Comet 67P/Churyumov-Gerasimenko and Cometary Biology

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Abstract

The long-awaited rendezvous of ROSETTA with its target Comet 67P/Churyumov-Gerasimenko is expected at best to give indirect evidence for cometary panspermia and the presence of microorganisms in comets. Prodigious out gasing of water vapour observed at large heliocentric distances, low albedo and a terrain of alternating rough and smooth areas already provides consistency with cometary biology,

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ROSETTA's decade-long mission to Comet 67P/Churyumov-Gerasimenko following its launch in 2004 is fast approaching its climax. In January this year (2014) the spacecraft exited a phase of hibernation and began to gear up for its ultimate landing (the lander *Philae*) on the comet's surface. The imaging of the nucleus accomplished to date has revealed a smallish sized comet of average diameter 4km rotating with a period of 12.7 hours. Further results of the mission as they emerge will watched with eager anticipation, in particular for signs of any connections that might relate to our own origins.

Since the first space exploration of a comet – Comet Halley – in 1986 – an earlier entrenched paradigm of a 'dirty ice comet' has been gradually replaced by a class of model that is now widely admitted to have a possible link to an origin of life on the Earth. The evidence of life-related organic material in Comet Halley was dramatically displayed both in ground-based infrared spectra, and in mass spectroscopy carried by the Giotto spacecraft (1,2). The comet's dark non-reflecting surface was probably composed of a tarry residue overlying a frozen water-ice dominated terrain. The estimated visual albedo of A = 0.1 is consistent with 10% of the surface disrupted so as to expose underlying ice with A=1. Similar data relating to the dominance of complex organic molecules in comets have been confirmed since 1986. Both the Deep Impact Mission of 2005, involving an impactor crashing onto Comet Tempel 1, and the Stardust Mission, which led to a sample return in 2006, confirmed that comets do indeed carry material that is relevant to biology (2). More recent studies of the distribution of organic molecules in cometary comae, notably of HCN, H_2CO and CH_3OH, with the deployment of ALMA (Atacana Large Millimeter Array) tell a similar story (2). The contentious issue relates to the presence of fully-fledged microbial life that seeded the Earth and possibly other planets in the galaxy. In the opinion of the present author such radio astronomical molecules as have been found are mostly the degradation of metabolic products of biology.

Recent detections of exoplanets by the Kepler Mission (3), combined with independent microlensing data (4). have led to an estimated total population of planetary systems of some 140 billion in the galaxy. The close separation of neighbouring habitable planetary systems permits the efficient exchange of comets and bolides by well-attested dynamical processes (5), thus greatly strengthening the case for cometary panspermia. The recent discovery of cometary bolides (L-chondrites) in terrestrial sediments dated at 470 million years ago, coinciding with the time of the most extensive explosion of species in the geological record, gives further credence to a comet-life connection (6).

The idea of comets carrying bacteria and viruses is, however, still viewed with scepticism in orthodox circles; for this reason no explicit life detection experiment was included in the ROSETTA mission package. Although the present writer along with Max Wallis were included in the original ROSETTA Radio Science Team, the lack of any interest in biological detection did not encourage us to continue our participation. The best that could be accomplished with the on-board ROSETTA equipment would be to secure indirect evidence that might point to biology.

The recent report (7) that Comet Churyumov-Gerasimenko was losing water prodigiously at a rate of 300g/s could be interpreted as such evidence, implying the resumption of subsurface microbiology as the comet approaches perihelion. On 6 June 2014 the comet was at a distance of R=5.83 x 10^{13} cm from the sun. The comet's rapid rotation with a period of 12.7 hours implies that it intercepts solar energy on one hemisphere whist re-emitting infrared radiation over the entire surface. Thus we have

$$(1-A)\frac{L}{4\pi R^2}(\pi r^2) = \epsilon\sigma T^4(4\pi r^2) \tag{1}$$

where A is the optical albedo, ϵ is the infrared emissivity, L the solar luminosity, T is the temperature, r is the comet's radius (assumed spherical) and σ is the Stefan-Boltzmann constant. The equation (1) gives the result T = 130K, assuming A=0.1 (as in Halley's comet) and ϵ = 1. The rate of loss of H_2O from a water-ice surface at temperature T can be readily shown to be

$$\left(\frac{m_{H2O}}{kT}\right)^{\frac{1}{2}} p(T).\, 4\pi r^2 f \qquad \text{g s}^{-1} \tag{2}$$

