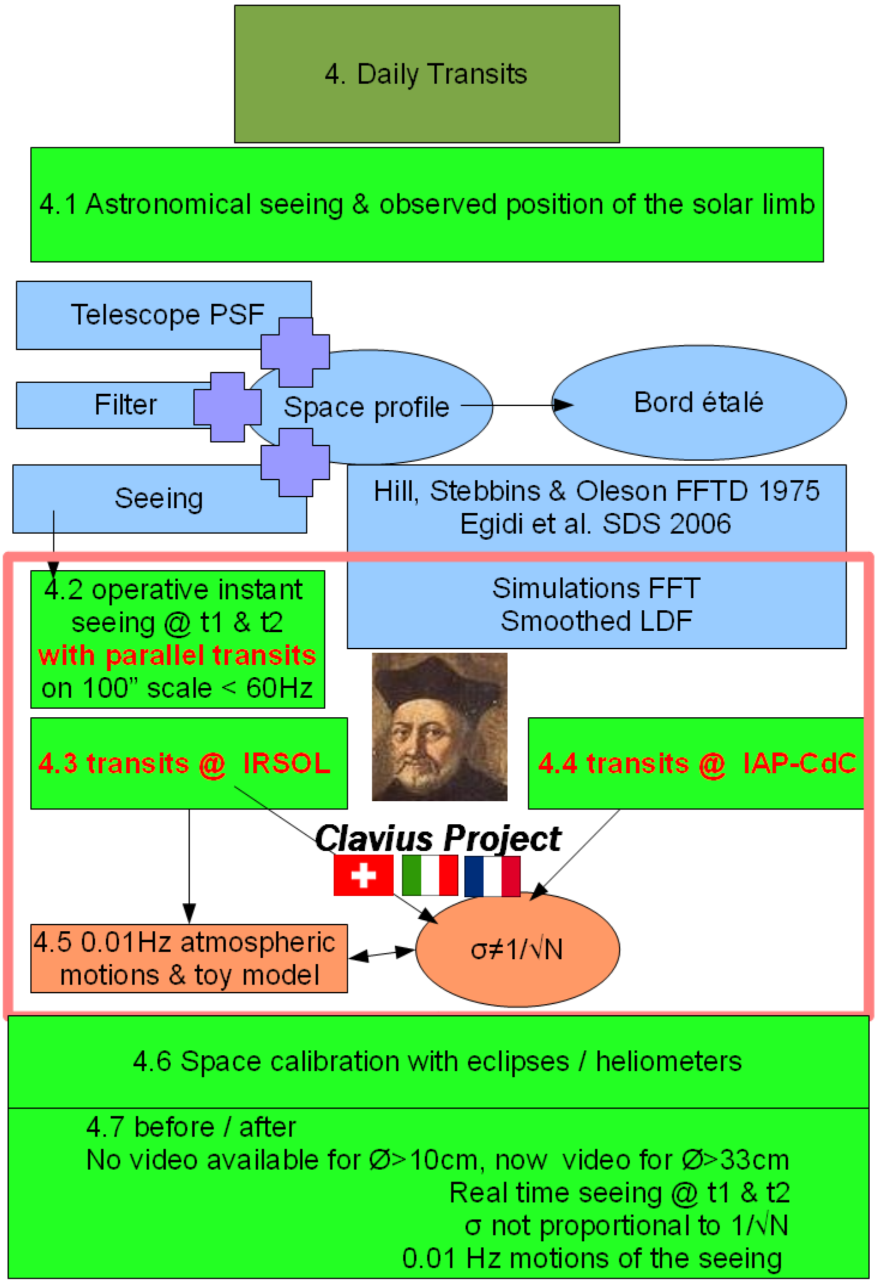
Chapter 4: Daily Transits



4.1 Seeing and observed position of the solar limb

The influence of the seeing on the observed position of the maximum of the maximum of the derivative of the luminosity profile of the Sun is here described.

The Limb Darkening Function used for the evaluation of the effect of the seeing on the inflection point position is the one of Rogerson (1959)[1] with the analytic formula used in Hill, Stebbins and Oleson

1 Rogerson, J. B. Jr, *The Solar Limb Intensity Profile*, Astrophysical J. **130** 985 (1959)

(1975).[2]

The seeing effect is represented with a gaussian Point Spread Function with Half Width Half Maximum=0.5", 1" and 1.5".

The analytic formula[3] for the PSF is PSF=exp(-((x-xo)/HWHM)^2).

In the figure 4.1 this is represented.

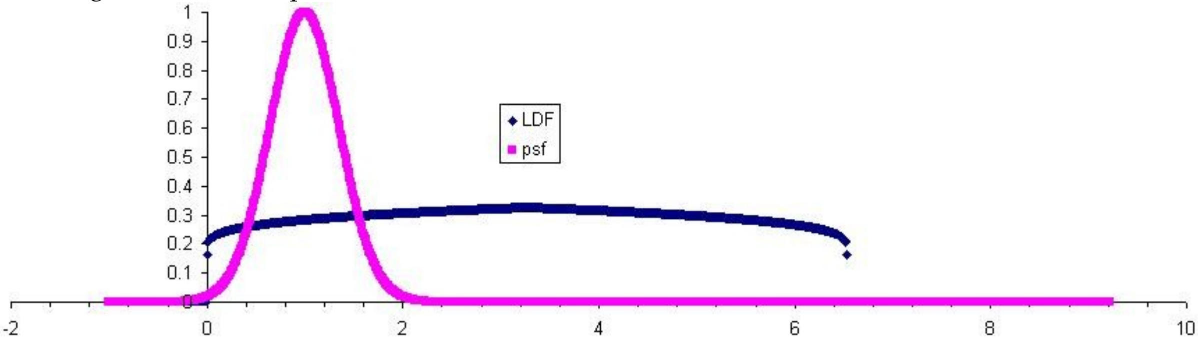


Fig. 4.1 The Point Spread Function is a gaussian of given HWHM, to represent the seeing. The Limb Darkening Function formula is from Rogerson (1959); it has been adapted to 1024 points in order to perform the FFT.

In order to studt the regions near the inflection points, in this numerical example, I have created a Limb Darkening Function composed by two mirrored parts representing the regions around the two inflection points. The LDF in the center of the Sun is not interesting for this study and does not affect the positions of the inflection points. Moreover the points are 1024 and the synthetic LDF is included within some points at zero value. This is in order to avoid the Gibbs' phenomenon and border effects during Fourier transforms. Through Fast Fourier Transform algorithm and the convolution theorem, the LDF is convoluted with the PSF and the new positions of the inflection points are detected through the maxima of the first derivative. The results are normalized at the standard solar diameter.

