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The history of cometary astrometry at the Skalnaté Pleso Observatory

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Abstract. Programmes of obtaining the precise positions of comets at the Skalnaté Pleso Observatory and results obtained are described. The observations have been carried out since 1946. Three telescopes (0,6-m f/5.5 Newtonian reflector, 0.3-m f/5 astrograph and 0.61-m f/4.2 Newtonian reflector) and two different methods (photography and CCD) have been used. The description consists of characteristics of observing methods, measurements and calculations.

In total, 3737 precise positions of comets have been obtained. These were continually published first in the International Astronomical Union Circulars and later on in the Minor Planet Circulars. Complete data together with the lists of reference stars and dependences were published in the journal Contributions of the Astronomical Observatory Skalnaté Pleso. A list of collaborators is also given, together with their part in photographing, measuring and reducing the positions.

Key words: comets – astrometry

1. Introduction

Our observing site Skalnaté Pleso has ocassionally been used for photographic astrometry of comets since 1946. During the photographic programme (1946-1999), a few new minor planets were also discovered.

Up to the end of May 2005, 2487 accurate positions of comets were obtained on photographic plates and 1250 CCD frames exposed at the Skalnaté Pleso Observatory. A minimum of two positions were secured for all the observed comets.

The positions have been published in two series. First, they were sent to the Minor Planets Center and, occasionally, in the case of extraordinary interesting objects, to the Central Bureau for Astronomical Telegrams and used for determination of preliminary orbits. As the possibility of improving orbits in the future by re-measuring and re-determination of the positions is not negligible, in addition, the positions supplemented with the data on the reference stars and dependences were published in the journal Contributions of the Astronomical

Observatory Skalnaté Pleso. Astrometrical results obtained during our first period of cometary observations were published in two extensive articles (Kresák and Antal, 1966; Antal, 1973). Since 1965 the articles that comprised positions from one to three years intervals have been published.

2. Site and instrumentation

Until 1965, comets were observed at the Skalnaté Pleso Observatory at the Newtonian focus of the 0.6-m f/5.5 reflector (focal length 3.29 m) located at the east dome of the observatory and the results were published mainly in this journal.

Since construction of the 0.3-m f/5 Zeiss astrograph (focal length 1.5-m) in the west dome of the Skalnaté Pleso Observatory in 1965, photographic observations of comets have been one of its regular programmes. During the period 1965-1999 altogether 1811 precise astrometric positions of comets were obtained. Simultaneously, this telescope was used for photographing asteroids as well.

The topographical coordinates of the Skalnaté Pleso telescopes were remeasured in August 2005 (Mojzeš and Papčo, 2005). The system ITRS and the quasigeoid GMSQ03CF were used. The topographical coordinates are as follows:

• 0,6-m f/5.5 Newtonian reflector:
$\lambda = -\ 1^h\ 20^m\ 56.184^s$,
$\varphi = +49^\circ\ 11'\ 21.77''$,
h = 1784 m above sea level.

• 0.3-m f/5 astrograph and 0.61-m f/4.2 Newtonian reflector (both the telescopes were placed on the same mounting in different epochs):
$\lambda = -\ 1^h\ 20^m\ 56.117^s$,
$\varphi = +49^\circ\ 11'\ 21.77''$,
h = 1786 m above sea level.

The difference in λ is caused by the distance between the east and the west dome of the observatory. However, the difference in the positions of both instruments is negligible from the point of view of determining the parallactic factors for comets.

Comets were observed at our institution also by smaller instruments, e.g. by the parabolic reflector with 0.24-m diameter of mirror and 1.2-m focal length and the Maksutov camera with 0.34-m meniscus lens, 0.44-m diameter of mirror and 0.95-m focal length at the Skalnaté Pleso and the parabolic reflectors with 0.4-m diameter of mirror and 2.0-m focal length and the second one with 0.2-m diameter of mirror and 0.9-m focal length at the Lomnický Štít Observatory.

3. Methods of photographic observations and measurements

The photographic observations of comets were made in such a way that a given star field was exposed twice within a time interval of 0.5-2 hours. The comets were photographed on ORWO plates with ZU 1, ZU 2, ZU 21 and NP27 emulsions and Kodak plates with 103aO emulsion. The dimensions of the plates at the astrograph were 9x12 and 24x24 cm, which roughly corresponds to fields of 3 x 4 and 8.5 x 8.5 degrees of arc.

As noted by Kresák and Antal (1966), the difficulties of guiding moving cometary images accurately enough during longer exposures were removed by the construction of an auxiliary device for independent motion of the plate holder. This device permitted guiding on a star in the neighbourhood of a comet, and following the comet's predicted motion - if an ephemeris was available - by the orientation of the plate holder in the direction required. Employing this device, A. Mrkos succeeded in recovering 3 periodic comets at magnitude about 18.

The comets were identified on the plates by means of a blink comparator produced by the Zeiss Company, using ephemerides published in the IAU Circulars and the Minor Planet Circulars by Marsden and his collaborators, and later also using the ephemerides published in Comet Handbooks (e.g. Nakano, Green, 2003).

