



Giornate RSN1, Naples, 10/02/2026

Little Red Dots at early cosmic times

Dr. Roberta Tripodi

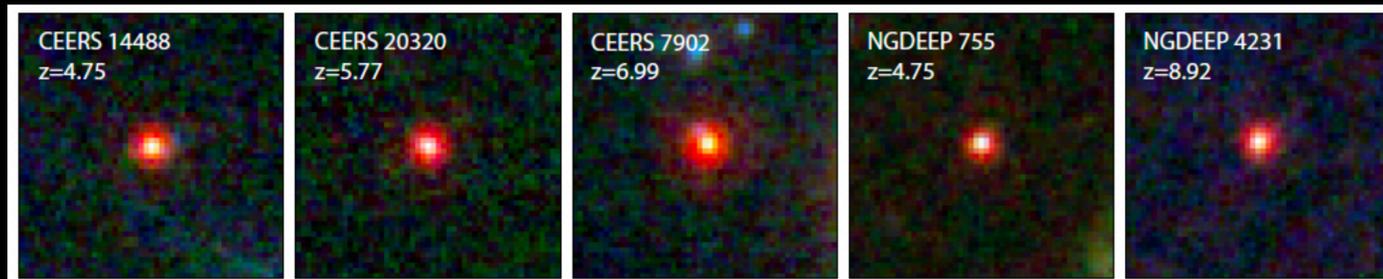
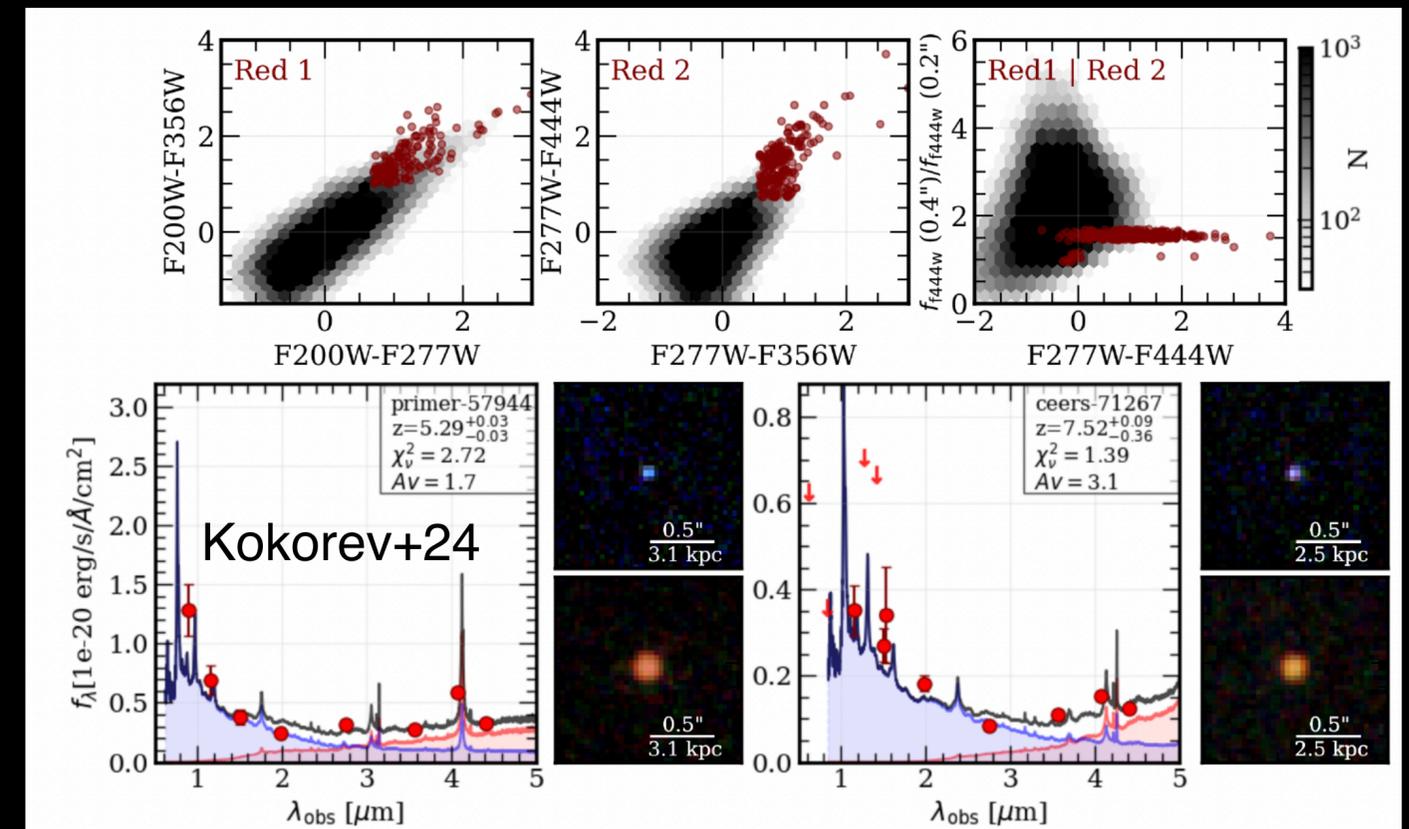
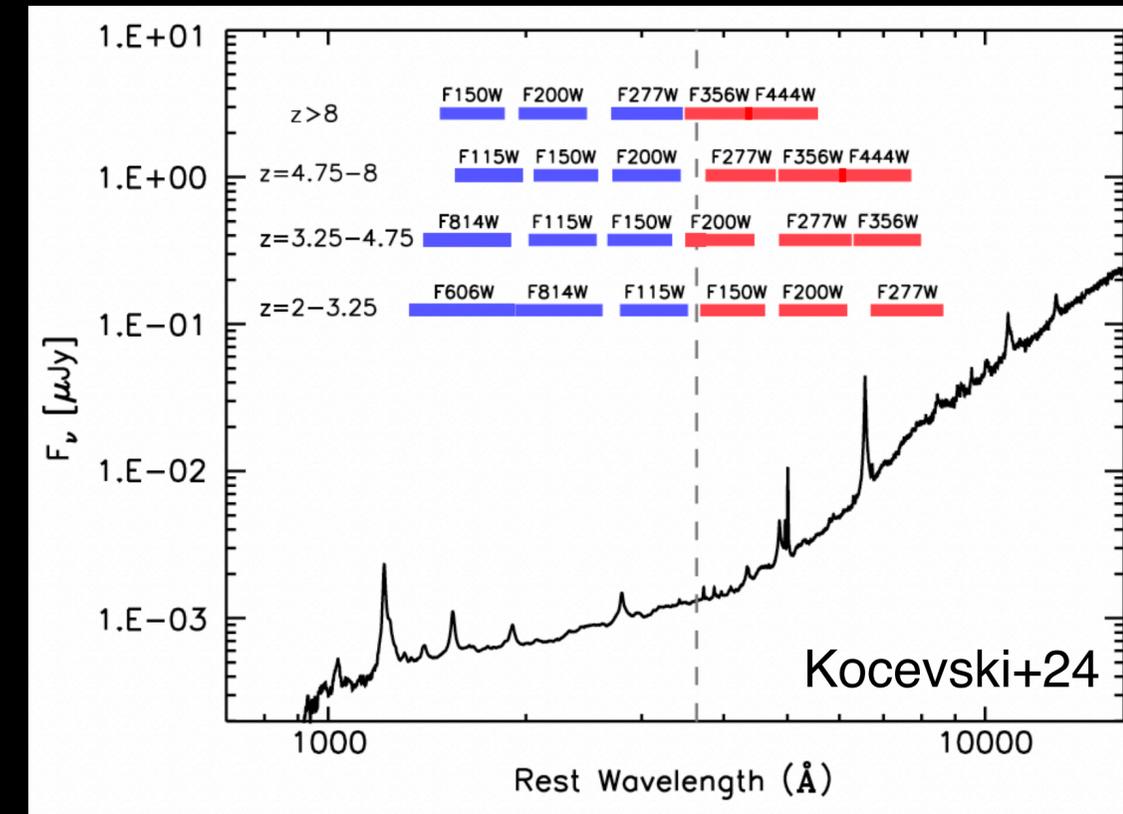
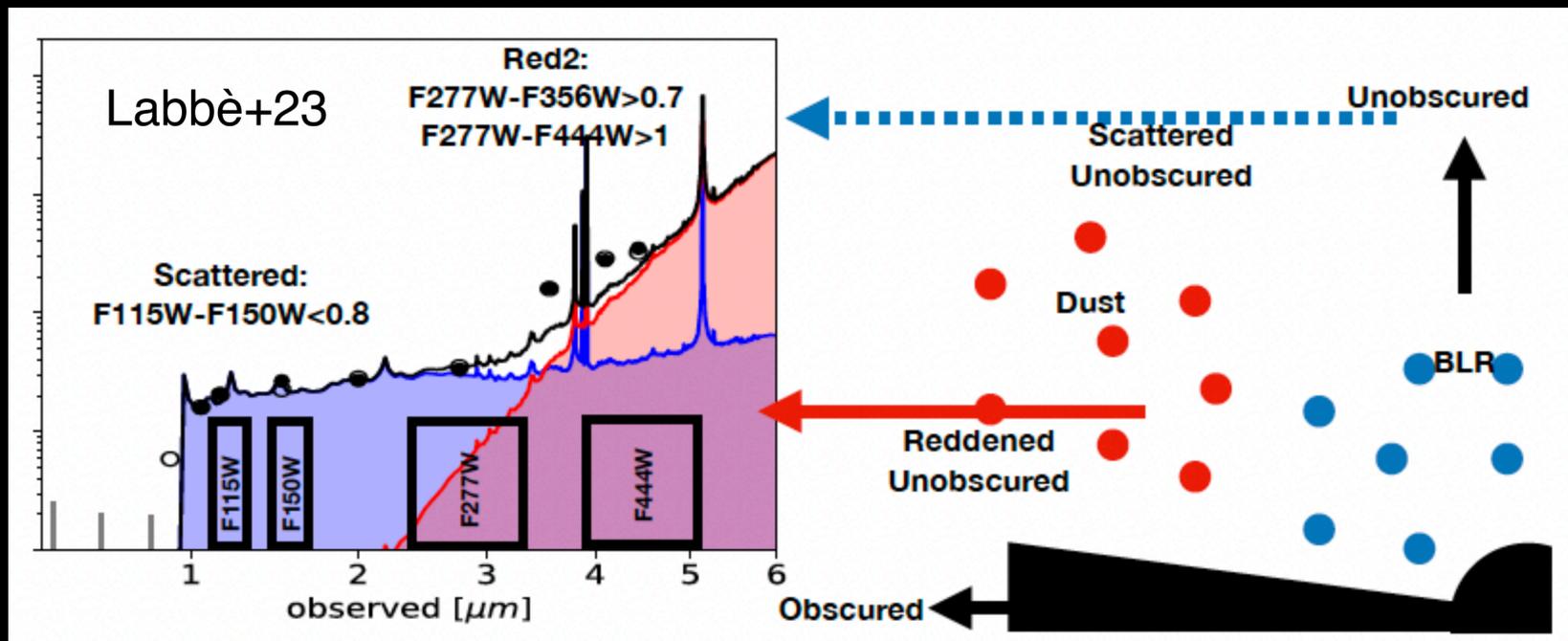
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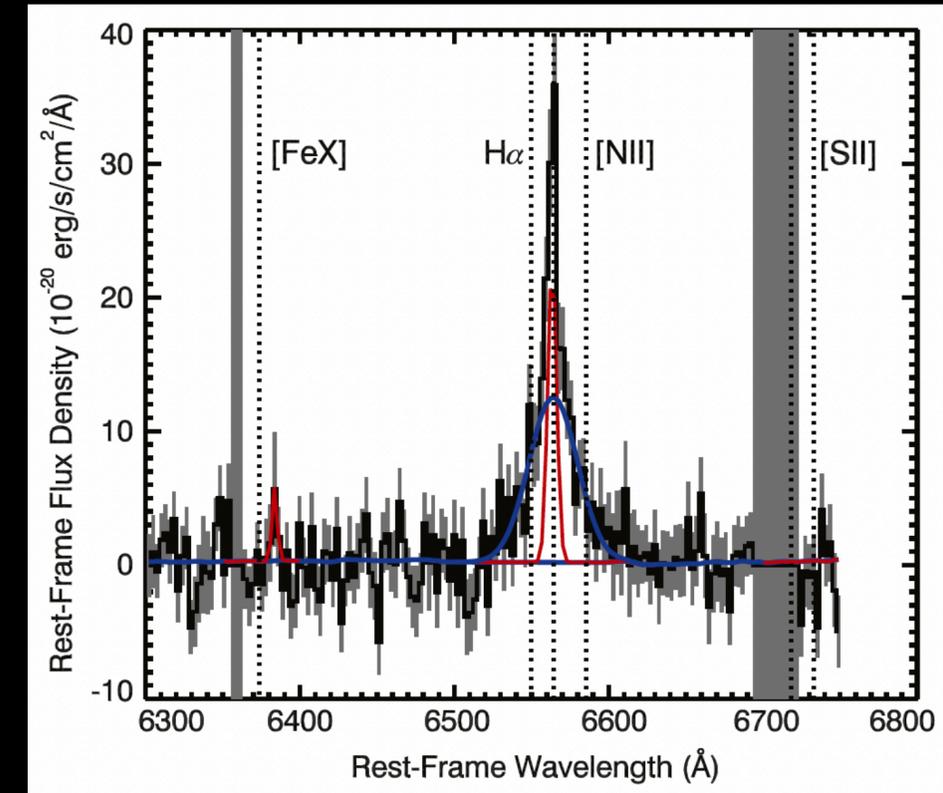
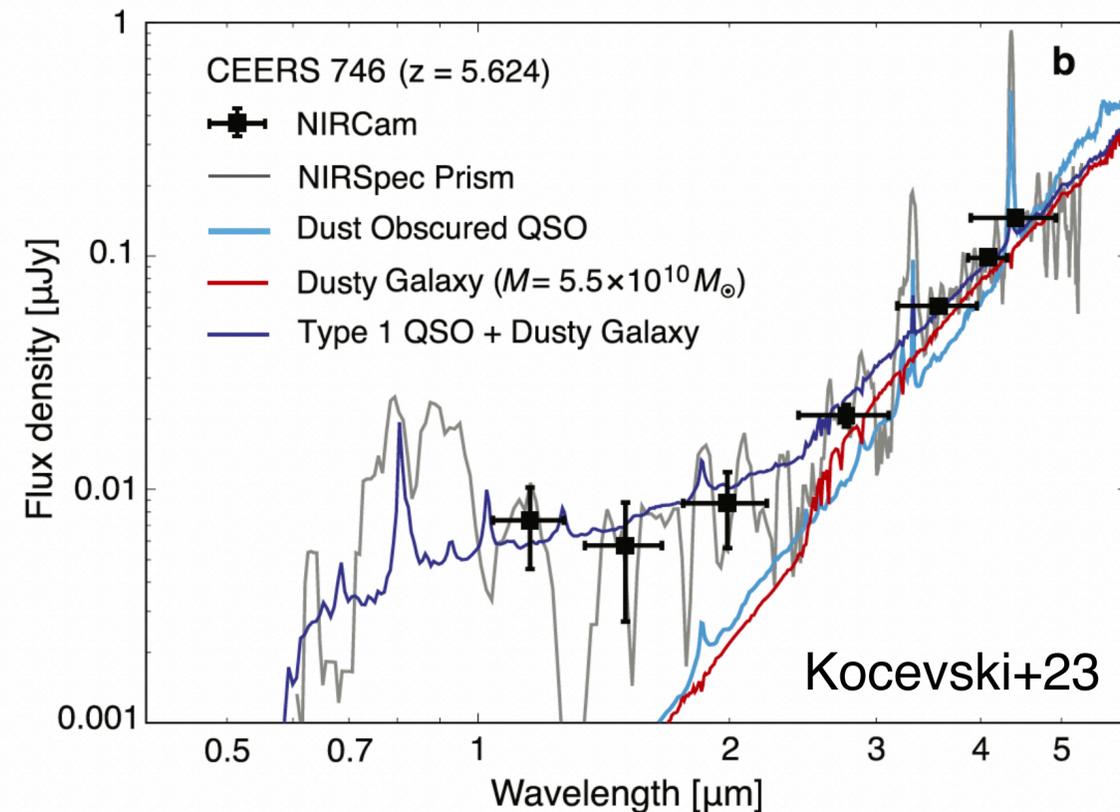
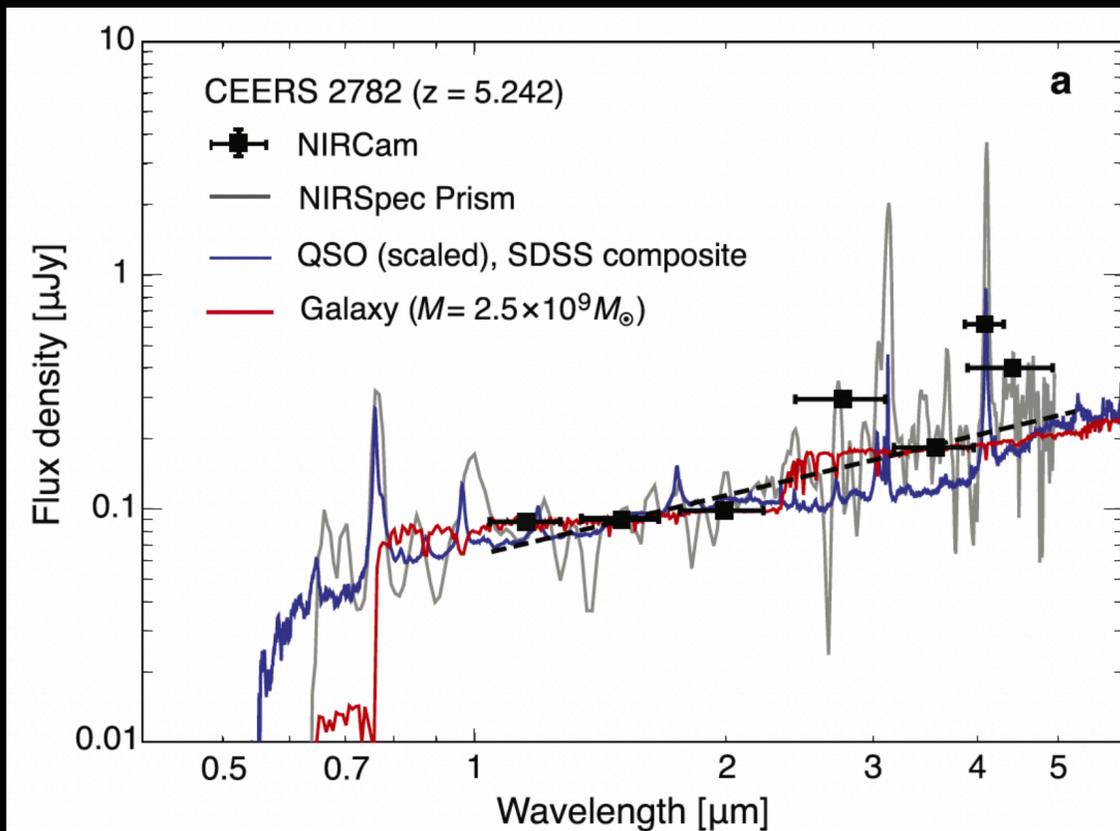
Defining a population: the LRDs

Compact + V-shaped spectrum



First spectra

- ◉ First spectroscopic confirmations: real blue-red continua + broad lines!!



