Thermal Inertia Estimation of Tiny Asteroids by Light Curve Phase Lag Method

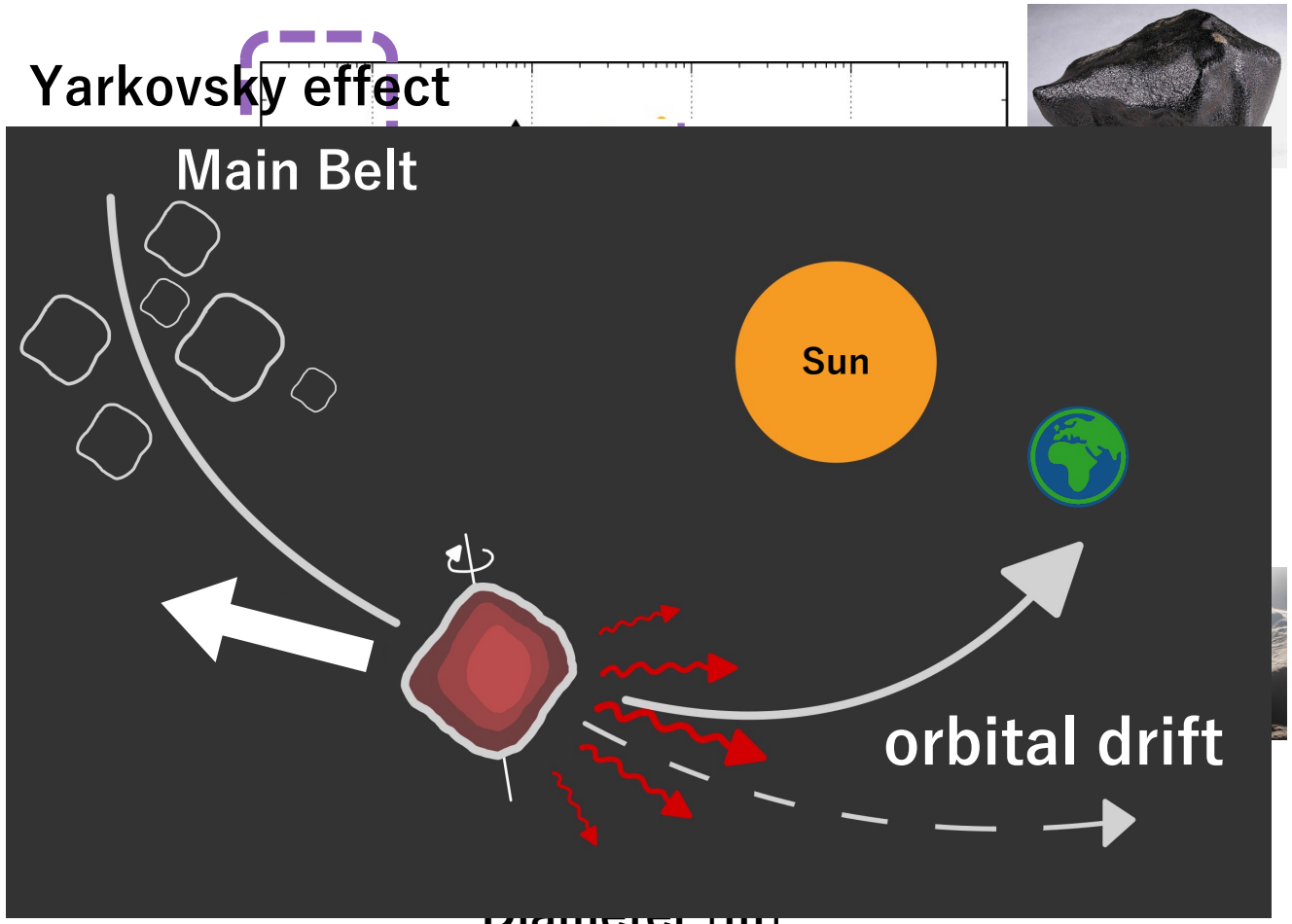
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EAMA 11th
December 11th , 2025
Toki Messe

