17TH MARCEL GROSSMANN MEETING 2024

TEXAS
The University of Texas at Austin

DETECT SUPERMASSIVE DARK STARS WITH ROMAN SPACE TELESCOPE

Keywords: detectors, early universe, dark matter, first stars

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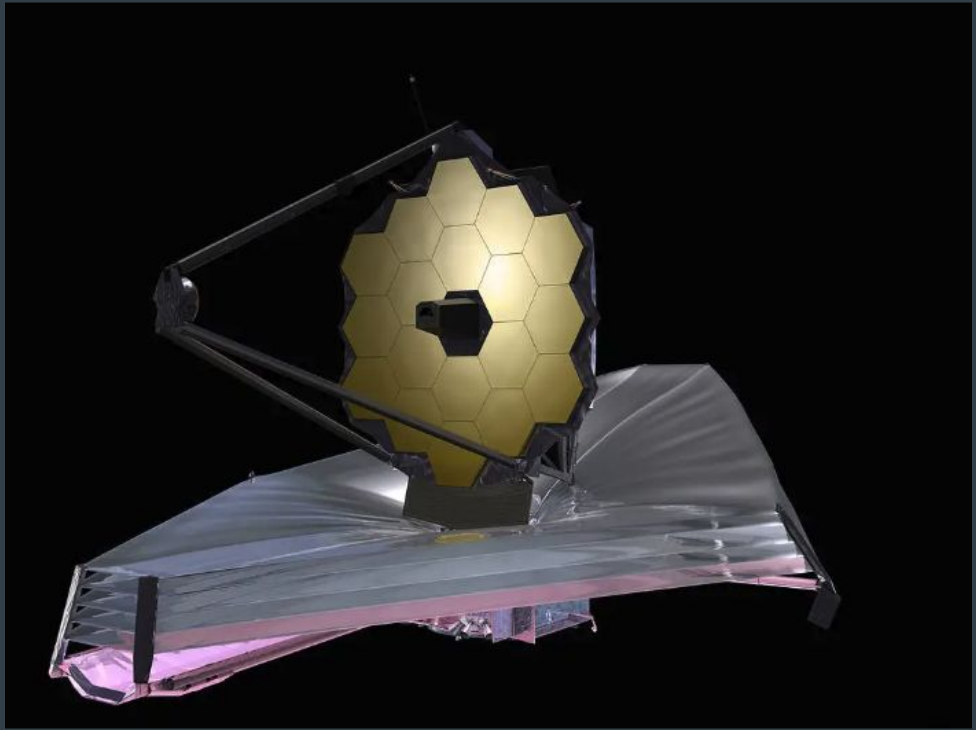
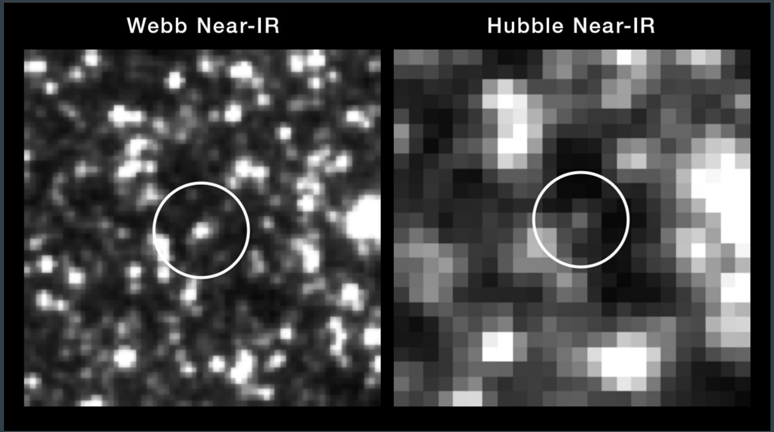
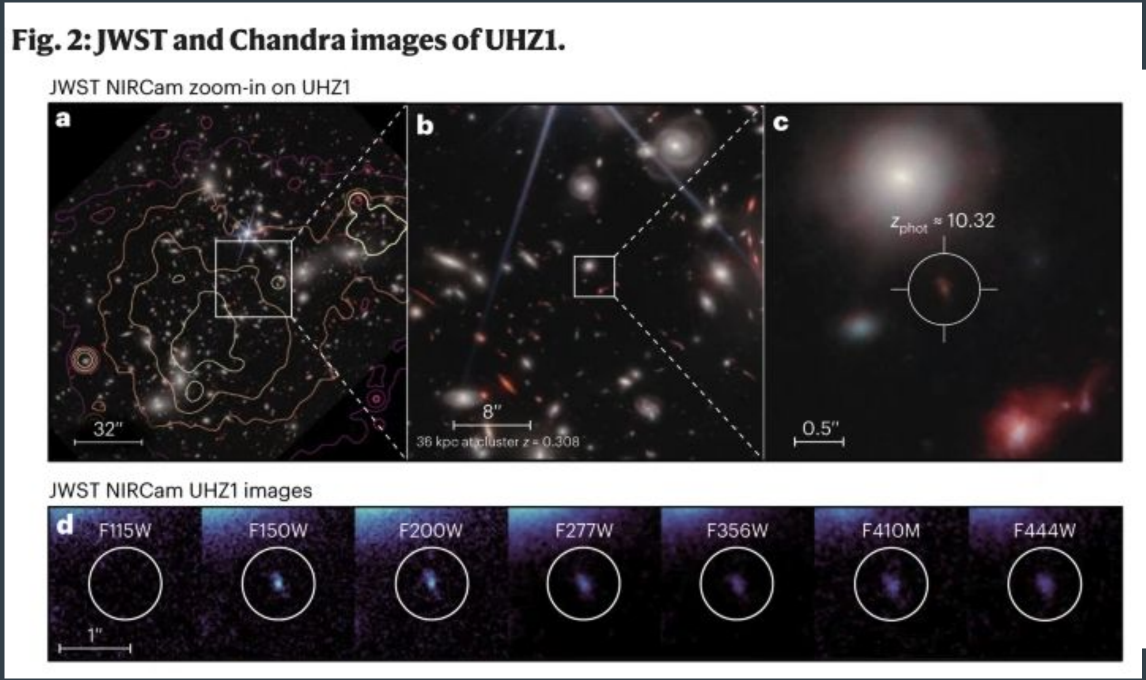
James Webb Space Telescope (JWST)

