Multi-Static Laser Ranging To Space Debris Targets: Tests and Results

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[2] AIUB: Astronomical Institute, University of Bern
[3] BKG: Laser Station Wettzell
[4] SGF: Space Geodesy Facility Herstmonceux
[5] DLR: German AeroSpace Center Stuttgart
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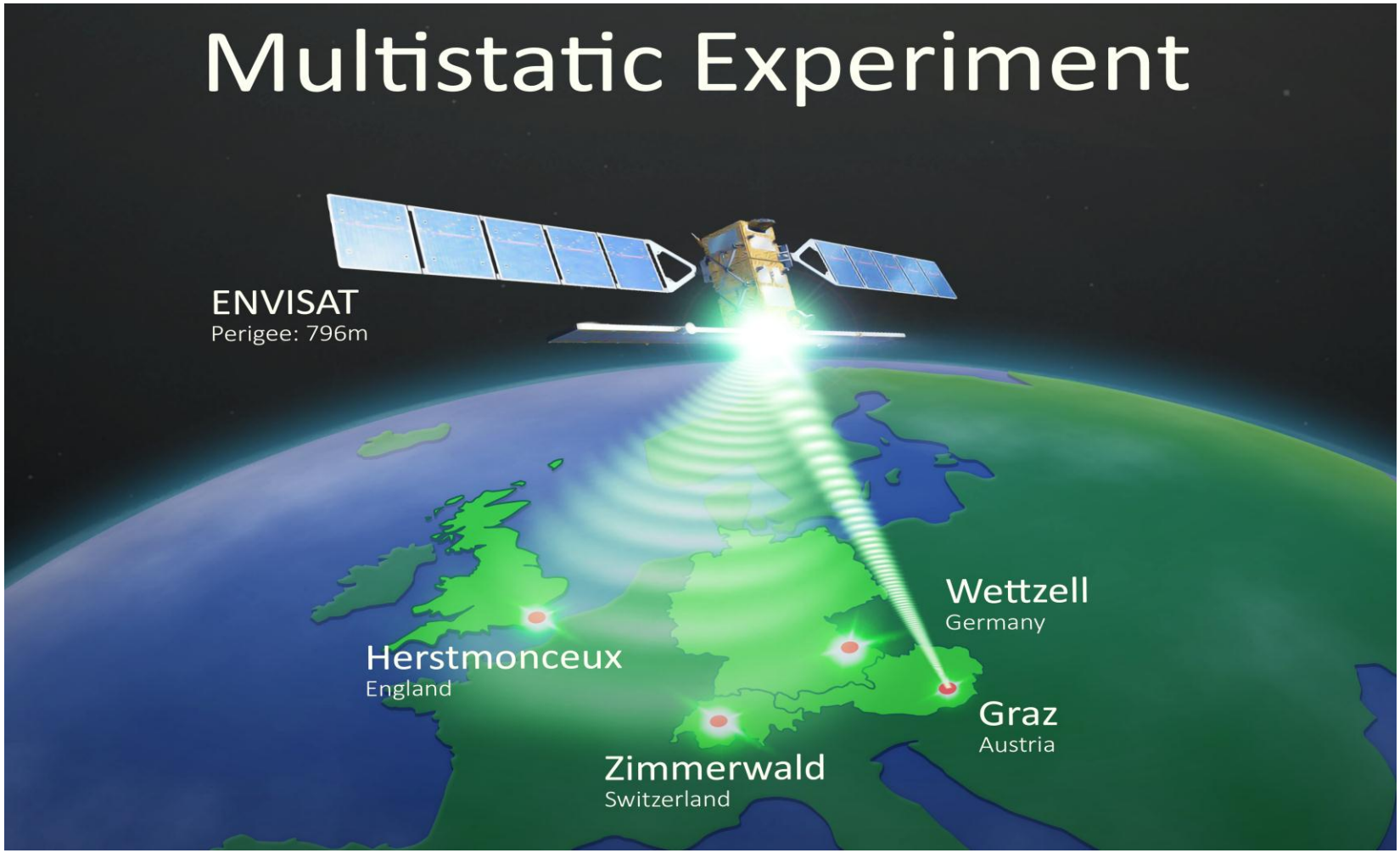
What is ‘Multi – Static’ ???



