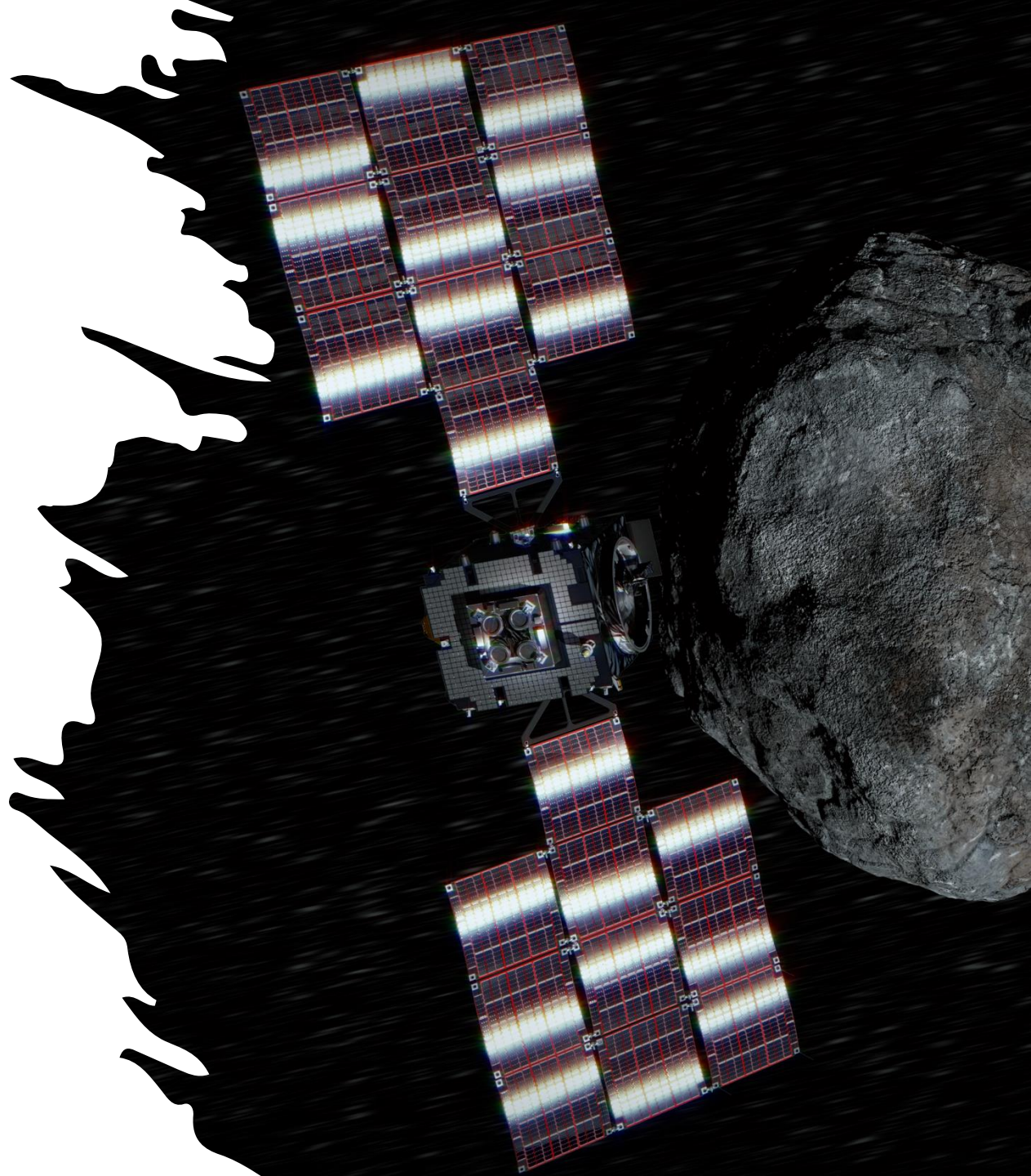
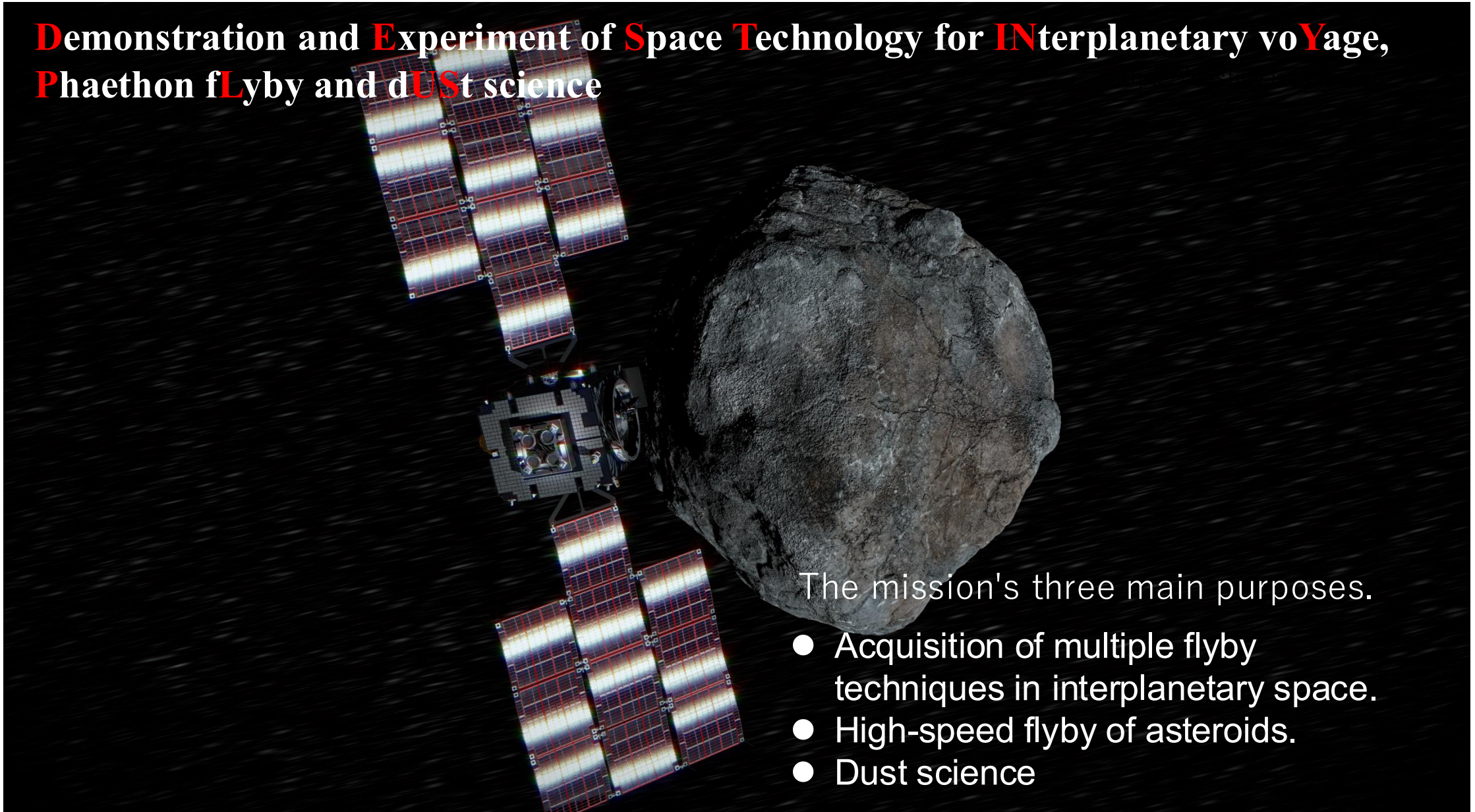
DESTINY+ Mission – Apophis (99942) and Phaethon (3200) flyby – supporting with occultation observations

Fumi Yoshida
(UOEH/PERC)



DESTINY+ mission

Demonstration and **E**xperiment of **S**pace **T**echnology for **IN**terplanetary vo**Y**age, **P**haethon f**L**yby and d**US**t science



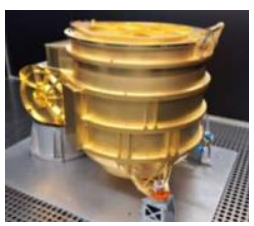
The mission's three main purposes.