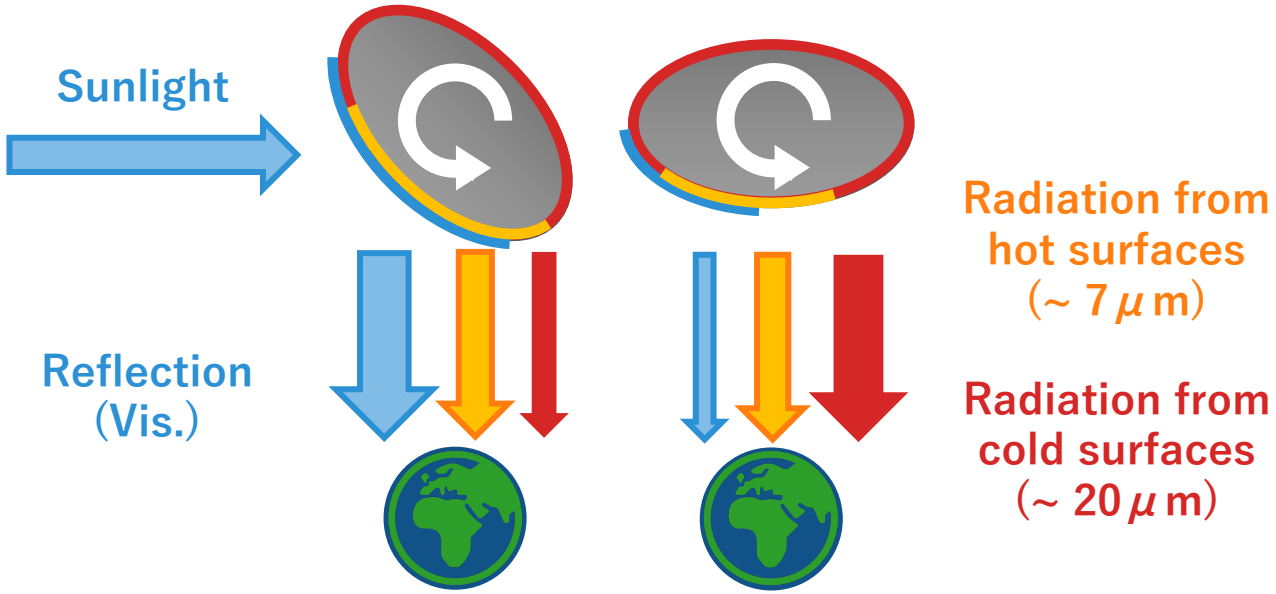
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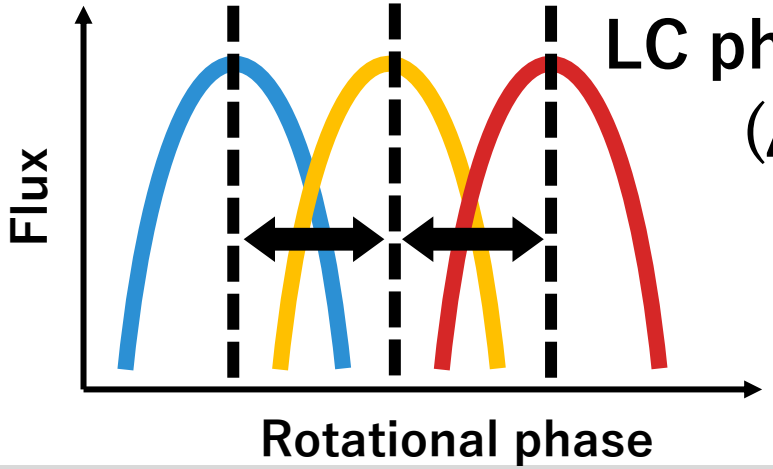
Thermal Inertia of tiny asteroids



- Asteroids brought water to early Earth. (Peslier+2017)
- The orbital evolution is driven by Yarkovsky effect. (Vokrouhlicky 1998)
- The effect strongly depends on **thermal inertia(TI).**
- **TI of tiny asteroids is estimated for only 5 objects.** (Novaković+2024, Fenucci+2025)

