The Spin-Rate Limit of Jupiter Trojans – A Result of **FOSSIL Survey**

https://www.fossil-survey.org
Please visit our web page.

As for details of FOSSIL project/survey, please see F. Yoshida's slides
There is a link to the Slack

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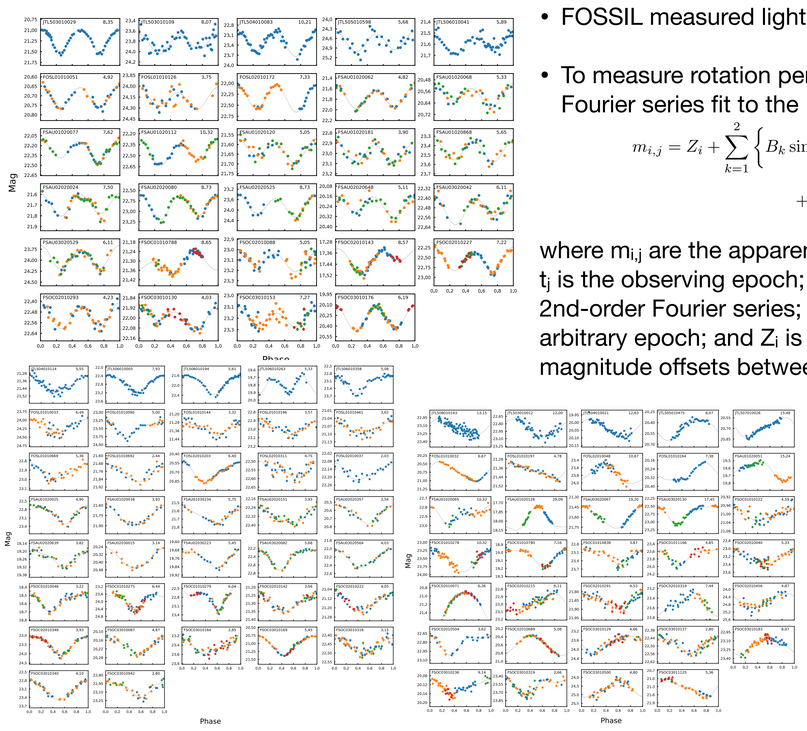
Observations of FOSSIL survey in 2020

Run	Field numbers	Filter	Exp	Detection limit (mag)	Cadence	Date (UT)	Hours (hr)
201904 (L5)	5	g	90s	24.5	10min	2019-04-10	8.82
202005 (L5)	2	r2	300s	25.6	11min	2020-05-19	3.8hr
				25.7	11min	2020-05-20	3.8hr
202008(L4)	3	r2	300s	25.6	16min	2020-08-21	4.5hr
				25.6	16min	2020-08-22	4.0hr
				25.5	16min	2020-08-23	4.1hr
202010(L4)	3	r2	150s*2	25.5	15min	2020-10-14	3.4hr
				25.4	15min	2020-10-15	3.4hr
				24.0	15min	2020-10-16	1.0hr
				24.0	15min	2020-10-17	1.0hr
202010a1(L4)	4	r2	150s*2	25.0	21min	2020-10-14	0.9hr
202010a2(L4)	4	r2	150s*2	25.0	21min	2020-10-15	1.3hr

We surveyed the L4, and L5 JT sky areas of 37.7 deg^2 in total, in 2020.

- High-cadence observations were performed targeting the L4 and L5 Jupiter Trojan (JT) clouds.
- The 19Apr data is from a previous survey, and not part of the original FOSSIL proposal.
- FOSSIL was originally awarded four nights in both May (2020A) and September (2020B) when the L5 and L4 JT clouds were near the oppositions, respectively. However our scheduled observations 2020A were impacted by the shutdown of Mauna Kea due to the COVID-19 pandemic, and our 2020B nights were rescheduled to August and October due to necessary Subaru maintenance which had been deferred due to the pandemic. The change in our observing schedule necessitated the cancellation of our planned JT color measurements, but we were still able to make useful JT lightcurve measurements during time we managed to observe.

