Spatially-resolved stellar kinematics of the CLoGS brightest group early-type galaxies

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Abstract. Galaxy groups within the local Universe contain over half of all observable galaxies. Furthermore, galaxy groups host the majority of both baryonic and dark matter content in the Universe. Therefore galaxy groups are excellent laboratories for studying galaxy evolution. Of particular importance are the brightest group early-type galaxies (BGEs) roughly located at the centre of each group's gravitational potential well. By studying the stellar kinematics of these BGEs, we hope to better understand the mass-assembly histories of these galaxies. The Complete Local-Volume Groups Sample (CLoGS) is a statistically complete survey of 53 galaxy groups in the optical, X-ray, and radio bands. We measure the spatially-resolved stellar kinematics of the BGEs of 18 of these groups. The spectra of these galaxies were obtained via optical spectroscopy with the Southern African Large Telescope (SALT). The stellar kinematics are obtained with full-spectrum fitting software. The radial profiles of both the stellar velocity dispersion and stellar rotational velocity of some of these BGEs are presented. We find a diverse range of stellar kinematics for the BGEs, for example, some BGEs show strong rotation and others no rotation. We further measure the steller velocity dispersion slopes of these BGEs and compare them to other galaxy surveys and galaxy evolution simulations.

1. Introduction

Galaxies can be found within a variety of different environments such as clusters, groups, fields and voids, each with a different concentration of baryonic- and dark matter. Of particular importance are galaxy groups which host over 60 % of all observable galaxies [1]. The dominant, central galaxy within each group is typically found close to the centre of the group's dark matter halo [2]. The mass assembly histories of BGEs are strongly tied to its group environment's baryonic- and dark matter content and are understood to result from prior merging processes [3]. However, the exact mass assembly histories of BGEs are still poorly understood and more unique than previously thought [4] [5] [6]. To constrain the mass profiles of BGEs and their group environments, the dynamical mass of these galaxies can be determined by measuring their stellar kinematics [5] [6]. These mass profiles can in turn be used to build galaxy evolution models and simulations, which improve our understanding of how galaxies evolve within group environments [7]. In this study, we will measure the spatially-resolved stellar kinematics of 18 of the CLoGS BGEs. Our results will be compared with other galaxy surveys and galaxy evolution simulations to compliment existing data.

CLoGS is a sample of 53 optically-selected galaxy groups located within 80 Mpc [8]. As part of the selection criteria, these groups are fully virialised and contain a central early-type galaxy

(BGE) [8]. 23 of these BGEs, observable from the Northern hemisphere have already been studied with the Hobby-Eberly Telescope [10]. To compliment this, we study 18 CLoGS BGEs observable from the Southern hemisphere with SALT as listed in Table 1.

Table 1: CLoGS BGEs subsample with their coordinates.

Name	z	D (Mpc)	Group	α (J2000)	δ (J2000)
ESO 507-25	0.011	45 ± 8.9	LGG310	12 : 51 : 31.85	−26 : 27 : 07.70
NGC 128	0.013	60 ± 51.8	LGG006	00 : 29 : 15.07	02 : 51 : 50.60
NGC 193	0.015	74 ± 0.4	LGG009	00 : 39 : 18.58	03 : 19 : 52.90
NGC 1395	0.006	21 ± 25.2	LGG097	03 : 38 : 29.79	−23 : 01 : 39.70
NGC 1550	0.012	53 ± 13.8	LGG133	04 : 19 : 37.92	02 : 24 : 35.60
NGC 2292	0.007	30 ± 3	LGG138	06 : 47 : 39.80	−26 : 44 : 46.00
NGC 2911	0.011	45 ± 20.3	LGG177	09 : 33 : 46.10	10 : 09 : 08.90
NGC 3078	0.009	34 ± 19.6	LGG185	09 : 58 : 24.60	−26 : 55 : 35.90
NGC 3325	0.019	80 ± 0	LGG205	10 : 39 : 20.46	−00 : 12 : 01.00
NGC 3923	0.006	20 ± 25.2	LGG255	11 : 51 : 01.78	−28 : 48 : 22.40
NGC 4697	0.004	18 ± 24.9	LGG314	12 : 48 : 35.90	−05 : 48 : 02.50
NGC 5044	0.009	38 ± 16.7	LGG338	13 : 15 : 23.97	−16 : 23 : 08.00
NGC 5061	0.007	28 ± 8.8	LGG341	13 : 18 : 05.05	26 : 50 : 14.00
NGC 5084	0.006	23 ± 12.4	LGG345	13 : 20 : 16.92	−21 : 49 : 39.30
NGC 5153	0.014	60 ± 4.9	LGG351	13 : 27 : 54.33	−29 : 37 : 04.90
NGC 5903	0.009	36 ± 13.4	LGG398	15 : 18 : 36.53	−24 : 04 : 06.90
NGC 7252	0.016	66 ± 27.0	LGG457	22 : 20 : 44.78	−24 : 40 : 41.90
NGC 7377	0.011	46 ± 19.4	LGG463	22 : 47 : 47.51	−22 : 18 : 43.50

