The low thermal conductivity of the super-fast rotator (499998) 2011 PT

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Motivation

It is supposed that:

- Small and fast rotators are **monolithic** objects
- Rocky monoliths have **high thermal inertia**
- High thermal inertia makes the Yarkovsky effect **less** effective

However:

- **Del Vigna et al. 2018** and **Greenberg et al. 2020** found small objects with fast Yarkovsky drift
Case study: (499998) 2011 PT

Characteristics:

- \( H \sim 24 \) mag \( \Rightarrow D \sim 35 \) m
- \( P \sim 11 \) min
- **Yarkovsky effect** detected by
  - Del Vigna et al. 2018
  - Greenberg et al. 2020
  - JPL SBDB

Goal:

- Constrain the **thermal conductivity** (thermal inertia)
Methods: model vs. observed Yarkovsky drift

\[
\left( \frac{da}{dt} \right)(a, D, \rho, K, C, \gamma, P, \alpha, \varepsilon) = \left( \frac{da}{dt} \right)_m
\]

Parameters:
- \(a\) semimajor axis
- \(D\) diameter
- \(\rho\) density
- \(K\) thermal conductivity
- \(C\) heat capacity
- \(\gamma\) obliquity
- \(P\) rotation period

Method:
- Assume distributions for all the parameters but \(K\)
- Solve for \(K\) the model vs. observed equation
- Use a Monte Carlo method for statistical analysis
Results of the Monte Carlo simulations

The distributions are always **bimodal**.

- **First peak** in $K$ at around $\sim 7 \cdot 10^{-5} \ W \ m^{-1} \ K^{-1}$
- **Second peak** in $K$ at around $\sim 5 \cdot 10^{-3} \ W \ m^{-1} \ K^{-1}$

$P(K < 0.1 \ W \ m^{-1} \ K^{-1}) > 0.95$
Comparison with other asteroids

The estimated thermal inertia for 2011 PT is

$11^{+7}_{-5}$ and $88^{+90}_{-45}$

Low thermal inertia is usually associated to *regolith*

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>$D$ (km)</th>
<th>$\Gamma$ (J m$^{-2}$ K$^{-1}$ s$^{-1/2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceres</td>
<td>923</td>
<td>10 $\pm$ 10</td>
</tr>
<tr>
<td>Pallas</td>
<td>544</td>
<td>10 $\pm$ 10</td>
</tr>
<tr>
<td>Vesta</td>
<td>525</td>
<td>20 $\pm$ 15</td>
</tr>
<tr>
<td>Eros</td>
<td>17</td>
<td>150 $\pm$ 50</td>
</tr>
<tr>
<td>1950 DA</td>
<td>1.3</td>
<td>24 $\pm$ 20</td>
</tr>
<tr>
<td>Ryugu</td>
<td>0.87</td>
<td>225 $\pm$ 45</td>
</tr>
<tr>
<td>Bennu</td>
<td>0.49</td>
<td>310 $\pm$ 70</td>
</tr>
<tr>
<td>Itokawa</td>
<td>0.32</td>
<td>700 $\pm$ 200</td>
</tr>
</tbody>
</table>
Conclusions

- First evidence supporting the hypothesis that regolith can be retained on small and super-fast rotators (Sanchez & Scheeres 2019, *Icarus*).
- Large rocky boulders with low thermal inertia were found on Bennu and Ryugu. However, 2011 PT is an E-type asteroid.
- 2011 PT might be a rubble-pile, but it is highly unexpected.

Future works and opened questions

- More studies and characterization of asteroids with $D < 100$ m are needed for the planning of deflection or Asteroid Redirect missions.
- What are the processes and timescales of regolith formation on fast rotators?
- Is 2011 PT a good representative of the population of asteroids with $D < 100$ m?