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POPULATION SYNTHESIS MODELS FOR NORMAL GALAXIES WITH DUSTY DISKS

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ABSTRACT

To investigate the SEDs of galaxies considering the dust extinction processes in the galactic disks, we present the population synthesis models for normal galaxies with dusty disks. We use PEGASE (Fioc & Rocca-Volmerange 1997) to model them with standard input parameters for stars and new dust parameters. We find that the model results are strongly dependent on the dust parameters as well as other parameters (e.g. star formation history). We compare the model results with the observations and discuss about the possible explanations. We find that the dust opacity functions derived from studies of asymptotic giant branch stars are useful for modeling a galaxy with a dusty disk.

Keywords: galaxies, evolution, infrared, dust, extinction

1. INTRODUCTION

The spectral energy distribution (SED) of a galaxy reveals the extinction and re-emission processes in the interstellar medium as well as the radiation from many types of stars. A theoretical population synthesis model is sensitively influenced by the property of the radiative processes and completeness of the spectral library of stars. The spectrophotometric synthesis is the only method that can do a population synthesis. The population synthesis model calculation combines several factors as the initial mass function (IMF), star formation rate (SFR), libraries of evolutionary tracks and model atmospheres which give an effect to the evolution of galaxies.

In this paper, we investigate the SEDs of galaxies considering the extinction processes in the dusty disks. We use PEGASE (Fioc & Rocca-Volmerange 1997) to model the galaxies with dusty disks with standard input parameters for stars and new dust parameters.

2. DUST GRAINS IN GALAXIES

We use silicate and graphite dust grains for extinction in the dusty disk of galaxies. For silicate, we use the optical constants of cool silicates derived by Suh (1999) and the ones from Draine & Lee (1984) for comparison. For graphite, we use the optical constants from Draine & Lee (1984).

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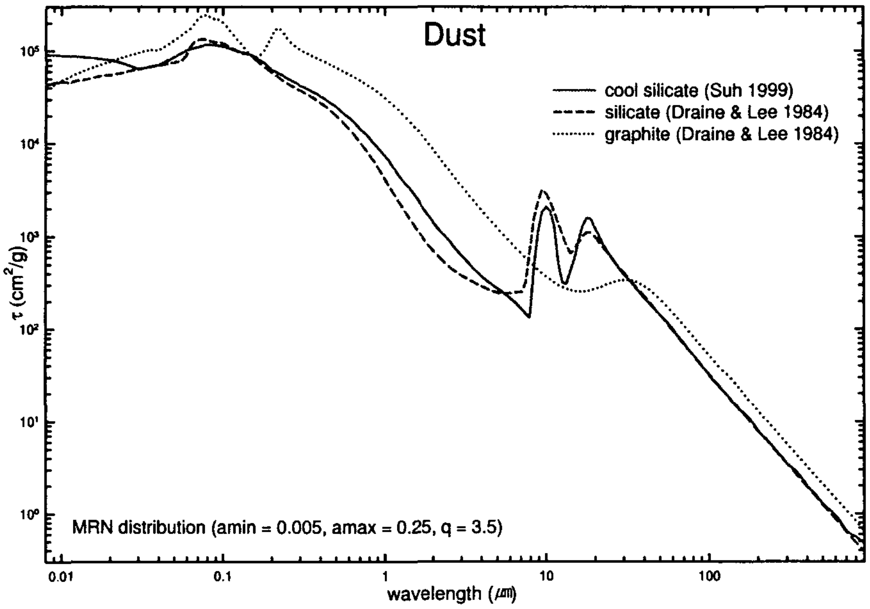

Figure 1. The opacity functions of dust grains.

We calculate the opacity functions assuming that the MRN (Mathis, Rumpl, & Nordsieck 1977) size distribution of the spherical dust grains. Fig. 1 shows the opacity functions. The ratio of silicate and graphite depends on the metallicity. Adopting the mixture obtained by Pei (1992) for our Galaxy, we use 57.73 % of silicate dust grains and 42.27 % of graphite dust grains by number for this paper.

