Thermal and Optical Characterization of a GNSS Retroreflector Array at the SCF_Lab

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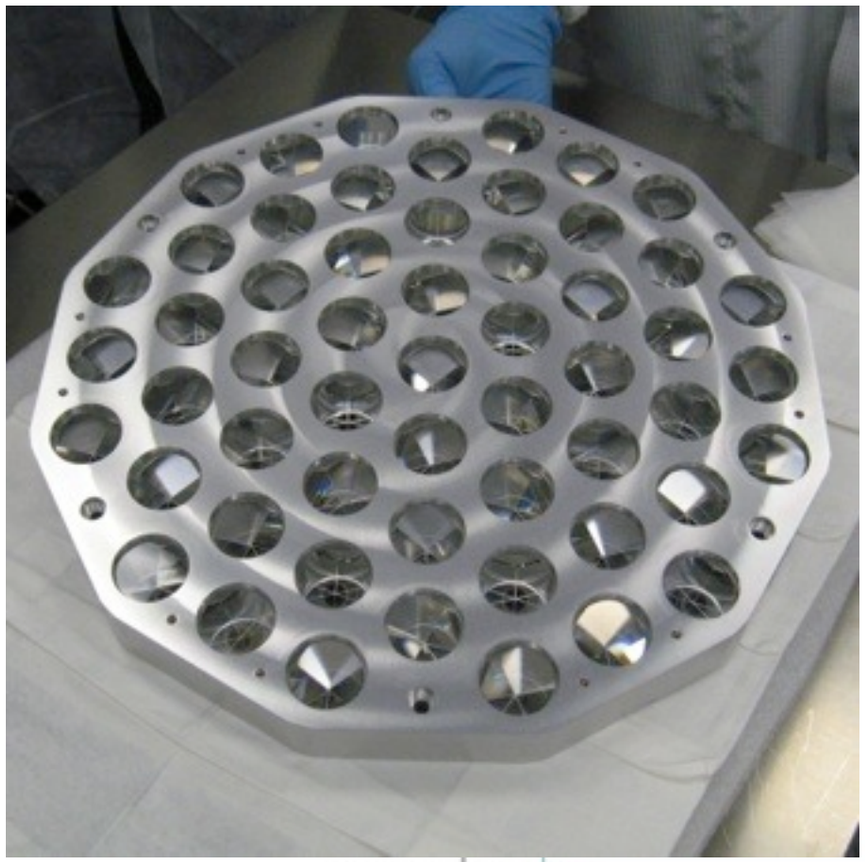
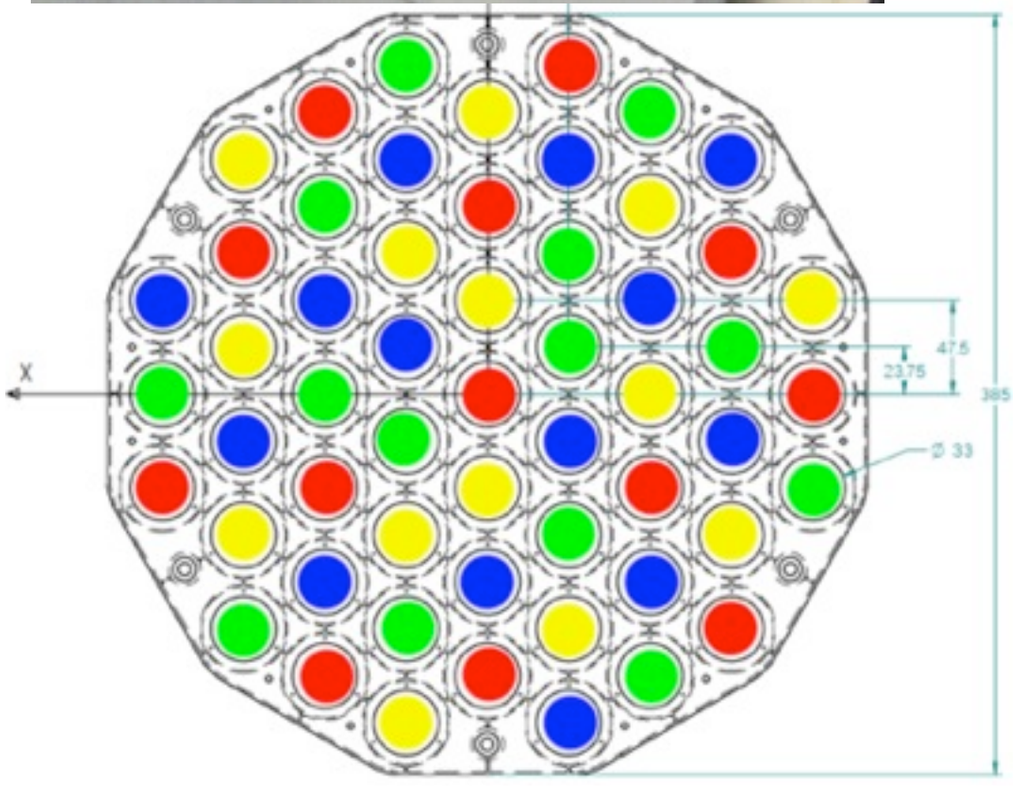
Outline

- GRA optical and mechanical design
- Measurements at the SCF_Lab
- Results of the FFDP tests in Air
- Results of the default SCF-Test
- Results of the GCO measurements
- Optical simulations and comparison with measurements
- Conclusions and future work

GNSS Retroreflector Array: GRA

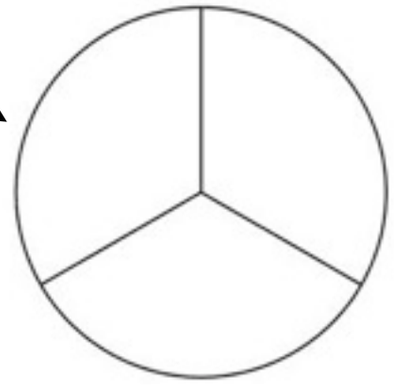




- 55 uncoated retroreflectors
- Fused Silica (Suprasil 1) CCRs with 33 mm front face diameter with DAO = 3× (0.0”±0.5”)
- Aluminum base
- Quasi circular shape
- Four azimuth orientations

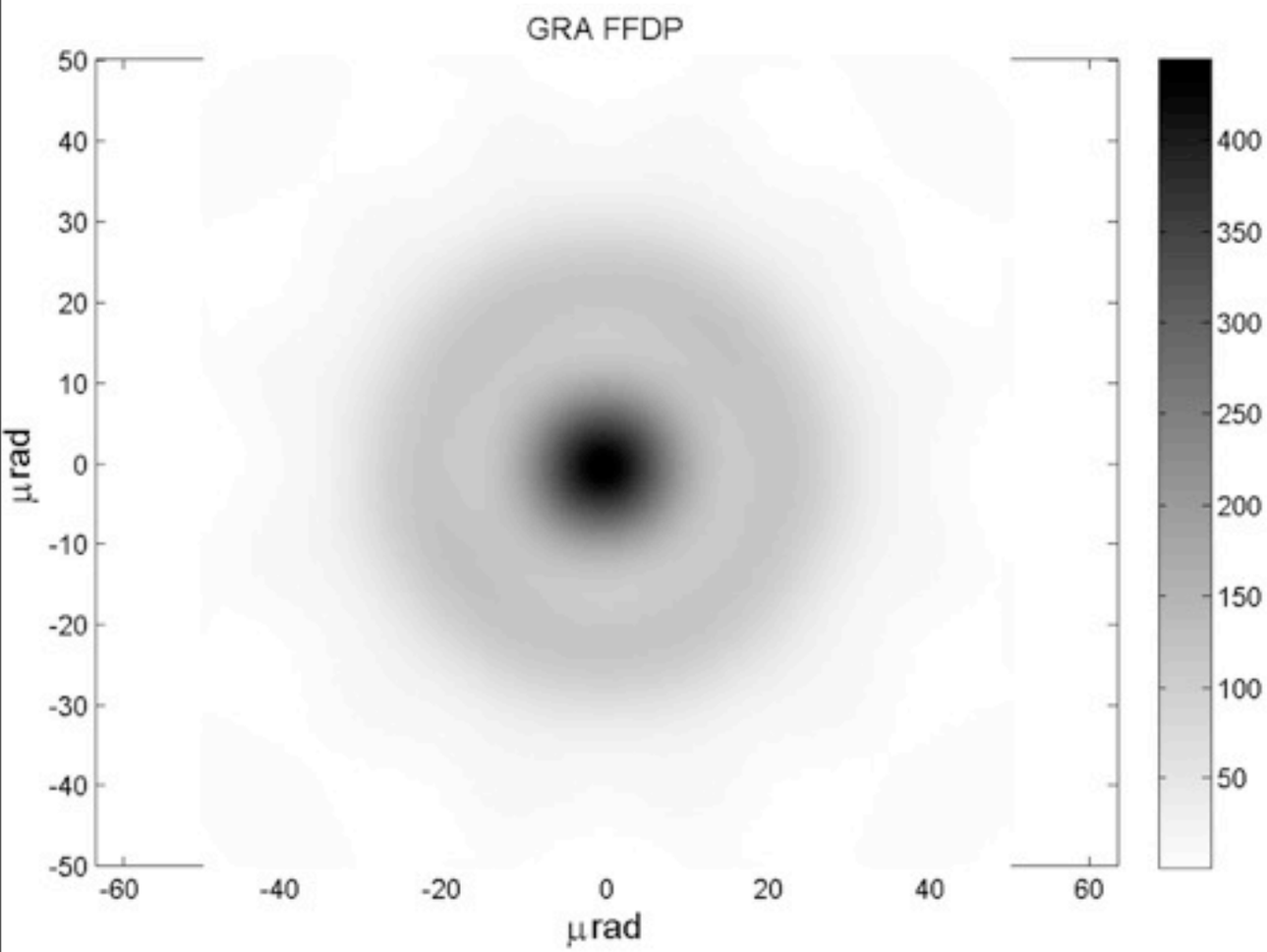
Clocking of CCRs orientation:

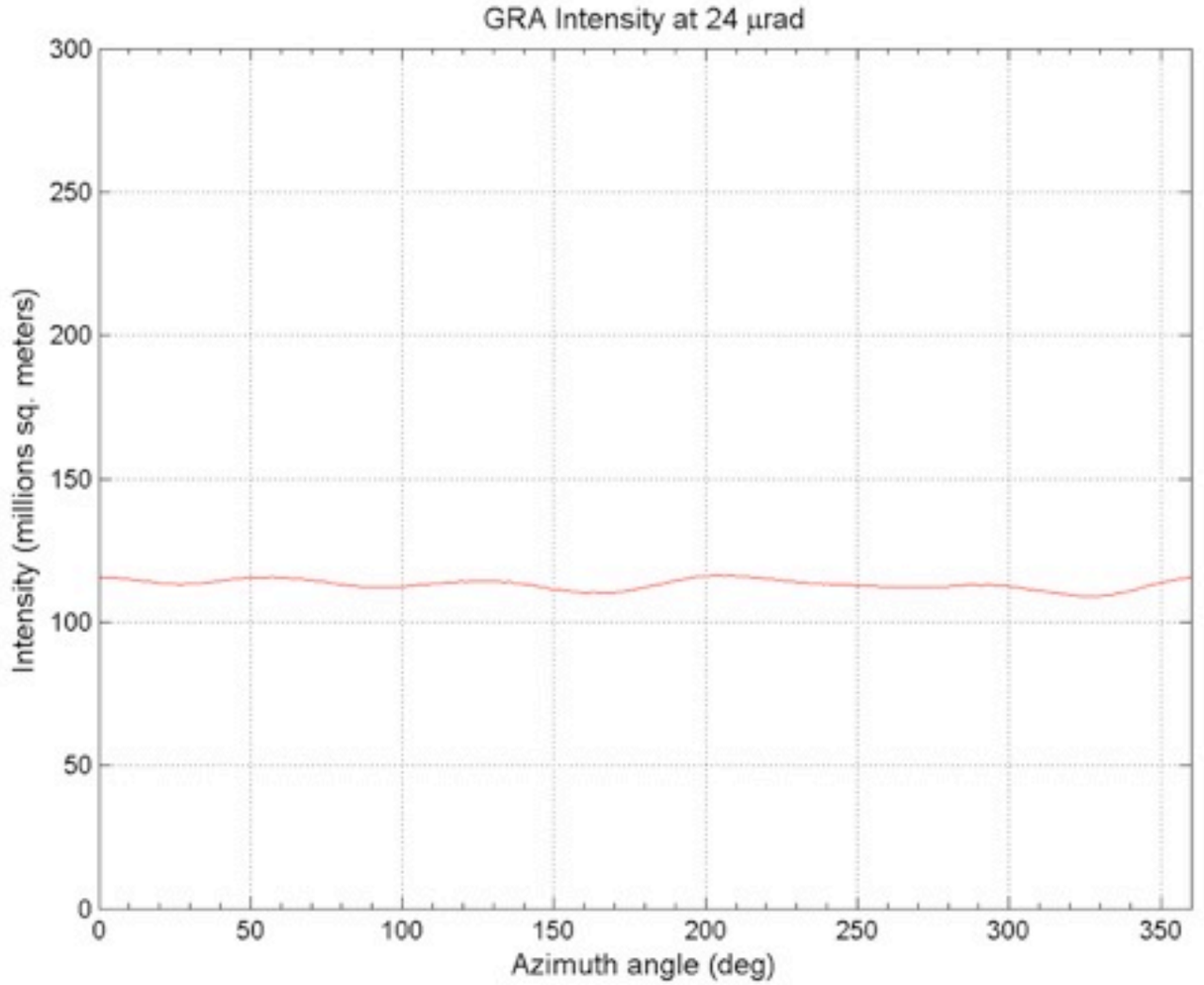
red=0º, green=30º, blue=60º, yellow=90º



DAO: Dihedral angle offset

GRA FFDP simulation



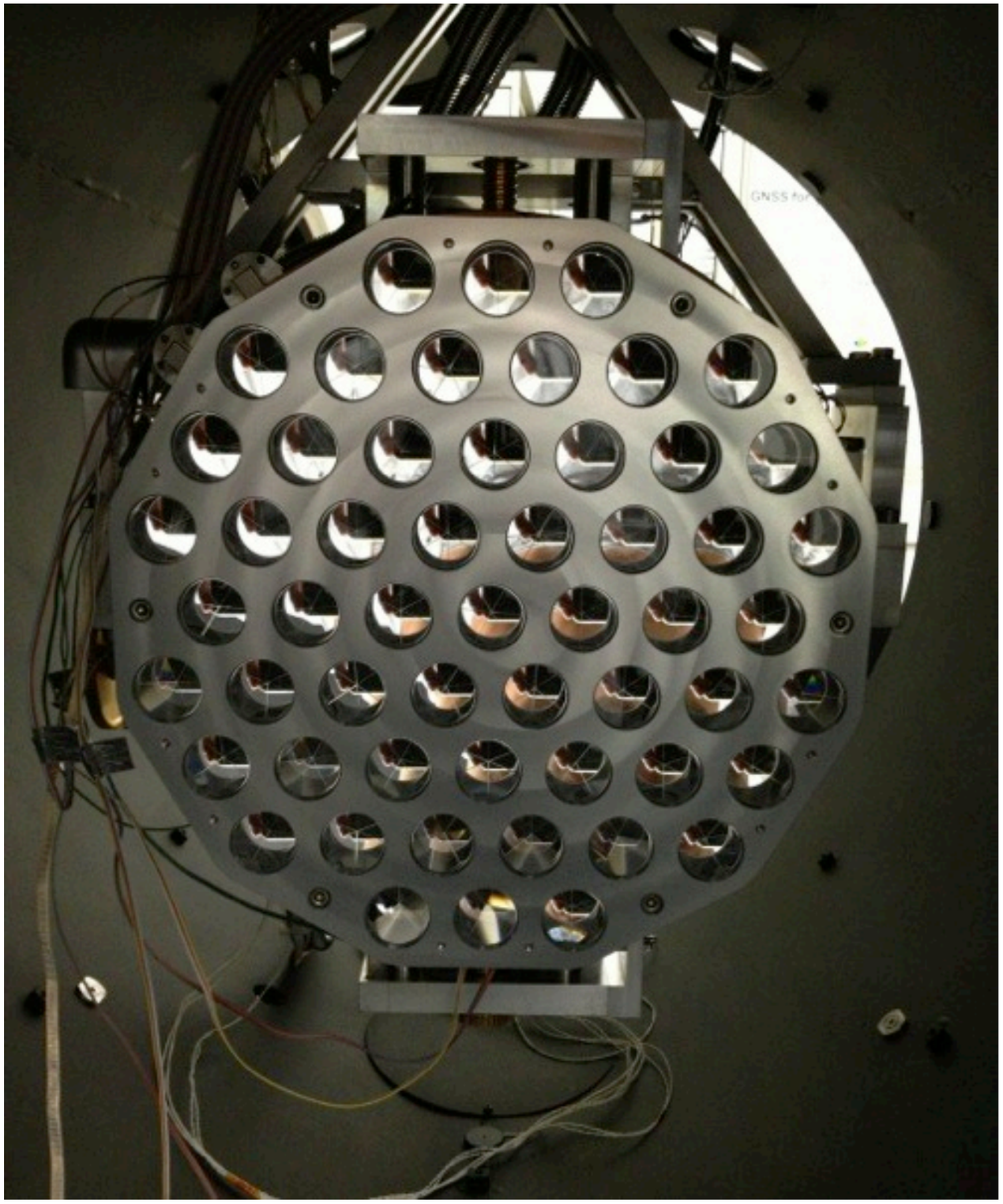


- 33 mm circular front face aperture
- CCR with DAO = 3× (0.0”±0.5”)
- velocity aberration ~24 µrad (Galileo IOV value)
- λ=532 nm
- horizontal polarization
- Intensity (OCS,Optical Cross Section) in 10^6 m^2 units

