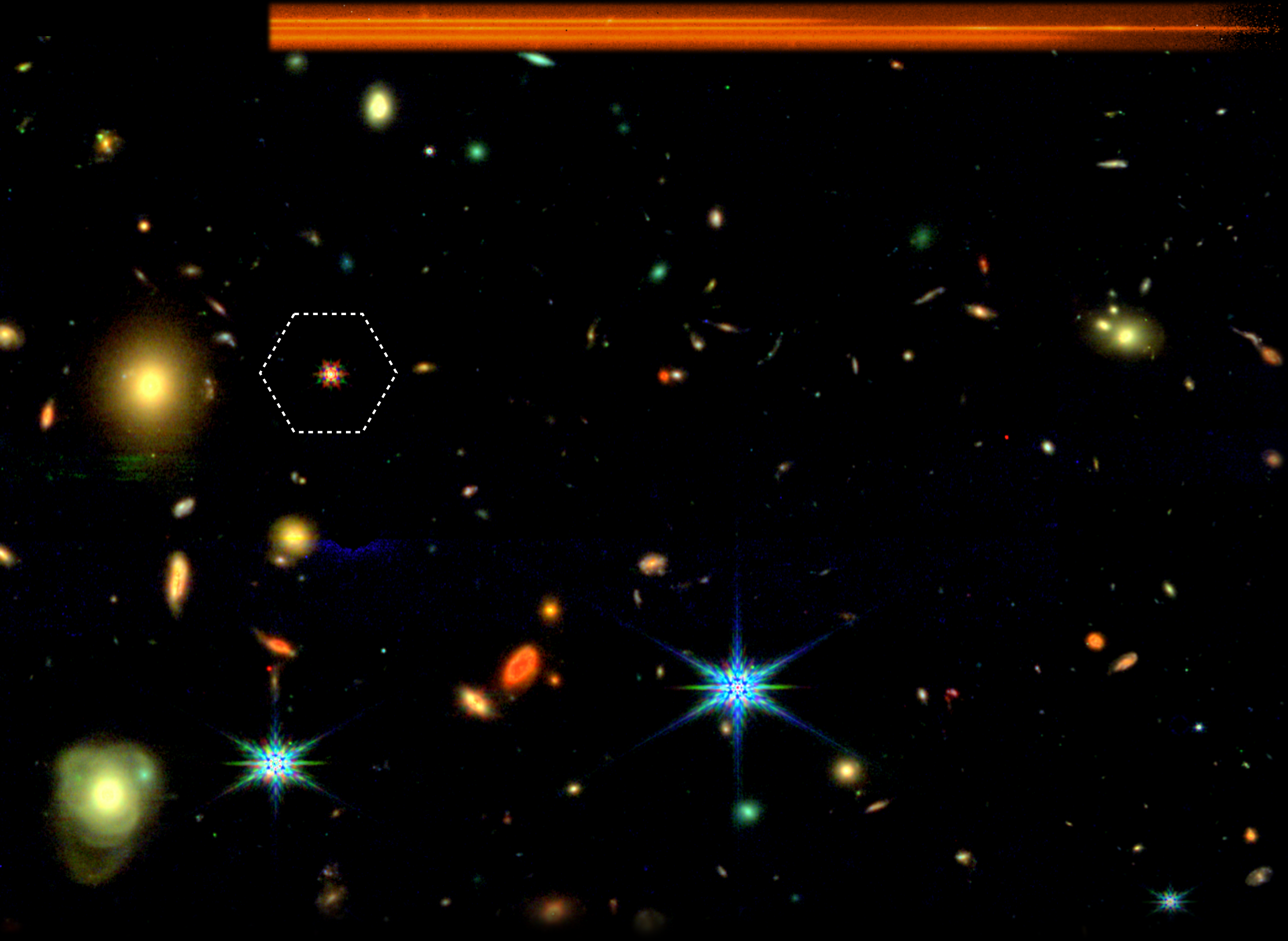
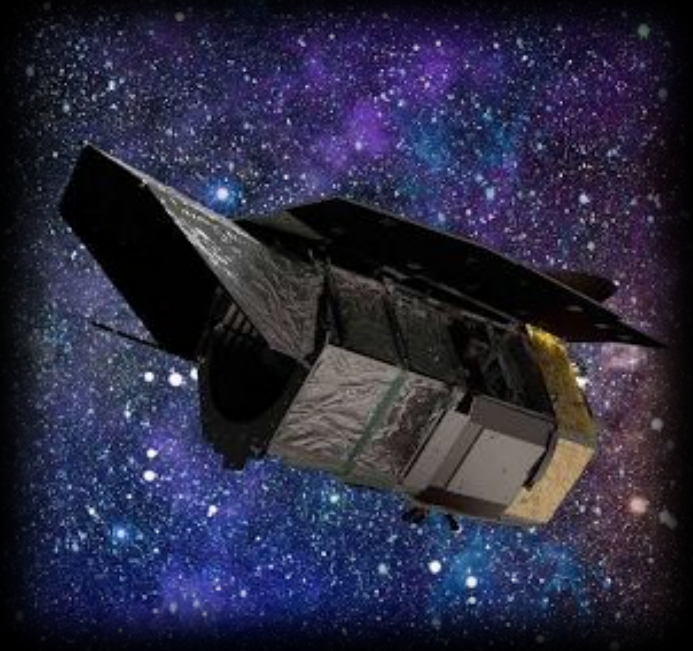


Probing Early SMBHs Using Roman and Rubin/LSST

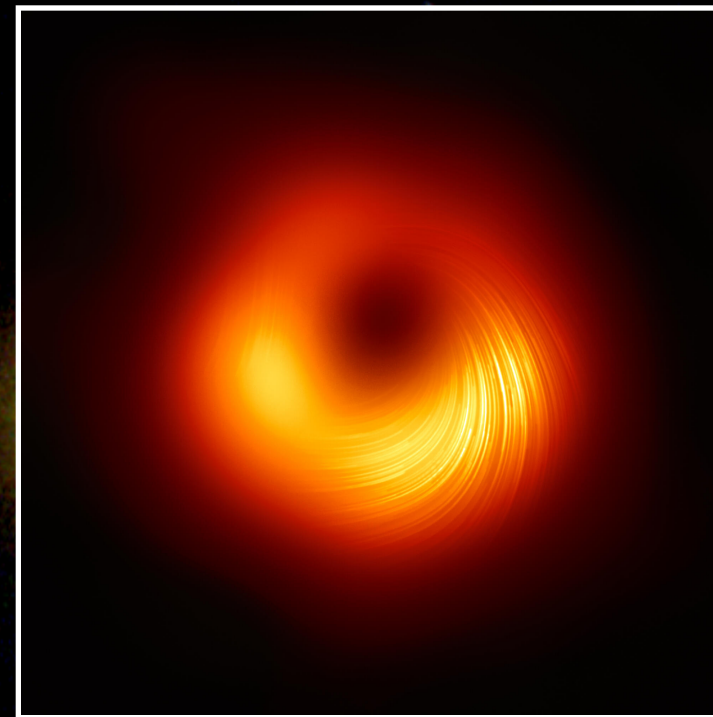


Jinyi Yang
University of Michigan
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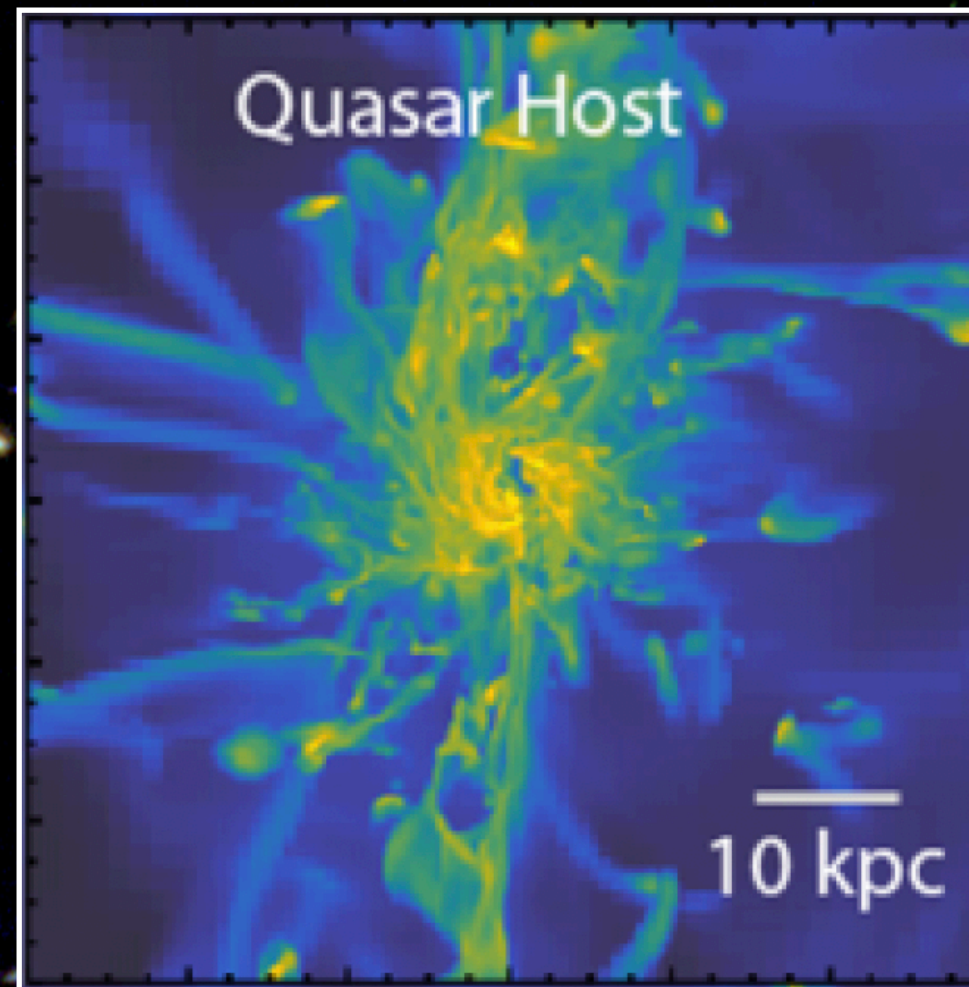


