

SESSION B

CURRENT AND FUTURE PROJECTS FOR
SOUTHERN HEMISPHERE REFERENCE SYSTEMS

OBSERVATIONS IN CHILE AND RESULTS RELATED TO SOUTHERN HEMISPHERE SYSTEMS

(Invited Paper)

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Abstract. The astrometric observations made at the Cerro Calán observatory with several instruments since 1962 are outlined. The resulting catalogues are in press or approaching publication, and are described in some detail. An account is given of the observational projects currently in progress.

The various catalogues are combined in order to demonstrate the large and well-determined systematic differences in $\Delta\alpha_s \cos \delta$ between the Cerro Calán observations and the FK4. It is concluded that the FK4 system requires some improvement if it is to fulfil the requirements of a fundamental reference system in the southern hemisphere.

1. Introduction

Several programmes of observations related to southern hemisphere reference systems have been observed at the Observatorio Astronómico Nacional de Chile since 1962, the year when the observatory was moved to its present location at Cerro Calán, and when a cooperation between Chilean and Soviet astronomers began under an agreement between the USSR Academy of Sciences and the University of Chile. This joint effort includes observations of the SRS and BS programmes with the Repsold Meridian Circle, absolute and quasi-absolute observations of FK4, FK4 Sup and FKSZ stars with the photographic vertical circle, the Zeiss broken transit instrument and the Pulkovo large transit instrument. The last three instruments were sent to Chile by Pulkovo Observatory and installed at Cerro Calán.

A Danjon impersonal astrolabe has been in operation at Cerro Calán since 1965 for determining latitude and time and corrections to right ascensions and declinations of bright fundamental stars. This instrument was installed at the observatory under an agreement between the European Southern Observatory and the University of Chile.

The purpose of this paper is to present the status of the catalogues already compiled from observations made at Cerro Calán Observatory, the progress of the current programmes of observations and finally, a system of corrections $\Delta\alpha_s \cos \delta$ to the FK4 positions compiled on the basis of the four catalogues presented and absolute observations of right ascensions made with the Pulkovo large transit instrument.

2. Catalogues Compiled from Observations made at Cerro Calán Observatory

Three catalogues of right ascension: the Santiago-Pulkovo Fundamental 1 (SPF-1), the Santiago-Pulkovo 2 (SP-2) and the Santiago-Pulkovo Fundamental 3 (SPF-3) and a catalogue of right ascensions and declinations, the First Astrolabe Catalogue of

Santiago have been compiled. The SPF-1, the SPF-3 Catalogues and the First Astrolabe Catalogue are already in press in *Publicaciones del Departamento de Astronomía de la Universidad de Chile* and the SP-2 Catalogue is now being prepared for publication.

The main characteristics of the catalogues are described below.

(1) The SPF-1 Catalogue gives the position of 1044 FK4 fundamental stars with an average mean epoch of observation of 1965.0. The methods of observation and reduction were described by Anguita *et al.* (1971). The catalogue contains the results of observations of Küstner series of the FK4 stars with the Repsold Meridian Circle ($d=19$ cm, $f=244$ cm) in the declination zone $+41^\circ$ to -90° (from -68° to -90° in lower culmination). 211 series of 6793 star observations were made from 1963 to 1968. The mean error of one observation reduced to the equator is $\pm 0^{\circ}020$ for upper culmination and $\pm 0^{\circ}022$ for lower culmination.

The reductions were made using the quasi-absolute method proposed by Zverev (1969) which implies that the reductions were made in the instrumental system with the conditions that the system coincides with the FK4 fundamental system in the equator and the pole. Figure 1 gives the systematic differences $\Delta\alpha_\delta \cos\delta$ in the sense SPF1 – FK4, and shows the conditions already mentioned. The results of the 82 stars observed in lower culmination were not combined with the results in upper culmination because the instrumental system may show some irregularities that may affect the individual star positions and for this reason they are listed separately at the end of the catalogue.

