MELODY: Moon multisEnsor and LabOratory Data anaLYsis

PROPOSAL PRESENTED IN RESPONSE TO THE BANDO PRIN INAF 2019 (RIC)

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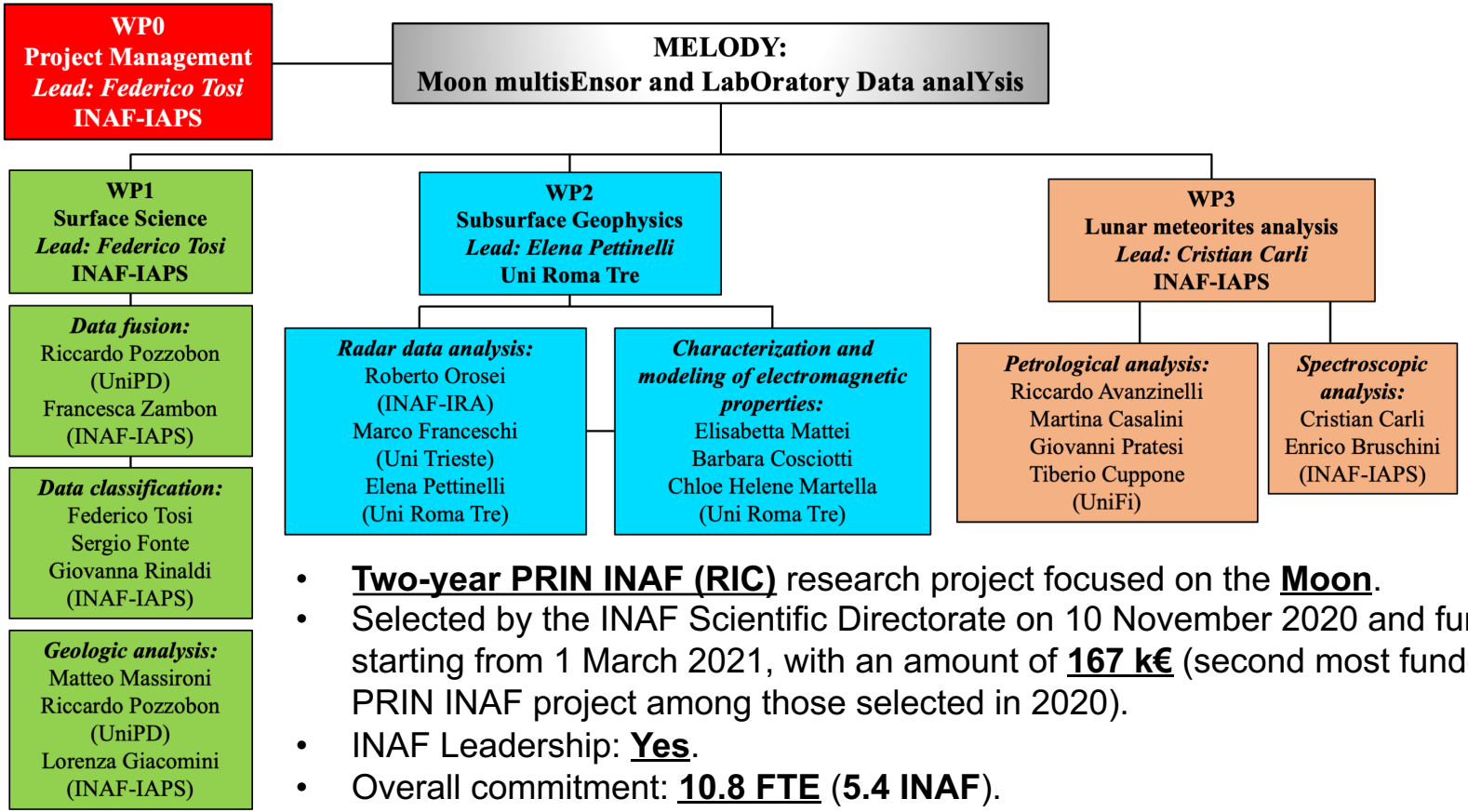
Audizioni INAF 2022, RSN3, Monday, 9 May 2022

MELODY: Key open question left by lunar exploration, and rationale summary

- Are there any connections among composition, subsurface structures/layers, and mass distribution in specific regions of interest (e.g., South Polar–Aitken basin, lava tubes)? How does this might better constrain the origin and age of those regions, and the distribution of ISRU therein?
- The PRIN INAF research project "***MELODY: Moon multisEnsor and LabOratory Data analYsis***" brings together the skills found at INAF and other Italian academic institutions.
- The project pursues a new and innovative way to re-analyze some publicly available, surface and subsurface lunar datasets obtained by previous orbital space missions, corroborating them with an unprecedented characterization of electromagnetic properties of lunar regolith simulants and a thorough mineralogical and geochemical analysis of lunar meteorites to be acquired during the project.
- The scientific objectives to be achieved will allow an INAF-led consortium to join those research institutes that are actively contributing for a concrete return to the Moon within this decade.

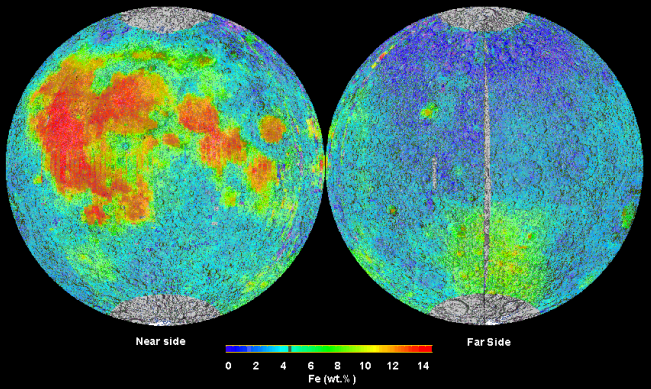
MELODY Work Breakdown Structure (WBS) and Team



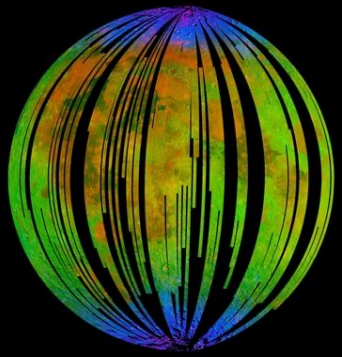
- **Two-year PRIN INAF (RIC)** research project focused on the **Moon**.
- Selected by the INAF Scientific Directorate on 10 November 2020 and funded, starting from 1 March 2021, with an amount of **167 k€** (second most funded PRIN INAF project among those selected in 2020).
- INAF Leadership: **Yes**.
- Overall commitment: **10.8 FTE** (**5.4 INAF**).

