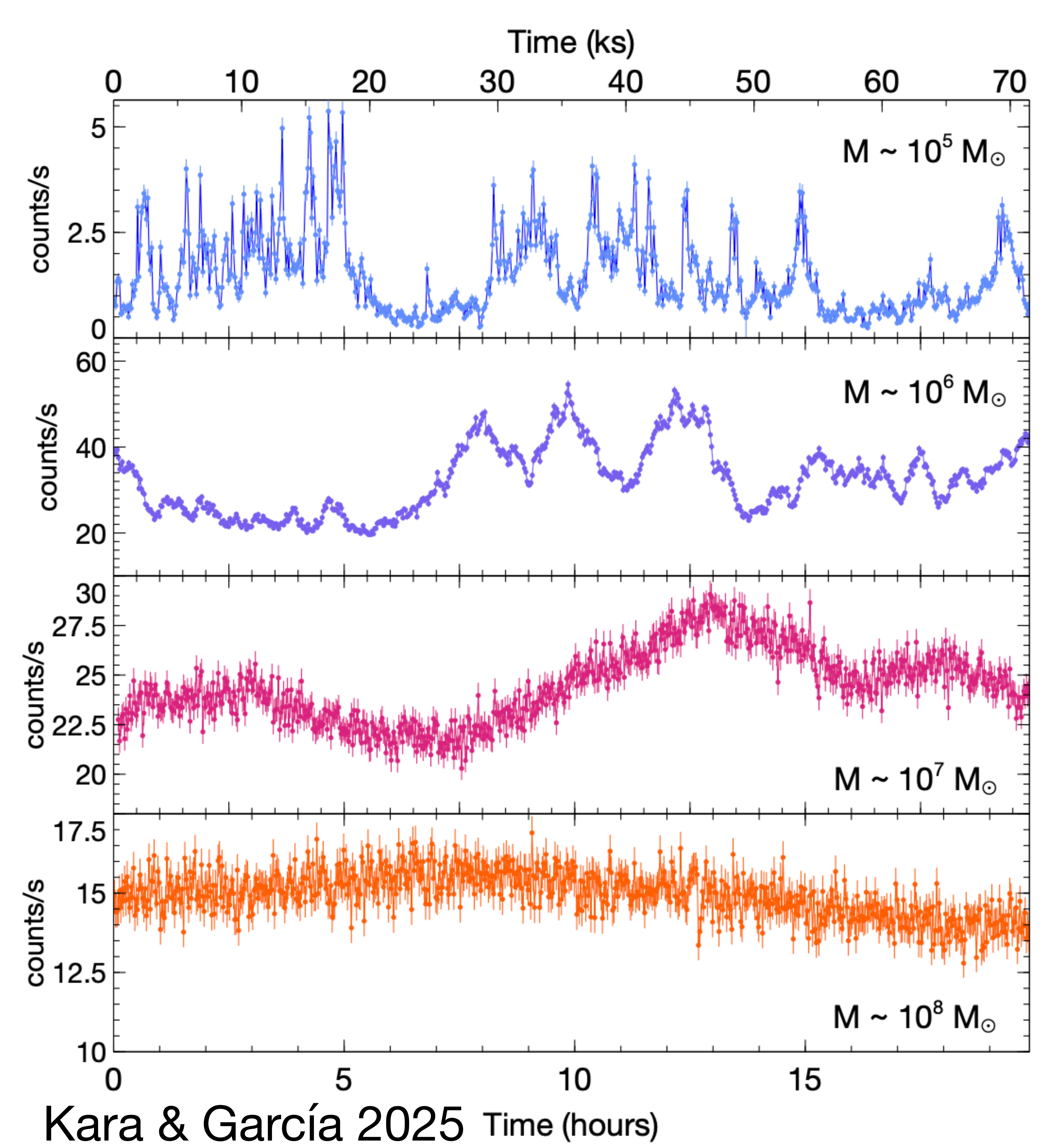
- Virial estimates: $M_{BH} \sim 10^{7-8}\, M_\odot$
- But if broad lines do not come from virialized BLR, those calibrations simply don't apply (Naidu+26, Rusakov+25, Torralba+25)
- Escape-velocity & Eddington arguments instead give **$M < 10^{5.1}\, M_\odot$** (Naidu+26, Sun+26)
- **2.5 dex of disagreement** in the most basic property of these objects



We need independent probes that don't rely on interpretation of line or SED

# A Light Curve Weighs the Black Hole

- Red-noise flickering from the accretion disk — seen in *every* monitored AGN (Kara & García 2025)
- Amplitude & timescale scales with M_BH: more massive → slower, lower amplitude (Ponti+12)
- Characteristic timescales: weeks–months rest-frame