3. THE POPULATION SYNTHESIS MODEL PARAMETERS AND THE MODEL SED RESULTS

We perform the evolutionary population synthesis model calculations using the following assumptions and parameters. For stellar tracks libraries, we use the ones from Lejeune, Cuisinier & Buser (1997, 1998). We use a fixed metallicity (Z=0.02). We assume that 70 % of the Lyman continuum photons are absorbed by the gas. The initial metallicity of the interstellar medium is zero. We prefer to start from a galaxy already constituted. The fraction of the star formation rate used to form substellar objects is zero. We assume that model there are no galactic winds that preventes star formation. The fraction of close binary systems used to compute ejecta of SNIa is 0.05. For the type of supernovae type II ejecta, we apply model B of Woosley & Weaver (1995). See Fioc & Rocca-Volmerange (1997) for details about the parameters.

A fundamental quantity for studying galaxy evolution is the IMF that specifies the distribution in mass of newly formed stars. We use the IMF from Rana & Basu (1992) as displayed in Fig. 2. The ξ(log m) is the IMF in units of stars/pc^2/(log m).

Another crucial parameter is the the star formation rate (SFR) history. We use the SFR functions assuming that the galactic mass is $10^{11} M_\odot$. For this paper, we use the two types of SFR scenario functions as discussed in Barbaro & Poggianti (1997) (Fig. 3, 4).

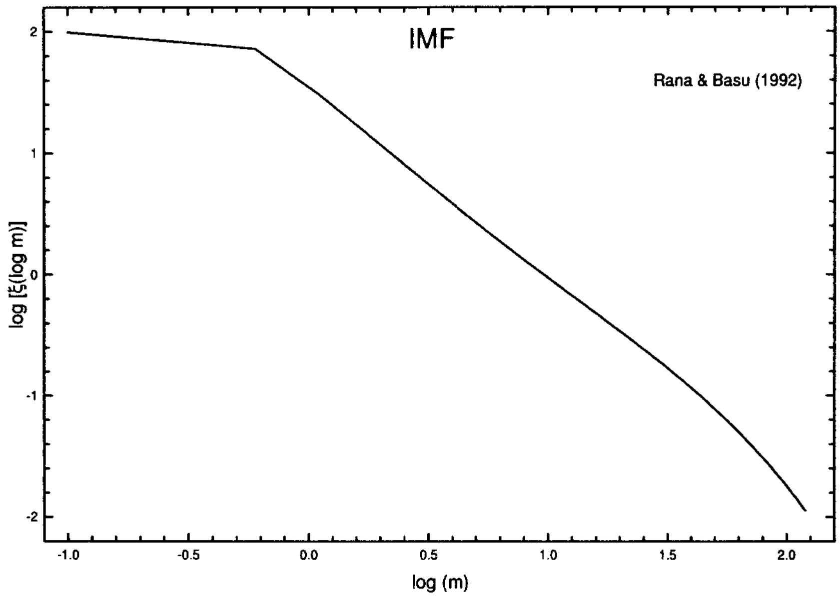

Figure 2. Initial mass function from Rana & Basu (1992).

The first type of the SFR history function is the exponentially decreasing one (Fig. 3).

$$SFR = p2\frac{\exp(-t/p1)}{p1} \tag{1}$$

Equation 1 is the SFR function used by PEGASE and the unit of p1 is Myr, and unit of p2 is $M_\odot$.

$$\psi(t) = \psi_0\beta\exp(-\beta t) \tag{2}$$

Equation 2 is the SFR function used by Barbaro & Poggianti (1997; see Fig. 3). The β parameter is related to the time scale of the star formation, ψ_0 depends on the galaxy mass. The parameters of these equations are related with β = 1/p1 and ψ_0 = p2. Table 1 lists the data from Barbaro & Poggianti (1997) which have been used for this paper (Fig. 3). The values of ψ_0 are the averaged ones from the data listed in the paper.

