Detecting subhalos with very steep inner-density profiles using strong gravitational lensing

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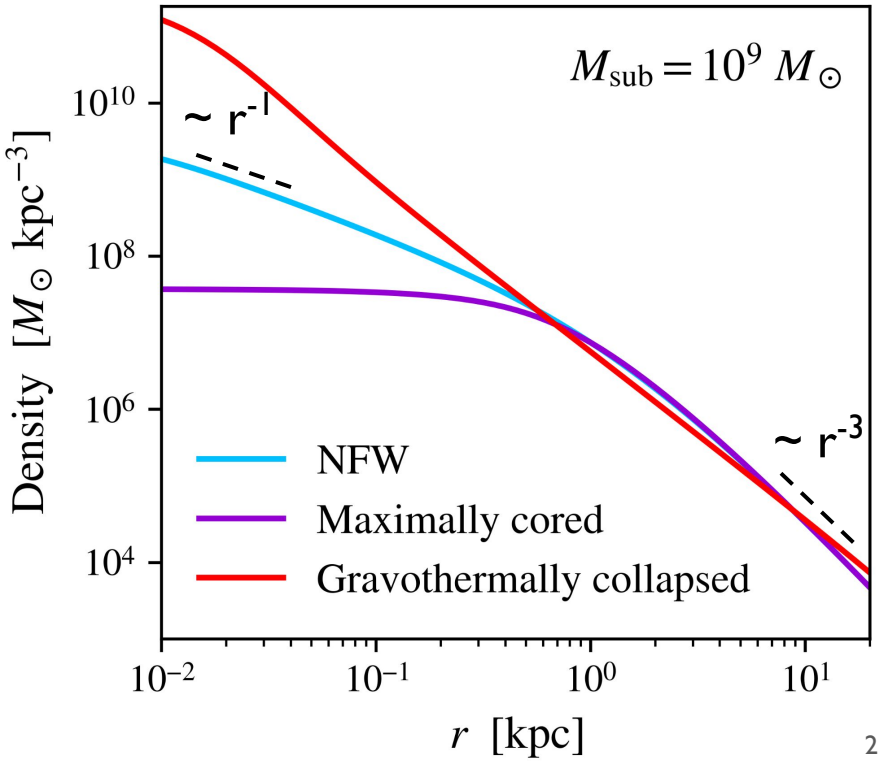
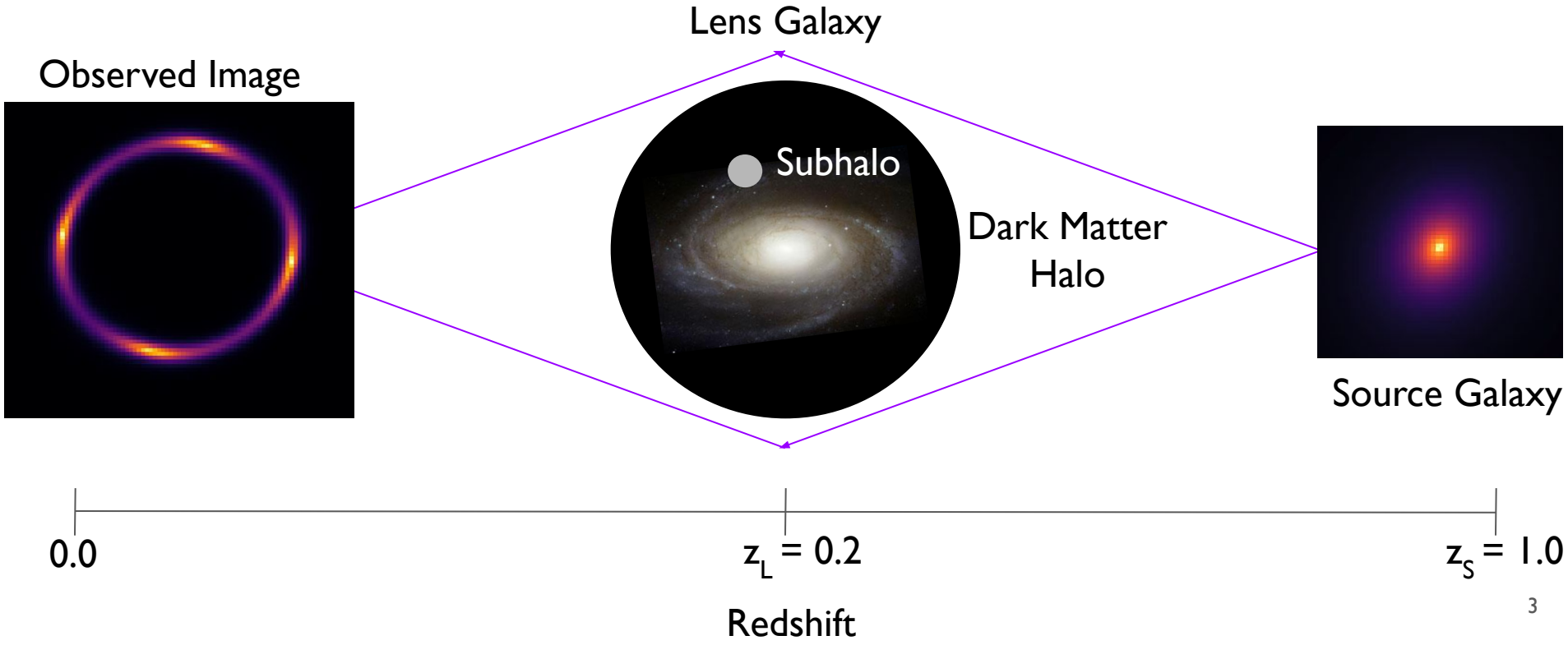
Navarro et al. (1996), (1997)
Spergel & Steinhardt (2000)

Dark Matter

- Cold dark matter (CDM)
  - Collisionless
  - Universal halo density profile
- Self-interacting dark matter (SIDM)
  - Self-interactions induce heat transfer in halo which can significantly impact halo structure