Kara & García 2025

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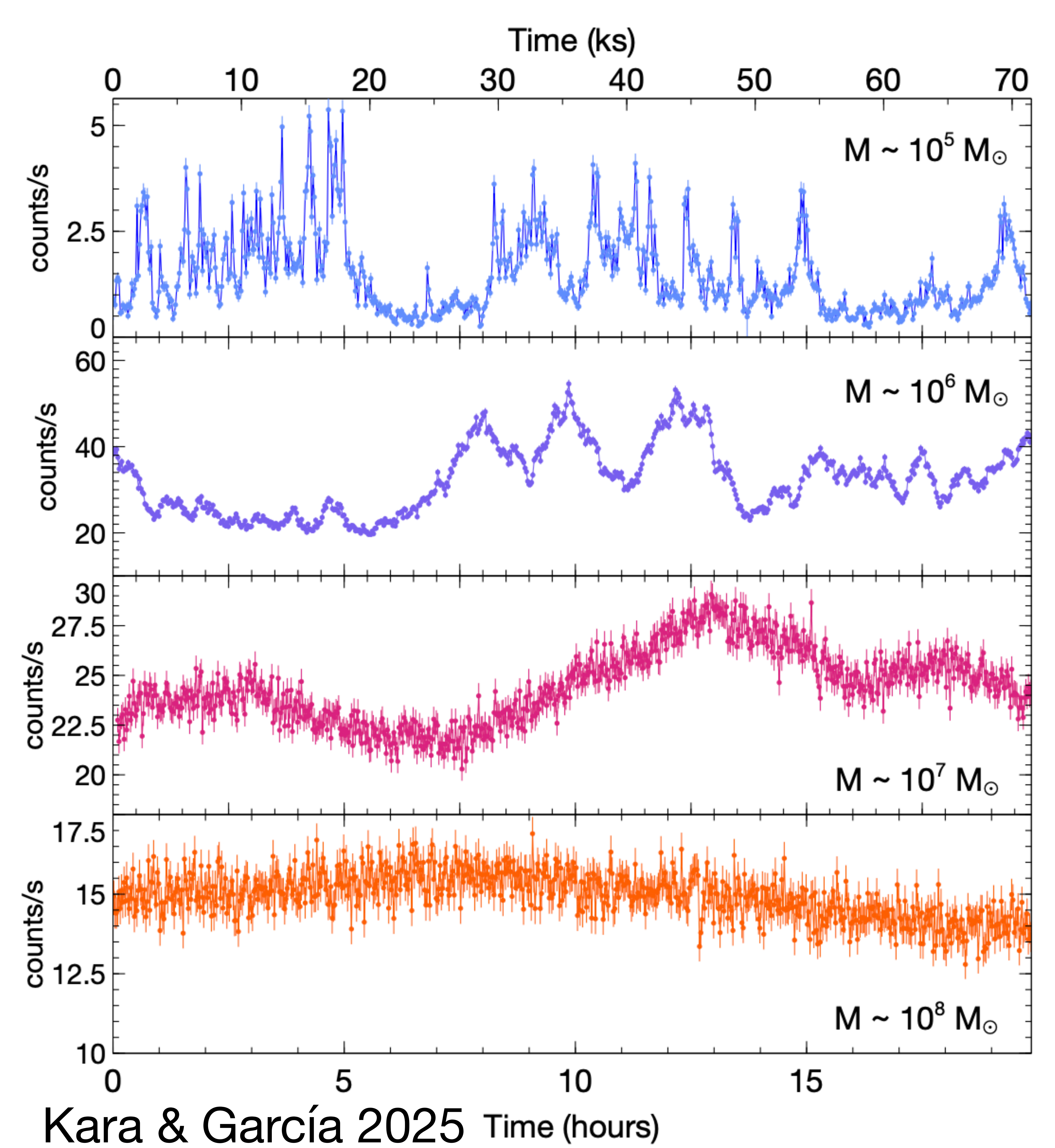
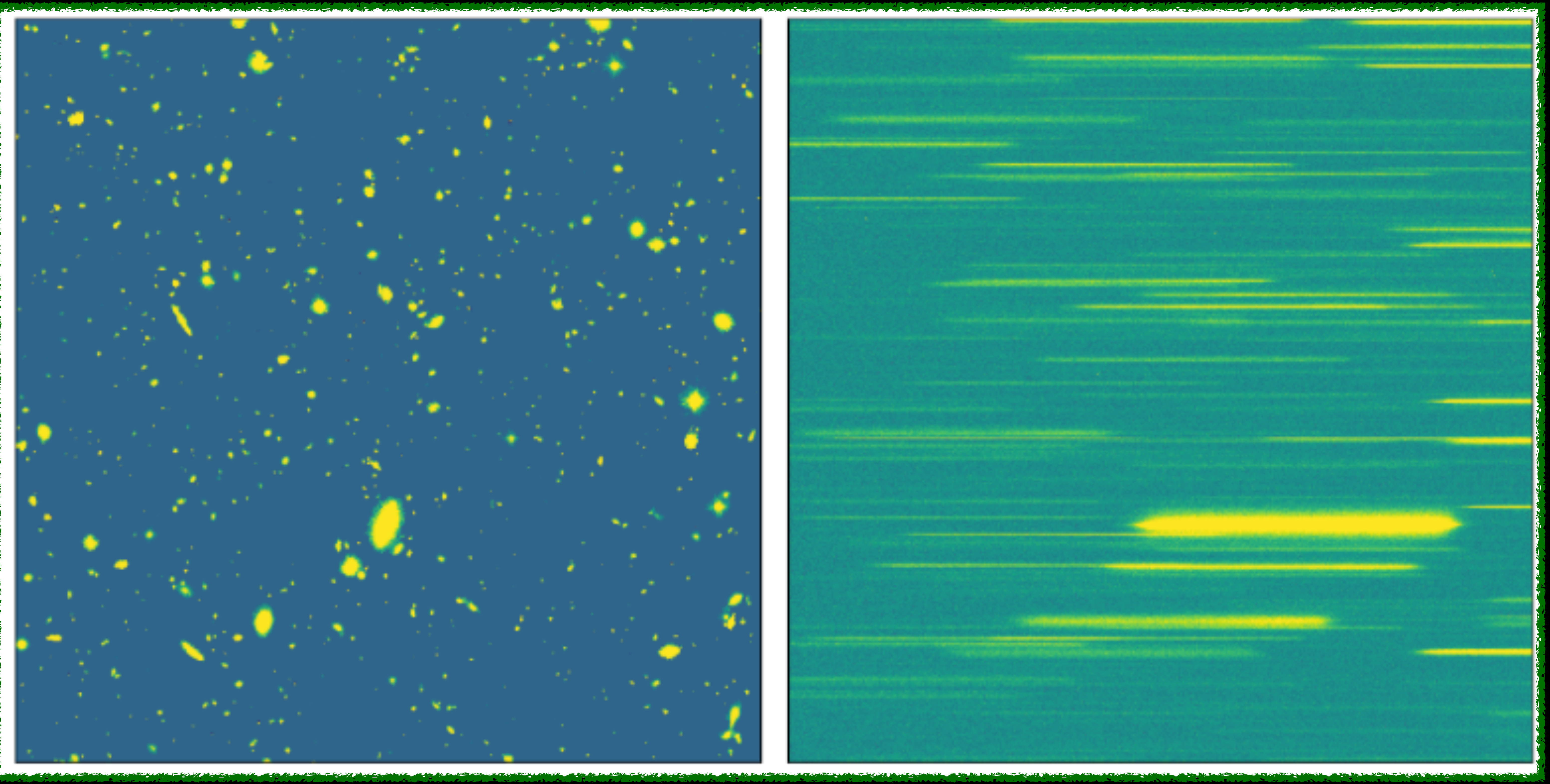
**If LRDs host normal black holes at their virial masses, JWST must see them twinkle.**




