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Letter to the Editor

Non-detection of the OH Meinel system in comet P/Swift-Tuttle

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Abstract. We report a search for emissions from the OH Meinel system in high-resolution near-infrared spectra of comet P/Swift-Tuttle. Because of the the large cometary heliocentric velocity and high resolution of the spectrograph, the cometary lines should be well separated from the bright OH sky lines. Contrary to the findings of Tozzi et al. (1994) – who report seeing cometary OH at intensities comparable to the sky emissions in their low-resolution spectra – we find no OH in these spectra, with an upper limit of 5% the value of the night sky lines. The non-detection of these cometary lines is consistent with theoretical calculations of expected emission strengths from prompt and fluorescent emission from cometary OH.

Key words: Comet – OH – Spectra

1. Introduction

OH is a primary dissociation product of water, the most abundant cometary constituent. Measurements of OH intensities at UV and radio wavelengths are often used to infer the production rate of cometary water. Thus, the report of detection of the near-infrared OH Meinel system using low-resolution visible spectroscopy in comet P/Swift-Tuttle gave hope that more readily-available optical telescopes could be used to measure OH intensities and thus monitor the water production rates in comets (Tozzi et al., 1994). P/Swift-Tuttle was a good test case, because the bright comet was closely monitored at many wavelengths, and the OH production rate was well know (Feldman et al. 1993, Bockelée-Morvan et al. 1994). However, the line strengths reported by Tozzi et al. are between 20 and 1000 times stronger than those predicted from calculations of the prompt or fluorescent emission strengths, requiring the existence of an unknown excitation mechanism for the OH Meinel system.

In an attempt to confirm the observations of Tozzi et al., we examined high-resolution spectra of comet P/Swift-Tuttle obtained just a few days after their observations. Because of the high resolution of the spectra and the large geocentric velocity of the comet, the positions of the cometary OH emission lines are well separated from the night sky lines, so we do not need to perform the difficult task of subtracting the sky lines to see the comet lines. A careful examination of the spectrum reveals 55 night-sky OH lines, but no cometary lines.

2. Observations

Observations of comet P/Swift-Tuttle were made using the 0.6-m coudé auxiliary telescope attached to the Hamilton echelle spectrograph at Lick Observatory (Vogt, 1988). Orders 58-149 of the cross-dispersed spectrum were recorded using a 2048^2 Ford CCD (binned 2 × 2 to decrease readout noise), giving essentially continuous spectral coverage from 3800 – 9800Å with a resolution of $\lambda/\Delta\lambda \sim 32{,}000$. The spectral aperture for the observations was 6.8 by 12.5 arc-seconds, which corresponds to an area of 6000 by 10000 km at the cometary position.

The comet spectrum was obtained at 2:02 UT on 18 November 1992, from a single 3000 second exposure with a median air mass of 1.65. Flat-fielding was performed by dividing the comet spectrum by the spectrum of an internal quartz lamp. The spectral orders are curved on the CCD chip, and we made a 3 pixel wide extraction by following the curvature on a template quartz spectrum. The grating blaze function was removed by fitting a smooth continuum to each order of the template spectrum and dividing the comet orders by that continuum.

Wavelength calibration was performed by comparison with a thorium-argon lamp with a large number of lines

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of known wavelength. A two-dimensional fit is made to simultaneously obtain a wavelength solution for all spectral orders. Based on comparisons with OH night emission lines and cometary CN lines of known wavelength, the wavelength scale is accurate to better than 0.05Å in the region of interest. The wavelength scale is then shifted to account for the 15.5 km s^{-1} geocentric comet velocity.

No absolute calibrations were performed, so we compare all intensities to the intensities of the OH night sky lines. From the experience of obtaining many calibrated lower resolution spectra, we believe that these intensities vary by no more than a factor of 2 to 3.

3. Results

A search of the visible and near-infrared regions of the spectrum reveals no OH emissions from the comet, but 55 OH sky emission lines from 11 different bands between 6200 and 9800Å, all shifted by the expected 15.5 km s^{-1} from the cometary positions. As an example, we show in Figure 1 a portion of the (7-3) band with the sky and expected comet OH positions marked.

