Thermal-optical design and preliminary simulation for the ETRUSCO-2 GNSS Retroreflector Array

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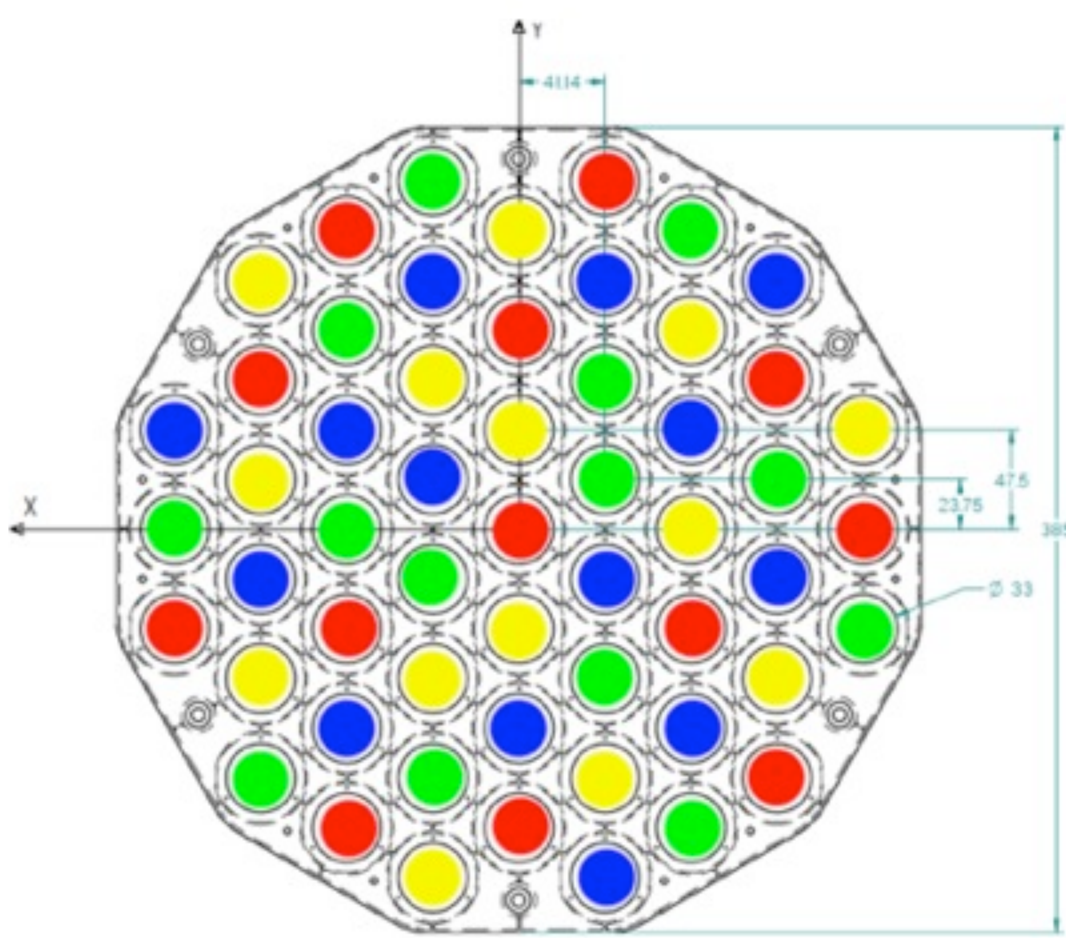
Joint ITLW-12/ ETRUSCO-2 workshop, Frascati (Italy) 07/11/2012

Outline

- GRA optical and mechanical design
- ThermaOptiSim WP for ETRUSCO-2
- Galileo simulated orbit (GCO)
- Thermal simulations
- Optical simulations
- Conclusions and future work

GNSS Retroreflector Array: GRA

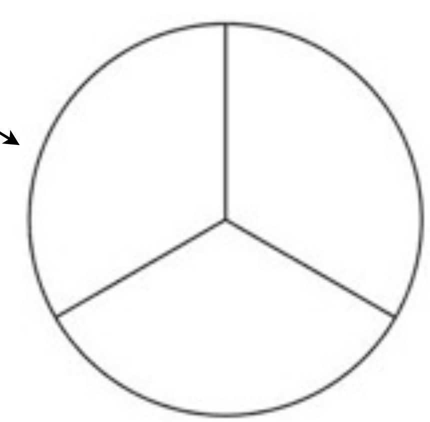
preliminary design



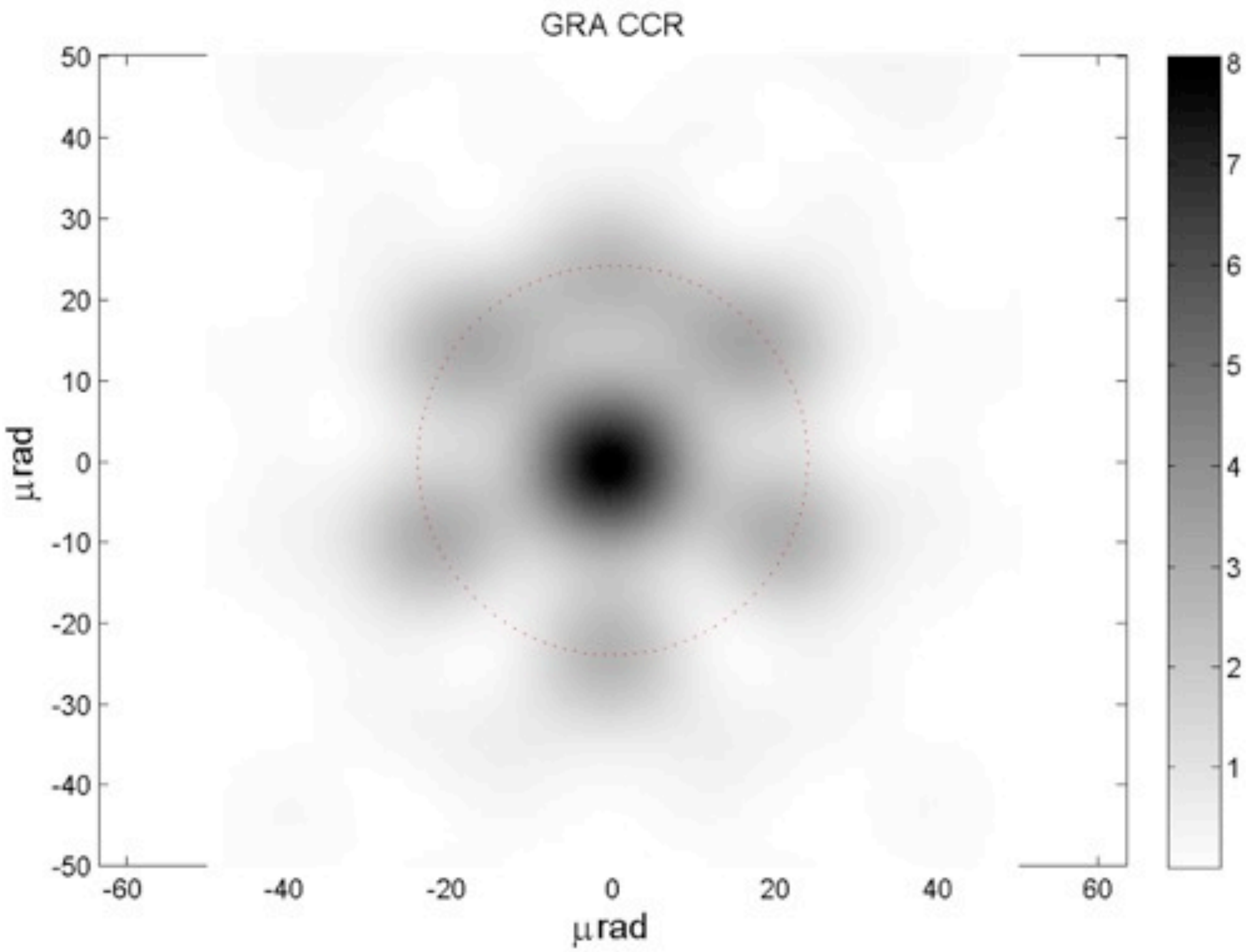
- 55 uncoated retroreflectors
- Fused Silica (Suprasil 1) CCRs with 33 mm front face diameter with DAO = 3× (0.0”±0.5”)
- LAGEOS satellite inherited mounting scheme
- Aluminum base
- Quasi circular shape
- Four azimuth orientations

CCRs random orientation:

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



GRA FFDP simulation



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

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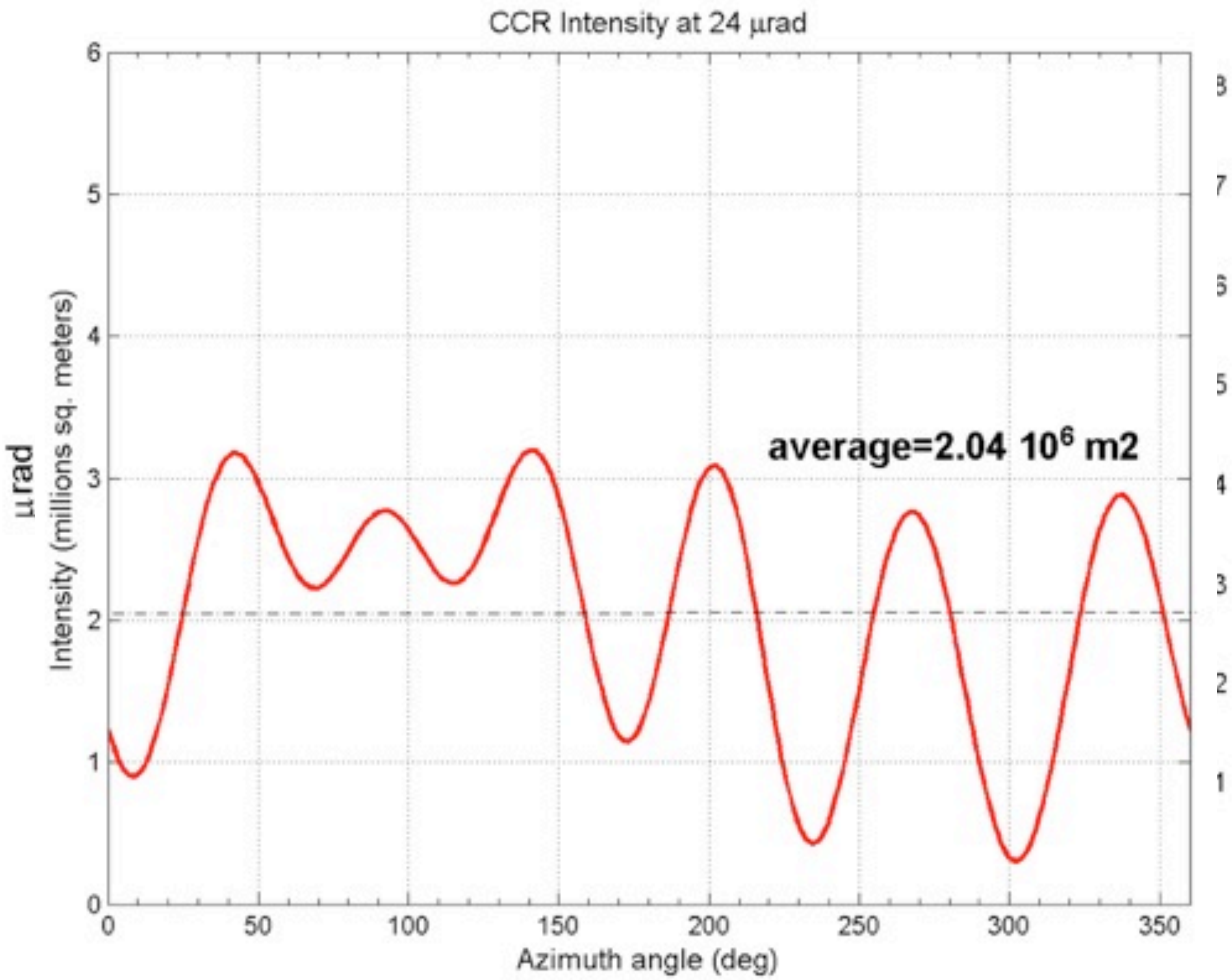

