SMPAG work by ESA

Status 2015 Nov

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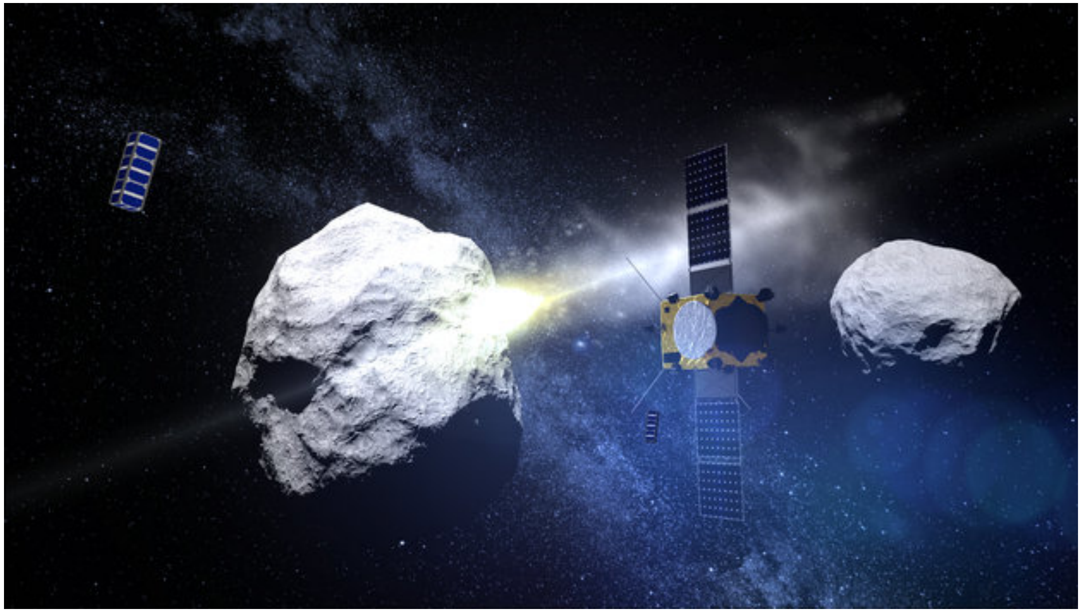
- **ESA leads task: Mapping of threat scenarios to mission types**
  - Task “Reference missions for different NEO threat scenarios” will define missions
  - This task will study detailed links between threat scenarios and mission types
- **Typical questions**
  - Optimum time slots for launch and deflection
  - Latest time for launch and deflection
  - Observation periods allowing to reduce impact uncertainty
  - Opportunities for implementing in-situ observation missions
- **Final goal**
  - Parametric mission designs as function of asteroid orbits and warning time
  - Timeline of events, mission duration, needed delta-v, and more

AIM = Asteroid Impact Mission

- **Part of AIDA (Asteroid Impact Deflection Assessment)**
- **Two parallel studies ongoing**
  - QuinetiQ in Belgium
  - OHB in Germany
  - http://www.esa.int/Our_Activities/Space_Engineering_Technology/Asteroid_Impact_Mission/CubeSat_companions_for_ESA_s_asteroid_mission



Other current studies

- **A Parametric Assessment of the Full PHA Phase Space, and Deflection Feasibility using Kinetic Impactors**
  - Performed by F. Bach within the mission analysis team at ESA/ESOC (J. Schoenmaekers)
  - Detailed slides and paper available
- **Parking orbits for asteroid characterization and deflection missions**
  - Performed by S. Maki, collaboration with TU Munich, Germany
- **Fly-by missions at asteroids – how much do they help mitigating a potential impact**
  - S. Schuster, P. Kollo, collaboration with TU Munich, Germany

Bach - Assumptions

Constructing PHAs

- circular Earth
- no seasons

→ 3 free parameters:

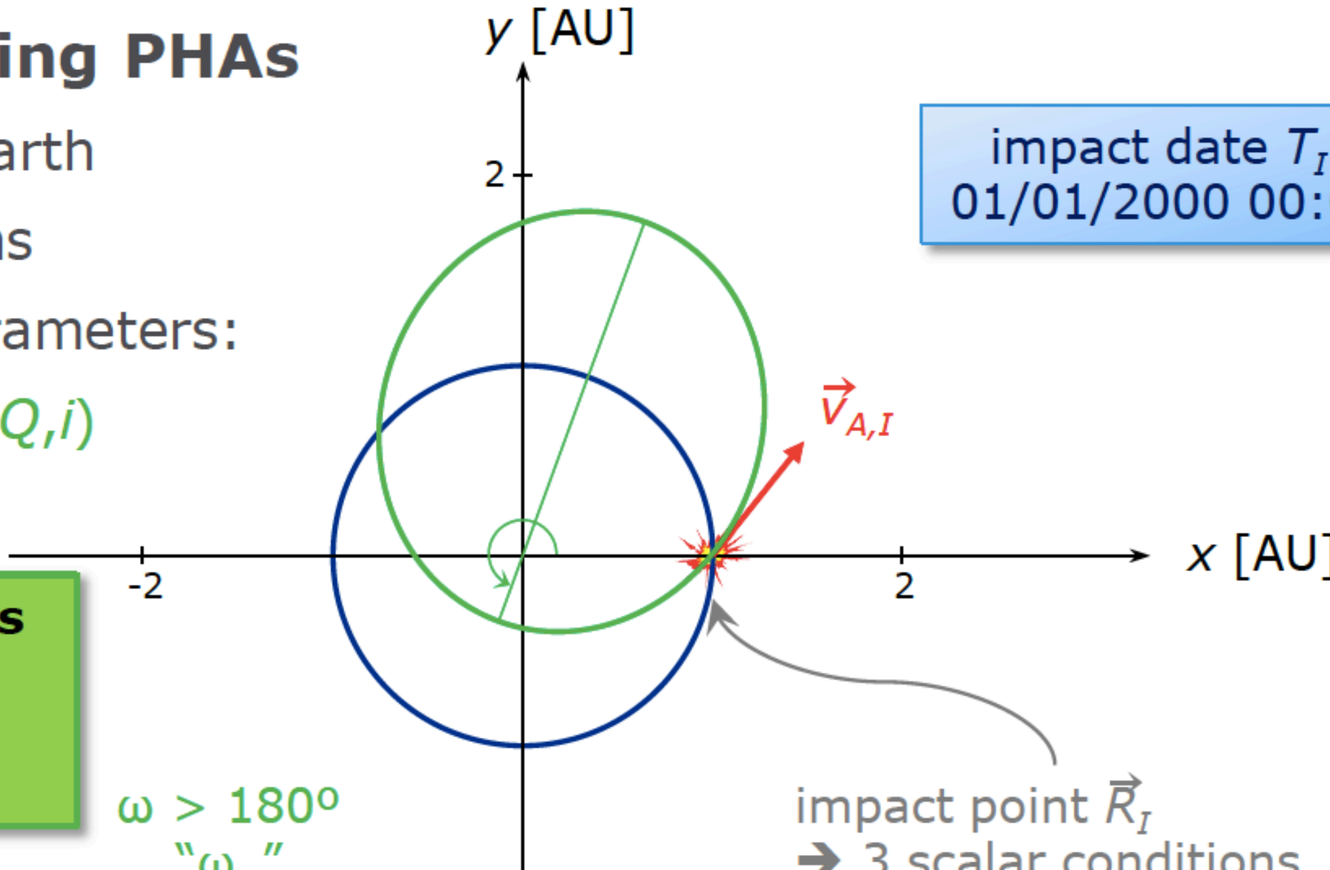
$\vec{v}_{A,I}$ or (q,Q,i)

PHA conditions

$q \leq 1$ AU

$Q \geq 1$ AU

$0 \leq i \leq 180°$



impact date T_I:
01/01/2000 00:00

$\omega > 180°$
"ω_+"

