CARLSBERG MERIDIAN CATALOGUES

LA PALMA

Numbers 1-11

Observations of positions of stars and planets
May 1984 to May 1998

COPENHAGEN UNIVERSITY OBSERVATORY
ROYAL GREENWICH OBSERVATORY
REAL INSTITUTO Y OBSERVATORIO DE LA ARMADA EN SAN FERNANDO

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LA PALMA

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Summary

This composite catalogue contains 180 812 positions and magnitudes of 176 591 stars north of declination –40°, 155 005 proper motions, and 21 944 positions and magnitudes of 184 Solar System objects obtained with the Carlsberg Automatic Meridian Circle on La Palma during the period May 1984 to May 1998. It includes Carlsberg Meridian Catalogues Numbers 1 to 11 (CMC1-11); i.e. it comprises all the observations made with the scanning–slit micrometer since the beginning of operation on La Palma. The positions of the stars are for the epoch of observation and the equinox J2000.0, and are referred to the new International Celestial Reference Frame. The limiting magnitude is $m_{\mathrm{v}} = 15^{\mathrm{m}}\!.4$.

The catalogue mainly comprises observations and proper motions for the following programmes:

36 000	International Reference Stars
30 000	faint reference stars in a global net
18 000	reference stars in the fields of radio sources
17 000	stars in the Lick Northern Proper Motion catalogue
5 000	reference stars for calibration of Schmidt plates
2 600	stars in the Gliese catalogue of nearby stars
5 000	stars in nearby OB associations
10 500	F-type stars within 100 pc
9 000	G-type d&g, K-type g stars within 300 pc
2 200	Unbiased sample of K/M-type d stars
19 400	Reference stars around Veron–Cetty galaxies
4 700	GCVS stars, mainly $12<\mathrm{mag}<14$
7 300	NLTT stars, mainly $12<\mathrm{mag}<14$

and several smaller programmes, each having fewer than 2000 stars, which are mainly aimed at galactic kinematics. Positions and magnitudes of 12 novæ and 8 supernovæ which occurred in the years 1991 to 1998 are included. The catalogue also contains observations of the following Solar System objects: Callisto, Ganymede, Rhea, Titan, Iapetus, Hyperion, Uranus, Oberon, Neptune, Pluto, 173 minor planets, and comet P/Wild 2.

The mean error of a catalogue position in the zenith is $0''\!.09$ in right ascension and declination in CMC4-5-6, improving to $0''\!.06$ in CMC7-11. The accuracy in magnitude is $0^{\mathrm{m}}\!.05$ in CMC4-10, improving to $0^{\mathrm{m}}\!.03$ in CMC11. The mean error of the proper motions, derived by combining the position in this catalogue with those at earlier epochs, is typically in the range $0''\!.003$ to $0''\!.004$ per year.

Cross-references are given to DM, AGK, SAO, HD and the Washington Double Star (WDS) catalogues.

The catalogue also contains 12 216 mean annual observed positions of the FK5 stars used initially in CMC4-9 to transfer the instrumental system to the FK5 frame.

A compilation of all the meteorological data and nightly atmospheric extinction for the years 1984-1998 is appended.

Resumen

Este catálogo múltiple contiene 180 812 posiciones y 168 989 magnitudes de 176 591 estrellas al norte de –40°, 155 005 movimientos propios y 21 944 posiciones y magnitudes de 184 objetos del sistema solar, obtenidas con el Círculo Meridiano Automático Carlsberg, en La Palma, desde Mayo de 1984 hasta Mayo de 1998. Incluye los Catálogos Meridiano Carlsberg Números 1 a 11 (CMC1-11); es decir todas las observaciones hechas con el micrómetro de rendijas móviles desde el principio de las operaciones en La Palma. Las posiciones se publican para la época de observación, referidas al equinoccio J2000.0 y en el nuevo Sistema International de Referencia Celeste. La magnitud límite es $m_{\mathrm{v}}=15^{\mathrm{m}}.4$.

El catálogo consta principalmente de observaciones de los siguientes programas:

36 000	estrellas de referencia internacional (IRS)
30 000	estrellas débiles de referencia en una red global
18 000	estrellas de referencia en campos de radio fuentes
17 000	estrellas del catálogo Lick Northern Proper Motion
5 000	estrellas de referencia para calibración de placas Schmidt
2 600	estrellas cercanas del catálogo de Gliese
5 000	estrellas cercanas en asociaciones O-B
10 500	estrellas F dentro de un radio de 100 pc
9 000	estrellas G y K dentro de un radio de 300 pc
2 200	estrellas de una muestra aleatoria de enanas K y M
19 400	estrellas de referencia en campos de galaxias en Veron-Cetty
4 700	estrellas de GCVS, principalmente en 12<mag<14
7 300	estrellas de NLTT, principalmente en 12<mag<14

y otros programas de menos de 2 000 estrellas para estudiar la cinemática galáctica. Contiene además posiciones y magnitudes de 12 novas y 8 supernovas aparecidas entre los años 1991 y 1998. El catálogo incluye observaciones de los objetos del sistema solar: Ganímedes, Calixto, Rea, Titán, Hiperión, Japeto, Urano, Oberón, Neptuno, Plutón, 173 asteroides, y cometa P/Wild 2.

El error medio de una posición del catálogo en el cenit es $0''.09$ en ascensión recta y declinación en los CMC4-5-6 y $0''.06$ en los CMC7-11. En magnitud es de $0^{\mathrm{m}}.05$ en los CMC4-10, y $0^{\mathrm{m}}.03$ en lo CMC11. El error medio de los movimientos propios, obtenidos combinando las posiciones de este catálogo con los de épocas anteriores, es típicamente $0''.003$ a $0''.004$ por año.

Se dan las referencias cruzadas con los catálogos DM, AGK, SAO, HD y con los estrellas dobles WDS.

También se incluyen las posiciones medias anuales observadas de 12 216 estrellas del FK5 usadas para referir en primer lugar el sistema instrumental en los catálogos CMC4-9 al sistema de referencia definido por el FK5.

Finalmente se añade una recompilación de todos los datos meteorológicos y del extinción atmósfera recogidos desde 1984 hasta 1998.

1 Introduction

This catalogue is the compilation of Carlsberg Meridian Catalogues Numbers 1 to 11 (CMC1-11), in the series observed with the 18 cm Carlsberg Automatic Meridian Circle on La Palma. It comprises all the observations made between May 1984 and May 1998 with the scanning–slit micrometer. Catalogues CMC1-8 were issued separately in five printed volumes (CMC1-4 1989; CMC5 1991; CMC6 1992; CMC7 1993; CMC8 1994). Catalogue CMC9 was issued on a CD-ROM in 1997. The space afforded by this CD-ROM was used to re-issue CMC1-8 and combine them with CMC9. Similarly, CMC11 is now issued on CD-ROM together with CMC1-10. Although CMC10 was not published separately – being overtaken by CMC11 – its separate identity has been maintained in the numbering sequence because the treatment of the observations was slightly different from CMC11. The periods covered by these catalogues are set out in §5 Table 6.

The operation of the instrument on La Palma was shared between Copenhagen University Observatory (CUO), the Royal Greenwich Observatory (RGO) Cambridge and the Real Instituto y Observatorio de la Armada en San Fernando (ROA). The Copenhagen University Observatory is a department of The Niels Bohr Institute for Astronomy, Physics and Geophysics. The three institutions set up a Management Committee to decide on the overall observing programme and other matters related to running the telescope. In general, an individual programme of stars took several years to complete and the results are published in a number of catalogues in the current series.

The geodetic coordinates of the telescope on the WGS84 system were determined in 1993 using a GPS receiver. The astronomical and geodetic coordinates are:

$$\text{Astronomical}\left\{\begin{array}{l} 17^\circ\,53'\,07\overset{''}{.}8\,\mathrm{W} \\ 28^\circ\,45'\,52\overset{''}{.}4\,\mathrm{N} \end{array}\right. \qquad \text{Geodetic}\left\{\begin{array}{l} 17^\circ\,52'\,56\overset{''}{.}70\,\mathrm{W} \\ 28^\circ\,45'\,35\overset{''}{.}97\,\mathrm{N} \\ \text{Altitude}\ \ 2326\,\mathrm{m} \end{array}\right.$$

All the observations in CMC1-11 were made with a photoelectric moving-slit micrometer. The original micrometer used in CMC1-4 was replaced by a new micrometer in May 1988 and this was used for CMC5-11. A description of the micrometer in use during CMC1-4 is given in Helmer & Morrison (1985). The refinements introduced with the new micrometer included reducing the length of the slits with a diaphragm, thereby reducing the background noise, and halving the scanning distance which allowed twice as many scans over an object in the same time. The micrometer was also improved by fitting a linear encoder.

Programme stars south of declination –20° were not observed in the small section of the slits due to the somewhat poorer seeing at low altitudes.

These refinements led to an improvement of the accuracy ($0\farcs19$ to $0\farcs15$) for a single observation at the zenith. A further improvement to $0\farcs12$ was achieved by smoothing observations from night to night (see Table 7).

Besides this development of the moving-slit micrometer, the following improvements were made to the system:

August 1985: An air circulation system was installed in the telescope tube to remove internal refraction (Høg & Fabricius 1988).

January 1986: An azimuth mark 130 m to the south was observed hourly and the change in azimuth deduced from this mark was subtracted from the observations thereafter.

December 1986: Another azimuth mark was introduced 50 m to the north.

May 1988: The new micrometer was introduced with a wider pass band which is nearly rectangular between 4885 and 6160 Å. The previous micrometer had a pass band close to Johnson V.

February 1989: A new collimator alignment micrometer was brought into use, making possible determinations of the collimation-free reading and horizontal flexure (see Helmer *et al.* 1991). Both the collimation and flexure were found to change smoothly during the night and the use of the alignment micrometer was discontinued after November 1994.

October 1991: The divided circle was replaced by a new glass circle manufactured by Heidenhain with *Diadur* division lines which gave improved definition. The mean error for the reading of one diameter, as determined from the measurement of the diameter corrections, reduced from $\pm0\farcs05$ to $\pm0\farcs03$.

August 1992: The photoelectric circle-reading micrometers were replaced by CCD cameras. A quick circle reading made 2 seconds before the observation starts enables the setting of the telescope to be given a final adjustment, resulting in a setting error of less than $0\farcs3$. This permitted the use of the smallest part of the scanning slits, thereby increasing the efficiency of the micrometer.

April 1995: A new electronic control system for the telescope and micrometer was installed. New bearings were fitted to the diaphragm in the micrometer.

December 1996: The clock system was replaced by a GPS receiver.