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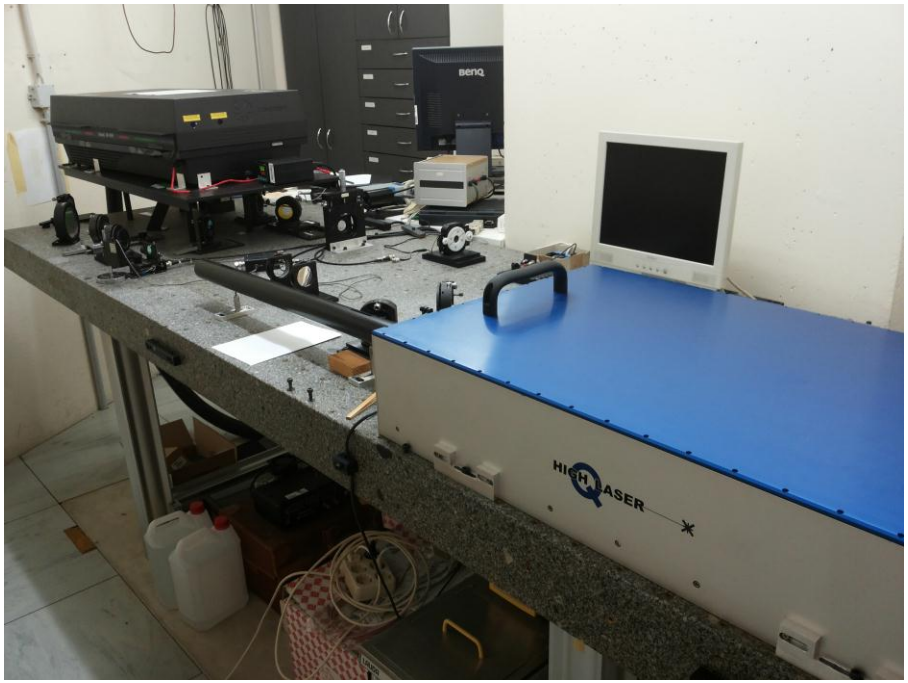
- ONE active station (Graz) fires the laser pulses
- Photons are diffusely reflected from sat body
- Several passive stations receive these photons

- Distance Graz – Zimmerwald: 600 km
- Distance Graz – Wettzell: 400 km
- Distance Graz – Herstmonceux: 1200 km

Graz: Active Station



Graz Laser bench:

- Foreground / blue box: HQ laser / 2 kHz: mm-distances to retros on satellites

- Background / black box: Debris Laser: 80 Hz, 200 mJ @532 nm, 3 ns; meter-measurements to debris; no retros …

- Graz: Uses Coherent Infinity Laser:
  - On loan from DLR Stuttgart
  - Flash lamp pumped amplifier
  - 200 mJ per pulse @ 532 nm / 3 ns
  - 99.9 Hz maximal ☹
  - 80.0 Hz used for multi-static ranging

- The Graz firing sequence (80 Hz; 12.5 ms) is synchronized to the 1 pps;