- Acquisition of multiple flyby techniques in interplanetary space.
- High-speed flyby of asteroids.
- Dust science

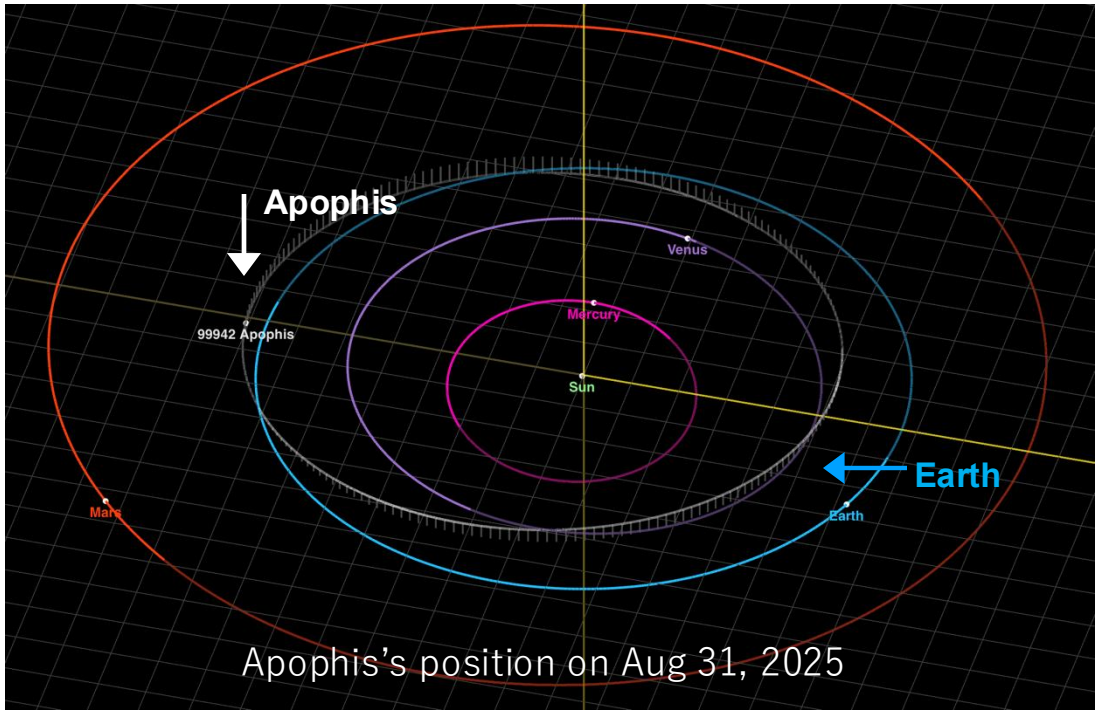
DESTINY+ mission

Dust Analyzer

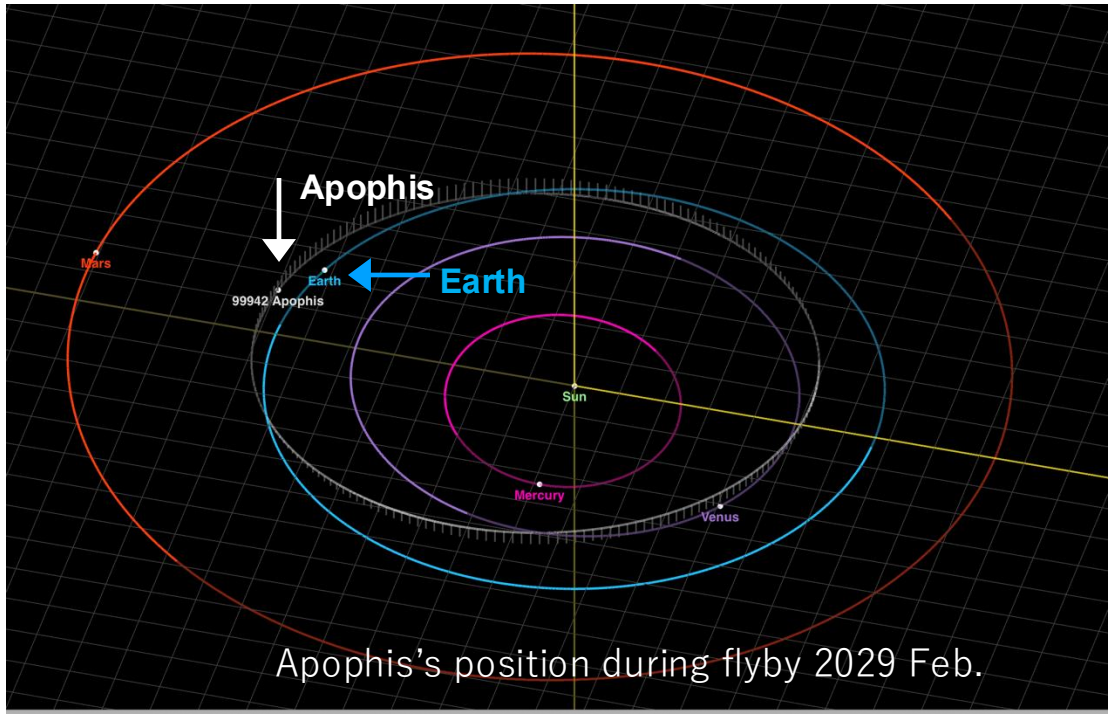
Analyze the dust's trajectory and composition



Apophis’s orbit



Apophis’s position on Aug 31, 2025



Apophis’s position during flyby 2029 Feb.

Near-Earth asteroid. Discovered in June 2004. Orbits in an elliptical path from just outside Earth's orbit to near Venus's orbit, completing one revolution in 323 days. Diameter is approximately 300 meters. Rotation period is 30.4 hours. Spectral type is Sq.

Apophis's orbit at closest approach

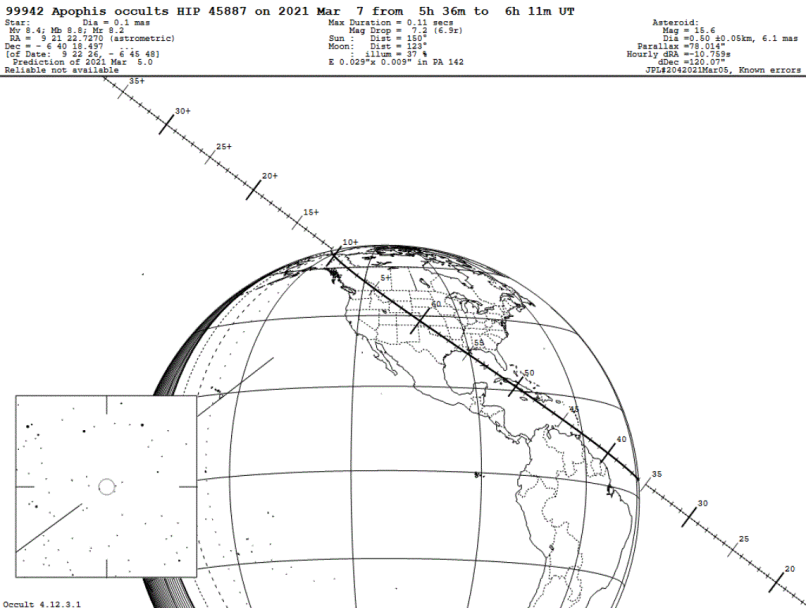
Other spacecraft will also explore Apophis

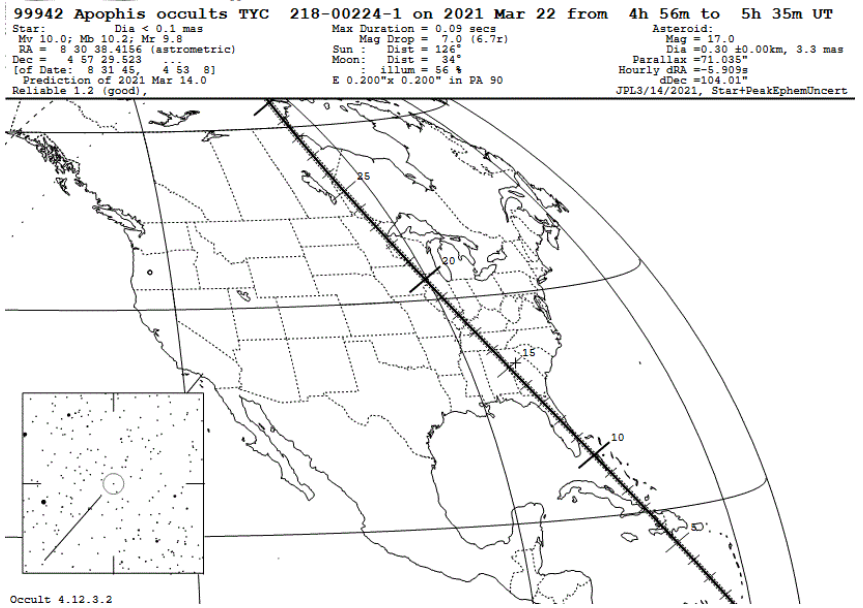
Let's support these missions through Apophis's occultation observations.

