ON DESIDERATA FOR STAR CATALOGS FOR THE REMAINDER OF THE TWENTIETH CENTURY: A REPORT ON CATALOG WORK NOW IN PROGRESS AT THE U.S. NAVAL OBSERVATORY

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ABSTRACT

The results of observations of Southern Reference Stars (SRS) of all participants in the SRS program (1961-1973) have been received at the U.S. Naval Observatory. It is anticipated that compilation of the final SRS catalog of mean positions will be completed by the end of 1984.
A supplementary list to the International Reference Star (IRS) catalog is described. It has been selected with a view to improving areal density and distribution in spectral type.
A comparison of solutions for equator and equinox corrections and corrections to the assumed elements of the earth's orbit from daytime observations of the Sun, Mercury, and Venus and nighttime observations of Ceres, Pallas, Juno, and Vesta from Six-inch Transit Circle observations made during the W5-50 program (1963-1971) shows that a very significant part of the systematic daytime error has been removed. A problem remains for observations of the Sun, particularly in declination.

COMPILATION OF THE SOUTHERN REFERENCE STAR (SRS) CATALOG

Results of observations of all participants in the SRS observing campaign (1961-1973) are now in hand with the recent arrival of the declination results of Pulkovo observed at Santiago, Chile. All observations have been referred to the system of FK4 either by the observer, or by the application of systematic differences (FK4-Instrument) determined at the U.S. Naval Observatory from the observer's own (O-C)'s for FK4 stars observed in the same program as the SRS list.

A preliminary SRS catalog of mean positions is now being formed from the data described above in which each observation receives equal weight, regardless of its source. The mean catalog value of an individual participant enters the overall mean of all values according to the number of observations made by the participant. This catalog, called SRS(I) on the system of FK4, will be used as the standard against which the observations of individual participants may be differenced and collected in 1

H. K. Eichhorn and R. J. Leacock (eds.), Astrometric Techniques, 669–676.

https://doi.org/10.1017/S0074180900077172 Published online by Cambridge University Press

hour by 5 degree cells in right ascension and declination, resp., on the celestial sphere. The variances of the cell differences for each participant will be collected and examined in order to arrive at weights to be used for the proper combination of observations. The mean epoch of observation will be computed using the same weights.

SELECTION OF THE INTERNATIONAL REFERENCE STAR (IRS) SUPPLEMENTARY LIST

It has been shown (Scott, 1967; Smith, 1980) that the distribution with respect to uniform density on the celestial sphere and spectral type of stars in the IRS list is seriously deficient in certain zones. To overcome, to some extent, these regional inhomogeneities, a supplementary list of stars has been chosen as follows:

TOTAL NUMBER OF STARS - 1,912

DECLINATION ZONE	NUMBER OF STARS	DEFICIENCY CORRECTED
-90 to -30	764	Many Late Spectral Types
-30 to -5	1,143	Low Areal Density
+85 to +90	5	Low Areal Density

Most of the stars in the IRS Supplementary list were added in the southern hemisphere. Unfortunately, the most southerly zone (-90 to -30) which was the zone most in need of stars with early spectral types was also the zone least in need of additional stars from the point of view of areal density. With a count of 10,210, this zone is already within 1% of having one star per square degree. The ideal solution would have been to delete about 2,000 stars of spectral type K thus bringing the percentage down from 64% to about 45% of the total number in that zone, a percentage much closer to that in the other zones, and then selecting 2,000 stars from among those of earlier spectral type. Such a radical approach seemed inappropriate because of the huge observing effort by San Juan, Santiago (Pulkovo), Perth(Bergedorf), and Leoncito(Washington) during the SRS observing campaign to secure observations in that far southern zone. The compromise finally adopted was to keep all IRS stars and to select about 750 new stars of spectral type G or earlier, always giving preference to stars of the earliest spectral type which also occurred in quadrilateral regions on the celestial sphere one degree on a side lacking an IRS star. The distribution of spectral type in the two principal southern hemisphere zones is as follows:

DECL. ZONE	B		A		F		G		K		M		TOTAL
-90 to -30	118	15%	250	33%	239	31%	157	21%	---	---	---	---	764
-30 to -5	72	6	174	15	273	24	252	22	346	30%	26	2%	1,143

