Sensitivity of Predictions for Close Encounters of NEAs with the Earth

Anatoliy Ivantsov[1,2], Daniel Hestroffer[2], Josselin Desmars[2,3], Dmitrii Vavilov[2], William Thuillot[2]

[1]Royal Observatory of Belgium, Uccle, BELGIUM

[2]IMCCE, Paris Observatory, PSL University, CNRS, Sorbonne University, Lille University, Paris, FRANCE

[3]IPSA, Institute of Polytechnic Science and Aeronautics, Paris, FRANCE

an.ivantsov@gmail.com

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 [1] and Running Tallies [2];
- the JPL Center for Near Earth Object Studies (CNEOS) [3];
- the ESA's Near-Earth Object Coordination Center (NEOCC) [4];
- the DynAstVO database of IMCCE at the Paris Observatory PADC center [5].

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, at best, with respect to the combined set of predictions.

Method

Online requests were made to the mentioned above world ephemeris services for getting lists of close encounters of asteroids with the Earth satisfying a sole criterion: the close approaches should happen within a one-year window starting on April 1, 2023. The lists of close approaches were cross-matched with each other using temporary designations and asteroid numbers. The final tables contain only those close encounters within the one-year window that have geocentric distances *declared* by either service to be less or equal to 0.05 AU. The results of cross-identifications are illustrated by the Venn diagram [7] plotted for the ephemeris services data, Fig. 1.

