INTERFEROMETRIC TECHNIQUES APPLIED TO HIGH RESOLUTION OBSERVATION OF THE SOLAR GRANULATION

Claude Aime

Astrophysics Department,I.M.S.P ,Parc Valrose,University of Nice,France.

ABSTRACT

Michelson,one-dimensional, and two-dimensional apertures are used to obtain the statistical properties of the solar granulation.The calibration of the power spectrum is performed via Michelson stellar interferometry as well as by the use of changes in seeing conditions during speckle-interferometric measurements.The correction of 40 analyses,determined with Fried's parameter r_0 ranging between 2.5 cm and 11.5 cm, provides satisfactory convergence for frequencies up to 3 cycles per arc second

1. INTRODUCTION

The solar granulation appears at the focus of a telescope as a weak brightness -fluctuation of the photosphere.Typical sizes for a granule range between 1 to 4 second of arc.Due to seeing effects and to photometric difficulties,the measurements of the statistical properties of the solar granulation found in the literature do not agree among themselves[1],either from the point of vue of the shape of the power spectrum,or for the r.m.s. brightness fluctuations (the most recent airborne measurements [2,3] vary between 8.7% and 29%) . We submit here several measurements using speckle techniques which converge toward one and the same result.

2. OBSERVATIONS

The solar granulation analysis is performed with a single photoelectric scanning detector , which allows both photometric precision and good acquisition rates . The isotropy of the solar granulation permits this one-dimensional study.The typical scanning speed used is 1 arc second per millisecond of time Three kinds of apertures were used .

https://doi.org/10.1017/S0252921100118895 Published online by Cambridge University Press

2.1 Small double and multiple apertures

We used these apertures for calibration of the solar granulation spatial power spectrum At Sacramento Peak Observatory , under good seeing conditions we used 2 and 8 hole apertures in line[4] Although the Michelson aperture is almost insensitive to seeing , this effect becomes very large for the 8 hole aperture . A comparison of these effects is shown in Figure 1, assuming the log-normal model of Korff[5-7] for the wave impinging on the aperture.

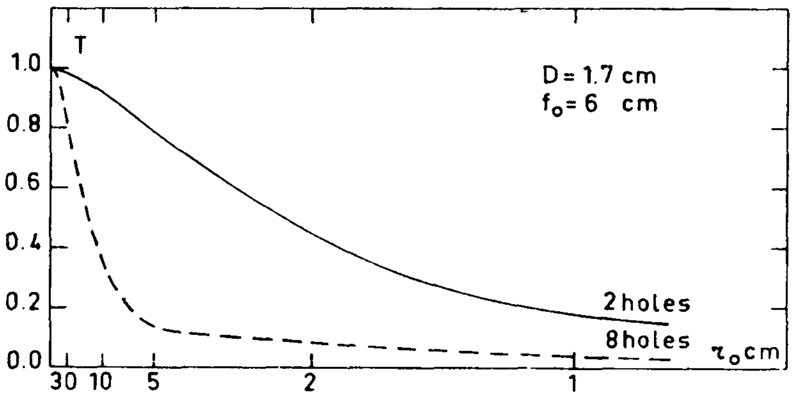

Figure 1.

Rate of the transmitted power as a function of r_o. Continuous line : Michelson aperture ; dashed line : 8 equispaced holes aperture. Hole diameter : 1 7 cm. ; distance between holes : 6 cm.

The experiment was run only under good seeing conditions The comparison of the power between 2 and 8 holes apertures leads to a Fried's parameter r_o of about 8 cm. , which implies seeing effects with the Michelson aperture less than 10%

The influence of an insufficient scanning rate (by reference to a parameter which is the ratio of the wind velocity to r_o) is shown to be a degradation of the spectral window employed in the calculation of the power spectrum.[8]

2 2 One-dimensional aperture

At Kitt Peak Observatory , in cooperation with J. Harvey , we made rapid scans of the granulation using a "one-dimensional" (2cm by 50cm) aperture in a direction parallel to the long dimension of the aperture,which scanned the elongated speckles[9] The energy transmission of the object spatial power spectrum is high since it varies as the inverse ratio of the number of coherent area N on the pupil The gain obtained here by comparison with a whole aperture is $\sqrt{N}$ versus N, while the signal to noise remains almost the same[10,11]. We used the Michelson results as a power reference The experiment leads us to the discovery of an exponential decrease of the solar granulation power spectrum up to 1 5 cycles per arc second. This potential technique appears to

https://doi.org/10.1017/S0252921100118895 Published online by Cambridge University Press

be a good compromise between standard speckle-interferometry and Michelson interferometry techniques for accurate high resolution measurements.

