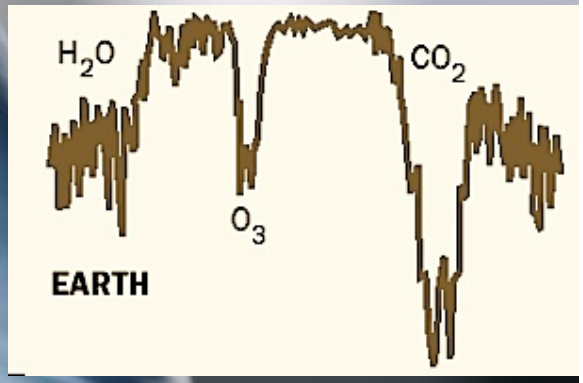
AtmoSpheres in a test tube

Giuseppe Galletta
Università di Padova



INAF OAPD
Dept. of Physics and Astronomy
Dept. of Biology

INAF IASP
INFN – LF
Dept. of Biology

INAF OAPA

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G. Micela	INAF, Oss. Astron. di Palermo
G. Piccioni	INAF, Ist. di Astrof. e Planet. Spaziale
D. Billi	Dip. di Biologia, II Univ di Roma
M. Cestelli Guidi	INFN, Lab. Nazionali Frascati
L Cocola	LUXOR –Photonics and Nano Tech. Inst. PD
M. D'Alessandro	INAF, Oss. Astron. di Padova
S. Erculiani	CISAS "G. Colombo" PD
M. Fedel	LUXOR –Photonics and Nano Tech. Inst. PD
G. Galletta	Dip. di Fisica e Astronomia Univ. Padova
E. Giro	INAF, Oss. Astron. di Padova
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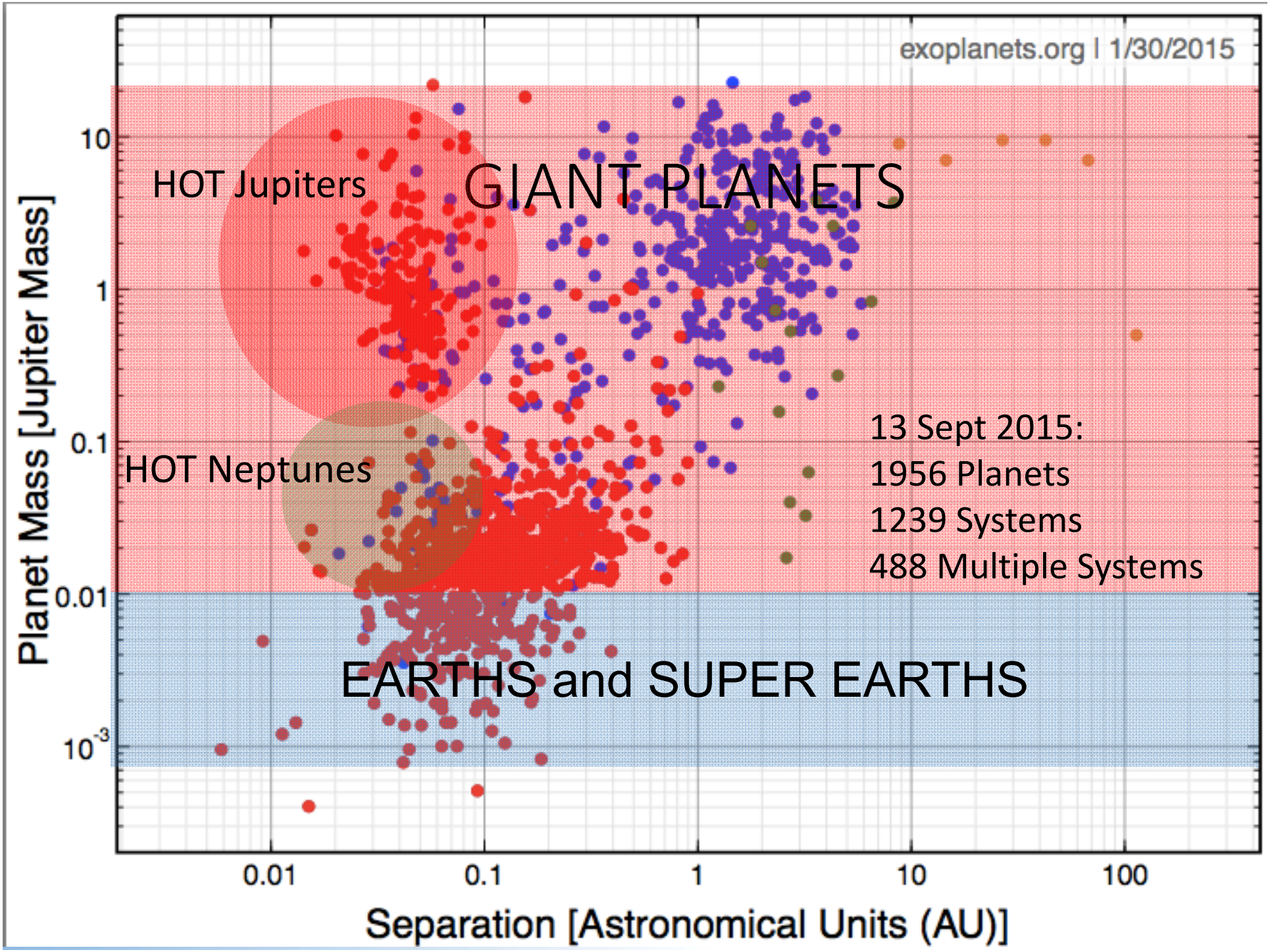
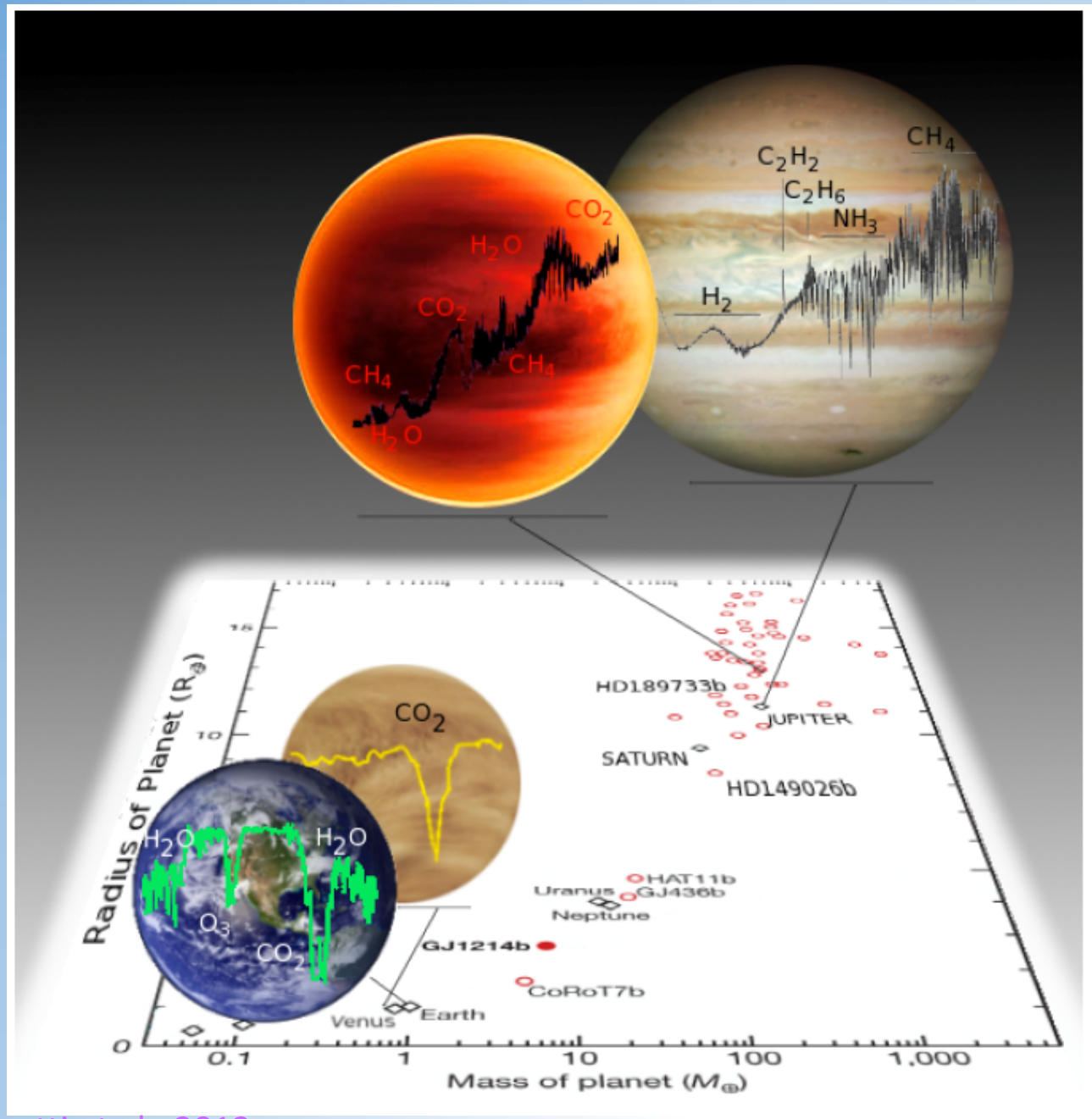
T. Morosinotto	Dip. di Biologia Università di Padova
L. Poletto	LUXOR – Photonics and Nano Tech. Inst. PD
D. Schierano	Dip. di Fisica e Astronomia Univ. di Firenze
S. Stefani	INAF, Ist. di Astrof. e Planet. Spaziale