2. Method

We obtain spatially-resolved optical spectra for our subsample of CLoGS BGEs using the Southern African Large Telescope (SALT) Robert Stobie Spectrograph (RSS). To measure the stellar kinematics of these BGEs, these spectra are fitted with the full-spectrum fitting software pPXF [11]. To constrain the measurements, pPXF is performed as a Monte-Carlo simulation of 50 iterations. An example pPXF fit is shown in Figure 1. We measure different apertures to create stellar velocity dispersion- and stellar rotational velocity profiles. The slopes of the stellar velocity dispersion profiles are fitted with the function: $\log(\frac{\sigma}{\sigma_0}) = \eta.\log(\frac{\mathrm{R}}{\mathrm{R_0}}) + \mathrm{c} \quad \mathrm{c} \in \mathbb{R}$, where $R_0 = 1\,\mathrm{kpc}$ and σ_0 is the central velocity dispersion measured up to R_0.

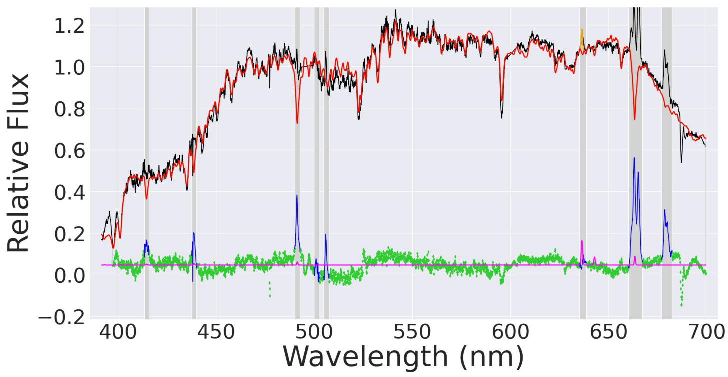

Figure 1: First iteration pPXF fit of ESO 507-25 using the MILES stellar library [9]. The observed spectrum is shown in black. The best pPXF fit is shown in red. The deviations are shown in green. The gas emission lines (shown in orange and blue) are masked in grey.

3. Results

We show the stellar velocity dispersion and stellar rotational velocity profiles of NGC 193 and NGC 5084 to illustrate the diversity of stellar kinematics observed.

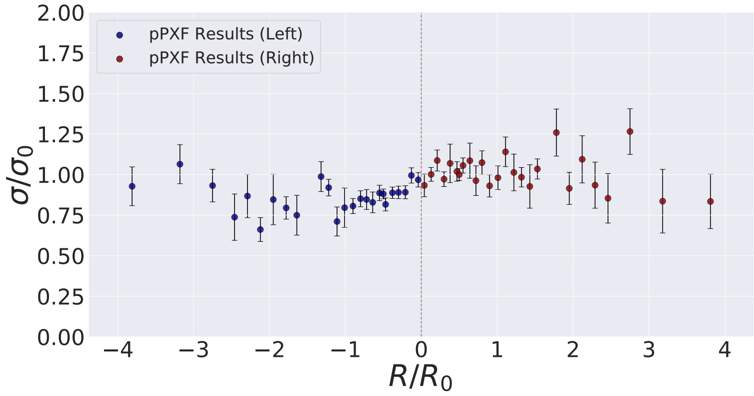

Figure 2: Stellar velocity dispersion profile of NGC 193. The radial profile is approximately symmetric about the galactic centre and flat overall.

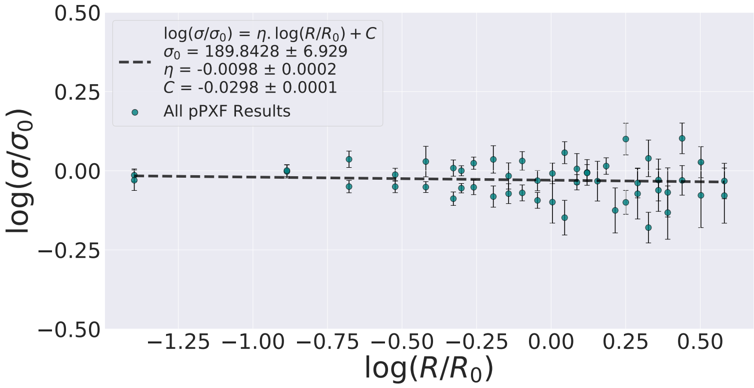

Figure 3: Stellar velocity dispersion slope of NGC 193. The slope is close to zero. The radial profile can be interpreted as flat with reasonable certainty.

