JWST NIRCam Proper Motion Survey of the Nuclear Star Cluster

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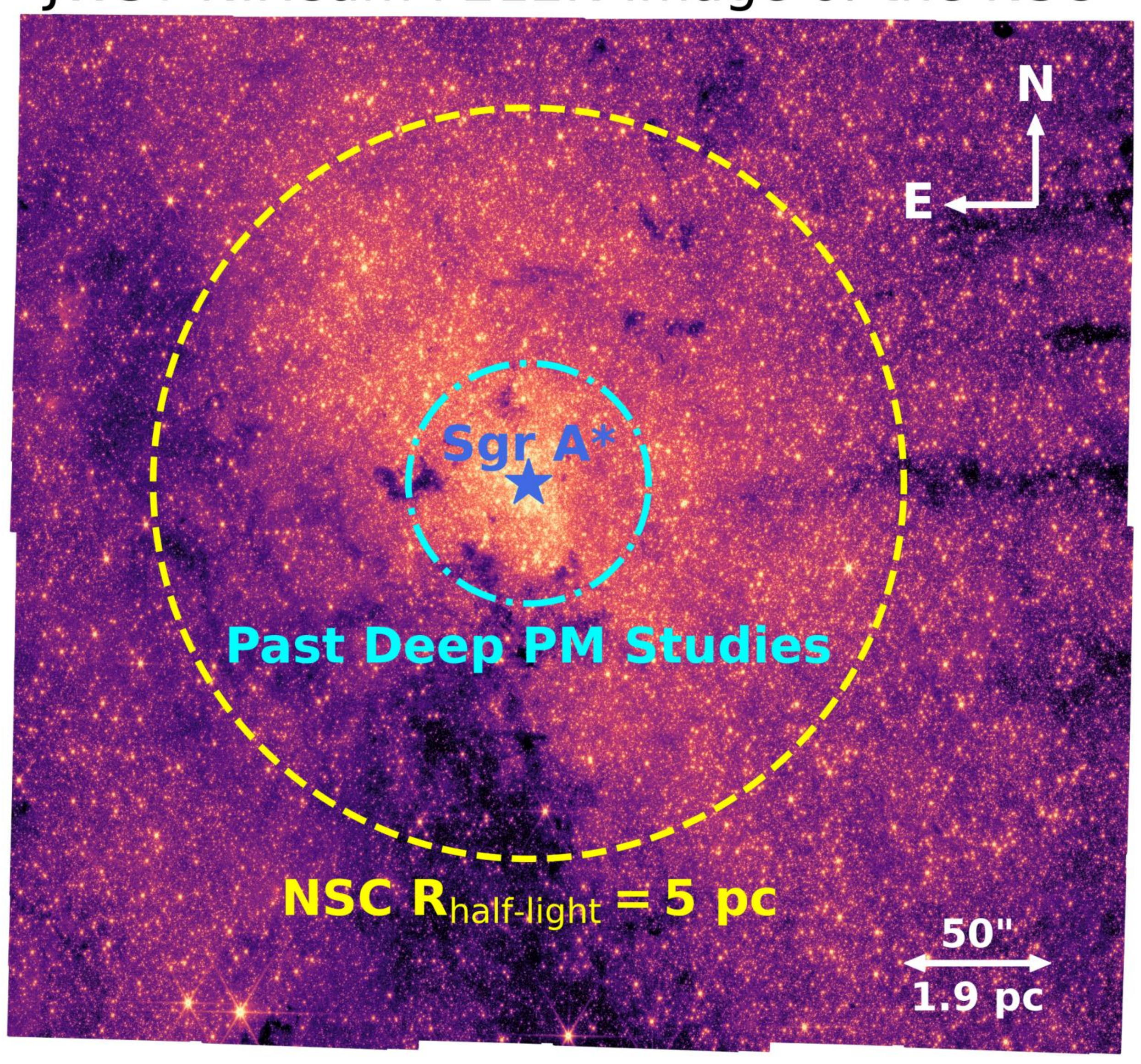
Motivation: How Did the Nuclear Star Cluster (NSC) Form?