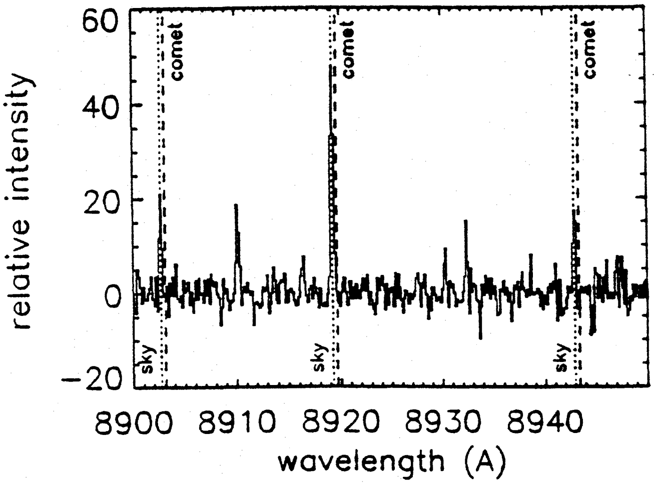

Fig. 1. A section of the OH (7-3) band showing the $P_2(3)$, the $P_1(2)$, and the $P_2(4)$ night-sky lines. These lines are typical of the signal-to-noise in the other 52 detected sky lines. The expected cometary emission positions are labeled by the dashed line. No OH emission from the comet are seen.

To search for faint emissions from the comet, we took all detected sky emission lines, shifted them to a common center, and combined them (either weighted by signal-to-noise of the sky line, or medianed). Because the spectrum is at constant dispersion, the expected cometary line position is always shifted by 3.14 pixels (15.5 km s^{-1}) from the sky line, so we look for faint emission at that location, as shown in Figure 2 (a) and (b). We fit a gaussian line profile to the composite sky line and show the residuals in Figure 2 (c) and (d). Based on these residuals, we place a 3-σ upper limit of 5% on the ratio between cometary and sky emission.

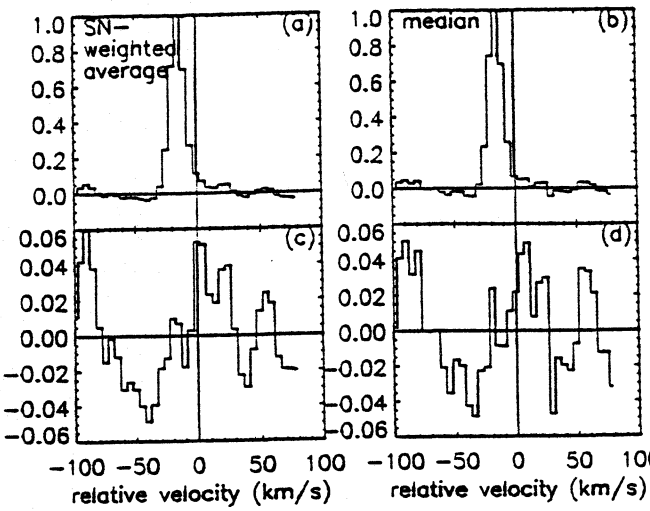

Fig. 2. A combination of all of the OH sky lines, shifted to a common center to increase signal-to-noise. In (a) the lines are weighted by the signal-to-noise and then averaged, in (b) a median of all of the lines is taken. The solid vertical line at a position of 15.5 km s^{-1} shows the expected position of cometary OH. Plots (c) and (d) show the residuals remaining after subtracting a gaussian profile fit to the sky line. From these residuals, we place a 3σ upper-limit of 5% to the comet/sky OH emission intensity ratio.

4. Discussion

Based on the *IUE* production rate obtained on 16 November 1992 (Feldman et al. 1993) and using the upper limits for prompt emission calculated by Tozzi et al. (1994), we estimate a theoretical upper limit to emission by water-photodissociation-excited OH of about 1 kR in our 6000 × 10000 km projected aperture. Assuming that the OH sky brightness for these 55 lines is approximately equal to the brightness Krassovsky et al. (1962) measured (a total of 14 kR for the 55 observed lines), we then predict an upper limit of 6×10^{-2} for the ratio of cometary to sky emission line intensities. As noted by Tozzi et al. (1994), intensities from pure fluorescent emission of OH are at least an order of magnitude lower. This theoretical upper limit is consistent with our measured upper limit of 5×10^{-2} for this ratio.

In contrast, Tozzi et al. (1994), using long-slit low-resolution spectra, reported detection of OH emission from P/Swift-Tuttle at an average level of about 75% of the sky. Because of dilution in our larger aperture, this level would correspond to an average ratio of about 40% in our observations, or about an order of magnitude above our 3σ upper-limit. Several convincing factors led Tozzi et al. to believe that their detections of OH emission lines were not spurious, including the reproducibility of the lines with different exposures and conditions, the structural differences between the cometary and sky lines, and the apparent (but non-Doppler) shift between the comet and sky lines. No explanation for these characteristics seemed plausible unless the OH lines had a cometary origin. Because the water production rate and therefore the OH density were known, an unknown excitation mechanism had to be invoked to explain the apparently high emission rate of OH.

