Mankind’s first attempt to change the orbit of an asteroid

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Motivation - Statistical data on publications related to the DART mission

September 5, 2022

ADS query with keywords “DART mission”

- 165 publications
- 30 refereed
  - **12 in 2022 (after launch of DART on Nov 24, 2021)**
  - 5 in 2021
  - 5 in 2020
  - 3 in 2019
  - 3 in 2018
  - 0 in 2017
  - 2 in 2016

Parameters of Didymos and impact

- The impact happened on **Sep 27 2002** at **heliocentric** distance: **1.049 AU**, and **geocentric** distance: **0.077 AU**
- Parameters used in the calculations:
  - Impact speed: 6.1 km/s
  - Mass of Dimorphos: 4.8e9 kg
  - Mass of impactor: 550.0e0 kg
  - Original orbital period: 11.92 hours
  - Distance Didymos – Dimorphos: 1.18 km
  - Mean orbital velocity: 1.73e-4 km/s

Calculation of orbital velocity changes

Use of conservation laws yields the velocity change.
New orbital velocity results in new orbital period.

- **Fully inelastic case:**conservation of momentum
  (Energy is transformed into heat, cratering, …)
  Vi =m1*v1/(m1+m2)
  change of Period: = -173 s 0.4%
- **Elastic impact:** Conservation of Momentum and Energy: Ve = (m1-m2)*v1/(m1+m2),
  change of Period: -346 s 0.8%

- In the papers: **from 73 sec 0.2%**
  to 10 min 1.4%

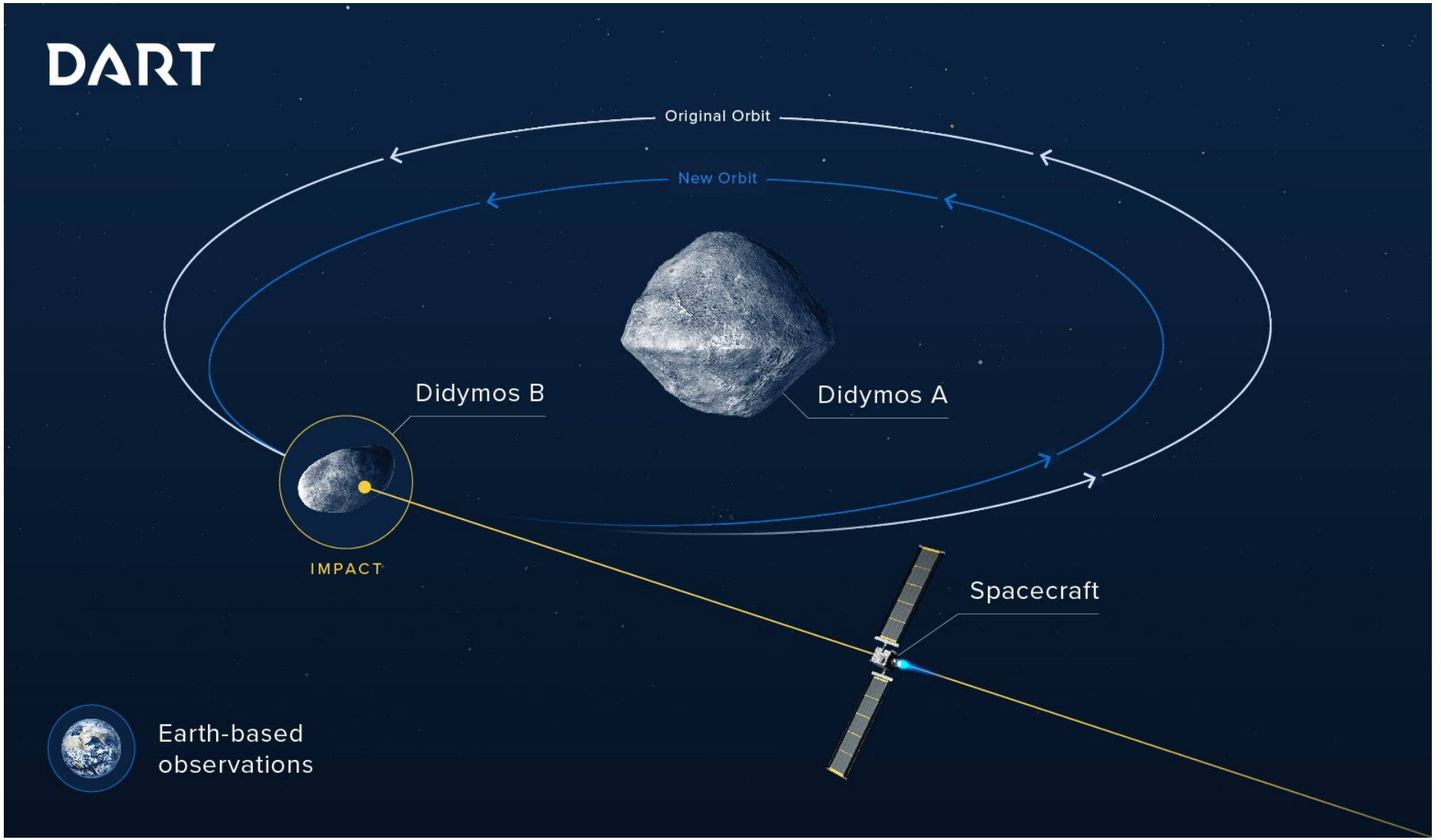
From new velocity to new orbital parameters

New velocity means new Energy and angular Momentum, quantities related to the orbital parameters (p and e of the new elliptical orbit):