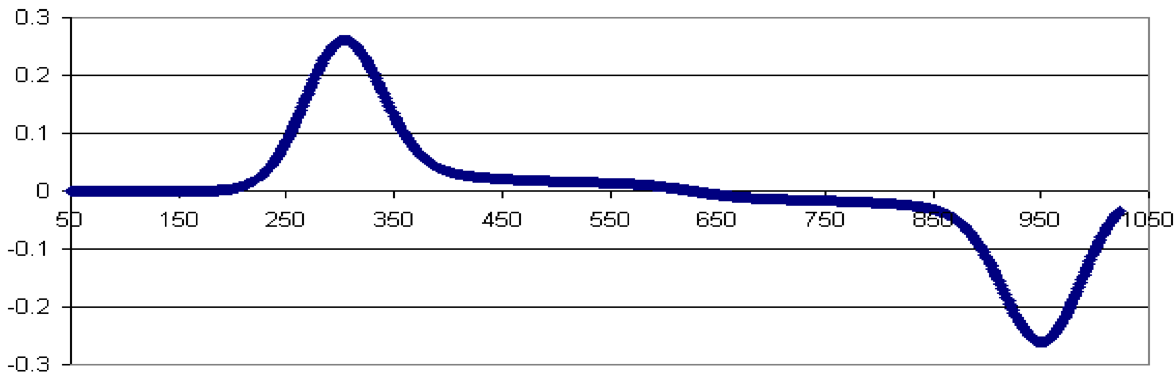


Fig. 4.2 The first derivative of the LDF convoluted with a gaussian Point Spread Function (see figure 4.1). The abscissa is in arcsec. The positions of the inflection points shift inwards. **PSF with HWHM respectively of 1; 2 and 3 arcsec give perceived diameters 0.07, 0.17 and 0.28 arcsec smaller than the unperturbed value.**

2 Hill, H. A., Stebbins, R. T. and J. R. Oleson, *The finite Fourier transform definition of an edge on the solar disk*, Astrophysical J. **200** 484 (1975)

3 Instead of the Gaussian there is also the Moffat formula I(r)=Io/[1+(r/ro)^2]^b with the parameter ro measuring the image's amplitude, slightly depending on the wavelength, b~3. I have preferred the Gaussian.

Similar results have been obtained either theoretically[4], [5],[6] and observationally.[7]
The work realized at the Observatoire de la Côte d'Azur, at the site of Calern, with the solar astrolabe and later with DORaySol has shown this phenomenon.

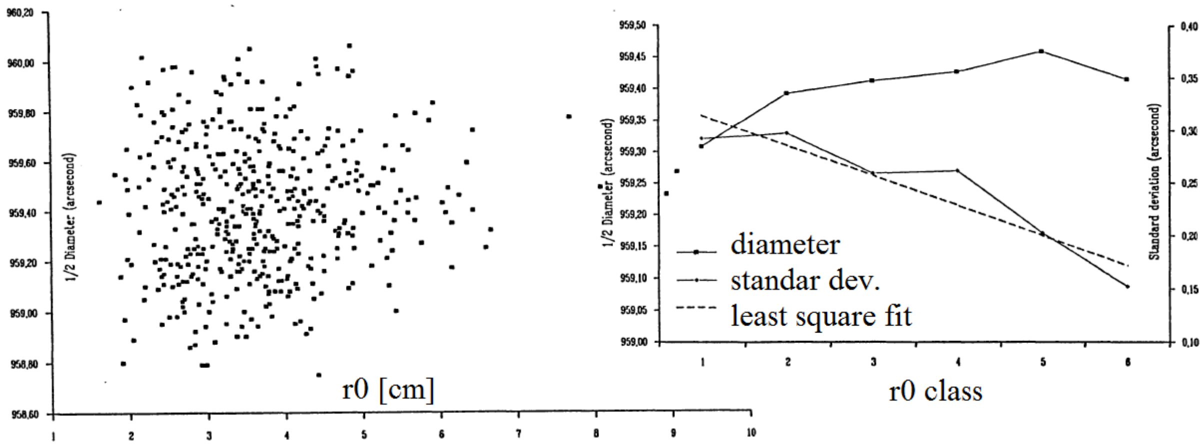


Fig. 4.3 Semidiameters of the Sun as observed at the Calern Astrolabe. Left: the distribution as function of the Fried's parameter r0. Right: Average values and their standard deviations. The difference between the observed diameters was less than 0.08 arcsec.[8]

The evolution of the error with the seeing parameter shows a decrease of the diameter measurement error with good seeing conditions as predicted by the theory. The figure 4.3 reproduced from fig. 10a and 10b of Irbah et al. (1994) has been plotted with the intent of observing the atmospheric effects on the diameter's value. Solar diameter measurements are represented in the left part, according to the seeing parameter values. The diameter values have been divided into 6 classes with equal width from r0=1 cm to r0=7 cm. A mean value of the solar diameter has been calculated for each r0 class and it is represented in the right part of figure 4.3. In this right part, however, it is shown a slight decrease of the solar diameter with a degradation of seeing conditions. The difference of solar diameter values corresponding to the worst and best seeing at Calern Observatory is of order of 0.08 arcsec. The standard deviation has been calculated for each r0 class. As already observed with the diameter measurement error, the results improve with good seeing. In fact the standard deviation of diameter values is about 0.3 arcsec when the r0 value is 2 cm and falls down linearly to 0.15 arcsec when r0 is equal to 7 cm.
The authors of this study concluded that "it can be noted that variations less than 0.08 arcsec could not be observed in the mean solar diameter. Since the maximum occurrence of the Fried's parameter during the observations at Calern Observatory is 4 cm, variations less than 0.26 arcsec of the solar diameter can not currently be observed".
The more simple approach to demonstrate the phenomenon of the shifting of the inflection point which reduces the observed diameter, expressed in French as **"étalement du bord"**, is the aforementioned numerical method of FFT of the LDF convoluted with the PSF of the seeing. The analytical formula ΔD(A, K, K1, r0, k) presented in the same paper, requires 4 parameters in addition

4 Borgnino, J. *Etude de la dégradation des images astronomiques diurnes par analyse statistique des fluctuation d'ange d'arrivée*, PhD Thesis, Université de Nice (1978).
5 Berdja, A. and J. Borgnino, *Modelling the optical turbulence boiling and its effect on finite-exposure differetial image motion*, Monthly Notices of the R. Astronom. Soc. **378**, 1177 (2007)
6 Berdja, A., *Effets de la Turbulence Atmosphérique lors de l'Observation du Soleil à Haute Résolution Angulaire*, PhD Thesis, Université de Nice-Sophia Antipolis (2007)
7 Irbah, A., Laclare, F., J. Borgnino and G. Merlin, *Solar diameter measurement with Calern Observatory astrolabe and atmospheric turbulence*, Solar Physics **149** 213 (1994)
8 Irbah, A., Laclare, F., J. Borgnino and G. Merlin, *Solar diameter measurement with Calern Observatory astrolabe and atmospheric turbulence*, Solar Physics **149** 213 (1994) Fig. 10a and b.

to r0. These parameters have to be adjusted from observations. I prefer a single parameter[9] formula, depending only on r0: the advantage of the whole formula does not seem of any suitable use in practical cases. Moreover the authors declare that 0.08 arcsec is the maximum sensitivity of the Astrolabe at the seeing conditions of the Calern site: this is one more reason to use my linear fit from a numerical approach.
The numerical approach has the advantage to put in clear evidence the physical origin of the phenomenon: the convolution of a PSF with the LDF. With other types of LDF (as a step function) this phenomenon could not appear as well.

Already in 1975 Hill Stebbins and Oleson did show the effect of a convolution with Gaussians of the Limb Darkening Function, as it is shown in their figure 2.

