# Maximizing the output of SLR station Graz: Tracking 140 targets

Georg Kirchner, Franz Koidl

Institute for Space Research

Austrian Academy of Sciences

# SLR Graz: Tracking 140 targets ☹

Session relevant questions – and their quick answers:

- What is limiting our performance?
  - Weather ☺ …. lucky Yarragadee ….

- Are we tracking too many satellites ?
  - No…. There is still space for more targets ☺

- How should future systems be designed for better performance?
  - kHz / high rep rate; or kHz / high rep rate; or kHz / high rep rate, or…..
  - 10 Hz systems are much too slow for high number of targets

- How can procedures be improved to improve performance?
  => Main part of this talk

# SLR Graz: Actual list of our 140 targets ☺

| ILRS Satellites: | ILRS Satellites: GLONASS | ILRS Satellites: GALILEO | NON-ILRS Targets: Varias | NON-ILRS Targets: Defunct Glonass | |
|---|---|---|---|---|---|
| 6503201 BeaconC | 0606203 Glonass101 | 1106001 Galileo101 | 9105001 ERS1 | 8900101 Glonass040 | 0206001 Glonass089 |
| 7501001 Starlette | 0606201 Glonass102 | 1106002 Galileo102 | 9502101 ERS2 | 8900102 Glonass041 | 0206003 Glonass090 |
| 7603901 Lageos1 | 0606202 Glonass103 | 1205501 Galileo103 | 9205201 Topex | 9004501 Glonass044 | 0206002 Glonass091 |
| 8606101 Ajisai | 0705202 Glonass105 | 1205502 Galileo104 | 0105501 Jason1 | 9011001 Glonass047 | 0305601 Glonass092 |
| 8900103 Etalon1 | 0705201 Glonass106 | 1405001 Galileo201 | 0503101 Oicet | 9011003 Glonass049 | 0305602 Glonass093 |
| 8903903 Etalon2 | 0706501 Glonass107 | 1405002 Galileo202 | 0900205 Sohla1 | 9102501 Glonass050 | 0305603 Glonass094 |
| 9207002 Lageos2 | 0706503 Glonass109 | 1501701 Galileo203 | 9604601 Adeos1 | 9200501 Glonass053 | 0405302 Glonass095 |
| 9306102 Stella | 0907001 Glonass116 | 1501702 Galileo204 | 0205601 Adeos2 | 9204701 Glonass056 | 0405303 Glonass096 |
| 0201201 GraceA | 0907002 Glonass117 | 1504501 Galileo205 | 0600201 ALOS | 9204702 Glonass057 | 0405301 Glonass097 |
| 0201202 GraceB | 0907003 Glonass118 | 1504502 Galileo206 | 9305501 FIZEAU | 9402101 Glonass062 | 0505003 Glonass098 |
| 0304206 Larets | 1000701 Glonass119 | .... | 0904907 Blits | 9402102 Glonass063 | 0505002 Glonass099 |
| 0803201 Jason2 | 1000703 Glonass120 | .... | 0505101 GioveA | 9402103 Glonass064 | 0706502 Glonass108 |
| 0702601 TerraSarX | 1000702 Glonass121 | .... | 0802001 GioveB | 9405001 Glonass065 | 0804601 Glonass110 |
| 1001301 CryoSat2 | 1004103 Glonass122 | .... | 8597602 OptusA1 | 9405002 Glonass066 | |
| 1003001 TandemX | 1004102 Glonass123 | .... | 8510903 OptusA2 | 9405003 Glonass067 | |
| 1104301 Hy2a | 1004101 Glonass124 | .... | 8707801 OptusA3 | 9407601 Glonass068 | |
| 1200601 Lares | 1100901 Glonass125 | .... | 9205401 OptusB1 | 9407602 Glonass069 | |
| 0200901 Envisat | 1105501 Glonass126 | Space for the next | 0901801 CompassG2 | 9407603 Glonass070 | |
| 1300901 SARAL | 1106403 Glonass127 | 18 Galileos ☺ | 8802801 Gorizont15 | 9500901 Glonass071 | |
| 1306702 SwarmA | 1106401 Glonass128 | …. | 6700101 Intelsat2F | 9500902 Glonass072 | |
| 1306701 SwarmB | 1106402 Glonass129 | …. | 9101505 Meteosat5D | 9503701 Glonass074 | |
| 1306703 SwarmC | 1301901 Glonass131 | …. | 9704905 Meteosat7R | 9503702 Glonass075 | |
| 9806714 SpinSat | 1401201 Glonass132 | …. | 8403106 SL12 RB | 9503703 Glonass076 | |
| 1303401 IRNSS1A | 1403201 Glonass133 | …. | 8407806 SL12 RB | 9506801 Glonass077 | |
| 1401701 IRNSS1B | 1407501 Glonass134 | …. | 8005002 Cosmos1188 | 9506802 Glonass078 | |
| 1304201 Kompsat5 | | …. | 9502604 Sl6RB2 | 9506803 Glonass079 | |
| 1201801 CompassM3 | | …. | 9600601 PakSat1 | 9807701 Glonass080 | |
| 1101301 CompassI3 | | …. | 9900803 SunSat | 9807702 Glonass081 | |
| 1107301 CompassI5 | | …. | | 9807703 Glonass082 | |
| | | …. | | 0006302 Glonass084 | |
| | | …. | | 0105303 Glonass086 | |
| | | …. | | 0105302 Glonass087 | |
| | | …. | | 0105301 Glonass088 | |

- Targets tracked by Graz with 400 µJ / HQ Laser, and/or with Single-Photon Counter (Light Curves);
- Not included here are uncooperative debris targets, which are tracked with the 200 mJ debris laser

