

Too Quiet to Be Ordinary: **Little Red Dots**

The 6th BRICS-AGAC Symposium 2026, Hangzhou, China

Indu K. Dihingia · Ningbo University

What are little red dots?

Compact, very red JWST sources at z ~ 4–8, roughly 0.6–1.5 billion years after the Big Bang.

Broad Hα lines, a sign of accreting black holes.

Weak X-rays and no detected hot dust torus.

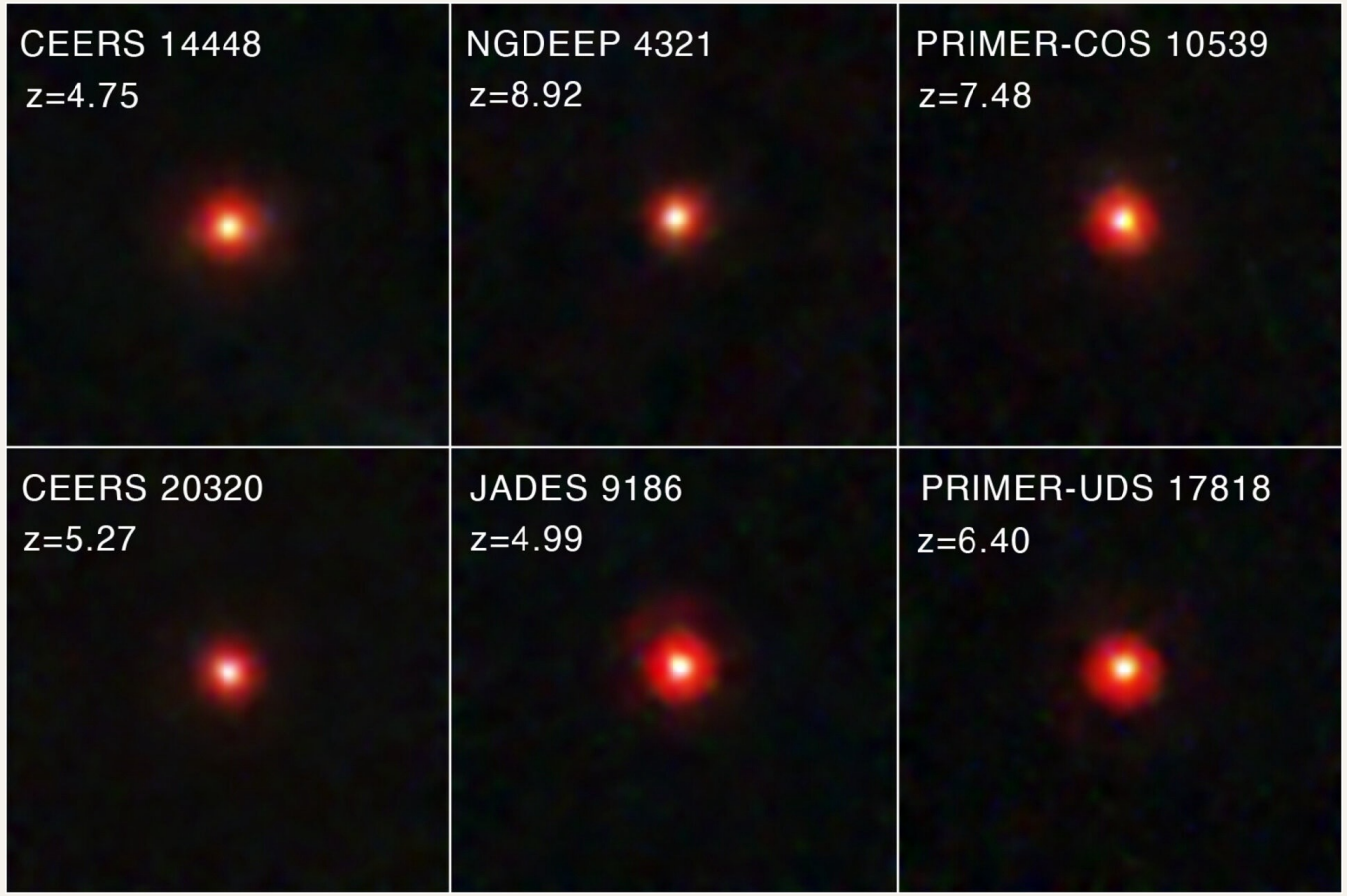


Image credit: NASA, ESA, CSA, STScI, D. Kocevski (Colby College)

Nature still debated (Super-Eddington, Supermassive star, black hole stars): super-Eddington black holes are a leading idea.

