

Observation Strategy to Avoid Satellite Pollution

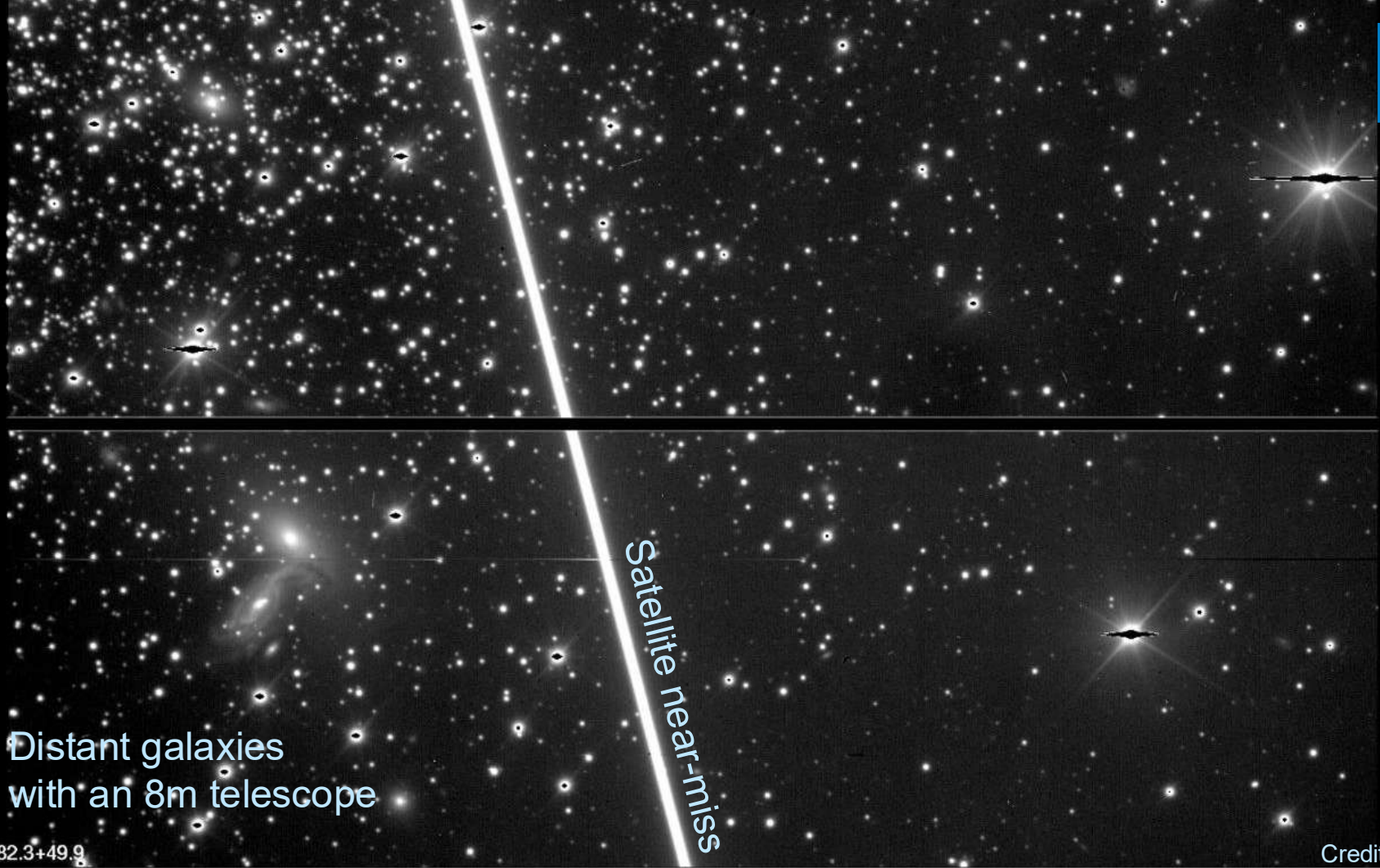
A practical approach to observation preparation
in the optical

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UN/SKAO Workshop on Dark and Quiet Skies for Science and Society 2025



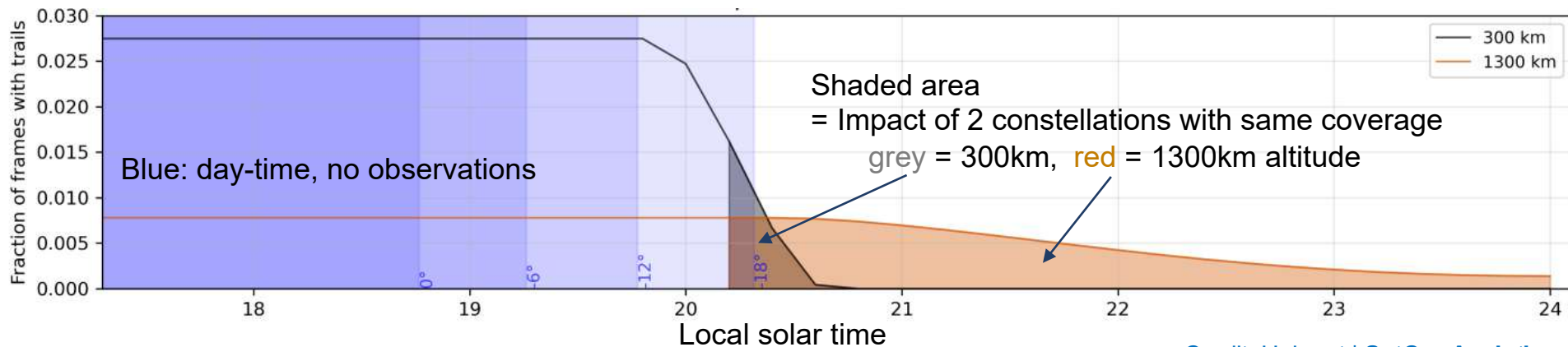
Credit: **ESO | APICAL**



Mitigation

- **Constellation design:**

- Less satellites
- Low altitude satellites



Credit: Hainaut | [SatConAnalytics](#)