# SLR Graz: Tracking 140 targets ☹

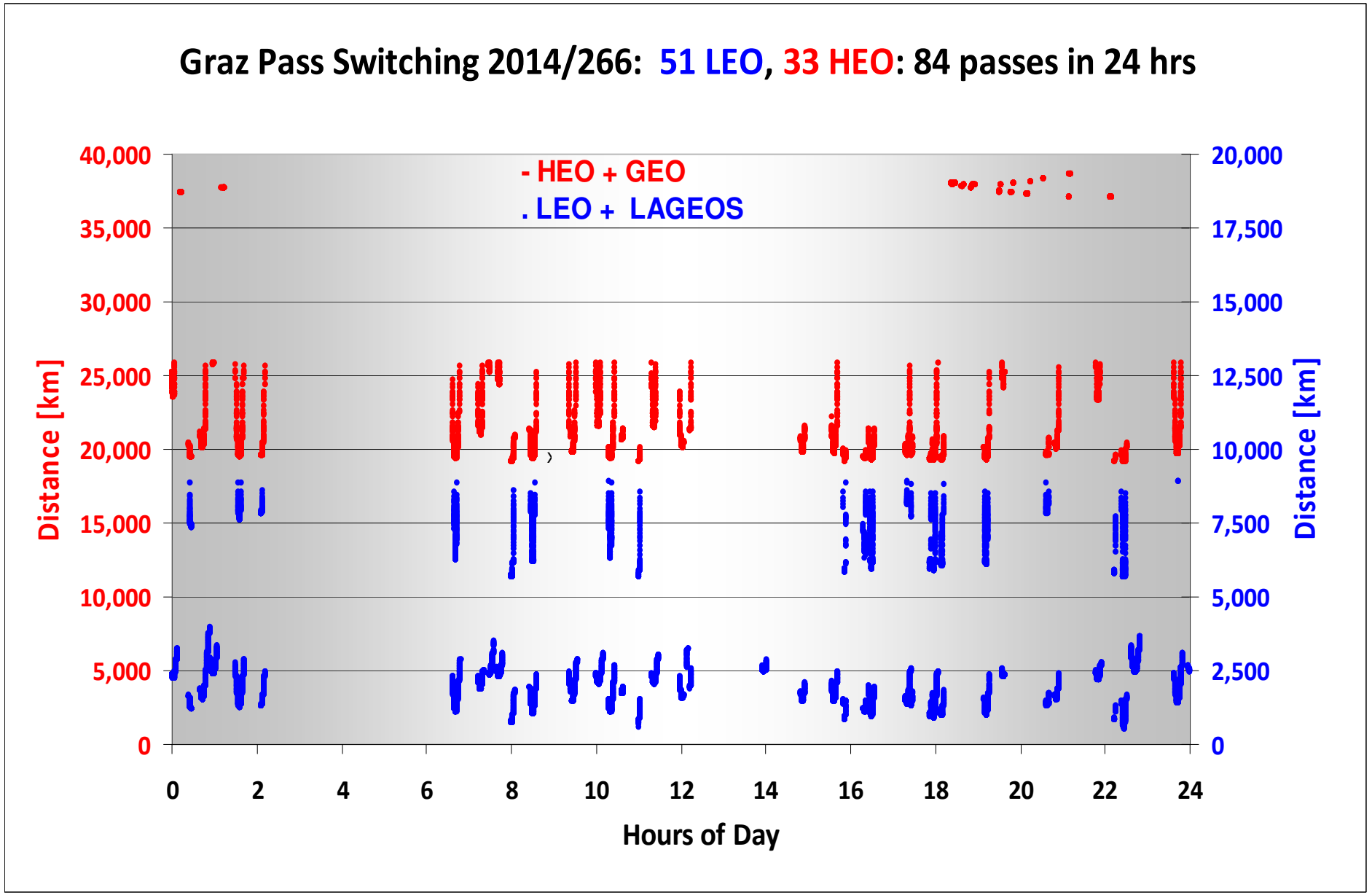
What is necessary to track a large number of targets (assuming 1000 points / NP for maximum precision at SLR Graz) ?

- kHz SLR system:
  - Collects 1000 pts (1 NP) within few seconds (LEOs);
  - Needs < 1 minute for 1000 pts (1 NP) for GNSS / HEOS;
  - This allows for a NP of 3 – 4 different GNSS in the *same* 5-minute NP bin

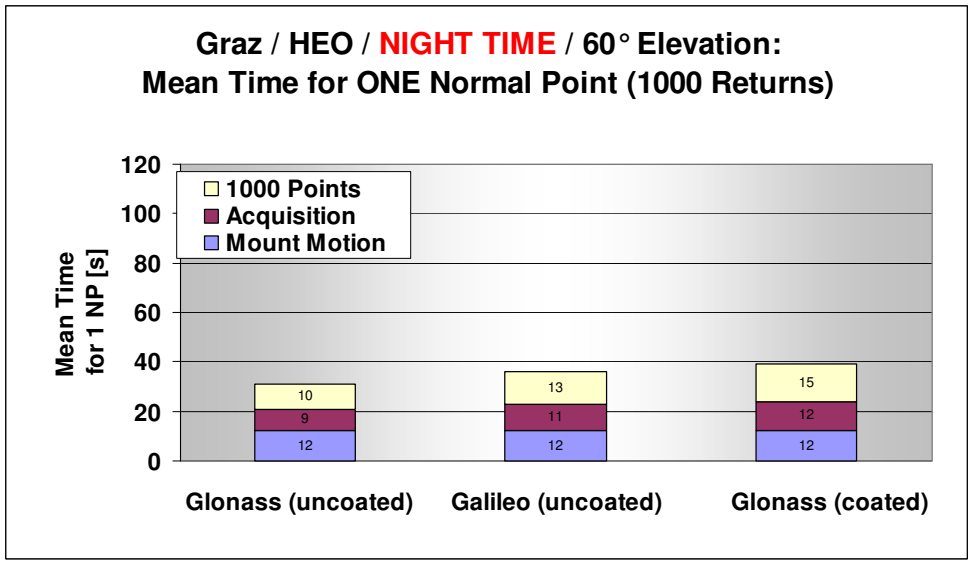
- Fast pass switching:
  - 10 secs between tandem satellites (due to minimal mount / dome motion)
  - < 40 secs (night, average) for other satellites; more during day time