In order to reduce the random errors due to the inaccuracy of the positions of the reference stars - in particular due to unknown proper motions accumulated over several decades - it was customary to select reference stars that were as faint as possible. The reference stars required to compute positions using Schlesinger's method of dependences were selected: six stars were combined into two independent triangles. Until 1966 the Yale Catalogues, the AGK2 and the proper motion catalogue EBL2 were used for the reduction of observations. More recently, the data about reference stars were exclusively taken from the Star Catalog of the Smithsonian Astrophysical Observatory. Both the reference stars and the comets were always measured 4-6 times. The mean error of the plate measurements was $0.3''$. For especially ill-defined comets without any central condensation the error could be on the level of $2''$. The difference between independent determinations of the equatorial coordinates, for the two triangles, represents a measure of the precision (but not the accuracy of the object's position). The rectangular coordinates of the reference stars and the comets were measured with the aid of instruments for measuring coordinates manufactured by Zeiss - a Koordinatenmessgerät and an Ascoremat E-60.

The positions were measured in the B1950.0 system and then converted to J2000.0 following the formulas published by the System Transition Commitee of the IAU Commission 20 (Yeomans, 1990). The formulas used can be found, for example, in Svoreň (1998).

The selection of observation programmes has mainly been limited by capabilities of our 0.3-m astrograph. The limiting magnitude for difuse images of comets was about total magnitude 14.3 for a 60 minute exposure under excelent atmospheric conditions. The mean exposure time used was 20 minutes. It is clear that only bright comets could be observed.

4. CCD observations and the new mirror telescope

Since summer 1999 we have used the 0.30-m astrograph equipped with a ST8 CCD camera manufactured by the Santa Barbara Instrument Group. In 1999 both photography and CCD were used. Since January 2000, the CCD camera only has served as a detector.

On December 1, 2000, a new 0.61-m f/4.2 mirror telescope replaced the astrograph on its mounting. Since then the CCD camera at the Newtonian focus has been exclusively used for observations of comets. A majority of frames have been taken in the R and V spectral bands. The CCD camera ST-8 is equipped with a Kodak KAF 1600 chip of 1530 x 1020 elements (9x9 μm). Due to very good light-gathering power, the field-of-view is as large as 13 x 19 arc minutes. This field is large enough not to cause problems with an insufficient number or poor distribution of reference stars usually present when CCDs are mounted on medium-sized and large telescopes. The maximum quantum efficiency of the camera is 42% between 700 and 800 nm. A single-stage thermoelectric cooler is used. The limiting magnitude is 20 for a 180-second exposure in R under good atmospheric conditions.

The software Astrometrica 3.2 produced by Herbert Raab and USNO-A2.0 catalogue are used for measuring and reducing positions.

5. Observational statistics

Tab. 1 shows the numbers of astrometric observations of comets obtained at the Skalnaté Pleso Observatory in the given period. In the most successful year, 2003, 371 positions of comets were obtained.

Table 1. Number of observations

years	expositions	years	exposures
photography		photography	
1946-1950	130	1981-1985	374
1951-1955	169	1986-1990	393
1956-1960	146	1991-1995	311
1961-1965	232	1996-1999	172
1966-1970	190		
1971-1975	255	CCD	
1976-1980	115	2000-2005	1250

6. List of collaborators

It must be emphasized that the present paper summarizes the results of collective work of the Interplanetary Matter Division of the Astronomical Institute of the Slovak Academy of Sciences staff. The share of individual collaborators in photographing, measuring and reducing the positions during the past 60 years is shown in Table 2.

Table 2. List of collaborators of photographic programme

name	exposures	measurements	reductions
A. Aldor	–	170	–
M. Antal	769	636	–
A. Antalová	13	25	128
A. Bečvář	8	–	–
P. Bendík	2	–	–
J. Borošová	7	2	–
E. Buchar	6	7	7
G. Červák	984	988	–
T. Čiško	29	–	–
Š. Dendis	7	55	–
M. Dzubák	1	–	–
J. Fabrícius	36	71	–
M. Husárik	195	195	–
M. Jakubík	29	29	–
T. Jančík	12	–	–
M. Kamenický	113	113	–
Z. Kaňuchová	22	22	–
J. Klobušník	41	32	–
L. Kornoš	25	31	26
Ľ. Kresák	83	92	357
M. Kresáková	41	22	70
A. Mrkos	130	–	–
L. Neslušan	31	27	86
Ľ. Pajdušáková	50	43	–
P. Paľuš	1	3	–
L. Petrík	15	–	–
E.M. Pittich	–	–	543
M. Plavec	–	21	21
R. Podstanická	2	–	–
P. Rychtarčík	1025	1049	–

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Table 2. List of collaborators of photographic programme - continued

name	exposures	measurements	reductions
P. Schalling	41	19	–
B. Šternberk	–	20	20
J. Svoreň	6	60	1680
J. Tremko	13	–	–
V. Vanýsek	–	5	5

7. Conclusion

Determinations of precise positions of periodic and newly discovered comets constituted our main programme in the years 1946-1964. Many of those positions were used to calculate preliminary orbits. After the programme was moved from the 0.6-m reflector to the 0.3-m astrograph, we had fewer possibilities of observation of new comets and so since 1965 our observations have been only used for an improvement of definitive cometary orbits in the Central Bureau for Astronomical Telegrams.

In the years 1985-1986 our observatory successfully took part in activities of the Astrometric Network of International Halley Watch campaigne. More than 130 precise positions of the periodic comet 1P/Halley were used for corrections of orbits of the space vehicles VEGAs and GIOTTO, which encountered the comet in space near its perihelion in February 1986. Nowadays, the astrometric programme of the Skalnaté Pleso Observatory (both comets and asteroids) is restricted to the most interesting objects only. Observing time is used mostly to measure different photometric characteristics of asteroids and comets.

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