Astronomy Seminar

Group 1: Observation

Ionut-Rares Pavel – ESPACE M.Sc.

Simone Gaisbauer – GuG M.Sc.

Isabel Hölzl – GuG M.Sc.

Antonia Bieringer – GuG M.Sc.

Outlook

- **Scope**
- **Observation Principle**
- **Equipment**
- **Calibration**
- **Measurements**

1. Scope

- Despite progress, there still is a lack of policy regarding debris removal [1];

- Current models do not agree quantitatively [2];

- But all conclude that space operations will become hampered in the next decades;

- The debris population in near-Earth space - extensively studied during the last decade [2];
  - Information on objects > 2000km is still sparse;
  - Best detected by optical telescopes;
  - Many similarities with NEO observations.

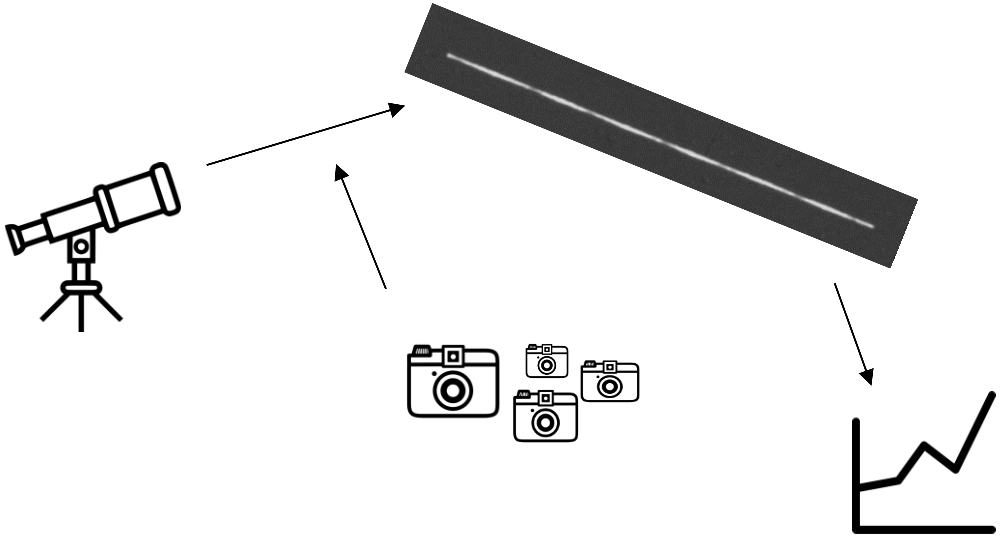
2.1 Observation Principle [3]

Radar – limited to low-orbiting objects; area > signal wavelength;
LADAR – Laser Radar – point clouds from 3D scans;

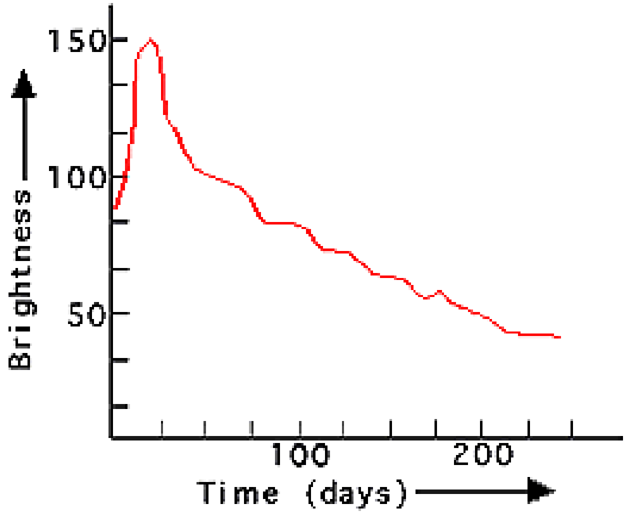
Light curves - time-varying brightness measurements that result when sunlight reflects off the surfaces of a moving space object and reaches an observer;

- Used for stars, asteroids, and now space debris.
- Time intervals depend on the object’s movement.

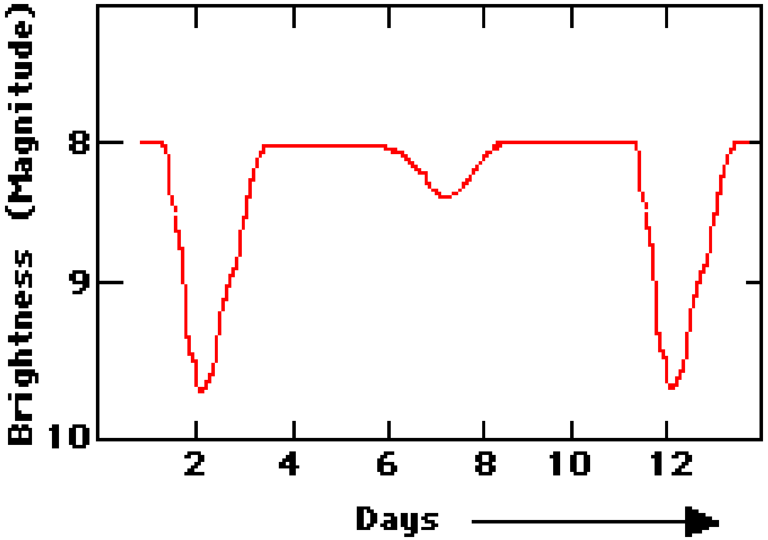
Brightness change → Size
→ Shape
→ **Rotation!**



2.2 Light Curves



Light curve of a supernova [4].



Light curve of a binary star system [4].

2.2 Light Curves

- Optical surveys provide statistical information [5]:
    - rough characterization of the orbits, information on the magnitudes of the objects.

- Magnitudes ⟶ physical sizes: knowledge of surface properties shapes [5];
    - analysis of properties: observations of individual objects with large aperture, small FoV telescopes;
        - Tracking of individual objects: precise ephemerides (catalogue of precise orbits).

- Most objects have brightness variations with frequencies of [mHz] up to [dHz], corresponding to tumbling or rotation rates of the order of a tenth to many rotations per minute [5].

2.3 Mathematical Models [3]

Shape modelling

SO with i facets; facet with area A_i. Relative orientation of facet to body (B) is given by:

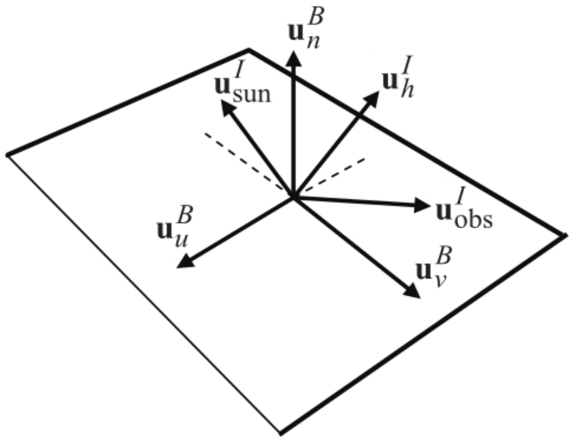
$$\mathbf{u}^B_{u(i)} \times \mathbf{u}^B_{v(i)} = \mathbf{u}^B_{n(i)}$$

Relative orientation of the Body (B) and Inertial (I) frames is described by the A_{true} matrix:

$$\mathbf{v}^B = A_{\text{true}}\mathbf{v}^I$$

The estimated attitude matrix A will include the error vector:

$$\widehat{A} = \exp\{-[\boldsymbol{\delta\alpha}\times]\}\, A_{\text{true}} \approx (\mathrm{I} - [\boldsymbol{\delta\alpha}\times])\, A_{\text{true}}$$



Vector system of facet *i* [3]

Light reflection modelling

$$F_{\text{sun}(i)} = C_{\text{sun,vis}}\rho_{\text{total}(i)}\left(\mathbf{u}^I_{\text{sun}} \cdot \mathbf{u}^I_{n(i)}\right)$$

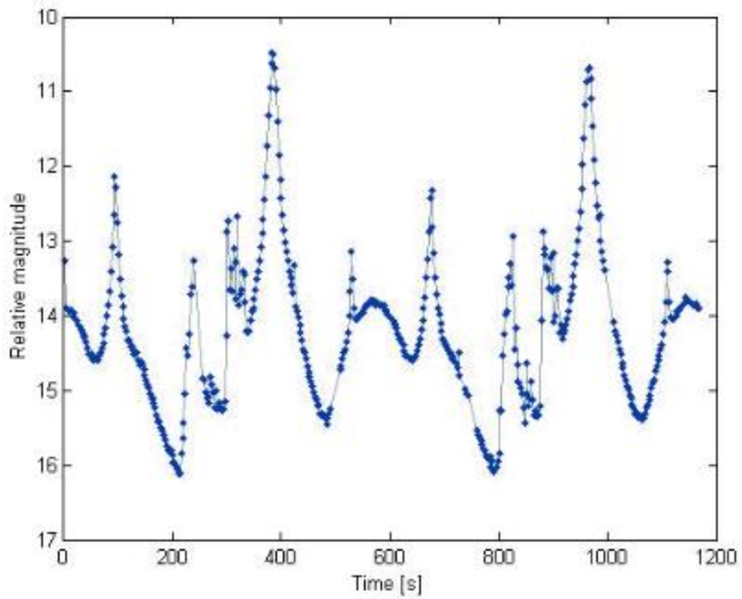
$$\rho_{\text{total}(i)} = \rho_{\text{spec}(i)} + \rho_{\text{diff}(i)}$$

$$\rho_{\text{spec}(i)} = k_{1(i)}\frac{\rho_{\text{spec}_{\text{num}}}(i)}{\rho_{\text{spec}_{\text{den}}}(i)}F_{\text{reflect}(i)}$$

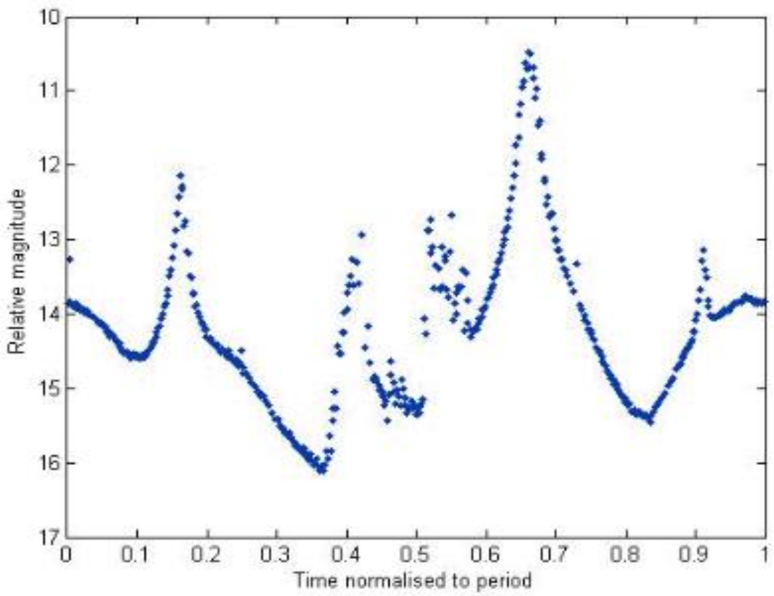
$$\rho_{\text{diff}(i)} = k_{2(i)}\left[1 - \left(1 - \frac{\mathbf{u}^I_{\text{obs}} \cdot \mathbf{u}^I_{n(i)}}{2}\right)^5\right]\left[1 - \left(1 - \frac{\mathbf{u}^I_{\text{sun}} \cdot \mathbf{u}^I_{n(i)}}{2}\right)^5\right]$$

2.4 Extraction Methods [6]

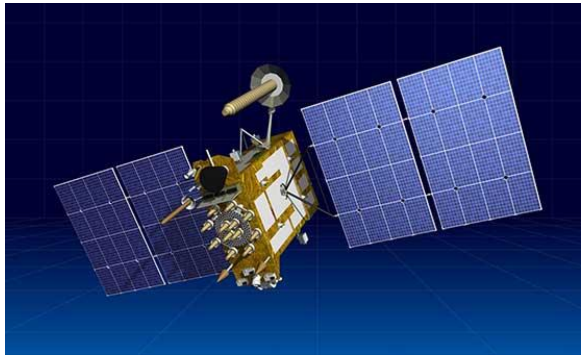
1. Fast Fourier Transform → Commonly used for space debris observation - baseline
   Requires equally spaced data points – difficult in practice
2. Epoch folding method
3. Lomb-Scargle periodogram
4. Phase reconstruction



Measured light curve of PAKSAT (07.11.2014)



Reconstructed phase with 581s period.