(2) The SP-2 Catalogue contains the results of observations of FK4 stars in zone observations of SRS stars with the Repsold Meridian Circle. 15160 FK4 star observations were made from 1963 to 1968 in the zone -47° to -90° , the Russian

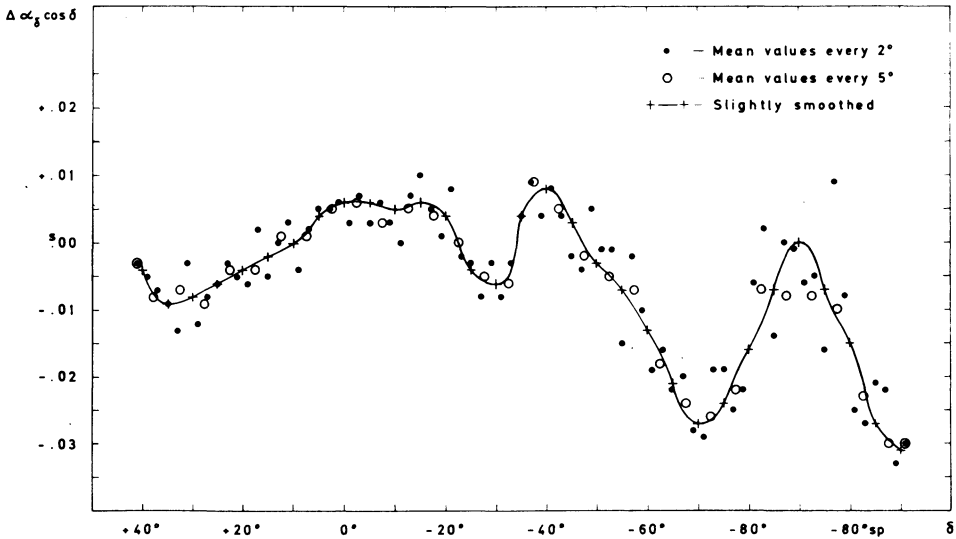


Fig. 1.

commitment of the SRS programme. The mean error of one observation, reduced to the equator is $\pm 0^{\circ}.016$ for upper culmination and $\pm 0^{\circ}.020$ for lower culmination. The results are just complete in the zone -25° to -47° , the Chilean commitment of the SRS. The mean error of one observation in this zone is $\pm 0^{\circ}.015$. All the reductions were made in the FK4 system and in the instrumental system of the Repsold Meridian Circle.

(3) The SPF-3 Catalogue was derived from quasi-absolute observations made with the Zeiss broken transit instrument ($d=10$ cm, $f=100$ cm) of a special programme described by Loyola and Shishkina (1968). The programme consisted of 726 stars from