July 14 2026 @ Caltech

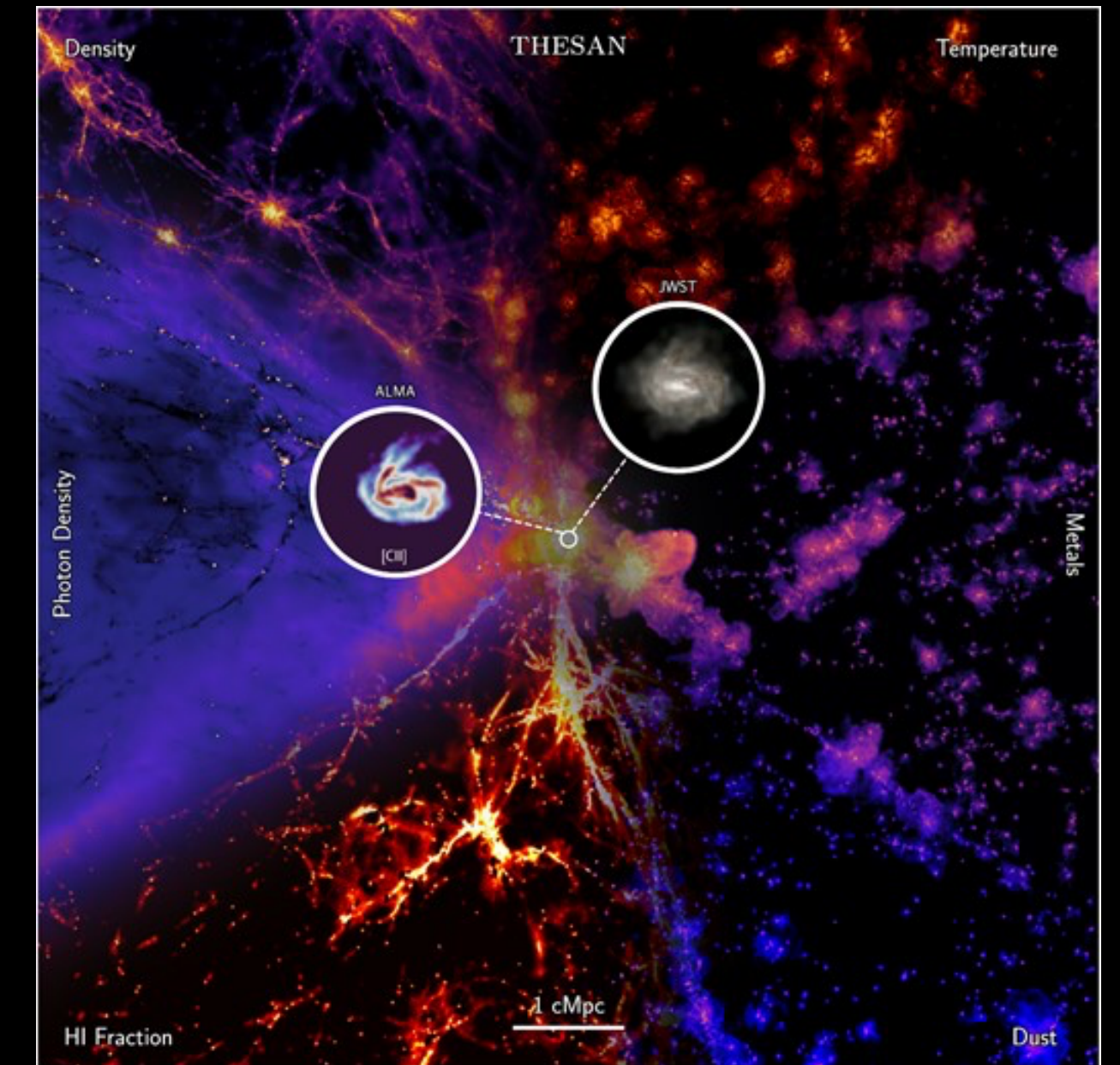
SMBHs in Early Universe



$10^{-5} - 10^{-2}$ pc
Seed and growth of
the earliest SMBH

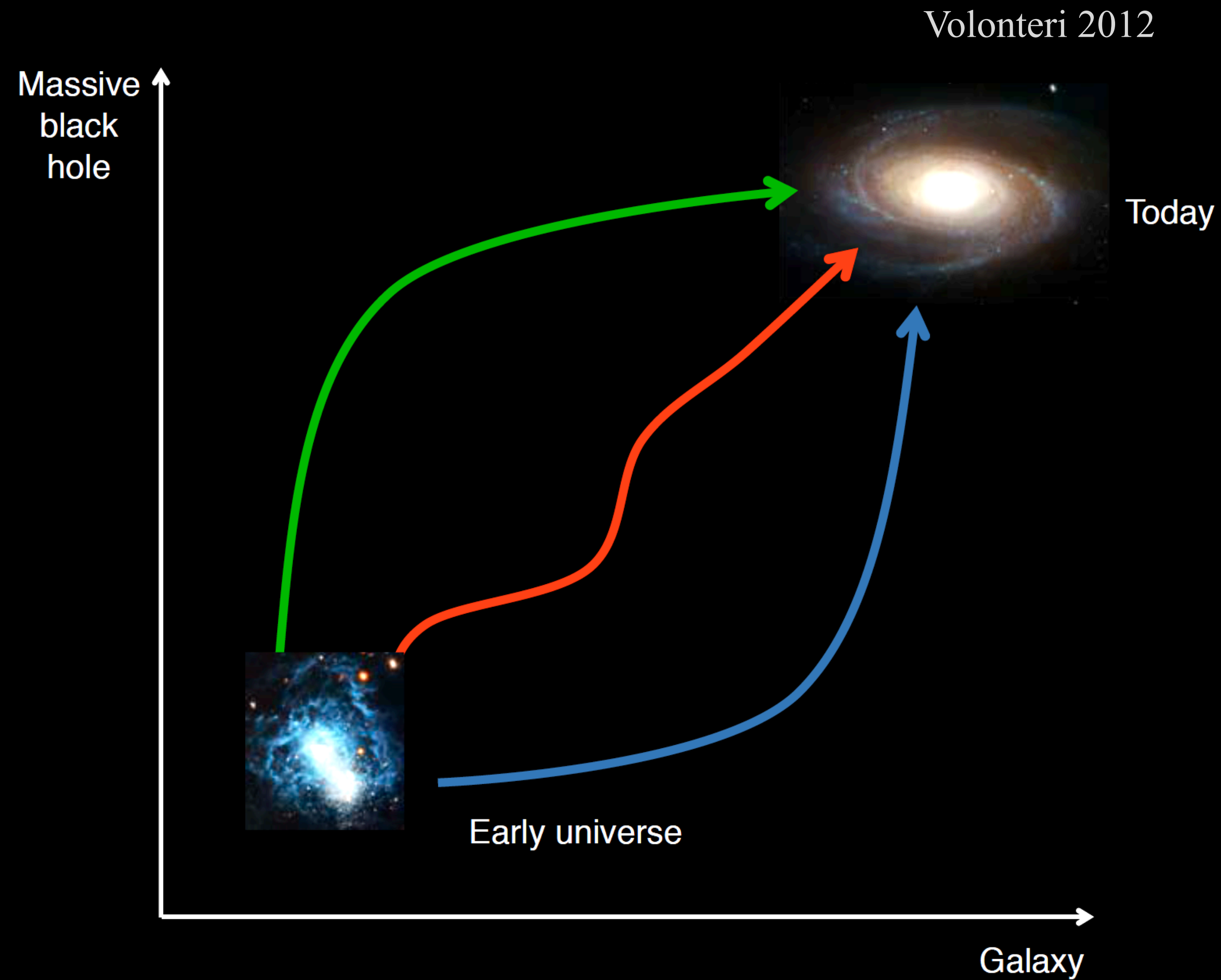


10 -100 kpc
Quasar feedback and
BH/galaxy co-evolution
at cosmic dawn

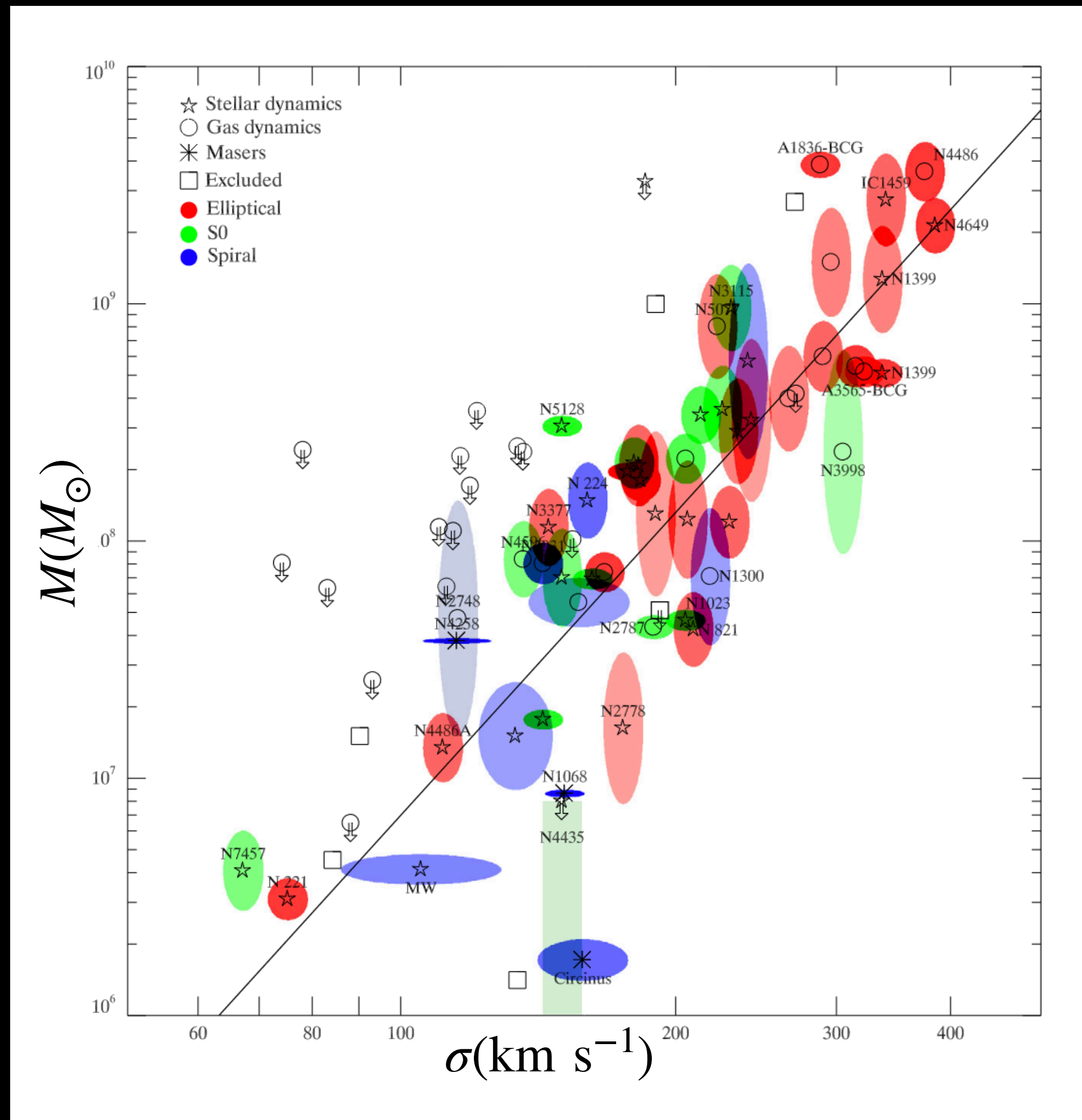


10-100 Mpc
Tracing the early large scale
structure and the history of
cosmic reionization

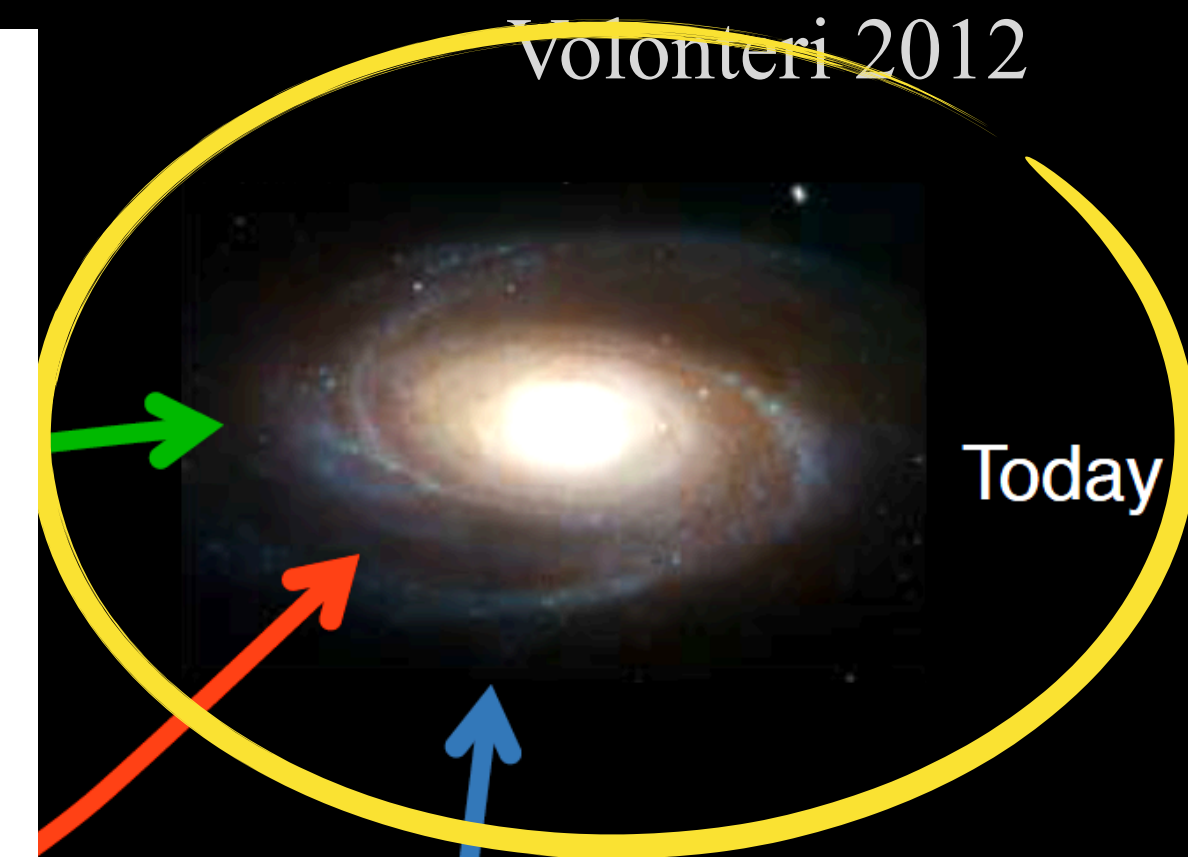
SMBH Growth and BH - Host Galaxy Co-evolution Across Redshifts



SMBH Growth and BH - Host Galaxy Co-evolution Across Redshifts



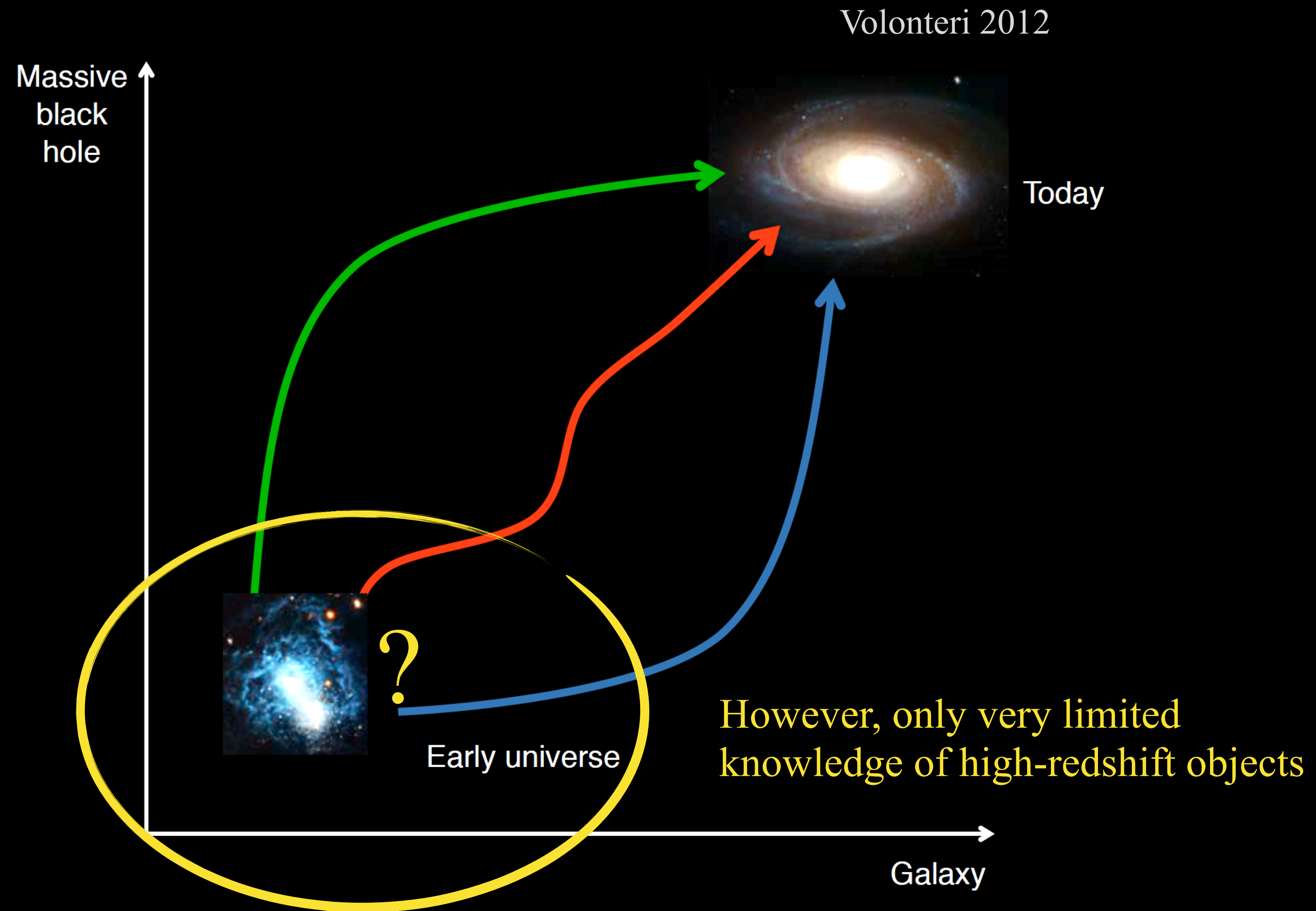
Gültekin, Richstone, Gebhardt et al. 2009

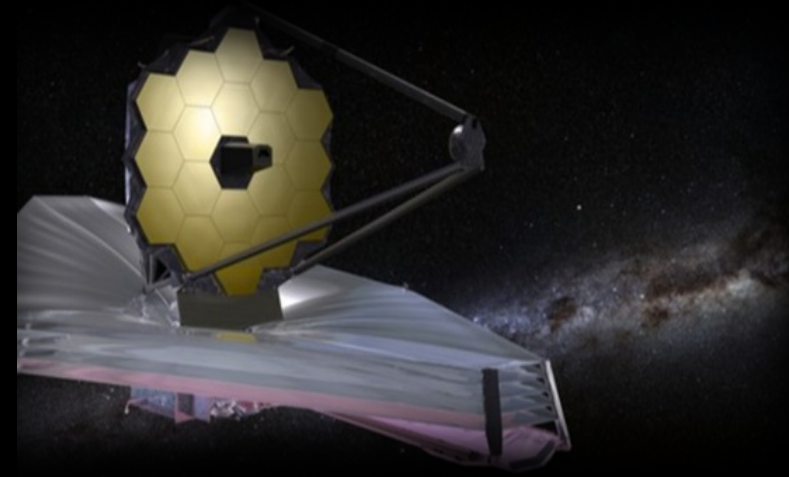


Relations between BH mass and galaxy properties have been observed at local Universe

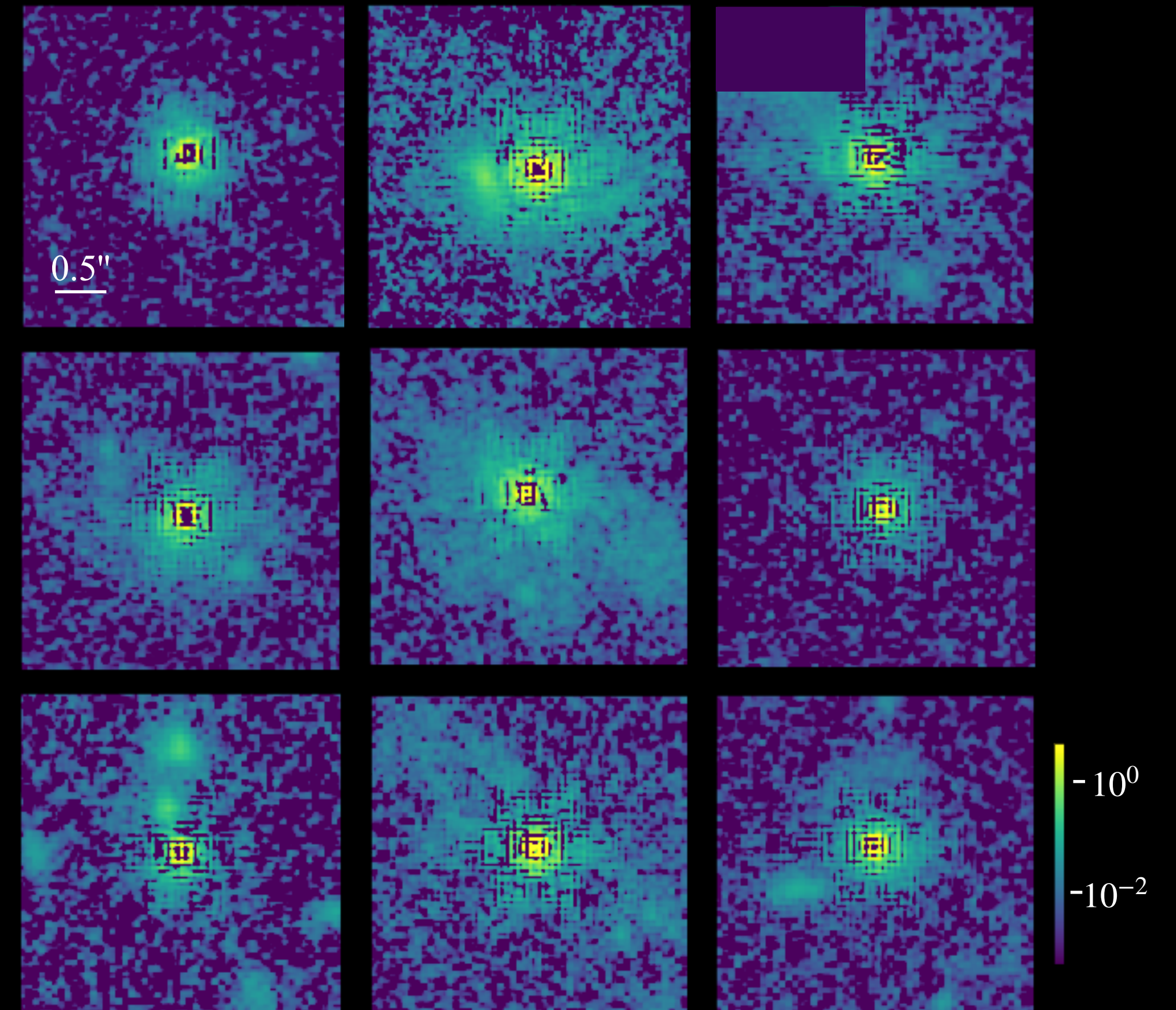
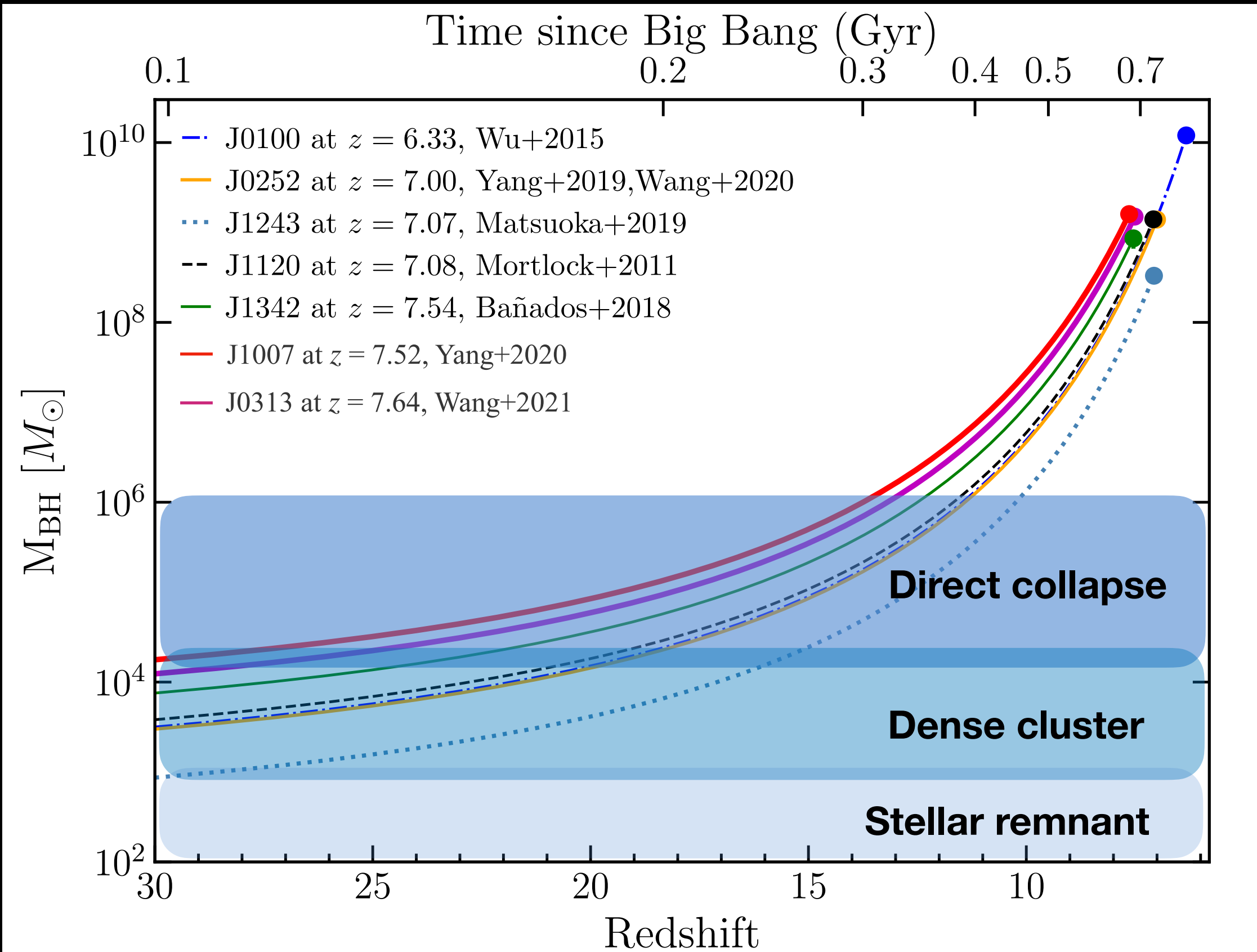
Galaxy