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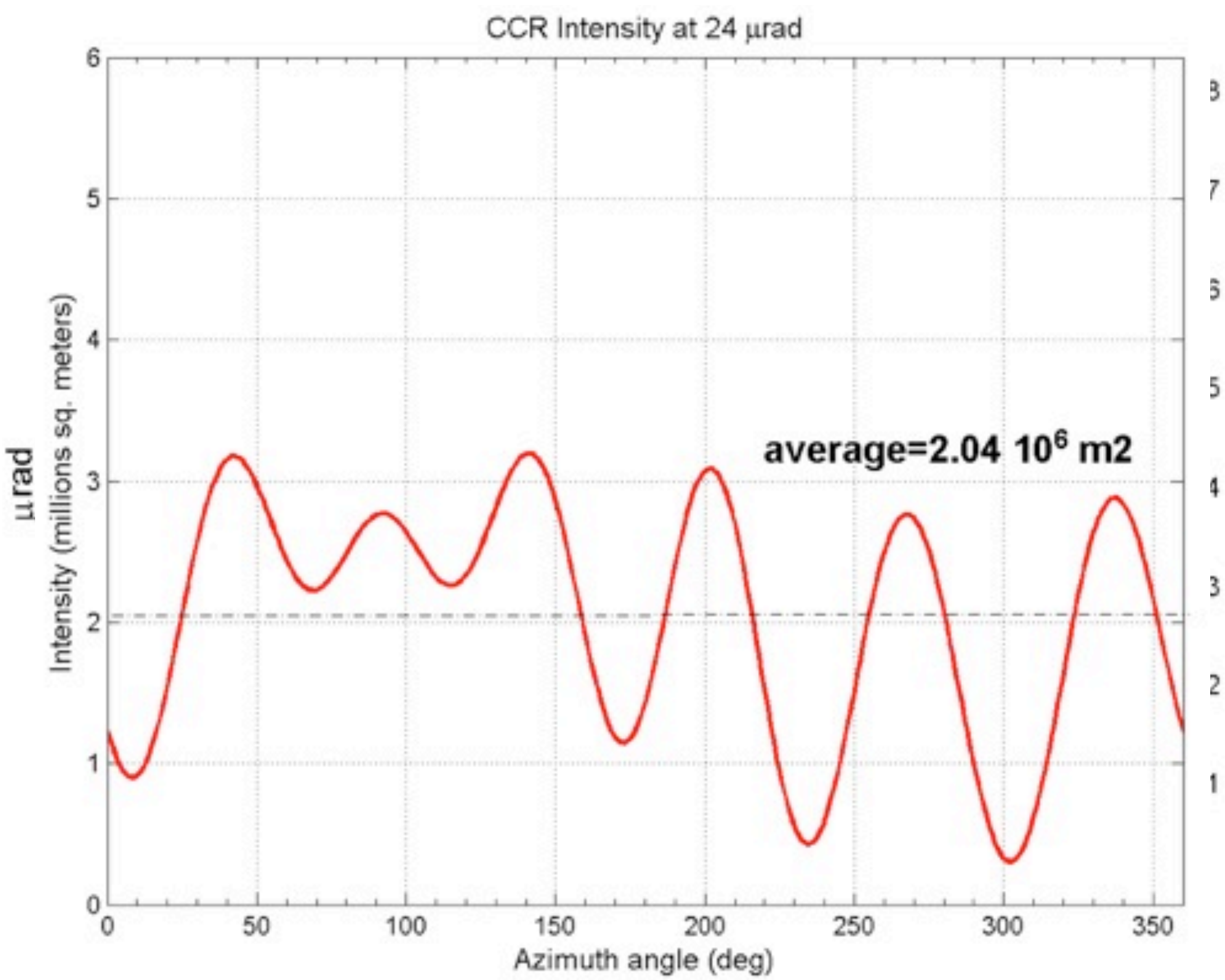

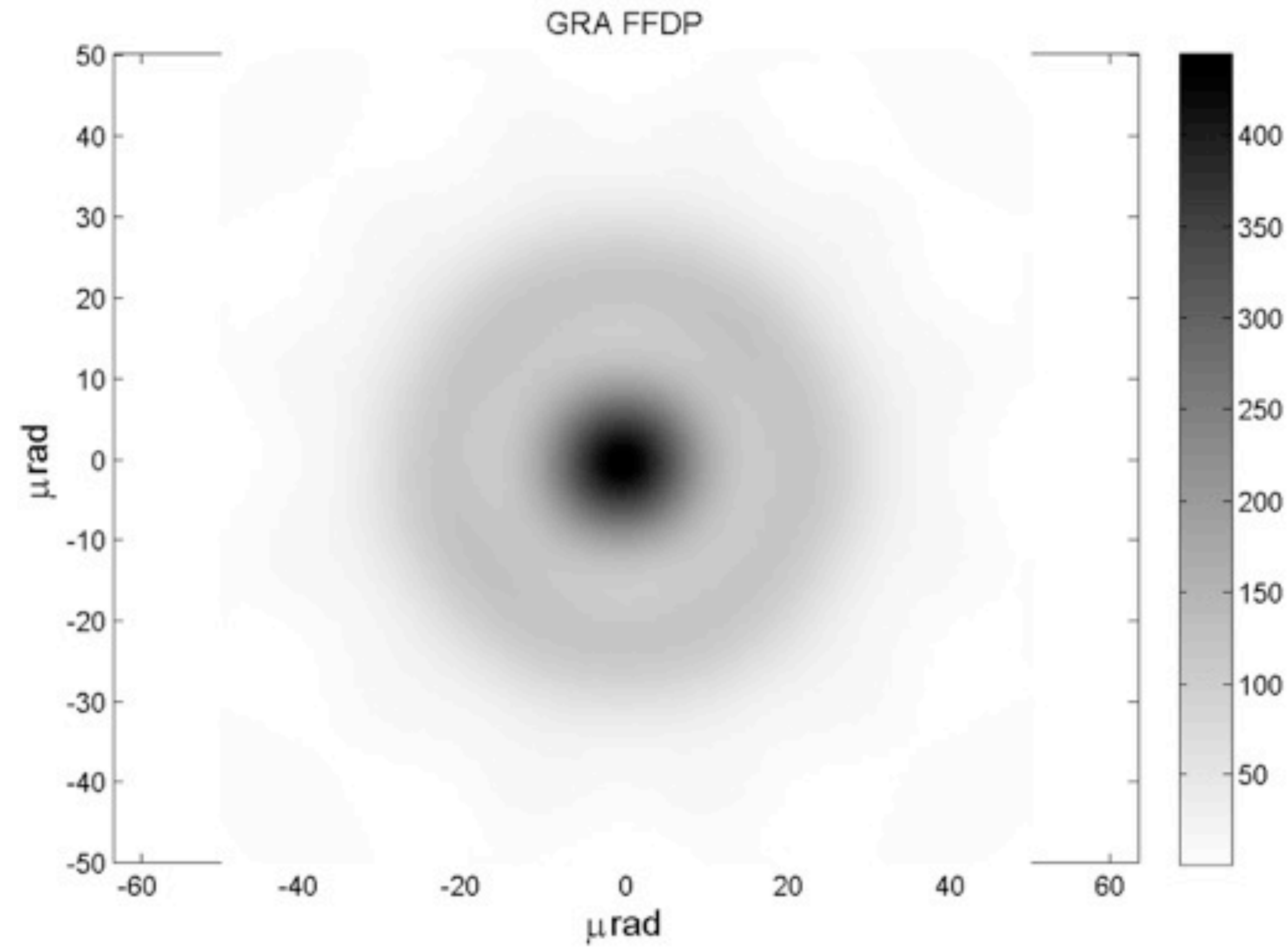

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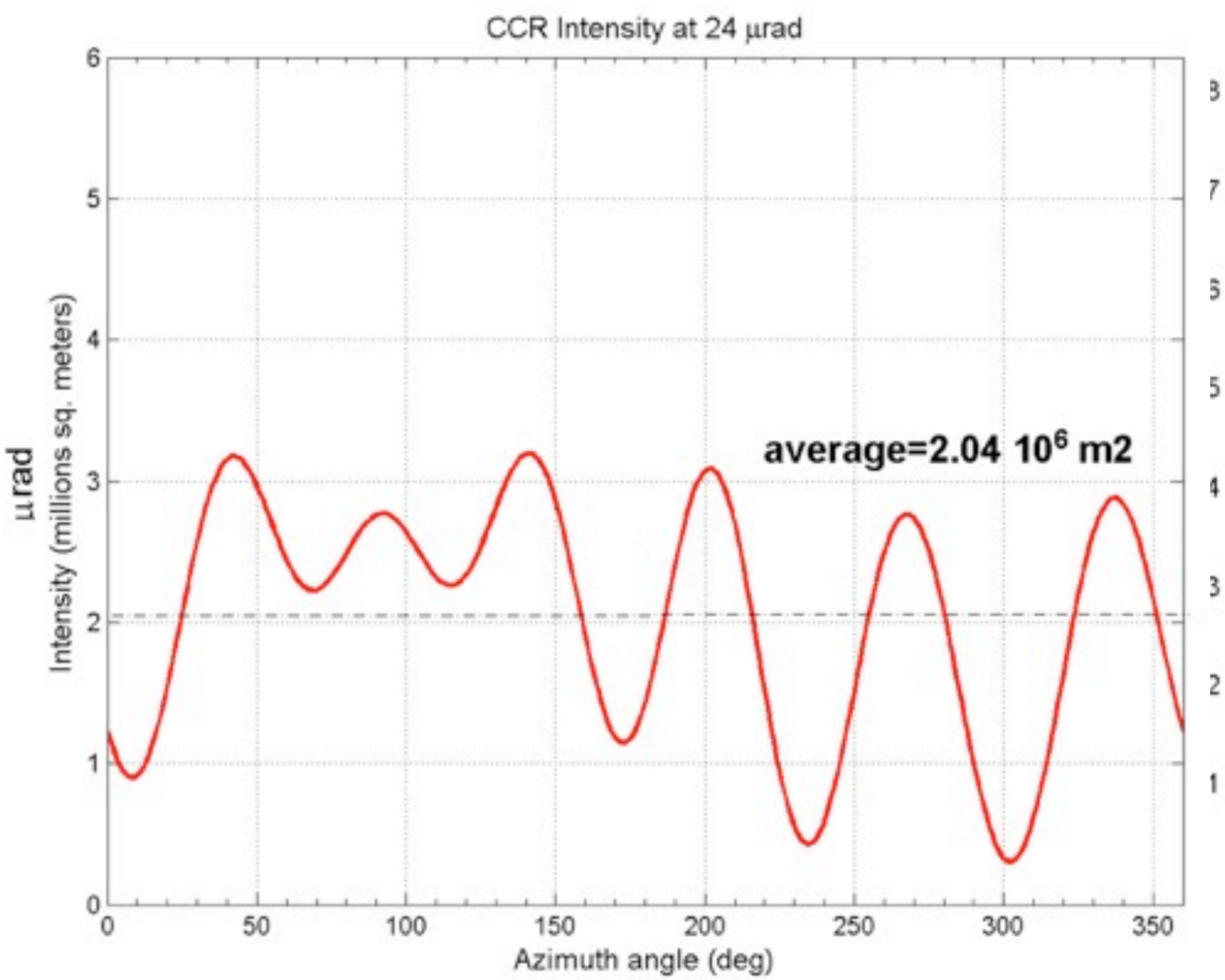