Population overview

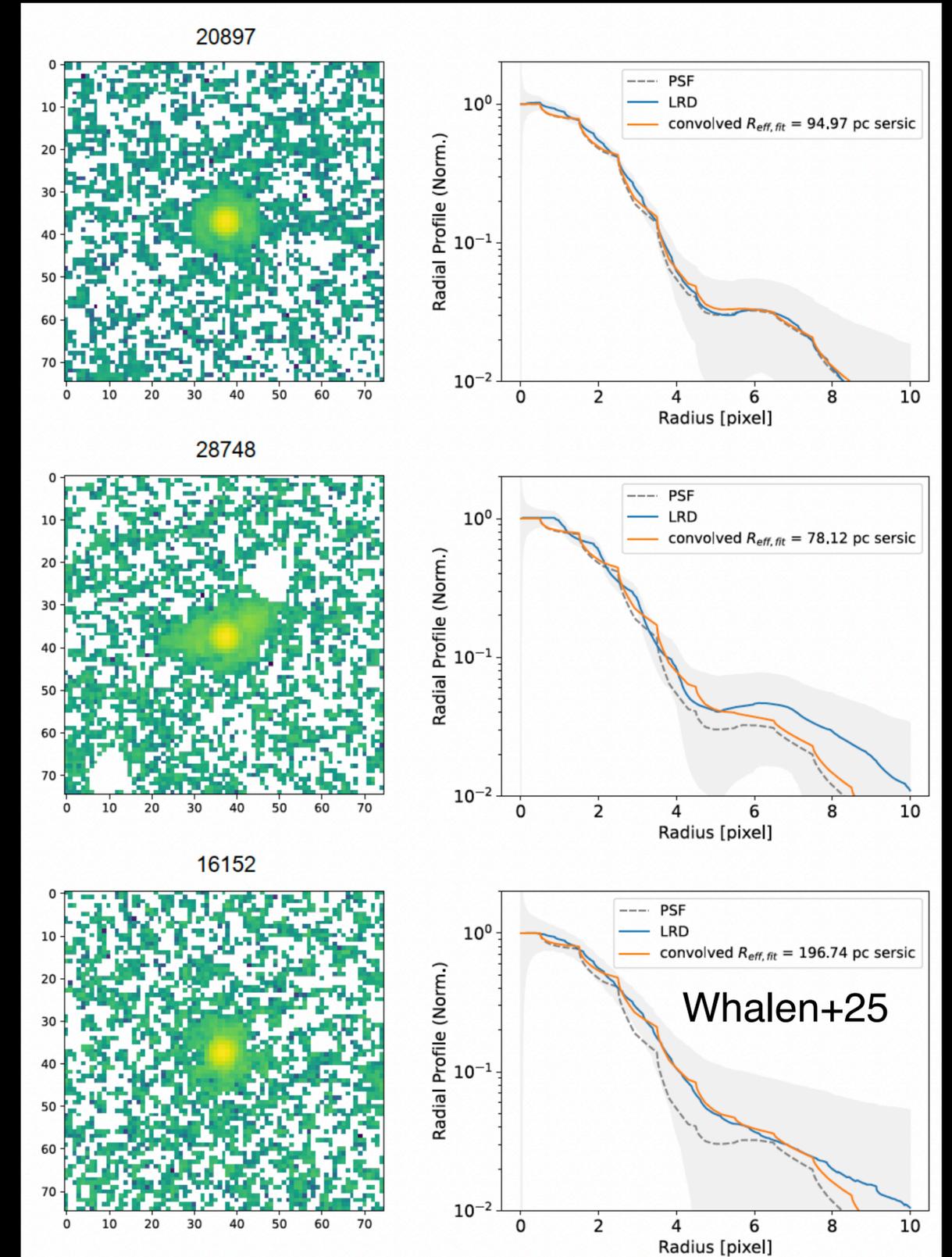
- >300 LRDs across CANUCS, CEERS, JADES, PRIMER, UNCOVER, NGDEEP
 - $z \approx 2-10$, peak at $z \sim 6-8$; $F444W \approx 24-27$ mag
 - Effective radius < 300 pc (mostly unresolved)
 - Blue UV ($\beta \approx -2$), red optical ($\beta > 0$) continuum

Greene+23, Labbè+23, Williams+23, Akins+24, Ananna+24, Barro+24, Barrufet+24, Casey+24, Durodola+24, Fenney+24, Furtak+24, Gonzalez+24, Hainline+24, Huang+24, Iani+24, Kocevski+23,+24, Kokorev+24, Labbè+24, Lambrides+24, Li+24, Ma+24, Maiolino+24, Matthee+24, Merida+24, Pizzati+24, Rinaldi+24, Schindler+24, Yue+24, Wang+24, Taylor+24, Akins+25, Barro+25, Brazzini+25, Casey+25, De Graaff+25, D'Eugenio+25a,b, Graham+25, Greene+25, Inayoshi&Maiolino+25, Inayoshi+25, Ji+25, Jiang+25, Jones+25, Juodzbališ+25, Kido+25, Kokubo+25, Lambrides+25, Lin+25, Ma+25, Maiolino+25, Merida+25, Morishita+25, Naidu+25, Nikopoulos+25, Pacucci+25, Quadri+25, Rusakov+25, Setton+25, Xiao+25, Tanaka+25, Taylor+25, Torralba+25a,b, Tripodi+25a,b, Whaler+25, Zhuang+25, Asada+26 Zhou+26, Caputi+26, Hviding+26, Yanagisawa+26, Ma+26, Pacucci+26, Marzsewski+26, Sun+26, Brazzini+26, Baggen+26 and others

Morphology and variability

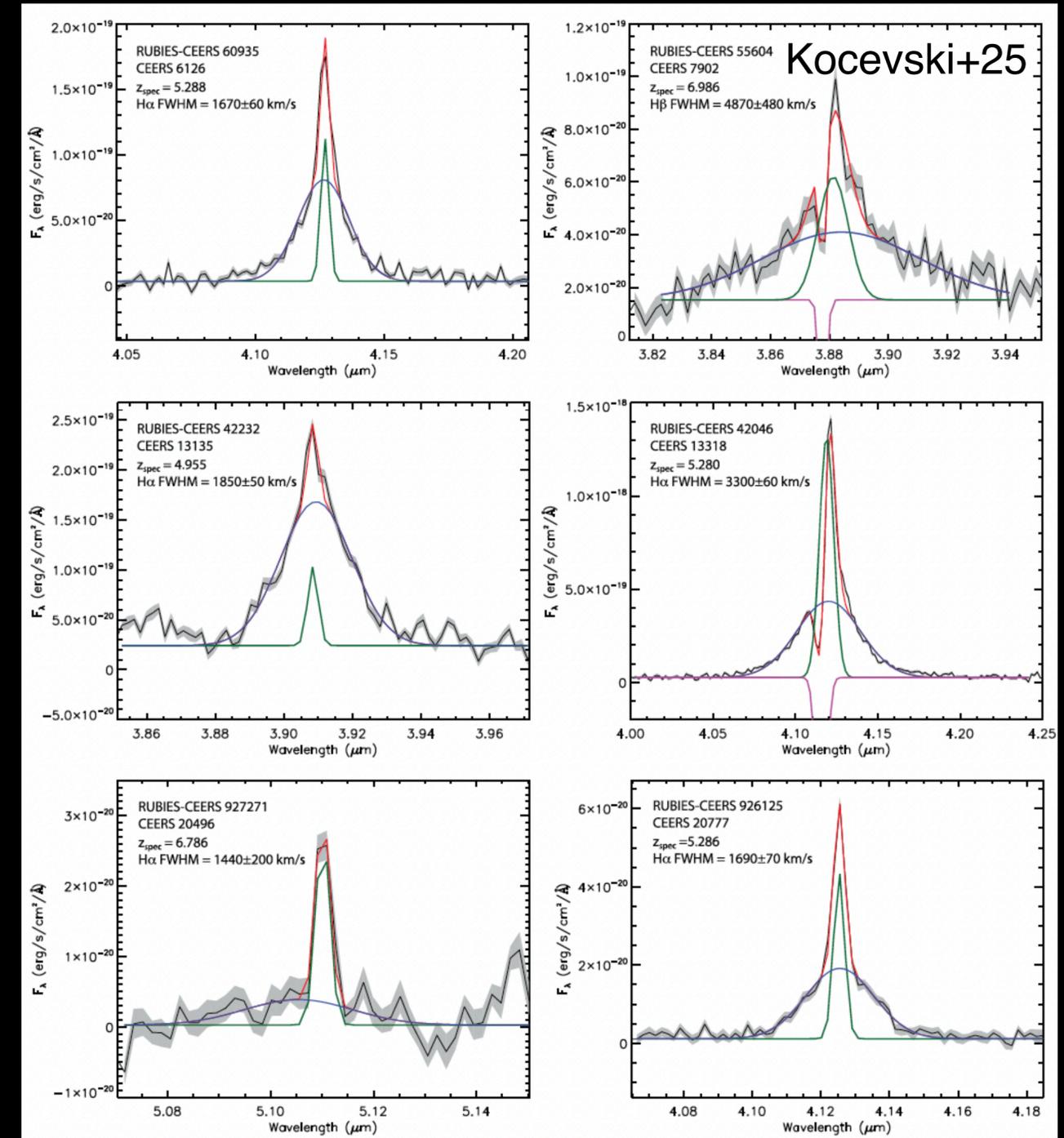
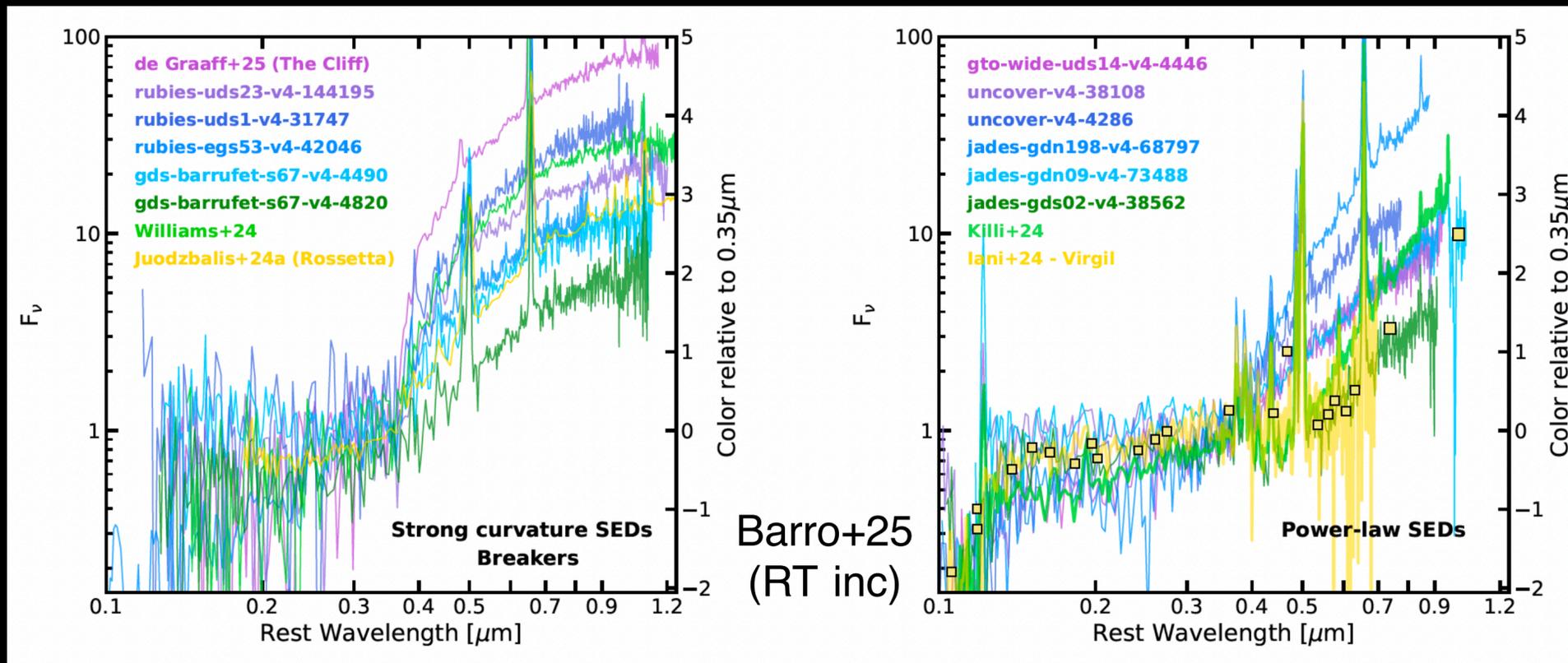
- $R_e < 0.3$ kpc (point-like in NIRCam)
- 85% PSF dominated
- 15% $R_e > 0.15$ kpc