April 1997: Remote operation was introduced using the Internet.

A full description of the improved micrometer and its operation can be found in Helmer *et al.*(1991).

The limiting magnitude of the telescope increased as a result of these improvements. This is shown in Table 1.

Neutral density filters were used to reduce the magnitudes of the brightest stars. These are listed in Table 2.

The position of the clamp of the telescope is displayed in Table 3.

Table 1: Limiting magnitude of Catalogues.

Catalogue	Limiting mag. (V)
CMC1-4	13.0
CMC5-6	14.8
CMC7-11	15.4

Table 2: Neutral density filters.

Catalogue	Filters	
	Brighter than 6.0	Brighter than 2.0
CMC1-4	——	6-mag
CMC5	4-mag	not observed
CMC6-11	4-mag	8-mag

Table 3: Telescope clamp.

Clamp	Dates	
	From	To
West	1 May 1984	8 June 1987
East	9 June 1987	21 February 1988
West	16 May 1988	4 November 1990
East	5 November 1990	2 October 1991
West	3 October 1991	27 May 1998

The observation programme comprised five categories of objects:

1. Stars belonging to stellar reference frame programmes, such as the FK5, IRS and special reference stars around QSOs etc.;
2. Stars being re-observed primarily to improve the accuracy of their proper motions which are required for stellar kinematics;
3. Variable and high proper motion stars with poor positions;
4. Bodies in the Solar System, comprising the outer planets, some of their satellites, and minor planets whose positions are required for improving their orbits.
5. Calibration sources for determining the zenith point correction, level, azimuth, collimation and flexure.

The strategy of the observing programme was such that these programmes could be carried out simultaneously, with their rates of completion being determined by pre-assigned priorities allotted by the Management Committee. Details of the observing programme are given in § 7.

In catalogues CMC1-9 the observations were initially reduced differentially with respect to the FK5 and later adjusted to the new International Celestial Reference Frame (ICRF) using observations of stars common to the Hipparcos Catalogue (ESA, 1997). CMC10-11 were observed differentially with respect to the Hipparcos Catalogue which became available in a pre-release form in 1996. The method was not completely differential because the nightly fitting to the reference catalogue involved only zero-point corrections in right ascension and declination, orientation of the telescope axis and a correction to the coefficient of refraction. Variations with time of the pointing angles of the telescope were removed from the observations by measuring these angles at regular intervals throughout the night using the calibration light sources within and near the dome.

Beginning with CMC7, zonal adjustments, consisting of a simple displacement of the segment of sky containing each star, were also applied in order to smooth out night-to-night variations introduced by unknown changes in the instrumental system and anomalous refraction. These adjustments gave a 10–20% reduction in the internal mean error. Details of this procedure are given in § 4.6. Further improvements in accuracy in CMC10-11 were achieved by observing differentially with respect to the Hipparcos Catalogue rather than the FK5.

The positions on this CD-ROM for catalogues CMC1-11 supersede all previously printed and electronic versions which are available through the Centre de Données Astronomiques de Strasbourg. All the corrections in the errata lists of those catalogues have been made in this CD-ROM compilation. A new match of the catalogues with the Durchmusterung catalogues revealed many new pairings which have been carried through to the CD-ROM. Besides these changes, several hundred observations have been omitted here because they are astrometric doubles and this had been overlooked in the earlier compilations.

2 Personnel

The telescope was operated by 27 different observers in the course of the production of the catalogues CMC1-10. Beginning in May 1997 (during CMC11), the telescope was operated remotely by the three participating institutions in turn and no-one was present at the telescope. Table 4 gives the main areas of effort for each observer.

Table 4: Observers and main areas of effort.

Observer[a]	**Inst.**	**CMC**	**Observing and differential reduction**	**Formation of observing list**	**Formation of catalogue**	**Software/ hardware development**	**Daily management**
G Ameyugo	ROA	4	×				
R W Argyle	RGO	5-11	×	×		×	
K Augustesen	CUO	1-9	×				
F Belizón	ROA	8-11	×				
M E Buontempo	RGO	1-11	×	×		×	
F Cano	ROA	1-5	×	×			
J C Coma	ROA	2-5	×				
O H Einicke	CUO	1-11	×			×	
P Eldridge	RGO	1-5	×	×			
C Enriquéz	ROA	5-6	×				
D W Evans	RGO	5-11	×	×		×	
C Fabricius	CUO	1-9	×		×	×	
A Fernández	ROA	5	×				
P Gibbs	RGO	1-5	×	×	×	×	
F Gutierrez	ROA	3-4	×				
H Hansen	CUO	2	×				
L Helmer	CUO	1-11	×			×	×
P Herridge	RGO	7-9	×			×	
B Jensen	CUO	1-8	×				
P Jensen	CUO	1-8	×				
T Knudsen	CUO	1-11	×			×	
L V Morrison	RGO	1-11	×		×	×	×
J L Muiños	ROA	1-11	×	×	×		
R H D Swifte	RGO	1	×			×	
C Thoburn	RGO	1-4	×	×		×	
M Vallejo	ROA	8-11	×				
R Villamil	ROA	5-9	×				

[a] Until May 1997

3 Real-time selection and observation

The selection of celestial and calibration objects was performed in real-time, according to a pre-assigned priority, from an input catalogue of more than 300 000 stars. Each star was normally observed on six different nights.

The percentage of time spent on different categories of objects varied slightly over the course of the observation of the eleven catalogues in this compilation. The following are average values: 10% on calibration objects, 73% on programme stars, 15% on FK5 or Hipparcos stars, except in CMC11 where the percentage rose to $\sim$40%, and 2% on planets.

The two observing slits were $4''$ wide and $77''.4$ (1 mm) long in the vertical direction, but only a section of one slit was uncovered at any one time during an observation. The possible section lengths were $12''.4$ (small), $23''.6$ (medium) and $70''.0$ (long) vertically. The small section was only available from the time of the introduction of the new micrometer (May 1988). It was brought into regular use after the telescope setting had been refined in August 1992.

When a star was observed for the first time the medium section was used, scanning some $14'' \times 14''$ of the sky. After August 1992, the subsequent observations were made using the more efficient small section where some $3'' \times 3''$ of the sky may be regarded as fully scanned. Obviously this was only possible when the input position was known with some accuracy and the telescope could be set with great precision.

If the input position of the star was poorly known, the longest section of the slits was used for the first observation, provided it was not too faint to obtain a reasonable signal-to-noise ratio. The availability of the HST Guide Star Catalogue in 1992 greatly facilitated the identification and correction of the input positions of target stars.

The slit plate was driven at a constant velocity of $38\overset{''}{.}72\,\mathrm{s}^{-1}$ and the integration time was fixed at 32 ms. The velocity (ν) relative to the star in the forward scan was

$$\nu = 38\overset{''}{.}72 - 15'' \cos\delta\cos h,$$

and

$$\nu = 38\overset{''}{.}72 + 15'' \cos\delta\cos h$$

in the reverse direction, where h is the hour angle. The scanning time was approximately 16 s, 32 s, 64 s and 100 s for stars brighter than $9\overset{\mathrm{m}}{.}5$(visual), stars from $9\overset{\mathrm{m}}{.}5$ to $11\overset{\mathrm{m}}{.}0$, stars from $11\overset{\mathrm{m}}{.}0$ to $14\overset{\mathrm{m}}{.}0$ and stars fainter than $14\overset{\mathrm{m}}{.}0$, respectively. However, reference stars at zenith distances greater than 60° were observed for 32 s, and those greater than 75° for 64 s, irrespective of their magnitude. The actual time that the star spent in the slits ($5\overset{''}{.}5$ in the direction of scan) depended on the scan length. For stars in the small section of the slits, the time spent partially and completely in the slits was about half of the total scan times given above. For stars in the medium section, it was about a quarter, and for the long section, about an eighth.

Stars were observed up to 40 s from the meridian. Due to the rather poor quality of the observations at large zenith distances, the selection of new programme stars south of declination –40° was restricted.

After August 1992, the FK5 stars, and later, Hipparcos stars, were observed in the small slit section, except those at a zenith distance greater than 70° which were observed in the medium section.

4 Differential reduction to the FK5/ICRF

4.1 Nightly reduction (general)

The real-time reduction to micrometer coordinates of the photon counts for the stars was carried out as described in Helmer *et al.* (1991).

A preliminary, differential reduction to the FK5 system (CMC1-9) or to the Hipparcos system (CMC10-11) of the observations for each night was carried out the following day by the observer using interactive computer programs. The differences between the calculated and observed apparent positions of the FK5/Hipparcos stars were used in a single least-squares adjustment for the whole night containing about eight to ten FK5 stars per hour, spread between zenith distances ±84°. This increased to over 20 Hipparcos stars per hour in CMC10-11. FK5/Hipparcos stars above +67° in declination were observed at either upper or lower culmination.

Magnitudes were derived by fitting the observations to about 50 photoelectric standards spread through the night. This increased to about 200 in CMC11.

The least-squares solutions in α, δ and m were applied to the programme stars, and their mean places at J2000.0 were computed using the 1976 IAU system of astronomical constants, as described in the Supplement to the Astronomical Almanac 1984. These preliminary mean places of the stars were compiled daily into a catalogue. When the required number of mutually consistent observations was reached, the star was automatically omitted from the observing list.

Table 5: Differential correction to the Pulkovo refraction.

Type	Coefft. of tan z	
	ΔR	
O	$+0\overset{''}{.}0860$	
B	$+0.0808$	
A	$+0.0741$	
F	$+0.0696$	–default value for stars
G	$+0.0649$	–used for all Solar System objects
K	$+0.0549$	
M, R, N, S	$+0.0328$	

4.2 Refraction

The astronomical refraction was taken from the Pulkovo Observatory Tables (4th edition). The temperature, pressure and humidity were read with each observation. The temperature used to enter the Pulkovo Tables was the average of three thermometers situated along the opening of the telescope enclosure. Table 5 gives the differential correction to the Pulkovo refraction due the rectangular bandwidth (4885-6160 Å) of the detector system introduced with the new micrometer in May 1988. These corrections were first applied in January 1990. The previous detector system had a bandwidth close to Johnson V and no correction was applied to the Pulkovo Tables.

This correction is particularly important for the reference stars which are observed at very large zenith distances. The correction was applied to all stars of known spectral type, beginning on 1 January 1990. Where the spectral type was unknown, the correction for type F was adopted. In these cases a correction to the declination may be added later when the spectral classification is known. A correction of

$$\Delta\delta = (\Delta R - 0\overset{''}{.}0696)\tan(\delta - 28^\circ\,45'\,52\overset{''}{.}4)$$

should be **added** to the declination.