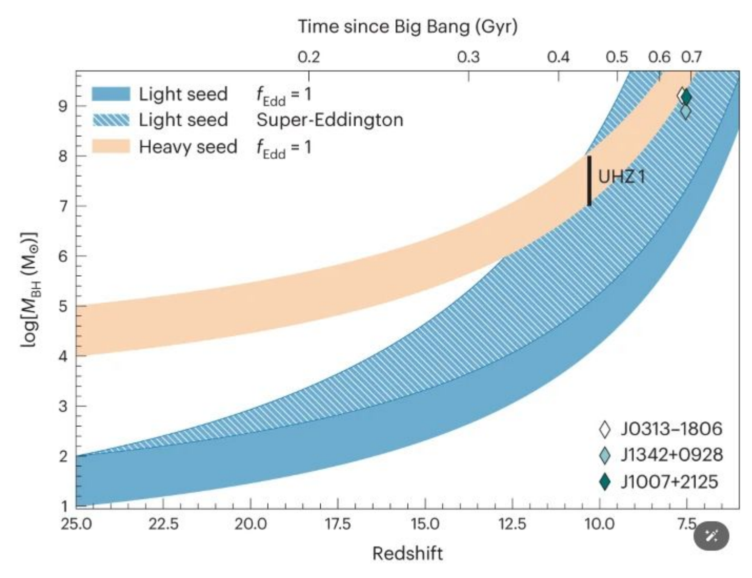


https://www.nasa.gov/image-article/james-webb-space-telescope-jwst/



Some Recent Discoveries by JWST





z=10 AGN: UHZ-1

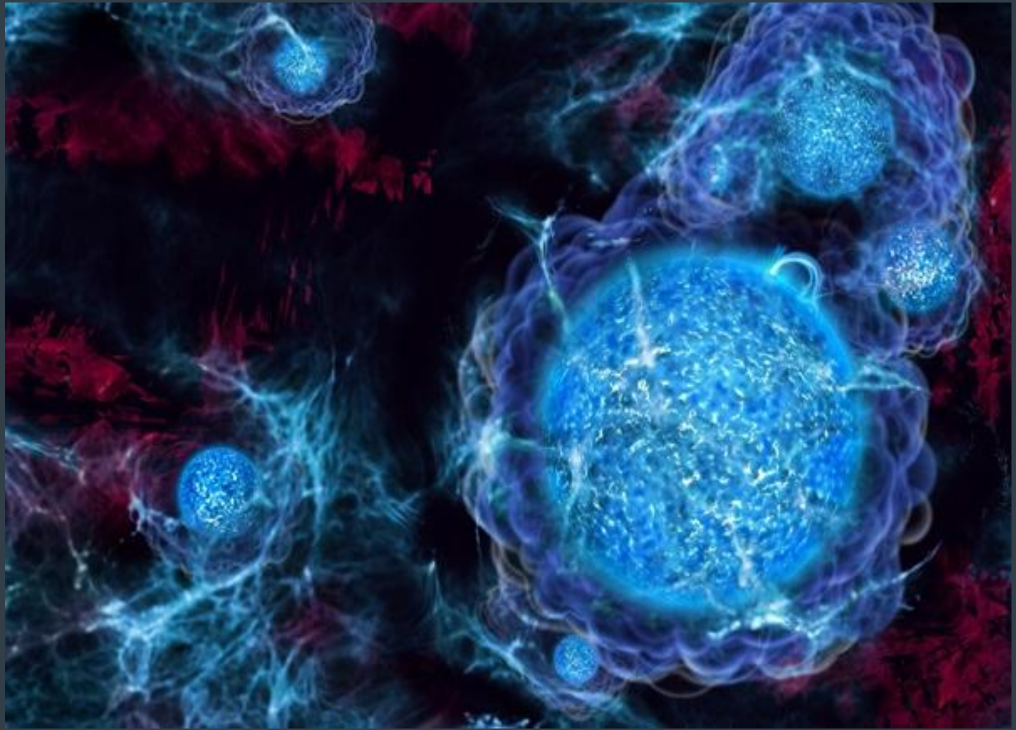
Bodgan A., et al. (2024)

What are the Dark Stars?*

Freese, K. et al. 2008; Freese, K. et al.2016

- Formed in the early universe (z~10-50)
- Powered by dark matter (WIMP) annihilation
- Giant, cool and puffy stellar object
- Two formation scenario: Adiabatic Contraction(AC) and Capture of DM
- Accrete mass from surrounding to grow supermassive
- Potential seeds for supermassive black holes
- Possible Candidates Detected by JWST*

Freese, K. et al. 2010; Ilie, C. et al. 2012; Ilie, C. et al. 2023



About Pop.III Galaxies

- Formed from low metallicity gas (almost pure H and He)
- Galaxies made mainly of population III stars
- Can grow as large as ~10^7 solar mass in Lambda-CDM universe*, and even larger in other scenarios

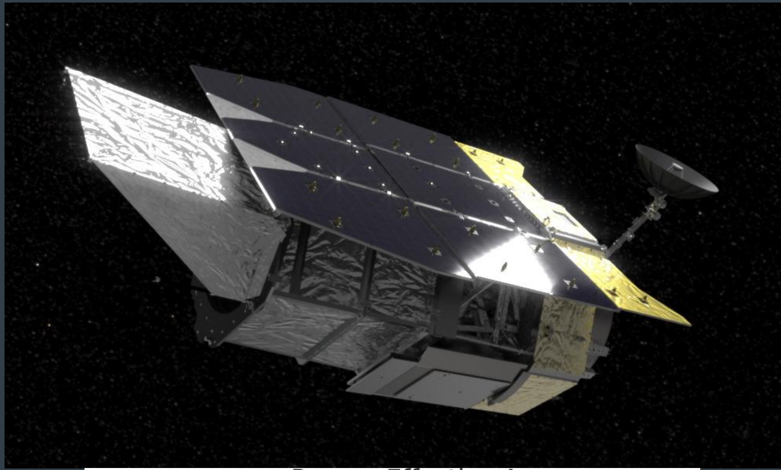
Jaacks, J., et al. 2018

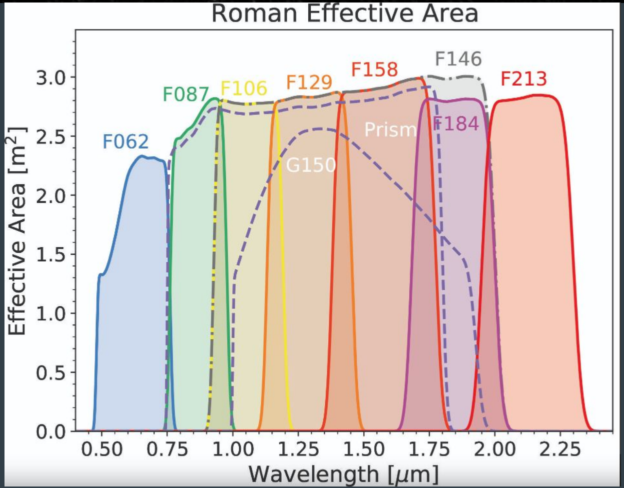
- Evolutionary spectrum modeled by YggDrasil*, and detectable by JWST

