

The first SMBHs

Indications from models

arXiv:1902.07982

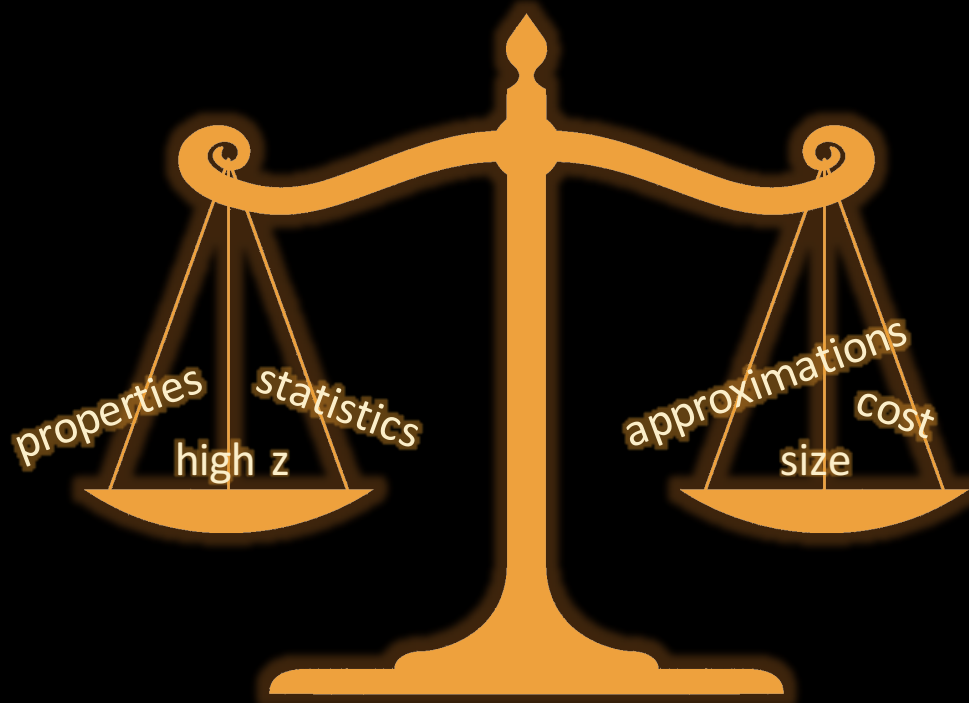
Stergios Amarantidis et al.
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Goal of this project

- Study the AGN/SMBH population at EoR
- Using cosmological galaxy formation and evolution models
- Predictions for the next generation of telescopes
- Comparison and indications from the models

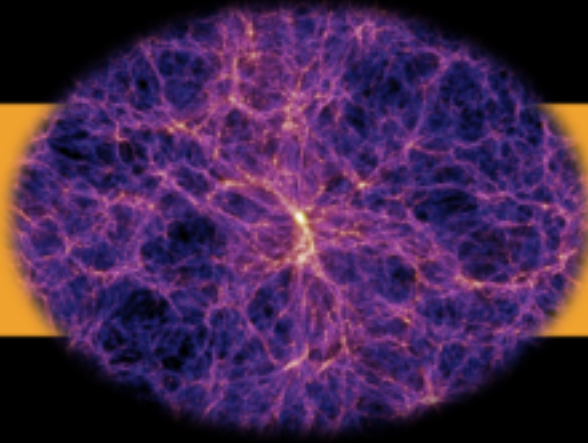
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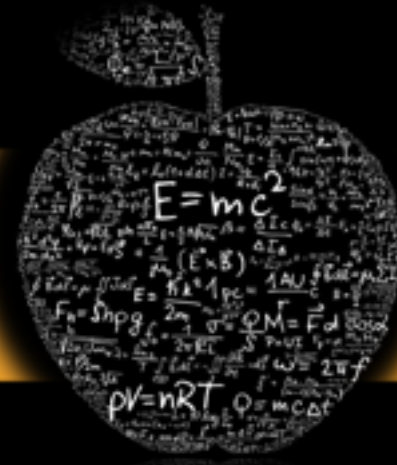


Galaxy formation models

- Semi-Analytic Models (SAMs) – 4 models
 - ~ 500 Mpc ~ 5 kpc $\sim 10^8 - 10^9 M_{\odot}$
- Hydro-dynamical simulations (HDSs) – 4 models
 - ~ 100 Mpc ~ 1 kpc $\sim 10^6 - 10^7 M_{\odot}$



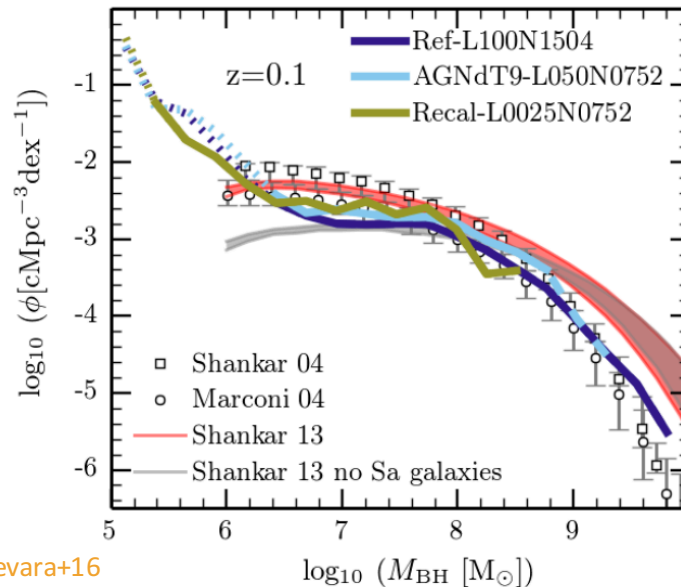
Dark Matter



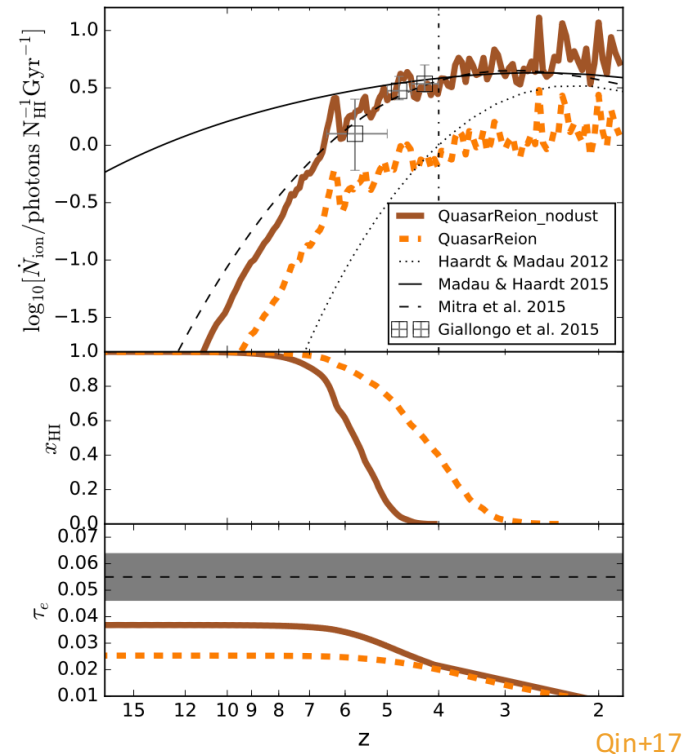
Models

Galaxy formation models

- Predictions for the local and high z Universe
- Comparison with observations – tuning of parameters
- Future telescopes (SKA, Athena, JWST, etc)



