K2 DDT proposal – observing Rosetta's comet

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Scientific Justification

Rosetta is an ESA flagship mission (with key contributions from NASA) that is currently in orbit around comet 67P/Churyumov-Gerasimenko. It has already been a spectacular success, including the delivery of the lander Philae to the comet's surface in 2014, and a string of results from the instruments onboard the orbiter that are changing our understanding of comets, and therefore the process of planet formation [e.g. 1,2,3]. The mission will continue until the end of September 2016, when the spacecraft will be landed on the nucleus.

There is a world-wide campaign of observations of the comet in support of the mission (see www.rosetta-campaign.net). Earth-based observations are important for two main reasons: 1. They provide large scale context, allowing us to measure the 'total' activity of the comet [4,5] and study its coma and tails on 10^3-10^6 km scales[6], which Rosetta doesn't see as it is embedded in the core of the coma, 10-100 km from the nucleus; 2. They provide the link to other comets that are observed only with telescopes, allowing us to measure how 'typical' 67P is, and to validate observation techniques against ground-truth from Rosetta measurements. The unique opportunity to observe an astronomical object in parallel with in-situ investigation by spacecraft gives a better understanding of cometary phenomena on all scales.

The ground-based campaign can follow 67P until July 2016, after which the solar elongation of the comet prevents further observation. For the last 2-3 months of the Rosetta mission our context information will be missing. However, 67P passes through the K2 campaign 10 field in September, meaning that we can get remote observations just before the end of the mission. Kepler photometry can provide the following key measurements at a time when no other platform can observe the comet:

1. Total brightness of the comet. This relates directly to the amount of dust being released and therefore gives a critical 'total' activity measurement, which can be compared with the instantaneous (but local) measurements from various instruments on Rosetta.
2. Variability of the comet. There are two sources of variability; changing amounts of dust in the coma, and the underlying light-curve of the nucleus (its non-spherical shape reflects more or less sunlight as it rotates).

The measurements from Kepler will extend the total activity curve to almost the end of the Rosetta mission, meaning that data in the last months of Rosetta will not rely on extrapolation of the earlier Earth-based observations. As the final months will be some of the most exciting – as Rosetta spirals down and makes local measurements from incredibly close to the nucleus – this context information is very important in this phase.

The short-term (hours to days) variability of the comet is also important, and is an aspect that Kepler is uniquely capable of adding to, with its high photometric stability and uninterrupted view. As we will know the true rotation period of the nucleus (around 12 hours) from Rosetta measurements, we will be able to test whether we can recover the nucleus light-curve despite the contaminating coma contribution. Coma subtraction techniques have been applied to observations using the HST [e.g. 7], but this is a unique opportunity to show that the results from such techniques are reliable. If not, and we find instead that short-term variation in the dust release of the comet is the more significant effect, this will also be very useful – we will be able to correlate the changes in the overall comet with events recorded by Rosetta (i.e. detect *and explain* small outbursts).

67P will be on silicon between the 8 and 22 of September, moving at a rate of ~33 "/hr, or ~4 pixels per half hour exposure. This will not smear significantly with the Kepler PSF at the comet's position. Its predicted magnitude is K_p=20.6, giving S/N~10 – sufficient for our science goals. The comet's activity will be relatively low and the coma will not be very extended – a mask 15 pixels wide will be sufficient (mainly driven by the PSF and the fact that the comet is faint). The comet will move mostly in the column direction (crossing channels 69 & 70) during the 13 days in the FOV, giving a tracklet length of 2200 pixels. To cover this full period, to be able to search for outbursts, will therefore require 33,000 pixels. To provide the minimum observations (total activity) we would instead read out 3 tracklets corresponding to the beginning, middle and end of the visibility window, in each case covering 36 hours on the comet (averaging over 3 rotation periods), requiring a total of 13,500 pixels.

Legacy value of the programme

The opportunity to perform parallel observations of a comet with in-situ observations is unique. Kepler will return the last images of the whole comet during Rosetta's mission. These observations will provide essential context and also test comet observing techniques used elsewhere.

DDT justification

At the time of the campaign 10 proposal deadline the Rosetta mission extension into 2016 was not confirmed, nor was the extent of the anticipated mission extension known – we did not know that the mission would continue to operate into September 2016.

References

[1] Sierks et al 2015, Science 347, a1044; [2] Altwegg et al 2015, Science 347, a0387; [3] Rubin et al 2015, Science 348, 232; [4] Snodgrass et al 2013, A&A 557, A33; [5] Snodgrass et al 2016, A&A in press; [6] Moreno et al 2016, A&A in press; [7] Lamy & Toth 1995, A&A 293, L43

Object	J2000 Right Ascension (deg)	J2000 Declination (deg)	Kp (mag)	Cadence (min)	Proper motion ("/yr)		extent (arcsec)	Comments
					δRA	δDec		
67P/Churyumov-Gerasimenko			20.6	30			~5	Solar system target