Kara & García 2025

# Do JWST's Little Red Dots TWINKLE?

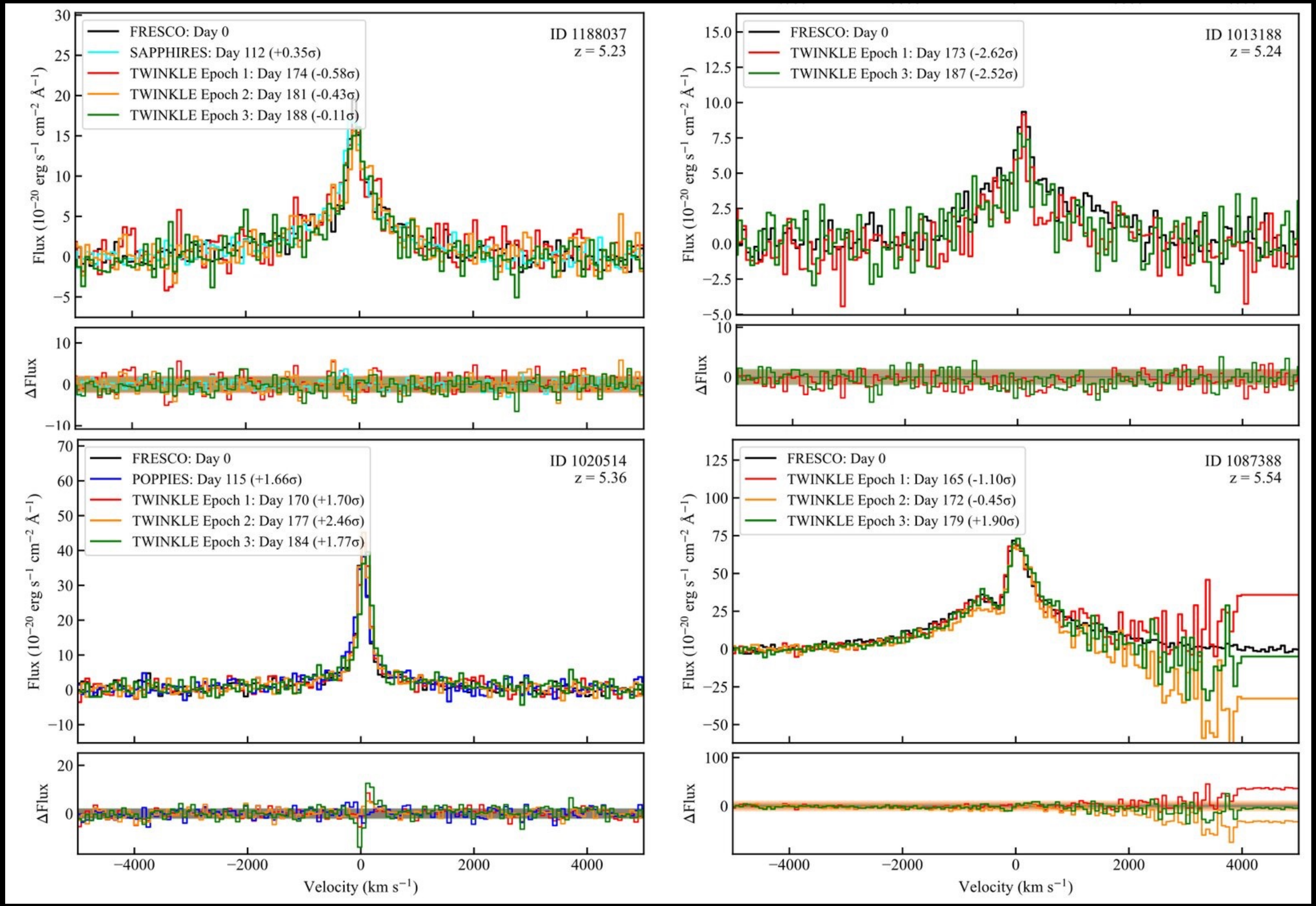
GO7404, PI: Naidu, Matthee, Chisholm



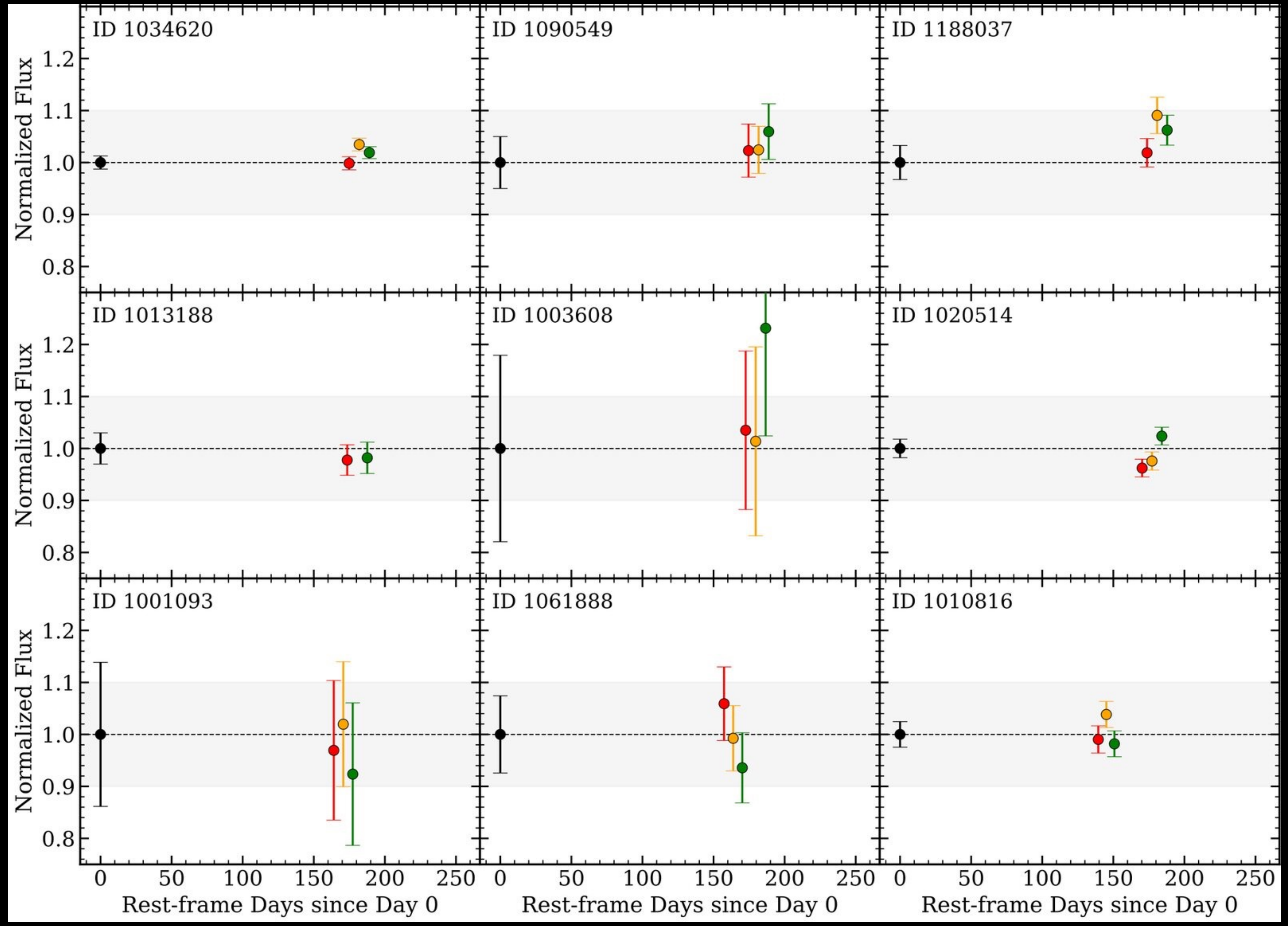
- One exposure = all spectra at once
- Hα profile and continuum in the same shot
- no slits, no target selection, no slit losses
- Five epochs over 3 yr: week / month / half-year baselines