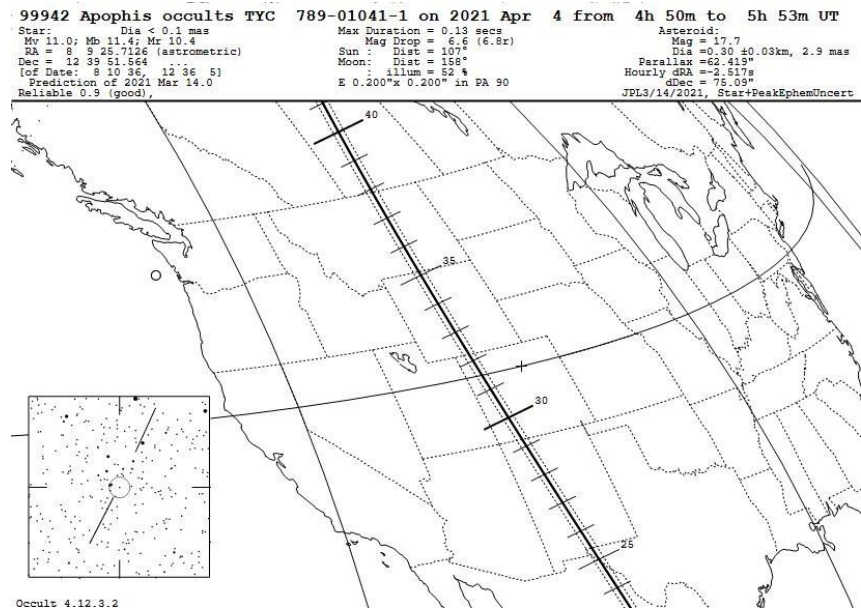
Previous Occultation Observations of Apophis

	Date（UT）	Star	Observers	Duration（sec）
1	2021.03.07	HIP 45887	D. Dunham/J. Dunham(2+, 3m), R. Nugent, N. Carlson(m), P. Ceravolo/D. Ceravolo(m), K. Getrost(m), B. Gowe(m), J. Moore(2m), M. Skrutskie(m), R. Venable(4m)	0.07
2	2021.03.22	Tycho2 0218-00224-1	R. Venable (1+, 4m), D. Dunham/J. Dunham(m), K. Getrost(m), A. Olsen(m), N. Smith/L. Dorsey(m)	0.09
3	2021.4月4日	Tycho2 0789-01041-1	N. Carlson, K. Getrost, R. Venable(1+, 3m)	0.13
4	2021年4月10日	UCAC4 528-046251	Hiroyuki Watanabe, Hideto Yamamura(m)	0.15
5	2021年4月11日	Tycho2 1376-00848-1	N. Carlson, K. Getrost, V. Sempronio	0.15
6	2021年5月6日	Tycho2 1929-01244-1	S. Aguirre, N. Carlson, T. George, V. Sempronio (m)	0.16
7	2022年4月9日	Tycho2 5782-01139-1	R Venable	0.01

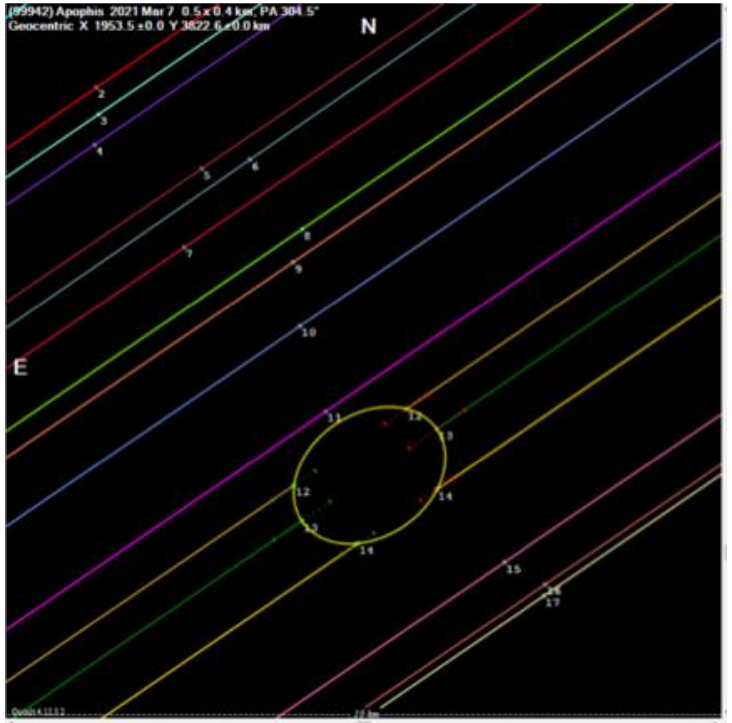
Occultations by Apophis have been observed several times in the past. In any cases, the duration time is around 0.1 seconds.







2021.03.07



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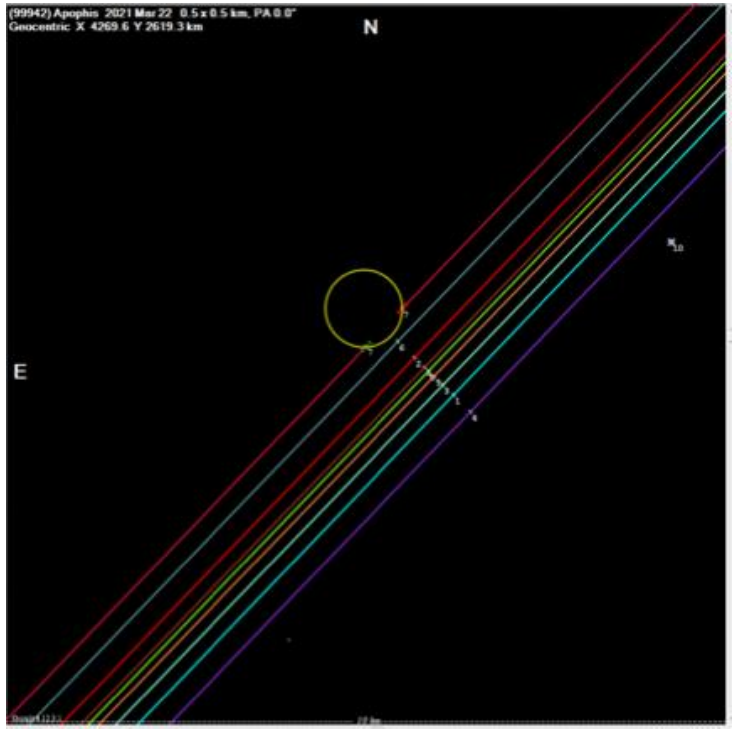
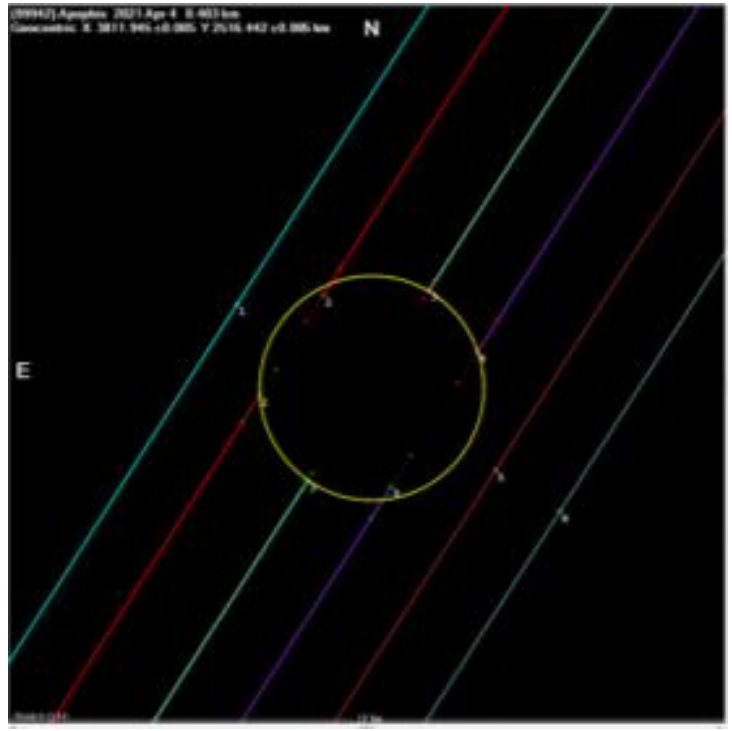


