A Search for Spectro-Dynamical Asteroid Families

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What are Spectro-Dynamical Families?

If an asteroid family results from the collisional disruption of a once-larger parent body, then the family members should meet TWO criteria:

- Follow similar orbits
- Be genetically related (ie: have spectral properties that make cosmochemical / petrological sense)

SMASSII study of families focused on region in semi-major axis between 2.7 and 2.8 AU (465 asteroids) - revealed spectral homogeneity within each of 19 families identified - No evidence for differentiated parent bodies.

Iniital results based on Hierarchical Clustering Method (HCM)

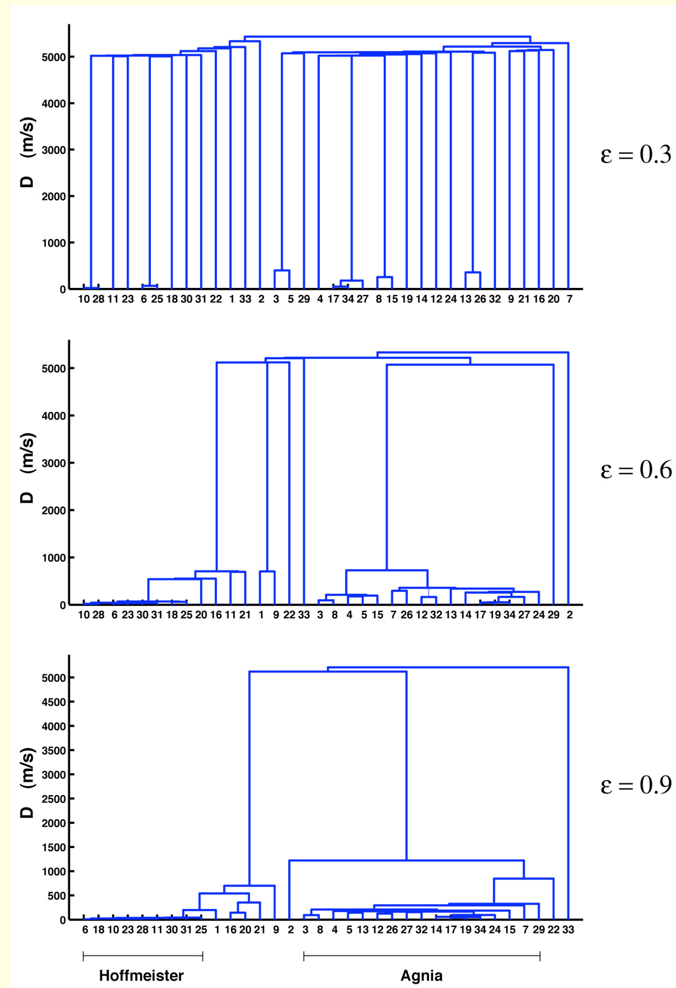
Transform proper elements (a,e,sin I) into dissimilarity matrix using D metric (Zappala et al. 1990, 1994, 1995).

Spectro-dynamical families identified while varying spectral dissimilarity cutoff, ε.

Advantages:

- Interlopers
- Better family boundaries
- Older, more dispersed families

Bias towards finding spectral homogeneity? Not really…



Expanded dataset

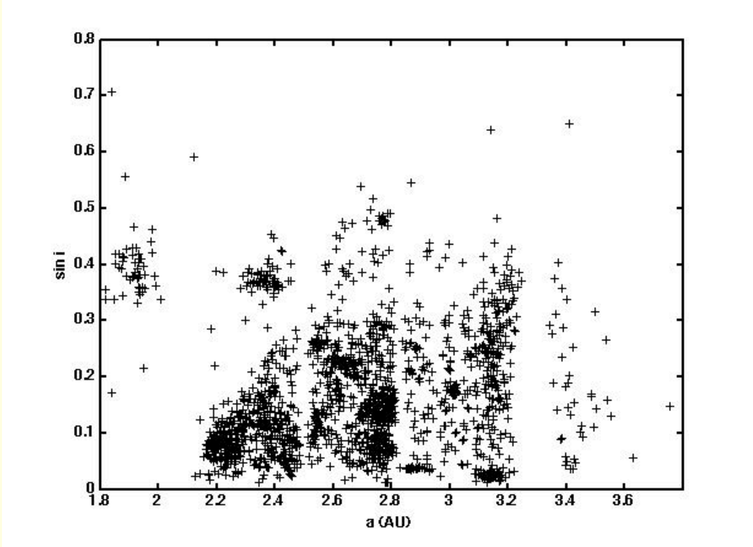
Idea for spectro-dynamical families revived with larger dataset that more evenly samples main belt:

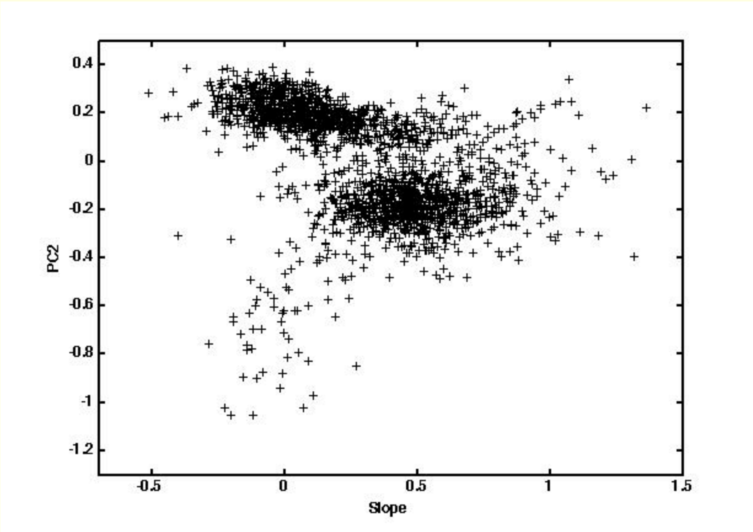
- SMASSI (Xu et al. 1995)
- SMASSII (Bus and Binzel 2002)
- S3OS2 (Lazzaro et al. 2004)

- 2,074 asteroid spectra

- 0.5 - 0.9 microns

Correct for systematic offsets between the three surveys.





Tale of Two Metrics (and TOO many clustering algorithms)

- D metric relates the orbital difference between two objects as a velocity - linear relationship.
- Spectral dissimilarity is not linear.
- The QUESTION: How should these two metrics be combined??
- HCM is agglomerative (versus divisive) clustering technique, and is best suited to clusters of similar size and density
- Literature is FULL of alternative clustering algorithms.
- Current focus is on Shared Nearest Neighbor (SNN) algorithms - much less sensitive to differences in family sizes or to variations in the local density of data points.

Shared Nearest Neighbor (SNN) Clustering

Examine local neighborhood around each data point, and count the neighbors shared between each pair of data points. The higher the number of shared neighbors, the greater the similarity between that pair of points. SNN density is defined as the number of neighbors with SNN similarities greater than a set value, Eps (method of Ertoz et al. 2003).

Advantages:

- Much less sensitive to changes in local density or family size
- Rejection of ‘noise’ points

Disadvantage:

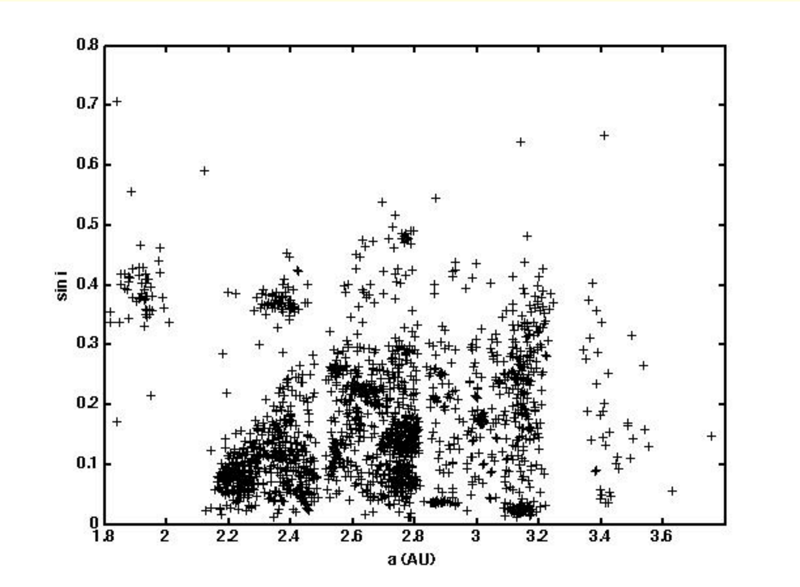
- Results vary with user-defined parameters (k, Eps, MinPts)