Box-wing satellite - GLONASS

2.5 Conclusions

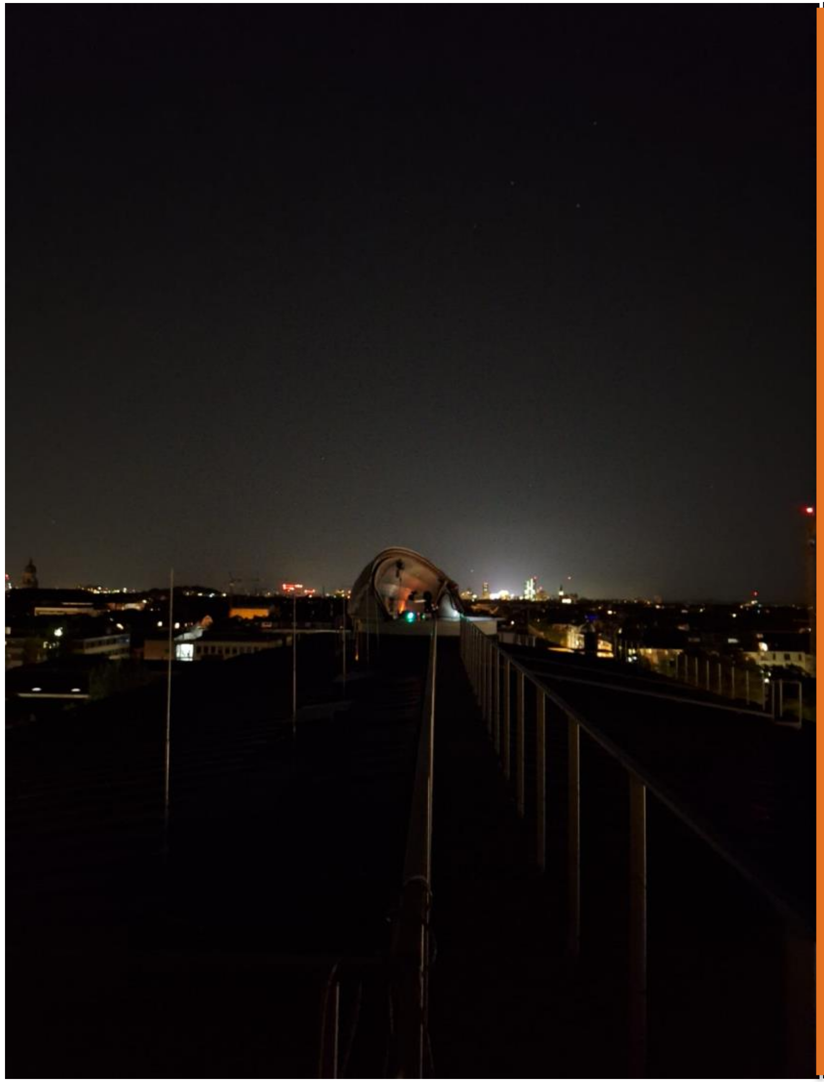
Challenges

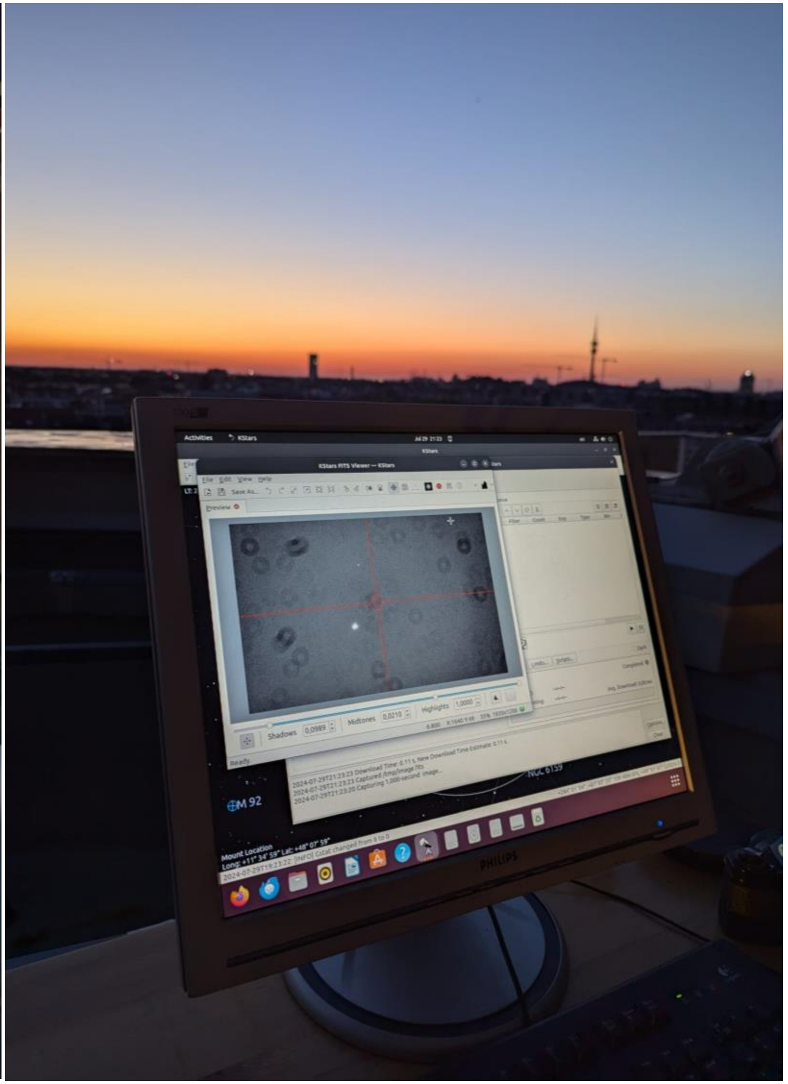
- **Limited Resolution**: Detecting and tracking small debris (<10 cm) in LEO [7]
- **Short Observation Windows**: limited data collection due to brief observation periods [8];
- **Weather & Atmospheric Conditions**: Ground-based telescopes are affected by weather, limiting observation times;
- **Ambiguity**: Light curves from different objects can sometimes look very similar, making it hard to identify specific debris;
- **Tumbling Complications**: Objects that are tumbling rapidly create complex light curves that are harder to interpret [5].

Future trends

- **Machine learning approaches**: automated light curve analysis, object classification [9];
- **Multi-site stereoscopic observations**: improved 3D reconstruction [10];
- **Integration of spectral data with light curves**: enhanced material characterization [11];
- **Improved models**: non-rigid body dynamics for tumbling objects [12].

3.1 Equipment – Hardware





3.1 Equipment – Hardware

Telescope

CELESTRON EdgeHD 11"

https://www.celestron.com/products/edgehd-11-optical-tube-assembly-cge-dovetail#description

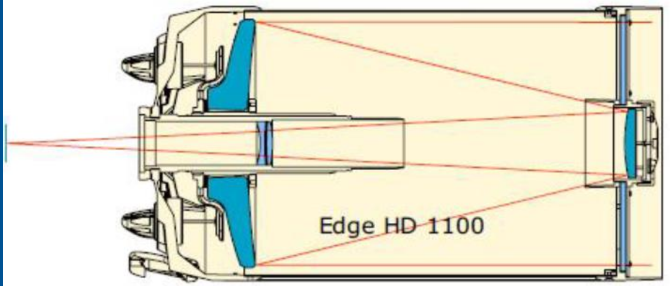


Image source: CELESTRON WHITEPAPER 2013, p. 3

3.1 Equipment – Hardware

Telescope

CELESTRON EdgeHD 11"

https://www.celestron.com/products/edgehd-11-optical-tube-assembly-cge-dovetail#description

Mount

10Micron GM2000 HPS

https://10micron.eu/montierungen/aequatoriale-montierungen/gm2000-hps-ii-combi-goto-montierung

3.1 Equipment – Hardware

Telescope

CELESTRON EdgeHD 11''

https://www.celestron.com/products/edgehd-11-optical-tube-assembly-cge-dovetail#description

Camera

QHY174GPS

https://www.qhyccd.com/qhy174gps-imx174-scientific-cooled-camera/

Mount

10Micron GM2000 HPS

https://10micron.eu/montierungen/aequatoriale-montierungen/gm2000-hps-ii-combi-goto-montierung

3.1 Equipment – Hardware

Telescope

CELESTRON EdgeHD 11"

https://www.celestron.com/products/edgehd-11-optical-tube-assembly-cge-dovetail#description

Camera

QHY174GPS

https://www.qhyccd.com/qhy174gps-imx174-scientific-cooled-camera/

Mount

10Micron GM2000 HPS

https://10micron.eu/montierungen/aequatoriale-montierungen/gm2000-hps-ii-combi-goto-montierung

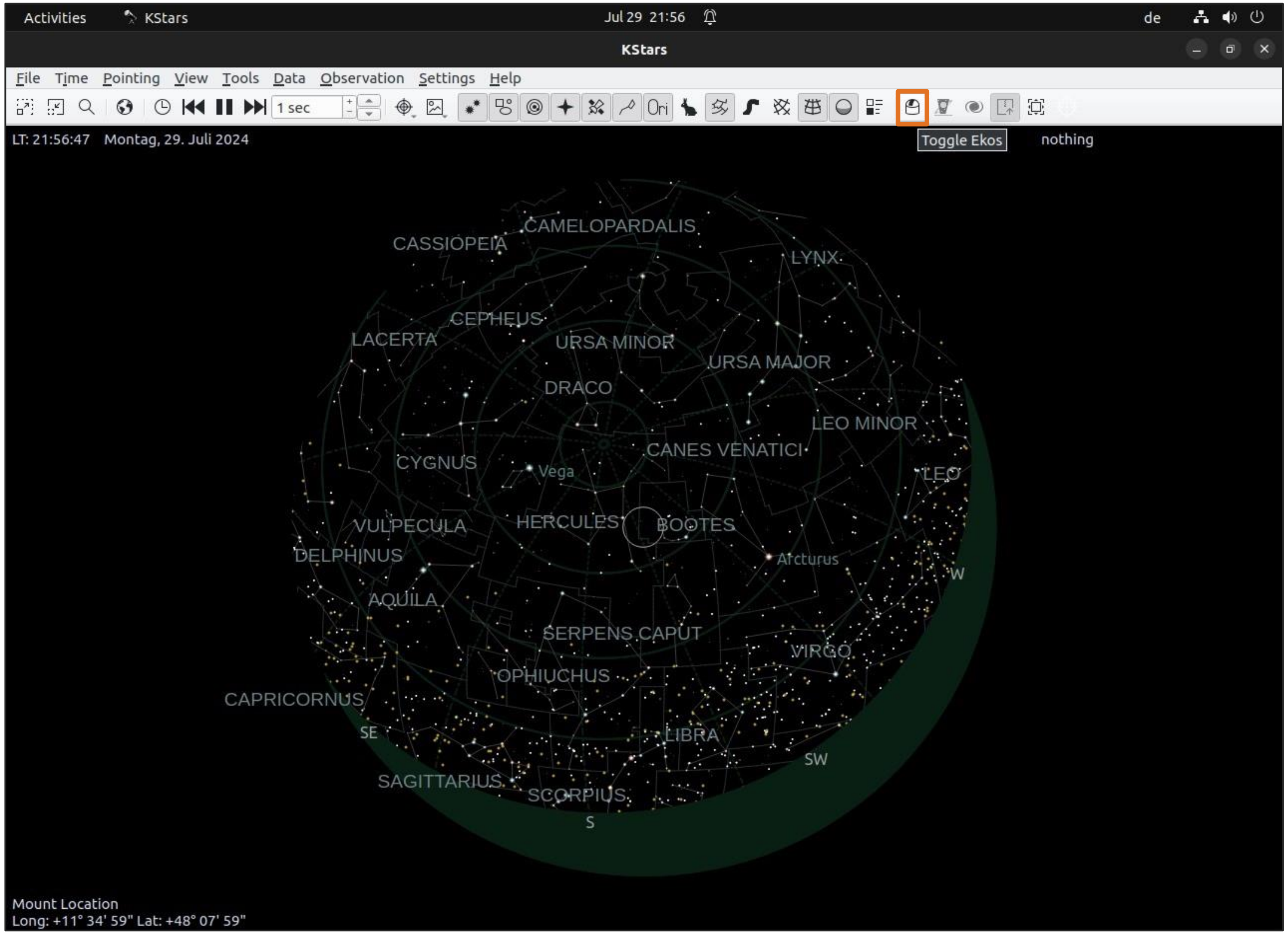
GNSS Receiver

QHY174GPS

https://www.deepspaceproducts.com/uimages/qhy/174GPS-3_b.jpg

3.2 Equipment – Software

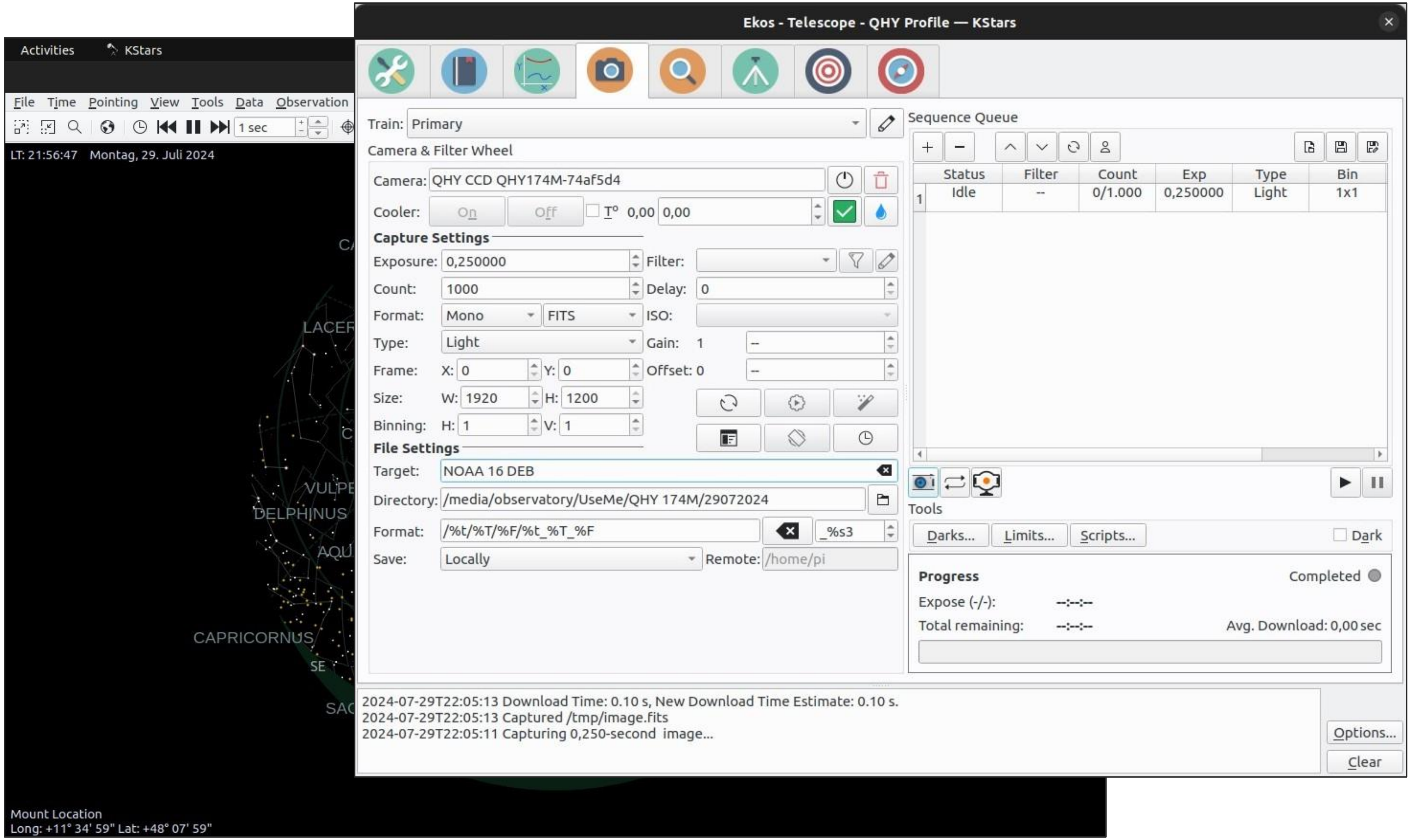
kstars
(astronomy software)



