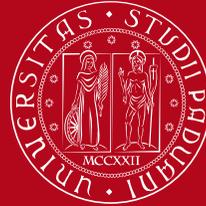


1222·2022
800
ANNI



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

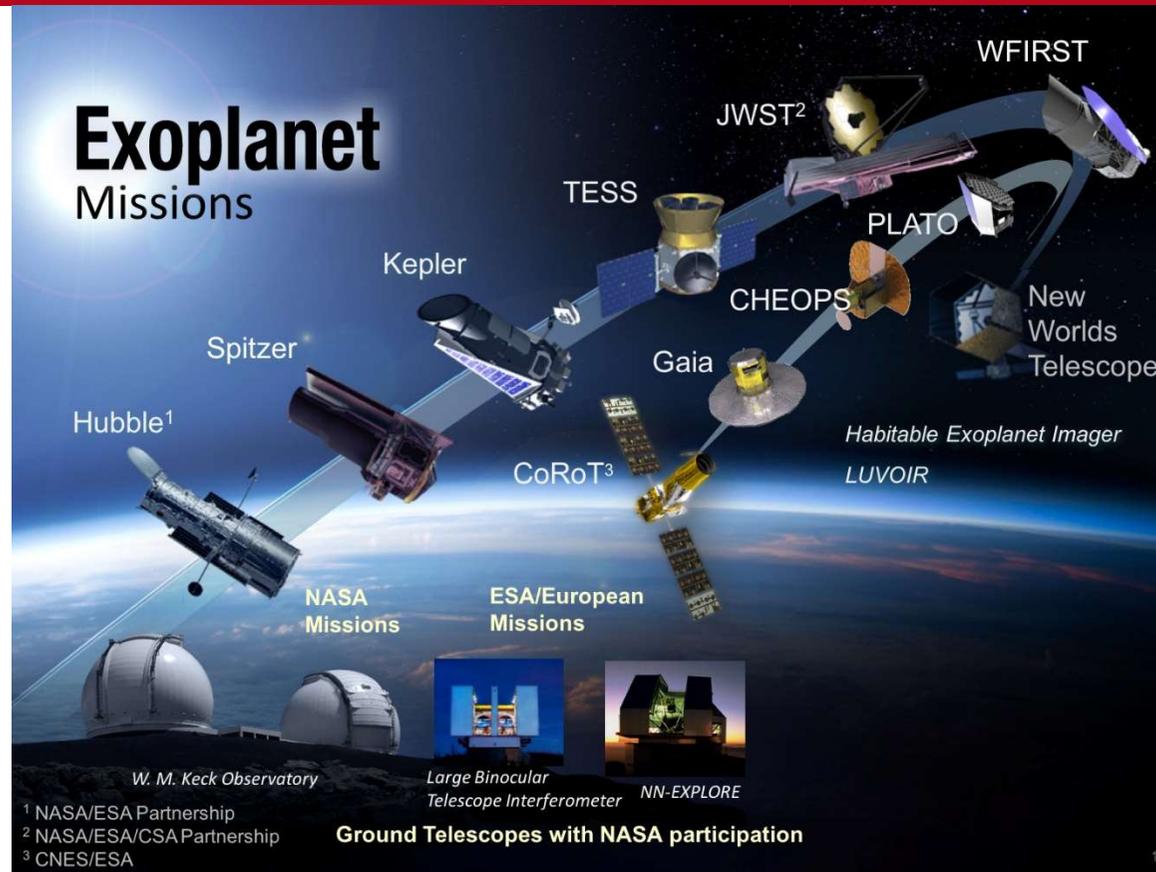
Studies on photosynthetic organisms as a tool for improving the success of future space missions

Mariano Battistuzzi - 33th Cycle

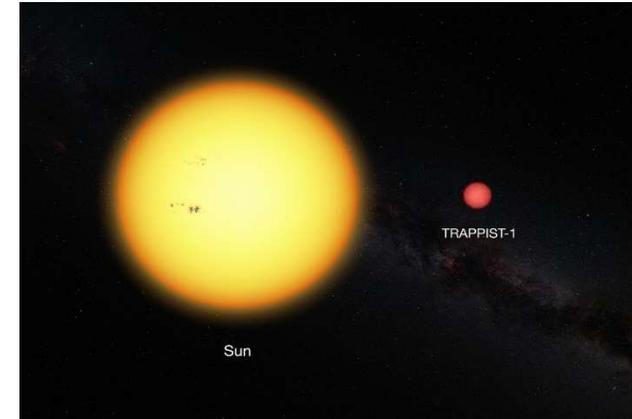
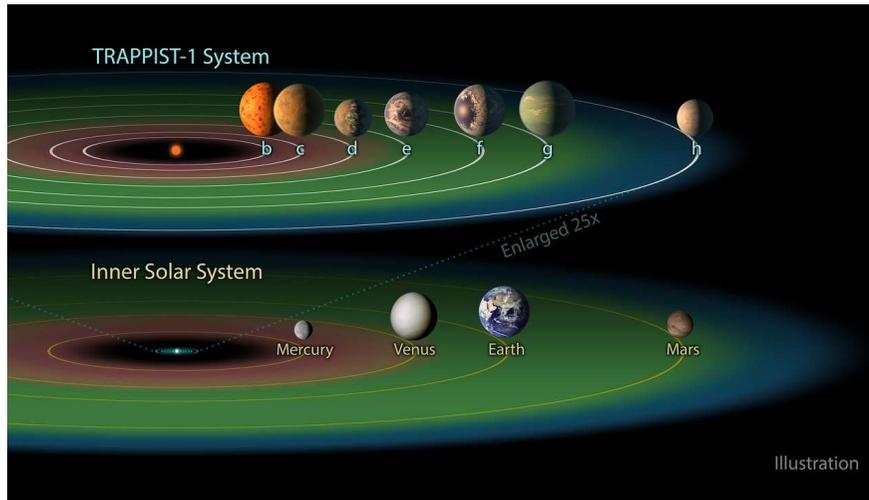
Supervisor: Prof. Nicoletta La Rocca CO-Supervisor: Prof. Giampiero Naletto

Meeting - 06/11/2020

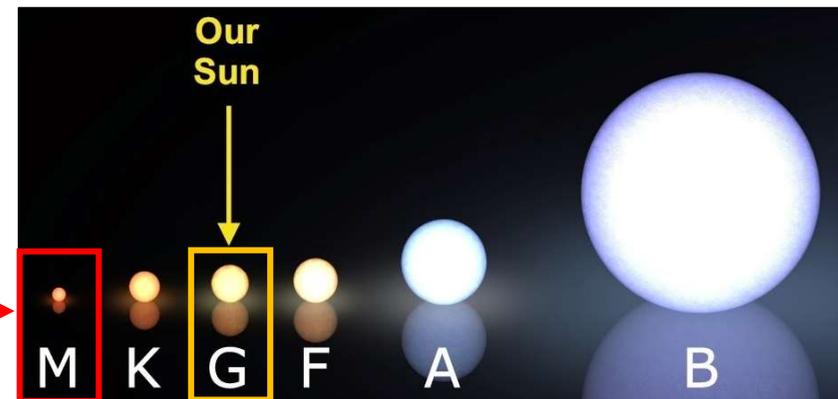
Almost 4300 new exoplanets

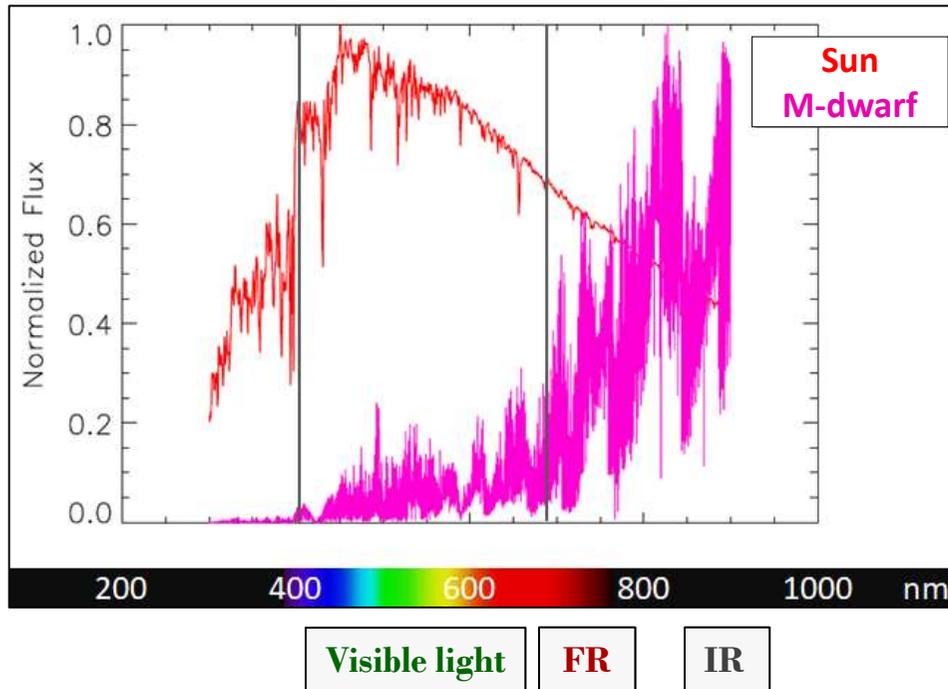


Rocky exoplanets orbiting M-dwarfs



Rocky terrestrial exoplanets in the Habitable Zones of M-dwarf stars





Host numerous rocky terrestrial exoplanets in their HZ

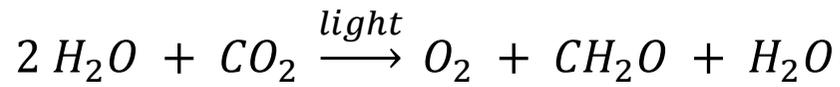
Live long enough to sustain life evolution