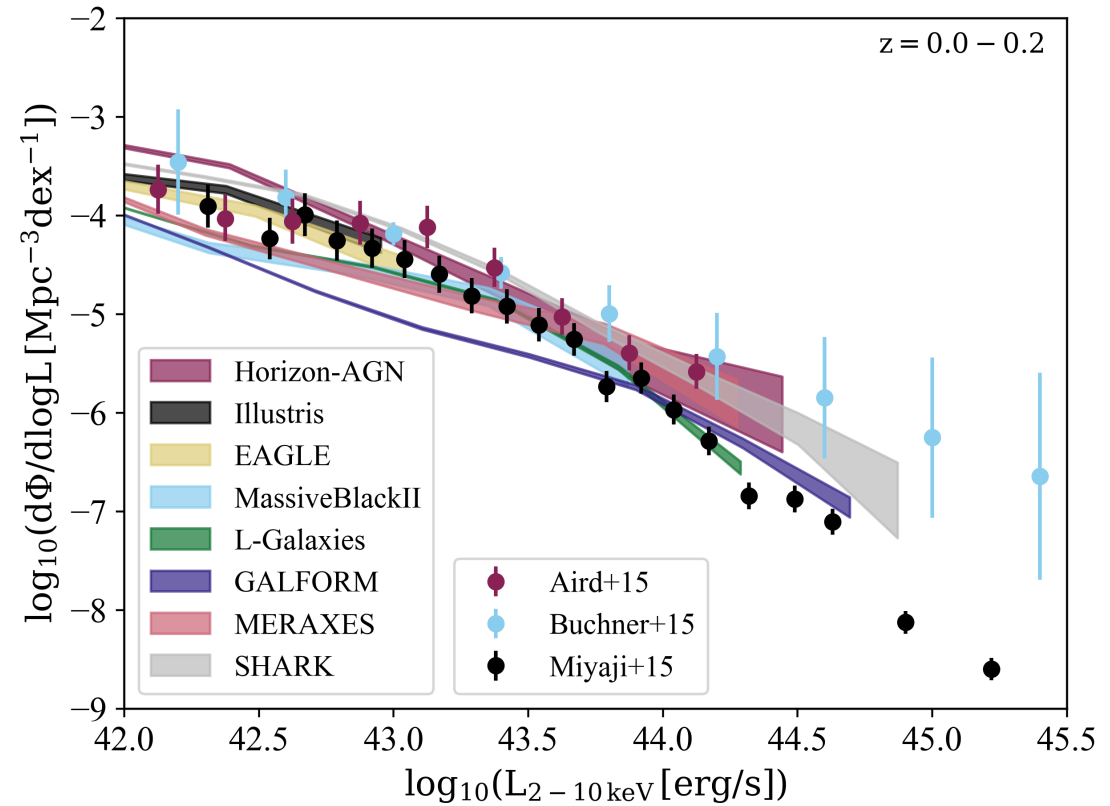
Rosas-Guevara+16



Qin+17

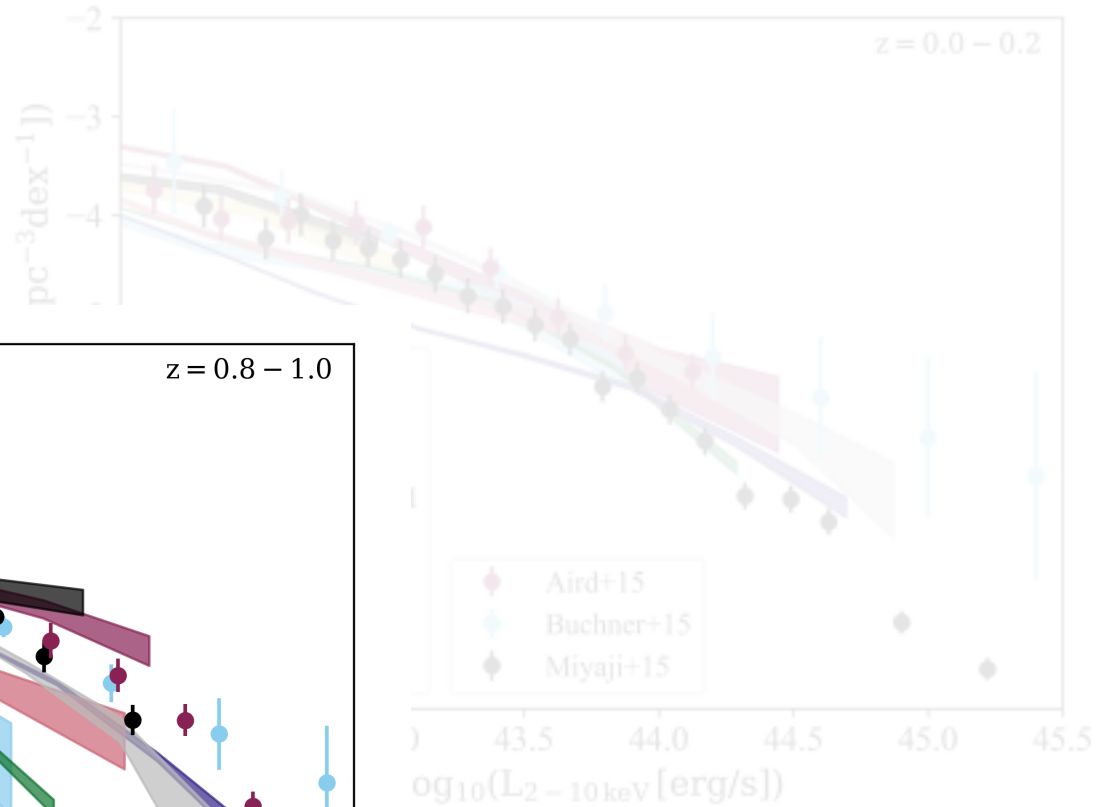
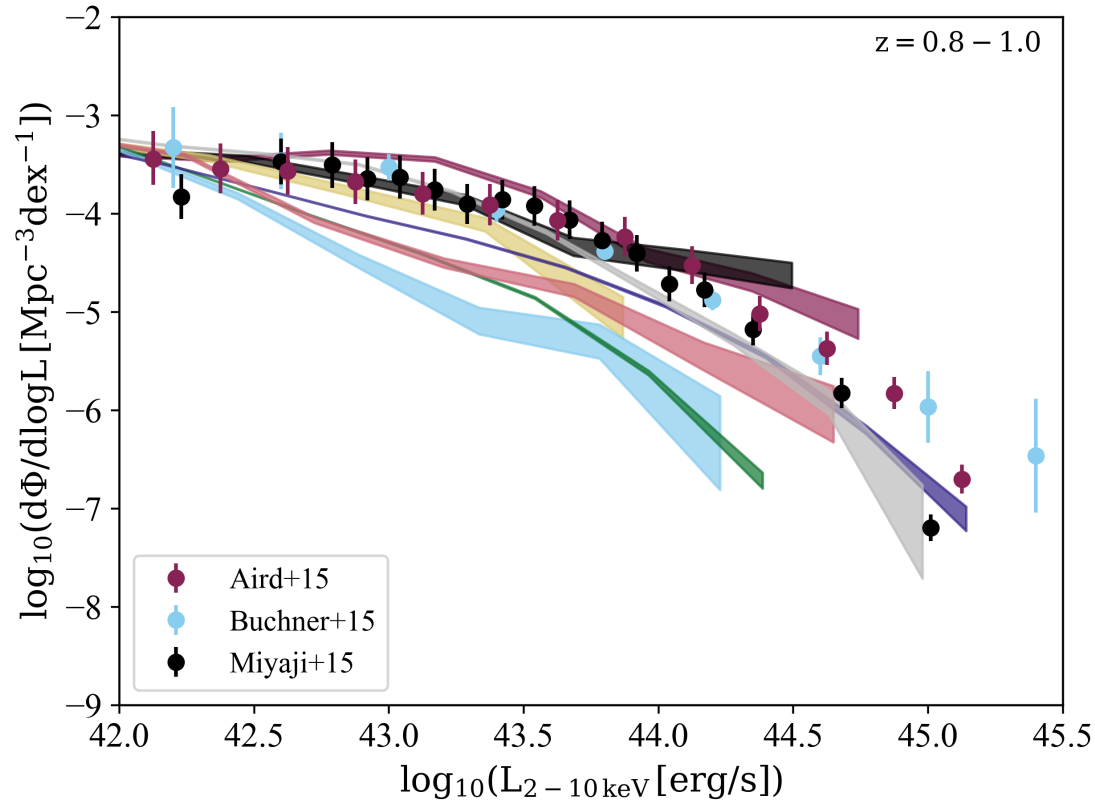
X-ray LFs: local

