中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

AGN luminosity in the simulated Universe

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Motivation

- Previous models: relies on statistically determined relations.
- Our model: calculate AGN SED base on BH mass and accretion rate.

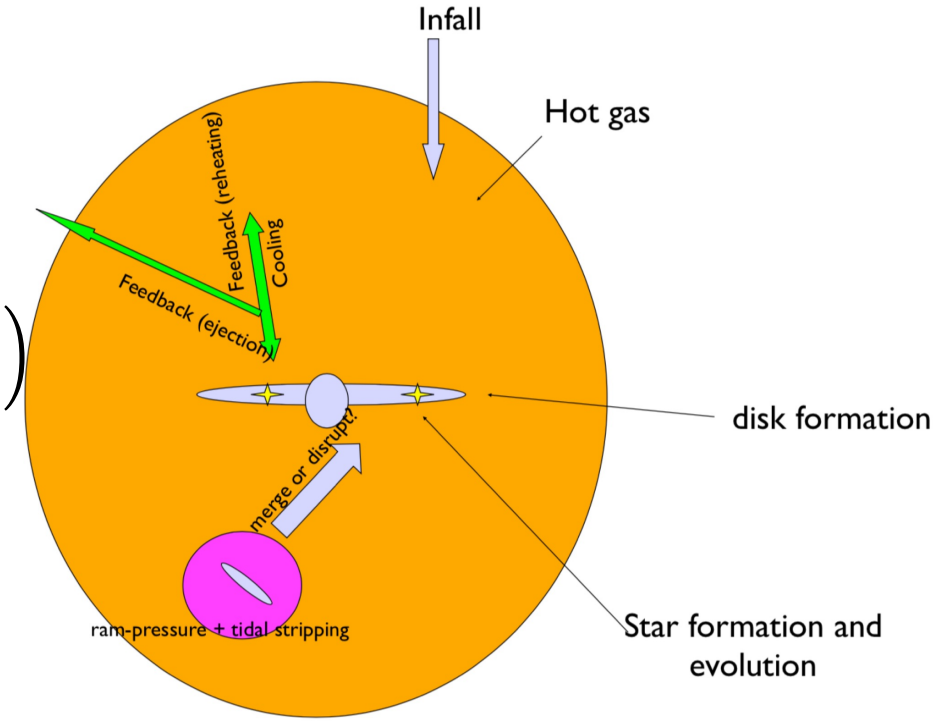
Outline

- SAM
- Disk geometry and model description
    - the ADAF
    - the disk-corona model
- results
- summary

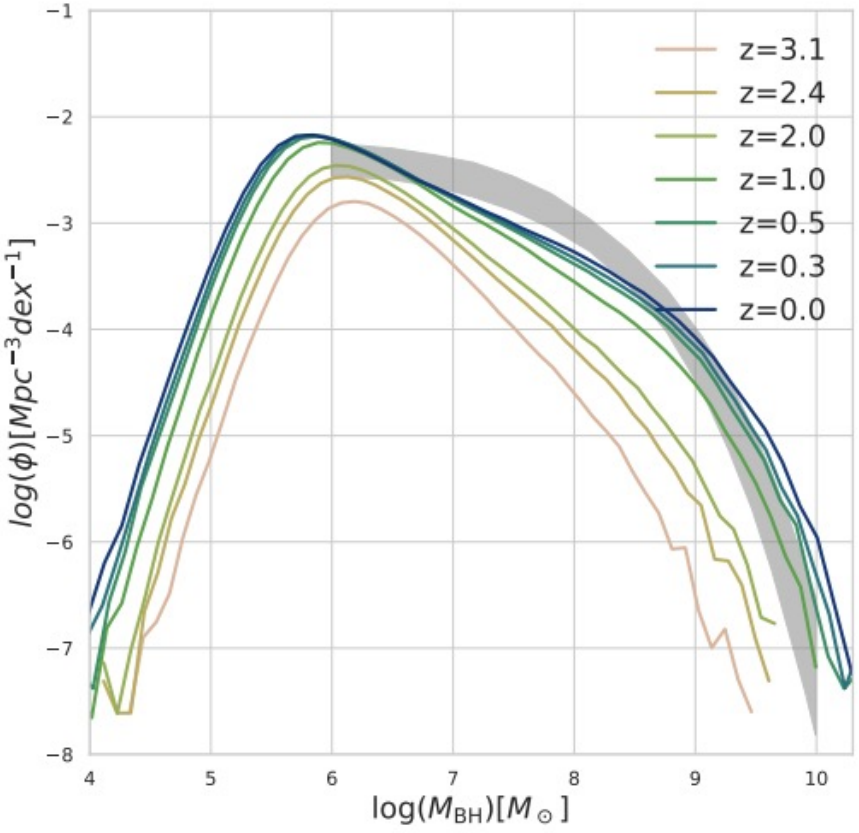
BHs in L-galaxies

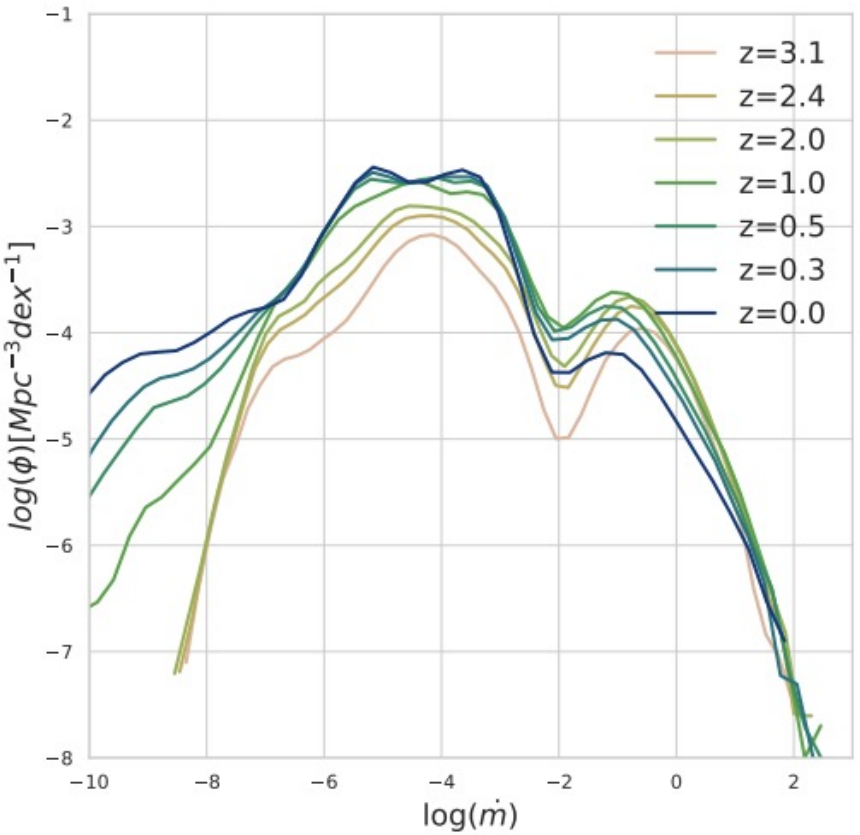
- Growth
  - merger: $\Delta M_{BH,Q} = \frac{f_{BH}(M_{sat}/M_{cen})M_{cold}}{1+(V_{BH}/V_{200c})^2}$
  - accretion: $\dot{M}_{BH} = k_{AGN}\left(\frac{M_{hot}}{10^{11}M_{\odot}}\right)\left(\frac{M_{BH}}{10^{8}M_{\odot}}\right)$

