CHAPTER - 3

NIGHT AIRGLOW STUDIES WITH A FABRY–PEROT SPECTROMETER

The use of Fabry-Perot in high resolution spectroscopy is known since the early part of this century when Fabry and Buisson observed the Orion nebula. But the Fabry-Perot Spectrometer (FPS) was not a popular instrument particularly for weak emissions due to heavy transmission losses suffered from the metallic coatings. After the advent of multilayer dielectric coatings, which substantially enhance the net etalon transmission, FPS with its large throughput was realized as a scanning spectrometer.

They have been widely used for last three decades to measure thermospheric winds and temperatures from the line-of-sight Doppler shift of atomic oxygen emission line at $\lambda$ 6300 Å e.g. Armstrong (1969), Hays and Roble (1971b), Jacka et al. (1979), Rees et al. (1982), Hernandez (1982) and many more workers.
3.1 **Fabry-Perot Spectrometer (FPS)**

The basic theory of a FPS has been discussed in many standard text books Steel (1967), Cook (1971), Meaburn (1976) etc. In its simplest form the FPS comprises two parallel, flat transparent plates, coated with reflective films and separated by a spacer. The cavity formed by this spacer has resonant wavelengths determined by the optical thickness $t_g$ of the gap. Maximum transmission occurs at resonant wavelengths and at other wavelengths, there is a destructive interference. The FPS thus transmits a narrow spectral band at each series of wavelengths which is given by

$$n\lambda = 2\mu t \cos\Theta \quad \cdots (3.1)$$

here $n$ - order of interference  
$\mu$ - refractive index of the medium  
$t$ - geometric spacing  
$\Theta$ - angle of incidence

FP can be used as a high-resolution scanning spectrometer by changing the refractive index $\mu$ of the spacer medium although a more sophisticated method is now available where the spacer length $t$ can be varied by active servo-controlled piezoelectric spacers
(Rees et al, 1981). However, the former method is essentially a slow and the latter a fast method which could be used to an advantage. Refractive index scanning is achieved by changing the gas pressure in an enclosed chamber containing the FP etalon assembly. This type of instrumentation is described in the following section.

3.2 Basic design of FPS for line-width measurements

Figure 3.1 shows the schematic diagram including the optical layout of the Fabry-Perot spectrometer used for night-airglow studies. An optically contacted etalon was used having a 100 mm useable aperture. The optically contacted etalon is made up of three quartz pieces placed between the etalon plates such that the polished surfaces of these pieces and plates (λ/100 or more) have a very close contact which allows molecular forces to bind them tightly in place. This type of etalon is a permanently parallel, optically stable, high finesse Fabry-Perot which is also mechanically very stable. The fringe system obtained from the source (sky observation or laboratory source) is imaged at the focal plane of an objective lens of focal length 500 mm. A circular scanning aperture is placed at this plane to isolate the central fringe for line profile scans. Table 3.1 gives the FPS specifications.
fig. 3.1 : Schematic showing the optical layout of the Fabry-Perot interferometer used for night airglow studies.
TABLE 3.1

Fabry-Perot Spectrometer Specifications

1. Etalon Plates: (Optically contacted etalon from I.C. Optical, London)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective useable aperture</td>
<td>100 mm</td>
</tr>
<tr>
<td>Flatness</td>
<td>( \lambda/100 )</td>
</tr>
<tr>
<td>Parallelism of Assembly</td>
<td>( \lambda/15 )</td>
</tr>
<tr>
<td>Reflectivity at 6300 ( \AA )</td>
<td>0.5%</td>
</tr>
<tr>
<td>Absorption of coatings</td>
<td>1%</td>
</tr>
<tr>
<td>Spacer (Schott &quot;Zerodur&quot;)</td>
<td>10 mm</td>
</tr>
<tr>
<td>Plates are 30 mm thick, Spectrosil D</td>
<td></td>
</tr>
</tbody>
</table>

2. Objective lens

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>110 mm</td>
</tr>
<tr>
<td>Focal length</td>
<td>500 mm</td>
</tr>
</tbody>
</table>

3. Scanning Aperture Diameter

| Value | 3 mm |

4. Instrument Field of View

| Value | 0.34° |

5. Interference Filter (Temperature controlled)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>50 mm</td>
</tr>
<tr>
<td>FWHM</td>
<td>3 ( \AA )</td>
</tr>
<tr>
<td>Peak Transmission</td>
<td>32%</td>
</tr>
<tr>
<td>Peak wavelength</td>
<td>6300 ( \AA ) (at 16°C)</td>
</tr>
</tbody>
</table>

