近太陽小惑星からの質量放出と、新天体の可能性について

Dust Ejection from Near-Sun Asteroids and Possibility of the Detection

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2. Active Asteroids

A Population of Comets in the Main Asteroid Belt

Henry H. Hsieh* and David Jewitt

Comets are icy bodies that sublimate and become active when close to the Sun. They are believed to originate in two cold reservoirs beyond the orbit of Neptune: the Kuiper Belt (equilibrium temperatures of ~40 kelvin) and the Oort Cloud (~10 kelvin). We present optical data showing the existence of a population of comets originating in a third reservoir: the main asteroid belt. The main-belt comets are unlike the Kuiper Belt and Oort Cloud comets in that they likely formed where they currently reside and may be collisionally activated. The existence of the main-belt comets lends new support to the idea that main-belt objects could be a major source of terrestrial water.

Temperatures in the outer parts of the protoplanetary disk of the Sun, beyond a critical distance known as the snow line (*1*), were low enough for water to condense as ice. The icy planetesimals that formed beyond the snow line are the progenitors of today's comets—ice-rich bodies that sublimate when close to the Sun, producing distinctive unbound atmospheres ("comae") and tails (*2*). The active lifetimes [~10^4 years (*3*)] of comets that pass inside Jupiter's orbit are short relative to the age of the solar system (4.6 × 10^9 years). This means that currently active comets must have only recently arrived in the inner solar system from cold reservoirs elsewhere, otherwise they would have exhausted their volatile material long ago. Two such originating reservoirs are well established. The Kuiper Belt (*4*) beyond Neptune (~30 to 50 AU from the Sun) supplies the so-called Jupiter-family comets (JFCs), whereas the much more distant Oort Cloud (*5*) (~3000 to 50,000 AU) supplies ice down to much smaller heliocentric distances (*7*), and it has long been suspected that other populations (such as the Hilda asteroids at 4 AU and the jovian Trojans at 5 AU) might be ice-rich, dormant comets (*8*, *9*). However, the active comet population we see today consists mainly of objects from the Kuiper Belt and Oort Cloud that have been scattered onto Jupiter-crossing orbits by gravitational interactions with the giant planets (*3*, *10*). Even the dynamically peculiar comet 2P/Encke is believed to have originated in the Kuiper Belt, albeit with an orbital evolutionary history strongly influenced by nongravitational forces induced by cometary outgassing (*11*, *12*).

Despite occupying a thoroughly asteroidal orbit in the main belt between the orbits of Mars and Jupiter, asteroid 7968 Elst-Pizarro (also known as comet 133P/Elst-Pizarro) was observed to eject dust like a comet when near perihelion in both 1996 and 2002 (*13*, *14*).

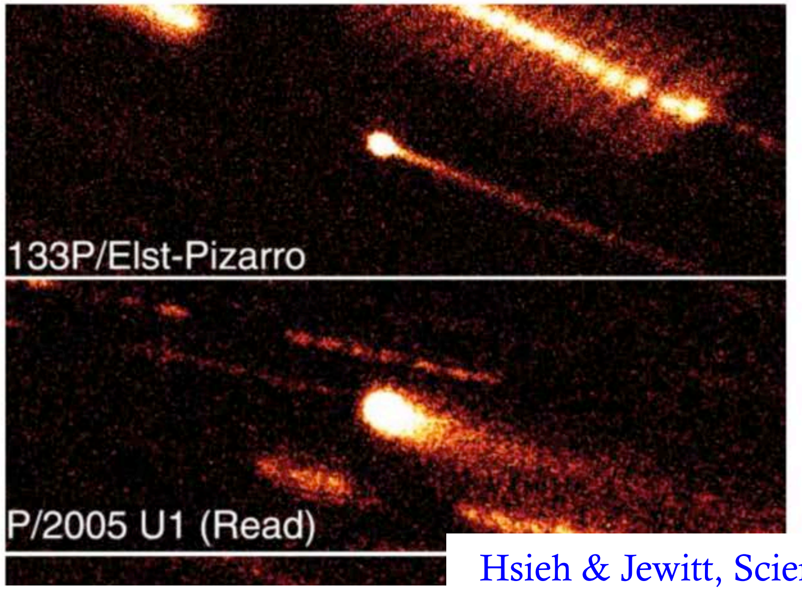
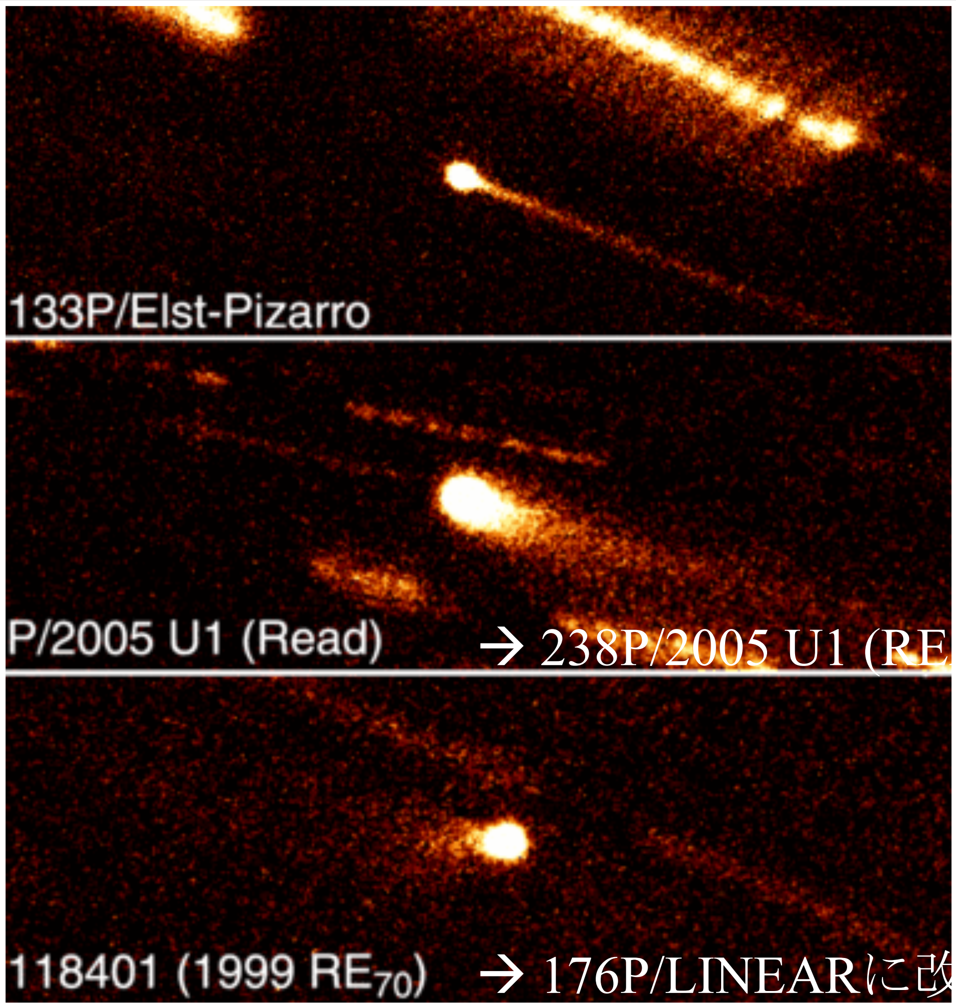


