Characterizing the Low Surface Brightness structures of galaxies in the DESI Legacy Imaging Survey

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Abstract The influence of assembly history on galaxy formation could be constrained by trends in stellar halo properties with galactic observables (such as the total galaxy mass, color or gas fraction). Our goal is to develop the uniform, automated measurements of bulk stellar halo properties that are easy to apply to large datasets and to compare with models. We have analyzed the stellar halo and reproduced the result from the Dragonfly survey (Merritt, et al. 2016) using images from the Dark Energy Spectroscopic Instrument Legacy Imaging Survey (DESI-LS) (Dey et al. 2019). In this poster we describe our sample, the DESI-LS data and the basis of the methods we are developing. In future, we will apply these methods to much large numbers of galaxies in DESI-LS to study large-scale trends of stellar halo properties.

Stellar halo

- **Understanding the formation and evolution of galaxies**: The stellar halo is a diffuse, roughly spherical component of a galaxy consisting of low surface brightness (LSB) stellar structures which including stellar shells, tidal streams and tidal tails formed during major mergers. The properties of halo stars can offer valuable insights into the formation and evolution of the galaxy.
- **Exploring the properties of dark matter:** As the universe evolves, smaller structures merge to form larger ones. During this process, the stars from the dwarf galaxies contribute to the stellar halo of the galaxy like Milky Way. Moreover, the structures and kinematics of the stellar halo can be used to probe the gravitational potential of the dark matter halo.