6. Photomultiplier (EMI - 9063 D/350, Photon counting type)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum Efficiency at 6300 ( \AA )</td>
<td>7%</td>
</tr>
<tr>
<td>Photocathode</td>
<td>S20</td>
</tr>
<tr>
<td>Effective Aperture</td>
<td>9 mm</td>
</tr>
<tr>
<td>Dark Count (at - 15°C)</td>
<td>10 counts/sec.</td>
</tr>
<tr>
<td></td>
<td>(at 25°C) 450 counts/sec.</td>
</tr>
</tbody>
</table>

7. Resolving Power

| Value | 101000 |

8. Operating Order

| Value | 31754 |

9. Free Spectral Range

| Value | 500 mK (0.193 \( \AA \)) |

10. Overall instrument Finesse

| Value | 5.7 |


3.3 **FPS Parameters**

For an ideally mono-chromatic source, the output profile of the FPS (using a small scanning aperture) is given by an Airy function. But in actual practise, the instrumental profile is not just an Airy function, but gets modified due to several factors. The etalon plates are not perfectly flat and parallel, and there are non-uniformities over the useable aperture of the etalon due to micro-topographical flatness imperfections. All these effects tend to broaden the ideal etalon's Airy function. Another broadening parameter is the finite size of the scanning aperture used. The Airy function and each of these broadening functions are discussed in the following sections.

3.3.1 **Airy function**

The Airy function describing the effect due to multiple reflections within the etalon cavity is given by the following expression (Hays and Roble, 1971a).

\[
AI(\sigma) = AI(\sigma_0) \frac{(1-R-A)^2}{(1-2R \cos x + R^2)} \quad \ldots (3.2)
\]

where \(AI(\sigma)\) = Intensity at wave number \(\sigma\)
\(AI(\sigma_0)\) = Peak intensity at line centre \(\sigma_0\)
R = Reflectivity of the plates
A = Absorption of the coatings

Figure 3.2 shows this function (normalised to unity) for the FPS used in the night airglow study. On the x-axis the displacement $\Delta \sigma$ from the line centre is shown in units of mK. The full width at half maximum (FWHM) of the Airy function is given by

$$\delta \sigma_{\text{Airy}} = \Delta \sigma_{\text{FSR}} / N_R$$

where $\Delta \sigma_{\text{FSR}}$ = Free spectral range = \frac{1}{2} \mu t

$N_R$ = Reflective finesse = $\pi \sqrt{R/(1-R)}$

3.3.2 Spherical defects function (or plate defects function)

The broadening function representing the spherical defects of the etalon plates due to bowing from an ideal plane surface has been shown to be rectangular in shape by considering the sagitta $r(1-\cos \Theta) = \lambda / n$ i.e. as a fraction of the wavelength (Chabbal, 1953). The plate defects finesse is given by

$$N_{PD} = m / 2$$

For the $\lambda / 100$ plates used (Table 3.1), we have

$$N_{PD} = 50$$
AIRY FUNCTION
FWHM=25.89mK

Fig. 3.2 : Airy function for the etalon with R=85% and A=1%. The reflective finesse $N_R$ is 19.3.
The rectangular function in $\sigma$-domain is given by the following expression (Hays and Roble, 1971a)

$$PD(x) = \frac{\Delta \sigma_{FSR}}{4\pi d_f} \prod(x) \quad \ldots (3.4)$$

where $d_f$ = half width at full maximum (FWHM/2)

$$d_f = \frac{\Delta \sigma_{FSR}}{2N_{PD}}$$

and $\prod(x)$ = 1 for

$$\begin{align*}
\frac{2\pi d_f}{\Delta \sigma_{FSR}} &> |x| \\
\frac{\pi}{2} &\leq |x|
\end{align*}$$

$$\begin{align*}
0 &< |x|
\end{align*} \quad \ldots (3.5)$$

Figure 3.3 shows the rectangular function representing the plate defects function for the etalon used.

3.3.3 Misalignment function

This type of broadening arises due to a lack of parallelism in the etalon plate assembly. The conventional way to represent the departure from parallelism as a fraction of wavelength is $\lambda/K_p$. This value is quoted by the manufacturer as $\lambda/15$.