Mitigation

- **Constellation design:**

- Less satellites
- Low altitude satellites

- **Satellite design:**

- Smaller / Darker satellites

IAU recommendation: "Fainter than $V=7$ "

= Not visible by eye & does not saturate Vera Rubin Observatory

- **Observation planning:**

- Don't observe where/when satellites are there

- **Data processing:**

- Find / flag satellite trails (but affected pixels *cannot* be repaired)



600x too bright...

Credit: AST Mobile

Mitigation: Observation

- **Predictive: Calculation**

Compute the position of *all* satellites for time and place of observations

- Requires catalogue of *all* satellites
- Requires very high accuracy + precision + very recent orbital elements
- Requires numerous complex calculation

Mitigation: Observations

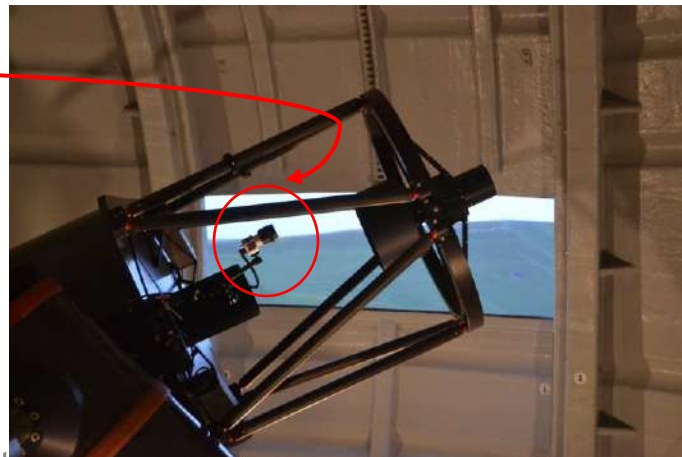
- **Predictive: Calculation**

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- **Predictive: Observations**

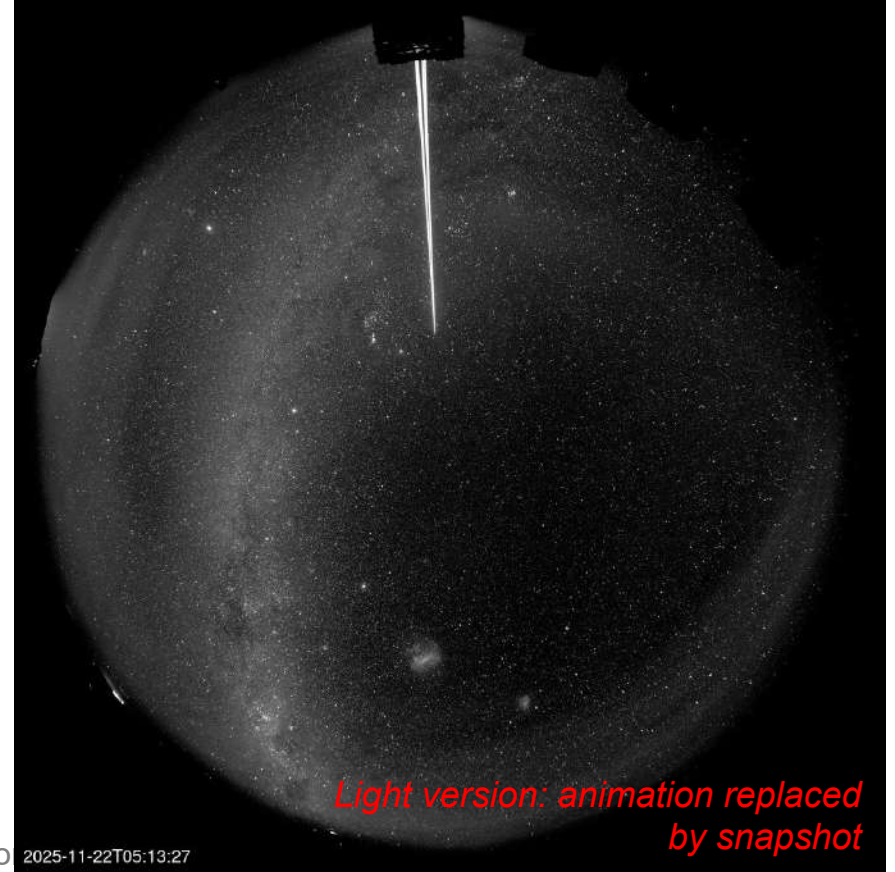
- Camera to monitor the field
- Software to find incoming satellite
- Close the shutter to let satellite through (or flag affected data)