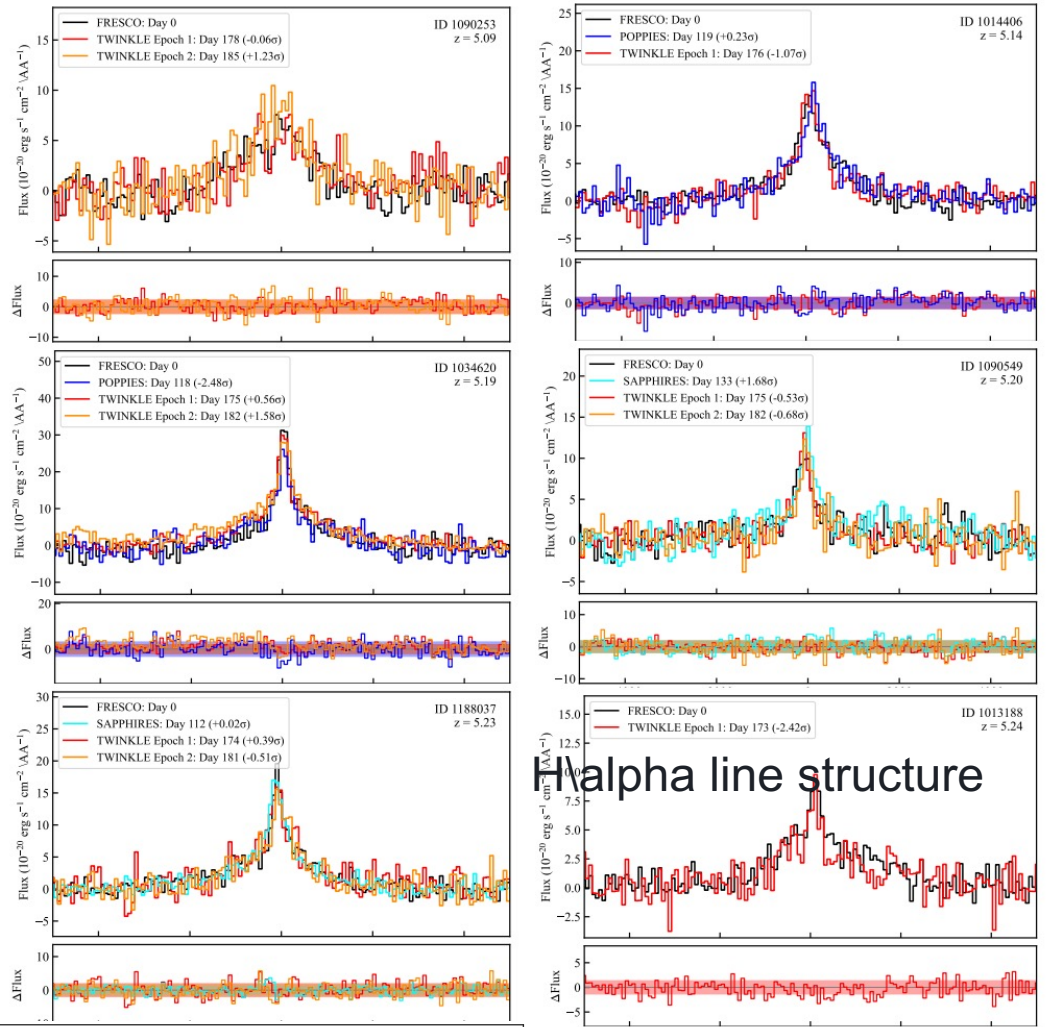
Variability searches so far

Zhang+25: variability in only a few percent of ~300 LRDs

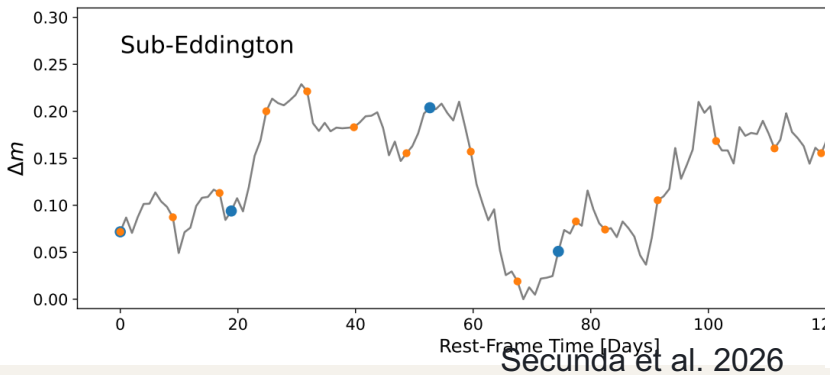
Kokubo & Harikane 25, Tee+25: none in small samples

