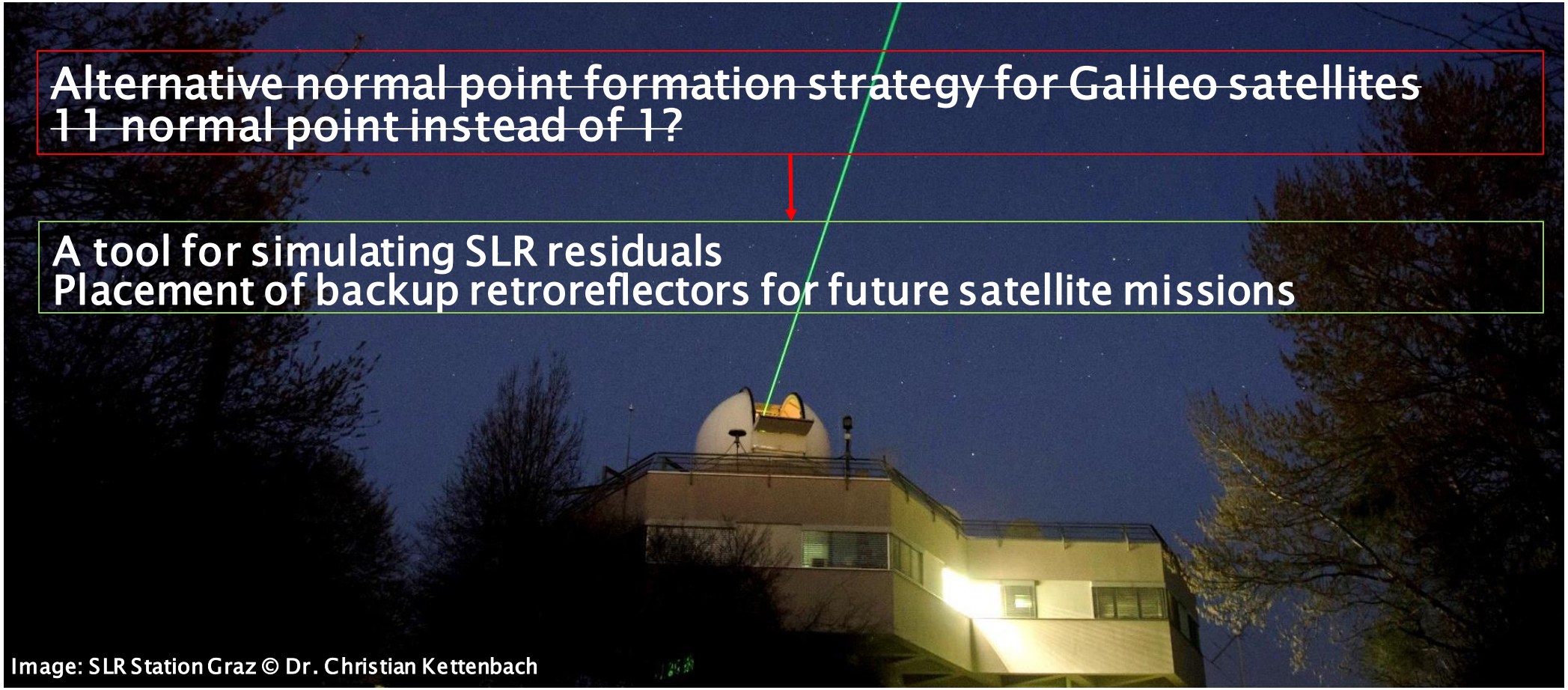
ÖAW IWF

REFLECTOR-BASED ATTITUDE DETECTION SYSTEM



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CHANGE OF PLANS

Original talk: necessary from funding agency side to withdraw talk

- Alternative normal point formation strategy for Galileo satellites
  - Yaw steering, symmetry conditions, relative to observer
  - Satellite signature -> multiple retros at equal range
  - E.g. 11 CCR rows forming during observations
  - Possible to calculate incident angle on panel -> validation of attitude
  - Form normal point of all rows central CCRs -> up to 11 normal points instead of 1 normal point
  - Up to 4 mm offset of central normal point to regular normal point
  - Comparison to Galileo POD -> new normal points closer to POD orbit

Backup talk:

- Reflector-based attitude detection system -> Residual simulation tool

RESIDUAL SIMULATIONS IN A NUTSHELL

RADS: Retroreflector-based attitude detection system // in a nutshell

- Software tool: Simulation of satellite laser ranging observed-minus-calculated range residuals

Highly modular software setup

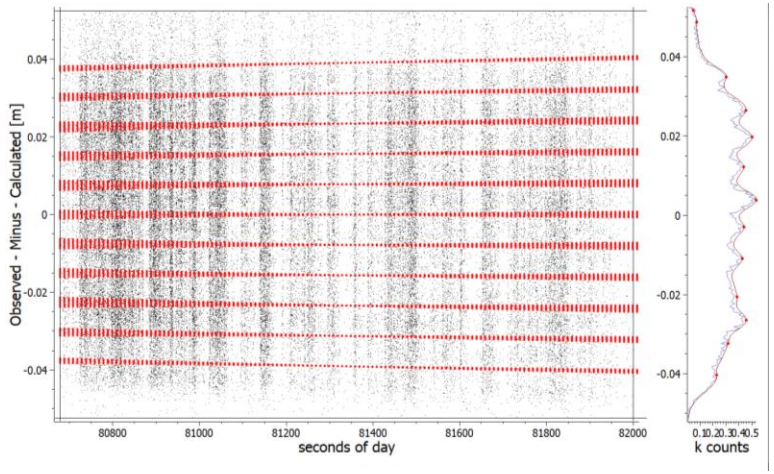
1) Input files: Satellite, CCR position + normal vector + FOV, rotation period + axis, reference frame, pass times
2) Orbit predictions: SGP4, TLEs or CPFs, SLR station coordinates
3) Coordinate transformations: TEME, ITRS, GCRS, Yaw, Orbit normal
4) Lagrange interpolation: e.g. orbit: 120 sec, simulation: 0.1 sec -> computation time
5) Rotate satellite: around fixed axis in reference coordinate frame (RCF)
6) Calculate residuals: Apply rotated CCR position to RCF axis (GCRS, nadir, yaw steering…)

