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Recent polarimetric observations of comet 67 P/Churyumov-Gerasimenko

Anny-Chantal Levasseur-Regourd[1], Edith Hadamcik[1], Asoke K. Sen[2], Ranjan Gupta[3], and Jeremie Lasue[4,5]

[1]UPMC Univ. Paris 06 / LATMOS-IPSL, BP 3, 91371 Verrieres, France
email: aclr@latmos.ipsl.fr
email: edith.hadamcik@latmos.ipsl.fr

[2]Assam Univ., Silchar 788001, India
email: asokesen@yahoo.com

[3]IUCAA, Post Bag 4, Ganeshkhind, Pune-411007, India
email: rag@iucaa.ernet.in

[4]LPI, 3600 Bay Area Blvd, Houston, TX 77058-1113 USA
[5]LANL, Space Science and Applications, ISR-1, Mail Stop D-466, Los Alamos, NM 87545 USA
email: lasue@lpi.usra.edu

Abstract. Remote observations of solar light scattered by dust in comet 67P/Churyumov-Gerasimenko coma are of major importance to assess the properties of the dust and thus to prepare the rendezvous of the Rosetta spacecraft with comet 67P/Churyumov-Gerasimenko. We present polarimetric data obtained from India in December 2008 and France in March 2009. Compared with previous observations of this comet and of other Jupiter family comets, they confirm that it is dust-poor, although it may exhibit outbursts leading to the ejection of dust particles from its subsurface, especially after its perihelion passage.

Keywords. Techniques, polarimetric, comets, individual (67P/Churyumov-Gerasimenko)

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1. Introduction

Evaporation of ices from cometary nuclei releases gases that carry out solid particles of dust. Together, they contribute to the bright coma, visible when a comet is not too far from the Sun on its elongated orbit. Understanding the properties of such dust particles is of major interest, not only to assess the diversity of comets and understand the processes that allowed their formation in the early solar system, but also to better describe the environment of the nucleus. This latter issue is of major importance to prepare the ESA Rosetta mission that will rendezvous in 2014-2015 with comet 67P/Churyumov-Gerasimenko, observe the surface of the nucleus, deploy a lander onto the nucleus and follow the evolution of the coma (Glassmeier *et al.* 2007).

Remote observations of solar light scattered by dust, and more specifically measurements of its partial linear polarization, provide unique opportunities to estimate some of its properties, i.e. size distribution, morphology and complex refractive indices (see e.g. Levasseur-Regourd 1999, Kolokolova *et al.* 2004). Intensity and polarization images are derived from images of four polarized components with fast axis at 45° from one another, thereafter called Z_0, Z_{45}, Z_{90} and Z_{135}. Properties are evaluated through a comparison of the dependence of the polarization upon phase angle and wavelength of the observations, location within the coma and temporal evolution, with results from light scattering experimental and numerical models (e.g. Hadamcik & Levasseur-Regourd 2003; Hadamcik *et al.* 2007a, Levasseur-Regourd *et al.* 2008, Lasue *et al.* 2009).

Table 1. Log of the observations, including date, number of days before or after perihelion, geocentric distance Δ, heliocentric distance R, predicted visual magnitude, phase angle α, Sun position angle and code of the filters.

Date	Days to perihelion	Δ (AU)	R (AU)	m_v (predicted)	α (°)	Sun PA (°)	Filter (code)
2008, India							
25 Dec.	-65	1.67	1.45	14.2	35.8	70.5	CR
26 Dec.	-64	1.67	1.46	14.2	35.8	70.4	CR
27 Dec.	-63	1.67	1.46	14.2	35.8	70.3	CR & CB
2009, France							
17 March	+17	1.72	1.26	13.5	34.7	69.9	R
18 March	+18	1.73	1.27	13.5	34.7	70.0	R
19 March	+19	1.73	1.27	13.5	34.7	70.2	R

A joint effort between French and Indian teams, already familiar with polarimetric measurements, has been made in 2008-2009, to provide remote observations of the dust coma of 67P/Churyumov-Gerasimenko. It was indeed the last apparition of this comet, the period of which equals 6.57 years, before Rosetta rendezvous.

2. Instrumental conditions

In December 2008, observations were performed from IUCAA observatory at Girawali, near Pune, India, with a 2 m Cassegrain telescope and an Imaging Polarimeter (achromatic rotating half-wave plate; Wollaston prism as analyser; 2x2 binning for present observations; see e.g. Ramprakash *et al.* 1998). In March 2009, soon after perihelion, observations were performed from OHP observatory near Marseille, France with a 0.8 m Cassegrain telescope (4 polaroid filters on a rotating wheel; resolution 0.21 arcsec, in the present observations a 4x4 binning for present observations; see e.g. Hadamcik *et al.* 2007b). To minimize the contribution of cometary gaseous emissions, observations were performed, as previously in France, with a special red filter (R for 650 nm ± 45 nm). In India, ESA narrowband filters were used in the blue (CB for 443 nm ± 2 nm) and red (CR for 684 nm ± 4.5 nm) domains. Table 1 summarizes the conditions of the observations.

