

FIRST MEASUREMENTS OF THE SURFACE COMPOSITION OF 67P USING THE *PTOLEMY* MASS SPECTROMETER. I.P.Wright, D.J.Andrews, S.J.Barber, S.Sheridan, G.H.Morgan and A.D.Morse. Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes. MK7 6AA UK. (i.p.wright@open.ac.uk).

Introduction: Launched in 2004, and having awoken from deep space hibernation early in 2014, the *Rosetta* spacecraft [1] arrived at the comet designated 67P/Churyumov-Gerasimenko [2] on 6th August 2014. The spacecraft is currently in orbit around the comet and will hopefully continue to provide high quality science data for several more months to come. On 12th November 2014 the *Philae* lander element of the mission [3] was successfully deployed to the surface of the comet. Following the initial touchdown the so-called “First Science Sequence” was initiated. One of the instruments that was operational during this time was *Ptolemy*, a gas chromatograph-mass spectrometer system. We have previously described some of the operations that were planned to take place both before and after the landing [4, 5]. *Ptolemy* was primarily designed to undertake elemental and isotopic analyses of *surface* materials. But, as was witnessed during the fly-by of asteroid 21 Lutetia, it can also be operate in a remote, stand-alone capacity, i.e. in space, as opposed to being on a cometary surface [6,7]. Herein we describe some of the results that were acquired as *Rosetta* approached the comet and, ultimately, as *Philae* made contact with the surface.

Ptolemy: As described previously [5,8] the instrument is a miniature analytical laboratory intended to determine the chemical and isotopic composition of cometary material sourced from beneath, on and above the surface of the target comet. In detail, the instrument has been designed to work with liberated volatiles and determine their concentration, chemical and accurate isotopic compositions (D/H, ¹³C/¹²C, ¹⁵N/¹⁴N, ¹⁸O/¹⁶O and noble gases). The primary intended purpose of *Ptolemy* is to analyse solid materials taken from the Sampler, Drill and Distribution system (SD2); these are heated in discrete increments of temperature, and any evolved volatiles ultimately passed to a quadrupole ion trap mass spectrometer for detection and quantification. As well as analysing solid samples, *Ptolemy* can passively adsorb coma material onto molecular sieve contained within one of the 26 SD2 sample ovens for later thermal release and analysis; we refer to this as “CASE” mode (Comet Atmosphere Sample Experiment). *Ptolemy* can also make direct “sniff” detections of the current spacecraft environment via a vent pipe. As reported previously [6,7] we were able to evaluate the performance of parts of the instrument during a campaign of activity accompanying the fly-by of 21 Lutetia, where we used *Ptolemy* to investigate the pos-

sible existence of an asteroidal exosphere. For this, the flight-demonstrated mass range of the mass spectrometer (10-140 Da) was particularly suited for detecting volatiles such as water, CO₂ and organics. *Ptolemy* made sniff measurements several hours either side of close approach (to provide background data), and near to closest approach whilst over the sub-solar point of the asteroid’s surface. Although the results showed no unambiguous detection of an exosphere, the total ion counts seen for differing mass spectral ranges (11-90 Da and 20-140) showed a rising and falling trend in the apparent pressure of the spacecraft environment.

Pre-Landing Science: During the comet approach *Ptolemy* was operated for the first time as part of the post-hibernation commissioning activities, at a distance of 5x10⁶ km from 67P. Further sniff mode runs were completed at distances of 15,000, 30, 20 and 10 km. Although we are still engaged with trying to interpret the results, the hugely successful output from the ROSINA mass spectrometer on-board the *Rosetta* orbiter [9, 10] makes this a rather low priority investigation. Ultimately it is likely to be subtle differences in the data sets from the two instruments that will be of most interest. But this requires a greater oversight of the ROSINA data. What is useful within the context of the surface operations of *Ptolemy* is the fact that the pre-landing measurements provide a baseline for subsequent comparative purposes.

The First Science Sequence: History records that the landing attempt on 67P did not go exactly as according to plan [e.g. 11]. The implication of this for *Ptolemy* is that our intentions of making isotopic measurements at the surface were subject to some changes in operational sequencing that had to be made without full ground testing (not least of all we used the CASE mode rather than analysing a sample collected by SD2). Although the instrument operated successfully, with data being successfully transmitted back to Earth, it is likely to be some time before we can offer a proper interpretation of the results. This is because we will need to undertake some laboratory experiments using our qualification model of *Ptolemy*, i.e. in order to simulate the instrument conditions that were used on the comet. Notwithstanding the difficulties experienced during the landing, which ultimately led to the First Science Sequence being abandoned, there were some unintended consequences that will nonetheless enable a scientific return. For instance, because the

lander was put into one of its safe modes *Ptolemy* was able to acquire 6 sets of sniff mode data at intervals over a period of about 30 hours (i.e. after the lander finally came to rest). Eventually we will be able to use these data to understand more about the chemical and physical processes taking place at *Philae's* ultimate resting place. But the results that we have been concentrating on in the short term are those that were acquired in a sniff mode experiment that was conducted 9 minutes after initial contact with the surface. This experiment was always planned and operated nominally (whilst the First Science Sequence was still running). Our intention had been to measure volatiles in the immediate vicinity of the landing site. As things turned out *Philae*, had touched (and disturbed) the surface and was, at the time, some tens or hundreds of metres away from where it had first made contact. However, we recorded a demonstrable signal that is far in excess of any background and clearly shows the presence of a diverse array of compounds. Whilst our efforts will go into understanding these data in terms of the chemical composition of the comet's surface, there is the further question of how the material in question actually made it into the body of the lander and ultimately into our instrument. Perhaps surface dust was "collected" during the touch down (perhaps on the 3 footpads of *Philae*) and this was subsequently converted into volatile species that were locally at a high enough pressure to enter *Ptolemy* in the gas phase. Alternatively, small dust particles may have entered the inlet to our instrument during the original touch-down and these subsequently may have started to out-gas as they were warmed to spacecraft temperatures. Clearly this will take some time to understand and needs to involve integration of results from other lander instruments.

Summary: *Ptolemy* was operated both before and after the landing of *Philae* on 67P. In principle we have measurements of coma gases, at various distances from the nucleus, and surface materials from two different landing sites. We hope that any hypotheses we are able to make at this point can be tested either by instruments on the *Rosetta* spacecraft, or, provided we get more good fortune, on the ground later in the year should the *Philae* lander wake up successfully.

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