Bologna, 22-24/06/2022 – Forum della Ricerca Sperimentale e Tecnologica in INAF

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

IAPS ISTITUTO DI ASTROFISICA
E PLANETOLOGIA SPAZIALI

Laboratori e Facilities

Stefania Stefani

in rappresentanza di tutto il personale coinvolto nelle attività

Introduction

Facilities

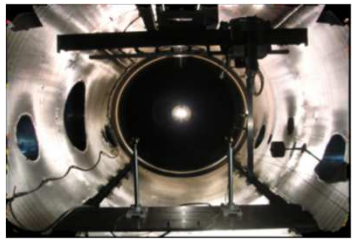
- Plasma Chamber SWIPS (Solar Wind and Ionospheric Plasma Simulation)
- Thermo-Vacuum chambers
- ROCT (Run Optical Chamber Test setup)
- Calibration of accelerometers , drop tower and MTGSE
- X-Ray
- Production of Polarized and Unpolarized Monochromatic X-rays

Laboratories

- Spectroscopy
  - Gas, dust, rocks, micro-meteorites
- Space materials Laboratory
- Space instrument for extra-terrestrial dust
- Ion-ENA Beam laboratory
- Cryogenic laboratory

Plasma Chamber SWIPS (Solar Wind and Ionospheric Plasma Simulation)

Referente: Piero Diego



Main features:

- Large volume experimental facility (about 9 m^3) for **realistic ionospheric** (density 10^{11}-10^{12} m^{-3} , electrons T 0.2-0.4 eV, Vion @ 8000m/s) and **interplanetary** (density 10^7-10^8 m^{-3}, electrons temperature 1-2 eV, Vion @ 350 km/s) environment simulation.
- Geomagnetic field nullified (residual < 0.01 G) or adjusted to simulate S/C orbits

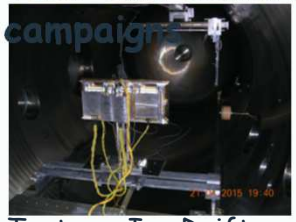
Experimental activities concern:

- Instrument development test and calibration
- Space plasma compatibility for materials and technologies for space applications
- basic plasma physics experiments such as interaction of neutral, charged, and magnetized bodies with plasma for the evaluation of thrust, etching or any kind of plasma-bodies interaction

Current Projects and Collaborations

o CNSA-ASI project Limadou2 : development of QM and FM of Electric Field Detector for CSES-02 satellite
o ESA-INAF project CUBE (CME Catcher Carousel): development of Plasma Analyzer
o IAPS-CIRA collaboration for the improvement of various space technologies
o IAPS-NSSC collaboration for the development of plasma sources and diagnostic systems

Test and Calibration



Tests on Ion Drift Meter and Retarding Potential Analyzer

Simulation of attitude effects on Electric Field Detector

Instrument development:

view of the electric field probe currently under development to be installed on CSES-02 satellite (launch foreseen for 2021 sun-syncronus orbit at 500 km altitude)

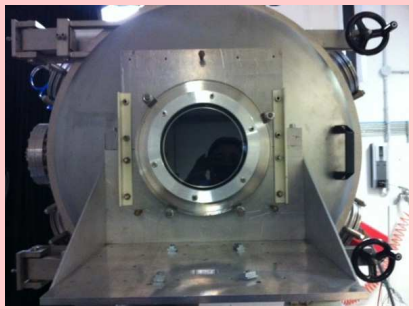
Mechanical sketch of retarding potential analyzer /ion capture meter developed to check solar wind velocity and species, and also suitable for cubesat.

Thermo-vacuum chambers
Referenti: G. Piccioni, D. Biondi e A. Boccaccini

The two test facilities have been employed to test and to qualify electronic, mechanical and optical parts of spatial instrumentations.

Main features
- ✓ **Volume 1600 l**
- ✓ **Vacuum limit 10^{-7}mbar**
- ✓ **Primary vacuum 10^{-2}mbar**
- ✓ **Temperature range -60°/+100°C**

The thermo-vacuum chamber is placed inside a clean room of 10000



- **Main features:**
  - ✓ **Volume: 90 l**
  - ✓ **Primary vacuum: 10^{-2}mbar**
  - ✓ **Max vacuum :10^{-6}mbar**
  - ✓ **Temperature range: -180/60°C**
  - ✓ **Optical window: 165mm CaF2**

