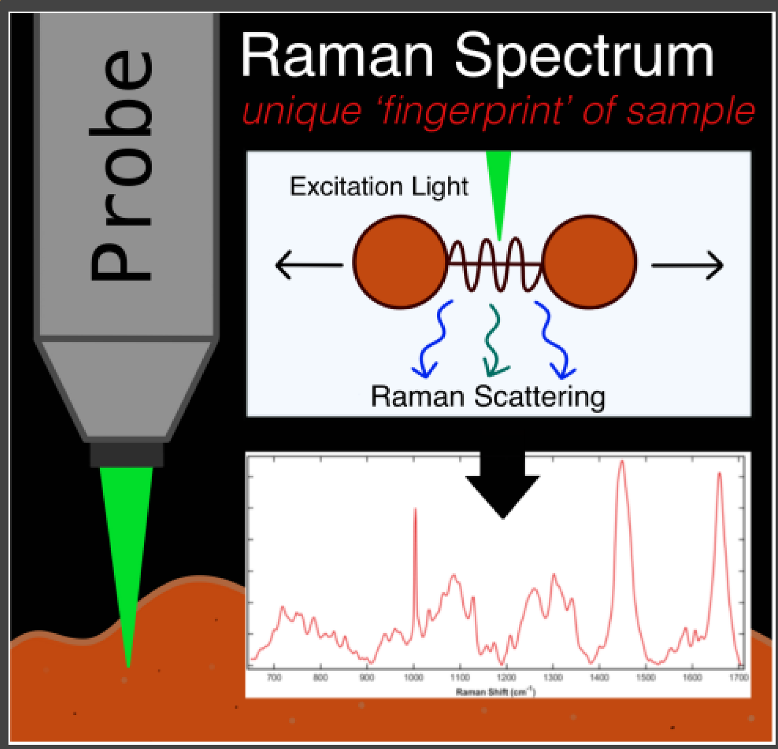
From Mars To Humans: Interactive Raman Spectroscopy Based Outreach Activities

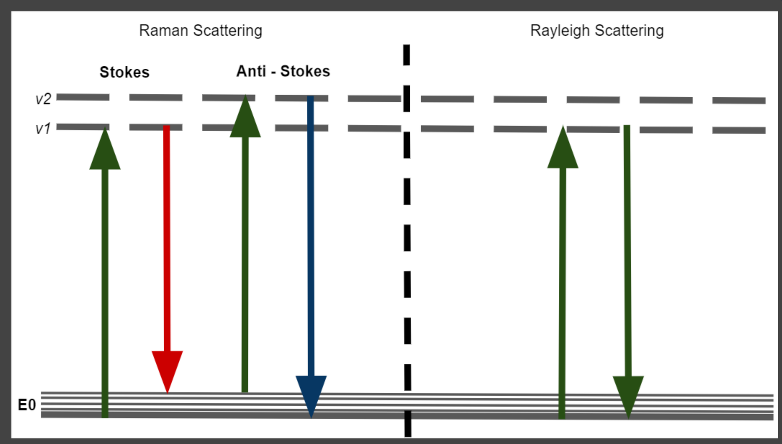
Jacob Kleboe[a], Helen Szoor-Mcelhinney[b], Hiroki Cook[a], Simon Lane[a], Niall Hanrahan[a], James Read[a], Tommy Loan[b] and Sumeet Mahajan[a]

[a] Department of Chemistry and Institute for Life Sciences, University of Southampton, Highfield Campus, University Road, Southampton, United Kingdom, SO17 1BJ

[b] School of Chemistry, University of Edinburgh, Old College, South Bridge, Edinburgh, Scotland, EH8 9YL

