SCF-Test of Galileo IOV retroreflectors

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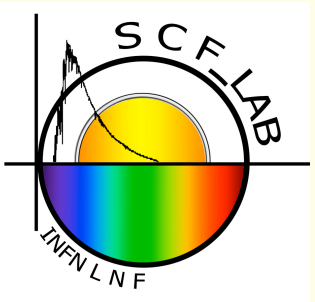
SCF_LAB

Satellite/Lunar/GNSS laser ranging and altimetry

Characterization **F**acilities' **LAB**oratory



INTERNATIONAL TECHNICAL LASER WORKSHOP 2012 (ITLW-12)
ETRUSCO-2 WORKSHOP

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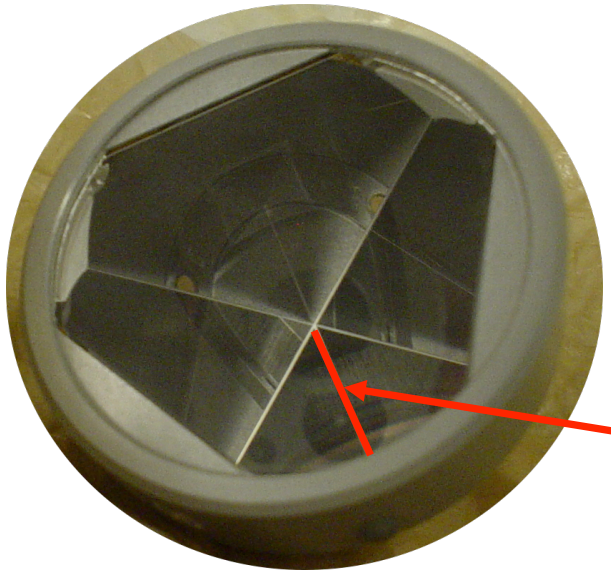
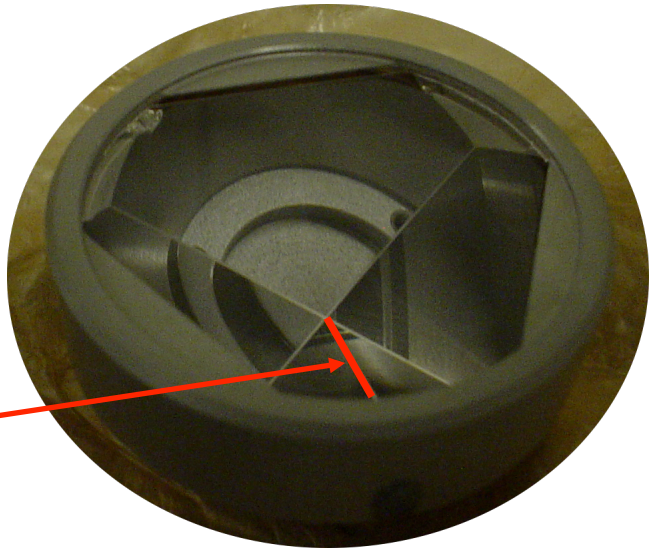
Frascati (Rome), Italy

Preliminary results from SCF-Testing of a prototype uncoated cube corner retroreflector (CCR) for Galileo IOV satellites provided by ESA



Optical breakthrough (BT) = loss of total internal reflection (TIR). Left photo: camera barely visible indicates beginning of BT at ~17° light inclination towards physical edge. Right: full BT above 17°



SCF-Testing of a "GNSS Critical Orbit", with:
Laser polarization horizontal
CCR physical edge horizontal
Solar simulator horizontal

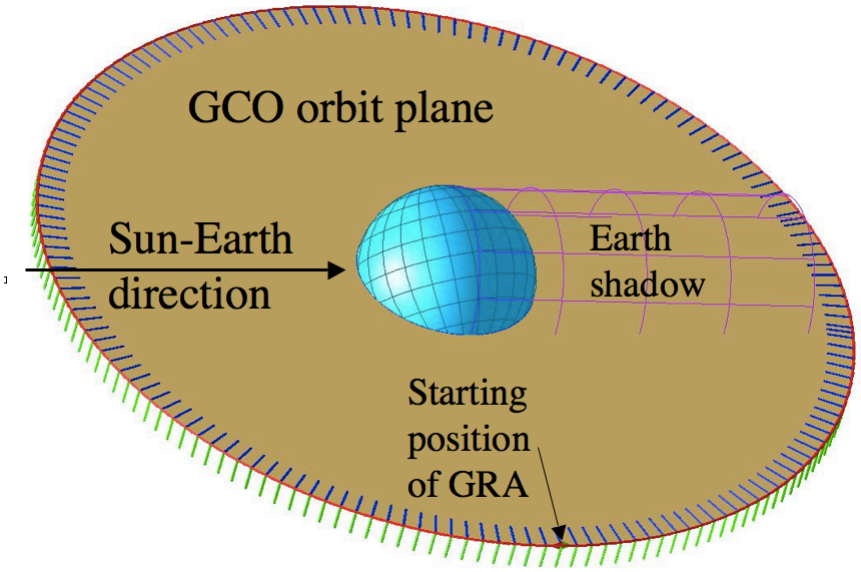
SCF-Test of GNSS Critical Orbit (GCO)

