Apophis 2029: Planetary Defense Opportunity of the Decade

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April 13, 2029
T-minus
9 yr 348 d 07 hr 17 m

Figure credit: P. Chodas (JPL)
Apophis is Coming – For Real

350m asteroid within 5.8 Earth-radii

A “close shave” 5 times larger than the Tunguska body. 100 times more massive.

Apophis will miss the Earth. Apophis will miss the Earth. Apophis will miss the Earth.

Friday
April 13, 2029

A once-per-thousand year event.
Two Centuries of Encounters (within < 0.5 Lunar Distances)

Size and Distance of Known Encounters
(Source: JPL CNEOS)

Earth Impact

Roche Limit

Geosynchronous

Tunguska

Apophis

Resurfacing Limit (Binzel et al. 2010)

Resurfacing Limit (Nesvorny et al. 2010)

Figure credit: Alissa M. Earle (MIT)
Apophis 2029 encounter is "sooo close," provides the potential to study . . .

- tidal distortion & interior strength of a PHA.
- down-slope movement & surface strength.
- spin rate changes & structural integrity.

\[
\text{Science Objectives} = \text{Planetary Defense Objectives}
\]

Nature is performing the experiment for us!
The 2029 close encounter by this potentially hazardous asteroid is a once-per-thousand year natural experiment that provides an opportunity for advancing small body knowledge for both science and planetary defense.

- SBAG encourages NASA and the small bodies community to determine the science and planetary defense goals for the 2029 Earth flyby of (99942) Apophis, and evaluate the opportunities, both in space and on the ground, that the flyby affords.

- SBAG encourages NASA to sponsor relevant workshops and to invest in possible mission concept studies.

Follow-on step: Apophis opportunity highlighted within Decadal Survey.
Apophis basic physical parameters are already known.

Radar mean diameter = 340 +/- 40 m

“Tumbling” spin state:

Precession period = 27.38 +/- 0.07h

Rotation period = 263 +/- 6h

P. Pravec et al.
Icarus 233 (2014) 48–60

M. Brozovic et al./Icarus 300 (2018) 115–128
Apophis basic physical parameters are already known.

Binzel et al. (2009); Icarus 200, 480. Reddy et al. (2018); Astron J. 155, 140.

\[ \text{Sq-type.} \]
Spectral model fitting to LL chondrites

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Avg</th>
<th>Max</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apophis diameter (m)</td>
<td>210</td>
<td>270</td>
<td>330</td>
<td>Delbo et al. (2007)</td>
</tr>
<tr>
<td>Grain density (g/cm(^3))</td>
<td>3.4</td>
<td>3.5</td>
<td>3.6</td>
<td>Britt and Consolmagno (2003)</td>
</tr>
<tr>
<td>Bulk density (g/cm(^3))</td>
<td>3.0</td>
<td>3.2</td>
<td>3.4</td>
<td>Britt and Consolmagno (2003)</td>
</tr>
<tr>
<td>Micro-porosity (%)</td>
<td>3.7</td>
<td>7.9</td>
<td>12.1</td>
<td>Britt and Consolmagno (2003)</td>
</tr>
<tr>
<td>Macro-porosity (%)</td>
<td>0</td>
<td>20</td>
<td>50</td>
<td>Britt et al. (2002)</td>
</tr>
</tbody>
</table>

Calculations for Apophis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Avg</th>
<th>Max</th>
<th>Itohawa-like</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – total porosity (micro + macro)</td>
<td>0.38</td>
<td>0.72</td>
<td>0.96</td>
<td>0.60(^b)</td>
</tr>
<tr>
<td>Mass (\times 10^{10}) kg</td>
<td>0.7</td>
<td>2.4</td>
<td>6.1</td>
<td>2.0(^c)</td>
</tr>
<tr>
<td>Kinetic energy(^d) (Mt TNT)</td>
<td>105</td>
<td>450</td>
<td>1100</td>
<td>375</td>
</tr>
</tbody>
</table>

\(^a\) Values used here as “Max” and “Min” are their mean + and – one standard deviation from their Table 4.

\(^b\) Total porosity of 40% from Abe et al. (2006).

\(^c\) For Apophis 270 m diameter, 3.2 g/cm\(^3\) bulk density.

\(^d\) For impact velocity 12.6 km/s (Chesley, 2005).
Knowledge Opportunity: What happens during the encounter?

"It's all about the encounter."

April 13, 2029

Transform: Situational Awareness

Application to the broad PHA population

Situational Understanding
"It's all about the encounter."

Surface accelerations
Talk by Dan Scheeres

Surface slope changes
Poster by Yaeji Kim

Implementations

Cubesat
Talk by D. Koschny

Multi-component
Talk by J. Deller

Discovery Class
MIT Project Apophis
Poster by A. Earle

Radar
Poster by M. Brozovic

Seismology
"InSight Apophis"

"Smart Marbles" poster by A. Earle.
"Seismic response" talk by J. DeMartini
"Interior changes" poster by O. Barnouin

Other implementation talks / posters by:
F. Siddique
J. Plescia
J. Bell
A. Boley
N. Schmerr

Other Aspects:
D. Tholen
L. Benner
A. Gianolio
The New Poster Child for Planetary Defense

Apophis is coming. Will Earth be ready?

Coming soon by a planet near you.

Friday April 13, 2029
The World Will be Watching
“It's time to get ready!”

Apophis: Naked eye over western Europe and Africa.
Evening skies April 13-14, 2029.

(Animation by Brian Warner)
The World Will be Watching
“It's time to get ready!”

naked eye visibility:
2 Billion People
Apophis is coming: It's time to get ready!

T-minus
9 yr 348 d 07 hr 05 m and counting

Sub-Earth point

Animation credit: M. Brozovic / JPL
Apophis is coming: It's time to get ready!

T-minus
9 yr 348 d 07 hr 05 m and counting

Animation credit: M. Brozovic /JPL
FIN