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DEEP Hα IMAGING OF STARBURST GALAXIES

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RESUMEN

Presentamos resultados preliminares de imágenes CCD en la línea de Hα de tres galaxias con brotes de formación estelar intensos: Tol 2, Mrk 67 y HS 1851+6933, las dos primeras clasificadas como galaxias Wolf-Rayet (WR). El trabajo comprende el análisis de las estructuras de alto y bajo brillo superficial, relacionadas con el gas ionizado de estas galaxias. En Tol 2 encontramos filamentos a baja intensidad cuya morfología sugiere la acción de vientos galácticos sobre la distribución de gas ionizado. A altas intensidades, Tol 2 y Mrk 67 parecen estar compuestas de varios brotes separados espacialmente (con tamaños lineales entre 100 y 200 pc), cuya diferente anchura equivalente en Hα, W(Hα), puede indicar: a) que el actual proceso de formación estelar no se ha producido en brotes estrictamente simultáneos, b) que la FIM de cada brote es diferente.

ABSTRACT

We present preliminary results on Hα CCD imaging of three starburst galaxies: Tol 2, Mrk 67 and HS 1851+6933, the first two ones classified as Wolf-Rayet (WR) galaxies. This work comprises the analysis of high and low surface brightness structures associated with the ionized gas of these galaxies. In Tol 2 we find low-intensity filaments whose morphology suggests the action of galactic winds over the ionized gas distribution. At high intensities Tol 2 and Mrk 67 seem to be composed of several knots (with linear sizes between 100 and 200 pc) whose different Hα equivalent width, W(Hα), may indicate that: a) the current star formation event has not proceeded in strictly coeval bursts, b) the IMF of each burst is different.

Key words: **GALAXIES: KINEMATICS AND DYNAMICS — GALAXIES: STARBURSTS — STARS: WOLF-RAYET**

1. INTRODUCTION

As a part of a four-years Ph.D. project, we are interested in the detection and study of high velocity kinematical components in starburst galaxies and —in particular— in WR ones, objects distinguished by the He II 4868 Å feature in their spectra, associated with the presence of a large number of WR stars (Conti 1991). WR stars have strong stellar winds and finish their lives as SN. The combined action of these stellar winds together with SN explosions in a relative small region and a short period of time can provide enough energy to produce large scale outflows which, in the case of dwarf galaxies, are likely to escape from the gravitational bounding, leading to a "Galactic Wind". These phenomena could influence the further physical and chemical evolution of the galaxy since the outflows can be selective and affect directly the surrounding interstellar gas, fuel for the subsequent star formation.

The aim of our work is to detect and then to study the functioning and behaviour of such high velocity motions in the framework of WR dwarf galaxies.

The first step to detect these structures is to know the morphology and distribution of the ionized gas in the galaxies. To do this, we have obtained several observing runs with the NOT telescope in La Palma. Here we present the preliminary results for a subset of the galaxies observed in our first run. All the images shown are the first Hα ones for the objects. The second step will consist of obtaining high resolution spectra of the more interesting zones of the galaxies (filamentary or shell-like low-intensity structures) and to study their kinematics.

2. OBSERVATIONS AND REDUCTIONS

Observations were carried out in May 1996 using the Brocam 2 CCD Camera operating in the 2.5-m Nordic Optical Telescope (NOT) at the Roque de los Muchachos Observatory (La Palma, Canary Islands). The Brocam 2 has a 2048 x 2048 pix CCD detector with a spatial resolution of 0.11 arcsec pix^{-1}. The choice of the narrowband filters (50 Å wide) for Hα as well as for the continuum (line free) for each galaxy was done taking into account their respective redshift.

We took a total number of three exposures for each object. The images were reduced, including flux calibration, continuum and sky substraction and correction for the contamination of [N II] nebular lines when posible, following standard procedures using the IRAF package.

At this point we realized that some of the objects showed, at high intensities, a complex structure of different knots of star formation. We studied these different knots by defining circular apertures around them and extracting the integrated flux. This was not indeed an easy job, since sometimes the separation between knots is not obvious. Due to this fact, all the following results and conclusions are somehow uncertain, but realistic in order of magnitude. To obtain the integrated flux of each aperture, we only took into account the pixels whose number of counts was higher than 3σ (the statistical standard deviation value for each image). Errors in the tables are related to variations of 1σ in these flux calculations.

