THE UNIVERSITY OF MELBOURNE

ASTRO 3D

CONSTRAINING PROPERTIES OF HIGH REDSHIFT QUASAR HOSTS WITH JWST

SABRINA BERGER (PHD STUDENT AT UNIVERSITY OF MELBOURNE)

SHEDDING NEW LIGHT ON THE 1ST BILLION YEARS OF THE UNIVERSE - MARSEILLES 2023

IMAGE CREDIT: NASA (M. KORNMESSER)

HIGH-Z QUASARS

- z greater than about 6
- Super luminous and highly accreting supermassive black holes — mysterious formation history!
  - $M_{BH} > 10^6$ solar masses. How did they get so massive?

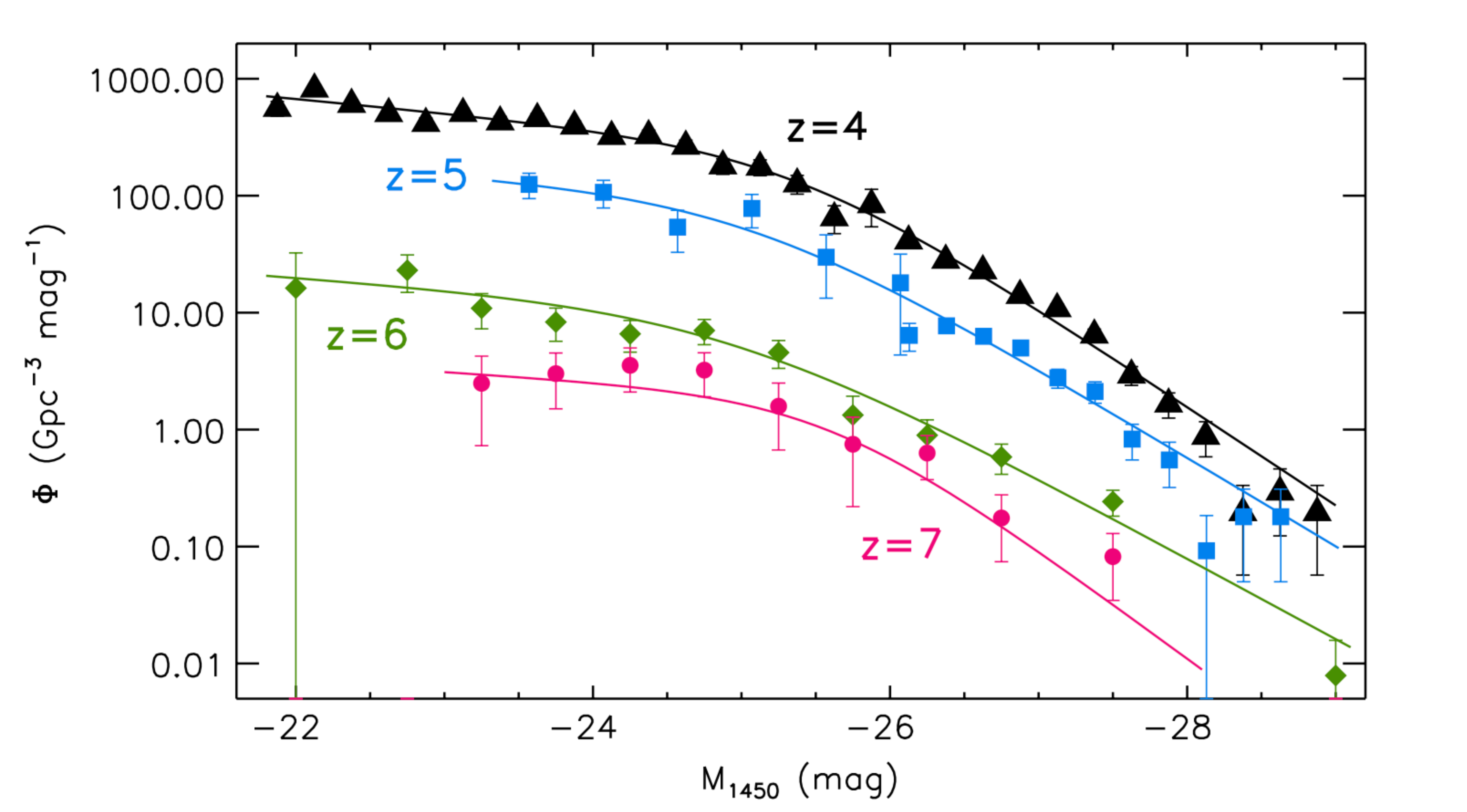


IMAGE CREDIT: MATSUOKA ET AL., 2023

HIGH-Z QUASARS

- z greater than about 6
- Super luminous and highly accreting supermassive black holes — mysterious formation history!
  - $M_{BH} > 10^6$ solar masses. How did they get so massive?
- Need to better constrain the stellar mass to black hole mass ratio
  - In the near IR (rest frame optical/UV), we can disentangle stellar and quasar light for more accurate measurements of stellar mass, radius, etc.

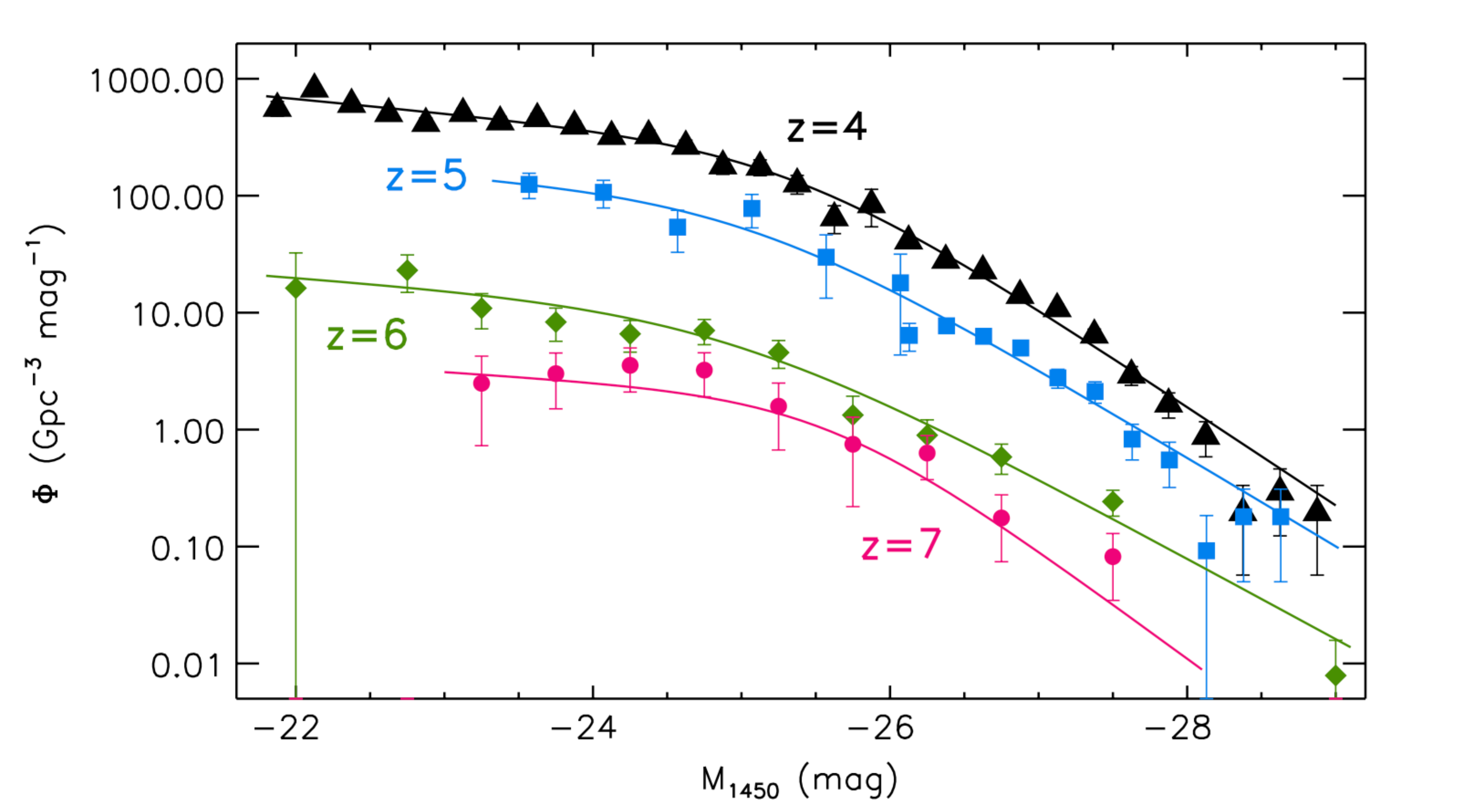


IMAGE CREDIT: MATSUOKA ET AL., 2023

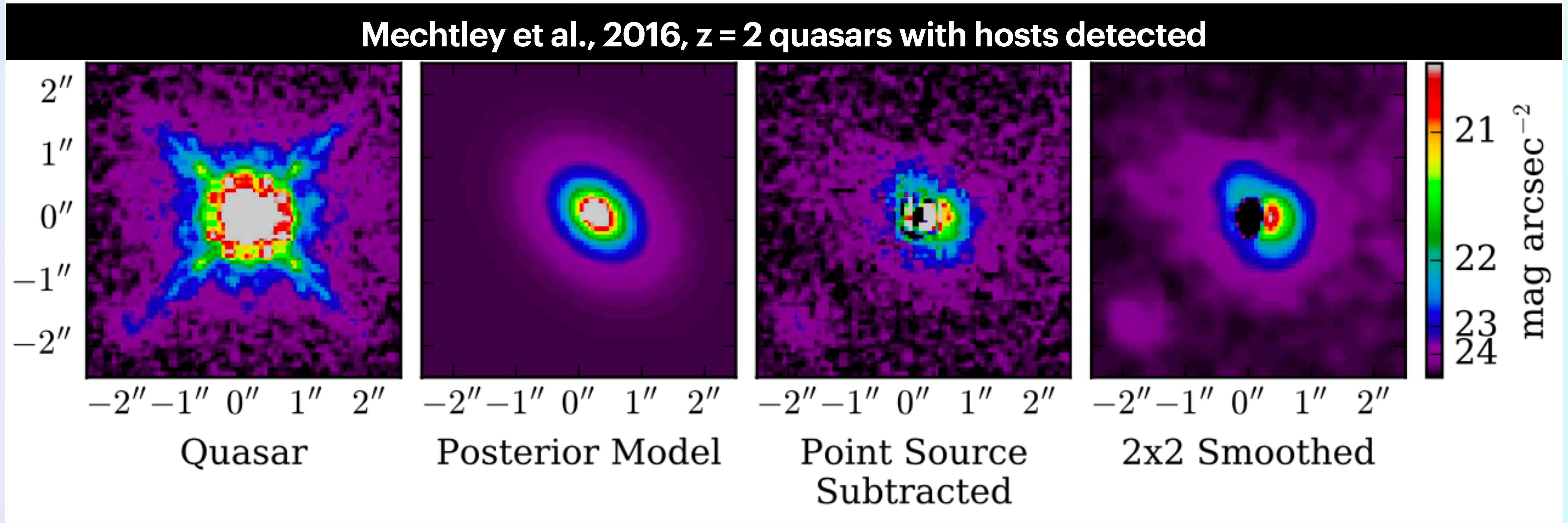
WHY JWST?

