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The effects of flattening and rotation on the temperature of the X-ray halos of elliptical galaxies

S. Posacki, S. Pellegrini, and L. Ciotti

Department of Physics and Astronomy, University of Bologna, Viale Berti Pichat 6/2, I-40127 Bologna, Italy, e-mail: silvia.posacki@unibo.it

Abstract. Elliptical galaxies have hot coronae with X-ray luminosities and mean gas temperatures that span over wide ranges. This variation can be partially due to the energy budget of the hot gas, that depends on the host galaxy structure and internal kinematics. With the aid of realistic axisymmetric galaxy models, we performed a diagnostic study focussed on the effects of galaxy flattening and rotational support on the hot gas temperature.

Key words. Galaxies: elliptical and lenticular, cD – Galaxies: fundamental parameters – Galaxies: ISM – Galaxies: kinematics and dynamics – X-rays: galaxies – X-rays: ISM

1. Introduction

The X-ray observatory *Chandra* allowed for a study of the hot gas halos in early-type galaxies (ETGs) with unprecendented quality and accuracy. With these data, an ETG sample with homogeneous measurements of the average hot gas temperature and luminosity has recently been built (Boroson et al., 2011), and provides the basis to test the hot gas properties against other major galaxy properties. For example, the hot gas content has long been known to be sensitive to the shape of the mass distribution, and possibly to the mean rotation velocity of the stars (see Pellegrini 2012 for a recent review). The same could be concluded in a recent study focussed on the gas temperature (Pellegrini, 2011). Here we show some preliminary results from an investigation of the effects of galaxy shape and internal kinematics on the gas temperature, and on the energy required to extract the gas from the galaxy potential well, for axisymmetric ETG models.

2. The galaxy models

The galaxy models include three mass components: a stellar distribution following the approximate ellipsoidal deprojection of the de Vaucouleurs profile, with axial ratio $0.3 \leq q \leq 1$; a spherically symmetric dark matter (DM) halo, described either by the singular isothermal sphere (SIS), the Hernquist, the Einasto, or the Navarro-Frenk-White profile; and a central massive black hole. We assume a two-integral phase-space distribution function, so that $\sigma_{\rm R} = \sigma_{\rm z}$, and the amount of ordered rotational support in the azimuthal direction is controlled by the Satoh (1980) k-decomposition: $k = 1$ corresponds to the isotropic rotator, whereas for $k = 0$ no net rotation is present, and the galaxy flattening is due to σ_φ only. The Jeans equations are solved with

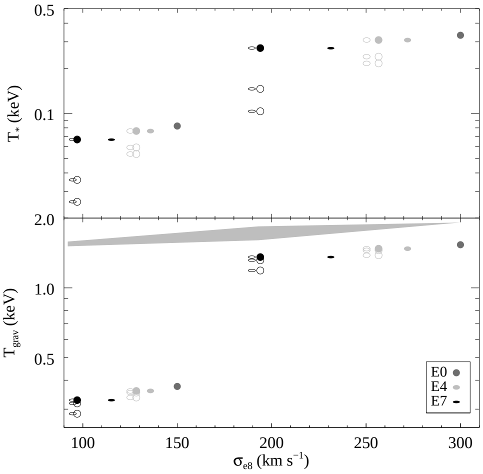

Fig. 1. T_* (top) and $T_{\rm grav}$ (bottom) for two EO-built sub-families with $\sigma_{\rm e8} = 150$ and $300\,{\rm km\,s^{-1}}$, as a function of morphological type and (k, γ). Round and elliptical symbols refer to the FO and EO view of the same models, respectively. Filled and empty symbols are for $k = 0$ and $k = 1$. $\gamma = (1, 0.5, 0)$ decreases from top to bottom for the empty symbols. The shaded area shows the range spanned by $T_{\rm inj}$.

a numerical code built on purpose, under the assumption of a constant stellar mass-to-light ratio. All the structural and dynamical properties are projected face-on (FO) and edge-on (EO), and the circularized effective radius ($R_{\rm e}$) and the luminosity weighted velocity dispersion within $R_{\rm e}/8$ ($\sigma_{\rm e8}$) are computed. The models are forced to follow the most important scaling laws, so that ($R_{\rm e}$, $\sigma_{\rm e8}$, L) satisfy the Faber-Jackson and Size-Luminosity relations. Finally we calculate fiducial ISM temperatures for the models, as defined in Pellegrini (2011), under the assumption that the mass sources are distributed as the stellar density. The temperature $T_* = T_\sigma + \gamma T_{\rm rot}$ measures the energy input due to the thermalization of stellar random (T_σ) and ordered ($T_{\rm rot}$) motions. The actual value of γ is not known a priori, since it depends on the relative motion between the freshly injected gas and the gas already permeating the galaxy. It can be obtained only from hydrodynamical simulations, that suggest it assumes small values (see Negri et al., this volume). The injection temperature $T_{\rm inj} = T_* + T_{\rm SN}$ takes into account also the contribution of the kinetic energy of SNIa explosions ($T_{\rm SN}$). Finally, $T_{\rm grav}$ quantifies the average energy per unit mass required to extract the gas from the galaxy potential well.

3. Results

We explored how T_*, $T_{\rm inj}$ and $T_{\rm grav}$ depend on (q, k, γ). The results presented here refer to a SIS halo truncated at $15\,R_{\rm e}$. The model families are built starting from a spherical object with luminosity L and effective radius $R_{\rm e}$ that represents the progenitor of a given family. The flattened models belonging to a family are built varying q, while keeping both $(L, R_{\rm e})$ and the DM halo fixed. Being $R_{\rm e}$ dependent on the line-of-sight (l.o.s.) direction, each family consists of two sub-families: a FO and an EO-built one. As a result, $\sigma_{\rm e8}$ and the temperatures depend on the choice of (q, k, γ) and l.o.s. direction. Figure 1 shows T_*, $T_{\rm grav}$ and $T_{\rm inj}$ for two EO-built sub-families. The models reproduce the observed correlation between the mean ISM temperature and $\sigma_{\rm e8}$ (e.g. Boroson et al. 2011), an aspect discussed in Posacki et al. (in preparation). The more the galaxy is flattened, the larger can be the effect of rotation: flatter models allow more rotational support, so that T_* spans wider ranges as a funtion of k (and consequently of γ). Instead, k variations have only mild effects on T_* of rounder systems. Both T_* and $T_{\rm grav}$ slightly decrease with q, and the $T_{\rm inj}$ values are dominated by $T_{\rm SN}$. If $T_{\rm inj} > T_{\rm grav}$ the gas can escape from the galaxy (see Pellegrini 2011 for a detailed discussion), thus smaller galaxies are more likely to host an outflow/wind region than bigger ones, as already observed (e.g. Pellegrini 2012). We found that these temperature trends are almost independent of the specific DM halo profile.

References

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