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Structure and Dynamics of the Fornax Cluster

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Abstract. We study the distribution in the phase space in the cluster of the galaxies of the Fornax to determine their structure and dynamic state.

Resumo. Estudamos a distribuição no espaço de fase das galáxias do aglomerado de Fornax para determinar sua estrutura e estado dinâmico.

Keywords. Galaxies: clusters: individual: Fornax – Galaxies: clusters: intracluster medium – X-rays: galaxies: clusters – Galaxies: kinematics and dynamics

1. Introduction

Groups and clusters of galaxies are large galactic structures believed to be formed from smaller structures and may be considered the largest ones in the universe. In the hierarchical scenario of structure formation, clusters are the last structures to be formed whereas groups of galaxies appear as intermediate structures formed in earlier times. The Fornax cluster, despite its apparent state of relaxation, is known to be packed full of substructures (Drinkwater et al., 2001), some still in course of relaxation (Iodice et al., 2016, 2017). We studied the phase space distribution of the galaxies of the Fornax cluster to determine their structure and dynamic state. Although the system has been studied in detail in the past, new spectroscopic data as well as new results obtained from deep X-ray observations show evidence of intense activity in the region.

2. Methodology

Optical data came from the HyperLeda database (http://leda.univ-lyon1.fr). We obtained a representative sample of the distribution of galaxies in an 8 degree region around the central galaxy NGC1399 (Fig. 1). The velocity distribution of the system was analyzed through the statistical methods provided by the ROSTAT routines package. By making an iterated use of the gap distribution of data and theirs probabilities (both given by ROSTAT), we arrived to a representative sample of Fornax cluster galaxies within the redshift interval $600 < cz < 2400$ km.s^{-1} with mean velocity (bi-weighted) $\overline{cz}$= 1469 km.s^{-1} ($\overline{z}$= 0.004900), and velocity dispersion (bi-weighted) σ_{cz} = 403 km.s^{-1} (see Fig. 2) Spectral X-ray data from XMM-Newton satellite were also included in our study, in order to obtain temperature and metallicities maps of the cluster central region (Figs. 4 and 5).

3. Results and Conclusions

As a first attempt to understand the overall cluster kinematic and dynamics, was divided the entire region into 6 rings of velocities sorted in distance from NGC1399. Then for each ring we calculated the mean velocity and velocity dispersion. As it can be seen the velocity distribution do not vary significantly as we move away from the cluster center (Fig. 3).

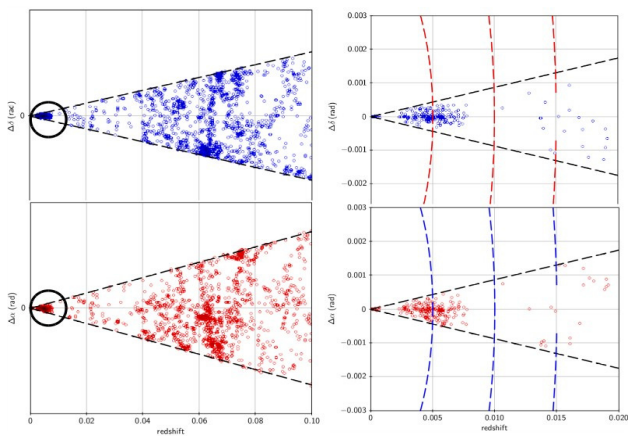

Figure 1. Cone diagrams of the 8° region showing the field of Fornax in depth up to redshift $z = 0.10$. The left panel displays the entire sample, whereas the right panel shows a zoom of the circled region on the left panel.

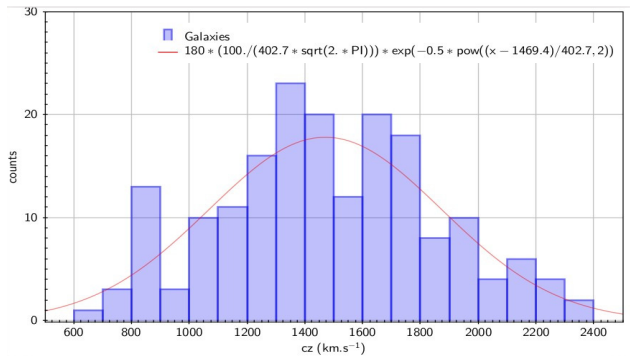

Figure 2. The velocity histogram of the Fornax cluster sample of galaxies. Superposed is a Gaussian profile with parameters given the ROSTAT bi-weighted estimators (see text).

