

# APOPHIS T-5 YEARS:

Knowledge Opportunities for  
the Science of Planetary Defense

**2024 April 22-23**

European Space Research and Technology Centre  
Noordwijk, The Netherlands



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For Registration, Local Information, and Program Updates: [https://www.cosmos.esa.int/web/hera-meetings/apophis\\_hera\\_04\\_2024](https://www.cosmos.esa.int/web/hera-meetings/apophis_hera_04_2024)

**Monday, April 22, 2024**

**SESSION 1: WELCOME AND INTERNATIONAL PERSPECTIVES FOR APOPHIS AT T-5 YEARS**

**10:00 a.m. ALL TIMES ARE CEST = GMT+2**

*Opening Session and International Perspectives for the Apophis 2029 Opportunity.*

**Chairs:** **Richard Binzel**  
**Patrick Michel**

- 10:00 a.m. Küppers M. \*  
*ESTEC and SOC Welcome and Workshop Logistics*
- 10:10 a.m. Binzel R. P. \* Michel P. Küppers M. Barbee B. Barnouin O. et al.  
*The Science Case for Apophis 2029 at T-5 Years to Encounter [#2058]*  
The 2029 April 13 close Earth encounter by the 340-m asteroid (99942) Apophis presents a once-per-thousand year science opportunity. Nature is doing the experiment for us. We outline the unique benefits to the science of planetary defense.
- 10:15 a.m. Johnson L. \* Fast K. E.  
*NASA Planetary Defense Coordination Office Perspective at Apophis T-5*
- 10:30 a.m. Moissl R. \*  
*ESA Mission options to Asteroid Apophis during the 2029 Close Approach with Earth – Programmatic and Strategic perspective [#2033]*  
An updated overview on the two Pre-Encounter Rendezvous mission options (Satis and RAMSES) to Apophis currently under study by the European Space Agency. This will be a high level overview, focusing on the Planetary Defence aspects.
- 10:45 a.m. All \*  
*Discussion: International Agency Perspectives at Apophis T-5*
- 11:00 a.m. *End of Session*

**Monday, April 22, 2024**  
**SESSION 2: ORBITAL DYNAMICS AND THE**  
**PHYSICAL RESPONSE OF APOPHIS TO EARTH'S TIDAL TORQUES**  
**11:00 a.m. ALL TIMES ARE CEST = GMT+2**

*Trajectory and possible physical effects on Apophis, resulting from its close encounter flyby past Earth.*

**Chairs: Naomi Murdoch**  
**Yaeji Kim**

- 11:00 a.m. Valsecchi G. B. \* Tommei G.  
*Disentangling the cascade of Apophis resonant returns [#2021]*  
We analyze the dynamics of Apophis after the 2029 Earth encounter, with the goal of understanding the sizes of the (now negated by the observations record) keyholes leading to resonant returns.
- 11:15 a.m. Granvik M. \*  
*Is Apophis a Fragment from a Tidal-Disruption Event at the Earth or Venus? [#2064]*  
Tidal disruptions of asteroids do occur in the inner Solar System. The orbit and size of Apophis match current model predictions for the fragments produced in tidal-disruption events at the Earth and Venus.
- 11:25 a.m. Kim Y. \* DeMartini J. V. Richardson D. C. Hirabayashi M.  
*Expected Tidally Induced Resurfacing of (99942) Apophis during the 2029 Earth Encounter [#2016]*  
We use a tidal resurfacing model to numerically investigate the motion of surface grains driven by the tidal forces on Apophis. Our current simulation result still supports the conclusion that surface grain motion will likely occur with a tiny scale.
- 11:40 a.m. Ballouz R.-L. \* Barnouin O. S. Agrusa H. Binzel R. P. DellaGiustina D. N. et al.  
*Tidally-Induced Tumbling as a Mechanism for Near-Earth Asteroid Surface Refreshing: Implications for (99942) Apophis' 2029 Earth Encounter. [#2062]*  
We discuss surface refreshing on Apophis through tidally-induced tumbling that causes surface destabilization and high-frequency seismic activity. We present supporting observational evidence that this mechanism may be operating on NEAs.
- 11:55 a.m. DeMartini J. V. \* Murdoch N. Garcia R. F. Richardson D. C.  
*DEM Simulation Results of Apophis' Physical Response to the 2029 Close Earth Encounter [#2039]*  
We summarize previous results of our DEM modeling of the full Apophis encounter, examining body deformation and spin change, then present new results regarding the seismic activity that our simulations predict during the encounter.
- 12:10 p.m. Murdoch N. \* Garcia R. F. Sournac A. Wilhelm A. Drilleau M. et al.  
*Seismic Exploration of Asteroid Apophis [#2048]*  
The tidal encounter of Apophis with the Earth offers the ideal scenario for the first in-situ seismic investigation of an asteroid. The Compact Seismometer can monitor the seismicity of Apophis and be used to image the asteroid's internal structure.
- 12:20 p.m. Dorogy N. A. \* Sava P. C.  
*Remote Seismic Imaging of Asteroid 99942 Apophis [#2001]*  
Subsurface imaging is paramount in discerning asteroid structure and composition. Seismic interferometry using laser Doppler vibrometry enables remote, high resolution investigation of asteroids like Apophis and relies only on natural seismicity.
- 12:30 p.m. All \*  
*Open Discussion Session 2*
- 12:45 p.m. *Lunch Break and Posters*

