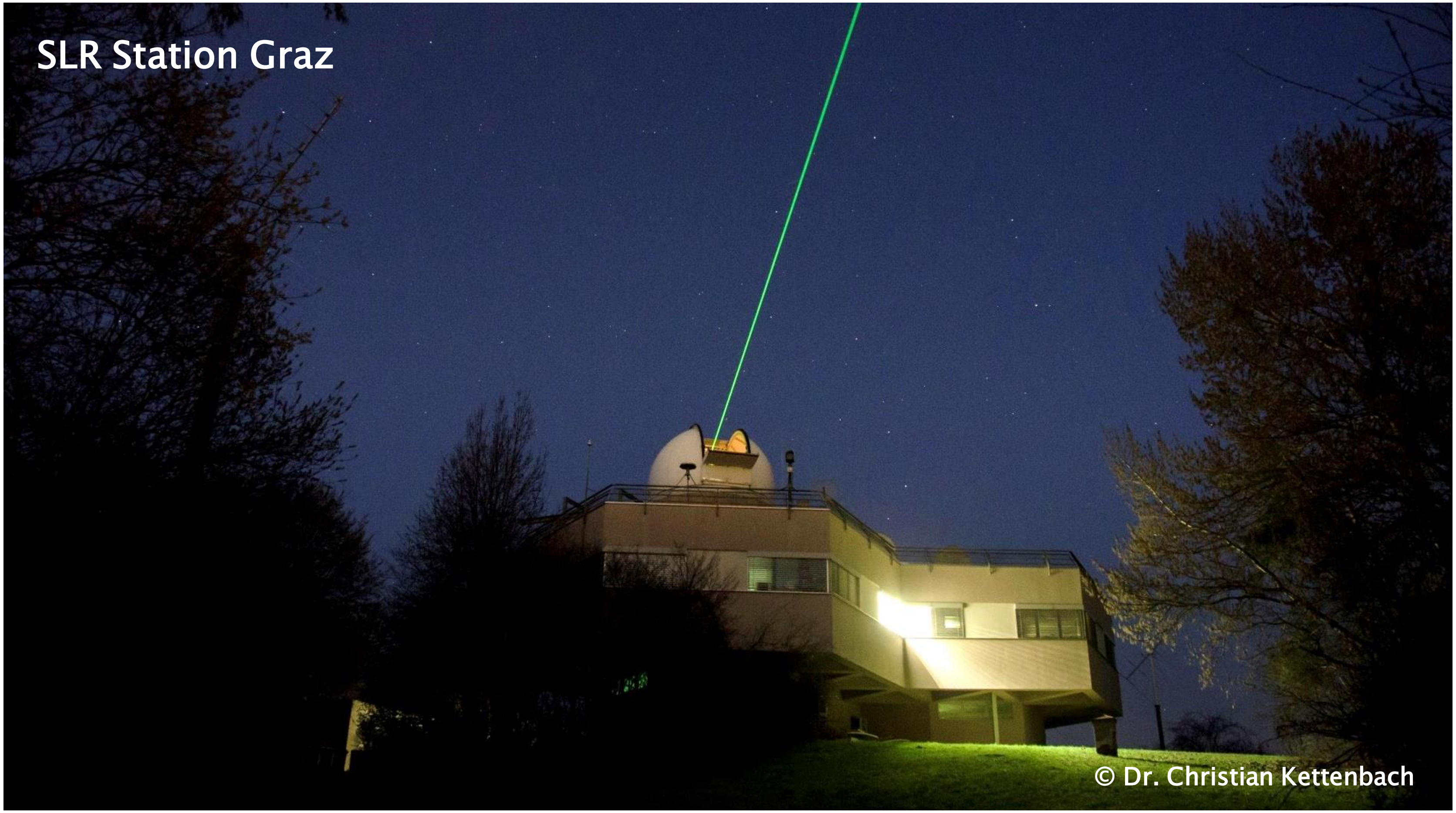
DAYLIGHT DEBRIS LASER RANGING



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Daylight Debris Laser Ranging

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3) First daylight space debris ranging results

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STARS DURING DAYLIGHT

Limiting factors --> best possible daylight contrast

1) **Field of view per pixel:** smaller FOV/pixel --> less sky background
2) **Airy disc** (star size, diffraction limited, optics): Airy [“] = 138 / Ø telescope [mm]
3) **Seeing:** approx. 2-3“ during daylight

Ideal: Object (Seeing + Airy disc + object size) = FOV/pixel

- Object < FOV/pixel: reduced contrast (more sky/pixel)
- Object > FOV/pixel: reduced amount of light/pixel (+ contrast lost in outer regions)
- Seeing > FOV/pixel: reduced contrast (object jumps from one pixel to other)

Choose telescope matching your sensor / seeing

- No need for large apertures
- Image quality + correct focus more important
- Bad TLE predictions need large FOV to see targets