The second type of the SFR history function is in an asymmetric Gaussian form as displayed in Fig. 4. The SFR functions in the Fig. 4 use the data from Barbaro & Poggianti (1997). The values of the SFR in Fig. 4 are 5 $\times 10^{-12}$ times the values in the Table 8 in Barbaro & Poggianti (1997) who derived the data only for spiral galaxies.

In Fig. 5 and Fig. 6, we present the model SED diagrams for a typical Sb type galaxy at various ages. The model results with the type I SFR function (Fig. 3) are displayed in Fig. 5 and the results with the type II SFR function (Fig. 4) are displayed in Fig. 6. The first panels of Fig. 5 and Fig. 6 display the results without any dust extinction, the second panels use silicate dust grains of Suh (1999), and the third ones use silicate dust grains of Draine & Lee (1984). We assume that the extinction by the dust grains in the galactic disk is due to the averaged viewing inclination angle.

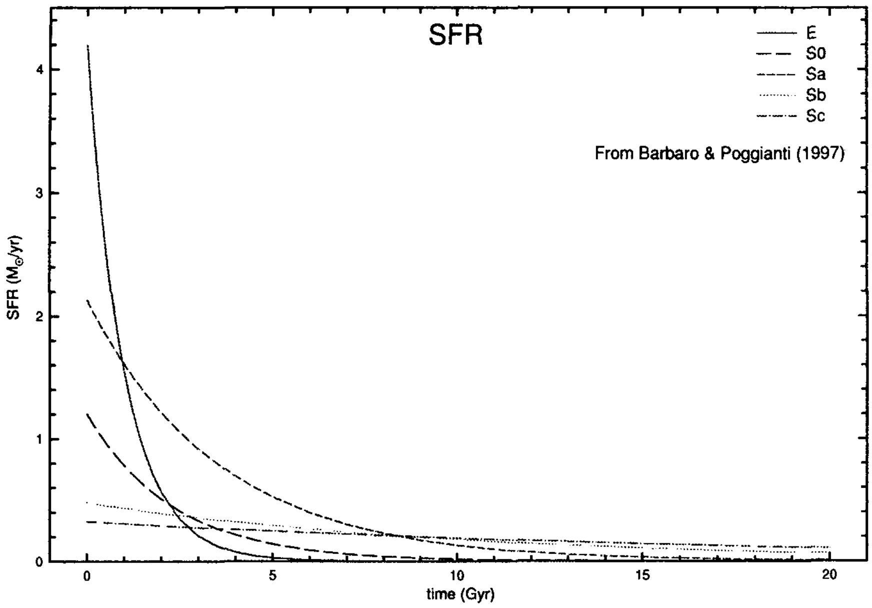

Figure 3. The type I SFR functions (see Table 1 for the parameters).

