

A closer look at the asteroids in Earth's neighborhood

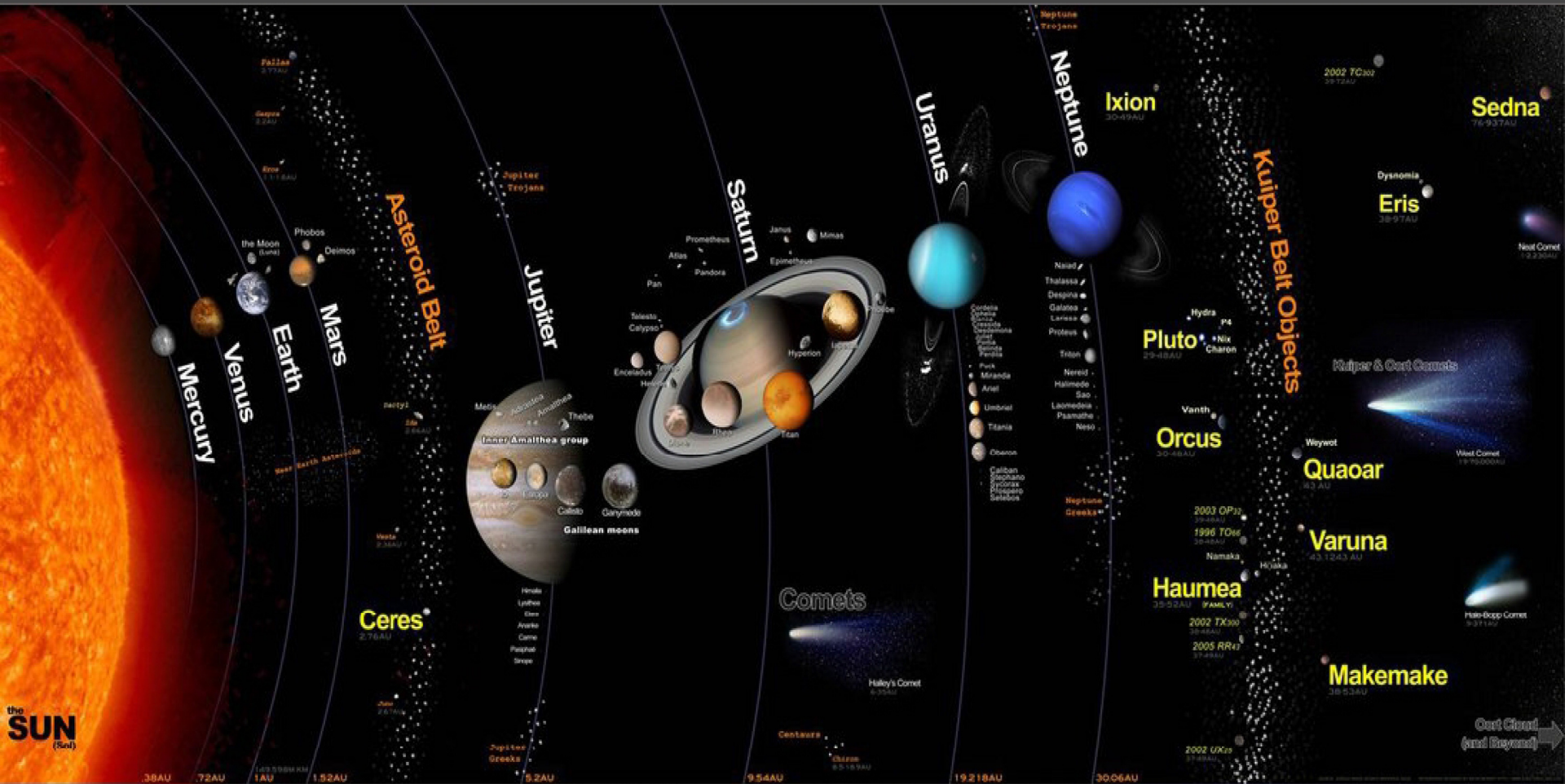


Bojan Novaković

Department of Astronomy, Faculty of Mathematics, Belgrade

Seminar of the Department of Astronomy - 28 May 2024

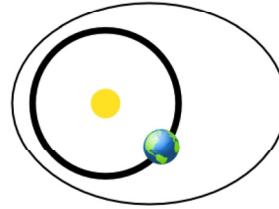
Solar System structure



Near Earth Asteroids Orbital Classes

Amors

Earth-approaching NEAs with orbits exterior to Earth's but interior to Mars' (named after asteroid (1221) Amor)



$$a > 1.0 \text{ AU}$$
$$1.017 \text{ AU} < q < 1.3 \text{ AU}$$

Apollos

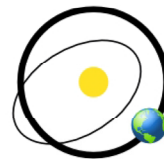
Earth-crossing NEAs with semi-major axes larger than Earth's (named after asteroid (1862) Apollo)



$$a > 1.0 \text{ AU}$$
$$q < 1.017 \text{ AU}$$

Atens

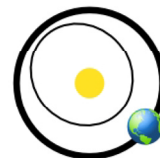
Earth-crossing NEAs with semi-major axes smaller than Earth's (named after asteroid (2062) Aten)



$$a < 1.0 \text{ AU}$$
$$Q > 0.983 \text{ AU}$$

Atiras

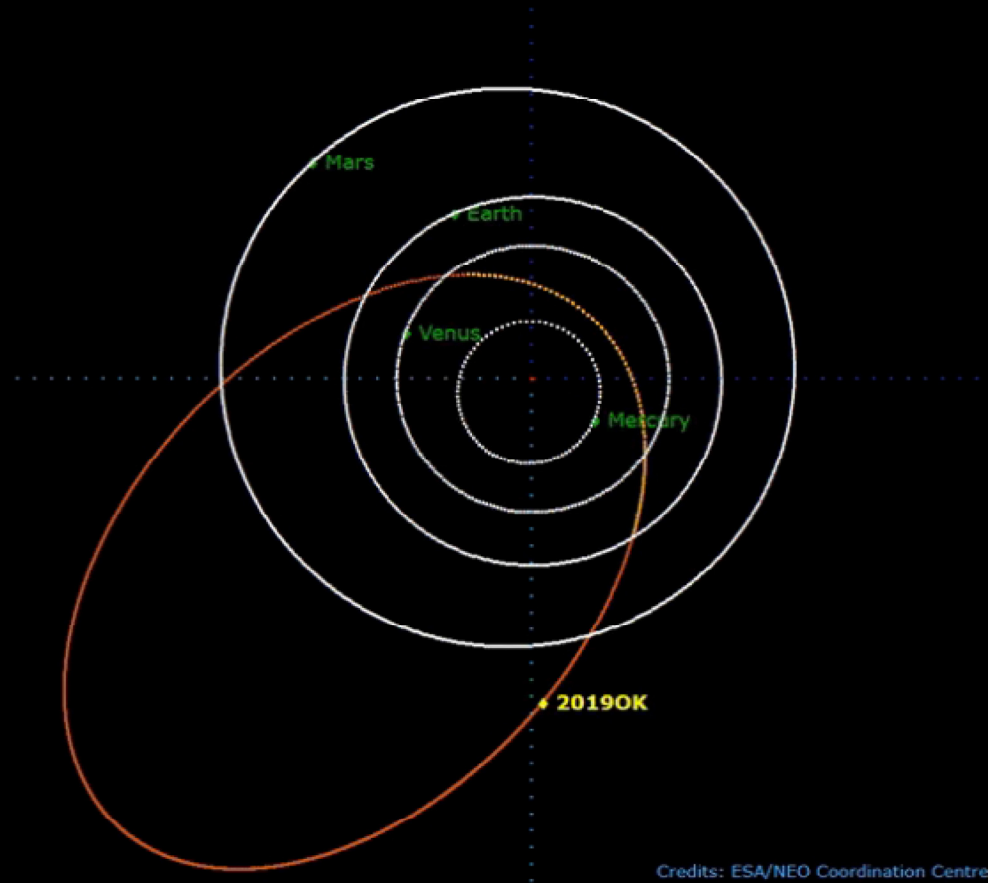
NEAs whose orbits are contained entirely within the orbit of the Earth (named after asteroid (163693) Atira)