2021.04.07



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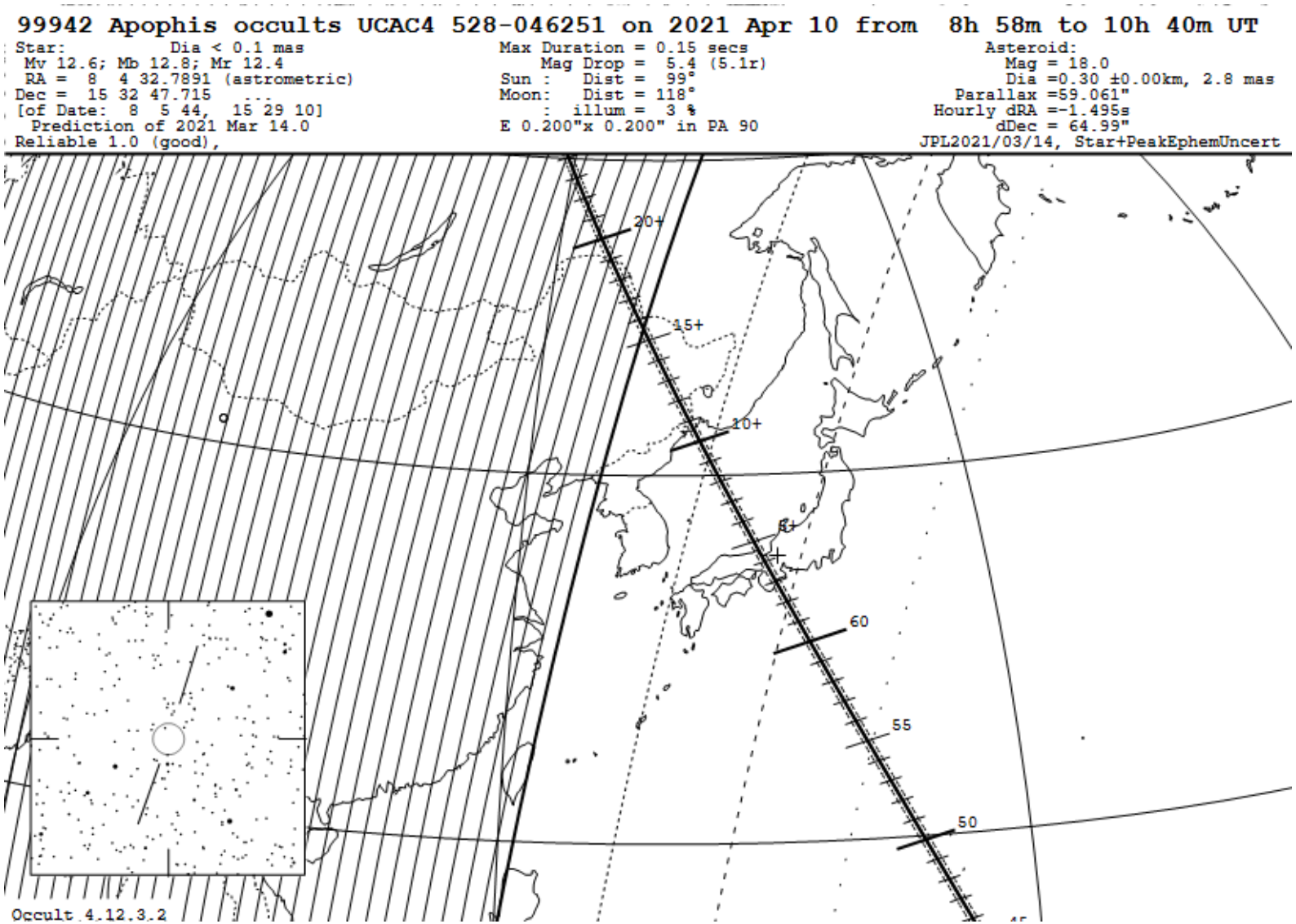
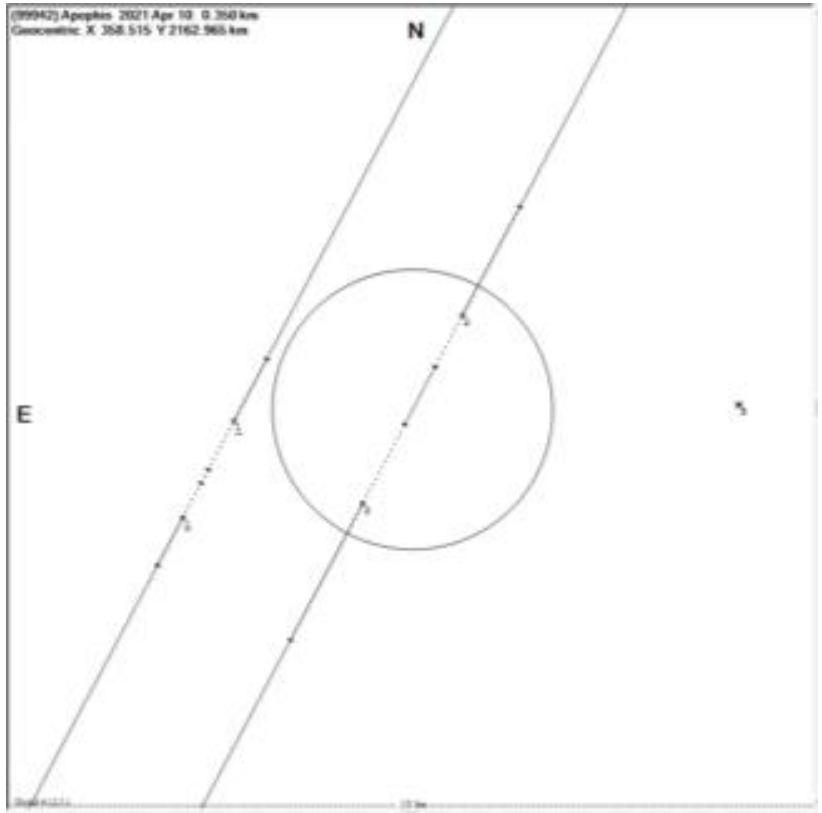
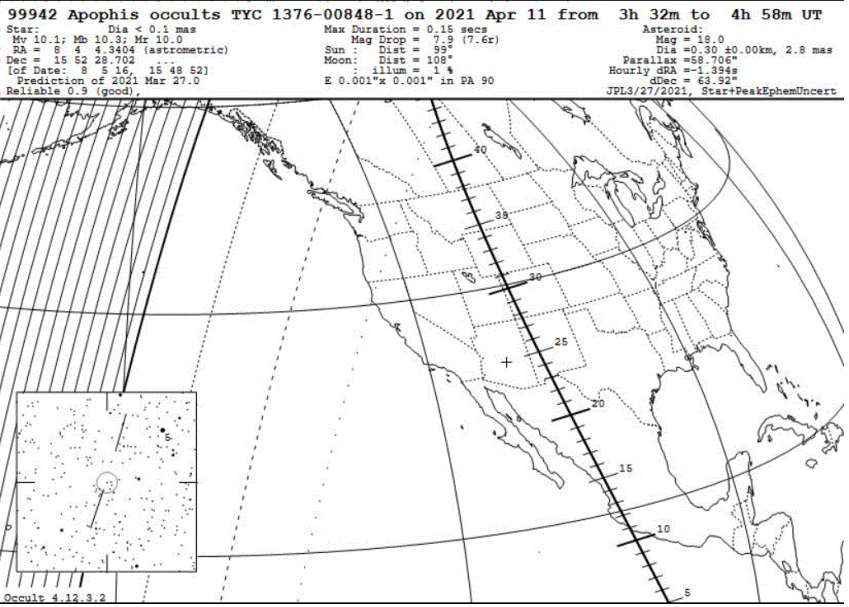
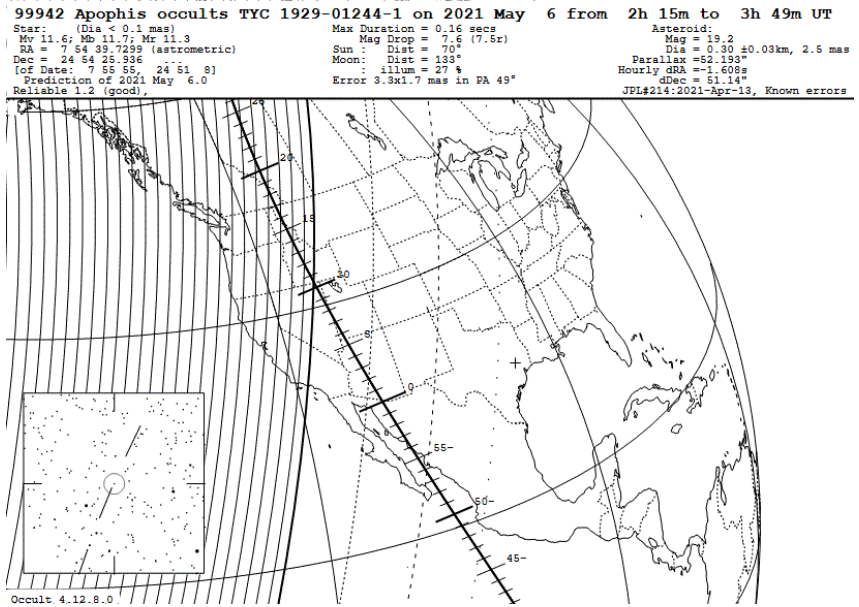
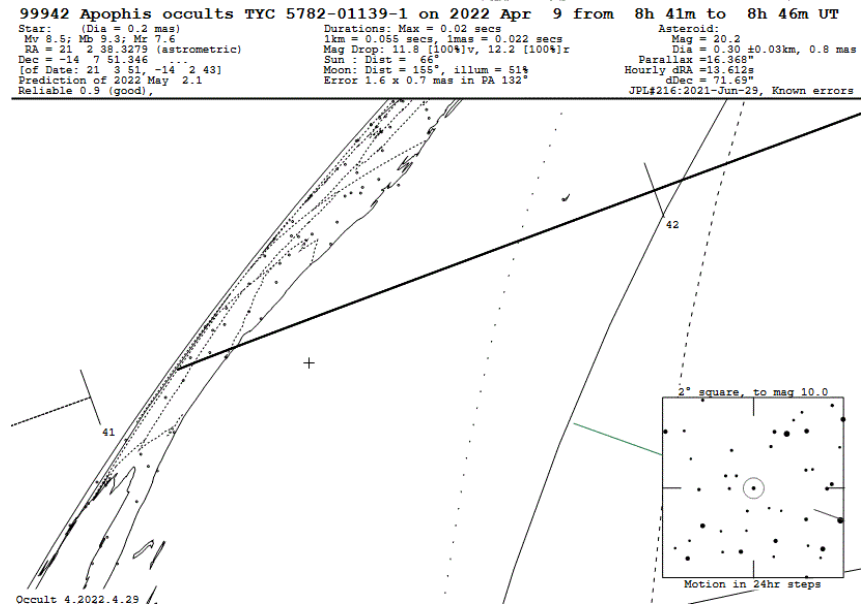