Most common stars in the Milky Way (76% of total stars)

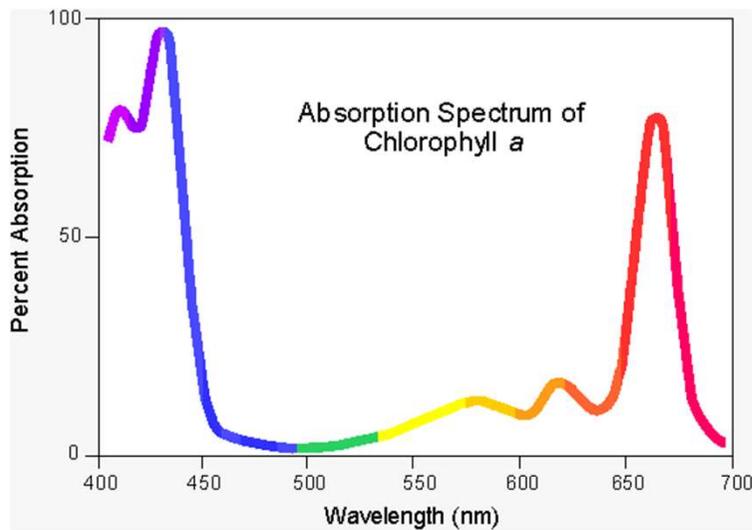
10 times less luminous than the Sun

Different light spectrum (very poor light in the visible)

Oxygenic Photosynthetic Organisms

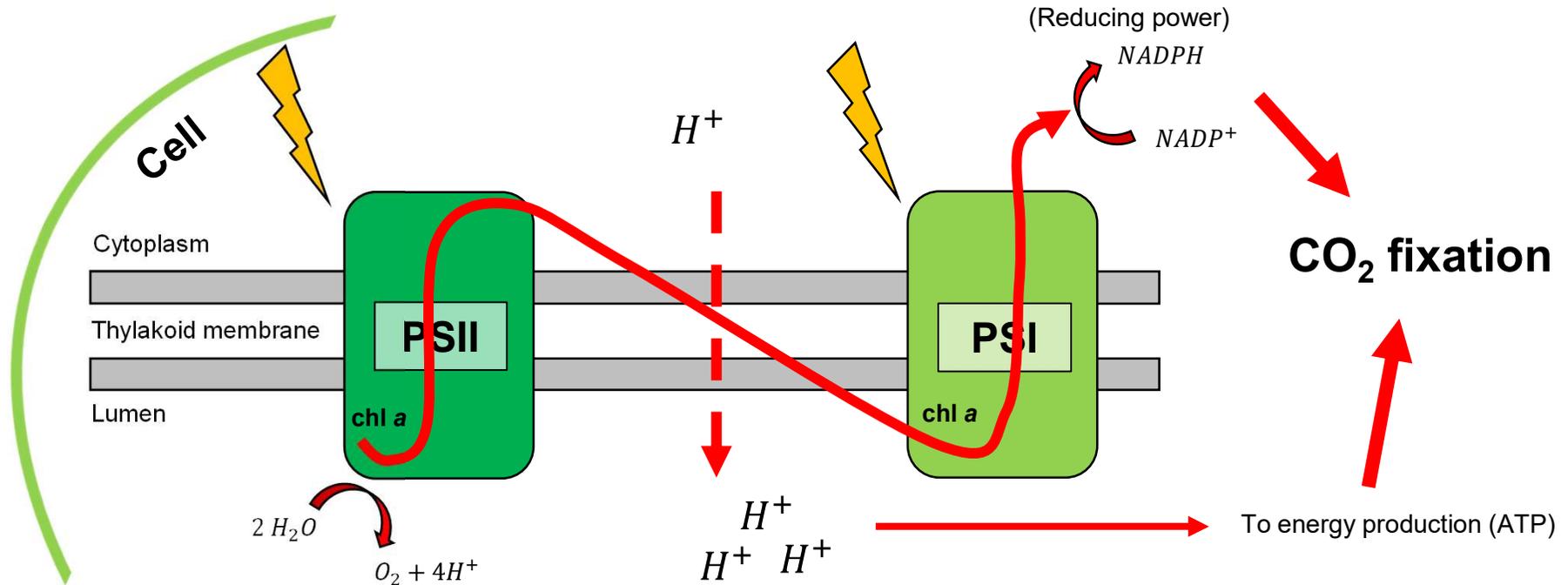
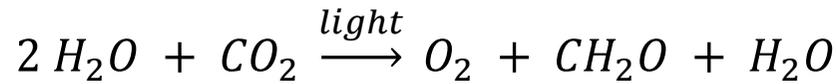


All have chl a



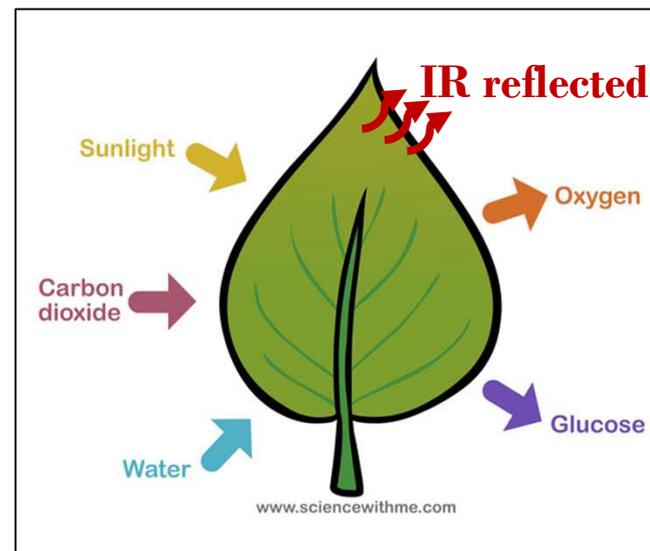
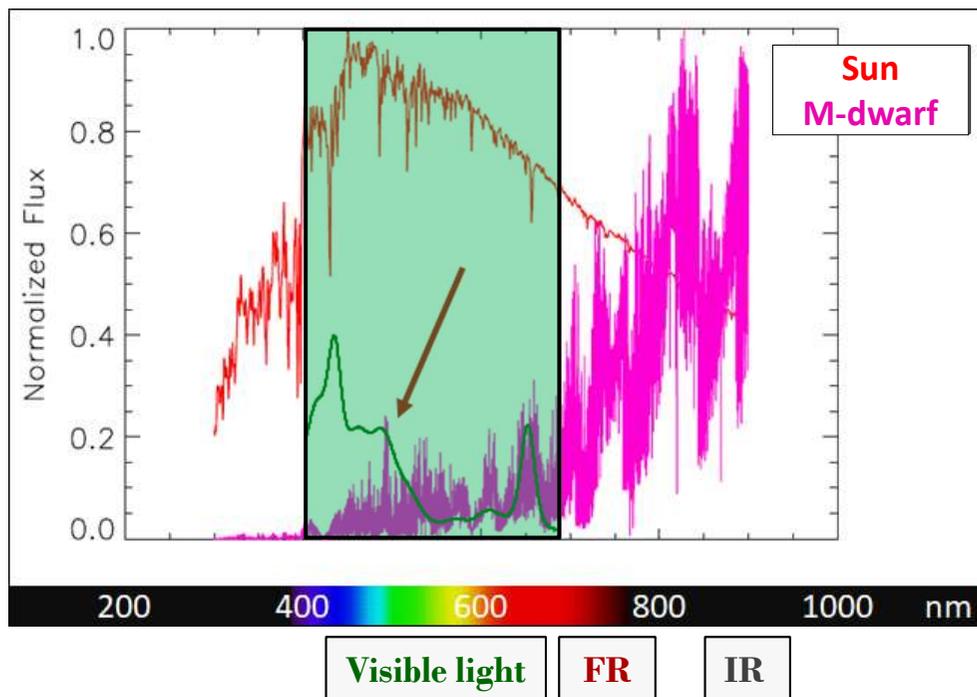
Oxygenic Photosynthetic Organisms

