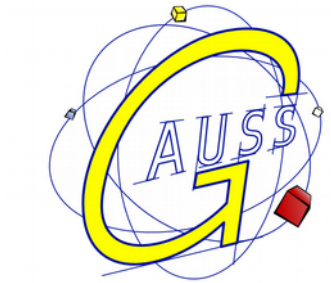

Photometry of space debris at the ISON-Castelgrande Observatory

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Keldysh Institute of Applied Mathematics
Russian Academy of Sciences

5th International Space Debris Re-entry Workshop
December 2, 2020
Darmstadt, Germany

Observatory Summary

- Location:

  South Italy, Basilicata Region, Province of Potenza, Comune of Castelgrande

  longitude – 15°.463387 E, latitude – 40°.817566 N

  height – 1250 m, time zone – CET
- Sky quality (measured by SQM-L):

  max – 21.47 mag/arcsec²

  average – 21.0–21.3 mag/arcsec² (Bortle scale class 3)
- Seeing:

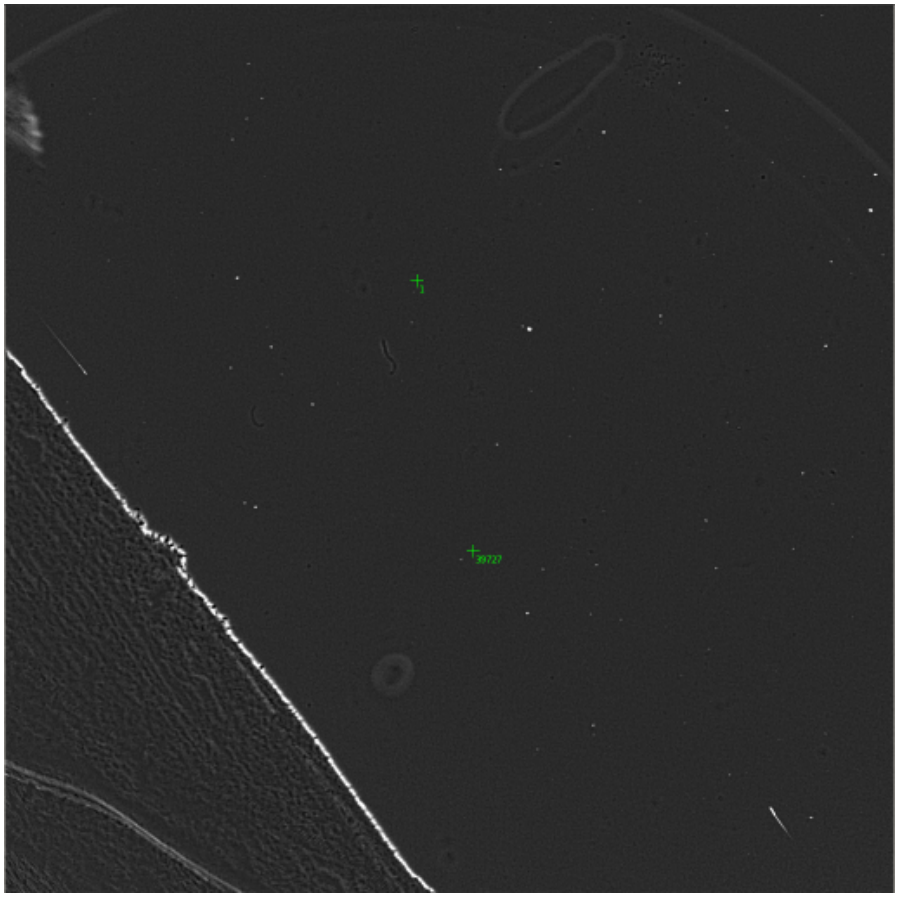
  average – 1.2 arcsec
- Number of observational nights:

  average – 150-180 per year

  up to 20-25 per month
- Horizon:

  entirely open in almost all azimuth directions

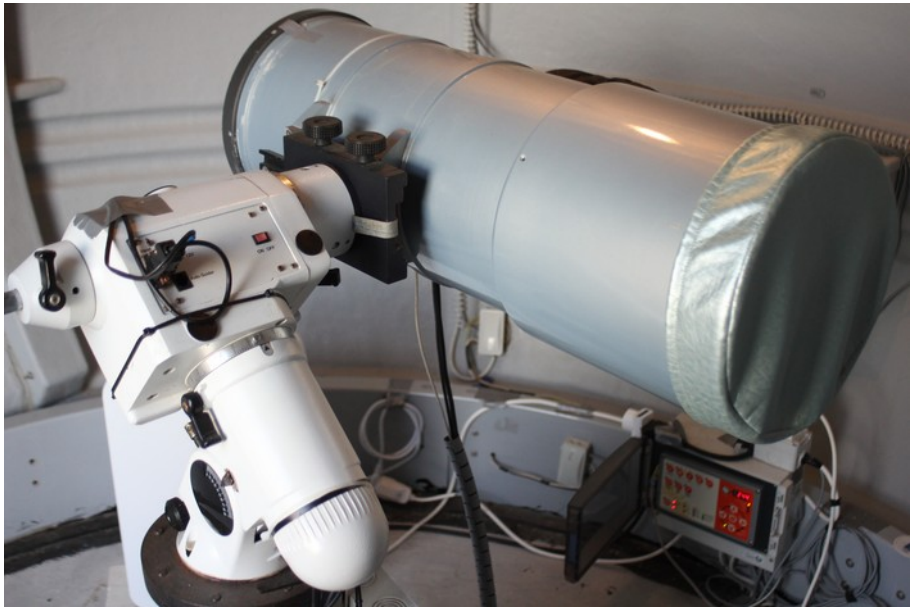
  satellites observable even at 0.5 deg above horizon



Observatory Setup

Currently: (remote control)

- 22-cm Newton-Hamilton custom-built telescope (f = 510 mm) on Skywatcher EQ-6 mount
- 3-m dome (Scopedome) → 35-cm telescope
- FLI CCD PL16803 (4096×4096 px, pixel size 9μ, pixel scale 3.56”/px, FOV 4°×4°)
- telescope control – FORTE, image processing – APEX & AstroImageJ (for trails), observation planning – custom Python scripts & Heavensat
- 2-m dome (Scopedome) → 22-cm telescope



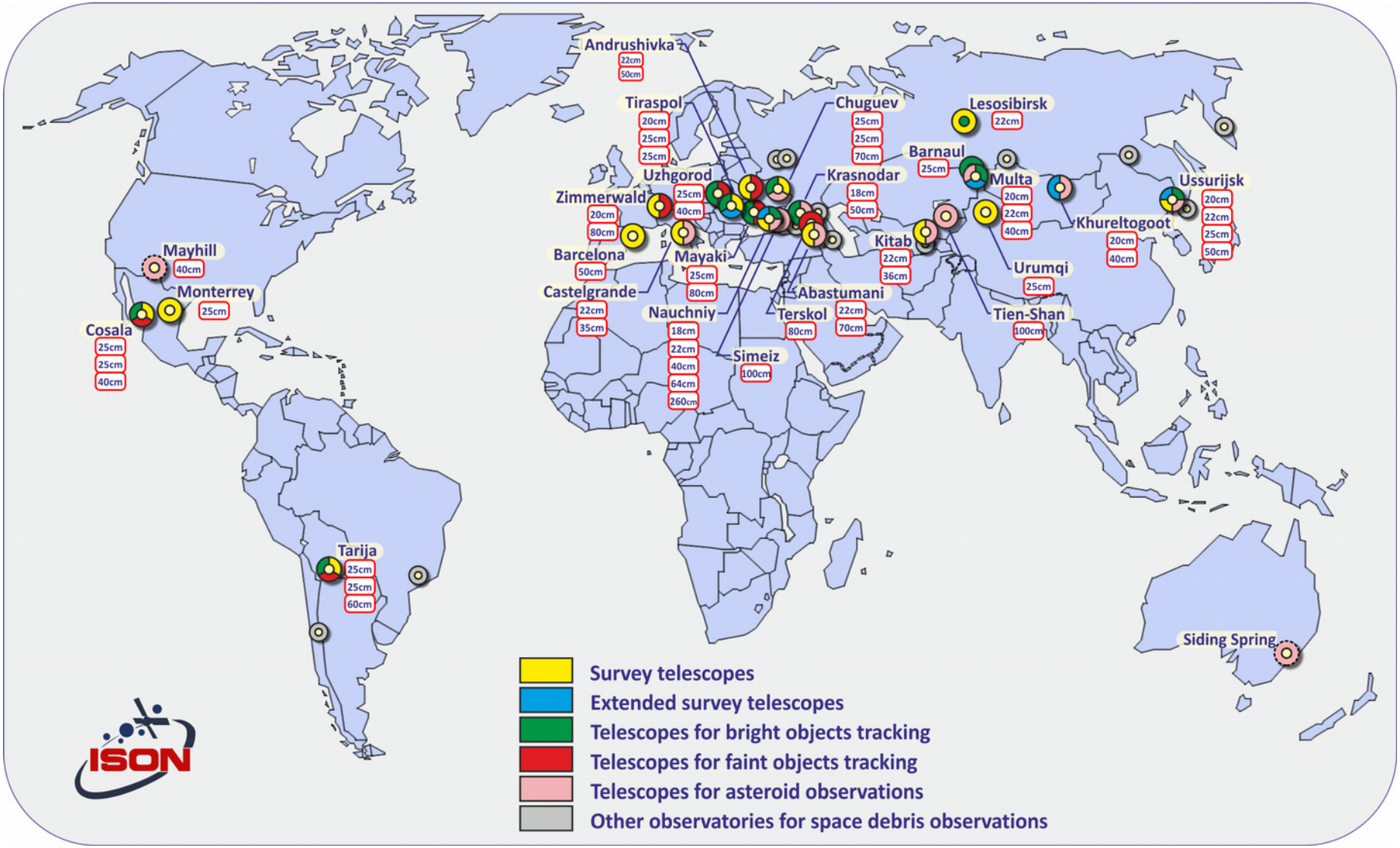
Observatory Setup

Soon:

