Previsioni. Temperature nel mondo: valori in calo nei prossimi 10 anni.

Studio termico e criogenico di strumentazione astrofisica (e non solo): un'attività scientifica, sperimentale, tecnologica inter-spettrale e multi-piattaforma

Gianluca Morgante, Luca Terenzi

What we do

- Thermal design of space, balloon-borne and ground based scientific instrumentation
- Design, development, testing and operation of cryogenic thermal control systems and test facilities
- Study, characterization and analysis/removal of thermal systematic effects on scientific observations
- Measurement of thermo-physical properties of materials at low temperatures

What we use – Software tools

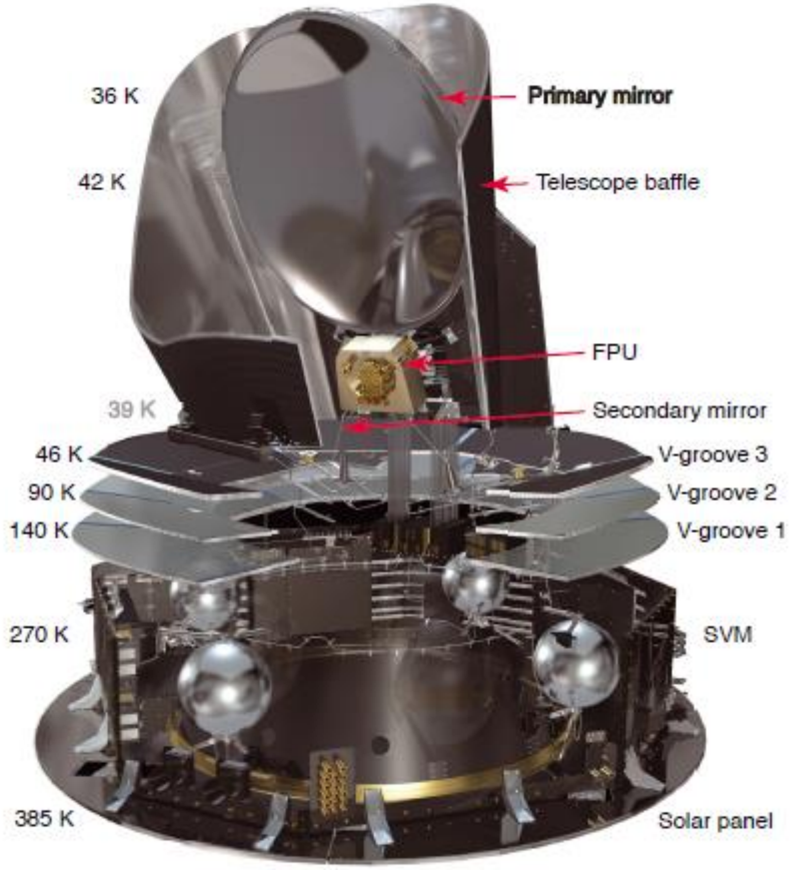
- Thermal modeling with the most common packages required by space agenices:
  - ESATAN - Thermal Modeling Suite
  - SINDA /FLUINT
  - Systema/THERMICA
- CAD Mechanical design interface AutoDesk Inventor, SpaceClaim, ANSYS
- Interface to project data analysis pipeline and Instrument End-to-End model

What we use – Cryogenic facilities

- Three cryochambers
  - Blue Barrel (samples cycling, properties measurement, sensors calibration)
    - cold stage 360mm diameter, 300 mm height.
    - One 2-stage cooler (1.5W@4K and 35W@50 K)
  - Big Coffin (cryogenic instruments characterization and calibration)
    - About 2mX1mX0.5m volume
    - Three 2-stage coolers (1.5W@4K and 35W@50 K, 5W@20K and 100W@80K, 12W@20K and 30W@65K)
  - The Bell
    - About 2 m diameter, 2m height
    - One 2-stage cooler 5W@20K and 100W@80K, two 50K coolers lifting the thermal tent
- Three vacuum benches available
- A set of more than 30 cryogenic temperature sensors, and readout system allowing 36 high accuracy temperature monitoring channels and 8 control loops

Planck LFI legacy

- Challenging thermal architecture solutions
- Successfully operated



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- Challenging thermal architecture solutions
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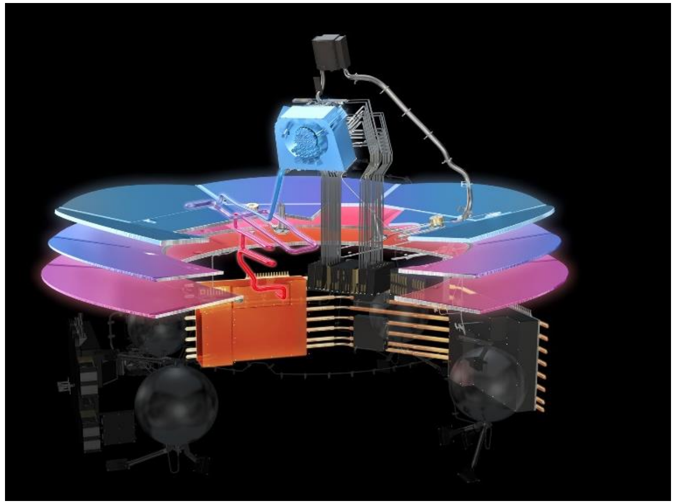
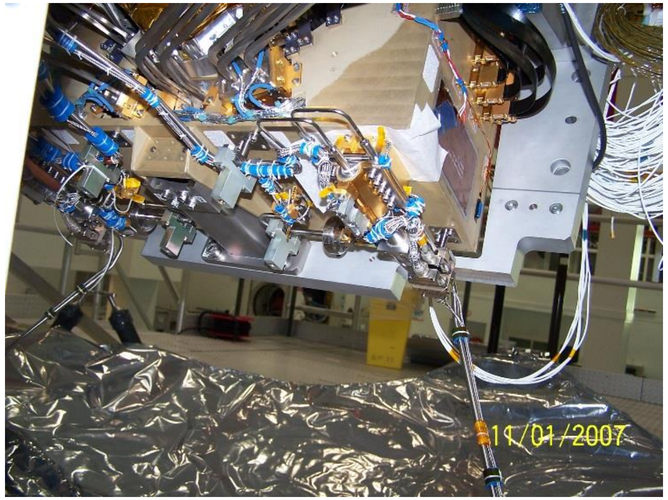
- Planck sorption cooler: new technology for scientific missions