SMBH Growth and BH - Host Galaxy Co-evolution Across Redshifts



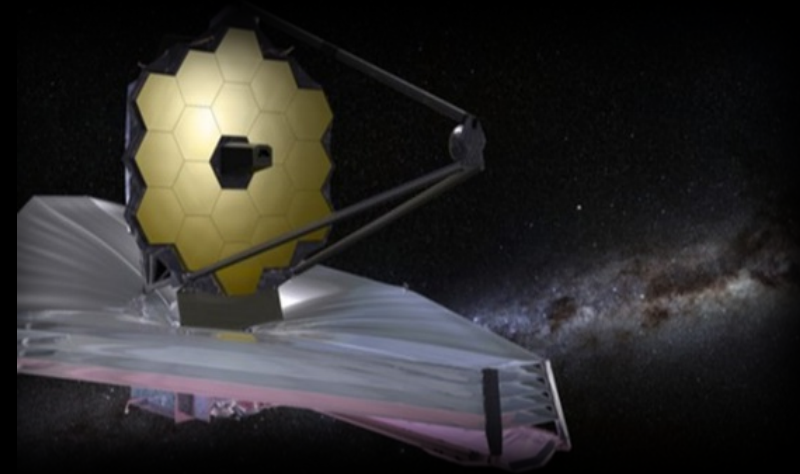


The *JWST* era

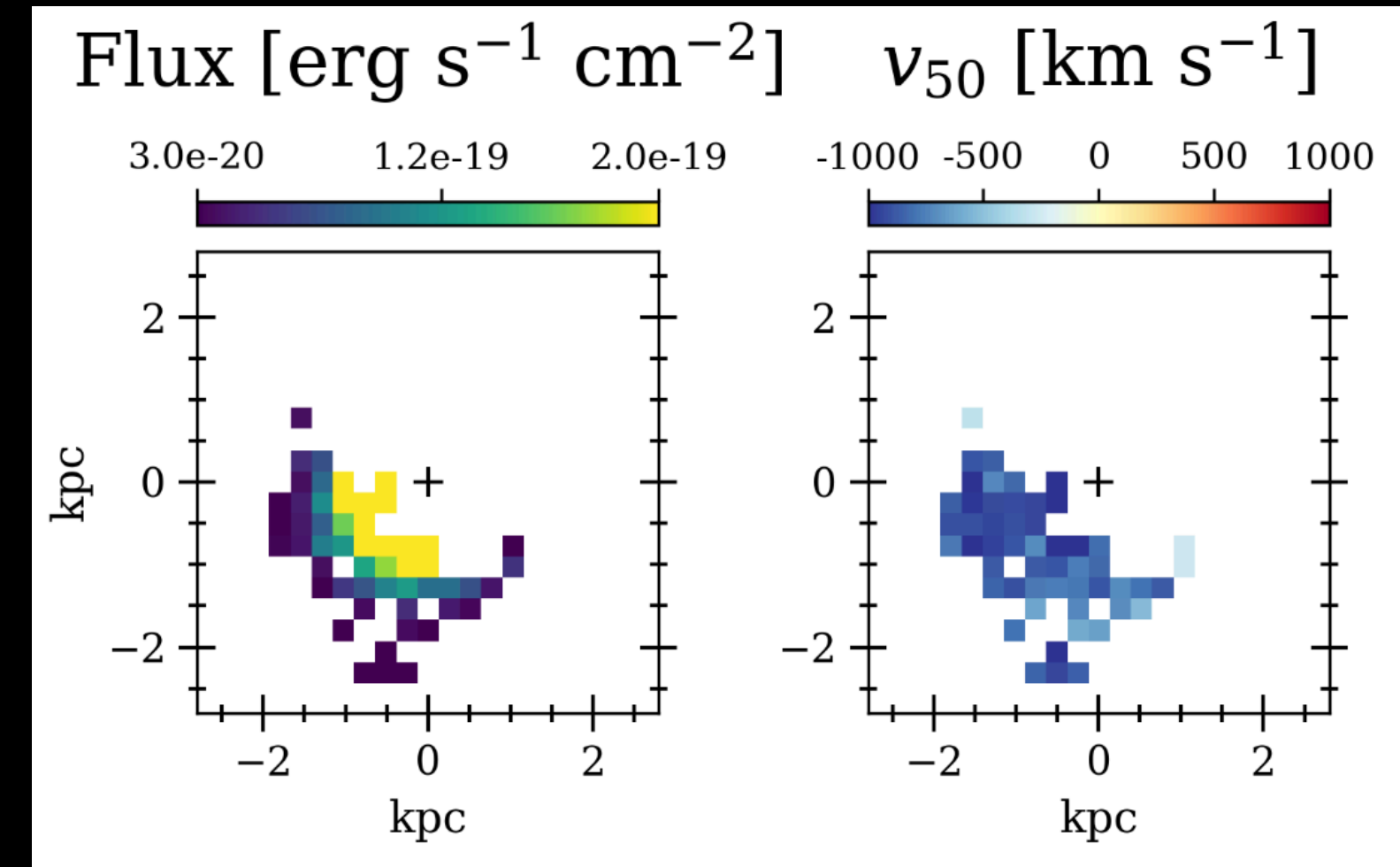


J. Yang et al. 2026 to be submitted

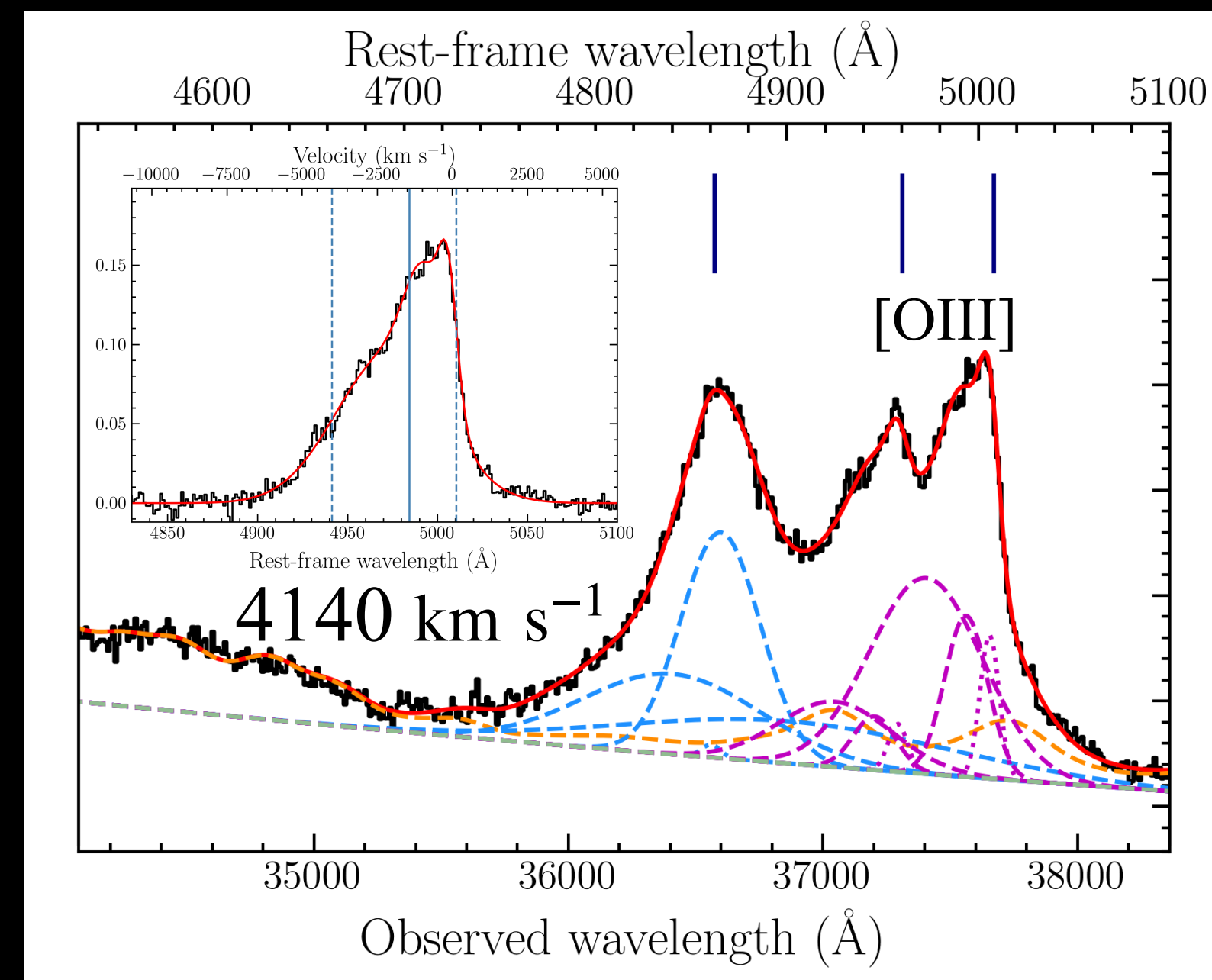
Massive BH seeds, rapid SMBH growth, diverse host galaxies, and complex small-scale environments