Before making the final differential solution used in this catalogue, several corrections were applied to the preliminary results obtained from the first solution. Small corrections were applied to right ascension and declination for the differences from their assumed values of the scale and inclination of the micrometer which were determined regularly from observations of near-equatorial stars.

No systematic differences were found in position or magnitude depending on whether a star was observed in the small or the medium section of the slits.

4.3 Instrumental calibrations

When available and reliable, the instrumental calibrations were interpolated to the time of observation and subtracted from the residuals of the reference stars before the final least-squares adjustment was made. These calibrations consisted of the zenith point, level, collimation-free reading, horizontal flexure and north and south azimuth marks. They were measured at an interval of $0\overset{h}{.}5$ during the first $1\frac{1}{2}$ hours of the duty and at $1\overset{h}{.}5$ thereafter. The collimation and flexure, however, were only measured at 3^h intervals because they were found to vary slowly. The use of the collimators to measure collimation and horizontal flexure was discontinued after 29 November 1994. The collimation-free reading was then wholly determined from the least-squares adjustment to the reference stars. A constant value of

$$-0\overset{''}{.}50 \sin z$$

was adopted for the horizontal flexure in CMC6–CMC9, inclusive. Otherwise, it was treated as an unknown.

The stars were assigned the following weights in right ascension, declination and magnitude, depending on their zenith distances; $\cos^{0.6} z$, $\cos^{0.9} z$ and $\cos z$, respectively. These are empirical relations derived from the scatter of the observations as a function of zenith distance.

4.4 Nightly least–squares adjustment in RA, DEC

The solutions in right ascension comprised the Besselian constants m and n as unknowns, and often the collimation. The first and second derivatives with respect to time of the collimation, and the first derivatives of m and n were used on about a third of the nights.

In declination the unknowns were always constant corrections to the zenith point and refraction (separately, south and north). On roughly half of the nights the first and second derivatives with respect to time of the zenith point were also included.

4.5 Nightly least–squares adjustment in MAG

In magnitude the unknowns were a constant (D_o) and colour term (C_o) in instrumental absorption, and a constant for extinction (E_o) at time θ_o, and, when needed, its hourly rate of change (E'). For the time of observation, θ, we have:

$$m = m_{obs} + D_o + C_o(B - V) + [E_o + E'(\theta - \theta_o)] \sec z.$$

The colour coefficient in instrumental sensitivity, C_o, was fixed at +0.036 in CMC5 and until 15 Feb 1990 in CMC6, and at +0.018 thereafter (see § 9.3).

With the increase in observation of Hipparcos reference stars in CMC11, it was possible to carry out a solution with greater temporal resolution. Rather than include only a fixed linear change in extinction for the night, the median of 10 successive observations was used to describe the temporal variation in extinction. This improved the standard error of the magnitude from 0.05 to 0.03 for stars of V$\sim$9 near the zenith.

When computing the magnitudes for this catalogue, the value +0.5 was assumed for $B - V$ for all programme stars; whereas, for the reference stars, the individual values of $B - V$ were used. The magnitude results are discussed in § 9.3.

4.6 Zonal adjustment (CMC7-11)

The behaviour of the telescope and the atmosphere normally do not obey the simple model assumed in the differential reduction described in § 4.1. As a result, the final residuals on any particular night for the reference stars often show variations with respect to time and zenith distance. These are partly due to zonal errors in the FK5 prior to CMC10. Starting with CMC7, efforts were made to reduce the contribution of these temporal and spatial variations in the observations.

In designing a solution to this problem, care was taken not to alter the system of the catalogues. The method adopted in the final adjustment of CMC8-11 is a slightly improved version of that used in CMC7. It can be summarized as follows.

Due to the method of reduction, programme stars were affected by the same regional distortions as reference stars. They formed a much denser net than the reference stars, so their residuals could be used to obtain a better estimate of the regional distortions. On any particular night, the residuals of the programme stars in the same segment or zone of the sky, will exhibit the same bias due to the imperfections of the simple model described in § 4.1. The residual for each star on a particular night is the difference between its position on that night and the mean of all its other observations which will normally be five in number, spread over about two weeks. Most stars on any particular night will have nearly contemporaneous observations because as a star is observed its priority is increased progressively until it has been completed. Provided that the regional distortions are more or less random from night-to-night, the mean position for each star will tend to average these out, and the residual from the mean on any particular night will reflect the regional distortion on that night. Distortions persisting over a week or more, originating from long-term deficiencies in the simple model, will be underestimated when only using programme stars.

As the same FK5 stars were observed over several months, they tended to show the long-term deficiencies as well as the night-to-night variations. Therefore, in CMC8 and CMC9, the residuals of the FK5 stars with respect to their mean positions were also included when calculating the regional distortions. In CMC10 and CMC11 many different Hipparcos stars were observed as reference stars and in general no particular star was observed repeatedly. So, the observations of Hipparcos stars could not be used in this manner. It must be emphasized that the FK5 positions themselves were not used in this process – only the difference between the individual observations and their mean. Any star observed over months rather than weeks would have the same effect. In summary, the inclusion of the FK5 residuals should have helped to remove inconsistencies between two stars in the same segment of the sky observed in different weeks, but it should not have altered the overall system of the catalogue.

The nightly zonal correction for each star was calculated as the mean of the residuals of the surrounding programme stars in a strip $2^{\rm h}$ in right ascension by $60°$ in declination. Each star had to be brighter than $12^{\rm m}$ and have at least four good observations in position on other nights. A magnitude residual was computed when three good observations were available on other nights. In contrast to CMC7, position and magnitude in CMC8-11 were dealt with separately in order to increase the number of contributing stars in deriving the positional corrections. If the strip did not contain at least seven stars, the right ascension was increased by steps of $1^{\rm h}$ and the declination by $30°$, up to a maximum of $5^{\rm h}\times150°$. If still fewer than seven stars were found, no correction was calculated.

These zonal corrections were applied to all the programme stars, and new means and standard deviations (mean errors) were calculated. The mean errors for stars in the zenith between $9^{\rm m}$ and $11^{\rm m}$ were:

	R.A.	Dec.	Mag.
Before	$0\farcs153$	$0\farcs143$	$0\fm049$
After	0.118	0.125	0.048[a]

[a] Further improved to $0\fm026$, as described in § 4.5

The improvement is clear in right ascension and declination, but not in magnitude. Nights which were bad photometrically were not included in the catalogue; so, significant zonal corrections are not to be expected in magnitude. A similar improvement was found for the scatter of the planet residuals with respect to the ephemerides.

4.7 Adjustment to the ICRF

4.7.1 CMC1-9

Whereas CMC10-11 were observed directly with respect to the ICRF via the Hipparcos Catalogue, CMC1-9 were necessarily observed with respect to the FK5. The positions in CMC1-9 were adjusted to the ICRF by applying retrospectively systematic differences as a function of RA and Dec. These were evaluated as follows.

From a preliminary comparison of the Carlsberg reference frame with the ICRF using positions of 63 extragalactic nebulæ and 26 radio stars, Argyle *et al.* (1996) found that the Carlsberg frame deviated from the ICRF in RA in the range $\pm 0\rlap{.}''05$ and in Dec in the range $-0\rlap{.}''05$ to $+0\rlap{.}''12$. Later, with the availability of the Hipparcos Catalogue, which is aligned to the ICRF to better than 1 mas, a more detailed study (unpublished) was possible using almost 60 000 stars (mainly IRS) common to the Carlsberg and Hipparcos Catalogues. This density of comparison stars allowed a 5° net of systematic differences, ICRF$-$Carlsberg, to be evaluated. These were applied to the positions of the stars and planets in CMC1-9. These systematic differences were not applied to the observed positions of the FK5 stars which are published in this CD-ROM.

4.7.2 CMC10-11

Although CMC10 and CMC11 were observed differentially with respect to the Hipparcos Catalogue, a comparison made after the formation of these catalogues revealed systematic differences of ~30 mas in RA and Dec. These varied smoothly, approximately as $\sin 2z$, where z is the zenith distance. This may be the consequence of under-parameterising the nightly adjustment of the observations to the ICRF, where only the simple Besselian constants were used. These systematic errors were so clearly defined that it was decided to remove them from CMC10 and CMC11. The resultant system of the positions should be within 30 mas of the ICRF.

4.8 Planets and satellites

The method of reduction of the planets was similar to that of the stars, but with allowance for their motion and defect of illumination. The corrections to the observed right ascension and declination for the defect of illumination were calculated from the following relations:

$$\Delta\alpha \cos\delta = +0.75\, s \sin\left(\frac{i}{2}\right) \sin Q$$
$$\Delta\delta = +0.75\, s \sin\left(\frac{i}{2}\right) \cos Q,$$

where s is the true semi-diameter, i the phase angle and Q the position angle of the greatest defect of illumination. The coefficient, 0.75, is taken from Lindegren (1977).

The final nightly zonal solutions obtained from the stars were applied to the planet positions, thus reducing them to the same reference frame. In common with the programme stars, a constant value of $B - V = +0.5$ was assumed in calculating the colour correction in magnitude discussed in § 4.1.

Table 6: Catalogue observation periods.

Catalogue	Period From	Period To	Hours of operation	Nights used	Nights rejected for mag.
CMC1-4	1 May 84	21 Feb 88	8872	955	111
CMC5	16 May 88	1 Jan 90	3892	415	61
CMC6	3 Jan 90	31 Dec 90	2478	254	57
CMC7	1 Jan 91	5 Aug 92	4479	466	69
CMC8	19 Aug 92	19 Dec 93	3415	364	77
CMC9	1 Jan 94	5 Apr 95	3562	365	55
CMC10	2 May 95	9 Dec 96	4564	446	65
CMC11	13 Dec 96	27 May 98	4710	369	100

Corrections for parallax were applied to the apparent topocentric declinations of the Solar System objects in order to produce apparent geocentric positions, except in the case of Geographos, where the topocentric position was retained because the parallax of the preliminary orbit was not known with sufficient accuracy.

5 Formation of the catalogue

About 1 047 000 observations of 176 600 stars carried out in 36 000 hours of operation on 3634 nights between 1 May 1984 and 27 May 1998 have been compiled into this catalogue. The details are given in Table 6.