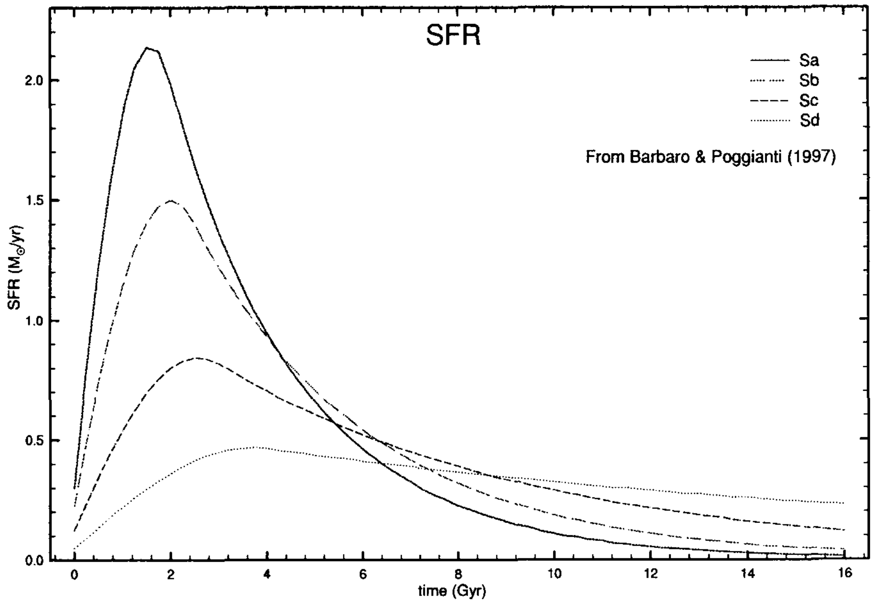

Figure 4. The type II SFR functions.

Table 1. Parameters for the exponentially decreasing (type I) SFR functions (see Fig. 3).

galaxy type	$\beta(Gyr^{-1})$	$\psi_0\ (M_\odot)$
E	1.000	0.042
S0	0.430	0.028
Sa	0.280	0.076
Sb	0.100	0.048
Sc	0.055	0.059

The SEDs in Fig. 5 and Fig. 6 show that the effect of the dust extinction is most significant at UV wavelengths and the effect is very minor at infrared wavelengths. Actually, the effect of dust is very large at infrared bands because of the emission from the dust grains (e.g. Panuzzo et al. 2003). The consideration of the emission from the dust grains is out of scope of this work.

4. 2-COLOR DIAGRAMS OF GALAXIES

We present the 2-color diagrams that compares the time evolution of the model results with the observations. The input parameters for the 2-color diagrams (Fig. 7 and Fig. 8) are identical to those for SED diagrams (see section 3; Fig. 5 and Fig. 6). The model results with the type I SFR functions (Fig. 3) are displayed in Fig. 7 and the results with type II SFR functions (Fig. 4) are displayed in Fig. 8. The first panels of Fig. 7 and Fig. 8 display the results without any dust extinction, the second panels use silicate dust grains of Suh (1999), and the third ones use silicate dust grains derived by Draine & Lee (1984).

We compare the positions of the model results at the age 13-14 Gyr (12 Gyr for Sc type in Fig. 7) with the observation ins Fig. 7 and Fig. 8 . The observation data were obtained by Aaronson (1978) for typical galaxies. We find that dust extinction is required to make a proper comparison with the observations.

For spiral galaxies, we find that the models with type II SFR functions and dust extinction produce the better fit with the observations. In this study, the silicate dust opacity functions from Suh (1999) which were derived for asymptotic giant branch stars fit the observations even better than the ones from Draine & Lee (1984) which were derived for interstellar dust. Comparing the two panels in Fig. 8, we find that the second panel shows the model results which fit the observations of Sb, Sc, and Sd type galaxies very well. This is due to different slopes of the opacity functions obtained by different schemes (see Fig. 1).

5. CONCLUSIONS

To investigate the population synthesis models for normal galaxies with dusty disks, we have used standard input parameters for stars and new dust parameters for the galactic disks. We find that the model results are strongly dependent on the dust parameters as well as other parameters (e.g. star formation history). Comparing the model results with the observations, we find that dust extinction is required to explain the observations properly. We find that the dust opacity functions derived from studies of asymptotic giant branch stars are useful for modeling a galaxy with a dusty disk.