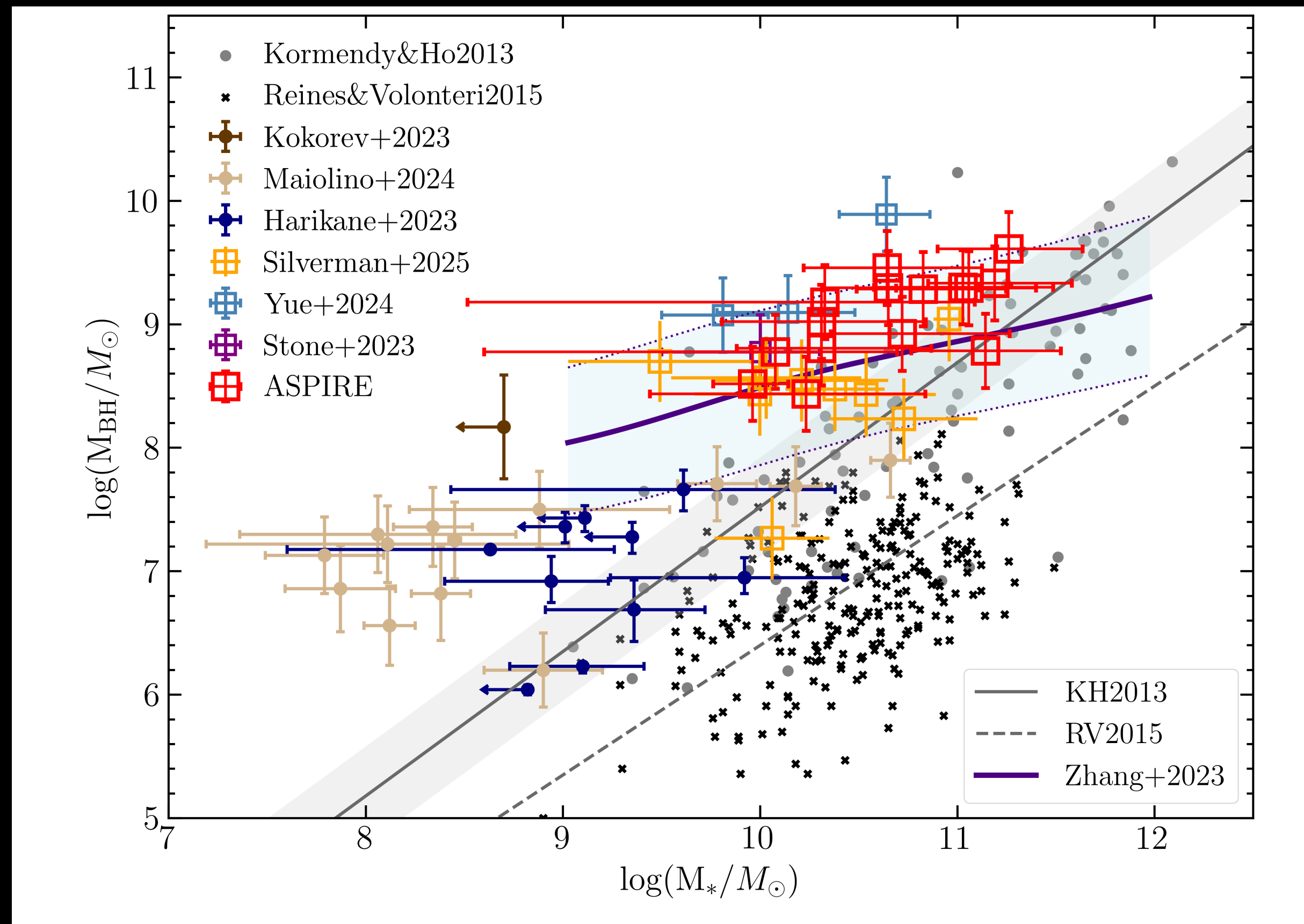
The *JWST* era



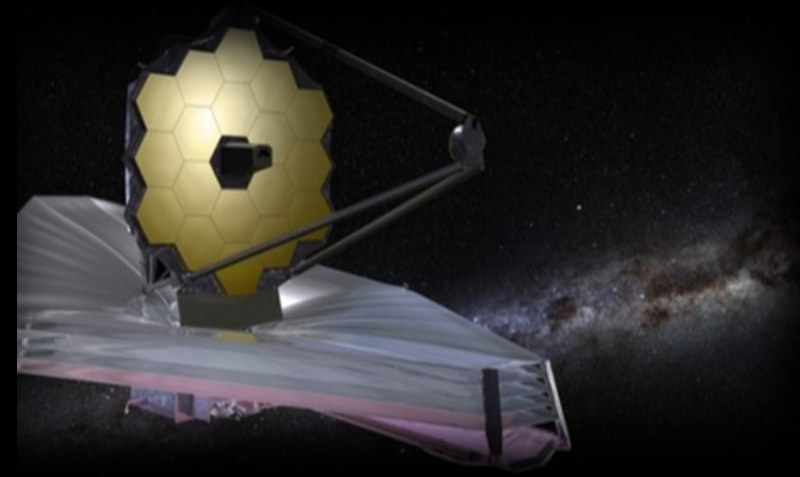
Liu, Fan, Yang et al. 2024



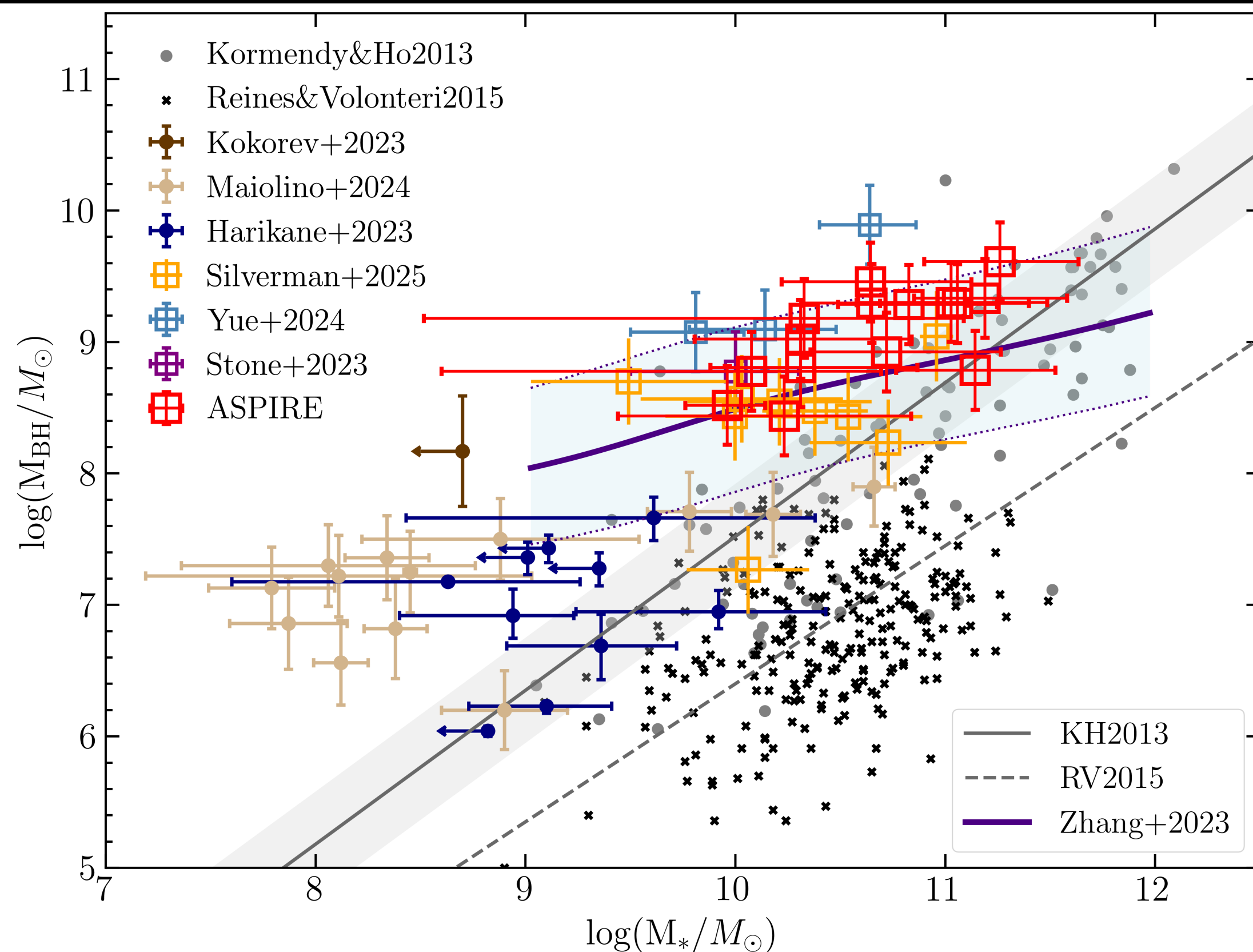
Yang et al. 2023



J. Yang et al. 2026 to be submitted



The *JWST* era



Whether there is a BH-host relation at $z > 6$
 — Yes

When and how the BH-host relation emerged

Whether and how the BH-host relation evolve over cosmic time

Targeting Early SMBHs in the Roman/LSST/Euclid era

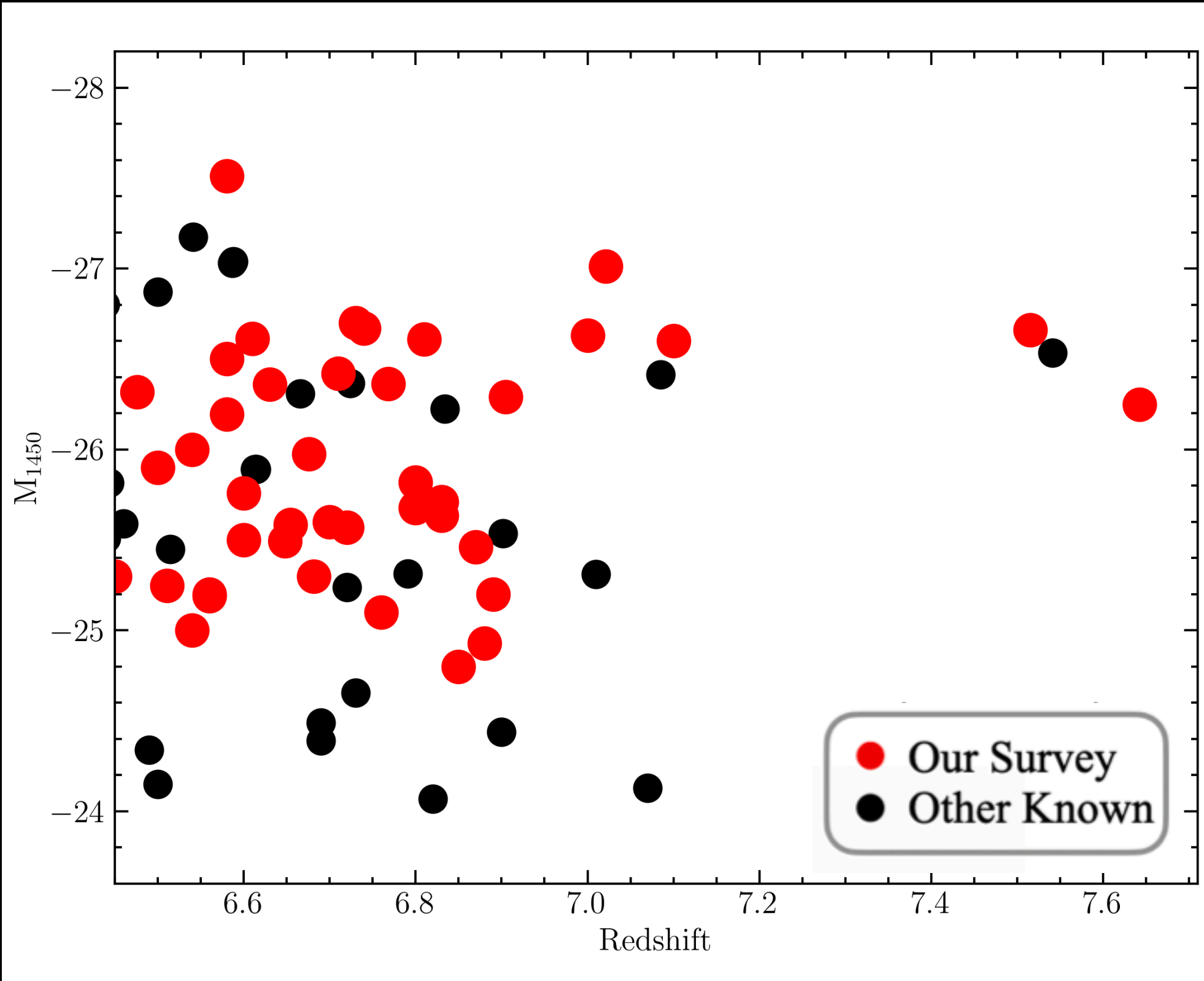
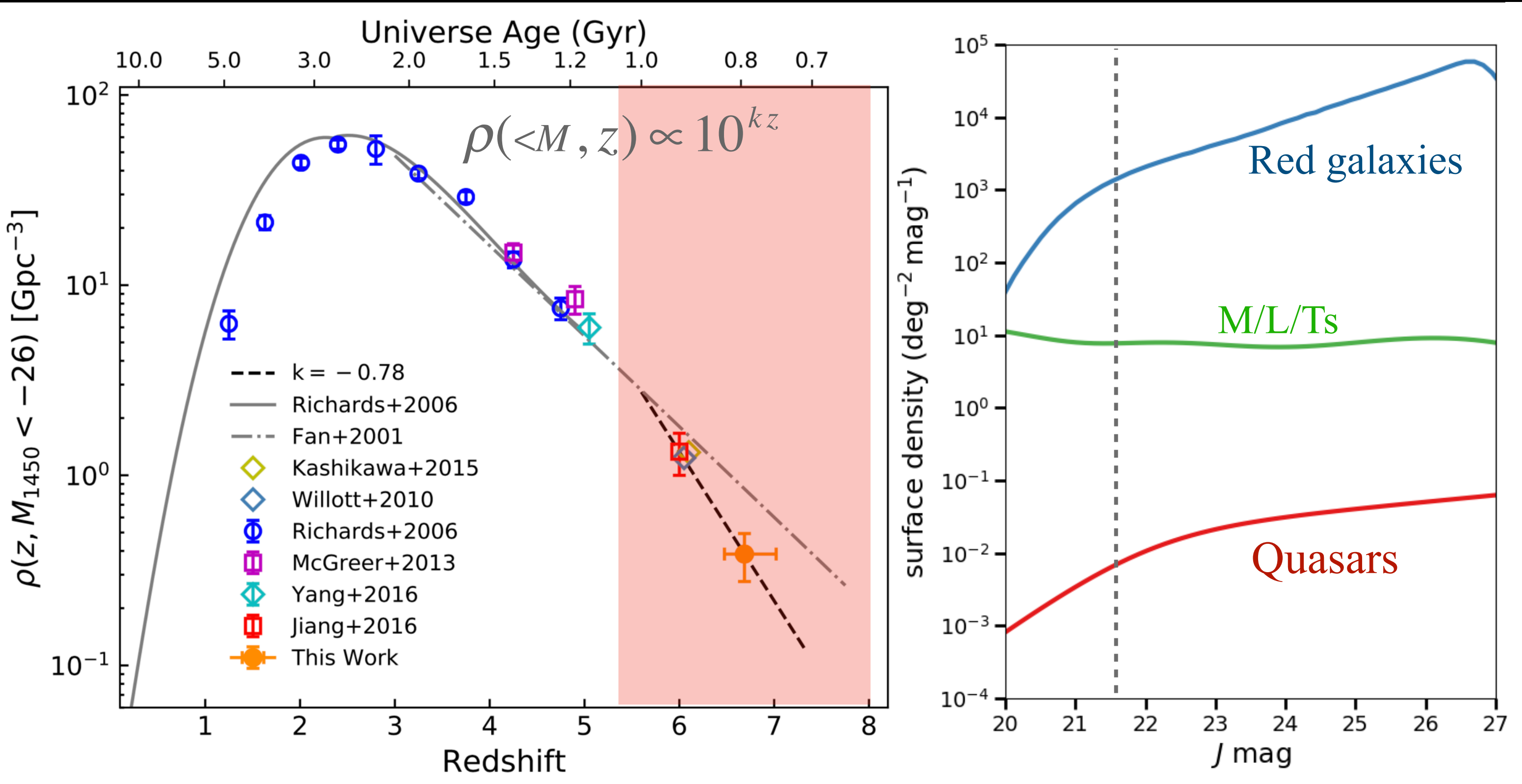
- $z \gtrsim 7$ quasars
- $z \sim 1-2$ Broad Line AGN (BLAGN) and Little Red Dot (LRD)

Reddened or obscured quasar/AGN *

Efforts started from quasar surveys in the past decade

Low density of high-redshift quasars

Contaminants have
 $10^3\text{--}5$ times higher densities



Wang, Yang et al. 2019

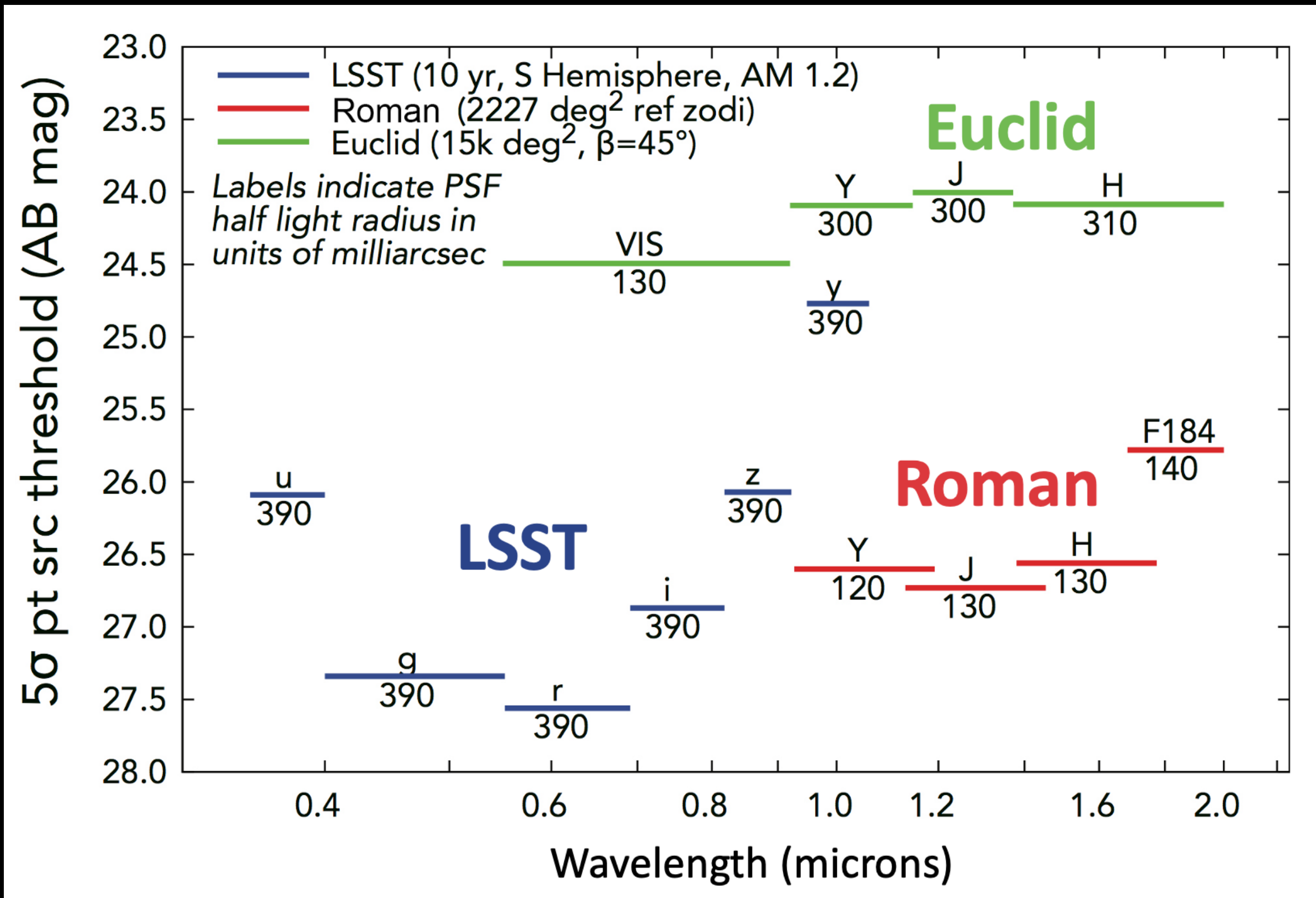
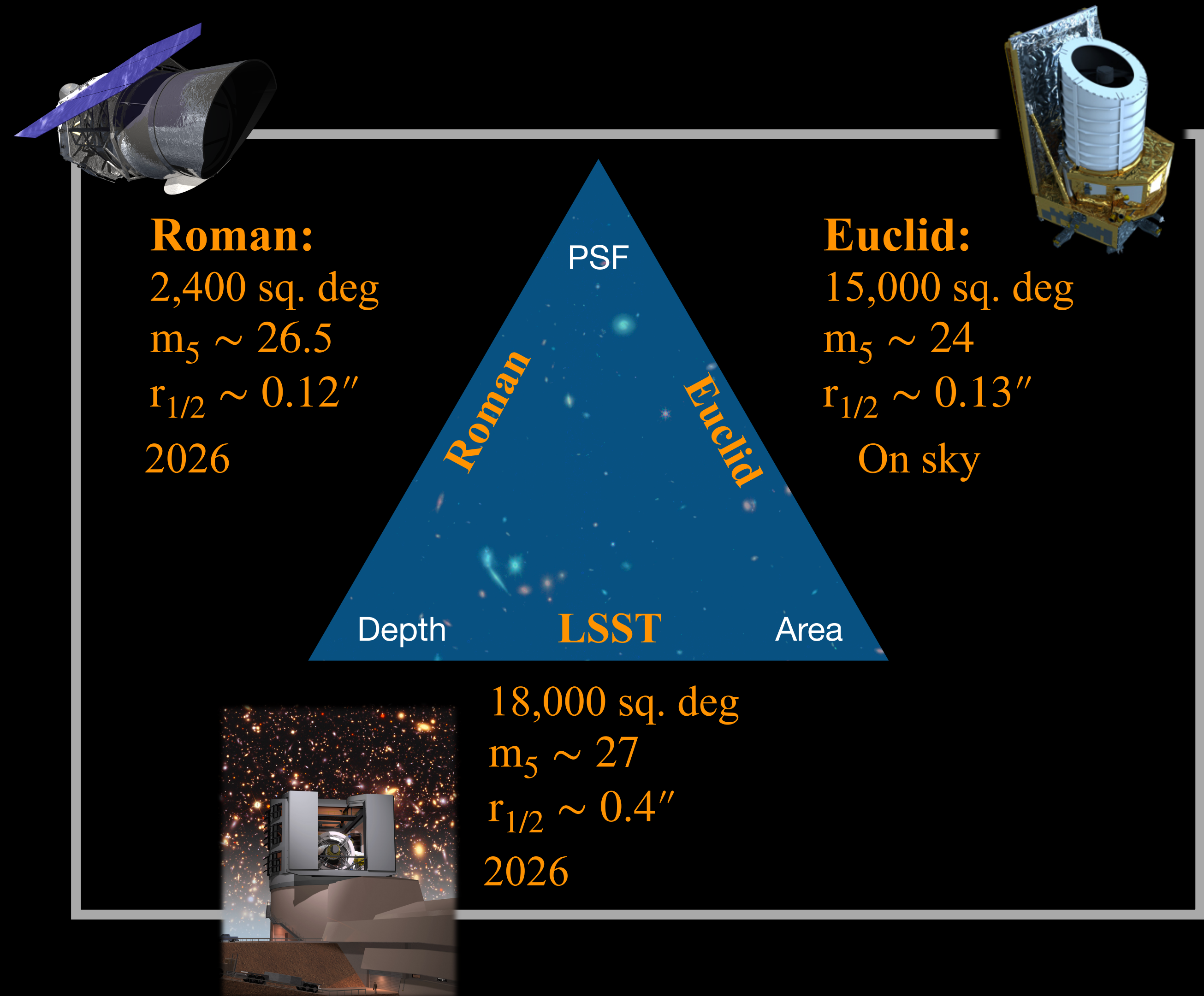
Tee ... Yang et al. 2023

