The case of APOPHIS

Jean-Yves Prado
CNES/DSP/E2U

February 14, 2012
A brief history of APOPHIS

The April 13, 2029 swing-by

Possible impacts in the future

Ephemeris improvement

A possible mission in 2028-2029

Conclusion
<table>
<thead>
<tr>
<th>Discovery</th>
<th>Roy A. Tucker, David J. Tholen, Fabrizio Bernardi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovered by:</td>
<td></td>
</tr>
<tr>
<td>Discovery date:</td>
<td>June 19, 2004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orbital characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphelion distance:</td>
<td>1.099 AU</td>
</tr>
<tr>
<td>Perihelion distance:</td>
<td>0.746 AU</td>
</tr>
<tr>
<td>Orbital period:</td>
<td>323.6 d (0.89 year)</td>
</tr>
<tr>
<td>Inclination:</td>
<td>3.331°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions:</td>
<td>~250 m (estimated)</td>
</tr>
<tr>
<td>Mass:</td>
<td>2×10^{10} kg</td>
</tr>
<tr>
<td>(estimated)</td>
<td></td>
</tr>
<tr>
<td>Rotation period</td>
<td>~30h</td>
</tr>
</tbody>
</table>

Mass of APOPHIS ~ 200 x @V=44,000 km/h
APOPHIS trajectory around the Sun
APOPHIS Flyby of the Earth on April 13, 2029

Earth Motion

Arrival Period 323 days

New Period 419+/− 2 Days

Sun
APOPHIS trajectory seen from the Earth
Update of the 2029 approach

• Zoom on the closest primary and secondary keyholes in the 2029 b-plane

• $3\sigma$ uncertainty ellipses in $\xi$ and $\zeta$ on the 2029 b-plane.

From David Bancelin PhD thesis
The Yarkovsky Effect

Prograde rotation

Retrograde rotation

Direction of Yarkovsky Force

Orbital motion

A.M.
P.M.

Yarkovsky drift

Thermal re-radiation
APOPHIS trajectory plotted in the Sun–Earth rotating frame

Observation possibilities for the 2004-2013 time frame

Dates format day/month/year

Not visible from the Earth
Distance < 0.7 AU but solar elongation <45°
Visible from the Earth
Distance [AU]

Elongation (deg)

V mag

Elongation

Date [yr]

Credit D. Hestroffer IMCCE
Needs for a tracking campaign in the 2012-2013 time frame

• There will be many ground-based observations of Apophis in the 2012-2013 time frame

• The assessment of impact risk for the future will change with time,
  - new observations coming,
  - better estimates of non-gravitational forces (Yarkovsky Effect) being calculated

• The medias and the general public can be disoriented and skeptical towards official announcements if conflicting previsions are released

• Needs to harmonize for releasing informations towards the public
  - reference frames
  - graphic presentation of the results in an easy to understand manner
  - cross-checking of the previsions for the 2029 fly-by and the possible subsequent close returns
Mission objectives

• characterization of the internal structure of the asteroid for
  • scientific objectives: formation mechanisms of small bodies
  • mitigation objectives: porosity, structural homogeneity

• take benefit from the external sollicitations by the Earth gravitational field in the perigee area
  • tide phenomena
  • internal response to the gravitational gradient

• strawman payload under investigation
  • a network of seismometers/gravimeters
  • radio tomography (inherited from ROSETTA/CONSERT)
  • IR and visible remote sensing
Conclusions

• Coordinated ephemerides improvement is of paramount importance to release publicly coherent estimations concerning Apophis swingby for 2029

• Also mandatory for assessing the impact risk for the future

• Apophis is an affordable target for space missions

• One or more missions to Apophis, dedicated to science and mitigation investigations, could be planned in a collaborative and complementary way under an Interagency Group similarly to what has been done for the Halley comet in the 80’s