2023 - 2026: Longest baseline enabled by JWST grism

# JWST's Little Red Dots Do not TWINKLE




*multi-epoch Hα profiles*

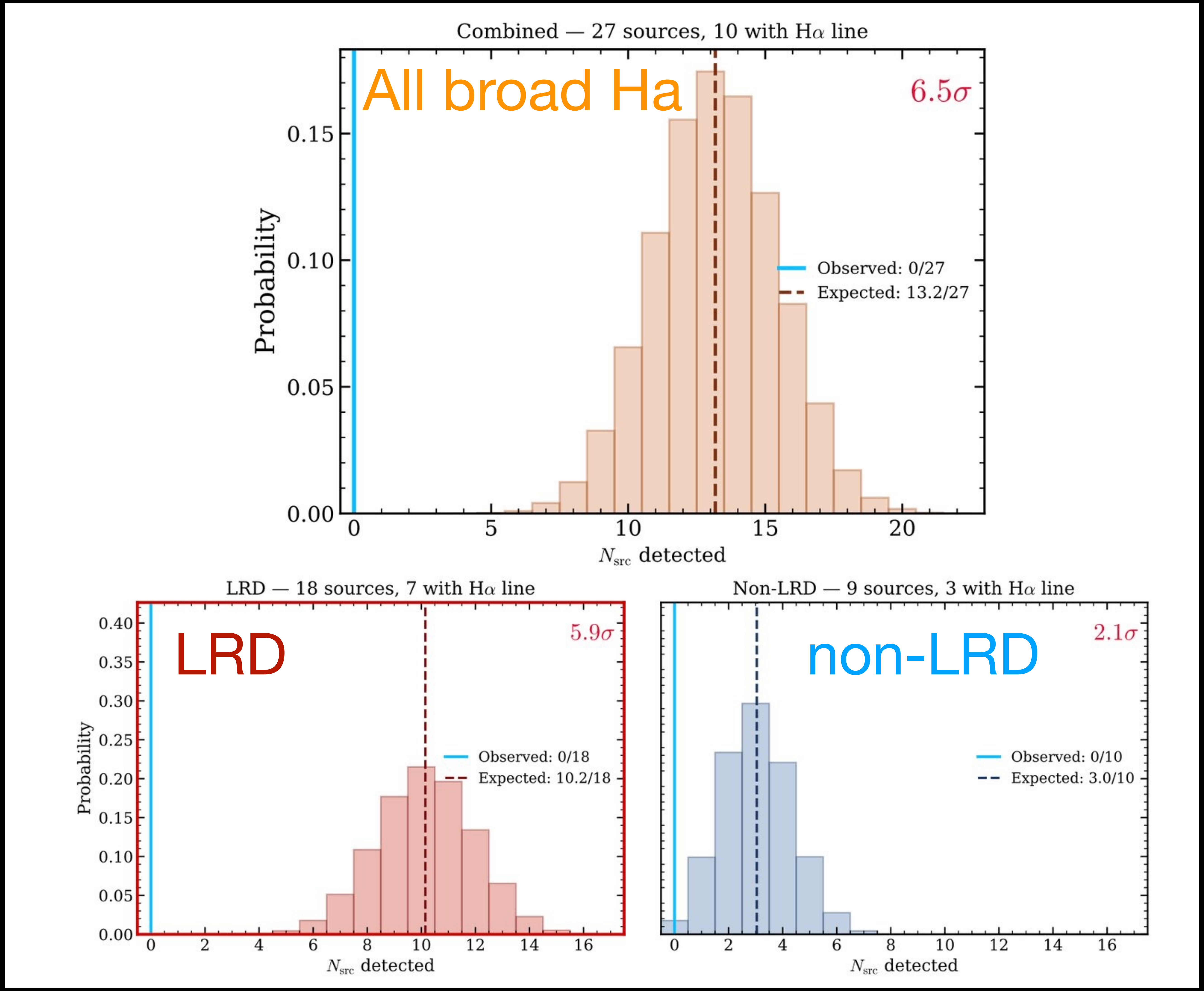



*grism continuum photometry*

**Liu+26**

# JWST's Little Red Dots Do not TWINKLE

- 27 broad-Hα emitters at z = 4–7, five grism epochs over 3 yr
- 6.5σ below classical SDSS AGN at any plausible virial mass
- LRDs and non-LRDs alike; continuum and Hα alike

