

The Last Meridian Circles

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Abstract: The aim is to document in some detail the last 35 years of meridian circles, a type of instrument with a fundamental role in astronomy for a very long time, and to do so while witnesses are still alive and can contribute. This is about finding facts. Meridian circles provided fundamental star positions for centuries. These positions were tied to a well-defined celestial coordinate system of right ascension and declination, and accurate proper motions ensured a transformation of the positions over long periods of time. This function of the meridian circles has been taken over by space astrometry and VLBI. The Hipparcos astrometric satellite was approved by ESA in 1980 and launched to a successful 3-year mission in 1989, and the successor, Gaia, has in 2025 completed a mission of over 10 years. An account is given of the last 18 meridian instruments, which were active for some part of the 35 years until 2015. This account is based on information found on the internet, and on input kindly supplied in correspondence with many colleagues.

Keywords: Astrometry, Meridian circles, History of astronomy

1 Introduction

The meridian circle (MC) was fundamental instrument for astrometry for over two hundred years. It had first shown its great potential for measurement of star positions when Ole Rømer set it up in 1704 near the village Vridsløsemagle 20 km west of Copenhagen. A *classical meridian circle* of Ole Rømer's design as shown in figure 1 is suited for accurate measurement of right ascension and declination of stars. Meridian instruments of *four other designs* are shown in some of the following figures 2-6. Pictures of meridian circles are found in the figures 1, 2, 6, 8, and 10 of Høg (2024a), and in many figures of Yershov (2025).

Ole Rømer had first set up a *transit instrument* in his house in Copenhagen in 1691, figure 2. It was the first of its kind with a telescope mounted on an east-west axis so that the meridian transit time could be measured accurately and provide the right ascension. The instrument had a scale (at F in the figure) which could be read with the microscope E. It was not yet a real meridian circle but both coordinates were determined, and both coordinates needed help from other instruments for the calibration. More information on meridian circles is given in Wikipedia (2025), including Ole Rømer's first real meridian circle shown in the section on the 17th century.

Observations with meridian circles served many astronomical purposes during a long period, but such astrometric instruments became obsolete when ESA's astrometry satellite Hipparcos delivered very accurate positions, proper motions and parallaxes. The catalogue with 120,000 Hipparcos stars published in 1997 gave reference stars so that MCs could be used to observe many fainter stars than Hipparcos, but MCs became obsolete also for this aim when the Gaia satellite reached out for 20 mag stars. Ten years with Gaia observations of 1.8 billion stars were completed in January 2025, and the first results for 1.1 billion sources were published already in 2016.

Meridian circles in La Palma, San Juan, USNO in Washington DC 2 instruments, Flagstaff, Mykolaiv (formerly Nicolaev), Kyiv (formerly Kiev) 2 instruments, Moscow 2 instruments, Pulkovo/Kislovodsk 4 meridian instruments, Tokyo, Bordeaux, Valinhos, and Cerro Calán were active in at least a part of the 35 years from 1980 to 2015 as shall be outlined in the following. Of these 18 instruments, the six meridian circles in La Palma, San Juan, Flagstaff, Mykolaiv, Kyiv, and Bordeaux were still active after the year 2000.

This account is based on a study of the literature and on input received from many colleagues on my request, and I have edited what I received in close correspondence, resulting in different details and styles. I prefer to keep some details if they could be of historical interest as time passes.



Figure 1. The classical meridian circle of Lund Observatory is now in permanent exhibition. Lennart Lindegren and the present author are shaking hands in 2023. Astrometry and this instrument had fascinated Lennart in 1973, just as had happened for me at the Brorfelde meridian circle 20 years before when I was as young as he was, see more in Høg (2024a). - Figure from the private collection of Lennart Lindegren.

