A closer look at the asteroids in Earth's neighborhood

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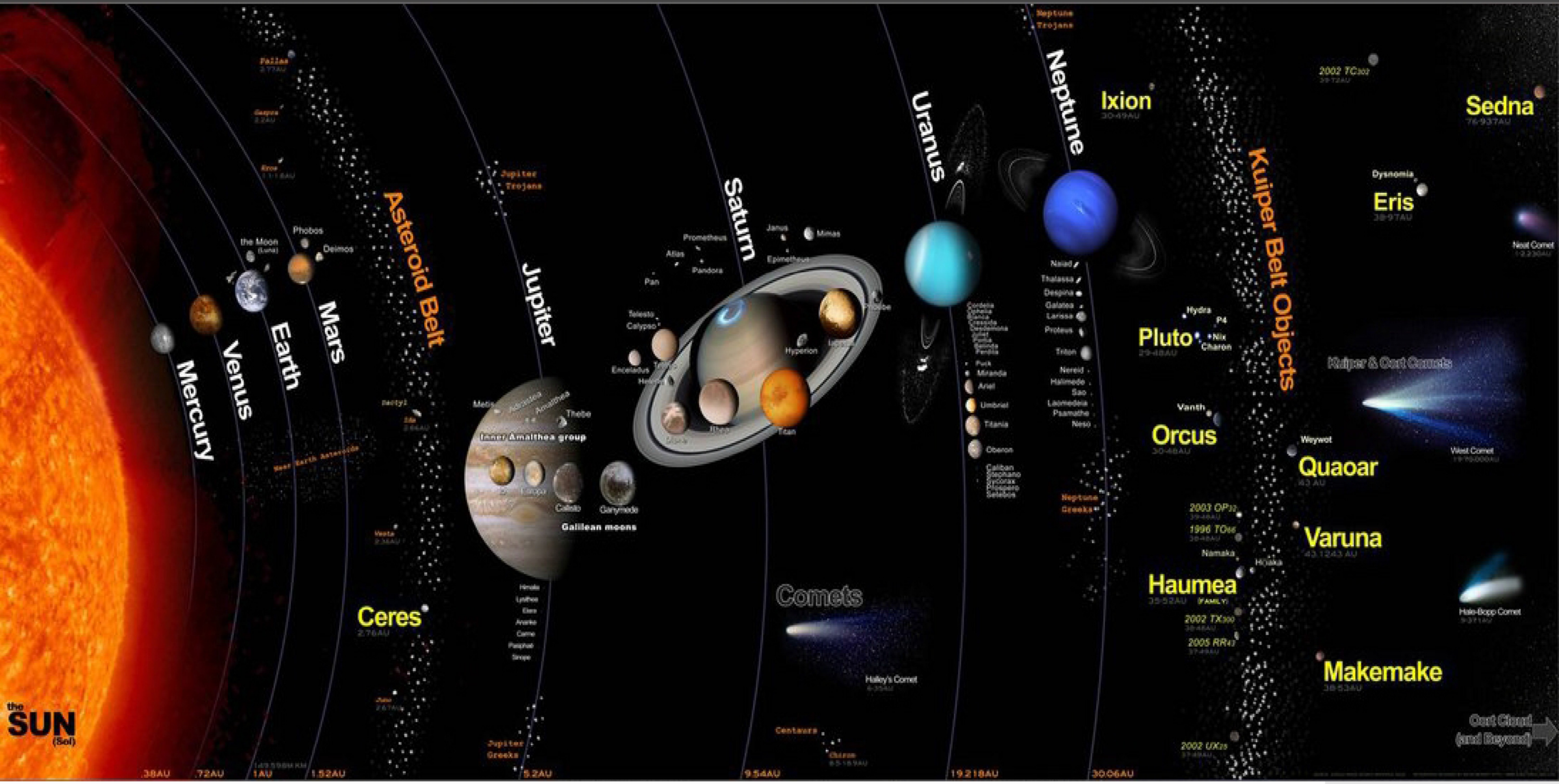
Seminar of the Department of Astronomy - 28 May 2024

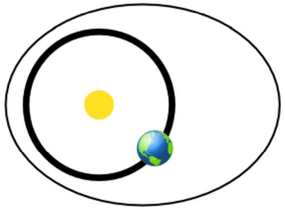
Solar System structure



Near Earth Asteroids Orbital Classes

Amors

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



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

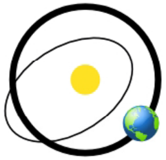
Apollos

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)



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

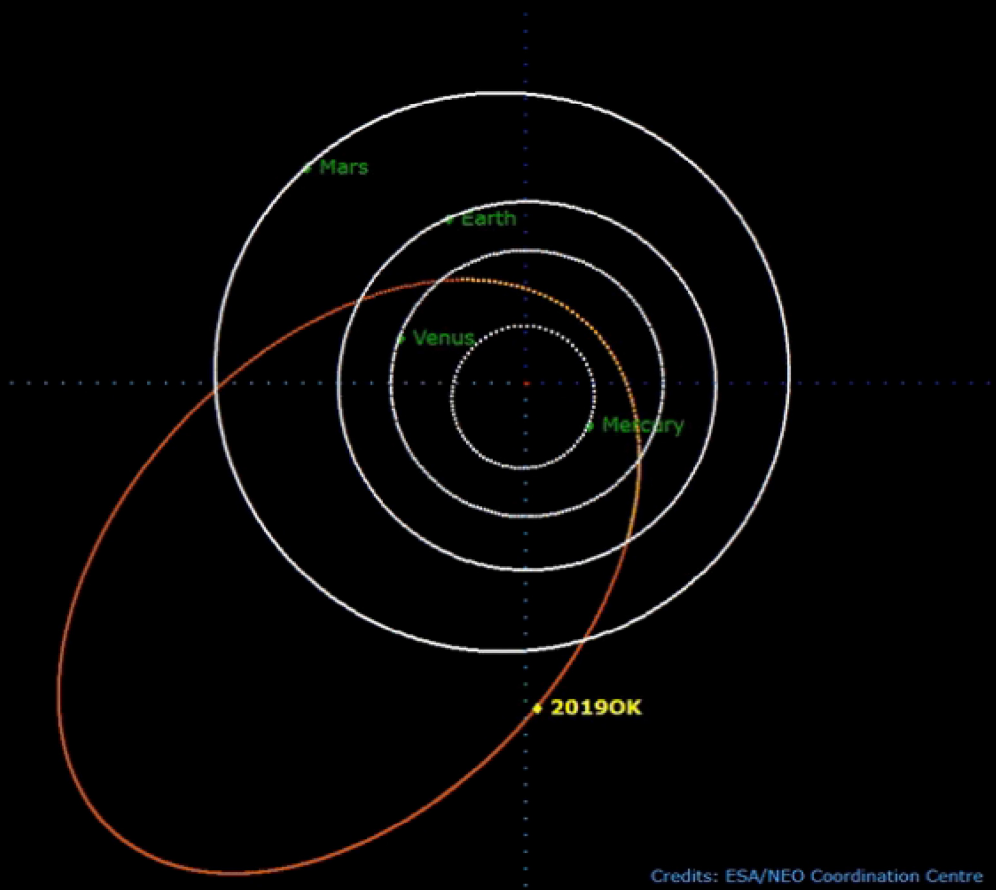
Atiras

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

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

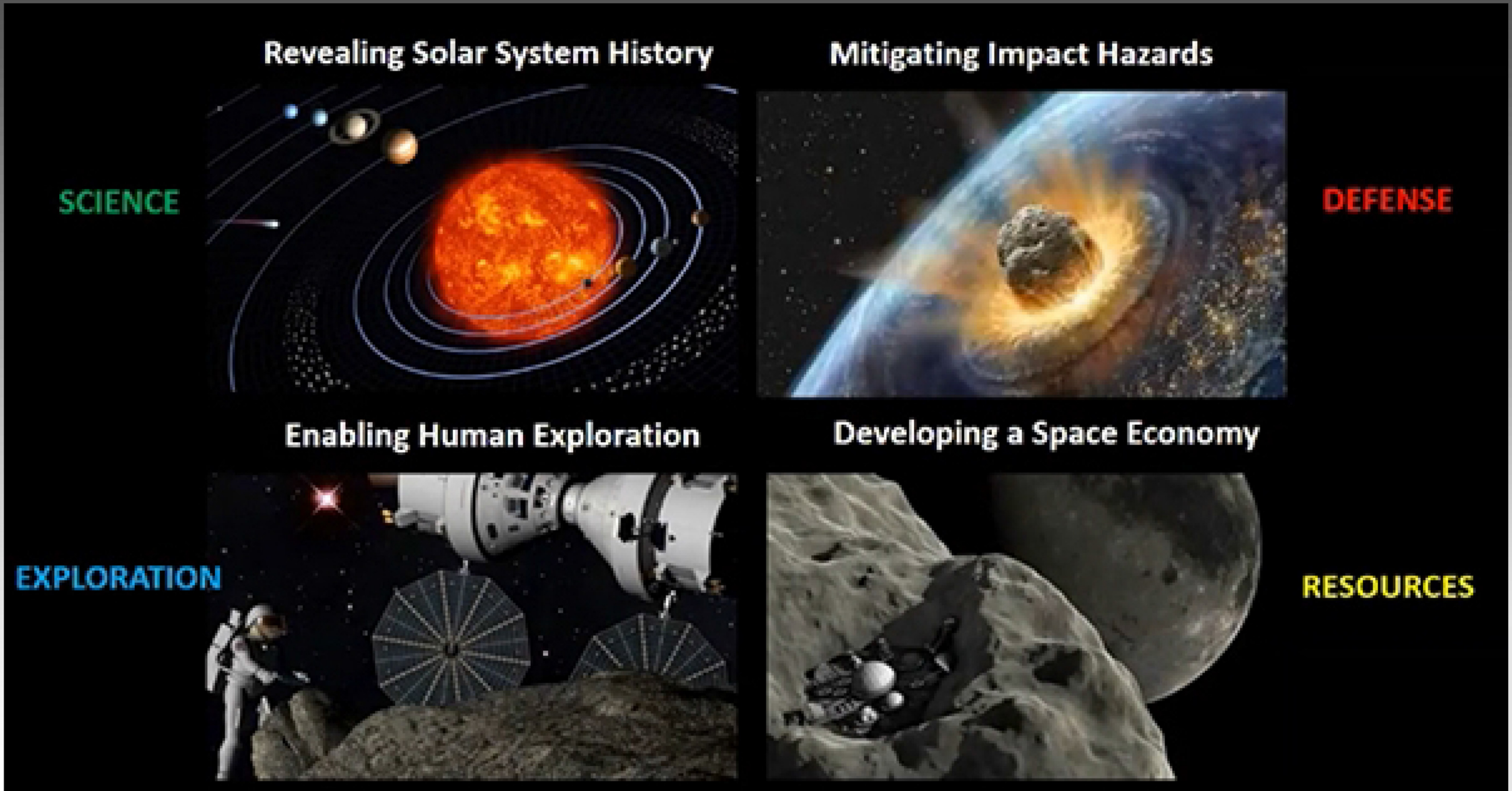
(q = perihelion distance, Q = aphelion distance, a = semi-major axis)