MELODY WP1: Surface science – Data fusion

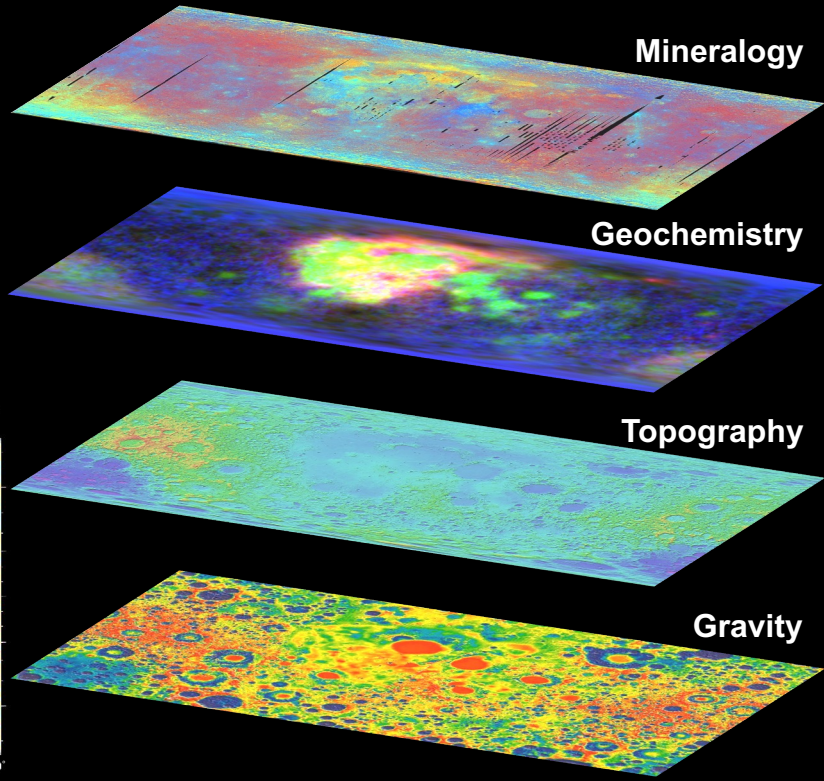
Clementine Iron Map of the Moon
Equal Area Projection



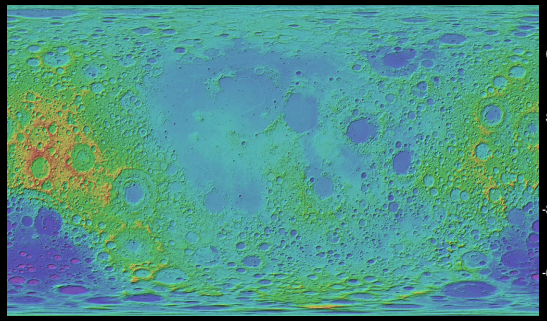
Chandrayaan-1 Mineralogical Map of the Moon



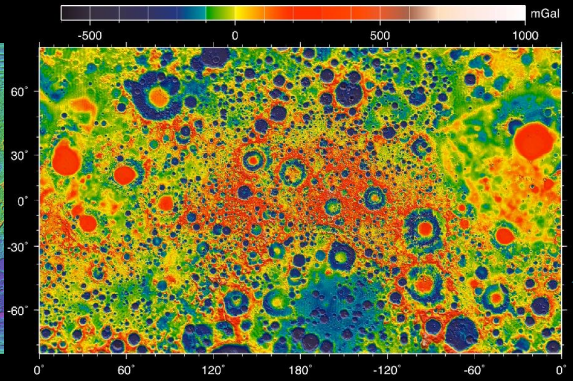
Aggregated Dataset



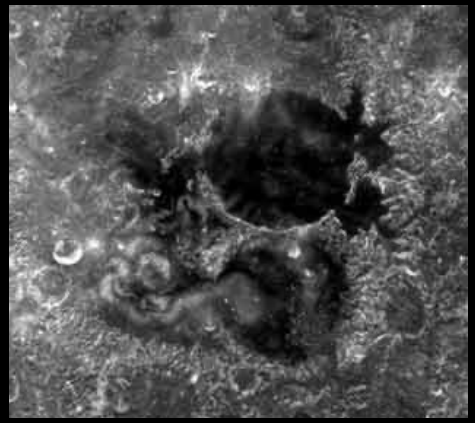
LRO Topographic Map of the Moon



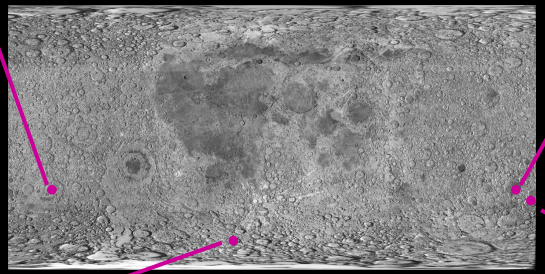
GRAIL Gravimetric Map of the Moon



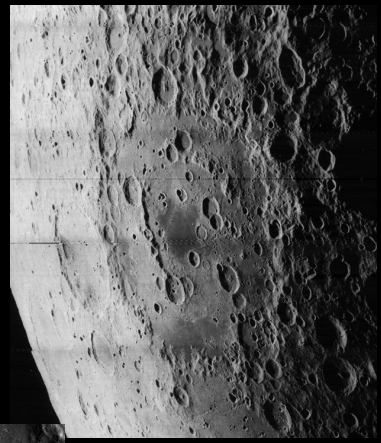
MELODY WP1: Surface science – Regions of Interest