Simulated GRA OCS = $113 \cdot 10^6$ m^2

IOV: In Orbit Validation

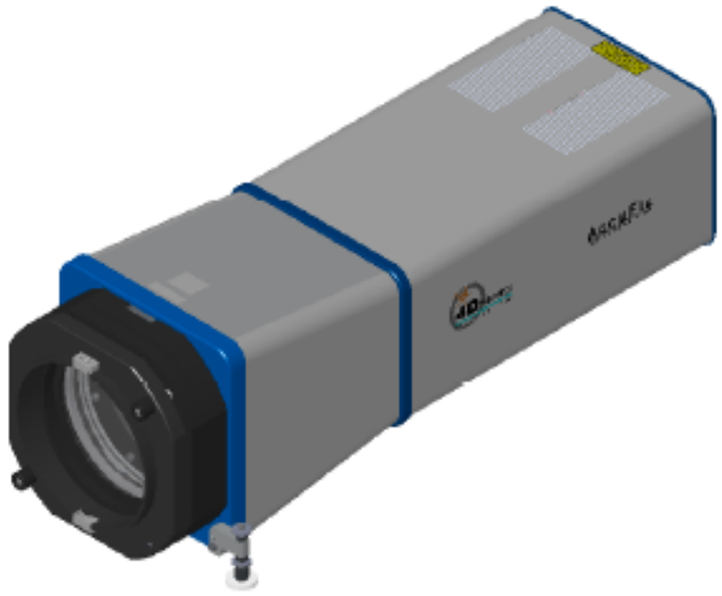
SCF-Test of the GRA at the SCF_Lab



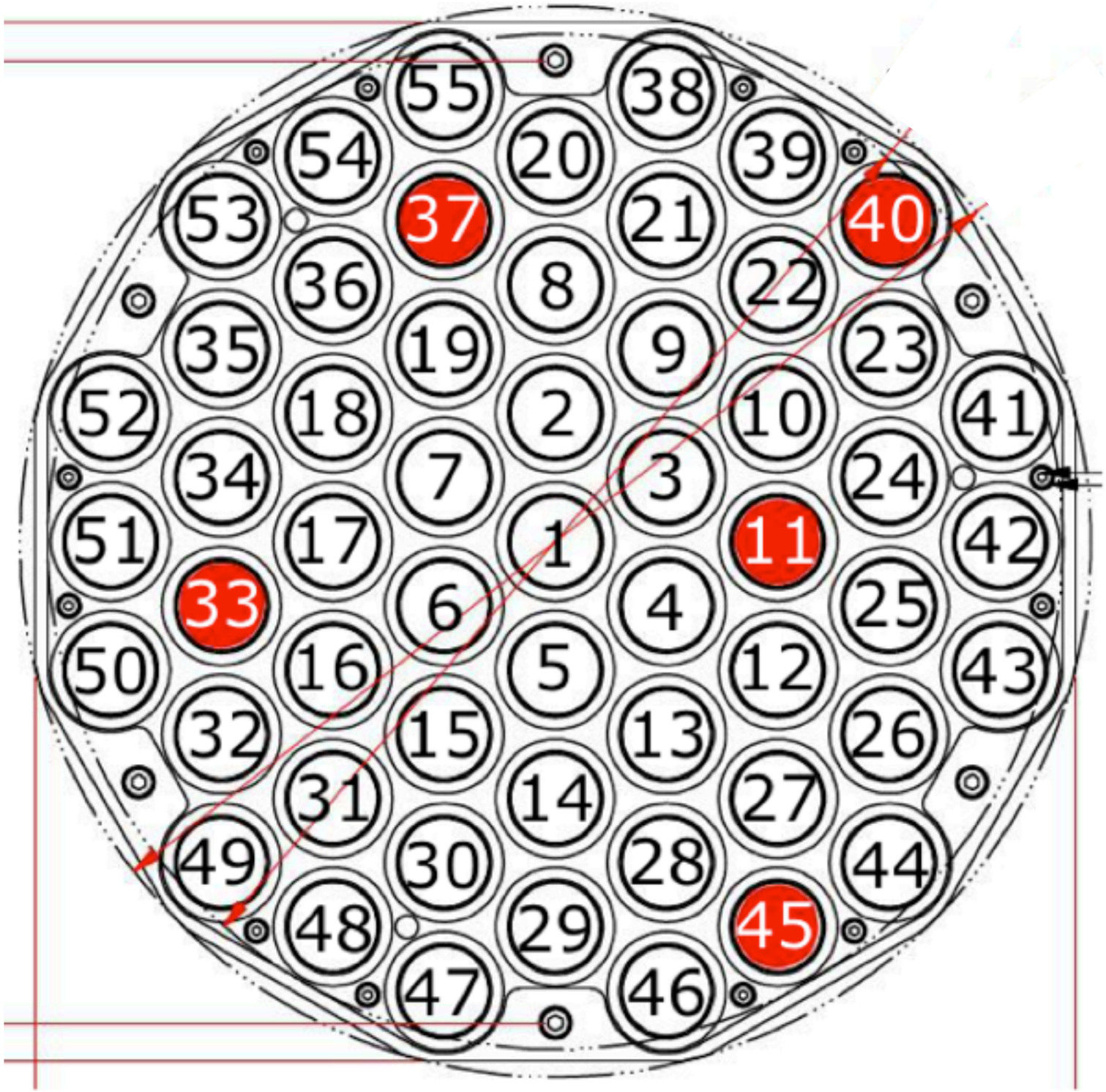
SCF_Lab measurements

- Far Field Diffraction Pattern (FFDP) measurement in Air of all 55 CCR
- Default SCF-Test (measure of CCR thermal inertia)
- Lab-simulated Orbital SCF-Test (probe critical thermal conditions)

