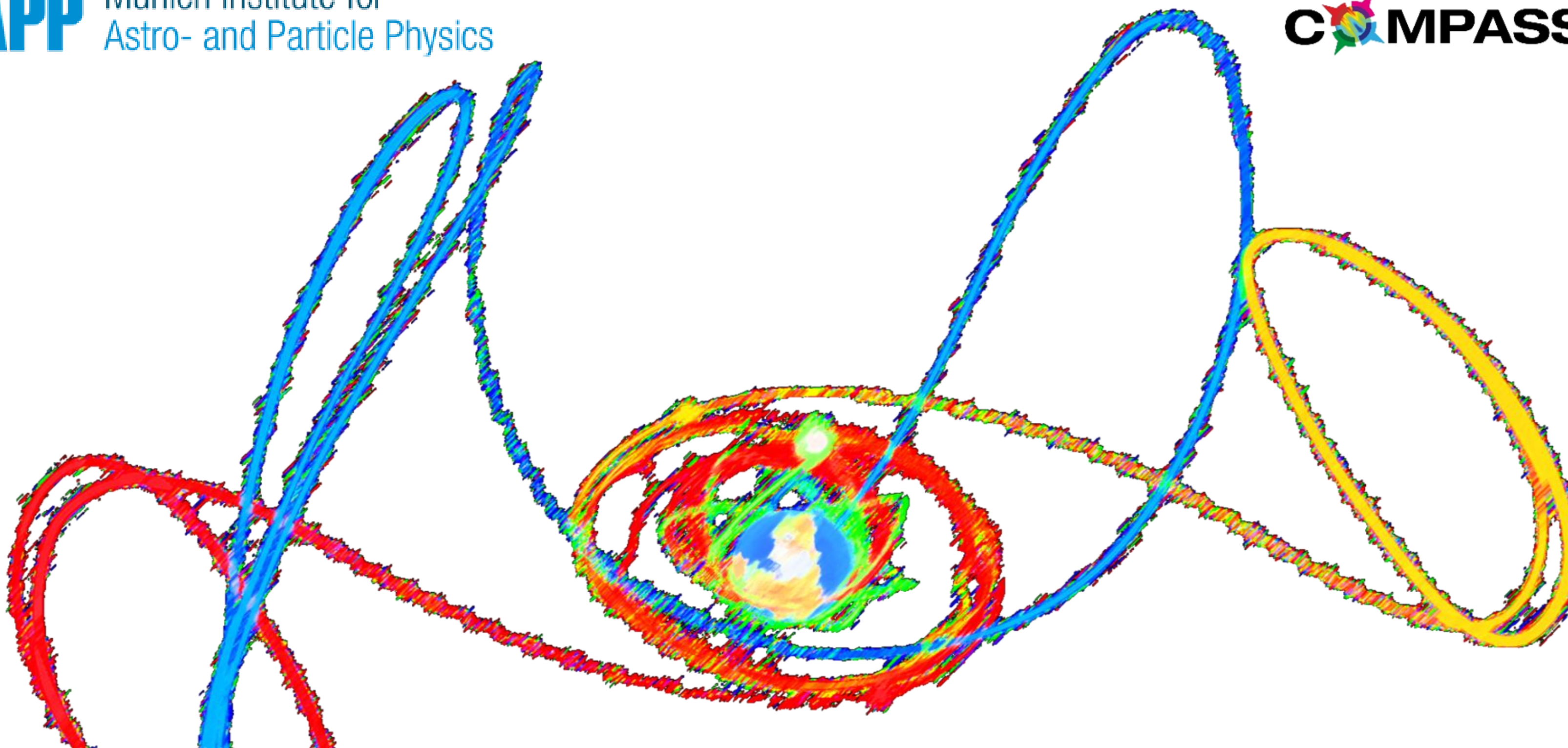
Munich Institute for Astro- and Particle Physics



Dynamics and Impact Monitoring

Camilla Colombo, Robert Jedicke, Detlef Koschny, Richard Wainscoat, Andreas Burkert

Near-Earth Objects: Properties, Detection, Resources, Impacts and Defending Earth