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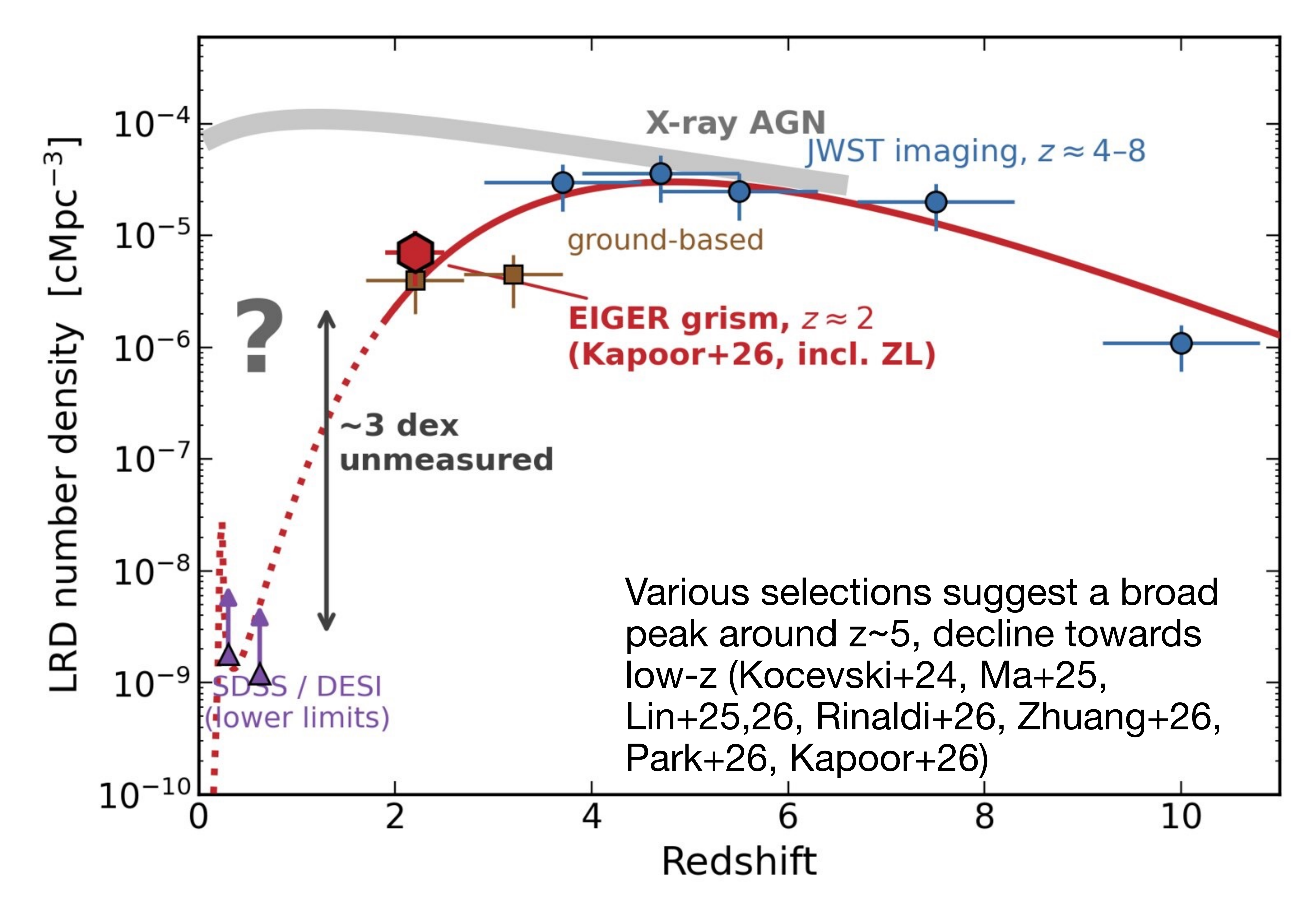
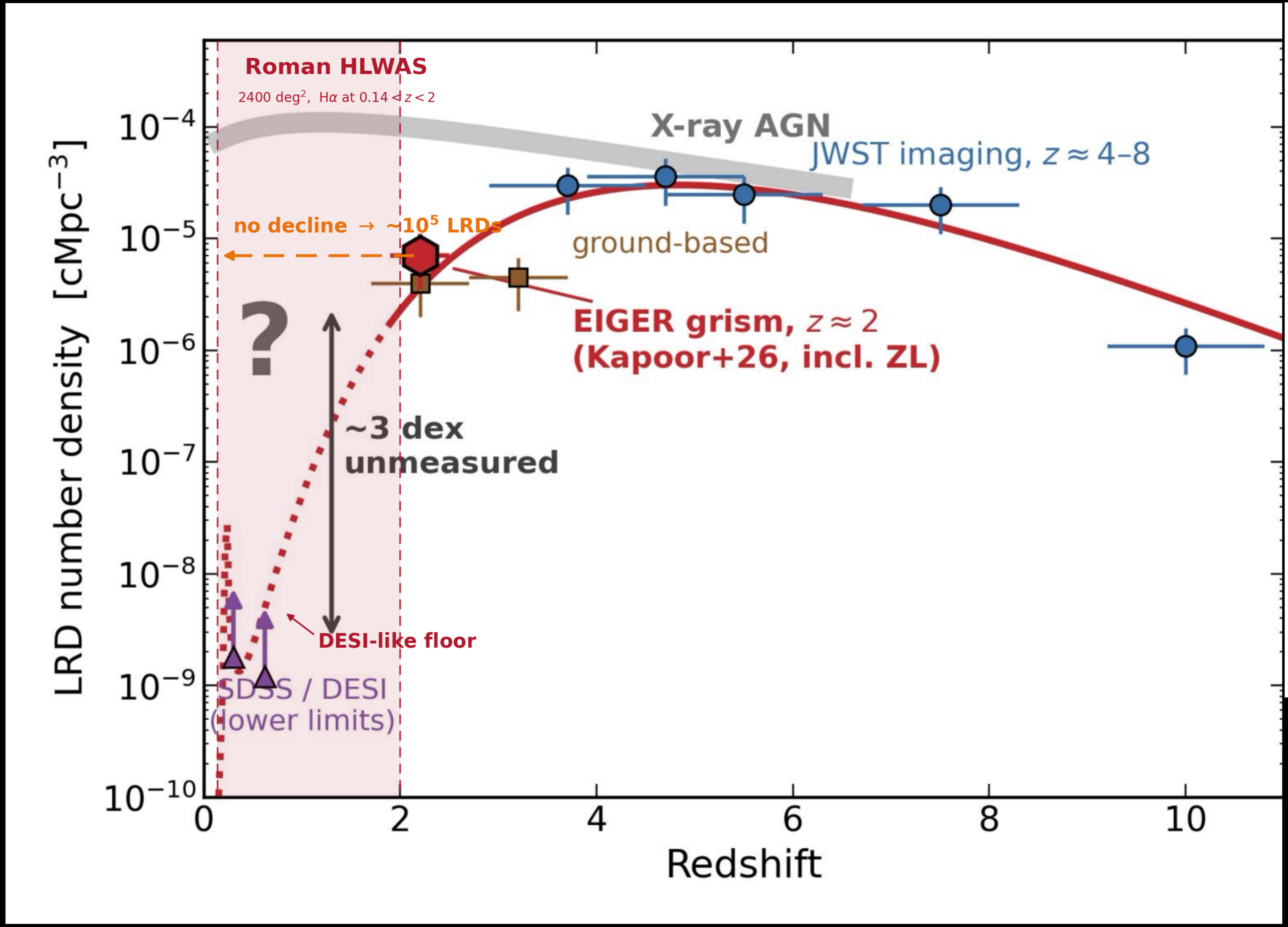
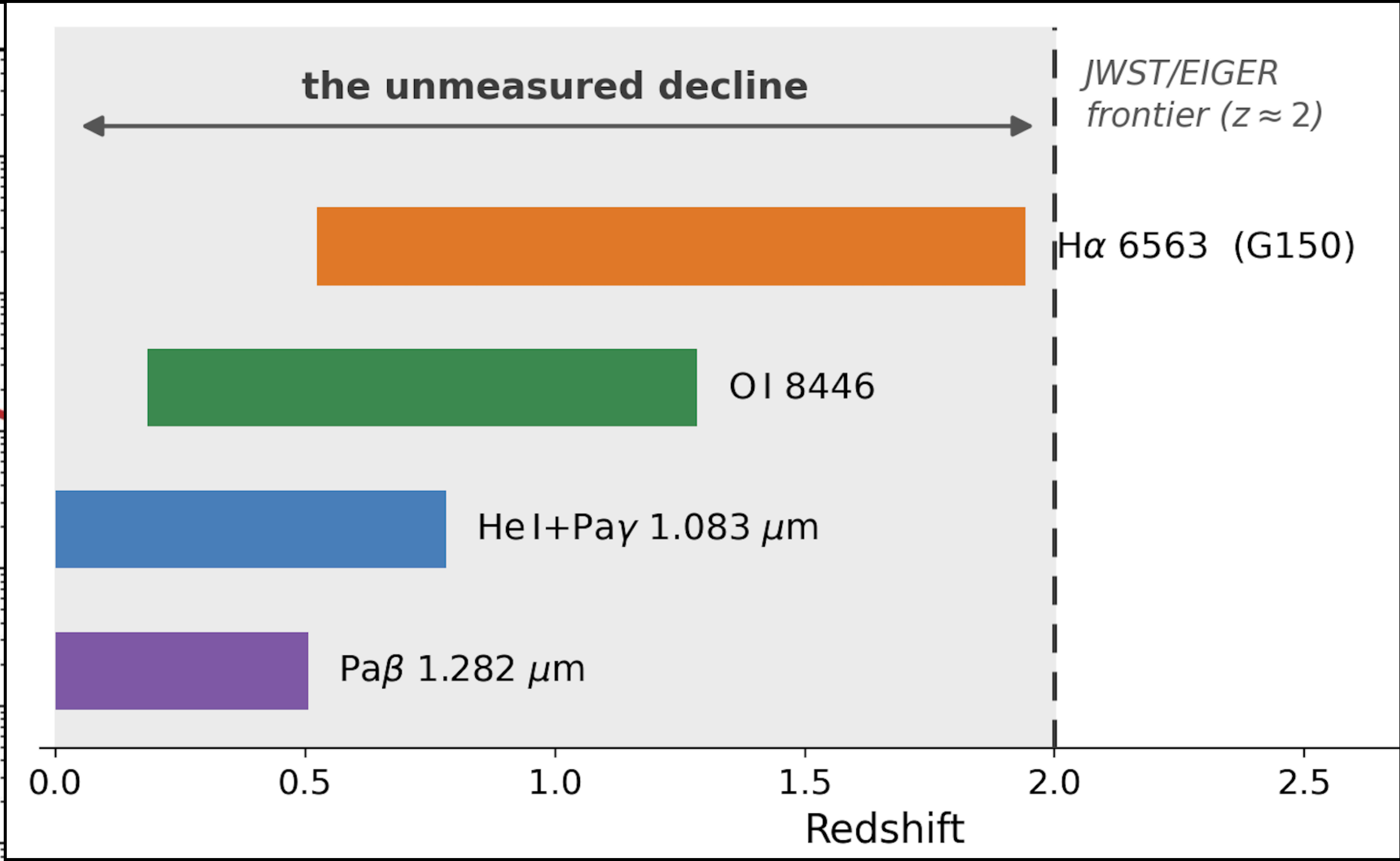
# The number density of LRDs peaks at z ≈ 5




- n(z) = the population's birth & death rate, lifetimes, halos
- The rise tracks newly formed 10^(10.5–11.5) M ⊙ halos, unlike X-rayAGN population (Kapoor+26, Inayoshi 25)
- Below z < 2: only lower limits. The decline where formation models diverge remain unmeasured.

