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The Beagle 2 optical microscope

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THE BEAGLE2 OPTICAL MICROSCOPE. S. F. Hviid¹, N. Thomas¹, H. U. Keller¹, W. J. Markiewicz¹, T. Bluemchen¹, P. Smith², R. Tanner², R. Reynolds², C. Oquest², J. Josset³, S. Whitehead⁴, C. Pillinger⁵ and B. Hofmann⁶

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Introduction:

The ESA Mars Express exobiology lander (Beagle2) (Launch 2003) has as part of its scientific payload an optical microscope.

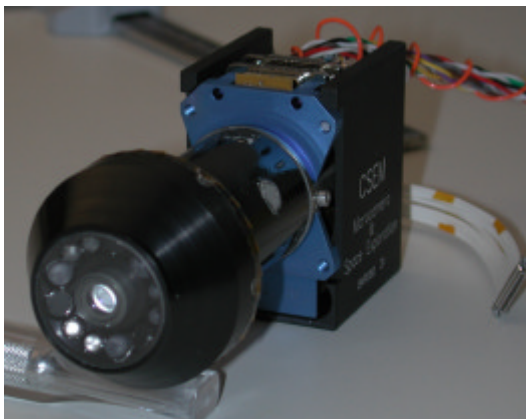


Figure 1. The Beagle2 microscope Qualification Model. At the front can be seen the entrance aperture and illumination LED's. The black box at the back contains the focal plane assembly and the readout electronics.

Technical Description:

The microscope is composed of three distinct parts: 1) A head containing the lens system and the built-in illumination system. 2) A structural carbon-fiber tube containing the baffling system. 3) The focal plane assembly containing the CCD and the CCD readout board.

The optically active elements is a Cook triplet with a spectral corrector that will cutoff the flux below 400 nm. The combined optics and CCD systems results in a pixel resolution of 4 $\mu\text{m}/\text{pixel}$. The full width half max (FWHM) of the total point spread function of the system is smaller than 8 μm . The microscope is focused at 12 mm from the entrance aperture with a depth of field of about 40 μm .

The illumination system is composed of 12 LEDs arranged symmetrically around the aperture of the microscope. There are four colours - red, green, blue, and UV (375 nm) with three LED's for each color. The UV LEDs have been selected to look for possible fluorescence of materials during imaging.

The CCD has a size of 1024 by 1024 pixel with a pixel size of 14 μm . The system uses a 10 bit ADC resulting in a dynamic range of 1024 DN.

Because of the small depth of field (40 μm) an active focusing mechanism is required. The microscope itself possess no focussing mechanism. All focusing operations

will be performed by positioning the whole microscope with respect to the target using the positioning mechanism included in the lander robotic arm.

The total mass of the microscope (excluding focusing stage) is about 165 g.

Scientific Objectives:

The scientific objectives of the microscope can be separated into four themes: 1) Rocks 2) Dust 3) Atmosphere 4) Biology.

1) Rocks.

The microscope will characterize the surface structure of a rock before and after any treatment process (Grinding). This information can be used to characterize the morphology and composition of the dust coating and possible weathering rind on the surface of the Martian rocks. A detailed investigation of the rock surfaces may give pointers toward the weathering processes that has been/is active on the surface of Mars. Also this information is required for modeling the surface reflection properties of unresolved surfaces under Martian illuminations conditions.

After removal of an external weathering rind, the microscope will identify physical (structural) and chemical (color) inhomogeneities in the interior of the rock sample (thereby providing constraints on the rock forming process) at a resolution of 8 μm .

2) Dust.

The resolution of the microscope is high enough that it may be able to resolve individual dust particles at the higher end of the size distribution. Information about the morphology of the individual dustgrains may further restrict the possible soil forming processes that is or have been active on the surface of Mars. For example if the dust particles turned out to be plate like, this would be indicative of a high concentration of clay minerals in the surface dust. This would again indicate that liquid water has probably been involved in the soil forming processes.

3) Atmosphere

The diffuse sky brightness on Mars is a consequence of the scattering by dust particles in the atmosphere. The size of these particles are, on average, larger than the wavelength of visible light. The shapes are thought to be irregular.

An investigation of the size and shape of individual dust particles which have precipitated out of the atmosphere may help to constrain the models of atmospheric scattering.

The microscope will provide a quantitative estimate of the dustsize distribution for particles larger than about 4 μm in diameter. This is the higher end of the size distribution.

