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Solar Observations made at the Malatya Station with Danjon Astrolabe*

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Abstract

The first results of astrometric solar observations made at the Malatya Station with a modified version of the Paris Observatory astrolabe are presented. This campaign was conducted as part of a cooperation between Inonü University and the Paris Observatory. The astrolabe, exactly the same as the one at Santiago de Chile [1], uses two reflecting prisms instead of transparent prisms in order to be able to observe at two zenith distances of 30° and 60°. The time is supplied by a Global Positioning System (GPS) receiver. The measurements (Table 1, 2) made between 1993 and 1994, were used in obtaining the annual mean solar semi- diameters reduced to one astronomical unit. The annual mean solar semi-diameter from CERGA, Santiago, San Fernando and Malatya are given in Table 3. The over all average value of the mean solar semi-diameter was found to be 959".46±0".08 which is in very good agreement with those obtained at Centre d'Etudes et de Recherches Godynamiques et Astronomiques (CERGA) Observatory (Table 4). Present observations do not reveal any real change in the solar semi-diameter.

1. Introduction

As the Malatya Station has been newly established, there has been need to determine the precise mean coordinates of the instrument. This determination was made by observing FK5 stars. The parameters of the Earth rotation given by the International Earth Rotation Service - Central Bureau (IERS/CB) have been used to compute the instantaneous apparent latitude and longitude which, in turn, were used in the correction

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of stellar observations. This procedure gives the mean position of station in the IERS system. The following coordinates were adopted for the position of the instrument [2]:

$L : 2^h 33^m 42^s.797$ East $\pm 0^s.003$

$\varphi : 38°19'44".52$ North $\pm 0".04$

The effect of irregularities of Earth rotation and polar motion may be added to these mean coordinates in order to calculate the real or apparent instantaneous coordinates which may be used to calculate the correction to Sun position and diameter. The necessary parameter are published by the International Earth Rotation Service (IERS).

The solar and stellar observations were started at the same time [3]. The preliminary results of this campaign have been presented at the 9^{th} National Astronomy Meeting [4].

Corrections to the orbital parameters of the Earth as well as the equinox corrections cannot be precisely determined from observations covering only two years. But, the corrections of the semi-diameter Δd of the Sun can be obtained immediately and independently of the other unknowns, $\Delta\alpha, \Delta\delta$ and Δz.

The astrolabe used at Malatya Station, whose optical system is different from that of the classical Danjon Astrolabe, gives correct results particularly in the case of observation of the Sun, which is one of the most difficult objects to observe in astrometry. Soon, the instrument will be equipped with a CCD camera, hopefully in 1999, in order to impersonalise the instrument completely and to automate it.

2. Results

The results presented here covers only a short period of time and, therefore, using these results it is not yet possible to determine, with sufficient accuracy, the apparent orbit of the Sun. In spite of this, by examining daily observations, the values of the corrections that should be applied to the solar position $\Delta\alpha, \Delta\delta$, to the diameter ($\Delta d$) of the Sun, and to the zenith distance (Δz) defined by the instrument, can be estimated. As a first step the unknowns Δz and $\Delta\delta$ can not be separated and are replaced by the new unknown $Y = \Delta z + \Delta\delta \cdot \cos S$ [5].

The equations which represent the residues corresponding to the observations of the two edges of the Sun, on East and West transit are [6]:

$$r_1 = |\sin a_1|.\cos\varphi.\Delta\alpha + Y + \Delta d \text{ (ESE)}$$
$$r_2 = |\sin a_2|.\cos\varphi.\Delta\alpha + Y - \Delta d \text{ (EIE)}$$
$$r_3 = -|\sin a_3|.\cos\varphi.\Delta\alpha + Y - \Delta d \text{ (WIE)}$$
$$r_4 = -|\sin a_4|.\cos\varphi.\Delta\alpha + Y + \Delta d \text{ (WSE)},$$

where ESE, EIE, WIE and WSE are East Transit of Superior Edge, East Transit of Inferior Edge, West Transit of Inferior Edge and West Transit of Superior Edge, respectively. The values $|\sin a|$, where a is the azimuth measured from the South, are close to each other.

In this relation, the value cos S of the parallactic angle of the observed object can be considered to be practically constant for a given date and zenith distance, whatever the observed edge of the Sun. For this reason, we thought that it would be unnecessary to include in our computations an index that would eventually disappear.

