Jacobus C. Kapteyn (1851–1922)
Born investigator of the Heavens

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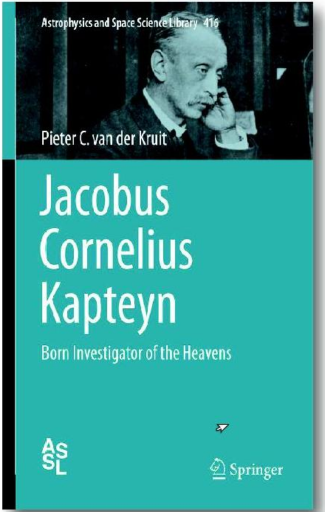
Mount Stromlo, November 2014

- What I will be presenting is based on my biography of Kapteyn.
- Expected to appear on December 14, 2015 in the Astrophysics and Space Science Library of Springer.
- It is expensive (199.99 €), but has 700 pages and 300 illustrations.
- Started this in 2010.



2015, XXIV, 698 p. 296 illus., 99 illus. in color.

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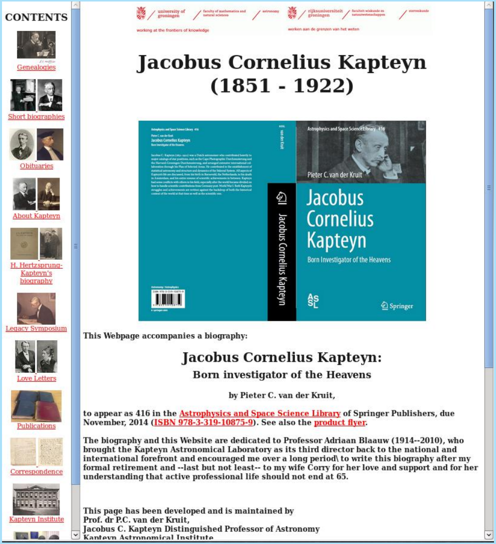

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Jacobus Cornelius Kapteyn
(1851 - 1922)

Astrophysics and Space Science Library 416
Pieter C. van der Kruit
Jacobus Cornelius Kapteyn
Born Investigator of the Heavens
Springer

This Webpage accompanies a biography:

Jacobus Cornelius Kapteyn:
Born investigator of the Heavens

by Pieter C. van der Kruit,

to appear as 416 in the Astrophysics and Space Science Library of Springer Publishers, due November, 2014 (ISBN 978-3-319-10875-9). See also the product flyer.

The biography and this Website are dedicated to Professor Adriaan Blaauw (1914--2010), who brought the Kapteyn Astronomical Laboratory as its third director back to the national and international forefront and encouraged me over a long period\ to write this biography after my formal retirement and --last but not least-- to my wife Corry for her love and support and for her understanding that active professional life should not end at 65.

This page has been developed and is maintained by
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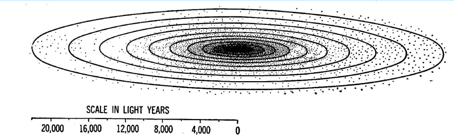
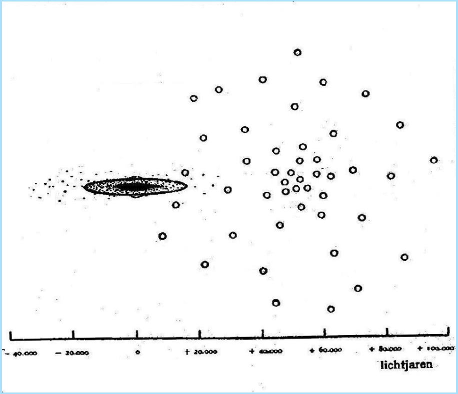
- I have designed a special Webpage to accompany the book.
- It provides access to any material on Kapteyn not protected by copyrights.
- Papers and publications of and about Kapteyn, Henriette Hertzsprung-Kapteyn's biography, letters from David Gill, etc.
- The URL is: www.astro.rug.nl/JCKapteyn

The Kapteyn Universe



- Kapteyn and van Rhijn (1920): model for the distribution of stars in the Sidereal System.
- Kapteyn (1922) completed this by considering its 'mechanics' based on equilibrium.
- Vertical dynamics based on random motions: correct.
- Horizontal based on rotation + random motions: incorrect.