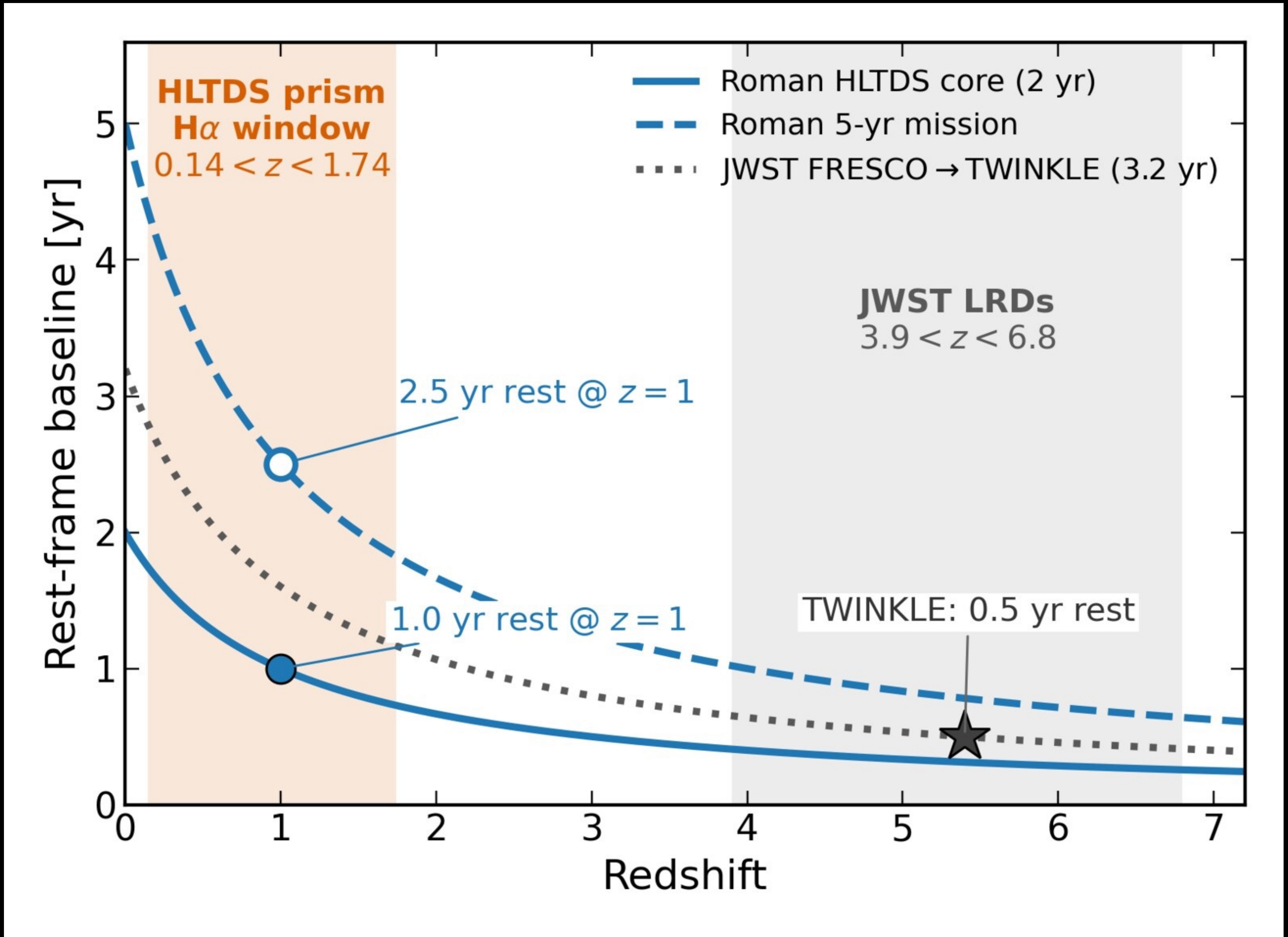
# Where do the little red dots go? — Count LRDs with HLWAS



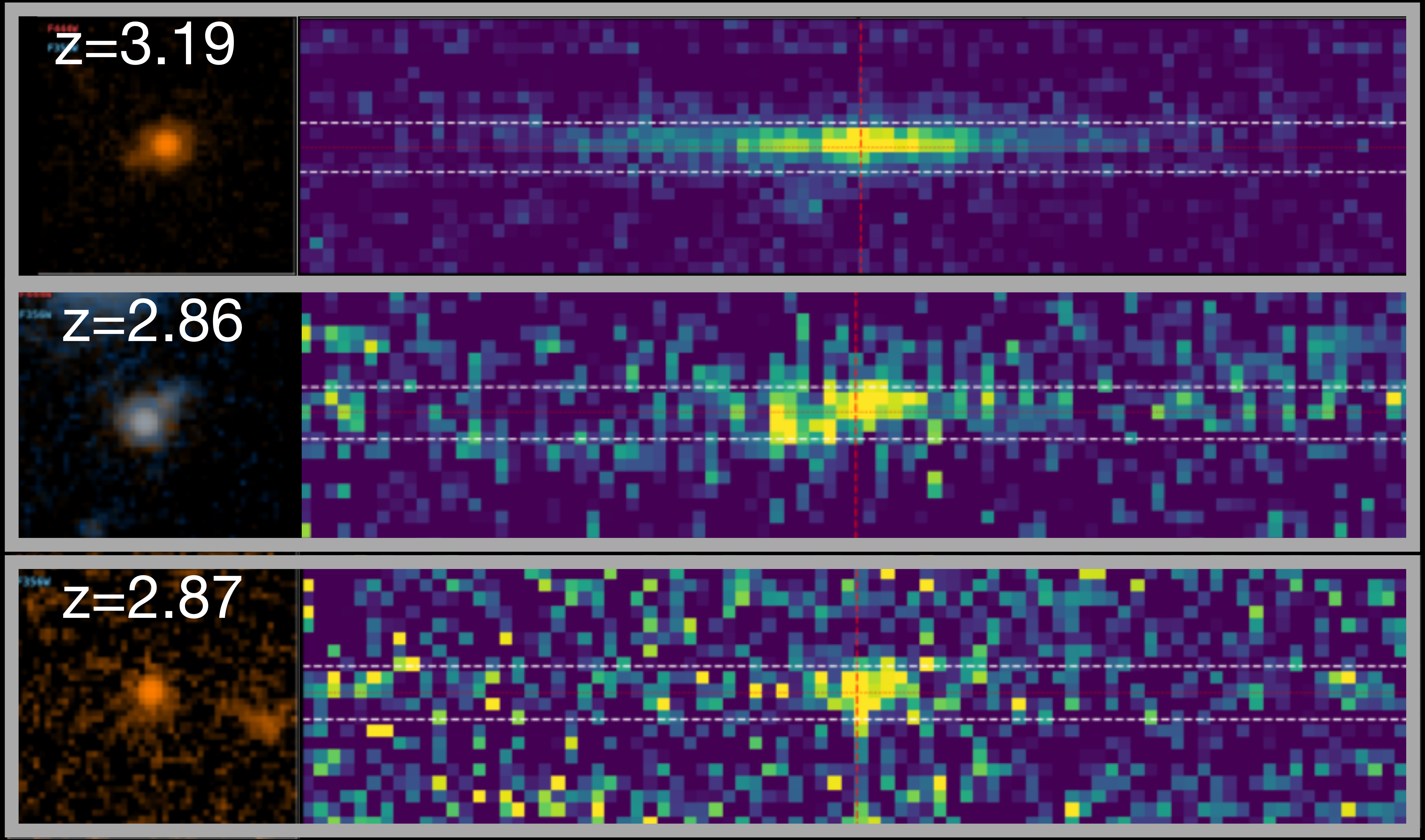

See Steve’s talk

# Where do the little red dots go? — Time LRDs with HLTDS




- P127 prism (Hα at $0.14 < z < 1.74$): 5.3 deg² every 5 days for 2 years
- The cocoon test: line vs. continuum variability on rest-frame years (Sneppen+26, Zhang+25)
- a calibration-free $M_{BH}$ for the population

