What Next at LNF: Scienze dei Materiali
<u>Space Applications</u>

S. Dell'Agnello (INFN-LNF, CSN5 Coordinator), E. Pace (UniFi & INFN)
For the SCF_Lab and DAΦNE-LIGHT Research Teams

INFN-LNF, Feb. 26, 2015

Outline

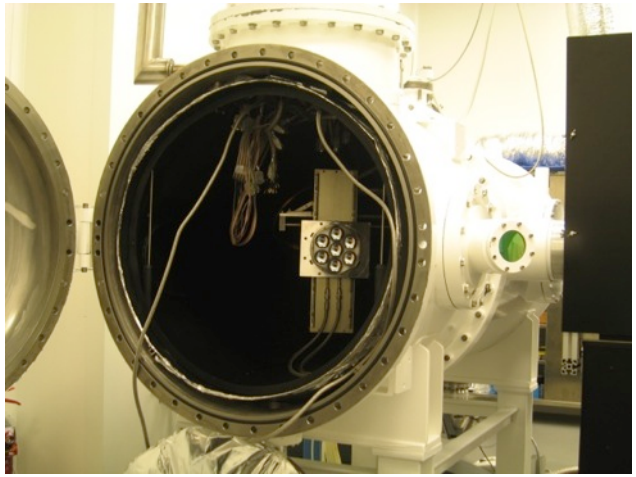
- Synergism between SCF_Lab & DAΦNE-LIGHT
- Specific CSN5 space research projects: EXOLIFE, ARIEL
- Start from INFN-NASA/SSERVI partnership (15-Sep-2014) and go beyond
- NASA/SSERVI Teams/Users which may exploit DAΦNE-LIGHT / SCF_Lab test capabilities

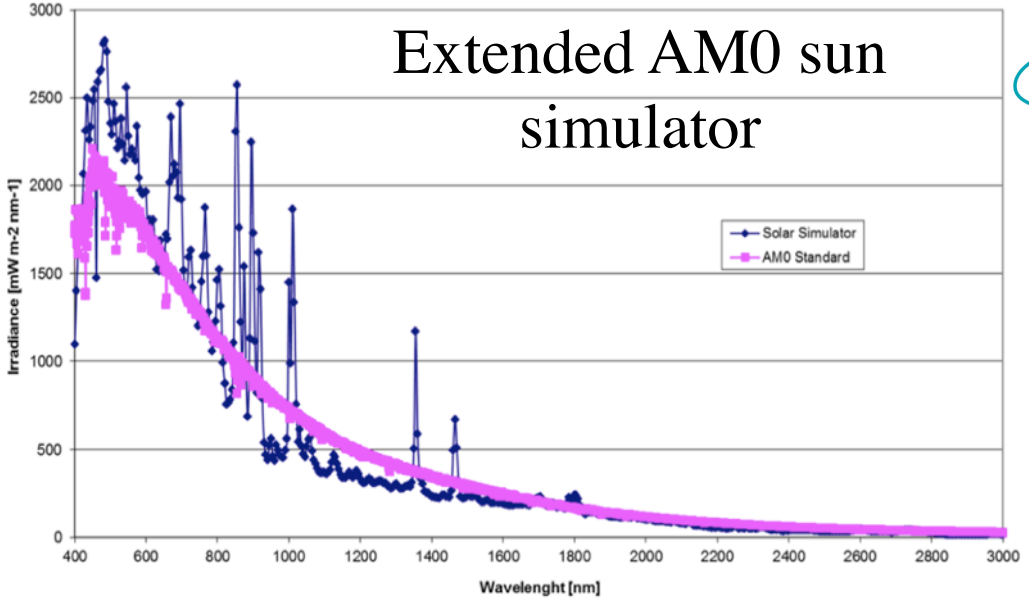
SCF_Lab & DAΦNE-LIGHT Synergism

- **Focus**: space exploration & planetary science, which typically involve instrument testing in the energy ranges of DAΦNE-LIGHT, in an environment 'à la SCF_Lab'
  - Instruments: service payloads, science/exploration payloads/detectors
  - Surfaces of Moon(s), planets, NEA (Near Earth Asteroids)
    - Also orbiting satellites
- Key experimental conditions & instrumentation
  - Full space environment → SCF_Lab
  - Solar Simulator (extended AM0), see next slides
  - DAΦNE-LIGHT test beams → See slides by A. Balerna
    - MS_Lab (Cimino et al): other contacts w/NASA-JPL
- CSN5 research. But also stimulate/help/expand space CSN2 activities, as requested by INFN/CSN2/LNF Management

SCF_Lab: laser retroreflector Cube/microsat and space environment characterization

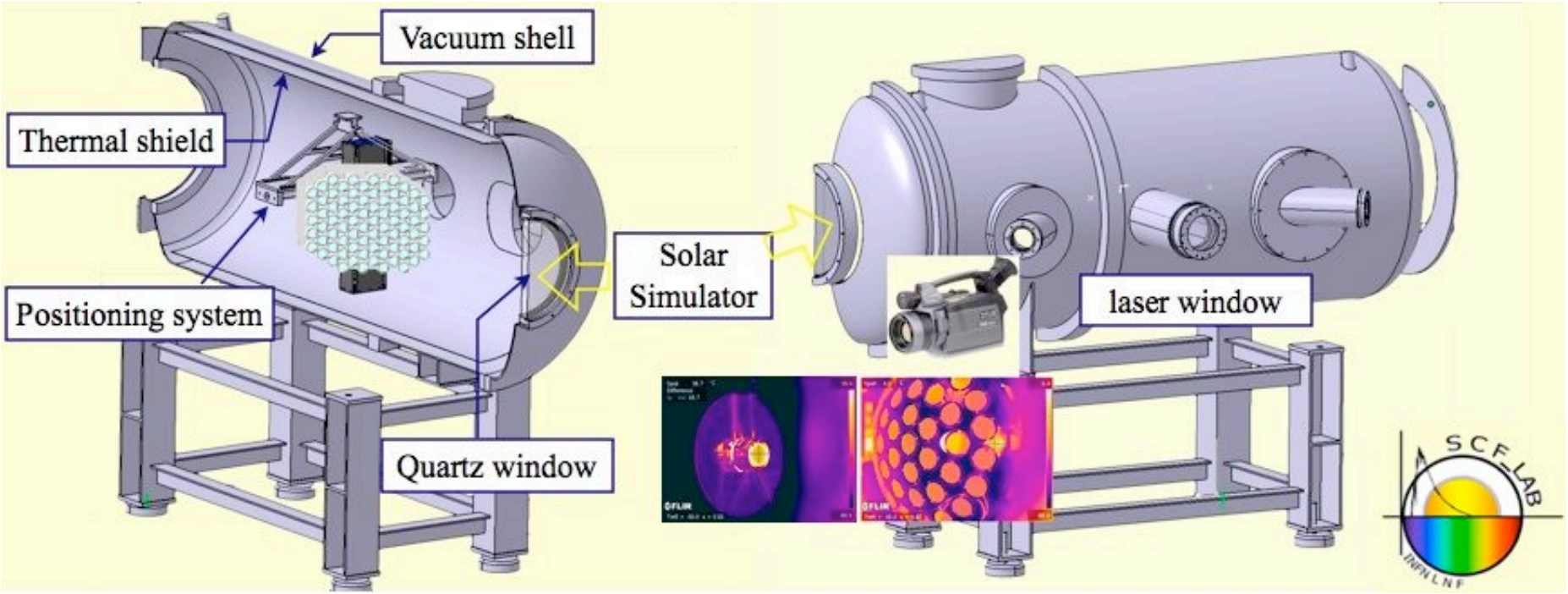
- Two Optical Ground Support Equipment (OGSE)
- SCF (top right) SCF-G (bottom right) dedicated to Galileo, other GNSS
- Two AM0 sun simulators, IR thermometry, Optical testing
  - J. Adv. Space Res. 47 (2011) 822–842