JWST NIRCam F212N Image of the NSC

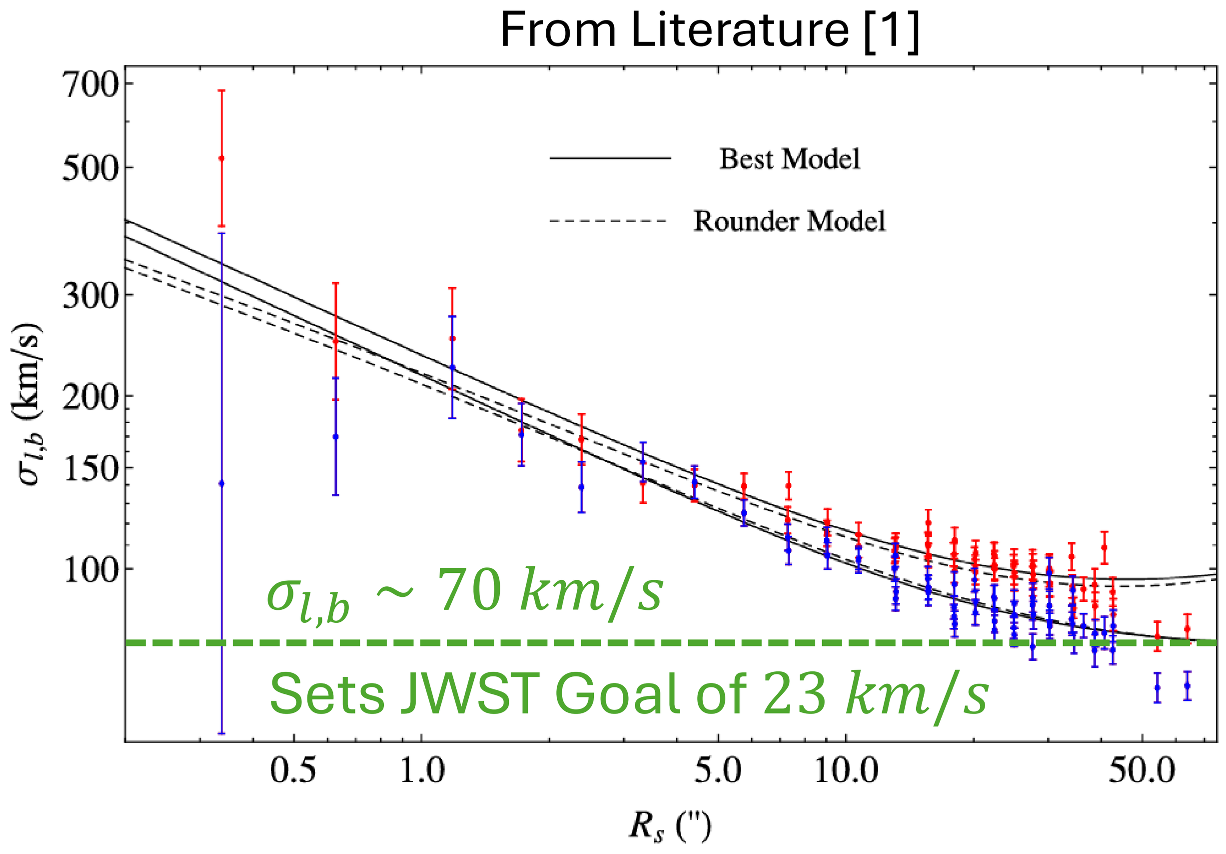


There are two major hypothesis of the Nuclear Star Cluster formation: 1. *in-situ* formation from gas deposition from the Milky Way (MW) disk; 2. infall of globular clusters that accumulates. Kinematic information is required to unveil this.

With a 3-cycle program of JWST NIRCam survey of the Milky Way's Nuclear Star Cluster (MW NSC), we will measure the proper motions (PMs) of 300,000 stars reaching 7 pc from the Sgr A* with a precision of 0.6 mas/yr (23 km/s) [1].