$$a < 1.0 \text{ AU}$$
$$Q < 0.983 \text{ AU}$$

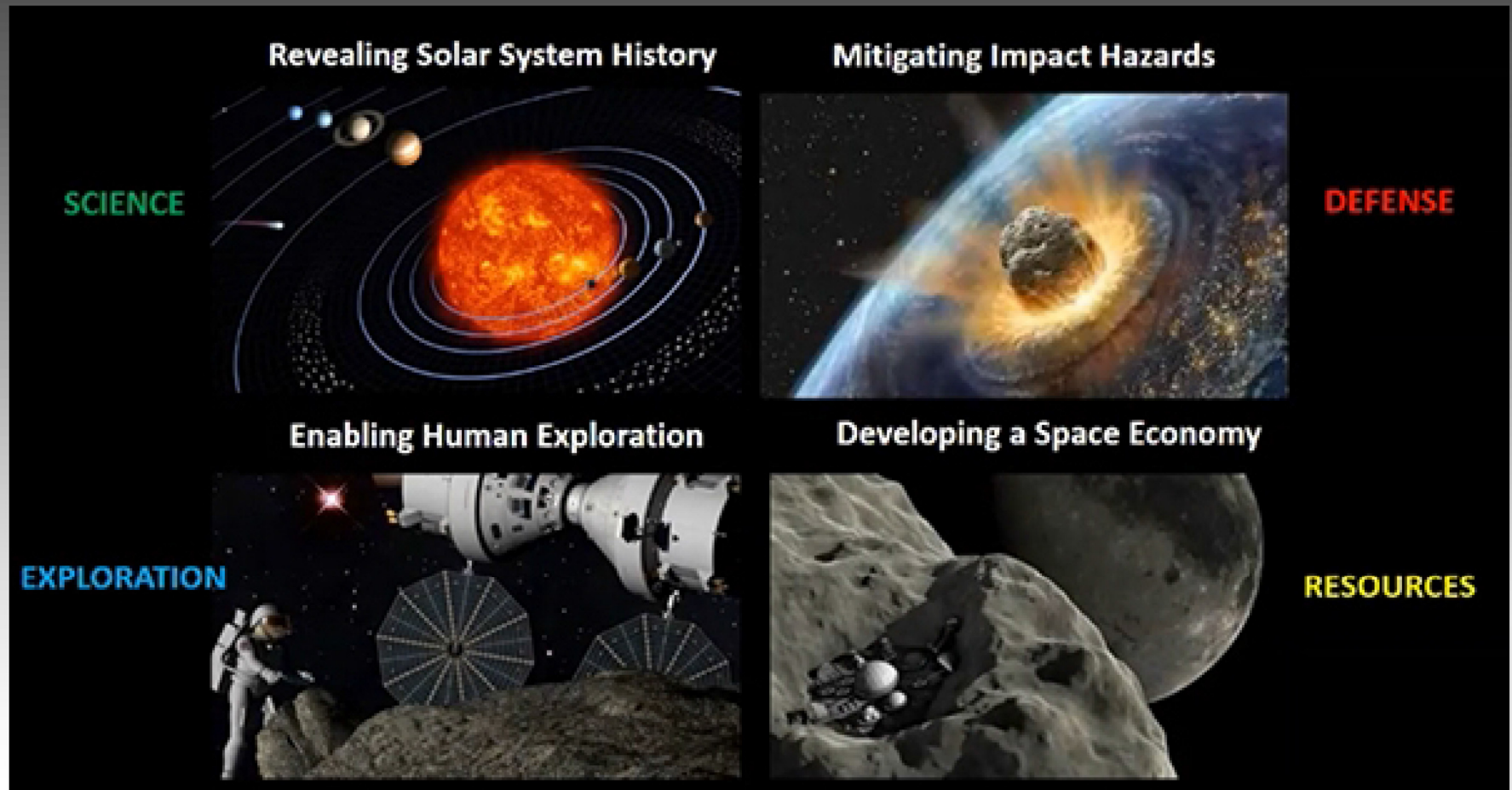
(q = perihelion distance, Q = aphelion distance, a = semi-major axis)

Near Earth Asteroids Orbital Classes



Why do we care about near-Earth asteroids?

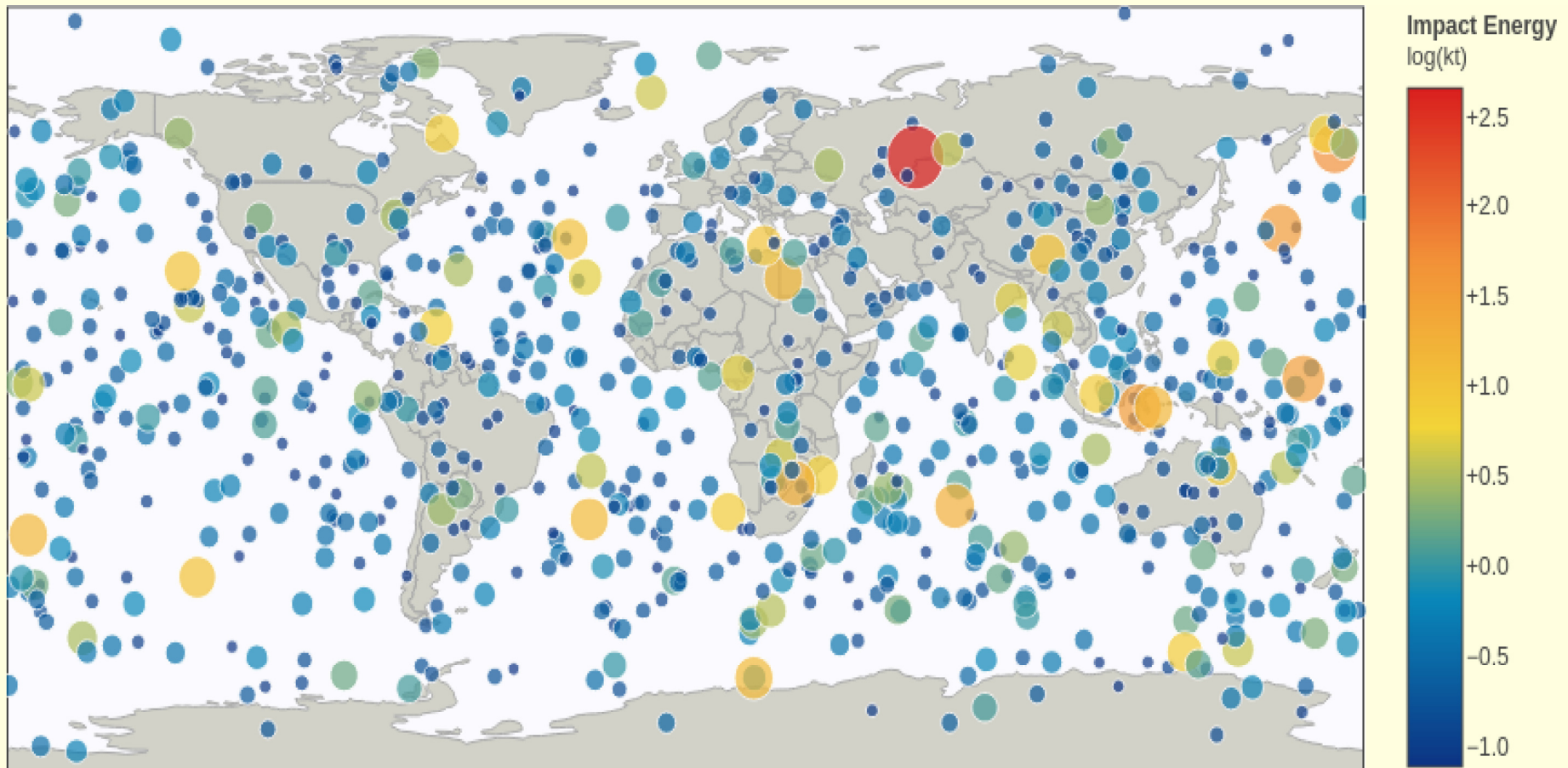
- Science, Planetary Defense, Exploration, and maybe Exploitation



Fireballs statistics

Fireballs Reported by US Government Sensors

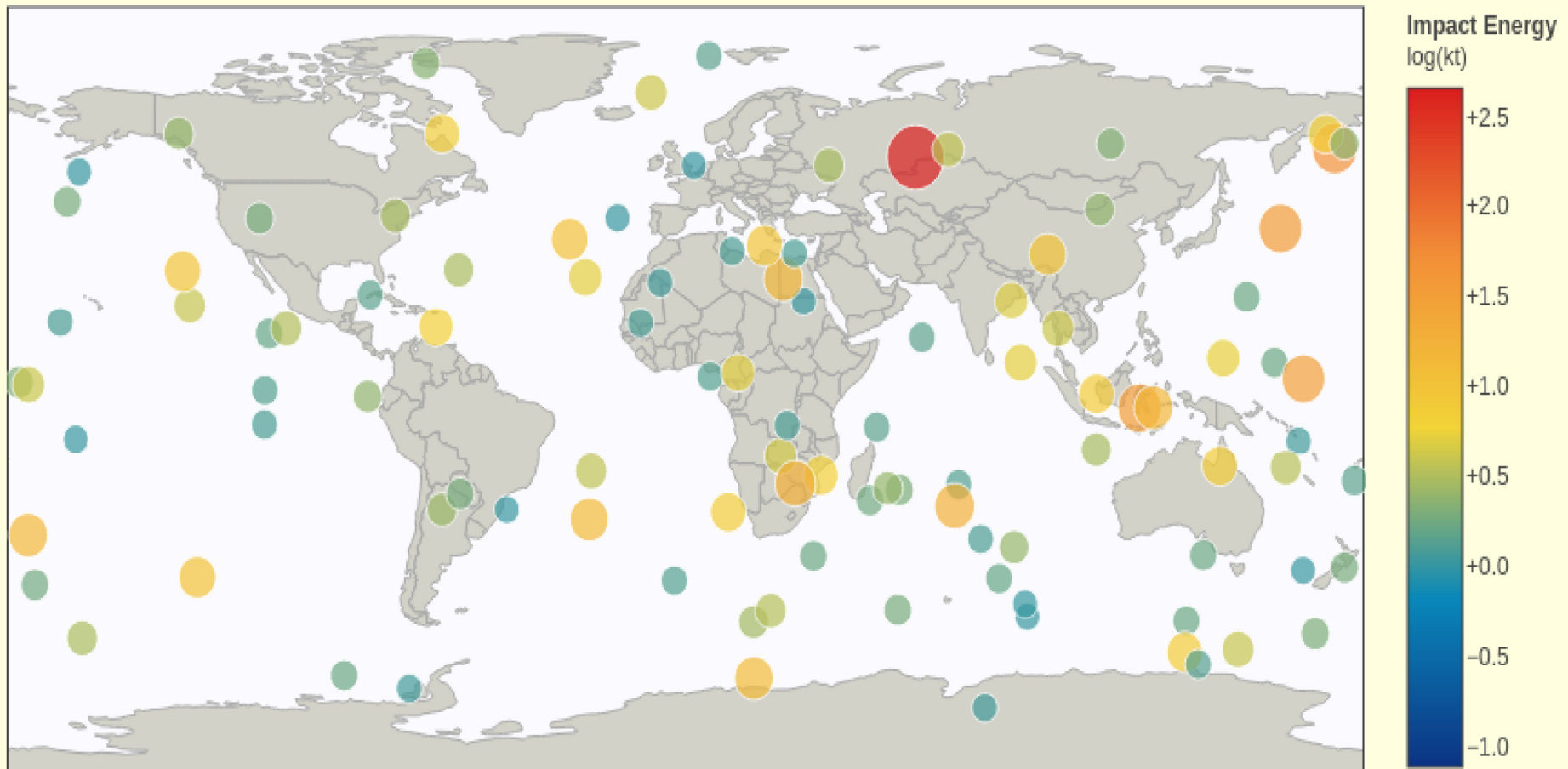
(1988-Apr-15 to 2024-May-24)