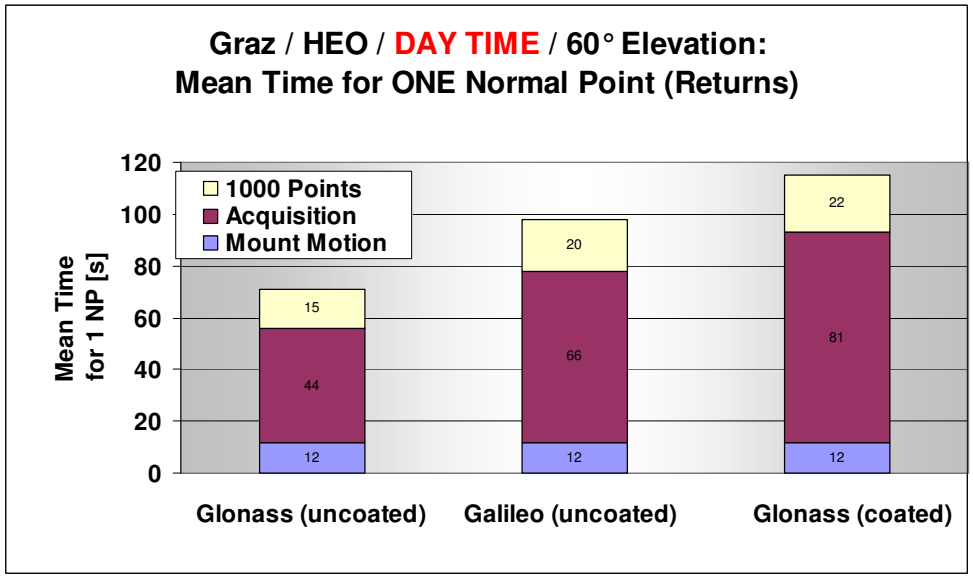
- For human operators: Efficient information & supporting systems / screens:
  - Info screen of all targets on sky above Graz
  - Overlay screen showing sky / cloud coverage

# Graz: Extensive Pass Switching



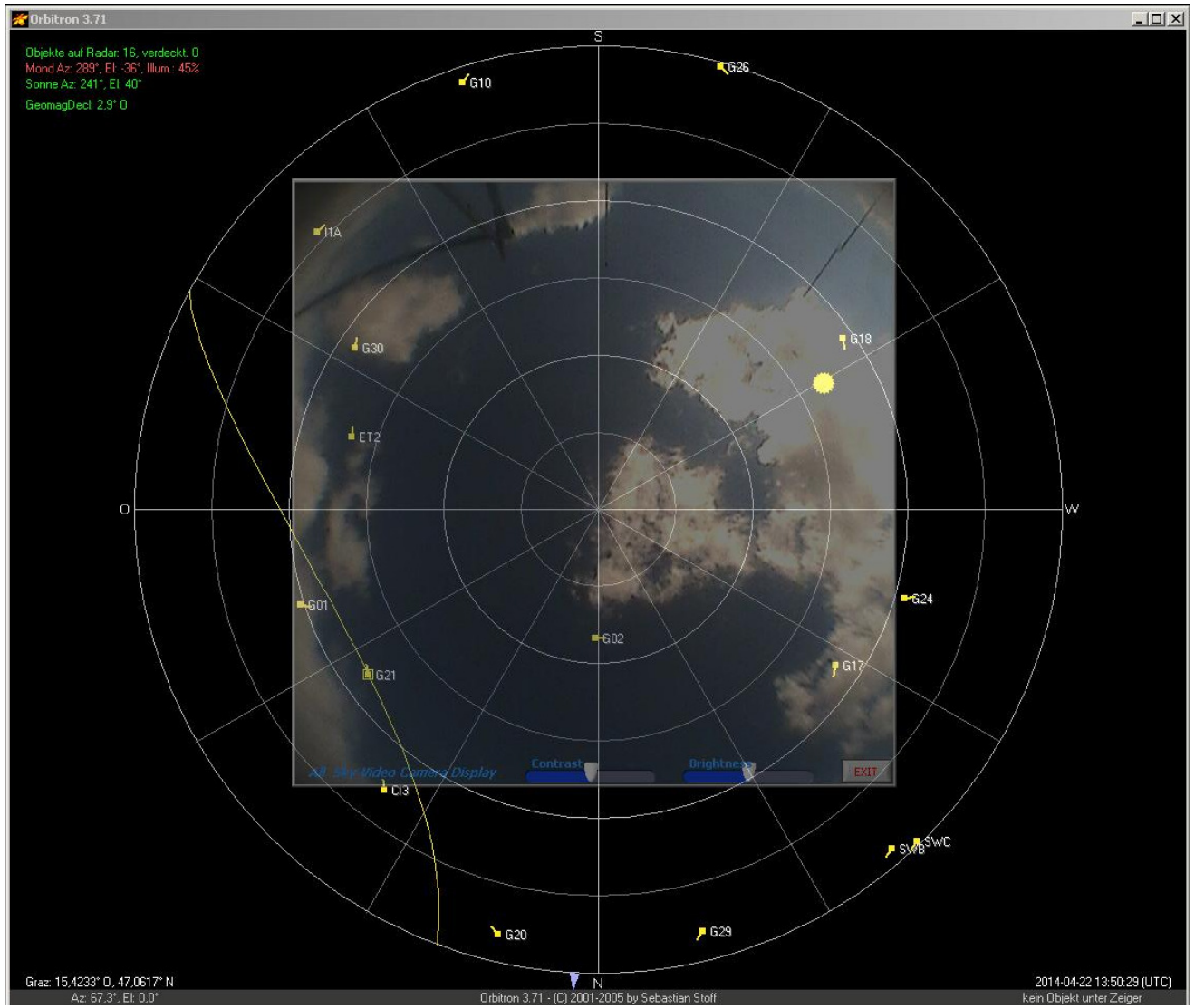
# Graz: Mean Time for 1 HEO NP (≈1000 valid returns)