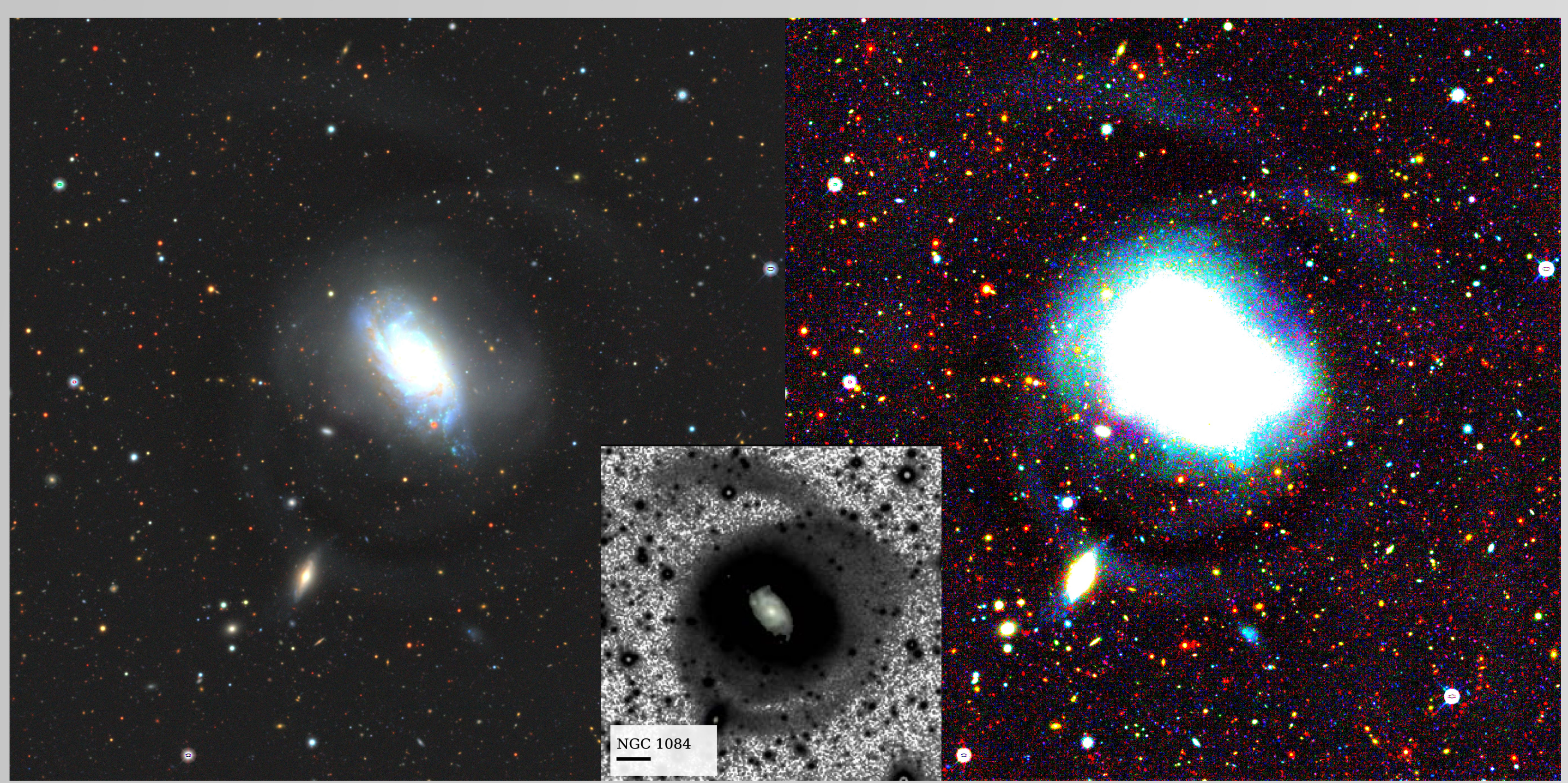

Fig. 1: *The left panel is the g-,r-,z- stack image of NGC1084 from DESI-LS, and the right panel is the image after adjusting the contrast and saturation, from which we can faintly see the existence of stellar halo and tidal streams. In addition, the structures can be seen more clearly in the small panel* (Merritt, et al. 2016), *especially the diffuse, roughly spherical stellar halo surrounding the host galaxy.*

Motivation

Most previous work on images of extragalactic stellar halos has focused on identifying and classifying individual LSB features (e.g. Sola et al, 2022). We are more interested in understanding the overall statistical properties of the entire stellar halo, rather than the individual LSB structures. To achieve this, we are exploring a different approach: **our goal is to develop uniform, automated measurements of bulk stellar halo properties that are easier to apply to large datasets and to compare with models.**

Ongoing and future work

- We are now developing a halo calculation method suitable for DESI-LS data based on the method of estimating halo fractions from Dragonfly surveys (Merritt, et al. 2016) and making it easier to do all-sky statistical analysis in the future.
- In the future, we will apply these methods to much large numbers of galaxies in DESI-LS to study large-scale trends of stellar halo properties.

References

[1] Sola, E., et al. 2022, A&A, 662A, 124S
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[3] Cooper, A. P., et al. 2010, MNRAS, 406, 744C
[4] Gómez, F. A., et al. 2013, MNRAS, 436, 3602G
[5] Cooper, A. P., et al. 2023, ApJ, 947, 37C
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Photometry method