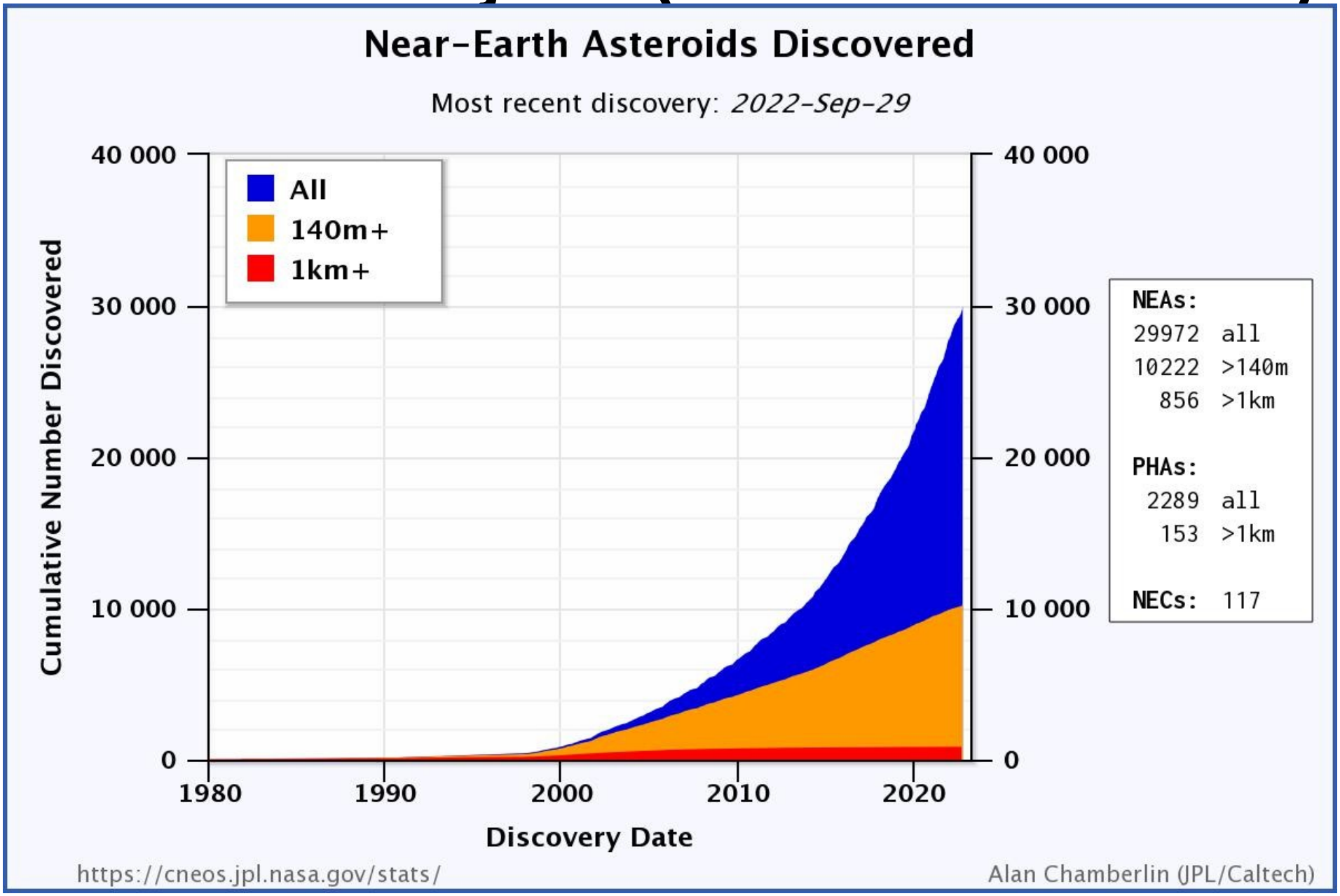
$$p = M^2/m^*\mu$$

$$e = \sqrt{1 + 2ME^2/m\mu^2}$$

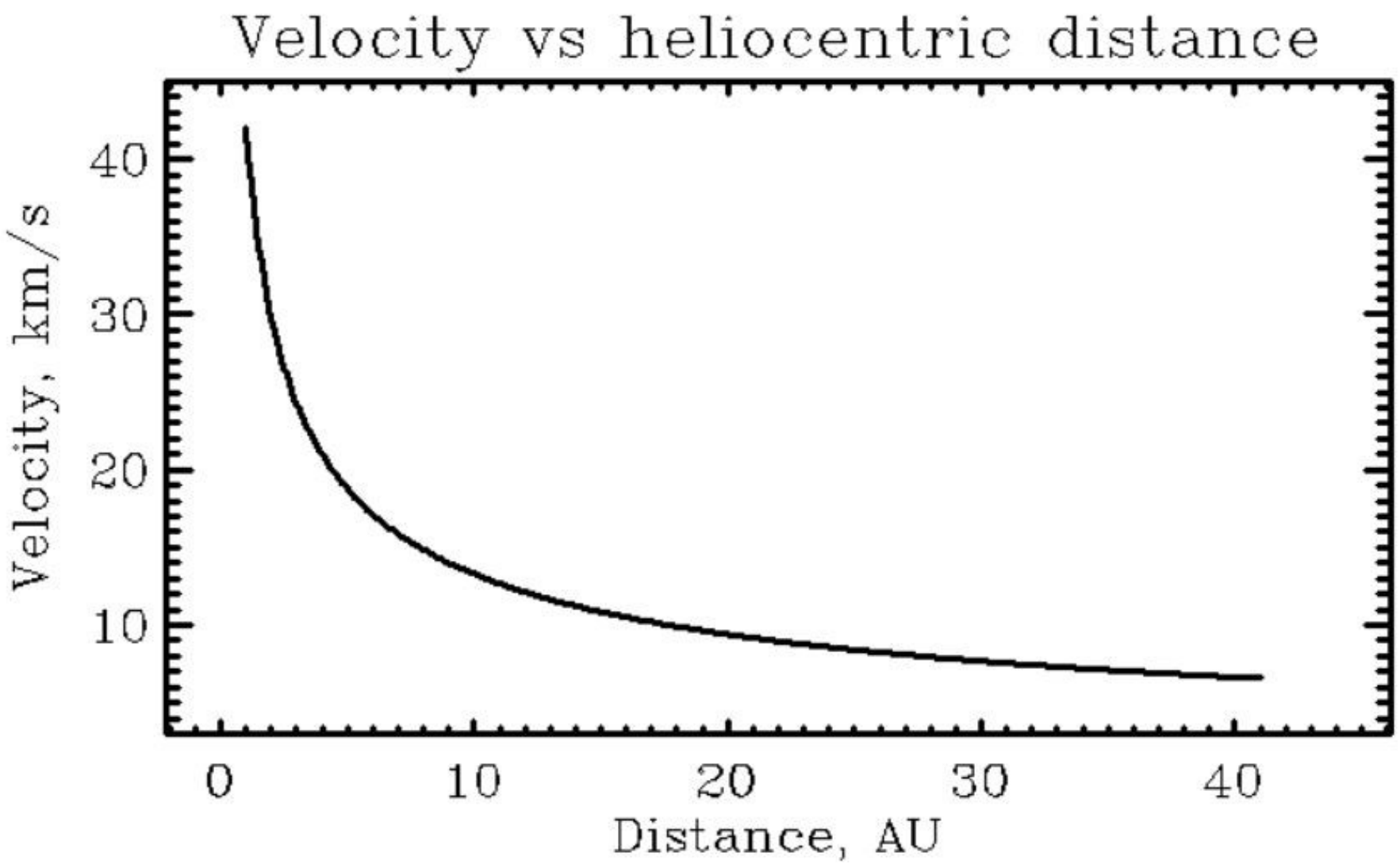
Orbit of Dimorphos before and after the impact