PSI: Photosystem I
PSII: Photosystem II



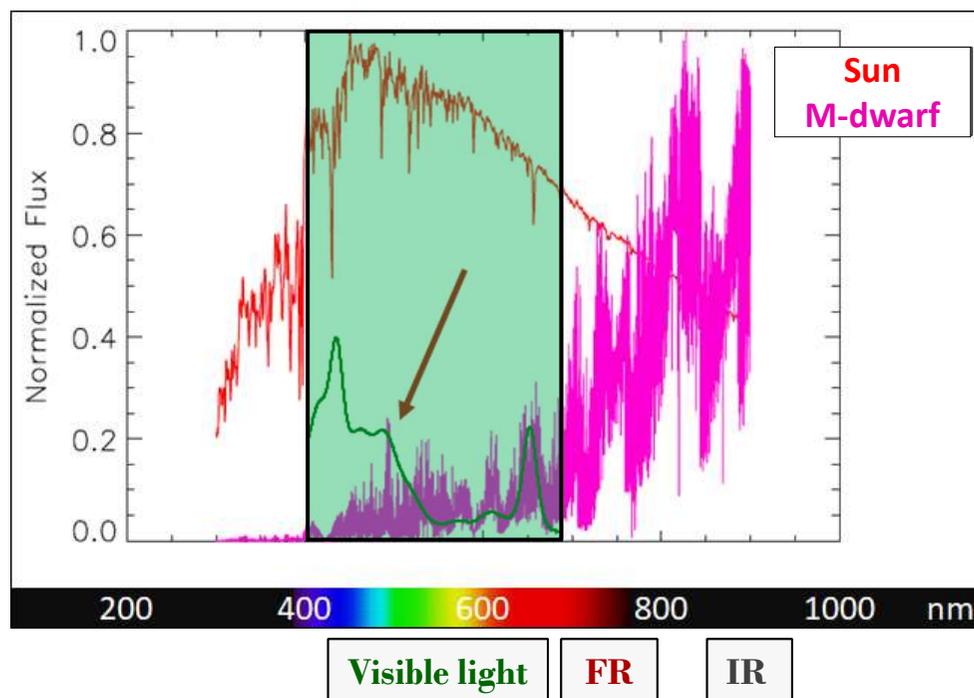
Oxygenic Photosynthesis uses only the Photosynthetically Active Radiation (PAR)

PAR = 400 – 700 nm



Oxygenic Photosynthesis uses only the Photosynthetically Active Radiation (PAR)

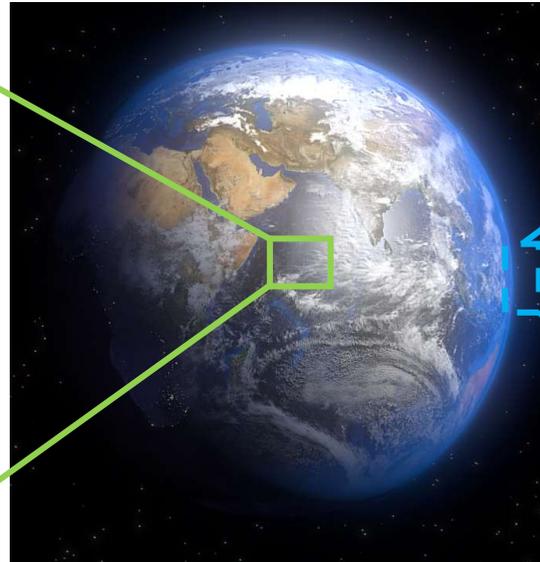
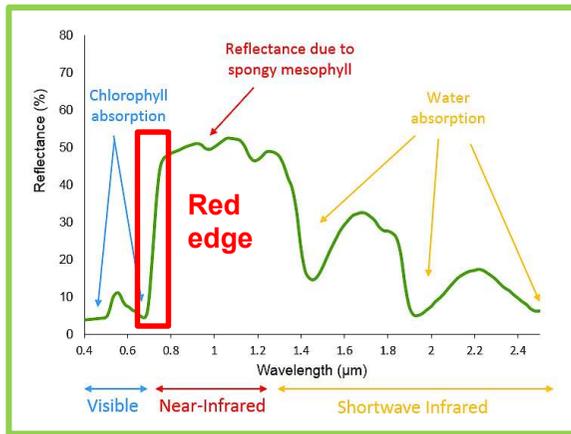
PAR = 400 – 700 nm



Kiang et al, 2007
Gale and Wandel, 2017
Ritchie, Larkum and Ribas, 2017
Takizawa et al, 2017
Wandel, 2018
Wandel and Gale, 2020

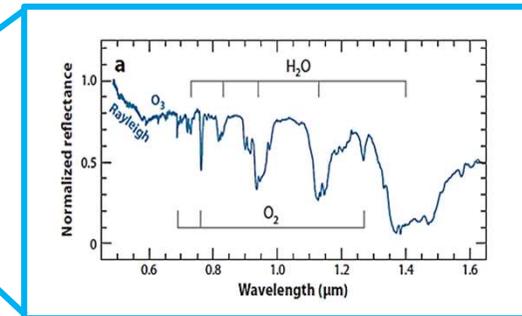
Surface biosignatures

chl a



Atmospheric biosignatures

O₂



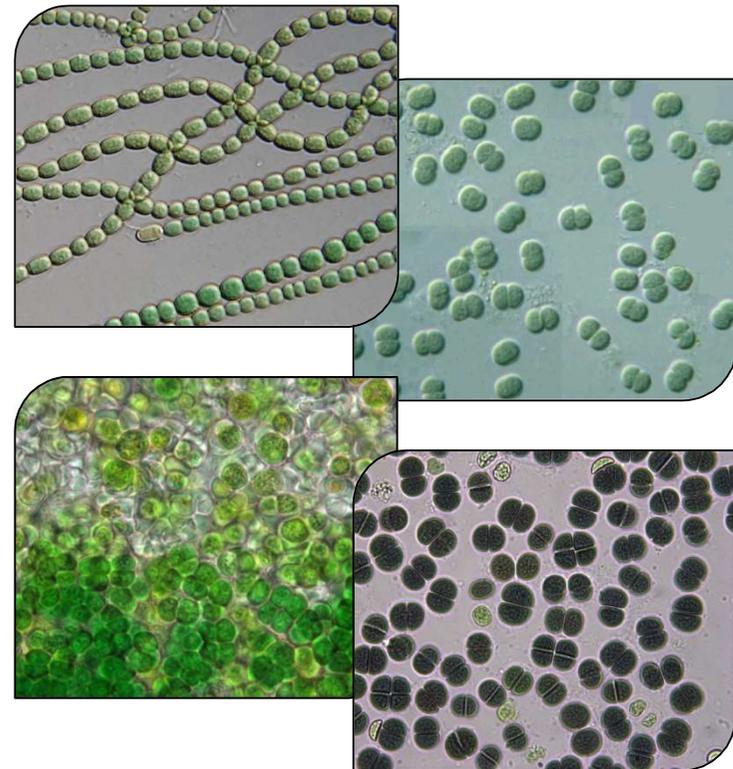
Simulate M-dwarfs light spectra and exoplanetary atmospheric compositions



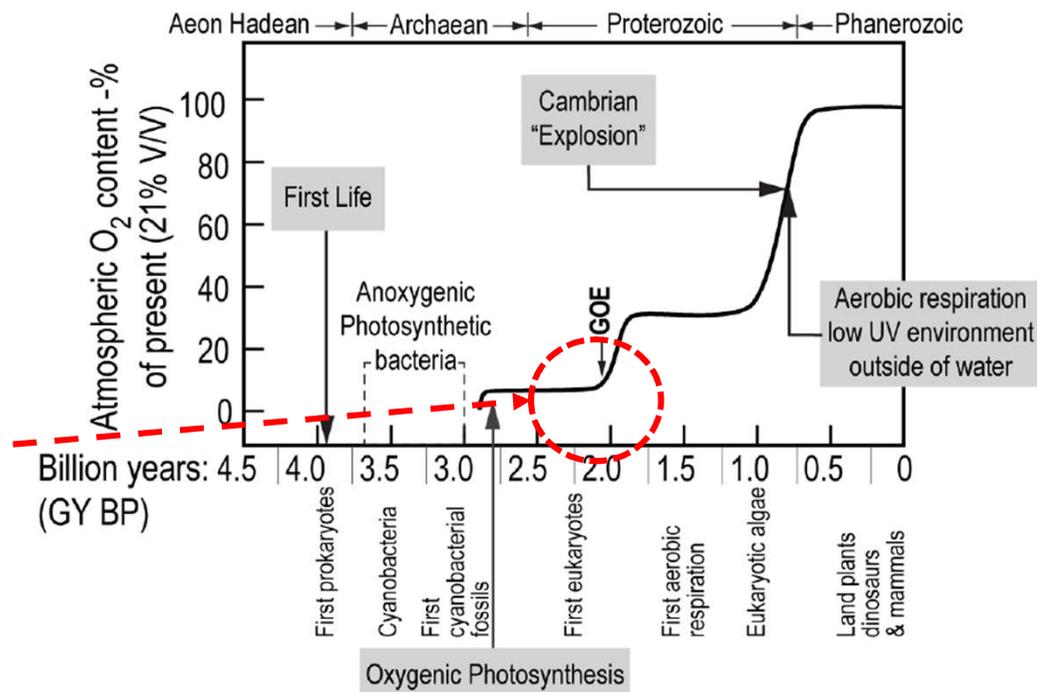
Test Oxygenic Photosynthetic Organisms survival and photosynthetic activity