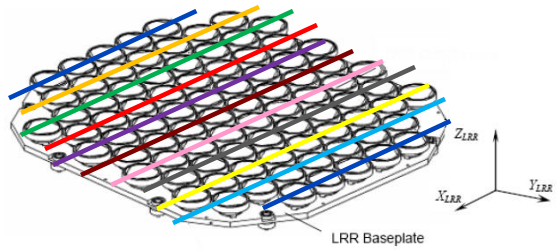
Aim of the project / tool

- Provide a tool to assess the positioning of backup-CCRs for optimal identification + attitude determination

GALILEO IOV: O-C RESIDUAL SIMULATION

- Individual CCRs on panel color coded
- Simulated SLR O-C residuals [mm]
- Different azimuthal orientations to observer
- Different laser beam incident angles
  - Overall residual spread





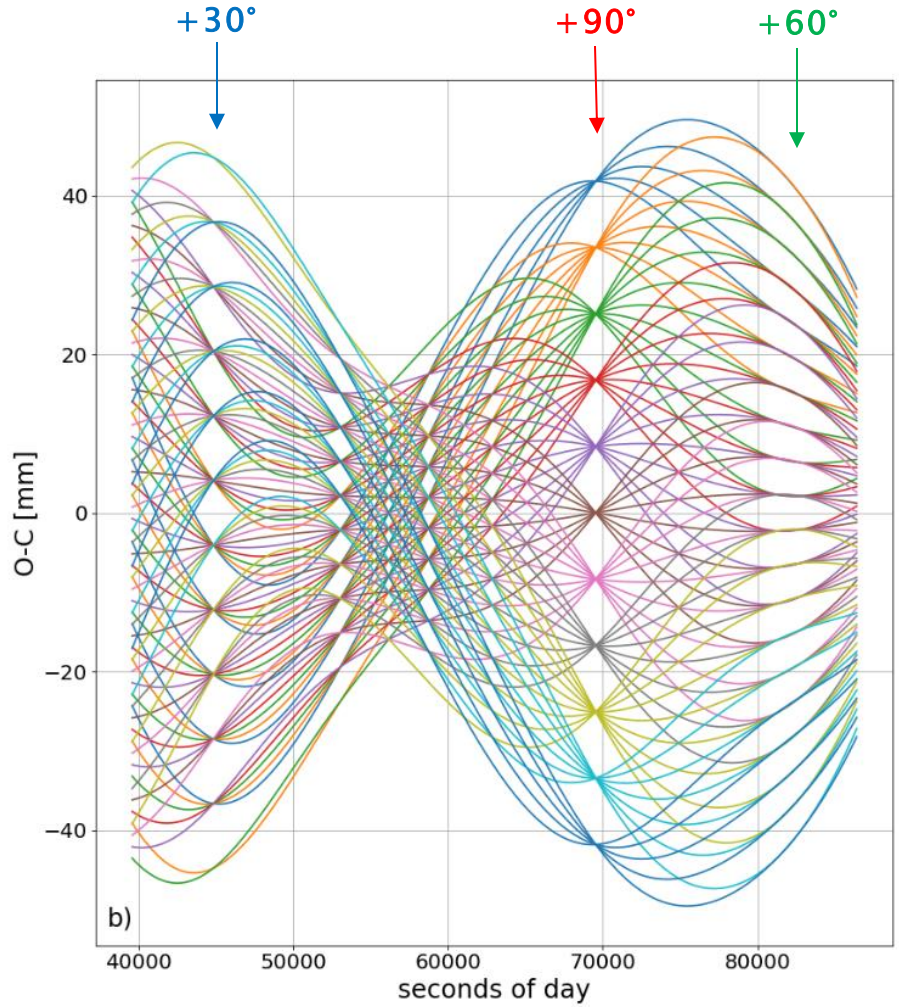
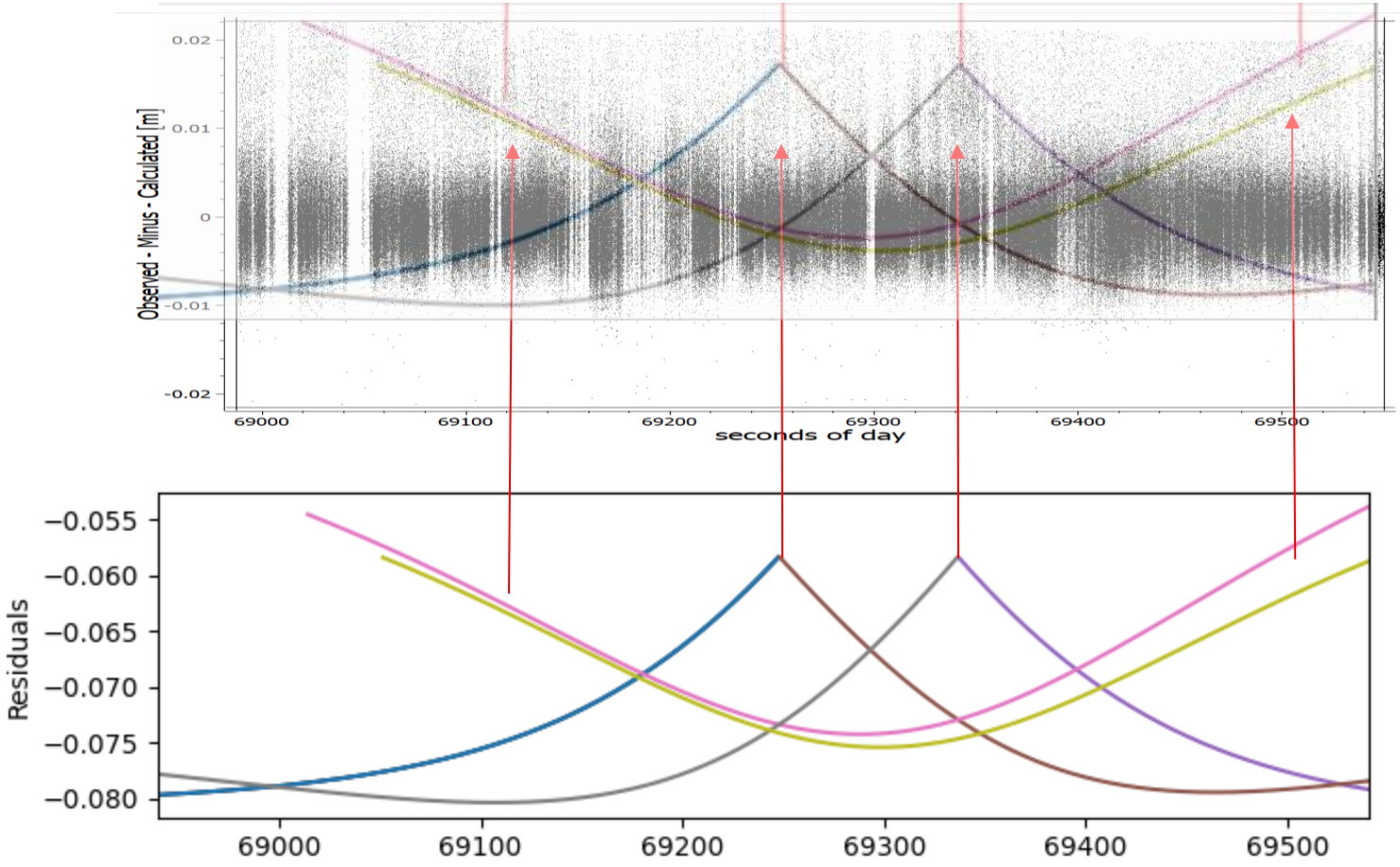