- For each SMBH: M , \dot{M} , α
- Bolometric luminosity
- Corrections
- Match with observations
- Tuning of models
- Radiative efficiency



X-ray LFs

- For each SMBH: M , \dot{M} , α
- Bolometric luminosity
- Corrections



Radiative efficiency (ϵ)

- Spin parameter

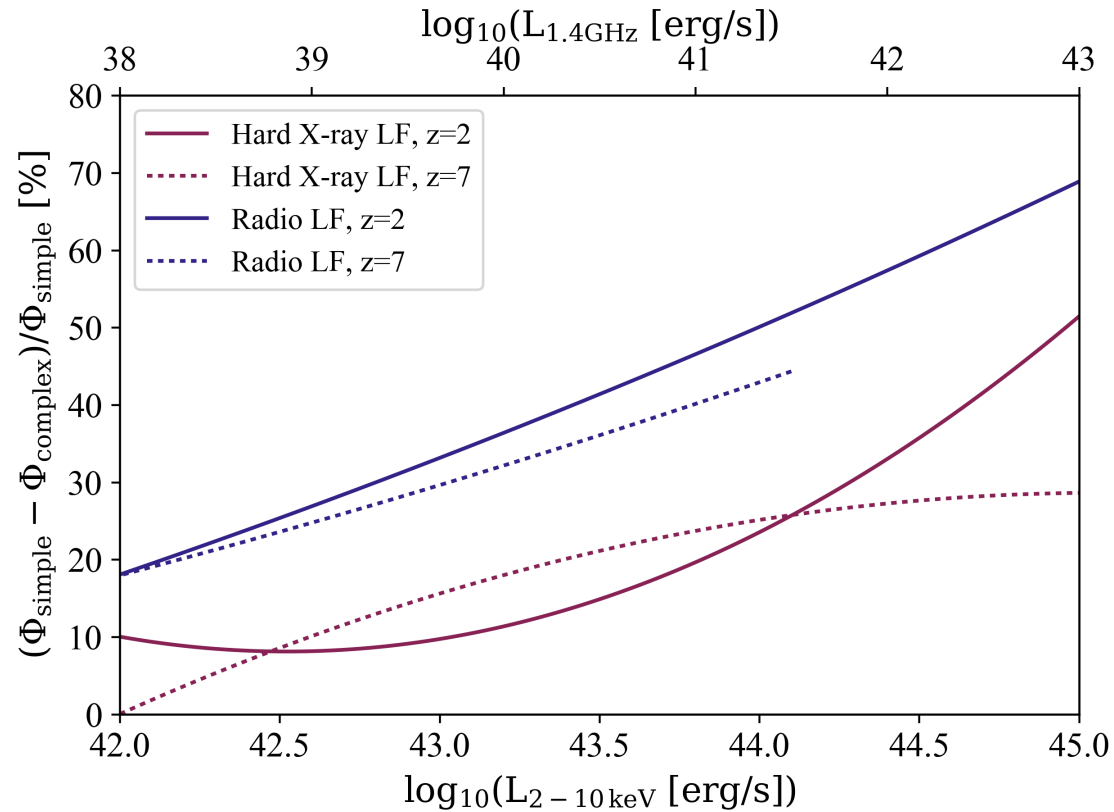
- $\epsilon = 1 - \sqrt{1 - \frac{2}{3} \frac{1}{r_{\text{ISO}}}}$

- $r_{\text{ISO}} = f(\alpha)$ (Bardeen+72)

- $L_{\text{bol}} = \epsilon \dot{M} c^2 \rightarrow L_{2-10\text{keV}}$

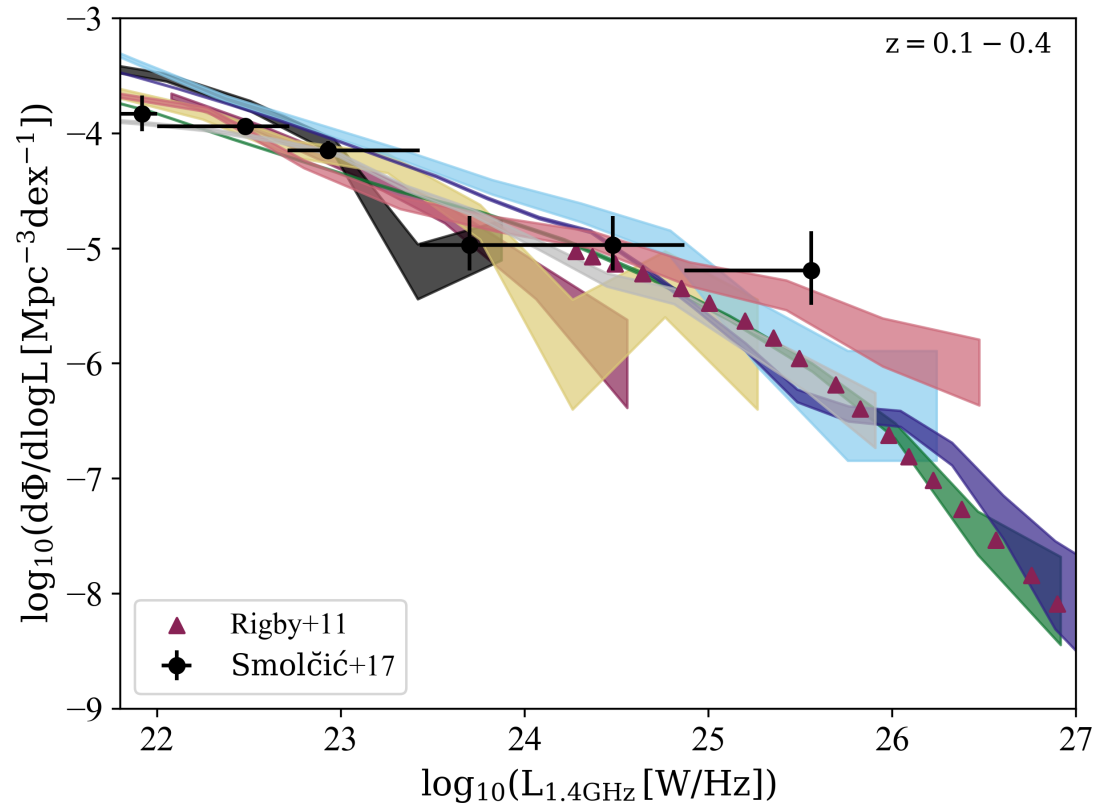
- $L_{\text{jet}} \propto \alpha^2 \rightarrow L_{1.4\text{GHz}}$ (Blandford+77)