Raman Spectroscopy





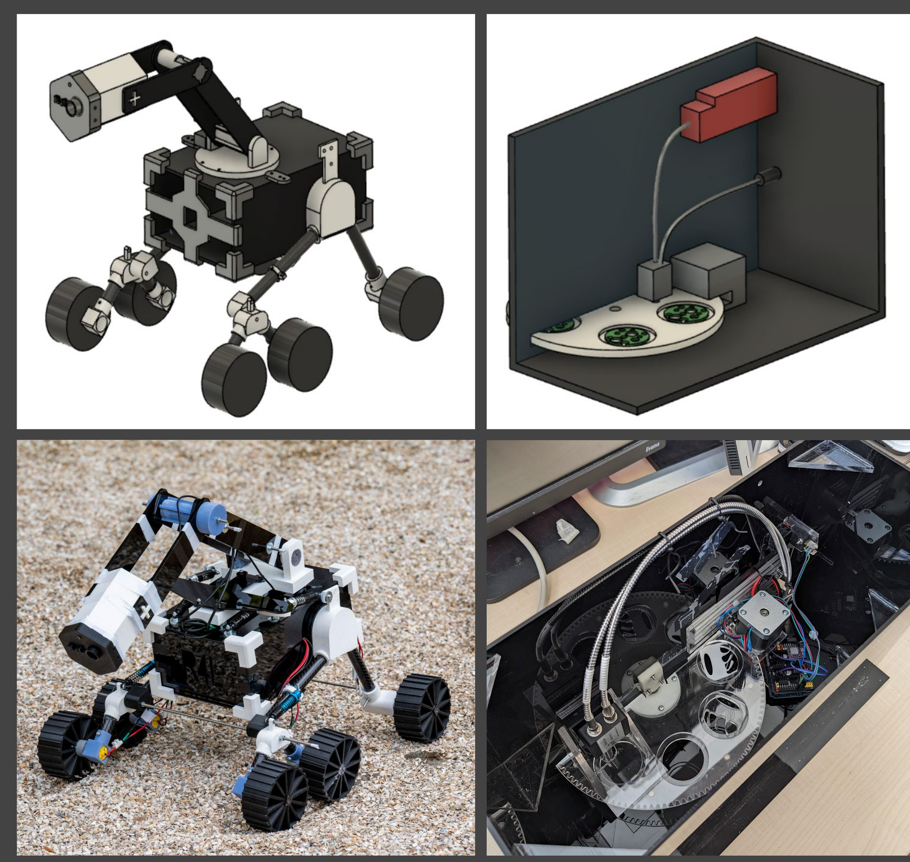
- *The spontaneous Raman effect occurs when photons are scattered inelastically when interacting with a molecule*
- *There are 2 types of shift, one caused by a reduction in frequency in the interaction and one by a gain in frequency*
- *A frequency loss is called a Stokes shift while a frequency gain is called a anti-Stokes shift [1]*

- Raman spectroscopy is based on the Raman effect that results in slightly shifted wavelengths of the scattered light compared to the excitation [2]
- It uses lasers to probe a materials vibrational structure
- It provides a characteristic spectrum which is often referred to as a chemical "fingerprint"
- The various components or molecules in a material, their structure and the nature of the bonds determine how the light is scattered in a Raman interaction to allow identification [3]
- Raman Spectroscopy is the technique that was demonstrated and explained during the "From Mars to Humans" outreach project, this is due to its wide variety of applications and its multidisciplinary nature

1. RAMAN, C. V & KRISHNAN, K. S. A New Type of Secondary Radiation. *Nature* **121**, 501–502 (1928).
2. Edwards, H. G. M. *Modern Raman spectroscopy—a practical approach.Ewen Smith and Geoffrey Dent. John Wiley and Sons Ltd, Chichester, 2005. Pp. 210. ISBN 0 471 49668 5 (cloth, hb); 0 471 49794 0 (pbk). Journal of Raman Spectroscopy* vol. 36 (2005).
3. Lu, R. *et al.* C-H stretching vibrations of methyl, methylene and methine groups at the vapor/Alcohol (n = 1-8) interfaces. *J. Phys. Chem. B* **109**, 14118–14129 (2005).

