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Limited Seeing Measurements at Mount Abu Infrared Observatory

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Abstract. Measurements of atmospheric seeing for the Mount Abu Infrared Observatory, Gurusikhar are presented. Observations made with a differential image motion monitor, between 6 December 1999 to 28 April 2000, give an error-corrected, median value of 0.91 arc second for the seeing during this period. Due to certain constraints, seeing measurements were possible only during a substantial fraction of, but not the complete observing season. The results therefore, may be considered to give, a qualitative idea of the seeing conditions at Mt. Abu.

Key words: Seeing, Differential Image Motion Monitor

1. Introduction

The 1.2-m telescope of the Physical Research Laboratory Ahmedabad is situated on Gurusikhar peak at Mount Abu, Rajasthan. The latitude, longitude and altitude of the observatory, as measured by GPS observations, are 72^0 46′ 46″ E, 24^0 39′ 11″ N and 1765 metres above mean sea level respectively. The telescope has been operational for close to a decade. The site is known to have the largest number of clear nights in a year vis -a-vis several other sites in India (Sapru et al., 1998). The seeing was also known to be good from observational experience and occasional seeing measurements made earlier. However systematic and fairly extended measurements of the seeing at the site had not been done earlier. The advent of low-cost, small-size and easy-to-operate differential image motion monitors (DIMM's) has been fairly recent. These instruments have helped greatly in measuring the seeing at established sites and also for the evaluation of proposed sites prior to the commissioning of large telescopes. Further, it has been well established that seeing values obtained using a DIMM agree well with seeing estimates

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made simultaneously using large telescopes (Sarazin and Roddier, 1990). In the following sections we present the results of the seeing at Mt.Abu, determined using a DIMM.

2. Instrumentation and Observations

The DIMM that was used for the observations consists of a 14-in. Celestron (C-14) telescope with a Santa Barbara Instrument Group ST-4 CCD camera. The C-14 was mounted on the middle block of the 1.2-m telescope whose drive system was used for tracking. Hence the seeing values reported here are seeing values within the dome that houses the 1.2-m telescope.

The CCD is controlled by a PC via a software program, written in Turbo Pascal, which was originally developed by Wood et al. (1995) for their seeing measurements at Freeling Heights and Siding Spring observatory. The software enables the acquisition, real time display and storage of the seeing data. The front of the C-14 was covered by a mask in which two circular holes of diameter 5 cm and 20 cm separation were cut out. One of the holes is kept open while the other is covered by a small angle prism. The prism marginally deviates the incoming light so that the two apertures of the C-14 form two separated images of the same star on the CCD . These two images which are formed along the line joining the center of the apertures, were separated by about 30 pixels in our observations. The centroids of both the star images, in terms of pixels, are determined by the program and, as discussed in the next section, it is the variance of these centroids for a set of several image frames that gives a seeing measure. In our observations, 10 ms exposures were given for each frame and a set of 100 such frames, covering a total time of 5 minutes, were used to give one seeing value.

The seeing observations reported here were made on 25 nights between 6 December 1999 and 28 April 2000 and comprise a total set of 762 seeing estimates. The bulk of the observations, however, were spaced out during the months of December, January and March of this period. The actual observational season at Mt. Abu extends approximately between October to May (a total of about 8 months). The monsoon period and other adverse weather conditions prevent observations during the rest of the time. Hence, our observations sample about 40 percent of the available observational time. Thus the statistics of the seeing measurements reported here may not represent the overall seeing conditions at Mt. Abu. Much as we would have liked, a more-extended study was not possible due to several constraints. Due to lack of a separate location for the C-14 telescope, uninterrupted and year-long observations could not be made. Hence, as mentioned earlier, it was mounted on the main telescope and the observations reported here were made at the expense of the observer's own time at the main telescope. In light of the above, the results presented here are intended to give a qualitative idea of the seeing at Mt. Abu.

