Cometary science with Rosetta: Striking, timely, and more to come

Marina Galand (Imperial College London) and Colin Snodgrass (Edinburgh)

Oral session:

Contribution: 12-15 min presentation followed by 5-8 min questions/discussion
Invitation: 20 min presentation followed by 10 min questions/discussion

10:00 – 10:30 **Welcome Tea**

10:30 – 11:00 **Ramy El Maarry [invited]**
The active surface of comet 67P witnessed by Rosetta

11:00 – 11:20 **Axel Hagermann**
Of ice. And dust. An experimentalist's view

11:20 – 11:40 **Nicholas Attree**
Constraining activity models with Rosetta trajectory, rotation and water production measurements

11:40 – 12:10 **Pierre Henri [invited]**
The surprising plasma environment at comet 67P revealed by Rosetta

12:10 – 12:30 **Peter Stephenson**
Multi-Instrument Analysis of FUV emissions in the Southern Hemisphere of comet 67P

12:30 – 12:50 **Alan Fitzsimmons**
Understanding Interstellar Objects through Rosetta

12:50 – 13:00 **Discussion on Rosetta outcome**

13:00 – 14:00 **Lunch**
The RAS cannot provide lunch, but many eateries can be found locally in Piccadilly.

14:00 – 14:30 **Geraint Jones (given by C. Snodgrass) [invited]**
The future Comet Interceptor mission

14:30 – 14:50 **George Brydon**
Comet Interceptor's EnVisS camera: Multispectral and Polarimetric imaging of a comet flyby

14:50 – 15:20 **Dominique Bockelée-Morvan [invited]**
AMBITION - Comet Nucleus Cryogenic Sample Return

15:20 – 15:30 **Discussion on future missions**

15:30 – 16:00 **Tea at the Geophysical Society**

16:00 – 18:00 **RAS Monthly A&G (Ordinary) Meeting**

18:00 – 19:00 **Drinks Reception (RAS Library)**

Poster session:

Helen Usher
Rosetta: The Bigger Picture

Cometary science with Rosetta: Striking, timely, and more to come
Marina Galand (Imperial College London) and Colin Snodgrass (Edinburgh)

Oral session:

10:00 – 10:30 **Welcome Tea**

10:30 – 11:00 **Ramy El Maarry (m.elmaarry@bbk.ac.uk) [invited]**
Birkbeck University

The active surface of comet 67P witnessed by Rosetta

Comets can be regarded as active planetary bodies because they display evidence for nearly all fundamental geological processes, which include impact cratering, tectonism, and erosion. Comets also display sublimation-driven outgassing, which provides a conduit for delivering materials from the interior to the surface. However, in the domain of active geological bodies, comets occupy a special niche since their geologic activity is almost exclusively driven by externally supplied energy (i.e. solar energy) as opposed to an internal heat source, which makes them "seasonally-active" geological bodies. During their active phase approaching the Sun, comets also develop a transient atmosphere that interacts with the surface and contributes to its evolution, particularly by transporting materials across the surface. Variations in solar energy input on diurnal and seasonal scale cause build-up of thermal stresses within consolidated materials that lead to weathering through fracturing, and eventually mass-wasting. The commonly irregular shapes of comets also play a major role in their evolution by leading to (1) non-uniform gravitational forces that affect material movement across the surface, and (2) spatially heterogeneous outgassing patterns that affect the comet's orbital dynamics and lead to tidal stresses that can further fracture the nucleus. In this talk, we review the surface morphology of comet 67P/Churyumov–Gerasimenko as well as its seasonal evolution as viewed by Rosetta from August 2014 to September 2016, their link to various processes, and the forces that drive surface evolution.

11:00 – 11:20 **Axel Hagermann (axel.hagermann@stir.ac.uk)**
University of Stirling

Of ice. And dust. An experimentalist's view

From Fred Whipple's dirty snowballs via fragile SL-9, via dust-mantle covered 1P/Halley, to the rocky, locally hard body with an ice-poor surface that 67P/CG seems to be: our theories on comet composition and related processes are evolving and expanding. Given that opportunities for in-situ science on comets are rare, laboratory experiments can be used to test these theories. The Stirling Planetary Ices Laboratory is one of the sites that can be used to simulate cometary environments. I will share a few of our recent discoveries exploring the (occasionally odd) interactions of ices and dust in space conditions.