14 May - 8 June 2018, Munich Institute for Astro- and Particle Physics (MIAPP)

Some questions…

- Dynamics of asteroids
  - Impact monitoring
  - Orbit resonances
  - Deflection

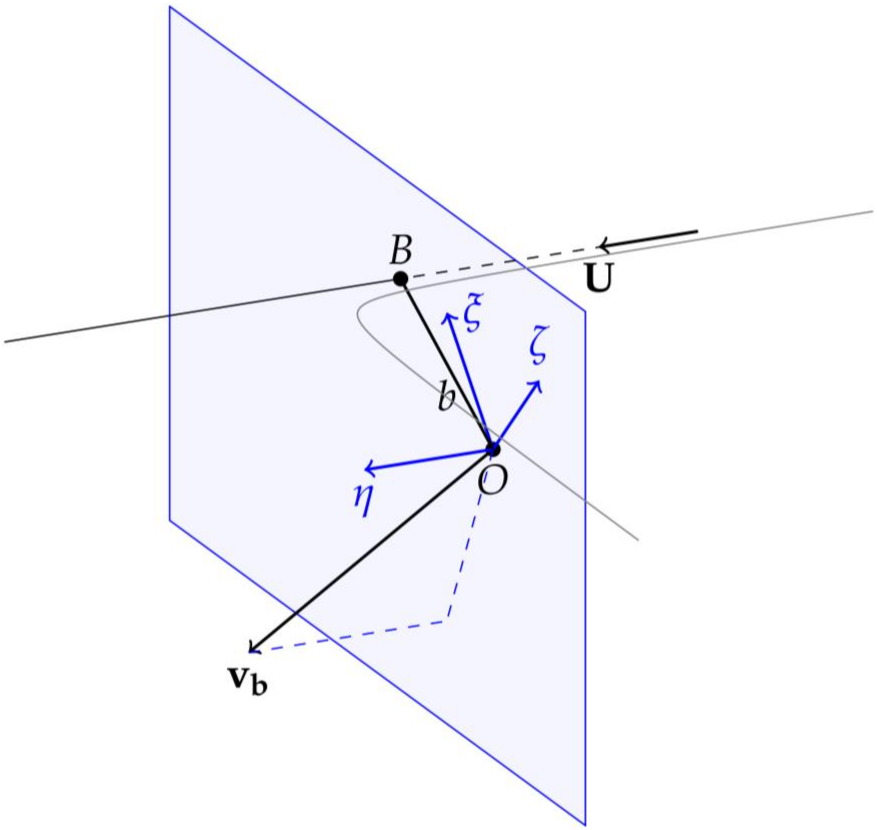
- Evolving risk assessment: how does the uncertainty for the hazardous impact objects evolve with time?
- How can dynamics finding be used for astronomical orbit determinations?

Dynamics and impact monitoring

Resonant encounters

- Öpik's theory for close encounters (extended to include near misses, Valsecchi, et al., 2003)
- The b-plane allows to conveniently characterise an encounter, as it decouples its two main parameters
- b-plane coordinates
  - ξ represents the geometric distance between the orbits
  - ζ represents the shift in arrival time of the object at the planet
- The impact parameter is defined as

$$b = \sqrt{\xi^2 + \zeta^2}$$



b-plane geometry (Letizia, et al., 2016)