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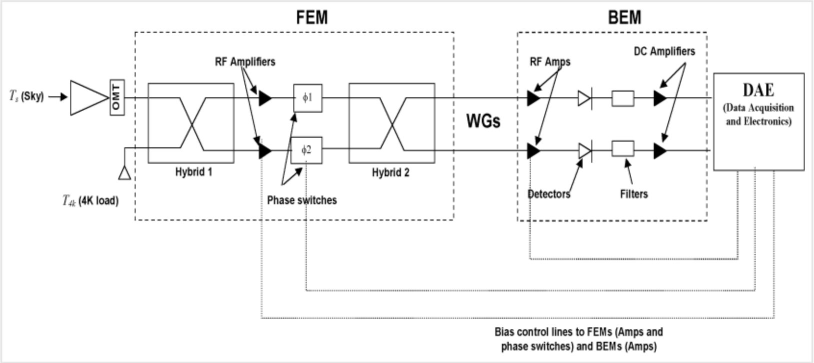
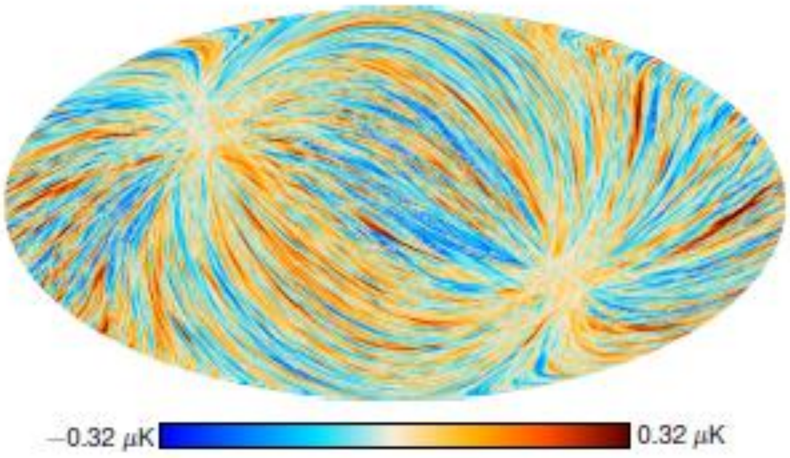
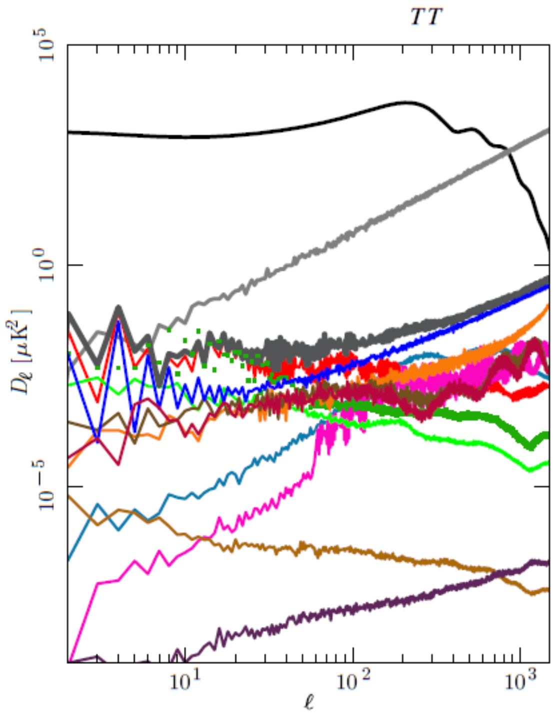
- LFI radiometer architecture called for strict control of thermal systematic effects



$$p(t) = ak\beta G_{FE} G_{BE} G_{DC} \left[\tilde{T}_s + T_{n1} + \frac{T_{n2}}{G_{FE}} - r\left(\tilde{T}_{4K} + T_{n1} + \frac{T_{n2}}{G_{FE}} \right) \right]$$





Planck LFI legacy

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- LFI radiometer architecture called for strict control of

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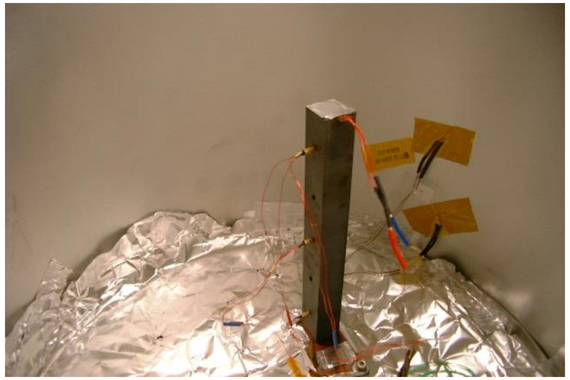
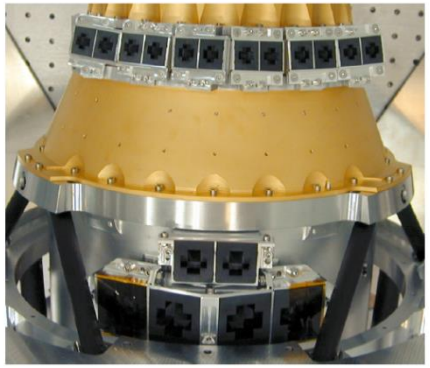
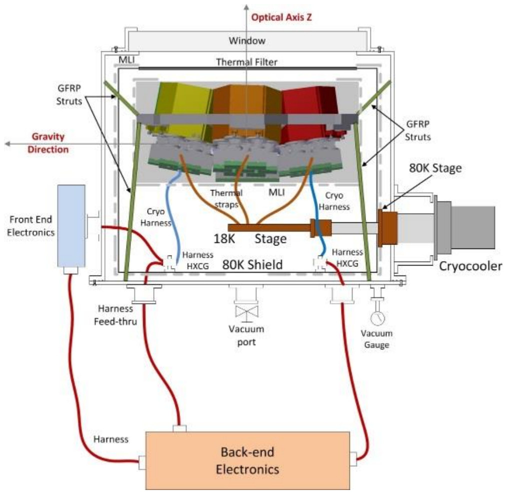
- The 4K reference load: designed, developed, integrated, tested in BO

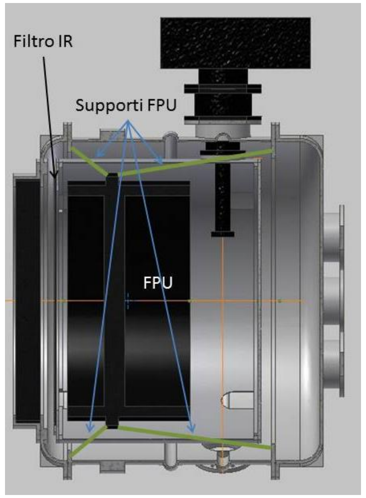




LSPE/STRIP

- Team OAS: G. Morgante, M. Sandri, F. Villa, L. Terenzi, F. Cuttaia
- Large collaboration involving INAF structures, Italian Universities and International research institutes
- One 3-years degree student (UniMI), 3 Master's degree students (UniBO, UniTs,UPSud-Saclay)
- Cryogenic system design and testing. Support to instrument calibration