Near Earth Asteroids Orbital Classes

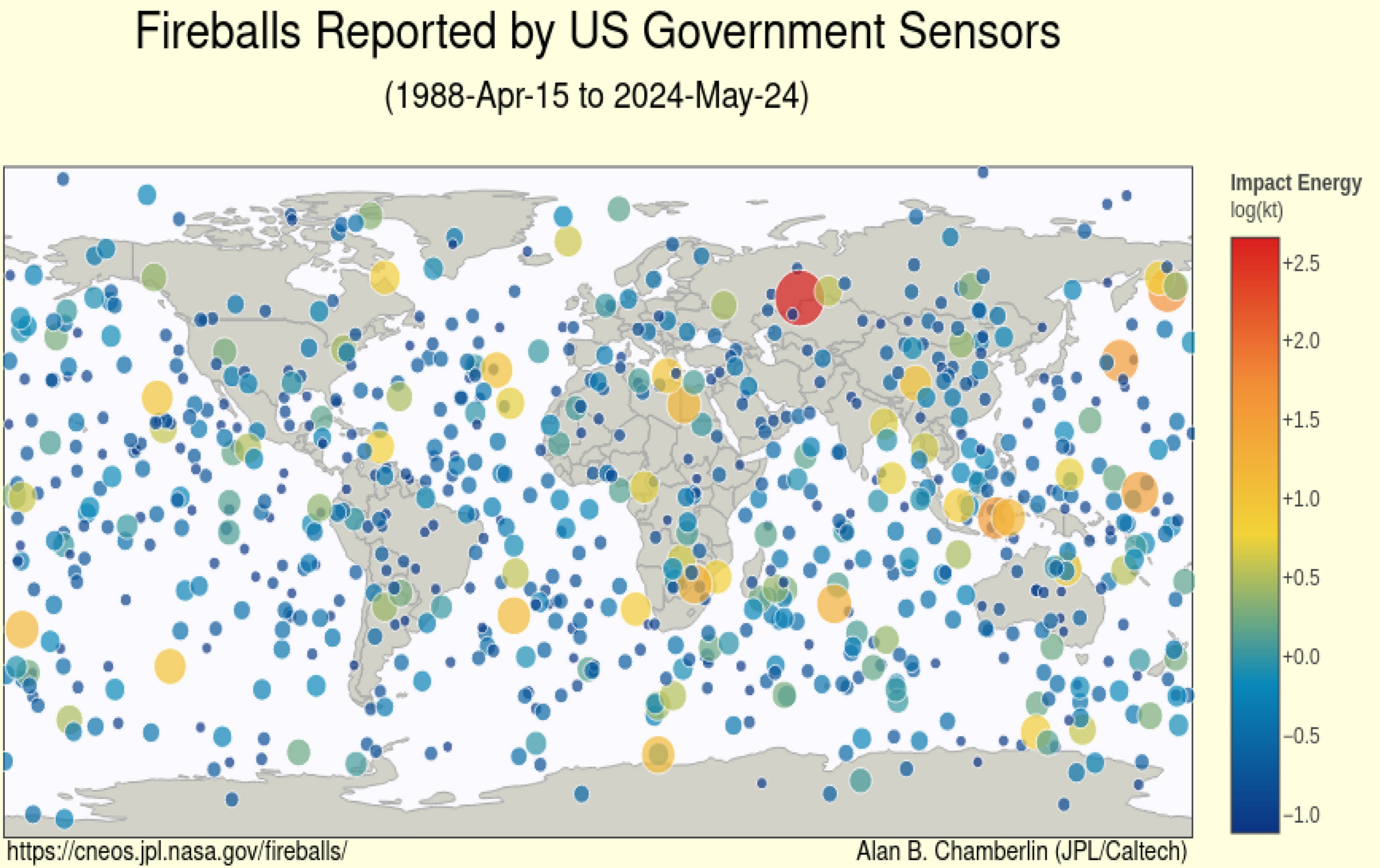


Why do we care about near-Earth asteroids?

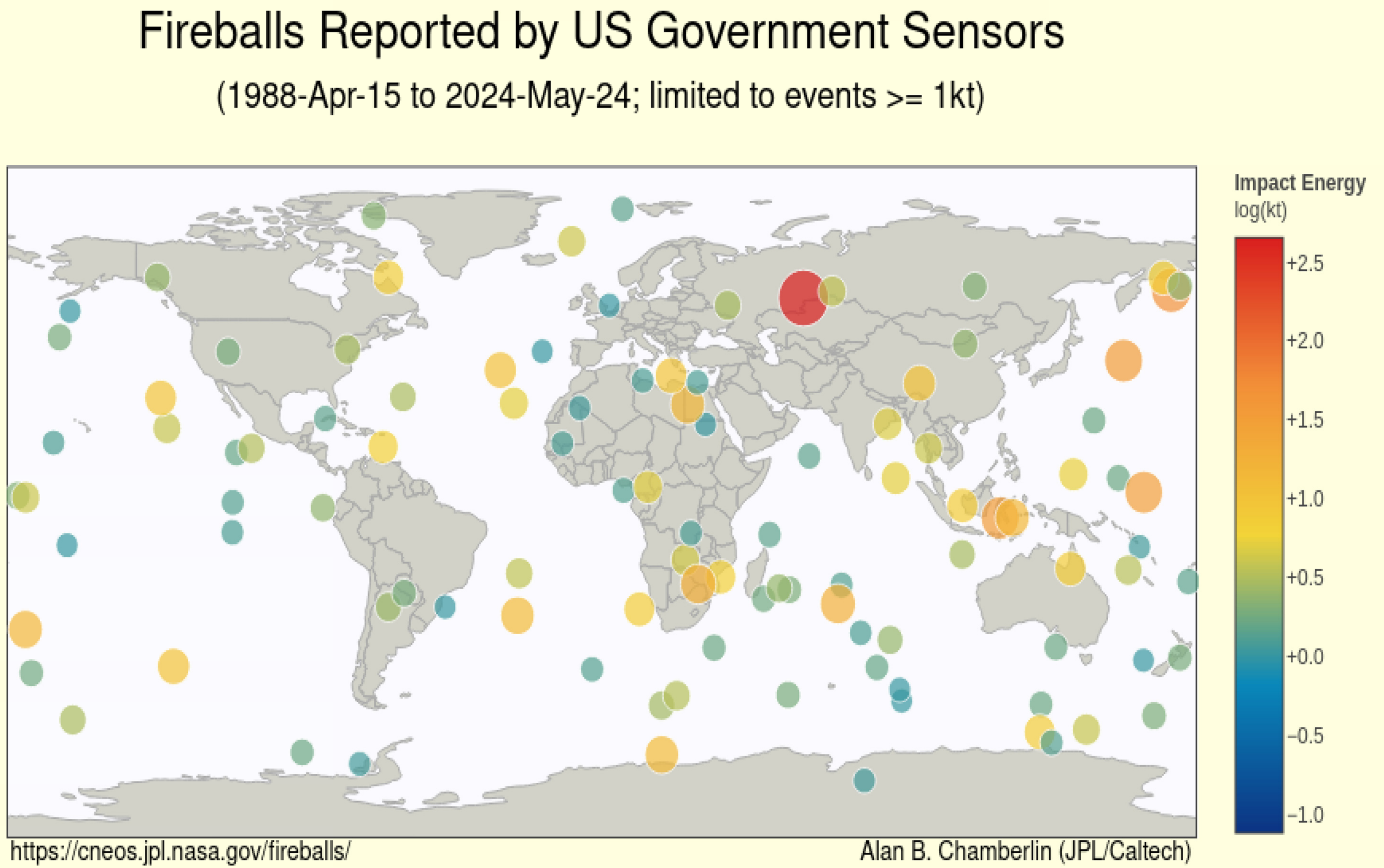
- Science, Planetary Defense, Exploration, and maybe Exploitation