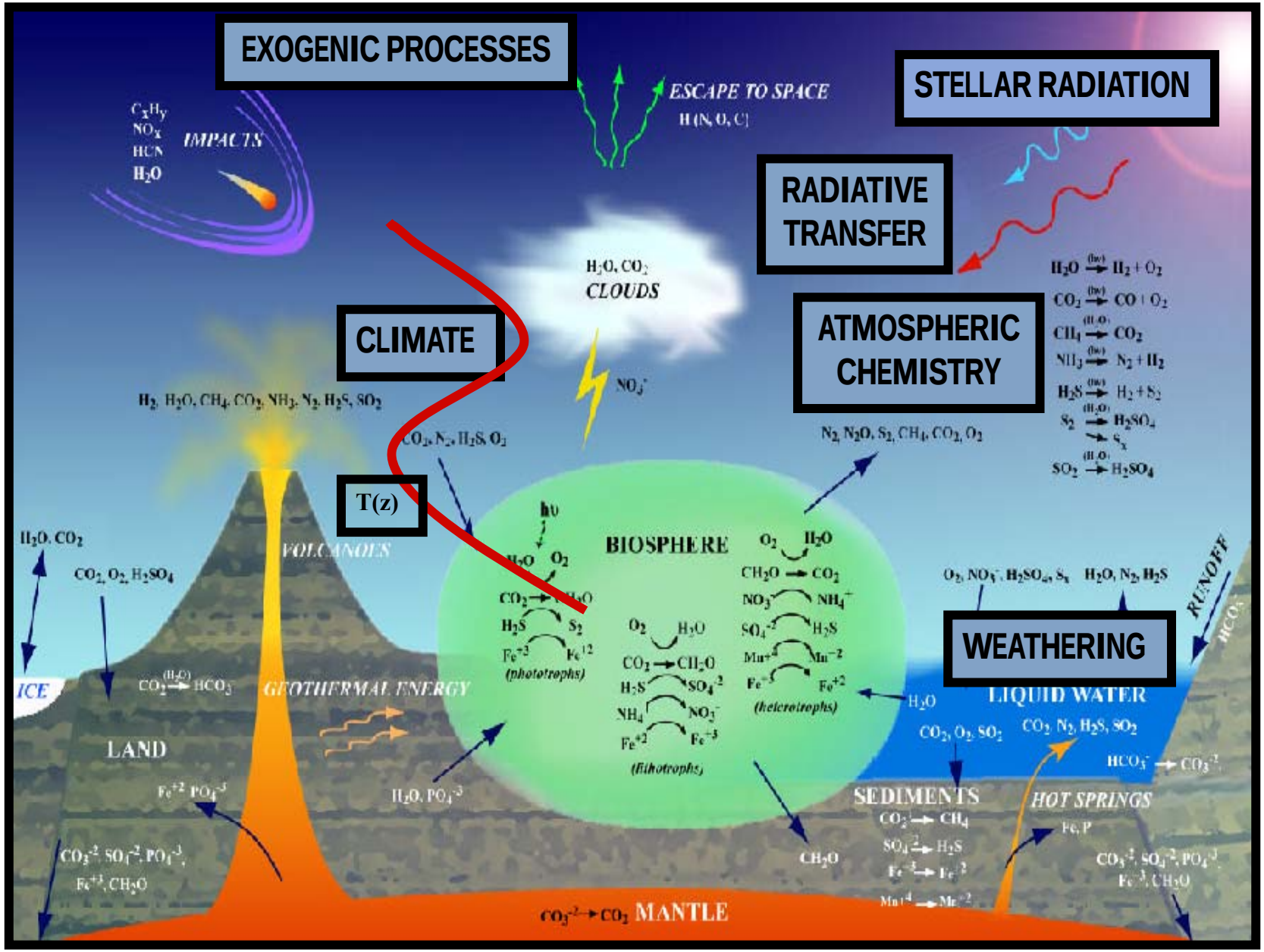

INTERNATIONAL
CHIANTI TOPICS
FOCUS WORKSHOPS
EXO-PLANETARY ATMOSPHERES:
models and laboratory analogues
Osservatorio Polifunzionale del Chian
San Donato in Poggio, Firenze (Italy
15-17 September 201
Chairman:
Emanuele Pace
Riccardo Claudi
SOC:
Giovanna Tinetti
Ignas Snellen
Ignasi Ribas
Christoph Mordasini
Diego Turrini
Giuseppe Piccioni
LOC:
Ruggero Stanga
Mauro Focardi
Steven Shore
Eugenio Simoncini
Marco Sergio Ercul
Vanni Moggi Cecchi
http://opc.msn.unifi.it/index.php/chianti-topics/EXO-PLANETARY
info@osservatoriodelchianti.it


5th Workshop of the Italian Astrobiology Society
Life in a Cosmic Context
15-17 September 2015, Trieste, Italy
https://www.ict.inaf.it/indico/event/106/
Scientific Organizers
Nadia Balucani
Daniela Billi
Alessandro Bressan
John Brucato
Julian Chela-Flores
Marco Fulle
Enzo Gallori
Giuseppina Micela
Raffaele Saladino
Giovanni Vladilo (chair)
Local Organizers
Aura Bernardi
Michele Maris
Fabio Pagan
Laura Silva
Italian Astrobiology Society - Società Italiana di Astrobiologia
Osservatorio Astronomico di Trieste
Astronomical Observatory of Trieste
SISSA
Scuola Internazionale Superiore di Studi Avanzati
Invited Speakers
Giuseppe Galletta
Ernesto di Mauro
Antonio Lazcano
Rocco Mancinelli
Mauro Mandrioli
Giuseppe Murante
Isabella Pagano
Sandra Pizzarello
Alessandro Sozzetti
Leonardo Testi
Serena Viti
Valfredo Zolesi


exoplanets.org | 1/30/2015
HOT Jupiters
GIANT PLANETS
HOT Neptunes
13 Sept 2015:
1956 Planets
1239 Systems
488 Multiple Systems
EARTHS and SUPER EARTHS
Planet Mass [Jupiter Mass]
10
1
0.1
0.01
10^-3
0.01
0.1
1
10
100
Separation [Astronomical Units (AU)]



Ref: Tinetti et al., 2012;

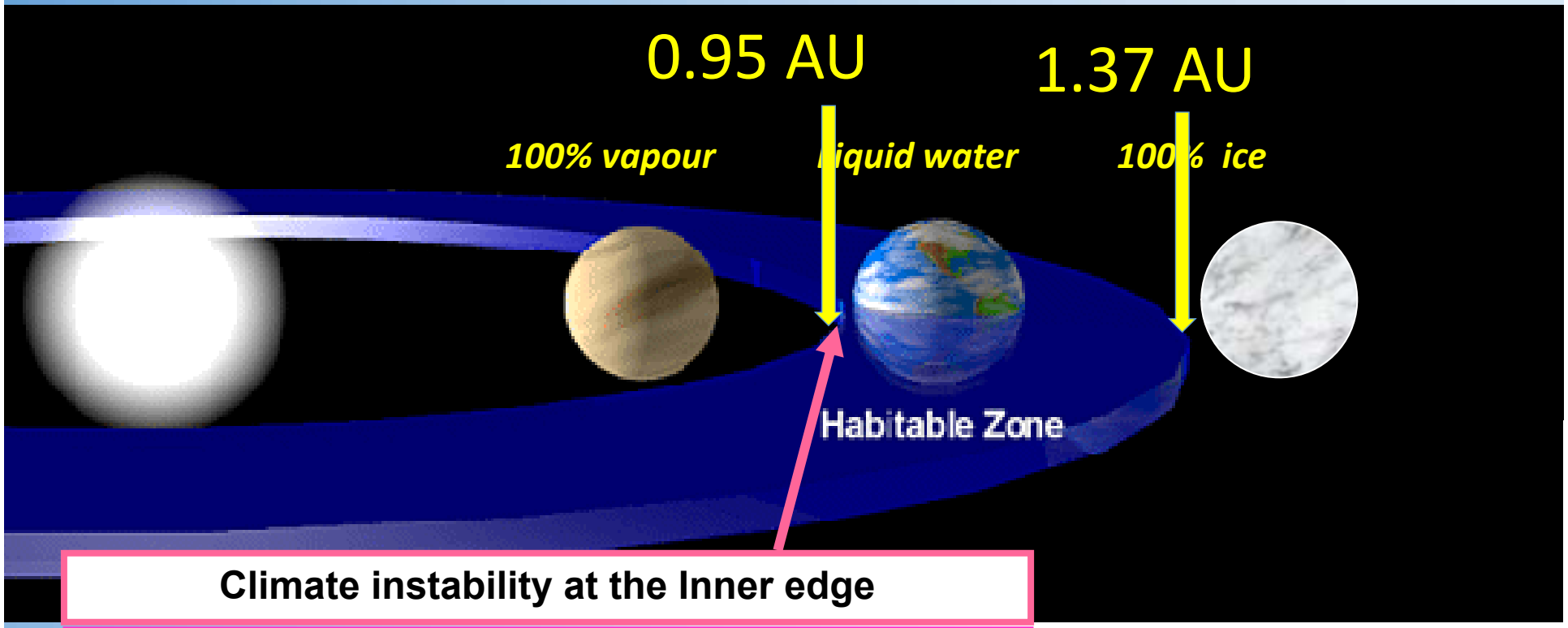


M. Allen, K. Nealson, V. Meadows

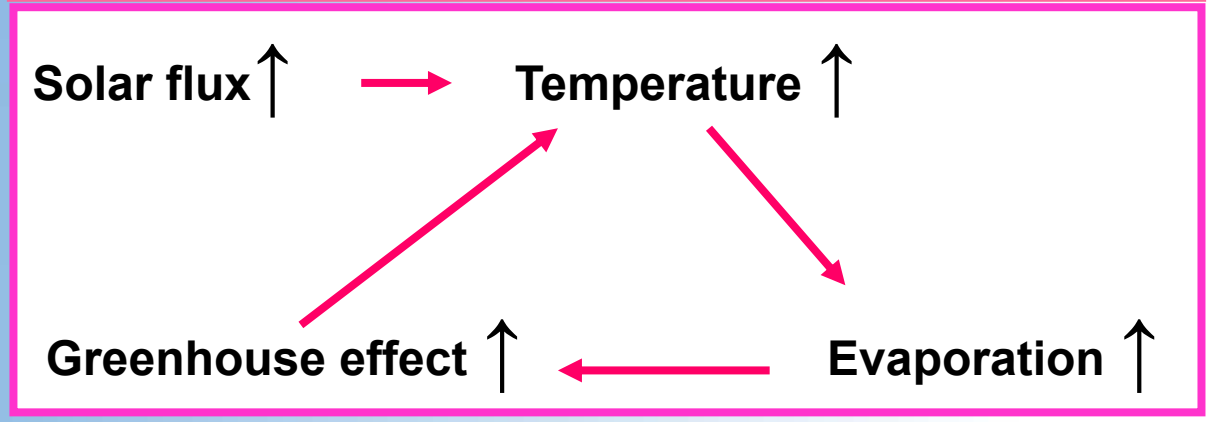
A planet's spectrum is the product of a complex interplay of environmental components and processes.

The habitable zone

(Kasting et al. 1993)

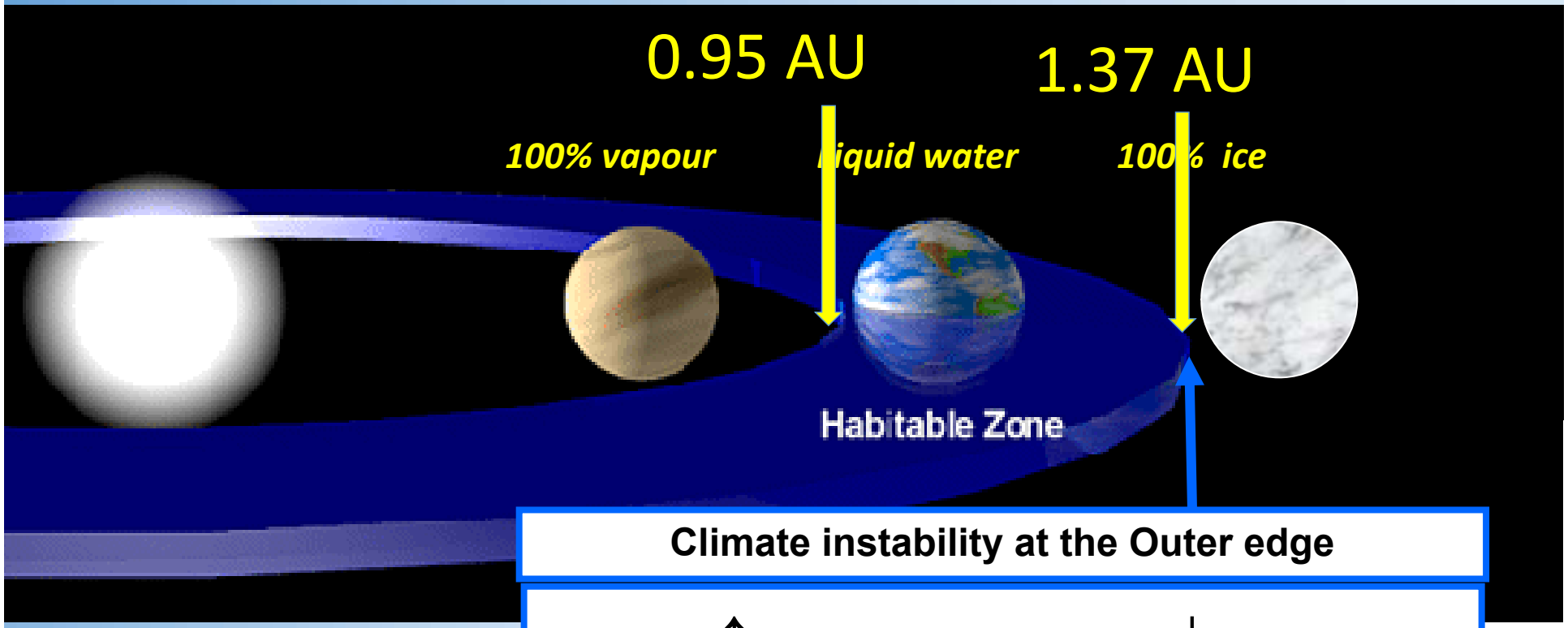


Climate instability at the Inner edge

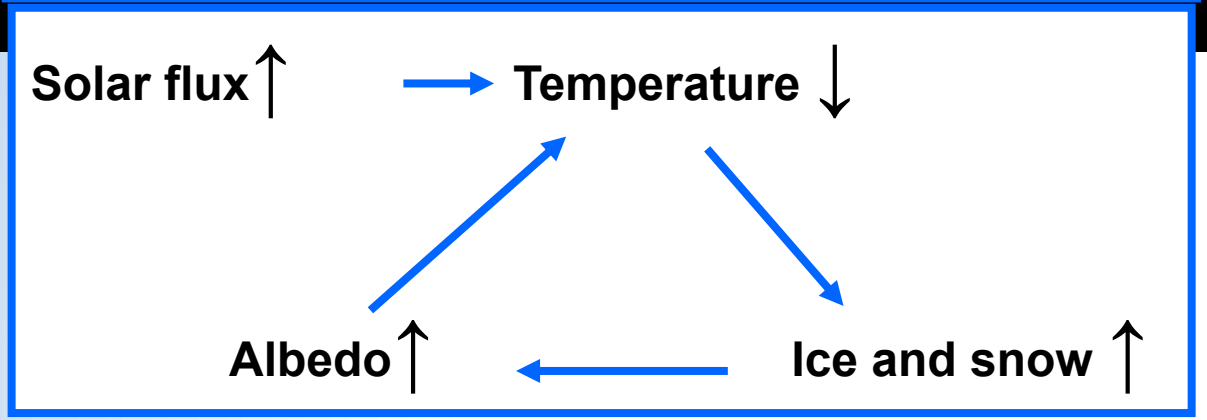


The habitable zone

(Kasting et al. 1993)



Climate instability at the Outer edge



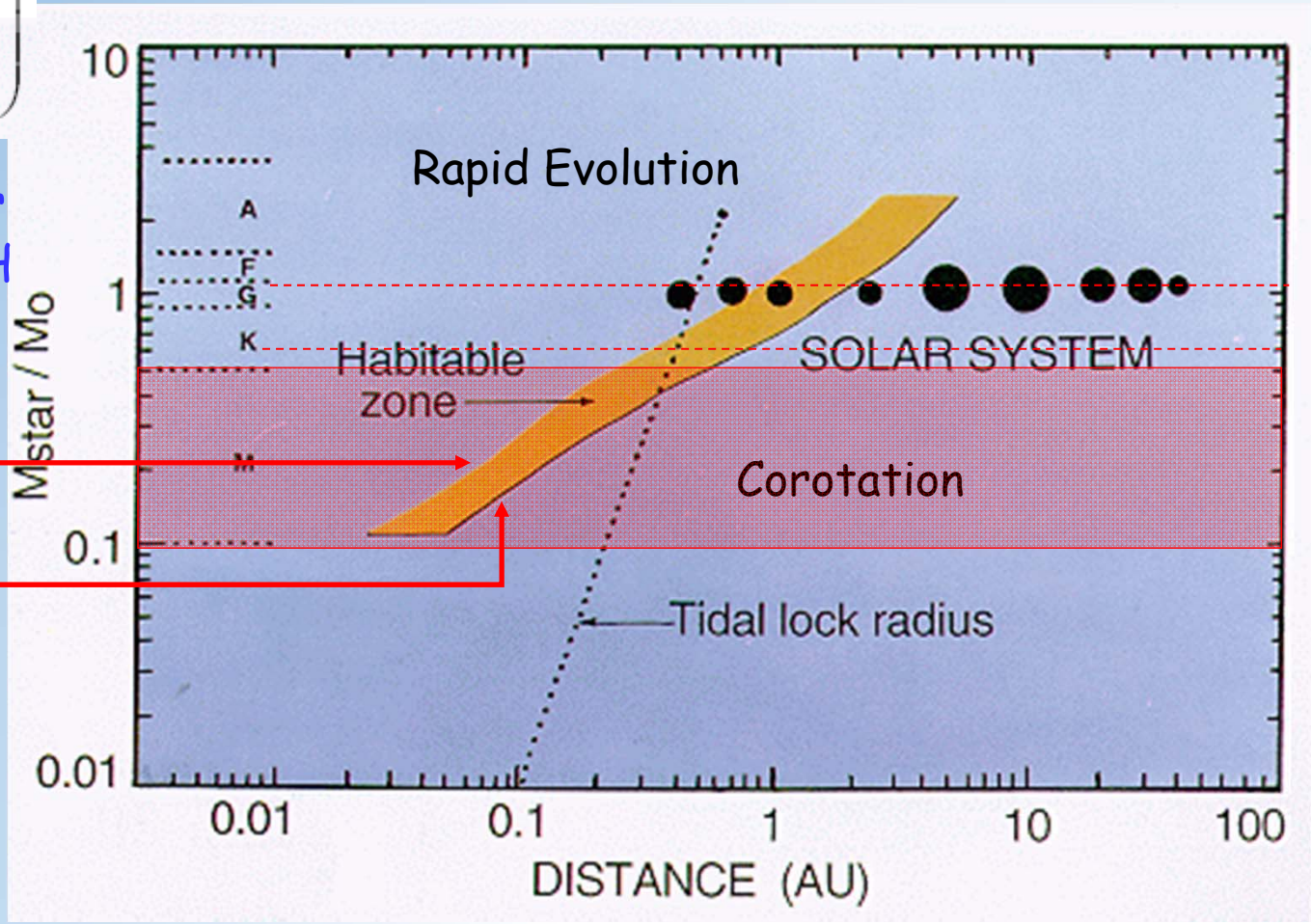
HZ for the other stars

The HZ limits around the other stars of different spectral type are given by:

$$d = 1UA\left(\frac{L/L_{sun}}{S_{eff}}\right)$$

Inner limit: water photoionization, H loss

Outer: CO_2 clouds, star light reflection



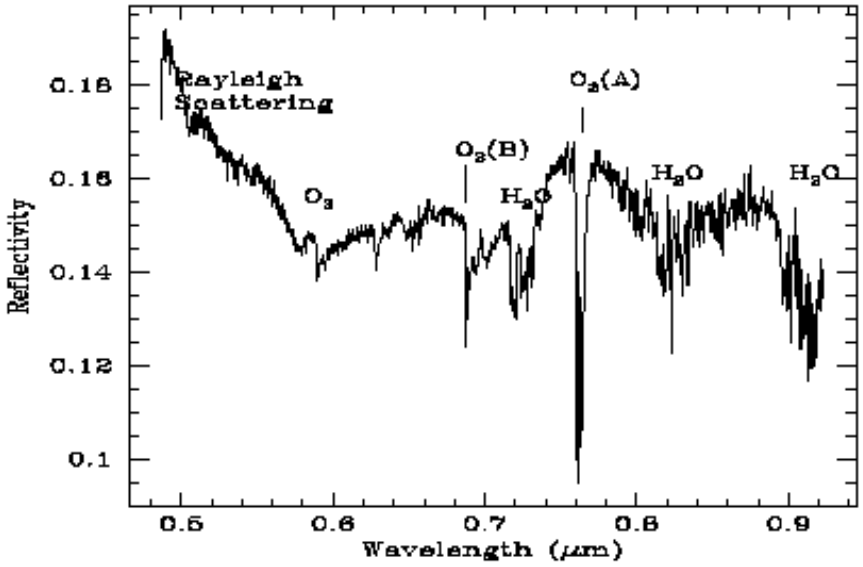
Characterizing Extrasolar Planets. Deduce from observations:

- **Environmental Characteristics**
  - host star, placement in solar system, moons, other planets
- **Photometric properties and variability**
- **Remote-sensing spectroscopic analysis**
  - the presence of an atmosphere and its chemical composition
  - albedo, thermal emissivity, temperature
  - atmospheric structure (T(z), P(z))
  - trace gas mixing ratios
  - temporal variations, phase and
  - seasonal variations

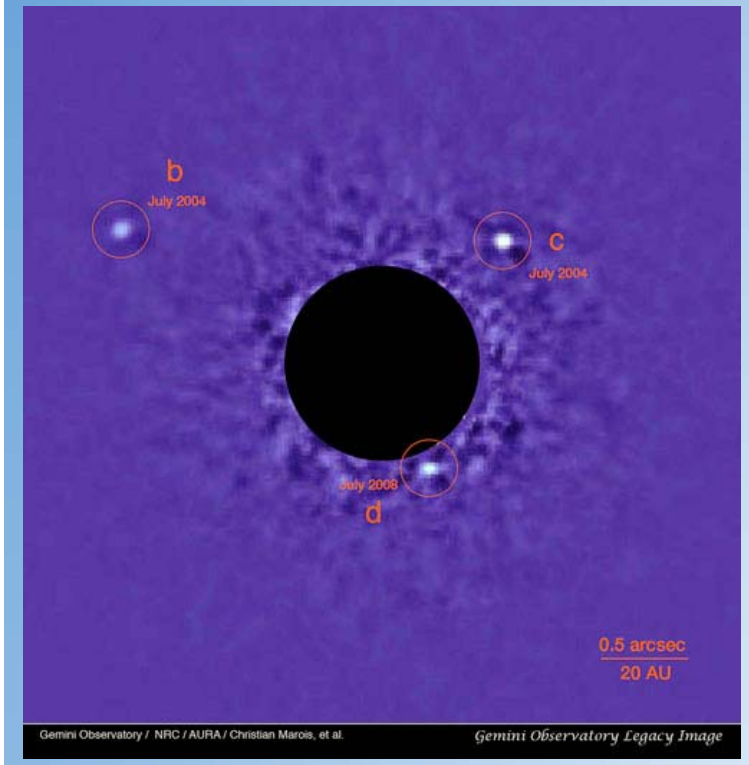
- **Astronomical Biosignatures**

  - photometric, spectral or temporal features indicative of life.

Integrate Ligth from earth, reflected by the dark side of the moon: Chlorophill, O_2, O_3, H_2O.



Direct Imaging of Exo-Planets



HR 8799
1.5 Msun,
130 light years from Earth.

- Rapid identification of the planet
- Determination of the orbit, no M *sin(i)* ambiguity
- Characterization of the planet
  - albedo, temperature, chemical composition

  => test of atmospheric models, of evolutionary models
- Access to a new (separation, age) domain
  - Planets around young stars
  - Larger separations (P > few years)
- Access to *all* types of stars
  - Early type stars
  - Active stars

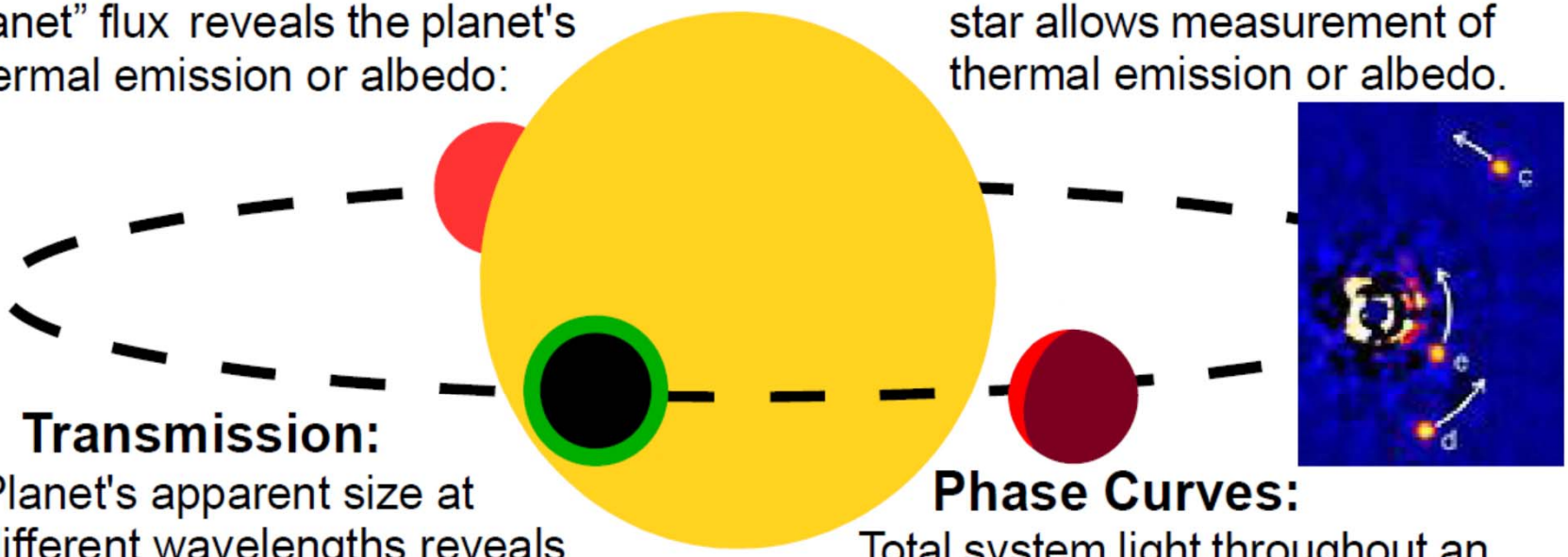
- But … difficult !

