(130) Elektra dynamical analyses on the region of the third moonlet

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The system

- The Main-belt Asteroid (130) Elektra is the first observed quadruple asteroid system.

- Alpha:
  - the central body
  - elongated and flattened shape
  - radius of 99.5 km (Hanuš et al. 2017)
  - density of 1.6 g cm^{-3} (Hanuš et al. 2017)

- Beta:
  - the first discovered moonlet
  - the largest and outer one
  - radius of 3 km (Berdeu et al. 2022)

- Gamma:
  - The second discovered moon
  - radius of 1 km (Berdeu et al. 2022)

- Delta:
  - the last discovered moonlet
  - It is the smaller and inner one
  - radius of 800 meters (Berdeu et al. 2022)

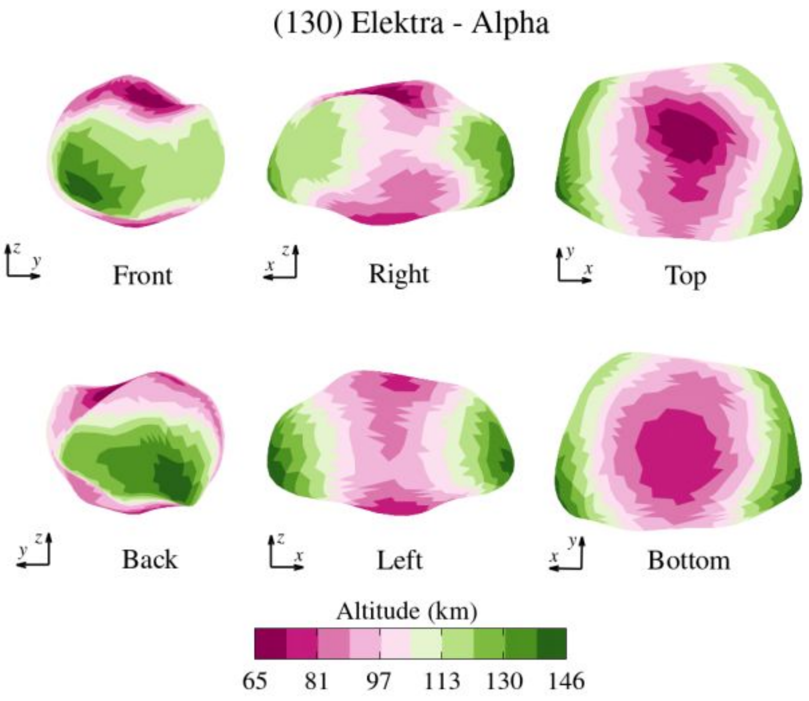

Figure 1: Altitude mapped across the surface of Alpha under different views.

Stability in the nearby environment

- Considering the reported orbital elements of Delta (Table 1) and the uncertainties still remaining in its orbit, we will analyse the stability of the region where Delta is supposed to be.

- Test particles for the massless case:
  - ~ 1 million
  - Semi-major axis 250 to 450 km
  - Eccentricity: 0 to 0.5
  - Inclination: randomly distributed in 19° to 57°
- System:
  - Integrated for 5 years
  - Beta and Gamma as massive spherical bodies
  - Alpha:
    - flattened format, reproduced by the inclusion of the J_2 coefficient
    - elongated and flattened format,,reproduced by the inclusion of J_2 and C_{22}
    - irregular shape model

Body	Semi-major axis	Eccentricity	Inclination (deg)	Orbital Period
Beta	1353.0 ± 17 km	0.09	6 ± 1	5.287 days
Gamma	501.0 ± 7 km	0.03	4 ± 5	1.192 days
Delta	**344.0 ± 5 km**	**0.33 ± 0.05**	**38 ± 19**	**16.296 hours**

Table 1: Orbital elements for each body of the system.

