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# Vibrationally highly-excited $H_2O$ molecules in cometary comae

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## Abstract

High resolution spectra of cometary comae in the 2.9 $\mu$m region have revealed the presence of $H_2O$ emission lines from upper states with high vibrational, but low rotational quantum numbers, so-called 'SH' (stochastic heating) lines. The method by which the high energy upper states of these transitions are populated is not yet understood, but it seems likely that photo-electrons are involved. We discuss the characteristics of SH lines, how we are investigating possible production mechanism and our plans to incorporate our results into a spatially-resolved dynamical model of cometary comae.

## 1. Modelling Cometary Comae

Comets represent some of the most primitive material in the Solar System: their study is key to understanding planetary formation and evolution. Models of comets, their comae and their tails are informed by in situ measurements (e.g Giotto, Deep Impact, Rosetta), and by ground-based measurements. Understanding cometary spectra is far from straightforward: molecules in the coma may be excited by solar pumping, stochastic heating and impacts (from photo-electrons and solar wind particles). These predominate at different distances from the nucleus, and become important for different molecules at different distances as a result of collisional rate and optical depth effects. Studying the spectra of different molecules enables us to gain crucial insight into the structure and physical/chemical evolution of the coma, and hence of chemical production rates and evolution.

## 2. Stochastic Heating (SH) lines

SH lines were first identified in 2.9 $\mu$m high resolution spectra of Comet 9P/Tempel 1 obtained immediately after the Deep Impact event [1]. The discovery was fortuitous, as the object of the observations had been to measure the relative intensities of well-known 'SPF' (solar pumped fluorescent lines) in this region. The initial discovery was followed up by observations of Comet 8P/Tuttle [2]. Long integration times were used, and eight weak $H_2O$ SH features were assigned. These were found to have a number of characteristics in common, which in addition to helping to define this new class of cometary line may hold clues to the physical processes involved in their production. Subsequently, it was discovered that many of these SH lines corresponded to weak features in other cometary spectra.

## 3. Comet Hartley 2

In October/November of this year, the appearance of 103P/Hartley 2 should provide an excellent opportunity to obtain long integration time, spatially-resolved, high resolution 2.9 $\mu$m spectra of its coma. These observations will greatly assist our understanding of the molecular excitation mechanisms. Specifically, we expect that observations of spatially-resolved SPF and SH $H_2O$ lines and also $NH_3$ lines will yield important information about the interaction between the coma and solar radiation, including the role of photo-electrons in exciting molecules into high vibrational states. The BT2 line list [3] will be our basic tool for investigating water emissions, and the new $NH_3$ line list [4,5] will, for the first time, enable identification of transitions from high vibrational states of ammonia. It is hoped that this will provide additional information about conditions in the inner coma.

## 4. Strategy

The wavelengths of all the strongest cometary SPF $H_2O$ lines in the 2.9 $\mu$m region are know to spectroscopic accuracy. These will be used as calibration lines. Since they originate at the target, there is no need to adjust for radial motion, which is a major advantage. The 2.9 $\mu$m region includes a large number of SPF and SH $H_2O$ lines and also temperature-dependent $NH_3$ lines in a single spectrometer setting. We will use a number of statistical techniques, including Fourier transform filtering, to examine data on a frame-by-frame basis. The $H_2O$ and $NH_3$ line lists referred to above will be used to assign spectral features. Temperature-dependent transmission strengths ('g' factors) are known for all the SPF water lines, and this will enable us to determine spatially-resolved temperatures and number densities, from observed line intensities. We plan to incorporate the findings into a spatially-resolved dynamical model of cometary coma.

## 5. Figures

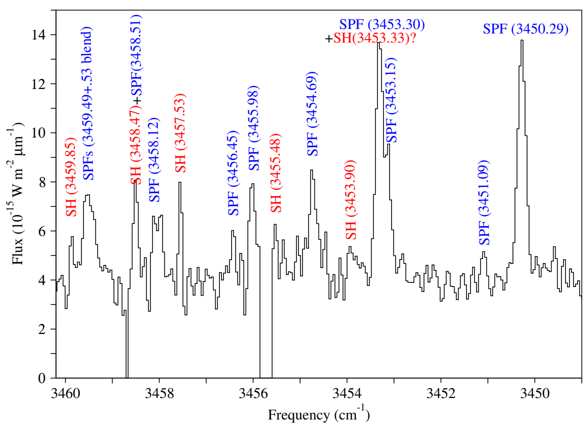


Figure 1: Spectrum of Comet 8P/Tuttle showing position of SPF and SH water feature - assignments made using [2]

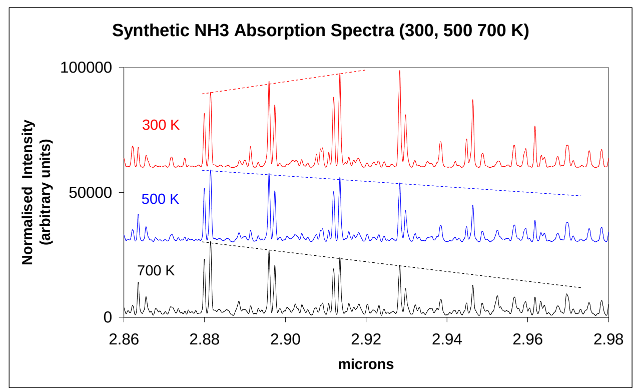


Figure 2: Synthetic spectra of ammonia at various temperatures produced with [5]

## References


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