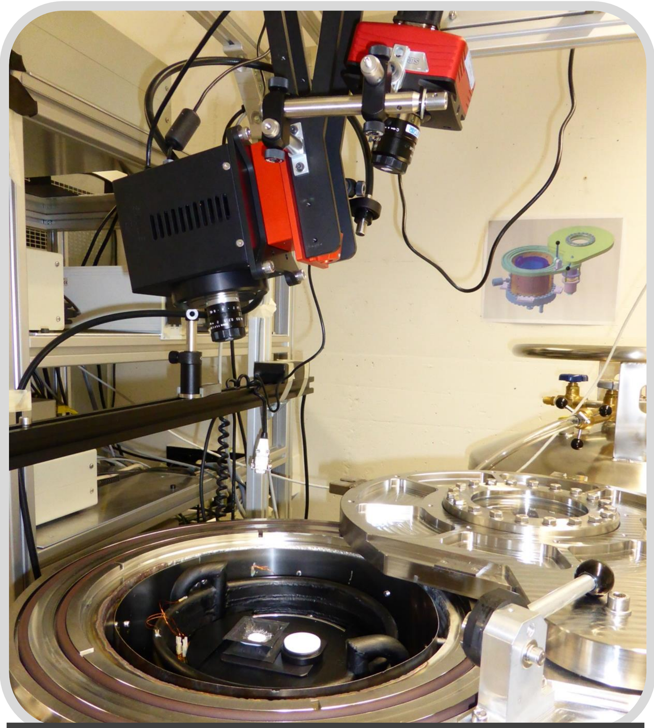
Laboratory insights into the detection of surface biosignatures by remote-sensing techniques

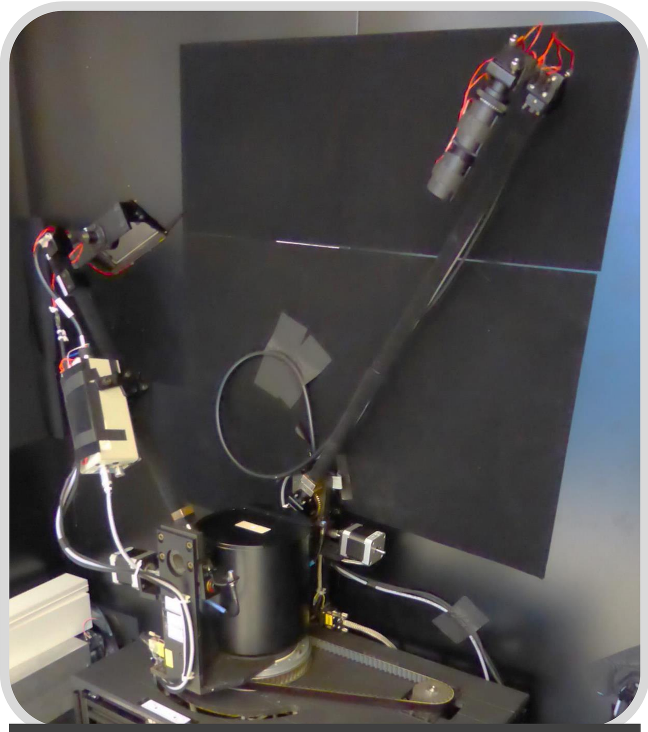
Olivier POCH[1], Antoine Pommerol[2], Bernhard Jost[2], Isabel Roditi[3], Joachim Frey[4], and Nicolas Thomas[2]

[1] **Center for Space and Habitability**, University of Bern, olivier.poch@csh.unibe.ch / [2] **Physikalisches Institut**, University of Bern
[3] **Institut für Zellbiologie**, University of Bern / [4] **Institut für Veterinär-Bakteriologie**, University of Bern

Context - With the progress of direct imaging techniques, it will be possible in the short or long-term future to retrieve more efficiently the information on the physical properties of the light reflected by rocky exoplanets. The search for visible-infrared absorption bands of peculiar gases (O_2, CH_4 etc.) in this light could give clues for the presence of life. Even more uplifting would be the direct detection of life itself, on the surface of an exoplanet. Considering this latter possibility, what is the potential of optical remote-sensing methods to detect surface biosignatures?