Introduced interferometric measurements from a commercial fizeau interferometer

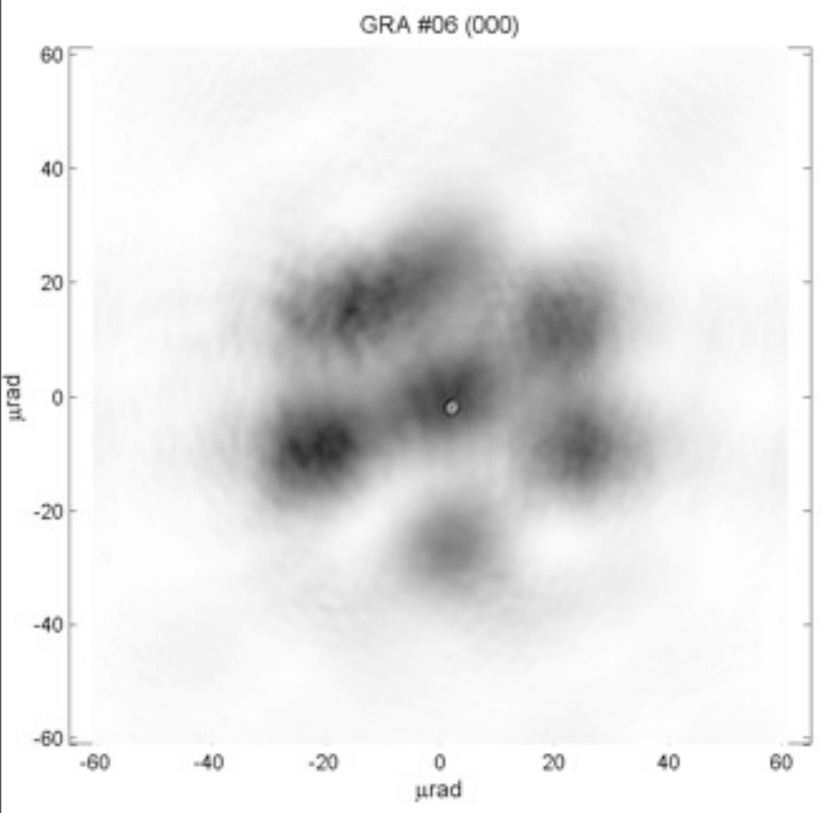


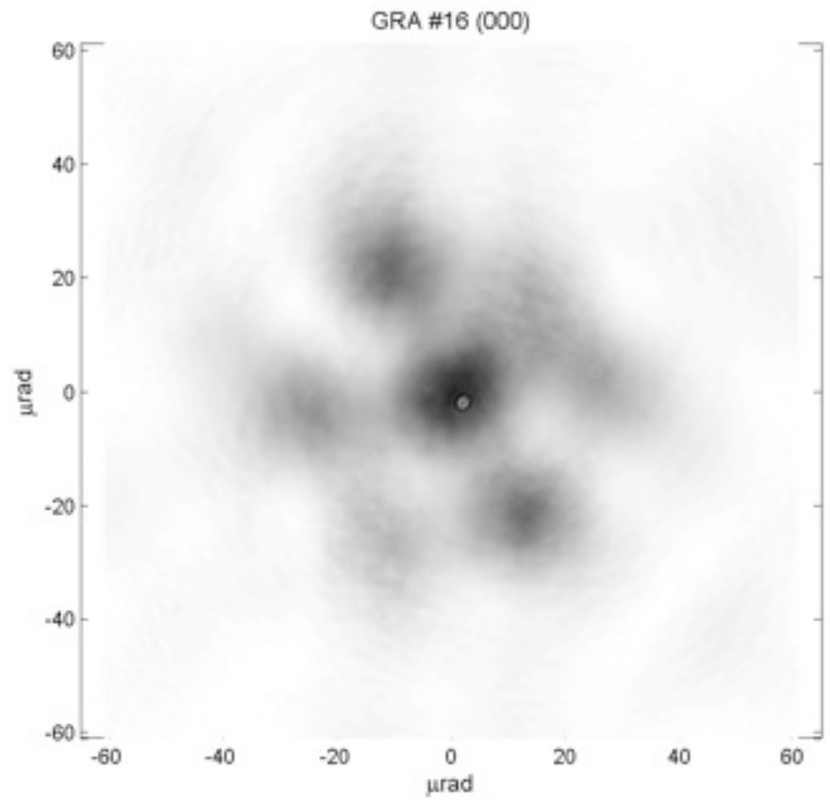
CCRs positions on the array

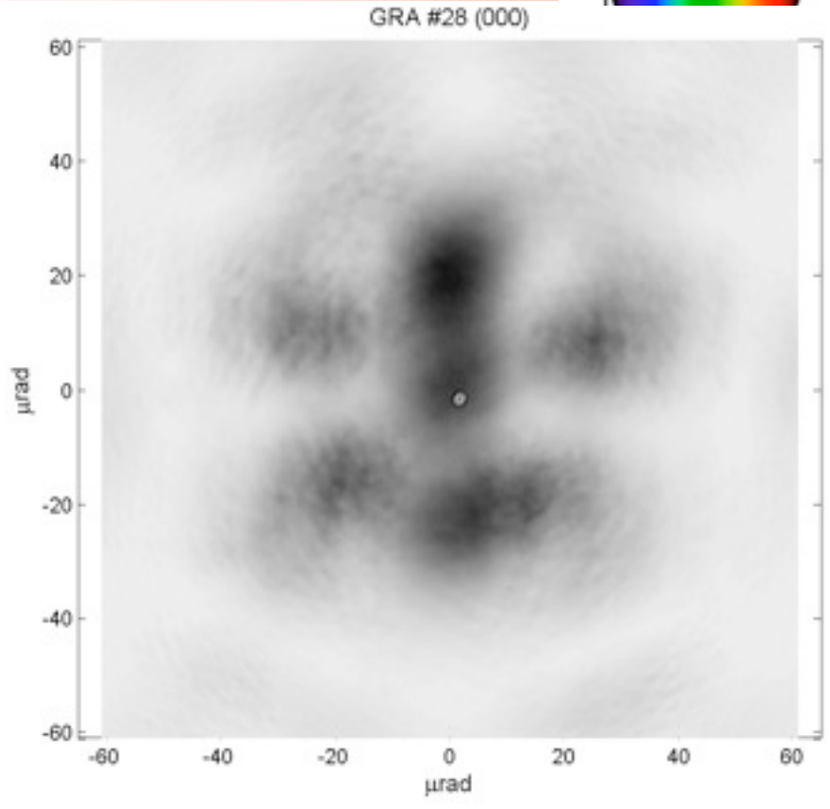


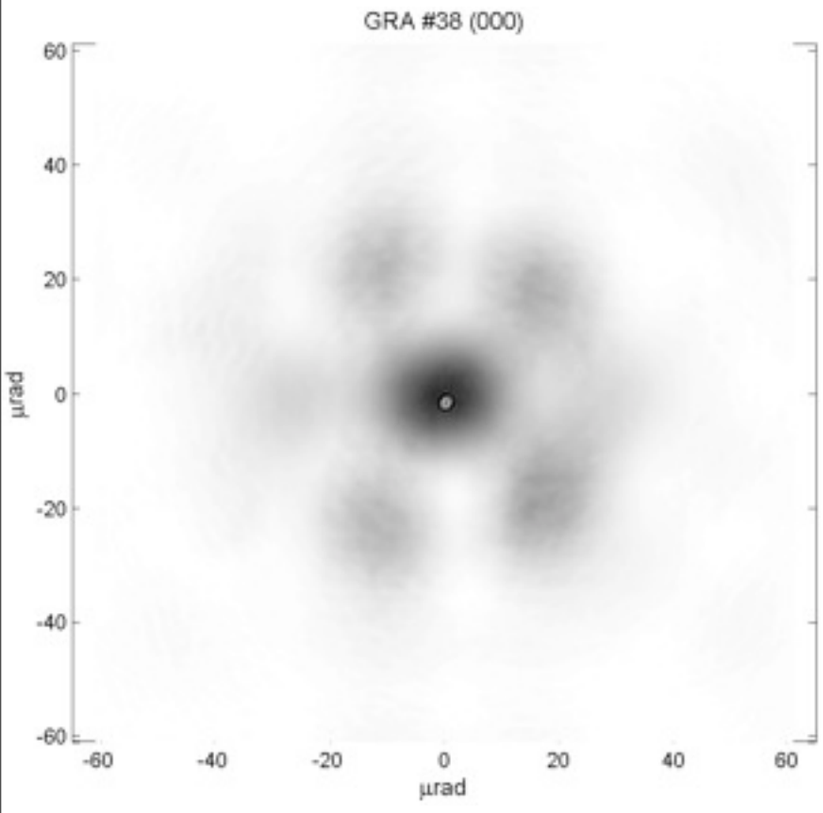
- White circles: CCRs in Suprasil1
- Red circles: CCRs in Suprasil311

