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Statistical Study of Potentially Hazardous Asteroids from 1990 To 2018

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Abstract: *Near-Earth Objects (NEOs) are small solar system bodies (approximately 10 – 1500 m in diameter) with some having orbits that cross Earth's orbit. They are considered to be the remnants of the early solar system. Potentially hazardous asteroids (PHAs) is reserved for those objects with absolute magnitudes H ≤ 22 and diameter > 140 m. In principle, PHAs could possibly impact the Earth within the next century, producing major damage. We present a comparative study potentially hazardous asteroids (PHAs) providing some insights on the nature, origin, evolution, physical properties, chemical composition and potential hazards of these objects. We obtained our data from National Aeronautics and Space Administration (NASA) catalogue using descriptive statistics in our analysis, for 1811 potentially hazardous asteroids spanning from 1990 to 2018 comprising 1528 Apollos, 163 Atens, 114 Amors and 6Atiras. Statistical analysis reveals that Apollos accounts for about 84.3% of the confirmed PHAs while Amors, Atens and Atiras accounts for 6.3%, 9%, 0.33% respectively of the known PHAs.*

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I. Introduction

A potentially hazardous object (PHO) is a Near – Earth – Object either an asteroid or a comet with an orbit that can make exceptionally close approaches to the Earth and large enough to cause significant regional damage in the event of impact (Asphang et al., 1998).

Potentially hazardous asteroids (PHAs) can have a minimum orbital intersection distance with Earth of less than 0.05 astronomical units (19.5 lunar distances) and an absolute magnitude of 22 or brighter (NEO Basics – potentially hazardous asteroids (PHAs) 2018). As of January 2018, there are 1,885 known PHAs (about 11% of the total near – Earth population), of which 157 are estimated to be larger than one kilometer in diameter (Boslaugh ,2008 and Clark 2003). Potentially hazardous asteroids are normally only a hazard on a time scale of hundreds of years as the known orbit becomes more divergent. After several astronomical surveys, the number of known PHAs has increased tenfold since the end of the 1990s (Davos ,2014 and Discovery statistics – cumulative Totals, 2018).

In this research we obtain our data from National Aeronautics and Space Administration (NASA) catalogue with a view to statistically analyze the distribution of the magnitude (H) and orbital period (P) of the different classes of Near – Earth Asteroids. Potentially Hazardous Asteroid (PHAs) remains a critical topic in planetary sciences, especially because these bodies are believed to have played a major role in the delivery of water and organic molecules to the early Earth. However, PHAs still remain of great scientific interest, because they currently represent a well-founded threat to human beings and life in general on our planet. Hence, we are inspecting PHAs data from 1990 to 2018 in order to gain scientific insight on the dangers these asteroids portray to our planet Earth and the group that may likely cause the greatest impact.

Therefore, this study aims to statistically analyze the distribution of the magnitude (H) and orbital period (P) of the different classes of Near-Earth Asteroids. This will enable us to extract available data associated with such asteroids particularly their physical parameters. Make a distribution of the magnitude and periods of these asteroids and gain insights on their potential threats

II. Materials

This research was carried out using the information on 1811 Potentially Hazardous Asteroids (PHA's) observed from 1990 to 2018. The data comprises of Amors, Apollos, Atens and Atira groups sorted out from the large sample of the National Aeronautics and Space Administration (NASA) catalogue hosted at https://ssd.jpl.nasa.gov/sbdb_query.cgi. The data consists of 114 Amor objects, 1528 Apollo objects, 163 Aten objects and 6 Atira objects. The corresponding magnitude (H) and the orbital period (P) of the different groups were taken from the NASA catalogue.

III. Method

In this research, we used descriptive statistics to investigate some of the parameters associated with this data. All plots and statistical calculations produced from this data were performed using the Python programming software. A number of Python packages such as numpy, matplotlib, and pandas were used in constructing the plots.