Two populations
1. AGN hosts
2. Compact starbursts



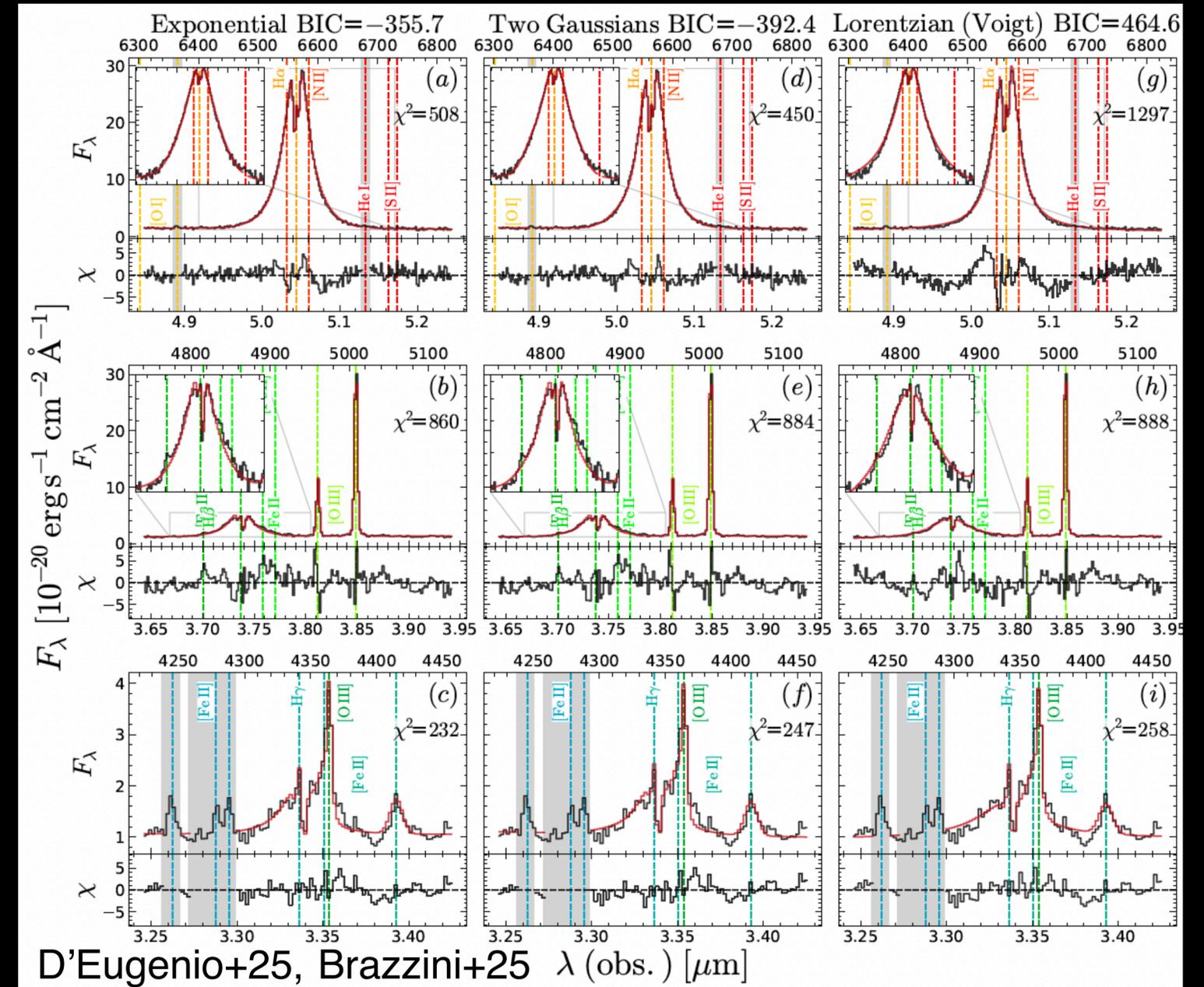
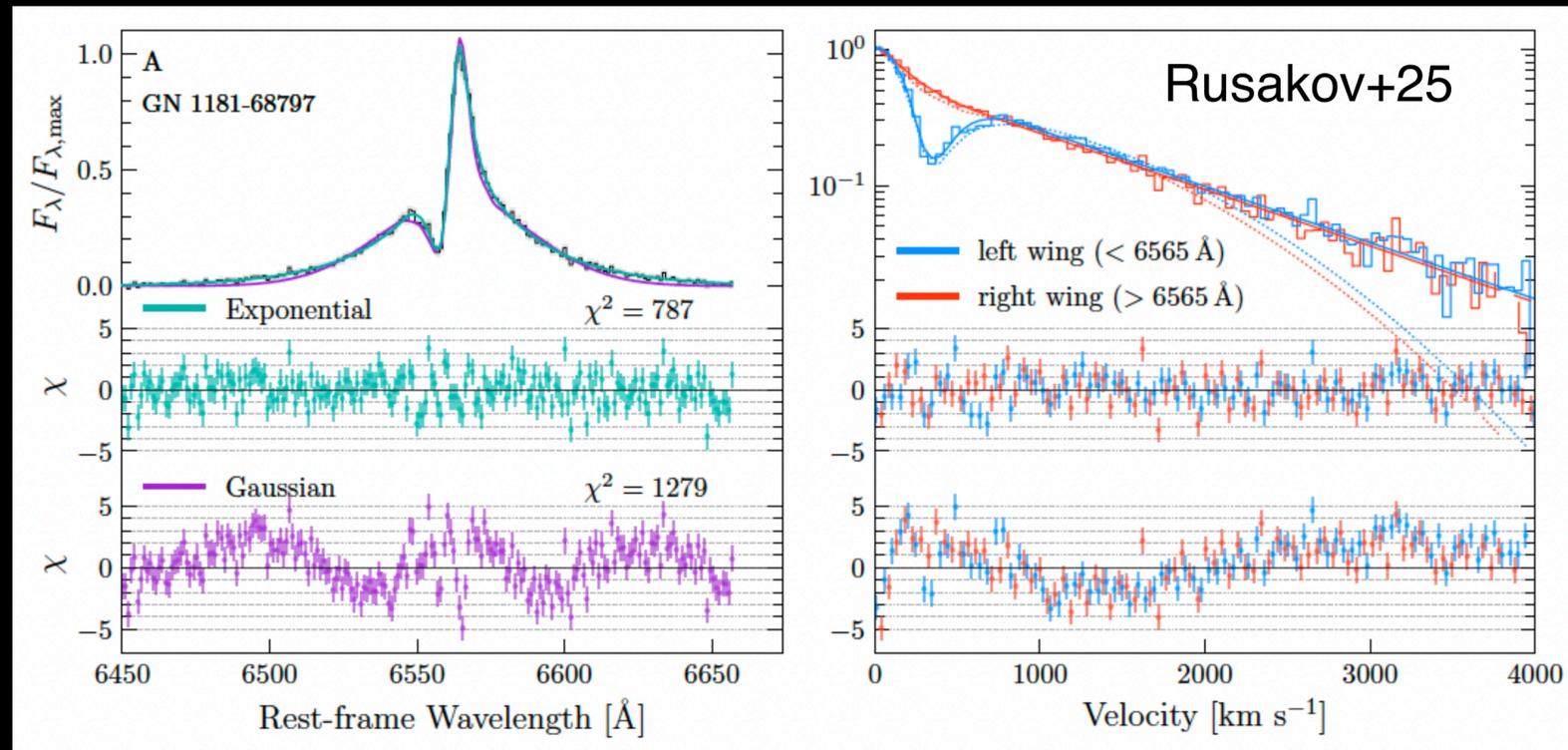
Spectroscopic highlights

- Broad H α , H β (FWHM $\sim 1\text{--}5 \times 10^3$ km/s)
- 90% of LRDs show broad emission



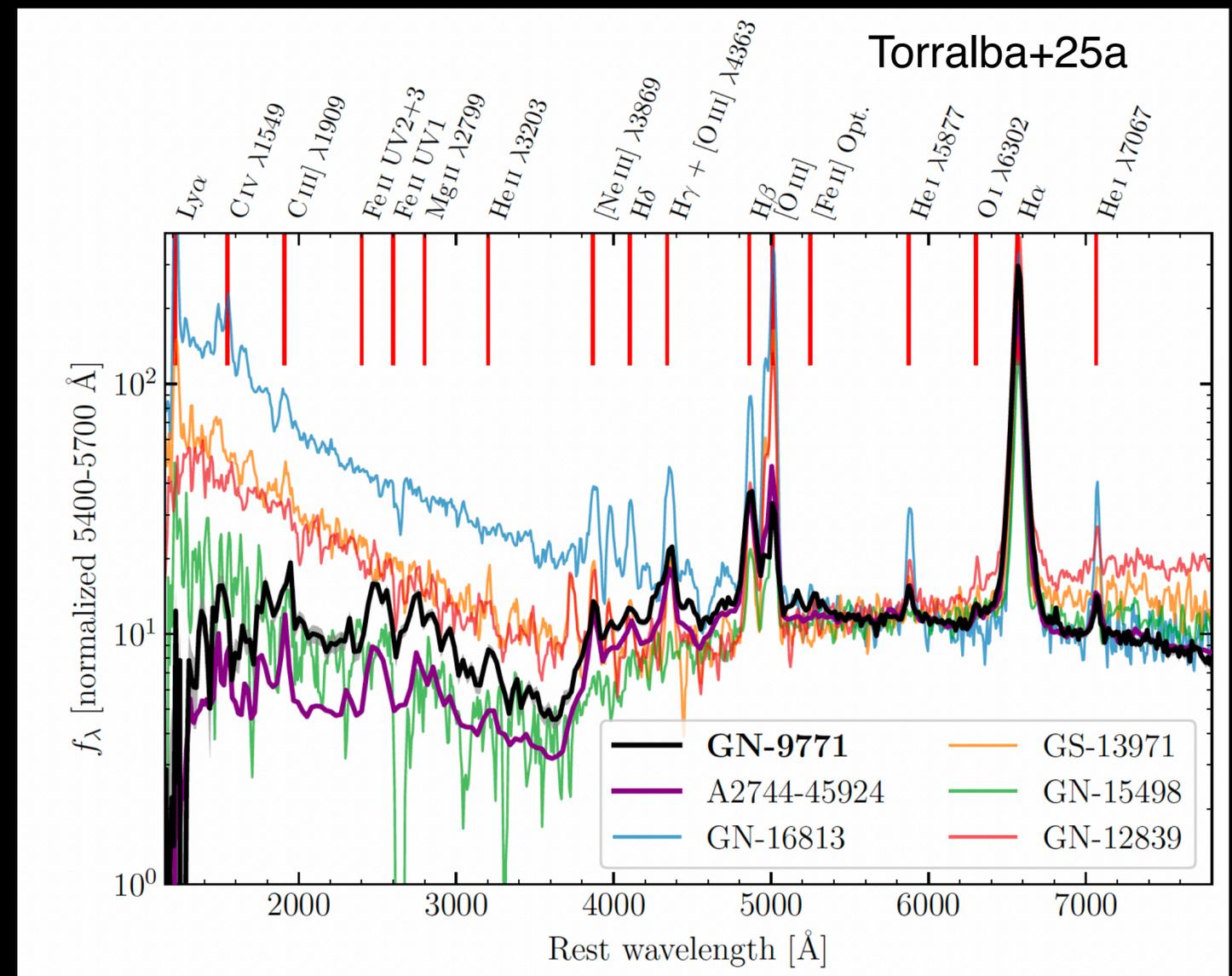
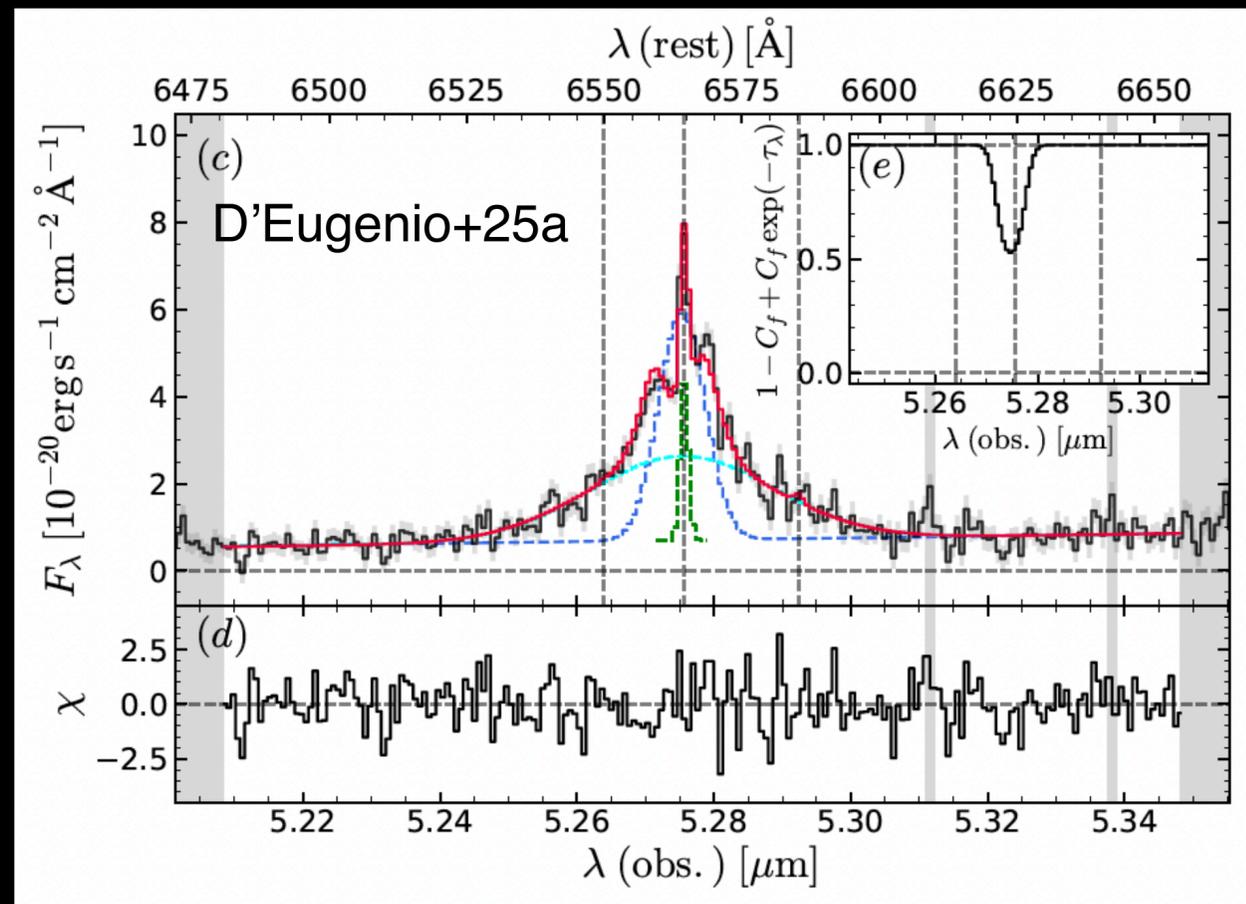
Electron scattering and BH masses

- MBH $\approx 10^5 - 10^7 M_\odot$
- What is the role of electron scattering?

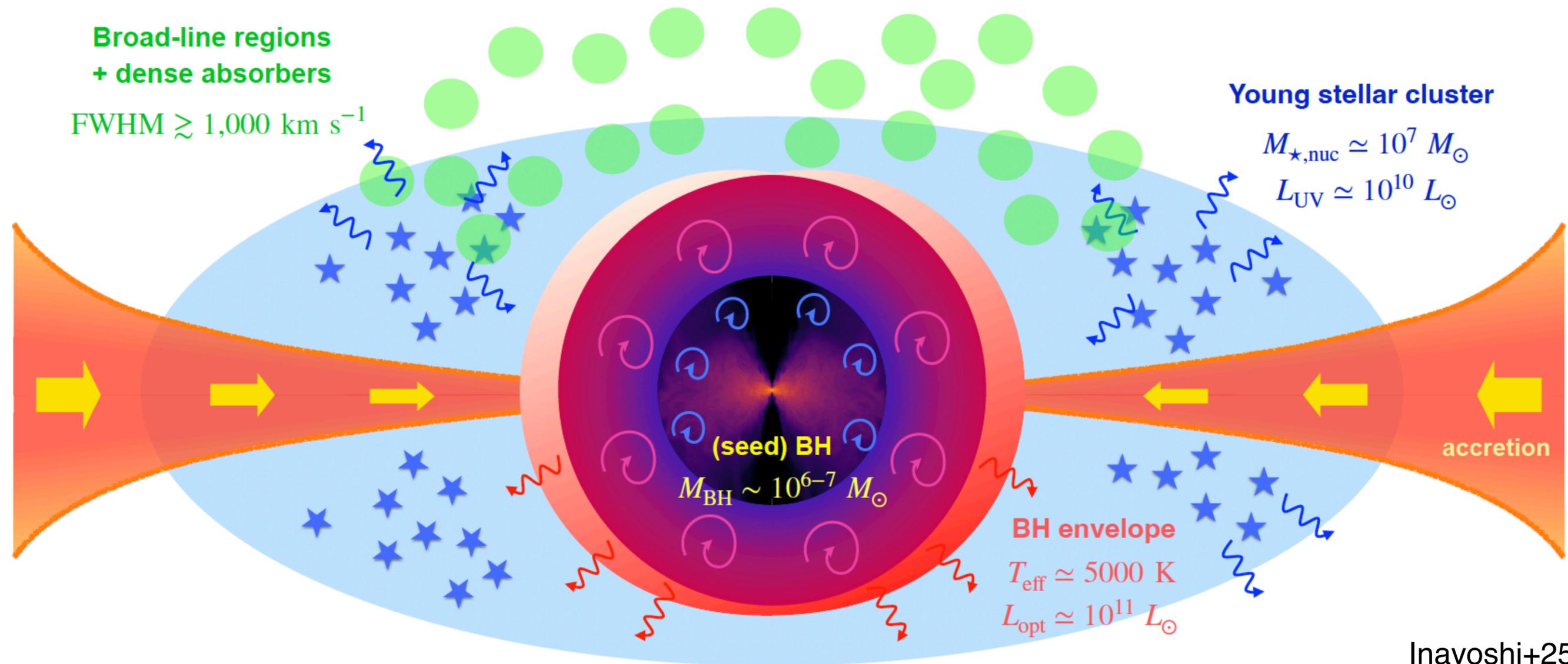


Fantastic Balmer features and how to explain them

- Balmer absorption + BB \rightarrow dense circumnuclear gas ($n \approx 10^{11} \text{ cm}^{-3}$)