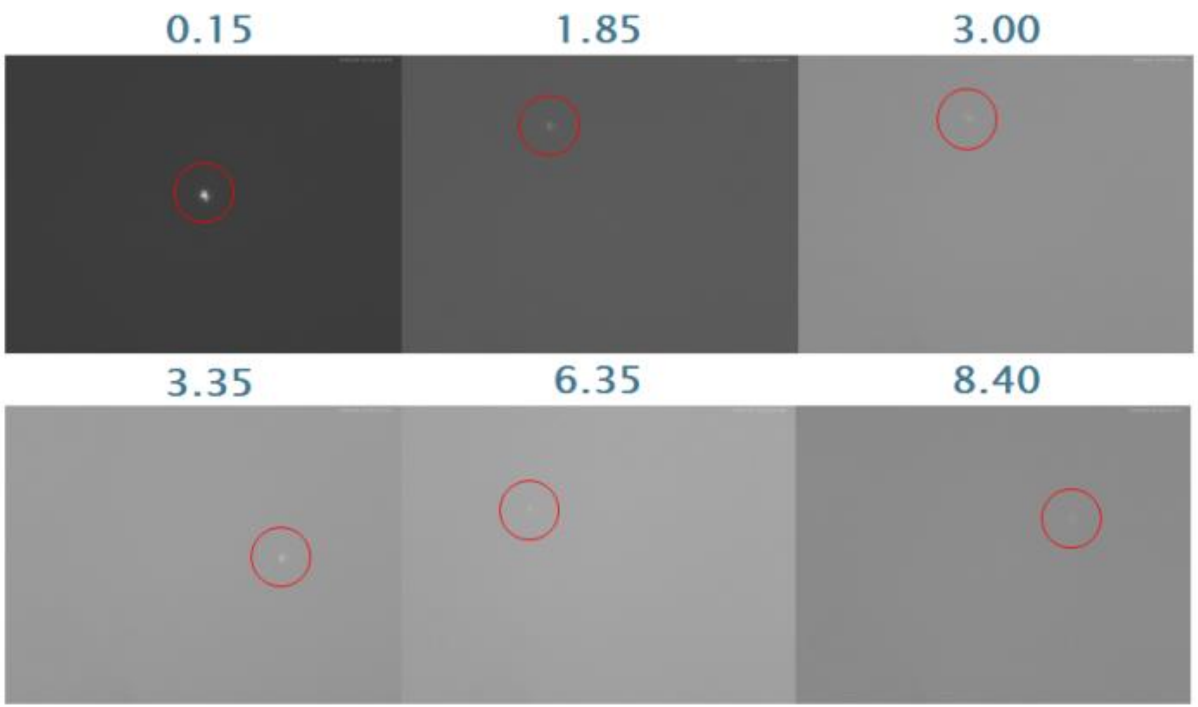
Ø [mm]	Airy ["]
50	2.76
75	1.84
100	1.38
125	1.10
150	0.92
175	0.79
200	0.69

f [mm]	FOV/pxl ["]
100	7.84
200	3.92
300	2.61
400	1.96
500	1.57
600	1.31
700	1.12

STARS DURING DAYLIGHT

Step 1: Observe stars during daylight

- Visual observations of different stars / Camera sensor: 4.8 mm x 3.6 mm
- Good atmospheric conditions: up to magnitude 8 visible
- Mag 6: limit naked eye during perfect night // Mag 8: Factor 6.25 dimmer



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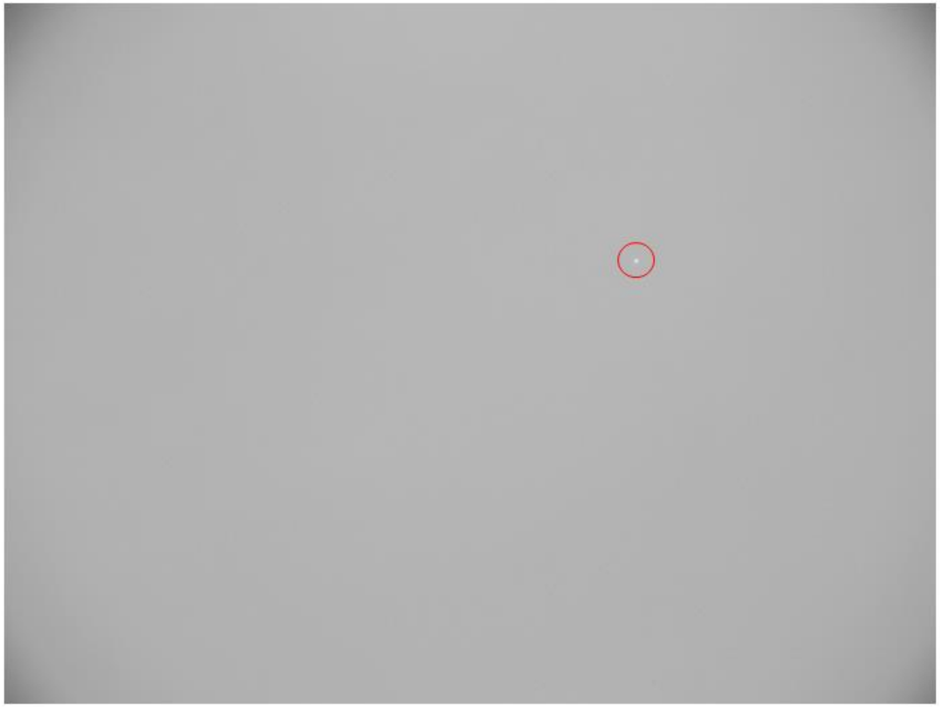
SPACE DEBRIS DURING DAYLIGHT

Step 2: Visual observations of different rocket bodies

- Camera sensor: 17.7 mm x 13.4 mm
- Example: SL-12 rocket body (NORAD 15772)
- So far: >40 different rocket bodies visually observed during daylight



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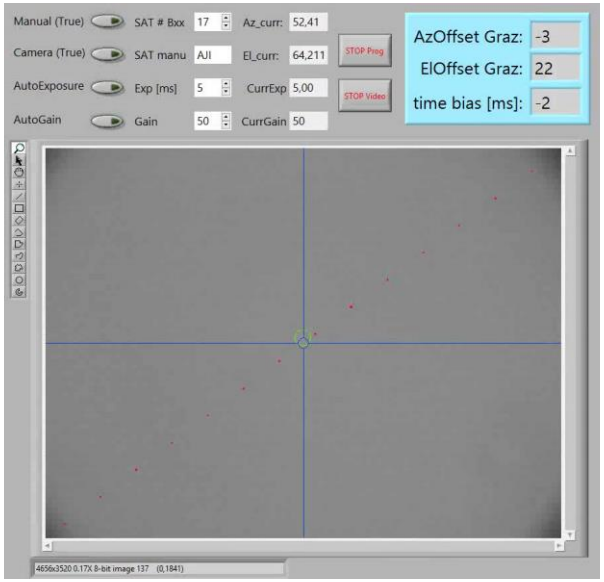
PIGGYBACK VISUAL TELESCOPE

Step 3: Correct time bias directly during observations / center target

- Meade LX50: d = 20 cm, f = 2000 mm
- Mounted directly on SLR receive telescope
- Software: Automatic debris detection and image analysis
- Time bias of debris calculated -> bad predictions corrected



