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The origin of high-metallicity structures in the core of the Fornax galaxy group

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Abstract. We discuss the correlations between intra-group gas temperature and metallicity maps obtained from X-ray observations collected by the XMM-Newton observatory.

Resumo. Discutimos as correlações entre mapas de temperatura e metalicidade do gás intra-grupo obtidos a partir de observações em raios-X coletadas pelo observatório XMM-Newton.

Keywords. Galaxies: groups: individual: Fornax – Galaxies: clusters: intracluster medium – X-rays: galaxies: clusters

1. Introduction

The Fornax group is the second most massive galaxy concentration within 20 Mpc after the Virgo cluster. Most of the bright ($m_B < 15^m$) cluster members in the core are early-type galaxies, including the brightest active galaxy NGC 1399 (z = 0.0478). The Fornax cluster hosts a large population of dwarf galaxies and ultra compact galaxies as well a population of globular clusters and planetary nebulae (e.g. D'Abrusco et al. 2016; McNeil-Moylan et al. 2012). Intra-cluster light has been also detected in the core of Fornax (e.g. Iodice et al 2018). There are suggestions that the mass assembly of this group is still ongoing (e.g. Drinkwater et al., 2001).

2. Methodology

Using data collected by the XMM-Newton observatory we obtained 2D maps of temperatures and metallicities ($n_{Fe}/n_{Fe\odot}$) in the core region of Fornax. These 2D maps were made in a grid, where each pixel is 512 x 512 XMM EPIC physical pixels, so that each cell grid is 25.6 arcsec x 25.6 arcsec (1.3 h_{70}^{-1} Kpc at z = 0.0478) . In each pixel we performed a simultaneous spectral fit to determine the temperature and metallicity (Laganá et al., 2015). The results are shown in Figure 1 below.

In order to understand the origin of the patchy distribution of temperatures and metallicities seen in Figure 1, we analyzed the *local* correlations between temperatures and metallicities aiming to find the signatures of processes proposed to explain the observed enrichment in the ICM: ram-pressure stripping (RPS, Gunn & Gott 1972), galactic winds (De Young 1978), galaxy-galaxy interactions (Gnedin 1998), AGN outflows (De Young 1986) and intracluster supernovae (Gerhard+ 2002). Numerical simulations (e,g Kapferer et al. 2007, Ruggiero & Lima Neto, 2017) suggest that in the central dense regions of galaxy clusters - the case here - RPS is the dominant process given the higher density of the IG gas and the fact that galaxies velocities are higher in the clusters centers. For the same reasons we should expect a suppression of galactic winds in the center of clusters. As discussed by Lovisari et al (2011) because gas lost by galaxies are generally colder and more metal rich than the IG gas, RPS processes should leave local characteristic signatures expressed by anti-correlations between local metallicities and temperatures occurring along the trails of galaxies being stripped. Another possibility is that of enhanced star formation in the tail of stripped gas. These star may evolve rapidly and explode as

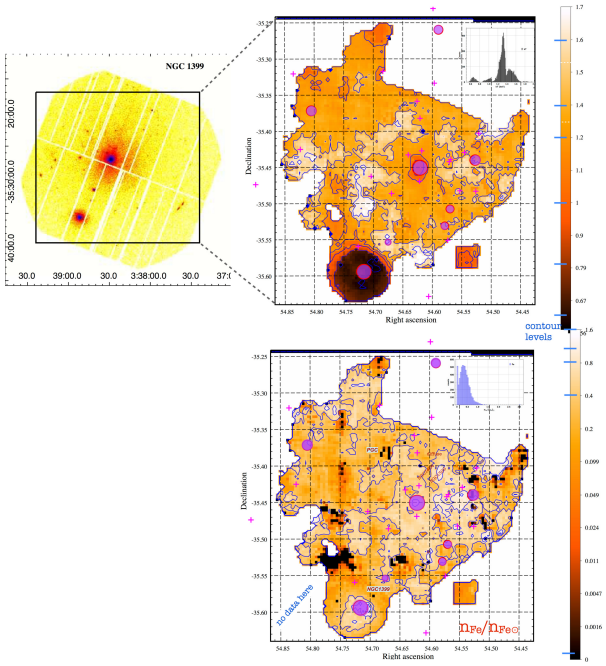

Figure 1. *upper left panel* XMM map of the X-ray emission in the central region of Fornax. Most of the emission in concentrated around the central galaxies NGC1399 and NGC1404. *upper right panel* Color coded map of the temperature (keV) of the intra-group gas in the central region of Fornax; the inset shows the histogram of pixel values of this map. *lower panel* The same as for the upper panel but for the gas metallicities as given by the Fe abundance (Fe $\hat{=}$ $n_{Fe}/n_{Fe\odot}$). The purple circles represent the galaxies belonging to the group with radius proportional to their B-magnitude (data from the HyperLeda database: http://leda.univ-lyon1.fr). Crosses are galaxies without measured m_B. The central galaxy is NGC1399. The southernmost galaxy is the NGC1404.

