Fluorescence Signatures and Detection Limits of Ubiquitous Terrestrial Bio-compounds

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Abstract – The measurements of fluorescence spectrum, lifetime and polarization are powerful methods of analysis in various fields of science [1]. Photometric technologies offer a repertoire of fast, simple and reliable identification and characterization methods for chemical compounds and microorganisms (sometimes in their natural environments) via their signatures. Biosignatures in general are defined as objects, substances and/or patterns whose origin requires a biological agent.

Finding appropriate criteria for recognizing, detection and comprehension of life phenomena is one of the "eternal" problems in astrophysics, geology, glaciology and marine ecology. From this perspective, a biosignature is a feature that is consistent with biological processes and that, when it is encountered, challenges to attribute either to inanimate or to biological processes. What is usually looked for are the compounds involved in the origin of life on Earth and the molecules considered essential for terrestrial biology: amino acids, amines, thiols and thioesters, biopolymers, aldehydes, ketones, carboxylic acids, fatty acids, fatty alcohols and polycyclic aromatic hydrocarbons [2].

Very suitable for this purpose is fluorescence spectroscopy, which is a type of electromagnetic spectroscopy that analyses fluorescence and primarily concerns with electronic and vibrational states of molecules. It allows quantitative measurements of an analyte in solution and provides information on dynamic processes on molecular environment and on dynamic processes down to the nanosecond timescale [3]. Among biopolymers, especially proteins are displaying strong intrinsic fluorescence due to the three aromatic amino acids phenylalanine, tyrosine, and tryptophan. Lipids, membranes, and saccharides are essentially nonfluorescent, and the intrinsic fluorescence of DNA is too weak to be useful [4].

Our approach primarily focused on fluorescence spectroscopy measurements of selected species of ubiquitous terrestrial bio-compounds as a model for future terrestrial and extraterrestrial applications. The main aims were (a) to verify that autofluorescence can be successfully used to differentiate between various biogenic compounds through identification of spectroscopic fingerprints and (b) to determine their minimal dilutions/concentrations that could be still detected. In the first part of this study we applied conventional fluorimetry by using spectrofluorimeter F8500 (Jasco Co.) to obtain cumulative spectra and intensities for bacteriorhodopsin, RNA, chlorophyll, histidine, ATP, NADH, tryptophan, phenylalanine, pyridoxine, riboflavin, arginine, alanine and FAD. The obtained results (partially presented in Figure 1) allowed determination of absorbance/emittance peaks characteristic for the examined molecular species. In the second part of our study we established detection thresholds for the compounds of interest.

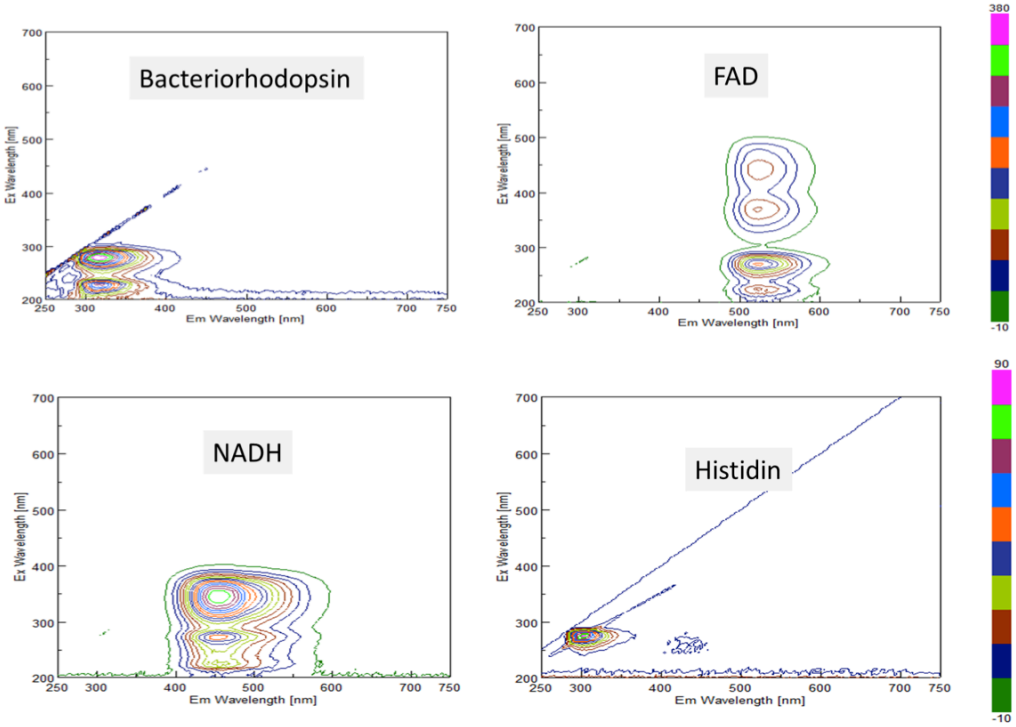

Fig.1: Emission/excitation diagrams showing the location of the corresponding peaks as illustrated by four different biological compounds. Differences in the peak distribution patterns are clearly visible

The information related to specific absorption/emission maxima will be used in designing and developing of compact LED-based fluorescence spectroscopy module that is supposed to be a part of the payload of the future autonomous sampling probes (for both terrestrial and space exploration missions).

References

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