UNIVERSITÀ DEGLI STUDI DI PADOVA

Machine Learning Algorithm for the Spectral Analysis of Solar System Bodies

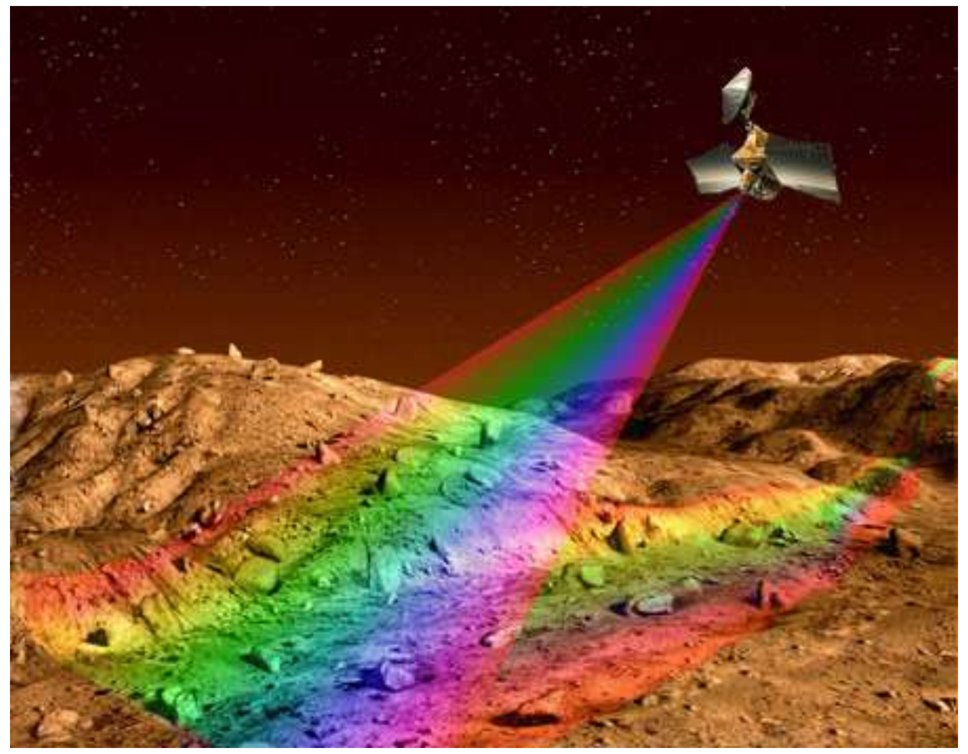
Joel Beccarelli - 39th Cycle

Presentation of the Proposed Research Program - 19/10/2023

Objective

Objective → *Determine the spectral behavior of SS bodies surfaces through machine learning algorithms promoting the digitalization of the PA*

How? → *Processing remote sensing data from space missions and develop/use ML algorithms*



Case Study → *SS bodies, Martian moons, asteroids and comets, icy satellites*

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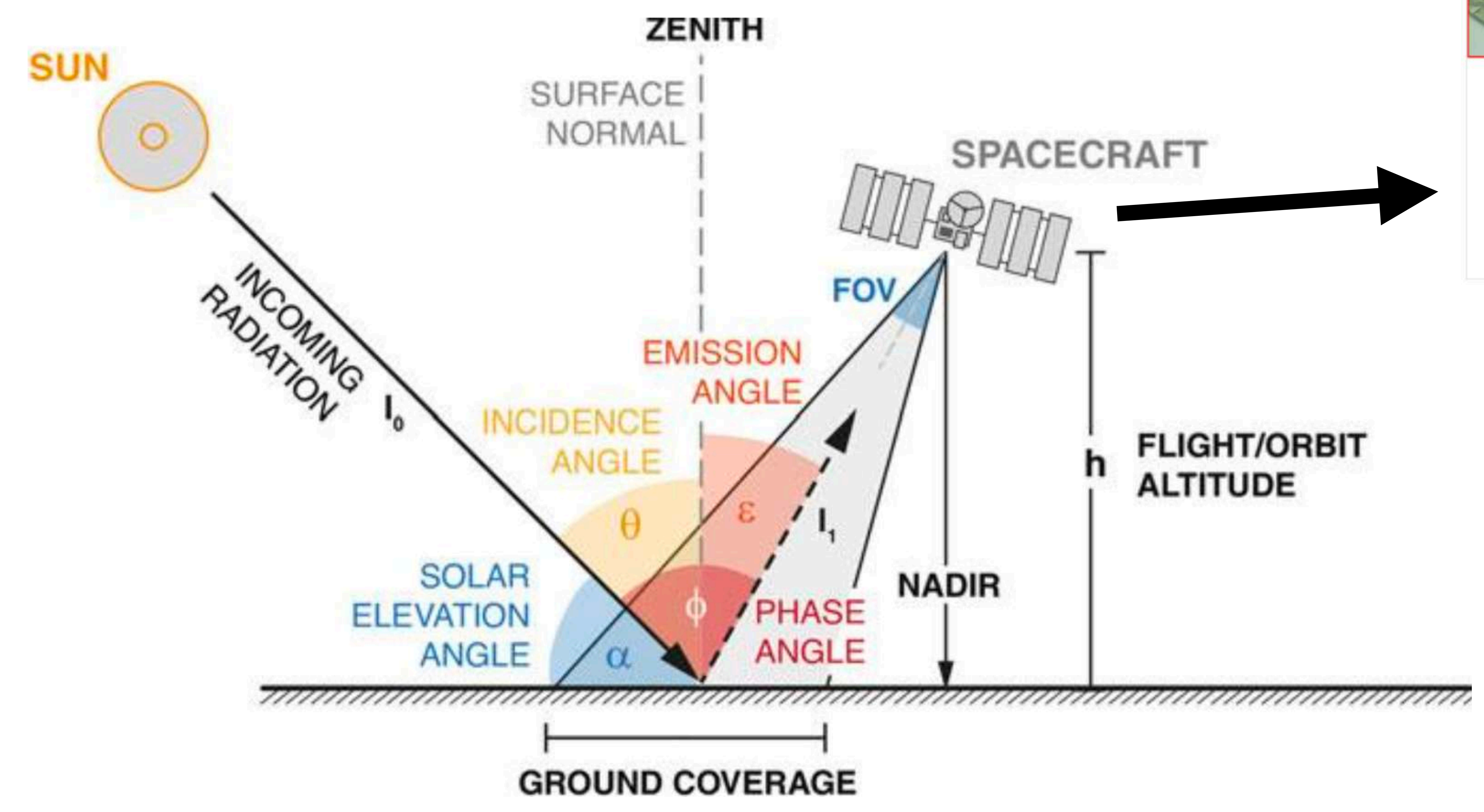
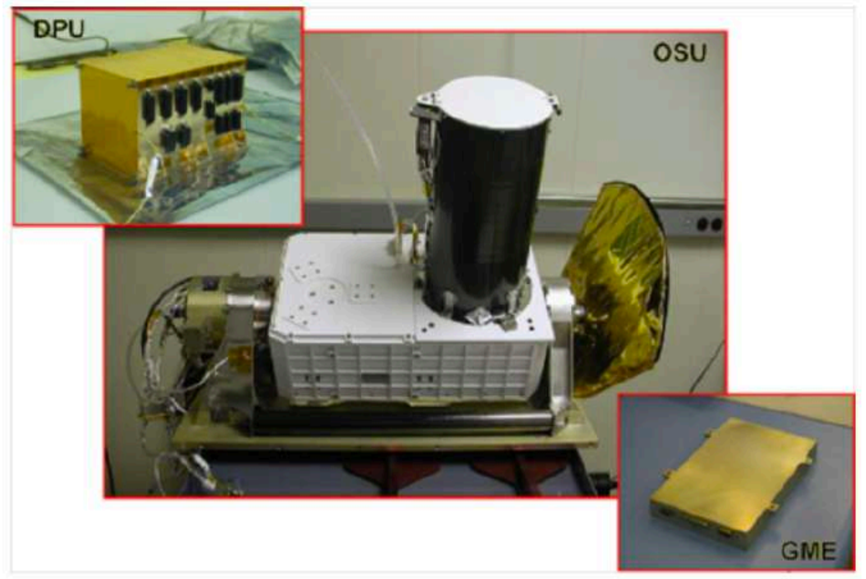
Remote Sensing Data