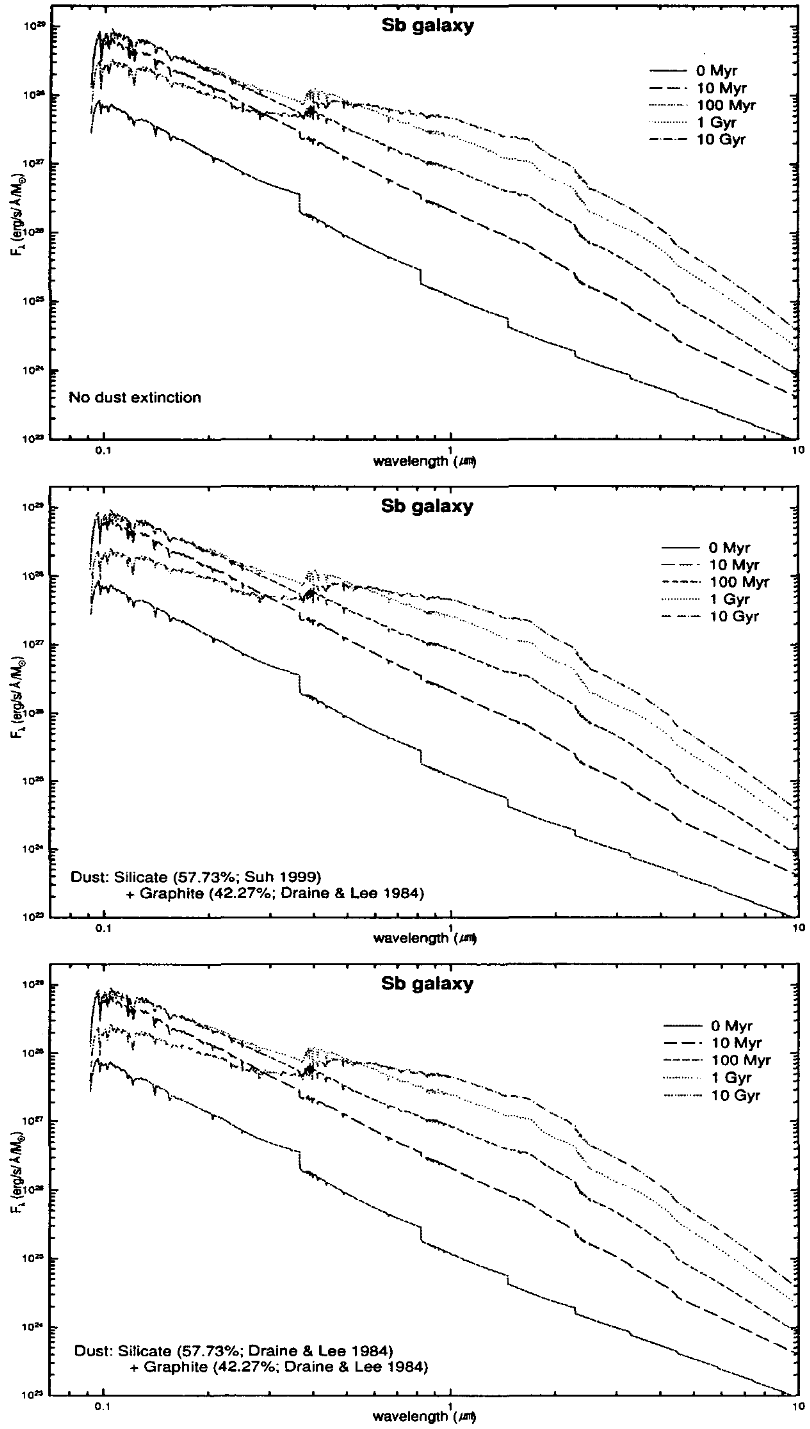

Figure 5. The model SEDs for the Sb galaxy with the type I SFR function (Fig. 3).

