TESS-avaruuskaukoputken komeettojen pölyvanahavainnot

Ursan aurinkokuntatapaaminen 2026

Markku Nissinen 7.2.2026

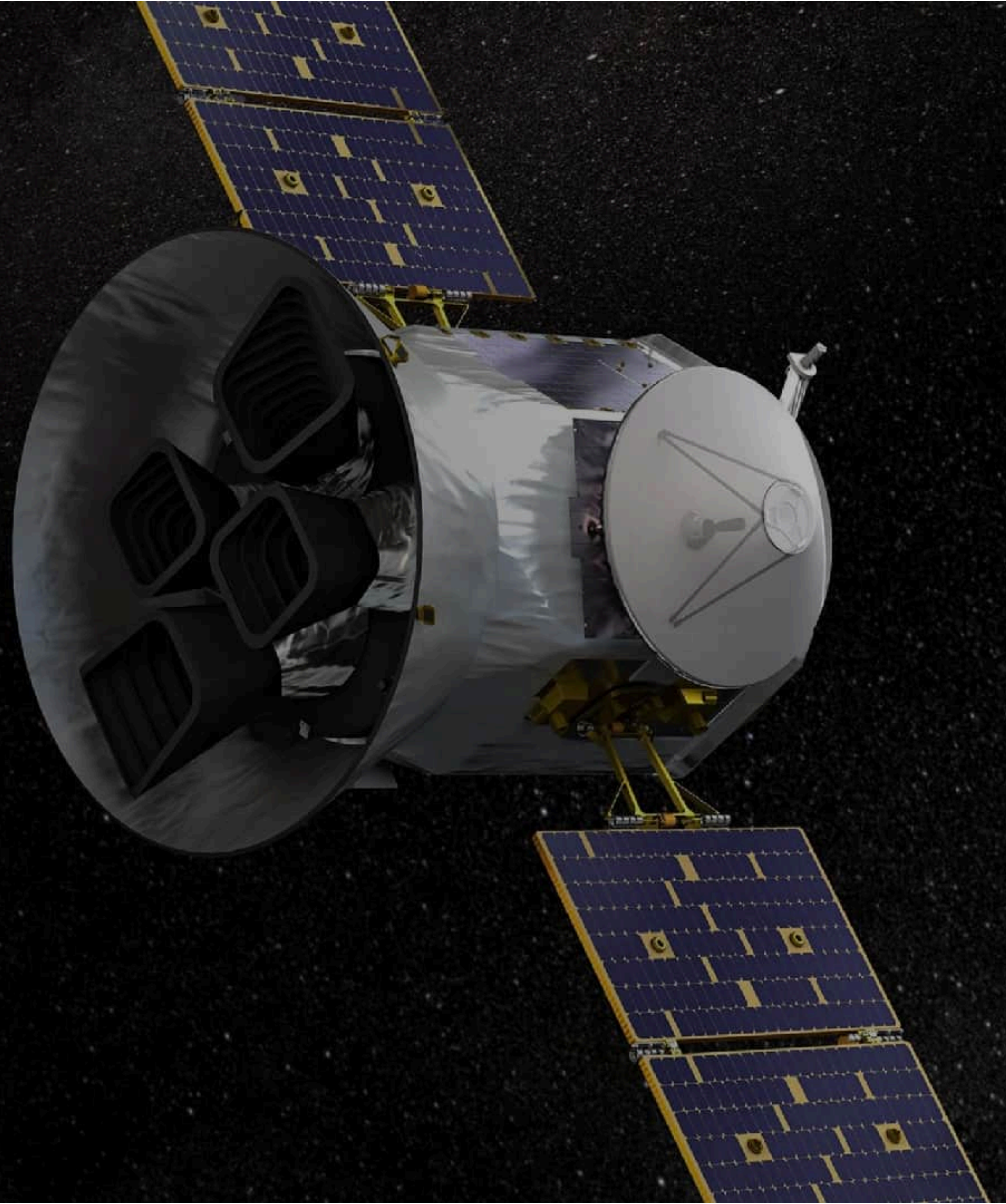
Transiting Exoplanet Survey Satellite (TESS)

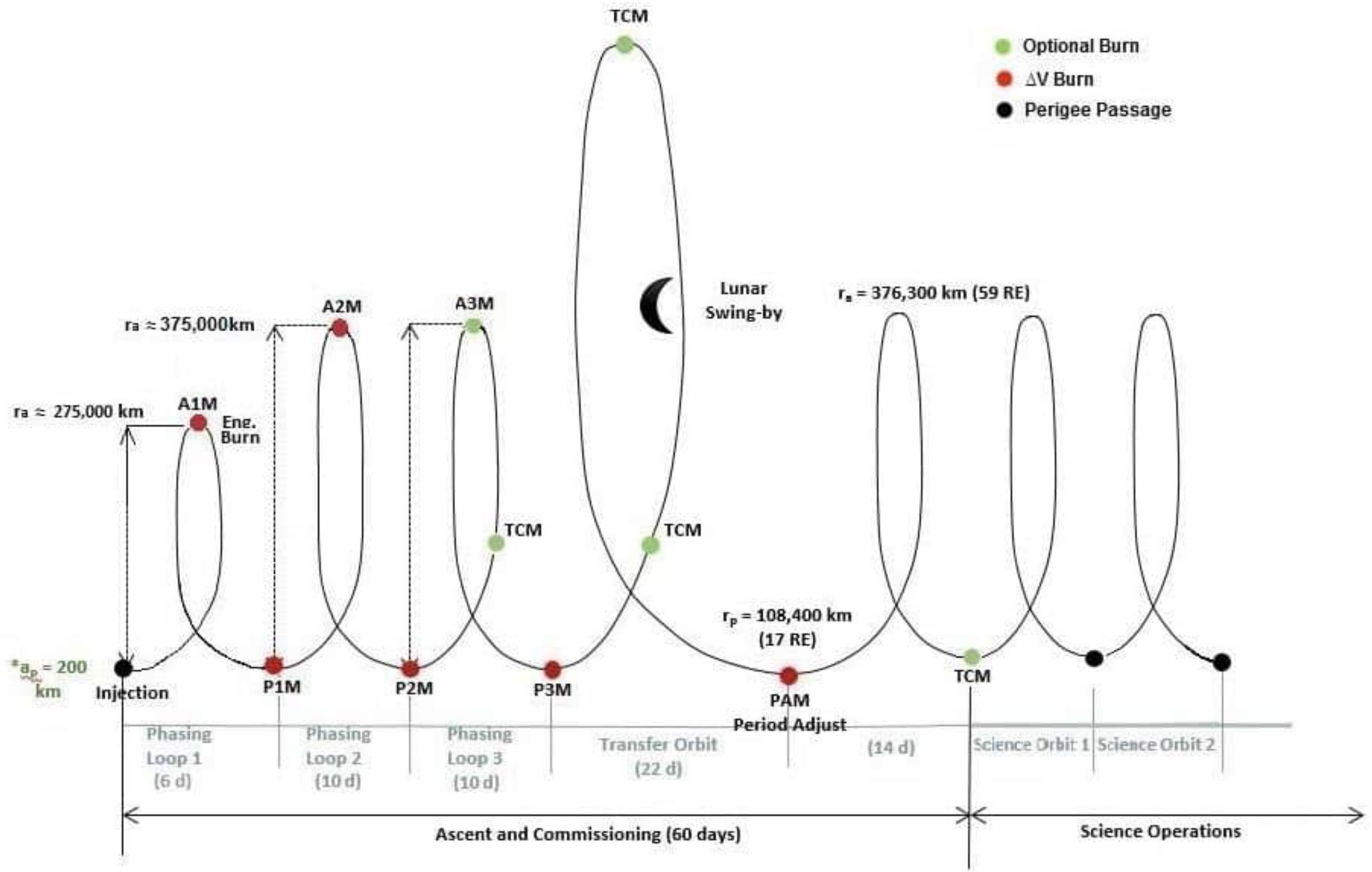
Explorer 95, TESS, MIDEX-7

- Avaruusteleskooppi, jolla etsitään ja havaitaan eksoplaneettoja.
- Laukaisu 18.4.2018 Space X Falcon 9 Cape Canaveral SLC 40.
- Elliptisellä 13,7 päivän radalla.
- Kahden vuoden tutkimus ja sen jälkeen ensimmäinen jatko.
- Tällä hetkellä toisella kolmivuotisella jatkolla, joka alkoi 2022 syyskuussa.
- Tällä hetkellä tällä toisella jatko-ohjelmalla aktiivisena.
- Kuvat: NASA ja Space X

TESS (Transiting Exoplanet Survey Satellite)

ACTIVE MISSION





TCM
Optional Burn
ΔV Burn
Perigee Passage
Lunar Swing-by
ra ≈ 375,000km
A2M
A3M
ra = 376,300 km (59 RE)
ra ≈ 275,000 km
A1M
Eng. Burn
TCM
TCM
rp = 108,400 km (17 RE)
*ap = 200 km
Injection
P1M
P2M
P3M
PAM
Period Adjust
TCM
Phasing Loop 1 (6 d)
Phasing Loop 2 (10 d)
Phasing Loop 3 (10 d)
Transfer Orbit (22 d)
(14 d)
Science Orbit 1
Science Orbit 2
Ascent and Commissioning (60 days)
Science Operations

