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# QUANTITATIVE DESCRIPTION OF GALAXIES' MORPHOLOGY

M. A. Trinidad

Instituto Nacional de Astrofísica, Optica y Electrónica, Tonantzintla, Pue., México;
mtrini@inaoep.mx

RESUMEN

La clasificación de las galaxias depende mucho de la habilidad que tenga el observador, aunque este proceso es subjetivo, aún así lo realizan muchos investigadores. Aquí mostramos un método de clasificación más objetivo, basado en el análisis de Fourier de perfiles azimutales. Nosotros calculamos la amplitud y la fase de los coeficientes de Fourier, ya que ellos dan información acerca de la posición angular de los brazos o estructuras que tengan alguna periodicidad. El método lo aplicamos a galaxias idealizadas, así como a la galaxia espiral NGC 4535, a la galaxia espiral barrada NGC 4593 y a la galaxia irregular NGC 4449.

ABSTRACT

The ability to classify galaxies depends on the observer; this process is subjective, but it is repeatable by different workers. We present an objective method of classification based on the Fourier analysis of azimuthal profiles. We obtain amplitude and phase of the Fourier coefficients, which give us information about the angular position of the arms or structures with some angular periodicity. We apply the method to theoretical spirals as well as to the spiral galaxy NGC 4535, the barred galaxy spiral NGC 4593 and the irregular galaxy NGC 4449.

*Key words:* **GALAXIES: GENERAL — GALAXIES: MORPHOLOGY**

## 1. INTRODUCTION

While the word "galaxy" still tends to conjure images of well defined spirals or giant ellipticals, today's world of galaxies appears to encompass an ever widening variety of possibilities. The most enduring fundamental classification system used today, is essentially one which was introduced some 70 years ago. Hubble (1926, see also Mihalas & Binney 1981), ordered the galaxies on the basis of their optical morphology, resulting in what is today known as the "tuning-fork diagram". While more sophisticated systems have been developed over the years, for example, the concept of the "classification volume" introduced by de Vaucouleurs (1959) or the "luminosity" or "anemic/gas-rich" classifications of van den Bergh (1960, 1976), the basic framework of galaxy classification has not changed significantly. Numerous categories have been introduced which do not attempt to be comprehensive classification schemes, but are rather groupings of galaxies based on specific observational trait. Therefore, it is important to introduce more objective classification scheme, which describes the form of galaxies on a more quantitative basis.

## 2. THE METHOD

The method consists of obtaining azimuthal profiles $I_r(\theta)$ of the images (Puerari & Dottori 1997). The behavior of these profiles is analyzed by mean of the Fourier transform given by

$$F_m(r) = \int_{-\pi}^{\pi} I_r e^{-mi\theta} d\theta \quad , \tag{1}$$

where $m$ is the angular periodicity (it gives the number of arms). The amplitude and phase of the coefficients give information about the angular position where the arms with some angular periodicity $m$ are present. Brightness maxima are found for different values of $m$ and their relative importance is determined.

We are presenting the first part of the research, which consists of transforming the image of rectangular coordinates to polar coordinates and to obtain $I_r(\theta)$. We plot points of brightness maxima of entire galaxy in plane $r - \theta$ ($r$ in pixels). We checked the programs with idealized two-armed spiral galaxies, a galaxy is represented by two vertical lines (the first at 0° and the second at 180°) and other by two horizontal lines (the first line at 90° and the second line at 270°). These galaxies are shown in Figure 1. This figure shows azimuthal profiles for representative radial zones of width one pixel.