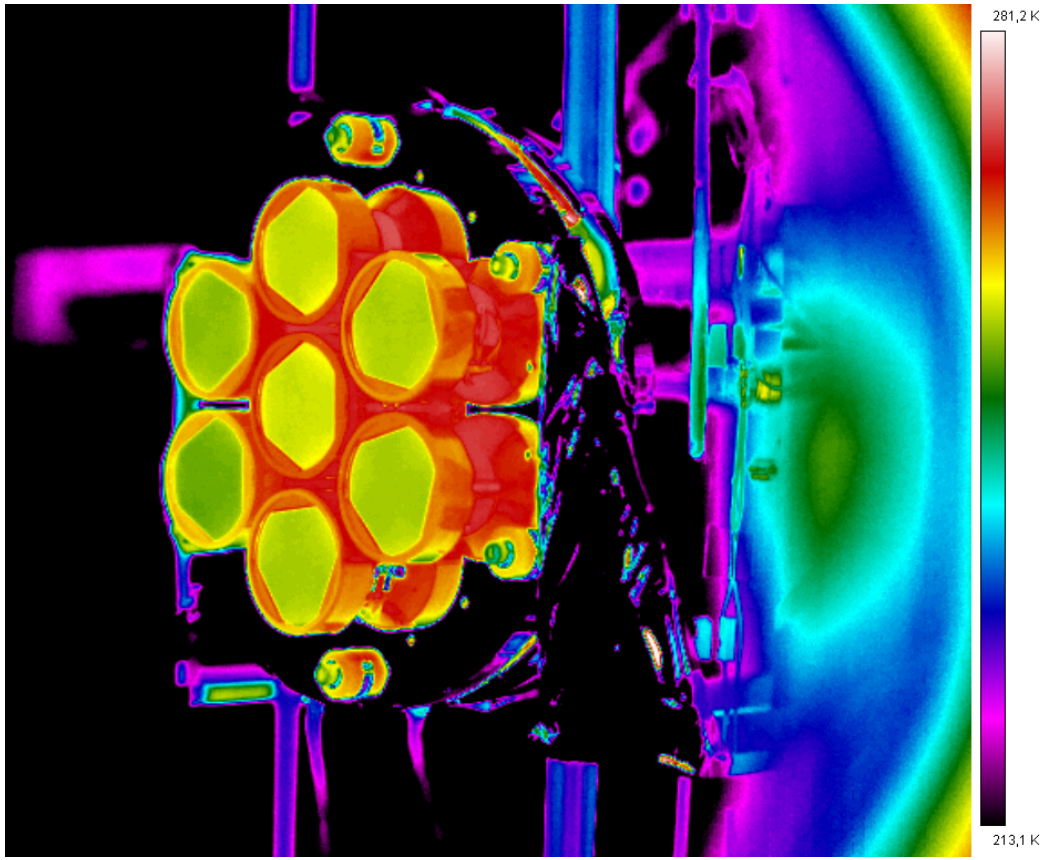
SCF_Lab space environment characterization

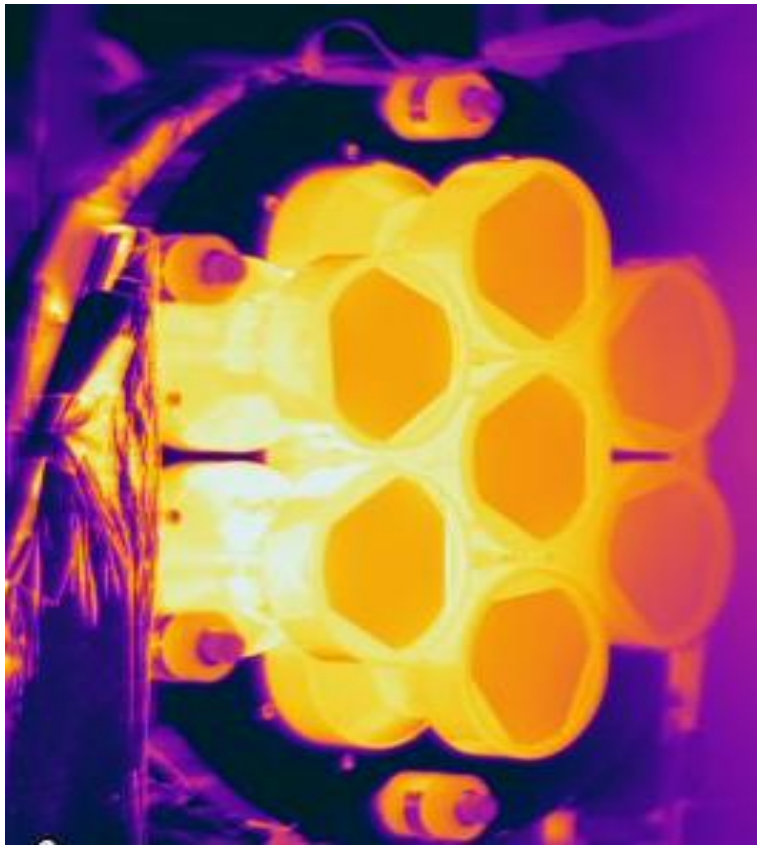
- Two Optical Ground Support Equipment (OGSE) and Space Environment Facilities
- (Better than) Class 10000 (ISO 7) Clean Room



