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STAR FORMING NUCLEI IN BLUE COMPACT DWARF GALAXIES

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RESUMEN

Una interpretación adecuada de los procesos de excitación asociados a los "starbursts" requiere de observaciones de alta resolución espacial y espectroscópica. Hemos empezado una serie de observaciones en el UKIRT con un Fabry-Perot, con una resolución de 350 km s^{-1} en un campo de 60″, para obtener imágenes en líneas de emisión en el cercano IR. Resumimos el análisis de imágenes en el contínuo en 2 μm y en las líneas Brγ y 1-0 S(1) de 3 galaxias compactas azules. No hay evidencia de remanentes de supernova y los mecanismos dominantes de excitación son la fluorescencia y las colisiones entre nubes.

ABSTRACT

A reliable interpretation of the excitation processes in starbursts requires both spatially resolved and spectroscopic observations. One way to achieve this is to obtain images of near-IR emission lines, and we have begun a series of observations on UKIRT using a Fabry-Perot with a resolution of 350 km s^{-1} and a 60 arcsec field. Our sample includes 3 blue compact dwarf galaxies for which we summarise an analysis of images of the 2 μm continuum and the Brγ and 1-0 S(1) lines. In all cases we can rule out supernova remnants, due to the thermal nature of the radio continuum, and X-ray irradiation as source of S(1) emission, concluding that the dominant mechanisms are fluorescence and cloud collisions. Although we see a variety of morphologies, there are underlying similarities characterised by very young compact nuclei and evidence of interaction.

Key words: **GALAXIES: STARBURST — INFRARED: GALAXIES**

1. INTRODUCTION

The star-formation history of dwarf galaxies has long been a controversial issue. Are the star formation episodes progressing stochastically? Or have they been triggered by interactions, and if so with what? How long do they last? One of the possible ways to address questions such as these is to look at the spatial distribution of the emission lines, an essential aspect when there are multiple regions exhibiting different properties. The near-IR lines of Brγ at 2.166 μm and ν = 1-0 S(1) at 2.122 μm are useful probes as they are associated with a variety of activities: while Brγ originates mainly in ionised nebulae, S(1) can be due to fluorescence at the edge of these nebulae, X-ray irradiation, and shocks in either supernova remnants or cloud collisions. It is also important to determine the chronology of events, which can be deduced from the equivalent width of the Brγ line, $W_{\mathrm{Br}\gamma}$. This will show whether the starburst occurs simultaneously throughout the galaxy, or whether it is triggered at different times. Another consideration, particularly for the future evolution of the galaxy, is the structure of the cluster that powers the starburst. This can be determined in principle from the S(1)/Brγ line ratio (Puxley et al. 1990) and the morphology of the emission lines (Sugai et al. 1996). We summarise here near IR observations of three blue compact dwarf galaxies: II Zw 40, NGC 5253, and He 2-10. For a more complete analysis refer to Davies et al. (1996).

2. II ZW 40

Observations of the optical morphology and velocity structure of II Zw 40 led Baldwin et al. (1982) to argue that a close interaction may be responsible for its tails and starburst. H I observations (Brinks & Klein

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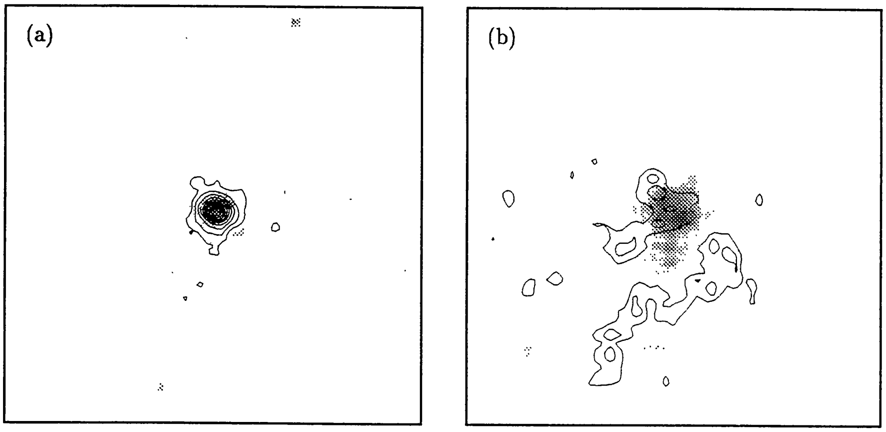

Fig. 1. II Zw 40. Greyscale: 2 μm continuum (the difference between (a) and (b) is due to variations in spatial resolution); Contours: (a) Brγ, (b) 1-0 S(1). The figures are 30 arcsec (1.5 kpc) across; north is up and east is left.