Image of Galileo panel: https://ilrs.gsfc.nasa.gov/missions/satellite_missions/current_missions/ga01_reflector.html

VALIDATION OF THE TOOL

Jason 3 (JA308219):

- Nadir pointing, JA308219, Single CCR on pyramid visible
- SLR residuals “orbit cleaned” in patches (baseline flat)



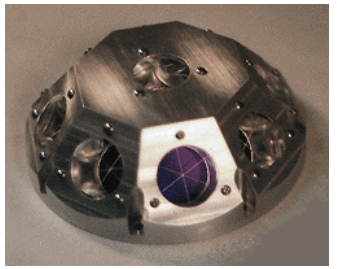


Image: Jason 3 POD pyramid © *https://ilrs.gsfc.nasa.gov/missions/satellite_missions*

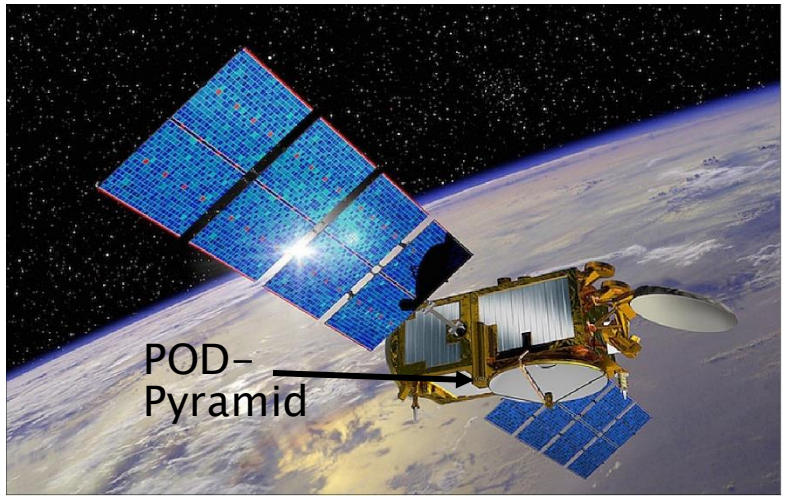


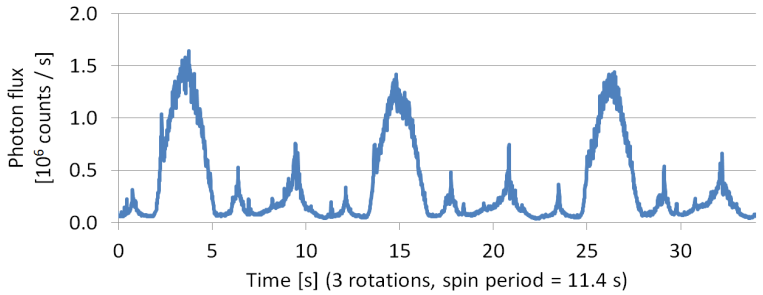
Image: Artist’s rendition of the deployed Jason-3 spacecraft ©CNES

