

70 years with astrometry

From meridian circles to Gaia and beyond

By Erik Høg For the meeting in Lund in July 2023

1953-1973

Basis for space astrometry was created

**thanks to meridian circles in Copenhagen, Brorfelde, Hamburg, and Lund
and to the vision of Pierre Lacroute about astrometry from space**

1974-2023

Hipparcos and Gaia era

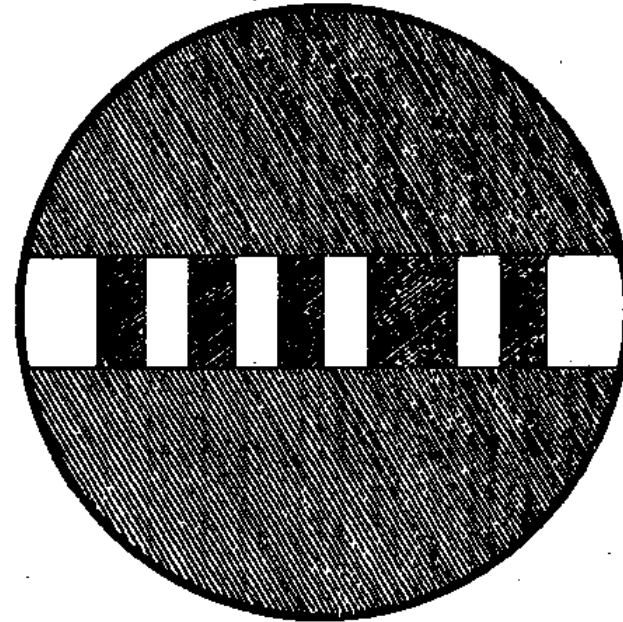
building on the astrometric tradition in Europe and on the ESA support

Copenhagen meridian circle

Photoelectric astrometry began in 1925



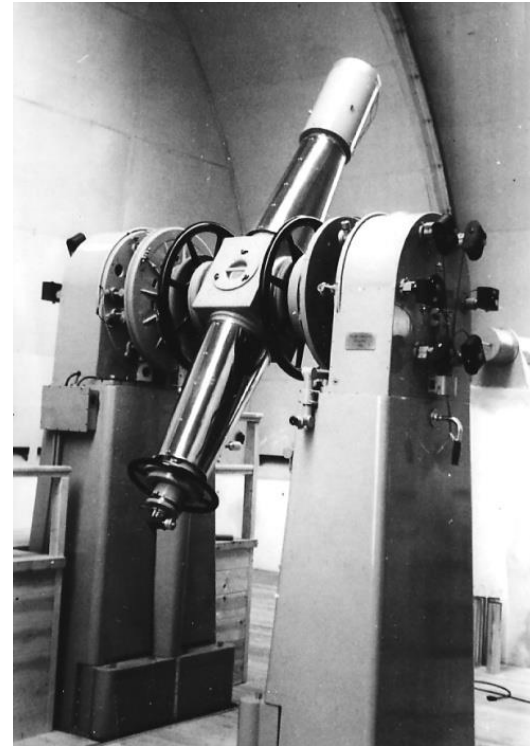
Courtesy: Steno Museum, Aarhus



In 1953 I learnt of
Bengt Strömgren's Experiments with
photoelectric recording of transits
*Vierteljahrschrift der
Astron. Gesellschaft 1933*



Bengt Strömgren (1957)



Bengt Strömgren professor of astronomy in 1940
Astrophysicist but a supporter of astrometry
He ordered a new meridian circle for a new Danish
observatory 50 km from Copenhagen
Erected 1953 at **Brorfelde** 50 km from Copenhagen

Brorfelde 1955

***From top of the
meridian building
towards the still
empty observatory
houses***

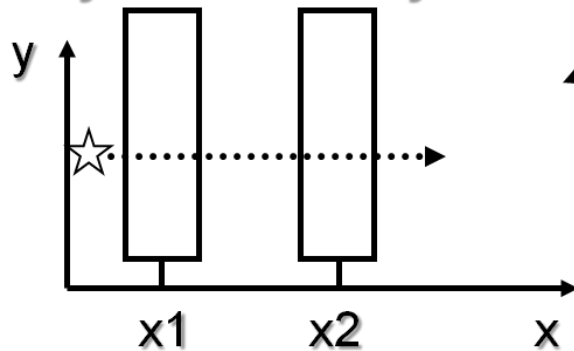


As a student of 22 years in 1954 I was sent to work with this instrument at Brorfelde, quite alone in the countryside
Slept sometimes in a haystack when clouds came
I became fascinated by the instrument and by astrometry