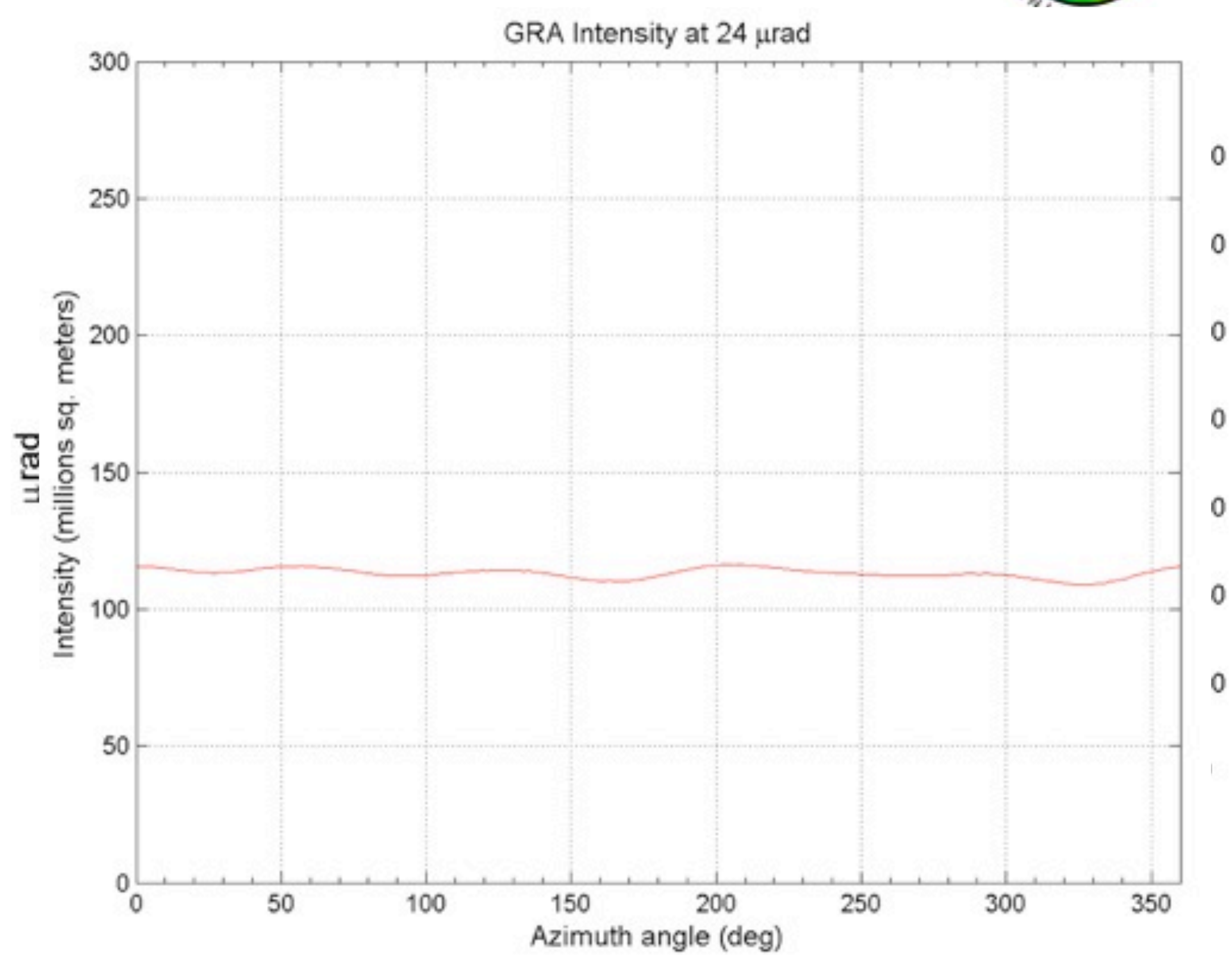

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$$Intensity\, GRA = 113 \cdot 10^6\, m^2 \text{ (OCS)}$$

ThermaOptiSim

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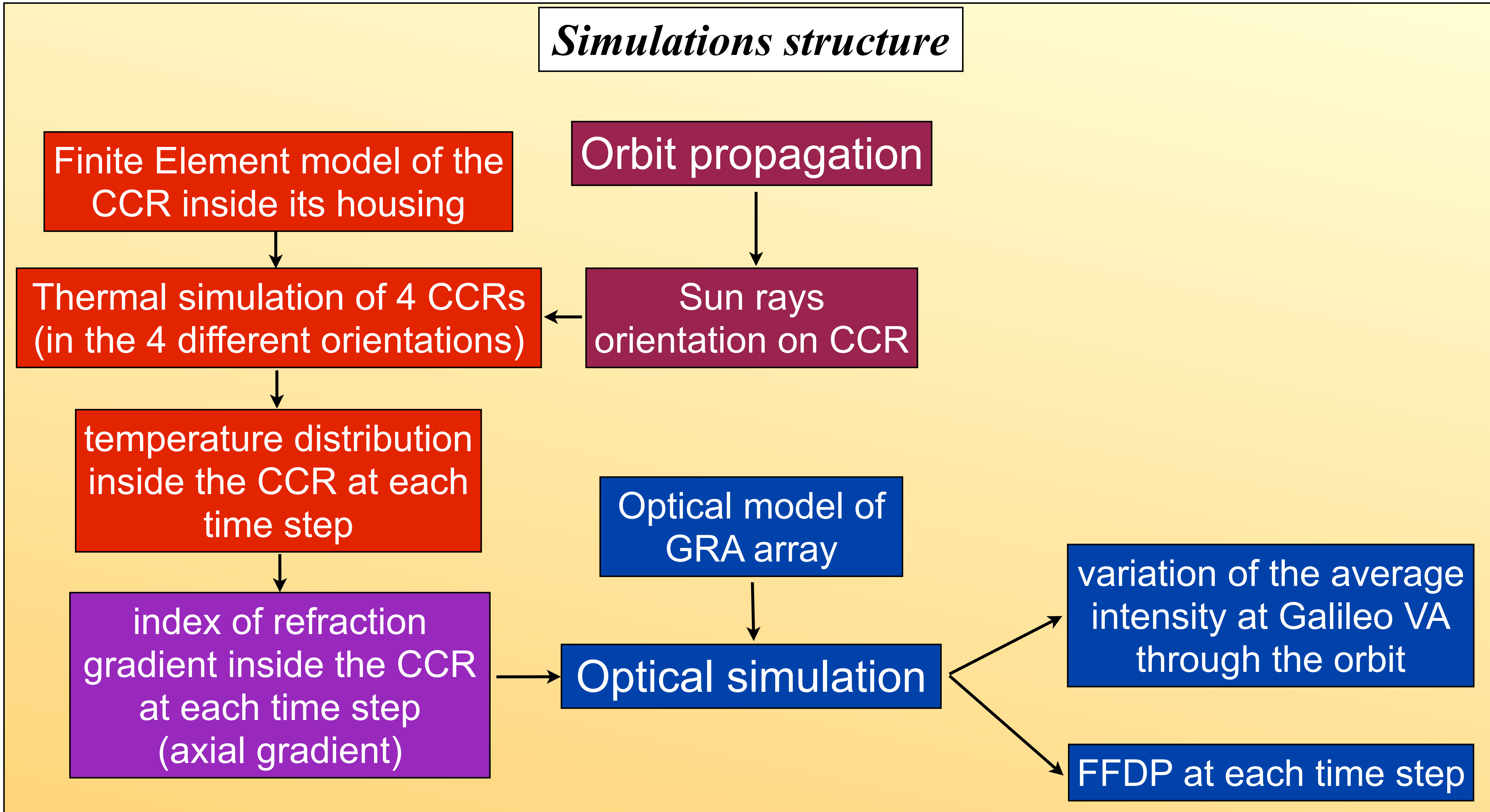

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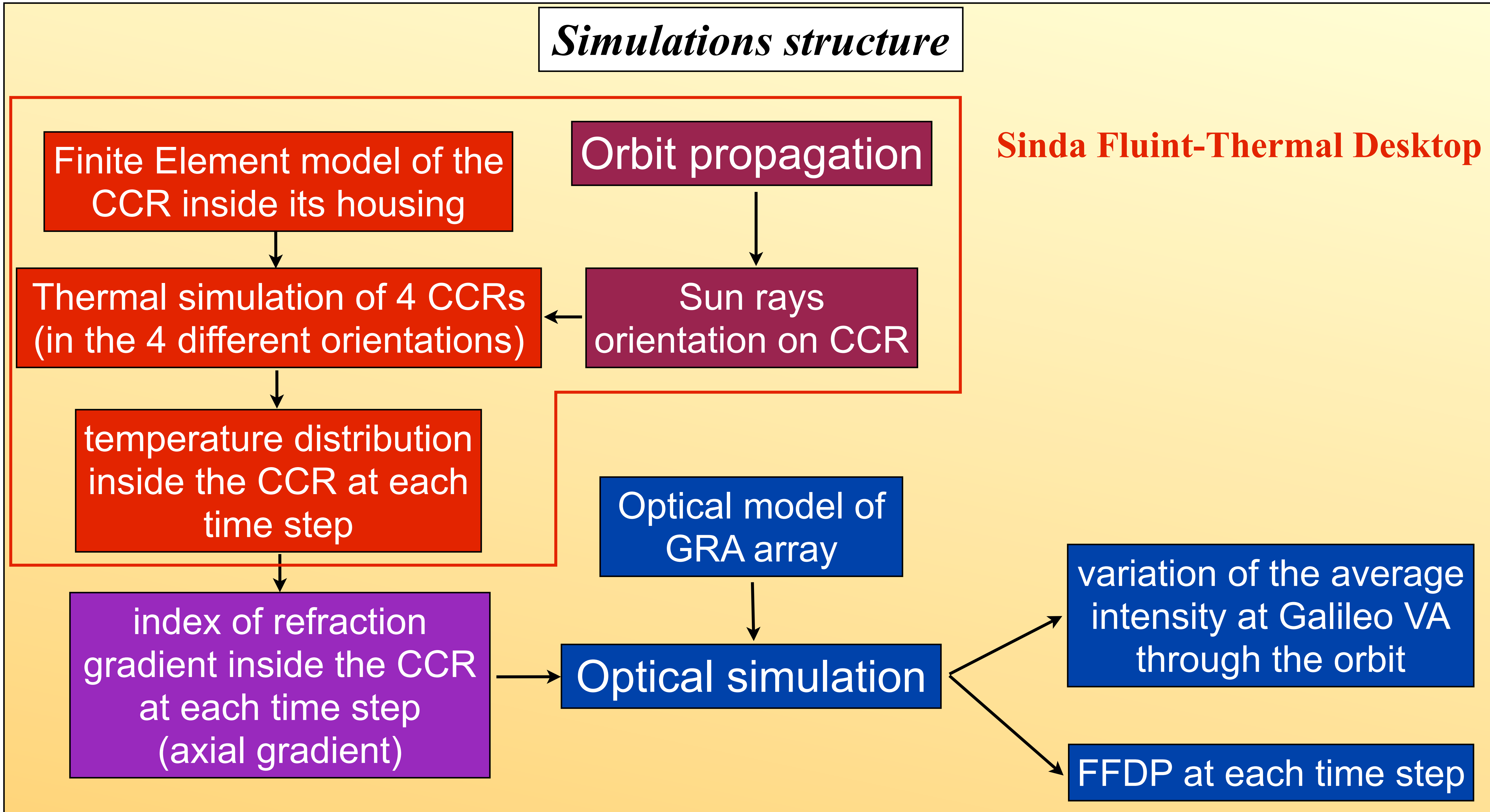

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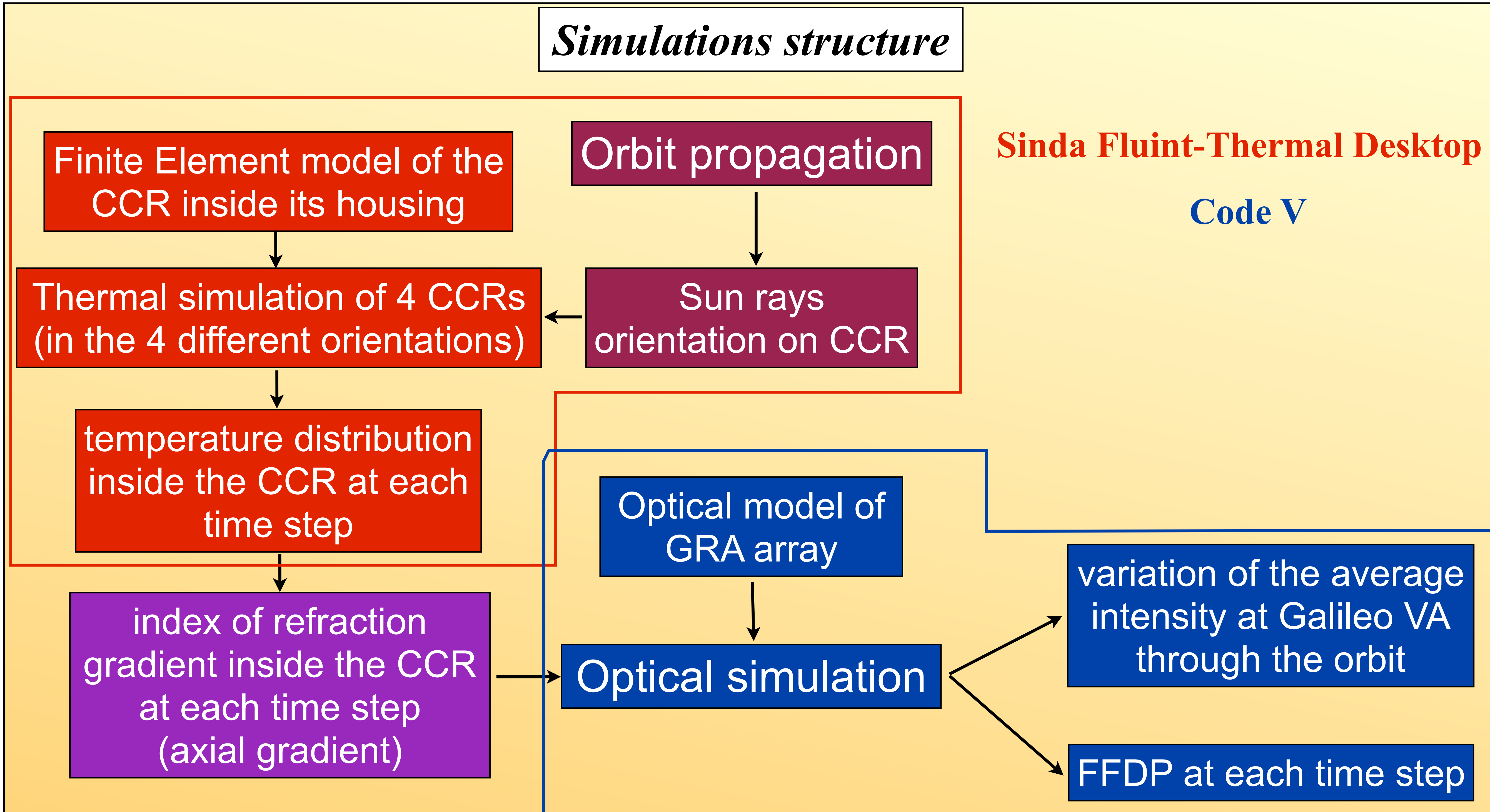

