# Is Far-Red Light Photoacclimation (FaRLiP) activated in cyanobacteria exposed to M-dwarf starlight simulated spectra?

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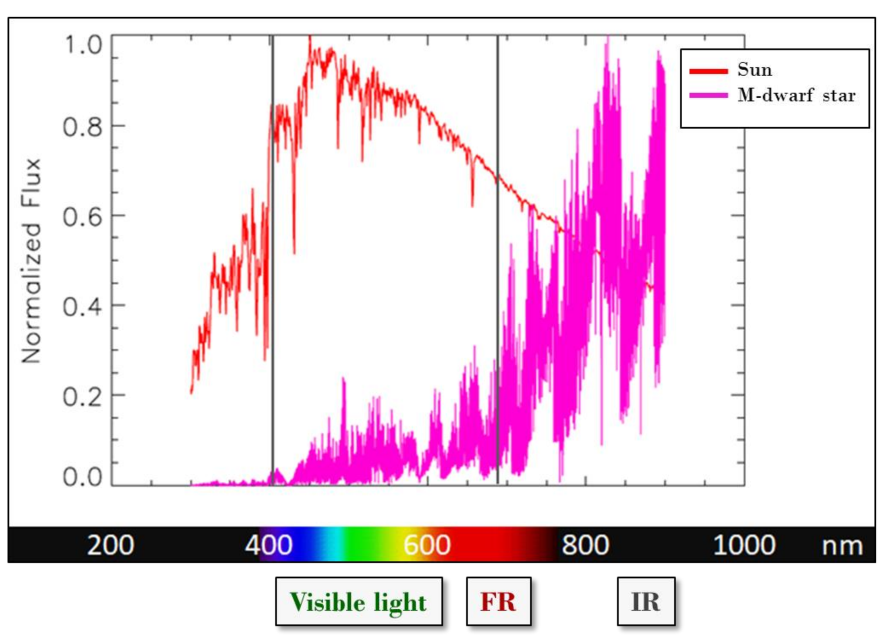
## Abstract

Recently, several Earth-like exoplanets were found orbiting the Habitable Zone of their host stars. Many of these planets orbit around M-dwarf stars, the most abundant and long-lived stars known in the Milky Way, making them ideal to potentially harbor life [1]. However, such stars have different spectral characteristics respect to stars like our Sun: they are less luminous, and their spectrum is shifted towards longer wavelengths, with major components being far-red and infrared lights, while very little is emitted in the visible part of the spectrum. These characteristics don't seem suitable for oxygenic photosynthetic organisms we know from Earth, that evolved to absorb only VIS light. Many researchers discussed the possibility of oxygenic photosynthesis in these worlds so far [2,3,4,5], but no experimental research as been done testing organisms under simulated M-dwarf spectra. A collaboration between the Department of Biology, the Astronomical Observatory (INAF) and the Institute of Photonics and Nanotechnology (IFN-CNR) led to the construction and development of a Star Light Simulator, an instrument able to simulate the emission spectra of different kinds of stars (Sun and M-dwarfs included) [6,7,8]. With this innovative instrument, we were able to perform growth and photosynthetic analyses on a few species of cyanobacteria irradiated with solar and M-dwarf simulated lights.