- Night: < 1 minute for 1 NP (1000 pts)
- Day: Longer acquisition times;
  sometimes no results at all ☹
- In any case: << 5 minutes; thus we can get several NPs (of different HEOs) in ONE 5‘ slot (up to 4 or 5 NPs)
- Mount: Needs ≈ 12 seconds average
- Graz is tracking ALL HEOs:
  - Glonass, Galileo, Compass, Indian)
  - **Negligible effect on LEO tracking** (HEOS are available for 4-5 hours)

# Graz strategy for tracking of HEOs / LEOs ☺




Typical / daylight

Actual: Glonass 121

Next: Glonass 102

Next: Glonass 130

Next: Etalon-2

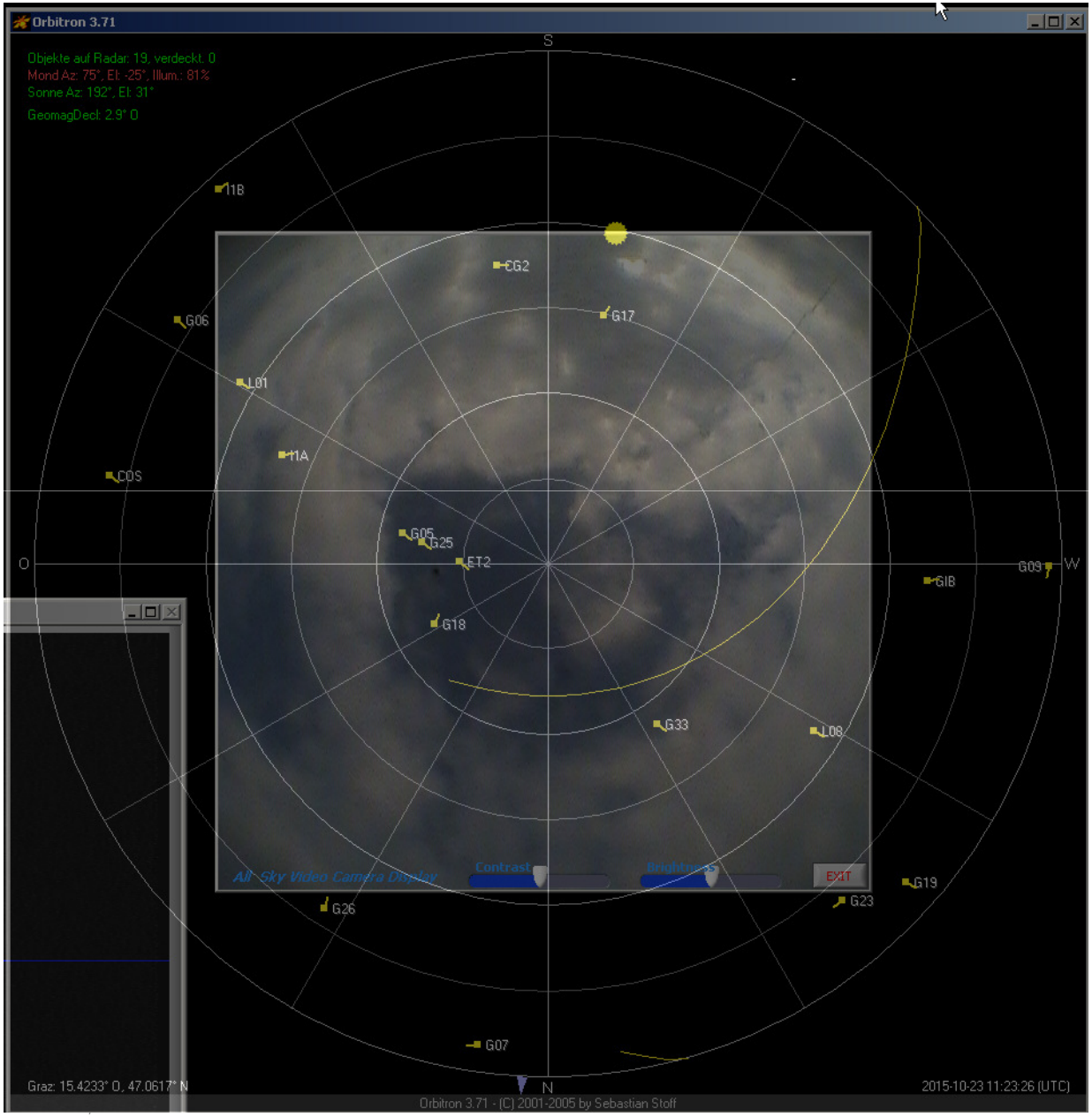
Next: Repeat sequence

Continue until next LEO

No LEO available now

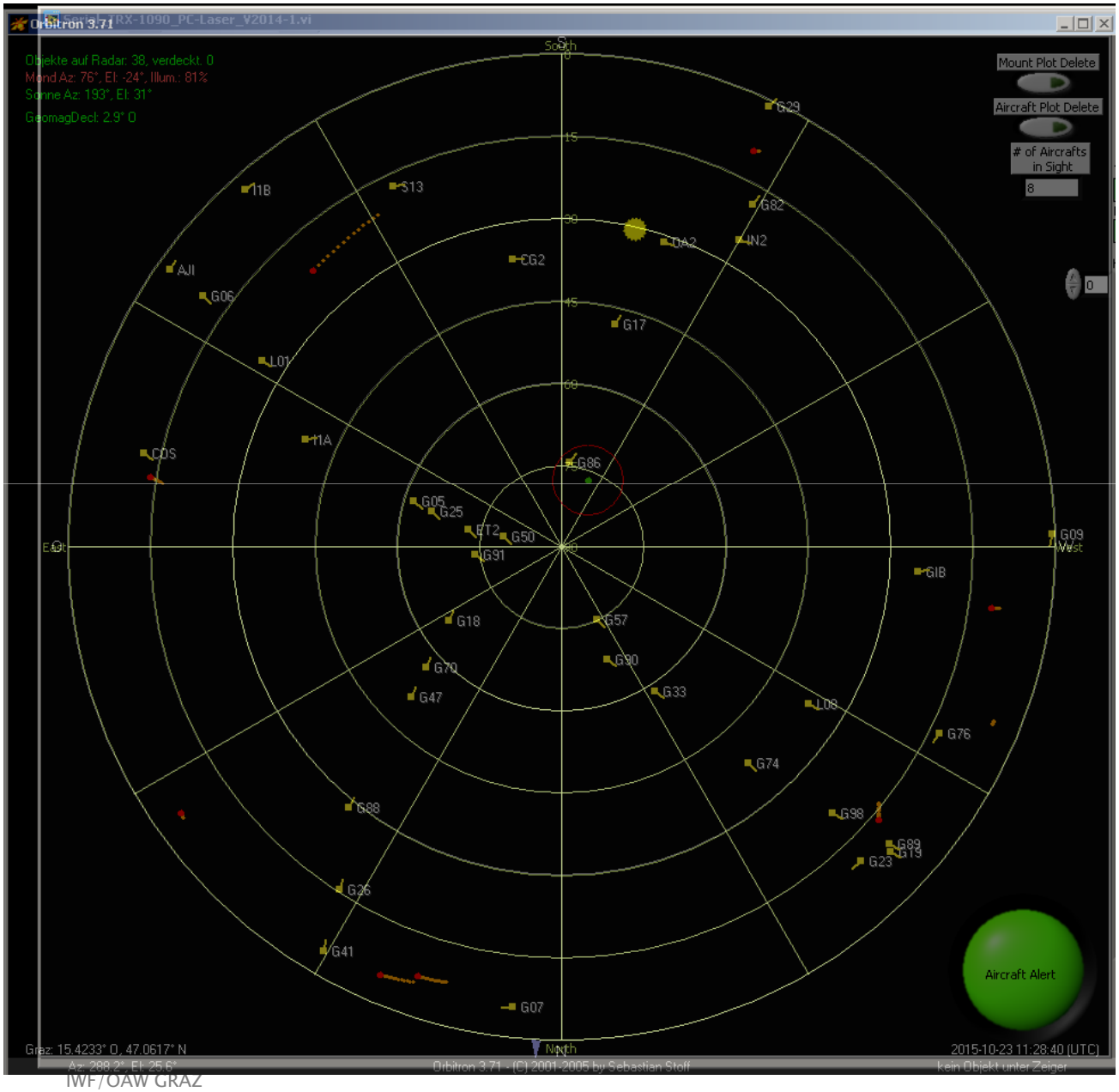
(SwarmB/C are too low)