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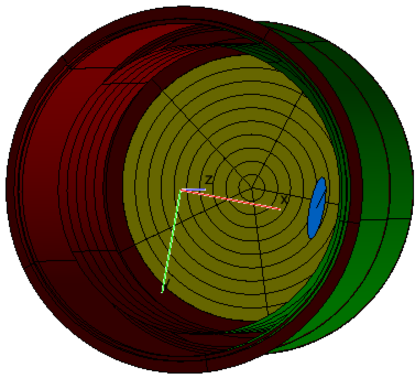
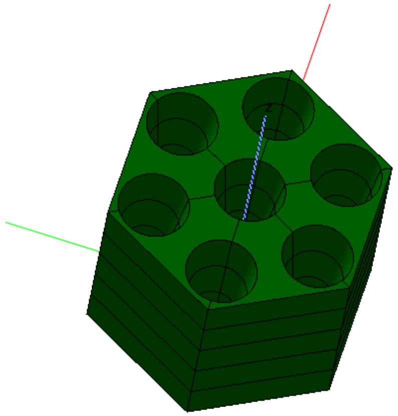
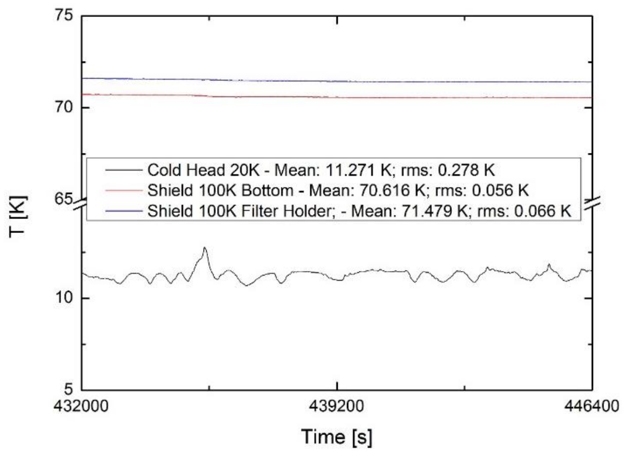
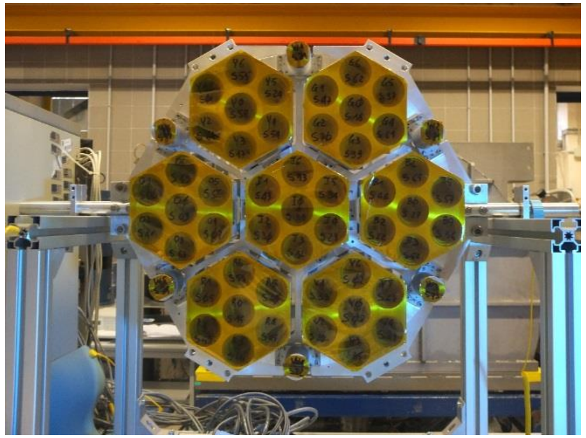
- Thermal systematics assessment and verification

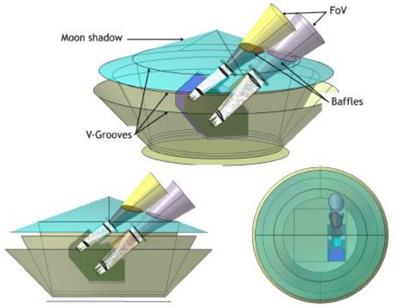


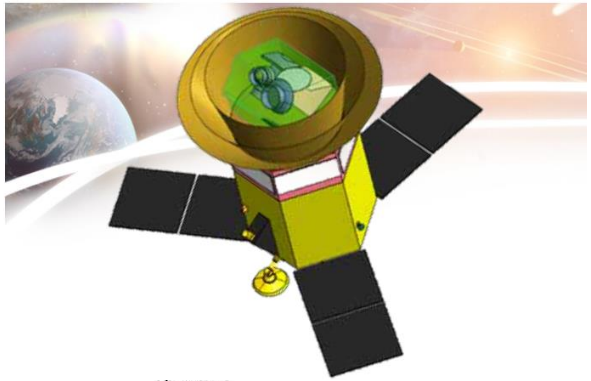






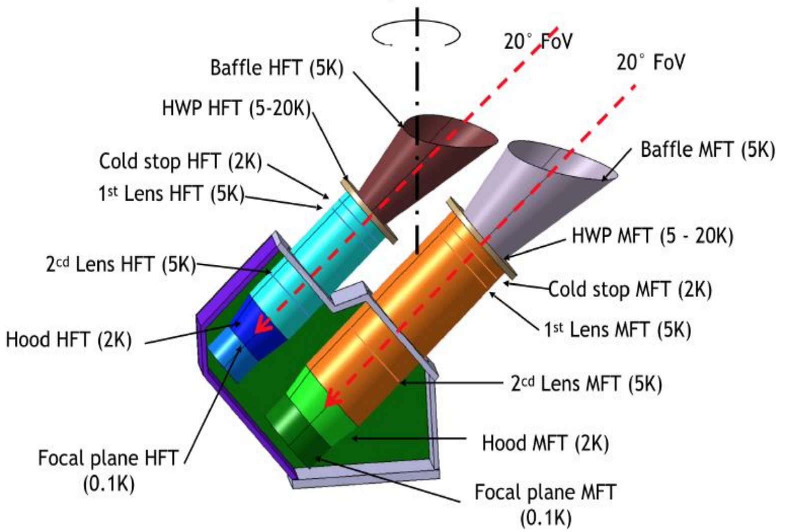
LiteBIRD

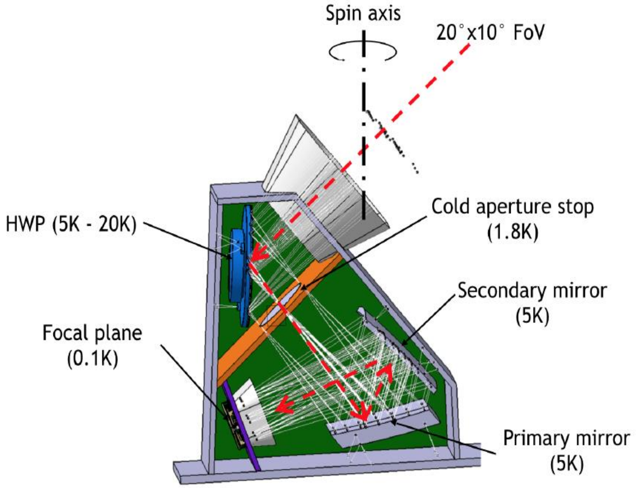




OAS Bologna (see G. Morgante slides):

- Participation and support to the ESA Concurrent Design Facility (CDF) study on the High Frequency Telescope (HFT) on board the LiteBIRD mission
- Trade-off analysis of the thermo-mechanical configuration of the HFT proposed optical designs for the selection of the baseline and possible alternative options
- Materials and technical solutions analysis for the optimization of the HFT thermal design
- Thermo-mechanical design optimization of the LiteBIRD HFT selected baseline