- Video: Magnitude 4 Star moved around field of view / automatic detection

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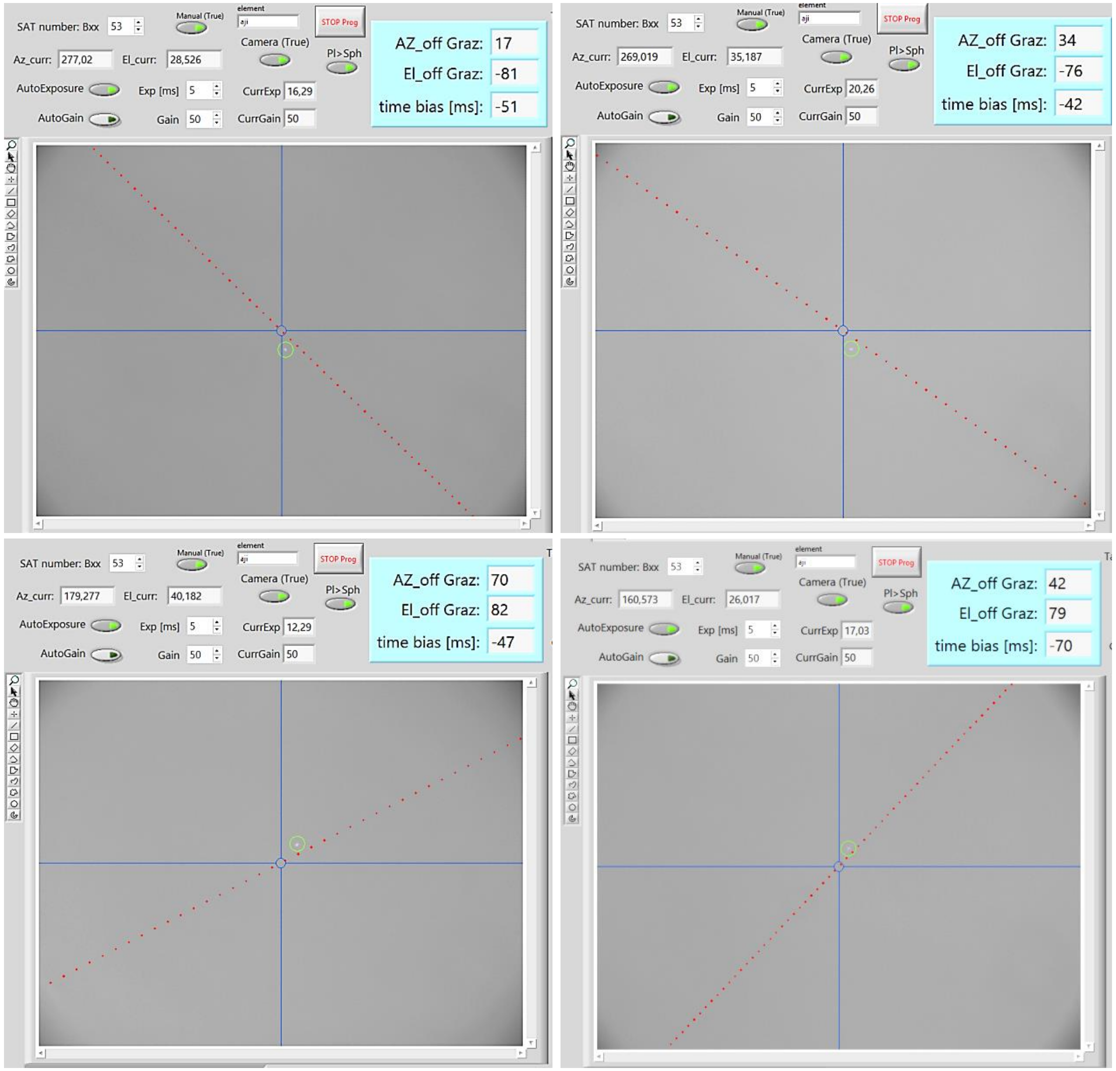
AJISAI BLINKING - DAYLIGHT

Ajisai blinking - daylight

- 2019/01/18 //11:10 local time
- Automatic detection (green)
- Predicted path (red dots)
- Time bias calculated
- Graz azimuth, elevation offsets
- Potential Errors:
  - Axis misalignment
  - Pointing model (daylight)
  - Range bias



FIRST RESULTS

Step 4: First daylight space debris ranging // Results

- 6 daylight passes
- 3 types of rocket bodies
- Different sun elevations

TYPE	NORAD ID	DATE	LOCAL TIME	SUN ELEVATION [°]	time bias [ms]	range bias [m]
SL-16 R/B	22285	2019/03/22	10:31	39.0	70	100
COSMOS 405 R/B	5118	2019/06/27	09:00	37.0	0	170
SL-16 R/B	23705	2019/07/24	20:24	2.0	200	415
SL-16 R/B	22803	2019/07/24	20:38	0.3	-157	135
SL-14 R/B	20511	2019/10/01	17:25	11.5	-38	385
SL-14 R/B	19275	2019/10/01	18:23	2.1	31	292