Transmission and occultation spectroscopy

Crossfield 2015

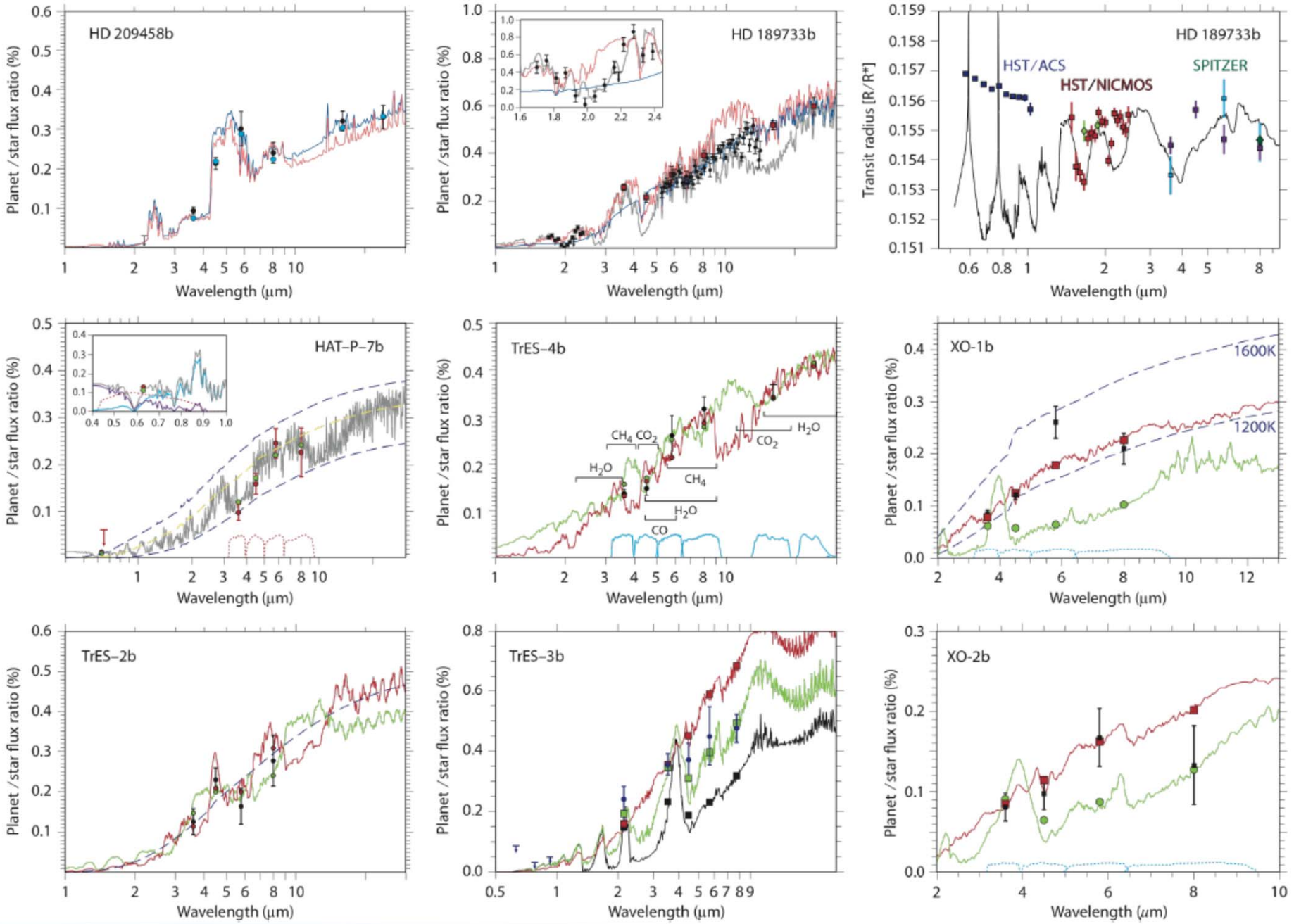
Eclipse:
Removing "star" from "star plus planet" flux reveals the planet's thermal emission or albedo:

Direct Imaging:
Spatially resolving planet from star allows measurement of thermal emission or albedo.



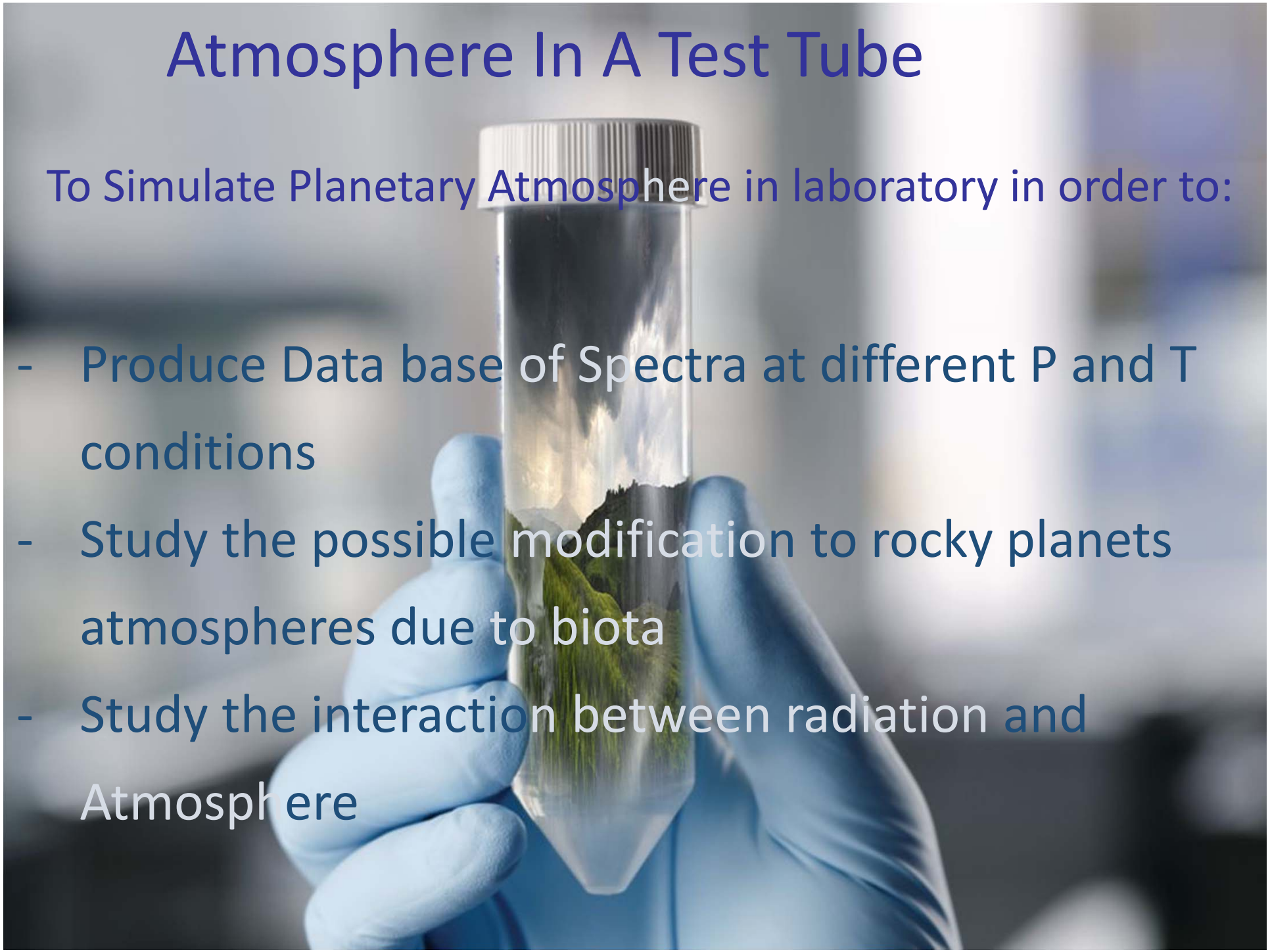
Transmission:
Planet's apparent size at different wavelengths reveals atmospheric opacity and composition.

Phase Curves:
Total system light throughout an orbit constrains atmospheric circulation and/or composition.



Seager & Deming 2010

Atmosphere In A Test Tube



To Simulate Planetary Atmosphere in laboratory in order to:

- Produce Data base of Spectra at different P and T conditions
- Study the possible modification to rocky planets atmospheres due to biota
- Study the interaction between radiation and Atmosphere

Experimental setup @ INAF-IASF

Giant planets atmospheres

FT-IR Specification:

Detectors:

DTGS	350-10000 cm^{-1}
MCT	850-12000 cm^{-1}
InGaAs	9000-12800 cm^{-1}
Si	9000-25000 cm^{-1}

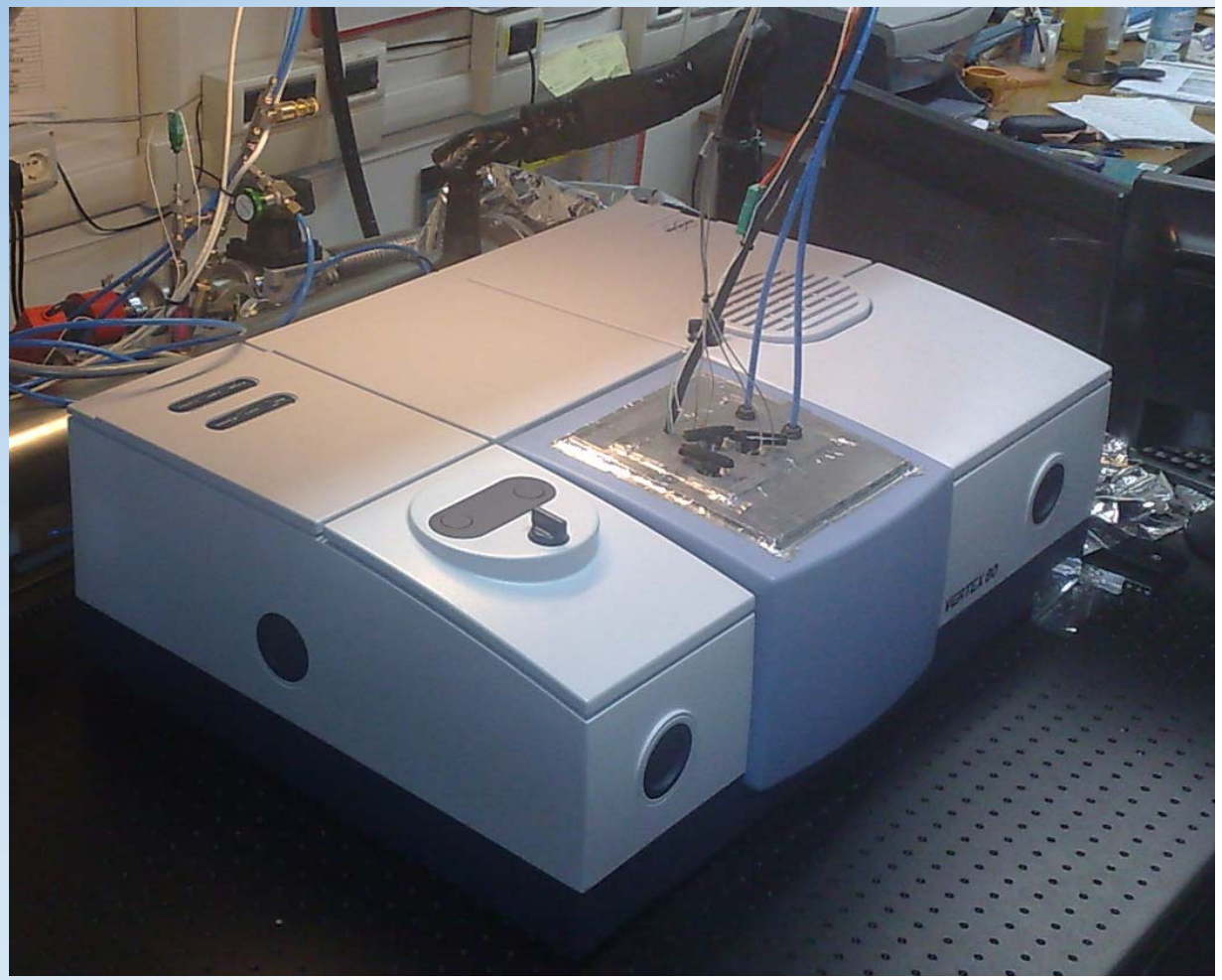
Sources:

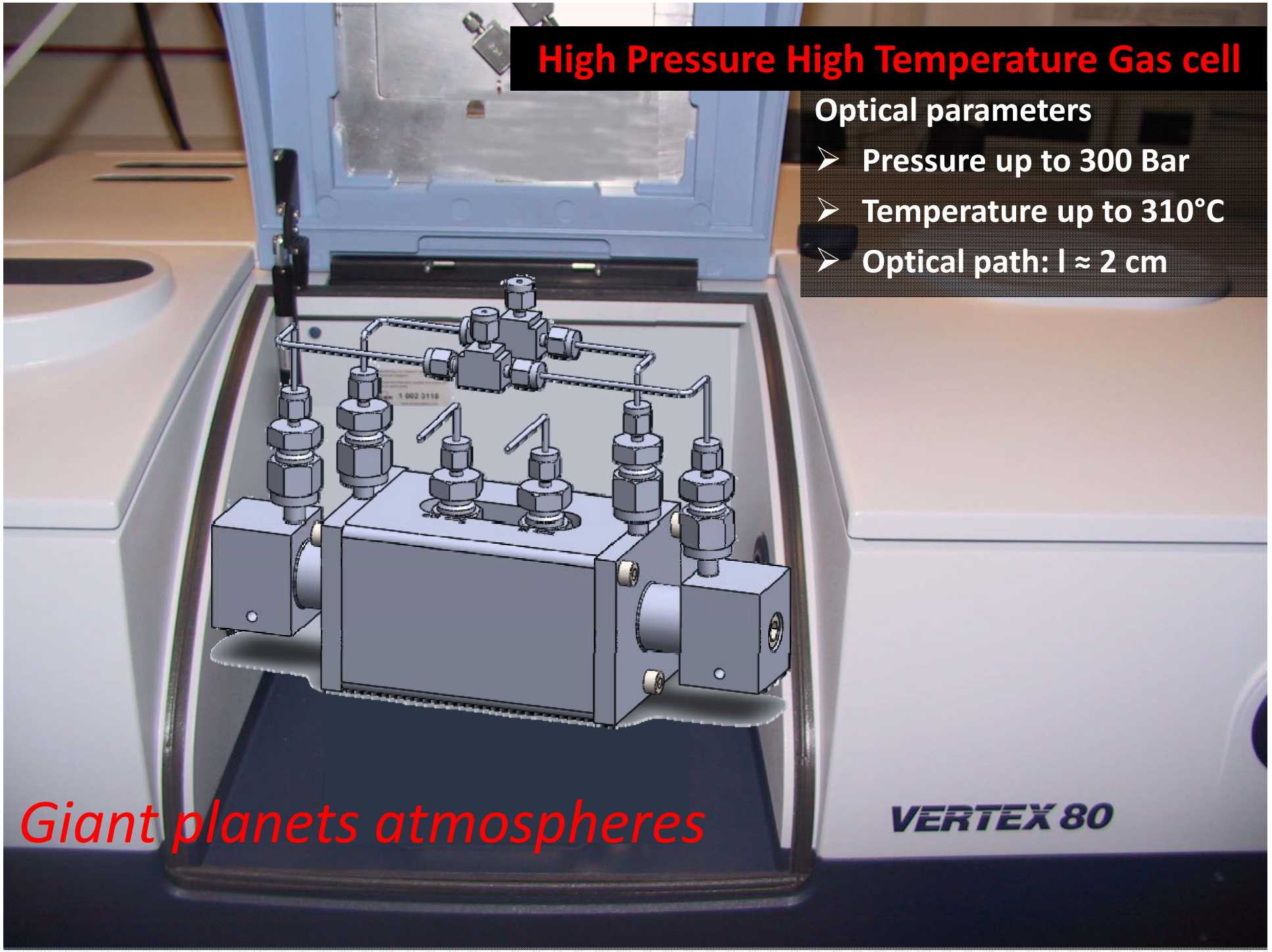
MIR	100-8000 cm^{-1}
NIR/VIS	3000-25000 cm^{-1}

Beam splitter:

KBr	380-10000 cm^{-1}
CaF_2	4000-50000 cm^{-1}

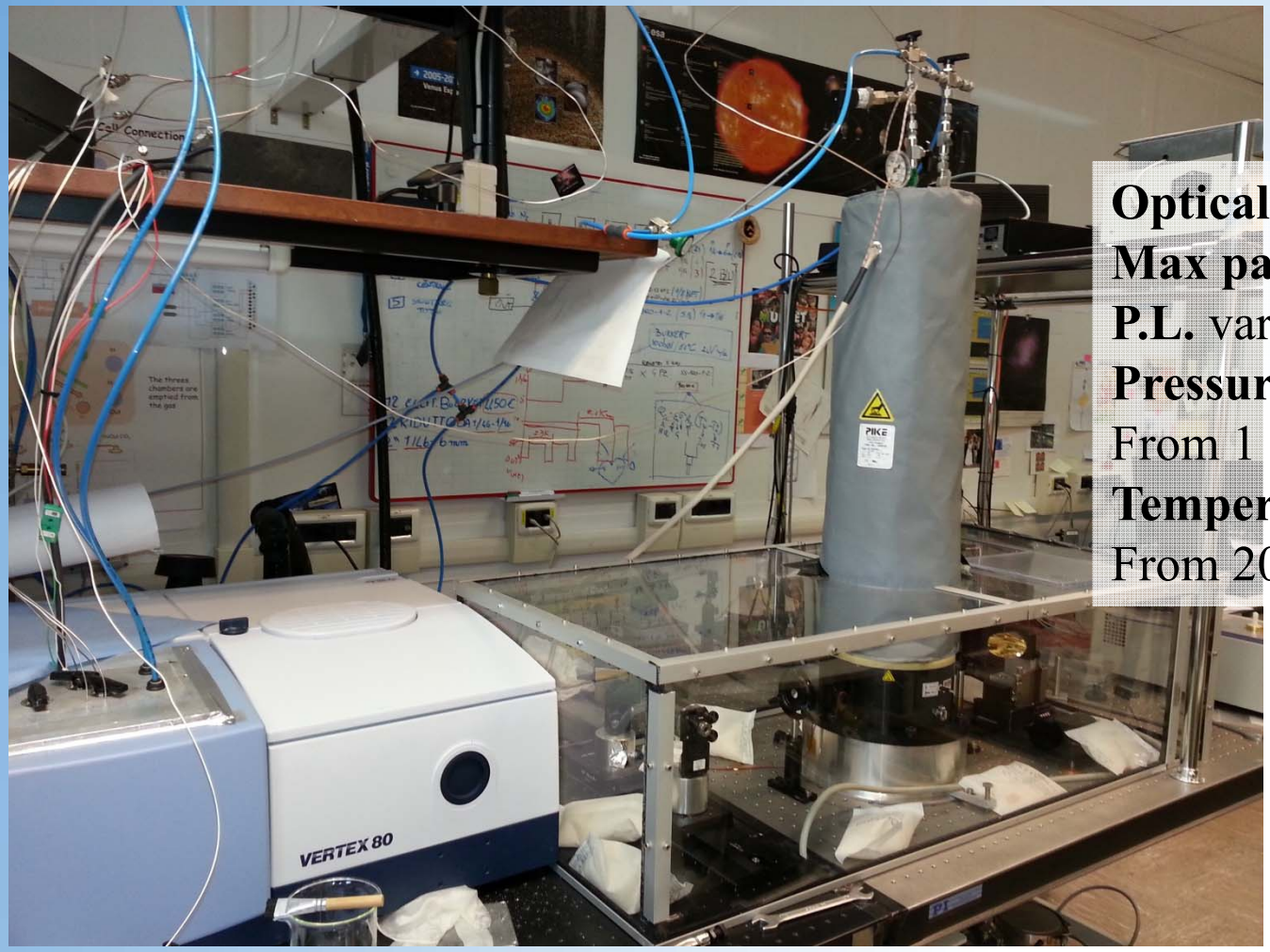
Resolution (10-0.07) cm^{-1}




High Pressure High Temperature Gas cell
Optical parameters
Pressure up to 300 Bar
Temperature up to 310°C
Optical path: l ≈ 2 cm
Giant planets atmospheres
VERTEX 80

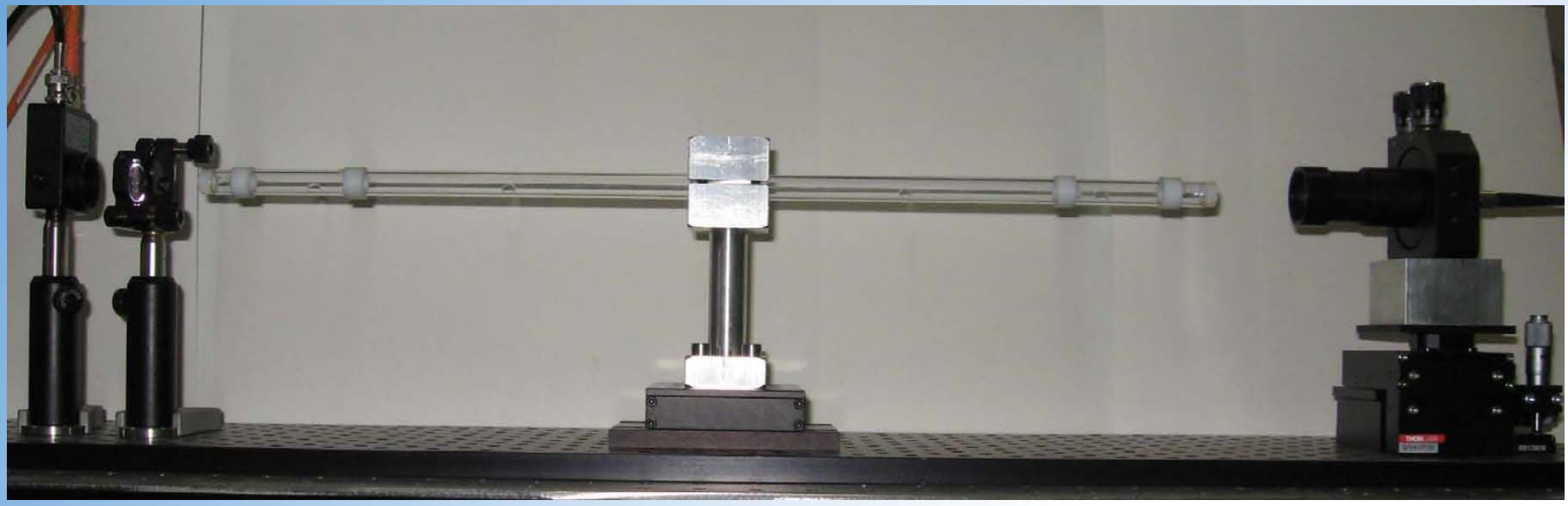
Giant planets atmospheres

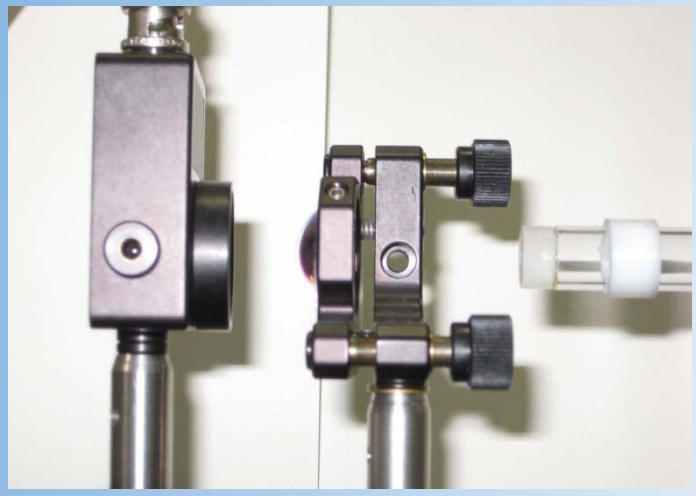
Multi pass gas cell @ intermediate pressure and high temperature



Optical Layout
Max path length: 30 m
P.L. variable from 2.5 to 30 m
Pressure
From 1 to 10 bar
Temperature
From 200 to 400K

Giant planets atmospheres
Cavity Ring Down (CRD) Cell





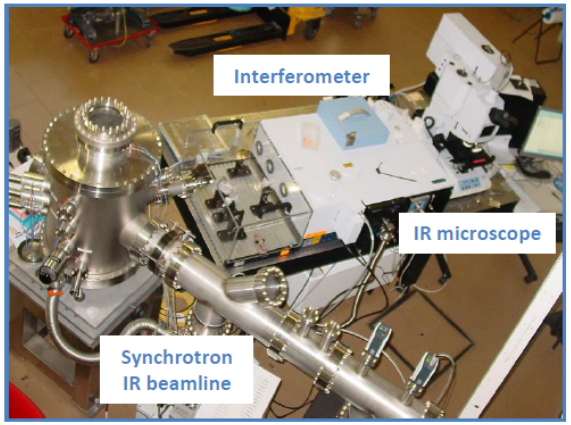
Quartz mirrors with a HR coating (99,97 %) have been glued on a quartz tube with several holes.