IR Temperature Characterization

Infrared Image of GALILEO IOV retroreflectors during SCF-Test at 0°C, heating phase





SCF_Lab space environment characterization

- Accurately laboratory-simulated space conditions
  - Thermo-Vacuum + Sun (AM0) **simulators**
  - IR and contact **thermometry**
  - Payload **roto-translations** and **thermal control**
- Several flexible in-out ports. Can be integrated w/BTF
- Current default characterizations
  - **Thermal behavior**
  - **Laser interrogation**
    - General application: Wavefront Fizeau Interferometer (WFI)
    - Specific application: laser retroreflector Far Field Diffraction Pattern (FFDP)

Specific Research Projects (slides by E. Pace)

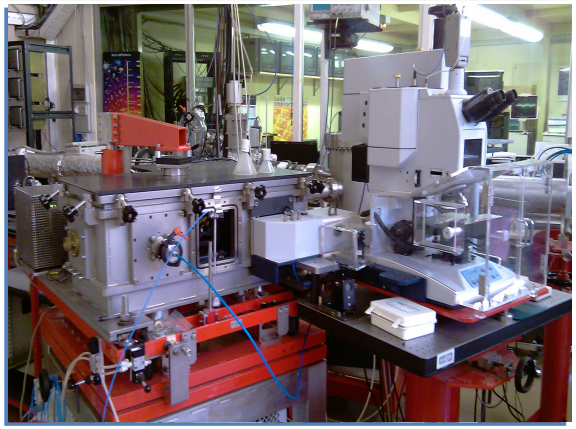
- **EXOLIFE:** Impact of exotic organisms on planet atmospheres and spectral characterization of biosignatures to search for Exolife …
  - SCF_Lab: bio sample irradiation with stellar-adapted Sun Simulators spectra, up to 2 simulators simultaneously, to model binary stars
  - FP7-SPACE-2013 to be re-considered for H2020
- **ARIEL** Atmospheric Remote-Sensing Infrared Exoplanet Large-survey
  - Submitted Jan 15, 2015 to ESA Call M4 (Middle class n. 4)
  - Italy proposed Spectrometer instrument; endorsement by ASI
  - E. Pace involved as UniFi
  - DAΦNE-Light, LNF: involved with M. Cestelli-Guidi & C. Marcelli
- Next slides: space applications

DAΦNE-L UV-IR synchrotron facility

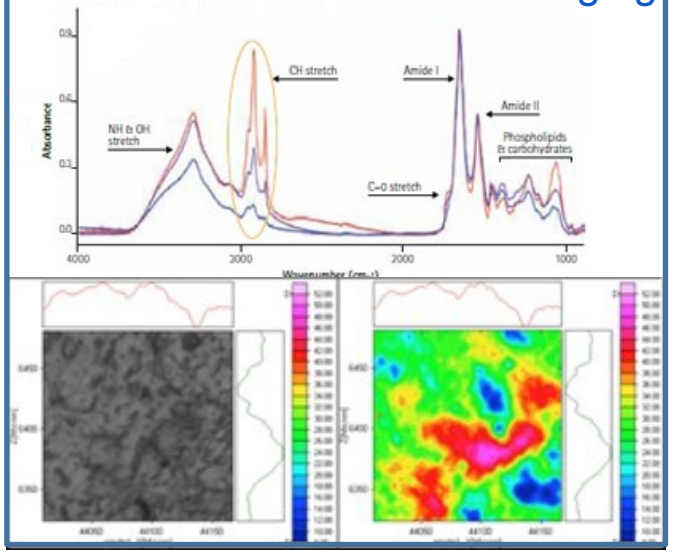
E. Pace

A unique facility combining Infrared and UV-VIS radiation and operating with synchrotron and standard sources is **open to external users** for non destructive analyses and testing of materials for space applications

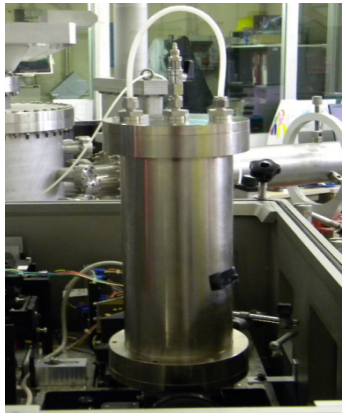
UV-IR experimental facility (1 mm – 0.5μm)



FPA detector for chemical imaging



Long path gas cell to characterize atmospheres.



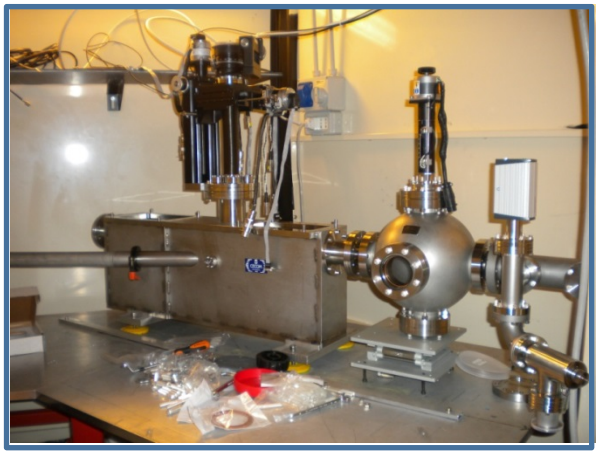
- Extended IR range (from Far-IR to NIR-VIS) for analysis of inorganic and biological materials
- Chemical microimaging of material samples as meteorites, organics in mineral matrices, etc.
- Extended UV-VIS range (120-650 nm) irradiation for material testing & photochemistry
- Real time study of UV photoageing & photochemical processes
- Planetary atmosphere evolution and biosignature characterization
- High temperature (1200°C) / high pressure (20GPa) setup simulating planetary environments
- Simulation and analysis of planetary analogues for exobiology and life science

SOURCE branchline in a 1000 class cleanroom

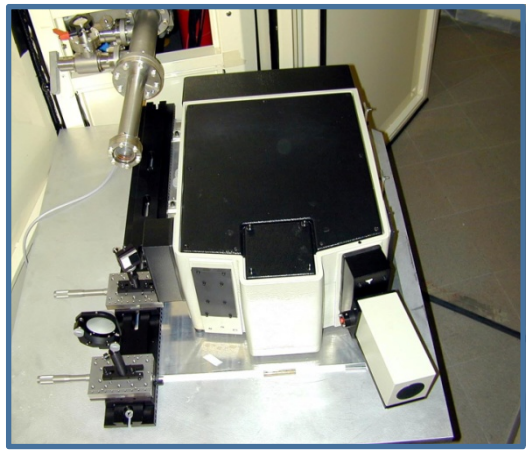
E. Pace

Interest of ASI, Selex ES, Optrim as UV-VIS optical testing facility.

