An Evolutionary Model for Collapsing Molecular Clouds and Their Star Formation Activity

Manuel Zamora-Aviles (University of Michigan & IRyA-UNAM), Enrique Vázquez-Semadeni (IRyA-UNAM), Pedro Colín (IRyA-UNAM)

We present an idealized, semi-empirical model for the evolution of gravitationally contracting molecular clouds (MCs) and their star formation rate (SFR) and efficiency (SFE). The model assumes that the instantaneous SFR is given by the mass above a certain density threshold divided by its free-fall time. The instantaneous number of massive stars is computed assuming a Kroupa IMF. These stars feed back on the cloud through ionizing radiation, eroding it. Our main results are: a) A giant molecular cloud (GMC) model ($M \sim 10^5 M_{\odot}$) adheres very well to the evolutionary scenario recently inferred by Kawamura et al. for GMCs in the Large Magellanic Cloud. b) A model cloud with $M \sim 2000 M_{\odot}$ evolves in the Kennicutt-Schmidt diagram first passing through the locus of typical low- to intermediate mass star-forming clouds, and then moving towards the locus of high-mass star-forming ones over the course of 10 Myr. c) The stellar age histograms a few Myr before its destruction agree very well with those observed in the $\rho$-Oph stellar association, whose parent cloud has a similar mass (imply that the SFR of the clouds increases with time; Palla, F., & Stahler, 2000). d) The SFR of our model clouds follows closely the SFR-dense gas mass relation recently found by Lada et al., during the epoch when their instantaneous SFEs are comparable to those of the clouds considered by those authors. e) A Monte Carlo integration of the model-predicted SFR($M$) over a Galactic giant molecular cloud mass spectrum yields values for the total Galactic SFR that are within half an order of magnitude from the relation obtained by Gao & Solomon.

Figure 1: Left: Stellar age distribution for our model with $M \sim 2000 M_{\odot}$, calculated at the end of the cloud’s evolution, compared with the corresponding distribution for the $\rho$-Oph association (Palla & Stahler 2000). Right: SFR as a function of dense gas mass for low- to intermediate-mass model clouds (open circles). The filled black diamonds represent Monte Carlo realizations of cloud ensembles taken at random evolutionary stages.

Our model thus agrees well with various observed properties of star-forming MCs, suggesting that the scenario of gravitationally collapsing MCs, with their SFR regulated by stellar feedback, is entirely feasible and in agreement with key observed properties of molecular clouds.

References: