MODELING THE TEMPORAL RESPONSE OF THE EMISSIONS FROM COMET 9P/TEMPEL 1 AFTER DEEP IMPACT OBSERVED USING THE KECK TELESCOPE AND THE HIRES INSTRUMENT.

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On July 4, 2005 the Deep Impact spacecraft sent a man made projectile into a comet (Comet 9P/Tempel 1) for the first time. The material released from the comet and its interaction with solar radiation was observed using the Keck telescope with the high-resolution echelle spectrograph on Mauna Kea. Excellent high-resolution spectra of the emissions from O(^{1}S), OH, CN, C_2, C_3, NH, and NH_2 radicals were measured. All of these emissions were previously observed from this comet before the impact but we have devised a method to separate the emission due to the impact from those that were present before the event and thus derive the temporal behavior of this emission. This is the first time in the history of astronomy that an astronomical event initiated by man could be followed in real time. It required the use of a NASA mission and the ability to use the Keck telescope with it large light gathering power, spatial and spectral resolution to achieve this. Using this information the time dependence of the changes in the emission spectra of Comet 9P/Tempel 1 after Deep Impact are derived. Typical examples of the results and the models used to fit them are shown in Figs. 1 and 2. In cases like H_2O shown in Fig.1, the model is a simple Haser two-step model involving the photodissociation of the parent H_2O and daughter OH. The rate constant for the OH radical is as accurate as the solar flux since the cross section for photodissociation is based upon the predissociation lifetimes of the excited state that can be measured easily to within 10%.[1],[2] The curve shown in the figure will fit the observed points with a rate constant for the photodissociation of water of 8 x 10^{-5} s^{-1}, which is in the high range of the reported rate constant for the photodissociation of H_2O.[3] This value is for photodissociation of H_2O at 1.51 AU for a quiet sun, which is at least a factor of 3 higher than the largest value reported in the literature.[3],[4]

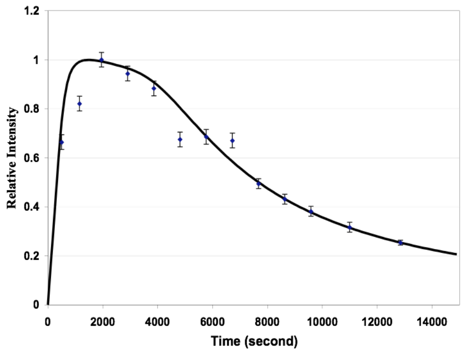
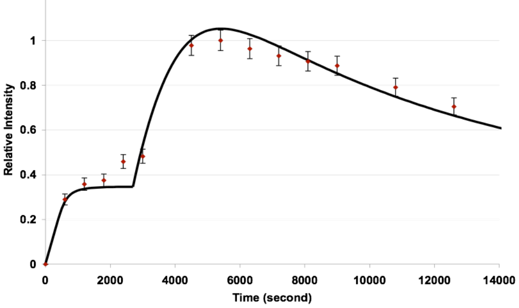


Fig. 1. The temporal response of the OH emission after the Deep Impact encounter, the points are the observations and the solid line is a two-step Haser model with the rate constants for k_p and k_d of 8 x10^{-5} and 3.0 x 10^{-6} s^{-1}, respectively.

Many of the radicals require more complicated models such as a two-step Haser model for CN with a delay of 2800 s as shown in Fig.2. In the case of some of the radicals the known rate constants provide a reasonable fit to the observed data but in others they do not. This can be solved in part by using a more complicated model that incorporates a second source of radicals that begins production 2700 s after impact. This second source is interpreted as the exposure of fresh ice buried beneath the surface of the comet as the dust thrown up by the impact dissipates. In the case of the CN radical both the prompt and delayed emission can be fitted with a two-step Haser model that uses the same rate constants for the k_p and k_d of 1 x 10^{-5} and 3 x 10^{-6} s^{-1}, respectively for both of them. Since this was derived for a comet at 1.51 AU the rate constants should be multiplied by 2.28 to compare with the 1 AU rate constants for the possible parents of CN. This means that HCN, C_2N_2 and HC_2CN are all possible parents of CN.

Fig. 2. The time dependency of the CN emssion initiated by Deep Impact with two 2-step models and a 2700 s delay



All of the observed emissions except OH and C_3 need both a prompt and delayed emission in order to fit the observed temporal emission after the Deep Impact event. This is consistent with a model of the comet nucleus that consists of a layer of dust that thermally insulates a deeper layer with more ice and dust. The upper layer slowly allows gas to percolate up to surface. If the flow rate is high enough it lifts off some of the dust and if not the gas escapes into the coma where it is dissociates into the observed radicals.

This and other implications of the results of modeling the temporal behavior of the emissions from Comet 9P/Tempel 1 will be presented. Acknowledgements: This work was funded by NASA Grant NNG04G162G (A.L.C.) and NSF Grant CHE-0503765 (W.M.J.) [1]Jackson, William M., *The lifetime of the OH radical at 1 AU*, Icarus, **41**, 147-152(1980). [2] Singh, P. D., E. F. Van Dishoeck, and A. Dalgarno, *"The Photodissociation of the OH and OD Radicals in Comets"*, Icarus, **56**, 184-189(1983). [3]Crovisier, Jacques, *Photodestruction rates for cometary parent molecules*, J. Geophys. Res., **99**, 3777-3781(1994). [4]Manfroid, Jean, D. Hutsemékers, E. Jehin, A. L. Cochran, C. Arpigny, W. M. Jackson, K. J. Meech, R. Schulz and J-M. Zucconi *"The impact and rotational light curves of Comet 9P/Tempel 1"*, Icarus, **187**,144-155(2007).