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STATIONARY STAR FORMATION IN DISK GALAXIES

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RESUMEN

Se presentan trazas evolutivas para galaxias de disco en el marco de un régimen de formación estelar estacionaria. Se comparan estas trazas con las propiedades integrales observadas de galaxias compiladas de la literatura. La comparación involucra fundamentalmente la historia de la formación estelar de las galaxias. Se obtiene una concordancia razonable en los casos de las correlaciones de tres parámetros luminosidad en el azul vs. masa de gas vs. densidad superficial y densidad superficial de gas vs. índice de color B-V vs. brillo en el azul.

ABSTRACT

Evolutionary tracks for disk galaxies are presented in the frame of a stationary star formation (SF) regime. These tracks are compared with the integral observed features for a sample of galaxies compiled from the literature. The tests carried out involve basically the SF history of the galaxy. We obtain a reasonable agreement in the cases of the three parameter correlations: blue luminosity vs. gas mass vs. surface density and surface gas density vs. B-V color index vs. B brightness.

Key words: **GALAXIES: EVOLUTION**

1. INTRODUCTION

The evolution of a galaxy is determined mainly by its SF history. An attempt to describe the evolution of a galaxy has to start from the physical conditions of a gas that, in a gravitational field, dissipates its energy and transforms itself into stars. Firmani and Tutukov (1992, FT) assume that the turbulent motion of the interstellar gas dissipates energy through cloud collisions, while in a disk galaxy the main energy source of the turbulence is from supernovae explosions. The energy balance determines the thickness and the density of the gas disk, the radius is determined by the angular momentum. While the disk thickness is rather sensitive to the SF rate (SFR) law, other important features of a galaxy such as the gas content and the SF history appear to be widely independent from the SFR law. The equations assumed by FT are stable in time, which means that their approach describes a time average evolution for the SF. Any effect related to SF bursts has to be considered as a fluctuation around the stationary regime defined in the framework of FT.

In this paper we will extend the grid of models of FT with the aim to compare the theoretical results with a sample of 331 late type galaxies compiled from Tully (1988) with color indexes from de Vaucouleurs et al. (1991, RC3).

2. THE EVOLUTIONARY TRACKS

Our theoretical approach concerns an elementary column of a disk constituted by a turbulent gas and a virialized star population. In principle, we can confront our models with the local properties of observed disk galaxies, but this requires observational data with a spatial resolution that is not available in the integral properties given by Tully (1988) and RC3. Due to this limitation we assume that our approach is representative of the integral properties of a given galaxy on the frame of a one zone model. We have calculated evolutionary tracks for closed models, where no external gas accretion is present and the only source for gas is stellar mass loss. We have also calculated open models in which the final mass is determined by a constant gas accretion rate. We have assumed a Salpeter IMF power law with exponent -1.35. The lower limit for the stellar masses has been taken to be 0.1 $M_\odot$ and the upper limit 126 $M_\odot$.

In Fig. 1 we show in the diagram $\log L_B$ vs. $\log M_g$ the evolutionary tracks for galaxies with present surface densities $\log \Sigma = 1, 2$ and 3 in units of $M_\odot/pc^2$, and the observational data best fits for the surface densities $log\Sigma = 1$ and 3. L_B is the B luminosity in unit of $L_{B\odot}$, M_g is the gas mass and the HI+He mass in $M_\odot$ for the models and the observations, respectively. The models have been calculated with a radius of 10 kpc. These may be scaled to other sizes by adding the logarithm of the disk area scaling factor to the coordinates. This transformation allows the evolutionary tracks to cover the entire strip of observations. The relevant point here concerns the agreement between theory and observations with respect to the surface density gradient; for a given gas mass, models and observations give the same dependence of luminosity with surface density.