- Feedback
  - thermal: $\dot{E}_{radio} = 0.1\, M_{BH}c^2$
  - kinematic

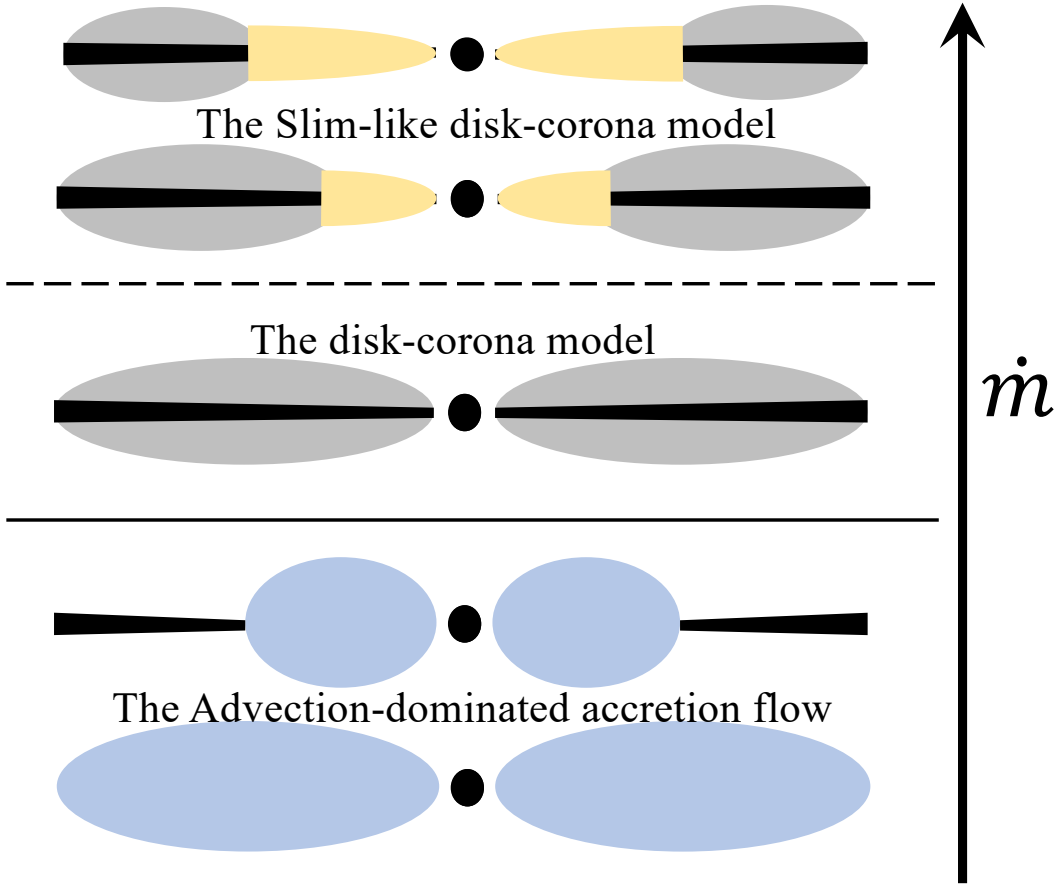


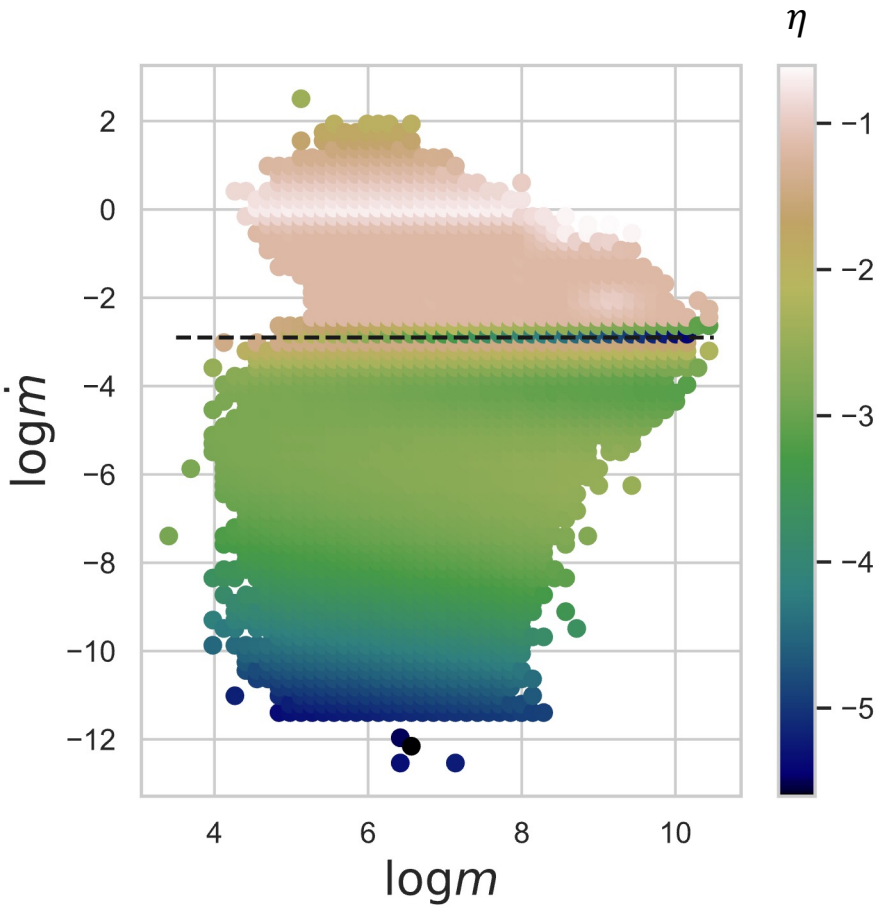
BHMF, accretion rate number density distribution



