

Astrometry and optics during the past 2000 years

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2011.05.03: Collection of reports from November 2008

ABSTRACT: The satellite missions Hipparcos and Gaia by the European Space Agency will together bring a decrease of astrometric errors by a factor 10000, four orders of magnitude, more than was achieved during the preceding 500 years. This modern development of astrometry was at first obtained by photoelectric astrometry. An experiment with this technique in 1925 led to the Hipparcos satellite mission in the years 1989-93 as described in the following reports Nos. 1 and 10. The report No. 11 is about the subsequent period of space astrometry with CCDs in a scanning satellite. This period began in 1992 with my proposal of a mission called Roemer, which led to the Gaia mission due for launch in 2013. My contributions to the history of astrometry and optics are based on 50 years of work in the field of astrometry but the reports cover spans of time within the past 2000 years, e.g., 400 years of astrometry, 650 years of optics, and the “miraculous” approval of the Hipparcos satellite mission during a few months of 1980.

2011.05.03: Collection of reports from November 2008. The following contains overview and link to the reports Nos. 1-9 from 2008 and Nos. 10-13 from 2011.

Direct quick connection to individual reports: www.astro.ku.dk/~erik/1104-index.pdf .

The reports are collected in two big file, see details on p.8.

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Overview with links to Nos. 1-9

No. 1 - 2008.05.27:

Bengt Strömgren and modern astrometry: Development of photoelectric astrometry including the Hipparcos mission

ABSTRACT: Bengt Strömgren is known as the famous astrophysicist and as a leading figure in many astronomical enterprises. Less well-known, perhaps, is his role in modern astrometry although this is equally significant. There is an unbroken chain of actions from his ideas and experiments with photoelectric astrometry since 1925 over the new meridian circle in Denmark in the 1950s up to the Hipparcos and Tycho Catalogues published in 1997.

www.astro.ku.dk/~erik/Stroemgren.pdf

Contribution to IAU Symposium No. 254 in Copenhagen, June 2008: The Galaxy Disk in Cosmological Context – Dedicated to Professor Bengt Strömgren (1908-1987).

No. 1A - 2008.06.10:

Bengt Strömgren and modern astrometry ... (Short version)

www.astro.ku.dk/~erik/StroemgrenShort.pdf

The same title as No. 1, but containing the short version posted at the symposium.

No. 2 - 2008.03.31:

Lennart Lindegren's first years with Hipparcos

ABSTRACT: Lennart Lindegren has played a crucial role in the Hipparcos project ever since he entered the scene of space astrometry in September 1976. This is an account of what I saw during Lennart's first years in astrometry after I met him in 1976 when he was a young student in Lund.

www.astro.ku.dk/~erik/Lindegren.pdf

No. 3 – 2008.05.28:

Miraculous approval of Hipparcos in 1980

ABSTRACT: The approval of the Hipparcos mission in 1980 was far from being smooth since very serious hurdles were encountered in the ESA committees. This process is illuminated here by means of documents from the time and by recent correspondence. The evidence leads to conclude that in case the approval would have failed, Hipparcos or a similar scanning astrometry mission would never have been realized, neither in Europe nor anywhere else.

www.astro.ku.dk/~erik/HipApproval.pdf

No. 4 - 2007.12.10:

From the Roemer mission to Gaia

ABSTRACT: At the astrometry symposium in Shanghai 1992 the present author made the first proposal for a specific mission concept post-Hipparcos, the first scanning astrometry mission with CCDs in time-delayed integration mode (TDI). Direct imaging on CCDs in long-focus telescopes was described as later adopted for the Gaia mission. The mission called Roemer was designed to provide accurate astrometry and multi-colour photometry of 400 million stars brighter than 18 mag in a five-year mission. The early years of this mission concept are reviewed.

www.astro.ku.dk/~erik/ShanghaiPoster.pdf

Presented as poster at IAU Symposium No. 248 in Shanghai, October 2007. Only the first three pages appear in the Proceedings.