Fig. 1. *R*-band (wavelength 0.65 μm) images of MBCs 133P/Elst-Pizarro on 7 September 2002 (*14*), P/2005 U1 (Read) on 10 November 2005, and 118401 (1999 RE_{70}) on 27 December 2005 (all dates UT). All images are composites (0.5′ by 1.5′ in size, with north at the top and east to the left) from data taken at the University of Hawaii 2.2-m telescope on Mauna Kea, and represent 1.1 hours, 1.9

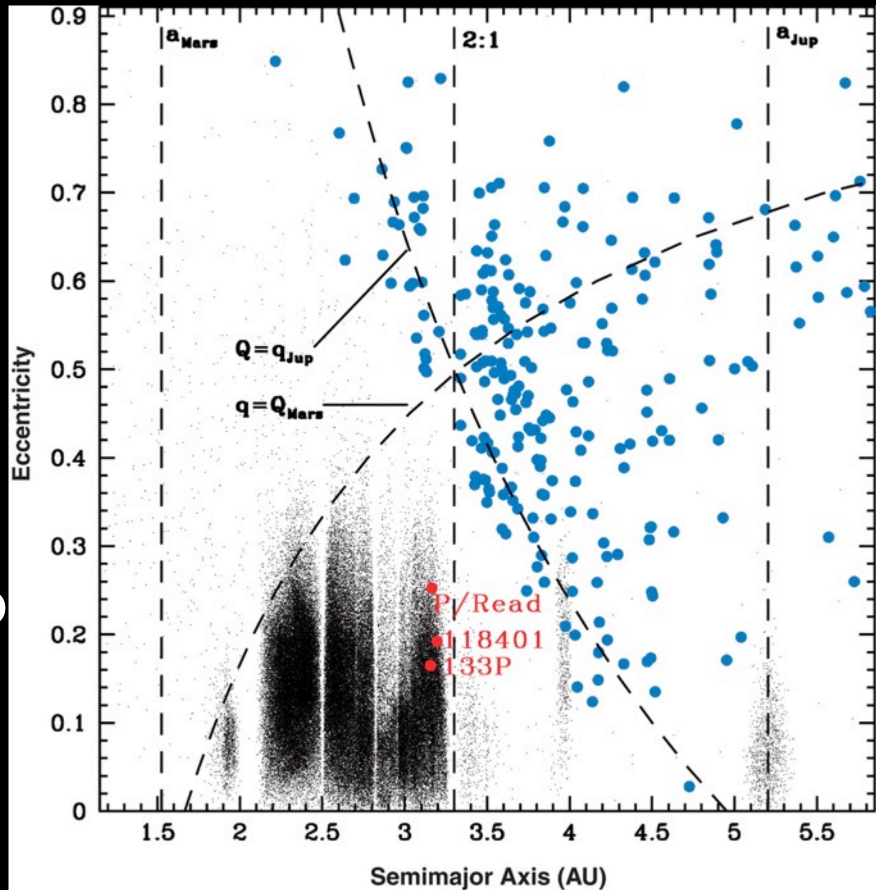
Hsieh & Jewitt, Science 312, 5773, 561, 2006