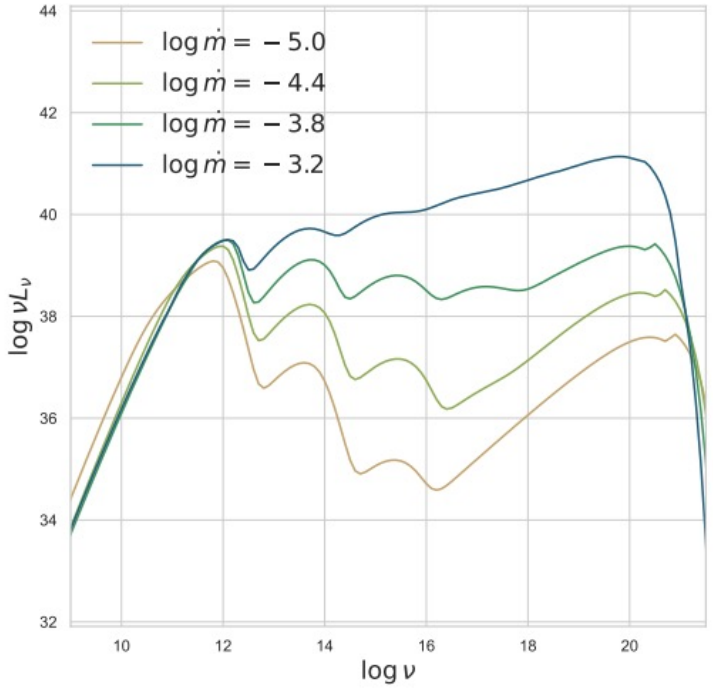


Disk geometry and radiative efficiency





The ADAF

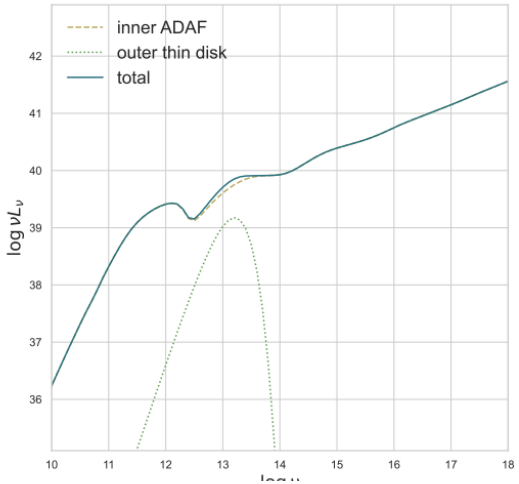


α	β	δ	s
0.05	0.95	0.2	0
Viscosity parameter	P_{gas}/P_{total}	Direct heating of electron	outflow

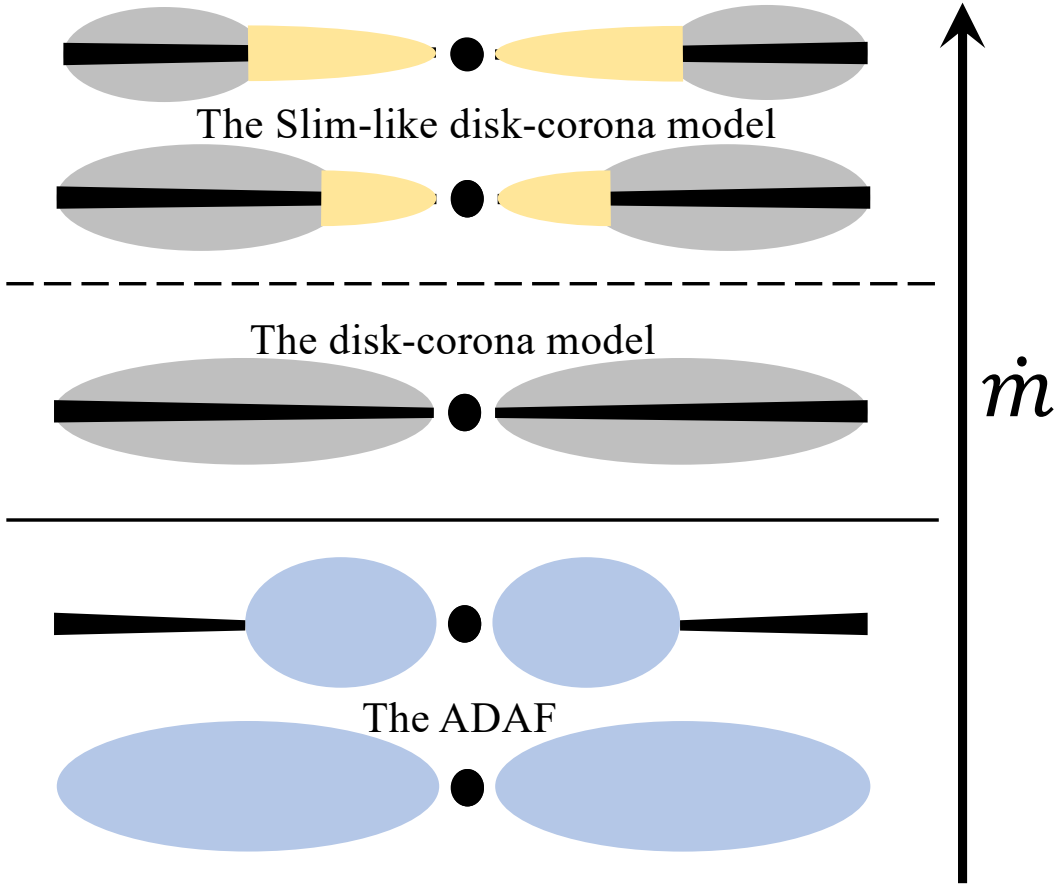
- Low radiative efficiency
- Corresponds to the low/hard state of AGN
- The disk is composed of inner ADAF, outer thin disk structure.

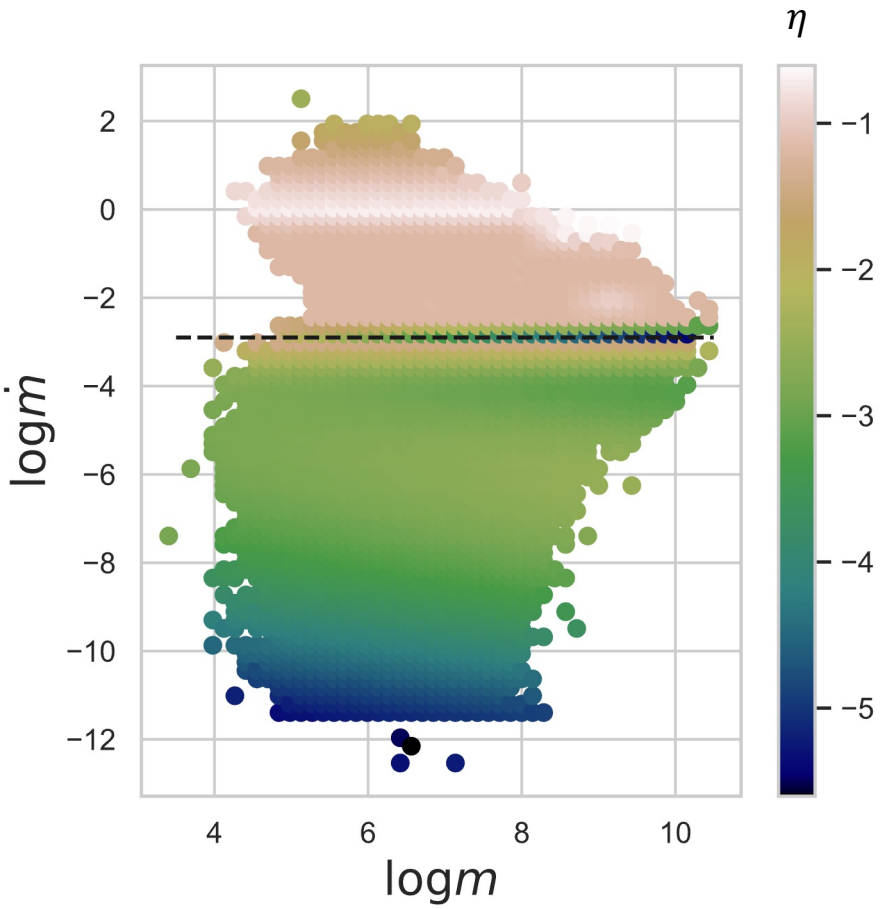
Truncation radius: (Taam et al.2012)