No. 5 - 2008.05.23, updated 2008.11.25.

Note in 2011: See further update in www.astro.ku.dk/~erik/History2

Four lectures on the general history of astrometry

Overview, handout, abstracts at: www.astro.ku.dk/~erik/Lectures.pdf

Brief overview :

Lecture No. 1:

Astrometry and photometry from space: Hipparcos, Tycho, Gaia

The introduction covers 2000 years of astronomy from Ptolemy to modern times. The Hipparcos mission of the European Space Agency was launched in 1989, including the Tycho experiment. The Hipparcos mission and the even more powerful Gaia mission to be launched in 2011 are described.

Lecture No. 2:

From punched cards to satellites: Hipparcos, Tycho, Gaia

A personal review of 54 years development of astrometry in which I participated.

Lecture No. 3:

The Depth of Heavens - Belief and Knowledge during 2500 Years

The lecture outlines the understanding of the structure of the universe and the development of science during 5000 years, focusing on the concept of distances in the universe and its dramatic change in the developing cultural environment from Babylon and ancient Greece to modern Europe.

Lecture No. 4, included on 2008.11.25:

400 Years of Astrometry: From Tycho Brahe to Hipparcos

Four centuries of techniques and results are reviewed, from the pre-telescopic era up to the use of photoelectric astrometry and space technology in the first astrometric satellite, Hipparcos, launched by ESA in 1989. The lecture was presented as invited contribution to the symposium at ESTEC in September 2008: **400 Years of Astronomical Telescopes: A Review of History, Science and Technology**. The report submitted to the proceedings is included as No. 8 among "Contributions to the history of astrometry".

No. 6 – 2008.11.25:

Selected astrometric catalogues

ABSTRACT: A selection of astrometric catalogues are presented in three tables for respectively positions, proper motions and trigonometric parallaxes. The tables contain characteristics of each catalogue to show especially the evolution over the last 400 years in optical astrometry. The number of stars and the accuracy are summarized by the weight of a catalogue, proportional with the number of stars and the statistical weight.

www.astro.ku.dk/~erik/AstrometricCats.pdf

No. 7 – 2008.11.25:

Astrometric accuracy during the past 2000 years

ABSTRACT: The development of astrometric accuracy since the observations by Hipparchus, about 150 B.C., has been tremendous and the evolution has often been displayed in a diagram of accuracy versus time. Some of these diagrams are shown and the quite significant differences are discussed. A new diagram is recommended and documented.

www.astro.ku.dk/~erik/Accuracy.pdf

The two diagrams, Fig. 1a and 1b, in black/white and colour :

www.astro.ku.dk/~erik/AccurBasic.pdf

www.astro.ku.dk/~erik/AccuracyColour.jpg

www.astro.ku.dk/~erik/AccuracyBW.wmf

www.astro.ku.dk/~erik/AccuracyColour.wmf

No. 8 - 2008.11.25:

400 Years of Astrometry: From Tycho Brahe to Hipparcos

ABSTRACT: Galileo Galilei's use of the newly invented telescope for astronomical observation resulted immediately in epochal discoveries about the physical nature of celestial bodies, but the advantage for astrometry came much later. The quadrant and sextant were pre-telescopic instruments for measurement of large angles between stars, improved by Tycho Brahe in the years 1570-1590. Fitted with telescopic sights after 1660, such instruments were quite successful, especially in the hands of John Flamsteed. The meridian circle was a new type of astrometric instrument, already invented and used by Ole Rømer in about 1705, but it took a hundred years before it could fully take over. The centuries-long evolution of techniques is reviewed, including the use of photoelectric astrometry and space technology in the first astrometry satellite, Hipparcos, launched by ESA in 1989. Hipparcos made accurate measurement of large angles a million times more efficiently than could be done in about 1950 from the ground, and it will soon be followed by Gaia which is expected to be another one million times more efficient for optical astrometry.