Explicit form of this function does not appear in the literature, although it is mentioned as a factor contributing to broadening by several workers: Chabbal (1953), Hernandez (1966, 1970), Atherton et al. (1981) and Platisa et al. (1983). As a matter of fact,
Fig. 3.3: Plate defects function for the etalon corresponding to \( \lambda/100 \) plates. The defect finesse is \( N_{PD} = 50 \).
unless the etalon parallelism is servo controlled, this function is much more likely to be the major broadening factor rather than the quality of flats (which with modern polishing techniques attain values as high as \( \lambda/100 \) or even better).

By considering the total useable aperture of the etalon as made up of a mosaic of micro-etalons of elemental areas and finding its variations over the entire aperture, it can be shown that the broadening function has the following relation to the misalignment \( \lambda/K_p \)

\[
\text{Mis}(x) = (1-x/P)^{1/2} \quad \ldots (3.6)
\]

where

\[
x = 4\pi\mu t (\sigma^- - \sigma^o)
\]

\[
P = 2\pi\mu/K_p
\]

with a finesse of \( N_{\text{MIS}} = K_p/\sqrt{3} \)

and

\[
\text{FWHM}_{\text{MIS}} = \sqrt{3} \Delta v_{\text{FSR}}/K_p \quad \ldots (3.7)
\]

The shape of this function is that of an inverted parabola as shown in figure 3.4. It is evident that this function's broadening is significant and must be accounted for while generating an instrumental profile.
Fig. 3.4: Misalignment function for the etalon assembly due to a lack of parallelism of the order of \( \lambda/15 \). The defect finesse is \( N_{\text{MIS}} = 8.6 \).
3.3.4 Microsmoothness function

Due to topographical irregularities on the plate surfaces, the plates are not perfectly flat and this results into a broadening function called the microsmoothness function. The microscopic defects are randomly distributed on the plate surfaces and thus a root-mean-square deviation from perfect flatness \((\zeta \times \text{tg})^{1/2} \sim \lambda / \text{Kg}\) can be considered to be a Gaussian distribution (Chabbal 1953). The defects finesse associated with this type of function can be shown to be

\[ N_{\text{MIC}} = \frac{\text{Kg}}{4.7} \]  \hspace{1cm} (3.8)

and the microsmoothness function as a Gaussian of the type

\[ \text{MIC}(x) = \frac{D}{\sqrt{\pi}} \exp\left(-x^2D^2\right) \]  \hspace{1cm} (3.9)

where

\[ D = \left(\Delta \sigma_{\text{FSR}} \sqrt{2\pi} \right) / 2\pi \text{dg} \]

and \(\text{dg} = \text{HWHM} \left(4.7 \Delta \sigma_{\text{FSR}} / 2 \text{Kg}\right)\)

For the IC optical etalon, a Fizeau interferogram (taken by the manufacturer prior to despath) was used to estimate \(\text{dg}\) and was found to be about
13.5 mK. Figure 3.5 shows the Gaussian function corresponding to this half-width.

3.3.5 Aperture function

The scanning aperture introduces a further broadening which is of the rectangular form with a full width corresponding to the wave number interval allowed by the diameter of the aperture (Hays and Roble, 1971a).

\[ \text{FWHM} = \frac{2 \sigma_o d^2}{4f^2} = 2 d_f \] \hspace{1cm} \text{(3.10)}

where \( \sigma_o \) = wave number for line centre
\( d \) = diameter of the scanning aperture
\( f \) = focal length of the objective lens
\( d_f = \text{FWHM} \)

P{inesse is given by \( N_{AP} = \frac{\Delta \sigma_{FSR}}{2d_f} \) \hspace{1cm} \text{(3.11)}

\( \text{AP}(x) = \frac{\Delta \sigma_{FSR}}{4\pi d_f} T(x) \) \hspace{1cm} \text{(3.12)}

is the rectangular function

where 1 for \( \left[ \frac{2 \pi d_f}{\Delta \sigma_{FSR}} \right] > |x| \)

\[ T(x) = \begin{cases} \frac{1}{2} & \text{for } |x| > |x| \\ 0 & \text{for } |x| < |x| \end{cases} \]
MICROSMOOTHNESS FUNCTION
FWHM=26.70 mK

Fig. 3.5: Microsmoothness function for the etalon plates due to \( \lambda / 88 \) r.m.s. deviations of surface irregularities. The associated defect finesse is 18.7.
For the present system a circular scanning aperture subtending \(0.34^\circ\) field of view in the sky was chosen. The rectangular function corresponding to this aperture is shown in figure 3.6. This is also one of the major factors contributing to broadening of the instrumental profile.