$$R_{tr} = 17.3\,\dot{m}^{-0.886}\alpha^{0.07}\,\beta^{4.61}R_s$$



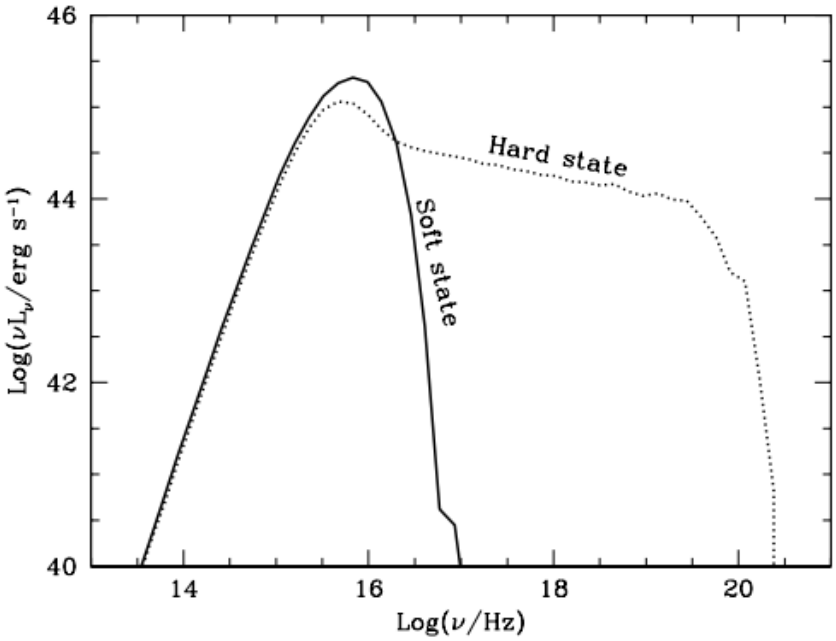
Disk geometry and radiative efficiency





The magnetic reconnection-heated disk-corona model

(B.F.Liu 2002)



- Same radiative efficiency as the SSD

$$\frac{B^2}{4\pi} V_A \approx \frac{4kT}{m_e c^2} \tau^* c U_{rad}$$

Reconnection heating

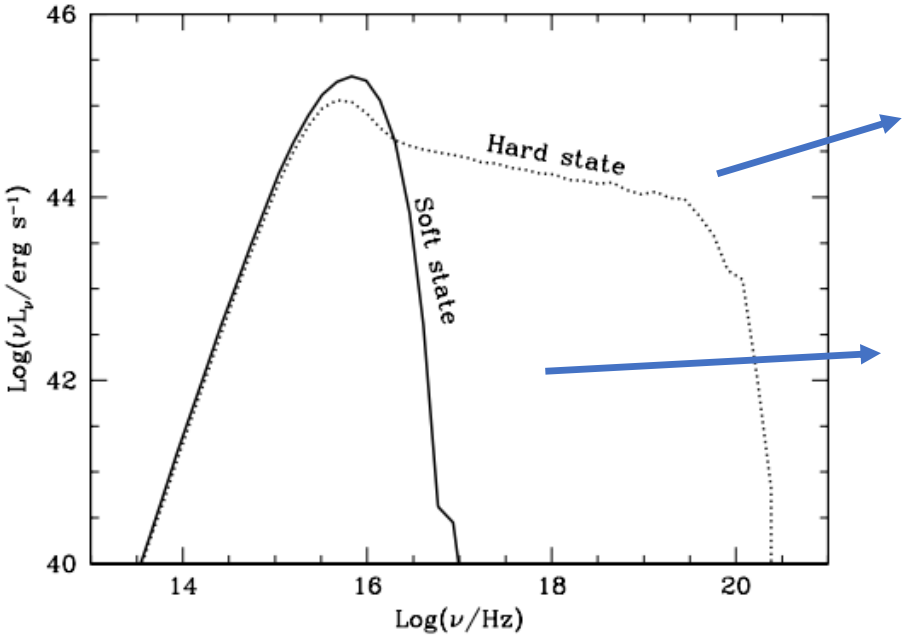
Radiative cooling

$$\frac{k_0 T^{7/2}}{l} \approx \frac{\gamma}{\gamma - 1} nkT \left(\frac{kT}{m_H}\right)^{1/2}$$

Thermal conduction

Mass evaporation

Original disk structure in Liu. 2002



gas pressure-dominated solution – Hard state

*Exists at all accretion rate
*Strong corona, weak disk

$$L_{down} = L_{soft}$$
$$L_{up} = L_G$$

radiation pressure-dominated – Soft state

*Exists only at relatively high accretion rate (inner region of the disk)