www.astro.ku.dk/~erik/Astrometry400.pdf

Invited contribution to the symposium in Leiden in October 2008:

400 Years of Astronomical Telescopes: A Review of History, Science and Technology

No. 9 - 2008.11.25:

650 Years of Optics: From Alhazen to Fermat and Rømer

ABSTRACT: Under house arrest in Cairo from 1010 to 1021, Alhazen wrote his Book of Optics in seven volumes. (The caliph al-Hakim had condemned him for madness.) Some parts of the book came to Europe about 1200, were translated into Latin, and had great impact on the

development of European science in the following centuries. Alhazen's book was considered the most important book on optics until Johannes Kepler's "Astronomiae Pars Optica" in 1604. Alhazen's idea about a finite speed of light led to "Fermat's principle" in 1657, the foundation of geometrical optics.

www.astro.ku.dk/~erik/HoegAlhazen.pdf

Contribution to the symposium in Leiden in September 2008:

400 Years of Astronomical Telescopes: A Review of History, Science and Technology

Overview with links to Nos. 10-13

No. 3.2 – 2011.01.27, update from a version of 2008.05.27:

Miraculous approval of Hipparcos in 1980: (2)

ABSTRACT: The approval of the Hipparcos mission in 1980 was far from being smooth since very serious hurdles were encountered in the ESA committees. This process is illuminated here by means of documents from the time and by recent correspondence. The evidence leads to conclude that in case the approval would have failed, Hipparcos or a similar scanning astrometry mission would never have been realized, neither in Europe nor anywhere else.

www.astro.ku.dk/~erik/HipApproval.pdf

No. 10 - 2011.03.26:

Astrometry Lost and Regained

From a modest experiment in Copenhagen in 1925 to the Hipparcos and Gaia space missions

ABSTRACT: Technological and scientific developments during the past century made a new branch of astronomy flourish, i.e. astrophysics, and resulted in our present deep understanding of the whole Universe. But this brought astrometry almost to extinction because it was considered to be dull and old-fashioned, especially by young astronomers. Astrometry is the much older branch of astronomy which performs accurate measurements of positions, motions and distances of stars and other celestial bodies. Astrometric data are of great scientific and practical importance for investigation of celestial phenomena and also for control of telescopes and satellites and for monitoring of Earth rotation. Our main subject is the development during the 20th century which finally made astrometry flourish as an integral part of astronomy through the success of the Hipparcos astrometric satellite, soon to be followed by the even more powerful Gaia mission.

www.astro.ku.dk/~erik/AstromRega3.pdf

No. 11 - 2011.04.06:

Roemer and Gaia

ABSTRACT: During the Hipparcos mission in September 1992, I presented a concept for using direct imaging on CCDs in scanning mode in a new and very powerful astrometric satellite, Roemer. The Roemer

concept with larger aperture telescopes for higher accuracy was developed by ESA and a mission was approved in 2000, expected to be a million times better than Hipparcos. The present name Gaia for the mission reminds of an interferometric option also studied in the period 1993-97, and the evolution of optics and detection in this period is the main subject of the present report. The transition from an interferometric GAIA to a large Roemer was made on 15 January 1998. It will be shown that without the interferometric GAIA option, ESA would hardly have selected astrometry for a Cornerstone study in 1997, and consequently we would not have had the Roemer/Gaia mission.

www.astro.ku.dk/~erik/RoemerGaia.pdf

No. 12 - 2011.01.15: On the website of the Niels Bohr Institute:

Surveying the sky

“An astrometric experiment in 1925 was the beginning of a development which Erik Høg, Associate Professor Emeritus, took part in for 50 years. A scientific highlight is the star catalogue Tycho-2 from the year 2000, which describes the positions and movements of 2.5 million stars and is now absolutely essential to controlling satellites and for astronomical observations.”