As mentioned in previous articles [5,7], it is possible to make use of complete passages for solving the system of 4 equations and 3 unknowns by the method of least squares.

Although a number of observers have joined the campaign since the end of 1993, only 356 measurements made by the first two authors were considered for reduction. These measurements are a part of complete passage measurements, the total number of observations being 418. Here, it should be mentioned that we were able to observe 85 % of the time, which reflects the good quality of the station. In our final evaluation, we disregarded the values of "σO" greater than 0.7 (see Tables 1 and 2). As a result, only the 50 complete passages (200 individual passages) were taken into account.

Table 1. The results of observations for $z = 30^\circ$.

No	Date	Jul.Date	O	$\Delta\alpha$			Y			D (1 AU)			σO
	1993	2400000+											
1	07 18	49186.978	2	$+0^s.109$	±	$0^s.029$	+0".09	±	0".30	960".29	±	0".30	±0".61
2	07 19	49187.978	2	+ 0.070		0.190	- 0.28		0.20	960.21		0.20	0.40
3	07 22	49190.976	2	+ 0.044		0.015	- 0.18		0.15	959.82		0.15	0.30
4	07 24	49192.975	2	+ 0.139		0.024	- 0.43		0.24	959.04		0.24	0.48
5	07 25	49193.975	2	+ 0.051		0.029	- 0.09		0.30	959.74		0.30	0.59
6	07 26	49194.974	2	+ 0.059		0.019	- 0.44		0.19	959.36		0.19	0.38
7	07 30	49198.971	2	+ 0.073		0.018	- 0.34		0.18	959.33		0.18	0.35
8	07 31	49199.970	2	+ 0.052		0.021	+ 0.11		0.20	959.05		0.20	0.41
9	08 01	49200.970	2	+ 0.127		0.002	- 0.31		0.02	959.23		0.02	0.04
10	08 02	49201.969	2	+ 0.137		0.011	- 0.77		0.10	959.21		0.10	0.20
11	08 03	49202.968	2	+ 0.073		0.003	+ 0.30		0.03	958.99		0.03	0.06
12	08 04	49203.967	2	+ 0.103		0.014	- 0.62		0.13	959.71		0.13	0.26
13	08 10	49209.960	2	+ 0.067		0.029	+ 0.19		0.25	958.56		0.25	0.49
14	08 15	49214.953	2	+ 0.127		0.322	- 0.62		0.25	959.30		0.25	0.50
15	08 18	49217.949	1	+ 0.163		0.014	- 1.13		0.10	960.11		0.10	0.21
16	08 20	49219.945	1	+ 0.158		0.021	- 0.82		0.14	959.87		0.14	0.28
17	08 21	49220.943	1	+ 0.216		0.030	- 1.83		0.19	959.70		0.19	0.38
18	08 22	49221.941	1	+ 0.097		0.055	- 0.53		0.34	959.78		0.34	0.68
19	08 23	49222.939	1	+ 0.082		0.059	- 0.64		0.35	959.38		0.35	0.69
	1994												
1	07 07	49540.981	2	+ 0.080		0.001	- 0.32		0.02	959.22		0.02	0.04
2	07 12	49545.980	2	+ 0.075		0.022	- 0.23		0.23	958.91		0.23	0.46
3	07 13	49546.980	2	+ 0.043		0.010	- 0.09		0.12	958.26		0.12	0.23
4	07 26	49559.974	2	+ 0.022		0.027	+ 0.79		0.27	959.16		0.27	0.53
5	08 03	49567.968	2	+ 0.114		0.021	+ 0.30		0.20	958.73		0.20	0.40
6	08 08	49572.963	2	+ 0.108		0.038	+ 0.66		0.33	958.76		0.33	0.67
7	08 17	49581.951	2	+ 0.069		0.022	+ 0.86		0.17	958.95		0.17	0.33
8	08 18	49582.949	2	+ 0.159		0.006	+ 0.83		0.04	959.07		0.04	0.09
9	08 24	49588.937	2	+ 0.072		0.024	+ 0.56		0.13	960.32		0.13	0.27

$\Delta\sigma$: correction to the right ascension
Y : $\Delta z + \Delta\delta \cdot \cos S$ where Δz is the correction to the zenith distance, $\Delta\delta$ is the correction to the declination and S is the parallactic angle,
D : semi-diameter reduced to the unit distance (1 AU),
σO : standard error of one complete passage.