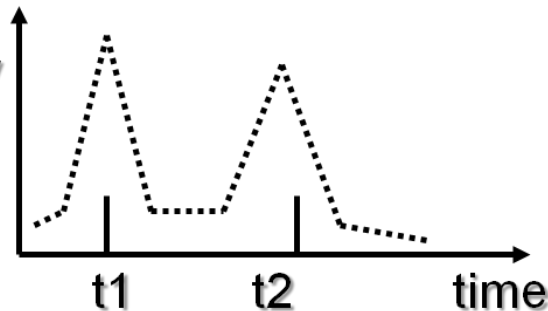
– From 1958 I stayed in Hamburg wanting **of course** to become an astrophysicist

1960: Photon counting astrometry

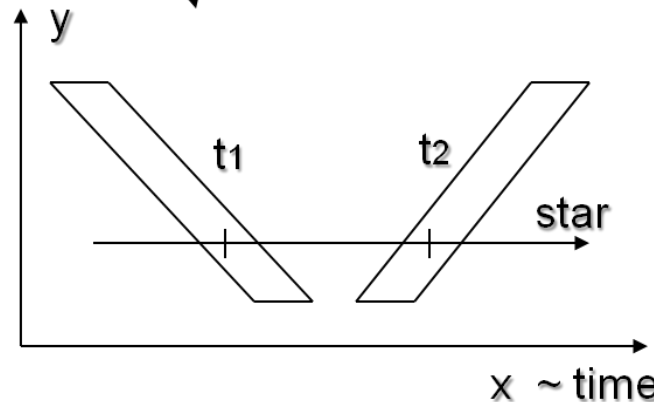
Slits + Photon counting vs. Time
=> Astrometry + Photometry



Light intensity
= Photons
per second



Ideas Høg 1960
in Hamburg



In France called: *Une grille de Høg*



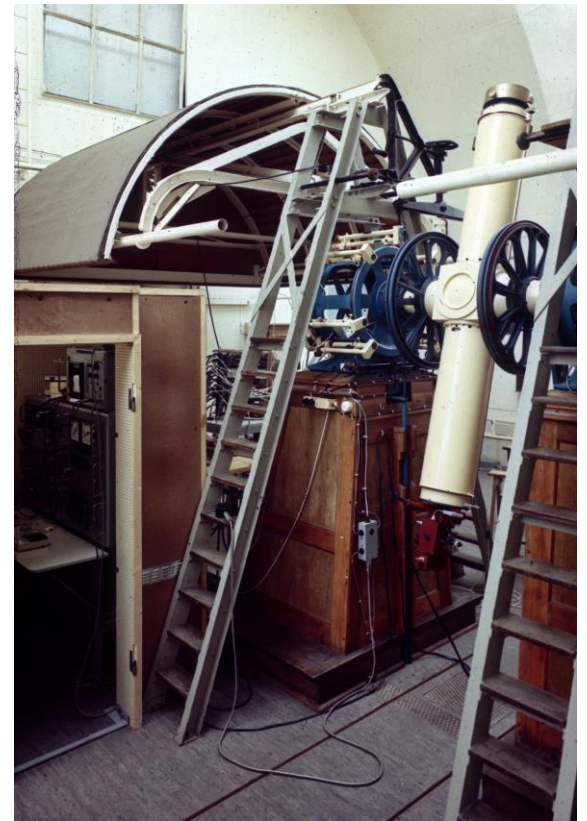
Erik 1963



2020

Photon counting astrometry

The new astrometric method was implemented on the Hamburg meridian circle 1960-67. - It was operated for 5 years in Perth (Western Australia) resulting in 1976 in a catalogue of 25,000 stars with an accuracy of ± 150 mas



