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STATISTICAL PROPERTIES OF H II REGIONS

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RESUMEN. El análisis de los datos de McCall *et al.* para 99 regiones H II en galaxias de diferente metalicidad permiten obtener una "secuencia de edad cero "en el diagrama WHβ vs O/H por el proceso de formación de regiones H II. También permite obtener límites para la masa máxima y la pendiente de la función inicial de masa. Se discuten las observaciones CCD de regiones H II en NGC 2442 tomando en cuenta la influencia de la evolución cuando se analiza una muestra grande de objetos. En ese caso particular el gradiente no se altera substancialmente, pero la metalicidad central sí.

ABSTRACT. The analysis of McCall *et al.* (1985) data for 99 H II regions in galaxies of different metallicities allow to obtain a Zero Age Sequence (ZAS) in the WHβ vs O/H diagram, for the process of H II regions formation as well as limits for the Upper Mass Limit (μ) and and slope (x) of the IMF, CCD observations H II regions in NGC 2442 are discussed taking into account the influence of evolution when a large sample of objects are analized. For that particular case the gradient is not substantially altered, while the central metallicity is.

Key words: **MASS FUNCTION — NEBULAE–H II REGIONS — STARS–FORMATION**

I. INTRODUCTION

Traditionally the study of metallicity gradient in galaxies has been carried out by observing a few giants or super-giant H II regions within a galaxy at different distances from the nucleus. As it is well known H II regions are objects of ephemeral life, and their properties change with the time as the massive stars evolve. What are we really measuring when a large number of H II regions within a galaxy are observed? Furthermore, is it possible to distinguish the effects of evolution within a large sample of H II regions even when they belong to different galaxies? In this paper we analize existing spectroscopical data on G and SG H II regions in galaxies of different metallicity and we show that it is possible to determine a ZAS for these objects as a function of the metallicity in the WHβ vs ([O II] + [O III])/Hβ diagram and that the μ and slope (x) of the IMF can be limited. In § III we present narrow band CCD photometry of H II regions in NGC 2997 which are compared with previously existing spectrophotometry at the Hβ and [O III]5007A emission lines and finally we discuss data of the same type for H II regions in the spiral galaxy NGC 2442.

II. PARAMETERS FOR GIANTS AND SUPERGIANTS H II REGIONS

The lowest number of parameters necessary to characterize a G or SG H II regions is matter of controversy (Terlevich and Melnick 1985; Mc Call *et al.* 1985; Dottori 1986). By analysing the McCall *et al.* (1985) spectroscopic observations for 99 regions in galaxies with different metallicities, we distinguish a well defined upper limit for the relation ([O II] + [O III])/Hβ vs WHβ which sets a relation WHβ vs metallicity of the form,

$$WH\beta = 0.99 \times ([OII] + [OIII])/H\beta + 1.85$$

The relation can be considered as the ZAS for the process of formation of G and SG H II regions and shows the influence of the metallicity on the process of star formation. The comparison of this result with our models (Copetti *et al.* 1986) for the evolution of [O III]/Hβ and WHβ shows that the μ of the IMF for H II regions of high metallicity may not exceed 20 to 25 $M_\odot$ with slope $x \geq 2.5$ (lower slopes would produce WHβ much higher than the observed ones). On the other hand the H II regions with the lowest metallicity require $\mu >$ 30 to 40 $M_\odot$ with slope $x \leq 2.0$. The influence of metallicity on the process of star formation was previously discussed by other authors in the last years (Shield and Tinsley 1976; Talent 1980; Terlevich 1985; Viallefond 1985). Our conclusion coincides qualitatively with that of Viallefond (1985), but our models allow us to set limits on both μ and x through the analysis of WHβ and ([O II] + [O III])/Hβ, provided we are dealing with G and SG H II regions and considering that the ionized association is formed in a burst. The dispersion of the H II regions in that diagram is mainly due to the influence of evolution. The ageing of an H II region takes place at constant metallicity and deplete continuously WHβ (Dottori 1981, Copetti *et al.* 1986). Figure 1 shows the diagram metallicity vs. WHβ with the ZAS as deduced from MRS data, on which curves of constant age, obtained from the data of Copetti *et al.* (1986) has been plotted. This data allow us to conclude that G and SG H II regions form a two-parameter family, characterized by the metallicity and the state of evolution (or age).

