Bennu and Ryugu:

Dynamical modelling of ejected particles to the Earth

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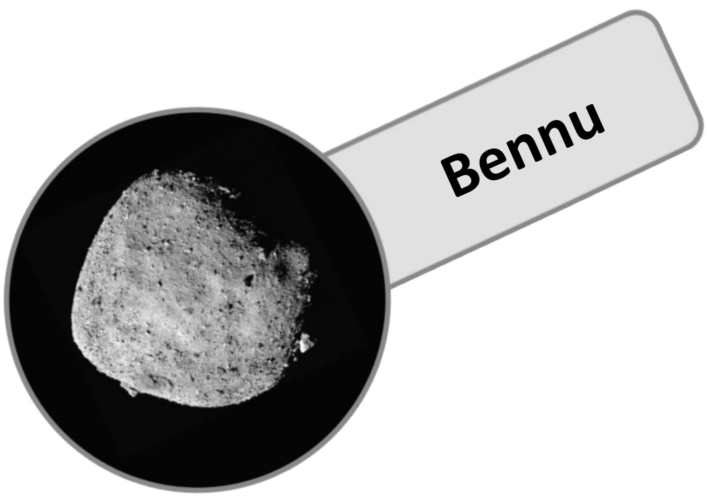

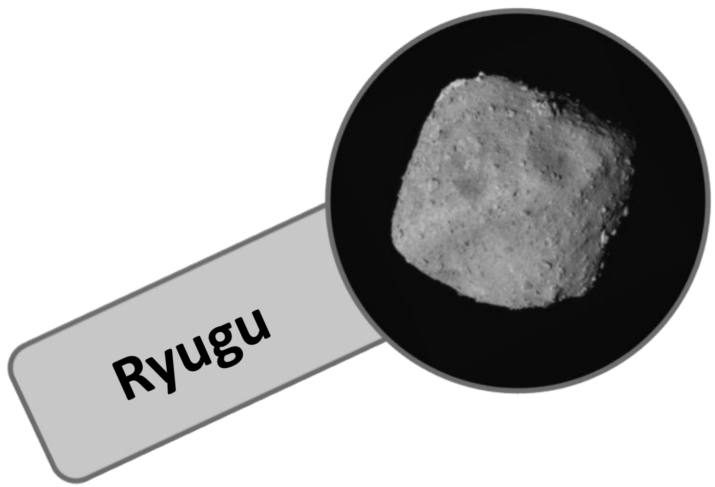

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Introduction

- Asteoids (101955) Bennu and (162173) Ryugu
  - Apollo type, NEO and potentially hazardous (discovered in 1999)
  - currently goals of sample return missions
- Hayabusa2 (JAXA)
  - mission exploring asteroid Ryugu
  - the spacecraft arrived at Ryugu in June 2018, in 2019 surface and subsurface sample retrieval took place
  - in December 2020 the samples should be delivered to the Earth
- OSIRIS-Rex (NASA)
  - mission exploring asteroid Bennu
  - in January 2019 spacecraft **detected material streaming from the asteroid**
  - sample collection is scheduled for October 2020 and it should return to the Earth in 2023
- **We studied the dynamical evolution of test particles ejected from the surface of the asteroids Bennu and Ryugu in order to determine probability of transportation to the Earth**

Simulation details

- For each asteroid 5000 test particles representing ejecta from the surface were integrated for 1000 yr (1600-2600)
- We use random isotropic distribution of initial velocities of test particles ranging from 0.05 ms^{-1} to 3 ms^{-1}
- Test particles were released regularly (in time) during the first period of asteroid since 1 January 1600
- We use predominantly IAS15 integrator available in REBOUND software package to integrate motion of planets, Moon and test particles

