THE DETECTION OF THE 5577.3 Å LINE OF [O I] IN COMETS

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Abstract. The spectral synthesis of C_2 Swan band sequence $\Delta V = -1$ indicates the intensity of the forbidden green oxygen line of 5577.3 Å to be about 3 to 5% of the 6300 Å line. Therefore, it appears that the green line should be observable in high-resolution spectra of a bright comet. Festou and Feldman suggest red/green $\geqslant 10$ means a water parent origin.

1. Introduction

The forbidden lines arising out of ^1D state of oxygen occurring at 6300.2 and 6363.9 Å have been seen in emission in many comets. Extensive analysis of the strong line at 6300 Å has been carried out, from which one can deduce the production rate of oxygen in comets. The other forbidden line of oxygen arising out of ^1S level is at 5577.3 Å which lies in the visual spectral region. Unfortunately, the Swan bands of C_2, corresponding to $\Delta V = -1$ sequence, are very strong in this spectral region and so the green line (5577.3 Å) is blended with C_2 Swan bands. One way to extract the 5577.3 Å line of oxygen is through comparative spectral synthesis of $\Delta V = -1$ C_2 Swan band sequence. Here, we would like to make an attempt in this direction.

The motivation for a search for the green oxygen line of 5577.3 Å in comets is the following. At the present time there is uncertainty as to whether the parent molecule of oxygen atom is H_2O or CO_2, although the observations seems to be consistent with H_2O as the source of oxygen atoms. The H_2O model calculations of Festou and Feldman (1981) has indicated the intensity of the green line to be weaker by a factor of 10 or so compared to that of red line. Therefore, if the green oxygen line is detected, the intensity ratio of green to red line could help in resolving this problem.

2. Observations

The cometary observations used here are those of Spinrad (1982) made with the Lick Observatory Shane 3-m telescope. The observations cover the spectral region of about 4600 to 7300 Å taken with a resolution of about 7 Å, and are well sky-subtracted, to remove terrestrial [O I]. The spectra clearly show the well known strong $\Delta V = -1, 0$ and $+1$ Swan band sequences whose wavelengths lie around 5635, 5165, and 4737 Å, respectively. For the present study, we have used the observations of periodic comets Tuttle

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and Encke. For more details with regard to instrumentation as well as for the reduction of the data, one may refer to Spinrad (1982). Since the spectral observations are available for all the three Swan band sequences, we would like to make a synthetic profile analysis of the other two features as well.

3. Calculations and Results

For the calculation of a synthetic profile, it is necessary to know the population distribution in various vibrational and rotational levels. This can be attained in principle from the solution of the statistical equilibrium equations of the entire system. Unfortunately, this is not practical at the present time. Therefore, we have followed the following procedure. For the vibrational population distribution, we have used the earlier result (Krishna Swamy and O'Dell, 1977, 1979), which is based on an extensive statistical equilibrium calculations. We have made use of Boltzmann distribution function for the rotational population distribution. The wavelength of the various transitions are taken from Phillips and Davis (1968). Since the observed profile is a superposition of many bands, we have, therefore, considered the following bands in the profile calculation: (0, 1) to (5, 6) for $\Delta V = -1$, (0, 0) to (3, 3) for $\Delta V = 0$ and (1, 0) to (6, 5) for $\Delta V = +1$. The resulting profile can easily be calculated from the superposition of various lines arising out of the various bands. The results of such calculations corrected for the instrumental effect are shown in Figures 1 to 3. The curves are normalized to unity for the first peak in the band sequence. The Figures 1a and 2a indicate a slight excess of flux at $\lambda \approx 5577$ Å compared to the expected flux. This probably is attributable to the contribution of oxygen line of 5577.3 Å. Therefore, one can infer that the intensity of oxygen line at 5577.3 Å should be roughly about 3 to 5% of the oxygen line at 6300 Å.