HOW TO IMPROVE FUTURE SATELLITE MISSIONS

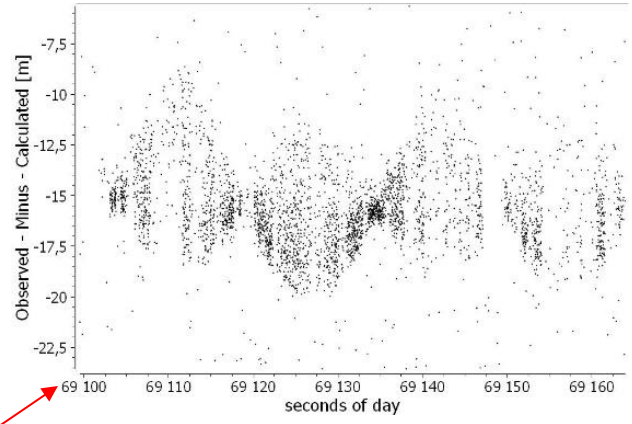
End of lifetime: satellites can start to tumble

- Outgassing
- Solar radiation pressure
- Magnetic torque
- Collision
- …

Graz data: single photon light curve (Topex)



Graz data: space debris laser ranging (SL16 R/B)



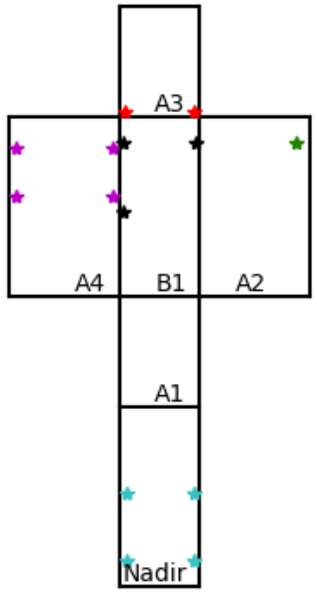
Tumbling behavior more difficult to monitor if no CCRs or just pyramid is on satellite

- Combination of multiple techniques: Light curves, space debris laser ranging, satellite laser ranging

How allow more stations collect attitude determination data?

- Placement of „backup“ CCRs on side faces
- Select CCRs and design placement of CCRs for better detectability and attitude determination

