Search for signs of life by means of ATR spectroscopy (experiment “MATROS”)

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MATROS

Microbiologic

Attenuated

Total

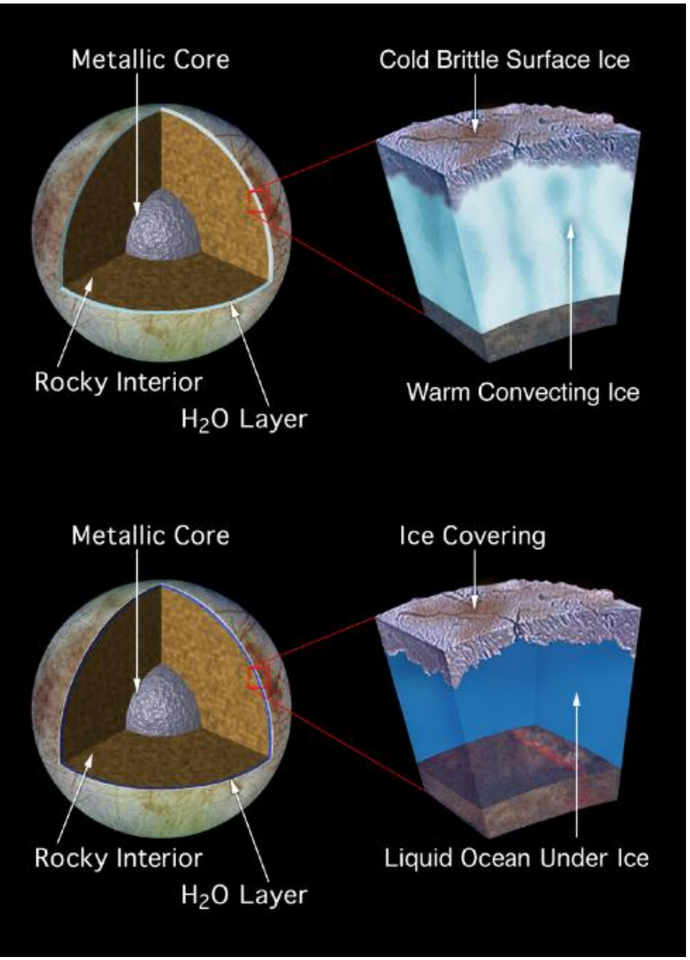
Reflection

Optical

Spectrometer

Space Research Institute	RAS
Biology faculty	Lomonosov Moscow State University
Soil Science faculty	Lomonosov Moscow State University
Institute for Spectroscopy	RAS

Objectives for Astrobiology



- Europa may have an sub-surface ocean and
it may be inhabited by Earth-like microbes
- Earth microorganisms in situ are proved to be very stable to radiation, low temperature, high pressure and other unfavorable factors present at Europa. Actually, the limits for cells surviving are not known yet.
- Fast freezing doesn't destroy bacterial cells, they transit to anabiotic state. Therefore, in frozen outbursts on Europa microorganisms may be present (at about 0.5m depth)

Objectives for methodology

- **Possibility of direct express in-situ analysis**
- **Method's multifunctionality**
- **Possibility of hardware operation at Europa surface environment**
- **Duration of the experiment must fit to spacecraft life time**

ATR spectroscopy

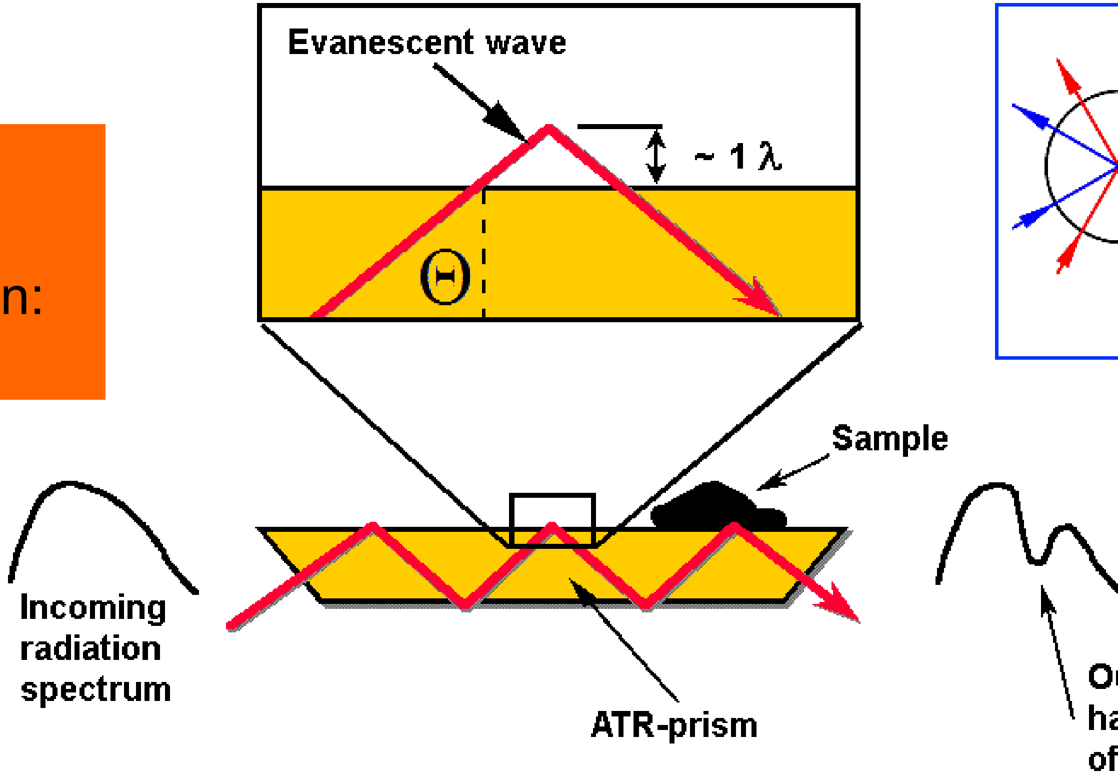
- **Fits to all above-listed requirements**
- **Does not request any complicated sample preparation**
- **Detects directly proteins, DNA/RNA, carbohydrates, lipids and other metabolites**
- **Does not destroy or damage cell, investigates object “as is”**
- **Can detect cell presence independently of its physiological state (viable or anabiotic)**