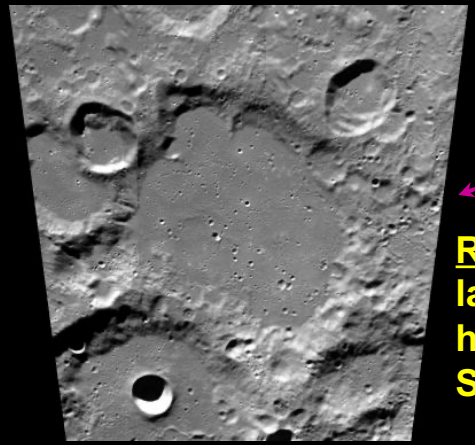


ROI #1: Mare Ingenii and Thomson crater



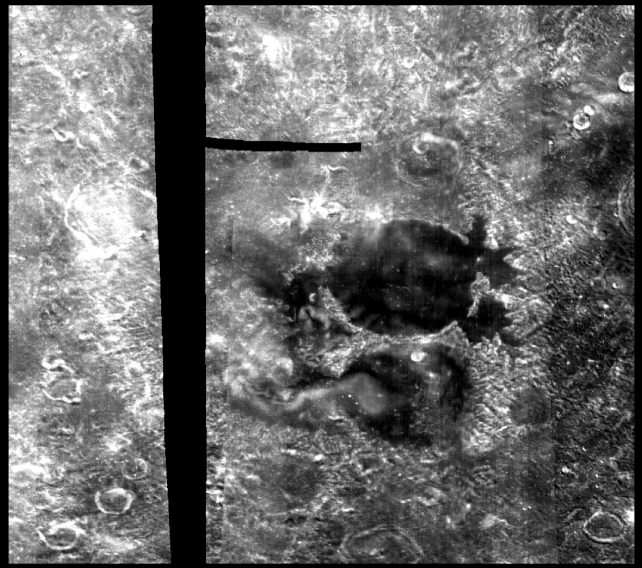
ROI #2: Specific craters within the South Polar–Aitken basin (Apollo, Von Karmann)



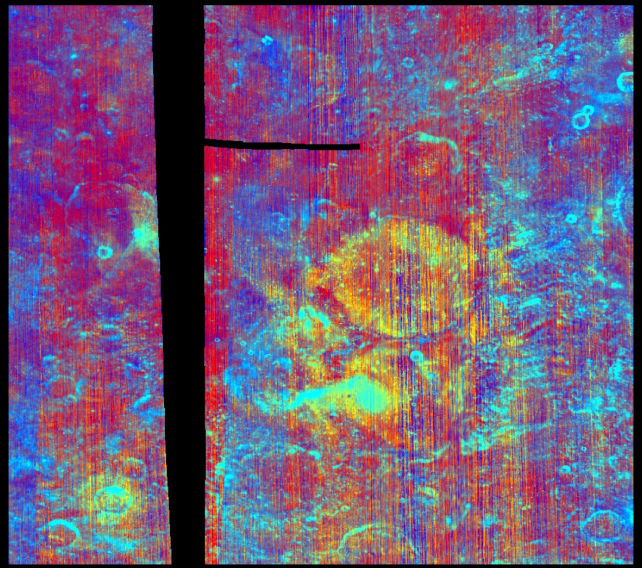


ROI #3: Potential landing sites for future human missions in the Southern Polar region

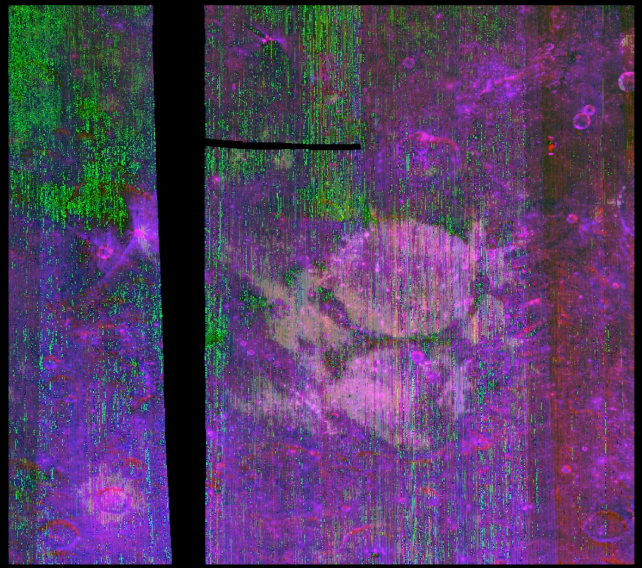
MELODY WP1: Surface science – Regions of Interest