2. Active Asteroids



→ 238P/2005 U1 (READ

→ 176P/LINEARに改名

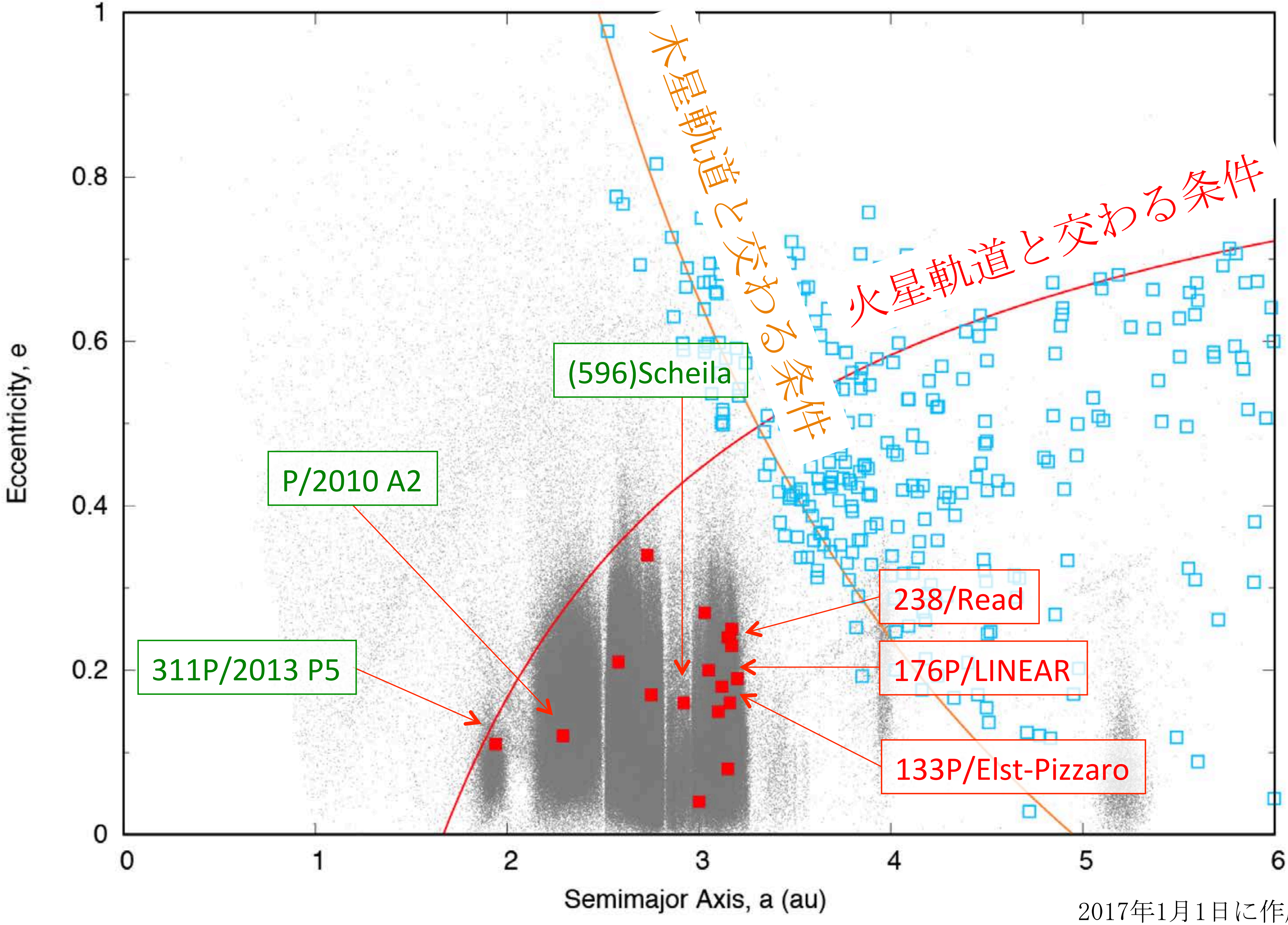


Hsieh & Jewitt, Science 312, 5773, 561, 2006

	a [AU]	e	i [°]	T_J
133P/Elst-Pizarro	3.16	0.16	1.4	3.18
176P/LINEAR	3.20	0.19	0.2	3.17
238P/2005 U1 (READ)	3.17	0.25	1.3	3.15

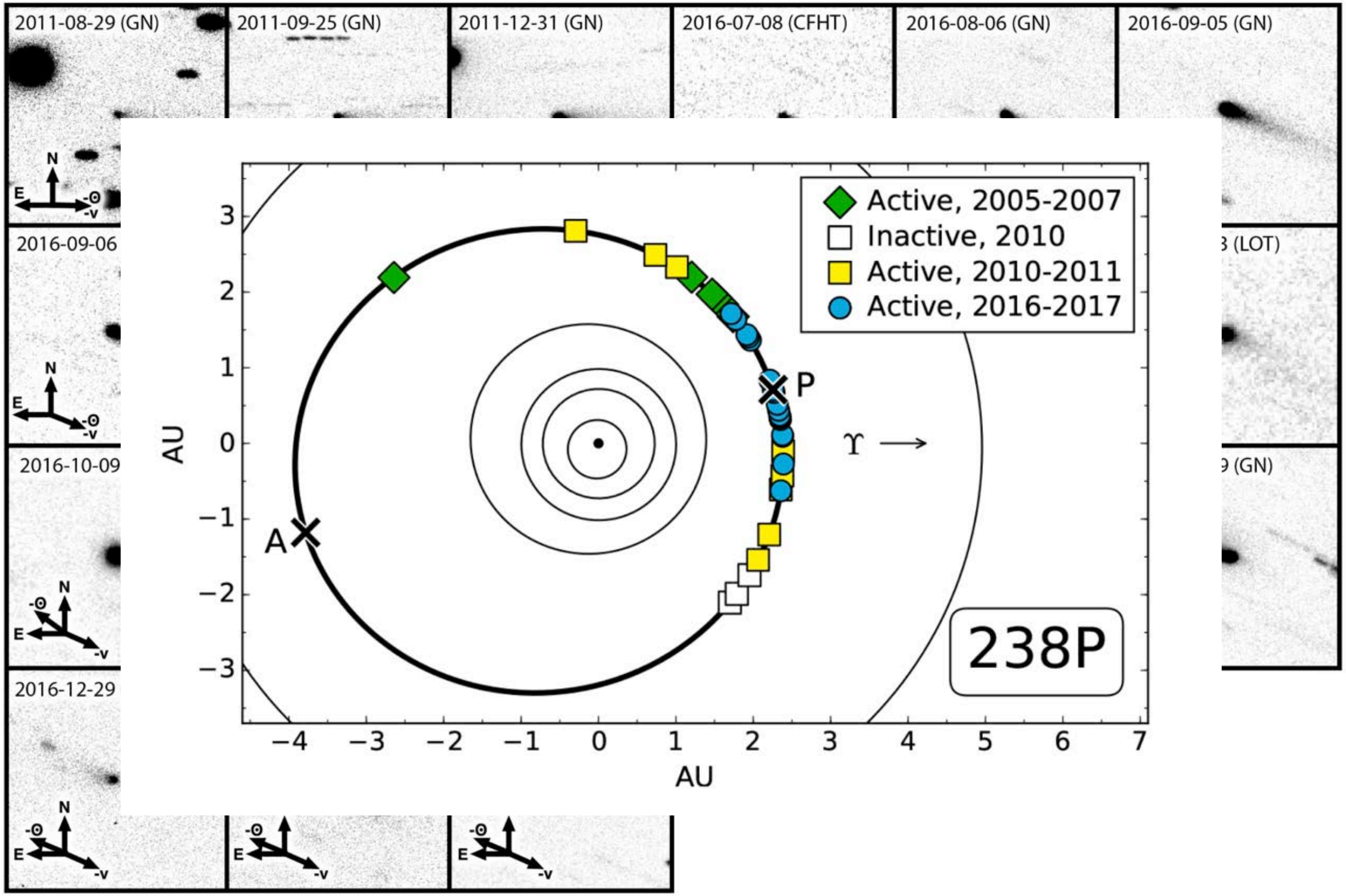
	a [AU]	e	i [°]	T_J
133P/Elst-Pizarro	3.16	0.16	1.4	3.18
176P/LINEAR	3.20	0.19	0.2	3.17
238P/2005 U1 (READ)	3.17	0.25	1.3	3.15
259P/2008 R1 (Garradd)	2.73	0.34	15.9	3.22
P/2010 A2	2.29	0.12	5.3	3.58
324P/2010 R2 (La Sagra)	3.10	0.15	21.4	3.10
(596) Scheila	2.92	0.16	14.7	3.21
288P/2006 VW139	3.05	0.20	3.2	3.20
331P/2012 F5 (Gibbs)	3.00	0.04	9.7	3.23
P/2012 T1 (PANSTARRS)	3.15	0.24	11.1	3.14
P/2013 R3 (Catakina-PANSTARRS)	3.03	0.27	0.9	3.18
311P/2013 P5 (PANSTARRS)	1.94	0.11	5.0	3.66
(62412) 2000 SY178	3.15	0.08	4.7	3.20
313P/Gibbs (P/2014 S4)	3.16	0.24	11.0	3.13
(493) Griseldis	3.12	0.18	15.2	3.14
P/2015 X6 (PANSTARRS)	2.75	0.17	4.6	3.32
P/2016 G1 (PANSTARRS)	2.58	0.21	11.0	3.37
P/2016 J1 (PANSTARRS)	3.17	0.23	14.3	3.11