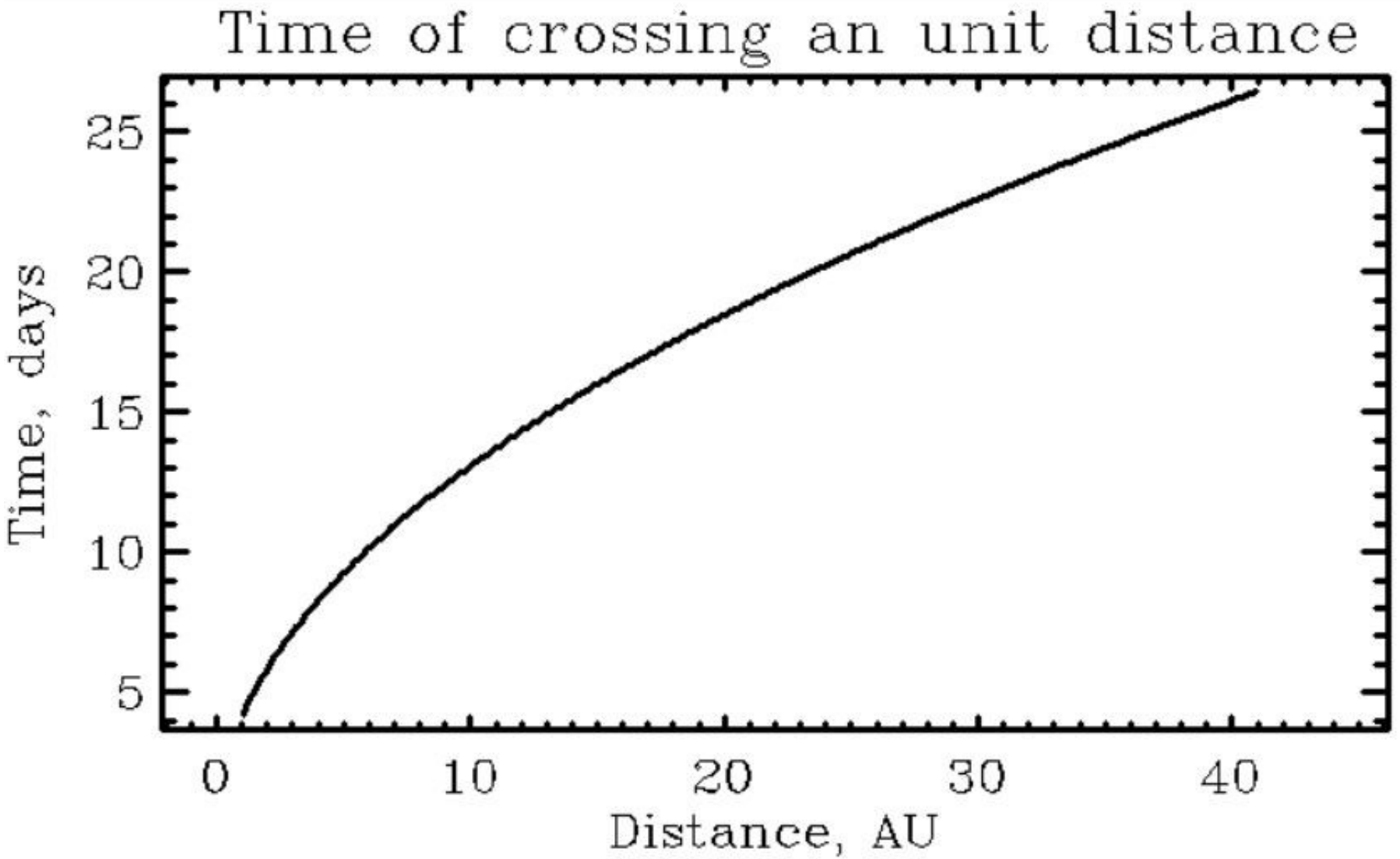
Near Earth objects (Discoveries vs time)



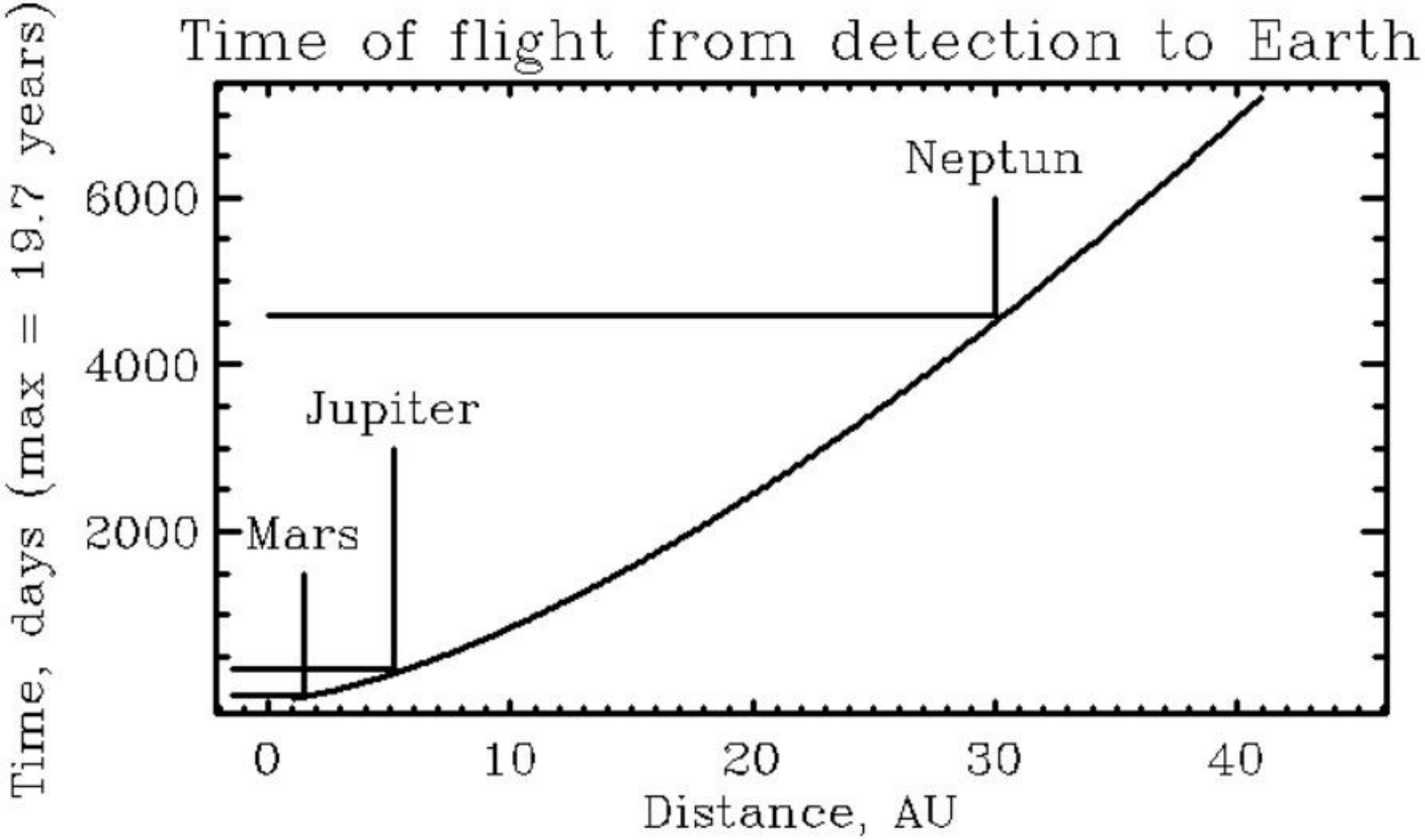
Calculating parabolic orbits (1)



Calculating parabolic orbits (2)



Calculating parabolic orbits (3)



How far an object can be detected?