# At z ≈ 2, they are still there: Promising Signs for Roman




Liu, in prep

Hundreds of LRDs at z=2-7 discovered in the JWST grism archive

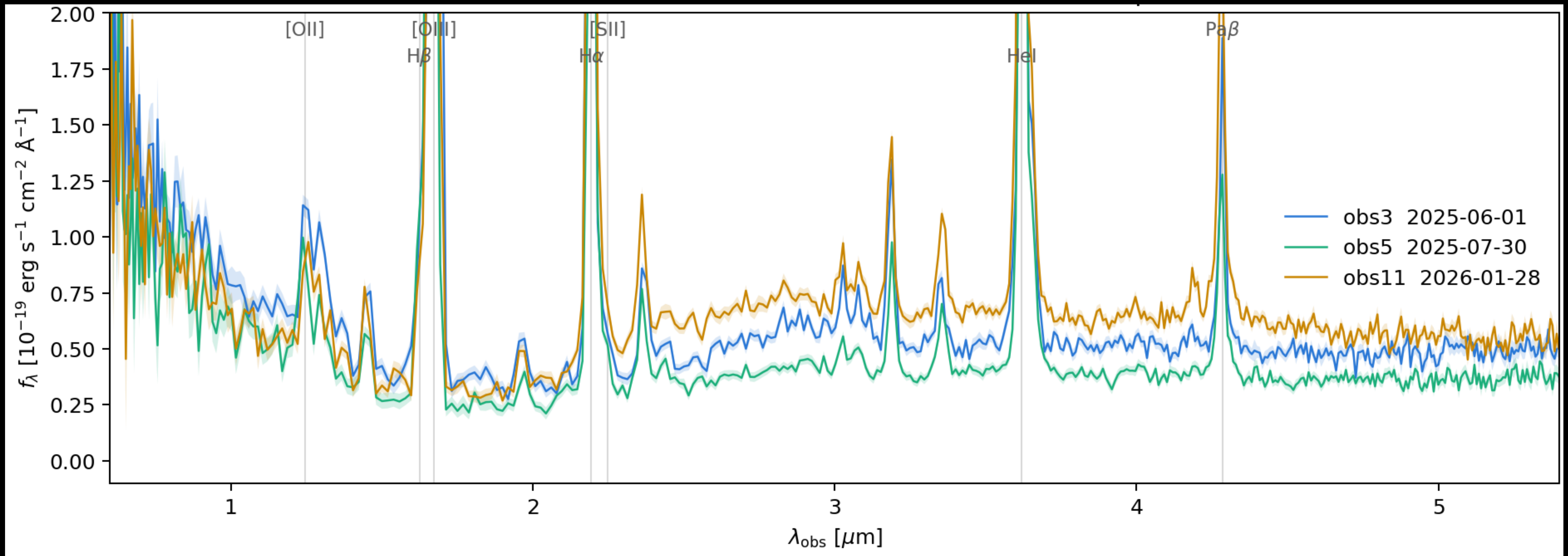
# Take-home message

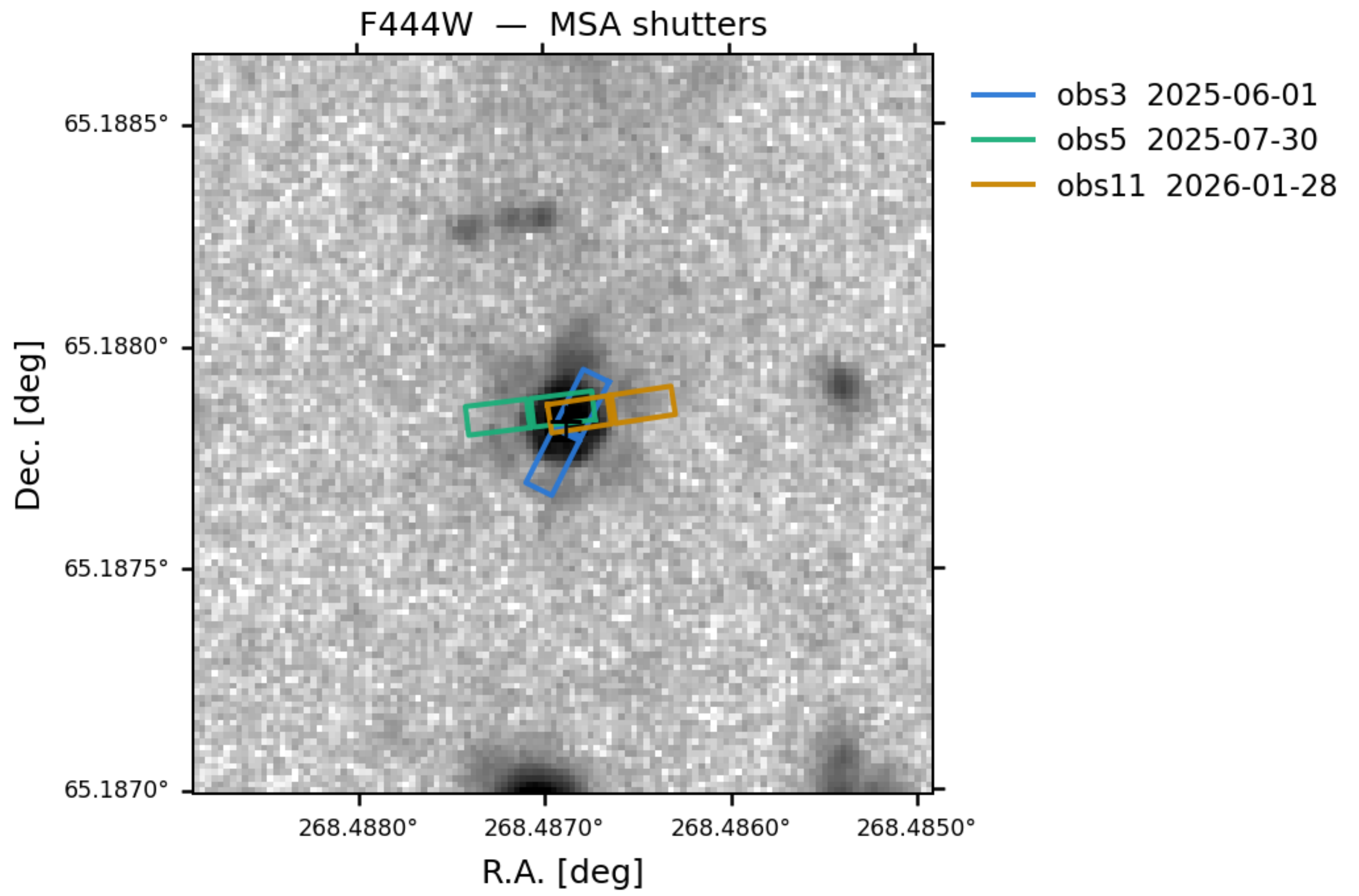
- LRDs are a new class of astrophysical objects, abundant at high redshift
- Roman will probe their evolution at $z = 0$–$2$
- 0/27 varied over 3 yr of JWST monitoring — virial masses calibrated on local AGN are not reliable
- Roman HLWAS: the low-z census
- Roman HLTDS: variability-based black hole masses