Evaluate impact on primeval atmospheres and red edge features

Simplest and most adaptable Oxygenic Photosynthetic Organisms

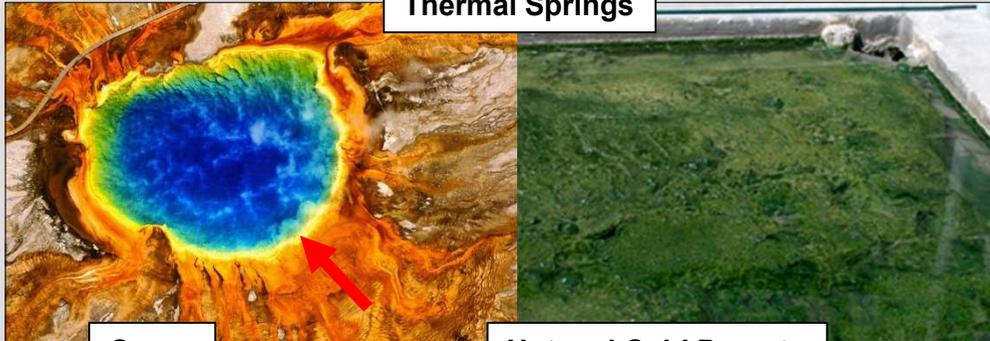


Cyanobacteria Responsible for the Great Oxygenation Event ~ 2,2 billion years ago

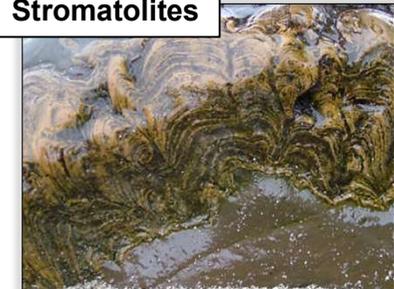
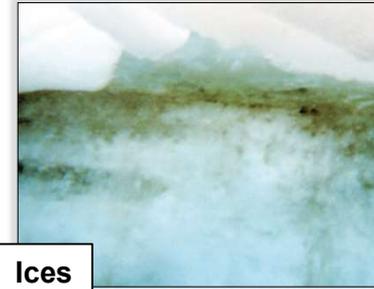


Cyanobacteria colonize extreme environments

Thermal Springs



Stromatolites



Ices

Caves

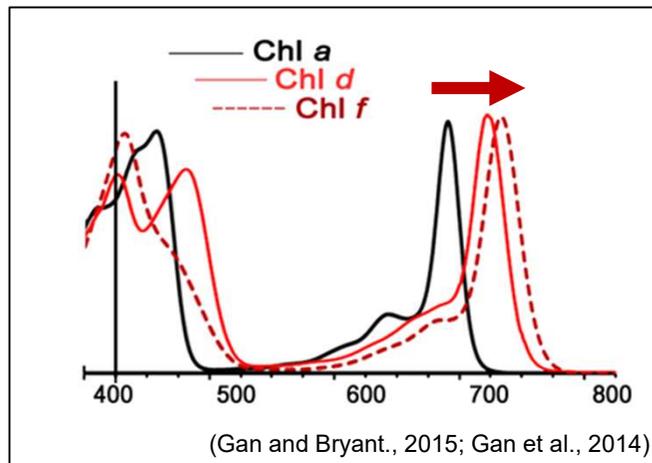


Hot and Cold Deserts



...and Space!

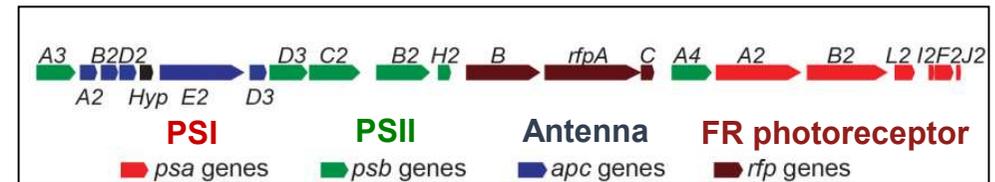
Photoacclimation to 720 nm FR light



Visible light

FR

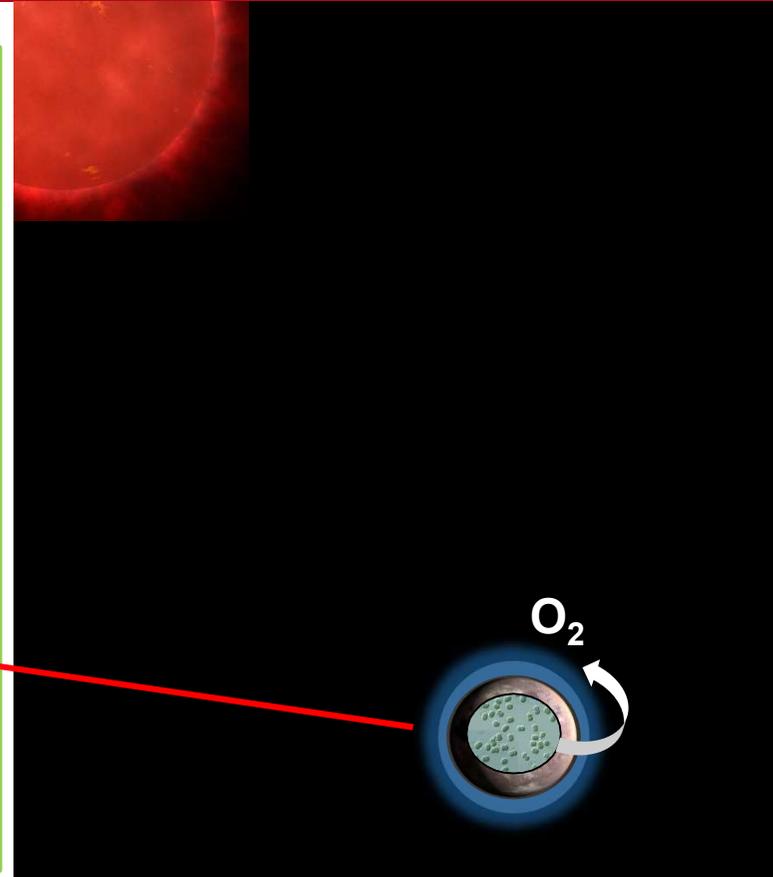
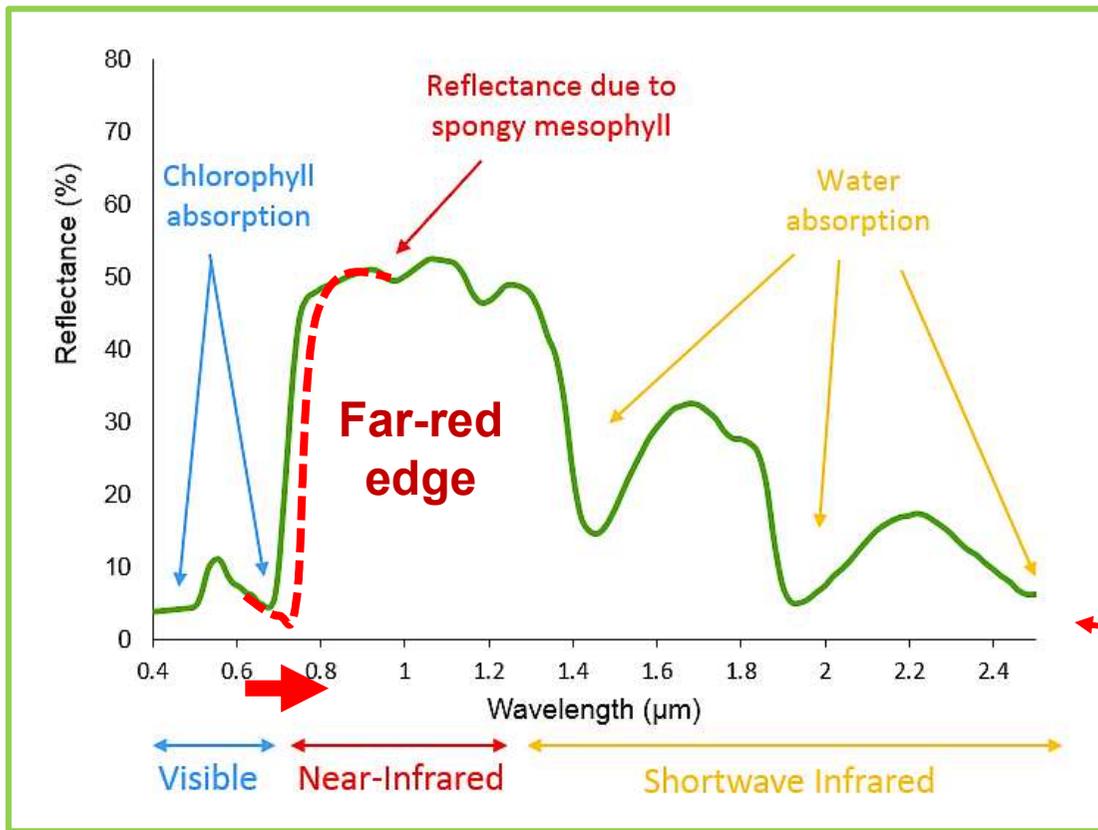
17 genes



FaRLiP

- Synthesis of Chl *d* and *f*
- Reorganization of the photosynthetic apparatus
- Photosynthesize (O₂ evolution) in FR

Cyanobacteria grow under FR lights... ...and under M-dwarf lights?