We calculated the flux in the different apertures for the continuum images too, this way we could estimate the equivalent width, W(Hα), of the different knots. We obtained the number of ionizing photons, Q(H^o), for all the apertures as well as the mass of ionized hydrogen, $M_{\rm H\,II}$, for each galaxy, using the values of the electronic density and temperature found in the literature. We calculated also the number of 07V stars needed to account for the total of ionizing photons emitted for each galaxy, taking into account the value of $Q_0^{07V} \sim 1.0 \times 10^{49}$ s^{-1} given by Leitherer (1990).

3. RESULTS

3.1. Tol 2

WR features in the spectrum of this galaxy were firstly detected by Kunth & Joubert (1985); Vacca & Conti confirmed this fact in 1992. The distance to this galaxy is about 13 Mpc. Its linear diameter is about 1.2 kpc. The continuum subtracted Hα images for this galaxy are shown in Figure 1*a* (high-intensity structures with the different apertures used to extract the flux) and in Figure 1*b* (low-intensity structures). In order to flux calibrate properly the Hα images, it was necessary to correct from contamination of the [N II] lines. This was done taking into account the [N II]/Hα ratio obtained by Vacca & Conti (1992). Information about the electronic temperature and density, and about the color excess was also found in the same paper.

Table 1 lists the results [W(Hα), Q(H_O), M_{HII} and N_{O7V}] for this galaxy. The mass of ionized gas and the number of ionizing photons seem to be consistent, at least in order of magnitude, with the estimations given by Vacca & Conti (1992).

At high intensities, the structure of the galaxy is fairly complex. We find at least seven different knots of star formation with somewhat different values of W(Hα). This fact suggests either:

a) the star formation was not strictly coeval for all the bursts (being E the youngest and H the oldest).

b) the slope of the IMF of the massive ionizing stars is different for each burst.

The linear diameters of the knots vary between 100 and 200 pc. At low intensities, there seems to be some interesting structures in the northern part of the galaxy (also in the south-west, but considerably fainter). These structures (filaments reaching linear sizes up to 700 pc) deserve future kinematical study to establish whether they are expanding or not.

3.2. Mrk 67

Salzer was the first one to detect WR features in the spectrum of this galaxy in 1990 (see Conti 1991). The distance to this galaxy is about 14 Mpc.

The continuum subtracted Hα image for this galaxy can be found in Figure 1*c*.

The [N II]/Hα ratio, to correct from contamination of the [N II] 6588, 6527 Å lines, the electronic temperature, density and the color excess were taken from the paper by Garnett (1990). This galaxy does not seem to have any kind of remarkable extended low-intensity structure (filaments or shell-like) with our