*Strong disk, weak corona

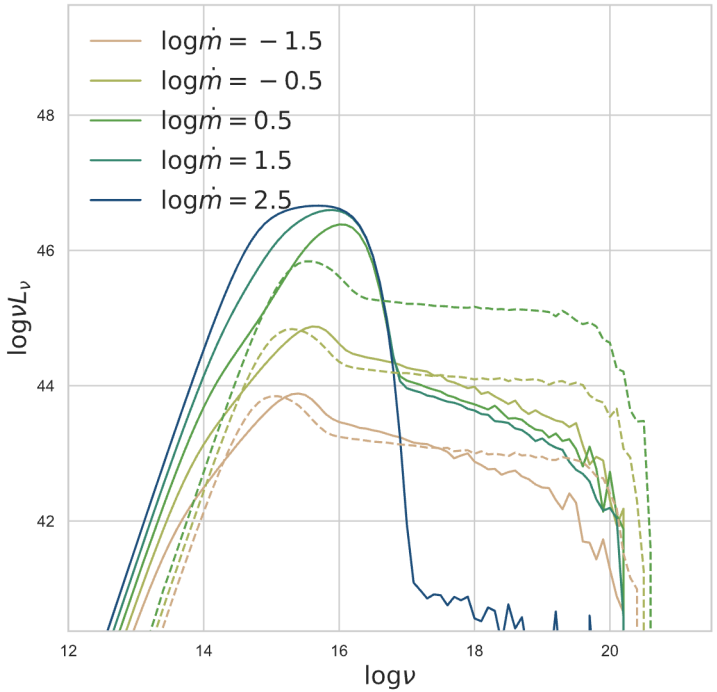
$$L_{up} = L_G$$

- Energy consistencies are checked after integrated over the disk surface,

$$L(\lambda_\tau, \lambda_u) = \int F(R, \lambda_\tau, \lambda_u)\, 2\pi R dR$$

- Coefficients λ_τ, λ_u are fixed values

Our modifications: inner slim-like region



gas pressure-dominated solution – Hard state

*Exists at all accretion rate
*Strong corona, weak disk

$$F_{down}(R) = F_{soft}(R)$$
$$F_{up}(R) = F_G(R)$$

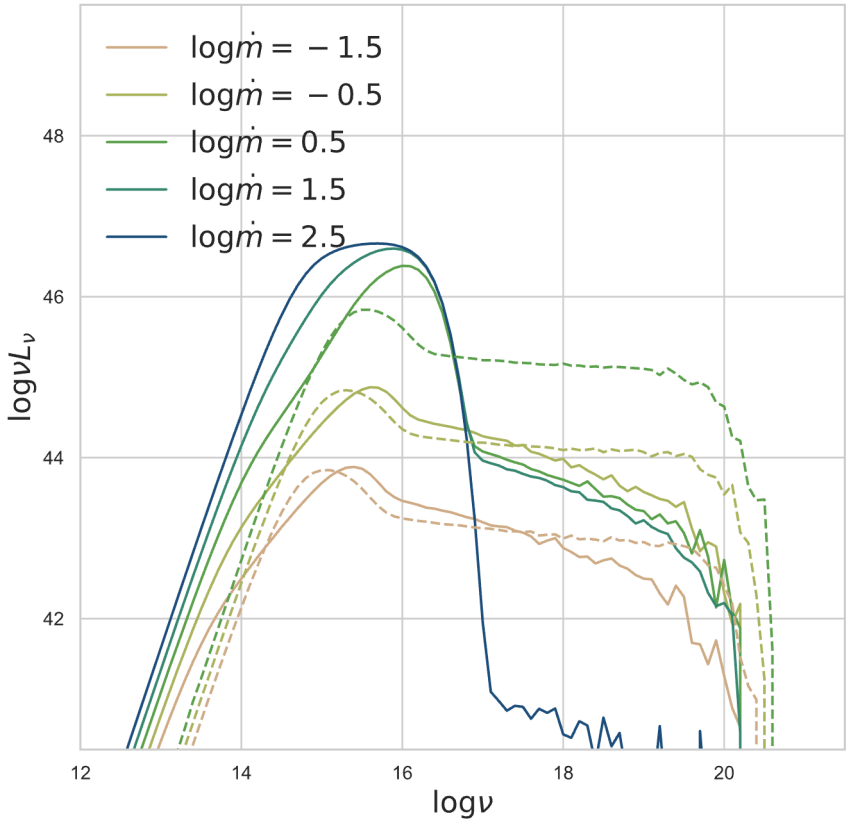
radiation pressure-dominated – Slim-like region

*Exists only at relatively high accretion rate (inner region of the disk)

*Multi-color blackbody

$$T_{eff} = 2.52\times10^7 f(\dot{m}, r)^{1/8} \left(\frac{m}{10}\right)^{-1/4} r^{-1/2}$$

- Energy consistencies are checked locally, $F = F[R, \lambda_\tau(R), \lambda_u(R)]$
- Coefficients λ_τ, λ_u are radius-dependent



- SED deviates pure hard state as accretion rate increases
- For relatively low accretion rate, there exists no radiative pressure-dominated solution, the radiative efficiency is the same as the standard thin disk

$$L_{bol} \approx 0.1\dot{M}c^2$$

- For relatively high accretion rate, slim-like region emerges in the inner part of the disk, the radiative efficiency is roughly the same as the slim disk

$$L_{bol} \approx 2\times\left(1+\log\left(\frac{\dot{m}}{2}\right)\right)\times L_{Edd}$$

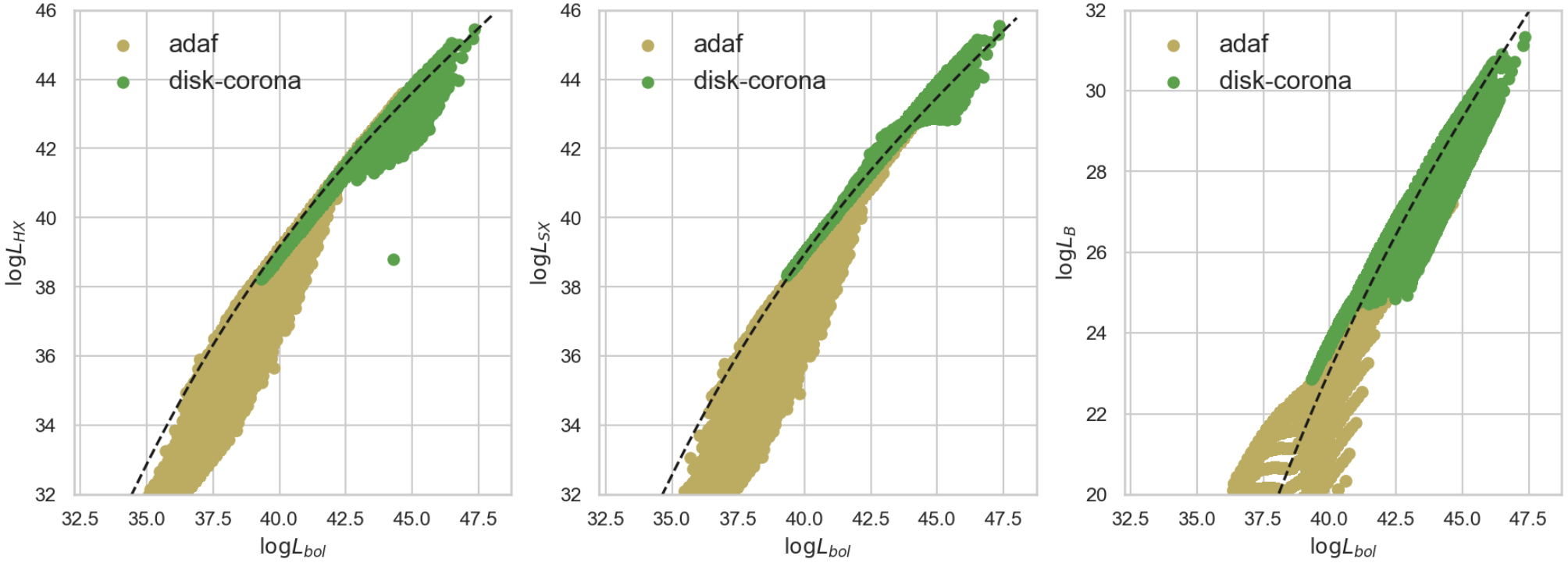
Smooth transition between the disk-corona model to the slim disk model.

