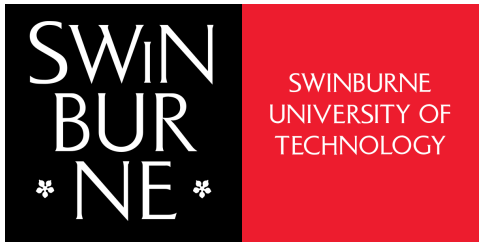
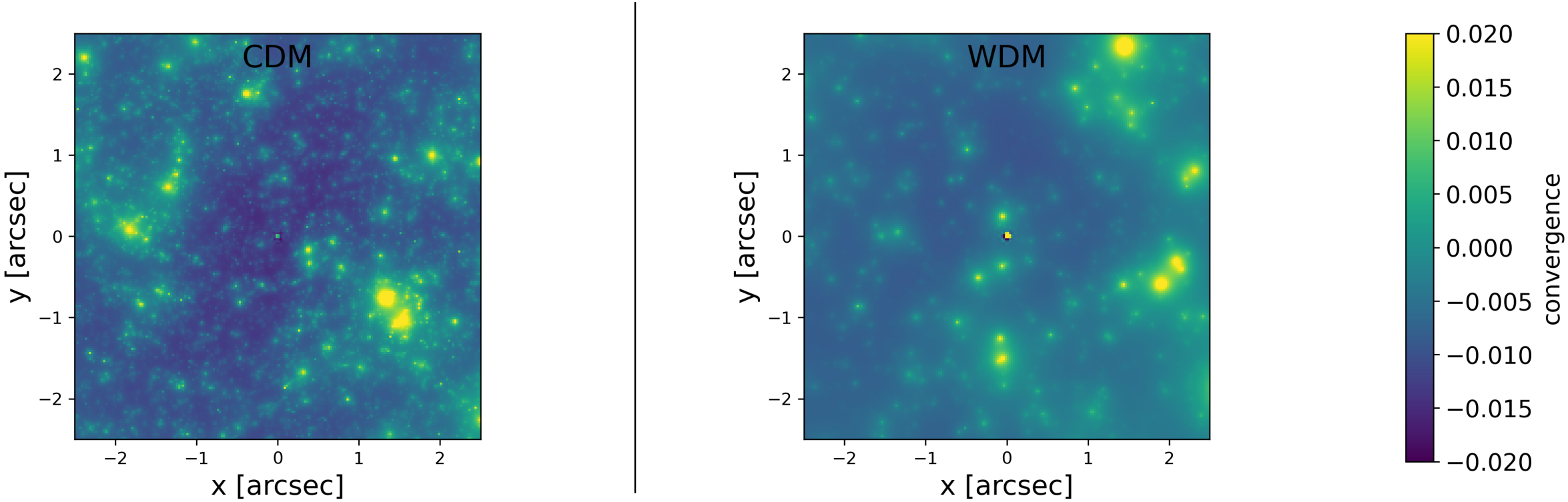
The effects of source morphology on machine learnings ability to identify dark matter substructure in strong gravitational lenses

