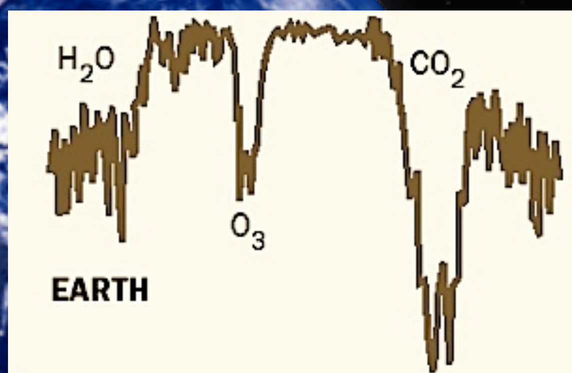
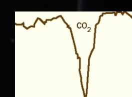
ATMOSPHERE IN A TEST TUBE



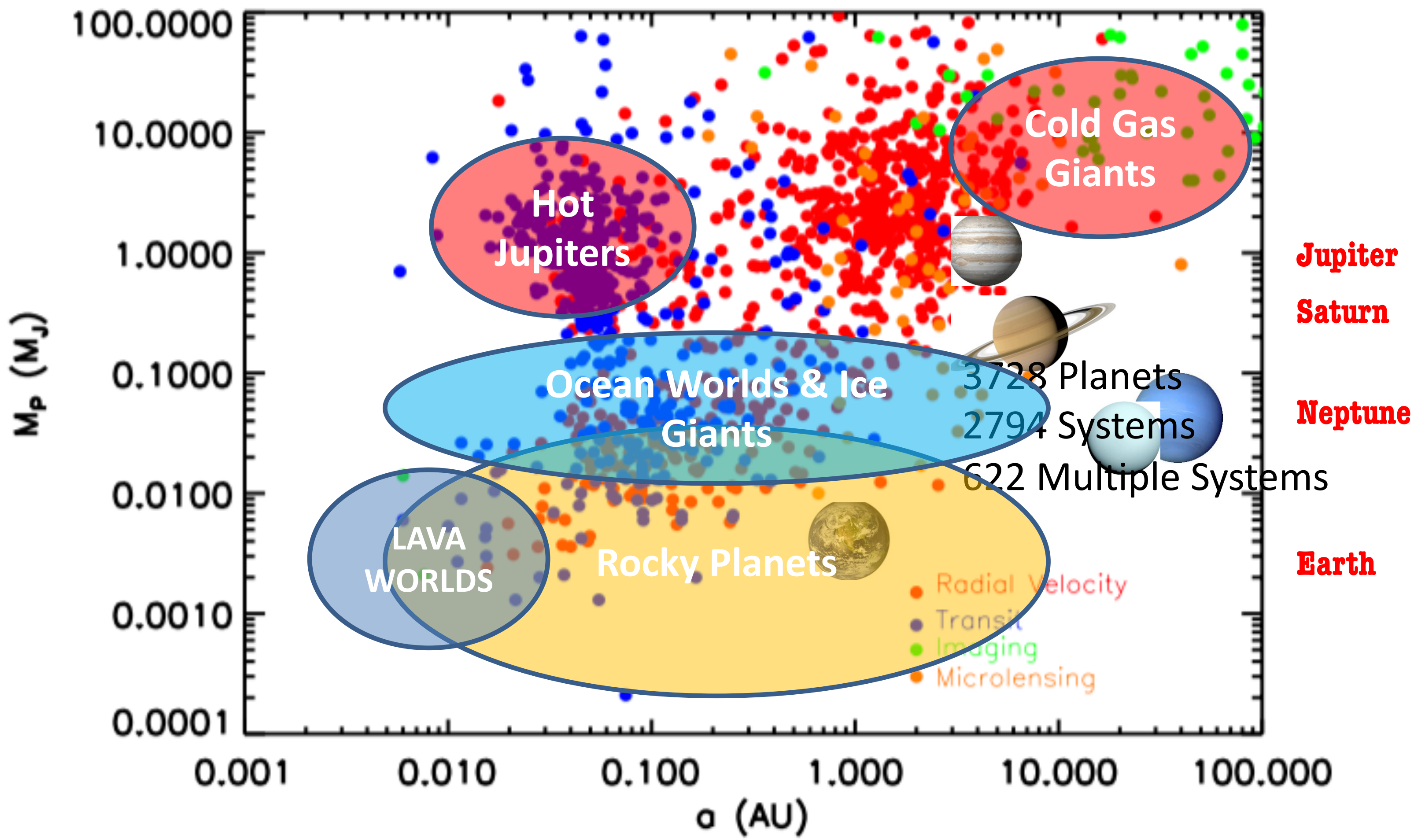


R. CLAUDI and …

INAF ASTRONOMICAL OBSERVATORY OF PADOVA

ARIEL Meeting 2018 Roma 2018-OCT-2-3

E. Alei	**INAF, Astron. Obs. of Padova**
A. Balbi	**Physics Dep. of the II Univ. of Roma**
M. Battistuzzi	**CISAS "G. Colombo" PD**
E. Bernieri	**Physics Dep. of the III Univ. of Roma**
D. Billi	**Biology Dep. of the II Univ of Roma**
A. Ciaravella	**INAF, Astron. Obs. of Palermo**
L. Cocola	**LUXOR –Photonics and Nano Tech. Inst. PD**
B. Cosciotti	**Physics Dep. of the III Univ. of Roma**
C. Cecchi Pestellini	**INAF, Astron. Obs. of Palermo**
A. Jimenez	**INAF, Astron. Obs. of Palermo**
N. La Rocca	**Biology Dep. of Padova Univesity**
S. Lauro	**Physics Dep. of the III Univ. of Roma**
E. Mattei	**Physics Dep. of the III Univ. of Roma**
G. Micela	**INAF, Astron. Obs. of Palermo**
E. Pace	**Firenze University, INFN Frascati**
E. Pettinelli	**Physics Dep. of the III Univ. of Roma**
G. Piccioni	**INAF, Inst. of Spatial Astroph. e Planet.**
L. Poletto	**LUXOR –Photonics and Nano Tech. Inst. PD**
S. Stefani	**INAF, Inst. of Spatial Astroph. e Planet.**



100.0000
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
M_P (M_J)
0.001
0.010
0.100
1.000
10.000
100.000
a (AU)
Hot Jupiters
Cold Gas Giants
Ocean Worlds & Ice Giants
LAVA WORLDS
Rocky Planets
3728 Planets
2794 Systems
622 Multiple Systems
Radial Velocity
Transit
Imaging
Microlensing
Jupiter
Saturn
Neptune
Earth

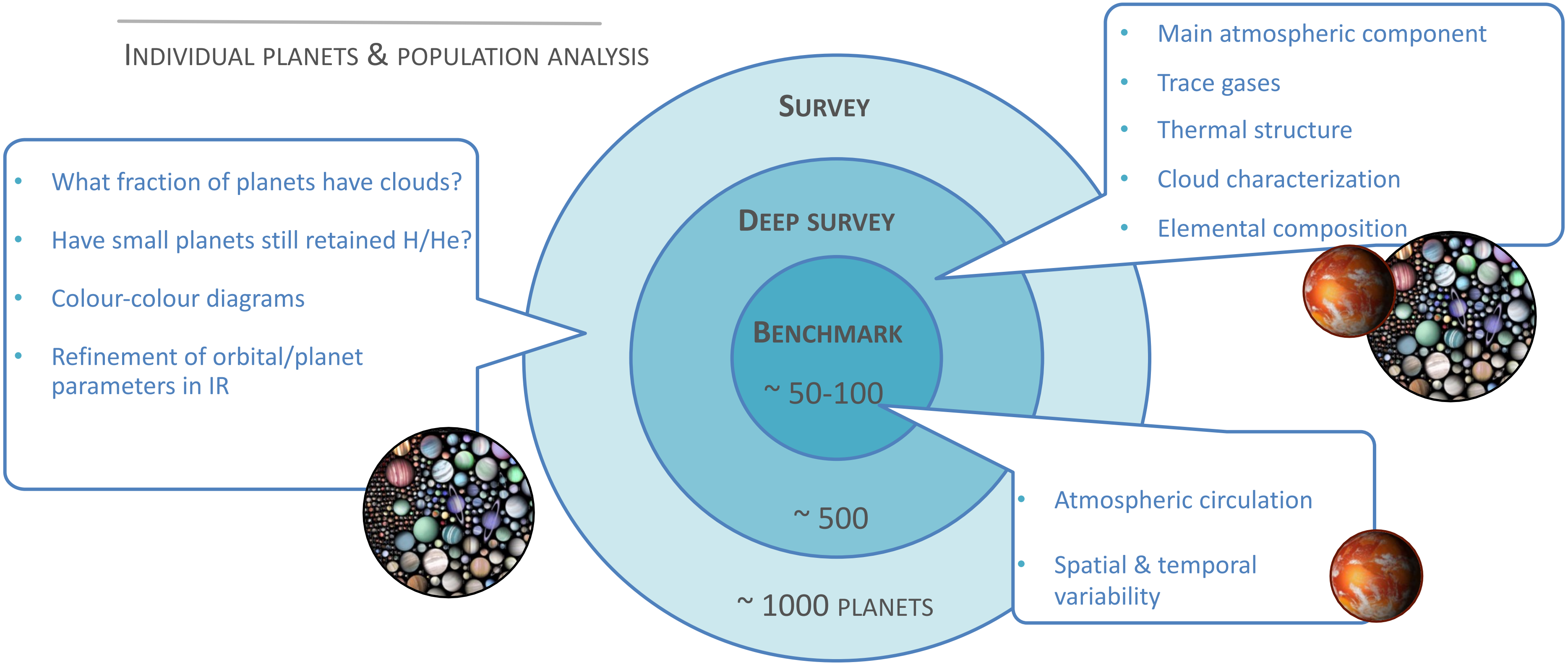
ARIEL Targets

- Gas Rich Exoplanets
- Rocky Planets
- Rare and Extreme conditions Planets
  - Planets in high eccentric orbits
  - Circumbinary Planets
  - Transiting Multi planet Systems
  - Disintegrating Planets and Planetesimals
  - Planets Around Flaring Stars

