EPSC Abstracts,
Vol. 4, EPSC2009-815, 2009
European Planetary Science Congress,

The Seasonal Activity of Main-Belt Comet 133P/Elst-Pizarro

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Abstract

We use lightcurve data of main-belt comet 133P to test that its activity is due to seasons. The data are consistent with the seasonal hypothesis and rule out solstice at 90° past perihelion. More observations at different geometries will be needed to rule out zero obliquity and definitely test the seasonal hypothesis.

Main Belt Comets

Main-belt comets (MBCs) are a newly identified class of objects that have asteroid orbits but, like comets, exhibit dust comae and tails driven by ice sublimation. MBCs are significant because they tell us the asteroid belt holds not only rocky asteroids but also icy objects which may have delivered water to Earth after it formed. For the ice to have survived so close to the Sun for the age of the solar system it must be thermally insulated by a dusty mantle. The leading idea to explain the observed activity is that occasional impacts by metre-sized objects excavate the mantle and expose the ice. When the exposed ice patch heats up by insolation it begins to sublimate and to drive the ejection of dust into a coma and tail. The activity would then be seasonal, occurring during summertime for the hemisphere containing exposed ice.

133P/Elst-Pizarro and the Seasonal Hypothesis

The first and best studied MBC is 133P/Elst-Pizarro. 133P is known to be active for 25% of its orbit, roughly starting at perihelion. If the activation mechanism described above and the seasonal hypothesis are correct, then the patch of ice driving the activity on 133P must be on the hemisphere that preferentially faces the Sun during that part of the orbit. Summer solstice must lie close to perihelion (see Fig. 1), or slightly past it. Plus, the obliquity must be non-zero ($\varepsilon \neq 0$).

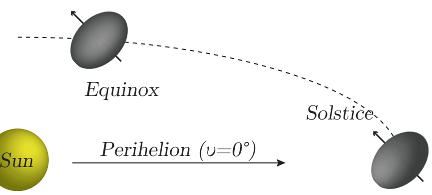

Figure 1: Orbit diagram showing the orientation of the spin pole of 133P predicted by the seasonal heating hypothesis.

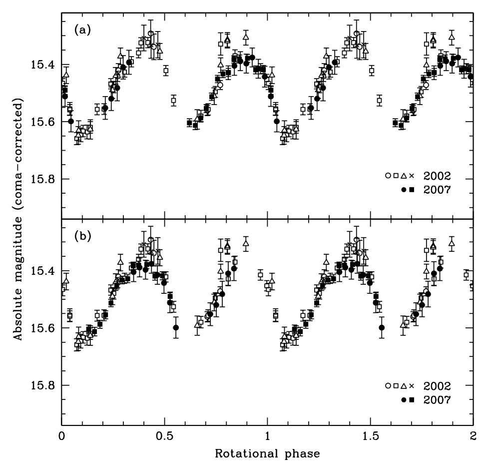

Figure 2: Lightcurves of 133P taken at perihelion (Jul 2007; filled symbols) and ~70° past it (Sep 2002; open symbols).

Photometric range as a test for the Seasonal Hypothesis

The photometric range (Δm) of an object is minimum at solstice as the spin axis is most aligned with the Sun direction, and maximum at equinox when the object is observed equator-on. Fig. 1 shows the case when solstice happens at perihelion — this is the scenario predicted by the seasonal hypothesis. Lightcurves of 133P taken at perihelion (Jul 2007) and ~70° past it (Sep 2002) are shown in Fig. 2. Each dataset was phased self-consistently to spin period $P = 3.9471 \pm 0.0001$ hr but the two epochs are just aligned by eye as

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the period uncertainty propagated for 5 years becomes too large. In Fig. 2a the alignment is such that Δm does not seem to have changed much from 2002 to 2007. In Fig. 2b, Δm seems to have decreased from $\Delta m_{2002} \sim 0.36$ mag to $\Delta m_{2007} \sim 0.25$ mag. The ambiguity is important because it has implications for the pole orientation of 133P and for testing the seasonal hypothesis.