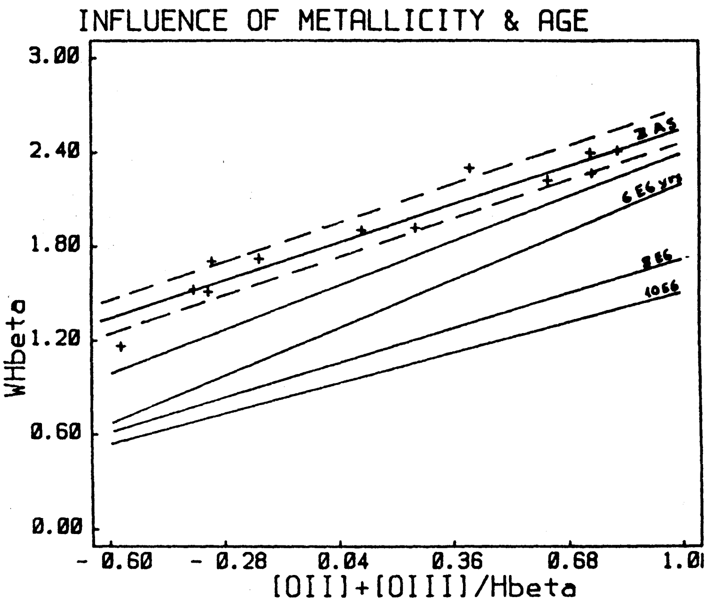


Fig. 1. ZAS obtained from the ([O II] + [O III])/Hβ vs WHβ relation of McCall *et al.* + are the regions which determine the ZAS, with mean deviation given by the dashed lines. The full lines label the time evolution of WHβ.

