NEOShield: A comprehensive approach to asteroid threat mitigation

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The NEOShield project

While catastrophic collisions of our Earth with asteroids larger than 10km are fortunately rare, impact frequencies for objects sized between 30m and 500m are non negligible (Harris 2009). Given the fact that roughly 1400 among the currently known Near Earth Objects (NEOs) are potentially hazardous asteroids (PHA), a comprehensive understanding of the orbital and physical properties of these celestial bodies is desirable in order to allow for a reliable threat assessment. As, for the first time in the history of the planet, Earth's inhabitants possess the means to actively avert asteroid impacts, the construction of a detailed picture of NEO deflection becomes necessary.

The NEOShield project (Harris et al. 2012) constitutes an international effort under European leadership to enhance our understanding of threat mitigation options regarding potential asteroid impacts. In the framework of this project different mitigation strategies such as blast deflection, kinetic impactors or gravity tractors (Fig. 1) are not only studied individually, but they are put in context of realistic threat scenarios. Detailed suggestions for a mitigation test mission will also be provided.

Figure 1: Primary mitigation scenarios studied in the NEOShield project. From top to bottom: blast deflection, kinetic impactor, gravity tractor. (Images courtesy Astrium)

High Precision Astrometry

One of the goals of IMCCE's team within the NEOShield project is to define prerequisites and bottlenecks in the prediction of NEO impact probabilities. So far, the uncertainties in both, a NEO's orbit and its numerical modeling have been identified as key-points that determine the reliably of impact threat assessments. Fig. 2, for instance, shows the differences arising in the impact solutions predicted with data from early 2012 for the asteroid 2011 AG5 when close approach interpolation algorithms are exchanged. A spline based interpolation of closest encounter distances reproduces published impact probabilities satisfactorily (P≈1/500), while a geocentric hyperbolic fit - more closely related to the common target plane analysis - tends to overestimate the impact risk.

A correlation between the number of observations, the length of the available data arc and the Current Ephemeris Uncertainty (CEU), i.e. the uncertainty in the observer's plane of the sky is visualized in Fig. 3.

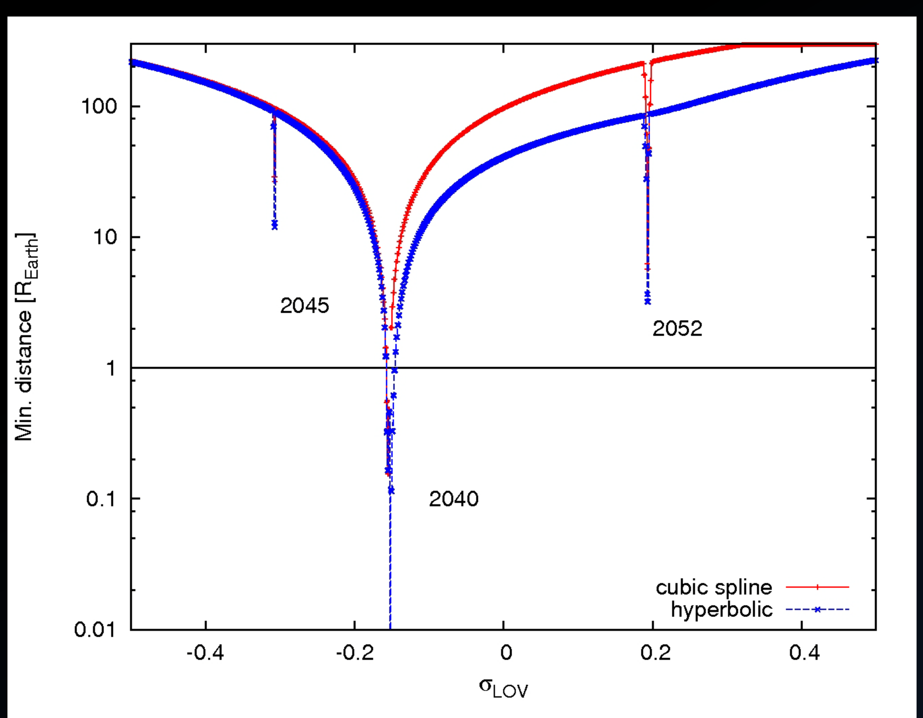

Figure 2: Minimum encounter distance of 2011 AG5 clones with Earth as a function of their position on the Line of Variations (LOV). Only orbit data available in mid 2012 has been used. Chaneing the close encounter distance evaluation algorithm leads to different impact probability estimates.