Members of IOTA/EA observed and successfully recorded this phenomenon.







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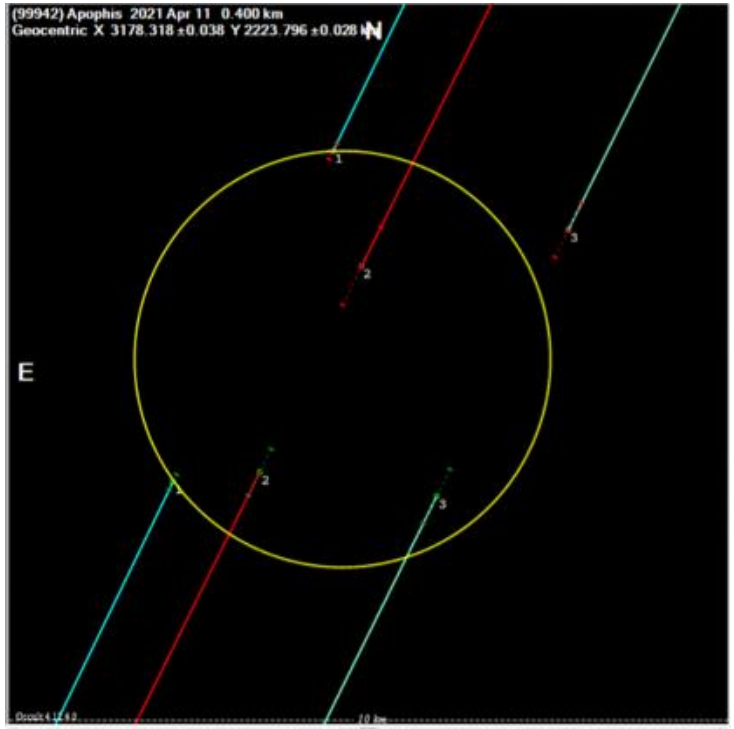
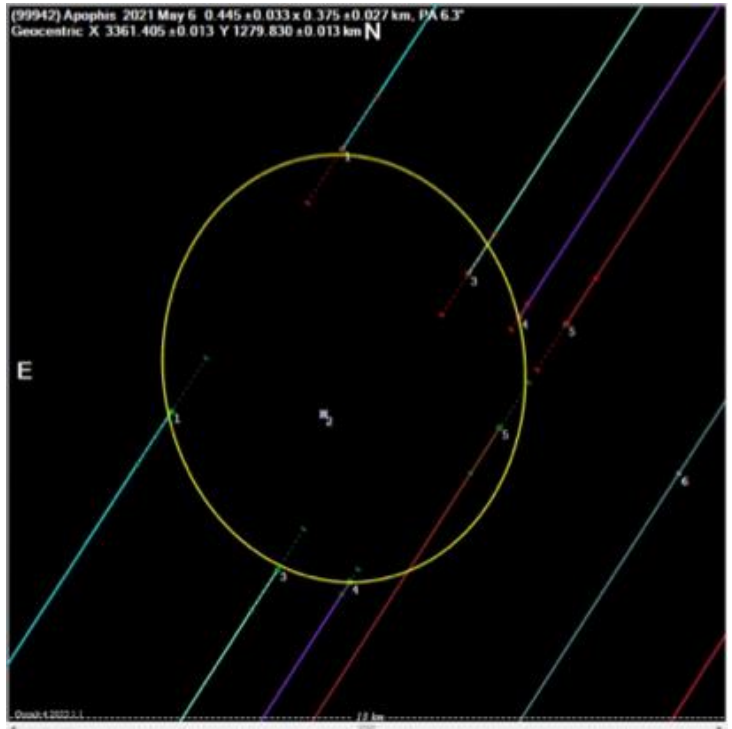


2021.05.06



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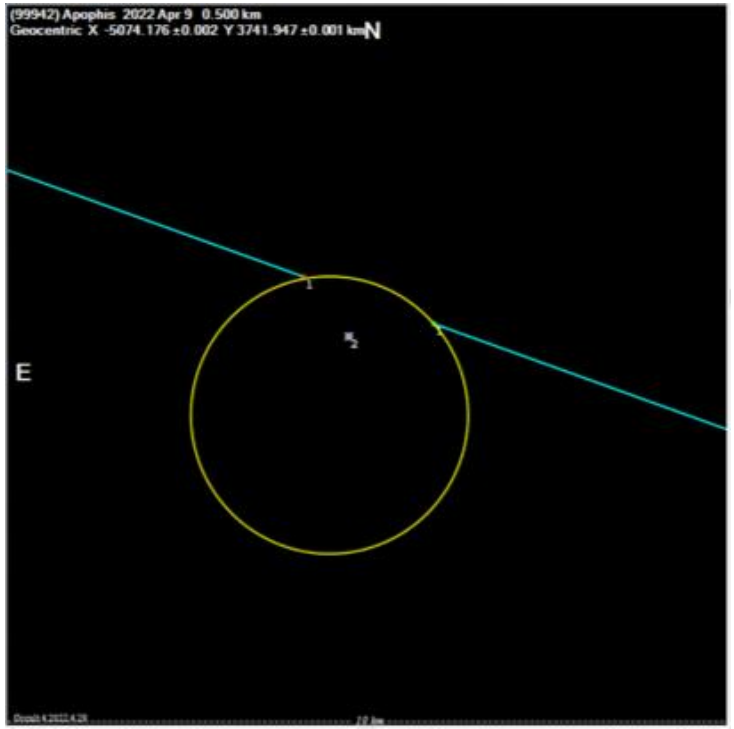