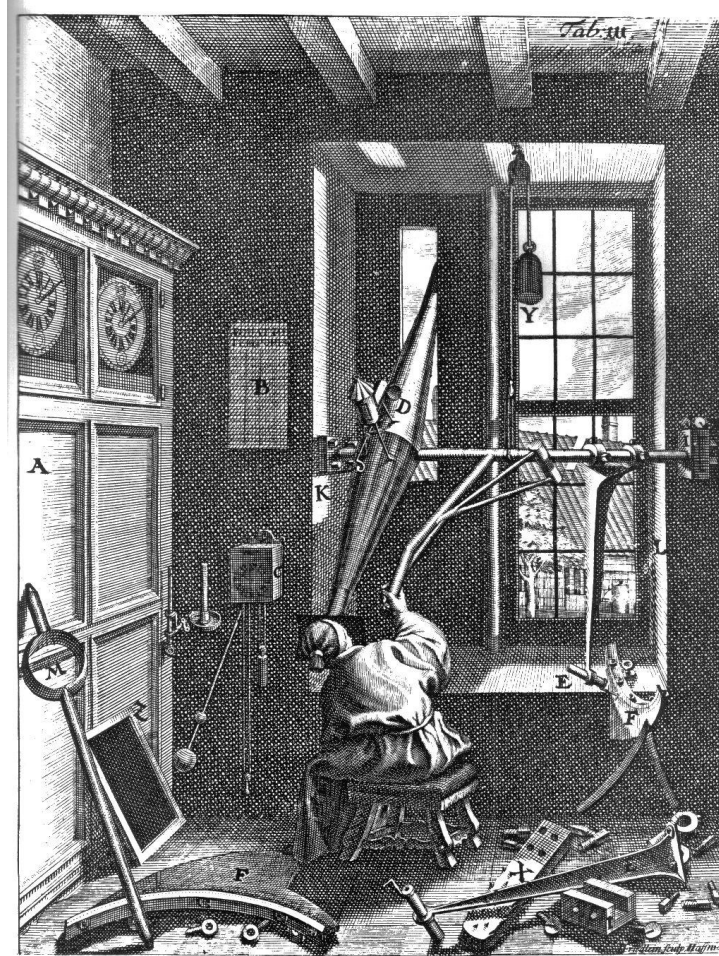


Figure 2. Engraving of Ole Rømer using his transit instrument. – From Peder Horrebow's *Basis Astronomiæ*.

1.1 About methods and changing techniques

A star is observed with a meridian circle while it crosses the meridian to obtain the right ascension and declination of the star. A micrometer at the focal plane measures the transit time needed for the right ascension, and it measures the position in the field-of-view along the meridian needed for the declination. The inclination of the telescope during this measurement is determined from readings of a circle with very accurate division lines on the east-west axis, and this is used with the measurement of the star to finally give the celestial coordinate of declination.

Stars were observed one by one, perhaps 200 in a good night, with manual setting of the telescope inclination before observation with the focal plane micrometer and reading of the circle. These stars could then by calculation be connected to a set of reference stars for which positions and motions were known from observation with meridian circles for more than 100 years. This was possible because a meridian circle is very stable during the night as it can only turn about an east-west axis resting in pivots on two solid columns. The net of reference stars since 1963 consisted of *1535 fundamental stars* on the whole sky listed in the FK4 catalogue, and the observer took care to observe some of them every night.

This situation changed completely with publication of the Hipparcos Catalogue, much more accurate than FK4, and in 2000 the Tycho-2 Catalogue appeared with data for 2.5 million stars also

observed with Hipparcos. At about the same time, CCD detectors had been installed at some meridian circles so that stars in a small area in the sky were observed simultaneously instead of only one star at a time. A strip of the sky was observed while the stars drifted across the CCD in so-called drift-scan mode (Time Delayed Integration, TDI) while the telescope stayed fixed. Drift-scan was also used in the Gaia satellite as proposed for an astrometric satellite called Roemer at a symposium in Shanghai in September 1992 (Høg 1993).

Some stars from Hipparcos or Tycho-2 were always present in the strip observed with the meridian circle to which the other stars in the strip could be connected. For such “relative astrometry”, the great stability of a meridian circle during a night was no longer essential and an accurate reading of the circle was superfluous. Therefore, the name *meridian circle* was no longer fitting, and it was replaced by *meridian telescope* in some cases.

Furthermore, a CCD is much more sensitive than a photomultiplier so that even fainter stars can be observed. Some meridian circles or meridian telescopes were therefore dedicated to surveys of large parts of the sky for faint stars. That was the case for the instrument on La Palma until 2011 and similarly for some of the six meridian instruments in San Juan, Flagstaff, Nicolaev, Kiev, Tokyo, and Bordeaux. Thus, all meridian circles are decommissioned by 2015 because the Gaia mission does not leave significant scientific tasks for these instruments, and this is rather the same time as the involved persons retire.

2 The 18 meridian instruments

2.1 Brorfelde: The Copenhagen University Observatory, CUO, established a new Observatory near the village Brorfelde 50 km to the west of Copenhagen where the main instrument was a meridian circle built by Grupp Parsons in England and erected in 1953. A photographic micrometer was developed and in use 1964-1976.

