

UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Optical Analysis and Design of Space Vis/IR Telescopes and Instruments

First Year Activities Report

Padova, September 10th, 2020

PhD Candidate: Paolo Chioetto

Supervisor: Dr. Paola Zuppella Co-supervisor: Dr. Vania Da Deppo

Introduction & Scope



- Optical design of **Visible and Near-IR** Telescopes and Instruments
- CNR-IFN Padova is participating to four related missions*:
 - two in development: **ARIEL** (Telescope and mirrors design) and **Comet Interceptor** (EnVisS optical head)
 - two already flying: **BepiColombo** (SIMBIO-SYS STC) and **Solar Orbiter** (Metis coronagraph)
- My main involvement during the first year of the PhD program: **ARIEL**

*see final slide for missions scientific attribution

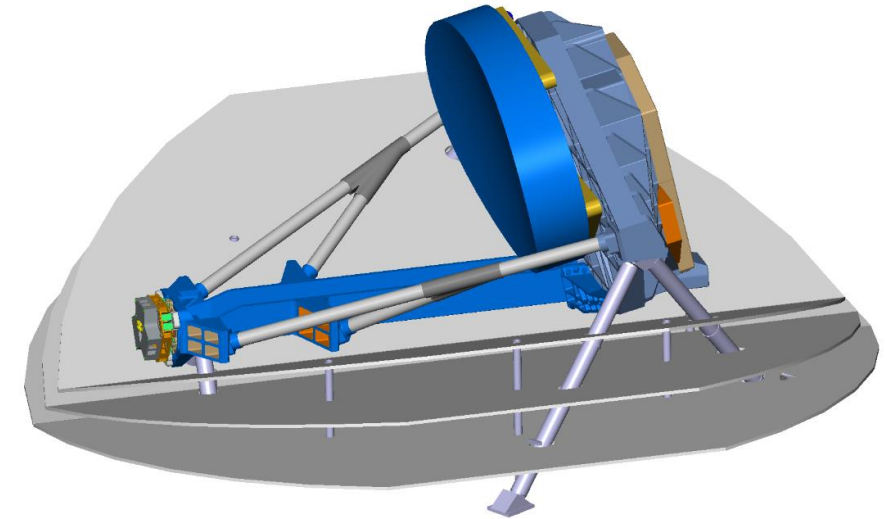


Artist's rendering of the ARIEL spacecraft from Phase A (credit: ARIEL/Science Office)

ARIEL – Quick Review



- ARIEL is the **M4 mission** of ESA Cosmic Vision program. It will survey **exoplanet atmospheres** through infrared transit spectroscopy
- **All-aluminum telescope** design, operating at **cryogenic temperature** (< 50 K). Off-axis, unobscured optical design.
- Two instrument modules: a **spectrometer** ($1.95 - 7.8 \mu\text{m}$), and a combined fine guidance system/visible photometer/NIR spectrometer
- Launch is scheduled for 2028



*ARIEL Telescope interim mechanical design
(credit: ARIEL Consortium)*

Review of Telescope Design and involvement in:

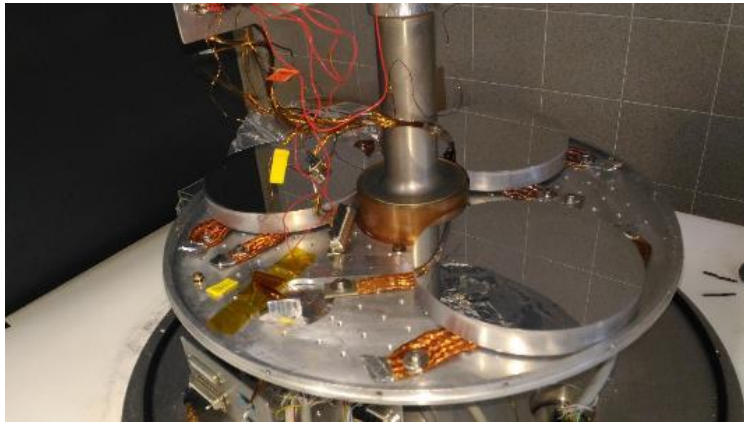
- Telescope performance requirements, throughput and reflectivity analysis
- Off-axis design refinement, discussions about moving to a free-form definition of the mirror surfaces
- Preliminary STOP analysis
- Primary Mirror Technology Development Activity (TDA), on aluminum samples and PTM (M1 technology demonstrator):
 - Mirrors substrate thermal stabilization
 - Machining and polishing
 - Optical coating qualification