It is of interest to see whether the oxygen green line could be observed in spectra taken at a higher resolution. With this in view, we have calculated the synthetic spectra of $\Delta V = -1$ band sequence of C_2 for a typical resolution of $\Delta\lambda_0 = 0.3$ Å. The calculated spectra is based on the solution of the statistical equilibrium equations of rotational levels with resonance fluorescence as the excitation process. We have included 80 rotational levels in each of the upper and lower levels of $3\pi_0$, $3\pi_1$, and $3\pi_2$ states. The synthetic spectra of C_2 corrected for the instrumental effect, in the wavelength region of interest is shown in Figure 4. We have also shown in Figure 4, the level of the expected intensity of oxygen 5577.3 Å line, if its intensity is about 5 or 10% of the line at 6300 Å. As can be seen from the figure that even with a resolution of $\Delta\lambda_0 = 0.3$ Å, which is feasible at the present time, the oxygen green line should be observable; it also will be Doppler-shifted from the telluric [O I] feature. For resolutions better than this, the line should be quite separate. Therefore, it appears that in high – resolution spectra of a bright comet, one may be able to clearly detect the oxygen green line. Figure 1 to 3 also indicate a C_2 'temperature', $T_{rot} \approx 3000$–4000 K, in good agreement with the result of Lambert and Danks (1983).