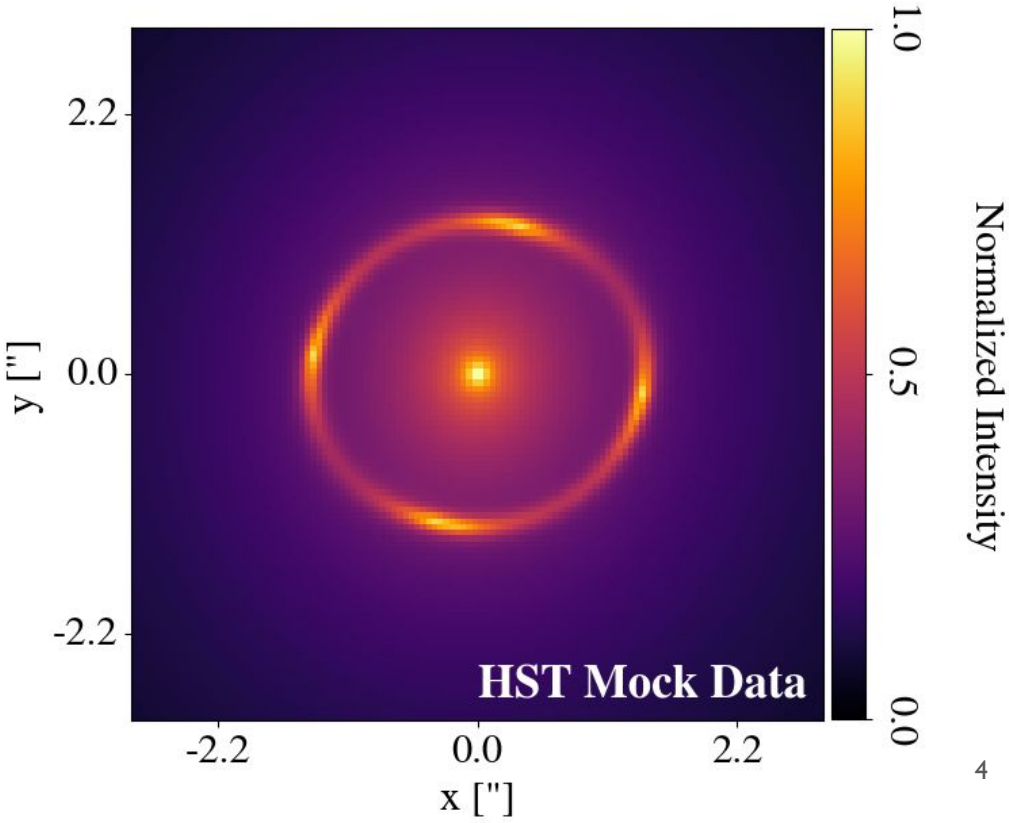
Galaxy-Galaxy Strong Lensing



This Work

1. How does the subhalo's inner density slope impact its detectability in a strong lens galaxy?

2. Can the subhalo's inner slope be accurately inferred from the data?

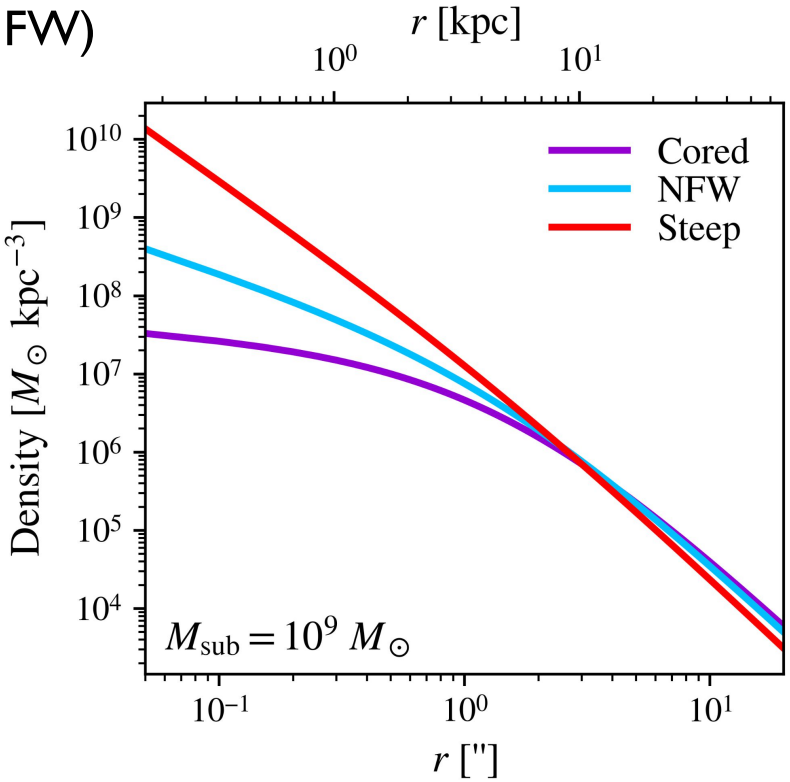


Subhalo Perturber

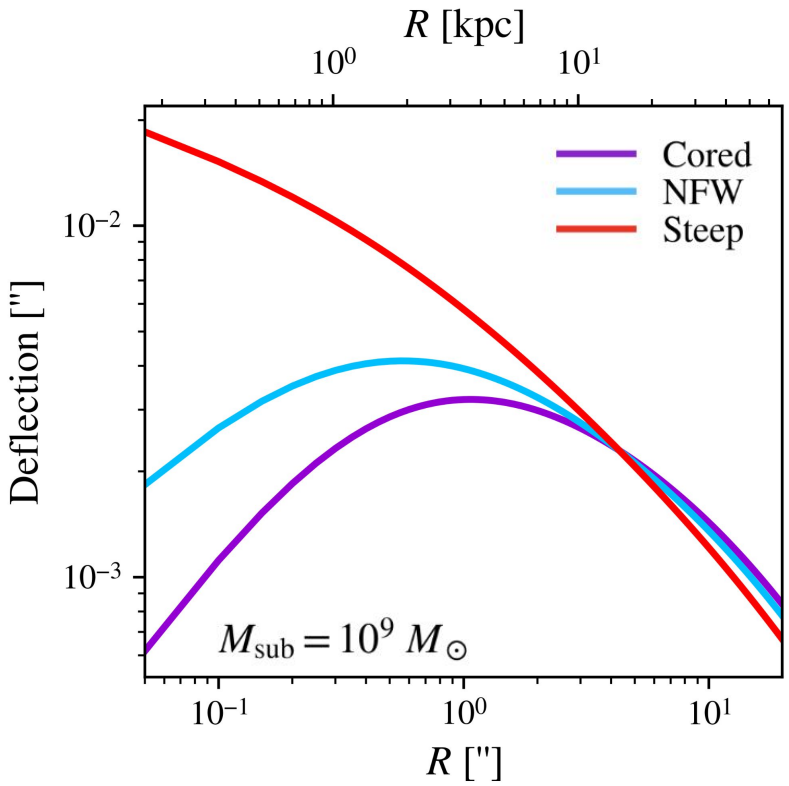
Simulate subhalos with a generalized NFW (gNFW) density profile