Liu+26 (TWINKLE): 0 of 18 variable, a 5.9σ deficit

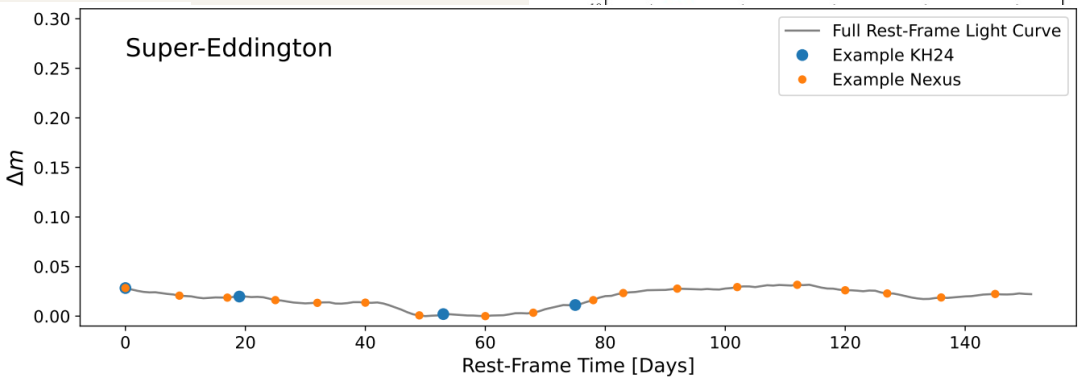
Simulations of super-Eddington disks give steady light curves (Secunda+26)

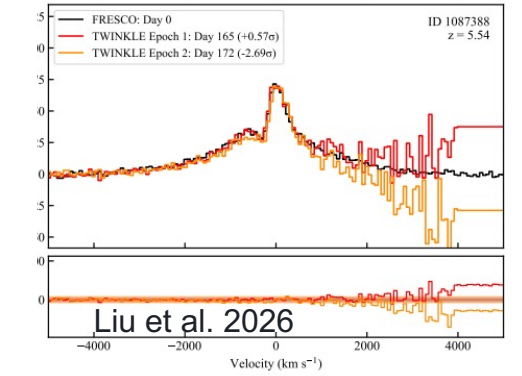


Halpha line structure



Secunda et al. 2026





Liu et al. 2026

Little red dots do not vary

0 / 18

TWINKLE LRDs variable over 140–220 d rest-frame

5.9σ

deficit relative to reverberation-mapped AGNs

~3%

variable in NIRCam multi-epoch imaging of ~300 LRDs

Q1. Why don't little red dots vary?

Q2. At which accretion rate does variability disappear, and how does that threshold depend on mass, wavelength, and baseline?

Q3. What would falsify the super-Eddington interpretation of LRDs?

How do these black holes formed in the early Universe?

