Jan Hendrik Oort (1900–1992)

Master of the Galactic System

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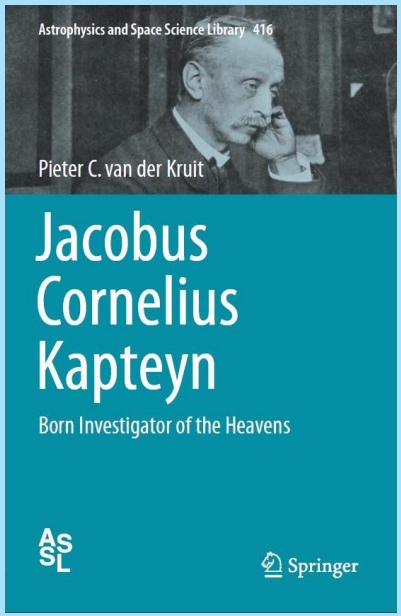
Colloquium Fall 2019

Background

- My biography of Oort appeared in July 2019.
- Astrophysics & Space Science Library of Springer.
- Website: www.astro.rug.nl/JHOort.



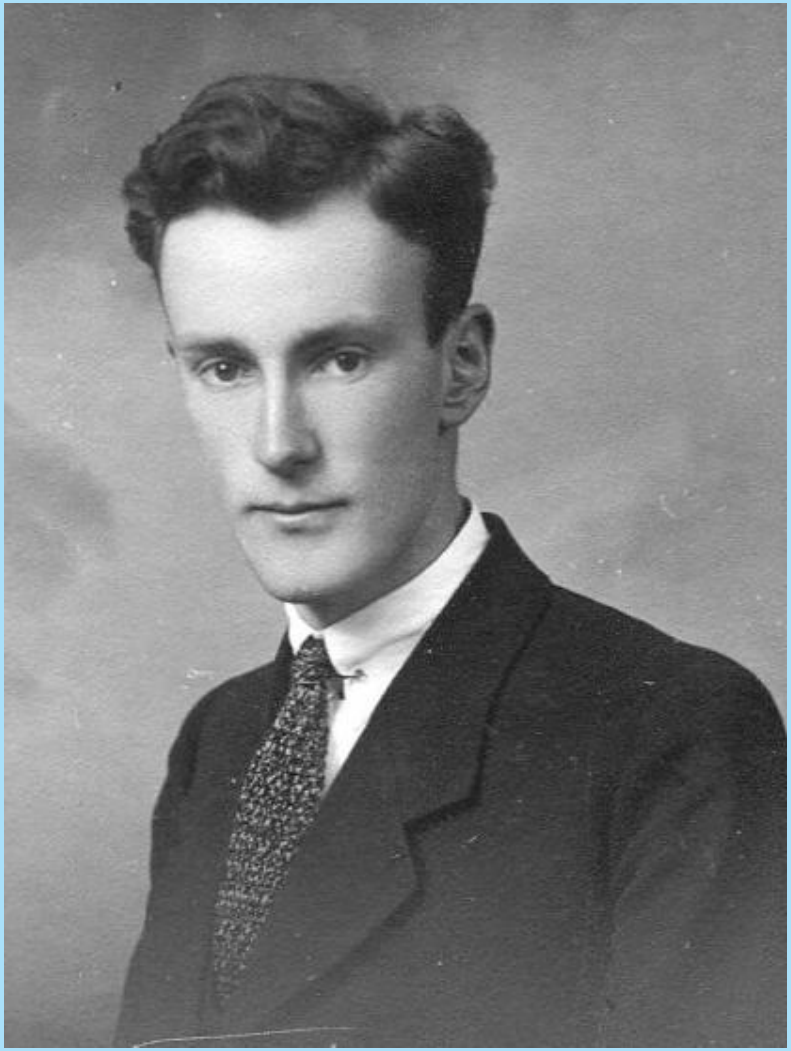
- 'Sequel' to Kapteyn biography; similar set-up, etc.
- Also over 700 pages.

- Abraham Hermanus Oort (1869–1942) was a psychiatrist, but his ancestors were all clergymen.
- Ruth Hannah Faber (1869–1957) also descended from clergymen.
- Oort Sr. worked for a few years at the asylum for lunatics in Franeker.
- There, on April 28, 1900, Jan Hendrik Oort was born.

- Abraham Oort became director of a sanatorium Rhijngeest for patients 'with neurotic disorders' in Oegstgeest.
- Oort grew up in Oegstgeest near Leiden.
- He was very good in mathematics and science, so he attended the HBS in Leiden.
- His older brother Hein also attended the HBS, but his younger brother John the Gymnasium. His sisters Jetskse and Emilie the HBS for girls.

Oort, Kapteyn and Kepler

- In 1917 Oort went to study physics or astronomy in Groningen mainly because of the fame of Jacobus Kapteyn.
- Through Kapteyn's lectures he quickly decided to become an astronomer.

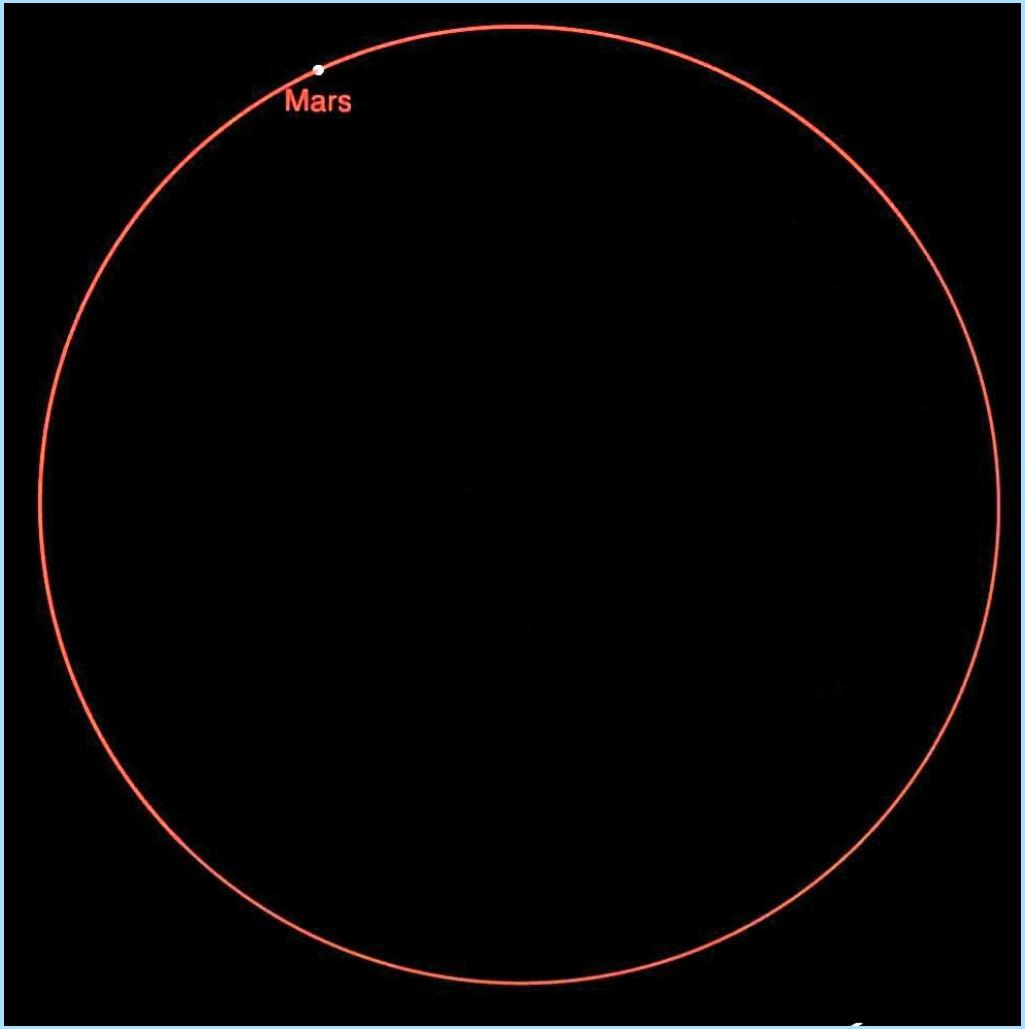


- Oort about Kapteyn:
  'Perhaps the most significant thing I learned – mainly, I believe, from Kapteyn's discussion of Kepler's method of studying nature – was to tie interpretations directly to observations, and be extremely wary of hypotheses and speculations.'

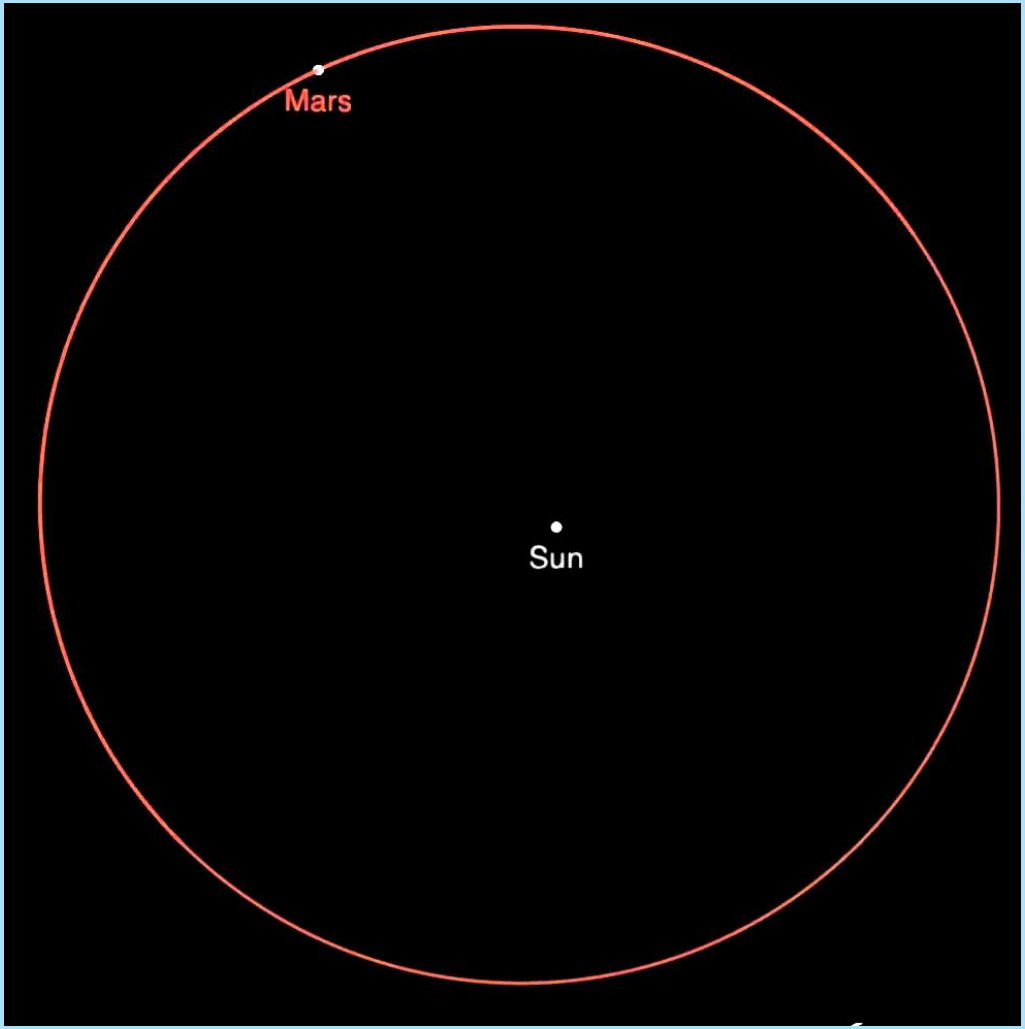
  'Two things were always prominent: first the direct and continuous relation to observations, and secondly to always aspire to, as he said, 'look through things' and not be distracted from this clear starting point by vague considerations.'

- What was Kepler's method of studying nature?
- What did Kapteyn cover in his lectures?
- The Oort Archives have Oorts notes from Kapteyn's lectures and for his own lectures.
- We have to go to the development of our understanding of the nature of the planetary orbits.

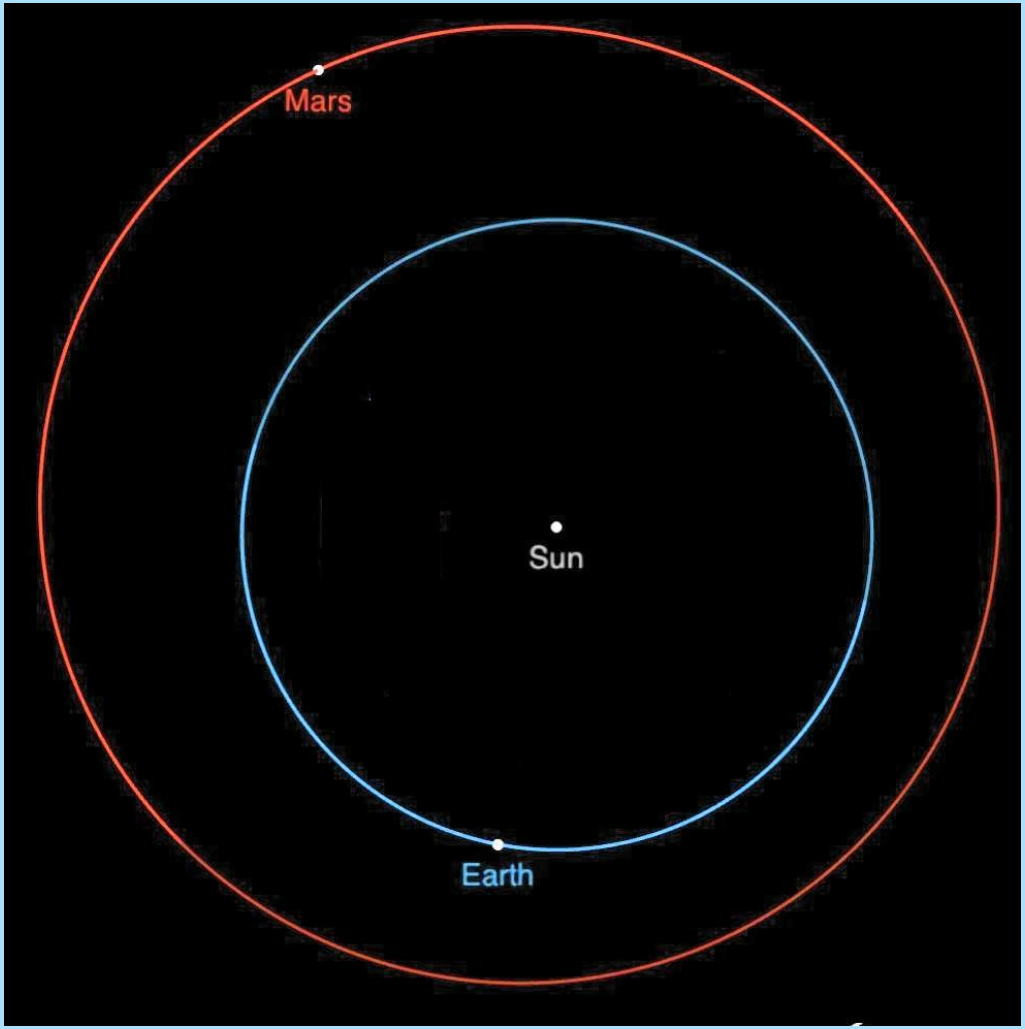
Johannes Kepler (1571–1630)



- Since Kepler we know that planets move in elliptical orbits with the Sun in one of the foci.
- This is Kepler's first law.
- Here is the elliptical orbit of Mars.

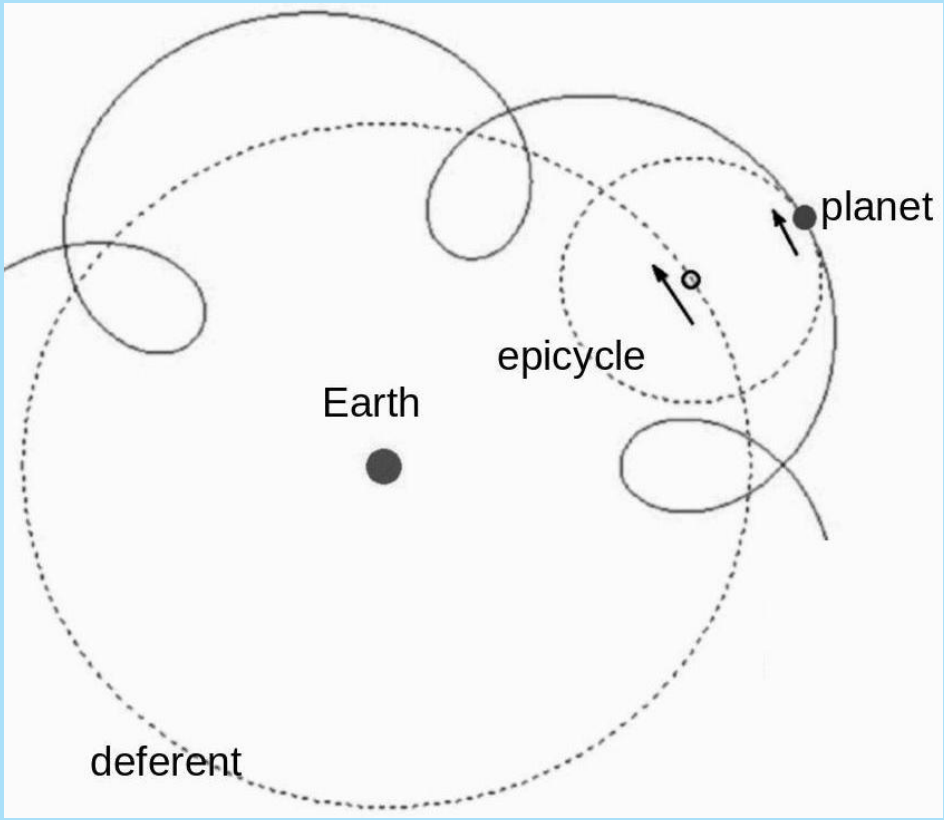


- Showing the position of the Sun shows the elliptical nature somewhat better.
- The planet moves faster when in perihelion (closest to the Sun) and slower in aphelion (farthest from it).
- This is Kepler's second law, or really conservation of angular momentum.

