N91-14109

# A Survey of the Properties of Early-Type Galaxies

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A compilation of the properties of elliptical and early disk galaxies has been completed. In addition to material from the literature, such as IRAS fluxes, the compilation includes recent measurements of HI and CO, as well as a review of the x-ray properties by Forman and Jones. The data are used to evaluate the gas content of early systems and to search for correlations with x-ray emission.

The interstellar medium in early-type galaxies is generally dominated by hot interstellar gas ($T \sim 10^7$ K; c.f. the review by Fabbiano 1989 and references therein). In addition, a significant fraction of these galaxies show infrared emission (Knapp, et al., 1989), optical emission lines, and visible dust. Sensitive studies in HI and CO of a number of these galaxies have been completed recently, resulting in several detections, particularly of the later types. We wish to understand the connection among these different forms of the interstellar medium, and to examine the theoretical picture of the fate of the hot gas. To do so, we have compiled observations of several forms of interstellar matter for a well-defined sample of early-type galaxies. Here we present a statistical analysis of this data base and discuss the implications of the results.

The sample we have chosen is a group of 467 galaxies from the Revised Shapley-Ames Catalog that were classified there as E, S0, SB0, Sa, or peculiars of those types. We include IRAS observations, x-ray properties, and radio data on HI, CO, and continuum emission, as well as the usual optical properties. Information from the literature has been supplemented by unpublished data on HI, CO, and x-rays.

As expected the later types -- the Sa's and peculiar Sa's -- commonly have observable quantities of interstellar material. More than 90 percent of the objects that have been searched with high sensitivity have emission at both 100 microns and in HI or CO. The early disk systems, the S0's, also are frequently found in the IRAS survey, and almost half of the objects surveyed with high sensitivity at radio wavelengths are found to have either HI or CO. However, it continues to be difficult to find observational evidence for significant amounts of cold matter in elliptical galaxies. Fewer than half are known to be 100 micron sources, and very few of the ellipticals surveyed with high sensitivity are detected in HI. This is in marked contrast to the hot component of interstellar gas; more than two-thirds of the ellipticals that have been searched at x-ray wavelengths were detected.

The HI detection rate for E's and for S0's is illustrated in Fig. 1 as a histogram of the HI mass normalized by blue luminosity. Both the value of this ratio and the frequency of detection is significantly different between these two galaxy types. Capture alone, which seems to be the case for the ellipticals, cannot account for the HI in (most) S0's unless a rather complex time and depletion mechanism is invoked. A census of the

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[1]Operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation

interstellar content of E's and S0's is displayed in Fig. 2. Note that only detections are shown; upper limits, often very stringent, are not included in this display. In this sample the x-ray, HI, and $H_2$ masses are typically in the range $10^8$-$10^{10.5}$ M⊙ while those for dust (from 100 microns) and emission line gas are $10^3$-$10^7$ M⊙ ($H_o$=50).

The data set offers the possibility of studying the correlation between various properties of early-type galaxies. For example, in a commonly-discussed model, the source of the x-ray emitting gas in ellipticals is stellar mass loss. Ejecta from one star colliding with ejecta from another star initially heats the gas, and infall deeper into the potential well causes additional heating. When other sources of heat are unimportant, the steady-state x-ray luminosity should be the product of the total mass loss rate and the square of the velocity dispersion (Sarazin and White 1988). Since the total mass loss rate is proportional to $L_{opt}$, one expects $L_x \propto L_{opt}\sigma^2$. The velocity dispersion is related to $L_{opt}$, which leads to the prediction $L_x \propto L_{opt}^{1.7}$ Using the 48 elliptical galaxies for which improved optical data are available, (Faber et al., 1989), and which have information about their x-ray emission, we find that $L_x \propto L_{opt}^{2.3}$, with an uncertainty in the exponent of 0.2. The discrepancy does not arise because of our use of the Faber-Jackson relationship. The quantities $L_x/L_{opt}\sigma^2$ and $L_{opt}$ are correlated, demonstrating that a modification of the theoretical model is required.

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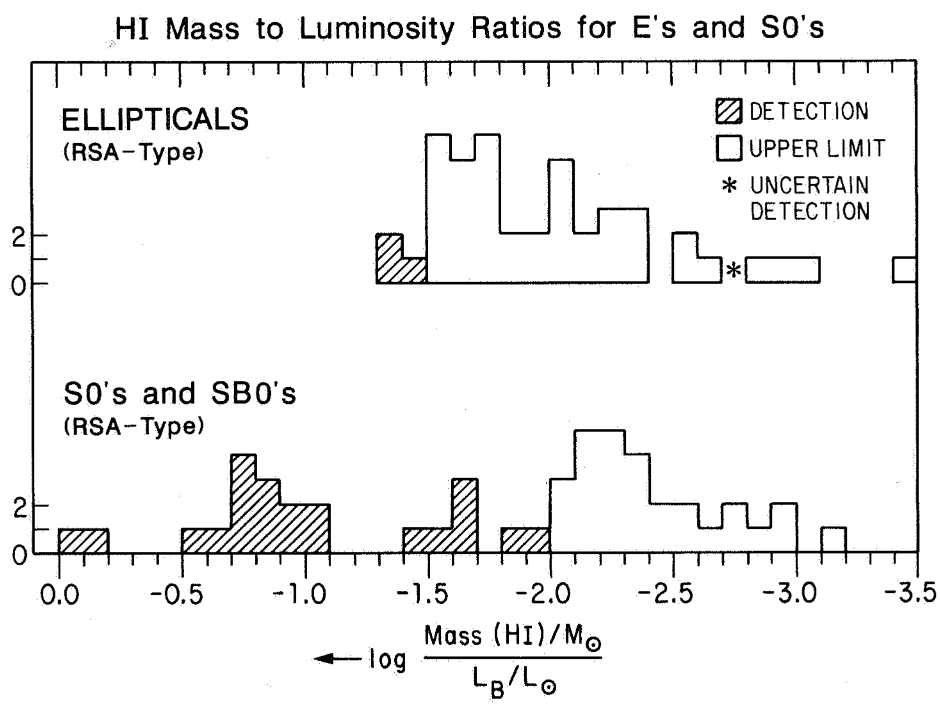


Fig. 1. Histograms of the ratios: log(HI mass/blue luminosity) for E's and S0's. Detections are cross-hatched, upper limits are shown as open blocks. Only upper limits less than the lowest detections are shown. Note: Revised Shapley-Ames classifications only are used.

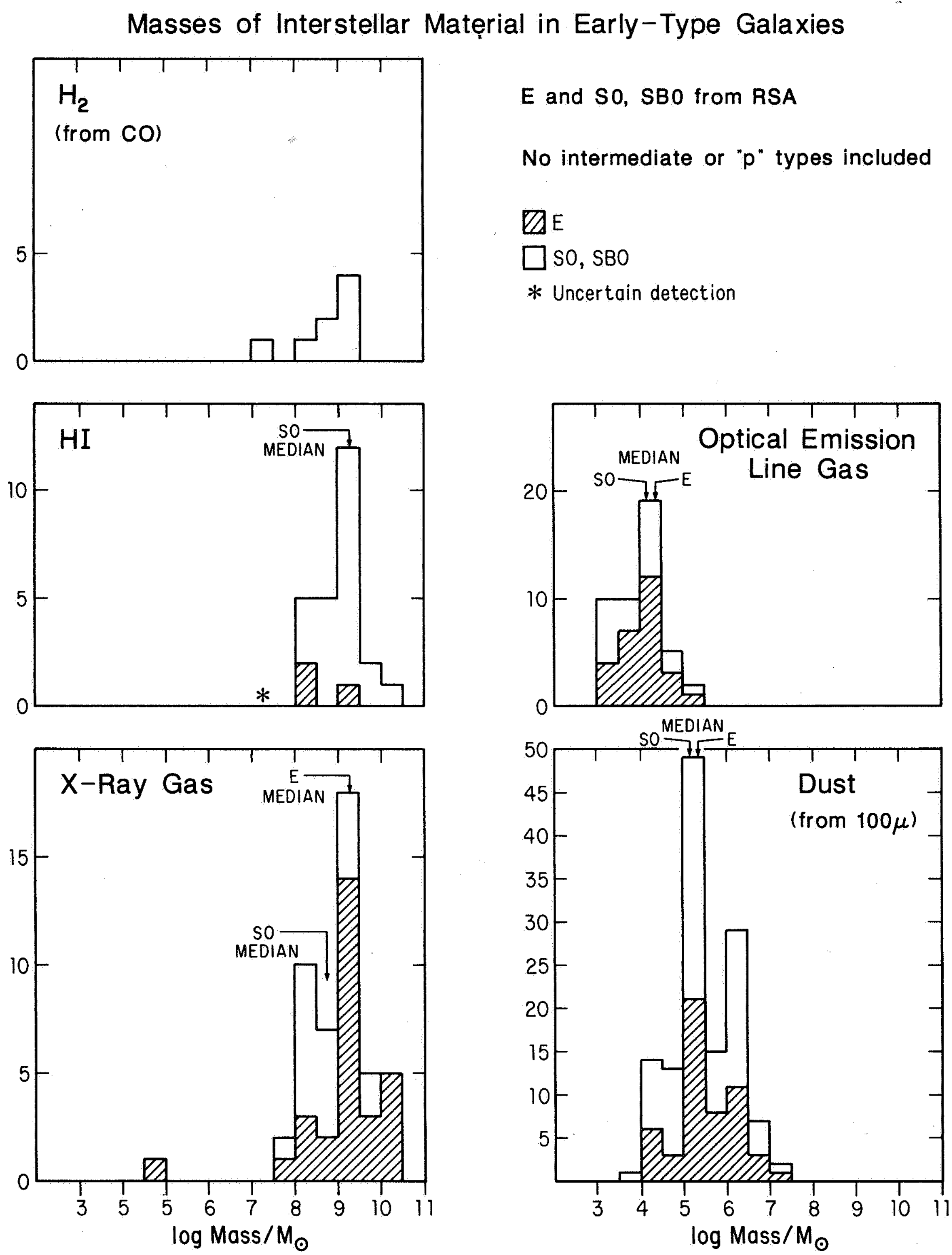


Fig. 2. A census of the amount of various forms of interstellar material in E, S0, and SB0 galaxies in the Revised Shapley-Ames Catalog, a magnitude-limited sample. Upper limits, often very stringent, are not illustrated.