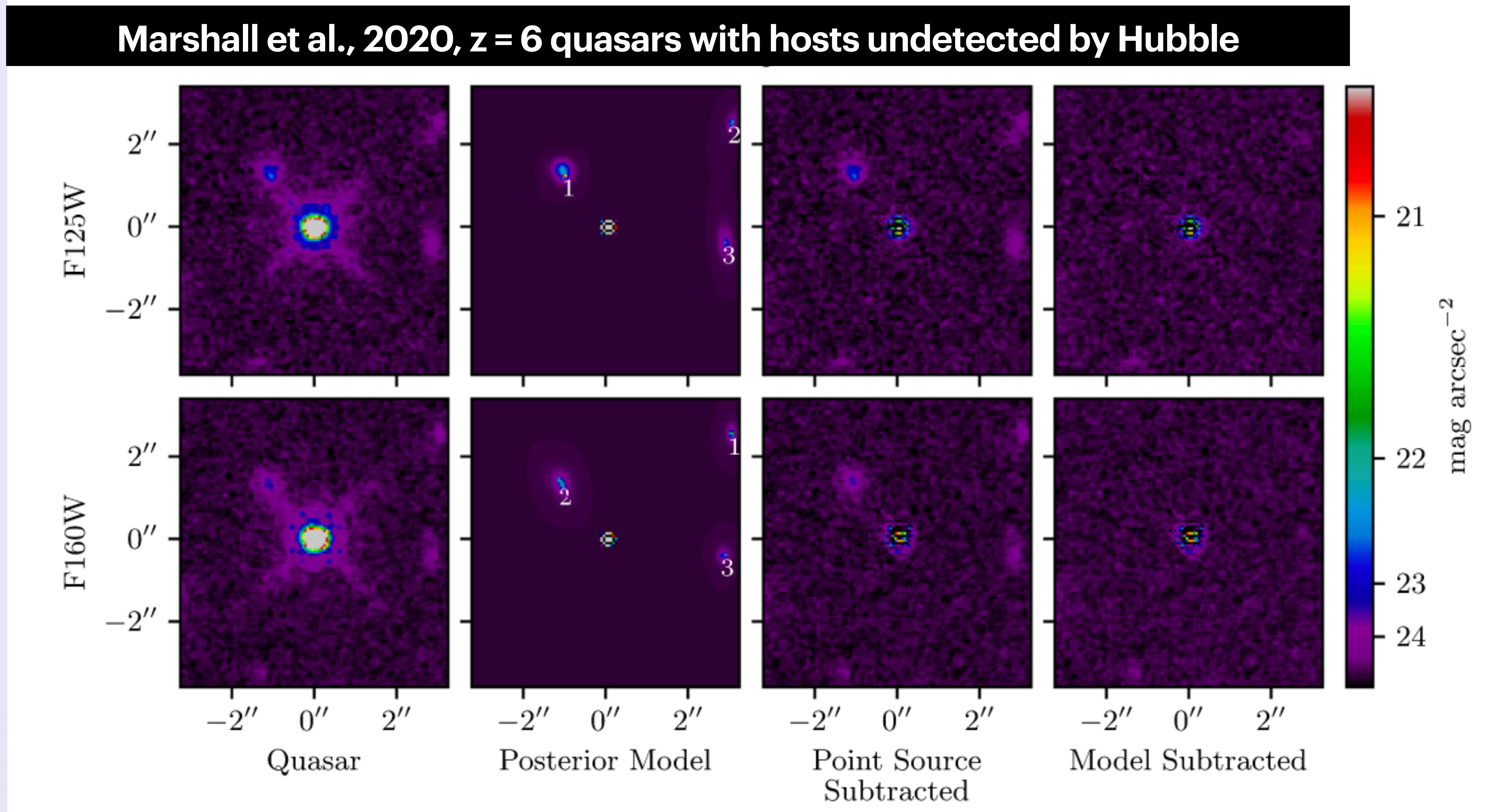
- Launched in 2021 and has already had immense impact on high-z science
- Much higher resolution than Hubble in the near-infrared
- NIRCam is the best instrument for imaging high-z quasars
  - observes between 0.5 to 5.0 micrometers and has 29 filters

MODELS: MATT THOMAS & AMAN CHOKSHI, IMAGE CREDIT: LEONARDO FERREIRA (UVIC)

WHY JWST?

- We need to carefully model the quasar's light to be able to subtract it off and see the underlying host
- Could only set upper limits on the infrared emission of high-z quasars with Hubble
- Needed a higher resolution that we have with JWST!





