Slow rotators among asteroids

Campaign summary

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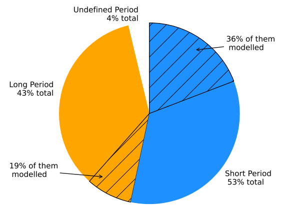
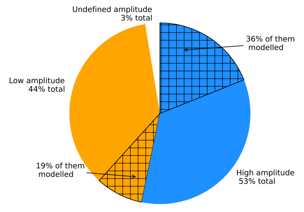
Introduction

- Asteroids with slow rotation and/or small lightcurve amplitude - challenging targets for spin and shape reconstruction
- Ground-based lightcurve surveys disfavoured targets with P>12 hours
- Scarcity of dense lightcurves → lack of spin and shape models → biased statistics
- 2013 - start of wide campaign to counteract these selection effects
- Until 2023 - total ∼ 20 000 hours on-target

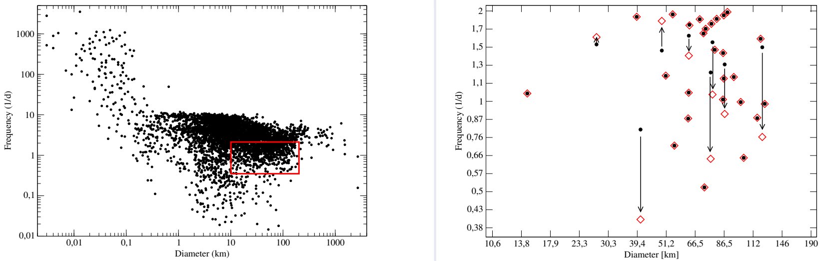




Statistics of periods and amplitudes of ∼ 1200 main belt asteroids (Marciniak et al. 2015).

Results for rotation periods

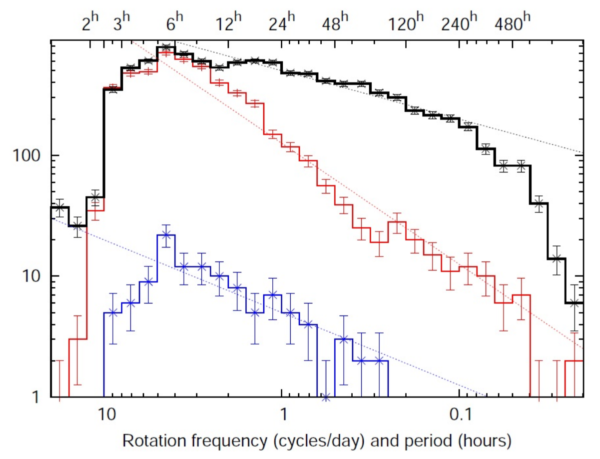
- Many slow rotators - big and bright asteroids (often D>100 km)
- Expected to be well studied
- Reality: for many of them even rotation period was wrong



Frequency-diameter plots (Warner et al. 2009, Marciniak et al. 2015).

Slow rotators in Kepler K2 and TESS surveys

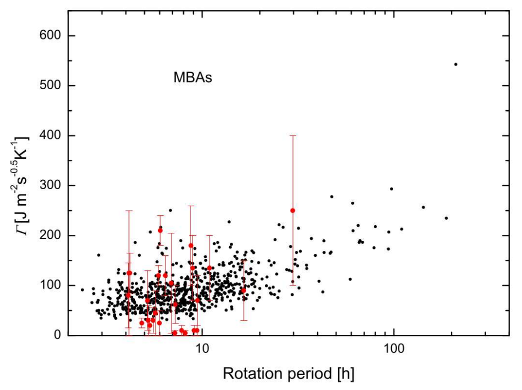
Slow rotators are ubiquitous among asteroids (results from Kepler K2 and TESS)



Histogram of asteroid rotation periods from ground-based observations (red), Kepler K2 (blue), and TESS (black) [Pál et al. 2020].

