Interplanetary Exchange of Meteoritic Material: from Europa to the Earth.

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Abstract

We present preliminary results of a study of the dynamics of ejecta launched to interplanetary space from the Jovian satellite Europa, possibly as a result of giant impact. We consider this as a mechanism for exchange of crustal material between Europa and other solar system bodies.

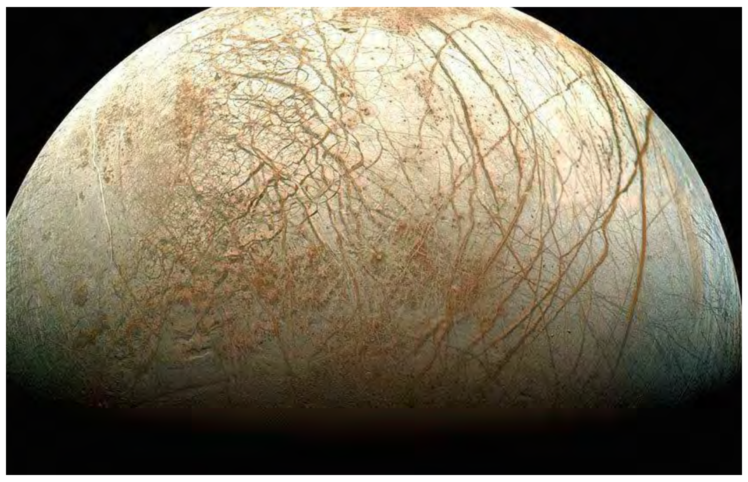


Figure: Gibbous Europa
Credit: Galileo Project, JPL, NASA; reprocessed by Ted Stryk,

1. Introduction

➢ Numerical simulations of the orbital evolution of small bodies has been used to study the interplanetary exchange of meteoritic material among different Solar System bodies (Gladman et.al 1997; Reyes-Ruiz et.al 2012; Belbruno et.al 2012).
➢ The estimation of the properties of the impactors producing the craters in different Solar System bodies suggest that some had enough energy to launch material to interplanetary space (Melosh,1989).
➢ It has been suggested that this mechanism may have astrobiological implications if ejecta contains organic material (Mileikowsky et.al 2001).

2. Model & Methods

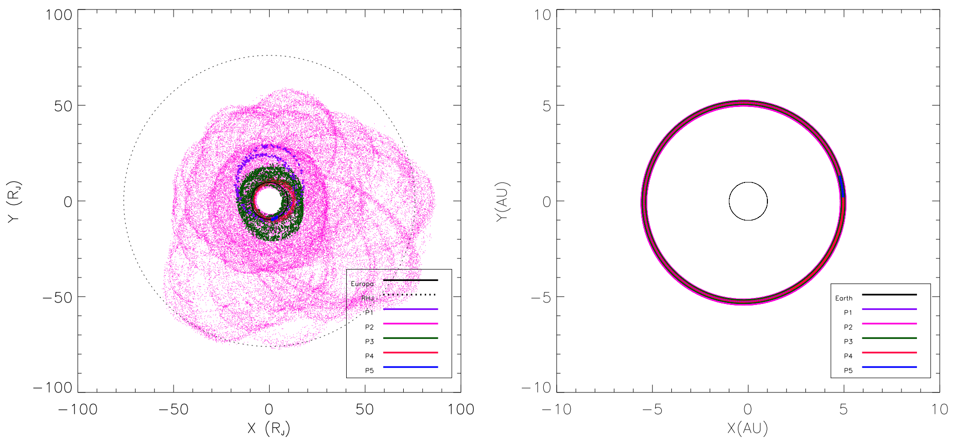
➢ Numerical simulations of a collection of test particles, representing the different ejection conditions of debris, are carried out for 3000 yr using the Mercury 6.5 code.
➢ We model ejecta as test particles with random initial positions uniformly distributed on a spherical shell of radius R_H (Europa's Hill radius with respect to Jupiter).
➢ The gravitational force of the Sun and planets, except Mercury, as well as Titan, Encelladus, Io, Europa, Callysto, & Ganymede is considered.
➢ The initial ephemeris are taken from the Horizons website corresponding to January 6 of 1999.
➢ The initial velocity of particles, V_{Ej}, is assumed radially directed away from Europa.