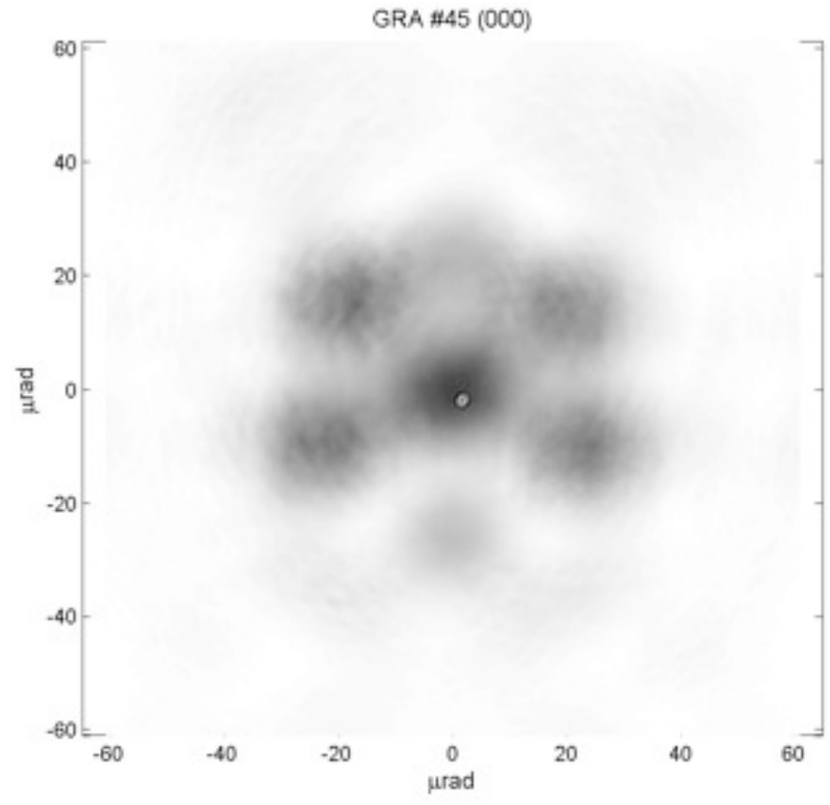
FFDP measurement in air

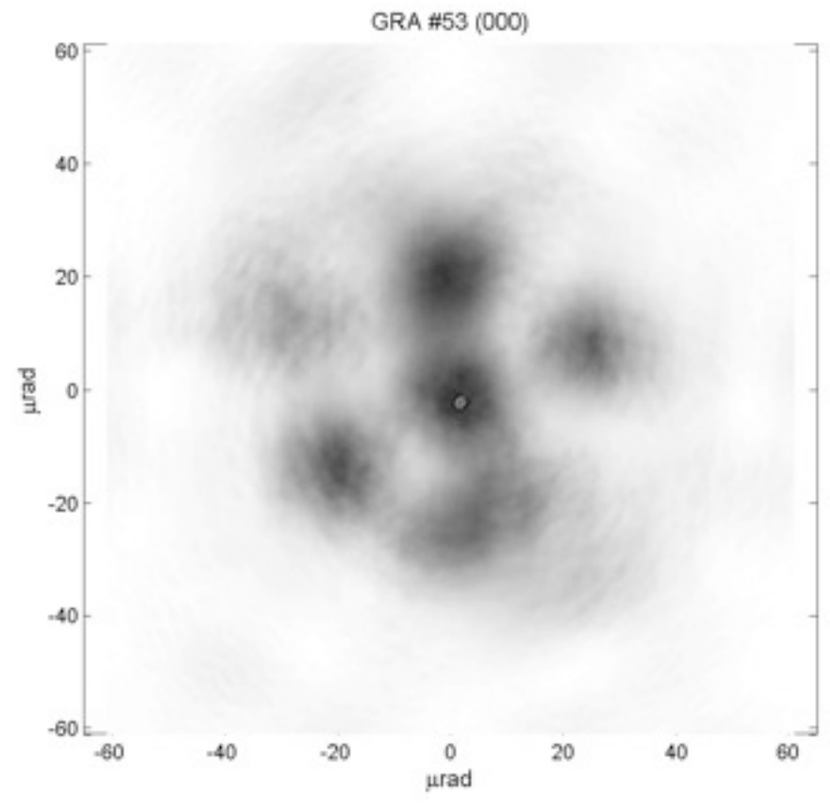








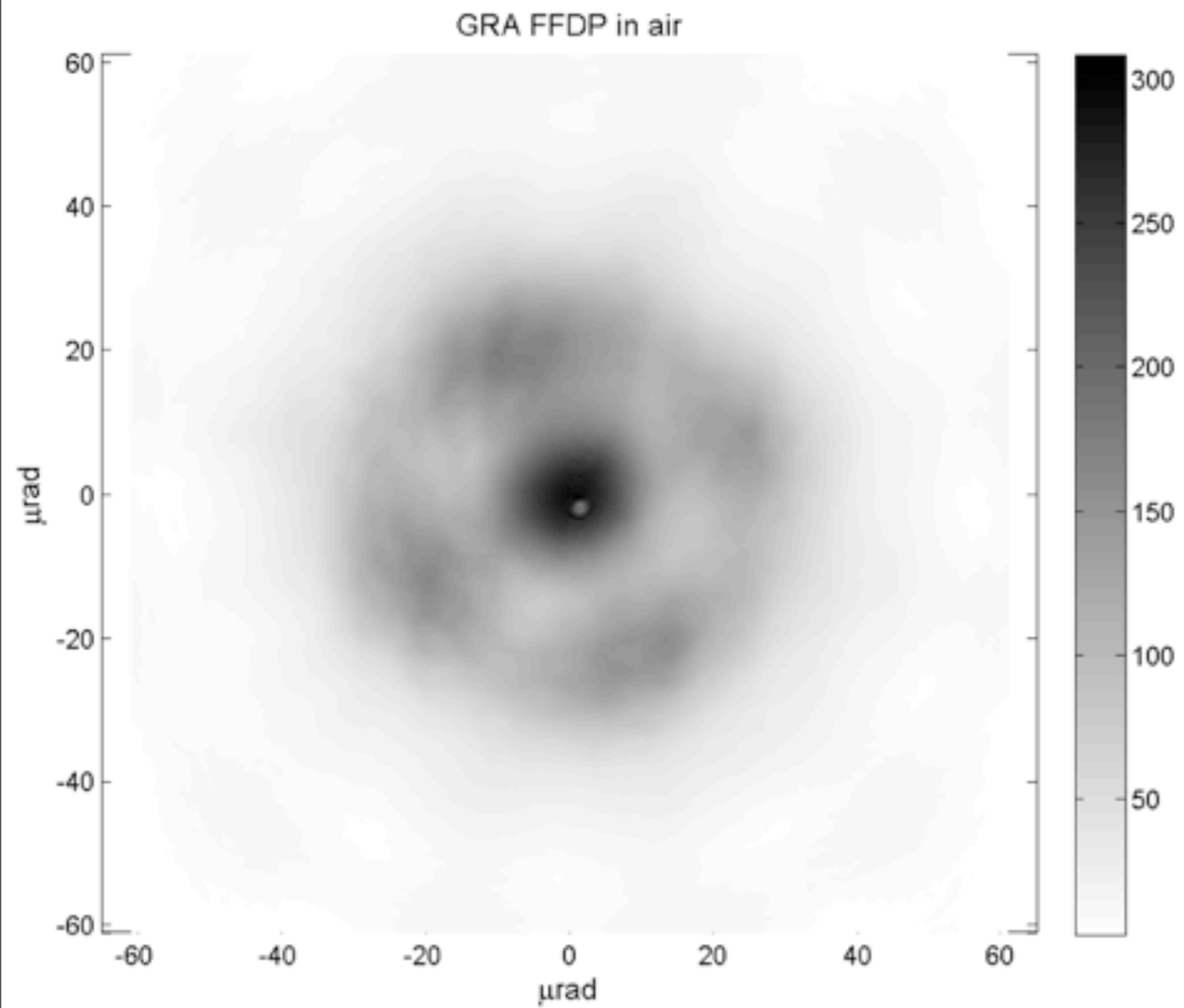




Measured GRA FFDP in Air

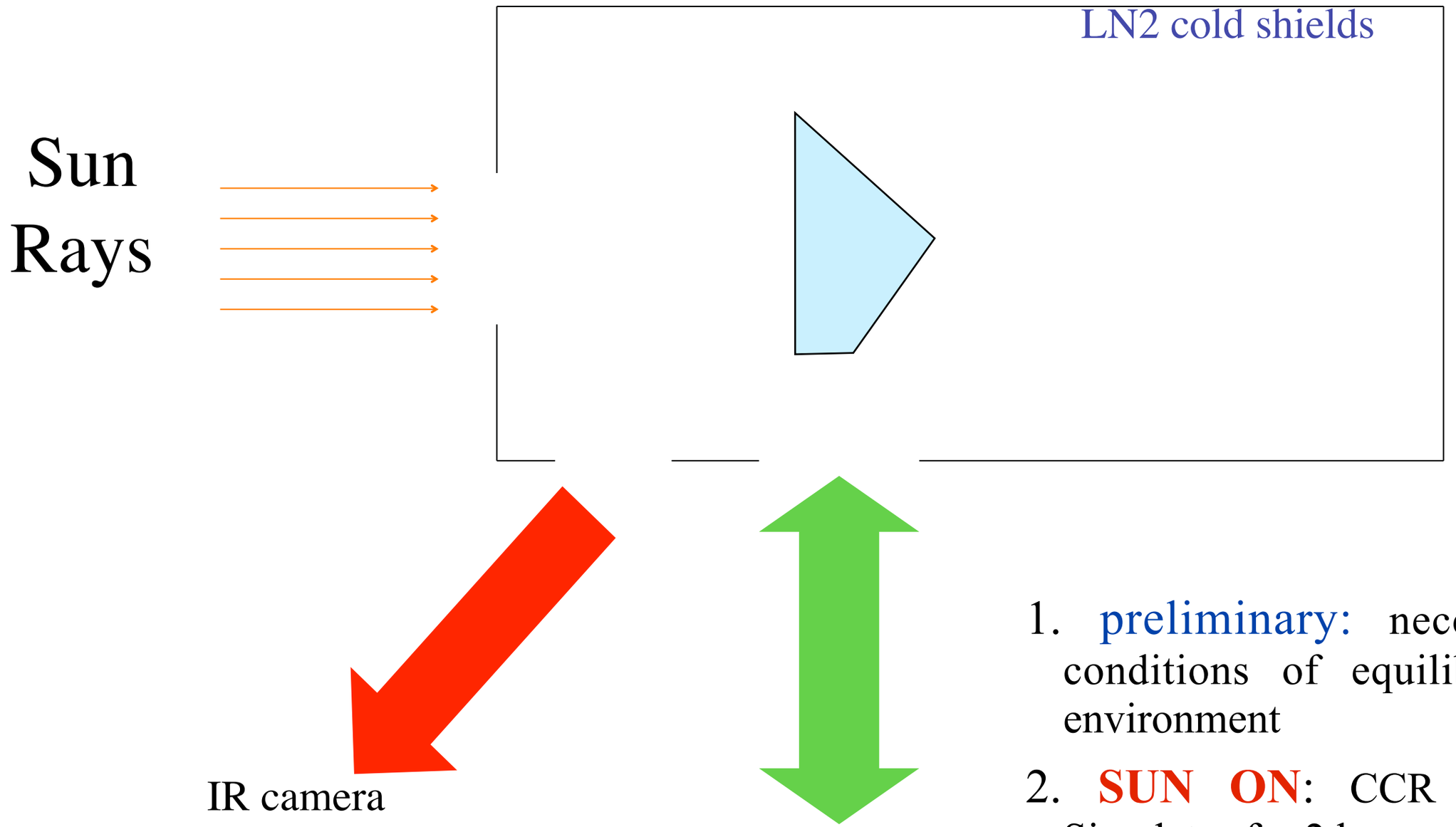
sum of the 55 CCRs FFDP

GRA OCS = $127 \cdot 10^6$ m^2 (relative error of ±15%)



The FFDP is not axial symmetric due to deviation of real manufactured retroreflectors from ideal conditions of simulations.

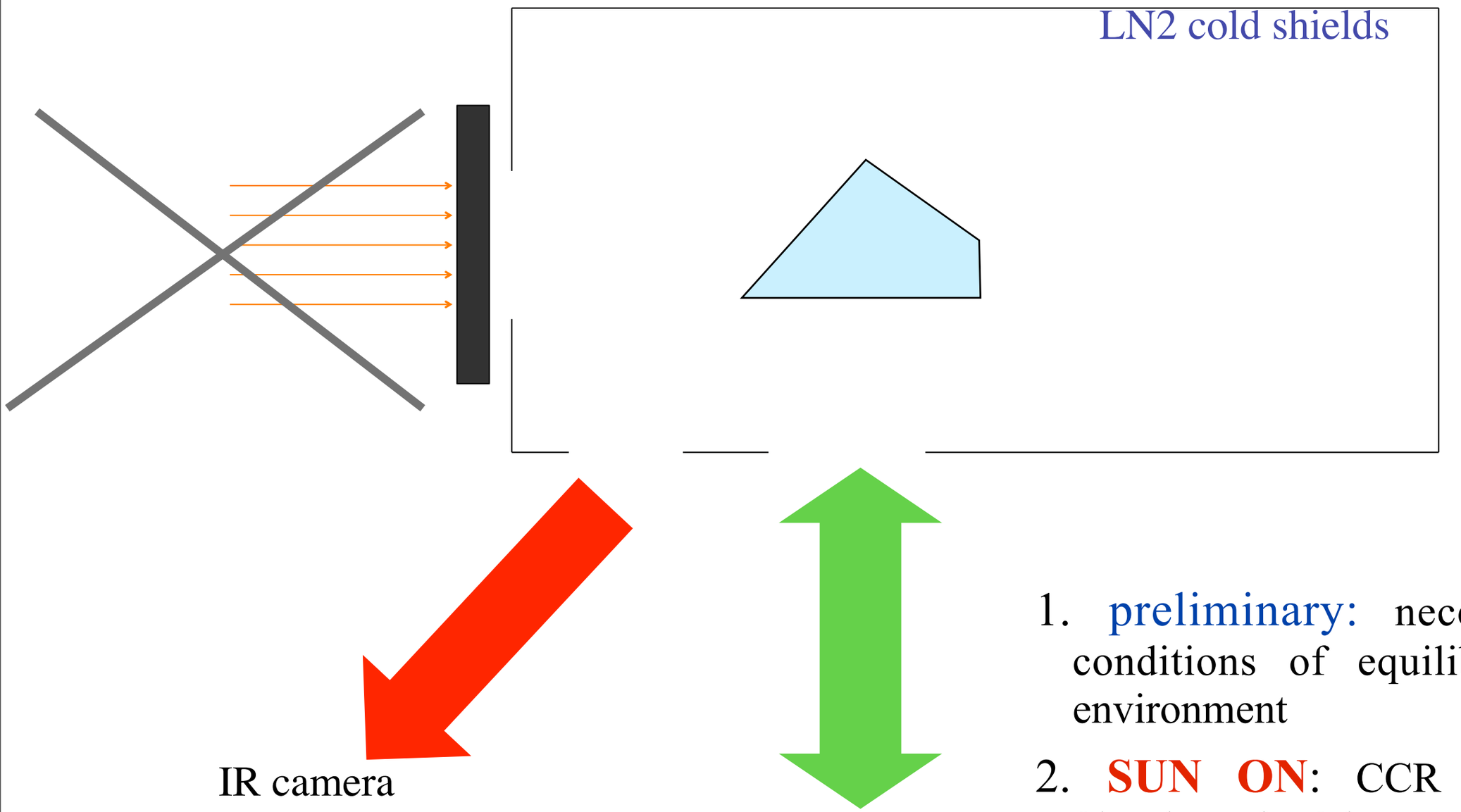
Default SCF-Test



1. preliminary: necessary to achieve conditions of equilibrium with space environment
2. **SUN ON**: CCR in front of Solar Simulator for 2 hours. (IR measurements)
3. **SUN OFF**: CCR in front of laser window (IR and FFDP measurements)

see Dell'Agnello et al., Creation of the new industry-standard space test of laser retroreflector for the GNSS and LAGEOS