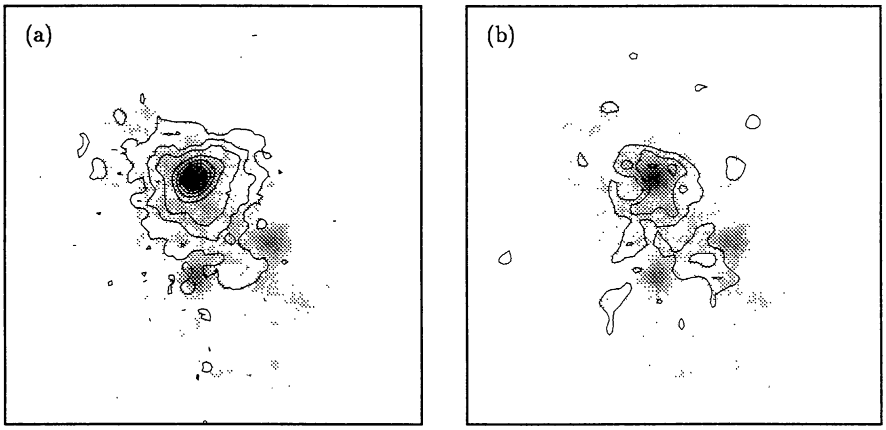

Fig. 2. NGC 5253. Greyscale: 2 μm continuum (the faint regions have been enhanced to show the underlying elliptical isophotes). Contours: (a) Brγ, (b) 1-0 S(1). The figures are 30 arcsec (400 pc) across; north is up and east is left.

1988) revealed two kinematically separate systems interpreted as interacting H I clouds. However, the spatial scales of the hypothesised interactions are considerably different. Our observations in Figure 1, indicate the presence of a single Brγ nucleus with a ratio S(1)/Brγ = 0.05 and $W_{\mathrm{Br}\gamma}$ = 350 Å (corrected for both nebula continuum and the evolved population), and much weaker extended emission. There are also extended S(1) tails on the same scale as Baldwin et al. (1982) which have no associated continuum, a morphology typical of shock excitation in cloud collisions during an interaction.

3. NGC 5253

Optical observations have revealed many H II regions in the core of NGC 5253, with the central one showing Wolf-Rayet features (Walsh & Roy 1989). It has been suggested that tidal interaction with M83 is responsible for triggering the starburst (Rogstad et al. 1974). Figure 2 shows faint elliptical isophotes in the continuum with three peaks, only one of which is associated with Brγ emission. This region coincides with diffuse S(1) emission and has a ratio S(1)/Brγ = 0.03, both typical of a compact star cluster. We have detected weaker extended

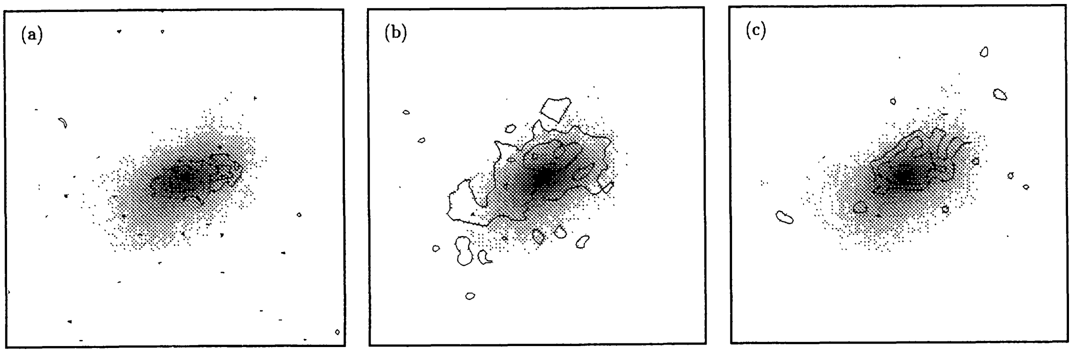

Fig. 3. He 2-10. Greyscale: 2 μm continuum (the faint isophotes have been enhanced to highlight the eastern star-forming region). Contours: *(a)* Brγ, *(b)* 1-0 S(1), *(c)* He I. The spatial resolution of the line images degrades from *(a)* to *(c)*. The figures are 20 arcsec (900 pc) across; north is up and east is left.

line emission including a region where it occurs between nuclei, indicating that it may be shock excited. The equivalent width of Brγ at the three sites indicates that only one is currently active, having $W_{\mathrm{Br}\gamma} = 260$ Å (corrected only for nebula continuum emission) consistent with an age of around 5 million years.

