Revista Mexicana de Astronomía y Astrofísica, **27**, 195-198 (1993)

METAL RICH HII REGIONS: THE SIZE OF THE IONIZING CLUSTER

E. Terlevich, R. Terlevich
Royal Greenwich Observatory, U. K.

and

J. Franco
Instituto de Astronomía-UNAM, México

RESUMEN

Los cúmulos ionizantes en regiones HII de alta metalicidad parecen ser más pequeños que aquéllos en regiones de baja metalicidad. Proponemos aquí una posible explicación para este fenómeno.

ABSTRACT

The sizes of the ionizing clusters in metal-rich HII regions seem to be smaller than their low metallicity counterparts. The possible origin for this behavior is discussed.

Key words: **GALAXIES: ISM — GALAXIES: STELLAR CONTENT — H II REGIONS**

1. INTRODUCTION

Observations of giant HII regions, which are easily seen on the discs of nearly face-on spiral galaxies, constitute one of the most useful tools providing information about the chemical composition of the interstellar medium in external galaxies. Constraints for chemical evolution models are derived from abundance variations of different elements, and the detailed study of element ratios provides tests on nucleosynthesis and stellar evolution theories.

It is known that HII regions of low excitation (as measured by the ratio [OIII]$\lambda\lambda$ 4959,5007/H_β) have relatively high metal abundance. Empirical methods, based on strong emission line intensities and calibrated with theoretical models (Pagel *et al.* 1979; Alloin *et al.* 1979; Edmunds & Pagel 1984; McCall *et al.* 1985; Dopita & Evans 1986; McGaugh 1991), have been devised to determine the metal abundance of low excitation regions, for which the temperature sensitive lines required for reliable abundance determination ([OIII] λ 4363 Å, [NII] λ 5755 Å) are either very weak or absent. These are the metal rich HII regions which are therefore much more difficult to study.

2. METALLICITY TRACERS AND MODELS FOR HII REGIONS

An improved method recently developed (see Vílchez & Pagel 1988 and references therein) requires an extensive spectral coverage (λ 3727-9532 Å) and uses simultaneous fitting of the empirical abundance parameter, R_{23} (Pagel *et al.* 1979), along with a parameter characterising the hardness of the ionizing spectrum, η', to an appropriate grid of theoretical models (e.g., Stasińska 1982). This method has been successfully applied to determine the physical parameters of HII regions in M33 (Díaz *et al.* 1987; Vílchez *et al.* 1988), and was extended to low excitation regions in M51 (Díaz *et al.* 1991). One of the main conclusions regarding high-Z HII regions is that the deduced T_{eff} and ages of coeval ionizing clusters are incompatible with the small observed H_β equivalent widths. A possible solution to this apparent inconsistency is that the metal rich HII regions are powered by a collection of clusters with different ages. The young ones provide the UV ionizing radiation, whereas the old ones provide most of the optical continuum.

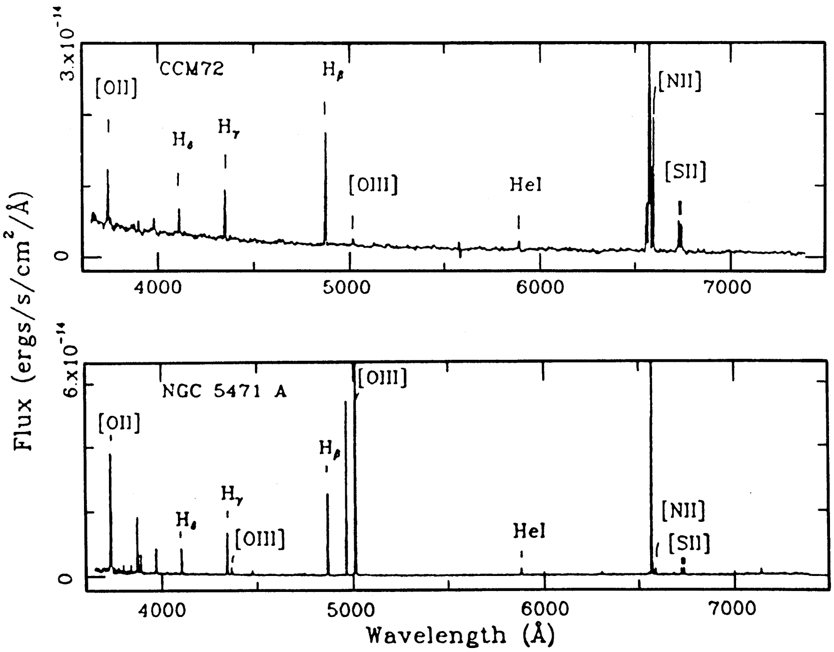

Fig. 1.— Spectra of NGC 5471 A in M101 (high excitation), and CCM 72 in M51 (low excitation). From Díaz *et al.* 1990.