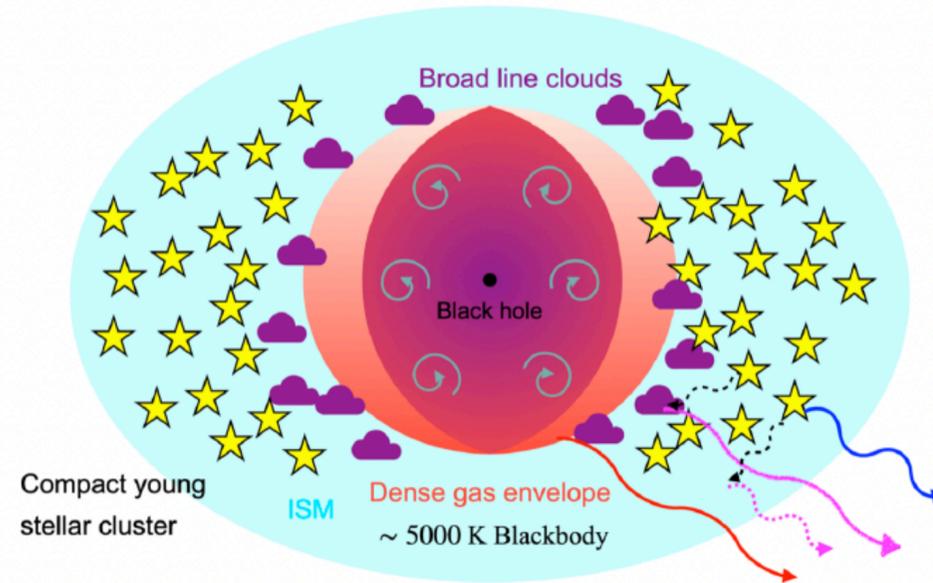


Fantastic Balmer features and how to explain them

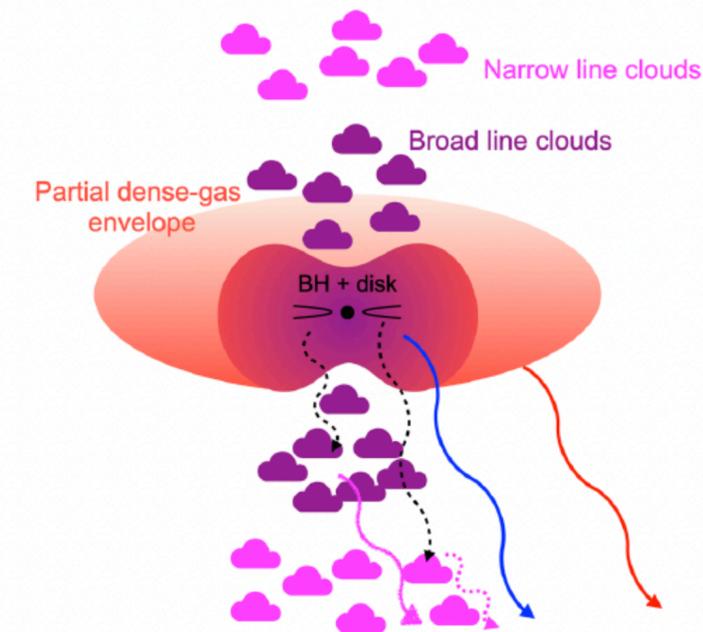


Fantastic Balmer features and how to explain them

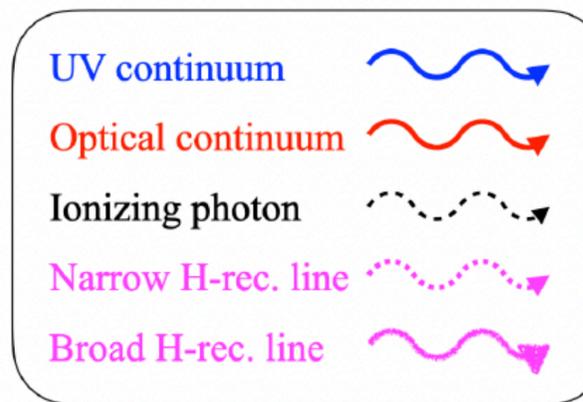
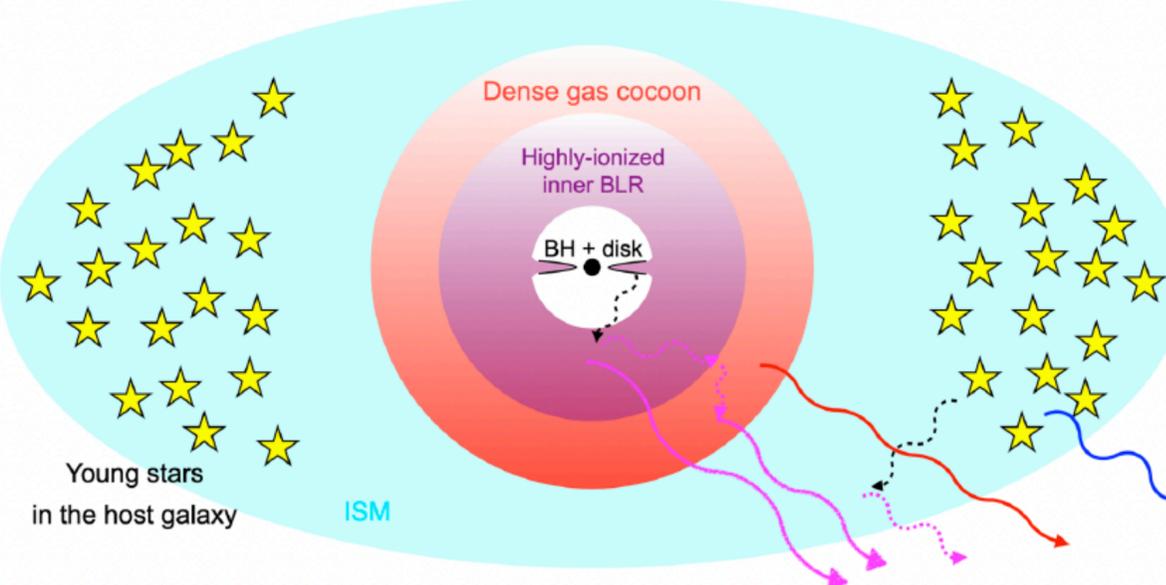
(a) Blackbody envelope model



(c) Non-spherical envelope model



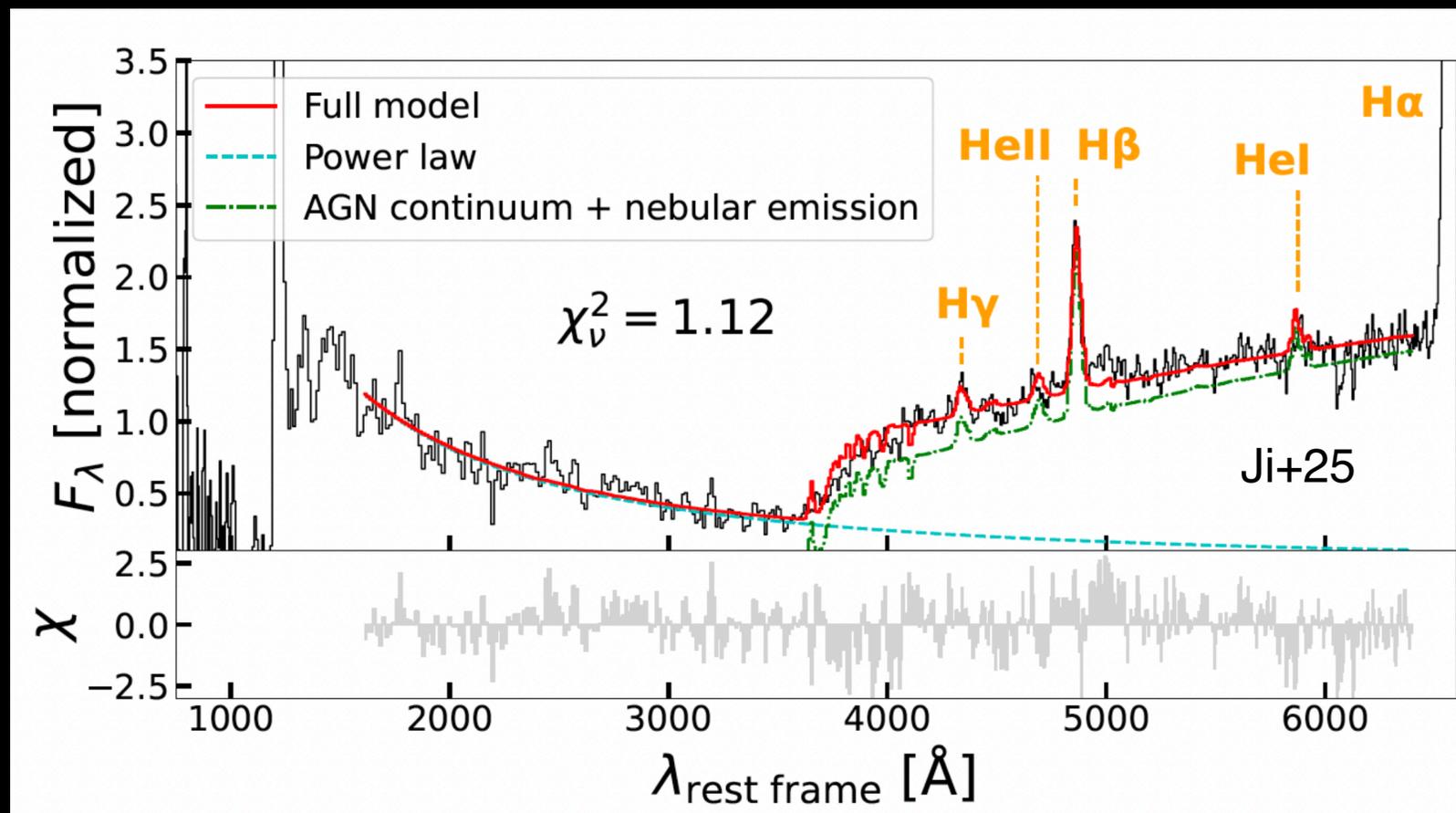
(b) Cocoon envelope model



Asada+26 (see also Sneppen+26)

Fantastic Balmer features and how to explain them

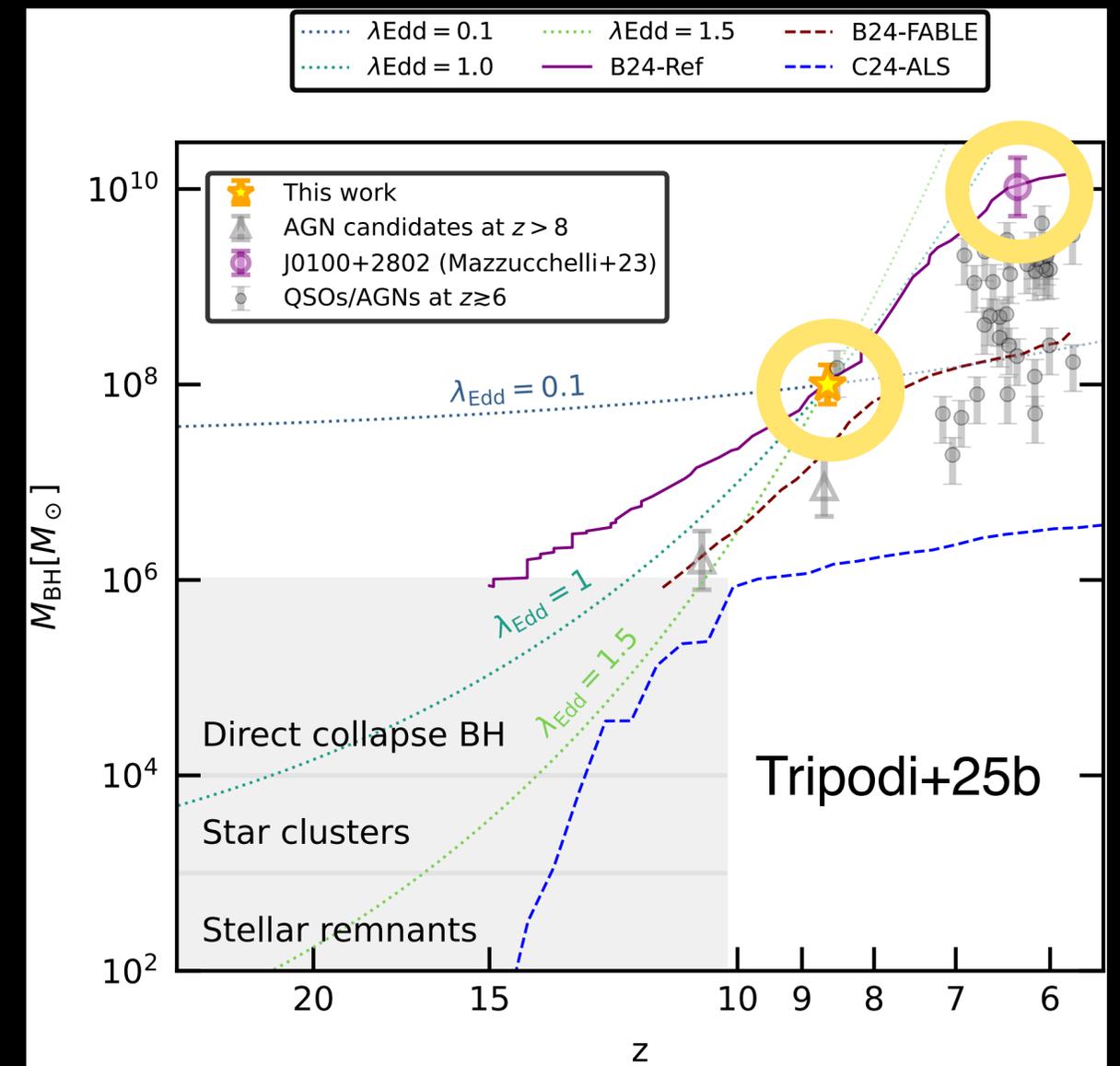
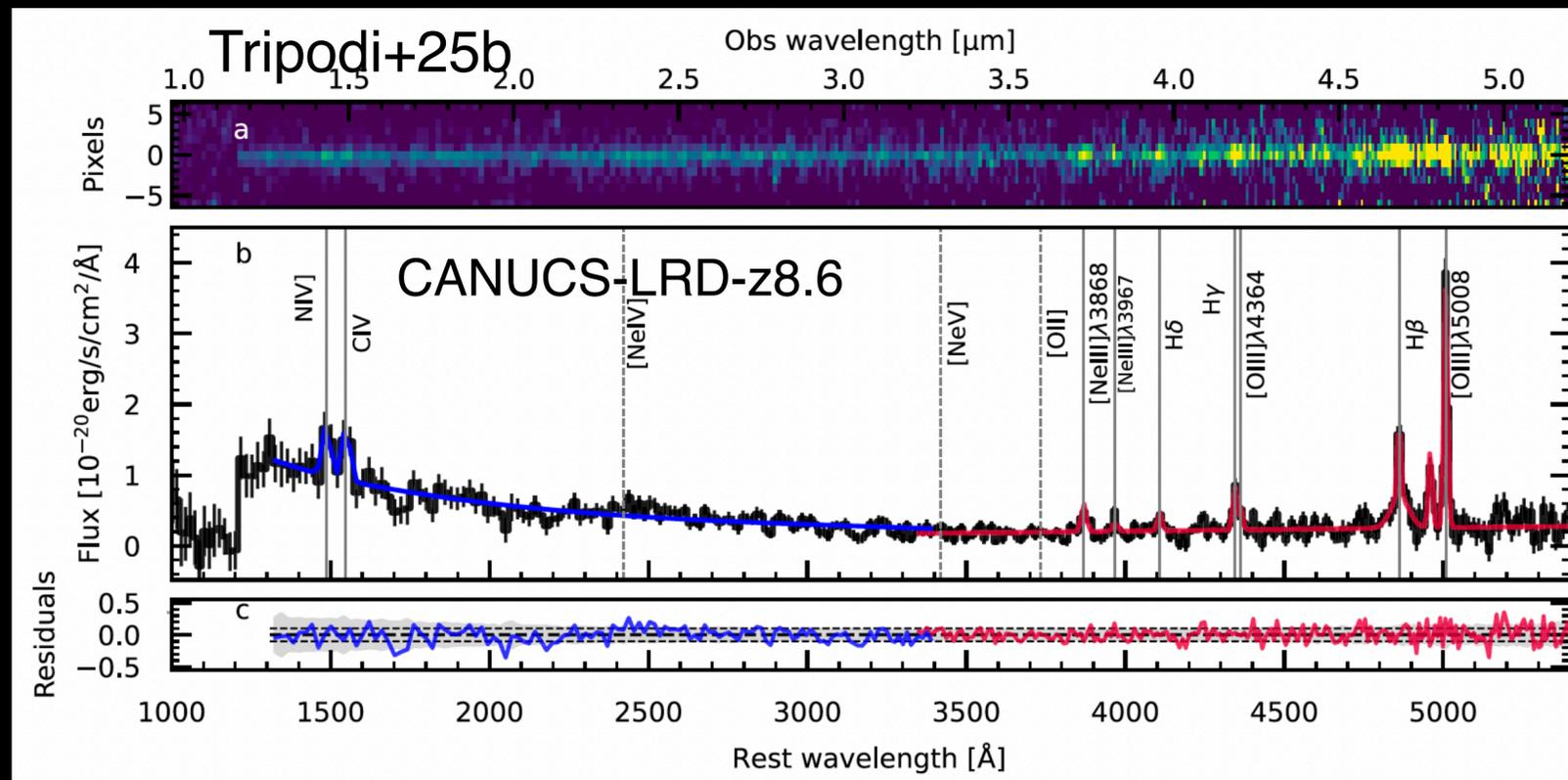
- Balmer absorption → dense circumnuclear gas ($n \approx 10^9 - 10^{11} \text{ cm}^{-3}$)
- Features explained by the model of Inayoshi & Maiolino (BH* model)