3.4 Instrumental Profile

The resultant instrumental profile is described by a function \(I\) which is a convolution of the five basic functions discussed earlier.

a) Airy (AI)
b) Plate Deflects (PD)
c) Misalignment (MIS)
d) Microsmoothness (MIC)
e) Aperture (AP)

\[
I = AI \ast PD \ast MIS \ast MIC \ast AP \quad \ldots (3.13)
\]

where \(\ast\) denotes the convolution operation defined by the following integral

\[
h(k) = \int_{-\infty}^{\infty} x(k-n) y(n) \, dn = x(k) \ast y(k) \quad \ldots (3.14)
\]

\(h\) being the resultant convolved function of the two input functions \(x\) and \(y\).
Fig. 3.6: Scanning aperture function corresponding to an aperture dia. of 3 mm (71.43 mK). The aperture finesse is 7.
Figures 3.2-3.6 show the five basic functions calculated for the spectrometer. All these functions were generated through a computer and the convolutions represented in equation 3.13 were performed. Figure 3.7 shows the instrumental function computed by equation 3.13 as a continuous curve. The '+' sign shows the instrumental profile taken from a single mode He-Ne laser at $\lambda 6328\,\AA$. The laser line is assumed to be a delta function as compared to the line widths of our interest.

Though the convolved profile at $\lambda 6300\,\AA$ and the observed profile at $\lambda 6328\,\AA$, are $28\,\AA$ apart, there is a remarkable fit between them. This is a consequence of the fact that the maximum broadening due to reflectivity and other factors on $28\,\AA$ shift is less than $1\,mK$. This suggests that a laser scan does approximate the instrumental profile at $\lambda 6300\,\AA$. Moreover this allows one to use a theoretically convolved profile instead of obtaining frequent laser scans while acquisition of night airglow data.

Also the instrument function was found to be very close to a Doppler broadened Gaussian function of $1000^0K$. This is expected since an Airy function when convolved with a broad rectangular function (corresponding to the scanning aperture) approximates a Gaussian function.
Fitting of the observed instrumental profile with the convolved profile computed by convolving five basic functions viz: Airy, Plate defects, Misalignment, Microsmoothness and Aperture functions. The effective instrumental finesse $N_1$ is 5.68.
3.5 **Optimization of FPS parameters for the present study**

For night airglow studies, where the source is very weak and slowly varying with time, it is desirable to optimize the choice of instrumental operating parameters for minimizing the uncertainty in the quantity being measured. The line widths and shifts are the quantities of prime importance in these studies. For the OI $\lambda$ 6300 Å airglow emission, the line width is essentially of the order of 0.035 Å (90 mK), if one assumes a neutral temperature of 1000°K. Corresponding to thermospheric neutral winds of the order of 100 ms$^{-1}$, shifts in the line position are about 0.002 Å (5 mK). As discussed by Chabbel (1953) and Hernandez (1982a), the optimum operating condition for the FPS is to keep the instrumental width nearly equal to the expected source width. For the present system this was achieved by selecting a proper aperture size (corresponding to 0.34° field of view in the sky) such that the net broadening due to the combined effects of all five basic functions is close to the expected source width of 90 mK. In figure 3.7, the instrumental width is 88 mK as measured by using a single mode He-Ne laser. This corresponds to an effective instrumental finesse of 5.7, which is quite adequate for the temperature and wind measurements in the thermosphere (Hernandez, 1982a).
Besides these, there are several other parameters that warranted considerations. The effective transmission of the FPS was kept as high as feasible by anti-reflection coating of the optical surfaces. Since photon-counting technique was to be used, a special photon-counting photomultiplier (EMI 9863 B), tested for Poissonian dark statistics, was utilized.

An optically contacted etalon with a plate figure of \( \lambda /100 \) and reflective finesse of 20 at \( \lambda 6300 \) was chosen. This choice was dictated by the limitations imposed due to misalignment, the best available being \( \lambda /20 \). An etalon spacer of 1 cm and a post-filter of 3 \( \lambda \) band-width was selected, thereby minimising the possibility of OH contamination as pointed out by Hernandez (1974).