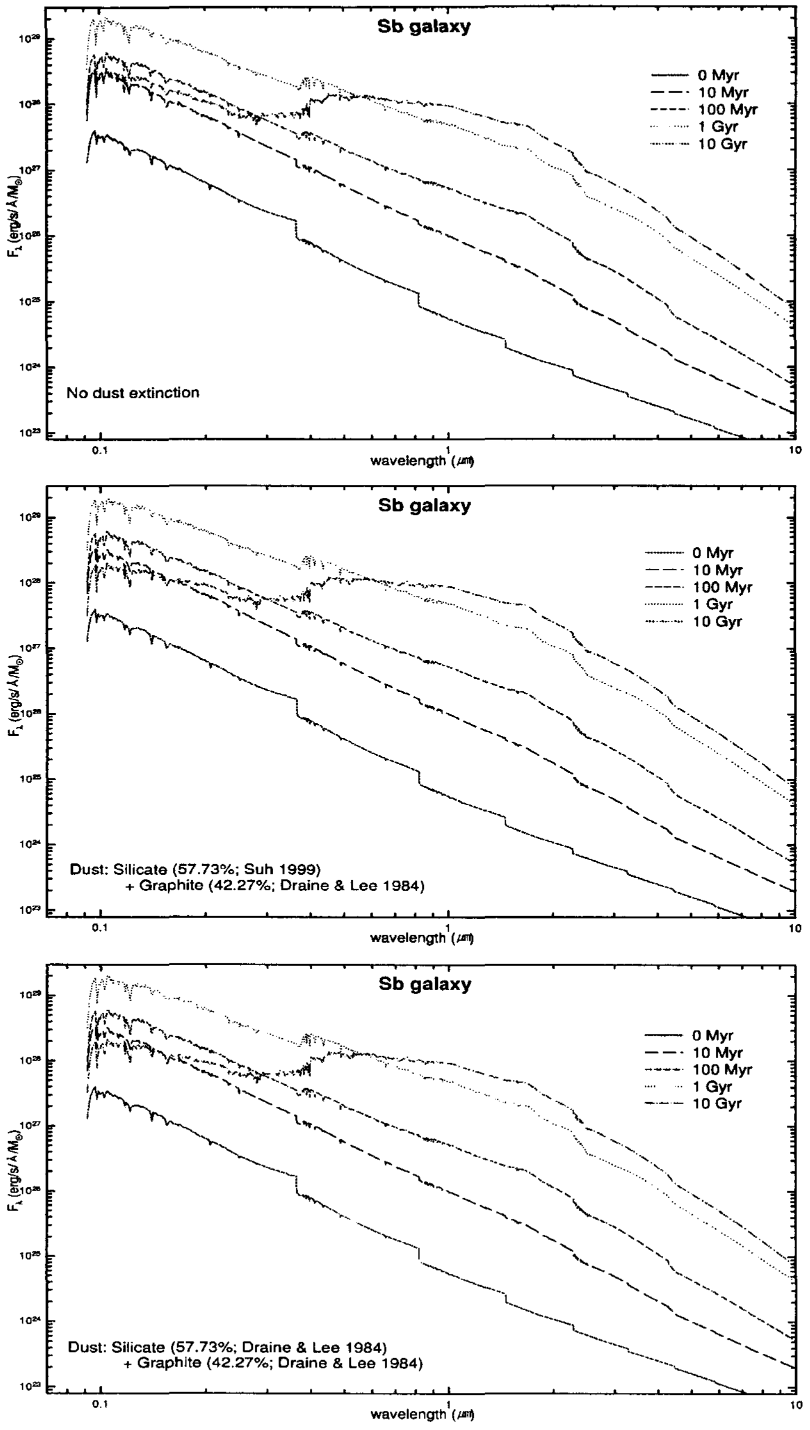

Figure 6. The model SEDs for the Sb galaxy with the type II SFR function (Fig. 4).