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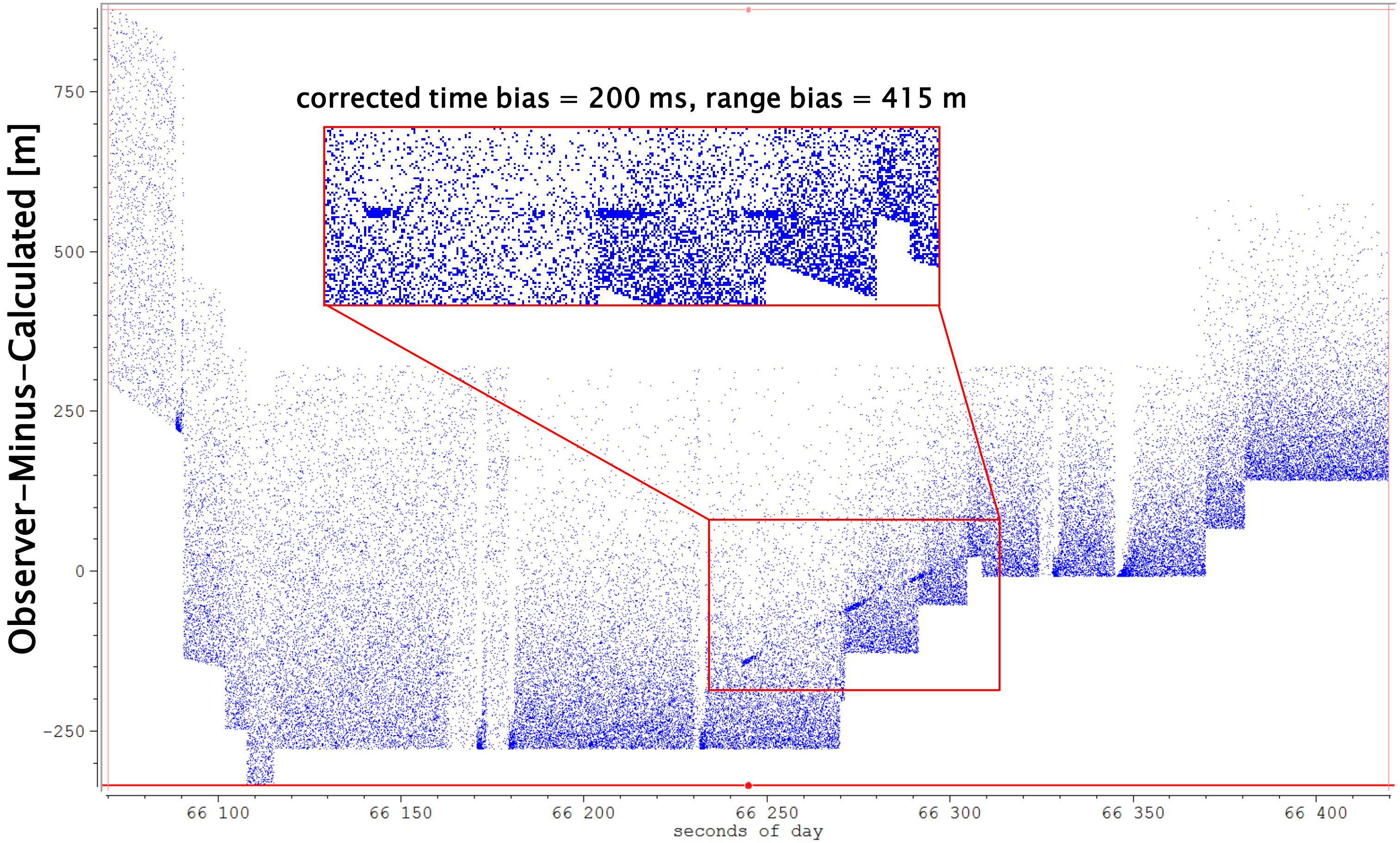
2019/07/24 // UTC 18:24 // SUN EL 2°

Pass 1) SL-16 R/B (NORAD 23705) // Sun elevation: 2°

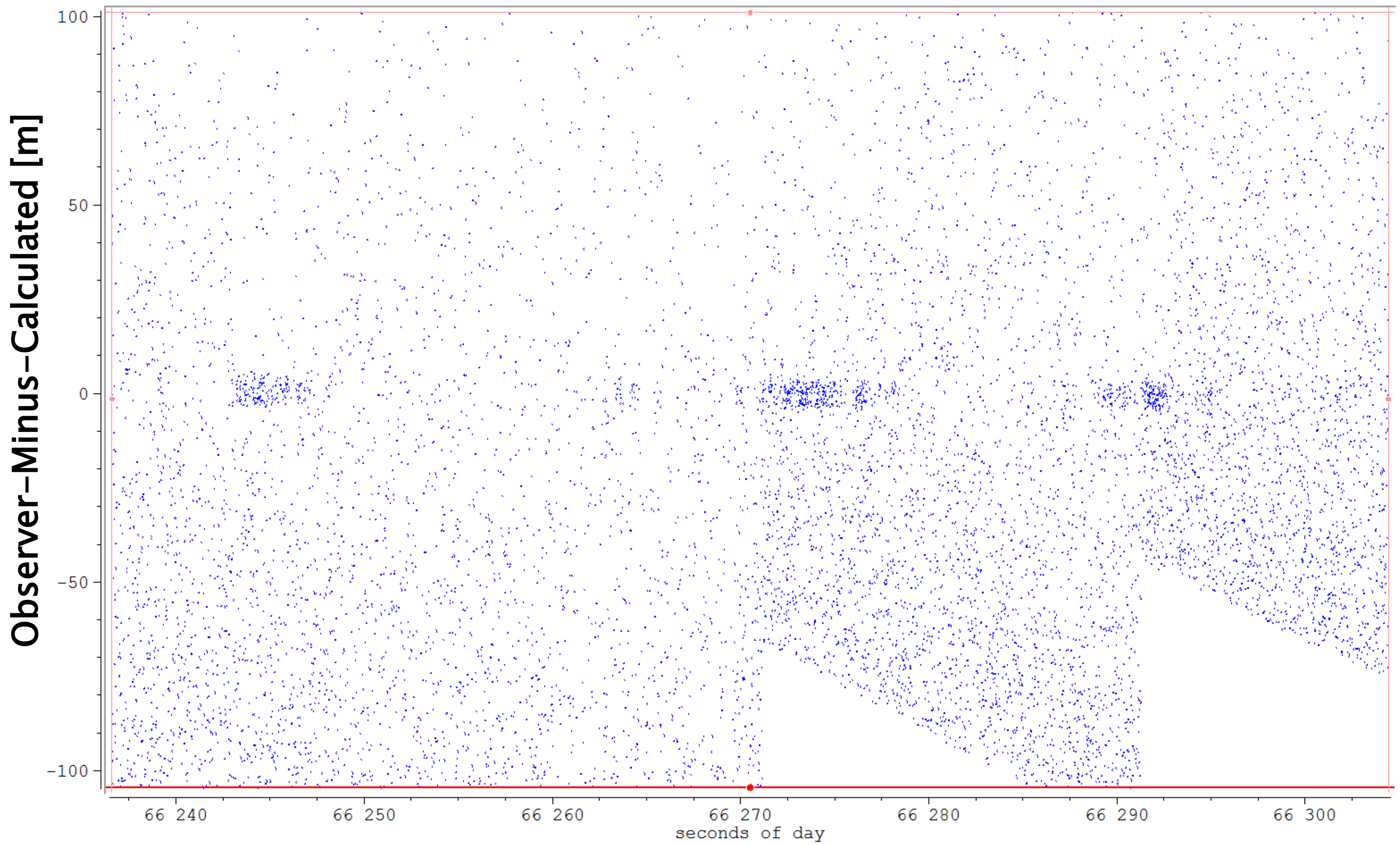
- found at: tb = 140 ms, rb = 0 m // true: tb = 200 ms, rb = 415 m