Present observations were used to deduce the solar semi-diameter only. While the values obtained for Y and right ascension involve errors related to the position of the instrument, these unknowns are those that can be used to evaluate the corrections to the parameters of Earth's orbit and to the position of the equinox in the FK5 dynamical system. The time interval of this campaign is too short for definite results, because only two orbits of the Sun have been measured. The observed values of the semi-diameter of the Sun are given in Table 1 and Table 2 after being reduced to unit distance.

Table 2. Solar observations for the zenith distance $z = 60°$.

No	Date	Jul.Date	O	Δα			Y			D (1 AU)			σO
	1993	2400000+											
1	08 11	49211.075	2	+ 0s.079	±	0s.011	- 3".17	±	0".13	958".86	±	0".13	±0".25
2	08 16	49216.071	2	+ 0.051		0.006	- 1.86		0.06	958.96		0.06	0.13
3	08 17	49217.070	1	+ 0.077		0.003	- 3.48		0.04	960.48		0.04	0.07
4	08 18	49218.069	1	+ 0.034		0.018	- 4.11		0.21	959.98		0.21	0.42
5	08 19	49219.069	1	+ 0.064		0.010	- 2.54		0.11	960.49		0.11	0.23
6	08 21	49221.067	1	+ 0.075		0.005	- 3.54		0.05	959.93		0.05	0.11
7	09 05	49236.052	1	+ 0.035		0.029	- 4.35		0.33	960.42		0.33	0.66
8	09 08	49239.048	2	+ 0.032		0.017	- 3.73		0.19	959.51		0.19	0.37
9	09 09	49240.047	2	+ 0.066		0.020	- 2.94		0.23	959.10		0.23	0.45
10	09 13	49244.042	2	+ 0.051		0.027	- 2.50		0.30	959.36		0.30	0.60
11	09 14	49245.041	2	+ 0.097		0.004	- 3.48		0.05	958.84		0.05	0.09
12	09 17	49248.037	2	+ 0.038		0.001	- 3.36		0.01	959.37		0.01	0.01
13	09 23	49254.029	2	- 0.063		0.021	- 3.97		0.22	958.82		0.22	0.44
14	09 24	49255.028	2	+ 0.003		0.007	- 4.46		0.07	959.32		0.07	0.14
15	10 04	49265.014	2	+ 0.021		0.004	- 4.64		0.04	958.80		0.04	0.09
	1994												
1	08 23	49588.065	2	+ 0.022		0.003	- 2.68		0.03	960.25		0.03	0.06
2	08 30	49595.058	2	+ 0.070		0.007	- 3.02		0.08	960.12		0.08	0.15
3	08 31	49596.057	2	+ 0.019		0.007	- 3.02		0.09	960.16		0.09	0.17
4	09 09	49605.047	2	+ 0.073		0.009	- 3.56		0.10	959.76		0.10	0.19
5	09 13	49609.042	2	+ 0.046		0.014	- 3.95		0.15	959.23		0.15	0.30
6	09 14	49610.041	2	- 0.019		0.009	- 3.30		0.10	959.59		0.10	0.20
7	09 15	49611.040	2	- 0.000		0.020	- 3.64		0.22	959.65		0.22	0.44

To get some idea about the quality of the measurements, we have made a comparison with the individual measurements obtained at Santiago (Chile) in 1990 - 1994. In addition, annual averages from Santiago [8,9,10 and 11] and CERGA [13, 14] were used together with our observations.

Figure 1, which gives the results from Santiago and Malatya , shows apparent variations of the solar semi-diameter between a minimum of 958".3 to a maximum of 962".0. It should be noted that the two instruments are completely equivalent and unique for solar observation. This might suggest that the apparent decrease of the solar diameter is real. However, this does not seem to be acceptable for a few reasons: the most obvious reason being it is impossible for the semi-diameter of the Sun to change so much in such a short period of time. As mentioned in the introduction, even for the first measurements made at CERGA from 1978 to 1984, the total amplitude of the variations recorded at that time was less than 0".7 [14]. But here, the variations is 3 times as much as the variations recorded at CERGA, and this would need an explanation. Another reason against a real change is that the annual averages obtained at CERGA from 1990 to 1994 are practically constant, between 959".38 and 959".47 [13,14] (See Figure 1). One can see from this figure that the results of Santiago are systematically larger than those of CERGA, the difference is about 1", 5. On the other hand, the results of San Fernando [6] are smaller than those of CERGA, the difference being about 1" (not shown in Figure 1). But the results of Malatya, although they appear to be more scattered, are in good agreement with the results of CERGA. Nevertheless, a decrease with time of the Santiago values recorded from 1991 to 1994 seems to bring the Santiago results closer to the results of CERGA and Malatya. It is more likely that all measurements are influenced by the observers, and the linear change is really a personal equation. A similar case was also observed in an experiment made at CERGA. In that experiment, it was established that the measurements made by two different observers gave systematically different results

[12].

