Agenzia Spaziale Italiana

Università degli Studi di Padova

e-geos AN ASI / TELESPAZIO COMPANY

100 kHz satellite laser ranging demonstration at Matera Laser Ranging Observatory

D. Dequal, C. Agnesi, D. Sarrocco, L. Santamaria Amato, M. Siciliani de Cumis, G. Vallone, P. Villoresi, V. Luceri and G. Bianco

24/10/19 – ILRS Technical workshop 2019 - Stuttgart

How far Can we improve SLR precision by acquiring more data?

$$\sigma_{NP} \propto \frac{\sigma_{FR}}{\sqrt{N}}$$

Test of very high repetition rate laser

Test of the Ekspla Atrlantic 60 for SLR

Parallel operation of two systems in interleaved mode

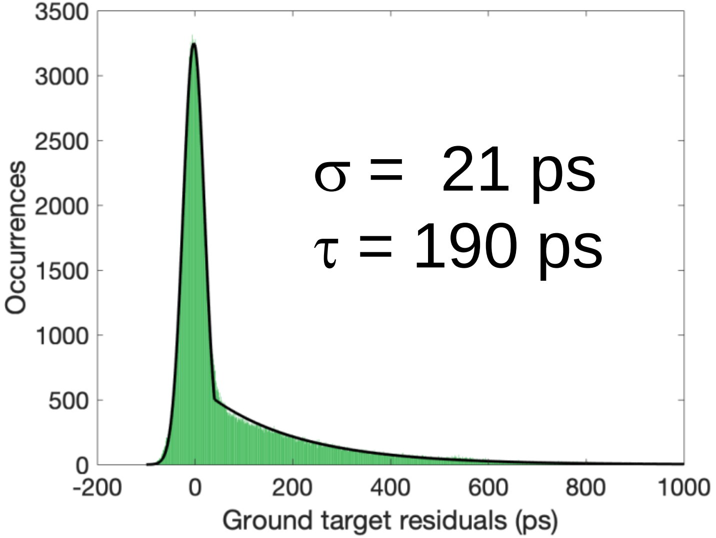
MLRO standard configuration	
Rep. rate	10 Hz
Pulse energy	100 mJ
Pulse width	50 ps
Detection technology	MCP-PMT (analog)

Ekspla configuration	
Rep. rate	100 kHz
Pulse energy	100 µJ
Pulse width	9 ps
Detection technology	SPAD (Geiger)

Common features	
Wavelength	532 nm
Telescope	1,5 m + coude
Clock	Cs clock
Time scale	UTC

Ground target…

Reference Target at 95 m



Typical detector shape:

Gaussian peak (σ_{det}) + exponential tail (τ)

$$f(t) = Ae^{-\frac{(t-t_0)^2}{2\sigma^2}}\Theta(t_1 - t) + Be^{-\frac{t-t_1}{\tau}}\Theta(t - t_1)$$

$$\sigma_{theory} = \sqrt{\sigma_{det}^2 + \sigma_{ele}^2 + \sigma_{laser}^2} = 20\ ps$$

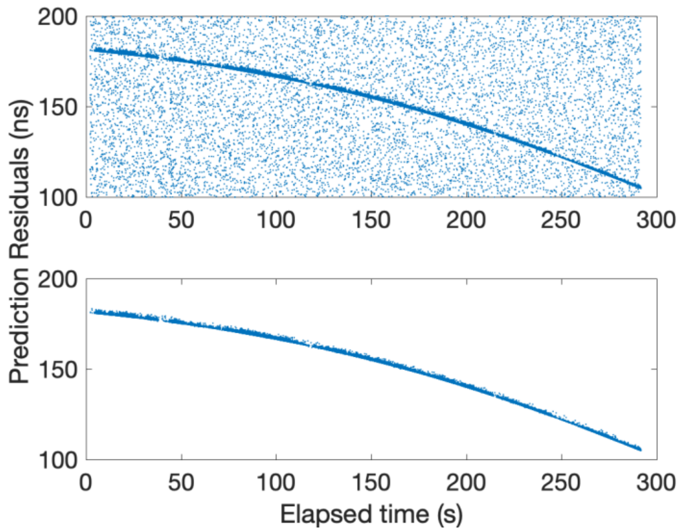
17 ps   10 ps   3.8 ps

…everything works!

And on satellite?

Satellite is not a fixed target (duh!)