3. Results

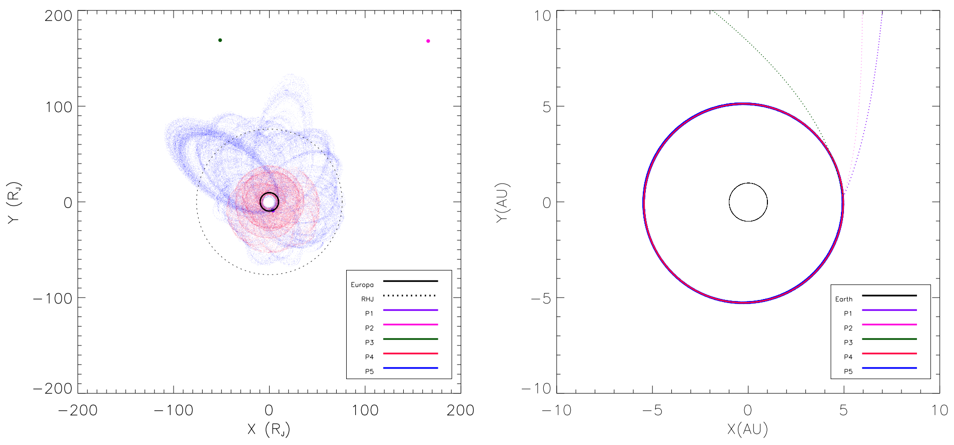
The following figures show the typical evolution of particles in a given simulation. We are particularly interested in particles reaching $r \leq 1$ AU as they may collide with Earth.

cont. Results

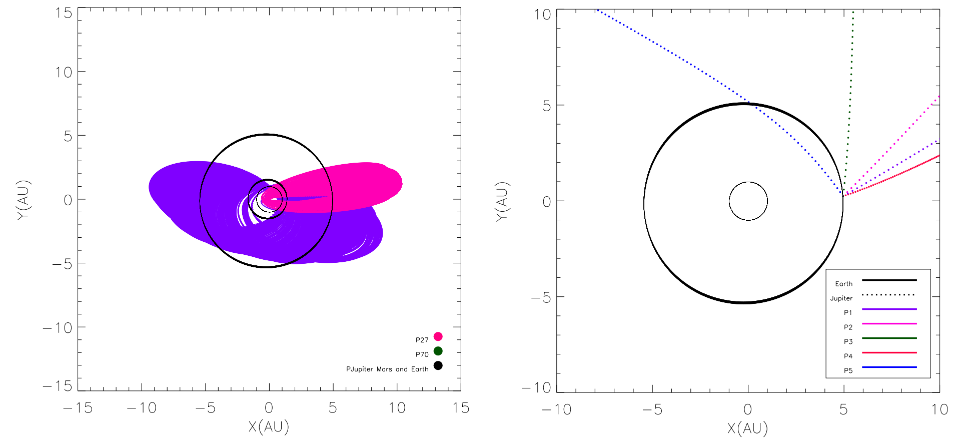
Case V_{Ej} = 4.04 km/s. Particles reach jovianocentric orbits. Ejecta with low escape velocity may become unstable due to close encounters with massive bodies and eventually escape in a diffusion-like maner.



