COMPARING NEA SURVEYS

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ABSTRACT

The vast majority of the known Near Earth Asteroids (NEAs) have been discovered by a small number of very capable NEA surveys. A natural question to ask is whether the most efficient surveys discover similar proportions of the various types of NEAs. We use the discovery statistics available at the MPC to address these questions.

Keywords: NEA surveys; NEA types.

1. INTRODUCTION

Asteroid surveys have been going on for many decades, and have been reviewed in a number of papers. The most recent ones are those by Jedicke et al. [4] and Yeomans [5], to which we refer the reader for further details. Here we want to compare the main surveys using an *a posteriori* approach based on the statistical data on NEAs available at the Minor Planet Center (MPC, `https://minorplanetcenter.net`).

Using MPC data downloaded on 7 January 2019, we consider the surveys that are currently the most productive in terms of NEAs discovered, as detailed hereafter.

- The 1.5 m telescope located on Mount Lemmon (Arizona), with MPC code G96. This telescope has a field of view of 5.0 deg^2, covers about 1000 deg^2 per night at a limiting magnitude of 21.5, and is operated by the Catalina Sky Survey (CSS, `https://catalina.lpl.arizona.edu`).
- The 0.7-m telescope located on Mount Bigelow (Arizona), with MPC code 703. This telescope has a field of view of 19.4 deg^2, covers about 4000 deg^2 per night at a limiting magnitude of 19.5, and, like G96, is operated by CSS. We consider it separately due to the many differences between it and G96.
- The two 1.8 m telescopes located in Maui (Hawaii), with MPC codes F51 and F52. Their field of view is around 7 deg^2, and their limiting magnitude is somewhat higher than that of G96; they are operated by the Pan-STARRS survey (`http://pswww.ifa.hawaii.edu/pswww`).
- The two 0.5 m telescopes located in Maui and in Big Island (Hawaii), with MPC codes T05 and T08. They have a field of view of about 28.9 deg^2, and can cover about 6500 deg^2 each per night, at a limiting magnitude around 19; they are operated by the ATLAS survey (`https://www.fallingstar.com`).
- The 1.2 m Palomar Schmidt telescope, with MPC code I41. It has a field of view of 47 deg^2, and covers about 7500 deg^2 per night, at magnitude 20.4; it is operated by the Zwicky Transient Facility survey (ZTF, `https://www.ztf.caltech.edu`).
- The NEOWISE, a 0.4 m, a space-based infrared telescope, withe MPC code C51, operated by NASA (`https://neowise.ipac.caltech.edu`).

2. SURVEY PERFORMANCES IN THE $MOID$ VS. H PLANE

While bright NEAs, those with absolute magnitude $H \leq 16$, can be detected by surveys even when they are rather far from the Earth, fainter NEAs need to pass closer to our planet in order to be discovered. Actually, we can consider that by now practically all NEAs with $H \leq 16$ have been discovered, irrespective of their orbits.

On the other hand, among all NEAs are present large values of the Minimum Orbital Intersect Distance ($MOID$), of the order of 0.3 to 0.5 au or even more; of course, NEAs with such large $MOID$s cannot pass by the Earth at a distance smaller than that.

In fact, among known NEAs are present a few cases of $MOID \approx 0.7$ au, and in the model population of Granvik et al. [1] are present a few instances of even larger $MOID$s. In this respect, Gronchi and Valsecchi [2], [3] have shown that, in principle, $MOID$ values close to 1 au are possible for the current definition of NEA.

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Given all this, it is not surprising that the most productive surveys are discovering faint NEAs characterized by low $MOID$s. In order to illustrate this aspect, we plot for the various surveys the NEAs discovered by each of them in the plane $MOID$ vs. absolute magnitude H.

In Fig. 1 we begin with G96; the plot contains all the NEAs discovered by this survey. The boxes on the right and on the top of the main plot contain the histograms (in black) relative to, respectively, H and the $MOID$.

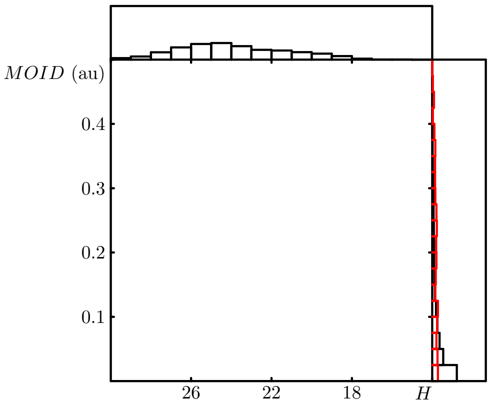

Figure 1. NEAs discovered by G96 in the $MOID$ vs. H plane; the boxes on the right and on the top contain the relevant histograms. The red histogram in the box on the right is for all NEAs with $H \leq 16$, for comparison.