The Tozzi et al. observations took place 12 and 14 November 1992 (6 and 4 days before these), and covered the (3-0) and (9-5) bands. The only direct spectral overlap with our observations is in 3 lines of the (3-0) band. A comparison between our spectrum and the measured values of Tozzi et al. (corrected for aperture dilution) for that band is shown in Figure 3. In addition, we observe 10 other bands which show no cometary emission, including the (9-4) and (9-3) which should respond to any unusual excitation in a manner similar to the (9-5) band.

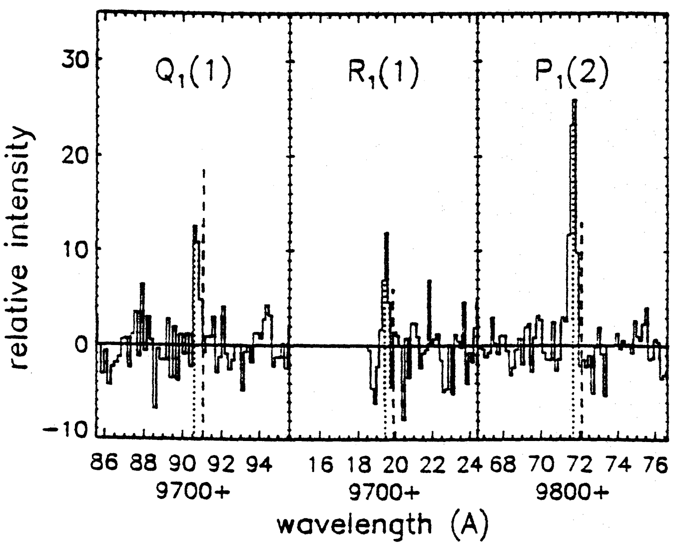

Fig. 3. A plot of the three lines common to these observations and those of Tozzi et al. (1994). The dotted line shows the position of OH night-sky emission, and the dashed line shows the expected position of cometary OH emission. The height of the dashed line corresponds to the relative intensity of the line measured by Tozzi et al., compared to the sky line.

The discrepancy between these observations is difficult to reconcile. While the observed variability of P/Swift-Tuttle might be invoked to try to explain the differences between these two observations, this explanation seems unlikely. Visible imaging of dust and gas jets shows that the nucleus was rotating with a period of about 2.8 days (Boehnhardt & Birkle, 1994). The two observations of Tozzi et al. were taken 2 days apart, so were about 100 degrees out of phase, and the apparent OH emission intensity was apparently similar for both observations. Our observation occured approximately 81 hours after their second observation, so the nucleus had rotated once and was approximately midway in position between the two Tozzi et al. observations, but showed no emission. If the enhanced OH emission was periodic with the nuclear rotation and was smoothly varying, we would expect our observations to show similar emissions. While it is possible that Tozzi et al. caught the nucleus at two special locations, this fortuitous arrangement seems unlikely.

Along with its spin-periodic variabilities, P/Swift-Tuttle could have exhibited more random variabilities between the times of the observations which could have potentially placed the OH in an unusual state. Because it was a bright well-placed comet, it was observed extensively during this time. Observations of Bockelée-Morvan et al. (1994) of the OH radio lines during this time show an OH production rate that is smoothly varying with heliocentric distance (though because of the large aperature these observations are insensitive to short-term variations). Boehnhardt & Birkle (1994) imaged the coma nightly between 12 and 27 November and saw no unusual non-rotational effects. However, in the same spectra in which they reported an OH detection, Tozzi et al. (1993) showed that the CN spatial profiles implied the presence of intense activity on the comet. While none of these observations is directly applicable to the near-infrared OH bands or the unknown excitation mechanism, they do give a general indication that the comet was active, but perhaps not unusually so, during the observations.

Finally, we consider observational effects. Tozzi et al. carefully discuss all reasonable effects that might have influenced their observations and conclude that the apparent OH emission lines are real. We can think of no additional mechanism which would cause spurious emission lines but point out that attempting to extract cometary lines in the presence of strong sky lines using a low-resololution spectrum is a difficult task in which errors could occur.

Based on the non-detection of the OH Meinel band in our observations and the difficulty of explaining the intensities and electron populations observed by Tozzi et al, we conclude that current estimates of fluorescent and prompt emission efficiencies are consistent with the observations and that no new excitation mechanism is required or revision of the OH physics is required. The prospect that cometary OH might be observable with readily available ground-based equipment remains intriguing, and efforts to observe these lines should continue.

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