AGN accretion disk
embedded in neutral
dense gas clumps

CANUCS-LRD-z8.6

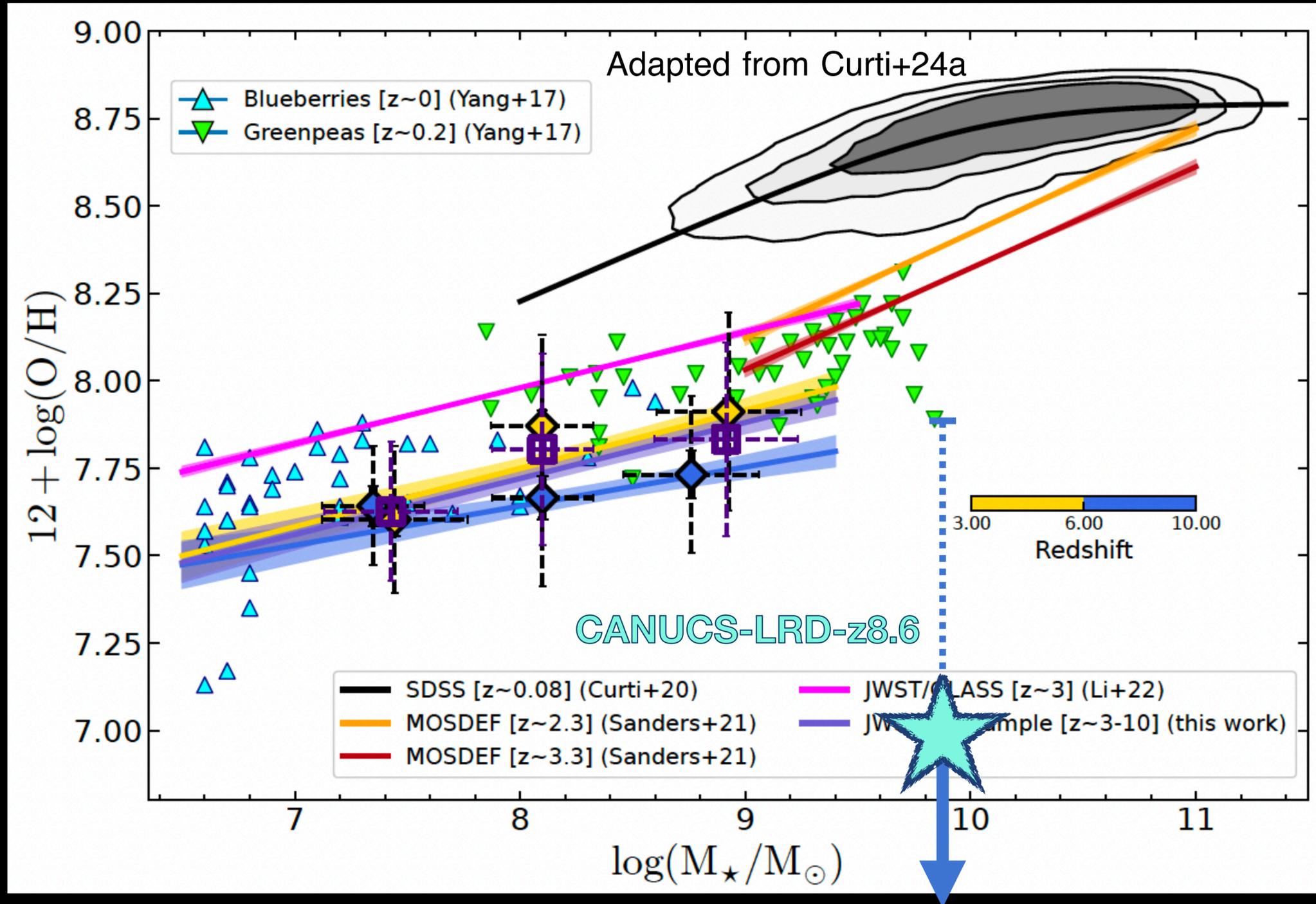
- Broad H β (FWHM $\sim 4 \times 10^3$ km/s)
- High-ionization UV lines: C IV, N IV]



- Origin from massive seeds (at Eddington) or stellar-remnants (at super Eddington)
- B24 reproduces both CANUCS-LRD-z8.6 and J0100+2802 (Bennett+24)

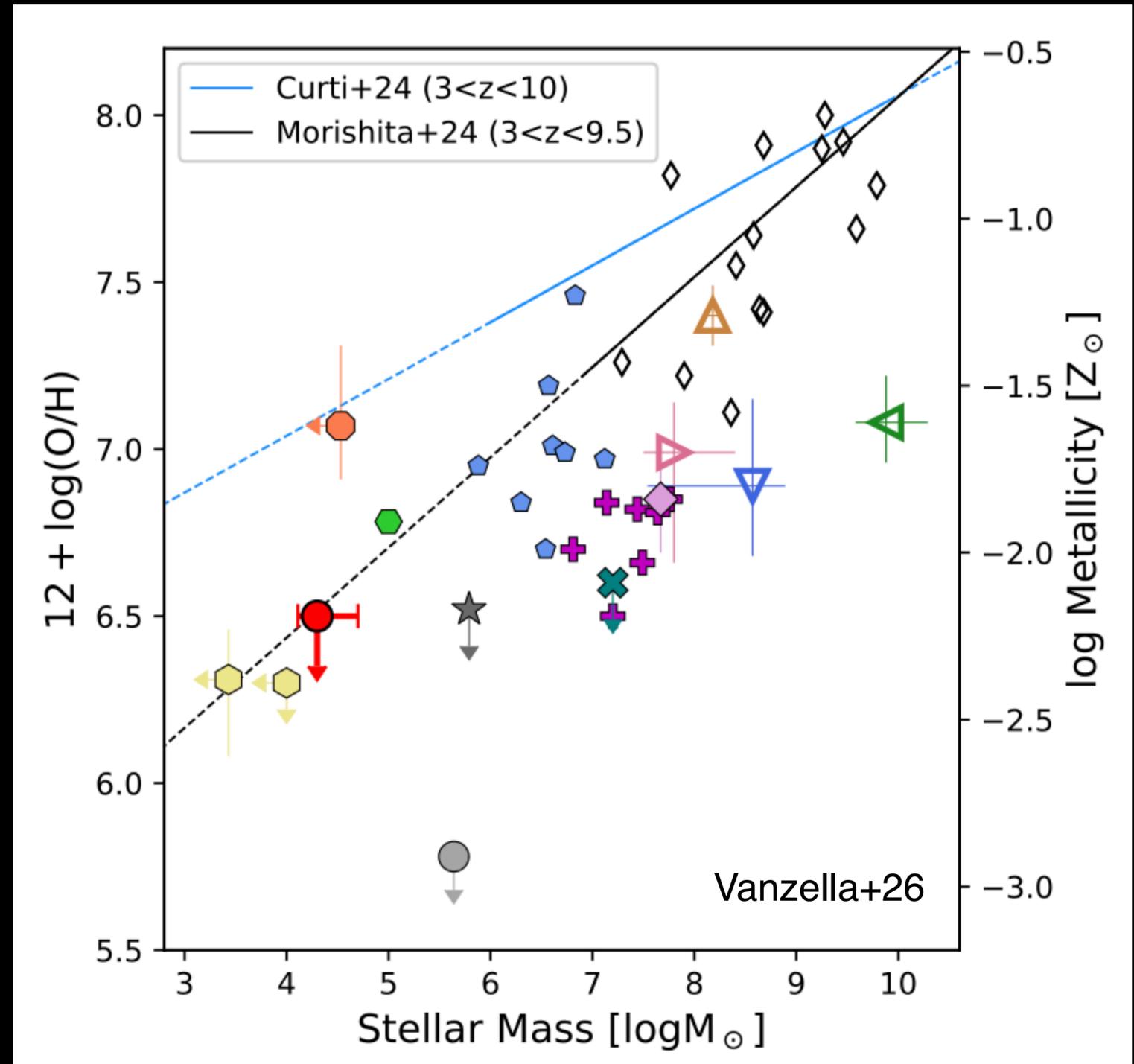
Metallicity and gas conditions

- $Z < 0.1 Z_{\odot}$, $T_e > 20,000$ K (e.g., Greene+24; Ji+25; Tripodi+25)
- Low C/N abundance



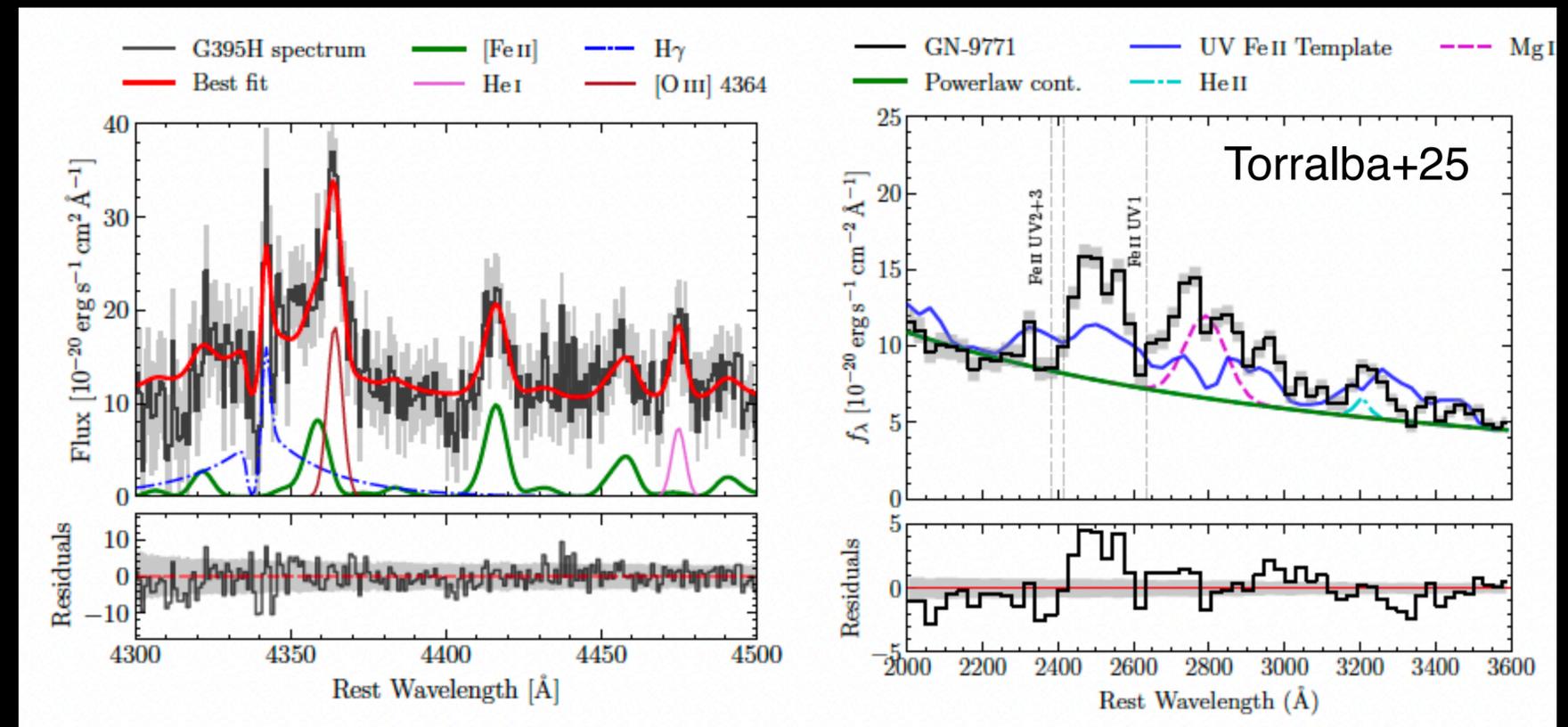
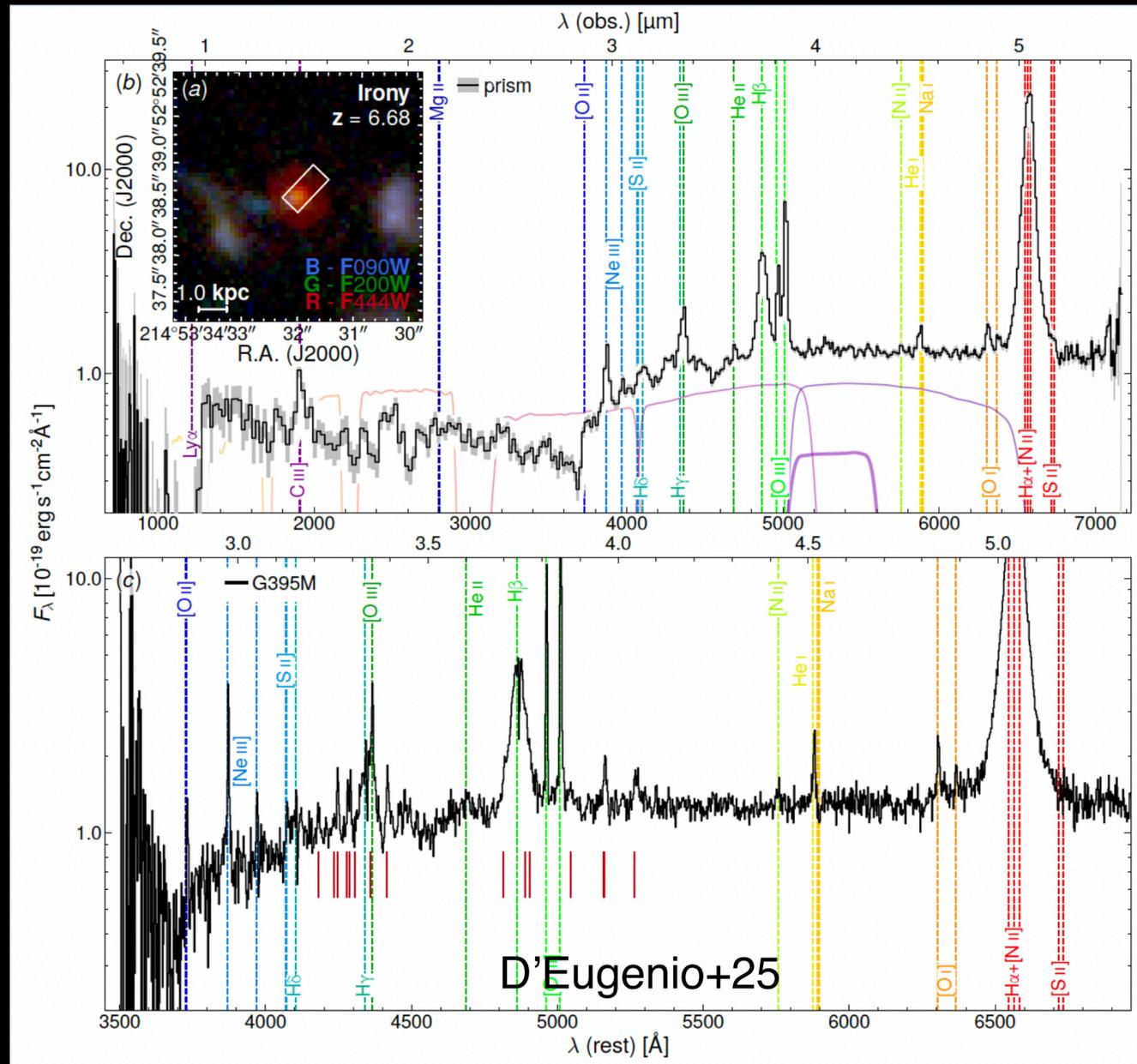
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Fe forests

