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A SEARCH FOR HIGH VELOCITY GAS IN REGIONS OF ACTIVE STAR FORMATION

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RESUMEN

Hemos realizado una búsqueda de gas a alta velocidad en una muestra de Regiones H II Gigantes Extragalácticas y Galaxias H II. Solo se ha detectado este fenómeno en un número limitado de objetos, apareciendo éste espacialmente localizado. El objeto mś peculiar de la muestra es NGC 2363, donde la emisión detectada en la zona nuclear es asimétrica.

ABSTRACT

Long slit spectra at high S/N of a sample of Giant Extragalactic H II Regions and H II galaxies, show evidence for very high velocity ionized gas. This kind of phenomenon appears to be localized in a limited area within the observed regions. The most peculiar object in the sample is NGC 2363, where the profiles of the emission lines detected in the nuclear zone suggest non–symmetrical motions.

Key words: **H II REGIONS – ISM: KINEMATICS AND DYNAMICS**

1. INTRODUCTION

Giant Extragalactic H II Regions (GEHR) and H II galaxies are ideal places to detect the presence of high velocity gas (HVG), originating from different sources that include the OB clusters that ionize the gas, the Wolf-Rayet stars present in the complex, and supernovae, the end points of massive star evolution (Chu & Kennicutt 1986; Yang, Skillman, & Sramek 1994). Clusters of OB stars can produce multiple shells with expansion velocities of hundreds of km s^{-1} within these objects. Wolf-Rayet stars can transfer 10^{51} ergs of energy into the interstellar medium during their lifetimes, the same order of magnitude of energy released by a supernova.

The combined effect of supernovae and stellar winds from massive stars can produce high velocity gas and flows at galactic scales. For example, it has been suggested (Campbell 1992) that the gravitational potential well of H II galaxies cannot retain the gas escaping the object via galactic winds generated either by supernovae explosions or stellar winds, introducing the possibility that the low chemical abundances of these objects may be the result of metals being lost to the intergalactic medium. It is also possible that the shock waves associated with the HVG could have an effect on the emission spectra of the objects and, by extension, on the estimated chemical abundances (Peimbert, Sarmiento, & Fierro 1991). The detection of HVG could then be crucial for the understanding of the chemical evolution of these objects.

With this aim, we have conducted in recent years a program to search for these phenomena within emission line complexes. We looked for evidence of weak, low surface brightness emission as compared to the main emission of the objects. That is, we searched for broad wings in the emission lines, in excess of the expected Gaussian profile. Our work began on the GEHRs of M101 (Castañeda, Vílchez, & Copetti 1990a, 1990b) and we have extended our sample to include a larger number of giant H II regions and several H II galaxies. We have adopted the following definition for HVG: assuming that for a typical H II region, the FWHM is ≈ 50 km s^{-1} and that for a Gaussian profile the FW at 5 % of peak surface brightness is ≈ 100 km s^{-1}, we can safely define HVG as FW (5 %) ≥ 200 km s^{-1}. To compare with results in the literature, we will also use the FWZI (Full Width at Zero Intensity).

2. OBSERVATIONS

To detect high velocity gas at low surface brightness we have selected a telescope-detector combination of high quantum efficiency, together with long integration times. High quantum efficiency detectors, large telescopes and high spectral resolution spectrographs make it possible to detect subtle effects in the kinematics of the gas of star formation regions. With long slit spectroscopy we can establish the spatial extension of the phenomena, and estimate the kinetic energy of the gas.

All the observations of this program were made with the IDS Cassegrain spectrograph of the 2.5-m Isaac Newton Telescope, using the 500 mm camera. We used the 1200R grating, giving us a dispersion of 0.35 Å per pixel, with a spatial sampling of 0.3″ per pixel. The grating was centered on the Hα line. The configuration of the system has been optimized to provide the maximum quantum efficiency and to detect low emission gas. Observations prior to 1992 were made with a GEC CCD (500 $\times$ 400 pixels) detector, and the remaining data were obtained with an EEV CCD. The slit was centered at the brightest knot of the object, and oriented according to its preferred symmetry direction. After the standard corrections of bias and flat-field, the 2D spectra were examined to search for areas with extended wings or asymmetries in the isocontour plots. At the same time, one-dimensional spectra were extracted with the binning matched to the seeing of the particular night, and profile broadening at a low intensity level was compared with the broadening expected for a Gaussian profile.