New method to estimate TI

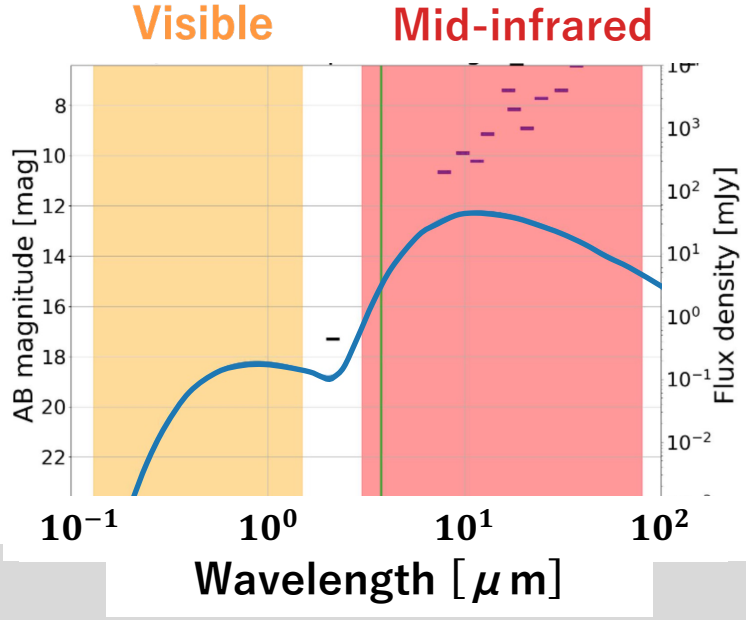




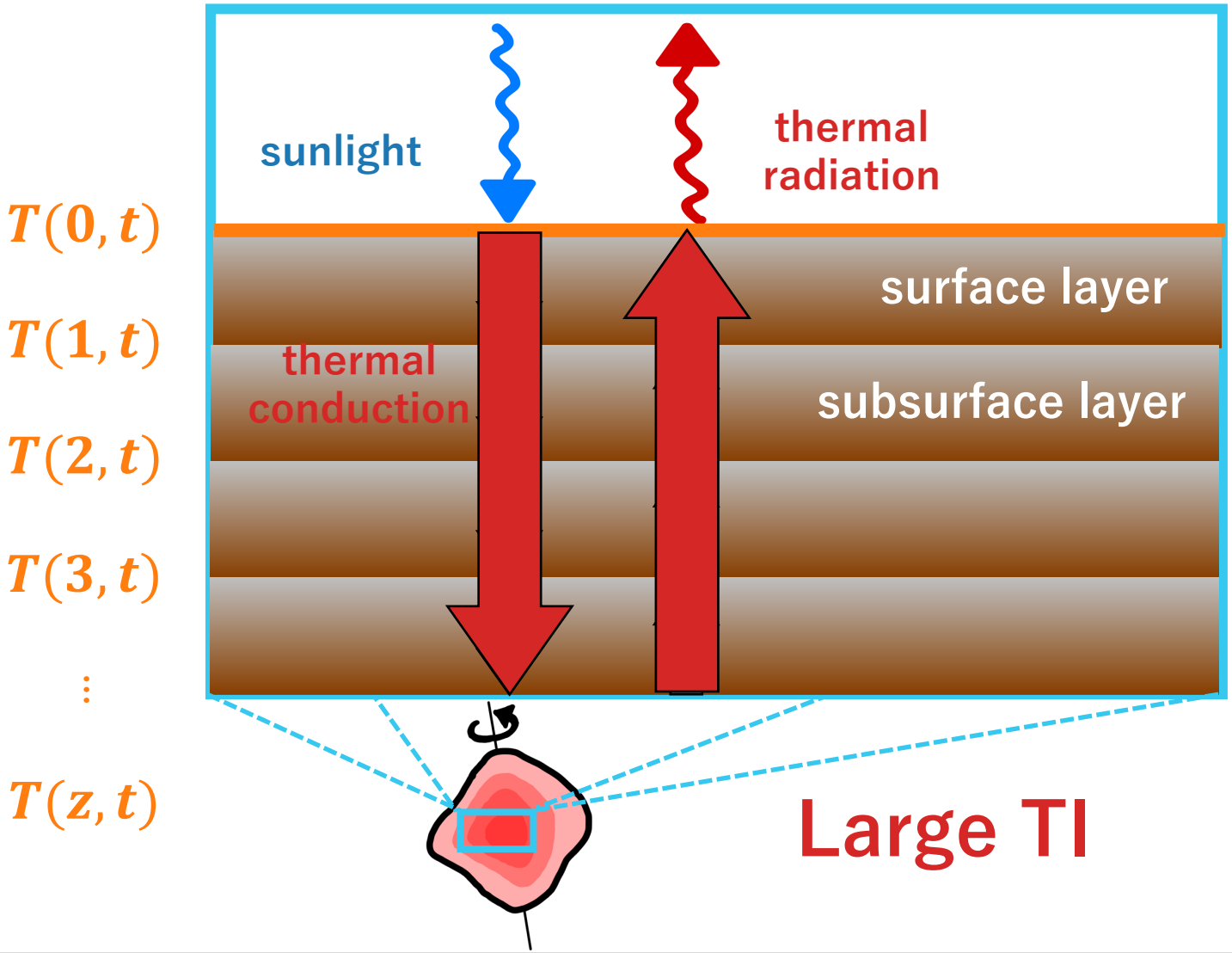
LC phase lags ($\Delta\omega$)

- The phase lags of light curves (LC phase lags) depend on TI.
- **We can estimate TI by observing phase lags.**
- Using this method, we can estimate the TI of typical tiny asteroids **in under an hour.**

Typical SED of asteroids

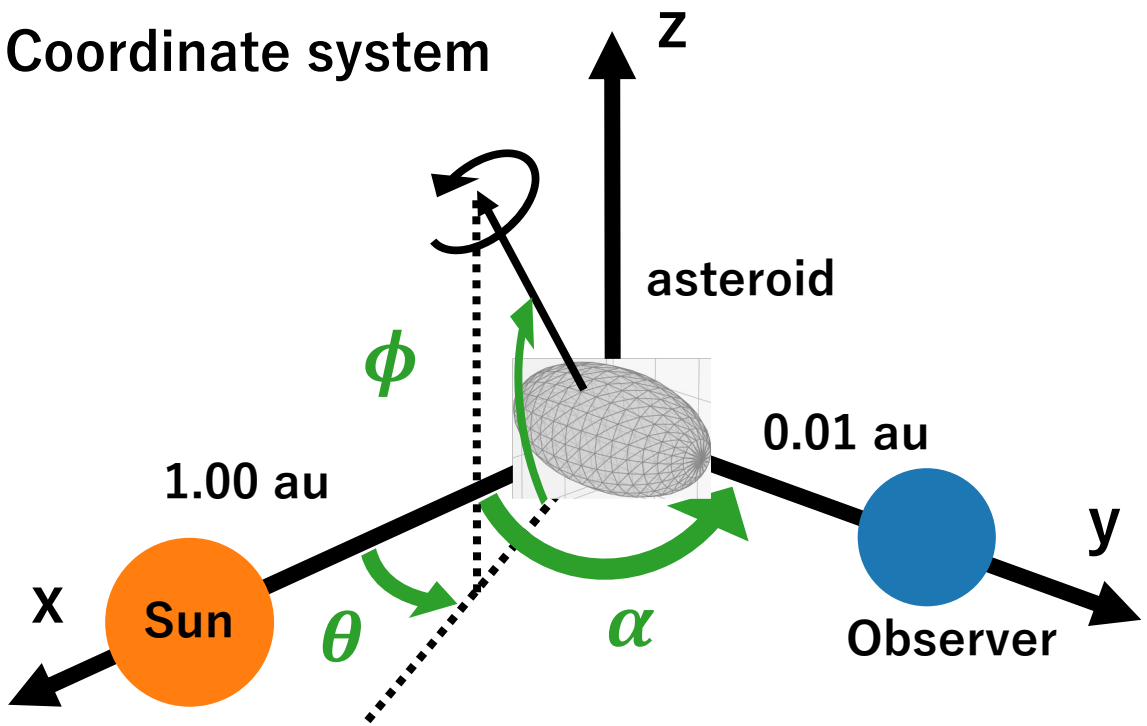


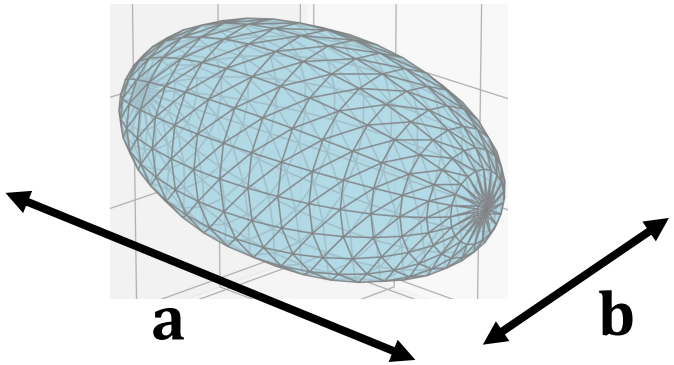
The calculation models



- Reflection: Lambertian
  - Isotropic scattering
- Thermal radiation: TPM (Delbo+2007)
  - Multiple-layer model
  - 1-D calculation (vertical)
- Definition of TI: $\Gamma = \sqrt{k\rho C_p}$
  - k: thermal conductivity $[\mathrm{W/m/K}]$
  - ρ: bulk density $[\mathrm{kg/m^3}]$
  - C_p: specific heat capacity $[\mathrm{J/kg/K}]$
- Large TI causes slow cooling and slow warming.