2. Active Asteroids



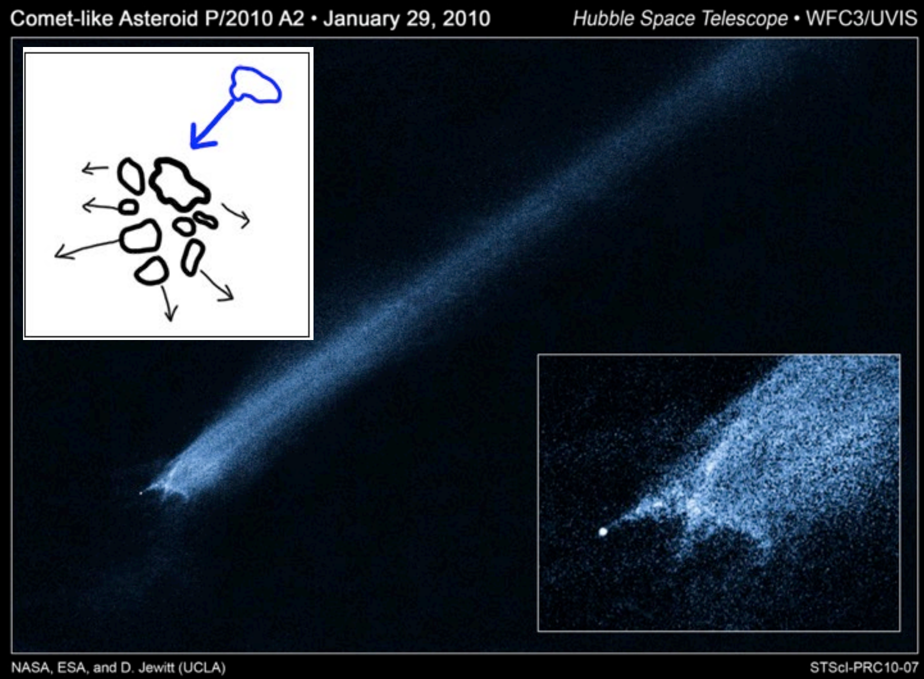
2017年1月1日に作成

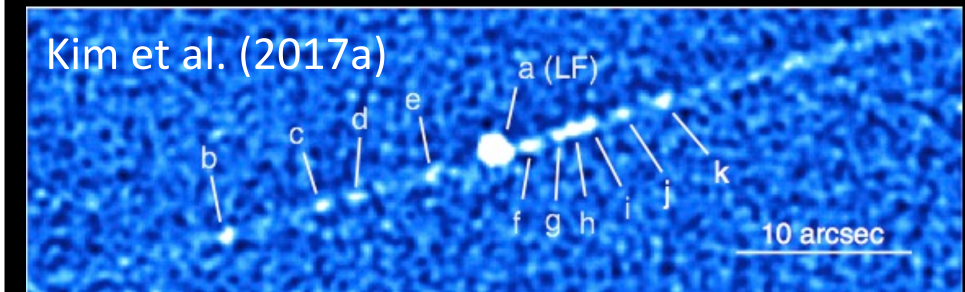
水の昇華による活動例(1)238P/Read

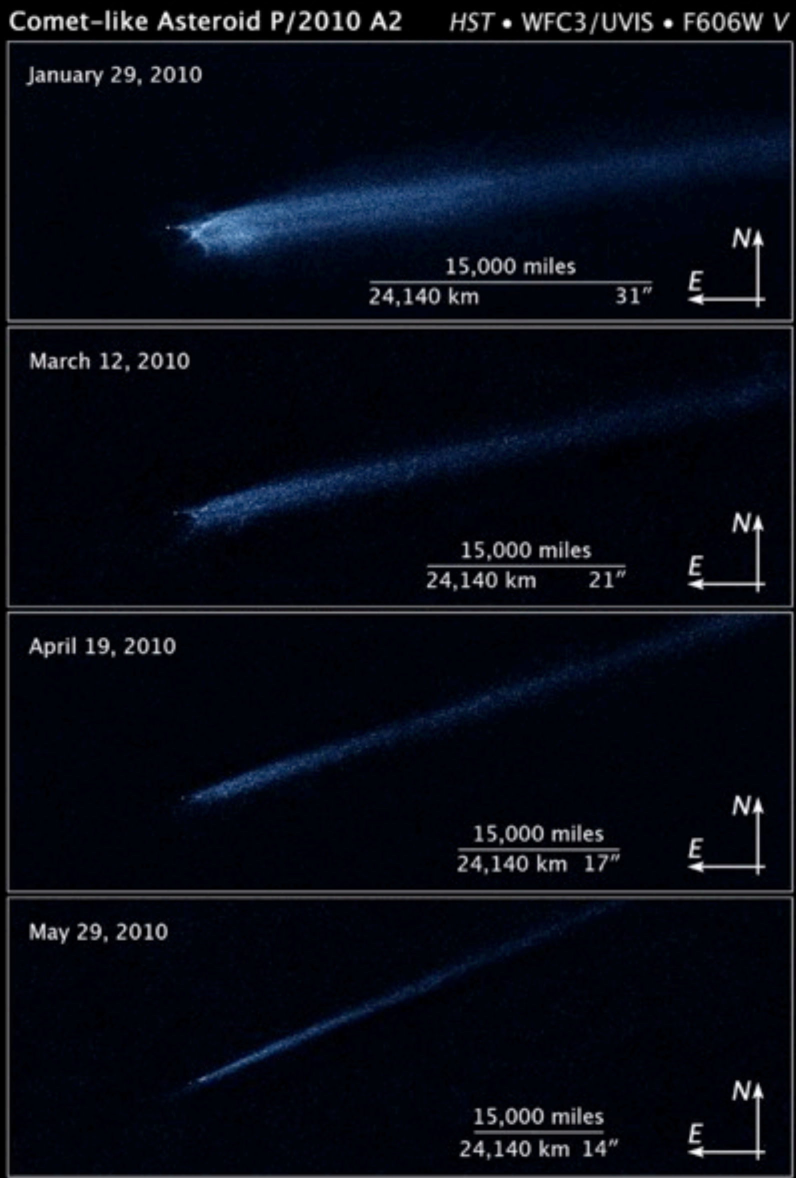