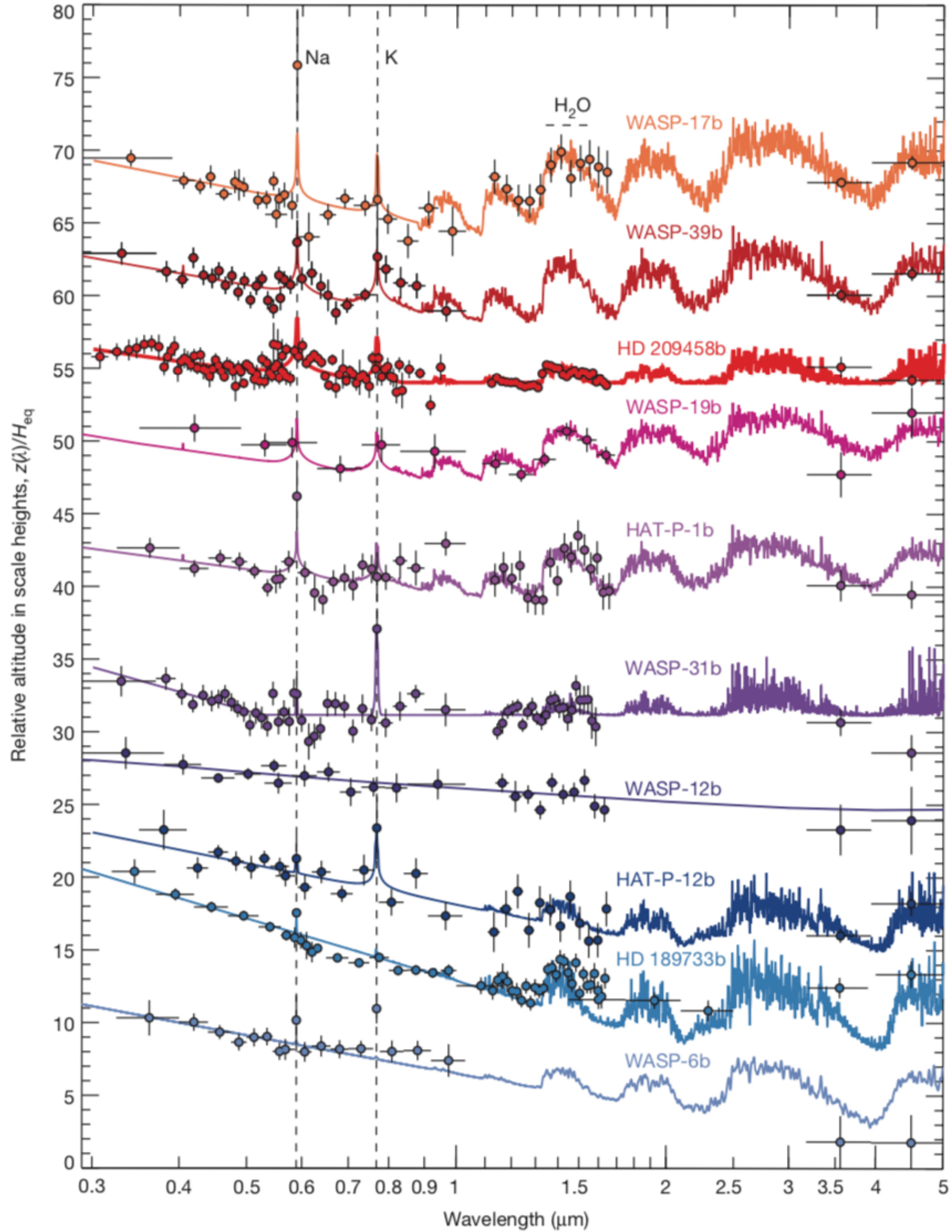
Tinetti et al, 2018

ARIEL 3-tier approach

INDIVIDUAL PLANETS & POPULATION ANALYSIS



Tinetti et al, 2018



Sing et al, 2016


nature astronomy
LETTERS
https://doi.org/10.1038/s41550-018-0397-0
Corrected: Publisher Correction
Haze production rates in super-Earth and mini-Neptune atmosphere experiments
Sarah M. Hörst[1]*, Chao He[1], Nikole K. Lewis[1,2], Eliza M.-R. Kempton[3], Mark S. Marley[4], Caroline V. Morley[5], Julianne I. Moses[6], Jeff A. Valenti[2] and Véronique Vuitton[7]

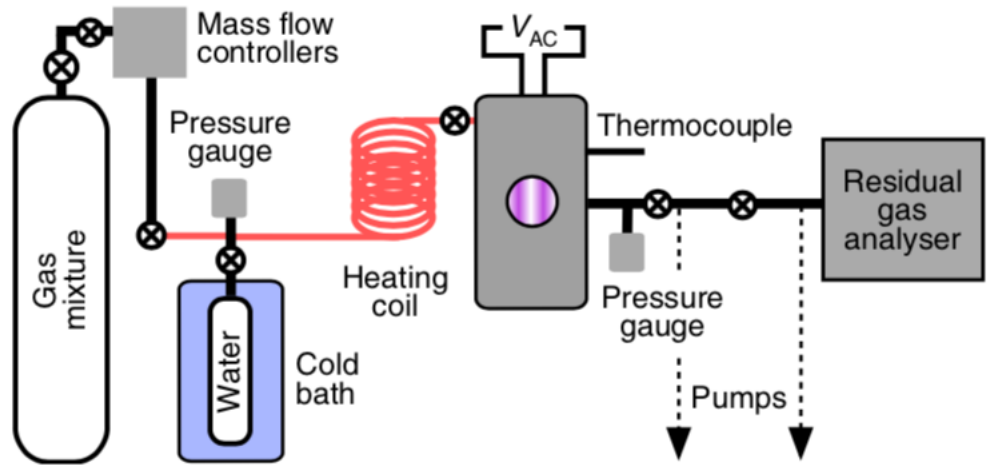
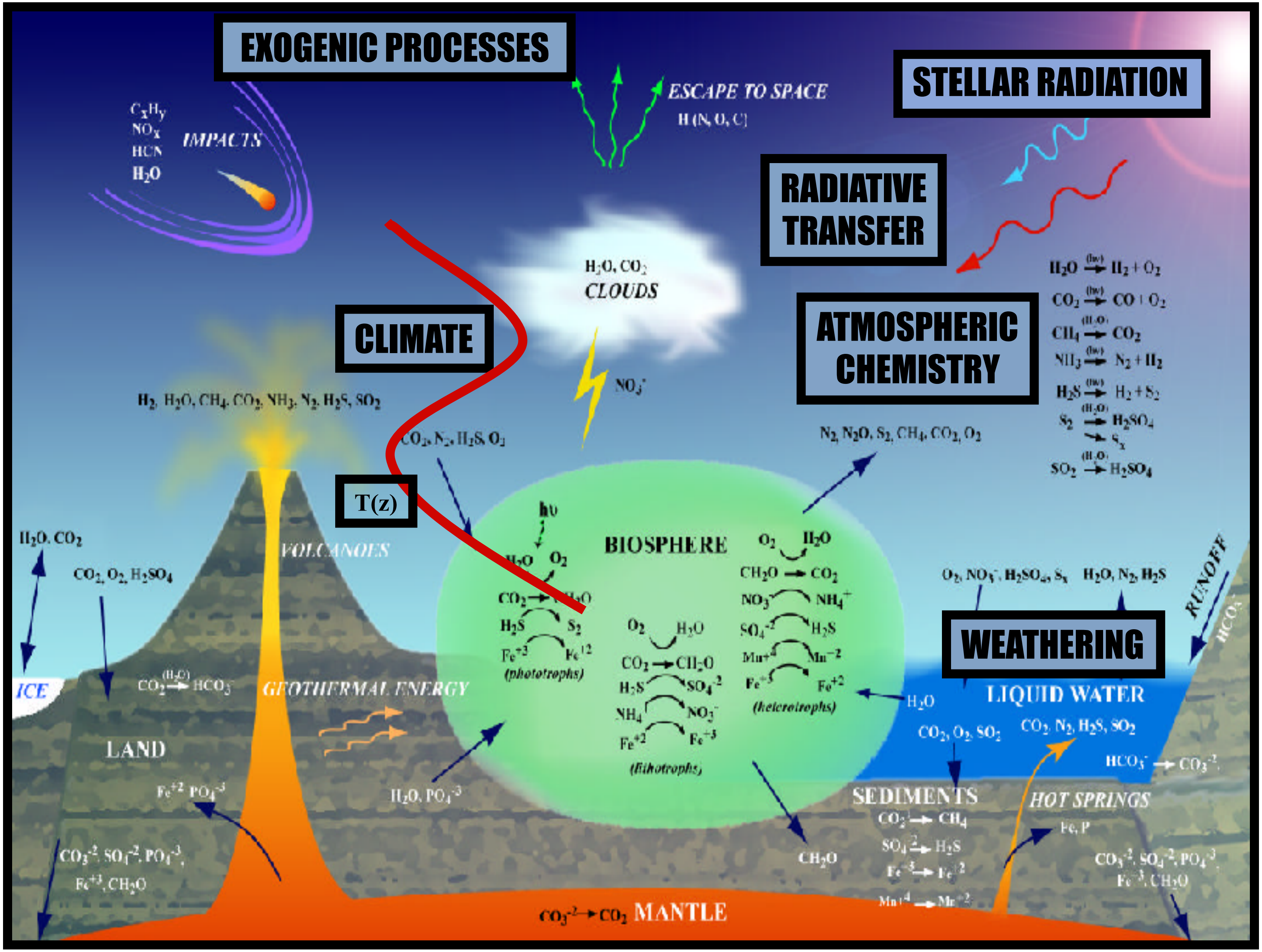


Table 2 | Measured production rates (mg h^{-1})

	100×	1,000×	10,000×
300 K	Film	10.43	Film
400 K	0.25	10.00	Film
600 K	0.04	0.15	0.31

Film indicates that a film is observed on substrates that were in the chamber, but there was not sufficient sample to collect and weigh.



M. Allen, K. Nealson, V. Meadows

A planet's spectrum is the product of a complex interplay of environmental components and processes.

Atmosphere in a Test Tube

To simulate planetary atmosphere in laboratory in order to:

- Study the possible modification of Exo Atmosphere due to different exoplanetary environmets
- Study the possible modification to rocky planets atmospheres due to biota
- Study the interaction between radiation and atmosphere
- Produce data base of spectra at different P and T conditions

INAF OAPD +
Physichs and Astronomy Dep+
Biology Dep.