3.2 Equipment – Software

kstars
astronomy software

ekos
astrophoto-graphy suite

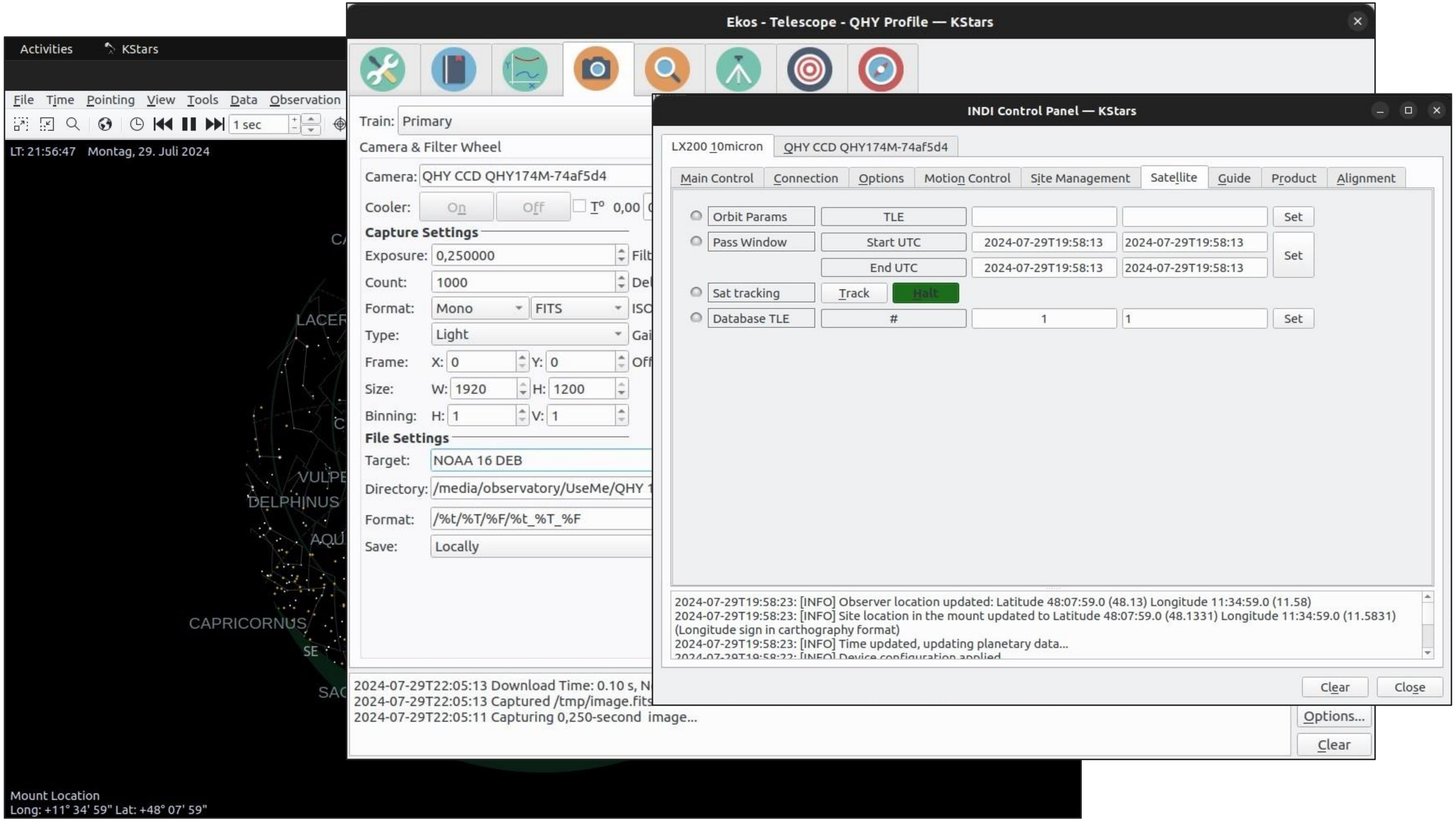


3.2 Equipment – Software

kstars
astronomy software

ekos
astrophoto-graphy suite

indi
control of hardware

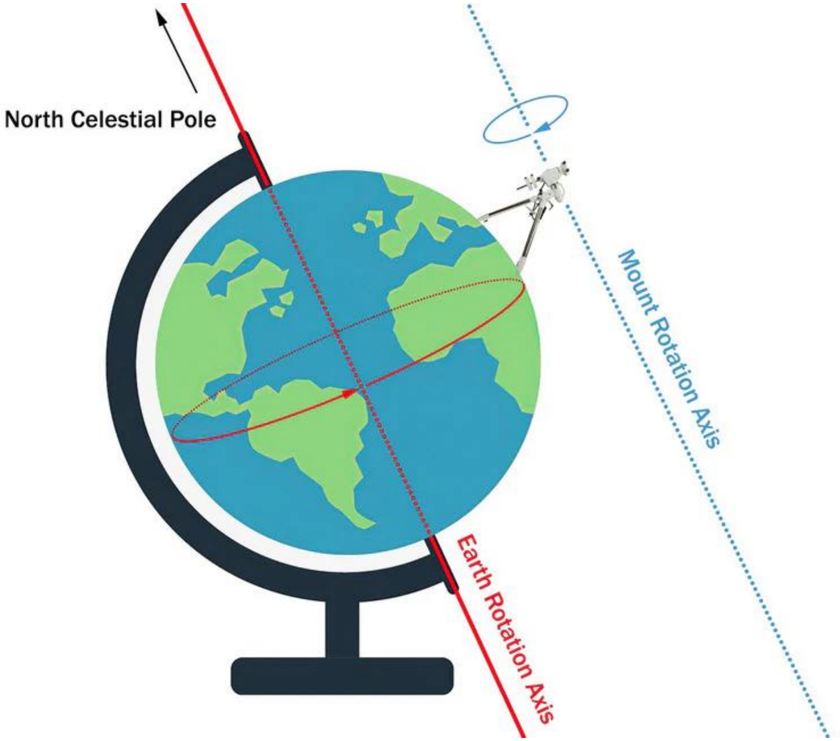


4.1 Calibration - Polar alignment

- Equatorial mount (2 movable axes):
  - Axis of right ascension
  - Axis of declination

- Alignment of right ascension parallel to earth rotation axis

- To follow movement of sky continuosly

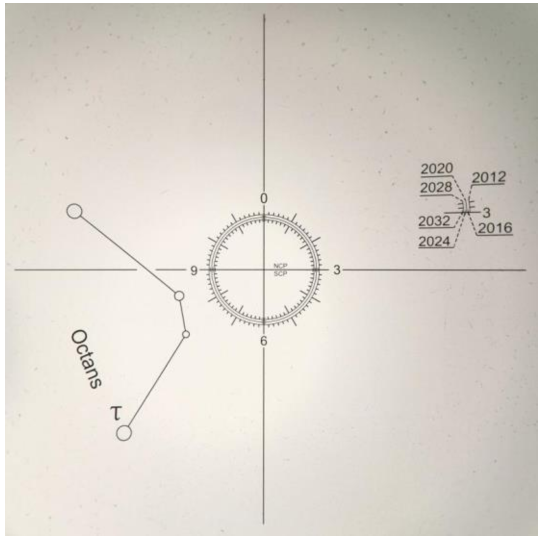


https://optcorp.com/blogs/deep-sky-imaging/polar-alignment-on-your-mount

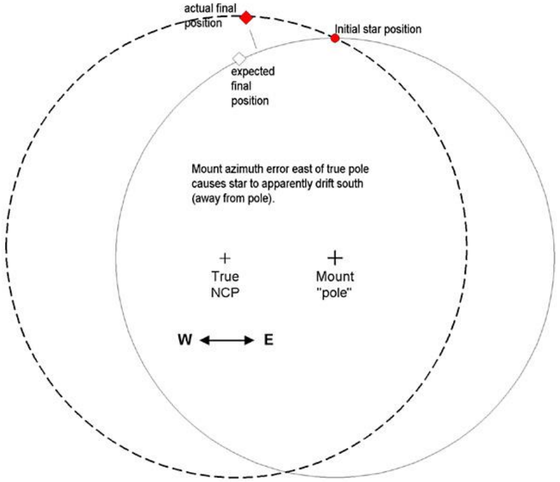
4.1 Calibration - Polar alignment

Methods:

- Rough alignment to Polaris with eyepiece of telescope
- Polar scope
- Drift alignment
- All-star alignment
  - One star align method
  - Two star align method



https://britastro.org/2021/using-a-polarscope



https://astrocamera.net/equipmnt/p-align/driftaz.htm

4.2 Calibration - Focusing

- The bigger the zoom the more difficult

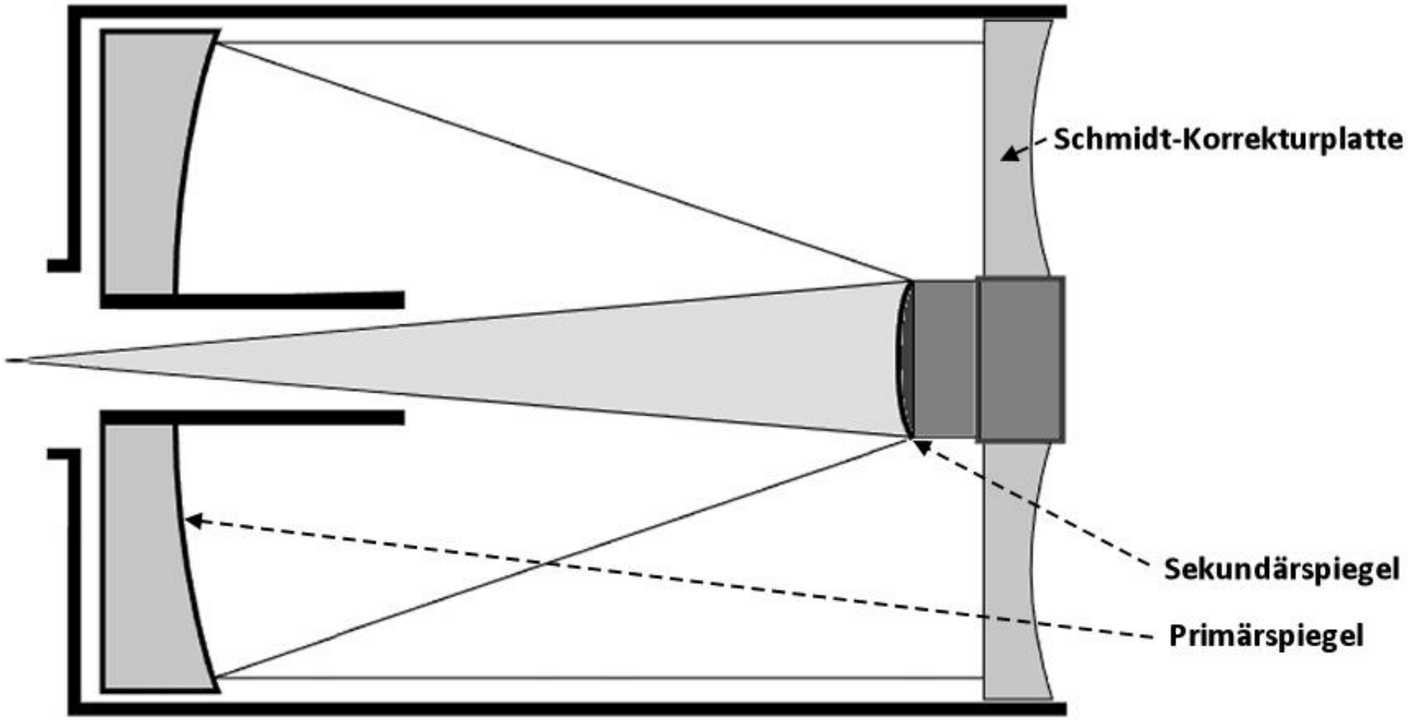
- Not stable → atmosphere (flickering, temperature changes)

= Putting the sensor into the focus plane of the telescope where all the beams of a star converge and the maximal amount of light is concentrated into the smallest possible area

Methods:
- Primal mirror focusing (rough way)
- Fine focussing, manual
- Fine focussing, motorized
- Masks:
  - Bahtinov mask
  - Scheiner mask