Preliminary Results

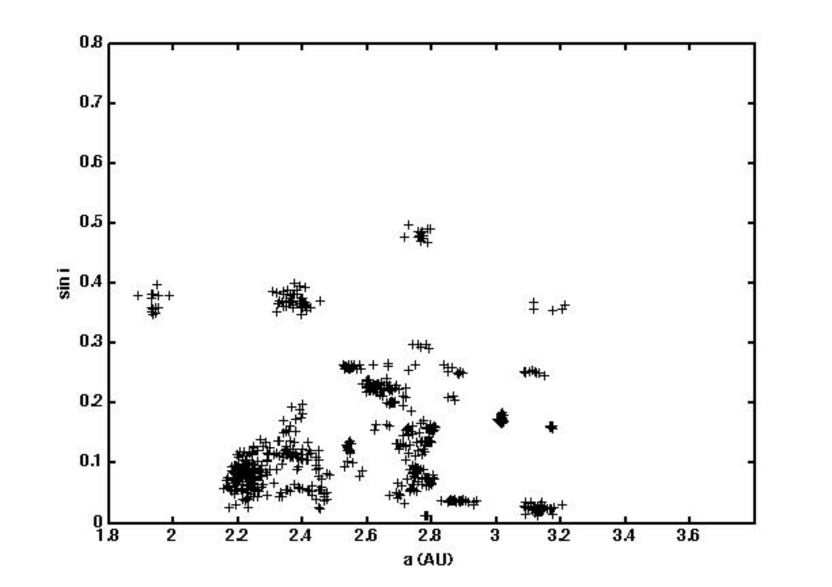
- Thus far, 42 spectro-dynamical families identified based on combined SMASSI - SMASSII - S3OS2 dataset (minimum number of objects which constitutes a family is 4).
- Full range of spectral types are represented between the different families.
- Magnitude of spectral variation among members of each family is the same (families appear quasi-homogeneous).
- No evidence for mixture of spectral types that could be interpreted as sampling different lithologic layers of differentiated parent.
- Further efforts are aimed at refining the combination of D and S metrics, and constraining input parameters for SNN algorithm.

Current Family Memberships

(plot of a versus sin i)