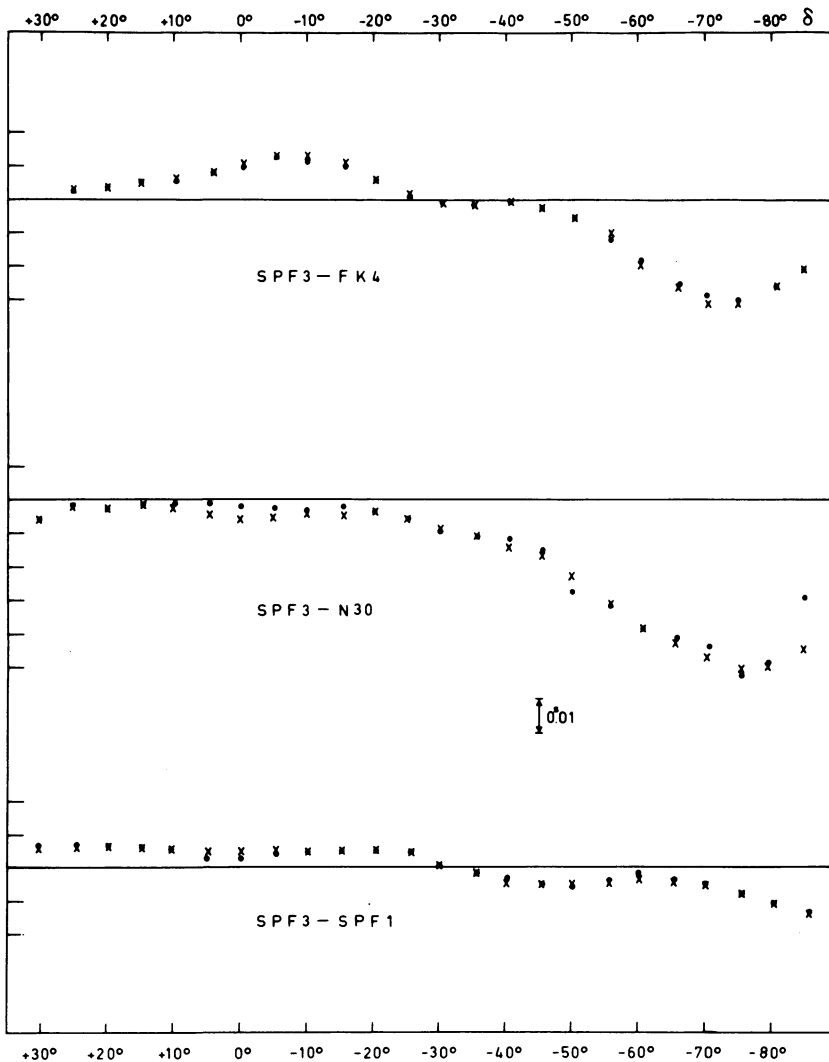


Fig. 2. Systematic differences of type $\Delta\alpha_{\delta} \cos \delta$.

+40° to -90° including 666 FK4 stars; 42 stars with declination from -75° to -90° were observed in lower culmination. Approximately 12800 star observations were made from April 1963 to September 1964 and the mean error of one observation is ± 0.024 .

Besides the series of observations of the main programme, a special programme was regularly observed, once a week, in order to determine the azimuth of the instrument. The series of observations of this auxiliary programme enabled us to smooth