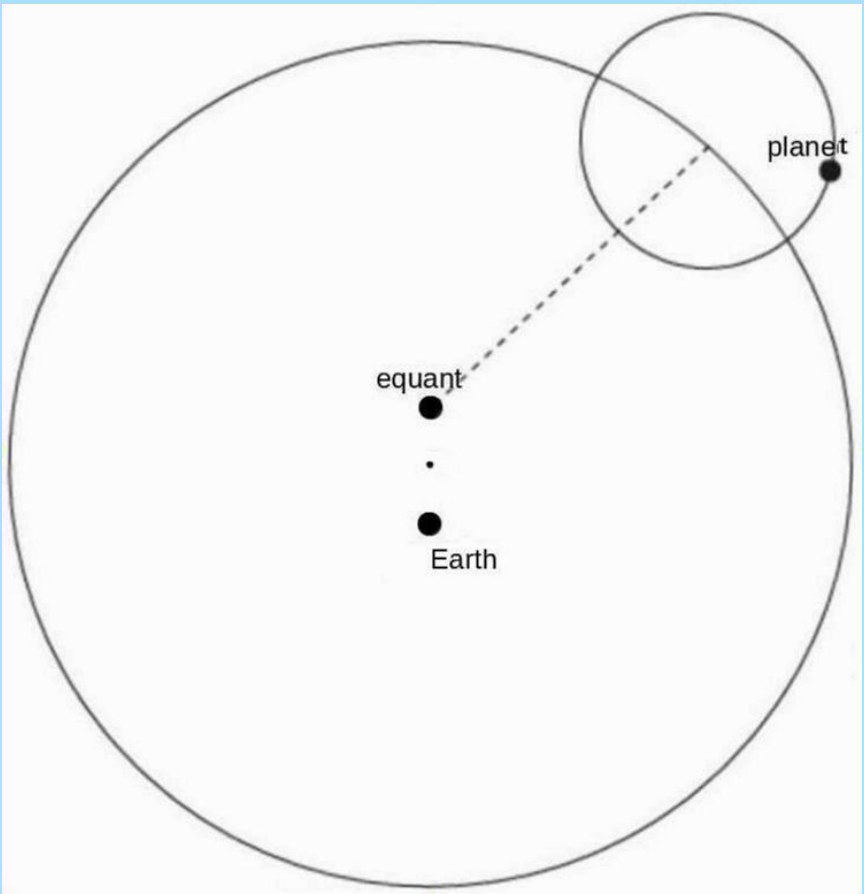


- Here the less elliptical orbit of the Earth has been added.
- How did Kepler arrive at his laws?
- This is the subject of Kapteyn's lectures (and Oort's and mine).
- We have to back to the geocentric model of Antiquity.

- The planets move in complicated orbits on the sky, because they are seen from a moving Earth.
- This maybe a loop or a Z-shape, due to slightly different planes of the orbits.
- This occurs around opposition.
- The problem was how to explain that.

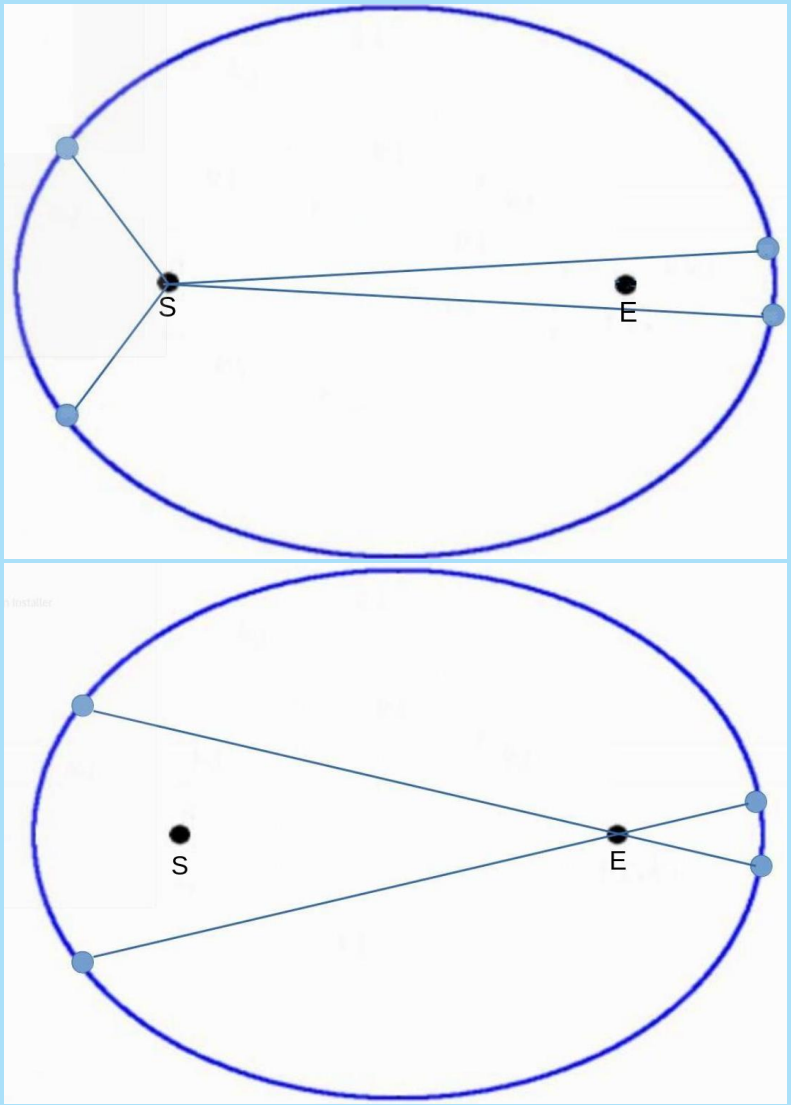


- The paths of the planets were described by an epicycle with its center moving on a deferent centered on the Earth.
- For outer planets the deferent really is the orbit of the planet around the Sun and the epicycle that of the Earth.
- The problem was that following Plato and Aristotle the motions were required to be on pure circles with uniform velocity.
- This is bound to give problems because these are really ellipses with varying speeds.



- Ptolemy ($\pm$100–$\pm$170) corrected for the differences by putting the Earth off-center and letting the angular velocity be constant from the equant.
- This may have been acceptable practice at the time, but would in modern times it will be seen as fudging or cheating.
- Why did this work so well?

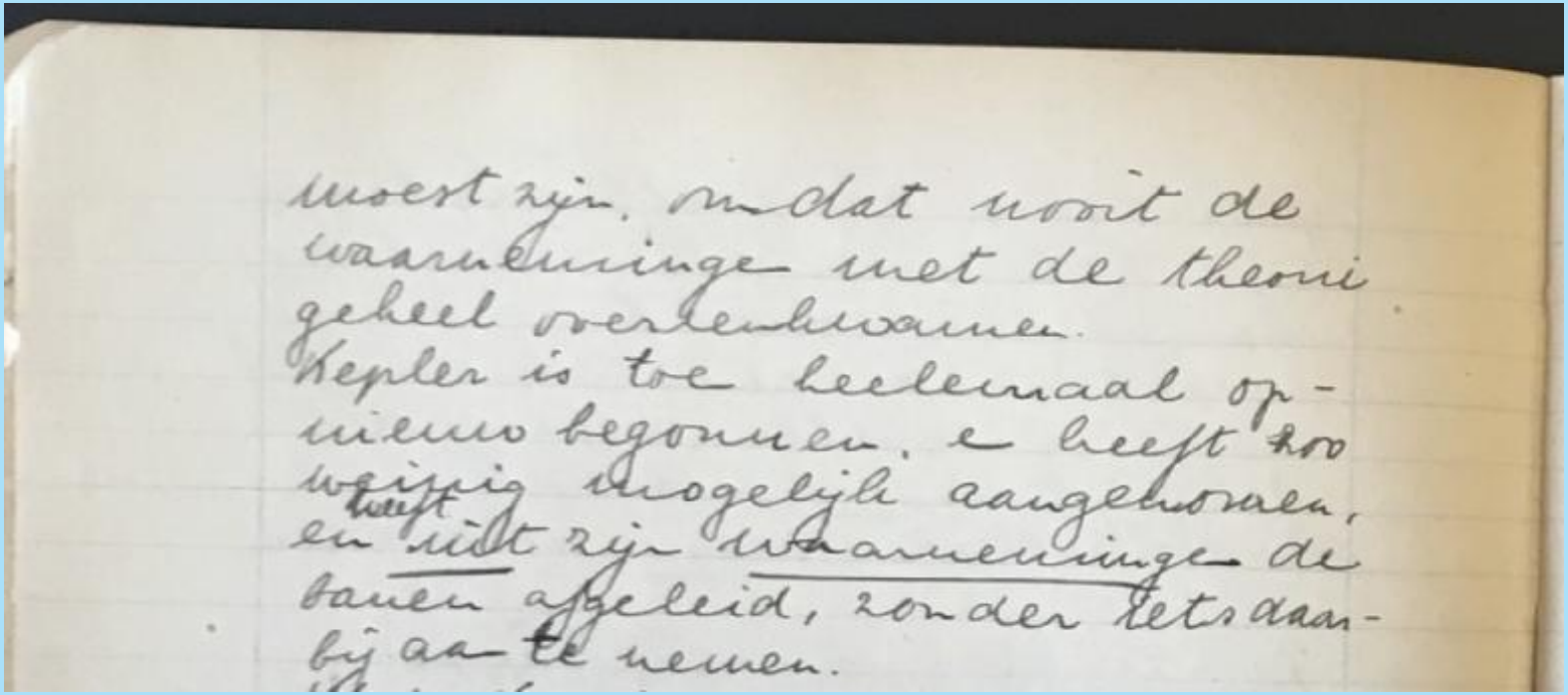
- The time interval between the two points left and the two points right is equal.
- (Top) From the Sun the areas of the two triangles are equal.
- (Bottom) From the empty focus angles are equal.
- So the angular velocity from the Sun varies.
- So the angular velocity from the empty focus is (almost) constant, just as Ptolemy's equant requires!



For astronomers:

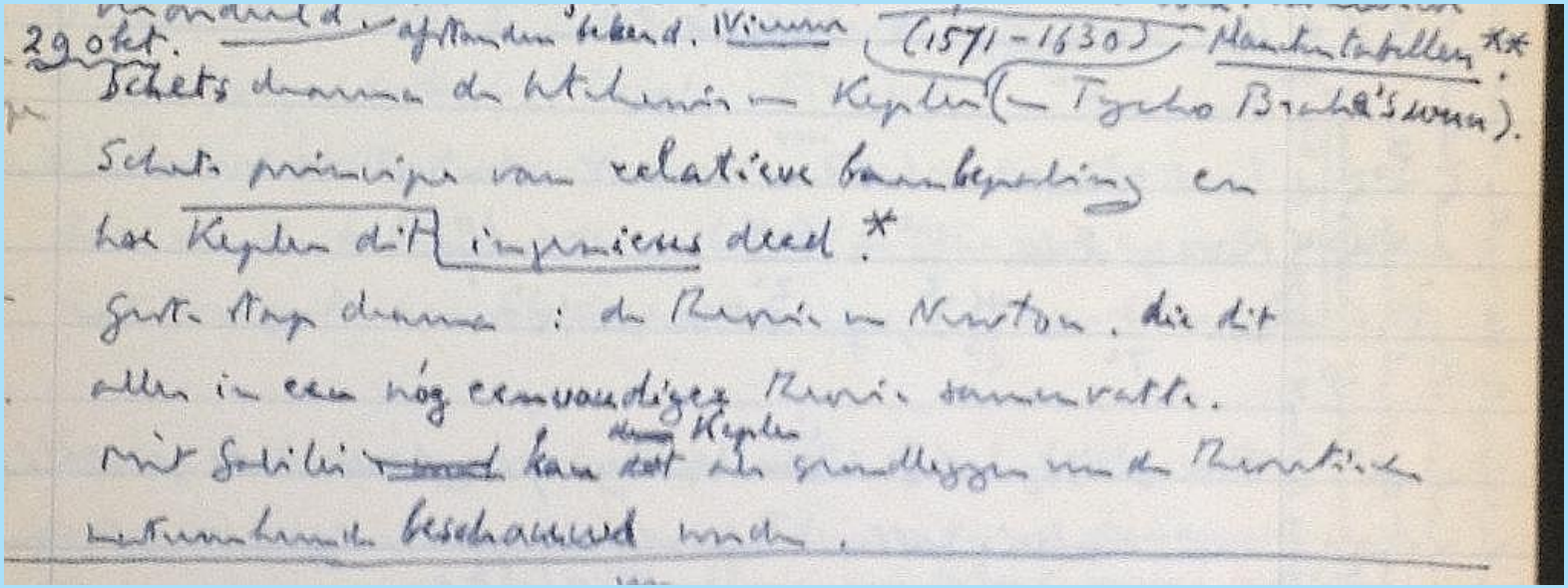
	Solar focus $\frac{d\nu}{dt} \propto \frac{\sqrt{1-e^2}}{(1-e\cos E)^2}$	empty focus $\frac{d\nu'}{dt} \propto \frac{\sqrt{1-e^2}}{1-e^2\cos^2 E}$
Earth (e=0.0167)	$\pm 3.4\%$	$\pm 0.014\%$
Mars (e=0.0934)	$^{+21.5}_{-16.3}\%$, $\pm 18.9\%$	$\pm 0.4\%$

- Tycho Brahe (1546–1601) measured the most accurate positions.
- Kepler had worked with him in Prague and used his data.
- He accepted the heliocentric model and thus variable orbital speeds.
- He tried various fits, including free equant positions.
- There remained an 8 arcmin discrepancy (1€ @ 10m).
- Too small for Ptolemy, but measurable for Brahe.



Oort's notes (1917) from Kapteyn's lectures.

'Kepler then started completely from scratch and made as few assumptions as possible, and deduced the orbits from his observations, without any hypotheses.'



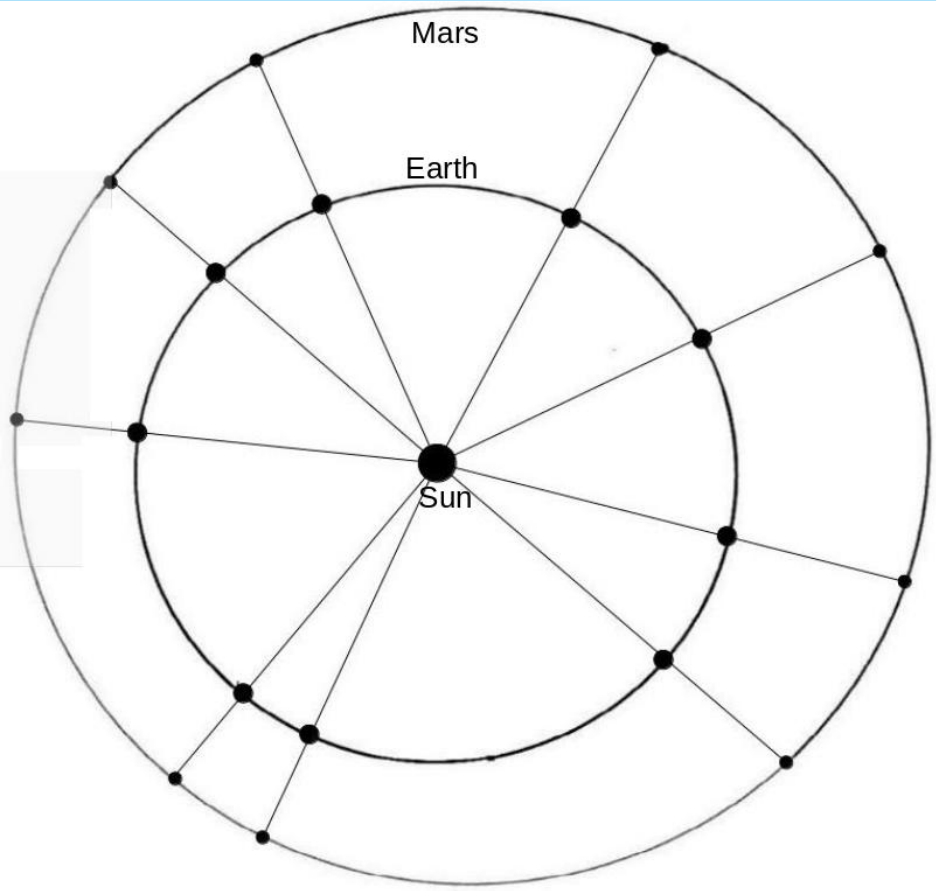
Oort's notes for his lectures on the planetary system (1964/5):
'Sketch the principles of determination of relative orbits and the ingenious manner in which Kepler did this.