A CRD time of about 17 ms corresponds with an optical path of about 5 km.

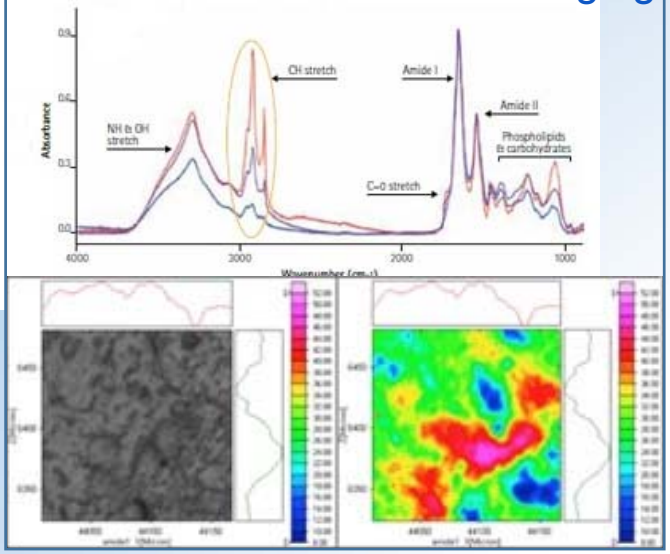
INFN DaFne-Ligh synchrotron facility

A synchrotron facility operating with syncrotron and standard sources in the Infrared and UV-VIS energy range is open to external users.

Sinbad IR beamline (1 mm – 0.5μm)

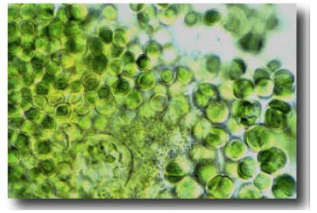


FPA detector for chemical imaging



Long path gas cell

- Extended IR range (from Far-IR to NIR-VIS)
- Chemical microimaging of materials
- Real time study of photoageing processes
- Exo-biosphere's evolution and biosignature characterization
- High temperature (1200°C) / high pressure (20GPa) setup

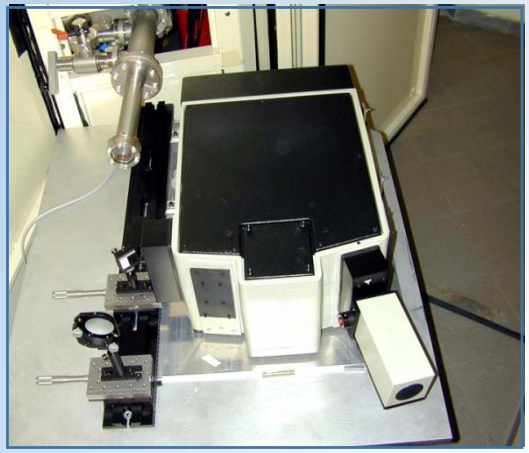


INFN

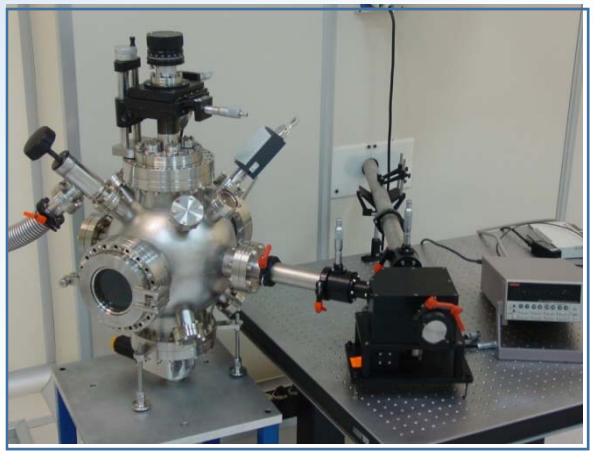
SOURCE branchline in a 1000-class cleanroom

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

VUV monochromatic radiation source (120-250 nm)



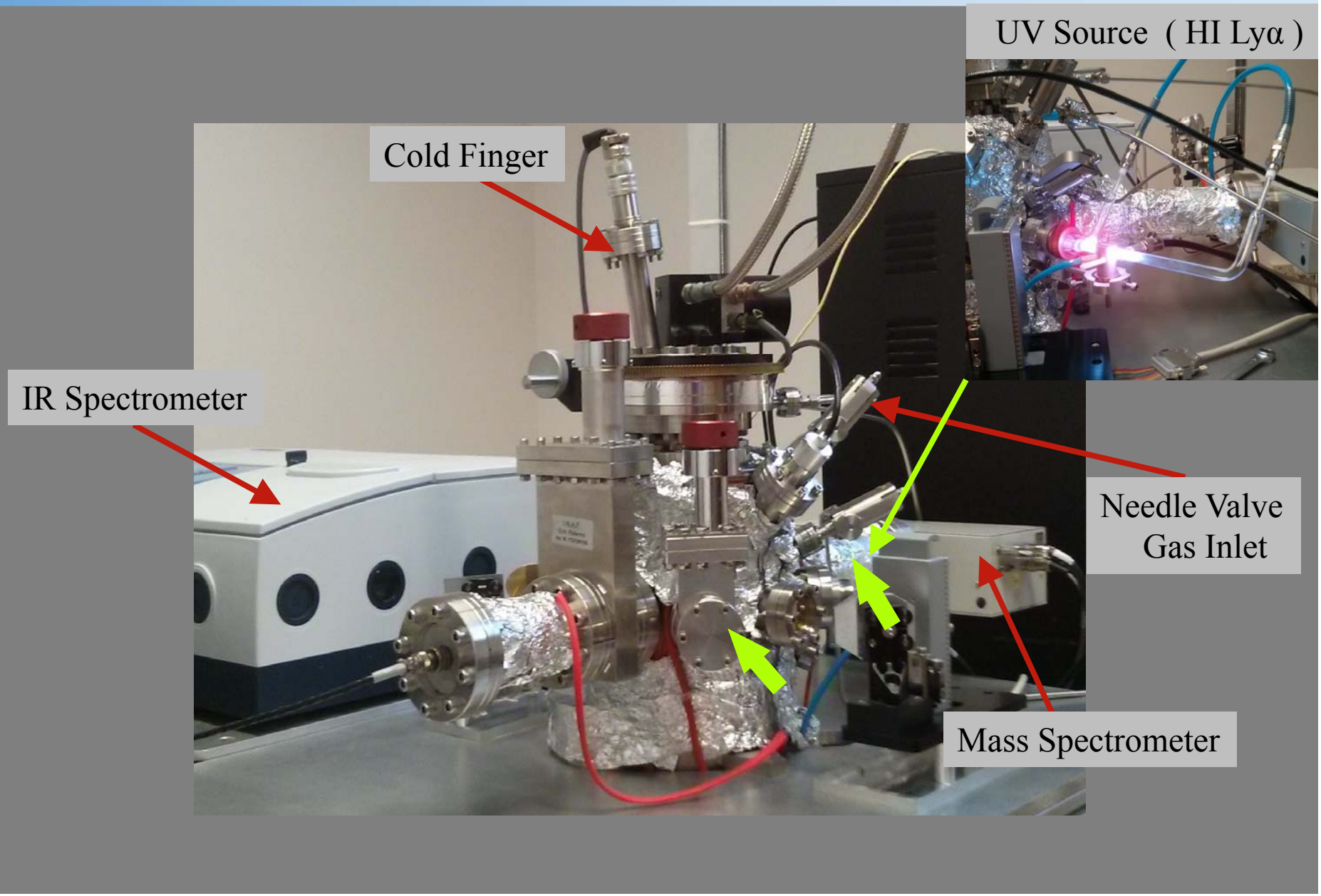
UV-VIS radiation source (200-650 nm)



- Large optical systems (up to 4 m) surface characterization
- UV photoageing of optical components and materials
- Detector calibration
- Photobiology and exobiology experiments

LIFE @ INAF OAPA

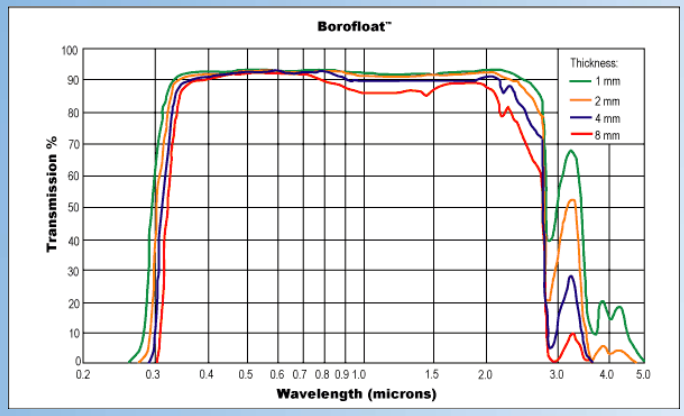
*(**L**ight **I**rradiation **F**acility for **E**xochemistry)*

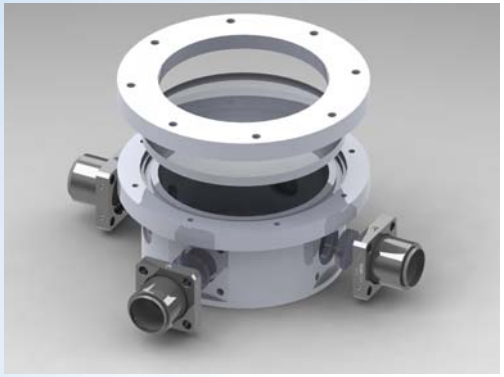


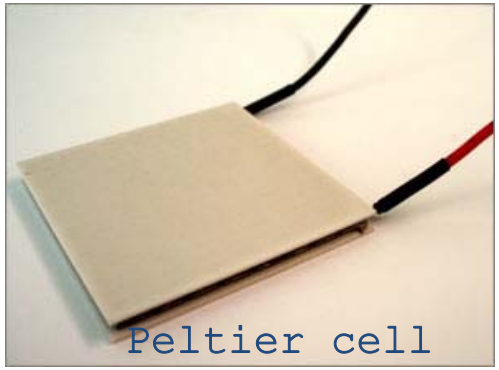
INAF OAPD- Padua Dept. Physics & Astronomy:

Rocky Planets atmosphere modification caused by biota

MINI-LISA
ambient
simulator







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.