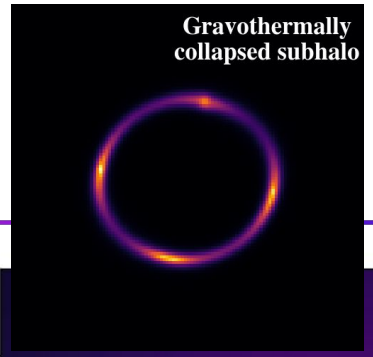
$$\rho_{gNFW}(r) = \frac{\rho_0}{\left(\frac{r}{r_s}\right)^{\beta}\left(1+\frac{r}{r_s}\right)^{3-\beta}}$$

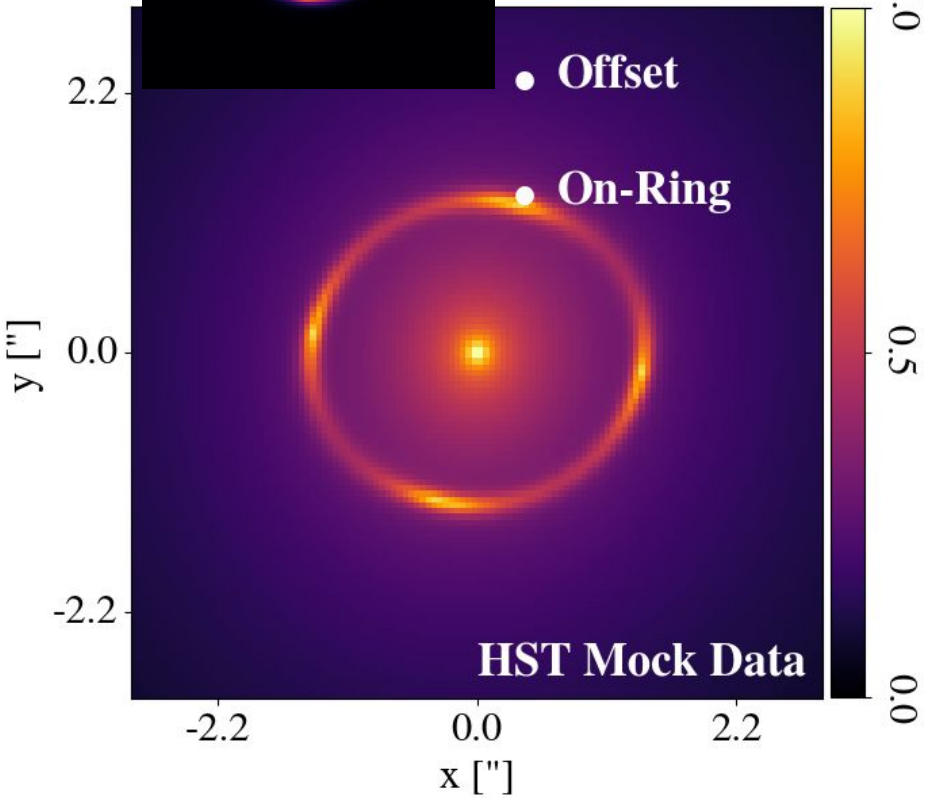
- $M_{200} = 10^{7.5}$ - 10^{10} $M_\odot$
- Inner slopes:
  - β = 0.2 (Cored)
  - β = 1.0 (NFW)
  - β = 2.2 (Steep)
- Concentration from Ludlow et al. (2016)