PLACEMENT OF BACKUP CCRS ON SIDE FACES

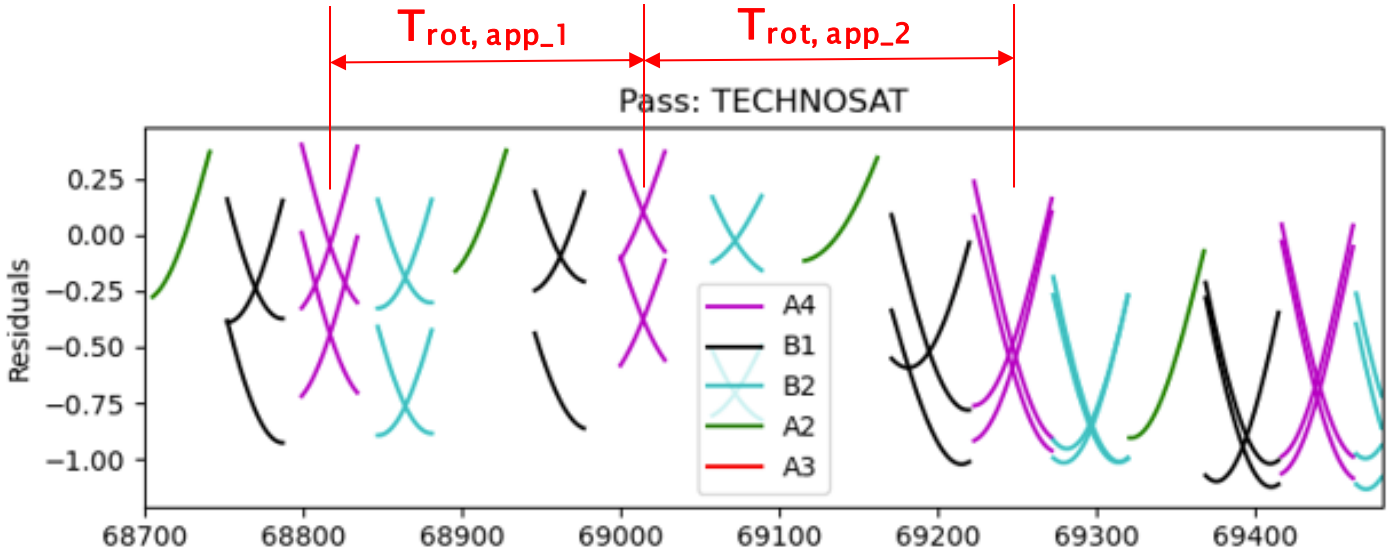


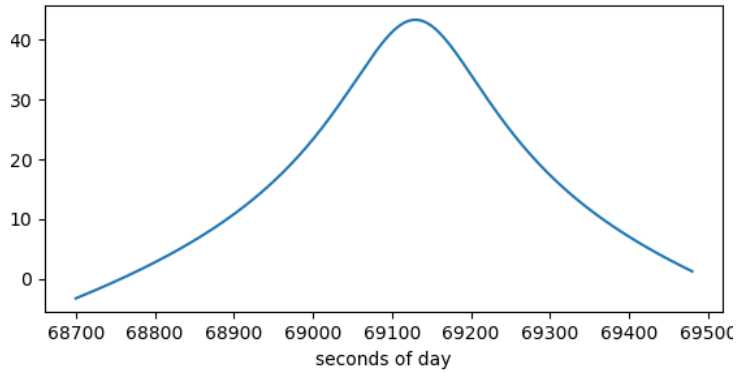
Basic simulation parameters:

- Cuboid satellite, 1-4 LLRs on each side, no CCRs on A1, Pass Technosat: el_max = 45°
- $T_{rot\_inertial}$ = 180 s, rotation axis = [1, 0, 0], through A1 and A3

Apparent rotation effect

- Satellite: more / less than one rotation to point to observer -> due to progress in pass
- Increased rotation period detectable from dataset: period larger than 180 s

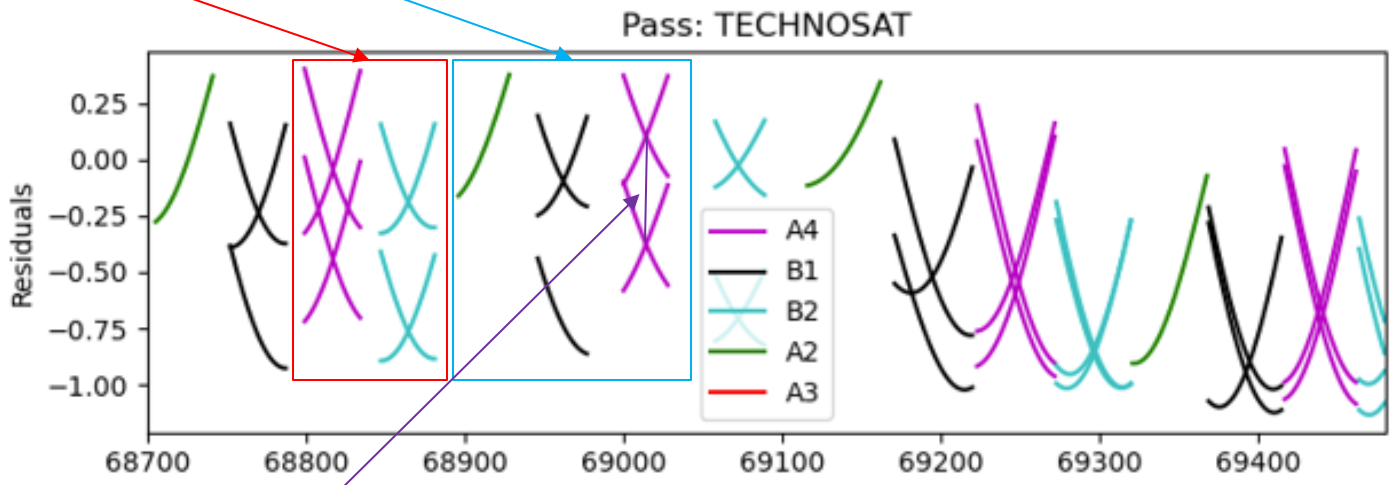


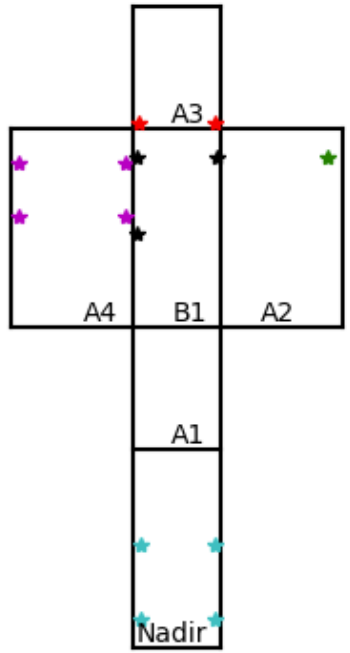


DISTINGUISH SURFACES

Distinguishability of surfaces

- **Case A:** Easy if any number of CCRs can be chosen -> number of tracks in SLR residuals
- **Case B:** Equal number of CCRs can lead to similar pattern: A4 (purple), Nadir (cyan)