**Monday, April 22, 2024**  
**SESSION 3: EARTH-BASED OBSERVATIONAL OPPORTUNITIES**  
**AND INTERNATIONAL COLLABORATIONS**  
**2:00 p.m. ALL TIMES ARE CEST = GMT+2**

*Opportunities for Earth-based asset contributions before, during, and after the Apophis 2029 encounter.*

**Chairs:** **Julia de Leon**  
**Cristina Thomas**

- 2:00 p.m. Durech J. \* Pravec P. Vokrouhlicky D. Hornoch K. Kusnirak P. et al.  
*Spin State and Shape of (99942) Apophis Reconstructed from its Light Curves [#2012]*  
We will present our attempts to reconstruct the spin state of Apophis uniquely from its light curves.
- 2:15 p.m. Pravec P. \* Durech J.  
*Apophis Observational Opportunities from Now till the 2029 April 13 Close Approach, to Improve Solution for Its Spin State [#2008]*  
Apophis's tumbling spin state needs to be robustly determined with dedicated photometric observations in 2027, 2028 and 2029. In this invited talk we review the observational opportunities and propose how to optimally run the observations.
- 2:30 p.m. Howell E. S. \* Vervack R. J. Jr. Fernandez Y. R. Hinkle M. L. Myers S. A. et al.  
*Putting Near-Earth Asteroid (99942) Apophis into Context [#2026]*  
We compare the spectrum of Apophis with other near-Earth asteroid of similar taxonomic classes, sizes and shapes to understand how it fits into the population. Potential spectral effects from the Earth flyby may freshen the surface and be observable.
- 2:40 p.m. Thomas C. A. \*  
*Telescopic Reconnaissance Opportunities for Apophis [#2055]*  
Five years remain until the Apophis flyby in April 2029. As a community we need to decide our observing priorities and plan the necessary observations.
- 2:55 p.m. de Leon J. \* Licandro J. Alarcon M. R. Popescu M.  
*Opportunities to Study Apophis Using the Canarian Observatories Before, During, and After its Close Approach in April, 2029 [#2054]*  
In this work we will present the Apophis observational opportunities before, during, and after its close encounter with the Earth in April 2029, using the telescope facilities of the Observatorios de Canarias (OCAN), in the Canary Islands (Spain).
- 3:10 p.m. Pradhan B. \* Mukherjee B. Anil Kumar A. K. Mehta I.  
*Apophis' 2029 Flyby: Assessing optical observational opportunities. [#2027]*  
We have performed the assessment of optical observational opportunities for the 2029 flyby of Apophis. The study focuses on repurposing existing and planned Indian assets in space and ground-based platforms based on physical & geometric constraints.
- 3:20 p.m. Benner L. A. M. \* Brozovic M. Naidu S. P. Giorgini J. D. Busch M. W. et al.  
*Goldstone Radar Observations of 99942 Apophis In 2029: Detailed Plans [#2061]*  
We present detailed plans for Goldstone radar observations of Apophis in 2029.
- 3:35 p.m. Rivkin A. S. \* Thomas C. A. Holler B. J.  
*JWST and Apophis: Prospects and Pointers [#2023]*  
In this presentation we'll consider how JWST is well- and ill-suited for Apophis observations.
- 3:45 p.m. All \* *Open Discussion Session 3*
- 4:00 p.m. *End of Session -- BREAK 30 MINUTES --*