Spectro-photometric measurement setups:


hyperspectral images

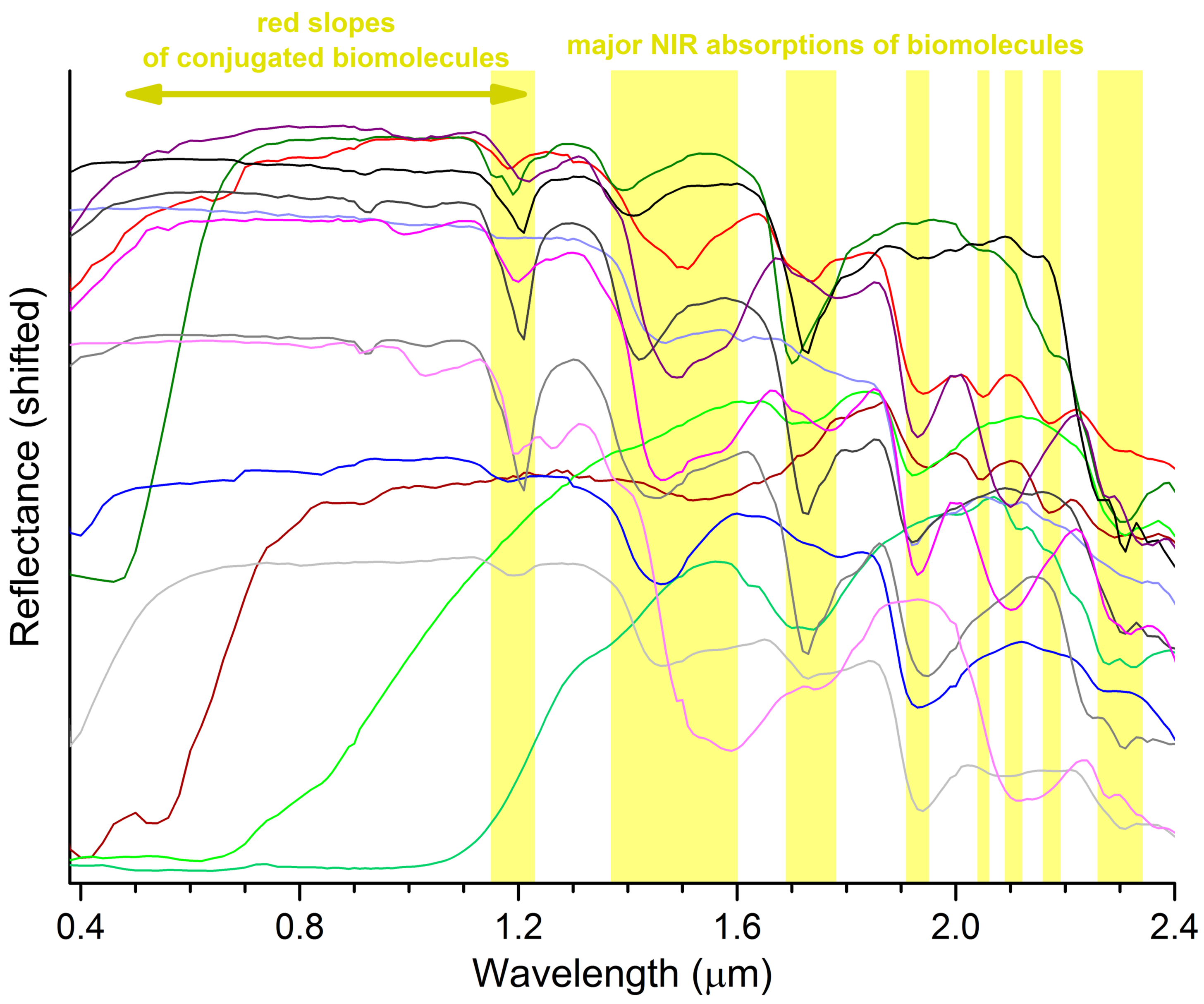

bidirectional reflectance

In this context, we have begun a laboratory study aiming at precising the potentiality of remote sensing techniques in detecting surface biosignatures.