- 35-cm Ritchey-Chretien custom-built telescope (FOV ~1°)
- on Skywatcher EQ-8 mount with a filter-wheel (Johnson-Cousins BVRI)

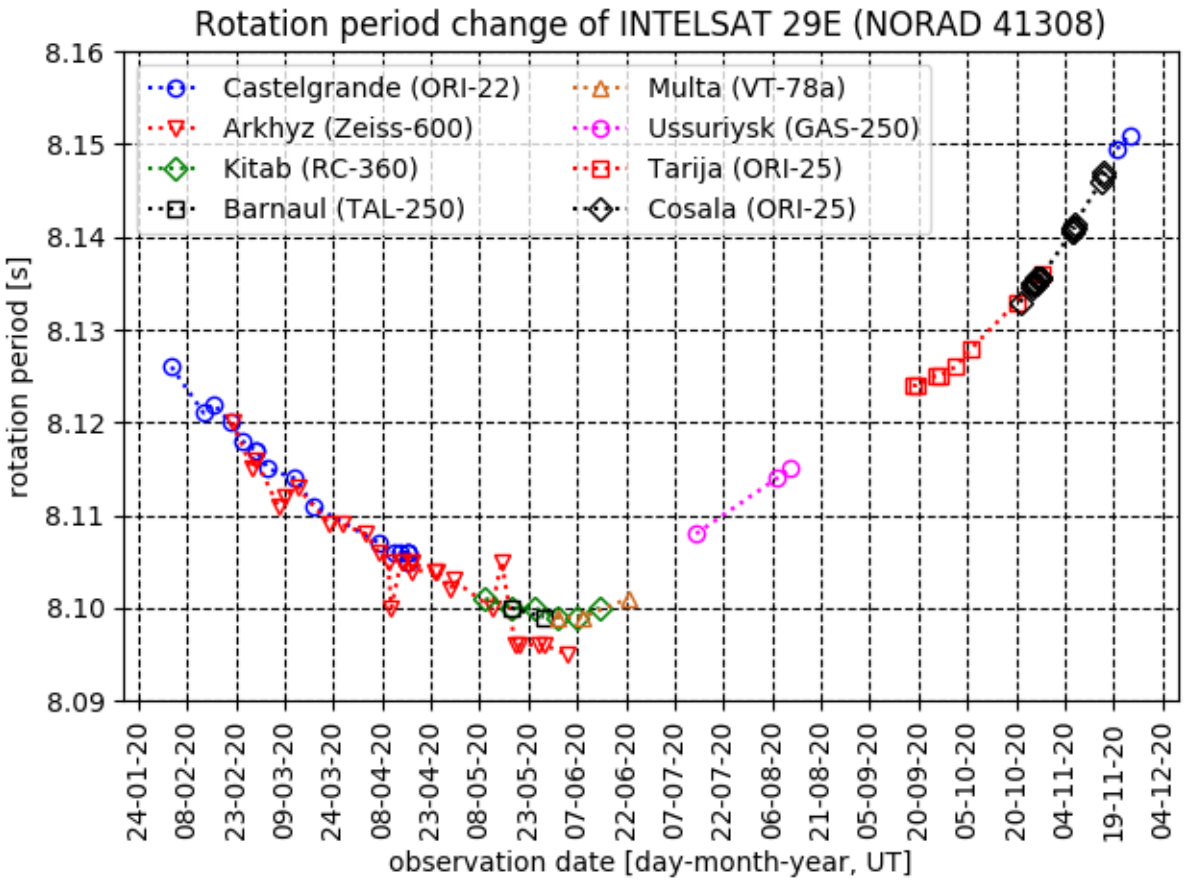
- Starlight Xpress Oculus 180 all-sky camera &
- Watec 902H2 Ultimate video-camera with Panasonic WV-LA908 lens (f=6 mm, f/0.75) → meteor showers / fireballs / **space debris re-entry**

ISON Network

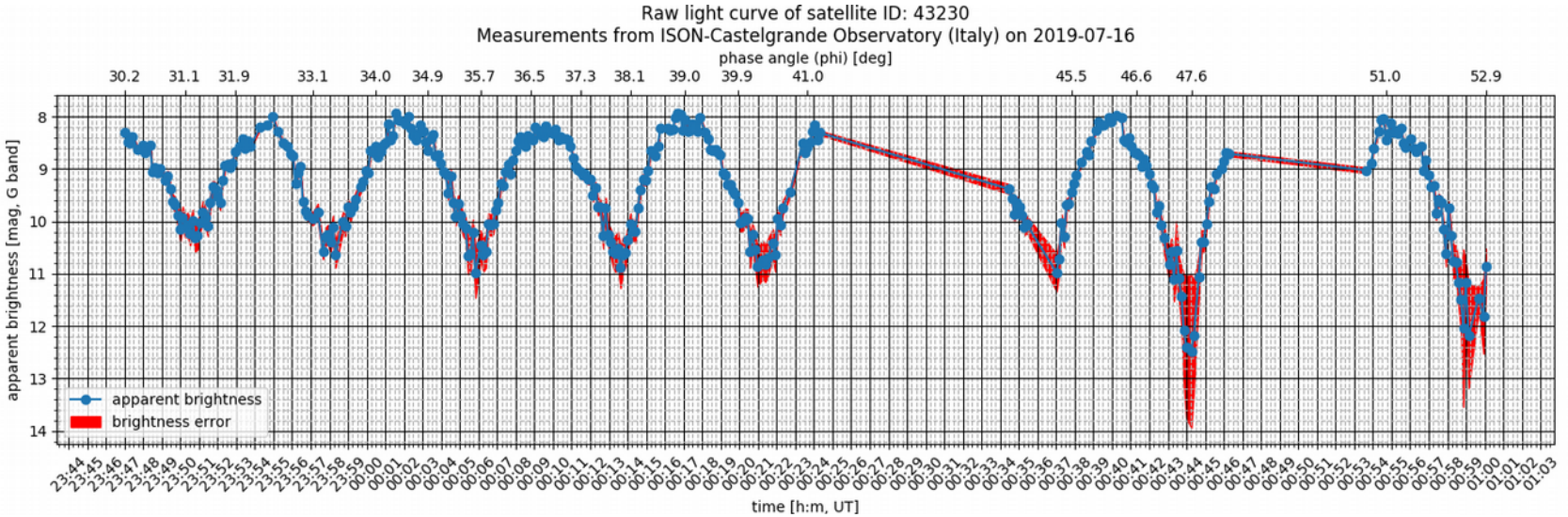


Photometry of Intelsat 29E

- rotation period change (03.02.2020 – 23.11.2020):



