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STELLAR FEEDBACK AND THE EVOLUTION OF YOUNG EMBEDDED STAR CLUSTERS

C. Weidner[1] and P. Kroupa[2]

RESUMEN

En esta contribución presentamos los primeros resultados de un intento teórico de abordar la pregunta sobre la escala temporal de evacuación, la eficiencia de formación estelar y la influencia de la retroalimentación en las estrellas más masivas de un cúmulo estelar. Usando modelos de evolución estelar, descripciones conocidas para la evolución de una esfera ionizada alrededor de una estrella y modelos que describen los vientos estelares, se estudian los efectos de las poblaciones estelares jóvenes de diferentes tamaños.

ABSTRACT

In this contribution we present the first results of an theoretical attempt to address the question of the evacuation time-scale but also the star-formation efficiency and the influence of feedback on the most-massive star in a star cluster. With the use of stellar evolution models, known descriptions for the evolution of an ionised sphere around a star and further models to describe stellar winds, the effects of young stellar populations of different sizes are studied.

Key Words: H II regions — ISM: clouds — open clusters and associations: general — stars: formation — stars: luminosity function, mass function — stars: winds, outflows

1. GENERAL

Stars form in star clusters which themselves are formed in dense molecular clouds. The clouds cover a wide range of masses ($50 < M_{\rm ecl} < 10^6\ M_\odot$, Lada & Lada 2003) and achieve very compact states during their final stages of collapse ($r_{\rm ecl} < 1$ pc, Testi et al. 1998; Gutermuth et al. 2005; Rathborne et al. 2006) and therefore very dense configuration. It is a long standing question exactly how and on what time-scales these clouds finally disperse. The dissolution mechanism then would define the star-formation efficiency of the cloud and the fate of the embedded cluster. Slow gas expulsion would lead to an adiabatic change of the potential and an increase of the number of remaining bound stars. While fast, "explosive", gas expulsion on a time-scale shorter to the cluster crossing time in contrast results in rapid expansion and significant star loss (Kroupa et al. 2001; Goodwin & Bastian 2006; Weidner et al. 2007; Wang et al. 2008). It can even destroy the whole cluster ("infant mortality", Bastian & Goodwin 2006).

[1]Departamento de Astronomía y Astrofísica, Pontificia Universidad Católica de Chile, Campus San Joaquin, Vicuña Mackenna 4860, 782-0436 Macul, Santiago, Chile (cweidner @astro.puc.cl).

[2]Argelander Institute for Astronomy of the University of Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany (pavel@astro.uni-bonn.de).

2. A VERY SIMPLE TOY MODEL

- A cloud of 500 to $10^5\ M_\odot$ with fixed or variable radii.
- Starts with an initial $\mathrm{SFE}_{\rm ini}$ of 0.01,
- Stars are drawn in a sorted way from an input IMF (from 0.01 to 150 $M_\odot$).
- Ionising photons give the radius and expansion velocity for the Stroemgren sphere $\longrightarrow t_{\rm evac}$.
- The radiative and mechanical (wind) luminosity of all stars is added and integrated over $t_{\rm evac}$.
- And after, taking into account "radiation leakages" and cooling of the cloud,
- the integrated luminosity is compared with the binding energy ($E_{\rm bind}$) of the cloud.
- If $E_{\rm bind}$ is not to overcome the SFE is increased and the calculation re-started.
- 100 Monte Carlo iterations to reduce scatter.

3. RESULTS

Figures 1 and 2 show the results one set of models. This calculation reproduces the observed $M_{\rm max} - M_{\rm ecl}$-relation (Weidner & Kroupa 2004, 2006) very well, provides reasonable numbers for the star-formation efficiency (SFE, around 20%) and shows a surprisingly short evacuation time scale of always below 2 Myr. Which means that star clusters are probably excavated from gas by the stellar winds of the massive stars and the PMS stars and not by supernovae type II.

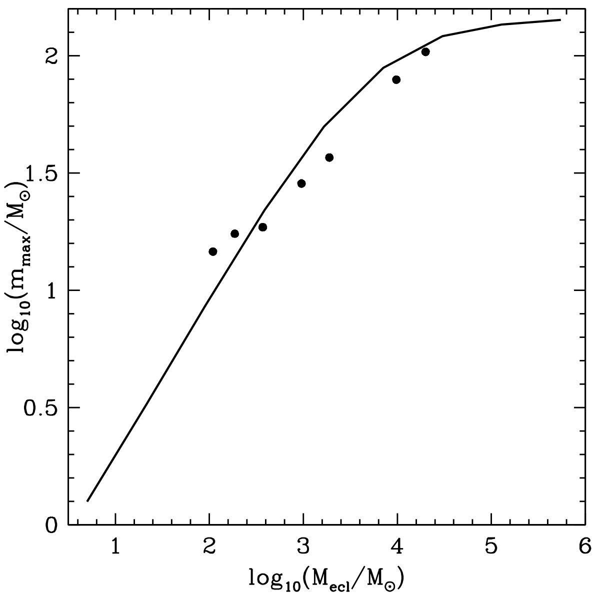

Fig. 1. The $M_{\rm max} - M_{\rm ecl}$-relation from the simulation (solid symbols). The solid line shows the Monte-Carlo model from Weidner & Kroupa (2006) which is closest to the observations.

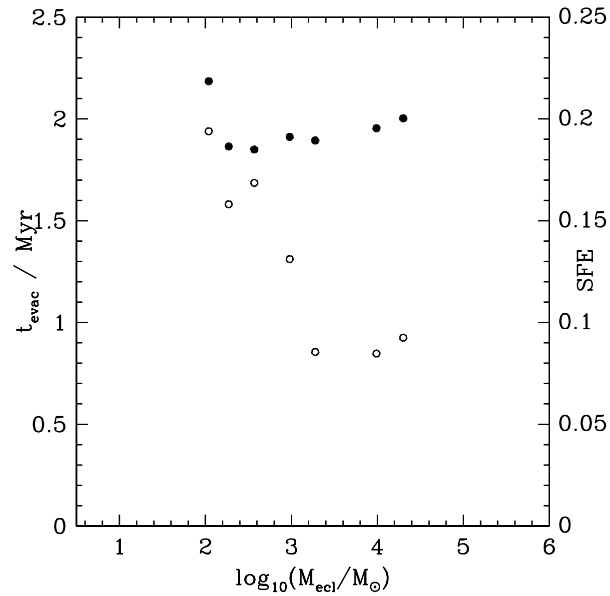

Fig. 2. Evacuation time (in Myr) vs. cluster mass (open symbols, left y-axis) and star-formation efficiency vs. cluster mass (filled symbols, right y-axis).

A large series of calculations using different initial conditions reveals:

- The shape of the $M_{\rm max}$-$M_{\rm ecl}$-relation hints to a fundamental upper mass limit for stars (see also Weidner & Kroupa 2004; Oey & Clarke 2005; Figer 2005; Koen 2006).
- The $M_{\rm max}$-$M_{\rm ecl}$-relation might be the result of stellar feedback terminating the star-formation in a cluster.
- This may also indicate a "bottom up" formation of clusters (low-mass stars first, massive ones later).
- Too "tight" ($r < 0.1$ pc) configurations result in too massive stars.
- Too "fluffy" ones ($r > 2$ pc) produce stars not massive enough and very low SFEs ($\sim 10\%$).
- In most models $t_{\rm evac}$ is lower than the first supernova (3 Myr).
- Only models with low energy conversion efficiency (~ 0.001) and moderate cooling ($\epsilon_{\rm cooling} \sim 50\%$) produce reasonable fits to the observed parameters.

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