Future Observation Opportunities for Apophis Occultations

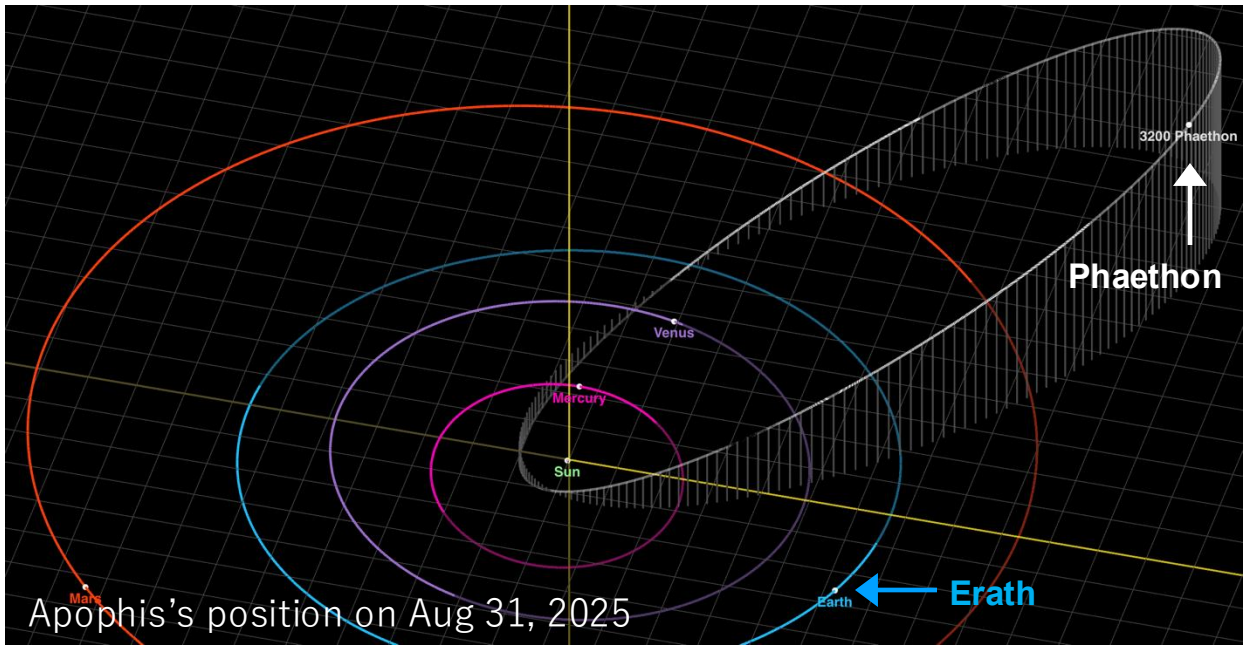
Between 2027 and the end of January 2029 (before flyby), there are 62 observation opportunities.
Twenty of these (yellow) are likely to be observable within the IOTA/EA coverage area.

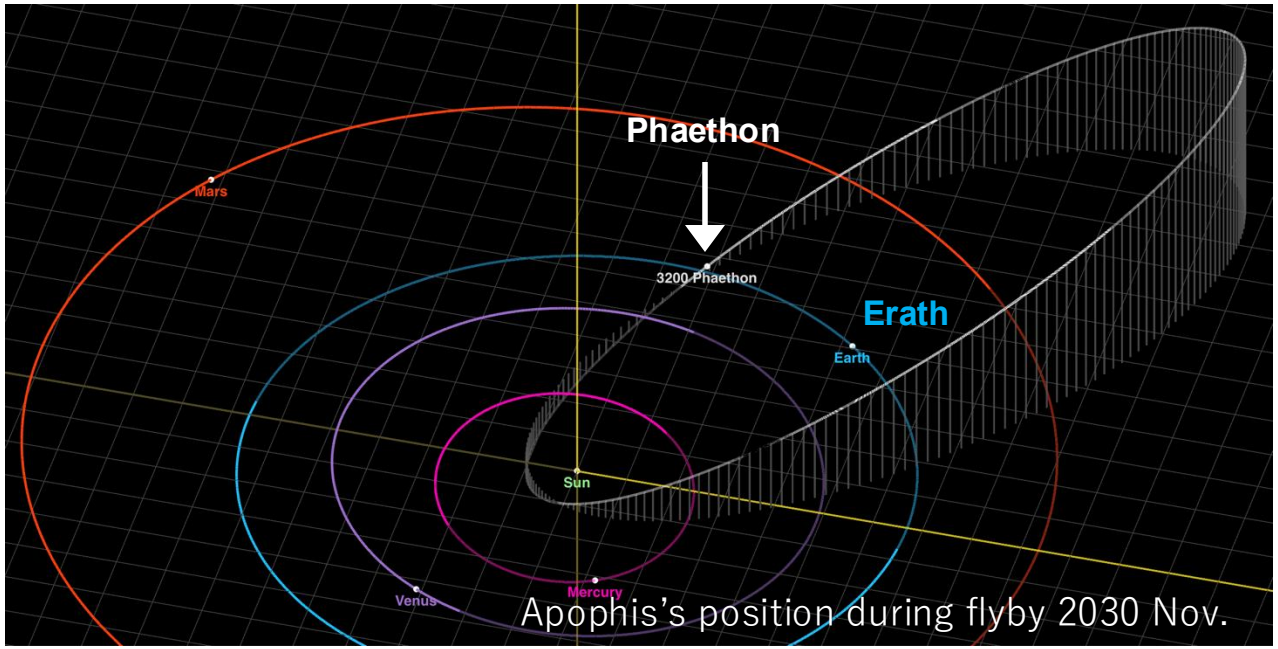
Predictions are available from here. **https://fumi-yoshida.wixsite.com/occultation-ws/apophis-occult-en**

Although there are many observation opportunities, each one requires precise timing to detect a dimming of about 0.01 seconds. It's very challenging.