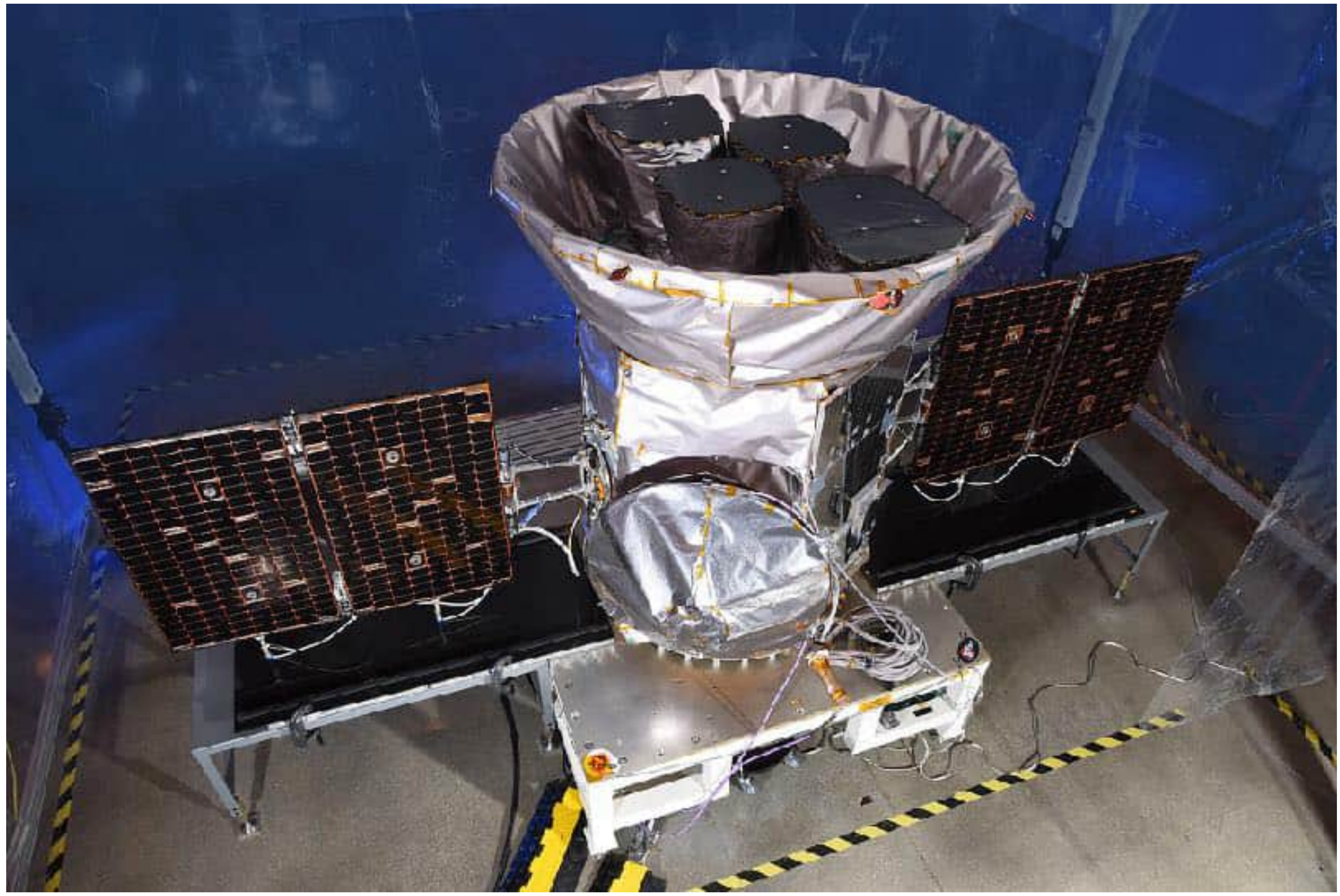
TESS

Rata

- Rata on 2:1 resonanssissa Kuun kanssa (P/2).
- Eli TESS kiertää Maapallon kaksi kertaa siinä ajassa kuin Kuu kiertää kerran.
- Radan on arveltu olevan stabiili vähintään 10 vuoden ajan.
- Rata on suunniteltu pohjoisen ja eteläisen avaruuden kuvaamiseen.
- Mahdollistaa kameroiden lämpötilan vakauttamisen.
- Rata on Van Allenin vyöhykkeiden ulkopuolella.
- Kuvat lähetetään kahden viikon välein ja lähetys kestää kolme tuntia.

TESS

Transiting Exoplanet Survey Satellite

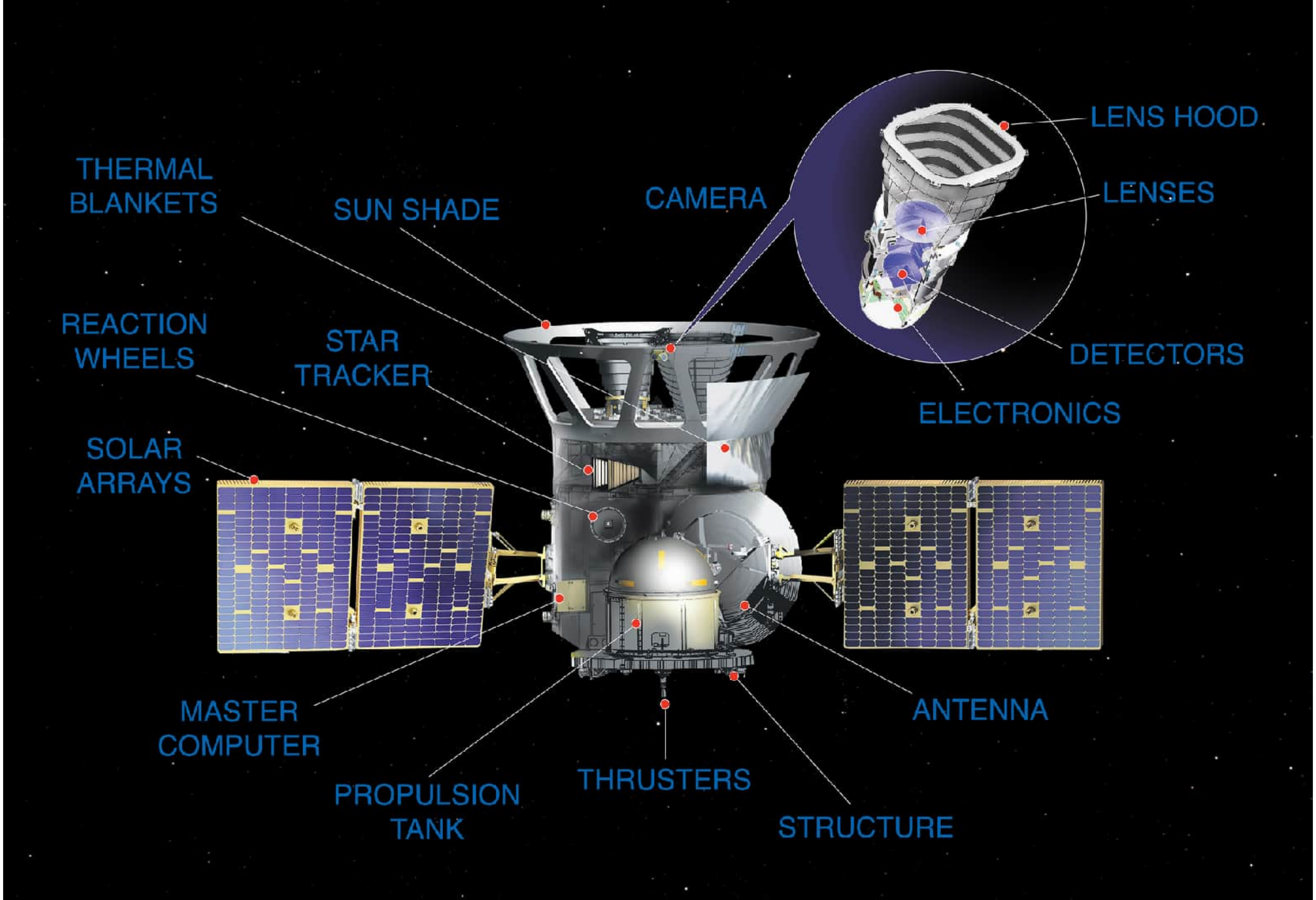


- 3.7 × 1.2 × 1.5 m (12.1 × 3.9 × 4.9 ft).
- Valmistaja Orbital ATK.
- Teho 530 W.
- Massa 362 kg lähdössä.
- Perigee 108000 km apogee 375000 km.
- Inklinaatio 37 astetta. Kiertoaika 13,7 päivää.
- Kuvat: Orbital ATK, NASA

TESS

Transiting Exoplanet Survey Satellite

- Neljä suurikenttäistä kaukoputkea
- CCD kennot.
- Kuvat lähetetään kahden viikon välein.
- Suunnittelu aloitettu 2005 MIT ja SAO
- Mukana myös Google.
- Kuva: TESS mission patch



LENS HOOD
THERMAL BLANKETS
SUN SHADE
CAMERA
LENSES
REACTION WHEELS
STAR TRACKER
DETECTORS
ELECTRONICS
SOLAR ARRAYS
MASTER COMPUTER
ANTENNA
THRUSTERS
PROPULSION TANK
STRUCTURE

TESS

Kamerat

- Havaintolaitteena 4 x 4 megapikselin CCD-kameran paketti.
- Neljä CCD:tä 2 x 2 yhteensä 16 megapikseliä kamera.
- Kameran kenttä 24 x 24 astetta. 105 mm objektiivi.
- Yhdistetty kenttä 24 x 96 astetta. F/1,4.
- Aallonpituusalue 600 nm (oranssi) - 1000 nm (NIR).
- Pölyhavainnoissa NIR herkkyys auttaa.

TESS

Kuvaus-sektorit ja kuvien käsittely ensimmäinen jakso

- Taivas on jaettu 26 kuvaus-sektoriin.
- Vuosi eteläinen taivas - 2019 ja vuosi pohjoinen taivas - 2020.
- Kaksi 13,7 päivän jaksoa kutakin sektoria kohti.
- Kamerat ottavat kuvia kahden sekunnin välein.
- 2 minuutin jaksoissa tallennetaan 15000 tähteä ja myös 20 minuutin jaksoissa.
- 85 % taivaasta 27 päivässä.

TESS

Toinen jakso ja kolmas jakso

- Toinen jakso 2020 heinäkuu - 2022 syyskuu.
- 2 minuutin välein 20000 tähteä sektoria kohti.
- 1000 tähteä sektorissa nopeammalla 20 sekunnin aikavälillä.
- Koko kentän aikaväli 20 minuutista 10 minuuttiin.
- Kolmas jakso 2022 - 2025 marraskuu.
- Koko kenttä 10 minuutista 200 sekuntiin.
- 2 minuutin välein kuvatut tähdet 8000 ja 20 sekunnin 2000 sektoria kohti.

24°
96°
ecliptic pole
ecliptic latitude 6°
ECLIPTIC POLE
OBSERVATION SECTOR
ECLIPTIC
27 days
54 days
81 days
108 days
189 days
351 days
JWST continuous viewing zone

TESS

Testikuva vuodelta 2018

- Testikuvassa Centaurus keskellä.
- Hiilisäkki sumu oikealla ylhäällä.
- Kirkas tähti alhaalla vasemmalla Beta Centauri.
- On kuvannut 400 kertaisesti tämän kentän kokoisen alueen.
- Kuvassa 200000 tähteä.
- Kuva: NASA/MIT/TESS

TESS

Eksoplaneettoja

- Eteläinen taivas:
- Pi Mensae, LHS 3844 b, HD 202772 Ab, HD 21749
- Pohjoinen taivas:
- DS Tucanae Ab, Gliese 357, ASASSN-19bt, TOI-700, TOI-1338, HD 108236, TIC 168789840, TOI-1231 b
- 2021 loppuun mennessä löytöjä 5000 eksoplaneettakandidaattia.
- Kuva: LHS 3844 b (taiteilijan näkemys). 1,3 x Maapallon massa.