Examples of Trans-Neptunian objects

- The smallest one: 486958 Arrokoth, 17 km,
  q = 42.6 AU, Q= 46.5 AU
- The largest one: 134340 Pluto, 2375 km,
  q = 29.8 AU, Q = 49.7 km
- The most distant: 90377 Sedna, 995 km,
  q = 76.4 AU, Q =944 AU,
  discovered at about 100 AU

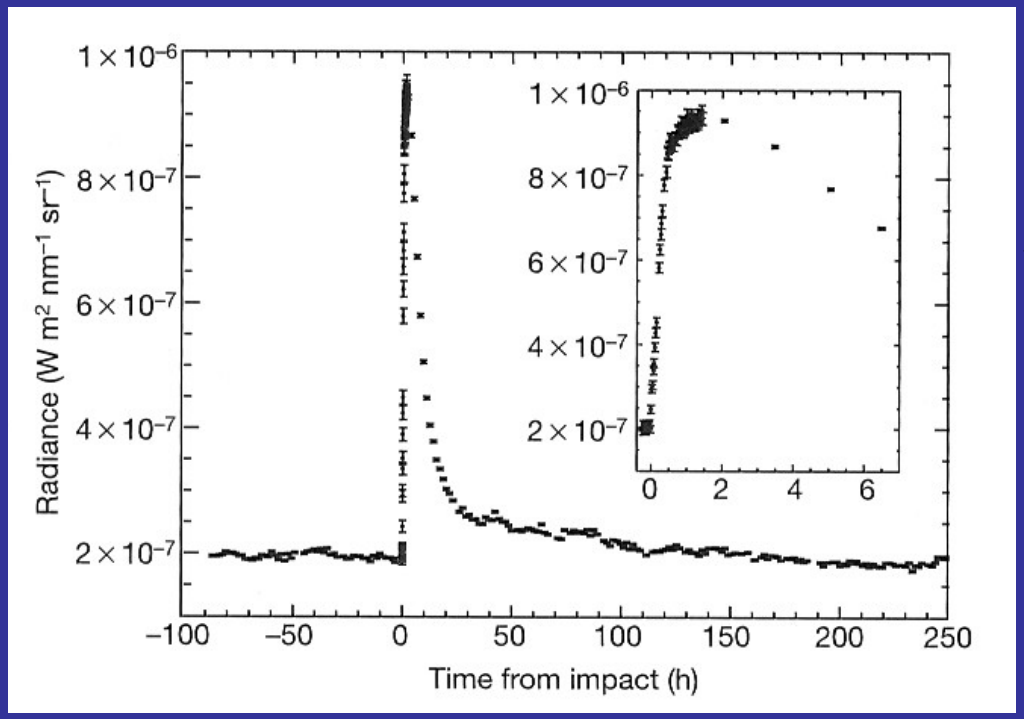
First Images from Italian Space Agency's LICIACube Satellite

(deployed from DART spacecraft on 11 September 2022, 23:14 UTC)

DART vs Deep Impact (DI) – similarities and differences

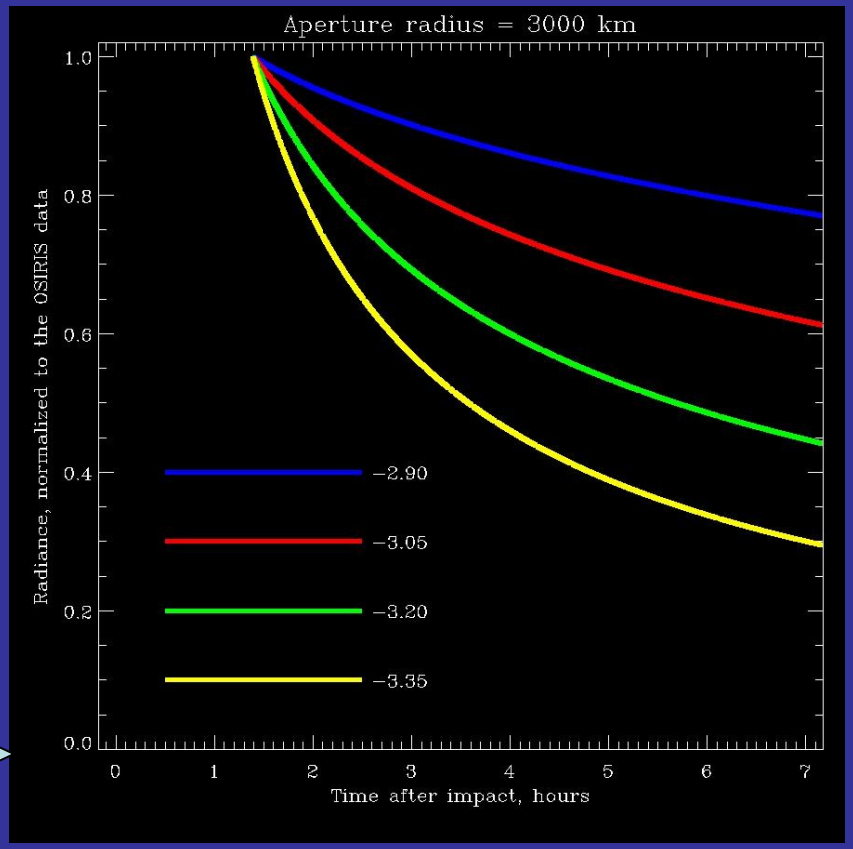
- **Similarity:** impact on a small Solar system body.
- **Differences:**
  - Aim of the missions: DI – to “see” what is the material below the surface of a cometary nucleus, DART – to practically check the possibility to change the orbit of an asteroid with a kinetic impact.
  - DI – the spacecraft carried an impactor, and survived after releasing it in collision course to the comet 9P/Tempel 1. DART – the spacecraft itself is the impactor.