Internal Collaboration:
- ✓ **Fasy**
- ✓ **INAF-To**
- ✓ **IXPE**
- ✓ **MAJIS**

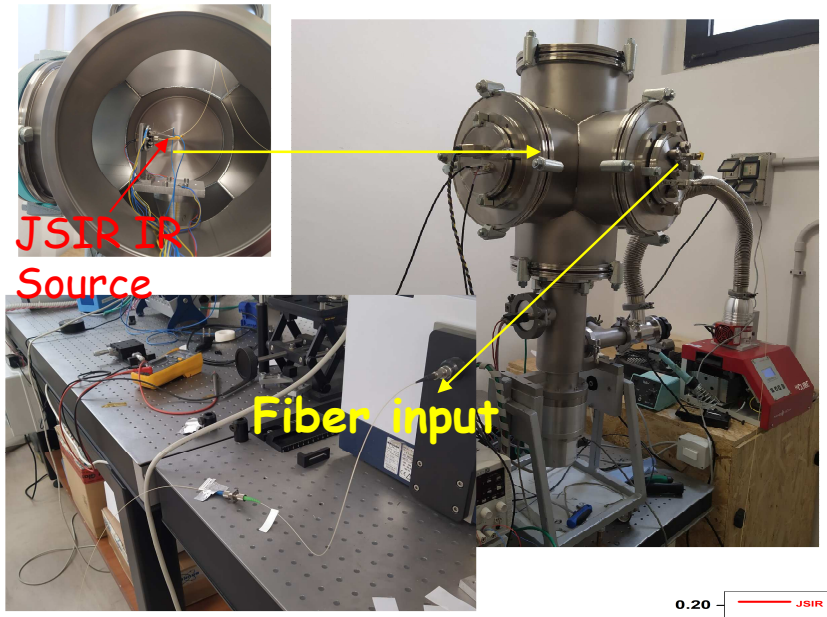
External Collaboration:
- ✓ **Bercella**
- ✓ **CGS**
- ✓ **IKR**
- ✓ **Kayser**
- ✓ **Leonardo**
- ✓ **OHB Italia**
- ✓ **Sab Aerospace**

Actually the TV chamber is placed inside of a clean room ISO 6

The CRV was employed to test optical and mechanical parts of the VIRTIS spectrometer on borad of the VENUS EXPREES, ROSETTA space mission of the SERENA/ELENA instrumentations on board of the BepiColombo

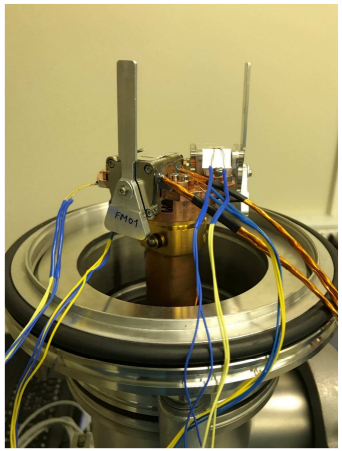
ROCT (Run Optical Chamber Test setup)
Referenti: G. Piccioni, S. Stefani, D. Biondi e A. Boccaccini

Project: MAJIS_JUICE

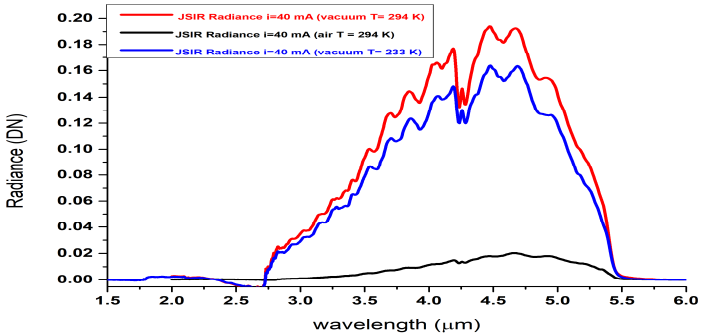


System:
Cryo-cooler 2nd stage:
Cooling Capacity:
1st **50/40W** at 43K
2nd **1.0 W** at 4.2K
Vacuum chamber: **10^{-6} mbar**
Principal activities:
1) Life time test on the FM of the Shutter which is a part of the MAJIS spectrometer on board of the JUIS space mission.

Operative Temperature **135** K
cycles performed without damage:
139,200



2) Optical test on the JSIR emitter source.
The signal coming from to the source, was acquires with a FT-IR spectrometer in the spectral range 2-6 μm



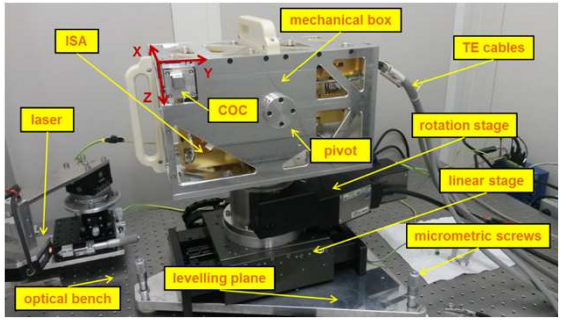
FACILITY di test, calibrazione e Mechanical and Thermal Ground Support Equipment (MTGSE)

Referenti: C. Lefevre, M. Lucente, E. Fiorenza

Progetti: ISA/BepiColombo (ESA/ASI), HAA/JUICE (ESA), GReAT (ASI)

FACILITY DI CALIBRAZIONE ACCELEROMETRI

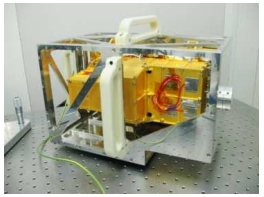
Sviluppata per ISA/BepiColombo e HAA/JUICE per la misura della direzione degli assi sensibili:

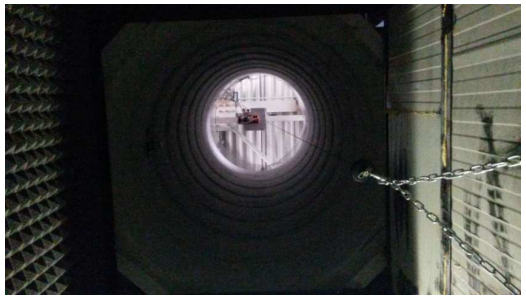


- ✓ Linear stage (0-50 mm) Aerotech ABL15005, con rool/pitch/yaw ± 0.5 arcsec, UUT fino a 35 kg
- ✓ Rotation stage Newport RV120HAT (± 170°, ~ 0.005°), UUT fino a 180 kg
- ✓ 3 laser a triangolazione Keyence (650 nm, 0.95 mW), per misure di piccoli spostamenti (range ± 18 mm, ~ 0.5 μm)

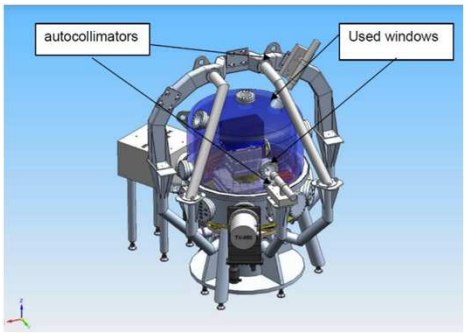
Torre di caduta

Struttura tubolare di 1.5 m di diametro e altezza 10 m, coibentata, acusticamente isolata, utilizzabile per prove di caduta.
Sviluppata per eseguire test di sgancio dell'accelerometro differenziale GReAT (General Relativity Accuracy Test in an Einstein Elevator), un esperimento per la verifica del Principio di Equivalenza di Einstein su pallone stratosferico (WEP).





MTGSE



Facility di test per effettuare analisi e caratterizzazioni di accelerometri in termo-vuoto controllato. Dotata di movimentazioni di precisione della Micos (tip-tilt).

- Sviluppata per accelerometri ISA e HAA
- Camera TermoVuoto (10-6/10-8 mbar, -40/+60 °C) con 2 cold plate.
- Volume interno ca. 600 l
- UUT fino a 30 kg
- Movimentazioni (tip-tilt, rotation stage)
- Autocollimatori
- Ambiente pulito (classe 100.000)
- Basamento e struttura esterna per scambiatori di calore, da realizzare.

X-Ray Facility

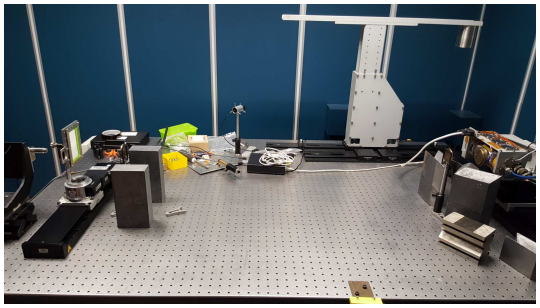
Referenti: Y. Evangelista, F. Ceraudo, M. Feroci

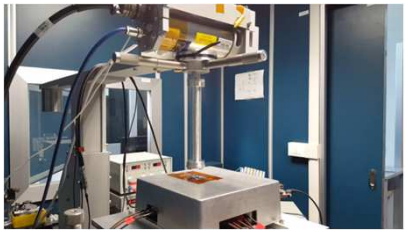
Projects: ADAM/PixDD, HERMES, eXTP

Evangelista et al. 2018, JINST 13, P09011, Campana, R. et al., 2011, NIMA, 633 11 22-30, Cirrincione, D. et al., 2019, NIMA, 936, 239

Lead-shielded chamber for X-ray studies
- Angular resolution of optical devices
- Point-by-point response of sensors

- Equipment list:
  - Optical bench
  - Manual and motorized linear (horizontal and vertical) and rotational stages
  - Motorized stages can be controlled remotely
  - Single-anode X-ray generators (Fe, Ti, Mo, Rh…) by Oxford
    - Emission lines and Bremsstrahlung continuum
    - 50 W max power (50 kV, 1 mA)
    - Interlock safety system connected to chamber doors and temperature monitor of X-ray tube
  - Range of collimators and diaphragms
    - Decrease spread of X-ray beam and increase spatial/angular resolution
  - Independent air-cooling system
    - Allows moderate temperature control
  - Lead-glass window
    - Enables optical inspection even during beam operation
  - Cable feed-throughs





- <u>Enhanced X-ray Timing Polarimetry (eXTP)</u>
  - Angular response of MCP collimators for the Large Area Detector (LAD)
  - Achieved beam properties at device under test:
    - 0.7 mm-diameter
    - 2.4 arcmin-divergence
  - Reference:
    - Ceraudo, F. et al., 2018, JINST 13 9 P0902 doi:10.1088/1748-0221/13/09/P09020