Using equipment that has been developed in our team for surface photometry studies (see pictures on the left), we aim to investigate the Vis-NIR reflectance spectra and bidirectional reflectance function of soils containing biochemicals or primitive cyanobacteria, in various environmental conditions. We also plan to extend the capabilities of our setup to performed circular polarization measurements, because it can be a marker of homochirality which is supposed to be a universal property of life. Our other activities in the lab are dedicated to the study of the spectro-photometric properties of analogs of planetary or cometary surfaces containing ices mixed with minerals and abiotic organics.

In this poster, we present preliminary results concerning the Vis-NIR reflectance of examples of the most abundant biomolecules, enabling us to identify the major Vis-NIR absorption bands of biomolecules, prior to the analysis of whole bacteria.

We have measured the Vis-NIR reflectance spectra of some examples of the most abundant molecules of life on Earth:



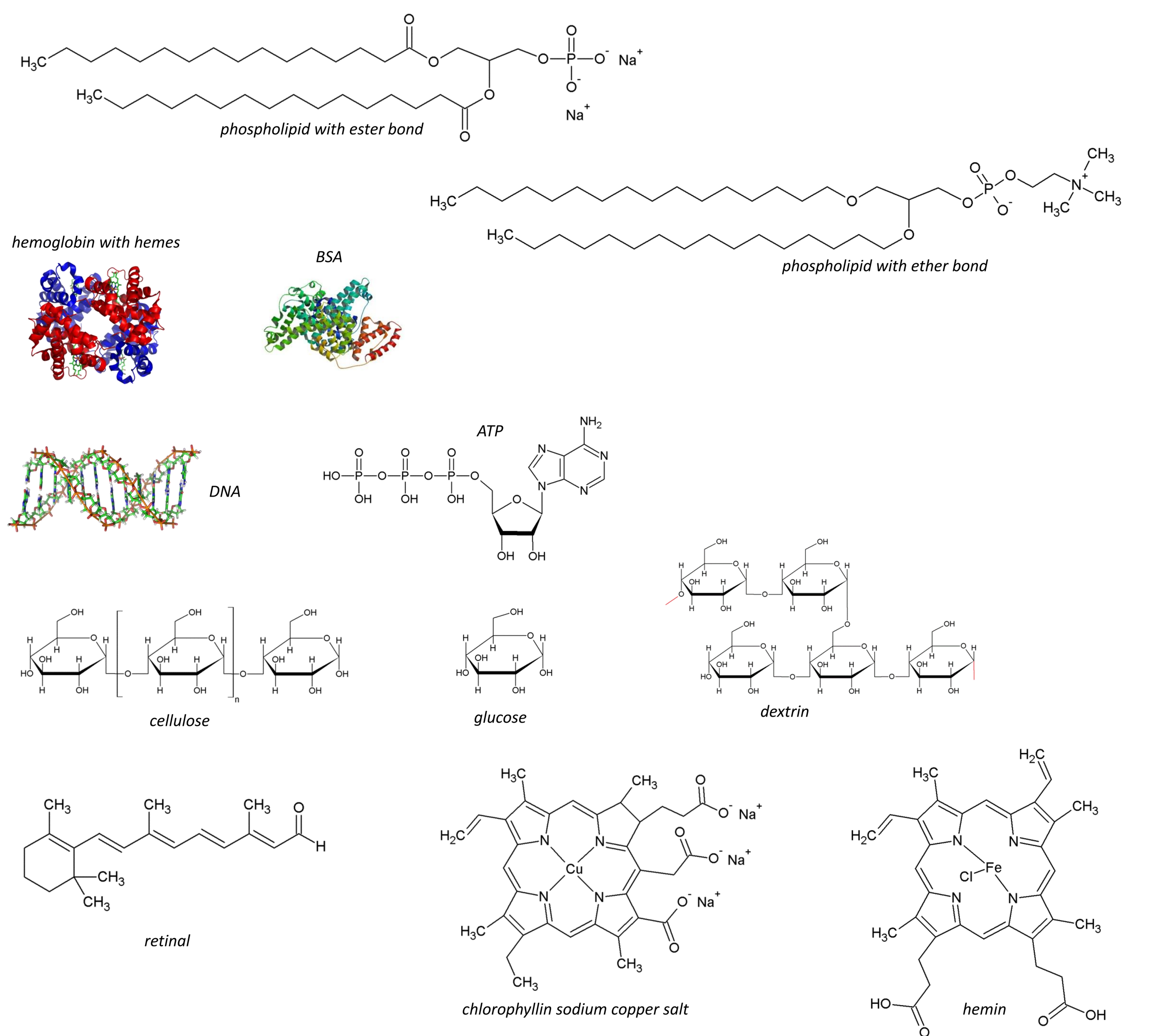
Phospholipids
- 1,2-dipalmitoyl-rac-glycero-3-phosphocholine
- 1,2-dipalmitoyl-rac-glycero-3-phosphatidic acid disodium salt
- 1,2-dihexadecyl-rac-glycero-3-phosphocholine
- lipopolysaccharides (LPS from E. coli)

