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DRIFT-TIME MEASUREMENTS OF THE SOLAR DIAMETER 1990-2000: NEW LIMITS ON CONSTANCY

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ABSTRACT

Drift-time measurements of the solar diameter have been made with two optically identical solar Gregory telescopes (aperture 45 cm) at Izaña/Tenerife and Locarno/ Switzerland. In contrast to some other authors the solar semidiameter R derived from these measurements does not show longterm variations in excess of about ± 0.0003 "/yr and does not show cycle-dependent variations in excess of about ± 0.05". Our mean value for the solar semidiameter at unit distance is R=(960.63±0.02)" from 7583 visual transit observations made at Izaña in 1990-2000, and R=(960.66±0.03)" from 2470 visual transit observations made at Locarno in 1990-1998. This applies to visual wavelengths of about 550 nm. At Izaña semidiameters were also measured photoelectrically from CCD transits at wavelengths of 486 nm and 583 nm; these are typically smaller by about 0.6" or 440 km.

1. INTRODUCTION

Since it was found that even the solar irradiation 'constant' is cycle-dependent (Willson et al., 1986; Willson and Hudson, 1988; Hudson, 1988) and varies in phase with the sunspot relative number (largest at solar maximum, smallest at solar minimum), the study of global properties of the sun, its outcrops of activity, and its influences on the earth and its climate has gained increased interest among scientists. Although solar-terrestrial relations are essentially one-way (there is no significant influence of the earth on the sun), the global properties of the sun, such as its energy output, activity cycle, differential rotation, diameter variations, oscillations, etc., are of utmost importance for life on earth and its future, and, therefore, merit close investigation.

2. MEASUREMENTS

Here we report about measurements of the solar diameter which were made with two optically identical solar Gregory-type vacuum telescopes (D =45 cm, f =25.0 m) at Izaña/Tenerife (latitude 28.30°, altitude 2413 m) and Locarno-Monti/Switzerland (latitude 46.18°, altitude 506 m). The latter telescope is an almost identical re-build of the telescope formerly operated at IRS/Locarno by the Göttingen University Observatory. The technique we employed is drift-scan timing, which is the equivalent of classical transit timing (as employed, e.g., at Greenwich in 1750-1939), but at arbitrary hour angle using an equatorially-mounted solar telescope (for details see Wittmann, 1977; Wittmann et al., 1981). The principle of the method is to measure the time is takes the solar disk to pass, due to diurnal rotation at the equatorial rate of ~15 "/s, across a fiducial mark representing a fixed hour angle (with the telescope at rest at that angle). The transit of both limbs (west limb preceeding, east limb following) is observed and timed either visually using a white-light projected image or electronically using a monochromatic CCD image and a fast frame grabber (see Wittmann, 1997). Both methods have their pros and cons, but from practical experience we conclude that a carefully-made visual observation is worth about eight or ten single CCD pictures. Figure 1 shows two typical transit sequences taken by CCD (visual transits can't be shown, but are looking quite similar): The first 8 frames of each series show the passage of the W-limb, the last 8 frames show the passage of the E-limb. The header of each frame carries an accurate timing mark (UT), which is also shown in Figure1.

