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DENSITY BOUNDED H II REGIONS: IONIZATION OF THE DIFFUSE INTERSTELLAR AND INTERGALACTIC MEDIA

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RESUMEN

Presentamos un estudio del gas difuso ionizado (DIG) en una muestra de galaxias espirales cercanas, tras haber construi do el catálogo de regiones H II para cada una de ellas. La emisión en Hα del gas difuso ionizado supone entre un 25% y un 60% de la total en Hα de las galaxias y es necesario un flujo muy alto de fotones ionizantes para mantener este gas ionizado. Proponemos que los fotones Lyman que escapan de las regiones H II más luminosas de una galaxia son la principal fuente de ionización del DIG; son más que suficientes para ionizar el DIG en el modelo en el que las regiones H II con luminosidad en Hα mayor que $L_{Str} = 10^{38.6}$ erg s^{-1}son limitadas en densidad. Mostramos además que este modelo permite cuantificar la ionización que ha sido observada en las superficies de las nubes de alta velocidad que caen sobre nuestra Galaxia y predice la ionización del medio intergaláctico.

ABSTRACT

We present a study of the diffuse ionized gas (DIG) for a sample of nearby spiral galaxies using Hα images, after constructing their H II region catalogues. The integrated Hα emission of the DIG accounts for between 25% to 60% of the total Hα of the galaxy and a high ionizing photon flux is necessary to keep this gas ionized. We suggest that Lyman photons leaking from the most luminous H II regions are the prime source of the ionization of the DIG; they are more than enough to ionize the measured DIG in the model in which H II regions with luminosity in Hα greater than $L_{Str} = 10^{38.6}$ erg s^{-1}are density bounded. We go on to show that this model can quantify the ionization observed in the skins of the high velocity clouds well above the plane of our Galaxy and predicts the ionization of the intergalactic medium.

Key Words: **GALAXIES: ISM — GALAXIES: SPIRAL — H II REGIONS — INTERGALACTIC MEDIUM**

1. OBSERVATIONS AND DATA ANALYSIS.

From complete photometric subarcsecond images of six selected spirals from the TAURUS camera on the 4.2-m WHT (La Palma) we obtained flux calibrated catalogues of their H II regions ($\sim$ 1000 regions/galaxy) and spatially resolved measurements of the diffuse Hα emission over their full discs. For a lower limit to the integrated diffuse emission, we assumed no diffuse emission above an H II region; for an upper limit we filled each projected H II region area with the flux level measured just outside the region. The ratio between the DIG luminosity and the total Hα luminosity is nearly constant with galactocentric distance; the DIG accounts for $30\% - 60\%$ of the total Hα emission. A close geometrical association of the diffuse Hα with, above all, the most luminous H II regions is evident in all the galaxies of the sample. The total diffuse Hα emission is of order 10^{41} erg s^{-1}and a high ionization rate is necessary to keep the gas ionized; its mean value for the galaxies analyzed is $\sim 3 \times 10^7$ ionizations s^{-1}cm^{-2}.

2. SOURCES OF IONIZATION: DENSITY BOUNDED H II REGIONS?

There is growing evidence (McCall, Rybski, & Shields 1985; Oey & Kennicutt 1998; Rozas et al. 1998; Beckman et al. 1999) that the most luminous H II regions are density bounded. For Hα luminosities $L_{H\alpha} > L_{Str} = 10^{38.6}$ erg s^{-1} an increasing fraction of Lyc photons leak out. These are available to ionize the DIG. A simple model based on this hypothesis allows us to compute this flux given the complete luminosity function (LF) in Hα for a galaxy (Rozas, Beckman, & Knapen 1996; Rozas et al. 1999; Zurita, Rozas, & Beckman 2000). Comparison of this calculation with the measured diffuse emission for our sample of galaxies shows that a significant fraction of this Lyc flux escapes completely from a galaxy.

3. THE IONIZATION OF THE IGM: BARYONIC DARK MATTER?

A plausible explanation for the discrepancy between "Big Bang" predictions of the cosmic baryon density ($> 0.03\,\Omega_{\rm o}$) and observations ($< 0.01\,\Omega_{\rm o}$) is a fully ionized intergalactic medium (IGM), consistent with absence of strong Lyman-α, absorption (e.g., Gunn & Peterson 1965; Persic & Saluci 1992). Simplifying with a constant IGM density and with a galaxy as a point source of Lyc photons whose escaping flux of ionizing photons is 5.0×10^{52} Lyc phot s^{-1} (a representative value for our sample of galaxies) we conclude that the ionization equilibrium of the IGM in our model implies that the escaping flux is enough to ionize virtually all the gas in the IGM. In fact, even assuming an uniform baryon density of $0.1\,\Omega_{\rm o}$, more than 80% of the hydrogen would be ionized up to a distance of 50 Mpc from a typical galaxy.

Blitz et al. (1999) have listed high velocity clouds in the IGM approaching the Galaxy. In some of these, Hα emission has been found at the velocity of the neutral cloud, e.g., for the Magellanic Stream. We have used the observational estimates of the emission measure (EM) to check if the required ionizing field is comparable to that predicted on the basis of density bounding in the most luminous regions (Zurita, Beckman, & Rozas 1999).

TABLE 1

Cloud	R (kpc)	EM(pc cm^{-6})	EM(pc cm^{-6})$_{model}$
MS IIA	50–60	1.0	1.3–0.9
MS III	30–60	0.5	3.4–0.9
MS IVB	30–60	0.5	3.4–0.9

Table 1 shows the measured surface brightness of the outer skins of the clouds of the Magellanic Stream at distances (R) from the Galactic plane (Weiner & Williams 1996), compared with the predictions of our model (last column).

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