Lightcurve models of 133P

In Fig. 3 we show 3D models of the nucleus of 133P and respective lightcurves in 2002 and 2007 assuming three different pole solutions. For obliquity $\varepsilon = 20°$, three solstice positions are shown, at mean anomalies $\nu_{\rm sol} = 0°$, 40° and 90°. A more detailed comparison of the Δm behaviour predicted for each pole orientation is shown in Fig. 4. For solstice at perihelion ($\nu_{\rm sol} = 0°$, Fig. 4a) the range Δm should remain unchanged for low obliquity $0° < \varepsilon < 10°$ or decrease for obliquities $10° < \varepsilon$. This is consistent with what is observed for 133P (Fig. 1). For solstice at $\nu_{\rm sol} = 90°$ (Fig. 4c) Δm is expected to remain unchanged from 2002 to 2007 if $0° < \varepsilon < 10°$ but it should rise if $10° < \varepsilon$ — this is not observed in the data. An intermediate case ($\nu_{\rm sol} = 40°$, Fig. 4b) shows that we are not sensitive to the exact position of the pole; more data is needed, at different points along the orbit.

Conclusions

Lightcurve data taken in Sep 2002 and Jul 2007 are used to test the seasonal hypothesis for the activity pattern of MBC 133P. The data are consistent with the seasonal hypothesis and rule out solstice at mean anomaly $\nu_{\rm sol} = 90°$. The data do not rule out zero obliquity — observations at different geometries are needed for that purpose.

References

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Additional Information

This work has been funded by the UK Royal Society through a Newton Fellowship.

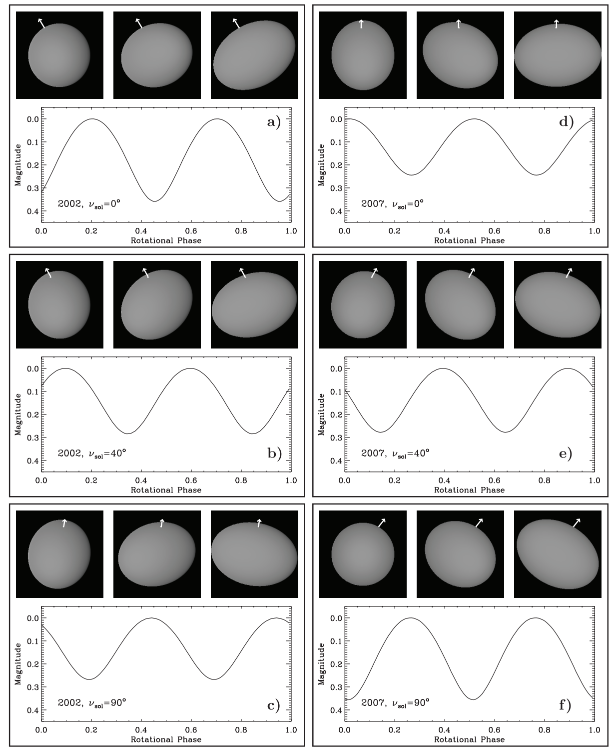

Figure 3: 3D models of the nucleus of 133P and respective lightcurves in 2002 and 2007 assuming three different pole solutions.

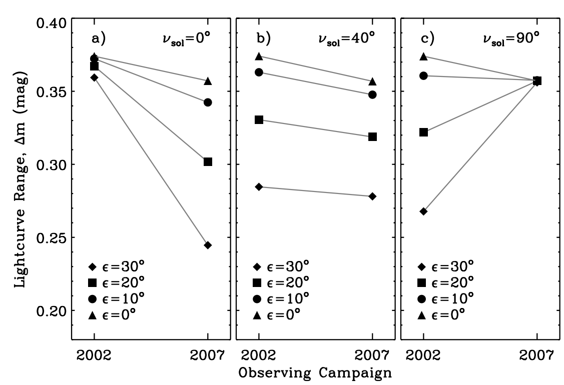

Figure 4: 3D models of the nucleus of 133P and respective lightcurves in 2002 and 2007 assuming three different pole solutions.