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An Infrared View of Galactic Spheroid Formation

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Abstract. A popular theory for the formation of galactic spheroids involves the in-fall of gas-rich satellites onto pre-existing dark matter halos. We have explored predictions on counts, colors and star formation rates in the mid-to-far infrared from this scenario. The upcoming Space Infrared Telescope Facility (SIRTF) mission will provide strong constraints on spheroid evolution and its contribution to the cosmic infrared background and star formation history.

1. Introduction

A number of theories exist for the formation of galactic spheroids and ellipticals: primordial 'monolithic' collapse of individual gas clumps (Eggen et al. 1962), hierarchical merging of pre-formed galaxies (Toomre & Toomre 1972), in-fall of gas-rich satellites onto pre-existing dark matter disk halos (Cole et al. 1994; Carlberg 1999), and 'secular' evolution where bulges form relatively late by gas-inflow from their pre-existing gas-rich outer disk (Norman et al. 1996). A conclusion is yet to be reached, although the observed properties of ellipticals and bulges of spirals strongly support a merger (or satellite accretion) hypothesis as predicted by standard hierarchical models for galaxy formation.

We present here predictions of number counts expected in the SIRTF (MIPS) bandpasses using a scenario where spheroids form by the continuous accretion of gas-rich satellites. Within a CDM framework, a simple model involving wind-regulated accretion of gas-rich satellites was proposed by Carlberg (1999). The model has attained considerable success at explaining some general bulge properties: the 'Kormendy (density-size) relations', residual angular momentum distributions, and mass-metallicity correlations. Complete details will appear in a forthcoming paper (Masci et al. 2001).

2. An Empirical Model for Spheroid Formation

The model (Carlberg 1999) uses a Monte Carlo simulation and takes as input the following: a merger rate (fixed empirically from studies of galaxy clustering), a mass spectrum for the pre-accreted satellites provided by the standard CDM paradigm, and stellar feedback (wind) parameters for determining gas stripping fractions.

Assumptions for deriving far-IR source counts - essentially the merger induced starburst events integrated over time for all forming bulges are as follows:

1. The final, fully assembled bulges are normalized to the total space density of local bulges (in spirals, S0, E-type etc..) in the optical. This fixes the comoving volume of the simulation.

2. The star formation rate is given by $SFR = M_{acc}/\Delta t$ with burst timescale $\Delta t \simeq 10^7 yr$. M_{acc} is the total accreted gas mass.

3. The above SFR is modified by a redshift dependent efficiency parameter

$$\epsilon(z) = 1 - [1 - \epsilon(0)] \exp(-\beta z), \tag{1}$$

where $\epsilon(0)$ (the local SF efficiency) and β are model dependent parameters.

4. The far-IR luminosity is linked to the above SFR through an empirical relation derived locally by Smith et al. (1998). A Miller & Scalo IMF is assumed with mass range: $1M_\odot < M < 100M_\odot$.

5. An IR-SED library for starbursts from the spectrophotometric models of Devriendt (1999) is assumed for the K-corrections. A dependence of SED shape on IR-luminosity that reflects observed IRAS colors is included.

While assumptions concerning burst timescales and the IMF (2 and 4) are weekly constrained by observations, our model is relatively insensitive to these parameters. Assumption 3 however, concerning the efficiency at which gas is converted into stars as a function of z has a significant affect on the relative number of faint sources predicted.

3. Results

The deep ISO (15μm) surveys constitute the best available statistics for probing evolution within the range $0 < z \lesssim 1.3$ (Elbaz 1999). In Figure 1 we have assumed a 'minimal' and 'maximal' model defined by two different forms for evolution of the SF efficiency (Eqn.1). These correspond to respectively factors of ≈ 6.7 and ≈ 17 increase in SF efficiency from $z = 0$ to $z = 1$. An open cosmology with $\Omega = 0.3$, $\Lambda = 0$ and $H_0 = 65 \mathrm{km\,s^{-1} Mpc^{-1}}$ is assumed.

4. Conclusion

The main conclusion is that evolution in *both* merger rate and star formation efficiency is required, consistent with findings by Roche & Eales (1998) and Blain et al. (1999). We also predict a contribution of $\approx$70% to the IR background at 60μm and $\approx$10% and $\approx$50% of the global star-formation rate density at $z = 0$ and $z = 1.5$ respectively from bulge-building alone.

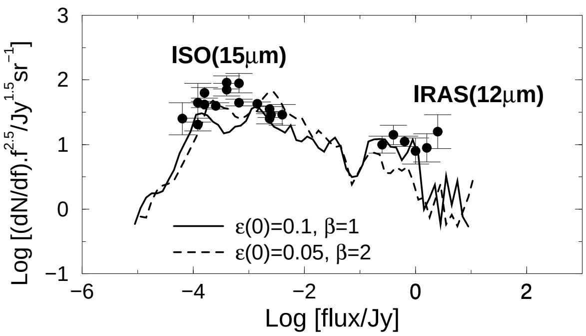

Figure 1. Euclidean normalised 15μm differential counts with data from Elbaz (1999) (15μm) and Spinoglio et al. (1995) (12μm).

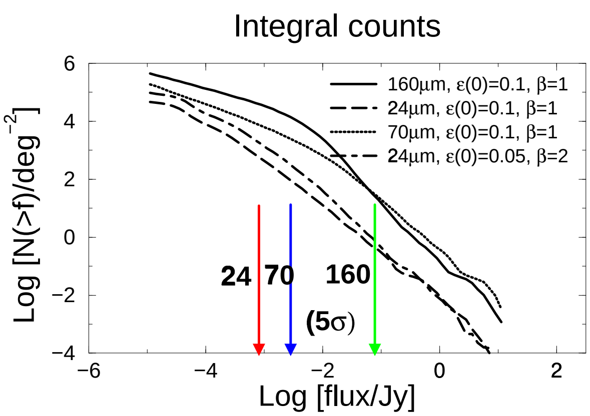

Figure 2. Integral counts in SIRTF's MIPS bands. Vertical arrows indicate 5σ sensitivities.

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