1967
Hamburg Observatory
Meridian circle
Digitized, semi-automatic

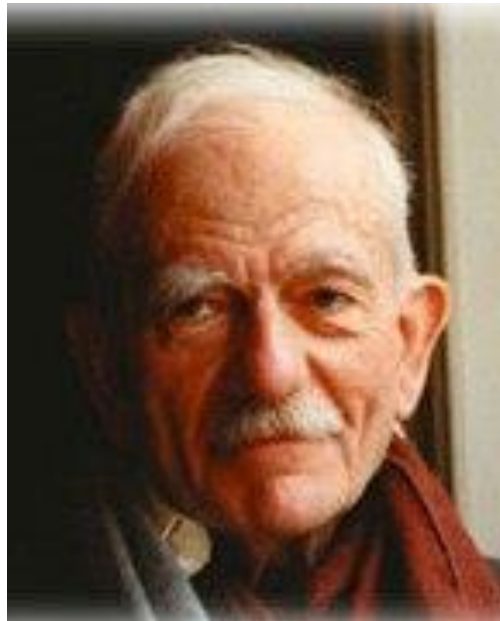
Photon counting astrometry in space

In **France**, the new method was adopted as basic for the great vision of a space-based astrometric mission by

Pierre Lacroute, the father of space astrometry

His work 1964-74 led him to propose
a scanning satellite with a split mirror

Pierre Lacroute
Jean Kovalevsky



Meridian Circle in Lund

**1973 Lennart Lindegren showed me the MC
He had become fascinated by the instrument
and by astrometry**

**I gave him the observations of planets from the
MC in Australia**

1973: With Lennart on board, the stage was set...

+++++

He made a brilliant analysis of the planets

**1976 He described the three-step method in four
weeks and joined the Study Team...**



2023 MC Erik Lennart

International Symposium on Space Astrometry in Frascati, Italy, 22-23 October 1974

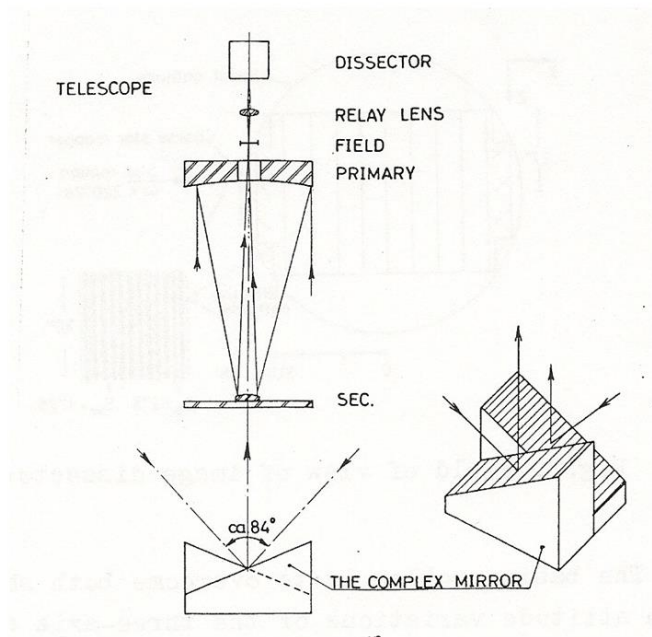
Conclusion: Set up a group for further studies in 1975

The automatic meridian
circle from Brorfelde was
moved to La Palma in 1984



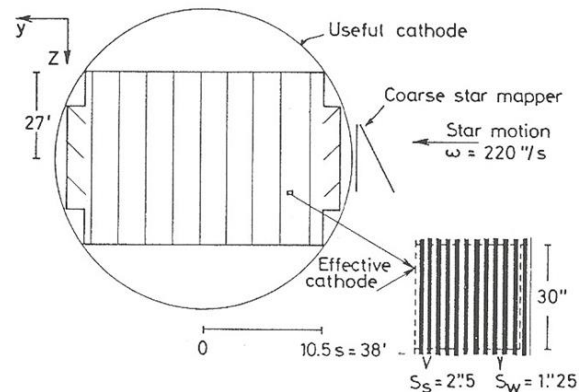
1975: Hipparcos design

1975: Study group meeting **changed my mind** about satellite astrometry



IAU GA 1976, Highlights of Astr., p.361

- Høg 1975-1976:
Expected 100 000 stars ~ 4 mas
with **16x16 cm aperture**
One-dimensional measurement
One image dissector tube + one PM



