2. OBSERVATIONS AND REDUCTIONS

Ever since the recording of spectrum of celestial bodies was developed, the need for the determination of absolute flux of radiation was felt. The earliest attempts were for the comparison of flux from stars with black body sources. The most direct method of recording flux is to place a detector behind the slit of the spectrograph. The technique of photography is very widely used but the serious disadvantages are those of limited range of intensity and the plate calibration accuracy. The non-linearity of the plate response with reference to the intensity also is very well known.

After the advent of photoelectric detectors in astronomical applications, very accurate flux measures have been made available. These measures are always made relative to standards and the accuracy achieved is about 1% (Oke, 1965). When one compares the photoelectric and photographic techniques, the linearity of the response of the photoemissive cathode immediately becomes evident. Although time resolution is lost in this, because only one of the regions of the spectrum can be recorded at a time, the higher quantum efficiency increases the accuracy. Another advantage is the higher precision, that can be obtained by increasing the exposure time, which is not possible with the photographic detectors (Code & Liller, 1962). Special detectors can increase the wavelength of operation from UV to IR.

The earliest record of such scanner applications is that of Dunham and Bruch (cf. Wright, 1962), who produced the solar Ca II
line profiles. This technique was used by Hall (1936) with an objective grating to scan the spectra of stars in the wavelength range of 4500 to 10,300 Å. Later developments of the instrument involved the movement of the slit to scan the spectrum. Further sophisticated versions employed the movement of the dispersive element, like the prism or the grating, and a stationary detector behind the exit slot.

Variety of applications other than the measurement of energy distribution have been attempted. The three parameter system of spectral classification based on the magnitude of Balmer discontinuity D, its position λ and the gradient Φ, in the blue by Chalonge (cf. Wright,1962) is a very important application. Walravens (cf. Wright,1962) have classified the stars according to luminosity and spectral type by means of a photoelectric spectrum analyzer. The study of the line profiles using photoelectric techniques is considered to be as efficient as the photographic technique as shown by Wright (1962).

The type of dispersive element that is adopted in such a photoelectric spectrum scanner is decided by the desired application. For measurement of colour, Trodahl et al. (1973) used a semicircular wedge. They covered a range of 4000 to 8000 Å for measuring the colour indices relative to standard stars. This scheme of stellar classification employed prisms. The continuum energy distribution studies and line profile analyses can be done with only gratings, which have the advantage of linear dispersion and wavelength independent reflecting surface.
Figure 2.1a The automated spectrum scanner at the Cassegrain focus of the 102cm reflector.

Figure 2.1b Schematic diagram of the scanner.
2.1 The Instrument

Various arrangements of optical elements for photoelectric spectrophotometry have been discussed by Code & Liller (1962) in great detail. The basic principle is to measure a sample of uniform width of each wavelength region. The selection of sample is achieved by rotating the grating so that the exit slot sweeps through the spectrum. The detector behind the slot records the different samples sequentially.

The 102 cm reflector of Kavalur Observatory has the provision for mounting a scanner at the Cassegrain focus (Bappu, 1977). The instrument has the optical system of Ebert-Fastie type as shown in Figures 2.1a & b. The collimator is a spherical mirror of one meter radius and matches with the f/13 beam from the secondary mirror of the telescope. Circular as well as rectangular slits at the entrance are available. Generally, the circular one of 800 µ is used, which corresponds to the 13 arcsec of the sky. The plate scale at the Cassegrain focal plane is 16 arcsec mm⁻¹.