Tyler Hughes

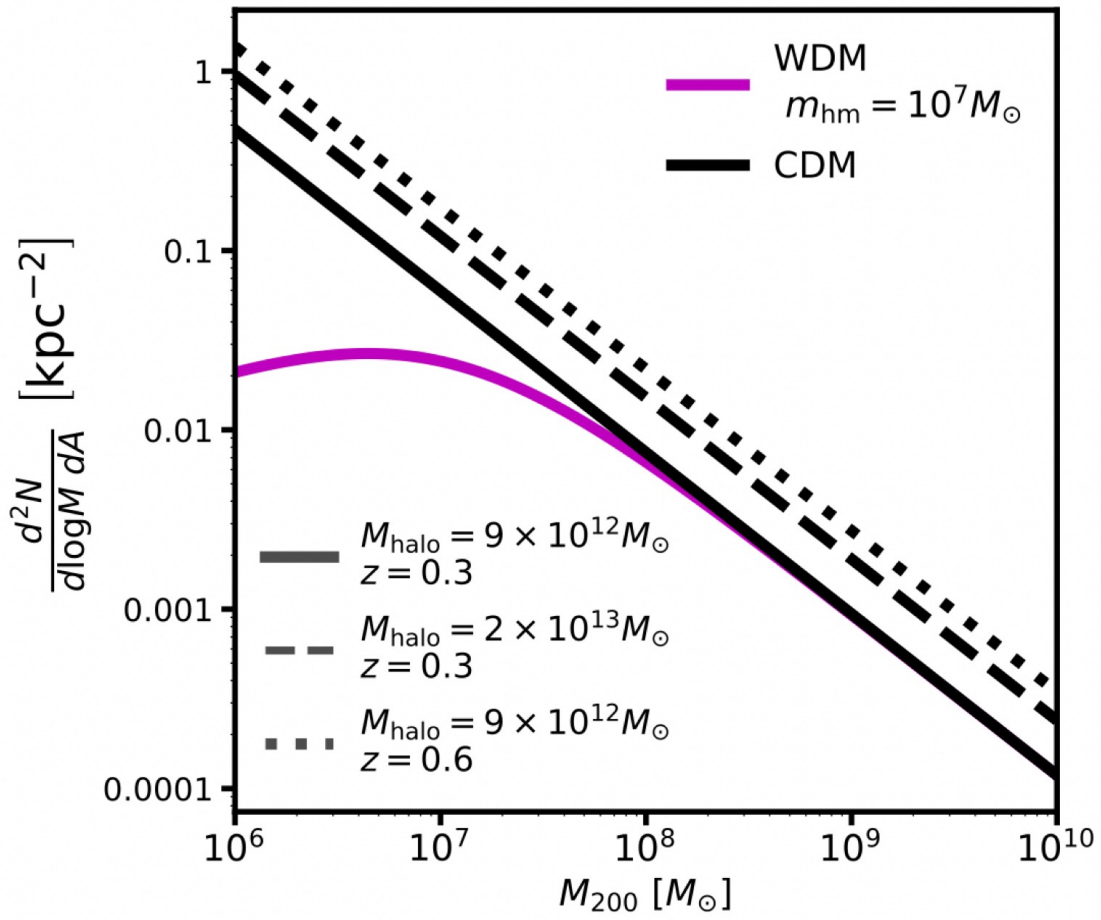


Dark matter substructure



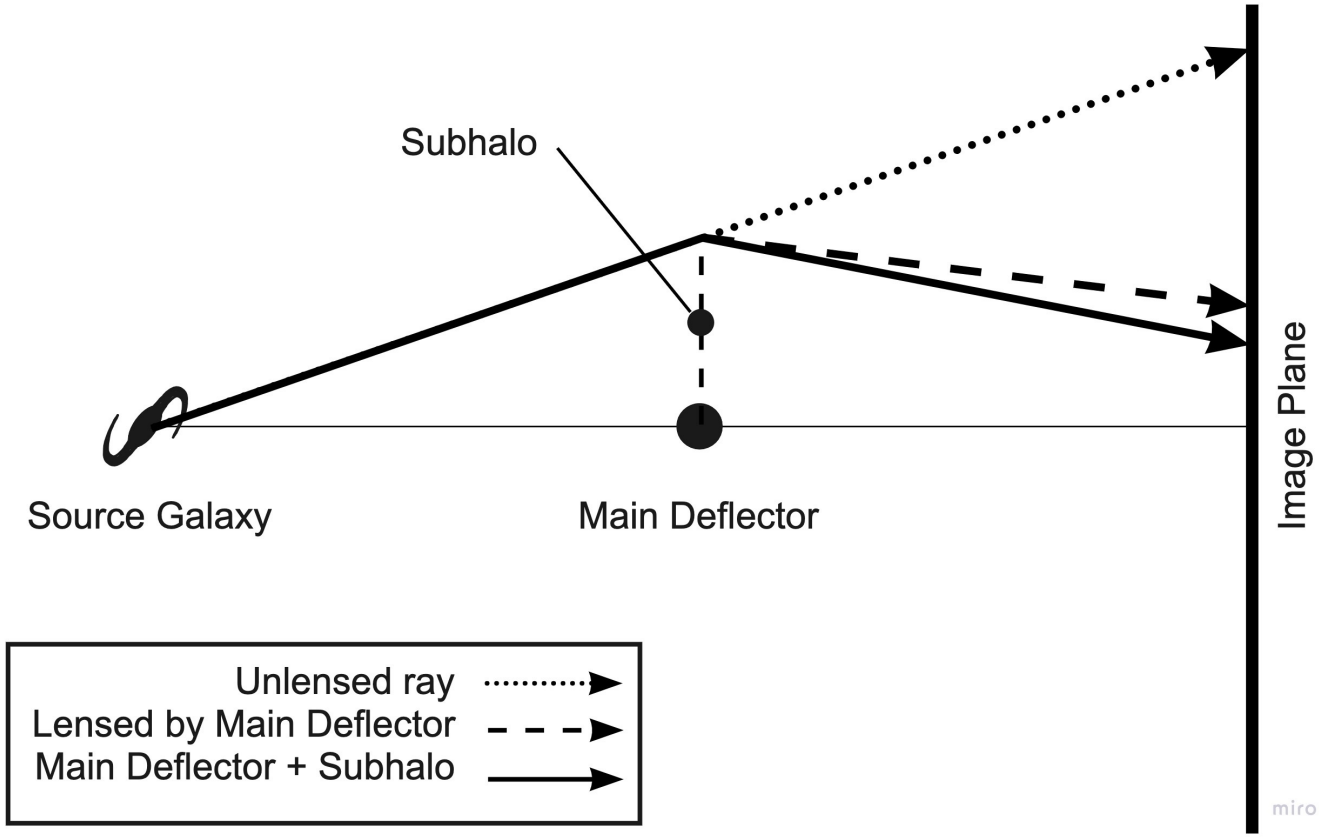
