A Physical, Chemical, Isotopic and Astrobiology Instrumentation Package

Dr Mark Bentley (m.s.bentley@open.ac.uk)

Dr Andrew Ball (a.j.ball@open.ac.uk)
Dr Simeon Barber (s.j.barber@open.ac.uk)
Prof Charles Cockell (c.s.cockell@open.ac.uk)
Overview of PSSRI

The UK’s largest planetary science group, ~60 researchers & support staff

Part of the new Centre for Earth, Planetary, Space and Astronomical Research (CEPSAR) at the OU.

Multidisciplinary – astronomy, geophysics, geochemistry, microbiology, instrument development and more!

‘Cleanest Place in Europe’
PSSRI has a long heritage of sample analyses, including:

- Meteorites
- Lunar samples
- Planetary analogue
- Genesis

... and shortly Stardust!

When this is not practical, we want to take these instruments to the sample...

⇒ lander instrumentation
Overview of Instruments

**DELVE**
- Search for polar volatiles at depth

**SOLVE**
- Isotopic study of volatile sources

**Magnetic Susceptibility**
- In situ analysis of space weathering

**Lunar Astrobiology Suite**
- Study of minimum mass for suite
The challenge: shrink a room full of equipment…

…to shoe box size!

All isotopic results from MODULUS instruments (lab, comet, Mars, Moon…) are inter-comparable due to on-board reference materials

Methods
Of
Determining and
Understanding
Light elements from
Unequivocal
Stable isotope compositions

Rosetta - Ptolemy

All rights reserved Beagle 2

Beagle 2 – Gas Analysis Package
An evolved gas analyser, utilising novel chemical sample preparation techniques, gas chromatography and an ion trap mass spectrometer aims to determine the chemical identity and isotopic composition of samples drilled from nucleus => source of water and its evolution.

Size 33 x 25 x 11 cm; Mass 4.5 kg

Science team (OU) + Engineering team (CCLRC Rutherford Appleton Laboratory)
Source Of Lunar Volatiles Experiment

understanding the source (cometary, volcanic, solar wind…) of lunar volatiles (H$_2$O, CO$_2$ ?, SO$_2$ ?, etc.) through measurement of their precise stable isotopic composition

- A new MODULUS instrument concept, evolved from Ptolemy
- Accepts solid samples from drill, mole, etc.
- Seals sample in oven
- Heats sample to release volatiles
- Chemical processing of volatiles
- Chemical and isotopic analysis by GC-MS (m/z 10-200)
- 4.5 kg, 15 W peak, 33 x 25 x 11 cm, 12 analyses each 1Mbyte
- Status: based on currently active Ptolemy FM
DEpth of Lunar Volatiles Experiment

understanding the depth distribution and physical/chemical composition of lunar volatiles (H₂O, CO₂, SO₂ etc.) through in-situ analysis on board an instrumented mole

- An evolution of PSSRI’s EVITA concept
- Passive collection of fines as mole descends
- Fines heated (hotplate/laser) in steps to release volatiles
- Chemical identification and quantification by ion trap mass spectrometer (m/z 10-200)
- Only limited isotopic information (¹⁸O/¹⁶O?) compared to SOLVE
- <400 g, <10 W, dia. 28mm x 65mm, 12 analyses each 1 Mbyte
- Status: prototypes working in lab, development ongoing on electronics

courtesy S. Sheridan, OU
Space Weathering

Spectral alteration from impacts and solar wind sputtering

VNIR mineralogy confounded

Degree of weathering from FMR

Correlates well with magnetic susceptibility
**In situ measurement of space weathering in support of remote mineralogy**

Mark S. Bentley (m.s.bentley@open.ac.uk), Andrew J. Bell, Ian P. Wright, John C. Zemecki, PSSRI, The Open University, U.K.

1. **What is space weathering?**
   
   The Moon is a unique body for which we have remotely sensed data, in situ measurements and returned samples for isotope analysis. When the first lunar samples were studied it was apparent that rock and regolith specimens with similar mineralogy had substantial differences in optical and magnetic properties.

   An example of this is shown in Figure 1 in which the VNR reflectance spectra of rock and regolith samples are plotted. The regolith spectrum is considerably darker, exhibiting a reddened continuum and broader absorption features. These changes correspond to the deposition of minerals on the regolith.

   In recent years, research on space weathering has concentrated on the identification of clays and iron oxide minerals in the lunar regolith. An example of this is shown in Figure 2.

2. **Optical effects of space weathering**
   
   Hapke (2001) has shown that reflectance spectra can be numerically ‘weathered’ given the mass and size distribution of SPM. In Figure 3 the spectrum of a soil using a sample is plotted. The sample was then exposed to simulated sunlight to estimate the small differences in the spectrum. Hapke’s technique is then used to weather the regolith spectra to simulate the effects of space weathering on the spectrum.