The 600 lines mm⁻¹ grating blazed at 7600 Å, yielding a dispersion of 25 Å mm⁻¹ at the exit slot was used. The resolution, \( r \), of the equipment may be calculated, in Å as,

\[
  r = \frac{50 \times a \times F}{g \times n \times f}
\]

where,

\( a \) = stellar image diameter in arcsec,

\( F/f \) = ratio of focal length of telescope to spectrograph collimator,

\( g \) = number of grooves per mm of the grating,
order of the spectrum (cf. Oke, 1965)

For the case with 600 lines mm\(^{-1}\) grating and first order, the resolution works out to be about 3 Å for seeing conditions of the order of 2 arcsec. However, for better S/N ratio the exit slot is opened to larger dimensions. Although there is a provision to open to almost 6mm, it was usually kept at a lower value. A reading of 40 on the circular scale was usually considered reasonable, where each division corresponds to about 0.5 Å, in the first order. This results in a channel dispersion of almost 10 Å and a resolution of nearly 20 Å in first order; these values are 5 Å and 10 Å in the second order respectively. The exit slot was sometimes opened to 100 divisions (~ 50 Å in first order) for very faint objects.

The rotation of the grating is achieved by a stepper motor with 200 steps per revolution. Each step corresponds to one channel, i.e. about 10 Å in first order. The position of the grating can be read out to an accuracy of one channel by a dial gauge. The calibration of this dial gauge is done with the help of a laboratory source, which is a mercury lamp in this case.

There is a provision to isolate the red region from the second order blue wavelengths by introducing a filter just before the exit slot. The filters that are generally used are W 25 or OG1 for the red region and BG 12 or BG 14 for isolating the second order blue region. GG 13 was used in the first order visual region.

The output from the photomultiplier was fed to an amplifier and discriminator, whose basic function is to amplify the small PMT output current of the order of nA and μA. One of the
The requirements of such an amplifier is the high input impedance. The discriminator converts the output from the amplifier to voltage levels compatible with a digital counter. This technique of pulse counting has the advantage of longer integrations, which is not possible with the conventional DC techniques. The pulse amplifier discriminator (PAD) has a very high input impedance. This unit was tested on a UBV photometer and the gain was so adjusted that it does not saturate for reasonably high pulse rates, at the same time attempting to achieve maximum efficiency for faint light levels. This procedure, called the 'dead time correction', essentially ensures that the pulses are not missed during counting, especially when the pulse rate is very high. This type of optimized gain adjustment and the smaller bandwidths employed in our work prevented the attainment of saturation even when stars as bright as $\gamma$ Gem ($m_\gamma = 1.93$) were observed.

The detector was generally the S20 surface. During the observing seasons of 1980-81 and 1981-82, the refrigerated EMI 9558B tube was used. The tube EMI 9804B also was occasionally used, for only the blue region. For the season of 1982-83 and later, a new EMI 9658R was made available, with a built-in PAD from 'Products for Research'. This could be fitted to either a thermo-couple cooled chamber or a dry ice cooled chamber. Suitable Fabry lenses were mounted onto these chambers. In 1985 another detector, RCA 31031, with a better response in the long wavelength region also was available. This was especially useful in deriving the continuum distribution up to almost 9500 Å.

The pulses from PAD served as input to an on-line computer.
TDG-12 (4k, 12 bits, 2 μs), where rapid counting was possible. There was provision for two modes of operation. The first one, called the sequential mode, permitted a continuous scanning of the spectrum, to a maximum of 200 channels (2000 A in first order). The second mode, called the random mode, would scan only certain wavelength bands, which may be specified in terms of channel numbers, through mercury lamp calibration. This mode was particularly useful in monitoring faint sources, where avoiding regions of very little interest, total observing time was saved. While observing the red regions, the unwanted (earth's) atmospheric absorptions also may be avoided by this mode. However, this has the serious disadvantage that the backlash of the motor would shift the region of interest in to a gap, after several number of observing runs. This demands the recalibration with the mercury, all too often.

The time spent at each channel, during a scan, could be chosen from 1 ms to 999 ms. This choice was mainly decided by sky conditions. The faintness of the source (star) decided the total number of scans per observing run. This meant that while a total duration of 4 to 5 minutes was sufficient for a brighter star (m_V = 6) in the blue region, about 15 to 20 minutes were needed for a fainter star (m_V = 10). The total time spent at each channel varied from 1 to 10 seconds.