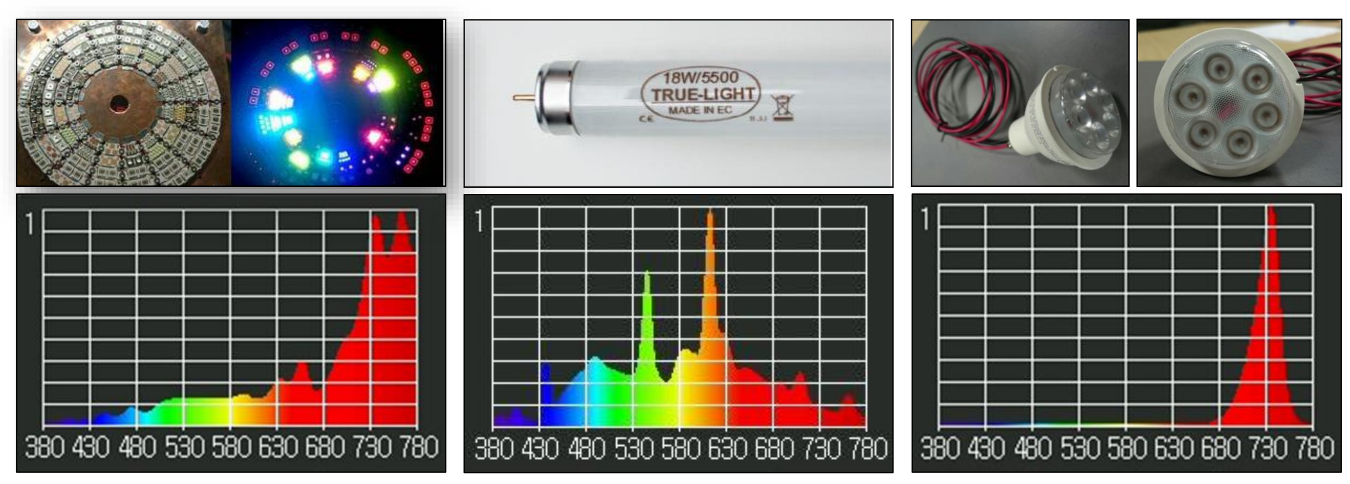
We have chosen cyanobacteria as our target microorganisms, as they possess extraordinary capacities of adaptation and demonstrated to be able to withstand every kind of environment on the Earth and beyond [9]. Moreover, they were the organisms that evolved the oxygenic photosynthesis in a primordial Earth that was much more inhospitable than it is now. Finally, few years ago, they were found a handful species able to perform the so called Far-Red Light Photoacclimation (FaRLiP), that allows them to survive and evolve oxygen in environments rich in far-red light, thanks to the production of special chlorophylls (chl *d* and *f*) and far-red absorbing forms of phycobiliproteins [10], that absorb light above 700 nm. This is extremely interesting in the contest of astrobiology, as they are the perfect candidates to test the possibility of oxygenic photosynthesis in exoplanets irradiated by M-dwarf spectra.




Comparison of the emission spectrum of an M-dwarf star and of the Sun.

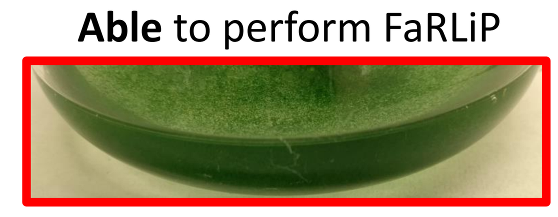
## Selected light spectra

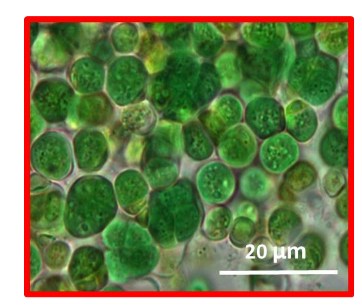
M-Dwarf light (M7L) | Solar light (SL) | 730 nm light (FRL)