Rotation periods of Jupiter Trojans



- FOSSIL measured light curves of 100 JTs.
- To measure rotation periods, we performed a 2nd-order Fourier series fit to the lightcurves of FOSSIL JTs:

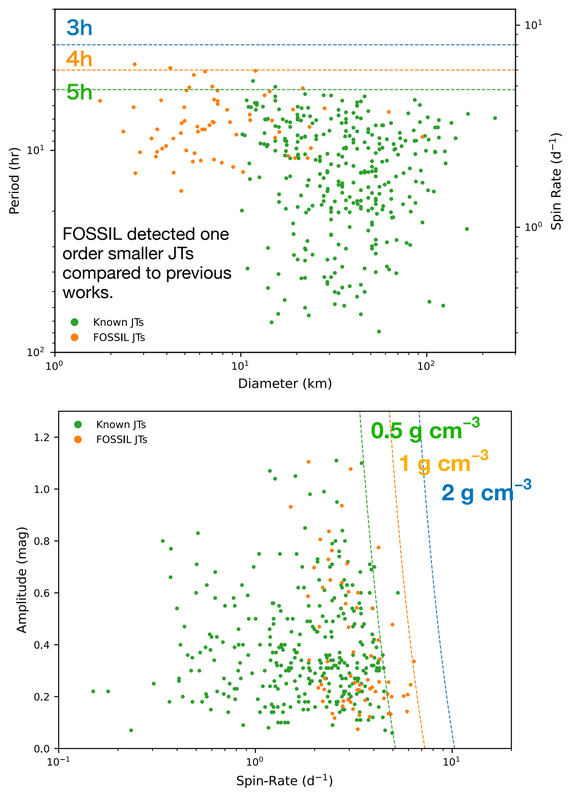
$$m_{i,j} = Z_i + \sum_{k=1}^{2}\left\{B_k \sin\left[\frac{2\pi k}{P}(t_j - t_0)\right] + C_k \cos\left[\frac{2\pi k}{P}(t_j - t_0)\right]\right\}$$

where $m_{i,j}$ are the apparent magnitudes in the observed band, t_j is the observing epoch; B_k and C_k are the coefficients of the 2nd-order Fourier series; P is the rotation period; t_0 is an arbitrary epoch; and Z_i is the constant to correct the magnitude offsets between the data sets obtained from different nights i.

The spin rate (f = 1/P) was explored from 0.25 to 100 d^{-1} using a step size of 0.01 d^{-1}.

- Covering full rotation period for 29 JTs, half rotation period for 37 JTs, and partial rotation period for 34 JTs.

Diameter vs rotation periods for the FOSSIL JTs



- FOSSIL JTs: orange dots Known JTs: green dots
- The green, orange, and blue dashed lines indicate rotation periods of 5, 4, and 3 hr, respectively.
- The FOSSIL data set extends the range of diameters of JTs with measured rotation periods from D=~10 km down to D=~1km.

Looking at the rotation period distribution of FOSSIL JTs, the spin limit of JTs can be ~4 hours instead of the previously published result of ~ 5 hr.

Assuming a rubble-pile structure for JTs, the minimum bulk density to withstand these objects can be calculated (Harris 1996) using

$$P = 3.3\left(\frac{1+\Delta m}{\rho}\right)^{\frac{1}{2}}$$

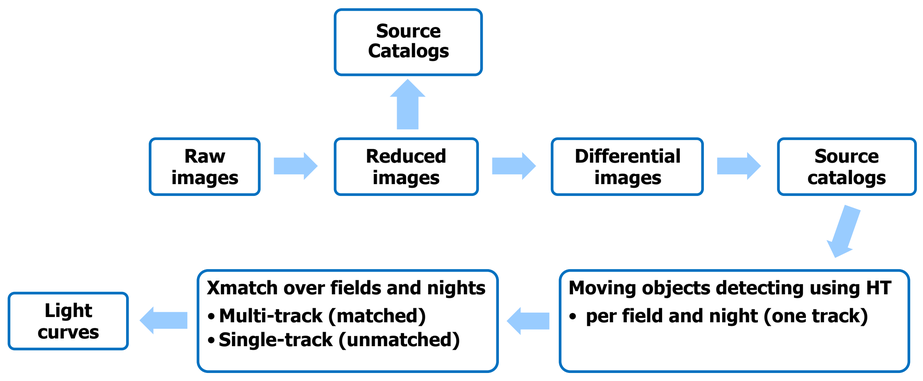
P: rotation period (hour), Δm: amplitude of light curve, ρ: bulk density (g cm-3)

Given the rotation rates measured for the FOSSIL JTs, we found that these objects need a bulk density of at least 1 g cm^{-3}, a value is consistent with the measurement of 1.08 g cm^{-3} from the binary JT system, (617) Patroclus–Menoetius system (Mueller et al. 2010).