**Monday, April 22, 2024**  
**SESSION 4: OSIRIS-APEX AND RELATED IN SITU INVESTIGATIONS**  
**4:30 p.m. ALL TIMES ARE CEST = GMT+2**

*Overview of the OSIRIS-APEX mission, its operations, and related science opportunities.*

**Chairs:** **Mike Nolan**  
**Olivier Barnouin**

- 4:30 p.m. Nolan M. C. \* DellaGiustina D. N. Golish D. R. Moreau M. C. Polit A. T. et al.  
*The OSIRIS-APEX Mission to Apophis. [#2015]*  
Overview of the OSIRIS-APEX mission.
- 4:45 p.m. Polit A. T. \* Golish D. R. Moreau M. C. Nolan M. C. Simon A. A. et al.  
*OSIRIS-APEX Proximity Operations at Apophis [#2017]*  
The OSIRIS-APEX spacecraft will conduct detailed characterization of asteroid Apophis (99942) over 18 months in 2029 and 2030. The mission phases are designed to address the APEX science objectives.
- 4:55 p.m. Barnouin O. S. \* Ballouz R.-L. Burke P. A. Toy-Edens V. L. DellaGiustina D. N. et al.  
*Investigating Experimentally Gas-Based Excavation of Regolith Surfaces with Applications for the Exploration of Apophis [#2030]*  
We present experiments to show how surface properties of Apophis can be measured from surface-gas interactions as planned by the OSIRIS-APEX mission.
- 5:05 p.m. Sakatani N. \* Kameda S. Kitsunai K. Kikuchi H. Kikuchi S. et al.  
*Hayabusa2 Thruster Plume Disturbances on Ryugu: Implication for OSIRIS-APEX [#2040]*  
This work found boulder motion on asteroid Ryugu by thruster injection during Hayabusa2 low-altitude descent operations, without physical contact with the surface.
- 5:20 p.m. Farnocchia D. \* Vokrouhlicky D. Capek D. Chesley S. R. DellaGiustina D. N.  
*The Yarkovsky Effect on Apophis: Bulk Density Constraints and Anticipated OSIRIS-APEX Science [#2046]*  
We review the knowledge of the orbit of Apophis. Then, we derive constraints on bulk density of Apophis from the Yarkovsky effect. Finally, we assess of large of a Yarkovsky change in 2029 could be measurable by the OSIRIS-APEX mission.
- 5:35 p.m. Walsh K. J. \* Klein V.  
*Apophis Cratering Experiment [#2047]*  
We define a mission concept to leverage the capabilities OSIRIS-APEX as an observer and perform a cratering experiment at Apophis with an independent impactor spacecraft more than 18 months after Earth close approach.
- 5:50 p.m. All \*  
*Open Discussion Session 4*
- 6:05 p.m. *End of Day 1*

**Tuesday, April 23, 2024**  
**SESSION 5: ESA'S RAMSES AND MISSION FOR**  
**PRE-ENCOUNTER IN SITU INVESTIGATION OF APOPHIS**  
**9:00 a.m. ALL TIMES ARE CEST = GMT+2**

*Overview for the RAMSES mission under study within ESA, cooperatively exploring Apophis prior to Earth flyby, thereby maximizing the Apophis 2029 knowledge opportunity for planetary defense as a collaborative international investigation.*

