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Physical and dynamical parameters of particles in outbursting Comet 17 P/Holmes

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Abstract

The time depending offset between the center of brightness and center of mass of the comet nucleus has been determined on the ground of positional observations of the comet. It is assumed that the offset is caused by the motion of particles ejected from the nucleus. The dynamic model of particles motion in the vicinity of the comet nucleus was developed. Calculations showed that the size of the particles should be about 53 m in diameter and had the initial velocity of 1.2 m/sec at the moment of outburst. Within 20 days after the explosion the size of particles decreased to about 5 mm. The motion of these particles allowed subsequent offset between the center of brightness and center of mass of the comet nucleus to be obtained from positional observations.

1. Introduction

The brightness of the comet 17P/Holmes was increased hundreds times on 23 October 2007. About two billion tons of gas and dust were ejected from surface of the comet nucleus at the moment of outburst [1]. Our goal is to estimate the physical and dynamical parameters of particles ejected during the explosion on the basis of positional observations of the comet.

2. The time depending offset

Determination of the comet's orbit from observations before and after the outburst shows a systematic deviation of the O–C for observations made after 23 October 2007. It has been suggested that this deviation is due to displacement of the center of brightness. We determined the comet's orbit from observations on the interval from 13.05.2007 to 05.01.2011. The components of the state vector at the initial moment and the parameters of the displacement of the center of brightness have been determined. The date 23.5 October 2007 was taken as an initial moment of time. It was assumed that because of the ejection of matter and its further motion the offset between the center of brightness and center of mass of the comet nucleus must be present in the positional observations. This offset has been approximated by polynomials of fourth degree with respect to time. Two polynomials (the first one approximating this offset in the direction of the comet – the Sun, the second one approximating in a perpendicular direction) were determined. The following coefficients of polynomials $a_1 = -0.0856 \pm 0.0041$, $a_2 = 0.00250 \pm 0.00015$, $a_3 = -0.232 \cdot 10^{-4} \pm 0.018 \cdot 10^{-4}$, $a_4 = 0.708 \cdot 10^{-7} \pm 0.072 \cdot 10^{-7}$ for the radial direction, and $b_1 = -0.703 \cdot 10^{-2} \pm 0.361 \cdot 10^{-2}$, $b_2 = -0.438 \cdot 10^{-3} \pm 0.134 \cdot 10^{-3}$, $b_3 = 0.675 \cdot 10^{-5} \pm 0.172 \cdot 10^{-5}$, $b_4 = -0.245 \cdot 10^{-7} \pm 0.070 \cdot 10^{-7}$ for the perpendicular and their errors in arcsec have been obtained.

3. Dynamics of particles

The following terms have been included in the equations of motion of particles in the comet head: the perturbing accelerations by the light pressure from the Sun, deceleration (or acceleration) from the flow of the sublimating gas, gravitational attraction from the comet's nucleus and the Sun. The expansion of the gas molecules was assumed to be spherically symmetric in the comet's head. It was also assumed that the particles were spherical and did not encounter with each other. The change of particle diameter due to sublimation of volatile matter contained in them has been taken into account. It was believed that the evaporation occurred isotropically from whole surface of the particle. The simplified model of the distribution of brightness was accepted when the brightness of the center coincided with the central particle in the ejected cloud.

4. Dynamics of the central particle

The dynamics of the central particle was investigated in the cometocentric coordinate system XYZ. The X-axis coincides with the direction of the Sun at the

moment of the outburst; the Y axis lies in the orbital plane and the axis Z (perpendicular to the orbital plane) complements the system.to right-handed. The velocity vector, *V*, and the particle radius, *R*, were calculated. Velocity vector was determined by its module, *V*, and by angles λ with the X axis and β with the Z axis, (see Figure 1). In addition, it was assumed that during some time interval Δ*t* a particle splits into N parts. Parameters *V* and *R* were determined by the least squares. The values of Δ*t* and N were determined by exhaustive search. The polynomials describing the displacement of the center of brightness obtaining from the positional observations have been used as observations. Because of the strong correlation between the angles λ and β the improvement of these variables was carried out by stages: in the beginning set of *V*, β, *R* was improved and then set of *V*, λ, *R* was improved. The results of the improvements and their errors are: *V*=1.18±0.06 m/sec; λ=-35°.16±0.01; β=68°.55±0.41; *R*=26.83±0.48 m.