Default SCF-Test



IR camera
Image acquisition

532 nm laser beam
FFDP acquisition

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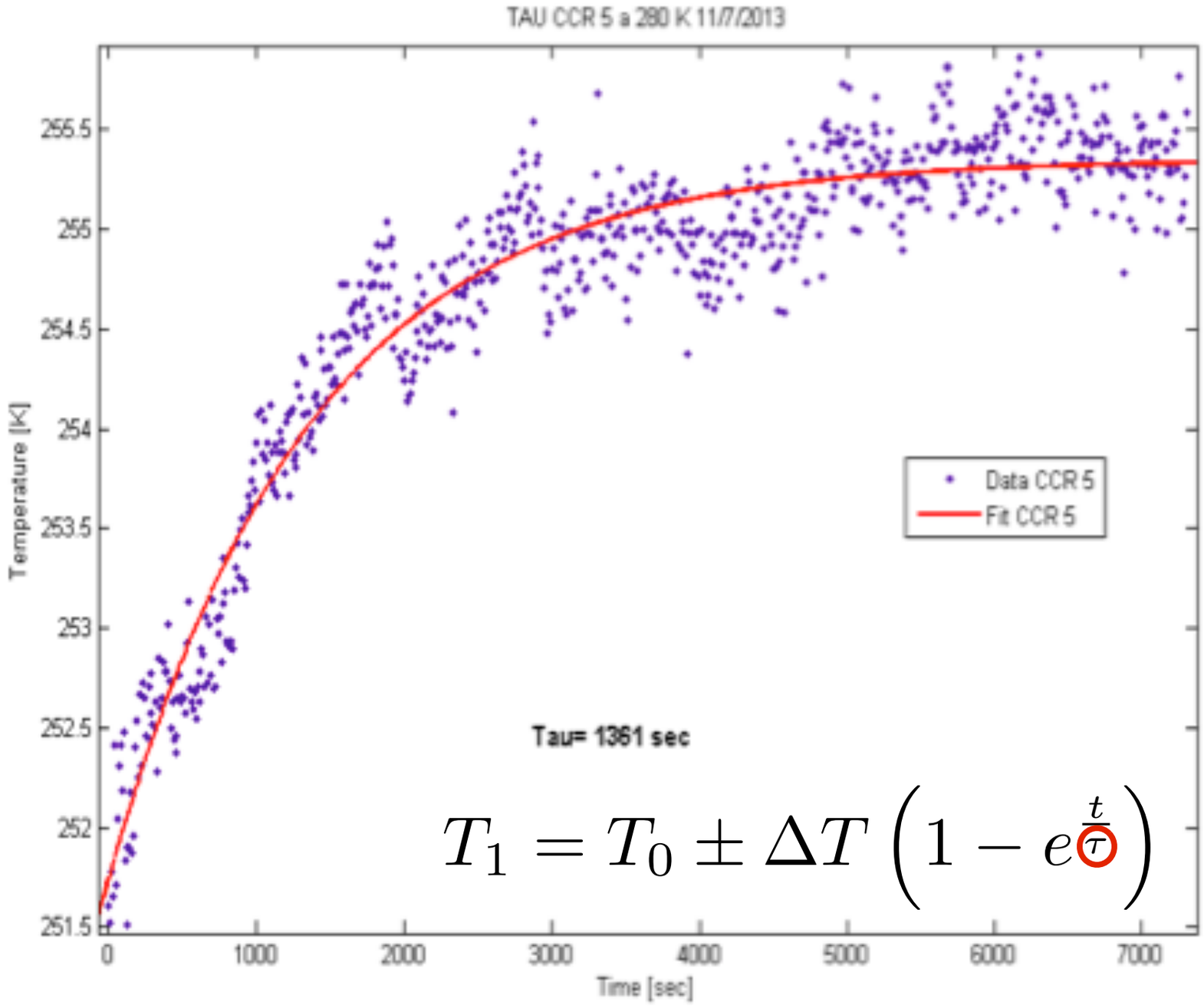
CCRs thermal relaxation times

The measurement was performed at three different fixed temperatures of the support aluminum structure: 280K, 300K, 310K.

We report the analysis of the seven CCRs in the center, easier to measure.



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TAU CCR 5 a 280 K 11/7/2013

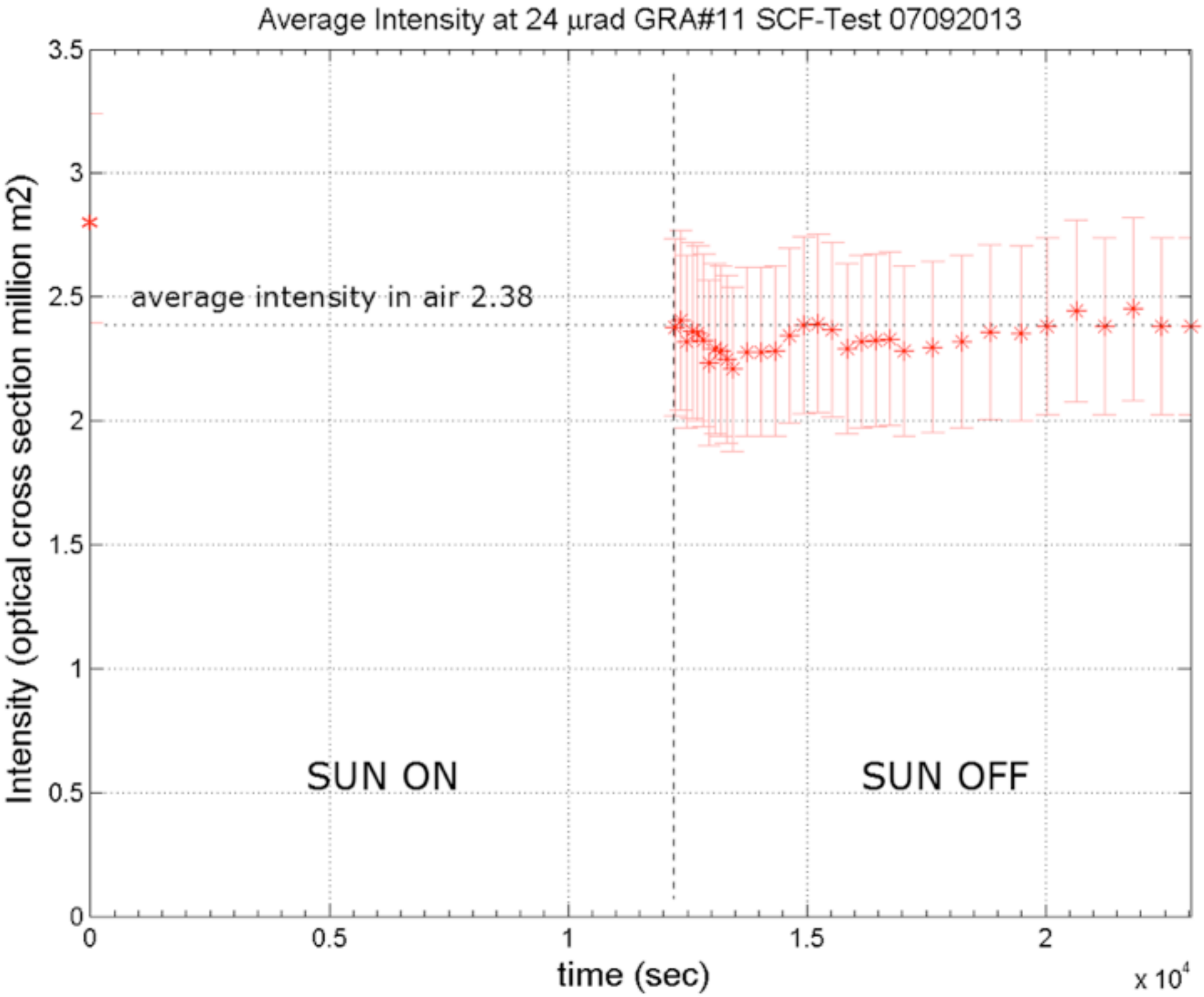
	T=280K [sec]	T=300K [sec]	T=310K [sec]
CCR 1	1518±156	1973±58	1313±157
CCR 2	1555±233	1595±28	1355±208
CCR 3	1340±2	1632±29	1635±398
CCR 4	1437±32	1893±33	1379±325
CCR 5	1531±101	1719±31	1784±500
CCR 6	1425±61	1925±28	1548±292
CCR 7	1423±63	1732±35	1535±428

Time [sec]