The role of the particle size distribution for the brightnes

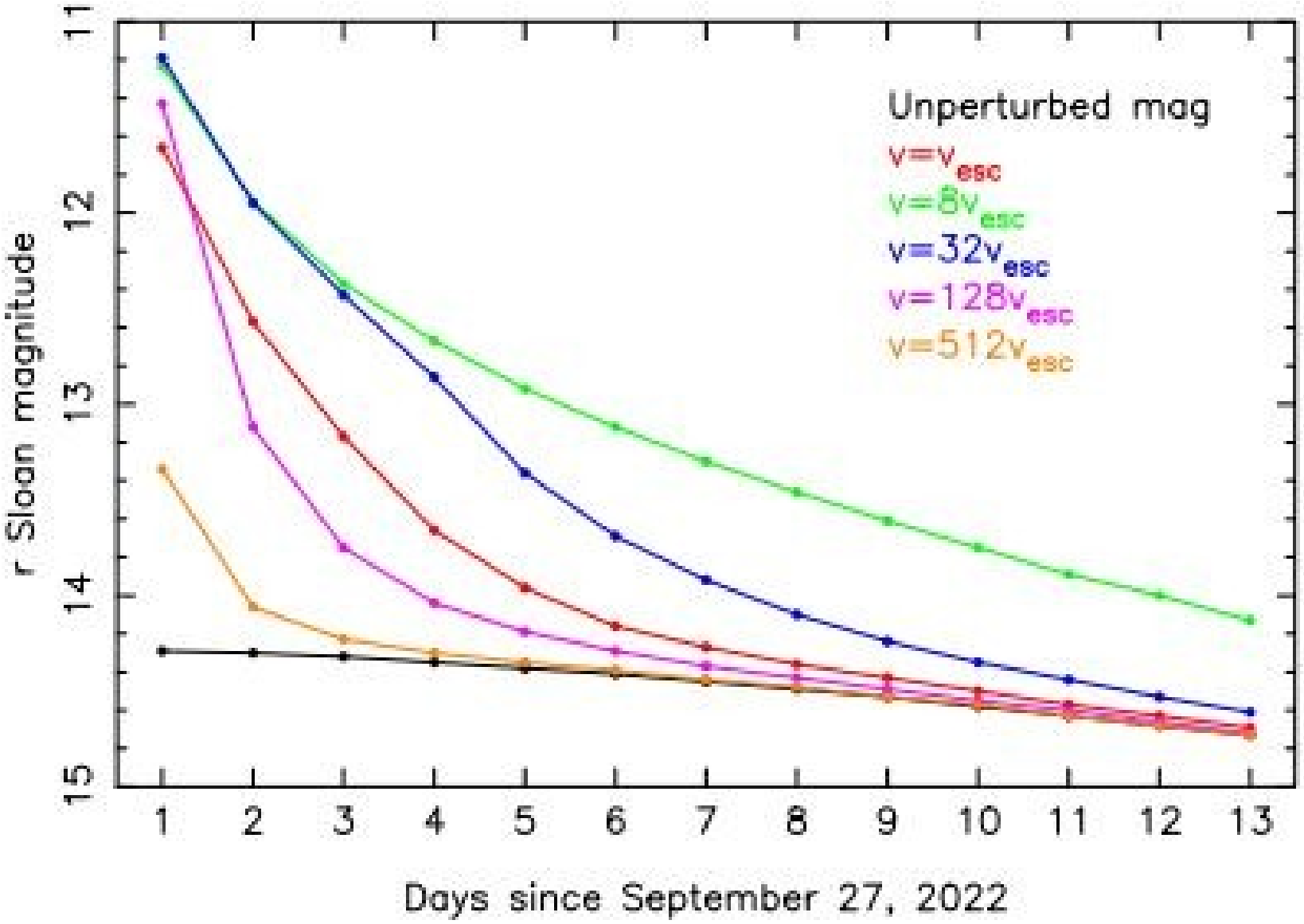


Light curve of the cometary dust obtained with OSIRIS.
Kueppers et al. 2005,
Nature, Vol. 437

Brightness decrease with the velocity law used in the Monte Carlo model, calculated for 4 different particle size distributions. The data are normalized to their maxima.

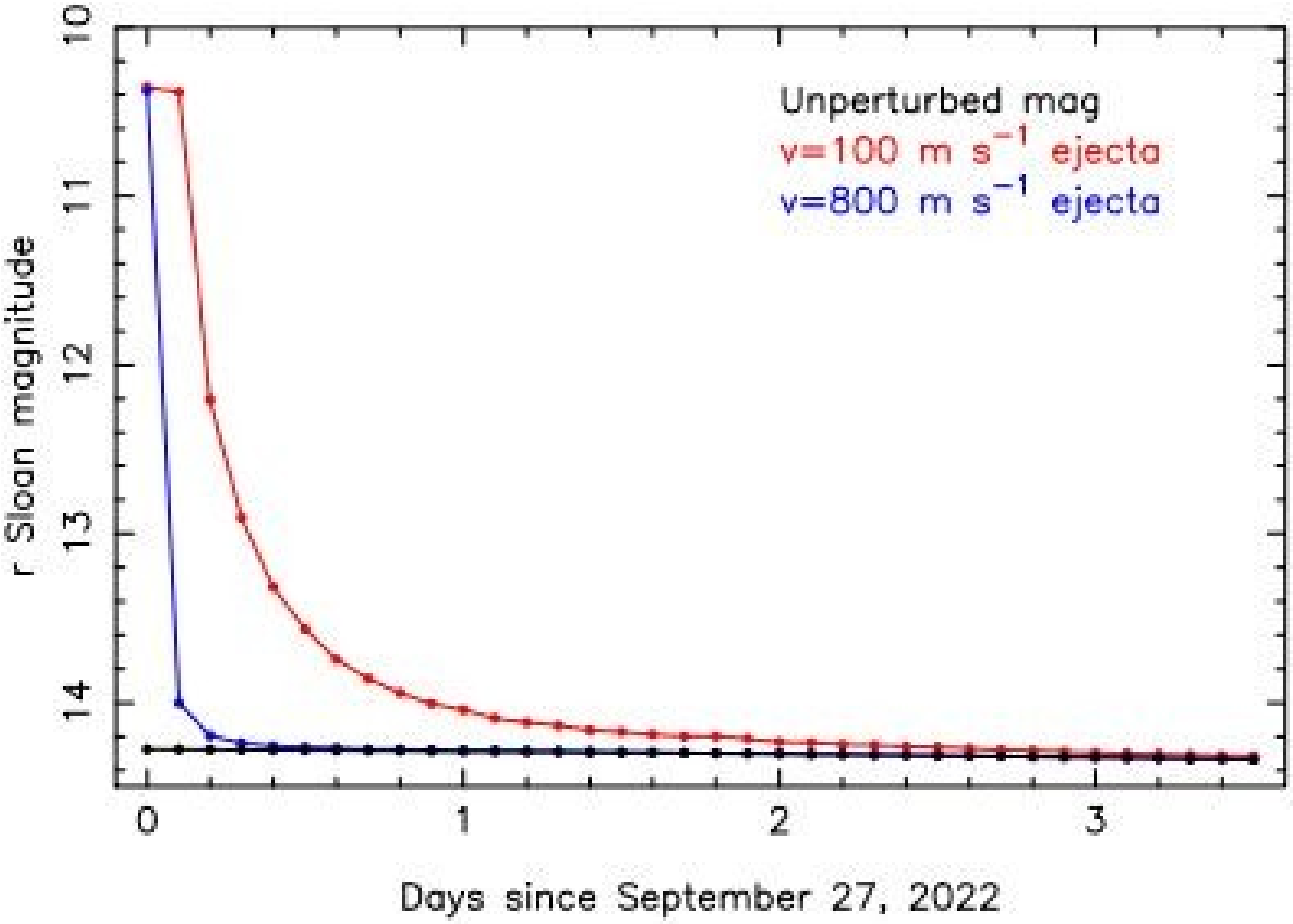


Magnitude vs time (V esc=0.09 m/s)