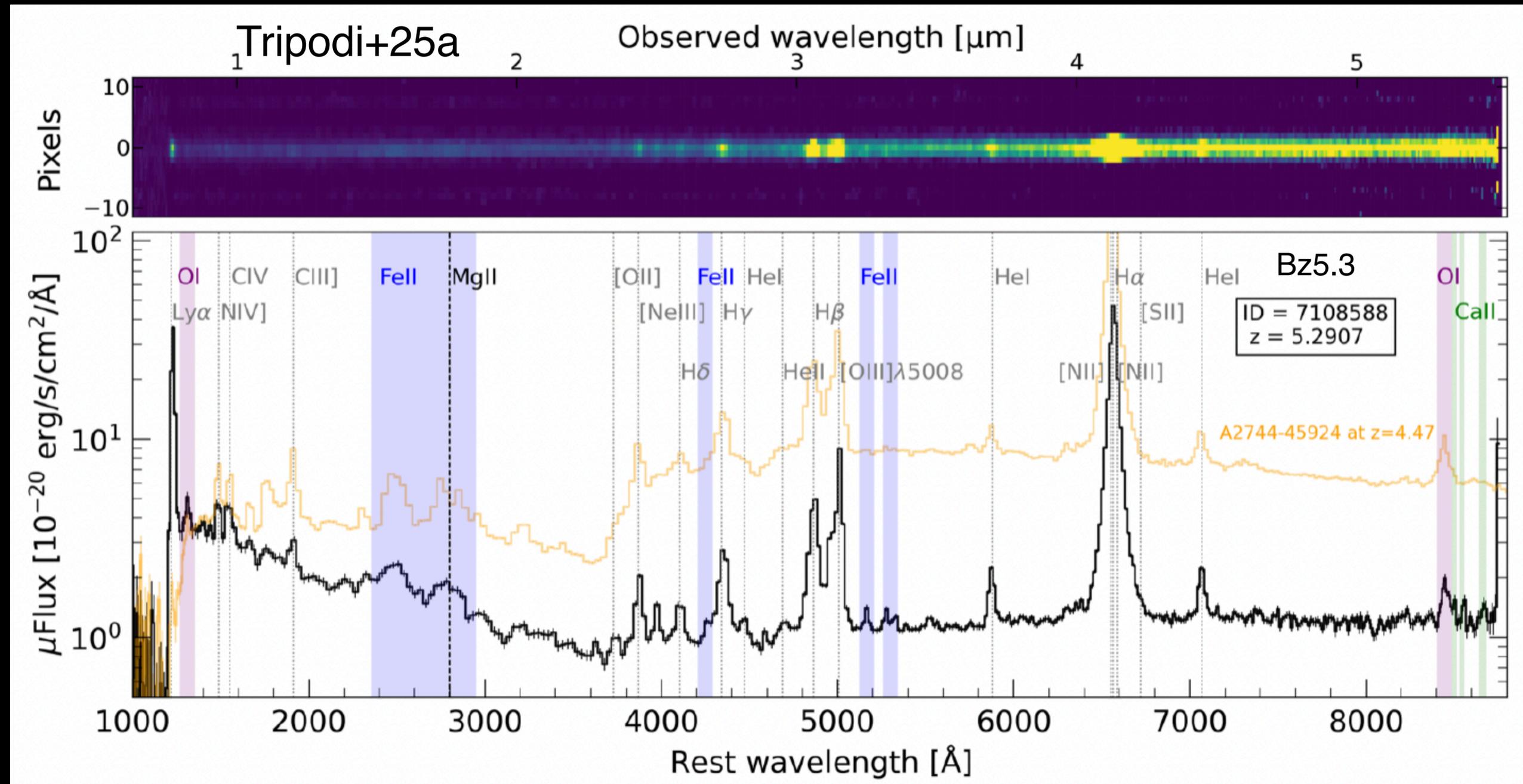
- Multiple FeII transitions detected in optical and UV



(See also Labbè+24, Kovacevic-Dojnovic+25, Lin+25, Kokorev+25, de graaff+25)

The case of Bz5.3

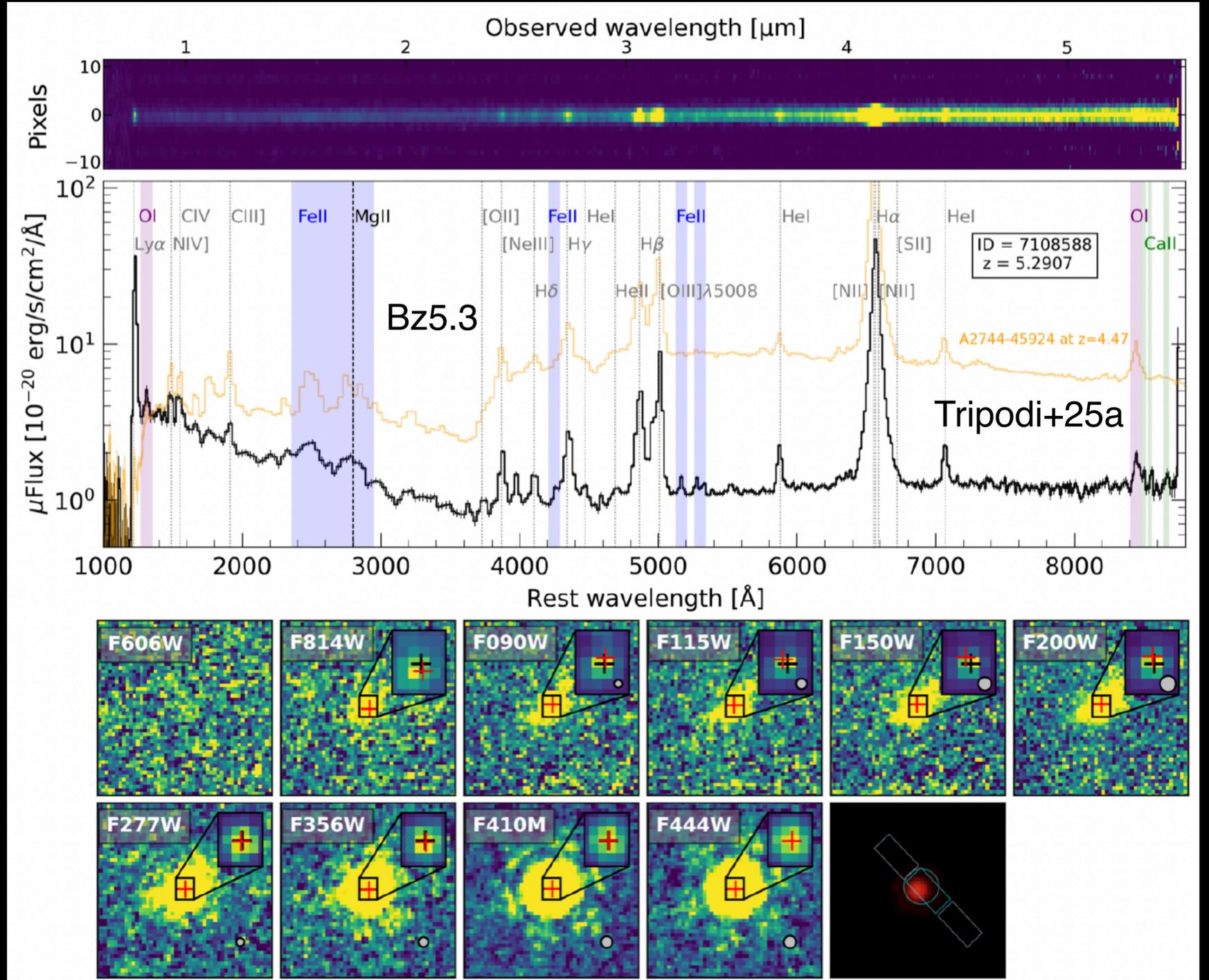
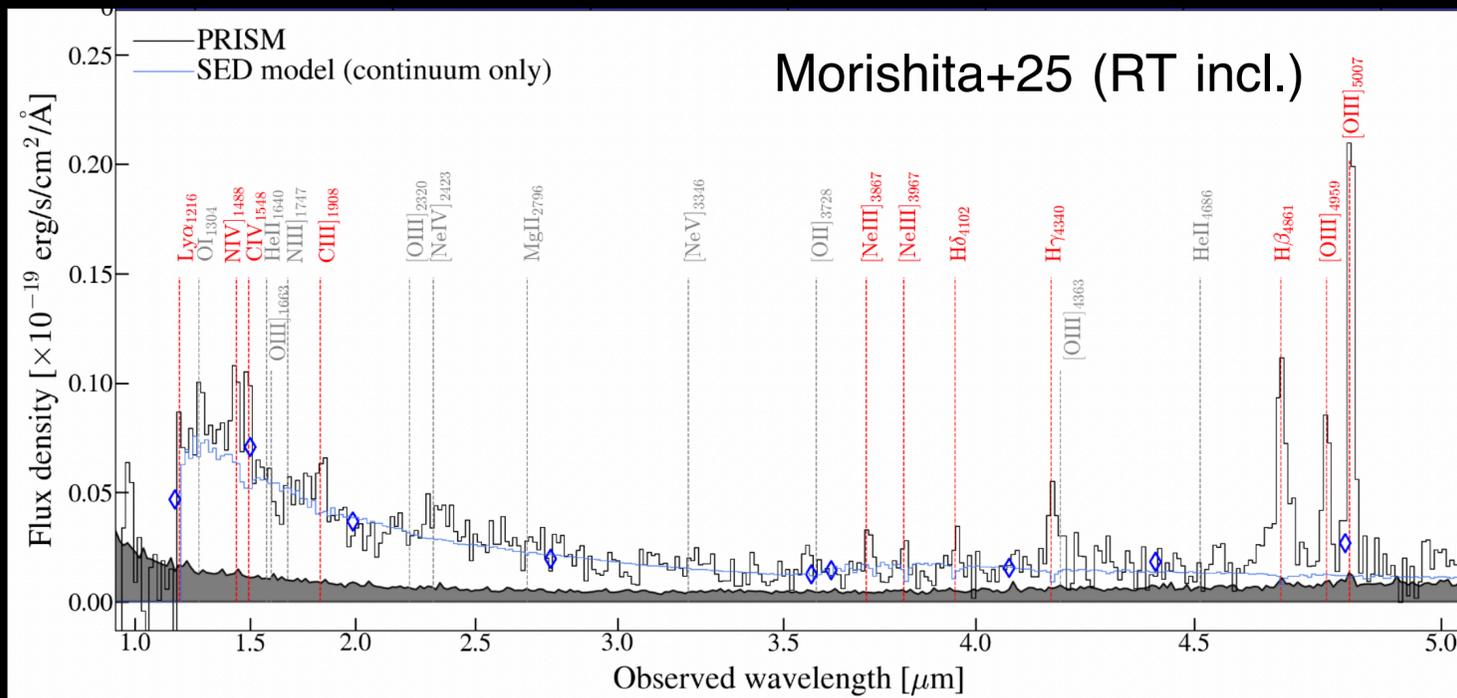
- LRD at $z \sim 5$
- Magnified by a factor of ~ 4 in the Bullet Cluster



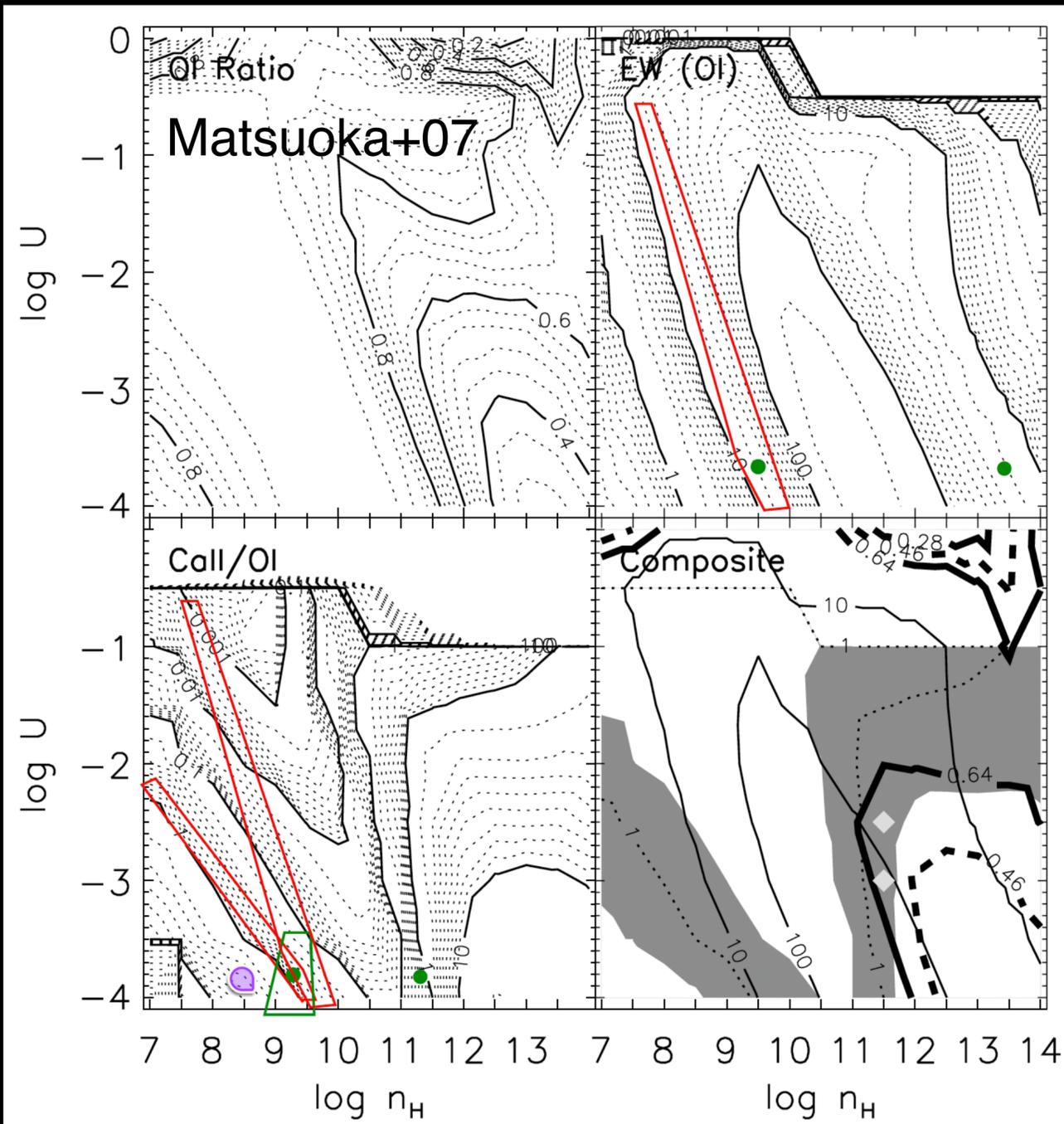
Fe forests + BLR diagnostics

OI λ 1304 at $z = 5.3$

- Multiple FeII transitions detected in optical and UV
- Call, OI in optical and UV