III. CCD OBSERVATIONS OF H II REGIONS IN NGC 2997 AND NGC 2442

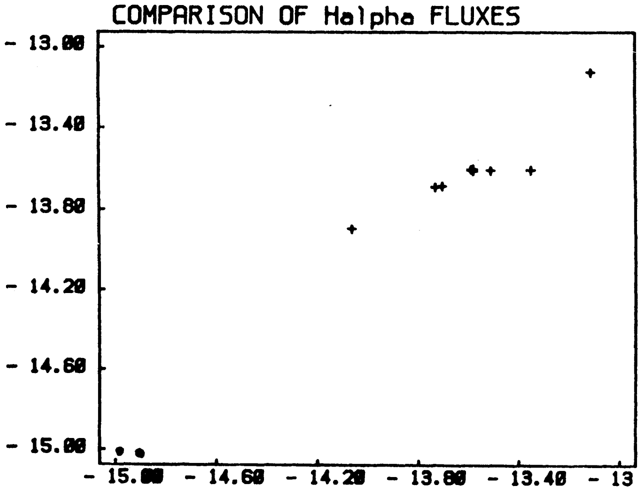
III.1 Observations and Reductions

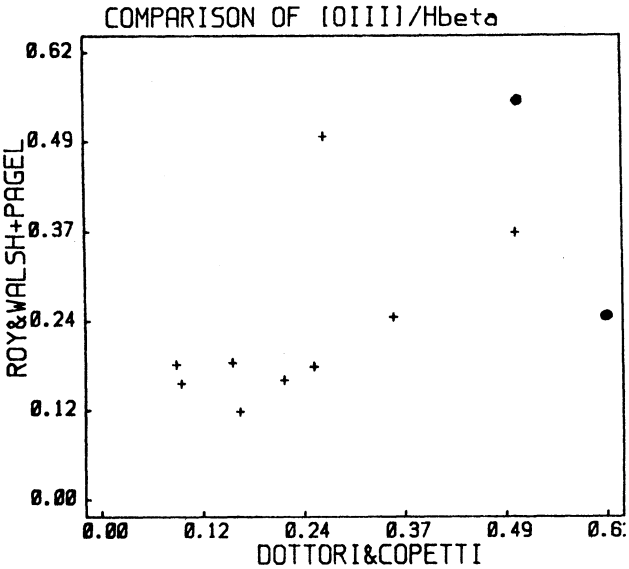
The observations were carried out with the *UV* extended TI CCD CTIO attached to the 90.0-cm Boller and Chivens telescope. The flat-fielding was performed with the standard procedure currently used at CTIO. The set of filters of the CTIO has been complemented with our own in order to take into account the redshift of the galaxies. The observations were calibrated spectrophotometrically by means of Stone and Baldwin's (1983) spectrophotometric standards. The typical integration time for a frame was of 3000 to 3600 seconds. Frames centered on the Hα, Hβ, [O III]λ5007 A and [O II]λ 3727 A as well as 4 nearby continua have been observed in order to obtain line emission.

The reductions were performed at the ESO headquarters in Garching, West Germany with the MIDAS facilities using standard procedures for cleaning cosmic rays and bad pixels, for reducing outside the atmosphere, for obtaining pure line emission and finally for calibrating line and continuum frames absolutely. Once identified, the H II regions have been measured with circular diaphragms.

III.2. Comparison with other Observers

NGC 2997 has been observed by Pagel *et al.* (1981) and by Roy and Walsh (1987). We have two and nine objects in common respectively. Figures 2 and 3 show the comparison for the absolute fluxes and the ratio [O III]/Hβ respectively. Pagel *et al.* quote for their regions specific intensity obtained from the first increment of their spectra instead of fluxes. In order to obtain corresponding values we have integrated both regions with the smallest diaphragm allowed by the MIDAS system (26 pixels). The values given by Pagel *et al.* for the Hβ specific intensities of their regions 2 and 3 are -15.03 and -15.00 erg s^{-1} cm^{-2} arcsec^{-1}, while our values are -14.92 and -14.99. The comparison shows that the integrated fluxes obtained by CCD imagery are highly reliable.





Figs.2 and 3. Comparison of our observations with Roy and Walsh regions A, B, C, D, E, G, I, J and K (+) and Pagel *et al.* regions 2 and 3 (•).

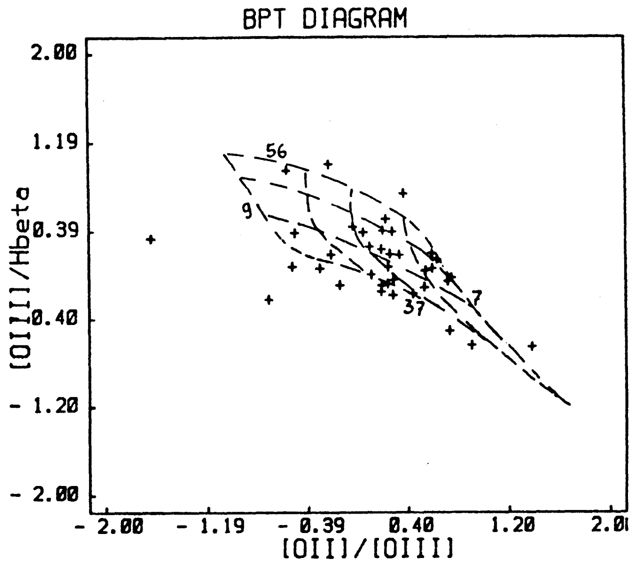


Fig.4: BPT diagram for the sample of H II regions. The curves represent Evans and Dopita models.