Mare Ingenii as seen by M³ at 550 nm

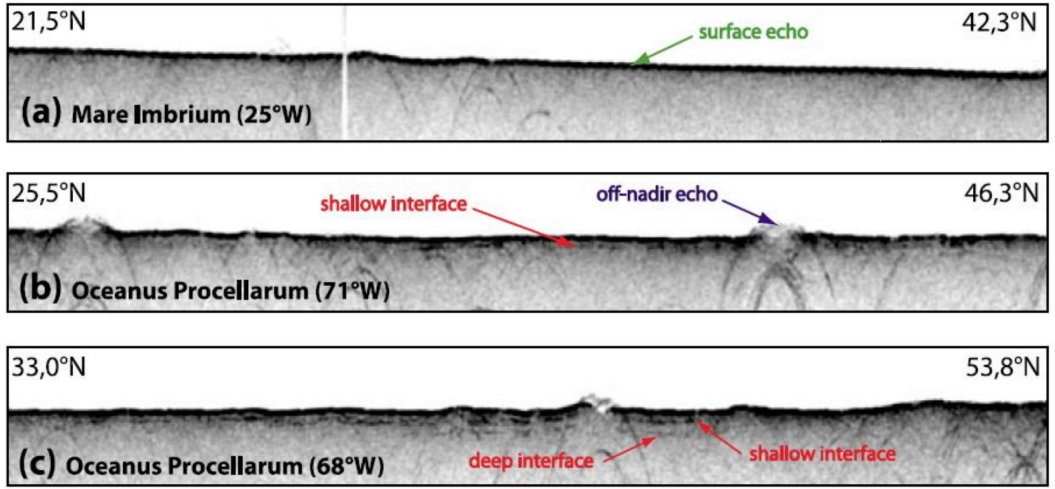


Mare Ingenii as seen by M³ in the "Clementine" color code

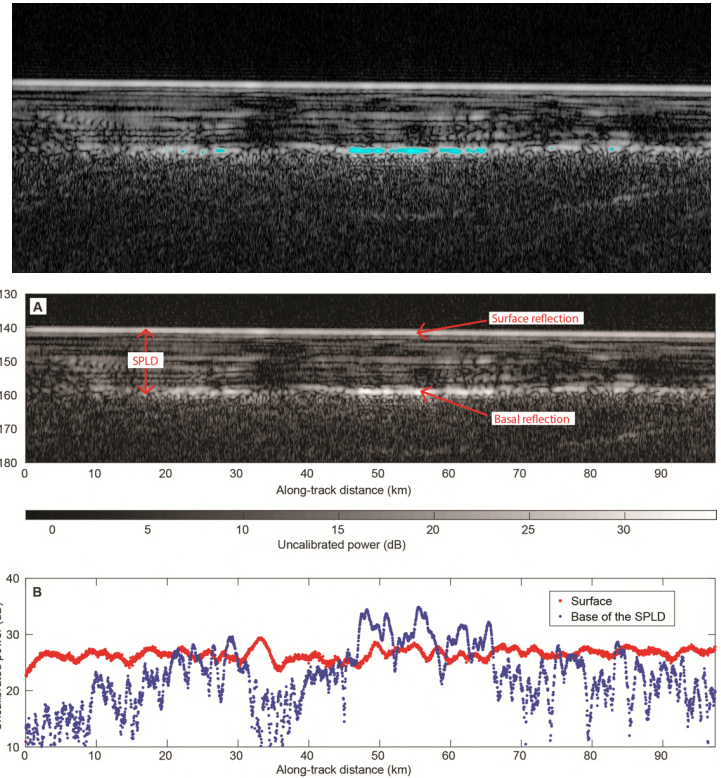


Mare Ingenii as seen by M³ in pyroxenes-relevant colors

MELODY WP2: Analysis of lunar radar data with improved techniques

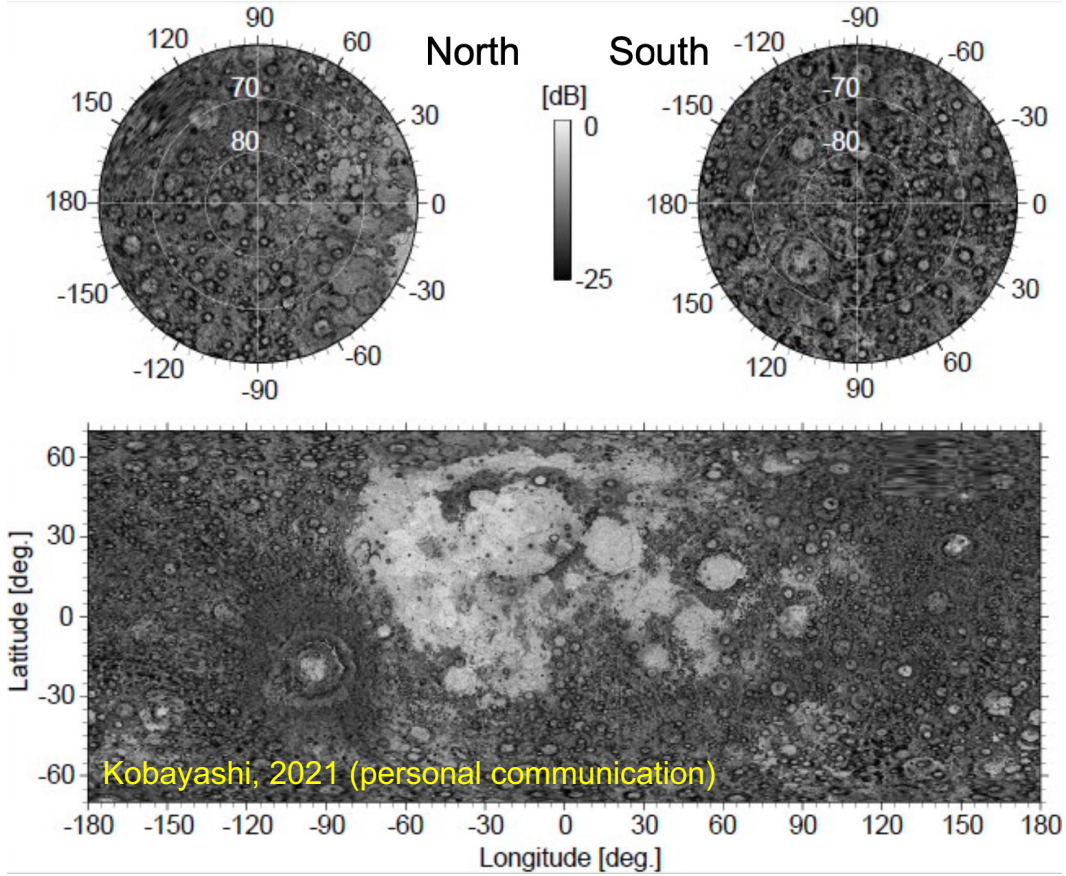


Orosei et al., 2018

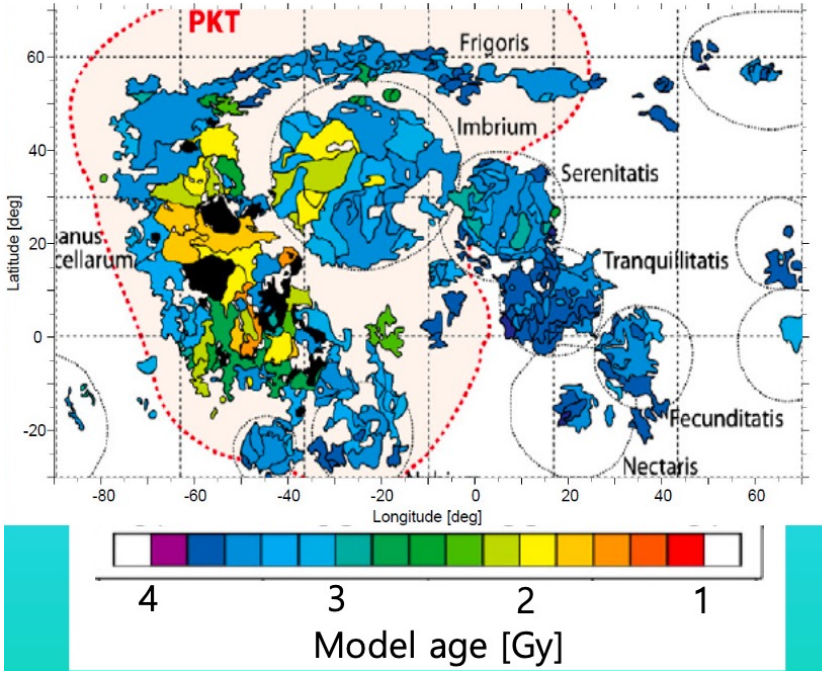


Simulation of lunar radar scattering, and comparison with publicly available datasets. Correlations among radargrams.