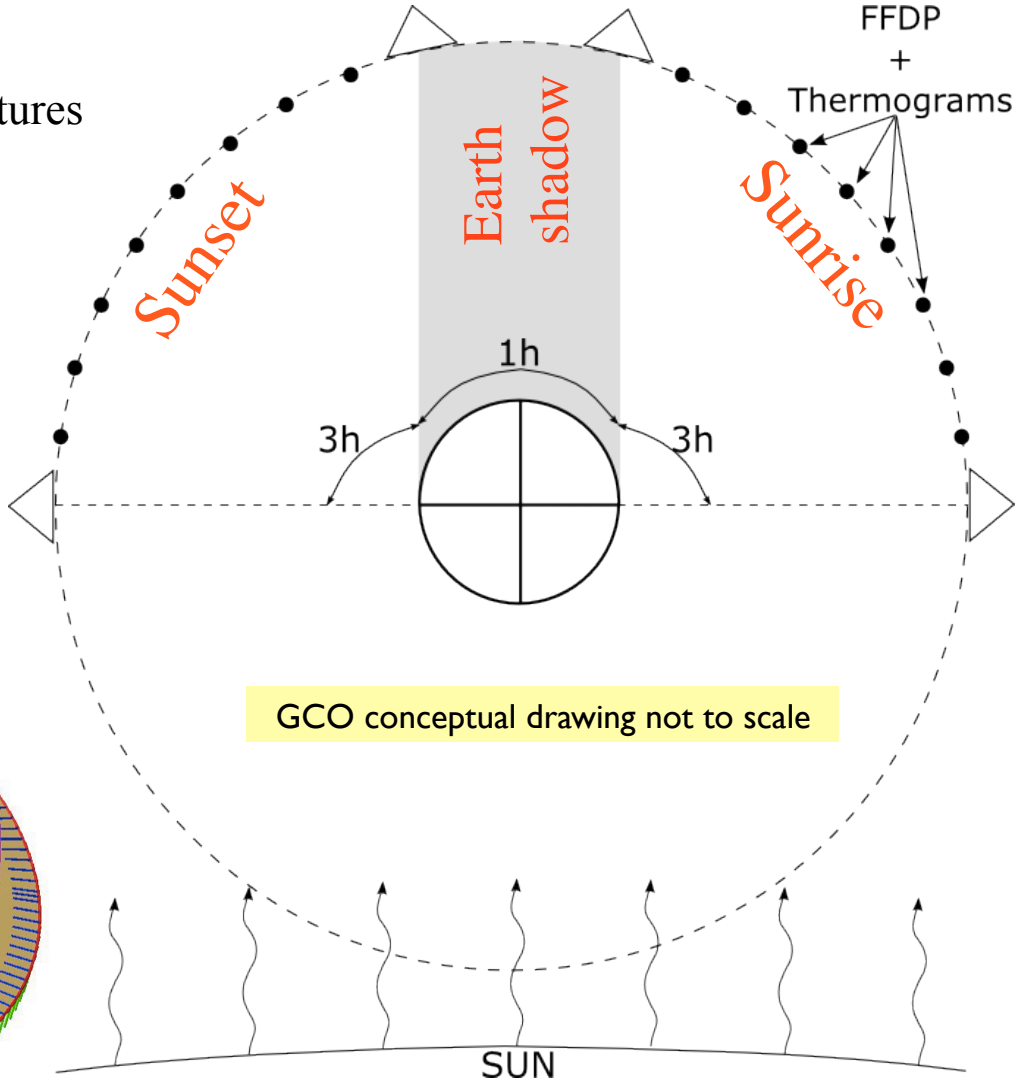
GCO: GNSS orbit with angular momentum normal to Sun-Earth direction.

Sunrise-Eclipse-Sunset probes critical features of the thermal and optical behavior of the CCR, including optical breakthrough.

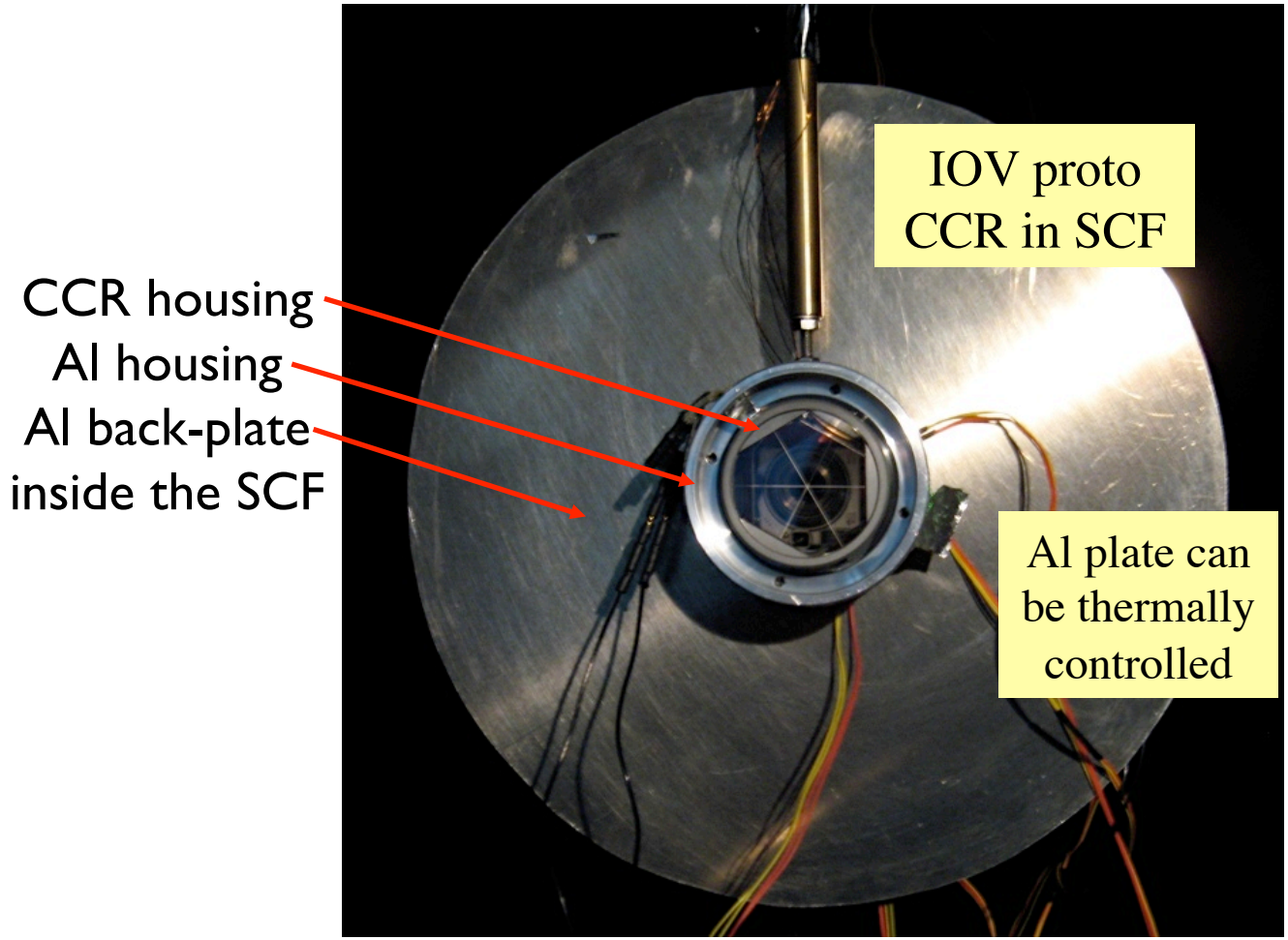
Galileo orbit:

- Altitude = 23222 km
- Period ~ 14 hr, shadow ~ 1hr





Galileo IOV CCR SCF-Test configuration

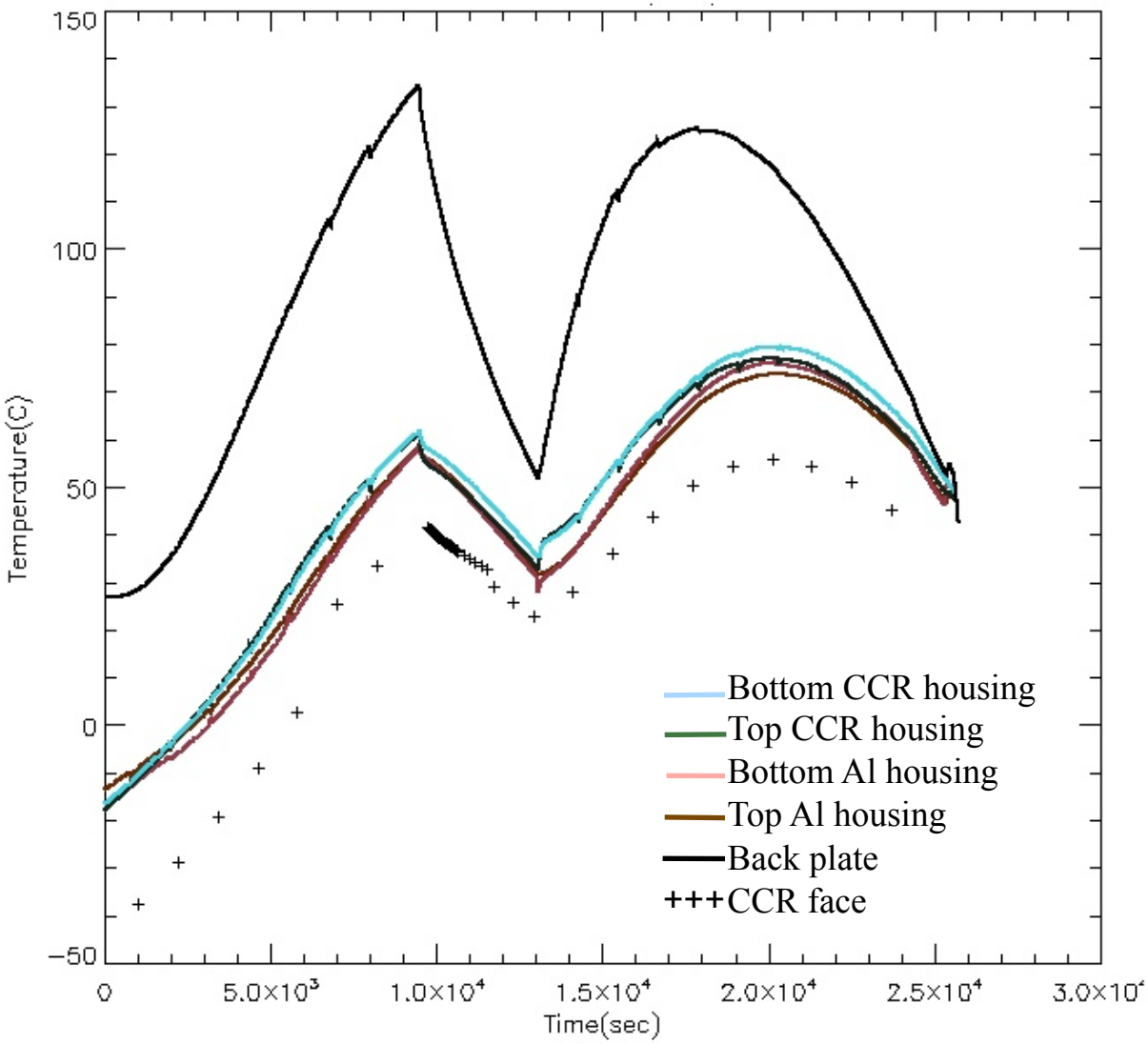


IOV CCR temperature measurements

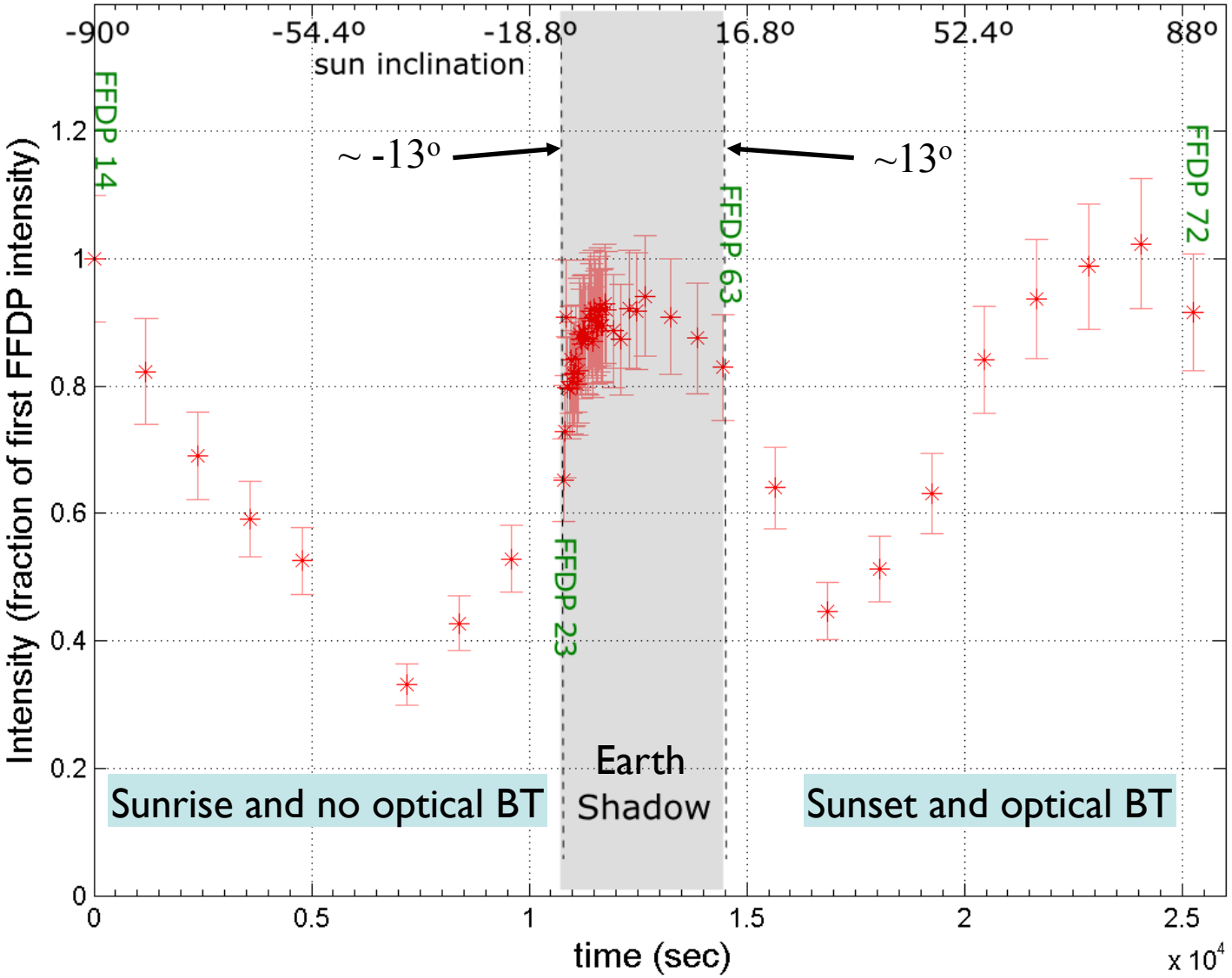
Measured temperatures vs. time (& vs. varying sun inclination):