From 1973 a photoelectric slit micrometer with photon counting was developed, and full automation of the instrument was begun. Contact with the Royal Greenwich Observatory, RGO, in England from 1976 led to a collaboration where the automatic instrument should be set up on La Palma, one of the Canary Islands, where a large observatory was established in the following years on a mountain top, Roque de los Muchachos. Soon also Spain joined this collaboration. Observations with the MC on La Palma began in May 1984.

A report in Danish about the development of astrometry and the Brorfelde Observatory has been published by Høg (2024b).

2.2 La Palma: Leif Helmer has informed about the photoelectric observations. The observations on La Palma in the 14 years from May 1984 to May '98 were obtained with two photoelectric slit micrometers, the first one being replaced with a new one after four years. The latter micrometer had cooling of the photomultiplier, there were three pairs of inclined slits of different height (implemented by one pair of slits where a diaphragm could cover different parts) so that stars with uncertain positions could be measured, and there was a measuring rod engraved on the slit plate.

The results were published annually in Carlsberg Meridian Catalogues Numbers 1 – 11, on CD-ROM in 1999. The entire catalogue contained 180812 positions and magnitudes for 176,591 stars with declination $> -40^\circ$, 155,005 proper motions and 25,848 positions and magnitudes for 184 solar

system objects. About 100,000 observations per year were obtained, so that the 181,000 positions are based on about 1.4 million observations with 8 observations/star.

A link from a Cambridge website by Evans (2014) contains a reference to CMC14 of 2005. This is a catalog observed with the CCD in drift-scan mode covering the sky from -30 to $+50$ degrees in declination, just completed and published before Copenhagen University left the project and Leif Helmer retired in 2006. It contains astrometry and photometry catalogue of 95.9 million stars in the red (SDSS r') magnitude range 9 to 17.

Finally comes the catalogue CMC15 which is the last of the series "Carlsberg Meridian Catalogue, La Palma" and comprises all the observations made between March 1999 and March 2011 with the Carlsberg Automatic Meridian Circle in El Roque de los Muchachos Observatory on the island of La Palma (Spain). It contains more than 122 million stars with right ascension, declination, and magnitude in the magnitude range $9 < r' < 17$ and declination range $-40^\circ < \text{dec} < +50^\circ$. For the catalogue, a mean value was formed from at least two observations per star, and the catalogue internal errors in astrometry are below 30 mas (milli-arcseconds) in both coordinates for stars brighter than $r'=13$, reaching 60 mas for $r'=16$. The internal magnitude error is below 0.020 mag for stars brighter than $r'=13$, and about 0.090 mag for $r'=16$.

This means almost 700 times (122 million/181,000) as many positions from the CCD-micrometers in 12 years as the 181,000 star positions in 14 years from the slit micrometers.

The last night of observing was on 2013/09/01. The Carlsberg Meridian Telescope has been decommissioned, and the Instituto de Astrofísica de Canarias (IAC) has plans of housing the telescope in a museum in Santo Domingo de Garafía on La Palma, but this museum has nothing to do with IAC. The MC building on the mountain will be removed and the new Liverpool instrument will be located there.

2.3 San Fernando/San Juan: Real Instituto y Observatorio de la Armada en San Fernando (ROA) collaborated on the La Palma instrument and operated its own instrument in San Juan, Argentina. It was built by Grupp Parsons in 1948 as a twin to the one for Brorfelde and it was originally erected at San Fernando in 1952.

Miguel Vallejo Carrion informed: Until 1986, it carried out numerous systematic visual observation campaigns of stars and objects of the solar system. In 1986 it was subject to an automation and robotization process, taking advantage of the collaboration started in 1980 with the RGO and CUO. In 1988 it was equipped with a photoelectric slit micrometer identical to the second one developed for the La Palma instrument.

When the automation process was finished in 1994 and after two years testing in San Fernando, the instrument was in '96 transferred to the Carlos Ulrrico Cesco (CUC) High Altitude Station, part of the Félix Aguilar Astronomical Observatory (OAFa) of the National University of San Juan (Argentina) thanks to a collaboration agreement between both institutions. The location is close to Leoncito, the American astrometric observatory.