Parameters and the values

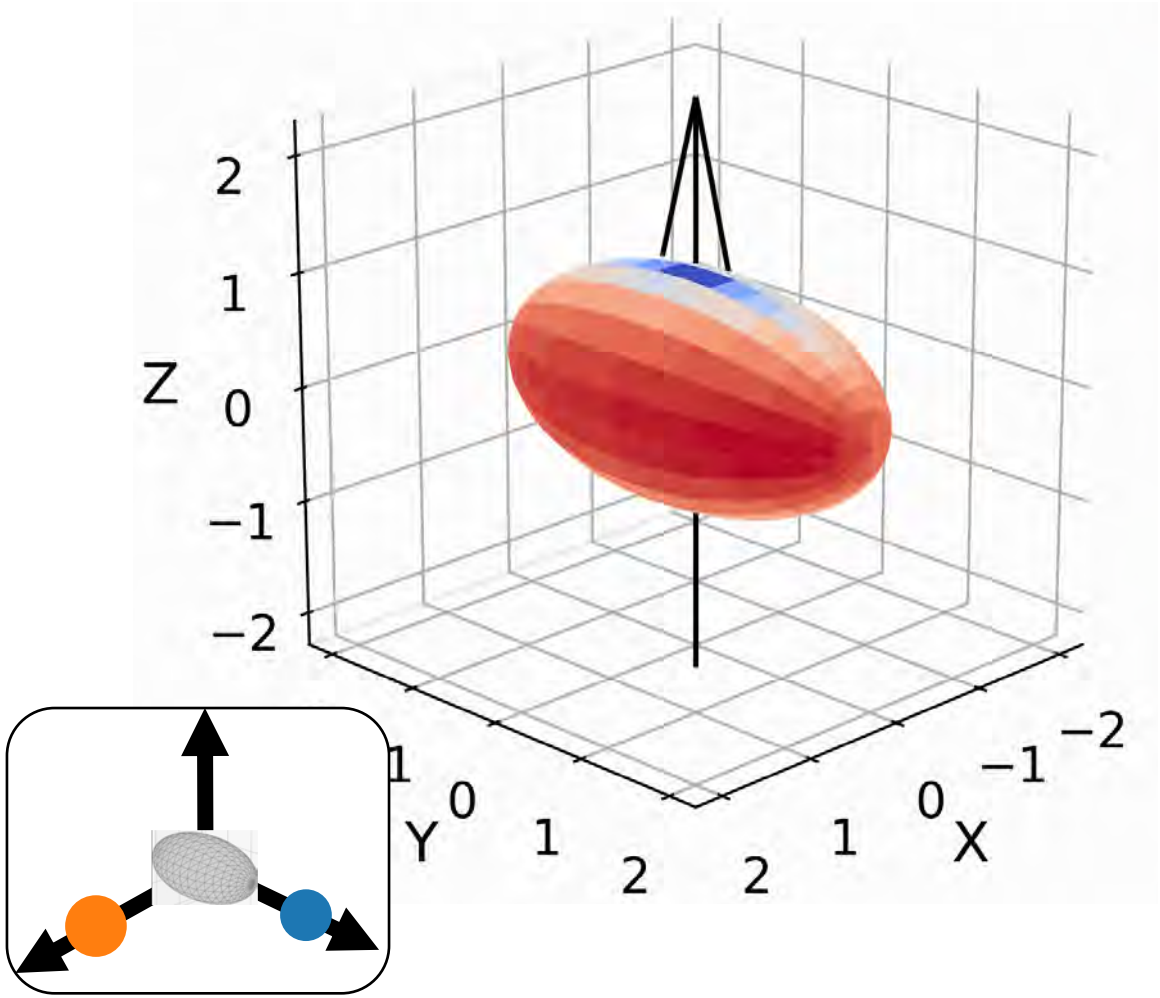


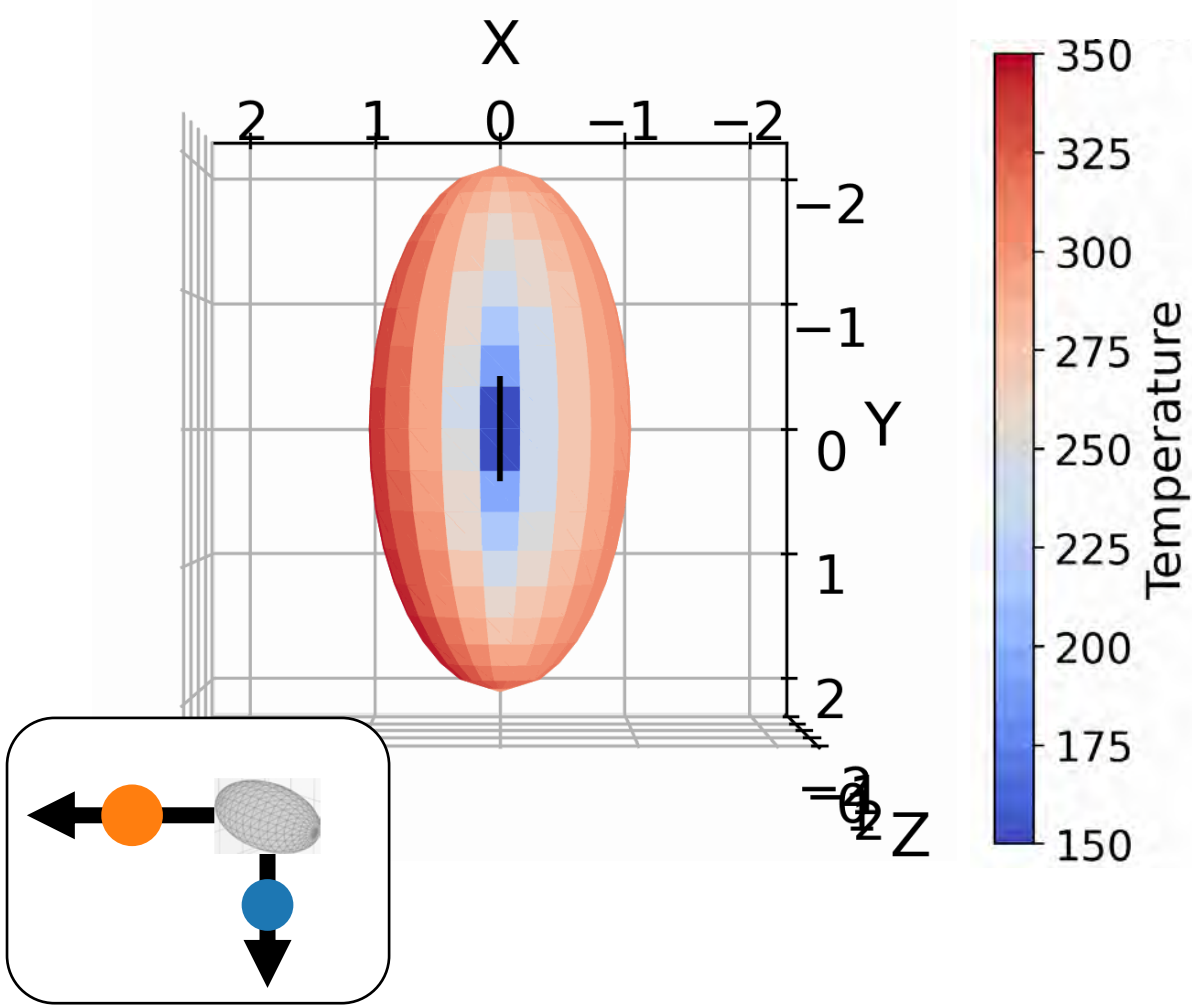


Parameters		Values
Thermal Inertia, TI	$\boldsymbol{\Gamma}$	$[10, \mathbf{100}, 1000]$ tiu
Rotational period	**P**	$[10, \mathbf{100}, 1000]$ s
Rotational axis	$\boldsymbol{\theta}$	$[-150°, -120°, \ldots, \mathbf{0°}, \ldots, 180°]$
	$\boldsymbol{\phi}$	$[0°, \pm 30°, \pm 60°, \pm \mathbf{90°}]$
Axis ratio	**a/b**	$[1.5, \mathbf{2.0}, 3.0]$
Solar phase angle	$\boldsymbol{\alpha}$	$[0°, 30°, 60°, \mathbf{90°}, 120°]$

The values in bold are the standard parameter set.