Scaling relations

$$\log_{10}(L_{\rm HX}/L_{\rm bol}) = -1.54 - 0.24\mathcal{L} - 0.012\mathcal{L}^2 + 0.0015\mathcal{L}^3$$

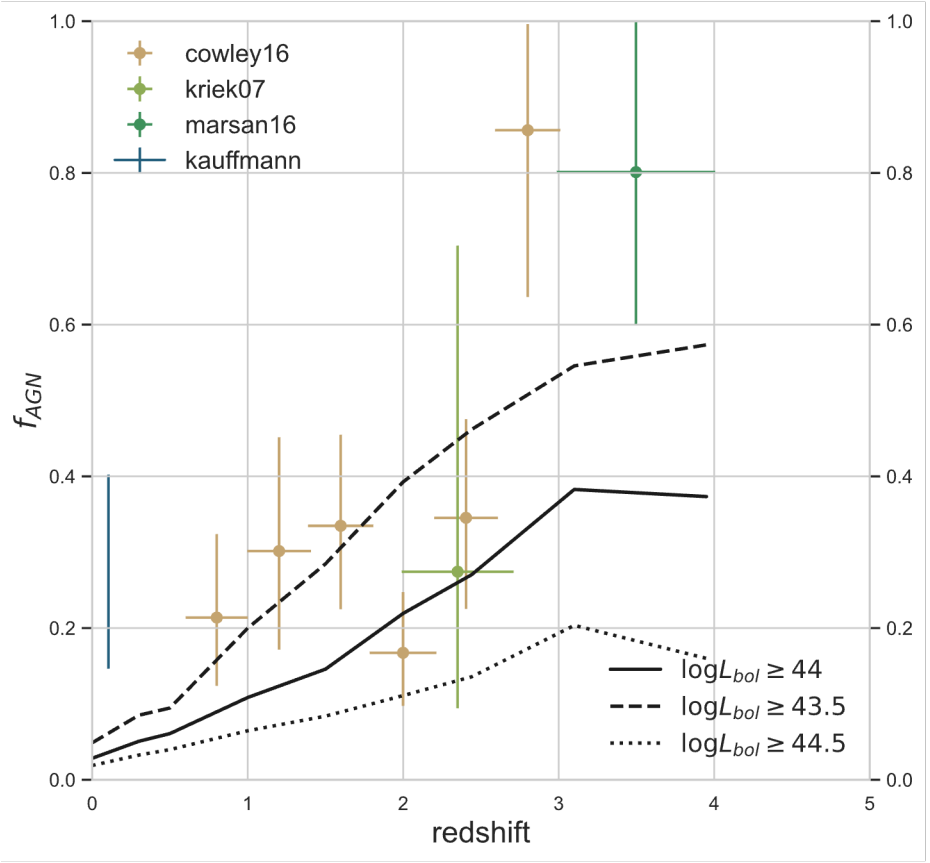
$$\log_{10}(L_{\rm SX}/L_{\rm bol}) = -1.65 - 0.22\mathcal{L} - 0.012\mathcal{L}^2 + 0.0015\mathcal{L}^3,$$

$$\log_{10}(\nu_{\rm B} L_{\nu_{\rm B}}/L_{\rm bol}) = -0.80 + 0.067\mathcal{L} - 0.017\mathcal{L}^2 + 0.0023\mathcal{L}^3$$ (Marconi. 2004)



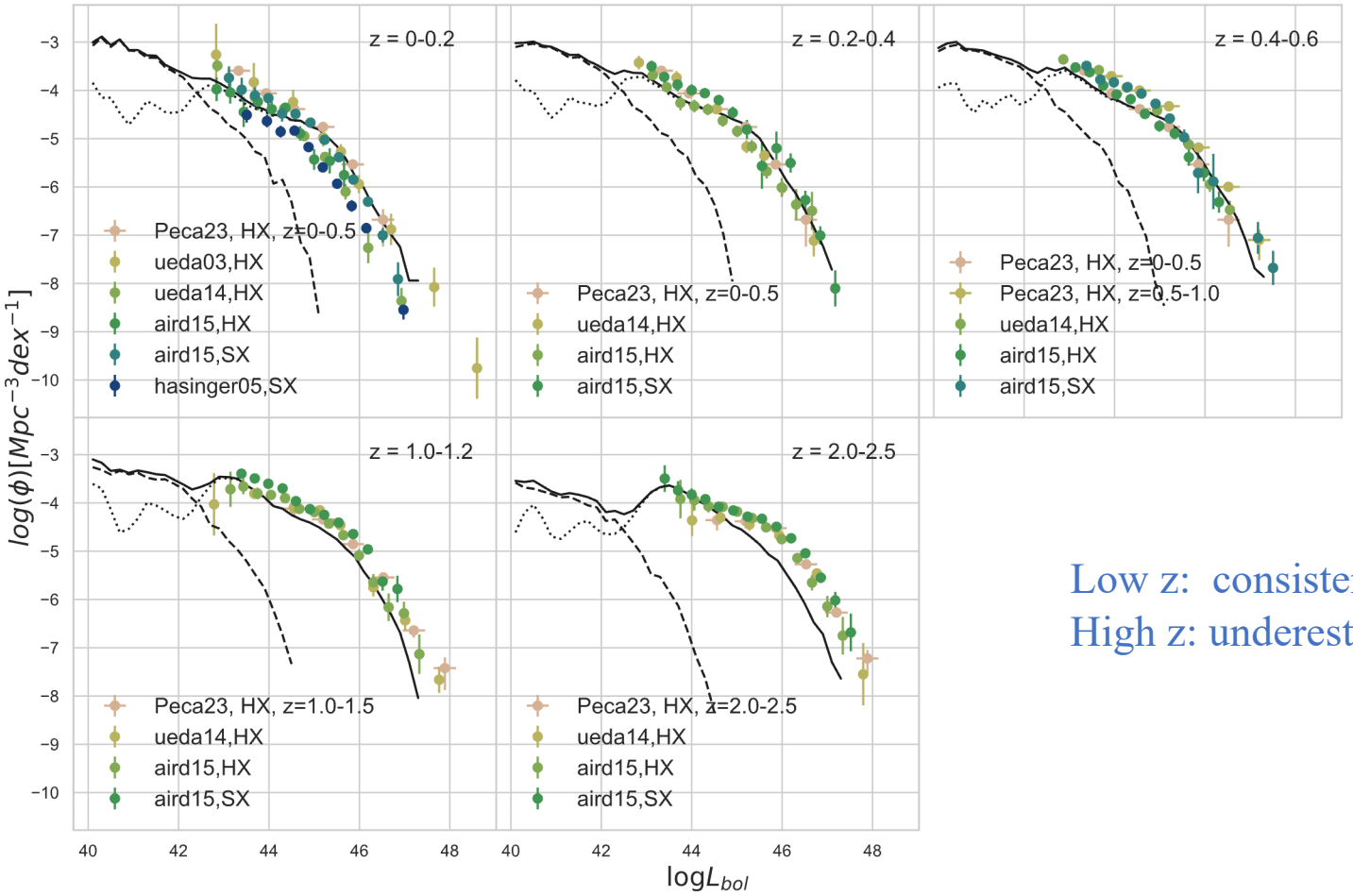
Time evolution of the fraction of active AGNs in massive galaxies