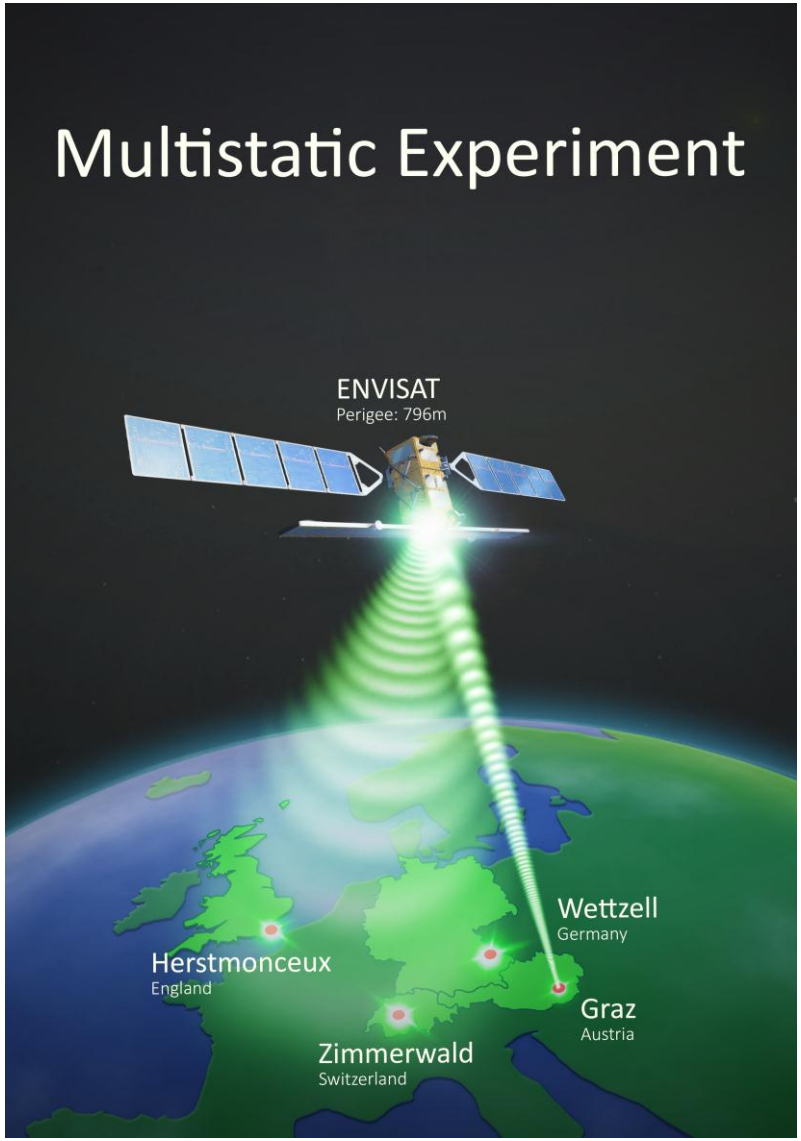
- The initial offset from the 1 pps is defined and fixed; the sequence of firing epochs repeats within each second

- Thus Graz firing epochs are known in advance

- Passive stations can calculate the expected receive epochs for Graz photons

- Overlap avoidance in Graz has to be OFF

Passive Stations: Zimmerwald / Wettzell / Herstmonceux



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- Successful passive stations:
  - Zimmerwald, Wettzell, Herstmonceux