One can see that accurate initial orbit determination is difficult at present, especially, when only short arcs have been observable. Quick discovery follow-up observations featuring high precision astrometry could significantly reduce the initial orbit uncertainty leading to faster and more accurate impact probability estimates.

Yet, accurate NEO orbit determination is not the only important contribution of high precision astrometry to asteroid threat mitigation. Understanding an NEO's physical properties is essential for deflection considerations as the information gathered over the past decades suggests a population of objects presenting a very high degree of diversity in terms of composition, shape, internal structure and rotational state (Jewitt 2012, Carry 2012). Especially important in this regard is the fact that roughly 15% of all NEOs are multiple asteroids consisting of two or more objects closely orbiting their common center of gravity (Fang & Margot 2012). Those asteroids constitute a special challenge, as potential deflection missions have to displace the binary's center of mass rather than change its mutual orbit. Knowledge on asteroid binarity is, thus, essential, if a mitigation mission is to be successful. Furthermore, binary asteroids are favorable targets for a mitigation demonstration mission (e.g. AIDA/DART, Cheng et al. 2012). High precision astrometry is a powerful method when it comes to discovering asteroid multiplicity, as is shown in Fig. 4.

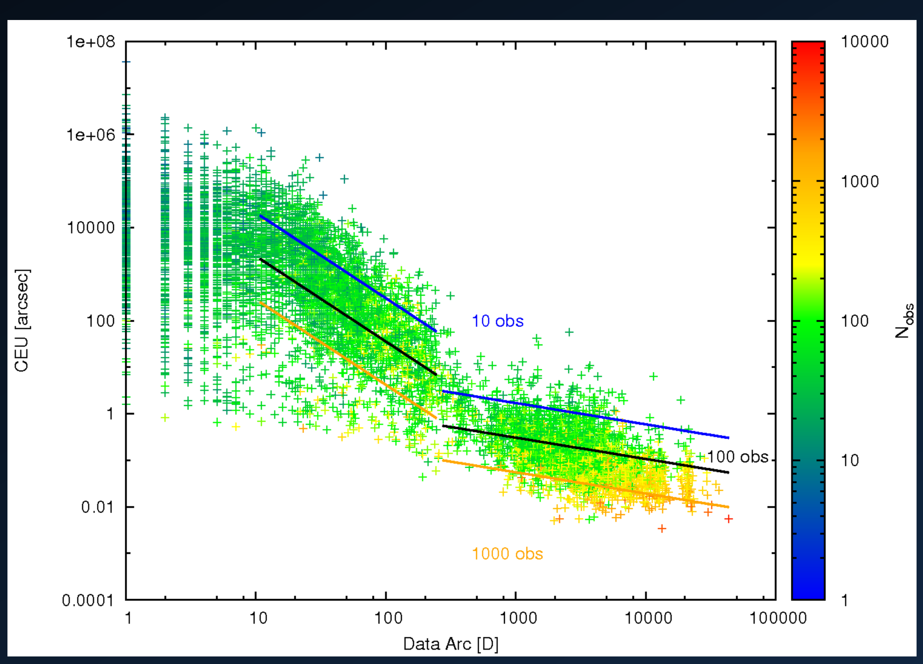

Figure 3: Current Ephemeris Uncertainty (CEU) of all NEOs known by the end of 2012 as a function of available data arc and number of conducted observations. Especially short arc observations would profit from high precision astrometry.