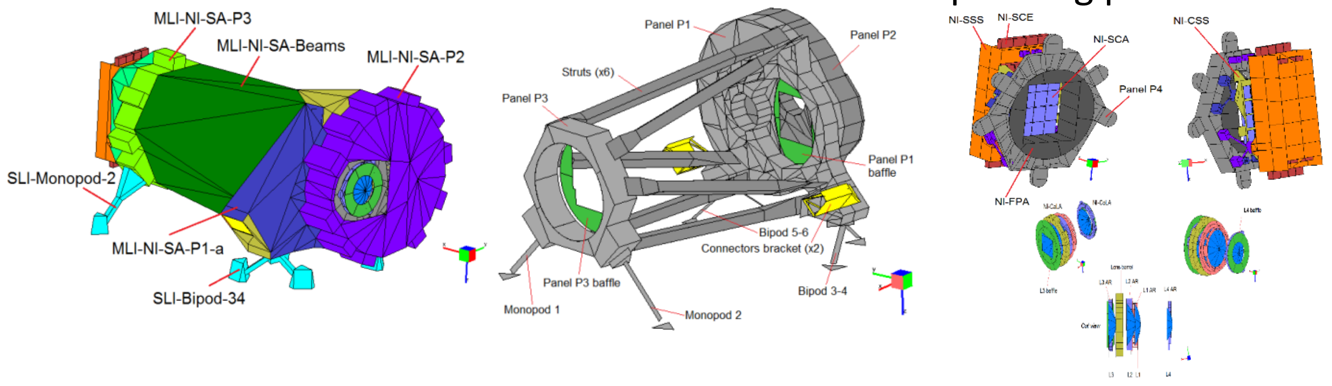


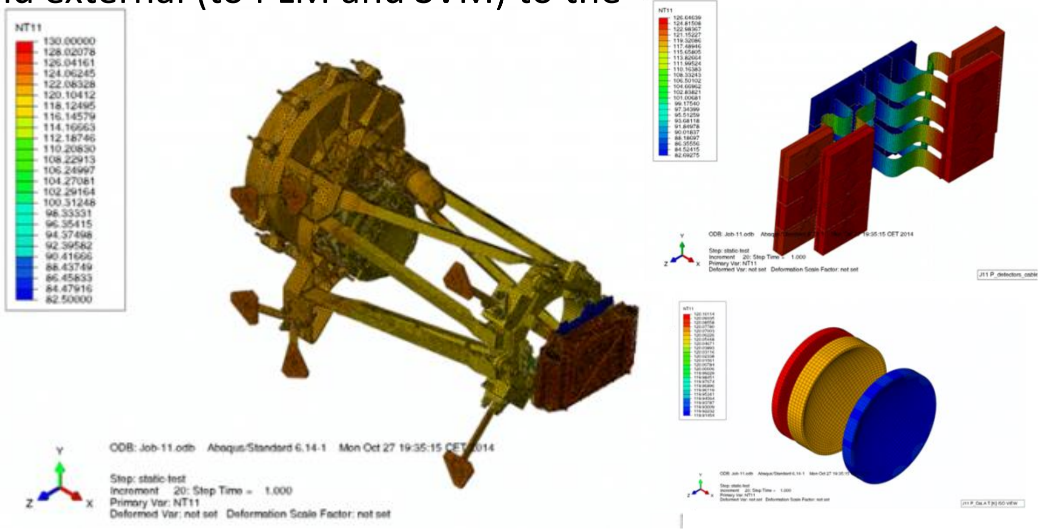
Team OAS: G. Morgante, M. Sandri, F. Villa, L. Terenzi, F. Cuttaia

Euclid - NISP

- Challenging thermal design
- Stability in time of optical element (lenses)
- Colder FPA over a warmer structure (NIOMA)
- OAS Bologna Thermal Activities:
  - Thermal Architecture Lead of the NISP Instrument
  - Thermal design and modeling of the opto-mechanical (NI-OMA) and detector (NI-DS) thermal control
  - Thermal analysis of NISP in the PLM operating environment and in the TV/TB test configuration.
    - A semi-detailed ESATAN-TMS G/TMM
    - A detailed thermal FEM in Abaqus (A. De Rosa)
  - System Thermal Engineering:
    - Definition and optimization of the thermal interfaces internal and external (to PLM and SVM) to the instrument.
    - Thermal AIV at sub-system and system level
    - Definition of the thermal control operating procedures