Low z: consistent
High z: underestimated



$(M_{steller} > 10^{11} M_{\odot})$

Bolometric luminosity function



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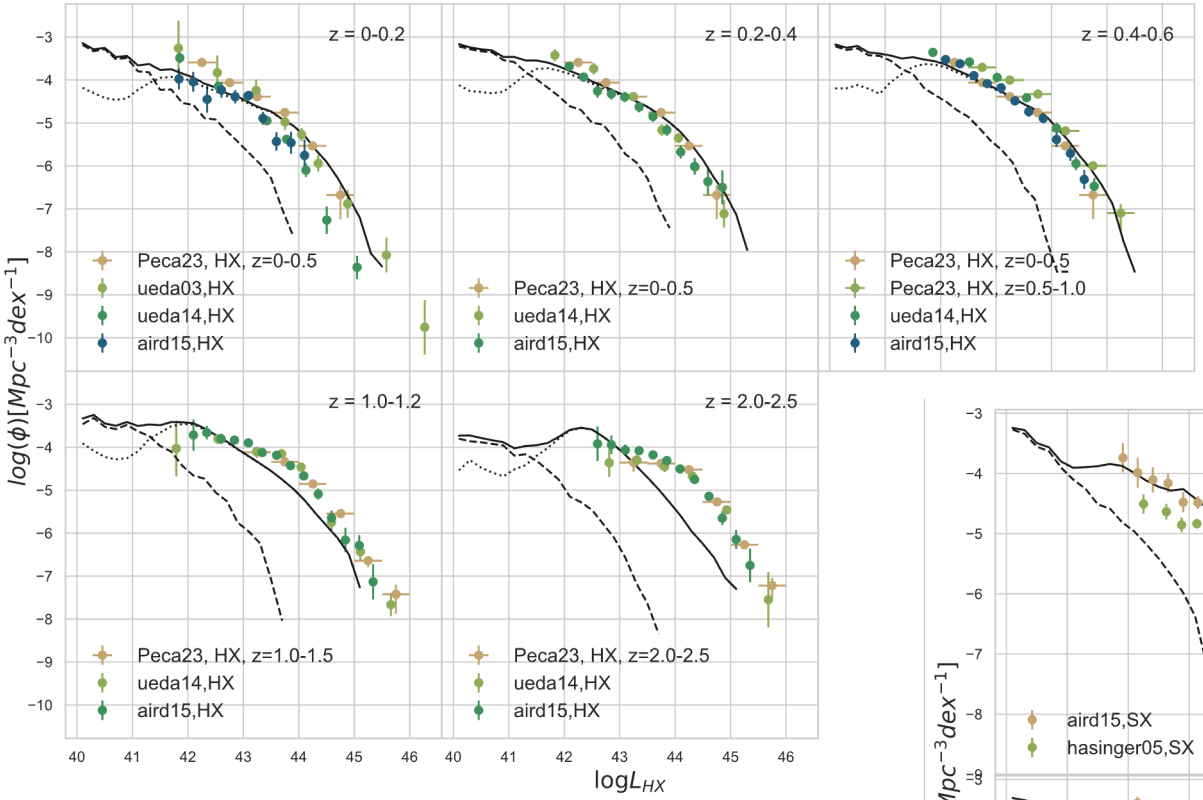
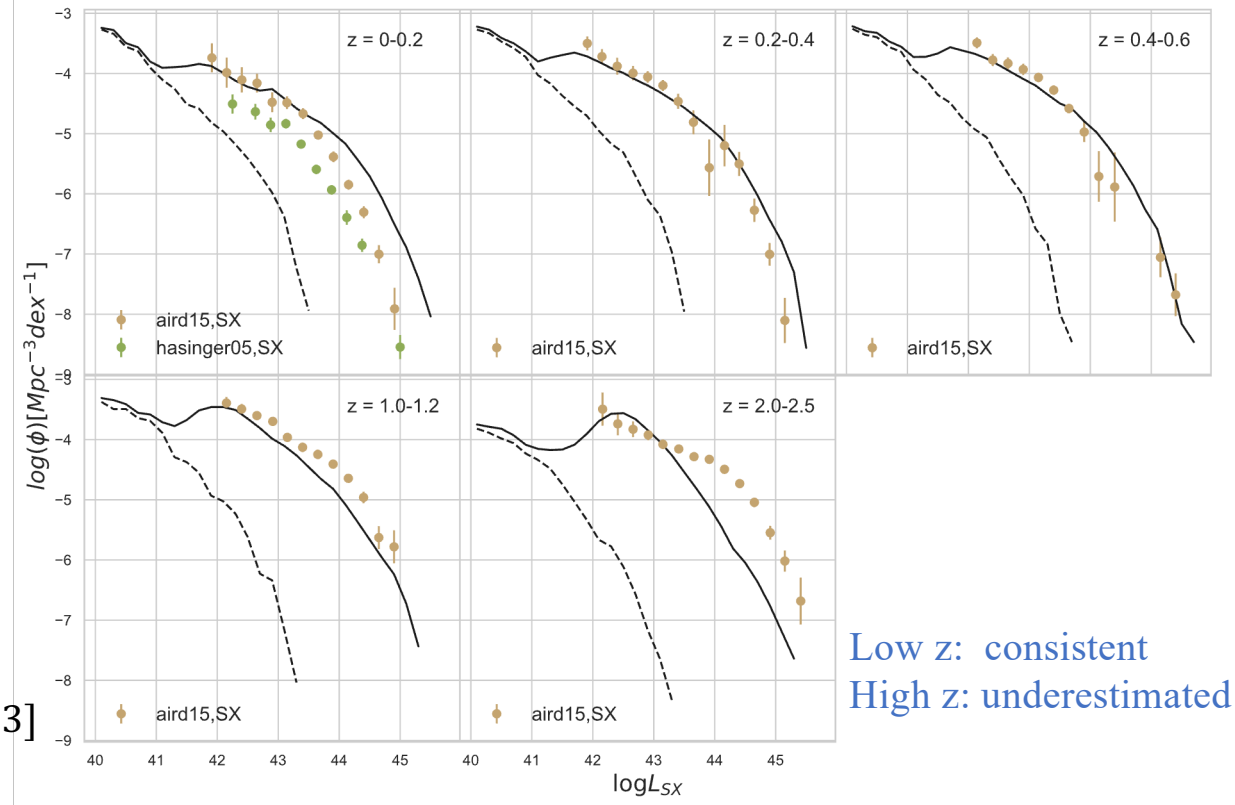


