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How Many Ch-Class NEOs Do We Expect?

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Abstract

The Ch asteroids are our best analogs to the hydroxyl-rich CM meteorites. Only a handful of Ch asteroids are known in the NEO population, though the discovery rate for NEOs has far outstripped the data needed to identify Ch asteroids in that population. Using models of delivery of objects from the main asteroid belt to near-Earth space and debiased models of the fraction of C-complex asteroids in the main asteroid belt and near-Earth space, we estimate that Ch asteroids should make up 3-12% of the NEO population, and that at least 20 Ch asteroids larger than 100 m and more accessible than the Moon should exist. Further work will be needed to identify such objects.

1. Introduction

Interest in the economic use of asteroidal materials has been increasing, with a particular focus on water. The CM and CI carbonaceous chondrites have hydroxylated minerals, with 5-10% water equivalent or more [1], and their parent bodies are natural targets for further investigation. Several different lines of evidence identify the Ch asteroid spectral group as the CM chondrite parent bodies [2-3]. Here we attempt to estimate the answer to a simple question: How many Ch asteroids should we expect to find in the NEO population?

2. Ch Asteroids in the Main Belt

The Ch asteroid class is defined by an absorption band near 0.7 μm. The subgroups within the C complex all have sufficiently similar albedos that comparisons to one another can be done without bias being a major concern.

Spectrophotometric [4] and spectroscopic [5] studies estimate that the Ch group makes up 30-50% of the C complex as a whole. Both studies also reported a size-dependent trend, with a smaller fraction of Ch asteroids as the size decreased. Rivkin reported a small variation in Ch fraction across the asteroid belt, from a low of 25% in the inner belt to a high of 55% in the outer asteroid belt.

3. Predicted Ch Asteroid Supply to NEO space

These numbers can be convolved with models of the supply of NEOs from various small body reservoirs [6]. Bottke et al. estimate 61% of the NEO population is derived from the inner main belt, with the central and outer main belt providing 24% and 8%, respectively. The remaining 6% is from the Jupiter Family Comet region, for which we set the Ch fraction at 0. The final necessary piece for this estimate is the fraction of asteroids belonging to the C complex in each reservoir. Bus and Binzel [7] provided a debiased estimate of the fraction of each spectral complex vs. semi-major axis in the main belt for objects > 20 km. The averages for the C complex in the inner, central, and outer belt are 37%, 47%, and 52%, respectively.

It is relatively straightforward to combine the numbers mentioned above [4,6,7] into an estimate for the expected fraction of Ch asteroids among the NEO population as a whole:

$$Ch\ fraction = (0.61)(0.37)(0.25) + (0.24)(0.47)(0.35) + (0.08)(0.52)(0.55) = 0.12.$$

By this estimate, 12% of all NEOs should be Ch asteroids. The C-complex should be 38% of NEOs via this same calculation. We note below that there are several implicit/explicit assumptions in this estimate.

4. Observed Ch Asteroids in NEO Space

The number of known Ch asteroids in NEO space is very small. In the nearly 2300 asteroids in the European Asteroid Research Node database [8], 740 of which have taxonomic types assigned at this

writing, only 3 are identified as Ch asteroids: (285263) 1998 QE2, 2002 DH2, and 2012 EG5. This very small fraction is highly affected by biases, of course, among them the popularity of 0.8—2.5 μm observations of NEOs, which cannot be used to identify Ch asteroids, eclipsing the popularity of 0.5-1.0 μm observations, which can. The most recent large survey of NEOs in the visible-near IR [9] reported 1 Ch asteroid out of 23 C-complex NEOs, which is again much smaller than 12% but may be affected by the statistics of small numbers. Surveys of the NEO region specifically find C-complex fractions that are smaller than the 38% estimated above. Stuart and Binzel [10] report a C-complex fraction of 10% in the NEO population, while Carry et al. [11] used SDSS data to find 23% of 230 NEOs were C-complex asteroids. These two numbers suggest a Ch fraction of ~3-7% in the NEO population.

When we look to the meteorites, both the implied Ch and C-complex fractions are smaller still. The Meteoritical Bulletin database [12] reports 16 CM falls and 45 carbonaceous chondrite falls out of 1153 total falls of non-Mars meteorites. The CMs making up ~1/3 of all carbonaceous chondrites is consistent with the estimates above. However, taken at face value the fall statistics imply that less than 2% of NEOs are CM and only 4% of them are carbonaceous, both roughly an order of magnitude smaller than the estimates based on NEO delivery models.

5. A Ch Asteroid Problem?

The mismatch between the CM meteorites seen in the meteorite collection and what would be expected from NEO delivery models is puzzling, though it is perhaps too soon to consider this a "problem". Nevertheless, it is not obvious how best to reconcile the estimate with the observed CM fraction. Lowering the fraction of C-complex asteroids in the inner belt, where most NEOs are derived, is not consistent with existing data. Similarly, reducing the fraction of Ch asteroids within the C complex is inconsistent with the observed data and is also inconsistent with the CM fraction of carbonaceous chondrite falls.

The estimates in Section 3 assume that the various steps between residence in the asteroid belt and sample collection after a fall do not discriminate in favor or against particular asteroid classes. This is almost certainly not the case, nor is the C complex the only group affected: for instance, the X-complex asteroids are thought to represent 34% of the debiased NEO sample [10], but all meteorite falls from groups that could be associated with this complex total only ~6.5% of the total. It is also possible that the minerals responsible for the 0.7-μm band that distinguishes Ch asteroids have been destroyed on the surfaces of many/most NEOs that had them in the main belt. This could have happened during a low-perihelion period like those described by Marchi et al. [13]. Whether there are truly "too few" Ch asteroids in the NEO population requires additional observations in the 0.5-1.0 μm region. Happily, these are relatively easy to make, and there are a large number of known C-complex objects that can be targeted.

6. How many Ch NEOs do we expect?

If we disregard the meteorite fall statistics as unrepresentative of what we might find in space, the range of estimates for Ch fraction among NEOs ranges from 3-12%. With 900 or so NEOs larger than 1 km, that suggests anywhere from ~25-100 Ch asteroids larger than that size, with correspondingly more at smaller sizes.

Looking at delta-v, roughly 3200 known NEOs (of all sizes) are more accessible than the Moon (6 km/s). If thoroughly mixed, we might expect ~100-300 of them to be Ch asteroids. Roughly 670 of these NEOs have H<23.1, suggesting at least 20 Ch asteroids > 100 m diameter should be more accessible than the Moon (using the average C-complex NEO albedo:[10]). The trick is to find them.

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