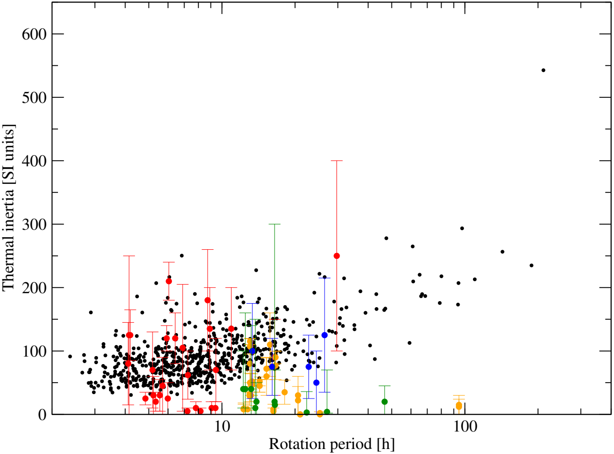
Thermophysical studies

- Slow rotators gained more importance in thermophysical studies
- Trends between thermal inertia and period have been suggested
- Yet, slow rotators have been poorly studied via thermophysical modelling (TPM)



Thermal inertia vs. rotation period (Harris & Drube 2016)

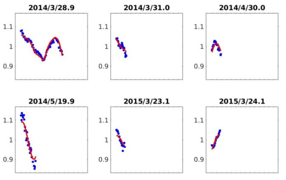
Thermal inertia vs. period



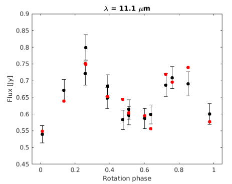
Thermal inertia vs. rotation period, updated
(Marciniak et al. 2018 (blue), 2019 (green); Hanuš et al. 2018 (orange)

Convex Inversion ThermoPhysical Model

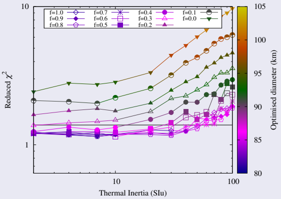
- Lightcurve inversion shapes used in TPM: results sensitive to small-scale shape variations (Hanuš et al. 2015)
- New method: simultaneous optimisation of shape (lighcturves) and thermophysical parameters (thermal data) (Ďurech et al. 2017)



Example of model fit (red lines) to visible lightcurves (blue points) for (667) Denise.



Thermal lightcurve fit (red) to WISE W3 data (black) for (667) Denise.



Reduced χ_2 vs. thermal inertia for various combinations of surface roughness (symbols) and optimised diameters (colours). Target: (667) Denise.

(Marciniak et al. 2021)

Sizes from CITPM confirmed by fitting models to stellar occultations

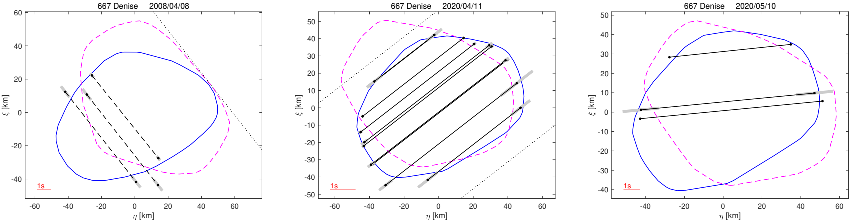


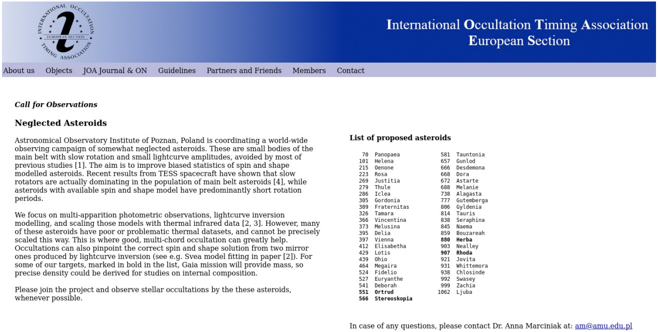
Figure: CITPM shape models of (667) Denise fitted to three stellar occultations. Pole 1 solution (blue) is clearly preferred over pole 2 (magenta).

Target	CITPM Pole 1	 Pole 2	occultation scaling Pole 1	 Pole 2
362 Havnia	92^{+6}_{-5} km	91^{+8}_{-3} km	84 ± 1 km	88 ± 1 km
618 Elfriede	145^{+15}_{-13} km	146^{+15}_{-16} km	145 ± 7 km	155 ± 2 km
667 Denise	83^{+4}_{-2} km	82^{+5}_{-2} km	83 ± 2 km	rejected

Table: Diameters of equivalent volume spheres from CITPM and from fitting these models to stellar occultations. (Marciniak et al. 2021)