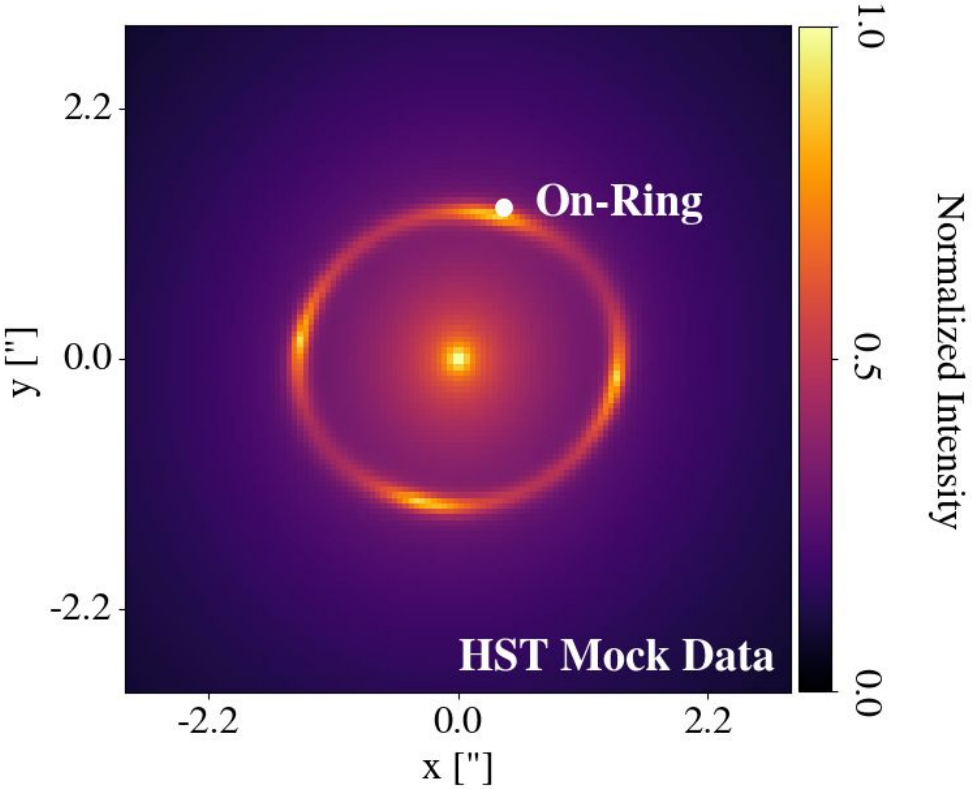
Subhalo Perturber

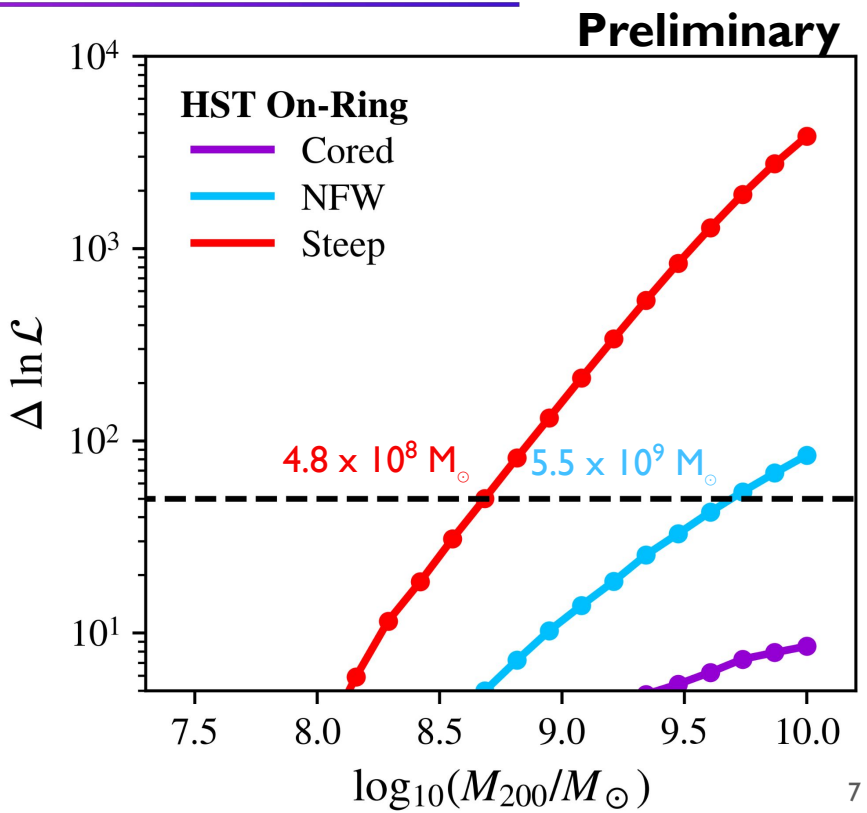




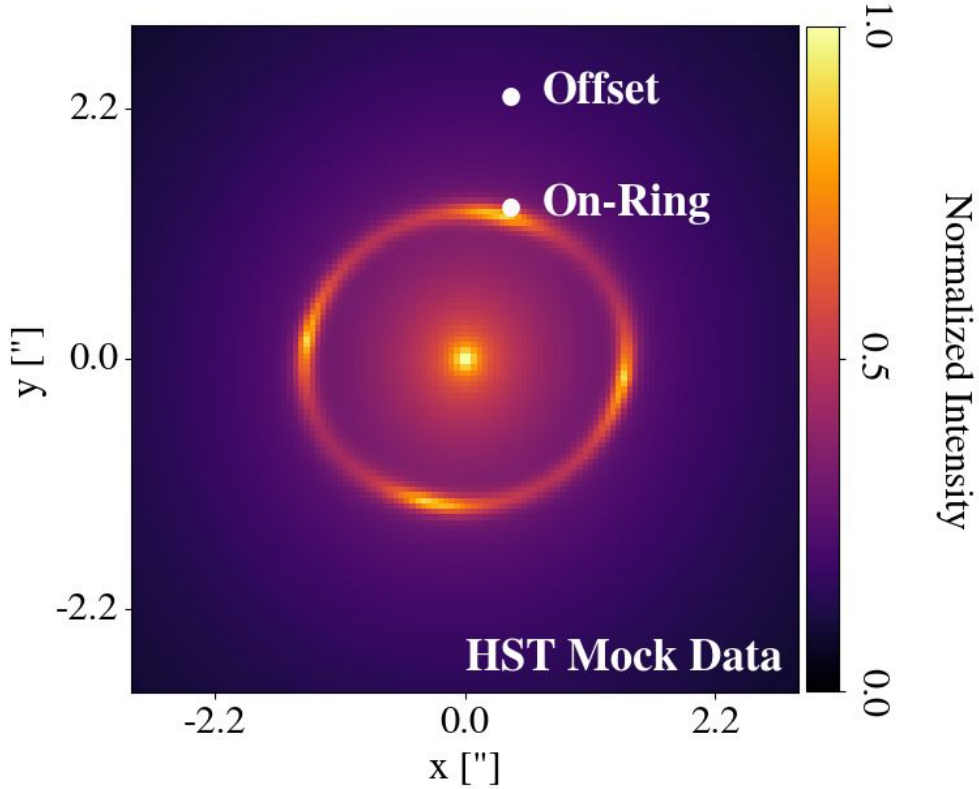


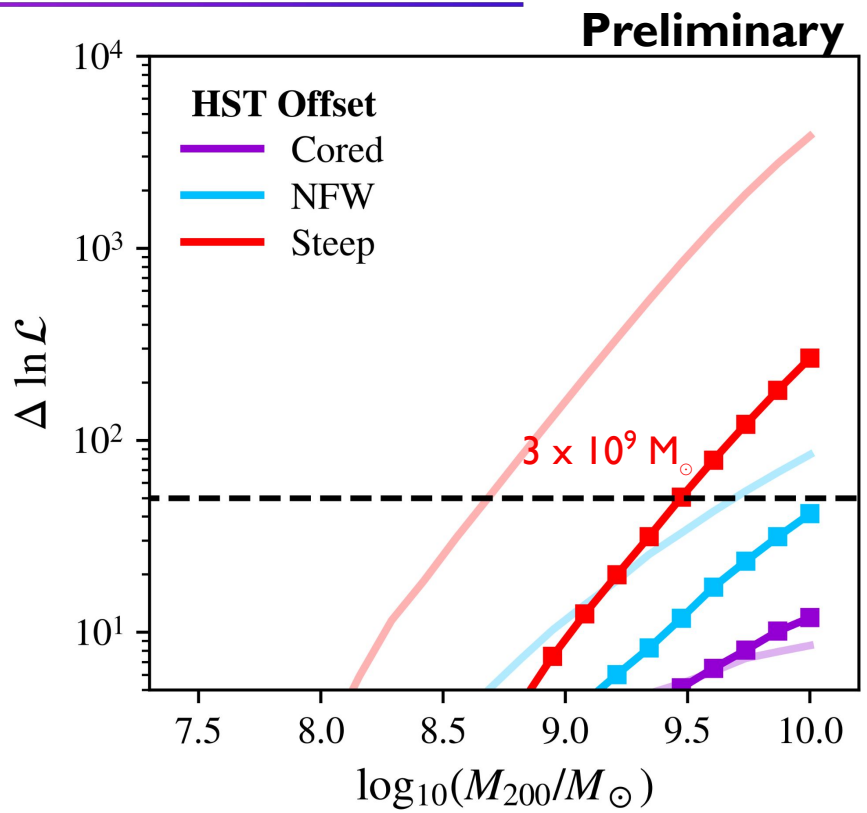
Subhalo Detectability





Subhalo Detectability

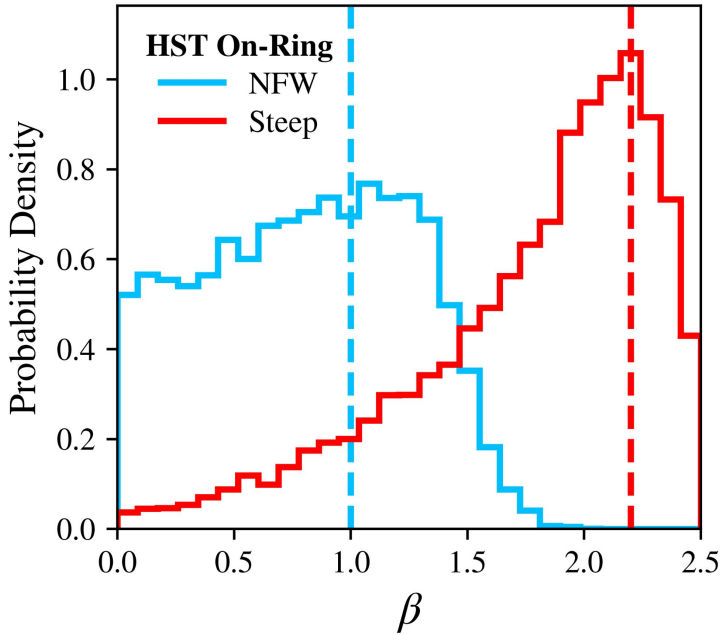




Inferring Inner Slope