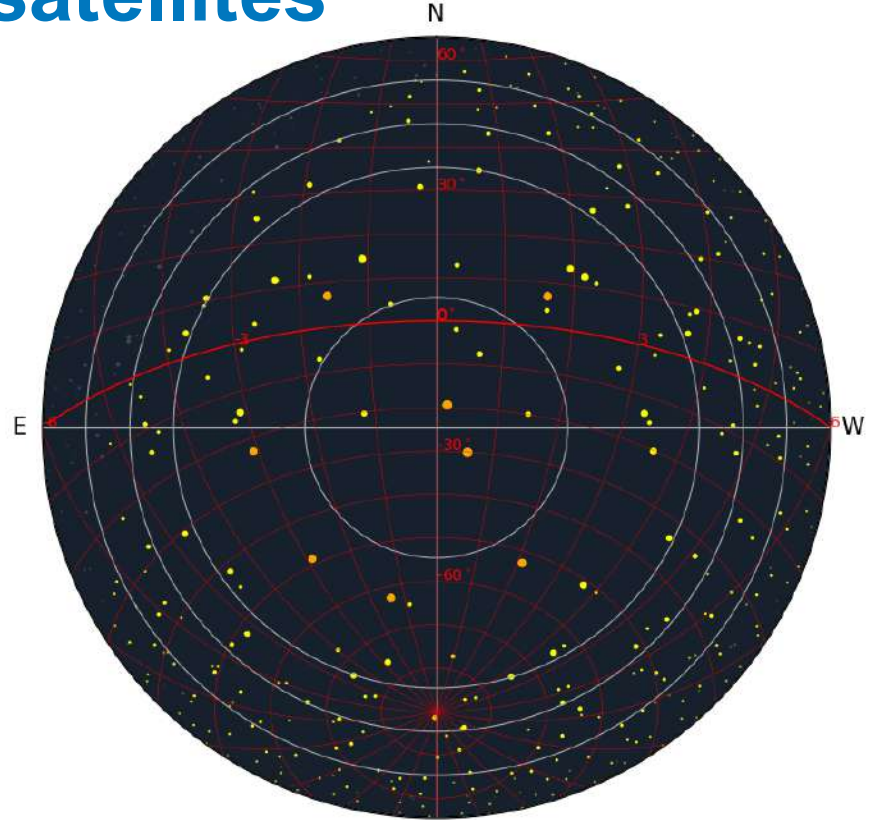
Mitigation: Preparation of the obs.

- **Preparation: short/medium term**
 - Few hours to few nights
- **Optimise for**
 - Observability of the targets (raise/set)
 - Conflict with the moon
 - Weather forecast
 - Priority of the targets
 - **Minimize Satellite impact <-- new**

Sky map

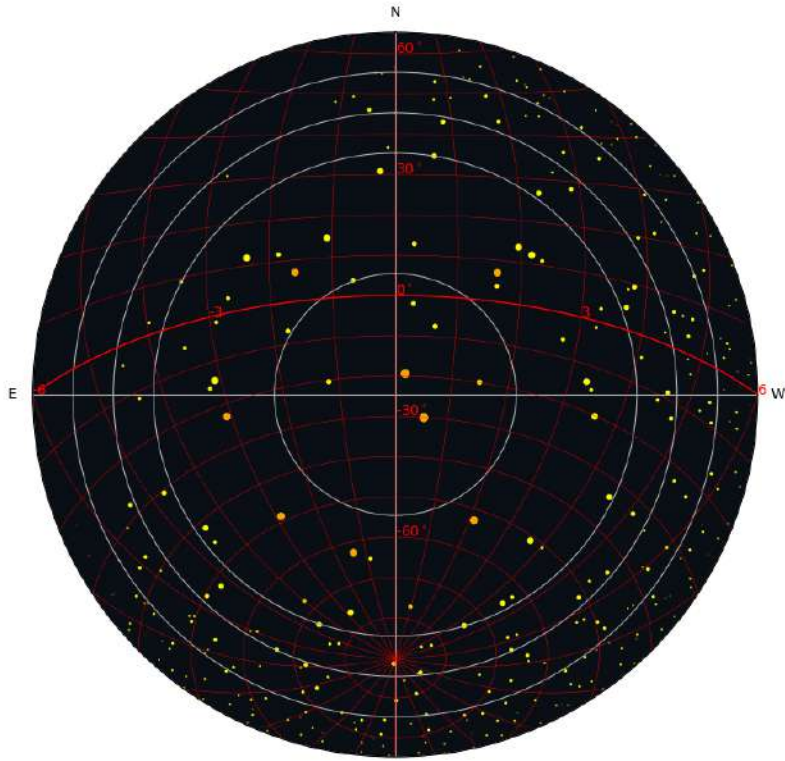


Sky map: individual satellites



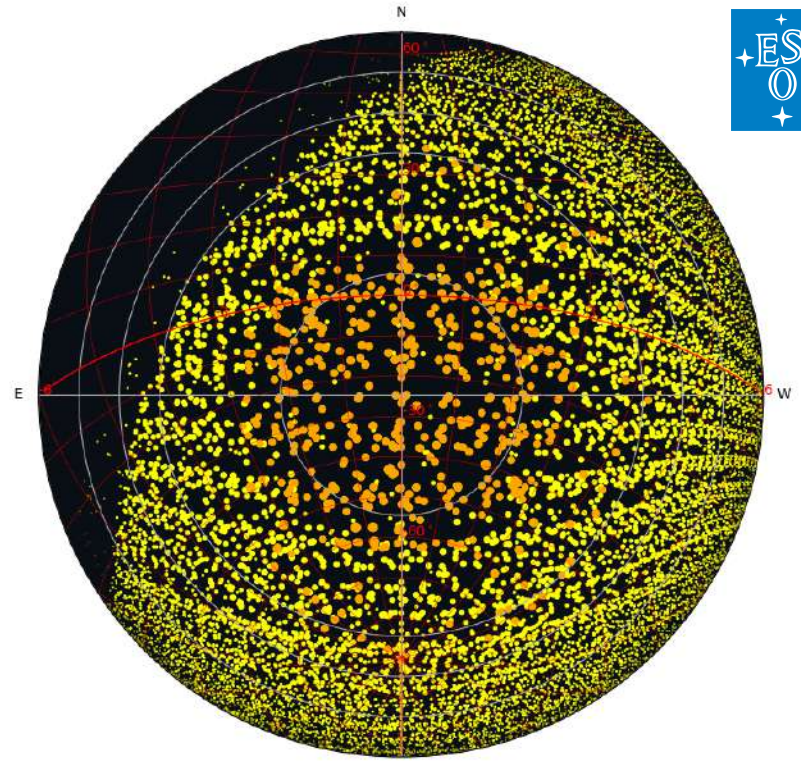
*Light version: animation replaced
by snapshot*

ct on Observations



Today: 9300 sat.