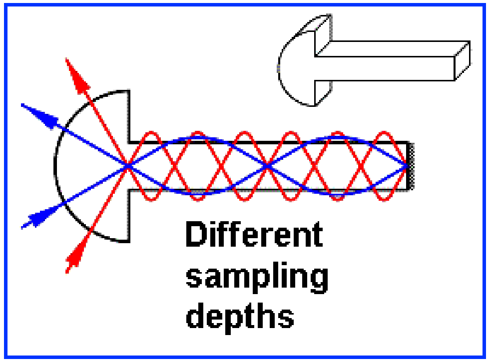
The principles of ATR spectroscopy

Total Reflection occurs, if $\theta > \arcsin[n_{substance} / n_{prism}]$
E.g., for ZnSe (n_p=2.4) and θ=45°: n_s <1.7

An ATR spectrum is:
- basically, spectrum of absorption
- spectrum of a very thin sample
- the bigger λ – the "thicker" sample

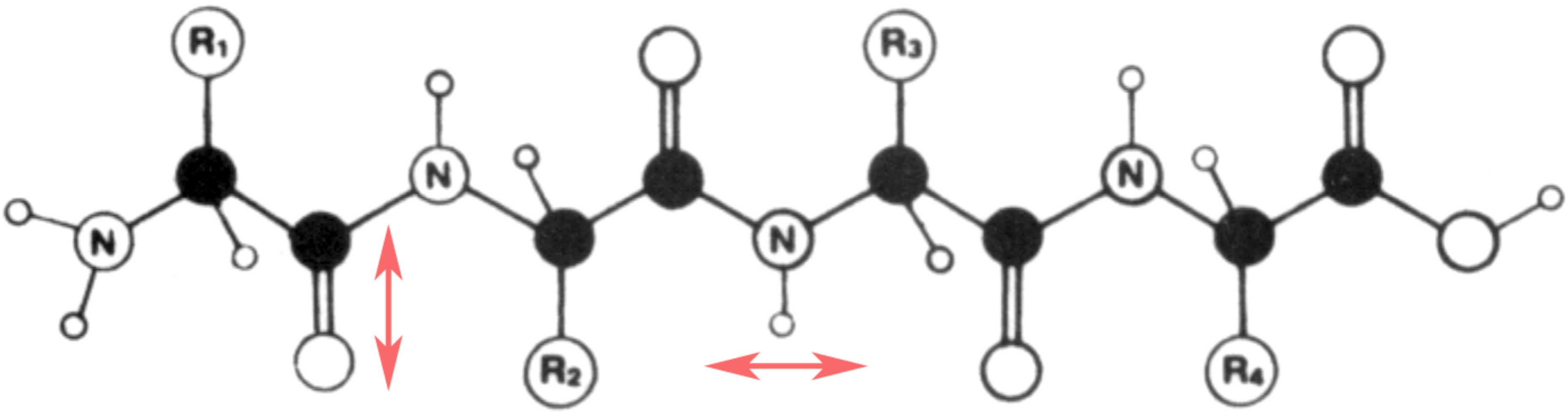
Spectral range:
2.5 - 25 µm
Spectral resolution:
5 - 10 cm^{-1}