- $\uparrow L \Leftrightarrow \uparrow \Delta\Phi$



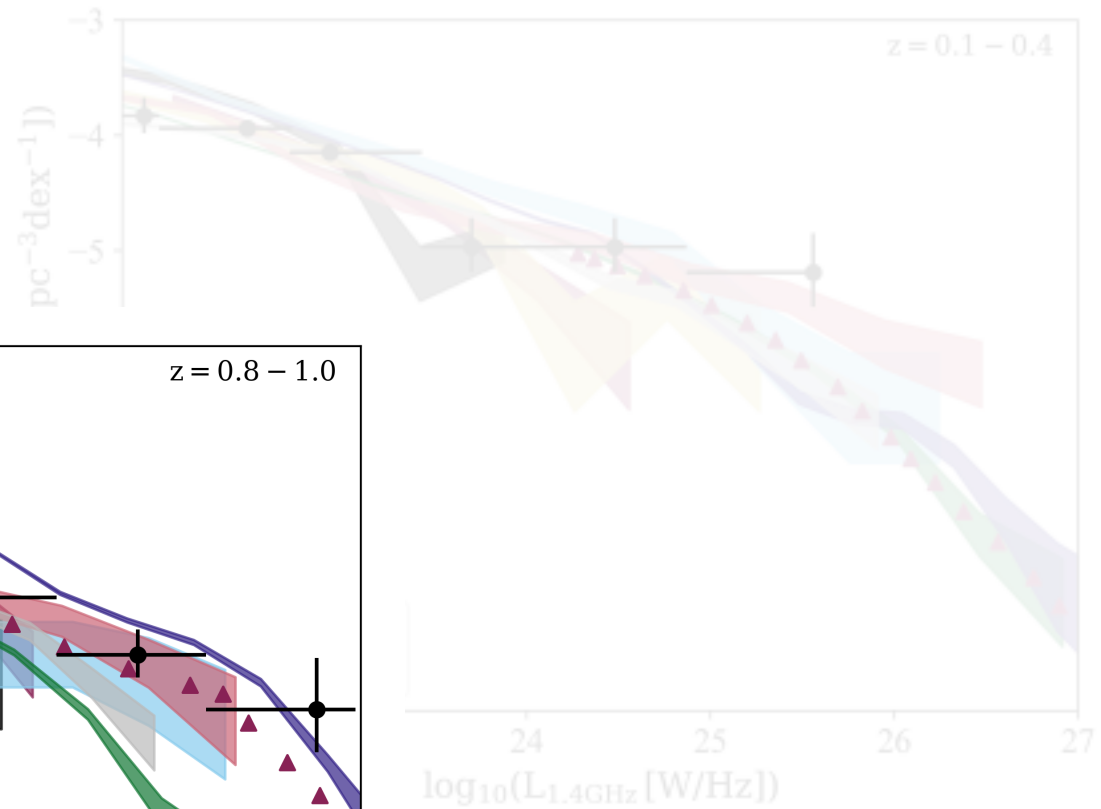
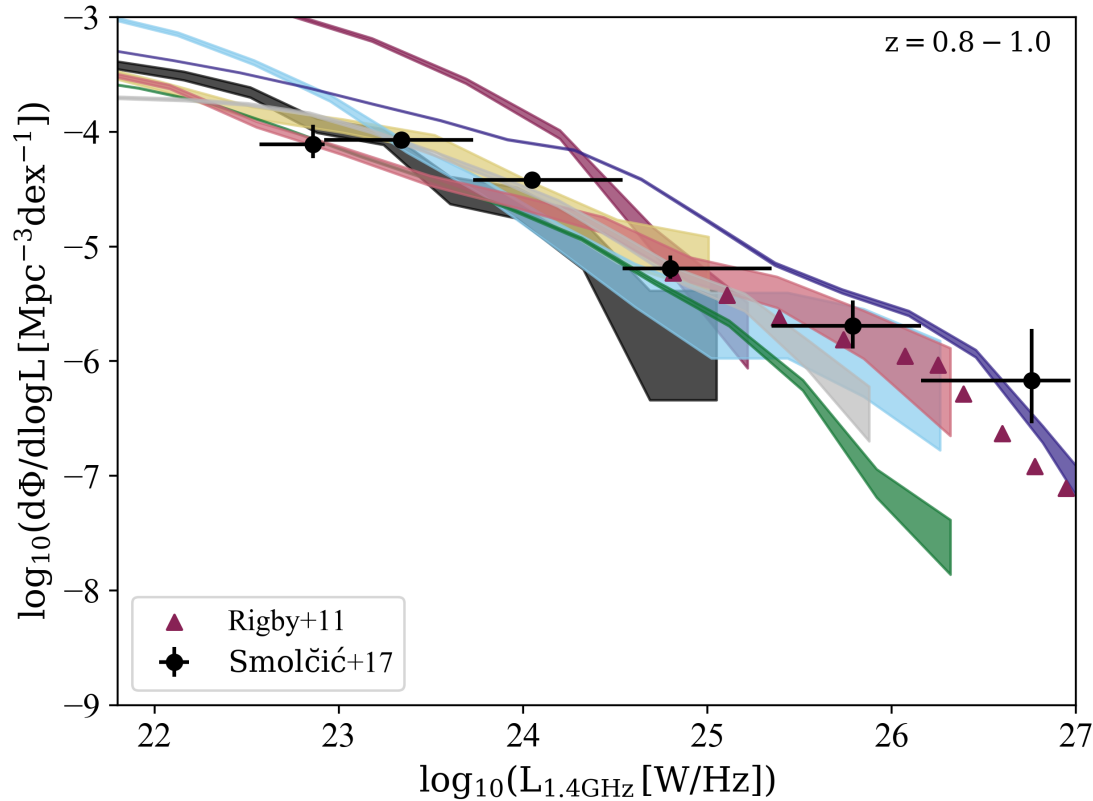
Radio LFs

- Match with observations
- 2 accretion scenarios
- Normalization parameters
- Degeneracy



Radio LFs

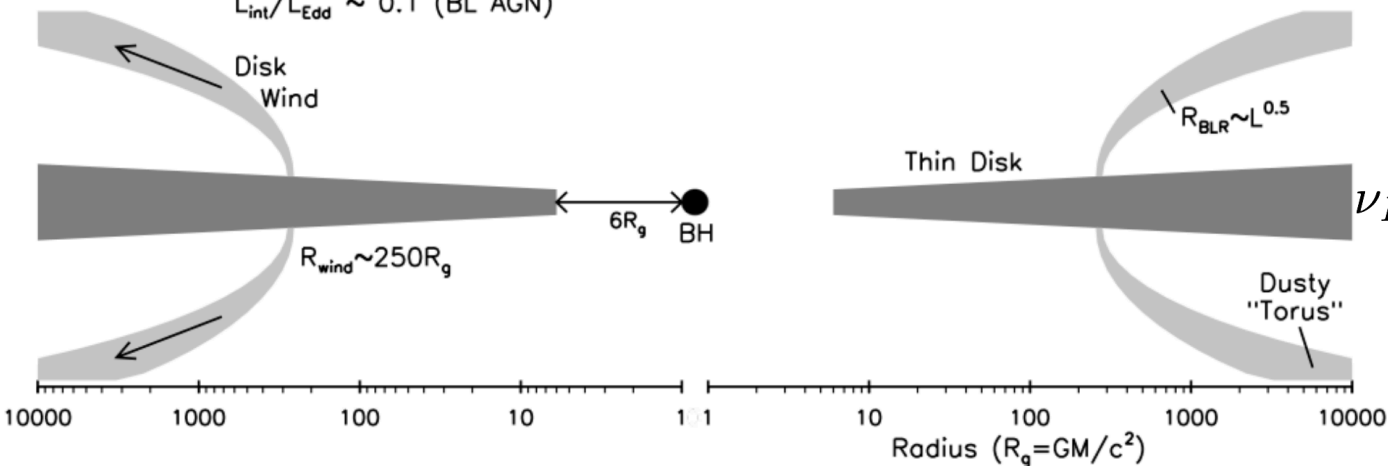
- Match with observations
- 2 accretion scenarios
- Normalization parameters



Accreting scenarios

Quasar mode - Thin disc (Shakura-Sunyaev model)

$L_{int}/L_{Edd} \sim 0.1$ (BL AGN)

