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Analysis of the Activity on Main Belt Comet 133P/Elst-Pizarro

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Abstract

We will present an analysis of the mechanisms responsible for the sublimation activity in the main belt comet 133P/Elst-Pizarro. This will include (i) the comparison of the spin pole orientation of 133P to that predicted by models of ice longevity in the asteroid belt, (ii) sublimation modeling of the heliocentric light curve of 133P and (iii) visual monitoring of activity of 133P along its orbit.

1. Introduction

Water (and other volatile species) played a key role in the planetesimal formation and alteration, and through dynamical scattering, has led to the current planetary inventory of the ingredients necessary for life. The discovery of the main belt comets (MBCs), which are believed to have water in the form of ice (rather than hydrated minerals known to be present in primitive asteroids), suggests that water ice was more prevalent in the asteroid belt and has a greater longevity than previously thought. We will explore the activity of 133P/Elst-Pizarro, using physical and photometric properties to gain a better understanding of the ices causing sublimation in this MBC.

2. Sublimation Activity

Having shown recurrent activity during the past three perihelion passages, it is now clear that in the case of 133P, the activity is the result of a thermally driven process. To constrain sublimation models of 133P, which attempt to describe the efficiency of heat transport through the nucleus, we require knowledge of the distances where sublimation occurs. While 133P is at perihelion and strongly active, taking short exposure images is sufficient to see 133P's comet like activity, but as it moves further away from the Sun, the activity decreases and requires composite images to look for faint activity.

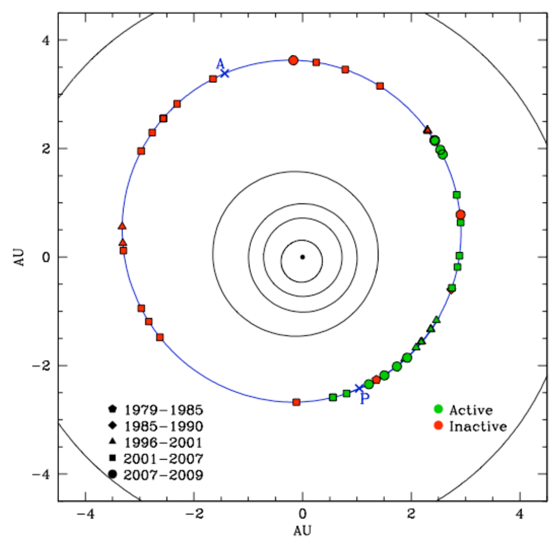

Figure 1: Observations of 133P as a function of true anomaly, with respect to perihelion (P) and aphelion (A). Note that 133P remains active nearly 1/3 of the way around its orbit post-perihelion. Data points shown consist of our 2002-2009 observations, as well as data published by several other groups [6].

Using composite images from our 2008 runs, we find that 133P exhibits activity out to a true anomaly of 109°, shown in Figure 1, extending the baseline over which 133P is known to be active by 20°. The thermal evolution models by [4] predict that 133P is potentially active at aphelion, so we are conducting a search for faint activity using composite images from 2009-2011, as 133P nears and moves away from aphelion.

3. Pole Orientation

One of the physical characteristics critical to models describing the longevity of ice on MBCs is the orientation of spin axes. Two models attempt to explain the source of MBC activity as the sublimation of ices [5, 4]. [5] found that if an icy object has a dusty surface layer, temperatures in the shallow subsurface ($\sim$ a few meters or greater) can remain low enough for ice to survive for long periods of time, and if the object also has a high obliquity, this will allow ice to survive over the age of the solar system. In the second study, [4] analyzed the longevity of ice for 133P using a detailed 3-D evolutionary calculation of heat transport in the nucleus. They find that only crystalline water ice can survive in the nucleus at depths ranging from $\sim$ 50 to 150 meters. They also conclude that the long-term survivability of crystalline water ice depends on the spin axis orientation, and they predict that MBC poles will have high obliquities. Determining the pole orientation is therefore critical to confirming water ice is causing the sublimation in MBCs and for understanding the longevity of ice in the asteroid belt.

We have used the light curve inversion software, `convexinv` [1], which employs a fast ray-tracing algorithm coupled with light curve data and a simple empirical scattering law, to simultaneously solve for the shape, spin and scattering model of 133P. Preliminary models suggest the spin pole has a high obliquity, $\sim 30^\circ$ in ecliptic latitude. Using data collected in late 2010 and early 2011, we will solve for a unique pole solution for 133P and test ice longevity models.

4. Sublimation Modeling

Another method to study activity as a function of orbit is to use photometric monitoring, usually in the form of a heliocentric light curve, which is more sensitive to detecting flux excesses than visual monitoring [3]. Not only does the heliocentric light curve allow us to pin point the regions in the orbit where 133P is active, but it also can be used in sublimation modeling. We have a program designed to model the activity of an object based on parameters such as distance from the Sun, fraction of surface which is active, and particle sizes of dust being lifted due to sublimation. By comparing this model with our data, we can constrain the species of ices that are causing the activity on 133P.

5. Summary and Conclusions

Using photometric observations, we have extended the baseline of comet like activity seen in 133P, as well as loosely constrained the orientation of the spin pole, showing that it has a high obliquity, which is consistent with predictions of ice longevity models. Coupling these results with sublimation modeling will provide us with significant insight into the source of the activity in MBCs.

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