QUASAR HOSTS DETECTED WITH JWST

RECENTLY TWO HIGH-Z QUASAR HOSTS WERE DETECTED WITH JWST: J2255+0251 AND J2236+0032

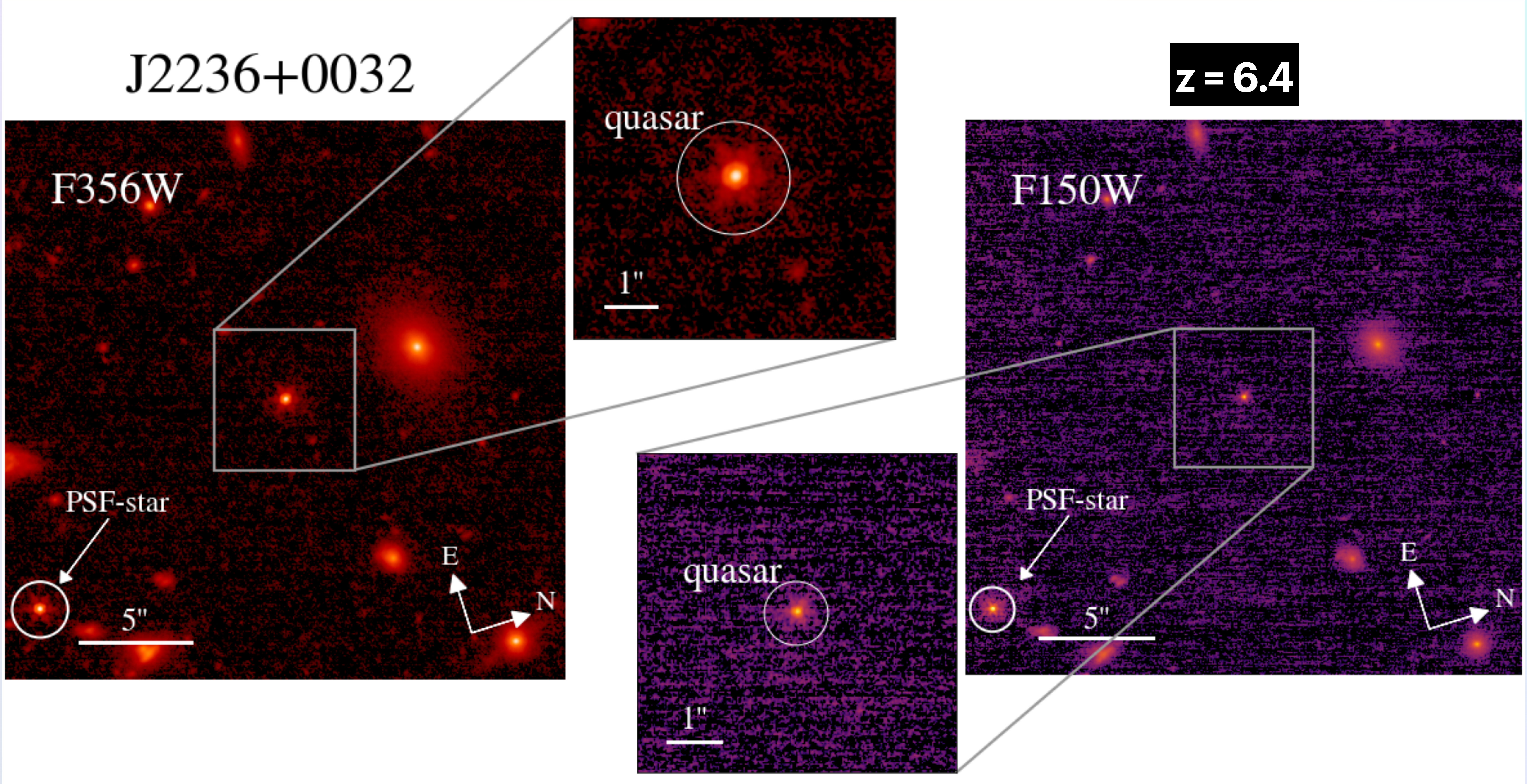


IMAGE CREDIT: DING ET AL., 2023

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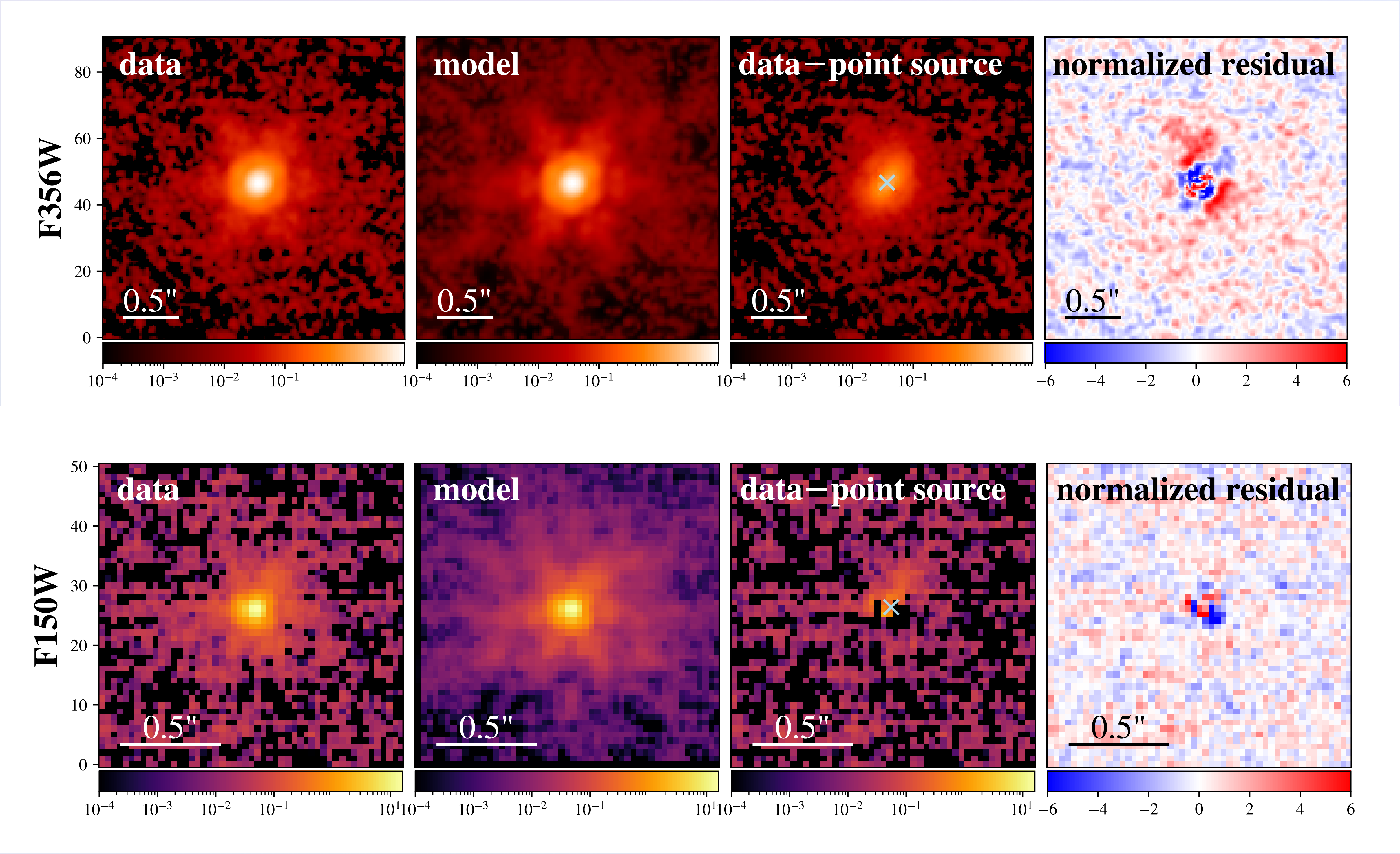
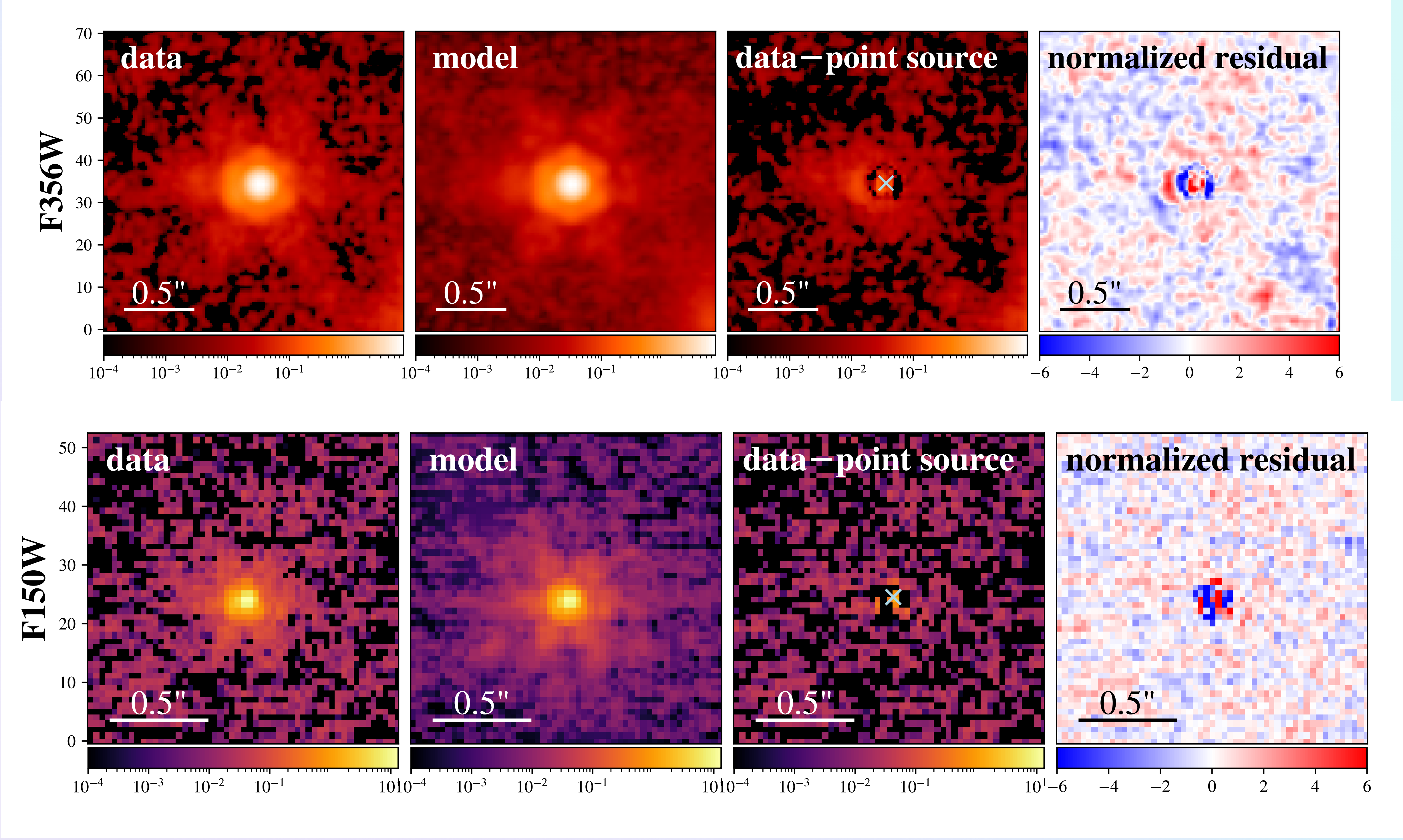
J2236+0032



J2255+0251



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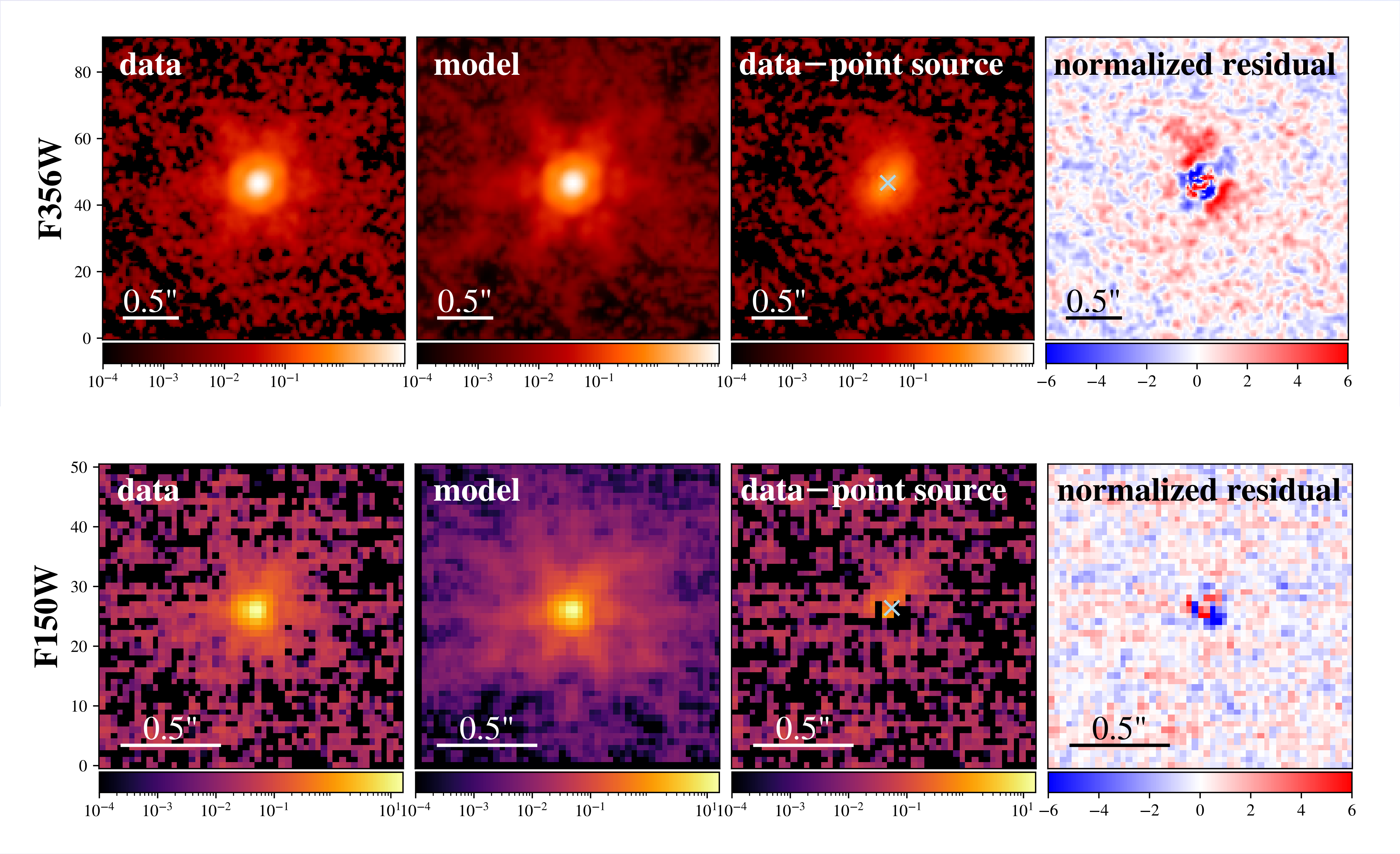
J2236+0032