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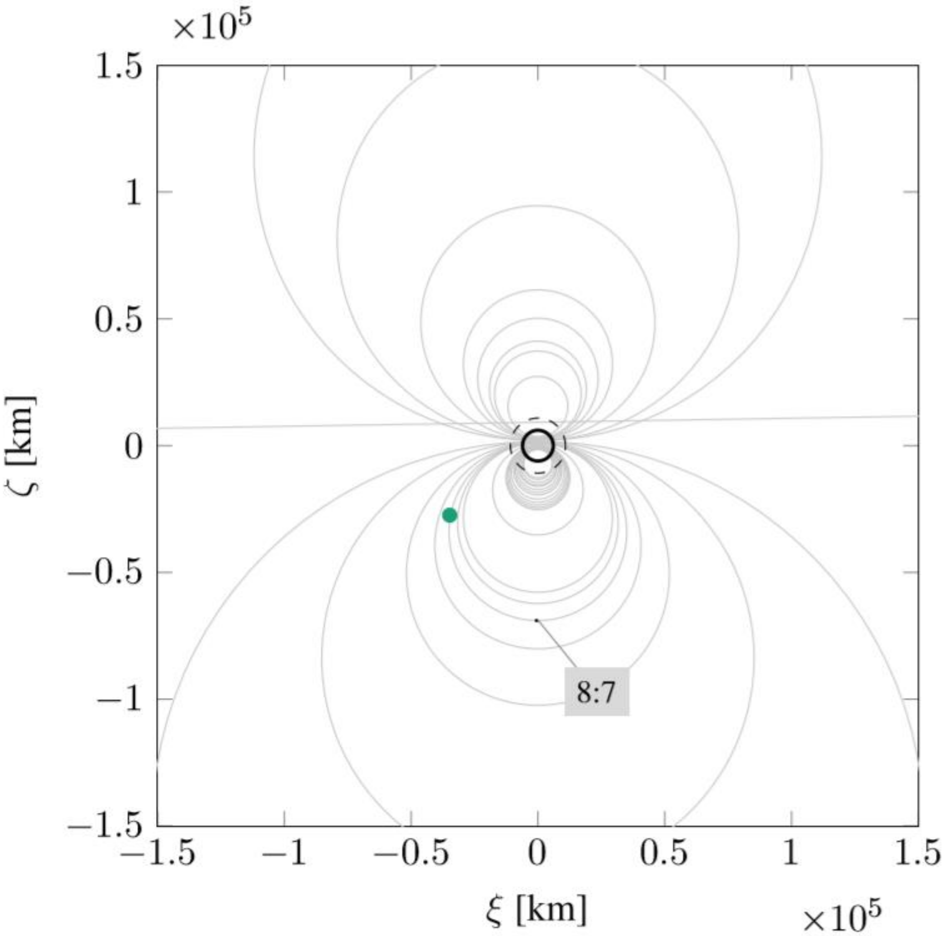
Resonant encounters

- In order to have a subsequent planetary encounter of the object, the following condition must be satisfied: $k\mathrm{T}_P = h\mathrm{T}', k, h \in \mathbb{N}$
- The normalised post-encounter semi-major axis can be defined as $\overline{a}' = \left({}^{k}/{}_{h}\right)^{2/3}$
- This parameter is associated to the post-encounter Θ angle
- The combination of this result with the description of the angles after the flyby gives the equation of a circle on the b-plane centred on the ζ axis in D, with a radius R



Example of b-plane resoant circles (Letizia, et al., 2016)