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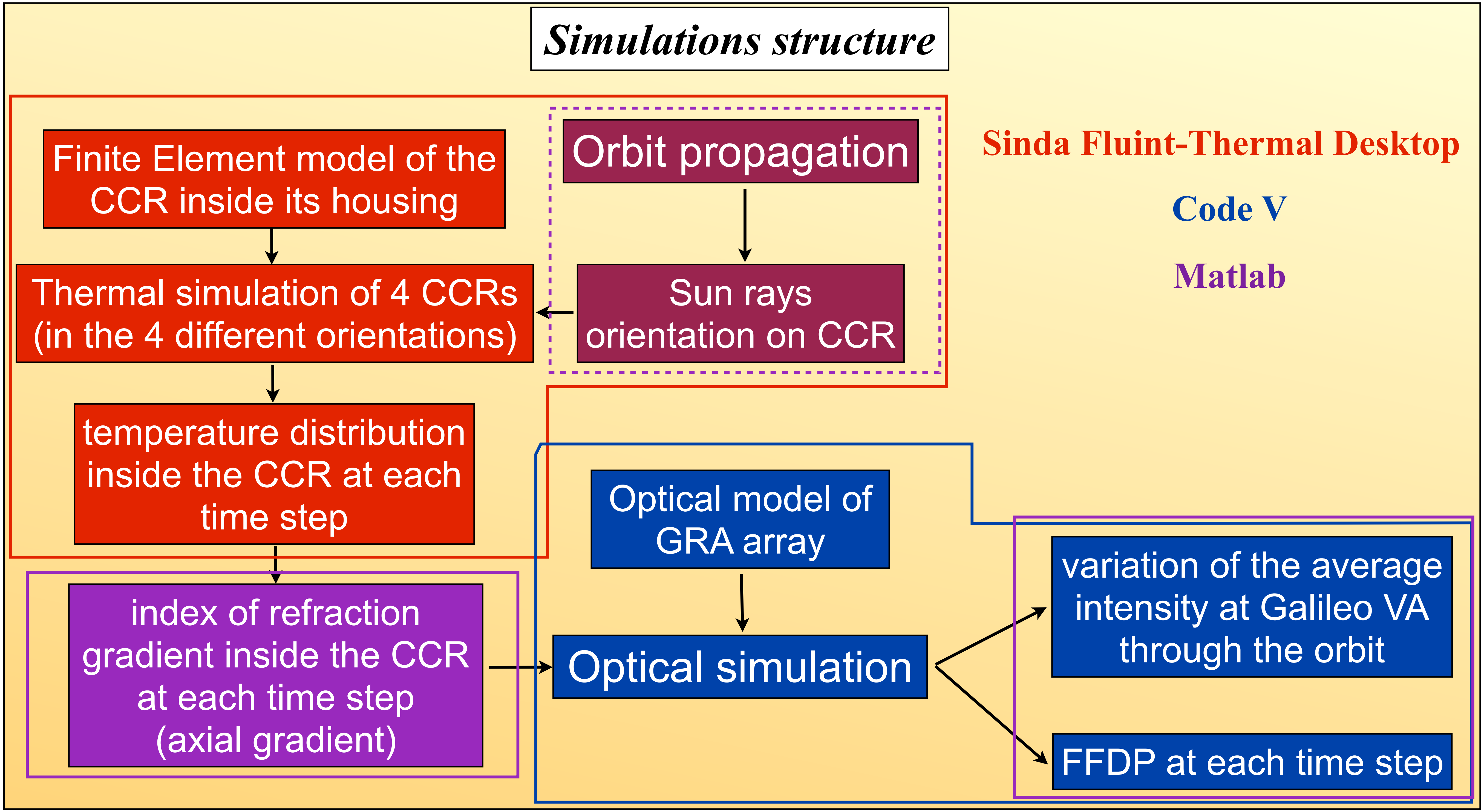
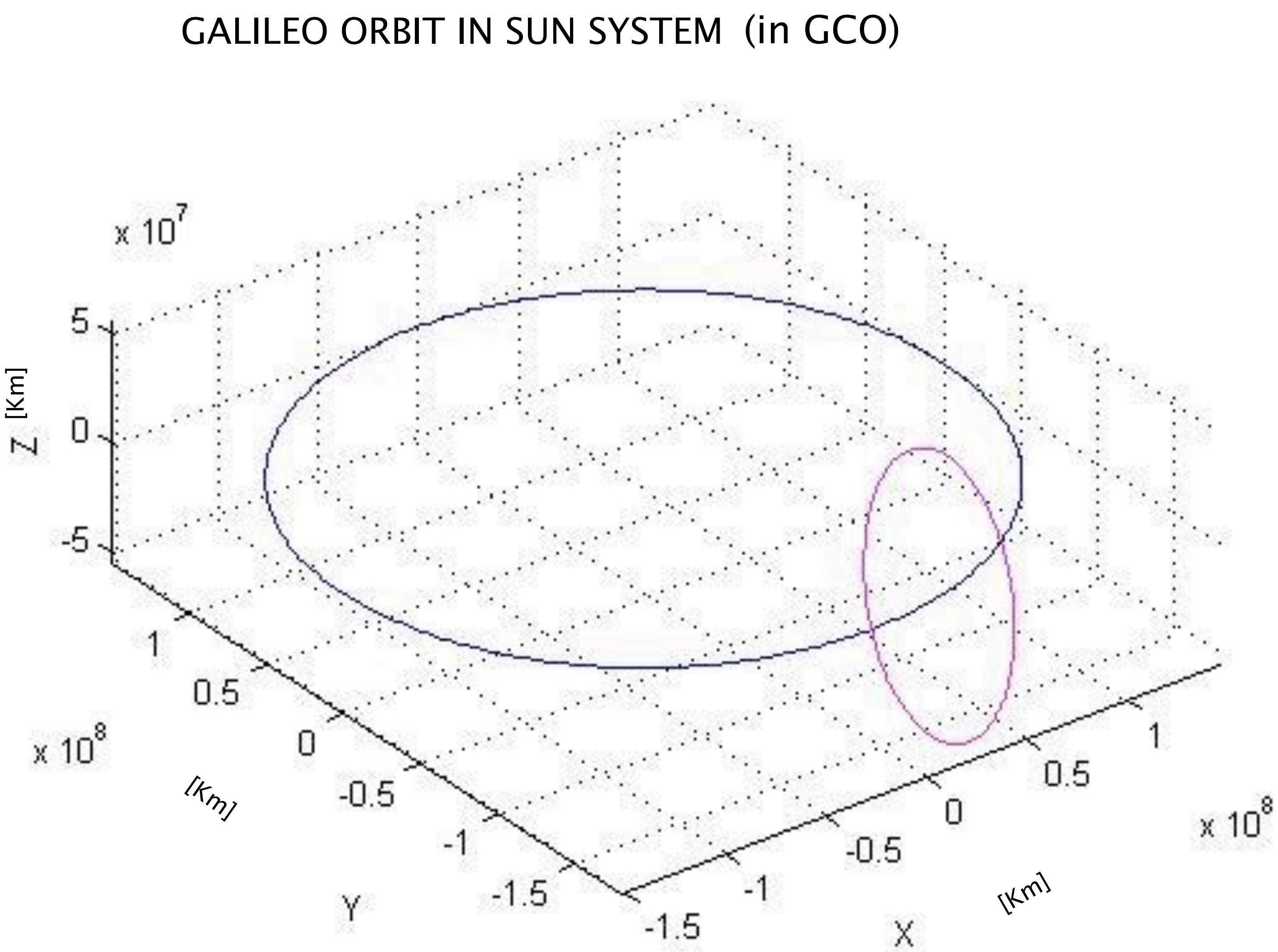


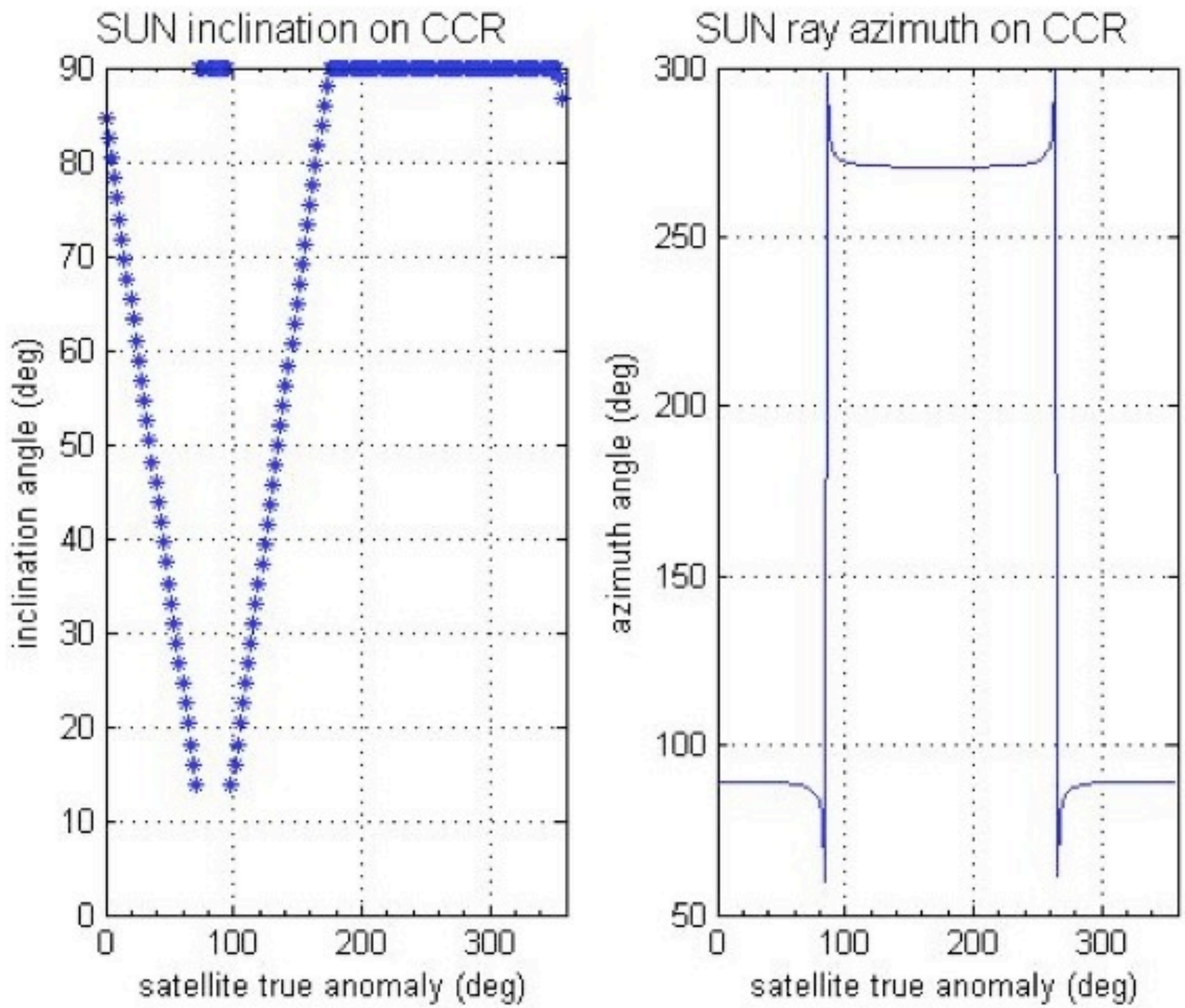
Galileo simulated orbit

- $a = 29600$ Km
- $e = 0.005069$
- $i = 54.7526^o$
- $\Omega = 123.2477^o$
- $\omega = 295.6757^o$
- $t_p = 0$ s