On average, each star received six independent observations of its position and magnitude. About 2000 stars were observed in more than one Catalogue. The observations in each catalogue were processed independently in the following manner. Before forming the unweighted means of the observed positions, bad observations were eliminated. Those with badly defined stellar images were excluded. If the image was not completely within the scanned part of the sky, the observation was rejected. Observations were also rejected if the images were very spread, thus making it difficult to determine the centre. If the real-time reduction process of the scans of the image found a mean error in either the x or y coordinate of $1\overset{''}{.}15$ or more, both the right ascension and declination were rejected. Similarly, the magnitude was rejected if the internal mean error was greater than $0\overset{m}{.}25$. About 4% of the observations were excluded due to these criteria.

In magnitude, as much as 27% of the nights in a Catalogue were rejected because they were not good enough photometrically (see Table 6).

In the final stage of examination, observations with residuals exceeding three times the mean error (see Table 7) of a single observation were rejected. As a result of this process, about 1% of the observations in right ascension and declination, and 4% in magnitude were rejected.

Observations of double stars where more than one component entered the slits were rejected if the resulting error in the position was greater than $0\overset{''}{.}1$. In this latest compilation which includes CMC1-9, further checks were made against the Washington Double Star catalogue, and as a result some stars were rejected which had been issued in 1997 on the CD-ROM comprising CMC1-9. The component codes were also revised for a number of stars.

Table 7: Mean error of a **single observation** as a function of zenith distance (z) for stars brighter than $m = 11$.

	CMC1-4	CMC5-6	CMC7-9	CMC10-11
$\epsilon_\alpha \cos\delta$	$0''\!.19\,\sec^{0.7}$z	$0''\!.15\,\sec^{0.7}$z	$0''\!.12\,\sec^{0.7}$z	$0''\!.12\,\sec^{0.5}$z
ϵ_δ	$0''\!.18\,\sec^{1.1}$z	$0''\!.15\,\sec^{1.1}$z	$0''\!.13\,\sec^{1.1}$z	$0''\!.12\,\sec^{1.0}$z
ϵ_m	$0^{\mathrm{m}}\!.05\,\sec^{1.0}$z	$0^{\mathrm{m}}\!.05\,\sec^{1.0}$z	$0^{\mathrm{m}}\!.05\,\sec^{0.6}$z	$0^{\mathrm{m}}\!.045\,\sec^{0.5}$z

Table 8: Zenith mean error of a **single observation** as a function of magnitude.

	CMC1-4[a]	CMC5-6[b]	CMC7-9
$\epsilon_\alpha \cos\delta$	$0''\!.19+(m-11)\times 0.05$	$0''\!.15+(m-12)\times 0.05$	$0''\!.12+\mathrm{e}^{(m-17.0)\times 0.8}$
ϵ_δ	$0''\!.19+(m-11)\times 0.05$	$0''\!.15+(m-12)\times 0.05$	$0''\!.12+\mathrm{e}^{(m-17.0)\times 0.8}$
ϵ_m	$0^{\mathrm{m}}\!.05+(m-9)\times 0.025$	$0^{\mathrm{m}}\!.05+(m-12)\times 0.05$	$0^{\mathrm{m}}\!.05+\mathrm{e}^{(m-16.3)\times 0.8}$
	[a]; $\epsilon_\alpha, \epsilon_\delta, m > 11; \epsilon_m, m > 9$	[b]; $m > 12$	

	CMC10	CMC11
$\epsilon_\alpha \cos\delta$	$0''\!.12+\mathrm{e}^{(m-18.3)\times 0.8}$	$0''\!.12+\mathrm{e}^{(m-18.3)\times 0.8}$
ϵ_δ	$0''\!.12+\mathrm{e}^{(m-18.3)\times 0.8}$	$0''\!.12+\mathrm{e}^{(m-18.3)\times 0.8}$
ϵ_m	$0^{\mathrm{m}}\!.04+\mathrm{e}^{(m-23.0)\times 0.4}$	$0^{\mathrm{m}}\!.03+\mathrm{e}^{(m-22.0)\times 0.4}$

Where stars were observed in more than one Catalogue, their independent mean positions are given in order of the epoch of observation.

6 Accuracy of the catalogue

The internal mean errors of the observations were calculated from the scatter of the observations about their unweighted means. These were averaged in 5° ranges of declination. The mean error for one observation as a function of zenith distance (z) for stars brighter than $m = 11$ are listed in Table 7. The accuracy of the observations has improved with time due to improvements in instrumentation (listed in § 1) and in reduction methods (see § 4). In particular, the introduction of the new micrometer in May 1988 led to the improvement in CMC5-6, and the zonal adjustment (§ 4.6) produced an improvement in CMC7-9. Further improvements were obtained in CMC10-11 with the introduction of the Hipparcos Catalogue.

The mean error of a single observation as a function of magnitude, reduced to the zenith, is given in Table 8.

A catalogue position is the mean of several independent observations, so the accuracy is better than that of a single transit given by the expressions in Table 8. It is assumed that the accuracy of a position based on n observations can be expressed as

$$\epsilon_n = \sqrt{a^2 + b^2/n},$$

where a is the asymptotic mean error and b is the internal mean error given in Table 8. Taking

Table 9: Mean error of a catalogue position as a function of number of observations n, zenith distance z and magnitude m.

	$\epsilon_\alpha \cos\delta$	ϵ_δ
CMC1-4[a]	$\left\{0\rlap{.}''035^2 + \frac{1}{n}\left[0\rlap{.}''19 + (m-11)\times 0.05\right]^2 \sec^{1.2} z\right\}^{\frac{1}{2}}$	$\left\{0\rlap{.}''049^2 + \frac{1}{n}\left[0\rlap{.}''19 + (m-11)\times 0.05\right]^2 \sec^{1.8} z\right\}^{\frac{1}{2}}$
CMC5-6[b]	$\left\{0\rlap{.}''035^2 + \frac{1}{n}\left[0\rlap{.}''15 + (m-12)\times 0.05\right]^2 \sec^{1.2} z\right\}^{\frac{1}{2}}$	$\left\{0\rlap{.}''049^2 + \frac{1}{n}\left[0\rlap{.}''15 + (m-12)\times 0.05\right]^2 \sec^{2.2} z\right\}^{\frac{1}{2}}$
CMC7-9	$\left\{0\rlap{.}''035^2 + \frac{1}{n}\left[0\rlap{.}''12 + e^{(m-17.0)\times 0.8}\right]^2 \sec^{1.4} z\right\}^{\frac{1}{2}}$	$\left\{0\rlap{.}''049^2 + \frac{1}{n}\left[0\rlap{.}''12 + e^{(m-17.0)\times 0.8}\right]^2 \sec^{2.2} z\right\}^{\frac{1}{2}}$
CMC10-11	$\left\{0\rlap{.}''035^2 + \frac{1}{n}\left[0\rlap{.}''12 + e^{(m-18.3)\times 0.8}\right]^2 \sec^{1.0} z\right\}^{\frac{1}{2}}$	$\left\{0\rlap{.}''049^2 + \frac{1}{n}\left[0\rlap{.}''12 + e^{(m-18.3)\times 0.8}\right]^2 \sec^{2.0} z\right\}^{\frac{1}{2}}$

[a]; $m > 11$ [b]; $m > 12$

Table 10: Mean error of a catalogue position for a star of m=11 with n=6.

z	$0°$		$30°$		$60°$		$68\rlap{.}°8$	
δ	$+29°$		$-1°, +59°$		$-31°, +89°$		$-40°$	
	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ
CMC1-4	$0\rlap{.}''09$	$0\rlap{.}''09$	$0\rlap{.}''09$	$0\rlap{.}''10$	$0\rlap{.}''13$	$0\rlap{.}''17$	$0\rlap{.}''16$	$0\rlap{.}''24$
CMC5-6	0.07	0.08	0.08	0.09	0.11	0.14	0.13	0.19
CMC7-9	0.06	0.07	0.07	0.08	0.09	0.12	0.11	0.17
CMC10-11	0.06	0.07	0.06	0.08	0.08	0.11	0.09	0.15

the values of a from Morrison *et al.* (1990), we derive the expressions listed in Table 9 for the external mean error of a catalogue position as a function of the number of observations n, zenith distance z and magnitude m.

Table 10 gives the mean error of a catalogue position calculated from the expressions in Table 9 for a star of magnitude 11 having six observations, which is the customary number. Table 11 gives the mean error of a catalogue position calculated from the expressions in Table 9 for a star of magnitude 13 having six observations.

The external mean error of a catalogue magnitude for stars having four or more observations was obtained by comparing the magnitudes of stars having photoelectric standards in the catalogue of Nicolet (1978) for CMC1-9 and Hipparcos for CMC10-11. The stars were limited to those brighter than $m_{\rm V}$= 11 because it can be seen from Table 8 that the mean error of individual observations increases for stars fainter than this limit. The average resultant external mean error of stars brighter than about $m_{\rm V}$=11.0 is $0\rlap{.}^{\rm m}045$ in CMC1-10 and $0\rlap{.}^{\rm m}040$ in CMC11 and it is independent of declination. For stars fainter than this the mean errors rise in accordance with the expressions in Table 8.

Table 11: Mean error of a catalogue position for a star of m=13 with n=6.

z	0°		30°		60°		$68\overset{\circ}{.}8$	
δ	$+29^\circ$		$-1^\circ, +59^\circ$		$-31^\circ, +89^\circ$		-40°	
	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ	ϵ_α	ϵ_δ
CMC1-4	$0\overset{''}{.}10$	$0\overset{''}{.}11$	$0\overset{''}{.}11$	$0\overset{''}{.}12$	$0\overset{''}{.}15$	$0\overset{''}{.}19$	$0\overset{''}{.}18$	$0\overset{''}{.}25$
CMC5-6	0.09	0.10	0.10	0.11	0.13	0.18	0.15	0.25
CMC7-9	0.07	0.08	0.08	0.09	0.11	0.15	0.14	0.21
CMC10-11	0.07	0.07	0.07	0.08	0.09	0.12	0.10	0.16

7 Number and distribution of observations

Tables 12 and 15 list the main programmes and numbers of observations in this compilation catalogue. About 2000 stars have more than one entry in this compilation. Sometimes the same star was re-observed under another number because it was not realized initially that the imprecise input positions referred to the same star. In some cases stars were re-observed deliberately, either to investigate some problem with the first observation, or to improve the accuracy of the position. Non-stellar objects are listed in Table 13, and novæ and supernovæ in Table 14.

The minor planets fall into several categories regarding their frequency of observation. Those being monitored for brightness variations, leading to the establishment of phase relations, were observed nightly. Minor planets requiring improvements in their orbits for observation by the Infrared Space Observatory were also observed nightly. Those included in the HIPPARCOS satellite programme were observed weekly in order to provide a long-term baseline extending beyond the duration of the space mission. Minor planets having their masses determined from mutual perturbations were scheduled every tenth night.