MELODY WP2: Analysis of lunar radar data with improved techniques



Subsurface radar echoes and their correlation with age

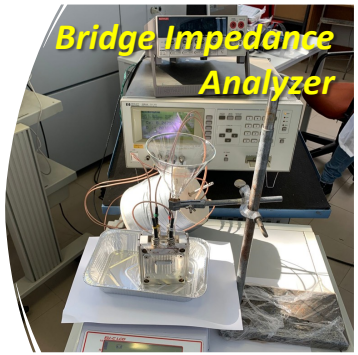


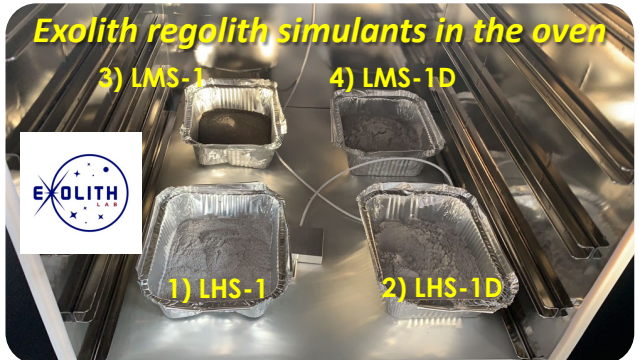
MELODY WP2: Electromagnetic measurements of lunar regolith simulants

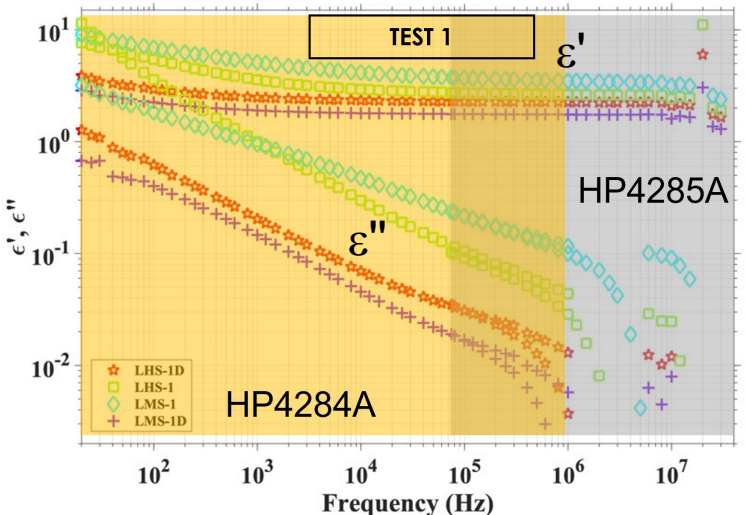
Frequency domain:

20Hz - 1MHz (**HP4284A**)

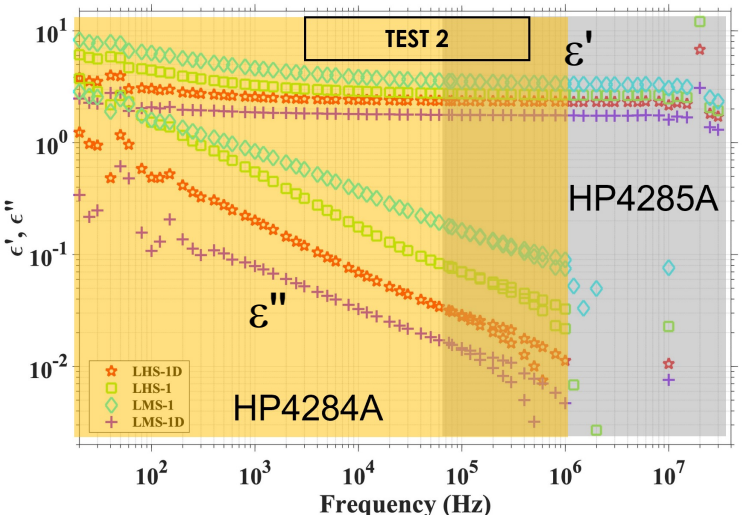
75kHz - 30 MHz (**HP4285A**)



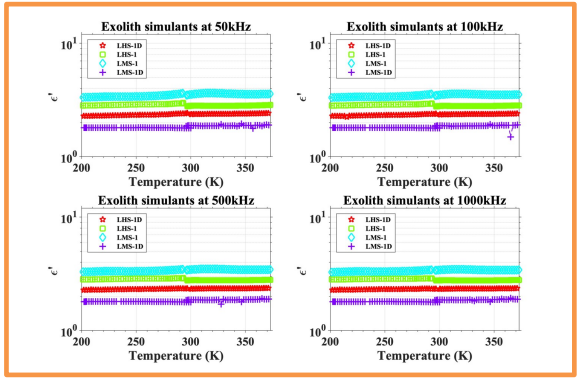


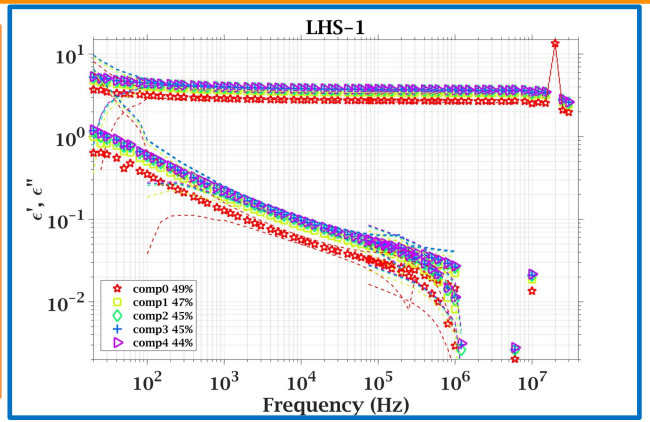


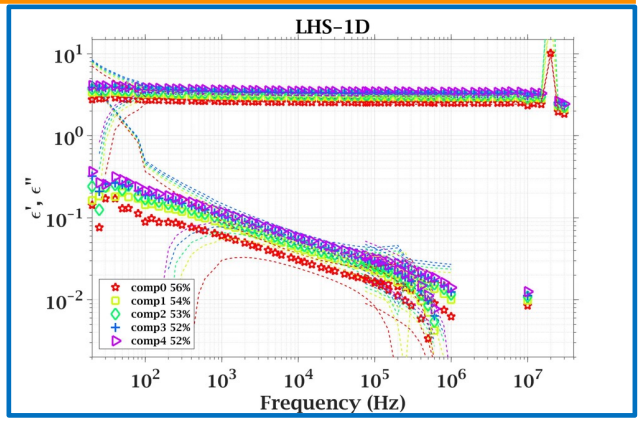
Real (ε') and imaginary (ε'') dielectrical permittivity of the four samples at the same conditions (anhydrous and no compaction) with both HP4284A and HP4285A systems.