Sources of bio-bands

Protein

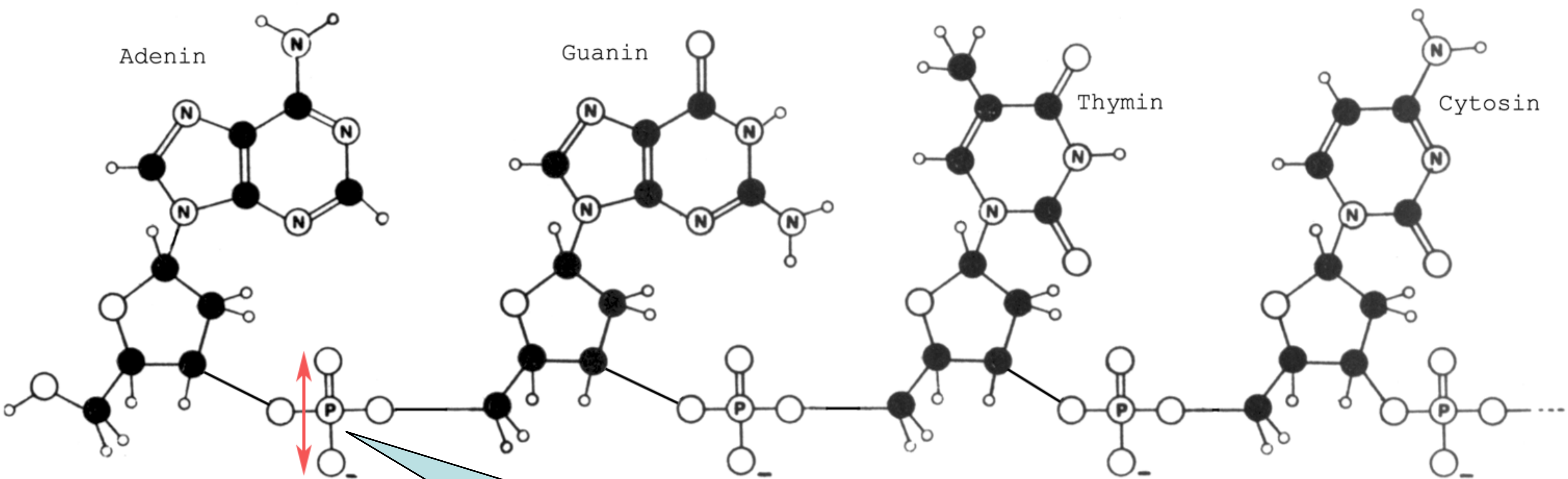


C=O stretch vibration gives main contribution to Amide-1 band

N-H bending vibration gives main contribution to Amide-2 band

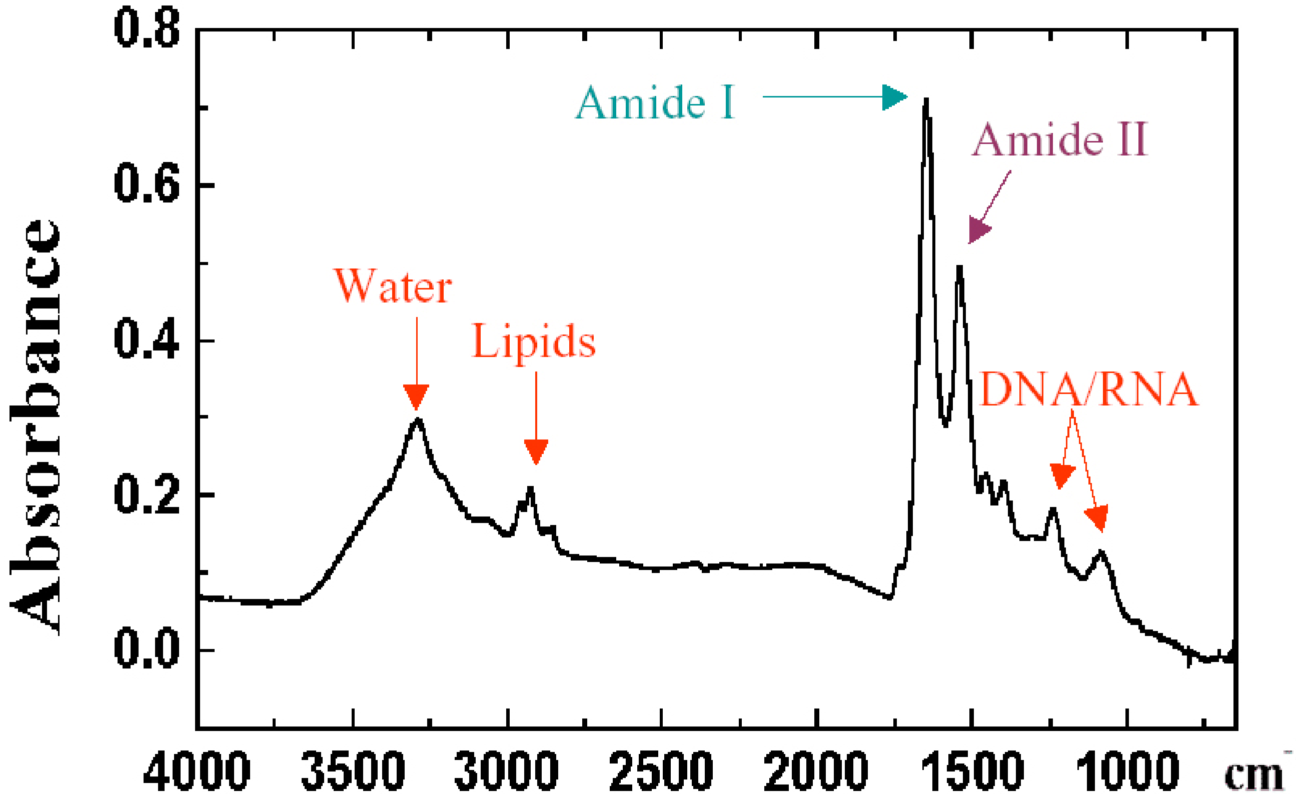
Sources of bio-bands

DNA



DNA characteristic band originates from vibrations in **O=P–O**$^{-}$ linking group