The distribution of the stars with magnitude is bimodal, reflecting the large survey programmes: IRS and Lick NPM with a median around 9 mag, and the faint and special reference stars around 12 mag. There is a general progression from brighter to fainter stars between CMC1-4 and CMC9 as a result of the completion of the IRS in the early years and the improvements in instrumentation which made the observation of fainter stars possible.

Table 12: Programmes and number of observations of stars.

Stars

CMC1-11	R.A.	Dec.	Mag.
Number of observations	1047966	1047016	822121
Number of stars	176591	176591	168989

Programmes	No. of stars in programme	No. of stars observed	Percentage completed
Reference frame			
International Reference Stars: mainly in Hipparcos Catalogue	35886	34632	97
Faint reference stars, 10<V<12: mainly AC; density 1 per sq deg	35600	33276	93
General Catalogue of 33342 stars (Boss)	24296	15634	64
Reference stars in radio source fields: mainly ICRF	11397	10061	88
Hipparcos Catalogue, V>11	2096	1783	85
Radio stars	280	238	85
Problematical AGK stars	857	687	80
Position and proper motion			
Gliese catalogue of nearby stars and CNS3 (12<V<14)	2808	2436	87
Luyten (NLTT, 12<V<14, $\mu > 0''\!.3$)	2955	2427	82
Luyten (NLTT, 12<V<14, $0''\!.18 < \mu < 0''\!.3$)	7508	4988	66
Variable stars (GCVS, 12<V<14)	3383	3029	90
Lick NPM catalogue	33053	18053	55
Proper motion			
F-type stars within 100 pc	10544	9631	91
G-type d&g, K-type giants within 300 pc	9243	8778	95
Nearby O-B associations	6555	5693	87
Sample of A5-G0 stars in N. Gal. Pole	3098	2985	96
Unbiased sample of K/M dwarfs	2241	2179	97
High-vel./ metal-poor stars	1277	1090	85
Disk and halo dwarfs	899	870	97
Gould Belt stars	1142	781	68
Peculiar F/K stars	1564	1096	70
Wide binaries in Galactic Pole	624	579	93
Special reference stars for -			
ESA *Giotto* mission to Comet Grigg-Skjellerup	1061	1057	99
NASA *Galileo* flyby of Asteroid 243 Ida	2030	1321	65
Schmidt fields for STScI GSC1.2 (equatorial band)	12547	11893	95
Stars 10<V<13 within 20 arc min of Veron-Cetty galaxies	-	19434	-
Stars in fields of Seyfert galaxies	583	516	89
Prediction of occultations by Neptune	604	343	57
Prediction of occultations by Pluto	716	388	54
Novæ & Supernovæ	-	20	-
Non-stellar objects	-	24	-

Table 13: List of non-stellar objects in CMC1-11.

Non-stellar objects

CMC No.	Name	CMC No.	Name	CMC No.	Name
408181	3C 273B	604912	Mark 421	714318	PG1634+706
605671	3C 273B	605513	PG1211+143	716343	Q1807+698
809567	3C 273B	609616	SS 433	716702	Q1821+643
504665	MS07546+39	701487	NGC 1068	800771	M 31
505011	PG0844+349	708322	Mark 1298	801455	Mark 359
506082	Mark 421	708527	WAS 26	806953	Mark 79
507138	Mark 231	711095	PG1351+64		
508442	Mark 478	711527	PG1411+442	903323	Q0422+004
510047	Mark 501	711816	Mark 1383		
510463	PG1718+481	712788	AP Lib		

Table 14: List of novæ and supernovæ.

Novæ & Supernovæ

CMC No.	Name	CMC No.	Name	CMC No.	Name	CMC No.	Name
807251	N Pup 1991	908250	SN 1993J	911862	SN 1994I	1001331	N Cass 1995
803614	SN 1992A	813501	N Aql 1993	909030	SN 1994AE	1017345	N Aql 1995
718963	N Cyg 1992	817814	N Cas 1993	915764	N Oph 1994	1016156	N Sgr 1996
715036	N Sco 1992	812327	N Oph 1993	908039	SN 1995D	1110802	N Sco 1997
716727	N Sgr 1992 No.2	910850	SN 1994D	907458	SN 1995E	1105767	SN 1998S

Table 15: Number of observations of Solar System objects.

Solar System CMC1-11

		R.A.	Dec.	Mag.
	Major planets			
	Uranus	883	883	483
	Neptune	1106	1106	645
	Pluto	380	380	269
	Satellites			
	Callisto	440	440	264
	Ganymede	218	218	165
	Rhea	12	12	8
	Titan	400	400	236
	Iapetus	231	231	187
	Hyperion	87	87	38
	Oberon	147	147	63
	Minor planets			
1	Ceres	340	340	273
2	Pallas	372	372	298
3	Juno	342	342	287
4	Vesta	264	264	217
5	Astraea	207	207	170
6	Hebe	336	336	288
7	Iris	344	344	286
8	Flora	388	388	322
9	Metis	232	232	202
10	Hygiea	530	530	428
11	Parthenope	192	192	151
12	Victoria	257	257	199
13	Egeria	265	265	204
14	Irene	207	207	162
15	Eunomia	309	309	248
16	Psyche	464	464	356
17	Thetis	161	161	107
18	Melpomene	303	303	248
19	Fortuna	304	304	243
20	Massalia	265	265	212
21	Lutetia	238	238	185
22	Kalliope	432	432	348
23	Thalia	229	229	182
24	Themis	153	153	107
27	Euterpe	193	193	162
28	Bellona	209	209	157
29	Amphitrite	285	285	228
30	Urania	188	188	146
31	Euphrosyne	151	151	94
32	Pomona	4	4	1
34	Circe	366	366	273
35	Leukotha	312	312	221
37	Fides	171	171	137
38	Leda	349	349	245
39	Laetitia	243	243	201
40	Harmonia	326	326	262
42	Isis	207	207	136
44	Nysa	278	278	222

		R.A.	Dec.	Mag.
	Minor planets (cont.)			
45	Eugenia	152	152	108
46	Hestia	102	102	62
49	Pales	40	40	18
50	Virginia	271	271	182
51	Nemausa	310	310	247
52	Europa	237	237	203
55	Pandora	428	428	337
57	Mnemosyne	22	22	14
63	Ausonia	193	193	146
65	Cybele	73	73	39
66	Maja	241	241	147
67	Asia	14	14	10
68	Leto	194	194	155
69	Hesperia	16	16	6
70	Panopaea	20	20	6
72	Feronia	208	208	161
74	Galatea	302	302	217
75	Eurydike	315	315	210
76	Freia	5	5	2
77	Frigga	359	359	232
82	Alkmene	277	277	192
84	Klio	31	31	22
87	Sylvia	293	293	198
88	Thisbe	282	282	224
89	Julia	116	116	82
91	Aegina	16	16	11
93	Minerva	6	6	3
97	Klotho	260	260	205
101	Helena	21	21	12
107	Camilla	29	29	17
109	Felicitas	13	13	4
110	Lydia	28	28	18
111	Ate	24	24	15
113	Amalthea	19	19	11
114	Kassandra	283	283	190
115	Thyra	149	149	112
117	Lomia	306	306	207
119	Althaea	291	291	225
121	Hermione	11	11	6
124	Alkeste	20	20	18
126	Velleda	19	19	12
129	Antigone	226	226	182
133	Cyrene	12	12	3
136	Austria	4	4	2
140	Siwa	24	24	10
147	Protogeneia	15	15	5
159	Aemilia	30	30	14
165	Loreley	20	20	12
170	Maria	10	10	4
171	Ophelia	20	20	4
192	Nausikaa	171	171	127
196	Philomela	257	257	214
				(cont.)

		R.A.	Dec.	Mag.
	Minor planets (cont.)			
197	Arete	23	23	9
201	Penelope	18	18	11
207	Hedda	3	3	1
216	Kleopatra	126	126	99
219	Thusnelda	199	199	134
221	Eos	8	8	7
224	Oceana	4	4	1
229	Adelinda	3	3	0
230	Athamantis	162	162	130
233	Asterope	251	251	165
242	Kriemhild	4	4	3
243	Ida	33	33	26
250	Bettina	28	28	17
251	Sophia	10	10	3
253	Mathilde	45	45	27
255	Oppavia	1	1	0
256	Walpurga	1	1	0
263	Dresda	4	4	1
271	Penthesilea	2	2	1
277	Elvira	6	6	2
287	Nephthys	15	15	7
289	Nenetta	6	6	3
294	Felicia	18	18	15
305	Gordonia	8	8	3
308	Polyxo	281	281	193
313	Chaldaea	25	25	12
314	Rosalia	10	10	2
324	Bamberga	261	261	212
337	Devosa	191	191	132
339	Dorothea	4	4	1
341	California	11	11	4
343	Ostara	2	2	2
347	Pariana	4	4	1
348	May	14	14	10
349	Dembowska	288	288	236
351	Yrsa	7	7	4
354	Eleonora	186	186	144
356	Liguria	6	6	3
357	Ninina	7	7	4
366	Vincentina	13	13	6
389	Industria	31	31	18

		R.A.	Dec.	Mag.
	Minor planets (cont.)			
401	Ottilia	2	2	2
410	Chloris	232	232	142
415	Palatia	18	18	9
423	Diotima	294	294	229
433	Eros	51	51	26
445	Edna	10	10	7
447	Valentine	9	9	2
451	Patientia	219	219	154
454	Mathesis	23	23	17
465	Alekto	2	2	1
471	Papagena	268	268	203
489	Comacina	10	10	4
491	Carina	12	12	4
492	Gismonda	1	1	1
494	Virtus	24	24	13
511	Davida	242	242	191
532	Herculina	221	221	170
534	Nassovia	10	10	2
540	Rosamunde	8	8	7
547	Praxedis	4	4	1
570	Kythera	189	189	125
579	Sidonia	9	9	3
589	Croatia	15	15	8
598	Octavia	6	6	3
628	Christine	22	22	15
631	Philippina	29	29	14
661	Cloelia	7	7	4
670	Ottegebe	15	15	7
701	Oriola	4	4	3
704	Interamnia	252	252	189
714	Ulula	15	15	4
720	Bohlinia	19	19	11
721	Tabora	63	63	27
739	Mandeville	10	10	2
757	Portlandia	14	14	10
786	Bredichina	15	15	10
804	Hispania	14	14	8
976	Benjamina	8	8	4
1539	Borrelly	8	8	6
1605	Milankovitch	2	2	1
1620	Geographos	16	16	13
4179	Toutatis	9	9	9
	P/Wild 2	23	23	13

8 Proper motions

The positions of stars in CMC1-11 were combined with observations at previous epochs in order to derive their proper motions. This work was divided into two main categories which evolved with time as the PPM catalogue (Röser & Bastian 1993) and the machine-readable version of the Astrographic Catalogue (AC) became available.