Velocity Dispersion of The NSC

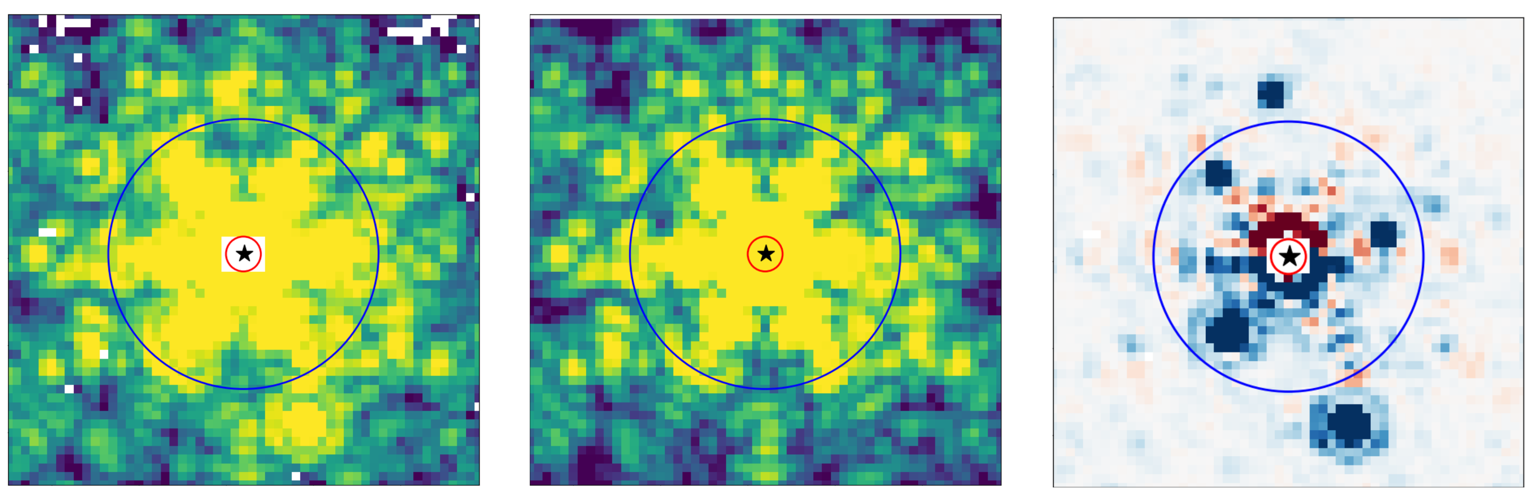
From Literature [1]