J2255+0251

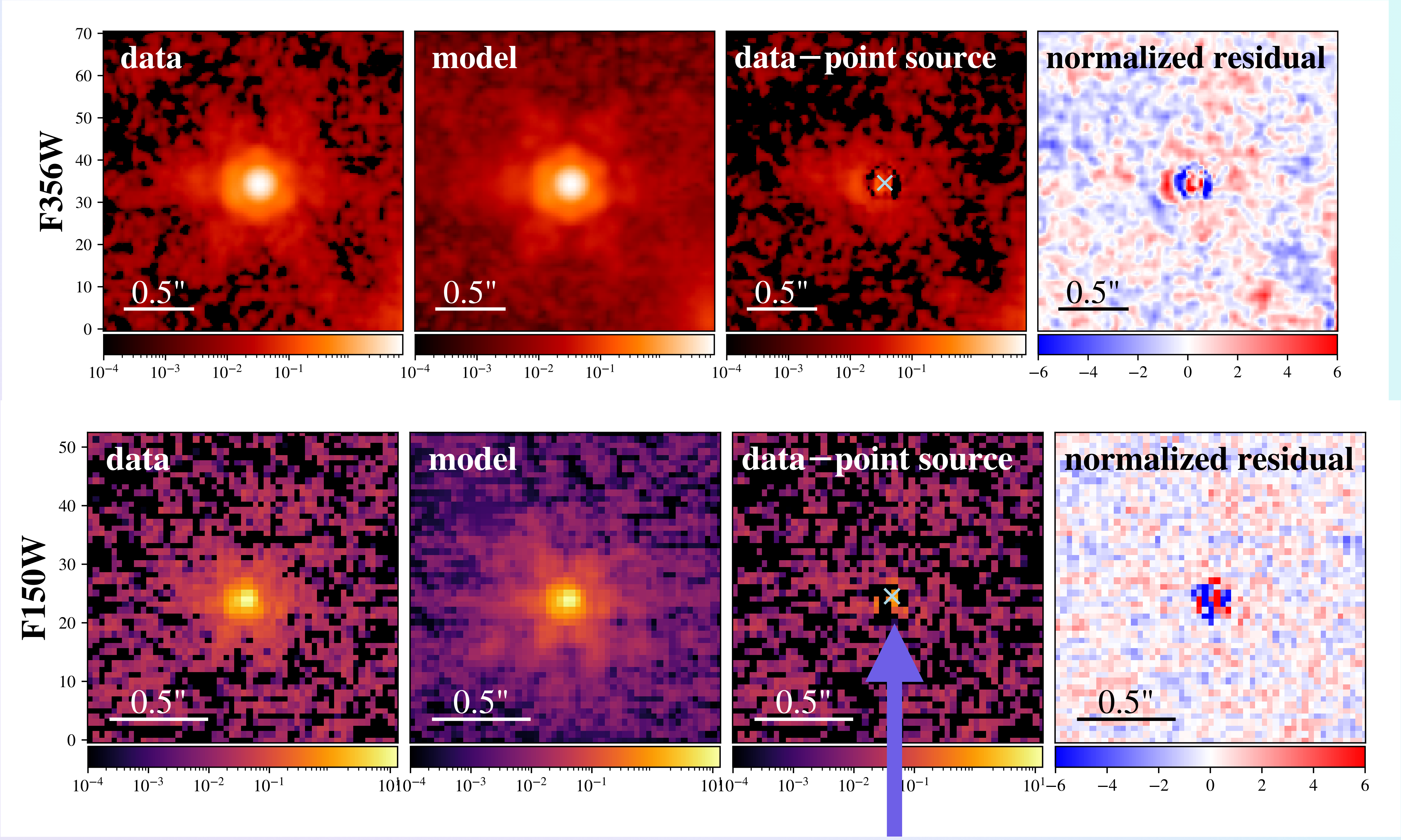


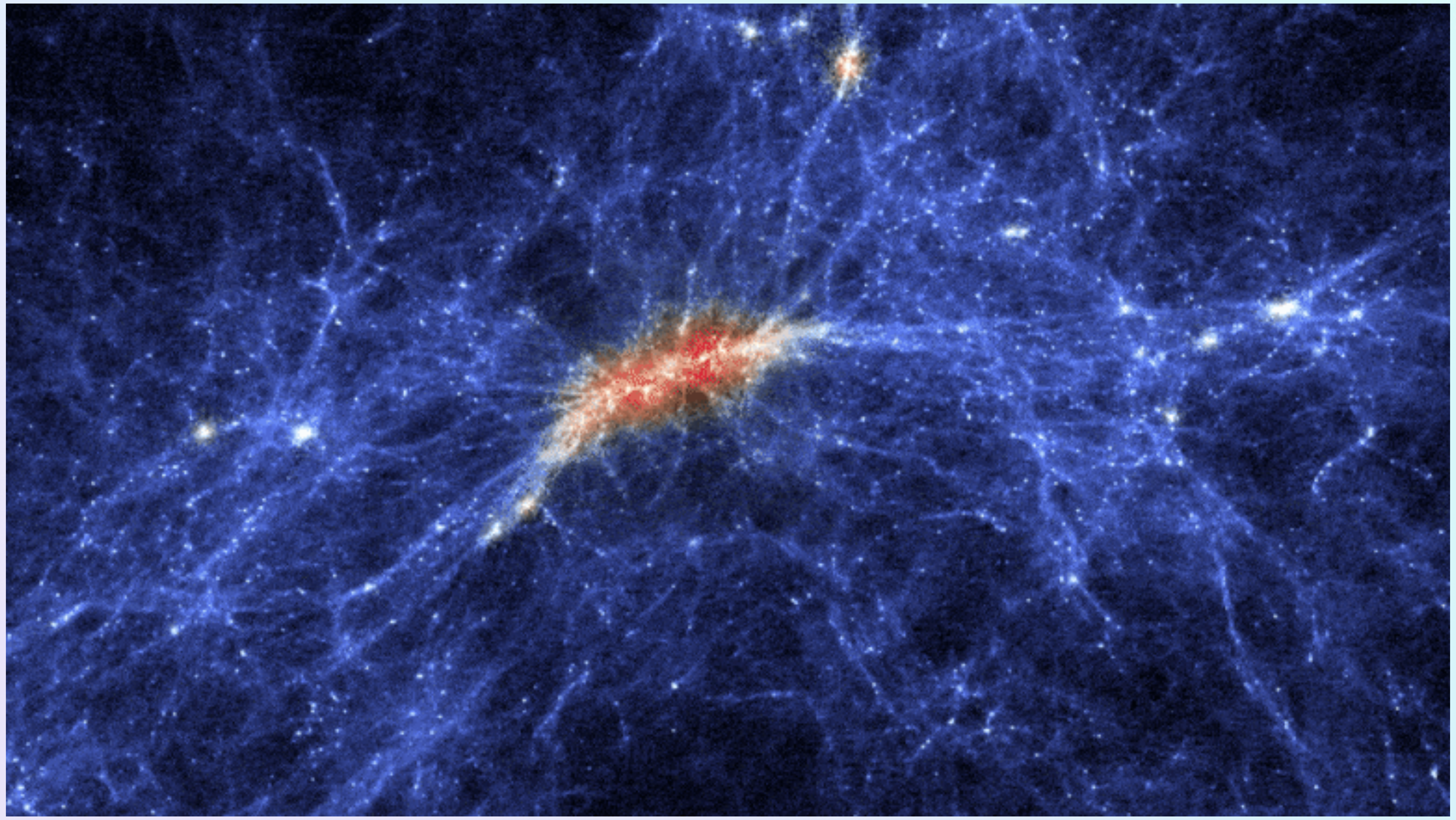
IMAGE CREDIT: DING ET AL., 2023

host not detected!

THE BLUETIDES SIMULATION

PROVIDES US WITH A MODEL FOR HIGH-Z QUASARS THAT WE CAN COMPARE WITH OBSERVATIONS

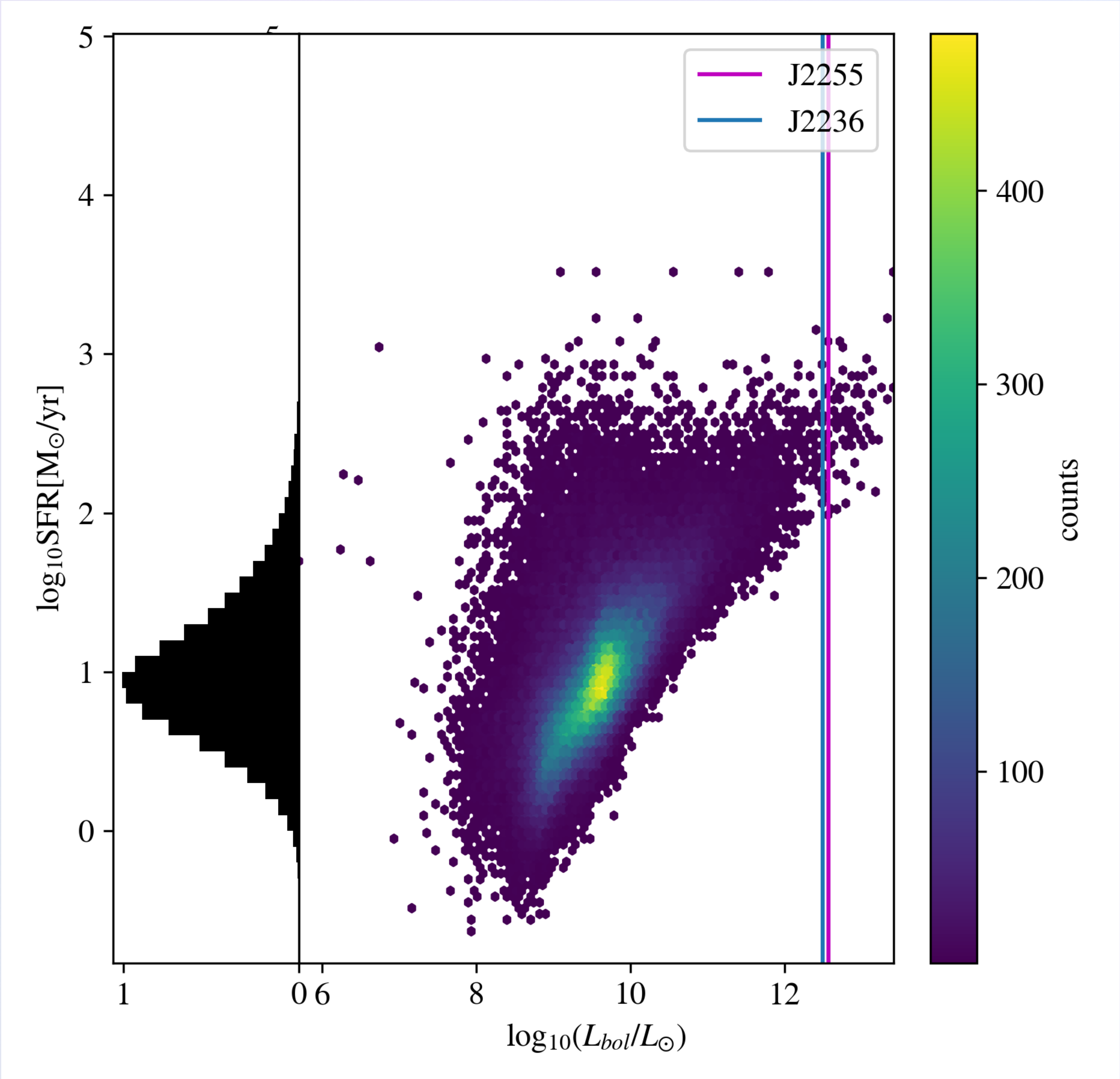
- full hydrodynamic simulation run between z = 7 to z = 99 (Feng et al., 2015)
- 2 x 7040^3 particles in a box with side length $400h^{-1}$ Mpc
- 200 million star-forming galaxies
  - We take 108,000 of the most massive BHs
- star formation, feedback processes, and black hole accretion included