Komeettojen pölyvanahavainnot TESS

Esillä Finlandia talossa EPSC-DPS 2025 konferenssissa

- EPSC-DPS 2025 Finlandia-talossa.
- Esitys Tony Farnham sekä posteri Maximus Hood.
- Posterissa myös 17P/Holmes pölyvanahavainto esillä.
- Kuvat: Jorma Ryske ja Kai Forssén

EPSC Abstracts
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https://doi.org/10.5194/epsc-dps2025-867
EPSC-DPS Joint Meeting 2025

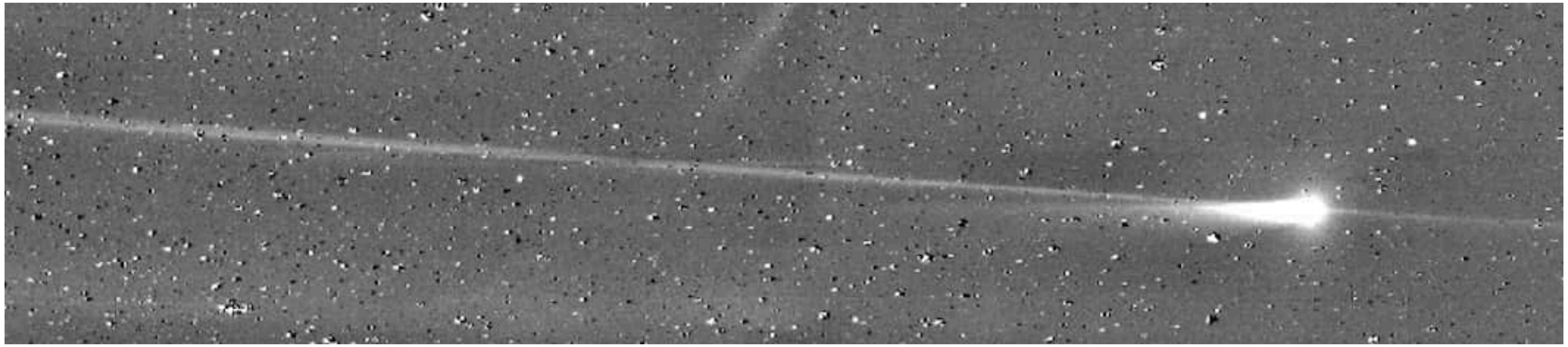
TESS Observations of Comet 67P/Churyumov-Gerasimenko

Tony L. Farnham, Maximus Hood, Jessica M. Sunshine, and Michael S.P. Kelley
University of Maryland, College Park, MD, United States of America (farnham@umd.edu)

The Rosetta spacecraft orbited comet 67P/Churyumov-Gerasimenko (C-G) from 2014-2016, where it characterized the comet's behavior in detail. Although the in situ mission is over, remote observations monitoring the comet's behavior should be continued, to reveal how the comet evolves over the course of subsequent apparitions.

The Transiting Exoplanet Survey Satellite (TESS) was designed to observe extrasolar planets by continuously staring at a wide-field (24° x 96°) sector of the sky for 27 days. Comets occasionally pass through the TESS field of view, where high-cadence images are recorded for as long as the comet remains in the field. We can use these images to study the long-term spatial and temporal behavior of the comet. TESS' excellent photometric qualities track the secular and rotational lightcurves of the comet to reveal how its activity changes with time. The continuous, extended duration of the observations is also ideal for monitoring for outbursts and other spontaneous transient events. The thousands of images obtained by TESS can also be registered on the nucleus and coadded to produce deep images that reveal faint morphological features. This capability has made TESS an excellent tool for discovering and characterizing cometary dust trails and for characterizing comae in weak and distant comets.

Due to fortuitous circumstances, comet C-G was ideally placed for TESS observations during its 2021 apparition. C-G passed through six consecutive sectors, where it was imaged almost continuously every 10 minutes for 159 days (21 Aug 2021 through 27 Jan 2022). These observations bracketed perihelion (r=1.2 AU), with r ranging from 1.5 AU inbound to 1.6 AU outbound, and provide a record of the object's long-term behavior during this time period. Preliminary analyses of the observations show activity levels that peaked about three weeks post-perihelion, with several small outbursts detected at random times. C-G displays a moderate dust tail as well as a bright dust trail that extends several tens of degrees from the nucleus (see figure).



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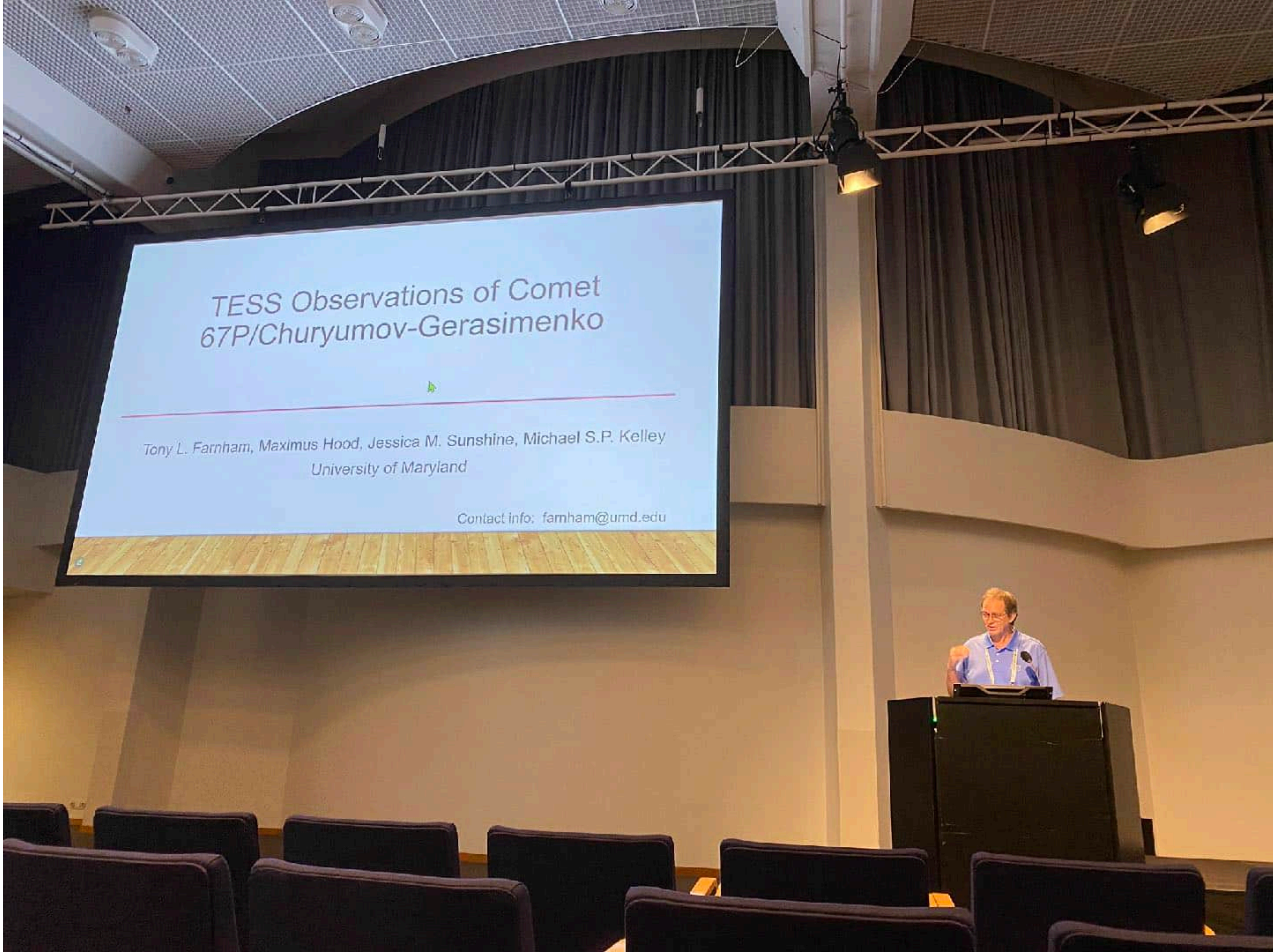
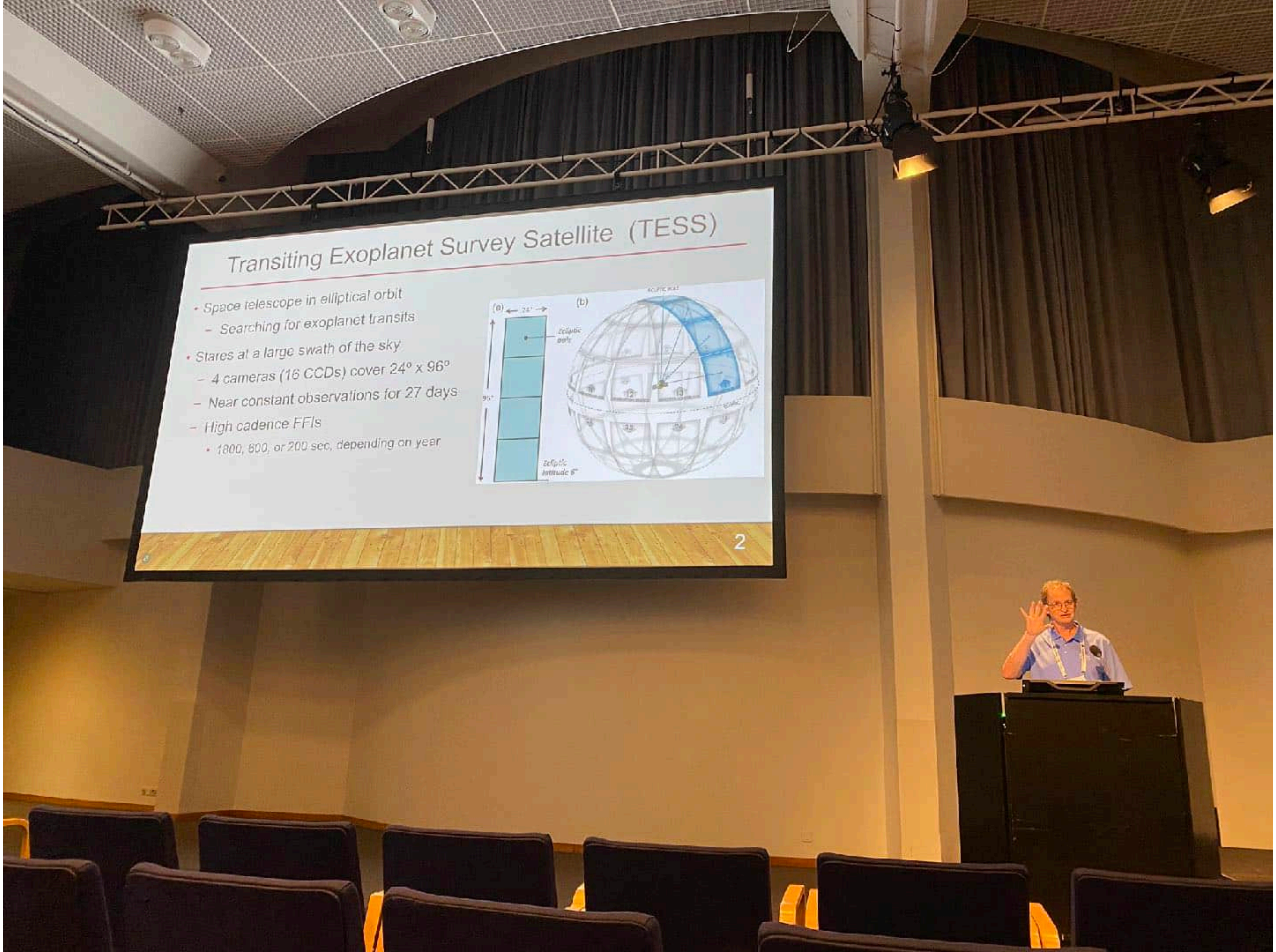