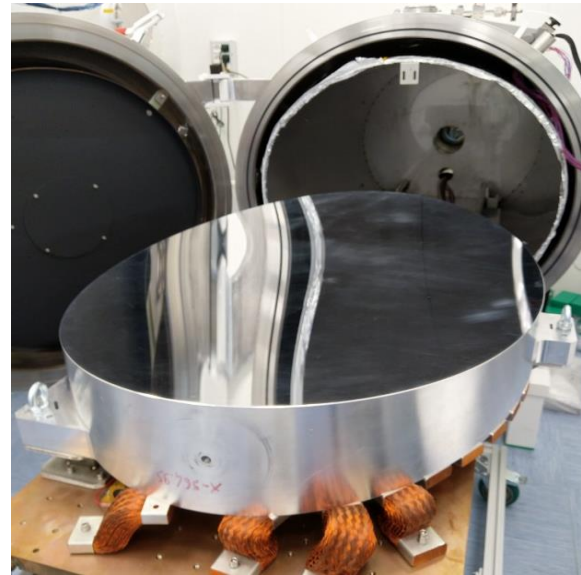
*ARIEL primary mirror demonstrator PTM
(credit: MediaLario S.r.l.)*

Mirror Substrate Thermal Stabilization

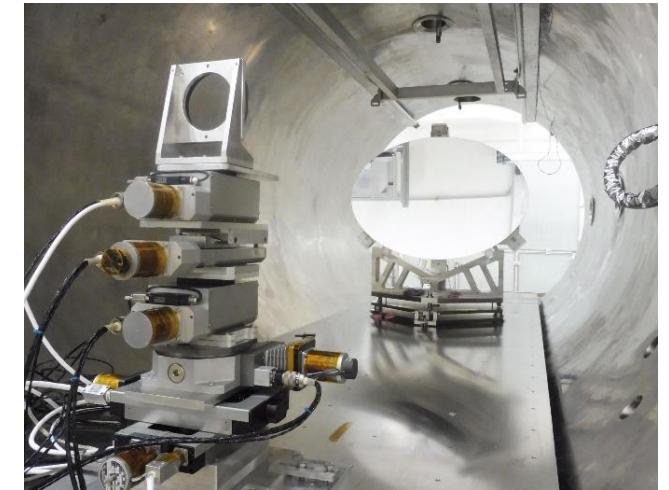
- Test of thermal stabilization recipe on 150 mm diameter disks
- Verification on PTM at room temperature (WFE measurements analysis before and after each cycle)
- Final cryogenic test of PTM



150 mm samples being loaded in a cryochamber (credit: G. Morgante/INAF OASBO)



PTM in front of a cryochamber for thermal cycling (credit: Cryotech S.p.a.)



Loading of the PTM in a cryochamber for testing (credit: Centre Spatial de Liege)

