Radio OH Observations of 9P/Tempel 1 Before and After Deep Impact

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We observed 18-cm OH emission in comet 9P/Tempel 1 before and after Deep Impact. Observations using the Arecibo Observatory 305m telescope took place between 8 April and 9 June, 2005, followed by post-impact observations using the National Radio Astronomy Observatory 100m Green Bank Telescope 4—12 July, 2005. The resulting spectra were analyzed with a kinematic Monte Carlo model which allows estimation of the OH production rate, neutral gas outflow velocity, and distribution of the out-gassing from the nucleus. We detected typically 24% variability from the overall OH production rate trend in the two months leading up to the impact, and no dramatic increase in OH production in the days post-impact. Generally, the coma is well-described, within uncertainties, by a symmetric model with OH production rates from 1.6 to 7.4×10^{27} mol s^{-1}, and mean water outflow velocity of 0.75 ± 0.03 km s^{-1}. At these low production rates, collisional quenching is expected to occur only within 20000 km of the nucleus. However, our best-fit average quenching radius is 64200 ± 22000 km in April and May.

We took advantage of the newly installed OH filters on the ALFA receiver, to observe seven positions across the coma simultaneously, and to investigate how the line strength varied both spatially and with time. The outer pixels of ALFA are arranged in a hexagonal pattern as shown in the Figure 1. The best-fit model spectrum is shown together with the observed line. The calibration noise diodes on the ALFA receiver do not work at this frequency, so the nucleus-centered line was observed for 20 minutes with the L-wide receiver, and calibrated using the system temperature and telescope gain curve.

In the dense inner region of the coma, collisions with electrons can quench the excitation of the Λ-doublet, which suppresses the inner coma contribution to the observed spectrum.

Quenching is not expected to be a major effect for comets with gas production less than 10^{29} mol s^{-1} (Crovisier et al., 2002). Nonetheless, we do see evidence for quenching in late April and May in our mapped observations of 9P/Tempel 1. The degree of quenching is well constrained by our mapping observations, because we directly observe the ratio of the OH line strengths towards the nucleus and at offset positions. Figure 2 shows a comparison of the quenched and unquenched models for 2 May, which is best fit with a quenching radius of 80000 km. To illustrate the difference in the on-to-off line ratios, we scaled the offset position models to fit the observations, as shown on the left. Only with quenching suppressing the OH line strength in the inner 80000 km does the resulting nucleus-centered model spectrum match the observations (right panel of Figure 2).