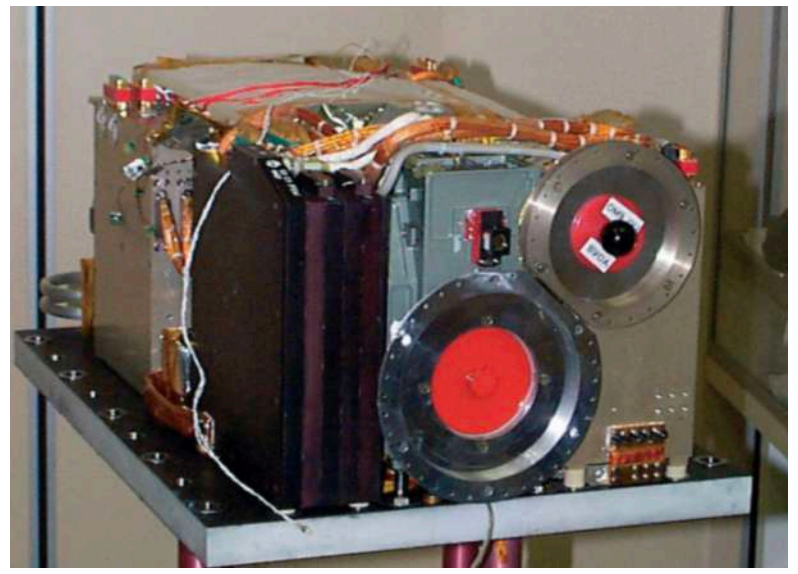
Van Gasselt et al. 2018

MRO/CRISM



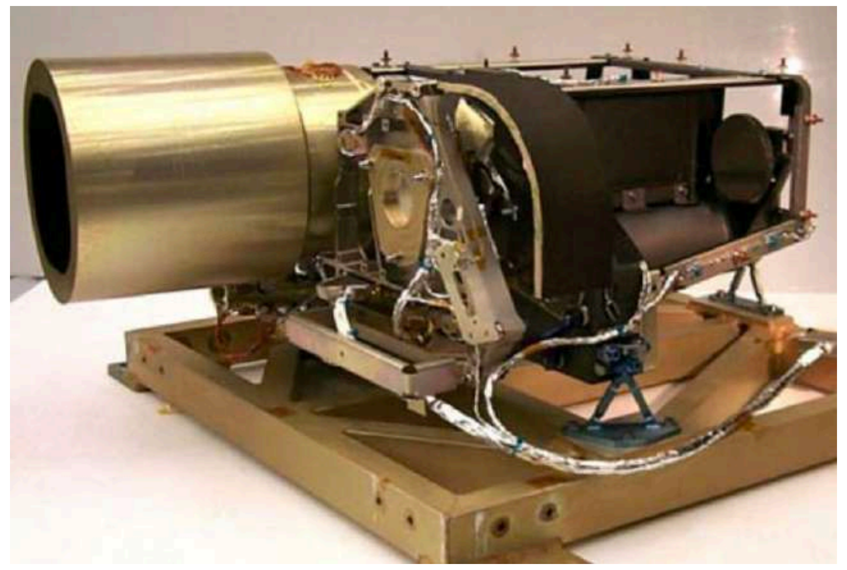
Murchie et al. 2002

MeX/OMEGA



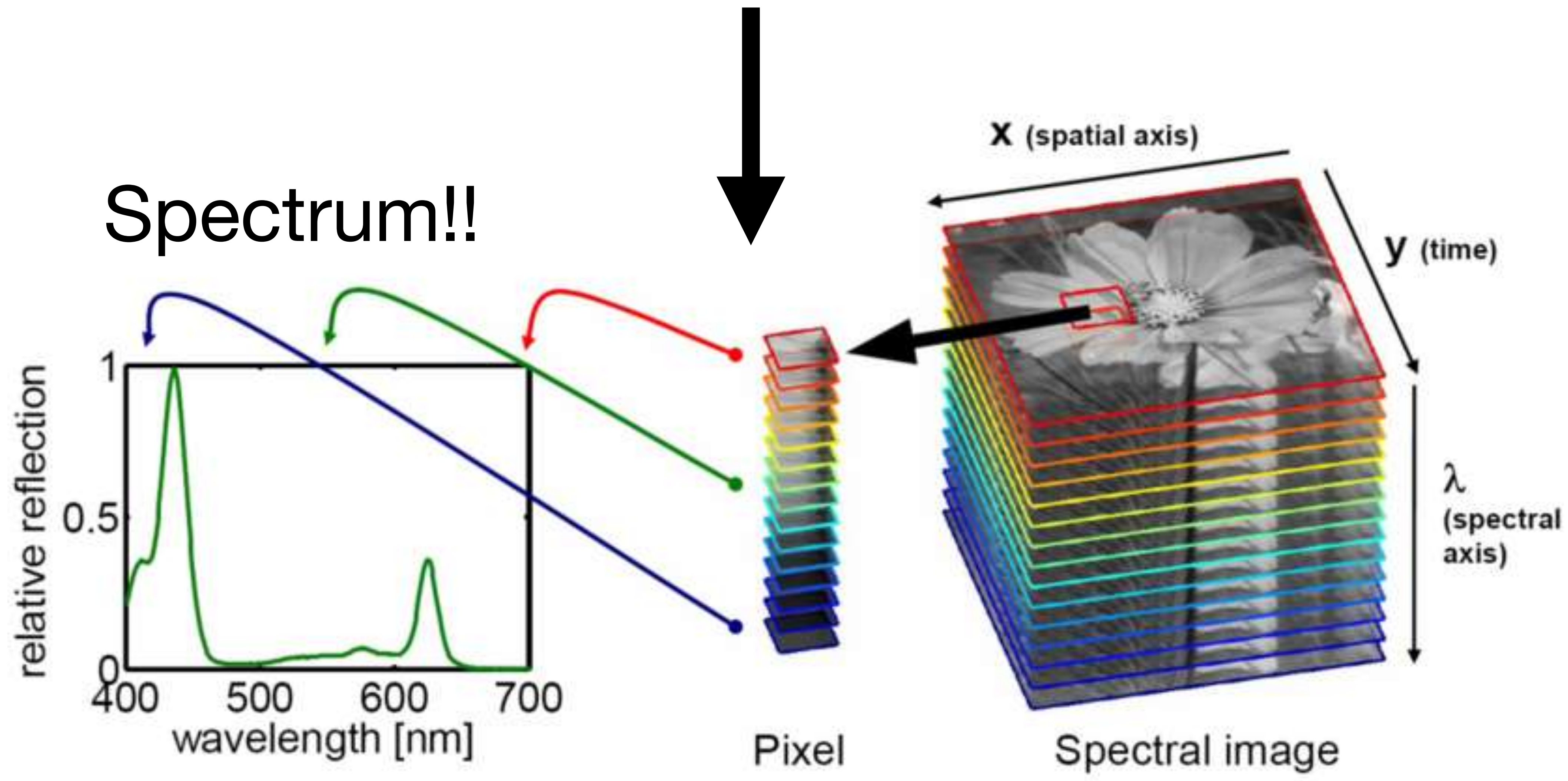
Bibring et al. 2004

Rosetta/ORIRIS-NAC

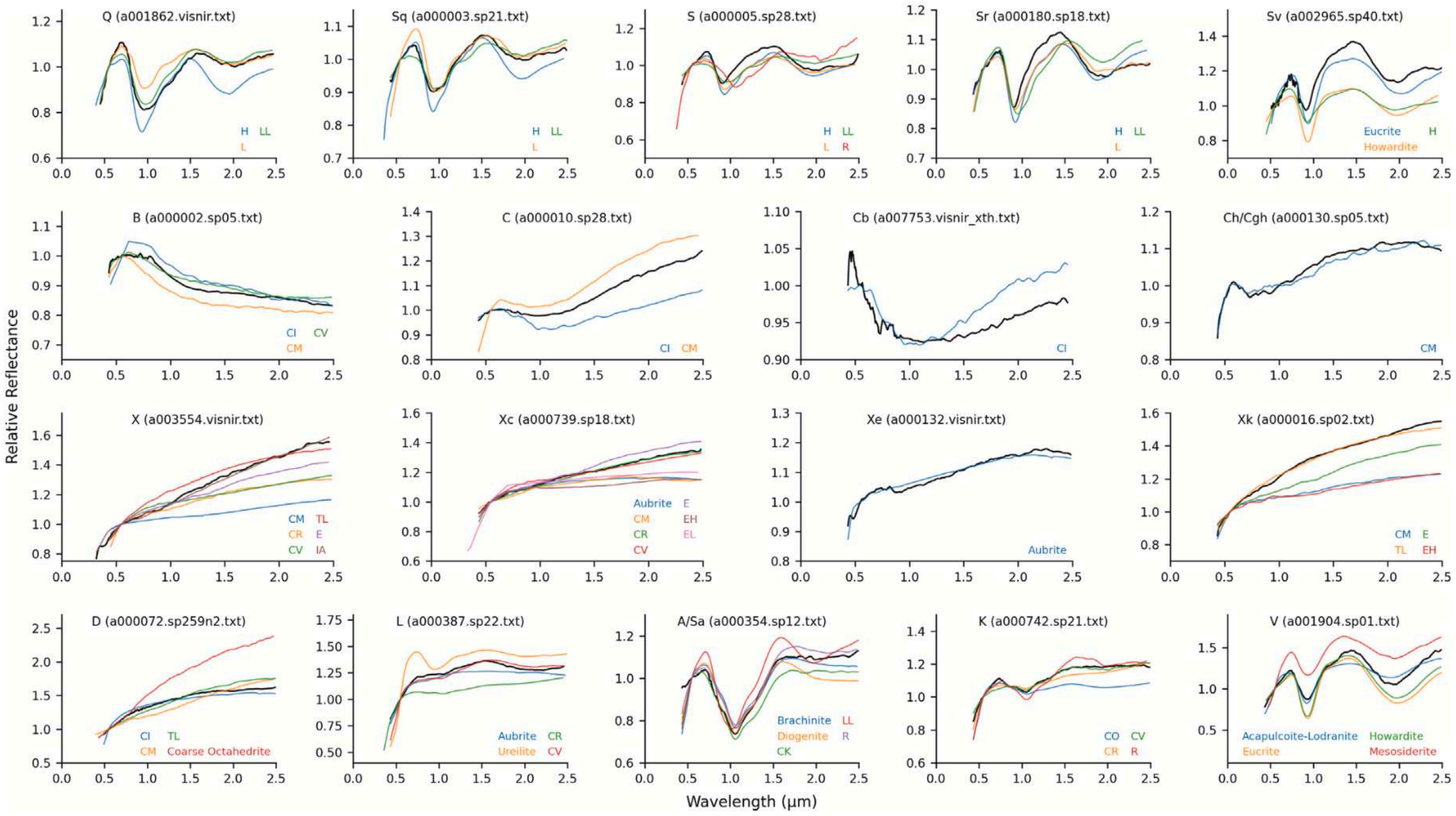


Keller et al. 2006

Spectrum!!



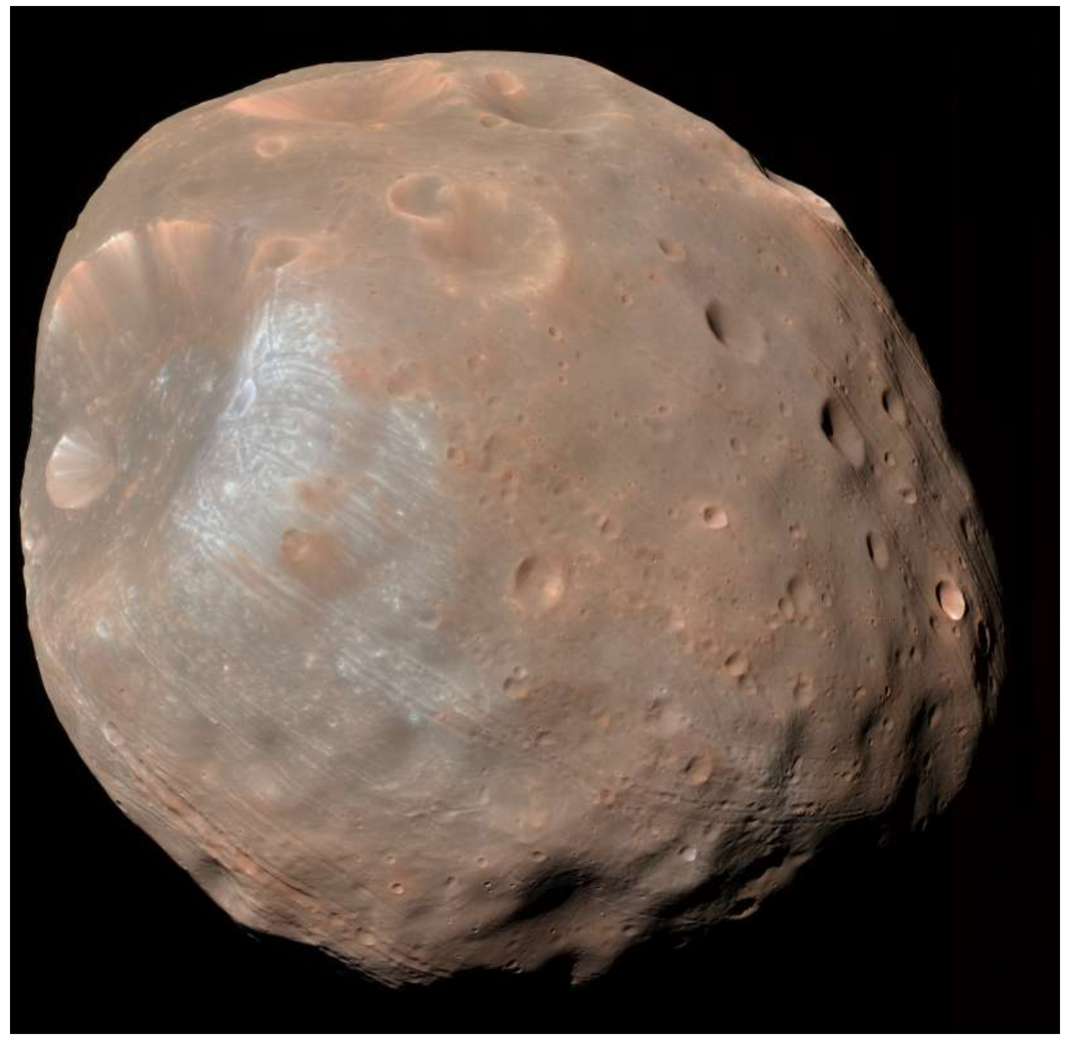
Spectral Analysis



De Meo et al. 2022

ML algorithm for the identification and characterization of absorption bands

Comparison with other spectra to obtain info about the mineralogy



NASA/MRO-HiRISE image of Phobos (PSP_007769_9015)

Working Plan

A. Background acquisition on *machine learning*

A.1. Attend machine learning lectures
A.2. Literature review about machine learning
A.3. General knowledge about machine learning

B. Development of ML algorithm to process remote sensing data