Zackrisson, E., et al. 2011

Roman Space Telescope

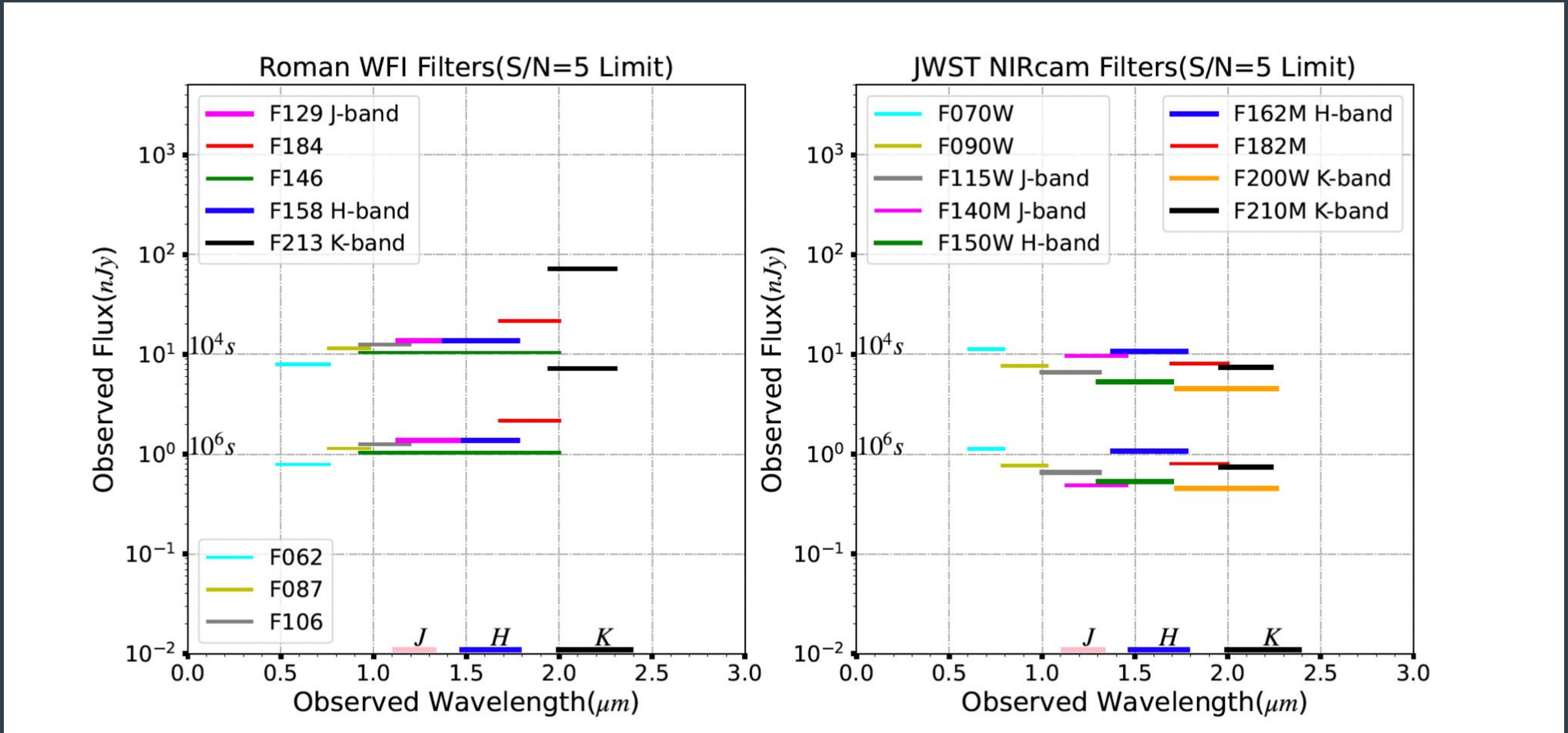
- Designed to launch in Oct 2026
- 0.28 deg^2 field of view, 100x larger field of view compared to Hubble Space Telescope
- Designed for Wide Field Survey, which will explore Dark Energy, Dark Matter, Exoplanet and Near-Infrared Science
- Wide Field Imaging covers wavelengths from ~0.5-2.3 microns
- Pandeia Engine for image simulation*