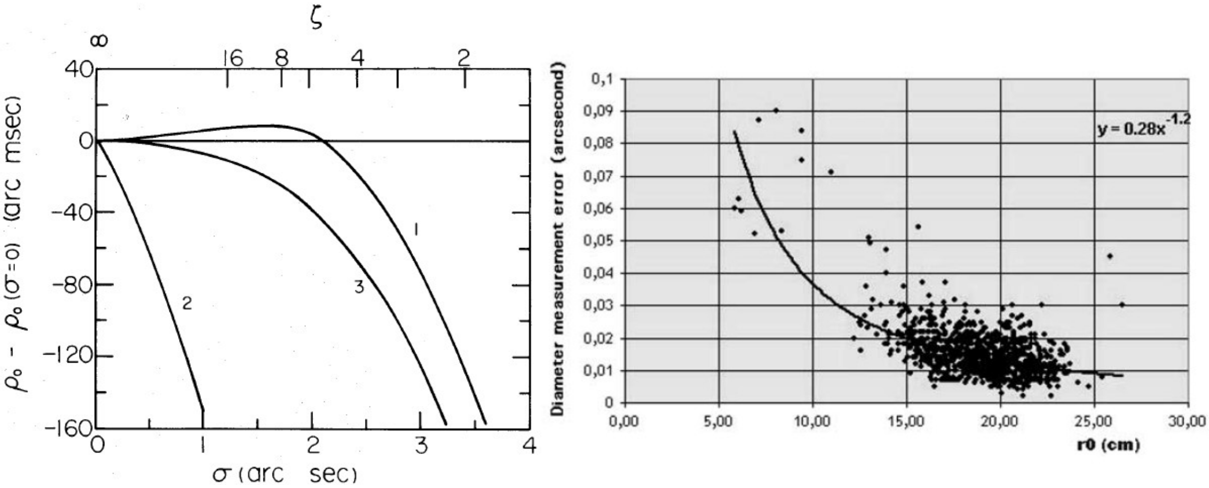


Fig. 4.4 Other Seeing – étalement relationships. Left: from Hill Stebbins and Oleson (1975) the reduction of the solar radius (displacement of the inflection point) as function of the seeing σ. The methods of edge definition are three: 1 stands for FFTD, 2 for second derivative technique and 3 for the integral definition. Right: from Rozelot, Lefebvre and Desnoux (2003).[10]

The diameter of the Sun in the paper of Rozelot, Lefebvre and Desnoux (2003) is considered at larger r0 parameter with respect to Calern. This is because the observations have been carried out at the Pic du Midi Observatoire at 2861 m on the Mounts Pyrenées, under exceptional seeing conditions.
Nevertheless, considering that r0=10 cm corresponds to 1 arcsec and r0=5 cm is 2 arcsec, the order of magnitude of the "étalement" is verified.
My synthetic numerical data are framed in the following synoptic **table 4.1**:

Seeing	1 arcsec	2 arcsec	3 arcsec
Fried's Parameter R0	10 cm	5 cm	3.3 cm
Δ Diameter FFT (this work)	-0.07 arcsec	-0.17 arcsec	-0.28 arcsec
Δ Diameter Hill&al.'75(aver.)	-0.12 arcsec	-0.22 arcsec	-0.32 arcsec
Δ Diameter Rozelot & al.'03	-0.038 arcsec	-0.10 arcsec	-0.17 arcsec
Δ Diameter Irbah & al. '94	-0.07 arcsec	-0.17 arcsec	-0.27 arcsec

9 *Entia non sunt multiplicanda praeter necessitate* (William of Ockham).
10 Rozelot, J. P., Lefebvre, S. and V. Desnoux, *Observations of the Solar Limb Distortions*, Solar Physics **217** 39 (2003).

4.2 Instantaneous measurement of the seeing

The method of parallel transits[11] is here presented.

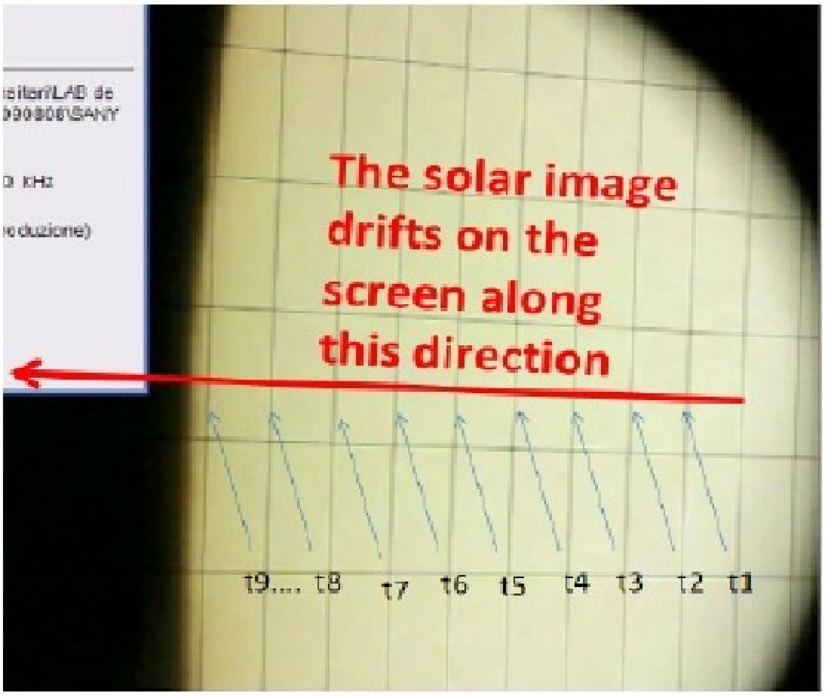


Fig. 4.5 Parallel transits technique: A regular grid is on the focal plane, the projected image of the Sun sweeps on the grid.

Without seeing the time intervals tn+1-tn are all equal. The standard deviation σ of time intervals is related to the seeing ϱ by the formula **ϱ″=15″·σ·cos(δ)** where δ is the solar declination This formula has been applied to calculate the contact errors in arcsec, for the figure 4.5.

The most simple way to measure the seeing is by projection of the solar image on a regular grid during a drift-scan observation. A videocamera records the transit of the solar limbs above the grid, and the time intervals required to cover the evenly spaced intervals of the grid are measured by a frame by frame inspection. The preliminary studies on this subject have been conducted at the Meridian Line of the Clementine Gnomon in Santa Maria degli Angeli in Rome. The advantage of this location is to have a fixed pinhole projecting the solar image on the floor at large distance. The image of the Sun is studied with a video frame by frame.

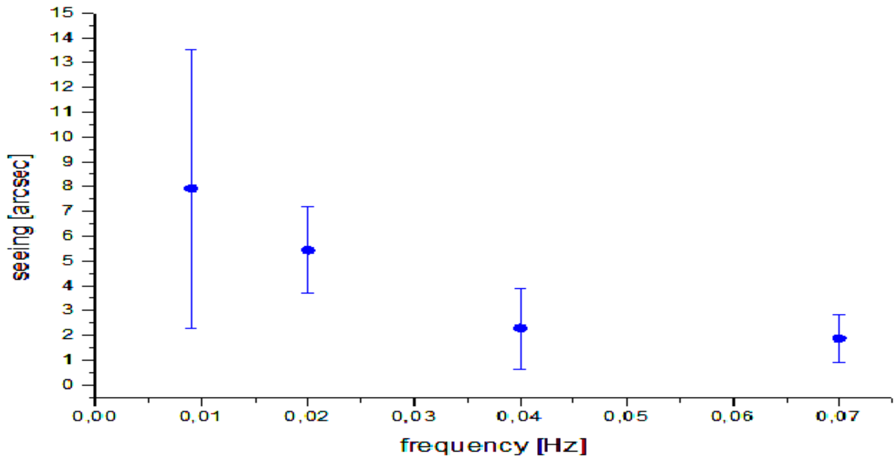


Fig. 4.6 Parallel transits technique: the power spectrum of the seeing. As an application of this technique we obtained the power spectrum of the seeing at discrete values of the frequence. The data around 0.07, 0.04, 0.02 and 0.01 Hz

11 Sigismondi, C., IAUC **233**, 522 (2006).

correspond to the time intervals measured over 1, 2, 4 and 8 rows respectively.[12]
The diffraction is the lower limit of the detectable amplitude of the seeing.

