OBSERVING REQUEST
University of Arizona Observatories

Year: 2024 **Term:** Feb–Jul **Proposal type:** short-term

Imaging Asteroid Satellites with SHARK-NIR

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Abstract of Scientific Justification

Detecting satellites around asteroids yields an accurate mass for the primary and thus allows an estimate of the primary's density. Density is a critical quantity to be measured for any object because it tells us about the body's internal composition and structure. Also, in many cases binaries were formed following the catastrophic collision of two bodies. By discovering more binaries in the solar system we provide more opportunities to validate and calibrate computer collision models. These models will lead to a better understanding of the role that impacts play in shaping bodies in the solar system. We will use the newly commissioned SHARK-NIR instrument to image existing satellites, and search for new satellites, around two asteroids, 130 Elektra and 269 Justitia. Elektra has three moons, the only known quadruple system among the asteroids. Justitia has no known moons, but has not yet been searched carefully. Justitia, one of the reddest bodies in the main belt and a suspected migrant from the TNO regions, is the subject of renewed interest; a recently announced UAE mission plans to land on Justitia. We will use the cutting edge features for high contrast imaging of SHARK-NIR to explore the region immediately surrounding each of these two bodies. If available, we will take advantage of the otherwise unused DX side of LBT by imaging Elektra and Justitia simultaneously at 3-5 μm and 0.3-0.9 μm using LBTI/ALES and SHARK-VIS.

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling Optimal	Scheduling Acceptable	Sharing Poss.	Sharing Adv.
1	LBT		SHARK-NIR	*	*	0.5	any	Feb+May	Feb+May	no	no

Scheduling constraints and unusable dates *(up to 4 lines)*: Justitia is observable at the beginning of the semester, and Elektra is observable at the end of the semester. We will observe each, along with PSF calibrators, for 2.5 hours (one quarter night each).

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a * appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	(130) Elektra	19 21 12.04	+00 19 57.5	Vmag = 12.9, RA/Dec for 2024-May-18
2	(269) Justitia	03 22 05.30	+12 41 07.5	Vmag = 15.6, RA/Dec for 2024-Feb-15

Approval for Instrument Use from PI: ______________________________

(have instrument PI send confirmation email to TAC chair

Graduate students *(If graduate students are listed as investigators, the advisor must email the TAC Chair to confirm general approval and also describe the specific role of the proposed research in each student's 2nd-year project and/or thesis.)*

Student's Name	Advisor's Name	Advisor's Email	2nd-yr	Thesis

Scientific Justification

It has been twenty-five years since the first asteroid satellite was discovered from an Earth-based telescope [1]. Today almost 500 asteroids are known to have orbitting moons, including 14 triple systems and one quadruple system (130 Elektra, one of the proposed targets for our program).

Detecting satellites allows an estimate of the primary's density. Density is perhaps the single most critical quantity to be measured for any object. It allows us to make inferences about composition and structure. We can see correlations among asteroid taxonomic types in the main belt, with C-type, for example, having surprisingly low densities.

Further, binaries, at least in the main belt, were almost certainly produced by collisions. These binaries give us a giant natural laboratory to study and calibrate computer collision models on scales that are not achievable in Earth-bound labs.

By observing the shape and size of a primary as well as a satellite, we can reduce the uncertainties in volume, and hence density substantially. In such cases, errors in volume traditionally dominate density estimates [2]. This has further implications in understanding the internal structure from porosity determinations. These measurements will go a long way toward revealing the nature and history of these asteroids, which contain clues to the dynamical and collisional evolution of the solar system. For example, based on results for Davida and spacecraft images of Mathilde, we speculate that giant craters caused by large impacts are still in evidence today [3]. Knowledge of the formation and evolution of smaller asteroids is enhanced by understanding the binary frequency and binary characteristics.

Consider asteroid 41 Daphne. Using a satellite to measure density led to a determination of that body's porosity and how impacts have altered its internal structure [4]. AO systems from 15 years ago were able to detect asteroid satellites, but only at low or moderate contrast ratios. Figure 1 shows the discovery image of Peneius orbiting 41 Daphne [5]. The SHARK-NIR system, newly installed on LBT, is able to improve on this contrast ratio by one to two orders of magnitude.

We will use SHARK-NIR to image satellites around two asteroids, 130 Elektra and 269 Justitia. We will also take snapshots of the primary to refine existing estimates of shape and size. Justitia is observable at the beginning of the semester, and Elektra is observable at the end of the semester. We will observe each, along with PSF calibrators, for 2.5 hours (one quarter night each).

The 3 panels in figure 2 show 3 moons orbiting asteroid 130 Elektra. The integral field spectrograph of the ESO SPHERE instrument was used to acquire these data, from which the third, inner moon was discovered [6]. To detect the inner moon a point spread function reconstruction algorithm was used to model and remove the asteroid halo.

We propose returning to Elektra with SHARK-NIR to confirm this discovery, but to use SHARK-NIR's coronograph [7] to remove the light from Elektra before applying post-processing methods similar to those used for the SPHERE result. In the right hand panel of figure 2 we show that the inner working angle for the Gaussian Lyot coronagraph is well matched for observing the moons of Elektra, while blocking the light of the primary.