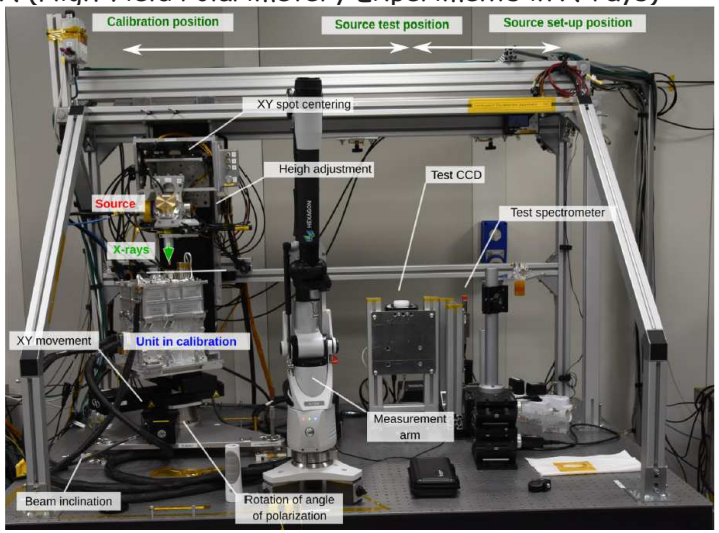
- <u>Pixelated Drift Detector (PixDD)</u>
  - Point-by-point response of multi-pixel Silicon Drift Detector (SDD)
  - Achieved beam properties at device under test:
    - < 50 μm-FWHM
  - Reference
    - Evangelista, Y. et al., 2018, JINST 13 9 P09011, doi:10.1088/1748-0221/13/09/P09011

Facility for production of Polarized and Unpolarized Monochromatic X-rays

Referenti: P. Soffitta, F. Muleri, S. Fabiani end E. del Monte

Projects: IXPE (Imaging X-ray Polarimetry Explorer), CUSP (Cubesat Solar Flare Polarimeter), Hype-X (High Yield Polarimetery Experiments in X-rays)

- Bragg diffraction at 45° (Polarized Monochromatic)
- Fluorescence lines (Unpolarized Monochromatic)
- Metrology system for angle and position determination
- X-ray tubes 50 W 1 mA plus crystals and collimator for Polarized X-rays
- Head-on X-ray tube 2W 1 mA for producing unpolarized X-rays
- Two stations: one in a ISO-7 clean room one in lead-shielded room
- Equipped with a X-ray Andor CCD, Amptek-SDD
- Computer controlled linear and rotary stages



Successfully employed for the ground calibration of the IXPE four detector Units (DUs)

Operated in total 160 days 7/7 days/week 24/24 hours/day

Energy	Configuration	Source settings	Rate [cts/s]	Polarization Degree [%]	Angle [deg]
2.04	Fluorescence of Zr target illuminated by Rh X-ray tube	19 kV, 0.95 mA	~177	1.12 ± 0.14	1.38 ± 3.62[a]
2.29	Fluorescence of Mo target illuminated by Ag X-ray tube	17 kV, 0.77 mA	~199	0.85 ± 0.11	1.32 ± 3.63[a]
2.70	Direct X-ray tube with Rh anode + 300 μm PVC filter	4.0 kV, 0.52 mA	~205	6.71 ± 0.10	−0.93 ± 0.41[a]
2.98	Direct X-ray tube with Ag anode + 6 μm Ag filter	4.0 kV, 0.06 mA	~215	13.20 ± 0.09	−0.19 ± 0.19[a]
3.69	Direct X-ray tube with Ca anode	5.4 kV, 0.003 mA	~213	Undetected, MDP(99%) = 0.22%	Undetected
5.89	^{55}Fe nuclide	4 mCi	~180	Undetected, MDP(99%) = 0.19%	Undetected

Unpolarized Monochromatic Sources Muleri et al., 2022

keV	Crystal	Line	Bragg angle
1.65	ADP(101)	CONT	45.0
2.01	PET(002)	CONT	45.0
2.29	Rh(001)	Mo L_α	45.3
2.61	Graphite	CONT	45.0
3.7	Al(111)	Ca K_α	45.9
4.5	CaF_2(220)	Ti K_α	45.4
5.9	LiF(002)	^{55}Fe	47.6
8.05	Ge(333)	Cu K_α	45.0
9.7	FLi(420)	Au L_α	45.1
17.4	Fli(800)	Mo K_α	44.8

Monochromatic Polarized Sources

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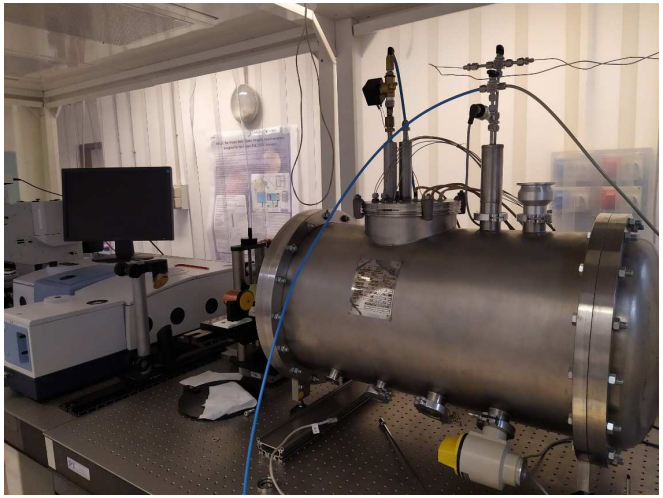
Laboratories

PASSxS (Planetary Atmosphere System Simulation for Spectroscopy)

