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Image quality at THEMIS: A case study(*)

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Summary. — We briefly present the first results of a program which evaluates the parameter r_0 of a set of solar granulation images taken at the center of the solar disk. This program might be useful for evaluating the overall optical quality of a solar site.

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1. – Introduction

Since the beginning of the seventies, when Fried's results [1] on evaluating the performances of optical systems including turbulent media in the ray path, become widely known and the parameter r_0 started to be used (and abused), the quality of observatory sites has been evaluated on the basis of their median r_0 deduced from atmospheric *in situ* measurements (*e.g.* [2]) as well using optical devices as those measuring the radial limb function on images of the Sun or the limb motions [3]. Nowadays, having large solar telescopes located in sites of astronomical excellence, it is possible to evaluate the optical quality of imaging systems (optics and atmosphere) using images of solar granulation.

To this purpose several exotic recipes have been proposed so far, however in our opinion, the main method is the analysis of the spatial spectrum of the granulation images. Moreover, the spatial spectrum leads to the evaluation of the parameter r_0 of the telescope, which can be easily related to the characteristic of the site. If the statistic of the results shows that the site is not as good as forecasted by *in situ* measurements, it might be the case that telescope seeing is spoiling the images and that some action might be undertaken to increase image quality.

In this paper we shortly discuss a program to evaluate the telescopic r_0 of the white-light images obtained with the IPM at THEMIS telescope [4]. In principle the method is very simple: we compute the image power spectrum and we consider the square root of

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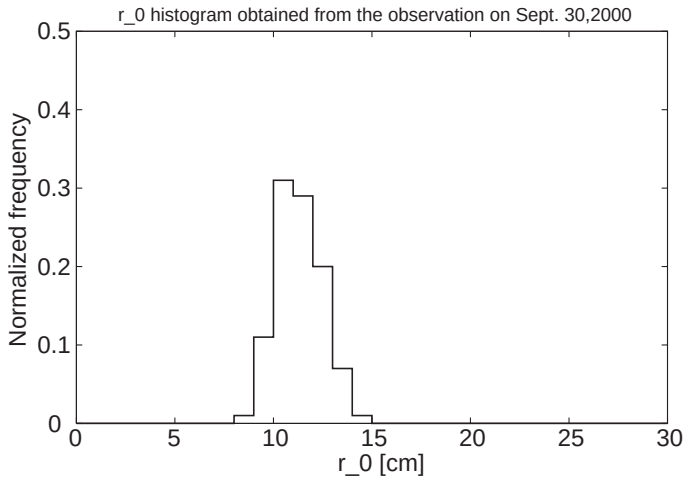

Fig. 1. – Histogram of the r_0 distribution as computed for the observations of Sept. 30, 2000 at THEMIS.

the spectrum as the profile of instrument band pass, the so-called Modulation Transfer Function (MTF). This assumption works as far as the cut-off frequency of the system is within the range in which the granulation spectrum may be considered almost white, or its reddening negligible in the bandwidth of the optical system. Fourier optics teaches that from the MTF we can compute the resolution of the optical system as the radius of the equivalent cylinder (in spatial frequency units). This parameter, in the case of optical degradation due to seeing-induced random phase fluctuations, is the r_0 parameter which can be also computed by integrating the structure parameter of the index of refraction structure coefficient $C_n^2(z)$ (*e.g.* [5]). This last parameter may be obtained from *in situ* measurements. In other words, the parameter r_0 gives the cut-off frequency of the perfect telescope working outside the atmosphere equivalent to the real one.

2. – The program

THEMIS IPM white-light images have been corrected for the CCD and telescope fixed pattern (flat field) and then masked with a circular mask, using a *cosbell* transparency profile in the last 20% data, in order to avoid the introduction of spurious high-frequency components in the radial spectrum. The final spectrum is then integrated on circular rings in the frequency plane and the radius of the equivalent cylinder calculated. The resolution is also calculated by fitting a straight line on the spectrum and evaluating the cut-off frequency. The results obtained with both methods are within the expected experimental errors.

3. – The preliminary results

Preliminary results have been obtained on several sets of observations performed during some observing runs at THEMIS IPM. We do not have yet the final results which however seem very promising. As an example we show in fig. 1 the histogram of r_0 obtained for the day September 30, 2000, distributed as confirmed in fig. 2, which is a

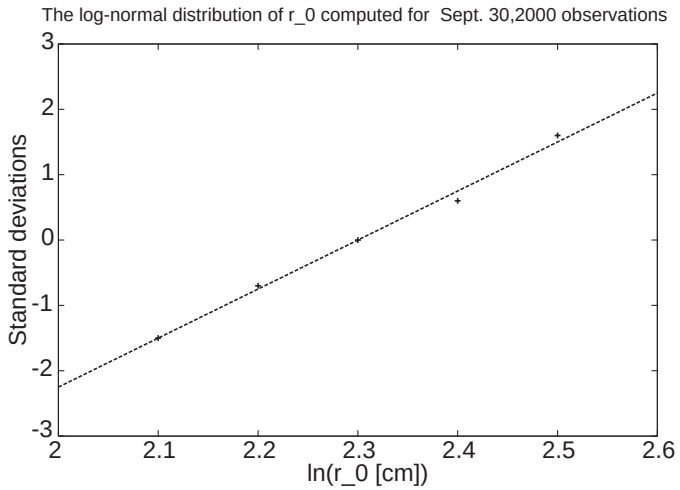

Fig. 2. – Log-normal plot of the r_0 distribution computed for the observations of Sept. 30, 2000 at THEMIS, the statistical errors are of the size of the crosses. The line fitting the points shows that the computed r_0 is log-normal, as expected, and for that day the median r_0 was $\simeq 10$ cm.

log-normal plot of the r_0 distribution and where we fit a straight line over the observed points.

4. – Discussion

We have shown a simple and straightforward method to evaluate the quality of the images which is supported by the well-known theory of Fourier optics applied to the presence of turbulent optical media. This method can supply on line estimate of the seeing at the telescope while observing, or it may be used for assessing *off line* the quality of the results obtained during the observing run. We suggest to use this method for an extended survey of the image quality obtained at THEMIS during these first years of operation in order to understand the quality limits of the site.

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