Thanks to the binocular nature of LBT, the possibility to take simultaneous observations with instruments on the DX side of the telescope exists. In particular, as of this writing, the SHARK-VIS instrument has begun commissioning on the DX side. In addition, the LBTI instrument is available for 3-5 micron observations on DX. For LBTI, using the ALES integral field spectrograph would provide the most benefit to our program. Using both of these instruments in fact could be possible. If any of these three DX possibilities, LBTI/ALES, SHARK-VIS, or both, are available for our program we will take advantage; yielding a rich data set at multiple wavelengths.

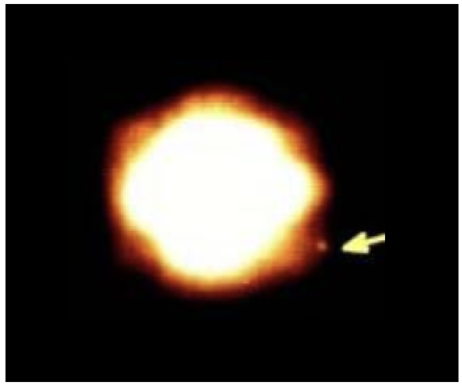

Figure 1: Discovery image from NIRC2 on W.M Keck Observatory of Peneius, satellite of 41 Daphne.

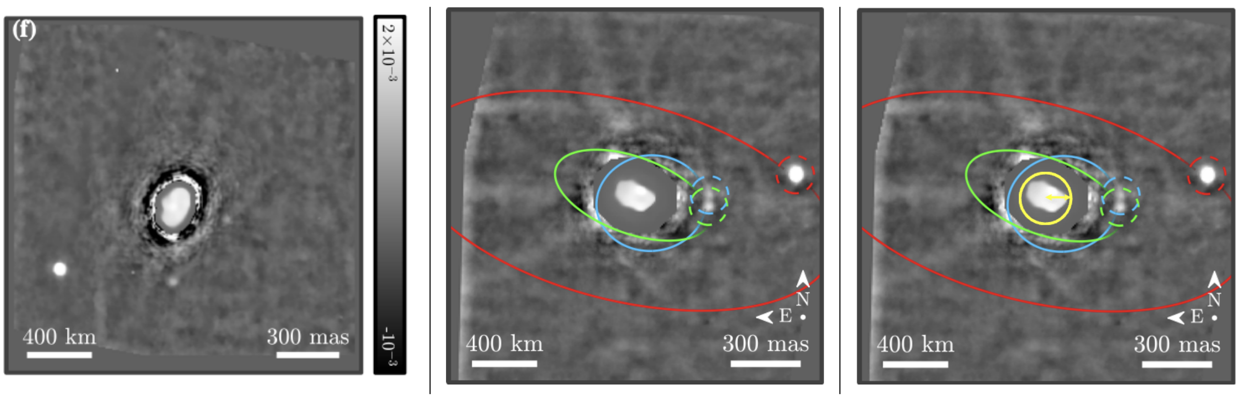

Figure 2: *Left:* SPHERE AO image of 130 Elektra and its 3 moons after extensive post-processing. The primary has been replaced by a less processed image to simultaneously visualize the primary and the moons [6]. *Center:* The 3 moons of Elektra shown together with their orbits [6]. *Right:* The orbit figure again with the inner working angle of the SHARK-NIR Gaussian Lyot mask (120 mas [7]) shown in yellow.

References

1. Merline, W.M. et al: 1999, Nature 401, 565
2. Merline, W.M. et al: 2002, Asteroids III, 289
3. Conrad, A.R. et al: 2007, Icarus 191, 616
4. Carry, B.: 2019, A&A 623, A132
5. Conrad, A.R. et al: 2008, IAUC 8930
6. Berdeu, A. et al: 2022, A&A 658, L4
7. Farinato, J. et al: 2023, SHARK-NIR Description

Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science.* ***(up to one page)***

Justitia is observable at the beginning of the semester, and Elektra is observable at the end of the semester. We will observe each, along with PSF calibrators, for 2.5 hours (one quarter night each). The observing sequence will be the same for each.

We will first observe a nearby PSF star of similar magnitude in the direct imaging mode. We will then move to the asteroid and take a similar direct imaging mode sequence. In both cases we will use the J filter and take 25 images, 5 at each dwell of a box-5 dither pattern.

Following this we will insert the Gaussian Lyot coronagraph and, after alignment, take a similar sequence as that used for the direct imaging. We will then repeat these two sequences, alternating direct imaging with coronagraph imaging, for approx. two hours. At the end we will re-observe the PSF calibrator.

Summary of Time Requested and Awarded *The TAC needs to understand the scope of this project — (1) tell us how many UAO nights you've already had for this project, how many you request this time, and (a good guess of) how many you need to complete the project; (2) if a substantial amount of observing for this project comes from non-UAO telescopes, tell us about that observing, and how the UAO part fits in; (3) if you are collaborating with people who have telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how UAO time and your participation fit in. (**up to one page**)*

Previous Use of Steward Facilities *List **all** allocations of telescope time for the present project and allocations for other projects on facilities available through UAO during the past 2 years, together with the current status of the data (cite publications where appropriate). Mark those allocations related to the present proposal (i.e, precede text with* `\related` *command). (**up to one page**)*

Other Information *Provide any additional program-related information including, for example, relation of current program to externally funded research, to the development of expanded capabilities for UA telescopes, or to individual timescales (e.g. PI is finishing postdoc appointment and this request would complete program). (**up to one page**)*

LaTeX 2_ε UAO Observing Proposal class, 'soprop.cls' v1.3 (2007 Aug 01 [RAJ]).