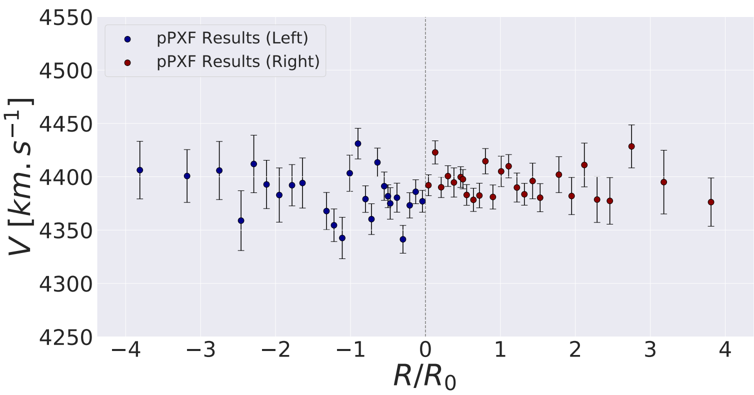

Figure 4: Rotational velocity profile of NGC 193. The pPXF results show that NGC 193 has no clear discernible rotation.

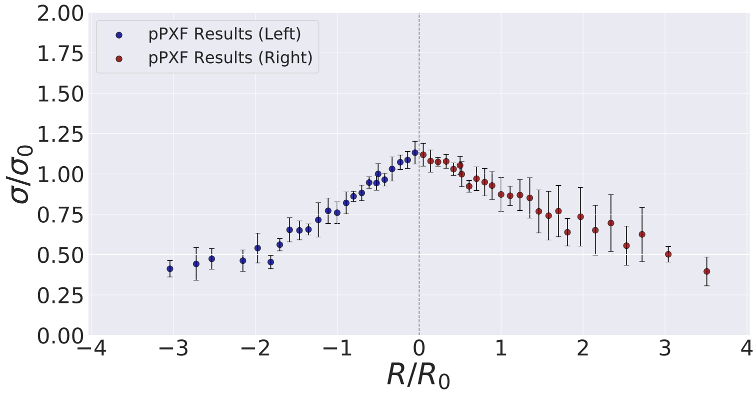

Figure 5: Stellar velocity dispersion profile of NGC 5084. The radial profile is approximately symmetric about the galactic centre and decreases to both sides.

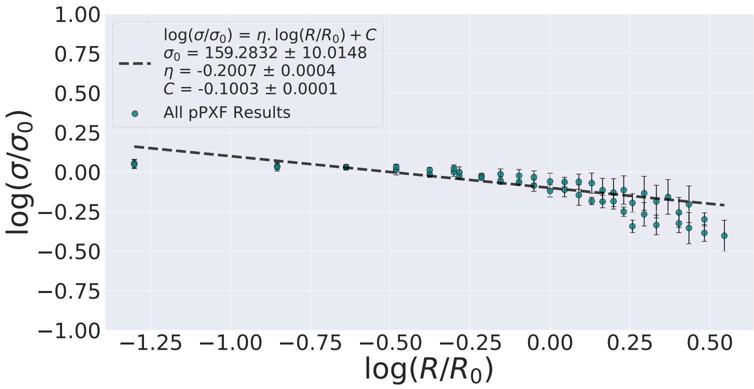

Figure 6: Stellar velocity dispersion slope of NGC 5084. The slope is small and negative. The radial profile can be interpreted as decreasing.

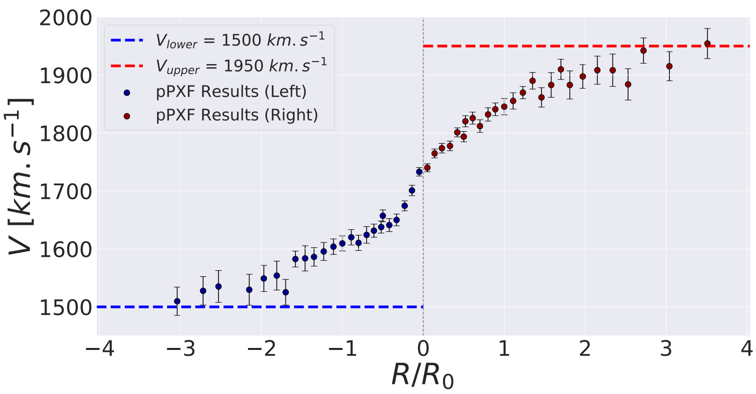

Figure 7: Rotational velocity profile of NGC 5084. The pPXF results show that NGC 5084 has very strong rotation with $V_{max} = (V_{upper} - V_{lower})/2 \approx 225\, km.s^{-1}$.

We summarise our results by plotting the velocity dispersion slopes of the CLoGS BGEs against that of other galaxy surveys and galaxy evolution simulations.