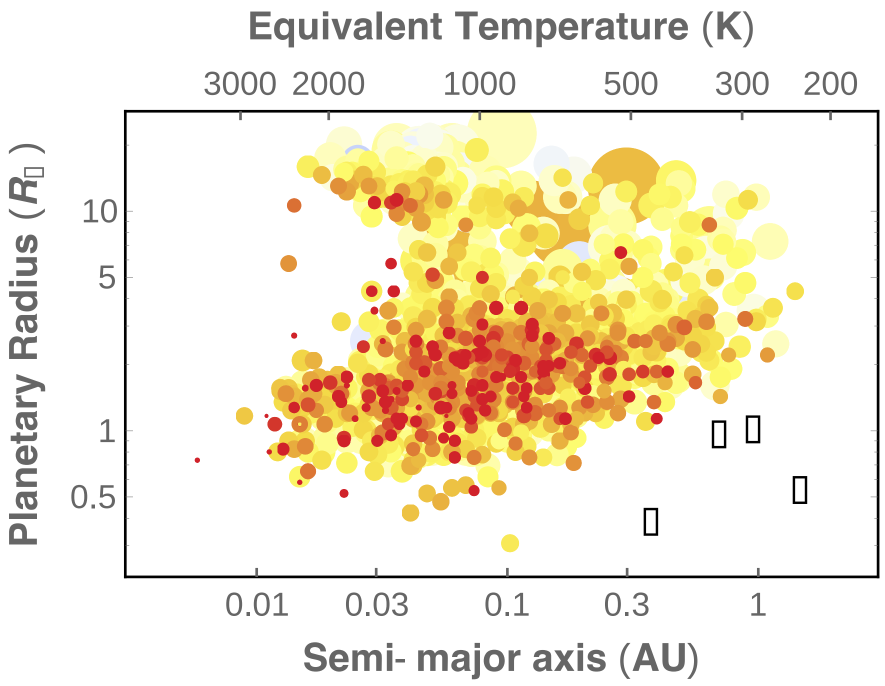
Team OAS: G. Morgante, A. De Rosa

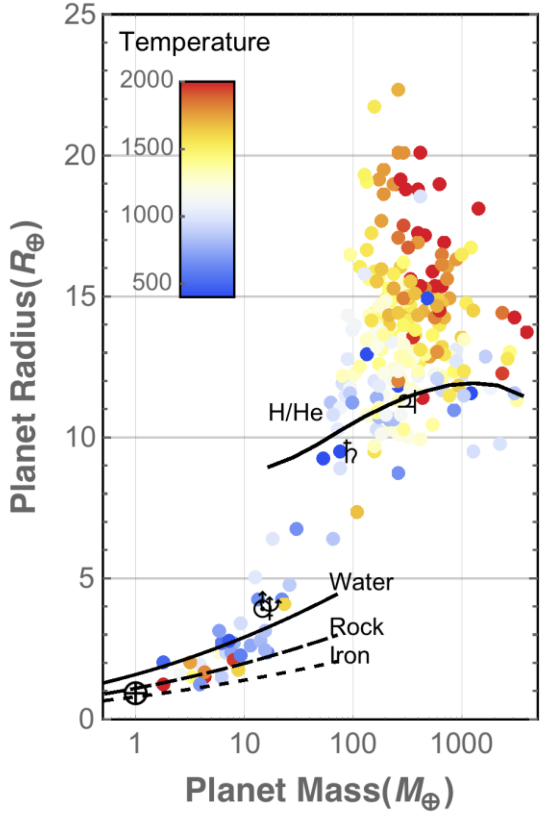




ARIEL PLM Thermal Activity

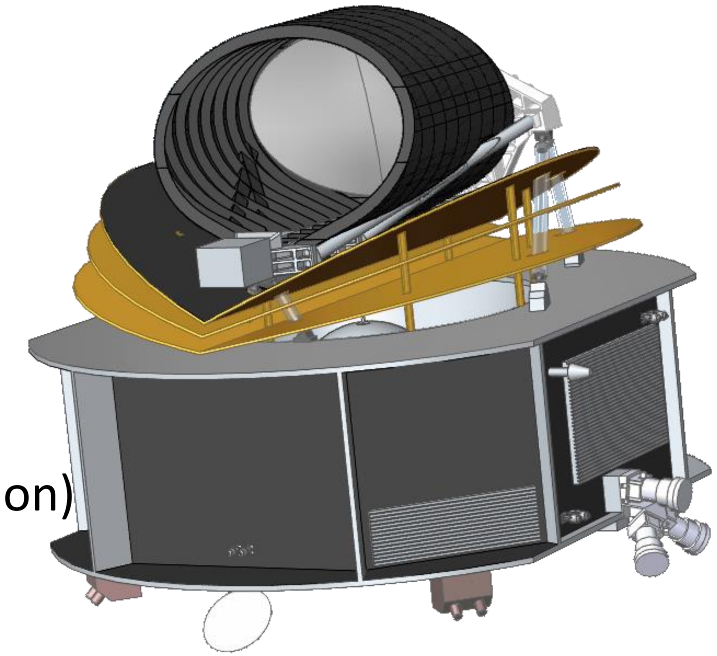
- 3500+ exoplanets in our Galaxy… and counting!
- Basic parameters, such as mass & radius, are not enough to understand how these planets look like, their history/evolution.
- Atmospheric chemistry gives access to the composition, history & evolution of the planet



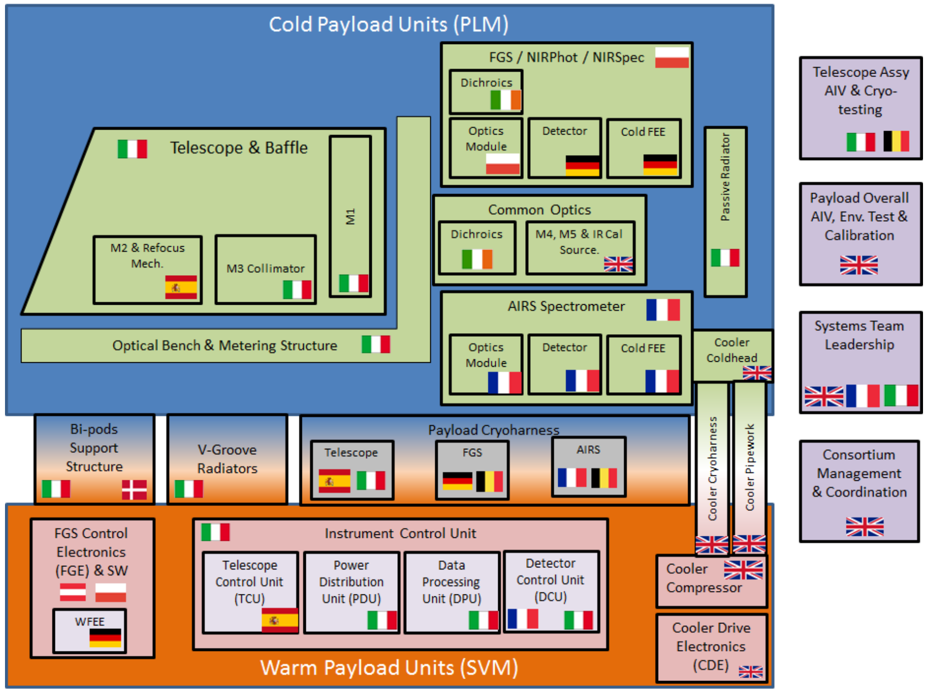


- What are (exo)planets made of?
- How did they form?
- How do they evolve?

ARIEL PLM Thermal Activity



- ARIEL recipe:
  - 1-m space telescope (agility + no Earth atmosphere)
  - Satellite in L2 (thermal stability + sky visibility)
  - Simultaneous spectra 0.5-7.8 micron (molecular detection + stellar activity)
  - R > 20 below 2 µm, R ≥ 100 in (1,95-3,90) µm, R ≥ 30 in (3,90-7,80) µm
  - > 500 (1000 expected) exoplanets observed, rocky + gaseous (large population)
- Challenging Thermal Design: Cold PLM sitting on top of warm SVM
  - Passive cooling down to 50K (Vgroovs + radiators)
  - Active cooling (Ne JT cooler) for spectrometer detectors
  - OAS contribution: GS, PLM thermal Lead, Telescope development
- OAS Team/Support:
  - G. Malaguti (GS Coordinator, co-PI)
  - G. Morgante (Thermal Architectre Lead, System Team)
  - L. Terenzi (Thermal Engineer)
  - One Master thesis student (PoliMi) ⍰ 12 mo's fellowship
  - ASI funded for Phase B1, HW/SW, travels, 1 TD, around 140K