The impact of the distribution given above on the original IRS distribution is neglible in the -30 to -5 degree zone, because the distributions are so similar. In the zone -90 to -30, the distribution before and after adding the supplementary stars is as follows:

	B	A	F	G	K	M	OTHER	TOTAL
IRS only	00.2%	03.2%	08.2%	19.9%	64.0%	04.3%	0.3%	10,210
With Supp.	01.2	05.2	09.8	19.9	59.5	04.0	0.3	10,974

The net result of having added stars is two-fold: First, the declination zone from -90 to -30 ends up with about 650 more stars than necessary to realize the ideal of one star per sq. deg.; and second, the distribution among early-type stars while substantially improved falls short of the distribution found over the rest of the celestial sphere from -30 to +90 by about a factor of two for spectral types B, A, and F. Little further improvement is possible without a very substantial and rather difficult to defend revision of the IRS list involving the deletion of many extremely well observed stars.

The IRS zone most in need of additional stars is the zone from -30 to -5 where the deficiency is very close to 17%. This follows because the area of the zone is 8,516 sq. deg. and there are only about 7,050 IRS stars to be found there. Elsewhere on the celestial sphere, the deficiency never exceeds four to six per cent, except within a few degrees of the north celestial pole where five more stars were added.

Software was developed capable of recognizing square regions 1.414... deg. on a side which contained no star from the IRS list. Such a region is called a "hole". A smaller region 1.2 deg. on a side and concentric with the hole was searched for stars from the SAO Catalog (SAO Staff, 1966). Criteria for the selection of stars were as follows:

* 9.4 >= m(vis) >= 7.0
* No double stars or variables
* Best observational histories
* -30 to -90 only, earliest spectral type available

Observational histories as indicated by the number of entries in the data base prepared by Corbin (1978) for his work on the proper motions of the IRS stars were invaluable for selecting the best observed stars. As a final step, a comparison was made with the Washington Double Star Catalog (Worley,1986) to eliminate stars with companions not so identified in the SAO catalog. If the companion(s) were separated by more than 8.5 arcsec, then the star was kept, regardless of the magnitude. If the separation was less than 8.5 arcsec, and if the companion was at least 3.5 magnitudes fainter than the principal star, then it was kept. All other double or multiple stars were deleted.

The magnitude distribution of the IRS Supp stars was as follows:

https://doi.org/10.1017/S0074180900077172 Published online by Cambridge University Press

	mv(SAO)	mpg(mv,Sp Ty)	mpg(SAO)
6.9 and brtr.	0	30	1
7.0 - 7.4	215	107	4
7.5 - 7.9	300	230	37
8.0 - 8.4	350	305	55
8.5 - 8.9	538	367	91
9.0 - 9.4	509	434	102
9.5 - 9.9	-	312	66
10.0 - 10.4	-	127	22
10.5 and fntr.	-	-	3

The first column of frequency of occurrence as a function of apparent visual magnitude as given in the SAO Catalog, mv(SAO), clearly shows the cutoff at magnitude 9.4. The second column gives the frequency as a function of the apparent photographic magnitude calculated from the visual magnitude and spectral type given in the SAO Catalog, mpg(mv,SpTy). Reduction parameters for conversion from the visual to the photographic scale were taken from Allen (1955). The third column gives the frequency as a function of the photographic magnitude for the small number of stars for which this quantity is given in the SAO Catalog. From an examination of the last two columns, one may conclude that the percentage of stars fainter than apparent photographic magnitude 10.5 is negligible. However, one-quarter to one-fifth of the IRS Supp stars are fainter than apparent photographic magnitude 9.5.