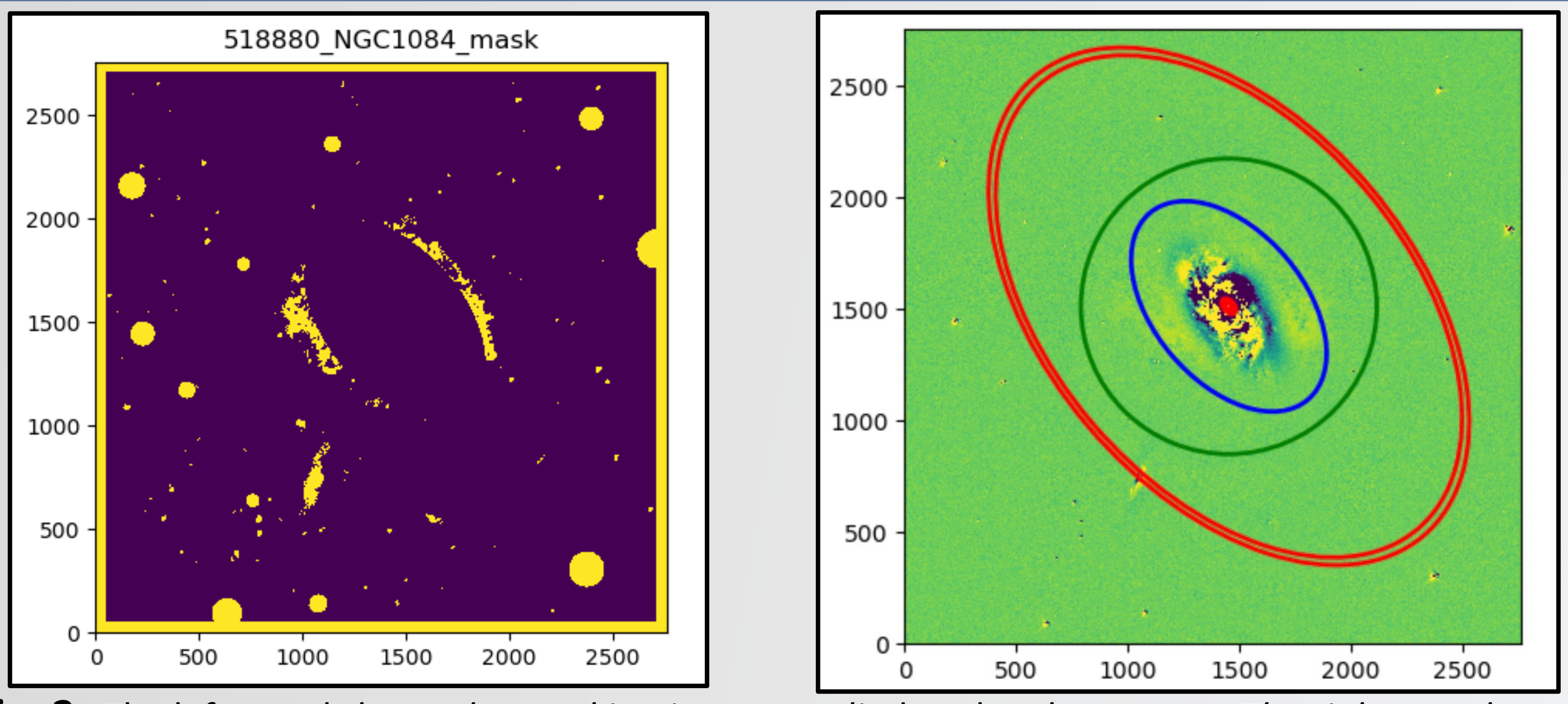

Fig. 2: *The left panel shows the masking image applied to the photometry. The right panel shows the photometric range, where the blue circle is the galaxy radius* (D_{26}) *and green circle is the five half-mass radii* ($5R_h$)*. The stellar halo fraction defined to measure outside of* $5R_h$ *here.*

Result

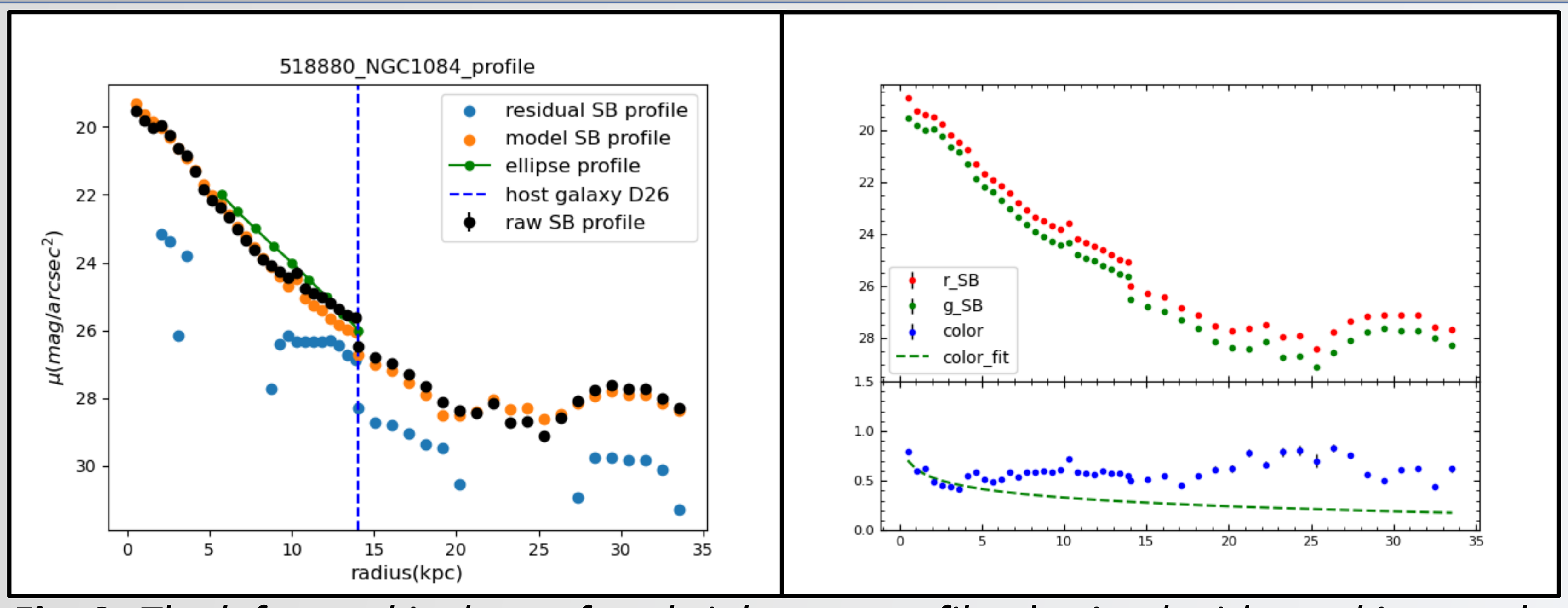

Fig. 3: *The left panel is the surface brightness profile obtained with masking method from Siena Galaxy Atlas 2020* (Moustakas, Lang, et al. 2023) *of NGC1084. The right panel is the observed* $g - r$ *color profiles.*