**Chairs: Michael Küppers  
Patrick Michel**

- 9:00 a.m. Küppers M. \* Martino P. Carnelli I. Michel P.  
*Status of ESA's Rapid Apophis Mission for SpacE Safety (RAMSES) Concept [#2053]*  
RAMSES is a study for a mission to be launched in 2028 to rendezvous with Apophis two months before the close flyby of Earth in April 2029. RAMSES will characterize Apophis in detail before and after the close encounter with Earth.
- 9:15 a.m. Cardi M. C. Mrs \* Corradino F. C. Mr Pavoni M. P. Mr Calvi D. C. Mr Zanotti A. Z. Mr  
*Re-use of Hera Milani Deep Space platform for RAMSES CubeSats implementation [#2022]*  
Compatibility assessment of the Milani platform with payloads potentially suitable for an Apophis mission was confirmed. Similar effort can be done considering additional payloads interesting for the scientific community.
- 9:25 a.m. Okada T. \* Tanaka S. Sakatani N. Shimaki Y. Arai T. et al.  
*Thermal Imaging to Reveal Thermophysical Properties of Asteroids for Planetary Defense Missions [#2031]*  
Thermal infrared multiband imaging is a useful method to characterize the thermophysical properties and composition of the target asteroids during flyby and rendezvous missions for planetary defense including Hayabusa2#, Hera, and RAMSES.
- 9:35 a.m. Noeker M. \* Ulamec S. Metz M. Gritzner C. Bachem E.  
*Possible German Contributions to the Scientific Investigation of 99942 Apophis as Part of the ESA RAMSES Mission. [#2002]*  
A large set of possible German contributions to the proposed ESA RAMSES mission has been determined. This work provides an overview of potential national contributions and is intended to aiding and facilitating the ongoing mission planning.
- 9:45 a.m. All \*  
*Open Discussion Session 5: RAMSES and pathways for international collaboration.*
- 10:00 a.m. *End of Session*

**Tuesday, April 23, 2024**  
**SESSION 6: RAPID RESPONSE PLANETARY MISSIONS -**  
**CONCEPTS AND OPPORTUNITIES FOR APOPHIS INVESTIGATIONS**  
**10:00 a.m. ALL TIMES ARE CEST = GMT+2**

*Apophis provides the highest priority, science-driven opportunity, to demonstrate a rapid response mission capability for the science of planetary defense.*

**Chairs: Carol Raymond, Brent Barbee**

- 10:00 a.m. Fodde I. \* Morelli A. C. Mannocchi A. Giordano C. Ferrari F. et al.  
*Science Opportunities and Payload Selection for a Rapid and Low-Cost Apophis Pre-Rendezvous Mission* [#2044]  
Discussing the scientific opportunities and possible payload suite for the RAMSES mission concept, focussing on readily available instruments to maximize the scientific output of the mission.
- 10:10 a.m. Karatekin Ö. \* Ritter B. Gundlach B. Güttler C. Patzek M. et al.  
*SATIS MISSION STUDY FOR APOPHIS: Science objectives and mission definition* [#2043]  
Satis is an ongoing ESA Phase A Planetary Defence mission study targeting Apophis. It consists of a stand-alone 12U-XL CubeSat that aims to rendezvous with Apophis prior to its Earth Close Approach.
- 10:20 a.m. Gundlach B. \* Güttler C. Patzek M. Karatekin O. Ritter B. et al.  
*Satis Mission Study for Apophis: Instrumentation and Operation* [#2050]  
Satis is an ESA Phase A study for a CubeSat mission to asteroid Apophis. As a stand-alone deep space mission it shall escort Apophis before, during and after its Earth closest approach. We present the status.
- 10:30 a.m. Barbee B. \* *Near-Earth Objects Workshops to Assess Reconnaissance for Planetary Defense*
- 10:45 a.m. Scheeres D. J. \* Bierhaus E. B. McCaa C. Kloska E. Brack D. et al.  
*Janus: Future opportunities relevant to Apophis* [#2071]  
The Janus spacecraft are now in storage awaiting future use. These spacecraft represent a very mature, low-cost pathway to realize critical data on Apophis prior to its Earth closest approach.
- 11:00 a.m. Raymond C. A. \* Amini R. B. Adell P. C. Bandyopadhyay S. Bellerose J. et al.  
*The DROID MISSION CONCEPT TO ACCOMPANY AND CHARACTERIZE APOPHIS THROUGH ITS 2029 EARTH CLOSEST APPROACH* [#2065]  
A mission concept to escort Apophis through its Earth close encounter has been developed in a collaboration between NASA/JPL and CNES to determine its shape, density, interior structure and any changes that occur as a result of the Earth flyby.
- 11:15 a.m. Pascal M. \* Nakamura-Messenger K. Djuran D. Cooley T. Schmidgall M. et al.  
*Exploration of Asteroid Apophis with the Exlabs Arachne Spacecraft* [#2063]  
The ExLabs Apophis spacecraft will carry JPL and CNES' DROID mission as a primary payload. ExLabs invites proposals for additional instruments, landers, or orbiters to fly on our spacecraft to Apophis.
- 11:30 a.m. Herique A. \* Plettmeier D. Michel P. Kofman W. Rogez Y.  
*Radar to Apophis: Probing the interior of 99942 Apophis in 2029 with Cubesats* [#2035]  
Radar to Apophis, a radar to image asteroid internal structure: a re-fly of the JuRa/Hera instrument able to operate in both bistatic and monostatic mode, for the proposed missions RAMSES/ESA and DROID JPL/CNES .
- 11:45 a.m. All \* *Open Discussion: International Collaboration in Rapid Response Characterization.*  
(NOTE: There is extended time for all Session 6 topics and discussion in the afternoon session.)
- 12:00 p.m. *Lunch Break and Posters*