The first category of proper motion applied to stars which are brighter than V$\sim$11 and were thus to be found in the PPM catalogue. The PPM proper motions were improved by combining the CAMC position with the covariance matrix in the PPM, employing the method given by Eichhorn (1974, section 3.2.2). The PPM positions are given at equinox J2000.0 in the FK5 system.

The PPM was not available for CMC1-4, and in this case the early epoch positions were taken directly from the GC, Cape Astrographic, First and Second Cape Photographic, Yale Photographic, AGK2, AGK3 and a few smaller catalogues. The positions in these catalogues were adjusted to the FK4 system, where this had not already been done, and then to the FK5. The systematic corrections (FK5-FK4) for the epoch of each catalogue were evaluated from a routine kindly supplied by Heiner Schwan of the Astronomisches Rechen-Institut, and applied to the extracted star positions. These systematic corrections did not include the changes of position and rotation resulting from the transformation to the 1976 IAU System. For the non-PPM stars the CAMC positions at equinox J2000.0 in the 1976 IAU system were transformed to the previous system at B1950.0 using the procedure given by Yallop *et al.* (1989). The positions so derived at B1950.0 were adjusted to the epoch of observation by subtracting the proper motion resulting from the difference in rotation between the frames of reference in the 1976 IAU system and the previous system. The CAMC positions were thus referred to the same reference frame as the catalogues used in deriving the proper motions. Finally, these proper motions were transformed to the equinox J2000.0.

The revised proper motions for some stars were found to be discordant with those in the PPM. The positions of these stars were taken from the AGK2 and AGK3 and compared with the CMC5-9. In most cases the AGK3 position was found to be discrepant, and in a few cases where the Astrographic Catalogue position was also available, both the AGK2 and AGK3 positions were found to be discrepant.

The second category of proper motion applied to stars fainter than V$\sim$11 for which only the AC could readily supply positions at previous epochs for the bulk of these stars. By courtesy of Siegfried Röser of the Astronomisches Rechen-Institut, Heidelberg, the AC first became available for CMC5 and CMC6, but only for the northern hemisphere. Both hemispheres were available for CMC7-CMC9. These AC positions were in the system of the FK5. For CMC10-CMC11 the AC 2000 (Urban *et al.*, 1998) became available. This version of the AC was referred to the system of the Hipparcos Catalogue. These positions were used directly with CMC10-CMC11 which were also referred to the system of the Hipparcos Catalogue. In general, each star has two or three independent positions in the AC.

The catalogue positions were weighted according to their mean errors at epoch of observation. A mean error of $0\farcs3$ in right ascension and declination was adopted for the Astrographic Catalogue. The mean errors for the other catalogues were taken directly from the published positions. The estimates of the mean errors of the CAMC positions were calculated from the expressions given in Table 9.

The mean errors of the proper motions were estimated from the weights assigned to the input positions. Comparison of the proper motions with provisional values from the HIPPARCOS results shows that these internal errors are underestimated by about 50%. So, whereas the average internal errors given in the catalogue lie in the range $\pm0\farcs002$ to $\pm0\farcs003$ per year, the average external errors lie in the range $\pm0\farcs003$ to $\pm0\farcs004$ per year.

The $\sim$21 600 stars with no determination of proper motion fall into the following categories: (a) stars fainter than V$\sim$11 in CMC1-4 where the AC was not available, and in CMC5-6 south of the equator where, again, the AC was not available; (b) stars fainter than the limit of the AC for which no accurate first epoch positions were readily available.

For the reasons given above, the coverage and accuracy of the proper motions has improved with time from CMC1-4 to CMC11. Thus, the proper motion of a star in this compilation which has more than one entry is likely to be more accurate in the latest catalogue.

A comparison with stars common to the Hipparcos Catalogue, shows that in proper motion the systematic errors lie mainly in the range $\pm 1.5\,\mathrm{mas\,yr^{-1}}$, with only a few small areas reaching $\pm 3.0\,\mathrm{mas\,yr^{-1}}$.

9 Comparison with standard catalogues and ephemerides

9.1 Hipparcos Catalogue

The aim has been to obtain positions differentially with respect to the ICRF, using the Hipparcos Catalogue as the realization of that frame in the optical waveband. The adjustment of the observations and catalogues to the ICRF is described in § 4.7. As a result of these procedures, the system of this catalogue should be within 30 mas of the ICRF at the epoch of the observations and for about ten years thereafter. Beyond that, systematic errors of the proper motions will vitiate this accuracy.

Below –40° in declination, corresponding to a zenith distance of 70° to the south, and similarly below the pole in the north, the CAMC system runs off uncontrollably from the ICRF in declination. This is probably due to errors in modelling refraction at these low altitudes. For this reason the catalogue is limited to a declination of –40°, apart from the FK5 stars observed during CMC1-9, which are given down to a declination of –60°.

9.2 JPL DE405, satellite and minor planet ephemerides

The observed positions of the major planets (referred to the ICRF) have been compared with the Jet Propulsion Laboratory Development Ephemerides 405 (DE405) (Morrison & Evans, 1998). The offsets of Ganymede and Callisto from Jupiter were calculated from the Connaissance des Temps (1985-1994) and those of Oberon from Uranus from the Supplement to the CdT. (1990-1994). The ephemerides of the orbits of the satellites of Saturn were kindly supplied by D.B. Taylor (Taylor & Shen, 1988).

The opposition means of the observations discussed by Morrison & Evans (1998) generally lie within $0\overset{''}{.}05$ of the ephemerides, except in the declination of Jupiter (derived from the observations of Callisto and Ganymede), which shows a fluctuation of amplitude $0\overset{''}{.}1$ with the synodic period of Jupiter (12 yr). This looks like a frame–tie problem. However, the most recent VLBI observations of *Galileo* preclude this interpretation because they fit very well to DE405. The CAMC positions of Uranus and Neptune, which were in the same region of the sky during the observational period of this catalogue, show a coherent pattern relative to DE405. From this we conclude that there are systematic errors in the CAMC observations which reach $\sim 0\overset{''}{.}1$.

The minor planets were compared with ephemerides generated from recent integrations carried out by Annick Bec-Borsenberger, Bureau des Longitudes, Paris. Again, the errors conform to those for a single observation given in Table 7 and Table 8. The CAMC magnitudes of many of the minor planets have been analysed to determine slope parameters and absolute magnitudes Piironen *et al.* (1996).

9.3 Johnson V

Since $B - V$ is generally not known for the stars in this catalogue, a value of $B - V = +0.5$ was adopted for ALL stars and Solar System objects when applying the colour correction to the observed magnitude. This colour correction to the magnitude changed with alterations to the filters and micrometer over the period of this compilation. The colour correction was derived for each catalogue by comparing the values in these catalogues with photoelectric standards. The expressions for reducing the magnitudes published in this compilation catalogue to Johnson V are:

$$V_{\rm J} = V_{\rm CMC1-4} - 0.015 + [-0.071 - 0.011(\text{Year} - 1984.0)]\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC5} - 0.022 + 0.036\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC6} - 0.005 + 0.036\,(B - V - 0.5) \quad (\text{Jan}\,3 \text{ to Feb}\,15)$$

$$V_{\rm J} = V_{\rm CMC6} - 0.005 + 0.018\,(B - V - 0.5) \quad (\text{Feb}\,16 \text{ to Dec}\,31)$$

$$V_{\rm J} = V_{\rm CMC7} - 0.011 + 0.018\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC8} + 0.018\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC9} + 0.018\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC10} - 0.010 + 0.013\,(B - V - 0.5)$$

$$V_{\rm J} = V_{\rm CMC11} + 0.002 + 0.024\,(B - V - 0.5)$$

In CMC10 it was found that the neutral density filters employed in the observation of brighter stars, as described in Table 2, were not quite linear. This was also found in CMC11. Corrections to remove these non–linearities were applied in CMC10 and CMC11, but not in the earlier catalogues in the series. The maximum systematic error in CMC1-9 due to the neglect of this effect is +0.02 mag near V=2 and V=6.

The periods covered by the catalogues are listed in Table 6.

10 Explanation and file formats

10.1 Star Catalogue CMC1-11 – decimal version – *star1.dat*

Record format – 2 records per star (in ascending order of right ascension, except for observations of the same star, where epoch of observation takes precedence).

Record length = 80 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
I9	RA (J2000.0, Epoch of date)	10^{-7} hour
I9	Dec(J2000.0, Epoch of date)	10^{-6} degree
I4	V magnitude (CAMC) [a]	10^{-2} mag
A1	var.=V; approx.=Y or I; 12.=X or R	
I4	Epoch of RA	10^{-2} year (–1900)
1X		
I4	Epoch of Dec	10^{-2} year (–1900)
3I2	No. of obs. RA, Dec, Mag	
2F5.2	Parallax factors in RA & Dec	
1X		
I7,I6	CAMC proper motion & error RA Set to 999990 and 0 if not determined	10^{-5} s/year
I6,I3	CAMC proper motion & error Dec Set to 999990 and 0 if not determined	10^{-4} ″/year
2X		
A2	Spectral type	
I9	DM=N×10000000+Zone×100000+Number N=±1: BD +89 to –22 deg N=–2: CoD –23 to –45 deg N=–3: CPD N=±4: DM assigned by CDS	
I1	DM double component number	
I6	SAO	
I6	GC	
I8	AGK	
I7	HD	
A14	WDS	Final letter(s)
9X		= comp^n obsd.
I10	Internal CAMC number	
8X		

[a] Where the CAMC did not measure the mag, an approximate value from other sources is given to a precision of 0.1 mag (Y or I in next col.). Stars fainter than ∼12 with unknown mag are given as 12. (X or R in next col.).