B.1. Thermal correction of the data
B.2. Extraction and automatic identification of spectrum absorption bands
B.3. Automatic comparison between extracted features with both laboratory data and other SS bodies spectra
B.4. Adaption of algorithm for PA cases studies (LESIA)
B.5. Creation of a database open to PA users (desiderata)

C. Interpretation of the obtained data from a scientific perspective and analysis of laboratory mineralogical analogs

C.1. Application of the algorithm to real remote sensing data and analysis
C.2. Application and adaptation of algorithm to PA context
C.3. Analysis and comparison of multiple laboratory analogs

D. PhD thesis finalization and future perspectives

D.1. Writing the Ph.D. thesis

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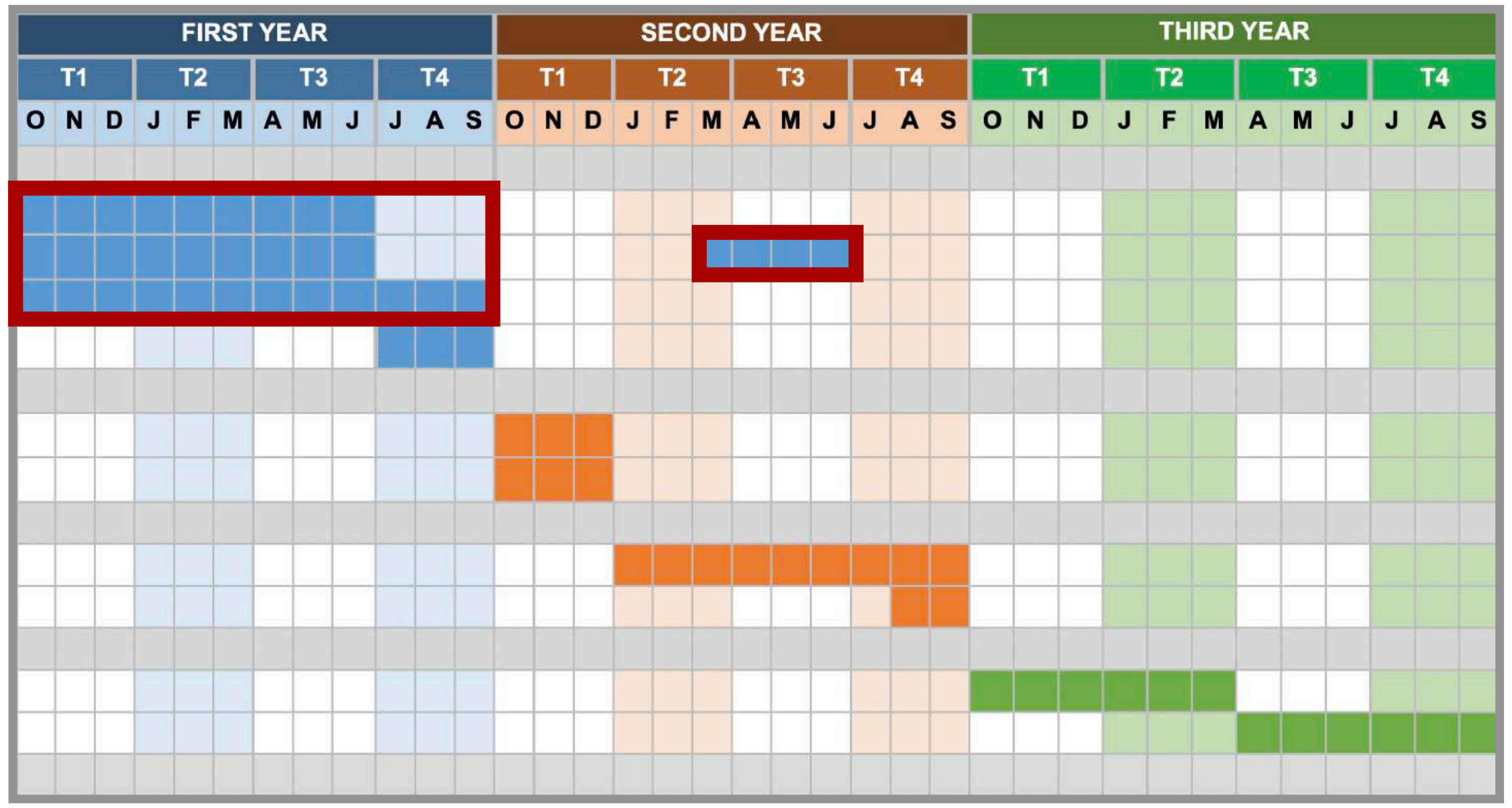
UNIVERSITÀ DEGLI STUDI DI PADOVA