Falcon 9 R/B (43230) † 2020-10-16

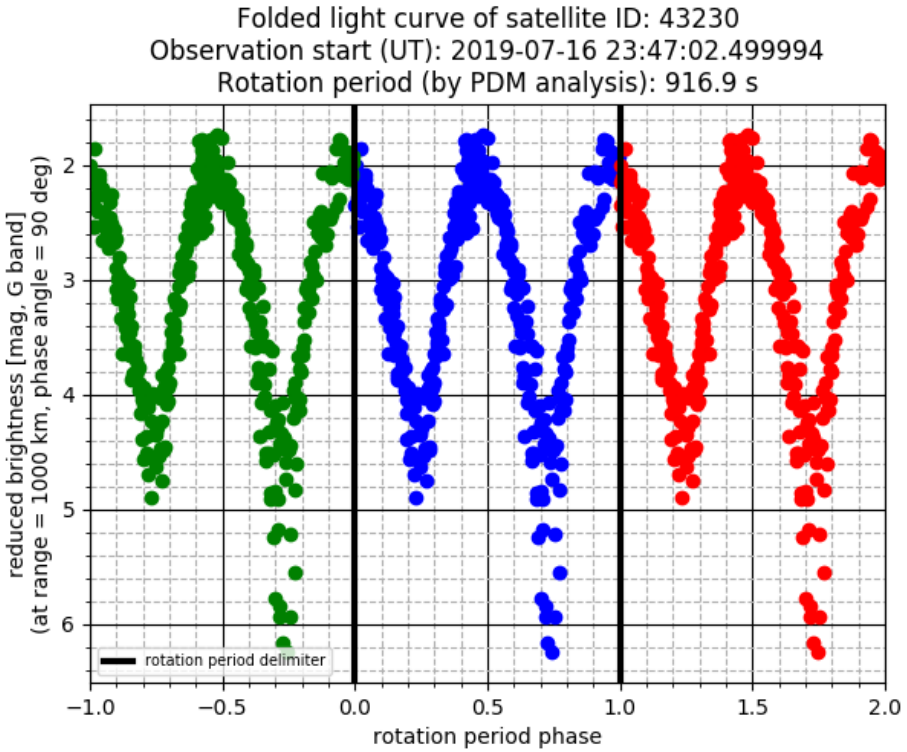


perigee height:
~ 159 km

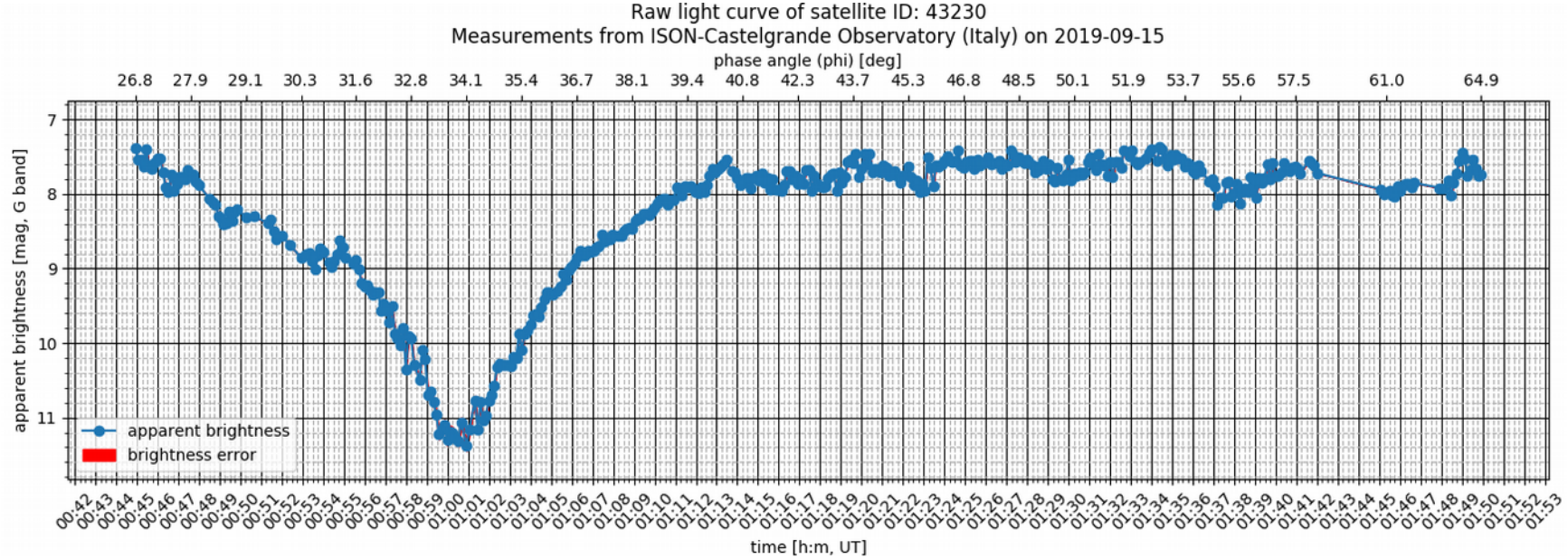
apogee height:
~ 18160 km

orbital period:
~ 321 min

rotation period:
~ 916.9 s



Falcon 9 R/B (43230) † 2020-10-16

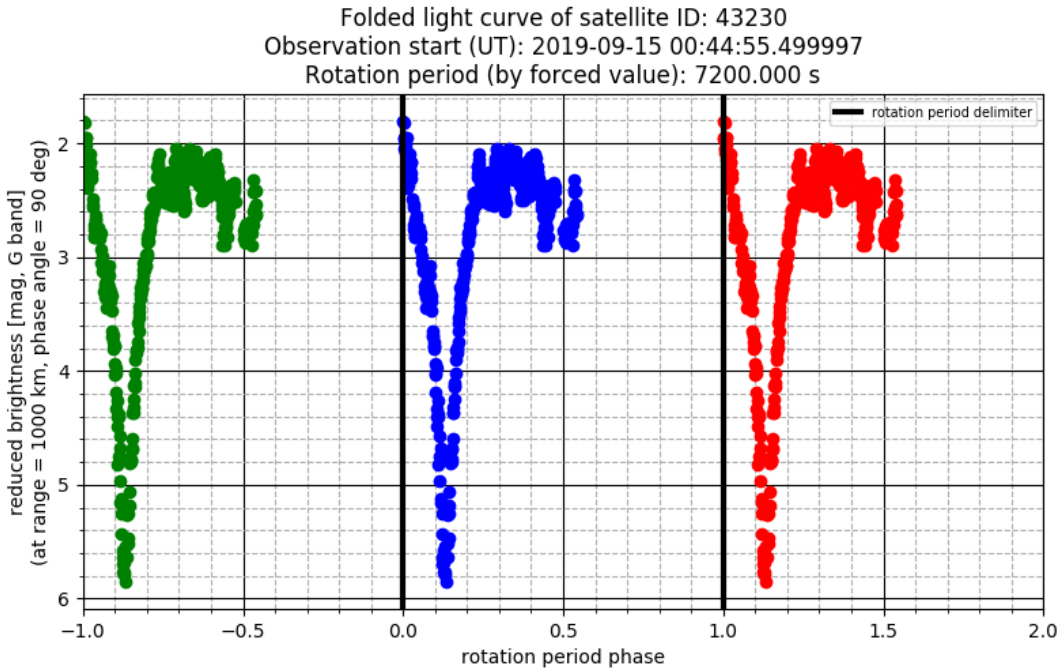


perigee height:
~ 147 km

apogee height:
~ 17147 km

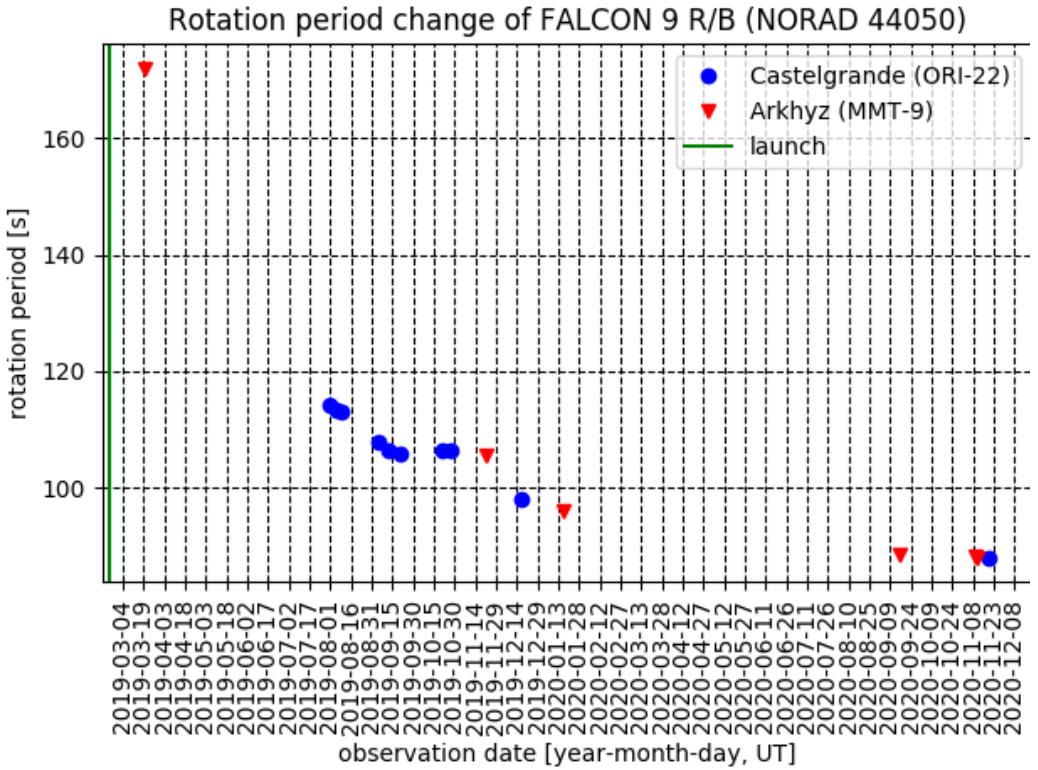
