DIFFRACTION CAMERA
FOR HUNTING UP THE MICROORGANISMS' TRACES

How to avoid a contradiction between a large-size file of a microscopic image and a narrow-band telemetry system

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Why we may hope to find microorganisms' traces on Europa's surface:

Due to a constant exchange of water phases on Europa

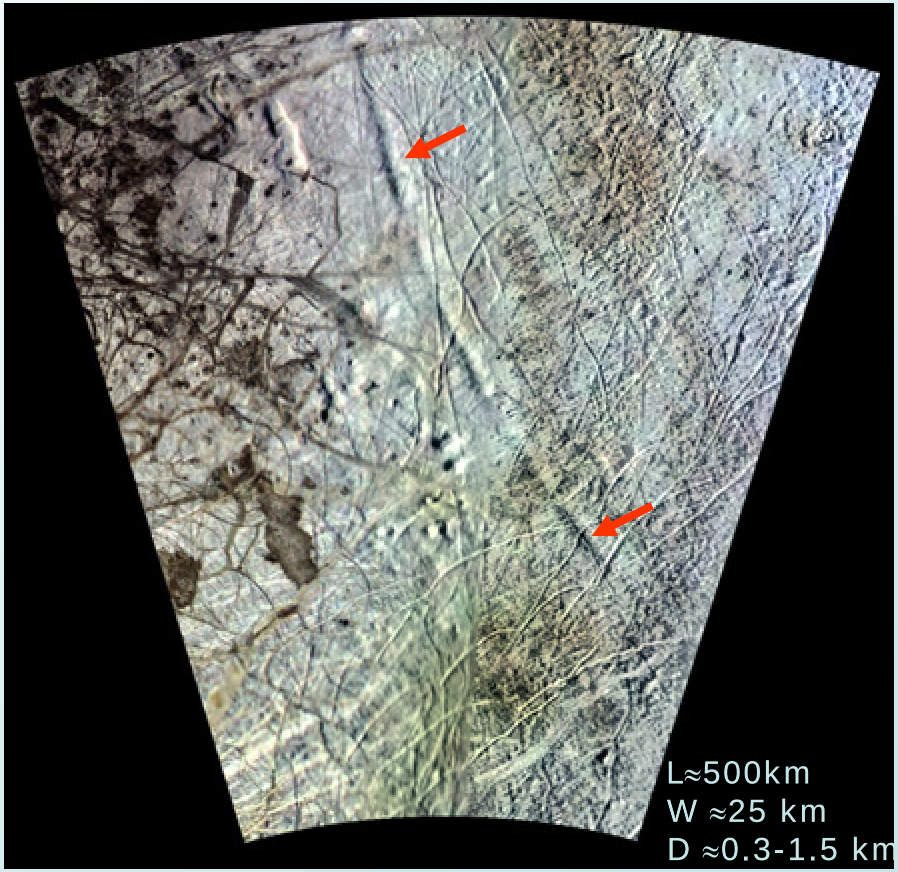
The previous findings, suggesting Europa has a subsurface ocean, have been recently supported by the results obtained by Schenk *et al* (*Nature*, 2008).

It was found that several arc-shaped troughs, spread far apart on the scarred surface of Europa, have just the right shape, size, and location to be the fractures generated, if the icy shell had sometime in the past rotated by 80°-turn about the tidal axis with Jupiter. The movement was gradual, over a period of years to decades, but it involved the entire shell.

A buildup of ice at the poles may have prompted the migration. Since a spinning body is most stable when its mass is farthest from its spin axis, the concentration of polar ice could have triggered the polar wander.

Such a reorientation of Europa's ice shell is possible, if the icy shell is latitudinally variable in thickness and decoupled from the rocky interior. This means that the ice shell floats on water, and there is a constant exchange of water phases on Europa.