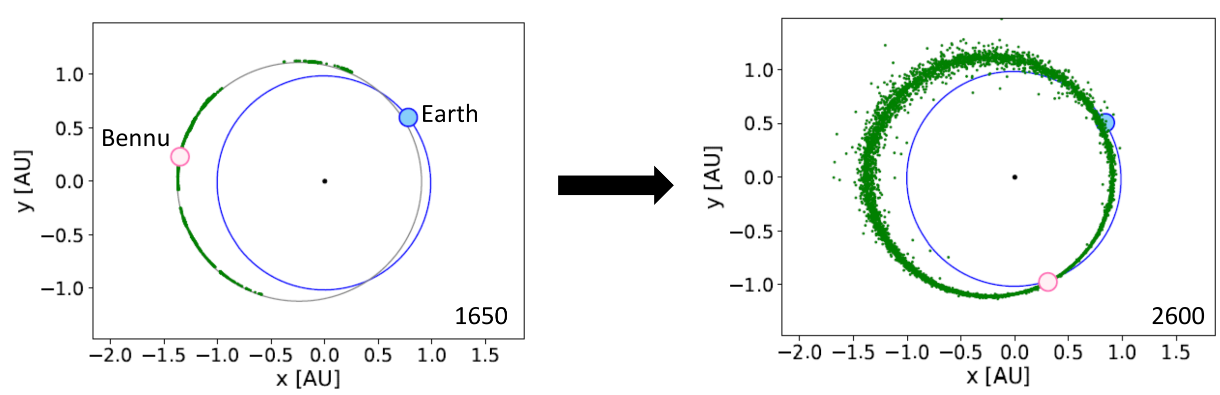

Fig. 1. As expected, test particles in the simulations started to spread along the orbits of asteroids. The figure illustrate the distribution of test particles along Bennu's orbit after 50 yr (left) and 1000 yr (right).

Orbital evolution

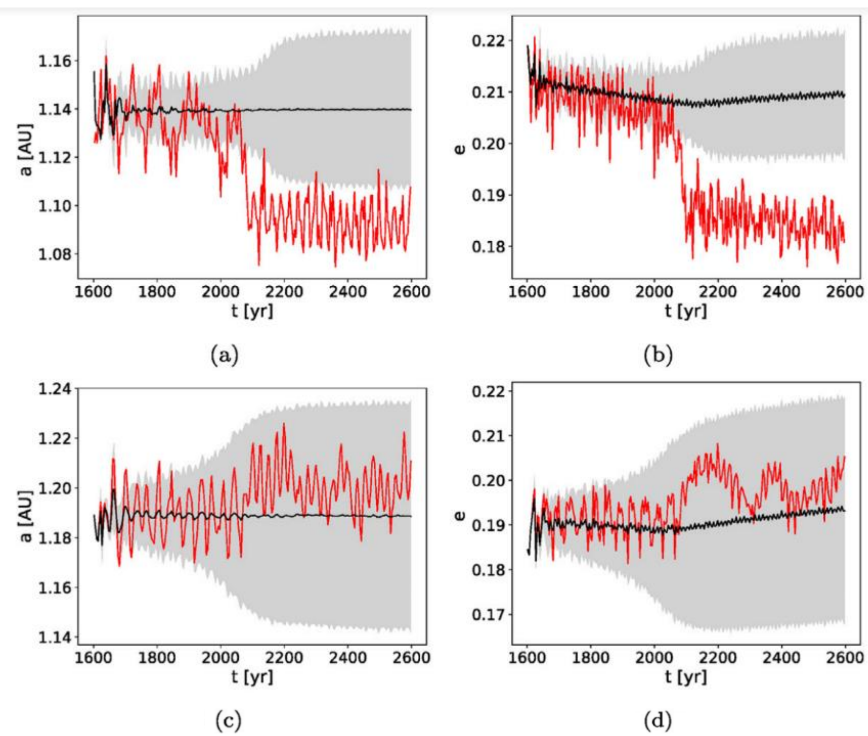

Fig. 2. Evolution of semi-major axis a and eccentricity e of Bennu (a), (b) and Ryugu (c), (d) (red lines). Black lines represent average value obtained from all related test particles and grey areas represent the range of standard deviation.

- During the simulation Bennu and Ryugu underwent several close approaches to the Earth
- Minimal geocentric distances:
  - Bennu: 0.0055 AU (2060)
  - Ryugu: 0.0105 AU (2076)
- Ryugu experienced also several relatively close approaches to Mars (0.08 – 0.09 AU)

