EPSC Abstracts
Vol. 8, EPSC2013-927, 2013
European Planetary Science Congress 2013

Are Main Belt Comets driven by water ice sublimation?

C. Snodgrass
Max Planck Institute for Solar System Research, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany
(snodgrass@mps.mpg.de)

Abstract

Main Belt Comets (MBCs) are objects with asteroid-like orbits in the main asteroid belt, which demonstrate comet-like appearances. While some of these objects can be explained by collisions between asteroids, which leave trails of debris, the repeated activity of some of the population suggests that their activity is driven by the same process as normal comets. Comets' activity is driven by sublimation of ice as they approach the Sun, with water ice thought to be the major driver at heliocentric distances less than about 3 AU, and activity possibly controlled by more volatile species (such as CO or CO_2) at larger distance. These gasses, or the daughter products that they are dissociated into, are detected in the comae of comets. In MBCs there has not yet been a direct detection of gas that would confirm the idea that they are also driven by sublimation. I will review detection attempts, what the expected level of gas production is, and present new results on the MBC candidate P/2012 T1 (PANSTARRS), which was observed with a variety of telescopes following its discovery in October 2012.

1. Main Belt Comets

MBCs were only recently identified as a population in their own right [1], following the discovery of additional objects like the puzzling 133P/Elst-Pizarro, which was first seen active in 1996 and caused some debate over whether it was a comet or collisional debris. The question has been convincingly settled for 133P, as it has returned to activity after each perihelion passage since its discovery, meaning that sublimation of ice is the only reasonable explanation [2, 3]. Other recent discoveries confuse the picture: While 238P/Read also shows repeated activity and is likely a bona-fide comet [4], other objects with comet-like appearance have been shown to be due to collisions or rotational break up (e.g. [5, 6, 7]). Modelling of the dust morphology can be used to differentiate between tails from comet activity which has lasted for many months, and trails of debris from single events. Repeated activity remains the best evidence we have for the comet-like nature of some of these objects. Ideally we would like direct confirmation that their activity is driven by sublimating ice – this requires detection of a gas coma.

2. Searching for gas

For normal comets direct spectroscopy reveals the presence of the gas and allows it to be identified. Water is found to be the main constituent of comets, which is split into OH and H by interaction with sunlight; a strong signature of emission by OH at 308 nm is seen in comet spectra (water itself is very difficult to detect from the ground due to Earth's atmosphere). The next strongest feature in comet spectra is normally the group of CN lines around 389 nm, which are far easier to observe, as the OH line is strongly affected by terrestrial atmospheric absorption, so it is difficult to detect from the ground. For this reason, ground based spectroscopy of MBCs to date has concentrated on the CN band, but has proven unsuccessful (e.g. [8, 9, 10]). The upper limits on water production resulting from these works are inconclusive – the authors assume a 'typical' CN:H_2O ratio based on traditional comets, and use this to derive a limit based on the CN non-detection. Unfortunately, the resulting limits are above the level expected for MBCs based on the observed dust production (MBCs are very weakly active comets), and also the underlying assumption, that MBCs have the same proportions of volatile ices to other comets, is likely to be incorrect. Modelling of the survival of subsurface ice within the snow-line indicates that only water ice will survive, and more volatile ices will be lost [11, 12]. The parent ice species for CN in normal comets is not certain, but a strong candidate is HCN, which is considerably more volatile than water (with a sublimation point of 95K), and is not expected to survive in MBCs.

An attempt was made to detect water around MBC candidate 176P/LINEAR using the ESA Herschel space telescope. This telescope operates at thermal infrared wavelengths, and is sensitive to water emission at 557 GHz. Unfortunately, the targeted comet did not return to activity when expected (the observations were scheduled to coincide with the same near-perihelion point in the orbit that activity was seen at in 2005), and no water was detected [13]. The upper limit on water production rate from these observations, $Q(H_2O) < 4x10^{25}$ molecules s^{-1}, is more sensitive than most of the limits from CN line observations, and would have been sensitive enough to detect water if MBC production rates follow the same empirical relationship to total brightness found for other comets [14]. This is unknown however, given the low level of activity of MBCs, and another approach (assuming a dust-to-gas mass ratio of one) implies that the total expected rate should have been only $2x10^{24}$ molecules s^{-1}. The authors were forced to conclude that it was possible that there was activity below their detection limit, although they did not know at the time that the comet had not returned to visible activity.

3. P/2012 T1 (PANSTARRS)

In October 2012 a new MBC candidate was discovered by the Pan-STARRS survey, with an orbit in the outer main belt (similar to 133P and others) and a comet-like appearance. The shape of the tail (a broad fan rather than the long thin trails associated with collisions), and the fact it kept this appearance over many months, suggest that this is a real comet. Follow up observations were performed by a number of groups, including spectroscopy using the Keck telescopes, which looked for CN but was again unsuccessful, with a limit on water production of $5x10^{25}$ molecules s^{-1} [15]. Direct spectroscopic searches were made for water using the Herschel space telescope [16] and the VLT. Our own VLT search used the X-SHOOTER spectrograph, which covers a wide range of wavelengths from the UV to near-IR. Critically, it is sensitive down to 300nm at the blue end, so can, in principle, detect the OH emission line at 308nm. Other water-related lines (such as the O[I] line at 630nm, and water lines in the NIR) are unfortunately not resolvable, as the relative velocity of the comet was not enough to shift the lines away from terrestrial atmospheric lines at the resolution we used. Both the Herschel and X-SHOOTER spectra have the advantage that they do not rely on any assumptions on the link between CN and water production, and can in principle detect water (or its daughter products) directly. For P/2012 T1 both resulted in non-detections, although the comet was visibly active in images taken at the same time as these observations. Detailed analysis of the data is ongoing, and I will present results on the derived limits to water production. These results show that MBCs have a very low level of activity, which requires steps beyond our current best instrumentation technology to measure. I will discuss the implications this has for P/2012 T1, and for MBC activity in general, and potential future steps to solve this problem.

References

[1] Hsieh, H. & Jewitt, D. 2006, Science 312, 561

[2] Hsieh, H., et al. 2010, MNRAS 403, 363

[3] Jewitt, D. 2012, AJ 143, 66

[4] Hsieh, H., Meech, K., & Pittichová, J. 2011, ApJL 736, L18

[5] Snodgrass, C., et al. 2010a, Nature 467, 814

[6] Jewitt, D., et al. 2010, Nature 467, 817

[7] Stevenson, R., et al. 2012, ApJ 759, 142

[8] Jewitt, D., et al. 2009, AJ 137, 4313

[9] Licandro, J., et al 2011, A&A 525, A34

[10] Hsieh, H., et al. 2012, AJ 143, 104

[11] Prialnik, D. & Rosenberg, E. 2009, MNRAS 399, L79

[12] Capria M. T., et al. 2012, A&A 537

[13] de Val-Borro, M., et al. 2012, A&A 546, A4

[14] Jorda, L., et al. 2008, ACM meeting, abs #8046

[15] Hsieh, H., et al., 2013, ApJ submitted

[16] O'Rourke, L., et al., 2013, ApJ submitted