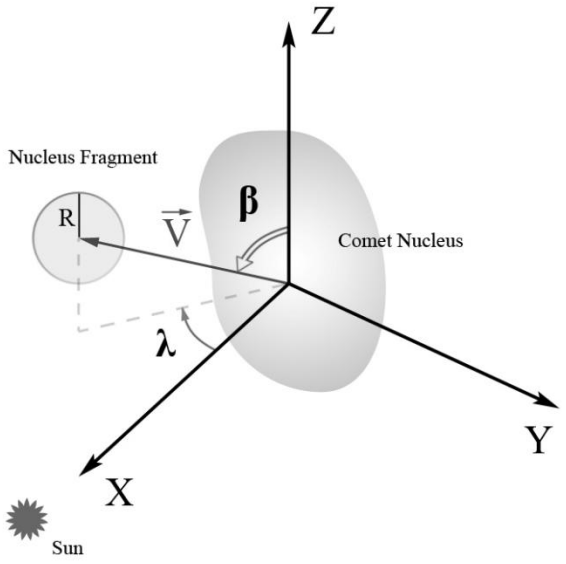

Figure 1: Coordinate system.

The values of λ and β and their errors were obtained by improving the first set of *V*, λ, *R* and second one of *V*, β, *R*, correspondingly. The values *V*, *R* and their errors were practical the same in both stages. The values Δ*t*, N found by sorting were equal to 20 days and 10,000, correspondingly. This means that the initial particle breaks up into 10,000 pieces within 20 days. Dynamics of the particle with the given parameters allows change in the center of brightness at 90 day interval to be predicted with the mean square error σ=0."184. Curves of the positions of the center of brightness (solid line) and the central particle (dotted line) are shown in the Figure 2. Curves are shown in a rotating cometocentric coordinate system. Here, the abscissa is Sun-ward directed, the ordinate - in the perpendicular direction. The values of the axes are expressed in arcsec.

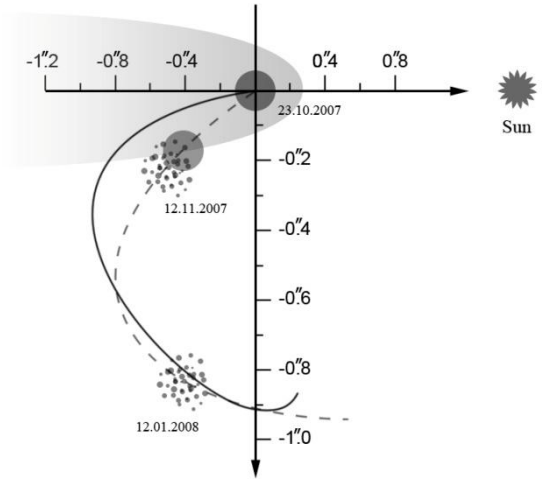

Figure 2: Positions of the center of brightness.

3. Conclusions

Thus, the offset of photocenter of Comet Holmes, derived from the positional observations can be simulated by the motion of large sublimating particle as large as 53 m in diameter, which during 20 days fly away from the nucleus at a distance 1,208 km (921 km in the radial, 646 km in the transverse and 441 km in the normal direction). Then it is divided into smaller particles as small as 5.3 mm. After that the displacement of photocenter is determined the center of cloud of these particles. 90 days after the explosion these small particles are found at a distance of 4,260 km (893 km in the radial, in the transverse - 3637 and 2032 km in the normal direction) from the comet's nucleus.

References

[1] Reach, W., Vaubaillon, J., Lisse, C., Holloway, M., Rho, J.: Explosion of Comet 17P/Holmes as revealed by the Spitzer Space Telescope, Icarus, Vol. 208, pp. 276–292, 2010.