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Star-Dust Geometries in Galaxies: The Effect of Interstellar Matter Distributions on Optical and Infrared Properties of Late-Type Galaxies.

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The presence of substantial amounts of interstellar dust in late-type galaxies affects observable parameters such as the optical surface brightness, the color, and the ratio of far-infrared to optical luminosity of these galaxies.

We conducted radiative transfer calculations for late-type galaxy environments to examine two different scenarios: one, the effects of increasing amounts of dust in two fixed geometries with different star distributions; and two, the effects of an evolving dust-star geometry in which the total amount of dust is held constant, for three different star distributions. The calculations were done for ten photometric bands, ranging from the far-ultraviolet to the near-infrared (K), and scattered light was included in the galactic surface brightness at each wavelength. The energy absorbed throughout these ten photometric bands was assumed to re-emerge in the far-infrared as thermal dust emission.

Our principal result is that frequently invoked measures of dust mass, such as brightness reduction due to extinction, reddening, and the ratio of far-infrared to optical flux ratios are highly unreliable indicators of the actual amount of dust present in a given system. The residual surface brightness of a galaxy is largely determined by the stars not directly obscured by dust, and so is the color excess. The ratio of far-IR to optical flux depends mainly on the ratio of stellar luminosity deeply embedded in dust clouds to that only lightly affected by dust. Thus, the star luminosity distribution relative to the dust is far more important than the actual dust mass. Models differing solely in the relative distribution of stars relative to dust differ by more than one order of magnitude in the ratio of L(IR)/L(Opt). (See Fig. 1)

We also considered the evolutionary contraction of a constant amount of dust relative to pre-existing star distributions. In a spherical geometry, the optical depth increases with the inverse square of the length scale. Again, the star distribution is critical in determining whether in the process of dust contraction a greater fraction of sources is freed from the extinction effects or whether a greater fraction of the light of the sources still remaining in the dust is now absorbed due to the increasing optical depth. Thus, the contraction of a constant amount of dust can lead either to an increase in the optical surface brightness and a decline in the ratio L(IR)/L(Opt), in the case of a uniform star distribution, or to a decrease in surface brightness and a substantial increase in L(IR)/L(Opt), when the star distribution is strongly concentrated in the volume of space toward which the dust contraction occurs. (See Fig. 2)