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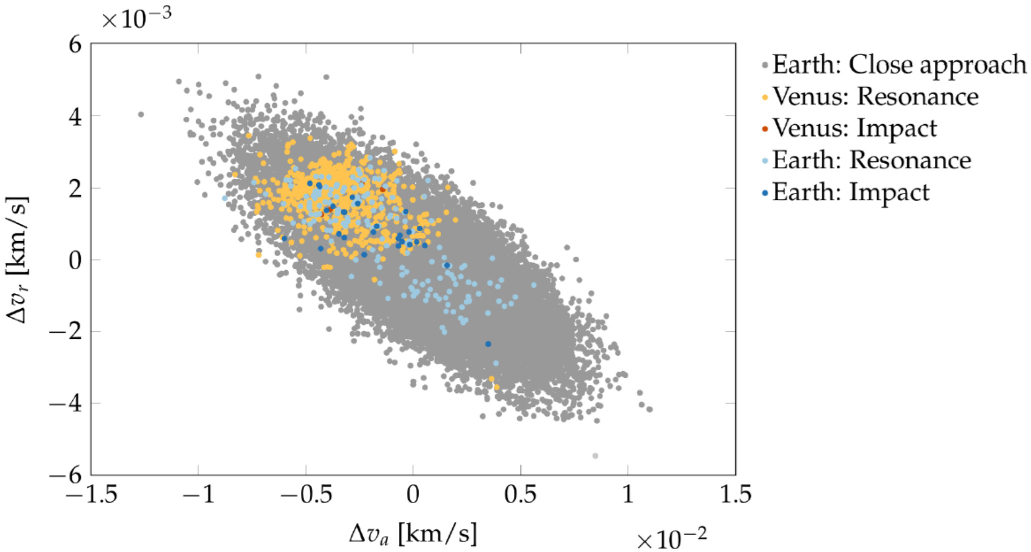
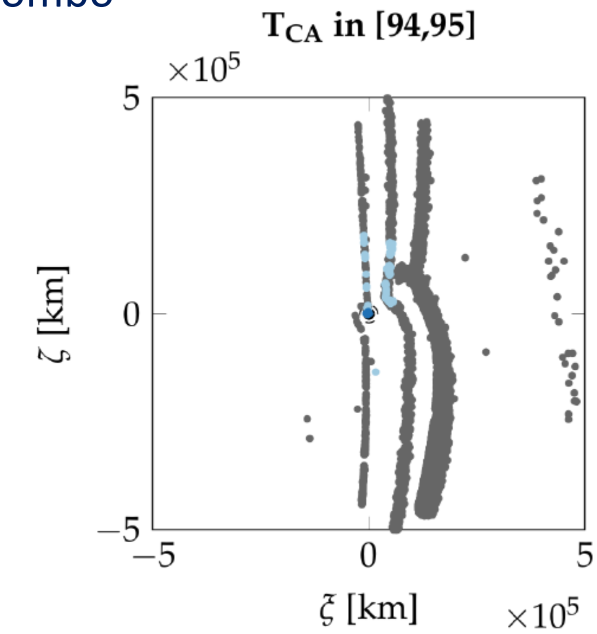
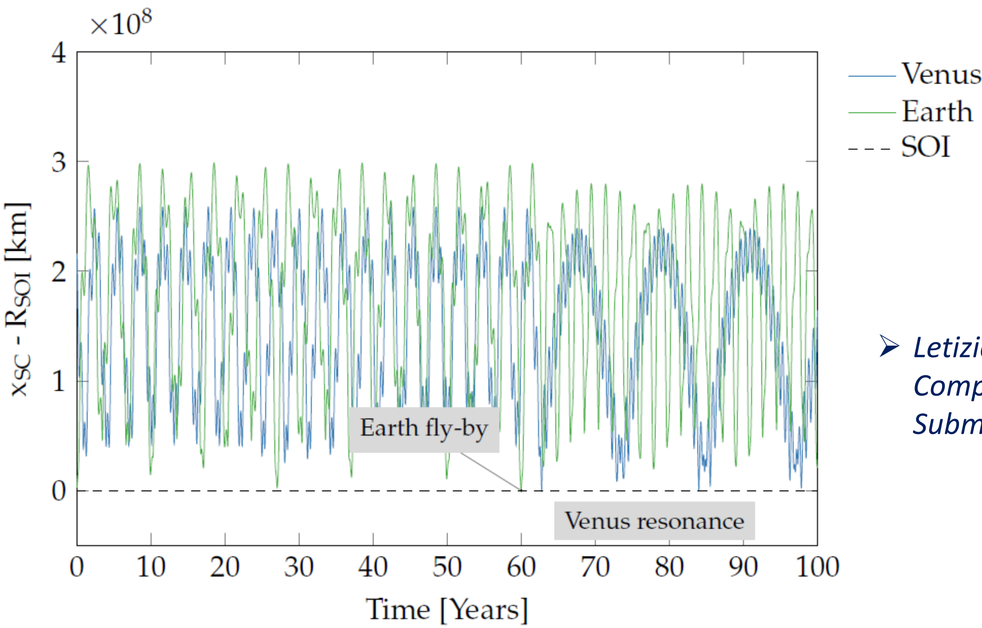
Example of resonant dynamics Ariane launcher of BepiColombo