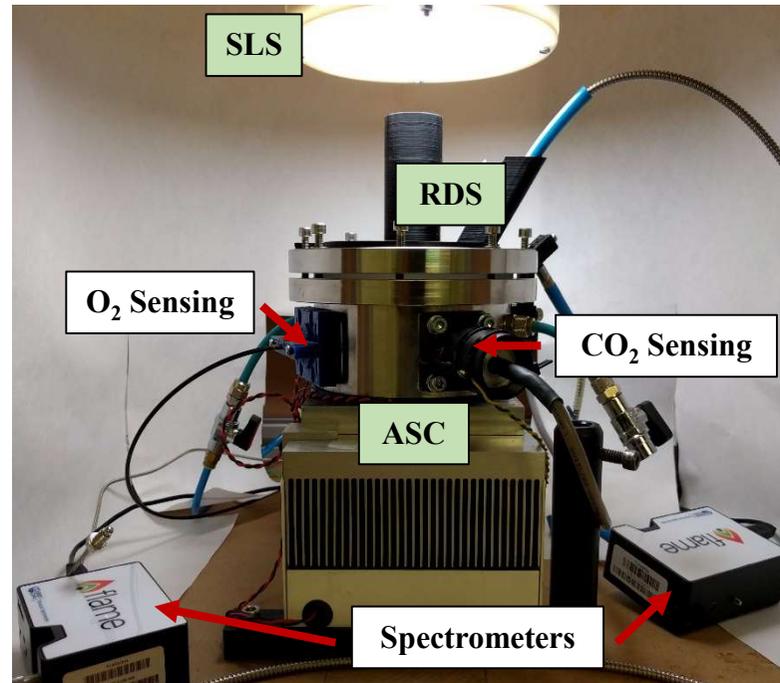


Gears and their improvement

Experimental Setup

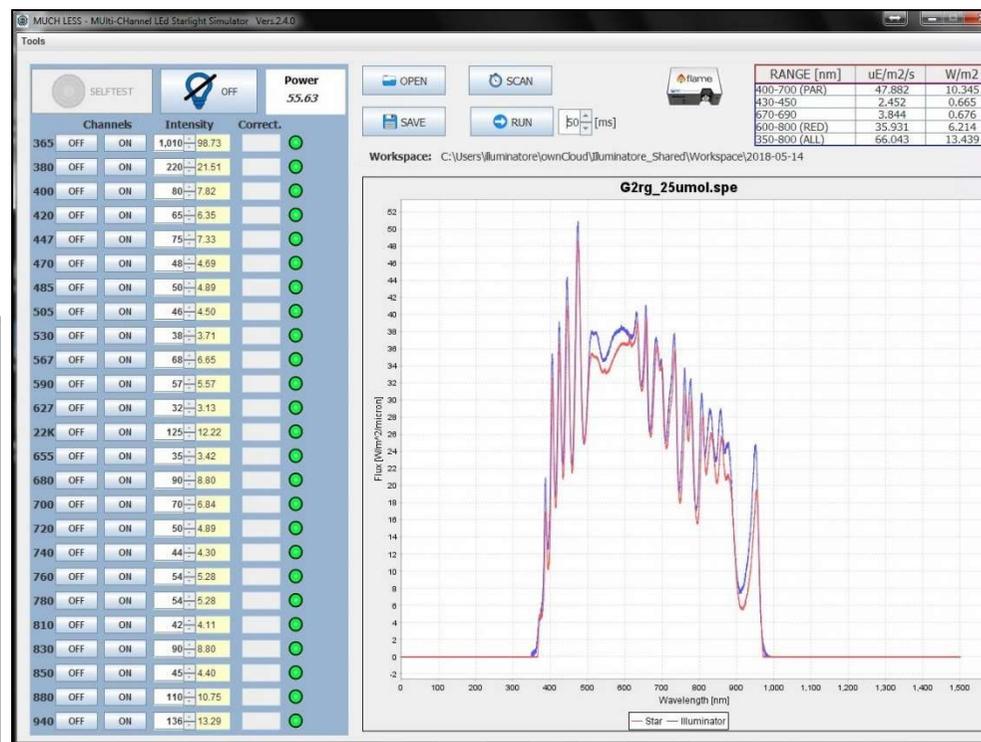


DIPARTIMENTO DI BIOLOGIA
UNIVERSITÀ DEGLI STUDI DI PADOVA



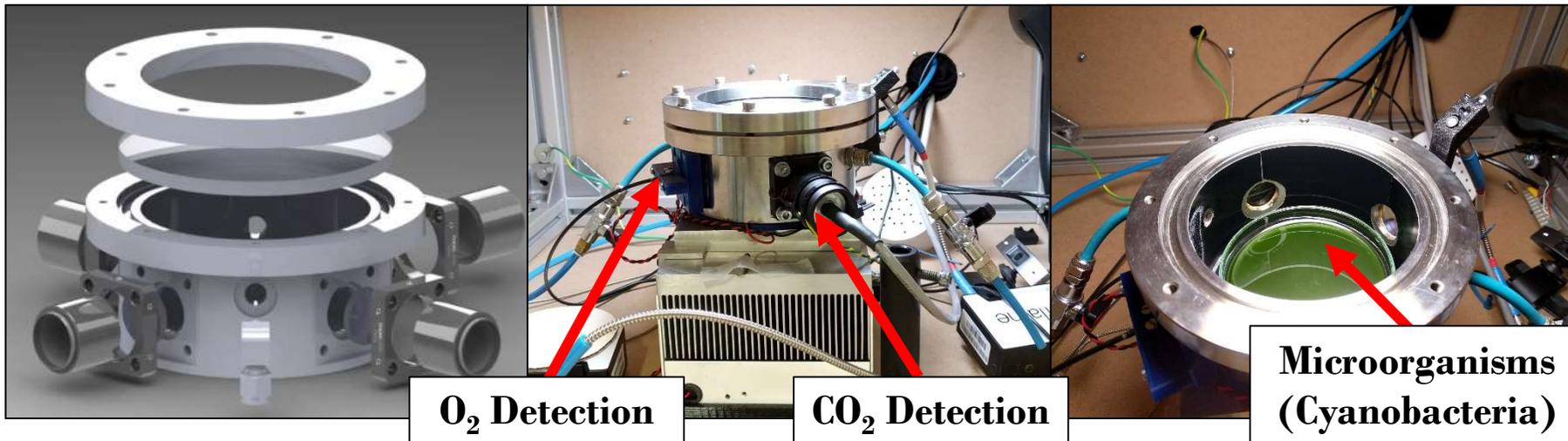
Battistuzzi et al, 2020

- 25 channels, 365-940 nm range
- Radiation of F/G/K/M stars

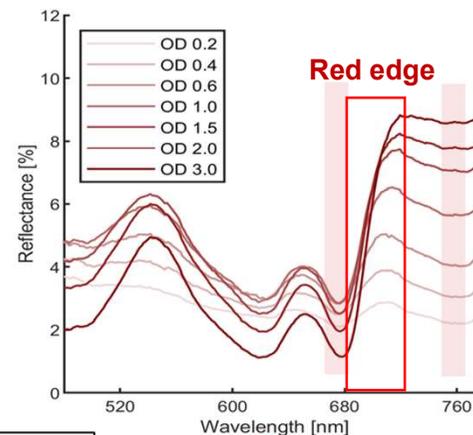
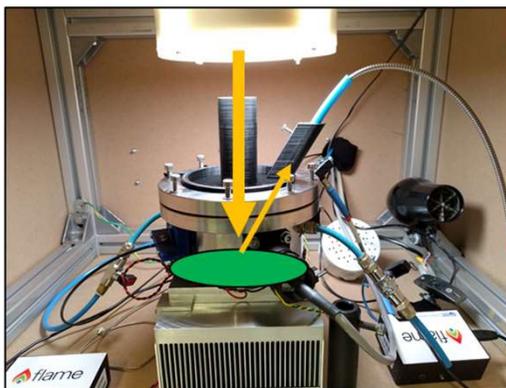


(Erculiani et al., 2016; Trivellin et al., 2016; Salasnich et al., 2018)

- **0,5 L sealed stainless steel growth chamber**
- **Glass window**
- **Temperature, Pressure and Atmospheric Composition tunable**
- **O₂ and CO₂ Sensors**



Battistuzzi et al, 2020



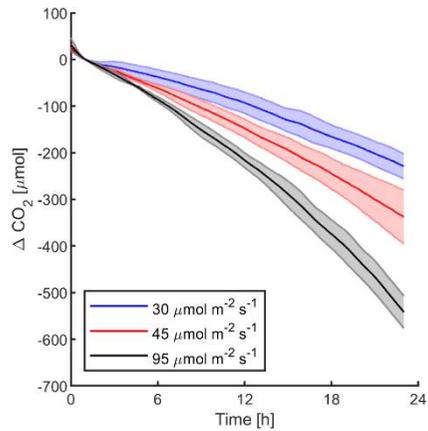
$$NDVI = \frac{Ref(745 \text{ to } 755nm) - Ref(675 \text{ to } 685nm)}{Ref(745 \text{ to } 755nm) + Ref(675 \text{ to } 685nm)}$$

