From Art Analysis to the Search for Life on Mars

The ExoMars rover, operated by the European Space Agency and Roscosmos, will be launched in 2020 on its mission to Mars, carrying the first Raman spectrometer into space. **Liam Harris** explains how Raman spectroscopy, a technique much more commonly associated with art and heritage studies here on Earth, might help to detect signs of past or present life on the Red Planet.

Have you ever gazed up at the countless twinkling points of light in the night sky and wondered if we're alone in the Universe? With over 300 billion stars in the Milky Way, it does not seem so far-fetched to imagine that some of these stars are orbited by planets that possess conditions that enable life to flourish, just as the Earth does. Thanks to simulation work carried out at the University of California, Berkeley, we now estimate that there could be up to 40 billion Earth-sized planets in our galaxy alone and it seems extremely probable that at least some of these could support life.

This is an exciting prospect, but how can we actually detect whether such life exists and where should we start looking? The tantalising possibility that life exists elsewhere in our Solar System, in our very own cosmic back yard, has captured imaginations for centuries, but detecting this life has remained just out of our grasp. However, researchers have now discovered that the method that could give us our best chance of finding life on another planet has been around for some time, but in a field quite different to planetary exploration: the world of art and heritage.

In 2006, Professor Howell Edwards, previously of the University of Bradford and currently a visiting researcher here at the University of Leicester, was invited to investigate the *de Brécy Tondo*, a Madonna and Child tondo painting, alongside Timothy Benoy of the de Brécy Trust. It is believed that the tondo was painted in the 16th century during the Italian High Renaissance and it has been attributed to the great master painter Raphael (who was a contemporary of Leonardo da Vinci and Michelangelo), largely due to stylistic similarities with his *Sistine Madonna*. As part of his investigation, Edwards analysed small flakes of the tondo's paint, approximately 1mm^2 in size, using Raman spectroscopy to try to shed more light on its origin.

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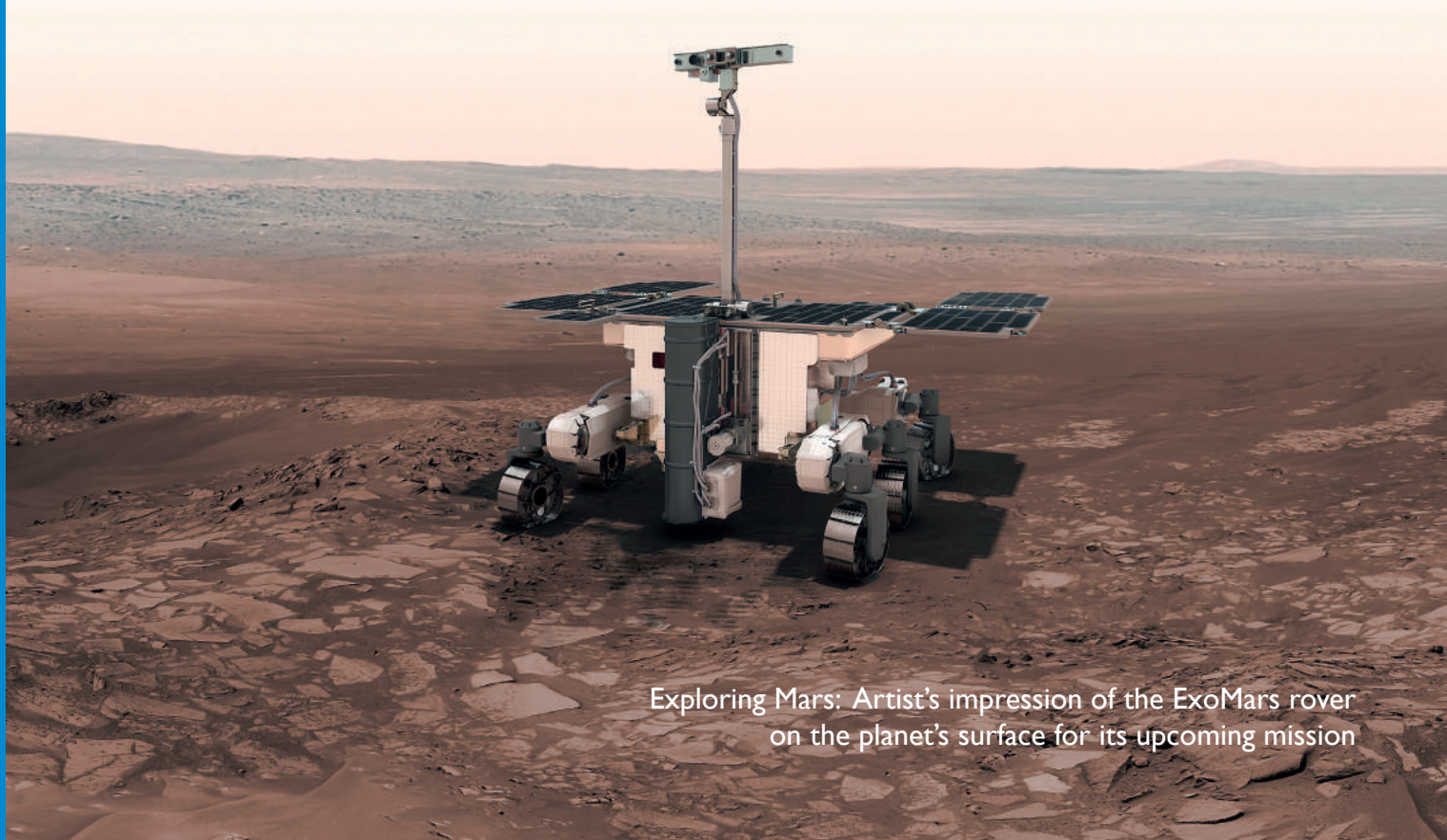