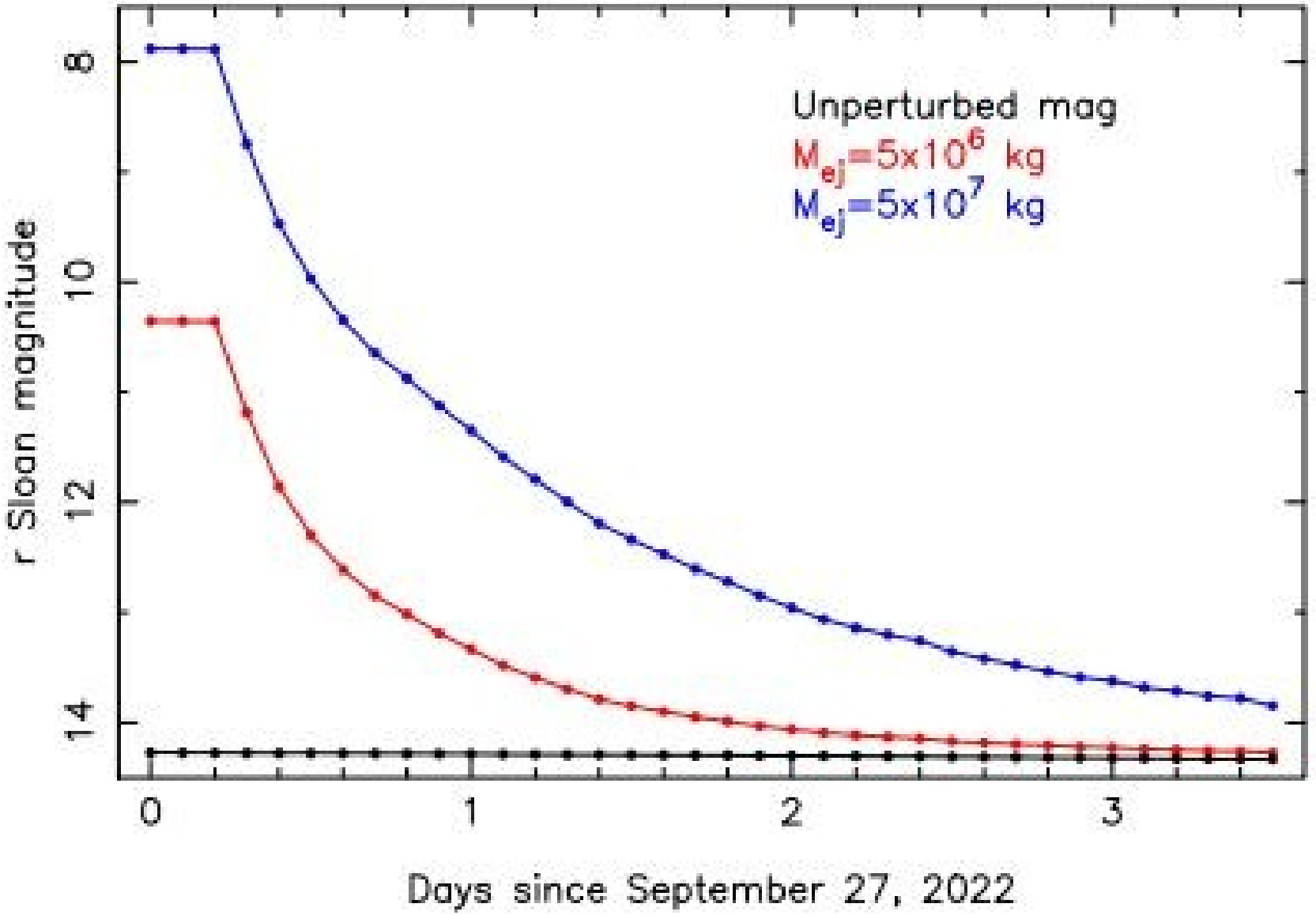
Moreno et al., MNRAS, 2178–2187 (2022)

Magnitude vs time (very high velocity



Moreno et al., MNRAS, 2178–2187 (2022)

Magnitude vs time (ejected mass)