Fireballs statisctics

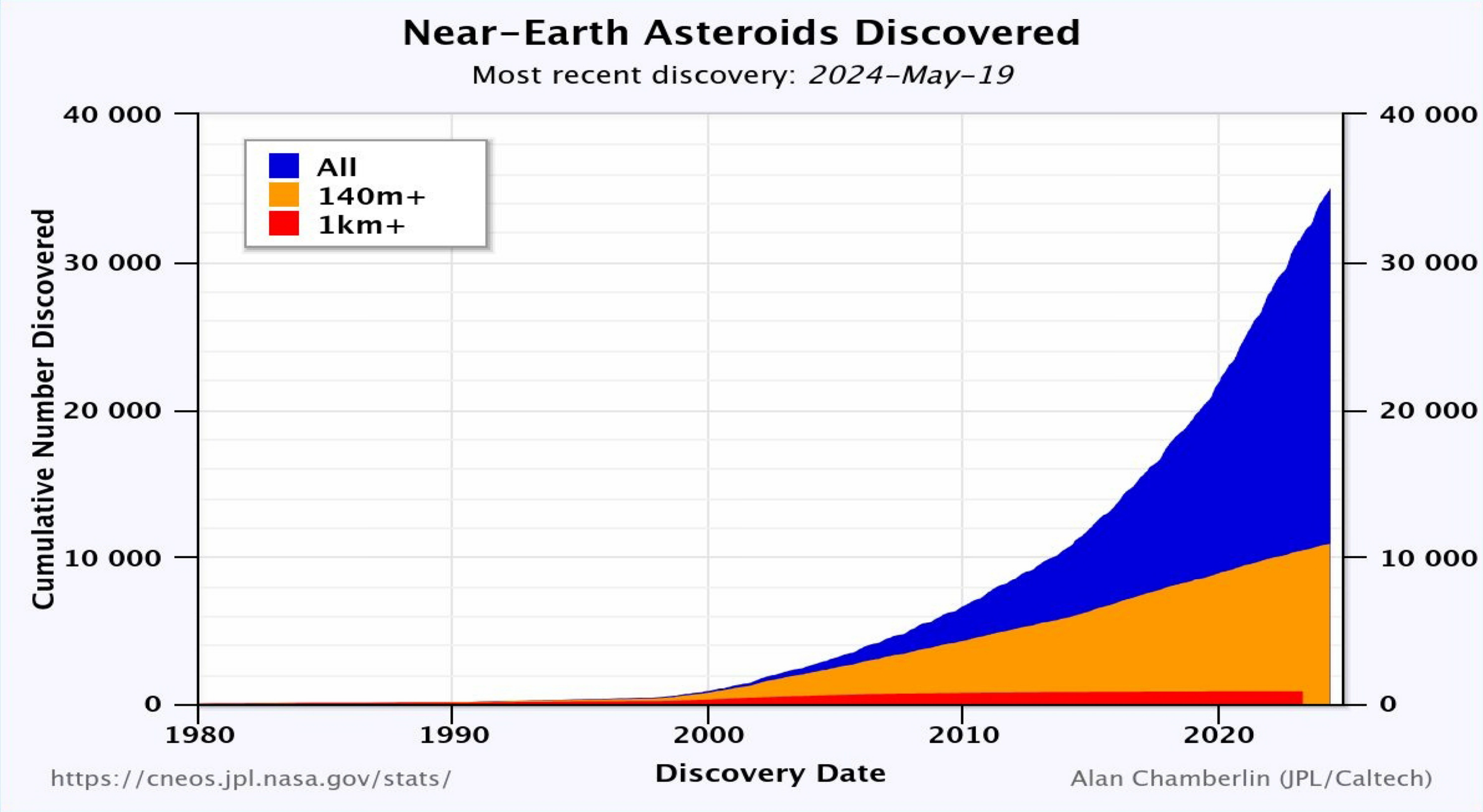


Fireballs statisctics

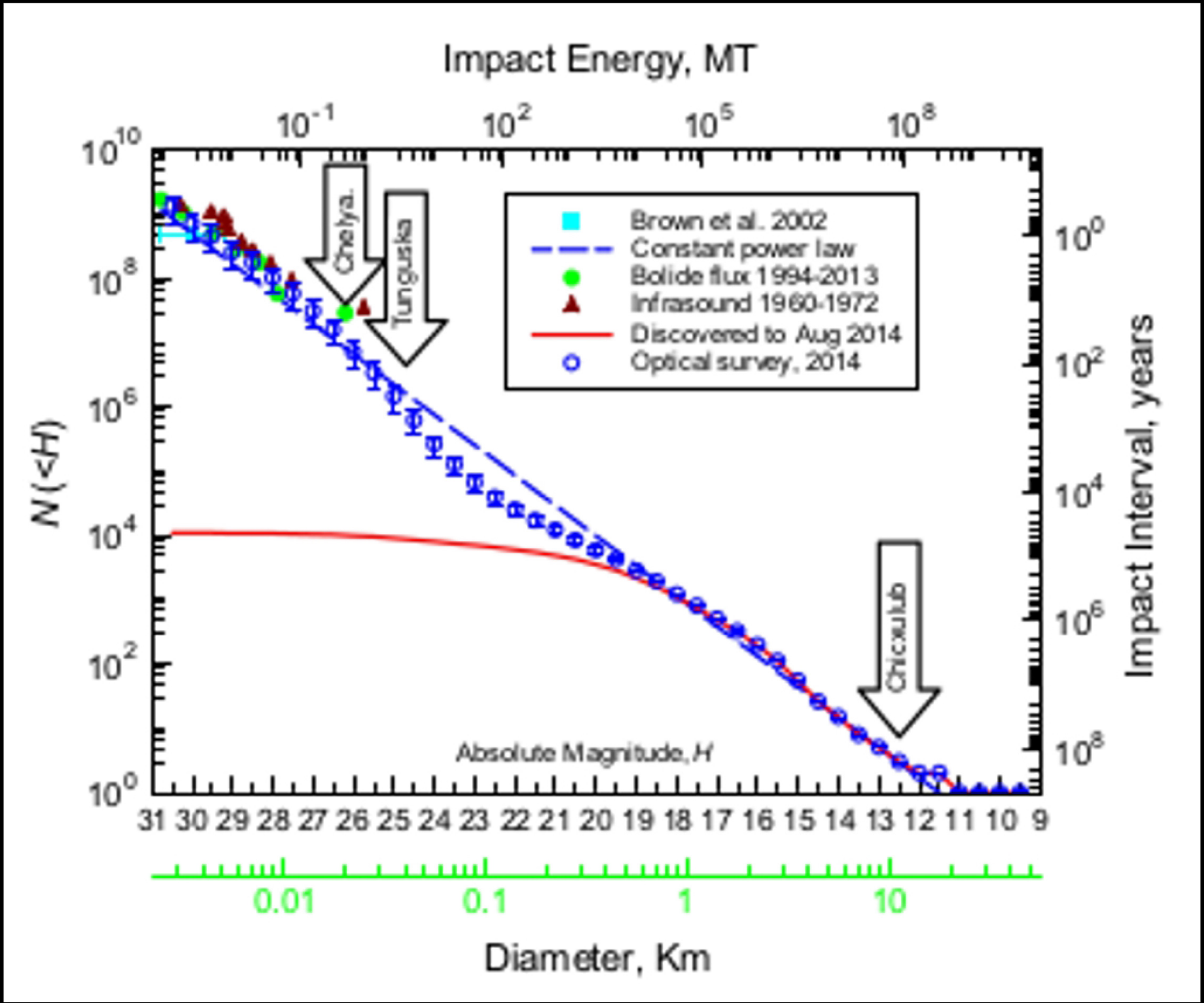


Rececnt
fireball over Spain and Portugal

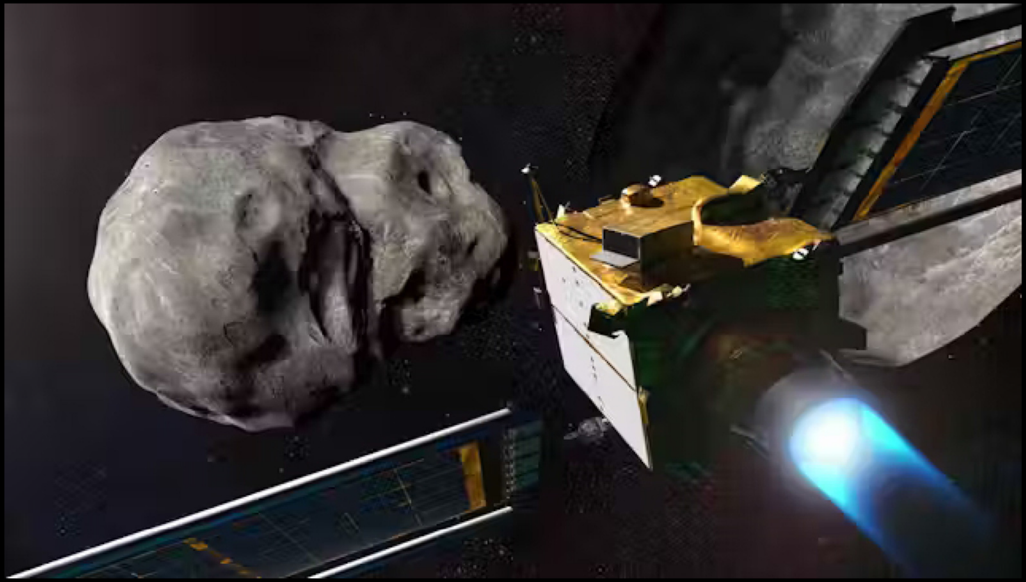
Discovery of Near Earth Asteroids



Near Earth Asteroids:
how many of them are there?