INAF IASP
INFN – LF
Biology Dep

INAF OAPA

PALERMO

G. Cassone

A. Ciaravella

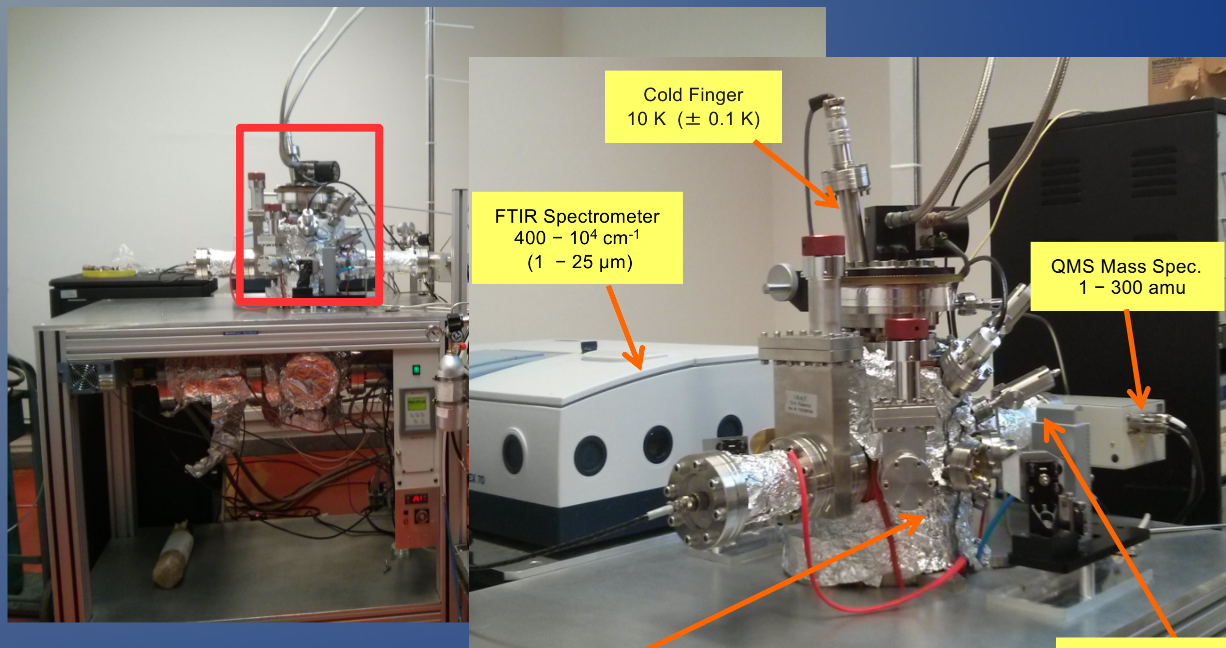
C. Cecchi Pestellini

A. Jimenez

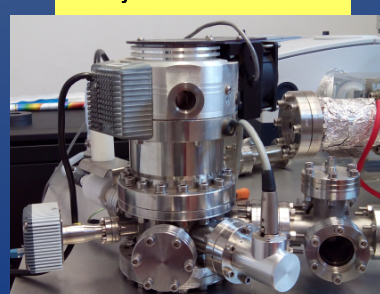
G. Micela

Light Irradiation Facility for Exochemistry (LIFE)

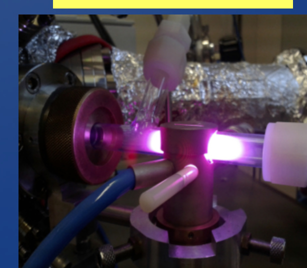
UHV Chamber (~ 6 × 10^{-11} mbar)

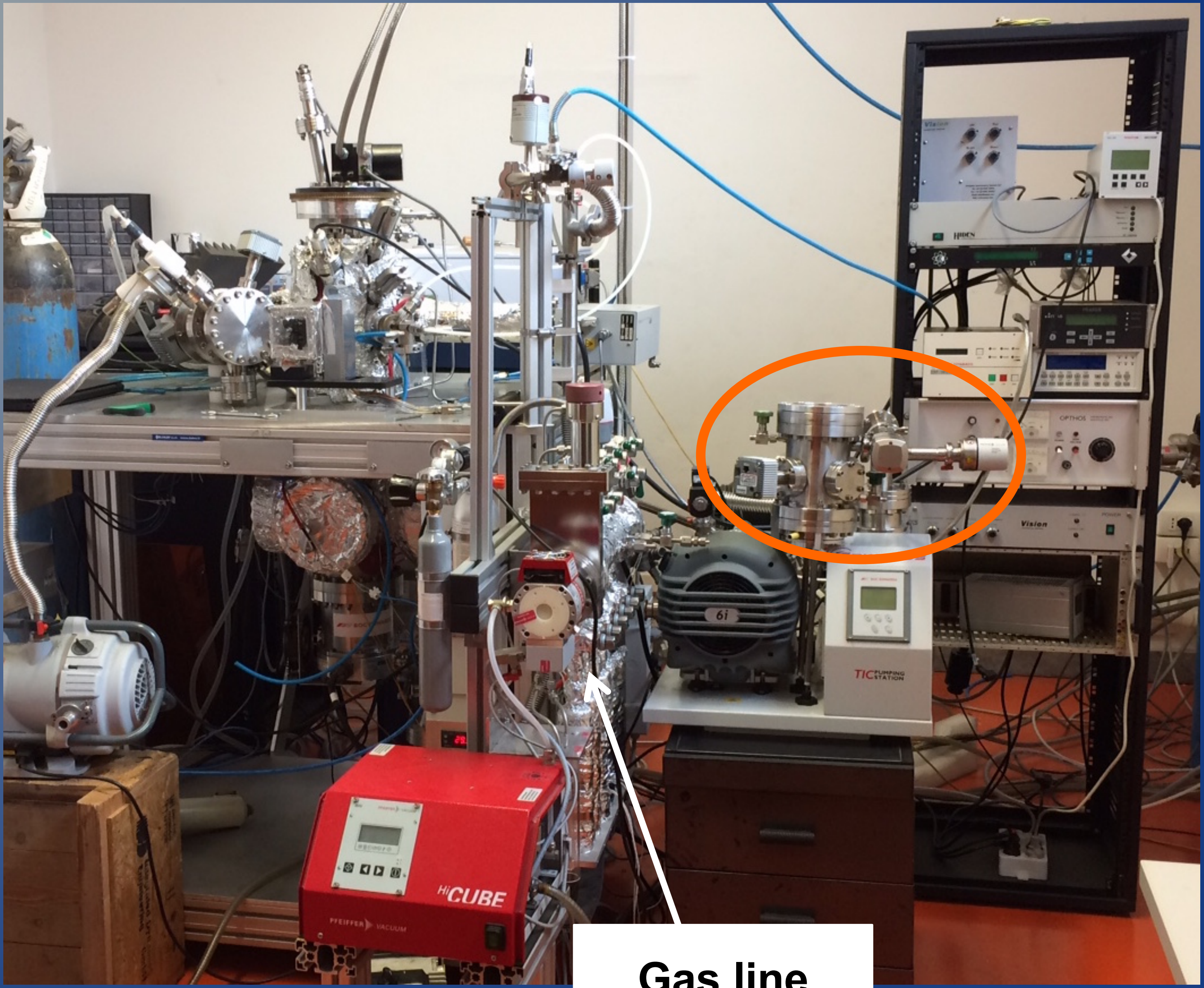


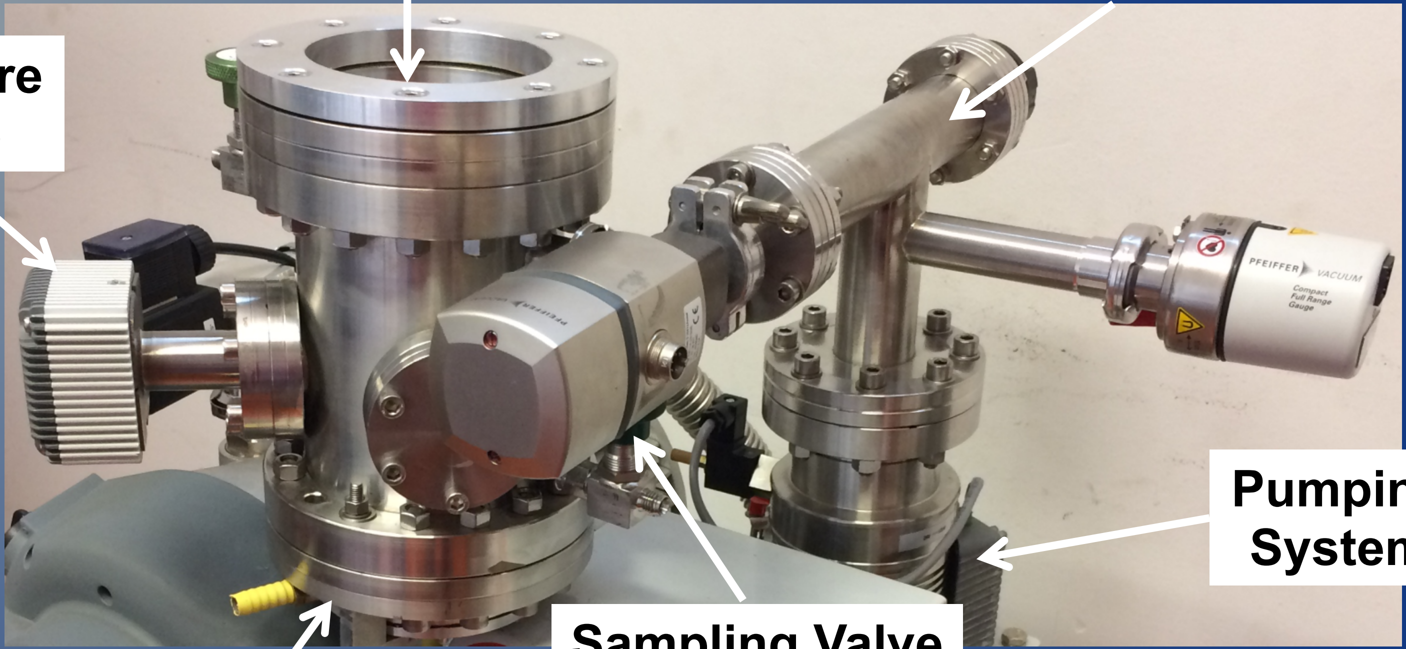
X-ray Source 0. 3 – 8 keV



UV HI Lyα 1216 Å
(1100 – 1800 Å)




HiCUBE
PFEIFFER VACUUM
TIC PUMPING STATION
Vision
Gas line



Chamber Characteristics:

- ✔ **pressure**: 10^{-5} - $2x10^{3}$ mbar
- ✔ **temperature** controlled
- ✔ **gas mixture** 1- 7 components

ROMA

ROMA TRE

Lazio UNO

S. Lauro

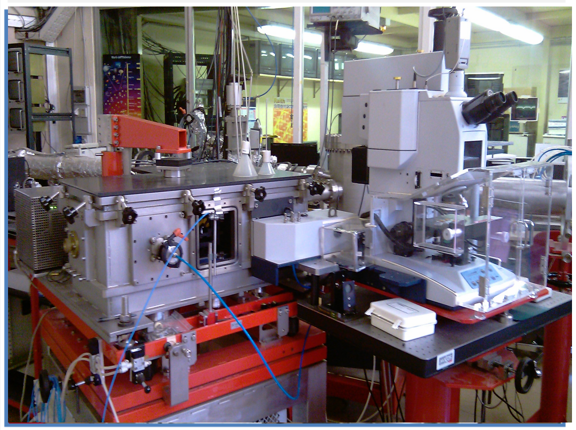
E. Pettinelli

UNIVERSITÀ DEGLI STUDI

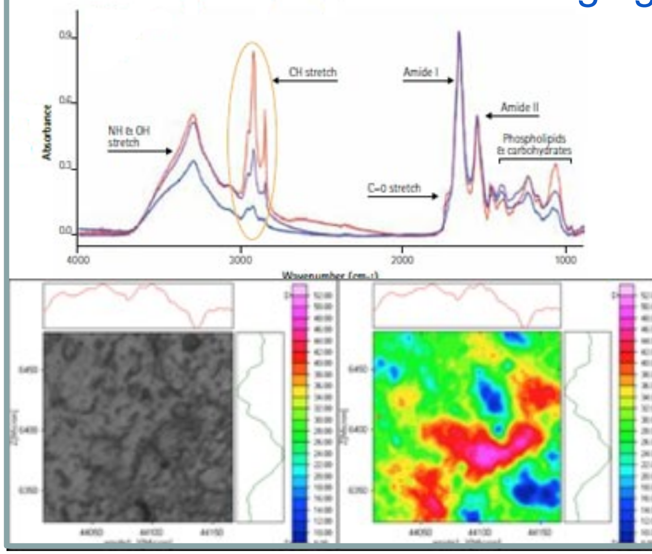
DaΦne-L UV-IR synchrotron facility

A unique facility combining IR and UV-VIS radiation operated with synchrotron and standard sources for non destructive analyses and testing of bio-materials.