- Pre-constellation
- 6000 SL at 550km
- 627 OW at 1200km



Tomorrow: 404 574 satellites

- 60 shells
- Starlink Gen-1 + Gen-2 / OneWeb-2red / Guo Wang-A59-2 / Amazon LEO / ESPACE Rwanda



Individual satellites --> density



70k satellites, ~30 constellation shells

- Pre-constellations: 2100 Upper-LEO + 500 Low LEO
- Constellations:
 - o 42 000 SL on 16 shells
 - o 6370 OW on 3 shells
 - o 13 000 GW on 7 shells
 - o 3 200 AK LEO on 3 shells

Individual satellite simulation:

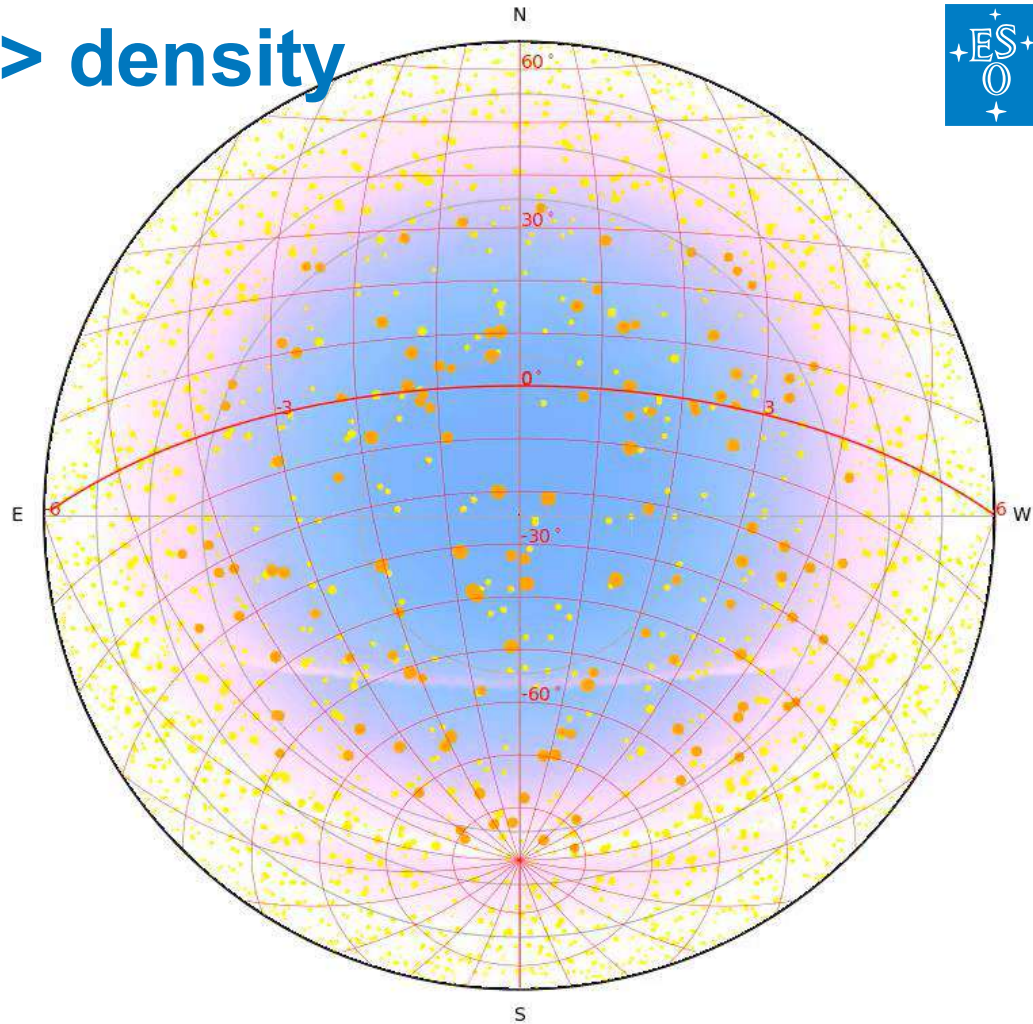
70k complex calculation, several times / second

Analytical model of the constellation density:

30 simple calculations, every few seconds

Exact: *not* an approximation

--> **3M x faster**

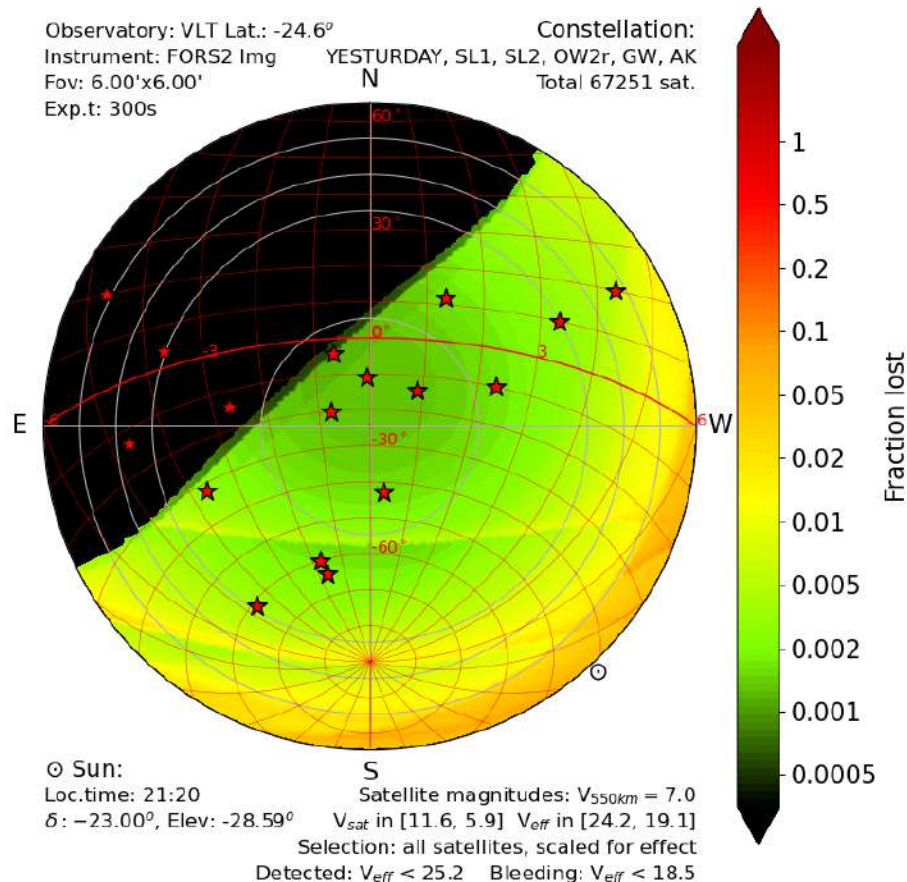


Sky map of effects on observations

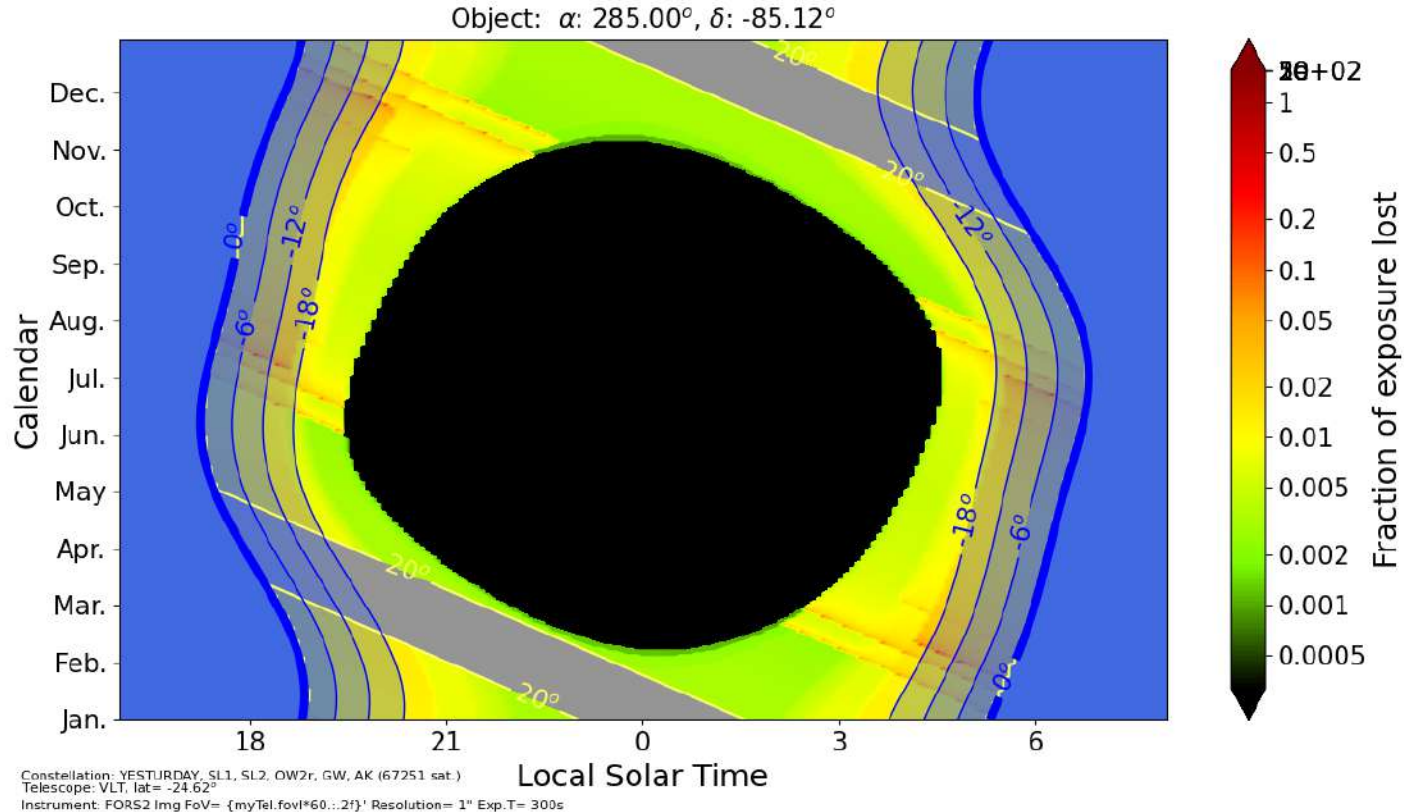
- 70k satellites, ~30 constellation shells
- Accounts for
 - o Field-of-view
 - o Resolution / quality of sky
 - o Exposure time
 - o Mirror size / limiting magnitude