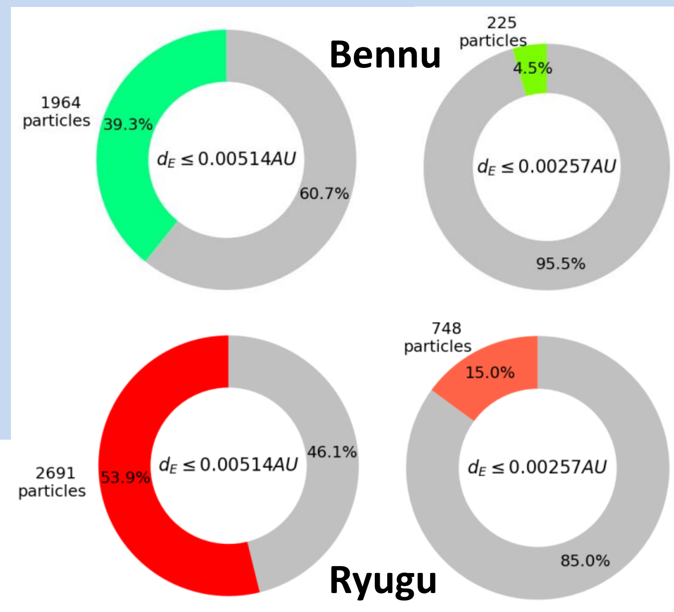

Fig. 3. Number of test particles that reached geocentric distance d_E smaller (or equal) than lunar distance (0.0257 AU) and two lunar distances (0.00514 AU) at some point during the simulations.

Potential meteor showers

	α [deg]	δ [deg]	v_G [kms^{-1}]	v_H [kms^{-1}]	L_S [deg]	D_{SH}
Bennu's shower	3.3	-34.7	6.00	31.46	180.5	0.007
σ	2.1	1.7	0.17	0.21	3.1	0.003
Ryugu's shower	1.3	54.3	4.60	32.43	249.4	0.009
σ	9.4	5.1	0.12	0.31	5.4	0.006

Table 1. Theoretical radiant of potential meteor showers related to Bennu and Ryugu. Values in the second row of each shower (σ) represent standard deviation to calculated values in the first row.

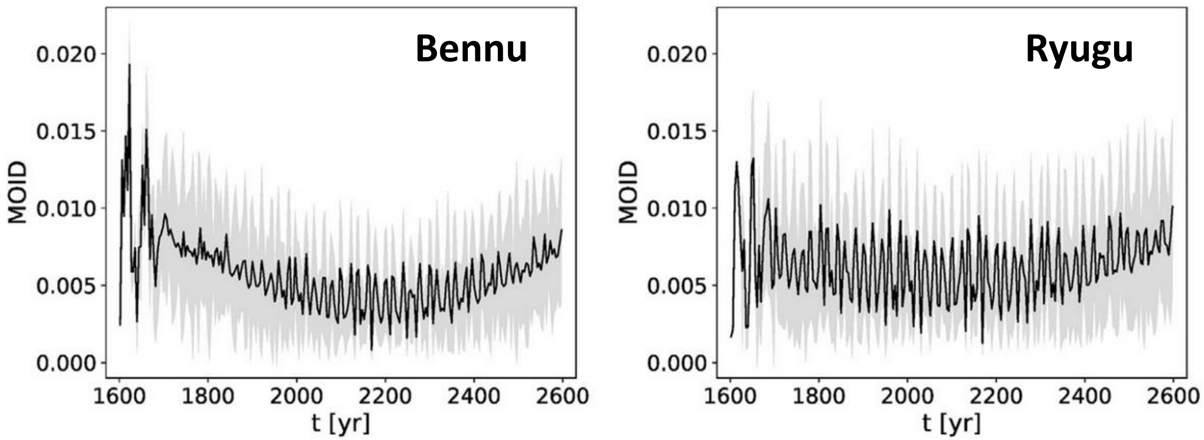

Fig. 4. Evolution of MOIDs with the Earth of test particles. Black lines represent mean value of MOID and grey areas the standard deviation interval. MOID values are in AU.

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Conclusion & Acknowledgement

Conclusion

- All test particles managed to reach MOID ≤ 2×10^{-5} AU at some point during the simulations
- In case of Bennu 92.8% of test particles even reach MOID = 0 AU, for particles related to asteroid Ryugu it was 91.9%
- We have shown that ejected material from both, Bennu and Ryugu, is able to reach the Earth
- Based on MOID evolution, both meteoroid streams show possible present activity and it appears to last for approximately next 400 – 500 yr
- However we expect the activity of such meteor showers to be extremely low (no meteor shower with similar parameters has been observed)
- Simulations dedicated to the effect of non-gravitational forces on smaller particles were also made, no significant influence was registered

Acknowledgement

This work was supported by the Scientific Grant Agency VEGA No. 1/0596/18, by the Slovak Research and Development Agency under the contract No. APVV-16-0148 and by the Comenius University grant UK/369/2020.

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