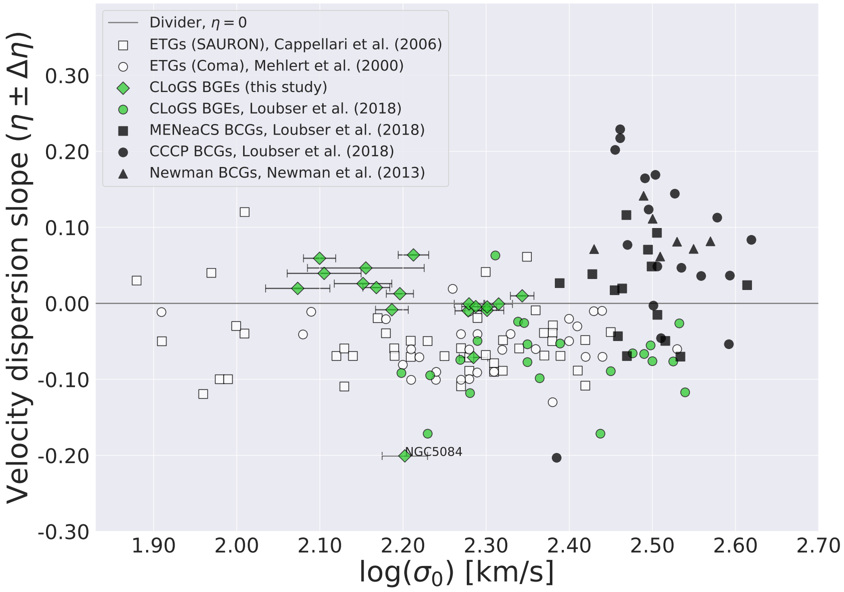

Figure 8: Velocity dispersion slope vs. central velocity dispersion. The early type galaxies (ETGs) from Cappellari et al. (2006) and Mehlert et al. (2000) are shown in white. The CLoGS BGEs are shown in green. The brightest cluster galaxies (BCGs) from Loubser et al. (2018) and Newman et al. (2013) are shown in black.

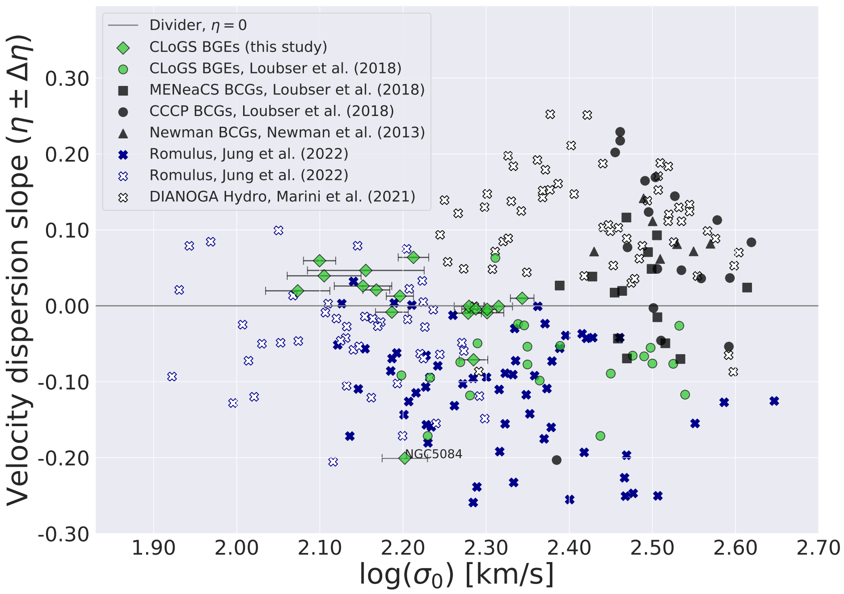

Figure 9: Velocity dispersion slope vs. central velocity dispersion. The CLoGS BGEs are shown in green. The results are compared with the latest simulation results: Romulus (shown in blue), DIANOGA Hydro (shown in white).

4. Concluding Remarks and Future Work

We measure a variety of different stellar velocity dispersion and stellar rotational velocity profiles for our subsample of CLoGS BGEs. Out of the 18 BGEs, 8 are rotating and 10 are non-rotating. All 18 BGEs have a nearly flat velocity dispersion slope, with $-0.10 \leq \eta \leq 0.10$, save NGC 5084 which has a slope of $\eta \sim -0.20$. As can be seen from Figure 8 the stellar kinematics of the CLoGS BGEs seem to more closely reflect field ETGs than that of BCGs. From Figure 9, it can be seen that the our measured range of velocity dispersion slopes differ from Marini *et al.* (2021) and Jung *et al.* (2022). It is unclear whether current galaxy evolution simulations can accurately model the kinematics of BGEs and the unique hydrodynamics of their group environment.

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