Adjusting the sequence &/or timing of observations can significantly reduce the effect of constellations

Light version: animation replaced by snapshot

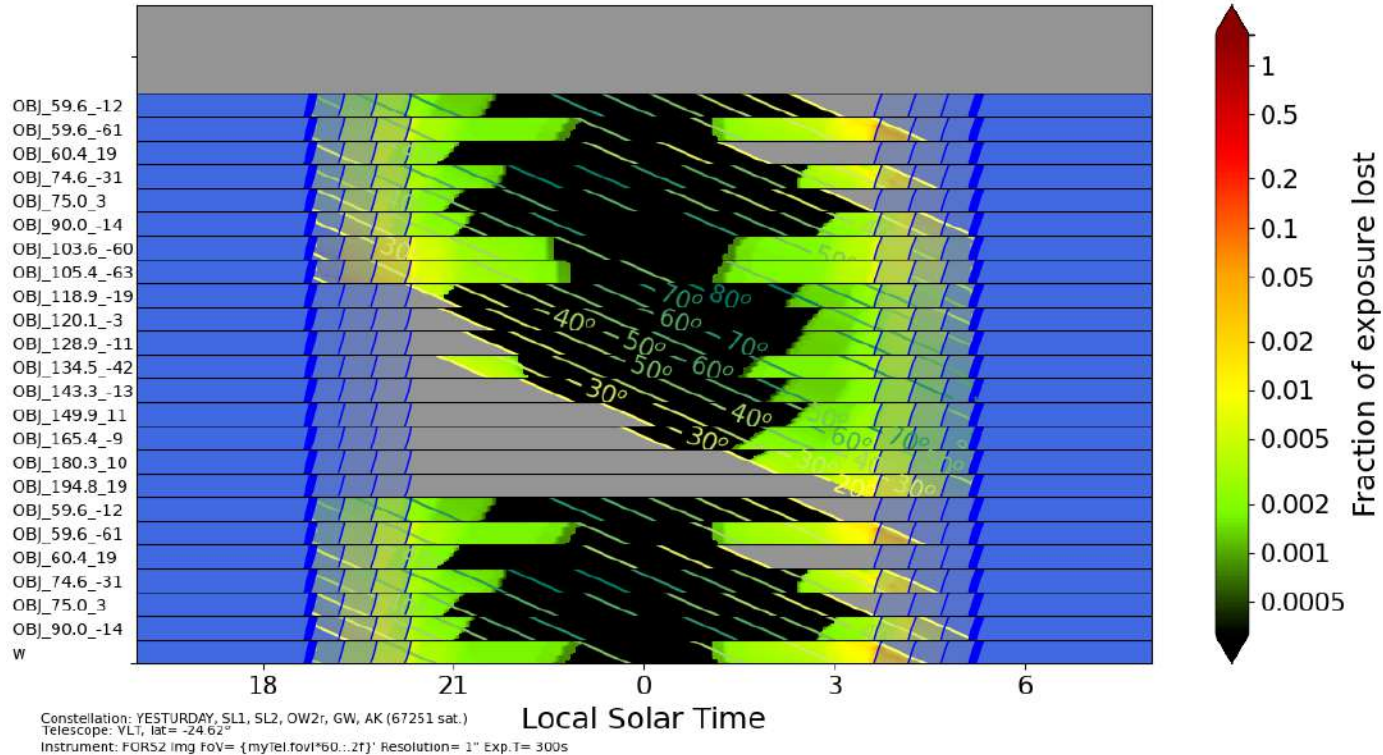


Calendar of effects on observations



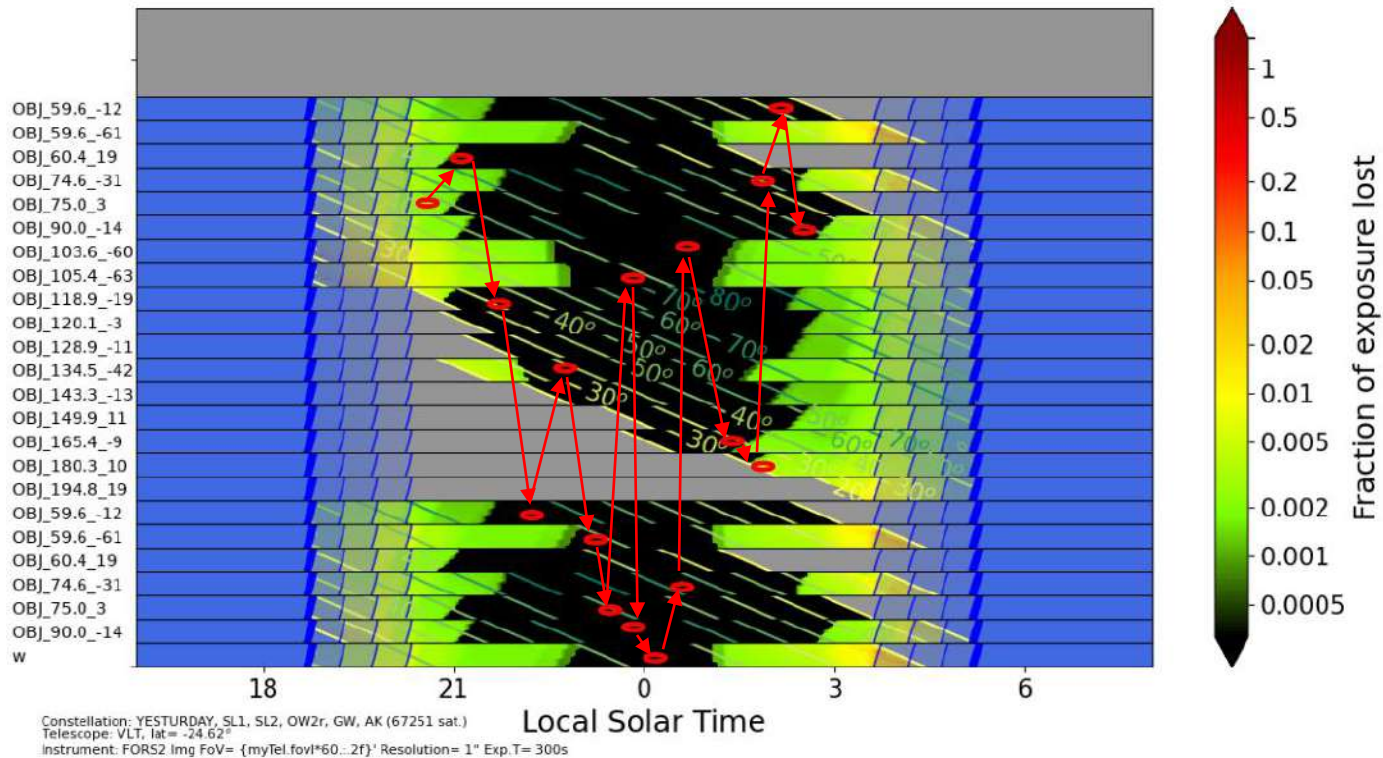
Optimize the observations

ESO-Paranal - 2025-Dec-09/10



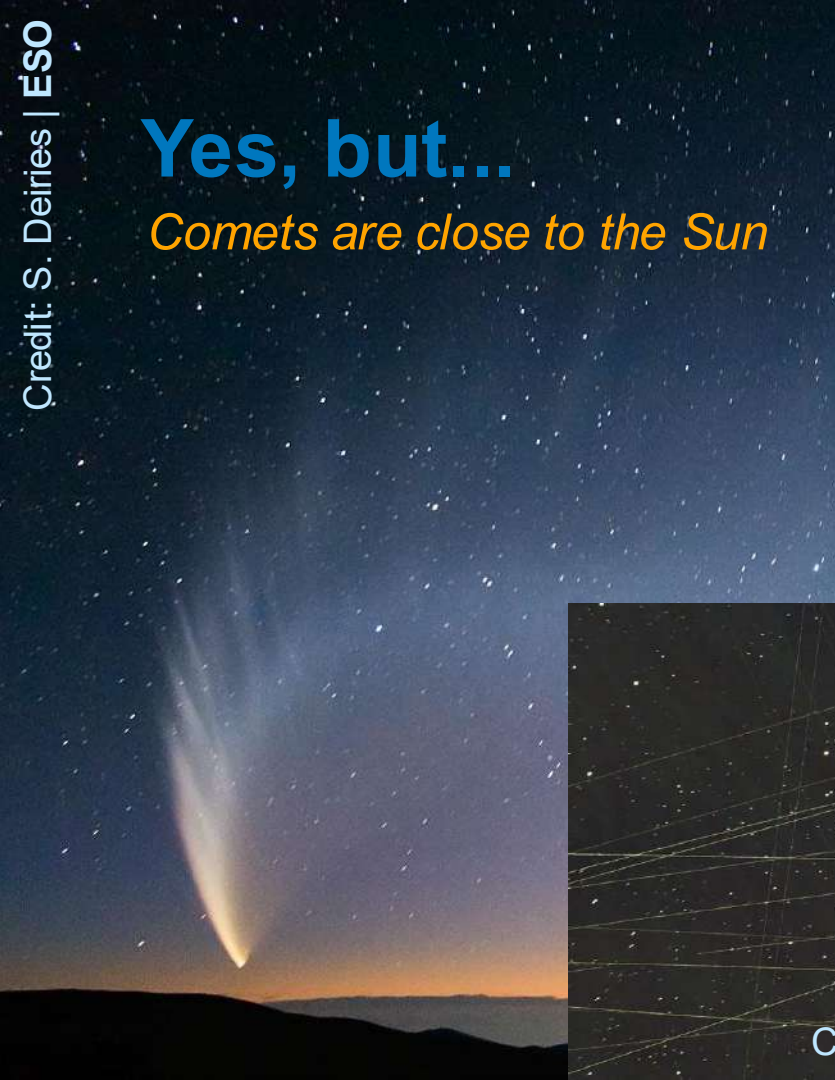
Optimize the observations

ESO-Paranal - 2025-Dec-09/10

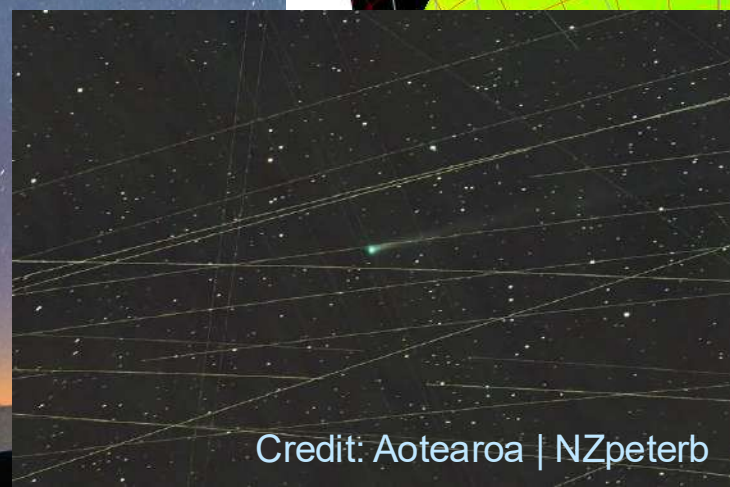
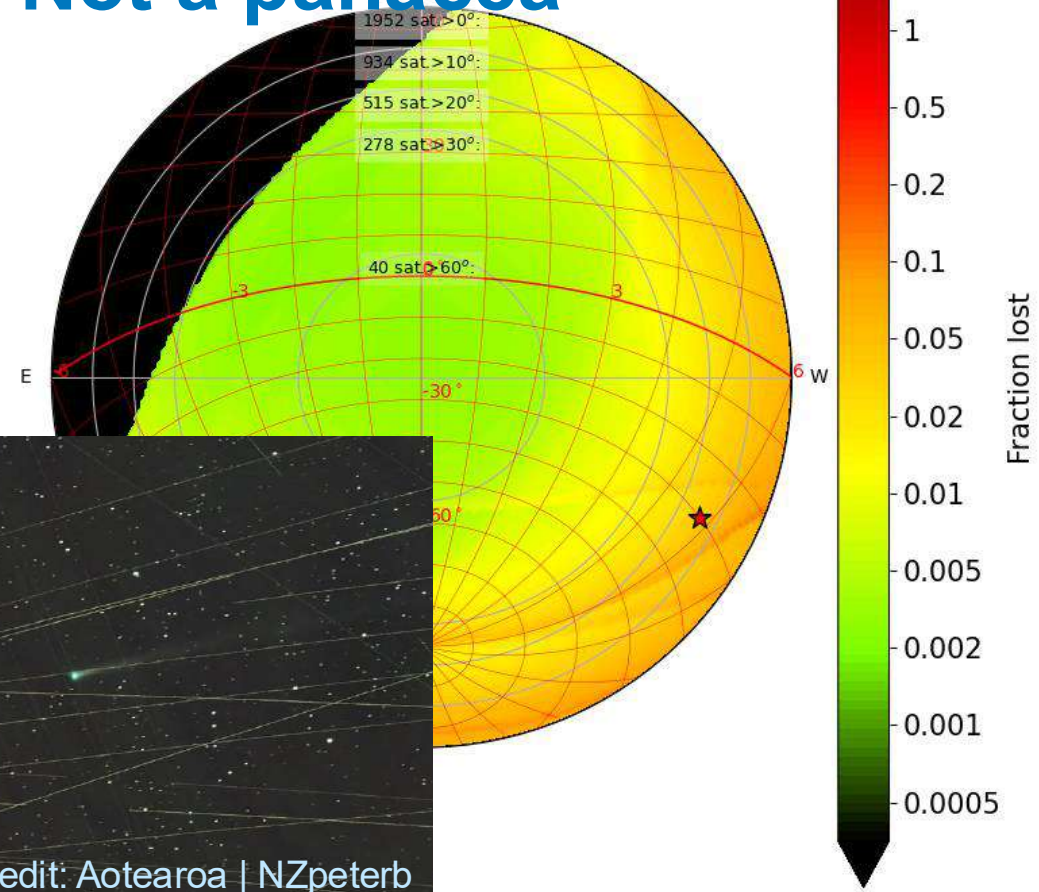