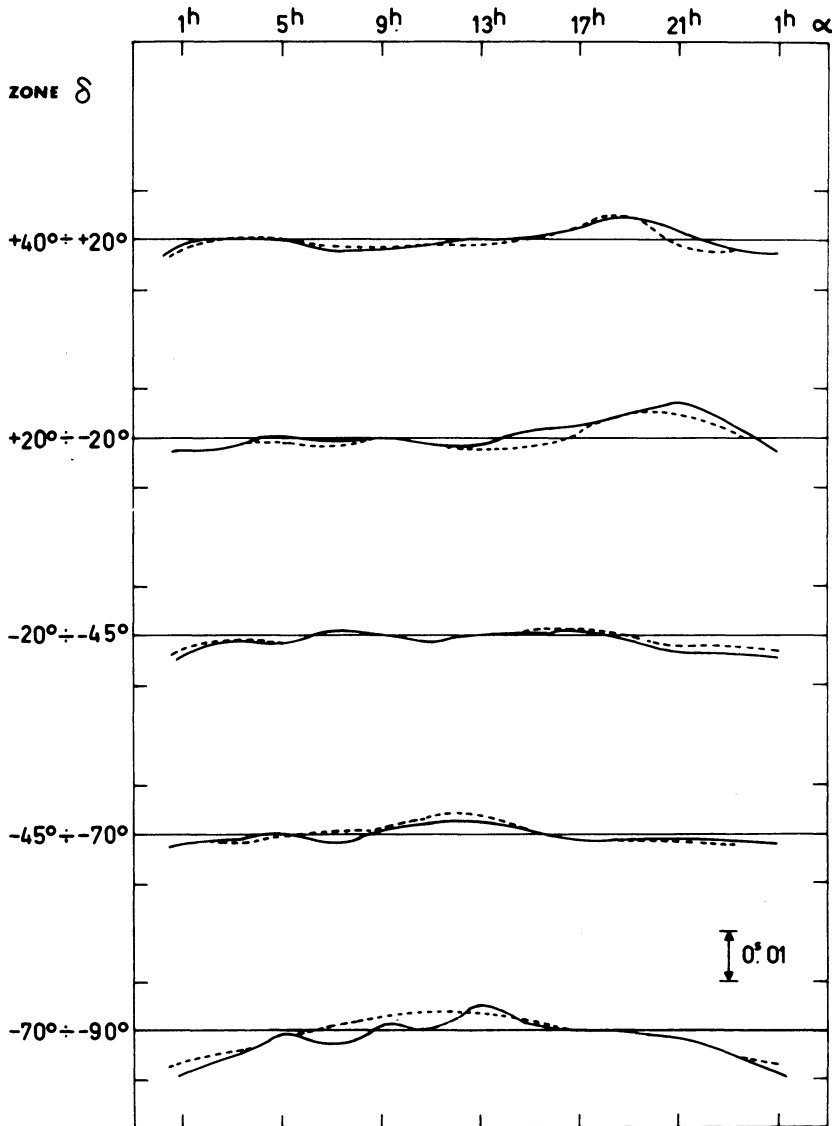


Fig. 3. Systematic differences $\Delta\alpha \cos \delta$ in the sense SPF3 - FK4.

the right ascension system obtained for the zenith zone (-21° to -45°) and to determine the systematic errors of the FK4 in this zone. The SPF-3 Catalogue is tied to the FK4 system in the zenith zone of Santiago but it is free from its $\Delta\alpha_x$ and $\Delta\alpha_\delta$ errors.

Figure 2 shows the systematic differences $\Delta\alpha_\delta \cos \delta$ of the SPF-3 from the FK4, N30 and SPF-1 Catalogues obtained by the classical method of comparing catalogues and the method developed by Brosche (1966). Figure 3 shows that the $\Delta\alpha_x$ errors of the FK4 are smaller than the systematic errors of the type $\Delta\alpha_\delta$.

(4) The First Astrolabe Catalogue of Santiago gives the positions of 540 FK4 and FK4 Sup stars with an average mean epoch of observation of 1969.4. The observing programme was described by Noël (1968). All suitable FK4 and FK4 Sup stars from -5° to -62° and brighter than magnitude 6.3 have been observed. A selection of 233 FK4 and 24 FK4 Sup stars of the zone was arranged in 11 groups of 28 transits distributed equally in azimuth. These are the 'standard groups' which define the system for the Astrolabe Catalogue of Santiago. The remaining stars were observed in the 'catalogue groups' such that each star could be observed in both transits. The first series of 11 catalogue groups of about 300 stars was observed in 1967 and 1968, and the second series of about 200 stars in 1969 and 1970. In 1971 and 1972 the observations of some catalogue groups of both series which had a rather low number of observations were completed. Table I gives the differences in right ascension and declination of the Astrolabe Catalogue and the FK4 as a function of declination. The results in declination seem to indicate that the FK4 declination system is probably more reliable than the right ascension system.

TABLE I
First Astrolabe Catalogue of Santiago
Systematic errors of FK4 fundamental system, as a function of declination
1969.4
Astrolabe-FK4

δ	$\Delta\alpha$	m.e.	N	δ	$\Delta\delta$	m.e.	N
- 9.5	0.001	0.001	63	- 9.5	0.05	0.02	63
- 14.0	0.006	0.001	71	- 14.0	0.05	0.02	71
- 19.7	0.004	0.001	57	- 19.7	0.00	0.02	57
- 25.2	- 0.002	0.002	51	- 24.7	- 0.05	0.04	46
- 30.9	- 0.004	0.002	54	- 27.6	- 0.11	0.07	17
- 35.8	0.002	0.003	52				
- 41.5	0.002	0.003	52				
- 46.4	- 0.002	0.003	55	- 50.3	- 0.03	0.07	14
- 52.1	- 0.009	0.004	50	- 52.8	- 0.02	0.04	43
- 57.5	- 0.023	0.005	46	- 57.5	- 0.04	0.03	46