More recently, García Vargas & Díaz (1993) performed evolutionary models for high metallicity giant extragalactic HII regions, and concluded that if the ionizing clusters are relatively massive (M> $0.6 \times 10^3\,M_\odot$) the required IMF parameters have to be different from those derived for the Milky Way and external galaxies. Alternatively, no changes in the "standard form" of the IMF would be required if the ionization is again produced by a collection of small clusters. This second alternative is more appealing because it has the additional advantage of explaining the low equivalent widths of H_β that are normally observed; sub-clustering can drastically reduce the production of massive stars. Thus, ionization by small stellar clusters provides a simple and natural explanation to the empirical fact that high metallicity HII regions have both low excitation and low equivalent width of H_β. In addition, given the abundance gradients known to exist along the disc of spiral galaxies, this translates into a radial gradient in excitation for the HII region population.

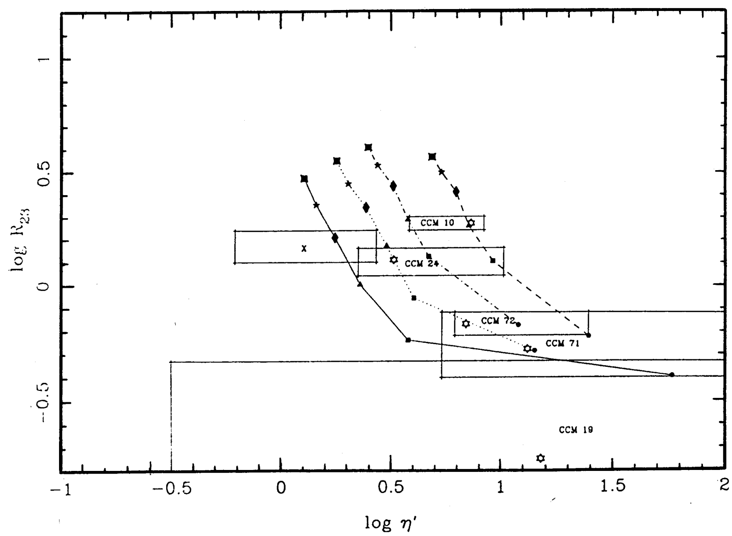

Fig. 2.— The R_{23} vs. $\eta\prime$ diagram for HII regions in M51. Boxes represent error bars, and stars represent the best fitting model. From Díaz *et al.* 1991.

3. THEORETICAL JUSTIFICATION

A simple physical explanation of these trends comes from a combination of the behaviour of dust opacity with heavy element abundances and the effects of tidal shear. Both seem to conspire to create smaller molecular cloud units in the inner, and more metal-rich, parts of spirals disks. First, the tidal radius for self-gravitating clouds is reduced as one moves towards the inner parts of the disk. Thus, star forming clouds tend to be smaller and denser at the more chemically evolved inner regions of the disk. Secondly, the transformation of diffuse clouds into the molecular phase requires a drastic reduction of the molecular photodissociation rate. The column density for high-opacity from dust grains, $N_{crit} \sim 5 \times 10^{20}$ $Z_{\odot}/Z$ cm^{-2} (Franco & Cox 1986), is the minimum value required to shield the inner cores of clouds from the external UV radiation and, hence, to allow the proliferation of different molecular species. Given the galaxian metallicity gradient, the value of N_{crit} decreases at the innermost parts of the disk and even small clouds can become molecular. Thus, the build-up of large cloud complexes from small molecular cloud units is more easily achieved in the inner disk than in the outer parts. Such a process also implies that a a large number of small stellar clusters may be preferentially created at the places with higher metallicities.

4. AN EXAMPLE

A recent study of the properties of large-scale propagating star formation (Palouš, Tenorio-Tagle & Franco 1993) illustrates these effects. The agglomeration of gas in shells of expanding multi-supernova remnants leads to new star forming centres and the process propagates through the whole disk. Given the rotation curve and the galactic radial gradients in surface mass density and heavy element abundances, the star forming cycle display different properties as a function of galactocentric distance.

First, the sheared disk defines the time scales for the cycle: the evolution of the resulting multi-supernova remnants proceeds faster in the inner disk than in the outer regions. As a result, the mass collected by the expanding shells decreases with galactocentric radius and the mass of the resulting clouds follow the same trend. Second, the critical column density value ($N_{crit} = 5 \times 10^{20}\, Z_{\odot}/Z\, \mathrm{cm}^{-2}$) is reached faster in the inner regions of the disk, and a larger fraction of small molecular clouds is achieved at these same regions. As a consequence of these two effects, the average mass of molecular clouds becomes a function of galactocentric distance: the most massive clouds ($M > 10^6\, M_{\odot}$) are formed in the outer parts, while low mass clouds ($M \sim 3 \times 10^5\, M_{\odot}$) tend to be clumped in the inner regions. This result is shown in Figure 3.

