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SUPPLEMENT

Astrometry of minor planets made at the Skalnaté Pleso Observatory in the year 1984

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Abstract. The paper presents results of position photographing of minor planets carried out at the Skalnaté Pleso Observatory in the year 1984.
51 observations of 14 minor planets are given together with a list of reference stars and dependences.

Key words: asteroids – astrometry

1. Introduction

Papers concerning the results of astrometry observations at the Skalnaté Pleso Observatory were published before. The series was interrupted for 11 years. The last paper on minor planets astrometry contained the observations obtained in the year 1983 (Svoreň, 1996) and results since 1995 up to date have also been published (Neslušan and Svoreň, 1995; and next). The present paper is the first one to bridge the above-mentioned gap and contains the observations made in the year 1984.

The observations were made with a 0.3-m f/5 Zeiss astrograph. The reduction constants of the Skalnaté Pleso astrograph are as follows:
$\lambda = -\ 1^h\ 20^m\ 58.70^s$,
$\varphi = +49^\circ\ 11'\ 20.0''$,
h = 1783 m a.s.l.,
$\rho = 0.99836$ of the equatorial radius of the Earth.
Asteroids were photographed on ORWO plates with ZU 21 emulsion, dimensions 9x12 cm, which roughly corresponds to a field of 3°x 4°. Reference stars required to compute positions using Schlesinger's method of dependences, from two independent triangles were selected from the Star Catalog of the Smithsonian Astrophysical Observatory (1966). Differences between independent determination of the equatorial coordinates, given for each position, provide some information about the accuracy of the measuring (but not about the accuracy of the object position). The rectangular coordinates of the reference stars and the minor planets were measured with the aid of instruments for measuring coordinates produced by Zeiss (Koordinatenmessgerät and Ascoremat E-60).

A total of 51 accurate positions of 14 minor planets are given. A list of reference stars and dependences and a list of collaborators are given, together with their share in photographing, measuring and reducing the positions.

2. Conversion from eqn. B1950.0 to eqn. J2000.0

The reference stars were selected from the Smithsonian Astrophysical Observatory Star Catalog (1966). The positions were measured in the B1950.0 system and then converted to the J2000.0 employing the formulas published by System Transition Committee of the IAU Commission 20 (Yeomans, 1990). The conversion from eqn. B1950.0 to eqn. J2000.0 is as follows:

Let α_0 and δ_0 are respectively object's right ascension and declination referred to 1950.0 system. Then the calculated rectangular components of the object's position vector $\mathbf{r_0}$ referred to the 1950.0 system are:

$$r_{0x} = cos\alpha_0 \;\; cos\delta_0, \tag{1}$$

$$r_{0y} = sin\alpha_0 \;\; cos\delta_0, \tag{2}$$

$$r_{0z} = sin\delta_0. \tag{3}$$

The astrographic position vector $\mathbf{r_1}$ is formed to remove the effects of elliptical aberration:

$$r_{1x} = r_{0x} - A_x + B\ r_{0x}, \tag{4}$$

$$r_{1y} = r_{0y} - A_y + B\ r_{0y}, \tag{5}$$

$$r_{1z} = r_{0z} - A_z + B\ r_{0z}, \tag{6}$$

where B is a scalar product of the vector transpose to $\mathbf{r_0}$ and the vector $\mathbf{A}$, i.e.

$$B = r_{0x}\ A_x + r_{0y}\ A_y + r_{0z}\ A_z, \tag{7}$$

and A_x, A_y, A_z are the rectangular components of the vector $\mathbf{A}$:

$$A_x = -1.62557 \times 10^{-6},$$
$$A_y = -0.31919 \times 10^{-6},$$
$$A_z = -0.13843 \times 10^{-6}.$$

If t is the Julian time of the observation, then the Julian centuries from the 1950 epoch to the observation time can be calculated as

$$T = (t - 2433282.423)\ /\ 36525. \tag{8}$$

The rectangular components of the object's position vector $\mathbf{r}$ referred to the 2000.0 system are:

$$r_x = X_x\ r_{1x} + X_y\ r_{1y} + X_z\ r_{1z}, \tag{9}$$

$$r_y = Y_x\ r_{1x} + Y_y\ r_{1y} + Y_z\ r_{1z}\ , \tag{10}$$

$$r_z = Z_x\ r_{1x} + Z_y\ r_{1y} + Z_z\ r_{1z}\ , \tag{11}$$

where $X_x, X_y, ..., Z_z$ are the elements of the rotation matrix (Murray, 1989):

$$\begin{aligned}
X_x &= +0.9999256794956877 - 0.0026455262 \times 10^{-6}\ T,\\
X_y &= -0.0111814832204662 - 1.1539918689 \times 10^{-6}\ T,\\
X_z &= -0.0048590038153592 + 2.1111346190 \times 10^{-6}\ T,\\
Y_x &= +0.0111814832391717 + 1.1540628161 \times 10^{-6}\ T,\\
Y_y &= +0.9999374848933135 - 0.0129042997 \times 10^{-6}\ T,\\
Y_z &= -0.0000271625947142 + 0.0236021478 \times 10^{-6}\ T,\\
Z_x &= +0.0048590037723143 - 2.1112979048 \times 10^{-6}\ T,\\
Z_y &= -0.0000271702937440 - 0.0056024448 \times 10^{-6}\ T,\\
Z_z &= +0.9999881946023742 + 0.0102587734 \times 10^{-6}\ T.
\end{aligned}$$

