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Emission band ratios of CO in comets

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The Cameron bands of CO arising out of intercombination transitions are intrinsically weak and has been detected only in recent times (Weaver et al. 1994). However, the Fourth Positive bands i.e., (A-X) bands, arising from singlet states are quite strong (Feldman and Brune 1976). The (A-X) bands fluoresce in solar radiation. Therefore, it has been used to estimate the abundance of CO in comets. In addition to CO coming directly from the nucleus, there could be a secondary source of CO at a distance ≥ 2000 km and peaking around 9000 km from the nucleus of Comet Halley, as seen from Giotto observations (Eberhardt et al. (1987). On the other hand, the most dominant process for the formation of Cameron bands is the photodissociative excitation of CO_2 (Weaver et al. 1994) and it has been used to estimate the abundance of CO_2 in comets. In a recent study, Feldman et al. (1997) have studied the emission bands of CO from several comets based on the observations carried out with the IUE satellite, which had a field of view ~ 3000 – 5000 km depending on the geocentric distance. The intensity of (A-X) and Cameron bands are comparable in these comets. For Comet Halley, $Q(CO_2) \approx Q(CO) \approx 3 \times 10^{28}$/sec with some variation. However, Hubble Space Telescope observations of Comets Hartley 2 and Shoemaker Levy with a field of view of 2870 × 954 km showed Cameron bands to be weak and (A-X) bands completely absent. The derived values are $Q(CO_2) \approx 3 \times 10^{27}$/sec and $Q(CO) \lesssim 10^{27}$/sec. The lack of detection of CO in these two comets is quite puzzling. Feldman et al. point out that this could be in principle due to smaller field of view covered by the HST observations or instrinsically the abundance of CO may be less in these comets.

The main aim of the present investigation is to study the general characteristic features of the (A-X) and Cameron bands in comets. For the study of (A-X) band, transitions arising from (A-X), (B-X), Angstrom bands from singlet states, Asundi triplet bands arising from triplet states and Cameron bands connecting singlet-triplet states are considered with 14 vibrational levels in each of them. The details of calculation under resonance fluorescence process are given in earlier papers (Krishna Swamy 1981, 1983). The solar excitation and de-excitation, and collision with the dominant H_2O species are taken into account in the ground electronic state. The collision cross section of Weaver and Mumma (1984) is used for all the levels with T = 200K. Morton and Noreau (1994) have given a good summary of the basic parameters such as oscillator strength, electron transition moment, etc. for the CO molecule. Mean solar radiation field is used which is adequate for the present purpose. Haser's density variation is used with $\tau_{CO_2} = 4.6 \times 10^5$ sec, $\tau_{CO} = 1.4 \times 10^6$ sec and $\tau_{H_2O} = 5 \times 10^4$ sec with $\upsilon = 1$ km/sec. The dominant photodissociative excitation of CO_2 leading to $CO(a^3\pi)$ state for which the rate coefficient given by Feldman et al. (1997) is used. The photoelectron collision excitation of CO is also taken into account as outlined by Weaver et al. (1994) with number density of electrons and electron temperature taken from Xie and Mumma (1992). For the case of the (A-X) band, some preliminary calculations were carried out with opacity effect taken into account based on escape probability method. In this approximation, the resultant effect on radiation trapping is equivalent to multiplying the Einstein coefficients by the photon escape probability (Bockelee-Morvan 1987). The time dependent population is used for the calculation of the integrated intensities over a given field of view.

The results are shown in Tables 1 and 2. As expected they show an increase in intensity with an increase in the field of view in the coma. The expected intensities of (A-X) and Cameron bands are roughly comparable as indicated by the observations. The observed intensities of (A-X) and Cameron bands in Comet Halley ~ 15×10^{-14} ergs/cm^2/sec/Å and corresponds to $Q(CO_2) \approx Q(CO) \approx 10^{28}$/sec. The observed intensity of Cameron band in Comet Hartley 2 should therefore be $\approx 1.5 \times 10^{-14}$ ergs/cm^2/sec/Å which corresponds to $Q(CO_2) \approx 2 \times 10^{27}$/sec. The nondetection of (A-X) band in this comet indicates $Q(CO) \lesssim 10^{27}$/sec. (Table 2). These results are similar to those of Feldman et al. (1997). The inclusion of the extended source of CO observed in Comet Halley (Eberhardt et al. 1987) has no appreciable effect on the results as the field of view of the present observations are small. Some sample calculations carried out with opacity effect indicate that the intensity of the bands with $\upsilon''=0$ to $\upsilon'=0,1,2,....$ is reduced as the population in the $\upsilon''=0$ level of the ground electronic state is dominant.

Table 1. Expected intensities (in ergs/cm^2/sec/Å) of Cameron (1,0) band of CO for several values of $Q(CO_2)$

Field of view (kms)	10^{27}	3×10^{27}	10^{28}	3×10^{28}	10^{29}
1000	7.0(−15)	2.2(−14)	7.0(−14)	2.2(−13)	7.0(−13)
3000	2.0(−14)	5.0(−14)	2.0(−13)	5.0(−13)	2.0(−12)

Table 2. Expected intensities (in ergs/cm^2/sec/Å) of (A-X) (1,0) band of CO for several values of Q(CO)

Field of view (kms)	10^{27}	3×10^{27}	10^{28}	3×10^{28}	10^{29}
1000	4.3(−15)	1.3(−14)	4.3(−14)	1.3(−13)	4.3(−13)
3000	1.2(−14)	3.5(−14)	1.2(−13)	3.5(−13)	1.2(−12)

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