Referenti: S. Stefani, G. Piccioni

Projects: VENUS-Express, JUNO-JIRAM- MAJIS-JUICE and ARiel

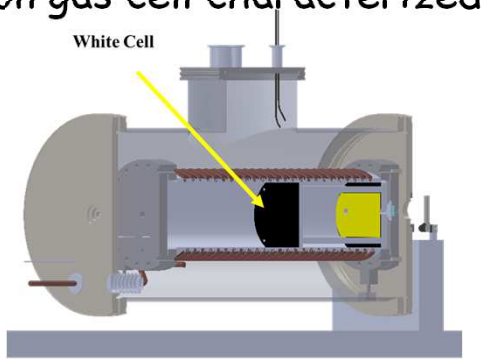


Goal: experimental set up used to characterize the optical properties of gases at typical planetary conditions high/low pressure (**mbar < P < 70 bar**) high/low temperature (**100 K < T < 500 K**) . In particular CO_2, H_2 and different mixing(H_2+ He, H_2+ H_2 and CH_4) typical of the Jupiter atmosphere. When coupled with a FT-IR spectrometer (as shown on the left), the chamber is equipped with a Multi Pass (MP) absorption gas cell characterized by an **optical path of about 9.2 m**.

Resolution: 0.01-10 cm^{-1}

Spectral range : [0.3-8] μm

the chamber is equipped with a White Cell (MP) absorption gas cell characterized by an **optical path of about 9.2 m**.

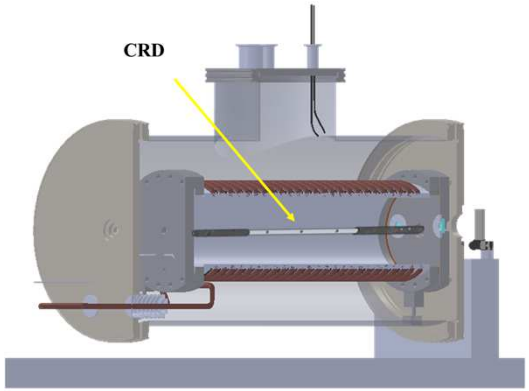


When coupled with a Cavity Ring Down (CRD) tube:

optical path of about 5 km

Thanks to the high reflectivity of the mirrors we can measure the total absorption of about 10^{-6}

Spectral range depends on the laser tunability



Actually the set up is placed inside of a Soft-wall ISO 6 chamber

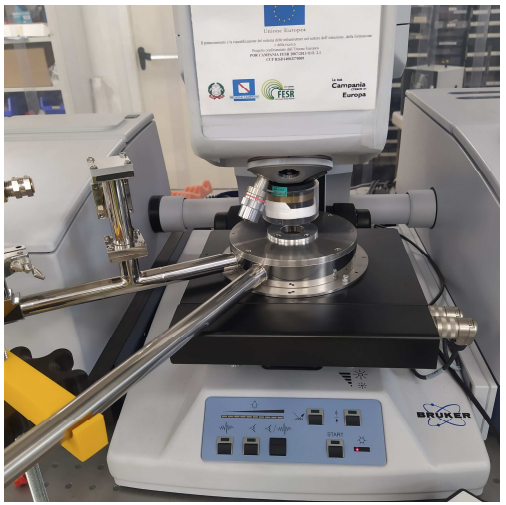
Reflectance and µIR spectroscopy (PLAb)

Referenti: S. Stefani and G. Piccioni

Projects: MAJIS-JUICE and others external collaborations

Goniometer accessory of Vertex 80

- ✓ Bi-conical Reflectance (low angle 13°): variable incidence and emission angle: (13-85°); minimum phase angle 26°;
- ✓ Spatial Resolution: spot of 5 mm in diameter;
- ✓ Motorized or manual controlled arm, fixed sample;
- ✓ spectral range: variable 400-16000 nm



µIR-spectroscopy connected to the Vertex 80 interferometer

- ➢ working range 0.4-14 µm
- ➢ used to acquire spectra in reflection and transmission mode on single feature with minimum dimensions of 50 µm
- ➢ Used to acquire IR images

Integrated with a micro-cryostat
Temperature range < 6 K (Lhe) to 475 K
Temperature stability < 50 mK
Older dimension about 1'
Will be employed to characterized optical filters, micro-meteorites, rocks @ different temperatures

Spectroscopy LAboratory (SLAb) and Sample Facility Preparation (SFP)

Referenti: C. Carli, E. Bruschini end A. Stephan

Main Project: SIMBIO-SYS (Bepicolombo) OI-BODIES (ASI-INAF 2018.HH.0) POSEIDON (H2020 Marie Curie)
Supported also by Dawn/ExoMars and different IAPS director funding for Laboratories.

