SELF-REGULATING STAR FORMATION IN ISOLATED GALAXIES

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Abstract

Recent investigation (Parravano, 1987) shows that the diffuse phases of the ISM condense mainly by the transition from warm gas to small cool clouds (WG $\rightarrow$ SC). In this work we introduce the new hypothesis that the star formation rate (SFR) in isolated galaxies is self-regulated in such a way that it maintains Pmax close to the ISM gas pressure. Here Pmax is the gas pressure at the marginal state of stability for the transition WG $\rightarrow$ SC. This hypothesis leads to a relation between global galactic parameters which appears to be applicable to various morphological groups of isolated galaxies.

The ISM Gas Model

As is shown in Figure 3 of Parravano (1987) the thermochemical equilibrium curve is strongly dependent on the Fuv parameter.* The Fuv parameter (Jura, 1976; Spitzer, 1978; Parravano, 1987) may be written as:

$$Fuv = \left(\frac{Ye/0.15}{\rho s/3\ g\ cm^{-3}}\right)\left(\frac{Qa}{a/2\ 10^{-6}\ cm}\right)\left(\frac{160\ Md}{Mh}\right)\left(\frac{U\lambda}{7.10^{-17}\ erg\ \ cm^{-3}\ A^{-1}}\right) \qquad (1)$$

where Fuv = 1 for the mean Galaxy conditions. The curve "log (Pmax) vs log (Fuv)" has a nearly linear dependence with a slope of 1.35. Thus, when Pmax is near the gas pressure, an increase (decrease) of the non-ionizing UV radiation tends to inhibit (further) cloud formation and consequently star formation.

For the ISM gas pressure a dependence $P \propto M^{\alpha} R^{-\beta}$ is assumed. Here α=2 and β=4 if the gas pressure is maintained by stellar energy input (Dopita, 1985) or α=2.5 and β=4.5, if hydrostatic equilibrium is assumed.

Hypothesis

In isolated galaxies, the critical pressure Pmax, above which the transition WG $\rightarrow$ SC occurs, is close to the ISM gas pressure P.

*See last page for a glossary of terms and a list of approximations.

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If the hypothesis is correct ($P \approx P_{max}$) and the assumed approximations are not far off, isolated galaxies should follow the relation

$$\log Mh = A + P1 \log(Mwd\ Lb\ d1/d2) + P2 \log d1 \qquad (2)$$

where P1=0.40 and P2=0.39 if the gas pressure is maintained by stellar energy input. If hydrostatic equilibrium is assumed P1=0.35 and P2=0.47.

Results

To test the validity of equation (2) we used the Sc and Sd galaxies of the sample of Chini et al. (1986), the irregular galaxies of the sample of Hunter et al. (1986) and M82 and the blue compact galaxy IZW18 of the sample of Gondhalekar et al. (1986). Figure 1 shows the relation log(Mh) vs 0.35 log (Mwd Lb d1/d2) + 0.47 log (d1) for these galaxies. A least-squares fit to the sample points gives a straight line with a correlation coefficient of 0.97 as well as the expected slope. The typical error bars are also shown in Figure 1 with the assumption that all the parameters have a relative error of 0.2.

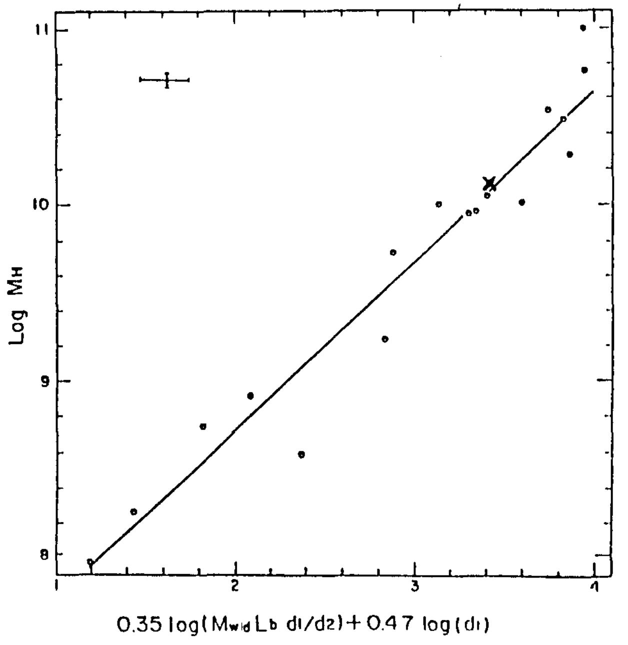

Fig. 1: The relation log(Mh) vs 0.35 log (Mwd Lb d1/d2) + 0.47 log(d1). The Galaxy is plotted as x.

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Discussion

It is necessary to improve the multiple approximation used to derive equation (2) in order to reach definitive conclusions; however many general conclusions may be given:

- For the assumed ISM gas model SFR is self-regulated in such a way that it holds Pmax close to the ISM gas pressure P.
- From all the parameters present in the model the mean energy density U_λ is the one which can vary most rapidly and can transport information most efficiently. Thus U_λ may be considered as the physical quantity that regulates star formation.
- Dust effects are important in determining the SFR in isolated galaxies.
- Blue Compact Galaxies have been described as galaxies that show intense bursts of star formation at the present epoch (Gondhalekar et al. 1986), but here it is shown that the high UV luminosity is due to the low dust content. The sample member NGC 1569 is the one which had the major deviation from the model. This was possibly due to a burst of star formation.
- Interaction between galaxies may produce perturbations in all the model parameters. If the interaction perturbs galaxy parameters to points above (below) the curve in Figure 1 the SFR tends to increase (decrease).

A model including the ISM inhomogeneities and the time lag between the WG → SC transition and star formation is necessary to reach definitive conclusions.

In a non-explicit manner, the galactic rate of supernovae plays an important role in this model. Many of the parameters used here are sensitive to the supernova distribution in space and time (i.e. the energy density of non-ionizing UV radiation, the ISM gas pressure and the WG filling factor). Additionally, it is well known that supernova shell fragmentation is an important source of neutral clouds.

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Glossary

WG - ISM warm gas
SC - ISM small cool clouds
Pmax - Gas pressure at the marginal state of stability for the transition WG → SC due to thermal instabilities
Ye - Mean efficiency for photoelectric emission
ρs - Solid density of grains
Qa - Grains efficiency factor for absorption
a - Mean radius of grains

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Mg - Total gas mass
MH - Total hydrogen mass
M* - Total stellar system mass
Md - Total dust mass
Mwd - Total warm dust mass (i.e. T~50 K)
U_λ - Mean non-ionizing UV density energy
Lb - Blue luminosity
d1 - Major galaxy diameter
d2 - Minor galaxy diameter

Approximations

i) U = Cte.Lb/(d1d2)

ii) Cte, Mwd/Md, MH/Mg and Mg/M* are the same for all the galaxies in the sample

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