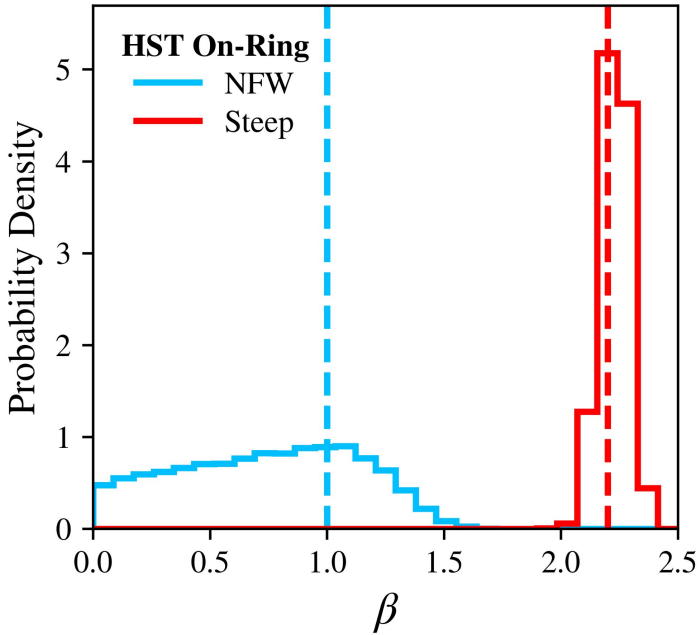
Minimum-mass detectable

$M_{NFW} = 5.5 \times 10^9\ M_\odot$ $M_{Steep} = 4.8 \times 10^8\ M_\odot$



Preliminary

$10^{10}\ M_\odot$

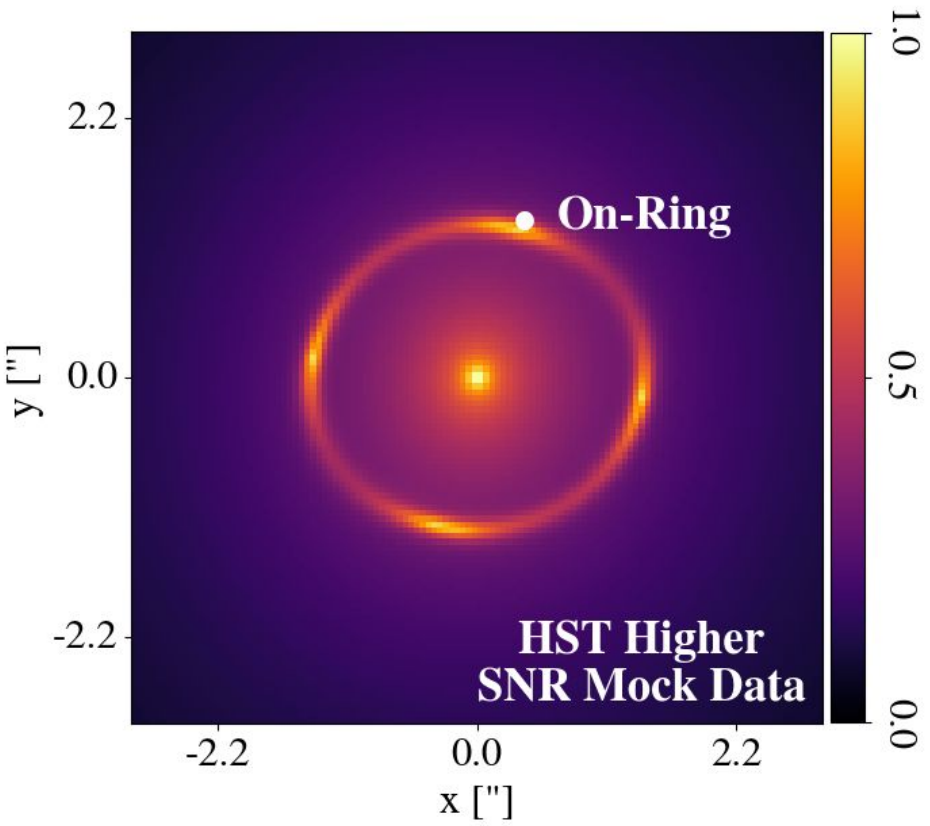


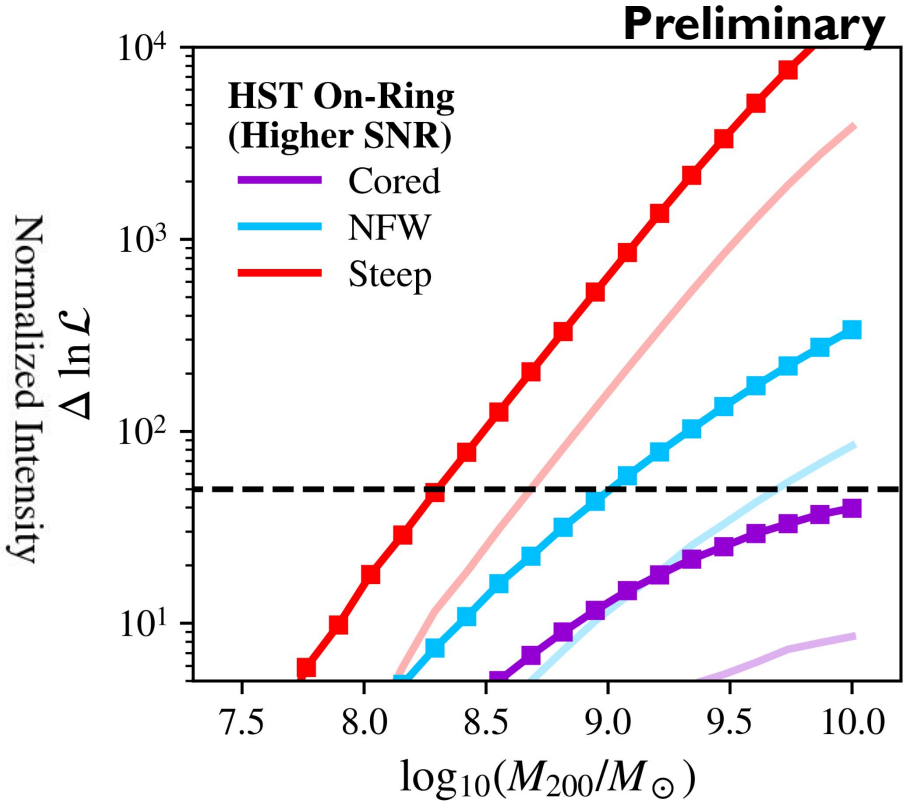
Conclusions

- Strong lensing is a promising probe of dark matter physics
- Detectability of subhalos along the Einstein ring is strongly dependent on β
- Strong lensing can robustly recover steep inner density slopes
- Additionally explored:
  - Variations to observation properties
    - Euclid-like data
    - JWST-like data
    - Varying SNR
  - Impact of lens model complexity (multipoles)