Three damping mechanisms in a slim disk

Advective attenuation

Inside r_trap ≈ 3.8 ṁ r_g only t_adv / t_diff of a fluctuation escapes

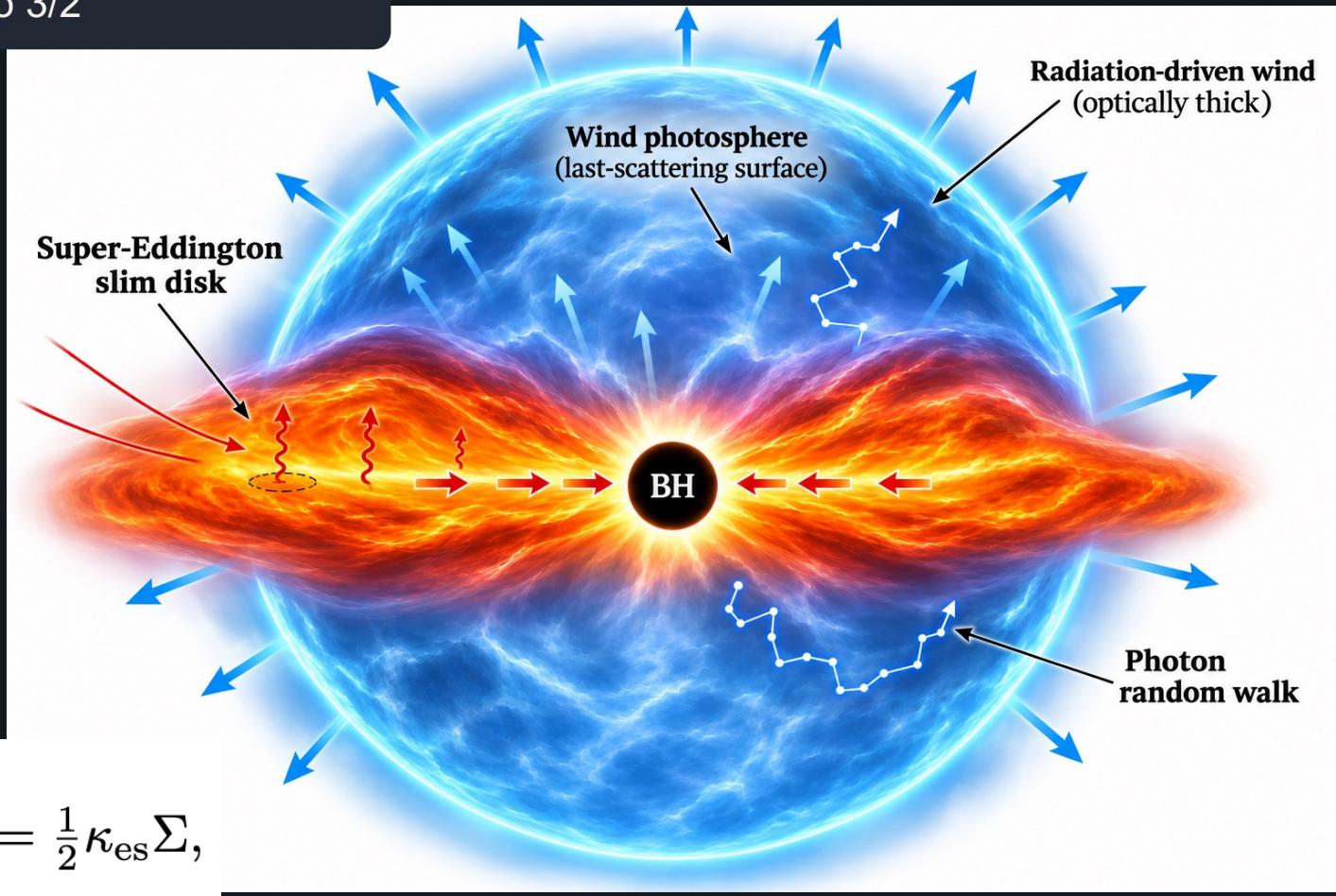
Photospheric averaging

Wind photosphere holds N ≈ 2(r_ph/H)² patches; damping N^-k, k from ½ to 3/2

Diffusion filter

Low-pass: G² = t_visc / (t_visc + t_diff) on each radial zone

Damped Random Walk



r_{trap} : inside this radius, light is carried into the black hole faster than it can escape — the disk radiates less than it produces.

r_{sph} : inside this radius, the disk is locally super-Eddington, puffs up, and expels the surplus gas as a wind.

$$t_{\rm adv} = \frac{r}{v_r} = \frac{t_{\rm dyn}}{\alpha h^2}, \qquad t_{\rm diff} = \frac{\tau_{\rm es} H}{c}, \qquad \tau_{\rm es} = \tfrac{1}{2}\kappa_{\rm es}\Sigma,$$

