

# Observing Ultra-Diffuse Galaxies in the Infrared with the JWST



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## Intro to Ultra-Diffuse Galaxies

- Ultra-diffuse galaxies (UDGs) are galaxies with extremely low surface brightness but relatively large radii<sup>1</sup>
  - Very few stars compared to average galaxies
- Classification proposed by van Dokkum et al.:<sup>1</sup> UDGs have effective radii  $r_{\text{eff}} \geq 1.5$  kpc and central surface brightness  $\mu(g,0) \geq 24$  mag arcsec<sup>-2</sup>
- Ultra-diffuse galaxy NGC 1052-DF2 (left) and dwarf spiral galaxy NGC 5474 (right) have similar sizes, but the UDG has a far lower surface brightness<sup>2,3</sup>



NGC 1052-DF2



NGC 5474

Image sources: NASA

## Research Aim

- Characterize the physical properties of a set of UDGs in Abell 2744, "Pandora's Cluster" ( $z \sim 0.3$ )
  - Surface brightness profiles
  - Mass estimates
- Test whether low luminosities are intrinsic or artifacts of dust obscuration
  - UDG structural properties have been analyzed in the nearby universe (visible wavelengths), but analysis is sparse in the near-infrared and infrared range
  - Dust obscuration (absorption of UV and visible light and re-emission in the NIR and IR) could contribute to low surface brightness measurements in the visible bands of nearby UDGs, but dust does not have a significant impact on light in the near-infrared and infrared wavelengths
- Categorize our set by potential relative dark matter quantities (future work)

## Relevance to Dark Matter Research

- UDGs are often found in dense galaxy clusters—gravitationally violent environments
- For a UDG to stay gravitationally bound, it requires a much higher mass than from our baryonic matter estimate
- Wide range of dark matter estimates across different UDGs<sup>4,5</sup>

## Our Dataset

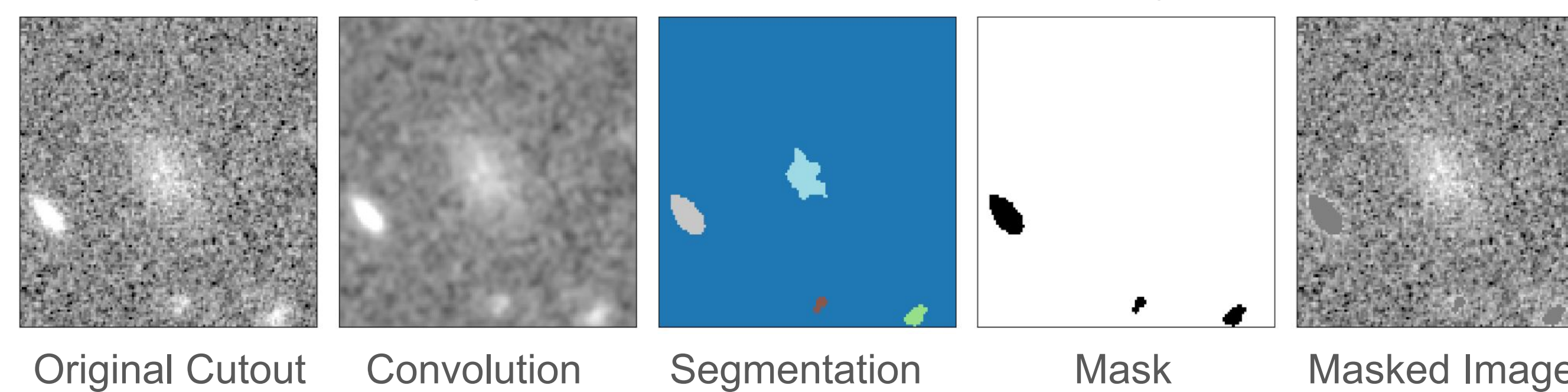
- Data from JWST and HST
- Mosaic of Abell 2744 processed by UNCOVER team
- Coordinates of 55 UDG candidates identified visually<sup>7</sup>
- Made cutouts centered around those coordinates