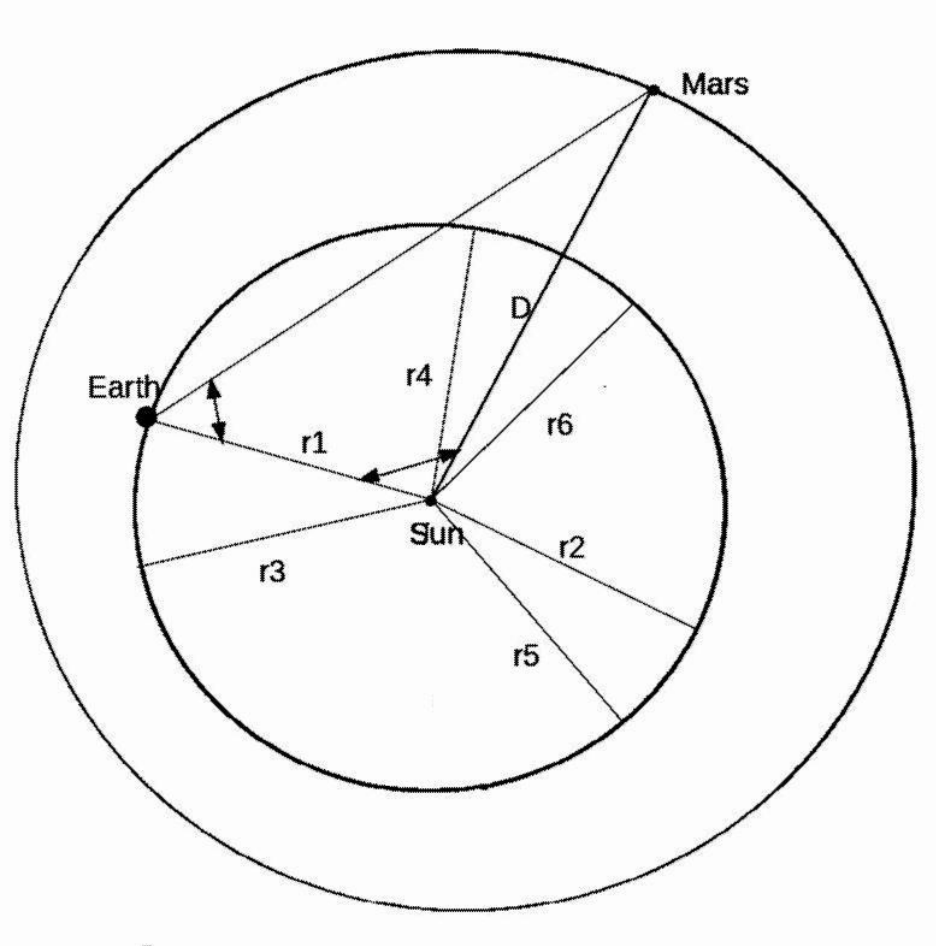
...

With Galileo, Kepler can be regarded as the founder of theoretical physics.'

- So what was this ingenious manner in which Kepler did this?

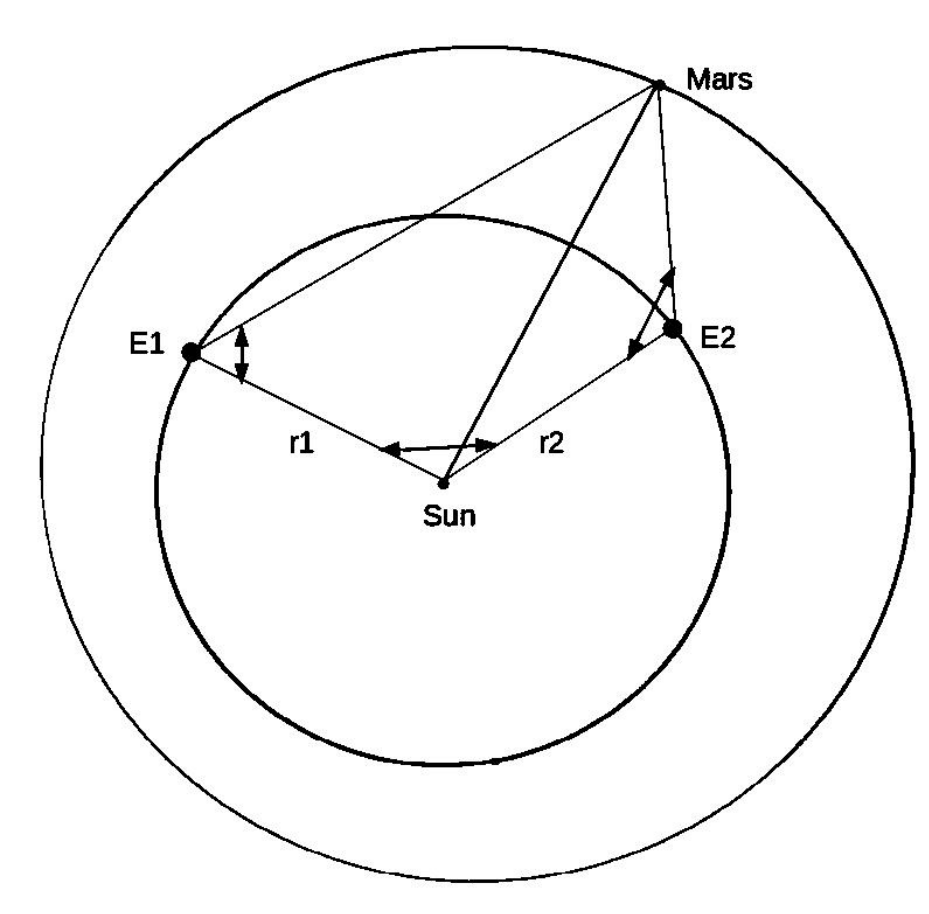
- Kepler started by collecting oppositions of Mars.
- The direction of the Sun w.r.t. stars gave the direction of the Earth from the Sun.
- So he knew many directions and times of Mars' orbit,
- This gave him the period of Mars (686.95 days).

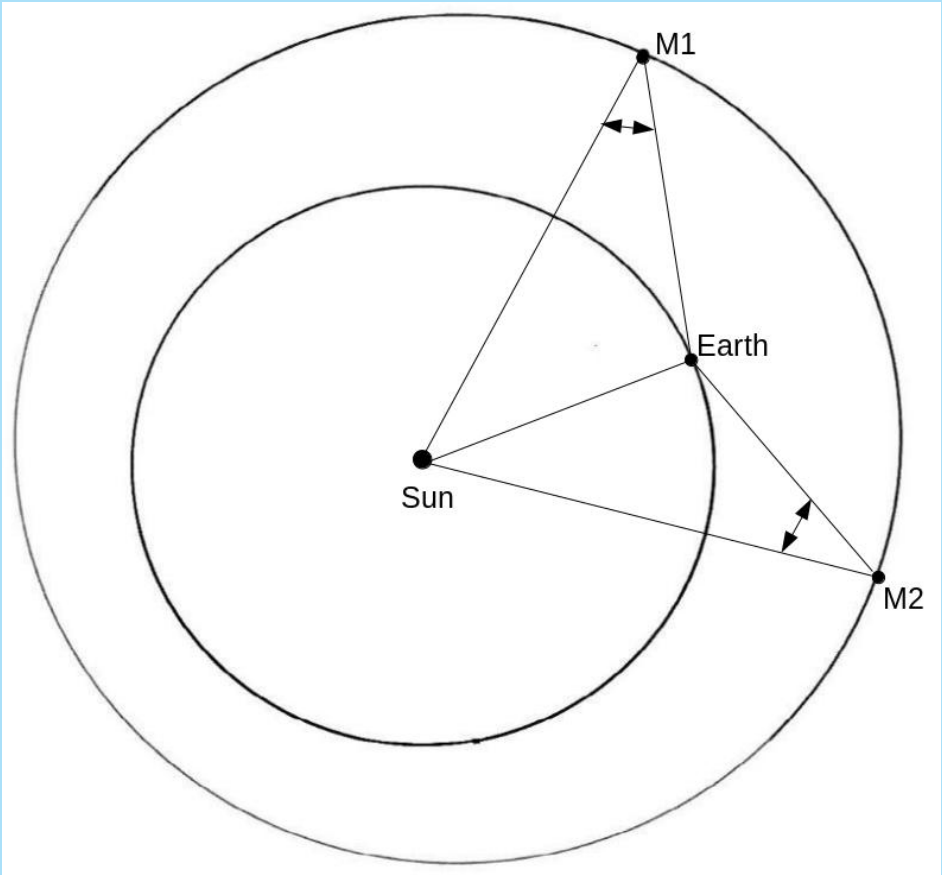




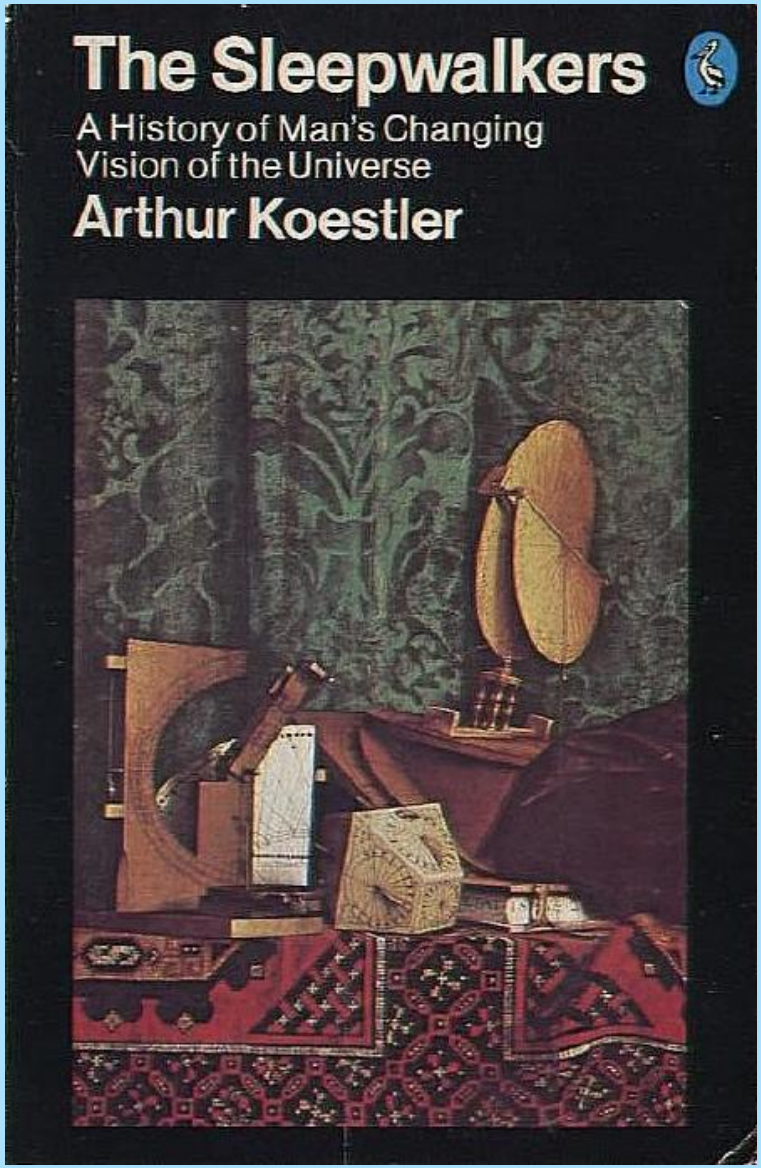
- He then selected dates at which Mars was in the same place in its orbit.
- Of the triangle Earth-Sun-Mars he knew now all angles.
- So he calculated $r1$ in terms of D ($r1/D$).
- He repeated that for $r2$, $r3$, etc., and determined the shape of the orbit of the Earth.

- He then took two observations during which Mars was at the same place in its orbit and the Earth at E1 and E2.
- Since he now knew the Earth's orbit, he knew $r1$ and $r2$, and the angle between these two.
- And for both observations of Mars he knew the angles between the Sun to Mars.
- So he could draw the two lines from E1 and E2 to Mars and where they crossed was the position of Mars.



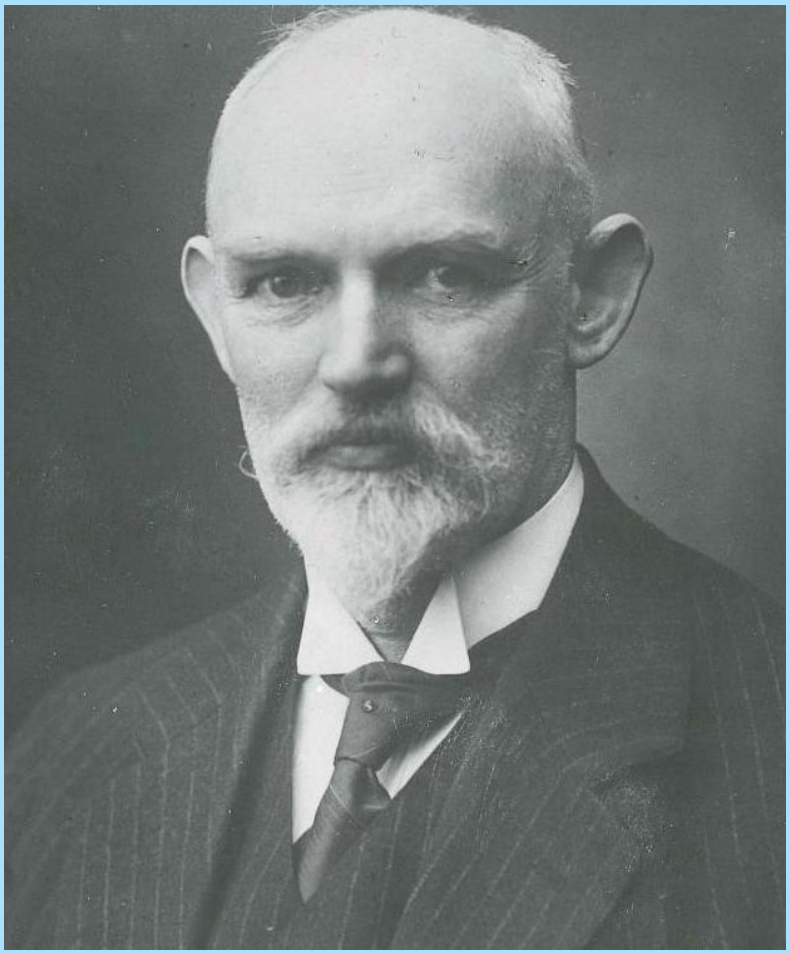


- Kepler then repeated this for many more such pairs and determined the orbit of Mars with respect to the orbit of the Earth.
- He then turned it around as if he were on Mars and selected instances where the Earth was at the same place in its orbit.
- In that way he found an improved orbit of the Earth and its linear velocity.



- Kepler dismissed all preconcieved conceptions and asked for the first time in almost two thousand years what the observations actually said about the planetary orbits.
- Arthur Koestler's (1905–1983) fascinating book describes all of this (and more).
- Apparently started as a biography of Kepler.
- I have given it as a present to all my students after defensing their thesis and obtaining their PhD degree.