# Cloud screen: Targets on last Friday, 11:30 UTC



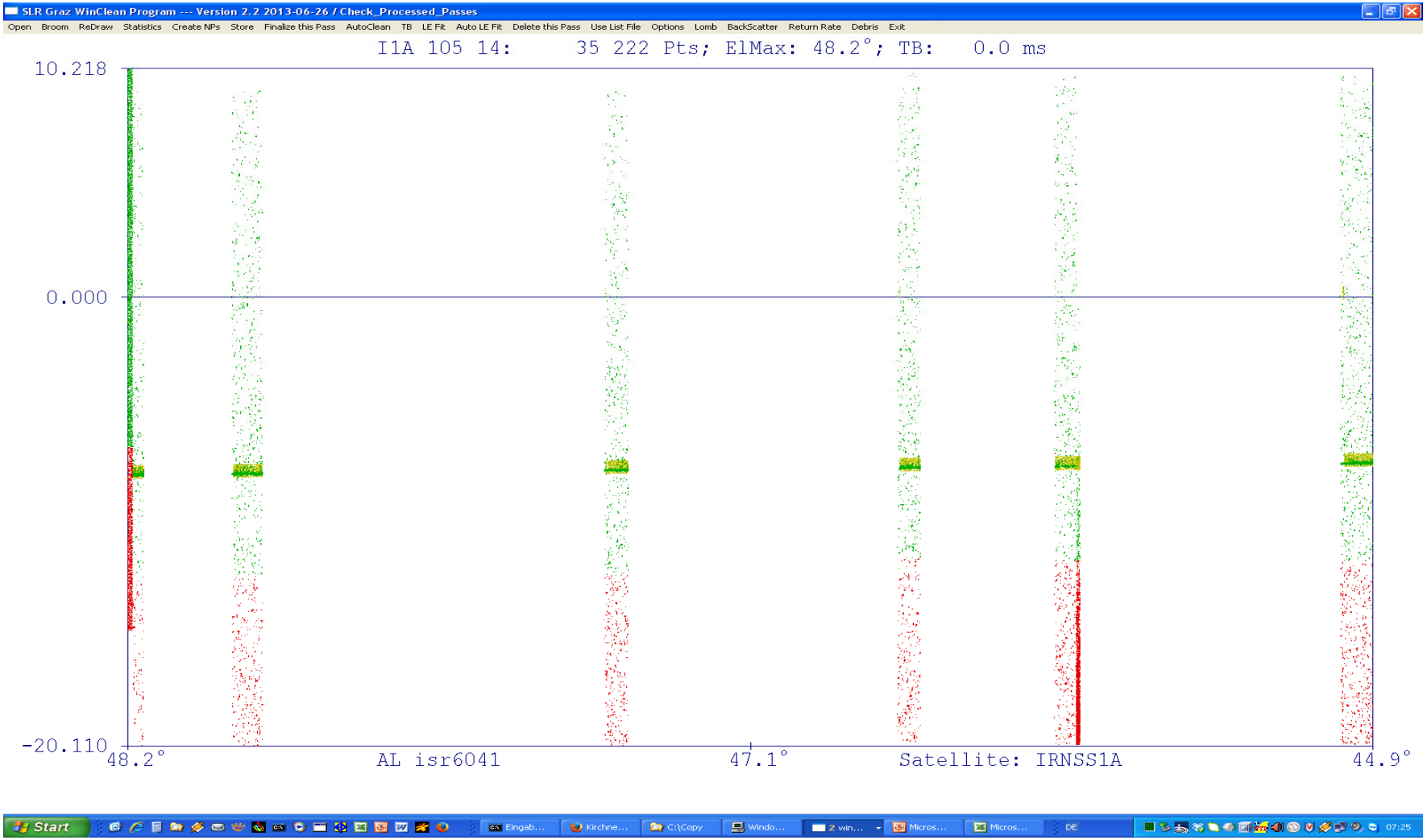

- Graz Real-Time Cloud screen:
- ILRS targets only shown
- Most targets behind clouds …
- 4 targets visible / no clouds
  - Easy for observers
  - No waisted time due to clouds
- Main problem: Too many clouds ☹

# Total Targets Screen: Last Friday, 11:30 UTC



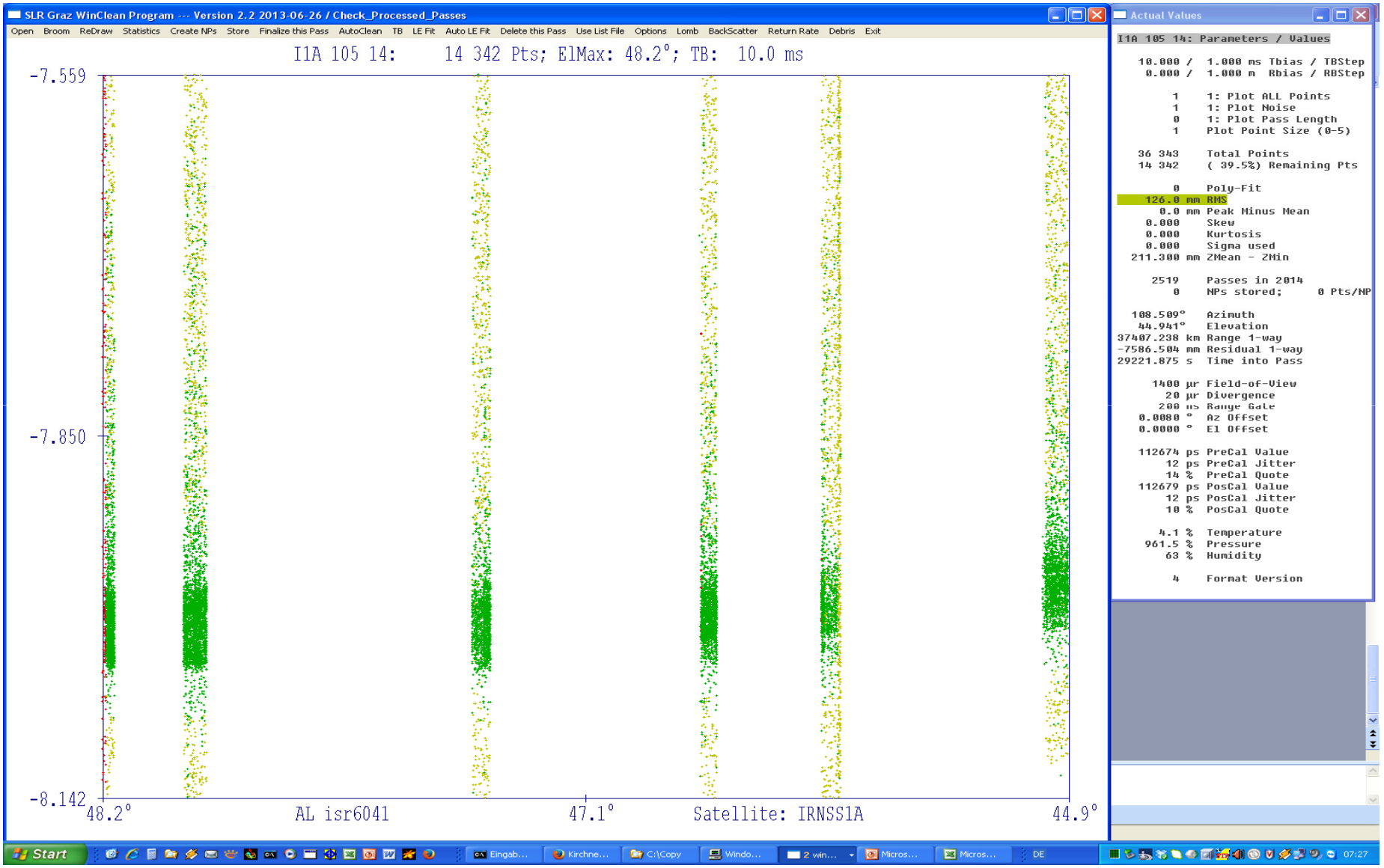

- Graz Real-Time target screen:
- Shows 36 targets above Graz
- Low elevation indicated
- Motion direction indicated
- Visibility / shadow indicated
- Aircraft paths indicated
- Sun / Moon indicated
- Laser Pointing shown

