A HIGH-RESOLUTION MID-IR OBSERVATION OF THE COLLISION BETWEEN DEEP IMPACT PROJECTILE AND COMET 9P/TEMPEL 1. S. Sugita[1], T, Kadono[1], T. Ootsubo[2], M. Honda[3], S. Sako[4], T. Miyata[4], I. Sakon[5], T. Yamashita[6], H. Kawakita[7], H. Fujiwara[5], T. Fujiyoshi[6], N. Takato[6], T. Fuse[6], and SUBARU/COMICS Deep Impact Observation Team, [1]Dept. of Complexity Sci. and Eng., Univ. of Tokyo, Kashiwa, Chiba 277-8561, JAPAN (sugita@k.u-tokyo.ac.jp). [2]Div. of Particle and Astrophys. Sci., Nagoya Univ., [3]ISAS, Japan Aerosp. Explor. Agency, [4]Inst. of Astoron., Univ. of Tokyo, [5]Dept. of Astron., Univ. of Tokyo, [6]Subaru Telescope, National Astron. Obs. of Japan, [7]Dept. of Phys., Kyoto Sangyo Univ.

Introduction: The 370 kg copper alloy projectile released from NASA's Deep Impact (DI) spacecraft made a successful collision with comet 9/P Tempel 1 on July 4, 2005 (UT). We observed the phenomena induced by the collision using the 8.2 m-aperture Subaru telescope and its mid-infrared detector, COMICS [1]. Mid-infrared observations are extremely important because this wavelength range is not covered by the DI onboard instruments [2] but can be transmitted through the coma around the comet, which is opaque in the visible wavelength.

Both imaging observations with seven band filters (8.8, 10.5, 12.4, 17.7, 18.8, 20.5, and 24.5 μm) and N-band (8-13.5μm) low-resolution (*R*~250) spectroscopic observations were conducted from July 3 to 5 (UT). This observation effort was conducted as a part of Subaru-Gemini collaboration, in which Subaru was focused primarily on N-band imaging and Gemini was on N-band spectroscopy [1, 3]. Although the initial results of the analysis are given by our earlier paper [1], there are many untapped data. Here, we present the results of our detailed analysis using more exhaustive sets of data

Impact-Induced Dust Plume: One of the most striking phenomena we observed after the collision is the rapid emergence, expansion, and dissipation of fan-shaped dust plume around the comet (Fig. 1). By about an hour after the collision, the brightness of the comet has reached the maximum value (4-5 times the pre-impact level) and monotonically decreased thereafter. The size of the plume increased at an approximately constant radial velocity ~125 m/s. The plume grew