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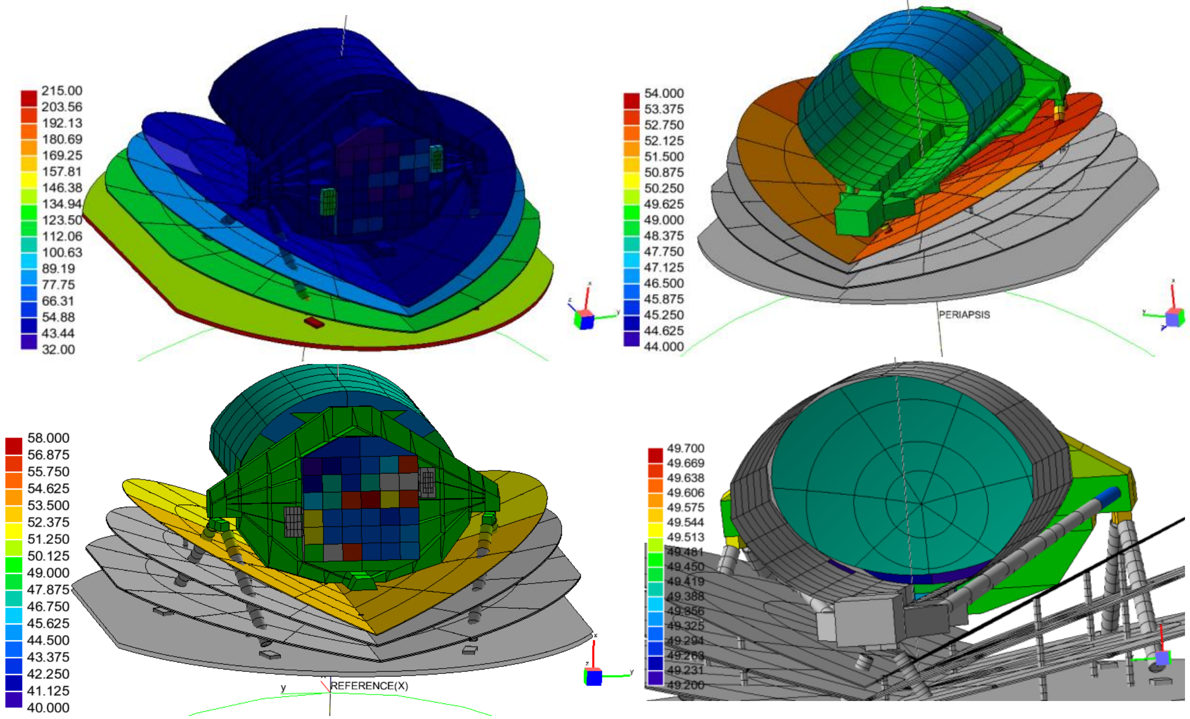
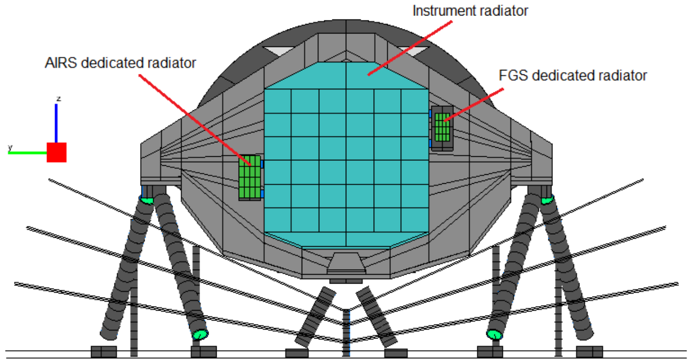
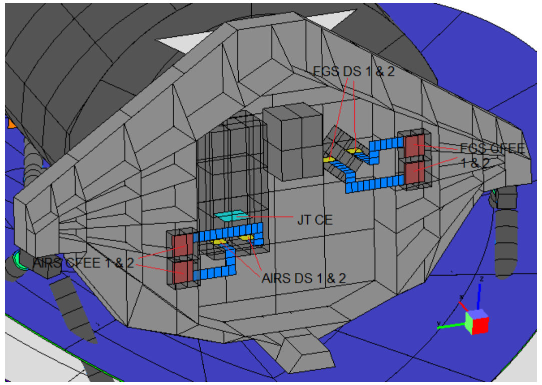


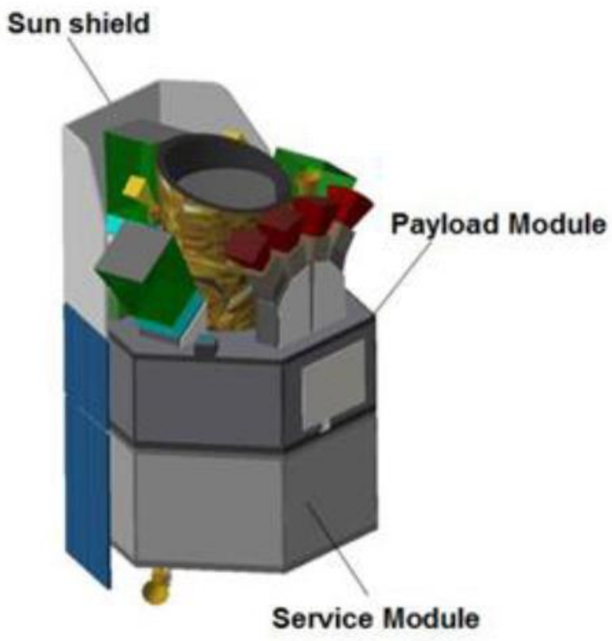


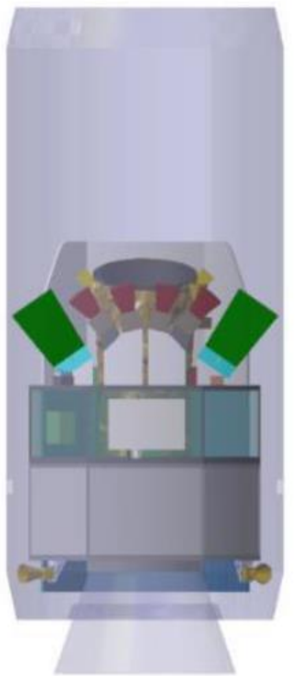


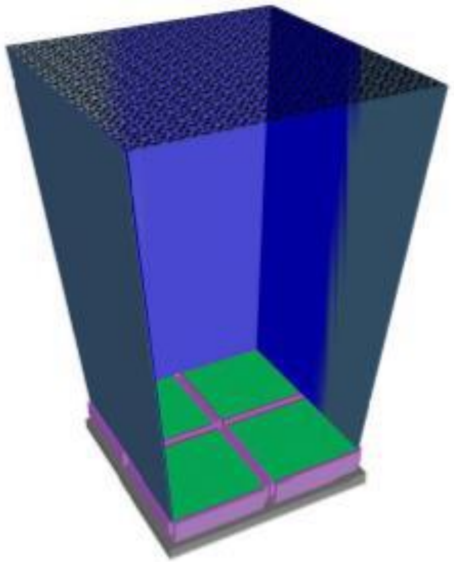
- OAS Bologna Activities (Thermal)
  - PLM Thermal Architecture Lead
  - System Thermal Engineering
  - PLM TMM
  - Requirements for all sub-systems
  - Development of M1 Prototype
  - Thermo-mech engineering of PTM and FM
  - Thermal and cryogenic test of PTM coating samples @ OAS

Theseus Thermal Activity

- OAS Bologna Thermal Activities:
  - XGIS thermal system engineering
  - XGIS (optics, detectors, electronics) thermal design
  - XGIS thermal modeling @ sub-system level