Optical behaviour during SCF-Test

Optical Cross Section variation at the Galileo velocity aberration ~24μrad

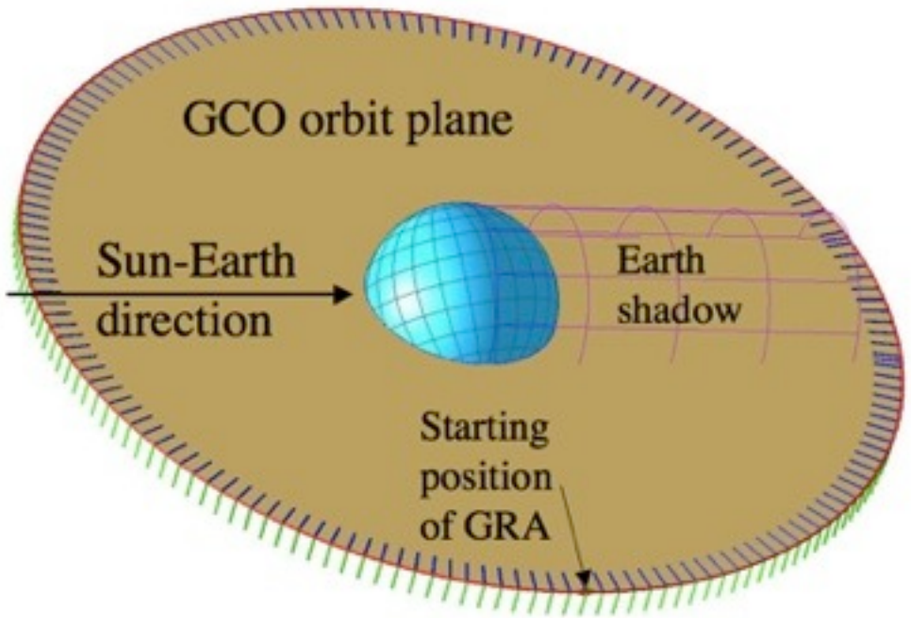
GRA @ 300 K

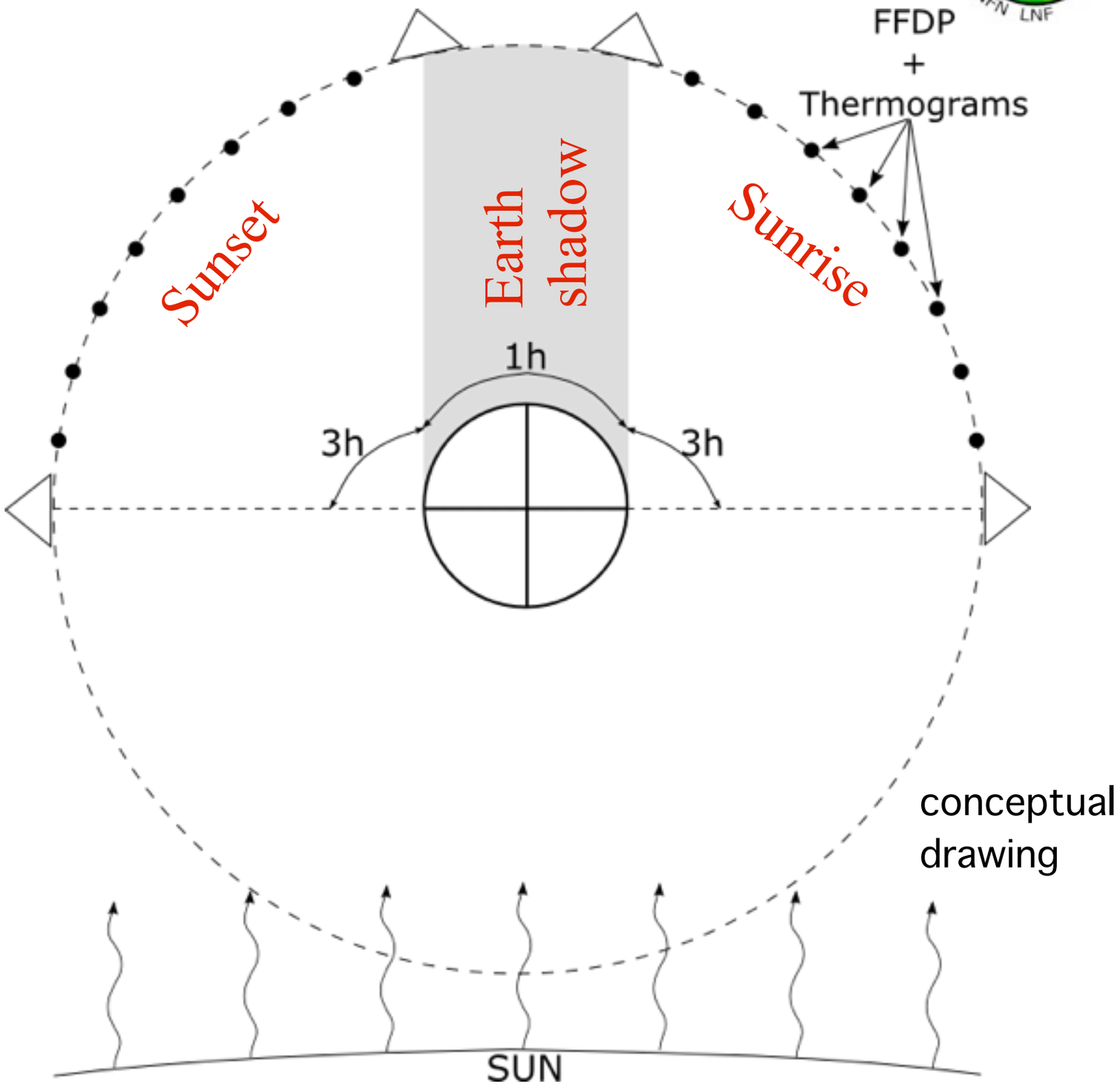


Lab-simulated Orbital SCF-Test

SCF-testing of GNSS Critical half-Orbit (**GCO**) Sunrise-Eclipse-Sunrise probes critical features of the thermal and optical behaviour of the CCR

Galileo orbit:
- altitude = 23222km
- period ~ 14 h
- shadow time duration ~1h (cylindrical approximation)



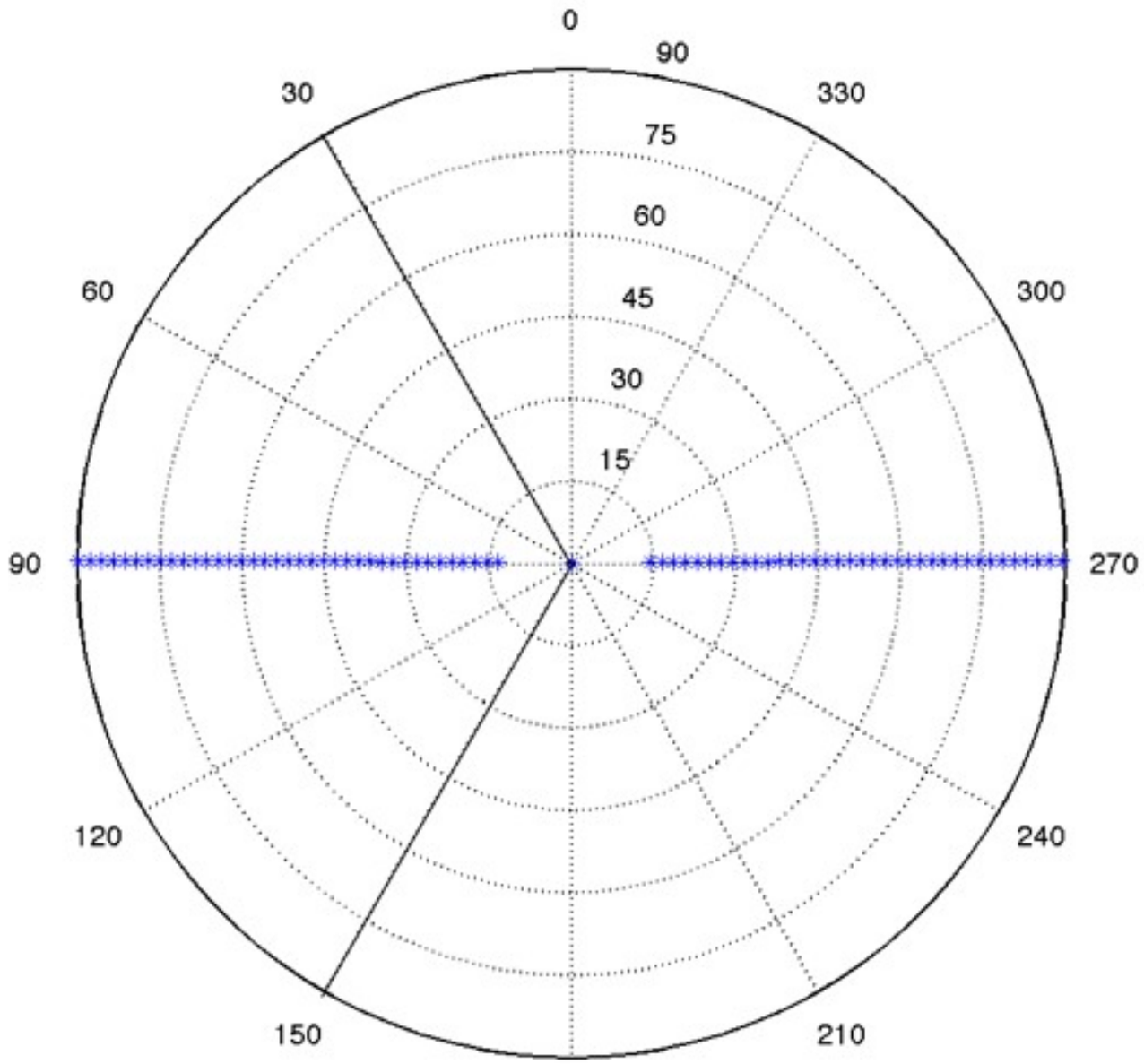


conceptual drawing

see Dell'Agnello et al., ETRUSCO-2: An ASI-INFN Project of Technological Development and SCF-TEST of GNSS LASER Retroreflector Arrays"

GCO trace on CCR front face

GCO (GNSS Critical Orbit) is the orbit whose angular momentum is orthogonal to the Sun-Earth line of sight.