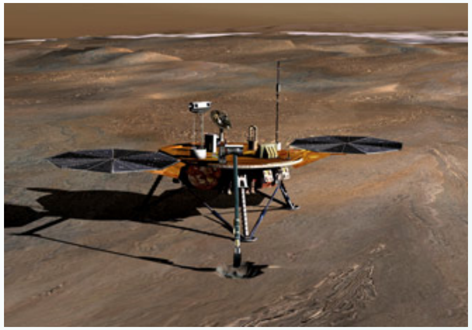
Therefore, if microorganisms exit (or existed) on Europa, even in non-active or probably latent form, their traces should inevitably be present in the surface rocks (or ices).



What is the most reliable way to get information about them?

A primary goal in investigating the unknown object: To get its image

One of the examples of the previous investigations

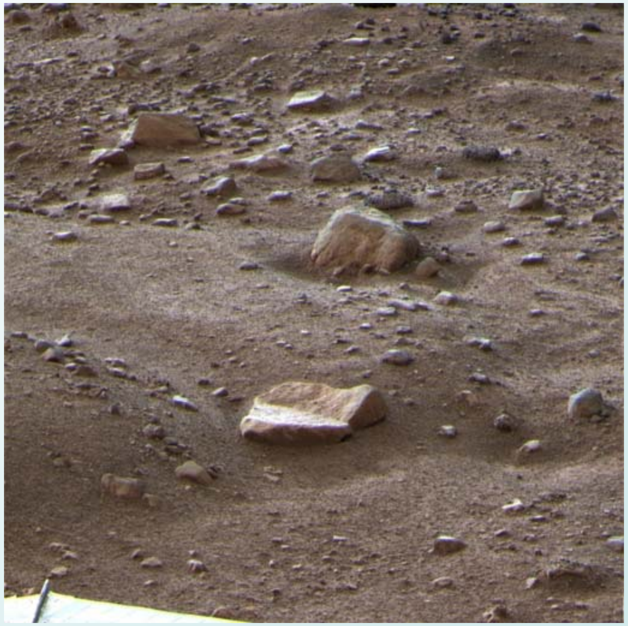


Phoenix Lander mission to Mars:

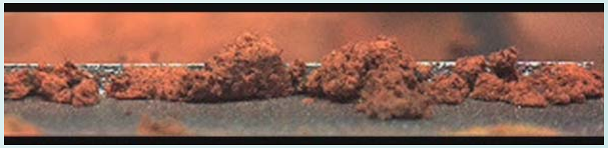
2 cameras: Surface Stereo Imager
Robotic Arm Camera

+

2 microscopes: optical (4 μm / px)
atomic-force (10 nm / px)



One Last Look at the Martian Arctic. This is a false color image taken by the Surface Stereo Imager camera on Oct. 27, 2008.



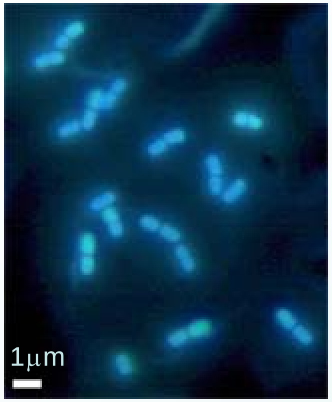
This view of fine-grained material at the tip of the Robotic Arm scoop was provided by the Robotic Arm Camera on June 20, 2008, at a resolution of 30 μm. The image shows small clumps of fine, fluffy, red soil particles collected in a sample called 'Rosy Red.'

This sample was taken from the top centimeter of the Martian soil, and this image from the lander's Optical Microscope demonstrates its overall composition. This image is 1 mm high.