F. Wang, J. Yang et al. 2019, ApJ, 884, 30
J. Yang et al. 2019, AJ, 157, 236
J. Yang et al. 2020, ApJL, 897, 14
F. Wang, J. Yang et al. 2021, ApJL, 907, 1
J. Yang et al. 2021, ApJ, 923, 262

Also Banados+, Fan+, Mortlock+, Matsuoka+, Reed+, Venemans+, and Willott+, in the past two decades.

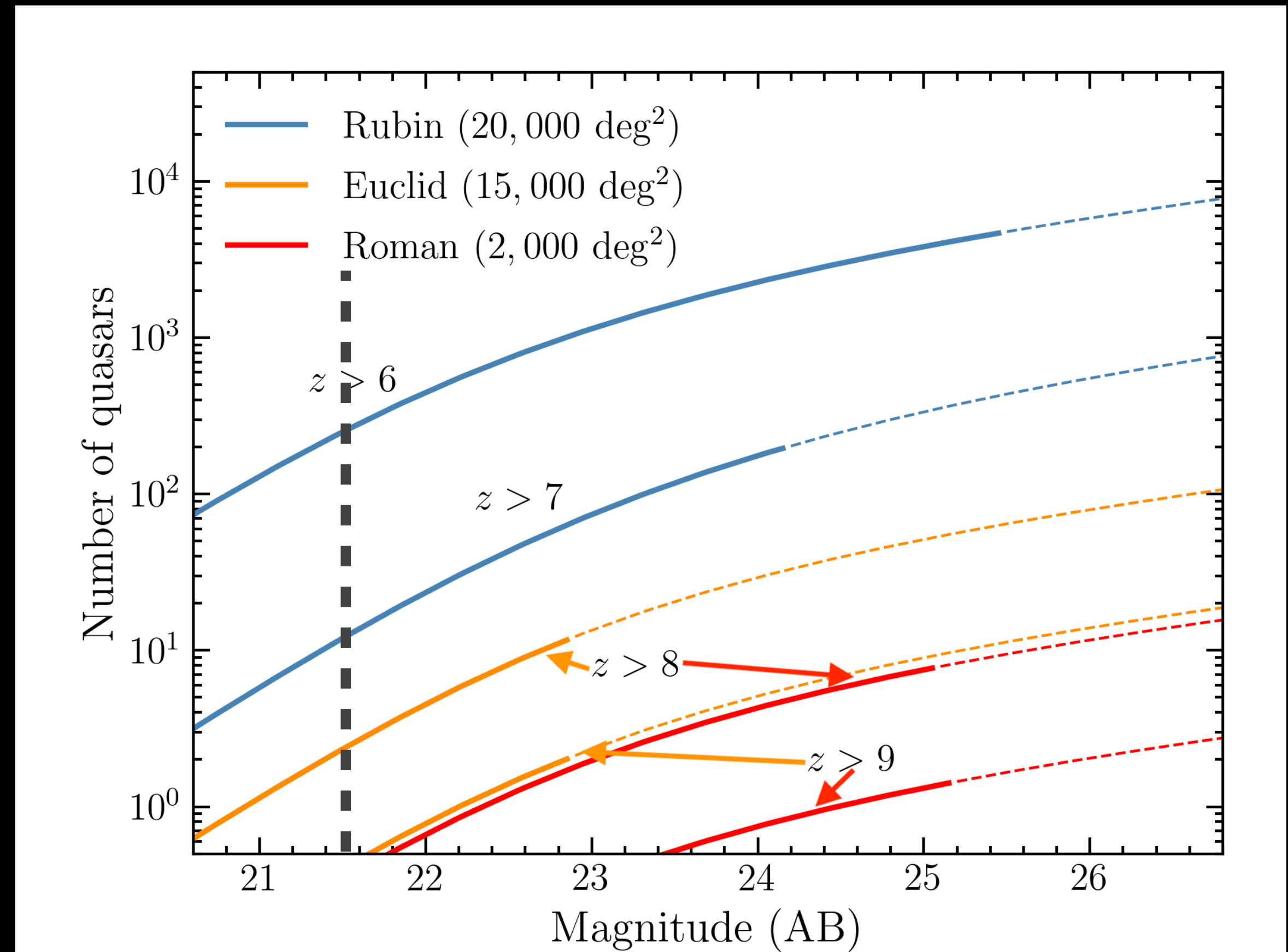
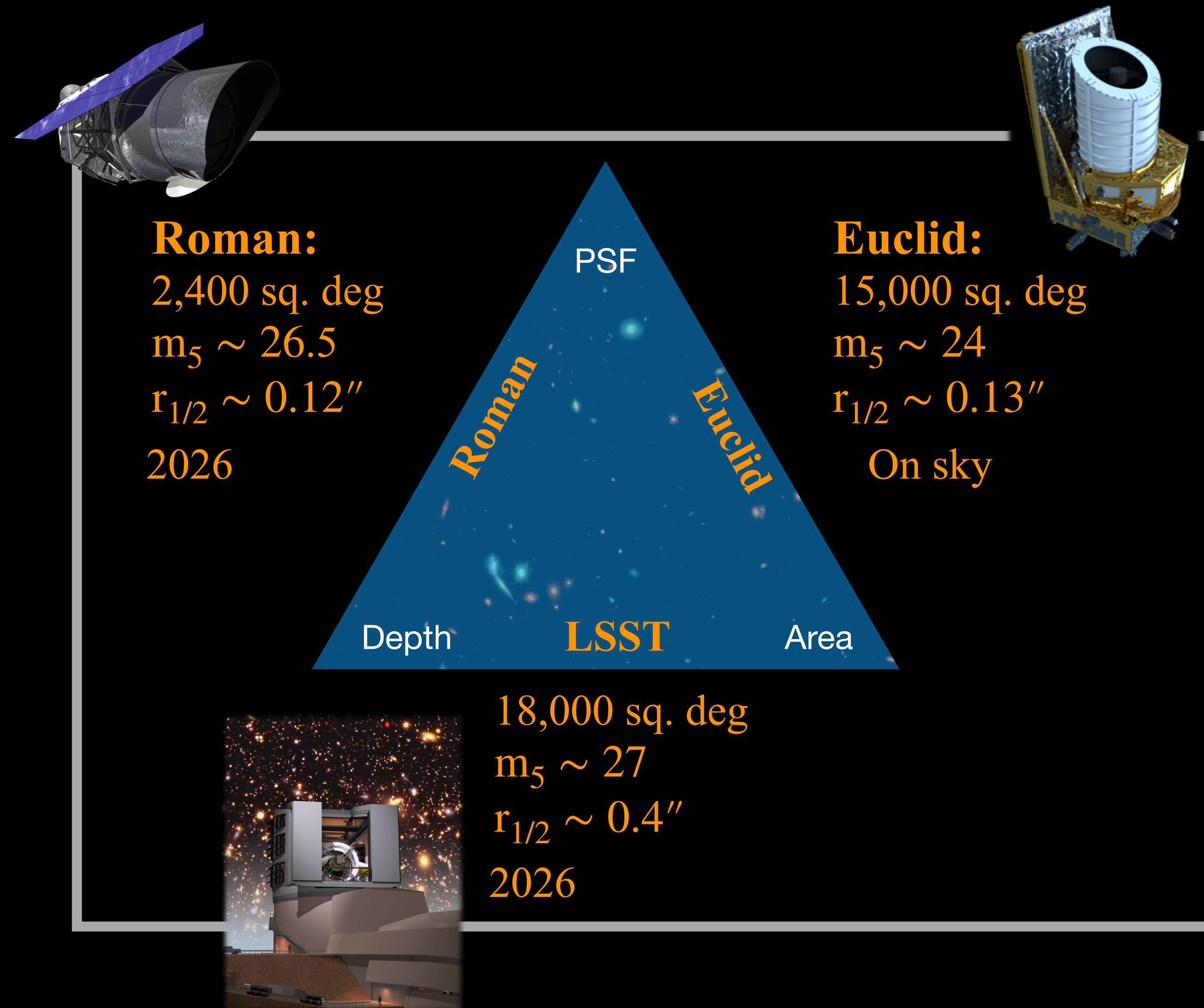
Roman/LSST/Euclid era

To target the “first” luminous quasar at $z \sim 9-10$, reaching to the fainter end and earlier phase of BH growth