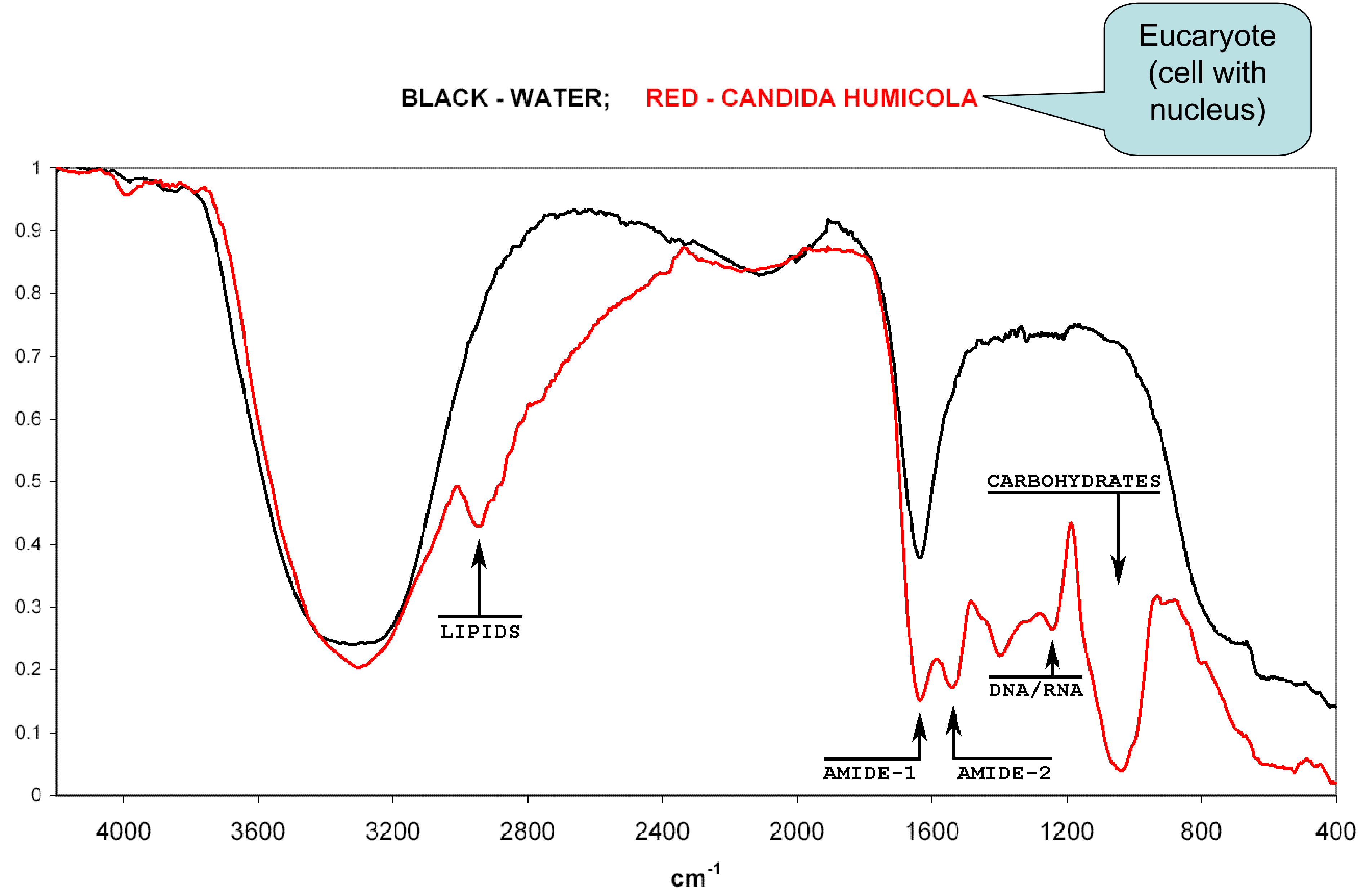
Sources of bio-bands



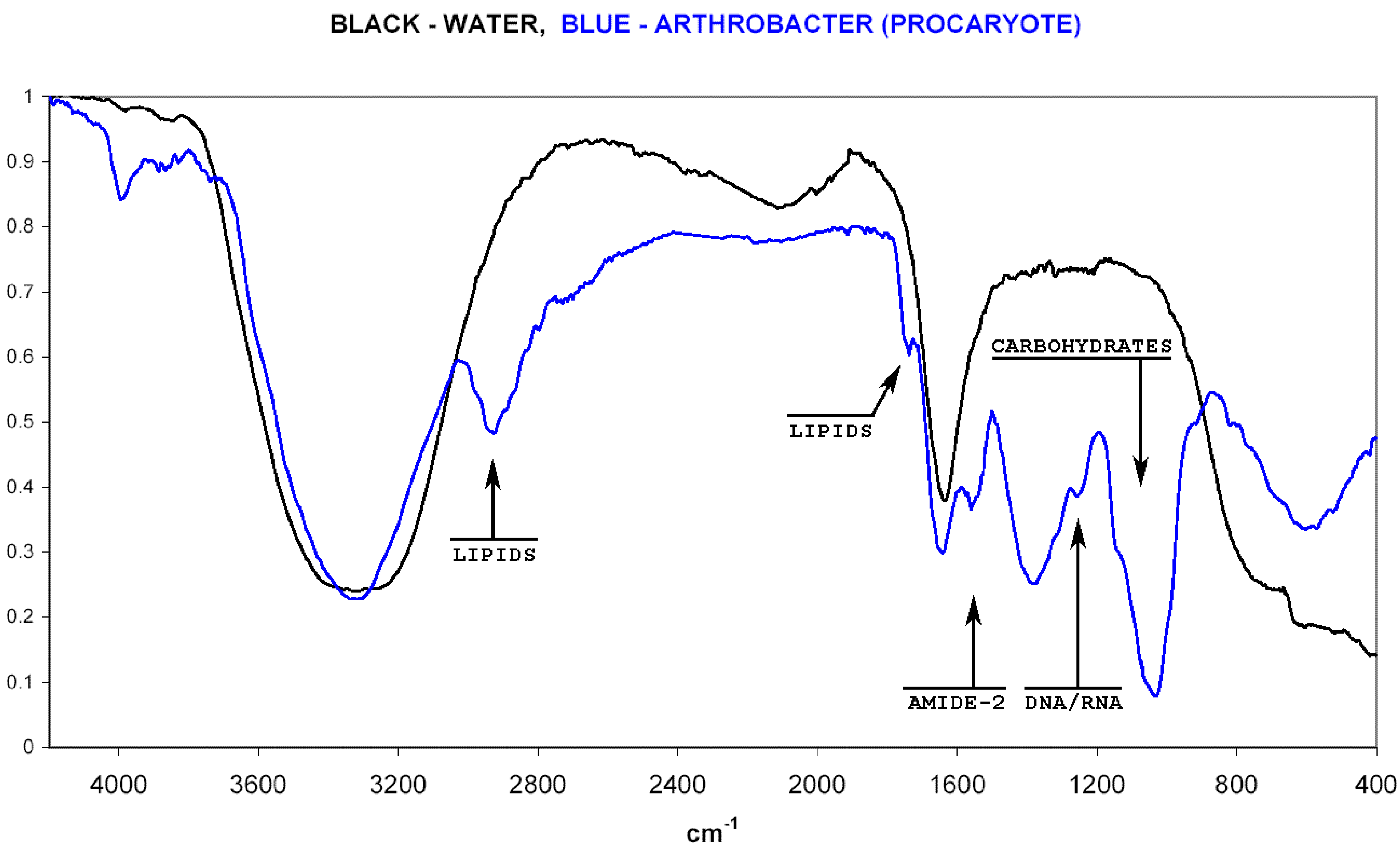
Typical IR absorbance positions:

Protein Amide I:	1690-1600
Protein Amide II:	1575-1480
Lipid $=CH_2$:	3100-3000
Lipid $-CH_2$, $-CH_3$:	3000-2850
Nucleic Acid $-PO_2^-$:	1225, 1084

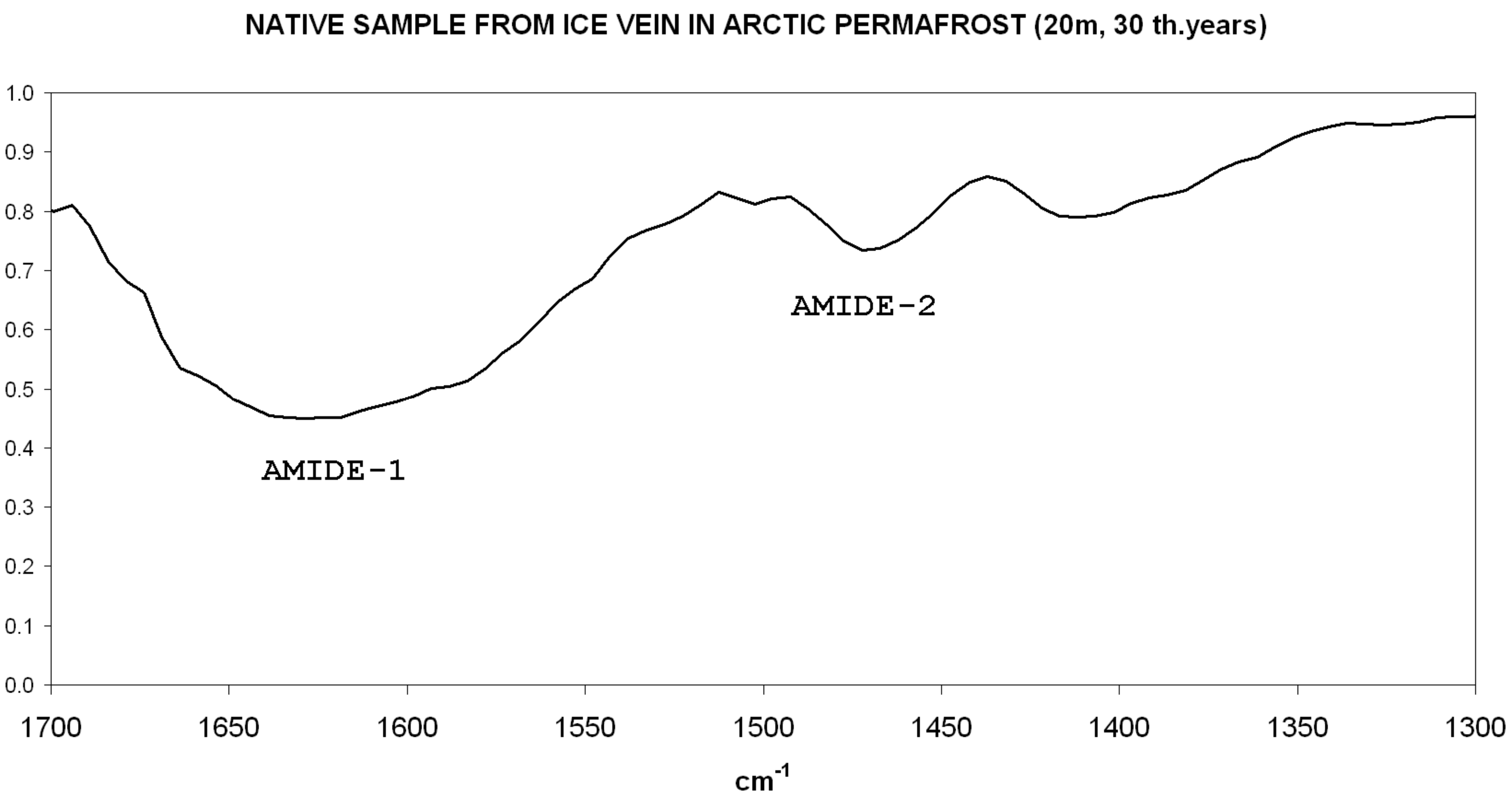
Spectral bands of bio-cells