3. Theory and data reduction

The variance of the image centroids of the star, for a set of 100 frames, are first converted from a pixel scale to an arc second scale by using the conversion factor of 0.845 arcsec/pixel in the x or longitudinal direction and 0.725 arcsec/pixel in the y or transverse direction. The longitudinal direction is defined as that which is along the direction joining the two star images or the apertures in the two-hole mask. If σ_l^2 and σ_t^2 are the variances of the relative image motion in the longitudinal and transverse direction, then as given by Sarazin and Roddier (1990)

$$\sigma_l{}^2 = 257\left(\frac{0.179}{D^{1/3}} - \frac{0.0968}{d^{1/3}}\right) r_{0,V}{}^{-5/3} \tag{1}$$

$$\sigma_t{}^2 = 257\left(\frac{0.179}{D^{1/3}} - \frac{0.145}{d^{1/3}}\right) r_{0,V}{}^{-5/3} \tag{2}$$

where D is the hole diameter, d is the hole separation and $r_{0,V}$ is the Fried parameter at the wavelength of observation (550 nm). From equations 1 and 2 , two values of the Fried parameter can be found and these can be used to calculate the $FWHM$ of the stellar image as would be found in a large telescope ($D >> r_{0,V}$) from the relation

$$FWHM_{observed} = \frac{0.98\lambda}{r_{0,V}} \tag{3}$$

Using equations 1, 2 and 3, two independent measures of the $FWHM$ are obtained. An average of these two values was taken to represent the seeing value. This average seeing value was then corrected for the airmass to give an estimate of the zenith-seeing by using the relation

$$FWHM_{zenith} = FWHM_{observed} cos(\gamma)^{3/5} \tag{4}$$

where γ is the zenith distance.

