A MODEL FOR SELF-REGULATING STAR FORMATION

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To model the nearly constant star formation rate, SFR, observed in most late-type galaxies (Gallagher *et al.* 1984), as well as the star-bursting behaviour of some interacting galaxies (Joseph *et al.* 1984) we have developed a phenomenological model of the regulatory coupling between the density of the star forming part of the interstellar medium, i.e. molecular gas, and the rate of formation of massive stars.

Models of the coupling between total stellar mass and active gas density have previously been developed by Shore (1981) and by Bodifee and de Loore (1985).

Ikeuchi and Tomita (1983) have modelled the coupling between a hot, a warm and a cold component of the interstellar medium. In our model we use *the rate of change of the SFR* since we feel this to be more directly related to observational parameters. To model the coupling between gas density and the rate of formation of massive stars we need to compute the resulting density of these stars. However, since the main sequence life time of an OB star is short compared to the characteristic time-scale of our model (a few × 10^8 years), the SFR is equal to the density of massive stars on the main sequence. This equality does not hold if low-mass stars are considered.

The rate equation for the SFR consists of two parts: an induced part, which is proportional to the product of the active gas density and the SFR itself, and a part giving the decay of the SFR when no active gas is supplied. The density of the star forming gas is increased by the conversion of atomic gas into molecular gas, stellar mass loss and accretion from outside the system, this is simply modelled as an accretion rate, possibly dependent on the gas density. The gas density decreases by ionization and disruption of the molecular clouds. Here we consider only induced disruption of the clouds through the process of star formation. We denote the SFR by S and the active gas density by D. The system equations become

$$\dot{S} = -k_1 S^{\alpha_1} + k_2 S^{\alpha_2} D^{\beta_1} \quad , \qquad (1)$$

$$\dot{D} = k_3 D^{\beta_2} - k_4 S^{\alpha_3} D^{\beta_3} \quad . \qquad (2)$$

If we set $\dot{S} = 0$ in eq. (1) and neglect the coupling between S and D, we obtain

$$S = \left[\frac{k_2}{k_1} \right] D^{\Gamma} \quad , \; (\dot{S} = 0),$$

where $\Gamma = \beta_1/(\alpha_1 - \alpha_2)$. As long as $\alpha_1 \neq \alpha_2$ this is the well-known Schmidt law for star formation. However, if we take both eq. (1) and (2) into consideration we get a nonlinear dynamical system with equilibrium points

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at (0,0) and (S_0,D_0). Only the latter equilibrium point is of interest here.

The model is analytically solvable for the special case of all α_i equal, and all β_i equal. However, this special case lacks structural stability. For the general case we have used perturbation analysis to investigate the stability of the system, and have solved the equations both analytically in a linearized version and numerically for the full nonlinear version.

With reasonable values of the coupling parameters and exponents the model is both structurally and dynamically stable. When perturbed it performs damped oscillations (sometimes critically damped) around the equilibrium point, cf. Figure 1. For most parameter values the response of the SFR to density enhancements is highly nonlinear, giving rise to very strong bursts of star formation when the gas density is slightly perturbed. The model is relatively insensitive to changes in the parameter and exponent values.

In systems of interacting galaxies, gas density enhancements above the equilibrium value can be achieved either by induced radial gas flows or by gas transfer from one of the interacting galaxies to the other. In the latter case we found that a decreased gas density will also induce oscillations in the SFR, but with a phase-delay compared with the galaxy of increased gas density.

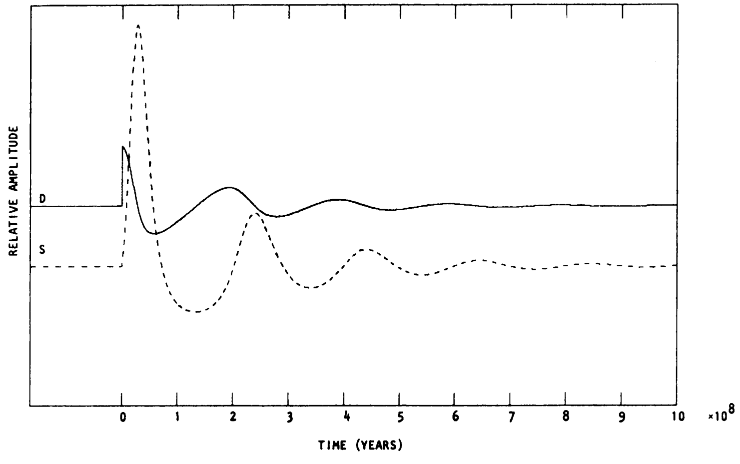

Fig. 1. The response of the system to an initial increase in the gas density. The exponential values are $\alpha_1=\alpha_2=\alpha_3=1$, $\beta_1=\beta_3=1$, and $\beta_2=0$. The coupling parameter values are $k_1 = 10^{-7}$ years^{-1}, $k_2 = k_4 = 10^{-6}$ years^{-1}and $k_3 = 10^{-9}$ years^{-1}.

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MOLECULAR CLOUDS AND STAR FORMATION NEAR THE GALACTIC CENTER

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We present the results of an extensive survey of ^{13}CO and CS emission in the inner 1 kpc region of our Galaxy. The properties of the clouds are very different from molecular clouds observed in the galactic disc: 1) The mean gas density is more than one order of magnitude higher ($\langle n \rangle = 10^4$ cm^{-3}). 2) The internal velocity dispersion is greater by a factor of 5 to 10 (v = 20 to 50 km s^{-1}). 3) Many of the clouds follow highly eccentric orbits about the center. 4) This region contains roughly 10% of the Galaxy's molecular mass, but much less than 10% of the newborn massive stars. Star formation may be inhibited by the large turbulent energy content of the clouds. Some of these properties may result from the large galactic tides in the inner Galaxy. In order for a cloud to remain gravitationally bound despite the shear induced by galactic rotation, the mean gas density must be greater than $\langle n \rangle = 10^4$ cm^{-3}. The velocity dispersion of the gas must be large to satisfy the virial theorem. The forbidden velocities and high latitude extent of some of the emission can be explained by the presence of a stellar bar and does not require a central explosion. Some of the thermal infrared and continuum features of the galactic center can be understood as the direct consequence of cloud-cloud interactions.

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