3. DISCUSSION

High velocity gas with low surface brightness was detected in only a small fraction of the studied objects. To present some of the results we separate the discussion between the two classes of objects studied.

The extension of the phenomena seems to be spatially limited over the area of the regions. Due to the nature of the phenomena observed (low surface brightness emission over the surface of the nebula) the physical parameters (such as extension) are dependent on factors including telescope/instrument and integration time. Dimensions of a high velocity region should be taken as lower limits to the true extension of the phenomena. Observations are required in both Hα and [O III] λ5007, to establish if the kinematic state is associated to the ionization conditions.

3.1. Giant Extragalactic H II Regions

We discuss in this section the two more representative cases for HVG in giant gaseous nebulae, beginning with the case of NGC 5471. This region is the outermost and most luminous giant H II complex in M101. Morphologically it has a halo diameter of 30″ and a core diameter of 13″. It has been extensively studied and we have reported previously the existence of high velocity gas. Castañeda et al. (1990) found a very high, low intensity HVG within an area less than 1″ in diameter at the position of knot C. The FWZI was $\approx$ 3300 km s^{-1}, for the broad component at $\approx$ 2 % of the peak surface brightness in Hα. Even with its low intensity, this gas represents an appreciable fraction (25 %) of the total emission of the ionized gas at the position of the knot. In NGC 5471 the knot C does not show the broad emission characteristic of WR spectra and there is not sufficient observational evidence to choose between the models of supernova remnants or stellar winds as possible sources for the high velocity gas.

The more peculiar object in our sample is NGC 2363 which is the largest H II region in the Irregular Magellanic-type galaxy NGC 2366, characterized by a high degree of excitation, low dust content, and very high surface brightness. A large expanding bubble (expansion velocity of 45 km s^{-1}) has been found by Roy et al. (1991). The dip in their spectra, below the continuum level defined in the Fabry-Perot data, was interpreted by the presence of an underlying broad emission component, that it is in fact discovered as a low intensity, broad spectral component with FWHM = 40 Å (2400 km s^{-1}) in Hα, Hβ, and [O III] (Roy et al. 1992). González-Delgado et al. (1994) have estimated an energy for the high velocity component of 2.7 $\times$ 10^{52} erg. In the case of NGC 2363, we were able to obtain spectra in both Hα and [O III] $\lambda\lambda$4959, 5007 to establish if the kinematic state of the gas is associated with the ionization conditions. The spectrum in [O III] was obtained after a total of 3900 s integration, for PA 270°; we measured HVG over an extention of 15″ (270 pc), with a FWZI of $\sim$ 900 km s^{-1}; a clear blue asymmetry is observed in the spectra of [O III] (see Figure 1), that it is also similar to the one detected in the HVG of NGC 5471 (notice that bright feature on the blue side of [O III] λ4959 is a cosmic ray). The Hα emission is less defined, and seems to be of smaller extension.