The counts were monitored at fixed time intervals (one or two minutes) at the end of which, the maximum and minimum counts were printed on a line printer. The scanning could be continued or halted on an inspection of these values. The spectrum can then be printed out as a table with running channel number, on
The computer TDC-12 was later replaced by a microprocessor controlled photon counting system. This equipment mimicked the performance of TDC-12 with several additional features. The size of the memory was increased to (16k ROM + 4k RAM) so that larger wavelength coverage was possible at a stretch. An oscilloscope displayed the building up of the spectrum, scan after scan, making the monitoring easier. Apart from this, the maximum and minimum counts were also displayed. The most important addition was the built-in clock, which facilitated the printing of the times of the beginning and ending of each observing run.

2.2 The Instrumental Performance

The instrument has already found a variety of applications from comets to stars (Sivaraman et al., 1977; Bappu et al., 1978; Shylaja & Prabhu, 1979; Babu & Shylaja, 1981, 1982 a & b, 1983; Shylaja, 1983, 1984, 1985; Shylaja & Babu, 1985). Applications to Wolf-Rayet stars in particular has been discussed by Bappu (1977).

For the present study, the blue region has been observed in the second order, so that emission lines are resolved. The red region has been covered in the first order. Some sample scans showing stars of different spectral types are shown in Figures 2.2 (blue). The figures include one nova, where even the violet absorption edge is clearly identifiable, in spite of the poor resolution. In case of peculiar A stars, the depression at 5200 Å is sticking in the scans even before any correction is applied.

It may be immediately seen that the instrument is suited for
Figure 2.2  Sample scans of the scanner in the blue region.
the study of broad band emission and absorption features.

2.3 Standard Stars

To determine the absolute energy distribution of a star, the observed scan should be corrected for various contributions from sky conditions, telescope optics, detector sensitivity and noises generated in the process. For this purpose α Lyrae is chosen as the primary standard. Many lists of the secondary standards are available in literature (Oke, 1964; Hayes, 1970; Breger, 1976). Generally these standards are all of spectral type A and B, and are not calibrated in the regions of convergence of the Balmer and Paschen lines i.e. 3600 to 4000 Å and 8200 to 8600 Å. To overcome this difficulty many O type standards (Kuan & Ruhí, 1976) and late type stars (Fay et al., 1975; Taylor, 1982) are made available. The list of standards used in the present study are compiled in Table 2.1.

On the same night at least three standards were monitored to cover a range of hour angles. They were chosen to be of spectral type similar to that of program stars. The procedure adopted for obtaining these scans was as follows:

1. Mercury lamp to fix up the wavelength region
2. Standard star #1 blue region
3. Sky near std. star in blue region
4. Std. star #1 in red region
5. Sky near std. star. red region
6. Program star #1 blue region
7. Sky near prog. star blue region
8. Prog. star #1 red region
9. Sky near prog. star red region
Table 2.1  List of standards used in the present study.