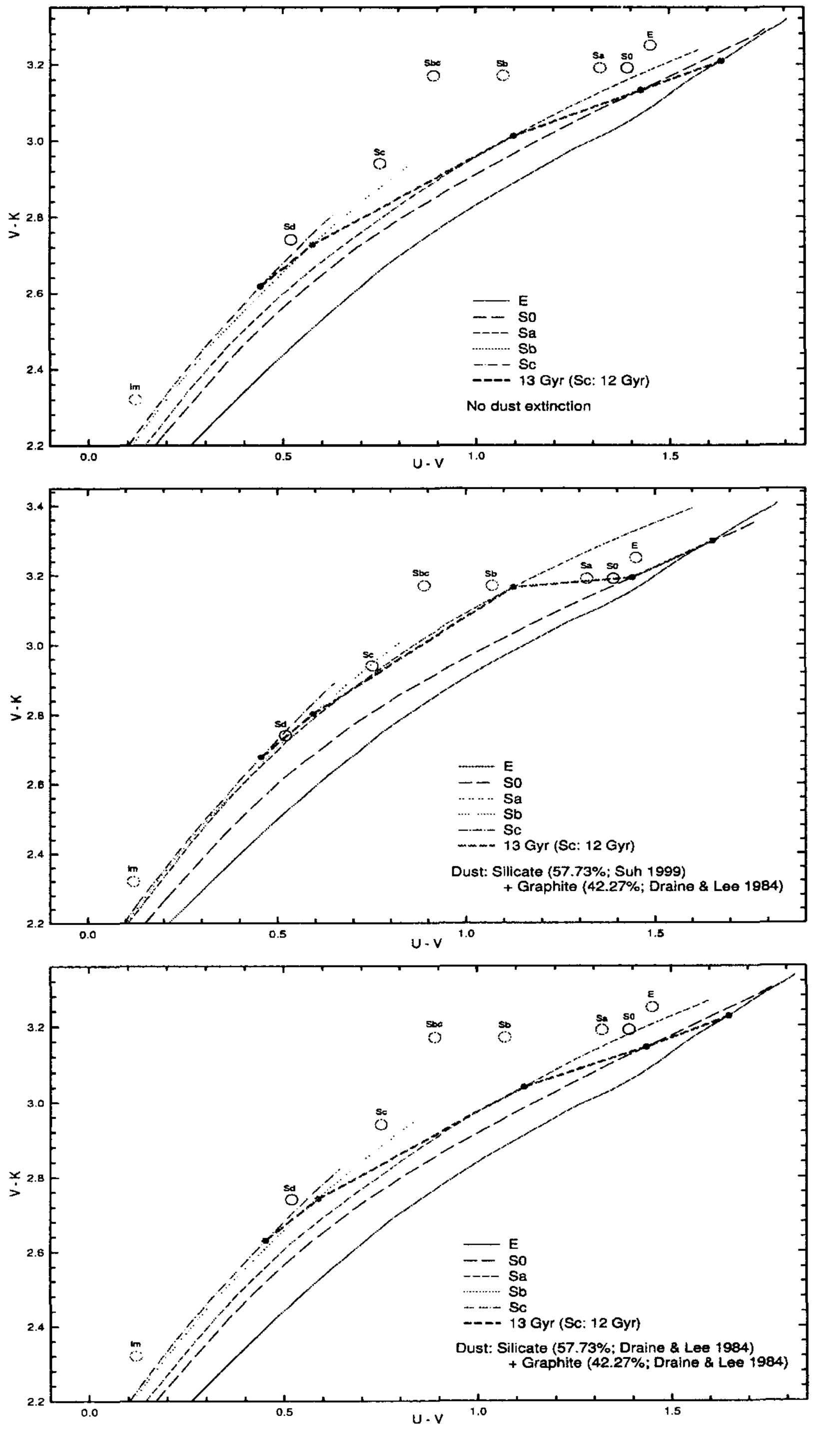

Figure 7. 2-color diagrams of various galaxy types with the type I SFR functions (Fig. 3). The circle symbols represent the observational data from Aaronson (1978).