Three damping mechanisms realization



Advective attenuation: falling lighthouse

AI生成



Photospheric averaging: thousand people waving

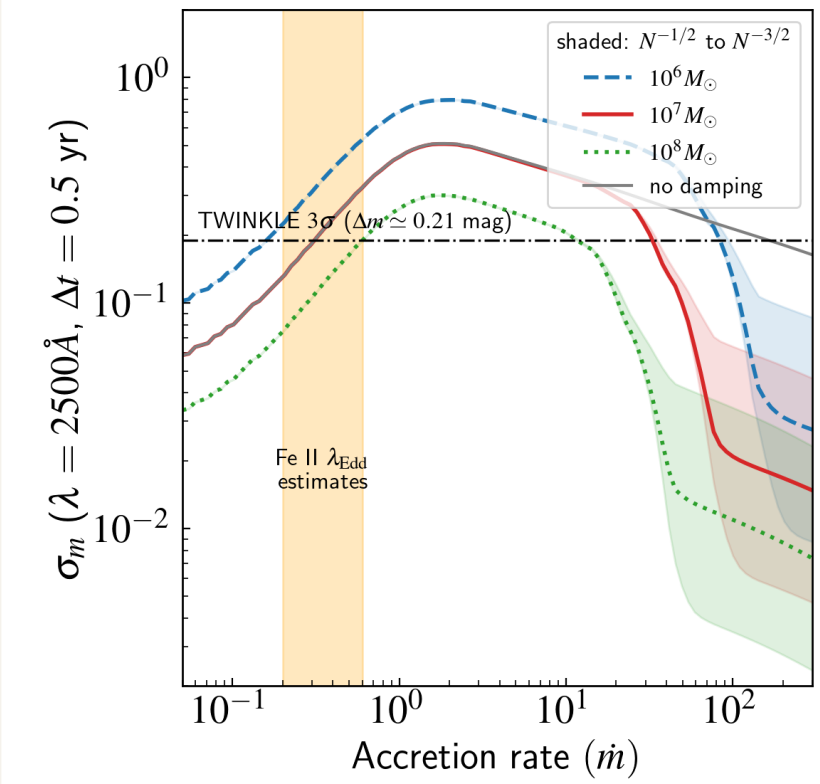




Diffusion filter: frosted glass

AI生成

Variability collapses above ṁ of a few



$$\sigma_m^2(\dot{m}, M_{\rm BH}, \lambda, \Delta t) = \sum_z \left[w_z\, \sigma_0 \sqrt{1 - e^{-\Delta t / t_{{\rm visc},z}}}\, \langle A_{\rm adv} A_{\rm ph} G \rangle_z \right]^2$$