The coordinates α, δ in J2000.0 system are calculated using the expressions:

$$\alpha = arctg\frac{r_y}{r_x} + 90.\ (1 - \frac{r_x}{|r_x|}), \tag{12}$$

$$\delta = arctg\ \frac{r_z}{\sqrt{r_x^2 + r_y^2}}. \tag{13}$$

3. Positions of minor planets

The data have been arranged according to serial numbers of minor planets. The individual columns of the table contain the following:
N - ordinal number of observation,
MP - number of minor planet,
Date U.T. - date and time of the middle of the exposure,
$R.A._{2000}$ - right ascension for the equinox 2000.0 (in h,m,s),
$Decl._{2000}$ - declination for the equinox 2000.0 (in °,′, ″),
A - the difference between independent determinations of R.A. in arc seconds,
B - the difference between independent determinations of Decl. in arc seconds.

N	MP	Date U.T.	$R.A._{2000}$	$Decl._{2000}$	A	B
1	1	1984 Aug. 29.01181	03 35 26.17	+09 59 59.2	0.3	0.4
2	1	1984 Aug. 29.06331	03 35 27.78	+10 00 01.2	0.8	0.5
3	1	1984 Sep. 30.01620	03 41 19.46	+09 50 22.7	0.3	0.8
4	1	1984 Sep. 30.04687	03 41 19.04	+09 50 20.4	0.5	0.5
5	1	1984 Oct. 01.01308	03 41 05.95	+09 49 10.2	0.4	0.1
6	2	1984 Aug. 04.93727	23 08 40.30	+07 54 23.6	1.1	0.6

N	MP	Date U.T.	$R.A._{2000}$	$Decl._{2000}$	A	B
7	2	1984 Aug. 04.97060	23 08 39.42	+07 54 09.4	0.4	0.2
8	2	1984 Aug. 18.86684	23 00 55.53	+05 53 30.0	0.1	0.2
9	2	1984 Aug. 18.88611	23 00 54.74	+05 53 18.1	0.2	0.5
10	2	1984 Aug. 29.94144	22 53 07.18	+03 49 53.8	0.4	0.2
11	2	1984 Aug. 31.95839	22 51 36.73	+03 25 17.1	0.1	0.6
12	2	1984 Aug. 31.98032	22 51 35.72	+03 25 00.5	0.5	0.2
13	2	1984 Sep. 04.94097	22 48 36.32	+02 35 15.0	0.7	0.5
14	2	1984 Sep. 04.97118	22 48 34.93	+02 34 52.0	0.4	0.4
15	2	1984 Sep. 30.87708	22 31 02.34	−03 04 18.4	0.4	0.7
16	3	1984 Jan. 26.79062	02 39 23.15	−00 03 12.1	0.1	0.5
17	3	1984 Jan. 26.84306	02 39 27.45	−00 02 37.0	0.1	0.5
18	4	1984 Jan. 30.78148	04 48 16.58	+20 22 19.7	0.2	0.1
19	4	1984 Jan. 30.84722	04 48 16.40	+20 22 30.7	0.2	0.2
20	4	1984 Feb. 08.78519	04 49 15.12	+20 50 09.5	0.2	0.4
21	4	1984 Feb. 08.80625	04 49 15.42	+20 50 13.8	0.6	0.1
22	6	1984 Oct. 26.03912	06 47 54.26	+04 43 30.9	0.6	0.7
23	6	1984 Oct. 26.07269	06 47 55.33	+04 43 20.8	0.7	0.3
24	7	1984 Aug. 31.97170	04 37 31.08	+26 23 57.7	0.2	0.7
25	7	1984 Aug. 31.99387	04 37 33.66	+26 24 02.0	0.6	0.2
26	7	1984 Sep. 30.96273	05 29 02.68	+26 59 35.1	0.5	0.3
27	7	1984 Oct. 01.02373	05 29 07.70	+26 59 33.4	0.8	0.8
28	11	1984 Apr. 25.93113	11 55 52.06	+07 14 50.8	0.3	0.7
29	11	1984 Apr. 25.96481	11 55 51.05	+07 14 55.5	0.3	0.4
30	25	1984 Aug. 28.99792	03 39 57.06	+21 23 07.2	0.1	0.5
31	25	1984 Aug. 29.05093	03 39 59.65	+21 22 51.9	0.5	0.6
32	25	1984 Sep. 29.99583	03 52 18.22	+17 13 21.5	0.3	0.3
33	25	1984 Sep. 30.93773	03 52 09.74	+17 03 05.7	0.1	0.5
34	25	1984 Sep. 30.99803	03 52 09.11	+17 02 25.2	0.1	0.1
35	39	1984 Jan. 26.81076	04 33 51.74	+08 51 43.3	0.7	0.3
36	39	1984 Jan. 26.85822	04 33 51.88	+08 51 59.4	1.0	0.6
37	39	1984 Jan. 30.80671	04 34 21.08	+09 14 48.0	0.7	0.2
38	39	1984 Jan. 30.85556	04 34 21.58	+09 15 04.4	0.9	0.1
39	39	1984 Feb. 08.79178	04 36 55.96	+10 08 45.4	0.3	0.1
40	40	1984 Aug. 30.03785	05 48 26.56	+21 14 58.8	0.1	0.2
41	40	1984 Aug. 30.10069	05 48 32.85	+21 15 03.2	0.1	0.4
42	148	1984 Apr. 25.94942	13 12 33.44	+22 30 26.4	0.1	1.0
43	148	1984 Apr. 25.97465	13 12 32.37	+22 30 32.4	0.2	0.8
44	389	1984 Aug. 22.94167	22 05 24.98	−01 18 36.4	0.1	0.3
45	389	1984 Aug. 22.98380	22 05 22.65	−01 18 43.7	0.3	0.6
46	389	1984 Sep. 02.91620	21 55 46.76	−01 56 40.7	0.8	0.1
47	704	1984 Aug. 28.81597	18 14 12.14	−19 27 39.8	0.2	0.2
48	704	1984 Aug. 28.84236	18 14 12.22	−19 27 35.6	0.1	0.1
49	704	1984 Aug. 29.83333	18 14 19.55	−19 24 24.1	0.1	0.4
50	1567	1984 Nov. 21.80278	02 05 06.52	+07 10 29.8	0.1	0.1
51	1567	1984 Nov. 21.87778	02 05 03.33	+07 10 36.1	0.2	0.1