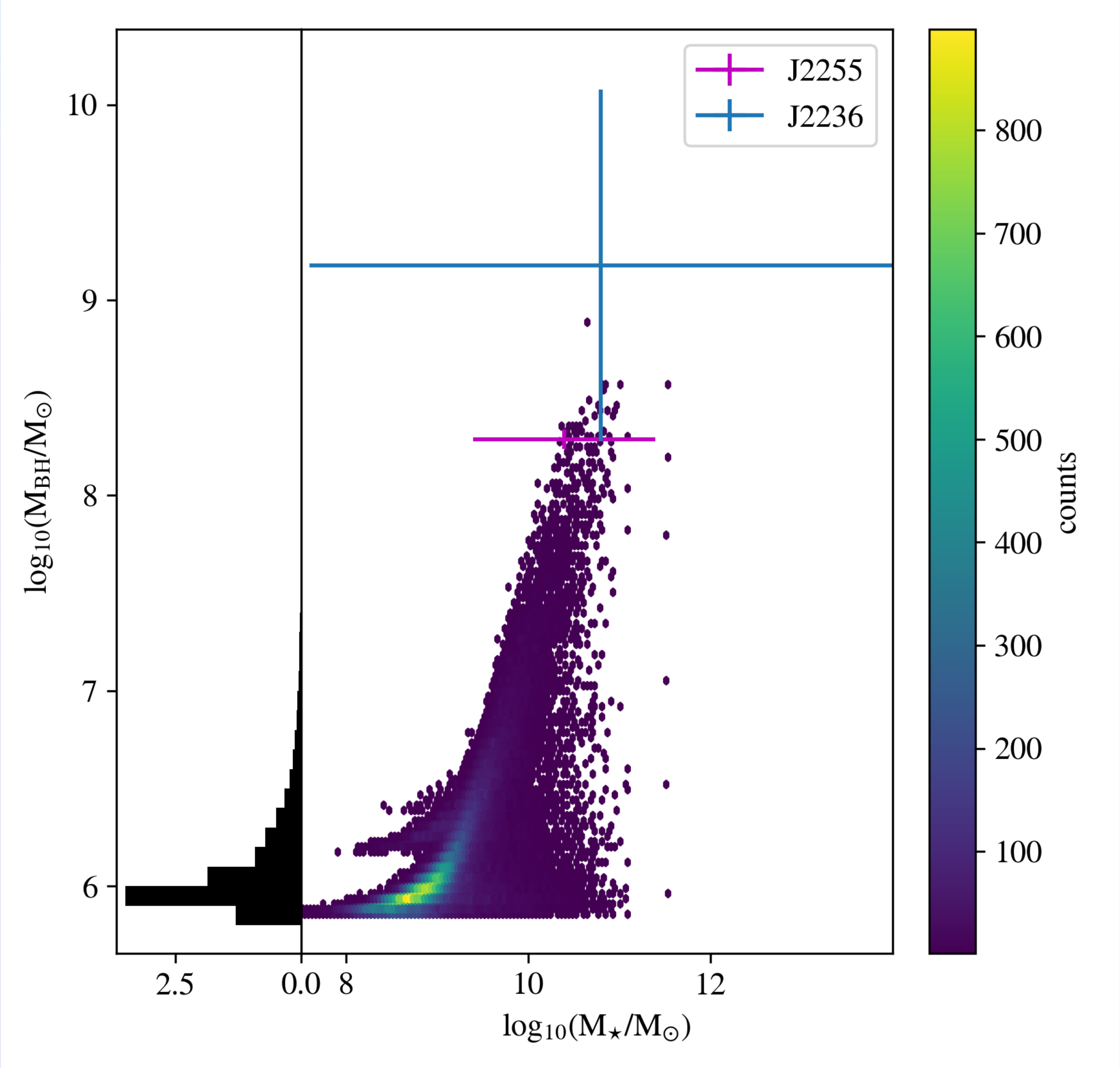


GIF CREDIT: Y. NI (CARNEGIE MELLON UNIVERSITY) AND L. HUSTAK (STSCI)

RESULTS

THESE HIGH-Z QUASARS SIT NEAR THE TOP END OF THE BLUETIDES SIMULATIONS AND HAVE VALUES CONSISTENT WITH THOSE PREDICTED BY BLUETIDES.

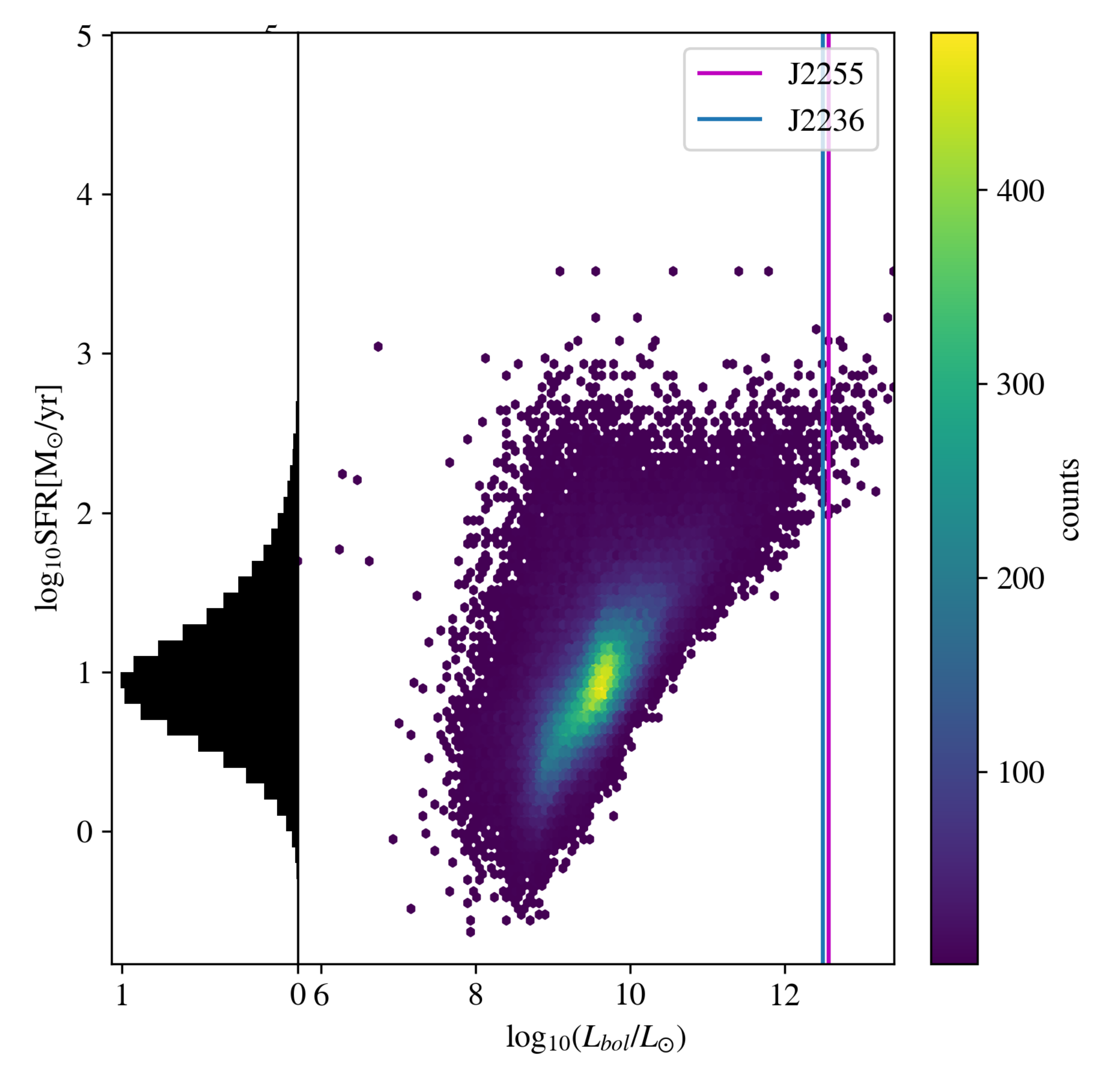


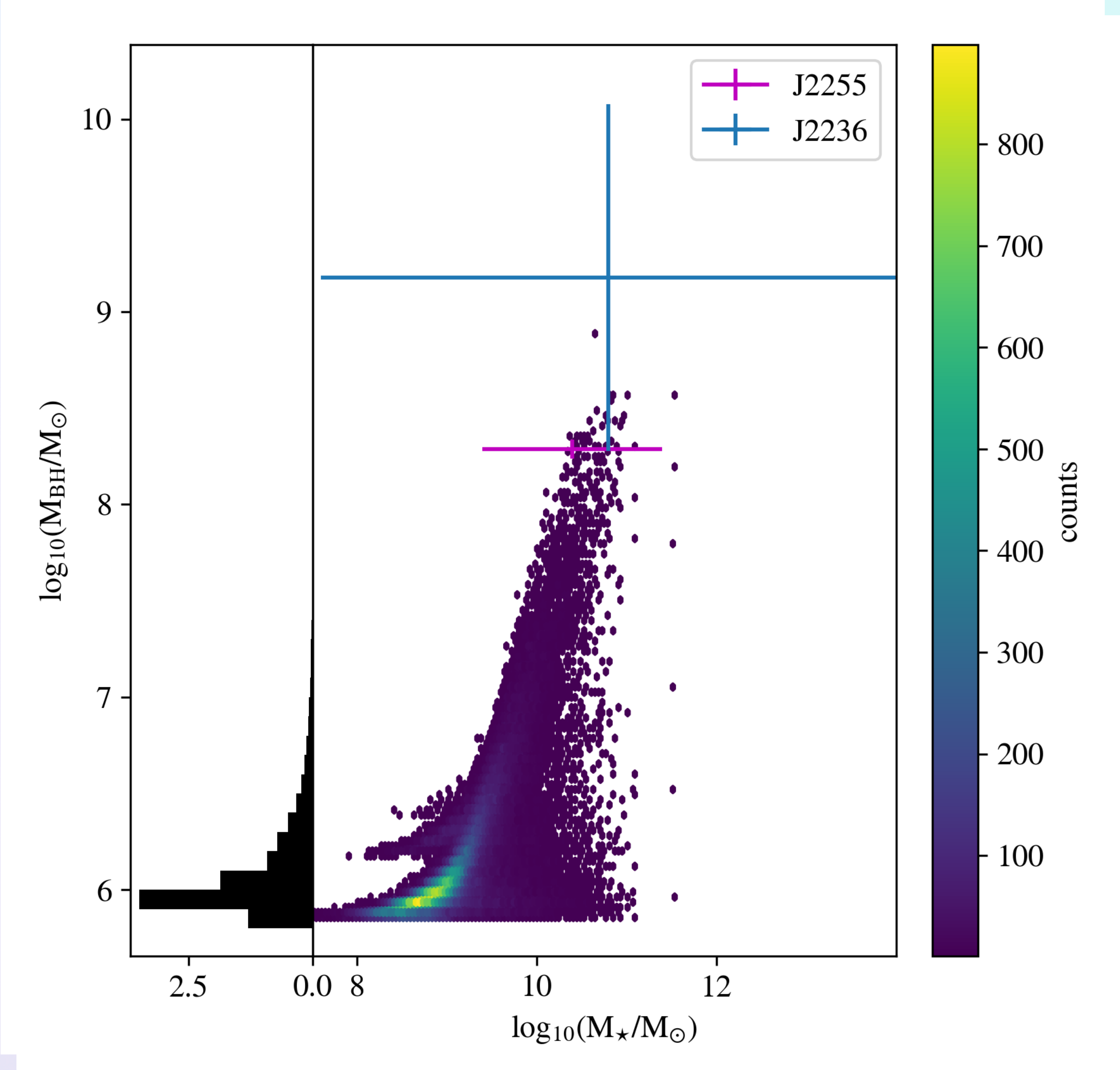


BERGER ET AL., 2023 (IN PREP)

RESULTS

WE CAN ALSO MAKE PREDICTIONS ON PROPERTIES SUCH AS THE SFR OF THE JWST QUASARS: SFR ~ $10^{2\text{-}3}$ SOLAR MASSES/YEAR.