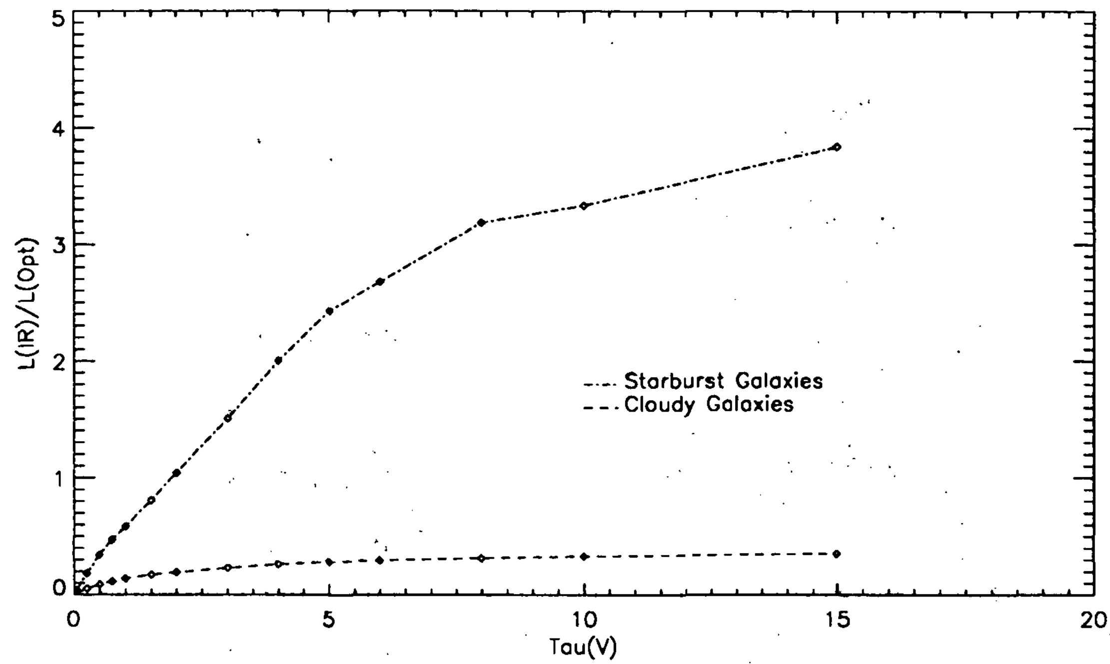

Fig. 1 – The ratio of infrared emission from heated dust grains, L(IR), to the total emitted starlight, L(Opt), for two environments as a function of V-band extinction optical depth, measured from the surface of the spherical geometry to the center. The dust occupies the inner one-third of the volume of these systems. The cloudy galaxy has a uniform star distribution, while the starburst galaxy has a radial luminosity distribution following a r^{-6} law.

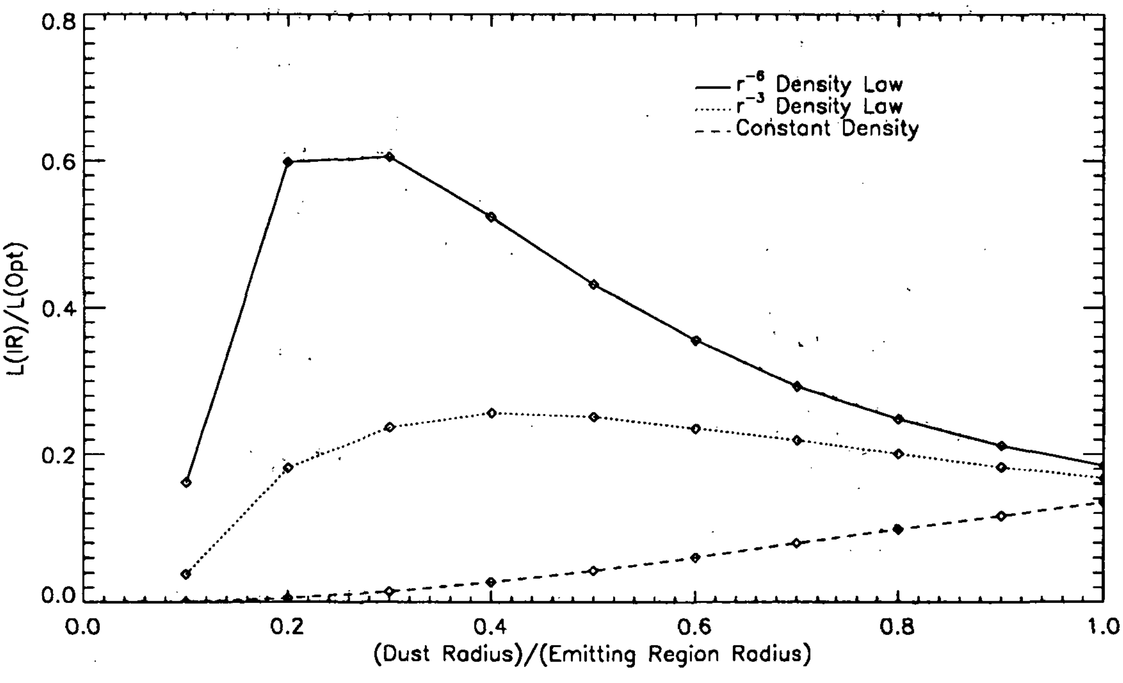

Fig. 2 – The ratio of L(IR)/L(Opt) for three different star distributions, in which a uniform dust distribution is allowed to contract from an initial V-optical depth radius of 0.25 (dust radius/radius of star distribution = 1.) to a final $\tau_v = 25$ (dust radius/radius of star distribution = 0.1). The three star distributions correspond to uniform density, a r^{-3} law, and a r^{-6} law.