Fireballs statistics

Fireballs Reported by US Government Sensors

(1988-Apr-15 to 2024-May-24; limited to events ≥ 1 kt)



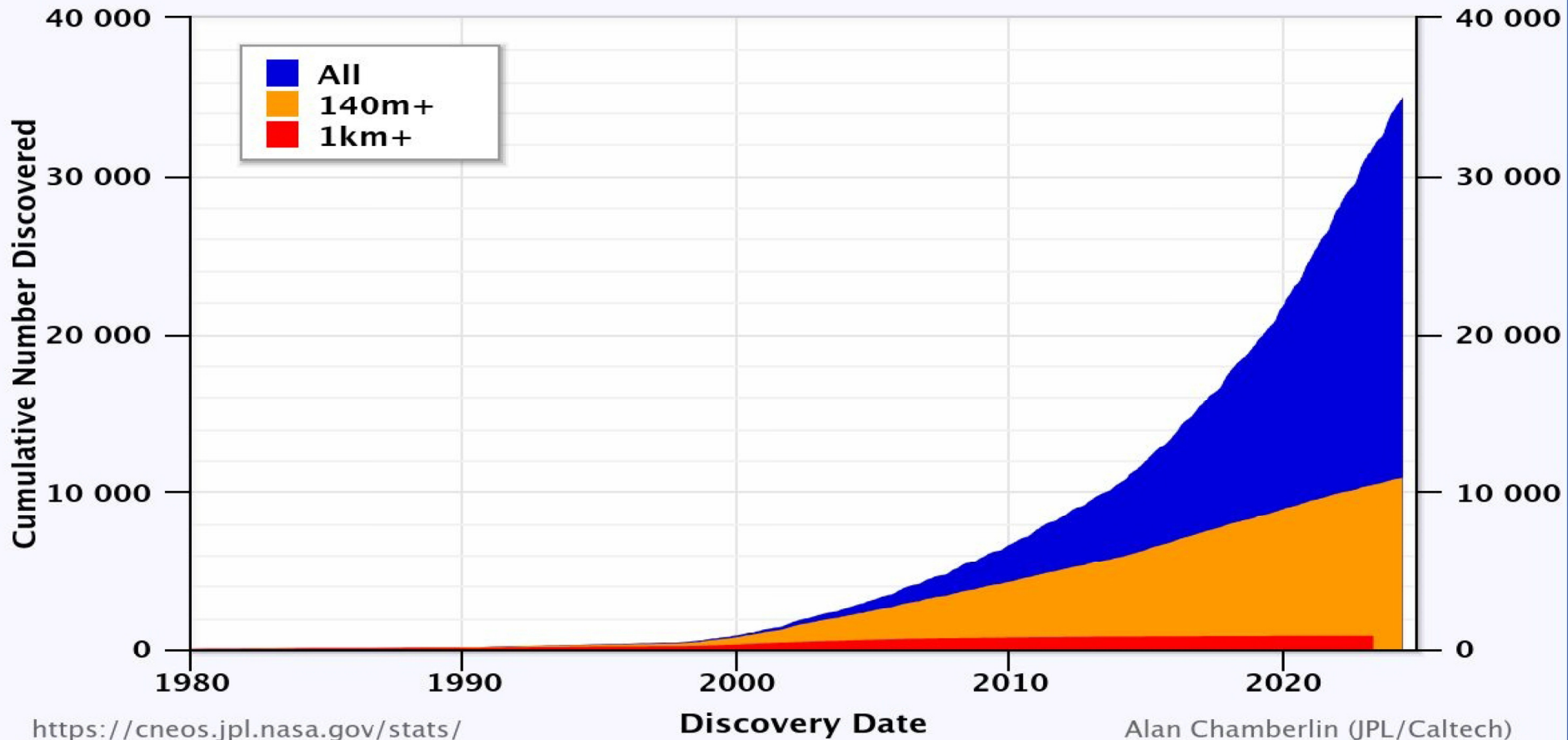
Recent fireball over Spain and Portugal



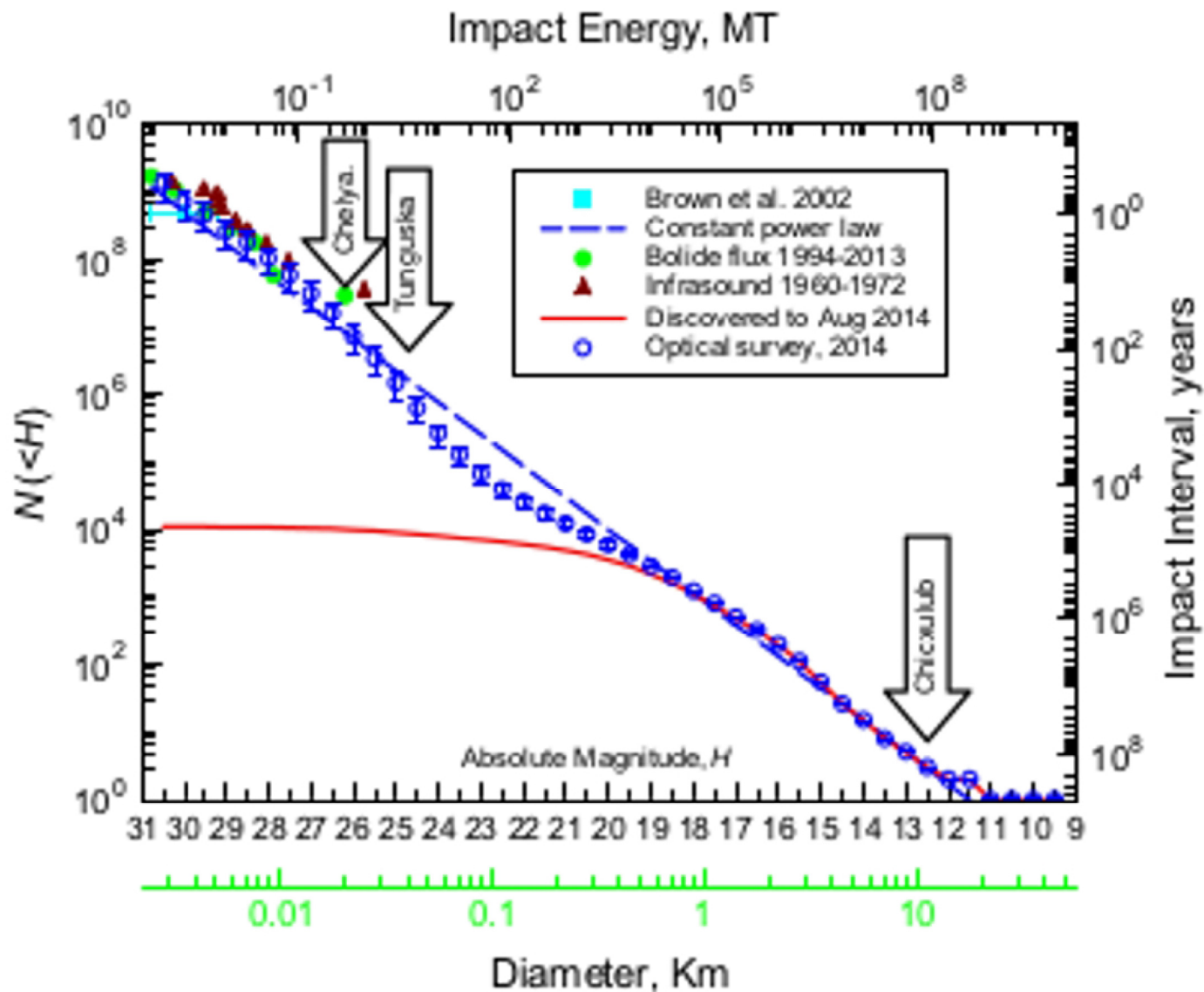
Discovery of Near Earth Asteroids

Near-Earth Asteroids Discovered

Most recent discovery: 2024-May-19



Near Earth Asteroids: how many of them are there?