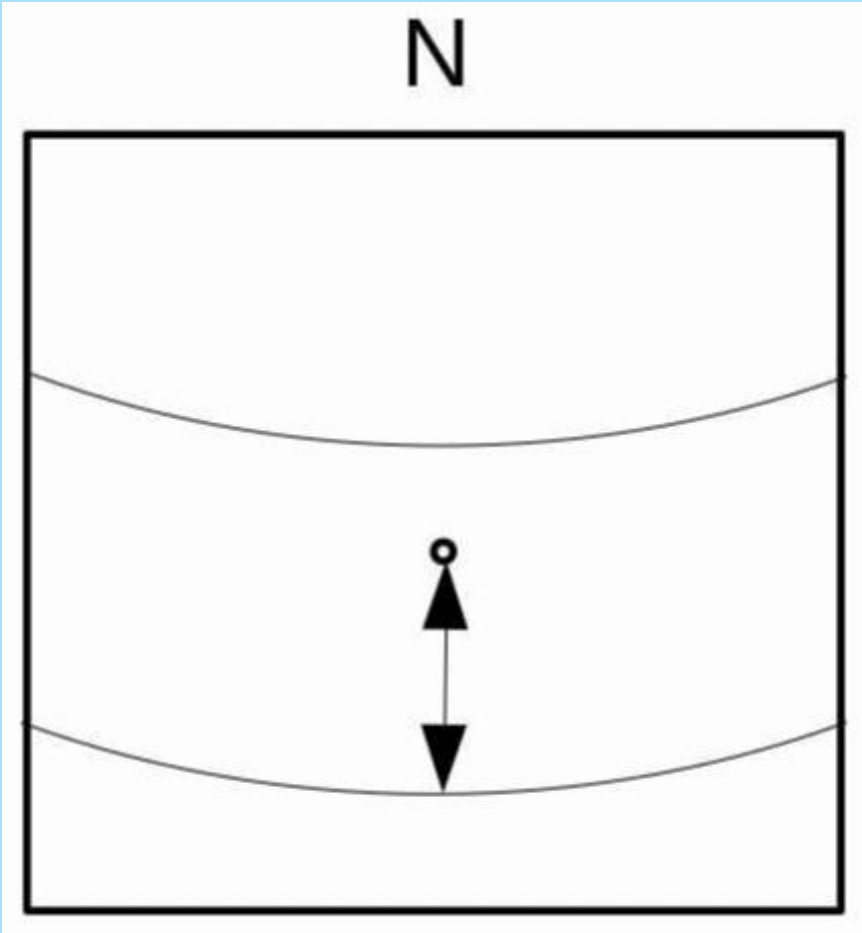
Oort as an observer



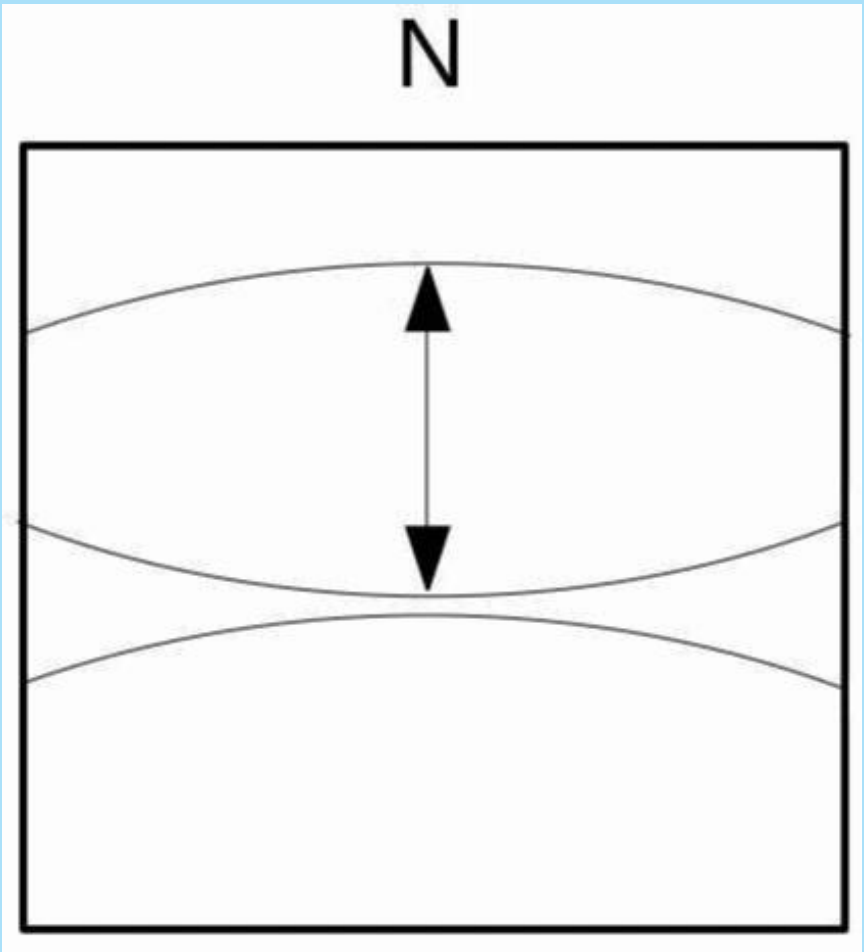
- Willem de Sitter had become professor of astronomy in Leiden in 1908.
- In 1918 became director and with Kapteyn's help had reorganized the Observatory.
- He himself led the Theoretical Department and Ejnar Hertzsprung Astrophysics Department.
- But could not get Anton Pannekoek hired to lead the Fundamental (astrometric) Department.
- So he offered the job to Oort (on Kapteyn's recommendation), but felt he needed astrometric experience first.

Yale Observatory

- De Sitter got Frank Schlesinger to offer Oort a fellowship at Yale Observatory.
- Oort worked at Yale from 1922-1924.
- The research was on latitude variations with a zenith telescope.
- Pole position important for star positions.
- The position of the pole on Earth changes semi-irregularly with amplitude about 10-15 m (corresponds to 0.3-0.5 arcsec or 1€ @ 10km).

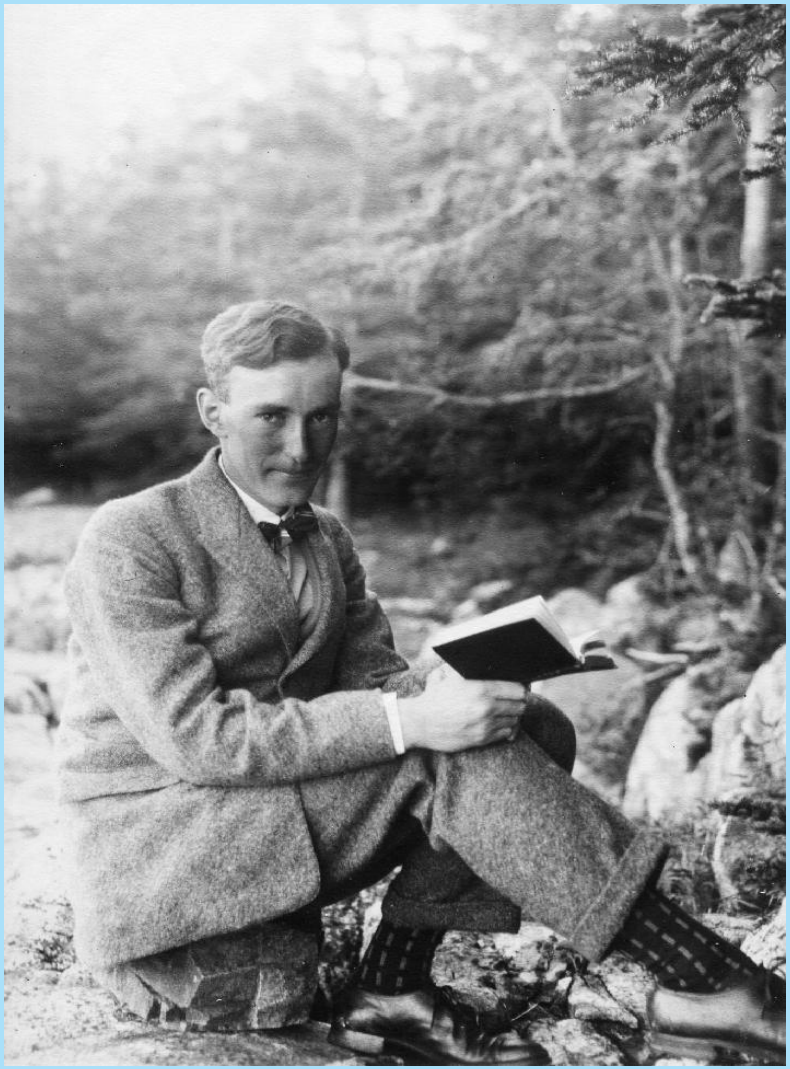


- Use of a zenith telescope.
- Photograph star trails near zenith of stars of known declination.
- Requires accurate knowledge of position of the zenith.
- Geodesist Friedrich Helmert (Berlin) wrote in 1890 (Astron. Nachr.) that measurements were inconsistent.

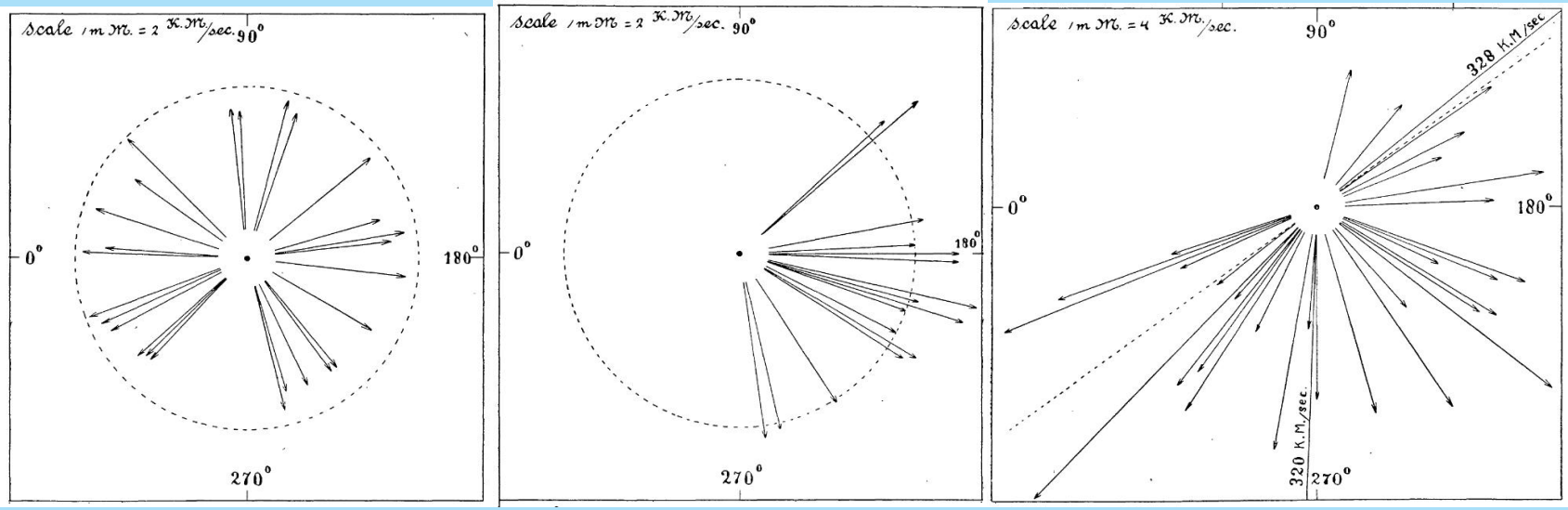


- Kapteyn read this and suggested to turn plateholder around halfway through the night.
- Kapteyn's letter published by Helmert in Aston. Nachr.
- Oort made such observations at Yale for two years with new zenith telescope.
- Lost time due to problems with objective lens.

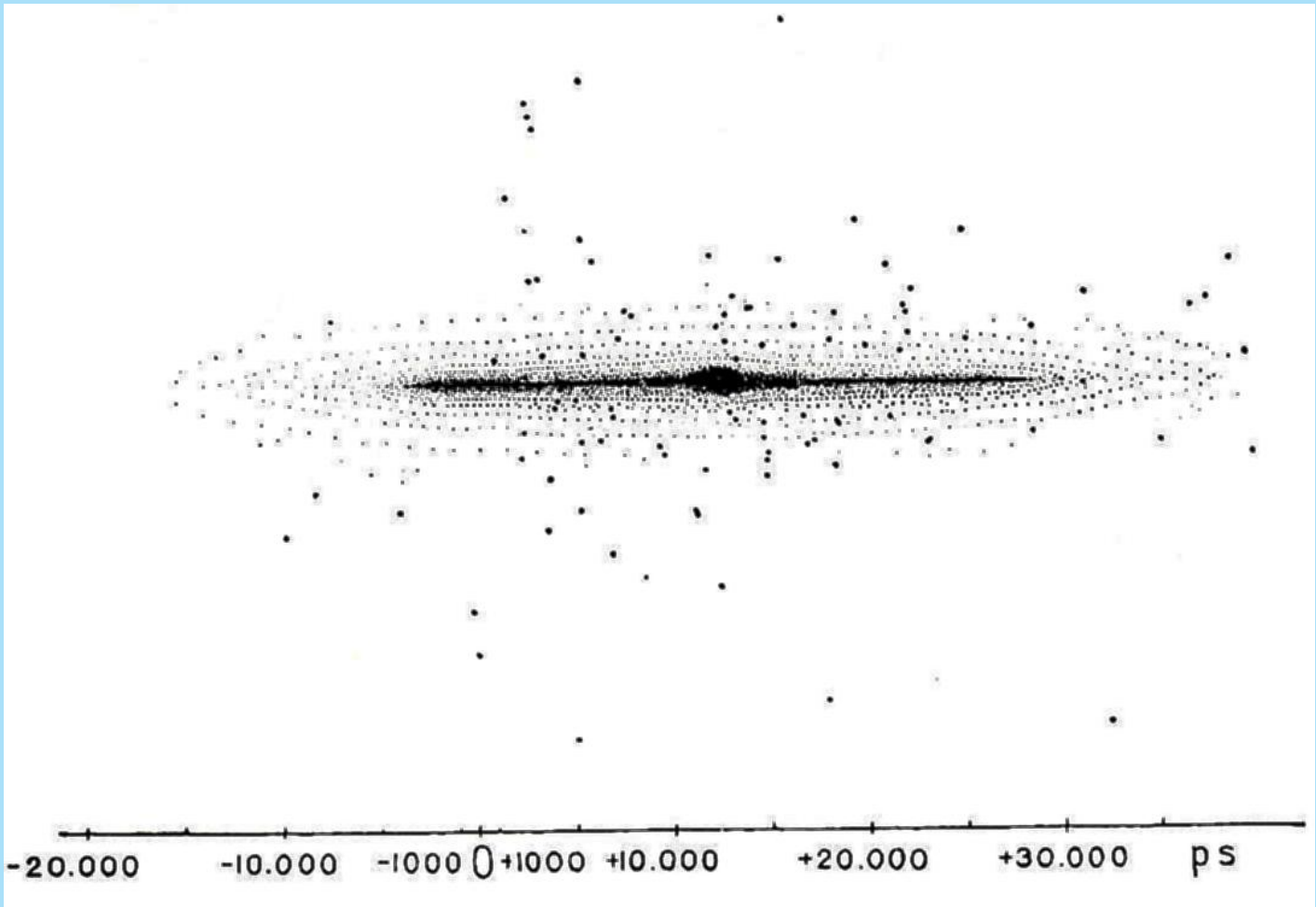
Leiden Observatory



- Schlesinger wanted Oort to help with Yale southern telescope.
- Arranged Oort's military service in summer of 1923.
- But de Sitter could not wait and Oort moved to Leiden Observatory in 1924.
- Here he worked on astrometric problems and on his thesis work concerning stars of high velocity.
- Yale data eventually proved useless, because of plate movements in plate holder.



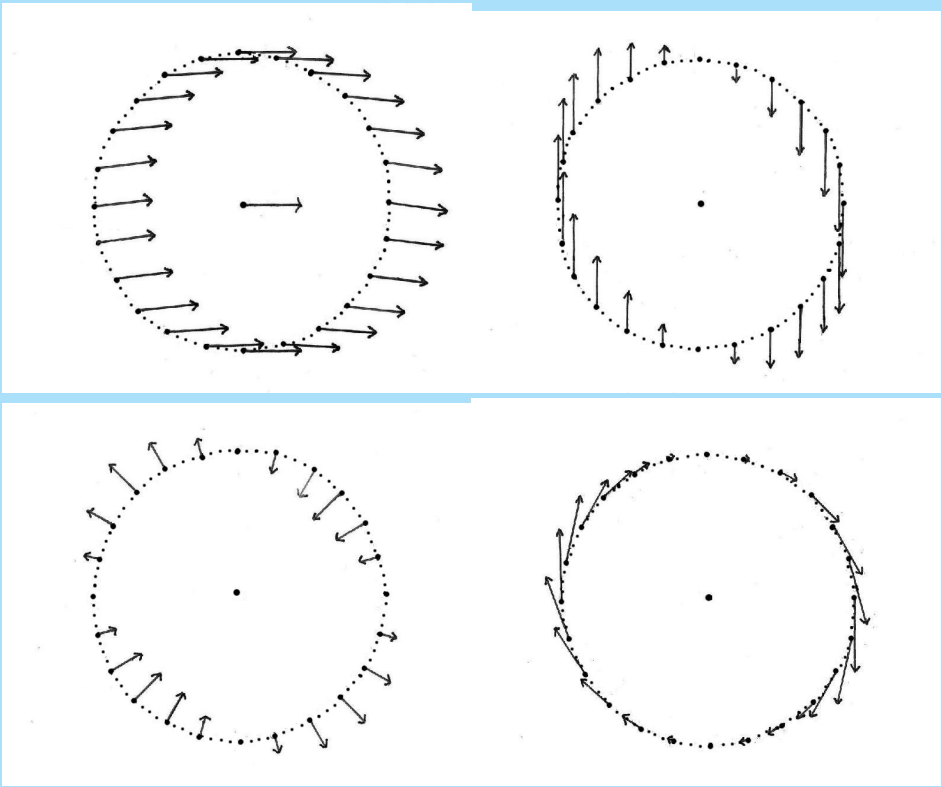
- Already as a student the high-velocity stars intrigued him.
- They seemed to come from only one hemisphere of the celestial globe.
- There was a sharp dividing line at ± 63 km/s.