11:20 – 11:40 **Nicholas Attree (n.o.attree@stir.ac.uk)**
University of Stirling

Constraining activity models with Rosetta trajectory, rotation and water production measurements

Cometary outgassing produces a reaction force on the nucleus that can alter its orbit and rotation state. For comet 67P/Churyumov-Gerasimenko, we have detailed measurements of: the nucleus shape and spin; the total water outgassing rate; and the non-gravitational trajectory, provided by Rosetta for the period 2014-2016. We can thus construct a numerical model of the expected outgassing, from insolation over the complex shape, and compare it to these datasets. I will present a fitted model and discuss how it constrains the activity pattern over the surface of 67P and the momentum transfer efficiency.

11:40 – 12:10 **Pierre Henri (pierre.henri@cnrs-orleans.fr) [invited]**
LPC2E, CNRS, Orléans &
Laboratoire Lagrange, Observatoire Côte d'Azur, CNRS, Nice, France

The surprising plasma environment at comet 67P revealed by Rosetta

While several cometary fly-by missions have enabled to pave the way towards the exploration of cometary environments, the Rosetta mission was the first space mission to escort a comet along its orbit around the Sun. During more than two years (2014-2016), the Rosetta orbiter has monitored comet 67P/CG and its ionised environment, at heliocentric distances ranging from 1.2 to 3.8 AU accounting for a variety of cometary activity, and at distances from the comet nucleus ranging from 1500 km down to the comet nucleus surface itself during the Rosetta Orbiter's final descent. This was the first extensive, long-term, in situ survey of the expanding ionosphere of a comet which interaction with the solar wind forms an induced magnetosphere.

In this context, I will review the results obtained from in situ observations made by the different instruments of the Rosetta Plasma Consortium (RPC), combined to state-of-art numerical modelling of cometary plasma environments, to give an overview of the current understanding of the structure and dynamics of a cometary ionosphere and induced magnetosphere. I will also summarise the scientific questions regarding cometary ionised environments still open after the Rosetta mission and discuss how some of them could be addressed by the recently selected multi-spacecraft Comet Interceptor mission.

12:10 – 12:30 **Peter Stephenson (p.stephenson18@imperial.ac.uk)**
Imperial College London

Multi-Instrument Analysis of FUV emissions in the Southern Hemisphere of comet 67P

Far-UltraViolet (FUV) emissions, OI1356, OI1304, Lyman-β, CI1657 and CII1335, have been observed in the coma of comet 67P by the UV Spectrometer. We use a multi-instrument analysis to identify their origin in the southern hemisphere at large heliocentric distances. Measurements from the Rosetta Plasma Consortium Ion and Electron Sensor (RPC/IES) are used to calculate the suprathermal electron flux. Several instruments are used to measure the column density of the neutral species along the line of sight of the FUV spectrograph: the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA), the Microwave Instrument for the Rosetta Orbiter (MIRO) and the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS). We first consider quiet periods to determine that dissociative excitation of neutral molecules by energetic electrons is a major source of FUV emissions in the southern hemisphere away from perihelion. We then focus on corotating interaction regions (CIRs). We conclude that the variations in the observed FUV brightness during these solar events are driven by the fluctuations in the suprathermal electron flux.

12:30 – 12:50 **Alan Fitzsimmons (a.fitzsimmons@qub.ac.uk)**
Queen's University Belfast

Understanding Interstellar Objects through Rosetta

The discovery of 1I/'Oumumua as an apparently inert object was a shock to the small body community, as interstellar objects (ISOs) were anticipated to be active cometary bodies. Many different theories on the formation, evolution, and nature of 'Oumuamua have been published in the peer-reviewed literature on the basis of ~2 weeks of intense observation. While the physical nature, composition and even size of 'Oumuamua remain uncertain, it is clear this natural body shares several characteristics with almost-dead cometary nuclei. On the other hand the second ISO, 2I/Borisov, is behaving very similarly to the many active Oort-cloud comets we observe, albeit with its own peculiarities. Placing two such very different bodies in a general understanding of ISOs is a challenging problem. Using our knowledge of the surface and activity of 67P as revealed by Rosetta, we can at least form a framework for understanding both ISOs.