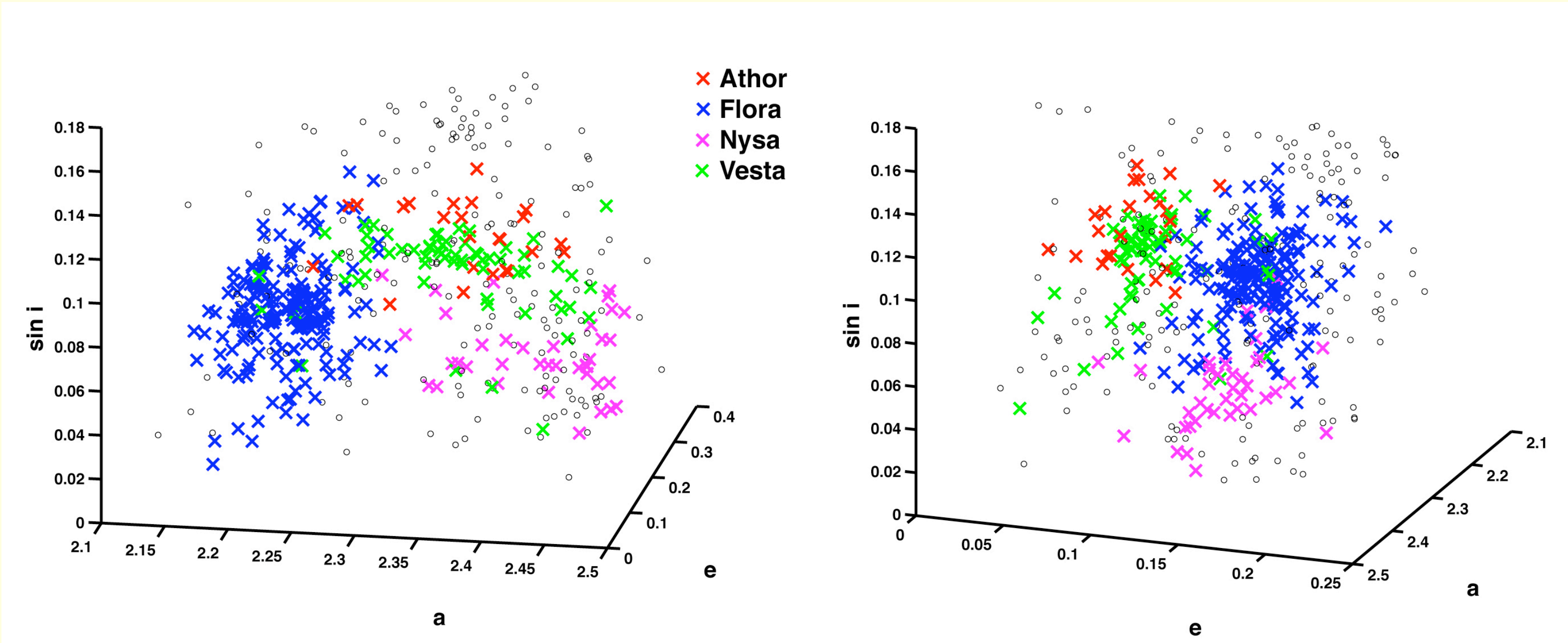


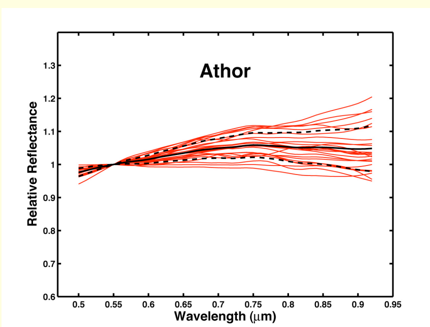
All 2,074 asteroids in sample

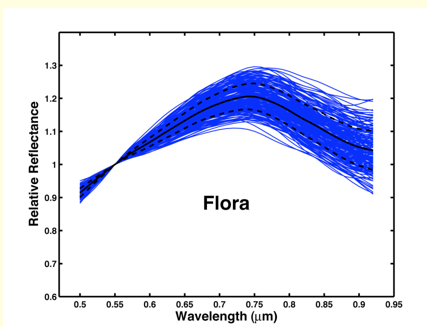


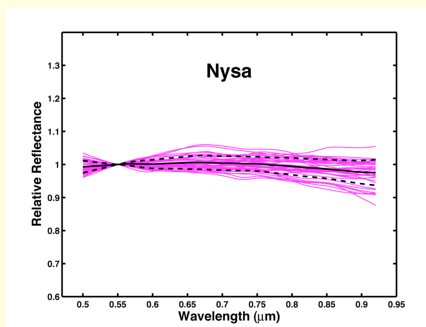
794 asteroids in 42 families

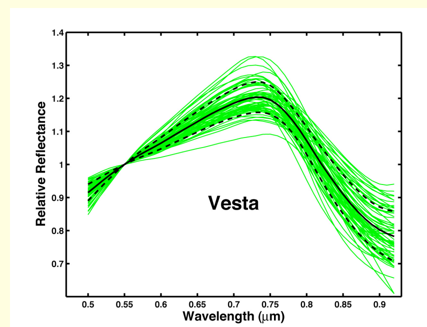
Sample Region #1



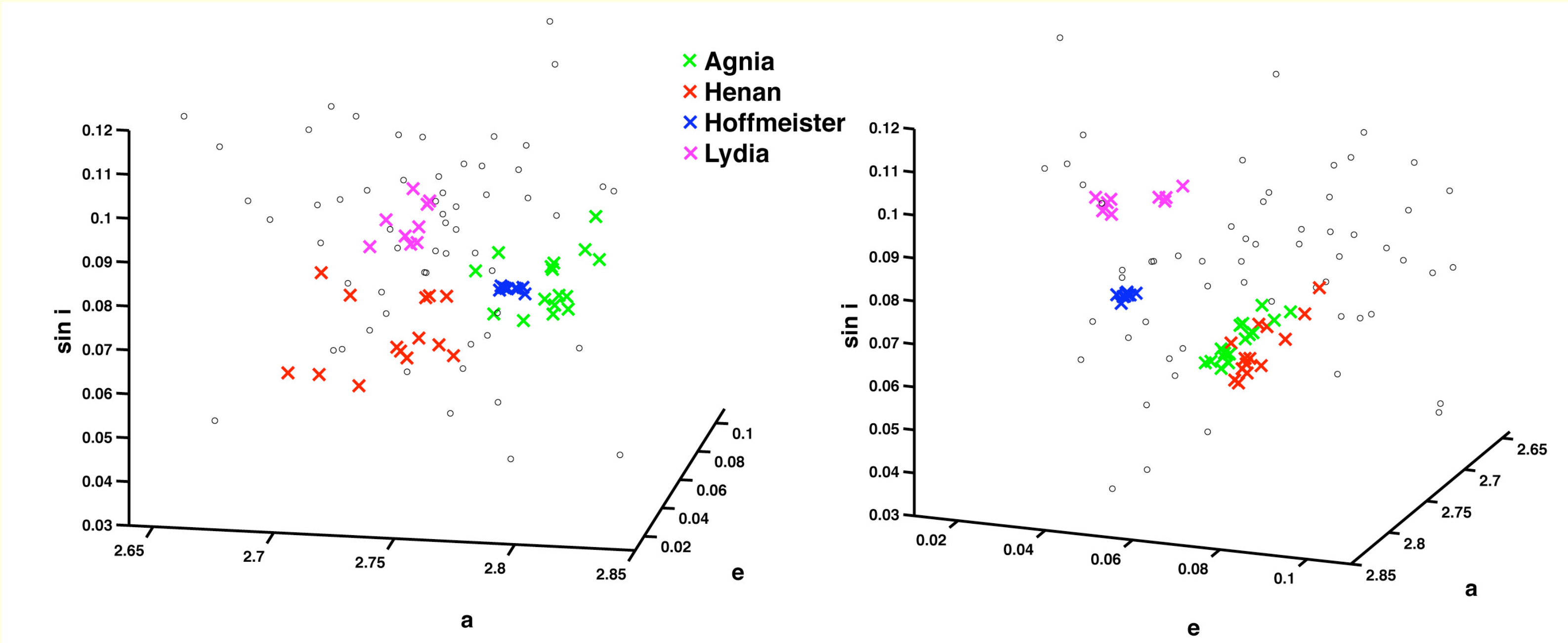


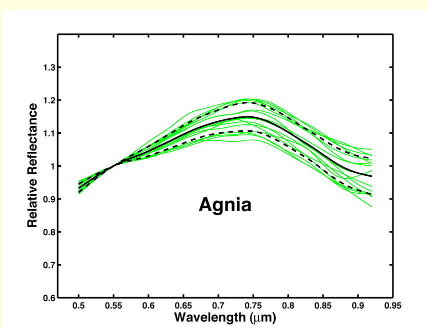


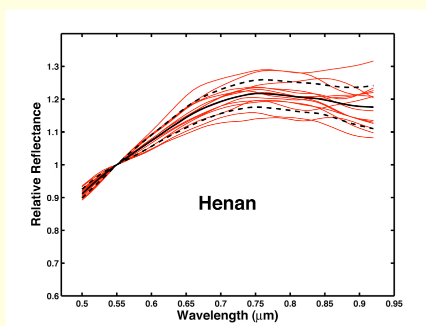