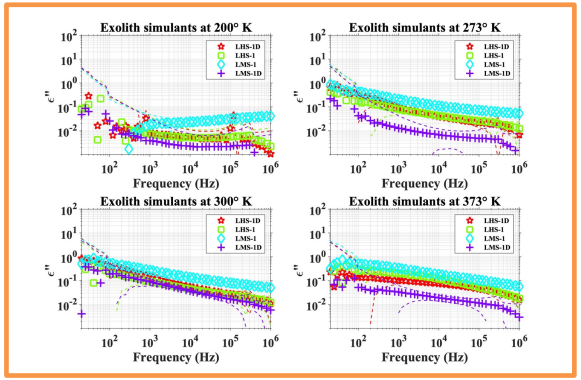
MELODY WP2: Electromagnetic measurements of lunar regolith simulants



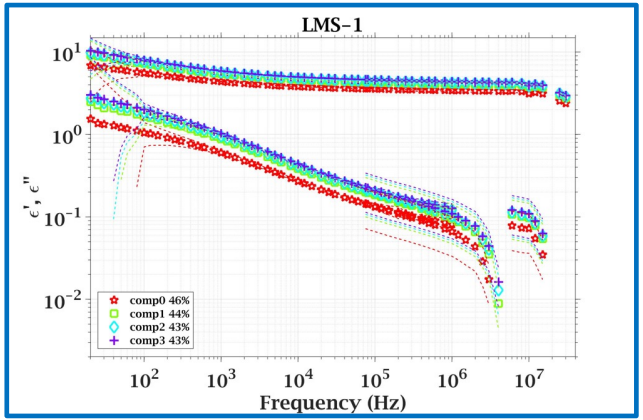


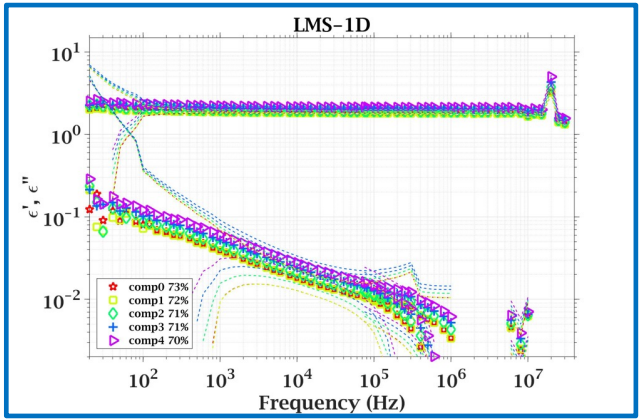


Ramp of hot and cold T



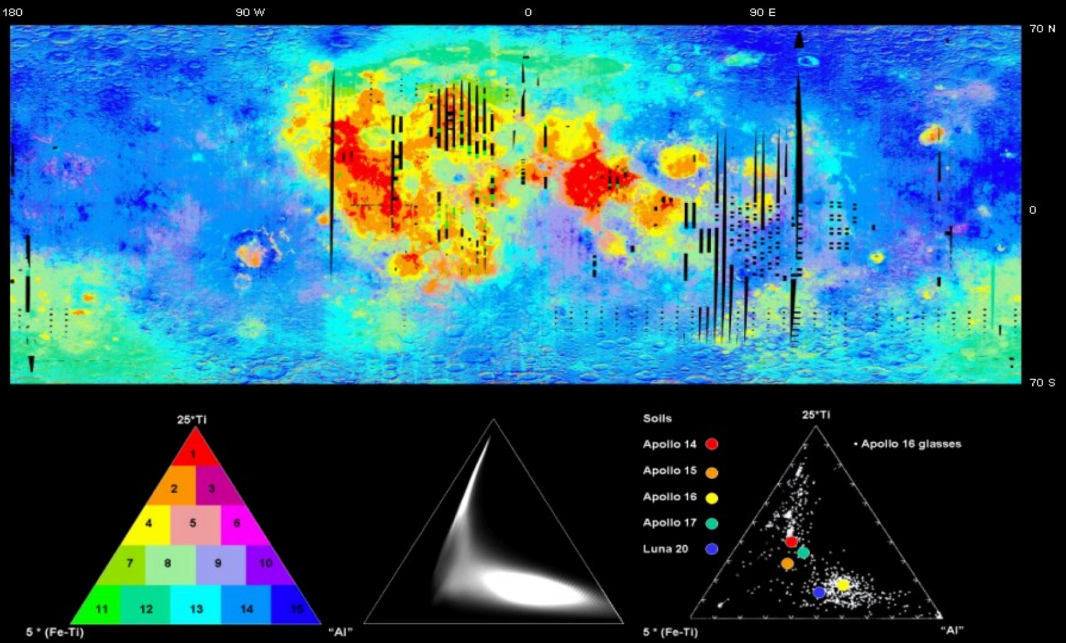
Different compaction states





MELODY WP3: Mineralogical analysis of lunar meteorites

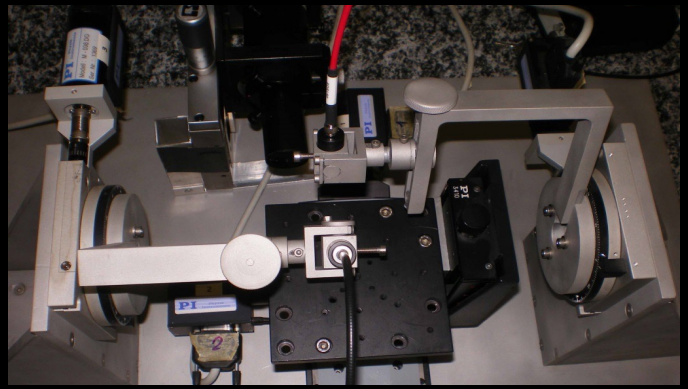
NWA13859 Lunar meteorite (feldspatic breccia)