Hsieh,et al. AJ 156, 5, 223 (2018)

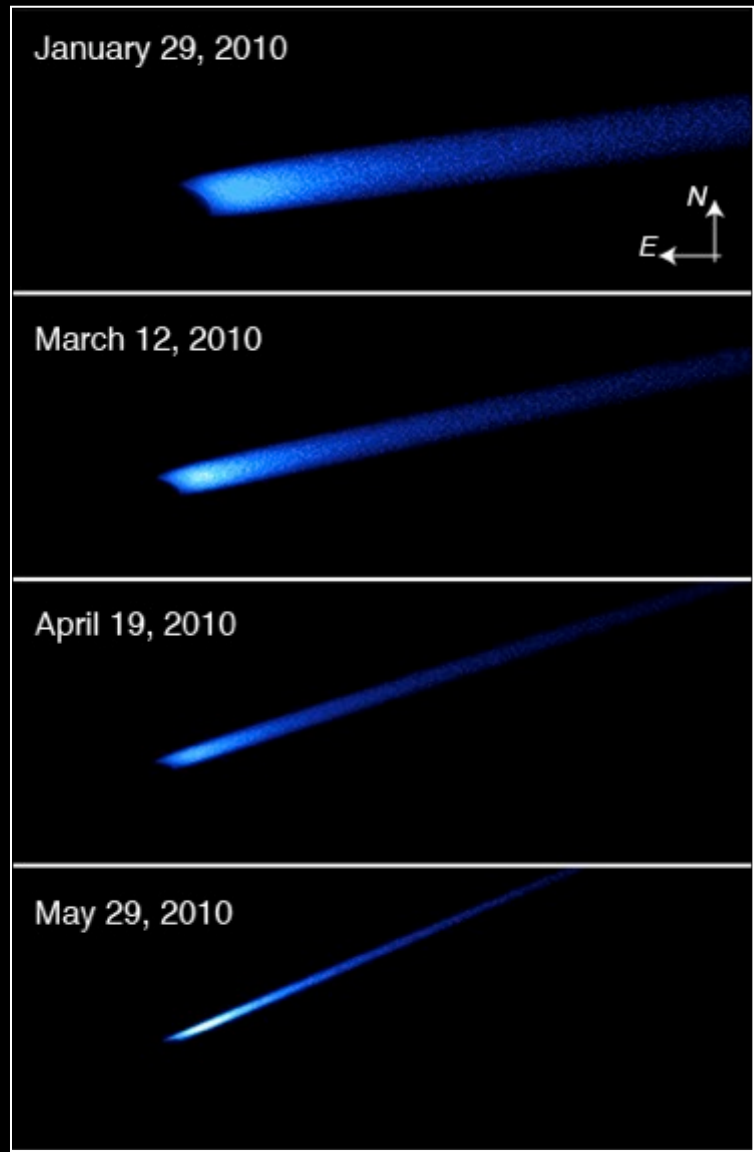
2.彗星？小惑星？：天体同士の衝突の事例







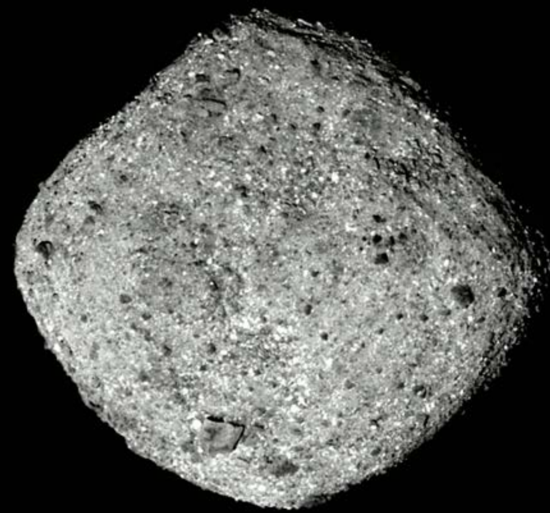
Jewitt et al. Nature 467, 7317, 817, 2010



