Tr. J. of Physics
23 (1999) , 1075 – 1081.

Stellar Observations made at the Malatya Danjon Astrolabe Station*

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Received 11.12.1996

Abstract

We give here the first results of astrometric stellar observations made at the Malatya Station with the modified astrolabe of Paris observatory. This campaign is conducted as part of a cooperation between Inönü University and the Paris Observatory. The astrolabe, which is strictly similar to that of Santiago de Chile, can use two reflecting prisms instead of the trnsparent prism of the Danjon Astrolabe. Consequently, it is possible to observe at the two zenith distances of 30° and 60°. The time is supplied by a GPS receiver which gives UTC with the necessary precision.

As the station is a new one, the precise mean coordinates of the instrument had to be determined. This determination was done by stellar observations of FK5 stars. We have also carried out solar observations during the same interval. In order to be free of Earth rotation irregulatirities, parameters of Earth rotation given by the International Earth Rotation Service/Central Bureau (IERS/CB) have been used to compute the instantaneous apparent latitude and longitude variations to correct the stellar and solar observations. This procedure gives the mean position of the station on the IERS system, which is also used to correct the solar observations.

Introduction

Optical methods for investigating the rotation of the Earth have been left aside since 1987 and, taking into account the fact that Earth-based observations will be necessary for the near future, astrometrists tried to modify and develop their instruments. In particular, in China, automatic, even single image, Astrolabes were put into service [1]. On the other hand, international collaborations were realized to establish the facilities necessary for astronomical investigations in some countries and also to develop new instruments with higher capacity and performance. Within the same framework, a solar astrolabe exactly similar to the one at Malatya began working at Santiago de Chile [2], and a slightly different solar astrolabe started at San Fernando [3]. The first results of the solar observations from these stations, as well as from the Malatya station, will be dicussed elsewhere.

This work, with this frame, gives the first results of the scientific cooperation realized between Turkey and France. The astrolabe used for the observations is that of the Paris Observatory which was established in 1956 for the observation of stars. This astrolabe was modified in 1988 for the observation of the Sun.

The astrolabe used in this work was brought from Paris Observatory in 1992 and installed at a station prepared for this purpose on the Malatya Inönü University campus, according to a protocol signed by the rector of İnönü University and the director of Paris Observatory [4]. This astrolabe is the same as the astrolabe that is being used at Santiago Station [2]. Long term observations of planets and stars with this instrument will contribute to several terrestrial or celestial reference frames [4].

Malatya Station

Taking into consideration the geographic location and observation conditions, Malatya has been chosen in 1992 as a Danjon Artrolabe Station in Turkey. This station has advantages over the Paris Observatory, especially for the observation of the Sun, together with its lower latitude (Malatya has 38° latitude while Paris has 49°). With this instrument, it is possible to observe celestial objects with declinations between -22° and +82° and brighter than $6^m.5$ at 30° and 60° zenith distances. The observations at this station can cover 90% of the orbit of the Sun, while the Paris station can only cover 65%.

In the beginning, there were no astronomical facilities at the observation site. With the help of Inönü University, a small station was built and a GPS receiver, used as a time service, was bought. The GPS gives time to an accuracy of about 1 microsecond, largely sufficient, and position determinations have an accuracy of about $\pm$ 0.1$''$ and may be compared with the astrolabe results.

Observation Program and Reduction Method

Since the observation site is new, its average coordinates should be determined very carefully. Although the mean coordinates of the GPS antenna, located at the station near the astrolabe, can be obtained whenever it is desired, they have also been obtained through standard stellar observations.

Within the framework of this program, 11 groups of stars were formed each consisting of 28 FK5 stars. The composition of the eleven star groups is given in Table 1, which gives the FK5 star numbers. The first observations were initiated immediately after the instrument was installed, in September, 1992. Although many groups of stars have been observed since then, some of them aimed at training new observers, 56 of them were considered to be worthy of evaluation.

