IMAGING FABRY-PÉROT OBSERVATIONS OF [OI] 6300 Å EMISSION IN THE COMA OF HALLEY'S COMET 1982i

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Abstract. The observation of [OI] 6300 Å emission in the coma of Halley's comet 1982i, using the imaging Fabry-Pérot spectrometer, was carried out from Gurushikhar (24°39′ N, 72°43′ E, 1700 m altitude), Mt. Abu, India on March 15, 1986 ($R = 0.90$ AU, $\Delta = 0.96$ AU). The analysis of the interferogram show the absence of the differential velocity of neutral oxygen above 5 km s^{-1}.

1. Introduction

The 6300 Å emission in the cometary atmosphere is produced due to the deexcitation of neutral oxygen atom from ^{1}D state to the ground state. These excited neutral oxygen atoms are mostly (Roesler *et al.*, 1987) the resultant of the dissociation of H_2O by solar ultraviolet radiation. Therefore, 6300 Å radiation can be effectively used as a probe for studying the water content in comets. Several high-resolution studies have been carried out using the Fabry–Pérot spectrometers in order to obtain the outflow velocities of oxygen by measuring the width of line profile at 6300 Å. These studies show that the outflow velocity of neutral oxygen in the coma of the comets ranges from 3.5 km s^{-1} to ~7.5 km s^{-1} (Kerr *et al.*, 1987; Roesler *et al.*, 1985; Huppler *et al.*, 1975; Debi Prasad *et al.*, 1988). However, since these measurements are made by using the central aperture, the derived velocities refer to only the integrated effect of the velocity field in the field of view and lose the information of the differential velocities in the coma, if they are present.

During the 1985–86 apparition of Halley's comet we obtained high-resolution spectroscopic observations in 6300 Å using an imaging Fabry–Pérot spectrometer which enables spatial mapping of the relative velocities of neutral oxygen in the cometary atmosphere. In this note the result is presented.

2. The Observations

The observation was taken in March, 1986, 15.0 UT with a Gen II image intensifier based imaging Fabry–Pérot interferometer, designed and fabricated by the authors, which is detailed elsewhere (Chandrasekhar *et al.*, 1988). The interferometer has a free spectral range of ~102 km s^{-1} and resolution of ~5 km s^{-1} at 6300 Å. The interferogram and the cometary image was taken on a Kodak 2415 emulsion in proximity contact with the intensifier phosphor screen.

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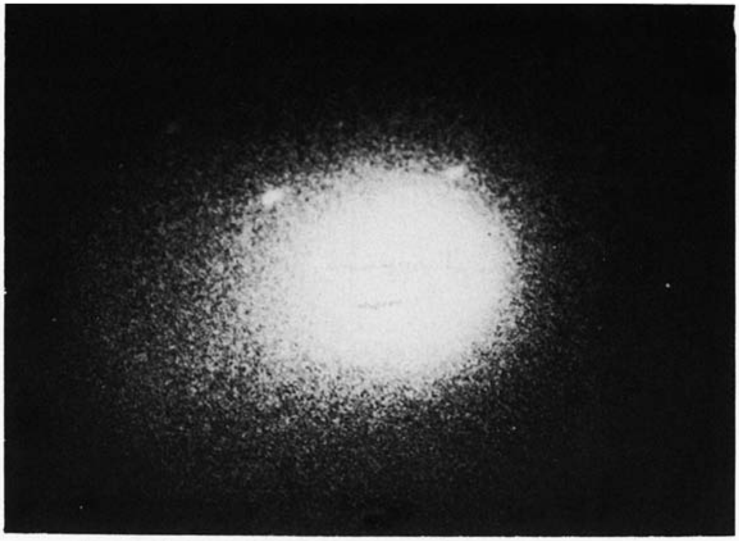

Fig. 1a. The white light image of the comet Halley taken on 1986 March 14.97 UT.