Kim, Ishiguro, et al. 2017

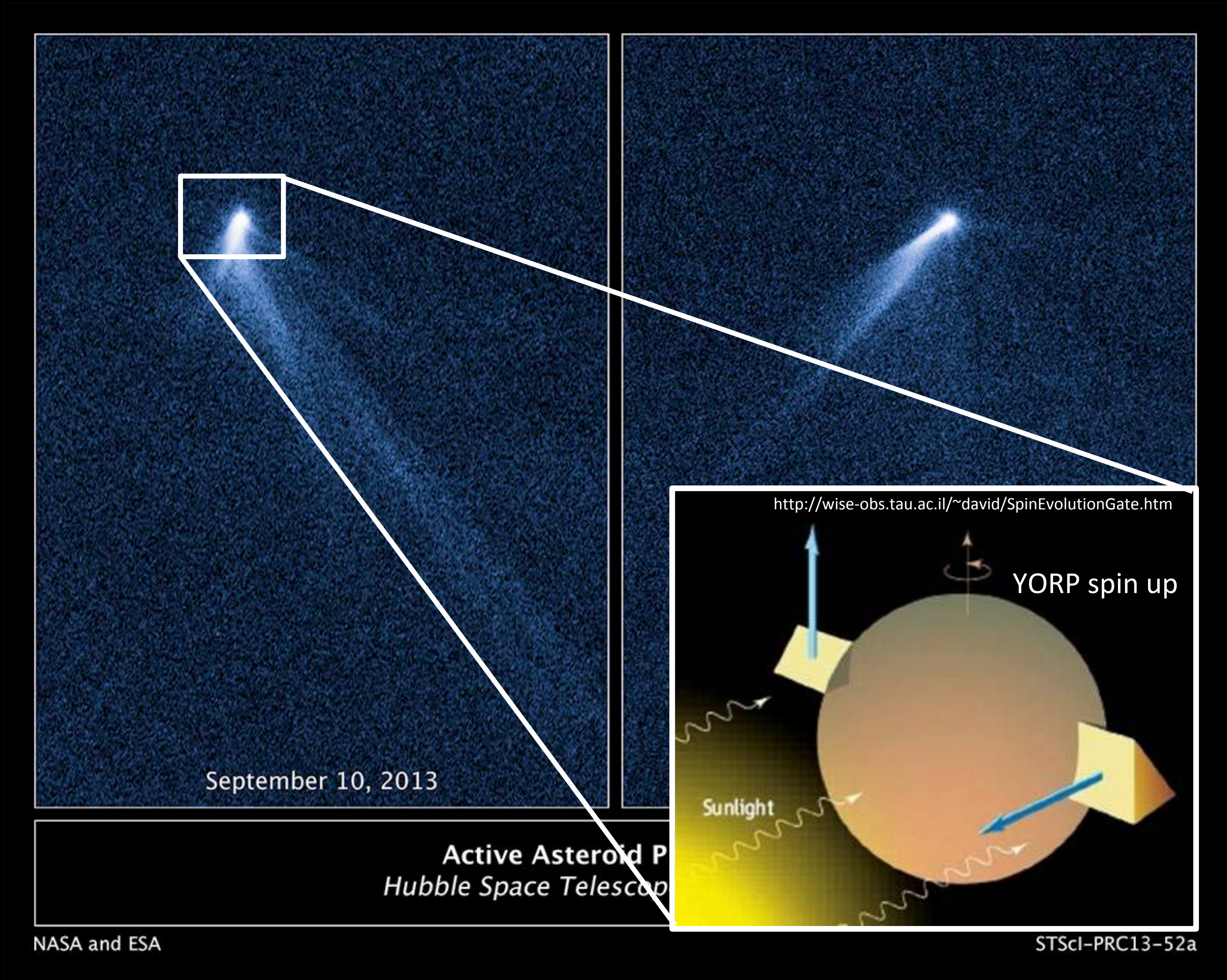
さらに…

Watanabe et al. (2019)



