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Kinematics and star formation in the green valley with integral field spectroscopy

F. Palacios, A. Schnorr Müller, M. Trevisan, A. C. Oliveira, & A. C. Santiago-Menezes

[1] Universidade Federal do Rio Grande do Sul
e-mail: `felicia.palacios@ufrgs.br`

Abstract. We divide green valley, main sequence and passive galaxies into different kinematic classes making use of integral field spectroscopic data from the MaNGA survey. By comparing the prevalence of each class in these populations, we explore the relation between cessation of star formation and stellar kinematics.

Resumo. Dividimos galáxias do *green valley* e das sequências principal e das passivas em diferentes classes cinemáticas, utilizando dados de espectroscopia de campo integral do MaNGA. Ao comparar a prevalência de cada classe nessas populações, exploramos a relação entre a cessação da formação estelar e a cinemática.

Keywords. Galaxies: evolution – kinematics and dynamics – star formation

1. Introduction

In a stellar mass–star formation rate (SFR) diagram, galaxies with ongoing star formation cluster around the main sequence, and those that have stopped forming stars can be found on the passive sequence. The green valley is situated between these two regions of the diagram and is populated by galaxies with intermediate properties. It is believed that these galaxies undergo processes that reduce their star formation, transitioning from the main sequence to the passive sequence (Salim 2015). Studies indicate that this transition is accompanied by morphological transformations (Gu et al. 2018).

This work aims to investigate the kinematics of green valley galaxies, drawing comparisons to main and passive sequence galaxies, in order to establish constrains to the physical mechanisms underlying the cessation of star formation and explore the relation of these processes to stellar kinematics.

2. Methodology

2.1. Sample selection

Using the criteria established by Trussler et al. (2020), we define the green valley as the region on the stellar mass-–star formation rate diagram bounded by the following lines two lines.

Stellar mass and SFR data were extracted from the GALEX-SDSS-WISE Legacy Catalog (GSWLC, Salim et al. 2018). We separated the galaxies in the sample into centrals and satellites according to the classification in the group catalog of Lim et al. (2017). Galaxies included in the MaNGA integral field spectroscopy survey were selected (Bundy et al. 2015).

Our final sample is comprised of 738 central galaxies and 435 satellite galaxies with stellar masses ranging from 10^9 $M_\odot$ and $10^{11.7}$ $M_\odot$ and with redshifts between 0.02 and 0.1.

2.2. Kinematic properties

We used 2D maps of kinematic properties and observed flux made available by the MaNGA collaboration to obtain the integrated ratio of stellar velocity and velocity dispersion, V/σ (Cappellari et al. 2007), and stellar spin parameter within 1 effective radius, λ_{Re} (Emsellem et al. 2007), using the following expressions:

$$\left(\frac{V}{\sigma}\right)^2 = \frac{\langle V^2\rangle}{\langle \sigma^2\rangle} = \frac{\sum_{i=0}^{N_{spx}} F_i V_i^2}{\sum_{i=0}^{N_{spx}} F_i \sigma_i^2} \tag{1}$$

$$\lambda_R = \frac{\langle R|V|\rangle}{R\sqrt{V^2+\sigma^2}} = \frac{\sum_{i=0}^{N_{spx}} F_i R_i |V_i|}{\sum_{i=0}^{N_{spx}} F_i R_i \sqrt{V_i^2+\sigma_i^2}} \tag{2}$$

where V_i, σ_i and F_i are the stellar velocity, stellar velocity dispersion and mean flux on the r band in the i-th spaxel, and R_i is the semi-major axis of the ellipse where the i-th spaxel lies.

In obtaining both V/σ and λ_{Re}, spaxels with velocity dispersion $\sigma < 50$ km/s where masked, and galaxies with 20% of their spaxels masked where removed from the sample.