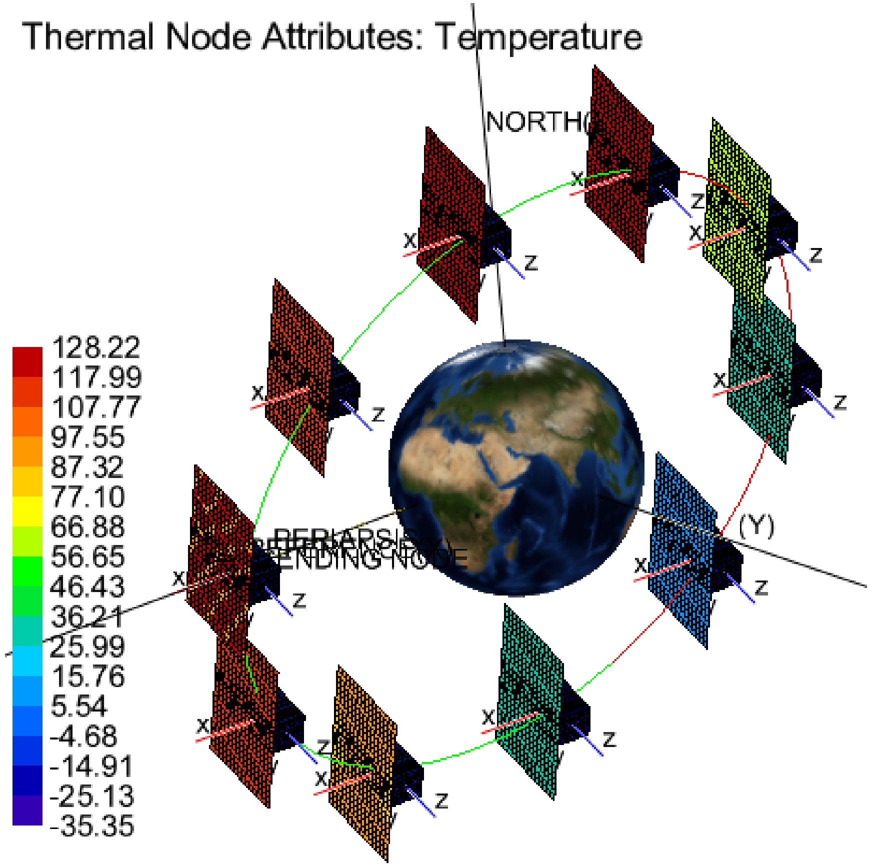


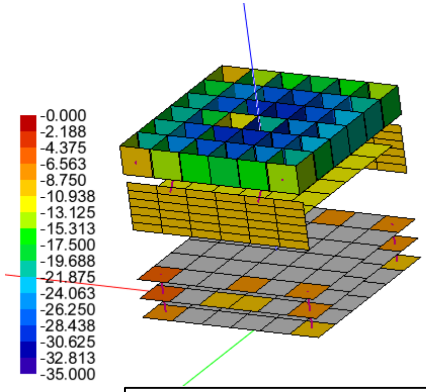


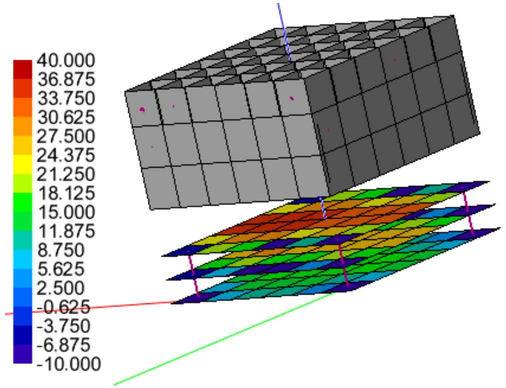


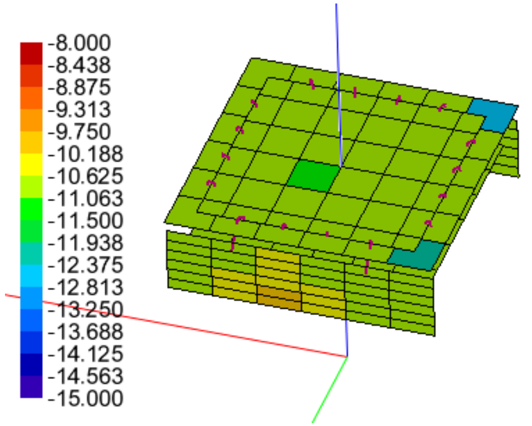
Team OAS: G. Morgante, L. Terenzi

HERMES – Thermal Activity









SDD average temperature is -12°C with ΔT 1° C

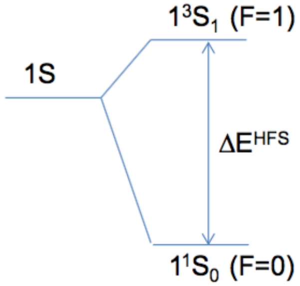
- OAS Bologna thermal activities:
  - HERMES thermal system engineering
  - PLM (optics, detectors, electronics) thermal design
  - PLM thermal modeling @sub-systemlevel and @ system level
  - Thermal orbits simulation

Team OAS: G. Morgante, F. Fuschino

FAMU Thermal Activity

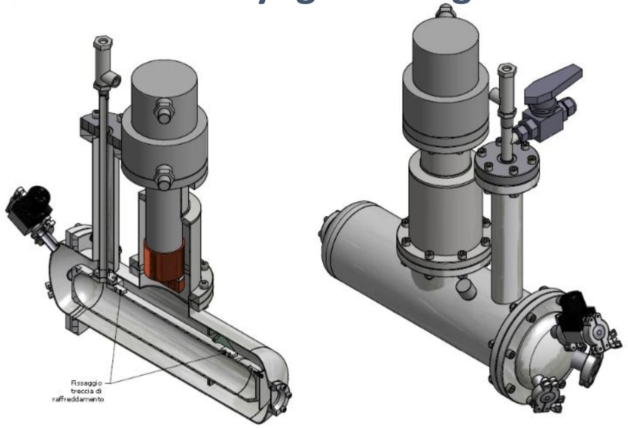
FAMU (Fisica Atomo Muonico), INFN project (Trieste et al.), high precision measurement of

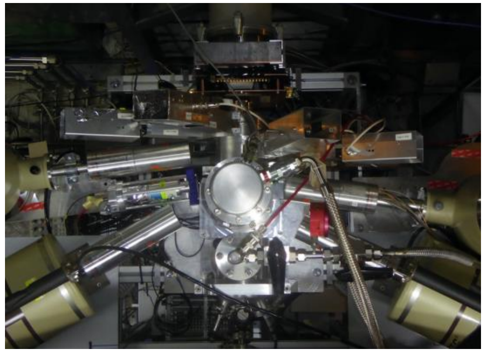
- ❑ $\Delta E_{HFS}(\mu p)$1S muonic hydrogen ground state hyperfine splitting
- ❑ Solve the proton charge radius puzzle



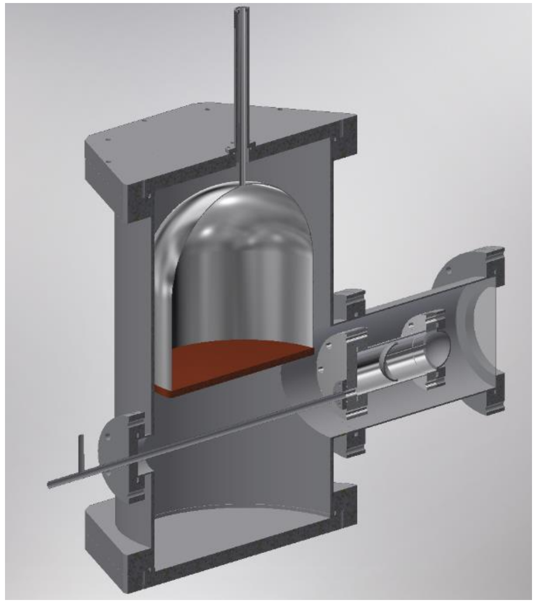
units fm	charge radius r_{ch}
e^--p scattering & spectroscopy	r_{ch} = 0.8775(51)
μ^--p Lamb shift spectroscopy	r_{ch}=0.84089(39)