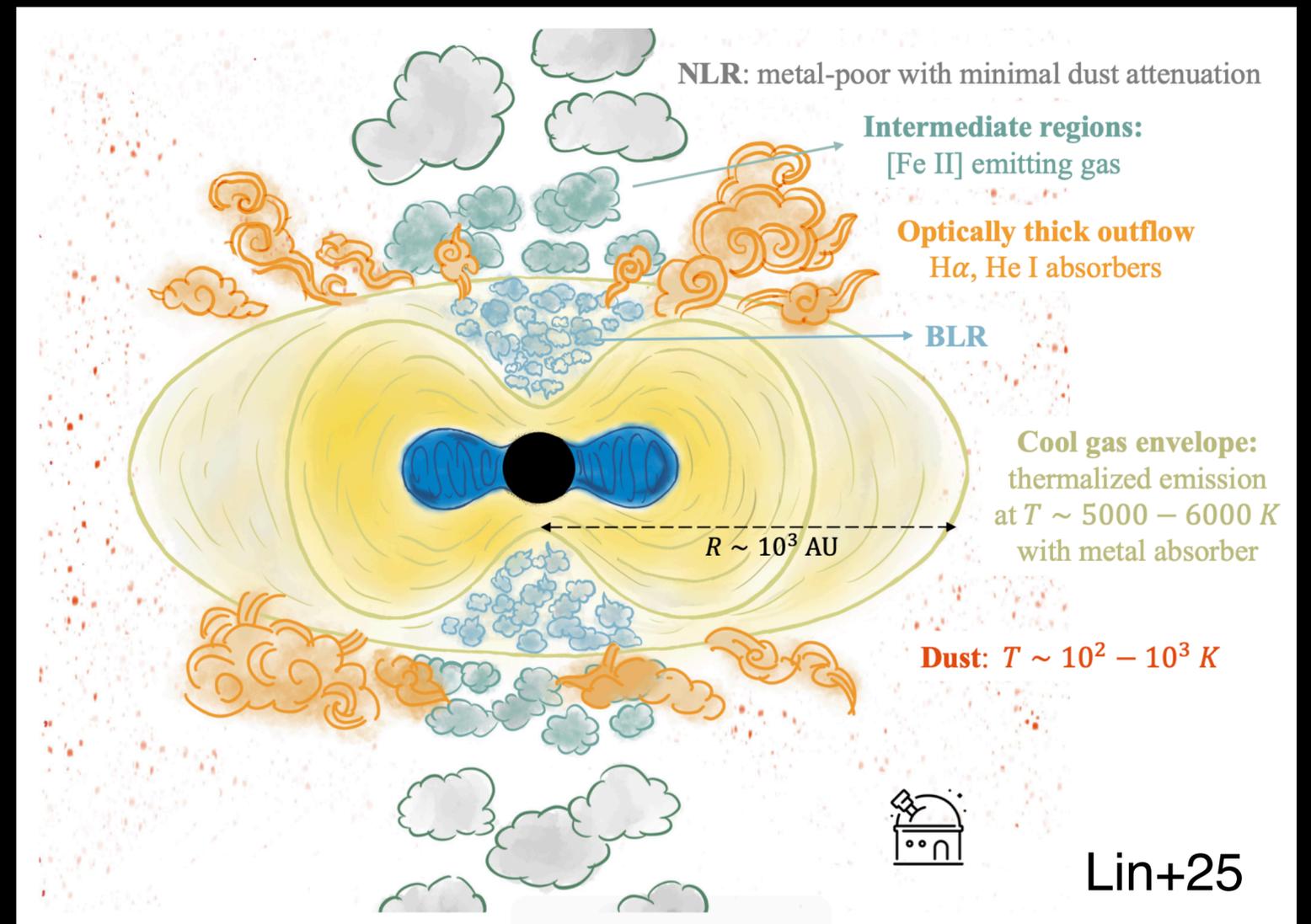
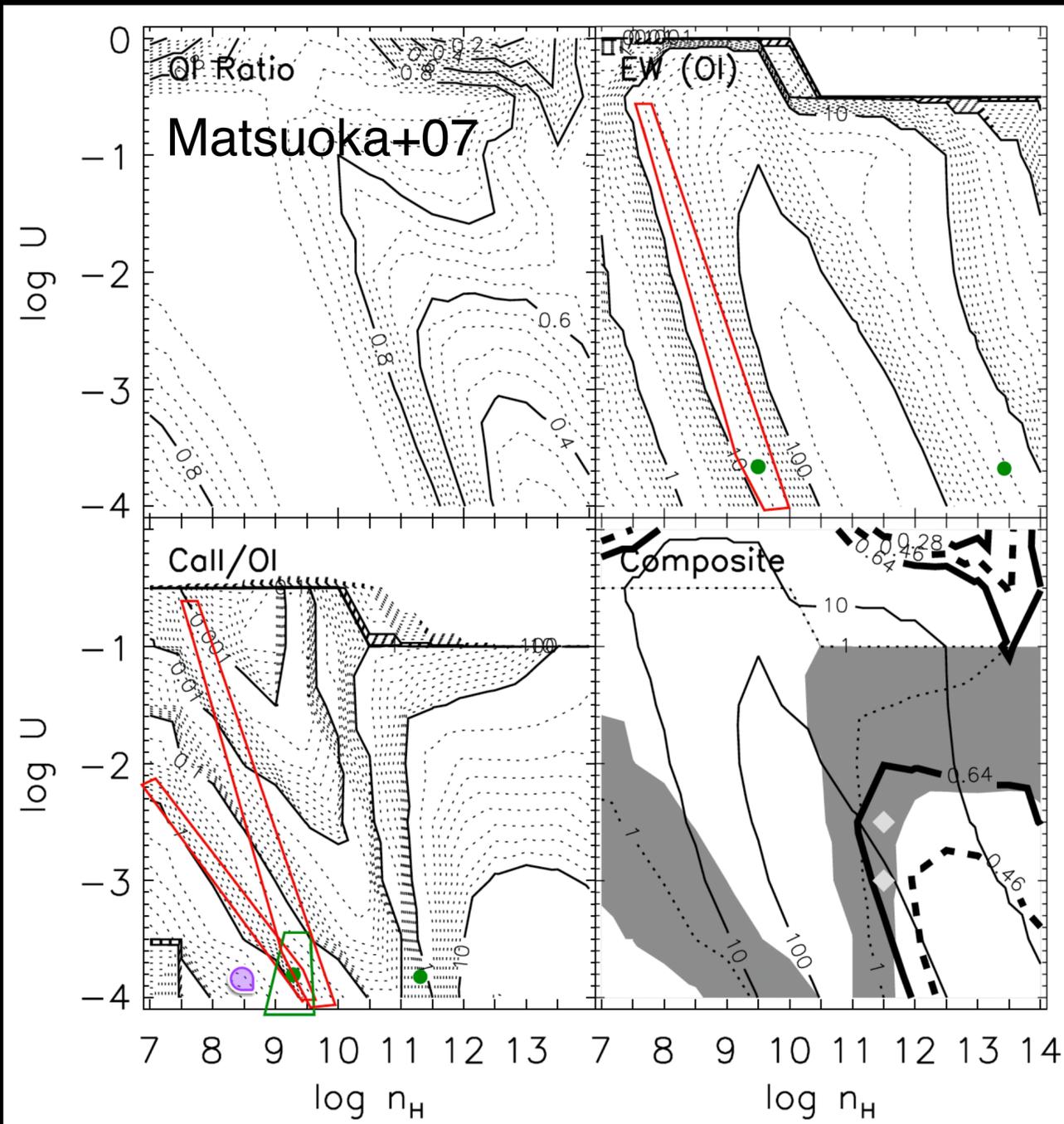
Deeper into the BLR: the case of Bz5.3



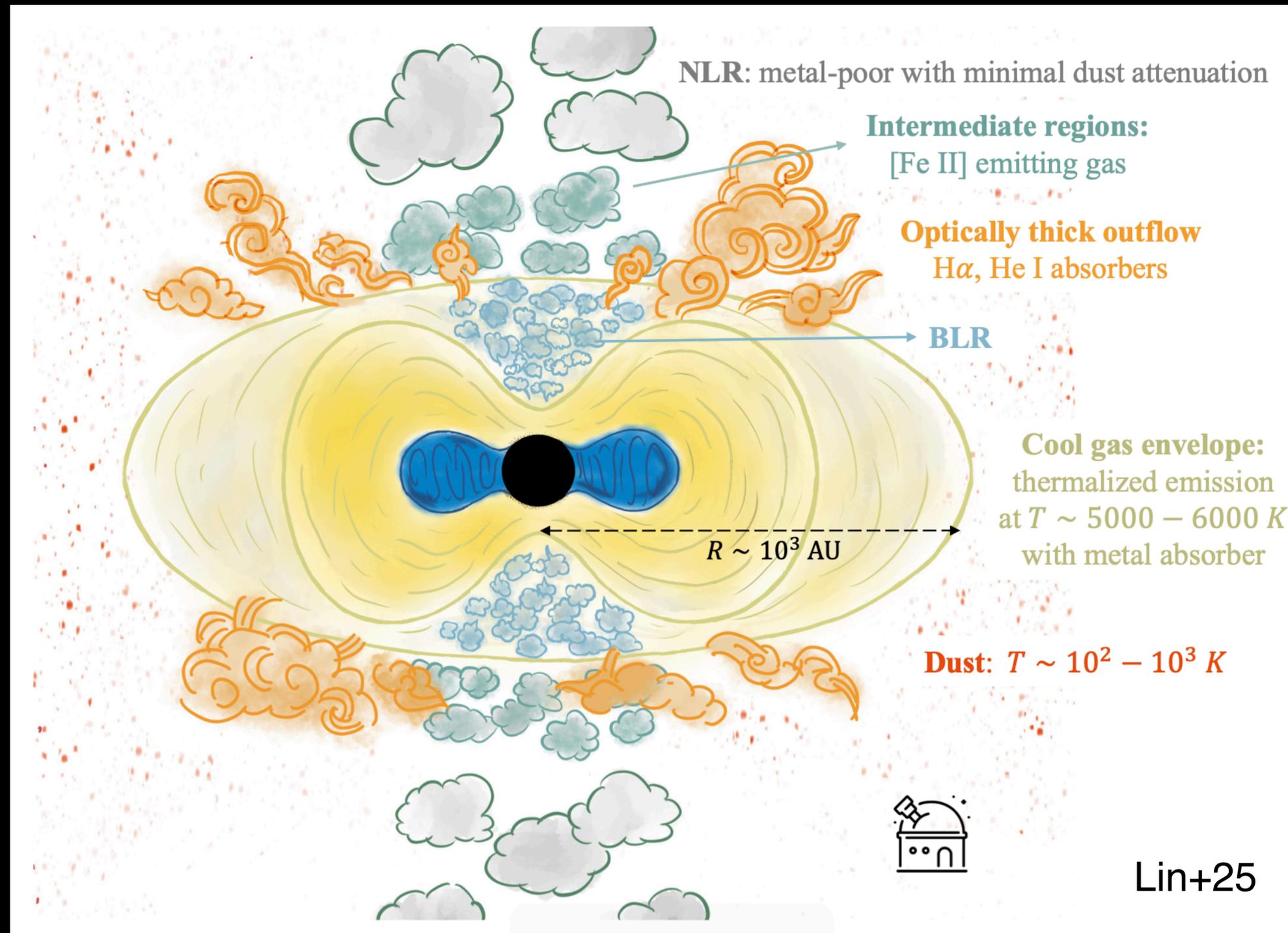
- Excitation mechanisms: fluorescence+collisional excitation

Deeper into the BLR: the case of Bz5.3

- Excitation mechanisms: fluorescence+collisional excitation
- BLR stratification: different conditions for OI, FeII, and Balmer lines



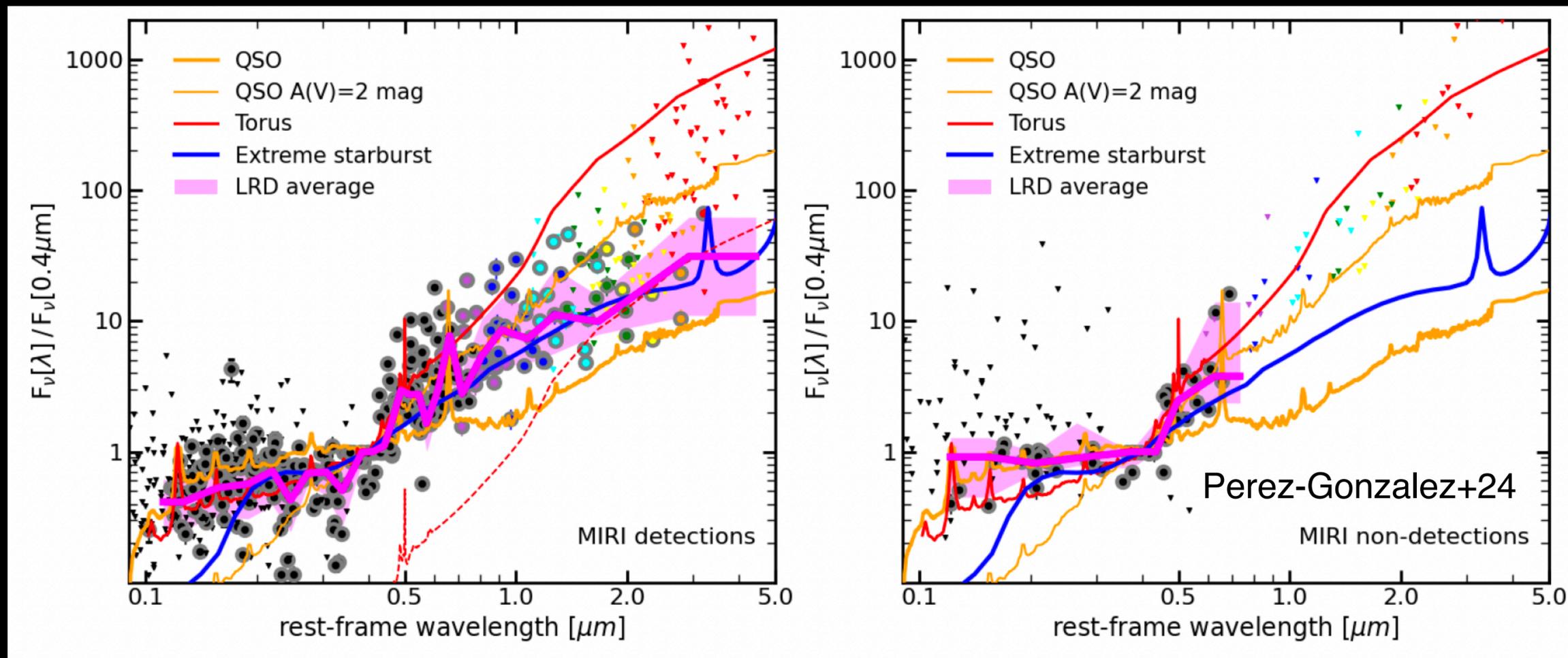
Deeper into the BLR: the case of Bz5.3



Is it all about AGN ?

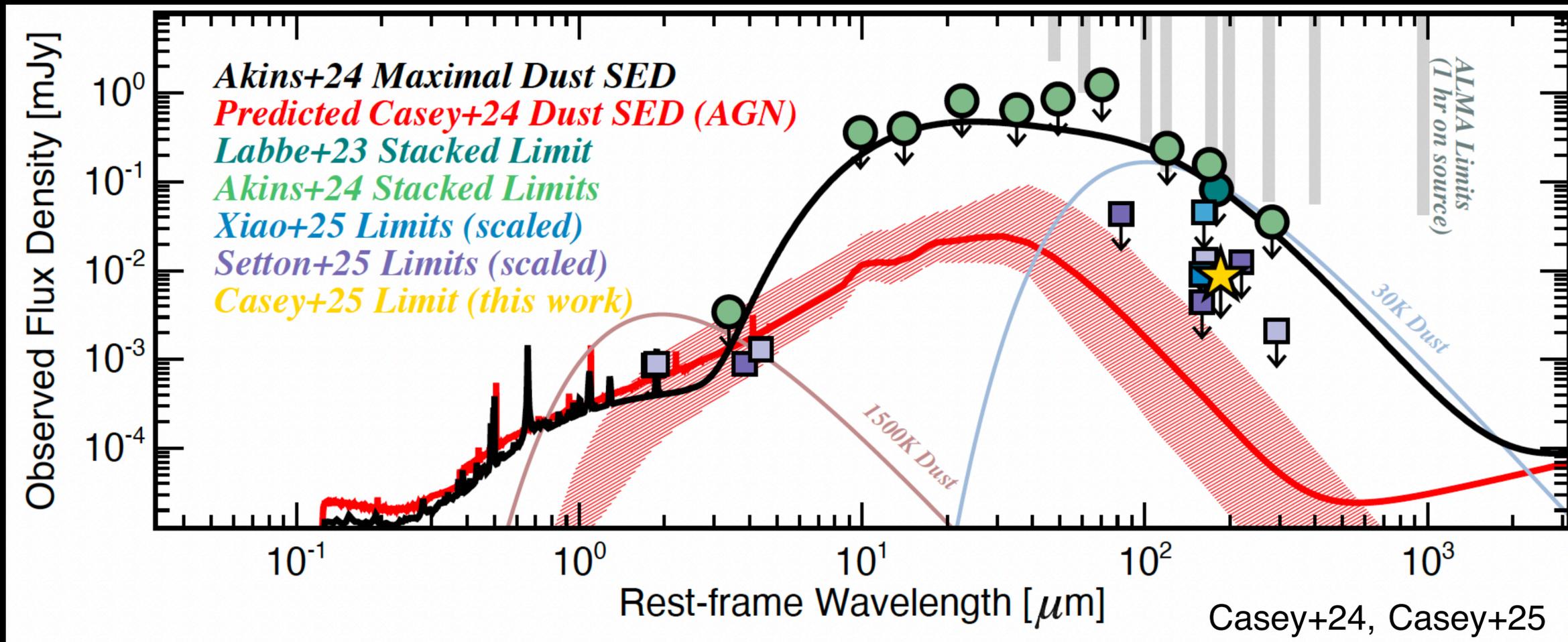
MIRI constraints

- MIRI regime is not dominated by AGN
A combination of stars, AGN and dust?



FIR constraints

Where is the dust?



$$M_{\text{dust}} < 10^{6-7} M_{\odot}$$

Issues with SED fitting

Composite (blue+red)

Red optical

QSO

Galaxy

+

Blue UV

QSO

Galaxy

QSO + QSO

a) red QSO + scattered light

QSO + Galaxy

b) red QSO + blue host

Galaxy + QSO

c) dusty galaxy + blue QSO

Galaxy + Galaxy

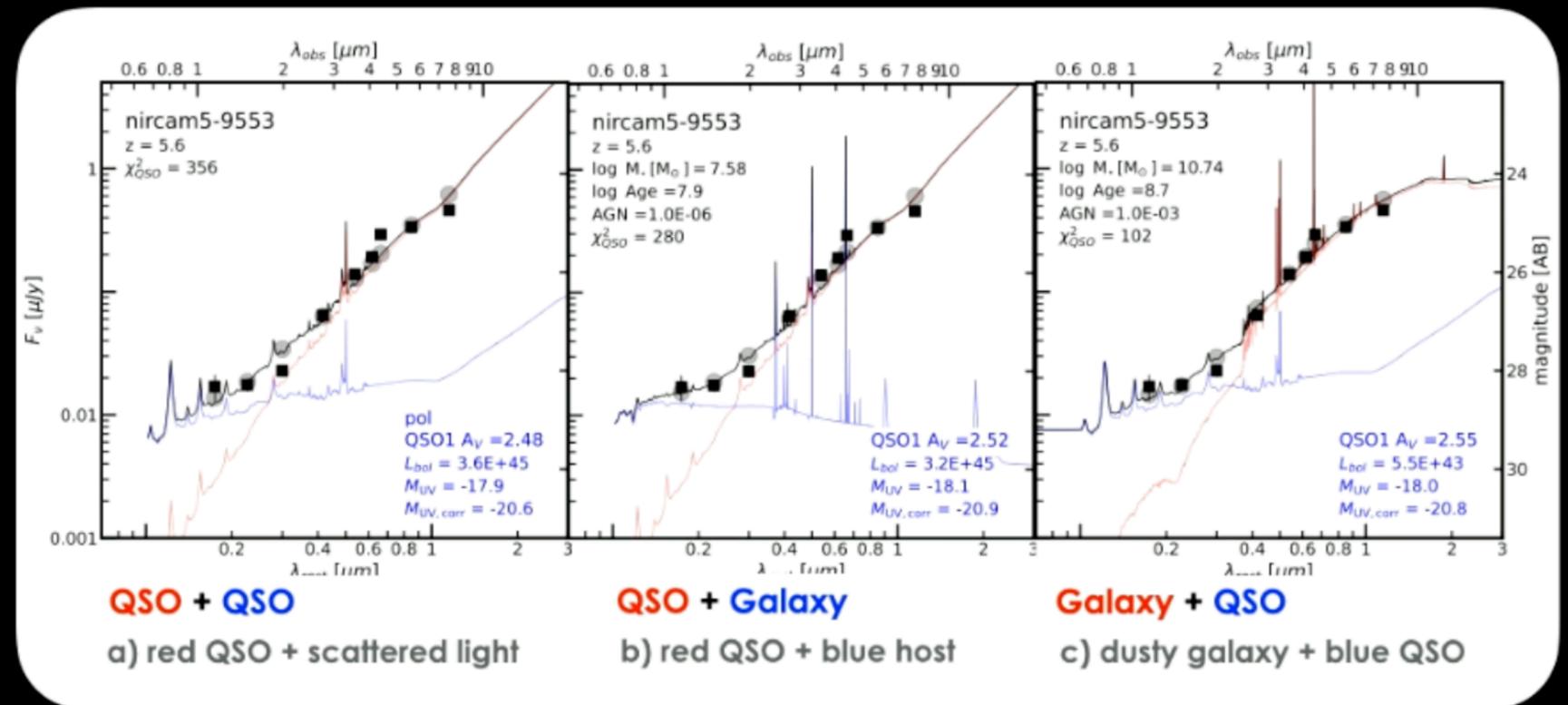
d) multi-component galaxy

✦ High degeneracy, equally good fits.