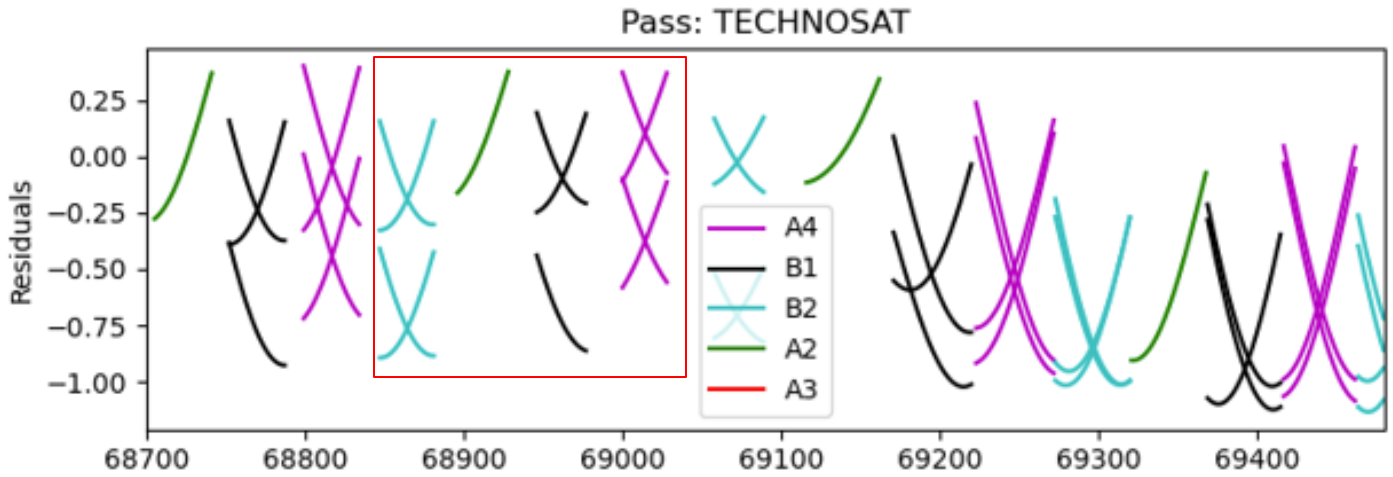


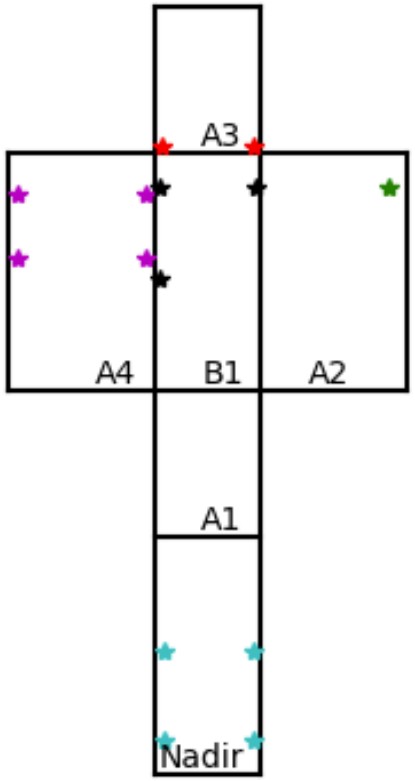
- **Central distance:** allows calculation of incidence angle to surface normal (if CCR positions known)

SEQUENCE OF SURFACES

Sequence of surfaces

- Indication of rotation direction
- cyan (4) -> green (1) -> black (3) -> purple (4)