4.2 Calibration - Focusing

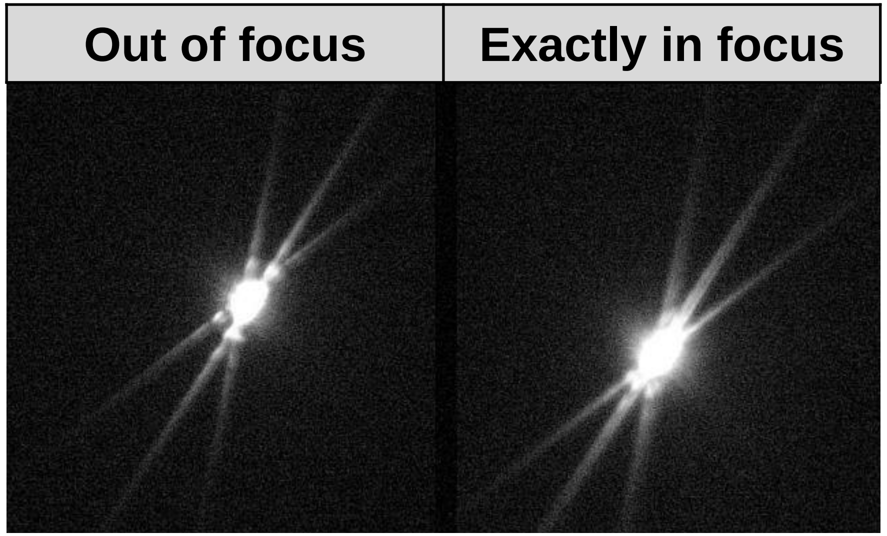
- Primal mirror focusing (Schmidt-Cassegrain-Telescope)



https://abenteuer-astronomie.de/was-ist-eigentlich-ein-schmidt-cassegrain-teleskop/

4.2 Calibration - Focusing

- Bahtinov mask:



https://www.gerdneumann.net/deutsch/astrofotografie-parts-astrophotography/bahtinov-masks-bahtinov-masken.html

https://www.gerdneumann.net/deutsch/astrofotografie-parts-astrophotography/bahtinov-masks-bahtinov-masken.html

4.3 Calibration - Bias, Dark, Flat frames

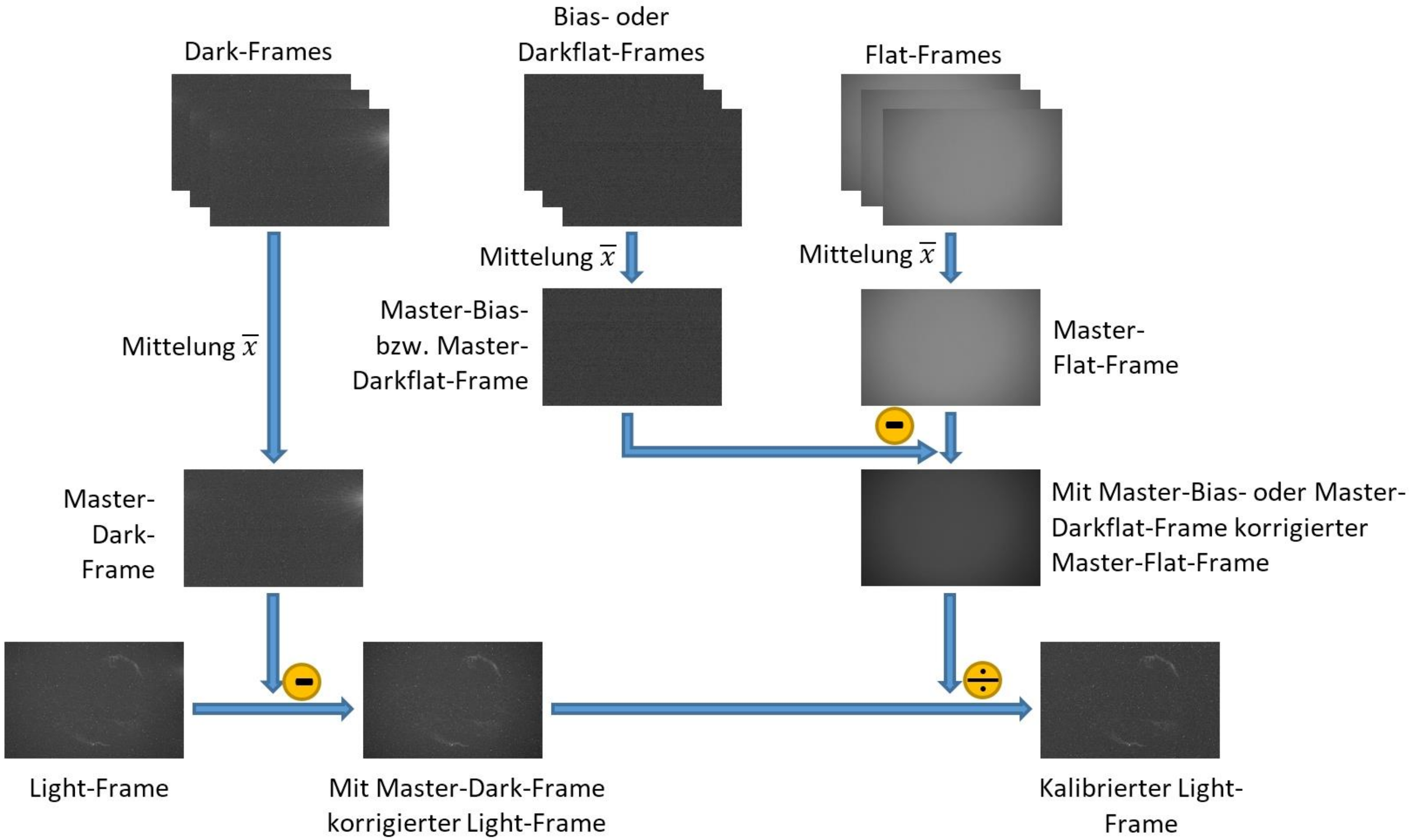
Image Calibration (Bias, Dark, Flat frames)

➔ To correct image errors and noise (Remove artifacts and interference)

- **Bias** frame: with shortest exposure time and closed shutter
  ⟶ contain offset and camera noise
- **Dark** frame: with closed shutter, same exposure time & temperature
  ⟶ to remove dark current, sensor glowing, hot-pixel & dead-pixel
- **Flat** frame: with same position, similar focal point & further settings
  ⟶ to correct vignetting and irregular illumination
- **Darkflat** frame: with closed shutter, same exposure time as flat frames
  ⟶ to remove offset and dark current

4.3 Calibration - Bias, Dark, Flat frames

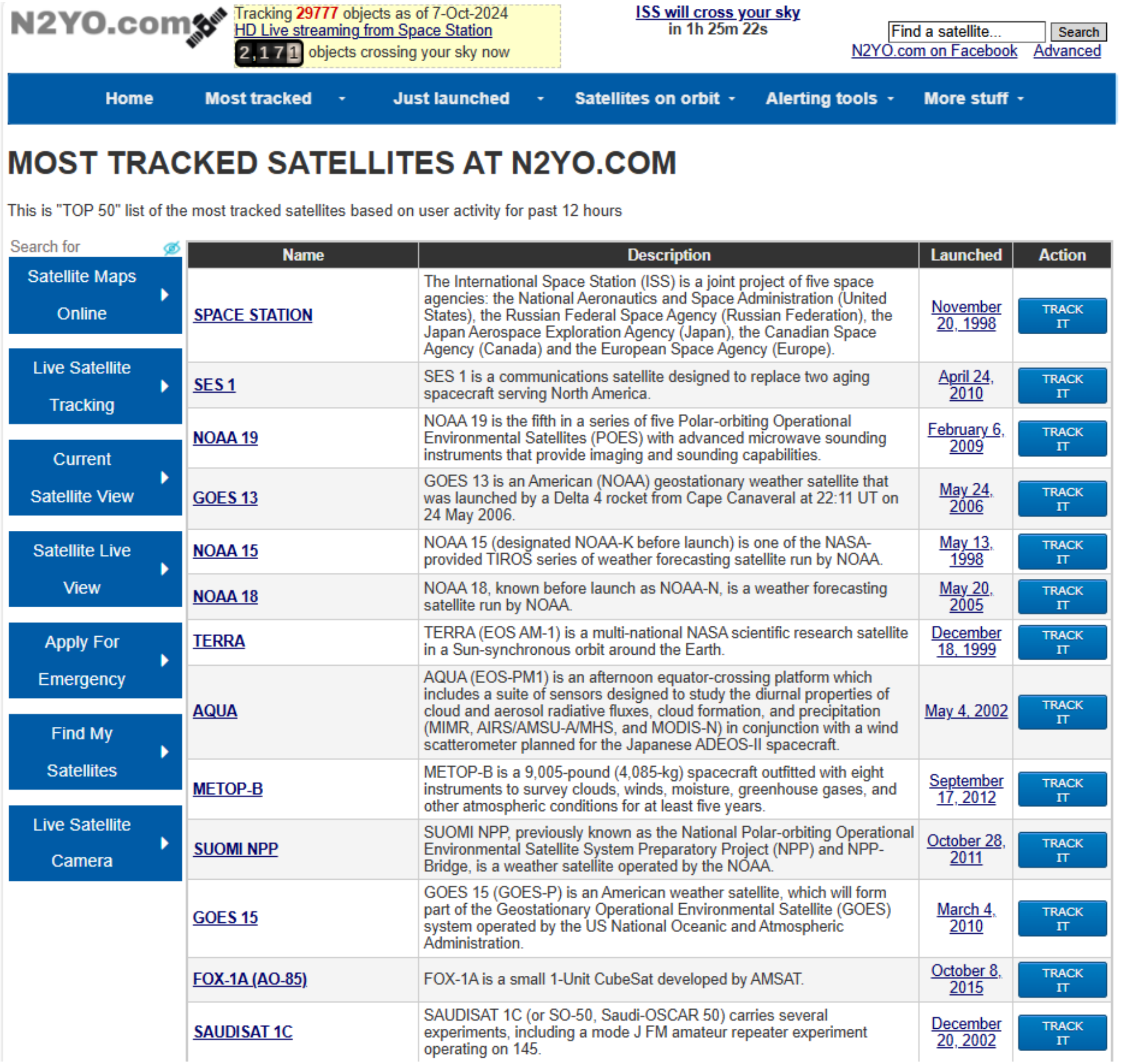
Schema:



https://astrobasics.de/grundlagen/bias-flats-darks-darkflats/

5. Measurements

Finding the satellites with the website N2YO



N2YO.com

Tracking 29777 objects as of 7-Oct-2024
HD Live streaming from Space Station
2,171 objects crossing your sky now

ISS will cross your sky
in 1h 25m 22s

Find a satellite... Search
N2YO.com on Facebook Advanced

Home | Most tracked | Just launched | Satellites on orbit | Alerting tools | More stuff

MOST TRACKED SATELLITES AT N2YO.COM

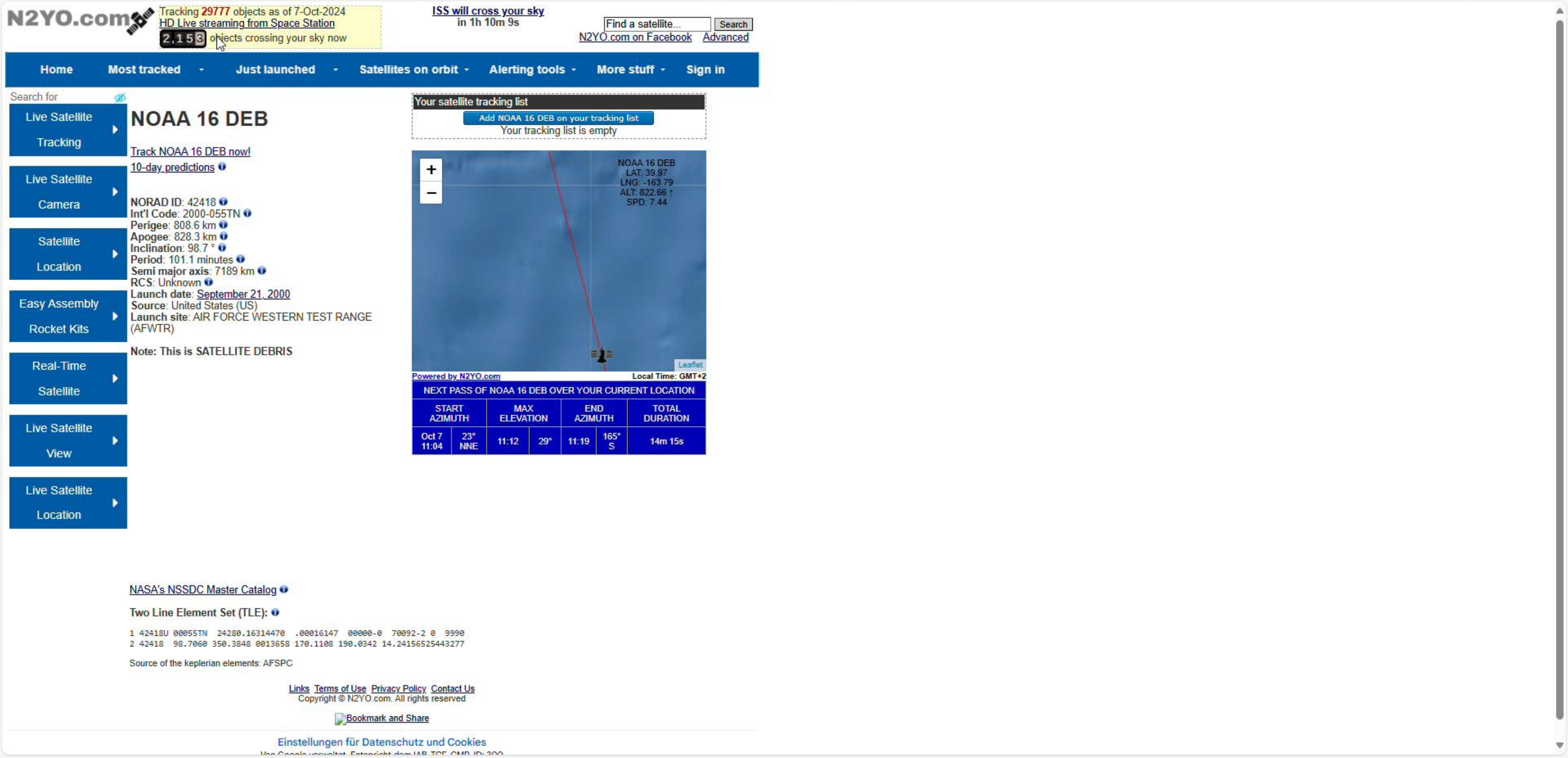
This is "TOP 50" list of the most tracked satellites based on user activity for past 12 hours