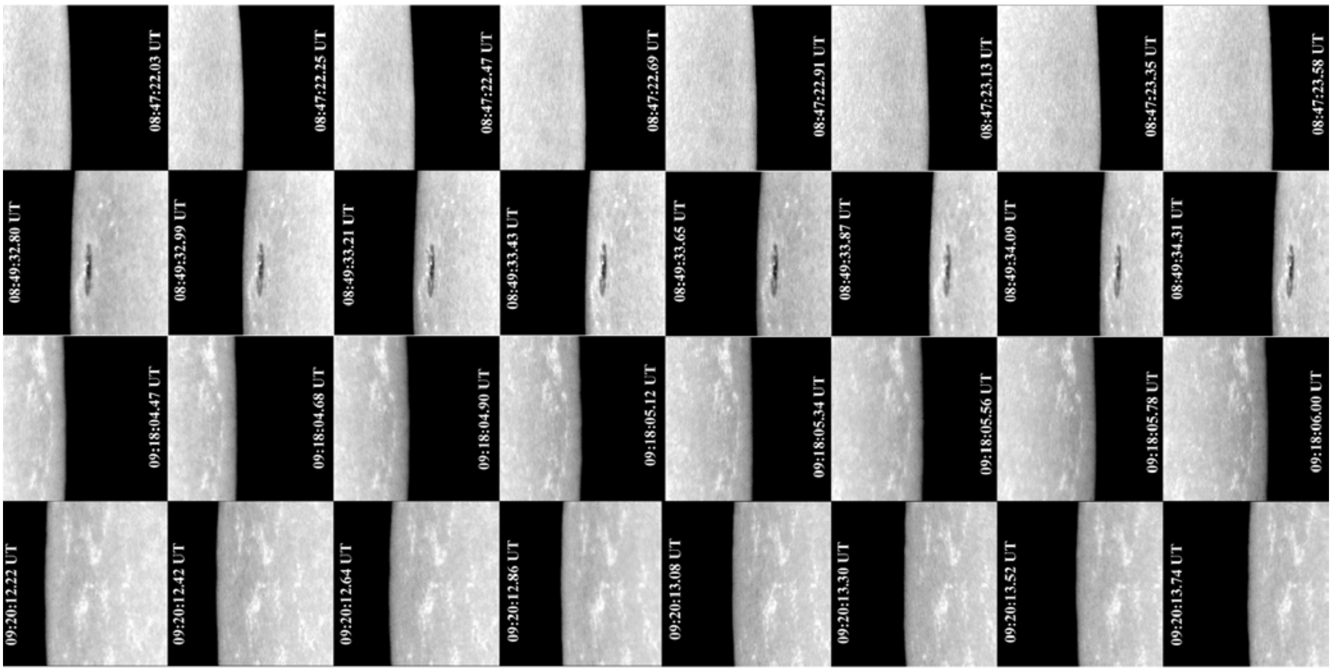

Figure 1: Drift scan observations made at the GCT on 11 August 1997 (486 nm, top two panels) and on 04 April 2000 (583 nm, bottom two panels; note the increased facular activity). Each CCD frame, of which 32 are shown here, has an angular size of 92 x 92". The upper two panels show, from left to right, the passage of the W-limb at 8:47 UT and the passage of the E-limb (with a sunspot) at 8:49 UT (T=130.85 s, R=959.81"). The lower two panels show the passage of the W-limb at 9:18 UT and the passage of the E-limb at 9:20 UT (T=128.62 s, R=960.09").

3. REDUCTION

The measured drift times T, which depend on the geocentric distance r, the geocentric declination δ, and the proper motion dα/dt of the sun, were reduced to the equator (δ = 0) and to unit distance (r = 1 au) using the formalism described by Wittmann and Neckel (1996). Our final results are tabulations of the measured drift time T (s) and of the semidiameter R (") at unit distance as function of date (e.g. JD) and time (e.g. UT).

Using numerical techniques of superposed epoch analysis and maximum entropy power spectral analysis we have analyzed our data in order to detect periodicities or other systematic variations, but - with perhaps one exception (a rotation-coupled modulation of shape at the limit of detectability, cf. Mikhailutsa et al., 2000) - we did not find such variations. We can neither detect a significant (i.e., larger than ±0.06") dependence on heliographic latitude in our observations, which - due to the seasonal change of the position angle of the sun's axis - cover a latitude range of only ± 26° around the equator.

4. RESULTS

Figure 2 shows the solar semidiameter measured at Locarno in 1990-1998 (top) and at Tenerife in 1990-2000 (bottom). Due to the priority of other observational projects at Locarno, the measurements there have last been made on November 7, 1998.