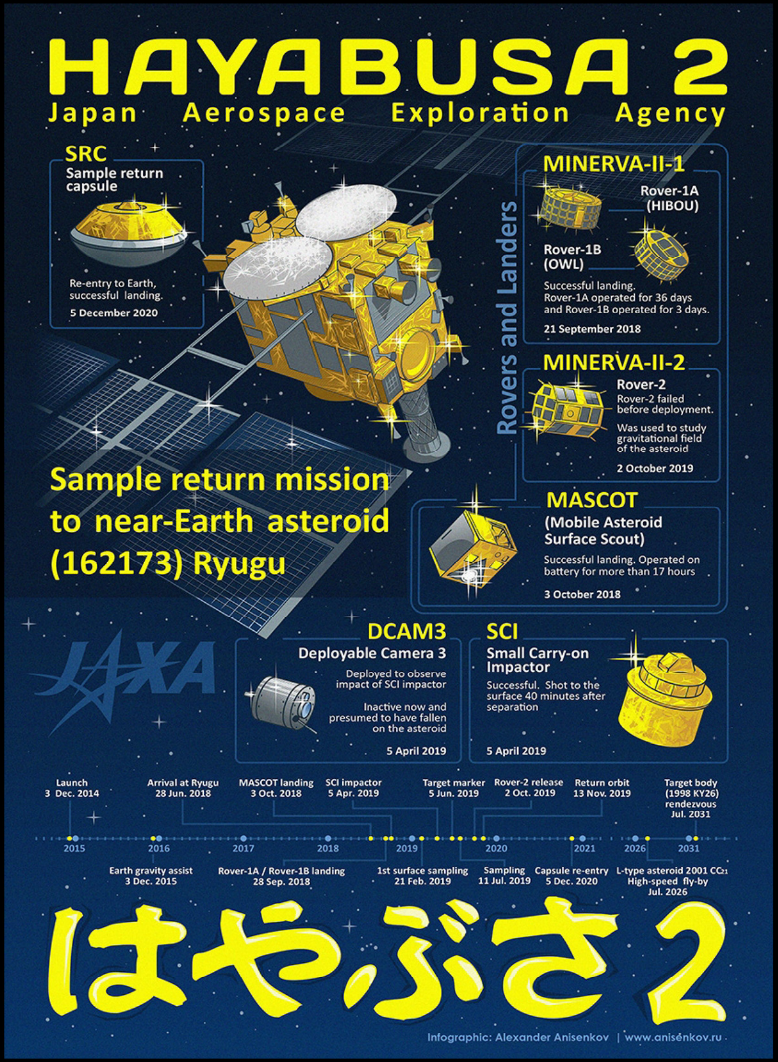


Recent space missions to NEAs



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

Hayabusa2: JAXA sample return mission to asteroid Ryugu



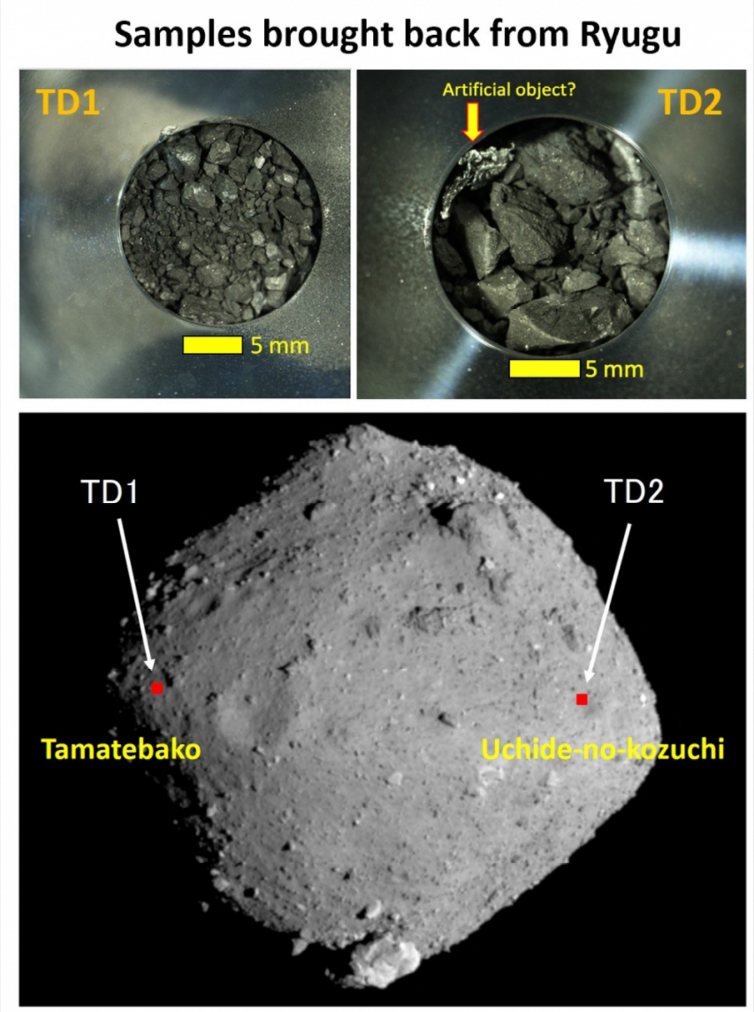


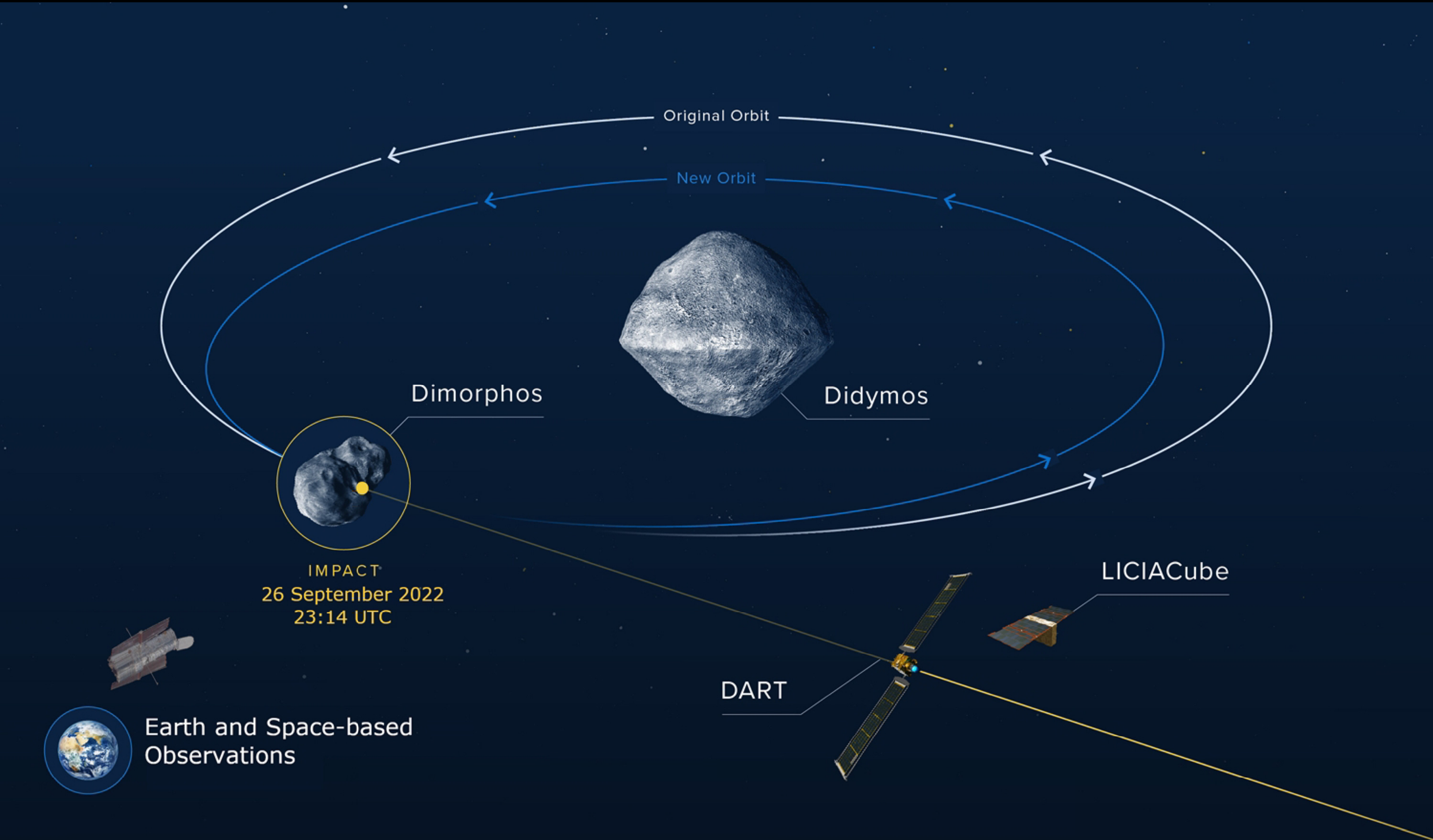
Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST

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

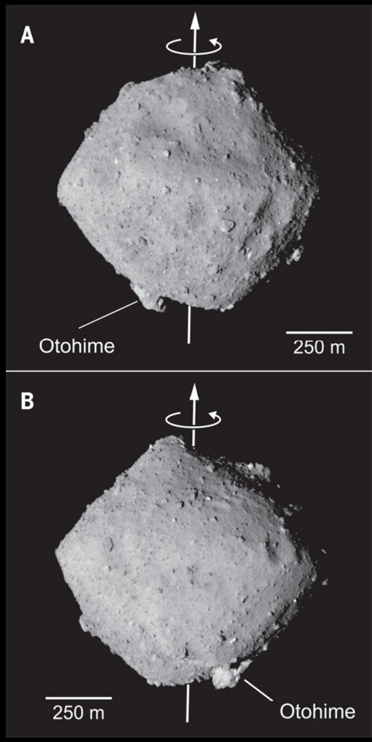


DART: NASA Double Asteroid Redirection Test mission

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

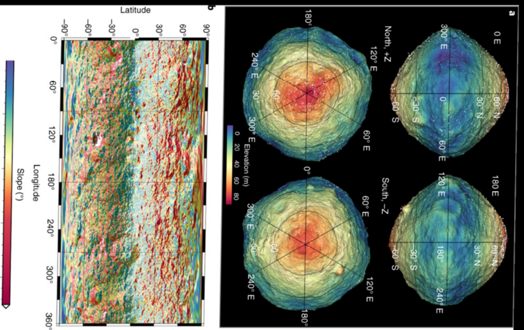
- Insights into the physical properties of asteroids are required for proper understanding of many processes, including the formation of planetesimals , bolides in planetary atmospheres, impact cratering, the evolution of the meteoroids parent bodies, and many others

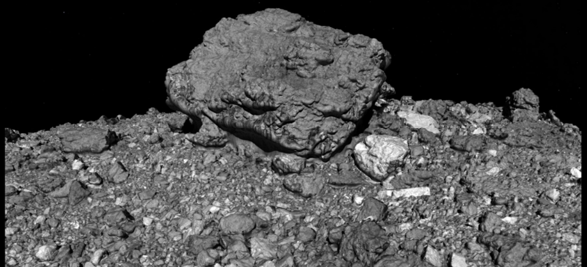


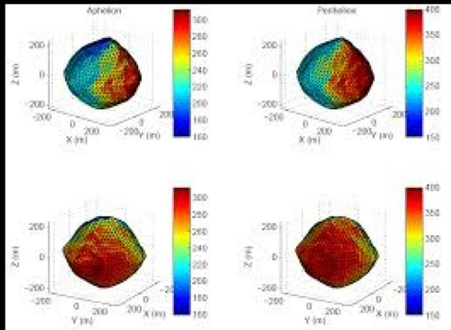
Near Earth Asteroids:
what we know about their physical properties

- 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

D-NEAs
Demystifying Near-Earth Asteroids

THE PLANETARY SOCIETY

Demystifying near-Earth Asteroids project

D-NEAs
Demystifying Near-Earth Asteroids

- 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

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

Parameters:

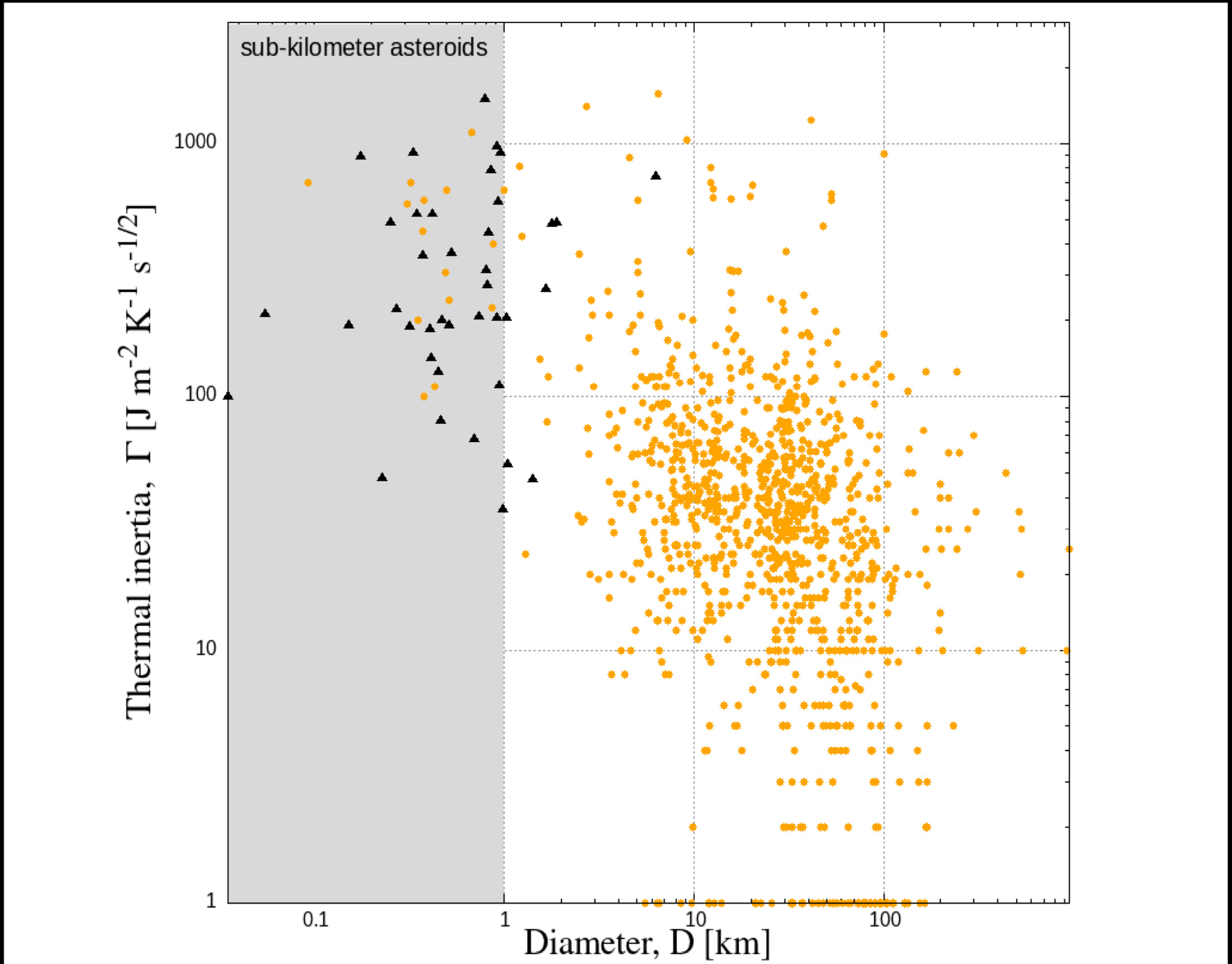
- **a** semimajor axis
- **D** diameter
- ρ density
- **K** thermal conductivity
- **C** heat capacity
- γ obliquity
- **P** rotation period

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

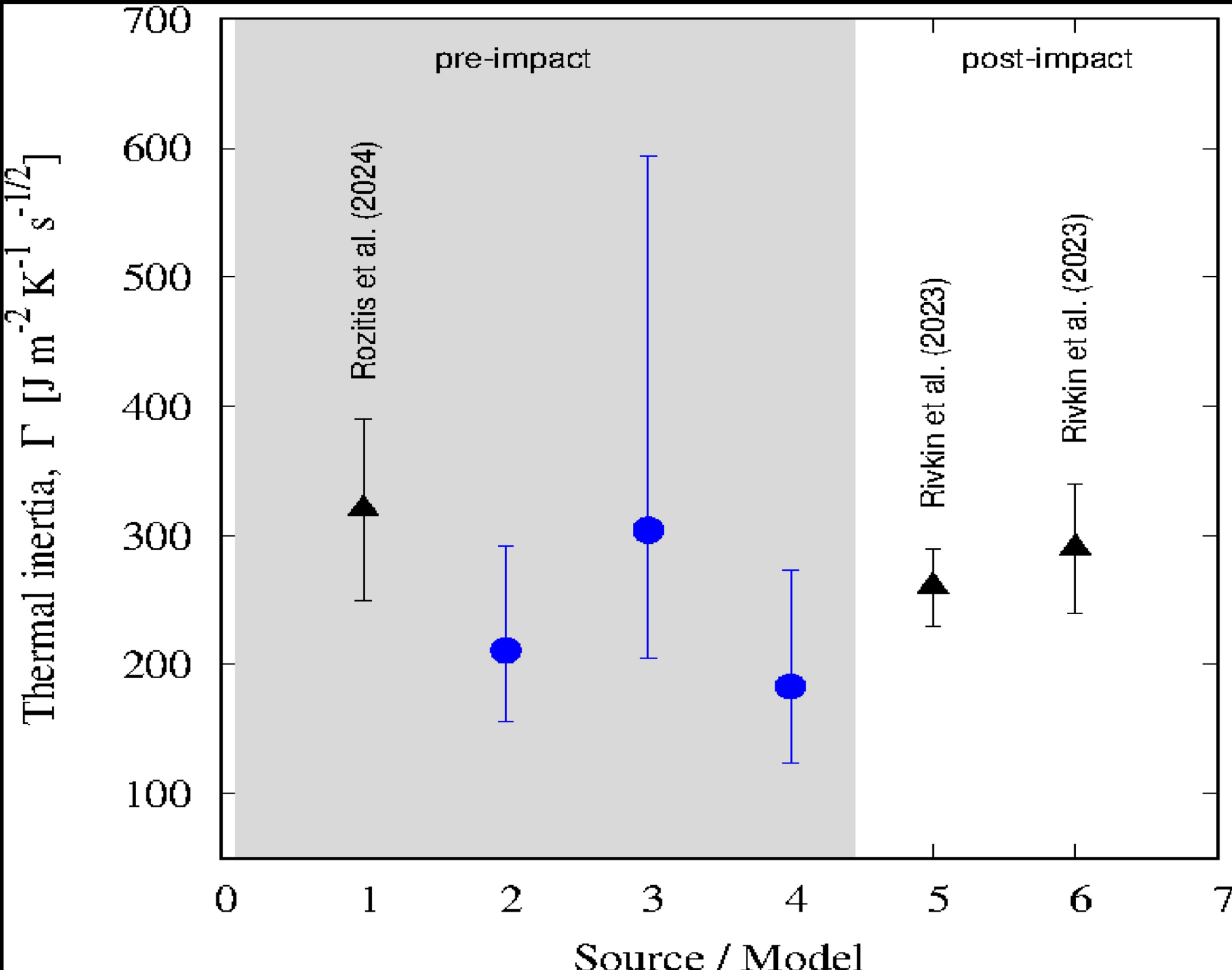
ASTERIA—Asteroid Thermal Inertia Analyzer