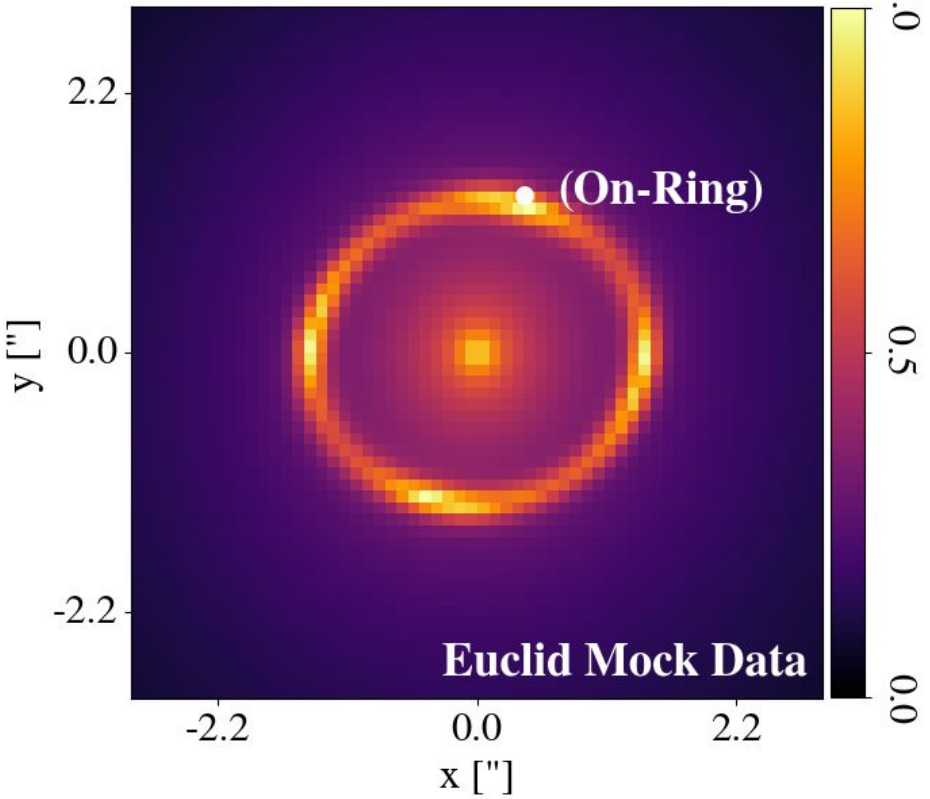
Extra Slides

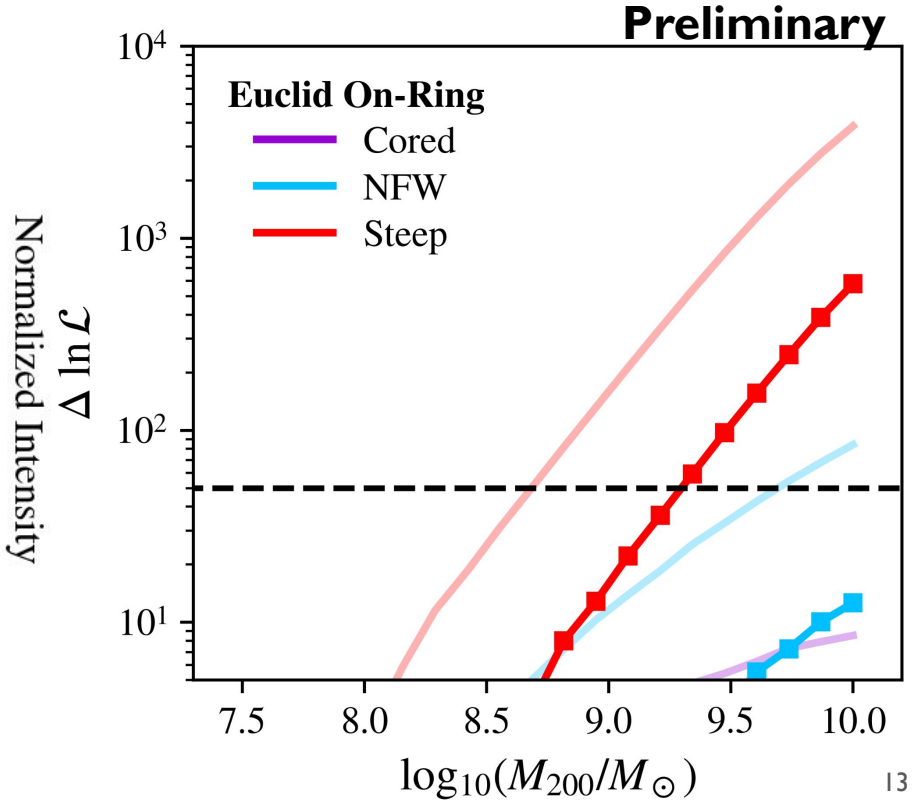
Subhalo Detectability: HST Higher SNR On-Ring