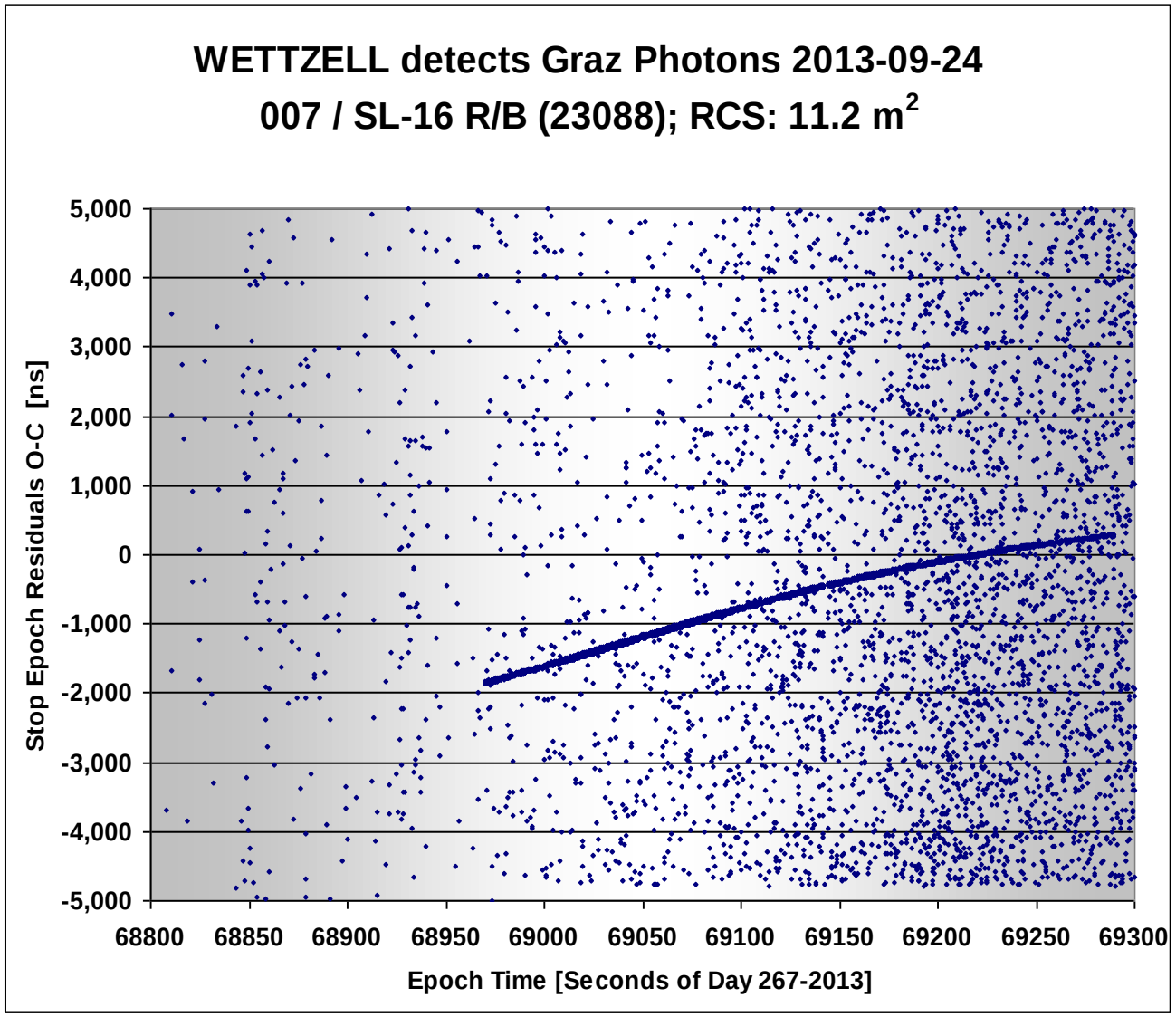
- Passive stations get tracking schedule
  - Up to 20 passes per session
  - TB exchange system is used to coordinate pass switching

- TLE predictions for debris targets are used (CPFs for ENVISAT)

- These predictions are not very accurate:
  - Time Bias up to ± 1 s; RB up to ± 1 km