1st Year (Oct. 2023 - Oct 2024)

A. Background acquisition on *machine learning*



1. *Attend machine learning lectures* → *Machine Learning MOD B (005PD - INQ0092522) + 1*
2. *Literature review about machine learning*
3. *General knowledge about machine learning*

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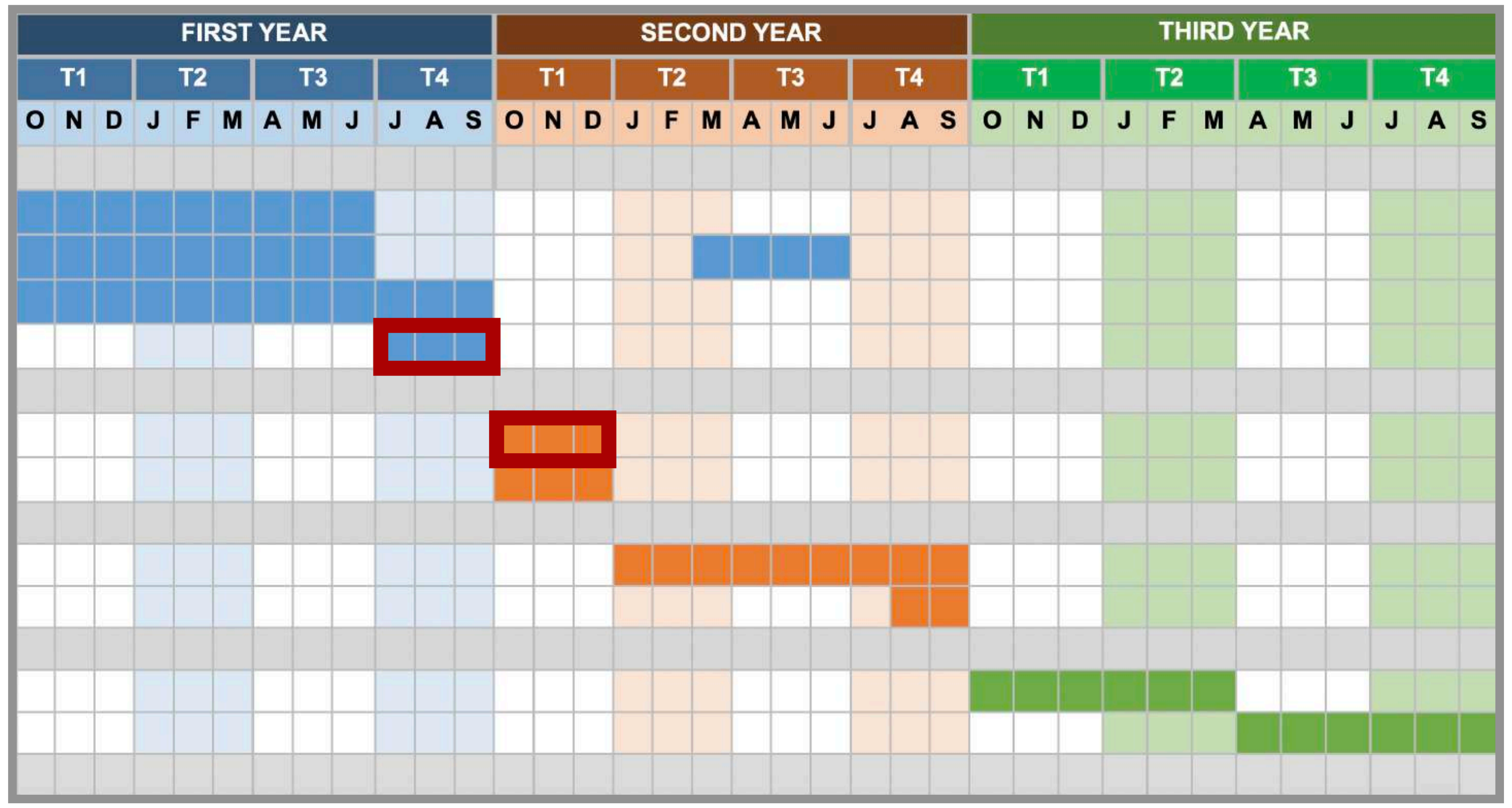
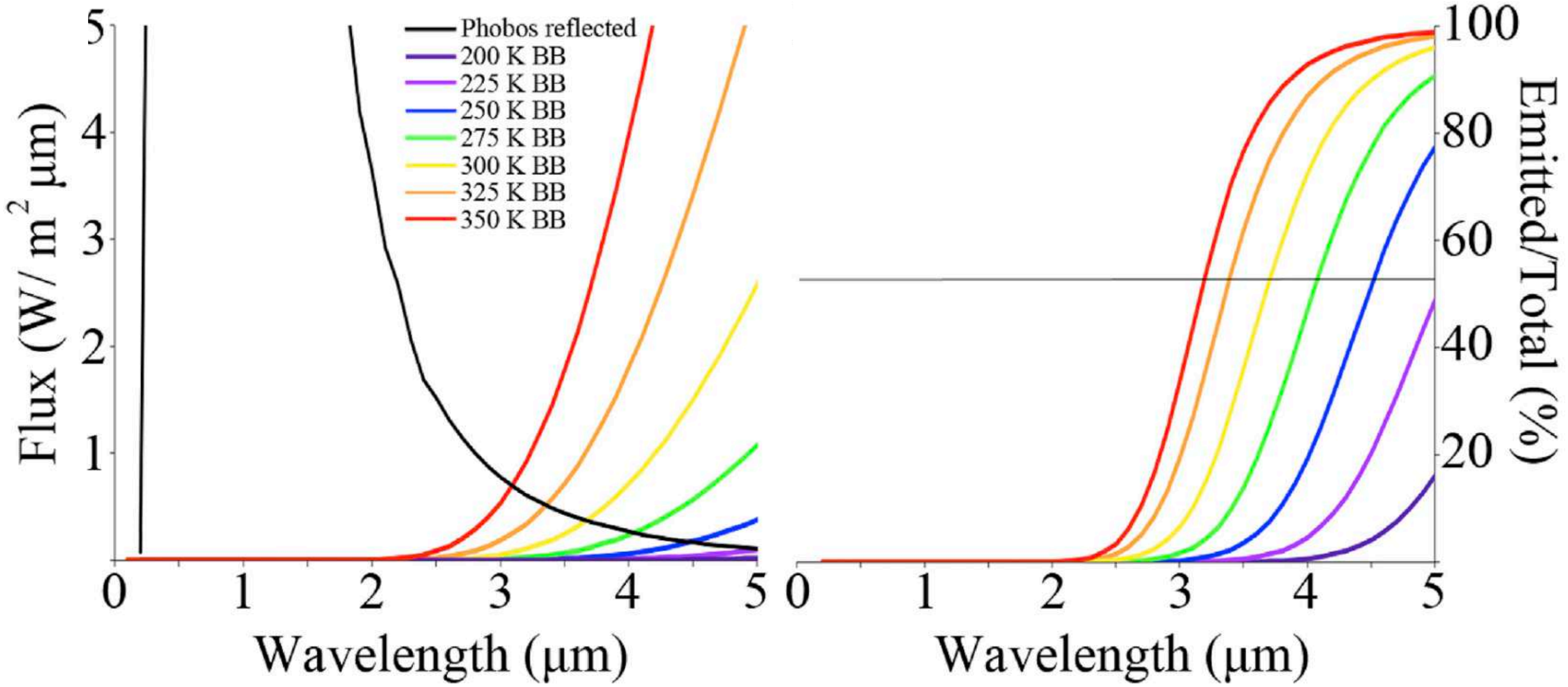
1st/2nd Year (July 2024 - Dec 2024)