<table>
<thead>
<tr>
<th>NAME</th>
<th>HR NO.</th>
<th>MAGNITUDE</th>
<th>B-V</th>
<th>SP. TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;^2 Cat</td>
<td>718</td>
<td>4.28</td>
<td>-0.06</td>
<td>B9 III</td>
</tr>
<tr>
<td>Y Gem</td>
<td>2421</td>
<td>1.93</td>
<td>0.00</td>
<td>A0 IV</td>
</tr>
<tr>
<td>27 CMa</td>
<td>2745</td>
<td>4.66</td>
<td>-0.19</td>
<td>B3 IIIe</td>
</tr>
<tr>
<td>&amp; CMa</td>
<td>2827</td>
<td>2.45</td>
<td>-0.08</td>
<td>B5 Ia</td>
</tr>
<tr>
<td>3 Pup</td>
<td>3165</td>
<td>2.25</td>
<td>-0.26</td>
<td>O5 I</td>
</tr>
<tr>
<td>3 Hya</td>
<td>3454</td>
<td>4.30</td>
<td>-0.20</td>
<td>B3 V</td>
</tr>
<tr>
<td>56 Crt</td>
<td>4468</td>
<td>4.70</td>
<td>-0.08</td>
<td>B9.5 V</td>
</tr>
<tr>
<td>109 Vir</td>
<td>5511</td>
<td>3.72</td>
<td>-0.01</td>
<td>A0 V</td>
</tr>
<tr>
<td>9 Bge</td>
<td>7574</td>
<td>6.23</td>
<td>+0.01</td>
<td>O8f</td>
</tr>
<tr>
<td>58 Aql</td>
<td>7596</td>
<td>5.61</td>
<td>0.10</td>
<td>A0 III</td>
</tr>
<tr>
<td>E Aqr</td>
<td>7950</td>
<td>3.77</td>
<td>0.00</td>
<td>A1 V</td>
</tr>
<tr>
<td>10 Cep</td>
<td>8469</td>
<td>5.04</td>
<td>+0.25</td>
<td>O6 I</td>
</tr>
<tr>
<td>10 Lac</td>
<td>8622</td>
<td>4.88</td>
<td>-0.20</td>
<td>O9 V</td>
</tr>
<tr>
<td>29 Psc</td>
<td>9087</td>
<td>5.10</td>
<td>-0.12</td>
<td>B7 III</td>
</tr>
</tbody>
</table>
10. Std. star #2 in red region
11. Std star #2 in blue region
and so on.

Care was taken to observe the program star as close to the meridian as possible. The calibration of the dial gauge was checked 3 to 4 times during the night with the help of the mercury lamp.

2.4 Atmospheric Extinction

2.4.1 Influencing parameters

The model suggested by Hayes & Latham (1975) has been used to determine the nightly extinction coefficients based on the observations of standard stars as follows.

Consider a monochromatic beam of wavelength $\lambda$ entering the atmosphere from outside, at a zenith angle $z$, with reference to the observer. The intensity as measured by the observer is decided by the optical depth $\tau$ of the atmosphere as,

$$ I(\lambda, \tau) = I(\lambda, 0) \exp[-\tau(\lambda, z)] $$

(1)

neglecting the angular effects.

The optical depth is defined as,

$$ \tau(\lambda, z) = k(\lambda) X(z) $$

(2)

where $k(\lambda)$ is the extinction coefficient and $X(z)$ is the airmass.

The optical depth at zenith distance zero is

$$ \tau(\lambda, 0) = k(\lambda) $$

(3)

Hence, (1) can be rewritten as,

$$ I(\lambda, \tau) = I(\lambda, 0) \exp[-k(\lambda)X(z)] $$

$$ \frac{3}{2} \ln I(\lambda, \tau) = -k(\lambda) $$

(4)

Therefore, a plot of the airmass versus the natural logarithm of the measured intensity gives the slope as $k(\lambda)$,
the extinction coefficient. The knowledge of the intensity prior to the entry into the atmosphere $I(\lambda, 0)$, is not necessary.

The extinction is caused by various factors. The main contributors are, Rayleigh scattering by molecules, molecular absorption and aerosol scattering. The Rayleigh absorption is defined as,

$$A_{\text{Ray}}(\lambda, h) = 9.4977 	imes 10^{-3} \frac{1}{\lambda^4} \left[ \frac{(n-1)\lambda}{(n-1)_{\lambda=1}} \right]^2 \exp \left( \frac{-h}{7.996} \right)$$

where $n$ is the refractive index at $\lambda$, in microns, $h$ is the altitude of the place, i.e. the Observatory.

The absorption due to ozone may be expressed as,

$$A_{\text{ozone}}(\lambda) = 1.11 T_{\text{ozone}} k_{\text{ozone}}(\lambda)$$

where $T_{\text{ozone}}$ is the thickness of ozone in atmosphere, which is independent of the altitude of the place.