IV. Results

In this section, the major objective is to statistically analyze the distribution of the magnitude (H) and orbital period (P) of the different classes of Near-Earth Asteroids. For a better understanding of their distribution, we will use descriptive method to quantitatively investigate each of these parameters (H and P). This is aimed at understanding the behavior of the different classes of potentially Hazardous Asteroids and sizing the potential threats in terms of their population, magnitude and orbital period.

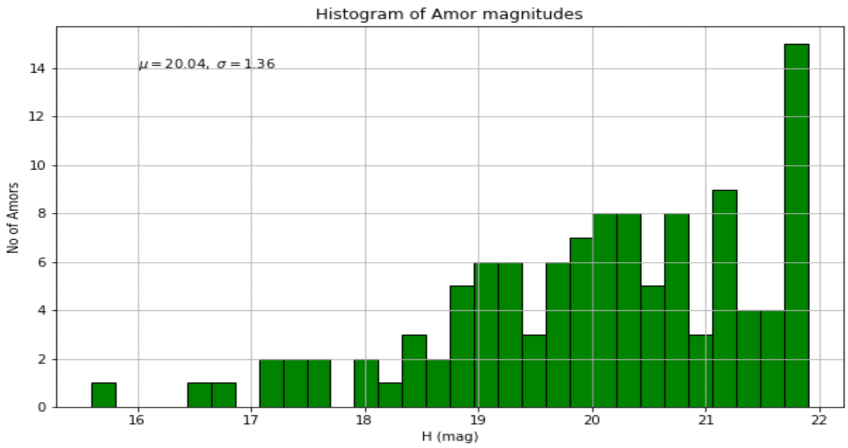

Figure 1.1: Distribution of the magnitude of Amor objects

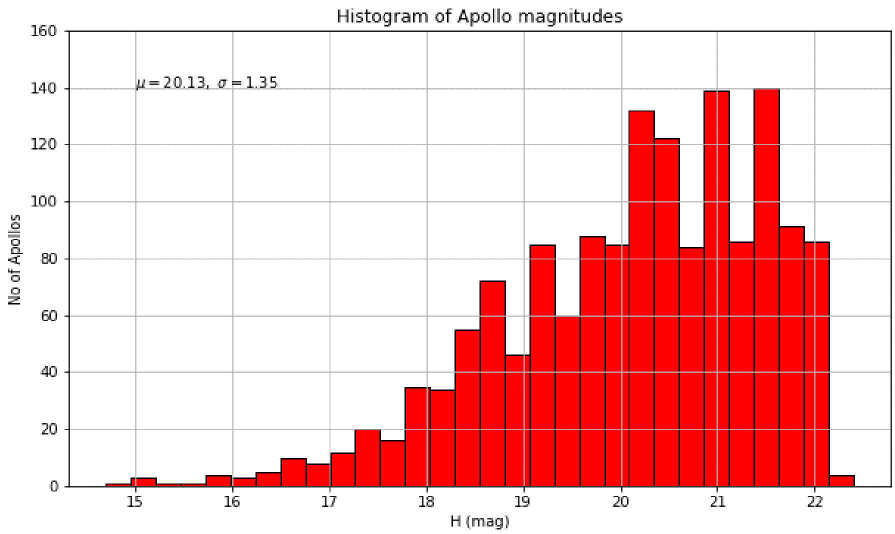

Figure 1.2: Distribution of the magnitude of Apollo objects

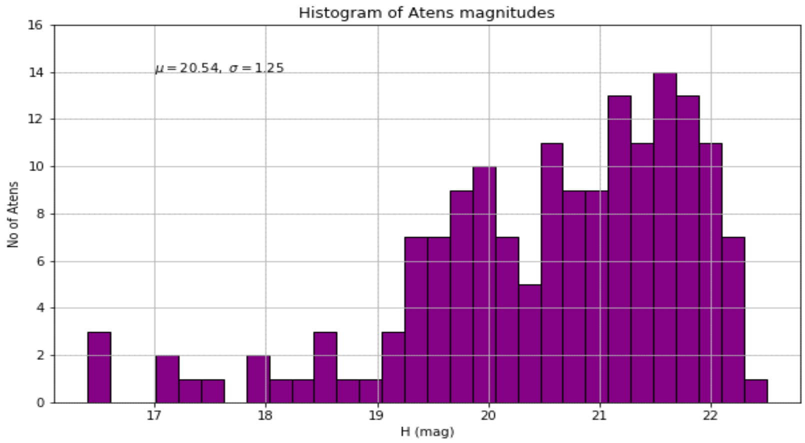

Figure 1.3: Distribution of the magnitude of Atens objects

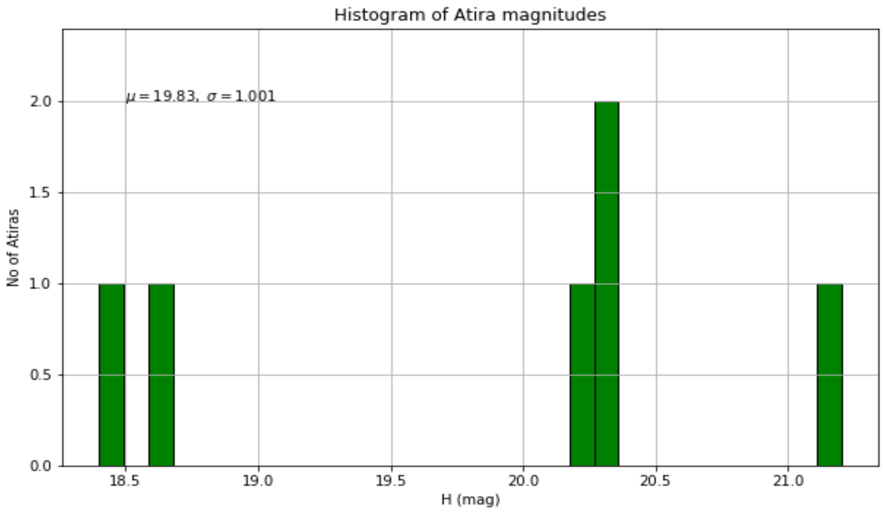

Figure 1.4: Distribution of the magnitude of Atira objects

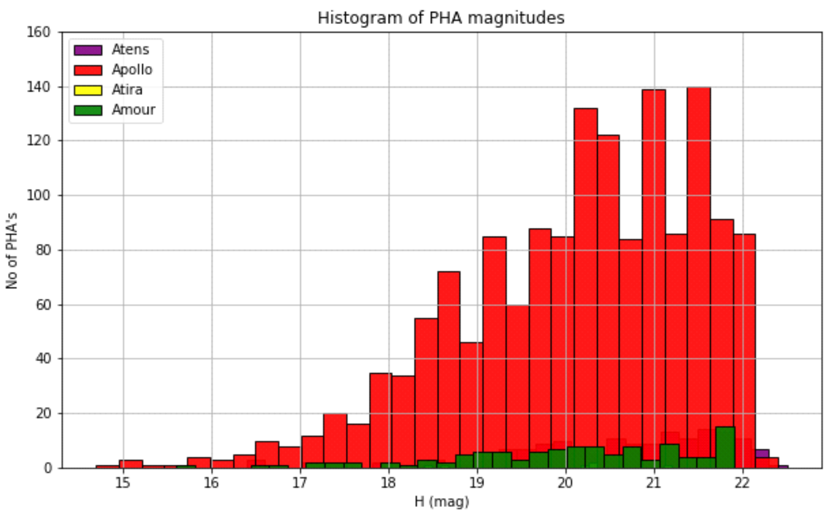