B. Development of ML algorithm to process remote sensing data





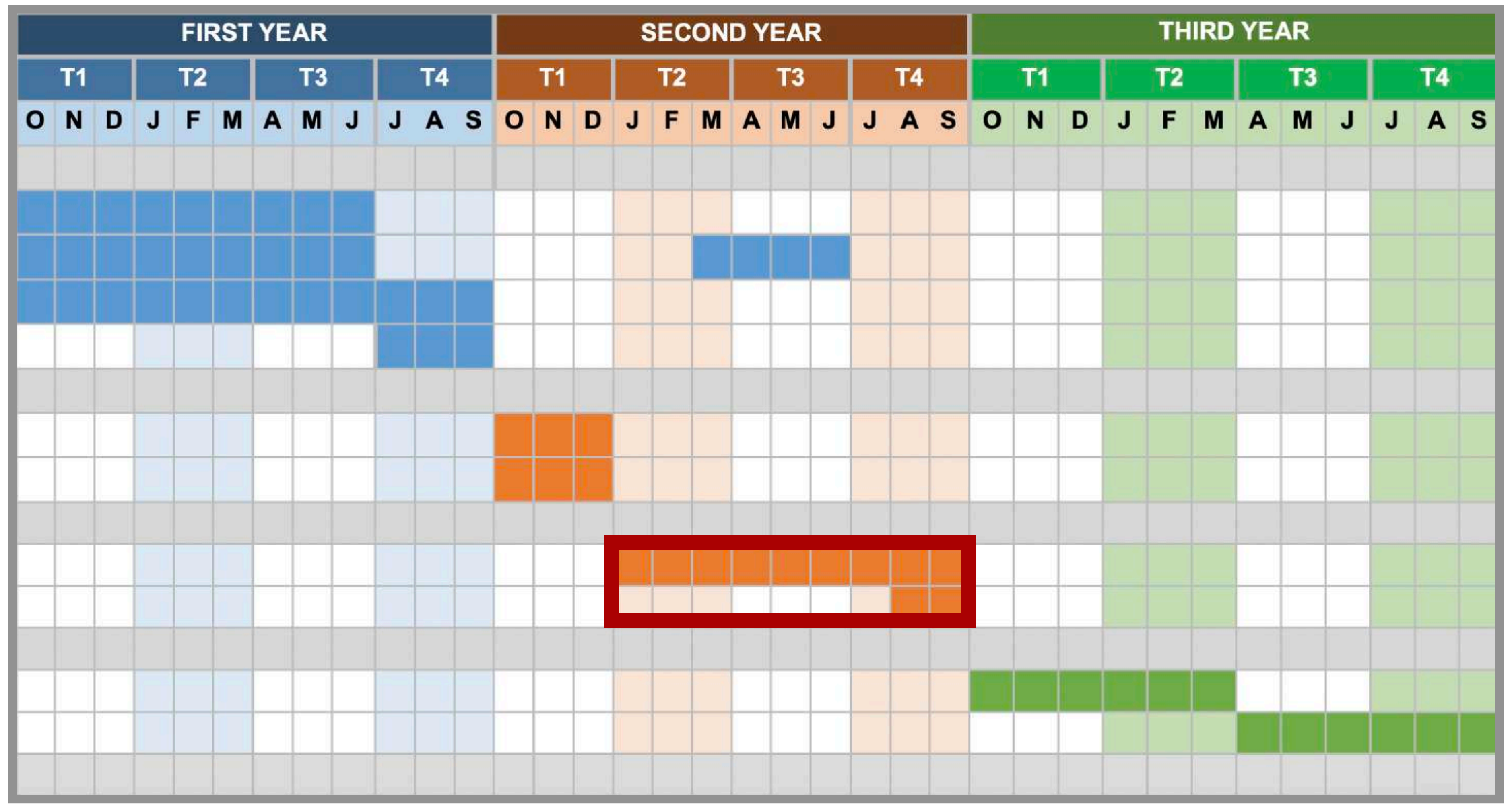
Pajola et al. 2018

1. *Thermal correction of the data*
2. *Extraction and automatic identification of spectrum absorption bands*
3. *Automatic comparison between extracted features with both laboratory data and other SS bodies spectra*
4. *Adaption of algorithm for PA cases studies (LESIA)*
5. *Creation of a database open to PA users (desiderata)*

UNIVERSITÀ DEGLI STUDI DI PADOVA

2^{nd} Year (Jan. 2025 - Oct. 2025)

B. Development of ML algorithm to process remote sensing data



1. *Thermal correction of the data*
2. *Extraction and automatic identification of spectrum absorption bands*
3. *Automatic comparison between extracted features with both laboratory data and other SS bodies spectra*
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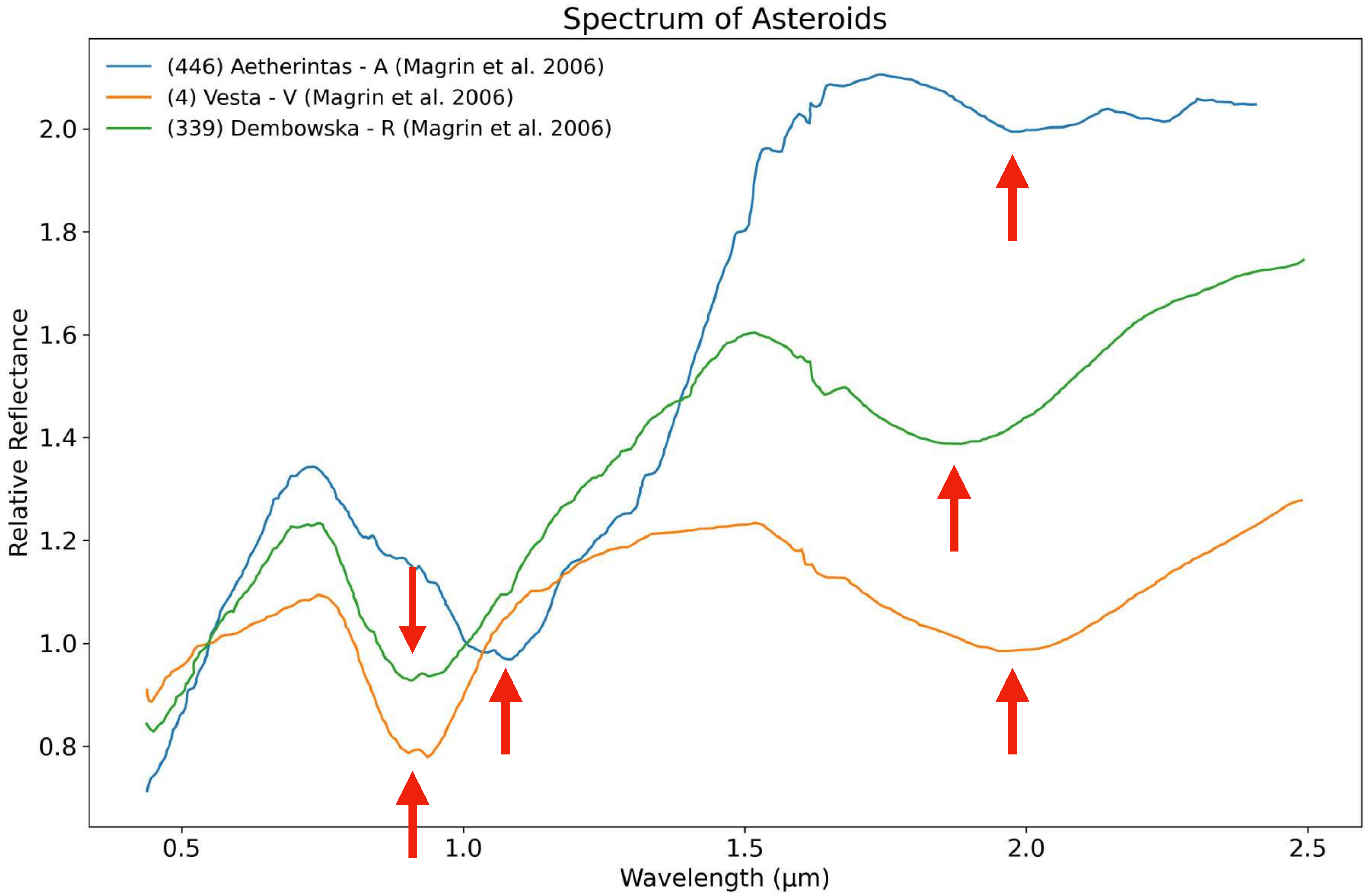
Characterization of Bands