Search for

- Satellite Maps Online
- Live Satellite Tracking
- Current Satellite View
- Satellite Live View
- Apply For Emergency
- Find My Satellites
- Live Satellite Camera

Name	Description	Launched	Action
SPACE STATION	The International Space Station (ISS) is a joint project of five space agencies: the National Aeronautics and Space Administration (United States), the Russian Federal Space Agency (Russian Federation), the Japan Aerospace Exploration Agency (Japan), the Canadian Space Agency (Canada) and the European Space Agency (Europe).	November 20, 1998	TRACK IT
SES 1	SES 1 is a communications satellite designed to replace two aging spacecraft serving North America.	April 24, 2010	TRACK IT
NOAA 19	NOAA 19 is the fifth in a series of five Polar-orbiting Operational Environmental Satellites (POES) with advanced microwave sounding instruments that provide imaging and sounding capabilities.	February 6, 2009	TRACK IT
GOES 13	GOES 13 is an American (NOAA) geostationary weather satellite that was launched by a Delta 4 rocket from Cape Canaveral at 22:11 UT on 24 May 2006.	May 24, 2006	TRACK IT
NOAA 15	NOAA 15 (designated NOAA-K before launch) is one of the NASA-provided TIROS series of weather forecasting satellite run by NOAA.	May 13, 1998	TRACK IT
NOAA 18	NOAA 18, known before launch as NOAA-N, is a weather forecasting satellite run by NOAA.	May 20, 2005	TRACK IT
TERRA	TERRA (EOS AM-1) is a multi-national NASA scientific research satellite in a Sun-synchronous orbit around the Earth.	December 18, 1999	TRACK IT
AQUA	AQUA (EOS-PM1) is an afternoon equator-crossing platform which includes a suite of sensors designed to study the diurnal properties of cloud and aerosol radiative fluxes, cloud formation, and precipitation (MIMR, AIRS/AMSU-A/MHS, and MODIS-N) in conjunction with a wind scatterometer planned for the Japanese ADEOS-II spacecraft.	May 4, 2002	TRACK IT
METOP-B	METOP-B is a 9,005-pound (4,085-kg) spacecraft outfitted with eight instruments to survey clouds, winds, moisture, greenhouse gases, and other atmospheric conditions for at least five years.	September 17, 2012	TRACK IT
SUOMI NPP	SUOMI NPP, previously known as the National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) and NPP-Bridge, is a weather satellite operated by the NOAA.	October 28, 2011	TRACK IT
GOES 15	GOES 15 (GOES-P) is an American weather satellite, which will form part of the Geostationary Operational Environmental Satellite (GOES) system operated by the US National Oceanic and Atmospheric Administration.	March 4, 2010	TRACK IT
FOX-1A (AO-85)	FOX-1A is a small 1-Unit CubeSat developed by AMSAT.	October 8, 2015	TRACK IT
SAUDISAT 1C	SAUDISAT 1C (or SO-50, Saudi-OSCAR 50) carries several experiments, including a mode J FM amateur repeater experiment operating on 145.	December 20, 2002	TRACK IT

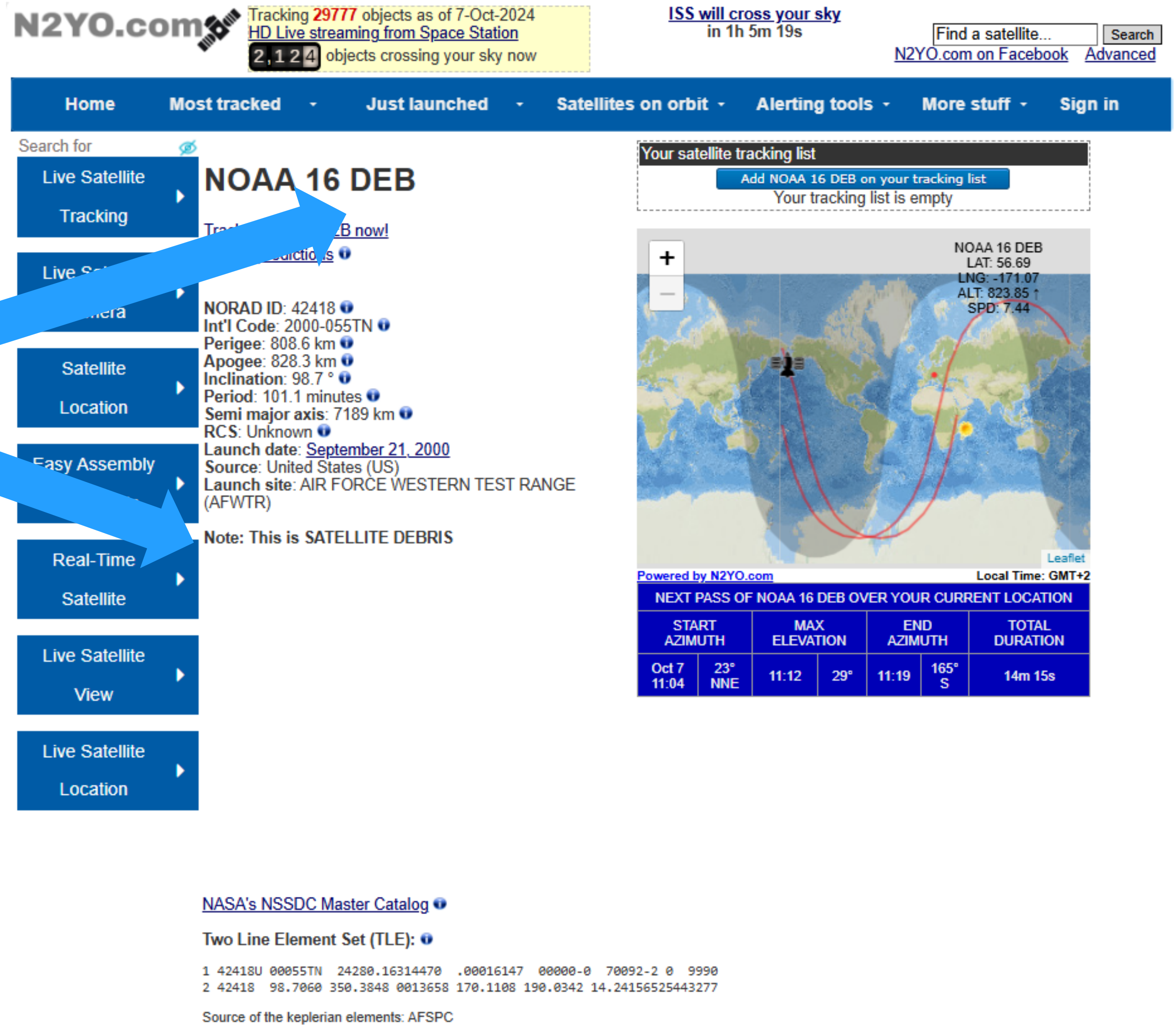
5.1 Measurements – example: NOAA 16 DEB



5.1 Measurements – example: NOAA 16 DEB

For us important:
DEB = Debris

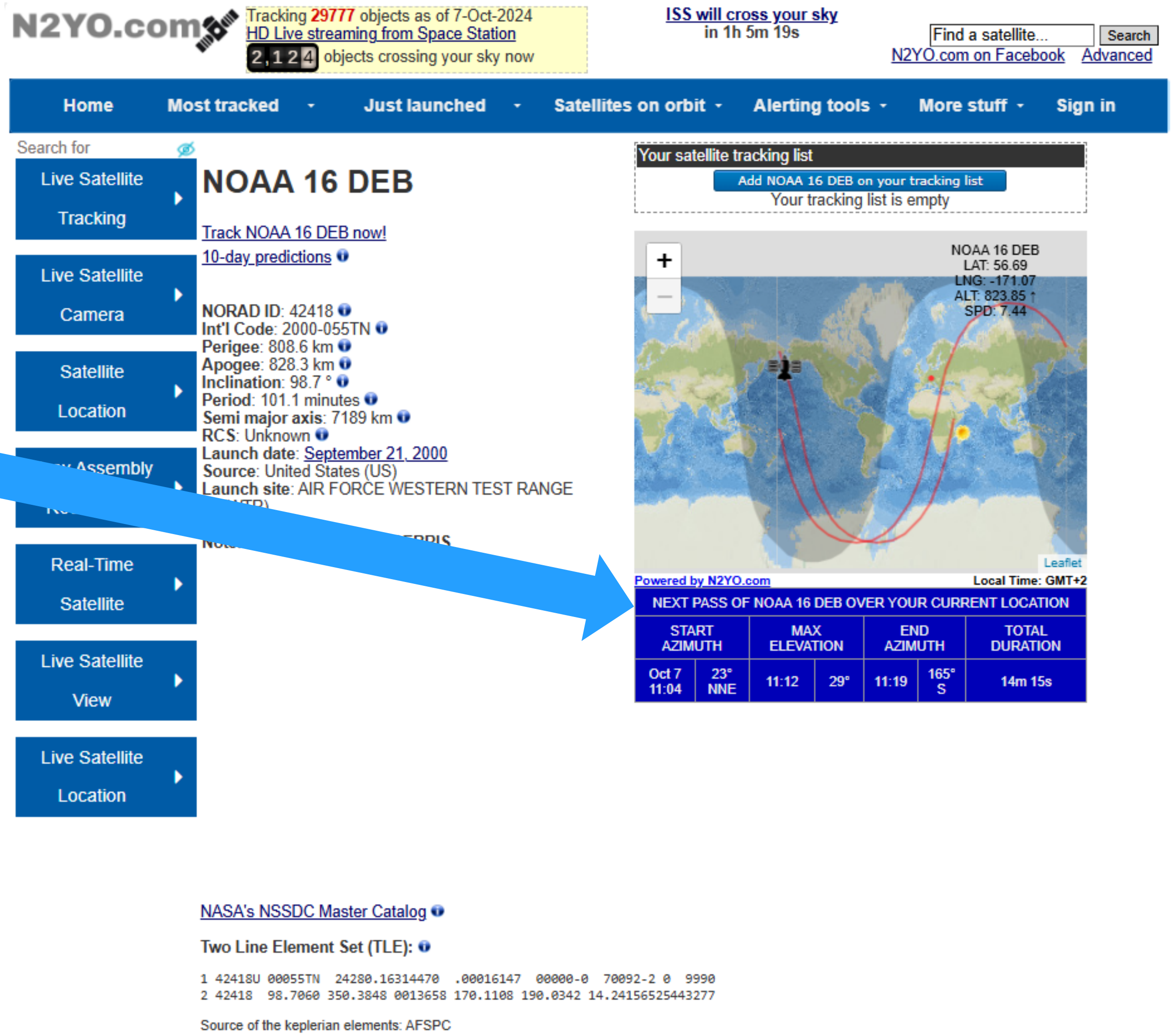
→ Space debris
→ Possible objects: De-functional satellites, burn-out boosters or stages of e.g. Ariane rockets



5.1 Measurements – example: NOAA 16 DEB

For us important:

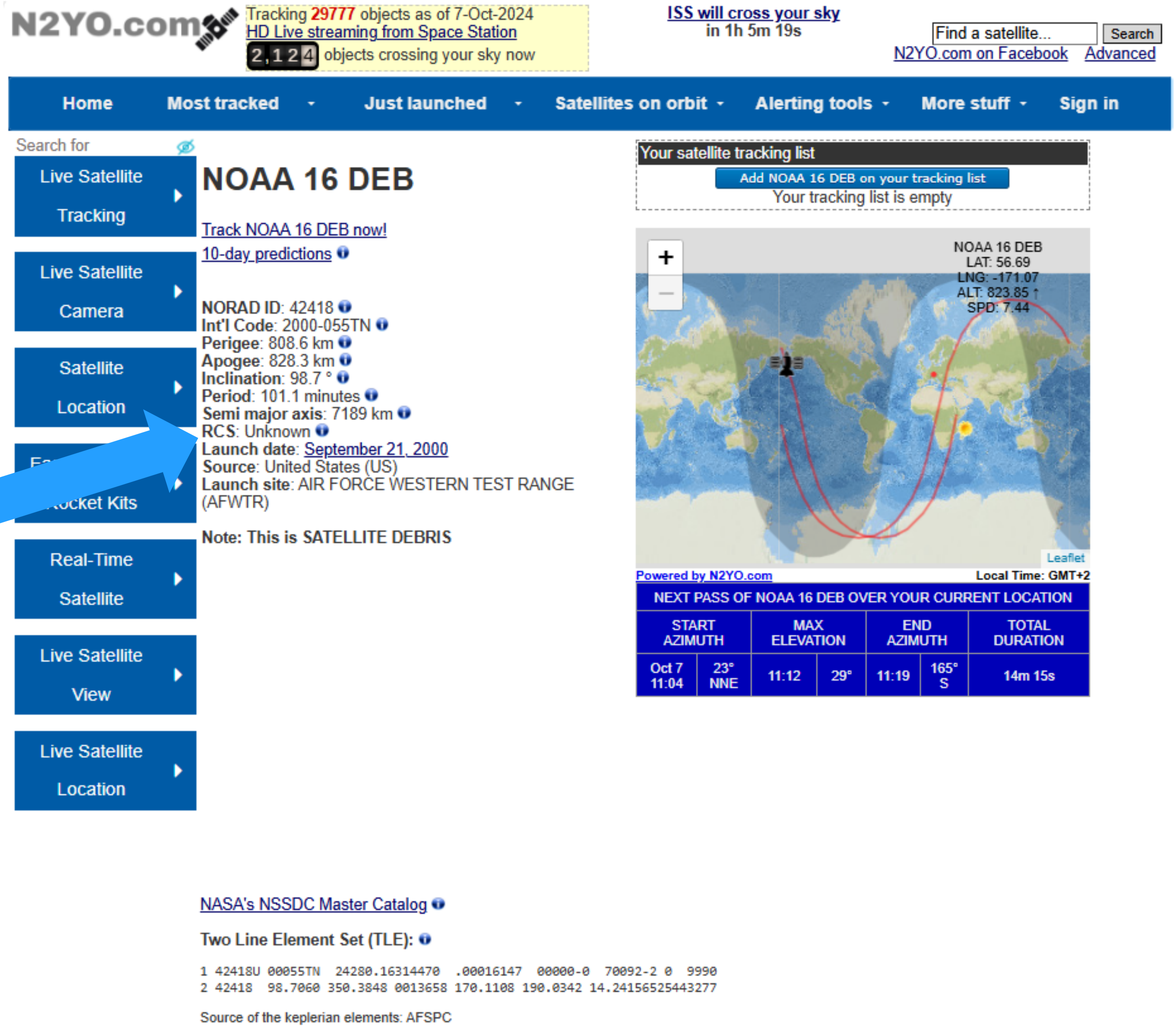
Criteria: Overpass in the next time with a suitable elevation