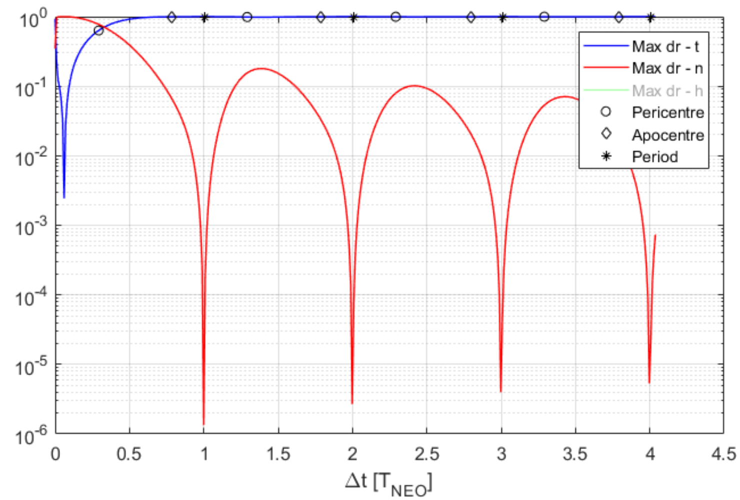


- *Letizia F., Van den Eynde J., Colombo C., Jehn R., "Evaluation of Compliance to Planetary Protection Requirements with SNAPPshot.", Submitted to Advances in Space Research, 2018.*

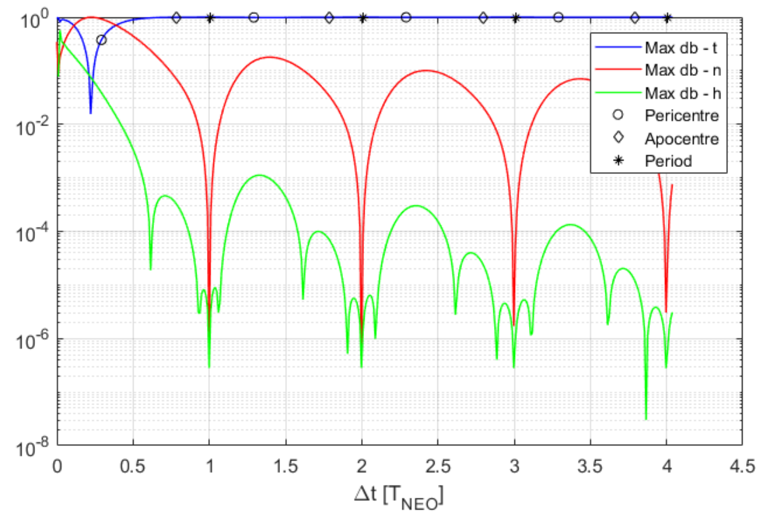
Dynamics and impact monitoring

Optimal deflection missions

- The maximisation of $d\xi$ is the only non-cumulative effect and the only one to present a periodic behaviour
- The maximisation of $d\zeta$ is therefore considerably more effective than that of $d\xi$, thus closely resembling that of db for long deviation times



