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Surface brightness profile reconstruction for elliptical galaxies: the case of Fornax A (NGC 1316)

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Abstract. We present and discuss a method to reconstruct the intrinsic surface brightness profile of elliptical galaxies which allows one to efficiently search for point-like sources and variables, to determine the distribution and the mass of dust, to measure the total luminosity and to infer the mass of galaxies. Our procedure is applied to the test case of the elliptical galaxy NGC 1316=Fornax A for which we determine some of the properties of the dust present within the body of the galaxy.

Key words. Dust – Galaxies: individual (Fornax A / NGC 1316) – Techniques: image processing

1. Introduction

Many elliptical galaxies are known to display dust absorption features that are commonly attributed to their capture of a dwarf galaxy or material stripped from one. Observations of quite a number of dusty elliptical galaxies are now available in public archives: in most cases these observations were made originally either to study the light distribution in the galaxy nucleus, or to search for globular cluster so as to determine their luminosity distributions, or to study the stellar populations, but usually not to study the properties, the nature and the mass of the dust responsible for the observed extinction.

In this paper we present and briefly discuss a method to reconstruct the intrinsic surface brightness profile of elliptical galaxies. Although our principal aim is to study the properties, spatial distribution and mass of dust in elliptical galaxy NGC 1316=Fornax A, our method can successfully be applied to all elliptical galaxies to efficiently search for point-like sources and variables, to measure the total luminosity and to infer the mass of galaxies.

Fornax A represents the ideal case for this kind of study because it displays very

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elaborate swirls of dust extinction distributed over most of its body, indicating a relatively recent capture of large quantities of diffuse material. Deep HST-WFPC2 images obtained in the wide-band B (F450W), V (F606W) and I (F814W), all with the same orientation, are available in the HST archive. In addition, we have complementary ground based observations, which cover the entire galaxy and the surrounding region in the optical (VLT $7' \times 7'$ B, V and I images; Gilmozzi et al. 2003, in preparation)) and in the near infrared (ESO 2.2m $3' \times 3'$ in J, H and K bands; Goudfrooij et al. 2001).

On this basis, our study proceeds along two parallel paths: (a) construct a surface brightness profile to estimate the extinction in each pixel and (b) obtain the color distribution to measure the pixel by pixel reddening and estimate the reddening vectors from color-color diagrams.

In previous works, the surface brightness profile reconstruction of elliptical galaxies based largely on some empirical function as the de Vaucouleurs law, the Hubble law, an exponential profile and an exponential profile plus a possible central gaussian component (see, e.g., Ferrarese et al. 1994 for details). For morphological studies the unsharp masking technique is commonly used that consists in a smoothing (convolution of the scientific image with a two dimensional gaussian function with a suitable HPW) and a subtraction of the convolved image from the original image, thus removing intrinsically smooth components and emphasizing the sharp features. Our method is solely based on an elliptical fit to calculate the isophotal intensities, with no a priori empirical function.

2. Data reduction and analysis

We have retrieved the three band WFPC2 images of Fornax A from the HST archive. The total exposure times are 5000s for F450W , 4000s for F606W and 1860s for F814W filters. Our analysis proceeds according to the following steps: 1. We align the images in all bands, and remove cosmic rays and hot pixels using the CRREJ task in the STSDAS-IRAF package.

2. We define a mask which excludes point sources and the edges of the images.

3. With this mask we have performed a first elliptical fit of the images with 3 free parameters, i.e. center, ellipticity, and position angle, in order to estimate the geometrical parameters of the ellipse.

4. We compute a "trial fit" using the preliminary image mask and the derived ellipse parameters; the isophotal intensities are estimated using the median.

5. Then, we compute the ratio of the observed image to the "trial fit", which defines a first guess of the extinction in each band.

6. We compute a new mask excluding all pixels with appreciable extinction (generally greater than 0.05 magnitudes).

7. With this new mask we compute the "final" fit and we inspect the residuals. If the residuals are appreciably higher than our set tolerance (0.05 magnitudes) then we iterate the fitting procedure, starting from step 3, i.e. estimating a new set of geometrical parameters.

3. Preliminary results

As an example, in Figure 1 we show the comparison between the "observed" (left-hand side) and the "reconstructed" (right-hand side) Planetary Camera (PC) images in the V band as obtained with our method. Note that the fit doesn't cover the semi-minor axis corners of the image, because there are not enough pixels to compute the intensities values. Figure 2 shows a comparison of the obtained map of the V-band extinction, defined as $2.5log(F_{obs}/F_{fit})$ (left-hand side) to the (B-V) color map (right-hand side). We note the overall close resemblance of the features seen in the two maps, or, in other words, that the extinction tracks the color excess rather well. This result, which might be interpreted as evidence for a dusty screen in front of the

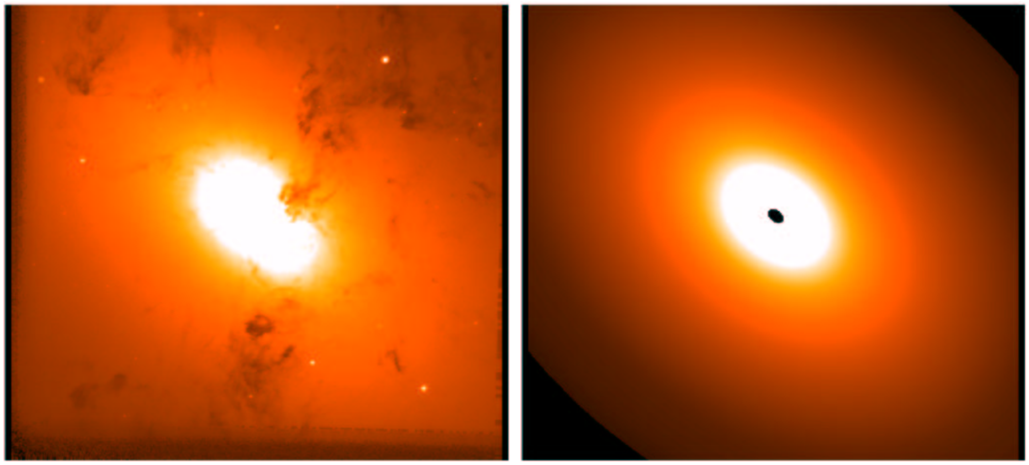

Fig. 1. Left panel: Observed PC image in the V band. Right panel: Reconstructed, intrinsic emission PC image in the V band.