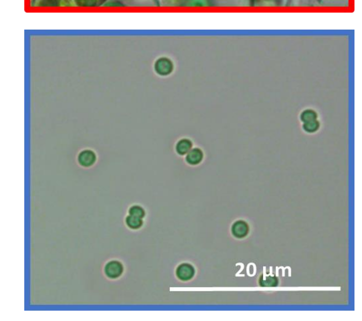
## Selected cyanobacteria

***Chlorogloeopsis fritschii* PCC6912**
**Able** to perform FaRLiP



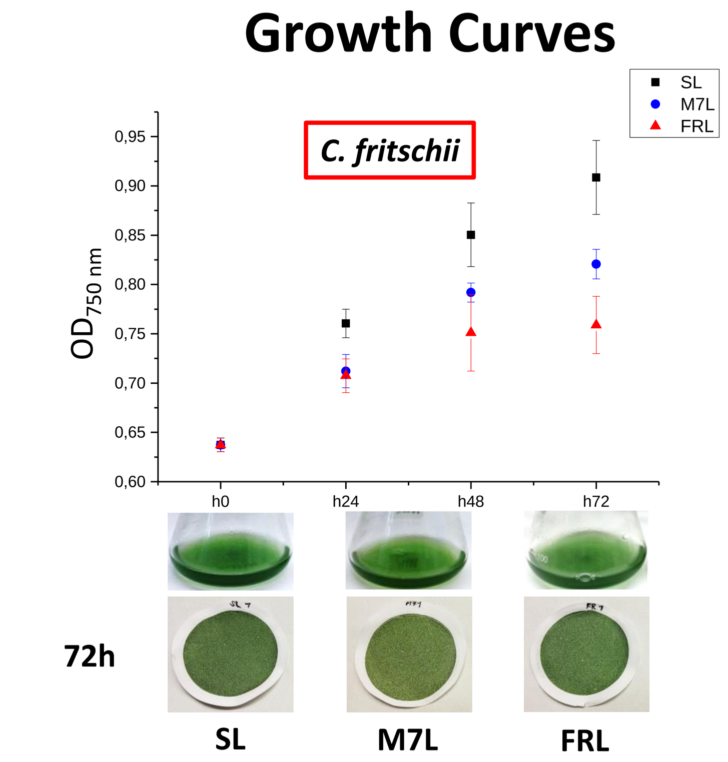


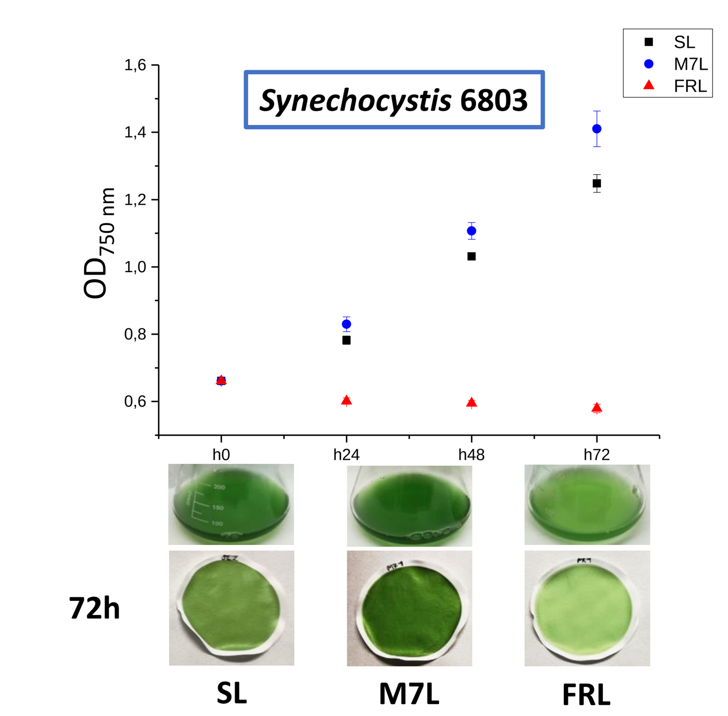
***Synechocystis sp.* PCC6803**
**Unable** to perform FaRLiP