REMARKS ON REDUCTION TECHNIQUE OF FUNDAMENTAL TRANSIT CIRCLE CATALOGS

The use of minor planet observations to calculate zero point corrections to the assumed origins of right ascension and declination of fundamentally observed transit circle series has been recognized and advocated by a number of workers in the field of astrometry (Dyson,1928; Clemence,1948). A rare opportunity to make a detailed comparison of solutions from minor planets observed at night and the Sun, Mercury, and Venus observed in the daytime has been presented by the completion recently of the discussion of the fundamental Six-inch Transit Circle catalog W5-50 (1963-1971) by Hughes and Scott (1982). The numbers of observations of the solar system objects which will be discussed here are as follows:

SUN	MERCURY	VENUS	CERES	PALLAS	JUNO	VESTA
990	234	668	296	179	121	356

When the day observations of the Sun, Mercury, and Venus are combined into a single simultaneous solution for the equator and equinox, the corrections to the elements of the earth's orbit, and corrections to the elements of the orbits of Mercury and Venus and then compared to the results of a similar type of solution from observations of the minor planets, the following results emerge:

	SUN-MERCURY-VENUS SOLUTION	CERES-PALLAS-JUNO-VESTA SOLUTION
	Unit=arcsec	
EQUINOX (Delta Right Ascension)	+0.44 +/-0.06(m.e.)	+0.45 +/-0.14(m.e.)
EQUATOR (Delta Declination)	-0.39 +/-0.02	-0.27 +/-0.02
MODIFIED MEAN ANOMOLY (Delta L0 + Delta Psi3)	-0.49 +/-0.03	-0.54 +/-0.07
OBLIQUITY (Delta Epsilon)	-0.22 +/-0.03	-0.15 +/-0.05
ECCENTRICITY (Delta e)	-0.09 +/-0.02	-0.13 +/-0.05
PERIHELION (e*(Delta Omega))	-0.12 +/-0.02	-0.15 +/-0.08

The day and night solutions are in excellent agreement, with the exception of the equator solution which shows a difference larger than what would be expected from the size of the mean errors alone. The generally good agreement is an indication that the systematic reduction of the day observations to the night system is adequate, particularly in right ascension. However, the poor agreement for the equator solution is a cause for concern, in-so-far as it signals some residual inadequacy in the day to night declination reduction technique.

In an effort to understand the possible origin of the disagreement in the equator solutions, the individual solutions for each object separately were examined. They are as follows:

EQUATOR SOLUTION W5-50 (Unit=arcsec)

SUN	-0.51 +/-0.02(m.e.)
MERCURY	-0.27 +/-0.07
VENUS	-0.26 +/-0.03
CERES	-0.37 +/-0.04
PALLAS	-0.34 +/-0.08
JUNO	-0.23 +/-0.08
VESTA	-0.23 +/-0.02

The equator solution from observations of the Sun alone is so different from all the other well observed objects that one must doubt the adequacy of the day to night reduction technique in declination in the case of the Sun. This conclusion is greatly strengthened by a systematic trend in equator solutions of Washington Six-inch and Nine-inch fundamental catalogs dating back to the beginning of this century, and by results of ob-

https://doi.org/10.1017/S0074180900077172 Published online by Cambridge University Press

servations from the Cape indicating that this result is not peculiar to northern hemisphere observations. The following table indicates that the magnitude of the systematic effect has been more or less the same over a period of several decades:

EQUATOR SOLUTIONS FROM DAY OBSERVATIONS OF THE SUN, MERCURY, AND VENUS

			SUN		MERCURY		VENUS	
W4-50	(1956-62)	6-inch	-0.23	+/-0.03	+0.04	+/-0.08	0.00	+/-0.05
W3-50	(1949-56)	6-inch	-0.06	+/-0.03	+0.15	+/-0.08	+0.20	+/-0.05
W2-50	(1941-49)	6-inch	-0.13	+/-0.03	+0.02	+/-0.08	+0.10	+/-0.05
W25/50	(1925-41)	6-inch	+0.09	+/-0.03	+0.47	+/-0.05	+0.38	+/-0.03
W40	(1935-45)	9-inch	-0.64	Wt=5	-0.33	Wt=1	-0.33	Wt=1
W20	(1913-25)	9-inch	-0.31	-	+0.19	-	+0.08	-
Cape3-25	(1932-36)		+0.14	-	+0.44	-	+0.34	-
Cape2-50	(1936-59)		-0.40	+/-0.03	-0.18	+/-0.03	-0.17	+/-0.01

In every case, the equator correction from observations of the Sun is more negative than the values given by observations of Mercury and Venus by amounts (0.2 to 0.4 arcsecs) which are entirely consistent with the W5-50 results from minor planets. This gives us a basis for believing that the problem is with the declination observations of the Sun, and not a problem with Mercury or Venus.