Pontoppidan, Klaus M., et al. 2016

JWST vs. Roman



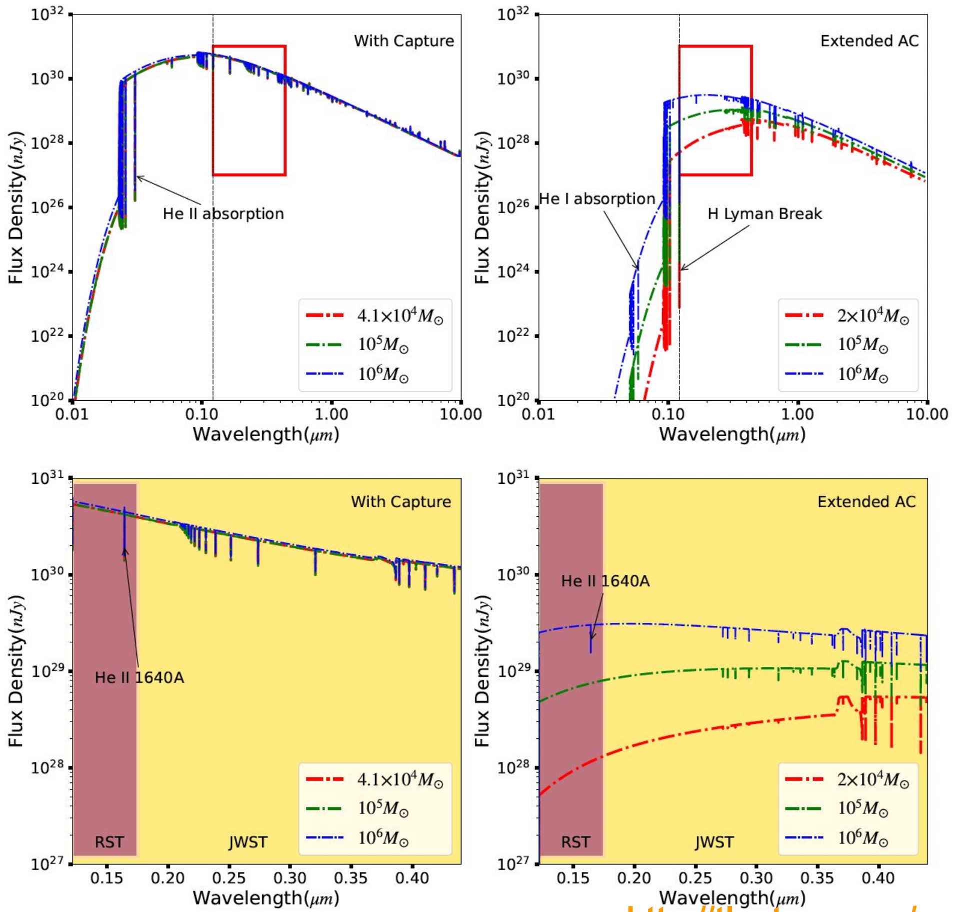
JWST vs. Roman

- Rest Frame Spectrum generated by TLUSTY*

  Hubeny, I., 1988

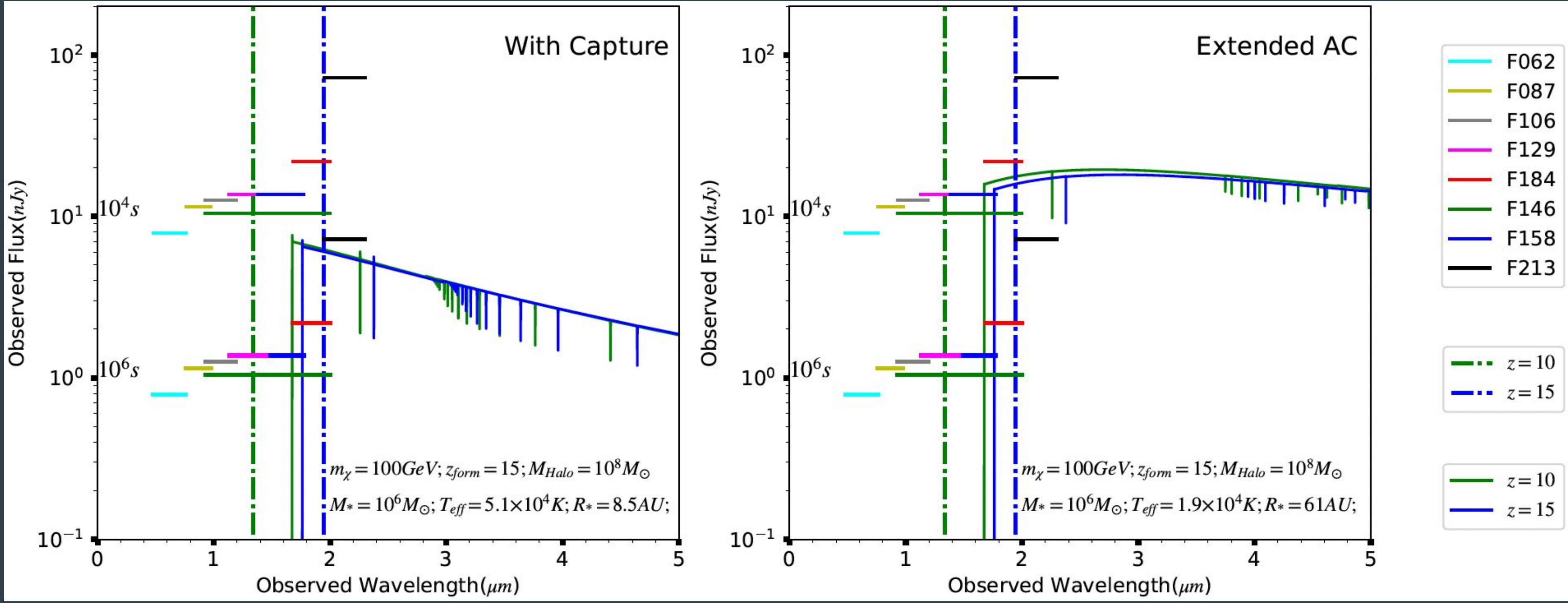
- He II 1640A absorption line as the smoking gun
- JWST covers wider wavelength while having smaller field of view compared to Roman
- Combine JWST and Roman to detect Dark Stars*

  Zhang, S., et al, 2024



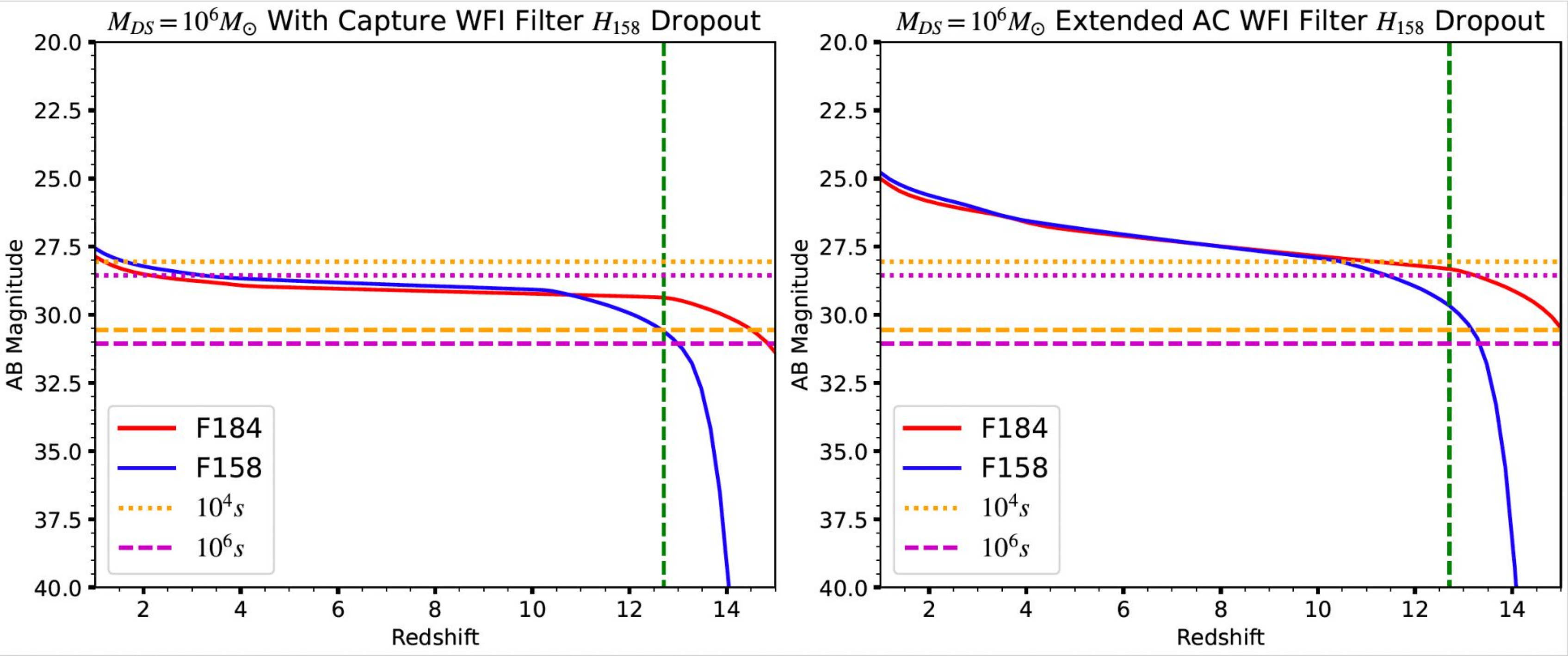
http://tlusty.oca.eu/

Photometry with Roman



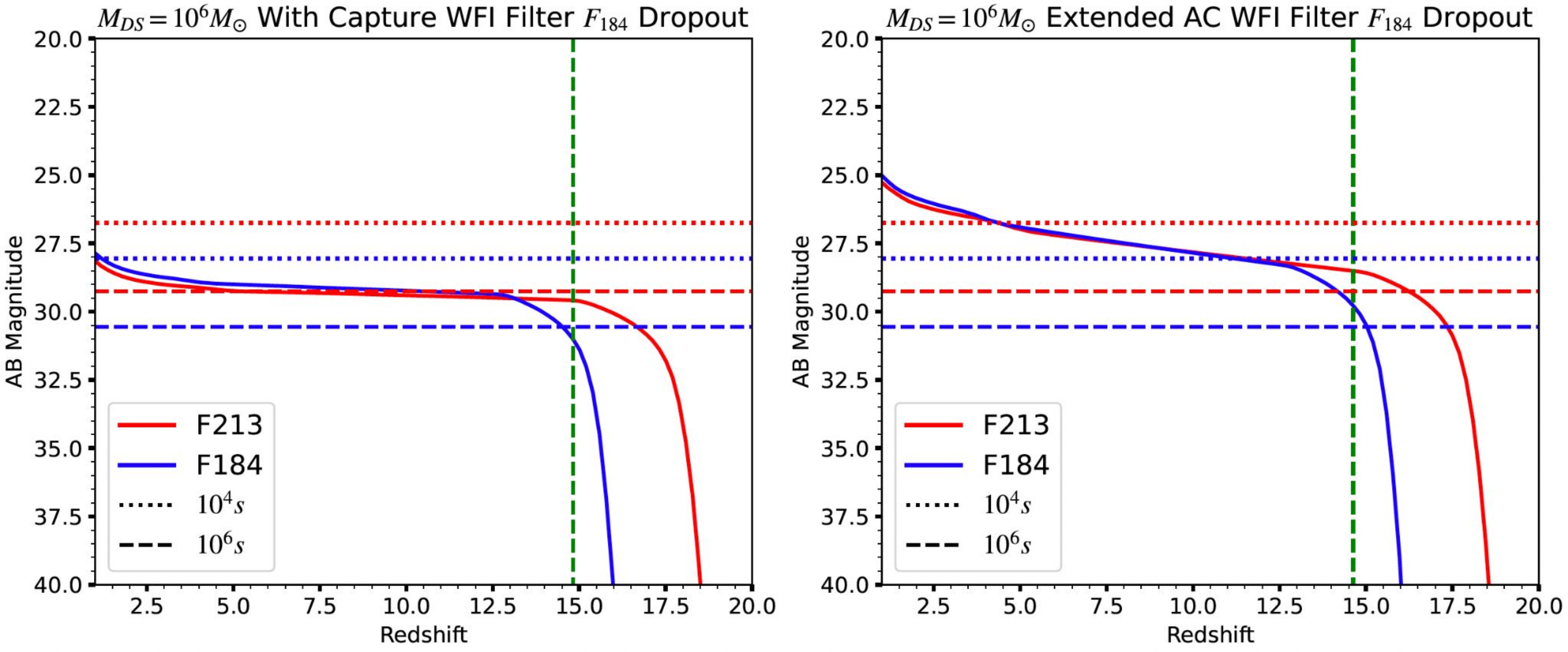
Zhang, S., et al, 2024

Magnitude Prediction



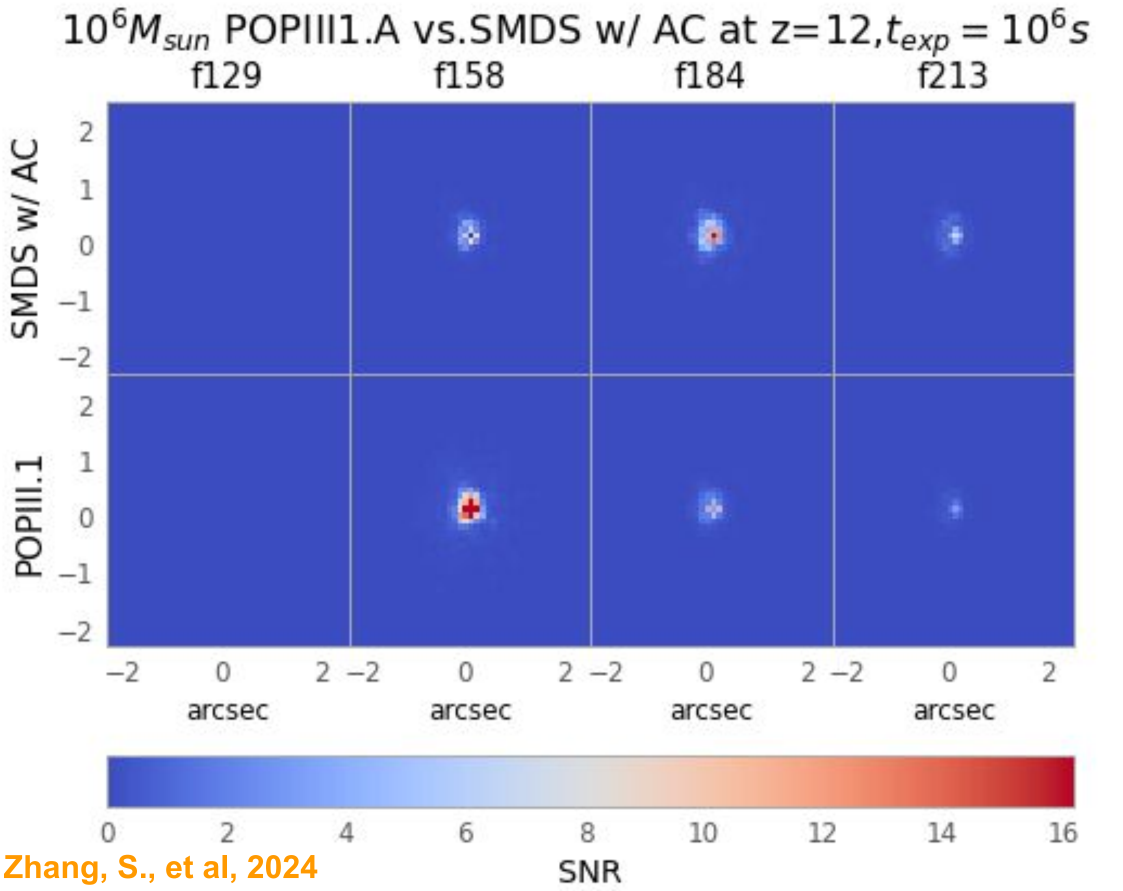
Zhang, S., et al, 2024

Magnitude Prediction



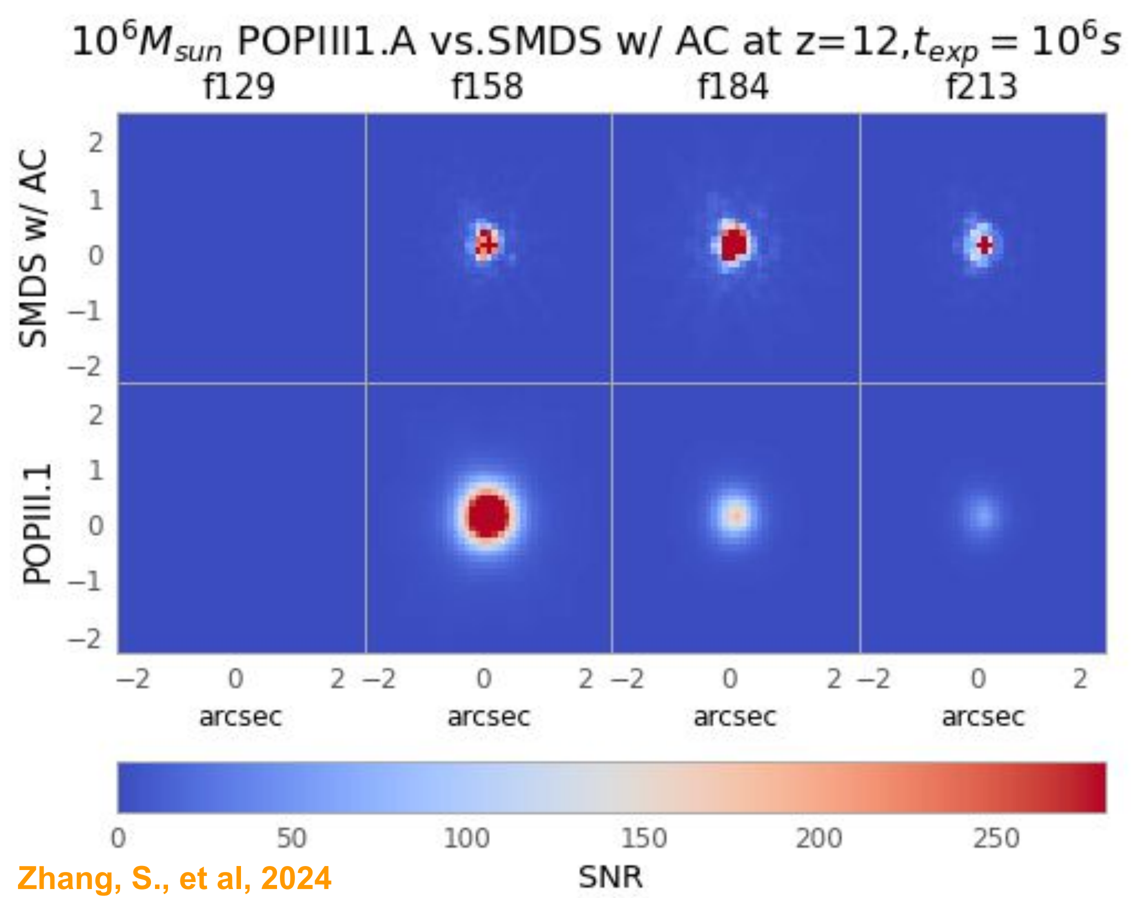
Zhang, S., et al, 2024

Without the effect of lensing, how the images might look like in the Roman Space Telescope?