ARIEL – Primary Mirror TDA

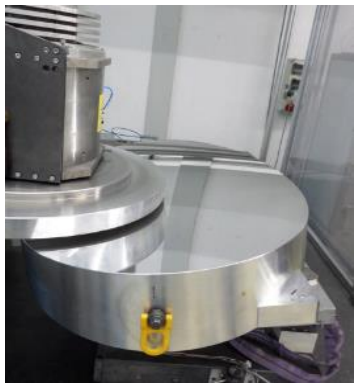


UNIVERSITÀ
DEGLI STUDI
DI PADOVA

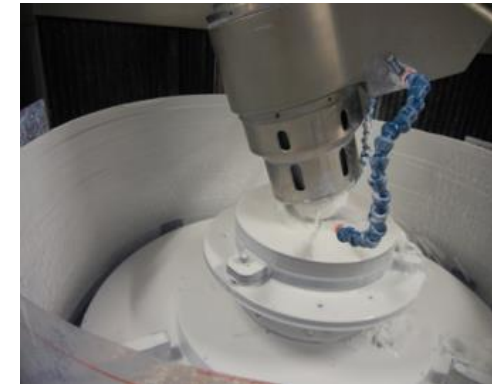
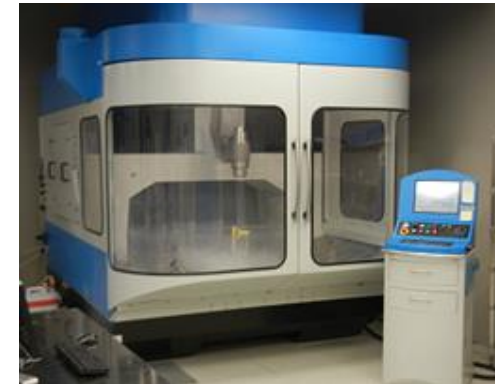


Machining and Polishing

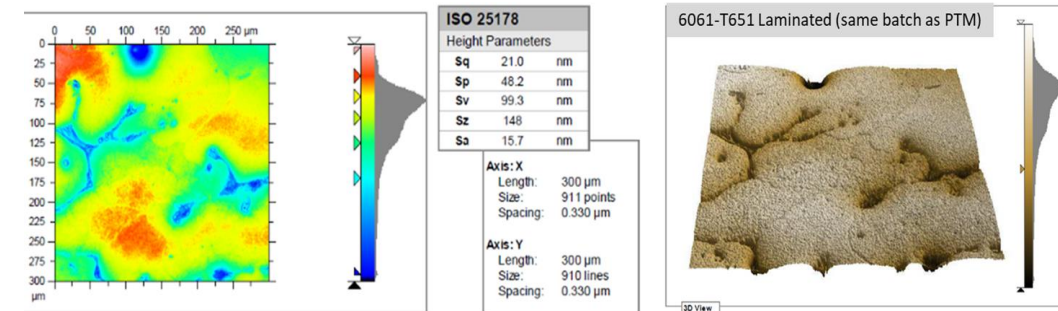
- Material specificities (Al 6061-T651 rolled plate)
- Fly-cutting and diamond turning technologies: pushing the limit on size
- Deterministic polishing technology: application to aluminum substrate



Fly-cutting (left) and SPDT (right) machines (credit: LT Ultra-Precision Technology GmbH)



Zeeko IRP 1200X robotic polishing machine (credit: MediaLario S.r.l.)



WLI measurement of Al sample after aggressive polishing (credit: MediaLario S.r.l.)