B. Development of ML algorithm to process remote sensing data

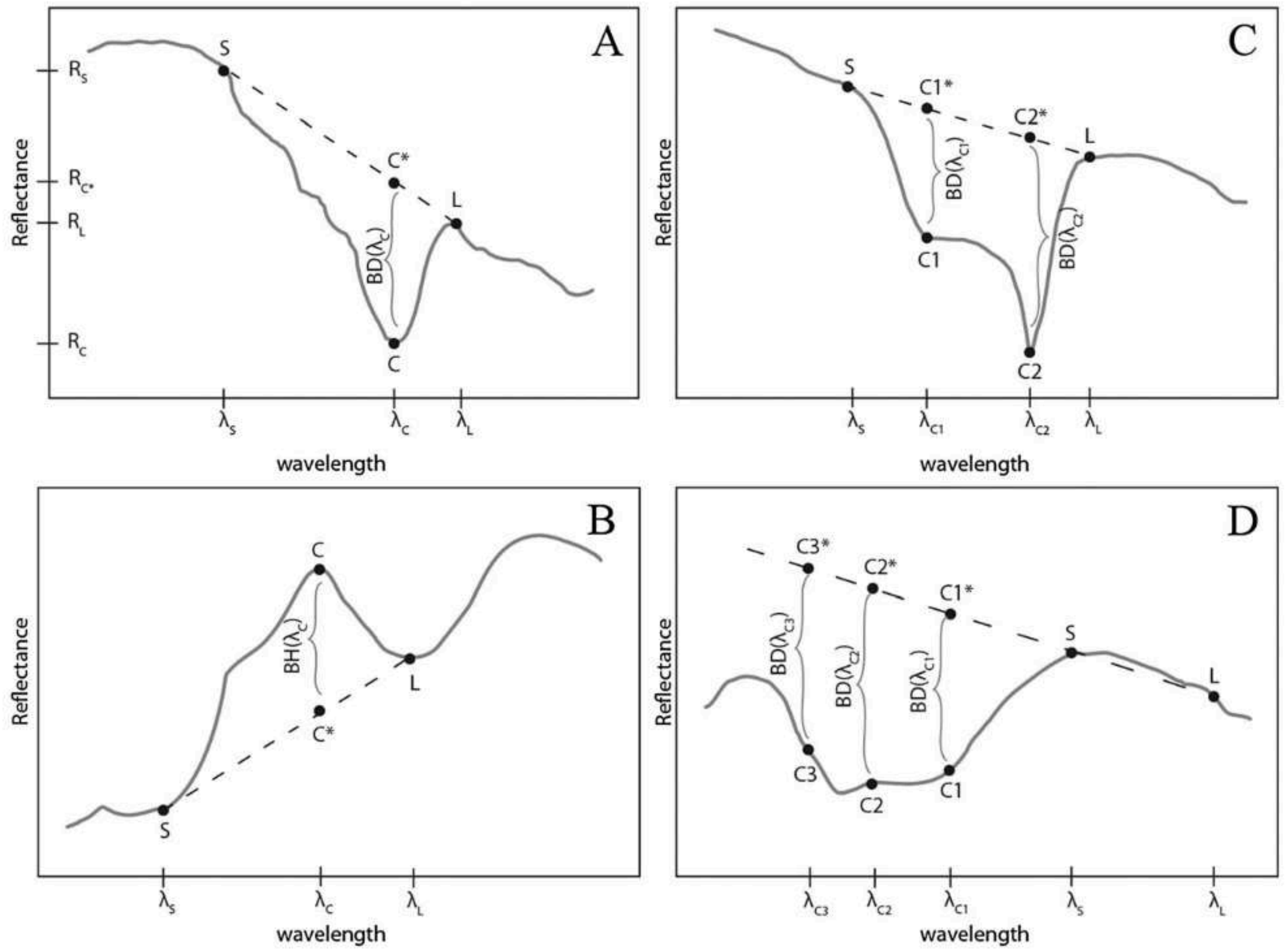


Target of the algorithm:

- Identification of the absorption bands
- Characterization of the absorption bands → Spectral parameters
- Comparison with other spectra → Mineralogy

ML Code For Spectral Features

B. Development of ML algorithm to process remote sensing data



Viviano-Beck et al. 2014

Band Depth

$$BD = 1 - \frac{R_{band}}{R_{cont}}$$

External Band Depth

$$BH = 1 - \frac{R_{cont}}{R_{band}}$$

Absorption Doublets

$$MIN(\lambda_1, \lambda_2) = min[BD(\lambda_1), BD(\lambda_2]$$

Wide Absorptions

$$BD(\lambda_N) = \sum_i D_i \cdot BD(\lambda_i)$$

Slope

$$Slope = 10 \cdot \frac{R(\lambda_1) - R(\lambda_2)}{R(\lambda_1)(\lambda_1 - \lambda_2)}$$

ML Code For Spectral Features

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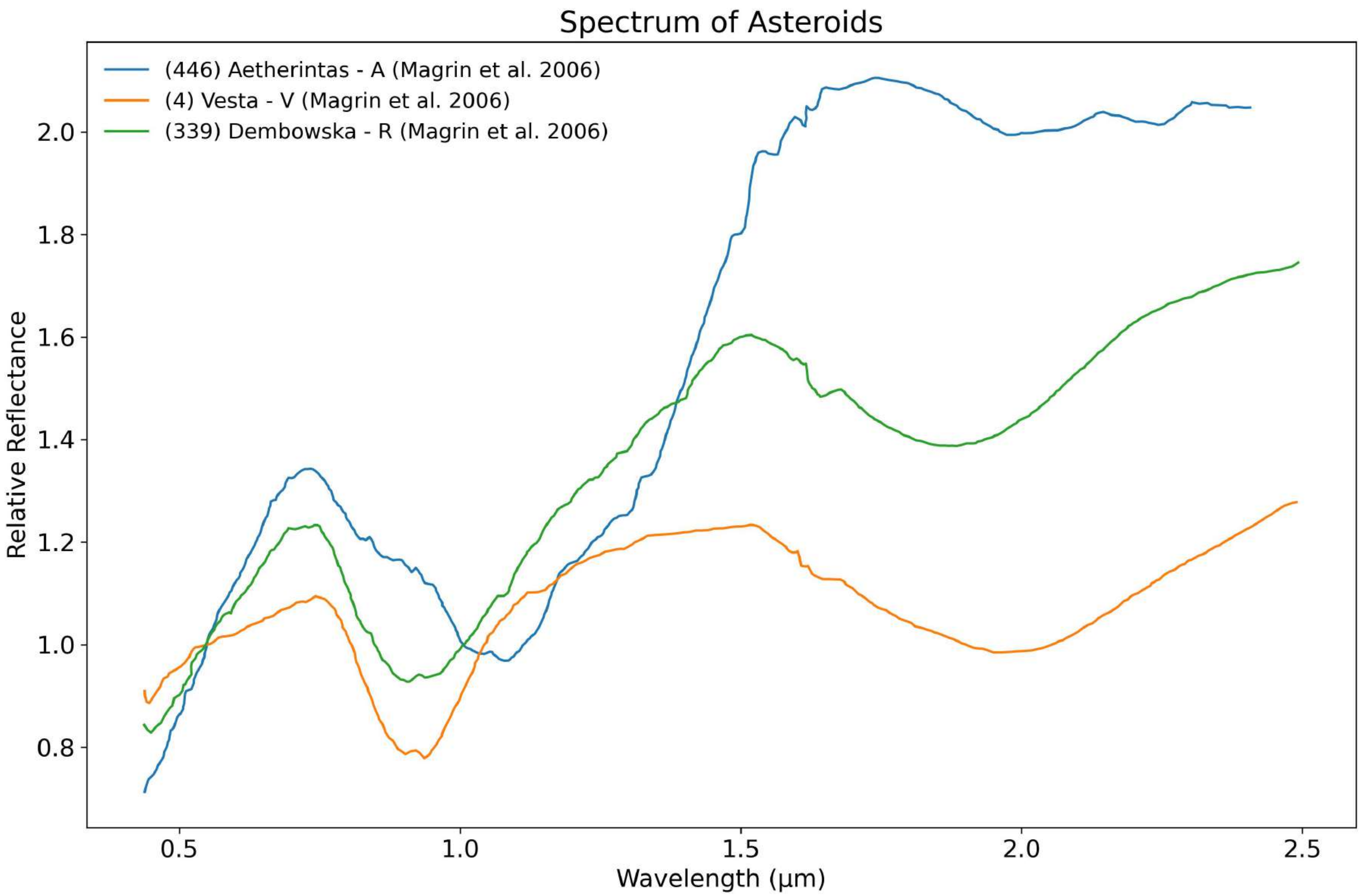
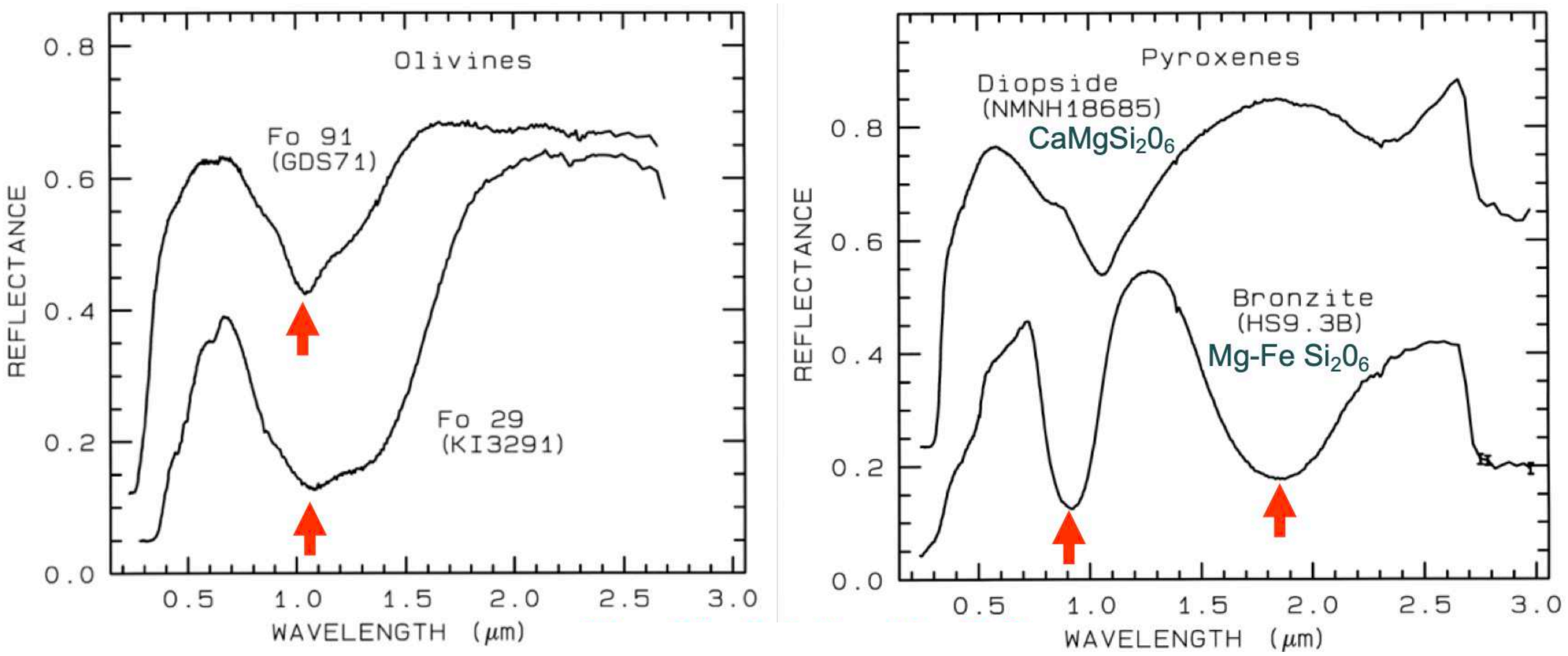