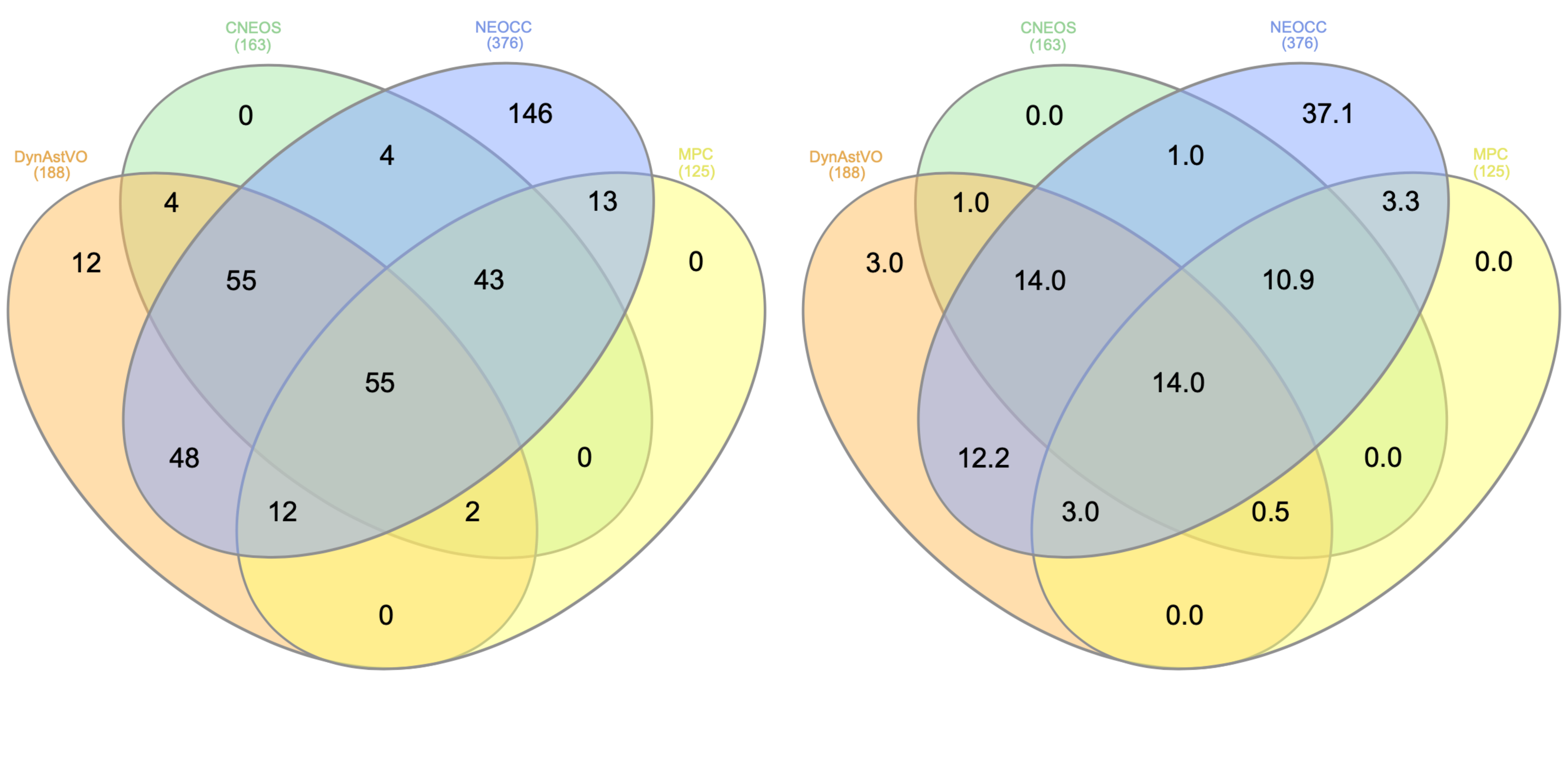

Figure 1: The Venn diagrams for cross-identification of the close approaches within a one-year window starting on April 1, 2023. The left figure in absolute values, the right is in relative percentages. The combined set consists of 55 close encounters that are 14% of the general set.

The moments and distances of all the close encounters were recalculated with the JPL Horizons on-line solar system data and ephemeris computation service [6]. Such comparison gives an independent view on the lists provided by the ephemeris services. The corresponding Venn diagram allows to show disagreements in the computed minimal distances, Fig. 2. While the DynAstVO database was last updated on March 13, 2023, it lists 4 close encounters with the objects 2010 GM_{52}, 2010 NS_{121}, and 2010 OG_{145} that are not used for the unique bodies anymore, and thus, the corresponding close approaches are useless. The encounters mentioned were removed as outliers from the further analysis.