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



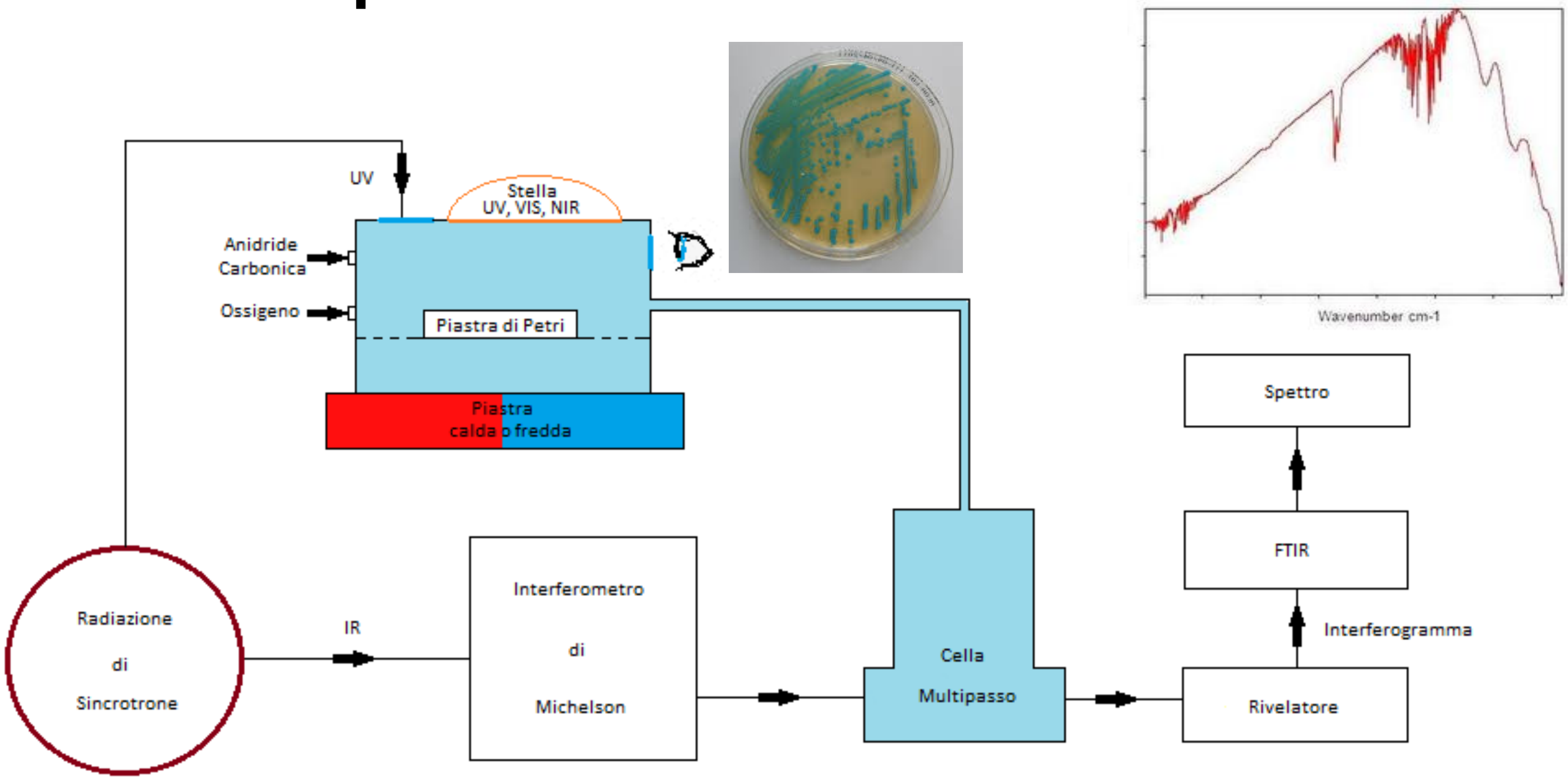
FPA detector for chemical imaging

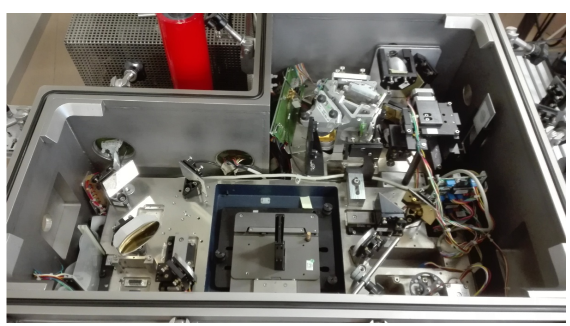


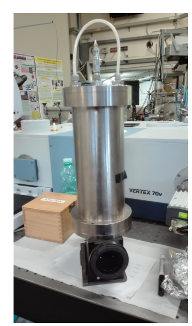
Long path gas cell to characterize atmospheres.

- 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

The experimental architecture







activities @IAPS plab

Experimental set up used to characterize the optical properties of gases at typical planetary conditions

People involved:

S. Stefani: stefania.stefani@inaf.it (technologist)
G. Piccioni: giuseppe.piccioni@inaf.it (senior scientist)
M. Snels: m.snels@isac.cnr.it (senior scientist)
A. Adriani: alberto.adriani@inaf.it (senior scientist)
D. Biondi: david.biondi@inaf.it (CTR)
A. Boccaccini: angelo.boccaccini@inaf.it (CTR)

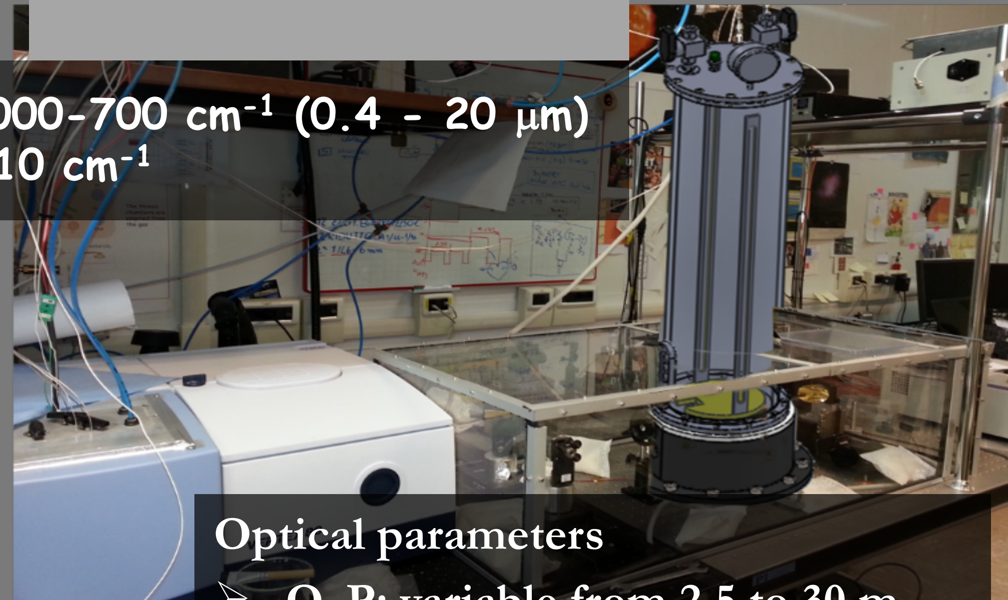
High Pressure-High Temperature Gas cell (HP-HT)

Spectral range 31000-700 cm^{-1} (0.4 - 20 μm)
Resolution 0.01 - 10 cm^{-1}

Optical parameters

- Pressure up to 300 Bar
- Temperature up to 573 K
- Optical path: l ≈ 2 cm

Multi Pass gas cell (MP)



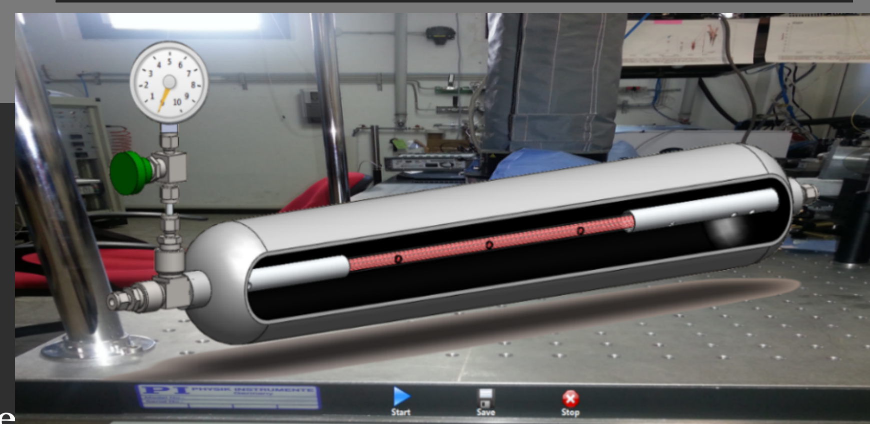
Optical parameters

- O. P: variable from 2.5 to 30 m
- Pressure: 1 - 10 bar
- Temperature: 294 - 473 K

Cavity Ring Down Gas cell (CRD)

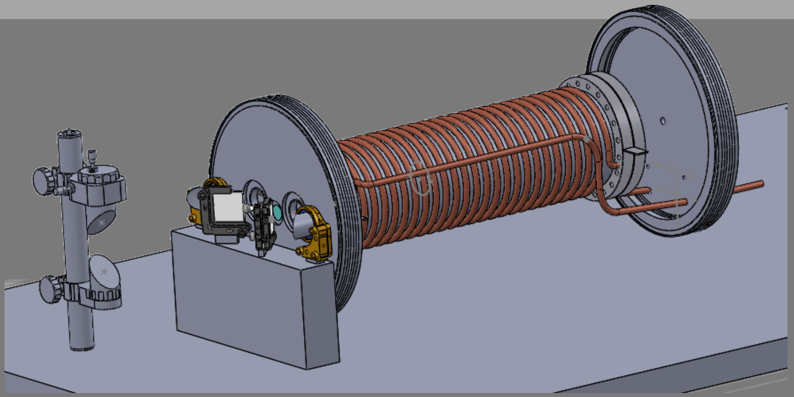
Optical parameters

- Pressure up to 100 Bar
- Temperature up to 400 K
- Optical path: l ≈ 5 km
- Spectral range: depends on the laser and on the mirrors (we worked from 1.79 to 1.81 μm)
- Resolution 0.01 nm

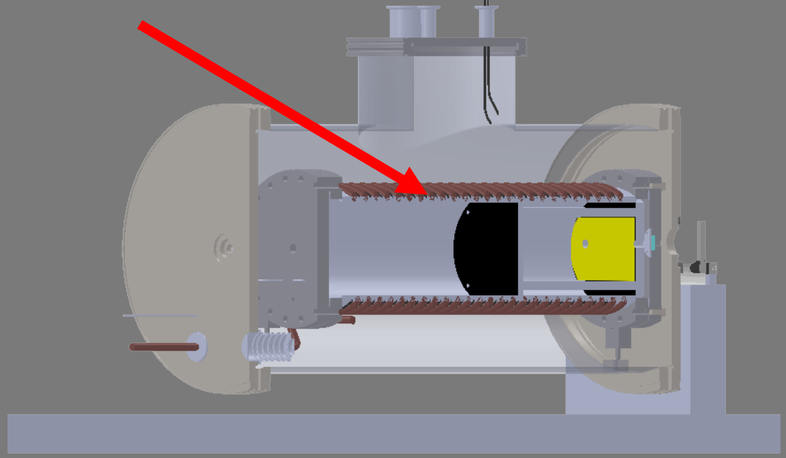


PASS (Planetary Atmosphere Simulation System):new chamber which consists of a heatable\ coolable cell.