   This technique can also be used in reverse to remove the effects of weathering if the amount of iron is known. Any measurements of the SPM can then be used to remove weathering trends from the data.

3. **Magnetic effects of space weathering**
   
   Metallic iron is the dominant ferromagnetic phase in lunar regolith. Magnetic techniques are therefore very sensitive to SPM. Using iron-rich regolith, SPM is superparamagnetic (SPM), with a magnetic susceptibility (K) orders of magnitude higher than single domain (SD) iron. The iron content can be measured at different temperatures and frequencies using this technique to determine the size distribution of SPM. Figure 4 shows the data taken from Stefferson (1999).

   Increasing the measurement frequency causes grains that were previously SPM to become SD, reducing the magnetic susceptibility of the sample. The frequency dependence is a very sensitive indicator of SPM and hence SPM in the lunar case.

4. **Space weathering in the solar system**

   Our understanding of space weathering comes almost exclusively from the Moon, but similar processes are expected on other planetary bodies. For example, the formation of a cold climate may lead to the formation of a dust layer on the surface of the Moon.

   Magnetic susceptibility depends on the methodology of the sample, and the amount of SPM present. Plotting the SPM value against the magnetic susceptibility shows a good correlation, but this should also be used with caution.

5. **Magnetic susceptibility**

   Magnetic susceptibility is well suited to mineralogy for data analysis. Figure 5 shows a commercial high-field sensor. It has been shown that a sensor can be used as an index of maturity (weathering degree). However, using this technology to determine the size distribution of SPM has been shown in Figure 6. The data taken from Stefferson (1999) shows the sensitivity of the sensor.

   The sensor can be deployed on a lunar rover or a rover, as shown in Figure 7, which is a model of the sensor.

   A development programme to produce a commercial sensor model could be undertaken at modest cost. The key issues to be addressed are the thermal stability of the sensor, and how much of a relative measurement would be required in the case of a more careful choice of the Lander mission armory.

6. **Acknowledgements**

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7. **References**

   Bentley, M.S., Bell, A.J., Wright, I.P., Zemecki, J.C., PSSRI, The Open University, U.K. (2001). In situ measurement of space weathering on the Moon. In Earth, Planetary, Space & Astronomical Research (CEPSAR). The work was carried out at the Open University, U.K.
PSSRI is involved in a three month definition study on the International Lunar Astrobiology Laboratory (ILAL), working with ESA and Alcatel.

The study will define:

1) The minimal mass laboratory required for biological studies on the moon, including life support and crew health monitoring,

2) The required minimum laboratory to be taken to other planetary surfaces, particularly Mars, for astrobiological studies,

3) The expertise needed in lunar astrobiology for a productive scientific presence on the moon.
Institute for Planetary Research

The Heat flow and Physical Properties Package (HP³): an integrated sensor suite for planetary subsurface studies

Original slides: Riccardo Nadalini
Modified and presented: Mark Bentley

Lunar Lander Workshop
ESTEC, 16th December 2005
**HP³: the components**

HP³ objective is the measurement of the INTERNAL heat flow of the planet. It does this with **Three Sensors:**

**TEM, Thermal Excitation and Measurement suite**
- Temperature ($\Delta T$)
- Soil thermal properties ($\kappa, c$)

**DEN, DENSitometer**
- Density ($\rho$)

**DACTIL, Depth, ACcelerometry and TILt suite**
- Position, attitude ($\alpha$), shape of borehole (by tracing)
  (Soil mechanical properties)
HP³: status

Critical design review held in October 2005
Breadboard integration and test: Easter 2006
Current Team

DLR Institute of Planetary Research (Berlin)
    System, Electronics, Structure, TEM
DLR Institute of Space Simulation (Cologne)
    Mole, DACTIL
Open University
    DEN
Oxford University
    Tether
Galileo Avionica (Milano)
    Surface Systems, Tether Length Sensor

**ESA-ESTEC**
    Financing the present developments (payl. dev, TRP)
PSSRI also involved in the HP$^3$/ DEN backscatter densitometer (being bread-boarded in PSSRI), and the spectroscopic follow-on X-Gamma (led by University of Leicester) and GEP (through the environmental sensor suite and UV spectrometer + possibly HP$^3$)

For further details on each of the instruments described, contact:

DELVE: Simon Sheridan (s.sheridan@open.ac.uk)
SOLVE: Simeon Barber (s.j.barber@open.ac.uk)
Space Weathering: Mark Bentley (m.s.bentley@open.ac.uk)
Lunar astrobiology: Charles Cockell (c.s.cockell@open.ac.uk)
DEN: Andrew Ball (a.j.ball@open.ac.uk)
HP$^3$: Riccardo Nadalini [DLR Berlin] (riccardo.nadalini@dlr.de)

http://pssri.open.ac.uk/