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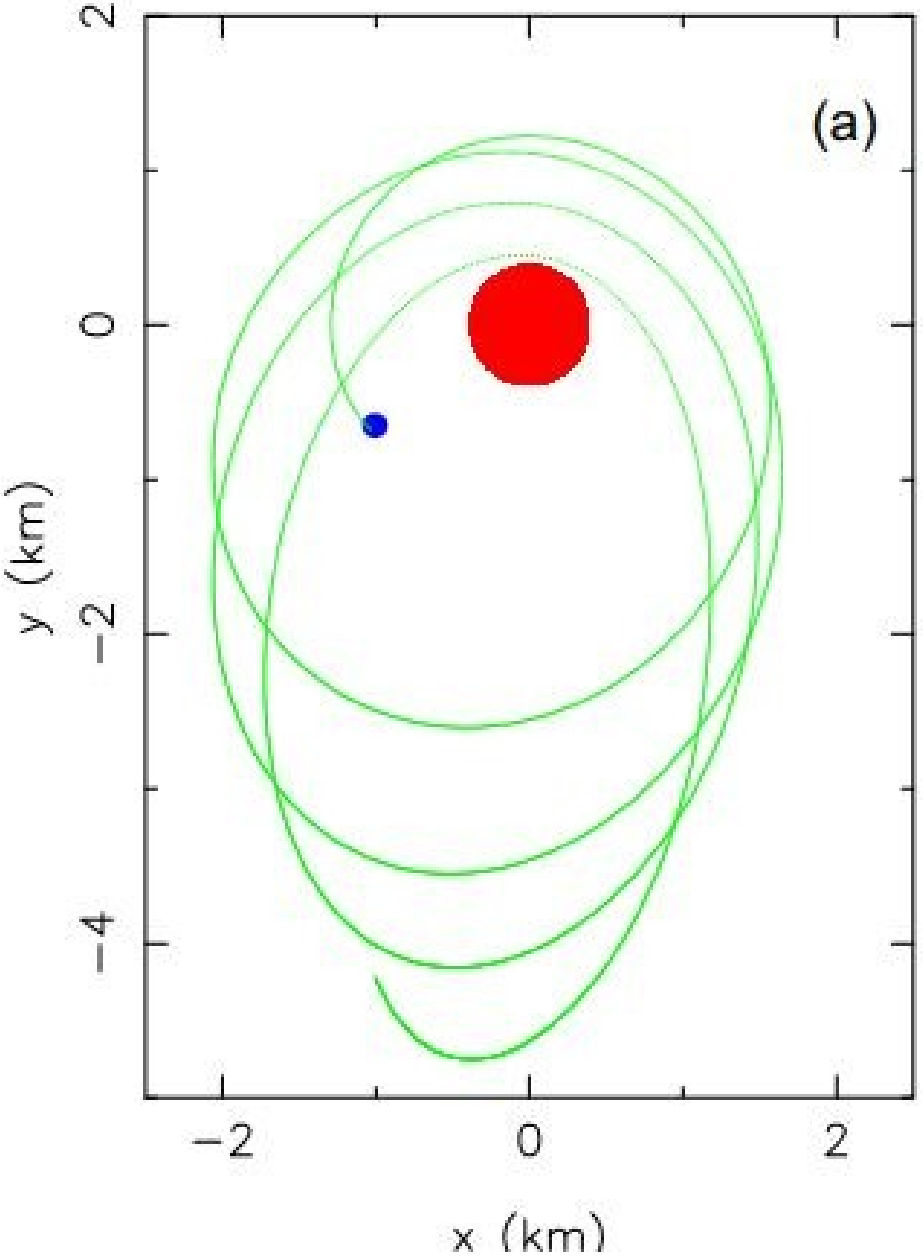
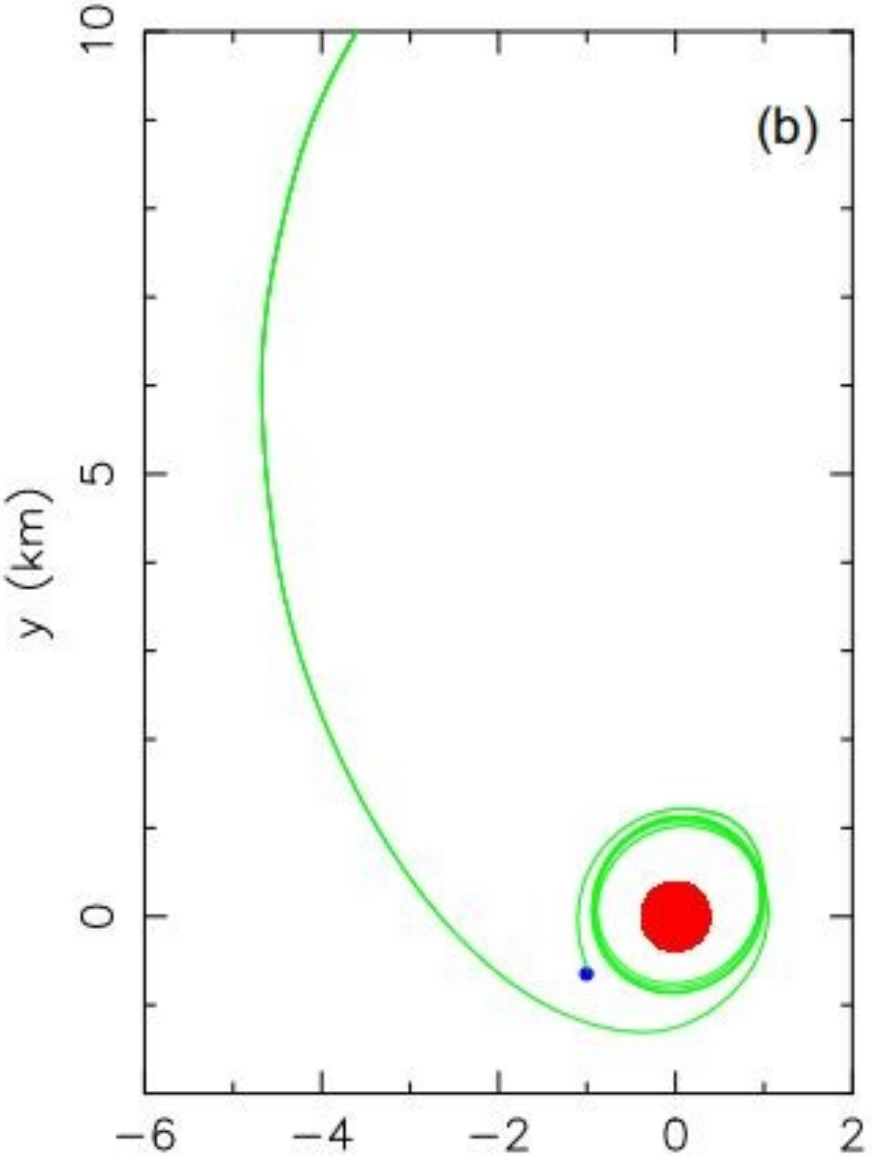
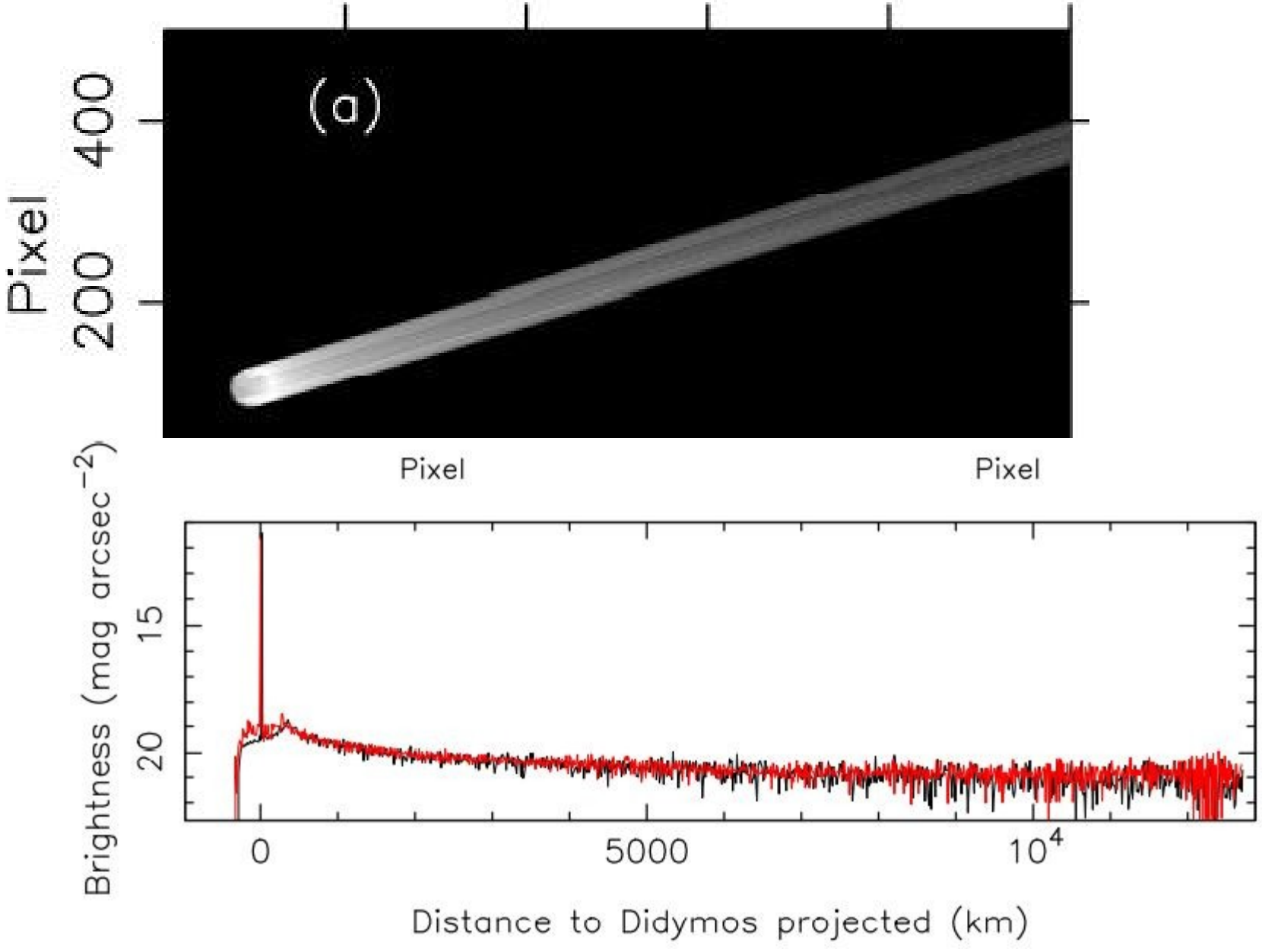
Orbits of particles ejected by impact