ARIEL – Primary Mirror TDA

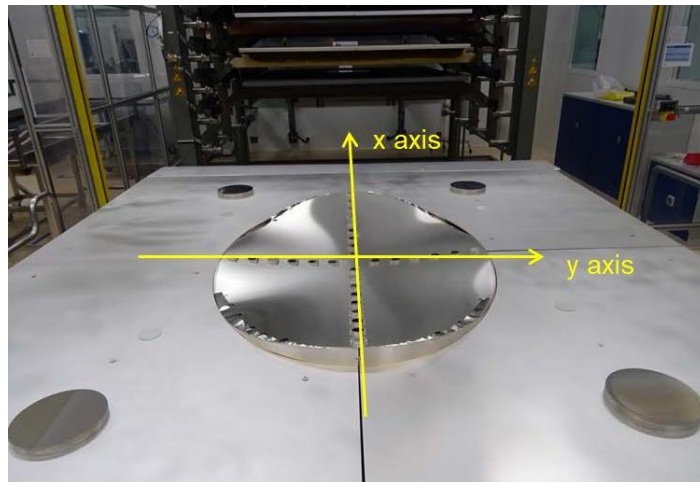


UNIVERSITÀ
DEGLI STUDI
DI PADOVA

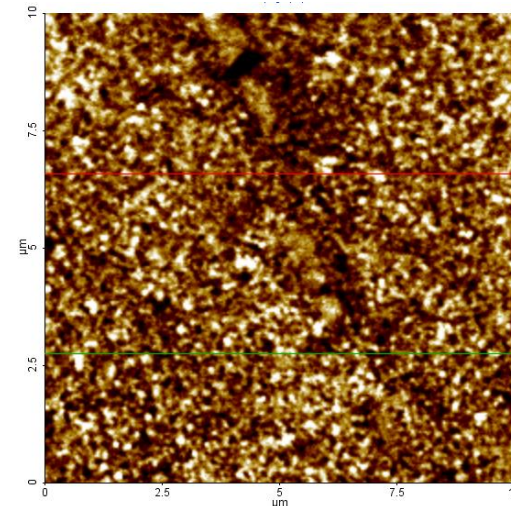


Protected Silver Coating Qualification

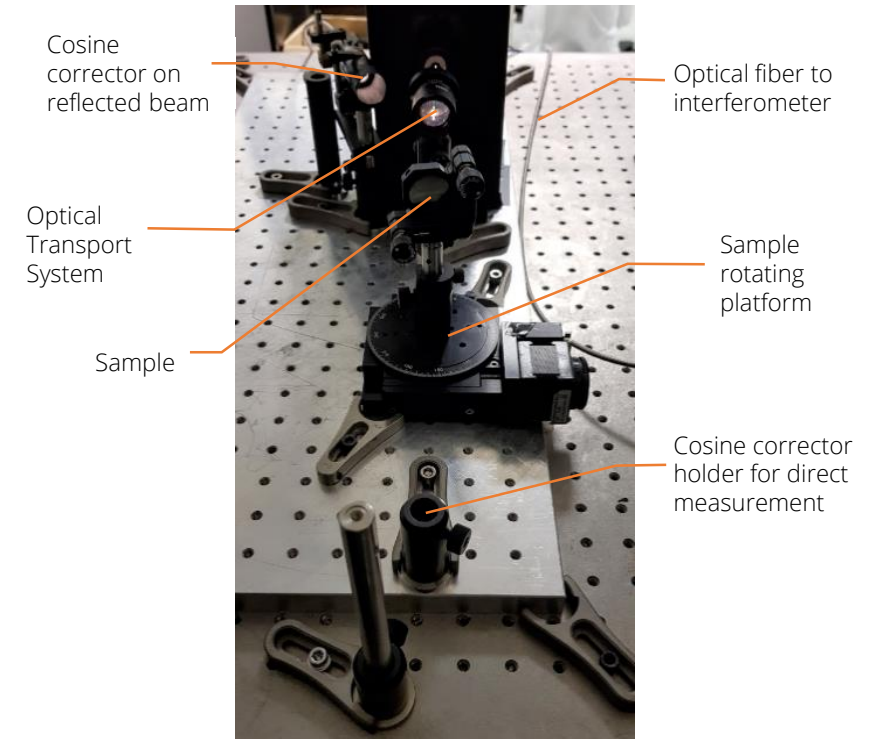
- Coating qualification on aluminum samples
- Environmental and adhesion tests
- Reflectivity and microscopy analysis



Coating loading tray with samples
(Credit: CILAS ArianeGroup)



