

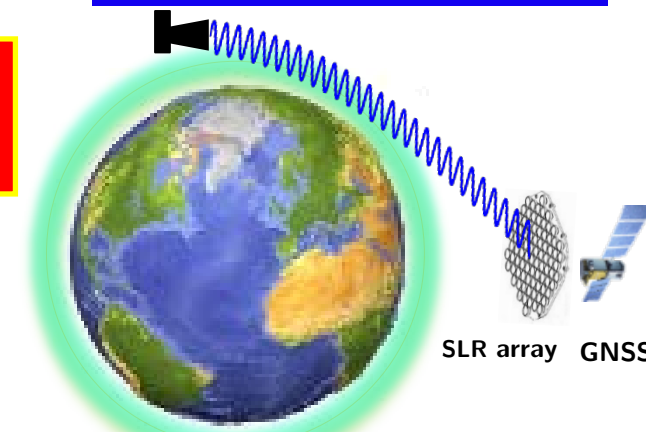
'Optical' GNSS Receiver GNSS-L (laser transceiver)

Optical GNSS Receiver for the ESA NGGM Gravity Mission and for LEO Satellites with the Highest Orbit Accuracy

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GNSS-LO GNSS laser-occultation

cw-laser: (IR) or UVA-(blue)
1064 nm/3=350-400-(450) nm
- UVA should be feasible for clouds



combined GNSS-RO + GNSS-LO
30x smaller 'wet' delay for GNSS-LO

GNSS

SLR array

Doppler measurements
on a continuous-wave laser
using a star-tracker

Observables:

- biased range
- (modulation → range)

1064 nm

cw-laser

Star-tracker
in LEO



GNSS

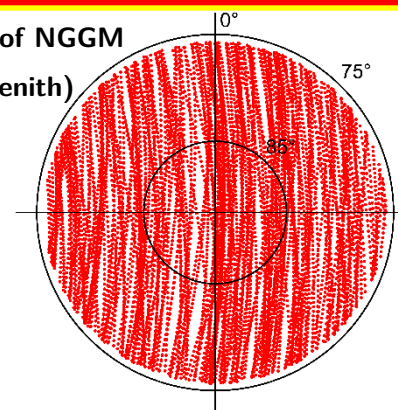
SLR array

"signature effect" removed
with single-differences between two LEOs

Noise level:
GNSS: $\lambda=20$ cm /1000=0.2 mm (+clock estimation)
Optical GNSS: $\lambda=1064$ nm /1000=1 nm (BIASED RANGE)

GNSS in the star-tracker of NGGM

($i=60^\circ$, FOV= 24° in zenith)



NGGM-A

NGGM-B

'Vertical GRACE'
providing the radial and cross-track link
between two LEO satellites
- complementing the 'horizontal GRACE'

Link Budget Equation

$$N_{pe} = n_q E_T \frac{\lambda}{\hbar c} \eta_T G_T \sigma_{Sat} \left(\frac{1}{4\pi R^2} \right)^2 A_T \eta_R T_A^2 T_C^2$$

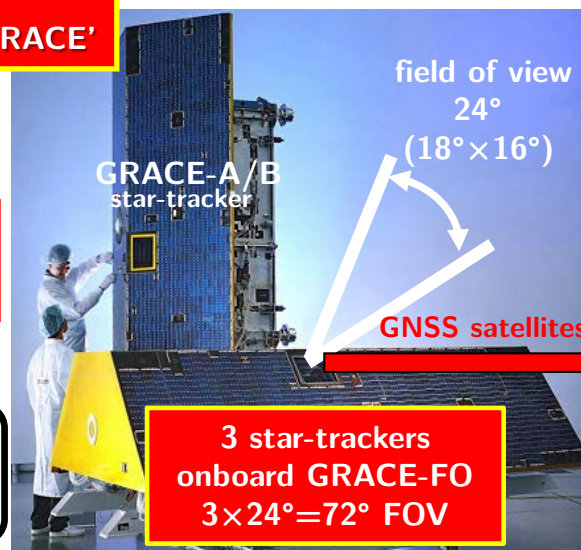
aperture area

atm. attenuation

star-tracker ↔ ILRS telescope
above ↔ below
atmosphere

Planetary Geodesy with the GRACE 'star-tracker+laser' for:

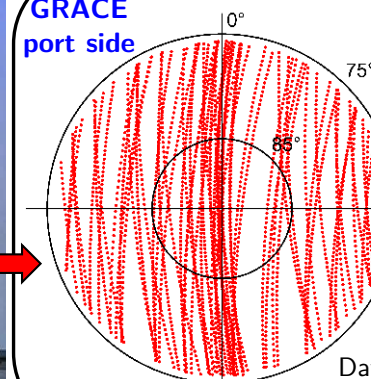
- Deep space optical precise orbits (Mars/Jupiter/Moon) + ILRS telescope on the Earth
- Precise orbits of the Lunar Gateway making use of the 6 LLR laser arrays on the Moon
- Precise orbits of the Mars satellites making use of the laser arrays on Perseverance



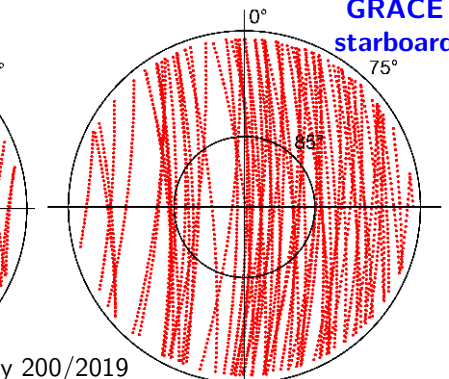
3 star-trackers
onboard GRACE-FO
 $3 \times 24^\circ = 72^\circ$ FOV

Galileo in the two GRACE-FO star-trackers
frame of the GRACE star-trackers at 45° zenith angle

GRACE
port side



GRACE
starboard



Day 200/2019

GNSS-L+2-3 star-trackers give 'radial' & 'cross-track'