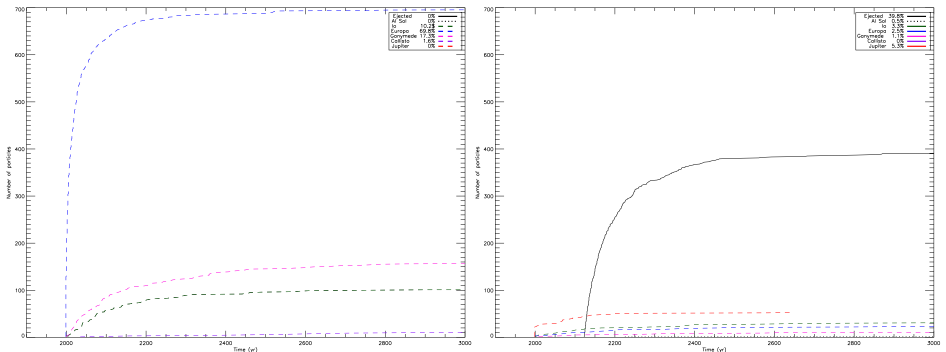
Case V_{Ej} = 10.1 km/s. As ejection velocity increases particles may reach heliocentric orbits characterized by a high eccentricity and may even be ejected from the Solar System. Also a fraction remain in the Jovian system.



Case V_{Ej}=24.24 km/s. The particles with high eccen tricity that reach heliocentric orbits directly after ejection, some have perihelia interior to the Earth's orbit.



For ejection velocities slightly greater than V_{Esc}, a large fraction of ejecta collide with bodies in the Jovian system. A large fraction of particles leaving Europa with a very high ejection velocity escapes entirely from the Solar System.
The following images show impact distribution of particles for the velocities of $V_{Ej} = 2.22$ and $V_{Ej} = 24.24$ km/s.

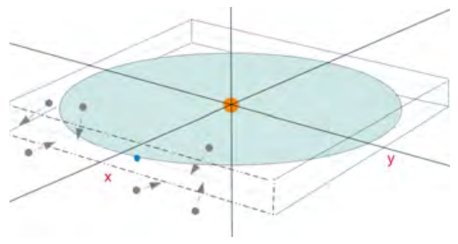


cont. Results

➢ The probability of particles colliding with Earth can be estimated by:

$$P_{pcol} = P_{cross} * f_{Nsp} * NP_{impact} * P_{area} \quad (1)$$

Where:
P_{cross}. Probability of particles crossing.
f_{Nsp}. Fraction of particles ejected from a big impact.
NP_{impact}. Average of total particles ejected from the surface in a big impact 10^8.
$P_{area} = \frac{A_{\oplus}}{A_{cross}}$. Probability of collision with Earth by ratio of areas.
A_{cross} The cross section of inputs and outputs of particles crossing).



Vel.	P_{cross}	N_{cross}	f_{Nsp}	P_{area}	P_{pcol}
10.10	0.001	64	0.023	2.98×10^{-008}	0.0043
12.12	0.001	291	0.014	3.15×10^{-008}	0.0250
16.16	0.003	176	0.007	6.48×10^{-009}	0.0023
24.24	0.060	739	0.002	3.93×10^{-009}	0.0340

Final Remarks

- Our results indicate that ejection velocities from Europa greater than about 10 km/s (5 times V_{esc}) are required to allow particles to reach Earth crossing orbits.
- Higher ejection velocities, in excess of 20 km/s, as may result from the impact of a long period comet with Europa, lead to an increasing fraction of particles in Earth crossing orbits.
- Particles ejected with $V_{eje} > 24$ km/s reach Earth crossing orbits directly after ejection in a very short timescale. Lower velocity ejecta take significantly more time to evolve to Earth crossing orbits but can still reach these in less than 3000 yr.
- A simple estimate of the collision probability of ejecta with Earth, indicates that for a high velocity impactor, which leads to high velocity ejecta, this can be as high as P_{col}=0.034 for a single impact.
- Our results sugest that the exchange of crustal material from Europa with Earth and other solar system bodies, is possible. Orbital evolution suggests that some ejecta may evolve into interestellar transfers.

References

Gladman, B.,1997.
Chambers, J.E. 1999.
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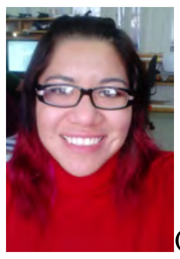

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