ṁ ≳ 30 for 10^7 M⊙ at Δt = 0.5 yr

ṁ ≳ 100 for 10^6 M⊙; 10^8 M⊙ already hides near ṁ ~ 10

Fe II estimates, ṁ ≈ 0.2–0.6, sit in the detectable region

$$A_{\rm adv}(r) = \min(1,\ t_{\rm adv}/t_{\rm diff})\,;$$

Advective attenuation

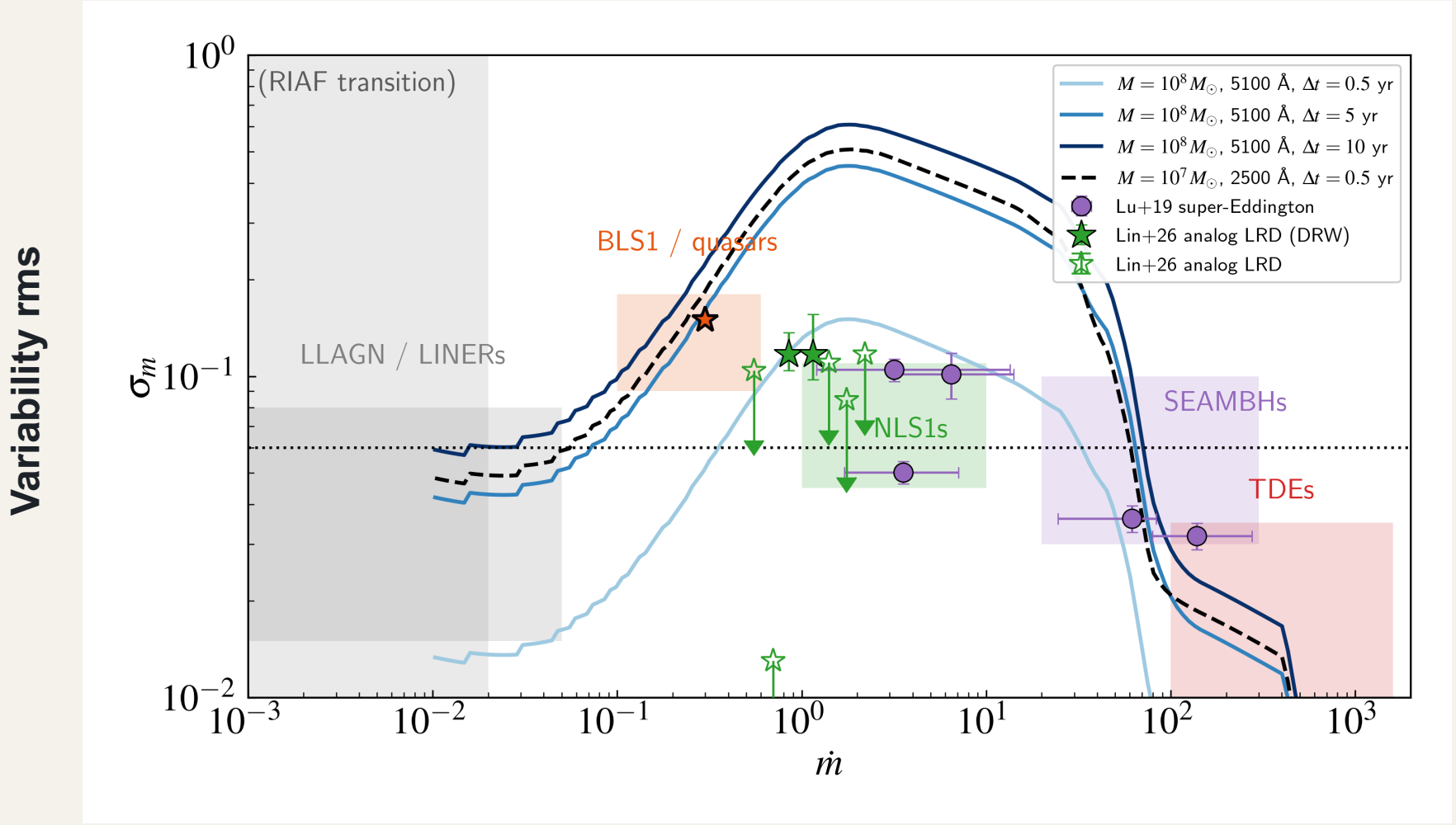
$$A_{\rm ph} = N^{-k}, \qquad k \in \{\tfrac{1}{2},\ 1,\ \tfrac{3}{2}\}.$$

Photospheric attenuation

$$G(f, r) = \left[1 + (2\pi f\, t_{\rm diff})^2\right]^{-1/2}.$$

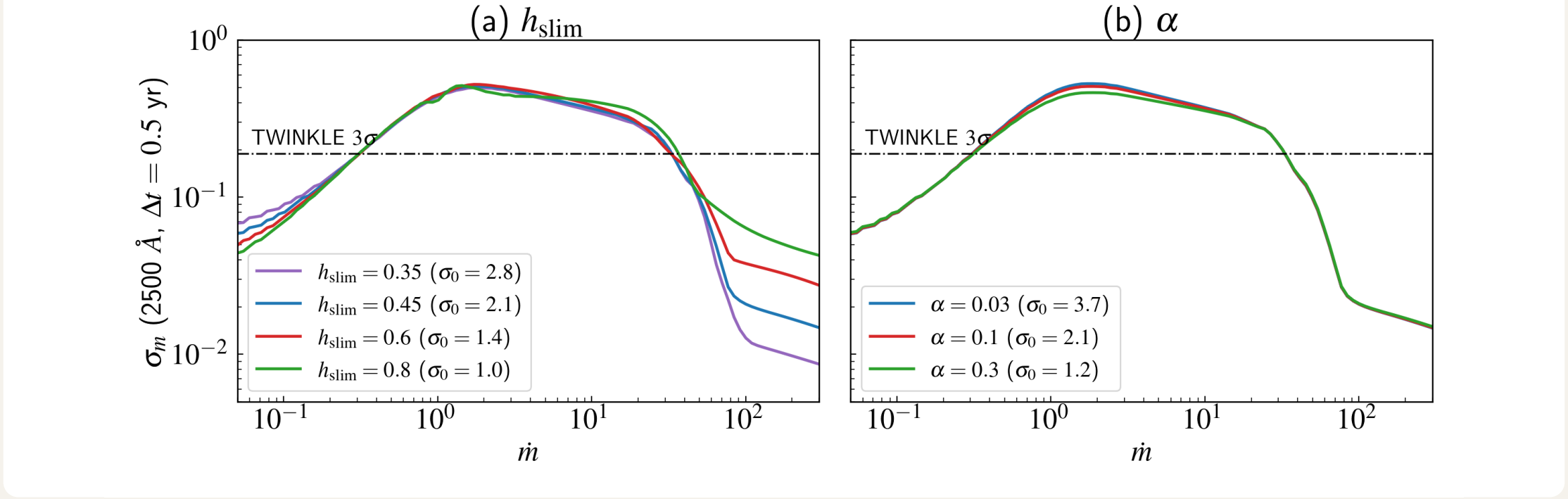
Diffusion low-pass filter:
Photon transfer function