Recent space missions to NEAs



- Hayabusa2:
- OSIRIS-Rex
- DART (Double Asteroid Redirection Test)

Hayabusa2: JAXA sample return mission to asteroid Ryugu

HAYABUSA 2

Japan Aerospace Exploration Agency

SRC
Sample return capsule
Re-entry to Earth, successful landing, 5 December 2020

MINERVA-II-1
Rover-1A (HIBOU)
Rover-1B (OWL)
Successful landing. Rover-1A operated for 36 days and Rover-1B operated for 3 days. 21 September 2018

MINERVA-II-2
Rover-2
Rover-2 failed before deployment. Was used to study gravitational field of the asteroid. 2 October 2019

MASCOT
(Mobile Asteroid Surface Scout)
Successful landing. Operated on battery for more than 17 hours. 3 October 2018

DCAM3
Deployable Camera 3
Deployed to observe impact of SCI impactor. Inactive now and presumed to have fallen on the asteroid. 5 April 2019

SCI
Small Carry-on Impactor
Successful. Shot to the surface 40 minutes after separation. 5 April 2019

JAXA

Sample return mission to near-Earth asteroid (162173) Ryugu

Timeline:

- 2015: Launch 3 Dec. 2014; Earth gravity assist 3 Dec. 2015
- 2016: Arrival at Ryugu 28 Jun. 2015
- 2017: Mascot landing 3 Oct. 2018; Rover-1A / Rover-1B landing 28 Sep. 2018
- 2018: SCI impactor 5 Apr. 2019; 1st surface sampling 21 Feb. 2019
- 2019: Target marker 5 Jun. 2019; Sampling 11 Jul. 2019; Rover-2 release 2 Oct. 2019; Capsule re-entry 5 Dec. 2020
- 2020: Return orbit 18 Nov. 2019
- 2021: Target body (1998 KY26) rendezvous Jul. 2031
- 2026: High-speed fly-by Jul. 2026

はやぶさ2

Infographic: Alexander Anisenkov | www.anisenkov.ru

Samples brought back from Ryugu

TD1

5 mm

TD2

Artificial object?

5 mm

TD1 **TD2**

Tamatebako **Uchide-no-kozuchi**

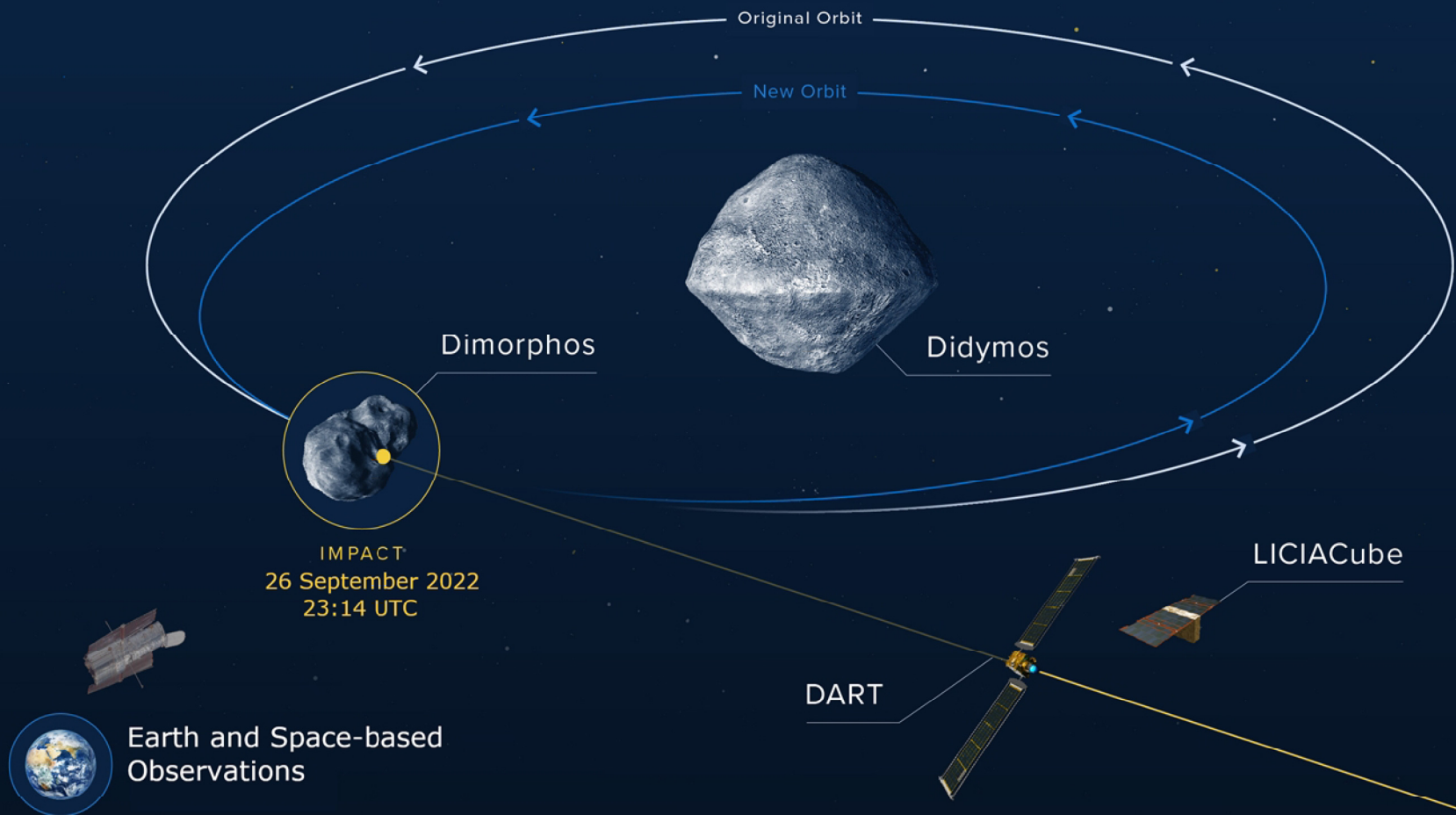
Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST

Hayabusa2 at asteroid Ryugu

Asteroid Ryugu imaged by Hayabusa2
from 20 km to ~1 km away

OSIRIS-Rex: NASA sample return mission to asteroid Bennu

DART: NASA Double Asteroid Redirection Test mission

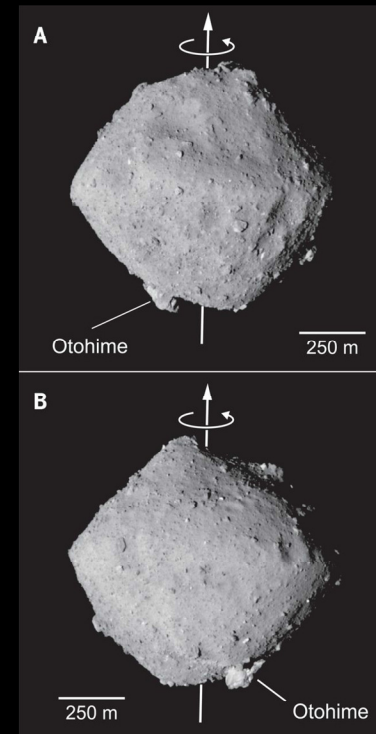


DART: NASA Double Asteroid Redirection Test mission



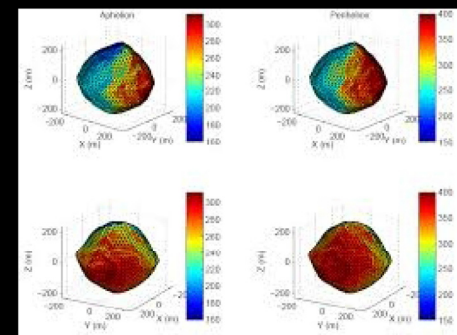
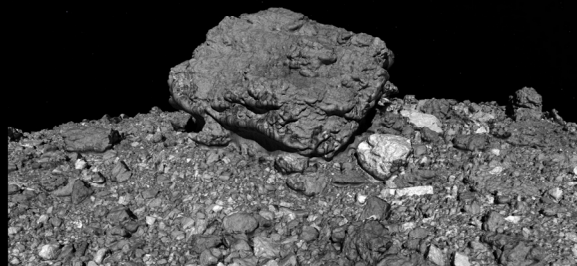
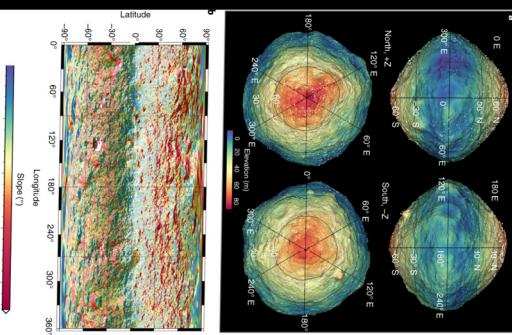
Near Earth Asteroids: what we know about their physical properties

- Knowledge of the surface and internal properties of NEAs is required for assessing their hazard potential and the effectiveness of proposed mitigation strategies , as well as for the design of lander and sample return spacecraft missions
- Insights into the physical properties of asteroids are required for proper understanding of many processes, including the formation of planetesimals , bolides in planetary atmospheres, impact cratering, the evolution of the meteoroids parent bodies, and many others



Near Earth Asteroids: what we know about their physical properties

- Despite their great importance, knowledge of the physical properties of most NEAs lags far behind the current rate of their discoveries
- Asteroid surfaces and internal structures are very diverse, and knowledge derived from a limited number of asteroids typically could not be safely applied to a large number of objects



Planetary Society STEP Grant 2021

Demystifying Near-Earth Asteroids

D-NEAs

(2022 - 2024)

Main Objective:

**Modeling surface thermal properties from
the ground-based data**



Demystifying near-Earth Asteroids project



- Demystifying near-Earth Asteroids (D-NEAs) 2022-2024: Planetary Society Step Grant
- Main Objective: Modeling surface thermal properties from the ground-based data