To facilitate the interpretation of the histogram of the $MOID$, we have plotted in the box on the right, in red, the $MOID$ histogram for all the NEAs with $H \leq 16$, irrespective of their discoverer. The reason for plotting this histogram is that this part of the NEA population has been discovered completely, so its $MOID$ distribution could be taken as representative of that of the entire population of NEAs.

As Fig. 1 shows, the H histogram for G96 is unimodal, and peaks at about 25; the $MOID$ histogram shows, as discussed before, a prevalence of small values.

Figure 2 shows the same quantities for 703. As seen before, this telescope is operated by the same team as G96, but differs from the latter since it covers much more sky per night, at a shallower limiting magnitude.

Also in this case the H histogram peaks at about 25, but is bimodal, with a secondary peak around 21; the $MOID$ histogram, on the other hand, shows a stronger prevalence of small values compared to G96.

Figure 3 shows the data relative to the two Pan-STARRS telescopes, that we have grouped together due to their basic similarities. At variance from the two CSS telescopes, in this case, the H histogram peaks around 24, and small values of the $MOID$ are much less prevalent.

The data regarding the two ATLAS telescopes are shown in Fig. 4. This survey covers much more sky per night

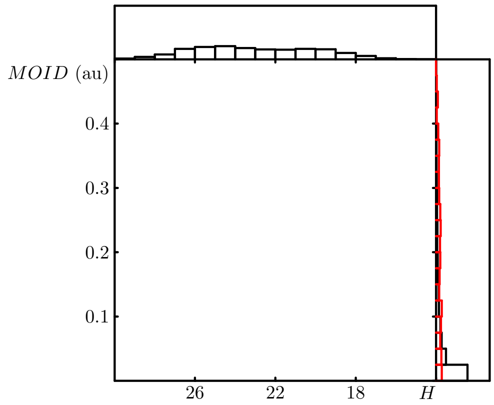

Figure 2. Same as Fig. 1, for the NEAs discovered by 703.

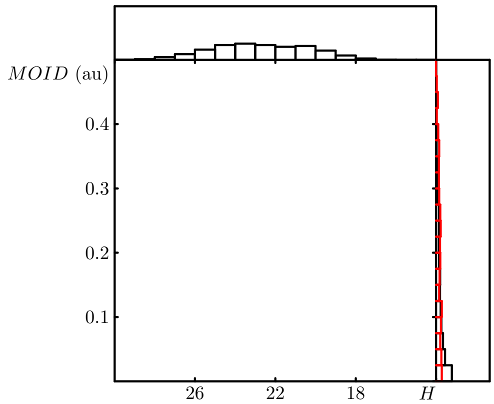

Figure 3. Same as Fig. 1, for the NEAs discovered by F51 and F52.

than the previous ones, but at a shallower limiting magnitude. The H histogram peaks around 25, with a secondary peak around 23, while the $MOID$ histogram shows a very strong prevalence of small values.

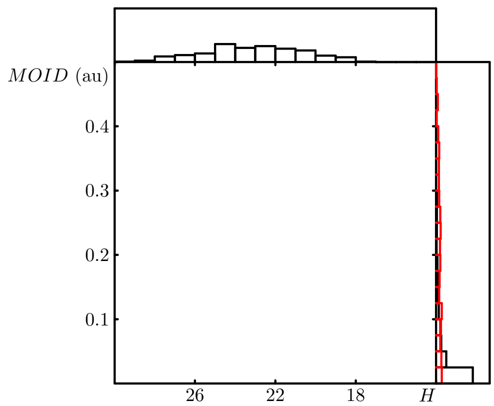

Figure 4. Same as Fig. 1, for the NEAs discovered by T05 and T08.

Figure 5 depicts the situation for the I41 telescope, operated by a team whose main goal is not the discovery of NEAs; on the other hand, the exceptionally large field of view for a telescope of relatively large aperture like this one makes it rather efficient also in terms of NEA discoveries.

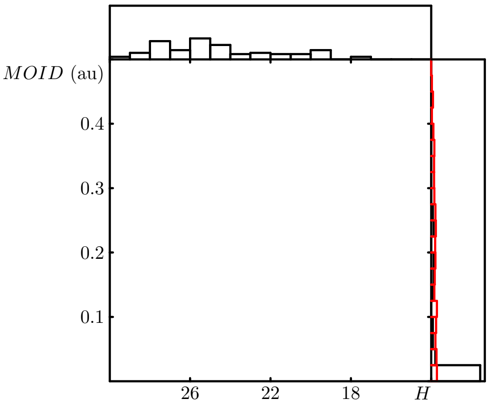

Figure 5. Same as Fig. 1, for the NEAs discovered by I41.

However, this survey has been in operation only since a short time, so there is not a clear trend identifiable in the data, apart from the very strong prevalence of small $MOID$s.