4. HE 2-10

He 2-10 is another Wolf-Rayet galaxy with an uncertain history. Johansson (1987) argued that the star formation had been triggered by the interaction of two dwarf galaxies; discovery of a large undisturbed optical envelope led Corbin et al. (1993) to conclude that the star formation must be proceeding stochastically. Figure 3 shows the strongly peaked 2 μm continuum and the much weaker starburst 8 arcsec to the east. There are several partially resolved knots of Brγ emission reminiscent of the UV hotspots observed by Conti & Vacca (1994). The central knot coincides with the detection of He I at 2.113 and 2.114 μm although most of the S(1) emission appears to originate from a region north of the Brγ. As all the Brγ occurs in compact knots we would expect to find a low ratio S(1)/Br$\gamma \sim 0.04$, but the observed ratio is 0.17. Therefore at least some of the S(1) emission must arise from a process other than fluorescence at the edge of giant H II regions, and both fluorescence from a population of non-ionising stars or shocks in cloud collisions are possible. However, we consider the former scenario to be astrophysically unlikely while the latter is plausible in an interacting system.

5. SIZE AND MASS

The mass of a star cluster can be estimated from the Brγ flux if we assume some form for the initial mass function. All the objects show evidence for a high effective temperature and a disproportionate number of the highest mass stars through the detection of the [S IV] λ10.5 μm line in II Zw 40 and NGC 5253 (Roche et al. 1991), the presence of WR stars in NGC 5253 and He 2-10, and a low far-IR luminosity with respect to ionising flux in II Zw 40 and NGC 5253. As they are also very young, so the lowest mass stars cannot have had time to form, we have used a Salpeter IMF in the range 5–100 $M_\odot$ to calculate the masses. We can impose an upper limit on the size of the cluster as it cannot be larger than the surrounding nebula. We derive masses on the order of 10^5 $M_\odot$ and sizes of less than a few tens of parsecs.

6. SUMMARY

We have presented near IR emission line images of three blue compact dwarf galaxies showing that the ratio of Brγ to 1-0 S(1) emission changes radically from region to region, as does the equivalent width of the lines. We have summarised an analysis indicating that fluorescence at the edge of H II regions and shock excitation in cloud collisions are the dominant processes involved. We have shown that while II Zw 40 has only one star-forming nucleus, NGC 5253 has several at different evolutionary phases, and He 2-10 has several concurrently active. The current starbursts are all young, with ages around 5 million years, and have a mass and size similar to those of globular clusters (Spitzer 1987). It is possible that compact starforming regions like these are the progenitors of such systems.

REFERENCES

Baldwin, J. A., Spinrad, H., & Terlevich, R. 1982, ApJ, 198, 535
Brinks, E., & Klein, U. 1988, MNRAS, 153, 471
Conti, P. S., & Vacca W. D. 1994, ApJ. 423. L97
Corbin, M. R., Korista, K. T., & Vacca, W. D. 1993, AJ, 105, 1313
Davies, R. I., Sugai, H., & Ward, M. J. 1997, in preparation
Johansson, L. 1987, A&A, 182, 179
Puxley, P. J., Hawarden, T. G., & Mountain, C. M. 1990, ApJ, 364, 77
Roche, P. F., Aitken, D. K., Smith, C. H., & Ward, M. J. 1991, MNRAS, 248, 606
Rogstad, D. H., Lockhart, I. A., & Wright, M. C. H. 1974, ApJ, 193, 309
Spitzer, L. 1987, in Dynamical Evolution of Globular Clusters (Princeton: Princeton Univ. Press)
Sugai, H., Ward, M. J., Davies, R. I., Malkan, M. A., & Mclean, I. S. 1996, in Interacting Galaxies: in Pairs, Groups, and Clusters, in press
Walsh, J. R., & Roy, J.-R. 1989, MNRAS, 239, 297