Developing R4L and Dr Raman

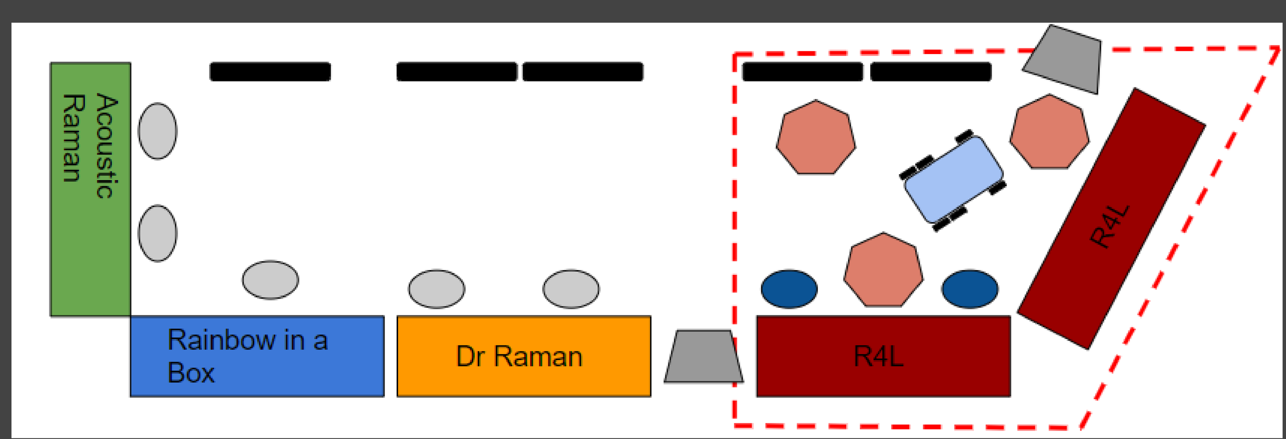
- The focal point of the activity included two home built devices. Dr Raman a clinical analysis demonstration and R4L an interactive Mars rover
- Both used functional Raman Spectroscopes (WASATCH) and integrated laser systems to produce real time spectra of materials
- Both designs were initially created using CAD software and then developed into functioning demonstrators
- Dr Raman was motorised to allow samples to move under the Raman probe for analysis; the samples were based out of common polymers such as PMMA cut on a laser cutter. The shapes resemble biological structures
- R4L is made through a combination of 3D printed parts and laser cut material
- R4L has a Raman spectroscope, controlled by a raspberry pi system that also controllers the motorised wheels



- Both devices included multiple development stages including wiring of circuitry, construction of parts and programing of the control system
- The aim was to produce devices that could demonstrate the application of Raman spectroscopy across multiple fields
- All the devices were created in a way to make them reproducible, this is so that educational institutions could create and develop their own versions for use in the classroom

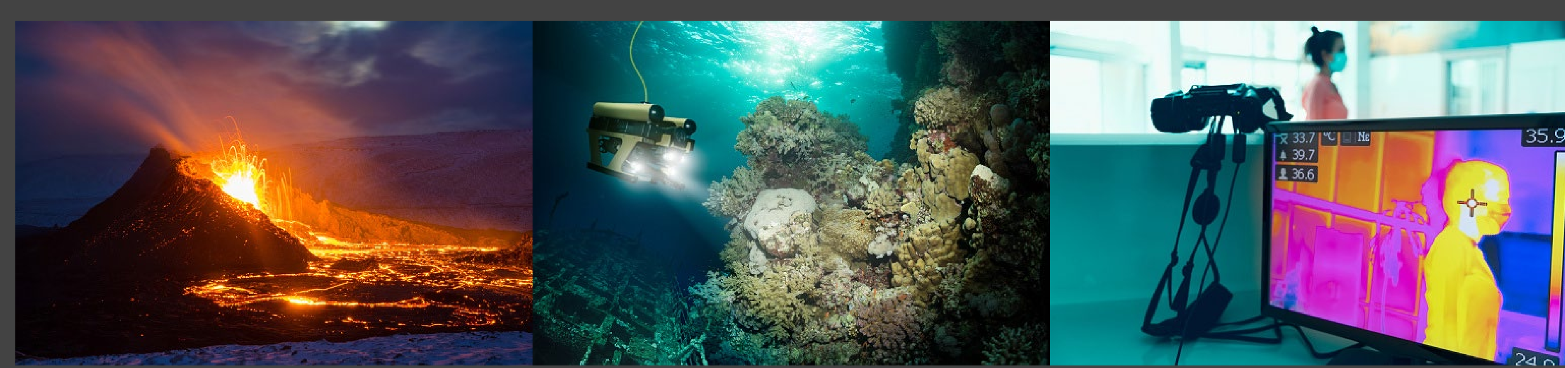
From Mars to Humans: Interactive Multi-staged Activity