4. Reference stars and dependences

The individual columns of the table contain the following:
N - ordinal number of the observation in agreement with Section 2,
Numbers of reference stars and dependences (SAO catalogue of reference stars is used at all the calculations),
T - the exposure time in minutes.

N	Numbers of stars and dependences						T
1	111258	.33139	93500	.19090	111287	.47771	
	93482	.27457	111247	.18516	111303	.54027	5
2	111258	.32266	93500	.19053	111287	.48681	
	93482	.27237	111247	.18240	111303	.54523	5
3	93500	.28802	111325	.36563	111430	.34635	
	111320	.34933	111356	.40968	111383	.24099	5
4	93500	.28791	111325	.36651	111430	.34558	
	111320	.35142	111356	.40843	111383	.24015	5
5	111303	.32215	111329	.28328	111389	.39457	
	111320	.41635	111356	.36516	11383	.21849	5
6	127952	.22870	127996	.41446	128015	.35684	
	127959	.45829	127972	.18854	128053	.35317	5
7	127952	.23106	127996	.41520	128015	.35374	
	127959	.46196	127972	.18604	128053	.35200	5
8	127867	.46649	127920	.42045	127942	.11306	
	127863	.09964	127875	.34799	127923	.55237	10
9	127867	.46791	127920	.42343	127942	.10866	
	127863	.09928	127875	.35155	127923	.54917	10
10	127803	.19649	127811	.50360	127837	.29991	
	127799	.16207	127811	.58669	127844	.25124	7
11	127794	.30975	127798	.54387	127837	.14638	
	127785	.59421	127789	.15197	127862	.25382	5
12	127794	.31044	127798	.54745	127837	.14211	
	127785	.60001	127789	.14801	127862	.25198	5
13	127729	.14142	127778	.42012	127785	.43846	
	127730	.20547	127760	.35797	127798	.43656	5
14	127729	.14649	127778	.42245	127785	.43106	
	127730	.20550	127760	.36394	127798	.43056	5
15	146093	.24519	146106	.30160	146166	.45321	
	146089	.37642	146164	.34549	146140	.27809	5
16	129997	.40746	110664	.24704	130080	.34550	
	110617	.47180	130074	.27963	110719	.24857	5
17	129997	.39381	110664	.25521	130080	.35098	
	110617	.46552	130074	.27322	110719	.26126	5