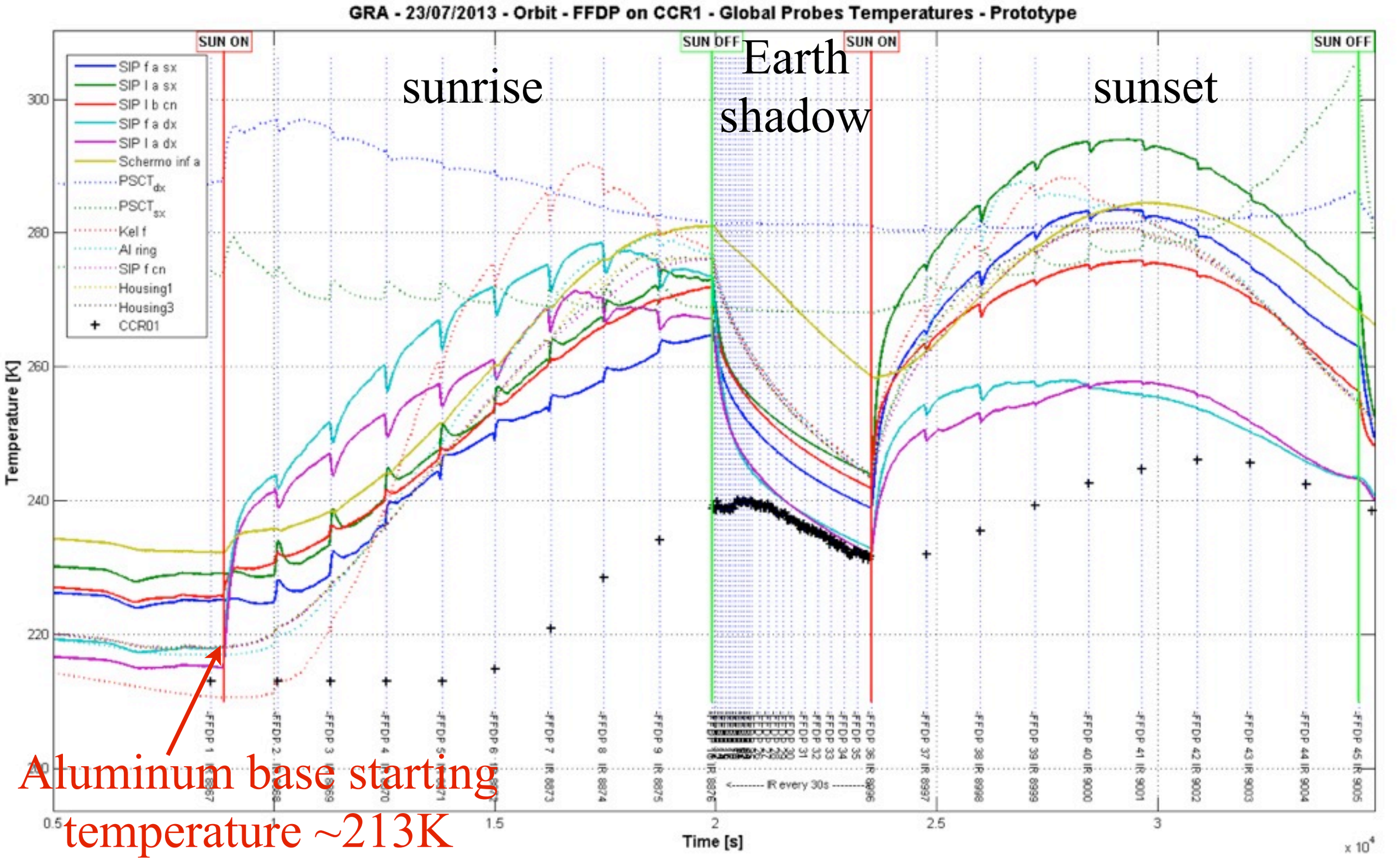
Inclination and azimuth on CCR GCO

GCO SCF-Test

Aluminum base starting temperature ~213K

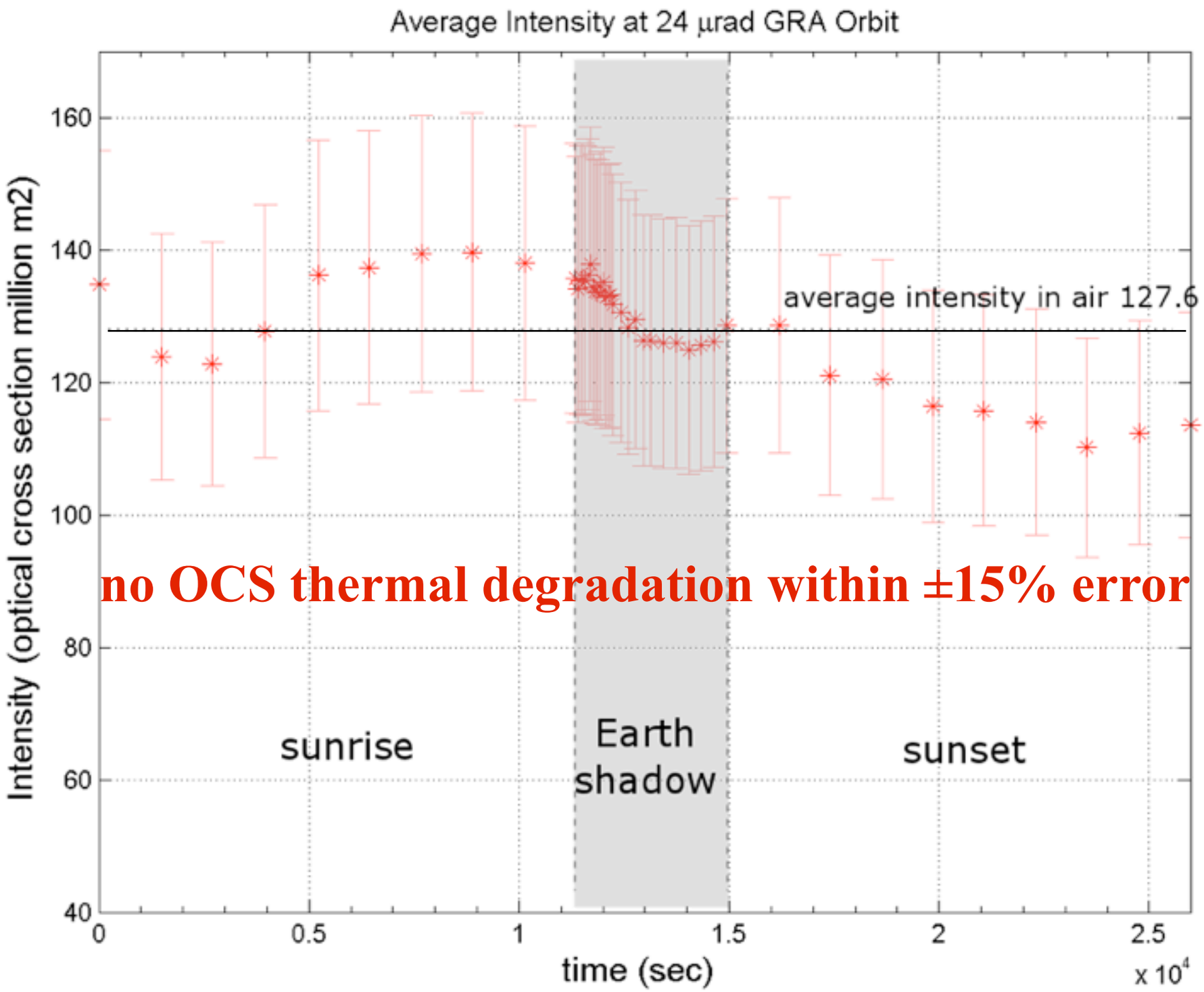
- 8 CCRs tested
- CCRs were numbered according to their positions
- White circles are CCRs in Suprasil1, while red circles are CCRs in Suprasil311
- CCRs tested were one for each rotation, and for each rotation we tested one CCR inside the array and one close to the edge (0deg-in/out, 30deg-in/out, 60deg-in/out, 90deg-in/out)

GCO SCF-Test


GRA - 23/07/2013 - Orbit - FFDP on CCR1 - Global Probes Temperatures - Prototype
SUN ON
SUN OFF
SUN ON
SUN OFF
sunrise
Earth shadow
sunset
SIP f a sx
SIP l a sx
SIP l b cn
SIP f a dx
SIP l a dx
Schermo inf a
PSCT dx
PSCT sx
Kel f
Al ring
SIP f cn
Housing1
Housing3
CCR01
Temperature [K]
Time [s]
x 10^4
<-------- IR every 30s --------
Aluminum base starting temperature ~213K

GRA OCS variation during GCO

OCS of the whole array extrapolated from the 8 CCRs measured



Conclusions and future work

- Completed a full SCF-Test campaign of the GRA.

- FFDP of retroreflectors, taken into account tolerances on DAOs, are in good agreement with design performance.

- Thermal relaxation times of retroreflectors are above 1000 sec, which show good thermal insulation within their housing.

- **No thermal OCS degradation within ±15% error** during orbit measurement. This is a very important result that proves the overall design of the array and the optimized CCR mounting system

- Based on laboratory measurements we fine-tune thermal-optical simulations.

- We are proposing GRA for 2nd generation Galileo (EGEP ESA Call).

Thank you for your attention.

Any question?

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