- 2 probes on CCR housing
- 2 probes on Al housing
- 1 probe on the back-plate
- IR camera thermograms of the outer CCR face

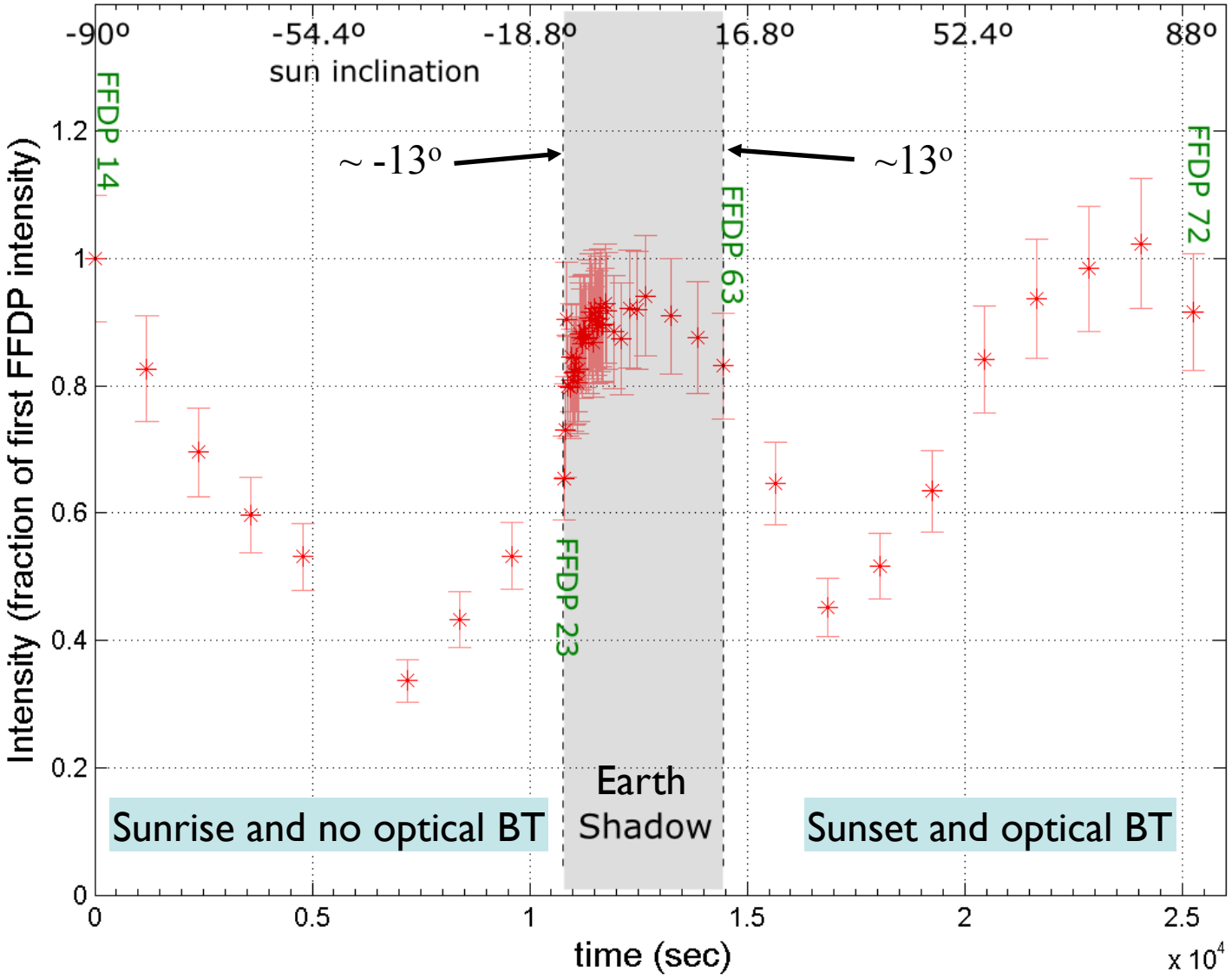
Note the very large temperature excursion, >100 K