We need to compare measured range w.r.t. prediction: prediction residuals (PR)

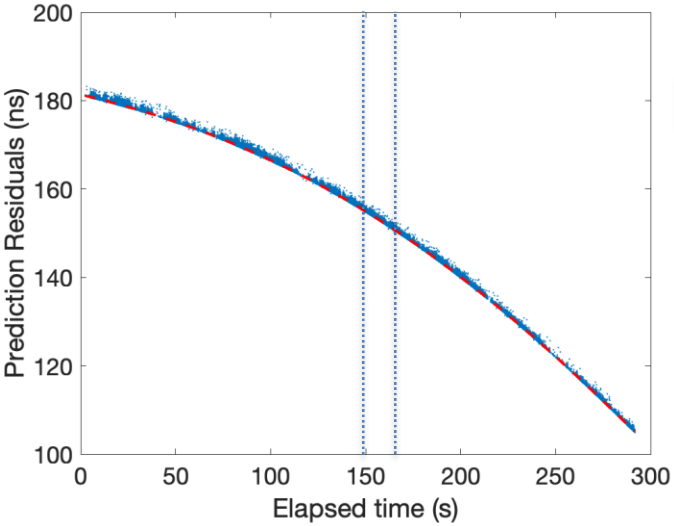


Jason 3-pass

- No gating on the detector
- Only night-time operations (no spectral filter available)
- S/N very high, easy rejection of background

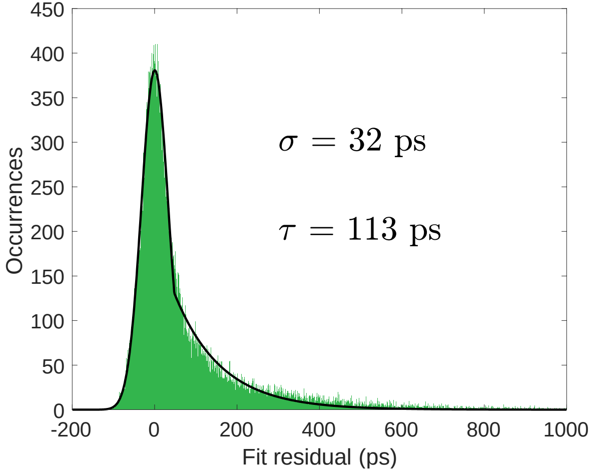
Estimation of full rate jitter

Polynomial fit on PR => fit residuals (FR)



Iterative 2.5 sigma clipping

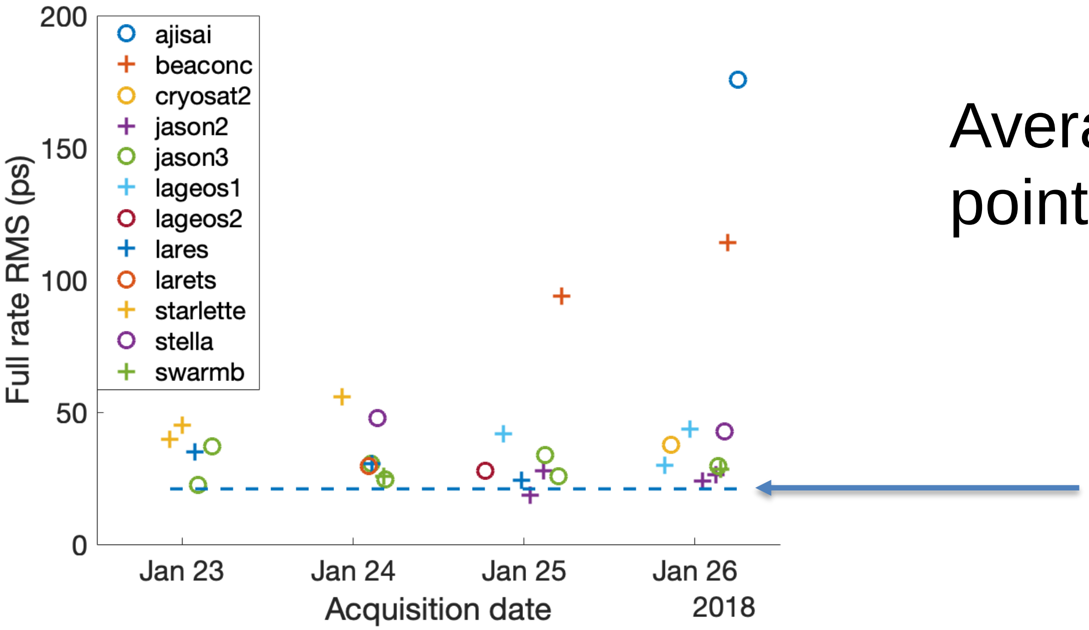
Returns in 15 s (SNPI)