3. Current Projects for Southern Hemisphere Reference System

The following projects are at present in progress at Cerro Calán:

(1) SRS Programme. The observations of the Chilean commitment in the zone -25° to -47° (5992 SRS and 805 BS stars) have been carried out with the Repsold Meridian Circle, and the reduction of observations in right ascension has been completed. The final catalogue will be ready by 1975.0.

(2) Absolute right ascension determinations of FK4 and FKSZ stars. This programme of absolute determinations of right ascensions contains 1894 stars including all the FK4 stars in the zone $+40^\circ$ to -90° and all the FKSZ stars from $+30^\circ$ to -90° . All the FK4 stars in zone -70° to -90° and all the FKSZ stars from -75° to -90° are observed in both culminations (130 stars).

40900 individual star observations were made with the Pulkovo large transit instrument ($d=18$ cm, $f=240$ cm) from May 1969 to October 1970. Then the objective glass and the ocular were interchanged and a new series of observations started in December 1970. The programme will be continued until the end of this year when there will be the same number of observations as were made in the first position of the instrument.

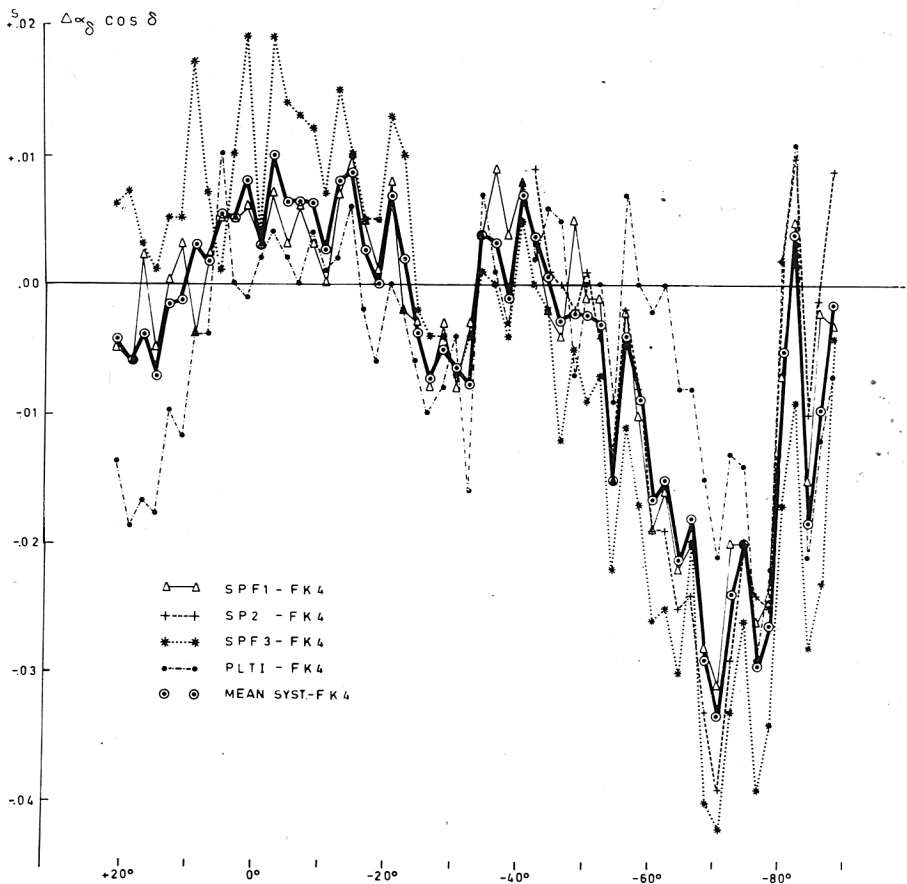


Fig. 4.