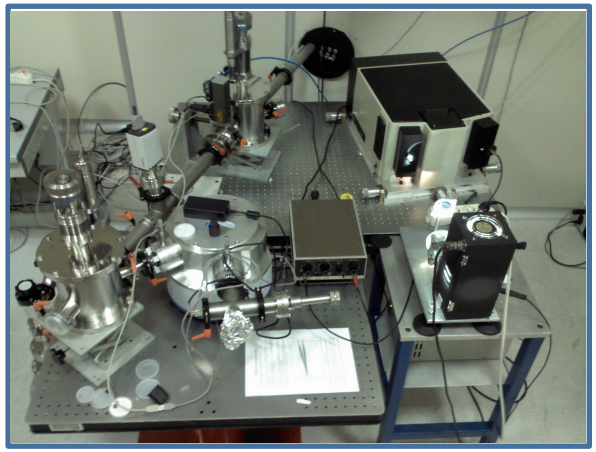
UV-VIS monochromatic radiation source (180-650 nm)



VUV monochromatic radiation source (120-250 nm)



UV-VIS radiation source (200-650 nm)



- Specifically suited for testing space instruments, like optical systems/payloads (up to 4 m) in a clean environment
- UV photoageing and characterization of optical components and materials
- Ultrafast time response of detectors (> 100 ps)
- Photobiology, photochemistry and **exobiology** experiments

EXO-biology & planets RD @DAΦNE-L

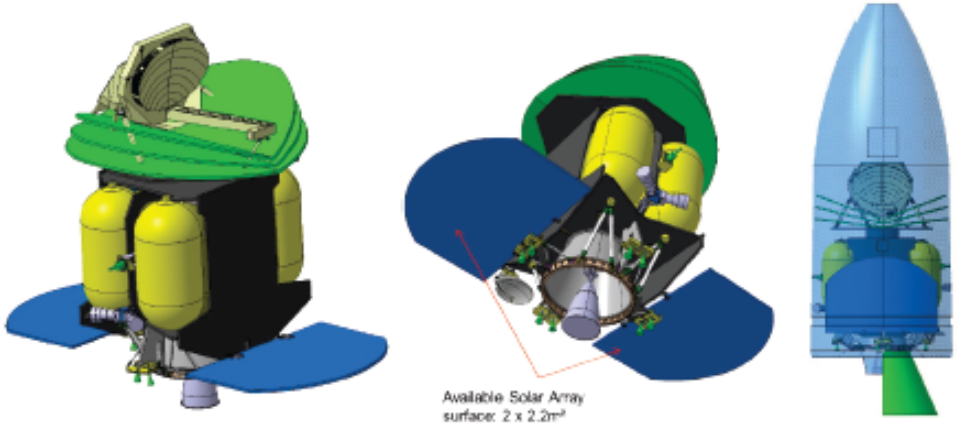
E. Pace

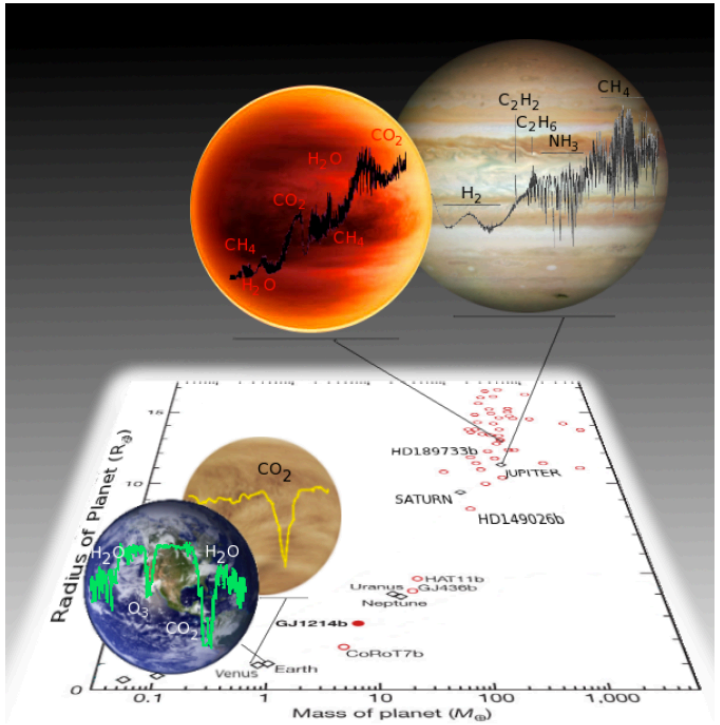
PROJECTS

ARIEL – M4 ESA Cosmic Vision

EXOLIFE – H2020

Atmospheres in a test tube – INAF





Use of the UV and IR synchrotron radiation, lamp sources and Solar Simulators (in collaboration with SCF_Lab) to:

- Study **exoplanetary** atmospheres
- Search for life markers in **exoplanetary** spectra
- Study of survival mechanisms of organic and biological materials in space environments

Collaboration with INAF (IAPS TO, PD, PA, Arcetri) UniRomaTV, UniFI and several international research institutes

