

# Uncovering the properties of galactic disks in GECKOS

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**Abstract.** The edge-on inclination of galaxies in the sky allows the observational study of their vertical structure, the thickness of their disks, and the identification of different disk components. Most disk galaxies show a morphological structure with two disks of different thicknesses: the thick and the thin disk. Thick disks are faint and deep observations with long integration times are needed to analyze them in detail, making observations challenging and works limited to a small sample. The origin of thick disks and their evolutionary connection with thin disks is still a matter of debate. In this work, we propose the study of thick and thin disks in the new integral field spectroscopy data from the GECKOS survey. The ongoing GECKOS survey, with a total sample of 35 edge-on galaxies observed with MUSE at VLT, provides an opportunity to put constraints on different formation scenarios for disk structures. For a subsample of 6 galaxies, we map stellar properties such as age, metallicity, and the abundance of  $\alpha$  elements, and extract the star-formation history of thick and thin disks. This will enable us to reconstruct the history of these thick disks and unveil their internal or external origin, complementing our findings with results from the literature on numerical simulations of galaxies of similar masses. Through a comparison between galaxies with a morphological structure featuring two distinct disks of different thicknesses and those with only one disk, we will investigate the mechanisms that lead to or prevent the formation of a double-disk structure and discuss the results of stellar formation history in terms of disk structure formation models.

**Resumo.** A inclinação das galáxias vistas de perfil no céu permite o estudo observacional de sua estrutura vertical, da espessura de seus discos e da identificação de diferentes componentes de disco. A maioria das galáxias espirais apresenta uma estrutura morfológica com dois discos de diferentes espessuras: o disco espesso e o disco fino. Discos espessos são pouco brilhantes, e observações profundas com longos tempos de integração são necessárias para analisá-los em detalhe, tornando as observações desafiadoras e os trabalhos limitados a uma amostra pequena. A origem dos discos espessos e sua conexão evolutiva com os discos finos ainda é tema de debate. Neste trabalho, propomos o estudo dos discos espessos e finos nos novos dados de espectroscopia de campo integral da pesquisa GECKOS. A pesquisa GECKOS, atualmente em andamento, com uma amostra total de 35 galáxias vistas de perfil observadas com o MUSE no VLT, oferece uma oportunidade de impor restrições a diferentes cenários de formação das estruturas de disco. Para uma subamostra de 6 galáxias, para as quais cubos de dados totalmente reduzidos do MUSE estão disponíveis para a equipe GECKOS, mapearemos propriedades estelares como idade, metalicidade e a abundância de elementos alfa, além de extrair a história de formação estelar dos discos espessos e finos. Isso nos permitirá reconstruir a história desses discos espessos e revelar se sua origem é interna ou externa, complementando nossos resultados com estudos da literatura baseados em simulações numéricas de galáxias de massas semelhantes. Por meio de uma comparação entre galáxias com uma estrutura morfológica que apresenta dois discos distintos de diferentes espessuras e aquelas com apenas um disco, investigaremos os mecanismos que levam ou impedem a formação de uma estrutura de disco duplo e discutiremos os resultados da história de formação estelar em termos de modelos de formação de estruturas de disco.

**Keywords.** Galaxies: structure, Galaxies: stellar content, Galaxies: evolution, Galaxies: kinematics and dynamics, Galaxies: abundances

## 1. Introduction

The study of galaxy structures plays a key role in putting constraints on galaxy formation theory. While face-on galaxies are widely studied for the comparison between disks and bulges, edge-on galaxies reveal complexities in disk components. When observed at high inclinations, disk galaxies tend to present two photometric components: the thin disk and the thick disk (Comerón et al. 2018). These structures show distinct stellar population properties, with the thick disk being composed, in most cases, of older, more metal-poor and  $\alpha$ -rich stars, whereas the thin disk presents young, metal-rich and  $\alpha$ -poor stars (Yoachim & Dalcanton 2005, 2008; Pinna et al. 2019; Martig et al. 2021).