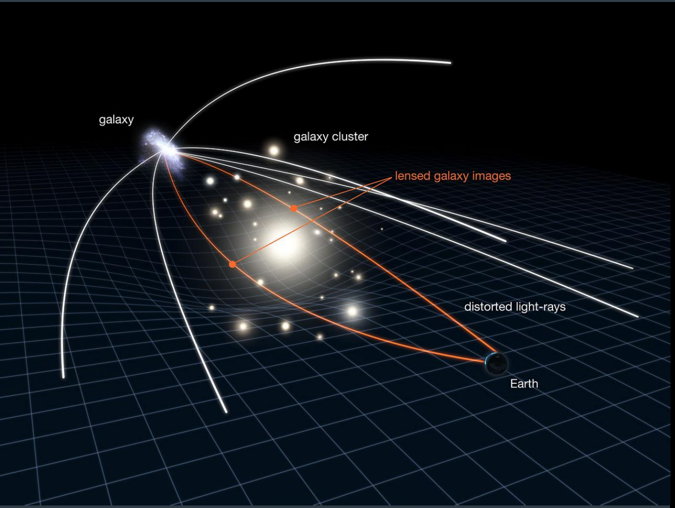
Zhang, S., et al, 2024

When the objects are magnified by 100x through gravitational lensing, then how the image might look like:

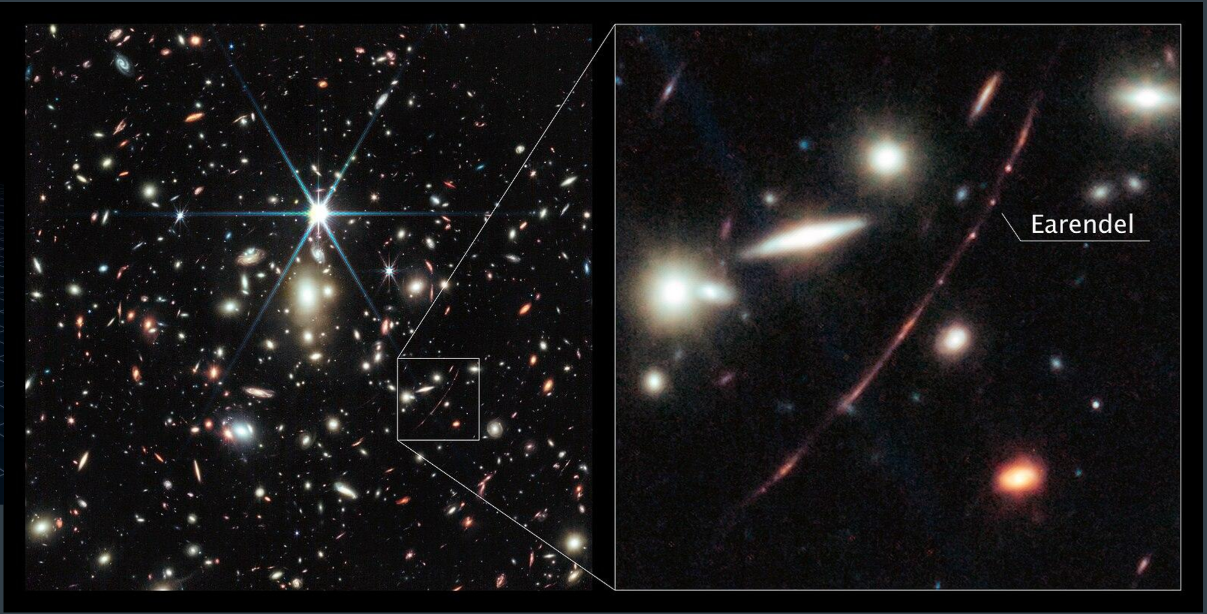


Zhang, S., et al, 2024

Earendel: an Example of Gravitational Lensing

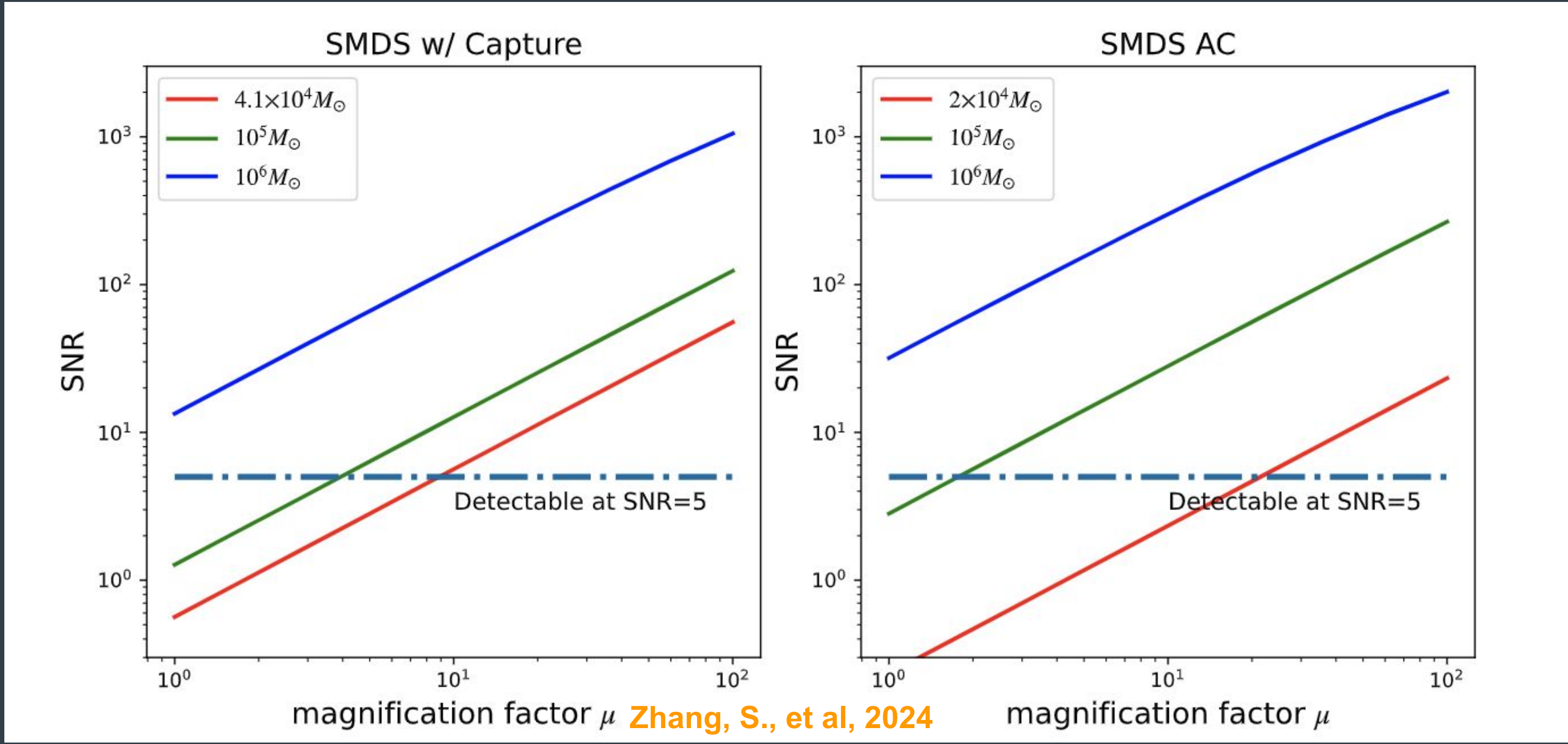


https://esahubble.org/images/heic1106c/



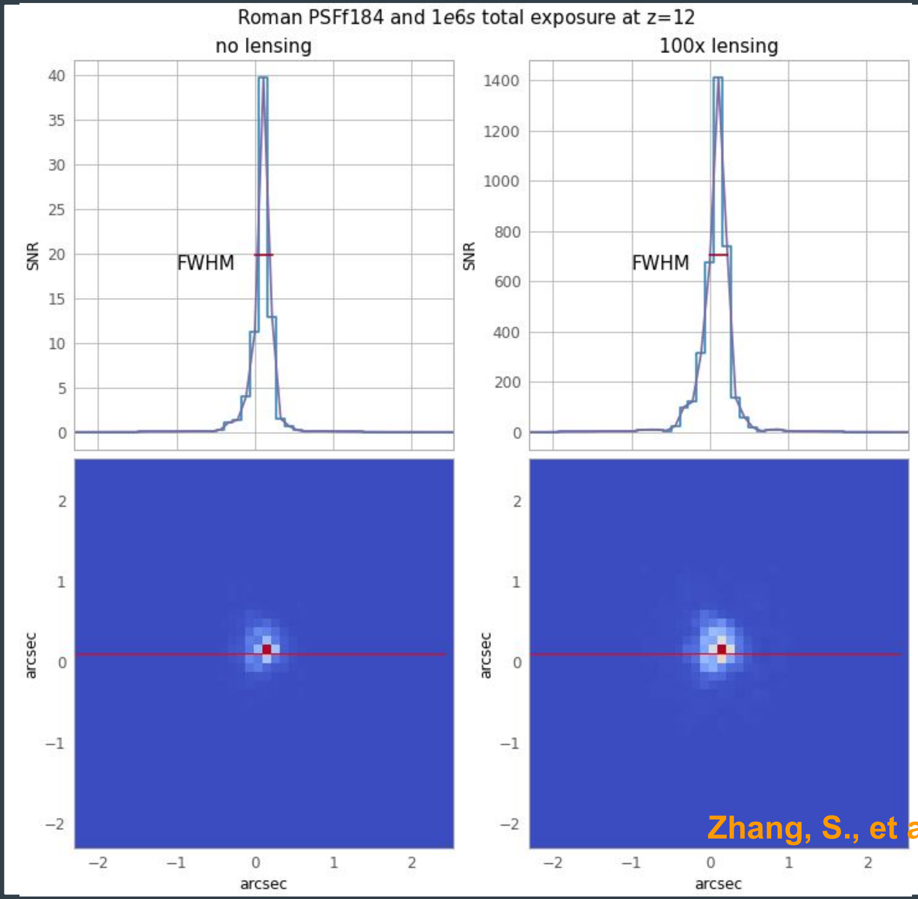
Welch, B., et al 2022

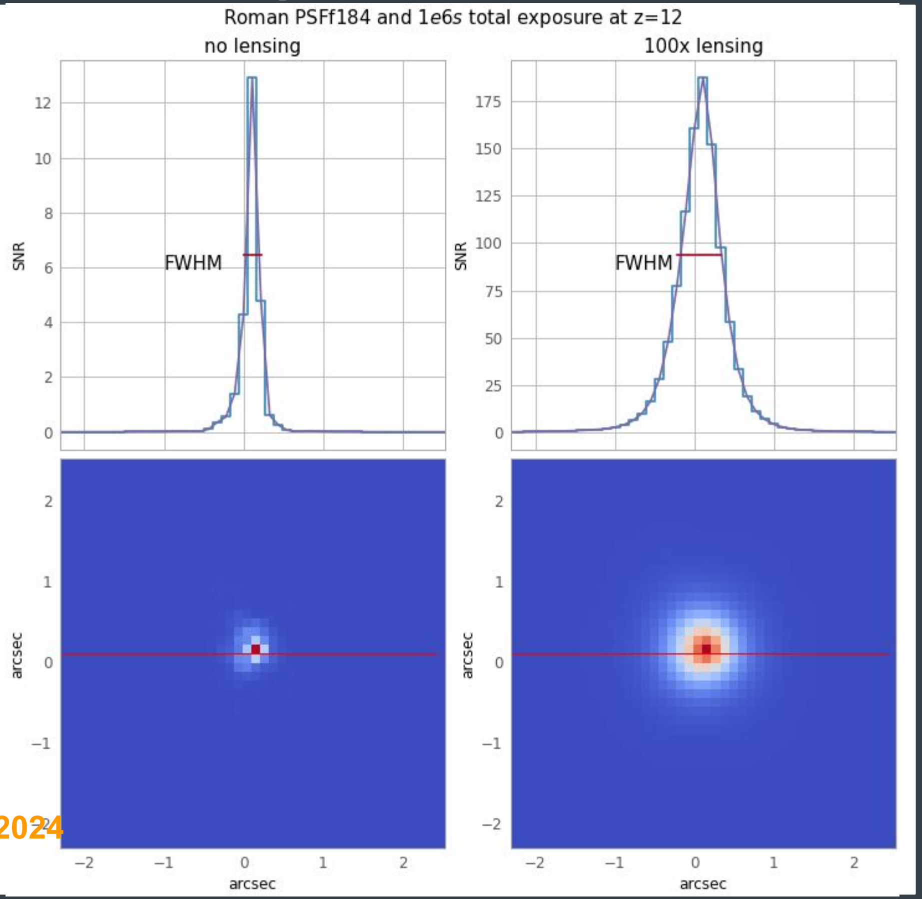
Photometric Detection with Lensing



Zhang, S., et al, 2024

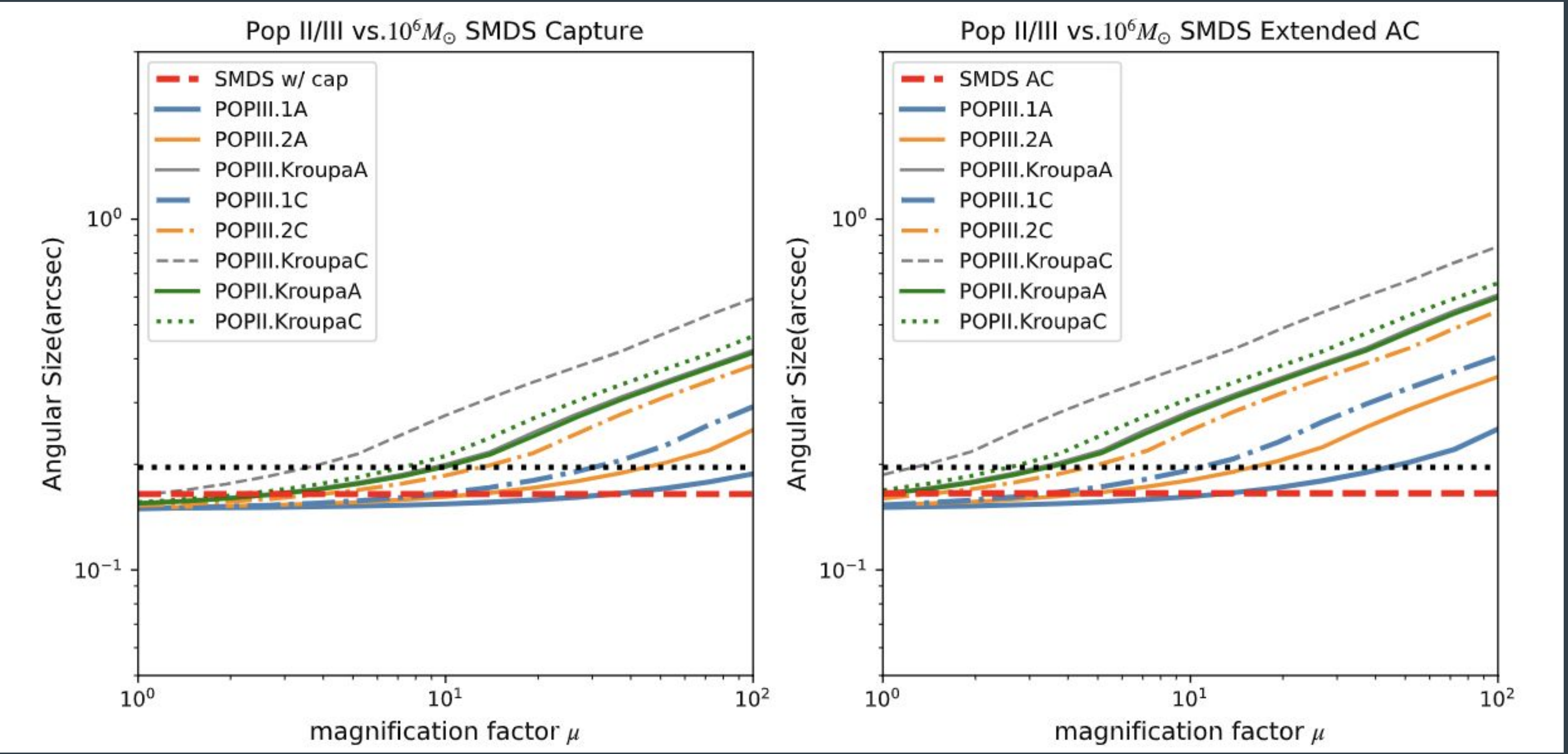
Effective size: SMDS vs. POP III galaxies





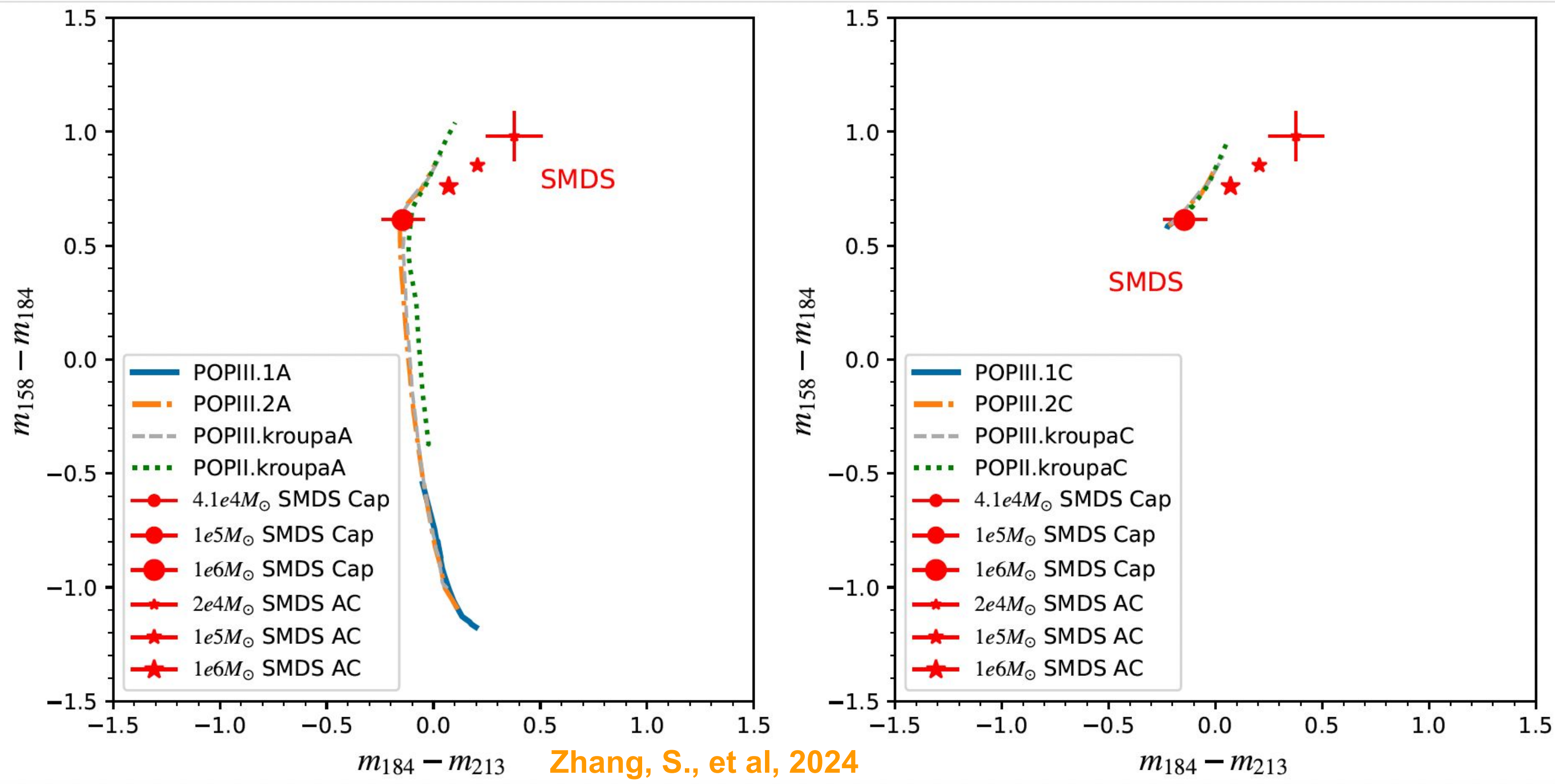
Zhang, S., et al, 2024

Effective size: SMDS vs. POP III galaxies



Zhang, S., et al, 2024

Color Index: SMDS vs. POP III galaxies



Zhang, S., et al, 2024

Summary of the results

- Super massive dark stars (~10^6 solar mass) could be observed by Roman Space Telescope without lensing
- With lensing, it is possible to resolve supermassive dark stars of lower mass (~10^4 solar mass) from other luminous objects based on color-color diagram
- With lensing by foreground clusters (μ~10), it is possible to tell SMDS from Pop III galaxies by their effective size
- It is more likely to distinguish super massive dark stars formed via adiabatic contraction from other objects than those formed by dark matter capture

Future Directions

- Find more possible Dark Star observational signatures
- Algorithm to distinguish between Dark Stars from objects (if enough data has been collected)
- Spectroscopic analysis of the SMDS Candidates
- Find more possible dark star candidates from available JWST dataset

Thank you!
Grazie!