Starburst in the interacting HII galaxy II Zw 40 and in non-interacting HII galaxies

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Abstract. In this poster, I summarize the results of our integral field spectroscopic observations of the nearby prototype of HII galaxies, II Zw 40. Observations with GMOS-IFU on GEMINI-North in the optical allowed us to make a detailed kinematic picture of the central starburst, while SINFONI with adaptive optics on the ESO-VLT gave us a near-IR view of the interplay between the ISM phases.

Here, I also address the question that not all starbursts require an external trigger such as a galaxy-galaxy encounter, as it seems to be the case for a fraction of low luminosity HII galaxies. We speculate that these may form stars spontaneously like “pop-corn in a pan”.

Kinematics and the ISM of II Zw40

We recall our study of the kinematic properties of the ionized gas in the dominant giant HII region of this well known HII galaxy: II Zw 40 (Bordalo, Plana & Telles 2009). With the 3D spectroscopy we obtained the Hα intensity map, the radial velocity and velocity dispersion maps as well as estimate some physical conditions in the inner region of the starburst, such as oxygen abundance (O/H) and electron density. The analysis of a set of kinematics diagnostic diagrams, such as the intensity versus velocity dispersion (I-σ), intensity versus radial velocity (I-V) and V-σ, for global and individual analysis in sub-regions of the nebula allowed us to separate the main line broadening mechanisms responsible for producing a smooth supersonic integrated line profile for the giant HII region. The deconvolution of the effects of stellar winds and possibly SN, i.e. bubbles, shells, revealed regions of “unperturbed” motions over the whole extent of the starburst which are still supersonic (∼ 30 km s⁻¹). We interpret these motions as being related to the underlying gravitational potential and dominant in very young regions when measured through the integrated aperture over the central starburst region. Our observations show that the complex structure of the interstellar medium of this galactic scale star-forming region is very similar to that of nearby extragalactic giant HII regions in the Local Group galaxies.

The central starburst region in II Zw 40 was also observed with SINFONI integral field spectroscopy in the near infrared with adaptive optics provided by MACAO on the VLT (Vanzi, Cresci, Telles & Melnick 2008). We assessed the interplay of the phases of the ISM by mapping the fluxes, radial velocities and

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velocity dispersions of Brγ, Fe[II] and molecular Hydrogen H2. The radiation emitted by the galaxy is dominated by a giant HII region which extends over an area of more than 400 pc in size and is powered by a very young stellar population. The spatial distribution and velocity field of different components of the ISM, mostly through the Bracket series lines, the molecular hydrogen spectrum and [FeII] tell us that [FeII] and H2 are mostly photon excited but, while the region emitting [FeII] is almost coincident with the giant HII region observed in the lines of atomic H and He, the H2 has a quite different distribution in space and velocity. The age of the stellar population in the main cluster is such that no SN should be present yet so that the gas kinematics must be dominated by the young stars. The starbursting region seems to be detached geometrically or dynamically from the large scale morphology of the galaxy. In other words, the properties of the starburst region does not keep memory of what caused it!

**Are all starbursts triggered by interactions?**

Our study on the morphology of a sample of HII galaxies has revealed that they are irregular dwarf galaxies with widespread recent star formation activity extending over most of the optical images (Telles, Melnick & Terlevich 1997). But we noted that the more luminous HII galaxies (type I) show signs of disturbances on their outer envelopes while the less luminous HII galaxies (type II) are more regular in their shapes. The most compact, with little or no signs of an extended envelope, were found among the least luminous galaxies. However, the position, number and sizes of the star forming regions or knots were unrelated to the their overall shapes. It seems natural to explain the disturbances in type I HII galaxies as being due to ongoing mergers and advanced interactions between dwarf galaxies. On the other hand, type II HII galaxies defy our attempts to insert them in the same scenario. The starburst regions do not consist of one or two knots but of ensembles of star forming knots which do not often concentrate in the optically deduced center of the galaxy (see also Loose & Thuan 1986). More recently, we used narrow band surface photometry to assess the morphology of the star-forming regions as compared to their true continuum emission (Lagos, Telles, & Melnick 2007). With higher spatial resolution observations an even more fragmented view of the starburst regions was revealed, where different star forming knots were associated with ensembles of star clusters spread over the extent of the galaxy with no relation with the overall morphology. Again, it seems that by the morphology, the multiplicity and likely other properties of the starburst region alone, we cannot infer its triggering mechanism. These dwarf starbursting galaxies cannot be products or debris of strongly interacting systems because they are not at all associated with giant galaxies (Telles & Terlevich 1993). In fact, they seem to populate low density regions and are not particularly more clustered than the normal field population (Telles & Maddox 2000). Other attempts have been made to search for companions around HII galaxies, though the results are inconclusive. Even then, one would still need to explain how smaller galaxies (Pustilnik et al 2001) or HI clouds (Taylor et al 1995) would have a significant tidal effect over large distances. A lesson is well learnt that interactions cause starbursts, but is the inverse question true?
Galaxies that form star clusters like “pop corn”