Diamond devices for space apps

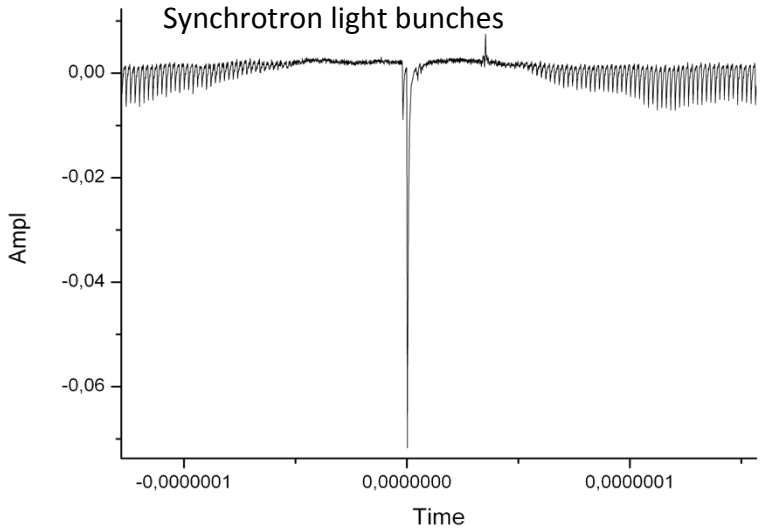
E. Pace

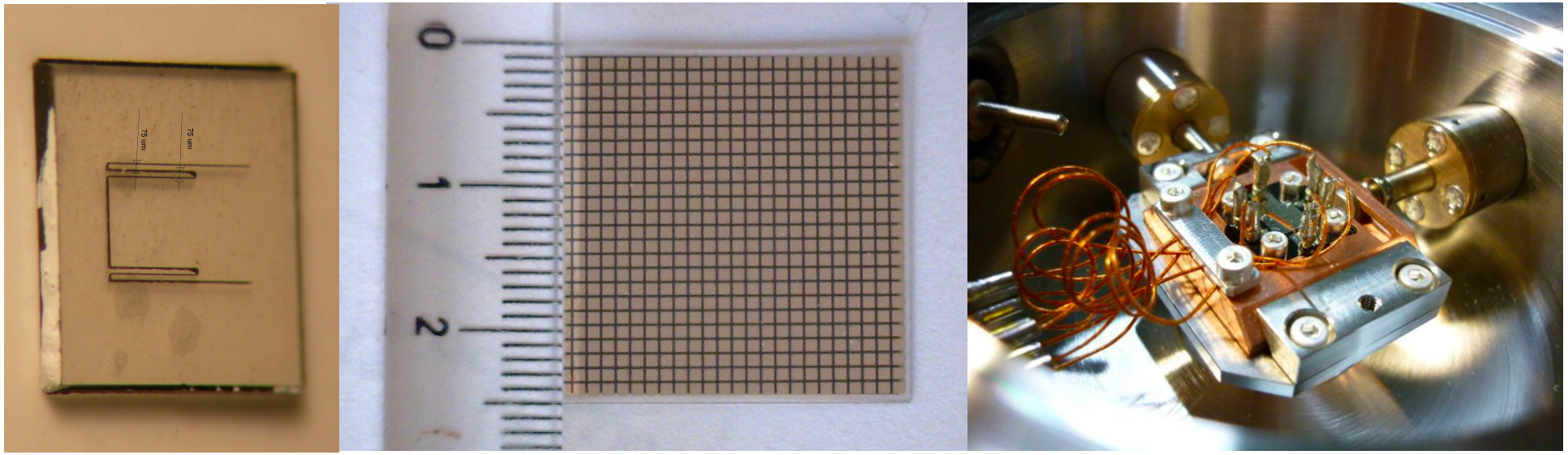
- UV & X-ray ultrafast and rad-hard detectors
- Dosimeters for astronauts and space environments
- Pixelated structures for imaging
- Microdevices and micropatterning

RADIA (FP7) & MONSTRE (H2020) EU projects

Heritage: DIAPIX and developments for ELETTRA/GILDA
DIASPACE on board ISS, Bion, Photon M3

Exploitation of the Device Fabrication Lab @ LNF and collaboration with XUVLab @ UniFI





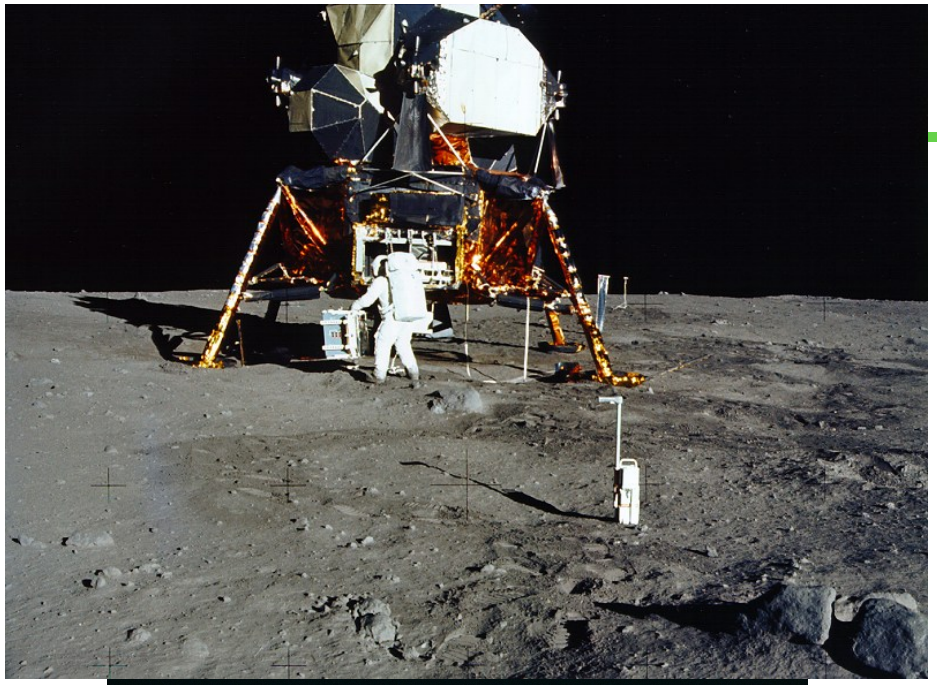
Affiliation of INFN to NASA/SSERVI

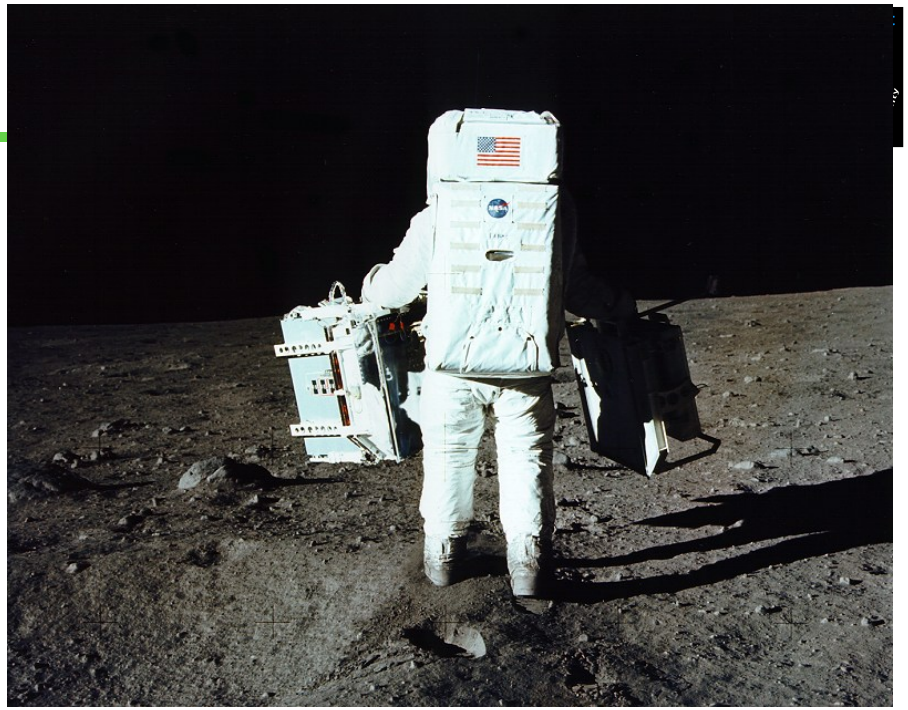
- SSERVI, **Solar System Exploration Research Virtual Institute**, centrally managed by NASA-ARC, California
  - **Moon, Mars, Phobos, Deimos, asteroids**
  - http://sservi.nasa.gov/nlsi-central/
  - http://sservi.nasa.gov/international/