← Hard X-ray LF

(2-10 keV)

(0.8-2 keV)

Soft X-ray LF →

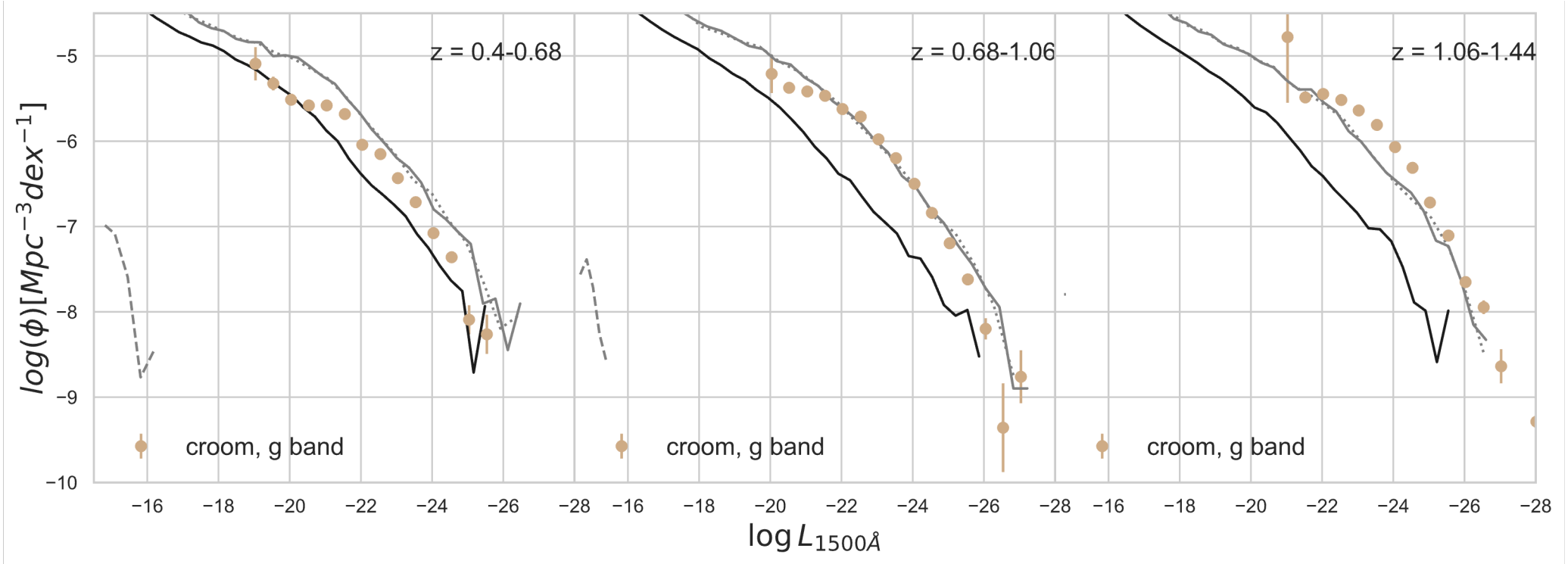


Visible fraction (Hopkins. 2007)

$$f_{vis} = f_{46}\left(\frac{L_{bol}}{10^{46} erg/s}\right)^{\beta}, [f_{46} = 0.609\ \beta = 0.063]$$

Low z: consistent
High z: underestimated

1500ANG luminosity function



Low z: consistent

High z: underestimated

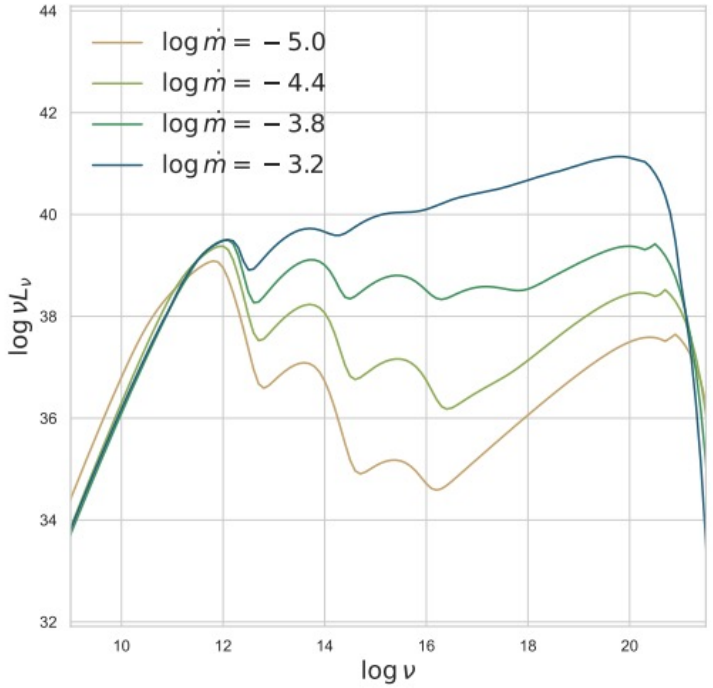
Summary

- ($SED = f(m_{BH}, \dot{m}_{BH})$) + L-galaxies

- Our model performs reasonably well at lower redshifts, but always shows scarcity of bright, active AGNs at higher redshift. We suggest this discrepancy may be inherent to semi-analytical model itself.

- Future works: emission-line properties in cosmological simulation; integrating our model into L-galaxies

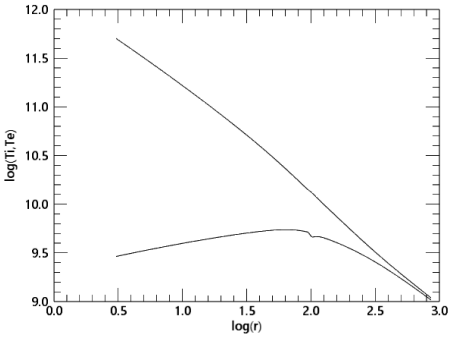
The ADAF



Energy equation:

$$(1-\delta)q^{vis} = q^{adv} + q^{ie}$$

$$q^{ie} = q^{rad} + \delta q^{vis}$$



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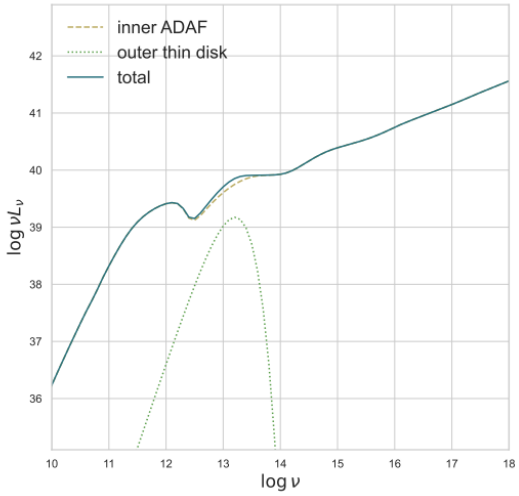

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