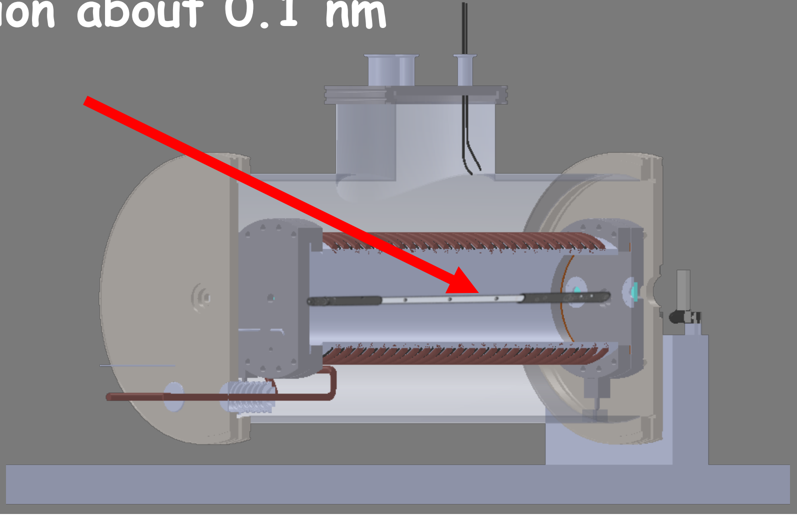
Temperature range: 100-520 K
Pressure range: 0-60 bar



Coolable/heatable MP gas cell
O.P. ≈ 10 m
Spectral range 31000-700 cm^{-1}
(0.4 - 20 μm)
Resolution 0.01 - 10 cm^{-1}



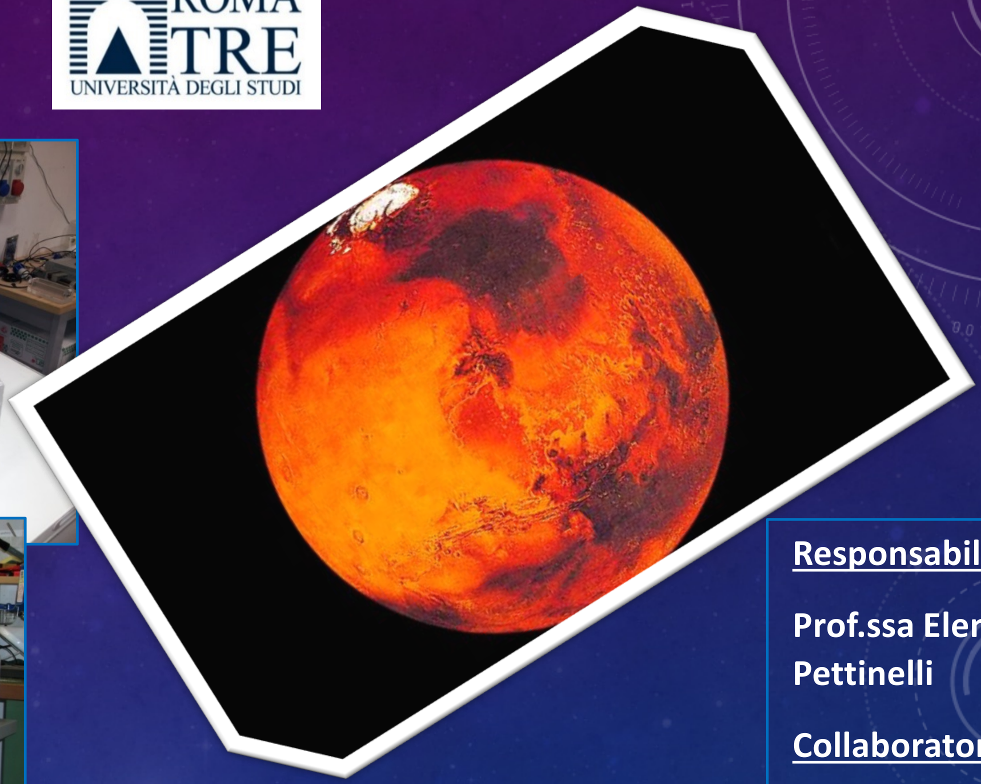
Coolable/heatable (CRD) System
O.P. ≈ 5 Km
Spectral range: depends on the laser tunability and on the mirrors (we worked in the range 1.79- 1.81 μm)
Resolution about 0.1 nm



GEOPHYSICS LABORATORY

Mathematics and Physics Department

ROMA TRE
UNIVERSITÀ DEGLI STUDI



Responsabile:

Prof.ssa Elena Pettinelli

Collaboratori:

Elisabetta Mattei

Sebastian Lauro

Barbara Cosciotti

ATMOSFERE IN PROVETTA

4-5/10/2018

EXPERIMENTAL ACTIVITY AND FACILITIES AT ROMA TRE UNIVERSITY MATHEMATICS AND PHYSICS DEPARTMENT

ELECTROMAGNETIC TECNIQUES:

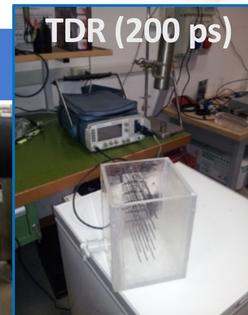
- **Time Domain Measurements**
  - Time Domain Reflectometry
- **Frequency Domain Measurements**
  - LCR meter (20 Hz – 30 MHz)
  - Vector Analyzer

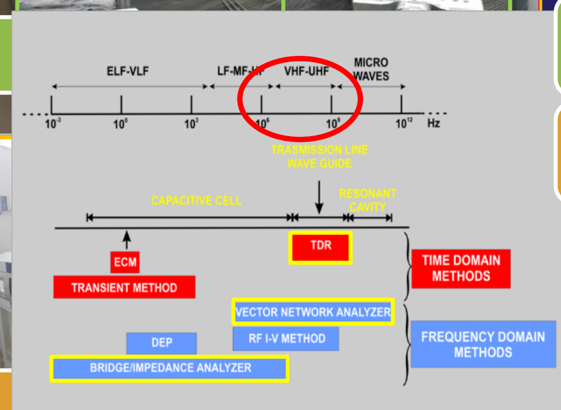
CUSTOM PROBES

- **Time Domain Measurements**
  - Coaxial, three wire and cage probes
- **Frequency Domain Measurements**
  - LCR meter: Capacitors and inductors
  - VNA: Coaxial, three wire /cage probes

CONTROLLED TEMPERATURE

- **Climatic chamber**





CLIMATIC CHAMBER

(200K ÷ 450K) + Nitrogen cooling down to 100K

4°C/min warming

2°C/min cooling

DIELECTRIC SPECTROSCOPY: OVERVIEW

ELECTROMAGNETIC PROPERTIES OF TERRESTRIAL AND PLANETARY ANALOGUES AS A FUNCTION OF

- **TEMPERATURE (100-290 K),**
- **FREQUENCY (1MHZ-1GHZ)**

INVESTIGATING LARGE VOLUME OF MATERIAL AND CONTROLLING ITS COMPACTNESS (POROSITY).

- **Dirty Ices** (Mixtures of Silicate Dust and Ice, Salty ices: Mirabilite, Epsomite and Perchlorates).
- **Rocky Materials** (powdered).
- **Magnetic Materials** (e.g. Containing Iron Oxides like Hematite and Magnetite).
- **Clay Soil Samples.**
- **Meteorites** (powdered and mixed with other materials).

ACTIVITIES ON GOING

DEVELOPMENT OF LABORATORY SIMULATIONS OF HABITABLE WORLDS

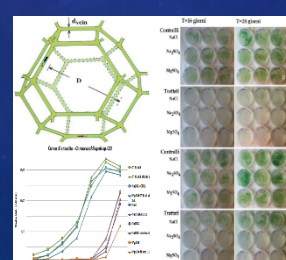
(in collaboration with Daniela Billi)

STUDY OF POTENTIAL HABITABILITY IN WATER ICE/SALTY MIXTURES ENVIROMENT:

investigate the possible habitable niches by growing ice-liquid water systems simulating salt /ice mixtures in the presence of an extreme-tolerant cyanobacterium.

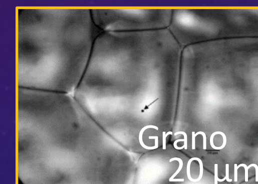
Different samples:

- water/salt solutions made of MgSO4, Na2SO4 and NaCl;
- bi-distilled water sample.



FUTURE WORK: RAMAN SPECTROSCOPY

- CCD detector: Peltier down to -55°C
- Exiting wavelength: 532nm (25mW) and 785nm (100mW) laser beam
- Motorized sample holder for spectral imaging
- Temperature range: between -196°C and 300°C



[Barletta et al. 2012,]

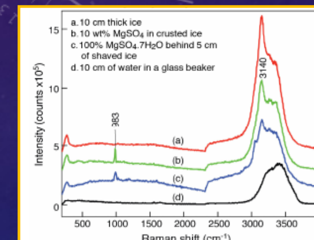


Figure 1. Raman spectra of liquid- and solid-H_2O-ice, and epsomite sample inside H_2O-ice at 120 m (laser 532 nm, 100 mJ/pulse, 15 Hz, slit width 50 µm; integrated over 15 laser shots). *Sharma et al.*, 2014

Raman spectrum of:

a) Pure ice

b) Crushed ice mixed to epsomite

c) Below 5cm thick layer of shaved ice

d) Below 5 cm thick layer of water

The hydrated sulfate is easily detected by the presence of SO_4 symmetric stretching band at 983 cm^{-1} that is Raman fingerprint of epsomite. The same Raman peak at $983cm^{-1}$ is also visible when the solid Mg $SO_4.7H_2$ O was placed beyond a 5cm thick layer of shaved ice. The intensity of the Raman spectrum in the shaved ice is lower because of attenuation of laser beam caused by scattering by the ice particles.