A promising explanation for this problem with the Sun and a fruitful area for further study has been suggested by work of Høg reported in this symposium (Høg,1986). He has shown that there is reason to suspect that a horizontal temperature gradient in the transit circle tube can introduce an anomalous refraction term in declination. During an observation of the Sun, an amount of thermal radiation far exceeding that of any other solar system object is introduced directly into the tube. It warms the micrometer and no doubt sets up convection currents within the tube which result in a much stronger horizontal temperature gradient in the case of the Sun than for any other celestial object observed with the transit circle. Furthermore, one would expect that the horizontal temperature gradient would increase at a much higher rate during an observation of the Sun than for any other object or at any other time.

The observation of minor planets has helped to resolve the question of where the main problem area is in the determination of the equator correction.

Another area of difficulty has been discussed by Rafferty(1986) in this symposium, involving the systematic errors which have been introduced into the declination systems of individual observational series by the use of inhomogenous variation of latitude results based on only the local Photographic Zenith Tube.

The fundamental transit circle programs of the U.S. Naval Observatory to be observed simultaneously over the next ten years from Washington and New Zealand with the Six-inch and Seven-inch Transit Circles, resp., will be substantially improved in a systematic way by the incorporation of improved knowledge of sources of systematic error such as have been discussed here. To the extent possible, we intend to apply the same knowledge to earlier catalogs of the Washington and other fundamental series with a view to improving the systemic basis of the individual series as a prelude to forming a new fundamental compiled catalog of positions and proper motions based entirely on twentieth-century observational series.

REFERENCES

Allen, C.W.: 1955, Astrophysical Quantities, Univ. of Florida, The Athlone Press, pg. 178.

Clemence, G.M.: 1948, Astronomical Journal, No. 1173, pg. 10ff.

Corbin, T.E.: 1978, I.A.U. Colloquium No. 48, Vienna, Eds.:Prochazka, F.V. and Tucker, R.H., pg. 505ff.

Dyson, F.: 1928, Transactions of the I.A.U., Vol. III, pg. 227.

Høg, E.: 1986, This symposium, Internal Refraction in Meridian Circles.

Hughes, J.A. and Scott, D.K.: 1982, Publ. of the U.S. Naval Observatory, Second Series, Vol XXIII, Part III, pg. 165ff.

Rafferty, T.J.: 1986, This symposium.

SAO Staff: 1966, Smithsonian Astrophysical Observatory Star Catalog, Smithsonian Publ. 4652, Positions and Proper Motions of 258,997 Stars for the Epoch and Equinox of 1950.0.

Scott, F.P.: 1967, International Reference Star Programs - Progress Report 1 August 1967 to Comm. 8 of the I.A.U. (Unpublished).

Smith, C.A.: 1980, Mitteilungen der Astronomischen Gesellschaft, No. 48.

Worley, C.E.: 1986, This symposium.

Discussion:

EICHHORN: Why do the data depend so strongly on the latitude correction?

SMITH: It is due to the fact that we applied the Washington PZT polar motion rather than the results of some international service. The origin of that, in turn, was a systematic error in the proper motions of the PZT stars. This produced an annual term in the Washington PZT data.

GLIESE: By which rules are the weights assigned to the various catalogues which contribute to the SRS Catalogue?

SMITH: We have two kinds of weights: Those determined from internal agreement within the catalogue itself; some of these are estimated by the observer, and then we have weights which are determined externally, from the agreement of the residuals (with respect to the mean of all observations) in small areas.

MURRAY: I don't understand how an erroneous variation of latitude can affect the equator point of the Sun, since this must have been observed all the year round.

SMITH: No, this only applies to Mars, where we have no observations between 0^h and 8^h.

HEMENWAY: If a series of minor planet observations is limited to near opposition, the solutions for corrections to the Earth's elements and the orbits are highly correlated. Do you observe the minor planets far enough from opposition to decouple these effects sufficiently?

SMITH: Yes. We try to observe from quadrature to quadrature. Our efforts toward this goal are sometimes defeated but only when the objects are too faint to be seen.