1976: **Lennart Lindegren** joined

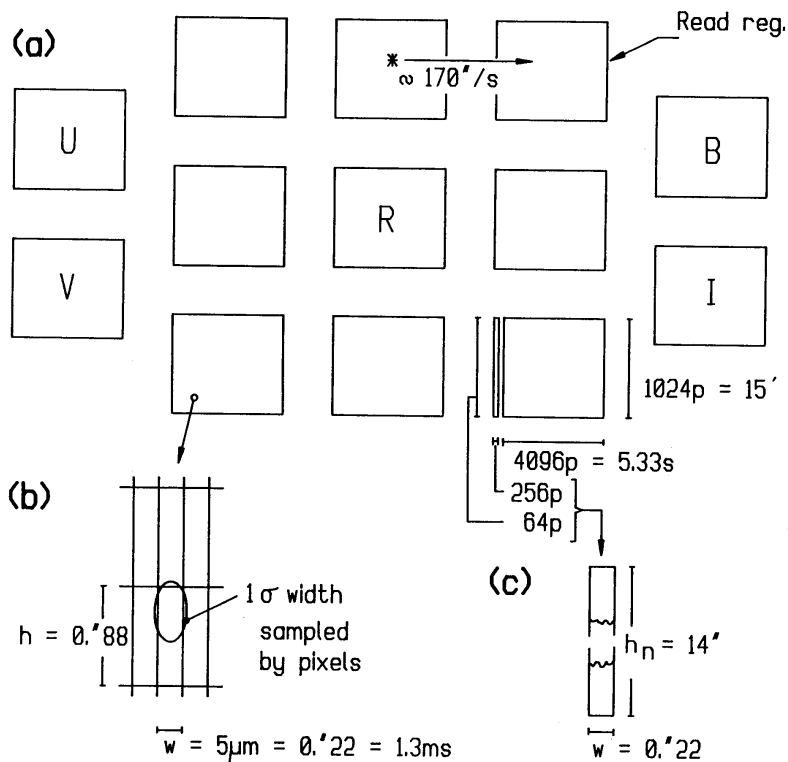
1980: Hipparcos approval, 1981: **Michael Perryman** project scientist

1989: Launch, 1997: Catalogue with 118 000 stars ± 1 mas ± 1 mas/year

2017: 2400 citations of the Hipparcos Catalogue

2000: **Tycho-2** with 2.5 million brightest stars in the sky. **2023: 2472 citations**

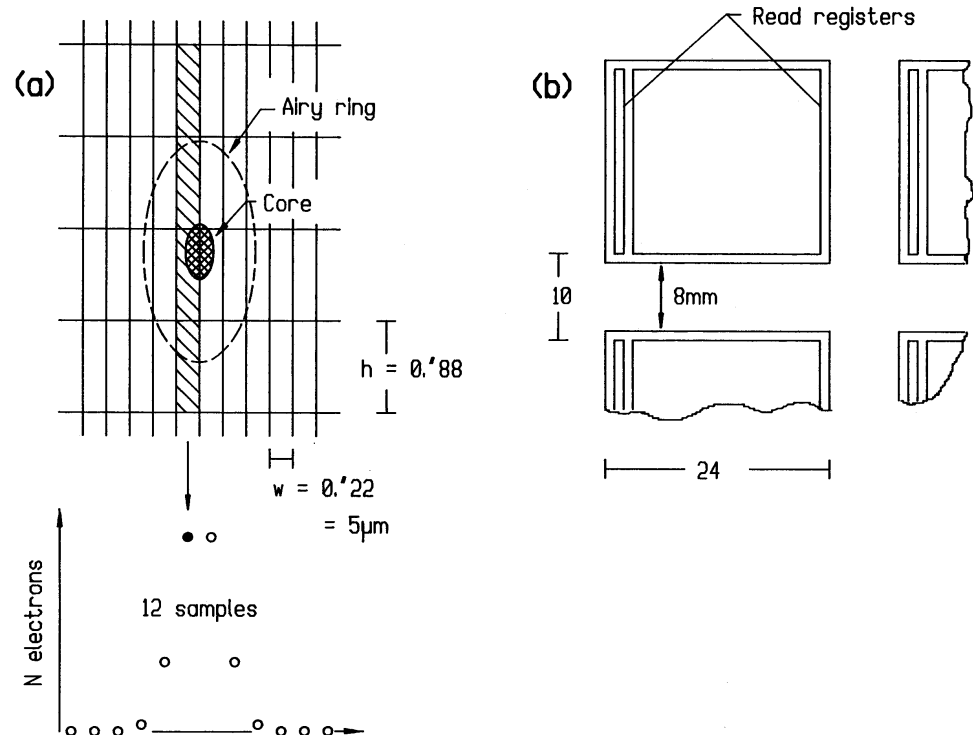
Focal plane of **Roemer** - Høg Sept. 1992 presented at an IAU Symposium in Shanghai