Yarkovsky effect in the orbital motion

Methods: model vs. observed Yarkovsky drift

$$\left(\frac{da}{dt}\right)(\mathbf{a}, \mathbf{D}, \rho, \mathbf{K}, \mathbf{C}, \gamma, \mathbf{P}, \alpha, \varepsilon) = \left(\frac{da}{dt}\right)_m$$

Parameters:

a semimajor axis

D diameter

ρ density

K thermal conductivity

C heat capacity

γ obliquity

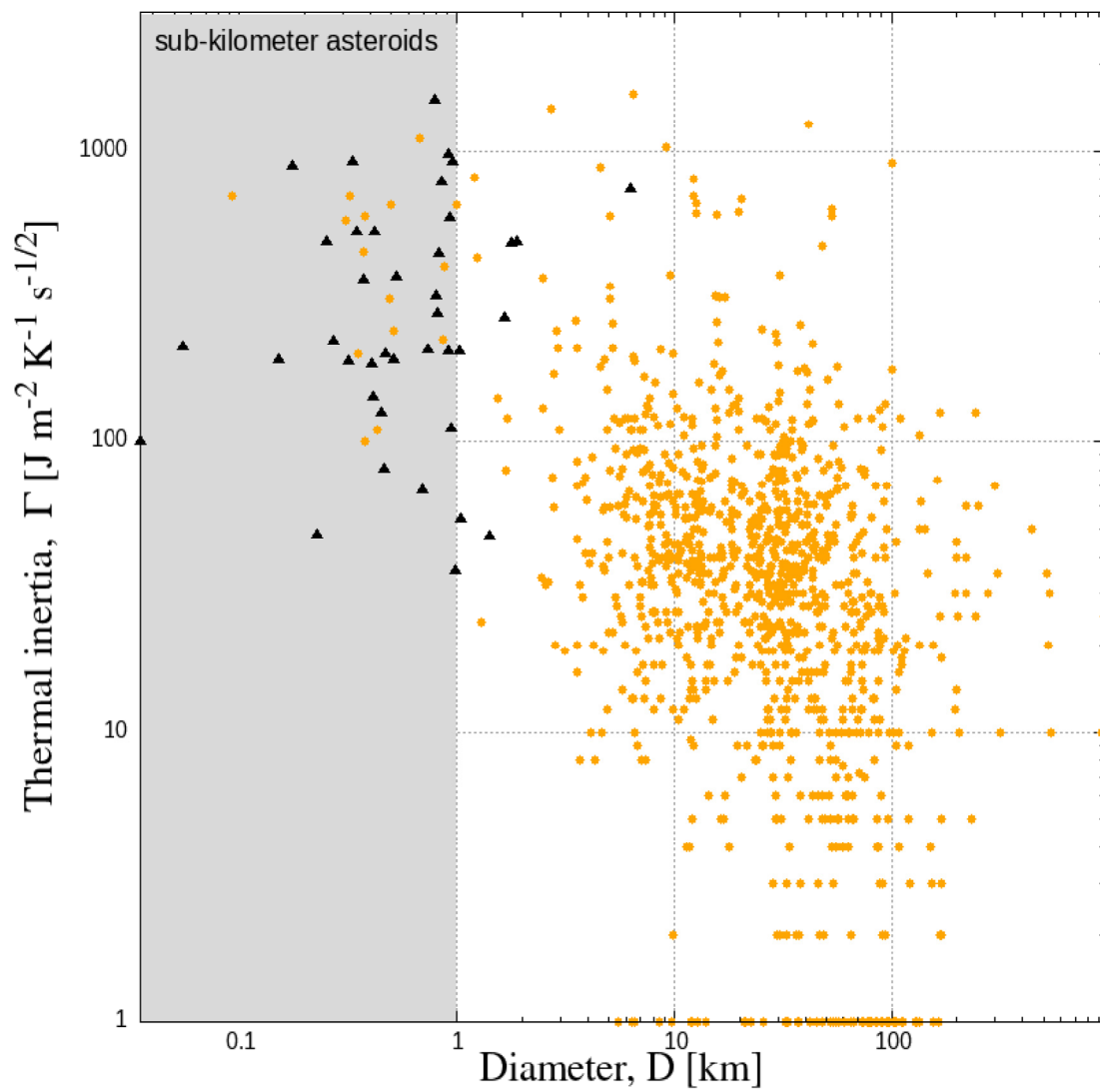
P rotation period

Method:

- Assume distributions for all the parameters but K
- Solve for K the model vs. observed equation
- Use a Monte Carlo method for statistical analysis

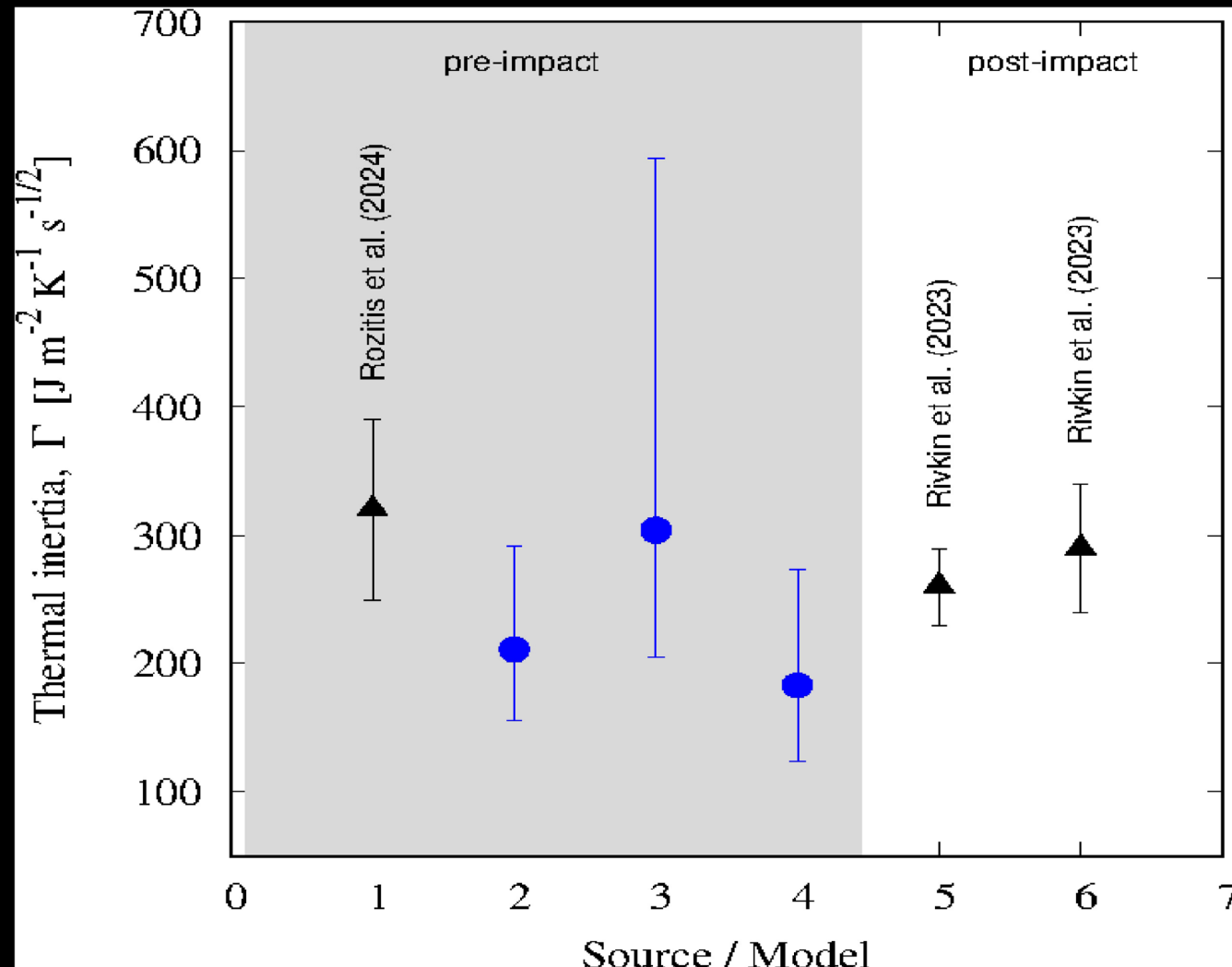
ASTERIA—Asteroid Thermal Inertia Analyzer