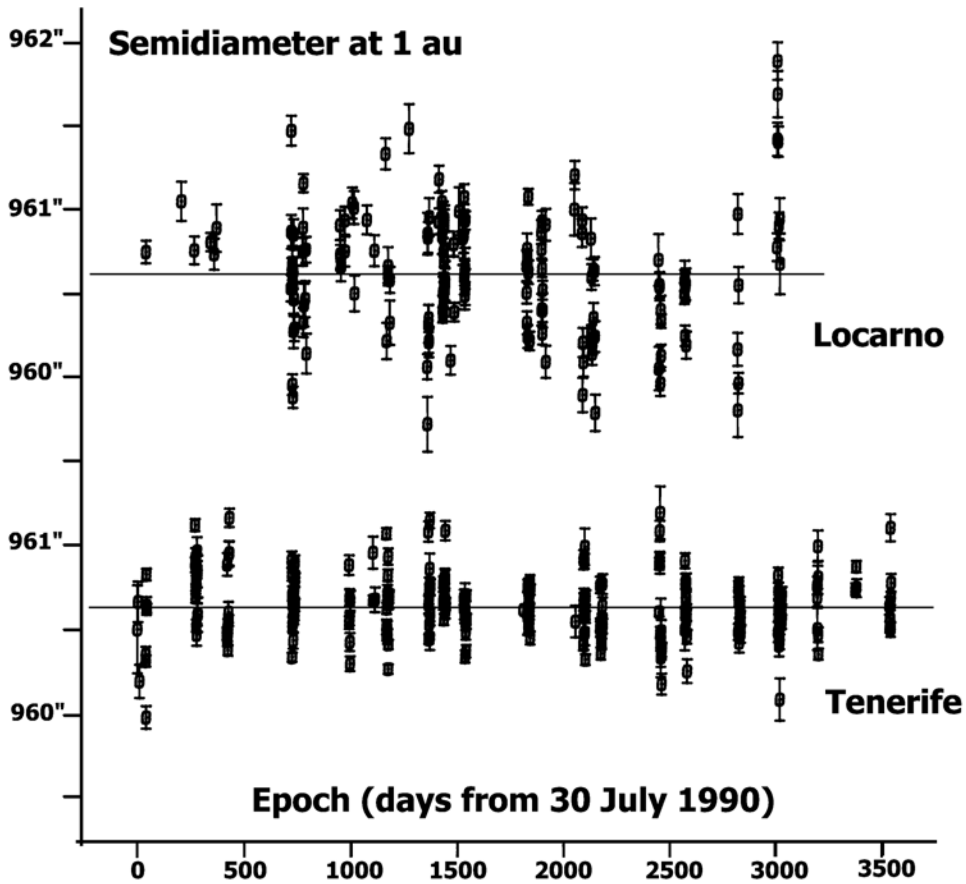

Figure 2: Semidiameter results from Locarno (1990-1998, top) and Tenerife (1990-2000, bottom). The daily mean values of the solar semidiameter (148 for Locarno, 232 for Izaña) are plotted as a function of time. One-sigma error levels are indicated by error bars (which, however, due to the relatively small dispersion of the diagram, mostly blend with their neighbors). Time is reckoned in days from 30 July 1990 0 UT, so that, e.g., 04 April 2000 0:00 UT is 3536.0 days from the initial epoch. The horizontal clustering of points reflects the distribution of the observing campaigns over the years (no drift observations were made during the winter season, when the conditions use to be fairly bad at both sites).

Table 1. Annual mean semidiameters (seconds of arc). N is the number of observations

Year	N	Wittmann	N	Noel	N	Bianda	N	Laclare
1990	363	960.48 ± 0.04	124	961.06 ± 0.07	48	960.74 ± 0.13	353	959.38 ± 0.02
1991	1002	960.71 ± 0.02	104	960.78 ± 0.06	92	960.83 ± 0.09	266	959.44 ± 0.02
1992	570	960.67 ± 0.02	160	960.63 ± 0.06	322	960.57 ± 0.04	293	959.40 ± 0.02
1993	802	960.63 ± 0.02	292	960.49 ± 0.03	266	960.74 ± 0.05	347	959.39 ± 0.01
1994	1176	960.68 ± 0.02	248	960.24 ± 0.03	655	960.66 ± 0.03	267	959.47 ± 0.02
1995	481	960.66 ± 0.02	230	960.08 ± 0.03	320	960.57 ± 0.04	273	959.48 ± 0.02
1996	879	960.59 ± 0.02	246	959.85 ± 0.03	265	960.43 ± 0.05	313	959.47 ± 0.02
1997	643	960.62 ± 0.03	240	960.00 ± 0.03	276	960.39 ± 0.05	392	959.52 ± 0.02
1998	1012	960.60 ± 0.02	316	960.27 ± 0.03	226	961.01 ± 0.08	357	959.52 ± 0.01
1999	359	960.68 ± 0.04	400	960.47 ± 0.03	----	-----------------	----	-----------------
2000	296	960.67 ± 0.04	258	960.41 ± 0.03	----	-----------------	----	-----------------
Mean:	7583	960.63 ± 0.02	2618	960.39 ± 0.01	2470	960.66 ± 0.04	2861	959.45 ± 0.02

Table 1 shows a comparison of annual mean values of the solar semidiameter as observed by A.D. Wittmann at Izaña/Tenerife until 10 April 2000, M. Bianda at Locarno until 7 November 1998, F. Noel at Santiago de Chile until 11 August 2000, and by F. Laclare at Calern until 25 September 1998 (the latter data were taken from the tabulation in the web pages of Observatoire de la Côte d'Azur).

Whereas some authors have found significant variations of the solar diameter during the 11-yr cycle (Delache et al., 1988; Delache et al., 1993; Jimenez et al., 1994; Ulrich and Bertello, 1995; Laclare et al., 1996; Noel, 1997; Noel, 1998; Rozelot, 1998; Noel 1999; Noel, 2000), we do not detect longterm variations, in particular cycle-dependent variations, in excess of about ± 0.0003 "/yr, and we do not detect short-term variations, in particular seasonal variations, in excess of about ± 0.05" (cf. Figure 2). This is in agreement with, e.g., Brown and Christensen-Dalsgaard (1998), who have not found long-term variations in excess of ± .05" in the HAO series of automated photoelectric transit measurements (Brown et al., 1982) during 1981-1987. Although Wittmann et al. (1993) have detected a sudden change in their diameter data, this is most probably due to the change of circumstances and the first interruption of the Locarno series in 1982.

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