At its new location, the instrument was renamed the Automatic Meridian Circle of San Fernando (CMASF) and was initially equipped with the slit micrometer (1997-1999). It carried out systematic observations of stars and small planets resulting in the publication in 2001 of the first Hispano-Argentinian Meridian Catalogue HAMC1 containing 6,192 positions and magnitudes of stars south

of declination $+40^\circ$, 5,400 proper motions and 923 positions and magnitudes of 92 objects in the solar system.

In 1999 a CCD camera replaced the slit micrometer and full automation was implemented, see Muiños et al. (1999). A segment of the sky was observed between declinations -55° and $+30^\circ$, but only the part south of equator was completed. This formed the Second Hispano-Argentinian Meridian Catalogue (HAMC2) published in 2008 containing more than 12,500,000 positions and magnitudes of stars between -30° and 0° in declination and magnitudes $9 < V < 16.5$.

The instrument was finally closed down in 2014 due to staff limitations and the fact that results obtained from astrometric observations by the Gaia Space Mission made it scientifically unprofitable to continue with ground-based observations of lower precision.

2.4 USNO: The US Naval Observatory at Washington DC was a center for fundamental astrometry with meridian circles for many years. Other kinds of ground-based astrometry were also pursued at the USNO but are not the subject here. Plans for fundamental astrometry from space were studied in the 1990s in the USA, see e.g. Johnston (1995) and the overview in Høg (2014).

The meridian circles at USNO and the work with them for 150 years have been described by Schmidt & Dick (2023) where the instruments are listed in Table 1. After 1980, two meridian circles were operated, the 6- and 7-inch Transit Circles, as quoted here:

The Six-inch Transit Circle would become the true workhorse of fundamental astrometry at the USNO in the 20th century, operating from 1899-1999 in the west transit building at the Massachusetts Avenue site in Washington, D.C. In that period, 974,000 visual observations were made with this instrument, 300,000 more than the Great Airy Transit Circle at Greenwich (1851-1954), perhaps more visual observations than any other transit circle in history.

The Seven-inch Transit Circle was the only meridian circle built at the Naval Observatory. It was nearly indistinguishable in design from its 50-year older cousin, the Six-inch Transit Circle. But while the Six-inch remained a visual instrument, the Seven-inch pioneered electronic imaging automation. These instruments were managed for most of their existence by separate USNO Divisions, yet each participated in the global campaign of the 1950s-1960s known as the International Reference Stars, and in the USNO Pole-to-Pole Program of 1985-1996.

Theodore Rafferty, made the final observations on the USNO Six-inch Transit Circle in 1999.

2.5 Flagstaff: In Arizona, USA, the Flagstaff astrometric telescope (FASTT) is described by Stone et al. (2003):

By the end of year 2003, the FASTT will have produced over 190,000 positions of solar system objects in a program to provide a very large and homogeneous database for each object that will extend over many years and include positions accurate to ± 47 to ± 300 mas, depending on the magnitude of each observed object ($3.5 < V < 17.5$). Moreover, extensive efforts have been undertaken to improve the systematic accuracy of FASTT equatorial positions by applying corrections in the reductions for differential color refraction, distortions in the focal plane, and correcting for a positional error that is dependent on magnitude. The systematic accuracy of FASTT observations is now about

± 20 mas in both right ascension and declination. FASTT data have contributed very significantly to recent successful spacecraft missions and to a dramatic improvement in the predictions made for occultation events.

My comment: The FASTT at Flagstaff was a transit telescope observing stars close to the meridian. It observed with a CCD since 1989. An upgrade started in 1997 and by 2003 a CCD with 2048^2 pixels covered a field of $51' \times 51'$. The positions were obtained by reference to the Tycho-2 Catalogue, thus the instrument was not working as a meridian circle where positions were derived by accurate observation of transit times and reading of the divided circle.

The FASTT continued to take observations of the Saturnian satellites until at least 2007, see Desmars et al. (2009).

Recently, Valeri Makarov said that FASTT was decommissioned by 2010 after R.C. Stone had passed away in 2005.

2.6 Mykolaiv: In Ukraine, the Axial Meridian Circle (AMC) of the Mykolaiv (formerly Nicolaev) Astronomical Observatory is a horizontal rotating telescope ($D = 180$ mm, $F = 2480$ mm) located in the prime vertical, paired with a stationary long-focal-length autocollimator ($D = 180$ mm, $F = 12,360$ mm) and equipped with a CCD micrometer operating in drift-scan mode, figure 3.