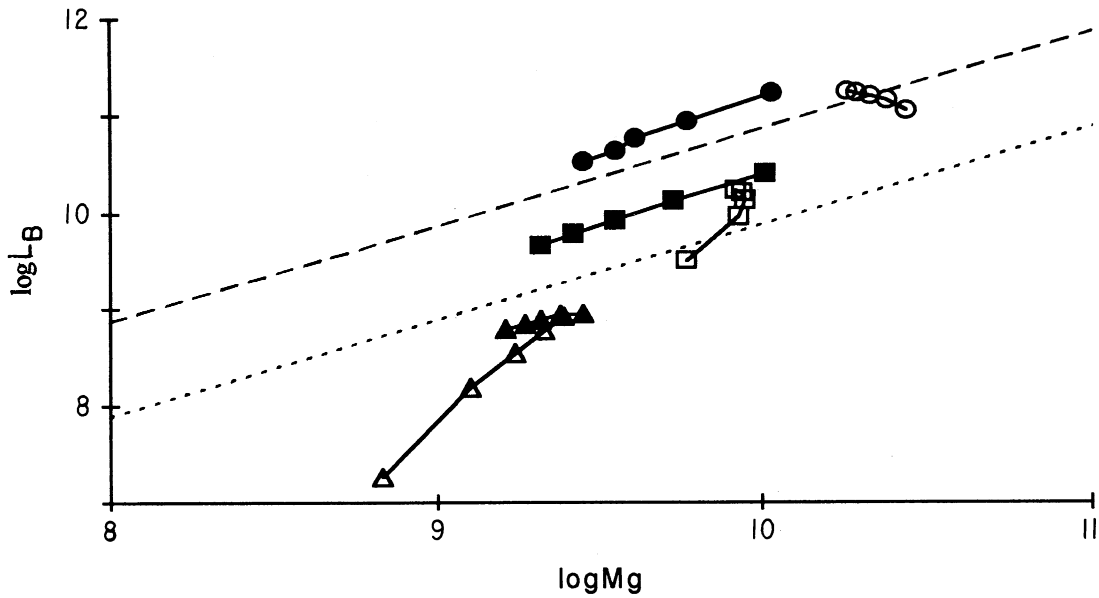

Fig. 1. The diagram $\log L_B$ vs. $\log M_g$ for evolutionary tracks of closed models (filled symbols) and open models (open symbols). Triangles, squares and circles indicate models with a final surface density $\log \Sigma = 1, 2$ and 3 in units of $M_\odot/\mathrm{pc}^2$, respectively. The symbols indicate times at 3, 6, 9, 12 and 15 Gyr. In all cases the evolution is faster during the early phases. The short (long) dashed straight line show the observational data best fits for $\log \Sigma = 1(3)$.

The relationship among gas surface density Σ_g, B brightness Σ_B and color index B-V is closely connected with the physics of the SF history. In fact Σ_g gives a measure of the "fuel" available for the SF, Σ_B is related to the surface density of the formed stars as well as to the present SFR per surface unit, and B-V strongly depends on the SF history of the last 10 Gyr.

In Fig. 2 we show the constant B brightness lines, in unit of $L_{B\odot}/pc^2$, in the $\log \Sigma_g$ vs. B-V diagram, where Σ_g is given in $M_\odot/pc^2$. The lines are obtained by interpolation from the evolutionary tracks. It is interesting to note that the constant B brightness lines are independent from the accretion regime of the models as well as from the coefficient of the SF power law. Fig. 3 shows the same diagram for the galaxies of the sample introduced previously.

Despite the scatter, a gradient of Σ_B may be appreciated. A statistical analysis shows a reasonable greement between theory and observations. In the linear approximation for a constant color index the bservations give $\Delta \log \Sigma_g = (3 \pm 1)\Delta \log \Sigma_B$ while the models give $\Delta \log \Sigma_g = 4\Delta \log \Sigma_B$. Any attempt to mprove the agreement between theory and observations has to be grounded on observational data that takes nto account the local features of the galaxies.