Finally, Fig. 6 contains the data relative to the only space based survey examined here; the plot and the histograms are in this case radically different from those of the ground based surveys. In particular, the H histogram peaks at about 21, and the $MOID$ histogram is much flatter than in all other cases.

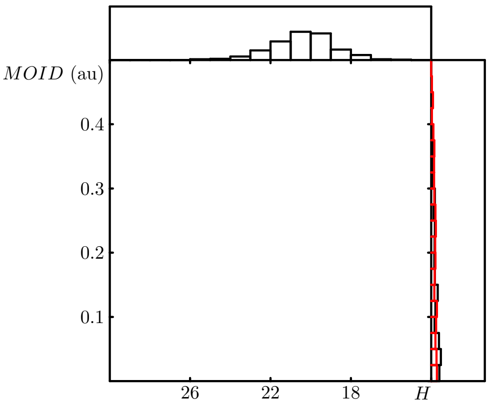

Figure 6. Same as Fig. 1, for the NEAs discovered by C51.

This quick overview of the results achieved by the various surveys in the $MOID$ vs. H plane can be summarized as follows:

- for surveys that scan less sky at a deeper limiting magnitude, like G96 and especially the pair F51-F52, the discoveries peak at a somewhat brighter H, and the prevalence of small $MOID$s with respect to what is the probable distribution for the whole NEA population is less marked;
- on the other hand, surveys scanning more sky, but at a shallower limiting magnitude, like 703, the pair T05-T08, and I41, tend to discover slightly fainter objects, with a correspondingly higher proportion of very small $MOID$s;
- finally, a space-based infrared survey like C51 seems not affected by the tendency to favour small $MOID$s.

3. SURVEY PERFORMANCES IN TERMS OF NEA TYPES PROPORTION

Another terrain of comparison for the various NEA surveys is in terms of the proportion of Amors, Apollos and Atens discovered (hereafter, we group within the Atens all NEAs with $a < 1$ au, irrespective of their aphelion distances). In order to have a point of comparison we consider that, among the 190 NEAs with $H \leq 16$ listed at the MPC website, there are 5 Atens, 92 Apollos and 93 Amors.

We can plot these proportions in a ternary plot, like the one given in Fig. 7; in it, the large black dot shows the proportion of NEA types for $H \leq 16$: the dot is far from the Atens vertex and close to the side joining the Apollos and Amors vertices.

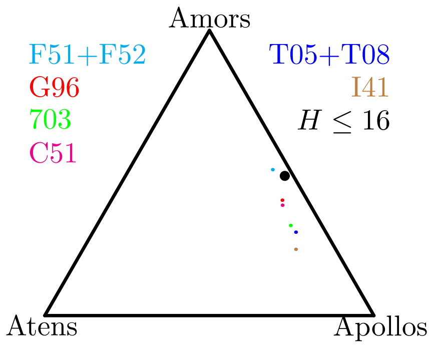

Figure 7. Ternary plot showing the proportions of Atens (including objects with aphelion inside the Earth orbit), Apollos and Amors. The large black dot is for the known NEAs with $H \leq 16$, while the coloured smaller dots are for the proportions of NEAs discovered by, respectively: F51 and F52 (cyan), G96 (red), 703 (green), C51 (magenta), T05 and T08 (blue), and I41 (brown).

If a given survey would discover Atens, Apollos and Amors in the same proportions as there are in the population of NEAs with $H \leq 16$, then the data point representing the survey would coincide with the large black dot in the Figure. However, the coloured dots corresponding to the different surveys show that this is not the case, and that the surveys show some interesting differences, just as they do in the $MOID$ vs. H plane.

Actually, all of the surveys discover a somewhat larger proportion of Atens than the reference proportion, and this is presumably due to the shorter orbital period of these NEAs, that make for more frequent opportunities to pass relatively close to the Earth.

For what concerns the proportions of Apollos and Amors, there are significant differences: the survey operating the largest aperture telescopes, i.e. F51-F52, discovers more Amors than the reference proportion, while all the others discover less Amors than Apollos. In particular, a trend is noticeable, in that the prevalence of Apollos seems to be correlated to the prevalence of small $MOID$s; in fact, the two extreme cases in this sense are I41 and the pair T05-T08, while for C51 this correlation seems absent.

4. CONCLUSIONS

An analysis of the performances of the various NEA surveys in terms of absolute magnitudes and $MOID$s of the NEAs discovered by each of them shows some interesting differences; these differences are reflected also in the proportions of Atens, Apollos and Amors discovered.

Surveys that scan less sky at a deeper limiting magnitude tend to discover NEAs with somewhat larger $MOID$s than surveys that scan more sky at a lower limiting magnitude. The C51 space-based infrared survey appears not affected by the tendency to favour small $MOID$s.

All the surveys tend to discover higher proportions of Atens and especially Apollos with respect to the proportions probably present in the real population; the exception is Pan-STARRS (F51 and F52), that discovers many more Amors than Apollos.

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