3.6 Data reduction schemes

Temperatures

When any source (sky observation or laboratory source) is observed through a FPS, the recorded profile (or the observed profile) \( \varphi \) is a convolution of the source profile \( S \) and the instrumental profile \( I \).

\[
\varphi = S \ast I
\]  

\[\text{...(3.15)}\]

The source profile can be retrieved by deconvolving the instrumental profile from the observed profile. There
are two main approaches, identical in principle, for recovering this information.

i) The first approach is based on the convolution theorem stated as follows:

Convolution of two functions is equivalent to an inverse Fourier transform of the product of their Fourier transforms. Analytically this can be expressed as

\[
x \ast y = \mathcal{F}^{-1}\left[\mathcal{F}(x) \cdot \mathcal{F}(y)\right]
\]  \hspace{1cm} (3.16)

where \( \mathcal{F}(x) \) and \( \mathcal{F}(y) \) are the Fourier transforms of the functions \( x \) and \( y \) and \( \mathcal{F}^{-1} \) is the inverse Fourier transform operation. To obtain representation of the source profile, the instrumental profile has to be deconvolved from the recorded profile. This can be achieved by extending the above logic as follows:

Take the Fourier transform of the recorded and instrumental profiles and divide the former by the latter in Fourier domain. Finally take the inverse Fourier transform for obtaining the source profile.

\[
S = \mathcal{F}^{-1}\left[\mathcal{F}(O) / \mathcal{F}(I)\right]
\]  \hspace{1cm} (3.17)

The source function thus obtained is fitted to a Gaussian profile. Parameters of the best fit give
estimate of the line width from which the Doppler temperature can be calculated. Sufficient care has to be taken while adopting this approach such that the noise in the recorded profile $O$, which is amplified by the deconvolution process, does not dominate the result. Jacka et al. (1980), Burnside et al. (1981) and several other workers have used this method.

ii) The second approach is to generate, a synthetic set of the expected recorded profile by convolving a set of Gaussian profiles for different temperatures (e.g. $500^\circ$K to $2000^\circ$K) with the instrumental profile. The actual recorded profile is then matched to this synthetic set for obtaining a best fit for a particular temperature. This technique is computationally lengthy, but gives a better idea of the observed profile fit as the complete profile can be visualized while the fitting process is undertaken. Hays and Roble (1971a), have described a version of this technique.

A modified method (in principle utilising the second approach just described) was used by Rajaraman (1982). A plot is made from the synthetic set of convolution of the instrumental profile with different temperature Gaussian profiles keeping $i/(i*d)$ and $d/(i*d)$ as variables. Here $i =$ instrumental profile width

$d =$ Doppler width of the Gaussian function

$i*d =$ width of the convolved profile
This curve for the spectrometer used is shown in figure 3.8 along with theoretically calculated curves assuming

a) \( I \) as a Gaussian form (G)

b) \( I \) as a rectangular form (F)

c) \( I \) as an Airy form (A)

From the plot it is clear that the instrument function is closer to Gaussian form as was mentioned earlier.

For any particular observation, \( i \) and \( i*d \) are known. The ratio \( i/(i*d) \) plotted on the ordinate is used to get a corresponding \( d/(i*d) \) value on the abscissa, from which the temperature can be calculated using the well known relation between line width and temperature.

\[
\frac{d}{i*d} = 7.16 \times 10^{-7} \times \frac{\sigma_o}{\sqrt{\nu/M}}
\]

where \( \sigma_o \) is the wave number at line centre and \( M \) is the atomic mass of the emitting species (16 for oxygen).

As an example for use of this curve, consider an observed width of 128 mK and instrument width of 90 mK. Then

\[
\frac{1}{(i*d)} = \frac{90}{128} = 0.703
\]

From the curve \( \frac{d}{(i*d)} = 0.607 \)

\[
\therefore d = 0.607 \times 128 = 79.4
\]
Fig. 3.8: Matching of $G*I$ with $G*G$ type function. $i$ is the instrument function width and $w$ is the width of convolved function $G*Y$ when $Y$ is a $G,F,A$ or $I$ type function. $d$ is the Doppler width of the Gaussian function.
Temperature $T = 1000^\circ K$.

This method is most suited for large amount of data and consequently was used in the present work.