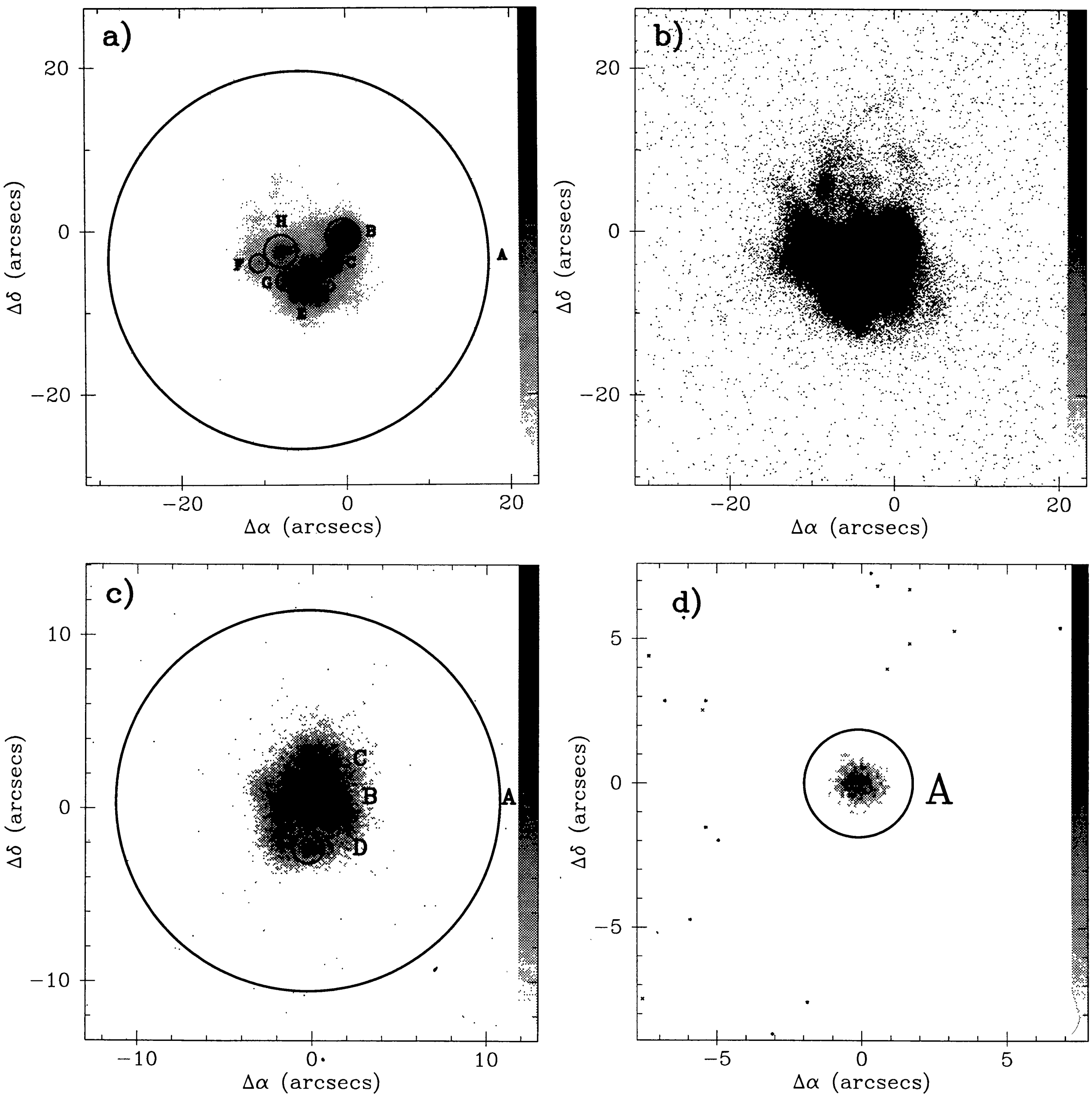

Fig. 1. *a*) Hα image for Tol 2 (high intensities), *b*) Hα image for Tol 2 (low intensities), *c*) Hα image for Mrk 67, *d*) Hα+[N II] image for HS 1851+6933. All the images are continuum subtracted. North is at the top and East is on the left. Extracted apertures for flux calculations are marked in black.

resolution and sensitivity. It presents an elliptical morphology with linear sizes of 600 and 500 pc for the major and minor axes respectively.

At high intensities, we defined three apertures (apart from the global one). Results can be found in Table 1. There seems to be a slight difference among the W(Hα) of the three knots. The dominant central knot B has higher W(Hα) than C and D. As in the case of Tol 2, this fact can be interpreted, as in the case of the previous object, either as a difference in the age of the bursts (being the dominant central one the youngest) or in the

TABLE 1

APERTURE PHOTOMETRY RESULTS

Galaxy	Aperture	-W(Hα) (Å)	log(Q(H^o)) (s^{-1})	log(M$_{HII}$) (M$_\odot$)	N$_{O7V}$
Tol 2	A(total)	340±294	52.51±0.05	6.20±0.05	3220±400
	B	402±47	...	...	...
	C	408±62	...	...	...
	D	301±25	...	...	...
	E	890±240	...	...	...
	F	292±74	...	...	...
	G	425±95	...	...	...
	H	122±13	...	...	...
Mrk 67	A(total)	173±75	51.89±0.05	7.40±0.05	790±99
	B	253±16	...	...	...
	C	112±11	...	...	...
	D	159±39	...	...	...
HS 1851+6933	A (total)	59±44	51.7±0.2	4.5±0.2	470±17

slope of the IMF for ionizing stars. The linear diameter of the central knot is 180 pc approximately. The other knots, not very clearly distinguished in Figure 1*c* because of the black and white representation, have linear diameters of the order of 100 pc.

3.3. HS 1851+695

Although this blue compact dwarf galaxy does not show any WR feature in its spectrum, we decided to include it in our sample due to the presence of very broad nebular emission lines suggesting rapid motion in the ionized gas with velocities up to 2000–3000 km s^{-1} (Izotov et al. 1996). This fact is likely to be associated with the mechanical effect of an intense and massive burst of star formation via possible galactic winds. The distance to this galaxy is about 101 Mpc

As it is shown in Figure 1*d*, it is not possible to see any kind of structure with our resolution and detection limit; that is, the object presents a star-like morphology with a linear diameter of 1 kpc. There is no information about the [N II]/Hα ratio for this galaxy in the literature so we could not account for this fact in the flux calibration of the image. Information about the color excess and about the electronic density and temperature was taken from Izotov et al. (1996). Our results for this galaxy are presented in Table 1.

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