IV. NGC 2442

In Figure 4 we show the BPT (Baldwin *et al.* 1981) diagram for our data of NGC 2442, on which models of Evans and Dopita (1986) have been superposed. We see that our observations fit quite well within the zone corresponding to the normal photoionized H II regions. Two regions deserve attention since they present high T_{eff} of the ionizing source. By comparison with other nearby objects these two regions do show a much weaker optical continuum, that lead to think that they are really very hot H II regions. The material is being analized and further discussion will be made in a forthcoming paper. In Figure 5 we show the distribution of [O III]/Hβ vs galactrocentric distance. By dividing the whole sample in 6 bins of approximately one kpc, we obtain a gradient of metallicity of -0.05 dex/kpc with an intercept of [O III]/Hβ = -0.15. The mean dispersion per bin of the points is 0.3, comparable to that quoted by Zaritzky (1989) for M33, when the whole set of observed H II regions in the galaxy is taken into account. Our result on the gradient of metallicity of NGC 2442 together with those of Zaritzky *et al.* (1989) for M33 lead to the conclusion that the observeddispersion is a real one and that it appears from the effect of evolution on the physical properties of the H II regions, which is strongly noticeable when a large set of H II regions are observed. By taking taking into account those H II regions in our sample which appear to be the least evolved we obtain a gradient of metallicity of -0.06 dex/kpc, rather similar to that for the whole sample, but with the intercept located at [O III]/Hβ = 0.22, a value substantially higher that the previous one, which leads to a higher metallicity on the central part of the galaxy.

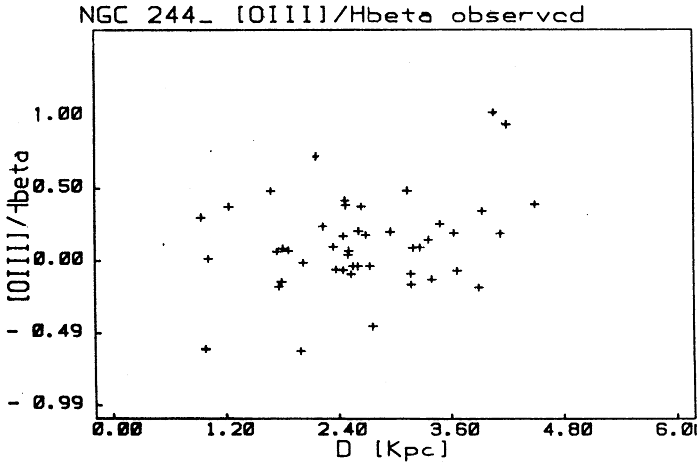


Fig. 5. Distribution of H II regions in the excitation diagram.

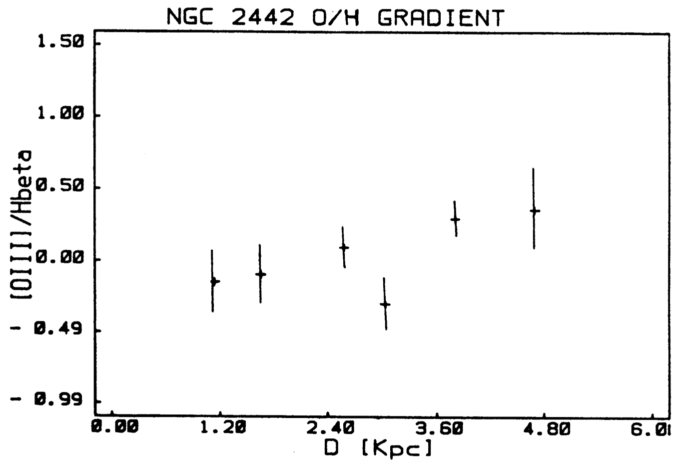


Fig. 6. Gradient of metallicity. The sample was divided in bins of about 1 kpc.

V. CONCLUSIONS

McCall *et al.* data (1985) reveal that G and SG H II regions form a two parameter family, being the free parameters the metallicity and the age. CCD imagery of NGC 2442 shows that the effect of evolution is present when a large number of H II regions is analized. We obtain for that galaxy a gradient of -0.05 dex/kpc with an intercept [O III]/Hβ $= -0.15$ which change to -0.06 dex/kpc and an intercept [O III]/Hβ $= 0.22$ when only the unevolved regions are taken into account. The comparison of the data for NGC 2997 with previous one shows that observations with narrow band filters and CCD with a relatively small telescope is suitable for this type of work.

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