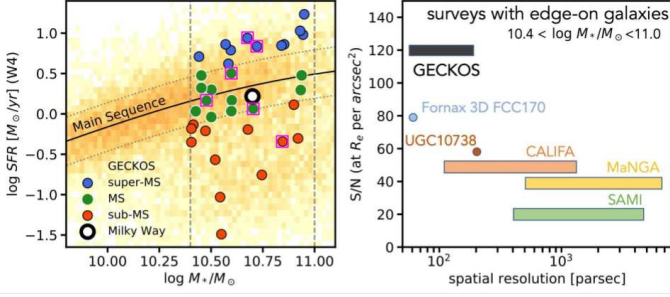
Despite the progress on the general properties of thick disks, there is little to no consensus on how these structures formed and how they evolved. The proposed mechanisms are: 1) *In-situ* formation at high redshift from turbulent gas (Brook et al. 2004); 2) Dynamical heating of stars formed in a preexisting thinner disk, which becomes thicker (Di Matteo et al. 2011), and 3) Accretion of stars from satellites through galaxy mergers (Abadi et al. 2003).

Previous integral-field spectroscopy observations (IFS) support a combination of the above-mentioned physical processes in the formation of thick disks. Moreover, recent observational studies have found that star-forming galaxies have younger thick disks with extended star formation histories (SFHs), compared to thick disks in more quiescent galaxies, suggesting that the formation process may depend on factors like star-formation rate (SFR) and environment (Sattler et al. 2024).

## 2. The Geckos Survey

The analyzed data is a new fully reduced GECKOS subsample of 6 galaxies: ESO484-036, ESO120-016, NGC5775, NGC0360, IC5244, and PGC044931. It makes use of the Multi Unit Spectroscopic Explorer (MUSE, Bacon et al. (2010)) is an integral-field spectrograph mounted at the Very Large Telescope (VLT, Paranal, Chile). Its high spatial resolution and optical wavelength range make it optimal to combine stellar kinematics and population properties, bringing the footprint of the history of galaxies.

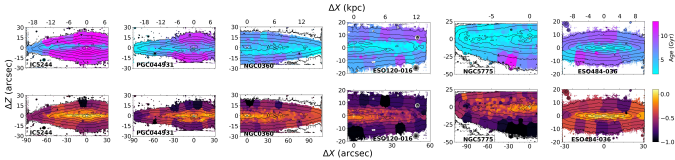
GECKOS utilizes the power of MUSE IFS to go out to a larger radius, higher signal-to-noise ratio ( $S/N > 40$  at  $\mu_g = 23.5$  mag/arcsec<sup>2</sup>) and higher spatial resolution ( $< 200$ pc) when compared to other IFS surveys (Sánchez et al. 2023), as seen in Fig. 1. The survey’s objective is to determine what physical mechanisms drive the chemical evolution of disk galaxies. Targets were selected from the S<sup>4</sup>G (Sheth et al. 2010) and HyperLEDA (Makarov et al. 2014) surveys within a distance of  $15 < D$  [Mpc]  $< 70$ , an edge-on configuration (inclination  $i > 80$ ) and a stellar mass range within  $\pm 0.3$  dex of the MW ( $5 \times 10^{10} M_\odot$ , Bland-Hawthorn & Gerhard 2016). GECKOS observations started in 2022 and finished in 2025.



**FIGURE 1.** *Left Panel:* SFR vs. Stellar Mass diagram for all the GECKOS sample, shown in color-coded circles according to the distance of the MS. The pink-squared circles correspond to the galaxies in our sample *Right Panel:* SNR vs. Spatial resolution comparison for different IFS surveys with edge-on galaxies.