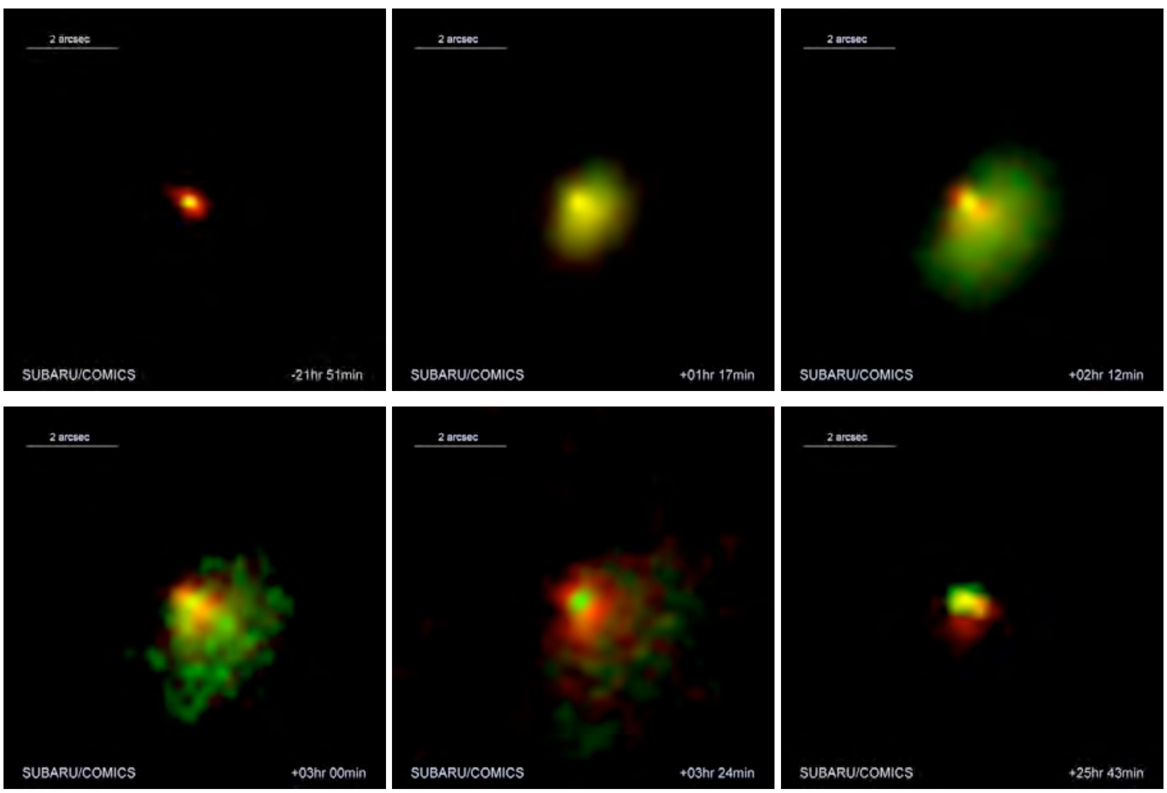

Figure 1. Mid-IR images of comet 9P/Tempel 1 before and after the collision with the DI projectile. Red shows the continuum component of the spectra: $I_{cont} = (I_{8.8\mu m} + I_{12.4\mu m})/2$, showing the light from carbon-rich dust and/or larger size silicate dust. Green shows the 10-μm silicate peak component: $I_{peak} = I_{10.5\mu m} - I_{cont.}$, showing the light from fine-grain silicate dust. The times when the images are obtained are shown with respect to the impact in each panel. Each image is subtracted by the image taken 2 days before the impact (i.e., UT 2 July 2005).

up to about 1600 km (after correcting for the point spreading function (PSF) of the telescope) along its symmetry line at 225° position angle within the first 3 hours and half after the impact.

This extremely large dust plume, however, had virtually dissipated by the beginning of the observation on the following evening on July 4 (UT) (Fig. 1). Theoretical model calculations show that the observed mid-IR light curve can be reproduce very well with a simple geometric stretching of radially expanding ejecta plume and do not require any dust destruction processes [4].

Spectroscopic Characteristics: Our N-band spectroscopic observations revealed a striking similarity in the spectral pattern of 10-μm silicate emission band between the plume of dust excavated from the interior of comet 9P/Tempel 1, a Jupiter-Family comet (JFC), and coma dust around typical Oort-cloud comets (OCC), such as Hale-Bopp and C/2001 Q4 (NEAT) [1]. The similar conclusion was also obtained by the Gemini observations [3]. Detailed spectroscopic analysis of the 10-μm silicate in the dust plume indicate that the observed N-band spectral pattern is best fit with a power law with an exponent of between -3.5 and -3.6 [1, 5]. Similarly, the mass ratio (~0.3) of crystalline to amorphous silicates estimated for the excavated dust is much larger than that (~0.02) for coma dust of comet 78P Gehrels 2, a JFC [6], but much closer to those of OCC's (0.2 – 0.7).

Ejecta Mass Estimate: Based on the estimated dust size distribution and the light flux measurements, we can calculate the total dust mass in the impact-induced plume.

Here, it is important to note that the choice of the largest size for dust particles influences the estimate for the total dust mass substantially. In fact, a spectroscopic analysis does not constrain larger end of the power-law size distribution very well. This is because large dust particles do not emit light efficiently. Nevertheless, our spectroscopic analysis indicates that the synthetic spectral shape improves gradually as the maximum grain size is increased to 10 μm. In contrast, when the maximum size is increased to significantly larger than 10 μm, the synthetic spectrum neither improves nor deteriorates. Thus, we conclude that the observed plume contains dust with size up to at least 10 μm in radius. When a power law with an exponent of -3.6 is used for the dus size distribution, the total mass M_{dust} of the dust in the plume is: $M_{dust} \propto a_{dust}^{-0.4}$ where a_{max} is the largest dust radius.

When the maximum dust radius is taken to be 10 μm, the total dust mass in the plume is 5.6 x 10^5 to 8.5 x 10^5 kg. Despite of the use of a rather conservative maximum dust size, the obtained total dust mass is very large. This large dust mass guarantees the intrinsic nature of the observed high crystalline ratio of the silicates, excluding the possibility that they may be devitrified by the DI impact heating. A simple energy-balance calculation shows that not more than 10% of observed silicate can be devitrified by DI impact energy.

Crater Characteristics: The estimated large dust mass (5.6 x 10^5 to 8.5 x 10^5 kg) is also consistent with gravity-controlled cratering; a pi-scaling calculation predicts that ~1.5x10^6 kg of ejecta with ejection velocity higher than the cometary escape velocity is produced by the DI collision [1]. If compaction and/or target strength plays an important role in cratering, the ejecta mass will be reduced significantly and become inconsistent with the observed dust mass. The gravity-controlled cratering style is also consistent with observation by the DI spacecraft that the crater ejecta curtain did not detach from the cometary surface [7].

If the dust plume contains dust particles much larger than 10 μm, the total dust mass would be significantly larger; 2.8x10^7 to 7.0x10^7 kg for 1 m radius of maximum ejecta size for example. Because either ground-based telescopes or DI onboard cameras cannot discern meter size blocks [7], it is not impossible to have many meter-size fragments in the dust plume. Nevertheless, these large ejecta mass estimates are not very plausible. They would be more than ten times larger than a standard gravity-controlled cratering theory predicts. It would require an additional process(es) to increase the cratering efficiency drastically. Note that gravity-controlled cratering exhibits the maximum cratering efficiency [e.g., 8]. Furthermore, such large meter size blocks are unlikely ejected from gravity-controlled crater with diameter on the order of 10^2 m. Ejection of large blocks would require significant strength in target matter, which would modify the cratering style very much. Thus, we infer that maximum ejecta size would be much smaller than a meter and that the total dust mass would be much smaller than 10^7 kg.

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