Average relative FFDP intensity at 24 μrad

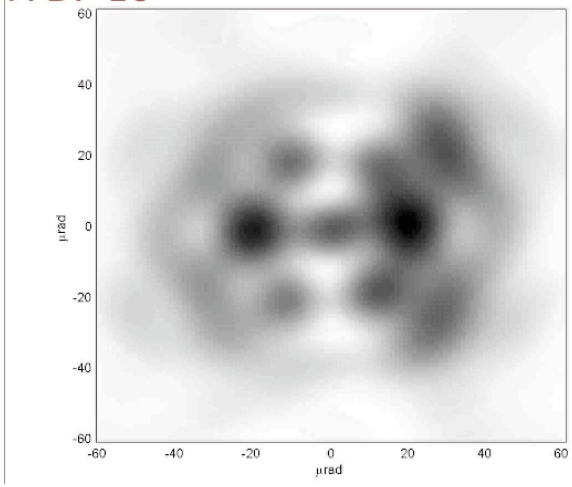


Average relative FFDP intensity in 22-26 μrad range

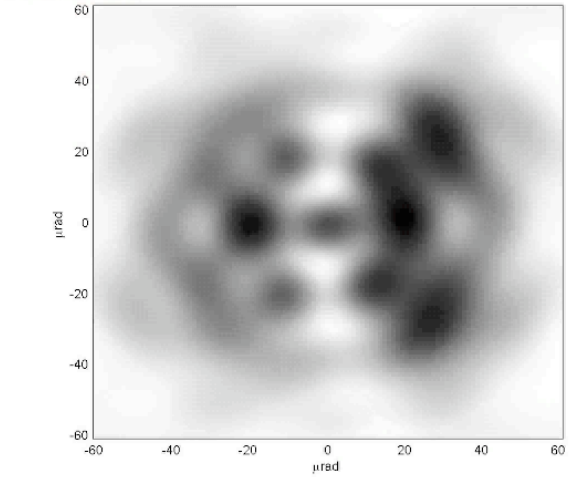


Some IOV FFDPs of previous plots

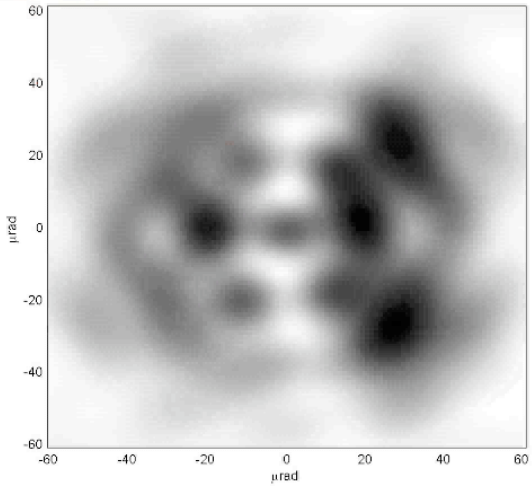
FFDP 16



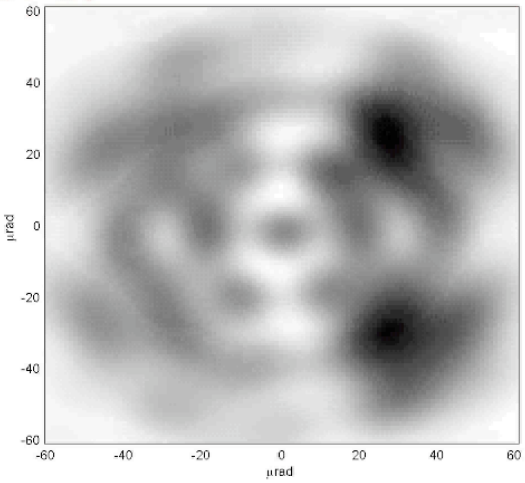
FFDP 17



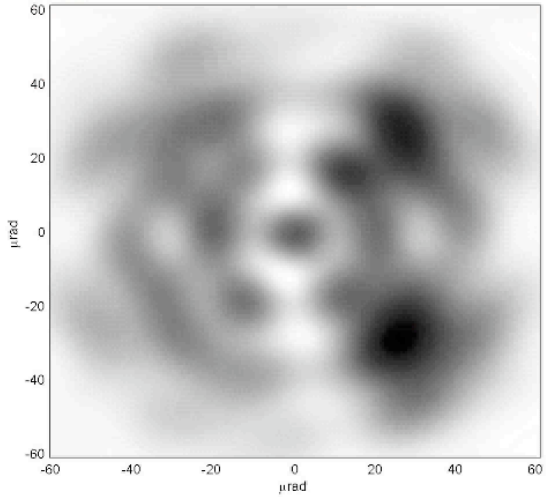
FFDP 18



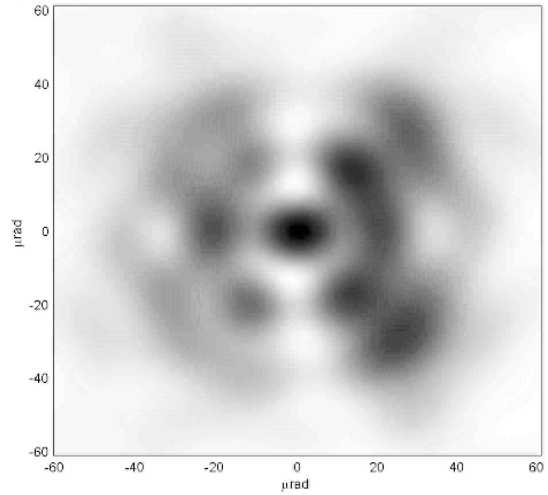
FFDP 20



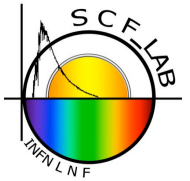
FFDP 21



FFDP 23



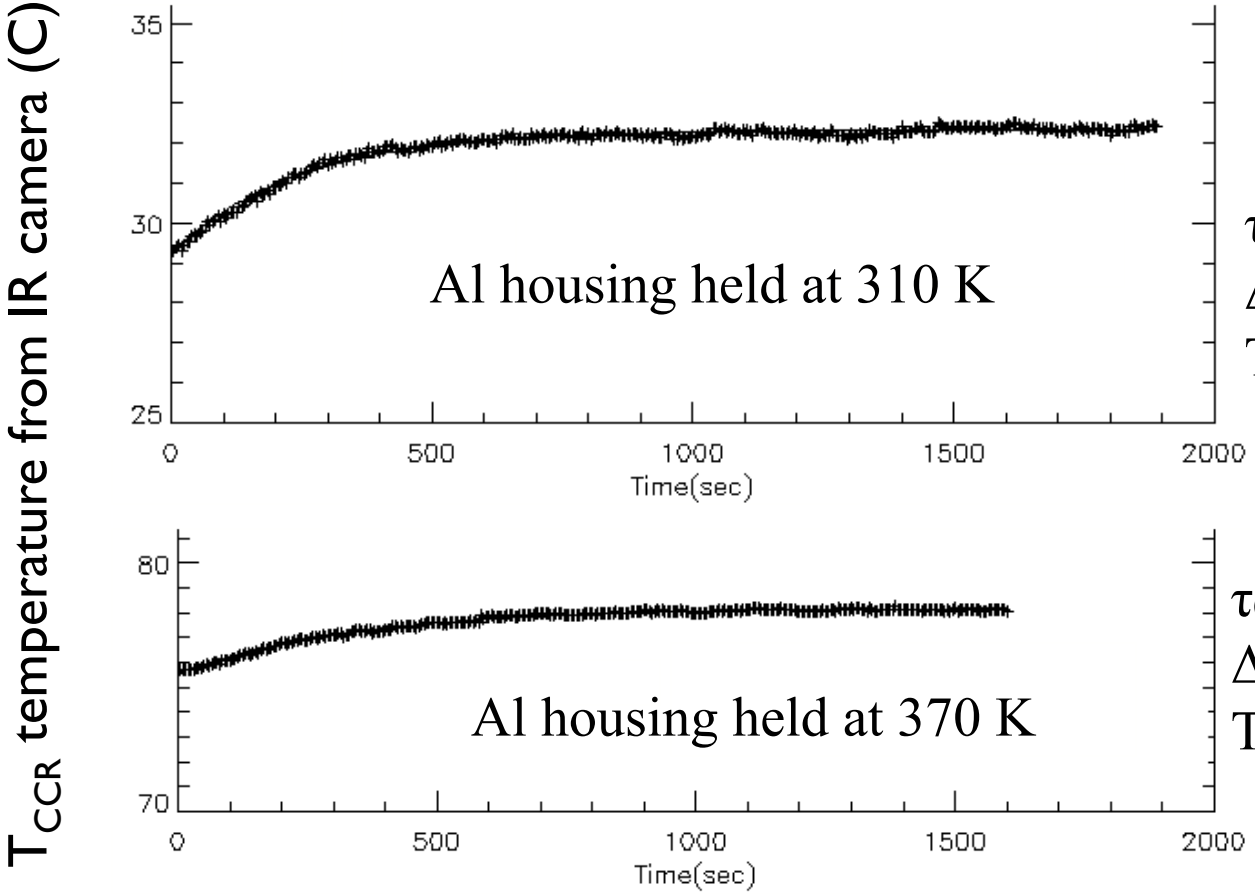
Preliminary indications & comparisons



- IOV GCO: **average** FFDP degradation ~35%
- (Uncoated) IOV FFDP degradation for 0° sun inclination (also from other SCF-Tests not reported here): ~25%

  This is ~15% for LAGEOS
- (Al-coated) GPS/GLON/GIOVE FFDP degradation for 0° sun inclination: ~ 87%, much larger than IOV
- IOV CCR shows FFDP degradation for expected optical BT inclinations > +17°, and for almost symmetric sun inclinations on the other side, < -17°, where there is no optical BT. We call this effect **"thermal BT"**
  - ✓ Thermal BT could be due to an IOV CCR mounting scheme with relatively large thermal conductance. Hypothesis can be studied with τ_{CCR} measurements reported in the following

Measurement of IOV τ_{CCR}



Exponential fits:

τ_{CCR}(T~310K)= 245 s
ΔT=3.0 °C
T_i= 25.8 °C

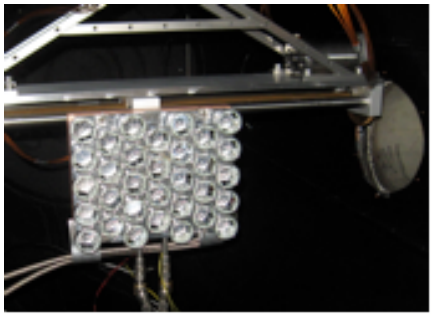
τ_{CCR}(T~370K)= 341 s
ΔT=2.6 °C
T_i= 75.5 °C

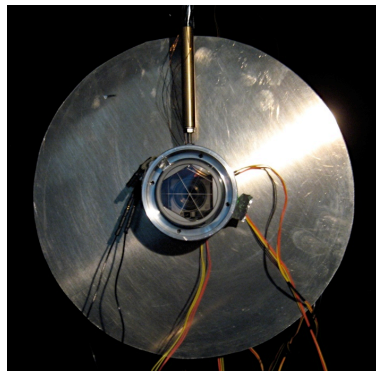
IOV τ_{CCR} increases with T of the Al-housing by ~30%

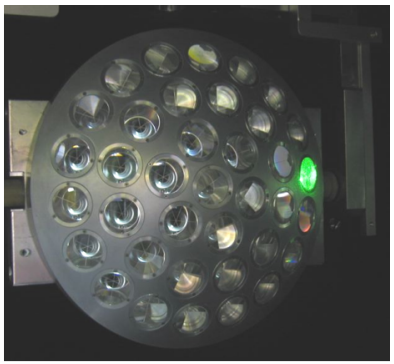
Instead, LAGEOS τ_{CCR} decreases with T of the bulk Al, as $1/T^3$

Preliminary indications from IOV τ_{CCR}

- IOV τ_{CCR}~250 sec at 310 K, shorter than previous SCF-Test measurements
  - ✓ Al-coated GPS/GLO/GIOVE CCRs of flight array and a prototype CCR: τ_{CCR}~700-1100 sec
  - ✓ Many uncoated CCRs of the LAGEOS "Sector", for which τ_{CCR}~ thousands of seconds
- IOV τ_{CCR} increases from 310 K to 370 K by ~30%; this indicates that in the CCR mounting heat conduction dominates.
- For LAGEOS we measured $\tau_{CCR} \sim 1/T^3$; this indicates that radiative heat exchange dominates in an optimized CCR mounting (confirmed by simulations)







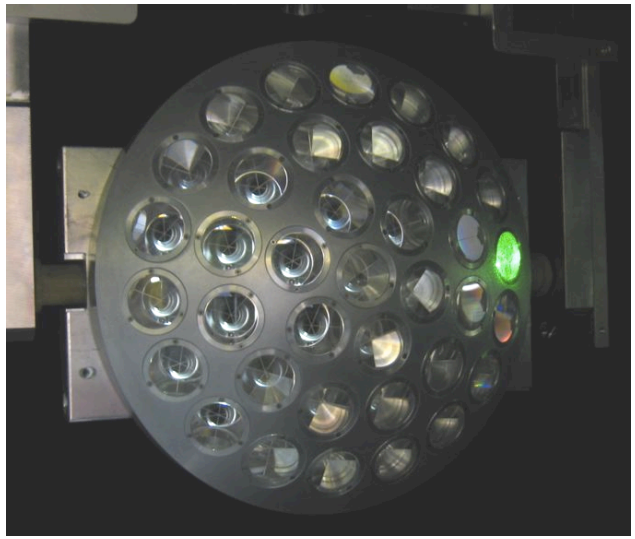
Conclusions and prospects

- New SCF-Test/Revision-ETRUSCO-2 (except for the WFI) applied to a prototype Galileo IOV CCR
- **This specific IOV CCR better than GLONASS/GPS/GIOVE**
  - Al-coating removed after 30 years
- With ESA we will SCF-Test more IOV retroreflectors
- Proposed SCF-Test of IRNSS

LAGEOS uncoated SLR payload standard

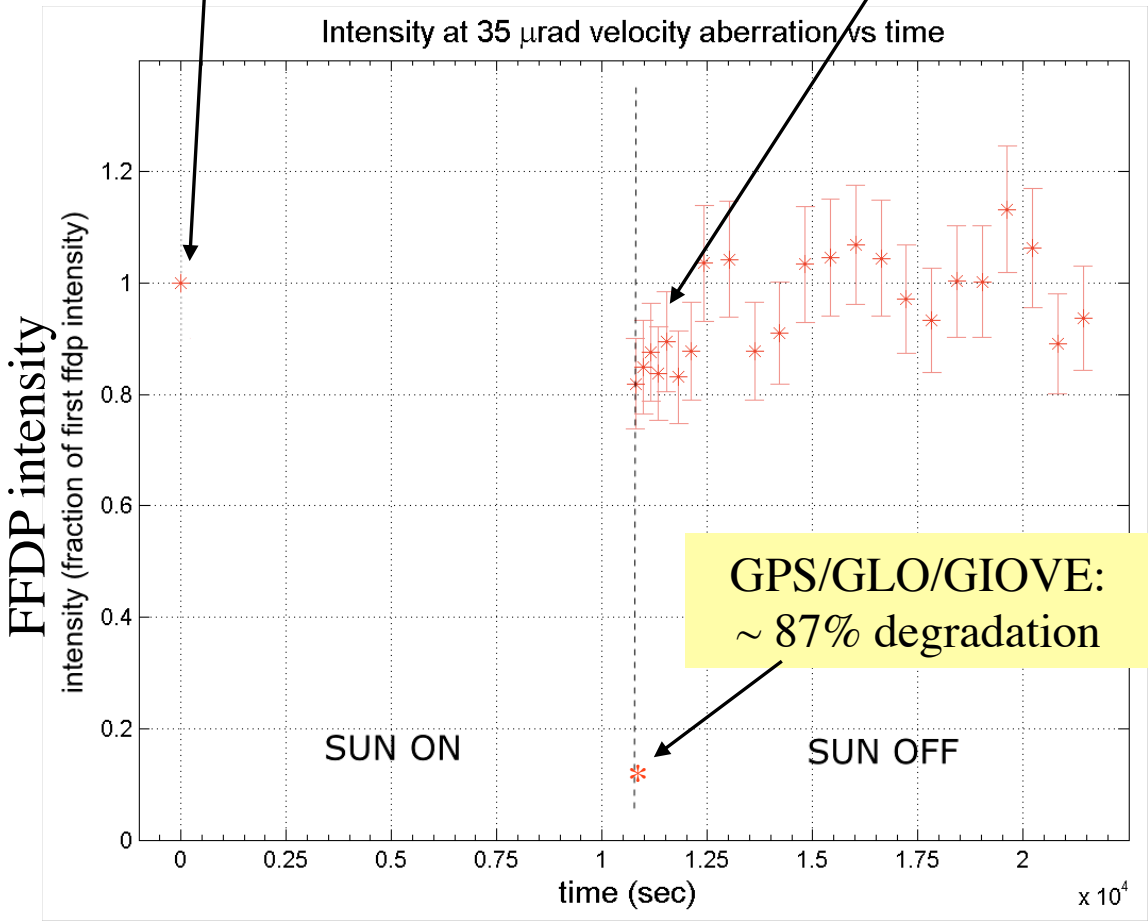
LAGEOS "Sector", engineering prototype property of NASA-GSFC. Inherits from Apollo.