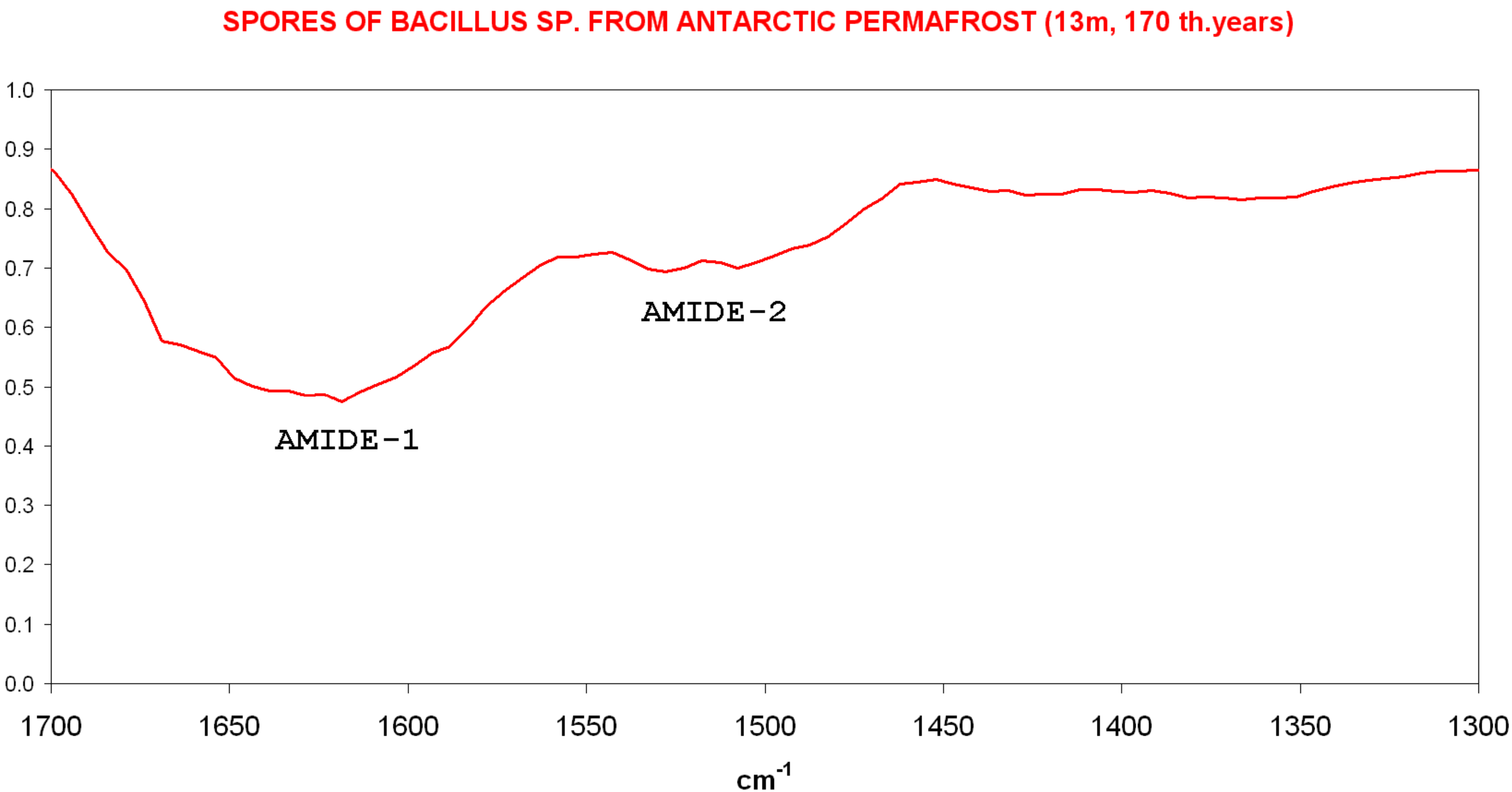
Spectral bands of bio-cells



Spectral bands of bio-cells



Spectral bands of bio-cells



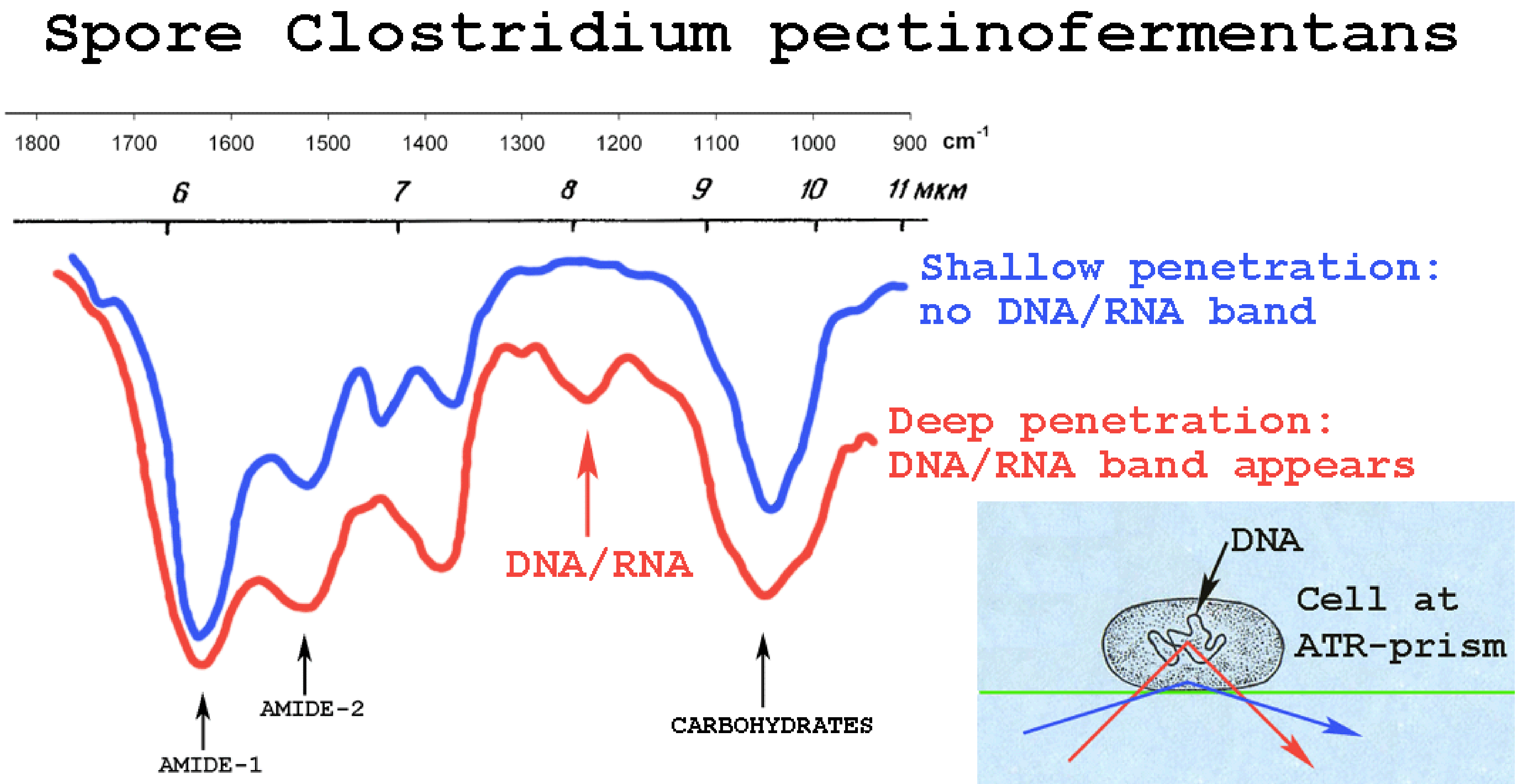
Bio-molecules or minerals?