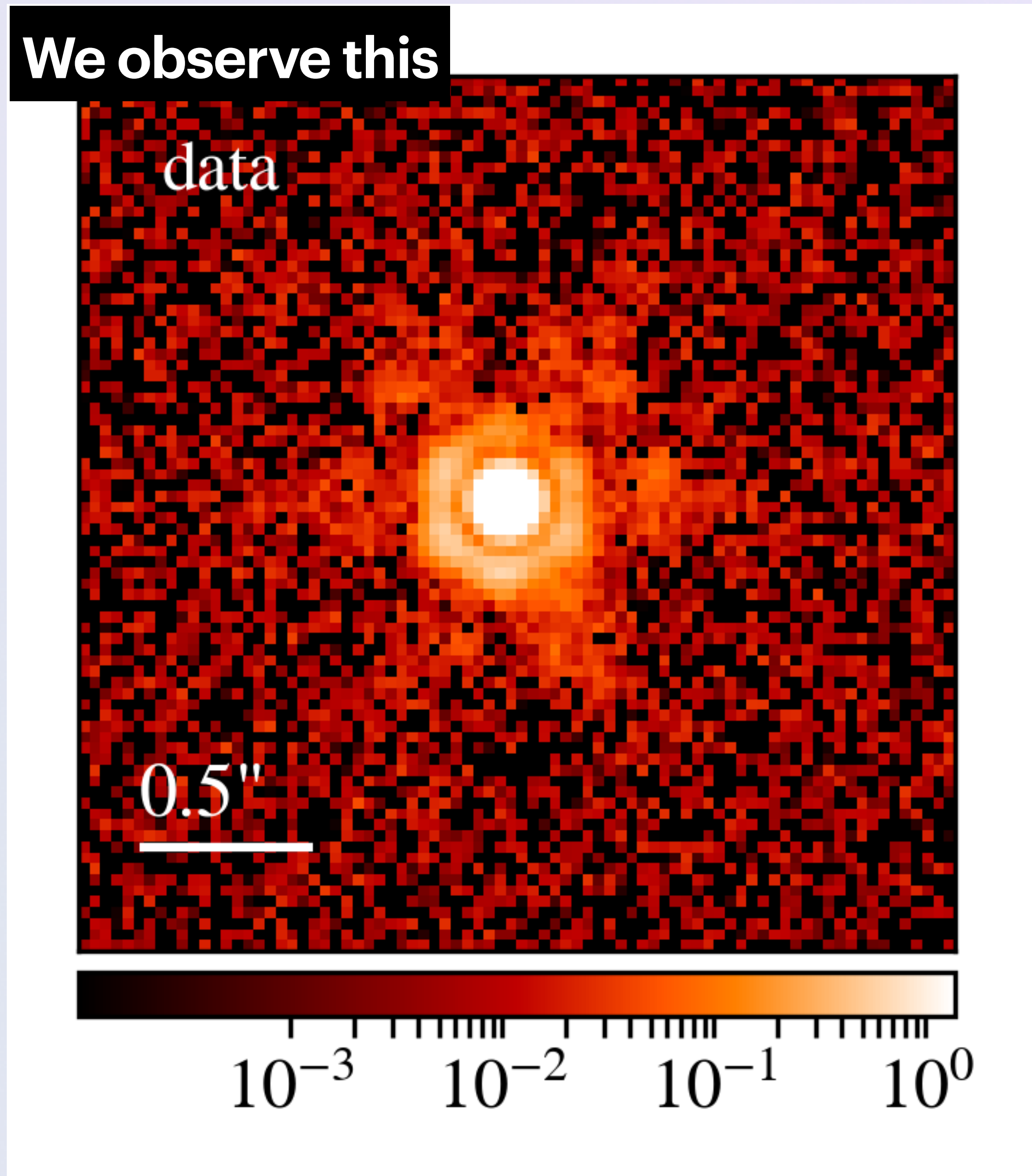
BERGER ET AL., 2023 (IN PREP)

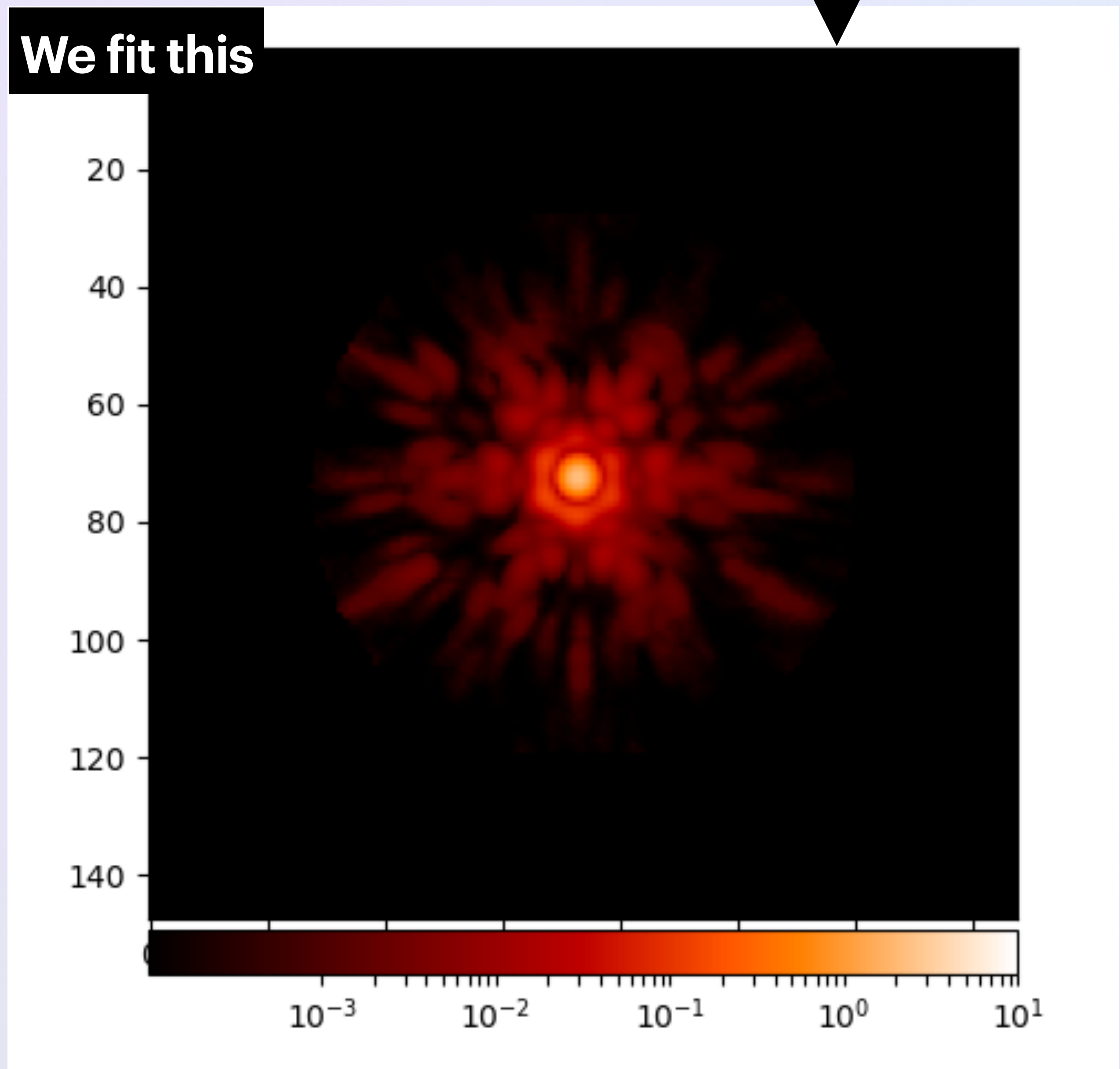
MOCK IMAGING

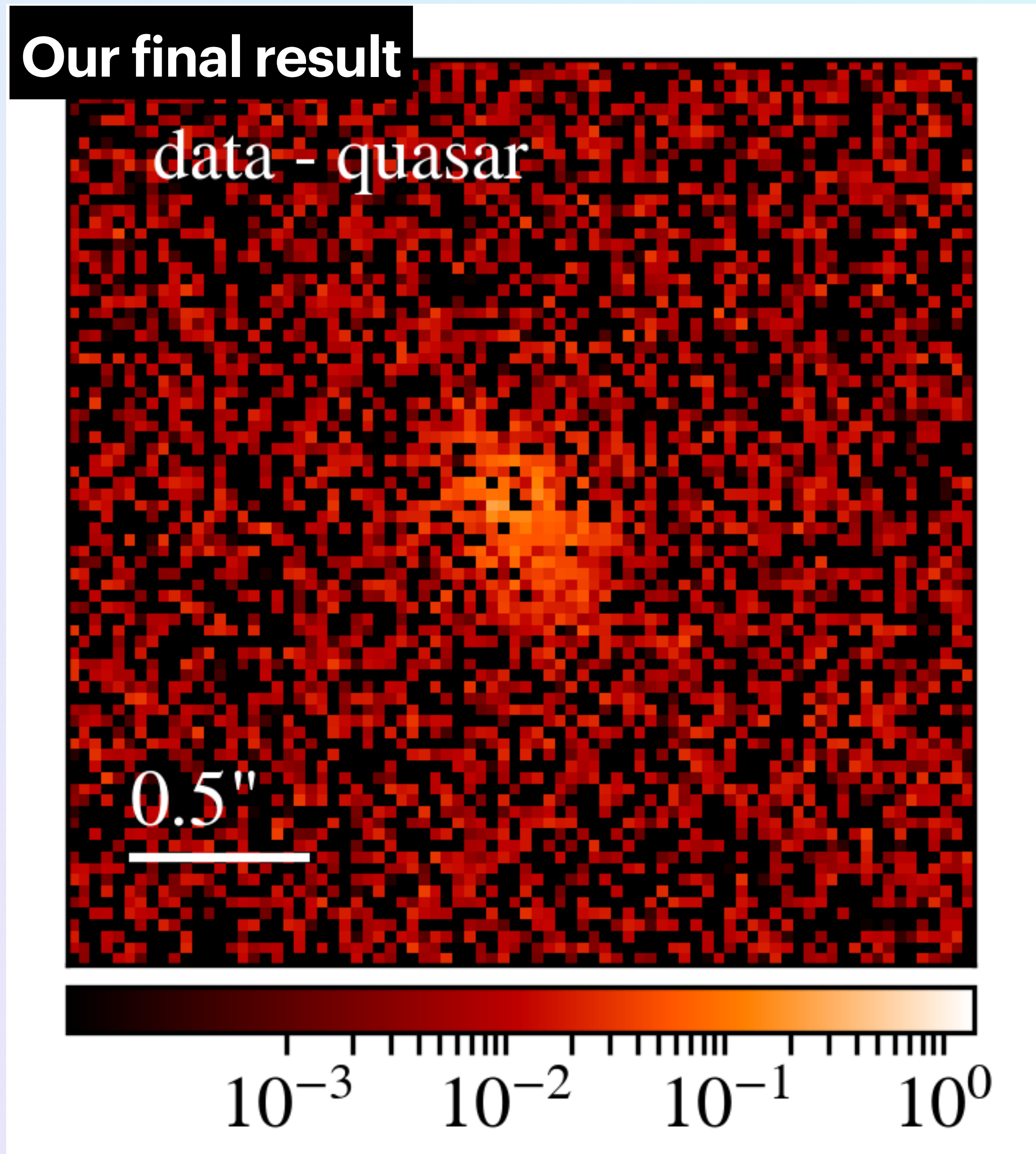
WE USE BAYESIAN METHODS TO DISENTANGLE THE QUASAR FROM ITS HOST.