(Figure from de Sitter, attributed to Oort.)

- This contrasted with Shapley's globular cluster distribution
- Kapteyn had neglected interstellar absorption; system had diameter of $\sim$ 15 kpc.
- But Shapley's distances too large also because of absorption; center at $\sim$ 20 kpc.
- Often seen as a contest won by Shapley and lost by Kapteyn.

- Already in 1926: Jan Hendrik Oort's acceptance lecture as 'privaat-docent' in Leiden had title *Non-light emitting matter in the Stellar System*.
- Assumption of absorption in space the 'least contrived' solution to Shapley – Kapteyn disagreement.

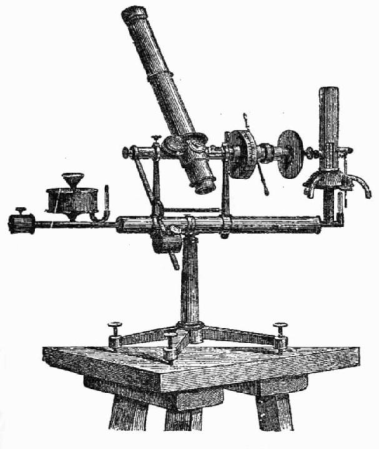
Jan and Mieke Oort after thesis defense.

- Oort found differential rotation and the Oort constants in 1928.
- Improved Kapteyn's analysis to derive the Oort limit in 1932.

What was wrong with Kapteyn's Universe?

Kapteyn's works

- Kapteyn studied in Utrecht with Buys Ballot and Grinwis.
- And obtained his PhD in 1875 under Grinwis.
- The title was *A study of vibrating, flat membranes*.
- There was no professor of astronomy at the time, so a thesis in astronomy was not possible.
- Yet he did much astronomy, as can be seen from his propositions.



- For example he said that the Zöllner photometer was the best one available.
- He had actually tried to do an astronomy thesis in Leiden.
- After his studies he was appointed 'observator' at Leiden Observatory.
- He worked there under the director Hendricus G. van de Sande Bakhuyzen.
- His work was mainly astrometry.

- He was appointed Professor of astronomy and theoretical mechanics in 1877 at the University of Groningen.
- He took up his chair in 1878 with inaugural lecture on *The parallaxes of the fixed stars*.
- In 1879 he married Catherina Elisabeth van Kalshoven
- In spite of many efforts he failed to obtain his own observatory.
- Some of this is due to obstruction by Leiden and Utrecht.

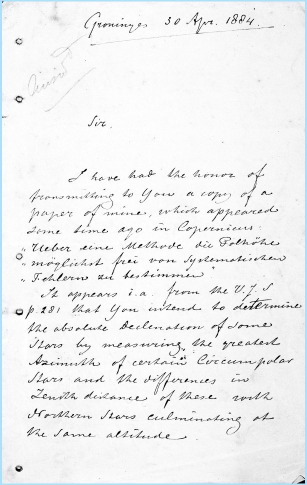
Stellar parallaxes

- Kapteyn felt that progress required the determination of parallaxes on a grand scale.
- Already in the 1880's he tried to measure annual parallaxes by differential meridian timing measurements.
- If parallax is 0.1 arcsec and its declination 50°, then parallax corresponds to time difference of 0.02 seconds of time.
- So you need extremely accurate timings.
- Only possible with many repeated measurements.
- Kapteyn used the Leiden meridian circle in 1885–1887 with a 'Registrir-Apparat'.
- He selected 15 stars with high proper motion that may be not too distant.
- Results published in Astronomische Nachrichten (preliminary) in 1889 and in Annals of Leiden Observatory in 1891.