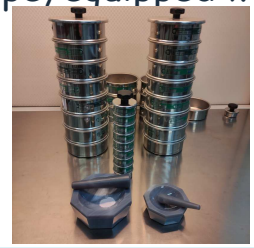
This lab supported also the sample preparation for measurements at IPAG in Grenoble, PSL at DLR in Berlin, at IAS and at SOLEIL Paris. Support to:
a) More then 20 publications,
b) 5 Ph.D. students and 10 Master/Bachelor Thesis or
c) SSHADE spectra library

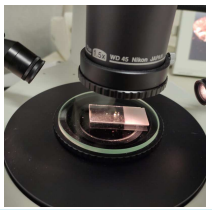
VNIR FieldSpec Pro coupled with a Goniometer

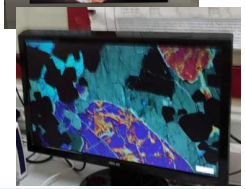
- ✓ Bi-Directional Reflectance: variable incidence and emission angle (0-65°), minimum phase angle 28°;
- ✓ Spatial Resolution: spot of 6 mm in diameter;
- ✓ Motorized arm and X-Y plane, controlled by computer;
- ✓ spectral range: 350 – 2500 nm, resolution 2÷12nm

Sample preparation: Build in 2010, using an already prepared set-up at which we dedicated a specific laboratory to work systematically on solids as analogues for planetary surfaces.

The facility is characterized by 2 machine rocks grounding, a saw for rocks cutting, an electronic sieving. Sieves are present for sizes from 2 mm up to 20 mm with a diameter of 10 cm and 2 series of 2.5 cm in diameter and from 200 up to 20 mm, plus ultrasound pool for cleaning.
Two different hand ground agata system. To produced samples from bulk rocks to cut sample and to powder at different grainsizes.
We have also an high precision balance and a drying cab. Recently we had also a plate for fining polish. A preliminary analysis can be done sing two different microscopes a stereoscope and a petrographic microscope, equipped with cameras.



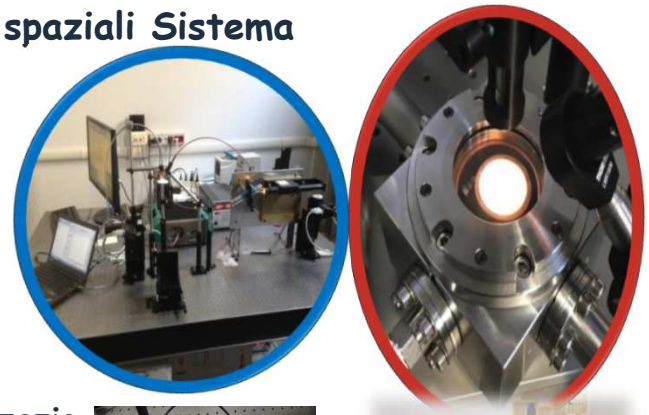




Laboratorio Spettroscopia Superfici C-Lab

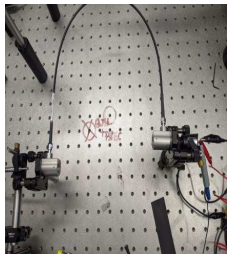
referenti: M.C. De Sanctis –1°ric, S. De Angelis –ric. TI, M. Ferrari –ric. TI, A. Frigeri –ric. TI, E. La Francesca –AdR, L. Rossi –BS, N. Costa –BS

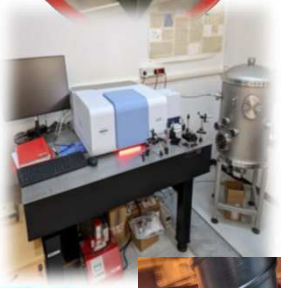
Missioni spaziali Sistema Solare
* ExoMars
* Dawn
* Prospect
* JUICE



Spettroscopia VIS-NIR-MIR-Raman * Analoghi superfici planetarie (Marte, Cerere, Luna, asteroidi, …) * Rocce/minerali/misture * Meteoriti * Target di riferimento (commerciali, FM spare)

Caratterizzazione Setup, Fibre Ottiche + Sorgenti IR
* Progetto TRIS





Sviluppo camere UHV
* Cella PT + Fspe4 / SPIM
* Progetto CAPSULA + FTIR
* Misure spettrali analoghi a condizioni variabili di P-T-atm

Attività sul campo
* Misure su terreno con prototipi / strumenti portatili
* Raccolta campioni per lab

Modelli di laboratorio / Spare di spettrometri spaziali
*Ma_MISS + Drill /ExoMars
* SPIM / Dawn

Pubblicazioni (Peer Review)
De Angelis S. et al., *PSS*, 101, 89-107, 2014
De Angelis S. et al., *PSS*, 117, 329-344, 2015
De Angelis S. et al., *Rev.Sci.Instr.*, 86, 093101, 2015
BostN. et al., *PSS*, 108, 87-97, 2015
Manzari P. et al., *Earth Sp.Science*, 3, 2016
De Angelis S. et al., *Icarus*, 280, 315-327, 2016
De Sanctis M.C. et al., *Astrobiology*, 17, 6-7, 612-620
De Angelis S. et al., *PSS*, 144, 1-15, 2017
Manzari P. et al., *MAPS*, 1-20, 2018
Ferrari M. et al., *Icarus*, 321, 522-530, 2019
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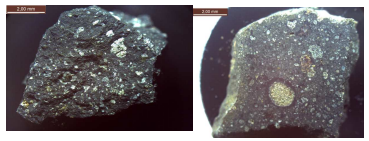
De Sanctis M.C. et al., *MNRAS*, 482, 2, 2407-2421, 2019
Singh S.K. et al., *Nature Communications*, 12:2690, 2021
Schroder S. et al., *Nature Communications*, 12:274, 2021
De Angelis S. et al., *JGR:Planets*, 126, 2021
Pisello A. et al., *Icarus*, 374, 114801
De Sanctis M.C. et al., *PSJ*, 2022