Is the model generic?



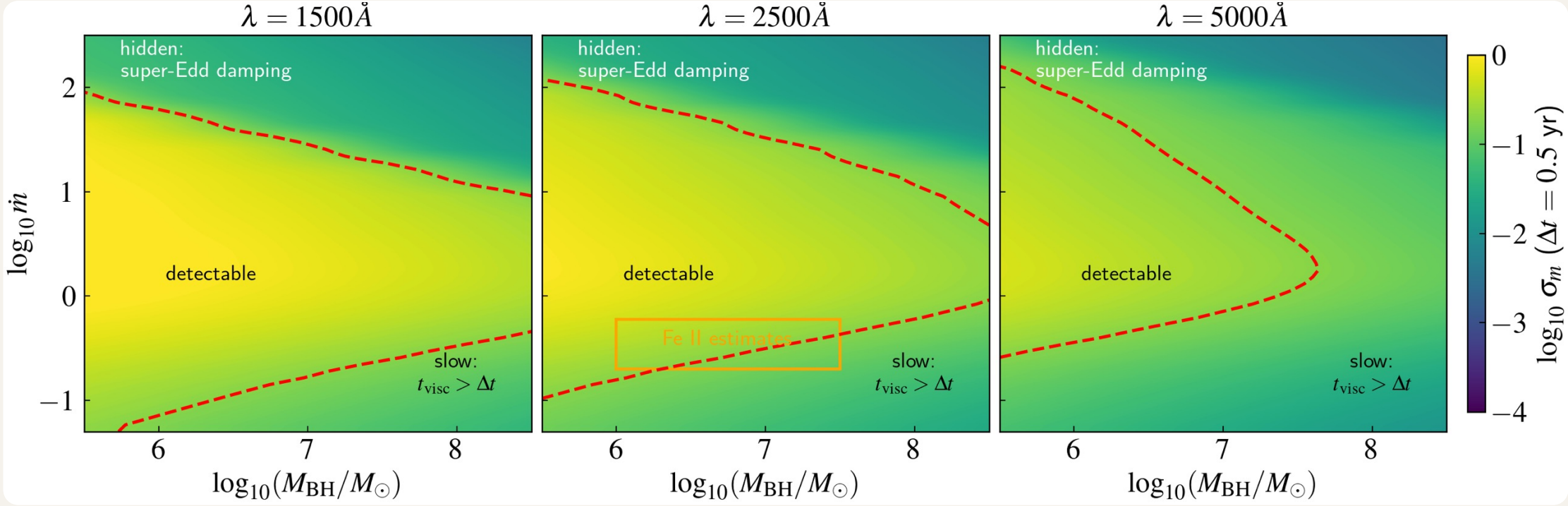
The model can roughly reproduce the observed trend of decreasing variability with increasing $\mdot$ across the major accretor classes, and it is quantitatively consistent with the super-Eddington population