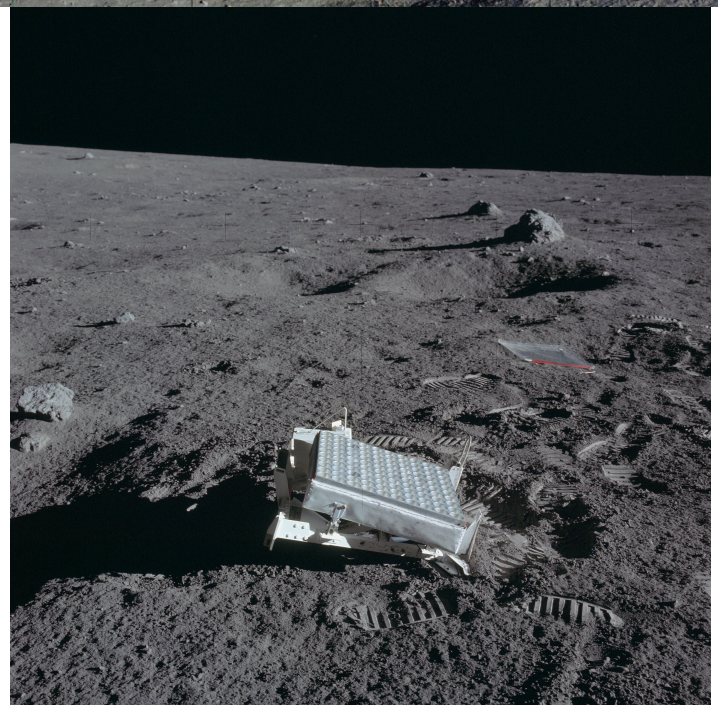
- INFN is the first Italian Partner of the SSERVI

- Others: UK, Germany, Canada, Korea Netherlands, Israel, Saudi Arabia

SCF_Lab with Elachi (NASA-JPL), Flamini (ASI)







Lunar Laser Ranging: only Apollo experiment still providing data since 1969 (2009 NASA patch)

Lunokhod 3 at NPO-Lavochkin, Moscow

“The” Laser reflector material: Suprasil fused silica

NASA Affiliation, CSN5/2 & Beyond

- Synergism of BTF & DAΦNE-Light with SCF_Lab and NASA/SSERVI research

- Further development/expansion upon request of INFN/LNF/ CSN2 Management
  - Example: **SCF_Lab/BTF** test of GAMMA-400 & CALOCUBE subsystems
  - Also: serve similar Italian/European space communities

- Next slides: NASA R&Ds & Teams that can be Users of **DAΦNE-Light/SCF_Lab**

SPRINGLETS: INFN Research Teams

- **INFN-LNF /** Laser Retroreflector SCF_Lab: S. Dell'Agnello (PI), G. Delle Monache, R. Vittori, C. Cantone, A. Boni, G. Patrizi, C. Lops, L. Porcelli, M. Martini, E. Ciocci, S. Contessa, L. Filomena, M. Tibuzzi, P. Tuscano, C. Mondaini, R. March, G. Bellettini, R. Tauraso, F. Muto, L. Salvatori, N. Intaglietta, A. Stecchi, E. Bernieri, M. Maiello
- **INFN-LNF / DAΦNE-Light** (Synchrotron radiation facility - IR/VIS/UV/X): A. Balerna (PI), M. Cestelli-Guidi, E. Pace, R. Larciprete, A. Di Gaspare, R. Cimino
- **INFN-LNF / BTF** (particle Beam Test Facility): P. Valente (PI), B. Buonomo, L. Foggetta
- **ILRS & ASI-MLRO** (Matera Laser Ranging Observatory): G. Bianco
- **INFN & Univ. Padova** (Laser Quantum Communication and Encryption): P. Villoresi (PI), G. Vallone, M. Schiavon, M. Tomasin, P. Salvatori
- **INFN Roma Tor Vergata / LARASE** (LAser RAnged Satellite Experiment): D. M. Lucchesi (PI), R. Peron, M. Visco, G. Pucacco

US Collaborators & SSERVI Teams/R&Ds

SLR/LLR/Lasercomm community

- S. Merkowitz (GSFC), J. Mc Garry (GSFC), M. Pearlman (ILRS/CfA), J. Degnan, D. Smith (MIT, GSFC-retired)
- D. Currie (UMD, Apollo Veteran), T. Murphy (UCSD), J. Chandler (CfA), I. Shapiro (CfA), C. Neal (U. Notre-Dame)
- B. Abhijit (JPL), M. Wright (JPL), M. Hoffmann (GRC), D. Raible (GRC)

Planetary Science/Space Exploration community

PIs of SSERVI-funded projects

SSERVI Teams / Research Topics

- **DREAM2**: Dynamic Response of Environments at Asteroids, the Moon, and moons of Mars;
- **Principal investigator William Farrell**, NASA-GSFC (Goddard Space Flight Center) in Greenbelt MD
- **Focus**: Plasma interactions, exospheres, radiation of exposed materials, space weathering, solar storms/solar wind http://ssed.gsfc.nasa.gov/dream/

SSERVI Teams / Research Topics

- **SEEED**: SSERVI Evolution and Environment of Exploration Destinations: Science and Engineering Synergism
- **Principal investigator Carle Pieters**, Brown University in Providence RI
  - Discovered and measured rate of formation of water on the Moon, induced by interaction of solar wind on regolith surface
    - Moon Mineralogy Mapper (M^3) instrument on Indian Chandrayaan-1 orbiter
- **Focus**: Thermal/chemical evolution of planetary bodies, origin and evolution of volatiles, remote sensing, space weathering of regoliths
  http://planetary.brown.edu/html_pages/brown-mit_sservi.htm