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N	Numbers of stars and dependences						T
18	94071	.36133	76776	.37924	94203	.25943	
	94103	.32434	76747	.42079	76817	.25487	5
19	94071	.36120	76776	.38017	94203	.25863	
	94103	.32337	76747	.42225	76817	.25438	5
20	94071	.20568	76776	.58501	94203	.20931	
	94103	.09223	76747	.54487	76817	.36290	5
21	94071	.20512	76776	.58560	94203	.20928	
	94103	.09144	76747	.54501	76817	.36355	5
22	114374	.33579	114441	.15710	114467	.50711	
	114389	.32244	114436	.26414	114450	.41342	6
23	114374	.33128	114441	.15453	114467	.51419	
	114389	.31465	114436	.26115	114450	.42420	6
24	76642	.29240	76675	.22480	76704	.48280	
	76642	.33830	76656	.21007	76725	.45163	5
25	76642	.28769	76675	.22510	76704	.48721	
	76646	.25782	76656	.32929	76725	.41289	5
26	77171	.41938	77213	.20620	77221	.37442	
	77159	.24687	77185	.47388	77263	.27925	5
27	77171	.39921	77213	.21304	77221	.38775	
	77159	.23873	77185	.47192	77263	.28935	5
28	119070	.24138	119105	.36783	119167	.39079	
	119082	.30296	119102	.36288	119172	.33415	8
29	119070	.24345	119105	.36682	119167	.38973	
	119082	.30471	119102	.36286	119172	.33243	8
30	76045	.35320	76050	.41353	76092	.23327	
	76037	.47546	76076	.24832	76090	.27622	12
31	76045	.35047	76050	.40410	76092	.24543	
	76037	.46506	76076	.25055	76090	.28439	12
32	93602	.26575	93632	.10827	93663	.62598	
	93608	.21846	93649	.26251	93654	.51903	10
33	93615	.36854	93642	.22049	93671	.41097	
	93608	.30309	93649	.23555	93662	.46136	6
34	93615	.37386	93642	.21306	93671	.41308	
	93608	.30668	93649	.22665	93662	.46667	6
35	111855	.35882	111899	.30508	111921	.33610	
	111856	.27360	111890	.43552	111920	.29088	5
36	111808	.22580	111882	.49045	112009	.28375	
	111794	.30484	940037	.27084	111945	.42432	5
37	111808	.31992	111882	.29565	112009	.38443	
	111794	.25662	940037	.40498	111945	.33840	5

N	Numbers of stars and dependences						T
38	111808	.32091	111882	.29333	112009	.38576	
	111794	.25586	940037	.40669	111945	.33745	5
39	93995	.25497	94037	.20840	111952	.53663	
	94008	.30041	111921	.18114	94048	.51845	5
40	77533	.32278	77603	.42620	77607	.25102	
	77549	.46642	77557	.29735	77663	.23623	8
41	77533	.29225	77603	.43581	77607	.27194	
	77549	.45810	77557	.28712	77663	.25478	8
42	82622	.14708	82731	.49928	82732	.35364	
	82638	.21743	82639	.26833	82784	.51424	10
43	82622	.14865	82731	.49907	82732	.35228	
	82638	.21759	82639	.26942	82784	.51299	10
44	145825	.28339	145846	.35914	145901	.35747	
	145829	.22093	145864	.62937	145878	.14970	8
45	145825	.28755	145846	.36170	145901	.35075	
	145829	.22830	145864	.63245	145878	.13925	10
46	145725	.28218	145748	.35116	145775	.36666	
	145706	.20355	145756	.41792	145769	.37853	8
47	161179	.13890	161190	.60138	161286	.25972	
	161160	.35407	161220	.50455	161241	.14138	10
48	161179	.13997	161190	.59999	161286	.26004	
	161160	.35397	161220	.50353	161241	.14250	10
49	161179	.18065	161190	.53179	161286	.28756	
	161160	.33469	161220	.46094	161241	.20437	12
50	110297	.37943	110307	.21925	110361	.40132	
	110288	.24542	110321	.44100	110365	.31358	15
51	110297	.38602	110307	.22252	110361	.39146	
	110288	.25238	110321	.44205	110365	.30557	15

5. List of collaborators

Name	Exposures	Measurements	Reductions
G. Červák	8	10	–
L. Kornoš	17	17	18
P. Rychtarčík	24	20	–
J. Svoreň	2	4	33

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References

Murray, C.A.: 1989, *Astron. Astrophys.* **218**, 325
Svoreň, J.: 1996, *Contrib. Astron. Obs. Skalnaté Pleso* **26**, 10
Neslušan, L., Svoreň, J.: 1996, *Contrib. Astron. Obs. Skalnaté Pleso* **26**, 73
Smithsonian Astrophysical Observatory Star Catalog. Parts 1-3, Washington, Smithsonian Institution, 1966
Yeomans, D.K.: 1990, *Conversion to FK5/J2000.0*, IAU Commission 20, The letter dated 5 December 1990