CLASSICAL ABSOLUTE/DIFFERENTIAL PROGRAMS

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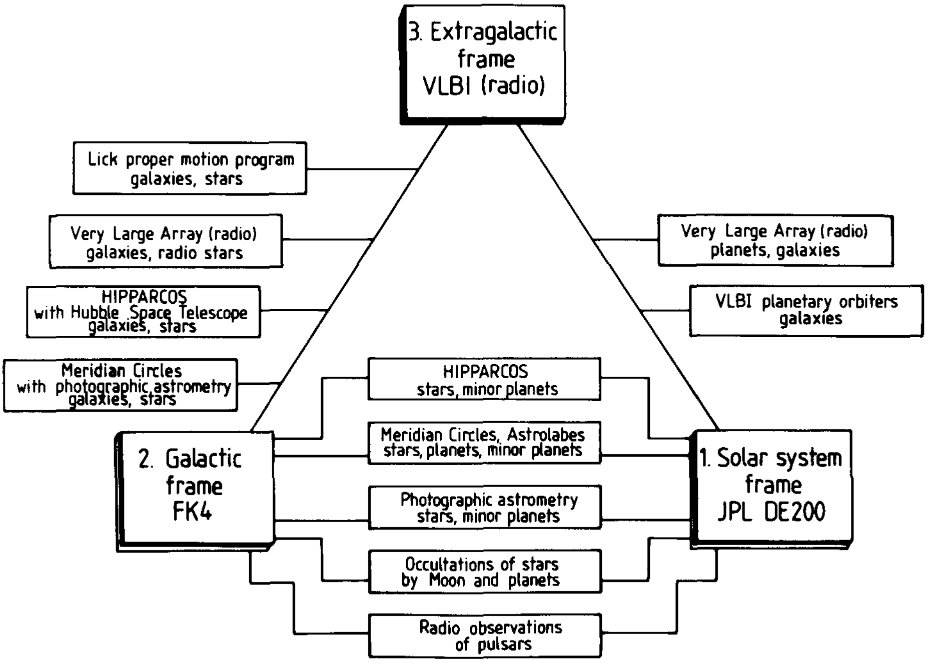
In astronomy we try to determine a non-rotating frame from analyses of the observed motions of three mechanical systems - the solar system, the galaxy and the extragalactic nebulae. The rotation of the extragalactic frame is of the order 10^{-10} arcsec per century, so, for all practical purposes, this frame may be regarded as having no rotation. The other two frames are model-dependent and, as such, cannot be regarded *ab initio* as constituting non-rotation frames of reference. These reference frames are linked by various techniques, as shown in the diagram below.



J.-P. Swings (ed.), Highlights of Astronomy, 77–80.

https://doi.org/10.1017/S1539299600006225 Published online by Cambridge University Press

I will restrict myself to the so-called classical (optical) techniques, using absolute and differential methods. The instruments involved are transit instruments (meridian circles, vertical circles), astrolabes and photographic zenith tubes (PZTs). These instruments are in use at the places listed in the following table.

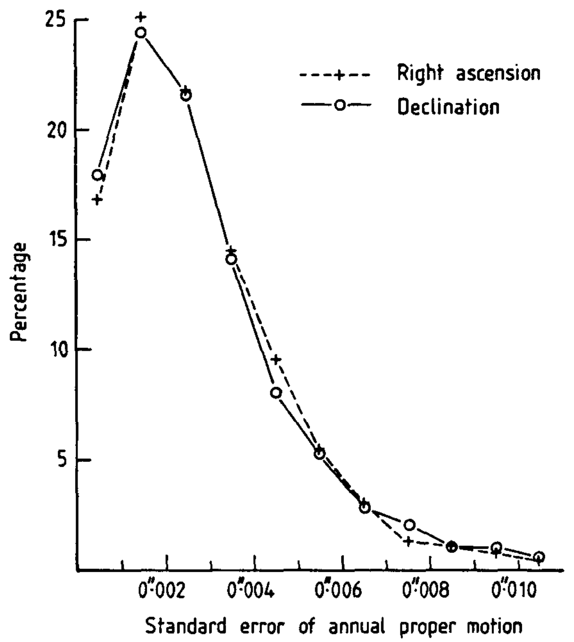
OBSERVATIONS BY MERIDIAN CIRCLES, ASTROLABES AND PZTs

ARGENTINA	San Juan
AUSTRALIA	Perth
BRAZIL	Sao Paulo
CHILE	Cerro Calan (Pulkovo), Santiago
CHINA	Beijing, Shaanxi, Wuchang, Yunnan
FRANCE	Bordeaux (Automatic Meridian Circle), CERGA
ITALY	Cagliari
JAPAN	Tokyo (Automatic Meridian Circle), Mizusawa
LA PALMA	Carlsberg Automatic Meridian Circle (Denmark, UK, Spain)
ROMANIA	Bucharest
SPAIN	San Fernando, La Palma (Carlsberg AMC)
NEW ZEALAND	Black Birch (USNO)
USA	Washington (USNO)
USSR	Kiev, Pulkovo (Main ADAS), Tashkent (Uzbek Ac. Sc.), Kasan, Sternberg Inst (High Alt. Middle Asia Obs.) Nikolaev
YUGOSLAVIA	Belgrade

Most of the classical work has been aimed at linking frames 1 and 2 (see diagram). Discussion of observations of the Sun and planets leads to the determination of the zero point and equator of the FK4. In principle, it should also give the precession from the observed motions of the perihelia and nodes; but in practice the observations are not accurate enough. The analyses of observations of the Sun and planetary system have revealed a spurious rotation in the right ascension of the FK4 frame (motion of the equinox) of $1''.27 \pm 0''.15$ per century. This is to be rectified in the FK5. Continued observational effort of solar system objects is required to reduce the uncertainty of $\pm\ 0''.15$ per century.

