EPSC Abstracts
Vol. 13, EPSC-DPS2019-1883-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Comparison of PHA's close encounter predictions

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Abstract

We report on the differences found in the prediction of the moments and distances of close encounters of asteroids with the Earth by four world ephemeride services. This problem is of primary concern for potentially hazardous asteroids due to their possible future collision with the Earth. While the services are generally using the same measurement data collected at the IAU Minor Planet Center, the cross-identification of the close encounters provides an agreement in one-third part only between the lists of events within a one-year period. The high sensitivity of the predictions is caused by the different orbital fitting process, and as far as no ephemeride can be guaranteed, so the additional observations of potentially hazardous asteroids at the moments of close encounters can be used for improving such predictions.

1. Introduction

Prediction of epochs and distances of close encounters of asteroids with the Earth allows us to identify *potentially hazardous asteroids* (PHA) and estimate their future collisional risks. Several professional services regularly provide predictions of future encounters of asteroids with the Earth:

- the IAU Minor Planet Center (MPC) by giving the lists for both Forthcoming Close Approaches To The Earth [2] and Running Tallies [6];
- the JPL Center for Near Earth Object Studies (CNEOS) [5];
- the ESA's Near-Earth Object Coordination Center (NEOCC) [7];
- the DynAstVO service of IMCCE at Paris Observatory PADC center [1].

While the observational data used in the orbital fitting of asteroids are assumed to be the same and consist of measurements collected by IAU MPC, there is an expectation to have similar and consistent predictions for the moments and geocentric distances of close encounters. We will demonstrate by the statistics of cross-matching between different lists of predictions generated by the mentioned services that the general agreement even in the number of close events predicted is a one-third part with respect to the combined set of predictions. Other cases will be considered in the presentation.

2. Method and Results

Online requests were made for identifying close encounters of asteroids satisfying two criteria: the close approaches should happen at the distance less or equal to 0.07 AU within 407 days windows from the starting dates (the numbers are slightly enlarged with respect to 0.05 AU (40%) and one year-window (11%) in order to raise the chances for identification events located close to both upper boundaries). The further cross-identification between different tables was done using the temporary designation or asteroid number within the length of the time window. The final table contains only those close encounters within a year window that have geocentric distances *declared* by either service to be less or equal 0.05 AU. Next, we applied different size windows to generate statistics of cross-identification within overlapping (one year) and non-overlapping (4 months) time intervals. On Fig. 1 we provide an example statistics of cross-identification done between different tables within a year window using the tool developed [4]. The total number of close encounters for a combined set is 128 while the number of events predicted by *all* services is 42 (33%). We consider that these disagreements are caused by use of different dynamical models, and different orbital elements used for each asteroid orbital propagation. As well as different orbital fitting and weighting scheme used, different catalog bias corrections, different frequency of updating the table [2], etc. Besides, we have recomputed the circumstances of all predicted close encounters using the JPL HORIZONS on-line solar system data and ephemeris computation service [3], and found that only 103 (80%) would have minimal geocentric distances $\Delta_H \leq 0.05$ AU within the same one-year window, Tabl. 1.

Table 1: Agreement of the geocentric distances with the JPL HORIZONS calculations (Δ_H).

Service	Unique findings	$\Delta_H \leq 0.05$ AU
DynAstVO	10	2
CNEOS	1	1
MPC	10	2
NEOCC	5	1

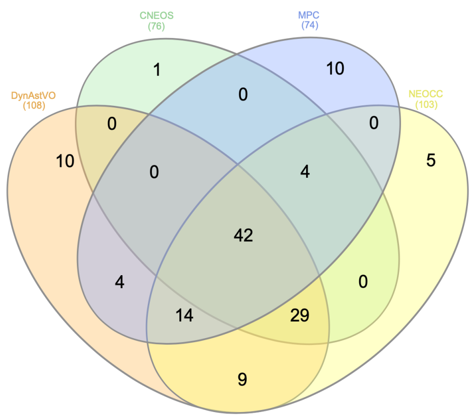

Figure 1: The Venn diagram for cross-identification of the close approaches within a one-year window starting on March 28, 2019: orange zone DynAstVO (108), green zone CNEOS (76), blue zone MPC (74), yellow zone (103) while the combined set consists of 128 close events.

3. Conclusions

The lists of predictions provided by all four services within a one-year window starting on March 28, 2019, share only one-third of the generalized number of PHA close encounters. This fact indicates high sensitivity of predictions made with respect to orbital fitting, as the services are generally making use of the same input measurement data. Prediction of close approaches of asteroids results from the application of several algorithms: search of close encounters while the orbital data is available, dynamical models of motion, the weighting of measurements at the orbital fitting process, etc. Any inconsistencies in the algorithms or a subjective choice of the weights will change the orbital fitting and, thus, the future prediction of close approaches for PHA.

The discrepancies found in predictions provided by the professional services indicate that the specific asteroids have different orbital propagations. Namely, these bodies require additional measurements (observations), as any algorithms developed always have limitations. Series of observations made at the moments of PHA close approaches can be used for reducing uncertainties in the prediction of such events, and thus improving the corresponding orbits.

Acknowledgements

A. Ivantsov acknowledges support by the TUBITAK 1001-project (118F036) and the support provided by Paris Observatory in 2018 through its transverse activity on space weather and near-Earth objects ESTERS.

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