TESS Observations of Comet
67P/Churyumov-Gerasimenko
Tony L. Farnham, Maximus Hood, Jessica M. Sunshine, Michael S.P. Kelley
University of Maryland
Contact info: farnham@umd.edu

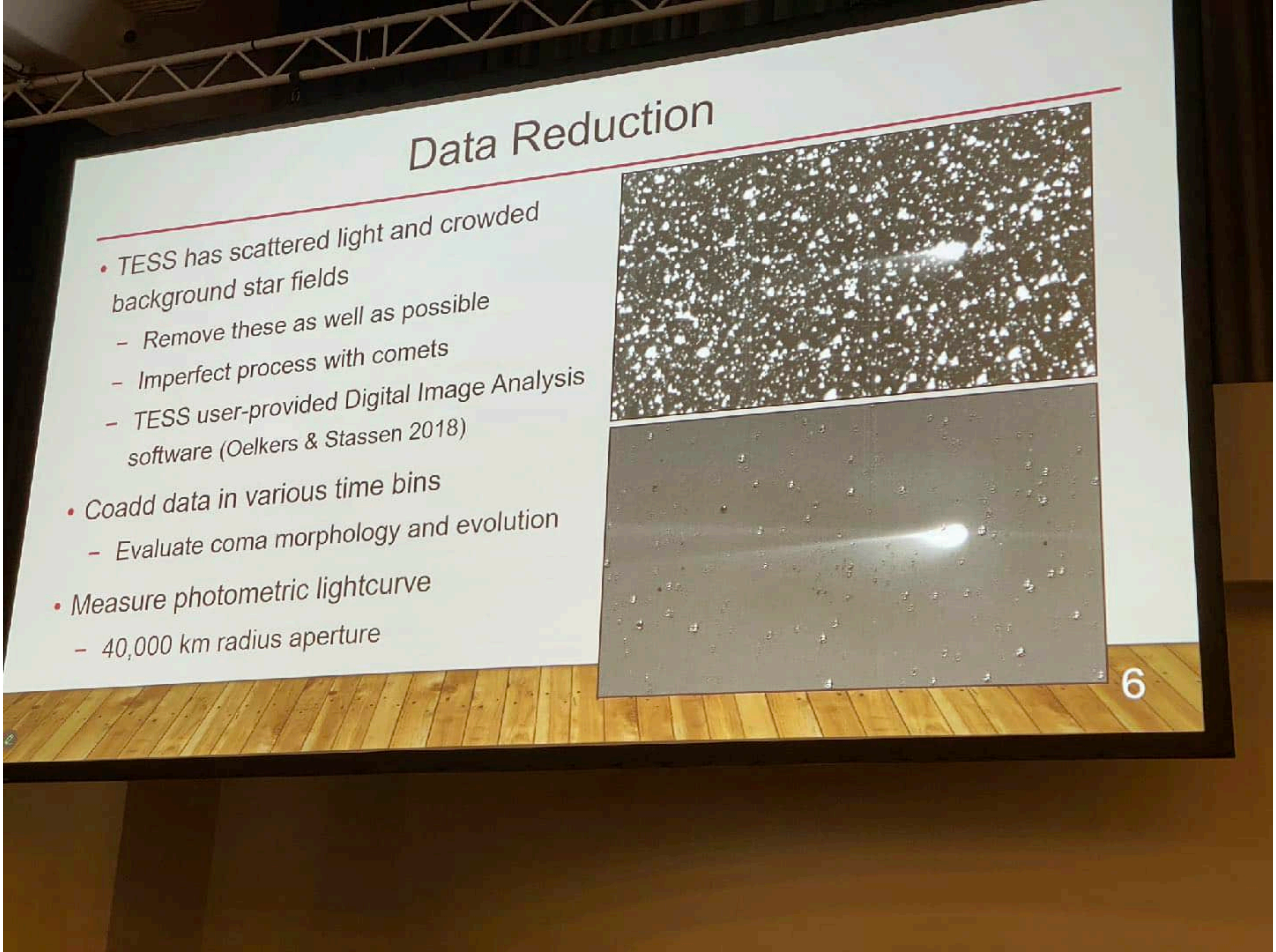

Transiting Exoplanet Survey Satellite (TESS)
• Space telescope in elliptical orbit
– Searching for exoplanet transits
• Stares at a large swath of the sky
– 4 cameras (16 CCDs) cover 24° x 96°
– Near constant observations for 27 days
– High cadence FFIs
• 1800, 600, or 200 sec, depending on year
(a)
24°
96°
Ecliptic pole
Ecliptic latitude 6°
(b)
2

Studying Comets with TESS

- Comets serendipitously pass through the TESS FOV
- Excellent opportunity to monitor temporal phenomena in comets
  - High-precision photometry
  - Long duration, high cadence observations can be used to evaluate:
    - Long-term secular behavior
    - Rotational variability and outbursts (very small ones for bright comets)
    - Coma morphology and evolution
  - Co-add data in different temporal buns to look for faint phenomena:
    - Faint or distant object activity (Discovered activity in C/2014 UN271)
    - Dust trails (26 new discoveries, 28 more possibilities - see Maximus Hood poster

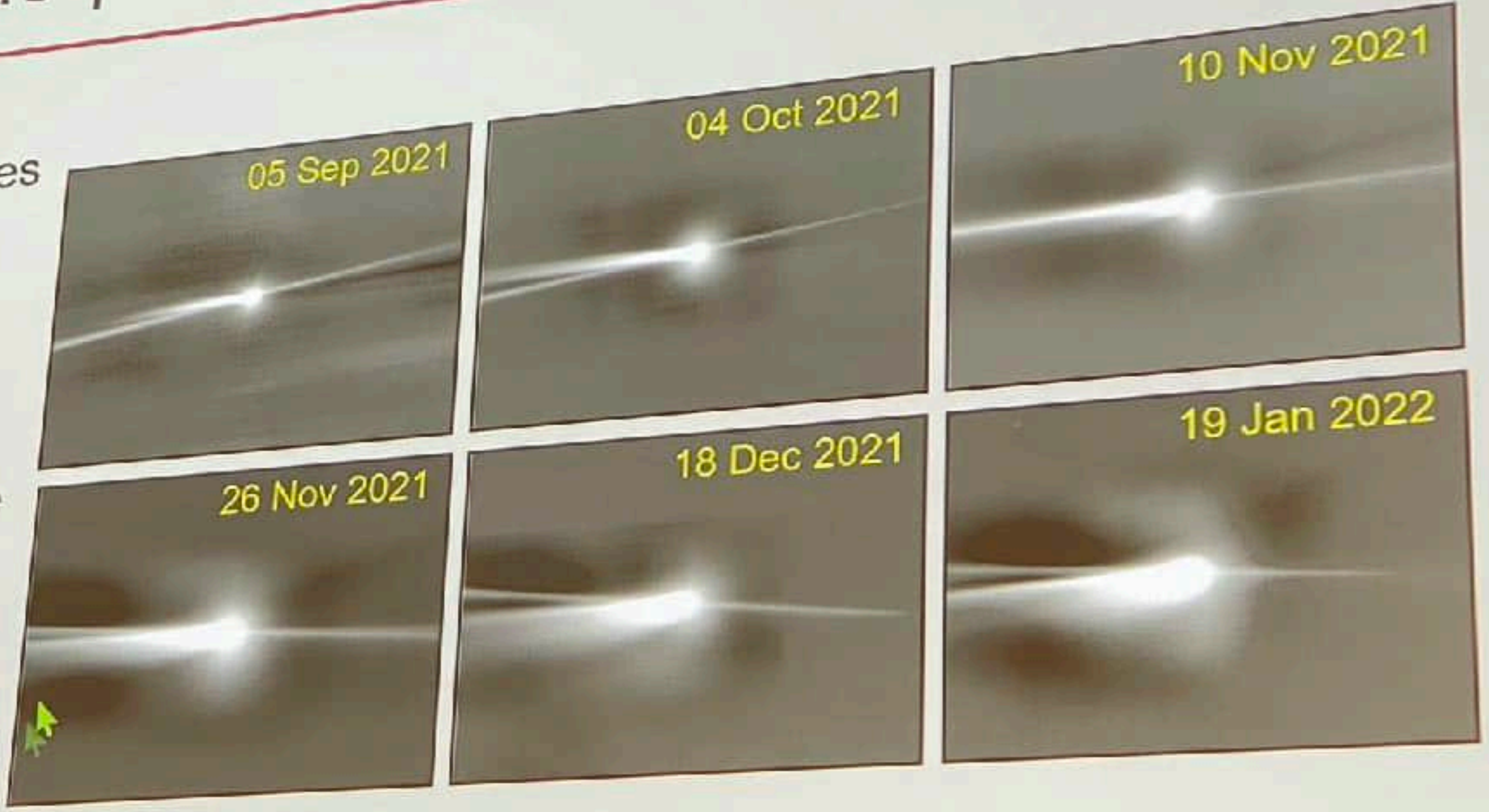
67P/C-G Observations

- Appeared in 6 sectors
  - 42 – 46, when the swath lay along the ecliptic
  - 47 – Partial sector
- Observations from 21 August 2021 – 27 January 2022
  - 159 days of coverage
  - Heliocentric Distance 1.52 – 1.21 – 1.61 AU (Bracketed perihelion)
  - Geocentric Distance 0.86 – 0.42 – 0.63 AU
  - Solar phase angle 6.9° – 50.0°
- Analyses underway – Preliminary results presented here