Novakovic et al. PSJ, 2024



Some other intresting cases: asteroid Didymos

Novakovic & Fenucci, 2024, submitted

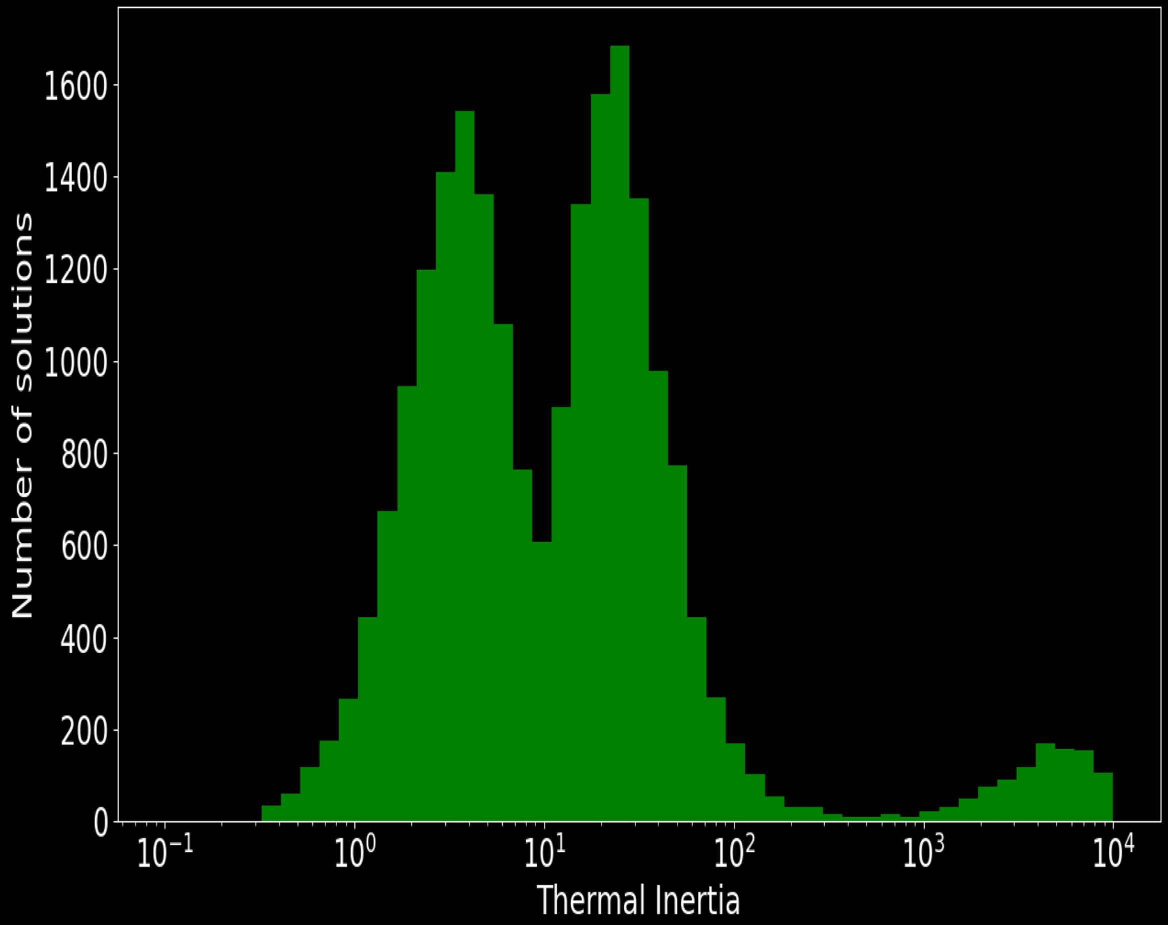


Some other intresting cases: 2016 GE1

2016 GE1: H ~ 26.7, e ~ 0.52, P ~ 33 s, da/dt ~ -0.0583 ± 0.0187 au/My

Result: very low TI

Fenucci et al. A&A, 2023



Project ENIGMA

ENIGMA

Science Fund
of the Republic of Serbia

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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

Project ENIGMA

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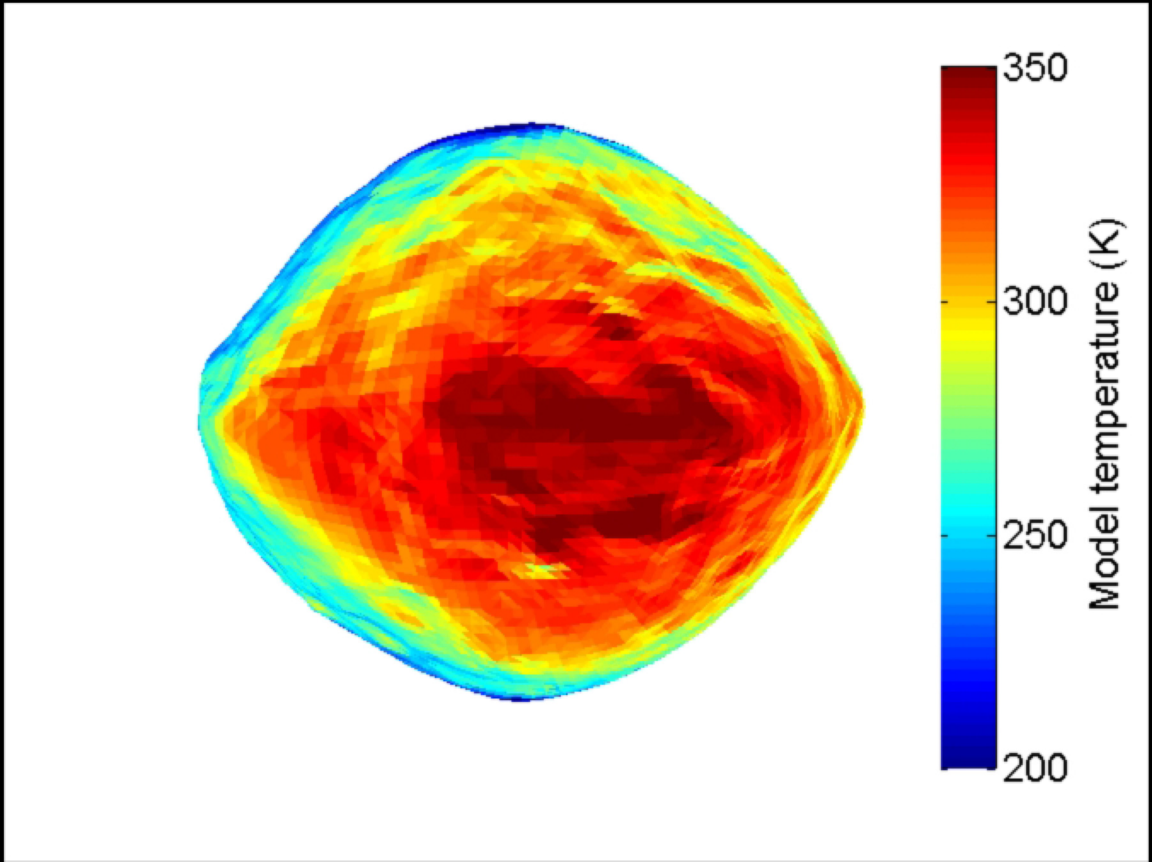
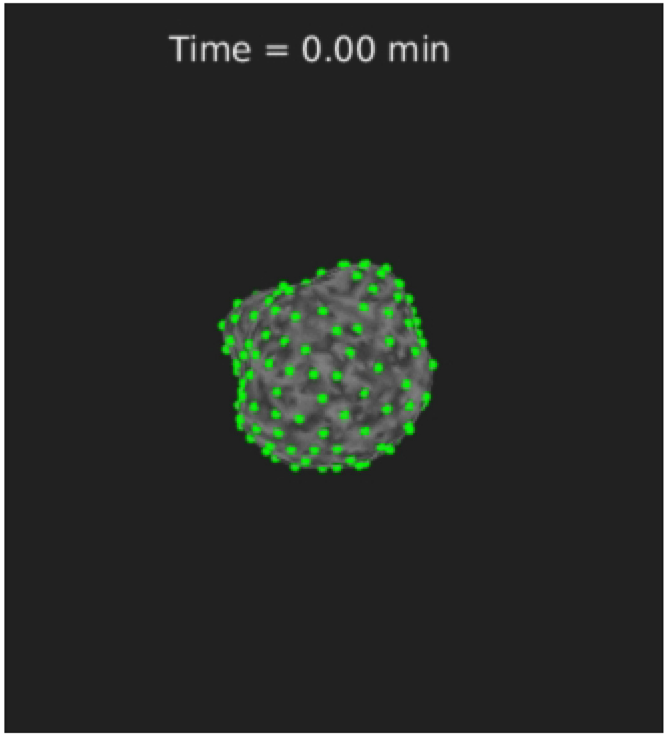
OBJECTIVE #1:

Validation of the Yarkovsky models for super-fast rotators



Thermal inertia and fast rotators



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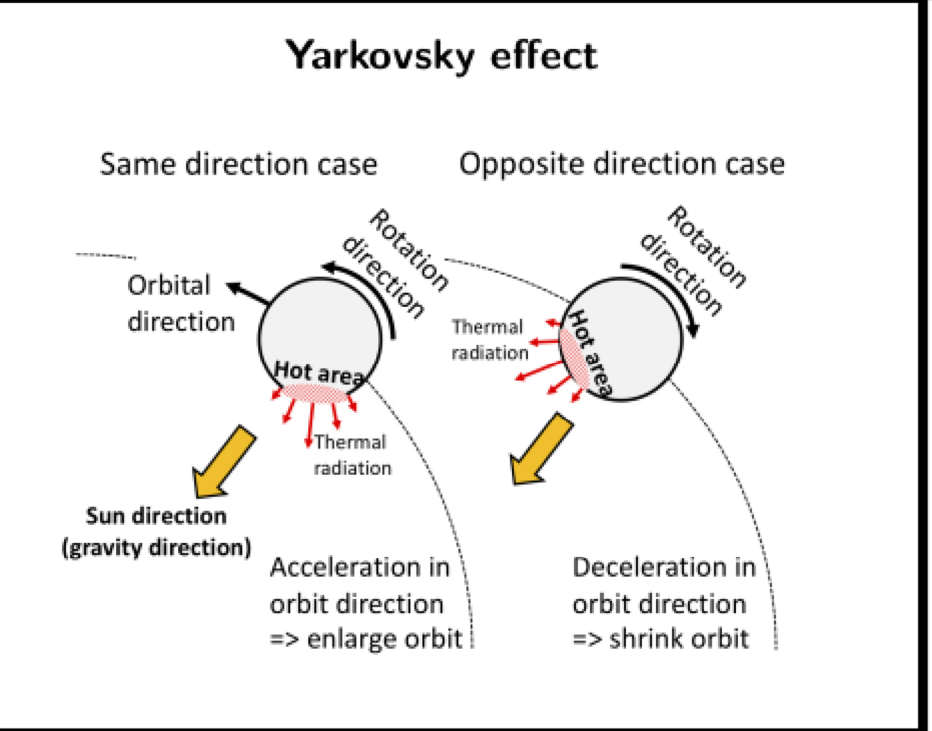
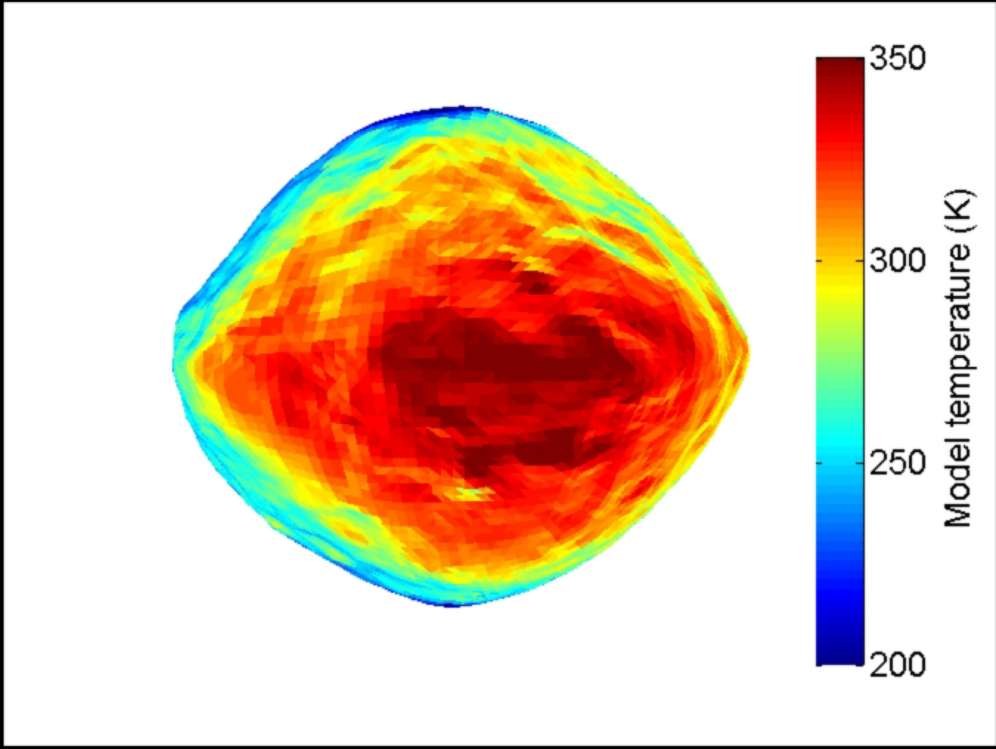
OBJECTIVE #2:
Numerical modeling of surface thermal properties





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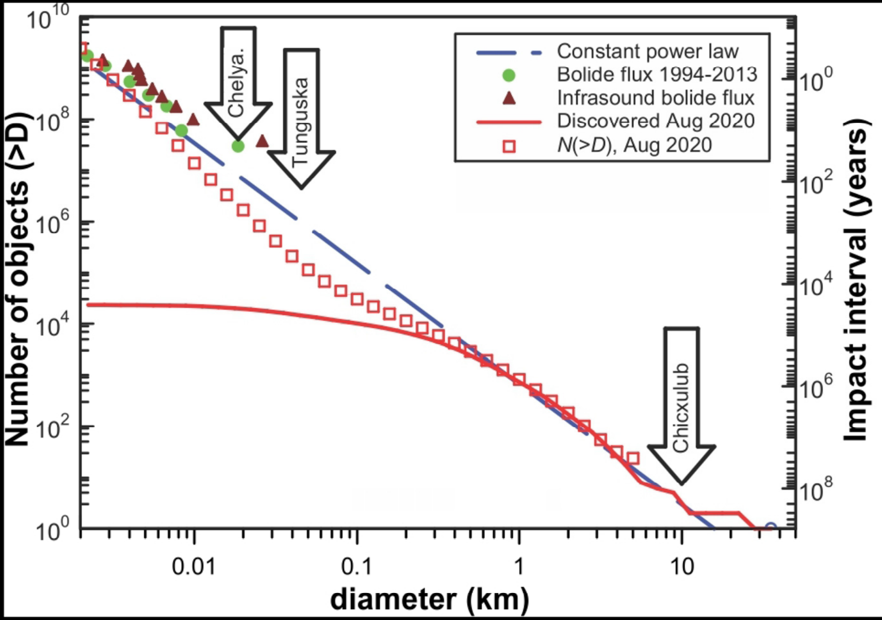
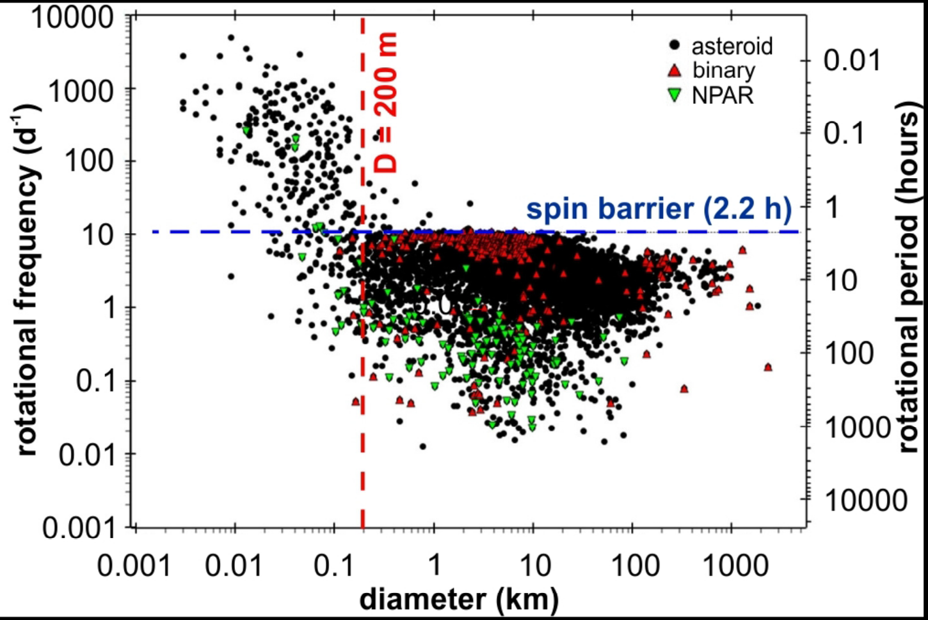
OBJECTIVE #3:

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





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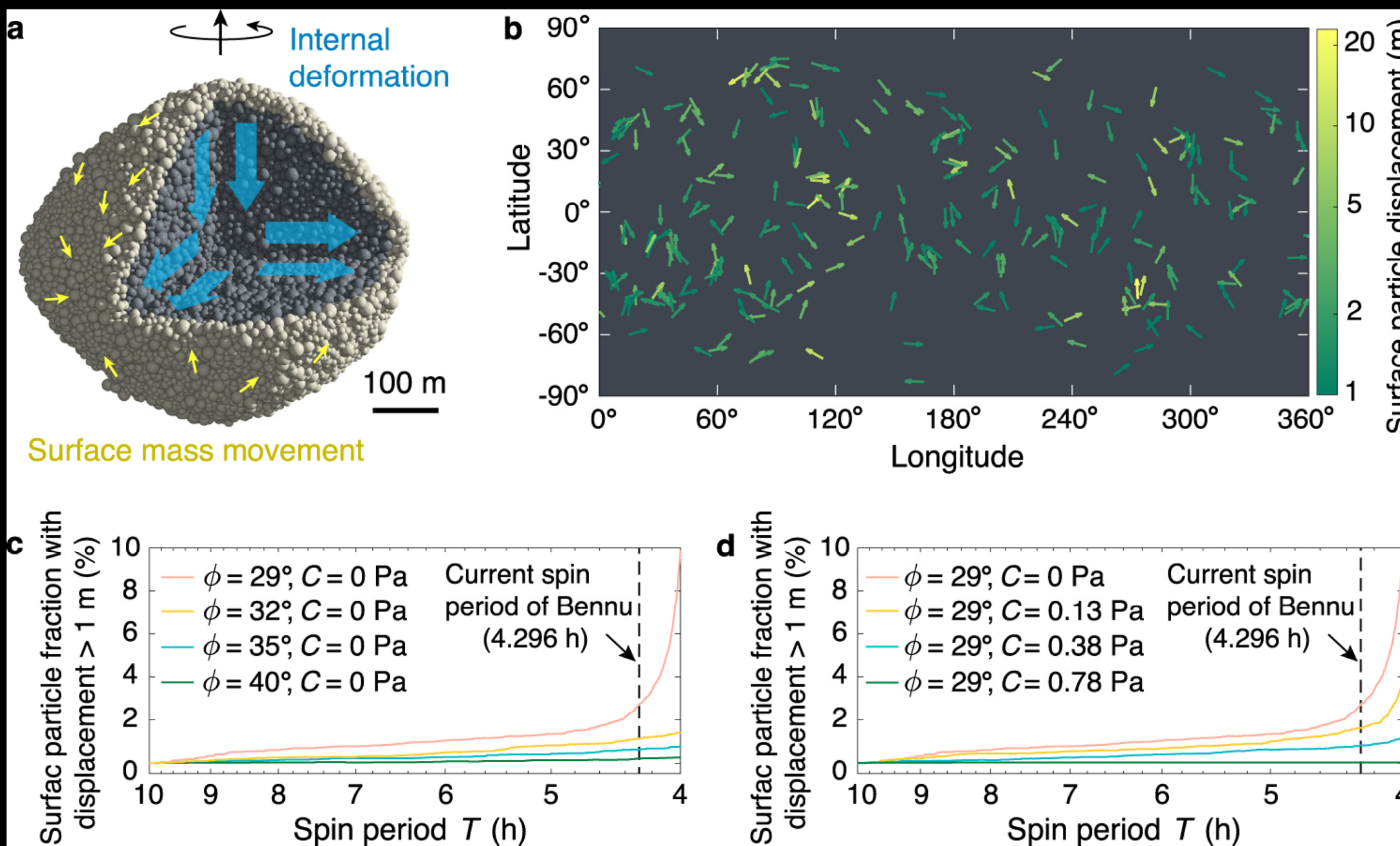
OBJECTIVE #4:

Structural properties of rapidly rotating asteroids



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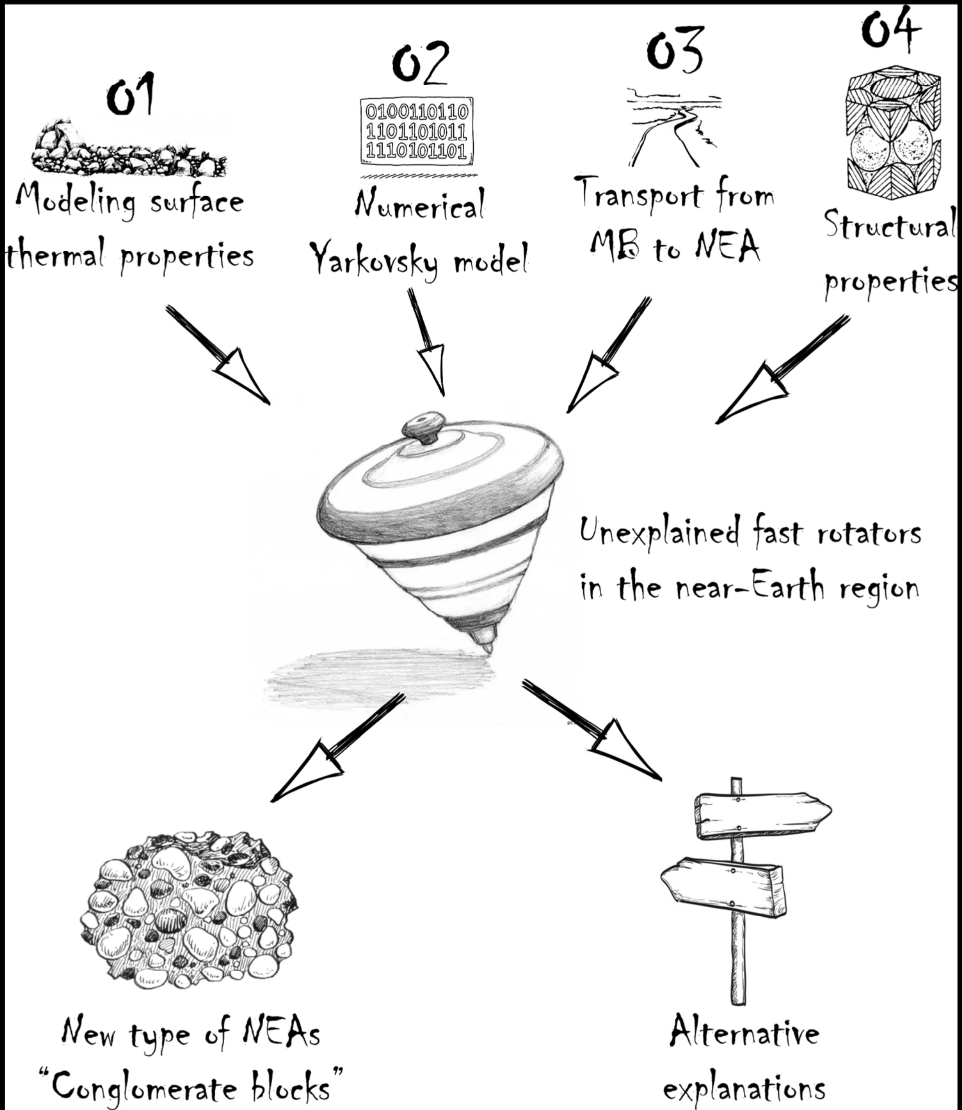

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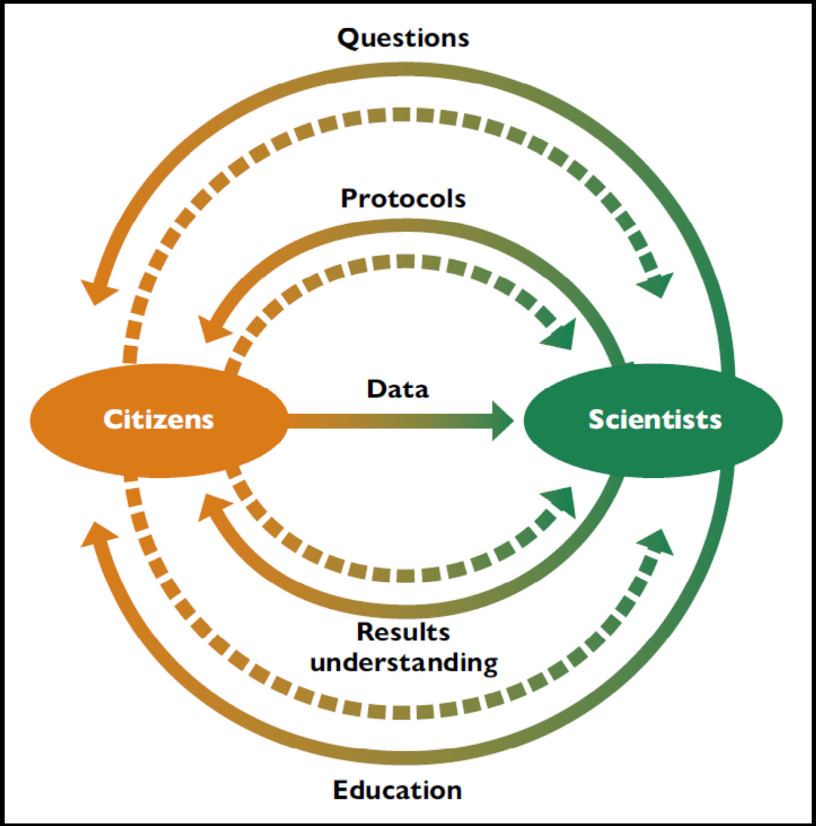
Citizen Science Project



Project ENIGMA - Citizen Science Project

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Project ENIGMA

Citizen Science Project

Starts in October 2024

Feel free to participate :)