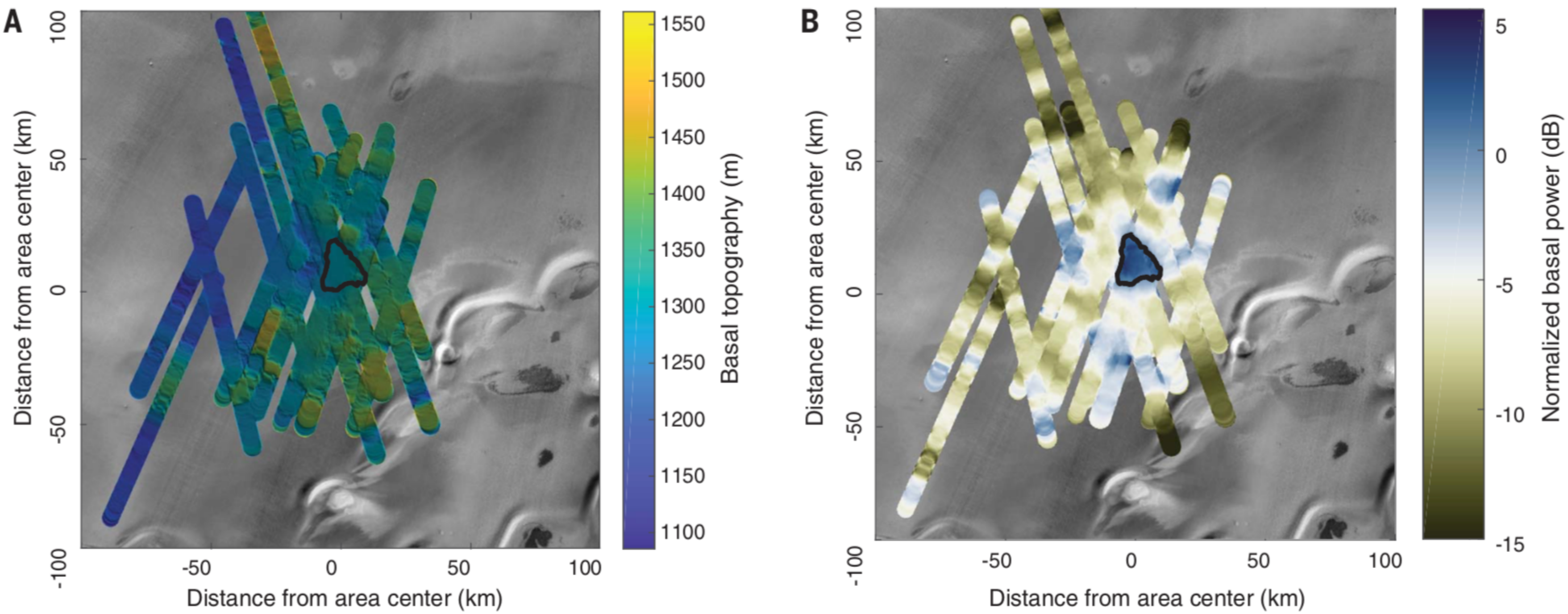


Fig. 3. Maps of basal topography and reflected echo power. (**A**) Color-coded map of the topography at the base of the SPLD, computed with respect to the reference datum. The black contour outlines the area in which bright basal reflections are concentrated. (**B**) Color-coded map of normalized basal echo power at 4 MHz. The large blue area (positive values of the normalized basal echo power) outlined in black corresponds to the main bright area; the map also shows other, smaller bright spots that have a limited number of overlapping profiles. Both panels are superimposed on the infrared image shown in Fig. 1B, and the value at each point is the median of all radar footprints crossing that point.

Orosei, Petinelli et al et al, 2018

PADOVA

E. Alei
R. Claudi
B. Salasnich

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

M. Battistuzzi
N. La Rocca

DIPARTIMENTO DI BIOLOGIA
UNIVERSITÀ DEGLI STUDI DI PADOVA

L. Cocola
L. Poletto

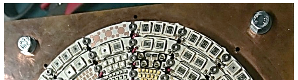
CNR IFN
Istituto di Fotonica e Nanotecnologie

Padova Experiment

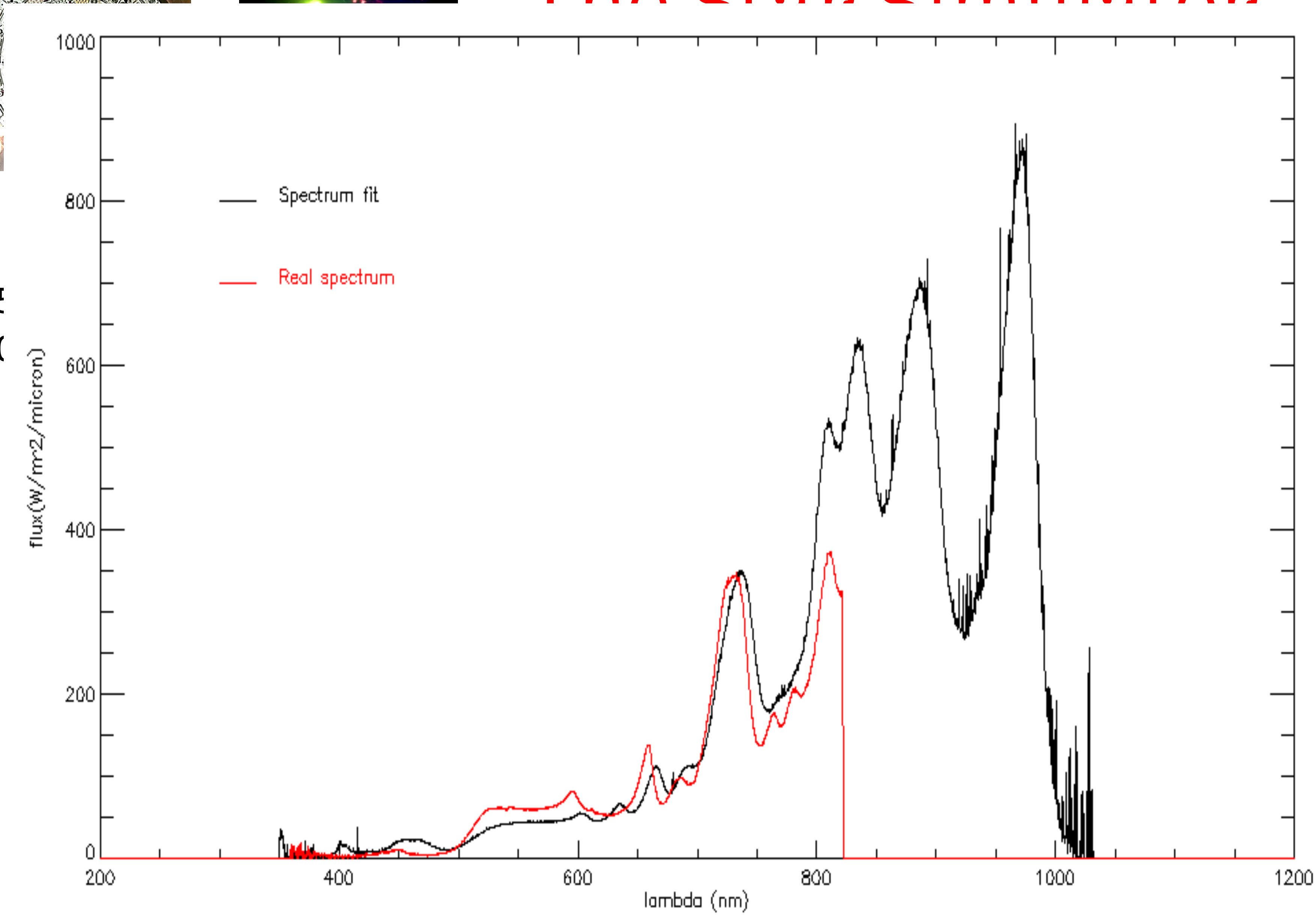
AIMS: Study the metabolism, vitality and gaseous production of photosynthetic bacteria when forced to live in a different environment, mimicing an **earth-like** planet orbiting around the HZ of an M type star.

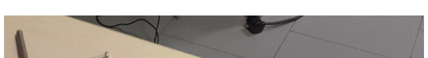
1. **Star simulator; Choice of Bacteria; Reaction Cell**
2. **Irradiation of bacteria in terrestrial conditions**
3. **Irradiation with M star simulator**
4. **Change of Fiducial environmental conditions: P, T, Gas Mixture ...**