10.2 Star Catalogue CMC1-11 – sexagesimal version – *star2.dat & star2*.dat*

Column 1:	Serial number=volume×100000 + serial number+double comp^n.
Columns 2-4 & 5-7:	Right ascension ($^{h\,m\,s}$) and declination ($^{\circ\,\prime\,\prime\prime}$) for equinox J2000.0 and epoch of observation.
Columns 8 & 11:	Number of observations in position and magnitude.
Column 9:	Mean epoch of observation in right ascension and declination.
Column 10:	Observed magnitude (V CAMC). No magnitude was determined for 7602 stars. For these stars the magnitude was either taken (to one decimal place) from an input catalogue or it was assigned a nominal magnitude of 12. If the star is present in the General Catalogue of Variable Stars, the faintest observed magnitude is given, followed by a "V". The individual observed magnitudes for these stars may be given in the file *varmag.dat*.
Columns 12 & 13:	Annual proper motion in right ascension (s/yr) and declination ($''$/yr) in the J2000.0 frame. A blank indicates that no position at an earlier epoch was found in the catalogues which were searched. The proper motion was derived independently for each entry of the star (see § 8).
Column 14:	DM number: BD +89 to –22 & CD –23 to –45. A few exceptions to this rule south of the zone –22 are marked by a C (Cordoba Durchmusterung) or a P (Cape Durchmusterung). The digit immediately after the zone number is the component code. The minus sign immediately after the degree zone indicates that the DM number has been assigned in the CSI.

Record format – 1 record per star (in ascending order of right ascension, except for entries of the same star, where the epoch of observation takes precedence.)

Record length = 80 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
A3	Double star component	
I2,I3,F7.3	RA (J2000.0, Epoch of date)	h m s
1X		
A1,I2,I3,F6.2	Dec (J2000.0, Epoch of date)	$^{\circ}\,'\,''$
1X		
I2	Number of observations	
1X		
F5.2	Epoch of observation	year (−1900)
1X		
A5	V magnitude (CAMC)	
A1	V=var.	
I2	No. of obs. in mag.	
F8.4	CAMC proper motion in RA	s/year (blank= no pm)
F7.3	CAMC proper motion in Dec	$''$/year (blank= no pm)
1X		
A11	DM number	

10.3 CMC1-11 stars with $\mu > 0''.18$/yr – mainly NLTT – *nltt.dat*

Column 1:	Serial number=volume$\times$100000 + serial number+double comp^n.
Columns 2-4 & 5-7:	Right ascension ($^{\mathrm{h\,m\,s}}$) and declination ($^{\circ\,\prime\,\prime\prime}$) for equinox J2000.0 and epoch of observation.
Columns 8 & 11:	Number of observations in position and magnitude.
Column 9:	Mean epoch of observation in right ascension and declination.
Column 10:	Observed magnitude (V CAMC). No magnitude was determined for some of the stars. For these stars the magnitude was either taken (to one decimal place) from an input catalogue or it was assigned a nominal magnitude of 12. If the star is present in the General Catalogue of Variable Stars, the faintest observed magnitude is given, followed by a "V". The individual observed magnitudes for these stars may be given in the file *varmag.dat.*
Columns 12 & 13:	Annual proper motion in right ascension (s/yr) and declination ($''$/yr) in the J2000.0 frame. The proper motion was derived independently for each entry of the star (see § 8). Where the proper motion could not be calculated, because no position at an earlier epoch was found in the catalogues which were searched, the proper motion was taken from the NLTT. These are indicated by an asterisk immediately following the proper motion in declination.
Column 14:	The star identification given in the NLTT. Where BD/CD is not available, the following are used: Oxf=Oxford AC, Grw=Greenwich AC, U=Upgren, R=Ross, L=Luyten No. in Bruce PM Survey, LP=Luyten-Palomar Survey. An asterisk indicates that a note is given in the NLTT "notes" file. "Not NLTT" means that the CAMC proper motion is greater than $0''.179$ per year, but the star was not found in the NLTT. In many cases the true value of the proper motion is probably less than the $0''.18$ limit of the NLTT.

Record format – 1 record per star (in ascending order of right ascension, except for entries of the same star, where the epoch of observations takes precedence.)

Record length = 84 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
A3	Double star component	
I2,I3,F7.3	RA (J2000.0, Epoch of date)	h m s
1X		
A1,I2,I3,F6.2	Dec (J2000.0, Epoch of date)	$^{\circ}\,'\,''$
1X		
I2	Number of observations	
1X		
F5.2	Epoch of observation	year (−1900)
1X		
A5	V magnitude (CAMC)	
A1	V=var.	
I2	No. of obs. in mag.	
F8.4	CAMC proper motion in RA	s/year
F7.3	CAMC proper motion in Dec	$''$/year
A1	NLTT proper motion flag	
A15	NLTT identifier	

10.4 Variable stars in CMC1-11 – *varpos.dat*

Column 1:	Serial number=volume×100000 + serial number+double comp^n.
Columns 2-4 & 5-7:	Right ascension ($^{\mathrm{h\,m\,s}}$) and declination ($^{\circ\,\prime\,\prime\prime}$) for equinox J2000.0 and epoch of observation.
Columns 8 & 11:	Number of observations in position and magnitude.
Column 9:	Mean epoch of observation in right ascension and declination.
Column 10:	Minimum observed magnitude (V CAMC). The individual observed magnitudes for these stars may be given in the file *varmag.dat*. Note that the number of observations of magnitude (col.11) is the number of consistent observations used in forming the mean magnitude. Since these stars are variable, the number of observations may be given as zero, when in fact there are observations in *varmag.dat*. Where no observations of magnitude were made, the magnitude was either taken (to one decimal place) from an input catalogue or it was assigned a nominal magnitude of 12. Note also that nights with just a few clouds were not normally flagged as non-photometric, so some false faint magnitudes could be expected.
Columns 12 & 13:	Annual proper motion in right ascension (s/yr) and declination ($''$/yr) in the J2000.0 frame. A blank indicates that no position at an earlier epoch was found in the catalogues which were searched. The proper motion was derived independently for each entry of the star (see § 8).
Column 14:	GCVS identifier.

Record format – 1 record per star (in ascending order of right ascension, except for entries of the same star, where the epoch of observation takes precedence.)

Record length = 80 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
A3	Double star component	
I2,I3,F7.3	RA (J2000.0, Epoch of date)	h m s
1X		
A1,I2,I3,F6.2	Dec (J2000.0, Epoch of date)	$^\circ\,'\,''$
1X		
I2	Number of observations	
1X		
F5.2	Epoch of observation	year (−1900)
1X		
A5	V magnitude (CAMC)	
A1	V=var.	
I2	No. of obs. in mag.	
F8.4	CAMC proper motion in RA	s/year (blank= no pm)
F7.3	CAMC proper motion in Dec	$''$/year (blank= no pm)
1X		
A11	GCVS identifier	

10.5 Positions of novæ and supernovæ in CMC1-11 – *novapos.dat*

Column 1:	Serial number=volume×100000 + serial number+double comp^n.
Columns 2-4 & 5-7:	Right ascension ($^{\mathrm{h\,m\,s}}$) and declination ($^{\circ\,\prime\,\prime\prime}$) for equinox J2000.0 and epoch of observation.
Columns 8 & 11:	Number of observations in position and magnitude.
Column 9:	Mean epoch of observation in right ascension and declination.
Column 10:	Minimum observed magnitude (V CAMC). The individual observed magnitudes for these stars are given in the file *novamag.dat*.
Columns 12 & 13:	(Annual proper motion – blank)
Column 14:	Nova/Supernova identifier.

Record format – 1 record per star (in ascending order of right ascension)

Record length = 80 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
A3	Double star component	
I2,I3,F7.3	RA (J2000.0, Epoch of date)	h m s
1X		
A1,I2,I3,F6.2	Dec (J2000.0, Epoch of date)	$^{\circ\,\prime\,\prime\prime}$
1X		
I2	Number of observations	
1X		
F5.2	Epoch of observation	year (−1900)
1X		
A5	V magnitude (CAMC)	
A1	V=var.	
I2	No. of obs. in mag.	
16X		
A11	N/SN identifier	

10.6 Reference stars in CMC1-11, 10<V<14, within 20$'$ of Veron-Cetty galaxy positions – *veronc81.dat, veronc82.dat, veronc83.dat*

veronc81.dat: Quasars (brighter than absolute magnitude −23).
veronc82.dat: Confirmed, probable or possible BL Lac objects.
veronc83.dat: Active Galaxies (fainter than absolute magnitude −23).

Column 1:	Serial number=volume×100000 + serial number+double comp^n.
Columns 2-4 & 5-7:	Right ascension ($^{\mathrm{h\,m\,s}}$) and declination ($^{\circ}\,'\,''$) for equinox J2000.0 and epoch of observation.
Columns 8 & 11:	Number of observations in position and magnitude.
Column 9:	Mean epoch of observation in right ascension and declination.
Column 10:	Observed magnitude (V CAMC). Where no magnitude was determined for stars, the magnitude was either taken (to one decimal place) from an input catalogue or it was assigned a nominal magnitude of 12. If the star is present in the General Catalogue of Variable Stars, the faintest observed magnitude is given, followed by a "V". The individual observed magnitudes for these stars may be given in the file *varmag.dat*.
Columns 12 & 13:	Annual proper motion in right ascension (s/yr) and declination ($''$/yr) in the J2000.0 frame. A blank indicates that no position at an earlier epoch was found in the catalogues which were searched. The proper motion was derived independently for each entry of the star (see § 8).
Columns 14 & 15:	RA and Dec offsets in arc min of the CAMC star position from the galaxy, in the sense CAMC *minus* Veron-Cetty.
Column 16:	Identifier of galaxy in Veron-Cetty & Veron (1998).

Record format – 1 record per star (in ascending order of right ascension of galaxy, and right ascension of star within entries for a galaxy).

Record length = 96 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+serial No.
A3	Double star component	
I2,I3,F7.3	RA (J2000.0, Epoch of date)	h m s
1X		
A1,I2,I3,F6.2	Dec (J2000.0, Epoch of date)	$^\circ\ '\ ''$
1X		
I2	Number of observations	
1X		
F5.2	Epoch of observation	year (−1900)
1X		
A5	V magnitude (CAMC)	
A1	V=var.	
I2	No. of obs. in mag.	
F8.4	CAMC proper motion in RA	s/year (blank= no pm)
F7.3	CAMC proper motion in Dec	$''$/year (blank= no pm)
I4	Offset in RA	$'$
I4	Offset in Dec	$'$
1X		
A19	Galaxy identifier	

10.7 Observed positions of FK5 stars - *fk5u.dat & fk5l.dat*

Two files contain 12 216 mean observed positions of the FK5 stars used nightly to transfer the instrumental system of CMC1-9 to the FK5. The circumpolar stars were observed at upper and lower culminations and these are given in two separate files: upper - 11365 positions; lower - 851 positions.

The system defined by these positions is that of the original versions of CMC1-9, before they were adjusted to the ICRF, as described in § 4.7. The system was not exactly that of the FK5, as explained in § 4.1, § 4.6 and § 4.7. In each year about 20 observations were made on the average of each FK5 star. The accuracy of these annual mean positions can be calculated from the expressions in Table 9. They tend towards the asymptotic errors of $0\rlap{.}''035$ and $0\rlap{.}''049$ found by Morrison *et al.* (1990).