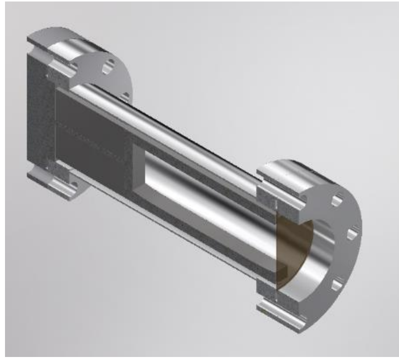
FAMU 2016 Cryogenic Target

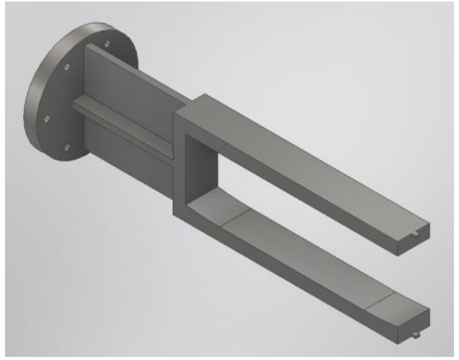




FAMU 2019 Cryogenic Target







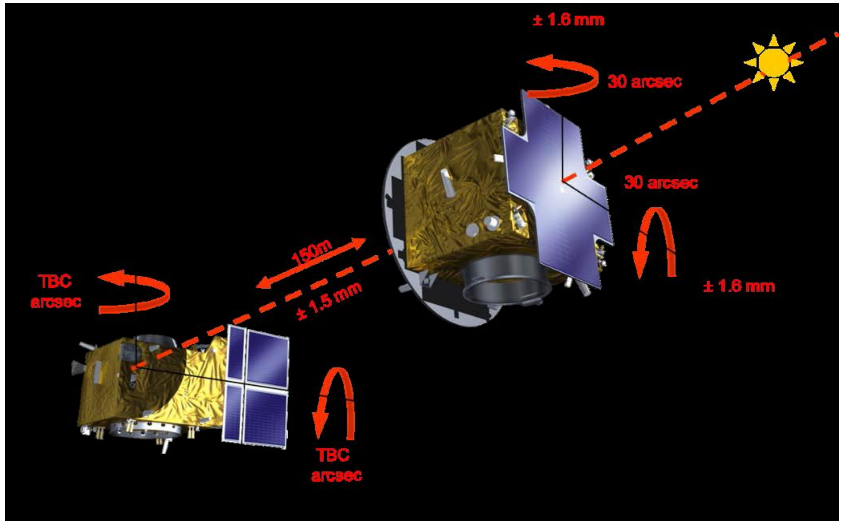
OAS Bologna Thermal Activity:

- ❑ Cryostat thermo-mech design
- ❑ Laser cavity thermo-mech design (vs optical)
- ❑ Trade-off thermo-mech vs optical

Team OAS: G. Morgante, F. Fuschino

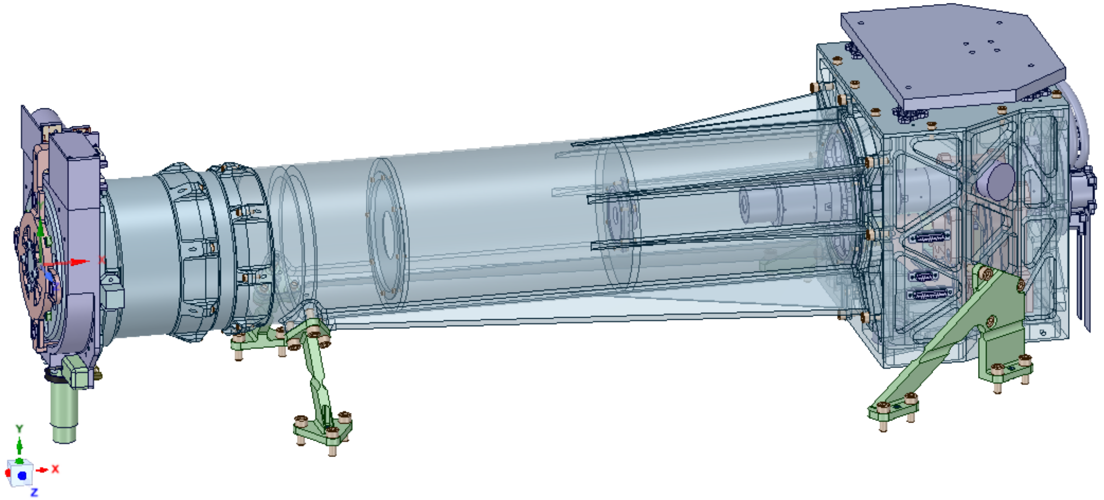
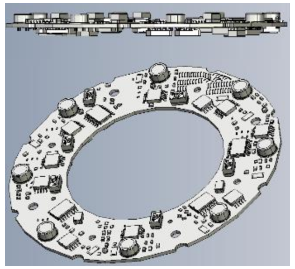
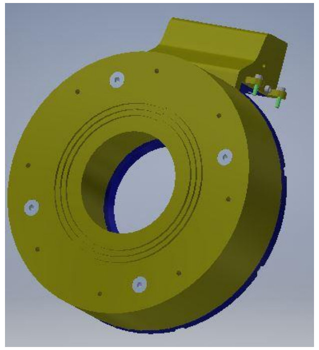
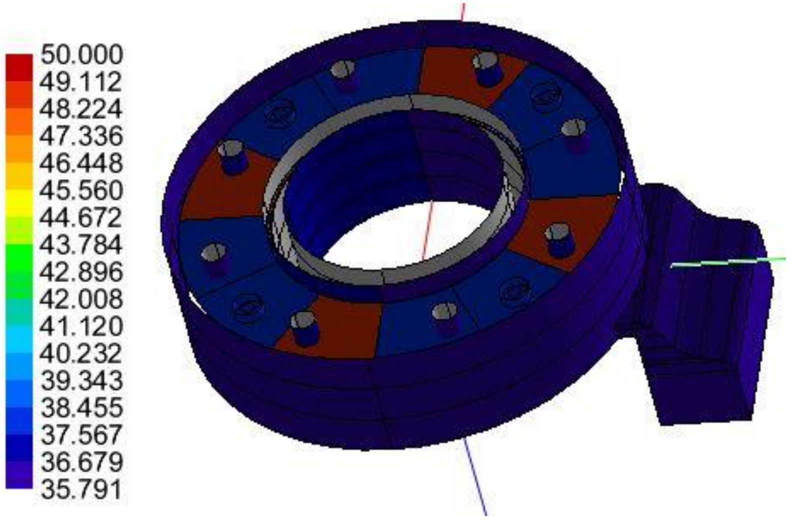
PROBA-3 SPS

- PROBA-3 is a mission devoted to the in-orbit demonstration (IOD) of precise formation flying (F^2) techniques and technologies for future ESA missions.
- PROBA-3 will fly ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun) as primary payload
- SPS (Shadow Position Sensor) is a metrology subassembly of the ASPIICS
- INAF collaboration with OATo, OAA, together with Italian and European companies



PROBA-3 SPS

- The activity is within the SPS development activities:
  - Thermal design and verification of the SPS
- The main driver has been to limit the load deriving from Sun radiation leaking without affecting other sub-systems

MAORY

- The activity is within the ThCS WP
- Thermal design and analysis
- Fluid loop design