M7
The Star Simulator

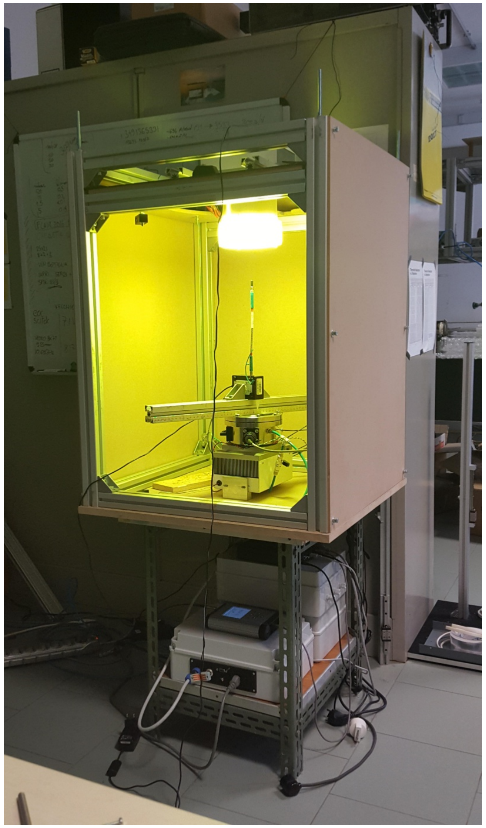


25
275
450
PC

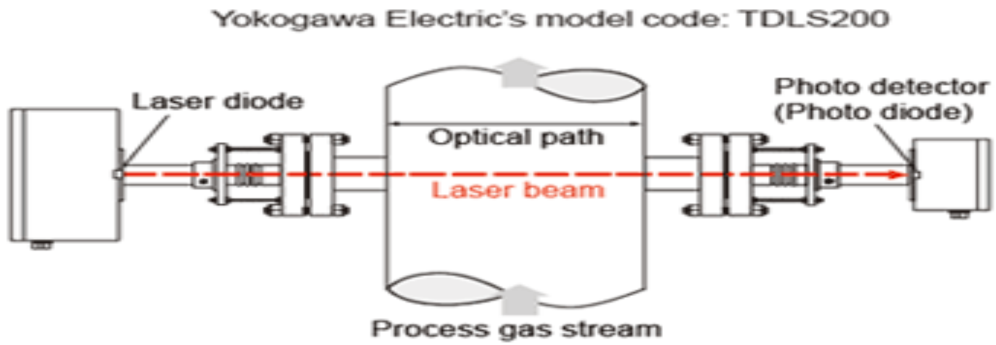


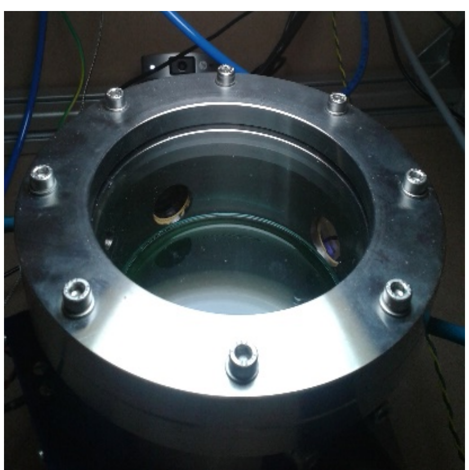


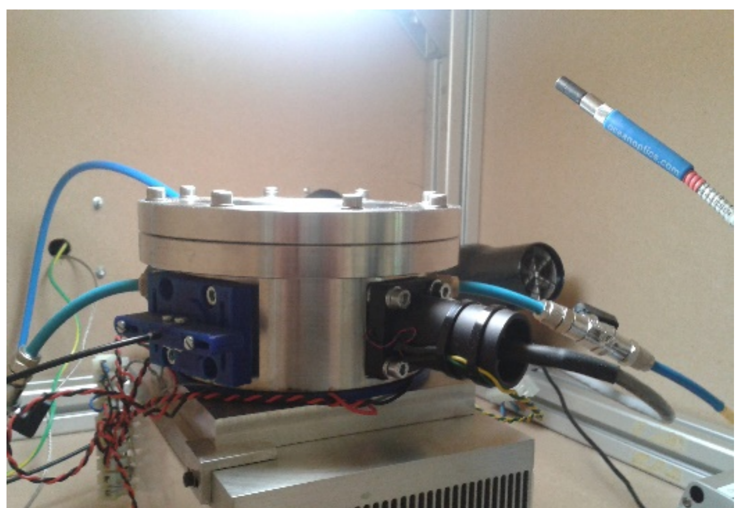
The Experiment Setup



Tunable Diode Laser Absorption Spectroscopy (TDLAS)



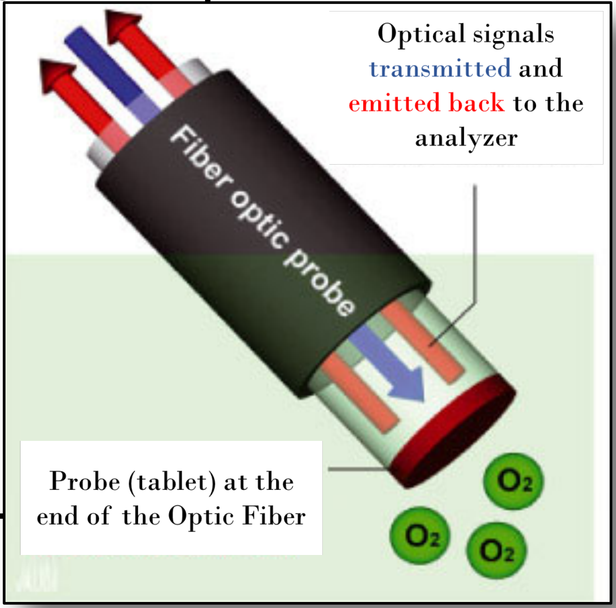




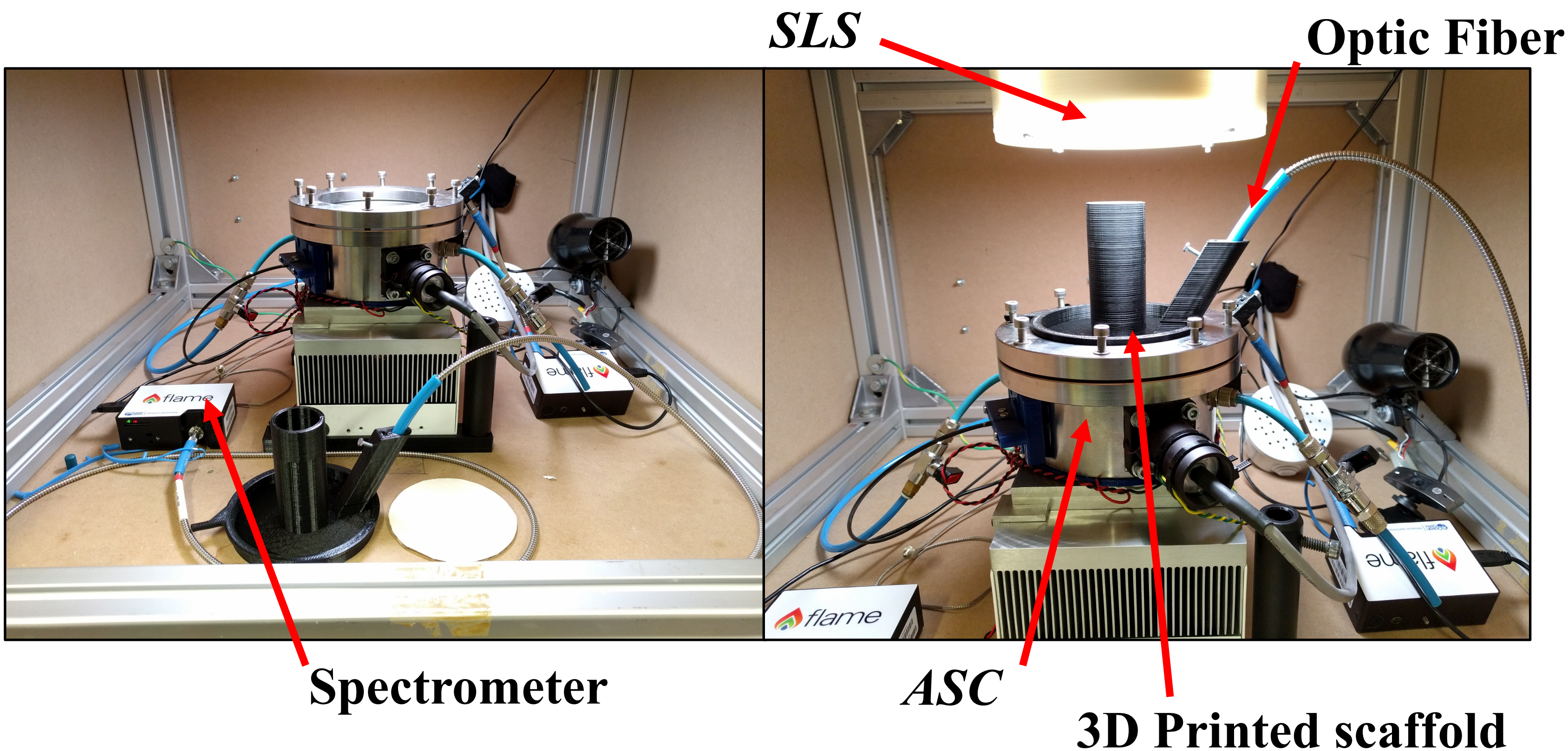
O_2 Detection System

- *NomaSense O_2 P300* (Vinventions), used in wine quality assessment
- Based on *Oxo-Fluorescence* Technique
- Blue light transmitted through fiber to a tablet inside the ASC
- Tablet reacts according to dissolved O_2 in the ASC
- Red light emitted back
- Amount of $\%O_2$ is measured
- Detects up to 15 μg/L of O_2