orbital period:
~ 305 min

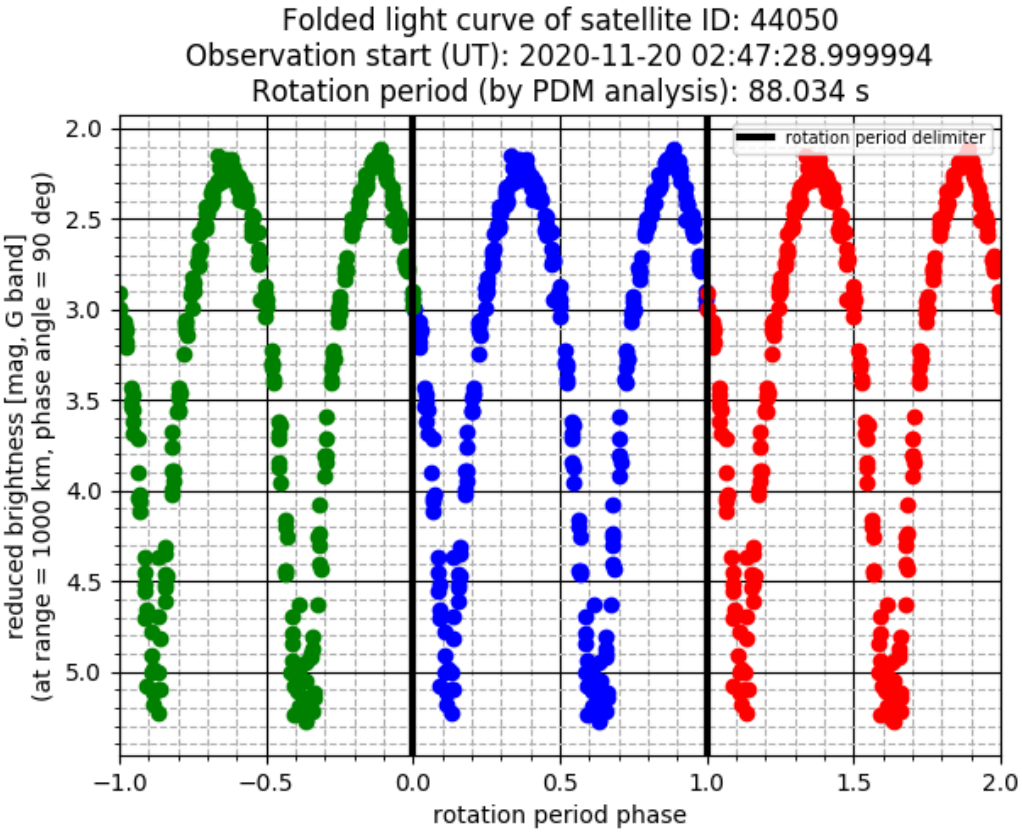
rotation period:
≥ 120 min



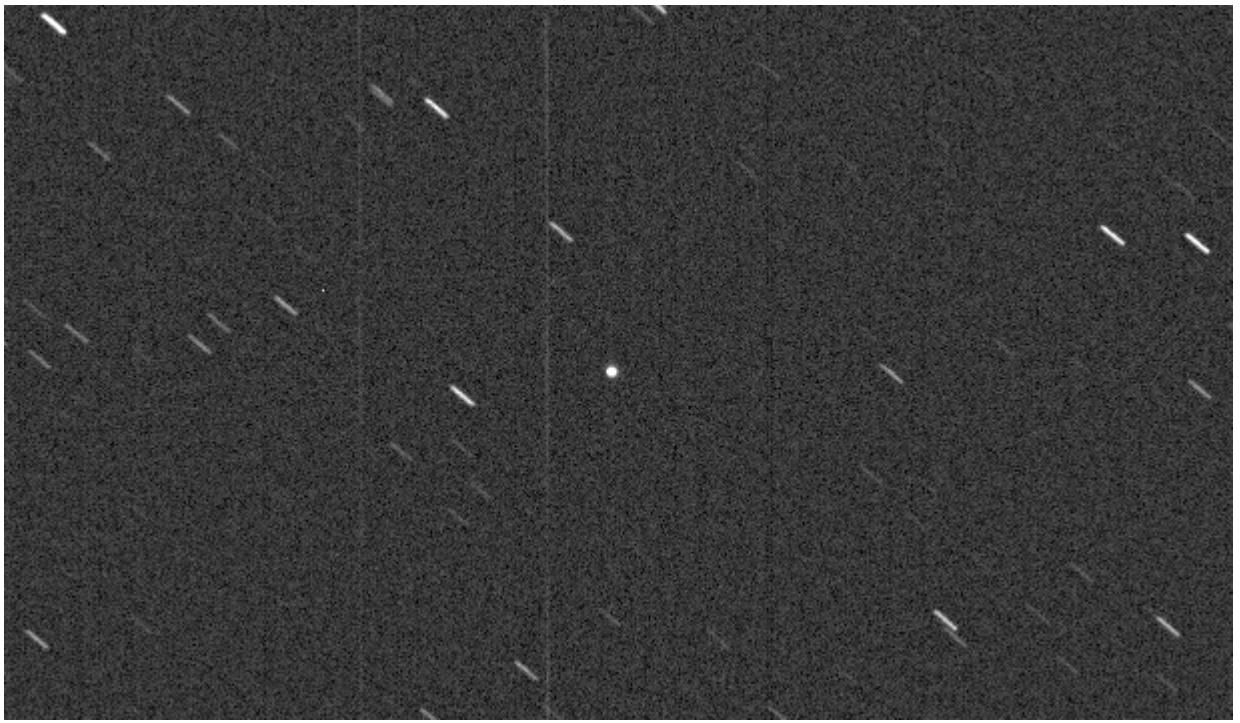
Falcon 9 R/B (44050)

- space-track.org:
- on 2020-11-05: **60day-msg decay prediction for 2020-12-31(!)** ← **wrong(?!)**
- on 2020-11-25:
  - apogee height: ~ 66488 km
  - perigee height: ~ 232 km
  - orbital period: ~ 1314 min