For our application we used the Lucernaria Dome indoors Basilica Santa Maria degli Angeli e dei Martiri in Rome. The Lucernaria lenses are fixed solar telescopes with opening 6.3 cm and focal lenght 20 m.[13] The resulting diffraction is 2.31 arcsec for $\lambda = 550$ nm.

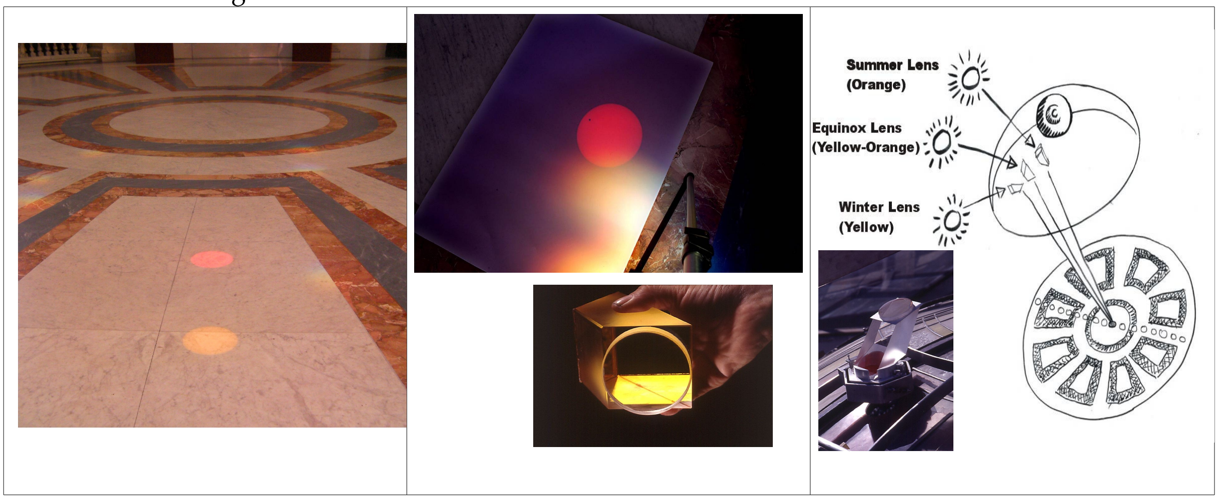


Fig. 4.7 Lucernaria lenses at Santa Maria degli Angeli in Rome. The red image of the Sun at the center of this collage is a summer image taken on June 8, 2004 during the transit of Venus. The yellow-orange and red ones are taken on August 21, 2009. The lenses are shown alone and built in the external part of the lucernaria dome. The lenses have been designed and settled by Salvador Cuevas Cardona.[14]

In another paper by Irbah et al. (2003)[15] based on Calern observations with the solar astrolabe gave larger errorbars on the diameter measurements. I report their figures in order to show the correspondance between errorbars in time and arcsec.

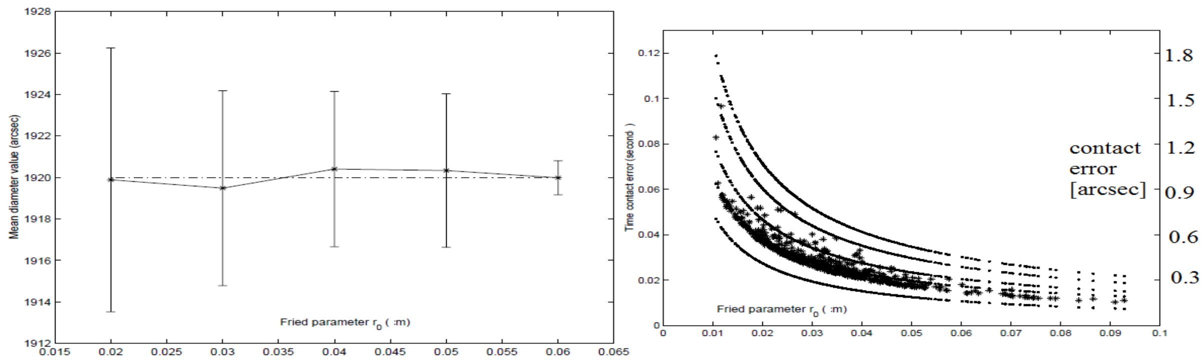


Fig. 4.8 Seeing – étalement relationships and time contact errors vs seeing. Left: the measured diameter as function of the Fried's parameter. Right: time contact errors from long to short exposure times (from bottom to top); the stars correspond

12 A. Raponi, X. Wang, C. Sigismondi, G. De Rosi, M. Bianda, R. Ramelli, M. Caccia, *The power spectrum of the seeing during solar observations*, 4th French-Chinese meeting, Nice 15-18 November 2011.

13 Cuevas, S., *Lucernaria Prismatic Lenses*, Il Cigno GG Roma, ISBN: 978-88-7831-213-4 (2009).

14 It is remarkable that S. Cuevas Cardona has studied at the école de optique in Paris, as the major optic engineers of Nice University. I come in contact with them independently. He professor of Astronomy at the University of Mexico City.

15 Irbah, A., Bouzid, A., Lakhal, L., Seghouani, N., Borgnino, J., Delmas, C. and F. Laclare, *Atmospheric turbulence and solar diameter measurement*, The Sun's Surface and Subsurface: Investigating Shape. Edited by J.-P. Rozelot., Lecture Notes in Physics, vol. 599, p.159-180 (2003).

to experimental values. Adapted from Irbah et al. (2003).

4.3 Transits at the IRSOL 45 cm Gregory-Coudé telescope

The tradition of solar diameter's measurements in Locarno goes back to the late years 1970s with visual observations. Two twin Gregory-Coudé telescopes of 45 cm aperture, designed for solar observations, operated simultaneously in Switzerland and Canary Islands with drift-scan methods between 80's and early 90's. The opening diameter of the telescope is larger than any turbulent atmospheric cell, allowing a better stability in the observed solar diameters.

Fig. 4.8 The Gregory-Coudé solar telescope at IRSOL, 500 m above sea level, and 300 above the Maggiore lake. This instrument benefits of very good seeing.