Table 1. Composition of the star groups. (The numbers refer to the FK5)

	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**
1	1077	891	2220	317	1238	1195	1259	3377	1491	778	1526
2	807	125	241	1193	1173	305	1378	1440	659	641	752
3	1050	1115	1052	2646	1157	2677	423	467	740	1565	746
4	831	175	1054	148	1252	1308	3135	1456	583	804	2
5	103	1020	89	340	221	2645	440	1316	3570	1469	1555
6	99	185	75	346	2621	1323	2880	1322	1508	1465	3570
7	81	1058	125	2705	379	317	394	655	591	835	733
8	109	164	1191	1113	416	2733	1412	641	584	643	25
9	108	123	2153	152	1201	478	1275	470	633	1570	778
10	885	159	2530	2325	405	2981	422	3397	757	772	1021
11	1057	182	208	1117	1188	497	2844	3370	3591	3377	1523
12	847	121	114	2743	2800	3007	444	676	571	653	1541
13	124	50	2594	184	277	1252	1416	507	1421	858	3594
14	862	20	286	326	387	396	3249	671	758	847	1004
15	2234	32	1169	2433	1279	509	3259	3310	3585	674	1521
16	131	17	1199	2730	380	380	1308	513	576	725	2071
17	134	1039	1094	175	441	500	416	500	3633	857	1539
18	852	2383	99	2398	2880	3036	1326	1382	777	869	3718
19	122	2082	93	1128	2525	355	551	1477	1484	1491	758
20	1089	1050	292	1133	279	486	554	3135	609	676	3610
21	882	1157	103	218	447	3124	1304	3063	752	3448	7
22	1094	1136	2217	211	2965	1244	598	3394	580	703	1040
23	1113	48	307	368	2527	527	420	526	725	3870	757
24	3889	1057	108	1258	1200	409	587	1442	598	1479	1549
25	3833	63	1188	355	2537	379	424	3083	782	826	3751
26	898	1148	277	185	458	1370	614	3443	595	684	782
27	2316	66	2342	386	1316	246	488	551	1416	3475	804
28	129	1118	159	192	423	1326	2925	633	767	891	826

In this work, we have an opportunity to apply a new method of reduction, using Earth rotation parameters (the x and y coordinates of the pole and UT1-UTC) as obtained with great accuracy from interferometry in radioastronomy or Lunar laser ranging methods. The reduction program we applied eliminates the influence of perturbations due to Earth rotation on our observations. The data needed for this was obtained from IERS/CB. Thus, each reduction gives, simultaneously and directly, the correction term that is necessary to place the average latitude and longitude of the station in the IERS local system. Results from observing the 56 stellar groups are given in Table 2. The columns denote the following:

Table 2. Results of observations

No	Date	Gr.	O	ΔL/IERS	PUT	UT Mean	ΔΦ	PΦ	R	N	PGR
1	19920915	10	1	0.0382	0.9	18.055	0.115	0.2	15.679	21	0.7
2	19920916	11	1	0.0451	0.9	19.911	0.227	0.4	15.795	17	1.2
3	19920918	11	1	0.0448	2.0	20.043	0.105	1.0	15.947	24	1.9
4	19920919	10	1	0.0510	1.5	17.768	-0.210	0.5	15.862	21	1.2
5	19920921	11	1	0.0579	0.8	19.778	0.128	0.5	15.961	26	0.8
6	19920921	1	2	0.0232	0.7	22.352	0.287	0.4	15.964	26	0.6
7	19920922	10	2	0.0200	0.6	17.611	0.145	0.2	15.803	21	0.5
8	19920922	11	1	0.0436	1.5	17.335	0.310	0.5	15.854	23	1.2
9	19920925	10	1	0.0435	1.6	17.355	0.313	0.5	15.855	23	1.2
10	19920927	10	1	0.0345	0.7	17.250	0.083	0.3	15.683	25	0.5
11	19920928	11	1	0.0011	1.4	19.399	0.150	0.9	15.822	26	1.3
12	19920929	11	1	0.0375	0.8	19.260	0.118	0.6	15.821	26	0.8
13	19920930	11	2	0.0085	0.5	19.350	0.578	0.3	14.061	19	0.6
14	19921001	11	1	0.0148	2.6	19.105	0.174	1.6	15.904	25	2.5
15	19921002	11	2	0.0355	0.4	19.146	0.153	0.2	16.037	20	0.5
16	19921002	1	1	0.0289	3.7	21.635	0.163	1.7	15.763	23	3.6
17	19921005	1	2	0.0323	0.5	21.564	-0.070	0.3	15.926	16	0.6
18	19921006	1	1	0.0467	2.3	21.311	-0.077	0.2	15.520	26	2.0
19	19921007	1	2	0.0320	1.4	21.273	0.223	0.9	15.644	23	1.5
20	19921008	11	1	0.0471	0.5	18.5620	0.065	0.3	15.696	16	0.7
21	19921008	1	3	0.0327	0.3	21.115	0.670	0.2	16.409	14	0.6
22	19921010	11	1	0.0429	1.1	18.652	0.227	0.6	15.843	19	1.5
23	19921010	1	2	0.0334	1.7	21.050	0.058	1.1	16.072	24	1.6
24	19921012	1	2	-0.0137	1.1	20.890	0.006	0.6	16.047	21	1.1
25	19921015	11	3	0.0295	0.8	18.149	0.088	0.4	15.837	17	1.1
26	19921017	11	1	0.0412	0.9	18.121	0.319	0.6	15.594	24	0.9
27	19921019	11	2	0.0420	0.3	17.989	-0.328	0.2	15.813	16	0.4
28	19921019	1	2	0.0146	0.5	20.501	-0.251	0.2	15.932	17	0.6
29	19921021	1	1	0.0446	1.8	20.354	0.136	0.9	15.924	28	1.3
30	19921030	11	1	-0.0173	3.6	17.251	0.190	2.3	15.777	24	3.9
31	19921030	1	2	0.0232	1.4	19.818	0.163	0.7	16.133	25	1.2
32	19921030	2	1	0.0401	1.0	21.824	0.038	1.1	15.759	19	1.5
33	19921031	11	1	0.0237	1.1	17.193	0.076	0.8	15.881	28	1.0
34	19921031	1	2	0.0029	1.1	19.728	0.184	0.6	15.947	24	1.0
35	19921102	1	2	0.0103	0.7	19.551	0.285	0.4	15.754	26	0.6
36	19921103	1	1	0.0217	3.1	19.451	0.106	1.4	15.881	24	2.6
37	19921116	1	2	0.0620	1.7	18.608	0.176	0.9	15.771	25	1.6
38	19921116	2	1	0.0343	0.6	20.631	-0.107	0.6	15.959	20	0.8
39	19921117	1	1	0.0475	1.9	18.643	0.050	1.1	15.735	23	2.0
40	19930528	8	2	0.0048	0.7	20.520	-0.431	0.4	15.858	20	0.8
41	19930601	7	1	0.0107	0.8	18.155	-0.289	0.5	15.365	20	1.0
42	19930601	8	2	0.0406	1.3	20.256	-0.356	0.8	15.944	23	1.2
43	19930604	8	2	0.0178	0.4	20.136	-0.618	0.3	15.830	20	0.5
44	19930604	9	1	0.0265	1.0	22.388	-0.159	0.8	15.604	24	0.9
45	19930612	8	2	0.0087	0.7	19.457	-0.405	0.3	15.793	22	0.6
46	19930614	8	2	0.0247	1.6	19.539	-0.117	1.1	15.836	21	1.7
47	19930621	9	2	0.0214	1.0	21.312	-0.162	0.5	15.806	20	1.0
48	19930623	9	3	-0.0022	0.6	21.191	-0.029	0.4	16.096	16	0.8
49	19930707	9	3	0.0012	0.5	20.276	-0.710	0.2	15.813	18	0.5
50	19930710	9	2	0.0376	0.8	20.028	-0.127	0.4	15.588	22	0.7
51	19930713	9	4	-0.0269	0.7	19.834	-0.157	0.4	15.606	23	0.7
52	19930906	11	4	0.0278	0.2	20.726	-0.006	0.1	16.095	17	0.3
53	19931018	11	2	0.0297	0.7	18.110	-0.120	0.3	15.824	21	0.6
54	19931018	1	5	-0.0216	0.6	20.748	-0.160	0.3	15.471	20	0.6
55	19931020	11	3	-0.005	0.4	18.005	0.400	0.2	15.488	21	0.4
56	19931020	1	5	0.0257	0.5	20.462	0.104	0.2	15.423	23	0.4