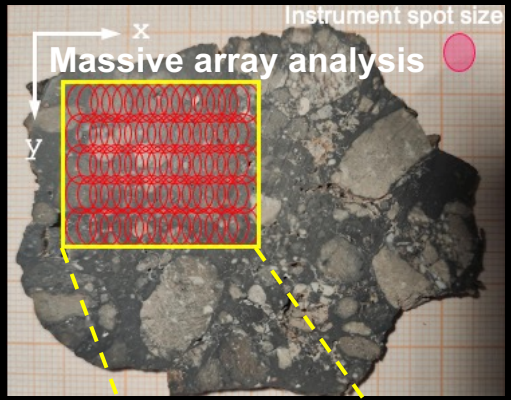


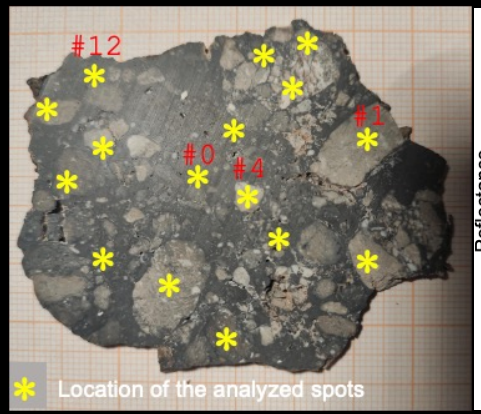
Unlike the lunar rocks returned by Apollo astronauts, ***lunar meteorites can come from virtually anywhere on the surface of the Moon****, including the farside. As such, their analysis can place these meteorite specimens in the* ***global geochemical and petrological context*** *of our natural satellite.*

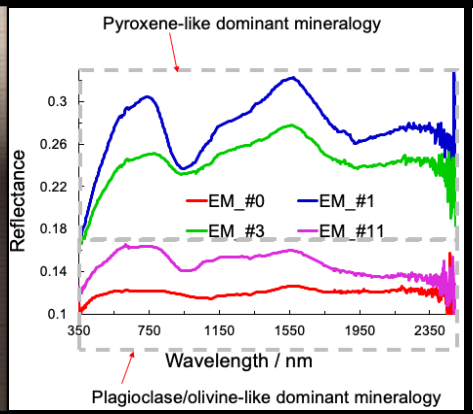
MELODY WP3: Mineralogical analysis of lunar meteorites

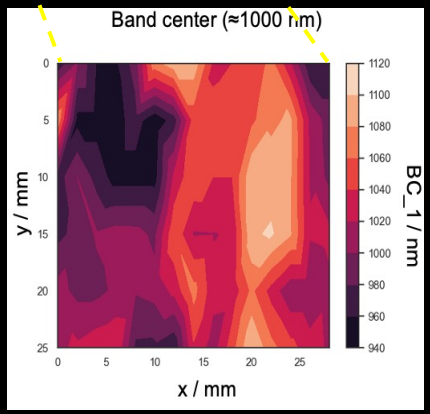
SLAB_REFL @INAF-IAPS: Bidirectional spectral reflectance measurements in the 0.35-2.5 μm range





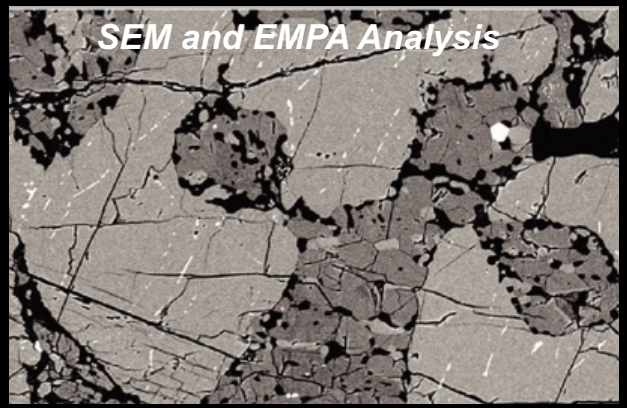


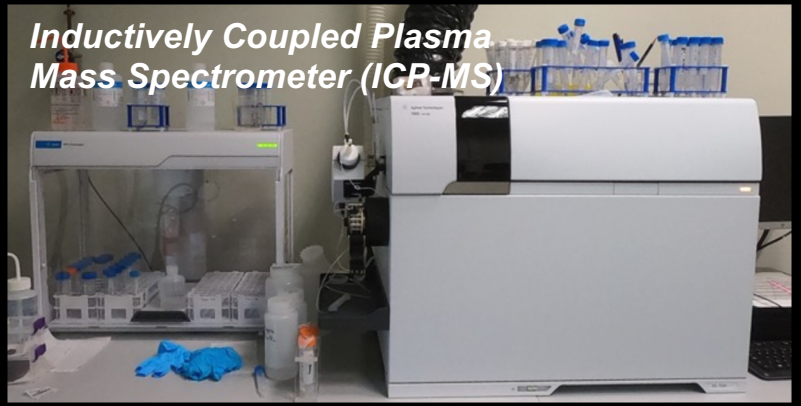


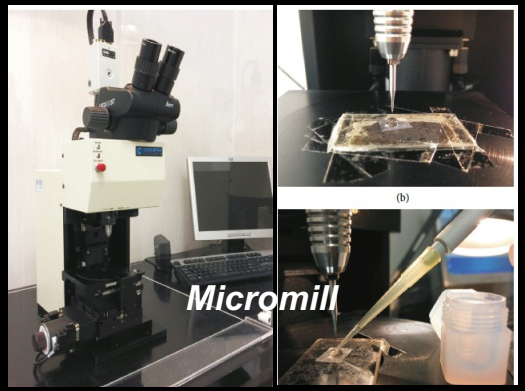


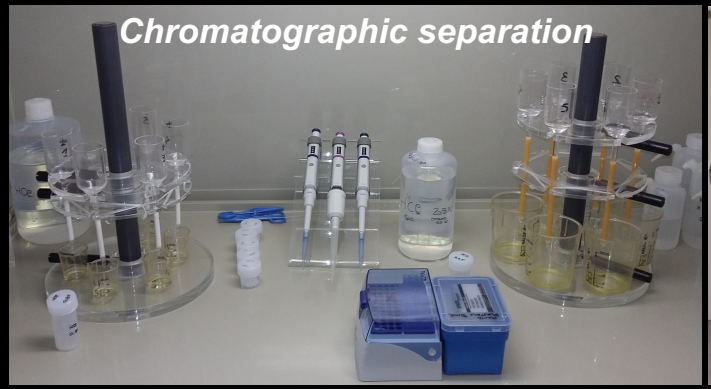
MELODY WP3: Geochemical and petrological analysis of lunar meteorites