We applied a correction for beam smearing, an effect related to atmospheric seeing and aperture that artificially increases observed velocity dispersion, described in Harborne et al. (2020)

2.3. Kinematic classification

We classified galaxies as slow rotators using the criteria of Cappellari (2016):

$$\lambda_{Re} < 0.08 + \epsilon/4, \text{ com } \epsilon < 0.4. \tag{3}$$

As in Fraser-McKelvie and Cortese (2022), the remaining galaxies were further divided into dynamically cold disks and intemediate systems using the distribution of log (V/σ) across three stellar mass bins, as shown in . For all bins, the distribution shows a peak at log $(V/\sigma) \approx 0$, corresponding to the dynamically cold disk population, with a long tail extending towards lower log (V/σ) values. We fitted a Gaussian mixture model to the distribution and defined the cut-off value separating dynamically cold disk from intermediate systems as $-\sigma_{dist}$ from the center of the distribution with the highest log (V/σ) values, where σ_{dist} is the standard deviation of this distribution.

3. Results

Table 1 shows the number fraction of each kinematic class for central green valley, main sequence and passive sequence in

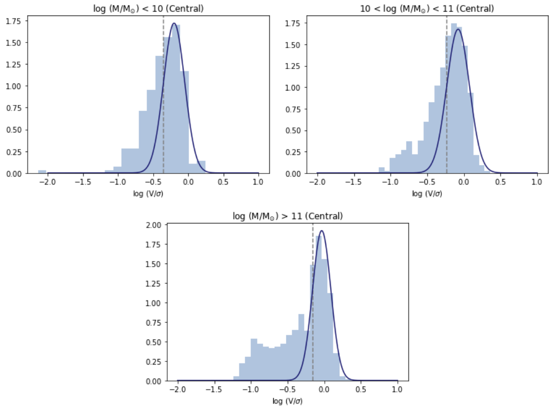

FIGURE 1: Distribution of log (V/σ) for three stellar mass bins of central galaxies. Satellite galaxies show similar distributions

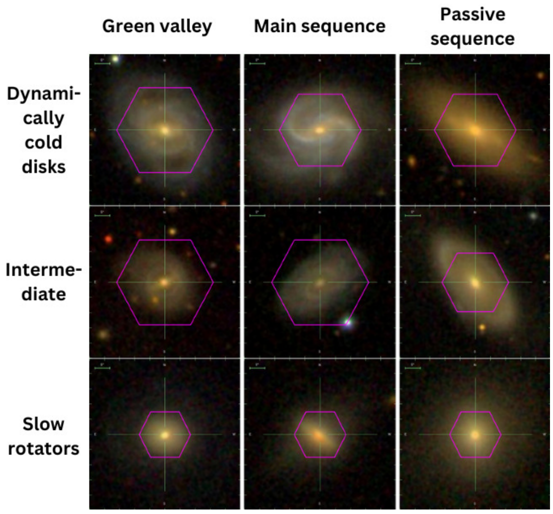

FIGURE 2: SDSS images of central galaxies with 10 < log (M/M$_\odot$) < 11 of each kinematic class.

Table 1: Number fractions of kinematic classes of central galaxies.

	Green valley	Main sequence	Passive sequence
log (M/M$_\odot$) <10			
Slow rotators	0.10	0.07	0.15
Dynamically cold disks	0.51	0.68	0.36
Intermediate	0.38	0.25	0.49
10 <log (M/M$_\odot$) <11			
Slow rotators	0.07	0.05	0.14
Dynamically cold disks	0.66	0.76	0.26
Intermediate	0.27	0.19	0.60
log (M/M$_\odot$) >11			
Slow rotators	0.05	0.05	0.30
Dynamically cold disks	0.59	0.71	0.09
Intermediate	0.36	0.24	0.61

three mass bins. Results were similar for satellite galaxies. The prevalence of the different kinematic classes in the green valley is similar to that of the main sequence, though it is noticeable that the green valley exhibits intermediate values between the main and passive sequences in terms of the fractions of dynamically cold disks and intermediate systems.

The higher fractions of intermediate systems in the green valley compared to the main sequence suggest that if galaxies do indeed transition from the main sequence to the passive sequence through the green valley, processes that reduce the degree of rotational support in a system must occur during the passage through the green valley.

We also find observe a significant fraction of passive disks in all but the highest mass bin, implying that processes must occur to curb star formation without affecting stellar kinematics.

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