**Tuesday, April 23, 2024**  
**SESSION 6 (CONTINUED): RAPID RESPONSE PLANETARY MISSIONS -**  
**CONCEPTS AND OPPORTUNITIES FOR APOPHIS INVESTIGATIONS**  
**2:30 p.m. ALL TIMES ARE CEST = GMT+2**

*Apophis provides the highest priority, science-driven opportunity, to demonstrate a rapid response mission capability for the science of planetary defense.*

**Chairs: Carol Raymond, Brent Barbee**

- 2:30 p.m. Squires S. \* Randolph T. Sanford T.  
*Blue Origin's Blue Ring Spacecraft Enables Detailed Investigation of Apophis Before, During, and After its Earth Encounter [#2056]*  
Blue Origin's Blue Ring spacecraft can rendezvous with Apophis months before the Earth encounter, supporting up to 13 hosted and/or deployed payloads that can investigate the asteroid in detail before, during, and after its encounter with Earth.
- 2:45 p.m. Ballouz R.-L. \* Graninger D. M. Adams E. Y. Atchison J. A. Barnouin O. S. et al.  
*Flyby Asteroid Reconnaissance (FLARE) Mission to Apophis: A Mission Concept to Apophis before its Earth Encounter to Demonstrate Flyby Reconnaissance for Planetary Defense. [#2060]*  
FLARE is a SmallSat mission concept that would fly by (99942) Apophis before its close approach in 2029 to demonstrate the utility of flyby reconnaissance missions for planetary defense.
- 3:00 p.m. Golovich N. \* Geringer-Sameth A. Grice T. Noland J. Yeager T. et al.  
*RA's CATS: Rapid Apophis Characterization with Two Satellites [#2068]*  
We will present an update to our effort to establish a flyby mission from Earth orbit that is low-cost (class D) and also offers valuable science and public engagement opportunities while complementing OSIRIS-APEX.
- 3:15 p.m. All \*  
*Expanded Time for Open Discussion of All Topics in Session 6:*  
*International Collaboration for Apophis Pre-Encounter Rapid Response Characterization*
- 4:00 p.m. *End of Session -- BREAK 30 MINUTES --*

**Tuesday, April 23, 2024**  
**SESSION 7: PUBLIC COMMUNICATION OF THE APOPHIS ENCOUNTER**  
**AS A SCIENCE OPPORTUNITY**

**4:30 p.m.** ALL TIMES ARE CEST = GMT+2

*Communicating about the Apophis 2029 Earth flyby as a worldwide science opportunity, not a hazard, is an imperative to counter over-sensationalism in the media.*