CCDs, direct imaging, elongated pixels, TDI, short CCDs for bright stars, sampling windows

Always reporting in the Hipparcos Science Team ...

Sampling and CCDs



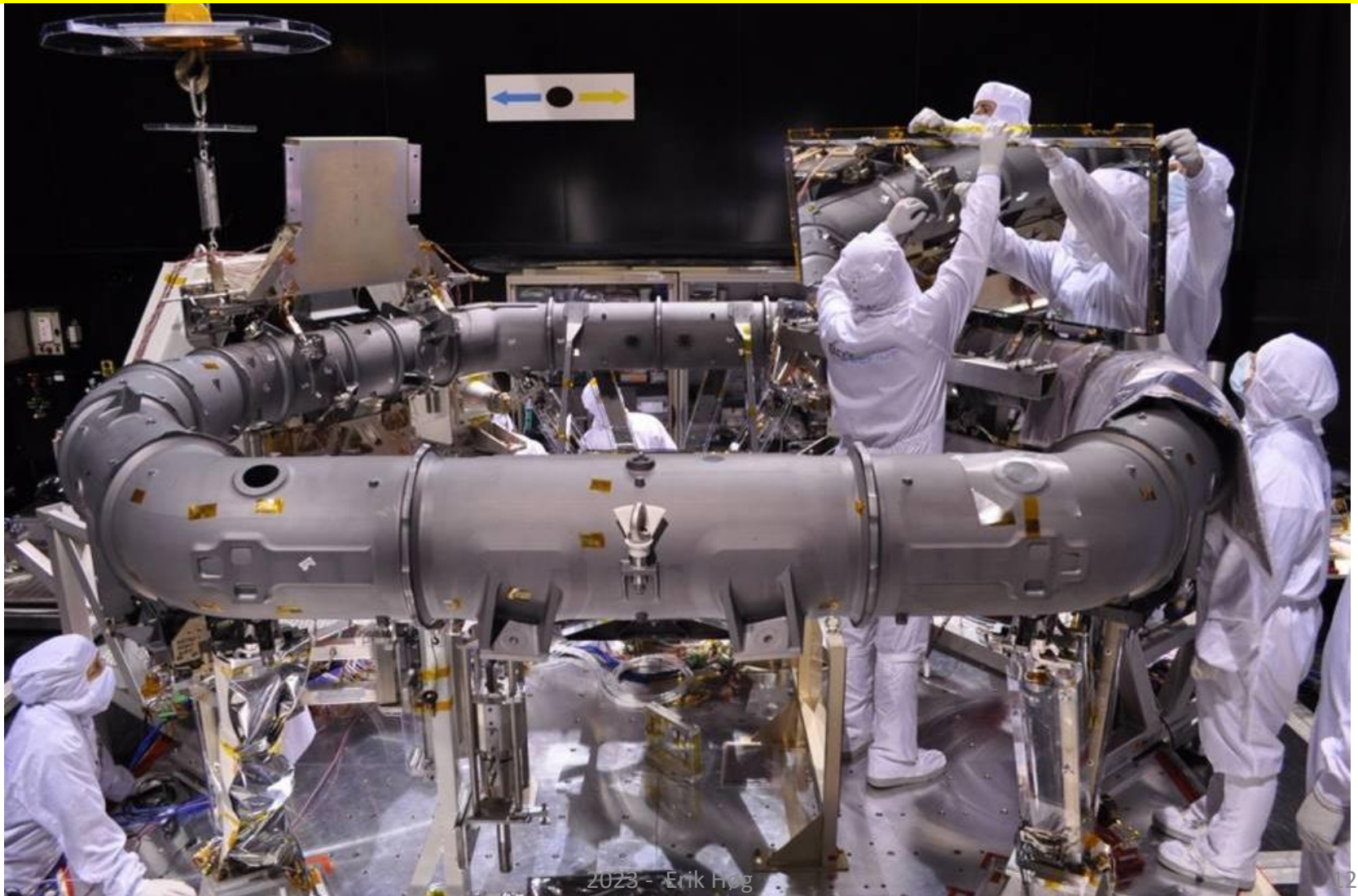
2 telescopes 26 cm \varnothing

5 years mission

Astrometry **+0.1 mas** at 14 mag

Photometry **+0.006 mag** in V ...

Gaia M1 and torus 2011



Astrometry satellites

1973 found Lennart

1975 my design of a scanning satellite

1989 Hipparcos launch

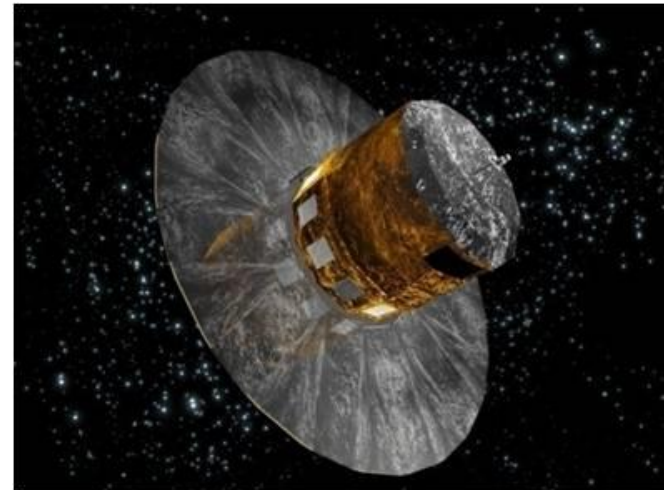
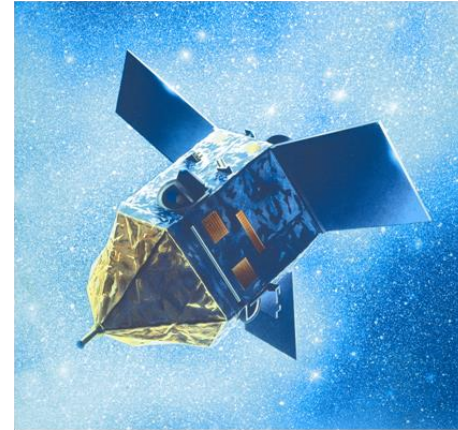
1992 my design of a satellite with CCD detectors

Launched in 2013 as **Gaia**

We now have 5000 times more accurate positions than we had 30 years ago

Also parallaxes, proper motions, photometry, and spectroscopy

A revolution in all branches of astronomy with almost 2 billion stars



My proposal to ESA in 2013: Gaia successor in 20 years

Similar astrometric performance as Gaia

Proper motions with 10 times smaller errors using
Gaia positions as 1st epoch

Parallaxes unaffected by motion in binaries

High-resolution photometry 140 mas FWHM

Altogether:

A new astrometric foundation of astrophysics

Gaia successor proposed in 2013

2015 David Hobbs joined

Observe obscured regions and very red stars with GaiaNIR

12 billion stars expected

Launch about 2045 probable

Gaia positions as first epoch + GaiaNIR -> 20 times more accurate proper motions

A new revolution for dynamics beyond Gaia



2013: Towards a Gaia successor

Much higher astrometric performance than Gaia

There were other considerations than mine around 2013 about a successor in which I was not involved at all

Anthony Brown led a proposal for (global) sub-microarcsec astrometry

No mission concept was presented, but the challenges on the road were analyzed

NIR sensitivity considered

Gaia successor proposed in 2013

2015 David Hobbs joined

Observe obscured regions and very red stars with GaiaNIR

12 billion stars expected

Launch about 2045 probable

**Gaia positions as first epoch
+ GaiaNIR -> 20 times more
accurate proper motions**

**A new revolution for
dynamics beyond Gaia**

