DEEP IMPACT: EXCAVATING COMET TEMPEL 1.

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Introduction: On 4 July 2005, Deep Impact delivered 19 GJoules of kinetic energy to the nucleus of comet Tempel 1, taking numerous images and spectra of the comet before, during, and after the impact. The preliminary analysis of the data has already lead to significant, new understanding of cometary properties and behavior [1] and this talk will summarize the present state of our understanding with details of some results in related talks.

Data Collected: Data from the impactor, all in the last 24 hours before impact, were limited to white-light images of successively smaller frames, taken with increasing frequency (1 per 2 sec at the end) as we approached the comet. These images provided, for example, a few-meter resolution image of the impact site. The multi-filter, high-resolution imager, near-infrared spectrometer, and multi-filter, medium resolution imager provided extensive coverage during two months of approach, detailed, high-frequency (every 65 msec) imaging of the impact event, and details of the nucleus and the ejecta both before and after closest approach until more than 2.5 days after impact. Although first results have been published [1], on-going analysis is leading to a continuing series of new results, many of which are being presented in companion talks in this session.

Nuclear Activity: The intense coverage during approach led to the detection of numerous outbursts, both from Deep Impact itself and also from both ground-based observatories [2] and HST [3]. Although not truly periodic, there was roughly one outburst per week, only some of which were large enough to have been seen from Earth if anyone was looking. The fact that many but not all of the outbursts are correlated with the nuclear rotational phase [1, 4] rules out exogenic causes, such as impacts or fluctuations in the solar wind or other solar activity, as causes of the outbursts. The outbursts that are correlated with rotational phase appear to arise from an area that is near sunrise at the time of the outbursts and they may be associated with the icy areas that have been identified on the surface [5]. This suggests migration of ice to the near-surface region which rapidly evaporates when heated by a very small amount of sunlight.

Spectroscopy on approach showed unidentified spectral features during the one outburst that coincided with spectral measurements. Furthermore, the ambient coma showed clear evidence for heterogeneity in the outgassing of volatiles, specifically in the ratio of CO_2 to H_2O, into different directions, thus providing good evidence for chemical heterogeneity in the subsurface ices in different parts of the nucleus [6].

Nuclear Surface: As described in companion papers in this session, the comet has many different terrains [7, 8]. Some of these terrains have distinctive photometric properties (particularly the roughness parameter) as do some terrains on comet Borrelly [9,10]. The differences in surface features suggest large differences from the surfaces of comets previously visited. Compositional differences compared to other comets visited *in situ* [4] may be related to differences in spatial resolution coupled with spectral range in the near-IR. We have also derived lower upper limits on thermal inertia than previously available for any comet [11].

Ejected Material: Based primarily on data obtained from Earth and from Rosetta [12, 13, 14], for both of which the fields of view were far larger than for our *in situ* measurements, the total amount of mass ejected was of order a few $\times 10^4$ tons, although there are still disagreements by a factor of two to three remaining to be resolved. Based on the above data and our own data, we conclude that there was a strong predominance of particles of diameter 1 to 10 microns, indicating that the surface material, which must be composed of larger particles [5], is composed primarily of very weak aggregates at the microscopic scale. Dust-to-ice ratios are uncertain but appear to be between 1 and 5, with our own estimates being nearer the lower end of this range.

The ejected material included grains of crystalline ice (of size < 10 microns) indicating little heating of the ejecta except in the first second, when the ejecta were very hot [1, 15]. There was a significant increase in the ratio of CO_2 to H_2O vapor after the impact, larger than can likely be explained by the fact that some of the water remained as ice. There was a much larger increase in the amount of organics relative to H_2O, but our spectral resolution does not allow us to separate the various organic constituents. There are also unidentified species, not previously seen in cometary spectra, in the ejecta. Because the line of sight is very close to the nucleus, the emission features are optically thick, making derivation of quantitative relative abundances very difficult.

Observations of the ejecta when looking back after closest approach have enabled us to deduce a rigorous upper limit on the strength of the material [16] at scales from the size of the impactor (1 m) to the size of the crater (~10^2 m) even lower than previous limits derived for larger scales from the disruption of comet Shoemaker-Levy 9 [*e.g.*, 17], simultaneously demonstrating gravitational control of the formation of the crater. We also observe material falling back to the surface, from which we derive a very low bulk density for the nucleus [16].

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