WEBB SPACE TELESCOPE

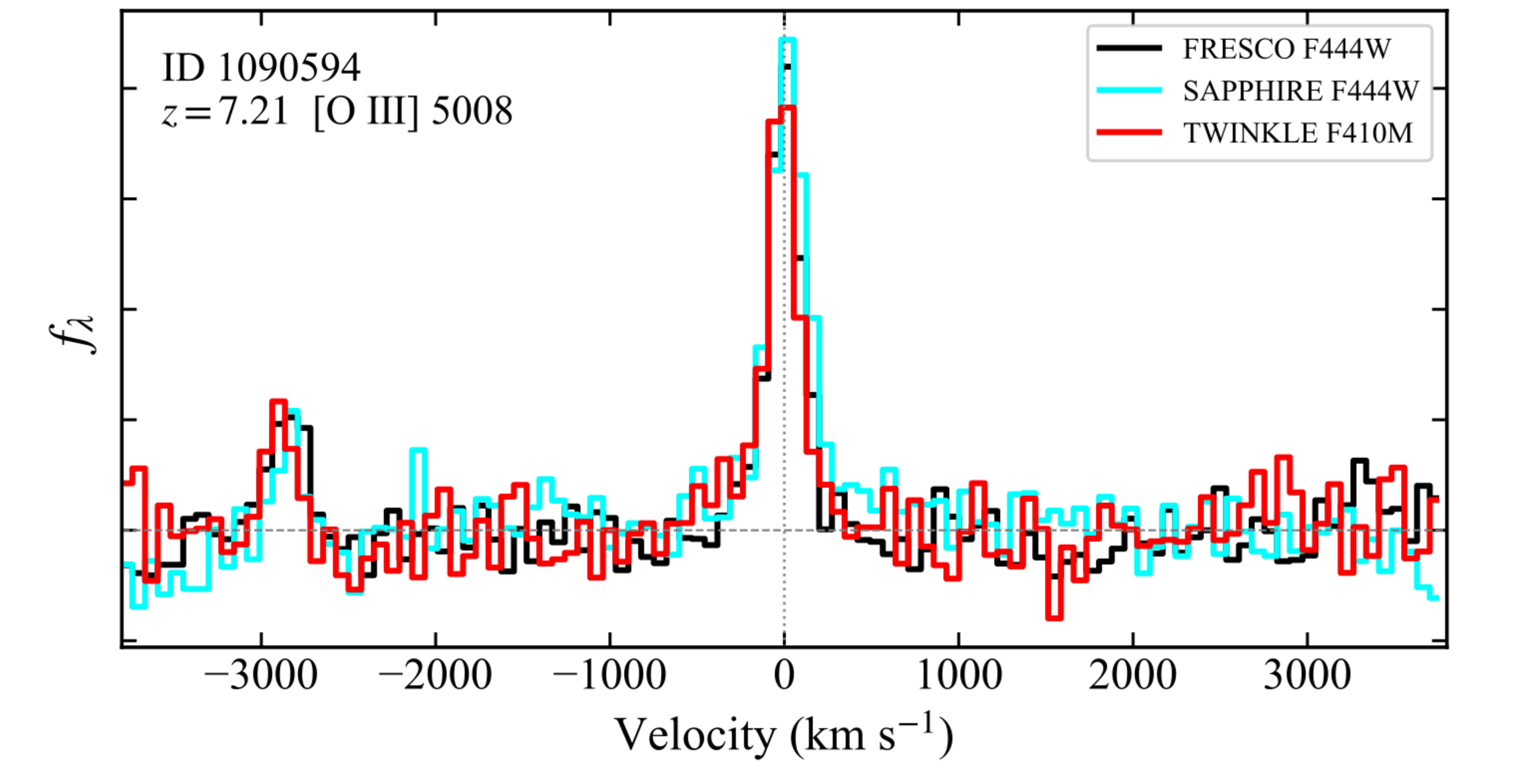
ROMAN SPACE TELESCOPE

# NIRSpec


[OII]
[OIII]
Hβ
[SII]
Hα
HeI
Paβ
obs3 2025-06-01
obs5 2025-07-30
obs11 2026-01-28
$f_\lambda$ [$10^{-19}$ erg s$^{-1}$ cm$^{-2}$ Å$^{-1}$]
$\lambda_{\rm obs}$ [$\mu$m]


F444W — MSA shutters
obs3 2025-06-01
obs5 2025-07-30
obs11 2026-01-28
Dec. [deg]
R.A. [deg]

# Grism calibration



# Super-Eddington Accretion Models

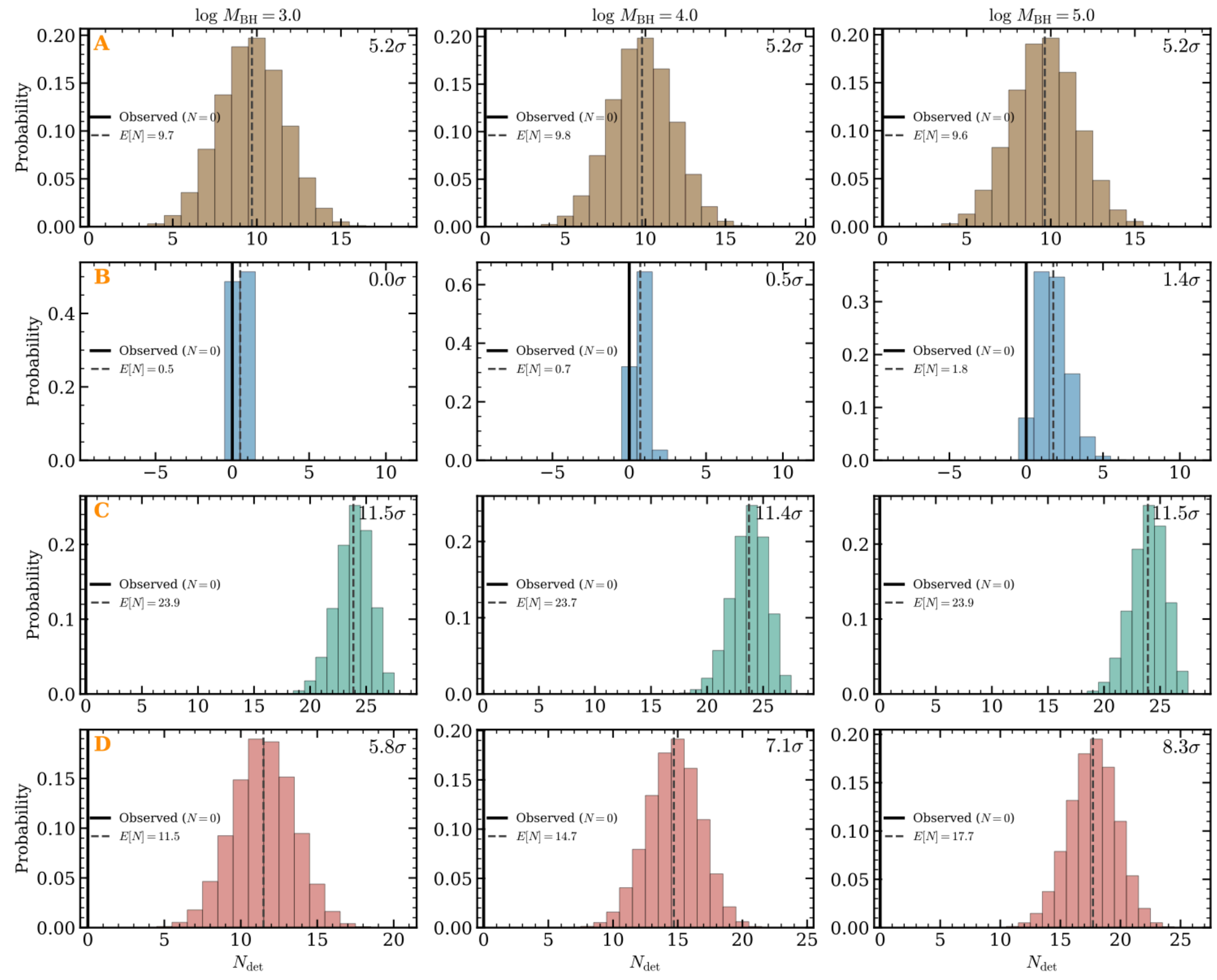



**Figure 11**: Expected number of variable sources ($N_{\rm det}$) under super-Eddington accretion models using mock light curves from Secunda et al. (2026). Each row shows the $N_{\rm det}$ distribution from 10,000 Monte Carlo realizations. **(A)** Unscaled — raw super-Eddington output ($\lambda = 3\times$), no mass or luminosity correction. **(B)** Mass-scaled — amplitude rescaled by $M_{\rm BH}$; detectability decreases toward lower masses. **(C)** Luminosity-scaled — amplitude rescaled by $L_{\rm obs}$. **(D)** Fully scaled — amplitude rescaled by both $M_{\rm BH}$ and $L_{\rm obs}$. Of all these flavors of models, the data are most consistent with those shown in the second row – super-Eddington ($L_{\rm bol}/L_{\rm edd} \approx 3$) black holes in the IMBH regime ($\approx 10^{3-5} M_\odot$).

**Liu+26**