2019/07/24 // UTC 18:24 // SUN EL 2°

Pass 1) SL-16 R/B (NORAD 23705) // Sun elevation: 2°

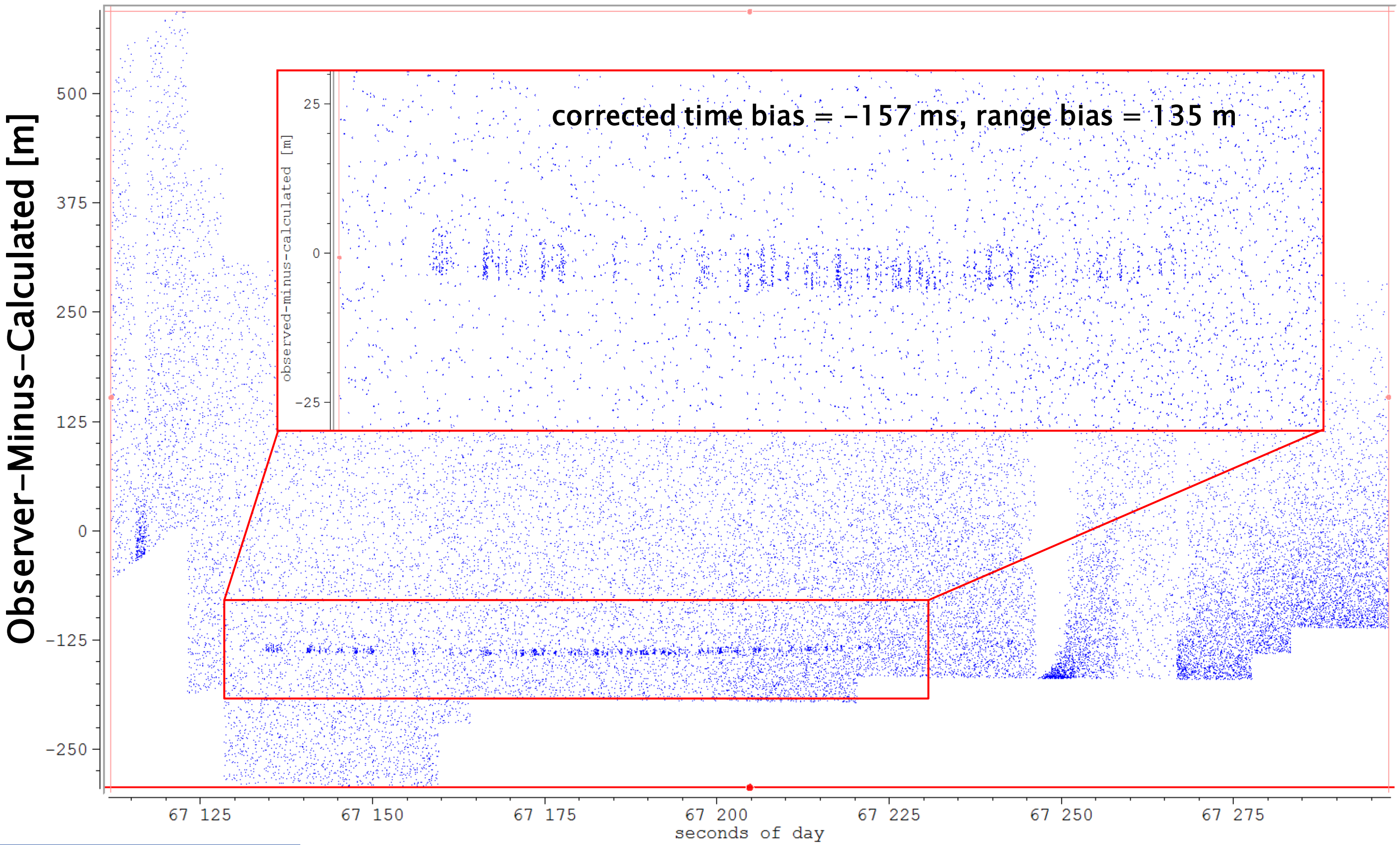
- found at: tb = 140 ms, rb = 0 m // true: tb = 200 ms, rb = 415 m