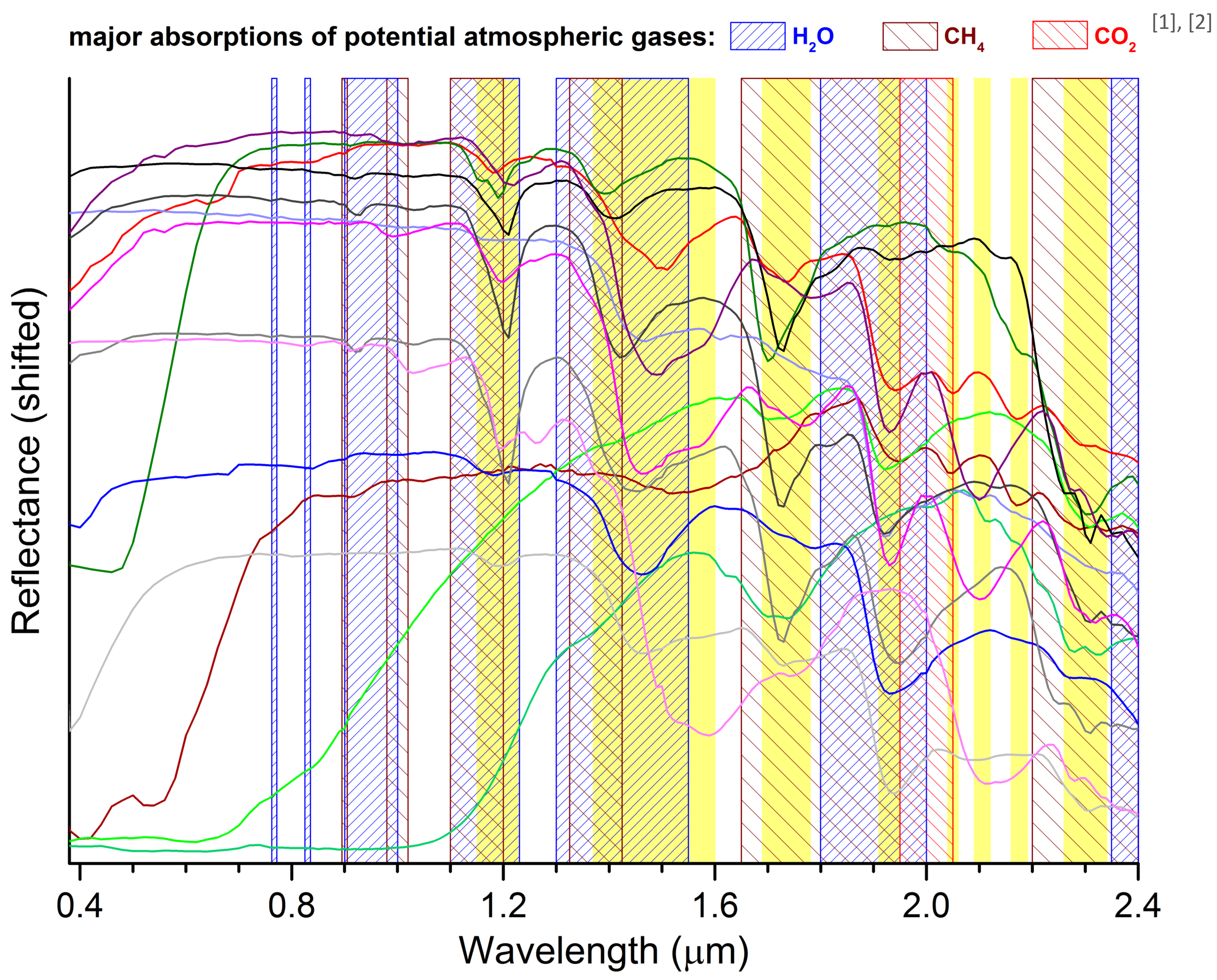
Proteins
- bovine serum albumin (BSA)
- hemoglobin with hemes