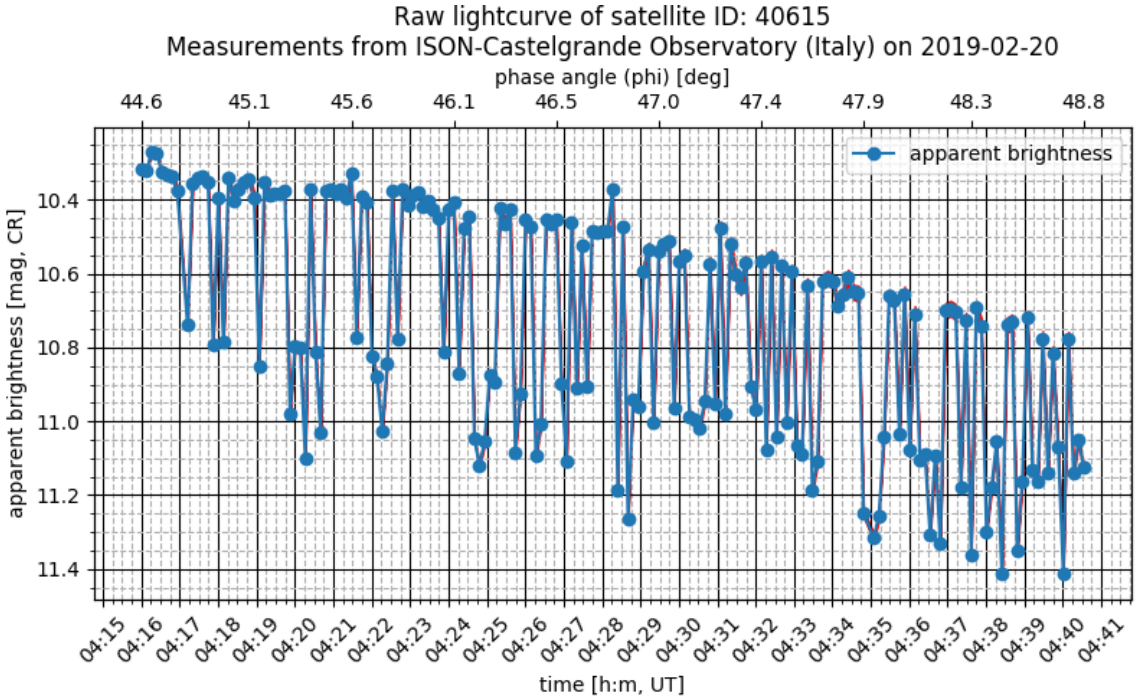


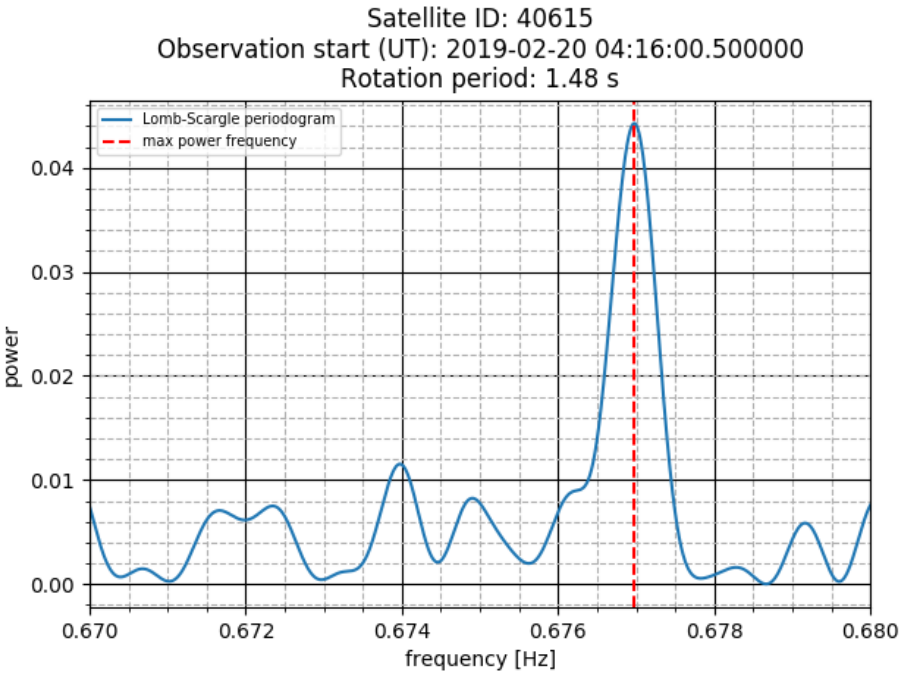
Classical (Tracking Mode) Photometry



– applicable only for GEO/MEO/**HEO** objects **at long distances**
– HEO objects **at short distances** and **LEO** objects
require **TRAIL PHOTOMETRY**

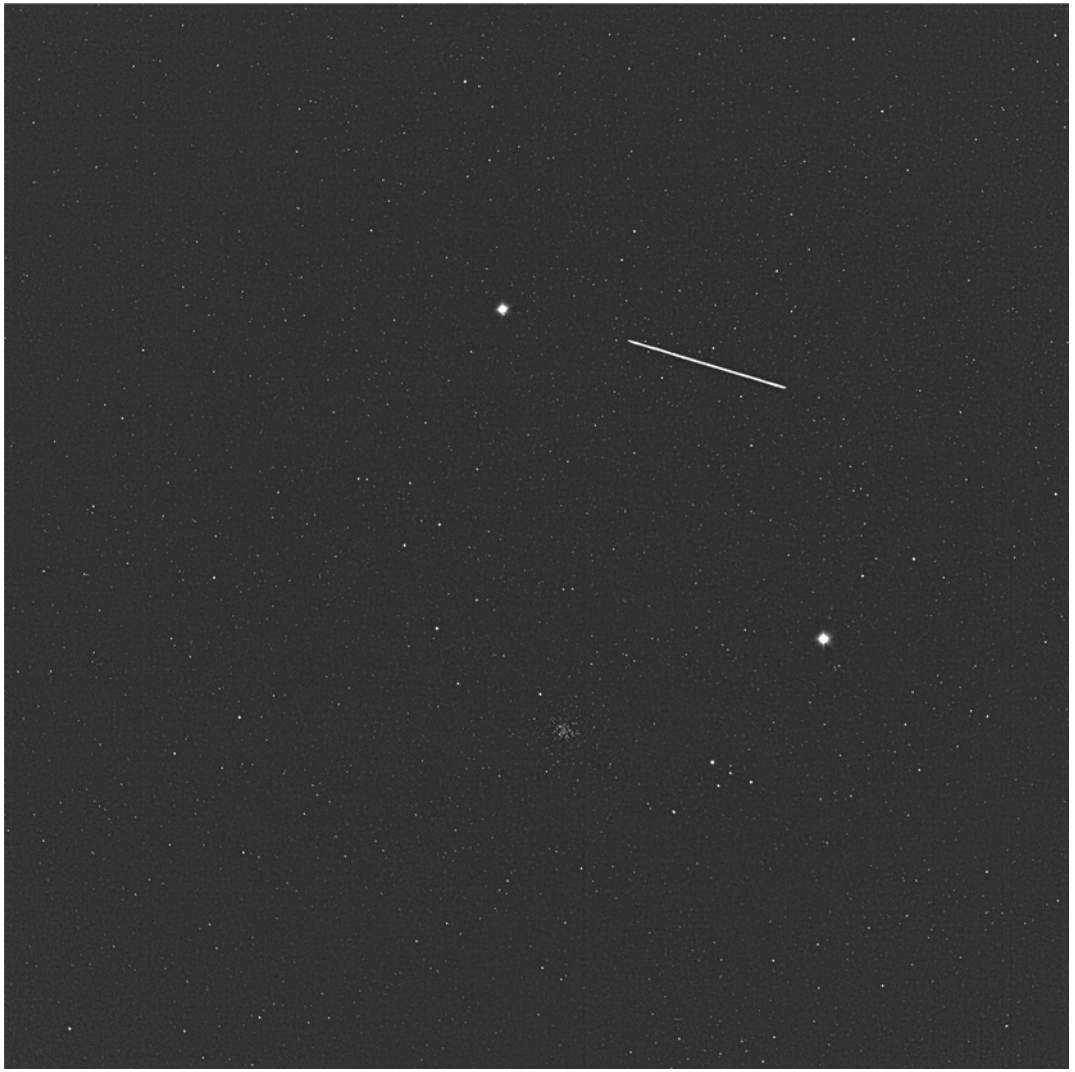
Classical (Tracking Mode) Photometry





– the exposure time is 5 s, the rotation period is ~1.48 s
– (sometimes!) possible only when **apriori info** is available
– rotation period was 1.47 s on 2019-02-16 (MMT-9 data)

Tiangong-1 Decay

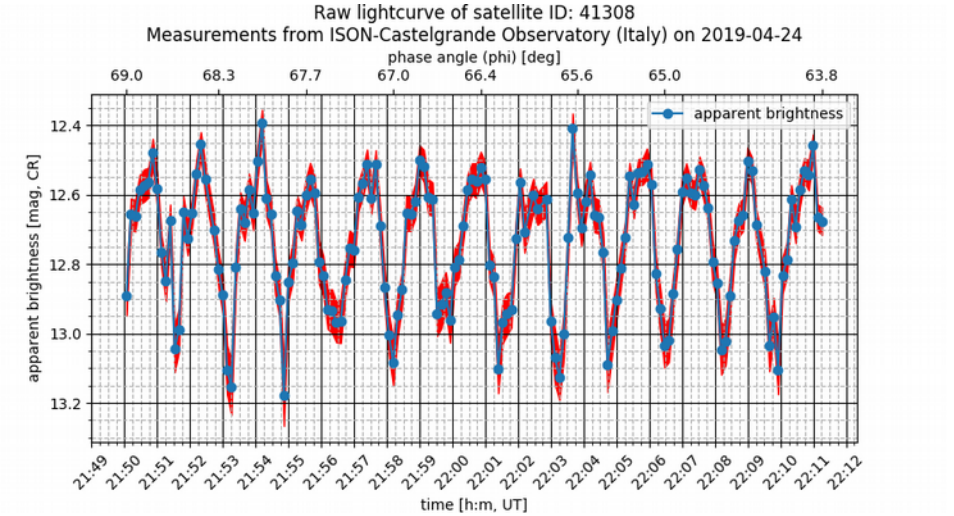


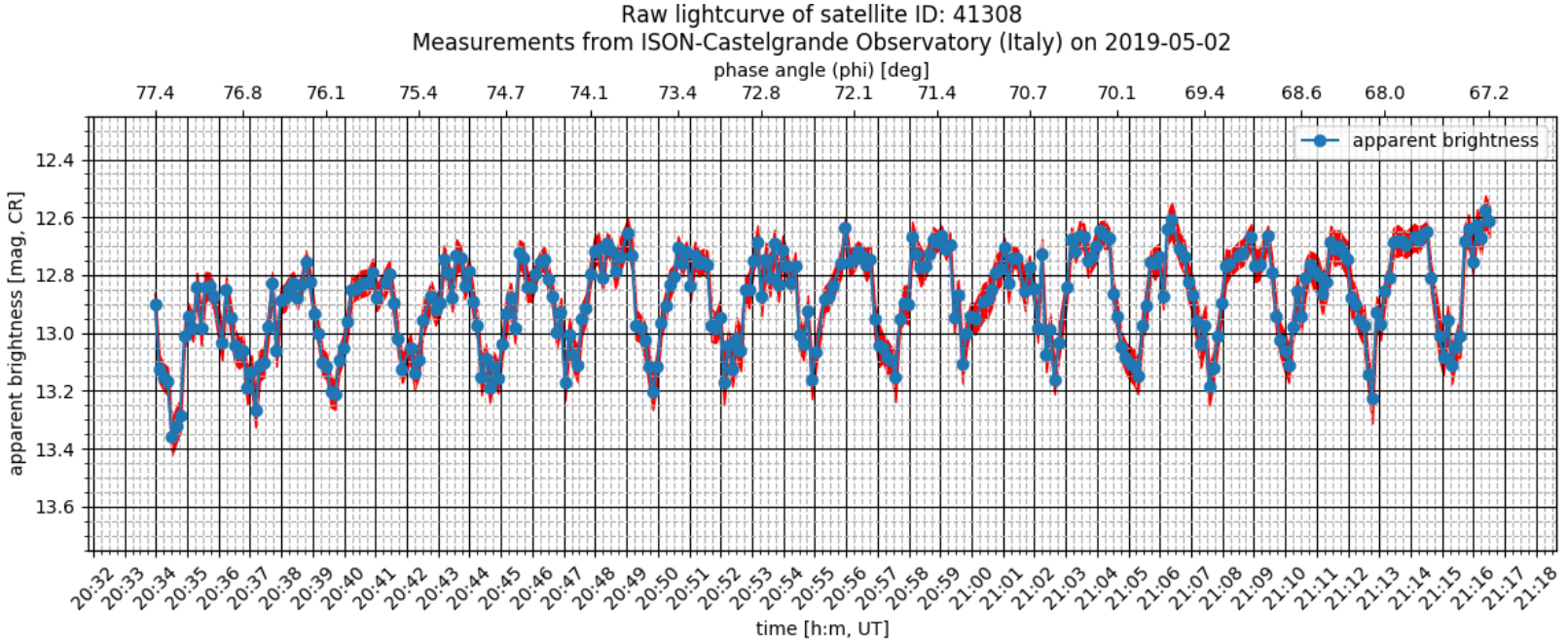
March 31, 2018; altitude ~ 150 km
exptime 0.5 sec, series of 6 images, 2 min tracklet arch
Mars (right), Saturn with two moons (top), M22 globular cluster (bottom)