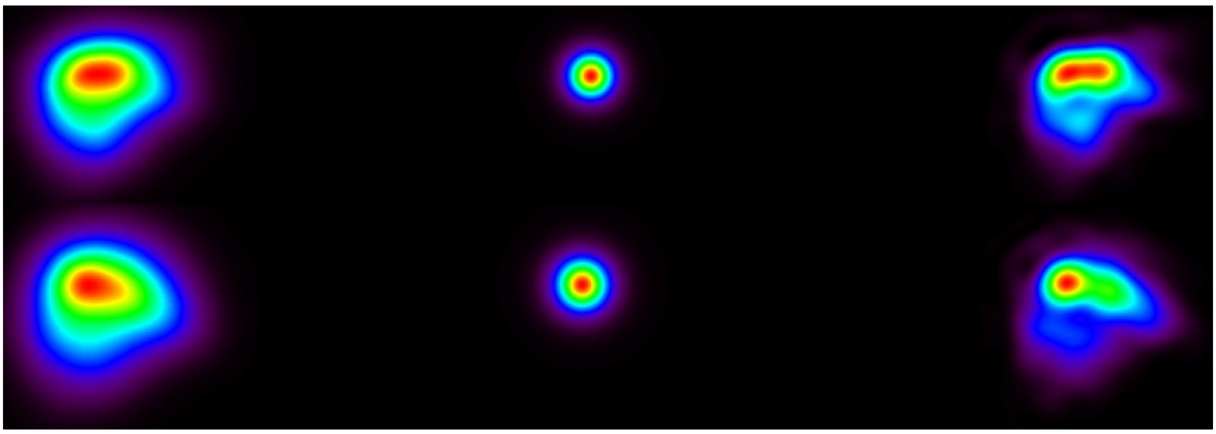


Fig. 4.9 PSF tests with Markab α Peg (up) and Sadamelik α Aqr (down) at IRSOL Gregory-Coudé solar telescope. The seeing spreads the instrumental PSF, but the asymmetries are due to misalignments in one secondary mirror.[16] Left and right mages are defocussed[17] images (encoder 530/554 and 624/648). Center: on focus

16 Jolissaint, L., J. Christou, P. Wizinowich, and E. Tolstoy. *Adaptive optics point spread function reconstruction: lessons learned from on-sky experiment on Altair/Gemini and pathway for future systems,* In Astronomical Telescopes and Instrumentation, volume **7736** of SPIE Proceedings, July 2010.

17 Roddier, C. and F. Roddier, *Wave-front reconstruction from defocused images and the testing of*

(encoder 589) ideal PSF.[18] An irradiation[19] effect 2.5 times the ideal PSF affects this telescope.

The study on the PSF is important in order to define the solar limb. Near the limb the PSF is convoluted with a rapidly variating Limb Darkening Function. A symmetrical PSF, and very sharp, is the ideal situation.
The different components of the seeing act upon different angular scales.
There are three main effects of the seeing: blurring, image motion and lensing. The blurring is at the arcsecond scale, the image motion involves all the figure of the Sun at a scale of about 2000 arcseconds, and the lensing corresponds to a deformation comparable with the full disk scale.

We have images of a 100 arcsec scale. From each image of the solar limb obtained during a drift-scan observation we reconstruct a regular arch of a circle from the distorted solar limb. We measure this medium scale effects of the atmospheric turbulence (seeing) by the irregularity of the motion of such arch.
The motion of an arch defined by a fitting curve over 100 arcsec is averaged over the same space scale. Therefore this motion is more regular than the motion of a single point. For this reason values of the seeing as low as 0.6 arcsec have been measured during August 2008 in Locarno.
The afternoon in Summer presents usually good observing conditions in Locarno, due to the presence of the lake, but the low value is a cumulative value on the whole observed arch.
A single point-like solar spot would produce a much more scattered motion, as observed with the solar heliometer at the National Observatory in Rio de Janeiro on 14 February 2011 and in Santa Maria degli Angeli Clementine Gnomon, which is a giant pinhole solar telescope, on 1st July 2006.

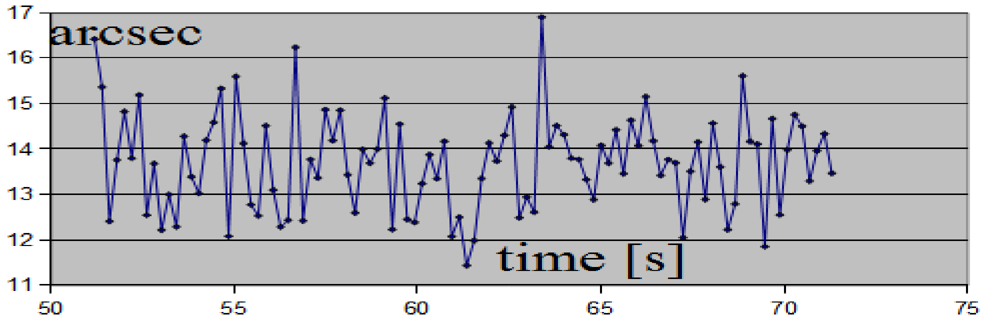


Fig. 4.10 Position of a small solar spot, observed at the Heliometer of Rio de Janeiro, in drift-scan mode. The seeing is the standard deviation of such oscillations:1.07 arcsec.[20]

This determination of seeing is strictly related with the measurement of the solar diameter: if the seeing is determined from the scatter of contact times, as in the solar astrolabes, this value has to be associated with the spatial scale of the fitting parabola, and not with a point-like source. Consequently the Fried's parameter changes, and in general, it increases.

The observation of the transits of the Sun at Locarno has been made with the Gregory-Coudé vacuum telescope of 45 cm aperture and 25.0 m of focal length. The instrumental field of view gives a portion

ground-based optical telescopes, Journal of the Optical Society of America A, **10**:2277{2287, November 1993.

18 Images obtained by Renzo Ramelli and Michele Bianda at IRSOL in November 2010, and elaborated by Laurent Jolissaint (Aquilaoptics.com)

19 See next section 4.4 for an operative definition of irradiation. It is due to the PSF wings beyond the diffraction limit.

20 The max and min position are 16.91 and 11.43 arcsec, and the corresponding standard deviation in case of uniform distribution would be 1.58 arcsec [(b-a)/√12].

(about 100 arcsec x 200 arcsec) of the solar image, from which we recover the curvature of the limb and the solar center.
The image of the Sun is projected on the CCD Baumer camera, and it is digitalized. The figures 4.10 hereafter represent the motion of the center of the Sun as recovered from the Northern limb, tracked for 1000 s, and the corresponding FFT power spectrum over frequencies, in abscissa, from 1 to 1/100 of such timespan.