Format of FK5 star files (upper and lower culminations, in ascending order of right ascension)

Record length = 55 char

Format	Quantity	Unit
I7	CMC serial number	Volume×100000+FK5×10 +comp^{n}
I9	RA (J2000.0, Epoch of date)	10^{-7} hour
I9	Dec(J2000.0, Epoch of date)	10^{-6} degree
I4	V magnitude (CAMC)	10^{-2} mag
A1	V=var.	
I4	Epoch of RA	10^{-2} year (–1900)
1X		
I4	Epoch of Dec	10^{-2} year (–1900)
3I2	No. of obs. RA, Dec, Mag	
2F5.2	Parallax factors in RA & Dec	

10.8 Observed magnitudes of variable stars – *varmag.dat*

The individual magnitudes of stars that are known to be variable are listed in file *varmag.dat*. The FK5 variables are included in this list.

Format of variable star file (in alphabetical order of constellation, star name and Julian Date within star entries.

Record length = 40 char

Format	Quantity
I8	CMC number = Volume×100000+serial number or FK5 number
1X	
A11	Variable star name
1X	
F12.4	Julian Date of observation
2X	
F5.2	Observed magnitude (V CAMC)

10.9 Observed magnitudes of novæ and supernovæ – *novamag.dat*

The magnitudes of 12 novæ and 8 supernovæ observed in the years 1991 to 1998 are given in the file *novamag.dat*.

Format of record (in order of discovery year)

Record length = 45 char

Format	Quantity
I8	CMC number = Volume×100000+serial number
2X	
A15	Nova/Supernova name
1X	
F12.4	Julian Date of observation
1X	
F6.2	Observed magnitude (V CAMC)

10.10 Observed magnitudes of suspected variables – *suspect.dat*

The magnitudes of a few stars were observed for suspected variability. The magnitudes are listed in the file *suspect.dat*.

Format of record (in order of right ascension and Julian Date within star entries)

Record length = 45 char

Format	Quantity
I8	CMC number = Volume×100000+serial number
2X	
A15	Star identification
1X	
F12.4	Julian Date of observation
1X	
F6.2	Observed magnitude (V CAMC)

10.11 Observations of planets, satellites and minor planets – *planet.dat*

Format of planet record

Record length = 83 char

Format	Quantity
1X	
I7	CAMC object code
4X	
A4	Minor planet number or blank
2X	
A12	Planet, satellite or minor planet name
2X	
F14.6	Julian Date(TT)[a] where TT = UT1 + (TAI–UT1) + $32\overset{s}{.}184$ UT1 = time of transit; TAI–UT1 is taken by interpolation from 5–day values published by the Bureau Central de l'IERS, Observatoire de Paris
A1	An * indicates an observation with an internal error greater than $0\overset{''}{.}75$ and less than $1\overset{''}{.}15$
2X	
2I3,F7.3	Apparent geocentric[b] RA (h m s) for equinox of date, referred to the 1976 IAU reference system
2X	
A1,I2,I3,F6.2	Apparent geocentric[b] Declination ($^\circ\ '\ ''$) for equinox of date, referred to the 1976 IAU reference system
2X	
F5.2	Observed magnitude (V CAMC) or blank

[a] The time argument in the printed volumes of CMC1-3 is TAI, and not TDT as stated.

[b] Except Geographos, which is topocentric.

10.12 Meteorological data – **.met*

The Carlsberg Automatic Meridian Circle carried out regular meteorological observations in the period 13 May 1984 to 27 May 1998 and the records are more or less continuous in that period. The devices used to measure temperature, pressure, humidity, wind speed and direction are as follows:

Temperature
Analog Devices AD590K
Range: –55° C to +150° C
Calibrated accuracy: 0.1° C
Situation: mast head; 6 metres above ground until 1991 May 16, then 10.5 metres above ground

Pressure
Ysi Sostman, 2014–19.2/25.7 HA–3–WH aneroid type barometer
Range: 650–870 mb
Resolution: 0.1 mm Hg
Hysteresis: $\leq$0.1 mm Hg
Situation: inside telescope enclosure (started 1 August 1984)

Humidity
Lambrecht KG, type 800 N 100 hair hygrometer
Range: 0–100% relative humidity
Resolution: 2%
Situation: inside the telescope enclosure until 1987 October 17 when it was moved to the outside north–facing wall of the telescope enclosure

Wind speed
From 1984 May:

> Malling, system 881.01 and 875 anemometer
> Range: 0–30 m/s
> Accuracy: 1 m/s

From 1988 January:

> Vaisala WAA 12 anemometer
> Range: 0–75 m/s
> Accuracy: ± 1% below 20 m/s;   ± 2% above 20 m/s

Situation: mast head; 6 metres above ground until 1991 May 16, then 10.5 metres above ground
NB: Until December 1994, wind speed averaged over several seconds and therefore insensitive to sudden gusts

Wind direction
Aanderaa, model 2053 (vane type)
Range: 0° – 360°
Accuracy: 5°
Situation: mast head; 6 metres above ground until 1991 May 16, then 10.5 metres above ground

For the years 1984, 1985 and 1986 meteorological readings are only available at 30 minute intervals. From 1987 January, the meteorological sensors were read automatically by a dedicated Olivetti PC. Readings were then made at 5 minute intervals throughout the day and night regardless of whether observing was in progress. Beginning in 1994 December, all readings were made at 20 s intervals and then averaged over 5 minutes. The 5-min averages of wind velocity are thus less prone to erratic fluctuations caused by gusts than single readings at 5 minute intervals.

No readings were available when any one of the computers was "down", or a sensor became faulty, or during periods of routine maintenance or when the telescope was being modified – for example when fitting the new micrometer or the new circle reading system etc. In particular, there are no meteorological data for the following periods:

1984 September 25 to October 8: data were inadvertently deleted from the computer file

1985 December 9 to December 31: technical fault

1986 January 1 to January 11: telescope out of operation due to technical fault

1986 March: no wind direction data because the transducer was broken by heavy icing

1986 September 12 to September 22: telescope out of action due to technical fault

1986 December 18 to December 31: telescope was closed down for this period

1988 February: breaks in the data due to the fitting of the new micrometer

1988 May to August 10: no wind direction values between north and north–east because direction indicator was faulty

1994 January: gaps in the data because some of the sensors broke free from the top of the meteorological mast due to severe icing and strong winds

1995 April: gaps in the meteorological data because a new telescope control system was installed and operation was restricted

1995 September 14 to 1995 November 16: no wind direction values due to a fault in the wind direction device

1995 November 16 to 1996 March 7: A/D converter produced 'noisy' background.

The meteorological data are given in 26 six-monthly files. The number of records in each file is as follows:

1984 Jun–Dec	3541
1985 Jan–Dec	5974
1986 Jan–Dec	7285
1987 Jan–Jun	47349
1987 Jul–Dec	45810
1988 Jan–Jun	50637
1988 Jul–Dec	46556
1989 Jan–Jun	50672
1989 Jul–Dec	51706
1990 Jan–Jun	51974
1990 Jul–Dec	49363
1991 Jan–Jun	50008
1991 Jul–Dec	49571
1992 Jan–Jun	51884
1992 Jul–Dec	51606
1993 Jan–Jun	50622
1993 Jul–Dec	52740
1994 Jan–Jun	50640
1994 Jul–Dec	51173
1995 Jan–Jun	49121
1995 Jul–Dec	53010
1996 Jan–Jun	50989
1996 Jul–Dec	49001
1997 Jan–Jun	50548
1997 Jul–Dec	51899
1998 Jan–May	42033

Format of meteorological data record

Record length = 60 char

Format	Quantity
1X	
I4	Year
1X	
I2	Month
1X	
I2	Day
1X	
I2	Hours UT
1X	
I2	Minutes UT
1X	
I2	Seconds UT
2X	
F5.1	Pressure in millibars
2X	
F6.1	Outdoor temperature in °C
2X	
I2	Wind speed in metres/second
1X	
I3	Wind direction: North is 0°; East is 90°
1X	
I3	Percentage relative humidity: measured inside the dome until 17 October 1987; outdoors thereafter
1X	
F6.1	Temperature inside the dome in °C
1X	
5I1	Acceptance flags for pressure, temperature, humidity, wind speed and wind direction: if 0 – reading ignored if 1 – reading accepted if temperature flag set to 2, then temperature is the indoor temperature as the outside value was unacceptable Inside temperature and acceptance flags are not available for the period June 1984 to December 1986.

10.13 Atmospheric extinction in Johnson V – *ext8498.dat*

The extinction in Johnson V was determined nightly from the photoelectric registration of standard stars. The parameters used in determining the nightly extinction were as follows:

Extinction: coefficient of sec(zd) determined by least–squares adjustment to calibration stars observed during the course of a night: the equation of condition also includes a constant term for the zeropoint of the instrumental system – see §4.1

Spectral band: Johnson V

Calibration stars: CMC1-9 Nicolet (1978); CMC10-11 (Hipparcos)

Magnitude range:

$2 < m_v < 7$ from 1984 May to 1990 January

$2 < m_v < 14$ from 1990 January

Zenith distance: down to 83° N and S

Number of stars per night: ∼50, but ranges between 20 and 80 until CMC11, when it increased to ∼200

Apart from gaps due to non-photometric nights, there are gaps in the extinction values due to other causes in the following periods:

1988 February: fitting of the new micrometer and photo-multiplier
1989 November to 1990 January: prolonged poor weather and technical problems
1992 August: installation of a new circle reading system
1993 July: computer fault preventing observation

The eruption of the volcano, Mount Pinatubo in the Philippine Islands, in 1991 June produced up to 0.1 magnitudes of extinction between 1991 September and the beginning of 1993 when its influence declined.

The extinction values and their hourly rate of change (where significant) for the period 1984 May to 1998 May are listed in file *ext8498.dat*.

Format and description of the extinction data record

Record length = 61 char

Format	Unit
1X	
I4	Year
1X	
I2	Month
1X	
I2	Day
2X	
I2	Hours UT
1X	
I2	Minutes UT
5X	
F4.2	Extinction in V (mag)
6X	
F5.3	Extinction mean error
3X	
F6.3	Hourly rate of change of extinction
3X	
F5.3	Mean error of rate of change
3X	
I3	Number of stars in solution

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[1]On the dissolution of the RGO in October 1998, the staff in the CAMC project were transferred to the Institute of Astronomy, Cambridge, where they continued to be funded by the Particle Physics & Astronomy Research Council.

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