Sizes of slow rotators

- Big, 100-km asteroids often lack good thermal data (saturate for WISE)
- Cannot be put to scale via TPM/CITPM
- Available sizes of slow rotators: often discrepant by more than 30–40% (MP3C database)
- Stellar occultations can precisely scale asteroid models, down to a few %
- New campaign: “Neglected Asteroids” / “SlowRotators” since October 2020, to observe stellar occultations by our target asteroids



Call for Observations

Neglected Asteroids

Astronomical Observatory Institute of Poznan, Poland is coordinating a world-wide observing campaign of somewhat neglected asteroids. These are small bodies of the main belt with slow rotation and small lightcurve amplitudes, avoided by most of previous studies [1]. The aim is to improve biased statistics of spin and shape modelled asteroids. Recent results from TESS spacecraft have shown that slow rotators are actually dominating in the population of main belt asteroids [4], while asteroids with available spin and shape model have predominantly short rotation periods.

We focus on multi-apparition photometric observations, lightcurve inversion modelling, and scaling those models with thermal infrared data [2, 3]. However, many of these asteroids have poor or problematic thermal datasets, and cannot be precisely scaled this way. This is where good, multi-chord occultation can greatly help. Occultations can also pinpoint the correct spin and shape solution from two mirror ones produced by lightcurve inversion (see e.g. Svea model fitting in paper [2]). For some of our targets, marked in bold in the list, Gaia mission will provide mass, so precise density could be derived for studies on internal composition.

Please join the project and observe stellar occultations by the these asteroids, whenever possible.

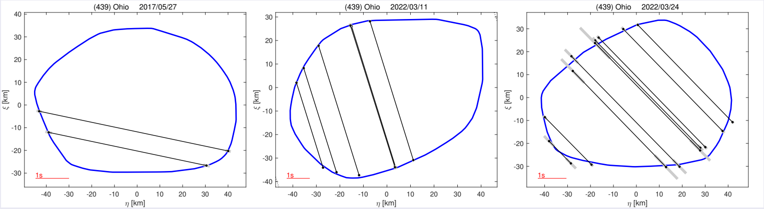
List of proposed asteroids

70	Panopaea
101	Helena
215	Oenone
223	Rosa
269	Justitia
279	Thule
286	Iclea
305	Gordonia
309	Fraternitas
326	Tamara
366	Vincentina
373	Melusina
395	Delia
397	Vienna
412	Elisabetha
429	Lotis
439	Ohio
464	Megaira
524	Fidelio
527	Euryanthe
541	Deborah
551	**Ortrud**
566	**Stereoskopia**
581	Tauntonia
657	Gunlod
666	Desdemona
668	Dora
672	Astarte
688	Melanie
738	Alagasta
777	Gutemberga
806	Gyldenia
814	Tauris
838	Seraphina
845	Naema
859	Bouzareah
880	**Herba**
903	Nealley
907	**Rhoda**
921	Jovita
931	Whittemora
938	Chlosinde
992	Swasey
999	Zachia
1062	Ljuba

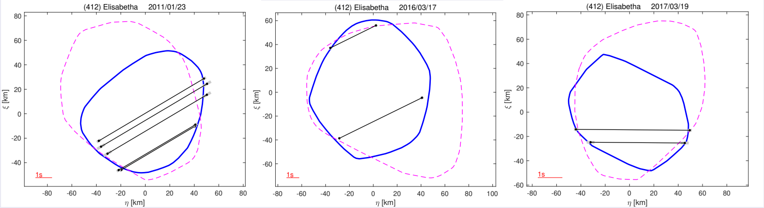
In case of any questions, please contact Dr. Anna Marciniak at: am@amu.edu.pl

https://www.iota-es.de/neglected_asteroids.html

Occultation fitting



(439) Ohio, volume equivalent diameter: 74^{+5}_{-8} km..



(412) Elisabetha, Volume equivalent diameter for preferred pole solution: 97^{+4}_{-14}.

(Marciniak et al., submitted to A&A)

Summary

- Slowly rotating asteroids: challenging, yet important targets
- Disfavoured by selection effects
- This study: multi-technique approach
- Photometric survey + thermophysical modelling + occultation campaign
- Result: spin and shape models of $\sim$ 50 slow rotators
- Provided precisely scaled models to the community → density determinations
- Resolved profound inconsistencies in diameter determinations
- Provided thermophysical parameters, e.g. thermal inertia
- Negatively verified trend of TI vs rotation period
- Utilize occultations to resolve mirror pole ambiguity, determine size, and estimate shape uncertainties

Special thanks to all the observers contributing to this work.