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STAR FORMATION FEEDBACK FOR COMPACT STELLAR SYSTEMS

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RESUMEN

Con la premisa de una alta densidad estelar hemos llegado a importantes resultados teóricos que resumimos aquí. La alta densidad estelar puede llevar a un modo muy eficiente de formar estrellas, lo que denominamos *positive feedback mode*. Las implicaciones del modelo son múltiples, en particular, la energía neta liberada por el brote es mucho menor y, además, mucha de la masa de los vientos de las estrellas masivas es reutilizada en formar más estrellas en el volumen del cúmulo. Este modo de formar estrellas debe ser importante en galaxias compactas y en sistemas estelares en galaxias, desde bulbos a los super cúmulos estelares. Es un modo de formar estrellas que conduce a la formación rápida de sistemas masivos y compactos con múltiples generaciones de estrellas con un rango grande en metalicidad.

ABSTRACT

We summarize recent theoretical results dealing with the formation of massive stellar systems. The key premise is the high stellar density which leads to a very efficient star forming process in the so called *positive feedback mode*. Multiple implications arise from such models, e.g., much less mechanical energy exits the starburst process and much of the mass provided by massive stars is used to form more stars within the cluster's volume. Such a star forming mode needs to be considered in the formation of compact galaxies and stellar systems in galaxies (e.g., bulges and super star clusters); a star forming mode that leads to the rapid formation of massive and compact systems with multiple stellar generations with a high metallicity spread.

Key Words: galaxies: evolution — galaxies: star clusters: general — galaxies: starburst — stars: formation — stars: winds, outflows

1. CONTEXT

The Hubble Ultra Deep field has unveiled the shapes of very distant galaxies: chain, clumpy, tadpole, spiral or elliptical shapes (see Elmegreen et al. 2005). More detailed studies point to stellar condensations originated on a turbulent disc (Elmegreen et al. 2010). The SINGs proyect has carried out the study of Clumps at high z (Genzel et al. 2011). They conclude that massive stellar systems may have formed in turbulent rotating discs in which a hierarchy of clumps coexists, some of which are more massive and likely proto-bulges or esferoids.

From much smaller systems, such as young superstar clusters (SSCs), we know that they return in a violent manner a significant fraction of their stellar mass to the ISM (Tenorio-Tagle et al. 2003). The general consensus is that within the SSC volume, the kinetic energy supplied by massive stars (stellar winds and supernova explosions) is "in situ" thermalized and transformed into a fast and hot wind. The result is: a high temperature plasma ($T > 10^7$ K) and the exit of the thermalized ejecta out of the cluster as a supersonic star cluster wind (Chevalier & Clegg 1985, hereafter C&C85). In the most extreme case there are the Supergalactic Winds (SGW) (see Tenorio-Tagle & Muñoz-Tuñón 1998, and references therein). SGWs remove the processed material from the host galaxy and together with the ionization inhibit further star formation; a process defined in the literature as *negative star formation feedback*. In galaxies with a large collection of SSCs, as in M82 (Melo et al. 2005), the winds from neighboring clusters interact and cool down by radiation forming an elongated (kpc long) filamentary structure (Tenorio-Tagle et al. 2003).

2. SF FEEDBACK; NEW MODELS

More recently, our theoretical studies have shown that the original adiabatic assumption of C&C85 is not always valid. Several observational facts took us to reconsider the adiabaticity. The X-ray emission in M82 extends less than expected in the model. In

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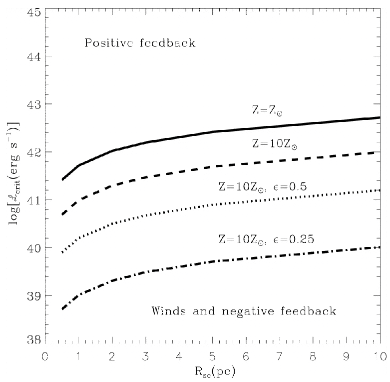

Fig. 1. Threshold Luminosity for different metalicities of the ejecta. Figure from Tenorio-Tagle et al. (2005).

Silich et al. 2003 (their Figure 1) it is shown how the extent of the X-ray emission is very much reduced when cooling by radiation is considered.

We also found that there is a **threshold line in the Cluster Mechanical Luminosity – SC size plot defining a Critical Luminosity**. The SSCs can be grouped in two regimes driven by the Cluster stellar density. For low mass clusters, when $L_{\rm mech} \ll L_{\rm crit}$ the C&C85 solution applies. Strong radiative cooling modifies, however, the temperature distribution outside the cluster when the star cluster $L_{\rm mech}$ approaches $L_{\rm crit}$. *For more massive clusters strong radiative cooling leads to the accumulation of the matter injected by massive stars within the cluster volume. As a consequence, the expelled $L_{\rm mech}$ is much lower than expected in e.g., starburst99 models.* The heating efficiency (η) defines the amount of energy that remains in the flow despite cooling. Low η implies that much of the energy is radiated away whereas high (η) means an efficient transformation into kinetic energy as a powerfull, high temperature, wind that extends far beyond the cluster radius. More details in Tenorio-Tagle et al. (2005, see Figure 1, 2007), Wünsch et al. (2008), Silich et al. (2009). A firm evidence for an incomplete transformation of the mechanical luminosity are the small HII regions surrounding young SSCs (Smith et al. 2006; Silich et al. 2007). This is only possible if the cluster $L_{\rm mech}$ is reduced by a factor η. Much of the energy (and mass) deployed by the massive stars is kept withing the cluster volumen. The scenario holds for more massive (and compact) objects as it can be the case for SCUBA, Clumpy galaxies or Lyα systems (Silich et al. 2010)

3. OBSERVATIONS AND TARGETS

In Tenorio-Tagle et al. (2010) we have derived a new observable, the line width, to measure η (see their Figure 3). Two supersonic emission lines are predicted for clusters above $L_{\rm crit}$: A broader and less intense line coming from the cluster wind material and a narrower and more intense line produced by the re-shocked wind matter that cools within the cluster volume. At low z we have confronted our model with spectra for several M82 SSCs in the bimodal phase. The line profiles are supersonic and can be fit with two gaussians, with lines ratios about 2, as our simulation predicts. The results have been submitted for publication (Muñoz-Tuñón et al. 2013, in preparation).

Some of the observations reported at hight z seem to fit our scheme. See for example Swinbank et al. (2004, their Figure 6) or Genzel et al. (2011, their Figure 7). In both cases the young starbursts show emission lines which are consistent with our numerical simulations. This would imply that, the massive clumps in the *Sings* survey or some SCUBA sources may be massive clusters formed in the efficient mode predicted by our *positive feedback scheme.*

We want to confirm the model with more observations. We are compiling targets at different z. Using COSMOS we have pre-selected some candidates. Higher z targets, up to $z = 1.5$ will be obtained from the SHARDs survey. The higher z cases are planned for EMIR. Some targets are included in the Scientific Case of MEGARA that once at the GTC will provide the spectral resolution needed.

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