where $p(T)$ is the saturation vapour pressure of water-ice and f is the fraction of the cometary surface comprised of exposed water-ice. With appropriate values of the physical constants this becomes

$$8.56 \times 10^8 f\, p(T) \qquad \text{g s}^{-1} \tag{3}$$

For a surface crusted over with a carbonaceous skin, as in the case of Comet Halley or Comet Temple 2, possessing an albedo of 0.1 it would be reasonable to set f = 0.1, which case we have an H_2O outgassing rate of

$$8.56 \times 10^7\, p(T) \qquad \text{g s}^{-1} \tag{4}$$

With the saturation vapour pressure of water at 130K being 10^{-7} dyne cm^{-2} (from tabulations and calculations by the author) the water emission rate is estimated at less than 10 g s^{-1}, 30 times less than has actually been found (7).

In spite of the uncertainties inherent in the present calculation, it is possible to interpret the surprisingly large outflow of water observed from the Comet Churyumov-Gerasimenko on June 6, 2014, when the comet was between Jupiter and Mars, as being indicative of biology. Although microorganisms in comets are generally in a frozen dormant state at aphelion, a sporadic resumption of metabolism will occur near perihelion if subsurface melting can take place. Metabolism builds up subsurface gas pressures of thousands of atmospheres, which is enough to cause cracks in the surface crust releasing gas and dust. Such melting could occur due to increased solar radiation or, on occasion when impacts of smaller bodies transfer kinetic energy that can be converted to heat. Comet Hale-Bopp showed sporadic activity when it was outside the orbit of Jupiter. We can argue that this activity in Comet Hale-Bopp, as well as the new evidence from Comet Churyumov-Gerasimenko, point to the resumption of bacterial activity in comets (8).

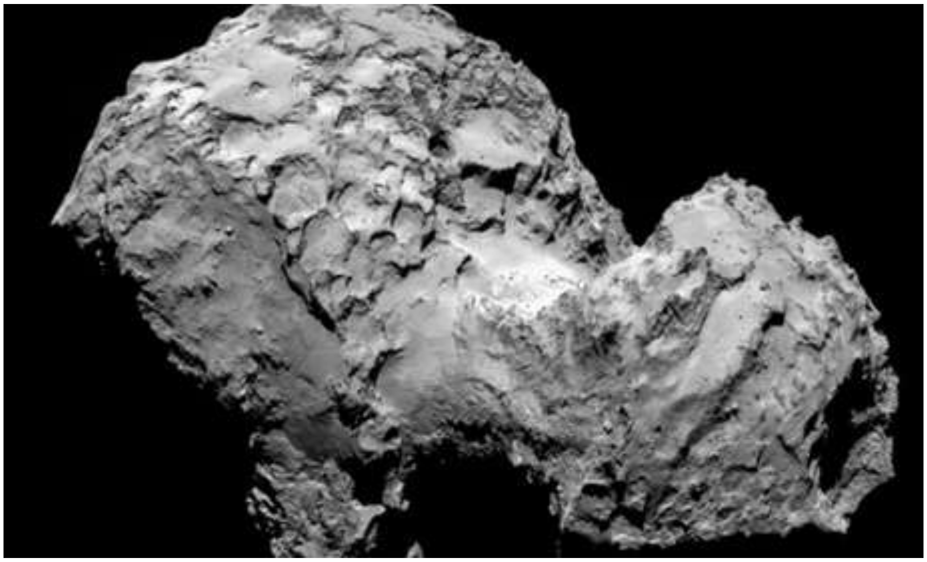

Fig.1 Image of surface of Comet 67P/Churyumov-Gerasimenko obtained by ROSETTA cameras on 7 August 2014 (Courtesy of ESA).

The rendezvous of the ROSETTA spacecraft with Comet Churyumov-Gerasimenko on 7 August 2014 led to stunning close-up images of its surface, revealing a highly structured terrain (See Fig.1). Roughened fractal regions were interspersed with smooth areas that could represent recently exposed subsurface lakes. A continuing high rate of outgasing and evidence of chemical activity, if discovered, could all point strongly to cometary biology. It is scarcely likely that new data from the ROSETTA mission as it unravels will not provide even more compelling evidence for a “living comet”. To continue describing this comet as “a hurtling lump of dust and ice” is a travesty of the facts, and harks back to the obsolete “Whipple dirty snowball” paradigm of comets

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