GCO Simulation

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



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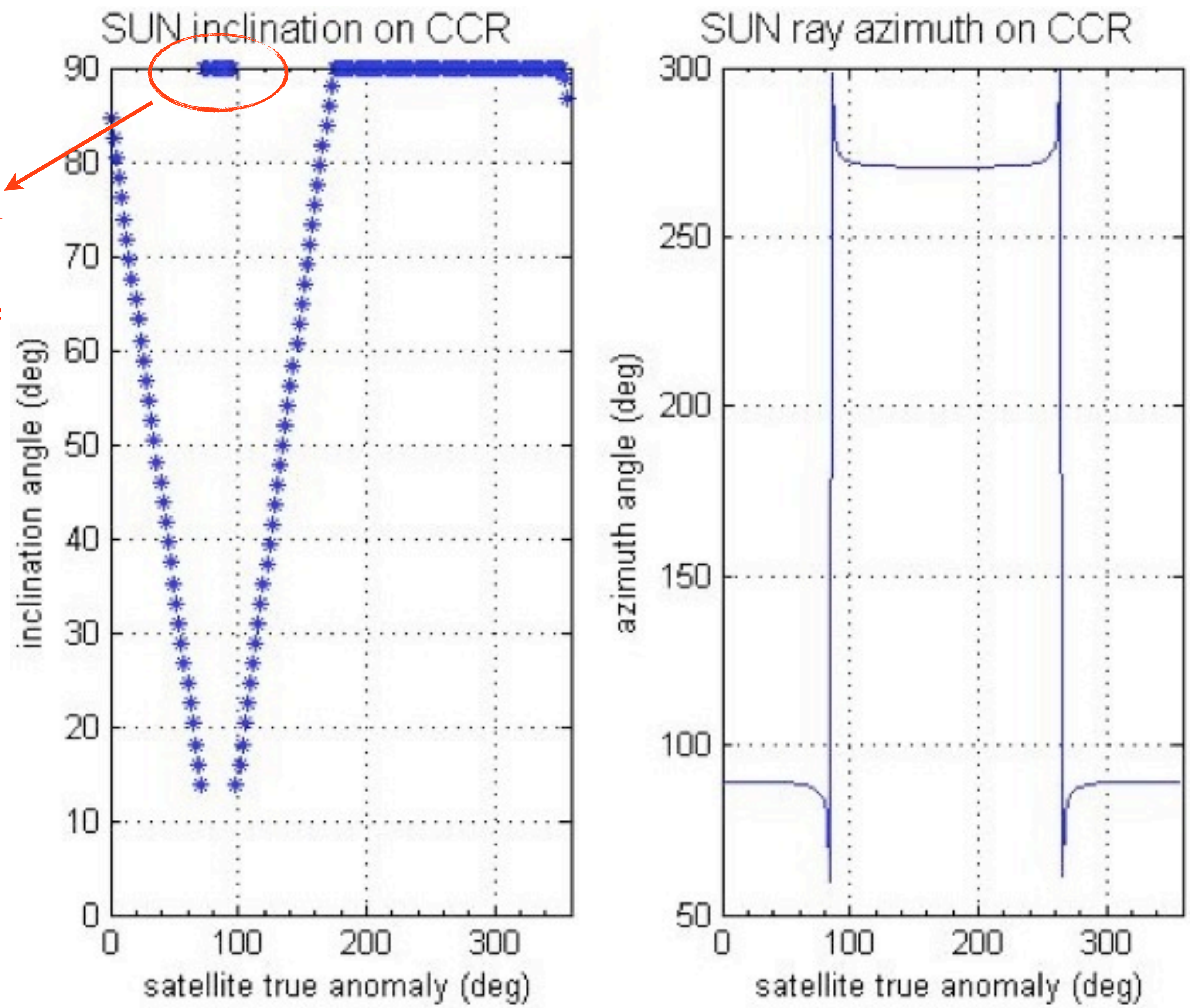
When the CCR enters the Earth shadow Sun rays do not hit the CCR, so in the simulation the inclination is set to 90°.



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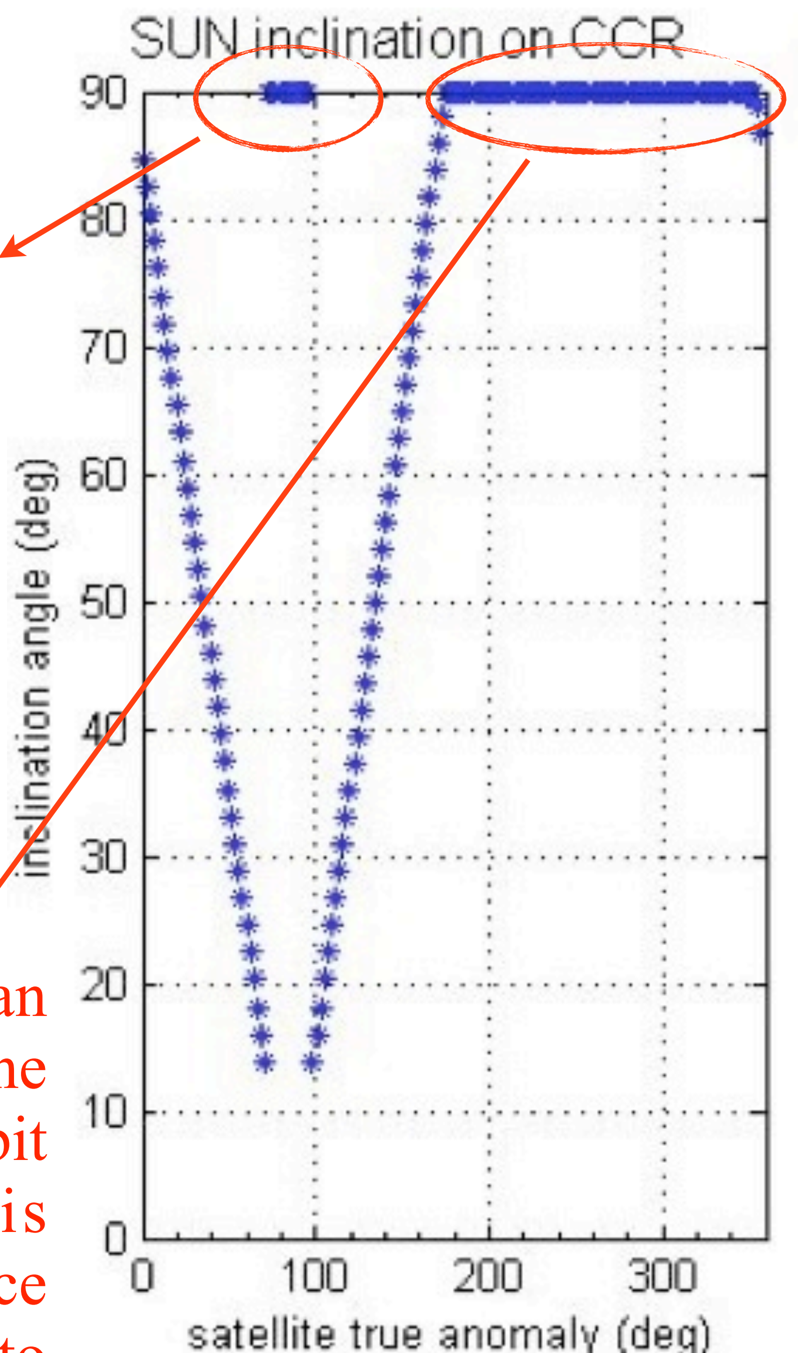