The threshold survives h_{slim} and α



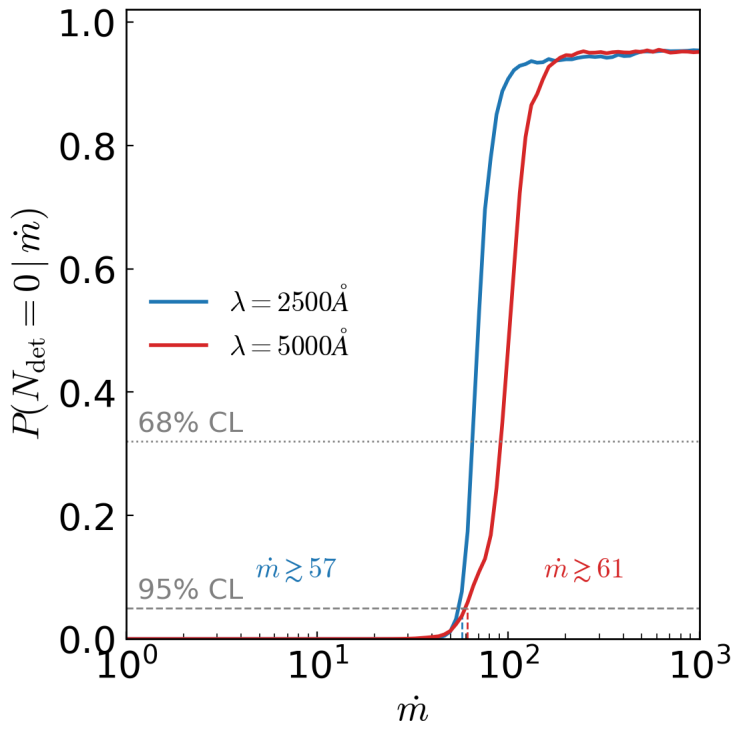
Each curve is recalibrated to the quasar anchor, so the crossing stays at ṁ ≈ 29–35. Curves separate only deep in the hidden regime.

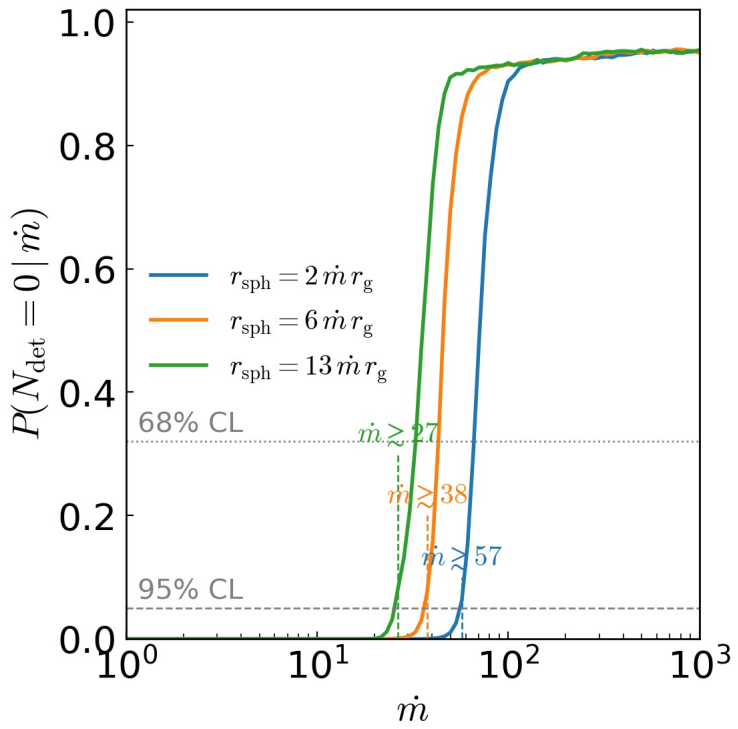
Mass and wavelength decide what can hide



Low ṁ and high mass hide because t_{visc} exceeds Δt. High ṁ hides by super-Eddington damping. The variable minority should be lower-ṁ or more massive.

Forward model: ṁ ≳ 60 at 95% confidence





18 sources, 12 epochs, 0.07 mag noise.

It is measured from 2 × 10^4 simulated light curves on a grid of 6 masses × 3 baselines.

Larger r_sph relaxes the limit to ṁ ≳ 27–38.

Non-detections are informative: evaluated at each light curve's own band and baseline, the model turns every null result into a likelihood, and jointly they rule out $\dot{m} \lesssim 60$ at 95%.

The bound is a cliff, not a slope: once $r_{\rm trap}$ exceeds the emission radius, σ_m plummets, so the limit survives any reasonable change in the assumed variability amplitude.

Takeaways

Photon trapping, photospheric averaging and diffusion suppress continuum variability by orders of magnitude.

TWINKLE non-detections require $\dot{m} \gtrsim 30$ at 10^7 $M_\odot$, and $\gtrsim 60$ $M_\odot$ at 95% confidence in the forward model.

