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PHYSICAL INTERPRETATION OF ASYMMETRY PARAMETER IN GALAXIES

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RESUMEN

Las galaxias tempranas parecen ser, en general, más simétricas que las galaxias tardías. Recientemente han habido intentos para cuantificar esta tendencía mediante un parámetro de asimetría, y usar este parámetro para determinar el tipo morfológico de galaxias lejanas. En estudios realizados en muestras de galaxias cercanas se encuentra una correlación razonable entre la asimetría y el tipo morfológico. Sin embargo, es importante comprender físicamente esta correlación antes de usarla para clasificar galaxias lejanas. Con este propósito realizamos un análisis multi-banda de la asimetría de galaxias cercanas. Encontramos una dependencia entre el parámetro de asimetría y la longitud de onda que puede ser explicada por un modelo en el cual las estrellas formadas recientemente juegan un papel importante. Los modelos tambien reproducen la correlación del parámetro de asimetría con cantidades globales de las galaxias, como el color y el flujo Hα. De esos análisis, concluimos que el parámetro de asimetría está muy ligado con la tasa de formación estelar actual, y por lo tanto su uso como un indicador morfológico es limitado.

ABSTRACT

Early type galaxies, in general, appear to be more symmetric than late type galaxies. There have been attempts to quantify this trend into an asymmetry parameter, aiming to determine the morphological type of distant galaxies. Studies conducted on samples of nearby galaxies find a fairly reasonable correlation between asymmetry and morphological type of galaxies. However, it is important to understand the correlation physically before the correlation could be used to classify distant galaxies. With this purpose we carried out a multi-band analysis of asymmetry of nearby galaxies. We find a dependence between asymmetry parameter and wavelength which can be explained by a model, in which recently formed stars play an important role. The model also reproduces the correlation of asymmetry parameter with global quantities such as color and Hα flux of galaxies. From these analyses, we conclude that asymmetry parameter is closely tied to the current star formation rate and hence its use as a morphological indicator is limited.

Key Words: **GALAXIES: FUNDAMENTAL PARAMETERS — GALAXIES: INDIVIDUAL (NGC 972)**

1. ASYMMETRY PARAMETER AND CORRELATION WITH GALAXY PARAMETERS

Interest in the study of asymmetry of galaxies is two-fold — (1) to infer merging events with small galaxies, and (2) its possible use as a morphological indicator, especially for distant galaxies. However, there is not yet a rigorous way to define asymmetry for galaxies. Methods used to quantify asymmetry vary from Fourier Transform techniques to simple comparison of intensities in diagonally opposite positions from the center. In this study, we look deeper into the methods of the second kind, taking the definition of Conselice (1997) for illustration. Accordingly, the asymmetry parameter A is defined as

$$A^2 \equiv (1/2)\sum (I_0 - I_{180})^2 / \sum I_0^2, \tag{1}$$

where the sum is over all pixels containing the galaxy. I_0 and I_{180} are the intensities before and after rotating the image about its center by 180°. Accordingly, A lies between 0 and 1, corresponding to completely symmetric and asymmetric cases. The images need to be cleaned of foreground stars before computing A. The value of A is not completely independent of the image resolution, centering and background subtraction. We estimate a nominal error of 0.03, by allowing for variations of the above quantities while computing A.

Conselice (1997) found a fairly good correlation between A and fundamental parameters of galaxies, such as morphological type, $B-V$ color, in a sample of 43 face-on galaxies selected from the database of Frei et al. (1996). The correlation is such that early type galaxies (redder), are more symmetric than the late type galaxies (bluer). Another intriguing result found by Conselice is that the galaxies tend to become more symmetric at longer wavelengths, although the conclusions were based on just two wavelengths (B and R bands). We analyzed the galaxies for which there exists 3-band data (*gri*) in the Frei et al. sample and found the value of A smoothly decreasing with wavelength in the majority of galaxies. We established this trend-all the way up to K-band in NGC 972, using the existing images in $BVRJHK$ bands (Mayya, Ravindranath, & Carrasco 1998).

2. EFFECT OF STAR FORMATION ON ASYMMETRY PARAMETER

We compiled the Hα equivalent width (EW(Hα)) of galaxies in the Frei et al. sample, finding a correlation between A and the EW(Hα), in the sense that galaxies which are more asymmetric have higher EW(Hα). EW(Hα) is strongly dependent on the star formation rate and hence the correlation implies that the asymmetry parameter, as defined above, may be very sensitive to recent star formation in galaxies. The residual map (numerator in the definition for A) strongly ressembles the distribution of H II regions in galaxies, identifying them as contributors to A. Hence we tried to estimate the role of star forming regions on galaxy asymmetry.

Our model is based on the assumption that the asymmetry at any wavelength, to a first order, is proportional to the relative contribution of the younger population to the total luminosity at the same wavelength. Hence we express the asymmetry parameter as, $A^2_\lambda = L^2_\lambda(young)/L^2_\lambda(total) + A^2_\lambda(old)$. The first term is directly related to the ratio, η_λ, of the contribution from the younger population to the total luminosity, while the second term is the asymmetry of the older disk. This formulation ensures that galaxies dominated by recent star forming regions have a value of A close to 1. Since young stars control the first term, it is expected to vary over shorter timescales as compared to the second term, which may be responding to the dynamically induced asymmetries. We parametrized A in terms of (a) η_B, the fractional contribution of the young population in the B-band, (b) spectra of a young population and (c) $A_\lambda(old)$, computing at the same time EW(Hα). L_λ(total) is computed assuming the old disk to have properties of a 10^{10} yr stellar population as modeled by Bruzual & Charlot (1993). The young stellar population is modeled as an instantaneous burst (IB) of constant star formation with a rate decreasing exponentially with e-folding time scale of 10 Myr (ESF10). ESF10 models, viewed at 10 Myr, fairly well reproduce the behavior of the asymmetry parameter with wavelength over the entire $BVRJHK$ bands in NGC 972. The correlation between EW(Hα) and A, including the dispersion in the relation, can be explained by IB models of ages between 3 to 5 Myr. A value of $A_\lambda(old) = 0.05$ (independent of wavelength) can explain the observed dependences. A study involving multi-band observations of a larger sample of galaxies is underway and will be presented in a forthcoming paper.

In conclusion, the asymmetry parameter A defined by Conselice (1997) is strongly dependent on recent star formation, making it unsuited to study the dynamically induced asymmetries in galaxies. Instead A measures the relative contribution of young stars to the total luminosity. This fraction is $\sim 25\%$ in B-band in galaxies having a high value of A. Hence A is a better indicator of star formation history than morphological type.

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