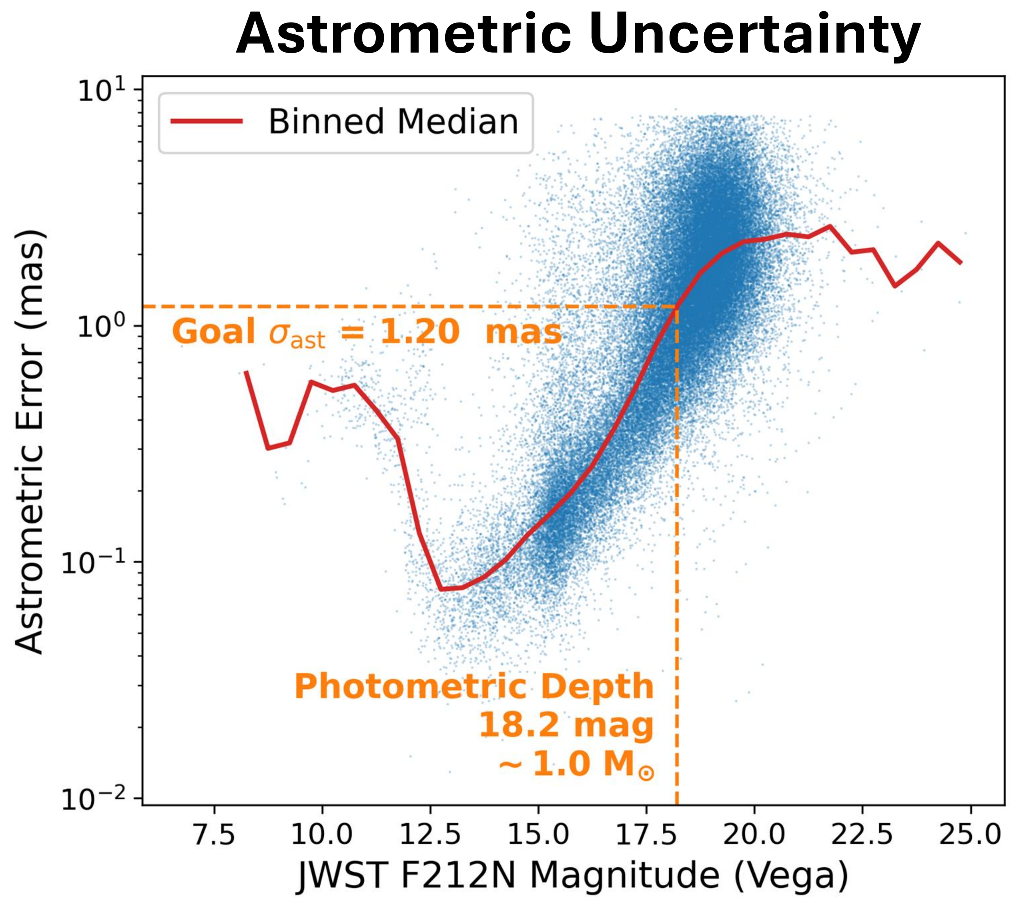
This allows us to: 1. Determine fundamental properties such as the mass and structure (e.g. shape, triaxiality, etc). 2. Characterize the rotation of the MW NSC and search for kinematic substructures to test theories for its formation. 3. Explore the connection between the MW NSC with the Nuclear Stellar Disk (NSD).