Timeline of the experiment

Step Zero:
-conception of an M starlight simulator
-Choice of bacteria
-Incubator build-up

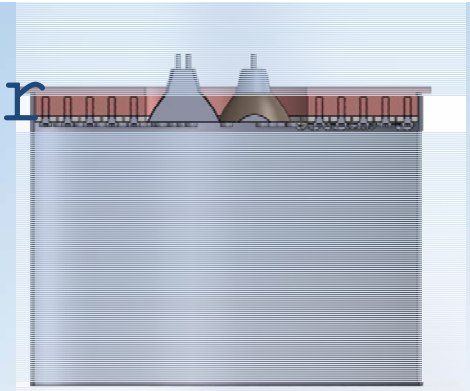
First step:
Irradiation of the samples with solar light in terrestrial conditions
- Analysis of gaseous abundances in the cells

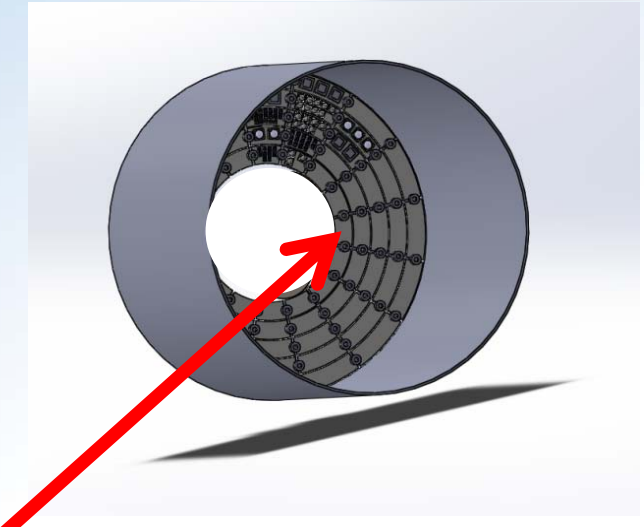
Second step:
-Irradiation of the samples with M star radiation,
-Analysis of gaseous abundances in the cells

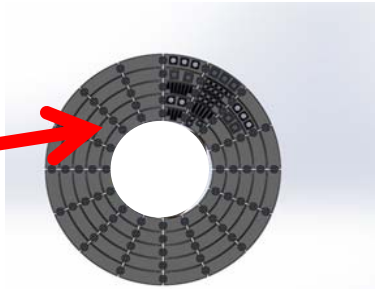
Third step:
-Irradiation of the samples with M star radiation at terrestrial pressure,temperature and extrasolar planet gaseous mixture,
-Analysis of gaseous abundances in the cells.

Ancillary science:Plants on M star planets

The Illuminator



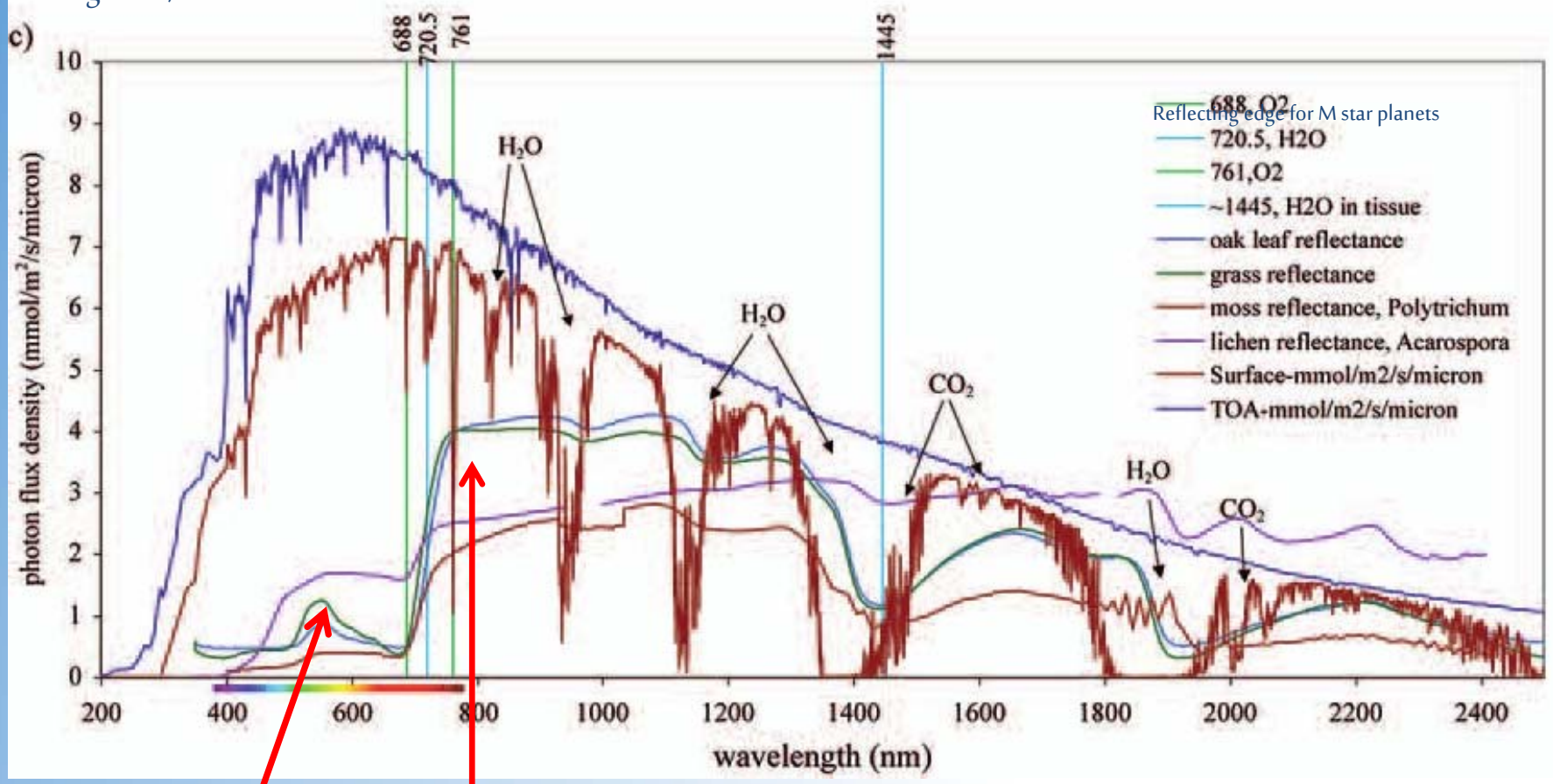




25 Wavelengths (0.36 – 0.94 µm)
275 LEDs
450 W dissipation
PC Controlled

LED Decks

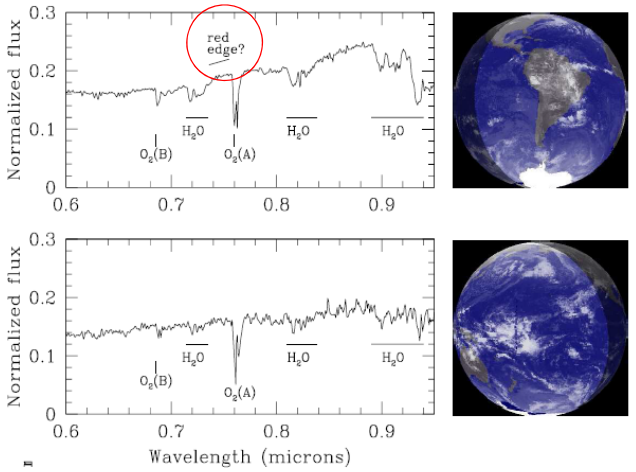
Kiang et al., 2007a



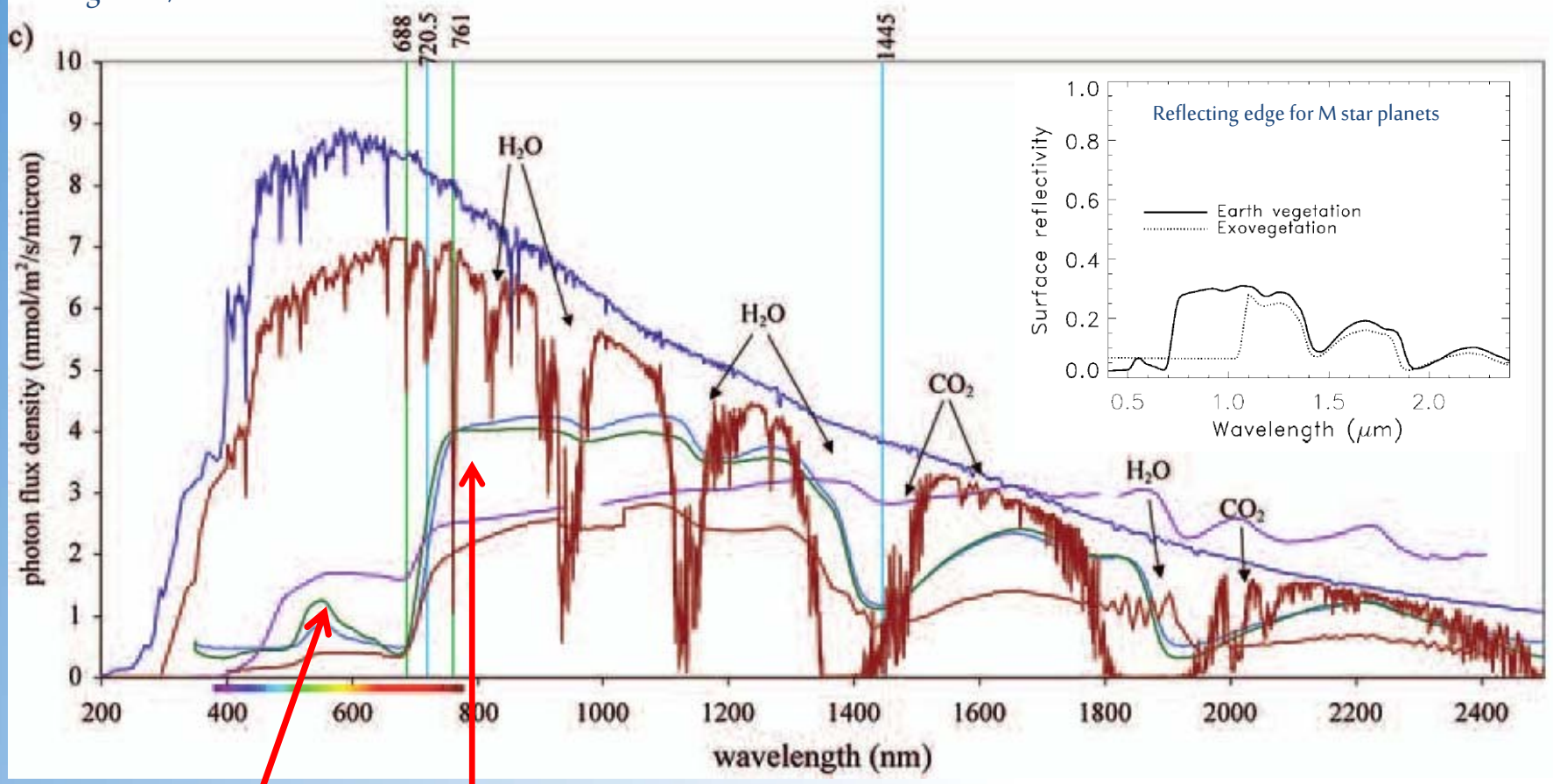
Reflecting edge for M star planets

Green bump

Red edge variated depending on the organism type, biomass, hydratation and leaf thickness and carbon content