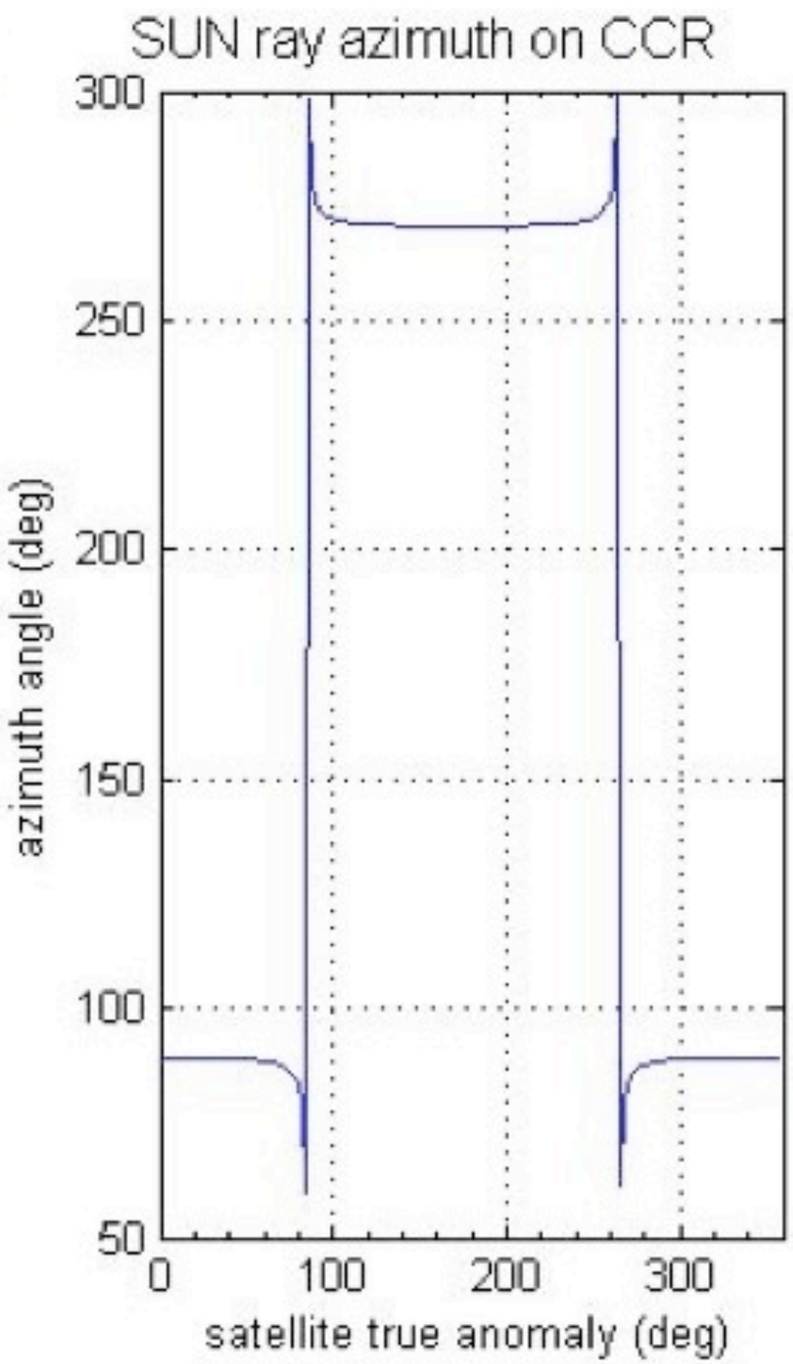

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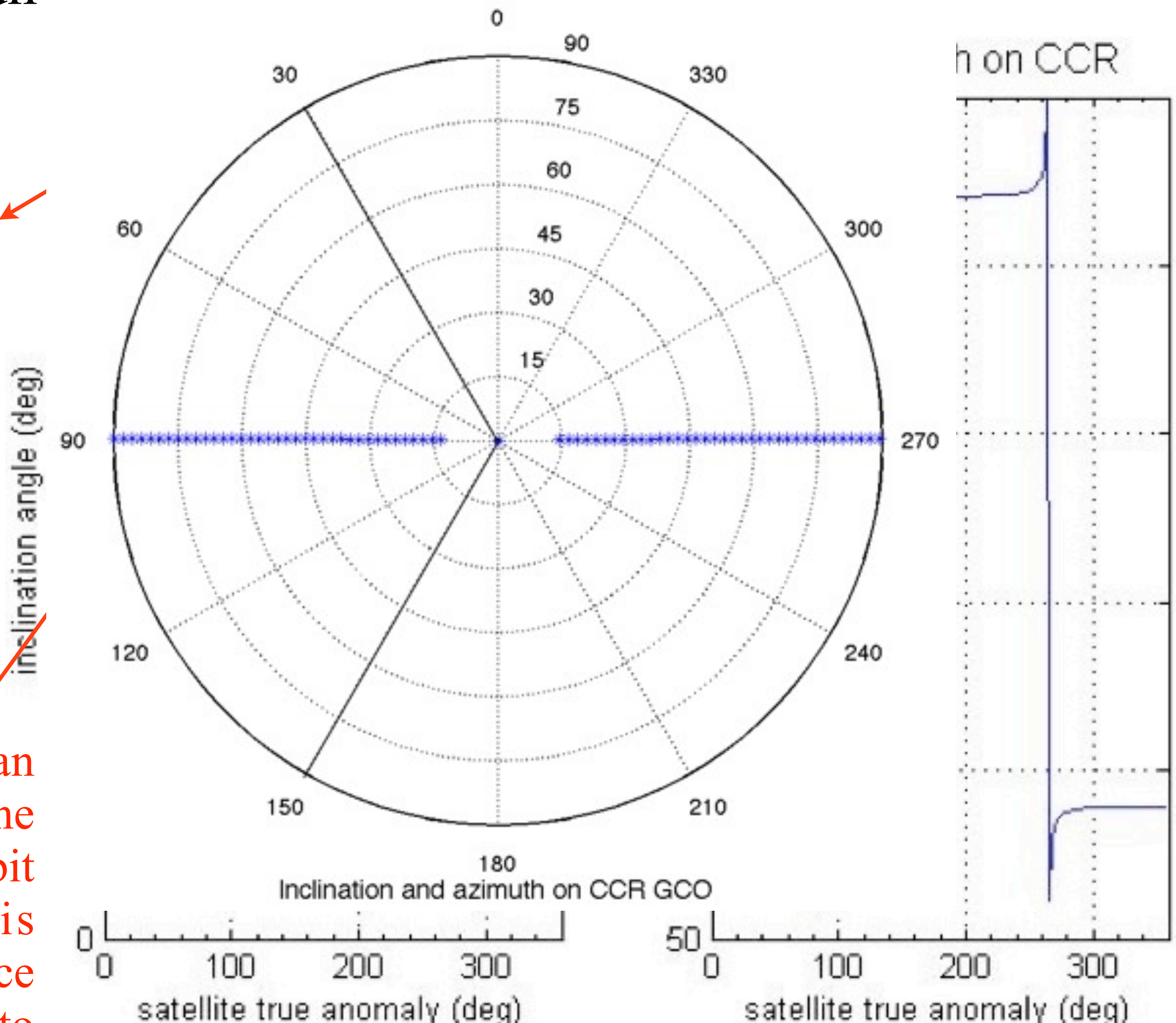

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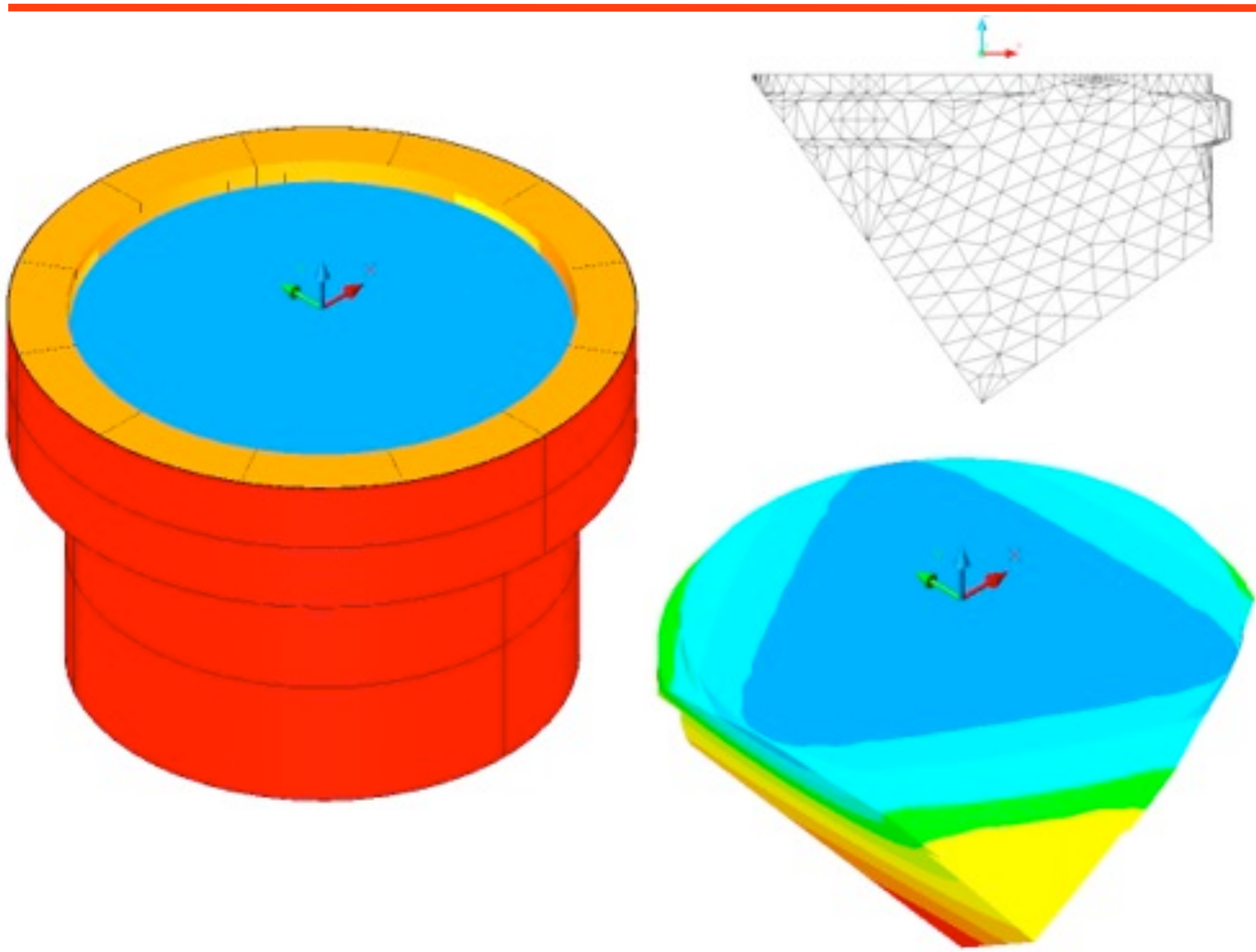
Thermal Simulations



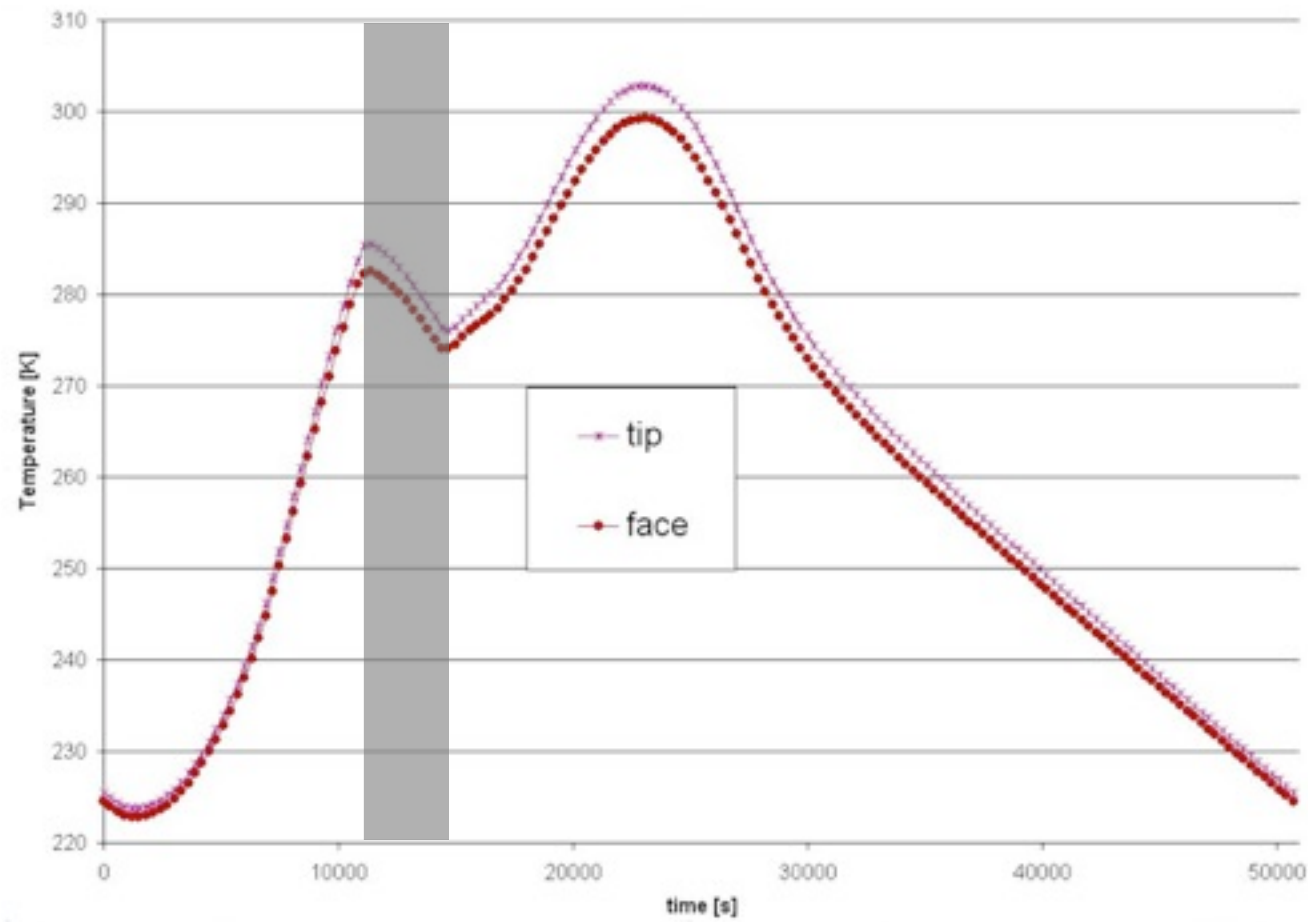
A finite element model of the GRA retroreflector is simulated inside a LAGEOS-like housing, in four different orientations w.r.t orbit plane.

Thermal response is simulated over the entire GCO.

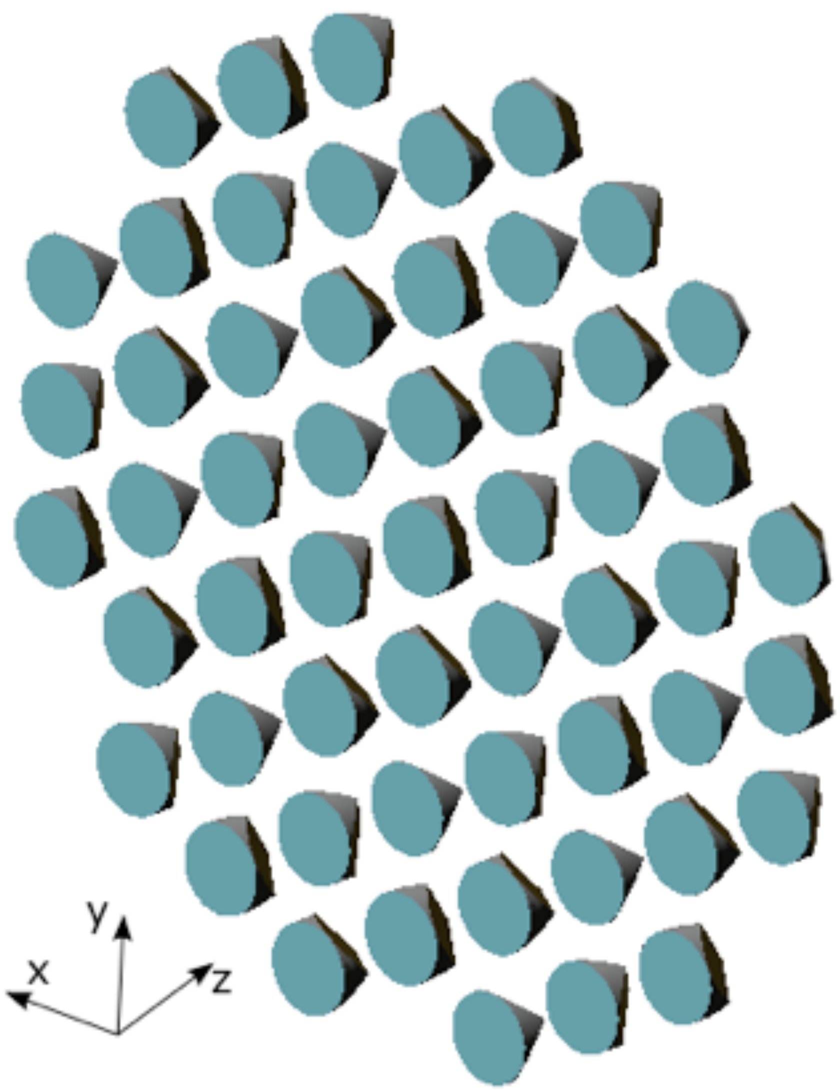
Output of the simulation is the temperature distribution inside the CCR at each time steps of the simulated orbit.