Preliminary Results: PSF Extraction, Astrometry Precision, and Photometric Depth

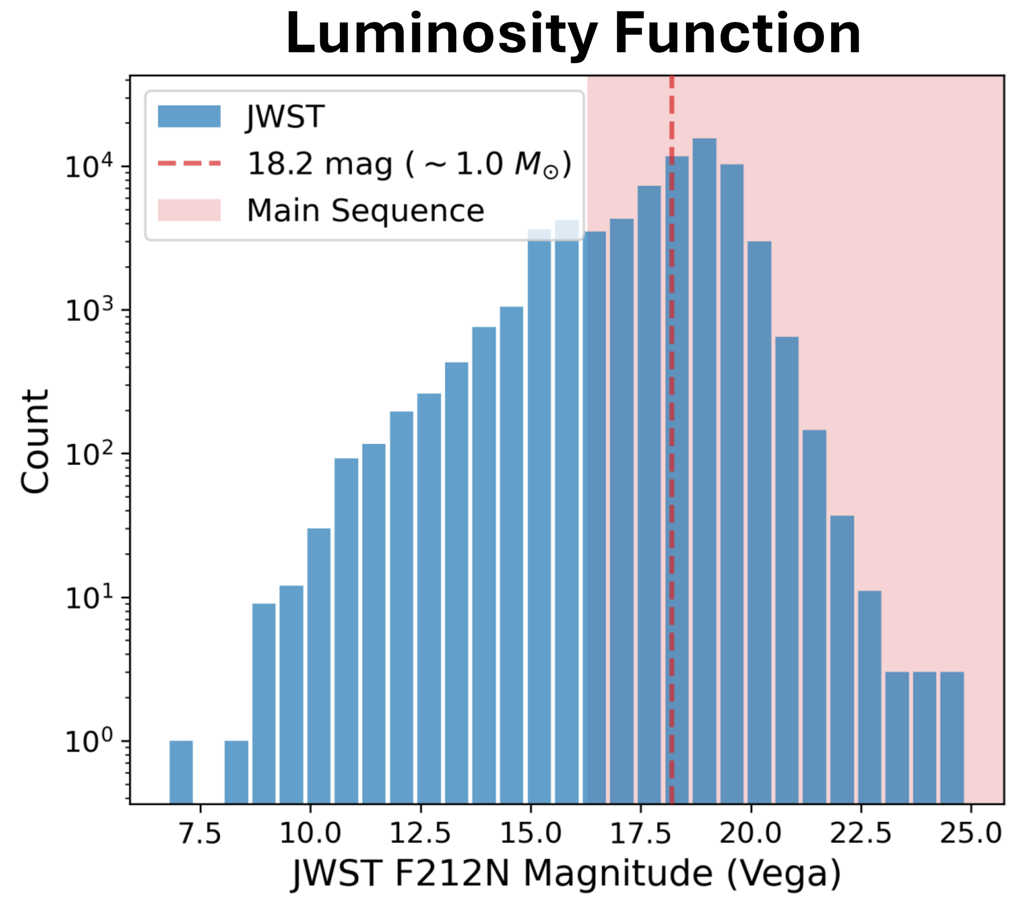
Original Image | STPSF Model | Residual



Astrometric Uncertainty



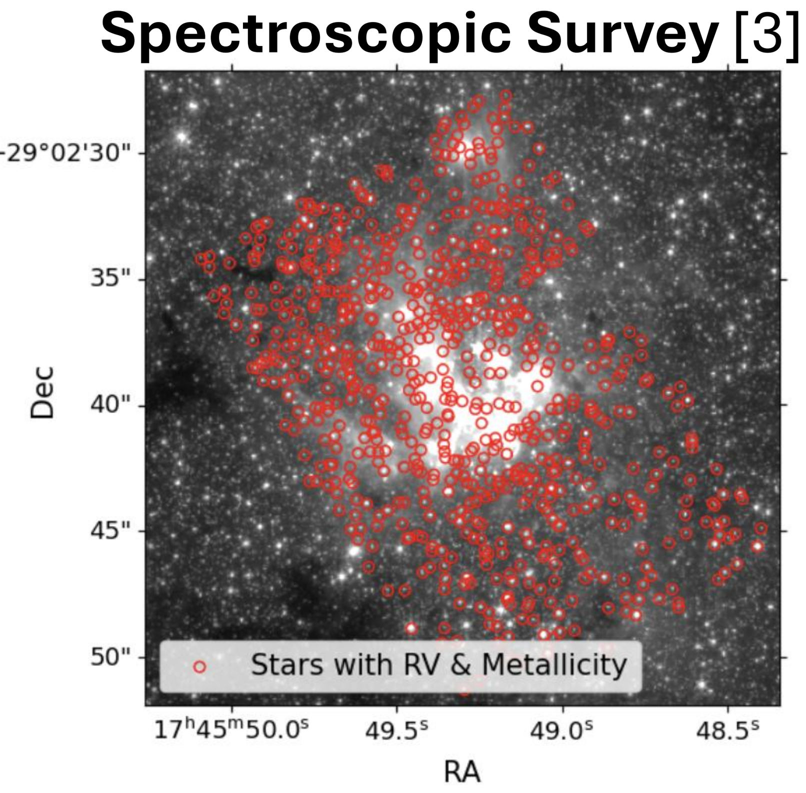
Luminosity Function



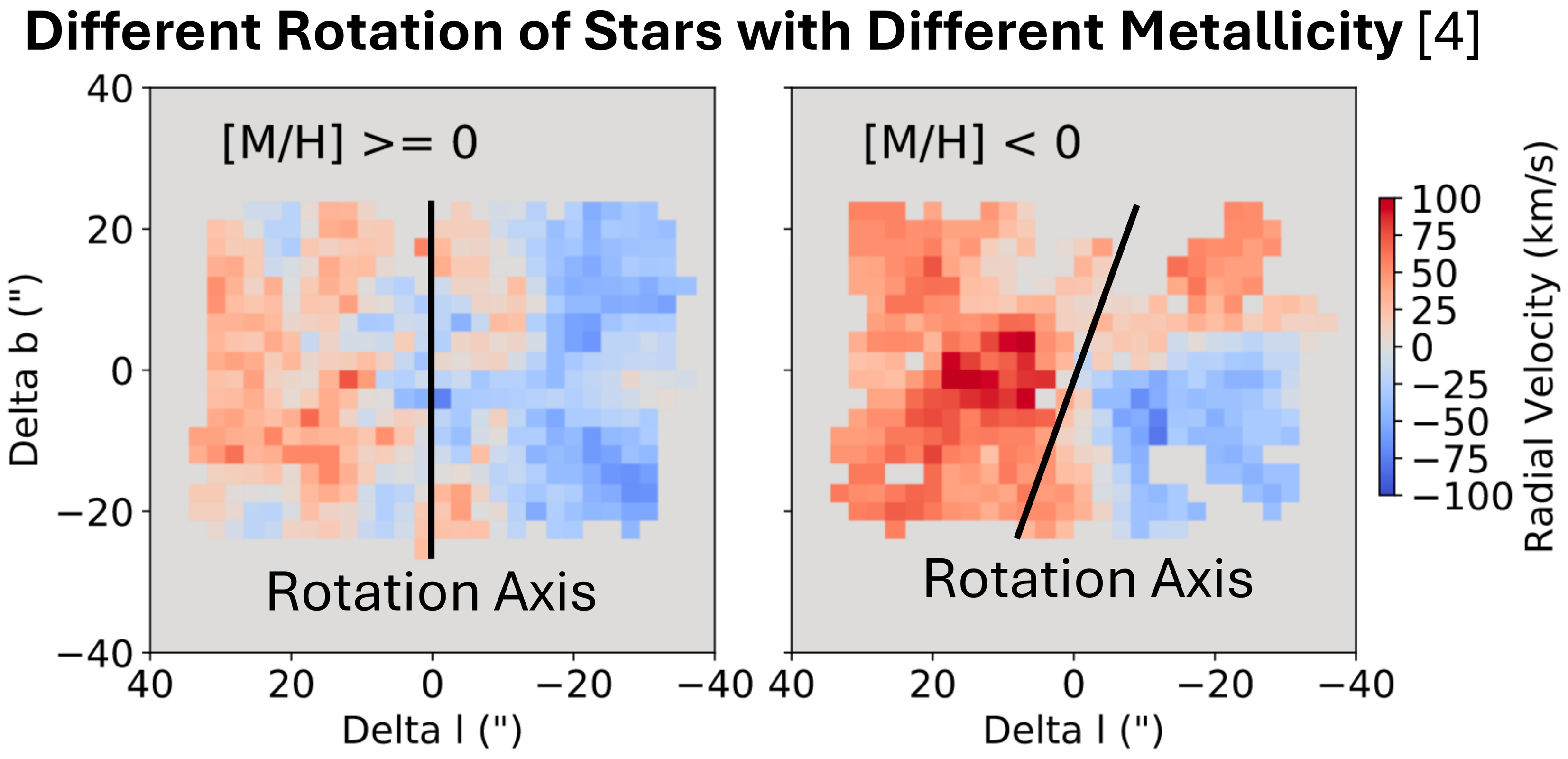
- **PSF Modeling Pipeline with STPSF in Crowded Field** (*left*): We developed an iterative PSF modeling pipeline with *photutils* for crowded fields. We found that STPSF performs better than empirical PSF in source detection.
- **High Precision Astrometry for Velocity Dispersion Measurement of Solar-Mass Stars** (middle): Velocity dispersion measurement requires a PM precision of 0.6 mas/yr ($\sim$23 km/s) to be statistically significant. To achieve this for solar mass stars, the astrometric uncertainty on 4 stacked images should be $< 1.2\ mas$ in each epoch. To reach this precision, the observed depth limit is 18.2 mag, or approximately 1.0 $M_\odot$.
- **Photometric Depth Reaches Solar Mass** (*right*): The luminosity function does not decrease until 19 mag, matching our goal photometry depth to include solar mass stars.