Moreno et al., MNRAS, 2178–2187 (2022)

Tail formation (Moreno et al., M(2022)

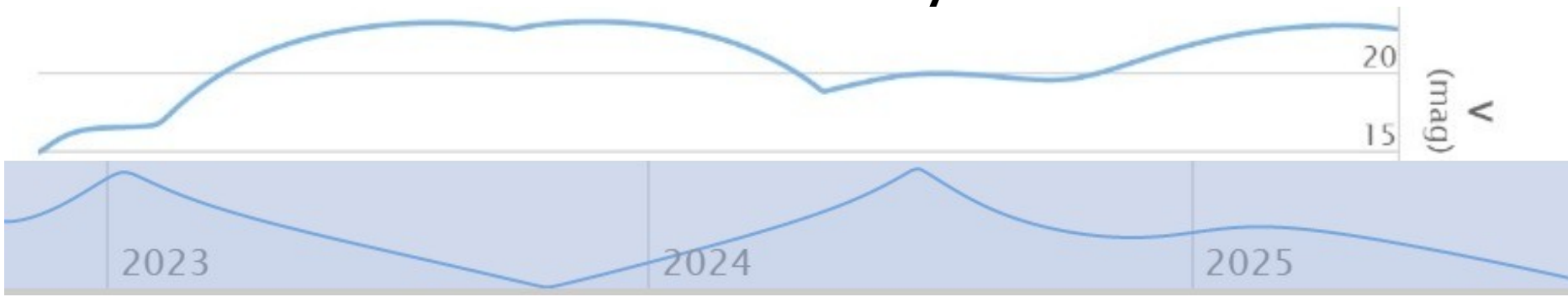


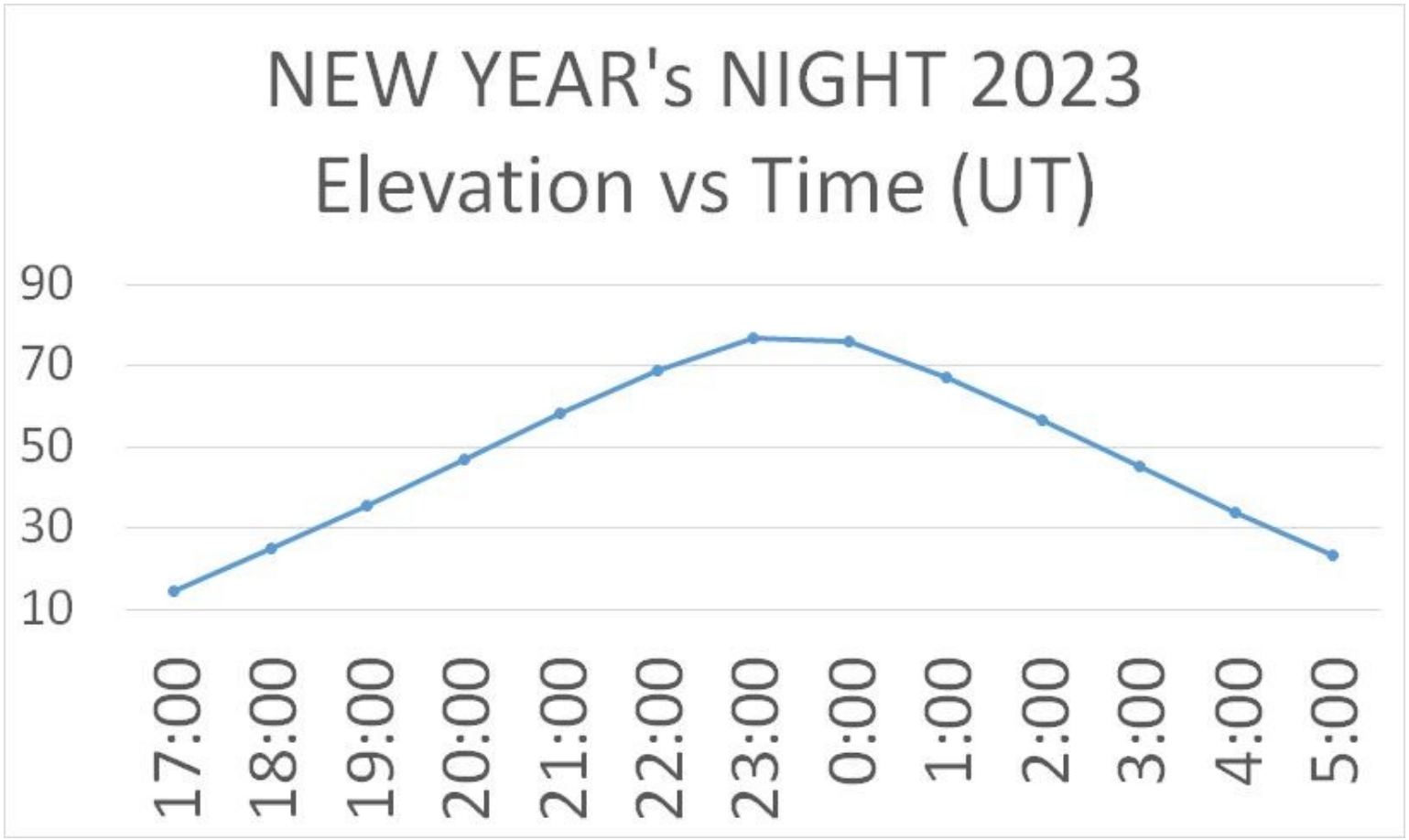
Post-impact observations

- First hours (probably days) with the aim to derive particle size distribution, total excavated mass, velocities of ejected particles,…

- Next weeks, months, probably years for derivation of the new orbital period, main quantity characterizing the efficiency of the kinetic impact.

Observability





Dimorphos last image

NEXT: 2024 launch of HERA mission of ESA.

On site investigation of Dimorphos surface structure, consequences of the impact, crater, …

Acknowledgements

If you want to find your objects use the Horizons Ephemeris Service…

Thank you,
QUESTIONS, please!