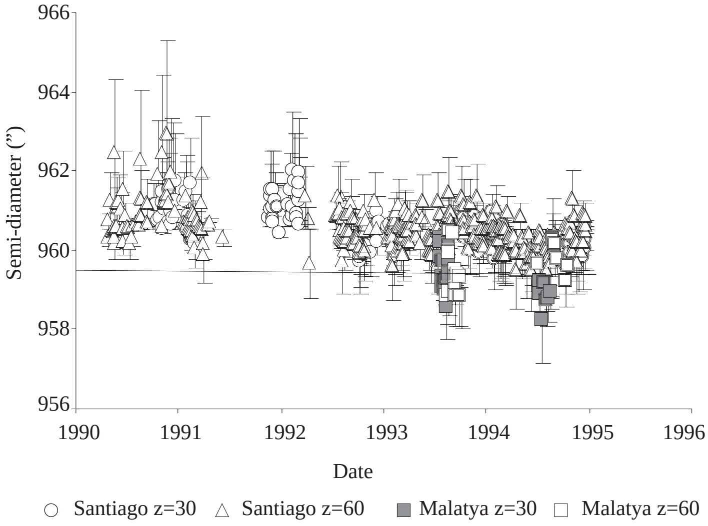

Figure 1. Solar Semi-diameter obtained by using Santiago, CERGA and Malatya observatories.

The annual averages obtained at Malatya, CERGA, San Fernando, and Santiago are given in Table 3. The over all mean values of the semi-diameter obtained at Malatya and CERGA are given in Table 4. One can see in Table 4 that the results of Malatya are in good agreement with those of CERGA.

Table 3. Annual mean solar semi-diameters from CERGA, Santiago, San Fernando and Malatya.

	1991	1992	1993	1994
CERGA(France) Laclare [13]	959".44 ± 0".02	959".40 ± 0".02	959".39 ± 0".01	959".47 ± 0".02
CERGA with CCD Laclare [13]	959".37 ± 0".02	959".41 ± 0".02	959".40 ± 0".02	959".40 ± 0".01
Santiago (Chile) Noël [1]	960".77 ± 0".09	959".64 ± 0".10	960".49 ± 0".03	960".24 ± 0".03
San Fernando (Spain) Sanchez [6]	958".59 ± 0".14	958".54 ± 0".12		
Malatya (Turkey) Present work			959".51 ± 0".09	959".38 ± 0".15

Table 4. The over all mean values of the semi solar diameter from CERGA and Malatya

Stations	reference	semi-diameter
CERGA (from visual observations, 1975-1994)	[13]	959".42 ± 0".01
CERGA (from CCD measurements, 1989-1994)	[13]	959".40 ± 0".01
Malatya (from visual observations, 1993-1994)	present work	959".46 ± 0".08

3. Conclusion

Present observations (see Fig. 1) are not enough in both quality and quantity to deduce any conclusive results about any change in the solar semi-diameter. However, although the observations at Malatya have not yet reached to the accuracy of the results of CERGA, together with Santiago they have began to supply additional information about the validity of observing the Sun with the astrolabes. (since 1978, CERGA had remained the only station where his kind of measurements had been made.) In spite of the more accurate results from CERGA, independent observations from a different instrument are needed for comparison. Although the optical configurations of the instruments at Malatya and Santiago are different from those at CERGA, these new stations have began to supply the necessary information. It would be appropriate to mention here the work continuing in Brazil [15], Spain [16,17] as well as projects in Romania and Poland all of them at least for the time being, are adaptations of Danjon Astrolabe [18]. In this context, a cooperation is being established with the Kandilli Observatory in İstanbul with a program of solar observations and modifying a Danjon Astrolabe [19]. In addition, another program of cooperation is being planned between the TÜBİTAK National Observatory in Antalya and the Malatya Station. The +36° latitude of Antalya makes this site more suitable for the observation of the Solar System objects. With the experience gained in France [5,6,7], Chile [1], and Spain [16,17], there seems to be no major problems to bring out concrete results in the near future.

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