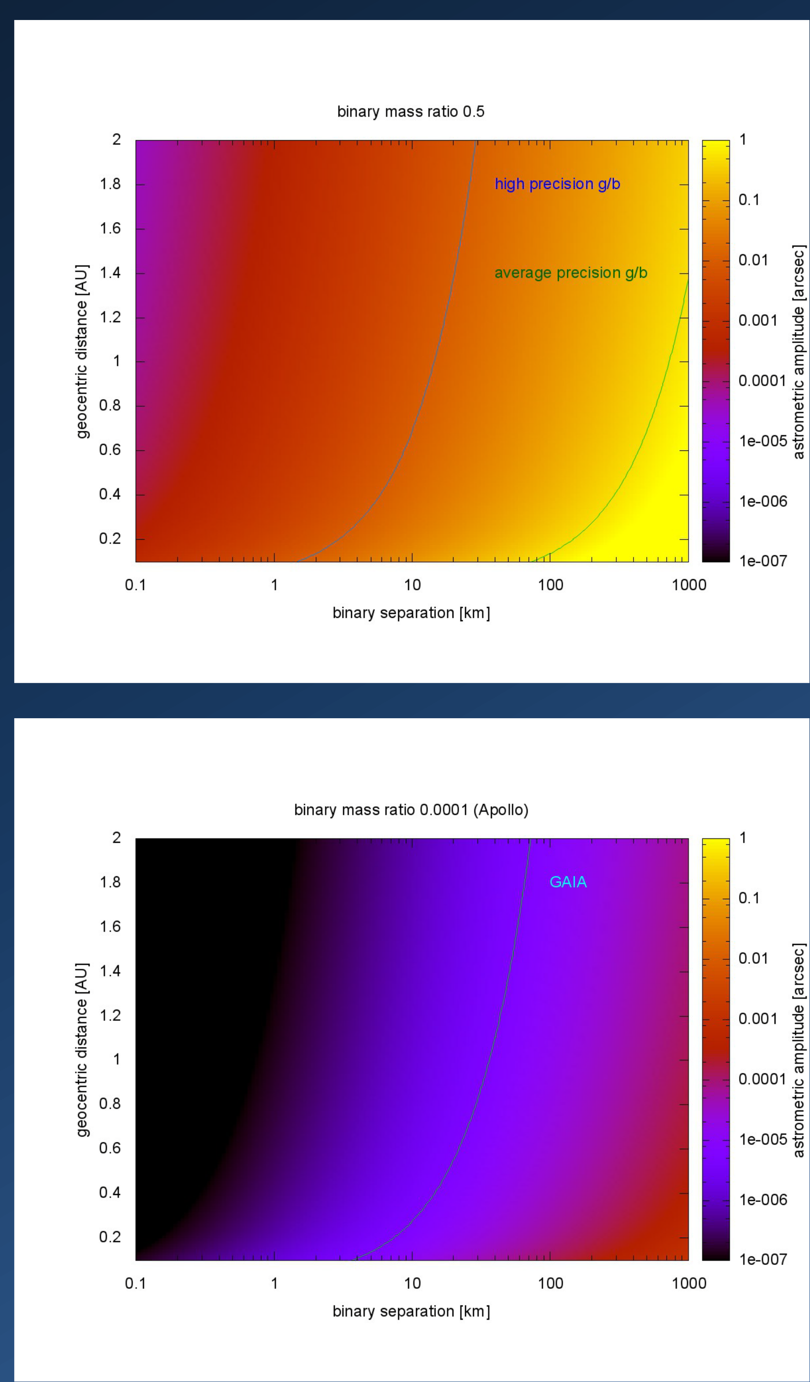

Figure 4: Asteroid binarity detectability via high precision astrometry . Top: binary asteroids with a mass-ratio m/(M+m) =0.5 can be identified as multiple systems via groundbased (g/b) astrometry, if their mutual separation is sufficiently large. Bottom: For very small mass ratios as in the case of (1862) Apollo, space based missions (e.g. GAIA) can determine asteroid multiplicity. Astrometric amplitdue estimates have been conducted following Eggl et al. (2013). Circular mutual orbits have been assumed.

Conclusions

Acquiring high precision astrometry of NEOs is essential for asteroid threat assessment and mitigation. On the one hand, such data can be used to reduce orbit uncertainties, which will allow for quick and precise estimates of impact probabilities. An early determination of asteroid multiplicity via high precision astrometry, on the other hand, permits an adaption of mitigation strategies, thus safeguarding us against the consequences of deflection failures.

Acknowledgments

The authors would like to acknowledge the support of the NEOShield project funded by the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement no. 282703.

References

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