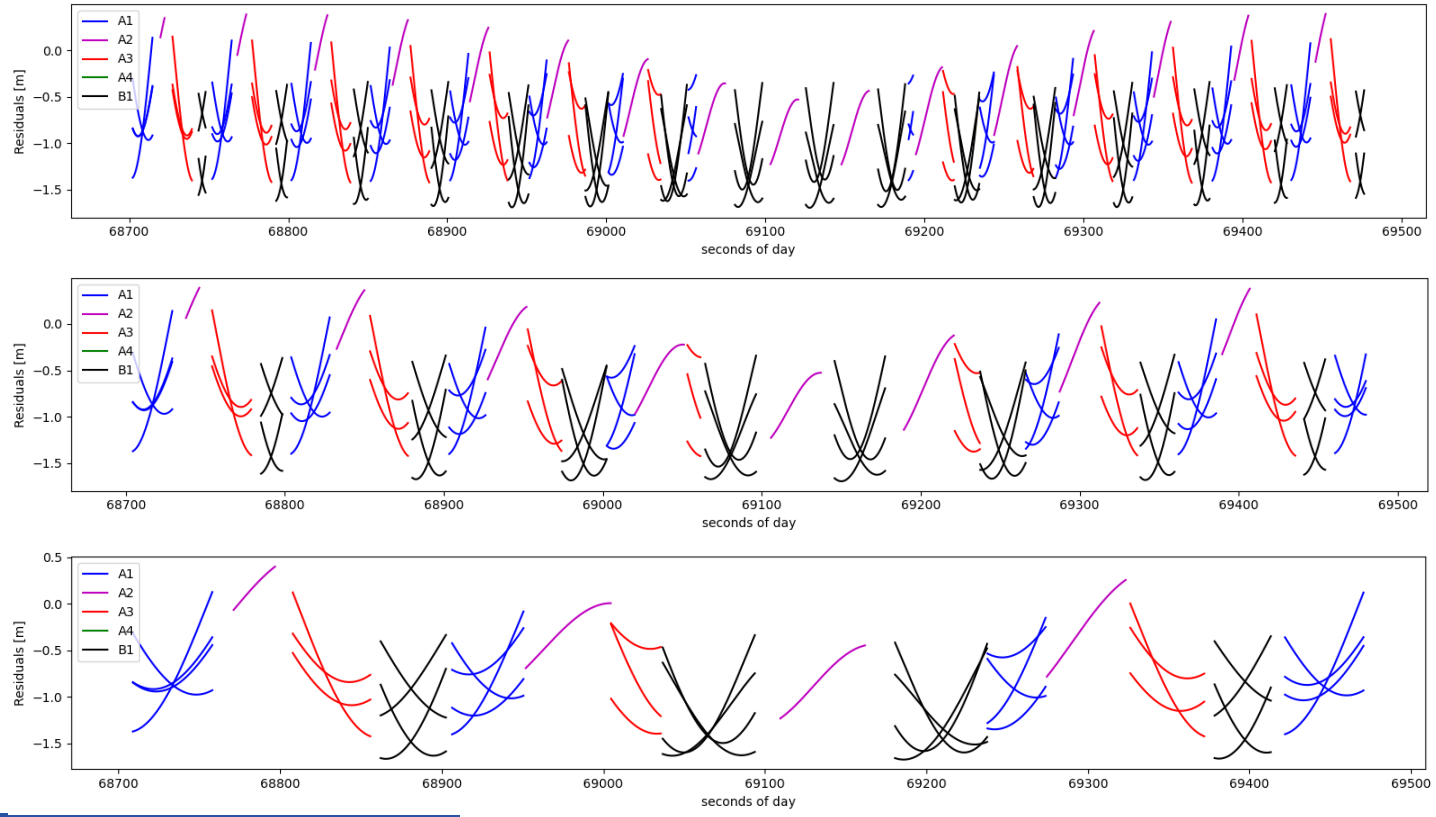


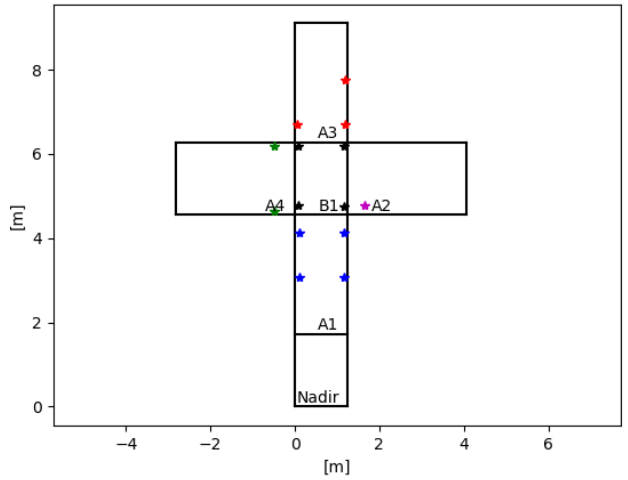


ROTATION PERIOD VARIATION

Rotation period variation

- axis = [0, 1, 1], T = 50 s, 100 s, 200 s
- Streching pattern, influence on apparent period