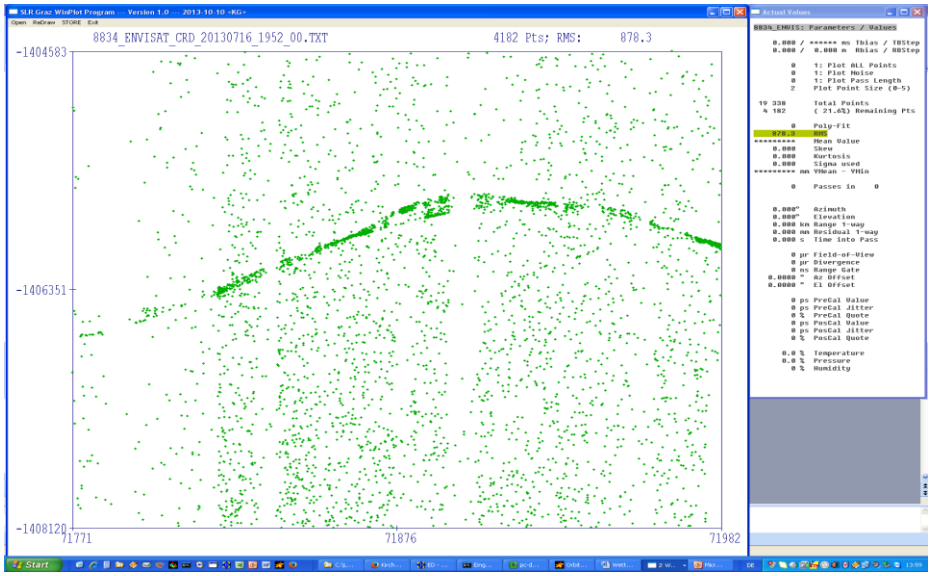
- Therefore: Sessions only during early evening:
  Targets in sun, stations in darkness:
  This allows to see the targets with CCDs

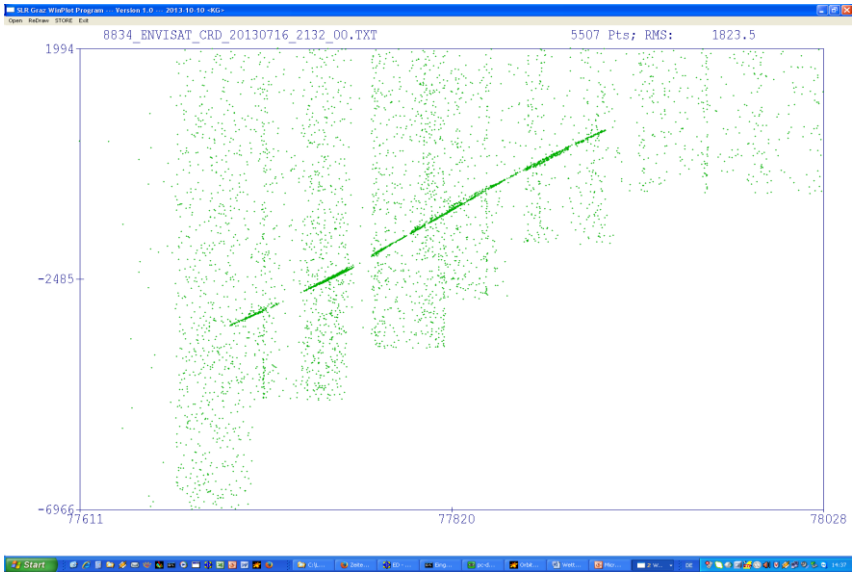
A rocket body passively tracked by Wettzell