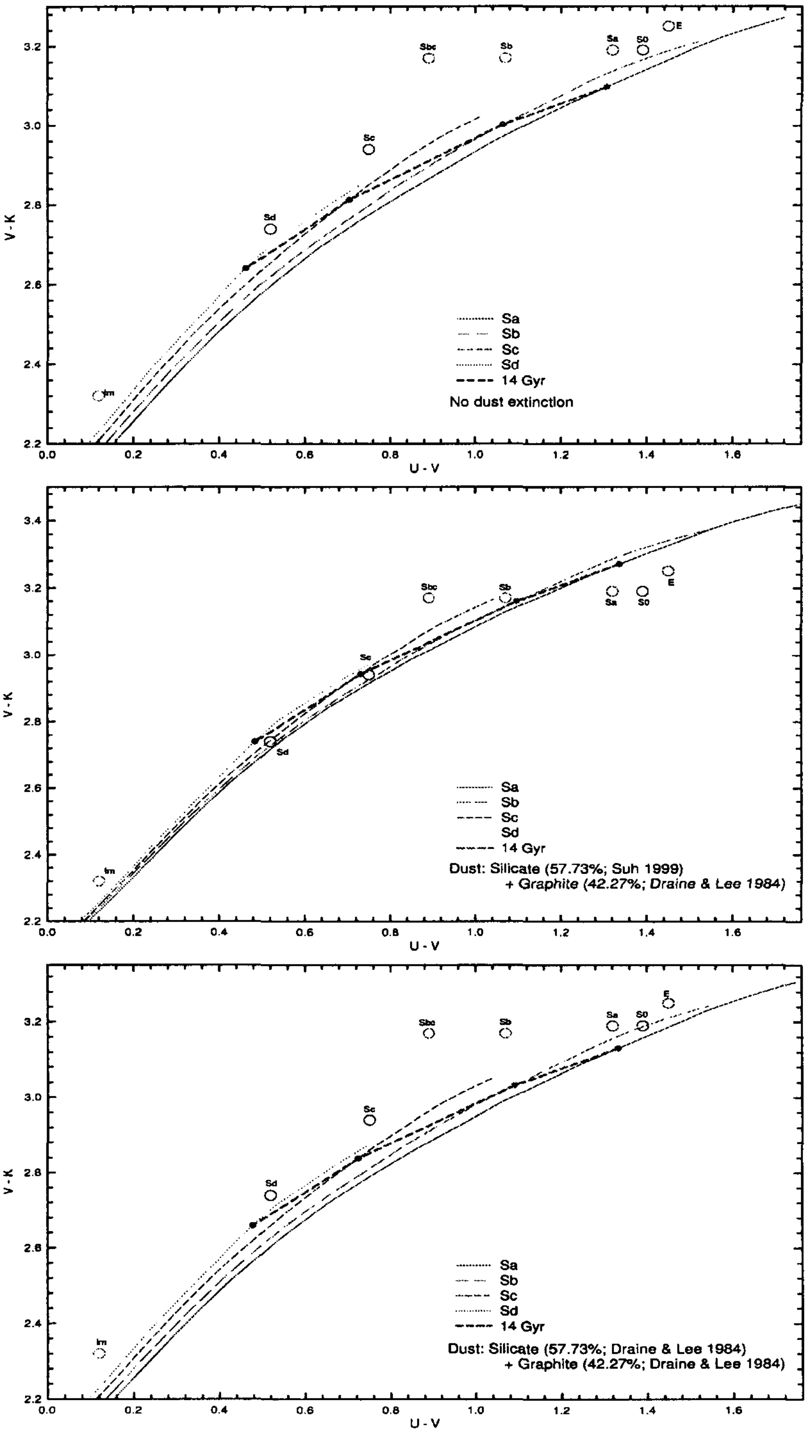

Figure 8. 2-color diagrams of various spiral galaxy types with type II SFR functions (Fig. 4). The circle symbols represent the observational data from Aaronson (1978).

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