- Probe collects reflected light from growing culture
- Spectrometer acquires Photon Counts
- Data is elaborated into Reflectance Spectra
- A Normalized Difference Vegetation Index (NDVI) is measured

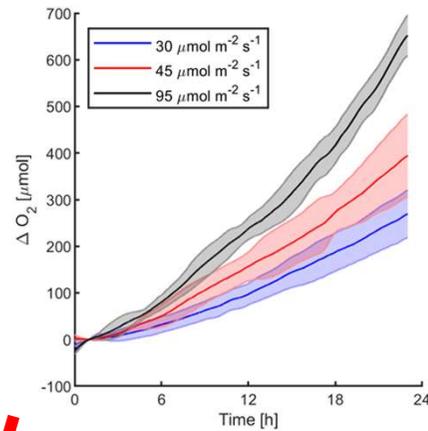
Validation of the Setup

Battistuzzi et al, 2020

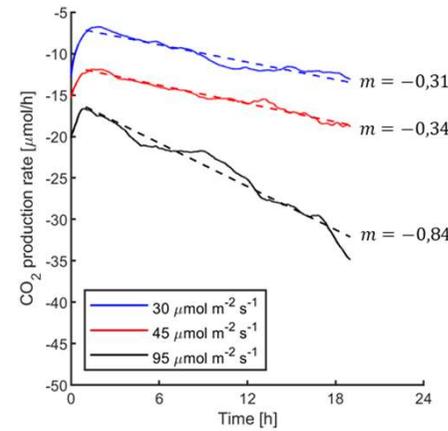
CO₂ consumption



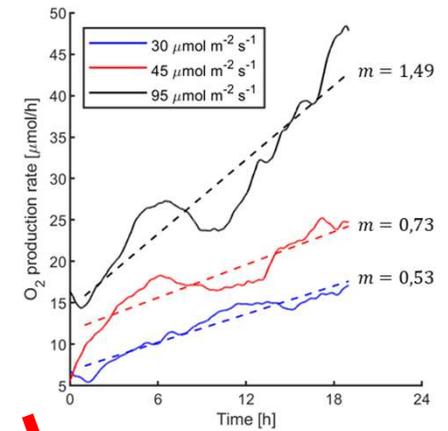
O₂ production



CO₂ consumption rate



O₂ production rate



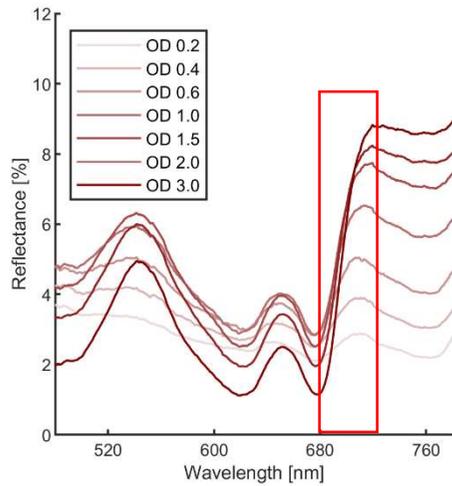
Evaluate impact on atmospheric compositions

Evaluate growth from remote

Validation of the Setup

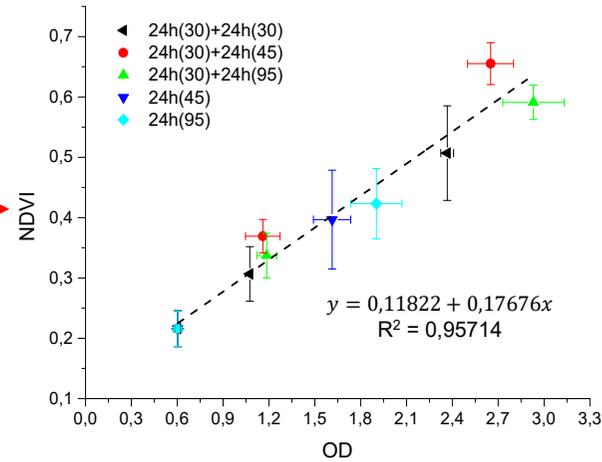
Battistuzzi et al, 2020

Reflectivity Detection to measure NDVI



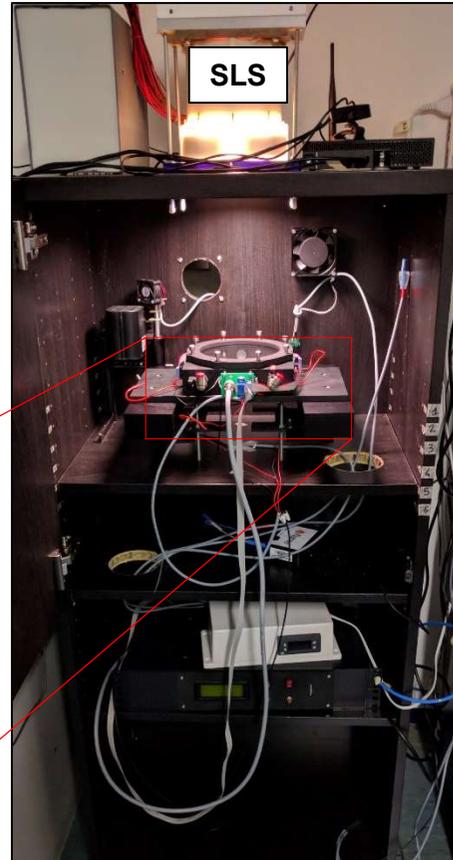
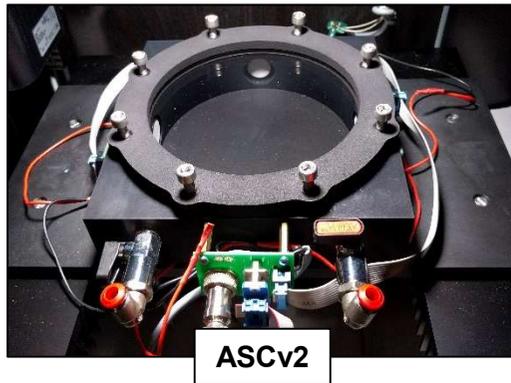
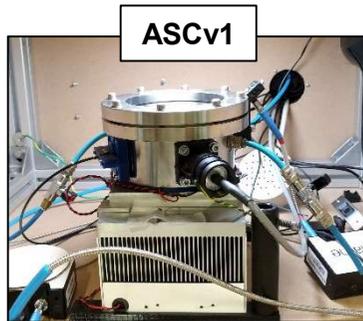
Evaluate impact on Red Edge

Calibration of NDVI with growth index



Evaluate growth from remote

Setup improvement

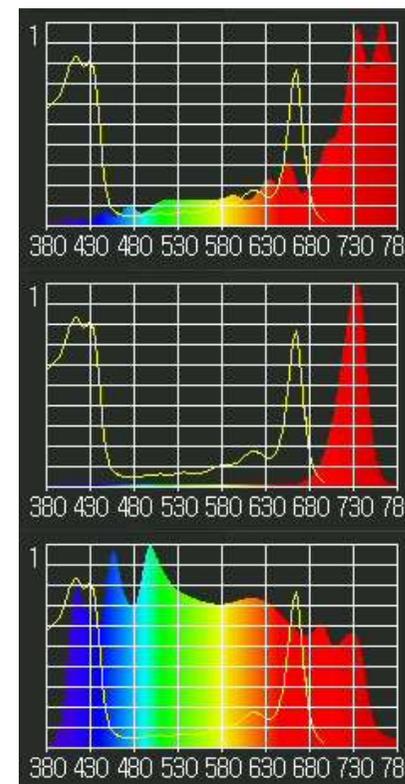
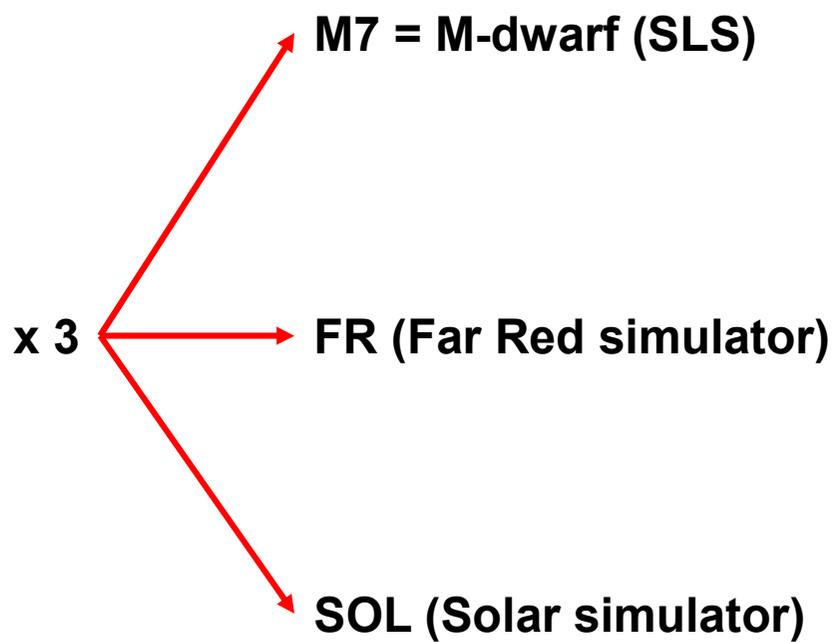


