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ON THE ORIGIN OF THE HII REGIONS ASSOCIATED WITH MASSIVE AND COMPACT SUPERSTAR CLUSTERS

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ABSTRACT

This contribution to the IV Korea-Mexico meeting deals with the hydrodynamics of the matter reinserted within super star clusters (SSCs) by both stellar winds and supernova explosions, results recently printed in The Astrophysical Journal (Silich et al. 2007). The motivation of such a project arose from the persistent presence of the small mass and compact HII regions that sit right on top of many massive and compact SSCs, from which one expects a large mechanical energy power. The data used for our calculations appear only recently (see Smith et al. 2006) for the massive and compact SSC M82-A1. We presented in our paper the calculated flow, derived through analytical and semi-analytical methods, which led to almost identical results. We have found out that the only way of accommodating a compact HII region (4.5 pc in radius, in the case of M82-A1) on top of a 6.3 Myr old and massive ($> 10^6$ $M_\odot$) SSC with a half light radius of 3 pc, requires of two assumptions: a very low heating efficiency ($< 10\%$) within the cluster, what leads to a bimodal solution (see Tenorio-Tagle et al. 2007) and a high pressure in the surrounding medium.

Key words : Galaxies: star clusters — ISM: HII regions — ISM: individual (M82-A1)

I. INTRODUCTION

Super Star Clusters (SSCs) are young massive stellar clusters. They have been detected in many starburst and interacting galaxies and represent a special mode of star formation.

Some SSCs are detected only in the stellar continuum. However there are also many examples of SSCs embedded into compact and dense HII regions. These are detected as the emission line nebulae either in visible (H_α, H_β) or in the IR (Brackett γ) regimes.

One of the puzzling characteristic of the HII regions associated with SSCs is an inconsistency between the photometric age of the cluster and the kinematic age of the HII region. M82-A1 is an example of such a cluster embedded into a compact, dense HII region.

II. RESULTS

Figure 1 shows the calculated outflow for M82-A1 and its associated HII region. A low heating efficiency promotes strong radiative cooling within the cluster volume, particularly in the central densest regions. The rapid loss of energy, temperature and pressure, inhibit the outflow of the matter reinserted within the volume affected by cooling (see Tenorio-Tagle et al. 2007 and Wünsch et al 2007). Only the less dense outer regions manage to organize a stationary outflow. Figure 1 shows the run of thermal and ram pressure, density and temperature of the streaming gas. There are several zones associated with the M82-A1 cluster in our model: the innermost zone bound by the stagnation radius where the injected matter cools down rapidly and forms clouds photoionized by the remaining massive stars. The outer skin of the cluster, $R_{st} \le r \le R_{SC}$, where the thermalized matter forms an stationary outflow. The free wind region, $R_{SC} \le r \le R_{RS}$, where R_{RS} is the reverse shock position, supported by the high pressure of the ISM. If the heating efficiency is low, the temperature in this region falls below 10^4K, and thus this zone also contributes to the total recombination line flux. The outer cooling region $R_{RS} \le r \le R_{cool}$, where matter reheated at the reverse shock cools down again and becomes exposed to the UV radiation from the cluster. The outer, flux bound, photoionized shell whose inner radius coincides with R_{cool} and the outer radius is defined by the number of photons, f_t, trapped inside the cluster and in the free wind region. This standing shell may be embedded into a high density neutral matter shell, that streamed across the photoionized shell at earlier time and that has been compressed by the high outer pressure ISM, once it cooled and lost its internal pressure. In order to calculate radii of these zones, the distributions of density, temperature and velocity in the outflow and the heating efficiency which is required in order to fit the observed parameters of the HII region, we use our semi-analytic code (see Silich et al. 2004) and integrate the stationary equations of mass, momentum and energy conservation. The den-

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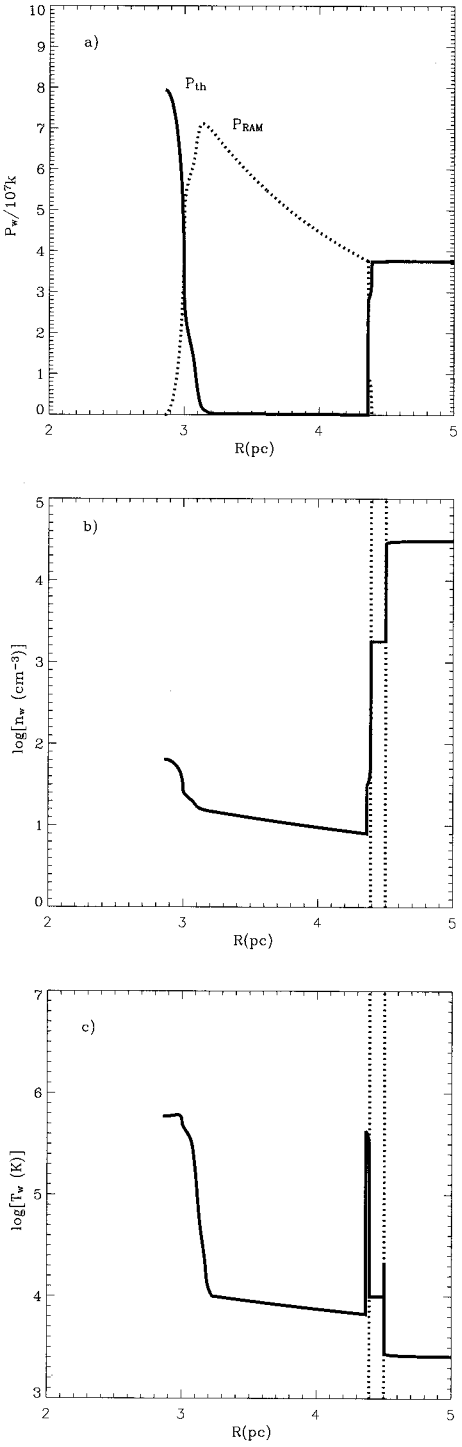

Fig. 1.— The distributions of the hydrodynamical variables inside the HII region. Panels a, b and c present the distributions of the thermal (solid line) and ram (dotted line) pressures, density and temperature, respectively. The size of the standing photoionized shell is indicated by the two vertical dotted lines. The calculations assumed that only a small fraction of the ionized radiation ($f_t = 0.1$) was trapped inside the cluster and in the rapidly cooling free wind region and that the adiabatic wind terminal speed is $V_{A\infty} = 1000$ km s^{-1}.

sity in the outer photoionized shell and its radius are then defined by the position of the reverse shock, R_{RS}, and by the value of the heating efficiency η. We iterate η and R_{RS} until the model density and radius of the HII region fit the observed values.

III. CONCLUSIONS

Our results imply that M82-A1 is a massive and compact cluster with a low heating efficiency (the calculated value of the heating efficiency is $\eta \approx 7\%$). This implies a completely different result from what one would expect from an adiabatic model, as a low heating efficiency leads to a bimodal hydrodynamic solution and with it to a low mass deposition rate into the ISM with a much reduced outflow velocity.

To match the observed parameters of M82-A1 and their associated HII region, our results lead also to a high pressure environment able to confine the cluster wind by setting a reverse shock close to the star cluster surface. In this way the outflow is thermalized, what leads to temperatures near the top of the interstellar cooling curve and thus to a rapid cooling of the strongly decelerated outflow. The wind becomes then target of the cluster UV radiation, composing a narrow standing shell of photoionized gas with the shocked wind matter that continuously traverses the reverse shock.

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