	Date/Time	Star	RUWE	Mag.	Mag. (R),	Dur.(sec)	Area	Uncertainty (sec)	Shadow's velocity (m/sec)	Distance from the Earth (km)	Fresnel number
0	2027 Apr 21 from 11h 13m to 11h 19m UT	UCAC4 554-021042	1.2	10.6	9.8	0.02	Japan				
1	2028 Jan 02 from 13h 00m to 13h 14m UT	UCAC4 404-000176	0.95	12.2	11.67	0.010	China, Japan	0.040	14454	44101452	0.85
2	2028 Jan 10 from 14h 39m to 14h 55m UT	UCAC4 426-001125	1.25	11.4	10.97	0.011	Thai	0.043	13905	45447833	0.83
3	2028 Jan 10 from 12h 39m to 12h 52m UT	UCAC4 426-001114	1.10	13.6	12.88	0.011	China	0.043	13911	45432873	0.83
4	2028 Jan 13 from 18h 18m to 18h 31m UT	TYC 4681-02316-1	0.85	11.6	11.22	0.011	EU	0.044	13680	46300541	0.81
5	2028 Jan 14 from 14h 43m to 14h 56m UT	TYC 4682-00516-1	0.90	12.0	11.48	0.011	Mid Asia	0.045	13621	46569817	0.81
6	2028 Jan 20 from 02h 32m to 02h 46m UT	UCAC4 451-002232	1.20	12.3	11.60	0.011	USA	0.048	13262	48499630	0.77
7	2028 Jan 26 from 11h 21m to 11h 37m UT	UCAC4 467-003011	0.95	13.6	12.98	0.012	China, Japan	0.052	12918	51237271	0.73
8	2028 Jan 26 from 03h 09m to 03h 25m UT	UCAC4 466-003007	1.10	13.1	12.40	0.012	USA	0.052	12934	51072713	0.73
9	2028 Feb 04 from 15h 25m to 15h 42m UT	UCAC4 486-004147	1.20	12.1	11.27	0.012	Thai	0.058	12561	55874805	0.67
10	2028 Feb 05 from 05h 13m to 05h 29m UT	UCAC4 487-004365	1.05	13.1	12.44	0.012	USA	0.059	12543	56188960	0.67
11	2028 Feb 19 from 21h 40m to 21h 56m UT	UCAC4 512-006229	1.05	12.8	11.94	0.012	EU	0.069	12338	64716039	0.58
12	2028 Feb 20 from 05h 13m to 05h 28m UT	UCAC4 512-006280	1.05	13.3	12.55	0.012	USA	0.069	12340	64910516	0.58
13	2028 Feb 23 from 00h 35m to 00h 50m UT	UCAC4 516-007323	0.95	11.7	11.07	0.012	SA	0.071	12361	66630892	0.56
14	2028 Feb 26 from 11h 10m to 11h 23m UT	UCAC4 520-007868	1.00	12.5	11.52	0.012	AU	0.073	12408	68755181	0.55
15	2028 Mar 11 from 12h 59m to 13h 15m UT	UCAC4 534-011745	1.10	12.1	11.26	0.012	China	0.080	12738	77401938	0.48
16	2028 Mar 13 from 10h 06m to 10h 22m UT	UCAC4 536-013164	1.15	12.6	12.08	0.012	Japan	0.080	12796	78538882	0.48
17	2028 Mar 13 from 01h22m to 01h 34m UT	UCAC4 535-012750	1.10	13.9	13.36	0.012	SA	0.080	12784	78314485	0.48
18	2028 Mar 16 from 10h 36m to 10h 52m UT	UCAC4 538-015011	0.85	13.6	12.96	0.012	Japan	0.082	12898	80334057	0.47
19	2028 Mar 17 from 10h 32m to 10h 42m UT	UCAC4 539-015548	1.00	12.9	12.05	0.012	AU	0.082	12935	80917488	0.46
20	2028 Mar 19 from 12h 31m to 12h 48m UT	UCAC4 540-017225	0.95	10.9	10.46	0.012	China	0.083	13015	82129231	0.46
21	2028 Mar 19 from 13h 58m to 14h 14m UT	UCAC4 540-017258	1.40	12.9	12.38	0.012	China, Taiwan	0.083	13017	82174110	0.46
22	2028 Mar 22 from 00h 55m to 01h 08m UT	UCAC4 541-018802	1.00	13.6	13.04	0.011	SA	0.083	13118	83580330	0.45
23	2028 Mar 25 from 22h 45m to 23h 00m UT	UCAC4 543-022004	1.00	12.1	11.51	0.011	North Africa	0.085	13287	85779419	0.44
24	2028 Mar 25 from 20h 23m to 20h 38m UT	UCAC4 543-021954	1.00	13.6	13.15	0.011	EU	0.084	13283	85734540	0.44
25	2028 Mar 25 from 03h 36m to 03h 50m UT	UCAC4 543-021493	1.00	13.6	12.85	0.011	USA	0.084	13252	85345585	0.44
26	2028 Mar 26 from 13h 40m to 13h 55m UT	UCAC4 544-021484	1.00	13.8	13.30	0.011	China	0.085	13314	86123494	0.44
27	2028 Mar 26 from 11h 41m to 11h 56m UT	UCAC4 544-021461	1.00	13.8	13.20	0.011	Japan	0.085	13311	86078615	0.44
28	2028 Mar 27 from 11h 35m to 11h 50m UT	UCAC4 544-021742	1.00	13.9	13.39	0.011	Japan	0.085	13355	86632127	0.43
29	2028 Mar 27 from 15h 57m to 16h 12m UT	UCAC4 544-021820	1.05	13.2	12.15	0.011	Mid Asia	0.085	13363	86721886	0.43
30	2028 Mar 29 from 15h 28m to 15h 43m UT	UCAC4 545-023310	1.05	13.5	12.96	0.011	Hong Kong?	0.085	13452	87798990	0.43
31	2028 Apr 02 from 22h 40m to 22h 52m UT	UCAC4 546-026969	0.90	12.2	11.72	0.011	SA	0.086	13641	90027999	0.42
32	2028 Apr 04 from 20h 59m to 21h 13m UT	UCAC4 547-028160	1.20	12.8	12.66	0.011	EU	0.087	13722	91000385	0.41
33	2028 Apr 05 from 18h 44m to 18h 59m UT	UCAC4 547-029041	1.00	13.7	13.33	0.011	North Africa	0.087	13760	91449178	0.41
34	2028 Apr 05 from 14h 16m to 14h 30m UT	UCAC4 547-028850	0.95	12.0	11.42	0.011	China	0.087	13752	91344460	0.41
35	2028 Apr 05 from 21h 20m to 21h 34m UT	UCAC4 547-029148	1.00	13.7	13.70	0.011	EU	0.087	13765	91494058	0.41
36	2028 Apr 09 from 14h 23m to 14h 37m UT	UCAC4 548-032524	0.85	12.1	11.53	0.011	China	0.088	13915	93259313	0.4
37	2028 Apr 11 from 23h 24m to 23h 36m UT	UCAC4 548-034607	1.20	14.0	13.51	0.011	SA	0.088	14011	94321458	0.4
38	2028 Apr 12 from 03h 01m to 03h 16m UT	UCAC4 548-034711	0.95	13.2	12.49	0.011	USA	0.088	14017	94396256	0.4
39	2028 Apr 13 from 14h 54m to 15h 07m UT	UCAC4 548-035859	1.10	12.4	11.82	0.011	China	0.088	14078	95039527	0.39
40	2028 Apr 17 from 09h 30m to 09h 41m UT	UCAC4 548-038178	1.00	13.2	12.71	0.011	AU	0.089	14233	96610305	0.39
41	2028 Apr 19 from 03h 34m to 03h 47m UT	UCAC4 548-039037	1.00	12.7	11.92	0.010	USA	0.089	14305	97298455	0.39
42	2028 Apr 21 from 10h 49m to 11h 02m UT	UCAC4 548-040000	1.00	11.7	10.92	0.010	Japan	0.089	14399	98151163	0.38
43	2028 Apr 23 from 11h 59m to 12h 12m UT	UCAC4 548-040752	0.95	12.9	12.51	0.010	AU	0.089	14480	98884193	0.38
44	2028 Apr 26 from 11h 01m to 11h 12m UT	TYC 1369-00345-1	0.95	12.3	12.05	0.010	AU	0.090	14592	99856579	0.38
45	2028 Apr 28 from 04h 19m to 04h 31m UT	UCAC4 547-041893	0.80	12.5	12.11	0.010	USA	0.090	14653	100380171	0.37
46	2028 May 20 from 02h 42m to 02h 55m UT	UCAC4 538-048196	1.30	12.8	12.20	0.020	USA	0.044	15062	104164997	0.36
47	2028 Jul 08 from 23h 02m to 23h 21m UT	UCAC4 498-057746	1.25	12.2	11.44	0.026	South America	0.049	11365	87754111	0.43
48	2028 Nov 07 from 10h 14m to 10h 47m UT	UCAC4 469-043431	0.85	12.3	11.72	0.047	USA	0.061	6418	61843760	0.61
49	2028 Nov 26 from 23h 32m to 23h 57m UT	TYC 4921-00526-1	1.05	10.5	10.06	0.041	Mid Asia	0.055	7403	64177487	0.58
50	2028 Nov 27 from 01h 40m to 02h 01m UT	UCAC4 441-053269	1.10	12.9	12.40	0.041	Africa	0.055	7404	64177487	0.58
51	2028 Nov 28 from 08h 54m to 09h 20m UT	UCAC4 439-052412	0.95	11.4	10.76	0.040	South America	0.054	7417	64132607	0.58
52	2028 Dec 07 from 22h 19m to 22h 46m UT	UCAC4 425-055405	1.05	13.2	12.20	0.041	Mid Asia	0.054	7363	63205100	0.59
53	2028 Dec 13 from 0Oh 55m to 01h 22m UT	UCAC4 418-054653	0.90	13.1	12.43	0.042	Africa	0.054	7218	62232714	0.6
54	2028 Dec 22 from 03h 58m to 04h 20m UT	TYC 5518-00851-1	1.10	10.9	10.56	0.044	Europe	0.055	6797	59764349	0.63
55	2029 Jan 06 from 20h 54m to 21h 27m UT	UCAC4 383-062610	1.00	12.3	11.79	0.052	China	0.058	5809	53675716	0.7
56	2029 Jan 09 from 23h 31m to 24h 04m UT	UCAC4 378-064946	0.95	12.5	11.97	0.054	Africa	0.059	5571	52239576	0.72
57	2029 Jan 13 from 05h 45m to 06h 15m UT	UCAC4 374-063757	1.15	13.7	13.12	0.057	South America	0.060	5309	50653839	0.74
58	2029 Jan 14 from 0Oh 15m to 0Oh 51m UT	UCAC4 373-065145	1.00	13.8	13.32	0.057	Africa	0.060	5245	50279844	0.75
59	2029 Jan 19 from 23h 16m to 23h 56m UT	UCAC4 365-062656	1.00	12.7	12.24	0.063	Africa	0.063	4746	47198128	0.79
60	2029 Jan 26 from 23h 19m to 24h 10m UT	UCAC4 356-066008	1.10	12.7	12.22	0.072	Africa	0.066	4161	43368423	0.86
61	2029 Jan 27 from 0Oh 56m to 01h 40m UT	TYC 6115-00954-1	0.95	10.8	10.01	0.072	Europa	0.066	4155	43338503	0.87

Phaethon’s orbit





Phaethon's orbit is inclined relative to the ecliptic plane.
Placing a spacecraft in such an orbit requires a lot of energy.
However, a small spacecraft cannot carry that much fuel.