Figure 1.5: Distribution of the magnitude of all PHA

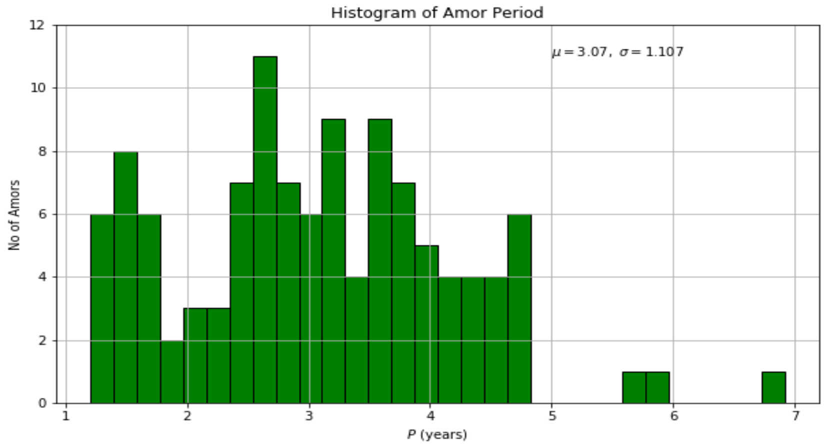

Figure 1.6: Distribution of the period of Amor objects

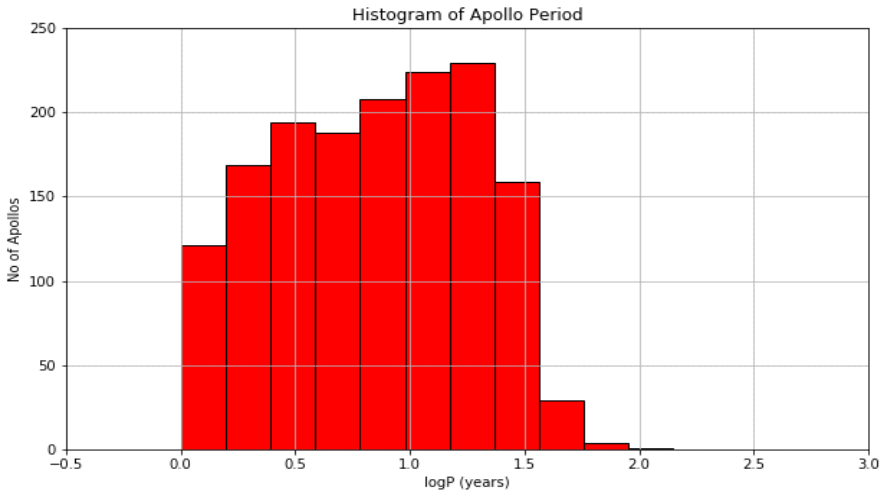

Figure 1.7: Distribution of the period of Apollo objects

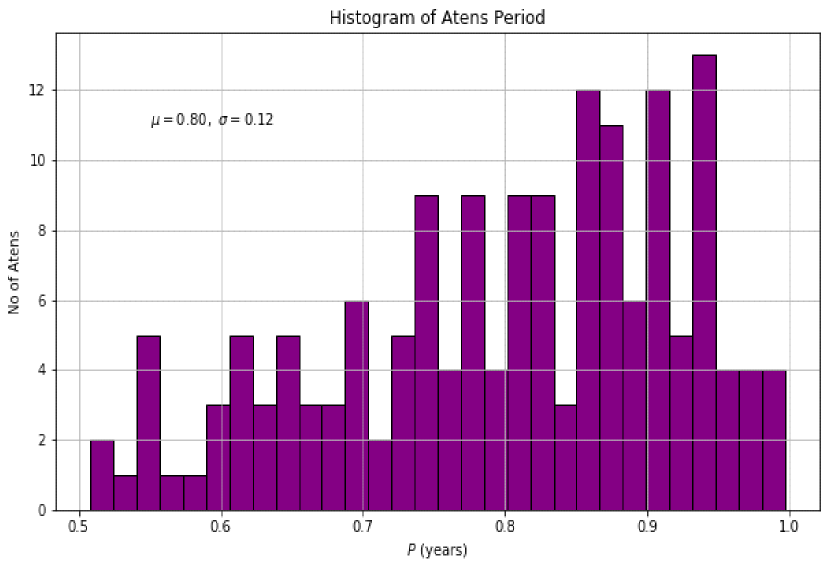

Figure 1.8: Distribution of the period of Aten objects

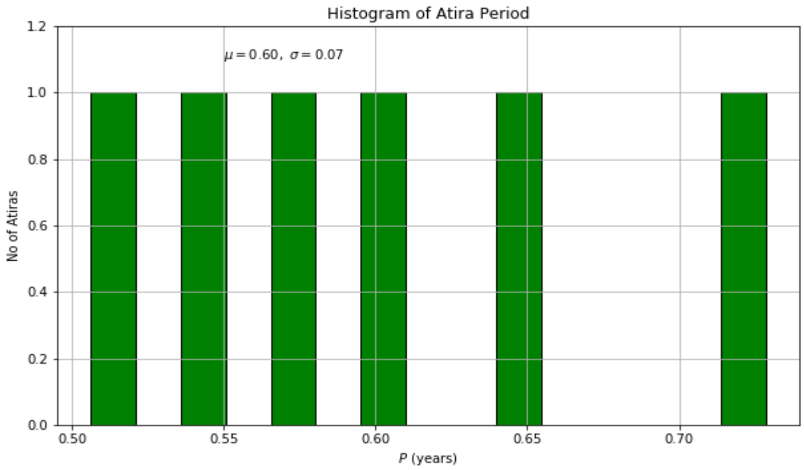

Figure 1.9: Distribution of the period of Atira objects

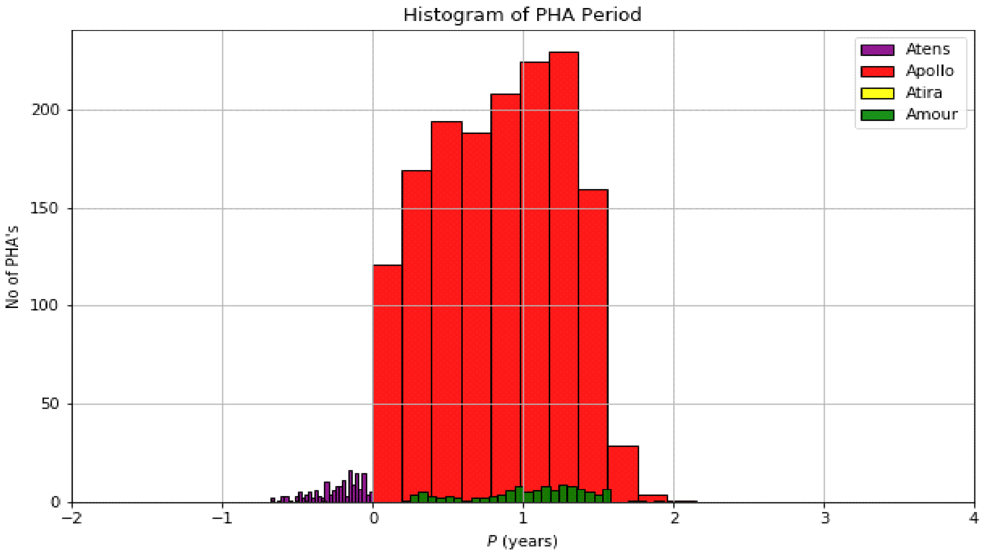

Figure 1.10: Classes of PHAs

Distributions of the Observed Parameters.
Histogram of Amor magnitude

The distribution of magnitude of 114 Amor objects is shown in Figure 4.1. The unimodal distribution departs from a normal distribution, thus skews to the left. The mean and median values of the magnitude are 20.04 and 20.21 respectively. The magnitude ranges from 15.7 mag to 22.0 mag. About 80% (~ 77%) of the Amor objects have magnitude in the range of 18.5 – 22.0 mag.

Histogram of Apollo Magnitudes.