impact point $\vec{R}_I$
→ 3 scalar conditions

Presented on behalf of J. Schonemaekers

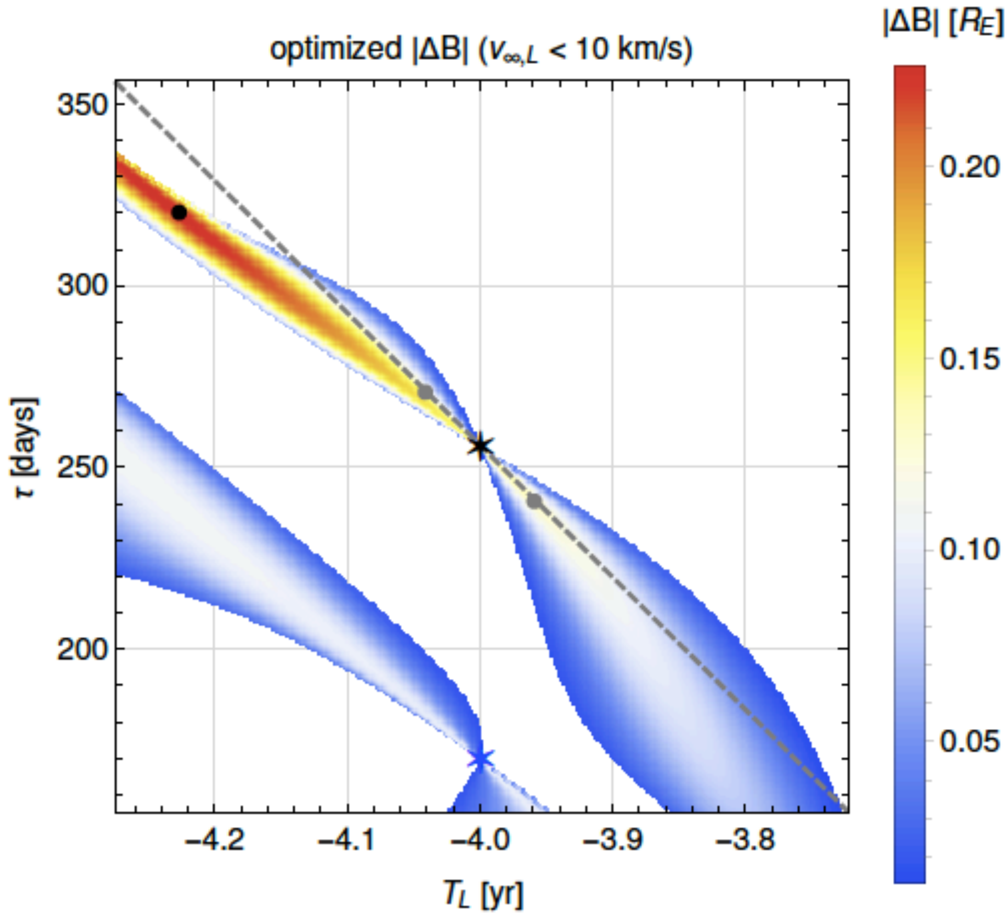
Bach - outline

- **Assumes deflection at 1 au**
- **Studies missions as function of period, eccentricity, inclination**
- **Resonant transfer as starting point for optimization**
- **Finds deflection merit ΔB (deflection in Earth radii)**

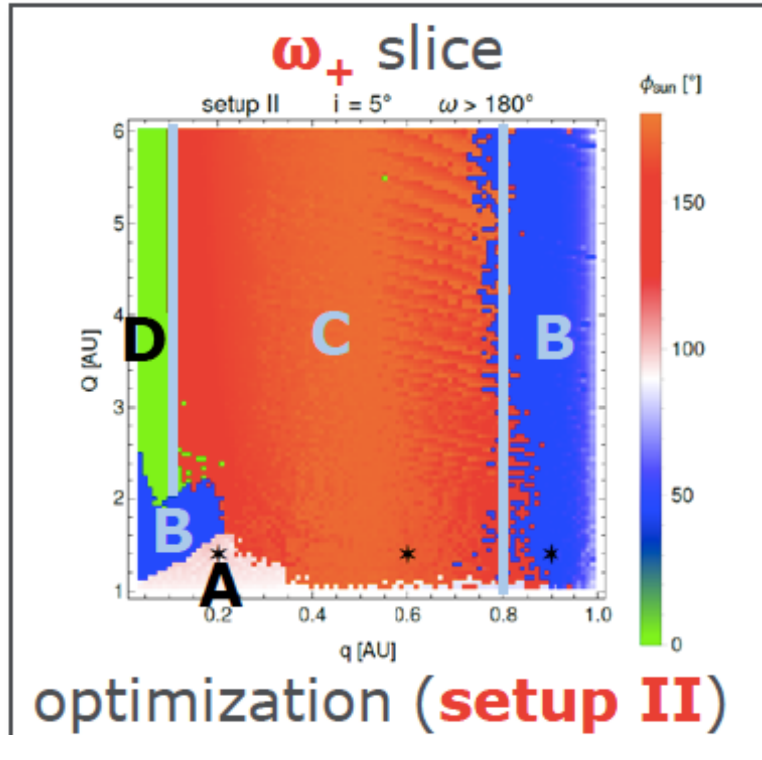
$$\Delta B = \underbrace{v_{A,I} \frac{\sin\gamma}{\rho} \frac{3a}{\mu}}_{\text{PHA orbit } \Phi_{\text{orb}}} \underbrace{\frac{\beta}{m_A}}_{\text{physical}} \underbrace{\left[\vec{v}_{A,D} \cdot \Delta\vec{p}_{K,D}\right] (T_I - T_D)}_{\text{merit function}}$$