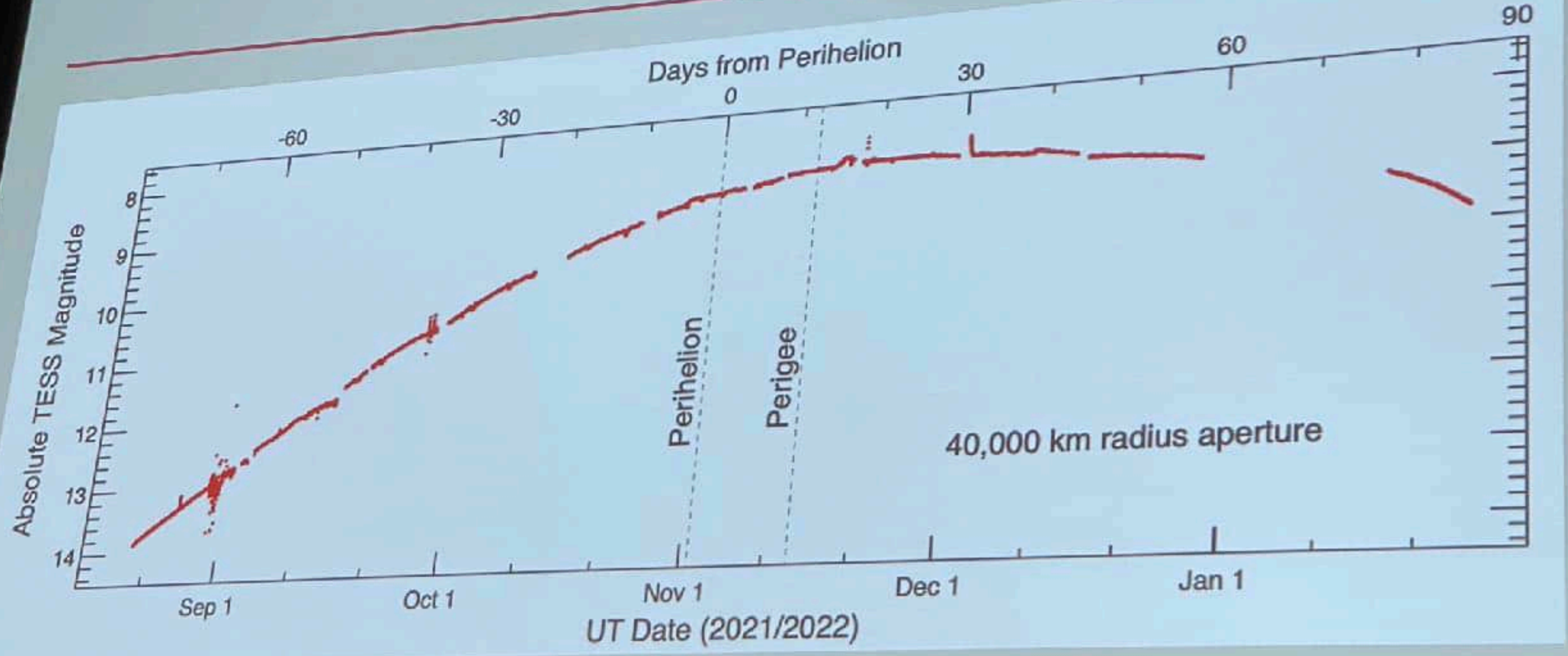

Data Reduction
• TESS has scattered light and crowded background star fields
– Remove these as well as possible
– Imperfect process with comets
– TESS user-provided Digital Image Analysis software (Oelkers & Stassen 2018)
• Coadd data in various time bins
– Evaluate coma morphology and evolution
• Measure photometric lightcurve
– 40,000 km radius aperture
6

Coma Morphology and Dust Trail

- Investigate the morphology in different bins of coadded images
- Featureless coma
- Dust tail develops and curves over time
- A well-defined dust trail is visible in data from all epochs
  - Covers the full CCD (12°) in images already processed
  - Probably extends across multiple cameras (may capture >96° of the orbit)