Space materials Laboratory
Referenti: E. Palomba, F. Dirri, A. Longobardo

Goals:

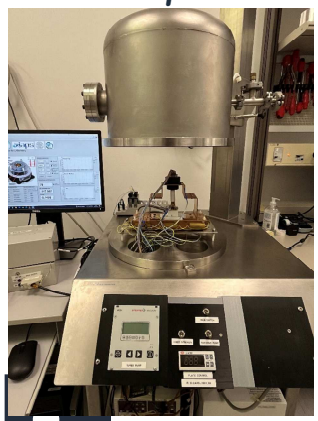
1. ***Meteorites and analogue mixtures characterization with FTIR spectrometer (spectral range:) for JAXA-Hayabusa2 (Ryugu), JAXA-DESTINY+ (3200 Phaethon asteroid) and ESA-HERA (Didymos-Dimorphos binary asteroid) Space Missions***

2. **Thermal setup at 500-700°C in vacuum chamber** to simulate thermal metamorfism on asteroids of meteorites/analogue mixtures

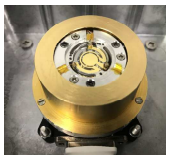


Goals:

1. ***Development of Microbalance device for Space Applications*** (dust and volatiles characterization in different planetary envirnoments)
2. ***Development and testing of Microbalance device for laboratory use*** (Materials outgassing evaluation in dedicated vacuum chambers)



CAMLAB (Contamination Assessment Microbalance for Laboratory) developed for "Development of a European Quart Crystal Microbalance" ESA-ITT Project (2017-2019)



CAM (Contamination Assessment Microbalance), developed for "Evaluation of an in-situ Molecular Contamination Sensor for space use" ESA-ITT Project (2014-2016)

VISTA(Volatiles In-SiTu Thermogravimeter Analyser) developed for HERA-ESA Mission onboard Milani Cubesat (2020-2023)

Space instruments for extra-terrestrial dust:

- *'in situ' measurements*
- collection and retrieval

Referenti: Vincenzo Della Corte[1], Alessandra Rotundi[2,1], Andrea Longobardo[1], Stefano Ferretti[2,1], Anna Musolino[1], AliceMaria

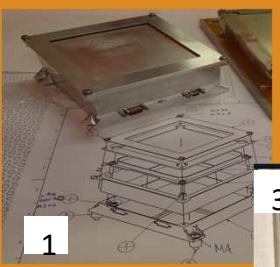
Extra-terrestrial dust particles dynamical properties «in situ» measurements: DISC

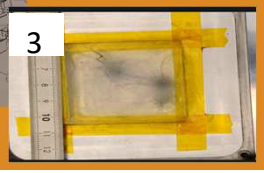
Project: DISC (Dust Impact Sensor and Counter), part of the DFP (Dust Field and Particles) suite, onboard ESA Fast space mission Comet Interceptor (Launch 2029).

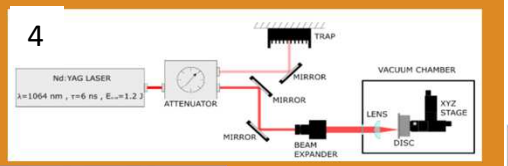
Heritage: GIADA onboard ESA/Rosetta space probe.

Activities: Instrument development and managment.

- **Bread Board sensor design and test (1).**
- **Dust shield for High Velocity impacts: design and test with hyper velocity facilities (2,3).**
- **Hyper Velocity Dust particle impacts simulation:**
  - **High power pulsed laser experimental setup (4)**
  - **Ansys/Autodyn simulation chain (5,6)**





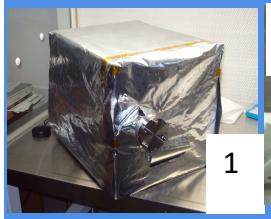


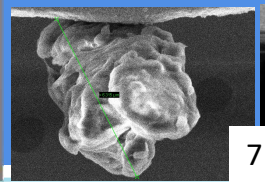
Extra-terrestrial dust particles collection in the Earth stratosphere & retrieval for laboratory analyses: DUSTER

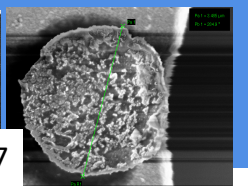
Project: DUSTER (Dust in the Upper Stratosphere Tracking Expirement and Retrieval), onboard stratospheric balloons.