Tracking Mode Photometry of Intelsat 29E

- satellite failure and control loss statement between April 7–18, 2019
- first photometric observations from Castelgrande between April 24 – May 9, 2019
- the rotation period was **mistakenly(!)** believed to be long and slowing down:

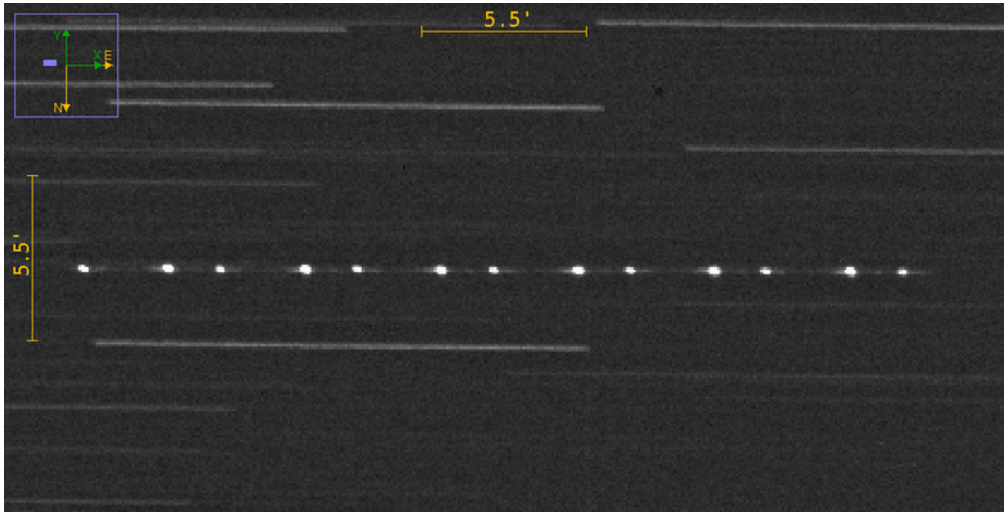
  - 2019-04-24 – 96.05 sec
  - 2019-04-27 – 115.39 sec
  - 2019-04-30 – 136.51 sec
  - 2019-05-02 – 152.04 sec
  - 2019-05-07 – 211.57 sec
  - 2019-05-09 – 252.37 sec

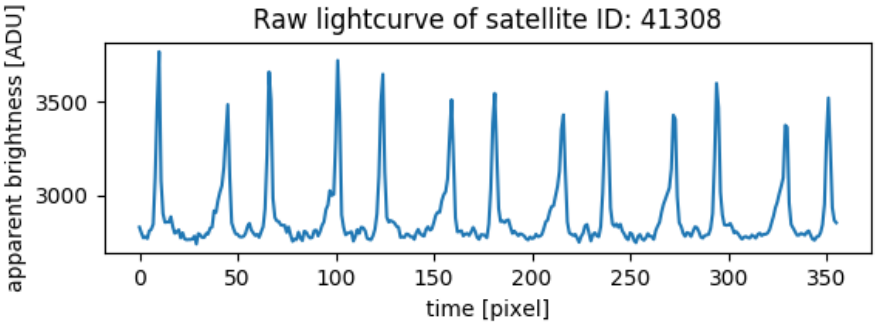


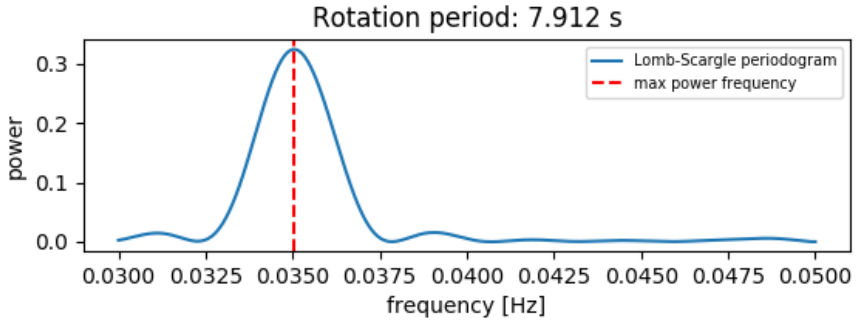


Trailing Mode Photometry of Intelsat 29E

- 2019-05-08 – 60-cm telescope at the Archyz Observatory with a fast read-out CCD showed rotation period to be 8.32 sec (and also later that it was speeding up)
- multiple trailed observations in Castelgrande since 2019-05-09 (still continued)
  - 2019-05-09 – 8.32 sec
  - 2019-05-11 – 8.24 sec
  - 2019-05-12 – 8.19 sec
  - 2019-05-17 – 8.14 sec
  - 2019-05-24 – 7.99 sec
  - 2019-05-29 – 7.91 sec
  - …