# Geostationary: About 2 hours of tracking; night

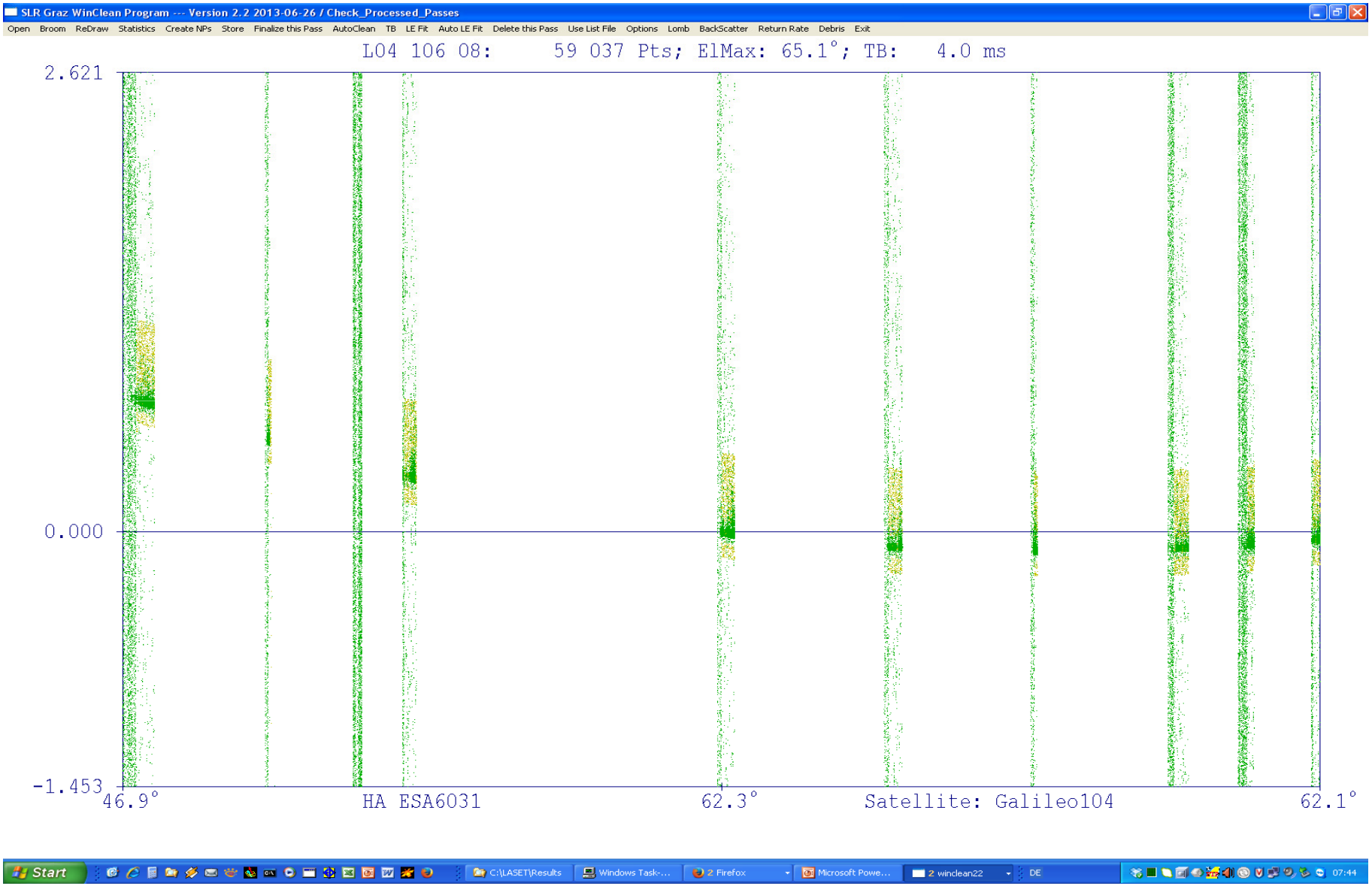



IRNSS1A: Indian GNSS: Geostationary orbit; each slot: ≈ 2 minutes, ≈ 1 k valid returns

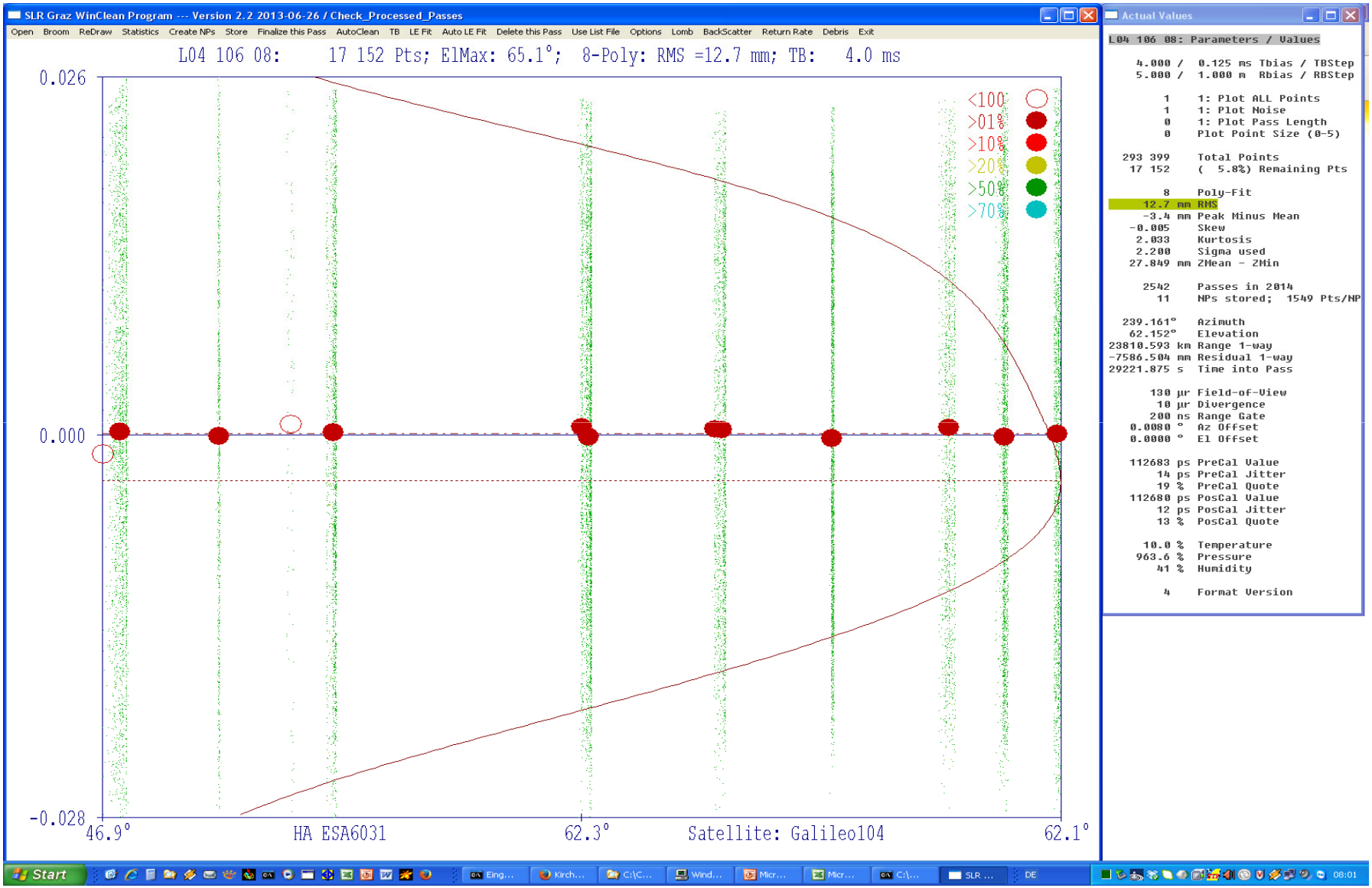
# A closer look to the same pass ….