Novakovic et al. PSJ, 2024



Some other interesting cases: asteroid Didymos

Novakovic & Fenucci, 2024, submitted

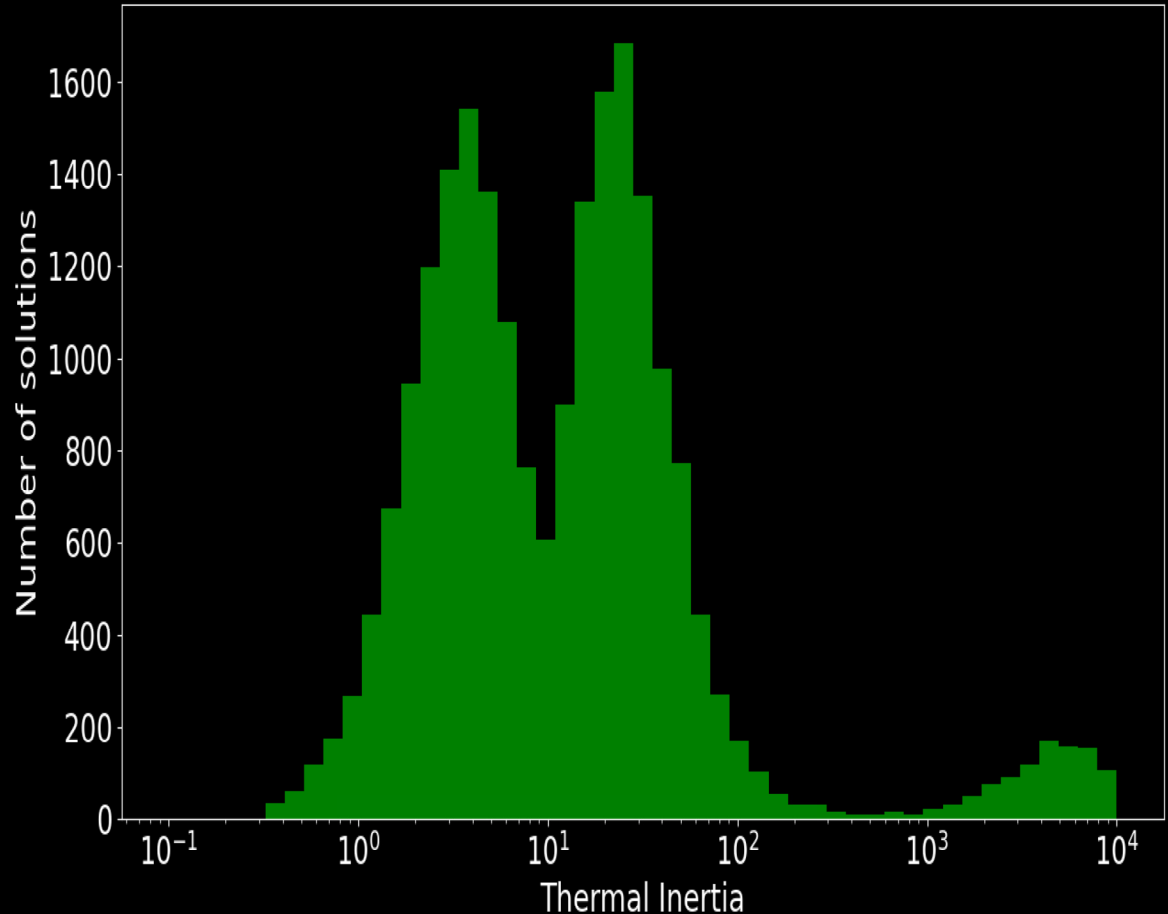


Some other interesting cases: 2016 GE1

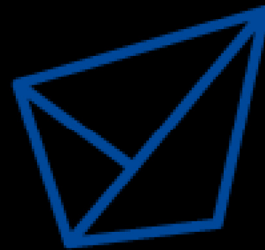
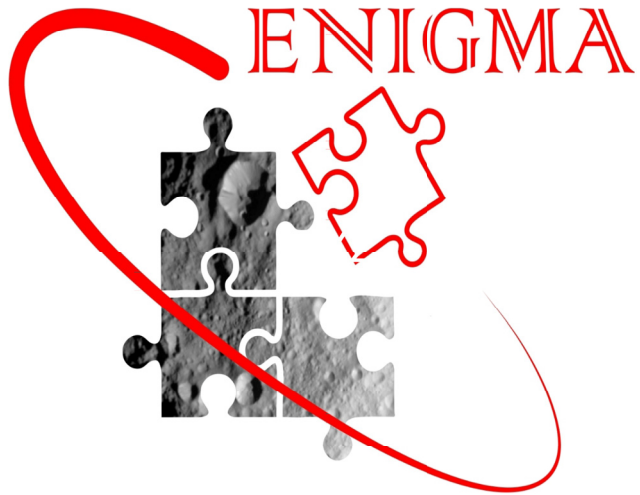
2016 GE1: $H \sim 26.7$, $e \sim 0.52$, $P \sim 33$ s, $da/dt \sim -0.0583 \pm 0.0187$ au/My

Result: very low TI

Fenucci et al. A&A, 2023



Project ENIGMA



Science Fund
of the Republic of Serbia

Project ENIGMA

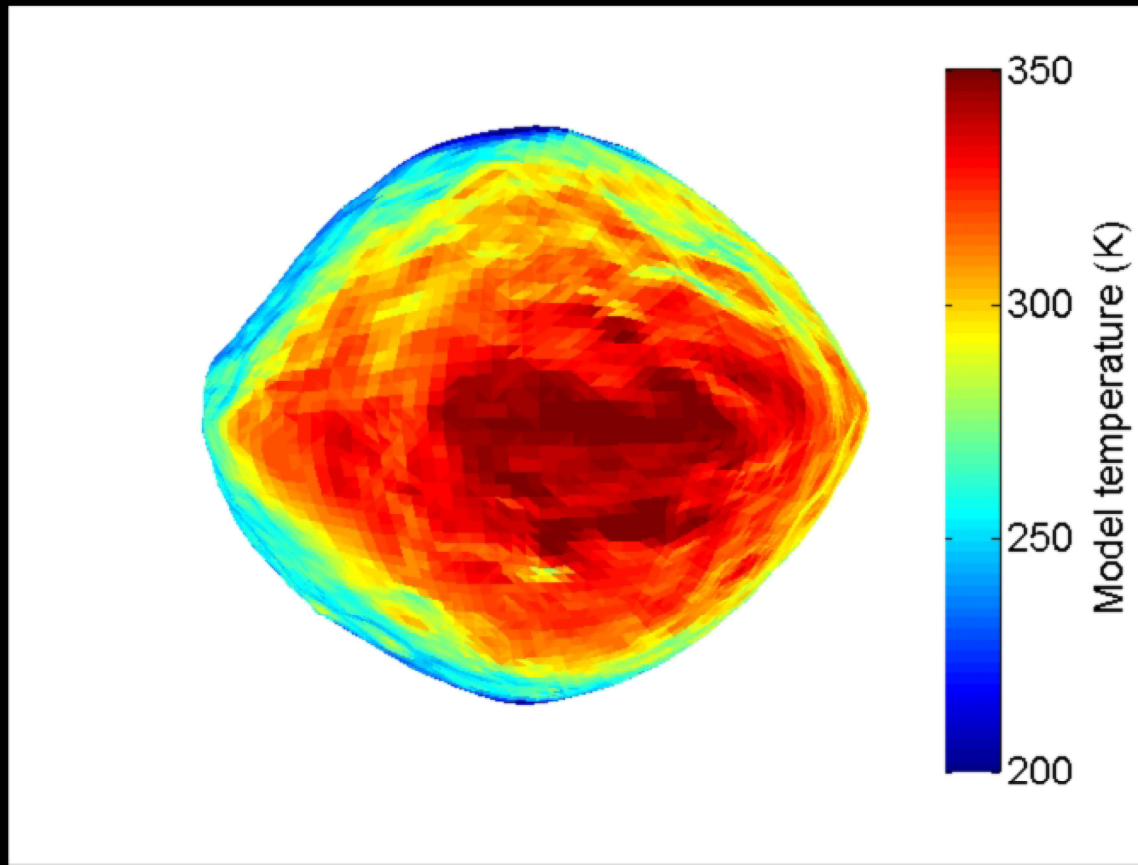
- Main objectives:
 - Numerical modeling of surface thermal properties
 - Validation of the Yarkovsky models for super-fast rotators
 - Explaining why rapidly rotating objects are common among the population of small near-Earth asteroids
 - Structural properties of rapidly rotating asteroids