2.3 Two-dimensional aperture

We made successive analyses of the same central-disc region of the sun using the 76cm vacuum tower at Sacramento Peak Observatory, and computed the power spectrum of each analysis . A calibration is obtained by taking into account the changes in the seeing conditions during the experiment.For a value $r_o(i)$ of Fried's parameter corresponding to the i^{th} analysis, the observed power spectrum $W_i(f)$ can be written:

$$W_i(f) = W_r(f).\langle|S_i(f)|^2\rangle.\ F(f) \qquad (1)$$

where f is the spatial frequency, $W_r(f)$ is the real solar granulation power spectrum, F(f) accounts for the various filtering processes encountered in the image analyses , and $\langle|S_i(f)|^2\rangle$ is the Wiener spectrum of the turbulence degraded short exposure point source image.

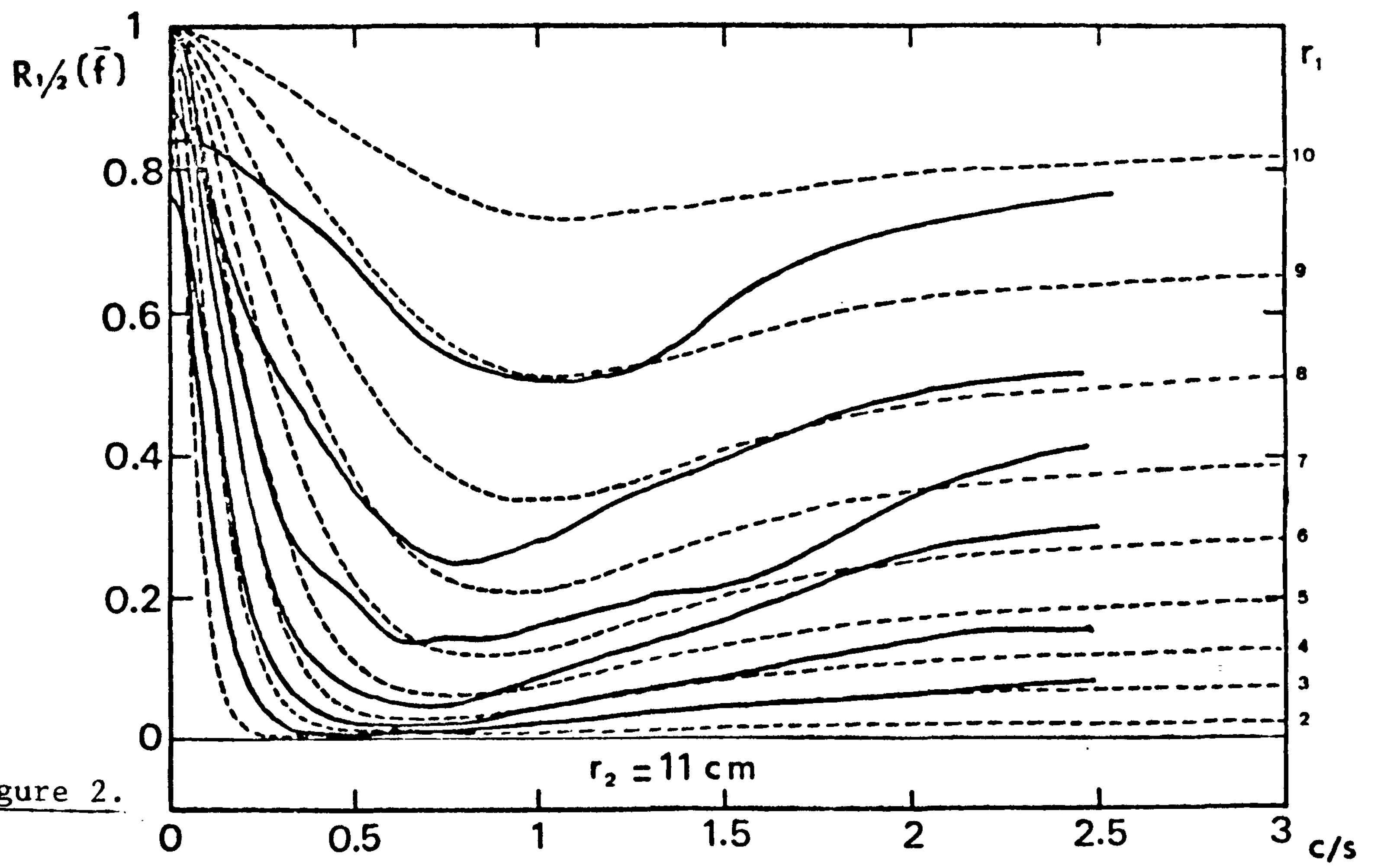

Figure 2.

By expressing the ratio $R_{1/2}(f)$ for two different values of $r_o(i)$,namely

https://doi.org/10.1017/S0252921100118895 Published online by Cambridge University Press