Figure 1. Mrk 36 (Haro 4) GEMINI-NIRI K-band image from Lagos et al. (2009, in prep). This high spatial resolution image shows unprecedented details and resolved star clusters spread over the whole extent of this HII galaxy.

HII galaxies and Blue Compact Galaxies have mostly identical properties, though they differ historically by their selection criteria. Despite of their original compact appearance in photographic plates, they have revealed a more complex structure when observed with high spatial resolution. Like in the more luminous interacting galaxies, HST has given us an impressive view of a myriad of Super Star Clusters (SSCs) in their starburst regions. Even with ground based observations, we have now been able to assess this complex structure, particularly in the near-Infrared. The star forming knots in HII galaxies, as in more luminous starbursts, are fragmented and consist of ensembles of star clusters. It seems, therefore, that the properties of the starburst are independent from its cause, and when ignited it loses memory of its origin.

The temporal and spatial analysis of these star forming knots through a combination of optical and near-IR observations have made it clear that the history of star formation must be traced not only in time but in its spatial distribution (Telles 2002). We have used the light gathering power and the superb image quality of GEMINI in the near-IR (Lagos et al. 2009, in prep.) to age date the resolved star clusters in a small sample of HII galaxies. Figure 1 shows a spectacular example of our findings in the nearby HII galaxy Mrk 36. Originally, this object was considered a bonafide example of a compact young galaxy. As it can be seen, star clusters are numerous over hundreds of parsec, with a regular envelope and no signs of double nucleus, nor of being a product of a merger. young ages (< a few $10^7$ yrs) and no sequential trend in ages across the galaxy. This alone rules out self-propagation as a dominant mechanism for star formation in galactic scales. These dwarf galaxies also lack spiral arms, so density waves and shear are not considered important triggering mechanism. What then triggers star formation in HII galaxies?
I wish to conclude this contribution by presenting a speculative view of the mode of star formation in these regular, low luminosity, isolated HII galaxies. The fact that the star clusters all have young ages and occur in galactic scales (> 1 Kpc) suggests that massive star cluster formation in starburst is simultaneous within these time scales measured by age differences among the SSCs. In other words, they occur in different places at the same time (< a few $10^7$ yrs) like “pop corn” in a hot oil pan! The “oil” in this caricature picture is the interstellar medium and “hot” is the necessary physical condition so that the “corn” (star clusters) will “pop” (form) here and there in the “pan” (the observable starburst region). What is then the physical condition that governs the star formation magnitude and efficiency? This physical condition has to achieve the necessary threshold simultaneously over these galactic scales so that star formation will occur in a stochastic matter. In this picture star cluster formation is simultaneous and stochastic within these time scales. This picture is all consistent and leads us back to the work of Schmidt (1963) who proposed the star formation rate (SFR) as a power law relation with gas densities. Kennicutt (1998) calibrated this law, in its observable form (known as Kennicutt-Schmidt law), as a power law relation between the surface SFR and surface total gas (atomic and molecular) density for star-forming disks of spirals, and extended to starburst galaxies. The recent work from the THINGS collaboration (see e.g. Leroy et al. 2008) has identified the molecular gas densities to be primarily responsible for the proportionality with SFR which seems to be a reasonable result since massive star and cluster formation ultimately occur in giant molecular clouds. Therefore, once the “oil” (molecular gas) is “hot” (reached a threshold surface density through gravitational collapse and infall) enough, small perturbations (Icke 1985) will trigger the “corn” (star clusters) to “pop” (form) here and there over the “pan“ (extent of starburst). Finally, the interplay of stellar feedback and gas dynamics will lead to the duration and fate of the present starburst, before it ceases and the galaxy undergoes a quiescent phase till gas falls back to heat the oil in an episodic matter (Pelupessy et al. 2004).

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