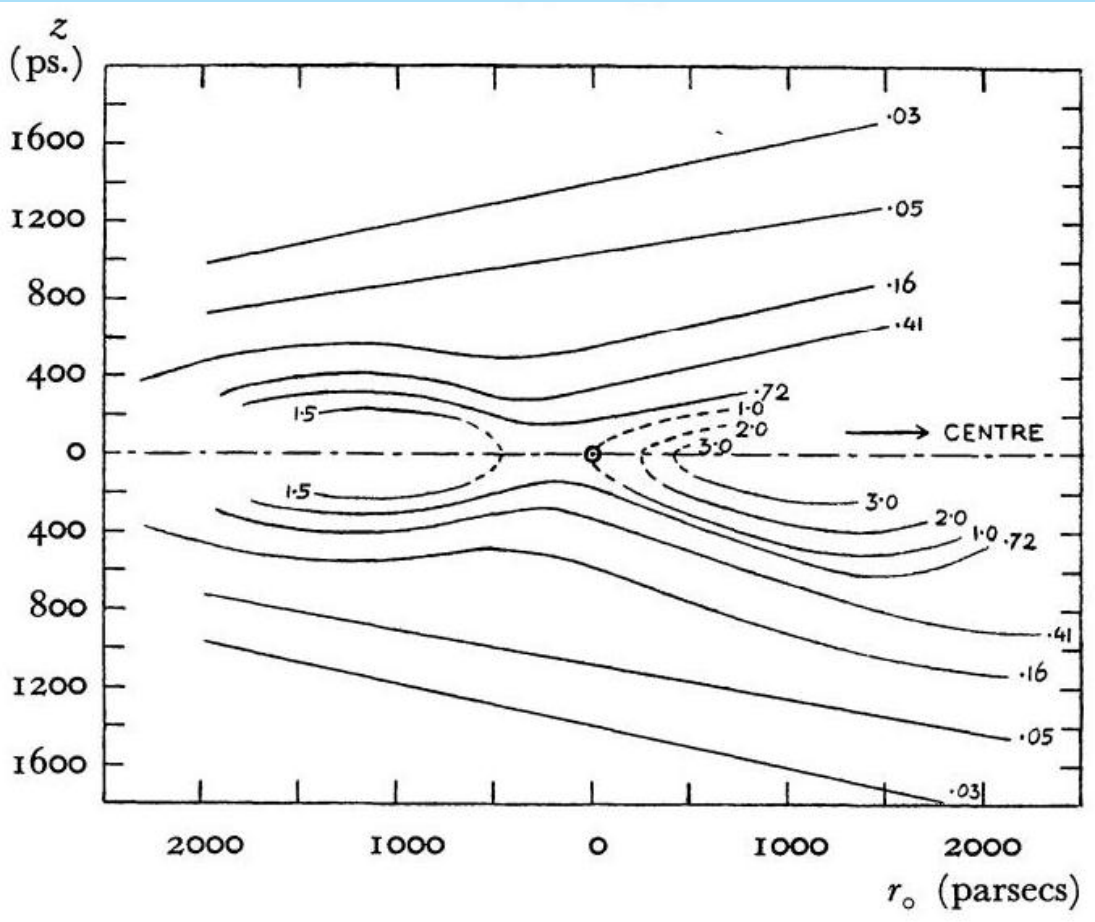
- High-velocity stars are part of the halo population.

- In 1926 Oort obtained his PhD in Groningen with Pieter van Rhijn as supervisor.

- Oort was already engaged to Johanna Maria (Mieke) Graadt van Roggen (b. January 7, 1906).
- They married in 1927.



- Throughoput twenties and thirties Oort worked on Galactic Structure:
  - Differential rotation.
  - Vertical force K_z.
  - Galactic structure including absorption.
- Used stellar dynamics, founded by Arthur Eddington and James Jeams.



- Oort used all information on Plan of Selected Areas.
- This is star counts, spectral type catalogues, proper motion surveys.
- Extinction corrections from galaxy counts by Hubble.
- He then did the analysis Kapteyn had designed the Plan for and produced a crosscut through the Galaxy in 1938.

- Oort had two important job offers:
- Harvard 1928.
  Too much teaching, no formal relation with the Observatory and observing facilities.
- Columbia 1930.
  No commitment for a telescope (60-70 inch reflector in the south).

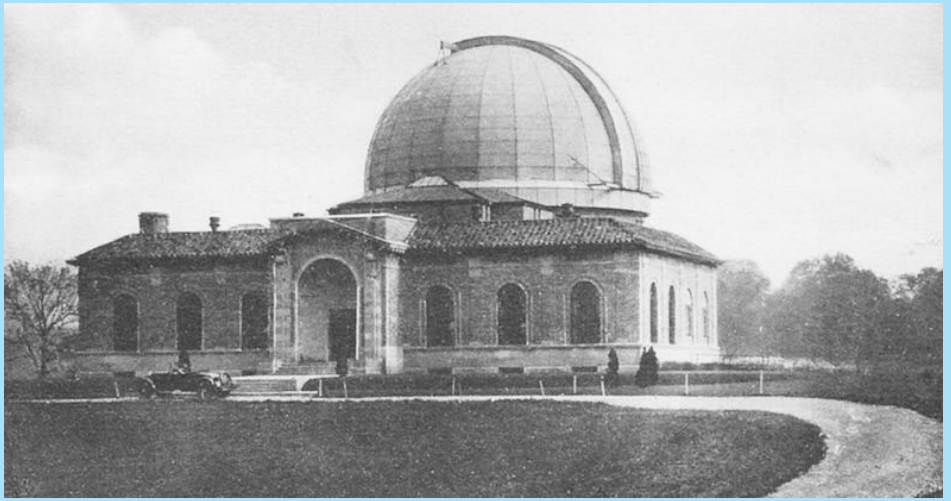
Perkins Observatory

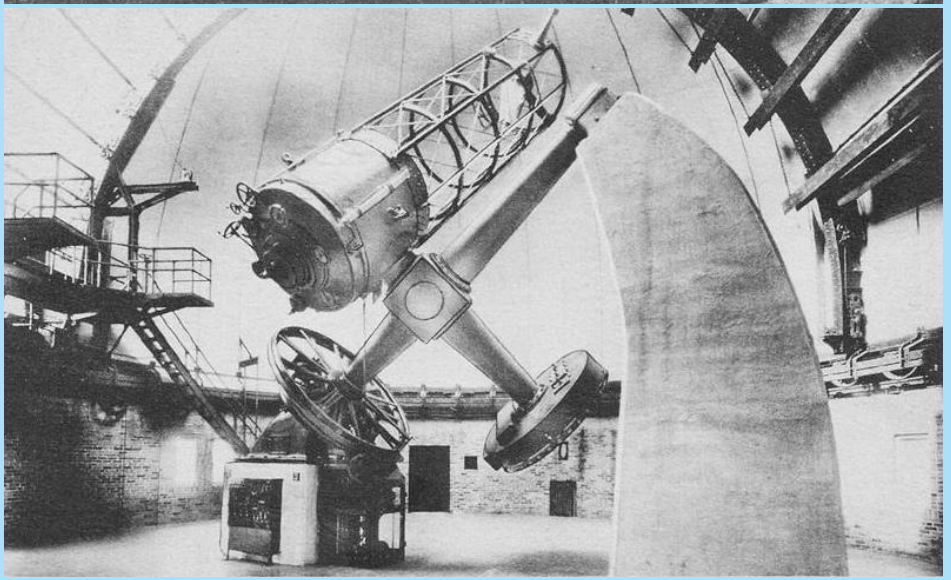
- Oort became interested in photometry of extragalactic nebulae.

Harlan Stetson, director of Perkins.

- IAU General Assembly in Cambridge, Mass. (1932).
- Oort and Mrs. Oort went to Perkins Observatory afterwards for a few months.
- New 69-inch telescope in Delaware, Ohio.

- Largest telescope in USA, except for Mount Wilson 100-inch.
- Aim was to obtain photographic plates of galaxies for surface photometry.
- First step towards dynamics of external galaxies.
- Poor weather (no surprise in Ohio).
- Did get some material though.





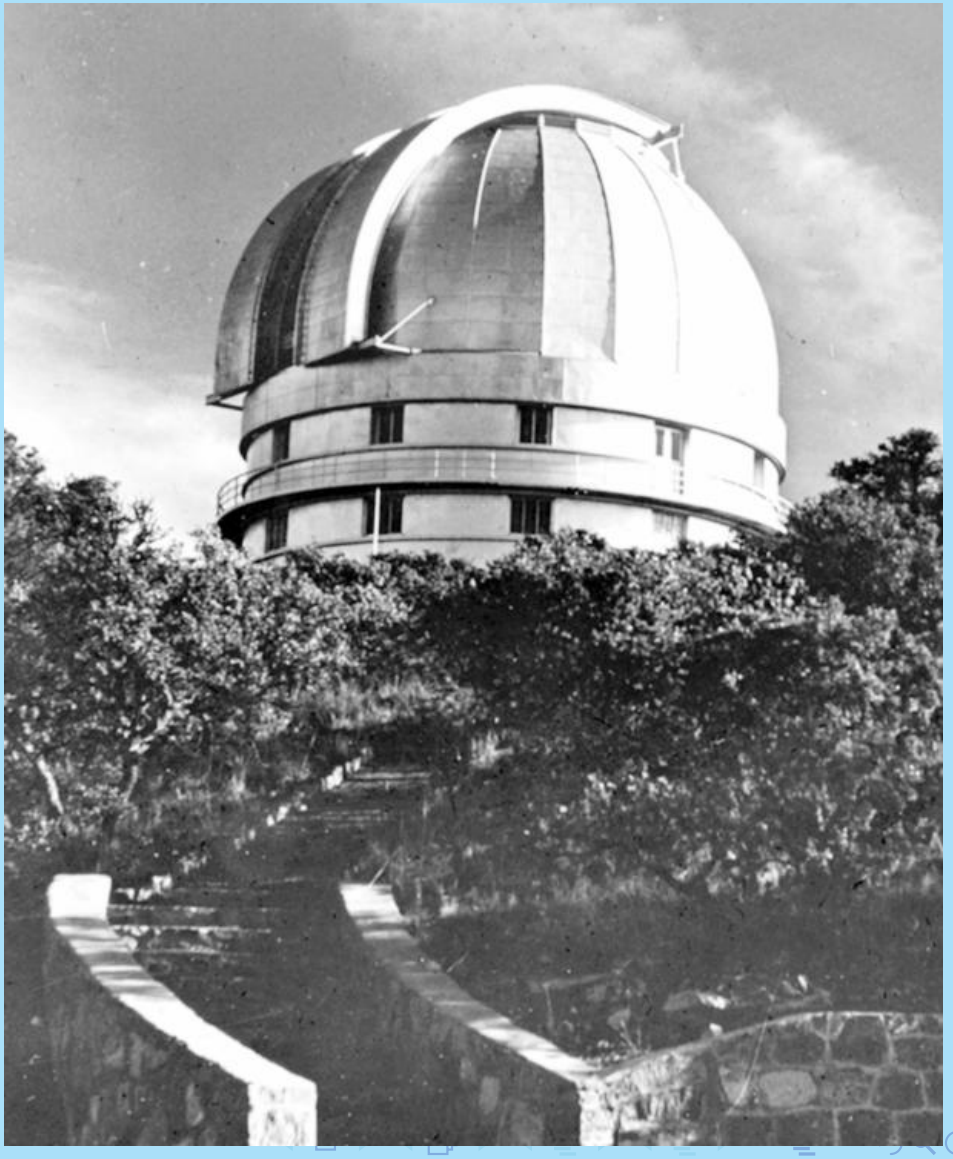

Wife of Noted Dutch Astronomer to Aid In Handling Huge Telescope at Wesleyan

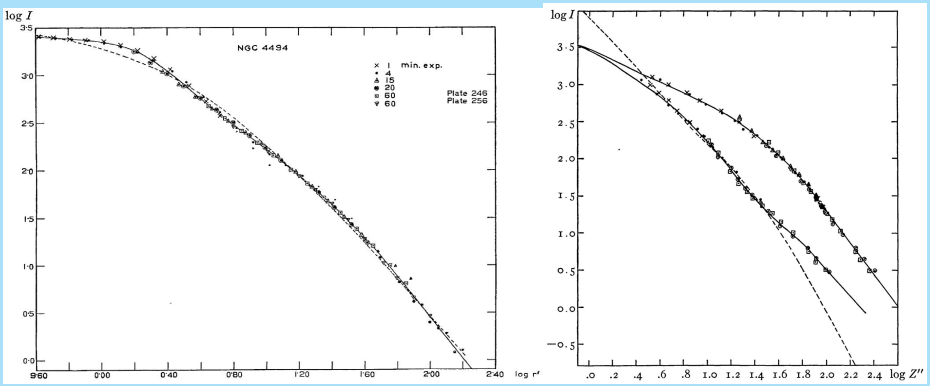
Dr. and Mrs. Jan H. Oort

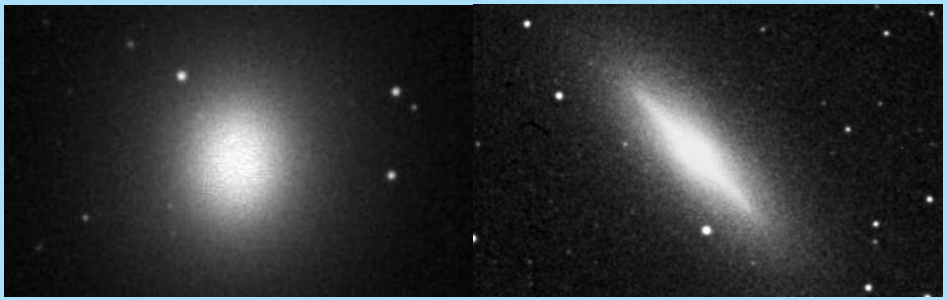
- Mieke Oort 'assisted' him.
- In the end plates proved unsuitable.
- Reason shift of mirror with hour angle.
- Pieter Oosterhoff, fellow at Mount Wilson, took some plates on 60-inch Telescope.

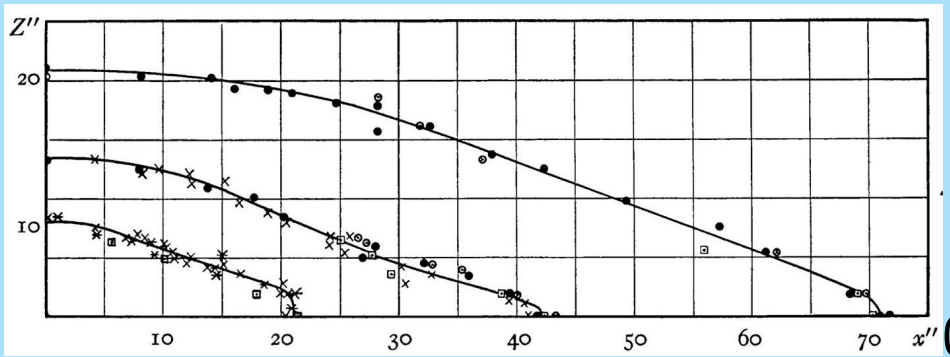
Mount Wilson Observatory

- In 1939 Oort tried again.
- Occasion was inauguration McDonald Observatory in Texas and its 82-inch telescope.
- Oort was a prominent speaker at the symposium.
- Here Oort presented his famous 1940-paper on vertex deviation and galaxy dynamics.