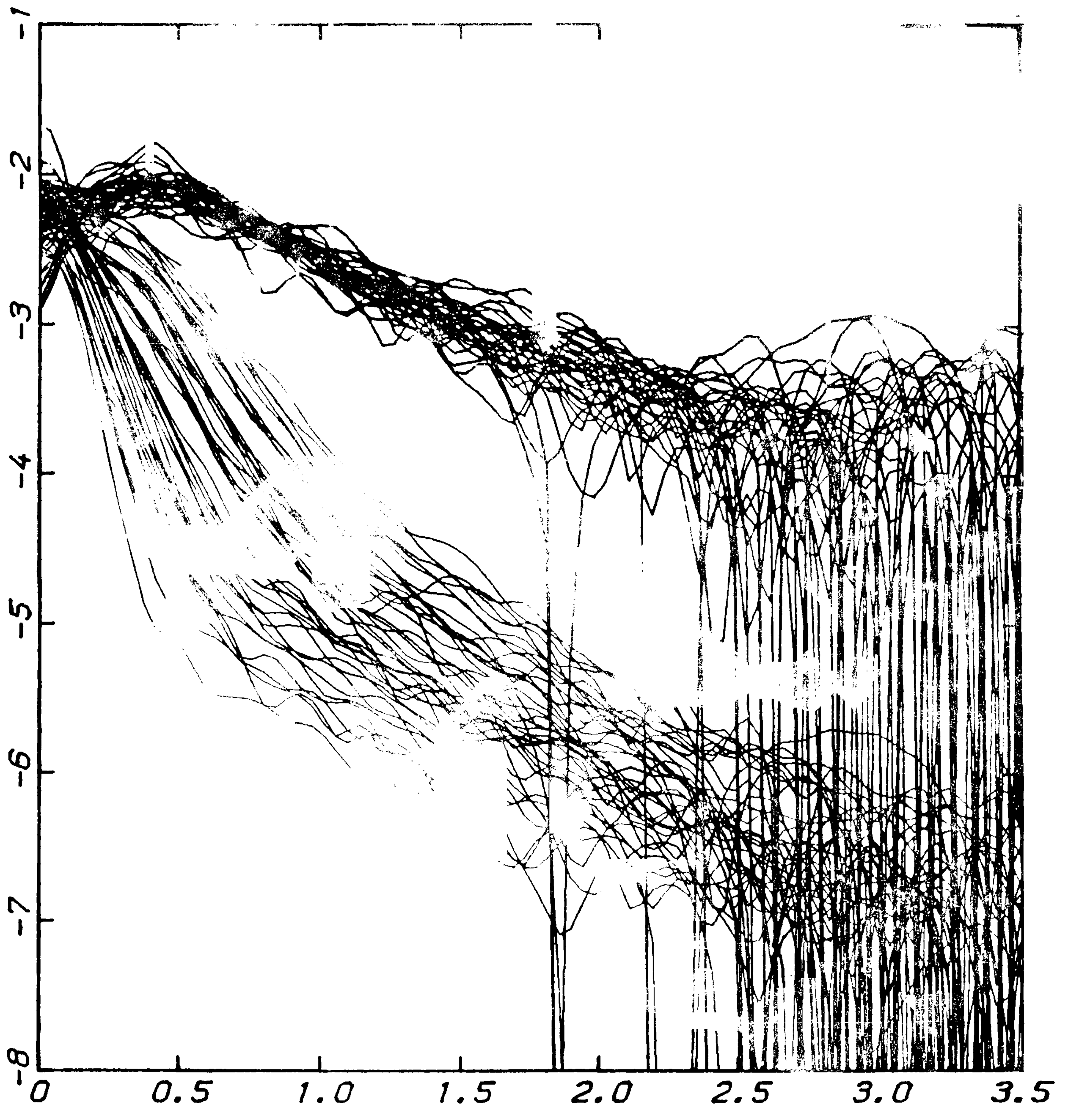

Figure 3.

Solar granulation power spectra per unit area drawn to a semi - logarithmic scale as a function of spatial frequency in cycles per second of arc . Forty analyses were obtained using the 76cm vacuum telescope at Sacramento Peak Observatory The Fried's parameter r_o was found to vary between 2.5 and 11.5 cm Observed power spectra : lower group ; corrected power spectra : upper group . Korff's theoretical assumptions are used for corrections

$i = 1,2$, $W_r(f)$ and $F(f)$ are both eliminated . Roughly , from this ratio two relations between $r_o(1)$ and $r_o(2)$ can be obtained : i) the high-frequency value of $R_{1/2}(f)$ gives the ratio of the number of speckles in each of the image,while ii) its low-frequency value expresses the relative spatial extents of the speckle patterns[12].An example of the comparison between the experimental ratio $W_1(f)$ / $W_2(f)$ drawn in full line and the theoretical ratio $R_{1/2}(f)$ drawn in dashed line is shown in Figure 2 . The log-normal assumption is used for the comparison , and is in better agreement than the normal model. Korff's model is used for correction . The observed and corrected power spectra are shown in Figure 3.