Direction of maximum deviation dr for 2010 RF_{12}

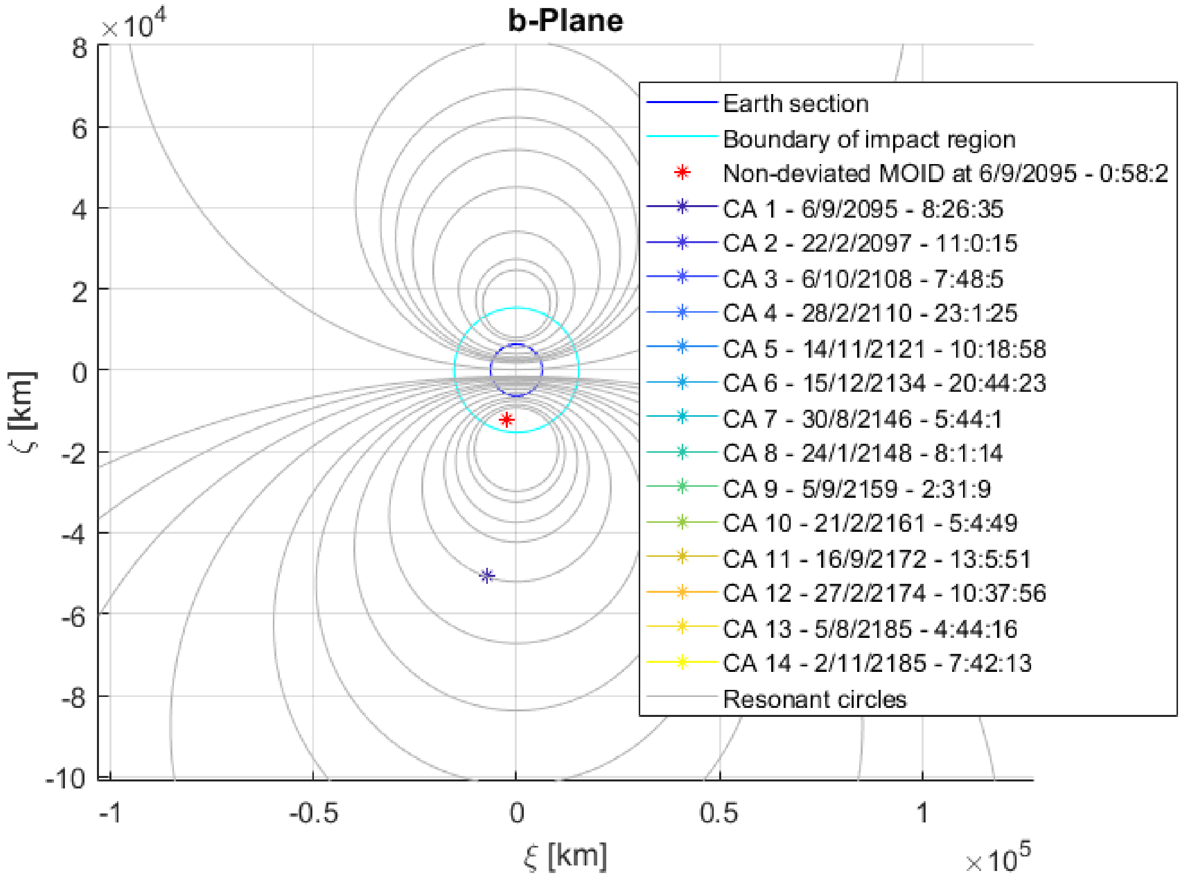


Direction of maximum deviation db for 2010 RF_{12}

Dynamics and impact monitoring

Deflection of resonant encounters

Propagation for 100 years after the deviation to observe the following close approaches on the b-plane



Example of post-deviation b-plane analysis for 2010 RF_{12}, only the first close approach is visible, as the others are far from the centre

- *Petit M., Colombo C., 2018.*

Some questions…

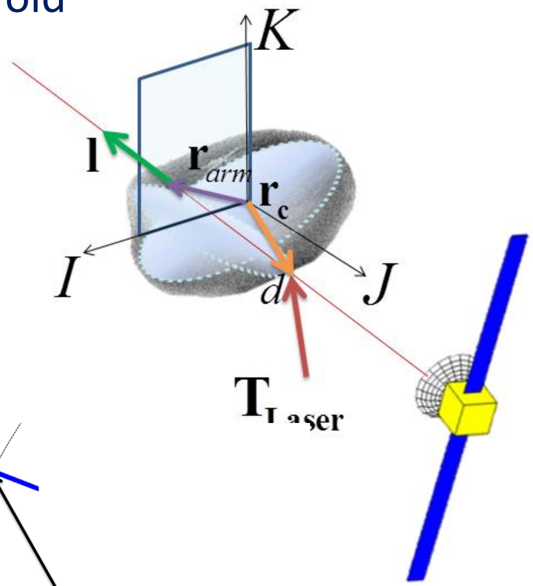
- Dynamics of orbits around NEOs
  - Specific to in situ studies
  - Specific to deflections
  - Manipulation

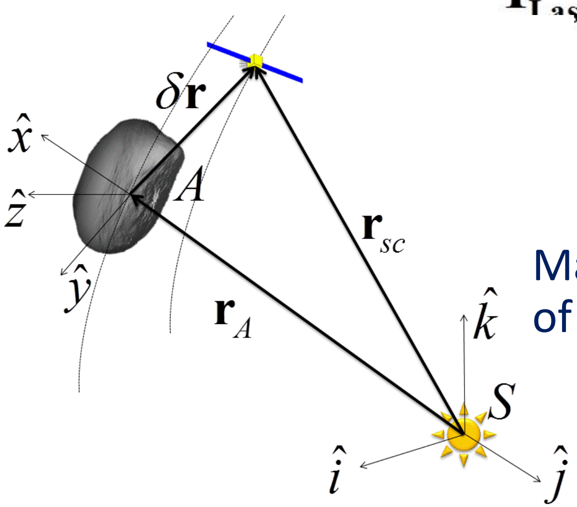
- What kind of orbits can we use for future missions?
- Sinergy between capture and deflection?

