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MASSIVE STAR FORMATION IN TWO SPIRAL GALAXIES: NGC 3938 AND NGC 3184; MULTIWAVELENGTH ANALYSIS

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RESUMEN

Se analiza la naturaleza grumosa de las galaxias espirales NGC 3184 (SAB(rs)cd HII) y NGC 3938 (SA(s)c HII) en varias longitudes de onda (8 and 24 μm, NUV, Hα, and CO) utilizando el algoritmo "Clumpfind2d" (Williams et al. 1994). Con los grumos encontrados por el algoritmo, se calculan las tasas de formación estelar en ambas galaxias utilizando varios métodos. La dispersión de los resultados obtenidos es grande. Para cada longitud de onda encontramos una relación entre la luminosidad y el área del grumo. Proponemos nuevas fórmulas para calcular la tasa de formación estelar para las longitudes de onda consideradas. Encontramos que la tasa media de formación estelar es 0.72±0.40 $M_{\odot}\,\mathrm{yr}^{-1}$ para NGC 3184 y 0.33±0.09 $M_{\odot}\,\mathrm{yr}^{-1}$ para NGC 3938.

ABSTRACT

The clumpy structure of two spiral galaxies NGC 3184 (SAB(rs)cd HII) and NGC 3938 (SA(s)c HII) is analyzed at different wavelengths (8 and 24 μm, NUV, Hα, and CO) using an algorithm called "Clumpfind2d" (Williams et al. 1994). Based on the clumps found by this algorithm, the star formation rates (SFR) of both galaxies are calculated by different methods from the literature, which vary depending on the wavelength used in each case. The dispersion on the results obtained from these methods is large. For each wavelength, a specific relation between the luminosity and area of each clump is found. New formulas for calculating the SFR at all the studied wavelengths are proposed. These formulas result from the extrapolation of the Hα formula taken from the literature via the relation found in this same project. The mean multiwavelength SFR for NGC 3184 is found to be 0.72±0.40 $M_{\odot}\,\mathrm{yr}^{-1}$, while for NGC 3938 it is 0.33±0.09 $M_{\odot}\,\mathrm{yr}^{-1}$.

Key Words: stars: formation — galaxies: individual (NGC 3938, NGC 3184)

1. INTRODUCTION

Stars are formed inside huge clouds of molecular gas. The aim of this paper is to study the process of star formation directly from the luminosity of clumps seen at different wavelengths involved with the process itself. The galaxies' images were taken from archive data: 24 and 8 μm images are from Sptizer, CO images are from BIMA, the Hα image of NGC 3184 is from JKT, the Hα image of NGC 3938 is from KPNO, and the NUV image of NGC 3938 is from GALEX. To be able to study the clumpy structure of the galaxies at each wavelength, the algorithm "Clumpfind2d" was used. This algorithm defines different clumps using the "friends-to-friends" routine, which groups pixels with some sort of connectivity among them, and inside a specific range in luminosity. Once the clumps are found, the SFR can be computed directly from the methods found in the literature.

Different methods for calculating SFR have been proposed throughout the years. The most widespread ones are those which relate directly the Hα luminosity with the SFR via synthesis models. In this research project the methods taken from the literature to calculate SFR are proposed by the following authors: 8 and 24 μm (Wu. et al. 2002), 24 μm and Hα (Calzetti et al. 2007), Hα and NUV (Kennicutt 1998), (NUV) (Iglesias-Páramo et al. 2006), and CO (Kennicutt et al. 2007). Both methods for Hα and NUV are derived directly from synthesis models; the rest are extrapolated from the Hα methods by finding a relation between the luminosity of Hα and some other luminosity related to the process of star formation.

The SFR found from these methods for NGC 3184 range from 0.05±0.02 $M_{\odot}\,\mathrm{yr}^{-1}$ at 24 μm (Calzetti et al. 2007) to 11.46±6.59 $M_{\odot}\,\mathrm{yr}^{-1}$ at 8 μm (Wu et al. 2002). For NGC 3938 the SFR range from 0.035±0.005 $M_{\odot}\,\mathrm{yr}^{-1}$ at 24 μm (Calzetti et al. 2007) to 2.49±0.25 $M_{\odot}\,\mathrm{yr}^{-1}$ at Hα (Iglesias-Páramo et al. 2006).

By studying the physical properties of the clumps, a relation between the area of the clumps and its luminosity (for a given wavelength) is found. This can be seen in Figure 1.

