Dust Production of Comet 21P/Giacobini-Zinner using Broadband Photometry. R. C. Blaauw[1], R. M. Suggs[2] and W. Cooke[2], [1]Dynetics Technical Services/MITS, Huntsville, AL, USA, 35812. Rhiannon.C.Blaauw@nasa.gov, [2]NASA/MSFC, Huntsville, AL, USA, 35812.

Introduction: Comet 21P/Giacobini-Zinner is a Jupiter family comet, approximately 2 km in diameter, and is established to be the parent of the Draconids, a meteor shower known to outburst. In 1933 and 1946 up to 10,000 meteors per hour were reported for the Draconids [1], and 2011 saw a minor Draconid outburst. Meteor stream modeling/forecasting being a primary focus for the NASA Meteoroid Environment Office, it was decided to monitor 21P for three purposes: firstly to find the apparent and absolute magnitude with respect to heliocentric distance; second to calculate $Af\rho$, a quantity that describes the dust production rate and is used in models to predict the activity of the Draconids; and thirdly to detect possible increases in cometary activity, which could correspond to future Draconid meteor outbursts.

A similar study was done for 21P during its 2004-2006 close approach to the Sun in which apparent and absolute magnitudes were found with various heliocentric distances, as well as the dust production [2]. At 2.32 AU from the Sun, 21P possessed an apparent magnitude of 17.05 and $Af\rho$ of 83 cm, and an apparent magnitude of 15.91 and $Af\rho$ of 130.66 cm at 1.76 AU from the sun.

Method: Images of 21P were were obtained in the Johnson R-filter from May 20, 2011 until October 24, 2011 (3.04 to 1.77 AU heliocentric distance) using a 0.5-meteor f/8.1 Ritchey-Cretien telescope on a German equatorial mount with an Apogee CCD camera located in the mountains of southern New Mexico. Analysis was done with Astrometrica [3] and FoCAs (FOtometria Con AStrometrica or Photometry with Astrometrica) [4], a program allowing multi-aperture photometry. A comparison of results obtained from this process was made with those produced by Wafrho, created by CARA (Cometary ARchieve for Afρ) [5] as a verification step. Corrections for phase angle were applied to all data, normalized at opposition [6].

$Af\rho$ is a quantity that describes the activity – dust production - of a comet and is typically expressed in centimeters. It is helpful in that it lets one ascertain the heliocentric dependence of the activity of a given comet. It lets observers compare data obtained at different sites, telescopes, and geometrical arrangements. $Af\rho$ is explicitly the albedo (A), multiplied by the filling factor of the grains (f), and the nucleocentric distance (ρ). It is calculated using the Earth-comet distance, Δ, nucleocentric distance, ρ, the flux of the Sun at 1 AU in the same filter used to image the comet, and the observed flux from the comet found using the apparent magnitude. $Af\rho$ is often reported for comet outbursts, results agreeing between both CCD filter photometry and spectrophotometry [7].

$$Af\rho = \frac{(2\Delta R)^2}{\rho}\frac{F_{com}}{F_{sol}} \qquad \text{[Equation 1]}$$

Results: Over the five months 21P was imaged, the calculated values of $Af\rho$ were in rough agreement with Pittichova et al's 2008 results, which covered 21P's previous orbit [2]. 21P brightened from an apparent magnitude of 19.6 to 15.7, corresponding to an absolute magnitude of 15.1 to 12.1. This correlated to $Af\rho$ of 6.88 cm to 65.36 cm, as presented in Figure 1 and Table 1. There were no significant outbursts during this time.

Dust production of 21P followed a logarithmic slope of -4.04 with respect to heliocentric distance. This slope can be extrapolated out to the perihelion (1.038 AU) of 21P to find an $Af\rho_q$ of 446 cm.

Figure 1. Dust production of comet 21P from May 20, 2011 to October 24, 2011. All data is corrected for phase angle.

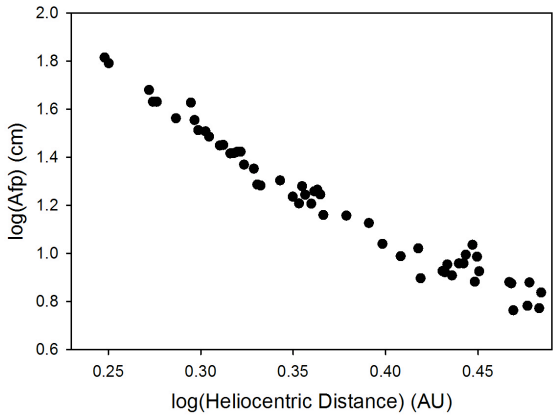

Table 1. Photometric analysis of comet 21P to yield dust production measurements. Starting date and end date of imaging run are included as well as selected days between.

Date	R (AU)	Δ (AU)	Phase Angle (°)	Apparent Magnitude	Afρ (cm)
May 20, 2011	3.04	2.15	10.7	19.60	6.88
June 23, 2011	2.82	2.11	17.16	19.00	8.44
July 19, 2011	2.62	2.19	22.25	18.54	10.51
Aug 24, 2011	2.32	2.33	25.16	17.72	17.60
Sept 23, 2011	2.05	2.37	24.95	16.96	28.28
Oct 24, 2011	1.77	2.31	23.81	15.71	65.36

Table 2: Dust production of comet 21P with various apertures.

ρ (km)	9000	18000	27000
Afρ at 3.04 AU (cm)	6.88	4.62	3.19
Afρ at 1.77 AU (cm)	65.36	60.38	48.73

The dust production was measured with 3 apertures, the quantity ρ describing the radius of the aperture in kilometers. As seen in Table 2, when 21P is 3.04 AU from the Sun - nearly a point source in the images, the dust production falls off significantly with increasing aperture size. However by 1.77 AU from the Sun, 21P has grown a pronounced coma, which extends into larger apertures. Results derived with an aperture with $\rho = 9000$ *km* were used for analysis in this paper, as this aperture provided the peak $Af\rho$.

Performing multi-aperture photometry also allows a derivation of the surface brightness profile of a comet. The average profile of the brightness of the comet's coma is described as a power law, which is represented by the slope of $\log(Af\rho)$ vs $\log(\rho)$ [8]. The growth of the comet coma growing with decreasing heliocentric distance is clearly seen by examination of the surface brightness profile. Table 2 shows this greater percentage of $Af\rho$ in larger apertures as 21P approaches the Sun.

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