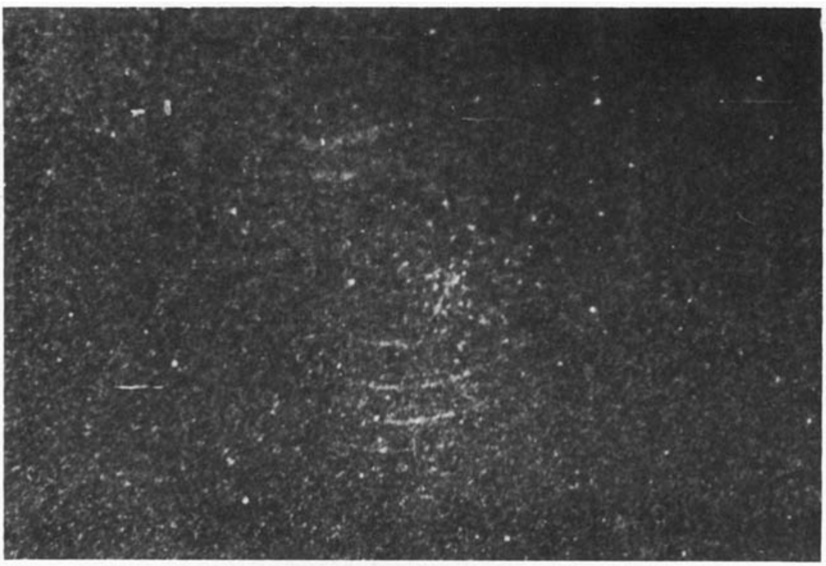

Fig. 1b. The Fabry–Pérot interferogram of the comet Halley in [OI] 6300 Å emission taken on 1986 March 15.0 UT.

Figure 1a,b shows the white light comet image and the [OI] interferogram. The coma size of the comet at the time of our observation was $\sim 10^6$ km, and the interferogram was recorded within $\sim 10^5$ km of the central coma. The field matching of the frames having comet image and the interferogram was carried out, which showed that the interferogram belongs to the central part of the coma of Halley's comet. The interferogram does not belong to the airglow emission is concluded from two considerations. First, the airglow emission being extended over the entire field of view of the instrument, must appear in full circles, which is not the case in the present interferogram. Moreover during the observing campaign such circular airglow fringes were obtained with a Kodak 2484 high speed film on another occasion. Secondly, our instrument with Kodak 2415 film is not sensitive enough to record airglow emission. At Mt. Abu, the typical airglow flux at the time of our observation is ~100 Rayleighs (Rao, 1971). Therefore, recording of the cometary [OI] interferogram in absence of airglow 6300 Å also enables us to put a lower limit on cometary 6300 Å intensity as >150 Rayleighs, towards the central part of the coma which is inconsistent with the values obtained by Kerr *et al.* (1987).

3. Analysis and Results

In the interferogram five Fabry–Pérot fringes are clearly seen. As a first step, coordinates of several points on the interferogram fringes were determined by using a Zeiss microdensitometer. The equation of circle was fitted to these points in order to determine the radius of various fringes. Table I gives the fringe number and the measured radius. The Fabry–Pérot fringe radius and the order number of a given fringe follows the relation,

$$2\mu t\left[1-\frac{R^2}{2F^2}\right]=n\lambda\ ,$$

i.e.,

$$R^2=\left[1-\frac{\lambda n}{2\mu t}\right]2F^2.$$

where μ = refractive index of the medium between the FP plates, t = distance between the $F-P$ plates, R = fringe radius, F = focal length of the imaging lens = 50 mm, n = order number and λ = wavelength under study.

TABLE I

Radius of the [OI] 6300 fringes of different order recorded in the interferograms

Order number	Radius R (mm)	R^2
n	1.818	3.306
$n-1$	2.426	5.877
$n-2$	2.970	8.819
$n-3$	3.333	11.111
$n-4$	3.636	13.223

This shows that R^2 vs n is a straight line for a fixed λ.