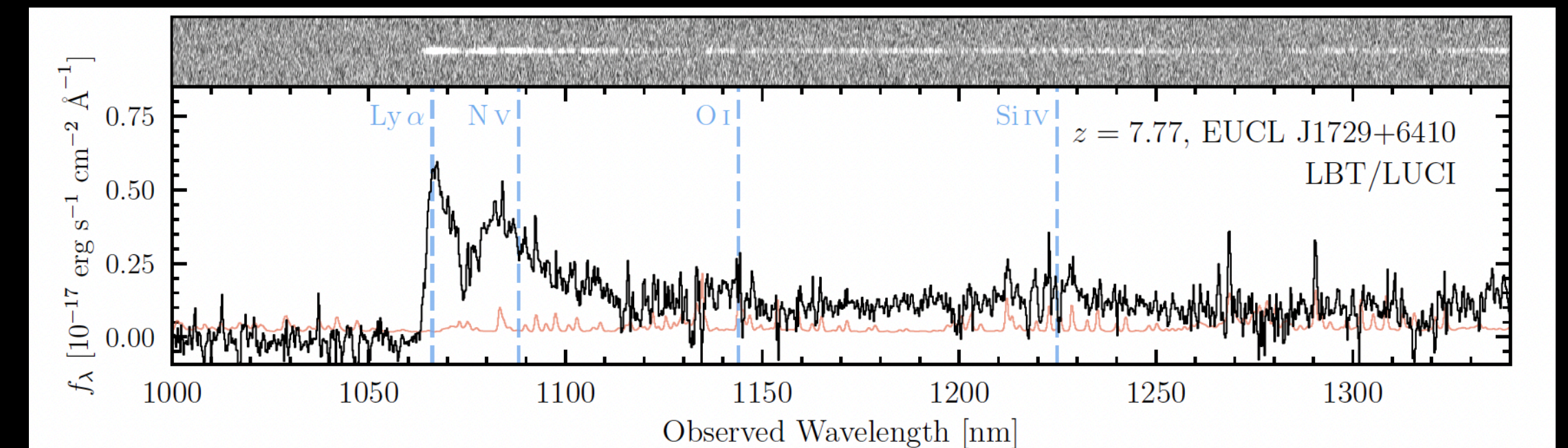
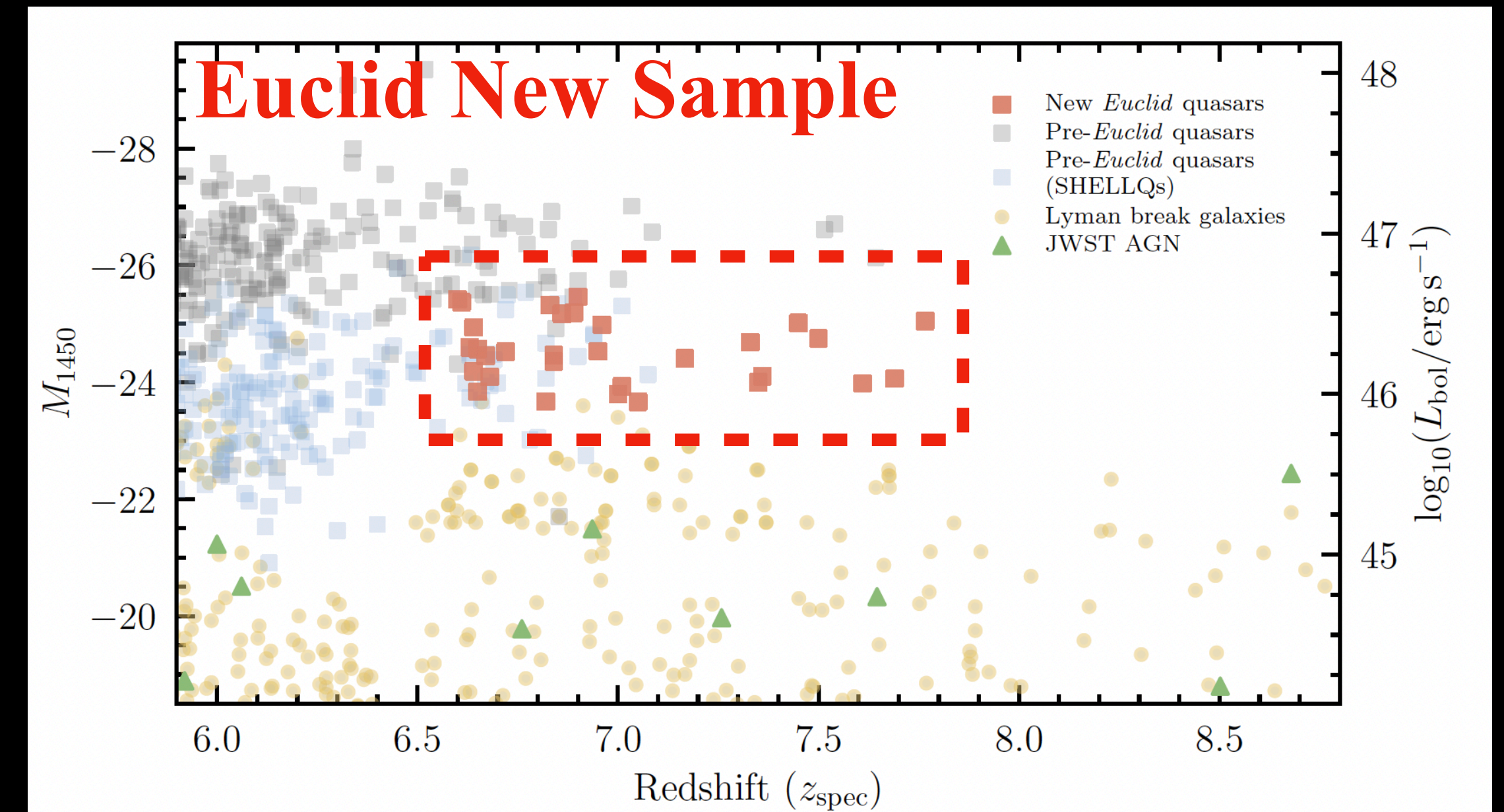
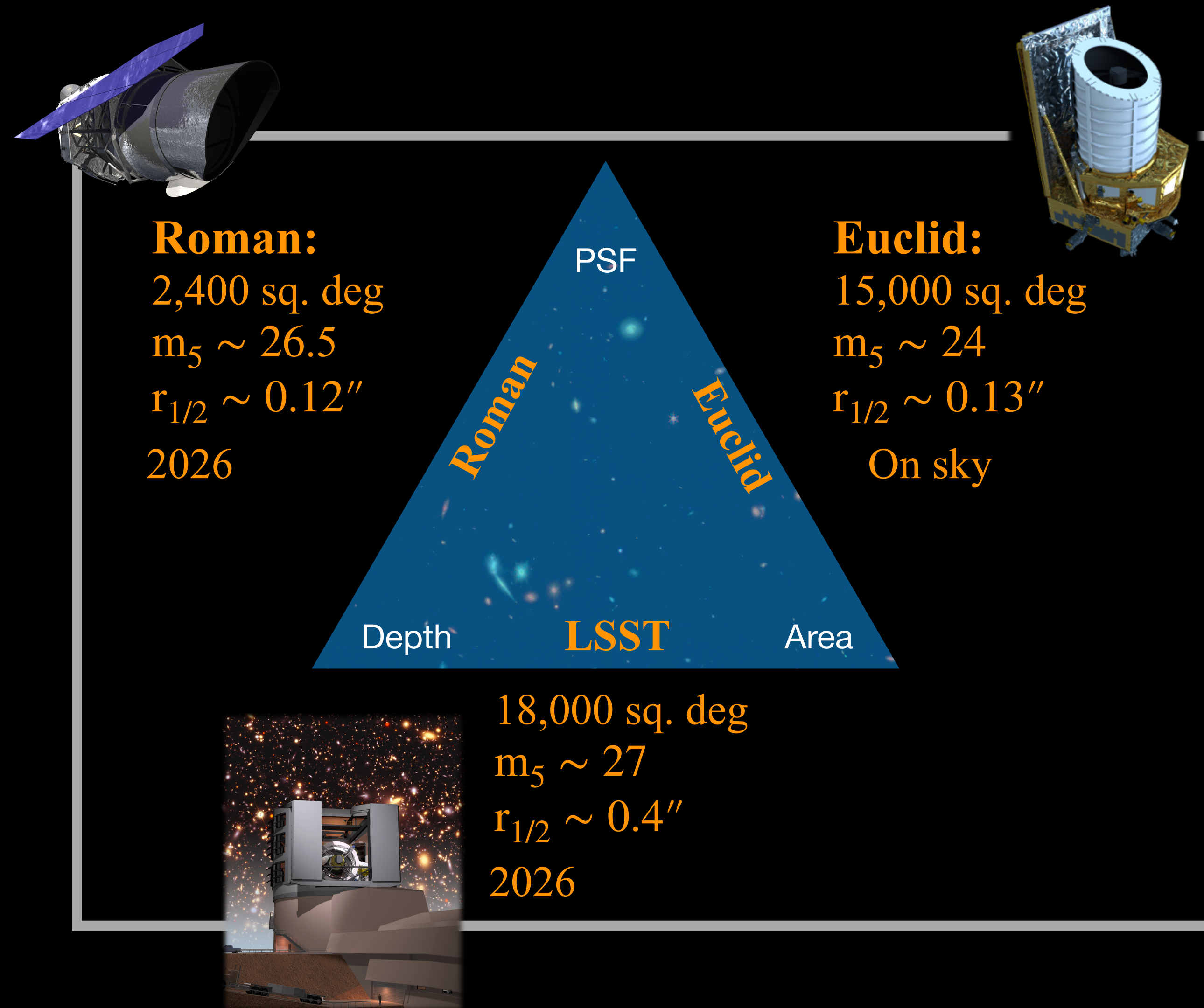
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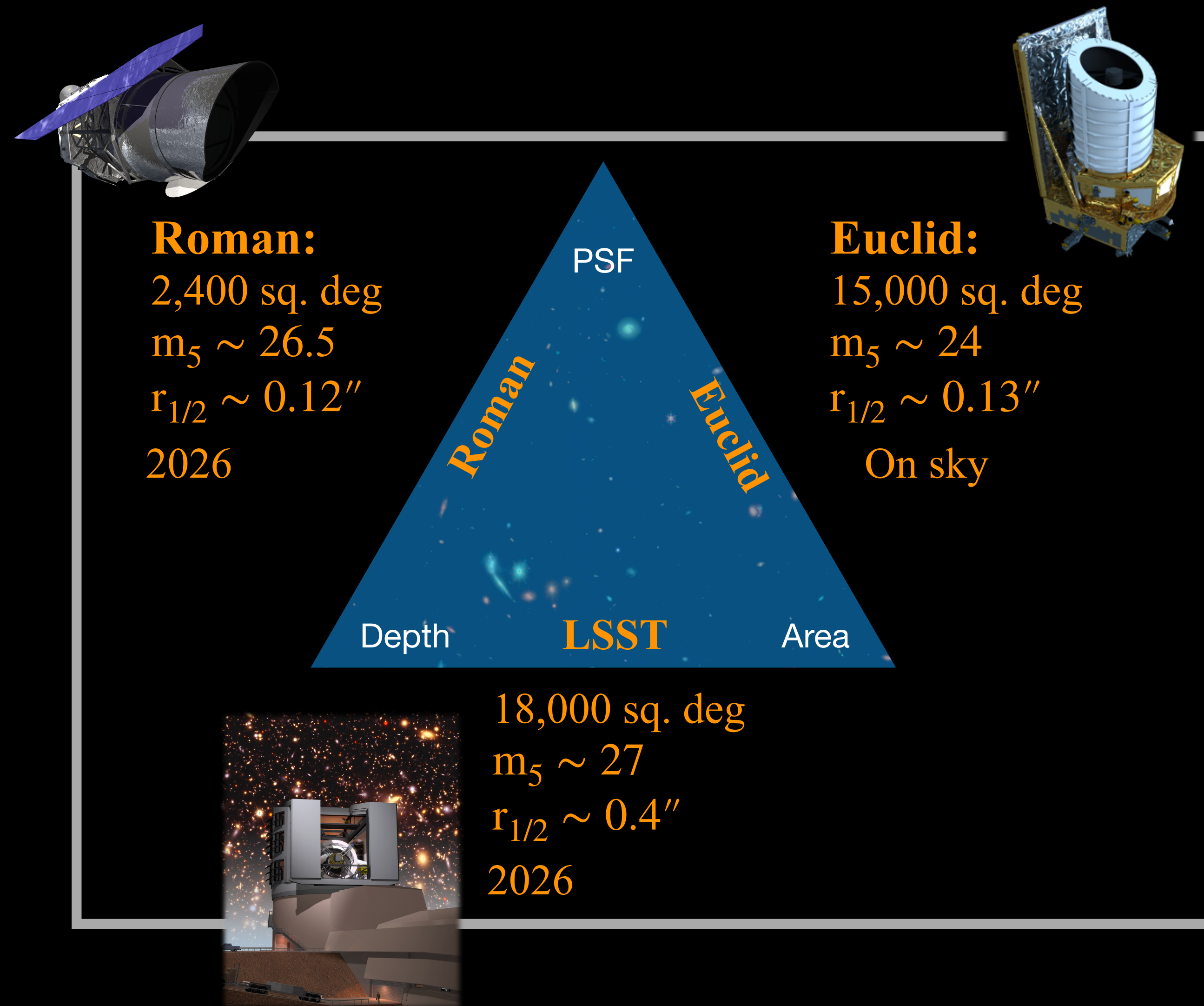
Roman/LSST/Euclid era

To target the “first” luminous quasar at $z \sim 9-10$, reaching to the fainter end and earlier phase of BH growth



Roman/LSST/Euclid era

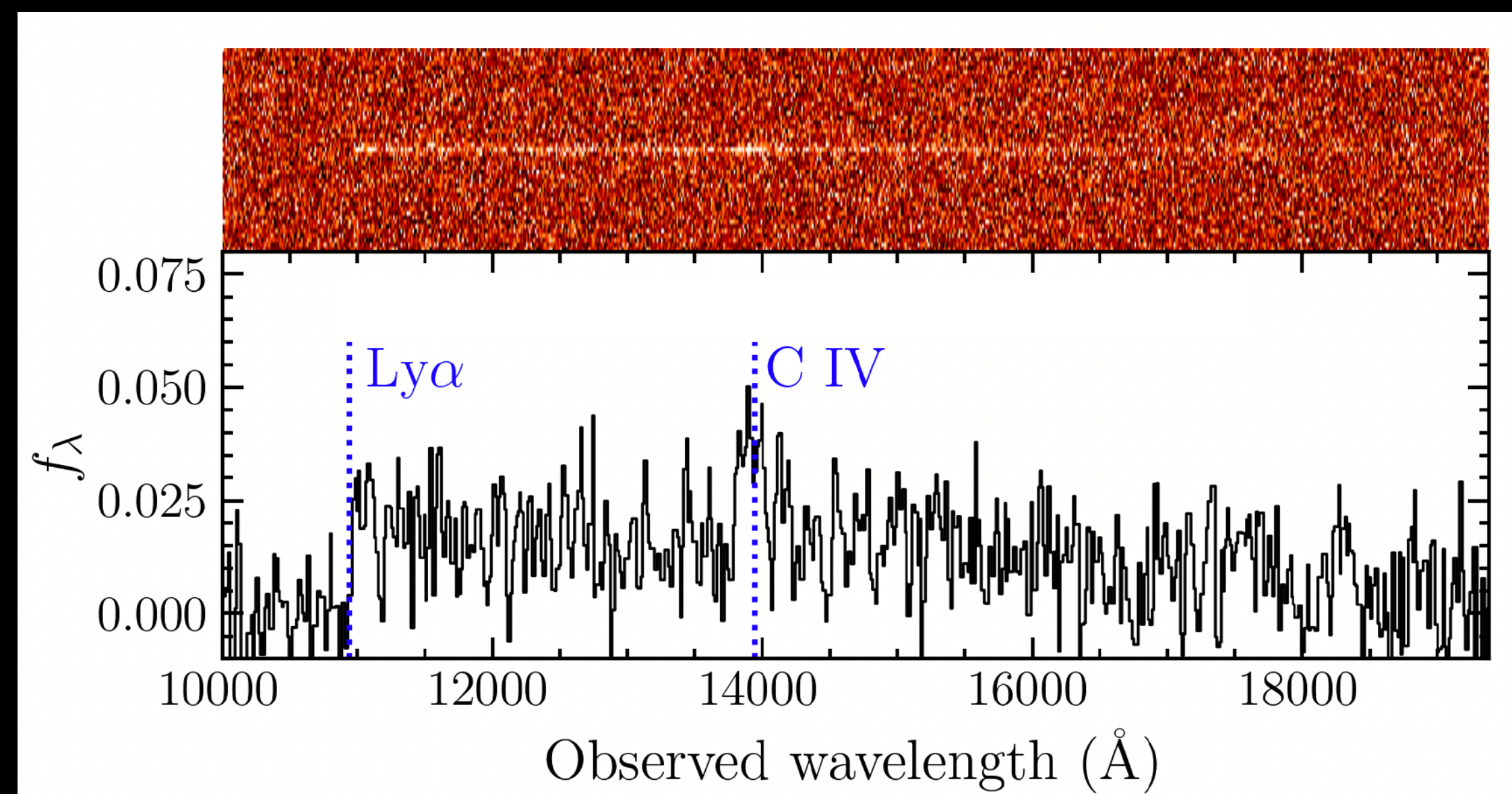
To target the “first” luminous quasar at $z \sim 9-10$, reaching to the fainter end and earlier phase of BH growth



In the first two years (Spectroscopy):

$\sim 3 - 12$ $z > 7.2$ quasars in the medium tier

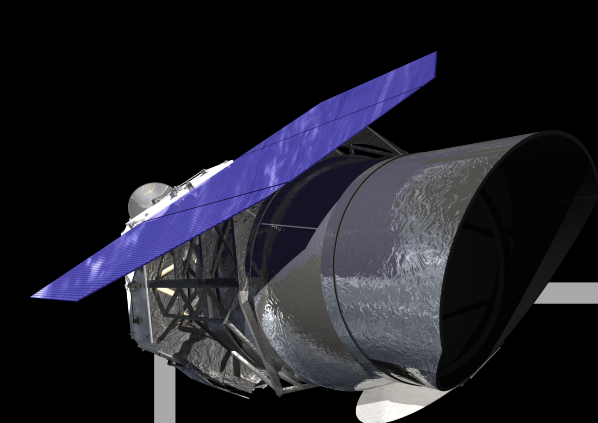
$\sim 0.5 - 4$ $z > 7.2$ quasars in the deep tier



Simulated Roman spectrum of $z \sim 8$ quasar

Roman/LSST/Euclid era

To target the “first” luminous quasar at $z \sim 9-10$, reaching to the fainter end and earlier phase of BH growth



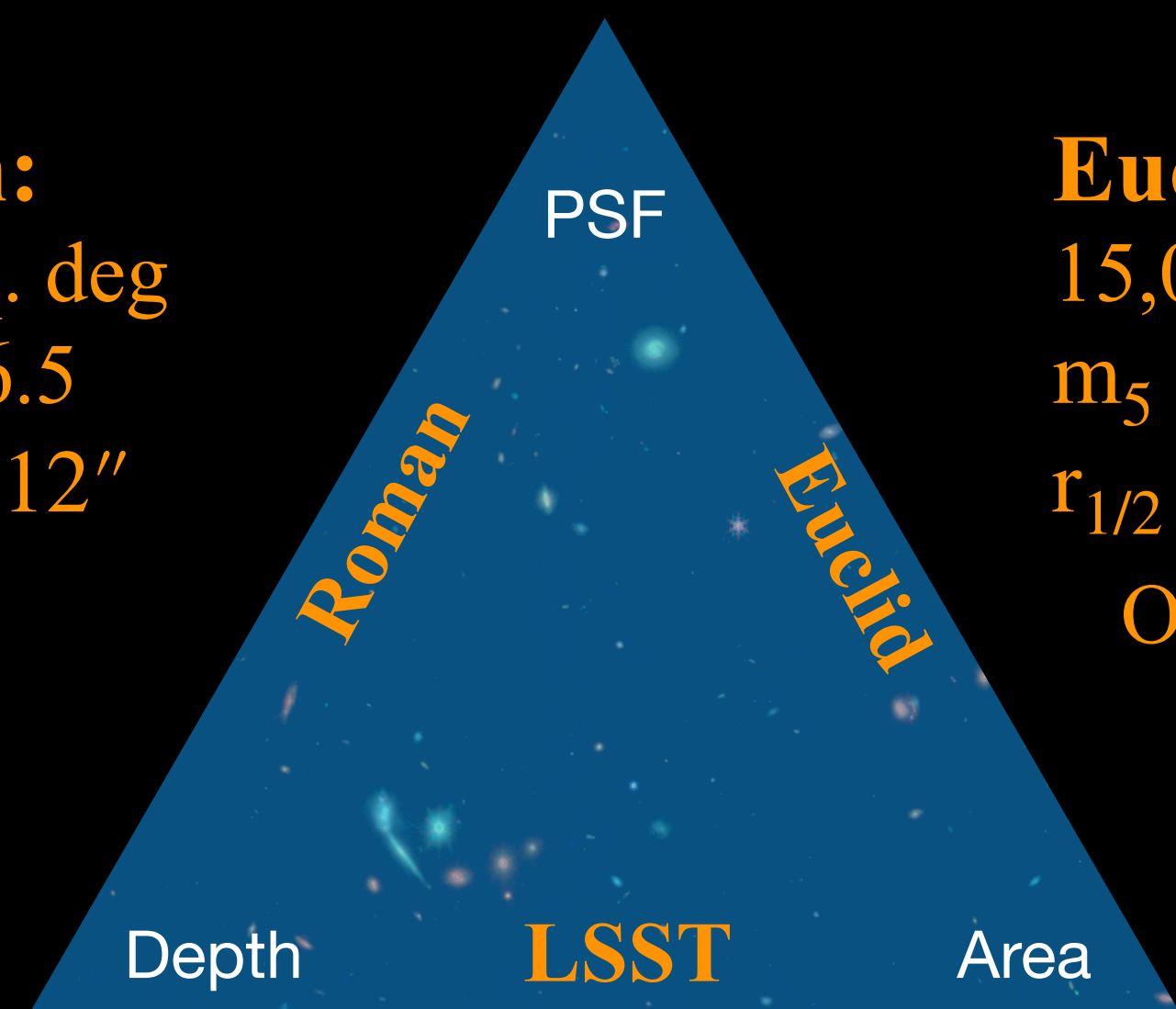
Roman:

2,400 sq. deg

$m_5 \sim 26.5$

$r_{1/2} \sim 0.12''$

2026



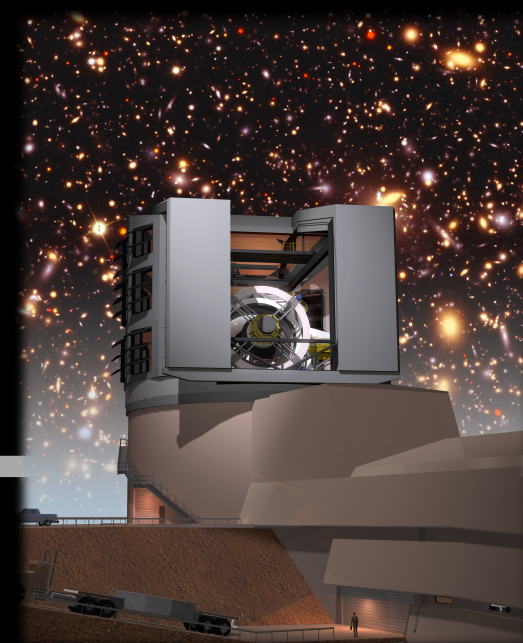
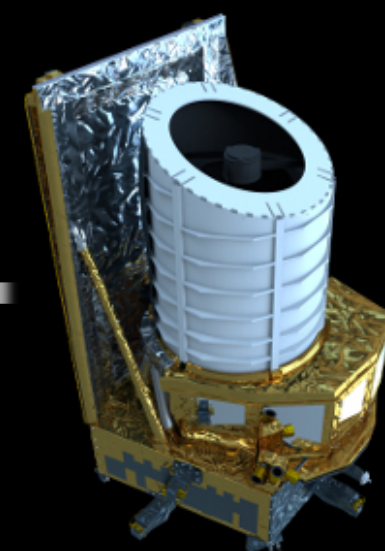
Euclid:

15,000 sq. deg

$m_5 \sim 24$

$r_{1/2} \sim 0.13''$

On sky



18,000 sq. deg

$m_5 \sim 27$

$r_{1/2} \sim 0.4''$

2026

In the first two years (Spectroscopy):

$\sim 3 - 12$ $z > 7.2$ quasars in the medium tier

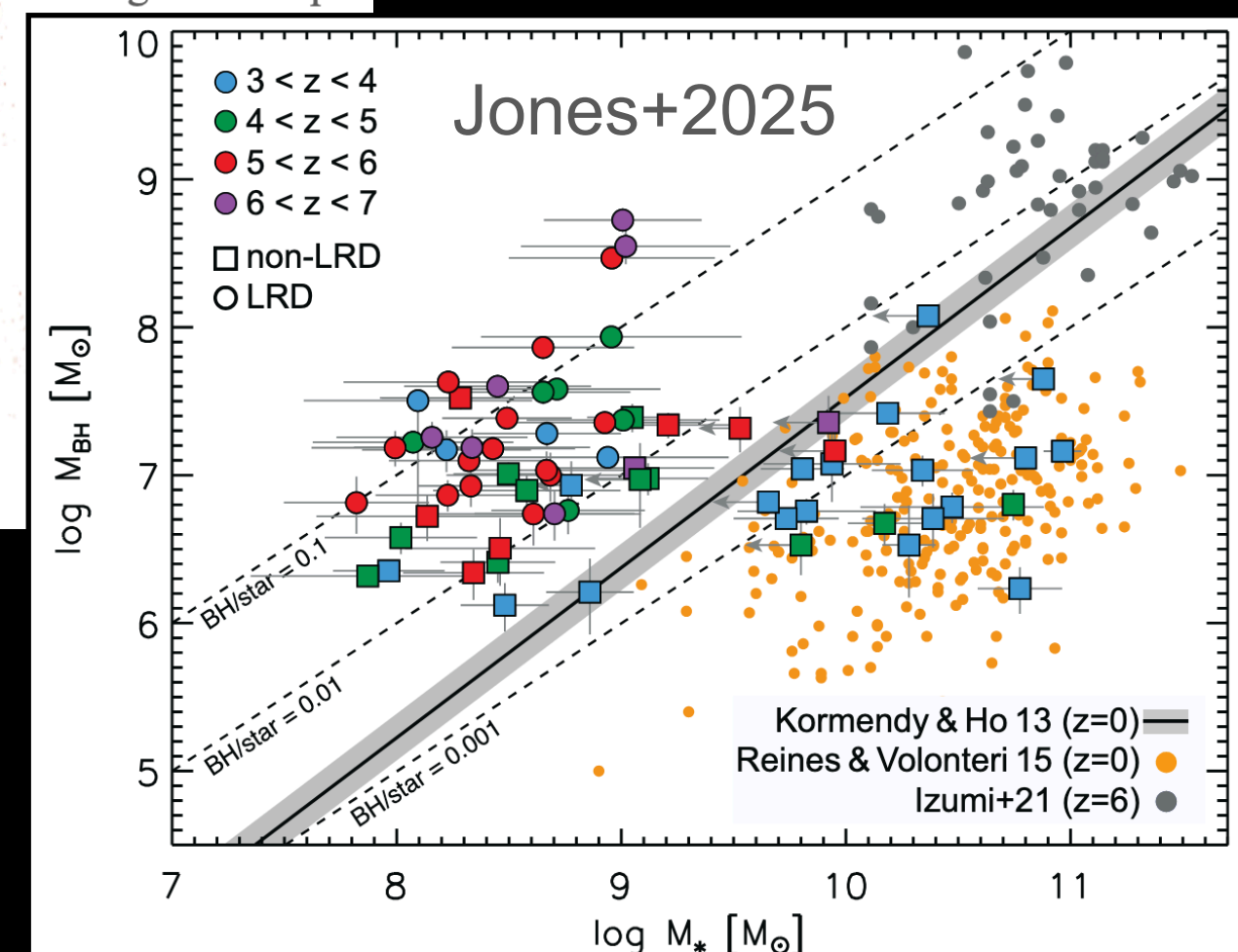
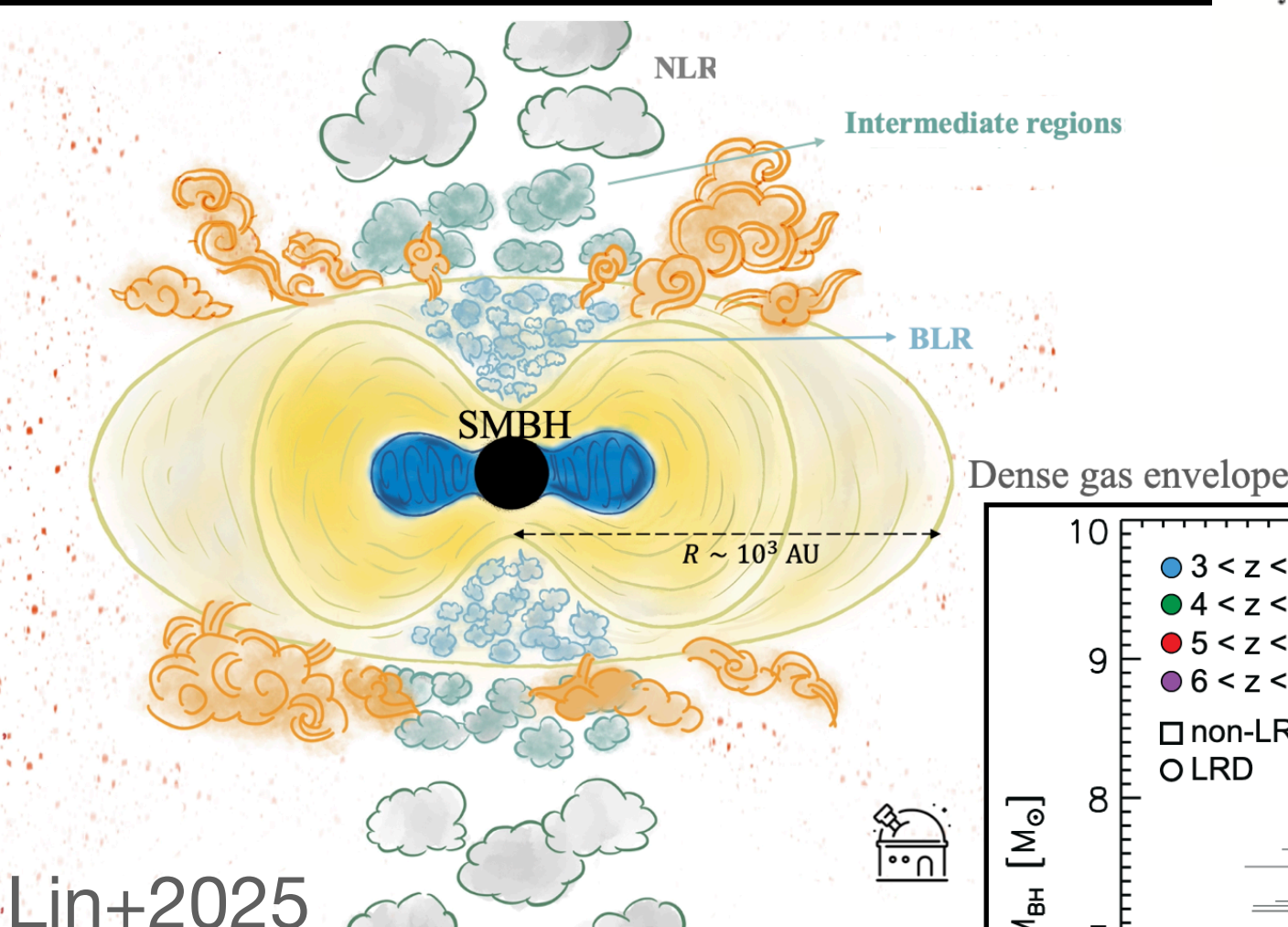
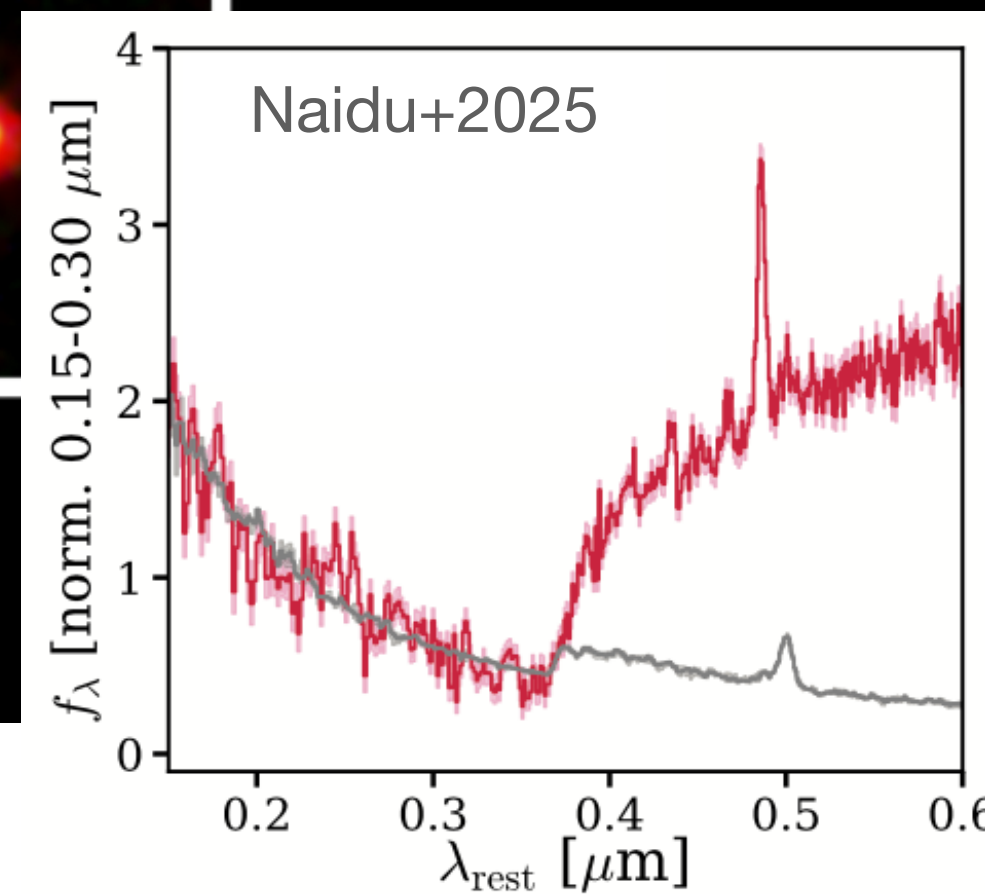
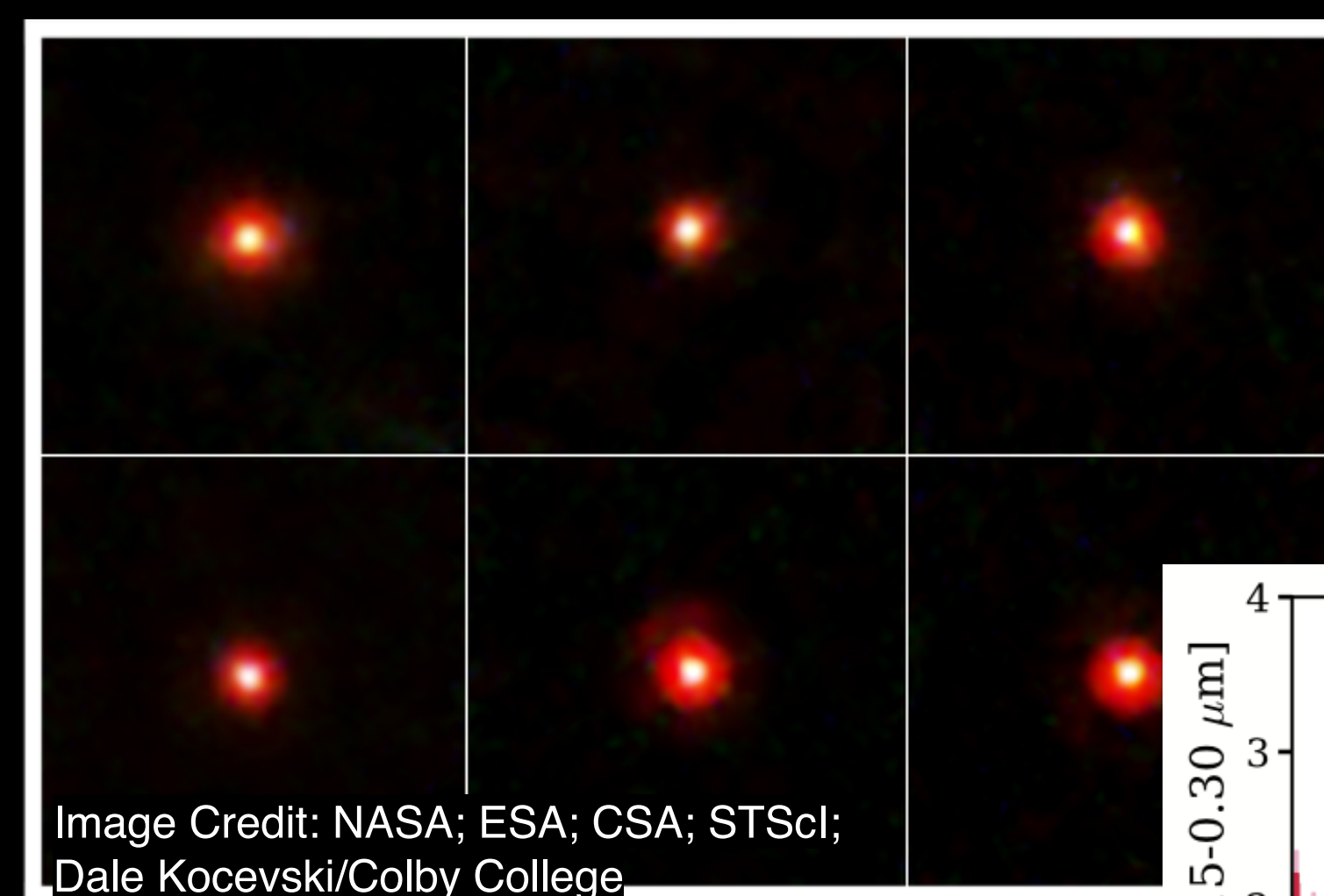
$\sim 0.5 - 4$ $z > 7.2$ quasars in the deep tier

Imaging selection + spectroscopic follow up:

$\sim 6 - 30$ $z > 7$ quasars in the medium tier (+LSST)

$\sim 3 - 100$ $z > 7$ quasars in the deep tier (deep F087)

Little Red Dots (LRDs)



- Highly deviated from previously known AGNs

e.g., Distinct “V-shape” continuum.

Almost NO detection in the X-ray, mid-IR, submm, and radio.

High fraction of broad Balmer absorption (10-20%).