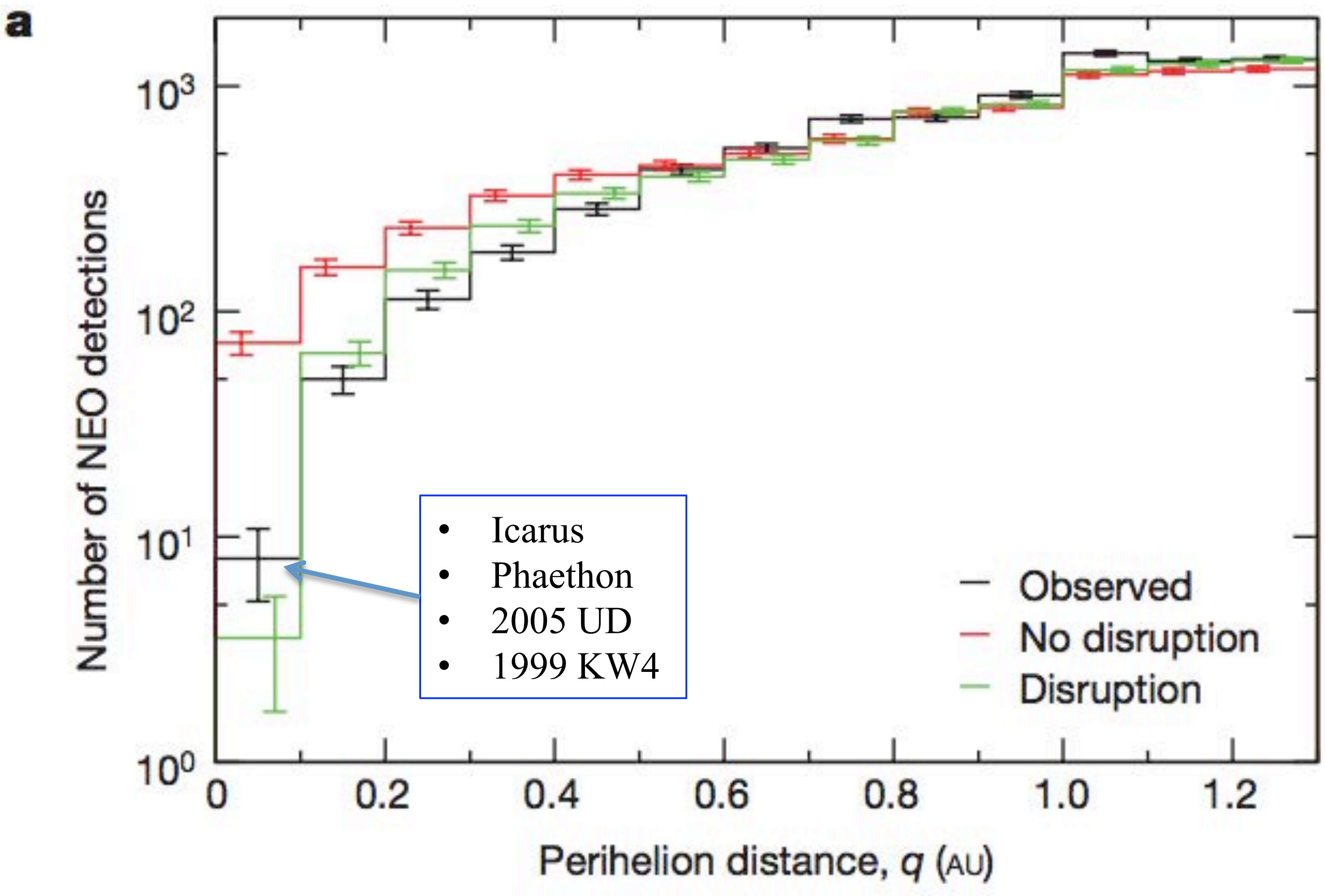
Lauretta et al. (2019)

2.彗星？小惑星？: 自転崩壊の例



Jewitt et al. 778, 1, L21 (2013)