SSERVI Teams / Research Topics

- **RIS^{4}E**: Remote, In Situ and Synchrotron Studies for Science and Exploration
- **Principal investigator Timothy Glotch**, Stony Brook University, NY
- **Focus**: Remote sensing of airless bodies, field operations and metrics for human exploration, reactivity and toxicity of regoliths, synchrotron analyses of samples, volcanics and impact crater analog research
  https://ris4e.labs.stonybrook.edu/

SSERVI Teams / Research Topics

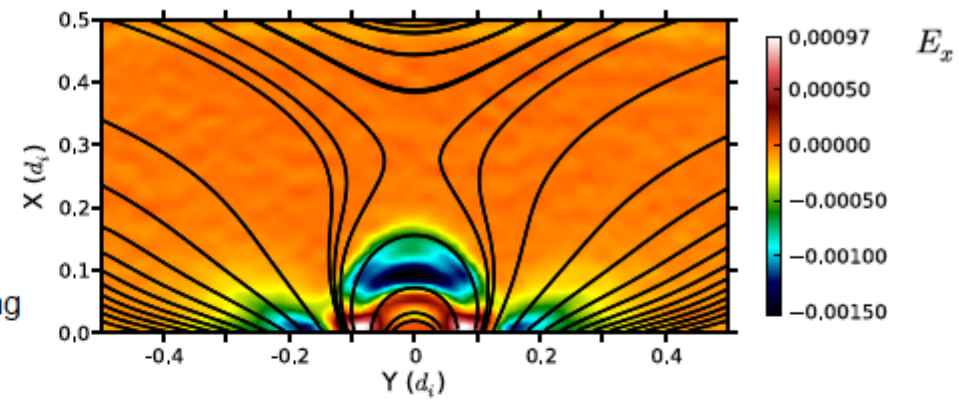
- **IMPACT**: Institute for Modeling Plasma, Atmospheres and Cosmic Dust
- **Principal investigator Mihaly Horanyi**, University of Colorado in Boulder CO
- **Focus**: Small scale impact studies/regolith gardening, plasma charging and mobilization of dust, near surface plasma environments, new advancements on **dust accelerator facility** http://impact.colorado.edu

Personnel Changes

Jan Deca RS-I as of 1/15/2015
(2014 Ph.D. with G. Lapenta, Belgium)

Refereed Publications (2/2015)

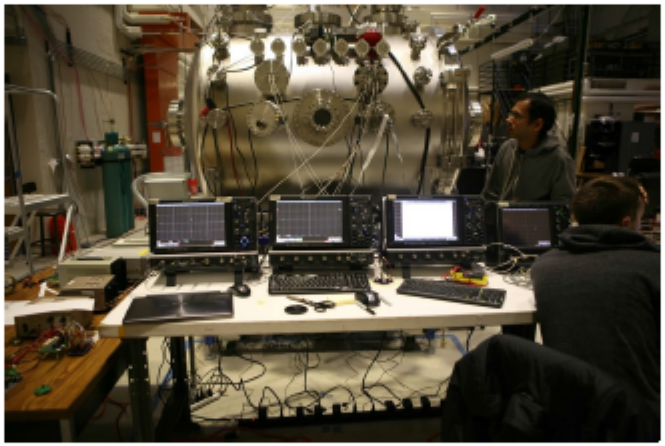
1) J. Deca, et al., Solar Wind Interaction with Lunar Magnetic Anomalies from 3-D PIC Simulations, JGR, submitted
2) M. Horanyi, et al., Detecting a permanent dust cloud engulfing the Moon, Nature, submitted

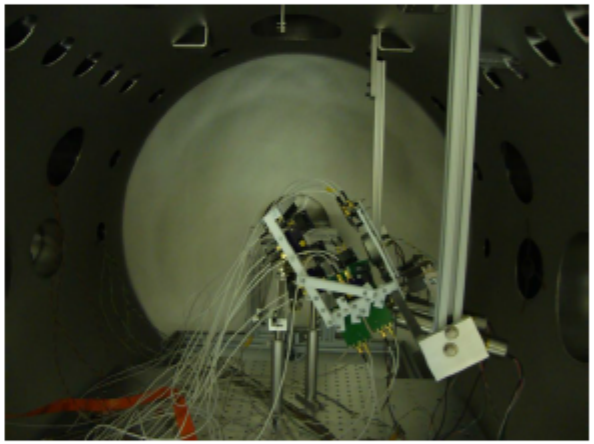


Accelerator Experiments

1) Impact generated plasmas and electromagnetic pulses.

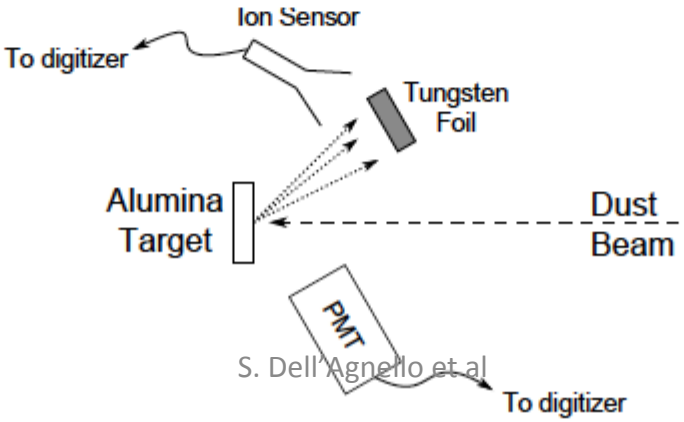
Stanford University 6 Aerospace Engineering Students (1/5-1/16)
PI: Sigrid Close

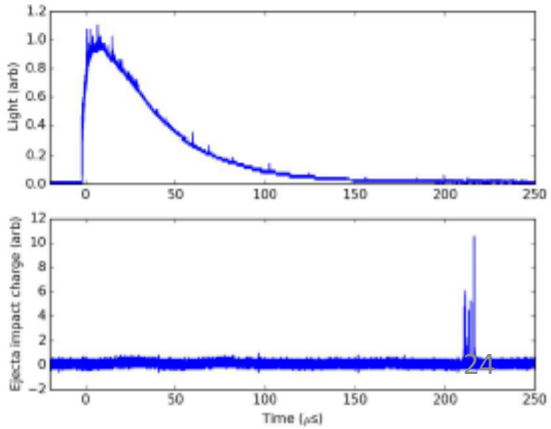




2) Speed and mass distribution from high-speed dust impacts.

Measuring the light flash from an impact of iron on alumina and the ions generated from the impacts of secondary ejecta particles on a tungsten foil located at a 30 degree angle to the target.