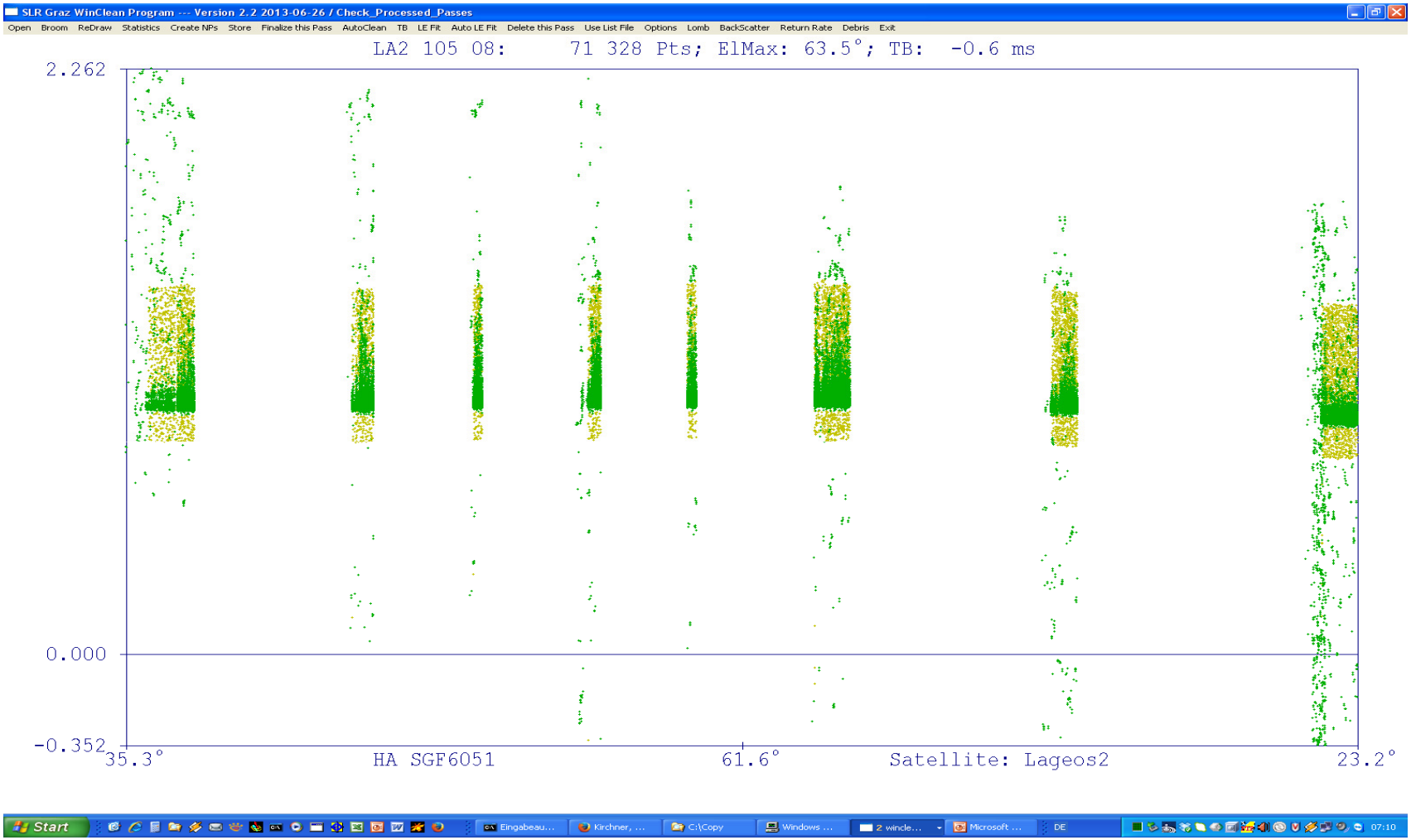
# Galileo 104: About 3 hours of tracking



# Galileo 104: About 2 hours of tracking;



# Effect for LEOs when tracking all HEOs: Negligible…




LAGEOS-2: Daylight pass; 8 slots; Shortest: 18 s / 2200 Pts; Longest: 71 s / 9000 Pts
Total: 18 NPs / 30 k points; 5.0 mm RMS (Leading Edge Post Processing)

# Thank you !