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Main Belt Comet P/2008 R1 Garradd: changes of activity

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Abstract

In this work we investigated long term changes of the water emission from a model comet of the size and orbital elements of comet P/2008 R1 (Garradd). We performed simulations for model cometary nuclei of different compositions and two different orientations in space. Our simulations indicate, that the decrease of water production from one orbital period to another one may be slow. The seasonal maximum of water production 500 orbital periods after activation of the comet can be as $7x10^{24}$ molecules per second. The upper estimate for the production of water derived from observations of P/2008 R1 (Garradd) by [1] is $5x10^{25}$. Hence, it is possible, that comet Garradd was activated not recently, but few hundreds orbital periods ago.

1. Introduction

The Main Belt Comets (MBCs) is a new class of objects identified in recent years. These objects exhibit cometary activity but their orbits are in the outer part of the main belt of asteroids. The known MBCs population is small, only seven objects have been discovered so far. The MBCs have asteroid-like semi-major axes and their Tisserand parameter is T_J > 3. Origin of MBCs is unclear. Long-term orbital simulations indicate that P/2008 R1 (Garradd) became unstable approximately 20 Myr ago [2], [1]. The activity of MBCs is consistent with a sublimation-driven dust emission. Usually it occurs close to perihelion passage and lasts several weeks. The emission of dust should be accompanied by the sublimation of near-surface ice but the emission of water is so far not confirmed by observations.

Main Belt Comet P/2008 R1 Garradd (hereafter P/Garradd) passed perihelion on 2008 July 25 and was discovered on 2008 September 24. The activity of the object was monitored over 46 days from September 26 (two days after discovery) to November 11 [1]. The authors derived an upper limit to water production rate $Q_{H2O} < 5x10^{25}$ s-1.

We attempted to estimate how long after an activation of P/Garradd some activity can be observed. For this purpose we calculated evolution of model nuclei of different structures and orientations. We considered the state after some hypothetical activation. We do not know, what fraction of the nucleus of P/Garradd is currently active. The nucleus is small, [1] estimated the radius for less than 0.7 km. Hence, an impact may activate large fraction of the surface. We decided to consider activation of the whole nucleus. This approach gives upper estimates for the production of water and for the possible period of observable activity.

In this work we investigate changes of the emission of water from a model comet of the size and orbital elements of Main Belt Comet P/Garradd. We use a new version of our model, originally developed to investigate the evolution of Comet 46P/Wirtanen and further significantly extended [3]. Our model describes evolution of the temperature and cohesion of the material, crystallization of amorphous water ice, if present, sublimation of volatiles and evolution of the dust mantle covering the nucleus. The latter includes thickening due to sub-dust sublimation of ice and local rejection of the dust when vapor pressure beneath it reaches sufficiently high value. In the present work we consider a model nucleus of spherical shape, composed of water ice and dust. More volatile components, like CO are not taken into account, because they are not likely to be present in the nucleus of Comet P/Garradd.

2. Model

In this work we consider model comet of the orbital elements the same as for comet P/2008 R1 Garradd. The nucleus has spherical shape. The radius is 700 m, and the rotation axis is perpendicular to the orbital plane. The nucleus is composed of mineral grains mantled by water ice, as well as mineral grains without ice. The latter form the dust mantle on the comet nucleus (the thermal conductivity 20 – 100 mW $m^{-1}K^{-1}$, the initial thickness 0.5 – 4.5 cm). The material beneath the dust mantle can evolve, while the dust layer has constant properties, except thickness. The ice mantling the grains can be: (i) crystalline everywhere in the nucleus (no amorphous water ice), or (ii) crystalline in a layer just beneath the dust mantle, and amorphous in the interior of the nucleus. The grains composed of dust and ice have equal radii 0.002 – 0.2 mm, and are either well, or loosely bounded. Sublimation of ice may lead also to ejection of the dust mantle. In our model the dust mantle can be removed when the vapour pressure beneath exceeds a threshold value. For comet Garradd this we have not found blowing out of the dust. One more process depending on warming of the surface is sintering of the ice-mineral grains.

The diffusion of heat in the nucleus depends on the temperature and properties of the nucleus material. Particularly important is the thermal conductivity. In this respect the considered layers are significantly different. The thermal conductivity is: (a) very low in the dust mantle (small contact areas between the dust grains), (b) high in the layer beneath the dust, composed of sintered grains of crystalline ice, (c) very low beneath the crystallization front (very low thermal conductivity of the amorphous water ice, possibly small contact areas between grains).

3. Results

Our simulations indicate, that the emission of water decreases from one orbital period to another one, but in some cases slowly.

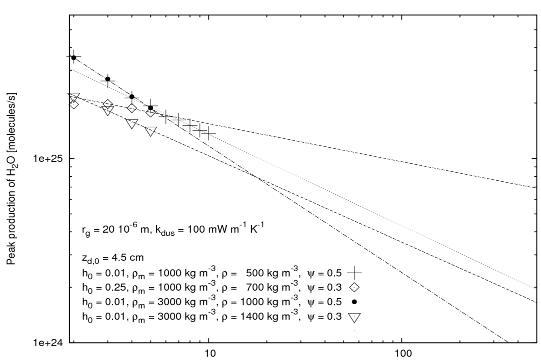

Figure 1: Peak emission of water from the nucleus versus number of the orbital revolution.

In Fig. 1 are shown profiles of the peak emission of water from the nucleus versus number of the orbital revolution. Rotation axis of the nucleus is perpendicular to the orbital plane. The nucleus is fine grained, rg = 0.02 mm, and is covered by dust of the thermal conductivity 100 mW m^{-1} K^{-1}. Density of the mineral cores of the grains is 1000 - 3000 kg m^{-3}, volume fraction of the mineral component is 0.25 – 0.35, and the volume fraction of water ice is 0.25 – 0.35. Hence, the nucleus has density 500 – 1400 kg m^{-3}.

We have found, that the seasonal maximum of the production of water: (a) does not depend on the presence of amorphous water ice in the nucleus; (b) depends on the initial temperature of the nucleus, but no longer than during the first three orbital runs after activation of the comet; (c) depends on the initial, i.e. after activation of the comet, (d) thickness of the dust, but no longer than the first 4 orbital periods; (e) depends on the orientation of the rotation axis of the nucleus; (f) depends on the density and {\it granulation} of the nucleus.

When the nucleus is composed of large grains the seasonal maximum of the production of water is initially fast, but quickly decreases. Opposite effect gives a decrease of porosity. Hence, the highest rate of the emission of water after many orbital periods can be expected when the nucleus is fine grained and has small porosity.

3. Acknowledgements

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References

[1] Jewitt D., Yang B., and Haghighipour N.: Main-Belt Comet P/2008 R1 (Garradd), The Astronomical Journal, Vol. 137, pp. 4313–4321, 2009.

[2] Haghighipour N., 2009. Dynamics, Origin, and Activation of Main Belt Comets. In: Fernandez, J.A., Lazzaro, D., Prialnik D. and Schulz R. (eds.). Icy Bodies of the Solar System Proceedings IAU Symposium No. 263, 207-214

[3] Kossacki, K.J., and Szutowicz, S.: Comet 17P/Holmes: Possibility of a CO driven explosion, Icarus Vol. 212, pp. 847-857, 2011.