Yes, but...

Comets are close to the Sun



Not a panacea



Yes, but...

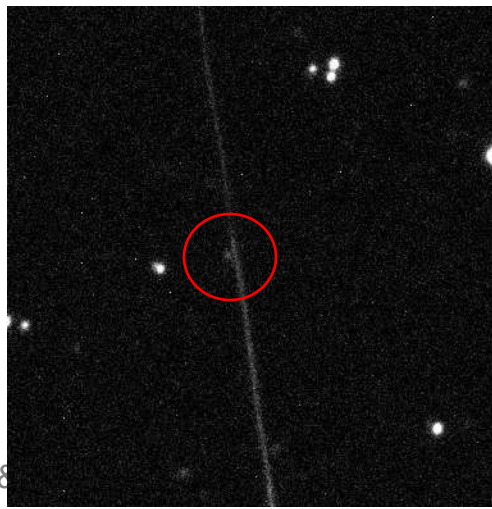
Not a panacea

Near-Earth Asteroids appear close to the Sun

2024YR4

(IAWN

warning in 2024)



*Light version: animation replaced
by snapshot*

Analytic model of constellations



- Very fast: real time calculation for many observations
- needs only the global parameters of constellation
- Optimize observation sequence to reduces effects of satellites



- Probabilistic: no 100% efficient where the satellites are illuminated
- Does not solve all science cases

Mitigation

ALL levels of mitigation are needed

- Constellation architecture
- Satellite design
- **Observation preparation -->**
- Data processing

Analytical model of satellite constellation

- Python package: SatConAnalytic
- GitHub: <https://github.com/ohainaut/SatConAnalytic>
- Astro:
Olivier Hainaut ohainaut@eso.org
- Policy:
Beatrice Kioko beatrice.kioko@eso.org

!! This is just in the optical !! Radio is a completely different set of problems and solutions