## Results

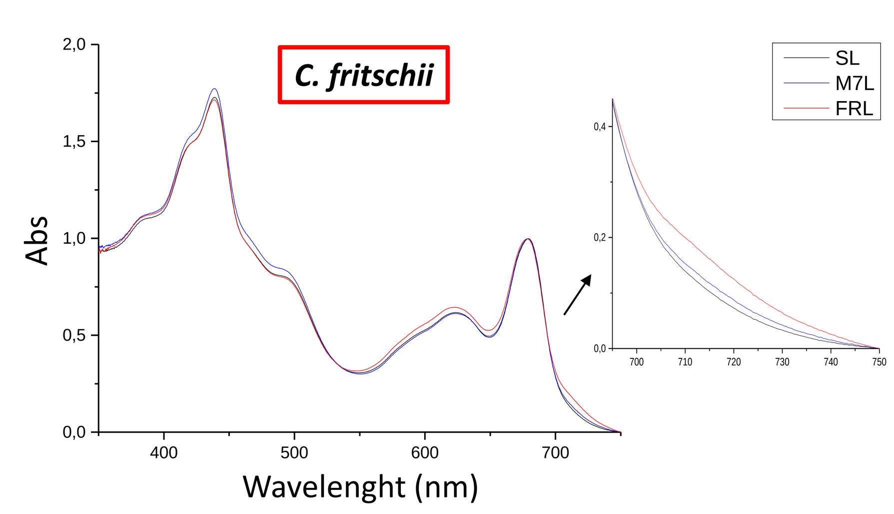
### Growth Curves



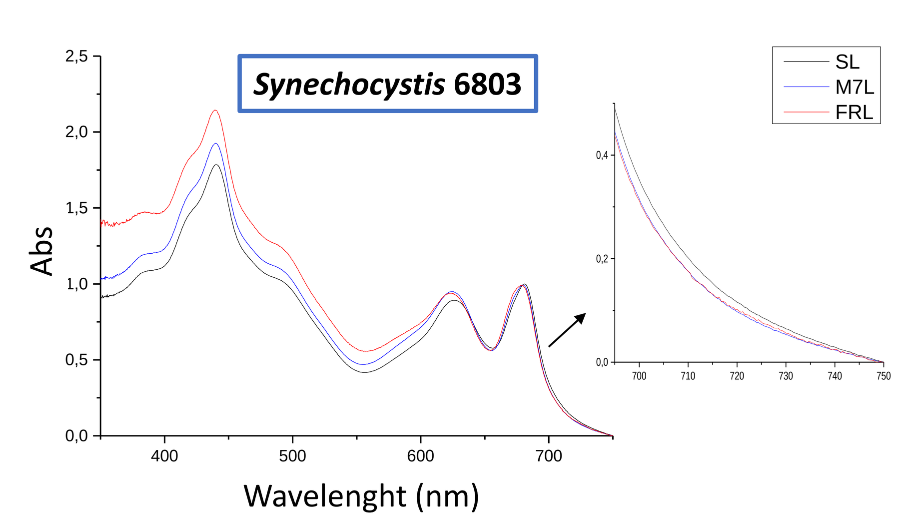




Both strains grow under M7L spectrum. *C. fritschii* cells grow (slowly) under FRL thanks to FaRLiP activation. No growth can be seen for *Synechocystis sp.* cells in FRL as expected.

### *In vivo* absorption spectra

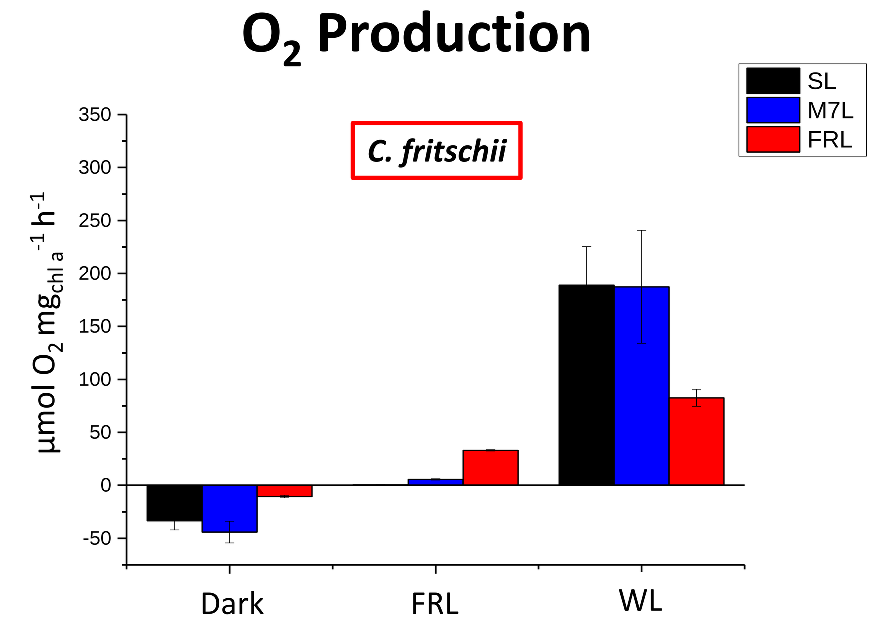



In *C. fritschii* no FaRLiP activation (shoulder above 700 nm) can be seen under SL and M7L spectra. FaRLiP is activated in FRL as expected.

