Monitoring of Comet 9P/Tempel 1 around the Deep Impact event with the OSIRIS NAC camera

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Abstract. OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) is the main scientific imaging system onboard the ESA Rosetta spacecraft. It comprises a high resolution Narrow Angle Camera (NAC) and a Wide Angle Camera (WAC). It was activated for more than two weeks around NASA's *Deep Impact* event and observed comet 9P/Tempel 1. We report here some of the results obtained with the NAC.

The NAC monitored the cometary dust in five different optical filters. By analysing the post-impact images, we derived the ejecta plume morphology: the material first forms a cloud around the nucleus and is then pushed in the anti-solar direction by solar radiation pressure. By analysing the brightness distribution of the cometary dust, we determined the basic development of the impact cloud: the flux from the ejecta is continuously increasing, then the brightness levels off, and finally starts to decrease (during the first 40, 50, and 90 min. after the impact, respectively). Furthermore, we detected regular variations in the intensity of Tempel 1 before and after the impact. The brightness changes regularly with a period consistent with the rotation period of 9P/Tempel 1 (~41 h). During the OSIRIS observations, the overall brightness of Tempel 1 decreased by about 10%. There was no long-term effect of the impact. Analysis of the light curves also provides insights into the velocity distribution of the expanding cloud created by the impact. By modelling the observed brightness distribution, the velocity distribution of the particles is derived. The material moved at ~200 m/s.

Our analysis suggests that the ejecta were quickly accelerated (by collisions with gas molecules). Much of the material left the comet in the form of icy grains which sublimated and fragmented within the first hour after the impact. Our results provide a more thorough understanding of the properties of the Deep Impact dust cloud and of the comet's interior.

1. Introduction

On 4 July 2004, the NASA mission *Deep Impact* fired a copper projectile of 364 Kg into the nucleus of 9P/ Tempel 1 with an energy of $2x10^{10}$ J. An impact crater was formed and material was ejected from the comet. **OSIRIS** (Optical, Spectroscopic, and Infrared Remote Imaging System), the scientific imaging system onboard the ESA Rosetta spacecraft, comprises a Narrow Angle Camera (NAC) and a Wide Angle Camera (WAC). The system was activated five days before the Deep Impact event, and observed 9P/Tempel 1 near-continously for more than two weeks. Here we report some of the results obtained with the NAC, which monitored the cometary dust in five different optical filters.

2. The Instrument

The Narrow Angle Camera (NAC) is an unobstructed mirror system designed to obtain high-resolution images for the study of the physical properties and the mineralogy of the surface of comet Churyumov-Gerasimenko. The NAC is equipped with 12 filters (over a wide spectral range from 250 to 1000 nm), with two filter wheels containing 8 position each, and with backside illuminated CCD detectors comprising 2048 x 2048 pixels with a pixel size of 13.5 µm. The NAC has a square field of view (FOV) of width 2.2°, has an instantaneous field of view (IFOV) of 18.6 µ rad (3.8 arcsec) per pixel, and is a moderately fast system (f/8). The system has a 717 mm focal length. It has a mass of 13.2 kg.

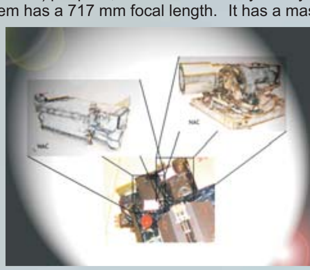

Fig. 1: The two OSIRIS cameras (top and left) mounted on the -x panel of Rosetta.

3. Ejecta Plume Morphology

We monitor the evolution of the ejecta plume by performing images with the clear filter and the NAC. For this process we subtract the pre-impact image from each of the post-impact co-added images (T - 7.25 hours), to leave just flux from the post impact material. The results are shown in Fig. 2, where the evolution of the plume is clearly seen. The material first forms a cloud around the nucleus and is then pushed in the anti-solar direction by solar radiation pressure.