### 3. Preliminary Results

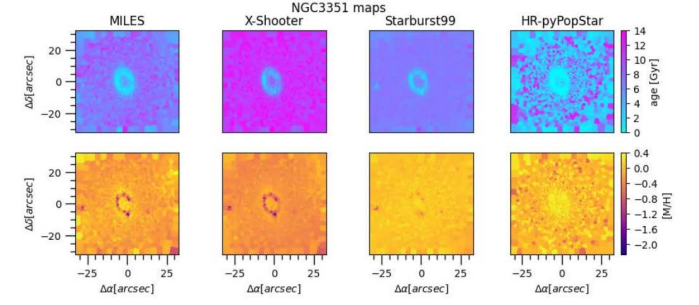
We produced preliminary age and metallicity mass-weighted maps for our sample using the nGIST (pPXF wrapper Cappellari (2017)) pipeline with MILES SSPs Vazdekis et al. (2015), seen in Fig. 2. Though our results are preliminary and further tests with other SSPs are needed, the dichotomy between the stellar populations of star-forming (SF) and quiescent galaxies is glaring. The age maps reveal that the younger stellar populations of galaxies such as ESO120-016 extend further away from the galactic plane compared to those of quiescent galaxies (IC5244). Concomitantly, the thick disk of IC5244 is significantly older than the thick disk of SF galaxies. This divergent pattern between the galaxies is also evident in the metallicity maps.



**FIGURE 2.** Age (top panels) and metallicity (bottom panels) color-coded mass-weighted maps for all galaxies in our sample estimated utilizing MILES SSPs. Galaxies are ordered by increasing SFR, so that the rightmost galaxy is the most star-forming. There is an increase in the thickness of the "thin disk", both in age and metallicity, with higher SFRs.

### 4. Forthcoming Research

There are multiple sets of stellar population models in the literature that can be used with pPXF. We wish to test how synthetic stellar population libraries impact the inferred SFH, compared with SSPs based on empirical libraries, as seen in Fig. 3.



**FIGURE 3.** Age (top panels) and metallicity (bottom panels) color-coded maps for NGC3351 using 4 different SSPs models: MILES Vazdekis et al. (2015), XSL Verro et al. (2022), Starburst99 Leitherer et al. (2014), and HR-pyPopStar Millán-Irigoyen et al. (2021). Extracted from Gonçalves et al. (in prep.).

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### References

- Abadi, M. G., Navarro, J. F., Steinmetz, M., & Eke, V. R. 2003, *ApJ*, 597, 21  
Bacon, R., Accardo, M., Adjali, L., et al. 2010., Vol. 7735, 773508  
Bland-Hawthorn, J. & Gerhard, O. 2016, *ARA&A*, 54, 529  
Brook, C. B., Kawata, D., Gibson, B. K., & Freeman, K. C. 2004, *ApJ*, 612, 894  
Cappellari, M. 2017, *MNRAS*, 466, 798  
Comerón, S., Salo, H., Peletier, R. F., & Mentz, J. J. 2018, *A&A*, 610, A5  
Di Matteo, P., Lehnert, M. D., Qu, Y., & van Driel, W. 2011, *A&A*, 525, L3  
Fraser-McKelvie, A., Falcon-Barroso, J., Martig, M., et al. 2024  
Leitherer, C., Ekström, S., Meynet, G., et al. 2014, *ApJS*, 212, 14  
Makarov, D., Prugniel, P., Terekhova, N., Courtois, H., & Vauglin, I. 2014, *A&A*, 570, A13  
Martig, M., Minchev, I., Pinna, F., et al. 2021, *MNRAS*, 508, 2458  
Millán-Irigoyen, I., Mollá, M., Cerviño, M., & Cardiel, N. 2021, *MNRAS*, 506, 4781  
Pinna, F., Falcón-Barroso, J., Martig, M., et al. 2019, *A&A*, 623, A19  
Miranda, M. S., Pilkington, K., Gibson, B. K., et al. 2016, *A&A*, 586, A10  
Sánchez, S. F., Fraser-McKelvie, A., Falcon-Barroso, J., et al. 2023  
Sheth, K., Regan, M., Hinz, J. L., et al. 2010, *PASP*, 122, 1397  
Vazdekis, A., Coelho, P., Cassisi, S., et al. 2015, *MNRAS*, 449, 1177  
Verro, K., Trager, S. C., Peletier, R. F., et al. 2022, *A&A*, 661, A50  
Yoachim, P., & Dalcanton, J. J. 2005, *ApJ*, 624, 701  
Yoachim, P., & Dalcanton, J. J. 2008, *ApJ*, 683, 707  
Sattler, N., Fragkoudi, F., Falcon-Barroso, J., et al. 2024