Figure 1.2 shows the distribution of magnitude of 1528 Apollo objects. A close examination of the distribution reveals that this multimodal distribution skews to the left with mean and median values of 20.13 and 20.3 respectively. The magnitude ranges from 14.3 mag to 22.5 mag. About 86% of the Apollo objects have magnitude in the range of 18.25 – 22.25.

Histogram of Atens Magnitudes

Figure 1.3 shows the distribution of the magnitude of 163 Aten objects. It can be seen that the multimodal distribution departs from a normal distribution as more values of the observed magnitude are packed on the right side of the plot, thus we can easily say the distribution skews to the left. The mean and median values of the magnitude are 20.54 and 20.80, respectively. The magnitude ranges from 16.0 mag to 22.2 mag. Approximately 79% of Aten objects have magnitude in the range of 19.5 mag -22.5 mag.

Histogram of Atira Magnitudes

The distribution of magnitude of 6 Atira objects shown in figure 1.4. a close examination of the distribution reveals that this multimodal distribution skews to the left with mean and median value of 19.83 – 20.25 respectively. The magnitude ranges from 18.4 mag to 21.2 mag. About 82% of the Atira objects have magnitude in the range of 18.5 – 21.0mag.

Histogram of all PHAs Magnitudes

The superposed distribution of the magnitudes of the various classes of the Potentially Hazardous Asteroids is shown in Figure 1.5. It can be seen that the plot departs from a normal distribution as more values of the observed magnitude are packed on the right side of the plot. Therefore, we can easily say that the distribution skews to the left. The distribution seems to suggest that the set of observed Potentially Hazardous Asteroids have more of high magnitudes (within the range of 18.5 – 22.5 mag). This is in accordance with the definition of PHAs as objects having an absolute magnitude (H) of 22.0 or less.

Histogram of Amor Period

Figure 1.6 shows the multimodal distribution of the orbital period of 114 Potentially Hazardous Amor group Asteroids. A close examination of the distribution reveals that it does not depart entirely from a normal distribution. The mean and median values are given respectively as 3.07 and 3.05. The orbital period ranges from 1.16 yrs to 6.8 years. Approximately 80% of Amor group objects have orbital periods in the range of 1.25 yrs – 4.25 yrs.

Histogram of Apollo Period

The distribution of the period of 1528 Potentially Hazardous Apollo Asteroids is shown in Figure 1.7. The plot shows a normal distribution with the logarithmic values of the orbital periods. The logarithm of the orbital period was used because of the large values of the orbital periods. The large value is a consequence of their proximity to Earth as given in Table 2.2 in their orbital periods as well as their perihelia distance.

Histogram of Atens Period

The distribution of the period of 163 Earth-crossing Atens objects is shown in Figure 1.8. The small value of the orbital period corresponds with the definition of Atens as Earth-crossers having orbital periods ranging from 0.51 – 1.00 years. Approximately 78% of Atens objects have orbital periods clustered in the interval of 0.55 – 0.95 years.

Histogram of Atira Period

The distribution period of 6 potentially Hazardous Atiras Asteroid is shown in figure 1.9 the small value of the orbital period corresponds with the definition of Atiras as Earth-Crossers having orbital periods ranging from 0.51 – 11.00 years. Approximately 79% of Atiras objects have orbital periods clustered in the interval of 0.53 – 0.78.

Histogram of PHAs Period

The distribution of 1528 Apollo objects, 163 Aten objects, 114 Amor objects and 6 Atiras is shown in Figure 1.10. It can be observed that Apollos make up a large population of the Potentially Hazardous Asteroids. This is a consequence of their proximity to Earth as well as the large values of their absolute magnitude. Also, NEOs of interest are those with sizes and semi-major axes comparable to that of Apollo objects, thus most of the observations geared towards finding these objects produce results that correspond with this class of Near-Earth Objects.

A summary of the statistical results of the magnitude of the different classes of PHAs are given in Table 1.1 and 1.2. Refer to the legend of figure 1.10 for the different class differentiation.

