The search for main-belt comets: The Pan-STARRS1 perspective

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In recent years, an increasing number of objects have been discovered in the main asteroid belt that exhibit comet-like activity. Some instances of activity are believed to result from sublimation of volatile sub-surface ice, and the objects exhibiting this type of activity have come to be known as main-belt comets (MBCs; Hsieh & Jewitt 2006). For most MBCs, the presence of gas is only inferred from visible dust emission, although water vapor outgassing has recently been directly detected from (1) Ceres (Kuppers et al. 2014), indicating that water sublimation on MBCs could also be possible. In other instances, comet-like dust emission has been found to result from impacts onto otherwise inert objects, rotational disruption, or a combination of effects (cf., Jewitt 2012). In these cases, the objects can be referred to as disrupted asteroids. Collectively, MBCs and disrupted asteroids are known as active asteroids.

MBCs have attracted interest in astrobiology due to theoretical studies indicating that material from the asteroid belt region could have been a significant primordial source of the water and other volatiles on the Earth. Icy asteroids also contain some of the least altered material from the inner protosolar disk still in existence today, presenting us with opportunities to learn about the earliest stages of our solar system's formation. The added bonus of the MBCs' relatively close proximity in the asteroid belt means that in situ spacecraft studies are entirely feasible using present-day technology.

Pan-STARRS1 (PS1) is a wide-field synoptic survey telescope located on Halekala in Hawaii. It employs a 3.2×3.2 deg 1.4 gigapixel camera and uses an SDSS-like filter system. As of 2014 March 31, the Pan-STARRS1 survey has discovered three MBCs — P/2006 VW139, P/2012 T1 (PANSTARRS), and P/2013 R3 (Catalina-PANSTARRS) — as well as one disrupted asteroid (P/2013 P5 (PANSTARRS)), two active Centaurs, 33 Jupiter-family comets, and 17 long-period comets. For the analysis presented here, we focus on the period between 2012 May 20 and 2013 Nov 9, during which PS1 made 760 475 total observations (which meet certain data quality criteria) of 333 026 unique main-belt objects, including two of its three MBC discoveries. This time period was selected to ensure consistent screening rigor across our sample, since our comet screening procedures have evolved over time.

Analysis of the discovery statistics of the PS1 survey over the time period in question indicates that there should be >50 currently active MBCs in the outer main belt within the detectability limits of a survey like PS1. We note, however, that a much larger population of MBCs will likely be detectable by more sensitive future surveys, and discuss prospects and recommendations for these future surveys based on our experiences with PS1. Considering the total currently known population of MBCs, including PS1-discovered objects, we find that examination of their orbital-element distributions reveals an excess of MBCs at moderate eccentricities ($0.1 < e < 0.3$) relative to the background asteroid population. We suggest that this eccentricity distribution could point to a plausible physical mechanism for explaining observed patterns of MBC activity.

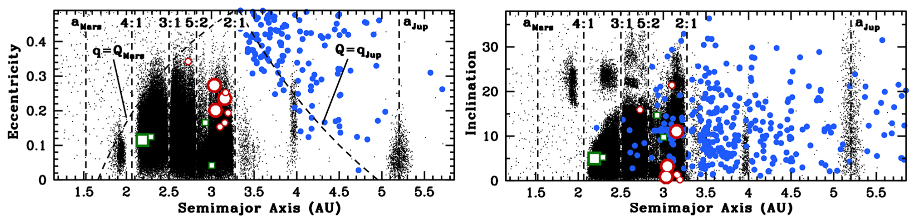

Figure: Semimajor axis vs. eccentricity (left) and semimajor axis vs. inclination (right) plots of asteroids (small black dots) and classical comets (blue filled circles), where PS1-discovered MBCs and disrupted asteroids are indicated with large open red circles and open green squares, respectively, and MBCs and disrupted asteroids discovered by others are marked with small open red circles and open green squares.

References: Hsieh, H. H., Jewitt, D. 2006, Science, 312, 561–563; Jewitt, D. 2012, AJ, 143, 66; Kuppers, M., et al. 2014, Nature, 505, 525–527.