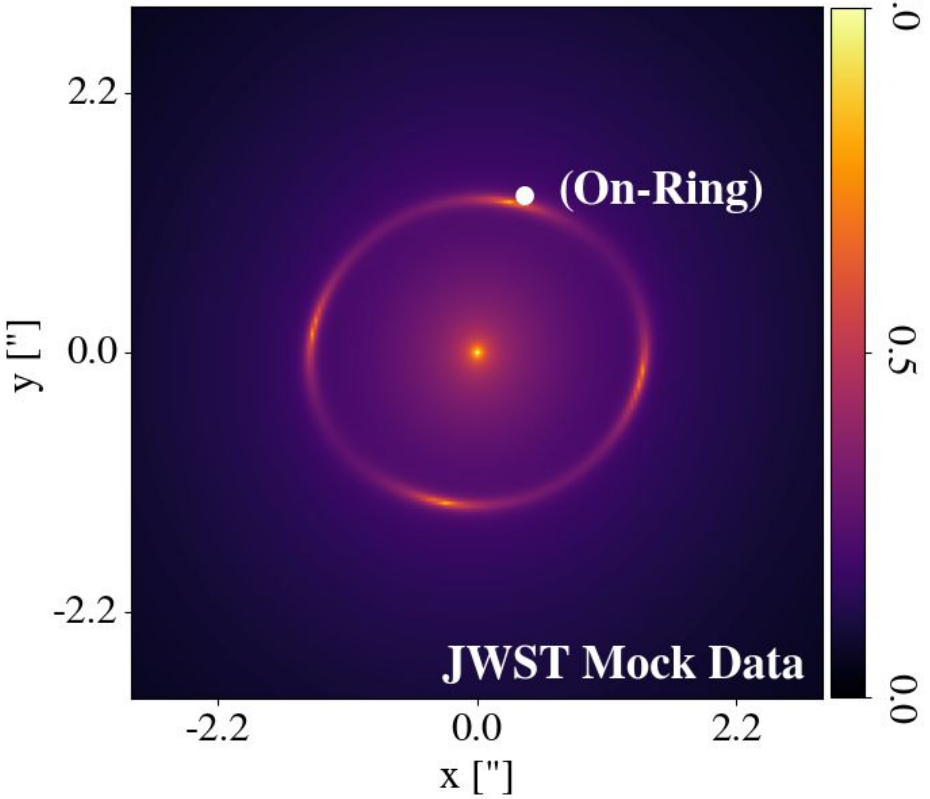


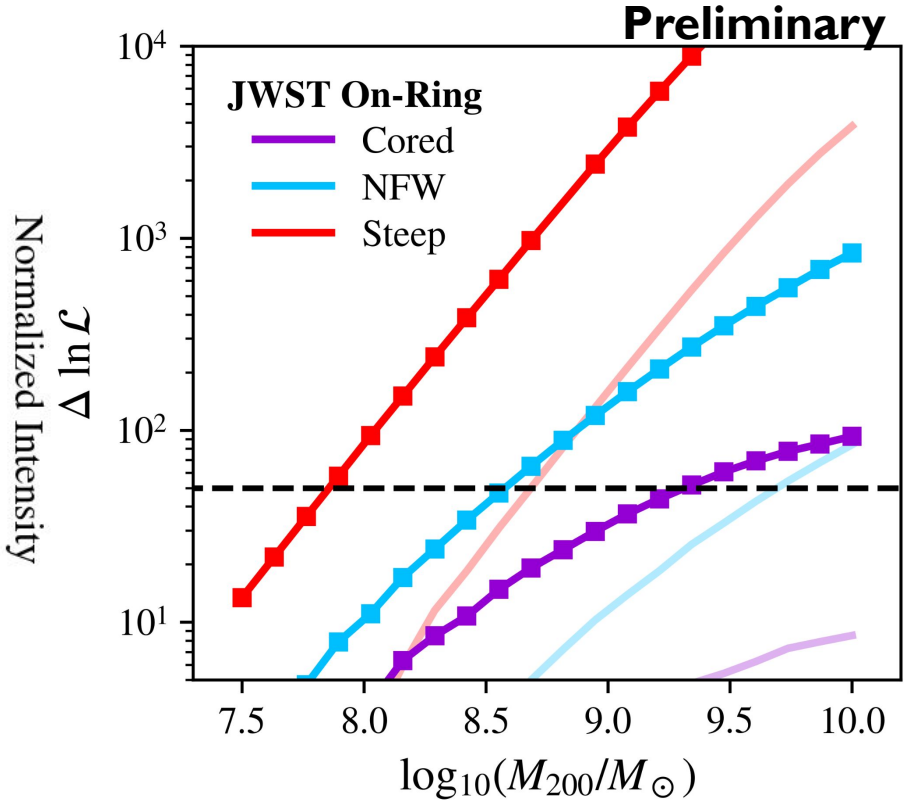
Subhalo Detectability: Euclid On-Ring



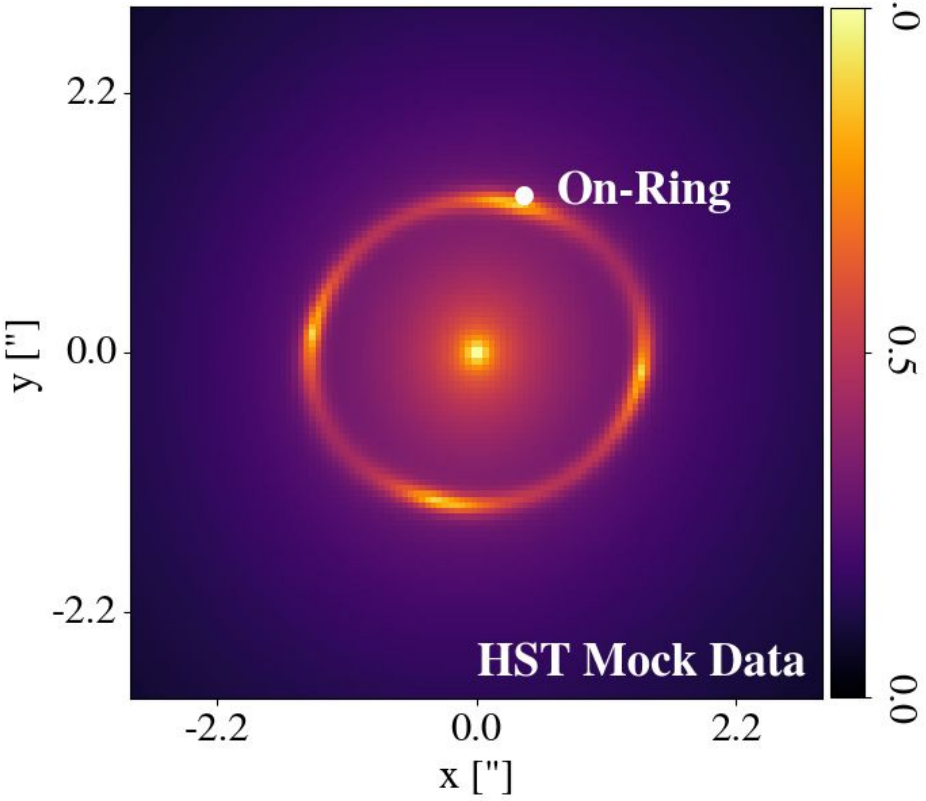


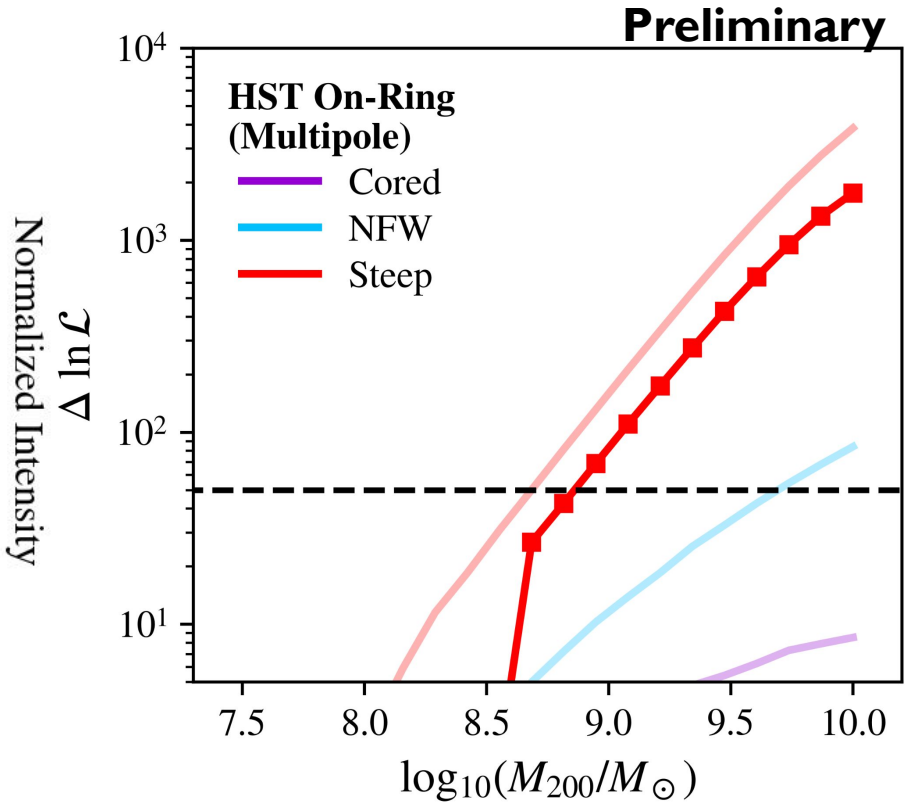
Subhalo Detectability: JWST On-Ring





Subhalo Detectability: HST On-Ring (multipoles)





Subhalo Detectability: HST Offset (multipoles)