- + Improved sample volume
- + Better light intensity control
- + Better temperature control
- + Improved CO₂/O₂ sensors

ASC improvement



Mariano Battistuzzi



Astrobiological experiments

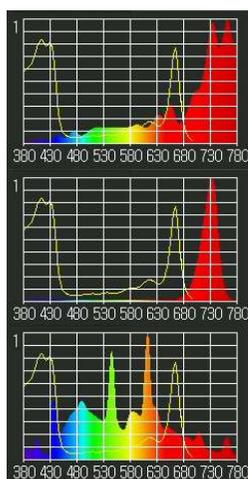
3 Light conditions

2 cyanobacterial species

M7

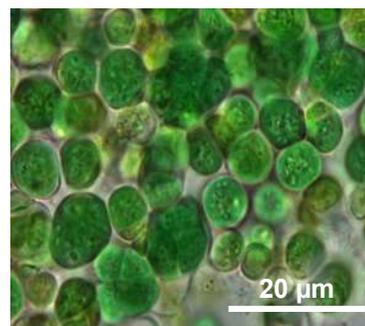
FR

SL



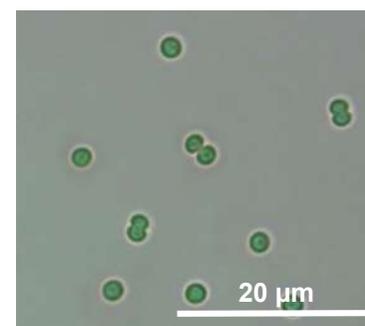
Light Intensity = 30
 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$
(380 – 780 nm)

Chlorogloeopsis fritschii PCC 6912



FaRLiP user

Synechocystis sp. PCC 6803

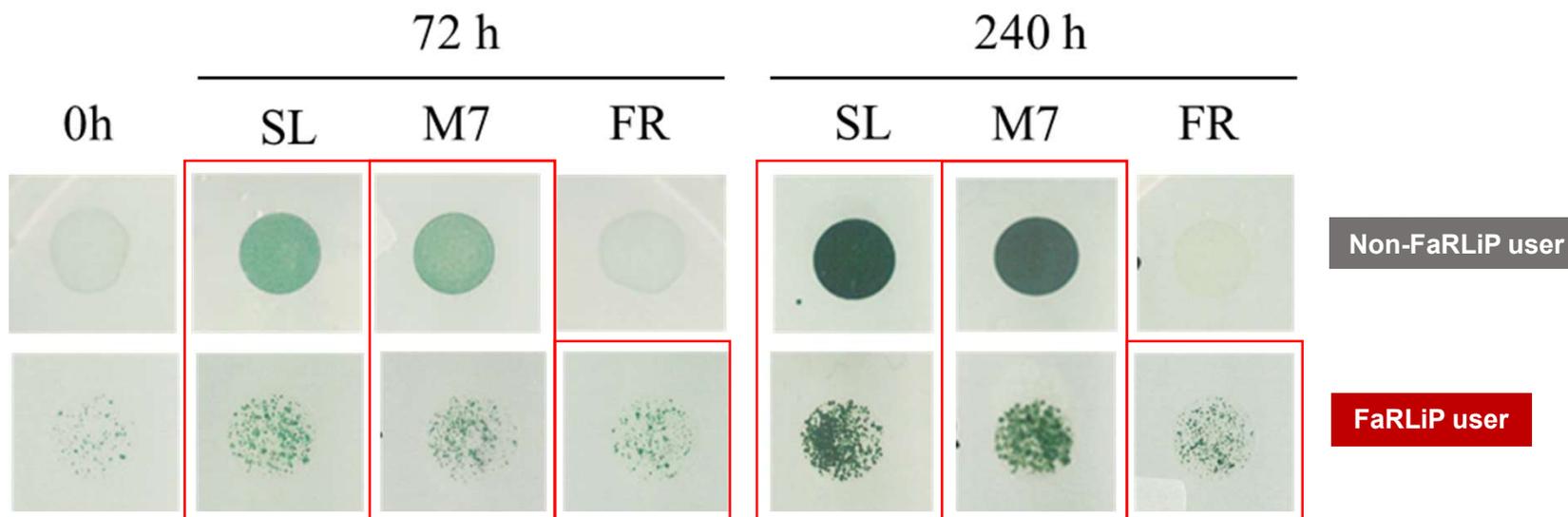


Non-FaRLiP user

P,T constant

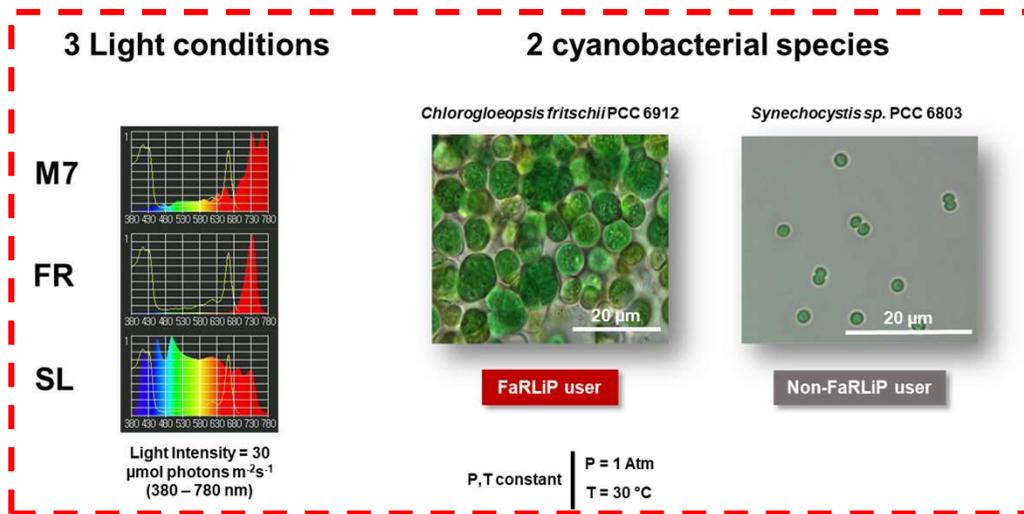
P = 1 Atm (Terrestrial atmospheric composition)
T = 30 °C

Growth on solid media



Claudi et al, submitted

Cyanobacteria grow in simulated SL and M7 conditions similarly



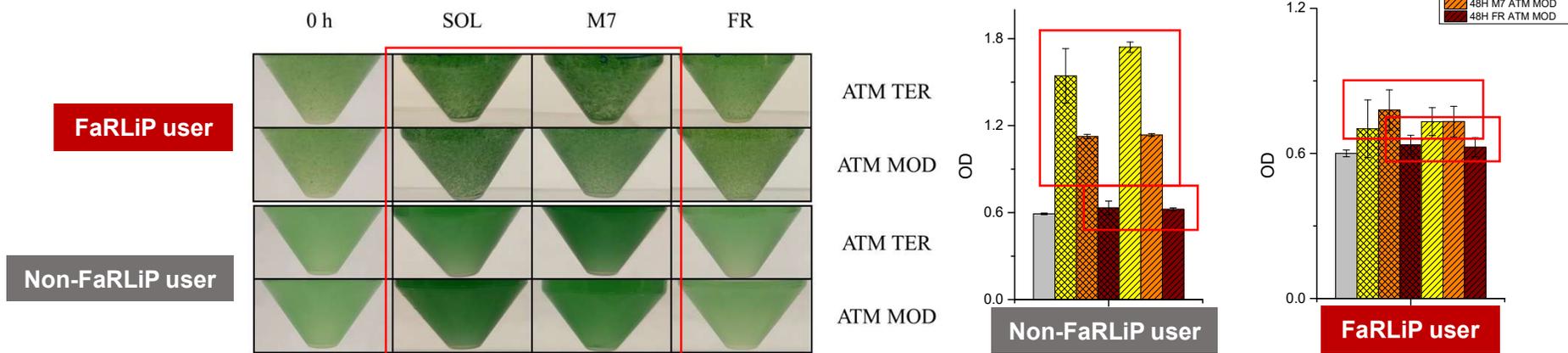
2 atmospheric conditions

Terrestrial-like atmosphere enriched in CO₂
75 % N₂, 20 % O₂, 5 % CO₂

Primeval atmosphere
95 % N₂, 5 % CO₂

Physiological measurements

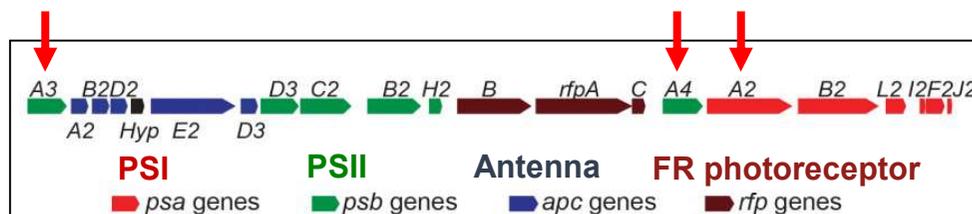
- Optical density (cell concentration measurement)
- Photosynthetic pigment content (Chl a concentration)
- Biomass



All tested conditions of atmosphere and light (except FR) favored cyanobacterial growth

...and at a molecular level?