5.1 Measurements – example: NOAA 16 DEB

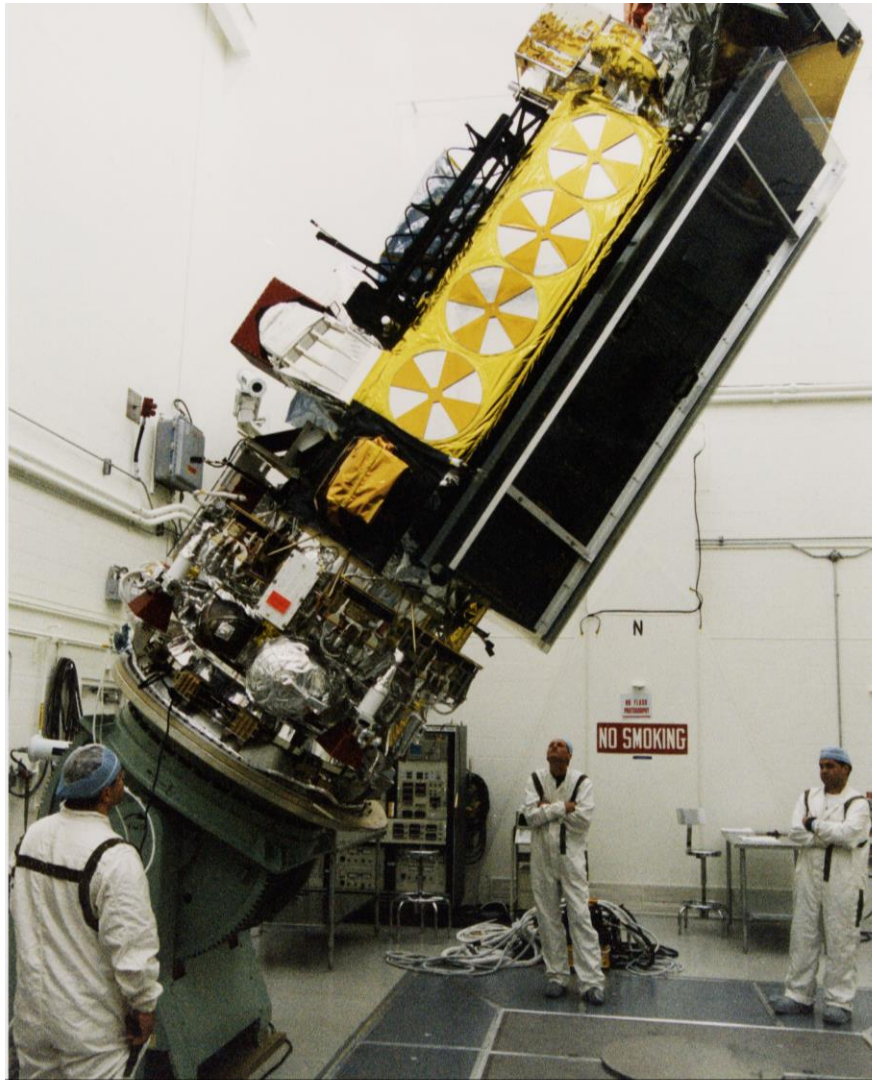
For us important:
RCS = Radar Cross Section

→ Determination of the exposure time that we will need
→ In this case unknown: estimating the exposure time by the size of the satellite



5.1 Measurements – example: NOAA 16 DEB

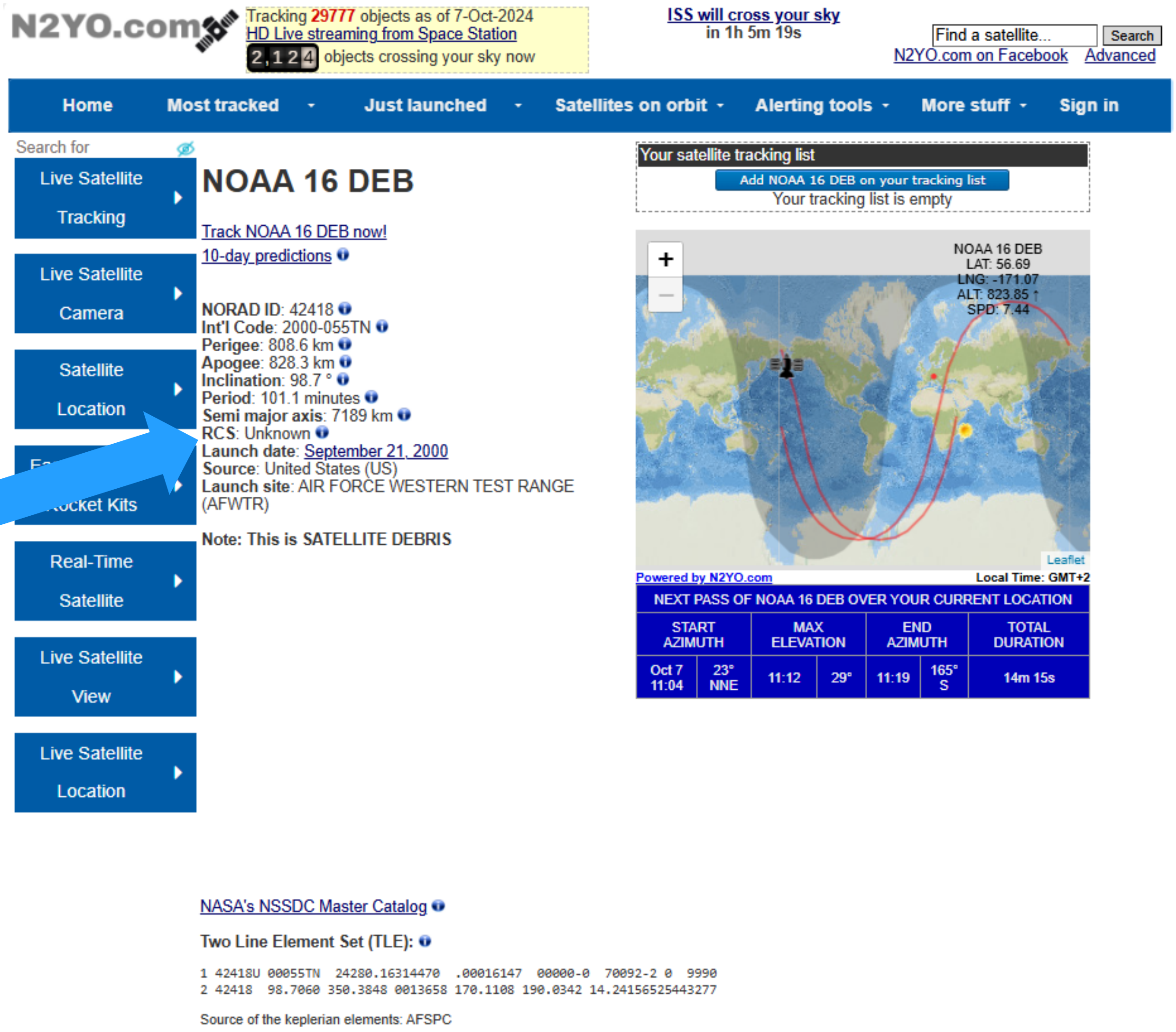
- operational, polar-orbiting, weather satellite
- decommissioned on 9 June 2014 due to an undefined "critical anomaly"



5.1 Measurements – example: NOAA 16 DEB

For us important:
RCS = Radar Cross Section

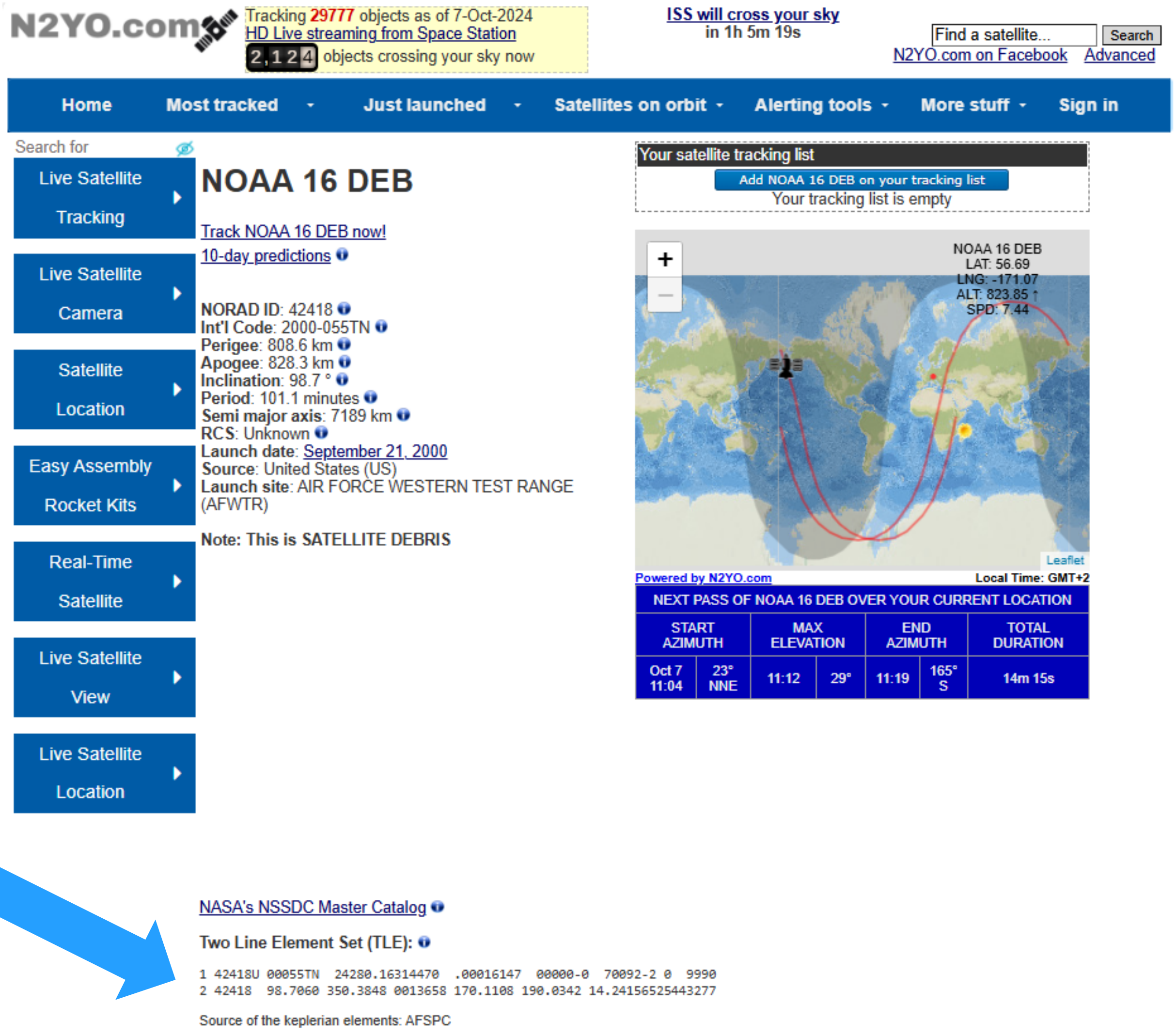
→ Determination of the exposure time that we will need
→ In this case unknown: estimating the exposure time by the size of the satellite
→ Chosen exposure time: 0.2 s



5.1 Measurements – example: NOAA 16 DEB

For us important:
TLE = Two Line Element Set

→ Position and velocity of the satellite
→ Using the Kepler elements to track the satellite
→ Import those lines into the software of the telescope (as Simone explained)



5.2 Measurements - TLEs

TLEs change over time

→ Changing Kepler elements
→ But what do the number stand for?