$$P(\text{image}(\text{pixel})|\theta) = \frac{1}{\sqrt{2\pi\sigma(\text{pixel})^2}} \exp\left(\frac{(\text{image}(\text{pixel}) - I_{CM}(\text{pixel}))^2}{2\sigma(\text{pixel})^2}\right)$$

where I_{CM} is the intensity of the convolved model we're fitting





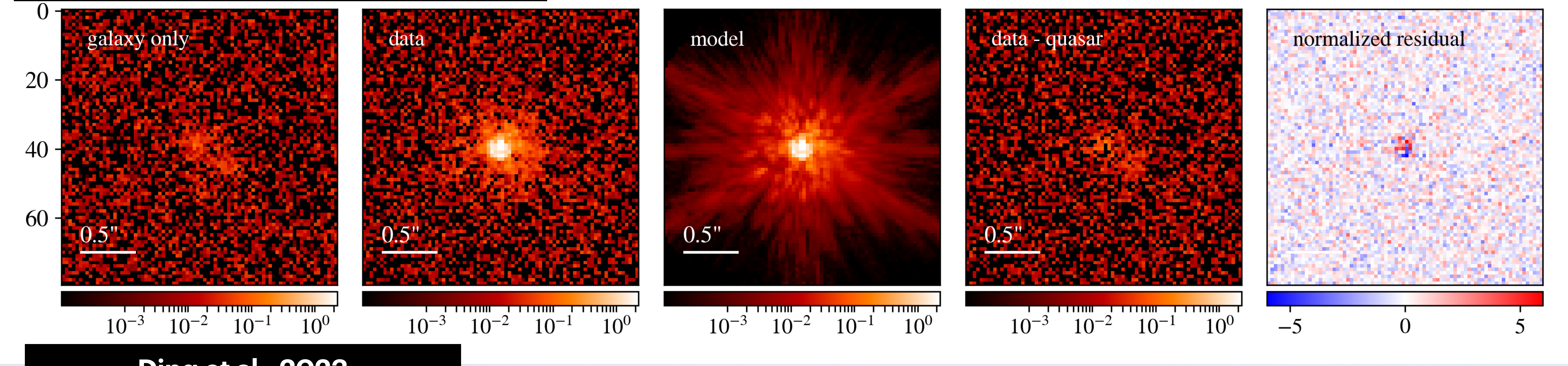


BERGER ET AL., 2023 (IN PREP)

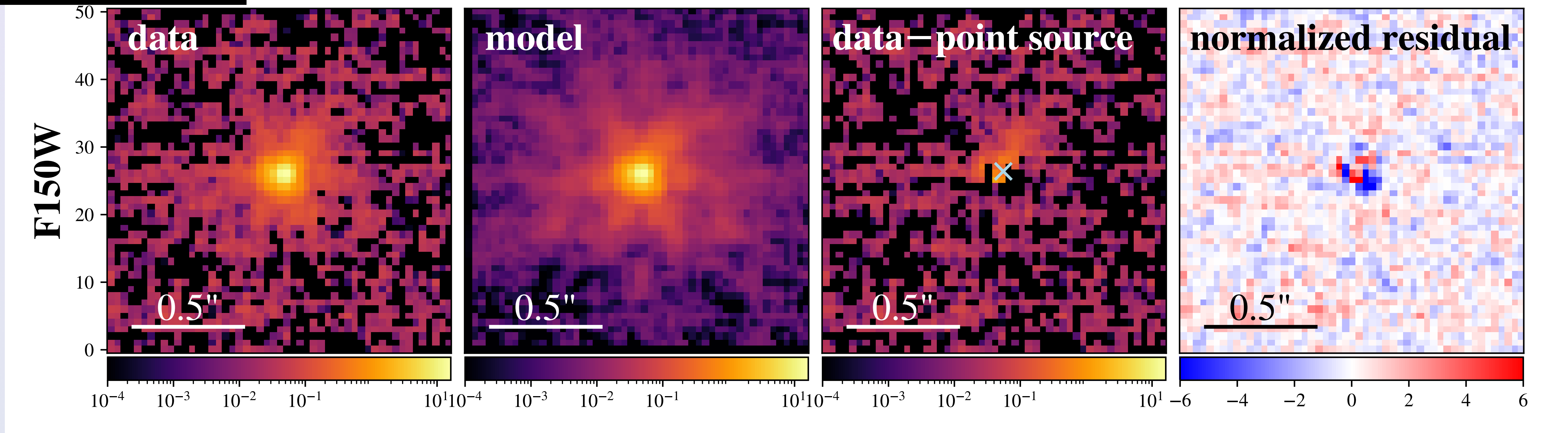
RESULTS

MOCK IMAGES OF QUASARS WITH SIMILAR BOLOMETRIC LUMINOSITIES AS THE JWST QUASARS

Berger et al., 2023 (in prep)
(BlueTides quasar)

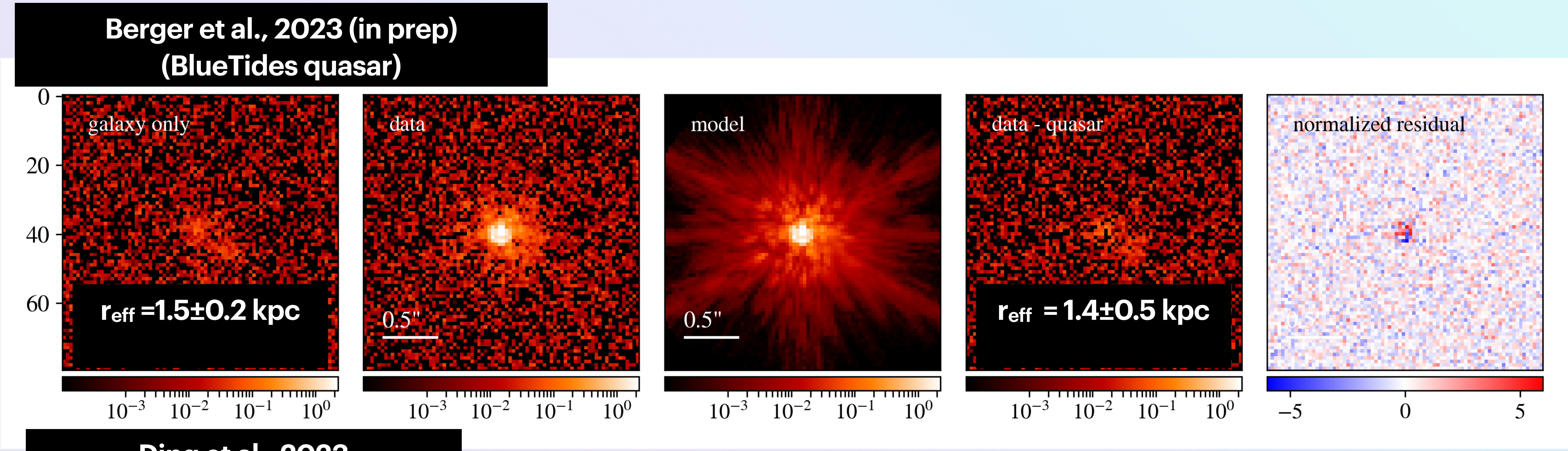


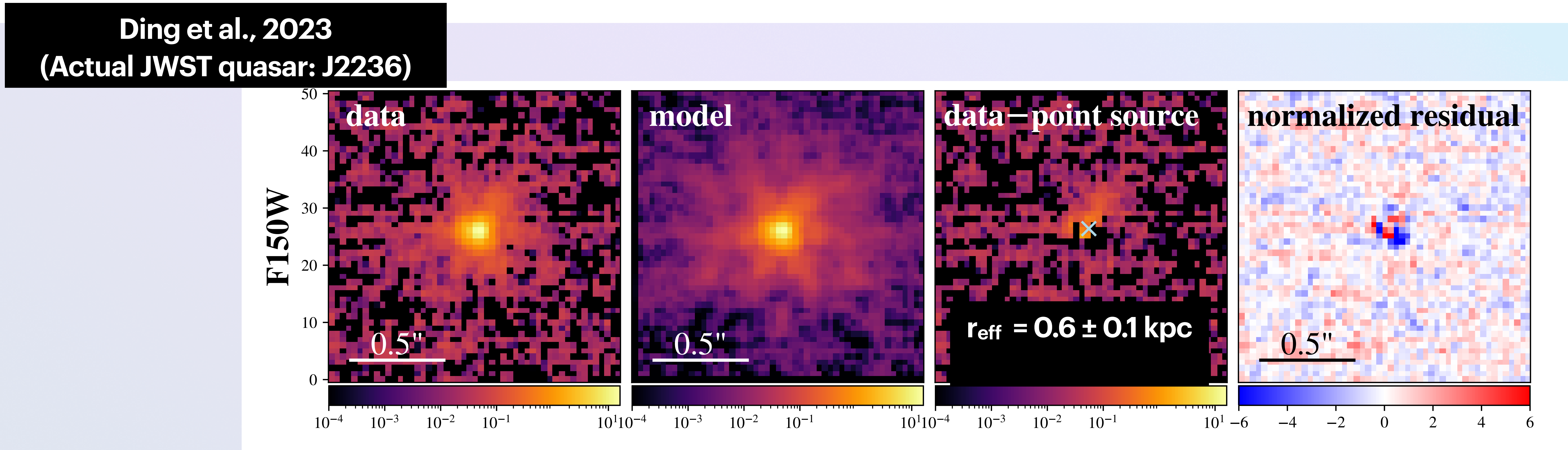
Ding et al., 2023
(Actual JWST quasar: J2236)