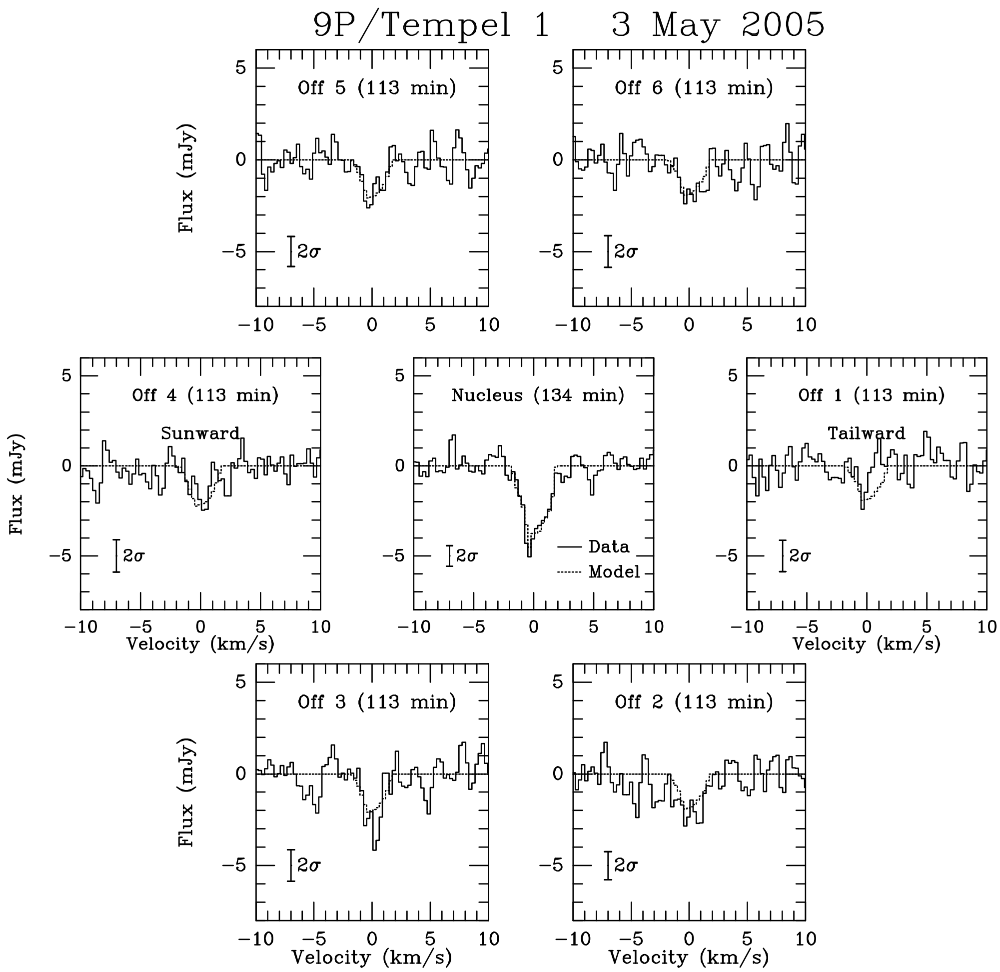

Fig. 1.— The OH 1667 MHz spectra observed at Arecibo on 3 May 2005 are shown. This map was made combining observations from the L-wide and ALFA receivers. The nucleus spectrum is the result of 134 minutes integration, the outer spectra are 113 minutes integration using ALFA. The outer hexagonal map of spectra was oriented with off position 1 (off1) in the tailward direction, and off position 4 (off4) in the sunward direction. The best model fits are shown on each spectrum as a dotted line. The errorbar indicates the rms noise in each spectrum.

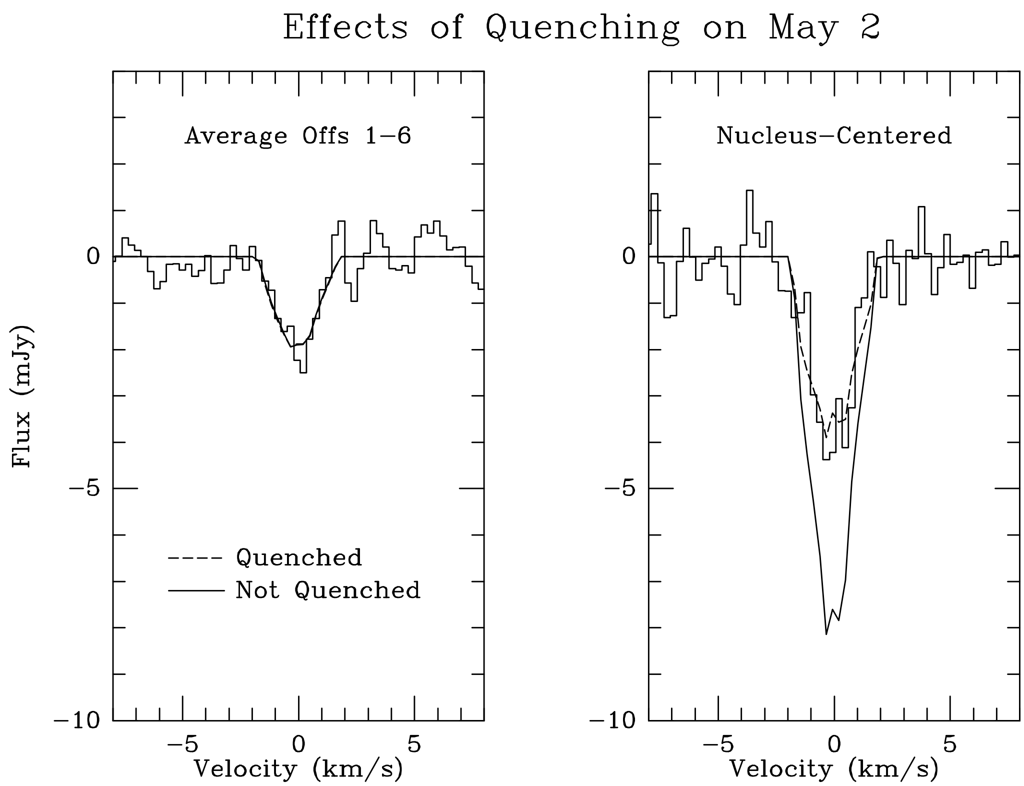

Fig. 2.— The effects of quenching are shown for the spectra taken 2 May. The left panel shows the average of all six off-center spectra together with the best-fit model which includes effects of quenching. Both models are scaled to match the average off spectrum. When the same scaling is applied to the nucleus-centered model spectra, shown on the right, it is clear that only the quenched model matches the observations.