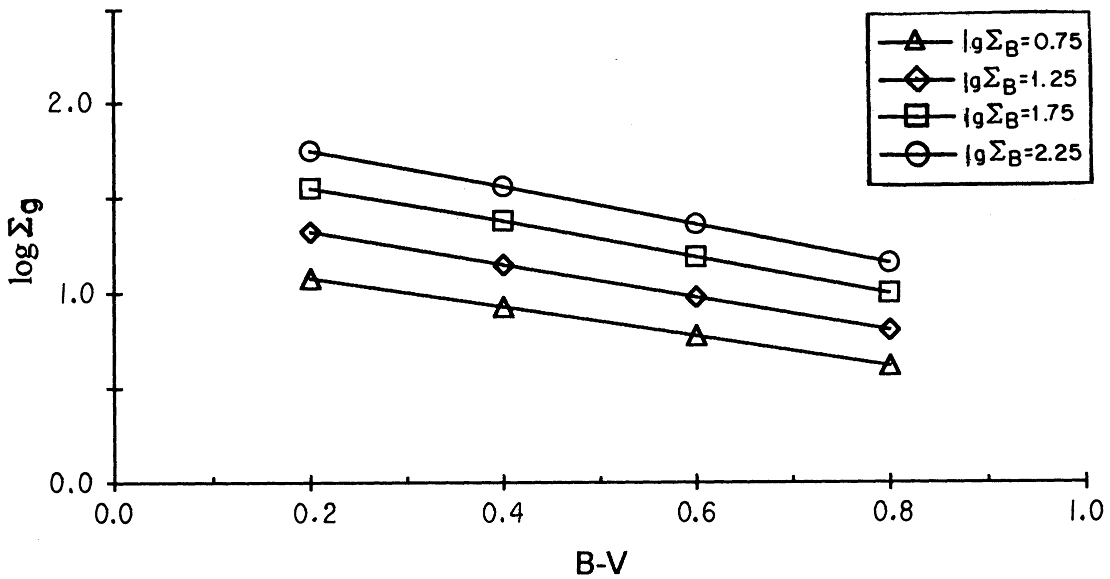

Fig. 2. The diagram $\log \Sigma_g$ vs. B-V for the constant B brightness lines obtained from the evolutionary tracks.

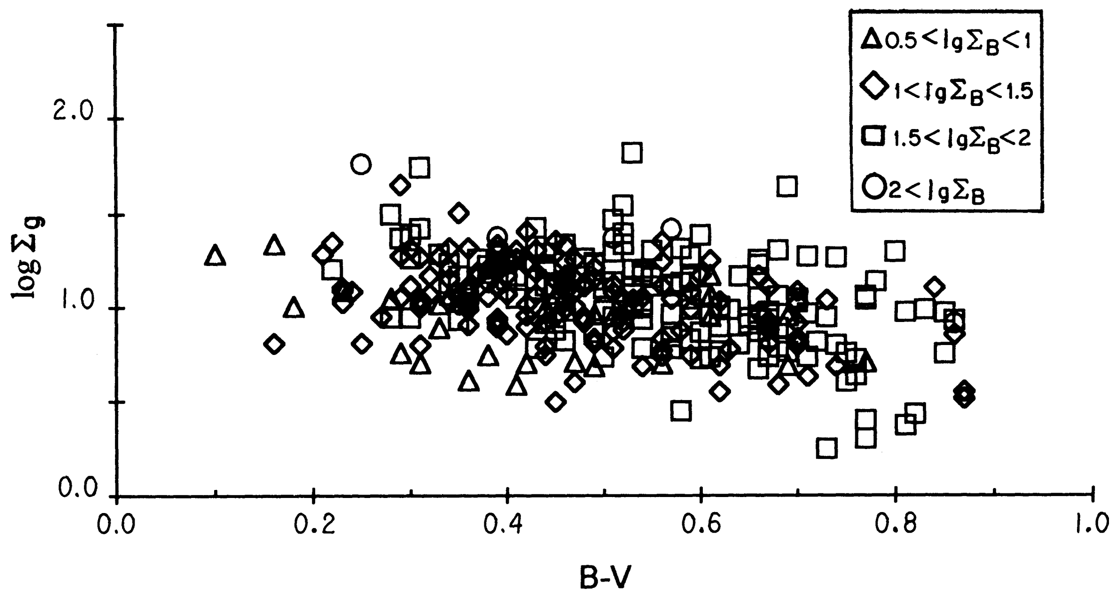

Fig. 3. The diagram $\log \Sigma_g$ vs. B-V for the galaxies of the sample described in the text. the symbols are related to $\log \Sigma_B$.

3. CONCLUSIONS

Stationary SF evolutionary models are compared with empirical relations obtained from a sample of late type galaxies compiled from Tully's (1988) and RC3 catalogues. Even if the models describe the local physics of a disk galaxy, they agree reasonably well with the integral observed features given by the catalogues. Particular attention is devoted to the $\log L_B$ vs. $\log M_g$ vs. $\log \Sigma$ and $\log \Sigma_g$ vs. B-V vs. $\log \Sigma_B$ correlations, that are intimately related to the SF history of a galaxy. In each case the third variable determines the scatter in the diagram of the first two variables. The models confirm this dependence. An interesting point is that the uncertainty in the SF law as well as in the gas accretion regime does not influence the theoretical result.

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