2019/07/24 // UTC 18:38 // SUN EL 0.3°

Pass 2) SL-16 R/B (NORAD 22803) // Sun elevation: 0.3°

- found at: tb = -145 ms, rb = 0 m // true: tb = -157 ms, rb = 135 m



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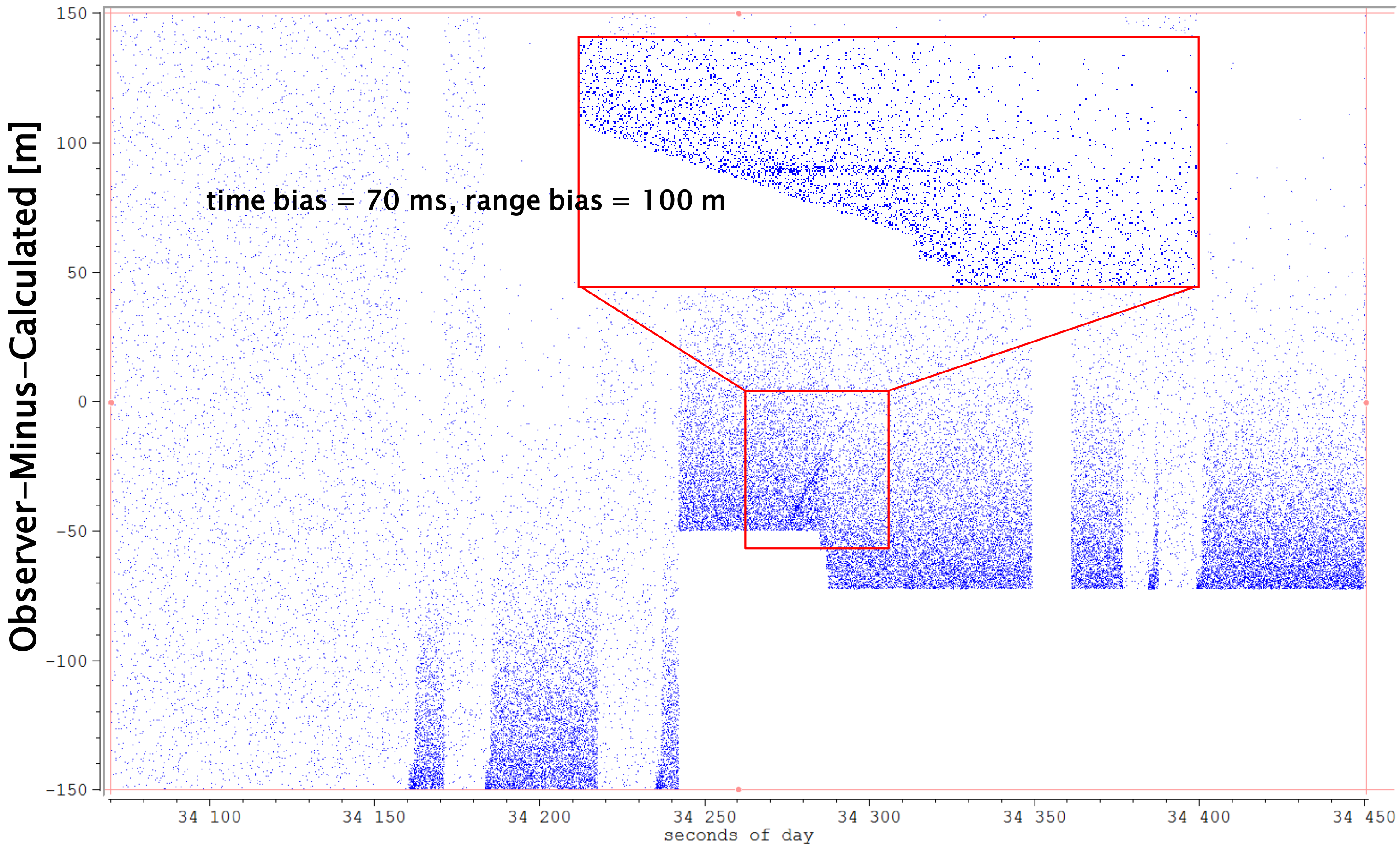
2019/03/22 // UTC 09:31 // SUN EL 39°

Pass 3) SL-16 R/B (NORAD 22285) // Sun elevation: 39°

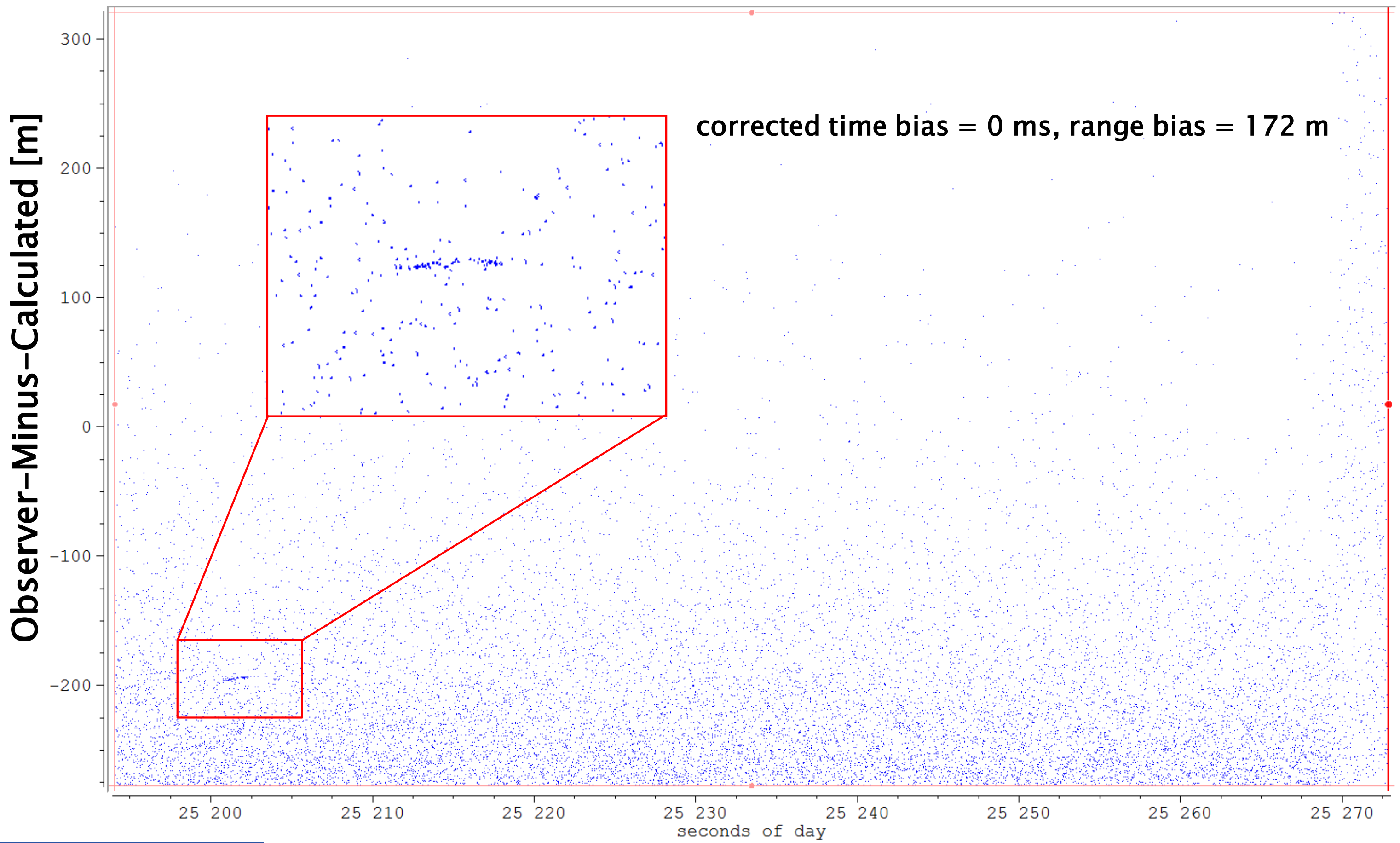
- found at: tb = 9 ms, rb = 0 m // true: tb = 70 ms, rb = 100 m