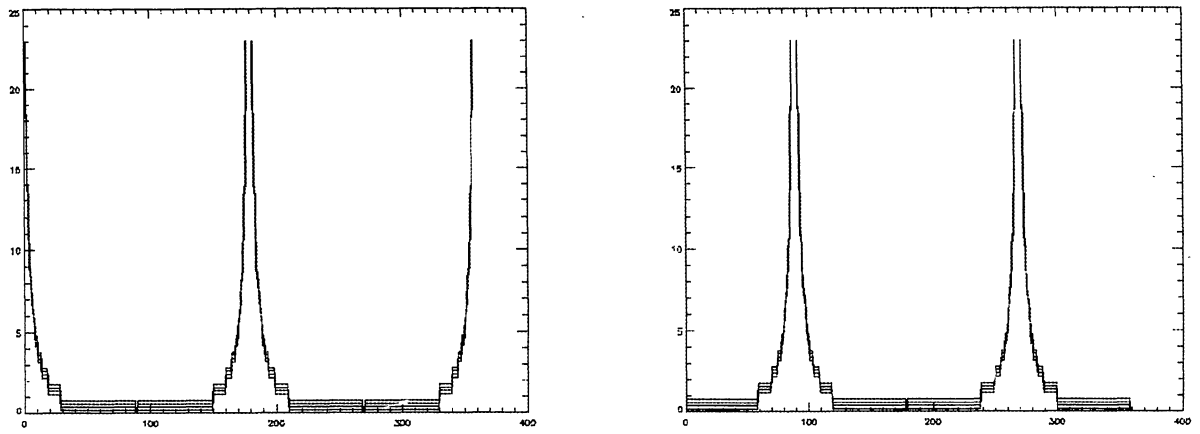

Fig. 1. Structure of idealized two-arm spiral galaxies in the $r-\theta$ plane. Galaxy of two vertical arms (left) and galaxy of two horizontal arms (right). The axis of abscissa is r in pixels and axis of ordinate is $\theta$ in degrees.

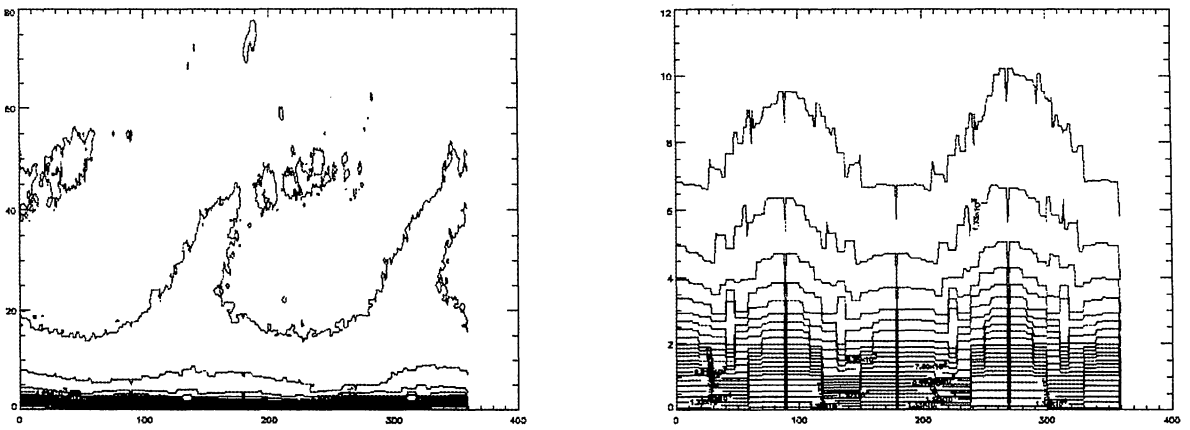

Fig. 2. Structure of spiral galaxy NGC 4535 (left) and barred spiral galaxy NGC 4593 (right). We can observe the length and windind of arms of NGC 4535, and the presence of bar at $\theta = 90°$ of NGC 4593.

## 3. ANALYSIS

The images of galaxies were obtained from digital catalog of images of 113 galaxies (Frei et al. 1996). These galaxies are all nearby, bright, large and well resolved, which were recorded with CCDs at the Palomar Observatory with the 1.5-m telescope and the Lowell Observatory with the 1.1-m telescope. The programs were applied to images without correcting them to face-on orientation. We choose galaxies with a small inclination angle, because large angles are expected to give incorrect results.

NGC 4535 is a Sc galaxy, we compared this galaxy with idealized two-arm galaxy (right Fig. 1). In Figure 2 (left), the lower part represents the nucleus. We can observe the existence of two arms, these arms are not straight, they are winding. NGC 4593 is a SBb galaxy, its structure is shown in Fig. 2 (right). We plot only the most inner part, which represent the bar. We can observe the presence of the bar at $\theta = 90°$ (to compare with Fig. 1 of right). This figure also represents the surface brightness of galaxy, which gives us an idea of dimensions of the bar and intensity of central part of galaxy.