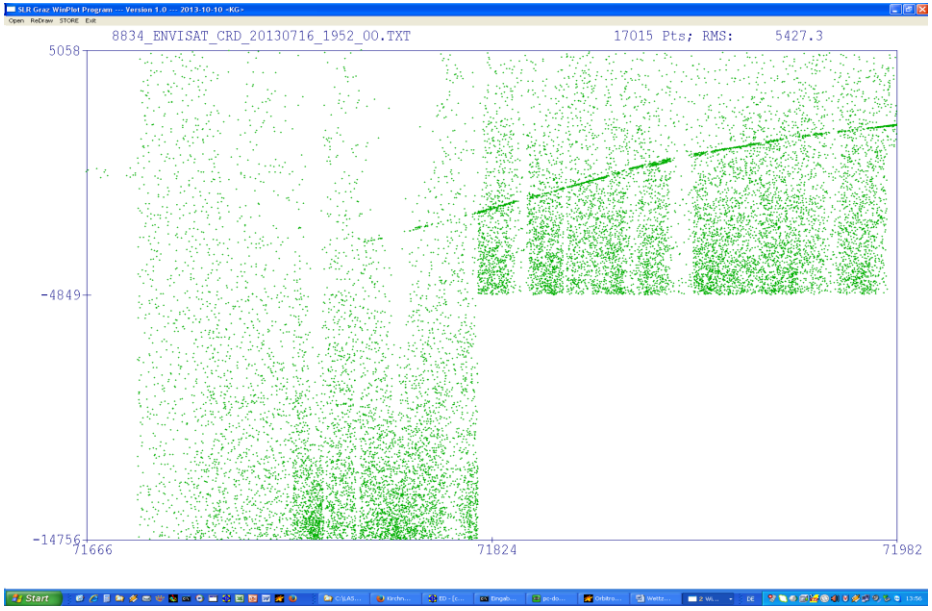


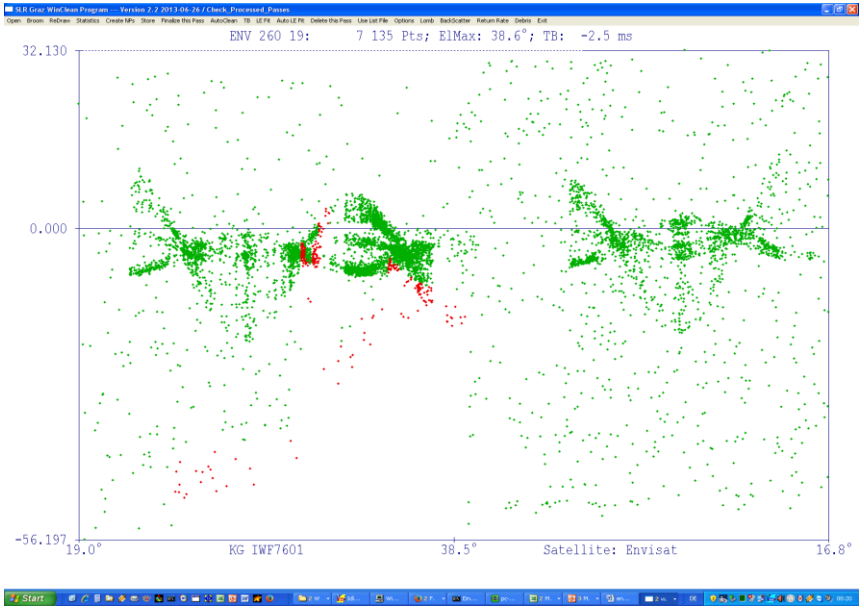
- Example: Graz fires to a big target (rocket body): 11 m^2 Radar Cross Section (Min. RCS needed: 0.3 m^2)
- Photons are reflected from target, and are detected in Wettzell: Clear signal …
- Distance: 1800 to 2500 km Elevation: 20° to 10° ↓ (as seen from Graz)
- Needed RG of some µs at Wettzell SLR station
- Debris Laser Firing Rate: 80 Hz or 100 Hz: Gives better S/N Ratio than kHz