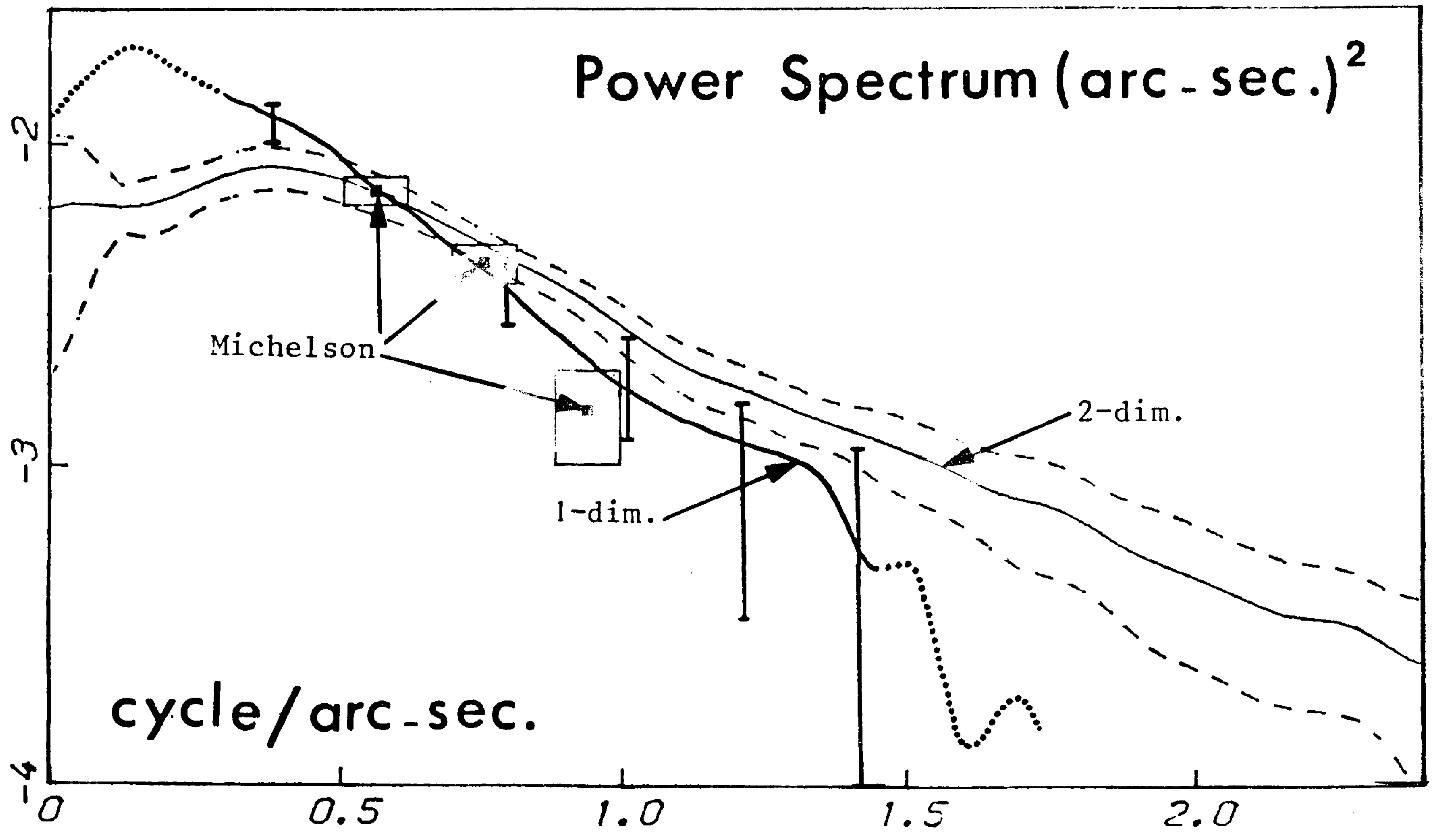

Figure 4.

3. SUMMARY

A comparison of the results obtained by the use of the three apertures is made in Figure 4 . In conclusion , interferometric techniques can be applied to non stellar astronomical objects . The check carried out on images of solar granulation is positive . Speckle interferometric determination of the atmospheric-lens M.T.F can be performed by use of changes in the seeing conditions between successive observations .

https://doi.org/10.1017/S0252921100118895 Published online by Cambridge University Press

REFERENCES

1) J.M. Beckers and R.L. Parnell, Solar Phys., 9, 39, 1969.
2) V.N. Karpinsky and V.V. Meckanikov, Solar Phys., 54, 25, 1977.
3) A. Wittmann and J.O. Mehltretter, Astron. Astrophys., 61, 75, 1977.
4) C. Aime, G. Ricort and G. Grec, Astron. Astrophys., 54, 505, 1977.
5) D. Korff, J. Opt. Soc. Am., 63, 971, 1973.
6) C. Roddier and F. Roddier, J. Opt. Soc. Am., 66, 6, 1976.
7) C. Aime and F. Roddier, Optics Commun., 19, 57, 1976.
8) C. Aime, Optics Commun., 26, 139, 1978.
9) C. Aime, G. Ricort and J. Harvey, Ap. J, 221, 362, 1978.
10) F. Roddier, J. Opt Soc. Am., 65, 664, 1975.
11) C. Aime and F Roddier, Optics Commun., 21, 435, 1977.
12) C. Aime, G. Ricort, C. Roddier and G. Lago, to be published in J. Opt. Soc. Am.

DISCUSSION

D.G. Currie: Are your results affected by the correlated scintillation out to an aperture separation of the order of 25 cm?

G. Aime: It has been shown[6] that for small aperture Michelson interferometers uncorrelated scintillation does not affect the power spectrum. The measurements we made use as a reference the continuum of the signal. The low frequencies were taken out by use of a differential method[4]. No correlated scintillation effect was detected, but then no particular attention was paid to its detection.