Winds

Neutral winds in the thermosphere can be measured by observing the Doppler shift in the OI $\lambda 6300 \AA$ line profile obtained from sky observations. The observed shift $\frac{\Delta \lambda}{\lambda_0}$ from a fixed wavelength reference $\lambda_0$ is related to the line of sight wind $v$ as

$$\frac{\Delta \lambda}{\lambda_0} = \frac{v}{c}$$

where $c$ is the speed of light.

The He-Ne laser line at $\lambda 6328 \AA$ (which is very close to the OI emission wavelength) is a convenient wavelength reference provided a single mode and frequency stabilised laser is used for such studies. Alternatively, there are two other methods to determine the Doppler shift.

In the method described by Jacka et al. (1979), the mean of the peak positions exhibited by pairs of airglow line profiles obtained successively in opposite azimuthal directions at the same zenith angle $\chi \sim 70^\circ$ is expected to be near the unshifted position. This method inherently assumes an uniform wind field over a horizontal spatial extent of twice the height of the emitting layer times
tan $\chi$ which is of an order of 1500 Kms. This assumption is not true always and wind fields over such extended regions may differ. The other method described by Hernandez and koble (1979), assumes the zenith measurement of line profile as the reference for the Doppler shift. Here again there is an assumption that there are no vertical winds but as shown by Hernandez (1982c) these cannot be used as (zero) reference with any degree of certainty.

In the present study, due to the non-availability of a single mode frequency stabilized laser with us, the emphasis was to look for changes in the wind in a particular direction rather than to obtain absolute values for winds. This was achieved by scanning more than two fringes (within 15 minutes) and obtaining the changes in fringe-to-fringe (i.e. free spectral range FSR) distance per scan. Thus over an uniform wind field (whose absolute value cannot be obtained due to our instrumental limitation) any change in the wind i.e. acceleration would reflect as a change in FSR.

3.7 Sources of error

The errors in the wind and temperature measurements could arise due to several factors. Broadly classifying, they could be due to the changes in the instrumental profile or the photon noise in the data.
The instrumental profile was obtained before commencing the observation session and the change in the shape of this profile was not measurable for the complete duration of observation. This is expected since we have used an optically contacted etalon which was highly stable throughout the observing period. The chamber containing the etalon was temperature controlled, thereby changes introduced in the FSR due to thermal expansion of the spacers were minimized. A cumulative effect of these uncertainties could give rise to a temperature error of ±25°K and a wind error of ±20 ms⁻¹. Since the wavelength scan was achieved using a stepper motor driven piston, an error due to a single step change (∼0.001 λ) would correspond to ±50°K in temperature and ±50 ms⁻¹ in winds.

At each pressure step, the number of photons (N) counted by the photomultiplier has a Poissonian statistical variation of ±√N. At times when the 6300 Å airglow intensity is low (<100 Rayleighs), the raw data would show large fluctuations and these after smoothing could give rise to uncertainties in the width and peak of the observed line profile. Estimated random error due to this type of scatter in the data is ±40°K and ±30 ms⁻¹ for temperature and wind respectively. The photomultiplier was thermoelectrically cooled below -15°C and consequently the
dark counts were always below 10. The probability of getting a larger dark count is very small since the photomultiplier (EMI 9063 D) was tested for Poissonian dark statistics. A change in the dark count of 2 to 3 would introduce errors of the order of $\pm 5^\circ K$ and $\pm 5 \text{ ms}^{-1}$ and can be neglected.

Considering all the above factors, the maximum probable error in the temperatures is $\pm 70^\circ K$ and in winds is $\pm 50 \text{ ms}^{-1}$.

3.8 Data collection

The Fabry-Perot spectrometer used for the night airglow work was a pressure scanned instrument with a photon counting detection system. At each pressure step the incoming photons were counted for 1 sec. or 4 sec. (according to the airglow intensity) and transferred to the digital printer and a mag-tape unit. About 2 1/2 fringes were scanned in 200 steps. As mentioned earlier a He-Ne laser was used for obtaining the instrumental profile.