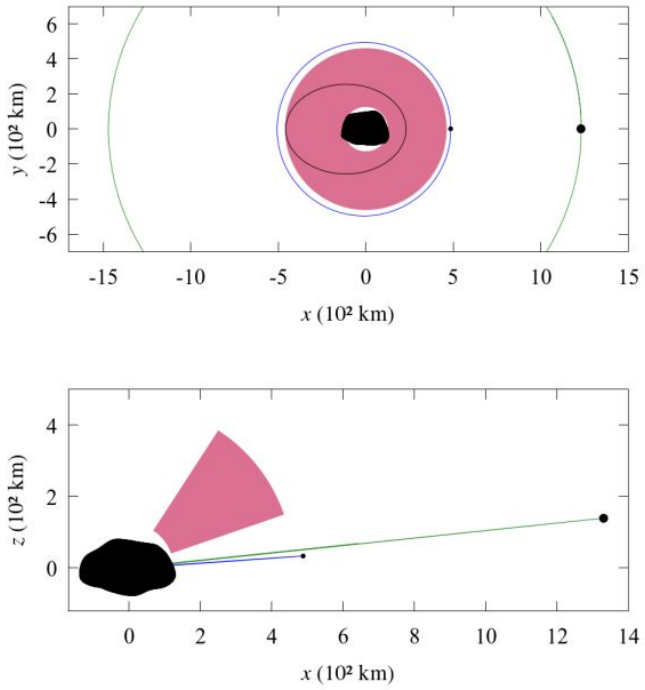

Figure 2: (130) Elektra system represented in the Alpha equatorial plane *xoy* (upper panel) and the *xoz* plane to show an inclination perspective (lower panel). The pink region corresponds to the initial condition of the particles

Stability in the nearby environment

Massless case:

- Model assuming only the J_2 coefficient:
  - the region internal to the orbit of Gamma is basically stable
  - some particles collided with Gamma

- Model assuming the J_2 and C_{22} coefficients:
  - regions with eccentricity smaller than 0.3 and semi-major axis larger than 300 km are mostly stable

- Model assuming the irregular shape of Alpha modeled by mascons:
  - results similar to the model assuming the J_2 and C_{22} coefficients
  - 72% of ejection and collision
    - 20% collision
    - 80% ejection

- We also consider cases with Delta as a massive body. However, no scenario was stable.

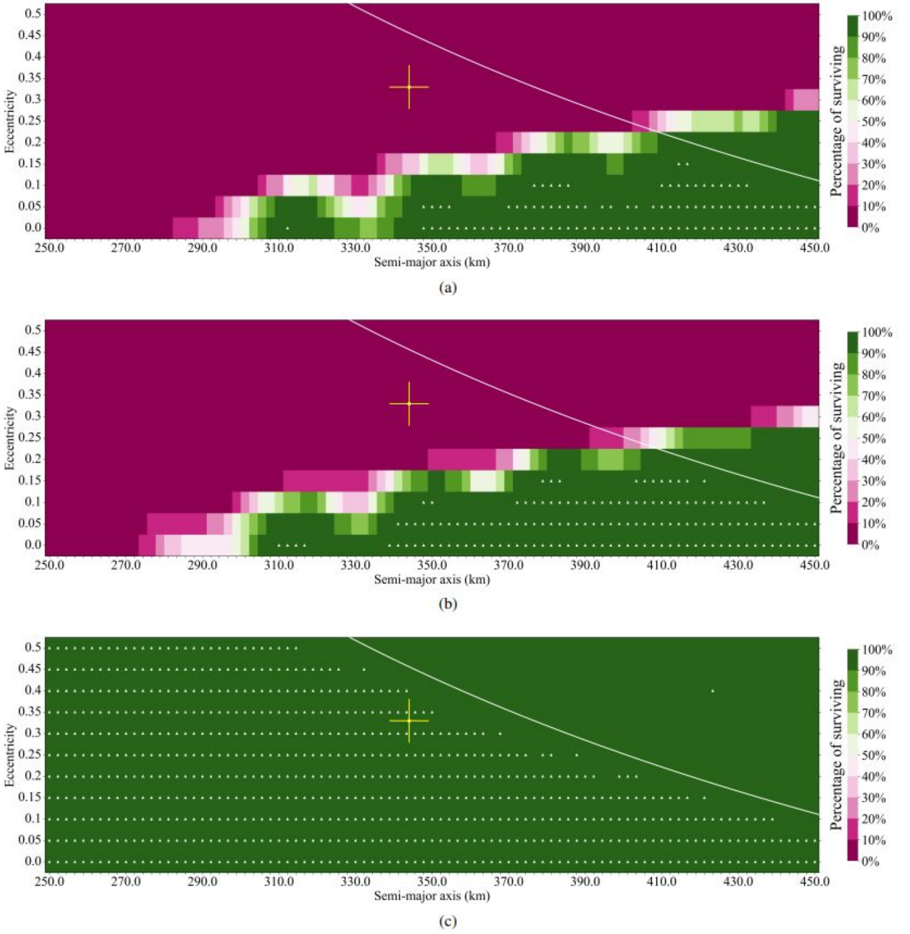

Figure 3: Diagram of stability for the region internal to the orbit of Gamma. Integration assuming (a) the full irregular shape of Alpha, (b) the model with the coefficients J_2 and C_{22} and (c) the model with the coefficient J_2.

Final Remarks

- The main instability is produced by the elongation of Alpha's shape.
- The region where Delta is reported to be is unstable.
- A new set of orbital elements for Delta may be derived considering the stable region internal to Gamma's orbit.
    - For this new search, at least the J_2 and C_{22} coefficients should be considered.

Questions?