Dark matter substructure

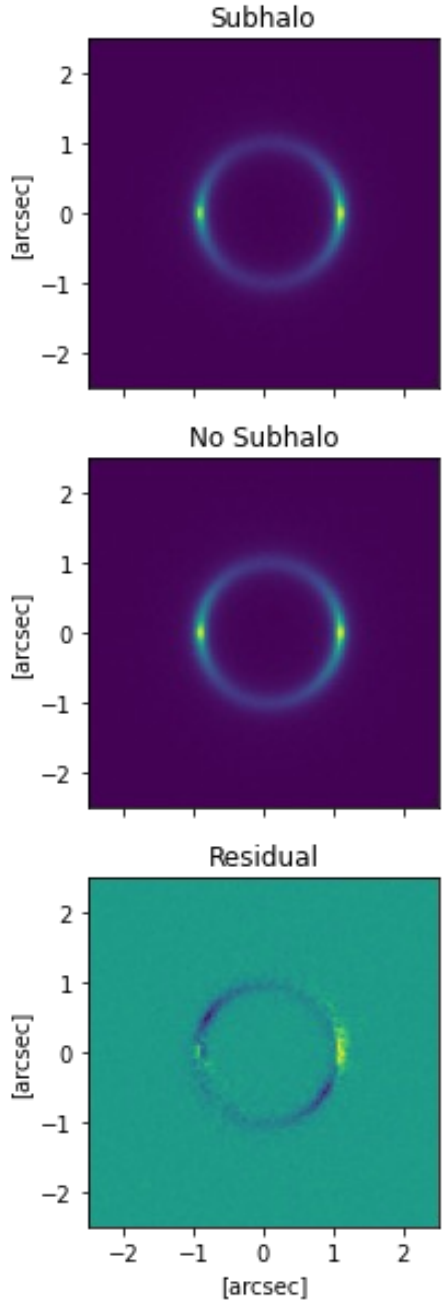
Gilman, D., Birrer, S., Nierenberg, A., et al. 2020, MNRAS, 491, 6077



