Asteroid Survey

Summarizer: Alyssa Pascuzzo

Gradie & Tedesco, 1982: In this historical context paper the authors attempt to address the compositional distribution of asteroids in the asteroid belt from 1.8 AU (∼Mars) to 5.2 AU (∼Jupiter) using spectral and albedo data. They classified 656 asteroids, which at that time was an improved sample size from previous studies, and showed that there were distinct compositional peaks in asteroid type abundance with heliocentric distance. Other improvements in their survey from previous studies included bias corrections with primary corrections accounting for closer, larger, brighter asteroids and distribution biases within types (corrected via fractions of types in each zone, Figure 1b).

In the end, they argue that the compositional distribution is not random. Showing that within their sample population there are particular types of asteroids dominating each region. Thus suggesting this trend is likely the result of asteroids forming *in−situ* and were not transported from elsewhere. Their survey showed that siliceous, moderate-low temperature asteroids (S/C-types) appear to dominate the main belt while low albedo, carbonaceous, icy asteroids (D/P-types) dominate the outer belt, which is consistent with chemical condensation models of the solar system at that time.

We briefly discussed how their conclusions seem completely reasonable and quite convincing given the amount of data available and technology at the time. The simplistic, generalized view of the the solar system's evolution, in terms of its temperature gradient, had more validity back then, however, we know now that the formation of the solar system and condensation of material in the primordial disk was much more complex and dynamic than what was believing the past. The heart of the discussion centered around their limited sample size compared to our present day knowledge of how many asteroids have been discovered in the main belt (1.1-1.9 million greater than 1km in diameter) in addition to using asteroid

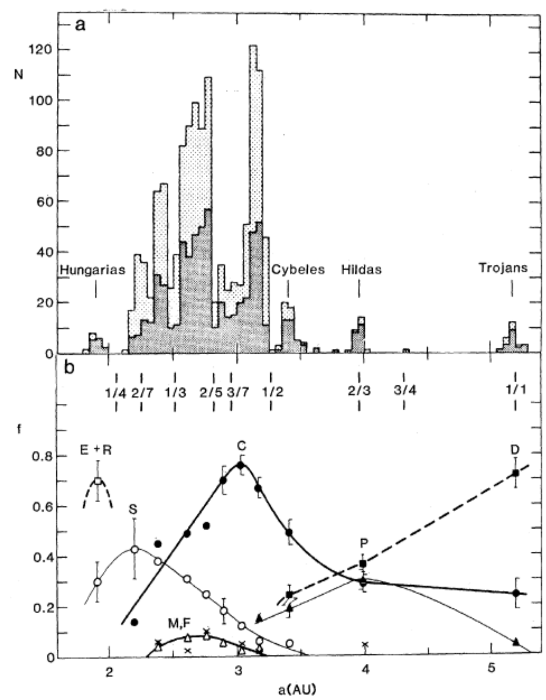

Figure 1: (a) The number distribution of 1373 asteroids in the belt. (b) Asteroid type distribution normalized to total number of asteroids classified in that type.

frequency opposed to mass in their distribution (which is addressed in the following paper discussions).

Levison et al., 2009: This article addresses how icy-rocky bodies may be present in the main belt when such observations defy simplistic primordial disk chemical condensation models. Using the dynamic events of the Nice Model they model what the type distribution of asteroids would be if perturbations of the outer planets orbits disrupted the indigenous asteroid population and Kuiper Belt Objects.

Before diving into the paper we discussed what the Nice Model is addressing. There are two main issues the model addresses: (1) Mars' small size (should be bigger) and (2) Neptune's large size (abnormally large for is distance in the disk if it formed in its current day position). This study addresses how the evolution of the Kuiper objects may have been effected by this dynamic event ultimately causing icy-Kuiper objects to scatter about the main belt and form the outer main belt (OMB).

In their distribution model they are asserting that the contaminating bodies are ice rich (aka comet/comet-like). Therefore, they argue that D/P type materials result from the Nice Model bringing in comet like bodies and resulting in contamination of the main belt. Their result suggest that the composition of the OMB objects (aka D/P-type asteroids) causes them to be weak and therefore giving an explanation to the lack of D/P-type material in the macrometeorite collection but may be a source for the micrometeorites.