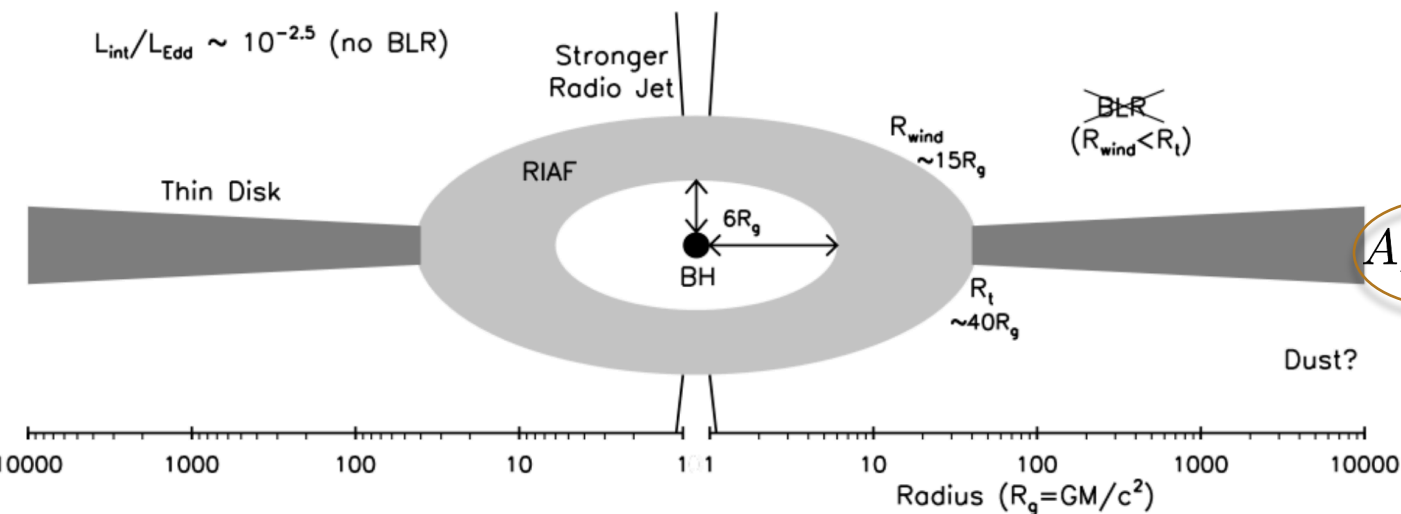


$$\nu_R L_{\nu R} = \frac{A_{TD} L_{jet} M_9^{0.32}}{(\dot{m}/0.01)^{1.2}}$$

$$\dot{m} = \frac{\dot{M}}{\dot{M}_{Edd}} = 0.01 \quad (\text{Meier+99})$$

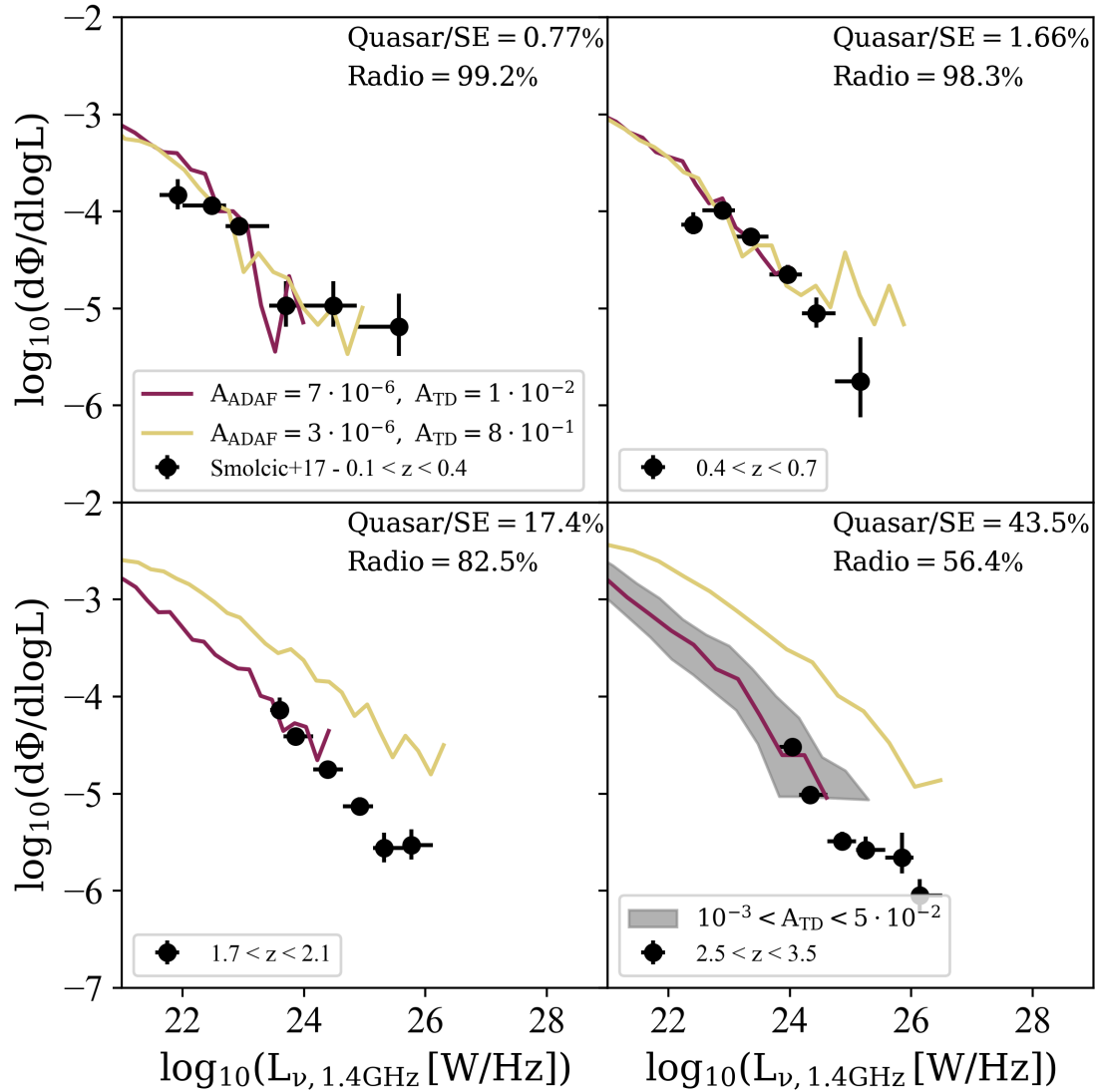
Radio mode - ADAF disc (advection-dominated accretion)

$L_{int}/L_{Edd} \sim 10^{-2.5}$ (no BLR)



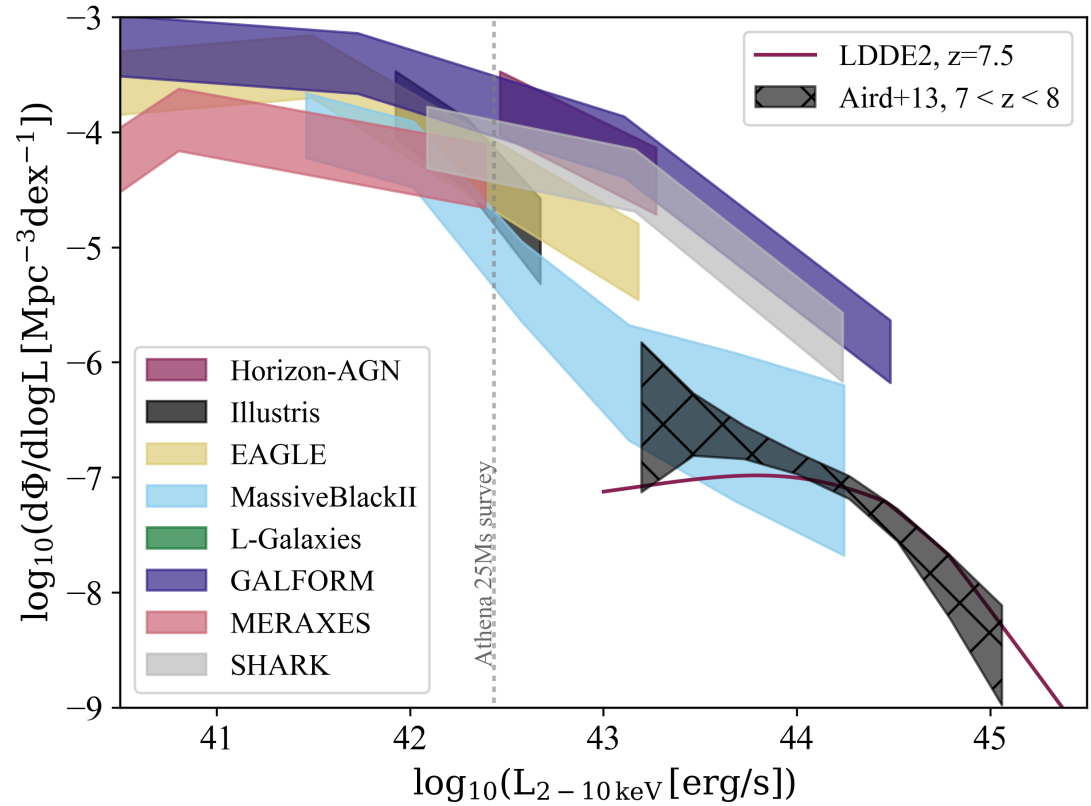
$$\nu_R L_{\nu R} = A_{ADAF} L_{jet} \left(M_9 \frac{\dot{m}}{0.01} \right)^{0.42}$$