(3) FKSZ programme. For inclusion of stars down to 9th magnitude, especially FKSZ stars, into the fundamental system, right ascension and declinations of 651 FKSZ stars in the zone $+40^\circ$ to -90° are being observed with the Repsold Meridian Circle. It is intended to make six observations of each star. The programme started early this year and will take about two years.

(4) Positions of optical counterparts of radio sources. A list of twenty radio sources used as calibrators is being observed with the Double Meniscus Maksutov telescope ($d=70$ cm, $f/3.0$). The aim of the programme is to give the positions of the optical counterparts of the radio sources in the FK4 system.

4. Compilation of a System of Corrections $\Delta\alpha_\delta \cos\delta$ to the FK4

Using the data of the SPF-1, SPF-3, the southern part of the SP-2 (from -42° to -90°) and the series of absolute determinations of right ascension made with the Pulkovo large transit instrument, Anguita *et al.* (1973) compiled a system of corrections $\Delta\alpha_\delta \cos\delta$ to the FK4 system. Figure 4 shows the systematic differences of these catalogues and the FK4, as given in the paper just mentioned. Table II gives the same

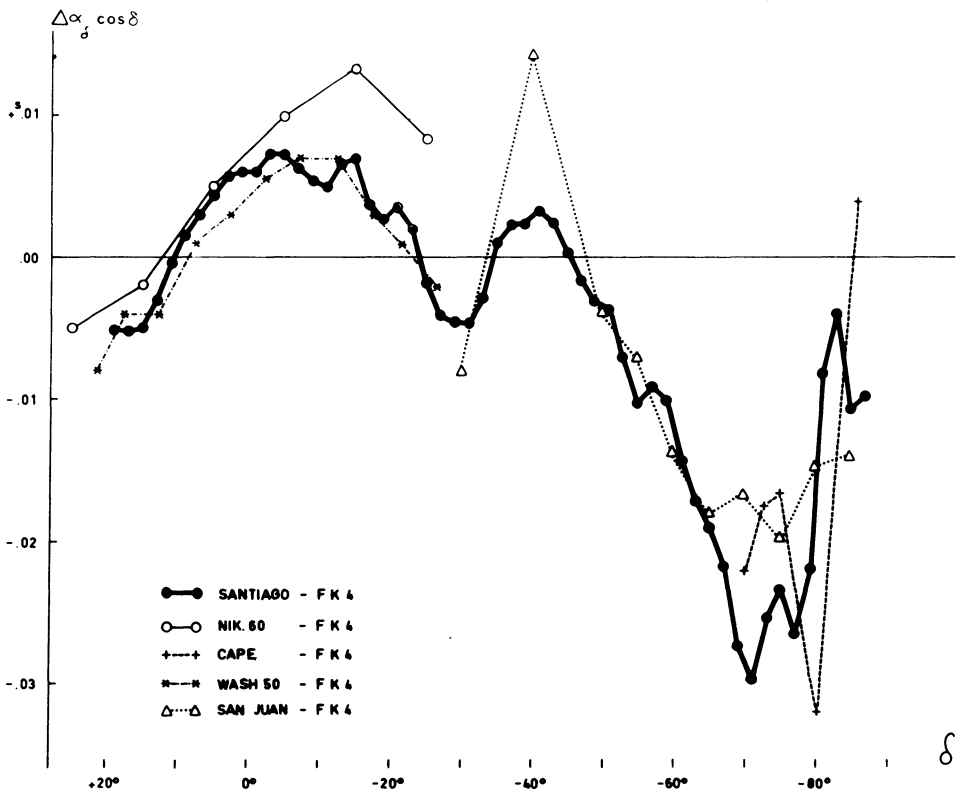


Fig. 5.