**Chairs:** **Patrick Michel**  
**Richard Binzel**

- 4:30 p.m. Billings L. Ph.D. \*  
*Apophis 2029: Communication Challenges [#2010]*  
The close approach of Apophis, in 2029, is already drawing public attention. While the small-bodies community has determined that this approach poses no risk of impact, media headlines highlight supposed risks. The science community must explain how it has eliminated risk.
- 4:45 p.m. Zambrano-Marin L. F. \* Marshall S. E. Brisset J. Venditti F. C. F. Nolan M. C. et al.  
*A Collaborative Platform for Asking about Apophis: Addressing Public Interest and Global Reach [#2069]*  
We are developing a user-friendly website where international citizens can ask questions about Apophis in their native languages, receiving answers from knowledgeable community members.
- 5:00 p.m. Michel P. \* Daou D.  
*The International Year Initiative for Planetary Defence 2029 [#2005]*  
It is proposed that the United Nations designate the year 2029 as the “International Year of Planetary Defence 2029 (IYPD2029)”. The year offers an opportunity to raise global understanding of small bodies that might impact our planet.
- 5:15 p.m. *Discussion follows in the next session.*

**Tuesday, April 23, 2024**  
**SESSION 8: COLLABORATIVE FINDINGS AND RECOMMENDATIONS**  
**AT APOPHIS T-5 YEARS AND COUNTING**

**5:15 p.m.** ALL TIMES ARE CEST = GMT+2

*Open discussion on findings and recommendations of the International Community at Apophis T-5 Years and counting, from which all input will be accepted by the Science Organizing Committee in compiling formal findings and recommendations.*

**Chairs:** **Richard Binzel**  
**Patrick Michel**

- 5:15 p.m. All \*  
*Time is of the essence: Open discussion on findings and recommendations of the International Community at Apophis T-5 Years and counting.*
- 6:15 p.m. *End of Workshop*



## SESSIONS 2-4 POSTERS

*Posters will be available for viewing during all breaks and dedicated poster sessions,  
Monday April 22 through Wednesday April 24.*

Posters should be sized to comfortably fit within the provided space  
120 cm wide by 180 cm high. Supplies for affixing posters will be provided.

Pedros-Faura A. French A. S. Bellerose J. McMahon J. W.

*Spacecraft Reference Trajectory Selection for Gravity Field Reconstruction of Asteroid 99942 Apophis [#2007]*

In this work, candidate spacecraft reference trajectories are identified for potentially hazardous asteroid Apophis and an error analysis is performed for the gravity field reconstruction before its Earth Closest Approach in April 2029.

Golish D. R. Bos B. J. Daly M. G. Hamilton V. E. Moreau M. C. et al.

*Anticipated Data Products from the OSIRIS-APEX Mission at Asteroid Apophis [#2018]*

We review the OSIRIS-APEX observations of Apophis that will yield a suite of data products similar to those produced from OSIRIS-REx observations of Bennu, directly addressing the scientific objectives of the APEX mission.

Kohout T. Korda D. Penttilä A. Rajamäki L. Palamakumbure L.

*Detection of local resurfacing on Apophis using machine learning analysis of hyperspectral data [#2019]*

Machine learning analysis of reflectance spectra can reveal local resurfacing events.

Liu P. -Y. Campo Bagatin A. Schwartz S. R. Parro L. M. Bartczak P. et al.

*Influence of Internal Structure on the Tidal Disruption of 99942 Apophis [#2020]*

This study simulates the tidal disruption of Apophis during a hypothetical flyby within the Roche limit of Earth.

Barnouin O. S. Mayorga L. C. Seabrook J. A. Daly M. G. Daly R. T. et al.

*Preparing for OSIRIS-APEX Laser Altimeter Observations at Apophis. [#2029]*

In preparation for the OSIRIS-APEX mission to Apophis, expected updates to the OSIRIS-APEX Laser Altimeter observations will not alter existing shape modeling efforts.

Çelik O. Ballouz R. L. Scheeres D. J. Kawakatsu Y.

*A Semi-analytical Understanding of Energy Loss in Low-speed Cratering [#2036]*

This work presents a semi-analytical model of energy loss in low-speed cratering which may be useful in understanding possible particle ejection events in Apophis encounter, or predicting deployable motion in proposed missions to Apophis.

Valvano G. Sfair R. Winter O. C. Machado Oliveira R. Borderes-Motta G.

*May Meteor Streams Happen due to the Apophis' 2029 Closest Approach? [#2037]*

We assume a hypothetical disc of particles around Apophis and studied its orbital evolution. We aim to discuss the possibility of a meteor activity due to the 2029 approach. A meteoroid stream on the Moon might happen, but not on Earth.