SCF-Tested @300K at INFN-LNF



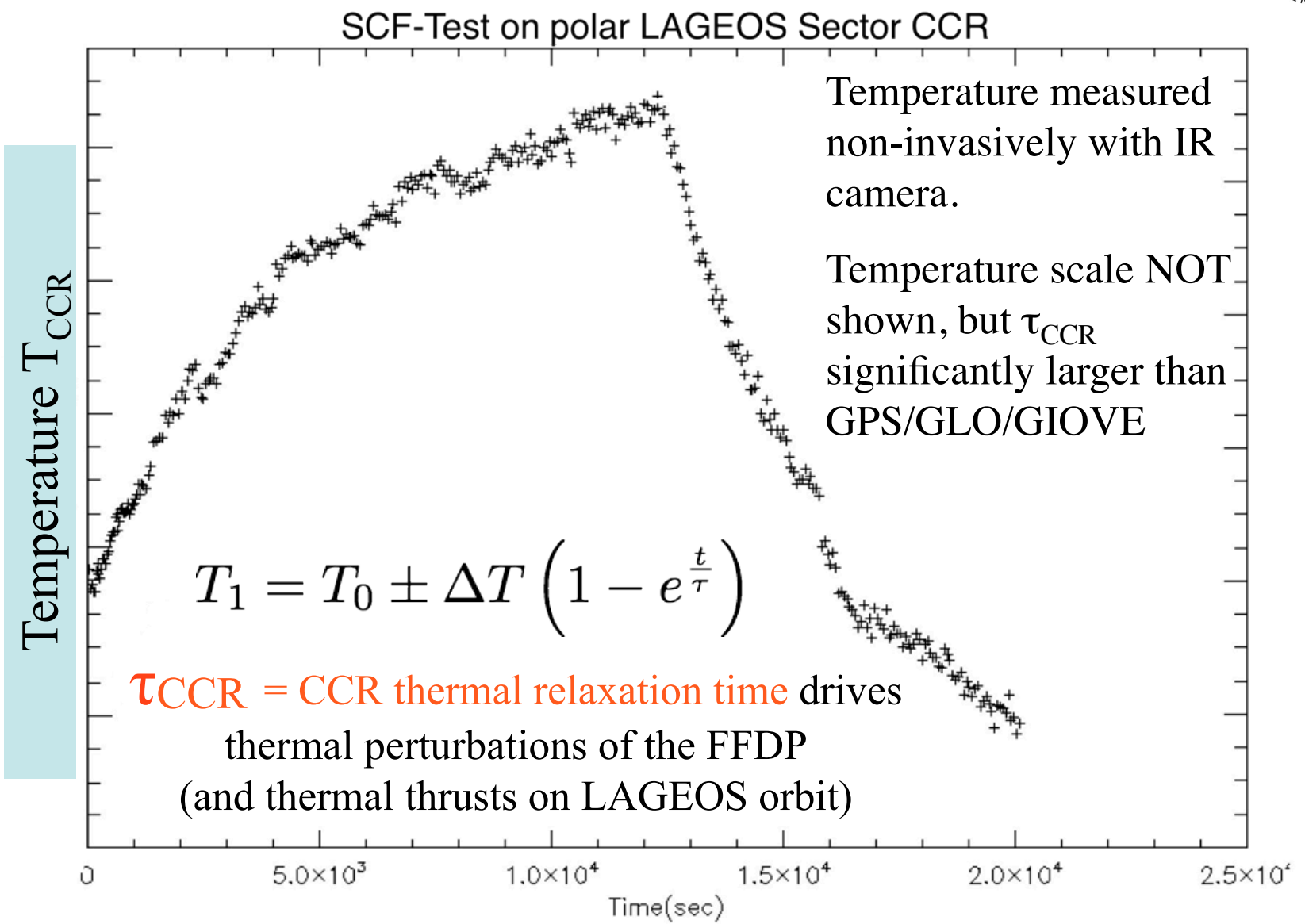
LAGEOS: laser return in space conditions not perturbed by Sun

LAGEOS: minimal degradation of laser return after 3 hr of Sun heating



GPS/GLO/GIOVE: ~ 87% degradation

LAGEOS Sector SCF-Test @300K



Temperature measured non-invasively with IR camera.

Temperature scale NOT shown, but τ_{CCR} significantly larger than GPS/GLO/GIOVE

$$T_1 = T_0 \pm \Delta T \left(1 - e^{\frac{t}{\tau}}\right)$$

τ_{CCR} = CCR thermal relaxation time drives thermal perturbations of the FFDP (and thermal thrusts on LAGEOS orbit)