Minerals have very different spectra and by a proper mixture one can construct any spectral features.

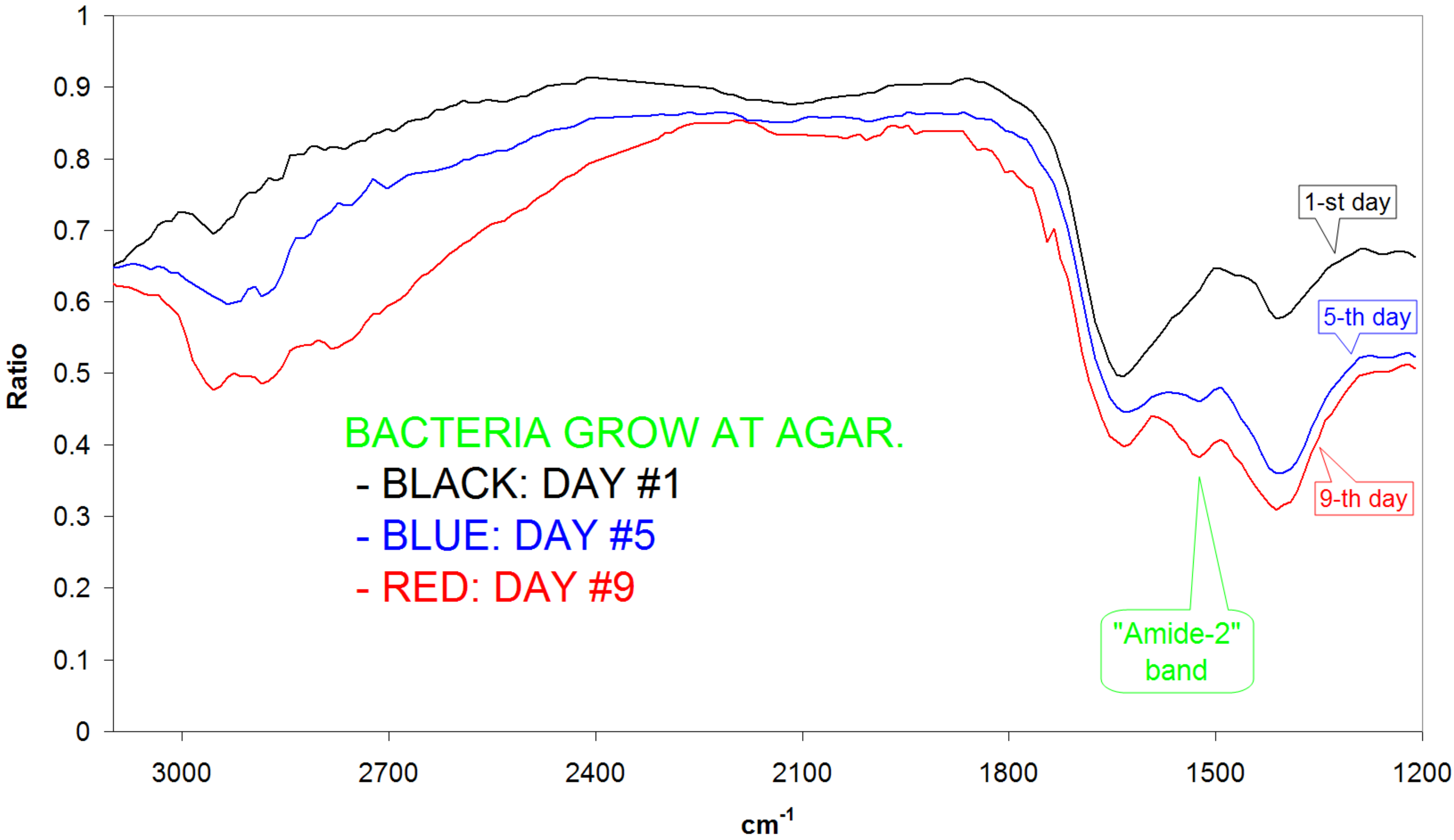
So, some *additional information* (except spectral bands position) is needed for sure detection of bio-cells:

- ✓ Study at different penetration depths
- ✓ Bands deepening due to bacteria propagation
- ✓ Dichroic ratio measurements in bio-bands

Study at different penetration depths



Bands deepening due to propagation



Dichroic ratio in bio-bands

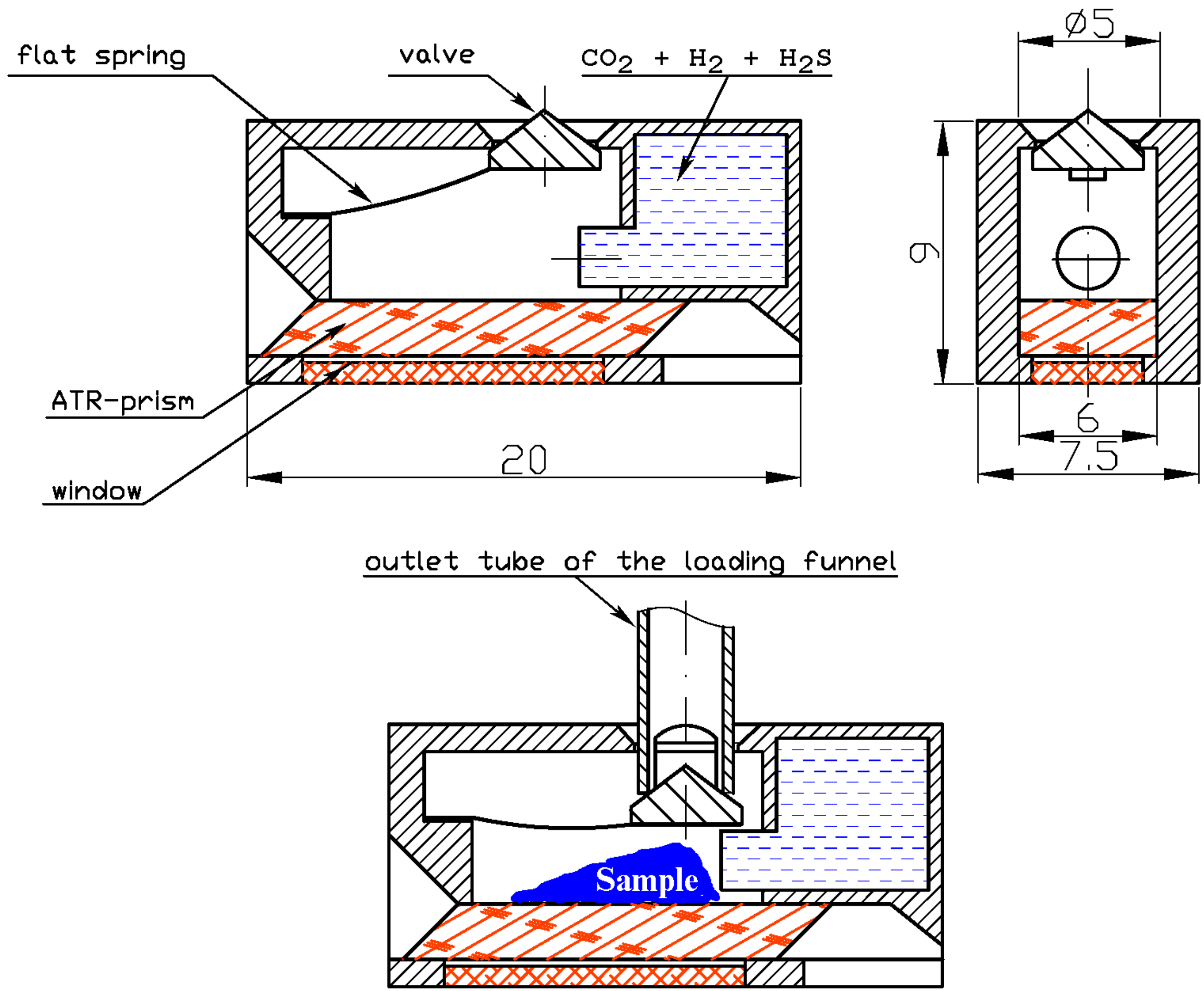
$$R = \frac{A_{\parallel}}{A_{\perp}}$$

In 1978 Korolev with colleagues for the first time implemented ATR measurements of dichroic ratio in bio-bands for investigation of bacterial spores (e.g., Mikrobiologiya. 1978. V.47. P.750). Dichroic ratio in cell membranes varies a lot, distinguishing them from minerals.

Now such measurements became a normal laboratory practice (e.g. D.Marsh. Biophysical J. ,1997 V.72 P.2710)

MATROS will have a polarizer for measurements of dichroic ratio. It will give an additional criterion for proving the biological origin of the bands.

Technical realization



Main parameters

Specification / Parameter	**Type / Value**	**Notes**
Spectroscopy technique	Attenuated Total Reflection	By now not used in planetary missions
Spectral range	2.5 - 25 μm	
Spectral resolution	5 - 10 cm^{-1}	Internal miniature Fourier-spectrometer
Size	11 x 17 x 13 cm	Internal miniature Fourier-spectrometer
Mass	2 kg	
Power consumption	6 W	Average, when operating
External assistance	Soil sample delivery	By spacecraft robotic arm, preferably from ~20cm depth

THANKS FOR ATTENTION!