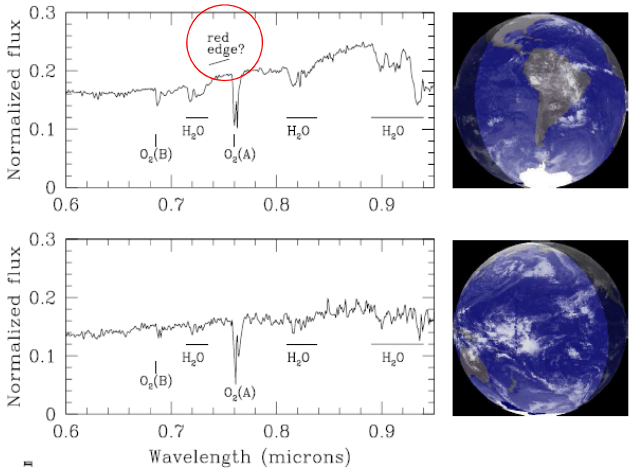


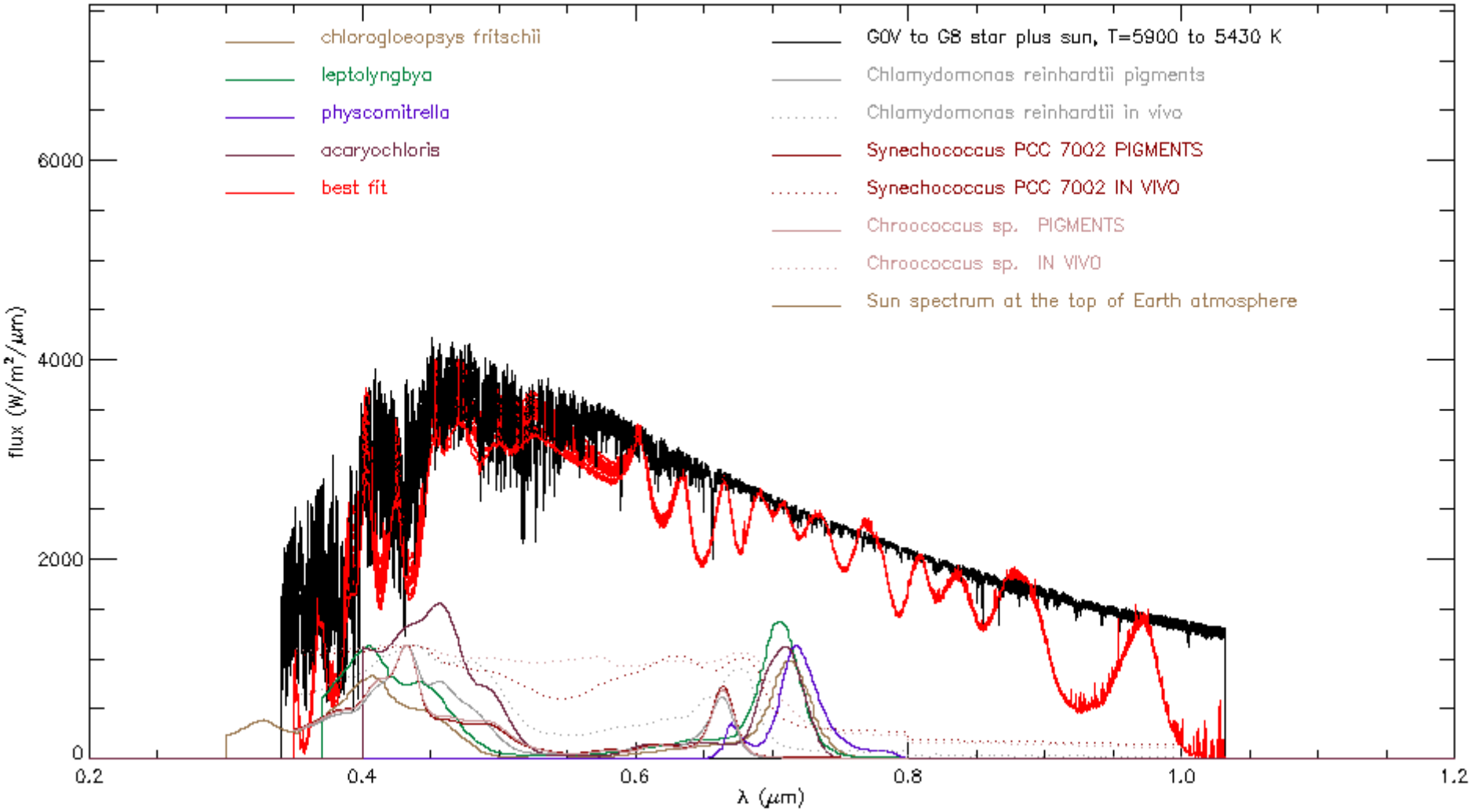
Kiang et al., 2007a

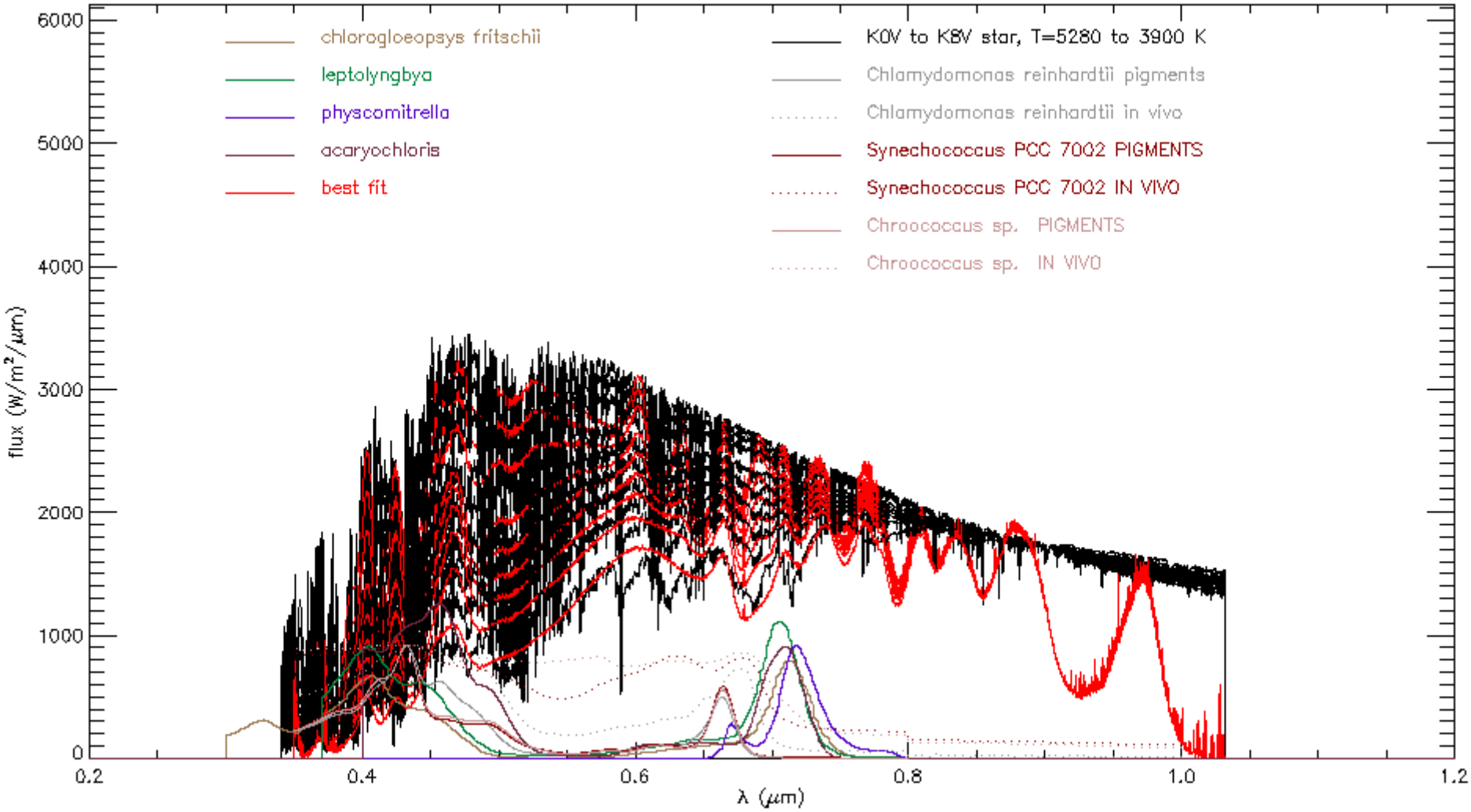


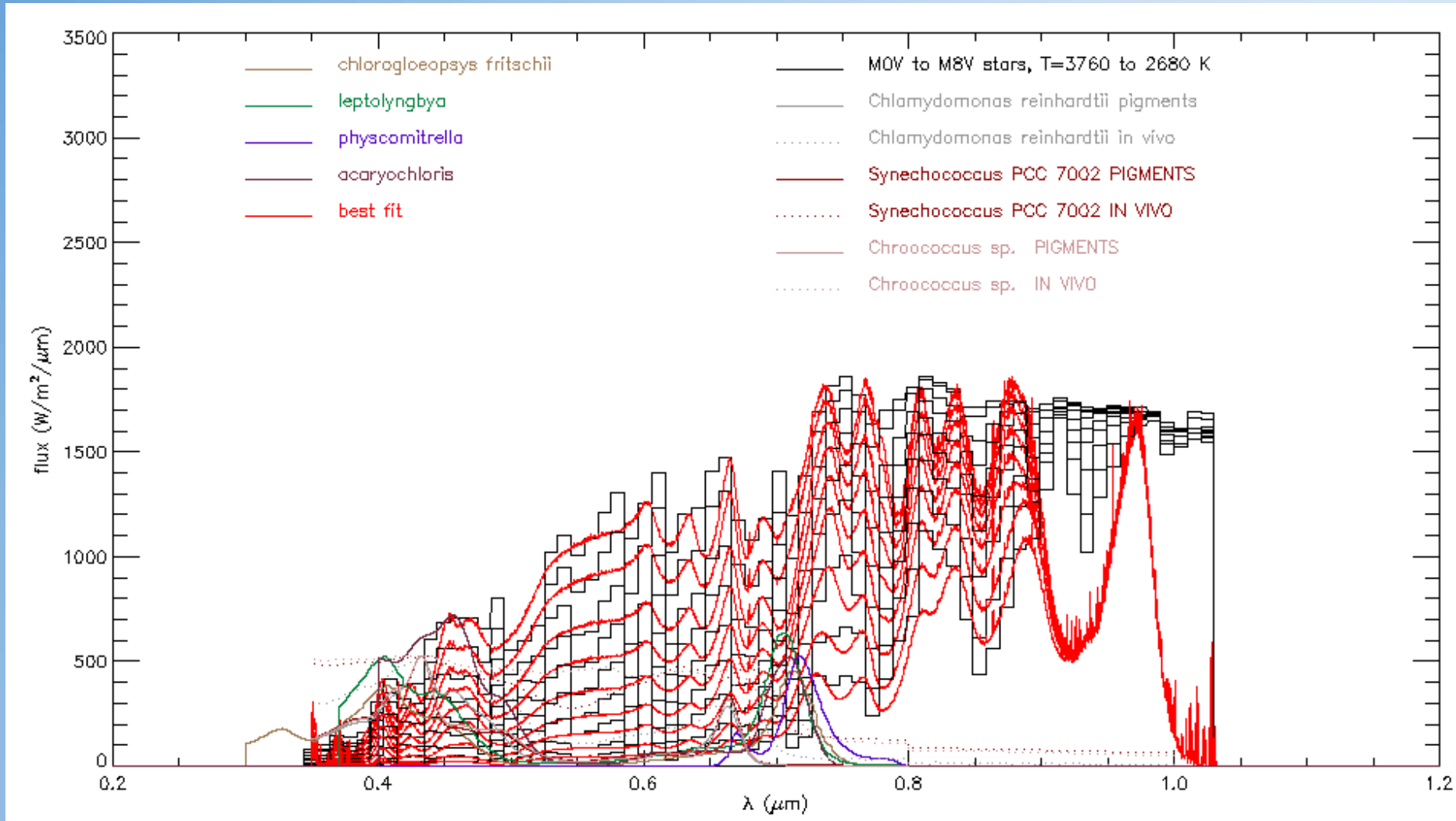
Green bump

Red edge variated depending on the organism type, biomass, hydratation and leaf thickness and carbon content




chlorogloeopsys fritschii
leptolyngbya
physcomitrella
acaryochloris
best fit
G0V to G8 star plus sun, T=5900 to 5430 K
Chlamydomonas reinhardtii pigments
Chlamydomonas reinhardtii in vivo
Synechococcus PCC 7002 PIGMENTS
Synechococcus PCC 7002 IN VIVO
Chroococcus sp. PIGMENTS
Chroococcus sp. IN VIVO
Sun spectrum at the top of Earth atmosphere
flux (W/m²/μm)
λ (μm)
0
2000
4000
6000
0.2
0.4
0.6
0.8
1.0
1.2


chlorogloeopsys fritschii
leptolyngbya
physcomitrella
acaryochloris
best fit
K0V to K8V star, T=5280 to 3900 K
Chlamydomonas reinhardtii pigments
Chlamydomonas reinhardtii in vivo
Synechococcus PCC 7002 PIGMENTS
Synechococcus PCC 7002 IN VIVO
Chroococcus sp. PIGMENTS
Chroococcus sp. IN VIVO
flux (W/m²/μm)
λ (μm)
0
1000
2000
3000
4000
5000
6000
0.2
0.4
0.6
0.8
1.0
1.2


chlorogloeopsys fritschii
leptolyngbya
physcomitrella
acaryochloris
best fit
M0V to M8V stars, T=3760 to 2680 K
Chlamydomonas reinhardtii pigments
Chlamydomonas reinhardtii in vivo
Synechococcus PCC 7002 PIGMENTS
Synechococcus PCC 7002 IN VIVO
Chroococcus sp. PIGMENTS
Chroococcus sp. IN VIVO
flux (W/m²/μm)
λ (μm)
0
500
1000
1500
2000
2500
3000
3500
0.2
0.4
0.6
0.8
1.0
1.2