SSERVI: Science vs Strateg. Knowled. Gaps

Science emphasis	Exploration emphasis (SKGs)
Role of Target Body(s) in revealing the origin and evolution of the inner Solar System	Regolith of Target Bodies
Target Body structure and composition	Radiation
Innovative observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe	Volatiles (in its broad sense) and other potential resources on Target Body(s)
Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes	In-Situ Resource Utilization (ISRU)/ Prospecting (Moon, NEAs, Mars)
Dust and plasma interactions on Target Body(s)	Propulsion-induced ejecta (Moon, NEAs, Mars)
Near-Earth asteroid characterization (including NEAs that are potential human destinations)	Operations/Operability (all destinations, including transit)
Geotechnical properties (Moon, NEAs, Mars)	Human health and performance (all destinations, including transit)

Conclusion & Next step

- Work in progress to create synergism on space applications
- Opportunity to interact with NASA/SSERVI Teams
  - INFN-SSERVI team-to-team meetings & teleconrefences
  - 3rd European Lunar Symposium:
  - "Science of the Moon" (General Relativity), "Science on the Moon", "Science from the Moon", "Future Lunar Missions"

SSERVI Teams / Research Topics

- **Inner Solar System Impact Processes**
- **Principal investigator David Kring**, Lunar and Planetary Institute in Houston TX
- **Focus**: Impact history and processes, geochemistry of regoliths, age dating of regolith materials, NEA identification and characterization
- http://www.lpi.usra.edu/exploration/

SSERVI Teams / Research Topics

- **VORTICES**: Volatiles, Regolith and Thermal Investigations Consortium for Exploration and Science
- **Principal investigator Andy Rivkin**, Johns Hopkins University Applied Physics Laboratory in Laurel MD
- **Focus**: Volatiles sources/sinks/processes and interaction with regoliths, evolution of regoliths on all target bodies, identification and exploitation of resource

SSERVI Teams / Research Topics

- **SWRI**: Institute for the Science of Exploration Targets: Origin, Evolution and Discovery
- **Principal investigator William Bottke**, Southwest Research Institute in Boulder CO
- **Focus**: Formation of terrestrial planets and asteroid belt, modeling of the Moon's origin and Phobos/Deimos, history of NEAs and lunar bombardment, NEA origins, identification and characterization
  http://www.boulder.swri.edu/

SSERVI Teams / Research Topics

- **FINESSE**: Field Investigations to Enable Solar System Science and Exploration
- **Principal investigator Jennifer Heldmann**, NASA Ames Research Center, CA
- **Focus**: Field operations and metrics for human exploration and analog research.
  http://finesse.arc.nasa.gov

SSERVI Teams / Research Topics

- **CLASS**: Center for Lunar and Asteroid Surface Science
- **Principal investigator Daniel Britt**, University of Central Florida in Orlando FL
- **Focus**: Studies of physical properties of regoliths: geotechnical properties, microgravity effects, impact ejecta, dynamics, hydration and weathering of NEAs, charging and mobilization of dust

SSERVI February 2015 Report
RIS^{4}E/Tim Glotch

Progress Report

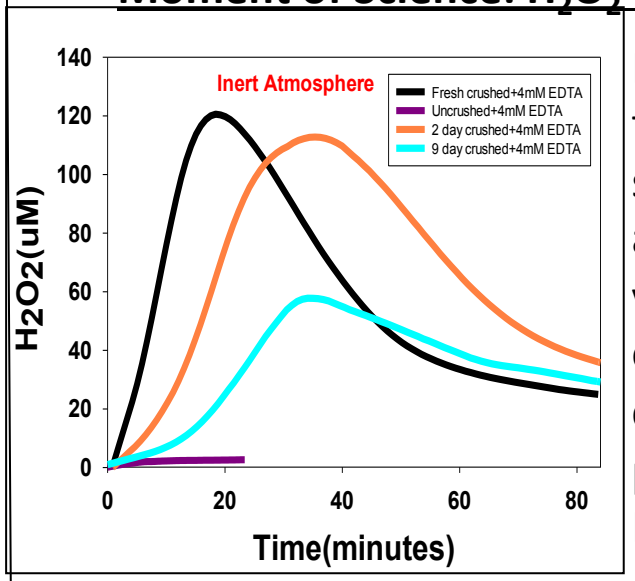
Science:

- Kelsey Young traveled to JSC to conduct handheld XRF analyses on the team's 2014 HI field samples.
- Caston and Demple continuing work on cell DNA damage. Simulant CSMCLS caused much more damage than other simulants. <64 µm JSC1A caused more damage than bulk JSC1A.
- Caston submitted grant proposal for additional supplies for DNA work to American Foundation for Ageing Research.

Recent and Upcoming Events

- 28 abstracts submitted to LPSC
- Glotch presented "New insights into lunar geology from mid-IR remote sensing measurements" at Lafayette College geology colloquium

Moment of Science: H_2O_2 production



H_2O_2 production for OB-1 lunar simulant crushed and left out for various lengths of time. Freshly crushed simulant produces most H_2O_2.

SSERVI: Science vs Strateg. Knowled. Gaps

					Britt		Heldmann						
	Heldmann				Farrell	Heldmann	Britt						
	Britt		Heldmann		Pieters	Britt	Farrell						
	Pieters		Pieters		Bussey	Pieters	Pieters		Heldmann				
Pieters	Bussey		Bussey		Bottke	Bussey	Bussey		Farrell	Heldmann			
Bottke	Bottke		Bottke	Britt	Kring	Kring	Kring	Farrell	Pieters	Bussey		Heldmann	
Kring	Kring	Farrell	Kring	Farrell	Horanyi	Horanyi	Horanyi	Horanyi	Bussey	Horanyi		Kring	
Horanyi	Glotch	Horanyi	Glotch	Horanyi	Glotch	Glotch	Glotch	Glotch	Glotch	Glotch	Britt	Glotch	Glotch
Role of Target Body(s) in revealing the origin and evolution of the inner Solar System	Target Body structure and composition	Innovative observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe	Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes	Dust and plasma interactions on Target Body(s)	Near-Earth asteroid characterization (including NEAs that are potential human destinations)	Geotechnical properties (Moon, NEAs, Mars)	Regolith of Target Bodies	Radiation	Volatiles (in its broad sense) and other potential resources on Target Body(s)	In-Situ Resource Utilization (ISRU)/ Prospecting (Moon, NEAs, Mars)	Propulsion-induced ejecta (Moon, NEAs, Mars)	Operations/Operability (all destinations, including transit)	Human health and performance (all destinations, including transit)

Science emphasis → Exploration emphasis (SKGs)