DYNAMICAL PROPERTIES OF THE DINKINESH-SELAM BINARY.

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Introduction: The Lucy spacecraft encountered the Main Belt asteroid (152830) Dinkinesh on 01 November 2023 revealing it to be a binary system with a first-of-its-kind contact binary secondary, now named Selam. However, despite the novelty of Selam's structure, most aspects of the Dinkinesh system can be considered in the broader context of similar Main Belt (MB) and Near-Earth Asteroid (NEA) binary systems.

Dinkinesh-Selam Dynamical State: Groundbased lightcurve photometry and imaging by Lucy throughout its encounter can be employed to constrain Dinkinesh's spin state. Ground-based lightcurves obtained from November 2022 to February 2023 showed a lightcurve with an amplitude of 0.39 magnitudes and a period of T = 52.67+/-0.04 hrs [1]. Lucy's L'LORRI instrument imaged the system during the encounter. Most relevant for understanding the spin state are resolved images obtained during the short period around close approach and a series of unresolved images obtained hourly from +4 hours to +95 hours after close approach at a phase angle of approximately 60°. The Lucy data have the advantage of a known configuration for the components that can be used to interpret the lightcurve.

Lucy lightcurve data will be searched for multiple periodicities, potentially corresponding to rotations of each component and to orbital motion [2]. It is also possible to employ feature-tracking in resolved images to validate any short periodicities found and to constrain the sense of rotation.

The system mass can be derived from the orbital period, T, and semimajor axis a as $M_{sys} = 4\pi^2 a^3/GT^2$. Furthermore, by using the volume estimation from shape modeling [3], we can determine the average bulk density for the system. Using the observed relative sizes and the assumption of equal density, it is also possible to derive the component masses and moments of inertia. Adding in the spin state of the primary yields the angular momentum of the system which can be used to categorize Dinkinesh relative to other binary systems (Fig. 1).

The eccentricity of the binary orbit likely cannot be directly derived from existing data and leads to uncertainties in the system mass and related quantities. The obliquity of the orbit plane can potentially be constrained from imaging and reconstruction of Lucy's trajectory through the system. Additional ground-based photometry, taken at multiple epochs, may be able to better constrain these quantities.

Small Main-Belt and NEA Binaries: More than 350 binary systems are known in the MB and NEA populations [4]. A large majority of these have been identified by radar and lightcurve observations from which relative sizes, orbital parameters, and spin states can be derived [5]. Among objects in the same size range as Dinkinesh, the most common dynamical state found is a synchronous secondary closely orbiting a rapidly spinning primary. Typical mass ratios are $m_2/m_1 < 0.2$. Total angular momenta are comparable to that of an object with the total system mass spinning at near-breakup – a hallmark of systems that form by mass-shedding events [6].

Tidal forces, YORP, and BYORP also play a role in shaping the dynamical state of the system. The timescale for tidal effects to align the long axis of a satellite radially relative to a primary is the shortest, typically $\tau_{sync} < 10^5$ yr [7]. Spin and orbit-pole reorientation by YORP has a timescale of less than 1 Myr for the spin-pole to approach 0/180° [8,9].

Where Dinkinesh fits in to the broader population of small asteroid binaries will be reviewed with an eye to constraining possible origin scenarios that might also help understand the genesis of Selam's unique structure.

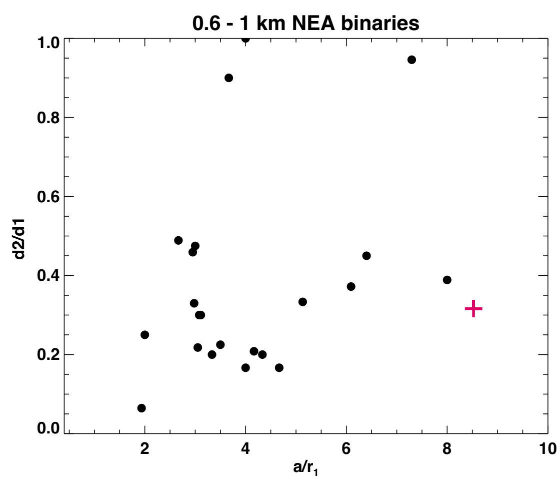

Fig.1 Relative component sizes of NEA binaries in the same size range as Dinkinesh [6] are plotted along with the semimajor axis normalized by the primary radius. Dinkinesh (red plus symbol) is typical with respect to the component sizes, but its orbit is wide compared to the median.

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References:

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