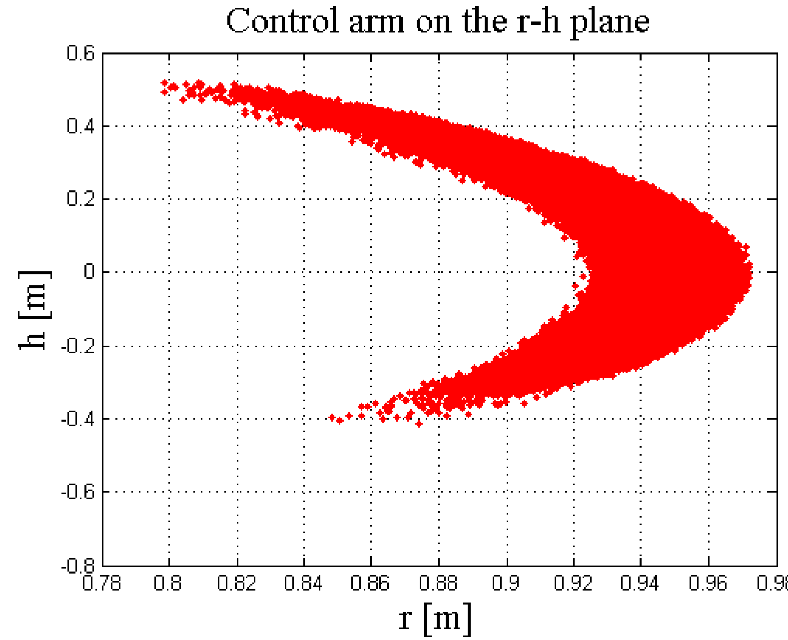
Dynamics and impact monit

Dynamics at asteroids

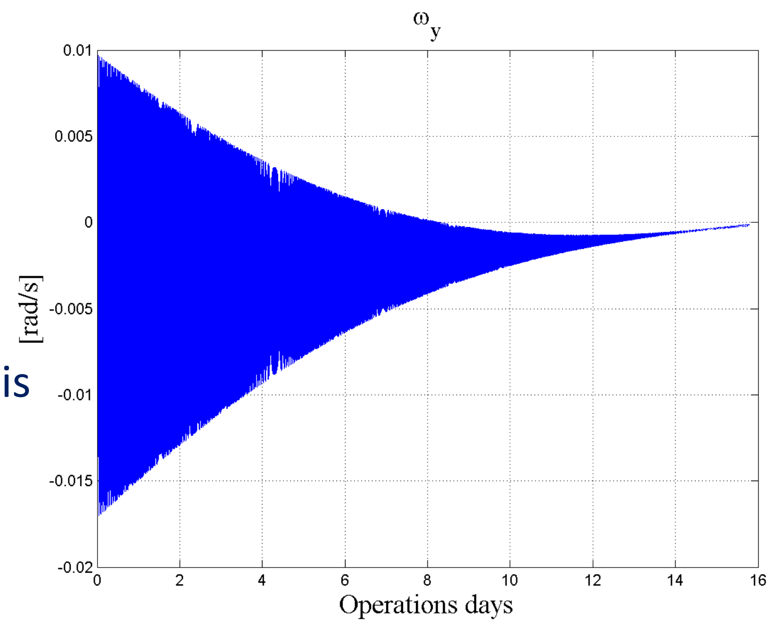
Rotating Hill frame A centred at the asteroid







Maximum velocity on the axis of maximum inertia



➢ *Vetrisano M., Colombo C., Vasile M., "Asteroid Rotation and Orbit Control via Laser Ablation", Vol. 57, No. 8, 2016, pp. 1762-1782.*