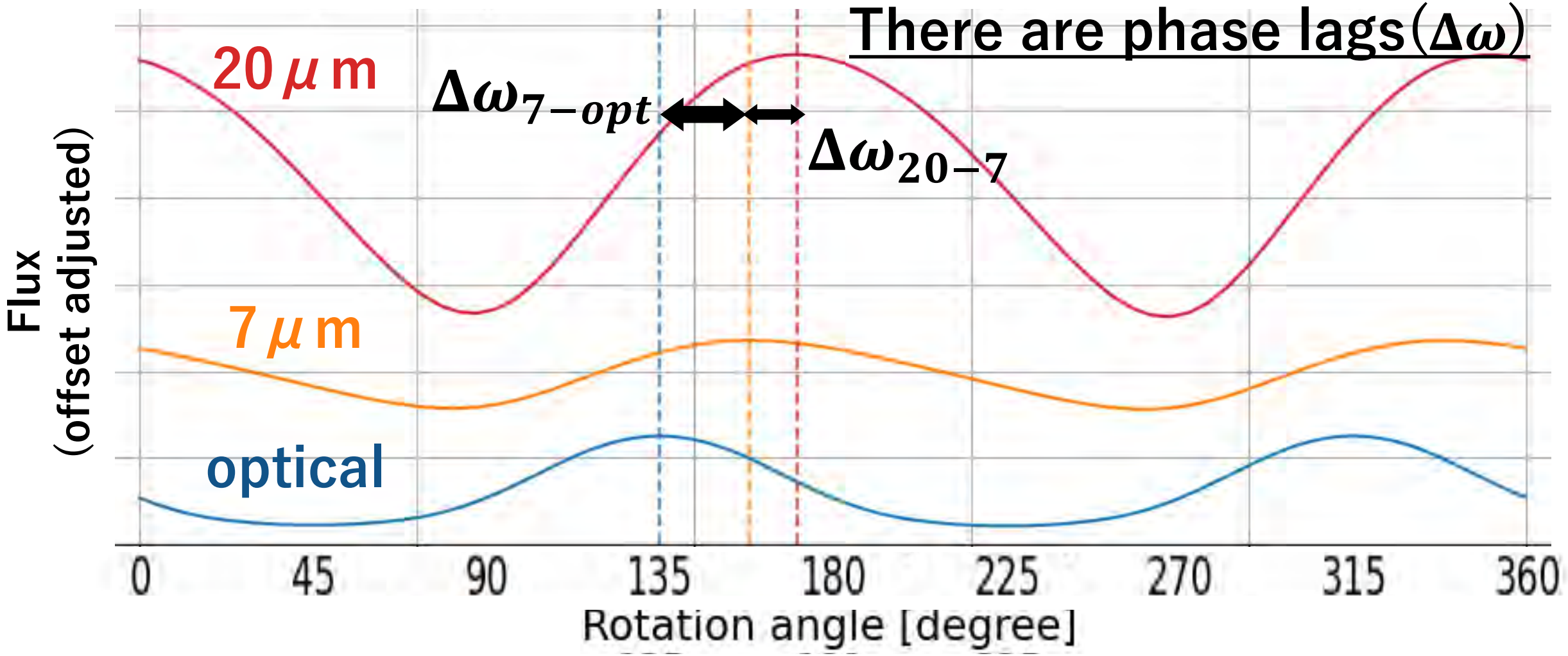
Surface temperature distributions





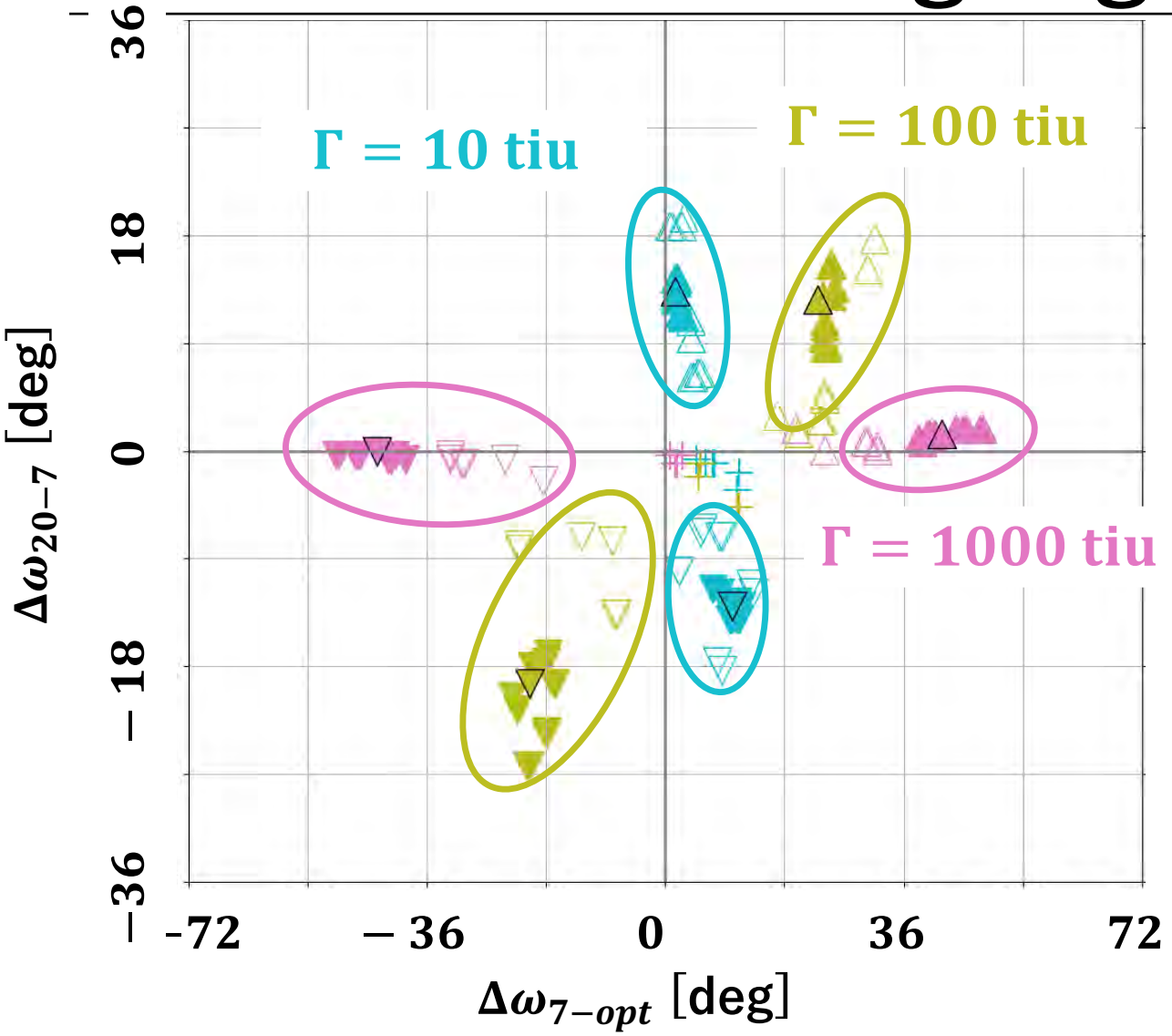
Parameters: $P, \theta, \phi, \Gamma, a/b, \alpha = 100\ \mathrm{s}, 90°, 90°, 100\ \mathrm{tiu}, 2.0, 90°$