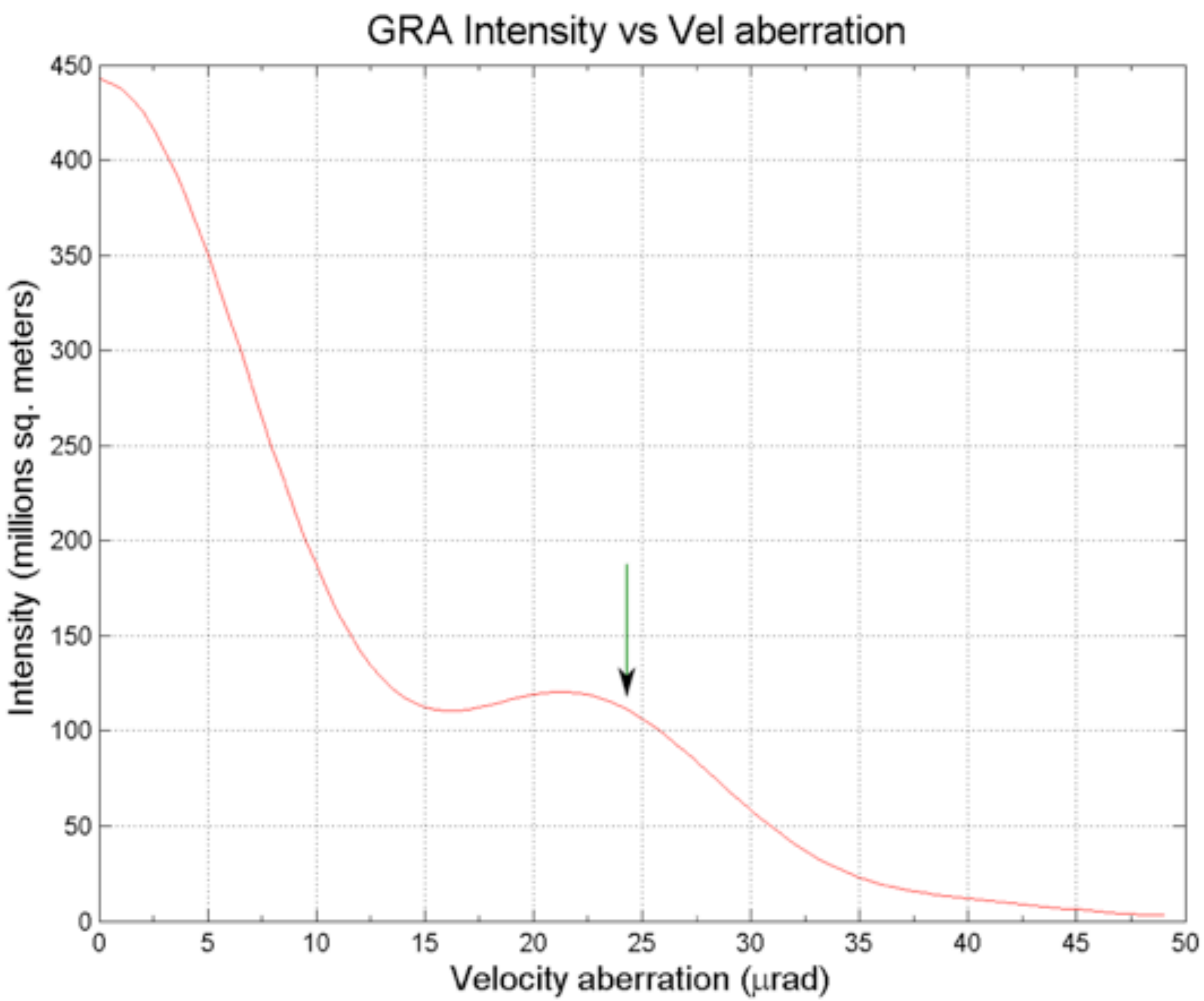
The temperature distribution is simplified in a temperature (index of refraction) gradient over the axis of the CCR.

$$T(z) = p_0 + p_1 z^4 + p_2 z^3 + p_3 z^2 + p_4 z$$



GRA optical model in CodeV

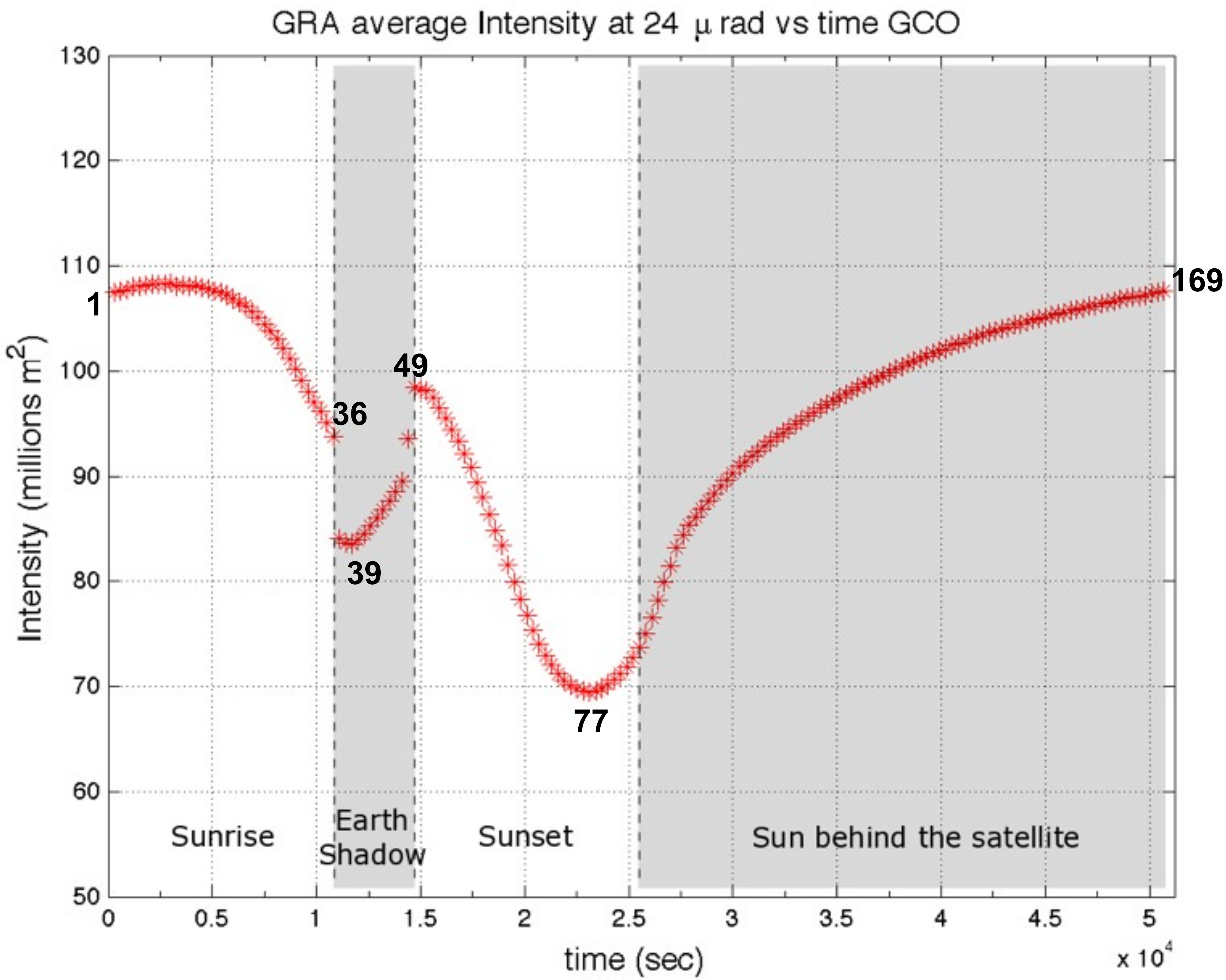




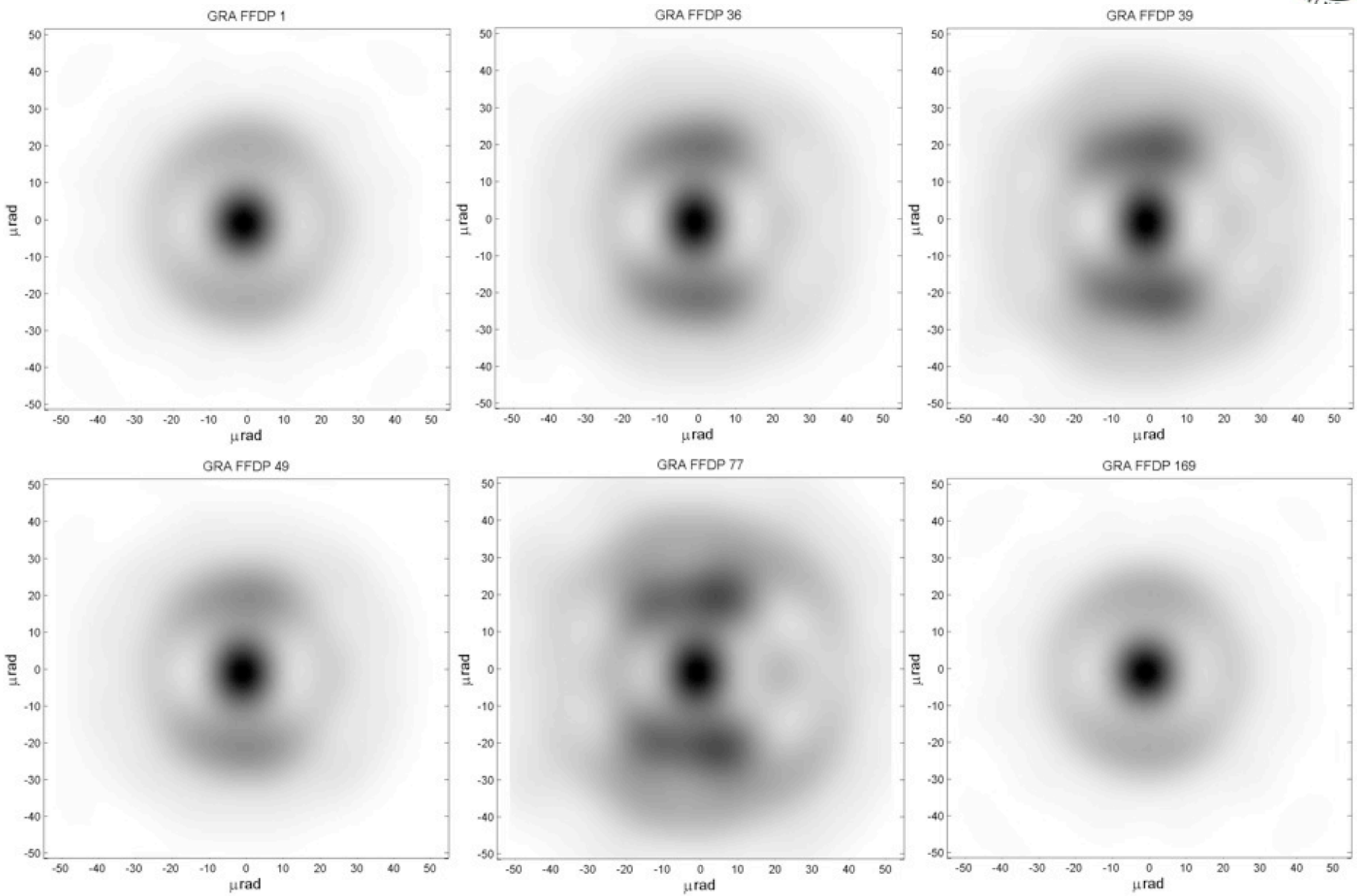
$$n(z) = a_0 + a_1 z^4 + a_2 z^3 + a_3 z^2 + a_4 z$$

Introduced in each CCR the thermal perturbation and simulated the FFDP for each time step. Output is the evolution of average intensity over the orbit.