To resolve structures in temperature and metallicity, the X-ray data were divided into small regions from which spectra can be extracted. The 2D maps were made in a grid, where each pixel; is 512 × 512 XMM EPIC physical pixels, i.e., each cell

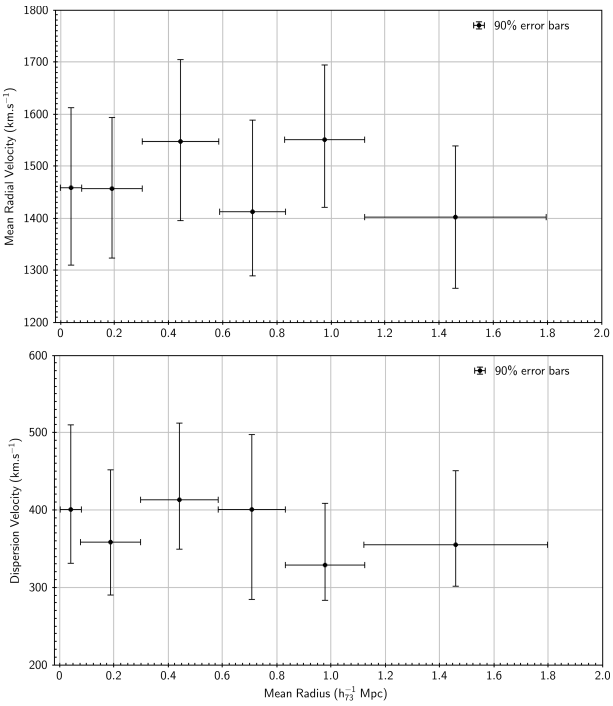

Figure 3. Bi-weighted estimates of mean radial velocities (*upper panel*) and velocity dispersion (*bottom panel*) for 6 concentric rings centered on NGC1399. Error bars are 90% confidence.

grid is 25.6 arcsec × 25.6 arcsec. In each pixel we performed a spectral fit to determine the temperature and metallicity simultaneously (Laganá et al., 2015). The results are shown in Fig. 4 and 5 below.

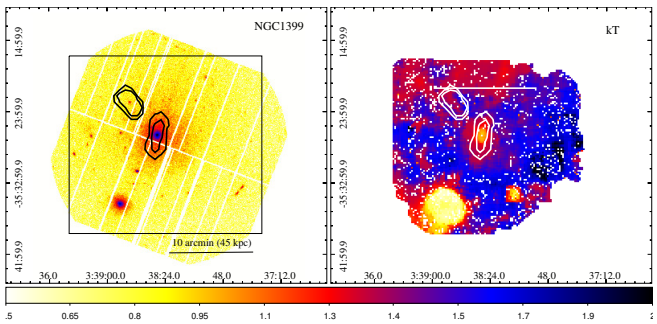

Figure 4. Maps of the X-emission (left) and of temperature distribution (right). Most of the emission in concentrated around the central galaxy NGC1399. Temperatures are lower in the central region, suggesting the cluster to be classified as Cool Core.

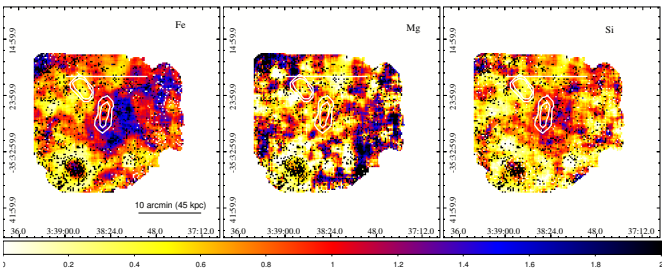

Figure 5. The map of Fe abundances (*left*), Mg (*middle*), and Si (*right*). The high Fe concentration is correlated with the distribution of galaxies in the central region of the system.

These figures suggest that in the neighborhood of NGC1399 the intra cluster gas is highly inhomogeneous both in temperature as in its chemical abundances, a situation which is reminiscent of that of the NCG4325 group (cf. Lagana et al., 2015). We have tried to correlate these inhomogeneities to the distribution and kinematics of the galaxies in the central region of Fornax. With this aim we calculated the adaptative map of the local velocity dispersion of galaxies as described by Biviano et al. (1996). The result is shown in Fig. 6 together with the contours of the regions with Fe abundance excess (the blue spots of Fig. 5, left panel). As it can be seen, the "hotter" regions in the galaxy distribution coincides with the regions with excess of Fe abundances suggesting a possible correlation.

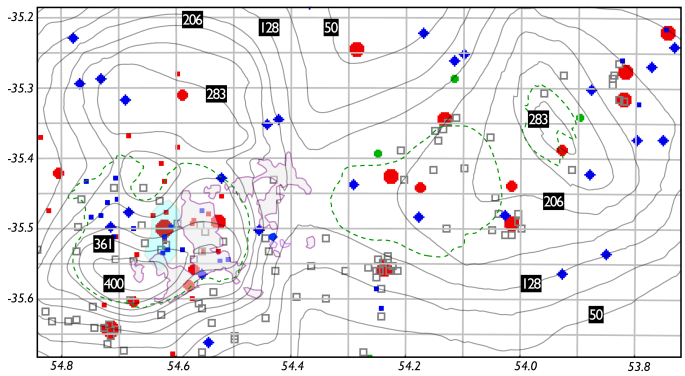

Figure 6. Isocontours of local velocity dispersion (km.s^{-1}; black continuous lines) superimposed to the map of galaxy positions of the central region of the Fornax, their diameters being proportional to the B-magnitude of the galaxy (*red points*: galaxies kinematically belonging to the cluster; *blue points*: galaxies with no redshift measurement; *open squares*: globular clusters). The *dashed lines* give the boundaries of regions for which the velocity dispersion map is significant at a 3-σ confidence level. The *purple* shaded region are the regions in excess of Fe abundances (see Fig. 5) whereas the *green* shaded region, which includes NGC1399, is the region where an excess of non-thermal radio emission has been detected (Killeen et al. 1988).

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