Light curves



$P, \theta, \phi, \Gamma, a/b, \alpha = 100\ \mathrm{s}, 90°, 90°, 100\ \mathrm{tiu}, 2.0, 90°$

Distribution on lag-lag diagram

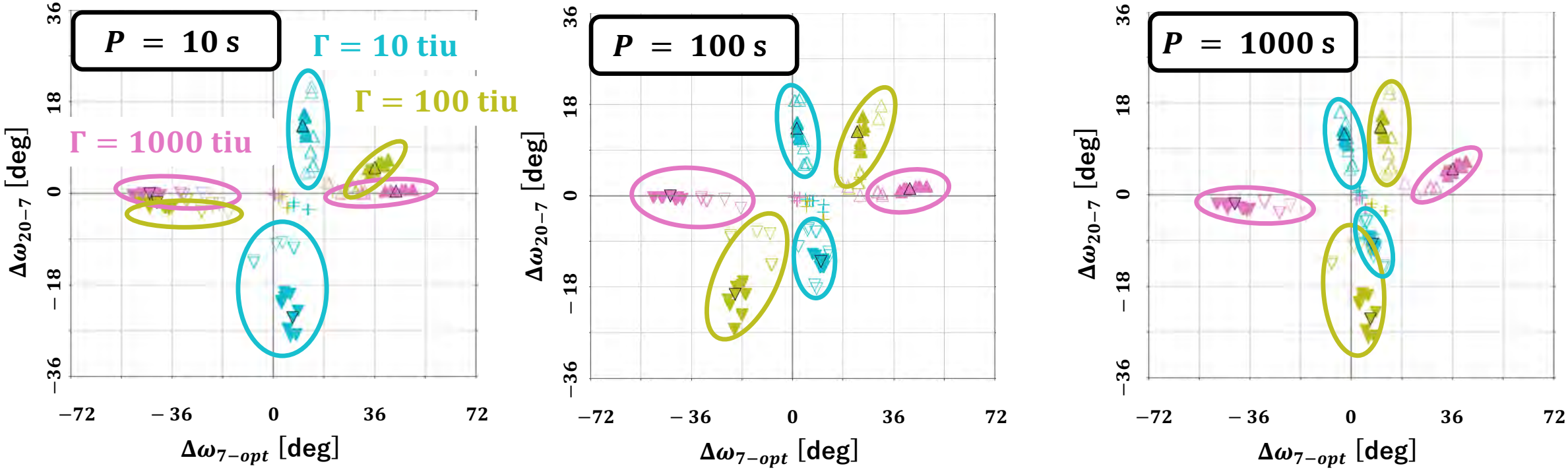


The distribution strongly depends on TI.

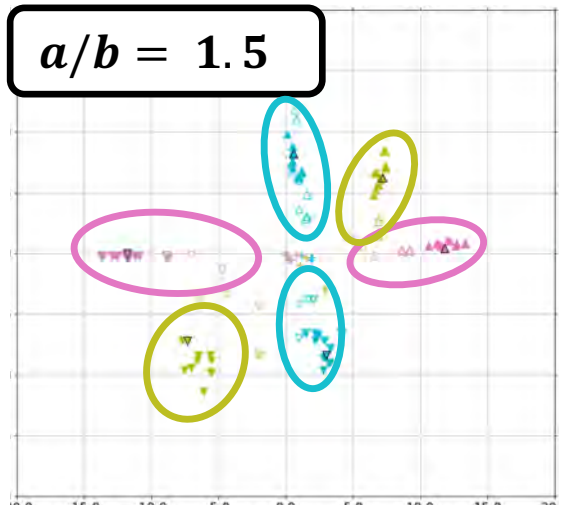
Parameters	Values
Γ	$[10, 100, 1000]$ tiu
θ	$[-150°, -120°, \ldots, 180°]$
ϕ	$[0°, \pm30°, \pm60°, \pm90°]$
P	100 s
a/b	2.0
α	90°

