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Some Effects of Dust on Photometry of High-Z Galaxies: Confounding the Effects of Evolution

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Photometric observations of very distant galaxies — e.g., color vs. z or magnitude vs. z — have been used over the past decade or so in investigations into the evolution of the stellar component. Numerous studies have predicted significant color variations as a result of evolution, in addition to the shifting of different rest wavelengths into the band of observation. Although there is significant scatter, the data can be fit with relatively straightforward, plausible models for galaxian evolution. In very few cases are the effects of dust extinction included in the models. This is due in a large part to the uncertainty about the distribution and optical properties of the grains, and even whether or not they are present in significant numbers in some types of galaxies such as ellipticals. It is likely that the effects of dust on broadband observations are the greatest uncertainty in studies of very distant galaxies.

We use a detailed Monte Carlo radiative transfer model within a spherical geometry for different star/dust distributions to examine the effects of dust on the broadband colors of galaxies as a function of redshift. The model fully accounts for absorption and angular redistribution in scattering. In this summary, we consider only the effects on color vs. redshift for three simple geometries each with the same total dust optical depth. Elsewhere at this conference, Capuano, Thronson, & Witt consider other effects of altering the relative dust/star distribution.

Some of our results are shown in the following figure, where we have plotted (heavy lines) the V-R colors vs. redshift adapted from the galaxian evolution models of Yoshii & Takahara (1988; ApJ, 326,1), which do not include effects of dust (heavy lines). The caption describes the characteristics of each model. Our results are the three lighter lines which show the effects of extinguishing the "A" model for three plausible geometries each with $\tau_V = 1$.

From $z \approx 0 \rightarrow 0.6$ our models show very little effect on the observed color, as expected: for modest optical depths, the reddening effects of absorption are almost exactly canceled by the bluing effects of scattering. Furthermore, for all optical depths, the composite stellar light remains dominated by the relatively unobscured stars closest to the observer (e.g., Mathis 1970; ApJ, 159, 263). Consequently, large amounts of dust may be present with little effect on the observed colors. Note, however, that significant absorption of stellar radiation by dust is possible. Thus, our models trivially produce high ratios of infrared-to-visual (i.e., dust-to-stellar) light in systems that are only slightly red.

However, beginning at $z \approx 0.7$ the UV is shifted into the V passband. For these rest wavelengths, conventional grains have a much lower albedo than at longer visual wavelengths. All other things being equal, distant galaxies will appear distinctly redder than closer systems. We note that in these (vastly oversimplified) models, galaxies may change color very significantly for a modest change in z as the wavelength regime most heavily affected by the dust is shifted into the passbands of observation. Such a sudden color change might be partially masked by the effects of stellar evolution, although as the figure indicates, broadband evolutionary effects may be much smaller than those of dust.

For clarity, we have not included the effects of different cosmological models in this figure. However, the effects of dust in our models are also larger than the effects of cosmology for $z \geq 0.7$. We emphasize that in addition to very poorly known geometries, the most significant uncertainty in our models are the grain optical parameters in the ultraviolet.

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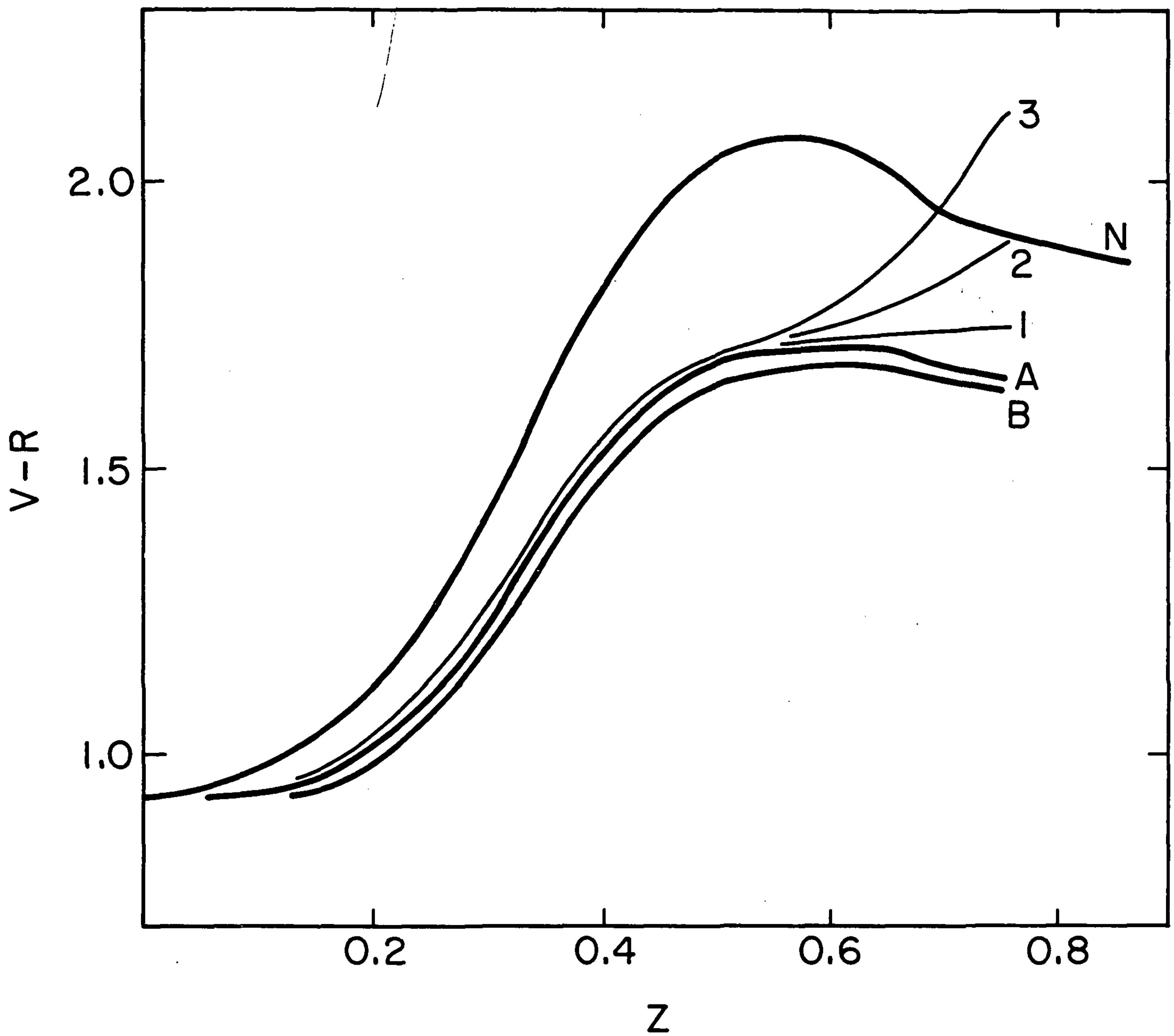

Figure 1: The effects of dust on the spectral energy distribution of galaxies may be both significant and difficult to predict. The three heavy lines show the predicted V-R colors as a function of z from the models of Yoshii & Takahara (1988), where "N" refers to no evolution and "A" and "B" represent colors predicted for systems formed at $z = 5$ and 3, respectively. The results of our spherical model transfer calculations are shown as the numbered lighter lines representing changes to "A" depending upon the dust/star geometry. Model "1" has a small sphere of dust centered on a larger sphere of stars; "2" is our model elliptical galaxy with a r^{-3} stellar distribution and r^{-1} dust distribution; "3" is a uniform mixture of stars and dust. In all cases $\tau_V = 1$ measured from the center to the surface.