Summary

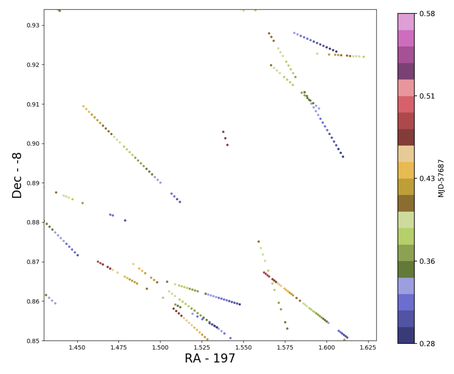
- Rotation periods of 100 small Jupiter Trojans (JTs) were derived using the high-cadence light curves obtained by the FOSSIL phase I survey, an intensive program of Subaru/Hyper Suprime-Cam (HSC).
- We found a rotation period limit at ~ 4 hr, instead of the previously published result of ~ 5 hr.
- Assuming a rubble-pile structure for JTs, a bulk density of ~ 1 g cm^{-3} is required to withstand this spin-rate limit, consistent with the value 1.08 g cm^{-3} derived from the binary JT system (617) Patroclus–Menoetius system (Mueller et al. 2010).
- Moreover, we found 8 JTs in the FOSSIL sample that possess lightcurve amplitudes > 0.9 mag. These objects are binary candidates, but they need confirmation by additional surveys.

Data process Flow Chart

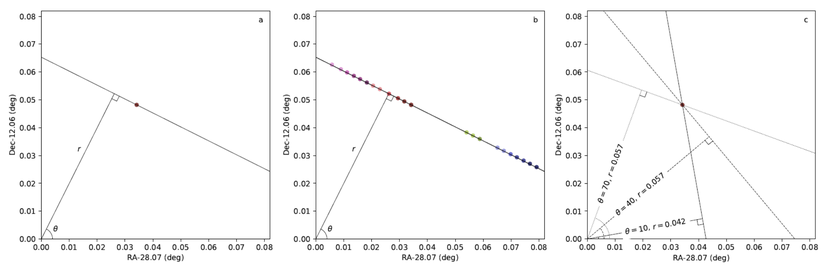


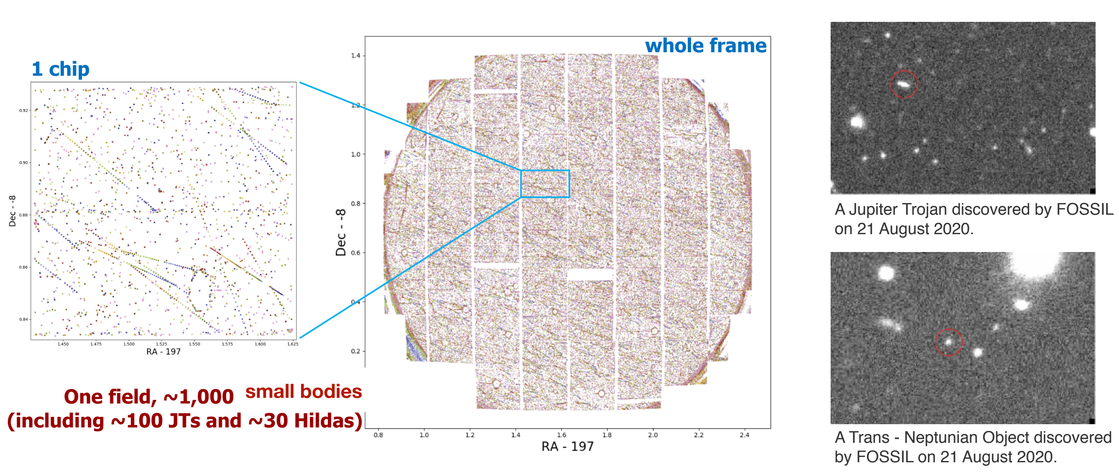
- All the images were processed using the HSC pipeline, hscPipe v8.3 (Bosch et al. 2018), with astrometry and photometry calibrated against the Pan-STARRS 1 catalog (Chambers et al. 2017). For each pointing, hscPipe was used to build a template image in order to produce differential images. The differential images were then processed by the same pipeline to generate source catalogs of potential moving objects.
- Since fast moving objects show trailed PSF during each exposure. In order to improve the photometry for the trailing moving objects, the trail-fitting method TripPy (Fraser et al. 2016a,b) was used to estimate the magnitudes of the moving object candidates.