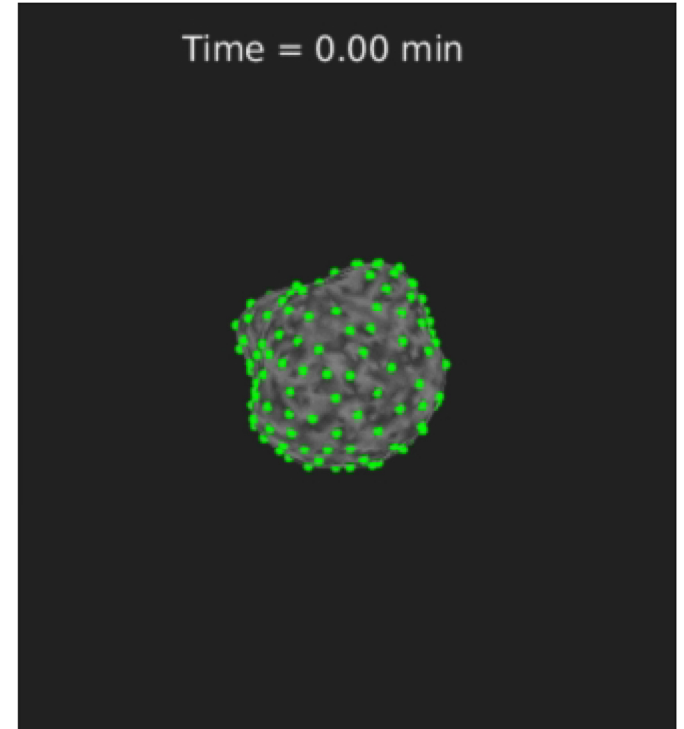
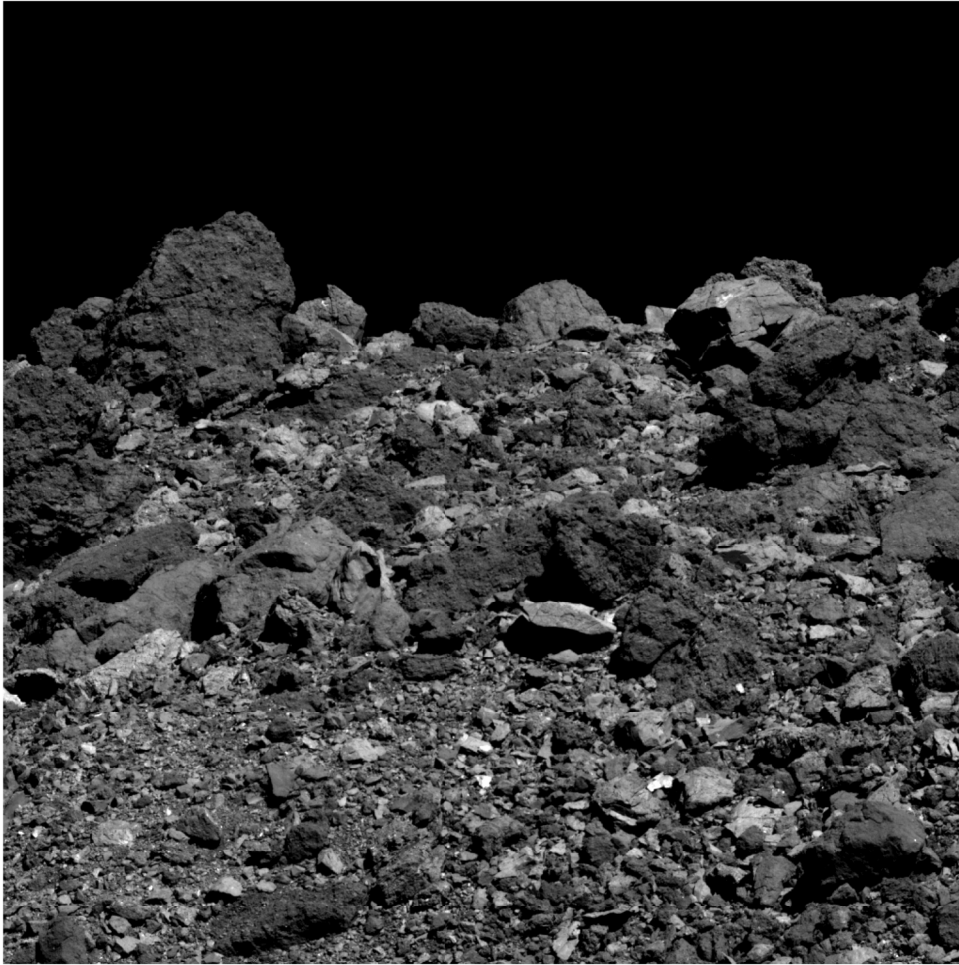
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OBJECTIVE #1:

Validation of the Yarkovsky models for super-fast rotators



Thermal inertia and fast rotators

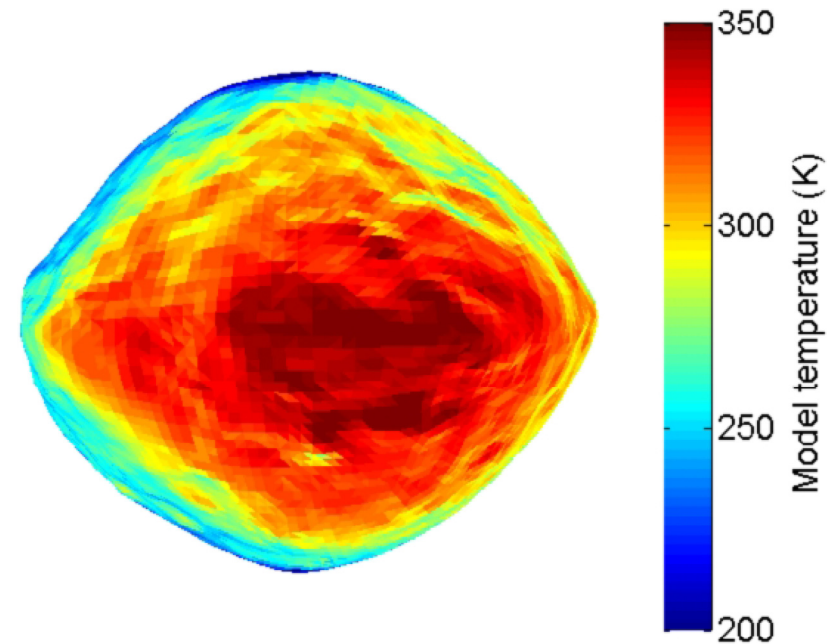
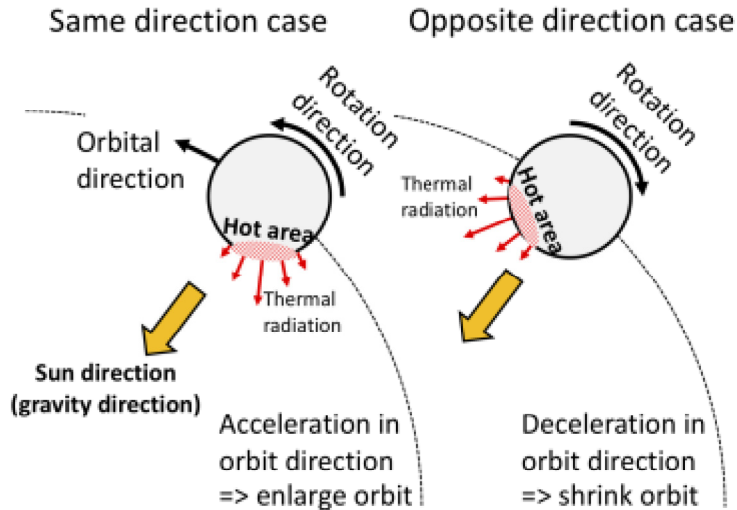


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OBJECTIVE #2:

Numerical modeling of surface thermal properties

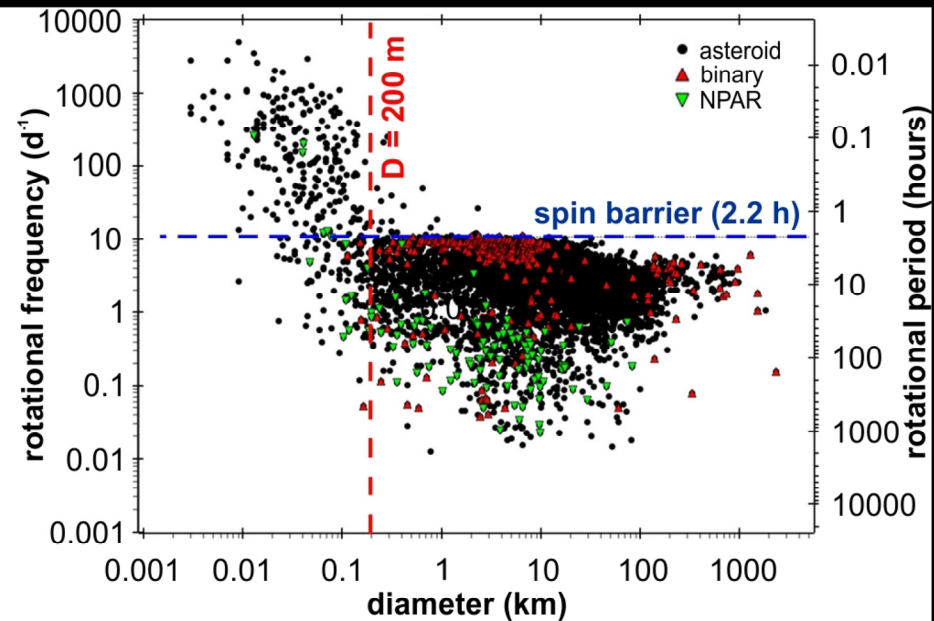
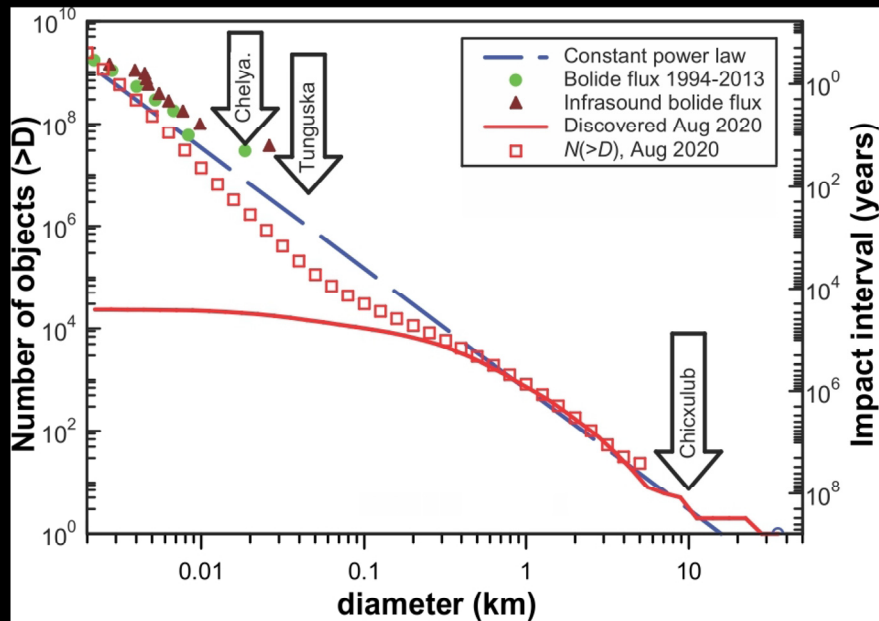
Yarkovsky effect



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OBJECTIVE #3:

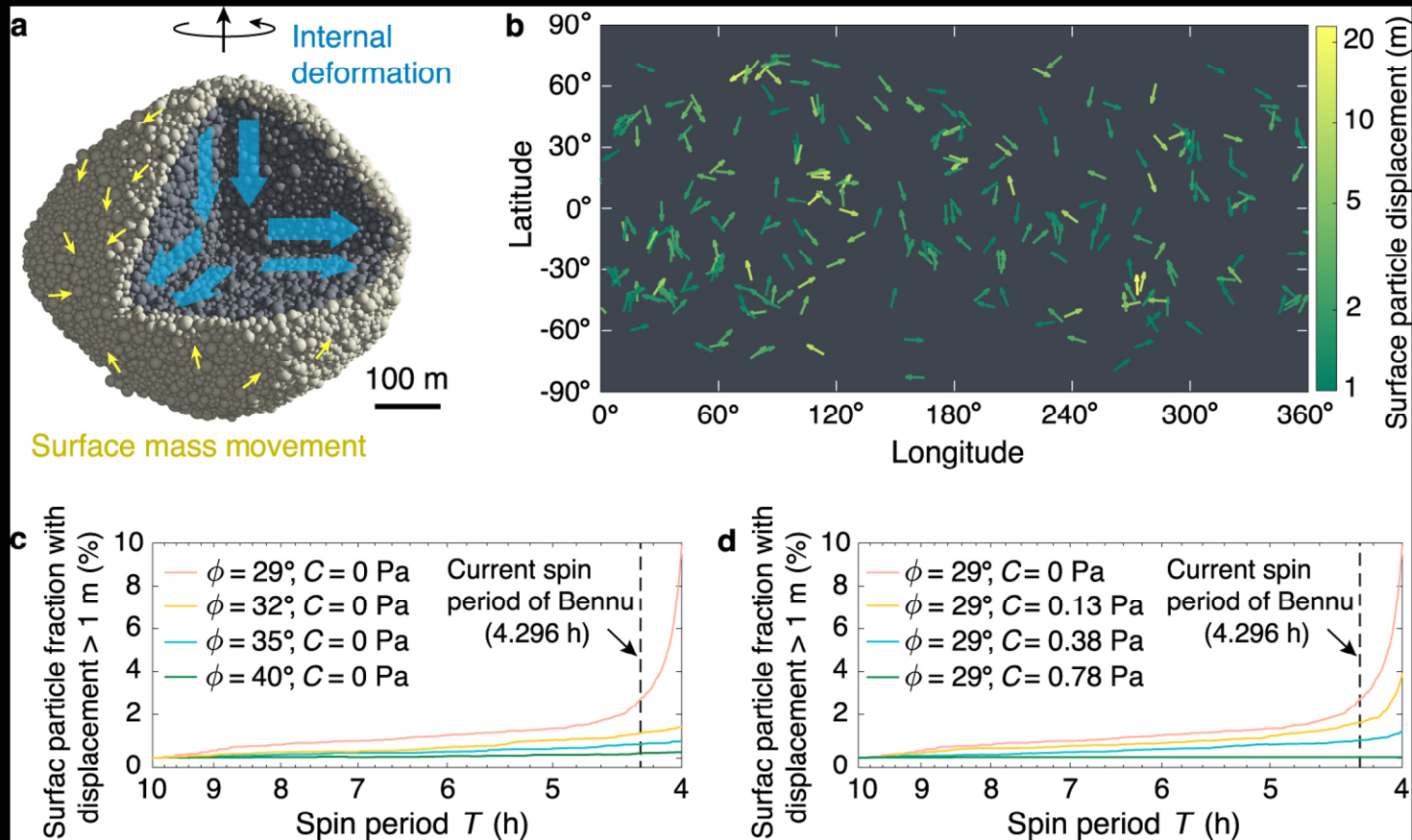
Explaining why rapidly rotating objects are common among the population of small near-Earth asteroids



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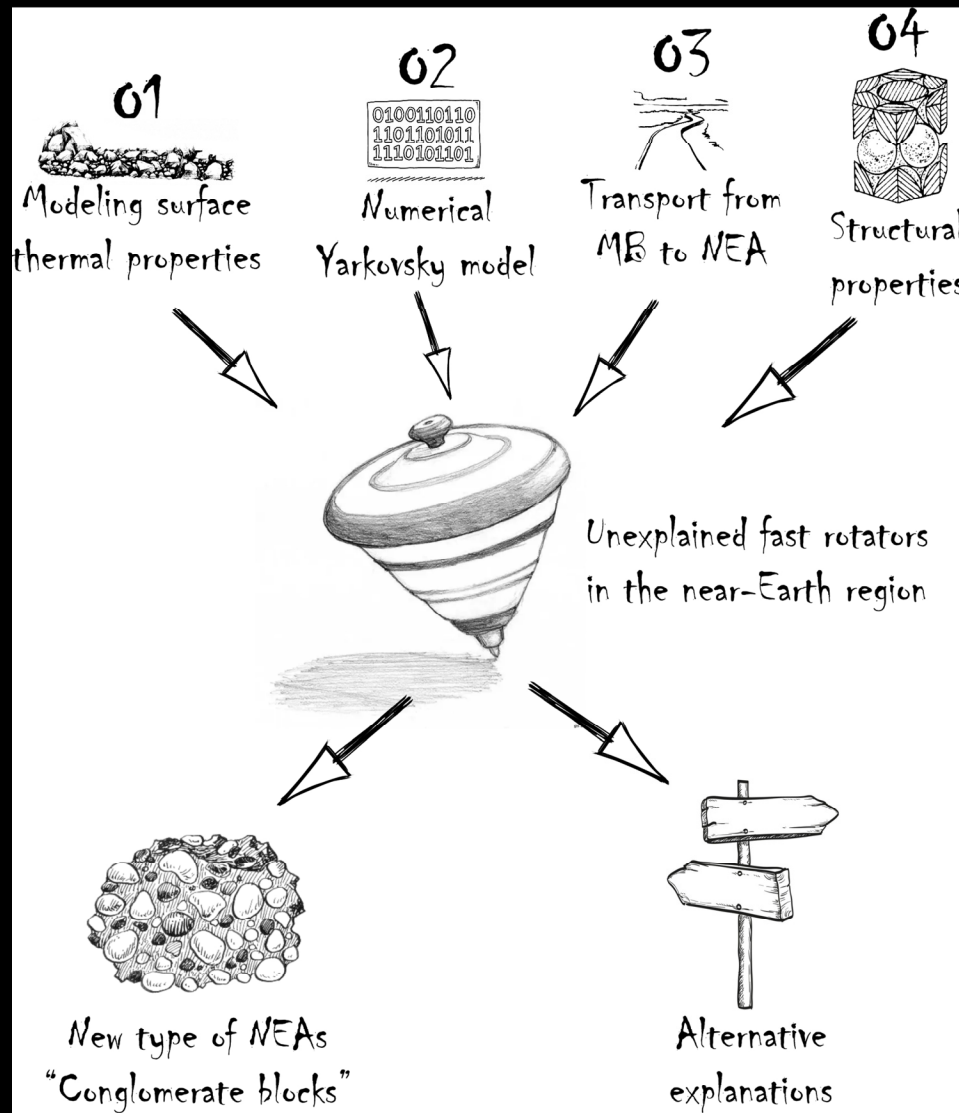
OBJECTIVE #4:

Structural properties of rapidly rotating asteroids



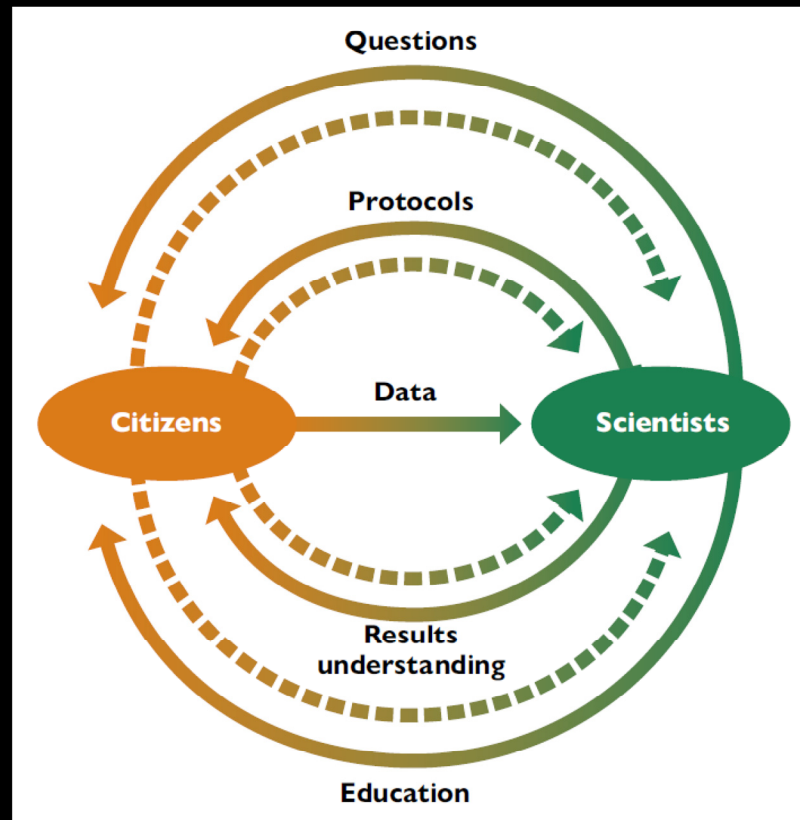


Project ENIGMA



Project ENIGMA

Citizen Science Project



Project ENIGMA - Citizen Science Project



Project ENIGMA

Citizen Science Project

Starts in October 2024

Feel free to participate :)