GRA GCO optical behaviour



GRA FFDP variation



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- lower or no thermal BT (compared to preliminary SCF-Test of Galileo IOV CCR); in fact simulations of GRA in the GCO show no thermal breakthrough (!) and reduced optical degradation due to optical breakthrough compared to IOV (~37% instead of ~55%)

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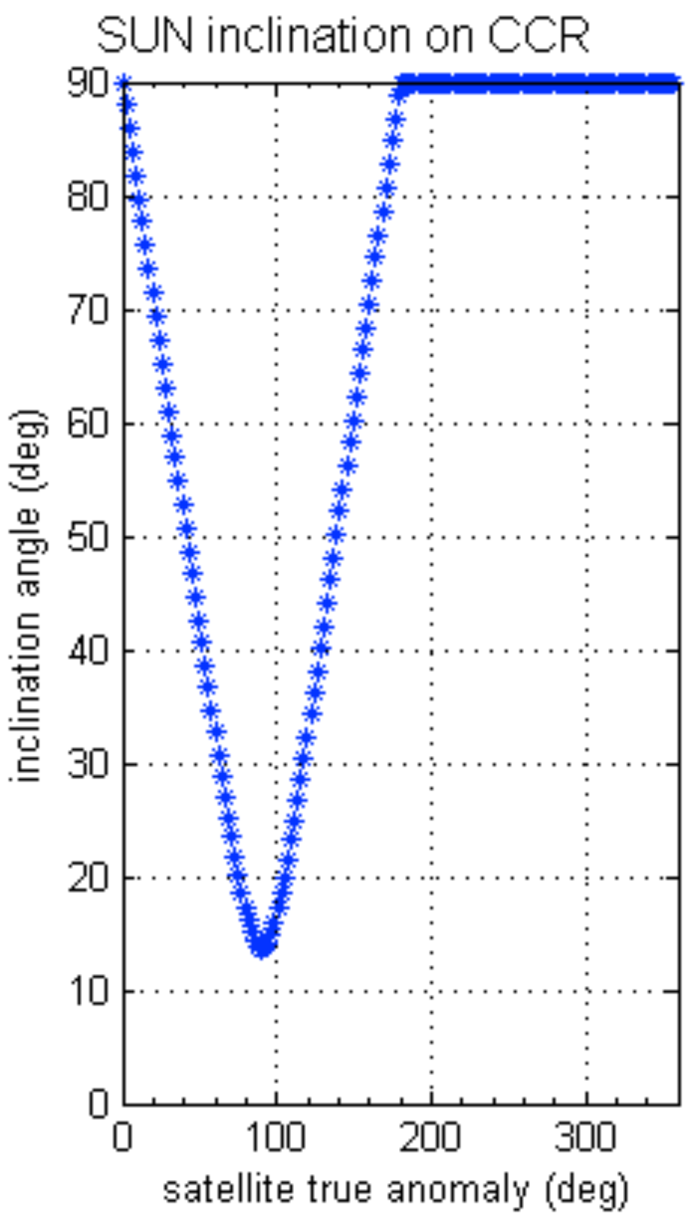
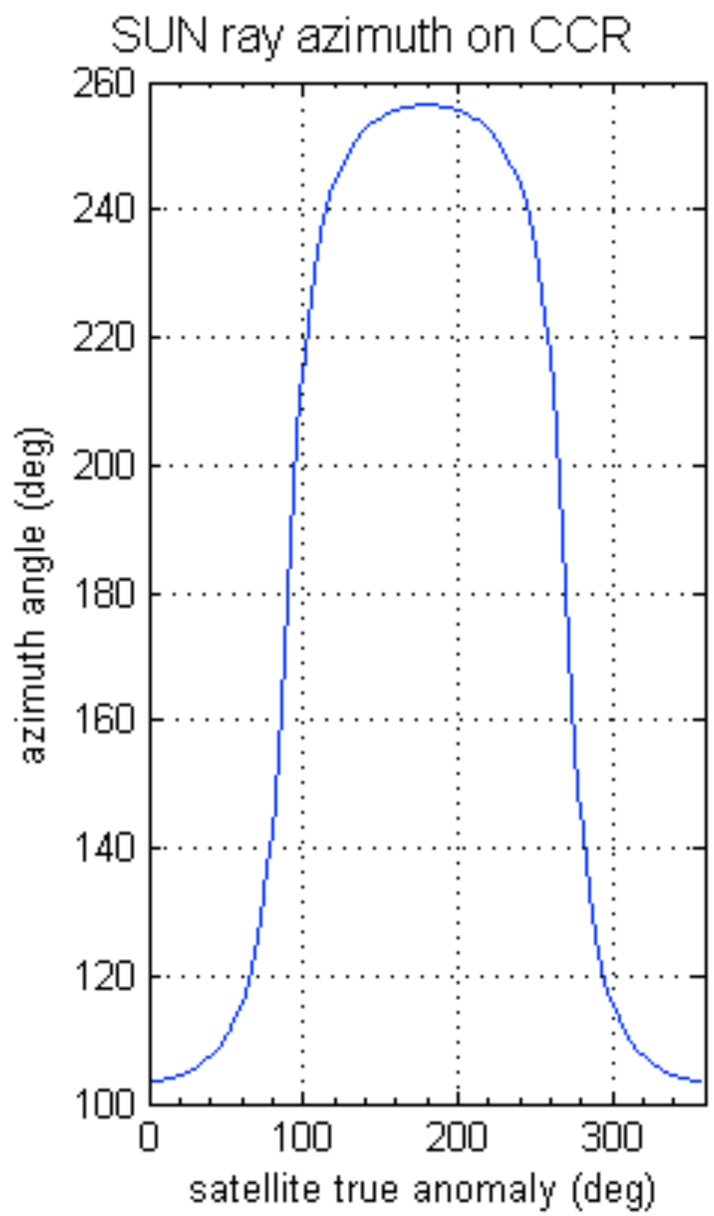
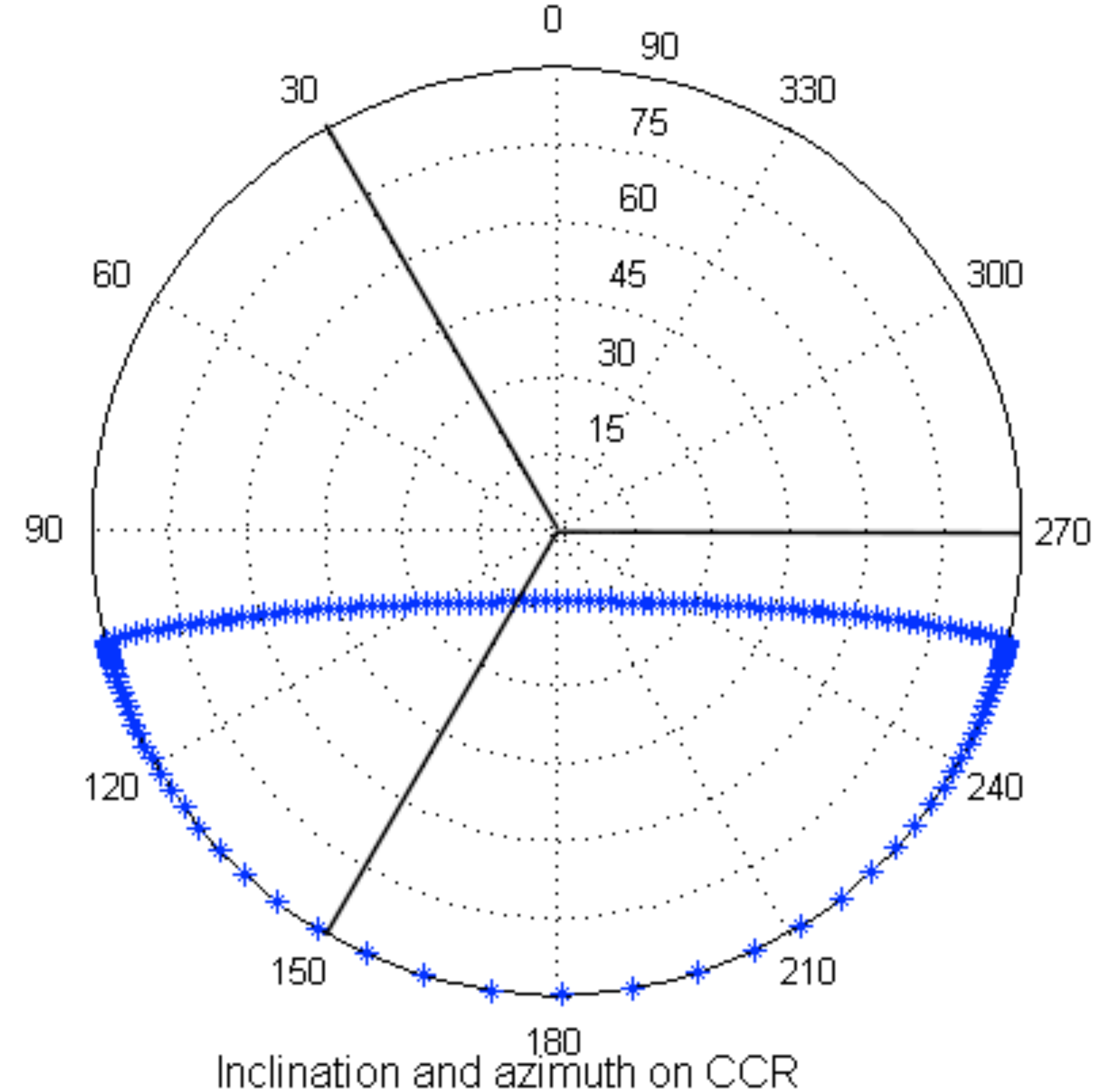
- Enhancements and completion of model(s).
  - GRA finite element model.
  - Introduction of a more general thermal gradient in CodeV model
  - Test the effect of different laser inclinations
  - Different orbits other than GCO (no Earth shadow, low Sun rays inclination..)

Some other interesting orbits







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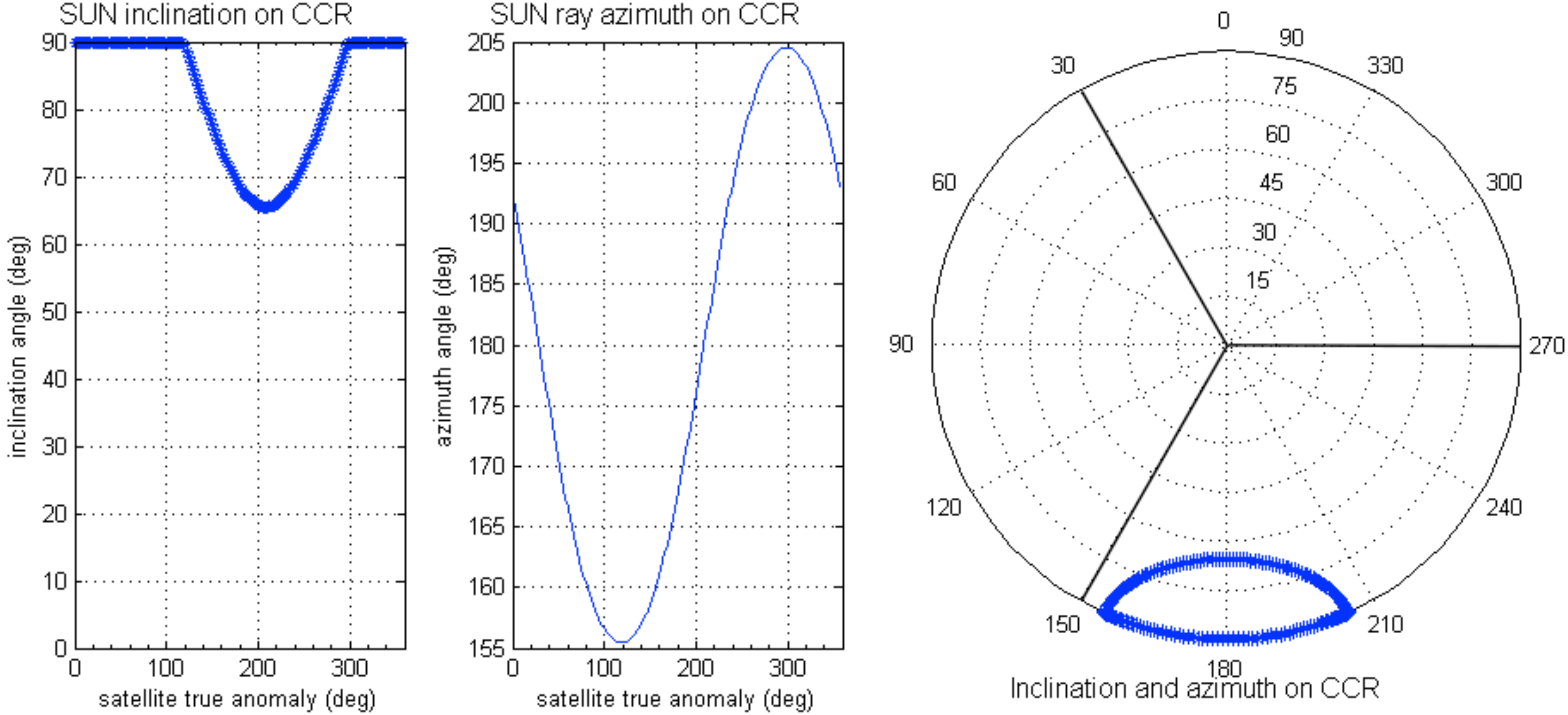

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Thank you for your attention.
Any question?

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