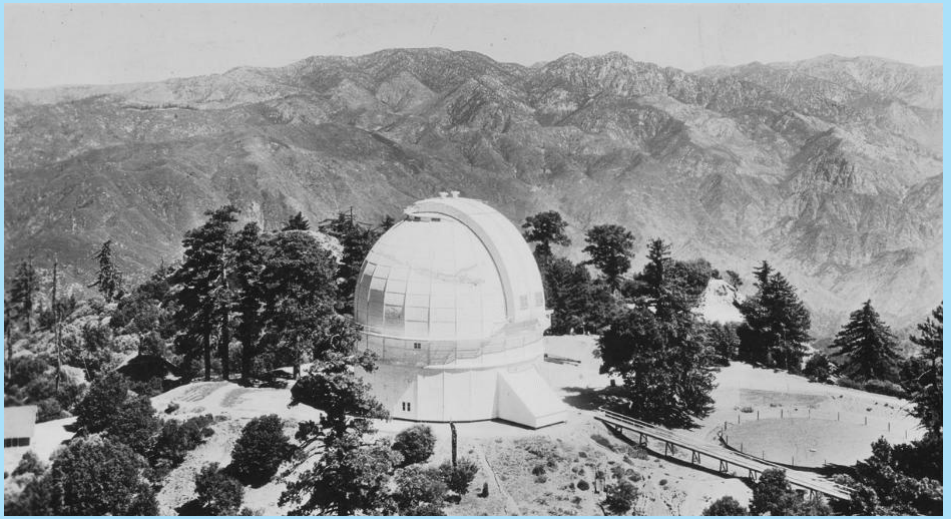


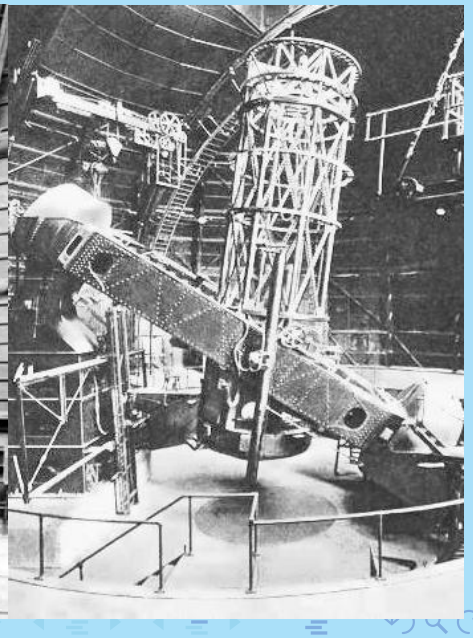




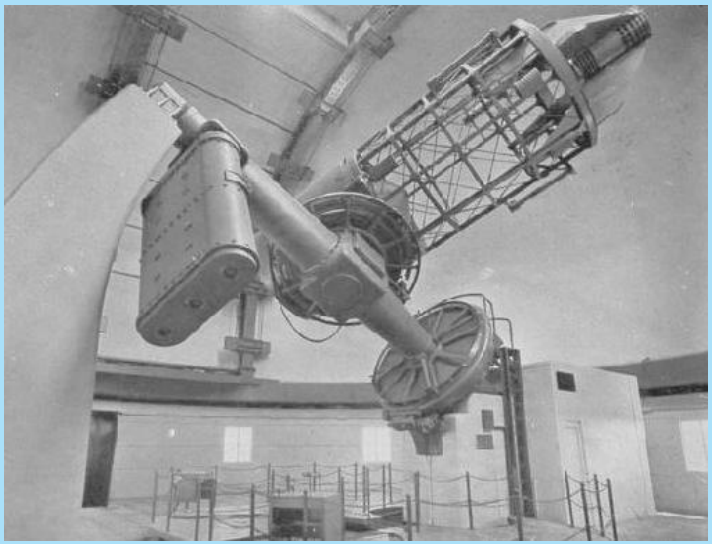
- Presented photometry of two systems from Oosterhoff's plates.
- Outlined deprojection analysis and dynamical studies of external galaxies.
- Applied to NGC 3115 with spectral data by Milton Humason.
- Inconsistent due to incorrect velocities.

- Afterwards Oort went to Mount Wilson, where he observed with the 60-inch and 100-inch telescopes.
- He took 60 plates of 17 galaxies (with Oosterhoff's plates this gave a sample of 20).
- Calibration was through sensitometer spots and out-of-focus exposures in Kapteyn Selected Areas.



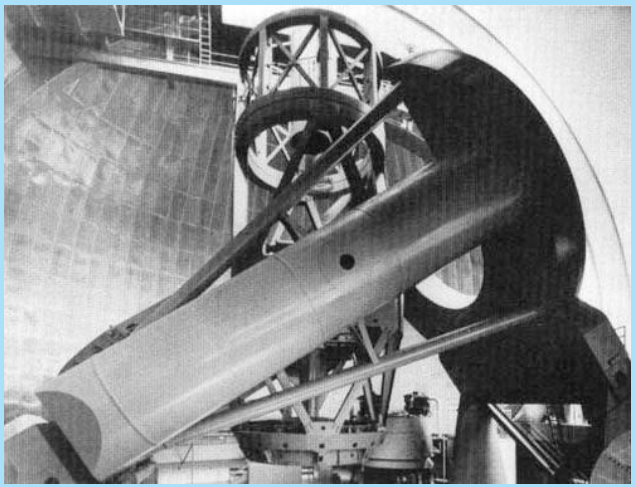


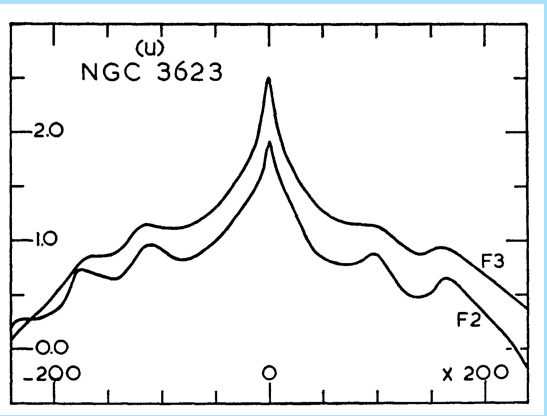
McDonald Observatory

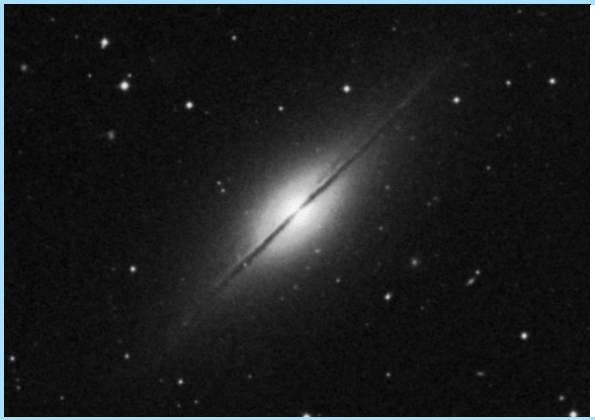


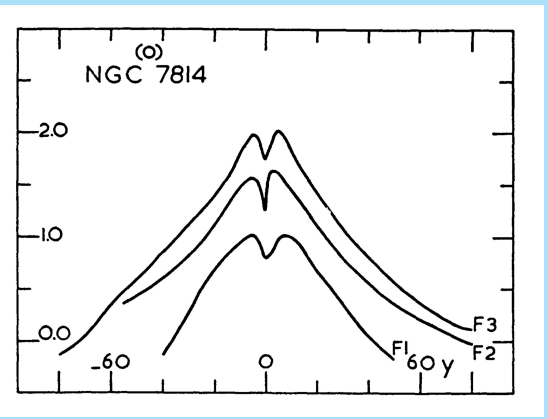
- Calibration ambiguous between spots and SA's.
- In 1947 Oort spent a few months at Yerkes.
- He obtained observing time at McDonald 82-inch with William Hiltner to try photoelectric photometry.

- Oort also visited Pasadena.
- Hubble took him to Palomar Observatory;
- Oort was one of the first to look through the 200-inch.





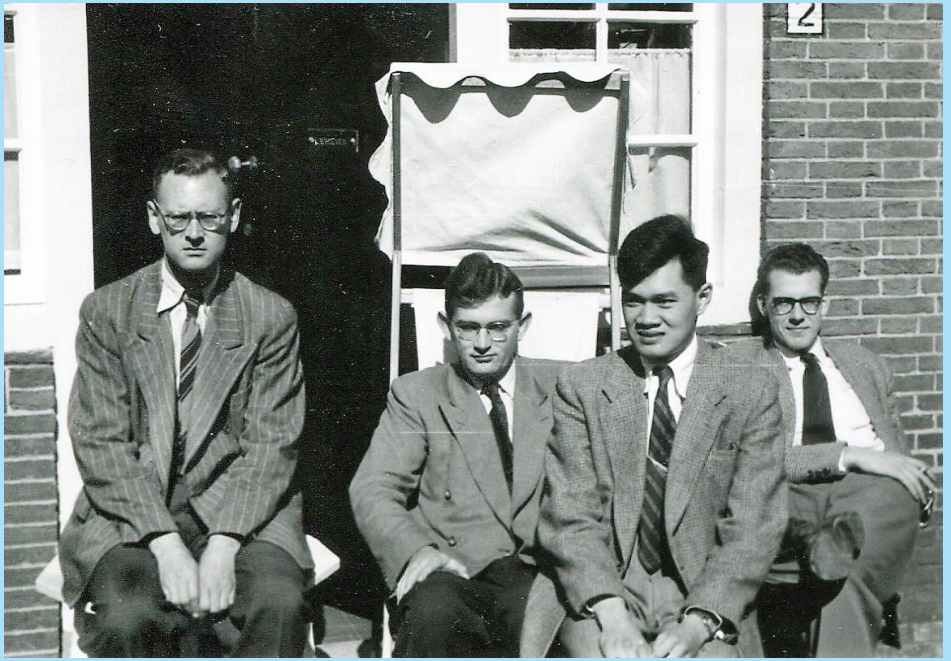




- Obtained photoelectric photometery of 7 galaxies.
- Data reduced by Kees van Houten; published in 1954.
- Proved out-of-focus SA stars as correct calibration.

- This opened the way to reduction of plate material.

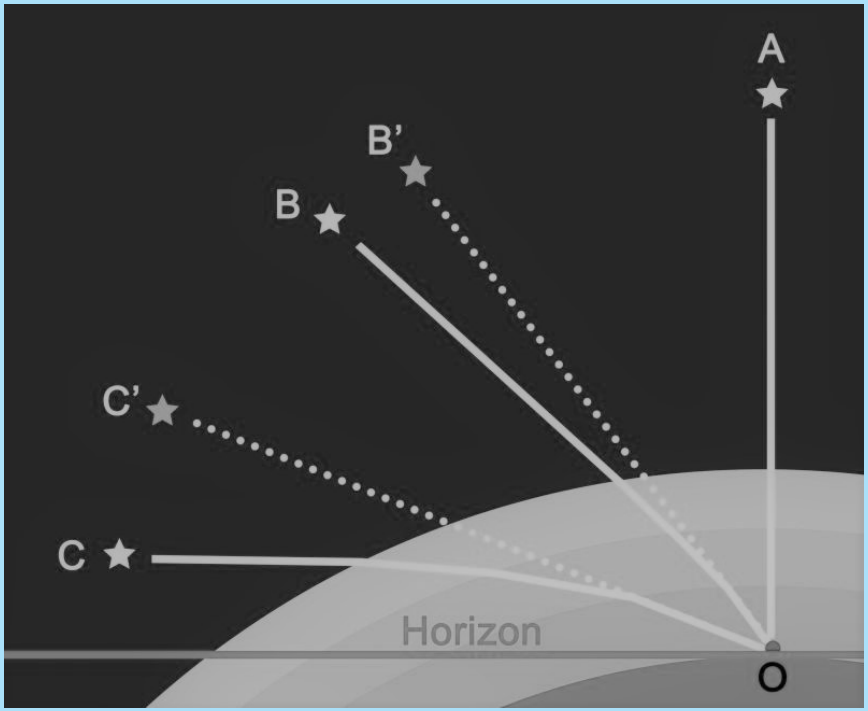
- In 1960 van Houten presented a PhD thesis with surface photometry of the twenty galaxies.
- Some of the very first two-dimensional surface brightness maps of a substantial sample of galaxies.



Kees van Houten, Gart Westerhout, King Kwee, Maarten Schmidt 1953.

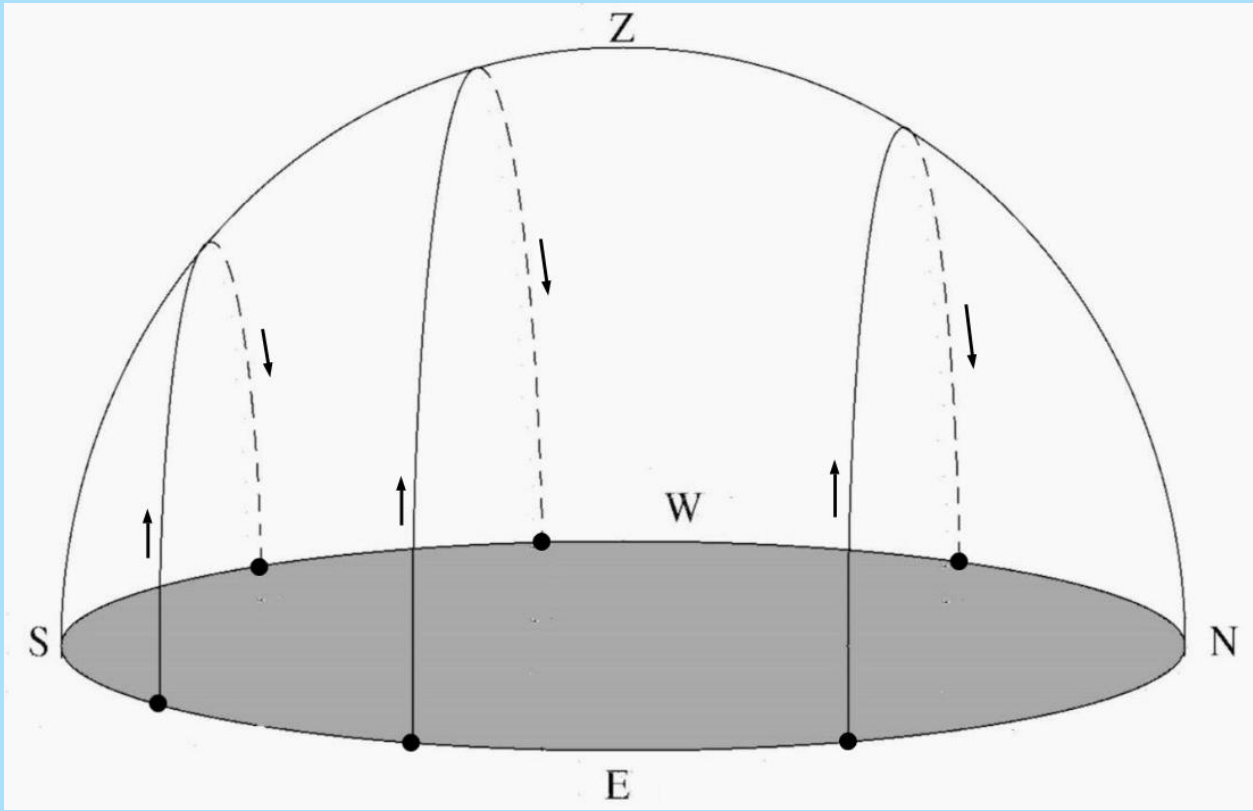
Kenya, Nova Persei and the Crab

Kenya expeditions



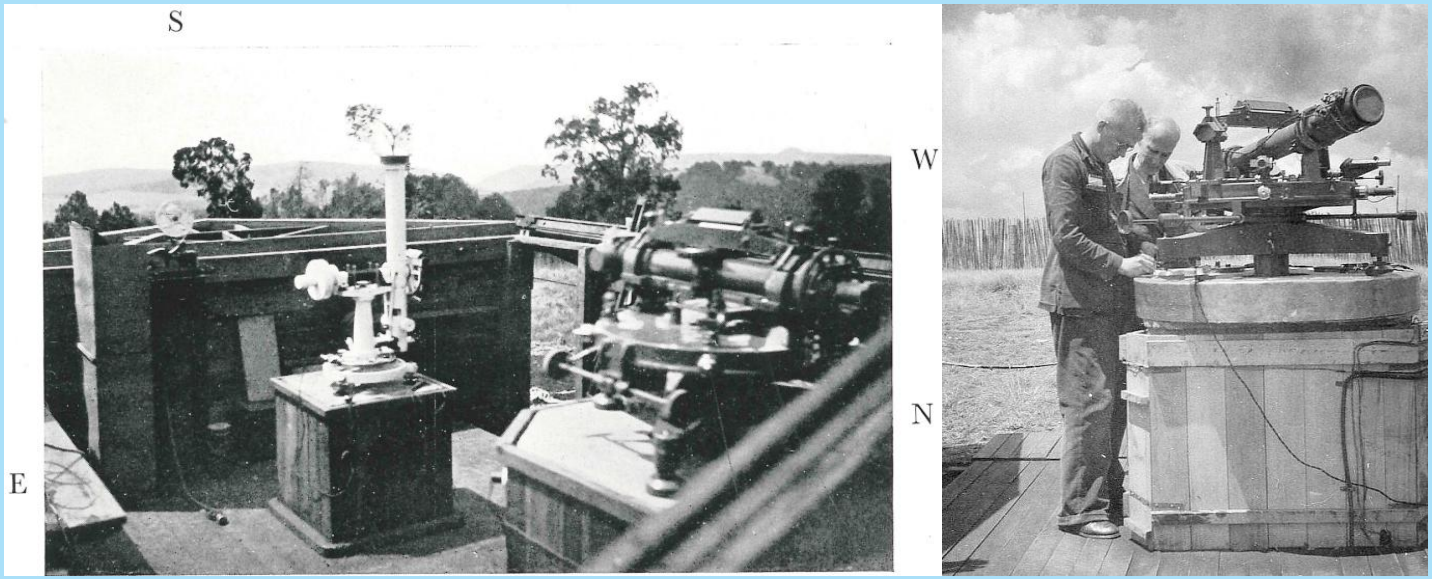
About 1 arcminute at 45°;
1€ @ 80m.

- Determination of declination is done by measuring altitude during meridian passage.
- Problems due to
  - Bending of telescope tube.
  - Atmospheric refraction.
- In 1884 Kapteyn had looked into this also and suggested a clever observing strategy.
- In 1925 Oort and de Sitter suggested three observatories, two at moderate latitudes to follow Kapteyns method and one near equator.