Sert H. Tasev E. Karatekin O. Meyer A.

*Changes in Rotational Dynamics and Surface Accelerations Induced by the Earth Encounter of Apophis [#2051]*

We simulate the F2BP between the Earth and Apophis during 2029 encounter to analyse the rotational changes of the asteroid due to the gravitational perturbations caused by the earth flyby.

Wang H. -S. Scheeres D. J.

*Uncertainty Estimation of Apophis Mass Distribution Across its Flyby [#2052]*

We explore a way to probe mass shifts within Apophis based on theoretical limit of the Goldstone radar observatory. Precision measurements of Apophis spin state before and after the flyby will provide insights into potential changes in its interior.

Popescu M. Simion G. N. Licandro J. de León J. Morate D. et al.  
*The Visible Color Indices of Near-Earth Asteroids* [#2057]

Here we report the latest results of an ongoing observational program for obtaining the visible color indices of NEAs. This observational technique allows to find possible heterogeneous compositions of the observed targets and the surfaces changes.

Adam C. D. DellaGiustina D. N.

*OSIRIS-APEX Astrometry Objectives for the Apophis-Earth Encounter* [#2059]

OSIRIS-APEX will observe Apophis in the weeks surrounding the Earth encounter, at unique geometries that will complement and supplement ground- and space-based observations to characterize spin state changes and search for evidence of mass shedding.

Verbiscer A. J.

*Apophis Earth Flyby at T-5 Years: Previous and Upcoming Campaigns to Observe Stellar Occultations by Apophis* [#2067]

Summary of previous ground-based campaigns to observe stellar occultations by Apophis and preview of upcoming events prior to the 2029 Earth flyby.

Morais R. H. Santos L. F. F. M. Silva A. R. R. Melicio R.

*Hypothetical Apophis Deep Ocean Impact – Energy Analysis* [#2004]

Modelling a hypothetical Apophis asteroid impact on the deep ocean, the study assesses vulnerabilities of coastal populations. Valid models offer insights adaptable to any Earth surface point. Tsunami emerges as the most threatening impact effect.

Renggli C. J. Hilchenbach M. Stenzel O. Walton C. R. Kleine T.

*Threat from a recent LL parent body disruption: The case for an Apophis sample return* [#2009]

We present a new interpretation of the origin of the LL ordinary chondrite asteroid Apophis, suggesting a shared origin with the Chelyabinsk meteorite that cause a severe airburst in 2013. Did a recent LL parent body disruption send NEAs to Earth?

Senel C. B. Karatekin O. Claeys P.

*Hypothetical Impact Assessment of Near-Earth Asteroid 99942 Apophis: Climatic Consequences* [#2070]

Here, we present post-impact climatic consequences following a hypothetical impact event of a near-Earth asteroid, in case the impactor Apophis heads toward Vienna through the 2029 Earth Flyby.

## SESSIONS 5-7 POSTERS

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Meginnis A. D. Acain J. Helms C. Lantukh D.

*Rendezvous mission profile to asteroid Apophis prior to 2029 Earth close approach [#2024]*

AstroForge mines asteroids to extract valuable minerals in space at a lower cost and smaller carbon footprint than the current terrestrial mining methods. We present an opportunity to re-purpose our existing vehicles for an Apophis mission.

Saita G. Di Tana V. Burattini C. Amabili P. Pereira M. et al.

*APOPHIS 2029, ATENA Concept: Mission Design and Satellite Architecture [#2066]*

The ATENA mission, fostering international collaboration between ASI, ARGOTEC and NASA/GSFC, offers a cost-effective option to rendezvous Apophis while still providing full scientific coverage.

Doumitt A. Heinsheimer T. Hinkley D. A. Melamed N. McVey J. P. et al.

*Multiple CubeSats Provide Close Apophis Imagery During Earth Passage [#2025]*

Twenty instrumented CubeSats make sequential observations as Apophis transits the Earth's gravity field when tidal forces can create changes in shape, rotational rate, spin axis and surface characteristics to be observed by a series of measurements.

Hilchenbach M. Stenzel O. Renggli C. J. Nathues A. Krupp N. et al.