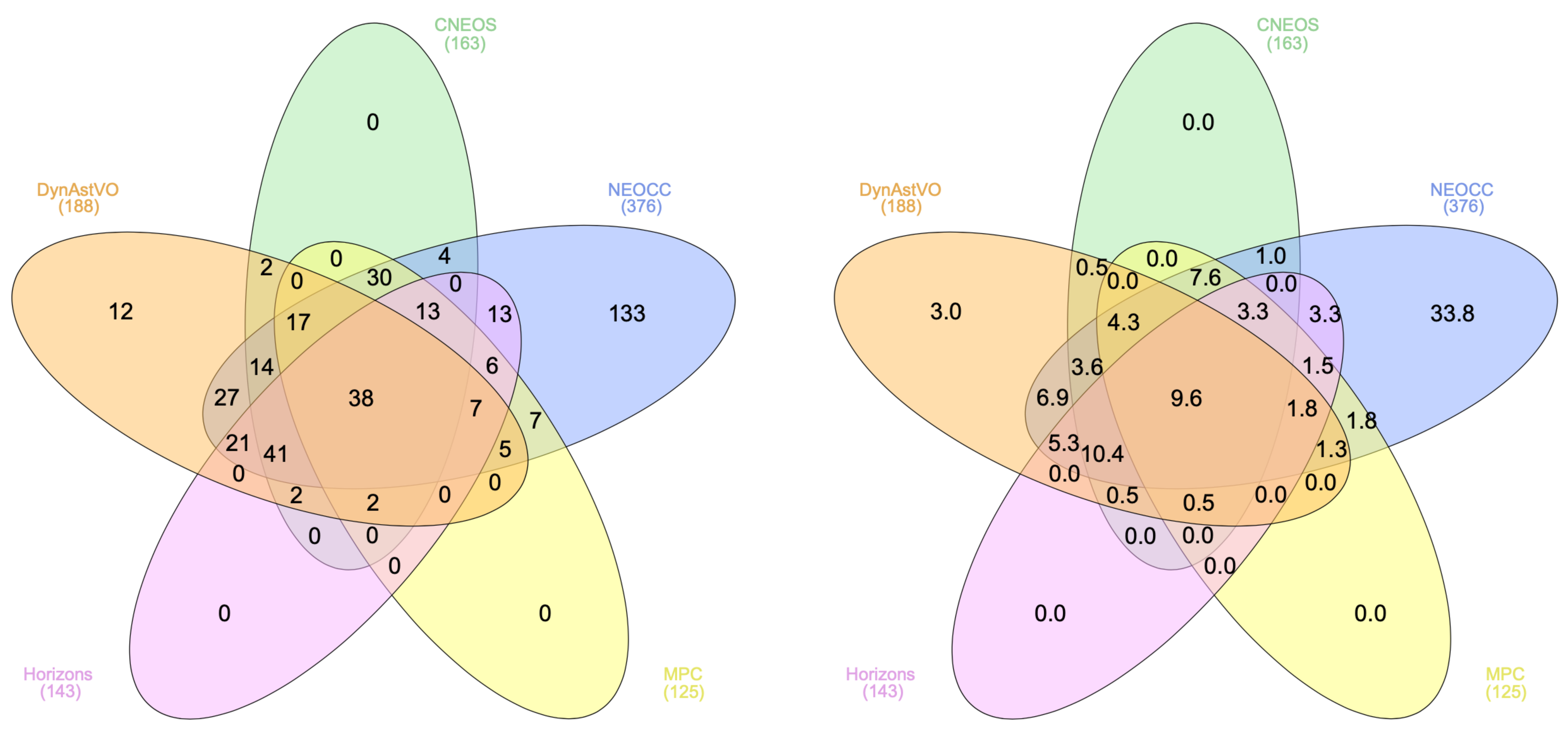

Figure 2: The Venn diagrams for estimation "accuracy" of close encounters prediction with respect to the JPL HORIZONS on-line ephemeris service. The events outside of the JPL HORIZONS set have close encounters distances declared less than 0.05 AU while the JPL HORIZONS provide for them distances greater than 0.05 AU.

Analysis

The Venn diagrams, Fig. 1, reveal a low level of agreement between ephemeris calculations done within the one-year prediction window. There are only 55 close encounters in the combined dataset which correspond to 14% only or one-seventh part. An explanation for the discrepancies discovered concerning the IAU MPC list of close encounters is simple. The last update of the Forthcoming Close Approaches To The Earth webpage was done on March 11, 2017. This date is also confirmed by the asteroids with the latest temporary designations starting in "2017" listed there [2]. The Running Tallies widget being updated continuously provides the list for one month back and one month ahead of the current moment [2], so it is not complete for the one year.

If we do not consider the list of MPC, the corresponding Venn diagram will provide us with the combined dataset which corresponds to 28% or one-third part of the general set, Fig. 3. It means that one of the reasons for the low agreement between the close encounter lists is the lack of regular updates.

