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BLUE BLOBS: STAR-FORMING REGIONS OUTSIDE GALAXIES

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RESUMEN

Utilizando datos en diversas longitudes de onda (HI, UV y óptico), hemos encontrado docenas de regiones con formación estelar en el puente de HI ubicado entre M81 y M82, y en las afueras del grupo compacto HCG 100. Hemos logrado establecer, a partir de sus propiedades físicas, que éstas son regiones jóvenes con formación estelar, las cuales se formaron en las zonas de baja densidad columnar de HI, en los restos de la interacción de marea. Hemos podido además establecer que en M81/M82 existe también una población vieja, la cual fue eyectada al medio intergaláctico durante la interacción de marea.

ABSTRACT

Using multi-wavelength data (HI, UV and optical data) we have found dozens of star-forming regions in the HI bridge between M81 and M82 and in the outskirts of the compact group, HCG 100. From their physical properties we have established that these are young star-forming regions which are formed in the low HI column densities of the tidal debris. We were also able to establish that in M81/M82 an old population is also present which was ejected into the intergalactic medium during a tidal passage.

Key Words: galaxies: interactions — H II regions — intergalactic medium

1. INTRODUCTION

In the past few years it has become clear that the evolution of galaxies in environments in which they strongly interact may have a major role in forming new objects with a broad spectrum of masses, from young clusters to tidal dwarf galaxies (e.g., Mendes de Oliveira et al. 2004, 2006; Ryan-Weber et al. 2004). The fate of these objects and their importance in galaxy evolution and formation, enrichment of the intergalactic medium, and globular cluster formation is still debatable. Recently, we have developed a method to find these objects. We use HI data in combination with FUV (GALEX) and optical data of interacting galaxies and here we present the results of two systems, the triplet formed by M81, M82 and NGC 3077 (de Mello et al. 2008a) and the compact group of galaxies, HCG 100 (de Mello et al. 2008b).

2. M81 AND M82

Studies of this triple system at radio wavelengths have shown an extremely disturbed HI distribution with tidal bridges connecting the three galaxies (Yun et al. 1994). Two prominent HI knots are seen to the east/north-east of M81, Holmberg IX and Arp's Loop (Arp 1965). This latter feature occurs at the intersection of the three tidal streamers. We use multi-wavelength observations (FUV(GALEX), HI(VLA)) including deep photometry obtained with Hubble's Advanced Camera for Surveys (ACS), to resolve the stellar population of FUV blobs in the Arp's loop, and thus determine its evolutionary status. The synthetic color-magnitude modeling shows the presence of a young population (< 10 Myr) together with an older component with ages > 1 Gyr with similar spatial distribution and a metallicity $Z \sim 0.004$. It is likely that the old stellar population was formed in the M82 and/or M81 galaxies and ejected into the intergalactic medium during a tidal passage ($\sim$ 200–300 Myr ago), whereas the young stars have formed since the encounter in the tidal debris. We estimate the number of O stars in Arp's Loop, using both the GALEX FUV fluxes and the nebular Hα luminosity of Karachentsev & Kaisin (2007), and find the equivalent to 13 O8V stars. Arp's Loop is then equivalent to $\sim$ 5 Orion nebulae. These rough estimates will increase if there is any internal extinction.

The tidal bridge between M81-M82 where Arp's loop is located ($N(\mathrm{HI}) \sim 5-30 \times 10^{20}$ cm^{-2}; Yun et al. 1994) appears to support star formation at rates which are intermediate between the extremely low levels seen in an object like the Magellanic bridge and very active tidal tails like those found in, for example, NGC 4676 ("The Mice"; de Grijs et al. 2003). This suggests that the tidal HI streams in the M81 system sit near the low end of a continuum of levels of

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star formation in gas-rich tidal matter. Star formation requires the production of gravitationally bound molecular clouds. Since tidal streams normally are at most only mildly gravitationally unstable on large spatial scales, star formation is not expected to behave in the same way as in the inner disks of galaxies which exist on the edge of large scale gravitational instability (Kennicutt 1989). Compression to the densities required to make bound molecular structures can be accomplished through post-shock compression (Christodoulou et al. 1997) or through turbulence which can enhance density perturbations more readily leading to molecular regions that can collapse to make stars in lower velocity cloud collisions (Bergin et al. 2004; Heitsch et al. 2006). In these models, sufficient columns of HI must interact with speeds of ≥ 10 km s^{-1} to produce local regions with $N(\text{H}\textsc{i}) \geq 10^{21}$ cm^{-2} that are required to readily shield molecular gas from radiative dissociation. Therefore, this can explain the diffuse star formation such as the ones seen in Arp's loop.

3. HCG 100

HCG 100 is at $v_{\rm R} = 5336$ km s^{-1} (76.3 Mpc) and it is formed by four late-type galaxies with accordant redshifts showing peculiarities in their morphologies and also in their velocity fields (Plana et al. 2003). Past encounters are also confirmed by an extended HI tail (Verdes-Montenegro et al. 2005). As in M81/M82, we used GALEX images in combination with HI images to search for star-forming regions. We have also obtained an R-band image with the CTIO Blanco 4 m telescope and a mosaic II CCD imager. We used SExtractor (SE, Bertin & Arnouts 1996) to detect sources in the FUV and matched that catalog with the NUV and R-band catalogs. Therefore, only objects with FUV detections were included in our final catalog. The cross-match in the three bands resulted not only in the four most luminous members of HCG 100 but also 16 other objects, within the $10' \times 10'$ field. Nine of these sources are within the HI tail and one of them is as far as 137.2 kpc from the main galaxies in the group.

We used the broad-band colors generated from stellar populations models by Thilker et al. (2008) to estimate the ages of the intragroup sources. We found that all objects are younger than 200 Myr (de Mello et al. 2008b). These ages were combined with the FUV luminosity to estimate the stellar masses ($10^{4.3} - 10^{6.5}$ $M_\odot$) with Starburst99 models (Leitherer et al. 1999).

The young age of these objects and the proximity to the tidal tail connects the OB stars formation time scale ($\sim 10^8$ yr) with the dynamic time scale of the tidal features. As in M81/M82, the HI clouds to which many of them are associated have column densities about one order of magnitude lower than the N(HI)$\sim 10^{21}$ cm^{-2} thought to be required for triggering star formation. So, in these cases, we have a strong indication that the HI clouds must have suffered recent collisions which could have then triggered the star formation process. Based on their ages, stellar masses and HI masses in their vicinities, we suggested that some of these objects are tidal dwarf galaxies with ongoing star formation and some are intergalactic HII regions or conglomeration of stellar clusters.

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