07.10.2024

Two Line Element Set (TLE):

```
1 42418U 00055TN   24280.16314470  .00016147  00000-0  70092-2 0  9990
2 42418  98.7060 350.3848 0013658 170.1108 190.0342 14.24156525443277
```

11.10.2024

Two Line Element Set (TLE):

```
1 42418U 00055TN   24284.94026301  .00061226  00000-0  26231-1 0  9996
2 42418  98.7079 355.1191 0013571 158.0412 202.1351 14.24396988443957
```

5.2 Measurements - TLEs

Two Line Element Set (TLE):

```
1 42418U 00055TN   24284.94026301  .00061226  00000-0  26231-1 0  9996
2 42418  98.7079 355.1191 0013571 158.0412 202.1351 14.24396988443957
```

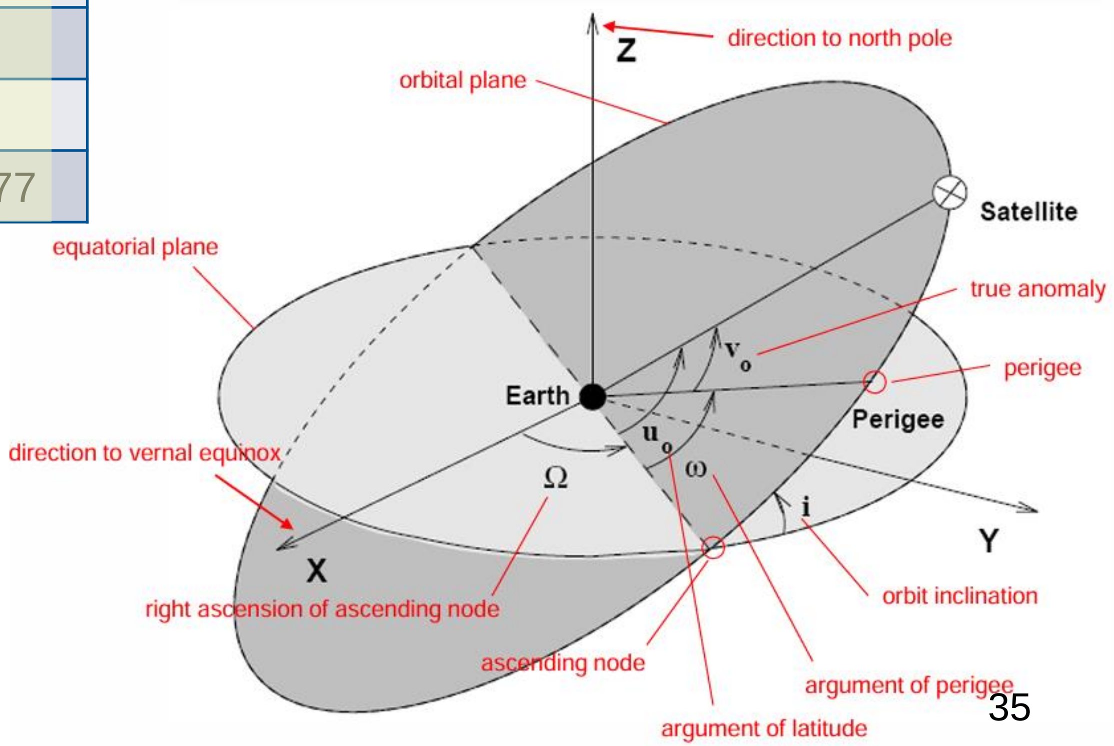
Line number	1
Satellite catalog number	42418
Classification	U
International Designator (launch number of the year)	00
International Designator (last two digits of launch year)	055
International Designator (piece of the launch)	TN
Epoch year (last two digits of year)	24
Epoch (day of the year and fractional portion of the day)	280.16314470
First derivative of mean motion; the ballistic coefficient	.00016147
Second derivative of mean motion (decimal point assumed)	00000-0
B*, the drag term, or radiation pressure coefficient (decimal point assumed)	70092-2
Ephemeris type (always zero; only used in undistributed TLE data)	0
Element set number. Incremented when a new TLE is generated for this object.	999
Checksum (modulo 10)	0

5.2 Measurements - TLEs

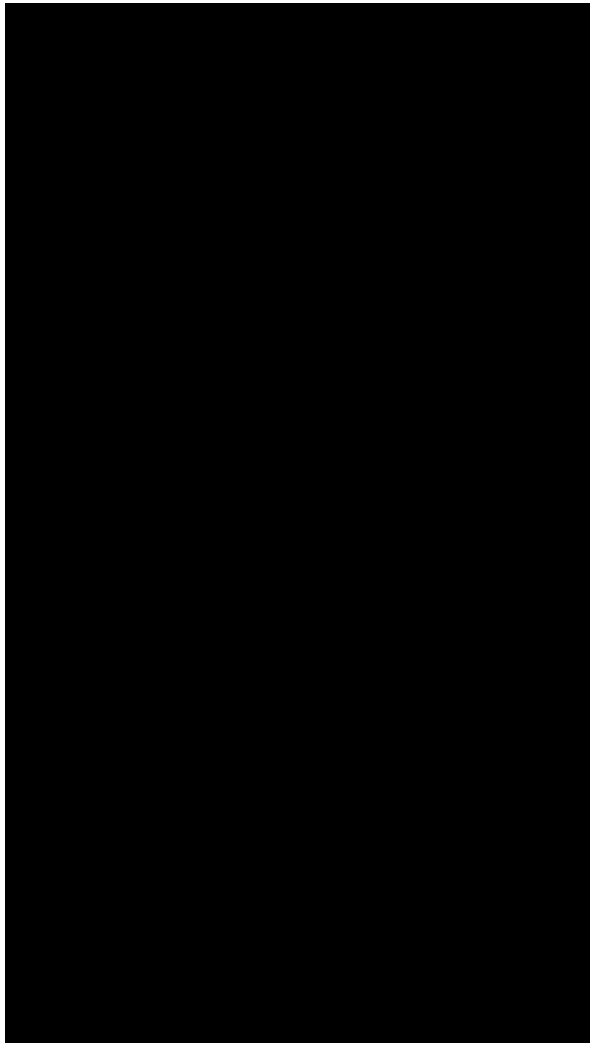
Two Line Element Set (TLE):

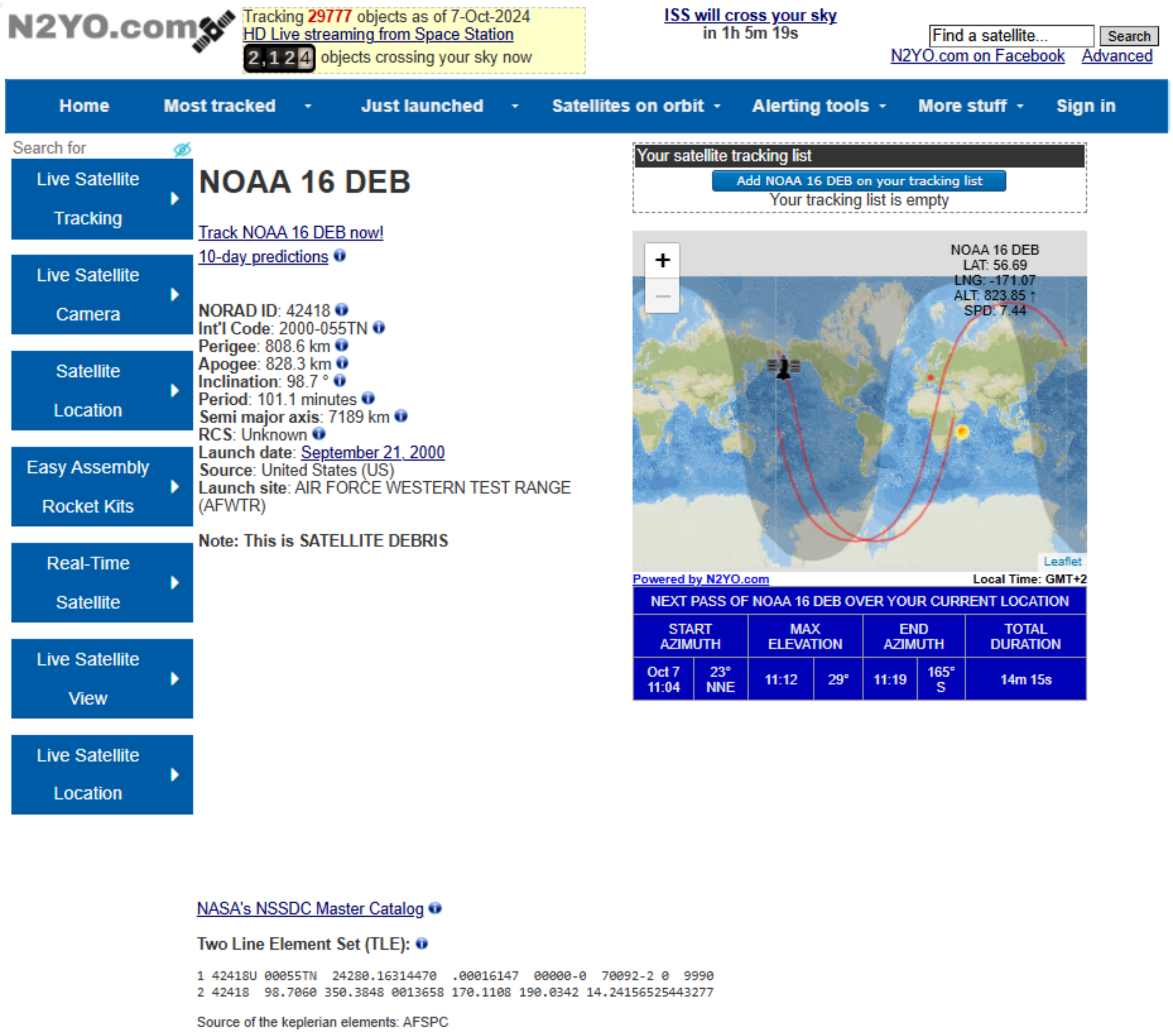
```
1 42418U 00055TN   24284.94026301  .00061226  00000-0  26231-1 0  9996
2 42418  98.7079 355.1191 0013571 158.0412 202.1351 14.24396988443957
```

Line number	2
Satellite catalog number	42418
Inclination (degrees)	98.7060
Right ascension of the ascending node (degrees)	350.3848
Eccentricity (decimal point assumed)	0013658
Argument of perigee (degrees)	170.1108
Mean anomaly (degrees)	190.0342
Mean motion (revolutions per day)	14.24156525443277



5.1 Measurements – example: NOAA 16 DEB





5.3 Measurements – other tracked objects

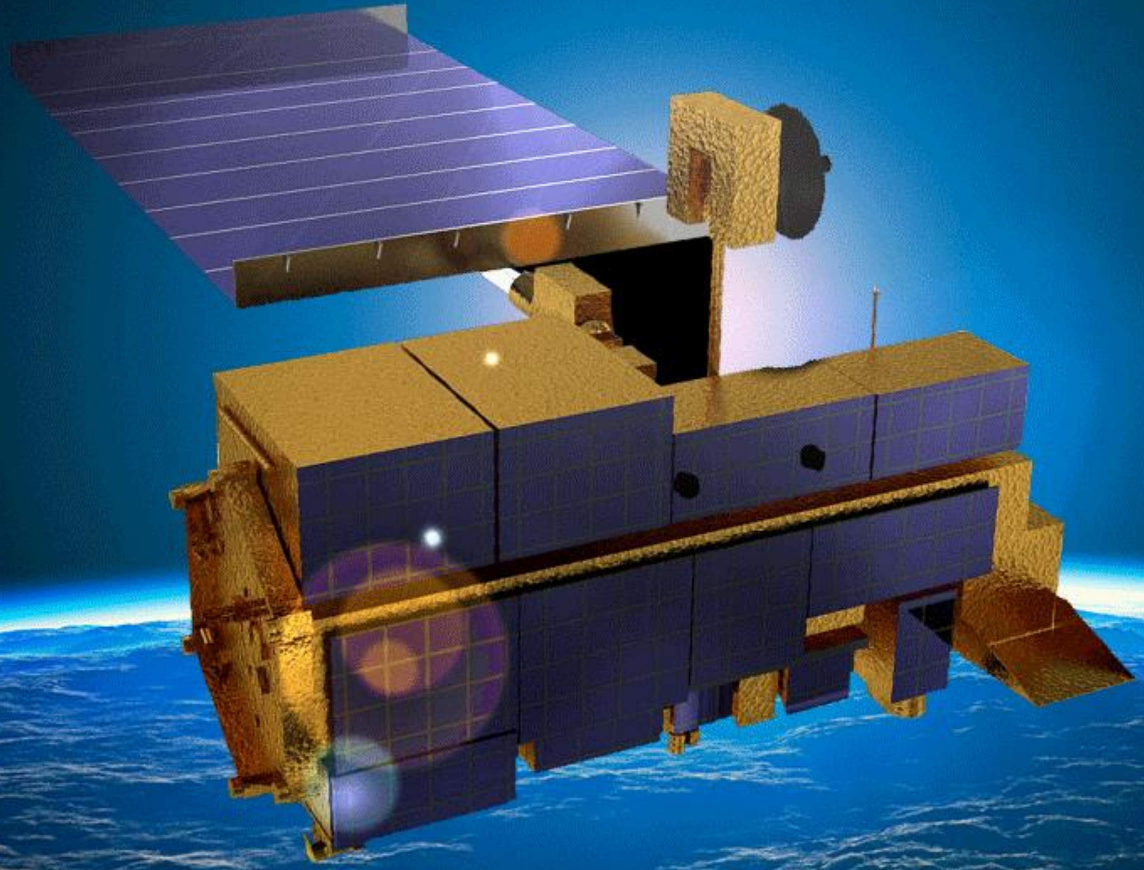
Lageos

- → Exposure time of 0.2s
- → Did not work: not visible in finder scope

5.3 Measurements – other tracked objects

Satellite TERRA

→ Exposure time of 0.02s
→ Did not work: some images, but then hardware failure of the motor



5.3 Measurements – other tracked objects

METEOR 2-17 DEB

→ Exposure time: 0.2 s

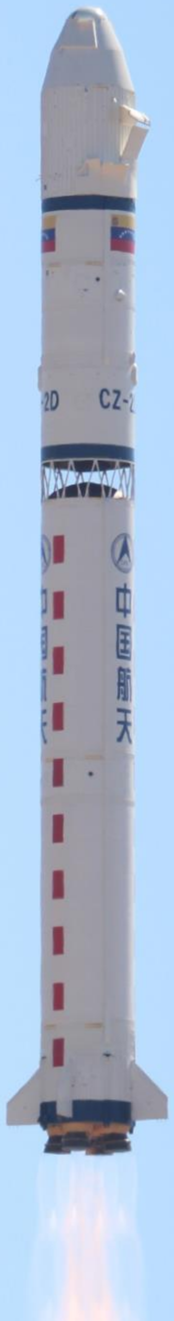
→ Did not work: not visible in finder scope