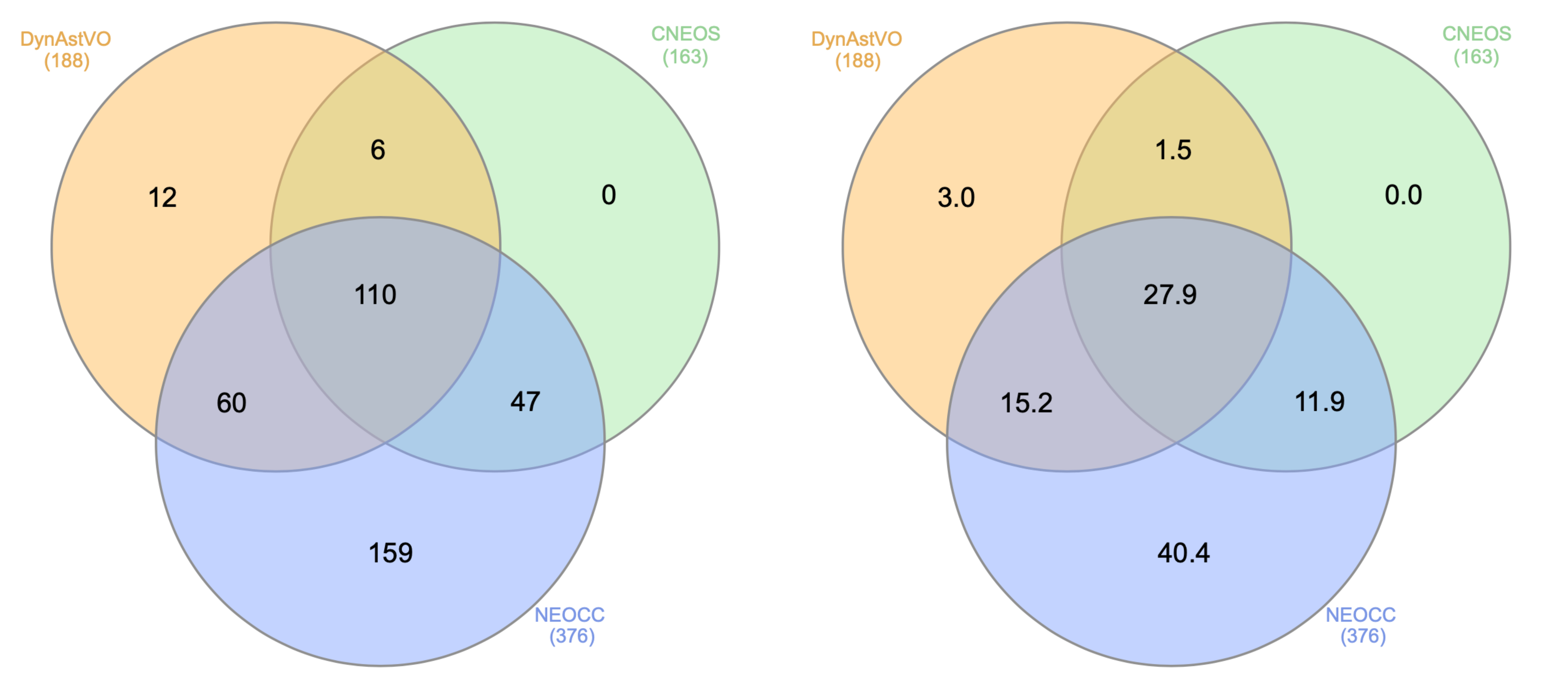

Figure 3: The Venn diagram in case we neglect the list of MPC. Notice a twofold increase in the combined dataset numbers with respect to Fig. 1.

While the combined dataset corresponds to some agreement between the corresponding calculations, the greatest interest is attracted to the unique findings that are lost by other services. Comparing the Venn diagrams on Fig. 1 and Fig. 2, one can deduce Tabl. 1.

Service	Unique findings	$\Delta_H \leq 0.05$ AU
DynAstVO	12	0
CNEOS	0	0
MPC	0	0
NEOCC	146	13

Table 1: Agreement of the geocentric distances with the JPL HORIZONS calculations (Δ_H) for the one-year window starting on April 1, 2023.

If the CNEOS list is computed using the orbital data of the JPL HORIZONS on-line service then the corresponding algorithm seems to have some leaks. In other words, one of the reasons to have discrepancies in the lists of close encounters can be the imperfection of the search algorithm.

The existence of the unique findings is evidence of different orbits resulting from the same observational data used. While it is not possible to avoid assigning different weights to the observations in the orbital fitting, and there can be different ideas on how to do that, it seems the only way to resolve the uncertainty in the prediction of close encounters is to organize observational campaigns of the particular asteroids.

Conclusions

- The Venn diagrams for the lists of close encounter predictions provided by four ephemeris services give various possible reasons for their low agreement, such as the rare list updates, imperfections of the search algorithm for close encounters, different dynamical modeling and orbital propagation, etc.
- The discrepancies found in the close encounter predictions can be considered as an indicator of the actual orbital uncertainty. Observational campaigns aimed at these particular asteroids at the moments of their close approach to the Earth can reduce these uncertainties most efficiently.

References

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