Exploring Mars: Artist's impression of the ExoMars rover on the planet's surface for its upcoming mission

Was it Raphael? – The *de Brécy Tondo* pictured here shows a striking similarity to the *Sistine Madonna*

Raman spectroscopy can be used to identify all manner of materials in an unknown sample (in this case, a few flakes of paint) by exposing the sample to light of a single wavelength or colour, usually from a laser. Some of the light is absorbed by the molecules within the sample, causing them to vibrate and resulting in a different colour of light being re-emitted. This change in colour is highly specific to each particular molecule, so acts like a fingerprint that can be used to determine the composition of the unknown sample.

Using this method to analyse three paint flakes from the tondo, Edwards found that the paint contained a starch-based binder (a component of paint that helps it to stick to the medium), a siccative (a compound that speeds the drying process of oils) and a number of pigments that were known to be used in Renaissance Italy. However, a synthetic pigment known as Prussian blue, which was created in 1706 (approximately 200 years after the estimated date of the painting of the tondo), was also identified. While this could have cast doubt over the provenance of the piece, Edwards stated that there could be a large number of explanations, both artistic and scientific, for the presence of this pigment on the tondo. Eventually the presence of Prussian blue in the *de Brécy Tondo* was attributed to an unrecorded restoration. Although the creator of the *de Brécy Tondo* has yet to be confirmed, Edwards' research has highlighted the need for both artistic and scientific expertise in the forensic analysis of art.

Raman spectroscopy has not only become a technique relied upon by art historians and conservators, but could also be used to tell us whether one of our closest planetary neighbours, Mars, is or has ever been home to life. Mars is not a particularly hospitable world so you'd be forgiven for assuming that life could simply not survive there, what with its almost non-existent atmosphere, oxidising soil, lack of liquid water and the harsh solar and cosmic radiation that constantly bombard the surface of the planet. But in recent years, microbial life has been discovered in places on Earth which were once thought to be completely inhospitable, including the Atacama Desert and the bottom of the Marianas Trench in the Pacific Ocean. Bacteria have also been found to survive in the Antarctic, where they must withstand extremely cold temperatures and high ultraviolet light (UV) exposure, conditions not entirely unlike those found on Mars. Interestingly, bacteria defy harsh conditions such as high UV exposure by producing coloured pigments, much like those used by painters, which act like sunscreen to protect them from damage. Fascinatingly, these pigments can be detected and identified using Raman spectroscopy in precisely the same way as those used on historical paintings such as the *de Brécy Tondo*.

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In 2020 the European Space Agency and Roscosmos, the Russian Space Agency, plan to launch the ExoMars rover, which, after 9 months of space travel, will touch down on the surface of Mars and begin to look for signs of life on the Red Planet. Amongst its many instruments the ExoMars rover will carry the first Raman spectrometer into space, which it will use to perform a forensic study of the Martian environment, much as Edwards did to analyse the composition of the *de Brécy Tondo*. The development of the camera for the ExoMars Raman spectrometer is currently being carried out by Dr Ian Hutchinson and his team here at the University of Leicester. If the rover and its spectrometer detect bacterial sunscreen pigments in the soil we will finally have evidence for the presence of bacteria on Mars. Furthermore, identifying these pigments will give the first indications as to how bacteria are capable of surviving seemingly impossible conditions on the surface of another planet.

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The analysis of works of art by Raman spectroscopy is a great example of a meeting between science and art and demonstrates that an appreciation of both disciplines is valuable. Likewise, the existence of extra-terrestrial life has preoccupied both scientists and artists ever since humans first looked to the night sky and wondered what's out there. While we're probably not going to meet any extra-terrestrial Raphael's anytime soon, with the imminent launch of ExoMars and its Raman spectrometer, will we be meeting some microscopic artists sometime in the near future?

References

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Liam Harris is a fourth year PhD student in the Department of Physics and Astronomy, doing research into the use of Raman spectroscopy as a tool for planetary exploration, mainly in preparation for the ExoMars rover mission, but also looking at exploring other places in the Solar System