- A 4-stage activity meant that we could teach Raman spectroscopy in stages, from lay explanations to physical principles and to advance spectroscopy techniques
- Acoustic Raman: used shaking of boxes to demonstrate how we can use vibrations to tell information about an object without seeing it. This area also included a singing bowl that demonstrated resonance effects.
- Rainbow-in-a-box: produces a spectrum from white light in the form of a rainbow, this is then detected by a spectrometer. This teaches how light can be split into different colours each of which corresponds to a different wavelength
- Dr Raman: brings these concepts together to demonstrate how Raman spectroscopy can be used for disease diagnostics. A laser and a Raman spectrometer is used to measure signals from dummy cells. The interactive task is to used the spectra obtained in real-time to determine which of these cells are sick
- Finally we get to **R4L** where the user gets to help guide the rover to targets within a course. When the targets are reached a spectrum is taken which the participants are then tasked with matching to a set of spectra consisting of 'signatures of life', rocks and minerals



Raman Spectroscopy: Across the Earth and Among the Stars

- The aim of the project is to promote interdisciplinary science while inspiring a new generation of scientists
- This is also to demonstrate how the same underpinning science and technology can have multiple far-ranging applications at the frontiers of human endeavour



There are many examples of this, a few highlighted below:

- Oceanography: the study of marine cultures, microplastic detection as well as chemical analysis [4]
- Geology: the study of rock and minerals, examples include studying volcanic activity and mineralisation [5]
- Security: the detection of illegal or dangerous substances, for example in border control or forensics [6]
- Medicine: detection of diseases and biological research [7]
- Nanoscience: Developing novel nanomaterials and their applications [8]

4. Cole, M. *et al.* Microplastic ingestion by zooplankton. *Environ. Sci. Technol.* **47**, 6646–6655 (2013).
5. Tripathi, P. & Garg, R. D. Integration of Raman, emission, and reflectance spectroscopy for earth and lunar mineralogy. *J. Appl. Remote Sens.* **15**, 1–24 (2021).
6. Izake, E. L. Forensic and homeland security applications of modern portable Raman spectroscopy. *Forensic Sci. Int.* **202**, 1–8 (2010).
7. Brozek-Płuska, B. *et al.* Breast cancer diagnostics by Raman spectroscopy. *J. Mol. Liq.* **141**, 145–148 (2008).
8. Zhang, Y. *et al.* Rolled-Up Ag-SiOx Hyperbolic Metamaterials for Surface-Enhanced Raman Scattering. *Plasmonics* **10**, 949–954 (2015).

Southampton Science and Engineering Festival (SOTSEF 2022)

- SOTSEF 2022 was the flagship event for "From Mars To Human"
- Details of the events success including feedback is included in the manuscript associated with this poster
- To summarise; the event showed that an interactive and multidisciplinary event like "From Mars To Humans" can be successful in demonstrating multiple topics with a linking theme
- We had many positive responses resulting from great engagement and fun and exciting activities
- The framework for this type of event as described in the manuscript has potential as an educational tool, to expose students to societal challenges that require interdisciplinary solutions and lots can be learnt from these kind of outreach activities
- Following the success of this event "From Mars to Humans" has high hopes to inspire the next generation of scientists at future events

Volunteers and Contributors: Isabel Crieth , Janette Thompson, Adam Lister, Peter Johnson, Sesha Venkateswaran and Mark Bradley

Contact Info: Jacob Kleboe - jk7g16@soton.ac.uk

Funding: EPSRC (EP/T020997) InLightenUs programme, Public Engagement with Research Unit (PERu) and the institute for life sciences (IfLS)

University of Southampton

InLightenUs Powered by light and curiosity

UKRI Engineering and Physical Sciences Research Council