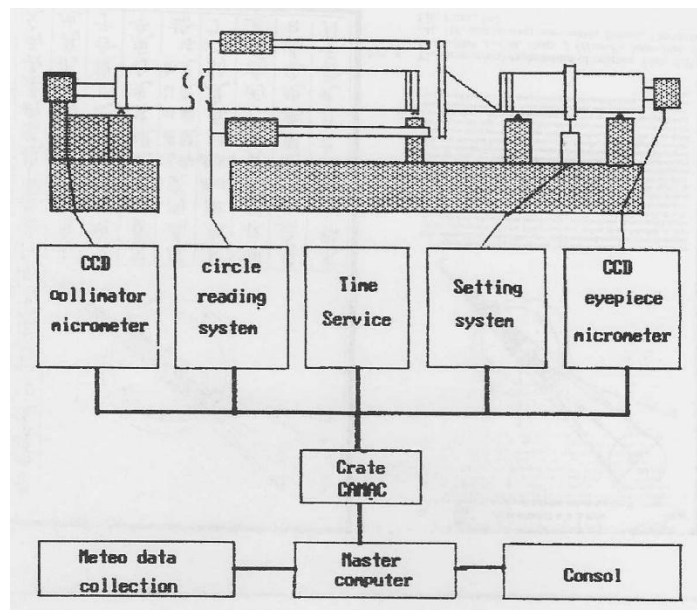


Figure 3. The Axial Meridian Circle (AMC) of the Mykolaiv Astronomical Observatory
– Diagram from Pinigin et al. (1995).

Since 1995, the telescope has undergone a series of upgrades, including the replacement of the CCD receiver with a modern more sensitive one. The telescope was equipped with an Apogee Alta F8300 CCD camera featuring high-resolution sensors (8.3 megapixels with $5.4 \mu\text{m}$ pixels), providing a 25×25 arcmin field of view and a scale of 0.45 arcsec/pixel. Astrometry is entirely derived from reference stars within the field. Observation campaigns with the AMC have been focused on ground-

based maintenance and extension of the Hipparcos reference system to fainter objects, see Kovalchuk (1997, 2000).

Details of the AMC design are given in Pinigin et al (2001). Observations in 2008–2011 are compiled in two catalogs with a total of 284557 objects by Maigurova et al. (2013) and Martynov et al. (2013). Stars with large proper motions were observed by Maigurova et al. (2016).

Astrometric observations performed by the Gaia Follow-Up Network for Solar System Objects (Gaia-FUN-SSO) play a key role in ensuring that moving objects first detected by ESA's Gaia mission remain recoverable after their discovery. An observation campaign on the potentially hazardous asteroid (99 942) Apophis was conducted during the asteroid's latest period of visibility, from 12/21/2012 to 5/2/2013, to test the coordination and evaluate the overall performance of the Gaia-FUN-SSO, see Thuillot et al (2015).

In 2015, observations were stopped in view of the much better results expected from the Gaia satellite.

2.7 Kyiv-1: From Ukraine, Liliya Kazanzeva sent information: “Our classical meridian circle was made by Repsold in 1870 and installed in Kyiv (formerly Kiev) Observatory 1872 in a special pavilion. It worked until 1996 in visual mode. When you arrived (the present author visited the meridian circle in 1978) you communicated with Chernega Mykola Yakimovich and he observed with this instrument for many years. Unfortunately, he has already passed away. Our observatory belongs to Kyiv University, but our employees also observed with the axial meridian circle at the other observatory in Kyiv, see Lazorenko et al. (2018) in the following section Kyiv-2.”

2.8 Kyiv-2: From Ukraine, Yaroslav S. Yatskiv sent information: The Main Astronomical Observatory of Kyiv, belonging to the Academy of Sciences, had an axial meridian circle. It was constructed at the observatory and very similar to the one in Mykolaiv.

Observations were carried out with a CCD camera in the years 2001 to 2015, see Karbovsky et al. (2011, 2017). They describe the results of the astrometric sky surveys with the telescope MAC which were performed in 2001-2015. They observed stars near the equator and stars in the fields with radio-sources which are ICRF objects. Astrometry was entirely derived from reference stars within the field of view.

About a catalog with astrometric observations of 219 828 stars in the period 2001-2003 with the axial MC, see Lazorenko et al. (2018).

2.9 Moscow: Valerian N. Sementsov at Moscow State University sent information which is here abbreviated:

Two meridian circles were installed and used in Sternberg Astronomical Institute, SAI, even after 1980:

1) Repsold's meridian circle

(D=148 mm, F=2000 mm, manufactured in 1847).