The aerosol scattering is caused by the smaller particles ($0.1 \mu \text{m} < \text{diameter} < 10 \mu \text{m}$) and this contribution may be estimated as,

$$A_{\text{aer}}(\lambda, h) = A_{a} \lambda^{-\alpha} \exp(-h/H)$$

Ozone is known to absorb in two bands (Allen, 1976). One in the UV region with the peak at 2700 A and the other is in the visible region with the peak at ~ 6000 A. Therefore, the region in the range, 3800 < $\lambda$ < 5000 A can be considered to be solely due to the aerosols and using (7) the coefficient $\alpha$ can be calculated, if corresponding data are available.

2.4.2 Comparison with Meteorological Data

In the present analysis, we analysed these atmospheric data in the following way. Four nights' data on very clear nights were chosen for this purpose (Table 2.2). The total absorption was
Table 2.2 Data used for extinction analysis and results.

<table>
<thead>
<tr>
<th>Date</th>
<th>Program Star</th>
<th>Standard Star</th>
<th>z</th>
<th>A</th>
<th>B</th>
<th>α</th>
<th>Abs. due to Gase</th>
<th>Drone measured cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980 Oct 29</td>
<td>$\delta$Aqr</td>
<td>$\nu$ Gem</td>
<td>24.73</td>
<td>0.063</td>
<td>0.0141</td>
<td>1.33</td>
<td>15</td>
<td>269</td>
</tr>
<tr>
<td>1981 Feb 27</td>
<td>$\eta$Hya</td>
<td>$\gamma$ Gem</td>
<td>30.00</td>
<td>0.050</td>
<td>0.0137</td>
<td>1.31</td>
<td>12</td>
<td>246</td>
</tr>
<tr>
<td>1983 Feb 4</td>
<td>$\xi$Cet</td>
<td>$\xi$ Pup</td>
<td>22.93</td>
<td>0.051</td>
<td>0.0158</td>
<td>1.14</td>
<td>6</td>
<td>243</td>
</tr>
<tr>
<td>1984 Dec 13</td>
<td>$\rho$Leo</td>
<td>$\zeta$ Pup</td>
<td>26.96</td>
<td>0.075</td>
<td>0.0142</td>
<td>0.92</td>
<td>7</td>
<td>241</td>
</tr>
</tbody>
</table>

Figure 2.3 The measured total absorption and that due to pure Rayleigh scattering per air mass, given as $K(\lambda)$ in magnitudes.
calculated from a set of standard stars. The variation of this absorption on one such night is shown in Figure 2.3. Following van den Bergh & Henry (1963) this absorption was fitted in to the coefficient as,

\[ k(\lambda) = A + B/\lambda^4 \]  

(8)

where \( \lambda \) is in microns.

The Figure also shows the effect of pure Rayleigh scattering. This was subtracted from the total absorption to get the contribution from other sources (Tug et al., 1977; Hayes & Latham, 1975). This accounts for the vertical shift between the two curves in Figure 2.3 i.e. the term \( A \) in equation (8). This residual absorption, when plotted on an expanded scale, shows a general increase in the region of ozone absorption (Figure 2.4). The ozone absorption coefficient from Allen (1976) also is shown in the Figure.

To check these effects, the data from India Meteorological Department on ozone measurements and \( T - \phi \) grams were obtained. It is possible to measure the amount of precipitable water content in the following way.

Consider the water vapour contained in an air-column of thickness \( dz \) and let its density be \( \rho_v \). Then the water vapour content is given by \( \rho_v \, dz \). If we extend this to the entire column of air to a height \( z \), we get,

\[ W = \int_0^z \rho_v \, dz \]  

(9)

The pressure in the element \( dz \) is given by,

\[ dp = - \rho g dz \quad \text{or} \quad dz = - \frac{1}{\rho g} \, dp \]  

(10)
Figure 2.4 Residual absorptions after removing the Rayleigh effect. The ozone absorption coefficient (Allen, 1976) also is shown in the top curve.
where \( \rho \) is the density of the particles.