As this work was completed, we learned of the likely detection of [O I] 5577 by

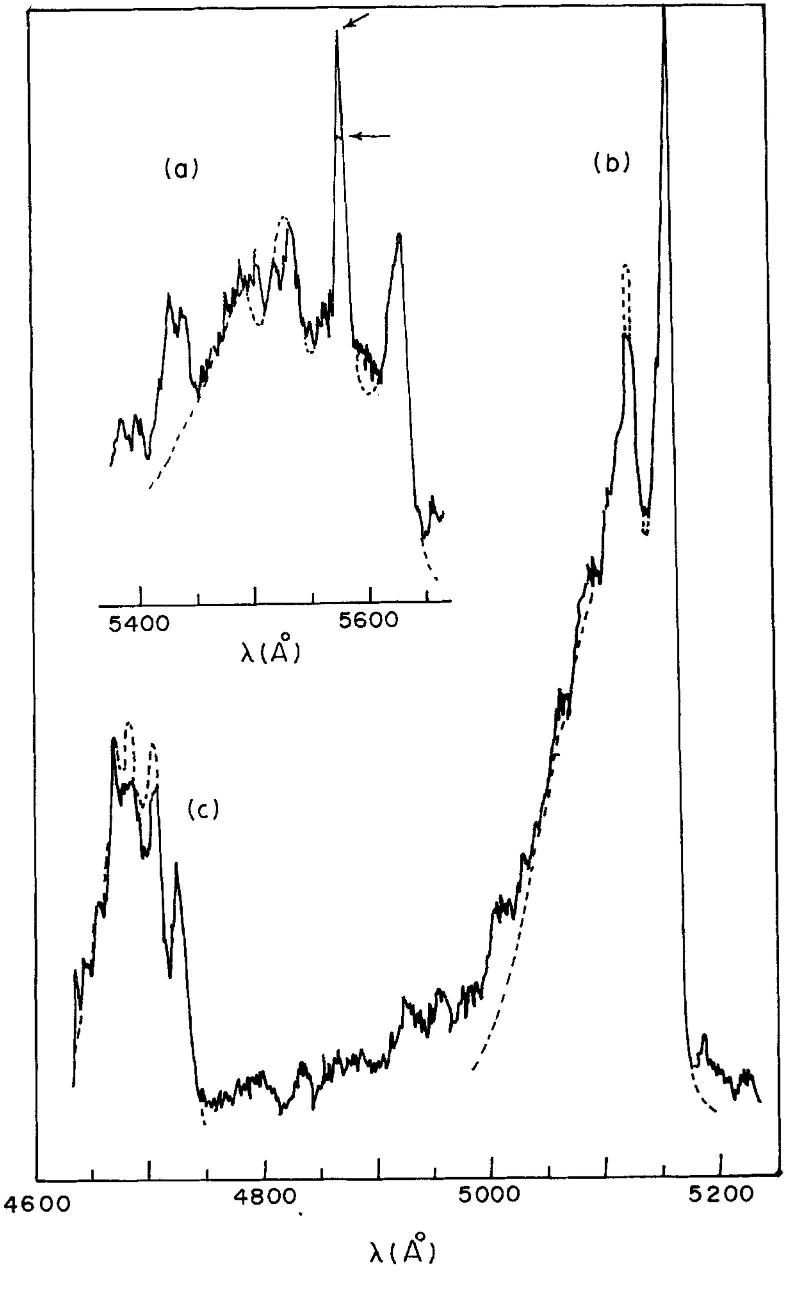

Fig. 1. Comparison of the observed (sky-subtracted) and calculated (dashed) profiles of Swan band sequences, $\Delta V = -1$ (a), $\Delta V = 0$ (b) and $\Delta V = +1$ (c) for Comet Tuttle ($r = 1.2$ AU). $T_{ex} = 4000$ K, $\Delta\lambda_0 = 7$ Å. Arrows near predicted excess flux at λ 5577 which should be [O I].

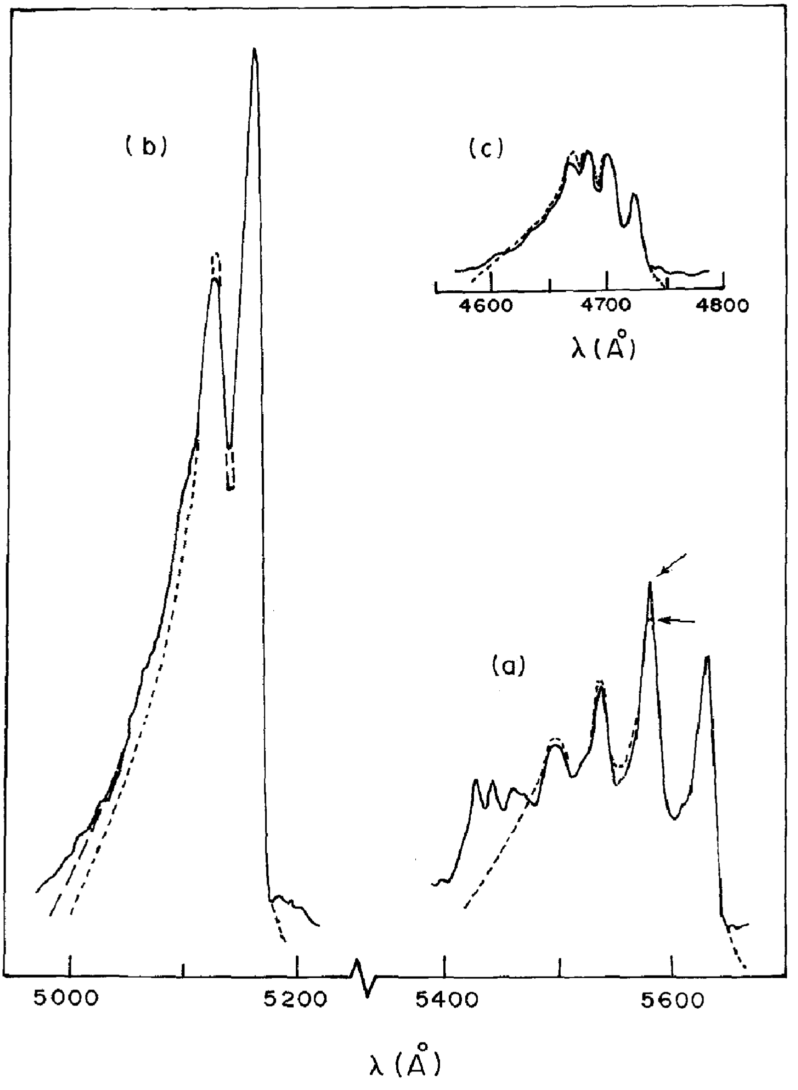

Fig. 2. Same as Figure 1 and for Comet Encke (r = 0.82 AU). Dashed and long dashed curves refer to T_{ex} = 3000 K and 3500 K, respectively.