https://ilrs.cddis.eosdis.nasa.gov/data_and_products/data/npt/npt_algorithm.html

5 nights analysis of full rate jitter

σ_{FR} often limited by satellite signature



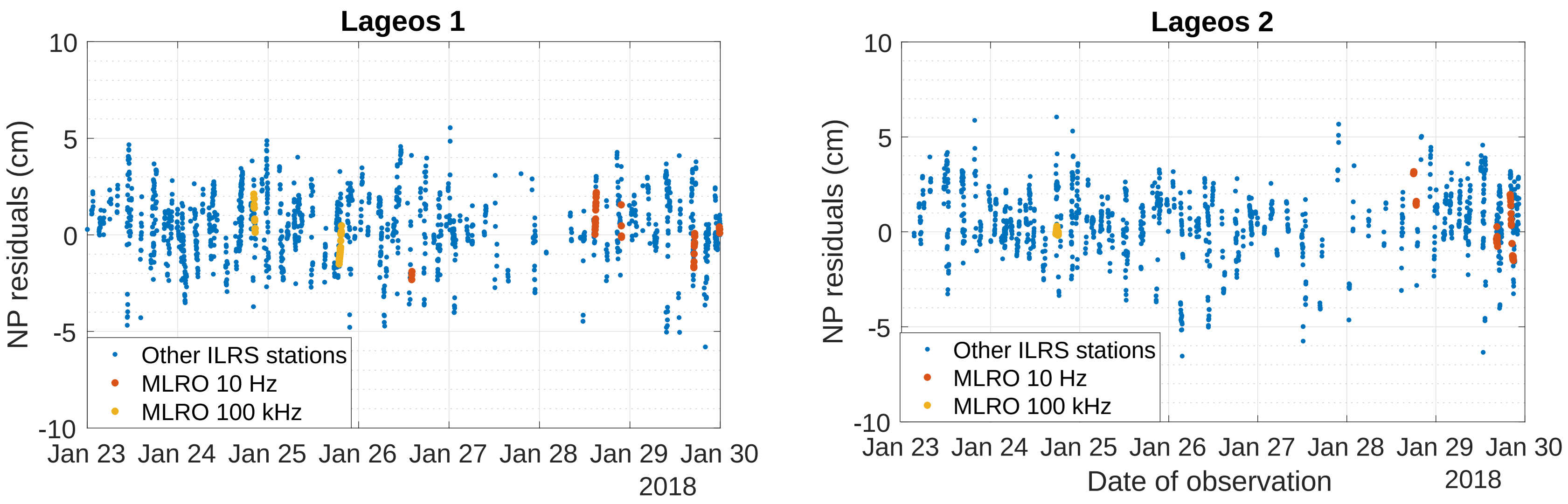
Average σ_{FR} for all normal point intervals in a pass

21 ps limit

Normal point analysis

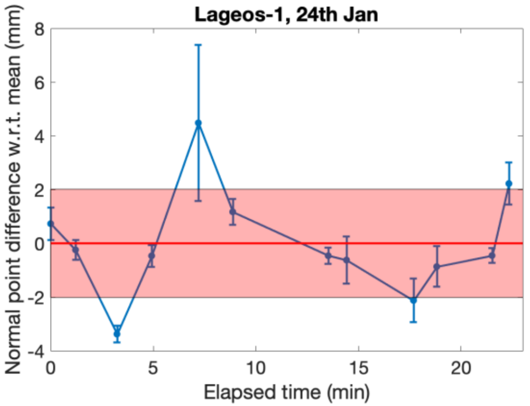
Lageos data analyzed with Geodyn

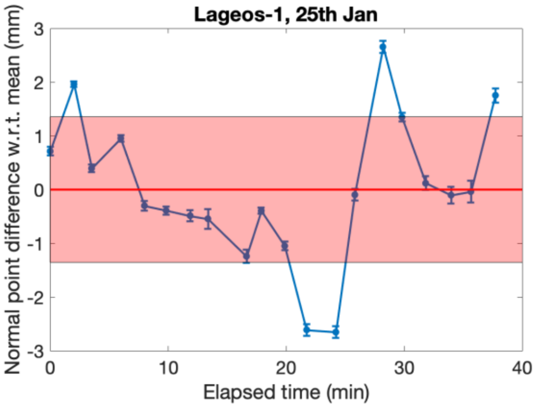
Residuals of experimental NP w.r.t. Geodyn calculated ranges