Comparison with:

- Spectra of meteorites
- Laboratory spectra
- Other remote sensing data



Clark in Rencz 1999

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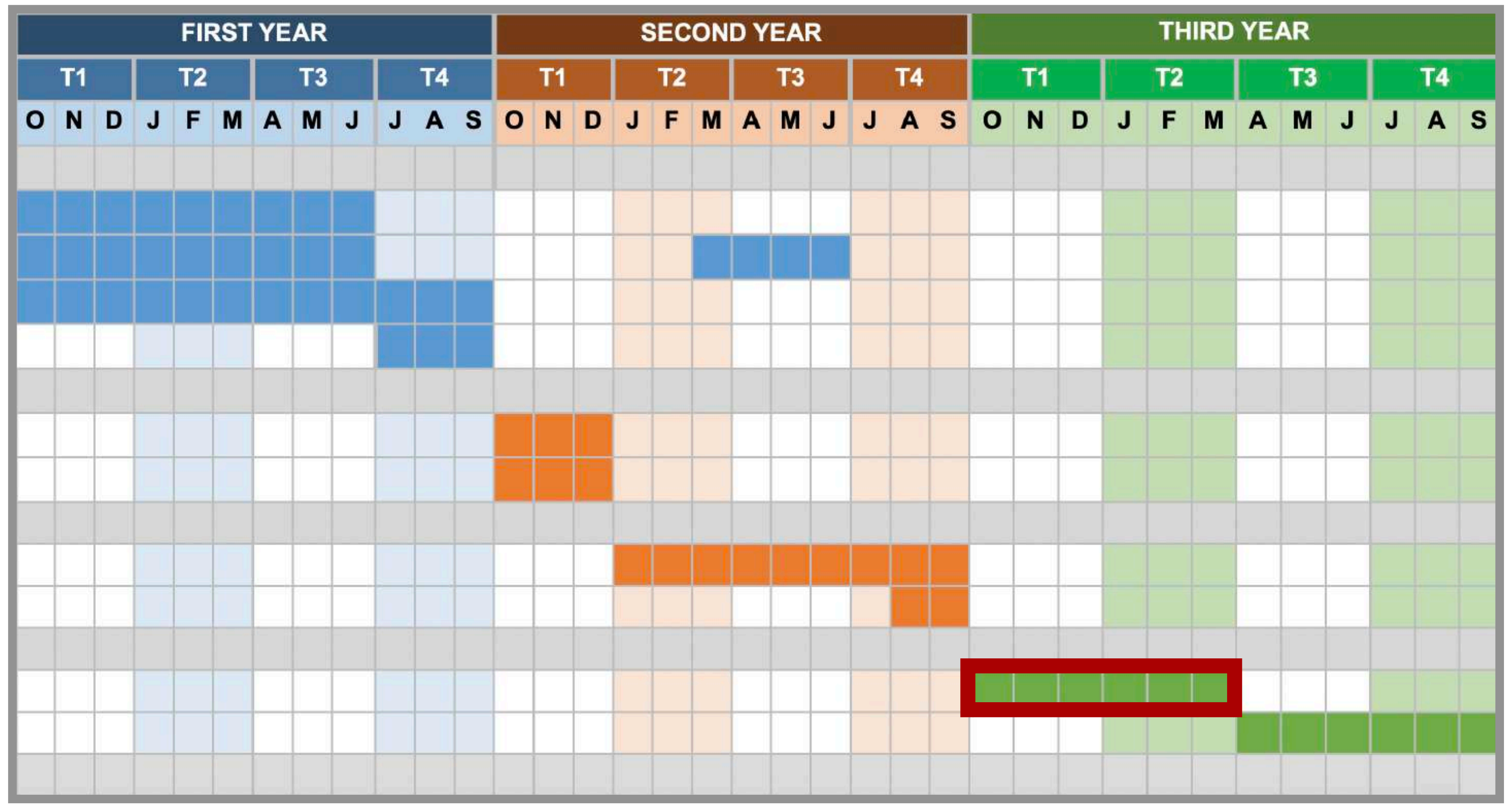
UNIVERSITÀ DEGLI STUDI DI PADOVA

3rd Year (Oct. 2025 - Mar. 2026)

CISAS G. COLOMBO

C. Interpretation of the obtained data from a scientific perspective and analysis of laboratory mineralogical analogs



1. Application of the algorithm to real remote sensing data and analysis

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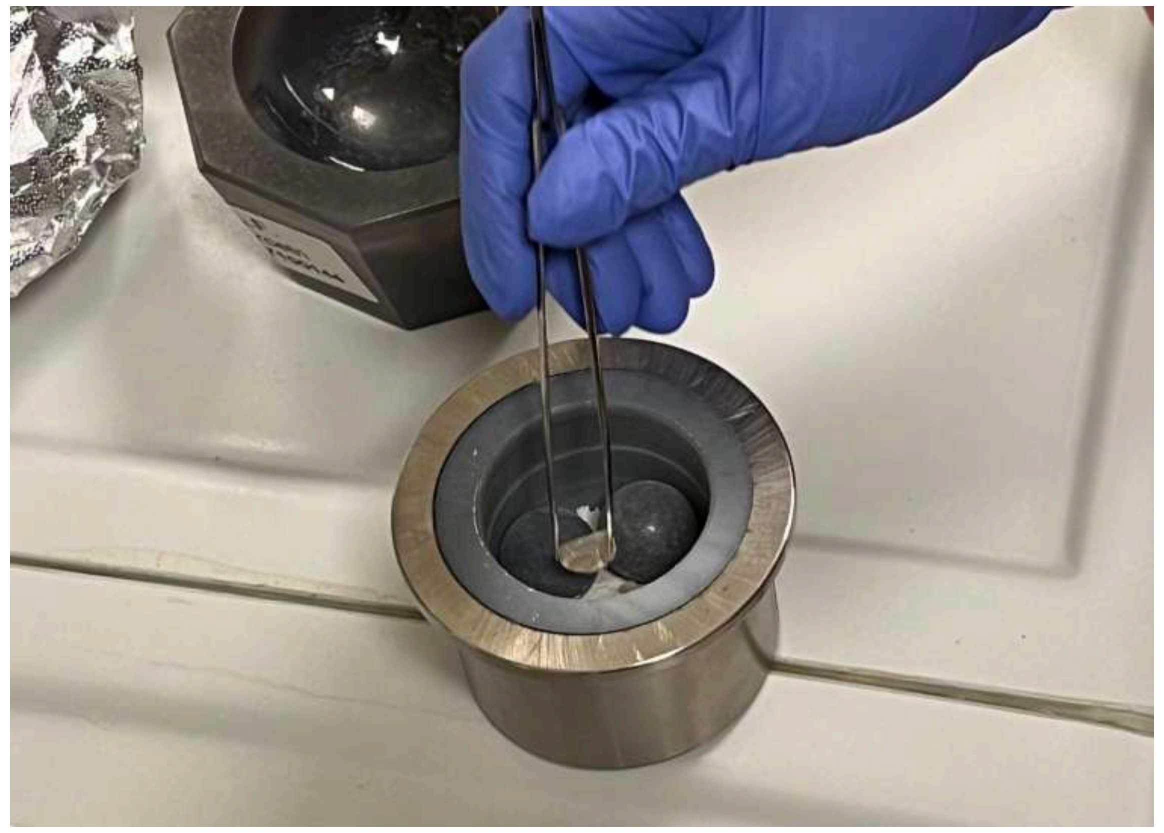
3. Analysis and comparison of multiple laboratory analogs → ***Observatory of Arcetri, Firenze***