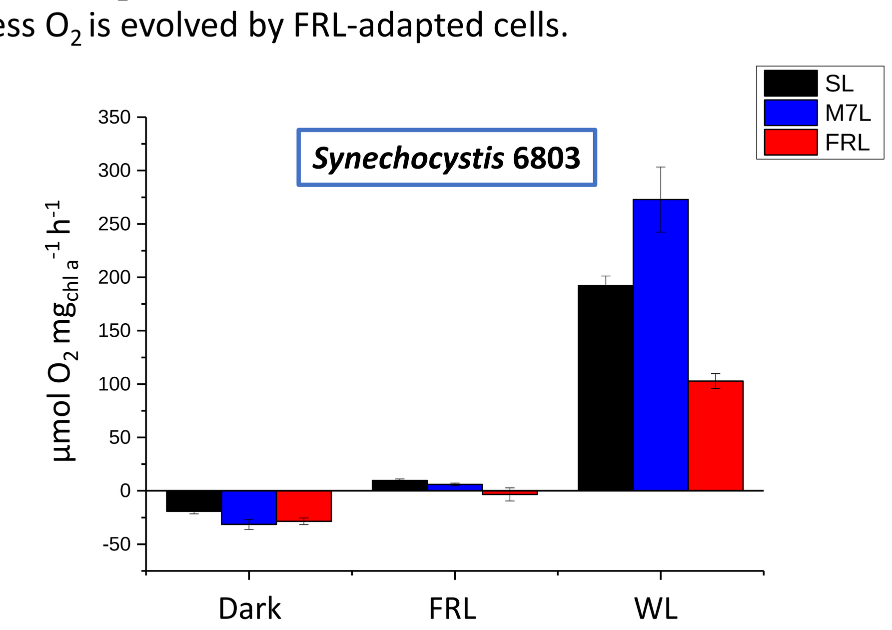



Pigment composition of *Synechocystis sp.* doesn't change in the three light conditions tested.