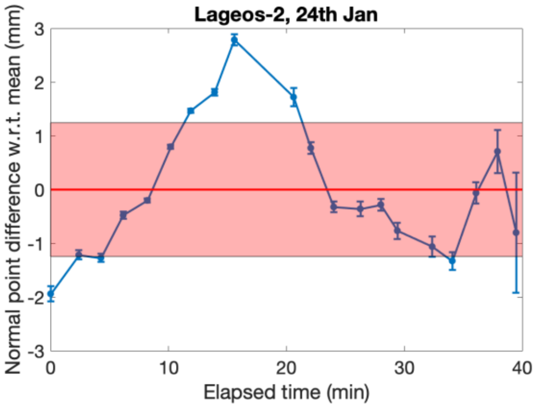


…a closer look

Data after linear fit to remove time and range biases







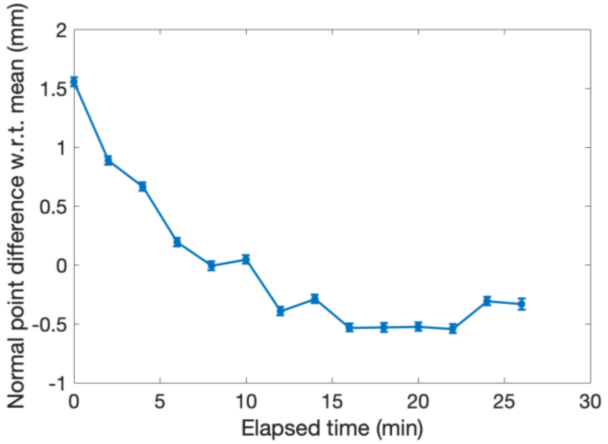
Blue bars: $\frac{\sigma_{FR}}{\sqrt{N}}$ << Red area: σ_{NP}

