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POSSIBLE PHYSICAL MECHANISMS OF STAR BURSTS IN GALAXIES

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RESUMEN

Se proponen dos mecanismos para explicar los brotes de formación estelar en una galaxia: una formación estelar que se dispara cuando la densidad del gas es mayor que un valor mínimo determinado por las fuerzas de marea, y una formación estelar inducida por una transferencia de gas hacia la región nuclear durante una interacción gravitacional galáctica. Se presentan algunas predicciones basadas en la teoría de la evolución de las galaxias discoidales.

ABSTRACT

Two mechanisms are proposed to explain star formation (SF) bursts in galaxies: a SF triggered when the gas density is greater than a threshold determined by the tidal forces, and a SF due to a gas inflow on the nuclear region induced by a galactic gravitational interaction. Several predictions are presented on the frame of the evolutionary theory of disk galaxies.

Key words: **GALAXIES: EVOLUTION — GALAXIES: STARBURST**

1. INTRODUCTION

The SF may be considered a continuous and smooth process only in an idealized scenario. Basically this approach is useful when the SF is studied as a global process in a large galaxy which includes many SF regions. According to wide observational evidence, the SF process may be highly discontinuous and repetitive in time with a moderate coherence radius of several hundreds parsecs (Searle et al. 1973, Gallagher 1992). The typical size of a galaxy is quite larger than the coherence SF size. The result is that a disk galaxy may be divided into many independent SF coherent cells interacting with their neighborhoods by supershells. This situation may be at the origin of a stochastic nature of a spiral pattern in a differential rotation disk (Seiden & Schulman 1990). A SF coherence extended on an entire galaxy may be induced by the stellar density wave of a spiral arm or by a stellar bar. Frequently the SF bursting is related to interacting galaxies (Larson & Tinsley 1978) as in the case of many bright IRAS galaxies (Rowan-Robinson 1991). In order to understand these problems we will analyze the SF bursting effects derived by the introduction of a minimum critical gas density for the SF and by a galactic interaction.

2. THE MODELS

The presence of a gravitational tidal force may influence deeply the gas physical conditions when the SF is taking place. In the simple case of a gas cloud submitted to the gravitational field of a mass M at a distance R, the gravitational contraction of the cloud proceeds only when its density is greater than the tidal critical limit $3\alpha M/4\pi R^3$, where α ranges between 1 and 3 and takes into account the galaxy rotation, the cloud angular velocity and the magnetic field. It is natural to assume the gas density must be greater than the tidal density as a necessary condition for the SF. If we introduce this condition in the equations that control the SF rate (SFR) of a disk galaxy (Firmani & Tutukov 1992) two possibilities can arise. When the stationary solution gives a density greater than the critical tidal density then the stationary SF regime is accessible, otherwise the SF proceeds through a sequence of bursts determined by the switching mechanism of the density. In order to explain the SF activity of the galaxy's spiral arms we assume that the gas density of the solar neighborhood is close to the critical condition. From the same equations we estimate the SFR equation coefficient $f \simeq 5 \times 10^7$ cm^3/g s. It is interesting to note that this value of f coincides with the estimate by Cox (1983) based on the ionization self-regulation mechanism.

In Fig. 1 we show the U-B vs. B-V diagram for a sample of 331 late type galaxies compiled from Tully (1988) with color indexes from de Vaucouleurs et al. (1991, RC3). The symbols are related to the radius in pc. On average, the red galaxies show a greater radius than the blue galaxies, while the scatter of the data in the blue is greater than in the red. The closed (CS) and open (OS) stationary models obtained on the grounds of the Firmani & Tutukov (1992) approach, and with a present surface density of $100 M_\odot/\mathrm{pc}^2$, explain adequately the average properties of the sample, however the scatter of the data is too large with respect to the narrow strip covered by the stationary models. The closed (CB) and open (OB) bursting models obtained using a critical tidal density of 1 cm^{-3} for the SF explain the spread of the data and offer the statistical support for the large fluctuations observed in the blue. In fact, for blue galaxies, the smaller radius decreases the number of SF cells and increases the color statistical fluctuations.