It was originally installed in the Krasnopresnensky Observatory of Moscow State University (approximate coordinates 55.758046N, 37.567800E).

The meridian circle was moved in 1981 to the observatory on Maidanak Mountain in Uzbekistan (Google coordinates 38°40'19 "N 66°53'55 "E). In February 1993, all equipment at Maidanak was nationalized by the Uzbek authorities. Currently it belongs to the Ulugbek Astronomical Institute under the Academy of Sciences of Uzbekistan. Golovko et al. (1984) mentions results.

2) Meridian circle of GOMZ (State Optical and Mechanical Plant) is shown in the undated figure at APM-4 (undated). It shows the APM-4 - meridian circle with photographic registration (created under the direction of V. V. Podobed and A. P. Gulyaev) (D = 180 mm, F = 2500 mm, installed d 1959-1961 in the pavilion with coordinates 55.701515N, 37.541488E).

Results are given by Tauber (1986). A catalogue of double stars (DS) and high-luminosity stars (HLS) declinations was obtained at the Moscow Observatory from observations with the meridian circle GOMZ. The observations were performed with the differential method by means of attachment to FK4 stars. The mean epoch of observations is 1982.70. The mean error of one observation is 0.30 arcsec.

The present author concludes that the two Moscow meridian circles have been used up to about 1985, provided with visual or photographic micrometers, but no description seems to be available. This brief text is sufficient for the present purpose, and it has been agreed with Oleg Malkov and Valerian N. Sementsov.

2.10 Pulkovo/Kislovodsk: In 1990, I visited the Pulkovo Observatory near Leningrad, later renamed St. Petersburg, invited to talk about the newly launched Hipparcos mission. My colleagues took me on a long trip, first to Moscow then to their observation station at Kislovodsk in the Caucasus Mountains. The visit to Kislovodsk had far reaching consequences for astrometry because I became engaged in discussions with my colleagues from Pulkovo: Mark Chubey, Valeri Makarov, and Vladimir Yershov, and soon also with Lennart Lindegren about a successor for the Hipparcos satellite. The discussions led directly to the Gaia mission as I report in section 14 of Høg (2024a).

Vladimir N. Yershov has sent the following information about four astrometric instruments which were in use after 1980, two meridian circles at Pulkovo and two other types of meridian instruments at Kislovodsk, and he sent the detailed illustrated paper Yershov (2025).

2.11 Pulkovo: A Toepfer meridian circle was modernized with a new 200 mm objective and called MK-200, see Ershov et al. (1986). "It had a scanning photoelectric focal-plane micrometer as the one developed in Brorfelde by Erik Høg. A CCD-based photoelectric circle-reading system was built which allowed automatic reading of four microscopes, simultaneously with the run of the scanning focal-plane micrometer. All output and input was on punched tape."

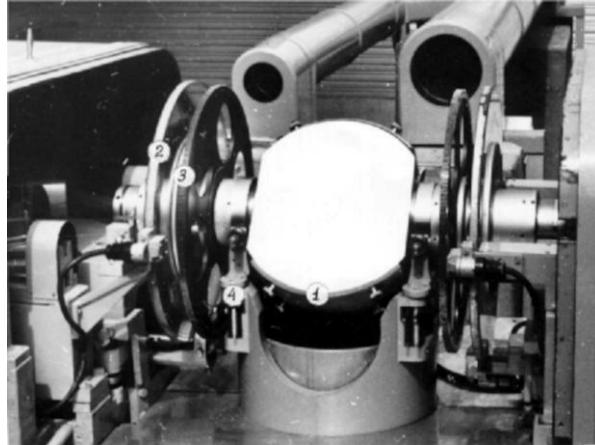


Figure 4. Sukharev Horizontal Meridian Circle of Pulkovo Observatory: 1- a flat mirror; 2- a graduated circle; 3 – a gear, 4 – an unloading system. – Photo about 1985 by the official Pulkovo photographer A.F. Sukhonos.