Stability assessment from ground target

Normal point procedure applied to ground target

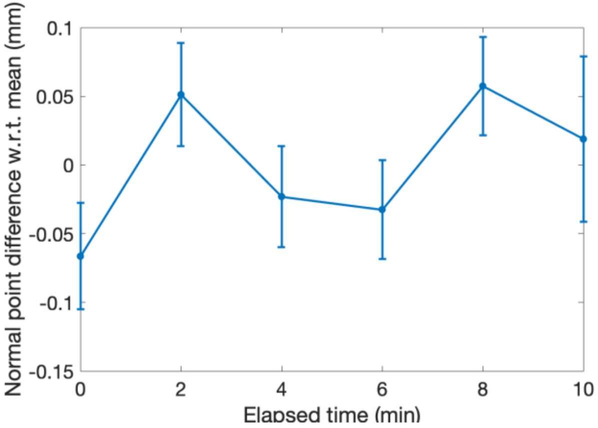
Worst case

σ_{NP} = 0,6 mm



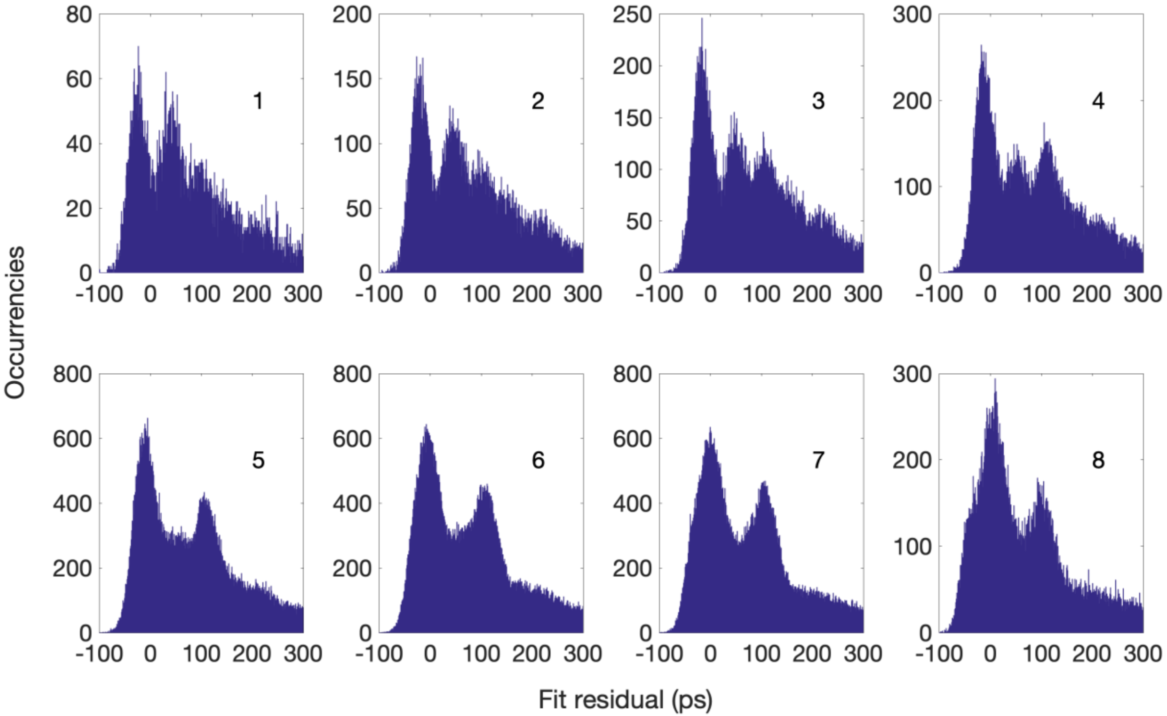
Best case

σ_{NP} = 0,05 mm



System instability does not explains $\sigma_{NP} >> \frac{\sigma_{FR}}{\sqrt{N}}$

Possible error on mean center of mass correction



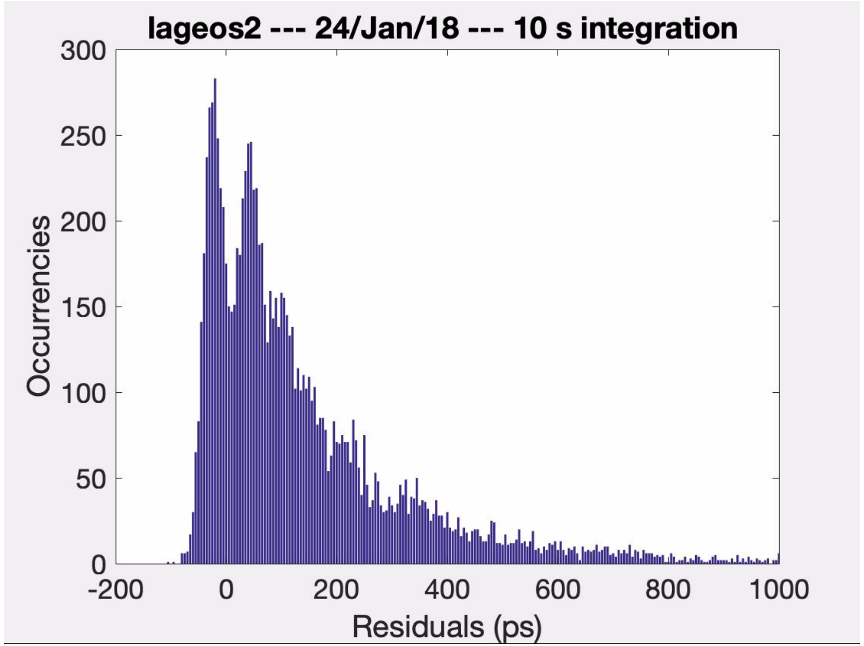
Lageos 2 pass 24th Jan.

One histogram per NP

Lageos are not spinning, average approximation on PDF does not hold

This might introduce systematics on analysis

A lot of information in return structure!



Prelaunch Optical Characterization of the Lager Geodynamic Satellite (LAGEOS 2)

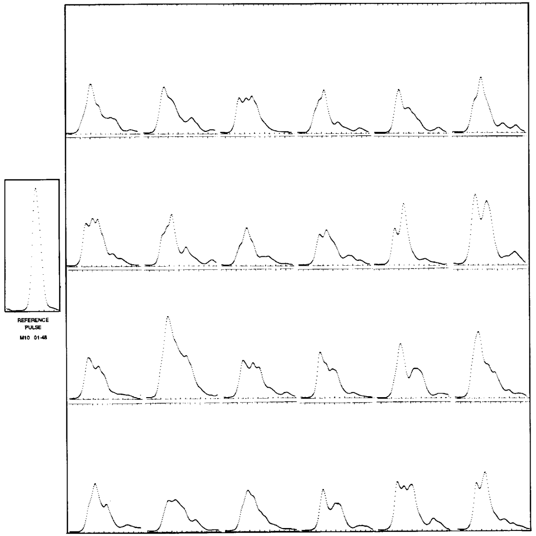


Figure 4.4.2.1-8. Reference and random orientation satellite returns using annulus.

4-41

Conclusions

- Successful campaign
- 100 KHz – 10 ps laser is an option for SLR
- GNSS could be tracked (return rate could be increased by more than x32 with optimization)
- Day-time operation to be studied (optimistic for high SNR)
- 1-mm precision limit is an open issue

- High rep. rate laser could allow determination of attitude and spin

Thank you for your attention

Setup Layout

10 Hz and 100 kHz working in parallel (interleaved mode)