No host

Low-mass host

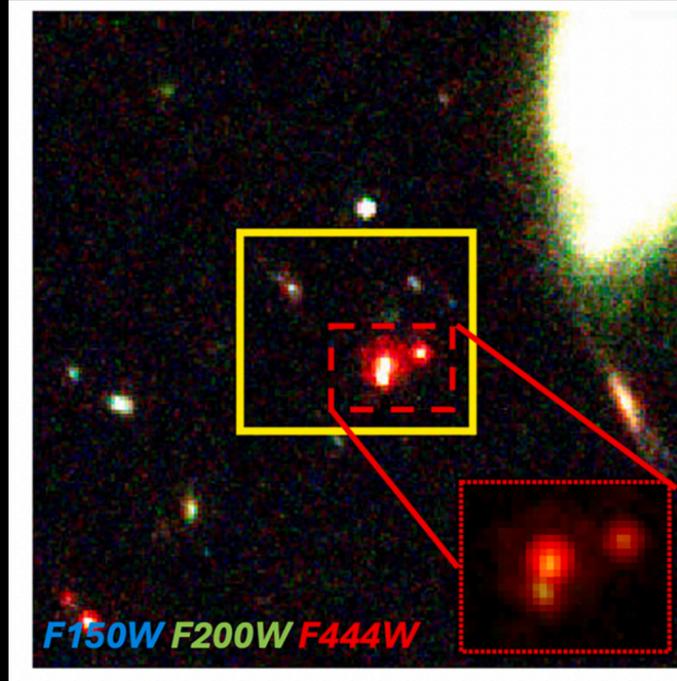
Massive host



Environment and clustering

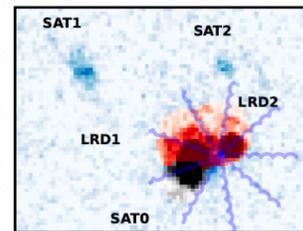
LRDs are also found in pairs

What is the role of environment in LRD evolution?

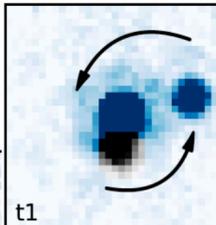


Merida+25 (RT incl.)

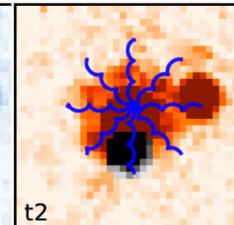
a) Direct environmental quenching



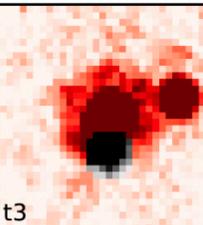
SF triggered by the interaction



LRD1 quenches due to internal processes and quenches LRD2

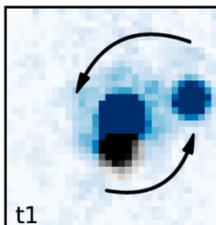


LRD1 and LRD2 are currently quenched

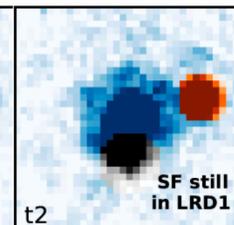


b) Environmentally triggered internal quenching

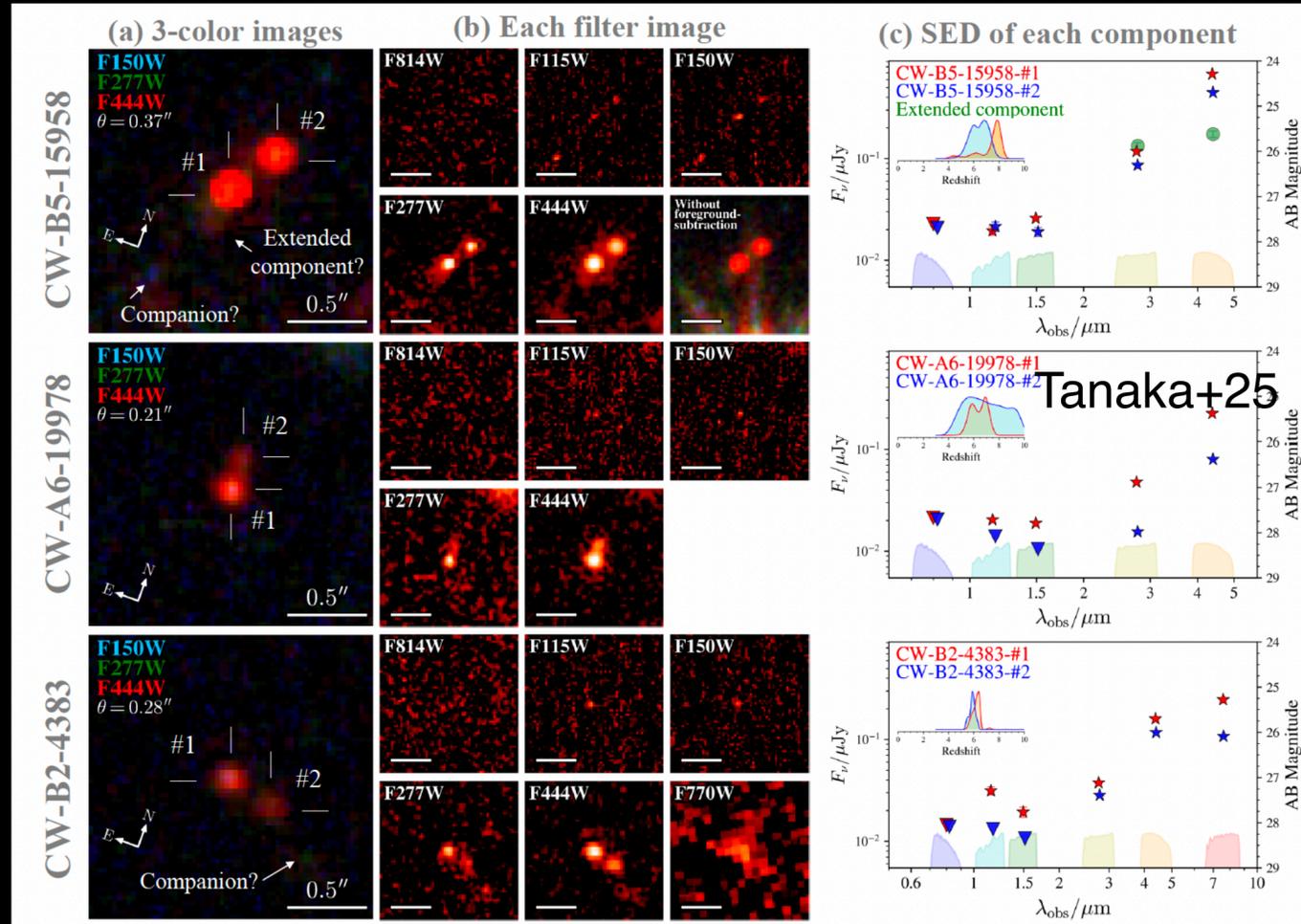
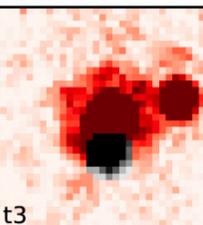
SF triggered by the interaction



LRD2 quenches via internal processes

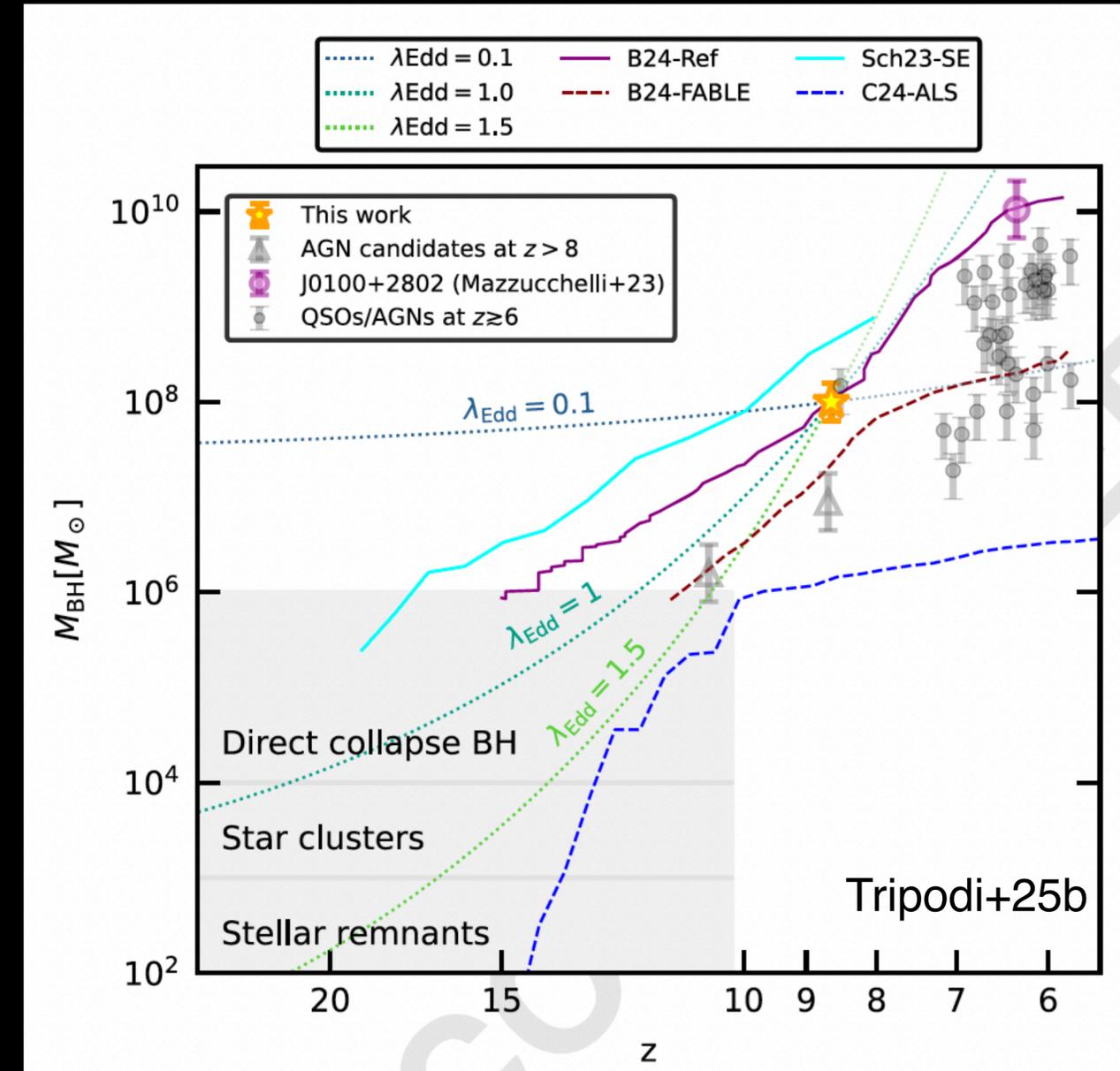
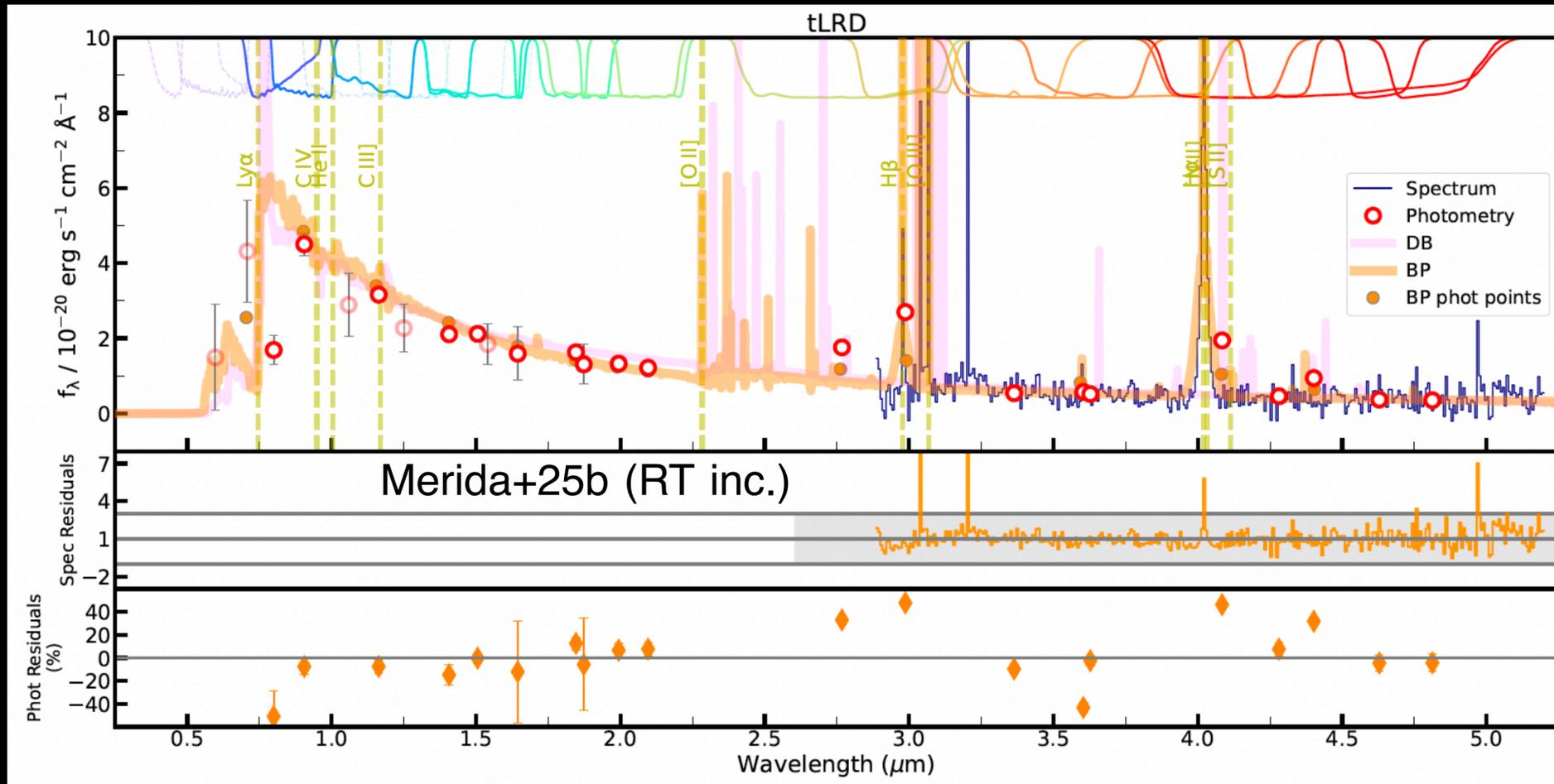


LRD1 and LRD2 are currently quenched



Evolutionary context

- tLRDs → LRDs → post-LRDs → quasars ?



Summary

Observational evidences

Whole population

- Compactness + 'V-shaped' spec
- No (low) dust content
- no X-ray
- no variability
- Low metallicity

Part of the population

- Most of LRDs show AGN signatures
- Broad Balmer lines, high-ionization lines, Fe forests, BLR tracers
- Strong BB + Balmer absorption
- Extended in the bluer filters
- Ly α emission

Open questions

- What is the origin of UV emission?
- What is the origin of NIR emission?
- Does the BH* model work for all LRDs?
- Duration of LRD phase?
- Trigger for transition to quasar?
- Contribution to total BH growth?