The positions and proper motions of the FK4 constitute the best reference frame constructed from classical optical observations. It provides a global coverage at a density of 1 star per 5^ox5^o, and has a limiting magnitude of around 7.5. Enormous effort has been expended in observing these stars by absolute and quasi-absolute methods. These have revealed systematic errors around epoch 1980 as great as $0''.2$ in position and individual errors of $0''.8$ per century in proper motion. From the analyses of fundamental proper motions, a rotation of $0''.44 \pm 0''.04$ per century about the direction RA = 6^h, Dec = 0^o, has been found in the FK4 frame. This is attributed to an error of $1''.10 \pm 0''.10$ per century in the constant of luni-solar precession. This will be corrected in the FK5.

The International Reference Stars (IRS), comprising the AGK3R and SRS (to be published soon), provides the best extension of the FK4 frame to fainter magnitudes. It gives global coverage at a density of 1 star per $1^{o}x1^{o}$ with magnitudes in the range 6.5 to 9.5. The mean epoch of the positions is around 1958 and the average standard error in proper motion is about 0".3 per century. It is very desirable to improve on this accuracy, so an international campaign to re-observe the IRS has been started. Special mention should be made of the USNO 'pole-to-pole' campaign whereby the whole of the IRS will be observed using the 6-inch meridian circle in Washington and the automated 7-inch which is now beginning work in the southern hemisphere at Black Birch, New Zealand. The Carlsberg Automatic Meridian Circle has already published the positions and revised proper motions of 3665 IRS stars with declinations in the range -45^{o} to $+90^{o}$ which were observed in its first period of operation (May to December 1984) on the Canary Island of La Palma (latitude $N29^{o}$).



The figure shows the frequency distribution of the standard errors of the revised proper motions obtained by combining the CAMC position with previous epoch positions taken mainly from the GC, AGK2, AGK3 and Yale. The standard errors of 42% of the proper motions are 0".2 per century or less, which compares favourably with the accuracy expected from HIPPARCOS. The Tokyo Automatic Meridian Circle is also about to start observations of IRS. Observations are also being carried out at several places in the USSR.

The extension of the FK4/FK5 frame to fainter magnitudes than the IRS, say $m_V \sim 11.0$, is now feasible with the increased power of the new

https://doi.org/10.1017/S1539299600006225 Published online by Cambridge University Press

generation of automated meridian circles. A Working Group of Commission 8 should be set up to consider the selection of the stars for this faint extension of the FK4/FK5.

There are two methods used in optical astrometry to link the galactic frame to the extragalactic one. The first involves observing the positions of reference stars close to the extragalactic objects. The reference stars are used to reduce photographic plates and thereby obtain the positions of the extragalactic objects in the FK4 frame. This can then be compared with the VLBI radio positions, care being taken to select point sources in both the optical and radio wavebands. A list of about 300 such sources was prepared by a Working Group of Commission 24 at the Patras meeting of the IAU in 1982. Observations of reference stars around these sources are being undertaken at many of the observatories listed above. In this context I should mention the Carlsberg Automatic Meridian Circle which has started a programme of observation of reference stars as faint as $m_V \sim 12$. This will eliminate the initial AGK3 or SAO stages in bridging the magnitude gap between the reference stars and the galaxies, and thereby give a tighter link between the galactic frame and the extragalactic one.

The positions and proper motions of radio stars are used in the second method to link the galactic and extragalactic frames. The VLA has recently measured the positions of about 30 radio stars relative to the extragalactic VLBI frame. The accuracy of the positions is about $\pm 0\overset{''}{.}03$. VLBI has also measured a few of the stronger radio stars with an accuracy better than $\pm 0\overset{''}{.}01$ in some cases. However, these stars come from a population of visual and spectroscopic binaries, symbiotic stars, flare stars, X-ray stars, and they need to be scrutinized carefully to establish the coincidence of the centres of the radio and optical emission. Comparisons between radio and optical positions of stars, whilst giving agreement to around $0\overset{''}{.}02$ in the zero points of right ascension and declination, produce an error distribution with standard deviation $\pm 0\overset{''}{.}1$. Many observatories are now observing these stars with the objective of reducing this standard deviation and thereby revealing some real discrepancies between the optical and radio positions. However, such attempts may be largely frustrated until the systematic errors inherent in the FK4 frame are removed with the publication of the FK5 in 1986.