French activities related to Apophis

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Presentation Overview

- APOPHIS reminder
- Ephemeris Improvement Opportunities
- APOPHIS 2029 first thoughts
- IMCCE Contribution
## APOPHIS

### Discovery

- **Discovered by:**
  - Roy A. Tucker,
  - David J. Tholen,
  - Fabrizio Bernardi

- **Discovery date:** June 19, 2004

### Orbital characteristics

- **Aphelion distance:** 1.099 AU
- **Perihelion distance:** 0.746 AU
- **Orbital period:** 323.6 d (0.89 year)
- **Inclination:** 3.331°

### Physical characteristics

- **Dimensions:** ~250 m (estimated)
- **Mass:** $2 \times 10^{10}$ kg (estimated)

Mass of APOPHIS ~ 200 x
APOPHIS Fly by of the Earth on April 13, 2029

Apophis close pass geometry

Apophis year = 426 days

V_{rel} = 5.86 \text{ km/sec}

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delta V = 2.83 \text{ km/sec}

28 \text{ deg}

Earth

Moon

Apophis year = 323 days
KEYHOLES

Orbit Uncertainty

+ Earth Gravity Assist

asteroid
Earth
APOPHIS Flyby of the Earth in 2029

Earth center = 5.73 Re
7/6 resonance = 885 meters
Total keyhole = 641 meters

Note: all calculations based on JPL data as of 6/20/06
Key Holes location evolution

KH for the 21st century

- Increasing number of resonant orbit with time
- About 1 / Year from ’90s
- 100 KH ~0.7 km in diameter split over a 3 σ uncertainty 3500 km wide
- ~ 1 in 50 chances for an impact with the Earth between 2036 and 2130
**Ground based observations**

### Observation criteria

- **Visual Magnitude < 23**
- **Elongation > 50°**

<table>
<thead>
<tr>
<th>periods</th>
<th>PdM 1m</th>
<th>ESO 8m</th>
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</thead>
<tbody>
<tr>
<td>A: Feb. — May 2011</td>
<td>2h</td>
<td>1h</td>
</tr>
<tr>
<td>B: Nov 2011 Sep 2012</td>
<td></td>
<td></td>
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<td>C: Dec 2012 June 2013</td>
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From visible and IR observations, expected improved knowledge in 2013 about rotation parameters, size, inertia, thermal inertia, preliminary 3D model.
Single launch on a GTO like orbit @ i=40° a few weeks before APOPHIS pass
Impactor + impact imager @ tp-1 h
Data reception system prepositioned after the perihelion
Interior sounding under investigation (MEX Marsis, Rosetta Consert heritage)
IMCCE Contribution

• IMCCE (Institute for Celestial Mechanics and Ephemerides Computation) is part of Paris Observatory

• Uses its own model INPOP (Intégration Numérique Planétaire de l’Observatoire de Paris) for the computation of the solar system ephemerides

• The results are totally independant from the ones produced by MPC or Pisa University who both use DE405 ephemerides from JPL

• High interest from this institute to be involved in the APOPHIS data processing

• Support from CNES can be envisioned as a contribution to the ESA’s SSA Programme

• see http://www.imcce.fr/