Therefore, the total water vapour content is given by,

\[
W = \frac{\rho}{\rho_o} \int \frac{\rho_v}{\rho} \frac{1}{g} \, dp
\]  

(11)

The term \( q \) is called the specific humidity, which is defined as the ratio of the water vapour to that of air (dry air + moisture). Then the total water vapour content in a column where the pressure varies from \( p_0 \) to \( p \) is,

\[
W = \frac{1}{g} \, \bar{q}(p_0 - p)
\]  

(12)

where \( \bar{q} \) is the mean specific humidity at that level. From the superposition of 'isohygrics', i.e. the curves of equal water vapour content, on the \( T-\phi \) grams, it is possible to read out the mixing ratio, for every 50 mb of pressure. This mixing ratio, defined as the ratio of mass of water vapour to mass of dry air is assumed to be differing from the mean specific humidity by a small fraction such as \( \epsilon = 0.1 \). Hence, we can measure the quantity for every 50 mb difference of pressure and compute the precipitable water vapour content from equation (11). When this is added over the entire air-column we get the total water vapour content.

These measurements are made from the balloon borne apparatus twice in a day at 5:30 am and 5:30 pm IST from selected places only. The nearest places for Kavalur were Bangalore (latitude: \( 12^\circ 55'\), altitude: 921m) and Madras (latitude: \( 13^\circ 04'\), altitude: 7m). It was decided to compare the measurements made from Bangalore. Table 2.3 includes all these measures obtained from IMD for
### Table 2.3  Comparison of water vapour measurements

<table>
<thead>
<tr>
<th>Date</th>
<th>Time UT</th>
<th>Amount cm</th>
<th>Name of star</th>
<th>Time UT</th>
<th>Absorption %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980 Oct 29</td>
<td>12:00</td>
<td>1.46</td>
<td>E Aqr</td>
<td>13:45</td>
<td>65</td>
</tr>
<tr>
<td>1981 Feb 27</td>
<td>12:00</td>
<td>0.96</td>
<td>HR 6216</td>
<td>14:10</td>
<td>56</td>
</tr>
<tr>
<td>1983 Feb 4</td>
<td>0:00</td>
<td>0.60</td>
<td>E Gem</td>
<td>17:55</td>
<td>38</td>
</tr>
<tr>
<td>1983 Feb 4</td>
<td>12:00</td>
<td>1.37</td>
<td>HR 1732</td>
<td>18:03</td>
<td>42</td>
</tr>
<tr>
<td>1984 Dec 13</td>
<td>0:00</td>
<td>0.47</td>
<td>E2 Cot</td>
<td>14:18</td>
<td>47</td>
</tr>
<tr>
<td>1984 Dec 13</td>
<td>0:00</td>
<td>0.47</td>
<td>E Pup</td>
<td>23:38*</td>
<td>42</td>
</tr>
<tr>
<td>1985 Dec 13</td>
<td>0:00</td>
<td>0.47</td>
<td>E Leo</td>
<td>23:55*</td>
<td>46</td>
</tr>
</tbody>
</table>

**Times of Dec 12**

### Table 2.4  Am stars observed on the same night.

<table>
<thead>
<tr>
<th>Name</th>
<th>HR #</th>
<th>Sp type</th>
<th>δ (1984)</th>
<th>z</th>
<th>θ (eff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>73 Vir</td>
<td>5094</td>
<td>A4m</td>
<td>-19 40</td>
<td>46</td>
<td>0.64</td>
</tr>
<tr>
<td>λ Vir</td>
<td>5359</td>
<td>Am</td>
<td>-13 19</td>
<td>39</td>
<td>0.50</td>
</tr>
<tr>
<td>60 Hya</td>
<td>5591</td>
<td>Am</td>
<td>-20 00</td>
<td>49</td>
<td>0.59</td>
</tr>
<tr>
<td>5762</td>
<td></td>
<td>Am</td>
<td>-19 38</td>
<td>40</td>
<td>0.53</td>
</tr>
<tr>
<td>5875</td>
<td></td>
<td>Am</td>
<td>-3 48</td>
<td>25</td>
<td>0.50</td>
</tr>
</tbody>
</table>
these four selected dates. From stellar measurements, it is possible to estimate the absorption at the 7100 Å band, after establishing the continuum energy distribution of the star. Such measurements made as close to the balloon launch times as possible also are included in Table 2.3. No apparent relation between the two is evident.