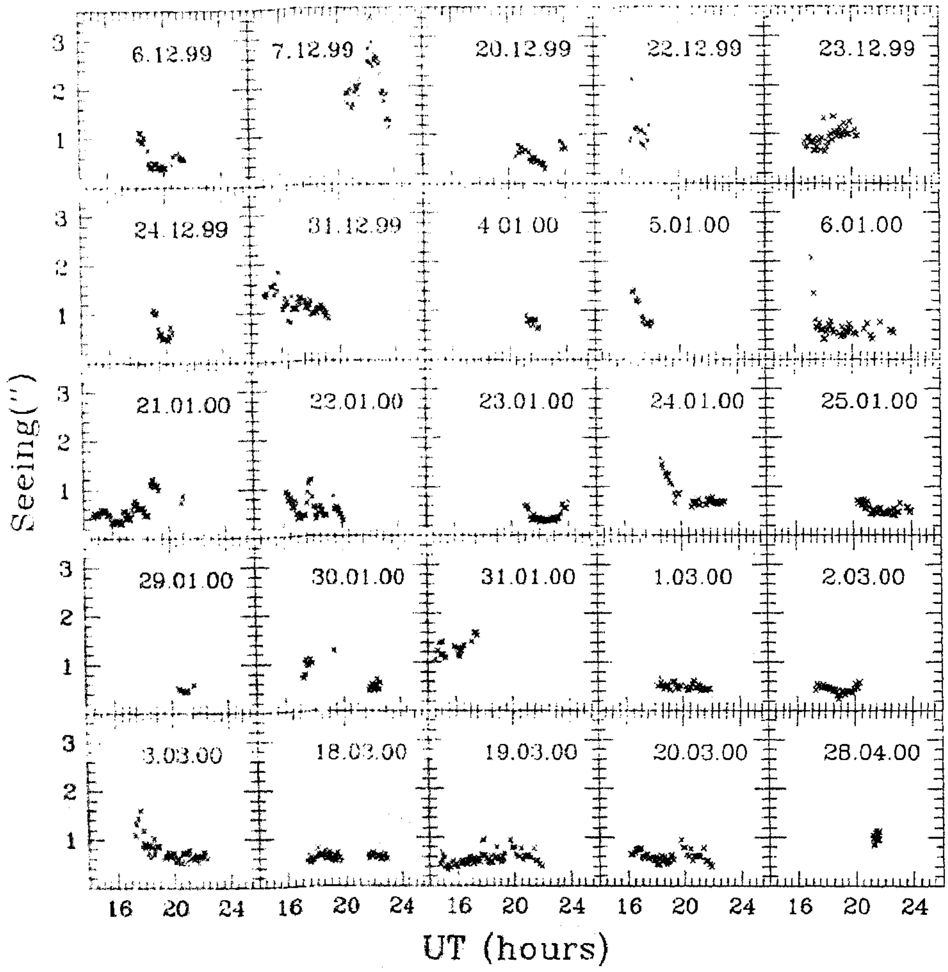

Figure 1. A mosaic of seeing versus time plots for all the days of observation.

4. Results and Discussion

In all succeeding graphical plots, the seeing referred to is the zenith-seeing described in the preceding section. The seeing values on different epochs are presented in Fig. 1 in a mosaic form. The scale is the same for each subgraph in this figure. To get a better feel as to how the seeing behaves in general, we have plotted all the observational data in Fig 2a. From this figure, it is clearly seen that the bulk of the seeing values tend to cluster around two bands in the range of 0.5″-0.6″ and 0.9″-1.0″ (which have to be corrected for errors as discussed below) respectively. This bi- modal distribution is more clearly seen in Fig. 2b in which a histogram of the seeing values has been plotted. The bin size for this histogram is 0.2″ with the first bin centered at 0.1″. The center of each bin has been marked with a cross. As seen from this figure the maximum frequency of the seeing values are in the 0.4″ to 0.6″ range. We have fitted a two-gaussian fit to this histogram, indicated by the bold continuous line. The two-gaussian curve fits the data quite reasonably well and the parameters of the fit indicate that the seeing values have a bi- modal distribution with peaks at 0.52″ and 0.90″. In Fig. 2c we have illustrated the quality of the seeing as a percentage of total observing time i.e. the percentage of time over which the seeing is less than or equal to a given value. The figure indicates that for 45% of the time the seeing is below 0.6″ and subarcsec seeing ($< 1.0''$) is obtained during 80% of the time. The median seeing is found to be 0.63″. However, the seeing values have to be corrected for errors which is discussed below.

The sources of errors in DIMM observations as described by Sarazin and Roddier (1990) are due to three factors viz. error due to determination of image centroids, statistical errors and errors due to exposure time. We follow their method of error analysis. Regarding the error due to centroiding, an independent lab test using pin holes (as described by Sarazin and Roddier (1990) or Ram Sagar et al. (2000)) was not conducted by us for determining this error. But since a similar CCD system (ST4) was used by us and Ram Sagar et al. (2000), it is reasonable to adopt their uncertainty in centroiding of 0.09 pixels to be valid for us too. This converts to an error of 3.5% in the seeing estimate. The statistical error, as per Sarazin and Roddier, depends on the number N of seeing values recorded in a minute - this being the approximate time scale over which the atmosphere maintains the same statistical properties. We can record about twenty images per minute from which forty estimates of the seeing are obtained in the two directions. If the errors in the longitudinal and transverse seeing estimates are assumed the same, then the statistical error works out to 13.5% for individual results.

Martin (1987) has shown how the contribution of winds in the turbulent layers of the atmosphere can cause underestimation of the seeing depending on the duration of the exposure time. Since we do not have actual data on wind speeds in the tropopause and high atmospheric levels, we can only make an estimate of their effect. We use Fig 8c and 8d of Martin in conjunction with the requisite parameters, viz. exposure time of 10ms, hole separation-to-diameter ratio of 4 and an assumed wind velocity of 20-25 m/s. The wind velocity is the primary factor in underestimating seeing and choosing a correct value for this parameter is necessary. As shown by Martin (1987), actual measurements show that a representative wind speed in the range 15-30 m/s is appropriate. The wind direction is assumed to have been, on an average, at forty five degrees to the line joining the apertures. This may be a reasonable conclusion to draw from Fig 3 where the longitudinal seeing has been plotted versus the transverse seeing. The line of regression