GR is the code number of the observed group; O is the observer code number: (1) Orhan Gölbaşı, (2) Hüseyin Kılıç, (3) Gülağa Kaçar, (4) Tuncay Özdemir, (5) Ahmet İskender. ΔL/IERS denotes the longitude correction relative to the IERS System in seconds of time; PUT=$0.006/\sigma^2$ is the weight for the time result, where σ is the standard error of the time solution (the unit is seconds of time); UT Mean denotes the Mean Universal Time of the group; dΦ denotes latitude correction relative to the IERS System in seconds of arc; PΦ=$0.008/\sigma^2$ is the weight of the latitude, where σ is standard error of the latitude solution (in seconds of arc) R is the zenith distance correction (in seconds of arc) N is the Number of observed stars in the group; PGR = $0.1/\sigma^2$ is the weight of the group, where σ is the standard error of the observed group. Relation between the weights of each observed group and standard errors are given in Table 3. The relation between weights and standard errors is of the form p=k/σ^2, where k=0.1 for PGR (weight of the group); k=0.006 for PUT (weight of the time solution); and k=0.0008 for PΦ (weight of latitude).

The average coordinates obtained here are effected by the systematic errors of the fundamental catalogue FK5. In this case, continuing these observations will be very useful for providing a complete unification amongst the IERS systems which are established with FK5 on extragalactic radio objects.

The mean coordinates obtained after observations at Malatya Danjon Astrolabe Station are as follows:

$$L : 2^h 33^m 42^s.798\ East \pm 0^s.003 \quad \varphi : 38°19'44''.52\ North \pm 0''.04.$$

To these coordinates, we have added the irregularities of the rotation of the Earth, calculated from the data of the Central Bureau of IERS. These values are also used as input data in the reduction of the observation of the Sun.

Conclusion and Future Prospects

At the Malatya Astrolabe Station, observations of both stars and the sun have been carried out by the same team. This kind of a multi-purpose station has been established in our country for the first time. With a new project supported by TUBITAK, astrolabe to be established at Kandilli observatory is being modified essentially for solar observations. In a third project in collaboration with Paris observatory, the Malatya astrolabe has been transferred to a station in Antalya as part of the TUBITAK National observatory, where solar observations with a CCD camera has already started. This astrolabe will be used for stellar, planetary and solar observations, with the final goal being to construct a fully automatic astrolabe system.

The site of the National Observatory is located at latitude +36° and compared to Malatya Station, is more advantageous for observing objects in the Solar System. Moreover, since the systems and reduction software, as well as the CCD itself, have been tested before at at other observatories with astrolabes (e.g the Paris and CERGA Observatory in France [5, 6, 7, 8], in Chile [2], and at the San Fernando Observatory in Spain [3, 9], there will be no major difficulties in establishing and operating the fully automatic system.

Table 3. Relation between weights and standard errors.

PGR	σ	PUT	σ	PΦ	σ
17.7 -	0".08	$\geq$8.8	$0^s.002$	$\geq$ 12.8	0".02
13.9	9	8.7-4.5	3	12.7-6.5	3
13.8 -	10	4.4-2.8	4	6.4-3.9	4
11.1	11	2.7-1.9	5	3.8-2.6	5
11.0-9.1	12	1.8-1.3	6	2.5-1.8	6
9.0-7.6	13	1.2-1.0	7	1.7-1.4	7
7.5-6.4	14	0.9-0.8	8	1.3-1.1	8
6.3-5.5	15	0.7	9	1.0-0.9	9
5.4-4.8	16	0.6	10	0.8-0.7	10
4.7-4.2	17	0.5	11	0.6	11
4.1-3.7	18	0.4	12	0.5	12
3.6-3.3	19				
3.2-3.0	20				
2.9-2.7	21				
2.6-2.4	22				
2.3-2.2	23				
2.1-2.0	24				
1.9	25				
1.8-1.7	26				
1.6	27				
1.5	28				
1.4	29				
1.3	30				
1.2	31-				
1.1	32				
1.0	33				
0.9	35				
0.8	37				
0.7	39				
0.6					

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