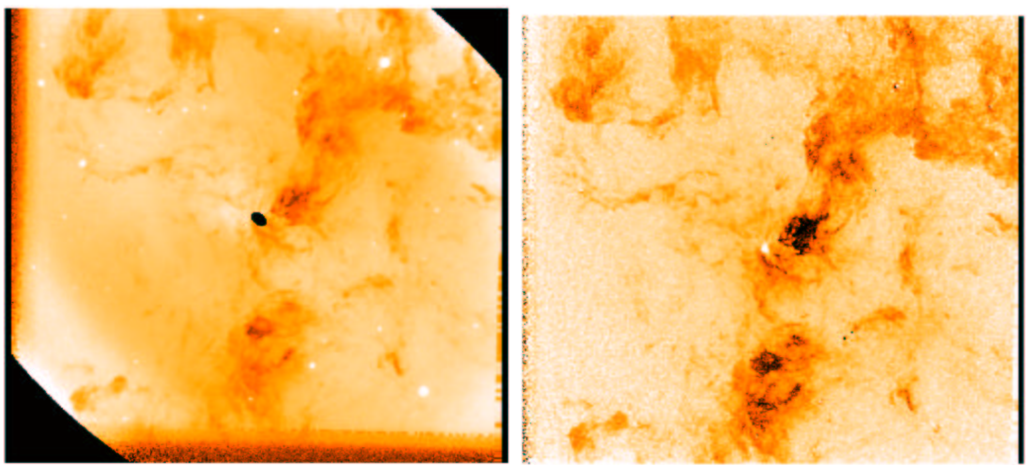

Fig. 2. Left panel: Derived extinction map in the V band. Right panel: Observed (B-V) distribution.

entire galaxy, can more realistically be understood in terms of layers of dust with generally moderate dust optical depths (say, $A_V < 2$) and which are embedded at different depths within the body of the galaxy.

Figure 3 (left-hand side panel) shows a color-magnitude diagram of individual pixels in B and V-band PC images. The various sequences correspond to elliptical annuli, each with a 2 pixel thickness, and selected a different semi-major axis radii. We note that the best-fit straight lines are almost perfectly parallel to each other, indicating both that the characteristics of dust are essentially the same over the entire area covered by the PC chip, and that the spatial distribution of the dust layers is statistically the same at all places in this central part of the galaxy .

The right-hand side panel of Figure 3 shows the color-color diagram for elliptical annuli, each with a 5 pixel thickness, and semi-

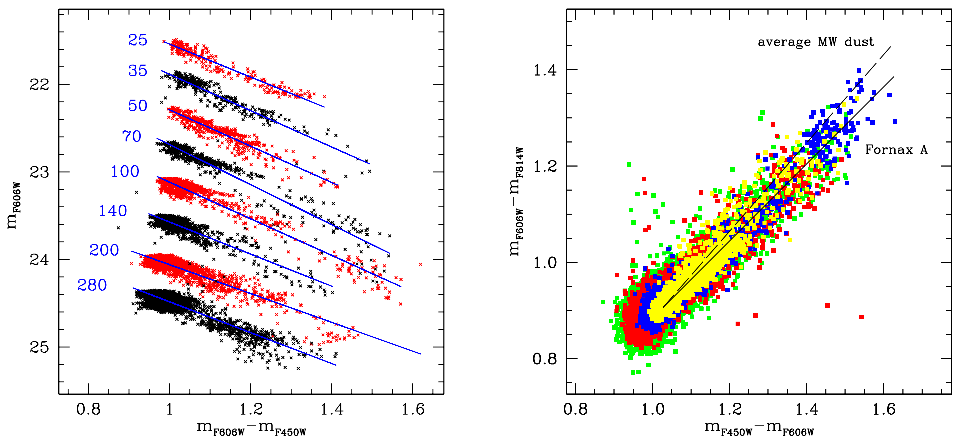

Fig. 3. Left: V-(B-V) diagram for elliptical annuli with different semi-major axis values (in pixels = 0.05″) and thicknesses of 2 pixels. Right: (B-V)*vs* (V-I) diagram for elliptical annuli with semi-major axis values of 50 (yellow), 100 (blue), 200 (red), and 300 (green) pixels and thickness 5 pixels.

major axis values of 50, 100, 200, and 300 pixels. We note here that the reddening vectors for the Fornax A and for the Milky Way are appreciably different. The shallower slope found for Fornax A implies that the grain dimensions of Fornax A dust are somewhat smaller than the typical size of MW grains.

Some of the results of this investigation will presented in Panagia et al (2003), which will outline the method and the first conclusions about the dust distribution in the central region of Fornax A as observed with the HST-WFPC2. The full account of our study of the dust content and properties in Fornax A, which combines the ground based optical and NIR observations of the entire galaxy with the partial area HST coverage, will be given and discussed in Valentini et al. (2003).

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