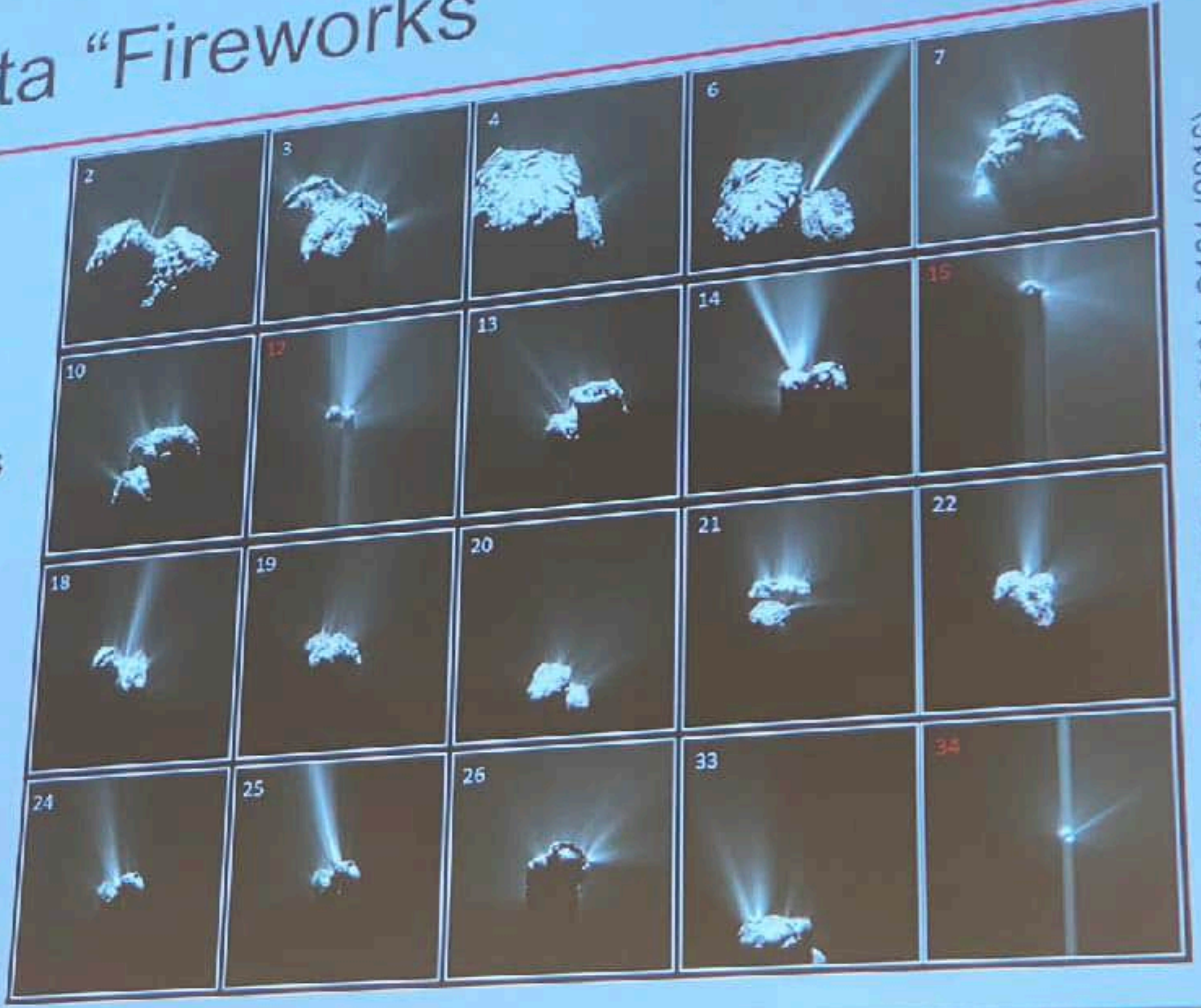
Lightcurve



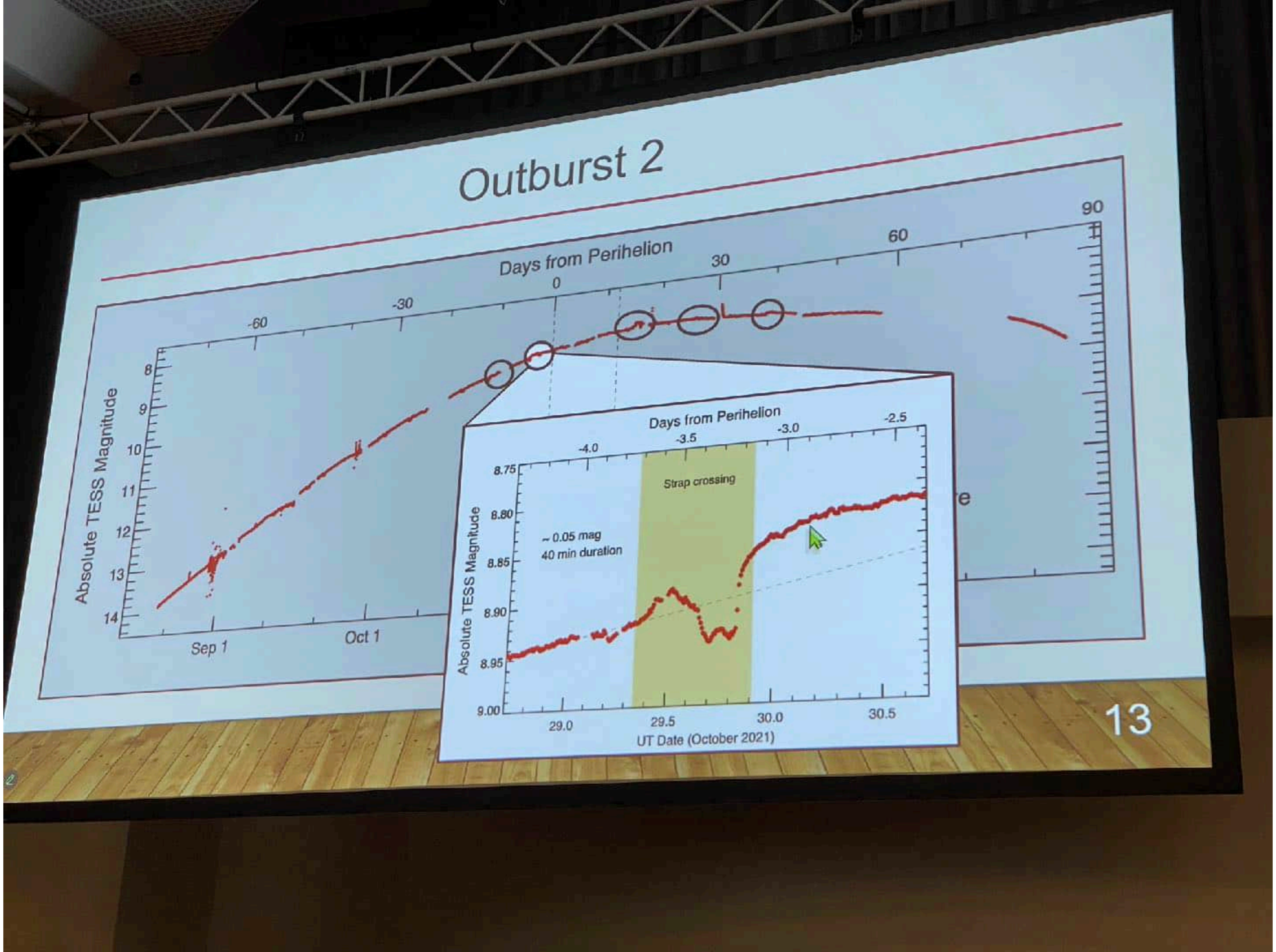
Days from Perihelion
-60
-30
0
30
60
90
Absolute TESS Magnitude
8
9
10
11
12
13
14
Perihelion
Perigee
40,000 km radius aperture
Sep 1
Oct 1
Nov 1
Dec 1
Jan 1
UT Date (2021/2022)

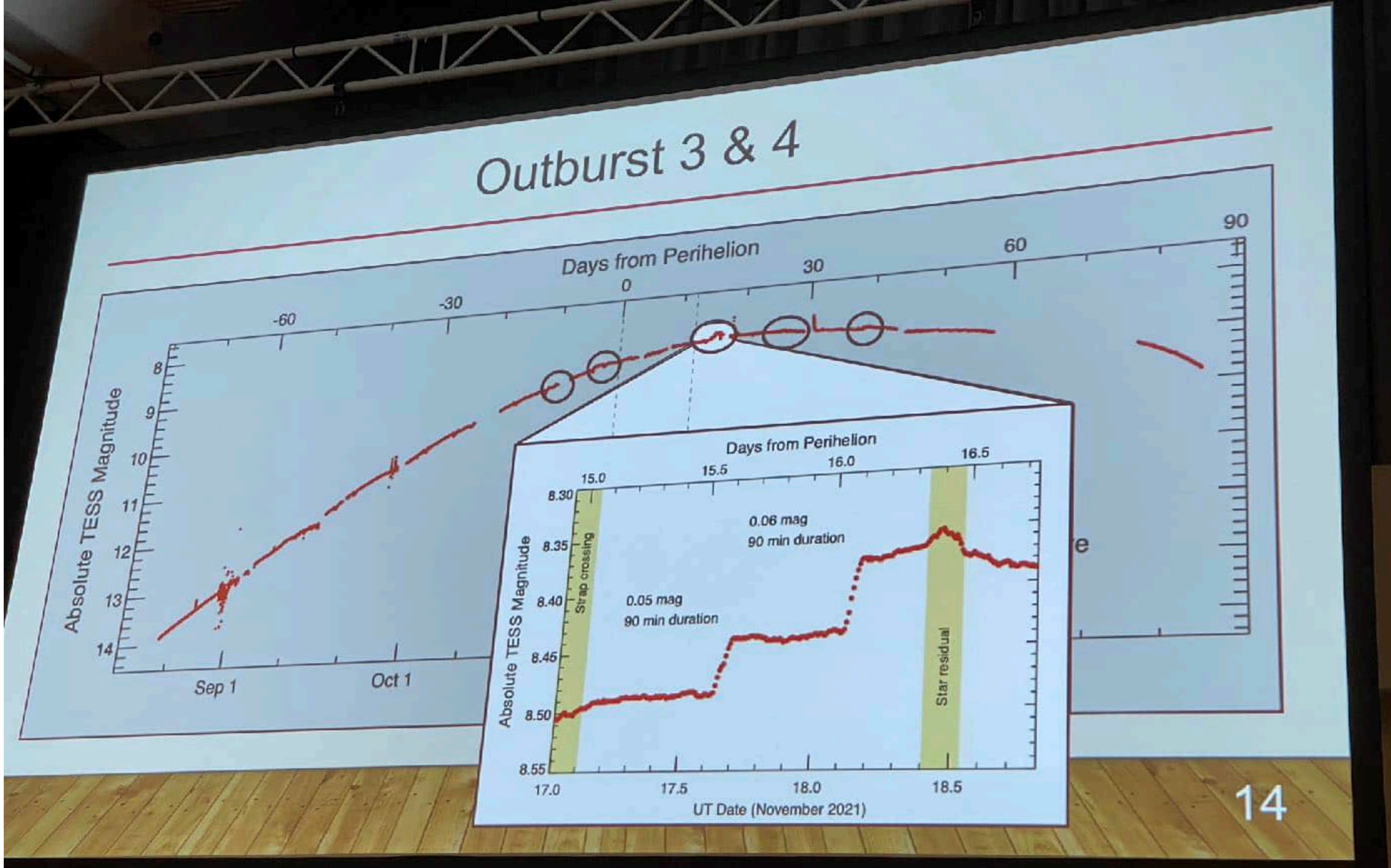
Rosetta "Fireworks"

- Rosetta recorded numerous small outbursts
  - Every 2-3 days average
    - Several on subsequent rotations
  - Wide range of luminosity
  - Durations generally unknown
    - Adopted a few minutes to estimate the mass ejected
  - Typical event produced ~10s of tons of dust



Vincent et al. MNRAS 462, S184–S194 (2016)


Outburst 2
Days from Perihelion
-60
-30
0
30
60
90
Absolute TESS Magnitude
8
9
10
11
12
13
14
Sep 1
Oct 1
Days from Perihelion
-4.0
-3.5
-3.0
-2.5
Strap crossing
~ 0.05 mag
40 min duration
Absolute TESS Magnitude
8.75
8.80
8.85
8.90
8.95
9.00
29.0
29.5
30.0
30.5
UT Date (October 2021)
13



Outburst 3 & 4
Days from Perihelion
-60
-30
0
30
60
90
Absolute TESS Magnitude
8
9
10
11
12
13
14
Sep 1
Oct 1
Days from Perihelion
15.0
15.5
16.0
16.5
Absolute TESS Magnitude
8.30
8.35
8.40
8.45
8.50
8.55
Strap crossing
0.05 mag
90 min duration
0.06 mag
90 min duration
Star residual
17.0
17.5
18.0
18.5
UT Date (November 2021)
14

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A Survey of Cometary Dust Trails in TESS

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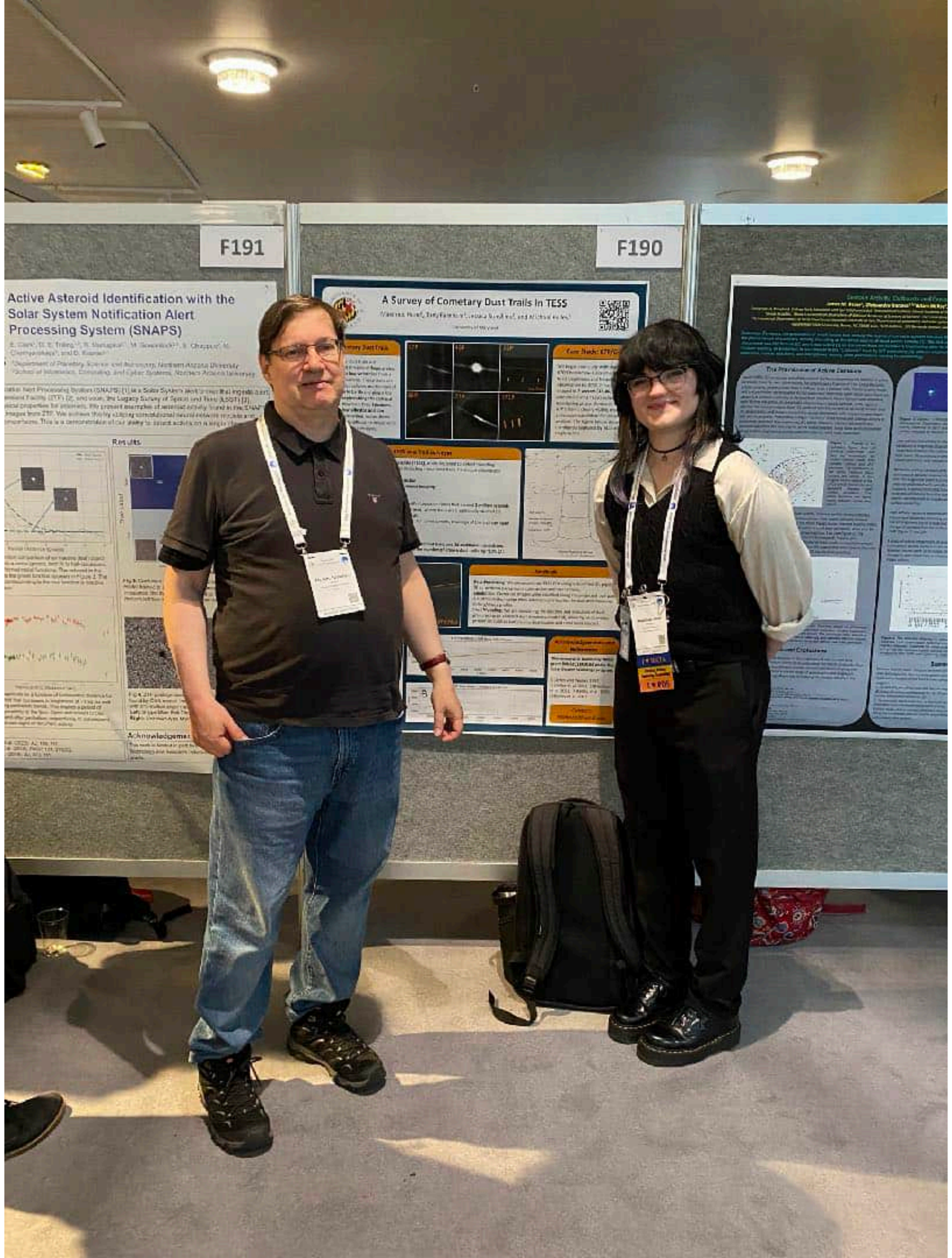
Cometary dust trails are long-lived streams of large grains ejected from comet nuclei at low velocities and are widely thought to be the major source of outer Solar System material migrating inward. These trails are considered to be one of the primary delivery methods of organic material on Earth and play a key role in replenishing zodiacal dust. However, their study is complicated by the steep size distribution of cometary dust, meaning smaller particles overwhelmingly outnumber larger ones and dominate the scattered sunlight. While radiation pressure quickly removes the smallest grains, the remaining dust trail consists of larger, dimmer particles that require long-exposure imaging to detect. This also means significant telescope time is needed to properly image them. We plan to perform a comparative survey of trails from multiple comets using the Transiting Exoplanet Survey Satellite (TESS).