Bach – results

- **Example =>**
- **Finds different regions in P/a/i phase space:**
  - A: 2π transfer accelerating asteroid
  - B: 2π transfer decelerating asteroid
  - C: π transfer
  - D: no solution



- **Deflection types in orbital parameter space**
- **For details: See paper**



A Parametric Assessment of the Full PHA Phase Space, and Deflection Feasibility Using Kinetic Impactors

Fabian Bach*
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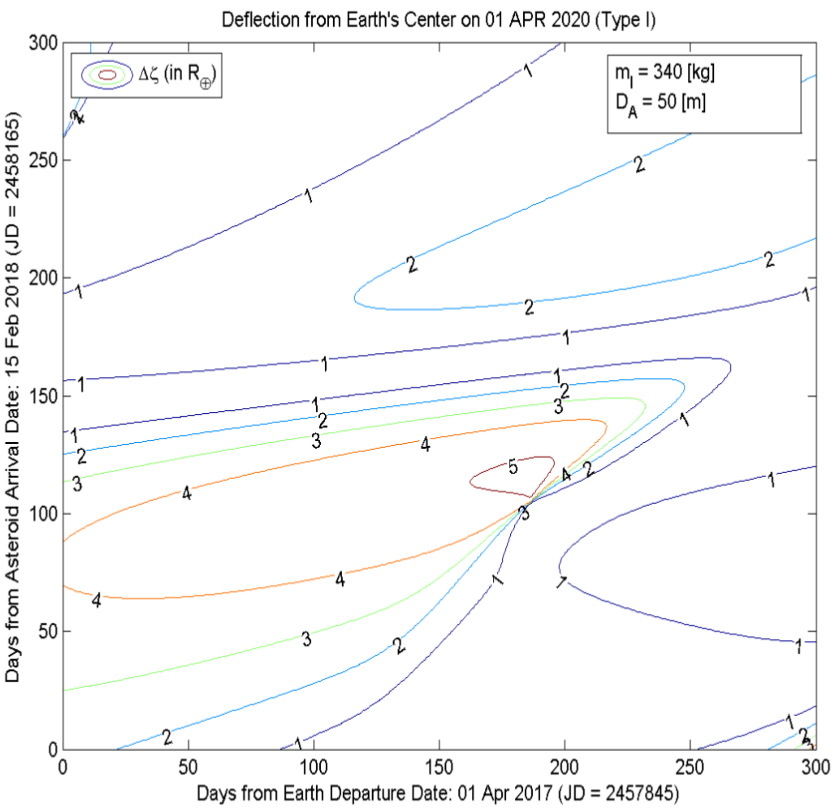
(Dated: October 13, 2015)

We systematically analyze the possibilities to deflect Potentially Hazardous Asteroids (PHAs) by means of a kinetic impactor mission, as a function of the PHAs' orbital states. To that end, we construct hypothetic threat scenarios to impact Earth at a set epoch, and scan the entire possible PHA phase space. For each point, an optimal ballistic deflection transfer is determined, accounting also for launcher performance and other technical limitations. Finally, we analyze the deflection merit as a function of the PHA phase space, identifying and discussing particularly interesting or problematic regions.