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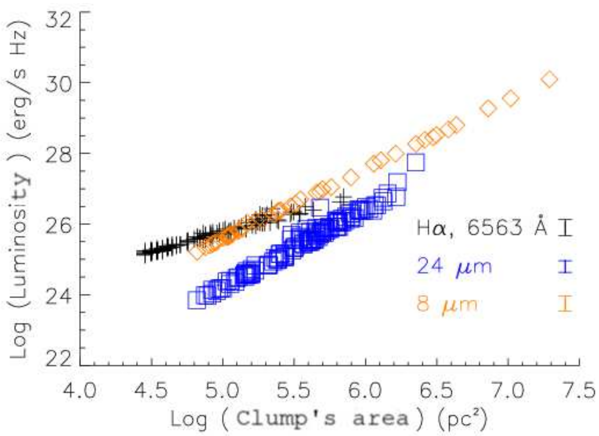

Fig. 1. Example of the relation found between the area of the clumps and its luminosity at certain wavelength. The color of the symbols matches the color of the wavelengths.

TABLE 1

SFR CALCULATED FROM THE METHODS PROPOSED IN THIS PROJECT

NGC 3184		NGC 3938	
λ	SFR ($M_\odot\,\mathrm{yr}^{-1}$)	λ	SFR ($M_\odot\,\mathrm{yr}^{-1}$)
8 μm	1.25 ± 0.39	8 μm	0.46 ± 0.10
24 μm	1.00 ± 0.19	24 μm	0.40 ± 0.05
CO, 2.6 mm	0.44 ± 0.07	CO, 2.6 mm	0.30 ± 0.05
Hα, 6563 Å	0.20 ± 0.11	**Hα, 6563 Å**	0.13 ± 0.02
		CUV, 2271 Å	0.36 ± 0.04

To be sure that this relation is real, and depends only on the wavelength studied in each case, new graphs were made. In these graphs the area and luminosity of the clumps of both galaxies for each wavelength were included. An example of the results can be seen in Figure 2.

The extrapolations from Hα used to calculate SFR based on other wavelengths are achieved by studying a great number of galaxies (~ 60) and finding a relation between two luminosities for the complete galaxies. Trying to do that with only two galaxies would be impossible. However, using the relation found above (Figure 2), we note that the Hα luminosity of a clump is proportional to its area. We can suppose that we have a clump of the same area at the other luminosity, and in the same way, this area is proportional to the clump's luminosity at the other wavelength. That is,

$$\log(L_\lambda) \propto \log(A_\lambda) = \log(A_{H\alpha}) \propto \log(L_{H\alpha})\,.$$

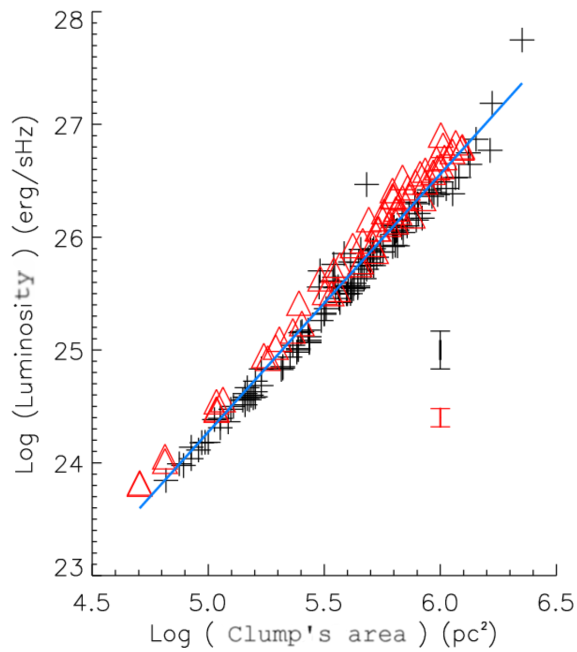

Fig. 2. Example of the relation found between the area of the clumps and its luminosity at certain wavelength for both galaxies. In this case the wavelength is 24 μm.The black points refer to NGC 3184, and the red ones to NGC 3938.

In this way, we can find the Hα luminosity that a given clump of certain area would have based on its luminosity at another wavelength. We can now extrapolate the original formula of SFR based on Hα luminosities to other wavelengths.

The SFR obtained by these formulas can be seen in Table 1.

The range on SFR values is considerably smaller than the one obtained from the methods in the literature. The final SFR for each galaxy was taken to be the average of the values shown in the tables. In this way, the mean SFR in NGC 3184 is found to be of 0.72 ± 0.40 $M_\odot\,\mathrm{yr}^{-1}$, and in NGC 3938 of 0.33 ± 0.09 $M_\odot\,\mathrm{yr}^{-1}$. These results agree with the values found for other spiral galaxies. Further study is needed in order to see if the relation between clumps' areas and luminosities is found in a larger sample of galaxies.

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