The spectrometer was operated from Mt. Abu (24°N) India, during January to April, 1984. Clear moonless nights were chosen for the observations.
3.9 Short period neutral wind accelerations

During 1904, a FPS with a 55 mm useable aperture (with similar specifications as of 100 mm etalon but with a spacer of 20 mm) was used for the night airglow studies. Later on, as mentioned earlier, 100 mm useable aperture FPS was fabricated for improving the signal to noise ratio in the data. This FPS was used in the period January-April 1905, but due to very few available clear nights and absence of any evidence for short period wind changes, results reported here are those obtained by virtue of the smaller etalon used in 1904.

Table 3.2 shows the observed neutral wind accelerations and corresponding neutral temperatures. The accelerations are deduced from the change in the separation between two fringes which are scanned within 15 minutes. The letters in the table denote the direction in which the observations were made and the elevation angle for these was 30°. Also shown in the table are the geomagnetic indices $\sum K_p$ for the days of observation.

The neutral temperatures do not deviate significantly from the Jacchia (1977) model values obtained for these nights. However, the neutral winds do show a significant change within the duration of the scan with largest value of about 400 ms$^{-1}$. 
TABLE 3.2

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME (IST) in hrs</th>
<th>Temperature $T(°K)$</th>
<th>Temperature $T(°K)$</th>
<th>Change in winds $v(\text{ms}^{-1})$</th>
<th>$K_p$</th>
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<tbody>
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<td>070</td>
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<td>015</td>
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</tr>
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<td>100 S</td>
<td>15+</td>
</tr>
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<td>29-03-04</td>
<td>2005</td>
<td>986</td>
<td>990</td>
<td>400 W</td>
<td>40+</td>
</tr>
<tr>
<td>29-03-04</td>
<td>2010</td>
<td>803</td>
<td>970</td>
<td>120 E</td>
<td>40+</td>
</tr>
<tr>
<td>29-03-04</td>
<td>2030</td>
<td>871</td>
<td>943</td>
<td>120 S</td>
<td>40+</td>
</tr>
<tr>
<td>29-03-04</td>
<td>2100</td>
<td>984</td>
<td>924</td>
<td>240 W</td>
<td>40+</td>
</tr>
<tr>
<td>30-03-04</td>
<td>2045</td>
<td>726</td>
<td>900</td>
<td>200 S</td>
<td>33</td>
</tr>
<tr>
<td>31-03-04</td>
<td>2040</td>
<td>792</td>
<td>900</td>
<td>170 S</td>
<td>30-</td>
</tr>
<tr>
<td>31-03-04</td>
<td>2055</td>
<td>720</td>
<td>840</td>
<td>300 E</td>
<td>30-</td>
</tr>
<tr>
<td>01-04-04</td>
<td>1950</td>
<td>863</td>
<td>090</td>
<td>300 N</td>
<td>34-</td>
</tr>
<tr>
<td>01-04-04</td>
<td>2000</td>
<td>800</td>
<td>053</td>
<td>100 E</td>
<td>34-</td>
</tr>
<tr>
<td>25-04-04</td>
<td>2035</td>
<td>901</td>
<td>868</td>
<td>220 S</td>
<td>30+</td>
</tr>
</tbody>
</table>
During an earlier study (Rajaraman, 1982), using a FPS of much inferior instrumental width and less stability (free spacers), rather large changes (upto 400 ms\(^{-1}\)) in the horizontal wind speeds were observed over durations as short as 10 minutes. With the present improved FPS, this type of short period changes in the horizontal wind speeds upto 400 ms\(^{-1}\) are established.

Thus we conclude that accelerations in the neutral wind upto \(\sim 60\) cm s\(^{-2}\) are not uncommon at F-region heights, at least over the latitude region (\(\phi =24^\circ \pm 3^\circ\)), where our observations were conducted. Further, as can be seen from table 3.2, the days when there are observed changes in the wind, there is a substantial amount of geomagnetic activity prevalent with values of \(\sum K_p\) more than 20 in most of the cases. One of the special nights worth mentioning is 29th March, 1904 when the \(\sum K_p\) is 40\(+\) and the wind field also showing large changes.

A possible mechanism for these rapid wind field changes could be the triggering by strong gravity waves with shorter time periods resulting in the vertical movement of F2 layer. This is further supported by our observations on short period gravity waves (\(\sim 15\) to 20 minutes) passing through the mesosphere by monitoring
airglow emissions from that region (discussed in the next chapter). The triggering of strong gravity waves on the observed occasions could be a result of geomagnetically disturbed conditions at higher latitudes and the subsequent transport of energy to lower latitudes as was discussed in detail in the previous chapter.