In English: <http://www.nbi.ku.dk/english/www/> and in Danish: <http://www.nbi.ku.dk/hhh/>

and

En landmåler i himlen

In Danish: En artikel i tidsskriftet KVANT, oktober 2010, om 50 års arbejde

Erindringer om 50 år med astrometrien, der begyndte ved en høstak syd for Holbæk og førte til bygning af to satellitter. Et videnskabeligt højdepunkt er stjernekataloget Tycho-2, der nu er helt uundværligt ved styring af satellitter og ved astronomiske observationer.

www.astro.ku.dk/~erik/kv-2010-3-EH-astrometri.pdf

No. 13 - 2011.03.26:

Lectures on astrometry

Overview, handout, abstracts at: www.astro.ku.dk/~erik/Lectures2.pdf

Brief overview :

Lecture No. 1. 45 minutes

Astrometry Lost and Regained

**From a modest experiment in Copenhagen in 1925
to the Hipparcos and Gaia space missions**

The lecture has been developed over many years and was held in, e.g., Copenhagen, Vienna, Bonn, Düsseldorf, Vilnius, Oslo, Nikolaev, Poltava, Kiev, Thessaloniki, Ioannina, Athens, Rome, Madrid, Washington, and Charlottesville - since 2007 in PowerPoint. Revised in 2009 and with the new title

Astrometry Lost and Regained it was held in Heidelberg, Sct. Petersburg, Rio de Janeiro, Morelia, Mexico City, Beijing, Montpellier, Groningen, Amsterdam, and Leiden.

Lecture No. 2. 45 minutes

Hipparcos - Roemer - Gaia

The lectures briefly outlines the development of photoelectric astrometry culminating with the Hipparcos mission. Development of the Gaia mission beginning in 1992 is followed in detail.

The lecture has been held since 2010 in Toulouse and at ESTEC in Holland.

Lecture No. 3. 45 minutes. Suited for a broad audience, including non-astronomers

The Depth of Heavens - Belief and Knowledge during 2500 Years

The lecture outlines the structure of the universe and the development of science during 5000 years, focusing on the distances in the universe and their dramatic change in the developing cultural environment from Babylon and ancient Greece to modern Europe.

The lecture was first held in 2002, and since 2007 in PowerPoint. Held in Copenhagen, Vilnius, Nikolaev, Athens, Catania, Madrid, and Paris

Handouts at: www.astro.ku.dk/~erik/DepthHeavens2.pdf
and www.astro.ku.dk/~erik/DepthHeavens.pdf

An article with the same title as the lecture appeared in Europhysics News (2004) Vol. 35 No.3. Here slightly updated, 2004.02.20: www.astro.ku.dk/~erik/Univ7.5.pdf

Lecture No. 4. 45 or 30 minutes.

400 Years of Astrometry: From Tycho Brahe to Hipparcos

The four centuries of techniques and results are reviewed, from the pre-telescopic era until the use of photoelectric astrometry and space technology in the first astrometry satellite, Hipparcos, launched by ESA in 1989.

The lecture was presented as invited contribution to the symposium at ESTEC in September 2008: **400 Years of Astronomical Telescopes: A Review of History, Science and Technology**. The report to the proceedings is included as No. 8 among the "Contributions to the history of astrometry".

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Further installments in preparation: On the Hipparcos mission studies 1975-79 and on the Hipparcos archives.

Best regards

Erik

<http://www.astro.ku.dk/~erik>

Reports from 2008 and 2011 on History of Astrometry:

Overview, summary and link to individual reports from 2008 and 2011 are placed in an index file which will give **direct quick connection to individual reports:** www.astro.ku.dk/~erik/1104-index.pdf .

The two collections of reports are placed in two big files at the following links, including overview and summary pages:

The reports from 2008 are placed at arXiv and in a file printing on 8+94 pages:
www.astro.ku.dk/~erik/HistoryAll.pdf and the title is:

“Astrometry and optics during the past 2000 years”

The reports from 2011 are placed at arXiv and in a file printing on 8+46 pages:
www.astro.ku.dk/~erik/History2All.pdf and the title is:

“Astrometry during the past 100 years”