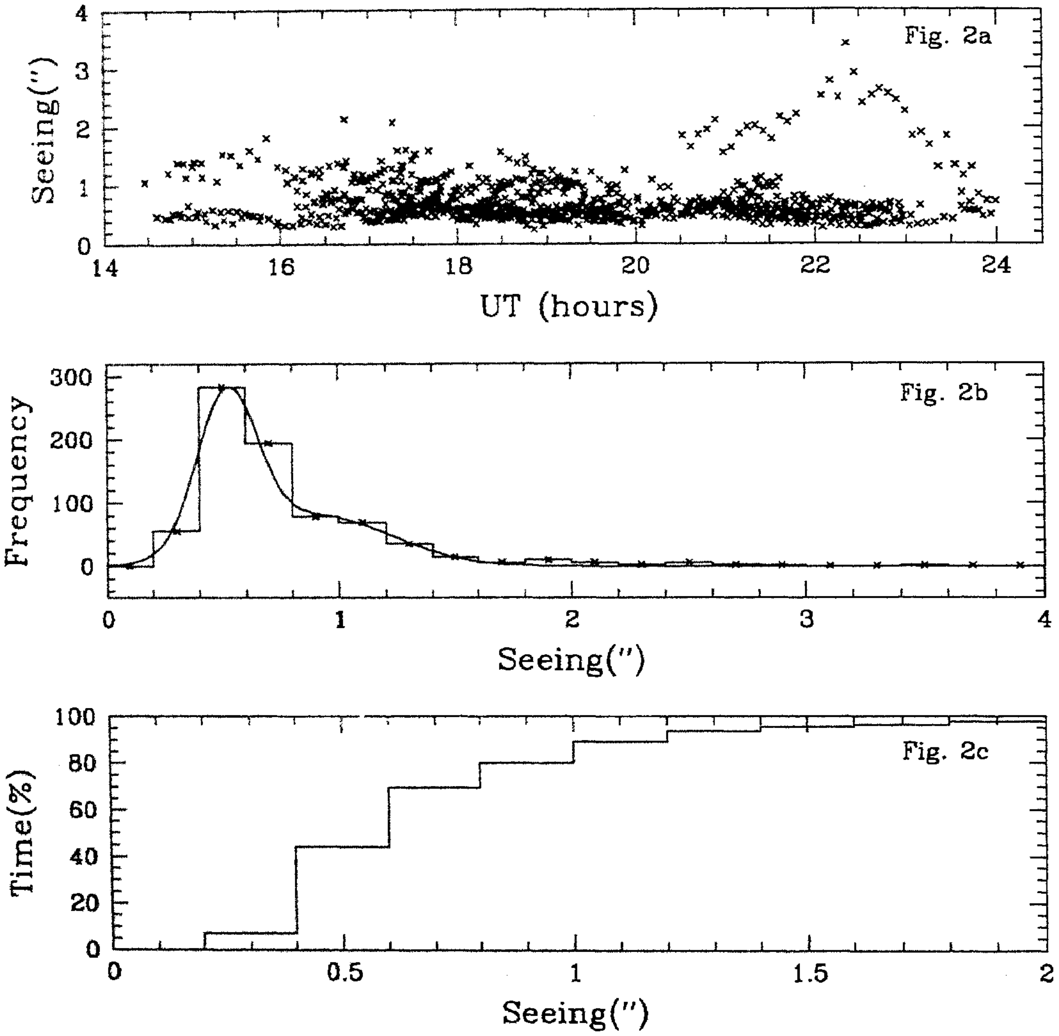

Figure 2. Fig. 2a shows the seeing versus time plot for the complete data set of seeing values. In Fig. 2b a histogram of the seeing is shown. A two gaussian fit to the histogram is indicated by the continuous line. The center of each bin is marked with a cross. Fig 2c. indicates, in histogram form, the percentage of time during which the seeing was below a certain seeing value. For example, the seeing is below 1.0″ for 80 percent of the time.