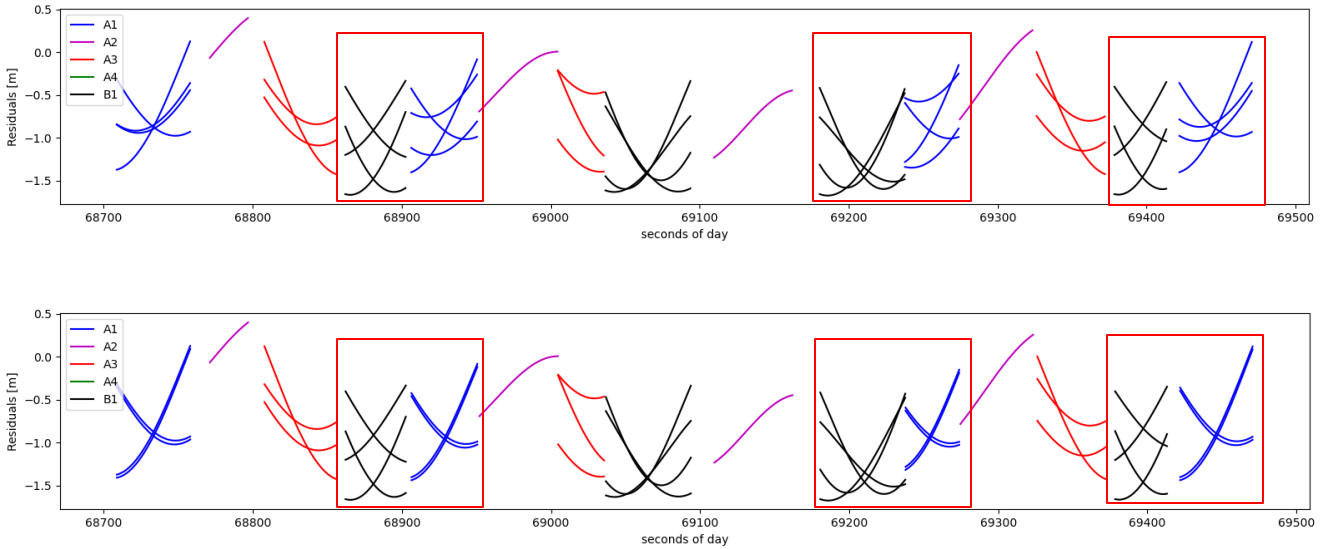


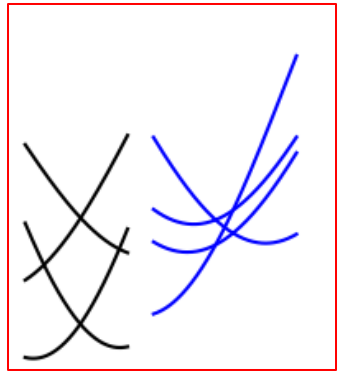


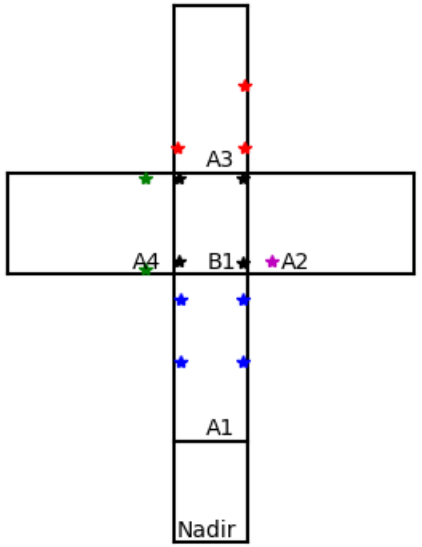
DISTINGUISHABILITY: EQUAL # OF CCRS

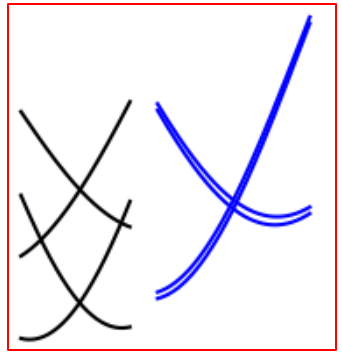
Distinguishability: patterns with equal number of CCRs

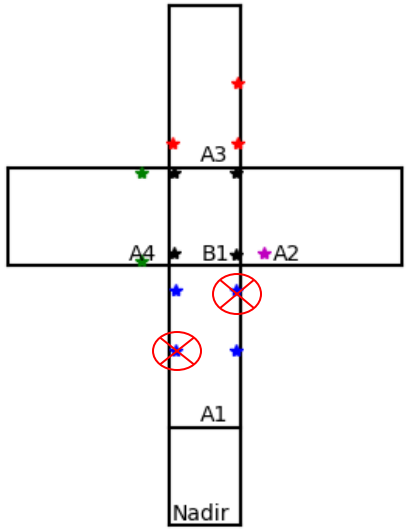
- Group e.g. two CCRs together
- E.g. 5 cm offset between two CCRs
- Still showing clear SLR offset at low











OUTLOOK / SUMMARY

Summary / outlook

- Tool to simulate SLR residuals
- Modular setup, simple to iterate through different setups
- Verified with measured SLR residuals to different satellites

Potential applications

- Test various CCR setups in different rotation conditions
- Validate different attitude determination techniques on simulated data
- SLR data post processing (leading edge, pattern recognition) -> MHz SLR

Acknowledgement

The work has been conducted within the framework of the ESA project „Reflector-based attitude detection system“

!!! THANK YOU !!!


SLR station Graz
© Christian Kettenbach


Alcantara
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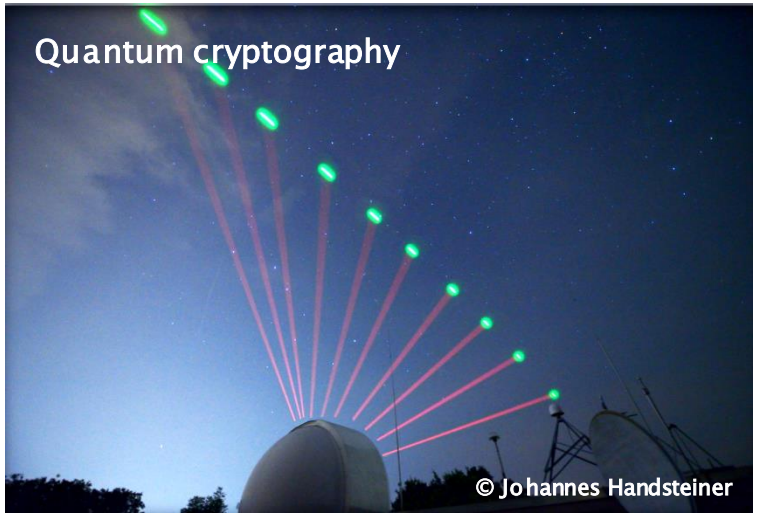
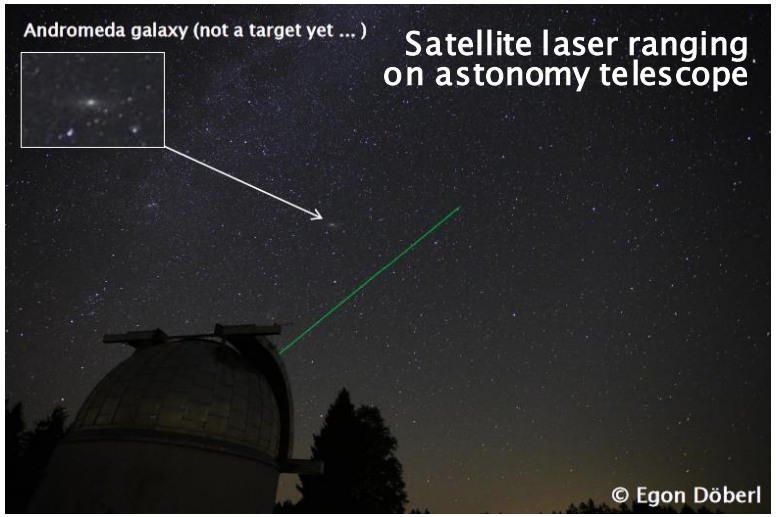

Quantum cryptography
© Johannes Handsteiner


Andromeda galaxy (not a target yet ...)
Satellite laser ranging
on astonomy telescope
© Egon Döberl

CCR FIELD OF VIEW

CCR Field of view

- 40° / 50° / 60° -> overlap of residuals from different surfaces