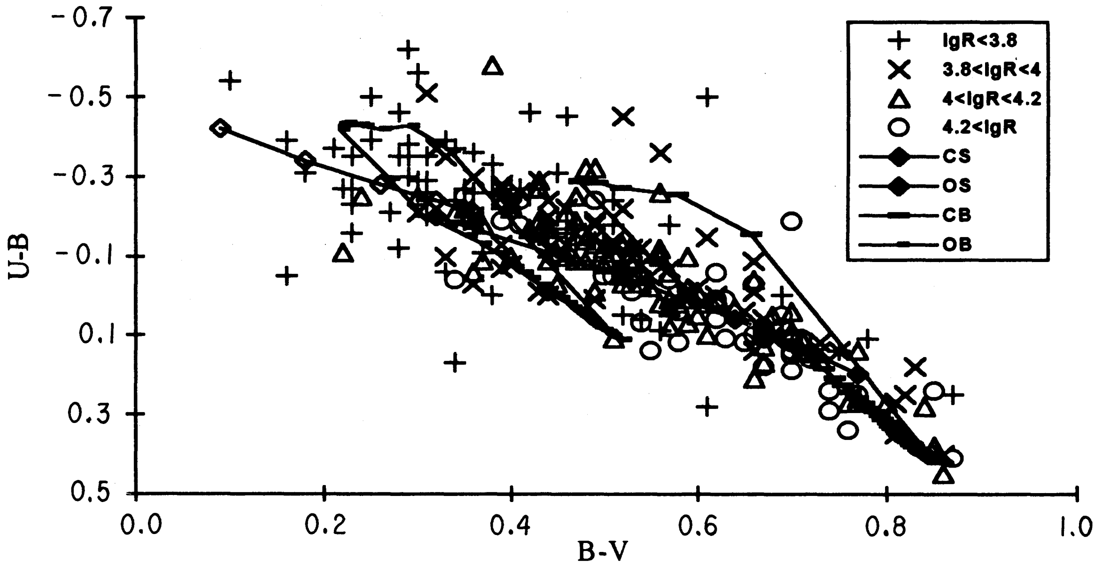

Fig. 1. The U-B vs. B-V diagram for the galaxies of the sample described in the text. The symbols are related to $\log R$ (pc). Closed (CS) and open (OS) stationary models as well as closed (CB) and open (OB) bursting models are shown with a present surface density of $100 M_\odot/\mathrm{pc}^2$.

The gravitational torque on the turbulent gas disk can increase significantly during a galactic collision or merging, slowing down the gas from the Keplerian motion and enhancing the accretion of the interstellar gas on the galactic nucleus. From simple analytical considerations we roughly estimate a gas accretion of 100 $M_\odot$/yr during about 100 Myr with a turbulent velocity of 100 km/s in a nuclear region with a radius of 500 pc.

Starting from these conditions we have obtained the evolutionary track for the nuclear region shown in the diagram of $\log L$ vs. $\log M_g$ of Fig. 2. The marks show time steps of 10 Myr. In the same diagram bright IRAS galaxies from Krügel et al. (1988) are included (circles). 70 Myr after the beginning of the gas inflow the gas turbulent dissipation allows the gravitational contraction to increase the gas density above the critical tidal density of roughly 1000 cm^{-3}. The SF starts and evolves through sequential bursts with a 20 Myr period. The radiation pressure dominates the gas hydrodynamics and establishes a self-regulation mechanism that determines the luminosity. The result is a compact Keplerian disk of stars, with a radius of 500 pc, a mass of $10^{10} M_\odot$, and a metallicity roughly twice the solar one. The track evolves precisely on the region occupied by the bright IRAS galaxies.

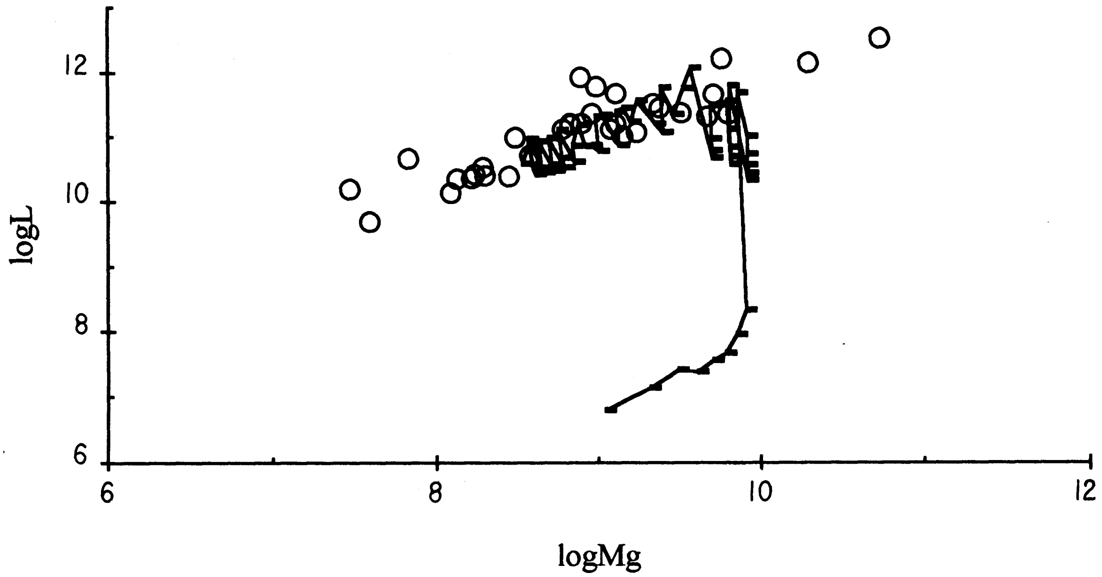

Fig. 2. The diagram $\log L$ vs. $\log M_g$ for bright IRAS galaxies (circles). The evolutionary track corresponds to the nucleus of an interacting galaxy with a gas inflow on the nuclear region. The marks indicate time steps of 10 Myr.

3. CONCLUSIONS

Two physical mechanisms, able to describe SF bursts, have been introduced in the disk galaxy evolutionary models from Firmani & Tutukov (1992). The first of them is the unavoidable instability condition of a gas in a gravitational field. The tidal critical density appears to be the natural threshold above which SF is possible. The result is a new determination of the coefficient of the SF law, which coincides with a previous estimate by Cox (1983) based on the ionization self-regulation mechanism. On average, the new models agree with the stationary ones, but they have the advantage that they are able to explain the scatter of the observations in the color indexes diagram. In the second mechanism, during a galaxy interaction, the gas slows down from the original Keplerian motion and flows in toward the nuclear region. The evolution of this region leads to conditions very similar to those of bright IRAS galaxies, and to the formation of a compact Keplerian disk of stars with high metallicity.

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