In order to understand the variation of water vapour content, the measurements made on the same night were analyzed. Stars of similar spectral type, at similar zenith distances, observed on the same night were used for this analysis. Table 2.4 lists these stars, whose effective temperatures have been estimated (Shylaja et al., 1985). The variation in the water absorption band at 7100 Å can be easily seen (Figure 2.5). This is also an important reason, other than the differences in times of observations and also in geographical locations of water vapour measures, for not finding any relation in the corresponding quantities in Table 2.3.

The solar irradiance measures of Dunkelman & Scolnik (1959) used the practical measures of ozone to show the effect of absorption. They showed that the Huggins band absorptions in the region 3000< λ<3400 Å, show a relationship with ozone measures.

For the above mentioned four nights of observation, the ozone measures were obtained from IMD. The nearest locations of these measurements were Kodaikanal(latitude: 10° 14', altitude: 2343 m) and Pune(latitude: 18° 41', altitude: 559 m). These values of ozone measurements are included in Table 2.2. It may be seen that there is a general increase in the ozone content from both measures during 1980. However, significant variations in ozone content in
Figure 2.5  Energy distributions of five stars of similar spectral type as observed on the same night at similar zenith distances. The difference in H$_2$O absorption with UT is noticeable. Details of observations are in Table 2.4.
time scales as small as a few hours are reported (cf. Hayes & Latham, 1975) and the meteorological measurements may represent only a mean value.

This comparative study definitely shows that within the accuracies achieved here, equation (8) is valid. It may also be remembered that Dunkelman & Scolnik (1959) have shown that the mean extinction curve lies 15% above the Rayleigh curve. Hence the term A can be used to evaluate the constant \( \alpha \) in equation (7) from the residual absorption measures in the region 3800 < \( \lambda \) < 5000 Å. These values of \( \alpha \) also are included in the Table 2.2. Similar studies by de Vou Couleurs (1965) have shown that the volcanic eruptions of Mt. Agung on the island of Bali (114°E 9° S), were effective in changing the value from 0.8 to 1.2 in 1963, at McDonald Observatory (104°W 30° N).

The values of A and B for different nights and seasons have been tabulated in Table 2.5 and shown in Figure 2.6 as well. The fluctuations in B are quite small and yields the average value around 0.014. The large variations in the value of A are real, as the variations in particle density and other contributors show, from the above discussions.

On occasions when the sky conditions did not permit the determination of A and B, a comparison star of known energy distribution, monitored immediately after or before the program star, was used, to derive the absolute flux.

2.5 Instrumental Corrections:

At the 12 wavelengths listed by Hayes (1970) for continuum measurements which are free of any effect from emission or
Figure 2.6 The variation of coefficients A and B during 1980-85.

Table 2.5 The extinction coefficients A and B during 1980-85.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>B</td>
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absorption lines, the observed counts were averaged over three channels and corrected for sky contribution. This is then converted to magnitude as, 

$$m_{\text{obs}}(\lambda) = -2.5 \log n^*$$

where $n^*$ is the number of counts per second per A. The air mass $X$ is known to be a function of the zenith distance $z$ as,

$$X = \sec z - 0.0018167 (\sec z - 1)^2 - 0.002875 (\sec z - 1)^3 - 0.0008083 (\sec z - 1)^4$$