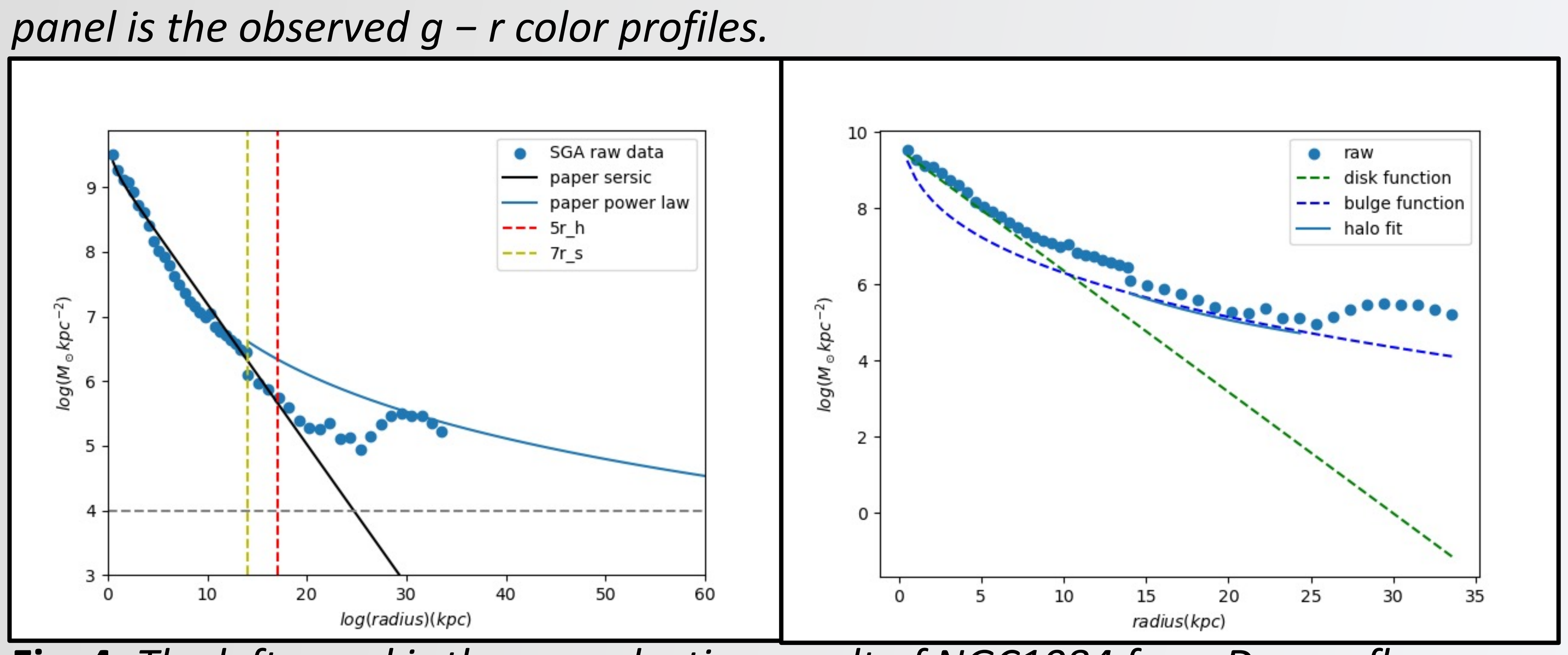

Fig. 4: *The left panel is the reproduction result of NGC1084 from Dragonfly survey* (Merritt, et al. 2016)*. The study used* $r > 7R_s$ *to fit the power law model because this region is beyond the last visible spiral arms. The right panel is a method we are developing to estimate stellar halos. Our goal is to apply it to a large number of galaxies, so we are looking for a more appropriate unified method.*

		NGC1084	NGC1042	NGC3351	NGC3368
Paper Result[2]	$M_{stell}/M_\odot$	4.32×10^{10}	1.53×10^{10}	5.84×10^{10}	8.91×10^{10}
	$f_{halo}(>5R_h)$	0.049	0.0001	0.0002	0.0037
Reproduce Result	$M_{stell}/M_\odot$	6.06×10^{10}	2.68×10^{10}	5.62×10^{10}	1.3×10^{11}
	$f_{halo}(>5R_h)$	0.044	0.0005	0.00037	0.0467
Our Method	$M_{stell}/M_\odot$	5.5×10^{10}			
	$f_{halo}(>5R_h)$	0.02			

Table. 1: *We reproduced the results of the Dragonfly survey using DESI-LS data, but there are still slight differences in the results due to different background subtraction and masking choices between the two. For NGC1084, we have attached the results of the new method, but the priori of the Sersic function of the galaxy itself has not been adjusted, so the results still have a certain error.*