Activities: Instrument development and management:

- **Instrument design/manufactoring (1)**
- **Campaign preparation (2,3,4,5,6)**
- **Campaigns: 2008,2009 Svalbard (Norway), 2011, 2019, 2021 Kiruna (Sweden)**
- **Collected dust particles identification (7)**
- **Collected dust particles analyses and classification (7)**





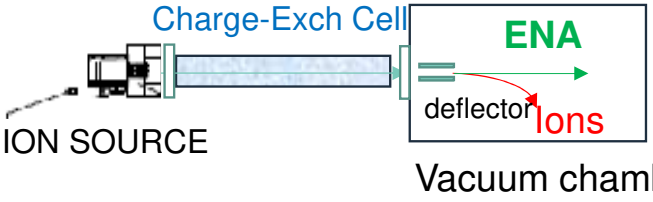


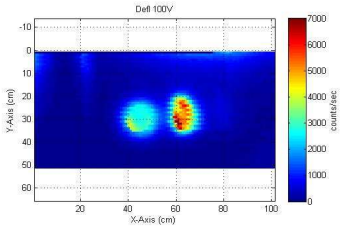
Ion-ENA beam Laboratory

Referenti: E. De Angelis, R. Rispoli, L. Colasanti, N. Vertolli, F. Nuccilli and M. Moroni

Main general tasks:

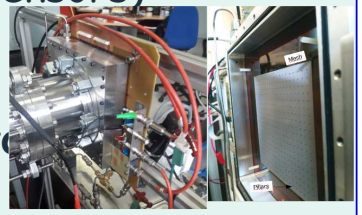
- **Development**, **testing and calibration** of space instruments for Ion and Energetic Neutral Atoms (ENA) detection devoted to Planetary Space Weather
- **Laboratory simulation** of interaction phenomena generated by Solar Wind with solar system bodies and environments.
- **Interaction** investigation of selectable ion/neutral beam with several samples (instrument devices, detectors, planetary analogues).





SWEATERS project (Space Weather ENA Sensors)
INAF-INFN with CERN and SWRI

➢ Development of innovative ENA sensor :
First ENA instrument based on Gas detect
(MPGD-Micro Pattern Gas detector)
for Space Weather application:



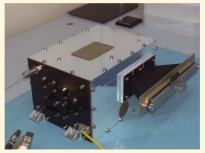
Ion/ENA beam on MPGD type detector

-Test @IAPS, set-up for detector chracterization
- Test on CarbonFoil/Graphene entrance window
- Study, simulation and testing for parameters refining

[ASI contract: «SWEATERS project»]

SERENA/ELENA: instruments on board the BepiColombo/Mercury Planetary Orbiter (launched October 2018- at Mercury 2025) **ESA-JAXA**

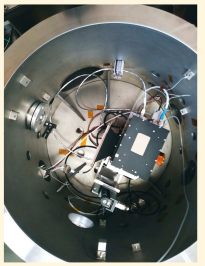
➢ ELENA Flight Spare activities
Test on ground during BC cruise phase:



ELENA FM (on-board BC mission)

Satellite simulator (MIS) allows to command Serena\ELENA FS in lab @Mercury beam condition:

- Mercury Lab simulation
- Test with ion and ENA beam to verify different flight instrument configuration
- Development and testing of on-board procedure and SW updates



ELENA FS (vacuum chamber @IAPS)

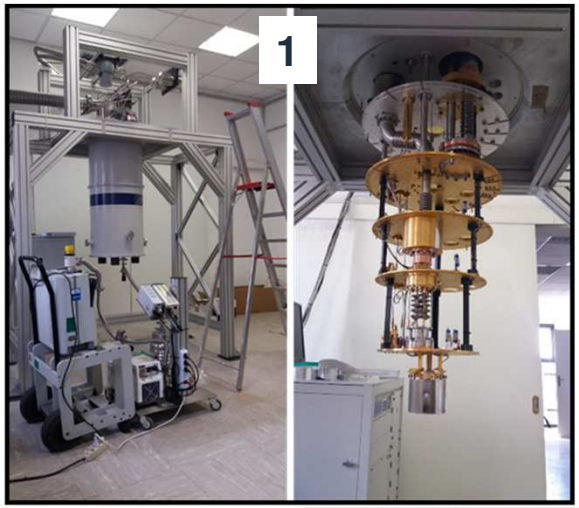
(ASI contract: «Serena/BC-Fase E»]

Cryogenic laboratory for X-ray Astrophysics:

more details at: http://www.iaps.inaf.it/2020/09/29/cryogenic-laboratory-for-x-ray-astrophysics-2

Referenti: C. Macculi, L. Piro, M. D'Andrea

Skills	Facilities	Comments
Cryogenics	**1) Pulse Tube + Dilution unit He3/He4** (Tbase < 10 mK, Cooling Power @50mK = 115 μW) **2) Pulse Tube + ADR** (T_{base} ~ 40 mK, Cooling energy @50mK = 17 mJ) **3) Pulse Tube** (T_{base} ~ 2.3 K, Cooling power @4K = 0.4 W)	• Transition Edge Sensor work at ~ 0.1 K • Electronics works at ~ 4K • Equipped with PID-type active thermoregulation systems, and dedicated instruments for monitoring and control • Optical inputs up to the lower temperature stages available
EMI/magnetic shielding + filtering	• **Faraday cage** • **Magnetic shielding** (at cryogenic and warm temperatures)	• The use of the SQuID calls for maximum noise current of $i_n(f)$ ~ 5 pA/rtHz up to few MHz • TESs require a residual magnetic field < μT in the sample space.



DRIVER:
- High resolution spectroscopy in X-ray
- Cryogenic Anticoincidence particle Detector
- Cryogenic and Warm Readout Electronics

REFERENCE MISSION: **Athena**. At present the facility is currently 100% committed until 2025.