Table 1.1: A summary of the statistical results of the magnitude of the different classes of PHAs

Classes	Mean (deg/d)	Median (deg/d)	Minimum value (mag)	Maximum value (mag)	Standard Deviation (mag)
Amors	20.04	20.2	15.6	21.9	1.35
Apollos	20.13	20.3	14.7	22.4	1.34
Atens	20.54	20.80	16.4	22.5	1.25
Atiras	19.83	20.25	18.4	21.2	1.00

Table 1.2: A summary of the statistical results of the orbital periods of the different classes of PHAs

Classes	Mean (deg/d)	Median (deg/d)	Minimum value (mag)	Maximum value (mag)	Standard Deviation (mag)
Amors	3.07	3.05	1.20	6.91	1.10
Apollos	2.83	2.40	1.00	349.97	9.13
Atens	0.80	0.81	0.50	0.99	9.13
Atiras	0.60	0.59	0.50	0.72	0.07

V. Discussions

The magnitude and period of the different classes of NEAs is an important factor in constraining them as members of the class of Potentially Hazardous Asteroids. From the distributions of the magnitude of PHAs, we observed that the different classes of the Potentially Hazardous Asteroids are of comparable magnitudes. These values lie mainly within the range of 15 – 22 mag and in agreement with (Evans et al. 2003, Delbo, 2002). It is expected that the magnitude of IEOs will be largest value because their orbits lie entirely within the Earth's orbit and as such can be easily determined but their distribution was not included because of sampling bias arising from sparse population. The results are in accordance with their prediction as members of the class of Potentially Hazardous Asteroids (Bottke et al.,2000). Also, the distributions of the orbital periods of PHAs reveal a trend in their orbital periods. It is evident that Apollo objects dominate with large values of 1.0 – 8.0 years.

Of the ~14,500 NEOs confirmed, ~11.5% poses the greatest threat to Earth. They are commonly referred to as Potentially Hazardous Asteroids. We have reported the magnitude, orbital periods, perihelia and aphelia distances for 1811 NEOs, all of which are Potentially Hazardous Asteroids. Analysis on the magnitude and orbital period of 1811 PHAs were carried out. The results obtained show that these objects seem to corroborate their predictions as PHAs.

Closely associated with the detection of NEOs is an attempt to understand some of the physical and thermal properties of NEOs as well as their mineralogical components. Researches on those NEOs have been shown to have comparable properties to those of the small solar system bodies (Ahrens ,1992;Asams et al 1998;Binzel 2013;Clark 2003).

More importantly, insights were provided on the nature of hazards caused by these fascinating astronomical bodies alongside the mitigation strategies and techniques and results show that we are close to the point where NEO deflection is technically and economically feasible (Lee and Deborah, 2012). Finally, NEOs have been critical in the history of life on Earth and they may provide a means for us to voyage out into the stars. The Earth is our home and will likely remain so for eons to come, but if we are to ensure the survival of our species for the ages, we must make plans to defend the Earth from NEOs and find a way to live beyond this fragile ball hanging in space. NEOs may have given us life and indirectly helped to bring us to our current position of dominance on the planet, but if we are not vigilant, they may one day rob us of our privileged position.

VI. Conclusion

In this research, we have statistically examined the magnitude and orbital period of 1811 Potentially Hazardous Asteroids spanning from 1990 to 2018 comprising of 1528 Apollos, 163 Atens, 114 Amors and 6 Atiras. The results of our statistical analyses reveal that Apollos accounts for about 84.3% of the confirmed PHAs while Amors, Atens and Atiras accounts for 6.3%, 9%, 0.33% respectively of the known PHAs. The results of our statistical analyses also show a trend in the distribution of the observed properties i.e. the distribution of these properties is not widely dispersed. Furthermore, our results for the magnitude and orbital period distribution confirms that 1811 objects that were analysed belong to the class of Potentially Hazardous Asteroids.

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