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Is there life on Earth?

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Abstract. Earth is the only planet known to be saturated with life since billions of years. Micro-organisms, viruses, fungi and DNA fragments have been found in the Earth atmosphere at various altitudes. Can those manifestations of life be detected from their interactions with the sun light? In other words, would far observers be able to detect the presence for instance of DNA in the Earth atmosphere through spectroscopic observations? Inversely, could a terrestrial observer detect life manifestations in the atmosphere of an exoplanet? Before thinking of life detection on another planet, the first step is to verify if life is detectable in the Earth atmosphere. In this context, laboratory experiments were performed by taking FT-IR spectra of different bacteria and of free DNA (damaged and not damaged). They were then compared with atmospheric spectra, taken from astronomical observations at high airmass in the same band width. First results are surprisingly interesting since a common pattern appear.

1. Introduction

When considering the whole terrestrial biodiversity (from microbes to plants and animals) it seems obvious that life has continuously and non-negligibly "polluted" our planet since at least 3.8 Gyr (Mojzsis et al. 1996; Dodd et al. 2017). Life on planet Earth is ubiquitous, particularly the microbial one, and wherever a sample of material is taken (liquid, solid or gaseous), the presence of living material or at least organic decomposed material - i.e., of biological residues - is found inside rocks, in the sea and in the atmosphere. Specifically, DNA molecules and their residues have also been collected in the terrestrial atmosphere (Wainwright et al. 2015).

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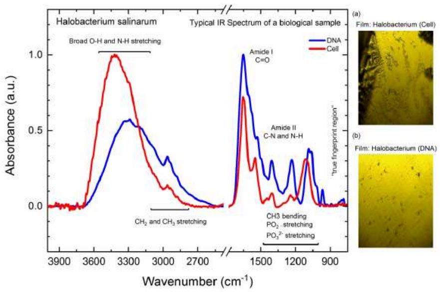

Fig. 1. Spectra of purified DNA and suspended cells of Halobacterium salinarum from microfilms of (a) whole cells or (b) purified DNA.

2. Bio-samples

The halophilic microorganism H. salinarum was selected as the biological source for this study because its robustness and previous detection in Earth's atmosphere (Maki et al. 2008). Strain NRC-1 was grown in hypersaline CM media (Robb et al. 1995), in a water bath incubator at 37°C with agitation at 125 rpm. Reference samples were cultured under standard growth conditions (Baliga & DasSarma 1999), at mid-log phase (OD600nm=0.5). Total DNA was isolated using DNeasy Blood and Tissues kit (Qiagen) following manufacturer's protocol for Gram negative bacteria.

We performed samples of:

- in vivo DNA : bacteria, extremophiles
- ex-vivo DNA: extracted and purified DNA
- sample with different concentration of DNA
- UV altered DNA

3. FT-IR spectra

The spectra of the extremophilic microorganism Halobacterium salinarum and of its purified DNA were taken by means FT-IR spectroscopy techniques combined with a microscope (see Figures 1 and 2). The advantage of this technique is that spectra can be obtained from a single point or from a 2D image of the sample (Clarke et al. 2002). The spectral resolution yielded by the instrumentation was 4 cm^{-1}.

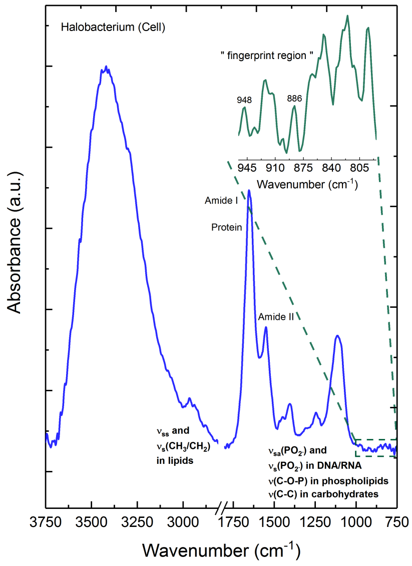

Fig. 2. Zoom on the fingerprint of the DNA.

4. Atmosphere spectrum

In order to integrate as much atmospheric bands as possible, data were collected under the highest available airmass i.e. 2.55, corresponding to roughly 30 km of atmospheric layer.

Data have been collected from European Southern Observatory archive (http://archive.eso.org/cms.htm). Chose instrument is VLT Imager and Spectrometer for mid Infrared (VISIR). We selected Low-resolution spectral yielding an observed region from 8 to 13 microns ($\simeq$ 770 to 1250 cm^{-1}) centered at 10.42 microns (959.69 cm^{-1}). Data reduction has been performed with the ESO-Reflex package (http://www.eso.org/sci/software/esoreflex/) using the Kepler workflow (https://kepler-project.org/).This package allows extraction and wavelength calibration of the target spectrum and remove the sky background. It is precisely this "sub-product" of the reduction package that was used to establish the 1D wavelength-calibrated atmospheric spectra (see Fig. 3). Lab and VISIR spectra were degraded to the same resolution.

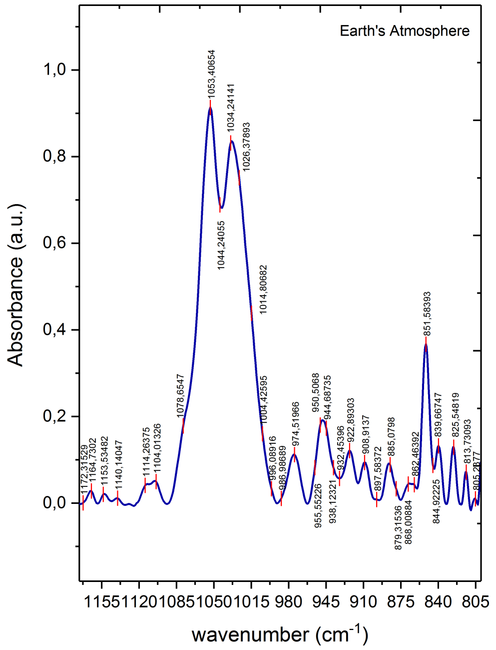

Fig. 3. The extracted 1D spectrum.

Table 1. Common spectral feature in atmosphere, purified DNA and cells

Assignment in DNA	Atmosphere	Purified DNA	Whole cell
Asymmetric stretching PO2 (1080)	1084	1086	1088
Z-DNA marker band (1018-1014)	1018		1018
RNA uracil whole ring motions (996)	996		996
DNA ribose-PO2- skeleton motions (970)	966	966	966
RNA ribose-phosphate skeleton motions (915)	918	915	912
A- and B-DNA motions (899-894)	888	900	900 893
B-DNA motions (840-830)	840 831	842 832	834

5. Results

We he used second derivative techniques to identify common feature both in sky and laboratory spectra. Specific DNA functional groups have been also detected in the atmospheric spectrum according to the spectra resolution (see Table 1).

6. Conclusions

We have developed an end to end strategy to check if we would be able to detect the bio signature in the terrestrial atmosphere by means of spectroscopic techniques. By comparing the lab spectra of bio cell and free DNA samples with on sky atmosphere spectrum in the same range of wave number, we are able to point out some common features which are encouraging to pursue our studies. Further work is planed such as:

– compare other sky spectra from different locations and different airmass
– make atmospheric balloon campaigns to collect bio cells in the atmosphere to quantitatively estimate the amount of bio molecules in order to derive the signal to noise ratio necessary for the detection on other targets than Earth.

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