3. Results and discussion

Intensity. Images are obtained by adding two polarized images corresponding respectively to ($Z_0 + Z_{90}$) and to ($Z_{45} + Z_{135}$), once the sky background is subtracted and the images are centered on the photometric center. The validity of the results is assessed by ensuring that ($Z_0 + Z_{90}$) and ($Z_{45} + Z_{135}$) be similar. As noticed in Fig. 1, the coma was elongated in the antisolar direction, with possibly a jet-like feature towards the North in late December 2008; bright structures were present in the solar and antisolar directions, with a fan-type structure suspected towards the South in mid-March 2009. A radial decrease in intensity is computed in order to estimate the deviation from an isotropic coma. As expected, its slope in log-log scale is equal to -1 on average. However, it is found to be steeper for photometric center distances larger than 2000 km in December and larger than 4000 km in March.

Polarization. Values are obtained by combining four polarized intensities, with the linear polarization (in percent) equal to 200 $[(Z_0 + Z_{90})^2 + (Z_{45} + Z_{135})^2]^{0.5}$ / $(Z_0 + Z_{90} + Z_{45} + Z_{135})$. Although the phase angles are similar in December and in March (of the order of 35°), the polarization appears to be about 1% higher in March than in December, while the error bars remain below 0.4 %.

Discussion. The intensity was higher than expected from ephemeris, by about 2 magnitudes, in mid-March 2009; this result agrees with Yoshida observations (2009). Intensity and polarization observations had already been obtained during previous apparitions, as reviewed by Levasseur-Regourd *et al.* (2004). Various authors had reported post-perihelion increases in intensity (see e.g. Marsden 1986; Kidger 2003; Ferrin 2007). As pointed out by Kidger (2003), this phenomenon seems typical of comets that have recently suffered a drop in perihelion distance and could originate in post-perihelion outbursts. Variability of the mean radial profile, together with a large pre/post-perihelion asymmetry, was also reported by Schleicher (2006) for the apparitions 1982-1983 and 1995-1996 apparitions.

Finally, a few polarimetric data had been obtained during the 1982-1983 apparition in the 12° to 38° phase angle range. (Myers & Norsieck 1984, Chernova *et al.* 1993). Although the phase angles were below 40°, the results, together with ours, suggest that 67P/Churyumov-Gerasimenko belongs to the low polarization class of comets. This is in agreement with the absence of any silicate emission feature in the near infrared (Hanner *et al.* 1995) and with the fact that Jupiter family comets are typically dust-poor comets (Hadamcik and Levasseur-Regourd 2009). The slight increase in polarization detected in March 2009, at a time when a sudden increase in intensity took place, fairly agrees with the fact that outbursts seem to be correlated with increases in polarization, at least for phase angles above about 35°, as typically noticed for 47P/Ashbrook-Jackson or C/1996 B2 Hyakutake (Renard *et al.* 1996, Desvoivres *et al.* 2000, Tozzi *et al.* 1997). More detailed results will be presented in Hadamcik *et al.* (in preparation).

4. Conclusions

Light scattering observations of 67P/Churyumov-Gerasimenko have been obtained in late December 2008 and mid-March 2009, during the last apparition of this comet before its encounter with the Rosetta spacecraft. A significant increase in intensity, possibly induced by a significant outburst activity, is noticed after perihelion, as for previous apparitions; the pre/post perihelion asymmetry leads us to emphasize the fact that it would be of great interest to tentatively extend the Rosetta mission after the perihelion passage. Our observations confirm that the comet behaves like most Jupiter family comet (i.e. is rather dust-poor) with relatively large dust particles in its coma.

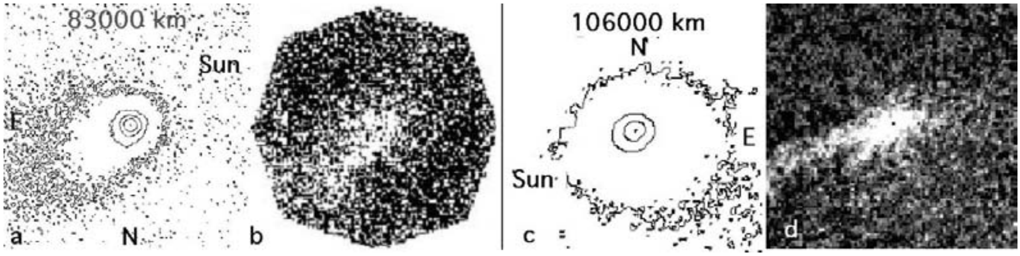

Figure 1. Typical intensity images of the dust coma of comet 67P/Churyumov-Gerasimenko, as obtained from IUCAA observatory on 27 December 2008 (average time 14:38 UT) and from OHP observatory on 18 March 2009 (average time 19:06 UT). Images a and c are isophotes in Log intensity scale. Images b and d (emphasized by rotational gradient technique) allow the detection of jet-like and fan-type structures.

The outburst, suspected in intensity and polarization data in March 2009, suggests that the coma may exhibit some drastic changes, with possible ejection of smaller grains from the subsurface. Last but not least, it is important to keep in mind that the resolution obtained for remote line-of-sight observations does allow the detection of any local variations in polarization in the innermost coma. The detection of changes in the physical properties of the dust particles at nucleus distances smaller than about 3000 km, e.g. with some dust particles consisting of large icy conglomerates, will only be possible from the Rosetta spacecraft after its rendezvous with the comet.

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