COMPARISON OF ASTEROID AND METEORITE SPECTRA BY PRINCIPAL COMPONENTS ANALYSIS. Daniel T. Britt, David J. Tholen, Jeffrey F. Bell, and Carle M. Pieters; (1) Dept. of Geological Sciences, Box 1846, Brown Univ., Providence RI 02912; (2) Institute for Astronomy, Univ. of Hawaii, 2680 Woodlawn Dr., Honolulu HI 96822; (3) Hawaii Institute of Geophysics, Univ. of Hawaii, 2525 Correa Rd., Honolulu HI 96822.

Introduction: A number of quantitative techniques have been used to classify asteroids on the basis of their spectral and albedo characteristics. All of these methods have been successful in separating the bewildering spectral variety of the asteroids into a number of distinct classes in statistical or albedo/color-ratio space. The validity of these classes is strongly supported by the distinct and relatively limited zones in the main asteroid belt occupied by each class. A logical next step is to extend this successful line of analysis to direct classification comparisons between the asteroids and their compositional analogs, the meteorites.

Methodology: To quantitatively classify the spectral characteristics of both asteroids and meteorites we used the technique principal components analysis as applied by Tholen [1]. This statistical technique can quantify the variance in a data set and represent this variance by projecting it into an arbitrary space of orthogonal principal components where distance between samples is a measure of dissimilarity. Asteroid spectra for the study were taken from the 8-color survey of Zellner et al. [6] and the meteorite spectra were taken from the extensive laboratory study of Gaffey [7]. The high-spectral resolution laboratory meteorite spectra were converted into the 8-color system by a computer resampling routine using digital versions of the filter band passes of the 8-color system. All spectra were scaled to unity at 0.55 microns to remove albedo as a factor in the analysis. The spectra of 412 asteroids and 116 meteorites were used in this analysis.

Results and Discussion: Shown in Figure 1 is a plot of the total data set. Asteroids are represented by the letter of their Tholen class (see [8] for an explanation of classes), and the meteorites are represented by symbols. To simplify this plot, Figure 2 is an enlargement of the densest portion of Figure 1. The individual asteroid data points have been eliminated and the zones of principal component space occupied by each asteroid spectral class are outlined. Only the individual meteorites are represented by symbols. In this analysis the first principal component tends to be sensitive to the general slope of the spectrum with red slopes having positive values and flat slopes having negative values. The second principal component is correlated with the strength of absorption bands in the IR and UV regions. A few general points can be made about the distribution of meteorites in principal component space. First, the analysis was successful in identifying basic similarities; mineralogically similar meteorites tend to plot near each other and meteorite groups tend to occupy definite areas. Second, the wider distribution of meteorites in principal component space demonstrates there is more variance in the meteorite spectra than is seen in the asteroid spectra.

Looking in detail at the relative positions of asteroids and meteorites tends to confirm some theories, but it also produces some surprises. Eucrites display substantial variance and plot away from the main body of asteroids and near the position of the asteroid Vesta, their suggested analog [9]. Ordinary chondrites also show large variance and overlap the area occupied by the eucrites. However, they also tend to plot near their suggested analog, the Q-class asteroid Apollo [10,11]. The other suggested analog for the ordinary chondrites, the S-class asteroids, are offset to the right and above the ordinary chondrites due to their weaker one-micron bands and red continuum slope.

The CM and CI carbonaceous chondrites, which have traditionally been linked with the C-class asteroids, plot near them but slightly below and offset to the right. They generally correspond to Tholen's G-class, which has a slightly deeper UV absorption than the C-class. The optically altered black chondrite meteorites also tend to plot with the low-albedo C and G-class asteroids [12]. Several authors have suggested that CO and CV carbonaceous chondrites may be analogs for some S-type asteroids and they argue for the creation of a new class "K" to represent these objects [2,13]. In this analysis the CO and CV chondrites plot in lower left of the S-class field along with those S-class asteroids suggested as possible members of the K-class. This supports the interpretation of class K asteroids (and the Eos asteroid family which contains most of them) as a possible source of the CO's and CV's [13,14]. The placement of the iron meteorites is surprising. Their suggested analogs are the M-class asteroids (shown as X in the plots), but these asteroids tend to be systematically less red sloped than their meteorite analogs. This may be due to the fact that Gaffey's spectra of iron meteorites were obtained from cut surfaces rather than powdered samples and probably do not adequately reproduce the scattering properties of real metal asteroid regoliths [15]. The enstatite chondrites are also offset from their suggested analogs, the E-class asteroids. Perhaps the most interesting result is that no meteorites plot with the F, B, P, or D-class asteroids, tending to confirm work that points to meteorite collections sampling a relatively limited portion of the asteroid belt [16].

Conclusions: In general, this analysis provides semi-quantitative support for most compositional interpretations of asteroids based on qualitative visual comparisons of spectra. The offset seen in iron, enstatite chondrite, and carbonaceous chondrite meteorites from their common asteroid analogs suggests a systematic suppression of the spectral red slope in these asteroids, perhaps due to regolith processes. For example, particle size has been shown to strongly affect the spectra of carbonaceous chondrites [17], and the particle size distribution on
asteroids is poorly constrained. The results of this analysis support the concept that the meteorite collection samples a relatively limited zone in the asteroid belt. The lack of similarity between the meteorites and the F, B, P, and D-class asteroids confirm a bias in the meteorite collections toward sampling the inner belt.


Figure 1: The first two principal components of a combined asteroid and meteorite spectral data set. Asteroids are denoted by the letter of their Tholen class and meteorites are denoted by symbols. The letter “X” refers to E, M, and P-class asteroids that tend to occupy the same principal component space.

Figure 2: An enlargement of the densest portion of Figure 1. For clarity individual asteroids have been eliminated and the area occupied by each asteroid class has been outlined. The lower left portion of the S-class area is the area for the proposed K-class.