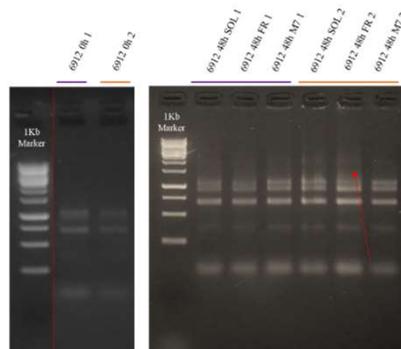
Molecular analysis



Sample recovery



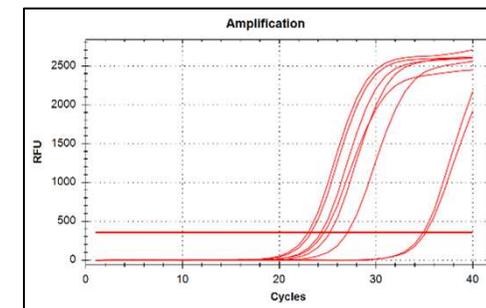
RNA extractions



qRealTime PCR



Data analysis



Survival and Growth of Oxygenic Photosynthetic Organisms is **possible under M7** light conditions and primeval atmospheres, **with or without** specific far-red **adaptations**

| |
|--|
| |
| |
| |

- **Complete molecular biology analysis**
- **Test a wider amount of atmospheres**
- **Collect the results in a database to be shared with the astro-community**

1222-2022
800
ANNI



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Publication Record



Papers:

M. Battistuzzi; L. Cocola; B. Salasnich; M.S. Erculiani; E. Alei; T. Morosinotto; R. Claudi; L. Poletto; N. La Rocca (2020); "A New Remote Sensing Based System for the Monitoring and Analysis of Growth and Gas Exchange Rates of Photosynthetic Microorganisms Under Simulated Non-Terrestrial Conditions"; *Front. Plant Sci.* 11:182;

S. Onofri; N. Balucani; V. Barone; P. Benedetti; D. Billi; A. Balbi; J.R. Brucato; B. Cobucci-Ponzano; G. Costanzo; N. La Rocca; M. Moracci; R. Saladino; G. Vladilo and the OPSS Project Team* (***M. Battistuzzi** included here) (2020); "The Italian National Project of Astrobiology—Life in Space—Origin, Presence, Persistence of Life in Space, from Molecules to Extremophiles"; *Astrobiology* 20(5):580-582;

M. Battistuzzi; R. Claudi, A.C. Pozzer, A. Segalla, D. Simionato, M.S. Erculiani, L. Coccola, L. Poletto, B. Salasnich, T. Morosinotto, N. La Rocca "M dwarf light simulated conditions support the growth and photosynthetic activity of cyanobacteria"; (In preparation, 2020);

R. Claudi, L. Poletto, E. Alei, **M. Battistuzzi**, L. Cocola, M.S. Erculiani, A.C. Pozzer, B. Salasnich, D. Simionato, V. Squicciarini and N. La Rocca; "Super Earths, M-dwarfs and photosynthetic organisms: habitability in the lab"; *Life* (Submitted, 2020);

N. Fattore, **S. Savio**, **M. Battistuzzi**, I. Moro, N. La Rocca and T. Morosinotto; "Regulation of electron transport plays a major role in regulation of photosynthesis in mesophilic red alga *Dixoniella giordanii*"; *Physiologia Plantarum* (Submitted, 2020);

Oral Presentations:

M. Battistuzzi; L. Cocola; C. Pozzer; D. Simionato; A. Segalla; T. Morosinotto; L. Poletto; R. Claudi; **N. La Rocca**; "Studying photosynthesis under Far-Red light and simulated M-dwarf star light: new experimental tools and suitable eukaryotic organisms with different positions in the tree of life", 1st Italian Space Agency workshop on Astrobiology – Online, 27-29 October 2020;

M. Battistuzzi; L. Cocola; R. Claudi; E. Alei; L. Poletto; T. Morosinotto; N. La Rocca; "Calibration and validation of an experimental setup to study by remote sensing cyanobacteria responses under exo-Earth simulated environments" General Assembly of the European Astrobiological Institute – Liblice, Czech Republic, 28-30 May 2019;

M. Battistuzzi; L. Cocola; R. Claudi; E. Alei; L. Poletto; T. Morosinotto; N. La Rocca; "An innovative setup to investigate by remote sensing growth and photosynthetic performances of cyanobacteria exposed to exo-earths simulated environments" XV Congresso Nazionale di Scienze Planetarie – Firenze, Italy, 4-8 February 2019;

M. Battistuzzi; R. Claudi; L. Cocola; E. Alei; L. Poletto; N. La Rocca; "An experimental setup to study by remote sensing analyses cyanobacteria growth and photosynthetic performances under non-terrestrial simulated environments", EANA2018 – Berlin, Germany, 24-28 september 2018.

R. Claudi; N. La Rocca; L. Poletto; E. Alei; **M. Battistuzzi**; L. Cocola, E. Pace; B. Salasnich; "M Dwarfs, Super Earths and photosynthetic bacteria: a mix for laboratory studies", European Planetary Science Congress 2018 – TU Berlin, Germany, 16-21 September 2018;

N. La Rocca; R. Claudi; L. Poletto; **M. Battistuzzi**; L. Cocola; E. Alei; B. Salasnich; T. Morosinotto; "Photosynthesis under Red Dwarf star light: exploring the limits of PAR radiation", 12th International Congress of Extremophiles – Ischia, Italy 16-20 September 2018;

R. Claudi; N. La Rocca; L. Poletto; E. Alei; **M. Battistuzzi**; L. Cocola; S. Erculiani, E. Pace; B. Salasnich; "Super Earths, M-Stars and Photosynthetic Bacteria", XIV Congresso Nazionale di Scienze Planetarie – Bormio (SO), Italy, 5-9 February 2018;

Posters:

M. Battistuzzi; A.C. Pozzer; D. Simionato; A. Segalla; L. Cocola; M.S. Erculiani; T. Morosinotto; L. Poletto; R. Claudi; N. La Rocca; "Is Far-Red Light Photoacclimation (FaRLiP) activated in cyanobacteria exposed to M-dwarf starlight simulated spectra?"; Department of Biology 4th Scientific Retreat – Padova, Italy, 3-4 February 2020;

M. Battistuzzi; L. Cocola; R. Claudi; E. Alei; L. Poletto; T. Morosinotto; N. La Rocca; "Calibration and validation of an experimental setup to study by remote sensing cyanobacteria responses under exo-Earth simulated environments" SBI-SIBV 2019 JOINT CONGRESS – Padova, Italy, 4-5 September 2019;

M. Battistuzzi; L. Cocola; R. Claudi; E. Alei; L. Poletto; T. Morosinotto; N. La Rocca; "An experimental setup to study by remote sensing analyses cyanobacteria growth and photosynthetic performances under non-terrestrial simulated environments"; Department of Biology 3rd Scientific Retreat – Padova, Italy, 30 January – 1 February 2019;

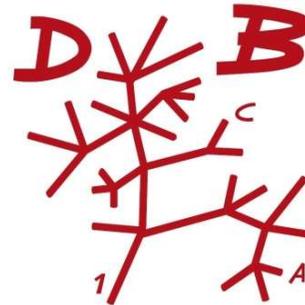
M. Battistuzzi; R. Claudi; L. Cocola; E. Alei; L. Poletto; N. La Rocca; "An experimental setup to study by remote sensing analyses cyanobacteria growth and photosynthetic performances under non-terrestrial simulated environments"; EANA2018 – Berlin, Germany, 24-28 september 2018.

M. Battistuzzi; M. Niero; L. Pedroletti; A. Segalla; F. Zito; B. Miroux and **E. Bergantino**; "Testing Synechocystis thylakoids as stores for recombinant membrane proteins", 10th european workshop on the molecular biology of cyanobacteria - Cluj-Napoca, Romania, 20-24 august 2017.

Aknowledgments



Lorenzo Cocola
Luca Poletto

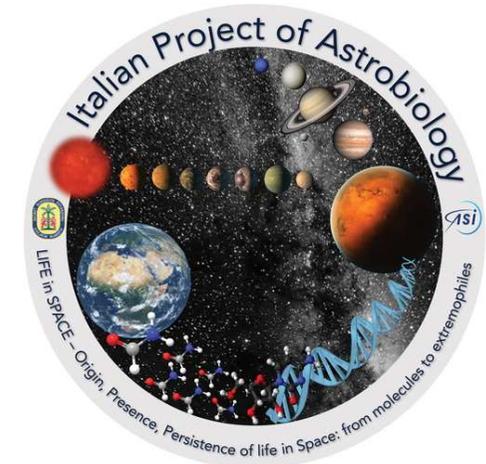


DIPARTIMENTO DI BIOLOGIA
UNIVERSITÀ DEGLI STUDI DI PADOVA

Nicoletta La Rocca
Tomas Morosinotto
Livio Trainotti



Riccardo Claudi
Bernardo Salasnich



Thanks for the attention

1222·2022
800
ANNI



UNIVERSITÀ
DEGLI STUDI
DI PADOVA