- **Subhalo mass function** is the number density of subhalos as a function of mass.
- **Warm Dark Matter** has a larger free streaming length in the early universe than **Cold dark Matter.**
- Large free streaming length limits the formation of low mass subhalos.

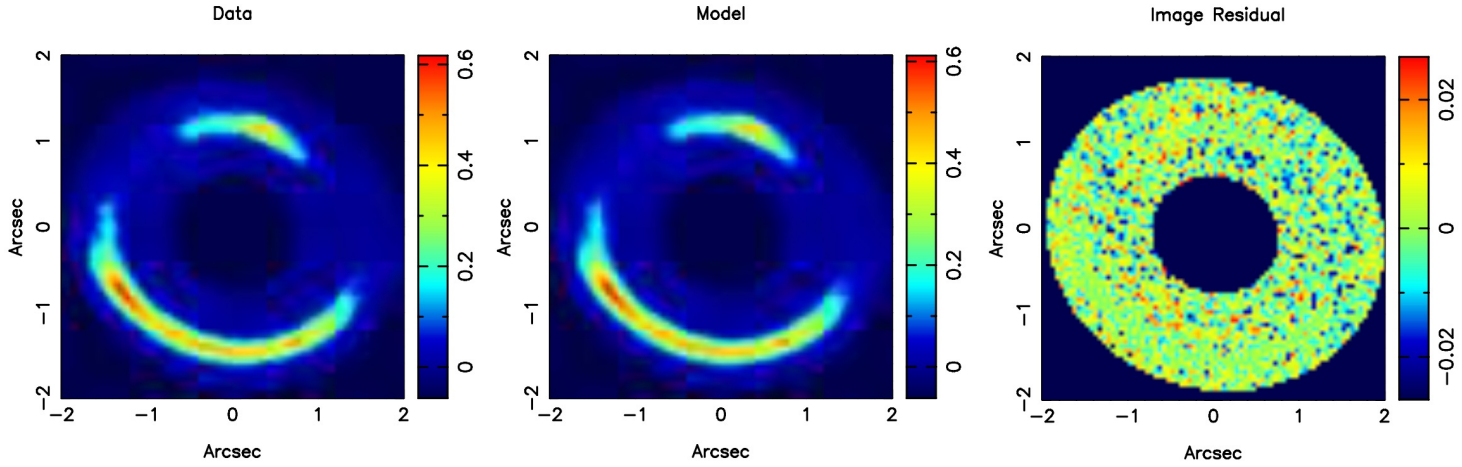
Strong Lensing to probe substructure





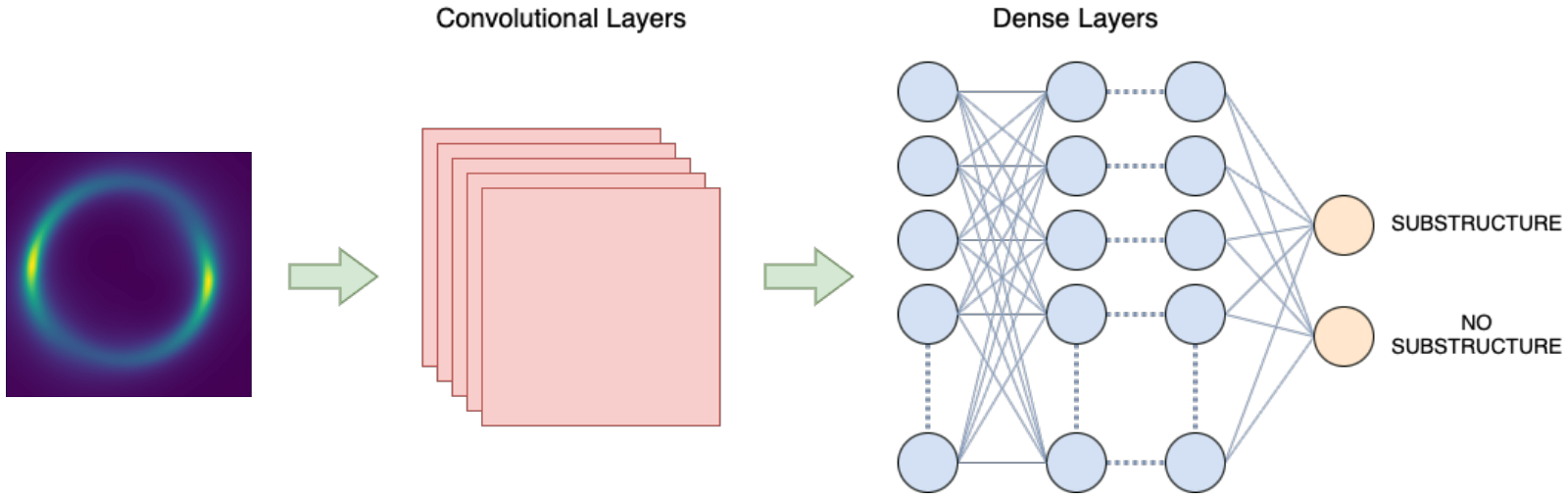
Detection methods

Smooth Mass Residual



S. Vegetti, et. al., MNRAS, ***408,*** *1969–1981, 2010*

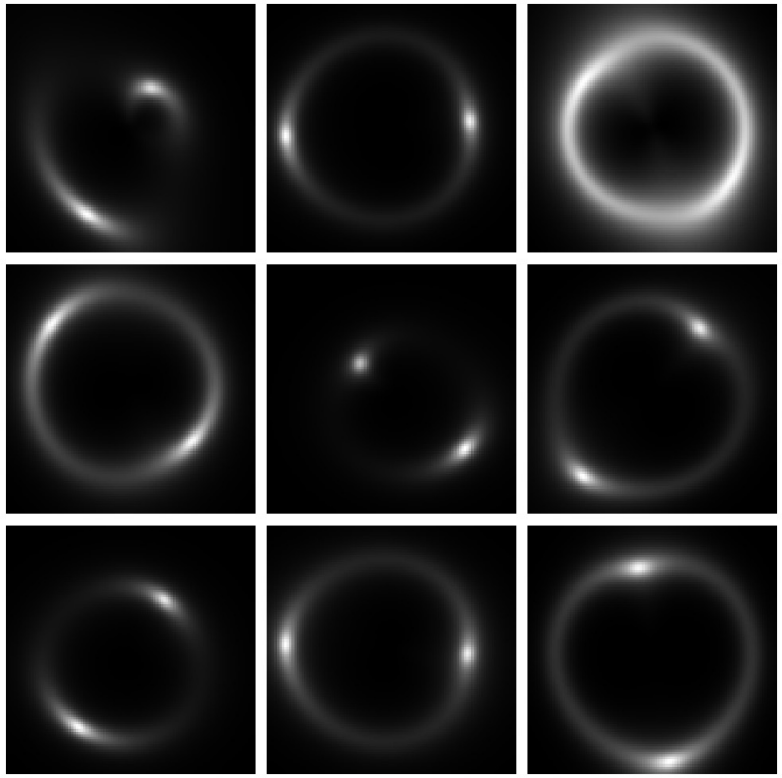
Machine Learning



Research questions:

- Does the source galaxy's morphology impact machine learning?
- If so, what constraints can we put on the source?