Abell 2744<sup>6</sup>

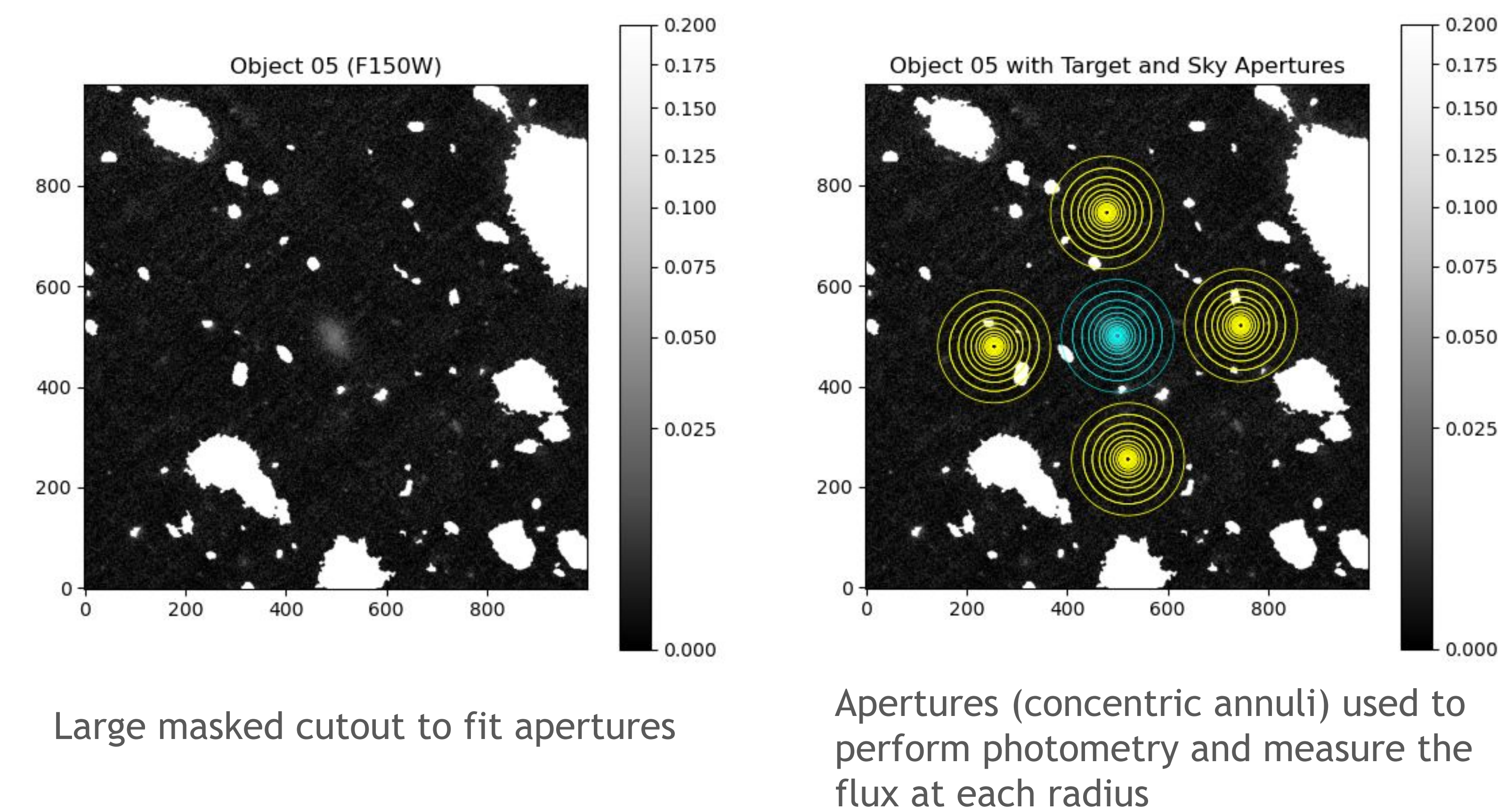
## Data Preparation: Masking

Masking Process of 5" × 5" Cutout of Object 05

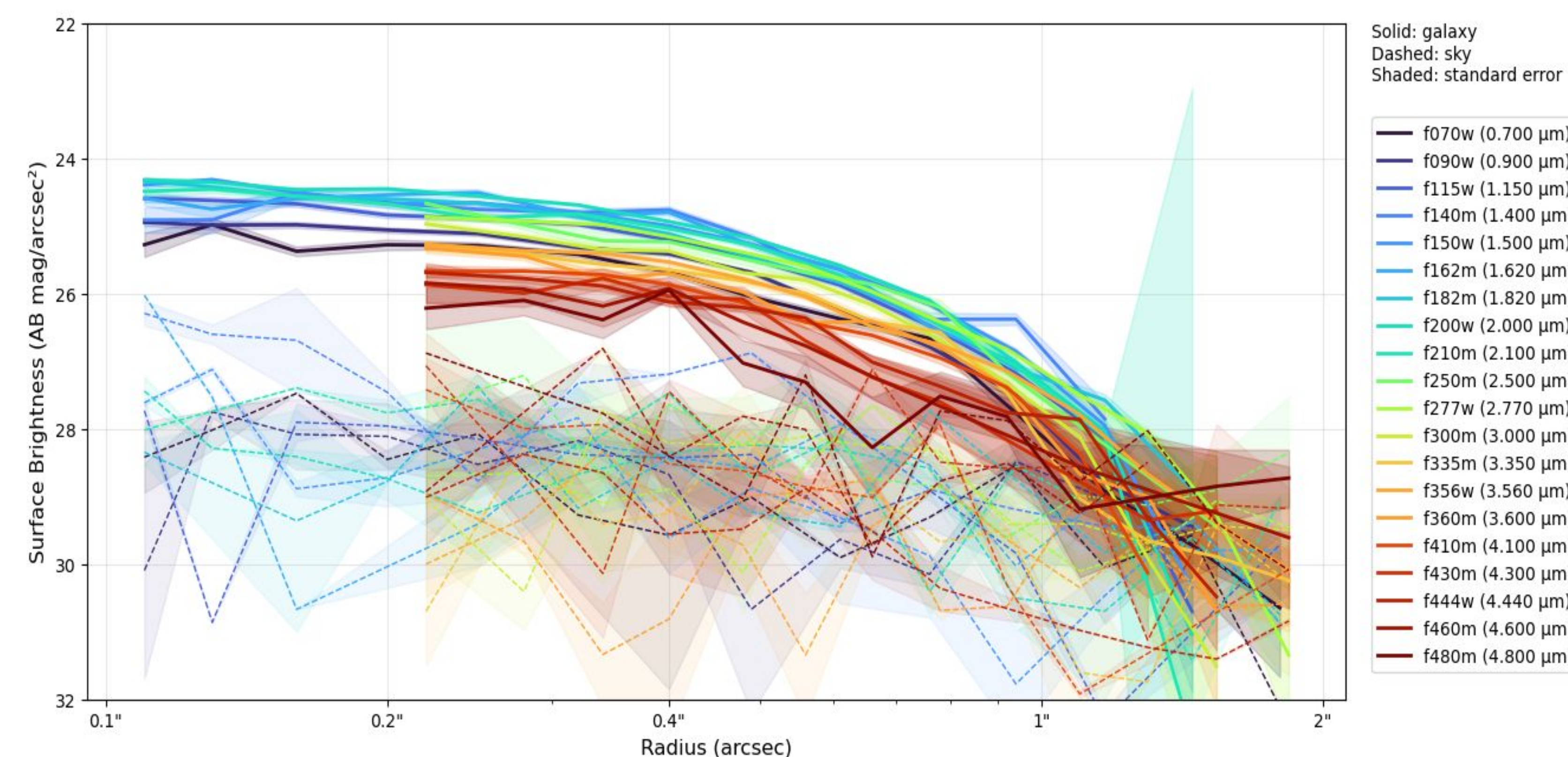


For each candidate, we used the Python library *Photutils* to block out light from background galaxies and foreground stars, allowing us to focus only on light from the target UDG.

## Surface Brightness Profiles



Surface Brightness Profile of Object 05



- Horizontal sky profiles represented by the dashed lines depict the sky value (the average across the four apertures) and marks where the galaxy ends
- Less than 24 mag/arcsec<sup>2</sup> in each band: satisfies UDG surface brightness criteria proposed by van Dokkum et al.<sup>1</sup>

## Catalog Matching

- Matched UDG coordinates with SUPER Catalog objects using 0.1" separation constraint
- Confirmed previous identification of 41 objects out of the set
- Extracted each photometric redshift for mass estimate

ra_udg	dec_udg	id	x	y	ra	dec
float64	float64	int64	float64	float64	float64	float64
3.641486145827083	-30.428672535375973	11789	2849.1481006799074	3480.2130373074737	3.641503414041862	-30.428664326505015

Portion of one object's properties from the SUPER Catalog, with our UDG coordinates and the catalog object coordinates

## Mass Estimates

- Computed preliminary mass estimates using a mass-to-light ratio of 0.47 for the 3.6 micron band (F356W)