TESS has revolutionized the field of cometary trail analysis. Although designed to detect transiting exoplanets, the large pixel size and the ability to coadd 27 days of continuous observations make it ideal for detecting faint, extended features like dust trails (Figure 1). TESS's wide-field coverage (24°×96° per sector) allows us to observe dust trails that extend across multiple sectors. With TESS data we aim to model trail brightness distributions to derive particle sizes and ejection velocities, quantify dust production rates and total mass ejected from comet nuclei, and constrain the mass transport rate of cometary material into the inner Solar System. To date TESS has detected potential trails in 56 comets, 32 of which are in comets that have not previously been known to exhibit dust trails. Previously, 44 comets were known to have trails (Kelley 2021), which means the new comets seen with TESS are likely to double the number of comets with identified trails.

To analyze this data, we will modify an established data reduction pipeline (Farnham et al. 2021), develop a new automated process for trail extraction and analysis, and adapt an existing dust dynamics model (Kelley 2023). Preliminary results and progress will be reported as the project advances.


F191
F190
Active Asteroid Identification with the Solar System Notification Alert Processing System (SNAPS)
A Survey of Cometary Dust Trails in TESS

University of Maryland

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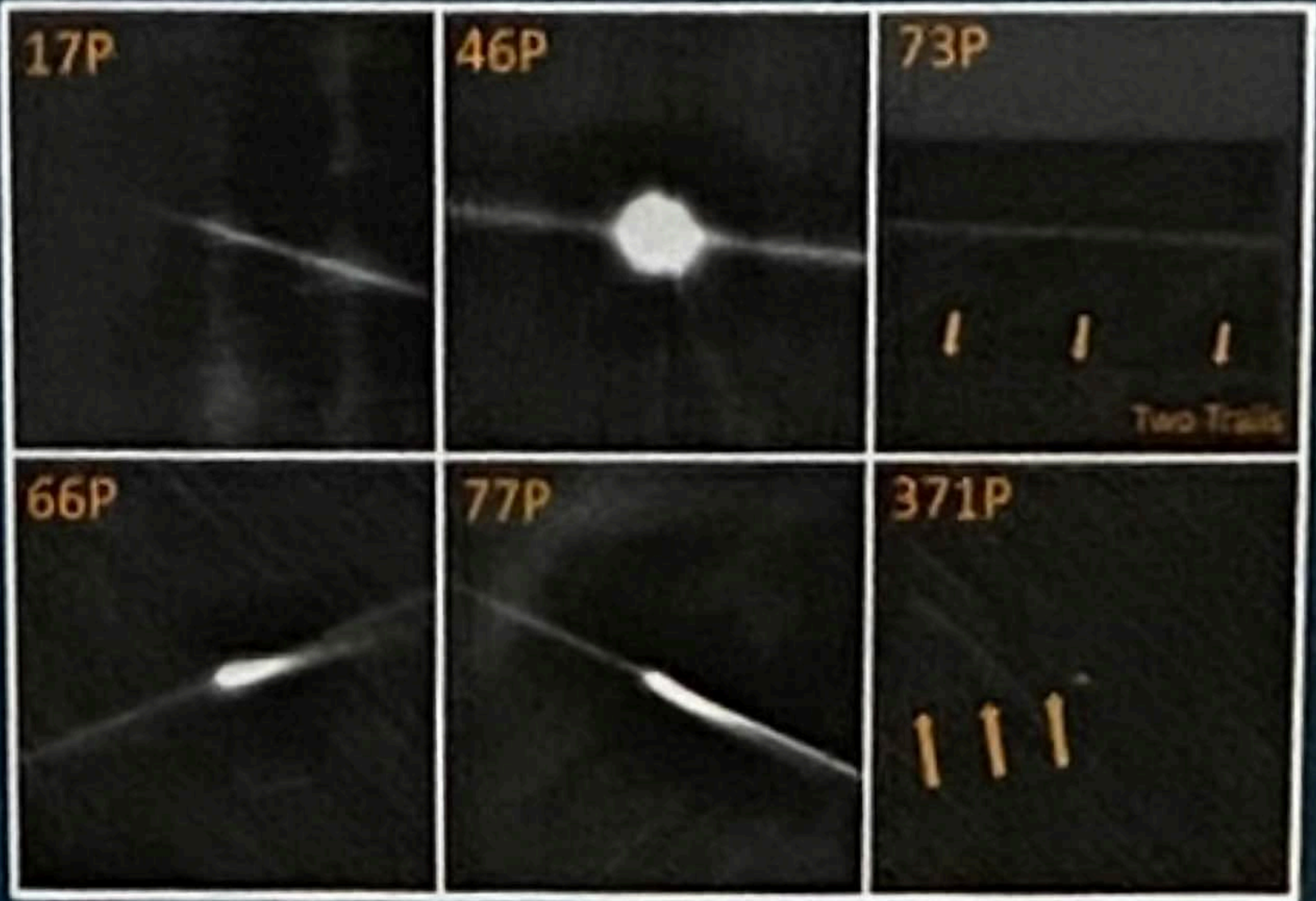