Degeneracy



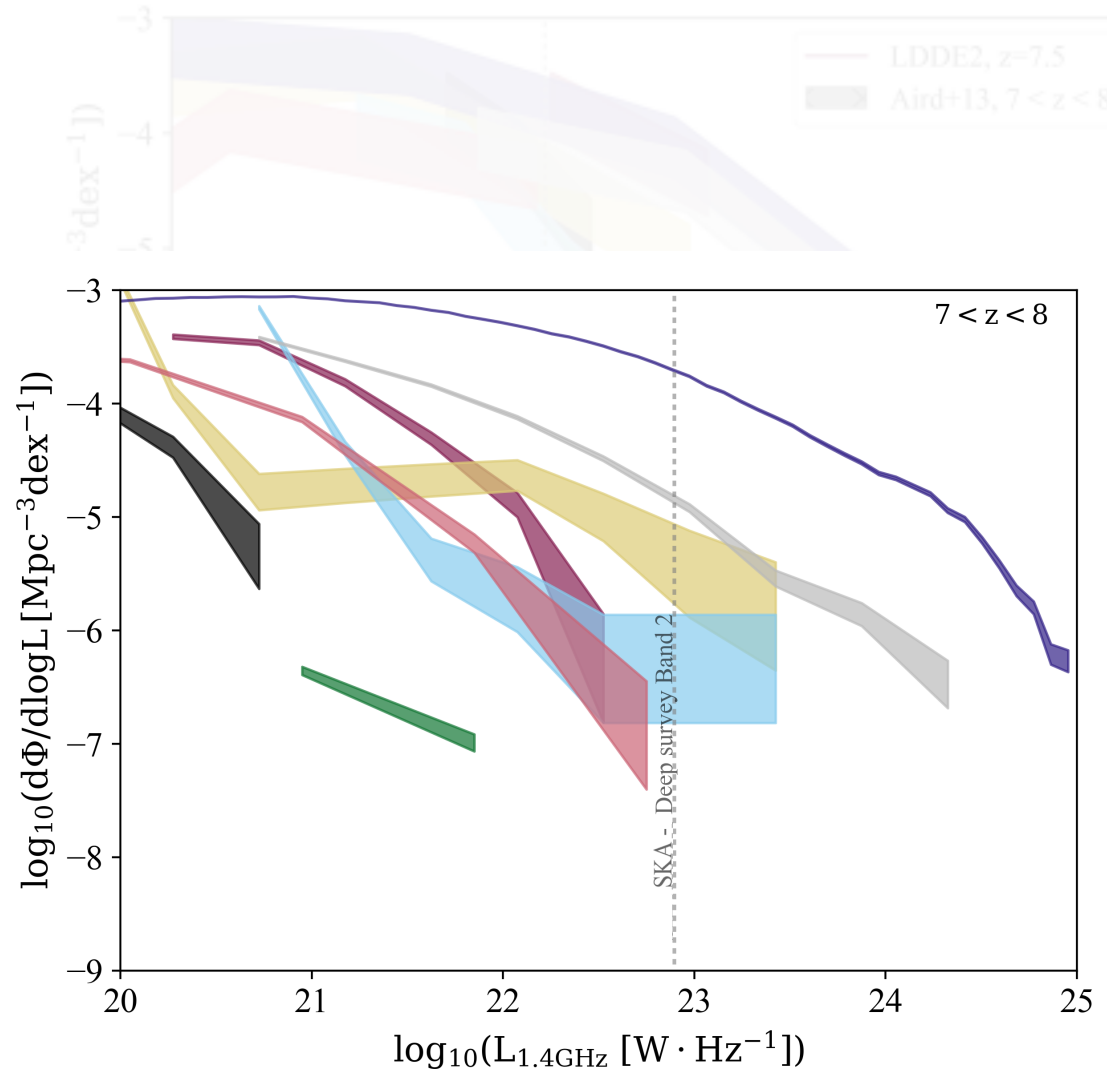
Results: EoR

- Athena 25Ms survey
- ~ 5000 SMBHs/deg²



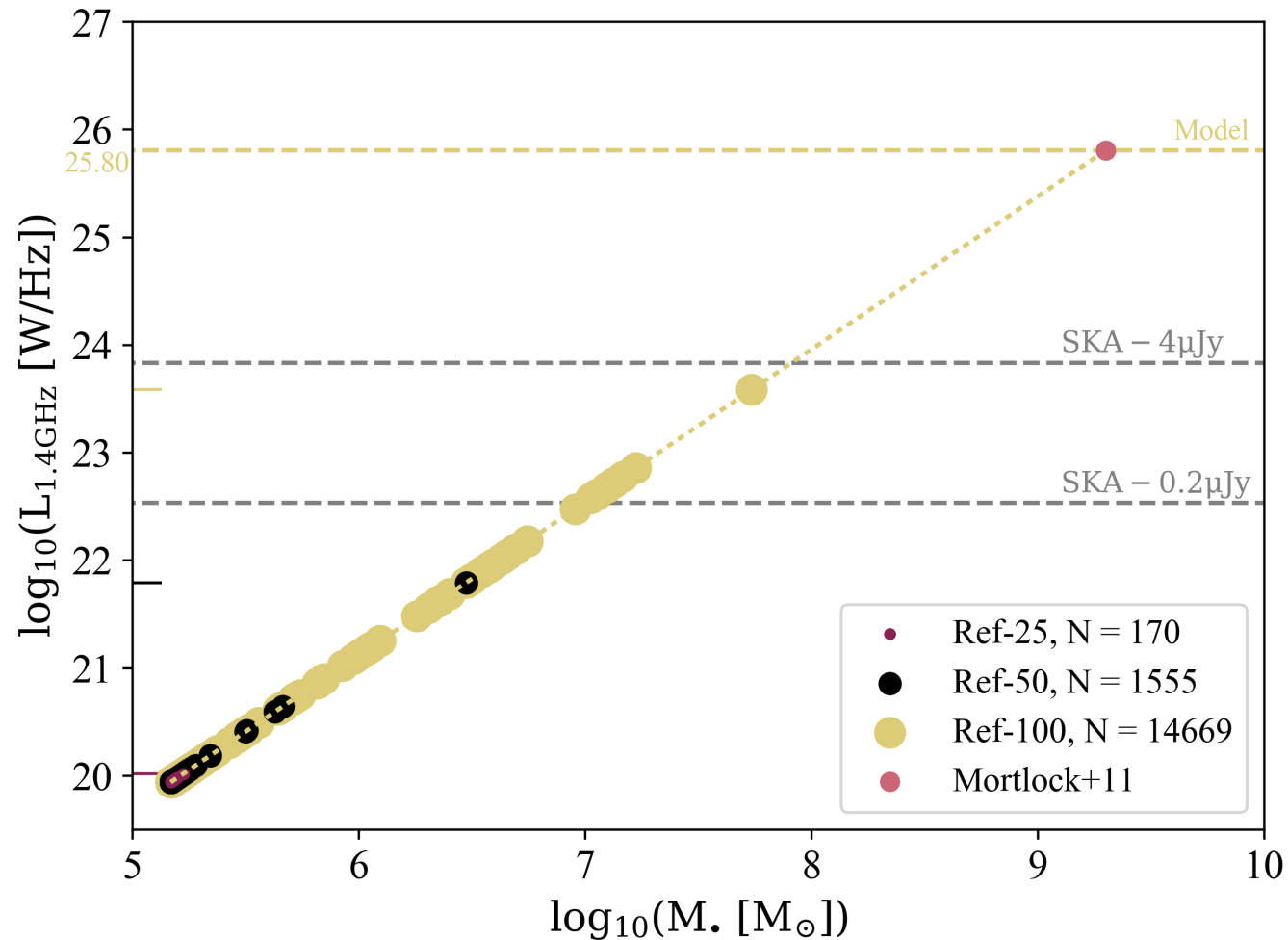
Results: EoR

- Athena 25Ms survey
- ~ 5000 SMBHs/deg²
- SKA deep survey band 2
- ~ 400 SMBHs/deg²
- Models vary substantially
- Limitations