Facilities available at the Filippo Olmi Laboratories of the DST-UniFI









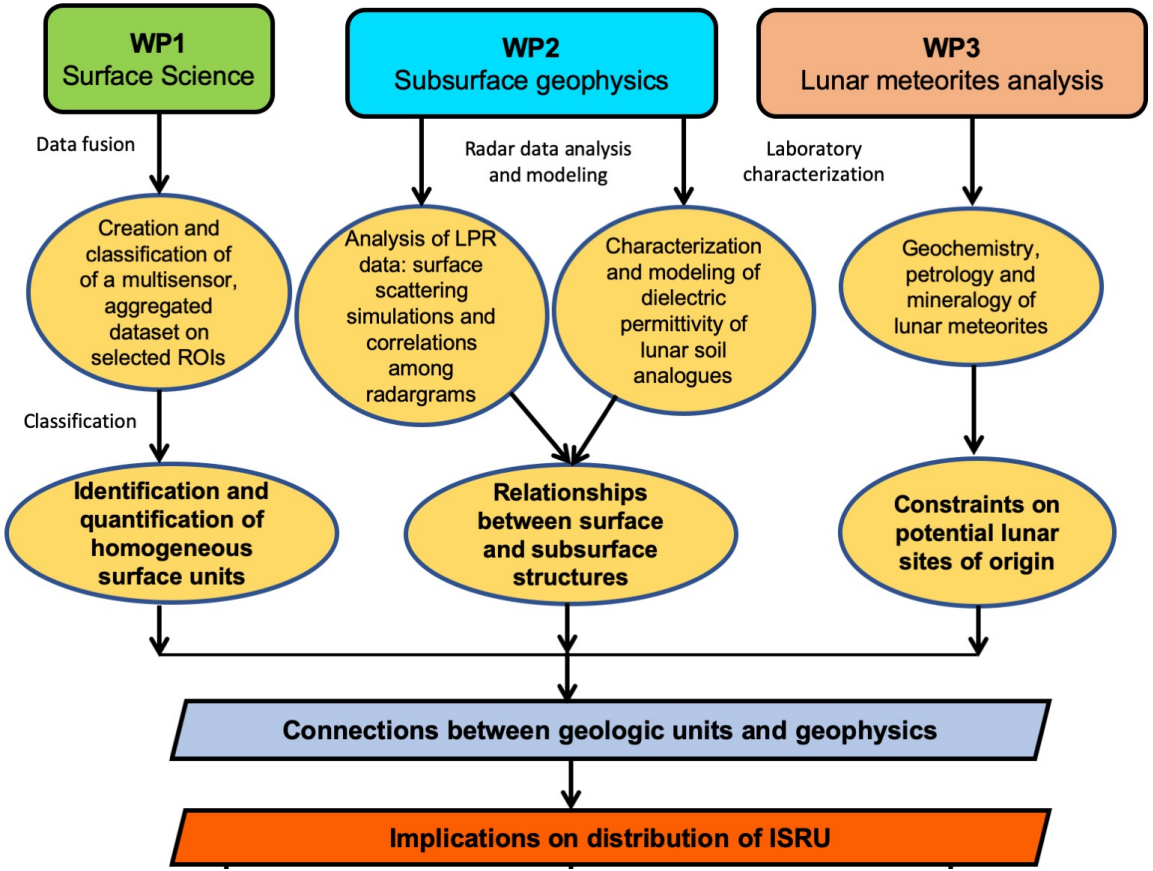
MELODY WP3: Upcoming new lunar meteorites for MELODY

Dhofar 1769 → anorthositic highland breccia contains clasts up to 1 cm, which are mainly anorthositic lithologies and crystalline impact melt breccias. This sample is not yet investigated and not yet characterized in reflectance.

NWA 14188 → rare lunar basalt recently discovered. With a primary fine textures, not yet investigated and not yet characterized in reflectance.

NWA 8687 → monomict brecciated sample representative of crust lithologies. Approximately 70% plagioclase, 25% olivine, 3% orthopyroxene. Primarily fine-grained plagioclase, olivine, and orthopyroxene 5-50 μm, scattered larger plagioclase and olivine 200-500 μm. Few aspects of this samples have been studied and not yet characterized in reflectance.

MELODY Program Evaluation and Review Technique (PERT) chart



MELODY: Scientific production

- 8th European Lunar Symposium (virtual / online-only), 12-14 May 2020. "*MELODY: Moon multisEnsor and LabOratory Data analYsis*": oral contribution.
- Lunar Surface Science Workshop 2021 – Fundamental and Applied Lunar Surface Research in Physical Sciences (virtual / online-only), 18-19 August 2021. "*MELODY: Moon multisEnsor and LabOratory Data analYsis*": oral contribution.
- ASI Workshop: "*A roadmap for the Moon: science and technology*" (virtual / online-only), 1-3 February 2022. "*MELODY: Moon multisEnsor and LabOratory Data analYsis*": poster contribution.
- 53rd Lunar and Planetary Science Conference (LPSC) (hybrid), 7-11 March 2022: "*Preliminary electromagnetic characterization of different lunar soil analogues*".
- XVII Congresso Nazionale di Scienze Planetarie, Napoli, 20-24 June 2022. Title TBC.
- Europlanet Science Congress 2022, Granada (Spain), 18-23 September 2022. Two contributions, title TBC.

- Work is in progress! → At least three scientific papers (one per WP) are foreseen next year, at the end of the analysis.

MELODY: Critical issues

1. One critical issue concerned the purchase of IT hardware. Due to the COVID-19 situation, the icreasingly limited availability of raw materials starting from spring 2021 has dramatically expanded the time required for the delivery of servers, workstations, and high performance laptops. As a result, the server dedicated to the MELODY project and ordered on April 30th, 2021, was delivered only in April 2022.
2. Lunar regolith simulants are produced mostly by US companies. The purchase of such products through an Italian public administration is not "business as usual" for those contractors, which required a dedicated negotiation and several further interactions to arrange a post-clearance payment for the shipped goods. Furthermore, dedicated paperworks are required for the customs clearance of the goods, with a consequent lengthening of delivery times.
3. The purchase of lunar meteorites is also a delicate matter: in this case, since many collectors are private, the seller must have a "company VAT number" in order to proceed with a purchase.
4. The PRIN INAF call does not usually allow any transfer of funds to third parties, unlike other national calls such PRIN MIUR. This creates a major complication if academic laboratories are involved that have to bear out-of-pocket expenses for maintenance and purchase of consumables (e.g., liquid nitrogen) required for the measurements.