12:50 – 13:00 **Discussion on Rosetta outcome**

13:00 – 14:00 **Lunch**
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14:00 – 14:30 **Geraint Jones and C. Snodgrass**
(g.h.jones@ucl.ac.uk; csn@roe.ac.uk) [invited]
MSSL/UCL; Edinburgh University

The future Comet Interceptor mission

Comet Interceptor was selected in the recent ESA call for 'fast' missions. The mission will launch (as secondary payload with M4 Ariel) to the Sun-Earth L2 point, where it will be 'parked' in a stable L2 halo orbit for a period of up to 2-3 years, until a suitable opportunity for a flyby mission to a dynamically new comet (DNC) presents itself. Once a target is found, expected to be within a few years based on predictions for comet discovery rates with LSST, the spacecraft will depart on an intercept trajectory. Shortly before the flyby, the main spacecraft will deploy 2 sub-spacecraft, allowing multiple paths through the coma and past the nucleus to be sampled. This will give a 3D snapshot of the comet at the time of the flyby, testing spatial inhomogeneity in the coma and interaction with the solar wind on all scales. This will be a unique measurement that was not possible with Rosetta, in addition to the fact that we will target a new class of comet (a much less evolved body), which will allow interesting comparisons to be made with the results from 67P.

14:30 – 14:50 **George Brydon (george.brydon.15@ucl.ac.uk)**
MSSL/UCL

Comet Interceptor's EnVisS camera: Multispectral and Polarimetric imaging of a comet flyby

The Entire Visible Sky (EnVisS) imager is a camera under development for the Comet Interceptor mission to a dynamically new comet. EnVisS will image the entire cometary environment and its constituents from multiple perspectives over the course of its flyby, contributing to the mission's multipoint measurements of its target.

EnVisS' novel design uses wide angle optics to capture images covering the entire sky as visible from the instrument's spacecraft. The camera will perform imaging polarimetry and phase function characterisation over a full 180 degree phase range. Additionally, spectral filters will allow the study of both dust and ion structures. Multiple images throughout the flyby will capture time evolution and 3D structure.

14:50 – 15:20 **Dominique Bockelée-Morvan (Dominique.Bockelee@obspm.fr) [invited]**
LESIA, Observatoire de Paris, Université PSL, CNRS,
Sorbonne Université, Université de Paris, France

AMBITION - Comet Nucleus Cryogenic Sample Return

We will present the White Paper « AMBITION - Comet Nucleus Cryogenic Sample Return » which was proposed for the ESA Voyage 2050 long-term plan. The White Paper summarizes some of the most important questions still open in cometary science after the successes of the Rosetta mission, many of which requiring sample analysis using techniques that are only possible in laboratories on Earth. Measurements, instrumentation and mission scenarios that can address these questions are presented with a recommendation that ESA selects an ambitious cryogenic sample return mission (L-class). Rendezvous missions to Main Belt comets and Centaurs are compelling cases for M-class missions, expanding our knowledge by exploring new classes of comets.

15:20 – 15:30 **Discussion on future missions**

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18:00 – 19:00 **Drinks Reception (RAS Library)**

Poster session:

Helen Usher (helen.usher@open.ac.uk)
Open University / Faulkes Telescope Project
Rosetta: The Bigger Picture

The Rosetta Mission invited amateur astronomers to be part of a ground-based observing campaign for 67P. Amateurs, with greater access to telescope time and wider geographical coverage, can add important temporal coverage and wider scale observations to complement those of professional astronomers. They add the bigger picture. This allows for a greater multi-scale analysis of comet activity.

With 67P coming back shortly, and future comet missions being planned, there is an opportunity to assess the effectiveness of the 67P amateur, and a related 46P schools', observing campaigns, and draw lessons for future campaigns.

This study presents details of the available data from the amateur 67P and the 46P schools' campaigns, an initial assessment of the challenges to analysis, and proposes approaches for that analysis.

Feedback has been sought from those who took part in the campaigns, and from amateur astronomers who might be encouraged to take part in future campaigns. The survey results are presented here, along with a discussion of how future campaigns may be made most effective.