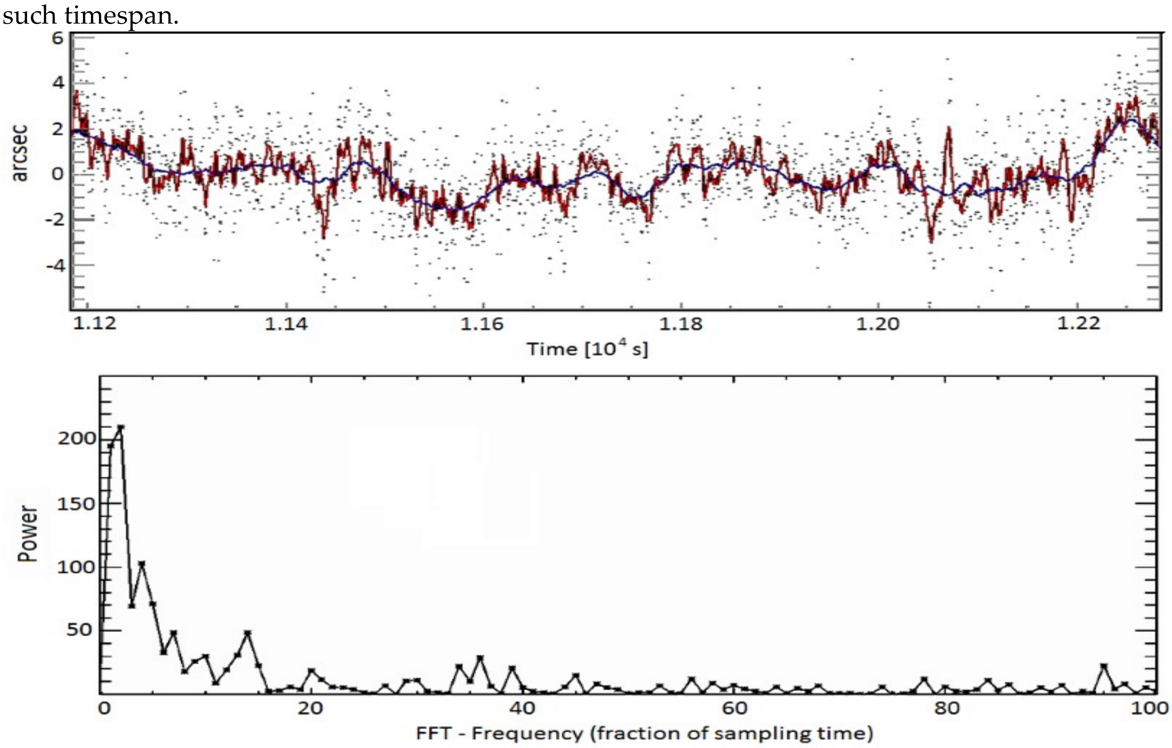


Fig. 4.11 Variation of the center of the Sun over 1000 s at IRSOL Telescope. The FFT shows clearly power at low frequencies, to be associated with slow image motion.

The Northern limb is considered as position angle P.A.=0 degrees. In this image, for the first time, the effect of "sub-Hertz" fluctuations is evidenced to the amplitude of one arcsecond.
This phenomenon explains the difference between two following measurement of the solar diameter made with drift-scan method, and this also explains the need of several measurements to be statistically averaged in order to give a reference value for the solar diameter.
But several measurements can occur under different meteorological conditions even in the same day, and the single measurements cannot be considered as statistically independent, as the Gaussian hypothesis requires.
That is the reason of the great scatter that the yearly averages published for Greenwich and Capitol Observatory both show.[21] Also modern CCD measurements show significant scatters within the same series of diameter measurements.[22]
The IRSOL telescope is larger than turbulence cells, and rather independent of them, while all solar astrolabes have objective lenses of about 10 cm, comparable with some of the turbulent atmospheric cells.
From 2008 this method has been included in the framework of the Project Clavius, among Italian and Swiss scientific Institutions, for the development of fast detector for physics and astronomy.
The drift-scan project at Locarno is being upgraded with fast imaging detectors, exploiting the idea of simultaneous measurement of the seeing and of the solar diameter.
We started with a commercial SANYO CG9 with CMOS detector at 60 frames per second, reaching a

21 Gething P.J.D., *Greenwich observations of the horizontal and vertical diameters of the Sun*, Monthly Notices of the Royal Astronomical Society, **115**, p.558 (1955).
22 Wittmann A. D., Alge E. and M. Bianda, *Detection of a significant change in the solar diameter, Solar Physics*, **145**, p. 205, 206 (1993).

resolution of 0.25″ for a single diameter measurement, and we used either a CCD Baumer camera as a detector and the ultra fast MIMOTERA CMOS detector.

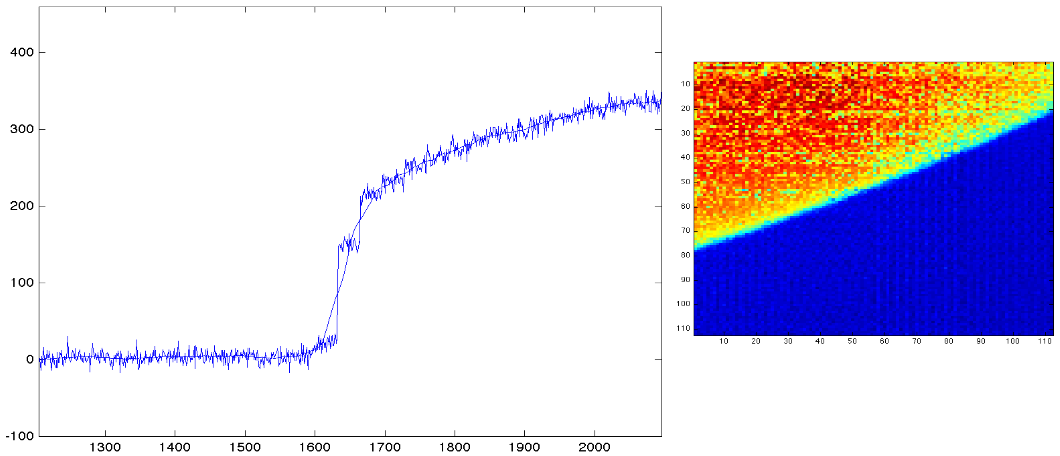


Fig. 4.12 MIMOTERA's image and profile of the radial luminosity of the Sun.

How the number of measurements improve the statistics? We can obtain more than 30 consecutive diameters (as in the 1990s) per day using the grid method. For this purpose we organized 4 observational sessions in coincidence with solar eclipses: August 1st 2008 partially visible from Locarno under clouds; July 22, 2009 not visible from Locarno; and January 4, 2011 completely clouded out in Locarno. Another observational session was conducted after July 10, 2010 eclipse, total over Easter Island and not visible from Locarno.

The conclusion of this study has been the following: the better determination possible with drift-scan method is to observe the Sun with two instruments in parallel: one wide field (about six solar radii) and another with narrow field of view (about 100/200 arcsec). With the wider field of view the image motion contribution can ben detected and isolated, in order to correct the diameter's measurement limb-to-limb.

4.4 Transits at the Carte du Ciel 33 cm refracting telescope

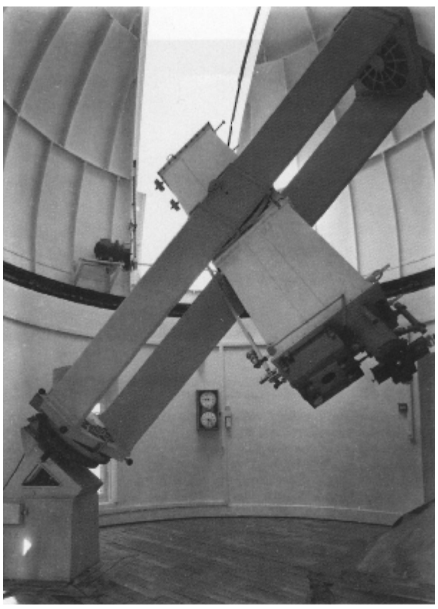
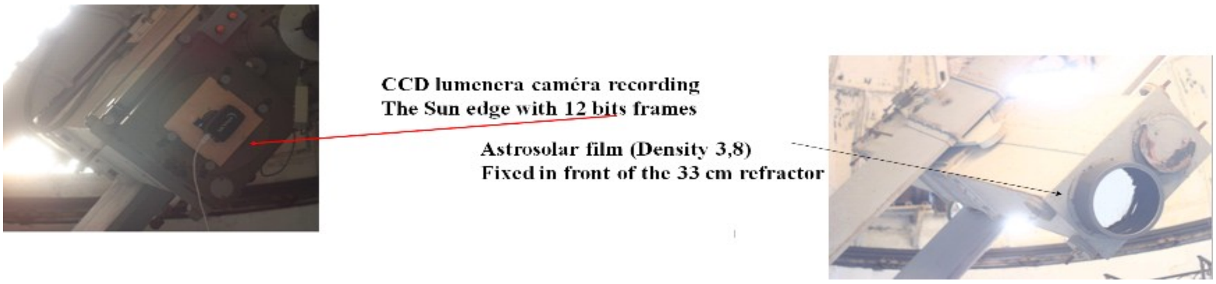


Fig. 4.13 The Carte du Ciel: two refracting telescopes of 25 (visual) and 33 cm designed for astrophotography.