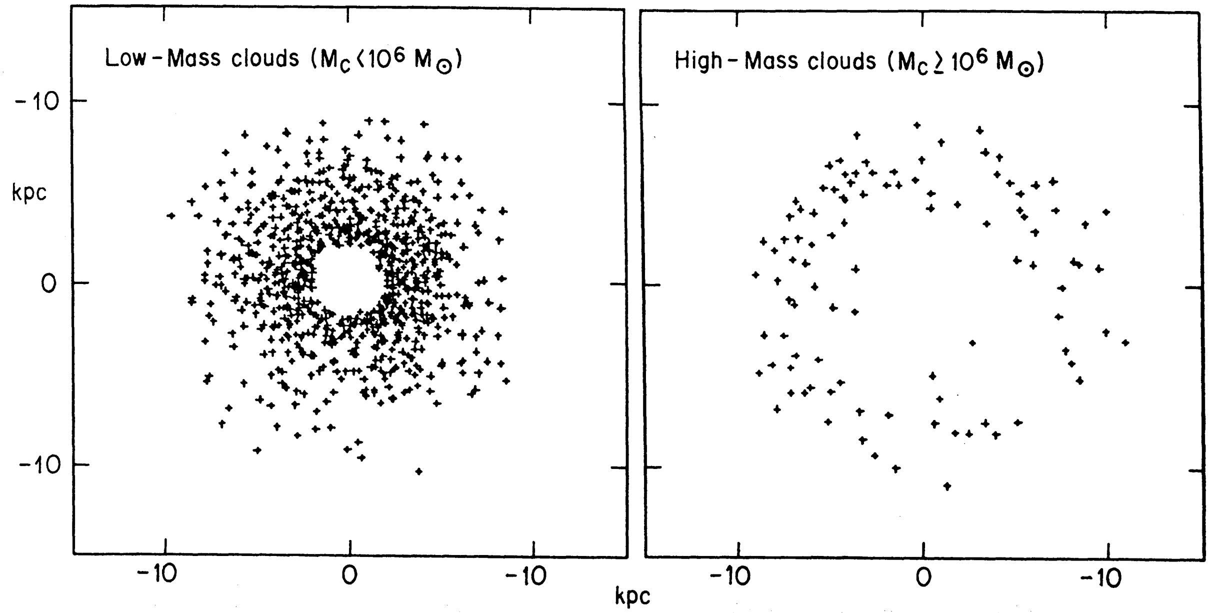

Fig. 3.— Radial distribution of model molecular clouds, separated according to their masses. Adapted from Palouš *et al.* 1993.

Acknowledgements: JF acknowledges partial support from DGAPA-UNAM through the grant IN103991. ET and RT acknowledge the kind hospitality of the Instituto de Astronomía-UNAM during the realization of this work.

REFERENCES

Alloin, D., Collin-Souffrin, S., Joly, M. & Vigroux, R. 1979, A&A, 78, 200
Díaz, A.I., Terlevich, E., Pagel, B., Vílchez, J.M. & Edmunds, M.G. 1987, MNRAS, 226, 19
Díaz, A.I., Terlevich, E., Pagel, B., Vílchez, J. M. & Edmunds, M.G. 1990, RMAA, 21, 223
Díaz, A.I., Terlevich, E., Vílchez, J.M., Pagel, B. & Edmunds, M.G. 1991, MNRAS, 253, 245
Dopita, M.A. & Evans, I.N. 1986, ApJ, 307, 431
Edmunds, M.G. & Pagel, B. 1984, MNRAS, 211, 107
Franco, J. & Cox, D.P. 1986, PASP, 98, 1076
García Vargas, M.L. & Díaz , A.I. 1993, ApJ, submitted
McCall, M.L., Rybski, P.M. & Shields, G.A. 1985, ApJS, 57, 1
McGaugh, S.S. 1991, ApJ, 380, 140
Pagel, B., Edmunds, M.G., Blackwell, D.E., Chun, M.S. & Smith, G. 1979, MNRAS, 189, 95
Palouš, J., Tenorio-Tagle, G. & Franco, J. 1993, MNRAS, submitted
Stasińska, G. 1982, A&A, 48, 299
Vílchez, J.M. & Pagel, B. 1988, MNRAS, 231, 257
Vílchez, J.M., Pagel, B., Díaz , A.I., Terlevich, E. & Edmunds, M.G. 1988, MNRAS, 235, 633

José Franco: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México.
Elena Terlevich and Roberto Terlevich: Royal Greenwich Observatory, Madingley Road, Cambridge CB3 0EZ, U.K.