We intend to apply this method to irregular galaxies in different bands. We will search if there are structures such as arms and bars in these galaxies, e.g., arms and bars. The first intention is to analyze the irregular galaxy

NGC 4449, which is a nearby galaxy that has long been considered to be representative of Magellanic irregulars. Because of its high surface brightness and relative proximity, NGC 4449 has been the target of numerous studies in the visual, in the infrared, in the radio, in the H I and the CO line.

In Figure 3 we show the contours of NGC 4449 in the $R$ band (left) and in the $J$ band (4500Å). We have compared this figure with the idealized two-arm galaxies of Fig. 1. This galaxy probably has a bar at $\theta = 145°$, which is not straight and a little arm inside each part of the bar. In the first part ($\theta = 145°$) the little arm has a $Z$-shape and at $\theta = 300°$ has an $S$-shape. If these structures exist, they are very dim. Subsequent analysis in other bands should show if these structures are significant.

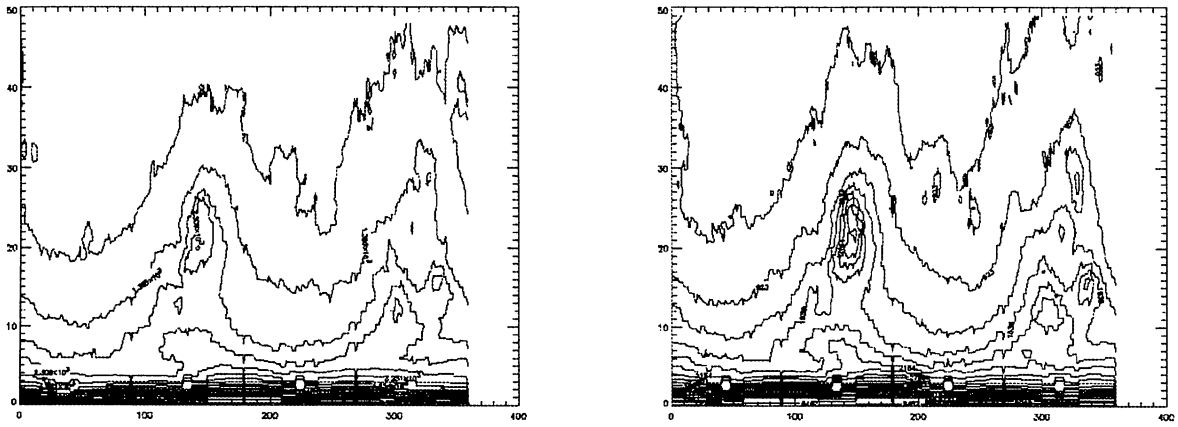

Fig. 3. Structure of irregular galaxy NGC 4449 in the $R$ band (left) and in the $J$ band (right). We are searching structures in this galaxy, analysis in other bands probably say us if exist them.

## 4. CONCLUSIONS

We present a method to determine a quantitative form of the morphology of galaxies. Plots of idealized galaxies are shown, which are used to analyze the behavior of galaxies and check the result when we apply this method to real galaxies.

We reproduce the structure of the three galaxies: NGC 4535, NGC 4593 and NGC 4449, which indicate that the adopted in this work is correct. We will analysis irregular galaxies in different bands and search structures in these galaxies.

## REFERENCES

de Vaucouleurs, G. 1959, In Handbuch der Physik, 53, 275
Frei, Z., Guhathakurta, J., Gunn, J., & Tyson, J. 1996, AJ, 111, 174
Hubble, E. P. 1926, AJ, 71, 231
Mihalas, D., & Binney, J. 1981, Galactic Astronomy, 2nd ed., (San Francisco: Freeman), 288
Puerari, I., & Dottori, H. 1997, ApJ, 474, 73
van den Bergh, S. 1960, AJ, 131, 215
_____. 1976, AJ, 206, 883