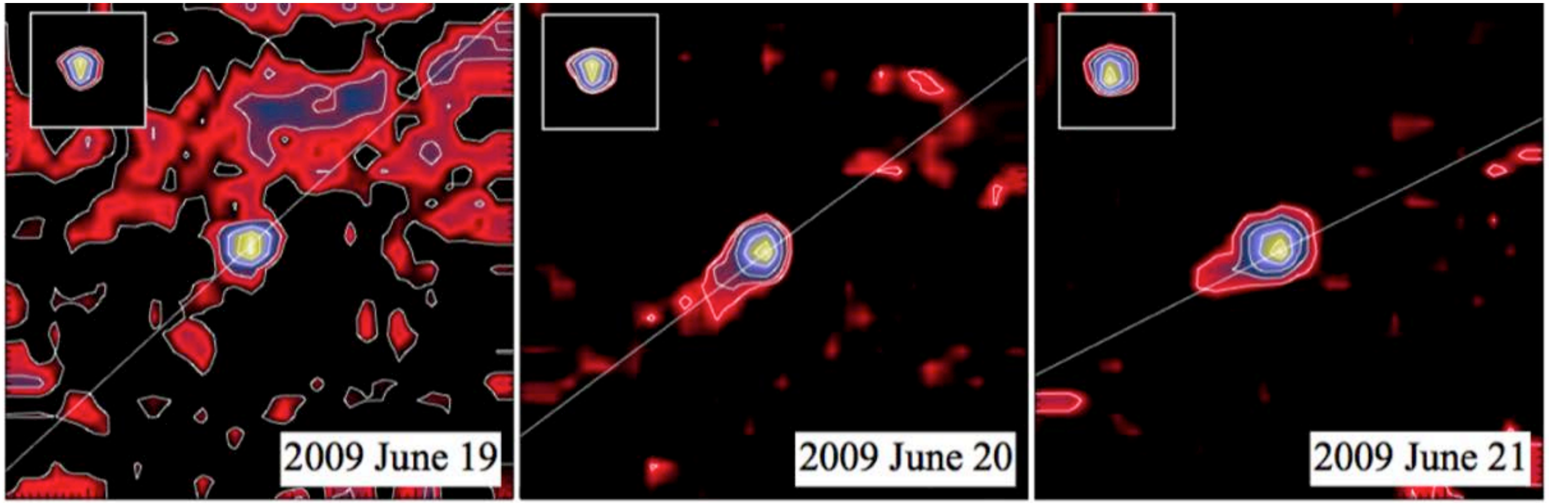
さらに、太陽に近い小惑星はこわれる説？



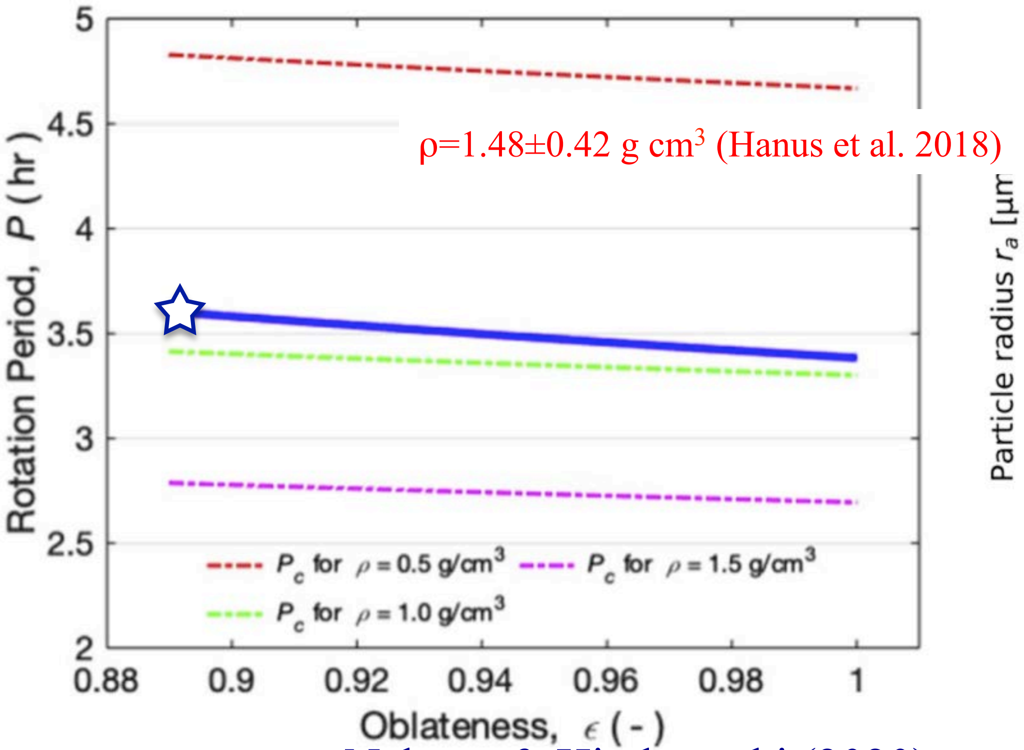
Granvik, M. et al. 2016, Natur.530..303G

4. 近太陽小惑星Phaethon

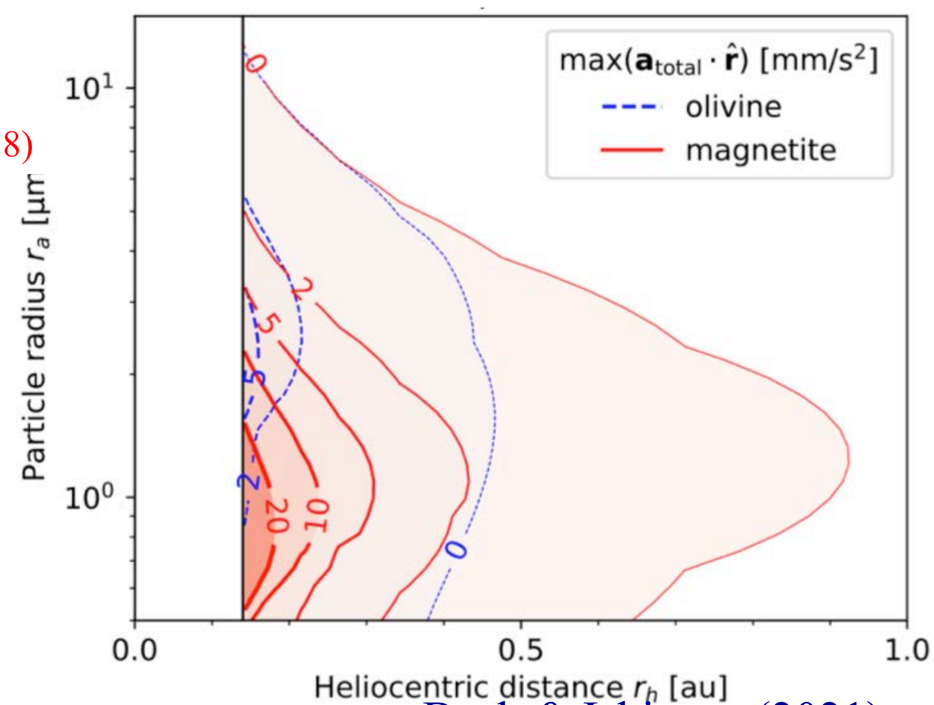
- 1983年IRASによって発見
- 発見直後からふたご座流星群との関連が指摘**(Whipple 1983)**
- 炭素質物質を主成分とするBまたはF型に分類
- 含水鉱物 vs 無水鉱物(Licandro+2007, Clark+2011)
- 近日点通過時に彗星活動（**1μm**程度の小さいダスト）
- **JAXA/DEXTINY^{+}探査天体(Arai+)**



Jewitt, Li, Agarwal (2013)



Nakano & Hirabayashi (2020)



Bach & Ishiguro (2021)

Rotational disruption of an asteroid

申し訳ありませんが、未論文化の内容は削除しています。

まとめ

- 小惑星は、氷の昇華や衝突、高速自転、さらに表面熱輻射などによってダストを放出する（→Active asteroids、新天体発見）。

- 条件次第では、衝突や自転で崩壊を起こすこともある。

- 特に、高速自転（周期4時間未満）の小惑星からの質量放出や地質学は、はやぶさ２とDESTINY+をつなぐ研究テーマであり、学術的価値は高いと考えられる。

Frequencies of Asteroids and Comets Outbursts

1. Comet Outbursts
    - Ikeya-Murakami class: 1~2 /year
    - Holmes class: 0.01 /year
2. Asteroid Impacts
    - Catastrophe : 1 /year
    - Cratering : 0.1 /year
3. Centrifugal disintegration
    - Asteroids >100-m: 10 /year

* Ishiguro, Kuroda, Hanayama et al. AJ (2016)

** Jewitt, Hsieh & Agarwal, Asteroids IV221 (2015)