This historical telescope (located at the Institute d'Astrophysique and Observatoire de Paris) used for astrophotography since 1885, has been equipped with a CCD camera Lumenera and screened with a panchromatic filter in astrosolar.



The Carte du Ciel 33 cm refracting telescope in Paris, used for our transit measurements, has a PSF particularly clean because of no obstructions in its optics, and a very small scattered light effect.

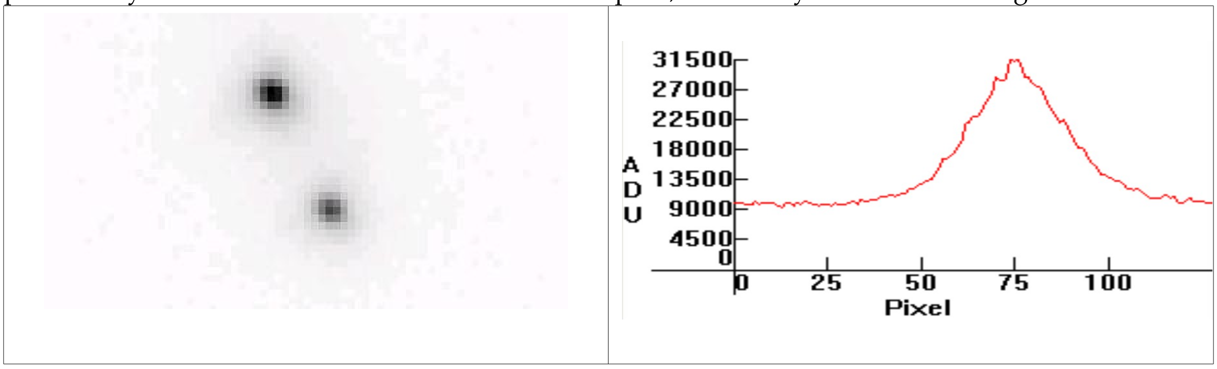


Fig. 4.15 Left: Epsilon 2 Lyrae as seen with the 33 cm refractor of the Carte du Ciel. The angular distance of the two components is 2.35 arcsec. **The FWHM of the PSF <0.5 arcsec, i.e. the instrument is diffraction limited. Right: Sirius spread function in daylight** (about 2.5 arcsec FWHM due to the seeing turbulence). A pixel corresponds to 0.1 arcsec.

The PSF test with epsilon 2 Lyrae has been realized with a blue filter of 460 nm, by the superposition of 66 selected images of 50 ms of exposure (22 october 2010). The same instrument, with an astrosolar filter, is used for the solar transits, under much more turbulence. The advantage of this instrument is the minimal irradiation. On the contrary, all other instruments used in the past, had an irradiation larger than 1.5 arcsec.

The Carte du Ciel is 3.6 meters F/21 telescope without central or offaxis obstructions and any secondary mirror, neither flat neither curved. It is well known that any secondary mirror introduces irradiation effects, and modifications of the PSF.

Thanks to these considerations the Carte du Ciel is an ideal instrument for the transits to measure the solar diameter with the drift-scan method.

The exposure time in Sun light is much smaller than 50ms, but the turbulence larger and the final effect on PSF can be as large as seen for Sirius on October 1st 2010 (fig. 4.15 right).

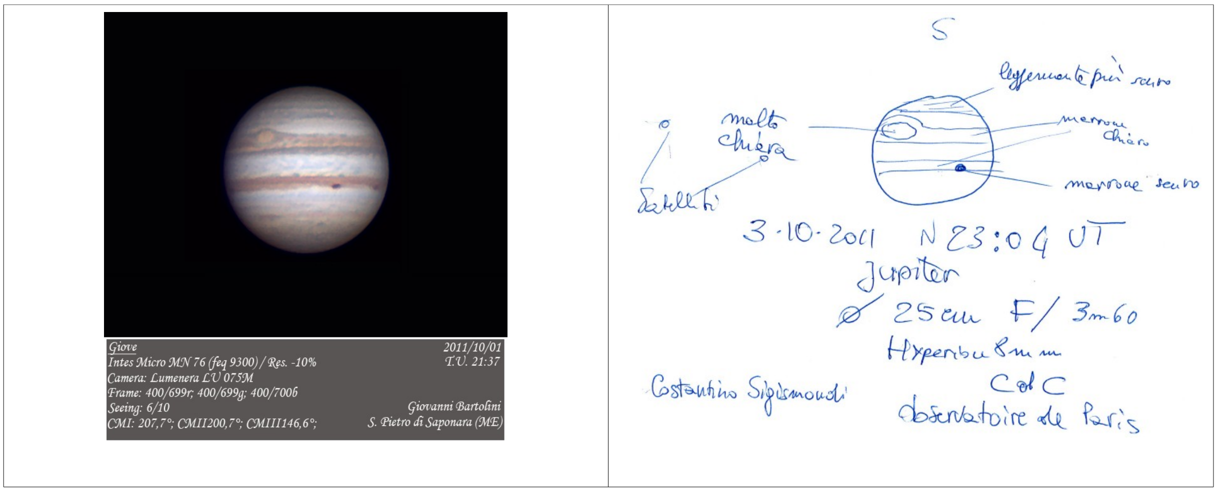


Fig. 4.16 Jupiter Left: with CCD; Right: drawn at the 25 cm refractor of Carte du Ciel on October 3, 2011. Alse the PSF of this telescope yields a stunning image.

4.5 Evidence of 1" slow image motion of the whole solar image

The diameters obtained in consecutive measurements are not consistent within all the experimental errors. The first results of the new measurements tests for both telescopes (2008-2010) are discussed: the effect of low frequency waves (0.01 Hz) in the atmosphere could explain the difference in the successive hourly circle transits' measurements. This finding can cast some light also on some ancient puzzling data (Rome - Campidoglio & Greenwich observations).

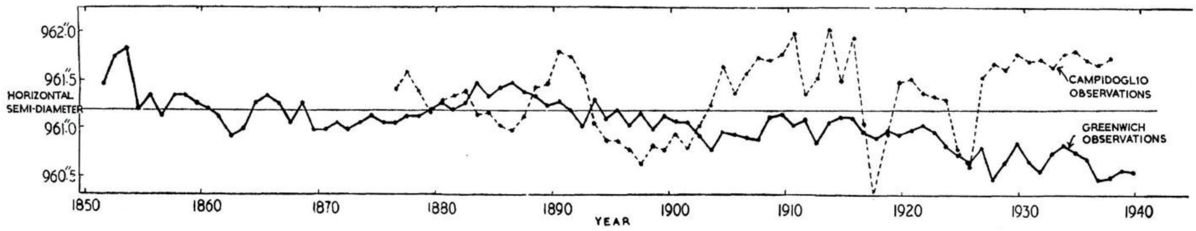


Fig. 4.16 The series of observations of the solar diameter in Greenwich and in the Capitol's observatory in Rome.