5.3 Measurements – other tracked objects

CZ-2 DEB

→ Exposure time: 0.2 s

→ Did not work: not visible in finder scope



5.3 Measurements – other tracked objects

SL-8 R/B

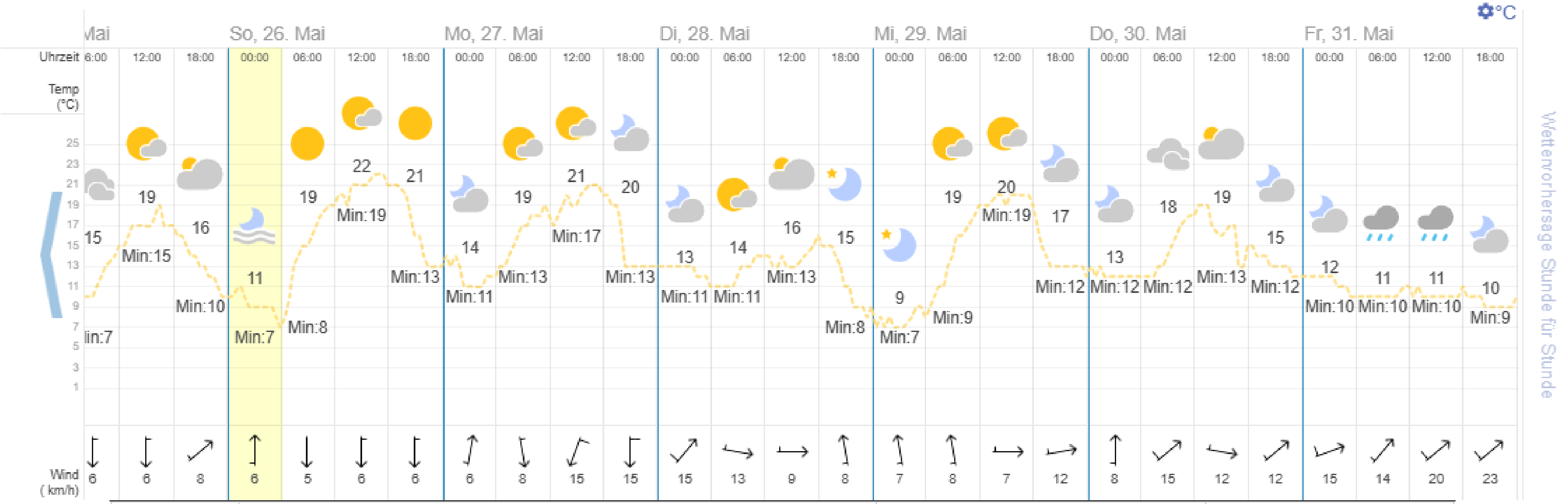
→ Rocket Body

→ Exposure time: 0.05 s

→ Did not work: not visible in finder scope

5.4 Cloudy summer

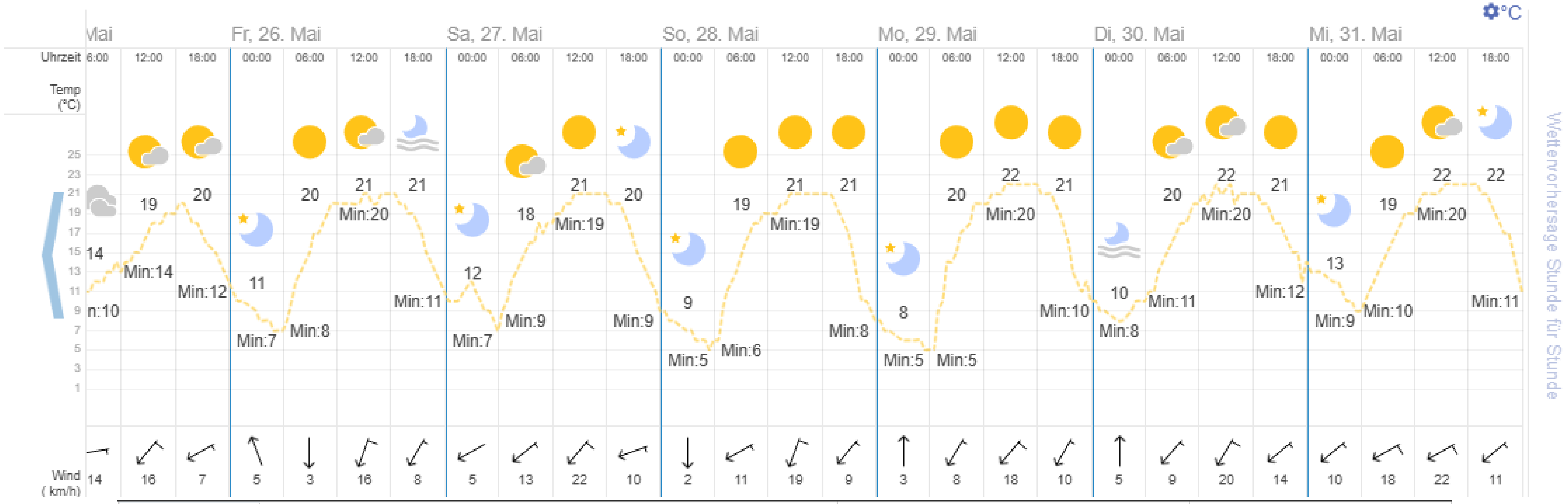
Wetter im Mai 2024 in München — Graph



Uhrzeit	Wetterbedingungen			Bioklima				
		Temp	Wetter	Wind		Luftfeuchte	Barometer	Sicht
20:20		15 °C	Vorüberziehende Wolken.	13 km/h	↗	94%	1016 hPa	k.A.
20:50		15 °C	Meist bewölkt.	13 km/h	→	94%	1016 hPa	k.A.
21:20		15 °C	Meist bewölkt.	9 km/h	↗	94%	1016 hPa	k.A.
21:50		15 °C	Meist bewölkt.	7 km/h	↗	94%	1016 hPa	k.A.
22:50		15 °C	Meist bewölkt.	9 km/h	↘	94%	1017 hPa	k.A.
23:20		14 °C	Bedeckt.	9 km/h	→	94%	1017 hPa	k.A.
23:50		14 °C	Meist bewölkt.	9 km/h	→	94%	1017 hPa	k.A.

5.4 Cloudy summer

Wetter im Mai 2023 in München — Graph



Uhrzeit	Wetterbedingungen			Bioklima				
		Temp	Wetter	Wind		Luftfeuchte	Barometer	Sicht
20:20		18 °C	Sonnig.	11 km/h		40%	1017 hPa	k.A.
20:50		17 °C	Sonnig.	7 km/h		42%	1017 hPa	k.A.
21:20		15 °C	Heiter.	6 km/h		51%	1017 hPa	k.A.
22:20		10 °C	Heiter.	4 km/h		76%	1017 hPa	k.A.
22:50		10 °C	Heiter.	6 km/h		76%	1018 hPa	k.A.
23:20		9 °C	Heiter.	6 km/h		82%	1017 hPa	k.A.
23:50		8 °C	Heiter.	4 km/h		87%	1017 hPa	k.A.

5.5 Problems and challenges

- Very cloudy and rainy weather this summer
- Hardware failure of motor
- Very often: debris was not visible in finder scope → measurement did not work
- Problems during the session probably related to tracking problem of kstars because alignment was good enough (saturn was in field of view)

5.6 Measurements – Fun Observations

Moon, Saturn, Galaxies, Polar Lights!

References – Observation Principle

[1] Priyant Mark, C., and Surekha Kamath. "Review of Active Space Debris Removal Methods." Space Policy 47 (2019): 194–206. https://doi.org/10.1016/j.spacepol.2018.12.003.

[2] Schildknecht, T. "Optical Surveys for Space Debris." Astronomy and Astrophysics Review 14, no. 1 (2007): 41–111. https://doi.org/10.1007/s00159-006-0003-9.

[3] Hinks, J. C., R. Linares, and J. L. Crassidis. "Attitude Observability from Light Curve Measurements." In AIAA Guidance, Navigation, and Control (GNC) Conference, 5005. 2013. https://doi.org/10.2514/6.2013-5005.

[4] NASA's "The Imagine Team," Dr. Barbara Mattson. https://imagine.gsfc.nasa.gov/science/toolbox/timing1.html.

[5] Schildknecht, Thomas, et al. "Color Photometry and Light Curve Observations of Space Debris in GEO." In Proceedings of Advanced Maui Optical and Space Surveillance Technologies Conference, 2008.

[6] Silha, Jiri, et al. "Optical Light Curve Observations to Determine Attitude States of Space Debris." In Proceedings of the 30th International Symposium on Space Technology and Science, Kobe-Hyogo, Japan, 2015.

[7] "Frontiers in Space Technologies." https://www.frontiersin.org/journals/space-technologies/articles/10.3389/frspt.2020.00002/full.

[8] Nussbaum, M. Simulation and Measurement of Multispectral Light Curves from Space Debris. PhD diss., Technical University of Berlin, 2020.

[9] Furfaro, R., et al. "Deep Learning for Autonomous Space Debris Detection and Characterization." Advances in Space Research 62, no. 11 (2018): 3305–3323. https://doi.org/10.1016/j.asr.2018.07.031.

[10] Schafer, E. Stereoscopic Light Curve Analysis of Space Debris Objects. Master's thesis, University of Würzburg, 2018.

[11] Jah, M., and T. Kelecy. "Space Object Behavioral Sciences." In Proceedings of Advanced Maui Optical and Space Surveillance Technologies Conference, 2019.

[12] Früh, C., and M. K. Jah. "Attitude and Orbit Coupling Effects on Space Debris Stabilization and Rotational Motion." Advances in Space Research 63, no. 1 (2019): 435–54. https://doi.org/10.1016/j.asr.2018.08.034.

References – Equipment (viewed 10.09.24)

CELESTRON WHITEPAPER 2013

Celestron Engineering Team (April 2013). Whitepaper EdgeHD Optics. Retrieved from https://celestron-site-support-files.s3.amazonaws.com/support_files/91030-XLT_91040-XLT_91050-XLT_91060-XLT_EdgeHD_OpticalTube_Manual_English_web.pdf

Celestron. EdgeHD 11" Optical Tube Assembly (CGE Dovetail) [Product specifications]. https://www.celestron.com/products/edgehd-11-optical-tube-assembly-cge-dovetail#specifications

Celestron (2009, July 16). EdgeHD Optics Tour. https://www.youtube.com/watch?v=77dLKd5g2_M

QHYCCD. QHY174GPS [Product Specifications]. https://www.qhyccd.com/qhy174gps-imx174-scientific-cooled-camera/

Baader Planetarium GmbH (January 2023). 10Micron Brochure. Retrieved from https://10micron.eu/fileadmin/Daten/downloads/10Micron_HPS_all-mounts/10micron-full-catalog.pdf

Baader Planetarium GmbH. 10Micron GM 2000 HPS II COMBI GoTo-Mount [Product Specifications]. https://10micron.eu/montierungen/aequatoriale-montierungen/gm2000-hps-ii-combi-goto-montierung

Jasem Mutlaq. The KStars Handbook. https://docs.kde.org/trunk5/en/kstars/kstars/index.html

References – Calibration (viewed 06.10.2024)

Celestron (2017). Celestron EdgeHD 11 Bedienungsanleitung. https://www.bedienungsanleitu.ng/celestron/edgehd-11/anleitung?p=68

Wikipedia (2023). Polar alignment. https://en.wikipedia.org/wiki/Polar_alignment

Astrofotografie Hohmann (2015). Astrofotografie: Fokussierung. https://astrofotografie.hohmann-edv.de/aufnahmetechniken/fokussierung.php

Legault, Thierry (2015). Astrofotografie. https://www.intercon-spacetec.de/media/pdf/Astrofotografie-4_Fokussierung-Kapitelauszug.pdf

Neumann, Gerd. Bahtinov-Masken. https://www.gerdneumann.net/deutsch/astrofotografie-parts-astrophotography/bahtinov-masks-bahtinov-masken.html

Wikipedia (2024). Bahtinov-Maske. https://de.wikipedia.org/wiki/Bahtinov-Maske

Wikipedia (2023). Scheinerblende. https://de.wikipedia.org/wiki/Scheinerblende

Täubert, Sebastian (2024). Astrobasics: Bias, Flats, Darks, Darkflats. https://astrobasics.de/grundlagen/bias-flats-darks-darkflats/

References – Measurements (viewed 11.10.2024)

Hugentobler, Urs (2024). Lecture on the two body problem. Course: Satellite orbits and sensors

Bering Optics (2018). Video footage of rocket body SL-8. https://www.facebook.com/watch/?v=775926139285290

Krebs, Gunter D (2024). “Meteor-2 (11F632)”. Gunter's Space Page. https://space.skyrocket.de/doc_sdat/meteor-2.htm

NASA (1976). Lageos. https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1976-039A

Wikipedia (2024). Noaa-L tilted in Vandenberg AFB clean room. https://upload.wikimedia.org/wikipedia/commons/0/04/NOAA-L_satellite_tilted_in_Vandenberg_AFB_clean_room.jpg

Wikipedia (2024). Two-line element set. https://en.wikipedia.org/wiki/Two-line_element_set

Geoimage (2024). Aster (Terra). https://geoimage.com.au/satellites/aster-terra

EU Space Surveillance and Tracking (2021). EU SST confirms no collision between space objects SL-8 R/B and OPS 6182. https://www.eusst.eu/newsroom/eu-sst-confirms-no-collision-space-objects-sl8rb-ops6182/

iStock (2020). https://media.istockphoto.com/id/1311336107/de/vektor/satelliten.jpg?s=612x612&w=0&k=20&c=XnJz9ZkgfRR_1WMm8Z_YdiizaiLQq2yU6CyqLn3aLvc=

RFA Space (2023).https://www.rfa.space/wp-content/uploads/AdobeStock_73724733-1-scaled.jpeg

Thanks for Listening!

Group 1: Observation

Ionut-Rares Pavel – ESPACE M.Sc.

Simone Gaisbauer – GuG M.Sc.

Isabel Hölzl – GuG M.Sc.

Antonia Bieringer – GuG M.Sc.