We study the luminous mass corrected by a non-universal Initial Mass Function (IMF), as a function of the dynamical mass inside the effective radius (r_e) of early-type galaxies (ETGs) to search for differences between these mass. We consider that the luminosity-dynamical mass dependence is due to the presence of dark matter. We perform Monte Carlo (MC) simulations of galaxy samples and compare them to real samples. The main results are: 1) MC simulations show that the distribution of the dynamical vs. luminous mass depends on the mass range where the ETGs are distributed (geometric effect). This dependence is caused by selection effects and intrinsic properties of the ETG. 2) The amount of dark matter inside r_e is not accurately estimated (0.5 ± 0.6). 3) This amount of dark matter is approximately three times lower than the minimum estimate (10%) found in the literature and one order of magnitude lower than the average (30%) of literature estimates. 4) These results must be taken as a general tendency given that the error associated with the determination of dark matter is relatively large.

The sample of ETGs

We use a sample of approximately 90,000 ETGs from the SDSS-DR9 (York et al. 2000) in the g and i filters which is distributed in a redshift interval 0.0024 < z < 0.3500. This sample will be called hereafter: "Virial-Sample". The selection criteria of the Total-SDSS-Sample are similar to those used in Hyde & Bernstein (2009) and Nigoche-Netro et al. (2010). The brightness profile of the galaxy must be well adjusted by a de Vaucouleurs profile. The de Vaucouleurs magnitude of the galaxy must be contained inside the interval 14.5 < m_r, dev < 17.5. These results must be taken as a general tendency given that the error associated with the determination of dark matter is relatively large.

The stellar mass and the virial mass of the ETGs

We use two methods to derive the mass of the ETGs. The first one uses the luminosity of the galaxy, the mass calculated in this way will be named "the stellar mass". The second method makes use of Newtonian dynamics, the mass obtained in this way will be named "the virial mass". In the following sections we shall discuss these methods.

The stellar mass considering an Universal IMF.

(5) Salpeter IMF stellar mass. In this case we make use of an equation for stellar mass-to-light (M/L) ratios obtained from fits of optical near-infrared galaxy data with simple stellar population synthesis models and considering an universal (Salpeter or Kroupa) IMF, (see Nigoche-Netro & Lagos 2010). Each sample of the virial mass in the logarithm range 9.5 - 12.5. For each value of virial mass the mass of the stellar was calculated and the average difference between both masses was found. From Table 1 we find the following:

The virial mass

The second method reconstructs the velocity distribution, and assumes that the galaxies are in virial equilibrium. It provides the following equation:

$$M_{\text{virial}} = -\frac{L^2}{G^2}$$

where $M_{\text{virial}}$ is the virial mass, $L$ the effective radius, and $G$ is the gravitational constant and it is a scale factor that for the case of de Vaucouleurs profiles takes the value of 5.953 (Cappellari et al. 2006).

The amount of dark matter inside ETGs from the SDSS-DR9 is demonstrated that for linear fits to sets of data with a high intrinsic dispersion, the value of the parameter of the linear fits performed to these points depend on the geometric form of the point distribution. This non-uniformity may cause a dependence of the amount of dark matter as an observational biases and arbitrary cuts performed in the observed samples. This effect has been called the geometric effect. The geometric effect also effects the virial mass. The mass calculated using equation 1.

The geometric effect also affects the amount of dark matter (in percentage) shown in Table 1 has been obtained considering the slope and the zero point of the fit for each sample, that is to say, for each sample of Table 1 we consider 100 values of the virial mass (homogeneously distributed in the logarithm range 9.5 -12.5). For each value of virial mass the mass of the stellar was calculated and the average difference between both masses was found. The average amount of dark matter considering only those samples with a universal IMF is 2.7% ± 21.5. This indicates that the estimated amount of dark is not affected by the profile used in the calculation of luminous and virial mass.

The average amount of dark matter considering only those samples with a universal IMF is 2.7% ± 21.5. If we correct for a non universal IMF the amount of dark matter is 2.6% ± 11.5. This indicates that the estimated amount of dark matter is not affected by the profile used in the calculation of luminous and virial mass.

The average amount of dark matter considering only those samples corrected for non universal IMF in large intervals of redshift (total and morphological samples) the amount of dark matter is 2.9% ± 21.5. However, if we correct only the samples restricted to redshift (homogeneous samples) the amount of dark matter is 2.5% ± 21.5. This indicates that the amount of dark matter is similar when we move from a wide to a narrow redshift interval.

**Conclusions**

The previous results indicate that a correction for a non universal IMF reduces the estimated amount of dark matter. However the associated errors are larger than the differences we found, due to which these differences cannot be considered conclusive. Considering this, the the estimates we give in this paper correspond to the average of the for the all the corrected for non universal IMF samples, that is approximately ± 22% of dark matter.

The amount of dark matter inside ETGs found in relevant works in the literature varies between 9% and 50%, reaching an average value of approximately 30% (Cappellari et al. 2001, Cappellari et al. 2006, Thomas et al. 2007, Williams et al. 2009, Barabáši et al. 2011, Thomas et al. 2011, Nigoche-Netro et al. 2011). Our estimate of the amount of dark matter is three times smaller than the estimated value given in the literature and even smaller than the error that we have found. However, as discussed in the literature and also in this paper, the calculated amount of dark matter and that of the literature usually assume that the dark matter is homogeneously distributed and that none of them is similar to the one used in this paper, and also the amount of dark matter is relatively large, our results may only be taken as a general tendency. In a forthcoming work we shall use other methods for the estimate of the amount of dark matter and we shall also analyze the possibility of dark matter on mass, wavelength, environment and redshift.

**References**