Analysis of the Spiral Structure in Disc galaxies using the FFT Transform

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1 Introduction

Our own interest in deprojection angles stems from the fact that we started a quantitative study of the properties of spiral structure in near-by disc galaxies, and for this we first need to deproject all our images. Indeed the list of all studies for which it is necessary to know the spatial orientation of the galaxy is too long to include here.

We will study the spiral structure, in disc galaxies, decomposing each image by means of bidimensional Fourier transforms. The first step is to deproject the galaxy image. It is thus necessary to determine the two deprojection angles, namely the position angle (hereafter PA) and the inclination angle (hereafter IA). The PA is the angle between the line of nodes of the projected image and the north, mesured towards the east, while the IA is the angle between the perpendicular to the plane of the galaxy and the line of sight.

Several methods have been proposed so far to obtain these angles. All of them suffer from some kind of systematic errors. The two methods we present can obtain very accurate values of the deprojection angles and also perform well for very low resolutions. This indicates that our methods can be used for very distant galaxies.

2 Deprojection methods

We introduce two methods, based on the Fourier transforms and which are closely linked to the two methods used by Garcia-Gomez and Athanassoula in [10] for HII region distribution in 1991. Let $I(u, \theta)$ be the image of the galaxy written in polar coordenates (r, θ), and $u = ln(r)$. We define the Fourier transform of this image as:

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$$A(p,m) = \int_{u_{min}}^{u_{max}} \int_0^{2\pi} I(u,\theta) e^{i(pu+m\theta)}\, d\theta du \tag{1}$$

In this equation, p corresponds to the radial frequency and m to the azimuthal frequency. Thus the $m = 1$ values correspond to one-armed components, the $m = 2$ values to two-armed components and so on. The values of $u_{min} = ln(r_{min})$ and $u_{max} = \ln(r_{max})$ are set by the inner and outer radius of the part of the image that we will analyze. Fixing the value of m, we can calculate the power associated to this compoment simply as:

$$P_m = |A(p,m)| = \left| \int_{-p_{max}}^{p_{max}} A(p,m) dp \right| \tag{2}$$

The p_{max} value is related to the resolution in Fourier space through $p_{max} = \frac{1}{2\Delta u} = \frac{N-1}{2(u_{max}-u_{min})}$ where N is the number of points used in the Fourier transform in the radial dimension, usually $N = 256$ or 512. In our first method we try to minimize the effect of the spiral structure by minimizing the ratio:

$$BAG1 = \frac{P_1 + P_2 + \cdots + P_6}{P_0 + P_1 + \cdots + P_6}$$

This is equivalent to maximizing the contribution of the axisymmetric component. Since a badly deprojected galaxy will look oval, and thus contribute to the $m = 2$ components as a bar, for our second method we simply minimize the ratio

$$BAG2 = \frac{P_2}{P_0}$$

We tested them using artificially generated, yet realistic, galaxies described by an exponential disk with spiral components

$$I(r\theta) = e^{(-r/\alpha)} + Ae^{(-r_0/\alpha)} e^{-(\frac{r-r_0}{\sigma})^2} cos(p \ln(r) + 2\theta)$$

We obtain very accurate values of the deprojection angles for a variety of situations; from inclinations greater of 80° to face on galaxies. One goal of the test is also the good performance of our methods in the case of very low resolutions, this indicates that our methods can be applied to very distant galaxies for cosmological interest.

3 Deprojection of the galaxies

We applied the two methods to the Frei sample galaxies as follows. First we constructed a grid covering all the possible range of values of PA and IA in increments of 2°. For each pair of angles (PA,IA) we deproject the galaxy image and we compute the Fourier transform (1) with the help of a polar grid. Using Eq. (2) we then calculate the power in each component and then the value of the ratios BAG1 and BAG2. We repeat this for every (PA,IA) pair in the grid. The optimum values are those for which we have a minimum. We illustrate the use of our methods with the help of galaxy NGC4501.

Finally, we perform correlations for comparing with other methods in the literature. Our two methods give mean correlation coefficients with the rest of the methods of 0.89 for BAG1 and 0.9 for BAG2 in the case of PA and of 0.87 and 0.88 for the BAG1 and BAG2 method respectively in the case of IA. This indicates that our methods are wel suited for the derivation of the deprojecton angles. In general, we can conclude that all the methods for deriving the deprojection angles are well suited from a statistical point of view.

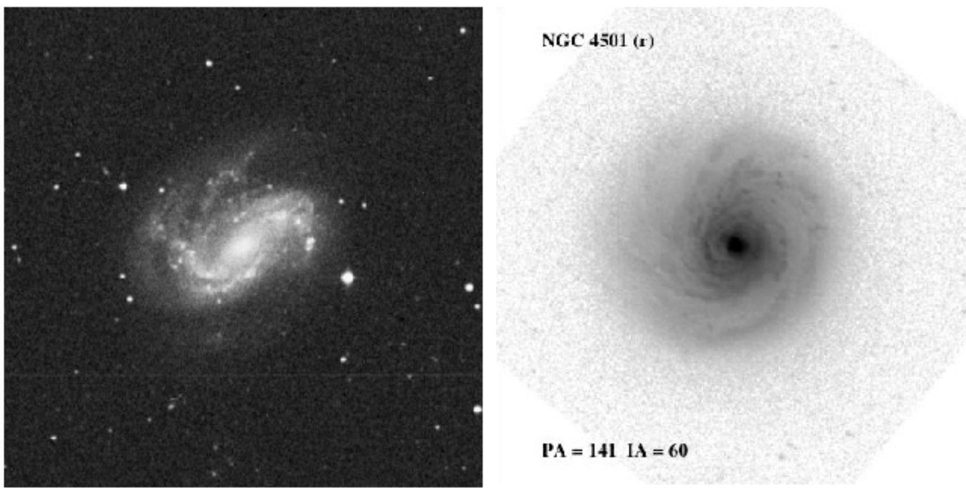

Fig. 1: Image of NGC4501 before and after deprojection

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