RESULTS

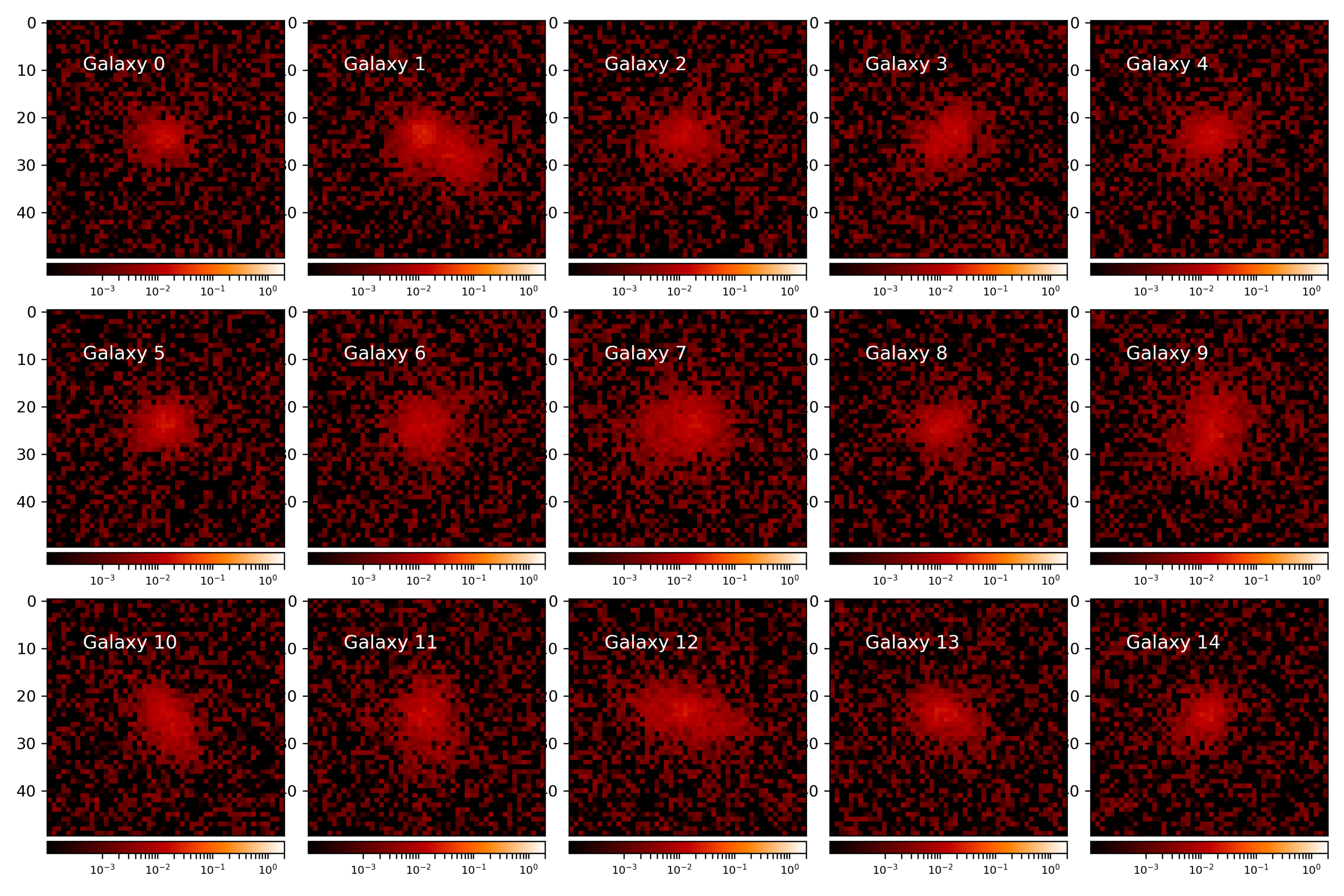
OUR MOCK IMAGES RECOVER SIMILAR EFFECTIVE RADII.





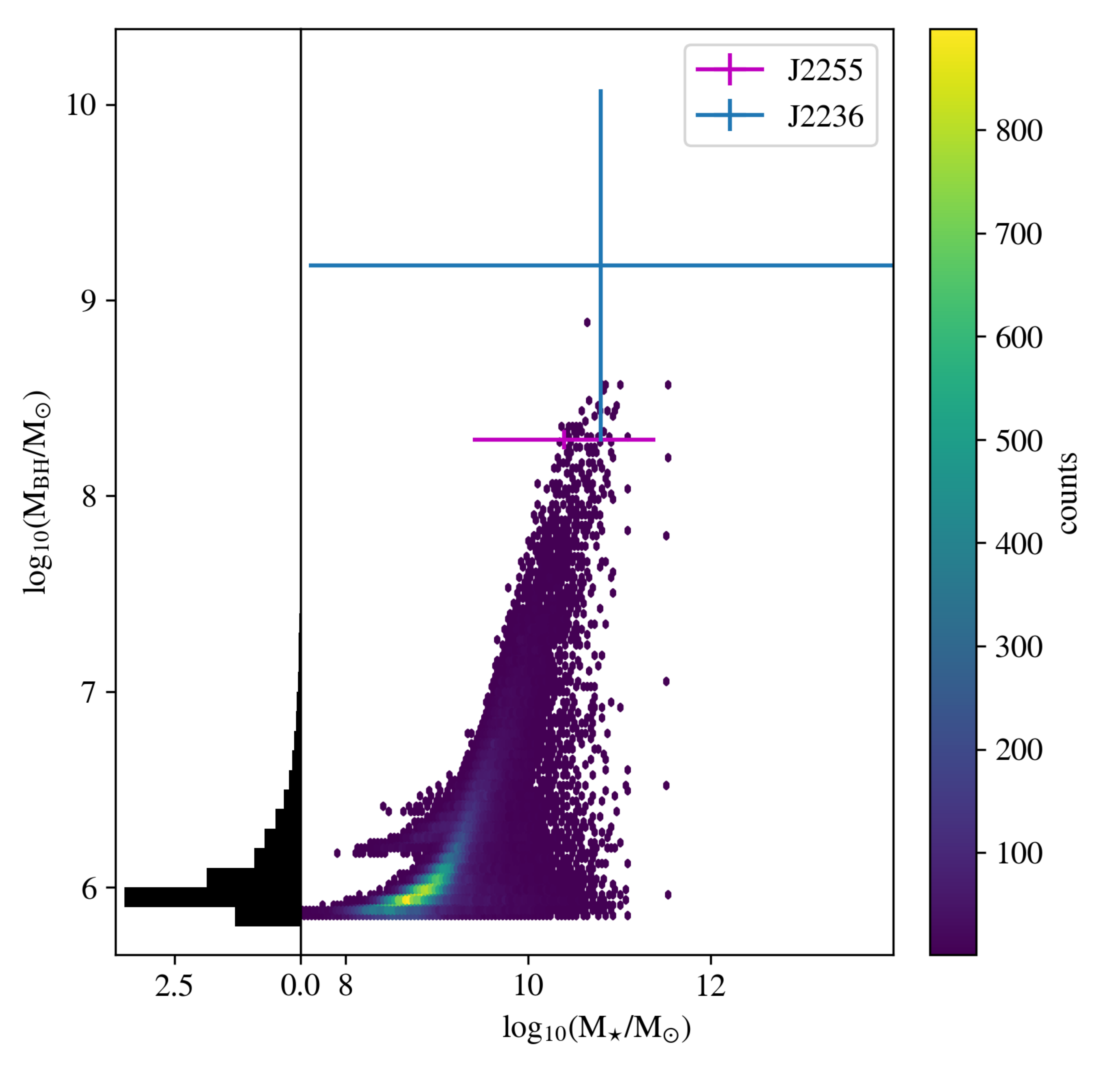
RESULTS

WE CAN ALSO MAKE MOCK IMAGES OF BLUETIDES GALAXIES WITHOUT A QUASAR FOR COMPARISON.



SUMMARY

- The newly observed quasar hosts with JWST match predictions from the BlueTides simulations
- Our mock imaging pipeline recovers accurate galactic radii post point source removal
- We can now make predictions for SFR, halo mass, etc. for the observed quasars using BlueTides data
- We're equipped with the tools to do more quasar host detection through our sensitive point source removal with future JWST data!



NEXT STEPS

- Our JWST observing window is open now, and we'll get *new* NIRCam images of higher luminosity quasars in the next few weeks (already have one!)
- We're keen to answer questions such as
    - how does the observational bias affect our radius measurement?
    - how accurately can we constrain the black hole to stellar mass ratio?

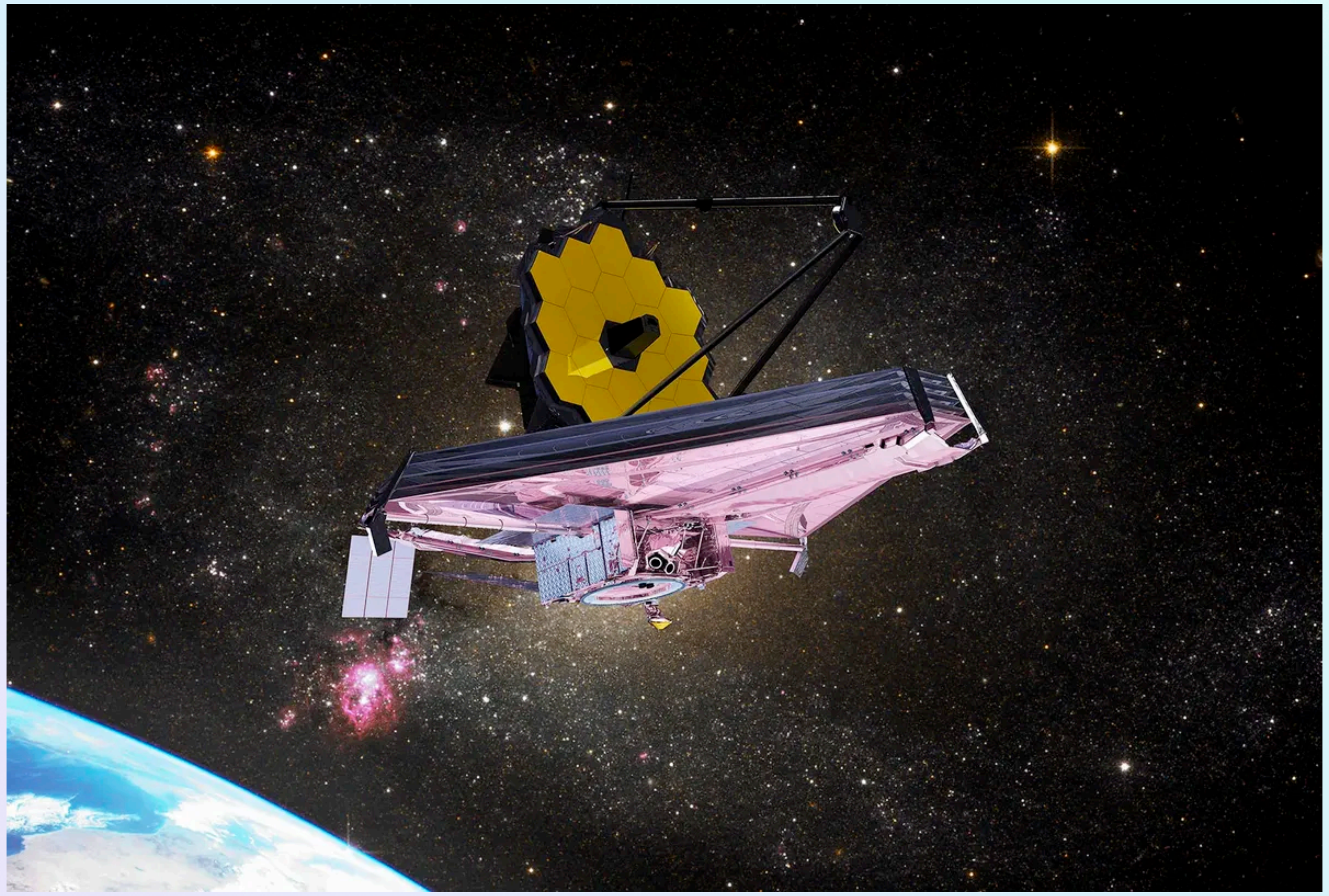


IMAGE CREDIT: NASA

QUESTIONS?

Thanks to my wonderful mentors!

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