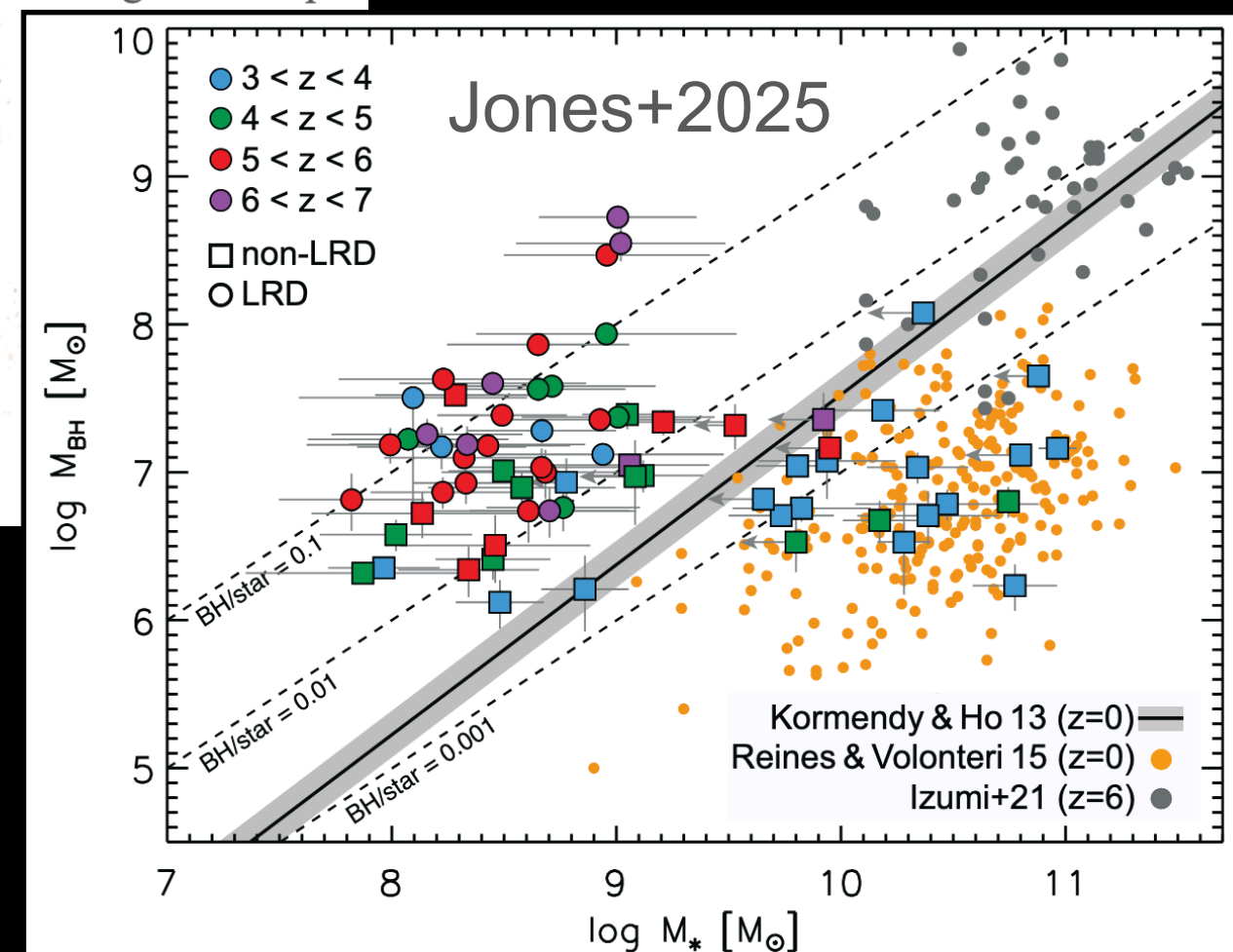
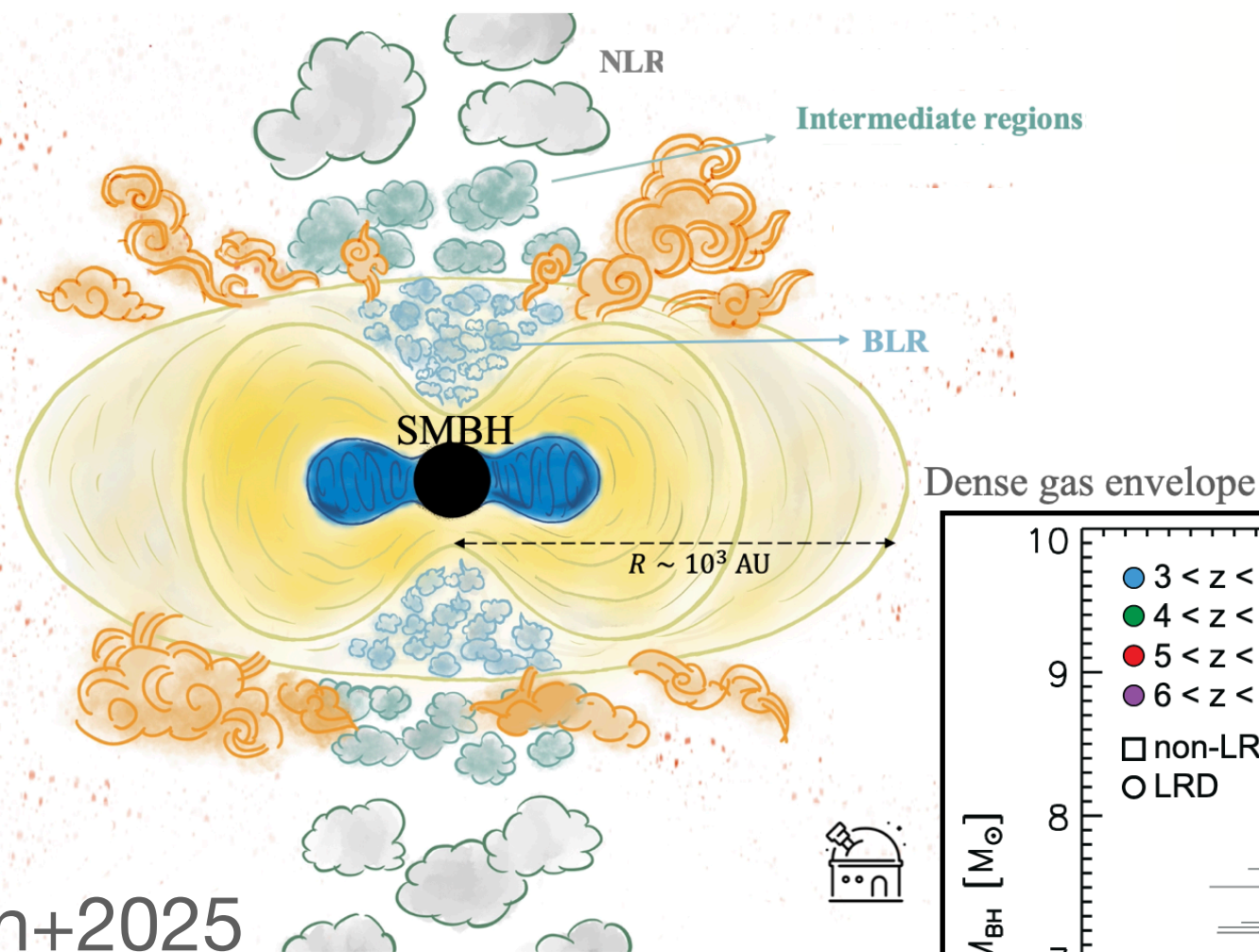
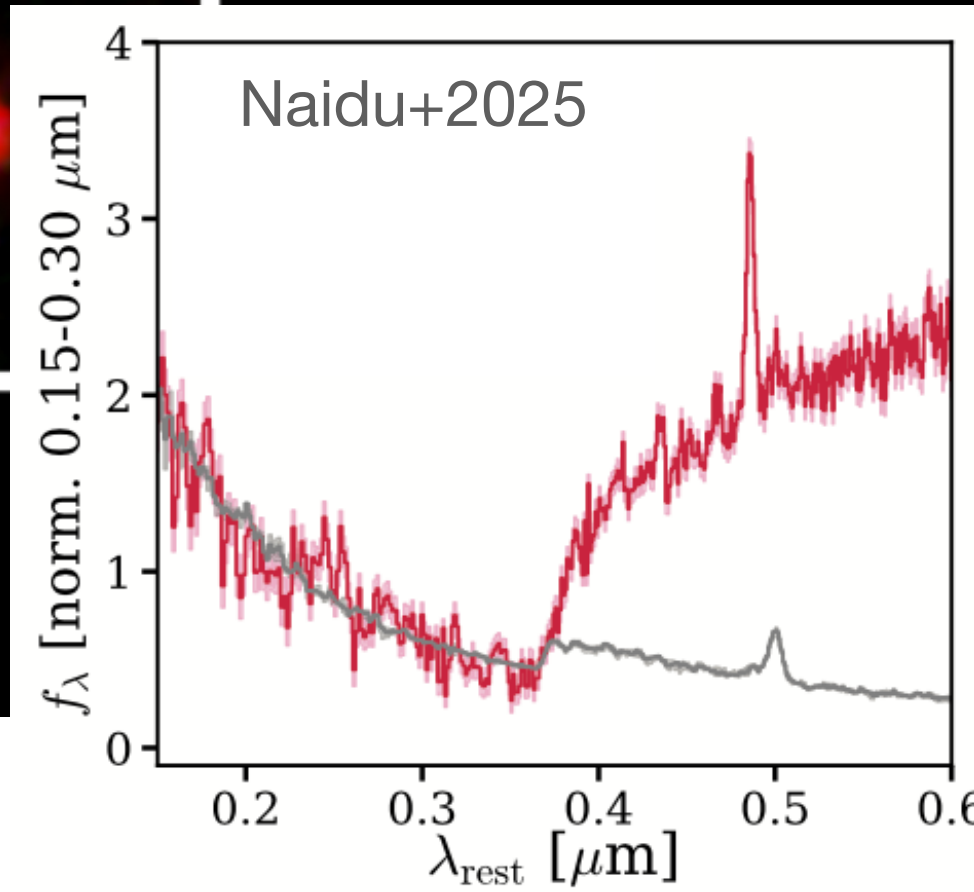
Only a few with variability.

- Highly unclear nature in widely different models

e.g., AGN with Supermassive Black Hole vs Compact Star-formation

Little Red Dots (LRDs)

Image Credit: NASA; ESA; CSA; STScI;
Dale Kocevski/Colby College



Whether there is a SMBH at the center;

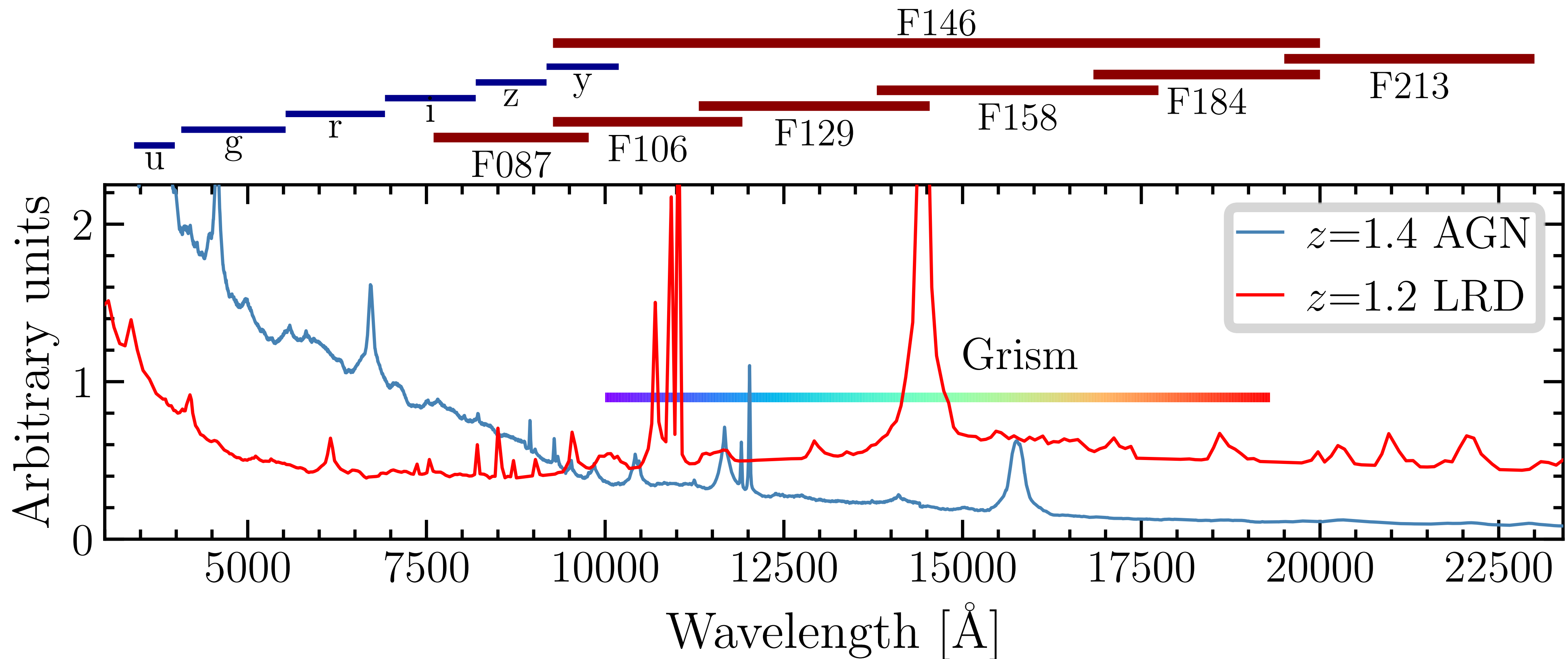
Whether LRDs represent a special early phase of BH growth;

and Whether they have the same structure as the AGNs we know.

Urgent need of a large uniformly selected sample
— Roman + LSST!

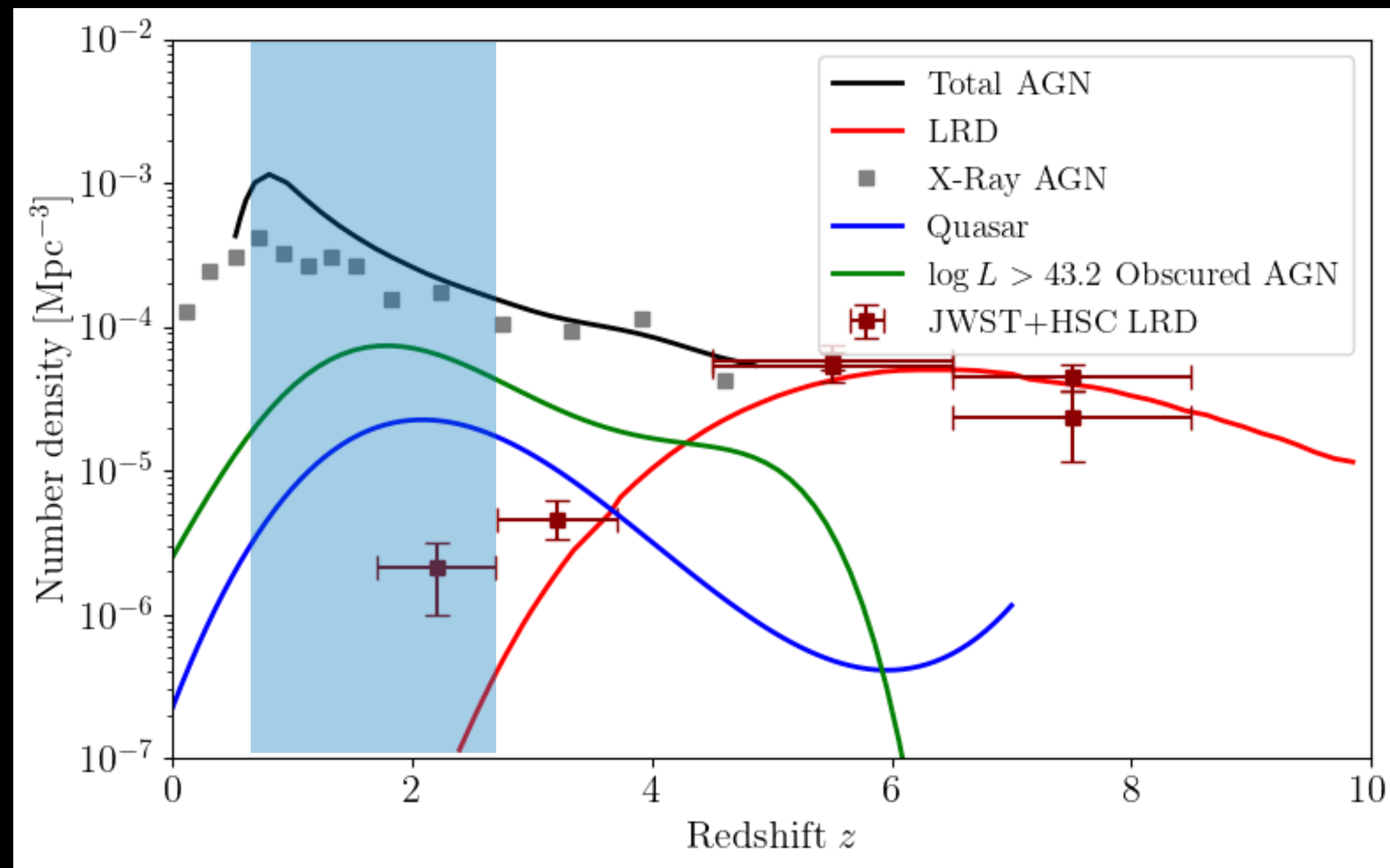
Roman+LSST: $z \sim 0.5$ -2.5 BLAGN/LRD survey

SED from Roman+LSST, spectra ($H\alpha$ and $H\beta$) from Roman, and variability from LSST



Roman+LSST: $z \sim 0.5$ -2.5 BLAGN/LRD survey

SED from Roman+LSST, spectra ($H\alpha$ and $H\beta$) from Roman, and variability from LSST



In the first two years:

Can expect a few hundred to few thousand LRDs

Whether it is a special early BH growth phase — redshift evolution

Whether the same structure — variability

Targeting Early SMBHs in the Roman/LSST/Euclid era

- ◆ $z \gtrsim 7$ quasars

Roman+LSST+Euclid+any available optical/IR data.

Will increase the number of high- z quasars by an order of magnitude.

Roman's spectra will directly cover bright quasars at $z \gtrsim 7-8$.

- ◆ $z \sim 0.5-2.5$ BLAGNs and LRDs

Roman + LSST.

Whether it is a special early BH growth phase — redshift evolution.

Whether the same structure — variability.