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4) Biology

The microscope will search for evidence of any biological activity that exhibits fluorescence using the UV illumination diodes. The microscope will search for structures and textures which on Earth are strongly connected with biological activity (e.g. pyrite framboids ...). Finally the

microscope will search for evidence of fossilized microorganisms (e.g. biolaminaea and cyanobacteria) which are known on Earth to be (typically) larger than the resolution of the microscope.

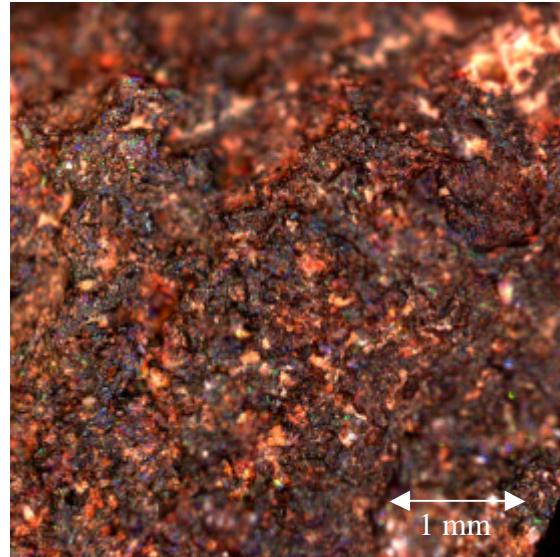
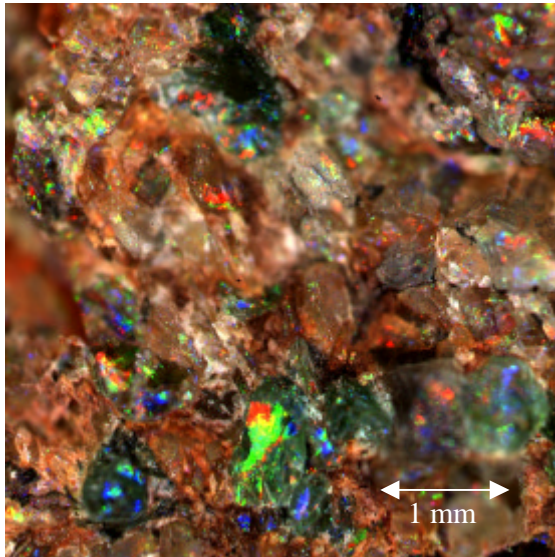


Figure 2. Misc. sample rock surfaces.

The color images have been acquired using the Red, Green and Blue illumination LED's. The patches showing discoloration are caused by specular reflecting facets in the surface, resulting in a locally overexposed red, green or blue image.

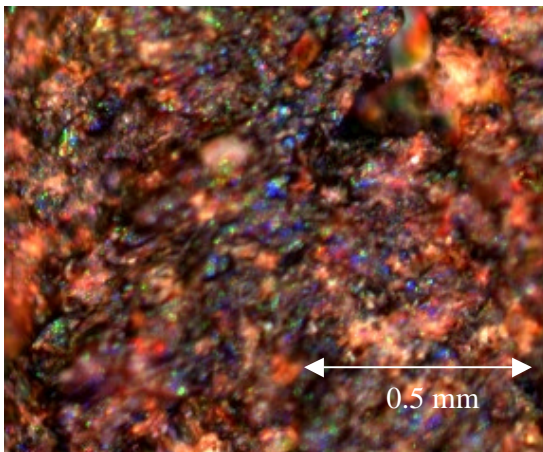


Figure 3. Full resolution image of a sample rock surface

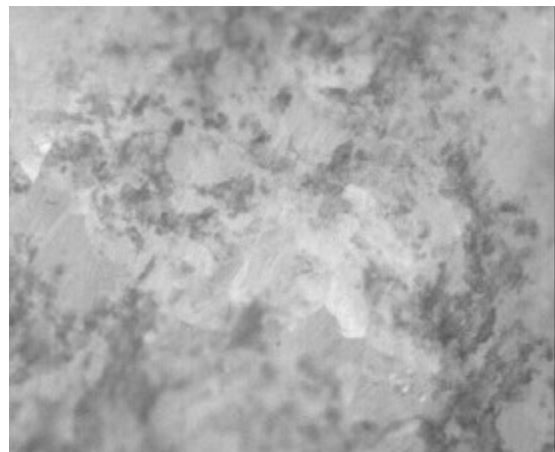


Figure 4. Detection of fluorescence using the UV LED. The image is a difference image between an image acquired without any illumination LED's and an image with the UV led switched on. The bright regions corresponds fluorescence in the rock surface.