W. D. Cochran at $\sim\frac{1}{30}$ the λ 6300 line intensity in high resolution digital spectra of the 'earth–grazing' comet (1983d) IRAS-Araki-Alcock.

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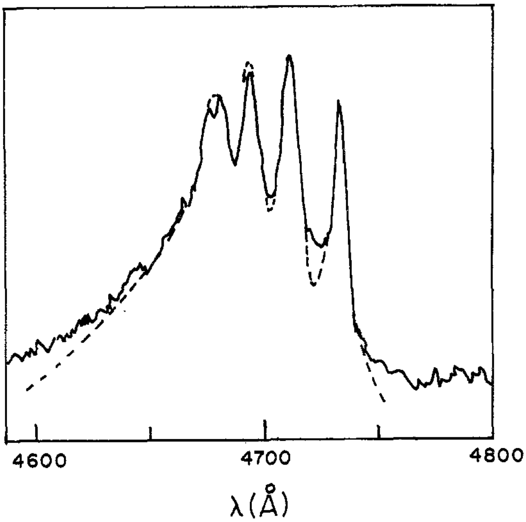

Fig. 3. Comparison of the observed and calculated (dashed) profiles for the Swan $\Delta V = +1$ sequence for Comet Kohoutek ($r = 0.98$ AU). $T_{ex} = 3500$ K, $\Delta\lambda_0 = 4$ Å.

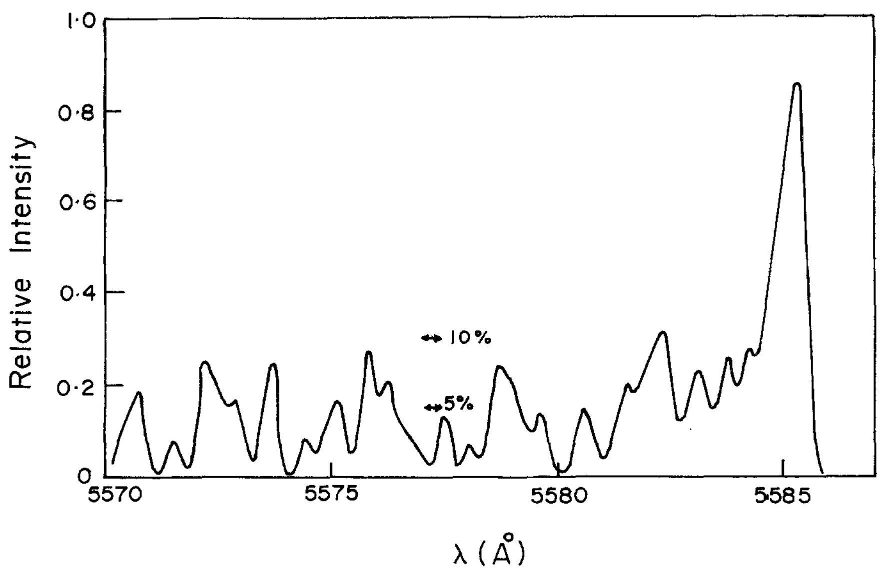

Fig. 4. A high-resolution synthetic profile of C_2 Swan band in the region of oxygen line 5577.3 Å. The level marked as 5 and 10% denotes the expected intensity of the green oxygen line with respect to that of 6300 Å line. $\Delta\lambda_0 = 0.3$ Å.

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