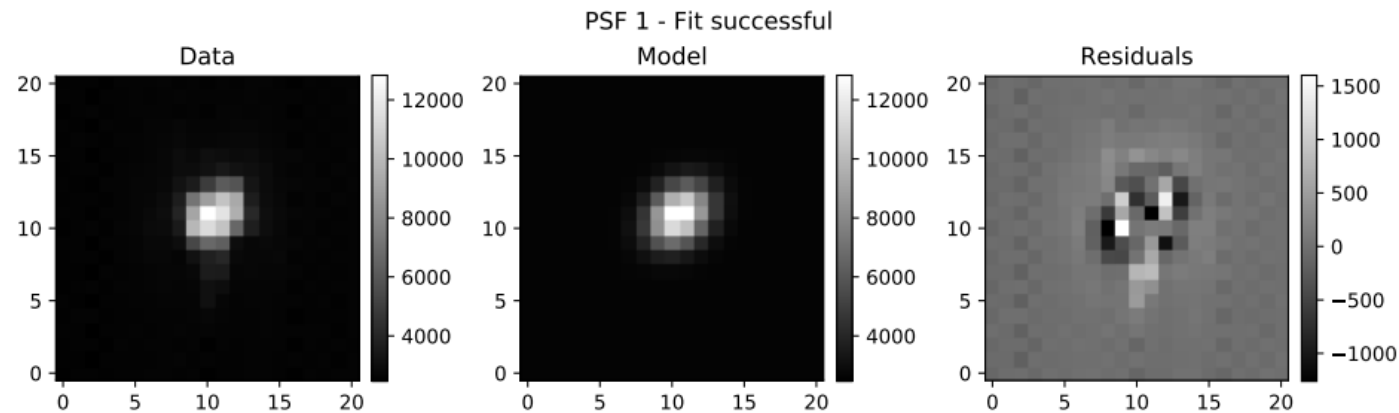
AFM image of coated sample
(Credit: CNR-IFN Padova)



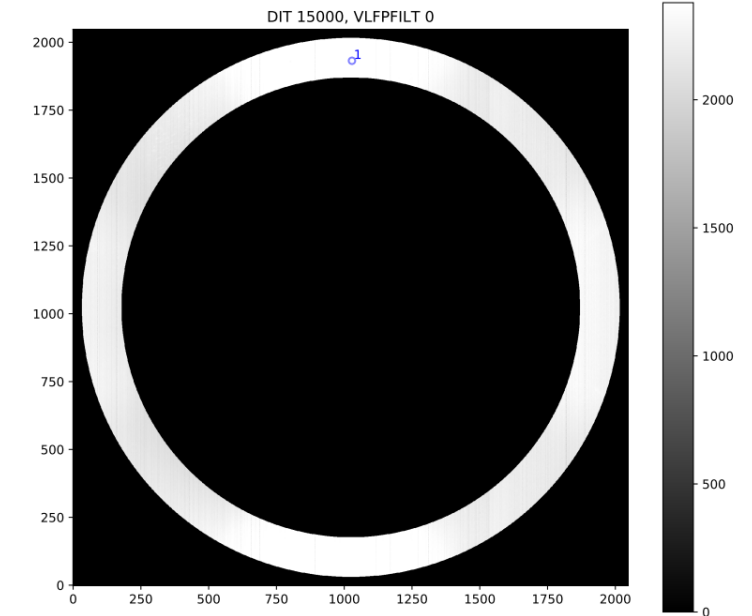
Reflectometry setup
(Credit: CNR-IFN Padova)

Preliminary Review

- SIMBIO-SYS STC: optical analysis
- Comet Interceptor EnVisS: preliminary review
- Solar Orbiter Metis: instrument optical analysis, image analysis