Strategy:

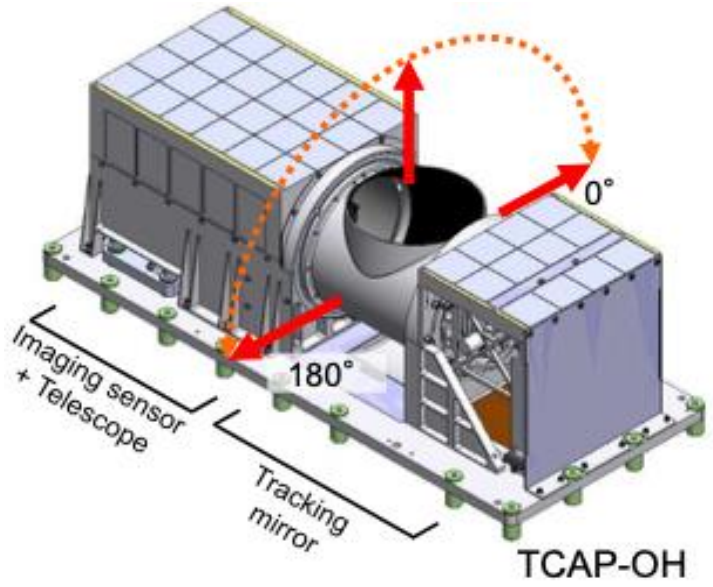
- The DESTINY+ spacecraft will orbit near Earth, it waits for Phaethon to approach the ecliptic plane.
- It will fly by in November 2030. At this time, the relative velocity between the spacecraft and Phaethon will be approximately 36 km/s (about 100 times the speed of sound).
- The spacecraft will approach 500 km of Phaethon, capturing images as it pass by.

DESTINY+ Probe-Mounted Cameras

TCAP

(Telescopic CAmera for Phaethon)

High-resolution
Field of view: 0.81 degrees x 0.81 degrees
Pixel size: 7.0 μrad/pixel

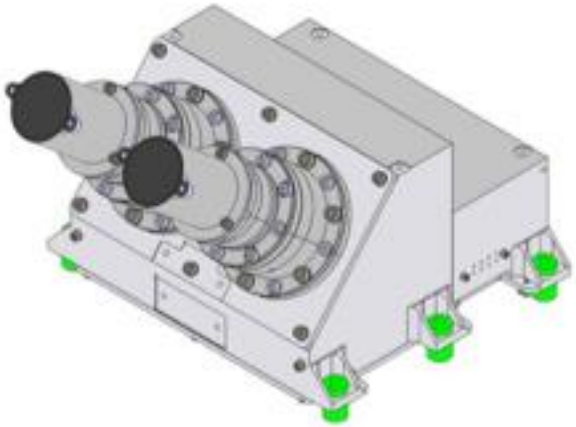


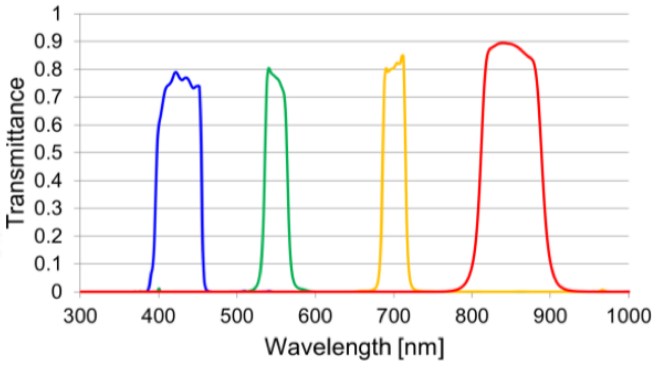
The TCAP is designed with a rotating mirror section that captures Phaethon while the spacecraft is moving at high speeds.

MCAP

(Multiband CAmera for Phaethon)

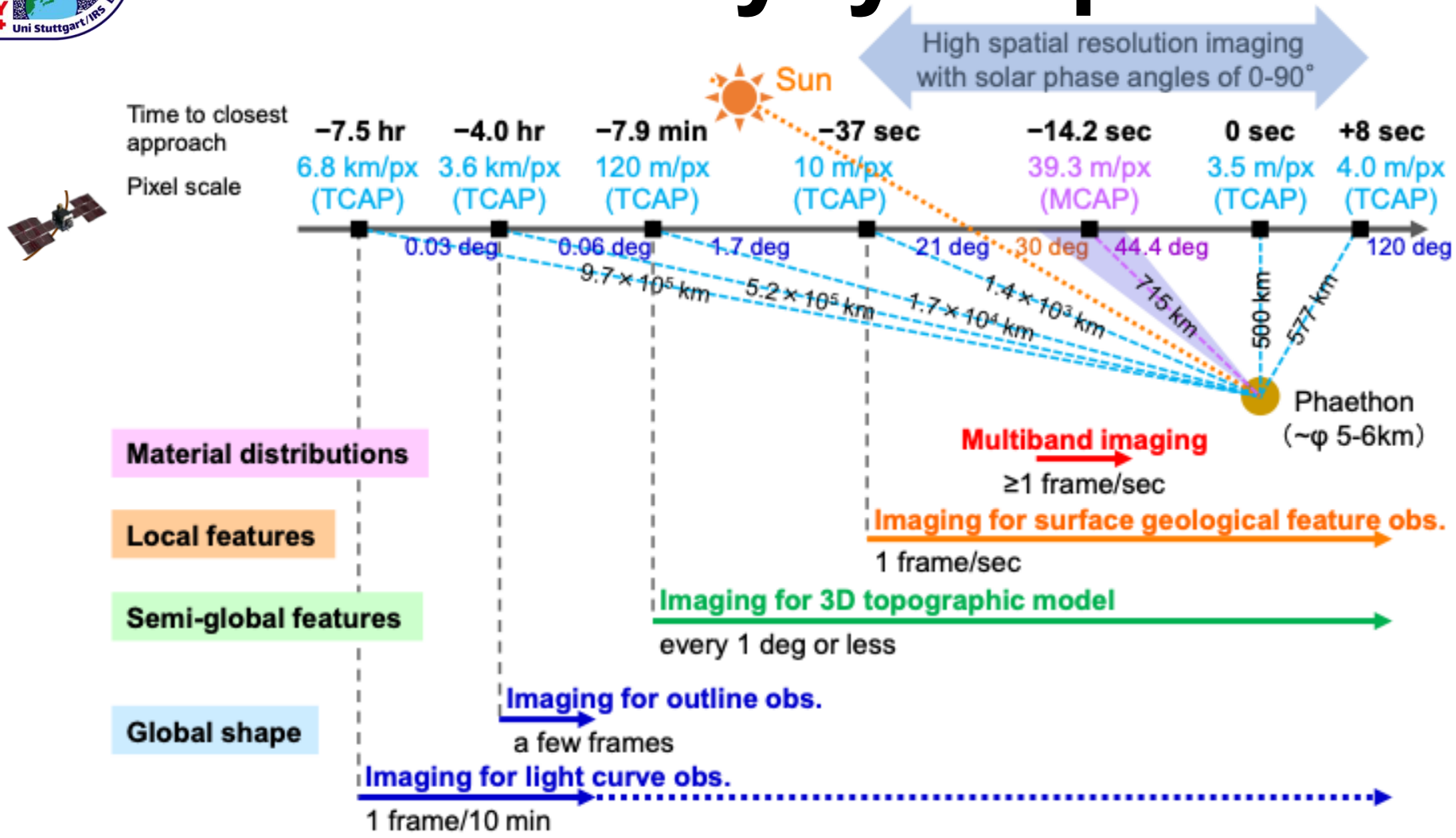
Simultaneous imaging with four filters
(425, 550, 700, 850 nm)
Field of view: 6.5 degrees x 6.5 degrees
Pixel size: 54 μrad/pixel





This camera does not have a rotation mechanism.
Widening the field of view makes it easier to keep Phaethon within the frame.
Observe color variations on Phaethon's surface.

Flyby sequence



1. 7.5 hours before closest approach: Imaging begins with TCAP. Capture one image every 10 minutes to observe Phaethon's brightness changes.
2. 4 hours before: Phaethon's outline begins to appear.
3. 7.9 minutes: Capture images each time the angle between Phaethon and the probe changed by 1 degree.
4. 37 seconds before: Capture images every second.
5. 14.2 seconds before: Switch to MCAP camera. Imaging every second.
6. At closest approach: TCAP captures high-resolution images of Phaethon (3.5m per pixel)
7. Until 8 seconds after closest approach: TCAP continues imaging Phaethon while turning back.

After Phaethon Flyby

The details are still undecided, but if the spacecraft is functioning properly and has enough fuel after the Phaethon flyby, then it is planned to fly by other asteroids one after the other.

Apophis flyby　　Phaethon flyby　　2002 SY50,　　2024 YR4 ….

There's still plenty of time until the launch and the Phaethon flyby. In the meantime, please continue to support the DESTINY⁺ mission.


Thank you for your attention.
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