  - Ratio from McGaugh & Schombert (2014), who demonstrated that the NIR mass-to-light ratio is effectively constant across disk galaxies<sup>8</sup>
- Stellar mass estimate of Object 05:  $2.142 \times 10^7 M_{\odot}$
- Median stellar mass of the 41 galaxies:  $1.53 \times 10^7 M_{\odot}$
- Consistent with past literature<sup>1</sup>

## Future Work

- Spectral energy distribution fitting for more robust mass estimates
- Measure UDG sizes by fitting Sérsic profiles using Bayesian inference
- Visually categorizing set of UDGs by globular cluster content - higher globular clusters suggest higher dark matter content

## References

- <sup>1</sup>van Dokkum et al., *ApJL* 2015, 798, L45
- <sup>2</sup>van Dokkum, ESA/Hubble & NASA
- <sup>3</sup>ESA/Hubble & NASA
- <sup>4</sup>Mowla et al. *ApJ* 2017, 851 27
- <sup>5</sup>van Dokkum et al. *Nature*, 2018, 555, 629-632
- <sup>6</sup>ESA
- <sup>7</sup>Alejandra Rodriguez and Dharlenny Soto, Wellesley College (2023)
- <sup>8</sup>McGaugh & Schombert, *AJ* 2014, 148, 77

## Acknowledgements

Thank you to Dr. Lamiya Mowla for providing me with this opportunity and for her continued guidance, Dharlenny Soto for collaboration and identification work, Alshimaa Ahmed for her collaboration, Alejandra Rodriguez for her identification work, Jonathan Kemp for his support and computing help, and Wellesley College for funding this research.