### $O_2$ Production

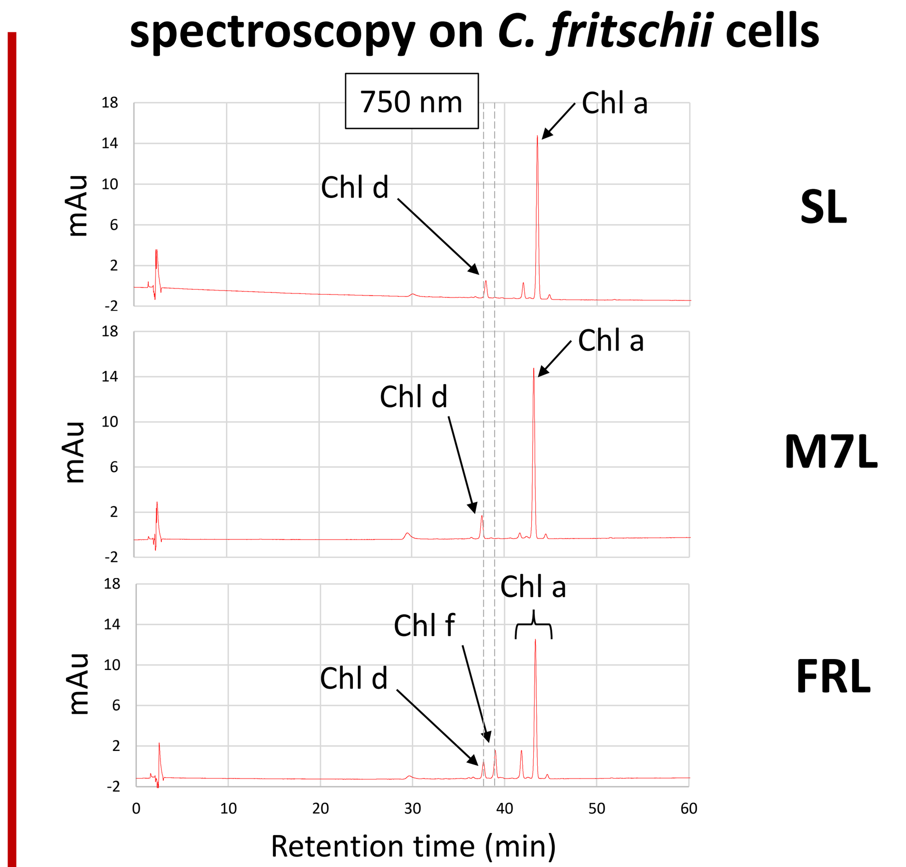



Only FRL-adapted *C. fritschii* cells are able to evolve significant amounts of $O_2$ if irradiated with a far red light source (FRL). Cells adapted to every spectra are able to evolve $O_2$ if irradiated with a white light source (WL), but less $O_2$ is evolved by FRL-adapted cells.

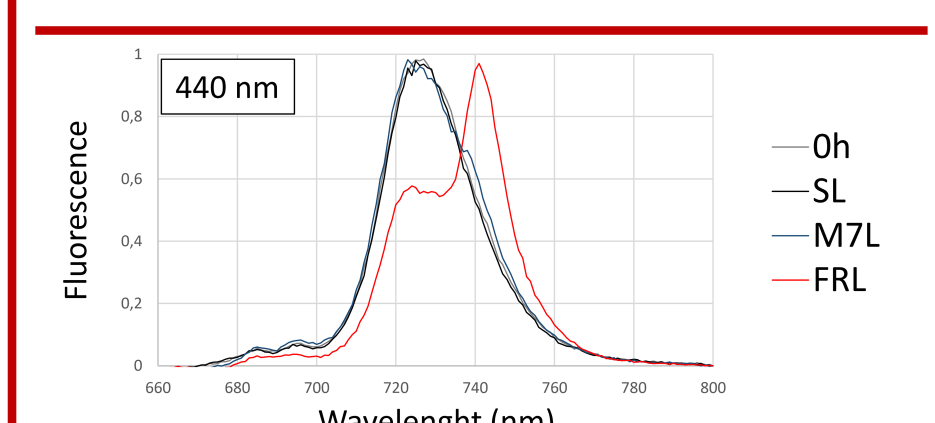



*Synechocystis sp.* cells are not able to evolve $O_2$ if irradiated with a FRL source, however they are able to do it if irradiated with a WL source. $O_2$ evolved is higher for M7L-adapted cells than for SL-adapted ones; lesser $O_2$ is evolved by FRL-adapted cells.

### HPLC Analyses and 77 K fluorescence spectroscopy on *C. fritschii* cells




Chl *d* is detected through HPLC in all conditions. Chl *f* is detected only in FRL-adapted cells.




FRL-adapted cells present a peak of fluorescence emission shifted up to 740 nm due to the synthesis of Chl *f*; M7L and SL-adapted cells don't show this shift.

## Conclusion

Growth curves and $O_2$ evolution data confirm that both strains are able to grow and photosynthesize when irradiated with an M-dwarf simulated light (M7L) spectrum; surprisingly, *Synechocystis sp.* cells grow at a higher rate under an M-dwarf simulated light spectrum than under a Solar light simulated one, the reason of this is still under investigation. As pigment analyses confirmed, FaRLiP response never triggered in M-dwarf-adapted cells of *C. fritschii*, but do triggered in FRL-adapted cells. We hyphotesize that the visible portion of the M-dwarf spectrum is more than sufficient to allow the growth and photosynthetic activity of the cyanobacteria. In particular, *C. fritschii* cells don't activate the FaRLiP response to exploit the additional light above 700 nm that a M-dwarf spectrum provides.

To confirm this assumption, 72 h growth experiments on *C. fritschii* irradiated with an M-dwarf simulated spectra depleted in the visible portion of the light (300-700 nm) are on-going, to check wheter or not the FaRLiP response is activated under this spectrum.

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