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PROPERTIES OF DISK GALAXIES IN PHENOMENOLOGICAL MODELS OF GALAXY FORMATION

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RESUMEN

Presentamos un modelo para comprender el origen y la evolución de la morfología de las galaxias, desde una perspectiva fenomenológica. El modelo incluye una receta -motivada por las observaciones- para la formación estelar en los discos galácticos, así como un modo de formación de brotes estelares activado por la fusión. Consideramos la formación de bulbos y de galaxias elípticas tanto durante las fusiones como en inestabilidades globales en los discos. Usamos nuestro modelo para investigar las principales propiedades de las galaxias de disco y los efectos de los límites del brillo superficial en los sondeos extensos de galaxias.

ABSTRACT

We present a model for understanding the origins and evolution of galaxy morphologies from a phenomenological perspective. The model includes an observationally motivated prescription for star formation in galaxy disks, as well as a merger-driven starburst mode of star formation. We consider the formation of bulges and ellipticals both in mergers and by global instabilities in disks. We use our model to investigate the fundamental properties of disk galaxies and the effects of surface-brightness limits on large galaxy surveys.

Key Words: **GALAXIES: FORMATION**

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1. INTRODUCTION

Our understanding of galaxy formation in a cosmological context has increased considerably over the last decade through the use of phenomenological models. In these models, stars form primarily in galaxy disks and bulges are assumed to form when two or more disk galaxies merge, or when bar instabilities lead to vertical heating of the disk. We use such a model for the evolution of galaxy morphologies to investigate the statistics of the fundamental parameters of disk galaxies. These results are particularly important for the interpretation of magnitude- or diameter-limited galaxy surveys, which may miss a significant population of low-surface-brightness (LSB) galaxies.

2. MODEL INGREDIENTS

The model used in this work is presented and discussed in detail in a paper soon to be published (Rimes, van Kampen & Peacock, in preparation). The basic ingredients are:

1. the merging history of dark-matter haloes, taken directly from an N-body simulation;
2. galaxy-galaxy merging and hot gas stripping;
3. the formation and evolution of gas disks, including the gravitational effects of the baryons;
4. star formation in galaxy disks according to a Schmidt law ($\Sigma_{\rm SF} \propto \Sigma_{\rm g}^{1.4}$) with a cut-off given by the Kennicutt threshold (Kennicutt 1989);
5. a merger-driven bursting mode of star formation;
6. injection of gas and metals from star formation into the cold ISM;
7. reheating of the cold ISM by supernovae;
8. stellar population synthesis, including the effects of dust extinction.

3. PROPERTIES OF DISK GALAXIES AT $z = 0$

In Figure 1 we plot the number density of galaxies as a function of central disk surface-brightness and exponential scale length in the B-band, as predicted by our model. The predicted distribution covers the full range of the observational data, which include surveys of both high and low surface-brightness galaxies, and extends well beyond the limits of current observations, with no significant fall-off in numbers seen until $\mu_0 \gtrsim 30$ B-mag as^{-2}. The existence of large numbers of LSB galaxies down to $\mu_0 = 25$ B-mag as^{-2} has been recognised for some time (e.g. Impey & Bothun 1997) and has important consequences both for observations and for theories of galaxy formation.

The lack of small, ultra-high surface-brightness galaxies is a consequence of disk self-gravity. Compact, self-gravitating disks are susceptible to bar instabilities (Efstathiou, Lake & Negroponte 1982), which lead to vertical heating and the eventual destruction of the disk.

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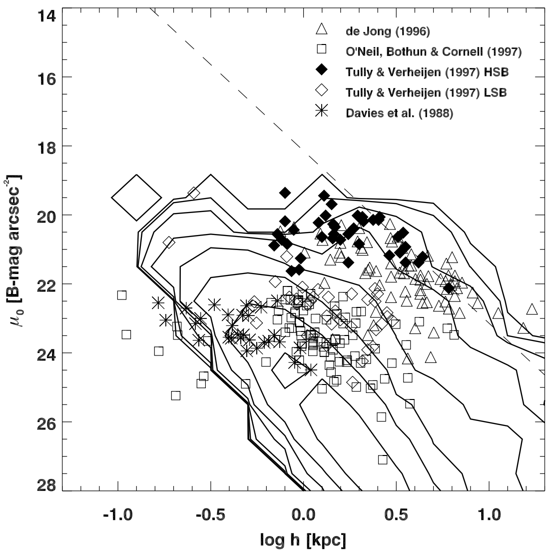

Fig. 1. Bivariate distribution of central disk surface-brightness against exponential scale length. Contours are the number density of galaxies as predicted by our model. The dashed line is the knee of the Schechter luminosity function.

4. SELECTION EFFECTS IN GALAXY SURVEYS

Understanding the processes that determine the spatial distribution of light in galaxies is important because it is this, not the total flux, that primarily determines whether or not a galaxy is included in an observational sample. It has been pointed out (Cross et al. 2001) that a large part of the variation in measurements of the faint-end slope of the luminosity function may be due to the different limiting isophotes of the surveys used. To test this, we created mock surveys of a $7^\circ \times 7^\circ$ area of sky by laying eight N-body simulation boxes end-to-end along the line of sight and selecting galaxies with isophotal magnitudes of $B_{\rm iso} < 25$ and isophotal diameters of $d_{\rm iso} > 2''$, for different limiting isophotes. In Figure 2 we compare the intrinsic B-band luminosity function of the galaxies in our simulation with the luminosity functions derived from our mock surveys. The intrinsic luminosity function has a faint-end slope far steeper than any of the observational measurements plotted in Figure 2, a problem that has traditionally been resolved by invoking strong feedback from supernovae to suppress star formation in dwarf galaxies. Our results demonstrate that, if selection effects in the observed samples are accounted for, strong feedback may no longer be necessary (our fiducial model has weak feedback).

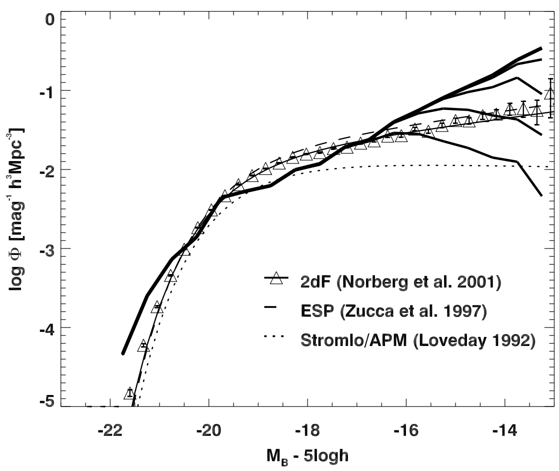

Fig. 2. The effect of isophotal limits on the field galaxy luminosity function. The heaviest solid line is the intrinsic luminosity function; the others are the predicted measurements for surveys with isophotal limits of (top to bottom) 26, 25, 24 and 23 B -mag as^{-2}.

In a future paper, we intend to model selection effects in real galaxy surveys and show that this can resolve many of the discrepancies between theory and observations.

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