https://www.vinventions.com/it/wine-quality-solutions



Reflectivity detection system

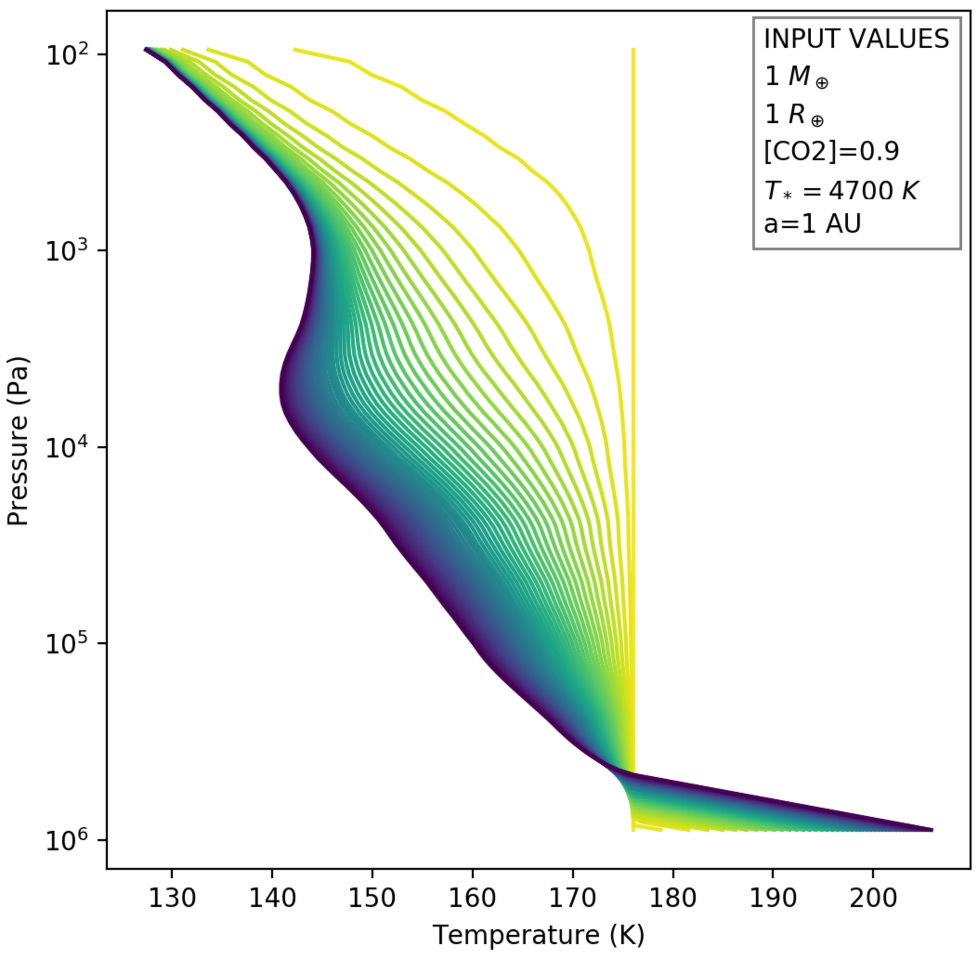


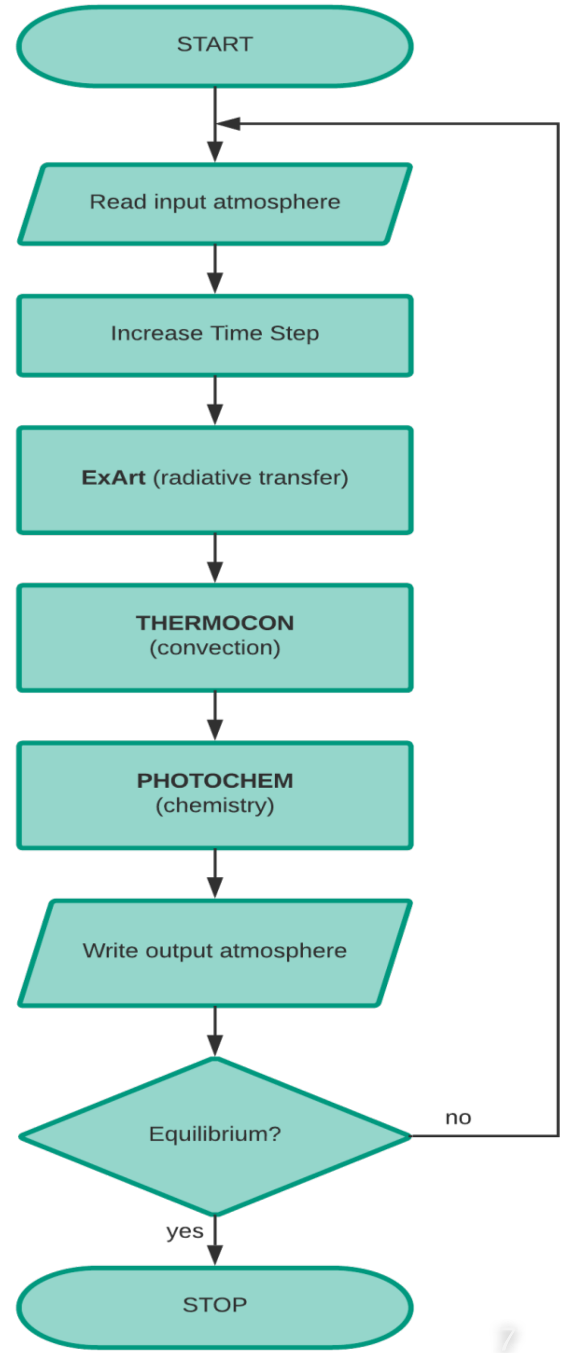
MAGRATHEA

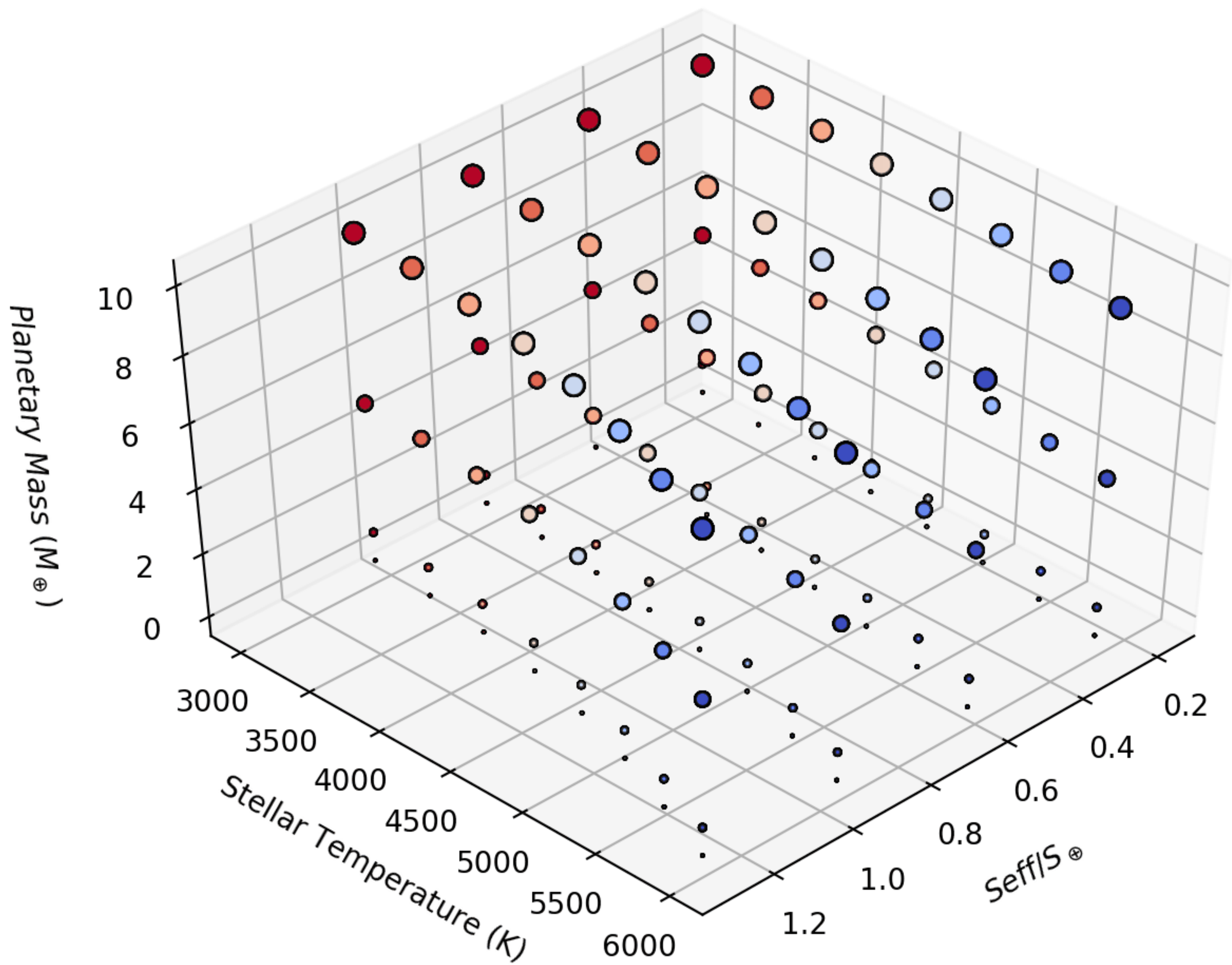
[...] And thus were created the conditions for a staggering new form of specialist industry: custom-made luxury planet building. The home of this industry was the planet Magrathea, where hyperspatial engineers sucked matter through white holes in space to form it into dream planets - gold planets, platinum planets, soft rubber planets with lots of earthquakes - all lovingly made to meet the exacting standards that the Galaxy's richest men naturally came to expect. [...]

"Magrathea is a myth, a faery story! It's what parents tell their children about at night when they want them to grow up to become economists!"

Structure

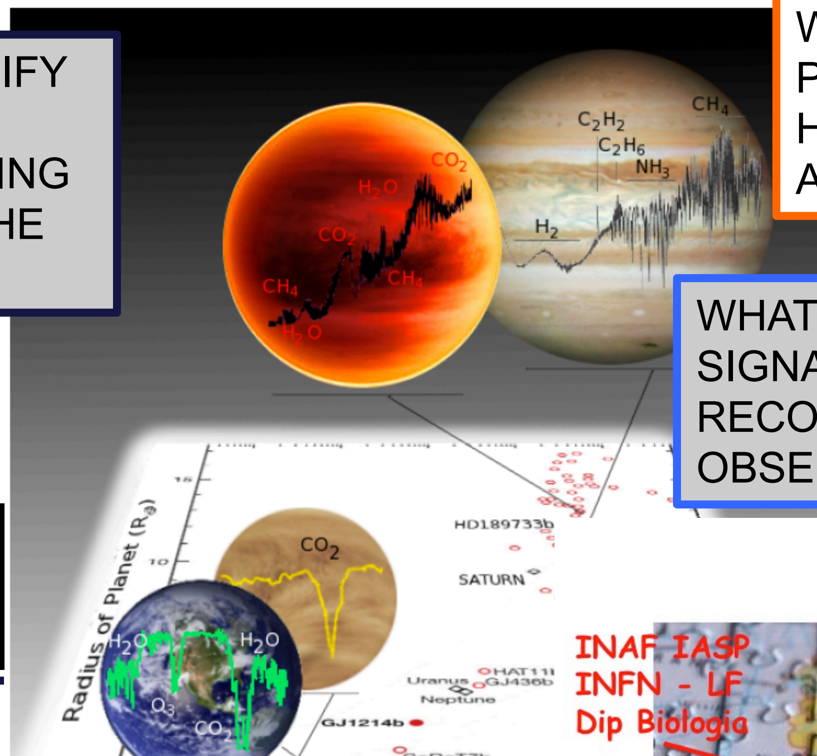

INPUT VALUES
1 $M_\oplus$
1 $R_\oplus$
[CO2]=0.9
$T_* = 4700\ K$
a=1 AU
Pressure (Pa)
10^2
10^3
10^4
10^5
10^6
130
140
150
160
170
180
190
200
Temperature (K)


START
Read input atmosphere
Increase Time Step
ExArt (radiative transfer)
THERMOCON
(convection)
PHOTOCHEM
(chemistry)
Write output atmosphere
Equilibrium?
no
yes
STOP


Planetary Mass (M$_\oplus$)
0
2
4
6
8
10
Stellar Temperature (K)
3000
3500
4000
4500
5000
5500
6000
Seff/S$_\oplus$
0.2
0.4
0.6
0.8
1.0
1.2

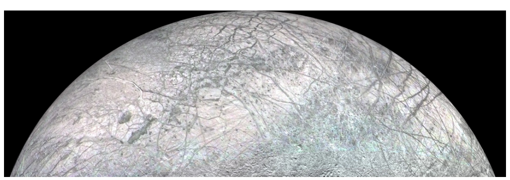
Atmosphere in a Test Tube
Laboratory Analogues of Solar System and Extra Solar Planet Atmospheres

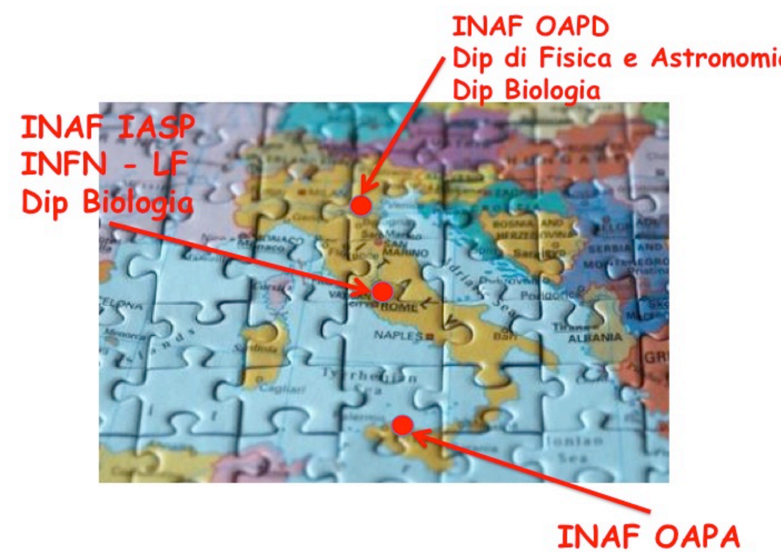
HOW LIFE COULD MODIFY THE ATMOSPHERE OF SUPER EARTHS ORBITING OTHER STARS THEN THE SUN?



WHAT ARE THE PHYSICAL PROCESSES AT WORK IN HOT JUPITER ATMOSPHERES?

WHAT ARE THE MAIN SIGNATURES OF LIFE RECOGNIZABLE BY REMOTE OBSERVATIONS?





MAY EXPLORATION FINDS TRACES OF BIOLOGICAL ACTIVITIES OUT OF THE SOLAR HABITABLE ZONE (MARS, EUROPA, TITAN …)?