Callisto's mysterious inclination

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Abstract: Magnetometer data from Galileo flybys of Callisto indicate that Callisto has a subsurface ocean beneath an ice shell[1]. Given its orbital inclination of 0.19° and an obliquity expected to be comparable[2], there should be obliquity tides in the subsurface ocean, which should damp inclination[3]. We approximate that Callisto should damp its inclination in less than 1 Gyr, meaning that the inclination cannot be primordial. The question here is why does Callisto still have a non-zero inclination? One explanation is that Callisto's physical properties are poorly understood and tides are actually damping inclination slowly. Changing Callisto's physical properties to within their uncertainties does not resolve the problem of how Callisto has a non-zero inclination. If tides on Callisto are indeed damping Callisto's inclination as expected, then a recent event had to excite its inclination to explain why it's non-zero. There is evidence to suggest that moons of the giant outer planets could be migrating outwards from their planets at faster rates than previously thought[4]. Under a frequency-dependent Q of Jupiter model, Callisto could have passed through several semi-major axis points corresponding to orbital resonances with the inner moons. We can reproduce Callisto's present-day inclination with some fine-tuning of the migration timescale. Note that only the most recent resonance crossing 0.5 Gya is needed to reproduce Callisto's inclination. Astrometry in future missions (e.g., JUICE) would be able to put constraints on this. Further constraints include Callisto's eccentricity evolution, surface heat flux, and Ganymede's orbital element evolution.

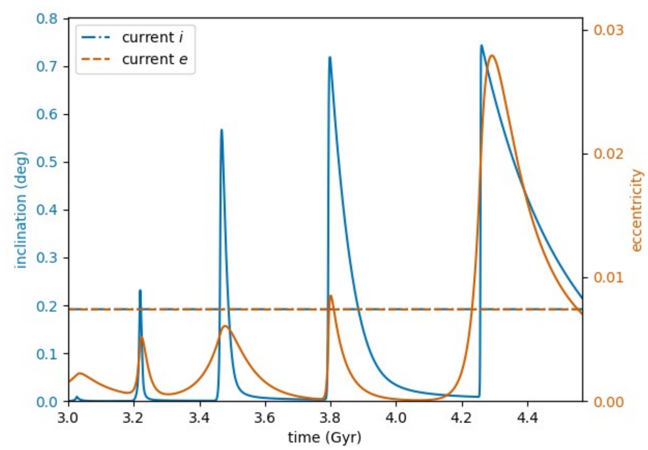

Figure 1: Callisto's inclination and eccentricity evolution over the last 1.5 Gyr. The orbital elements increase as Callisto approaches a resonance with Ganymede and decay due to tides.

[1] Zimmer et al. (2000) *Icarus, 147,* 329–347.
[2] Chen et al. (2014) *Icarus, 229,* 11-30.
[3] Chyba et al. (1989) *Astr. & Astrophy., 219*, L23–L26.
[4] Fuller et al. (2016) *MNRAS, 458,* 3857-3879.