DNA, ATP
- DNA (sodium salt, from calf thymus)
- adenosine 5-triphosphate (ATP)

Carbohydrates
- cellulose
- dextrin
- glucose

Pigments
- chlorophyllin sodium copper salt
- hemin
- retinal





The measurements were carried out at ambient temperature and pressure, on the dry powder of the biomolecules purchased from Sigma-Aldrich and Bachem, using an hyperspectral imaging system (picture above) composed of a MCT camera (0.84-2.40 µm), a CCD camera (0.38-0.84 µm) and a monochromator.

The obtained reflectance spectra (upper figure on the left) show absorptions in the near infrared due to combination tones and overtones of mainly C–H, O–H and N–H stretching modes. C–H absorptions are observed for all type of molecules, but are stronger for phospholipids and polysaccharides. O–H absorptions are also observed, especially for carbohydrates around 2.1 µm. Peptide bonds in proteins give characteristic combination bands at 2.05 and 2.17 µm. Finally, pigment molecules (porphyrins and retinal) give strong absorptions in the visible, in the form of red-slopes, due to electronic transitions in their molecular orbitals. The table below offers a more detailed analysis.

The lower figure on the left shows the Vis-NIR wavelength ranges of interest (yellow) when searching for biomolecules, coupled with the absorption ranges of atmospheric H_2O, CH_4 and CO_2 (stripes). When looking through an atmosphere of a potential Earth-like exoplanet containing these gases, the ranges of interest are fewer. However, in the case of an icy planet lacking a dense atmosphere, all the yellow ranges can be potentially investigated, for instance for their degree of circular polarization.

Major visible and near-infrared absorption ranges of terrestrial biomolecules:

Wavelength	0.4-1.4	1.15-1.23	1.37-1.6	1.69-1.78	1.91-1.95	2.05	2.1-2.12	2.17	2.26-2.34
Most absorbing molecules in this range	pigments	phospholipids, carbohydrates, (DNA), (proteins) H_2O	carbohydrates, phospholipids, DNA, proteins, H_2O	phospholipids, pigments, proteins, (DNA), (carbohydrates)	carbohydrates, DNA, proteins, phospholipids, H_2O	proteins	carbohydrates	proteins	phospholipids, pigments, carbohydrates, (DNA), (proteins)
Contributing group(s) [3]	–C=C–C=C– …	CH_3, CH_2, CH	O-H, CH_3, CH_2, NH	CH_3, CH_2, CH	O-H, C-O	NH, CO, -C(O)-NH-	O-H	NH, CO, -C(O)-NH-	CH_3, CH_2, CH, OH
Assignment [3]	e^- transitions in molecular orbitals	CH 2nd overtone	OH comb. + 1st overt., NH 1st overt., CH comb. + 1st overt.	CH 1st overtone	OH+CO combination, C=O 2nd overtone	NH+CO+peptide group combinations	OH combination	NH+CO+peptide group combinations	CH-CH and CH-OH combinations

References:

- [1] SCIAMACHY - Exploring the Changing Earth's Atmosphere, Manfred Gottwald, Heinrich Bovensmann, Springer, 2011
- [2] HITRAN 2004 via the *VPL Molecular Spectroscopic Database*, University of Washington,http://vpl.astro.washington.edu/spectra/
- [3] Practical Guide and Spectral Atlas for Interpretive Near-Infrared Spectroscopy, 2nd Edition, Jerry Workman, Jr., Lois Weyer, CRC Press, 2012

(credits of DNA and proteins images: Richard Wheeler, RCSB PDB)