Intra-night trajectories are linear



- The intra-night detections of the moving objects would appear as linear sequences with correlated epochs. The Hough Transform (Hough 1959; Duda & Hart 1972), an algorithm for line detection in images, was thus utilized to correlate the linear intra-night detections and find moving objects. This procedure is describe in detail in Chang et al. (2019).
- In Hough Transform, a line is defined as $r = x\cos\theta + y\sin\theta$.
- Line-up detections share common (r,θ)
- Explore (r,θ) for detections and find those in common (r,θ) with right time sequence



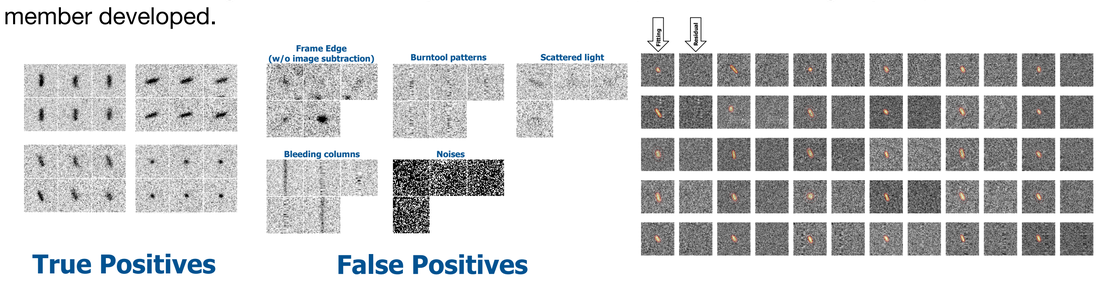


One field, ~1,000 small bodies (including ~100 JTs and ~30 Hildas)

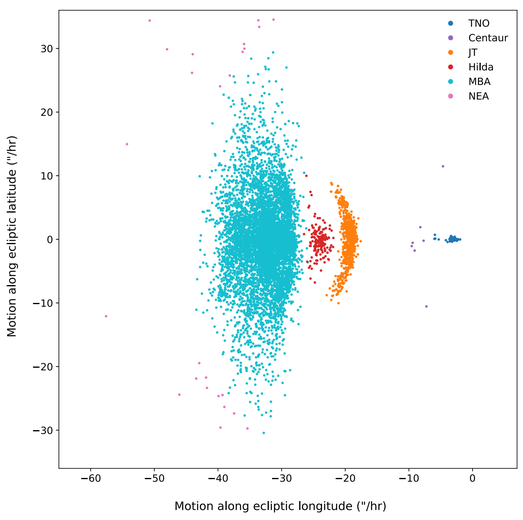
A Jupiter Trojan discovered by FOSSIL on 21 August 2020.

A Trans - Neptunian Object discovered by FOSSIL on 21 August 2020.

- We picked up real objects from numerous detection.
- We found ~1000 moving objects in each HSC field.
- We measured the brightness of each object with dedicated pipeline for moving objects, which our team member developed.



Motions along ecliptic longitude and latitude of the moving objects detected in the FOSSIL observations.



FOSSIL found: (unique objects)

206	TNOs
779	JTs
176	Hildas
7106	MBAs
22	NEAs

- Since observations were conducted near opposition, we are able to use the motion along Ecliptic longitude and latitude to distinguish different populations of moving objects: MBAs, Hildas, JTs, and TNOs. Moreover, several Near Earth Asteroids (NEAs) and Centaurs were also found.
- We picked JTs (orange points) for further orbit determination and rotation period analysis.

References

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