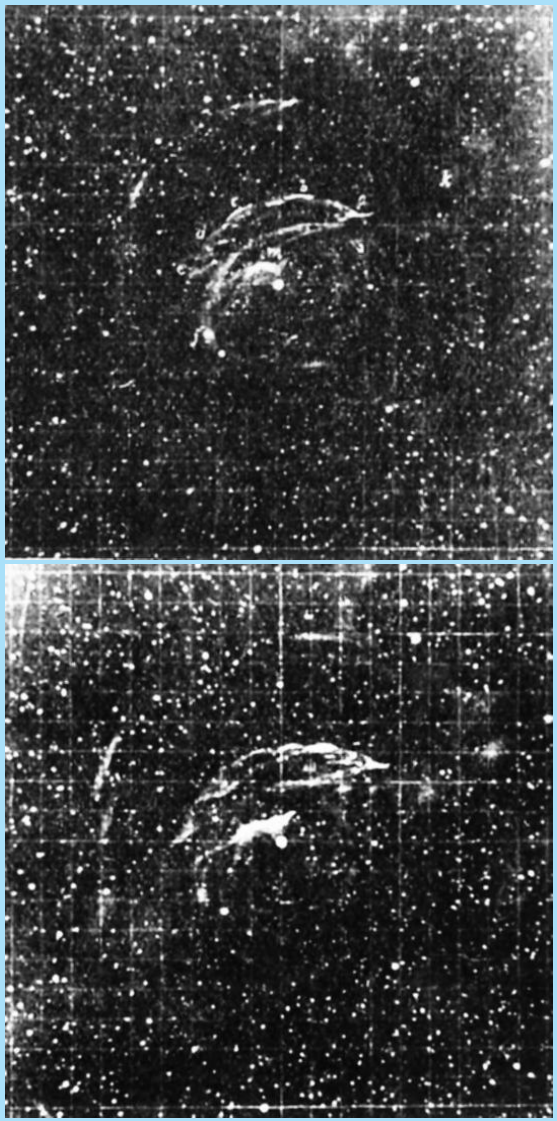
- Oort and de Sitter had proposed observing site to solve this.
- On the equator the poles are on the horizon.
- Declination follows from azimuths of rising and setting.

- There have been two expeditions by Leiden Observatory.
- The first took place 1931–1933 by Coert Hins and Gijsbert van Herk.
- De Sitter was in charge, but Oort took over when he died in 1934.
- Van Herk was Oort's first student (1936).
- Second expedition organized by Oort in 1947–1951.
- Van Herk was there all the time with his (second) wife and two children.

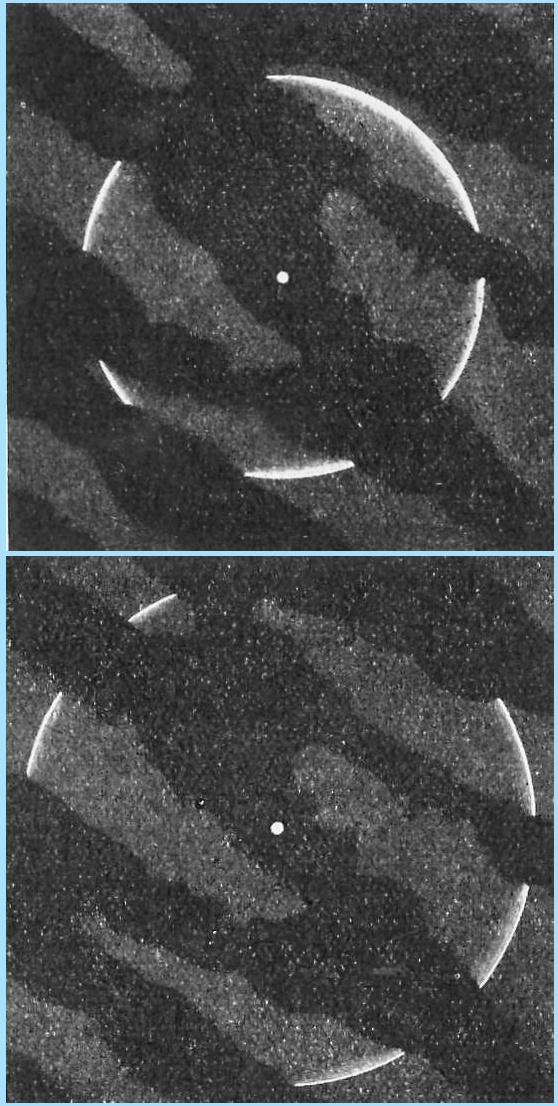


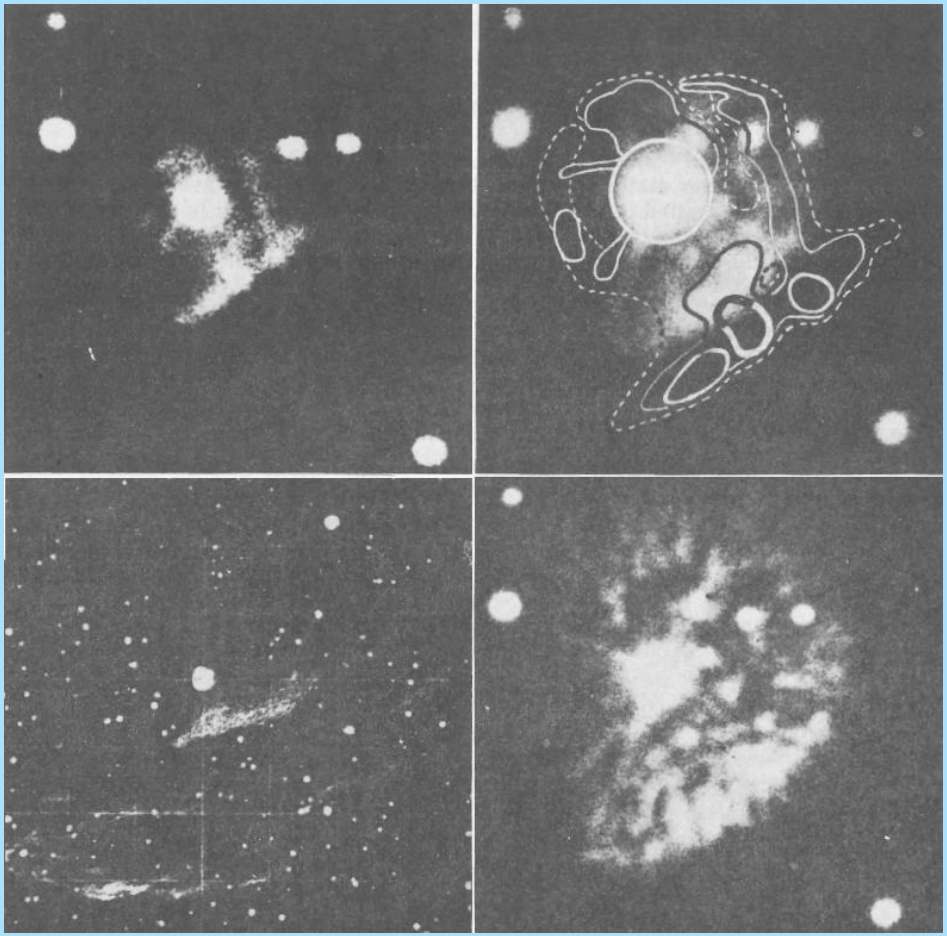
- The second observer was a volunteer, Willem van Zadelhoff, an officer in the Dutch Navy, also with his wife and two children.
- Other persons that spent some time in Kenya were Adriaan Blaaw and Maarten Schmidt.
- Oort visited in 1949.
- Program successful and results correct, but completey ignored.

Nova Persei



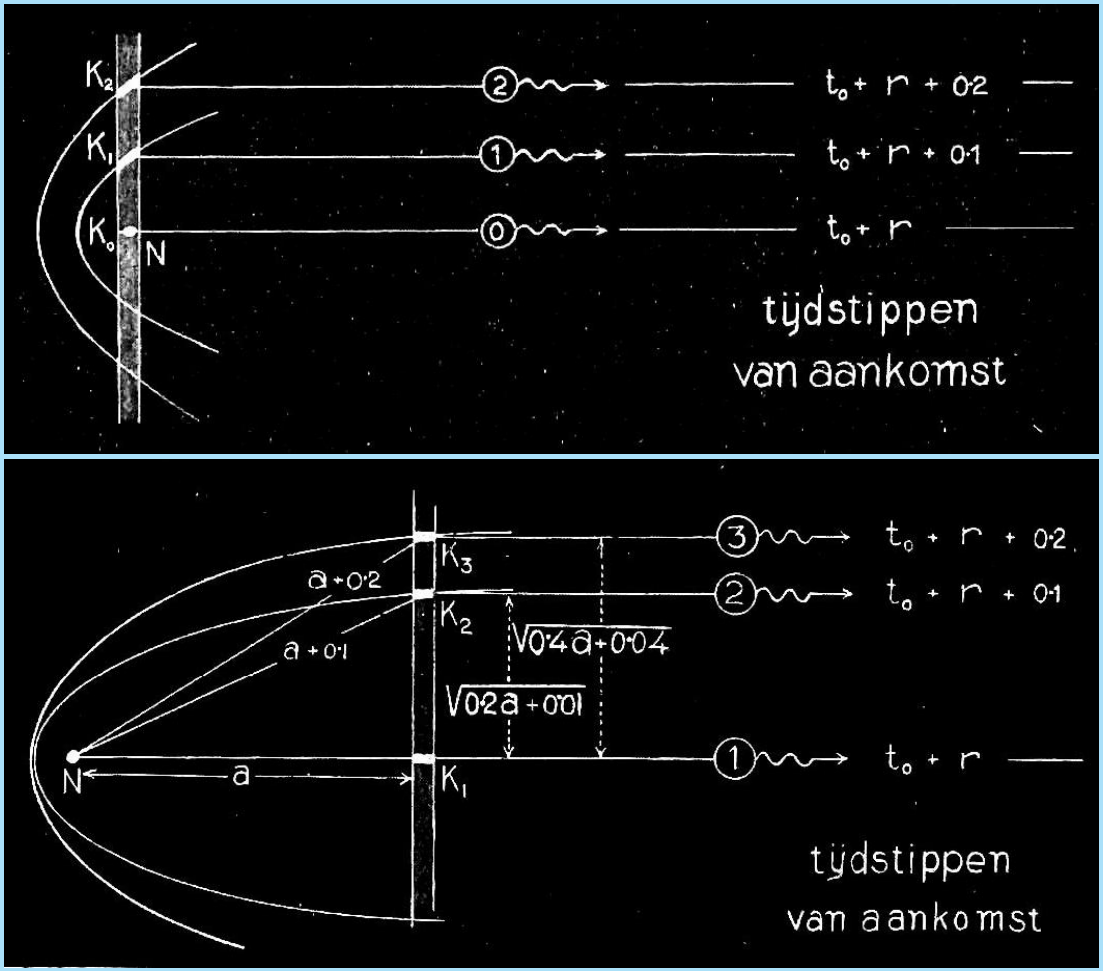
- Nova Persei (now GK Persei) exploded on 21 Feb. 1901.
- Very soon expanding filaments were noticed (drawings on 20 Sept. and Nov. 13: 1.5 arcmin in two months!.
- Kapteyn proposed it was lightfront moving on filaments of dust.
- So at speed of light and distance 90 pc.





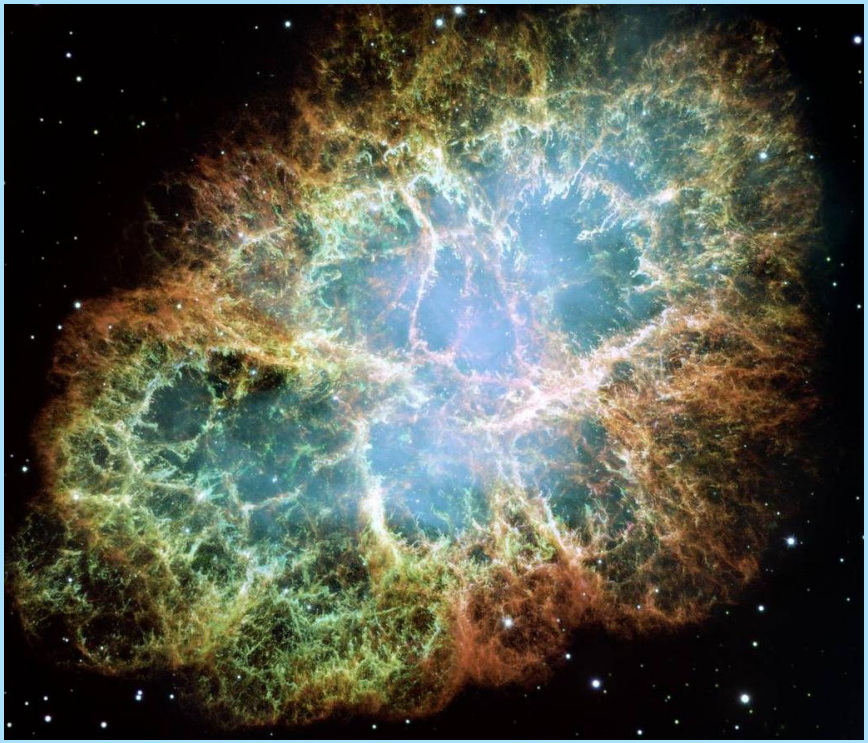
Nov. 15, 1917 and Oct. 3, 1934.
Nov. 13, 1901 and Sept. 28, 1943.

- From 1916 onwards expanding nebula itself observed.
- Spectra in 1934 indicated speed of $\pm$1200 km/s.
- Indicated distance of $\pm$700 pc and expansion speed of 7-8 times speed of light.
- Oort explained this as reflection of a sheet of dust in front of the Nova.



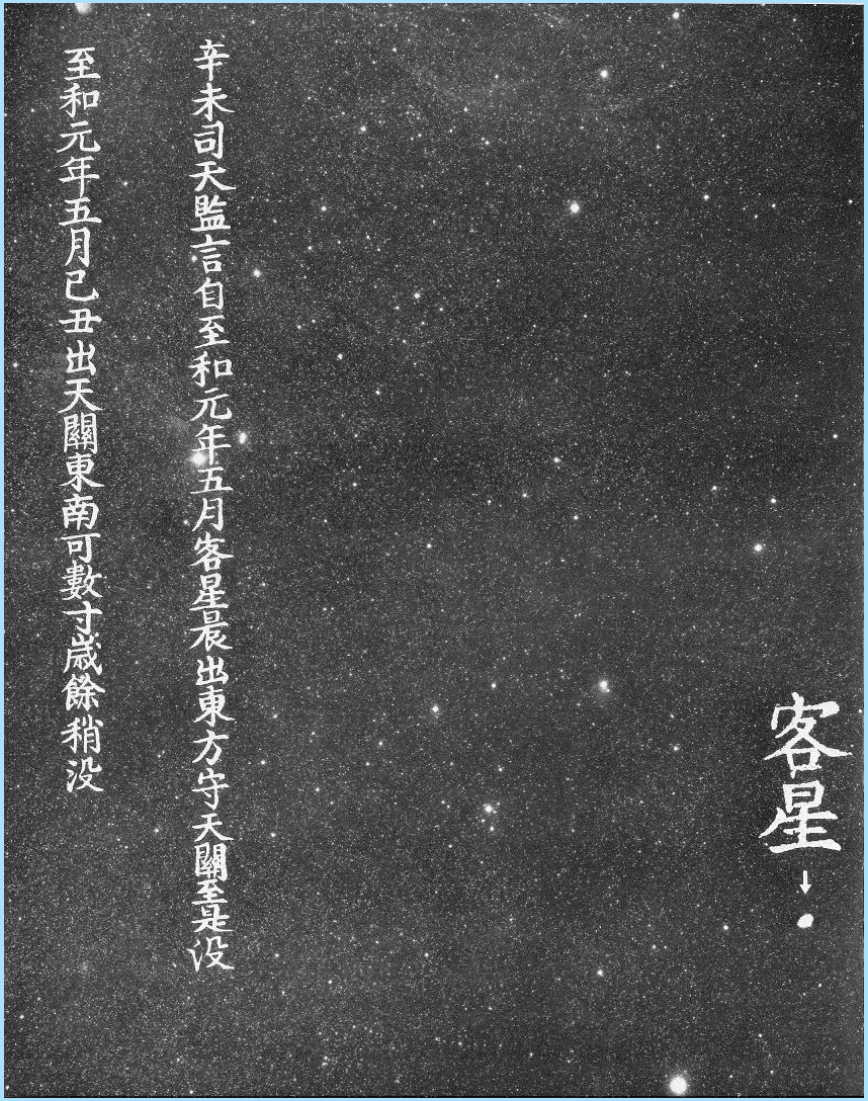
- If at 100 pc from it, then apparent expansion speed is 9 times speed of light.
- Paul Couderc from France had published the same solution, so Oort decided not to publish..
- After lecture at Nederlandse Astronomen Club a popular article was published by Jean Raimond in Hemel & Dampkring in 1942.