Their modeled results (Figure 2) show objects with eccentricity and inclination relationships fairly agreeable in distribution to the D-type asteroid locations in the solar system. This demonstrated that the Nice Model provides a means for scattering icy rich material into the main belt.

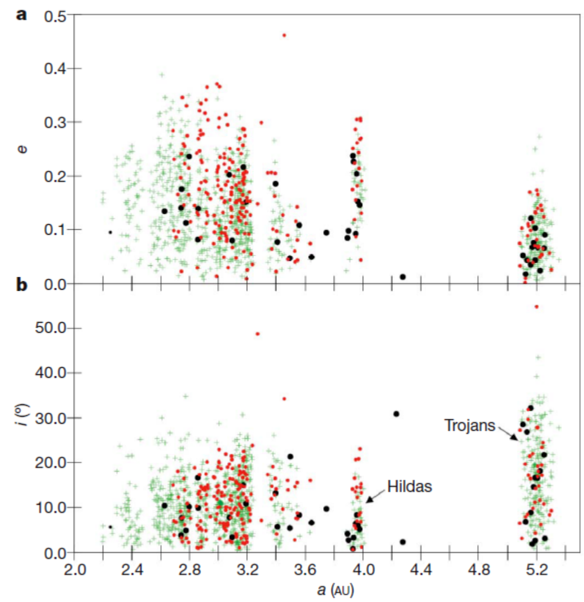

Figure 2: Distribution of objects with heliocentric distance through the belt. (a) distribution of eccentricity and (b) distribution of inclination. Black dots are classified D-type asteroids. Red and green dots are modeled results

Our discussion centered mainly around their size frequency distribution (SFD) model where they argue that captured cometary objects are weaker than native asteroids across a range of disruption patterns (Figure 3). To model disruption they used a factor f_q since the cometary disruption scaling law is not well understood. Larger f_q means there was more disruption and therefore less captured bodies were preserved. Smaller f_q means there was less disruption and therefore more captured bodies were preserved. However, in our discussion it was mentioned that changing the f_q factor causes the captured comets curve to vary within the error bars of the observed population curve (if they were to add them to the plot). Despite that caveat, panel (c) of Figure 3 shows modeled indigenous asteroids matching the observed population curve better than the captured comets.

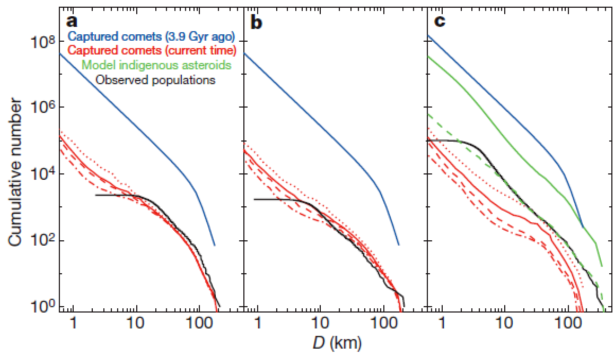

Figure 3: Beginning and end states of the SFDs in the three regions ((a)Trojans, (b)Hildas, (c)OMB objects. dotted, solid, dashed, and dash-dot red curves correspond to $f_q = 1, 3, 5, 8$).

Following this discussion we were still left wondering how their model compares to the real distribution of types and composition throughout the entire belt.

DeMeo & Carry, 2013: More recent work on asteroid surveys finally addresses the mass versus abundance issue that was never accounted for in prior studies. In this study they incorporate more data points, account for smaller asteroids, and present the distribution of asteroids in terms of mass, volume, and surface area.

First we discussed how they defined their new taxonomic classification. Previous studies used PCA (principle components analyses) to create the taxonomy. This type of analyses is a statistical procedure which converts observations (in this case spectra of asteroids) into a set of values of linearly uncorrelated variables. Each value (or PC band) is defined by the variance. For example the first PC band has the largest possible variance in the data set. Although this type of analyses is valid and usefully it doesn't translate directly to composition.