(13)

from Hardie (1962). Neglecting second order terms, $X$ can be replaced by $\sec z$ itself. From a knowledge of the constant $B$, the extinction coefficient, the instrumental magnitudes of the particular night at any wavelength can be derived as,

$$m_{\text{ins}} = m_{\text{obs}} - k_\lambda \sec z$$

(14)

where $k_\lambda = B/\lambda^4$. These would be the magnitudes observed if the instrument was kept above the atmosphere. These are normalized at 5000 A as,

$$m_{i\lambda} = m_{\text{obs}} - k_\lambda \sec z - m_{\text{obs}}(5000)$$

(15)

These are compared with known energy distributions in case of standard stars, which are also normalized at 5000 A, and the instrumental corrections are derived as,

$$\text{cor}(\lambda) = m_{\text{lit}} - m_{i\lambda}$$

(16)

Figure 2.7 shows sample of observed curve, instrumental magnitude, literature magnitude (known energy distribution) and derived corrections.

These corrections are to be applied to the program stars. The procedures for derivation of instrumental magnitude for program star is exactly similar to that of standard stars till equation (16). For the normalized magnitude the corrections are applied from (17) as,

$$m_{\text{prog}} = m_i + \text{cor}(\lambda)$$

(17)
Figure 2.7 A sample of observed curve, instrumental correction and absolute magnitude (normalised).

Figure 2.8 Energy distribution of 58 Aql obtained using 109 Vir as standard star.
When the corrections from equation (17) are derived for selected wavelengths only, they can be interpolated to all other intermediate wavelengths. The curves in Figure 2.7 show that this interpolation does not introduce any considerable error especially when the points are closely spaced.

The normalized magnitudes thus obtained are converted into flux as,

\[ m_\nu = -2.5 \log F_\nu + \text{const.} \]  

(18)

which can be in units of ergs/cm²/sec/Å or ergs/cm²/sec/Hz, depending on the value of the constant, since

\[ m_\lambda = -2.5 \log F_\lambda + \text{const.} \]  

(19)

The constant is -48.615 for (18) and -21.146 for (19), based on the definition of the energy of the primary standard α Lyrae, as 3.58 x 10⁻²⁰ ergs/cm²/sec/Hz (Hayes & Latham, 1975).

Figure 2.8 shows the comparison of the energy distribution known from other sources for 58 Aql, with the derived values using 109 Vir as the standard star.

2.6 Errors

The source of errors can be either optical or electrical. Bad seeing conditions lead to inaccurate flux determinations. Under such circumstances the diaphragm was opened to 1000 μ. This, however, reduces the accuracy by raising the general sky background. Similarly, changing sky conditions in a night give erratic values for the extinction coefficients. Again, on such occasions the comparison star monitored immediately before or after the program star was used for deriving the instrumental corrections from a mean value of the extinction coefficient.

Electrical noise can be photon noise or the digitising
Figure 2.9  Errors for different photomultiplier tubes.

Figure 2.10  Variation of error with apparent magnitude.

Figure 2.11  Variation of error with spectral type.
noise. The photon noise decreases with the number of integrations over the same channel. This may be represented by $(N_j)^{-1/2}$, where $N_j$ is the number of photons in channel $j$. The digitising noise has been found to be proportional to the pulse output from the descriminator (Lynds & Aitkens, 1965). It is shown that the signal to noise ratio is,

$$\frac{S}{N} = \left( \frac{6Tt}{f} \right)^{1/2}$$

where $t$ = time interval spent at each channel during a single run, called the counting interval, here,

$T$ = total time

$= Nt$, where $N$ is the total number of scans,

$F$ = frequency of the output of the PAD.

Since, this is also proportional to $F = (N)^{-1/2}$, it is better to integrate over a long duration. However, this increases $T$ and therefore one has to go in for a compromise.

The errors have been determined treating star of known energy distributions as unknown program star. The error as a function of wave length, is basically decided by the response of the photomultiplier tube, as demonstrated by the Figure 2.9. The faintness of the source also is partly responsible for errors (Figure 2.10). It is thus essential to choose a comparision of similar magnitude range. A difference in spectral type also is likely to introduce errors as shown (Fig.2.11); here the standard chosen was of spectral type A to derive the energy distribution of stars of spectral type O and G.