2019/06/27 // UTC 07:00 // SUN EL 37°

Pass 4) COSMOS 405 R/B (NORAD 5118) // Sun elevation: 37°

- found at: tb = 20 ms, rb = 0 m // true: tb = 0 ms, rb = 172 m



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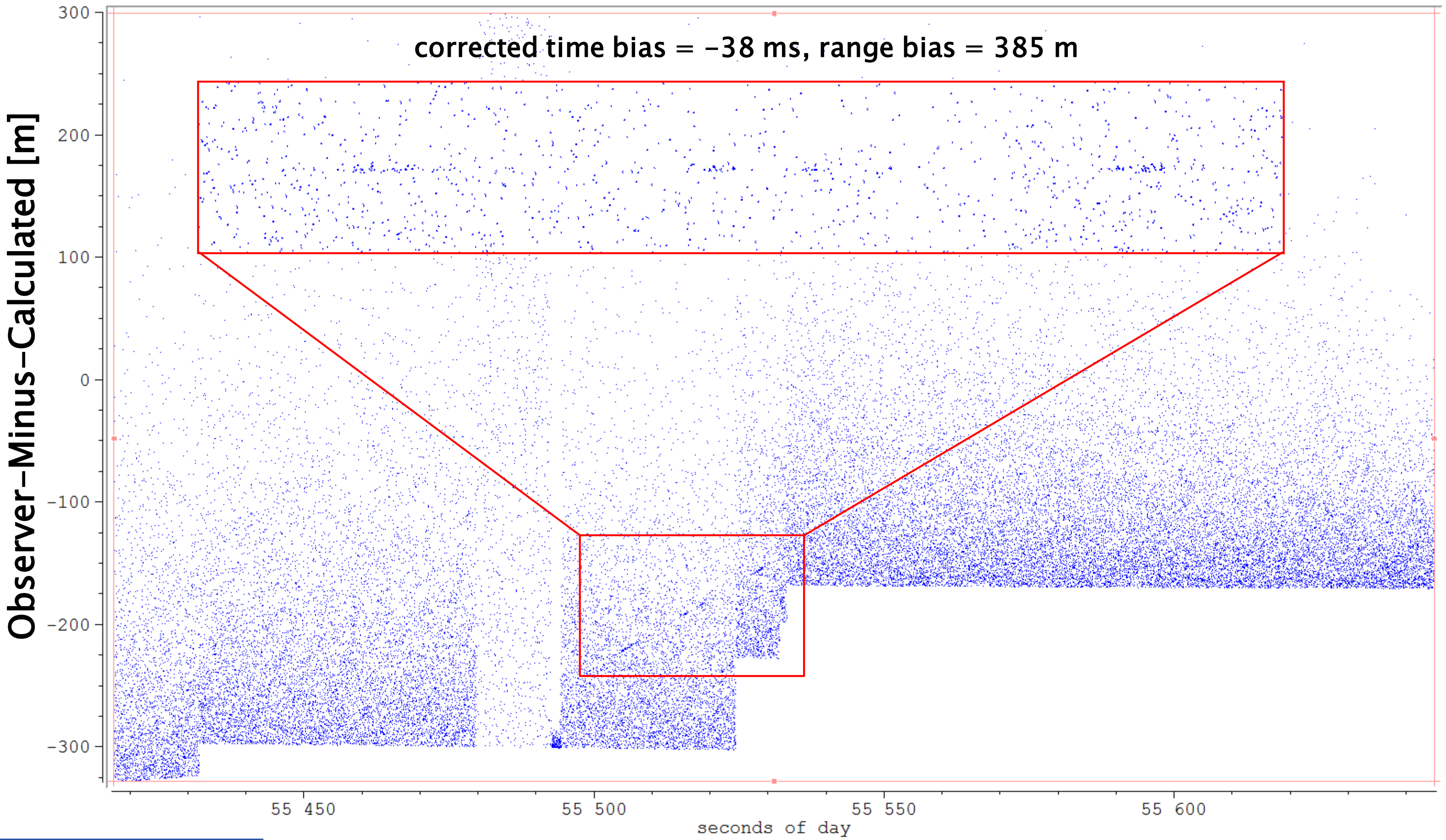
2019/10/01 // UTC 15:25 // SUN EL 11.5°