Method: simple source

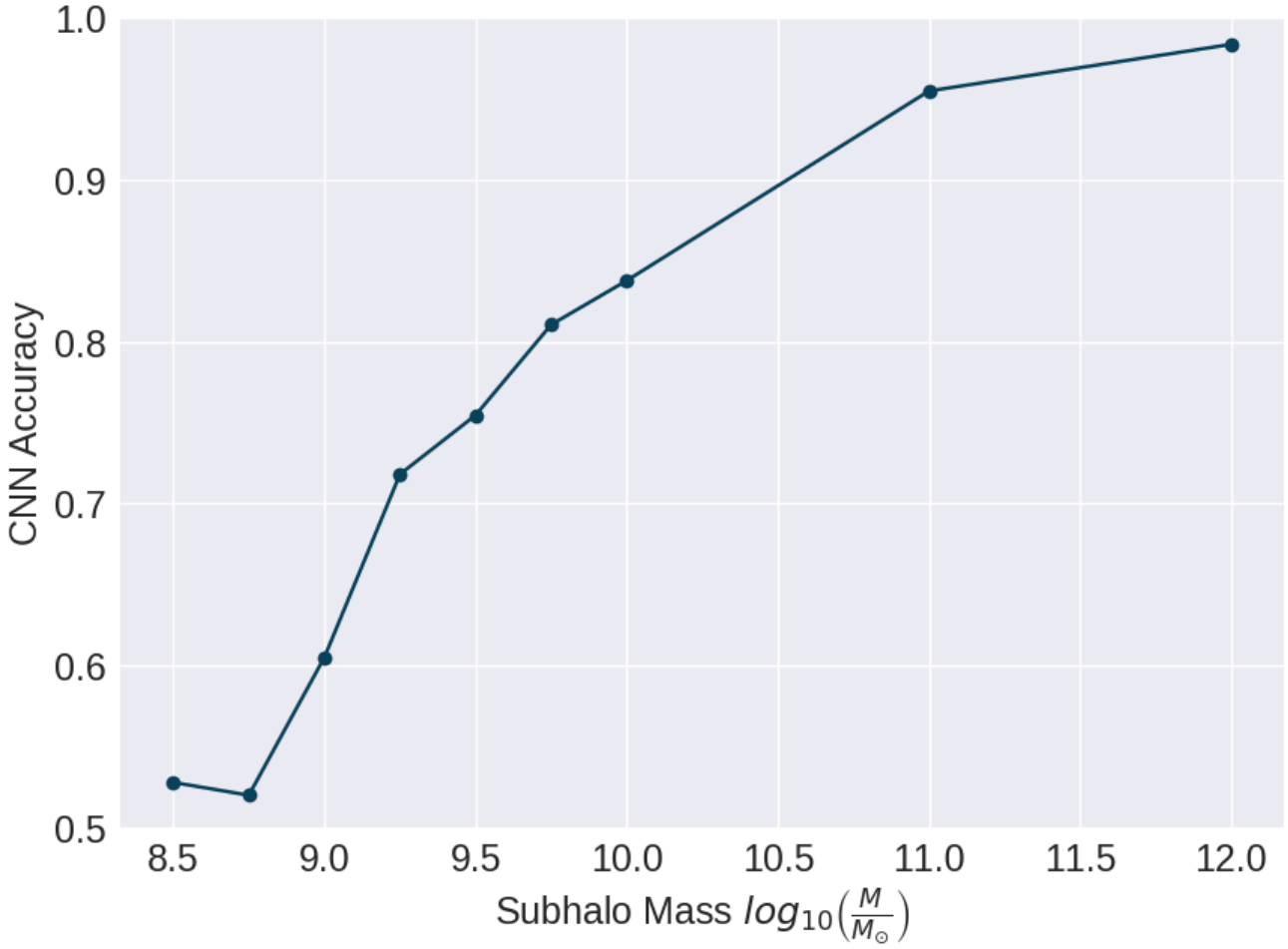


Dataset Sample

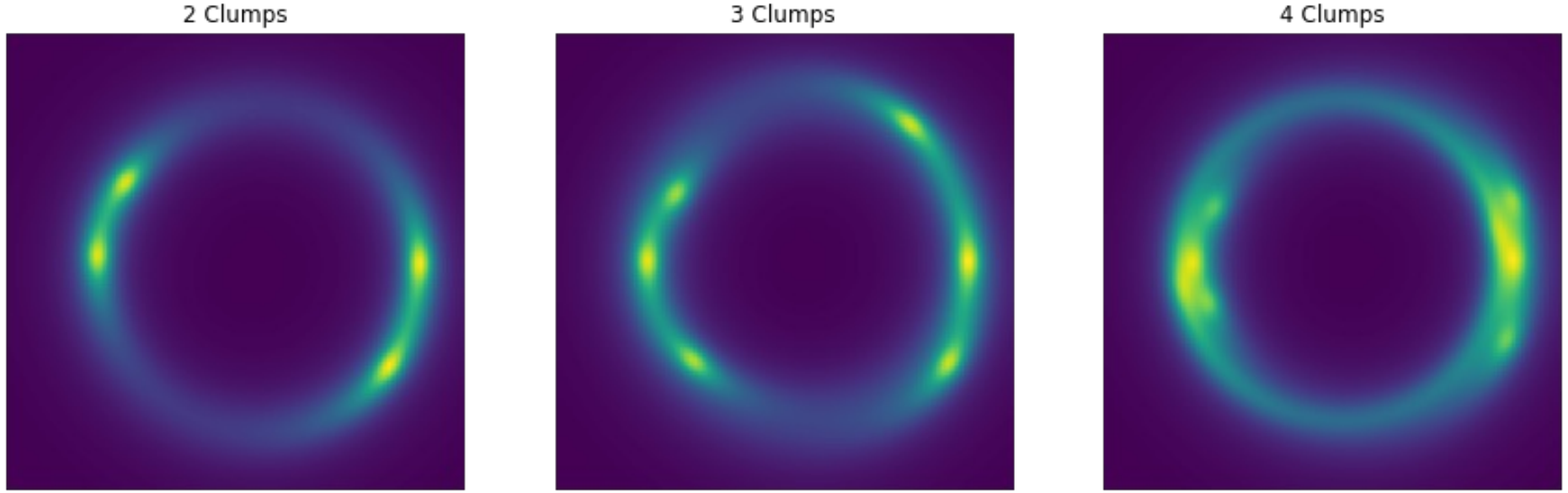
$$I(R) = I_e exp\left\{-b_n\left[\left(\frac{R}{R_s}\right)^{\frac{1}{n}} - 1\right]\right\}$$