Crab Nebula

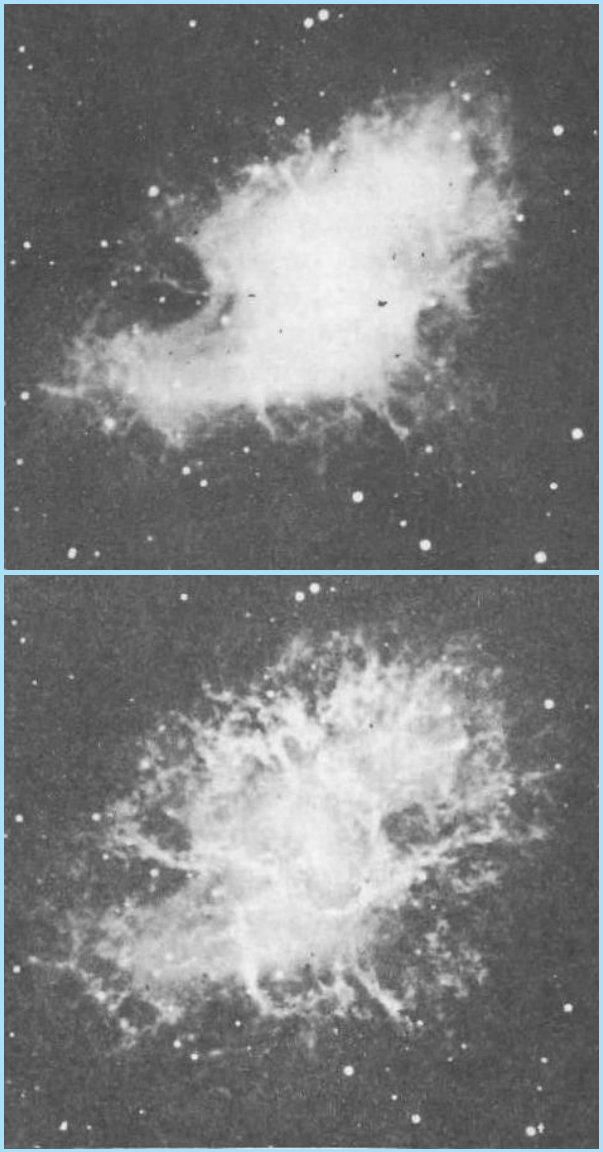


- Knut Lundmark had found mention of a 'guest star' in 1054 in Chinese chronicles.
- John Duncan had measured expansion on the sky and Vesto Slipher radial velocity (more accurately by Nicholas Mayall in 1940).
- Age about indeed 900 years.
- Distance 1.5 kpc (now rather 2 kpc).

- Oort wanted to know more about the supernova, such as the brightness.
- He got Jan Julius Lodewijk Duyvendak, professor in Chinese language and literature at Leiden, to look into the records more closely.
- The maximum brightness and duration were indeed like a supernova.
- With Mayall, Oort found a absolute magnitude of $-16\frac{1}{2}$.
- Consistent with a bright supernova.



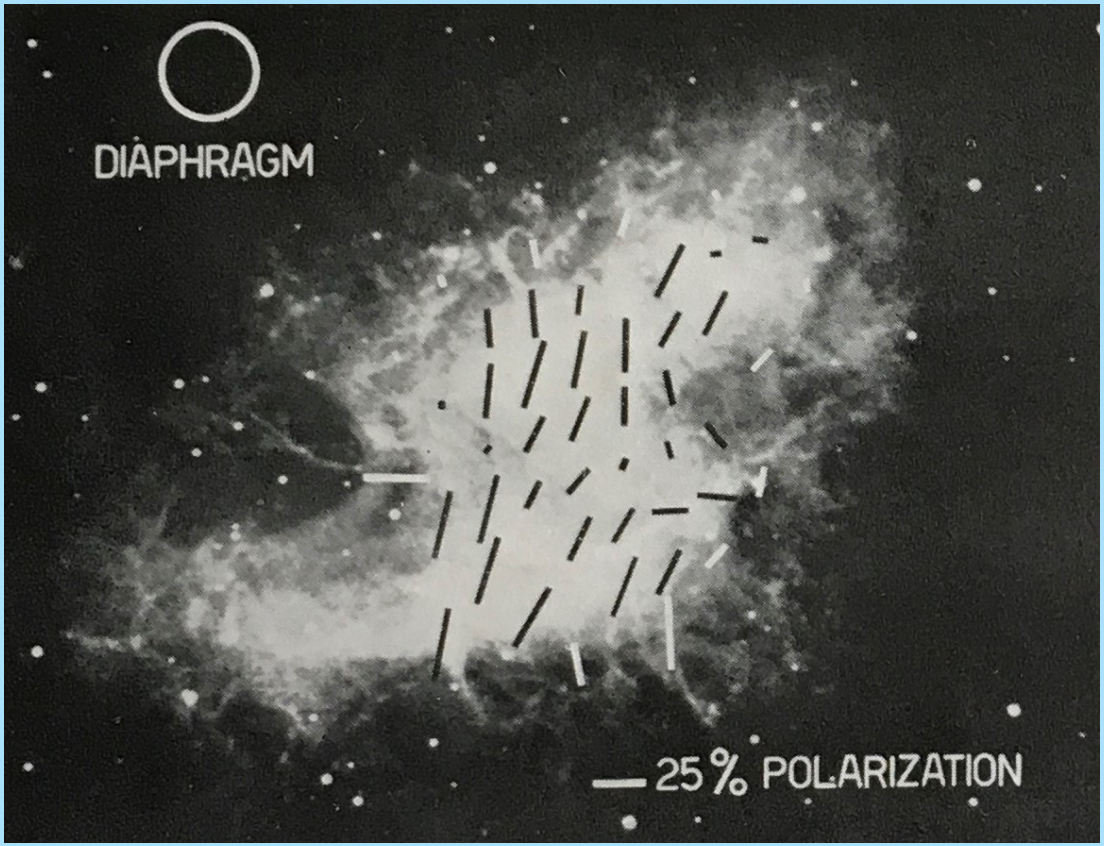
- The text near the arrow is: 'guest-star';
- The text on the left: 'On the day *hsin-wei* of the third moon of the first year of the period *Chia-uy*, [April 17, 1056] the Chief of the Astronomical Bureau reported that from the 5th moon of the 1st year of the period *Chih-ho* [June 9 to July 8, 1054] a guest-star had appeared in the morning in the eastern heavens, remaining in *T'ien-kuan* [ζ Tauri], which only now had become invisible'.



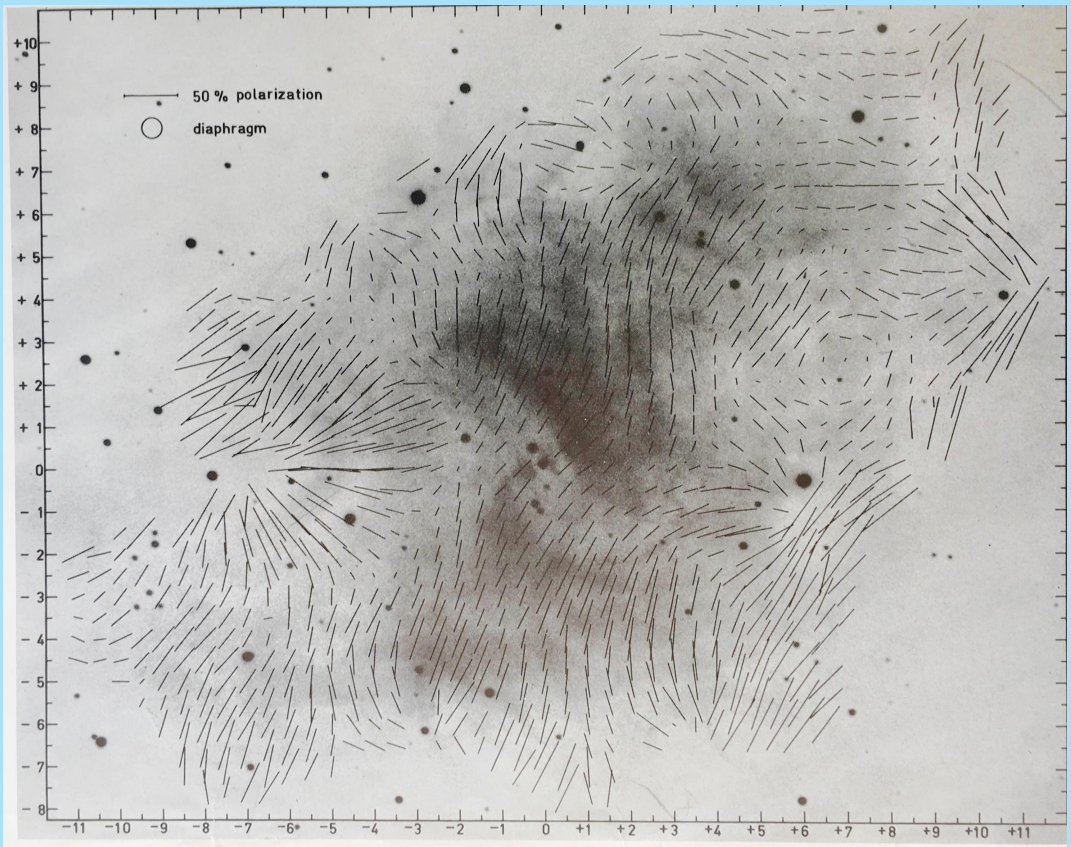
- But Oort was interested in measuring the decrease in surface brightness of the diffuse nebula.
- This would give information on the physics of the radiation mechanism and energy production.

Théodore (Fjeda) Walraven

- So he got Walraven to build a photometer to be used at the Leiden photographic telescope.
- This is a 33-cm telescope (with 15 cm guiding telescope and a English mount.
- The had heard about polarization measured by Russian astronomers.
- Walraven quickly changed the photometer into a polarimeter.



- They succeeded in doing that from the city center of Leiden in 1955.
- This proved that the emission was synchrotron radiation from relativistic electrons in a magnetic field.



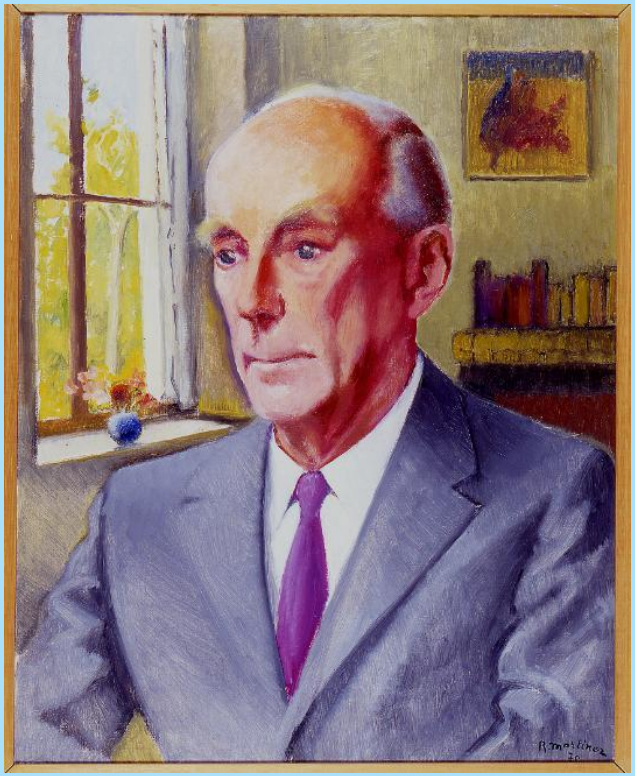
Lodewijk Woltjer

- Woltjer analysed 200-inch plates by Walter Baade into an impressive map.
- Woltjer produced a thesis under Oort in 1957.

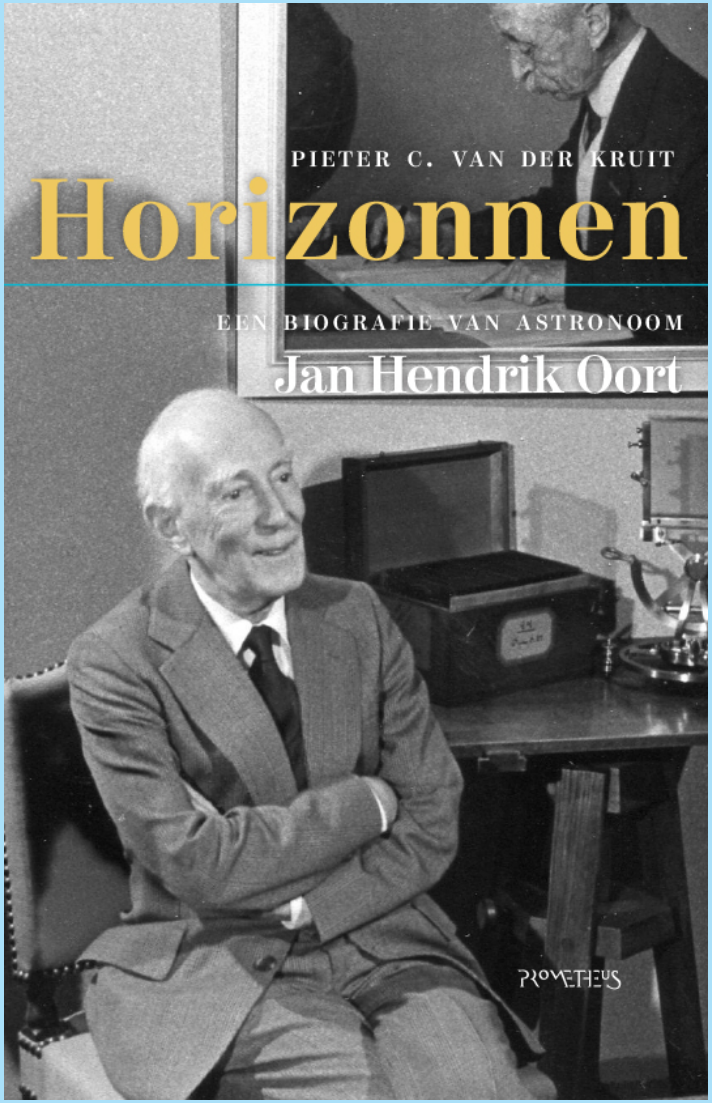
Concluding remarks

Oort did much more of course; not mentioned:

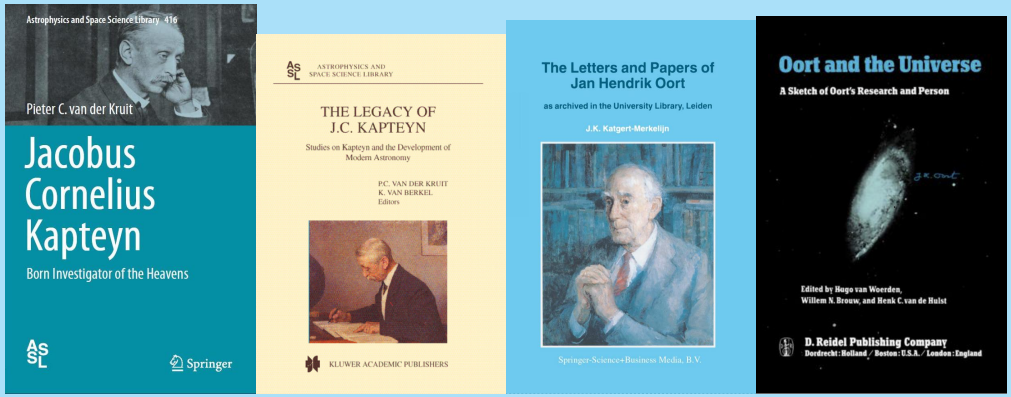
- Star clusters
- Insterstellar dust
- Kinematics of interstellar gas
- 21-cm HI line
- Spiral Structure
- Galactic Center
- High-velocity clouds
- Galaxy formation
- Large-scale structure



- International Astronomical Union
- Hartebeespoortdam Light Collector
- Kootwijk Radio Observatory
- Dwingeloo Radio Telescope
- European Southern Observatory
- Westerbork Radio Telescope



- Dutch version for wider audience and with fewer details.
- Title of Oort's Kyoto lecture.
- Will appear with Prometheus in January 2020.



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- Born investigator of the Heavens
- Master of the Galactic System

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Jan Hendrik Oort
(1900 - 1992)

This Webpage accompanies a biography:

Jan Hendrik Oort:
Master of the Galactic System

by Pieter C. van der Kruit,

volume 459 in the Astrophysics and Space Science Library of Springer Publishers, (ISBN 978-3-030-17800-0). See also the product flyer.

The biography and this Website are dedicated to the memory of Professor Jacobus Cornelius Kapteyn (1851--1922), who Oort described as 'mijn inspireerenden leermeester' (my inspiring mentor), and who laid the foundation for the boom of Dutch astronomy in the twentieth century and --last but not least-- to my wife Corry for her love and support.

PREVIEW
The eBook version is available via the Springer site. It offers free previews of the Front Matter (titlepage, Preface, Acknowledgments, Table of Contents) and Back Matter (Appendices, References,

- Website: www.astro.rug.nl/JHOort.
- Publications about and especially by Oort.
- Links to ADS.
- Scans of H&D en Zenit articles.
- Public part of the Oort Archives ($\sim$ 23k out of $\sim$ 27k pages).


THAT'S ALL
Folks!