OSCILLATING STAR FORMATION

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ABSTRACT.

As a consequence of positive feedback effects in interstellar chemical and star forming processes, a star formation region may undergo nonlinear oscillations.

A model has been built of a star formation region in which mass transformation processes take place, regulated by a throughflow of matter and the interactions between the components of the system. In this approach, a star formation region is regarded as a galactic dissipative structure (Nicolis and Prigogine,1977), sustaining itself as a more or less stable, ordered, non-equilibrium system, independent of the of the environment, except for supply of material and the removal of waste. The system of the model includes three components:

Cool atomic gas. This gas does not lead to collapse; no star formation is possible.

Cool and dusty molecular clouds. Due to efficient molecular cooling, this gas can collapse. However, external pressure by expanding HII regions applied for a collapse to set in.

Young stars with their HII regions. The stars are able to trigger further star formation in molecular clouds (Elmegreen & Lada, 1977).

It is assumed that the total mass of the system is constant:

The system is attached to two "reservoirs":

- cool atomic gas is available to replenish the mass that is removed from the system.
- matter that is permanently buried in stellar remnants as low-mass main sequence stars, is removed from the system ("waste" reservoir).

Mass transformations between components are described by a system of parameterized equations.

$$\frac{dX}{dt} = F(X)$$

where X is a vector of the component concentrations, and F a vector of nonlinear polyonomial and autonomous equations, that describe the transformation processes.

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THE PROCESS SYSTEM.

1. Inflow of atomic gas. This compensates for mass that leaves the system as old stars

$$\frac{d_1A}{dt} = -\frac{d_2S}{dt} = K_1S$$

2. Stellar evolution

$$\frac{d_2R}{dt} = -\frac{d_2S}{dt} = K_1S$$

3. Mass loss of young stars and recombination of ionized gas

$$\frac{d_3A}{dt} = -\frac{d_3S}{dt} = K_2S$$

4. Spontaneous star formation. Low-mass stars, that do not trigger further star formation, are themselves formed spontaneously.

$$\frac{d_4R}{dt} = -\frac{d_4M}{dt} = K_3M^{n_1}$$

5. Production of interstellar molecular gas. Molecular cooling allows cloud to collapse, leading to larger densities and faster reaction rates.

$$\frac{d_5M}{dt} = -\frac{d_5A}{dt} = K_4A^{n_2}(M+A)^{n_3}S^{-n_4}$$

6. Triggered star formation.

$$\frac{d_6S}{dt} = -\frac{d_6M}{dt} = K_5SM^{n_1}$$

Different types of system behaviour occur, depending on the parameter values. Within certain ranges the stationary state is stable, and the system evolves towards this state in a direct or oscillating way. Beyond some critical parameter values, the stationary state is unstable and self-sustained oscillations develop that behave like a limit cycle.

RESULTS OF CALCULATIONS.

Limit cycle oscillations occur for small values of the exponents n_1 and n_2 (both smaller than 2), and large values of n_3. The influence of the stellar radiation on molecular production, as expressed by n_4, has no effect on the oscillations. Atomic cooling dampens any oscillation drastically. For ≥ 0.2, no limit cycle can occur, whatever the values of the other parameters. The efficiency coefficient for triggered star formation has a strong influence: for small values the system evolves towards a stationary state after some initial oscillations. For increasing triggered star formation efficiency, the amplitude of the oscillations increase until eventually a limit cycle is established.

REFERENCES.

Elmegreen, B.G., Lada, C.J., 1977, Astrophys.J. 214, 725.
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