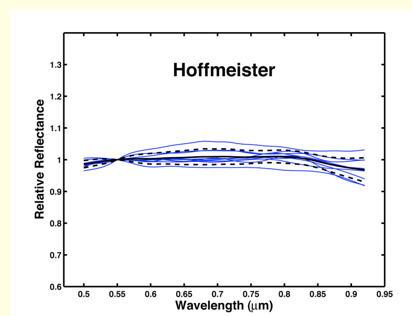


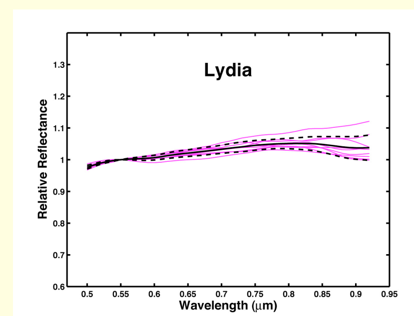
Sample Region #2



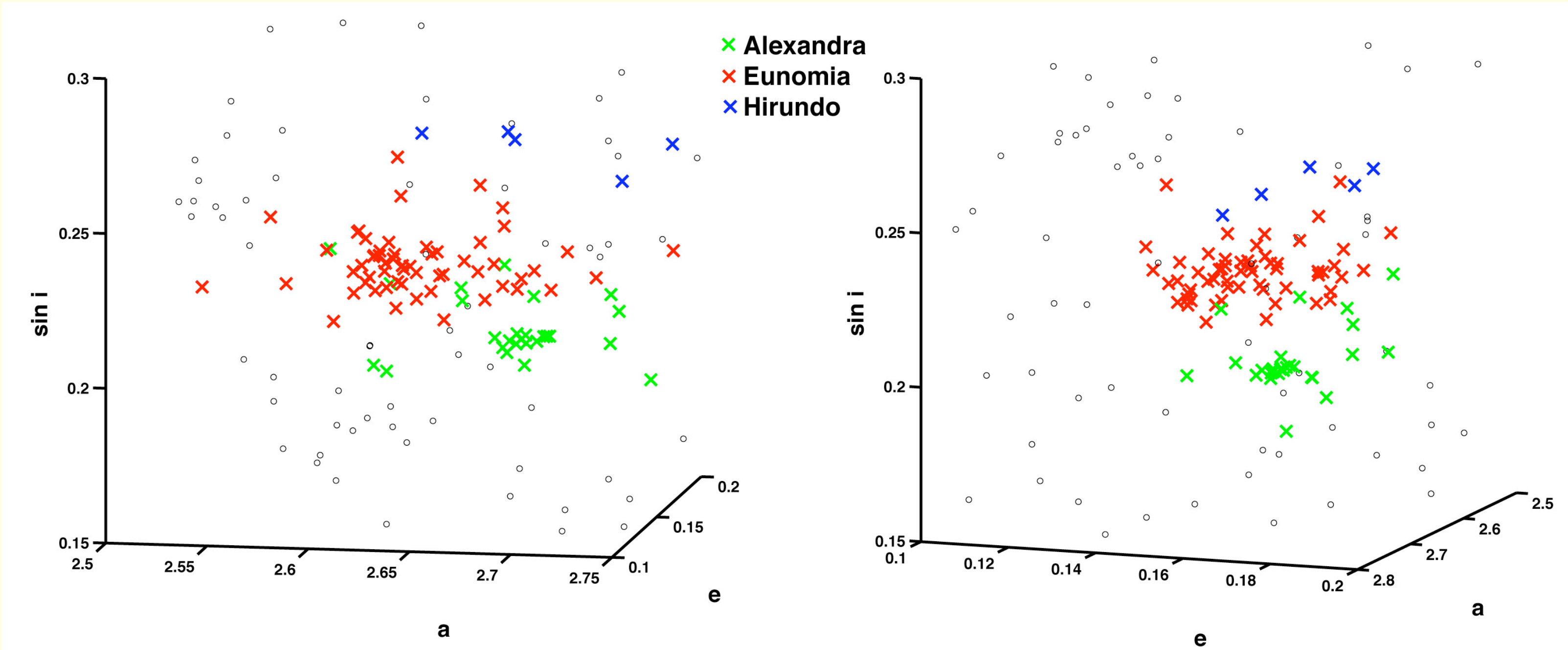


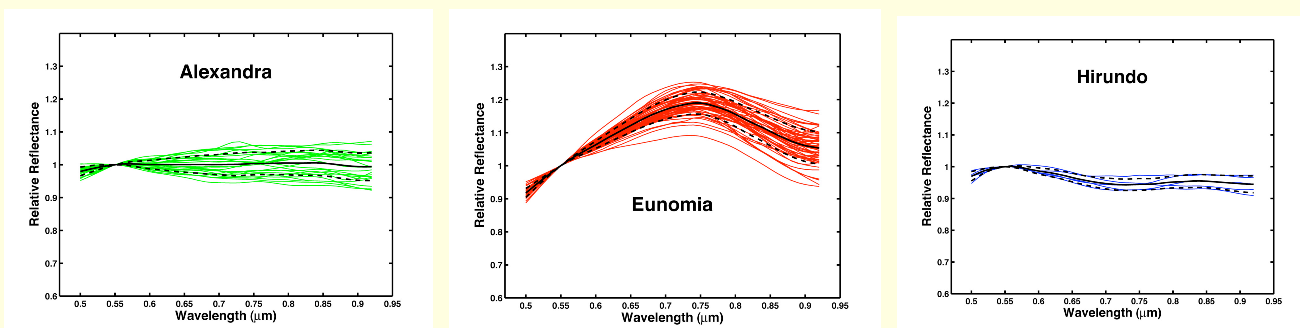






Sample Region #3





Conclusions

Advantages of combining orbital and spectral information in determining family memberships:

- Membership of known families more accurately defined
- Close / overlapping families can be separated
- Interlopers can be identified
- Older, more dispersed families can be recognized

Except for variations mostly in spectral slope, families seem to be quasi-homogeneous (no evidence for sampling the interiors of differentiated parent bodies).

Further work will focus on refining combination of D and S metrics, and optimizing clustering algorithm. Once optimized, this approach can be applied to much larger asteroid spectroscopic / color datasets (SDSS, GAIA, etc).