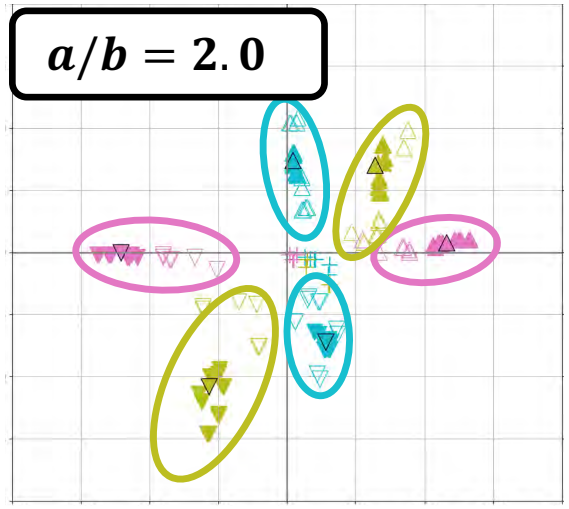
Estimation of TI with lag-lag diagram

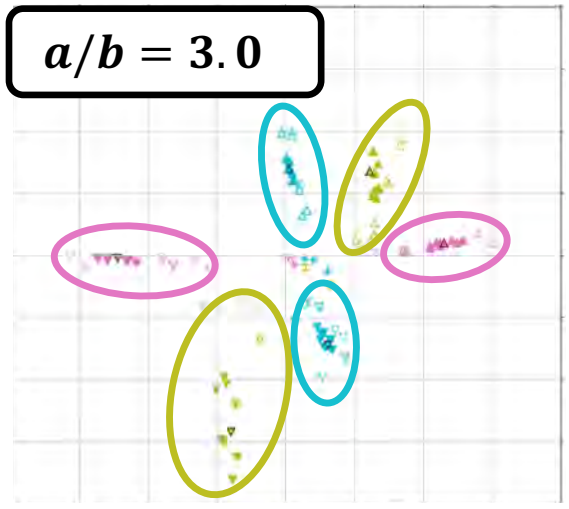
- The distribution also depends on TI for other parameter sets.
- The distribution clearly distinguishes TI.
- **We can estimate TI on this diagram.**

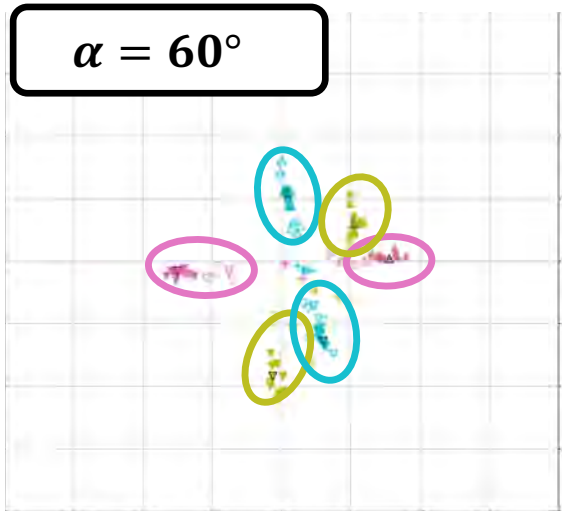


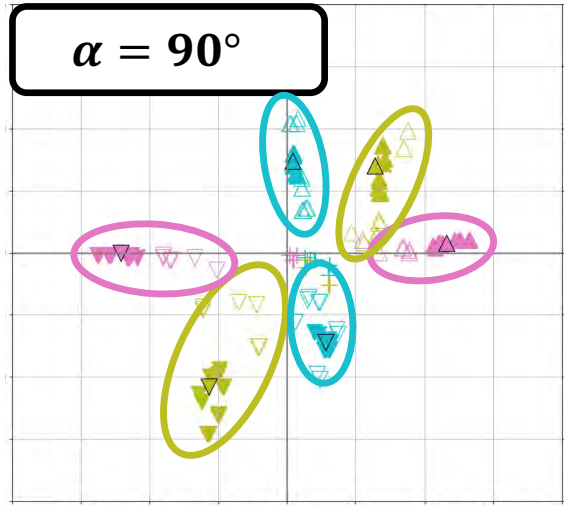
Lag-lag diagram of other parameters

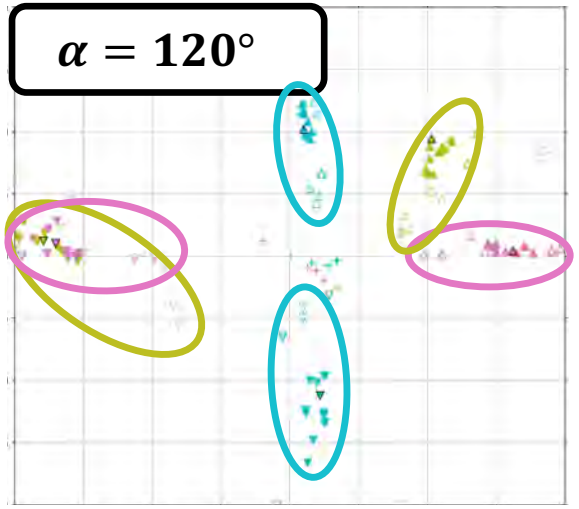












Summary

- **We have developed a new method to enable the estimation of tiny asteroids' TI in under an hour.**
- TI can be estimated utilizing a lag-lag diagram, plotted using observational light curves in optical and MIR.
- Our next goal is to confirm the applicability of this study in actual observations.