Therefore, in the cometary atmosphere, within the region of interferogram, if there does not exist any relative motion of oxygen atom in the line of sight, then the plot of R^2 vs n derived from the interferogram would follow a straight line. In order to find out the possible existence of such relative motion, R^2 vs n along with the best fit straight line was plotted as shown Figure 2. The deviation of individual points from the fitted straight line were calculated. The velocity corresponding to these deviations in radius were estimated. The mean deviation was found to be $\sim 5 \text{ km s}^{-1}$. However, the error in the measurements of fringe radius is $\sim 4 \text{ km s}^{-1}$. Hence, it is concluded that there does not exist any significant differential velocity of oxygen atoms within 10^5 km of the nucleus in the coma of Halley's comet. To be more precise, the velocity dispersion does not exceed $\sim 5 \text{ km s}^{-1}$ in the coma within 10^5 km of the nucleus at the time of our observations.

This result is inconsistent with the outflow velocity derived from the line profile measurements. Kerr *et al.* (1987) have measured the width of the line profile of [OI] 6300 Å emission on Jan. 15.363 UT. They have obtained the width of $3.9 \pm 1.5 \text{ km s}^{-1}$ using an aperture of 354 arc sec in size, which corresponds to 2×10^5 km of the comet. These results are due to the integrated effect of the velocity field in the field of view. Our spatially resolved data in the interferogram indicates the absence of outflow velocities $\sim 5 \text{ km s}^{-1}$ anywhere in the emission coma. Further, our results do not suggest any outflow of oxygen atoms into narrow fold angle since we do not see any sharp gradient above the measurement limits.

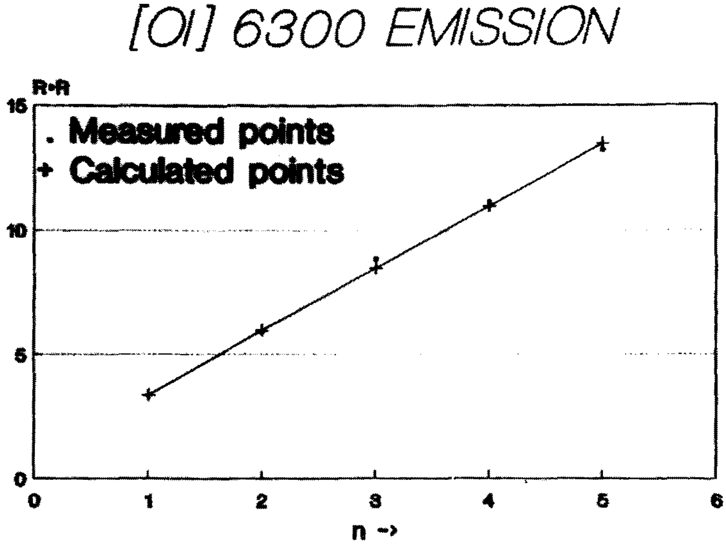

Fig. 2. Plot of n vs R^2 in [OI] 6300 Å interferogram (n = order of interference of various interference fringes; R = radius of the interferogram fringes).

The theoretical outflow velocity of oxygen atom due to the photodissociation process of H_2 is $\sim 1\ \mathrm{km\,s^{-1}}$. The in situ measurements of the H_2O velocity is $0.90+0.2\ \mathrm{km\,s^{-1}}$ (Krankowski *et al.*, 1986) to ~ 1.2 km/s at $\sim 10^5$ km (Lammerzahl *et al.*, 1987) and the IR measurements show a value of 0.9 ± 0.2 and $1.4 \pm 0.2\ \mathrm{km\,s^{-1}}$ for pre and post perihelion spectra respectively (Larson *et al.*, 1986). Hence if H_2O is the parent molecule for oxygen atom, it is not expected to exceed the upper limit to the velocities inferred by us. Therefore, our results are not inconsistent with the conjecture of H_2O as the parent for oxygen atoms.

Acknowledgement

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