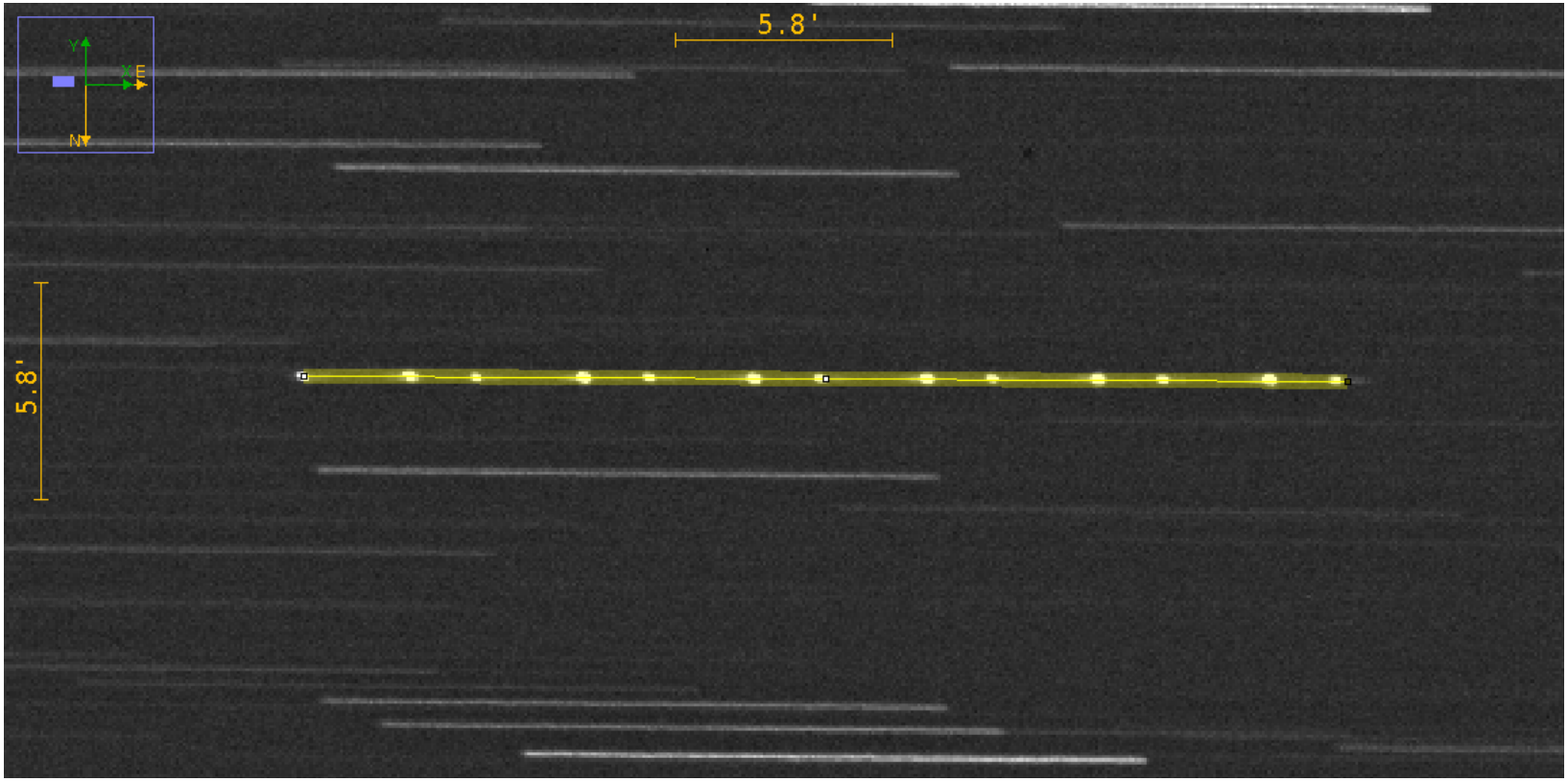






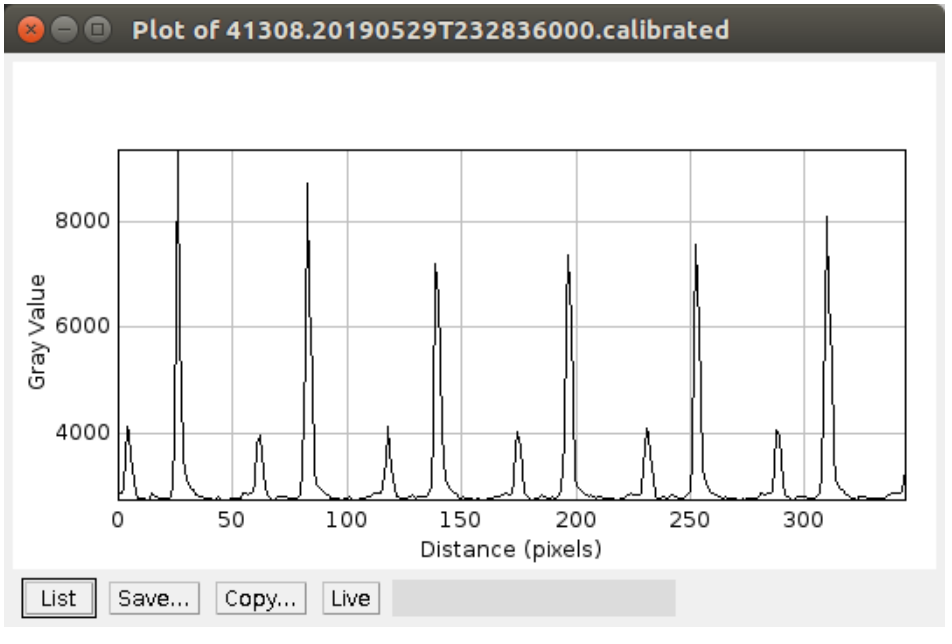
Trail Photometry Method

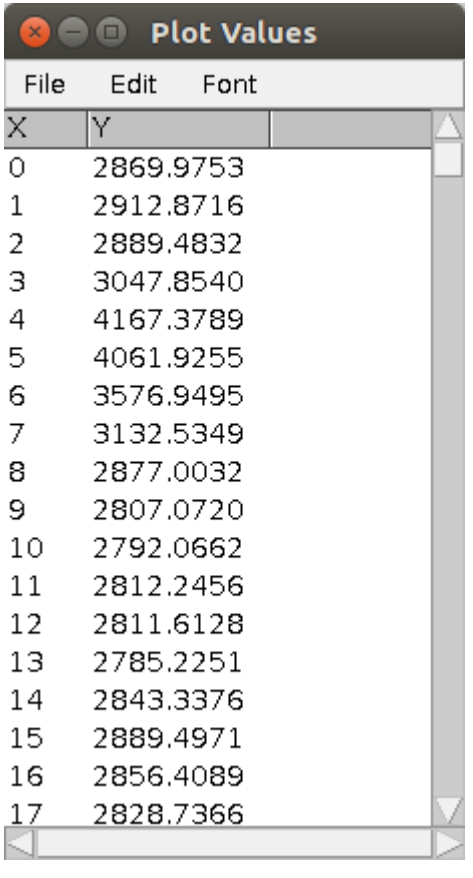
- apply **linear aperture** to the trail (in artsat movement direction) in original FITS image **using AstroImageJ** (set aperture pixel width by Edit → Options → Line Width):



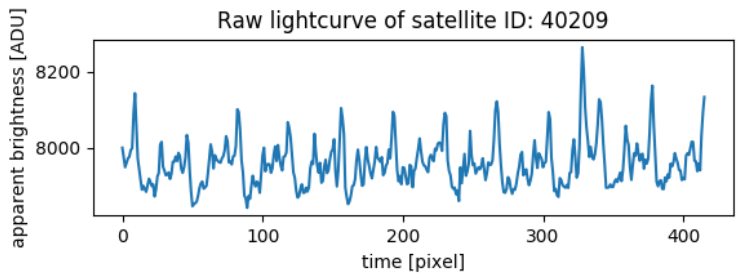
Trail Photometry Method

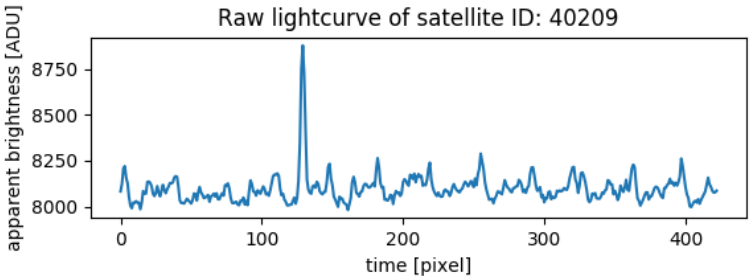
- select from the program menu “Analyze → Plot static line/box profile”, save the XLS file with data (“List” button), apply a Python script to determine the rotation period, using Lomb-Scargle periodogram imported from AstroPy, **taking into account the pixel scale of the image (pixel is a time unit!) and the mean angular velocity of artsat (calculated from the angular trail length by the equatorial coordinates of trail start/end on the basis of artsat ephemeris and exposure time)**:

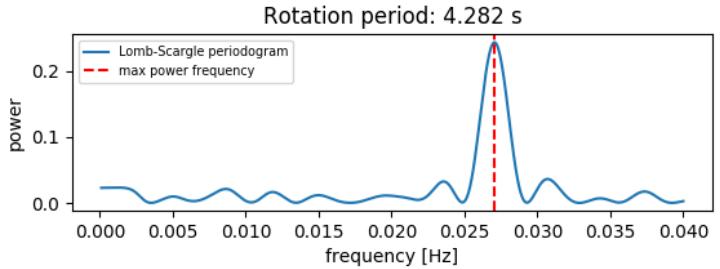


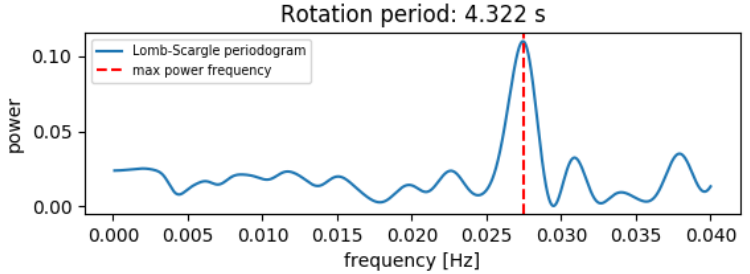


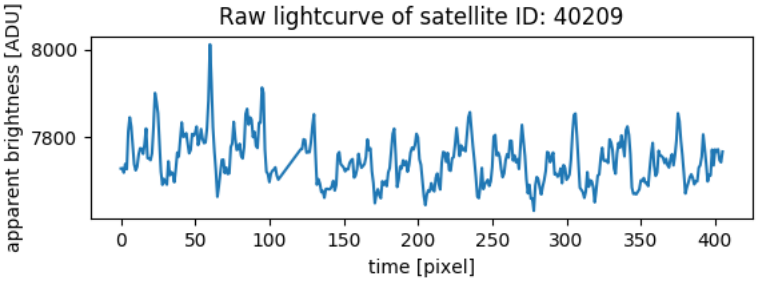
Rotation Period Error Minimization

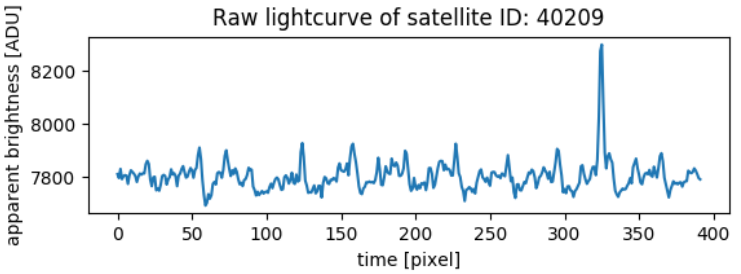


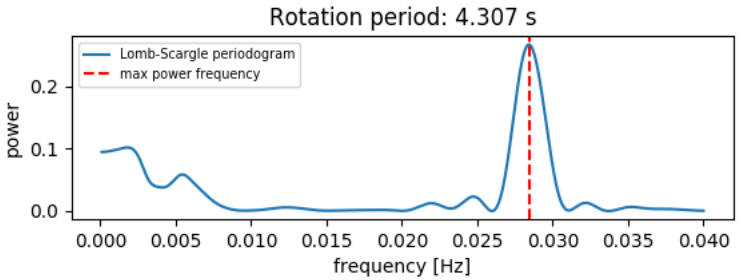


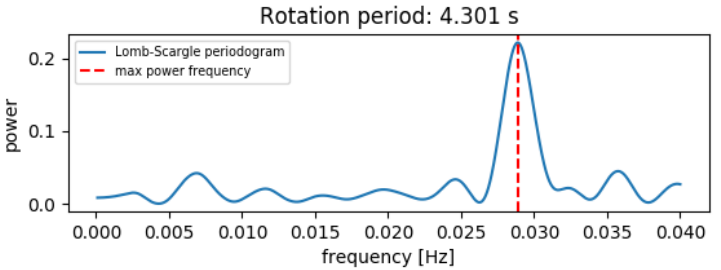








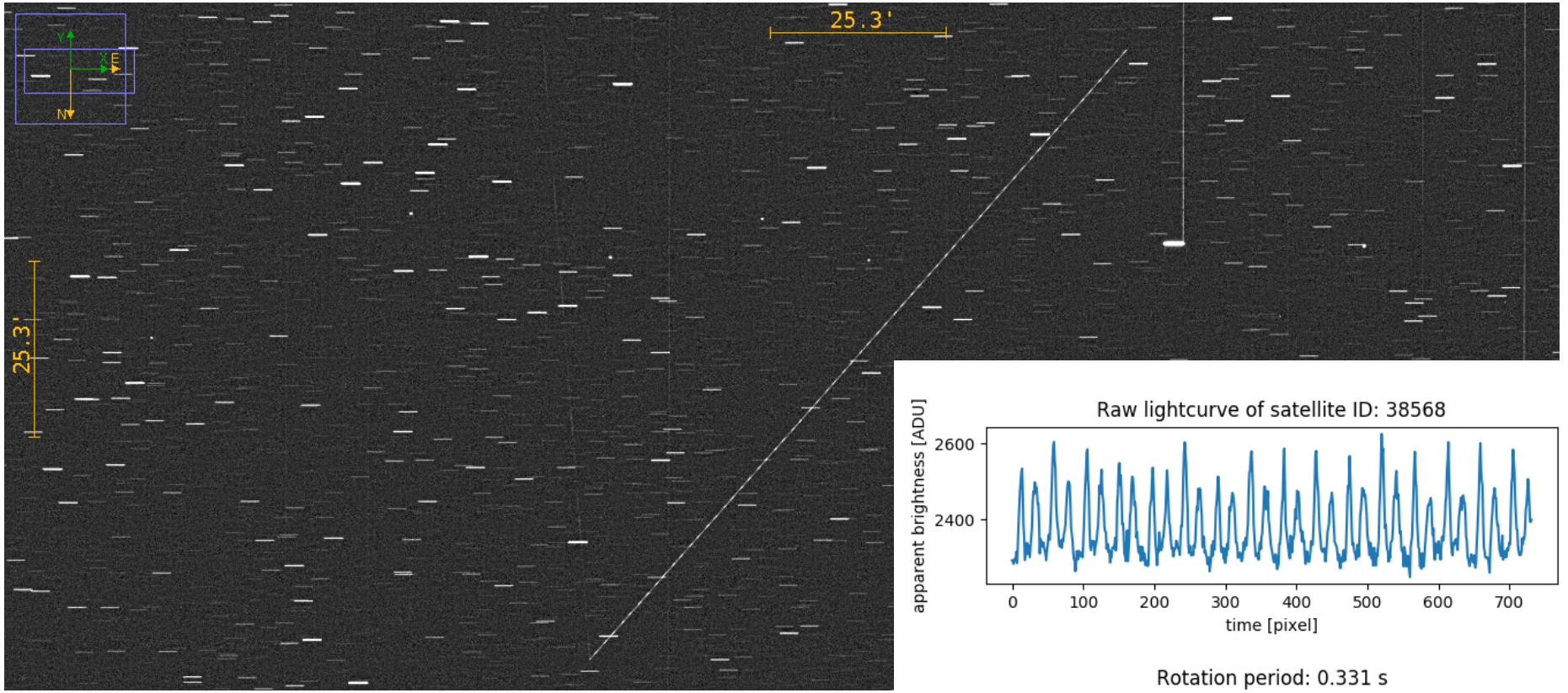


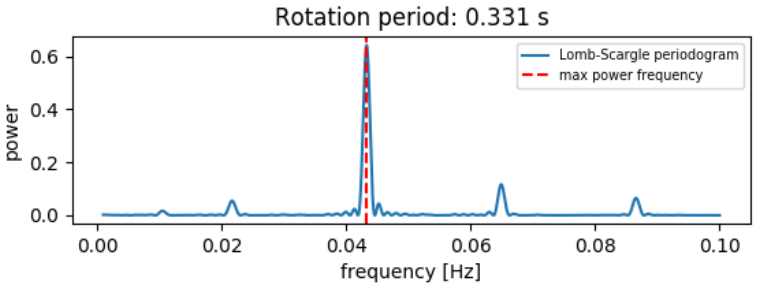


– mean rotation period 4.303 sec (in agreement with MMT-9 data) with negligible dispersion

The Fastest Rotator So Far

- BREEZE-M Deb (38568) in HEO, exptime 10 sec:



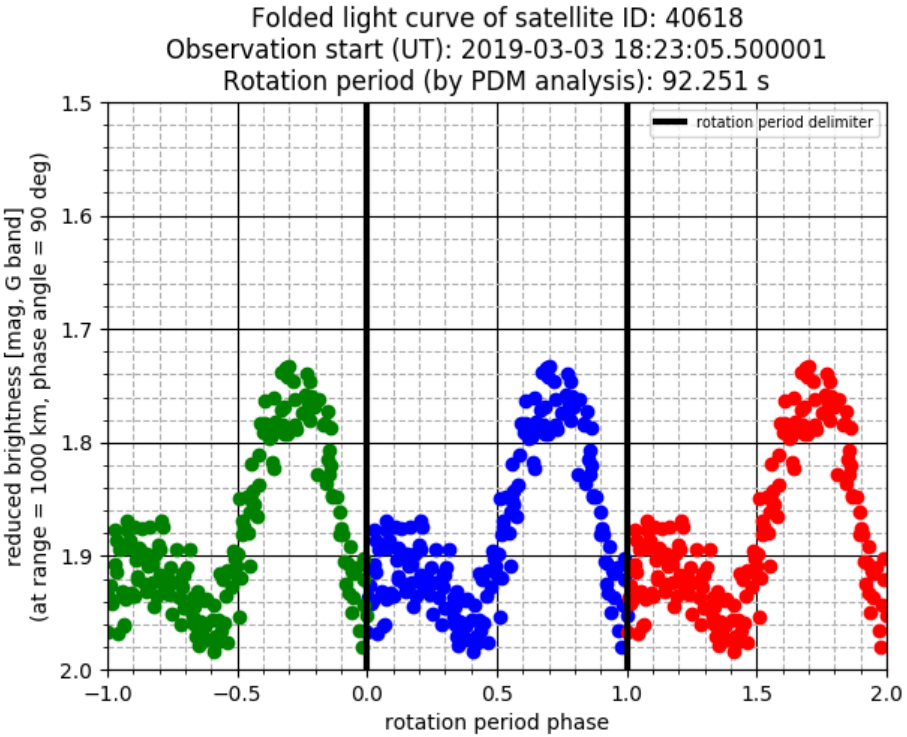


P_{Cast} = 0.331 (2019-05-17)

P_{MMT} = 0.3358 (2019-05-15)

Photometry Summary

- regular photometric observations for objects in GEO/HEO/MEO/LEO since February 2019
- brightness amplitude resolution:
  - ≥ 0.1 mag
- typical exposure times:
  - 1-5[-10] seconds
- limiting magnitude:
  - 15 mag in tracking mode
  - 12.5 mag in trailing mode
- obtained rotation periods:
  - from 0.331 s up to ~2 h
- rotation period precision down to 0.001 s
- by November 2020 obtained light curves of ~200 artificial space objects
- long-term observation campaigns for Falcon 9 R/B and Atlas 5 Centaur R/B upper stages in HEO and Intelsat 29E (NORAD 41308) in GEO
- international collaboration with a full globe coverage



Thank you!

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