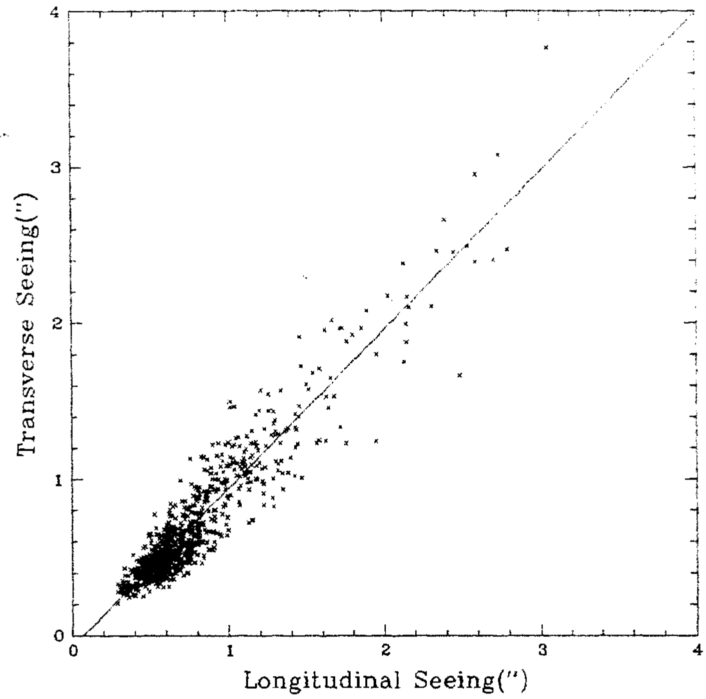

Figure 3. A plot of the transverse versus the longitudinal seeing for the entire data. The least-squares-fit to the data is the continuous line and has the form $y = 1.014x - 0.071$.

through the data points has the form $y = 1.014x - 0.071$ indicating that the longitudinal and transverse seeing estimates are almost the same and therefore appear to be affected to the same extent by the presence of winds. For the above parameters, we find that the mean square differential motion is underestimated by about fifty percent. The error in the seeing FWHM, due to finite exposure times, would therefore be three-fifths of this i.e. 30%.

It is therefore seen that the predominant source of error in the seeing values is caused by finite exposure times used for the observations. If the errors are all additive, then the seeing values are underestimated by approximately 47%. Hence the median value of the seeing is 0.91 arc second. Although the data does not sample the entire observational season at Mt. Abu (October to May), these results show that good seeing conditions generally prevail at the site. The seeing at a few other Indian and several international sites can be found in a compilation by Ram Sagar et al. (2000) and in the work of Das et al (1999). From the compilation of Ram Sagar et al. (2000) we find that the median seeing value reported here is quite consistent with that of other sites at similar altitudes.

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References

Das H.K., Menon S.M., Paranjpye A. and Tandon S.N., 1999, *B.A.S.I.*, **27**, 609.
Martin H.M., 1987, *P.A.S.P.*, **99**, 1360.
Sagar R., Stalin C.S., Pandey A.K., Uddin W., Mohan V., Sanwal B.B., Gupta S.K., Yadav R.K.S., Durgapal A.K., Joshi S., Brijesh Kumar, Gupta A.C., Joshi Y.C., Srivastava J.B., Chaubey U.S., Singh M., Pant P. and Gupta K.G., *Astron. Astrophys. Suppl. Ser*, **144**, 349.
Sapru M.L., Kaul R.K., Bhatt C.L., Mohapatra D.K., *B.A.S.I.*, **26**, 655.
Sarazin M. and Roddier F.,1990 *Astron. Astrophys*, **48**, 93.
Wood P.R., Rodgers A.W. and Russell K.S., 1995, *Publ. Astron. Soc. Aust.*, **12**, 97.