The are various puzzling problems that this figure presents.

The meridian transits have been averaged over a whole year for each point. The large scatter between each value (up to 1.5 arcsec in the case of Capitol's observations in 1917-18, at the end of the First World War) suggests that the data are not normally distributed.

If the N data for each year would be Gaussian, their average would be spread within √N, and so the large variations detected would be considered as real.

So what is the origin of these large scatters between the yearly averages?

To avoid "personal equations" the roman observatory employed four observers at each transit, which was projected on the ground on a grid of evenly spaced lines.

Each one evaluated the time of the contacts with the eye-ear method.

It happened that in 1917-18 only one observer operated, while for the Greenwich observations we have a single observer along the years, and ageing processes in his vision could contribute to systematic effects.

The differences among the yearly averages remain still unexplained, under a statistical and an experimental point of view. I wish to remember that these astronomers were very skilled observers and fine physicists, devoted to obtain the most accurate measurement possible.

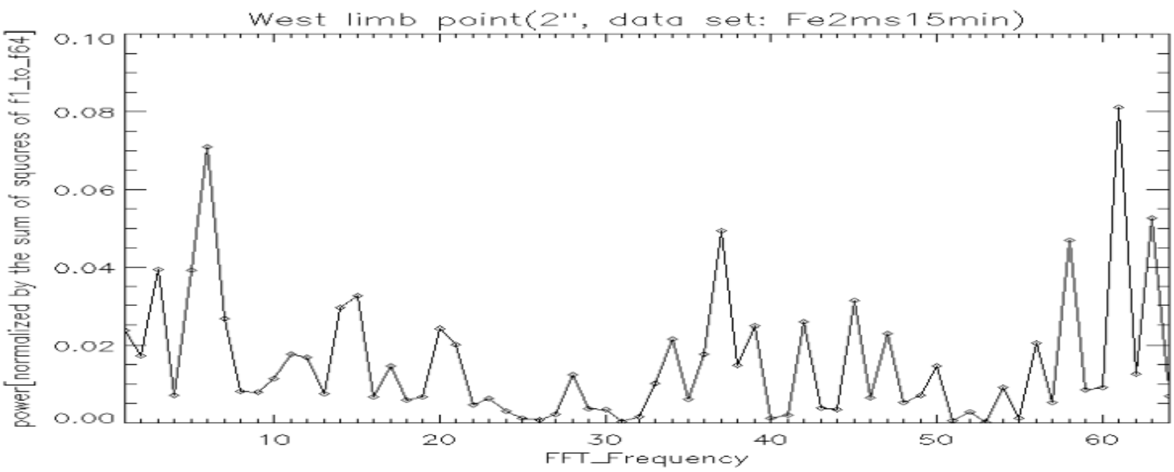
The discovery of the 0.01 Hz fluctuations of the atmosphere starts to unveil this mystery.

Also the consideration that the Airy's meridian circle in Greenwich was a 6 inches instrument, i.e. a 15.2 cm with its Point Spread Function effect, and the roman instrument was a 11 cm telescope can contribute to explain the larger scatter in the roman data.

Fig. 4.17 Left: **the observatory of Campidoglio in Rome**, as before 1937 when it was destroyed. It has been founded by pope Leo XII in 1829. Ancient photo.
Right: the telescope used for the meridian transits in the observatory of Campidoglio in Rome, gift of pope Pius IX in 1853.

Presently the instrument used in the Capitol Observatory (no longer existing since 1937) is conserved at the hall of Monteporzio Catone Observatory, with an incomplete label.

The measurements taken in Locarno (fig. 4.11) have been repeated in Huariou Solar Station (China, National Observatories).[23]
The observation of the full solar disk is performed with the Solar Magnetism and Activity Telescope (SMAT)[24] that is a telescope with a tele-centric optical system of 10 cm aperture and 77.086 cm effective focal length realized to investigate the global magnetic configuration and the relationship with solar activities. The birefringent filter for the measurement of vector magnetic field is centered at 5324.19 A (Fe) and its bandpass is 0.1 A.
The detector is a CCD camera, Kodak KAI-1020. it is used for the measurement of full disk. The image



size of the telescope is 7.4mm×7.4mm, and the size of CCD is 992×1004 pixels.
The frame rate of the CCD camera is 30 frame/s and its maximum transmission rate is 60 Mbyte/s.

23 A. Raponi , X. Wang, G. De Rosi, M. Bianda, R. Ramelli, *The power spectrum of the seeing during solar observations*, 4 meeting Franco-Chinois, Nice 15-18 November 2011.
24 Zhang, H. et al., *Solar Magnetism and the Activity Telescope at HSOS,* Chinese Journal of Astronomy and Astrophysics, **7**, pp. 281-288 (2007).

The exposure time is 2 ms.

Fig. 4.18 The power spectrum of the seeing at Huairou Solar Station (China). The timespan is 15 minutes, 60 corresponds to 1/60 of this time, i.e. 15 s; 30 to 30 s; 15 to 1 minute and 5 to 3 minutes. There is power at all these timescales.

4.6 Space calibration of transit's measurements

Combined observations space-ground: eclipses and drift-scan. In the occasions of two total eclipses of 1st August 2008 and 22nd July 2009 we have made drift-scan observations at Locarno observatory, and a third session was planned for 11 July 2010 eclipse. A single day of observations made with DORAYSOL on 23 September 2006 can be considered as overlapped with the annular eclipse of 22 September, observed in French Guyana.

The same strategy is planned between SDS and Picard. A new flight of SDS (after the one still unpublished occurred in october 2009), shall be done during the Picard mission to compare the space measurements with the balloon-borne ones.

These observations, after the discovery of sub-Hertz image motion, have to be done with two telescopes: one for the details with 100 arcsecond field of view, and the other in parallel with 4 solar radii field of view to see the image motion.

4.7 Before and after this work

The situation of this filed of research before and after this work is described, putting into evidence the new contributions.

The role of seeing fluctuations under 1/10 and 1/100 of Hertz is crucial in drift-scan measurements of the solar diameter, either meridian transits or almucantarat transits. This study firstly evidenced this effect in a clear way. The fluctuation's scale is not defined here, since we did not apply the analysis to a single point only, but also on solar limb arches of several arcseconds (from 200 for IRSOL to the whole disk for Huairou Solar Station). Consequently the scale of the seeing (composed by blurring + image deformation + image motion) depends also on the algorithm used to define the solar figure.

An average made with N points distributed over all 360° of position angles (Huairou Solar Station), is different by the one made over 12° (IRSOL), and by the one, discrete, made on the preceding and following limb at Santa Maria degli Angeli Lucernaria by visual inspection (about 20° of the solar limb involved).

All these measurements have in common the detection of significant energy at the low frequencies regions around 0.01 Hz of the power spectrum.

These effects have to be taken into consideration for a fruitful analysis of the solar diameter measured with these methods.

A full Sun imager would help to monitor the image motion occurred during a single transit observed with the drift-scan method.