*Snatching a probe of a Genuine Near-Earth Asteroid: Fast sample return opportunity in the frame of RAMSES mission scenario [#2011]*

Asteroid Apophis provides a unique opportunity to collect and re-turn a regolith sample from a Near-Earth asteroid (NEA) as it passes very close to Earth. A CE study will be presented for a mission design with a short duration sample return leg.

Männel J. Auster H. U. Grott M. Herique A. Kayal H. et al.

*A Potential German CubeSat Contribution to the RAMSES Mission [#2013]*

The mission aims to support the objectives of RAMSES by providing insights into characteristics and changes related to the ECA of (99942) Apophis. In addition, the magnetization and plasma interactions with Earth's magnetosphere will be characterized.

Plaschke F. Auster U.

*Opportunities of magnetic field investigation of Apophis by ESA Ramses mission [#2014]*

By measuring the magnetic field onboard Hera novel scientific insights can be generated. E.g. magnetisation of asteroid could provide information about the bolder structure. Scientific objectives as well as technical opportunities will be presented.

Nathues A. Kleine T. Sierks H. Hoffmann M. Sarkar R. et al.

*Use of the Dawn Flight Spare Camera at Apophis? [#2028]*

The Framing Camera (FC) has been successfully flown on NASA's Discovery Mission Dawn, visiting the large main belt asteroids (4) Vesta and (1) Ceres. We suggest to use one of the flight spares for ESA's potential RAMSES mission.

Poggiali G. Wargnier A. Brucato J. R. Barucci M. A. Pajola M. et al.

*Linking Micro-meters Regolith Grain Size Properties to Infrared Observation: New Laboratory Experiment and their Implication for Remote Sensing and Planetary Protection. [#2032]*

This contribution presents a new study on the influence of grains in the infrared properties of asteroids using analog materials with important applications in the interpretation of results from space missions and ground-based observations.

Hamm M. Grott M. Knollenberg J. Biele J. Okada T. et al.

*In-Situ Observations in Thermal Infrared on (99942) Apophis* [#2034]

Reviewing results from MARA at Ryugu, we demonstrate the value of in-situ observations in the thermal infrared region of the electromagnetic spectrum and propose a radiometer payload for a potential lander of the proposed RAMSES mission to Apophis.

Krupp N. Fränz M. Roussos E. Barabash S.

*Plasma spectrometer to characterize the environment of Apophis. Reusage of the instrument PEP/JEI on Juice onboard the RAMSES mission* [#2038]

Knowing the environment of a Near Earth Asteroid is essential to understand the object itself. We propose to fly the flight spare of the plasma spectrometer PEP/JEI onboard the RAMSES mission to investigate Apophis, and its space weathered regolith.

Ho T. M. Grundmann J. T. Biele J. Krause C. Ulamec S. et al.

*A nanolander for the RAMSES mission: how MASCOT at Apophis can contribute to planetary defense* [#2041]

We propose a MASCOT3 lander as surface science package for the RAMSES mission to Apophis. MASCOT3 is derived from the MASCOT that was onboard JAXA's Hayabusa2 mission would range between 10-15 kg and carry a suite of instruments.

Barabash S. Fataana Y. Holmström M. Krupp N. Fränz M. et al.

*The Apophis 2029 Flyby: A Unique Science Case for Space Plasma Physics* [#2042]

We demonstrate that the Apophis fly-by provides the unique opportunities to study asteroid – magnetosphere interactions and characterize the Apophis environment. Rendezvous missions to Apophis should carry plasma and magnetic field instruments.

Schmitz N. Vincent J. B. Otto K. Stephan K. Grott M. et al.

*Multi-Scale Imaging of (99942) Apophis* [#2045]

For a potential Apophis landed element, we propose the addition of a hyperfocal descent and lander camera based on the MASCOT lander's MASCam in order to observe the surface of (99942) Apophis on multiple scales and in multiple color bands.

Lasagni Manghi R. Zannoni M. Gramigna E. Tortora P. Paialunga G. et al.

*A Radio Science Experiment for the RAMSES Mission to Asteroid 99942 Apophis* [#2049]

In this work, we present a possible Radio Science Experiment onboard ESA's RAMSES mission and show its expected performance assuming a HERA-like concept of operations, which involves an inter-satellite link between RAMSES and two CubeSats.