SNIIe directly in the IG medium, contributing to gas contamination mainly with α-elements.

3. Results and Conclusions

Our study of correlations between local IG gas temperature and metallicity values is summarized in Figure 2. We start by assigning different colors to pixels according to temperature values following the kT distribution given by the histogram in the upper left panel of Figure 2. We divided the observed temperature range (0.5 – 2.0 keV) into 5 intervals and assigned 5 different colors to pixels (see Figure 2). This color assignment to pixels was then applied to the kT map of Figure 1, resulting in the map displayed in the left panel of Figure 2

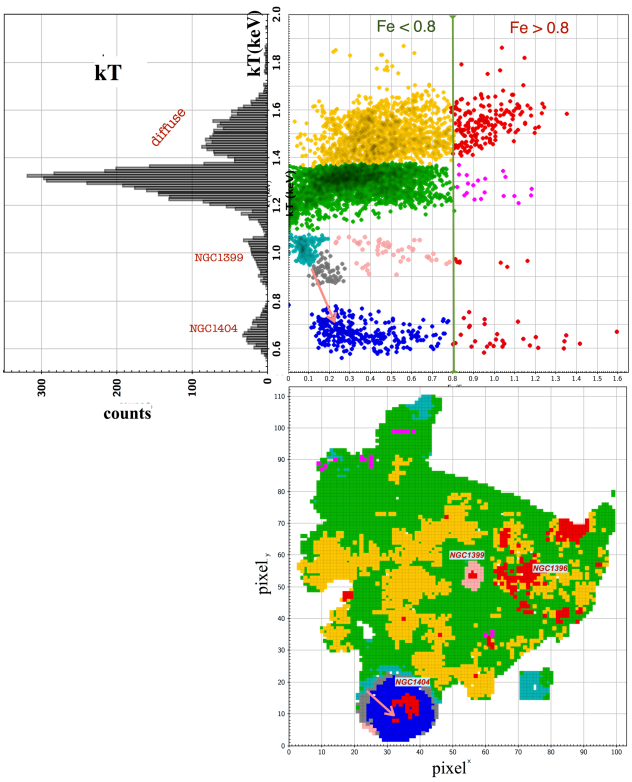

Figure 2. *upper left panel* Histogram of pixel temperatures (keV) corresponding to the map of Figure 1, upper panel. We distinguish 3 main temperature regions corresponding to the 2 brightest galaxies and to the diffuse IG gas. The gaps at kT ~0.8 keV and ~1.1 keV are instrumental; *upper right panel* Temperature × Fe abundance plot with colors roughly following the temperature distribution shown in the left panel. The arrow emphasize a temperature × Fe abundance behavior much similar to that predicted for a RPS process of NGC1404. This is reflected in the upper left panel distribution of colors; *lower panel* Plane of sky distribution of pixels following the rough classification defined in the upper panels. Notice that higher metallicity pixels, Fe > 0.8 (red points), are mostly concentrated east from NGC1399, in a diffuse gas region.

An examination of the upper panel of Figure 2 suggests a RPS event associated to the bright galaxy NGC1404. In the Figure this is denoted by a pink arrow pointing towards decreasing temperatures and increasing metallicities, characterizing a RPS event: the arrow points towards a putative galaxy moving through the IG gas and loosing its interstellar gas by the action of ram-pressure. When transferred to the temperature map, we find that the arrow points exactly to NGC1404 indicating the existence of a SW tail. This suggests that NGC 1404 is moving through Fornax in the west-south direction.

Another feature that should be highlighted in this analysis is the high metallicity gas (Fe > 0.8) found diffusely distributed within a large region going eastward the central galaxy NGC1399 up to NGC1396. There no hint of RPS processes going on in this region. However the detailed study by Iodice et al (2018) shows a clear excess of diffuse intra-cluster light (ICL) in this same region which also displays a rich distribution of globular clusters (D'Abrusco et al, 2016). This suggests that the high metallicity gas we detect here was produced else by *in situ* supernovae explosions or due to the galactic winds of the countless galaxies all around.

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