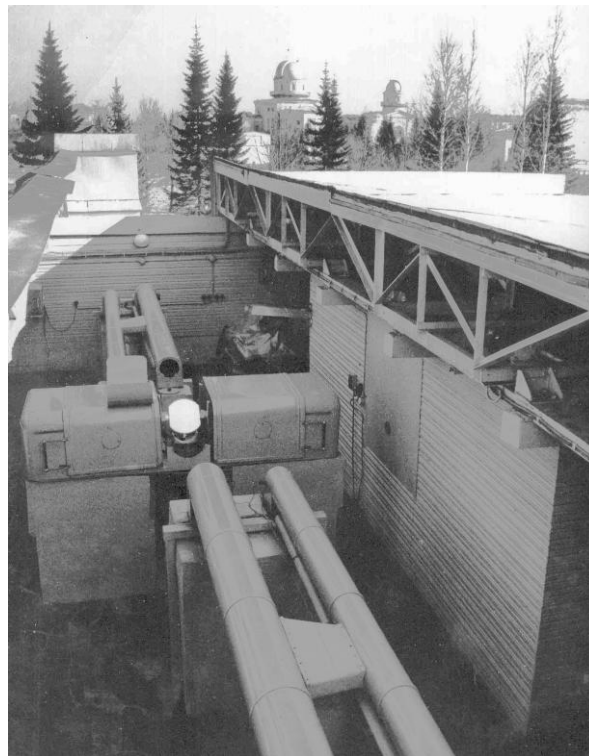


Figure 5. Flat-roof housing of the Sukharev Horizontal Meridian Circle. – Photo about 1985 by the official Pulkovo photographer A.F. Sukhonos.

Also at Pulkovo, a horizontal mirror meridian circle of special design by L.A. Sukharev was developed in the 1950s and after, see figures 4 and 5. In the 1980s, after development and study of an electronic control system, regular observations of bright and faint stars at both coordinates were carried out at the Sukharev Horizontal Meridian Circle in automatic mode, see Kirian et al. (1983).

The researchers obtained a catalogue of positions of the faint part of the FK5, as well as a differential catalogue of positions of reference stars located around radio sources.



Figure 6. Classical Ertel-Struve vertical circle (in front) and transit instrument (behind) at the Meridian Hall of Pulkovo Observatory (converted to an astrometry museum). – Photo from 2024 by Vladimir N. Yershov.

At the Kislovodsk Mountain Station of Pulkovo Observatory there were no meridian circles. Instead, two classical instruments, a vertical circle and a transit instrument (see figure 6) designed in XIX century by Struve and built by Ertel in Germany were installed in 1984 in two rhomb-shaped domes designed previously by Yu.S. Streletsky for a Large Transit Instrument installed at the Cerro-Calan National Astronomical Observatory (Santiago, Chile) in the 1960s-1970s. These two instruments were used for determining Right Ascensions and Declinations of Solar System bodies. The observations lasted from 1984 to 1989, and we have obtained 566 declinations of the Sun, 230 of Mercury, 413 of Venus, and 207 of Mars. Observations were visual, and the reductions were differential in the FK5 system.

Further observations from Kislovodsk were published by Devyatkin et al. (2009). From the abstract: A series of daytime observations [1983 to 1999] of the Sun and major planets are obtained at the mountain astronomical station of the Pulkovo Observatory using the Ertel-Struve meridian instruments. A series of declinations of Solar System bodies and major planets includes 4057 positions and that of right ascensions of Solar System bodies comprising 2057 positions. Based on the joint processing of observations of the Sun, Mercury, Venus, and Mars obtained with the Ertel-Struve vertical circle and large transit instrument.

2.12 Tokyo: The Tokyo Photoelectric Meridian Circle was a fully automated photoelectric meridian circle at the Mitaka campus of the National Astronomical Observatory of Japan in Tokyo, Japan. It was manufactured by Carl Zeiss Oberkochen, Germany and installed in Mitaka in 1982, see Wikiedia (2024).

Observations were published by Yoshizawa et al. (1993a, 1993b) about 3466 stars observed in 1989, and faint stars observed with CCD.

In Yoshizawa et al. (1994) the results are presented from ten years of work, and the development of a new CCD micrometer and future observational plans are discussed. During the years 1985-93 a total of 199,275 observations of 35,300 stars were obtained with the scanning slit micrometer, furthermore 3684 observations of solar system objects, including the Sun.

Yoshizawa (1995) gives positions of Pluto observed in 1994.

This message was received from Japan in December 2024:

Dear Erik Høg-san
Hello.

I am very happy to hear that you are doing well.

Tokyo PMC is not currently in use, and observations ended in 2000. It is now open to the public and is playing an active role in outreach.