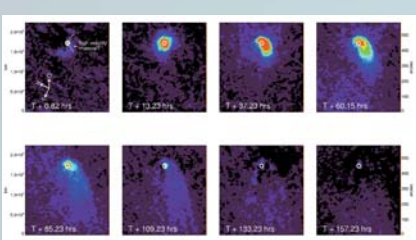

Fig. 2: Images of the ejecta plume. Post-impact images are substracted by the pre-impact image.

4.- Development of the impact cloud

We performed cometocentric circular aperture photometry on the images of 9P/ Tempel 1. In Fig. 3 we present the lightcurve obtained with the clear filter which shows the best signal/noise ratio. There the basic development of the impact cloud can be seen (Keller et al. 2006).

The flux from the ejecta is continuously increasing, then the brightness levels off, and finally starts to decrease (during the first 40, 50, and 90 min. after the impact, respectively). In particular, regarding the steep increase in the first 40 minutes, the brightness increase is much longer than that expected for crater formation. The probable cause of the long-lasting brightness increase is ejection of material from the impact crater in form of **icy grains** and decreasing of optical depth.

Moreover, we detected regular variations in the intensity of 9P/ Tempel 1 before and after the impact. The brightness changes regularly with a period consistent with the rotation period of 9P/ Tempel 1 (~41 h, Belton et al. 2005 and 2006). During the NAC observations, the overall brightness of 9P/ Tempel 1 decreased by about 10%. We did not detect a long-term effect of the impact.

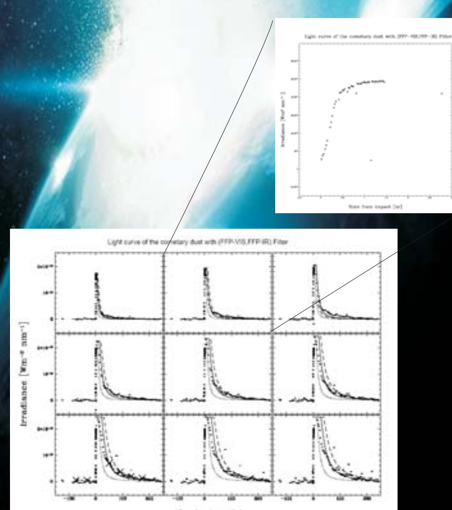

Fig. 3: Light curves of the cometary dust in the clear filter, for nine circular fields from 2 to 10 pixels or 3000 to 15000 km radius at the comet (from left to right). The coma subtraction error is estimated to be ~2 times the error bars. The dashed, solid and dotted lines show model profiles for velocities of 110, 160, and 300 m/s , respectively. The crosses on the bottom left panel are separated by 40.832 hours, the rotation period of comet 9P/Tempel 1.

5. Ejecta velocity

A first estimate of the ejecta velocity comes from the decay of the flux when the material leaves the different apertures seen in Fig. 3 (Keller et al., 2005, Küppers et al., 2005). Typical velocities derived this way are between 100 and 300 m/s (Rengel et al. 2006). As an illustration, Fig. 3 shows model lightcurves for particles with projected velocities of 110 m/s, 160 m/s, and 300 m/s. The velocity estimates do not vary with the size of the aperture, although we assume that the dust reaches its final velocity instantly at the time of impact. Dust with a velocity of 200 m/s reaches the edge of the smallest aperture (3000 km or 2 pixel radius) in slightly more than 4 hours. No impact ejecta are seen after 150 hours in any aperture

Conclusions

The observations with the two OSIRIS cameras provide important clues on the events that followed the impact of the Deep Impact projectile on comet 9P/ Tempel 1. The final velocity of the dust ejected by the impact was around 200 m/s. In the following days, the impact created cloud was accelerated in anti-solar direction by solar radiation pressure. There was no long-term effect of the impact. The ejecta cloud had dispersed after about a week. As pointed out by Küppers et al. (2005), this suggests that impacts are not the cause of cometary outbursts or splittings.

Our research suggests that the ejecta were quickly accelerated (by collisions with gas molecules). Icy grains were excavated from the comet, which sublimated and fragmented within the first hour after the impact cratering. Our results attempt to provide a more thorough understanding of the properties of the Deep Impact dust cloud and of the comet's interior.

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More information on:
http://www.mps.mpg.de/en/projekte/rosetta/osiris/