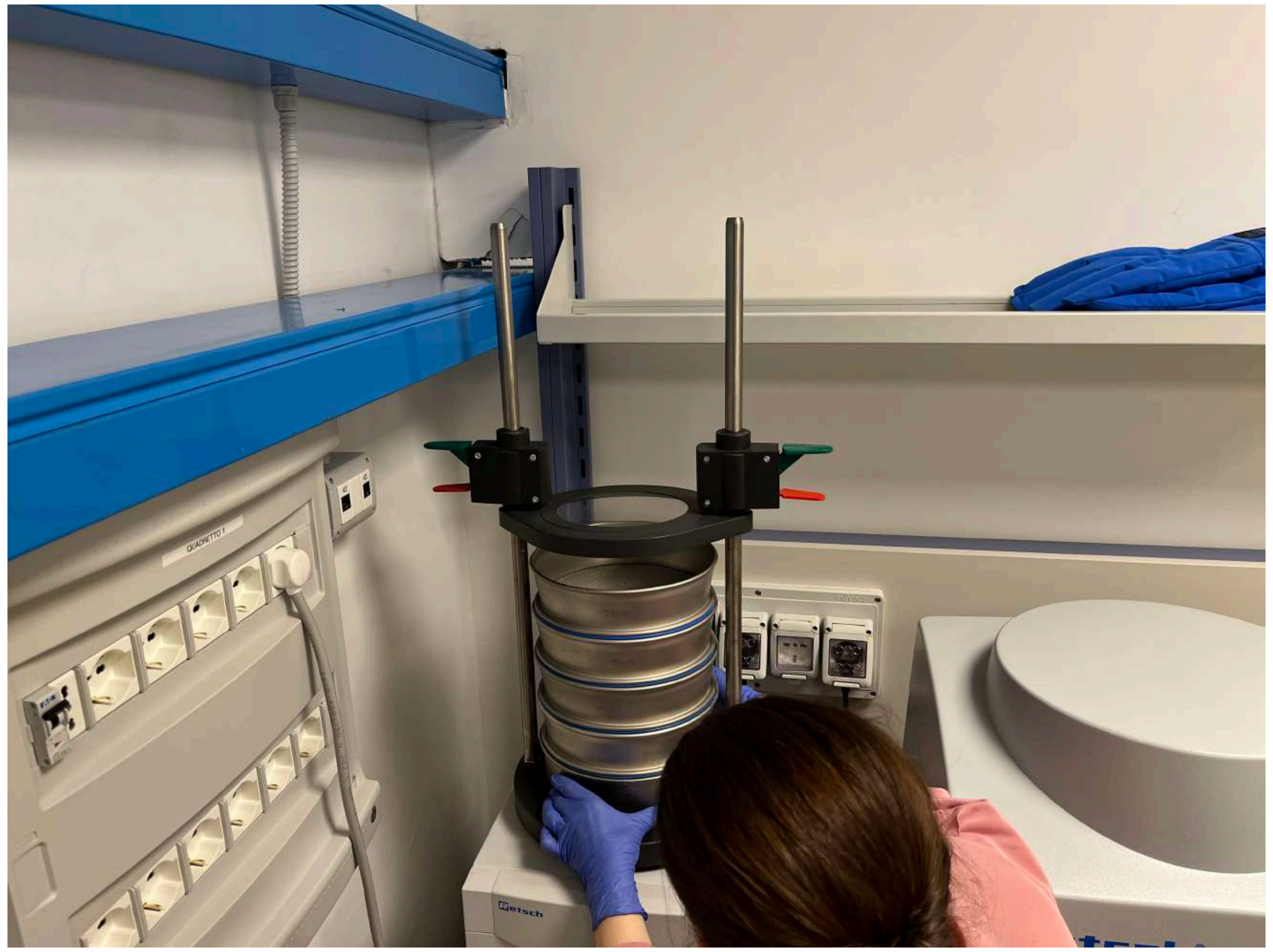
Laboratory

1. Creation of the powder from previous selected minerals



Credit: INAF-Osservatorio Astrofisico di Arcetri

2. Shaking procedure for grain size sorting



Credit: INAF-Osservatorio Astrofisico di Arcetri

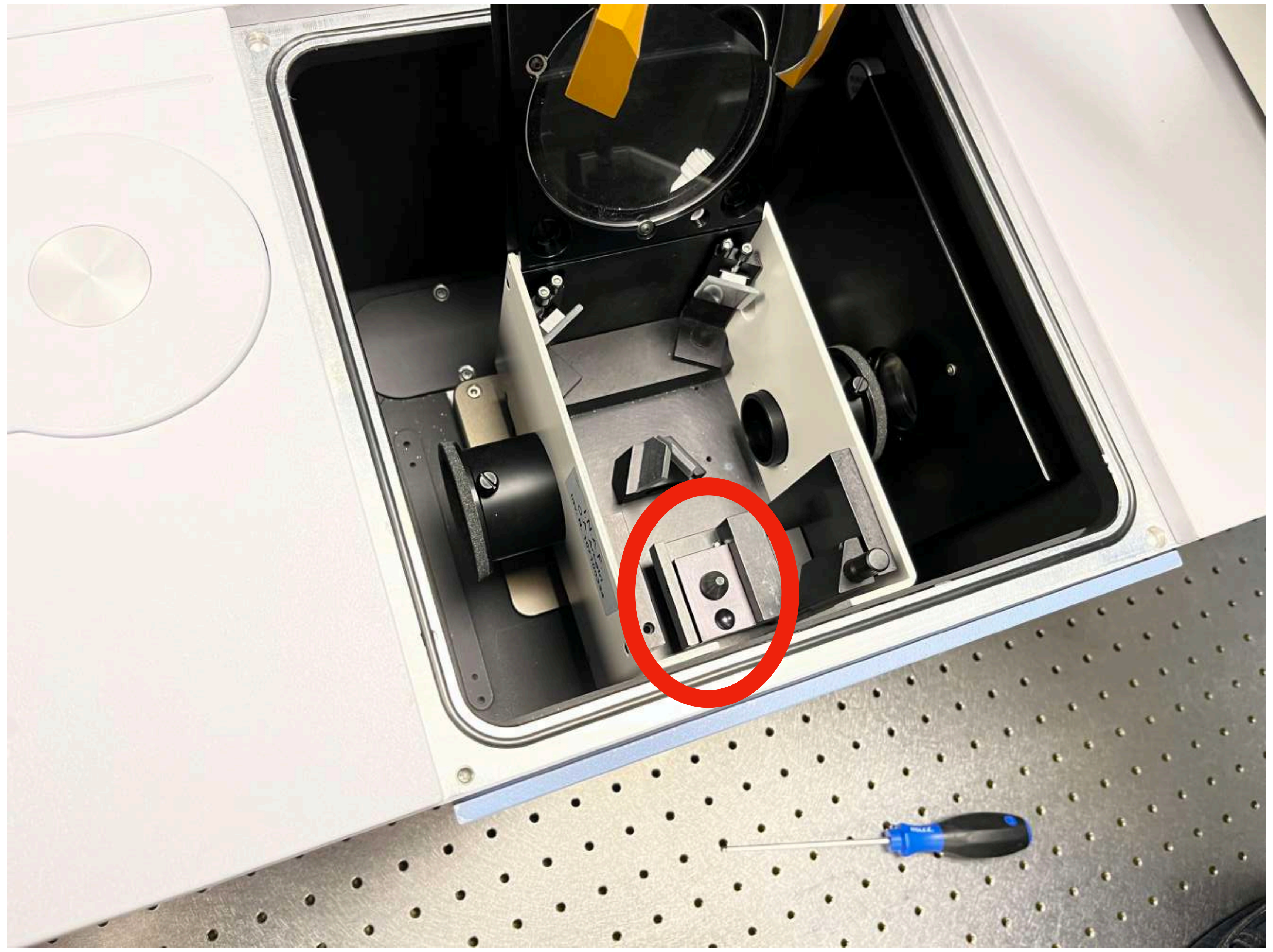
Laboratory

3. Cleaning from smaller grain sizes particles

Credit: INAF-Osservatorio Astrofisico di Arcetri

Laboratory

4. Taking the spectra



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Thanks for the attention!

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