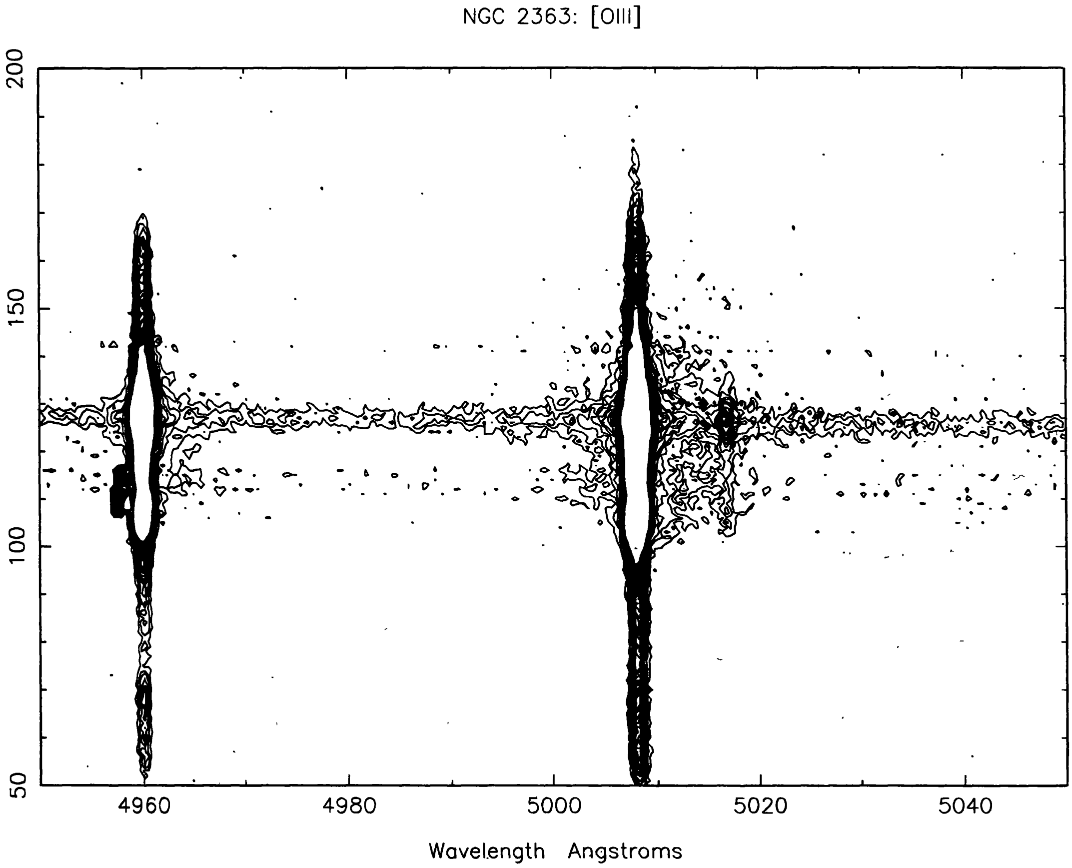

Fig. 1. High velocity gas in NGC 2363, in the zone of [O III] $\lambda\lambda$4959, 5007.

3.2. H II Galaxies

From the H II galaxies studied in our sample, I Zw 18 is the most relevant. It has one of the lowest metal abundances known (1/50 of solar abundance; see Skillman & Kennicutt 1993 and references therein), and is hence a crucial object for estimating the primordial helium abundance. Located at a distance of 10 Mpc, it is formed by two giant nebulae, separated by 5.8″. The two prominent condensations in the galaxy, which denote the most active centers of star formation, are called the NW (the brighter) and the SE condensations. The optical component coincides roughly with the strongest concentration of HI in the area. A broad component has been claimed by Skillman & Kennicutt (1993) in the NW knot, with an amplitude of 80 Å (equivalent to $\approx$ 3600 km s^{-1}) at 0.2 % of Hα FWZI.

The galaxy was observed in four different exposures, for a total integration time of 5400 s. We have marginally detected broad emission over the NW knot, as derived from the small "wings" detected in the isocontours of the long slit spectra ($\approx$ 1100 km s^{-1} FWZI, at 2 % of Hα). The difference between the Skillman & Kennicutt results and ours can be easily explained by the different orientation of the slit (39° PA for them vs. 25° ours), together with instrumental effects of integration time and telescope aperture. As our spectra included the [S II] λ6717 doublet, we have measured the ratio [S II]/Hα as test for SNR. While there is a factor of two in the ratio between the two knots, with the highest ratio in the NE knot, the value is still well within the expectations for normal H II regions (0.01 for the NW knot). The NW condensation has the shape of an incomplete ring, 3.3″ in diameter, and the shell-like structure could reflect some sort of violent activity associated with the existence of the very high velocity gas. Nevertheless, there is no appreciable effect on the velocity map of the object (Castañeda & Fuentes-Masip 1995).

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