Case Stu

We began our s
67P/Churyumov
to its brightness
observation by
imaged in **7 sect**
captured during
monitoring phas
67P's trail is clea
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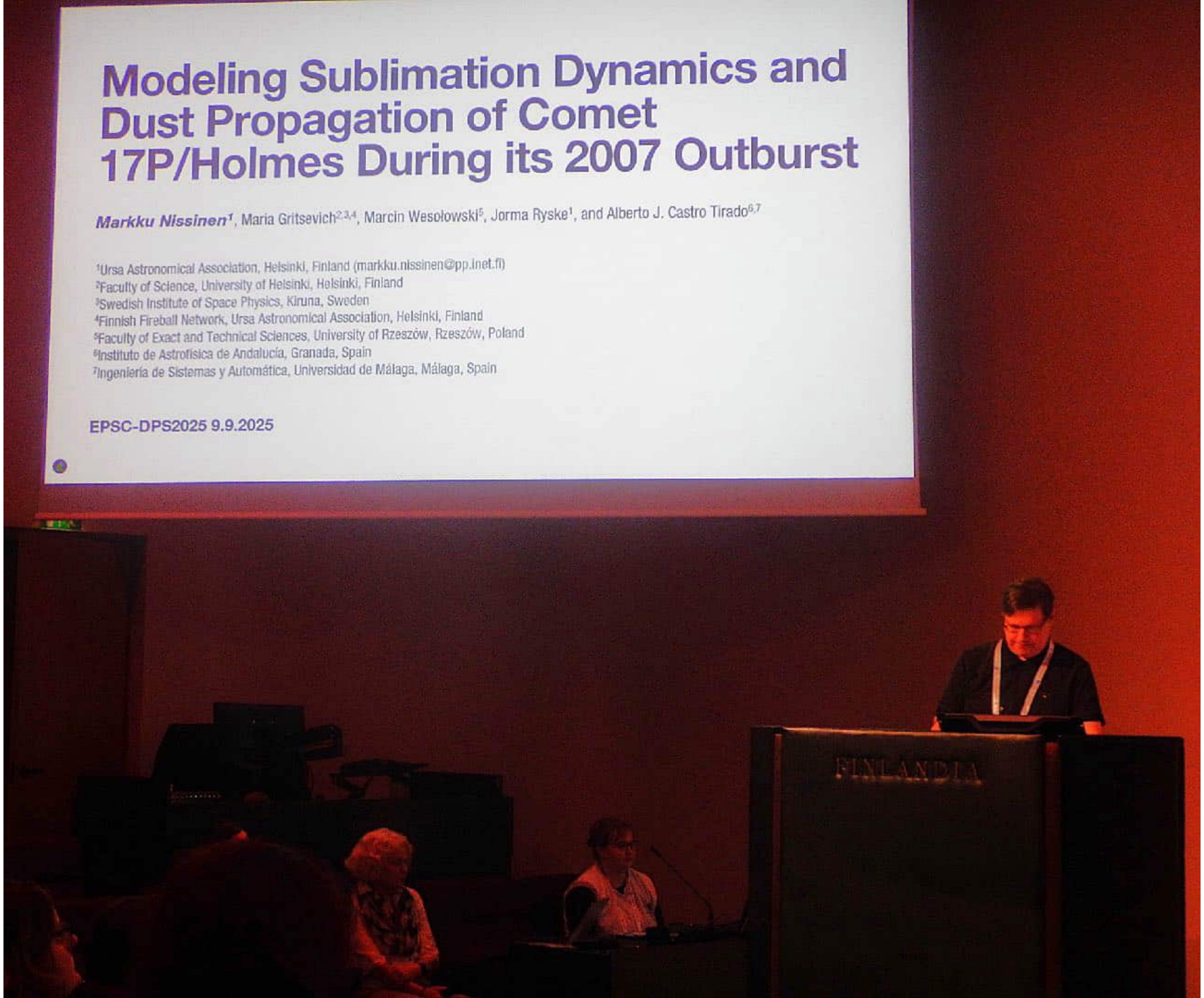
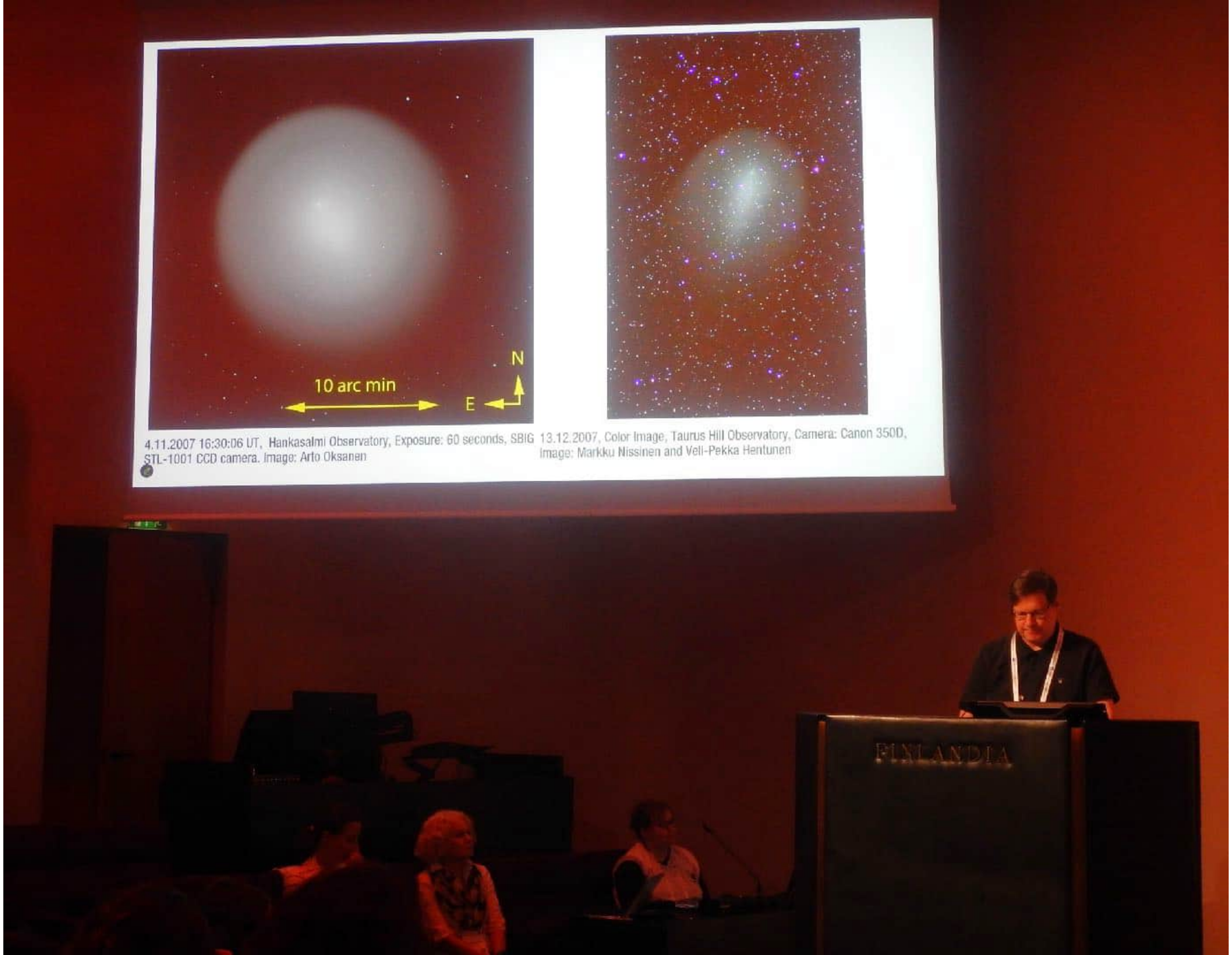
analysis. The figu
the objects captu
single sector.


Modeling Sublimation Dynamics and Dust Propagation of Comet 17P/Holmes During its 2007 Outburst
Markku Nissinen[1], Maria Gritsevich[2,3,4], Marcin Wesołowski[5], Jorma Ryske[1], and Alberto J. Castro Tirado[6,7]
[1]Ursa Astronomical Association, Helsinki, Finland (markku.nissinen@pp.inet.fi)
[2]Faculty of Science, University of Helsinki, Helsinki, Finland
[3]Swedish Institute of Space Physics, Kiruna, Sweden
[4]Finnish Fireball Network, Ursa Astronomical Association, Helsinki, Finland
[5]Faculty of Exact and Technical Sciences, University of Rzeszów, Rzeszów, Poland
[6]Instituto de Astrofísica de Andalucía, Granada, Spain
[7]Ingeniería de Sistemas y Automática, Universidad de Málaga, Málaga, Spain
EPSC-DPS2025 9.9.2025
FINLANDIA


10 arc min
N
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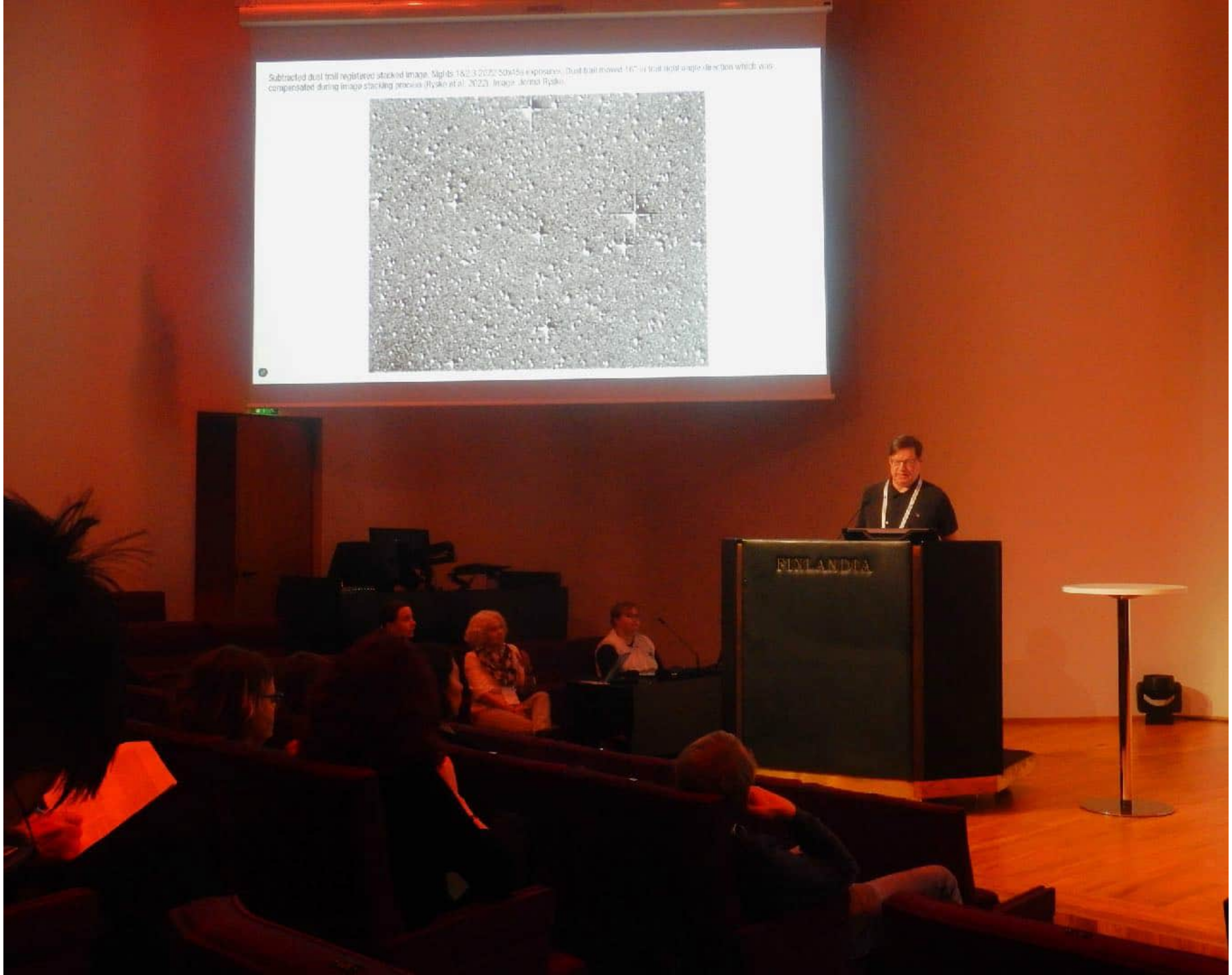
4.11.2007 16:30:06 UT, Hankasalmi Observatory, Exposure: 60 seconds, SBIG STL-1001 CCD camera. Image: Arto Oksanen
13.12.2007, Color Image, Taurus Hill Observatory, Camera: Canon 350D, Image: Markku Nissinen and Veli-Pekka Hentunen
FINLANDIA


Subtracted dust trail registered stacked image.
compensated during image stacking process
FINLANDIA

Referenssit

- Nissinen, M., Gritsevich, M., Wesołowski, M., Ryske, J., and Castro-Tirado, A. J.: Modeling Sublimation Dynamics and Dust Propagation of Comet 17P/Holmes During its 2007 Outburst, EPSC-DPS Joint Meeting 2025, Helsinki, Finland, 7–13 Sep 2025, EPSC-DPS2025-17, https://doi.org/10.5194/epsc-dps2025-17, 2025.
- Farnham, T. L., Hood, M., Sunshine, J. M., and Kelley, M. S. P.: TESS Observations of Comet 67P/Churyumov-Gerasimenko, EPSC-DPS Joint Meeting 2025, Helsinki, Finland, 7–13 Sep 2025, EPSC-DPS2025-867, https://doi.org/10.5194/epsc-dps2025-867, 2025.
- Hood, M., Farnham, T., Sunshine, J., and Kelley, M.: A Survey of Cometary Dust Trails in TESS, EPSC-DPS Joint Meeting 2025, Helsinki, Finland, 7–13 Sep 2025, EPSC-DPS2025-775, https://doi.org/10.5194/epsc-dps2025-775, 2025.