*Gaussian fit of PSF
(Credit: Metis Team/CNR-IFN Padova)*



*Metis Vis image, with PSF of Alpha Leonis
(Credit: Metis Team/CNR-IFN Padova)*

Publications

Technical Reports

- Chioetto, P., ARIEL LTU1 Mirror Sample Test Measurement. CNR-IFN Technical Report, Prot. 2071_240820 (2019)
- Chioetto, P., ARIEL LTU1 Mirror Sample Test Measurement – Setup Preparation Procedure. CNR-IFN Technical Report, Prot. 2072_240820 (2019)
- Chioetto, P., ARIEL AI Mirror Substrate Thermal Treatments. CNR-IFN Technical Report, Prot. 2076_240820 (2019)
- Chioetto, P., Coating Test Requirements. CNR-IFN Technical Report, Prot. 2075_240820 (2019)
- Chioetto, P., Ag Coated Al Samples Cryo Test Procedure and Results. CNR-IFN Technical Report, Prot. 2070_240820 (2019)
- Chioetto, P., Measurement Campaign at INAF/OASBO on 13-20 May 2019 . CNR-IFN Technical Report, Prot. 2073_240820 (2019)
- Chioetto, P., CILAS Run 2 Samples Incoming Inspection at CNR-IFN Padova. CNR-IFN Technical Report, Prot. 2074_240820 (2020)
- Chioetto, P., Coating Qualification Report. CNR-IFN Technical Report, Prot. pending (2020)

Papers/Proceedings/Presentations

- Chioetto, P. et al. Testing of a thermal treatment procedure for the opto-mechanical stability at cryogenic temperatures of the ARIEL mirrors. Poster presentation at ARIEL: SCIENCE, MISSION & COMMUNITY 2020, ESA/ESTEC, Noordwijk, The Netherlands (2020).
- Zuppella, P. et al. Cryotesting of a protected silver coating for the ARIEL telescope aluminum mirrors. Poster presentation at ARIEL: SCIENCE, MISSION & COMMUNITY 2020, ESA/ESTEC, Noordwijk, The Netherlands (2020).
- Ferrari, S. et al. The FLY-Spec instrument working on the Lunar surface [Abstract]. In European Lunar Symposium 2020 31-32 (2020).
- Zuppella, P. et al. FLY-SPEC prototype: UV-VIS-NIR reflectometry and laser induced breakdown spectroscopy. in Fiber Lasers and Glass Photonics: Materials through Applications II (eds. Taccheo, S., Ferrari, M. & Mackenzie, J. I.) 46 (SPIE, 2020). doi:[10.1117/12.2552460](https://doi.org/10.1117/12.2552460).
- Da Deppo, V. et al. The optical head of the EnVisS camera for the Comet Interceptor ESA mission, abstract accepted for SPIE – Astronomical Telescope + Instrumentation 2020, San Diego (USA) 13-18 December 2020.
- Zuppella, P. et al. Cryotesting of a protected silver coating for the ARIEL telescope aluminum mirrors, abstract accepted for SPIE – Astronomical Telescope + Instrumentation 2020, San Diego (USA) 13-18 December 2020.
- Chioetto, P. et al. The primary mirror of the ARIEL mission: testing of a thermal treatment procedure for opto-mechanical stability at cryogenic temperatures, abstract accepted for SPIE – Astronomical Telescope + Instrumentation 2020, San Diego (USA) 13-18 December 2020.
- Grimani, C. et al., A Radiation Environmental Study for the Metis Coronagraph on board Solar Orbiter, abstract submitted to AGU Fall Meeting 2020, San Francisco (USA) 7-11 December 2020.

- **Next Steps for ARIEL:** phase B1 to be concluded in 2020 with Mission Adoption. Continuation of involvement in mirrors design.
- **EnVisS:** support to the opto-mechanical design, from lens material selection to structural design and AIV.
- **STC and Metis:** work on performance models and on-ground calibration data.

ARIEL

- **PI:** Prof. Giovanna Tinetti, University College London, UK
- **Italian Co-PI:** Giuseppina Micela, INAF-Osservatorio Astronomico di Palermo, Italy

Comet Interceptor EnVisS

- **PI:** Prof. Geraint Jones, UCL Mullard Space Science Laboratory, UK
- **Co-Pi:** Dr. Vania Da Deppo, CNR-IFN Padova, Italy

BepiColombo SIMBIO-SYS:

- **PI:** Prof. Gabriele Cremonese, Università degli Studi di Padova, Italy

SolarOrbiter Metis:

- **PI:** Prof. Marco Romoli, Università degli Studi di Firenze, Italy