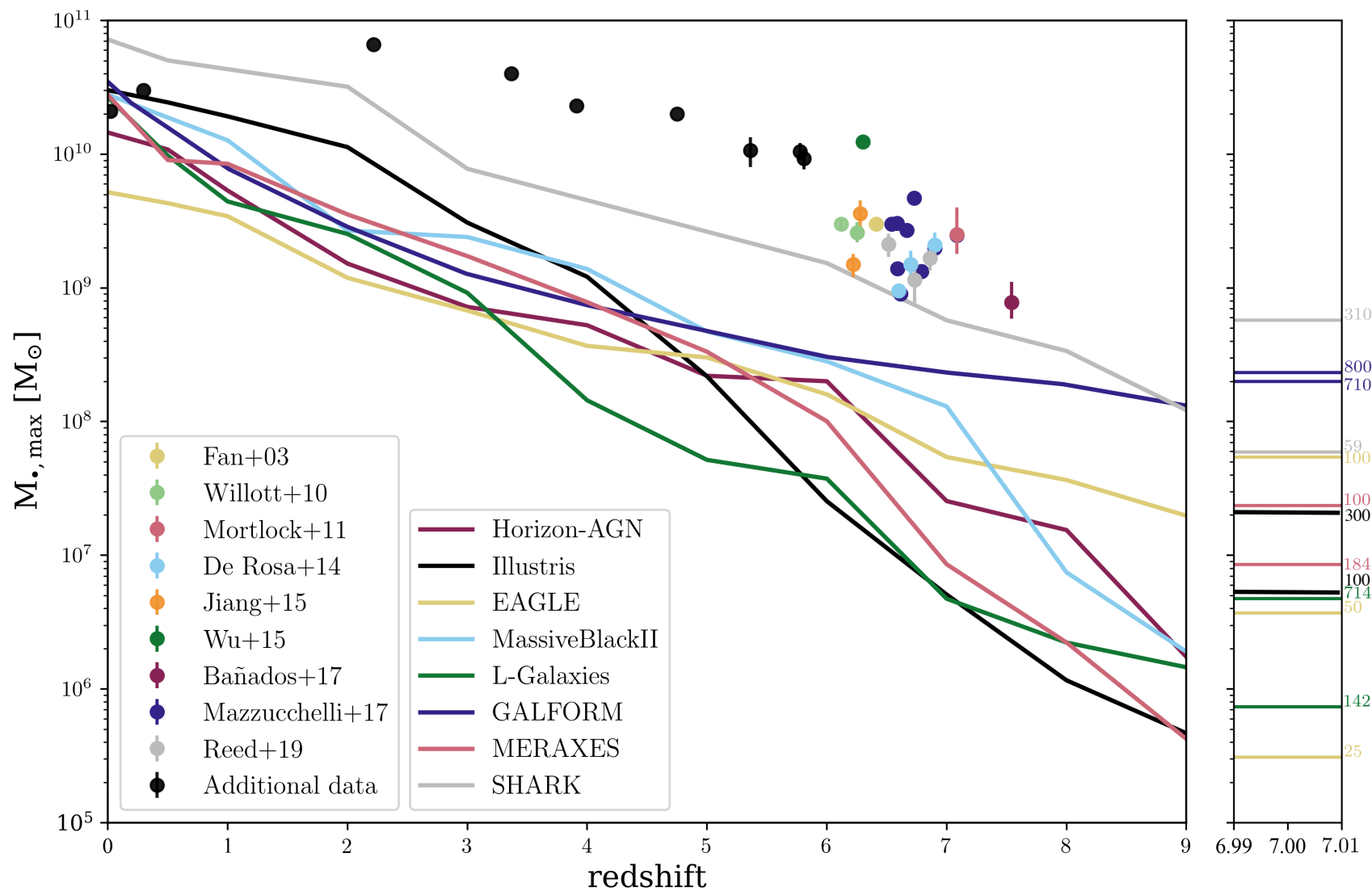


Indications from models: Volume

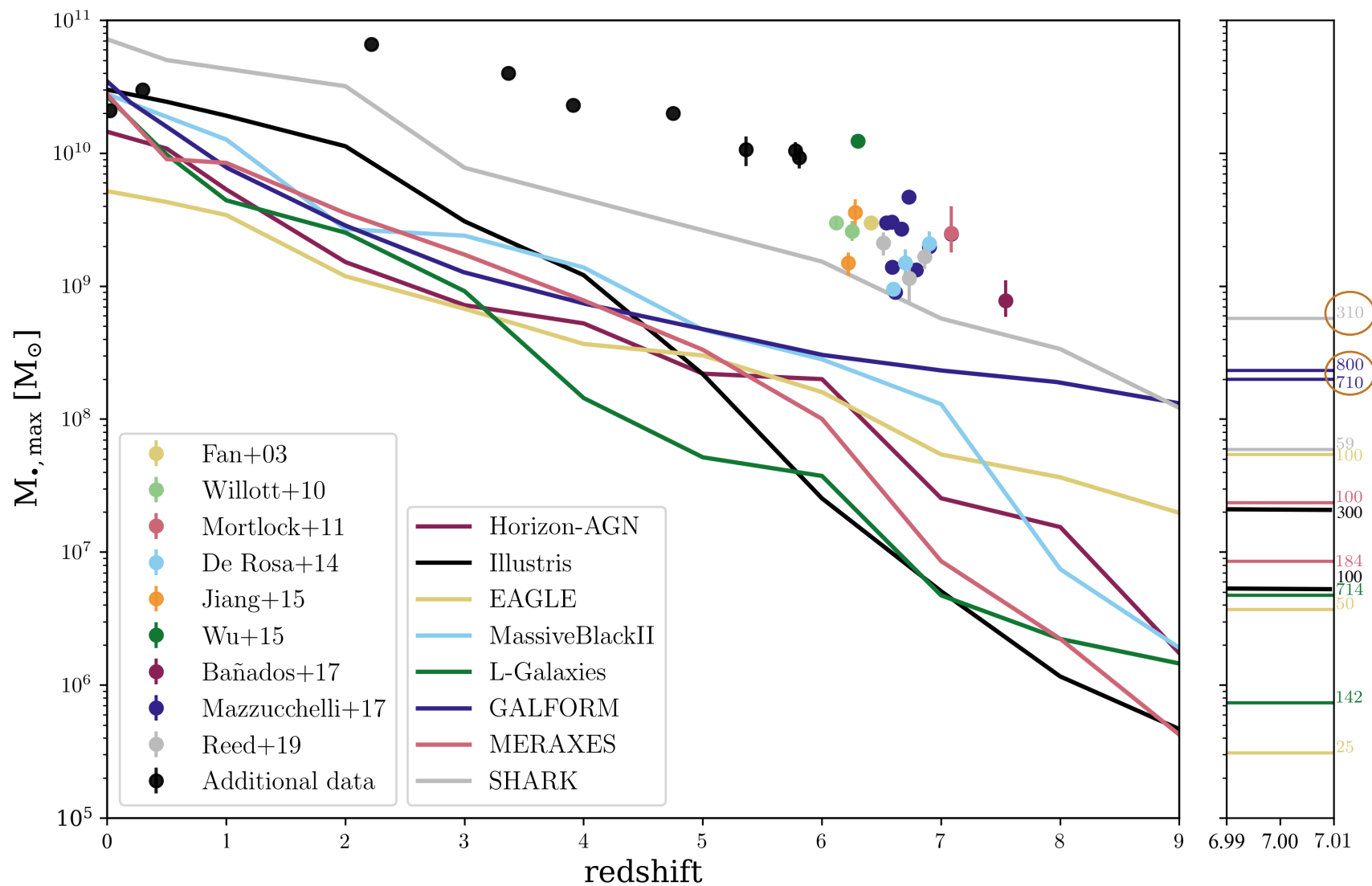
$$L_{\nu}^{TD} \propto M_{\bullet}^{1.42}$$