DeMeo and Carry used the spectral slopes and the drop in reflectance at longer wavelengths to define taxonomy instead of using PCA (Figure 4).

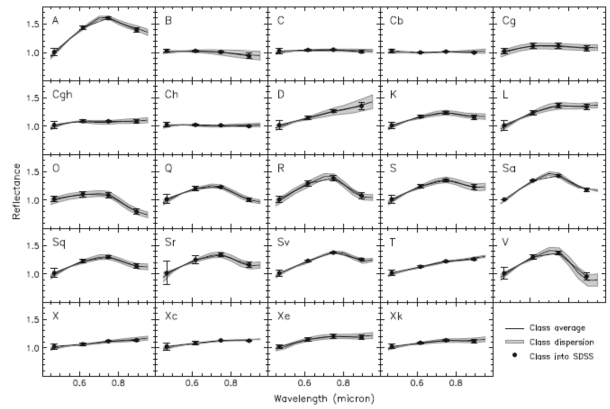

Figure 4: New taxonomy defined by DeMeo et al. (2009).

They went through MANY rigorous bias corrections which helped emphasize the importance of the various asteroid classes with distance. The most novel aspect from their work was using mass instead of abundance of asteroids since abundance means very little in terms of distribution if smaller asteroids are fragments of larger asteroids. Using the mass, volume, and surface area showed that there is not so much of a compositional gradient with distance as previously thought and thus proving Gradie and Tedesco's theory, that the asteroid belt formed at their present day location, to be wrong. However, there is a moderate compositional distribution showing S/V-types towards the inner belt and C/P/D-types towards the outer belt and the Trojans (Figure 5). Mass calculations showed that more primitive asteroids (C/P-types) dominates overall; more specifically these asteroids make up the bulk mass in the outer belt when compared to the fraction in the main belt. Finally, and possibly most intriguing is the verification that D-type asteroids are also found scattered throughout the main belt along with being dominate in the outer belt thus supporting the contamination theory brought upon by some early dynamic event in the solar system (Nice Model)(Levinson et al., 2009). However, this study discovered detections (small percentage) of D-type asteroids in the inner belt which was not predicted by Levison et al. (2009)'s model.

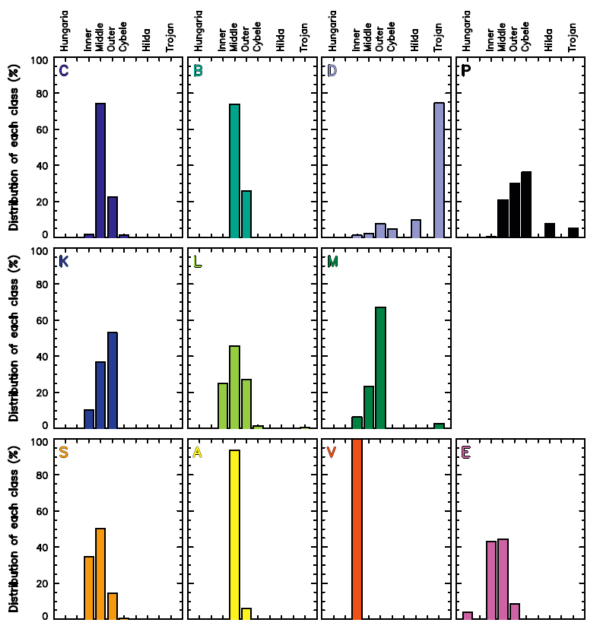

Figure 5: Mass fraction distribution of each class across the asteroid belt. Each class is summed to 100% across all zones.

References:

DeMeo, F. E., R. P. Binzel, S. M. Silvan, and S. J. Bus (2009) An extension of the Bus asteroid taxonomy into the near-infrared. Icarus 202, 160-180.

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Gradie, J. and E. Tedesco (1982) Compostional structure of the asteroid belt. Science, 216, 1405-1407.

Levison, H. et al. (2009) Contamination of the asteroid belt by primordial tran-Neptunian objects, Nature, 460, 364-366.