Future Analysis: Physical Properties, Kinematic Structure, and Formation of the NSC

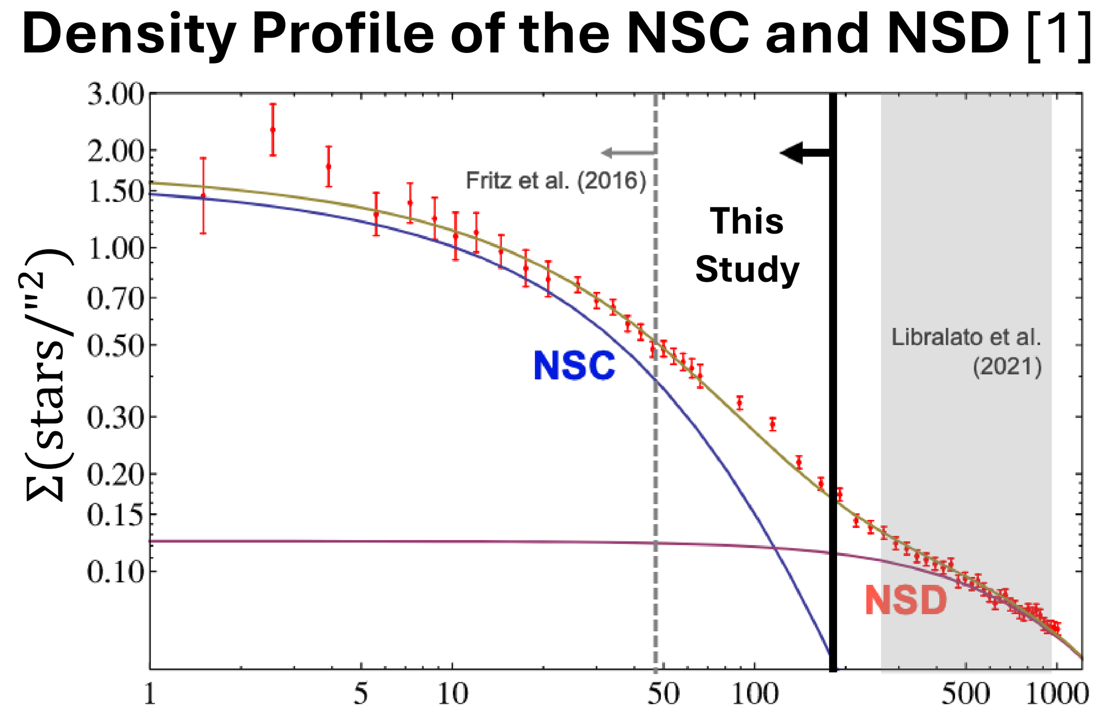
Spectroscopic Survey [3]



Different Rotation of Stars with Different Metallicity [4]



Density Profile of the NSC and NSD [1]



- **Alignment with Previous Surveys:** As Gaia sources are saturated in the field of view, we need the HST observations to construct a reference frame [2]. Additionally, spectroscopic surveys enables radial velocity (RV) measurement to construct 3D kinematic map [3].
- **NSC Kinematic Substructure Modeling:** PM measurements in the next 2 years allows the modeling of kinematic substructures within the NSC. For instance, RV maps of the MW NSC (*top left and middle*) show that there are distinctive kinematic components: Super- and sub-solar metallicity populations has different rotation axes and amplitudes [4]. JWST PM will provide extra kinematic information on the other 2 dimensions.
- **Connection with the NSD and Their Formation Histories** (*top right*): The kinematic relationship between the NSC and NSD is critical for understanding how NSC forms [5]. We will measure PMs beyond the $R_{half-light}$ to determine if these components are physically distinct by looking for kinematic signature differences. We will compare our results with other studies at larger radii to map the kinematics of the NSC to $> 30\ pc$ radius [6].

References: [1] Chatzopoulos, S.+, 2015, MNRAS, 447, 952; [2] Hosek M., et al., in prep.; [3] Feldmeier-Krause, A., et al., 2017 *ApJ*, 464, 194; [4] Do, T. et al., 2020, *ApJ*, 809 143; [5] Schultheis, M, et al., 2021, A&A 650, A191; [6] Schödel, R. et al., 2009, *AAP*, 502, 91;