ENVISAT Passes: Wettzell (and Graz…) see Graz Photons

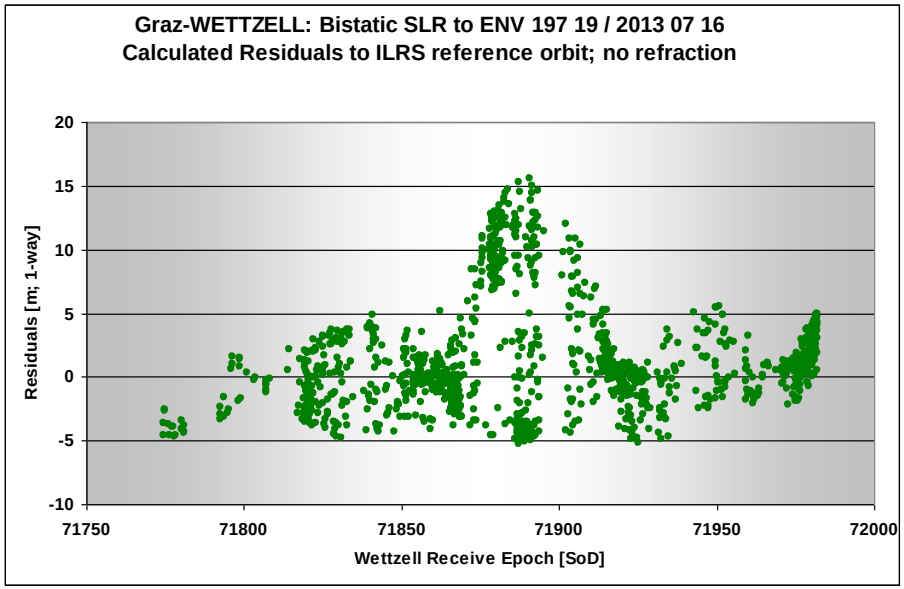


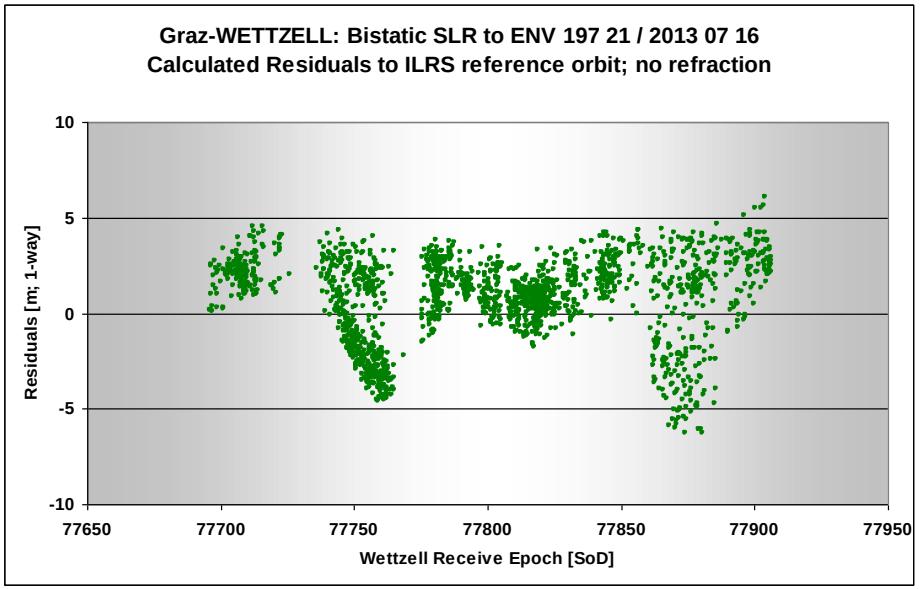


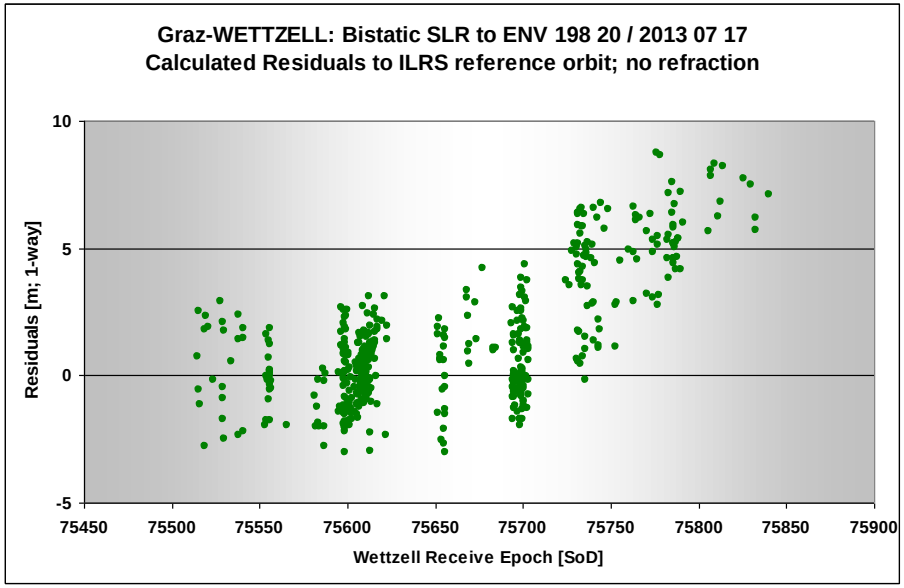


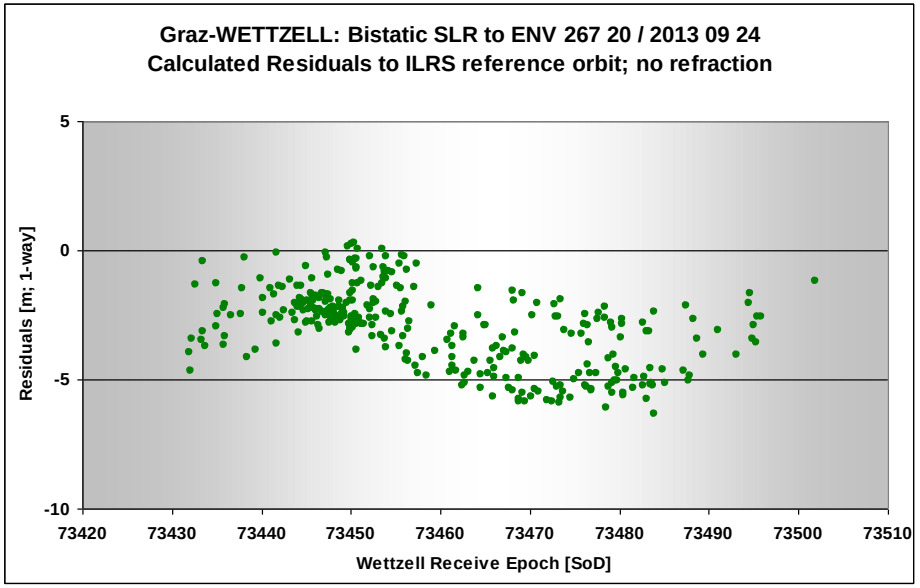


Wettzell: Passive only residuals to ILRS ENV Orbit









Conclusions

There is a unique concentration of SLR stations in Europe

- Use it e.g. for Multi-Static Ranging to Debris Targets:
  - We have demonstrated that it works with debris targets in LEO orbits
  - ENVISAT example was used here because an ‚ILRS reference orbit' is available

- Recommanded Specs for Space Debris Ranging Laser (Monostatic/multistatic):
  - Power: 20 to 30 W sufficient for targets > 0.3 m^2 in LEO orbits (up to 3000 km)
  - Repetition Rate: ≈100 Hz more suitable than kHz (better S/N ratio)
  - Pulse Duration: Several nanoseconds okay – no need for picoseconds
  - Wavelength: 532 nm okay for existing systems; 1064 nm: ≈ 4 times improvement

- Goal: POD of ***debris objects*** with ***very few passes / very few SLR stations***
  - For predicted conjunctions, POD with SLR can help to avoid anticollision maneuvres
  - Could be done within e.g. 2 days (conjunction warnings are several days ahead)
  - To handle weather problems, a few more ‚active' stations are needed…
    (with stronger debris laser)

Thank you !

http://www.youtube.com/watch?v=5o6OtPJKRJ8
Video of Graz SLR station ranging to ILRS satellites