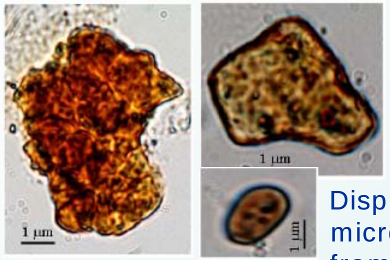
Our goal: To search for microorganisms in Europa's environment

The only positive experience we have: the identification of such objects on the Earth with the use of microscopes of different types

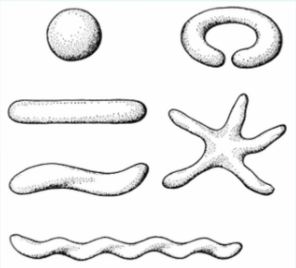
On Europa, the variety of microorganisms and their population density should be much smaller (if they exist at all).



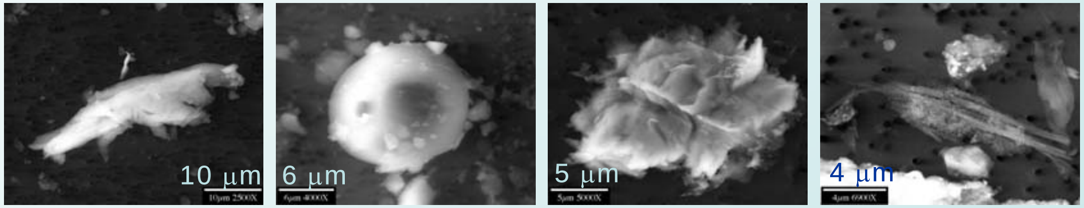
The epifluorescent microscopic image of *Psychrobacter cryopegella* isolated from a saline water lens within 40 thousand-year-old Siberian permafrost, where the *in situ* temperature is from -9 to -11°C



Display of pigmented microorganisms enriched from snow and aerosol samples.



The main bacteria shapes.
Sizes: from ~0.1 to 10-100 μm



The strange shapes found in ancient Antarctic ice (from as deep as 1249 m beneath Vostok Station) among the lifeforms, from fungi, algae, and bacteria to a few diatoms.

If microorganisms are observed with a microscope, it gives us a direct, "visual" answer allowing no ambiguous interpretation.

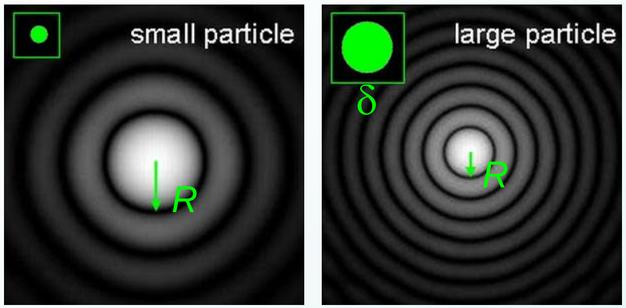
However, a large size of the microscopic image file imposes heavy demands on transmitting the information to the Earth.

Moreover, we cannot expect densely populated colonies of microorganisms on Europa.

Therefore, the image obtained with the onboard microscope may contain no information at all, or the image portion containing useful information may be rather small, and the most data volume transmitted may be "empty".

The way out: Step 1. To search for the large-scale signs of possible objects rather than the objects themselves

The phenomenon that can help us is diffraction, which is widely used for detecting microscopic defects, determining the sizes and sensing the structure of small objects, etc.



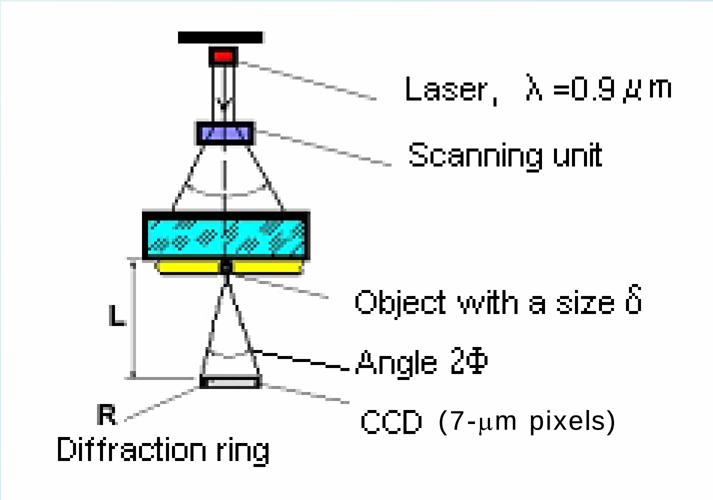
$R \sim 1/\delta$

δ is the size of the object

R is the radius of the first diffraction ring

The main idea of the camera:

The diffraction camera works as a detector of the objects, the concentration of which is low, and determines their sizes. If the scanning laser beam meets a small obstacle in the droplet on the object glass, the corresponding diffraction pattern appears in the CCD.



Optics parameters:

$D/F = 1.25$

$D = 4$ mm

→ Objects with sizes **0.9 - 28 μm** can be detected and measured

$\Phi = 1.22\,\lambda/\delta$ and $\Phi \approx R/L$ (since $R << L$)

$L = 50$ mm

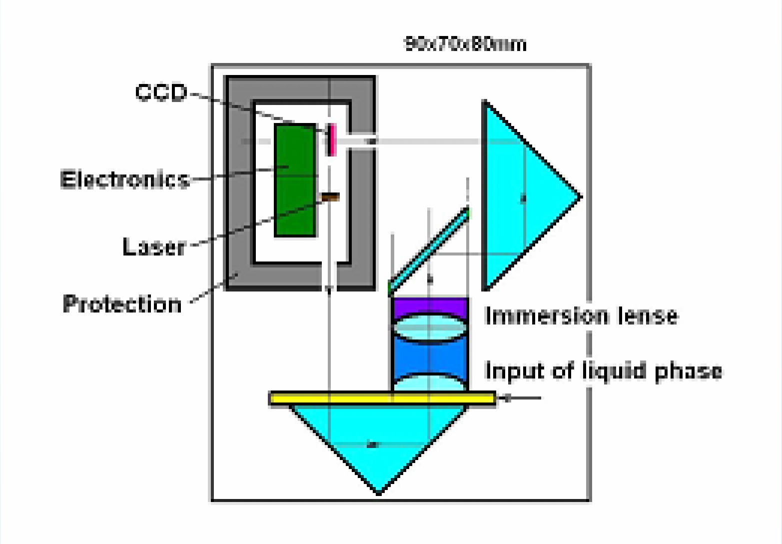
$\delta = 28$ μm

→ $R = 1.9$ mm

The size range 0.9 - 28 μm roughly corresponds to the mean sizes of the terrestrial bacteria.

The way out: Step 2. To observe the detected object with a microscope

When the diffraction pattern appears in the CCD, the instrument switches to the <u>microscope</u> mode.



If only 0.6 kB is allotted for one image, the compression software will produce a satisfactory picture of the microscope field of view.

Moreover, the detected video shapes can be replaced by their symbols.
In the code mode, the microscope field of view can be presented only by 10-12 bits: the possible cases of the objects' shapes, size ranges, mobility, etc expected in the droplet on the object glass are coded in the transferred bytes.
For this, the instrument is provided with a special logic unit.

Technical details:

Mass ≈ 0.6 kg
Power = 2 W
Telemetry requirement: 10 kB/session.

The CCD, the laser, and the electronic unit are in the protected chamber. Almost a half of the mass of the instrument is allotted to the protection from the radiation.

Summary

The advantages of the *Diffraction Camera* experiment proposed:

Importance for clear interpretation :

If microorganisms' traces exist on Europa, their observation with a microscope gives a direct, "visual" answer allowing no ambiguous interpretation.

Importance for a narrow-band telemetry system :

The diffraction method used for the preliminary detection of the interesting object offers a way to avoid a contradiction between a lot of useless data and only few bits of important information, when looking for microorganisms with the microscopic method.


Thank you for your attention!