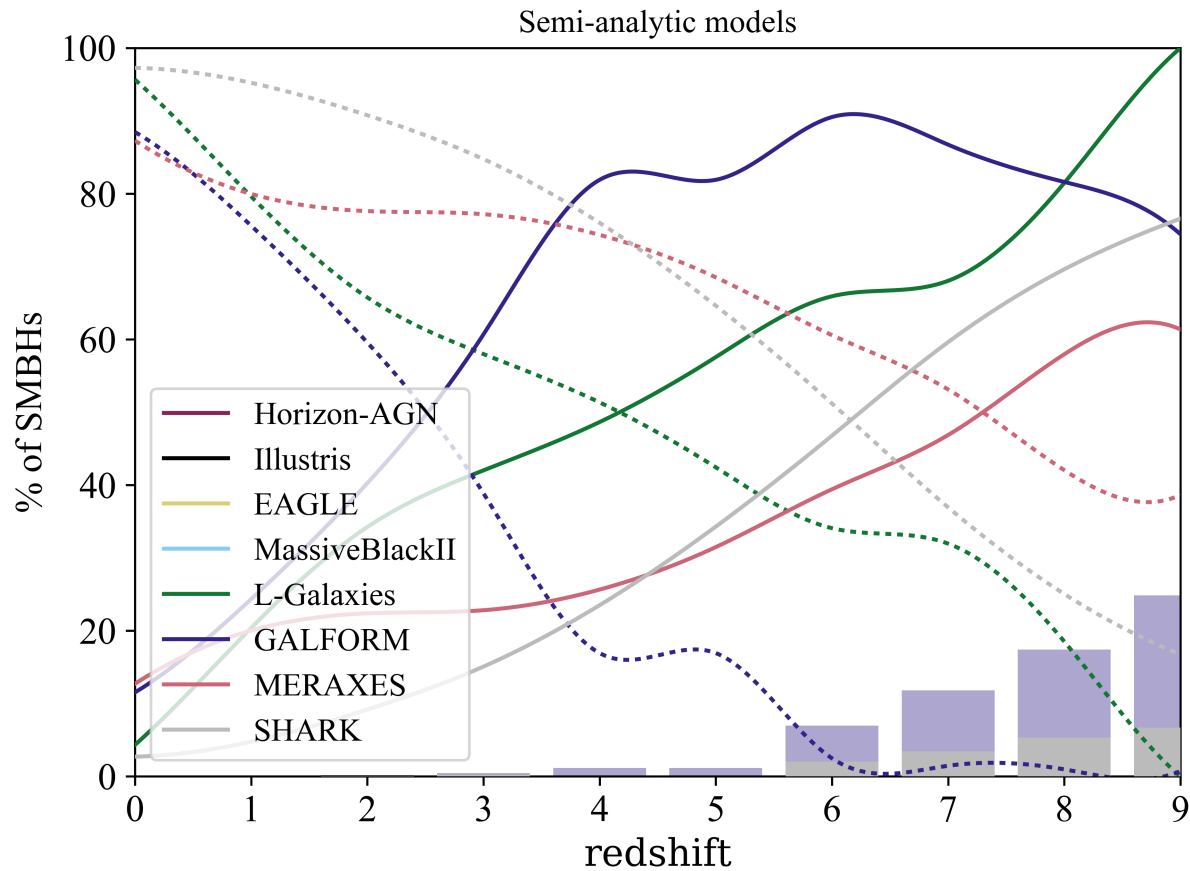
Indications from models: SMBH growth



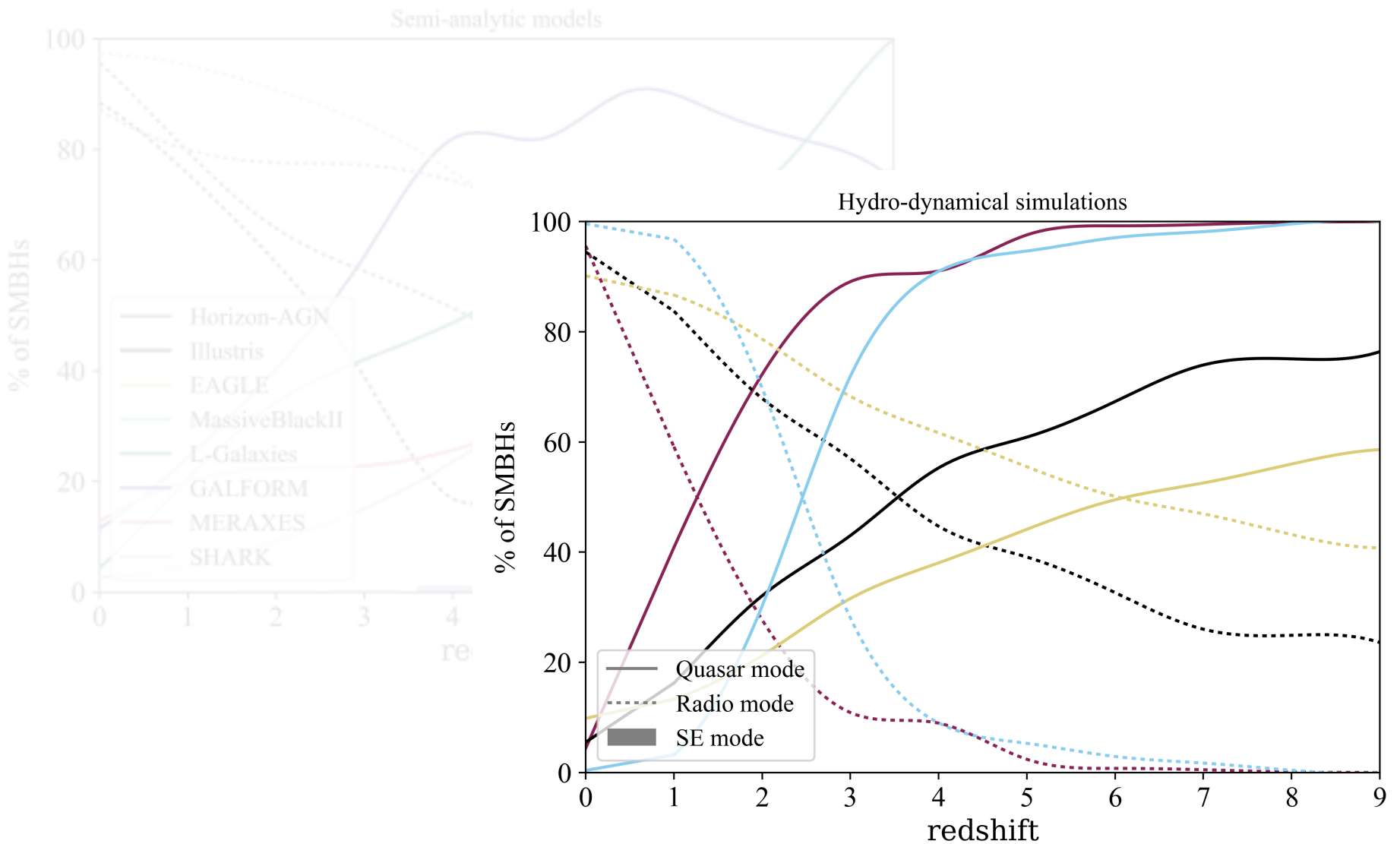
Indications from models: SMBH growth



Indications from models: SE accretion



Indications from models: SE accretion



Conclusions



- Use of cosmological models
- Predictions for future surveys/telescopes
- Limitations of predictions
- Volume/SMBH seeds/accretion physics
- Future improvements