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TABLE II
 Systematic differences $\Delta\alpha_3 \cos \delta$ (Catalogue – FK4)
 (Unit 0.001)

δ	SPF-1	SP-2	SPF-3	ASTR	PLT1	Mean system	Smoothed mean system	ε_i
+21	- 5		+ 6		-14	- 4.3		± 5
+19	- 6		+ 7		-19	- 6.0	- 5.1	6
+17	+ 2		+ 3		-17	- 4.0	- 5.3	5
+15	- 5		+ 1		-18	- 7.3	- 5.0	5
+13	0		+ 5		-10	- 1.7	- 3.0	4
+11	+ 3		+ .5		-12	- 1.3	- 0.4	4
+ 9	- 4		+17		- 4	+ 3.0	+ 1.6	5
+ 7	+ 2		+ 7		- 4	+ 1.7	+ 3.0	3
+ 5	+ 5		+ 1		+10	+ 5.3	+ 4.4	2
+ 3	+ 5		+10		0	+ 5.0	+ 5.8	2
+ 1	+ 6		+19		- 1	+ 8.0	+ 6.0	5
- 1	+ 3		+ 4		+ 2	+ 3.0	+ 6.0	0
- 3	+ 7		+19		+ 4	+10.0	+ 7.3	4
- 5	+ 3		+14		+ 2	+ 6.3	+ 7.2	3
- 7	+ 6		+13		0	+ 6.3	+ 6.3	3
- 9	+ 3		+12		+ 4	+ 6.3	+ 5.4	2
-11	0		+ 7	+ 2	+ 1	+ 2.5	+ 4.6	1
-13	+ 7		+15	+ 5	+ 2	+ 7.2	+ 6.2	2
-15	+10		+10	+ 6	+ 6	+ 8.0	+ 6.6	1
-17	+ 5		+ 5	+ 5	- 2	+ 3.2	+ 3.8	1
-19	+ 1		+ 5	+ 4	- 6	+ 1.0	+ 2.8	2
-21	+ 8	+ 6	+13	+ 2	0	+ 5.8	+ 3.7	2
-23	- 2	+ 5	+10	0	- 2	+ 2.2	+ 2.0	2
-25	- 3	+ 1	- 2	- 2	- 6	- 2.4	- 1.8	1
-27	- 8	0	- 4	- 2	-10	- 4.8	- 4.0	2
-29	- 3	- 2	- 4	- 3	- 8	- 4.0	- 4.4	1
-31	- 8	0	- 7	- 4	- 4	- 4.6	- 4.6	1
-33	- 3	0	- 4	- 2	-16	- 5.0	- 2.8	2
-35	+ 4	+ 3	+ 1	+ 2	+ 7	+ 3.4	+ 1.1	1
-37	+ 9	+ 1	0	+ 2	+ 1	+ 2.6	+ 2.4	1
-39	+ 4	0	- 4	+ 2	+ 3	+ 1.0	+ 2.4	1
-41	+ 8	+ 3	+ 5	+ 2	+ 8	+ 5.2	+ 3.4	1
-43	+ 4	+ 3	0	+ 1	+ 2	+ 2.0	+ 2.5	1
-45	- 2	+ 3	- 2	- 1	+ 6	+ 0.8	+ 0.4	1
-47	- 4	+ 4	-12	- 2	+ 5	- 1.8	- 1.4	3
-49	+ 5	- 4	- 5	- 3	- 7	- 2.8	- 2.6	2
-51	- 1	+ 1	- 9	- 5	0	- 2.8	- 3.0	2
-53	- 1	- 4	- 7	- 7	0	- 3.8	- 6.0	1
-55	-15	-14	-22	- 9	- 9	-13.8	- 8.8	2
-57	- 2	- 2	-11	-12	+ 7	- 4.0	- 7.6	3
-59	-10	- 8	-17		0	- 8.8	- 9.5	3
-61	-19	-19	-26		- 2	-16.5	-14.2	4
-63	-16	-19	-25		0	-15.0	-17.0	5
-65	-22	-25	-30		- 8	-21.3	-18.9	4
-67	-20	-24	-20		- 8	-18.0	-21.6	3
-69	-28	-33	-40		-15	-29.0	-27.3	5
-71	-31	-39	-42		-21	-33.3	-29.7	4
-73	-20	-29	-33		-13	-23.8	-25.2	4
-75	-20	-20	-26		-14	-20.0	-23.3	2
-77	-26	-24	-39		-29	-29.5	-26.4	3
-79	-24	-25	-34		-22	-26.3	-21.8	2
-81	- 7	+ 2	-17		+ 2	- 5.0	- 8.0	3
-83	+ 5	+10	- 9		+11	+ 4.3	- 3.8	4
-85	-15	-10	-28		-21	-18.5	-10.6	3
-87	- 2	- 1	-23		-12	- 9.5	- 9.7	4
-89	- 3	+ 9	- 4		- 7	- 1.3		3