- R_s = half light radius
- n = sersic index
- b_n. Is a function of n

CNN accuracy using simple source

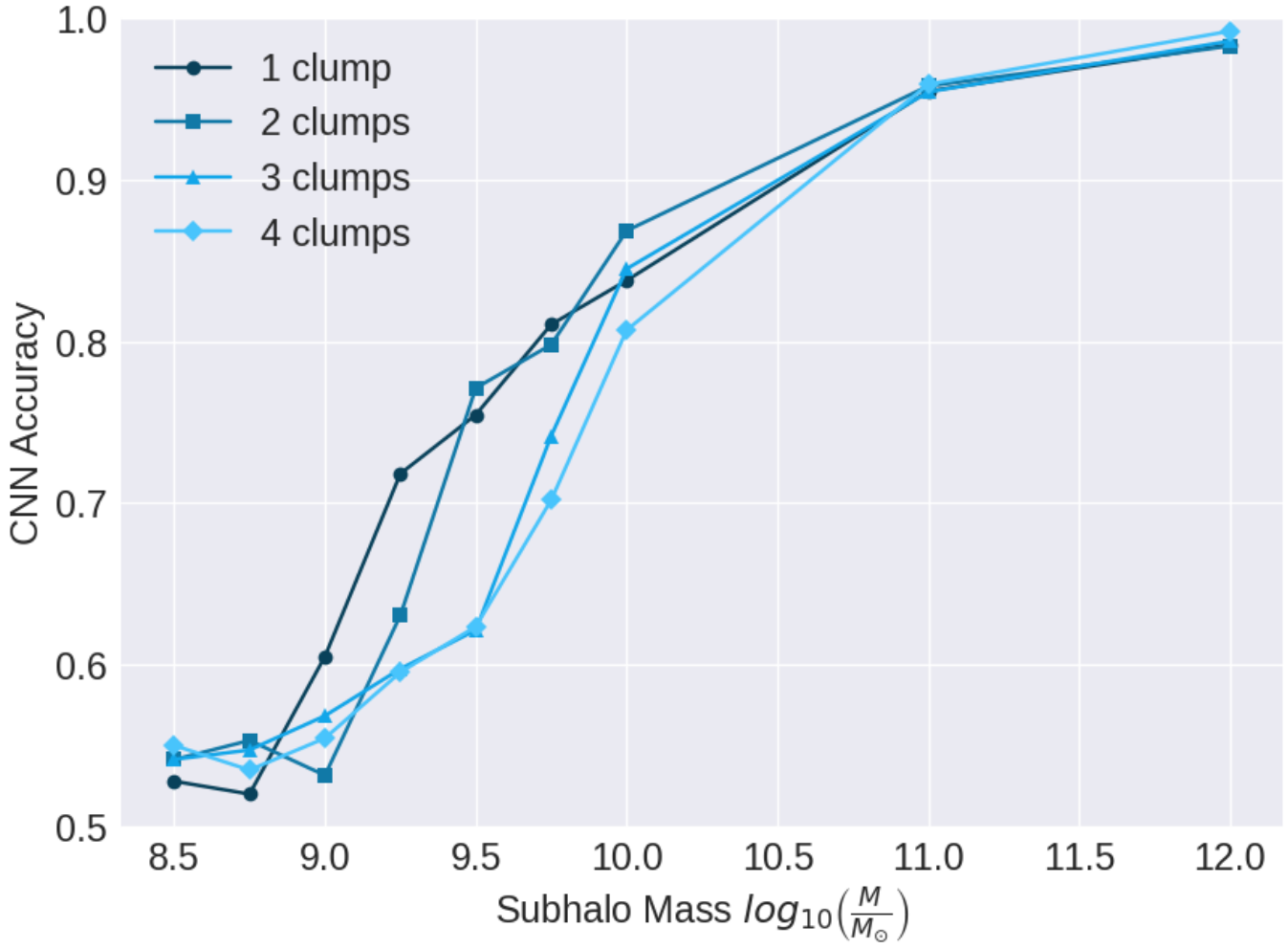


Method: Clumpy source

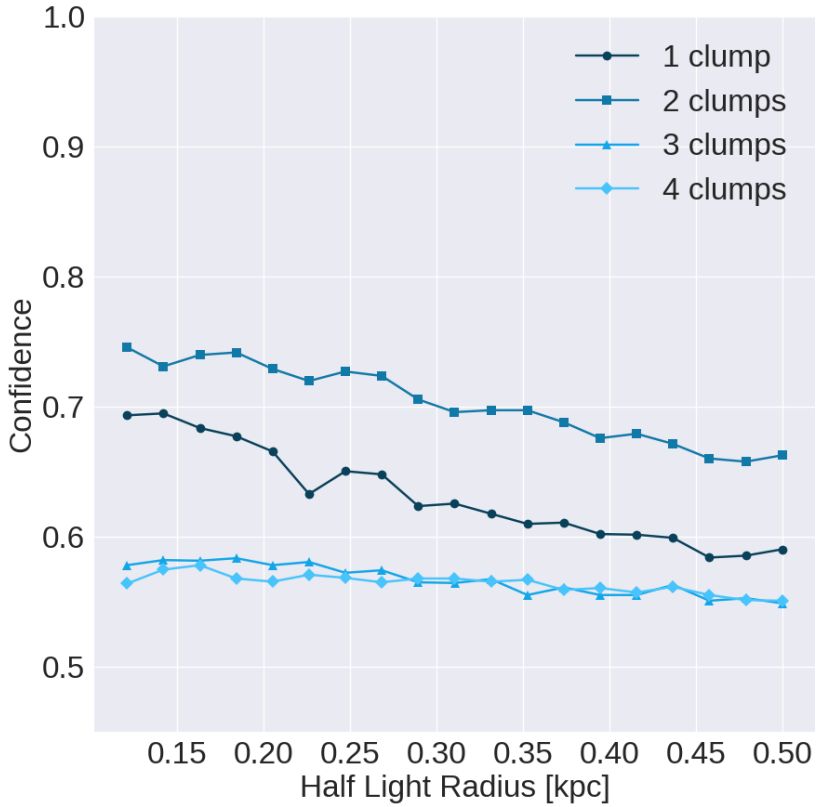


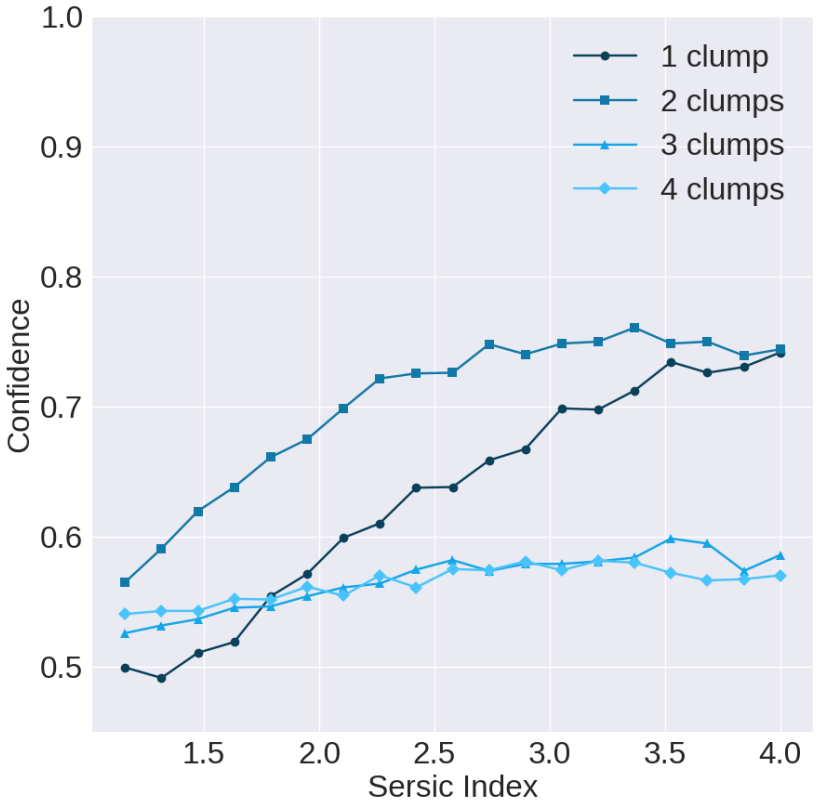
$$R_{mean} = \frac{\sum R_c}{N}$$

CNN accuracy using clumpy sources



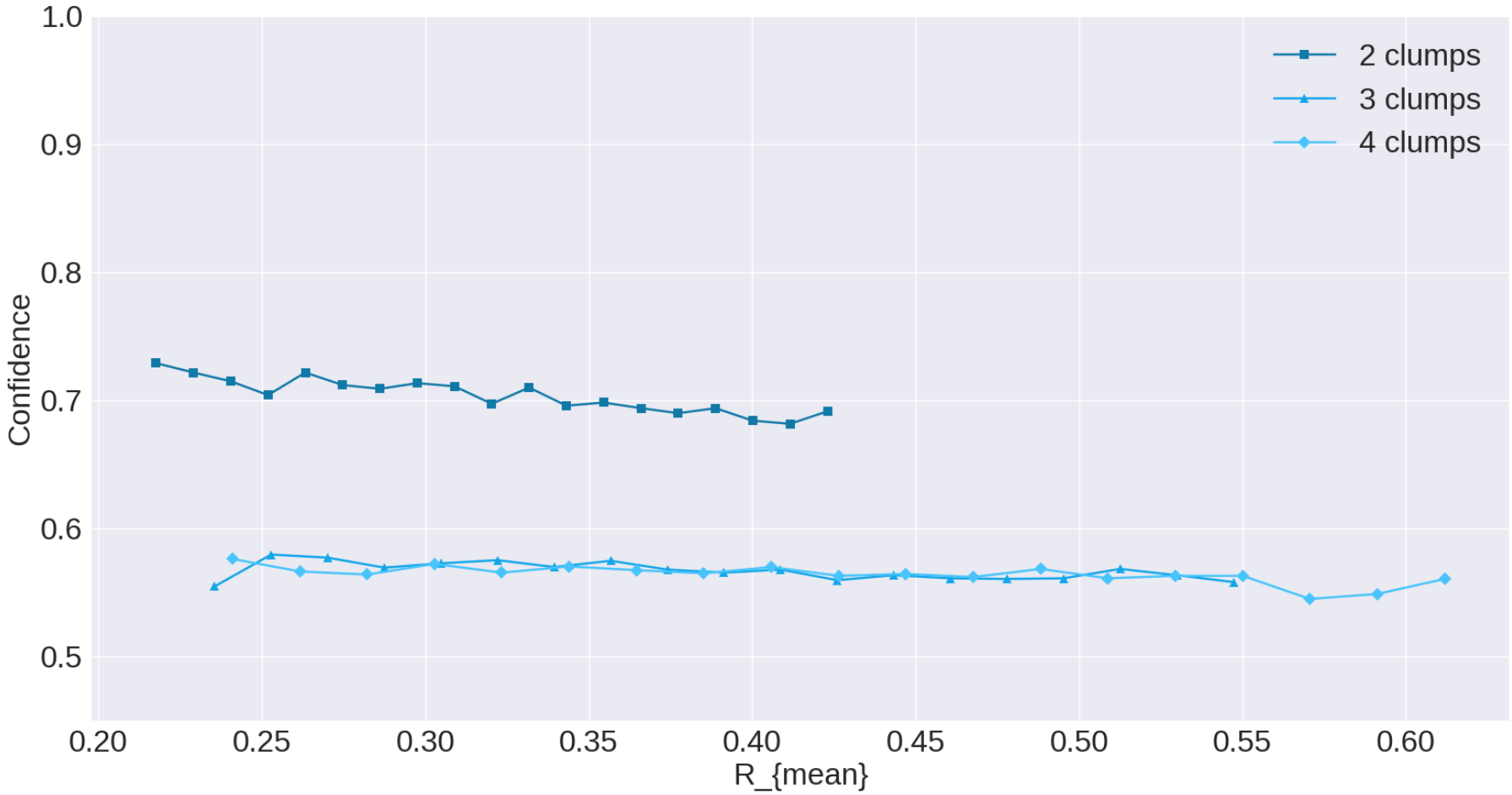
Constraints on source morphology