By the way, after Professor Masanori Miyamoto, who made an effort to build Tokyo PMC, retired at the end of fiscal year 1996, Yoshizawa-san was in charge of Tokyo PMC. I took up my post at the National Astronomical Observatory in fiscal year 1999 as Miyamoto-san's successor professor. However, I was not involved in Tokyo PMC, but instead started and focused on the study of a Japanese astrometry satellite mission. That is what led to the current JASMINE mission. JASMINE is moving towards realization. The Japanese government plans to launch JASMINE in fiscal year 2031. I appreciate your continued support.

I hope you have a happy new year.

Naoteru Gouda

2.13 Bordeaux and Valinhos: The meridian circles are described by Viateau (1999).

“A first CCD 512×512 camera working in scan mode (declination field $14'$) was mounted in 1994 on the Bordeaux CCD meridian circle. After a testing period, this camera was installed on the Valinhos CCD meridian circle (near Sao Paulo, Brazil) as part of a collaboration between Bordeaux Observatory and the Instituto Astronomico e Geofisico of Sao Paulo. A second improved CCD 1024×1024 camera, with a declination field of $28'$, was installed on the Bordeaux instrument in June 1996. The mean internal precision of a single observation is about $0.04''$ in both coordinates for $9 \leq V \leq 14$.”

Daniel Egret has informed me: I am sorry, but I have been unsuccessful, so far, in my attempts to get a full update about the status of the instrument.

A key point is the fact that the astronomy teams in Bordeaux have now left the historical site of the observatory. In 2017, the laboratory of astrophysics moved [to the University city site] and left the observatory site in Floirac. At that time, an association (Sirius) was created to counter the attempt by the university to sell the site. The sale project has since been abandoned but the site is almost abandoned: the instruments are starting to take on water...

Two of the last papers I have seen, beyond the observations of pre-main sequence stars together with the mexican colleagues are Ducourant et al. (2006) with proper motions of 2.6 million stars and Arlot et al. (2008) with observations of planets and satellites.

The meridian instrument of the Bordeaux observatory continued to produce observations until 2014.

2.14 Valinhos: This instrument is mentioned above, but we have no information about observations.

2.15 Cerro Calán: The Repsold meridian circle at Cerro Calán near Santiago de Chile was used for observations of major and minor planets in 1983 as reported by Carrasco & Loyola (1984). Carrasco et al. (1987) report about modernization of the instrument.

2 Conclusion, a brief status of astrometry

A few of the stunning results from the Gaia mission should be mentioned. The accuracy of positions for 1.8 billion stars is better than 0.001 arcsec based on the first 34 months of Gaia observations and published in 2022, see figure 3 in Høg (2024c). This is 100 times smaller errors than for the 1500 FK4 stars, the most accurate catalogue until the Hipparcos results appeared in 1997. Orbits for 155,000 minor solar system bodies have been reconstructed.

Gaia observations ended on 15 January 2025 after more than 10 years.

The large drift-scans with meridian circles on La Palma and San Juan resulted in positions and magnitudes for over 130 million stars. For solar system objects, 130,000 positions were obtained from La Palma, San Juan, and Flagstaff with accuracy about 0.1 arcsec. From Flagstaff is reported in 2003 that the astrometric data “have contributed very significantly to recent successful spacecraft missions and to a dramatic improvement in the predictions made for occultation events.”

Meridian observations have been used in connection with Gaia. Results from the drift-scans were used to check for discontinuities in the Gaia photometry of the first Gaia catalogue in 2016, but not later, and the results were not used in connection with Gaia astrometry. Thuillot et al. (2015) write: “Astrometric observations performed by the Gaia Follow-Up Network for Solar System Objects (Gaia-FUN-SSO) play a key role in ensuring that moving objects first detected by ESA's Gaia mission remain recoverable after their discovery.”

I guess many people who had been working a long time to improve and use ground-based instruments may have had mixed feelings about Gaia. But I much hope and believe they will feel satisfied that they have dedicated their efforts the best way they could to a good scientific purpose: astrometry, and I hope they are pleased to see the immense progress obtained by space astrometry. Ground-based astrometry paved the way to this progress and took an active part to make it happen.

3 Acknowledgements: I am grateful for the information and comments from Daniel Egret, Dafydd Wyn Evans, Claus Fabricius, Naoteru Gouda, Leif Helmer, Liliya Kazanzeva, Lennart Lindegren, Valeri V. Makarov, Oleg Malkov, Valerian N. Sementsov, Catherine Turon, Miguel Vallejo Carrion, Yaroslav S. Yatskiv, Vladimir N. Yershov.

4 References

APM-4 undated, meridian circle with photographic registration.

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