differences but adding now the data of the First Astrolabe Catalogue and the northern part of the SP-2 Catalogue (-20° to -45°). Column 8 of the table gives the smoothed mean system of corrections to the FK4 and can be seen also in Figure 5 together with the results obtained at the other observatories. The averaged standard error of one correction is $\pm 0^{\circ}0027$.

5. Conclusion

The catalogues compiled from observations made at Cerro Calán have indicated that the FK4 system of right ascension has very large systematic errors of the type $\Delta\alpha_\delta$ and that the system should be improved in order to fulfill the requirements of a fundamental reference system.

Also there are many southern FK4 stars which need large individual corrections in right ascension as well as in declination, according to the results of the Astrolabe Catalogue. However, the data of this catalogue seem to indicate that FK4 system of declinations is more reliable than that of the right ascensions.

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DISCUSSION

Fricke: I want to congratulate the team of observers from the Pulkovo and the Santiago Observatory on their fine results. Dr Anguita has mentioned that in view of the large deviations they found with respect to the FK4 it appears necessary to compile the SRS catalogue in an improved system. A decision on this question will be made in one or two years from now after consultation between the workers in Santiago-Pulkovo, Washington and Heidelberg. In my opinion it would certainly be best if the SRS catalogue could be given in the system of the FK5.

Wall: Any additional optical positions for quasi-stellar objects would be helpful in the position calibration of the Parkes telescope. Approximately how many such positions are you measuring?

Anguita: About twenty.

Luyten: I hope you will keep these plates taken with the Maksutov telescope on Quasars very carefully and that you will repeat them in 20–25 years. For then, if you measure the proper motion of the quasar relative to, say, 10–20 stars of about the same magnitude, you will get exactly what we have always wanted: the correction from relative to absolute proper motion for stars of a given magnitude.

Anguita: Yes, we will keep these plates on Quasars as carefully as the first epoch plates of the Proper Motion program observed with the Maksutov Astrograph, and we intend to repeat them in 20 years with the same purpose you mentioned.

Gliese: The mean epoch of the right ascension series observed at Cerro Calán is about 1966 or somewhat later. The small Cape polar catalogue observed in 1936 shows already nearly the same large $\Delta\alpha_\delta$ errors of the FK4 system which means that no significant proper motion corrections can be derived from that epoch difference of about 30 years and that, probably, errors in the fundamental proper motion system alone will not be responsible for that large $\Delta\alpha_\delta$ error in FK4.

Anguita: I agree with you. It seems to me that the large $\Delta\alpha_s$ errors in the southern part of FK4 in the 1960's are due mainly to the system of positions of the FK4 at the mean epoch of the catalogue and probably only a small fraction of them to the fundamental proper motion system. Probably this is what we may expect if the FK4 system in the southern part of the sky is based mainly on observations made with only one instrument: the Cape Transit Instrument.