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Supporting Online Material for

Parent Volatiles in Comet 9P/Tempel 1: Before and After Impact

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SOM Text
References

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S1: Each SCAM pixel subtends 0.178 arc-seconds (") in each direction, and the full image contains 256x256 pixels. The comet was imaged at 10-second intervals in light with wavelengths from 2.1 to 2.5 μm. The band-limiting filter passes light in the wavelength range 2.1-4.2 μm, but the SCAM detector array is not sensitive longward of 2.5 μm.

S2: The 3-pixel wide entrance slit of the NIRSPEC spectrometer has dimensions 0.43"x 24", the pixels subtend 0.144" (0.19") in the spectral (spatial) direction at the distance of Tempel-1.

S3: "Spectral setting" means a specific instrument configuration needed to measure a specific wavelength range. This requires choosing a specific entrance slit, a band-width limiting filter, the echelle grating angle, the cross-disperser angle, the on-chip integration time, and so forth. We used a common slit for all measurements. Light passing through the spectrometer entrance slit is diffracted, cross-dispersed, and sampled by a 1024 x 1024 InSb detector array, providing measurements of both the dust continuum and of spectral lines emitted by gases. To eliminate instrumental artifacts, calibration frames (flats, darks) were acquired for each setting before the instrument parameters were changed. Comparison spectra of an infrared flux-standard star were acquired (at a similar air-mass) for each instrument setting after Tempel-1 observations ended, and were used for overall intensity calibration.

We nodded the comet 6" in either direction along the slit in an ABBA sequence. Although the slit length is 24" and it subtends about 15,600 km at the comet, we nod (A, B frames) the comet + - 6" along the slit about its center. We then subtract the A and B frames to remove sky and telescope emission. We crop the difference frame and co-add spectra extracted from the A and B positions. The spatial extent over which we detected the spectral continuum was only 9 pixels (1.7") along the slit, or 1100 km at the comet and centered on it (the width of the slit subtends 280 km at the comet). The distribution along the slit was well fitted by a Gaussian, from which we extracted the area and the peak intensity.

S4: The three light curves shown in Fig. 1E are scaled individually to better reveal their shapes.

S5: Initial data processing included removal of high dark current pixels and cosmic ray hits using median- and sigma-filtering, and registration of spectral frames. The raw spatial-spectral frames are usually anamorphic in both spectral and spatial directions. We re-sampled the frames, straightening the A- and B-beams independently within each order such that the spectral dimension falls along a row and the spatial dimension is orthogonal to this. This process also adjusts the spectral dispersion to a common value, row-by-row. Spectra were extracted by summing nine rows about the center of each beam position, and combining the two beams.

S6: We measure the trend of these "spherical" production rates vs. distance from the nucleus (along the slit) and form a "symmetric" Q from the north-south mean at each offset position. The nucleus-centered extract is invariably too small (due to slit losses caused primarily by seeing), but off-nucleus extracts of the "symmetric" Q are less affected and they quickly reach a terminal value (unless a distributed source is also present. This terminal value is taken to be the "global" production rate. For Tempel-1, we measured the "global" production rate and its growth from the nucleus-centered value for H_2O, C_2H_6, and HCN; growth factors were measured for these species, and (in all frames) for dust. We use those growth factors to scale nucleus-centered production rates for other species (Table 1) (S1).

S7: For a steady source (e.g., pre-impact), the central pencil beam contains a constant number of a parent species, regardless of its lifetime. Moreover, about two-thirds (i.e., $2/\pi$) of the total number sampled by the pencil beam lie within the inscribed sphere — in this case, within about 140 km of the nucleus.

S8: The heliocentric distance, geocentric distance, and geocentric velocity were 1.540 AU, 0.764 AU, and 5.61 km/sec on UT 3 June. On UT 4 July, they were 1.506 AU, 0.894 AU, and 9.2 km/sec. All high dispersion spectra ($\lambda/\delta\lambda \sim 25{,}000$) were acquired with the 3-pixel wide slit (0.43" x 24" on the sky).

S9: We measure the flux and error for individual spectral lines of each molecular species; these are then combined with g-factors, rotational temperature models, and instrumental calibration factors to produce a weighted column number and effective production rates. A detailed line-by-line listing is beyond the scope of this paper.

S10: Production rates assume the standard model, and we use the analysis procedures developed for our extensive database of cometary observations. This is valid for a steady state coma such as is reasonable on UT 3 June and 5 July. On 4 July, we assume the comet to have both a steady source and a time variable one induced by the impact. The total number of molecules in the column of gas sampled by the 0.43 arc-sec x 1.71 arc-sec (3 pixels x 9 pixels) beam is given in column 5. We assume the steady source did not change as a result of the impact, and subtracted its contribution to the total column number for each species, using the mixing ratios for C_2H_6 and CH_3OH measured on 3 June (these are more accurate than those measured before impact on 4 July, because the comet was intrinsically brighter on 3 July and the total time on source (44 minutes) was much larger than on 4 July pre-impact (16 minutes). For post-impact observations on UT 4 July the total column number is a valid measure of the activity, but the formal total production rates should be regarded as indicators only.

References and Notes

[S1] N. Dello Russo et al., *Astrophys. J.* **621**, 537 (2005).