Maki - status

- **Similar to previous work, but focuses on transfers from parking orbits**
- **Can produce pork-chop plots showing not only the delta-v of the transfer but also the deflection**



Deflection Success Criterion

$$\Delta\zeta \geq 2R_{\oplus}$$

Mission Report

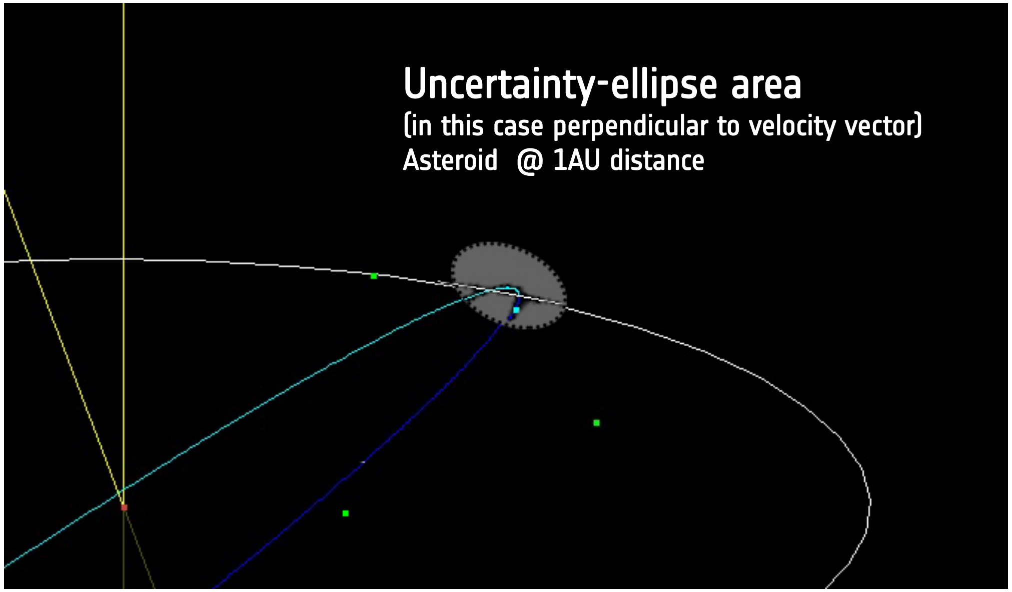
t_W = 1 year		D_A [m] 15	50	160	270
m_I [kg]	340	S	F	F	F
	1000	S	S	F	F
	6000	S	S	F	F

t_W = 3 years		D_A [m] 15	50	160	270
m_I [kg]	340	S	S	F	F
	1000	S	S	F	F
	6000	S	S	S	F

t_W = 10 years		D_A [m] 15	50	160	270
m_I [kg]	340	S	S	F	F
	1000	S	S	S	F
	6000	S	S	S	S

Schuster/Kollo

- **How much can we improve the orbit accuracy by spacecraft fly-by?**
  - Understand 'orbit accuracy', what's a good metric for it?
  - Assess existing missions – e.g. Rosetta at Steins/Lutetia
  - Which instruments do we need for flyby (=> task 'toolbox')
  - Quantitative assessment of orbit improvement as function of flyby distance/velocity and used instrumentation



Thoughts on metric for accuracy

I. **Line of Variation (LOV) approach** ***(length of line measure for uncertainty)***

II. **Use of existing accuracy metrics (*mpcorb*: U-parameter; *astorb*: CEU, PEU, next PEU, two greatest PEU)**

III. **Calculate the area of the uncertainty ellipse of the orbit at different points**

   i. Area of uncertainty ellipse at perihelion of the asteroid orbit (perpendicular to asteroid velocity vector)

   ii. Area of uncertainty ellipse at aphelion of the asteroid orbit (perpendicular to asteroid velocity vector)

   iii. Area of uncertainty ellipse at 1 AU asteroid orbit / sun distance (perpendicular to asteroid velocity vector)

   iv. Area of uncertainty ellipse at 1 AU asteroid orbit / sun distance (perpendicular to earth velocity vector)

IV. **Weighted average of the uncertainties of the Kepler elements**

V. **Calculate the volume of the uncertainty ellipsoid of the orbit at different points**

Summary

- **We are working on a classification for deflection missions**
- **We are assessing the usefulness of waiting for an object in a parking orbit**
- **We are assessing the potential of improving orbit accuracies by spacecraft flybys**

- **For discussion:**
  - What would be a good metric for the orbit accuracy?