Subhalo Mass = $10^{9.5}$ M

Clump concentration



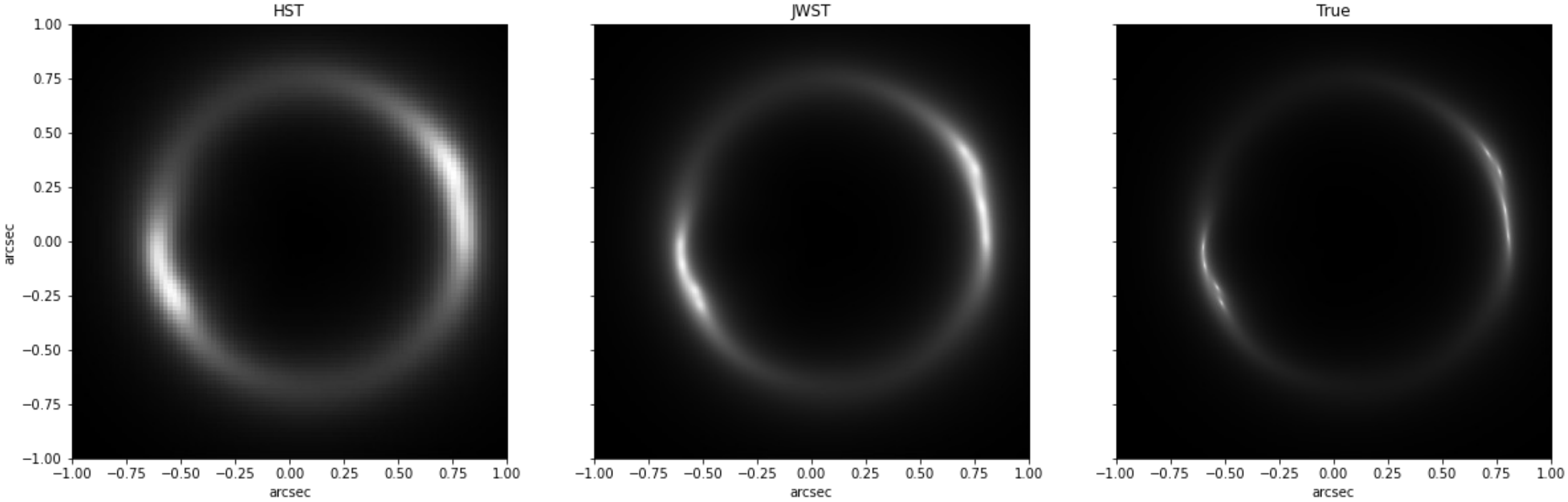
Subhalo Mass = $10^{9.5}$ M

Next steps

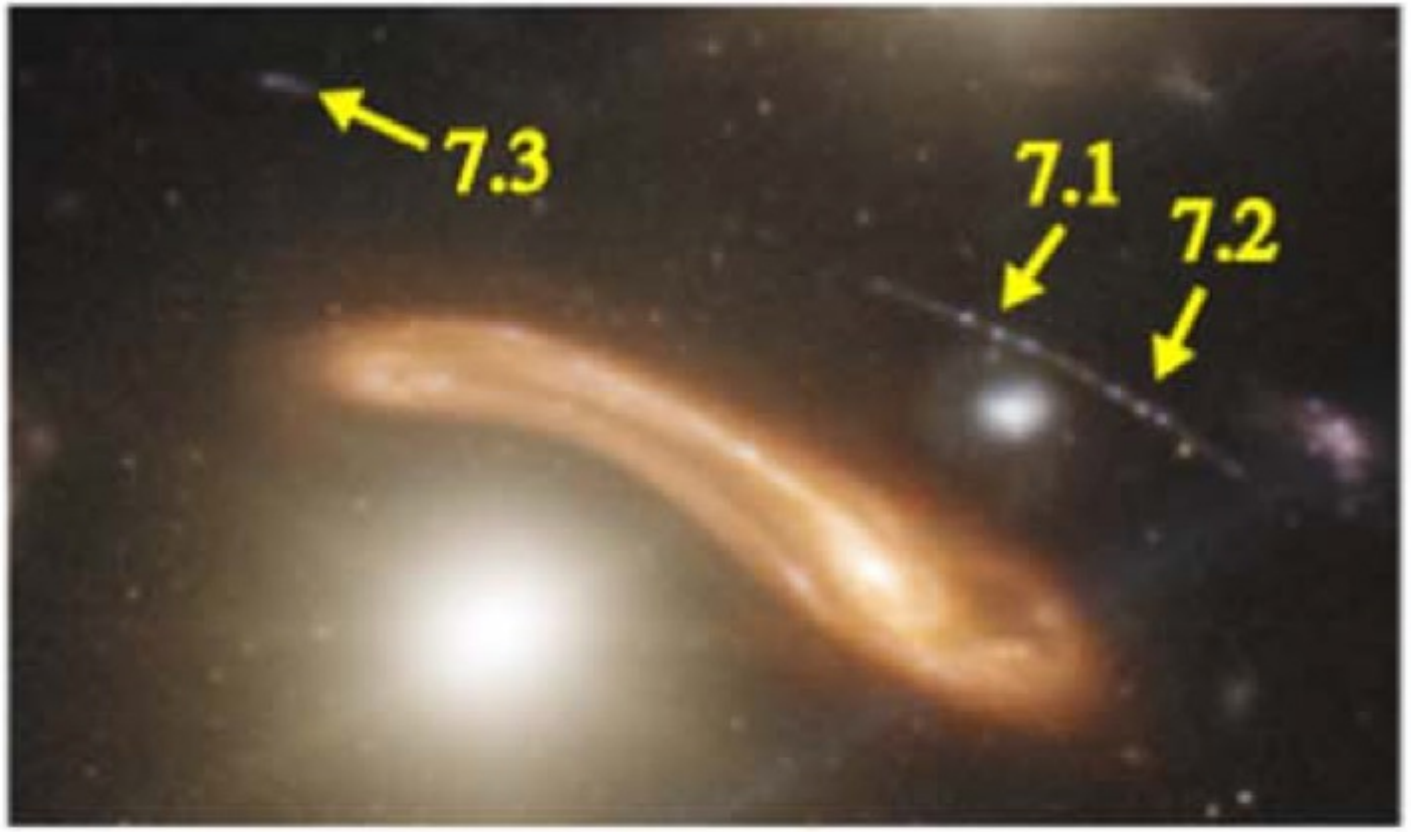
- Does source morphology influence the CNN differently for full CDM and WDM substructures?

- Could JWST's improved resolution and lookback time offer advantages for substructure detection.

JWST



JWST



*Massimo Pascale et al 2022 ApJL **938** L6*

Summary

- Early results indicate that more complex sources impair the CNN's sensitivity to lower mass subhalos.
- substructure is easier for CNN to detect when source is concentrated.
- CNN performance is invariant to clump distribution.
- Highly concentrated sources are commonly seen in JWST images which could be ideal for CNN performance as well as higher resolution.