Pass 5) SL-14 R/B (NORAD 20511) // Sun elevation: 11.5°

- found at: tb = -75 ms, rb = 0 m // true: tb = -38 ms, rb = 385 m



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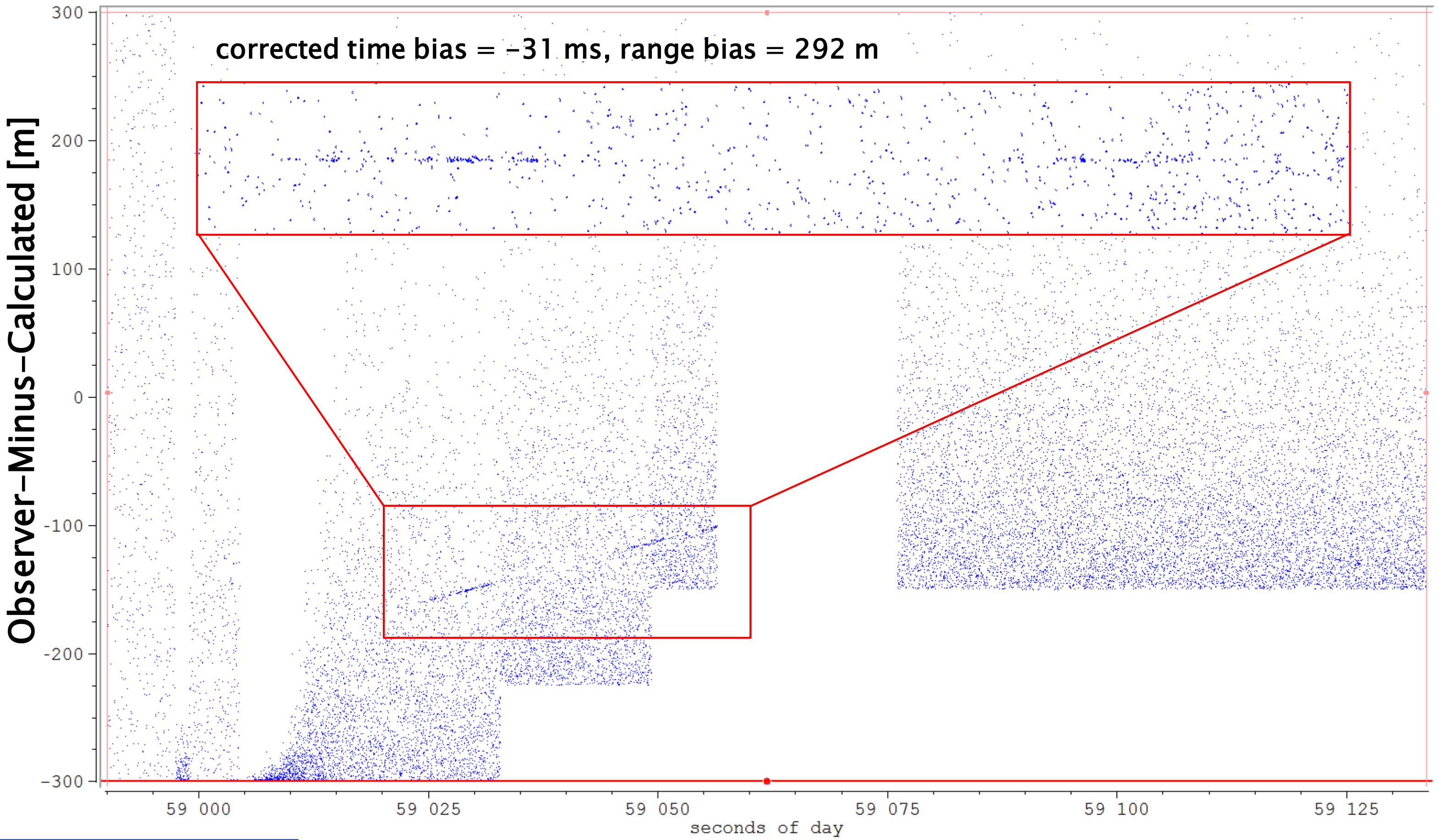
2019/10/01 // UTC 16:23 // SUN 2.1°

Pass 6) SL-14 R/B (NORAD 19275) // Sun elevation: 2.1°

- found at: tb = -50 ms, rb = 0 m // true: tb = 31 ms, rb = 292 m



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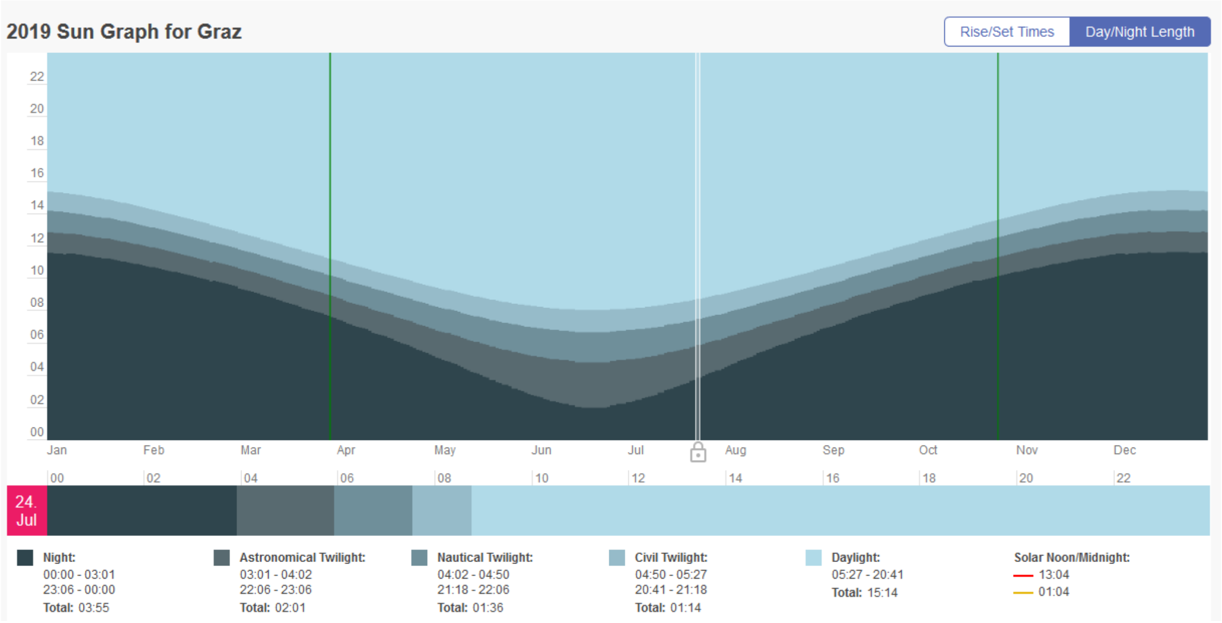
HOUR DAY NIGHT TWILIGHT

Daylight + terminator period space debris laser ranging

- Potential observation times in Graz: up to **22** hours / day

	Day	Night	Twilight
Sun elevation	> 0°	< -16°	-18° to – 6°
Duration	8 – 16 hours	12 – 2 hours	2 – 4.5 hours



SUMMARY

- First successful daylight space debris laser ranging passes
- Difficult - but possible ...
- !!! We need better predictions !!! -> lower time and range bias
  - higher chances to find target
  - lower time to search for target
- Time bias / Across track bias corrected via predictions / telescope pointing
- Large range bias is the main difficult (range gate --> 1 µs = 0.3 km --> noise)
- Daylight space debris ranging would increase output significantly

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!!! THANK YOU !!!