Star	p_{Kapteyn} milli-arcsec	HD	p_{modern} milli-arcsec	Remarks
BB VII 81 (pr.)	74 ± 27	79210	172.06 ± 6.31	Flare star; binary
		79211	156.45 ± 8.58	Flare star; binary
θ Ursa. Maj.	52 ± 26	82328	74.19 ± 0.16	Spectroscopic binary
BB VII 85	64 ± 22	84031	54.89 ± 0.92	Variable star
20 Leon. Min.	62 ± 29	86728	66.46 ± 0.32	High proper-motion star
BB VII 89	176 ± 24	88230	205.21 ± 0.34	Flare star
BB VII 94	101 ± 26	90508	43.65 ± 0.43	High proper-motion star
BB VII 95	38 ± 27	91347	26.48 ± 0.59	High proper-motion star
Lal. 20670	-6 ± 28	92855	26.84 ± 0.50	Star in double system
BB VII 104	428 ± 30	95735	392.64 ± 0.67	Flare star
BB VII 105	168 ± 27	–	206.27 ± 1.00	High proper-motion star
BB VII 110	30 ± 27	101177	43.01 ± 0.73	Spectroscopic binary
BB VII 111	16 ± 32	102158	20.29 ± 0.70	Star in double system
BB VII 112	139 ± 26	103095	109.99 ± 0.41	High proper-motion star
BB VII 114	-28 ± 42	104556	17.5 ± 0.51	High proper-motion star
BB VII 119	56 ± 34	105631	40.77 ± 0.66	High proper-motion star

This really is astonishingly good!!

Cape Photographic Durchmusterung

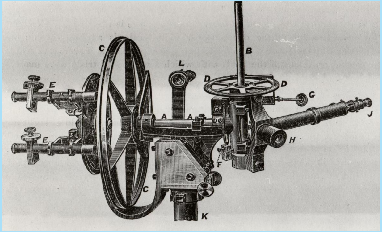

Groningen 30 Apr. 1884.

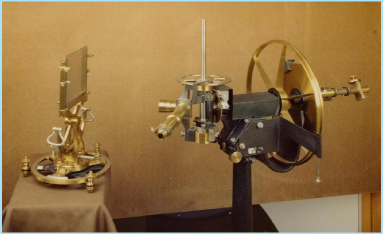
Sir,

I have had the honor of transmitting to You a copy of a paper of mine, which appeared some time ago in Copernicus: „Ueber eine Methode die Polhöhe „möglichst frei von systematischen „Fehlern zu bestimmen."
It appears i.a. from the V.J.S p.281 that You intend to determine the absolute Declination of some Stars by measuring the greatest Azimuth of certain Circumpolar Stars and the differences in Zenith distance of these with Northern Stars culminating at the same altitude.

- Declinations were very inaccurate due to telescope flexure and atmospheric refraction.
- Kapteyn devised a method to measure absolute declinations and polar altitude free from systematic errors.
- Only measurements of differences of comparable zenith distances, azimuths, timing of prime vertical passage.
- He sent the paper to David Gill at the Royal Observatory at Cape of Good Hope.

- Gill noted on photographs of the great comet of 1882 that there were many stars visible.
- David Gill wanted to produce a photographic Durchmusterung of the southern skies.





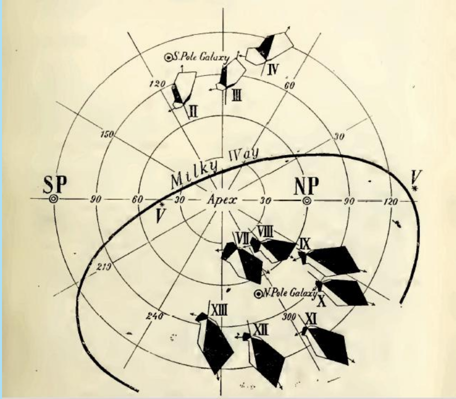
- Kapteyn was lured into offering to measure Gill's plates and produce the star positions and magnitudes.
- He invented the 'parallactic method'.
- The Cape Photographic Durchmusterung (454,875 stars) was published in three volumes in 1896, 1897 and 1900.

- Stars too distant to measure parallaxes in large numbers.
- Kapteyn decided to use secular parallaxes.
- Sun moves at 4 Earth-orbit radii per year.
- But then you need many proper motions and statistics.
- At the Carte du Ciel 1888 meeting, Kapteyn met Anders Donner from Helsingfors, who took many multiple exposure plates for proper motions and parallaxes.

- With his brother Willem (mathematics, Utrecht) de developed the necessary techniques.
- He proceeded making three assumptions:
  1. The 'luminosity curve', the distribution of absolute magnitudes, is the same everywhere.
  2. There is no preferred direction among the motions of the stars in space,
  3. There is no absorption of starlight.

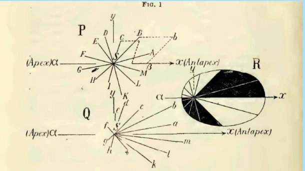
Star Streams and the Plan of Selected Areas

FIG. 2.

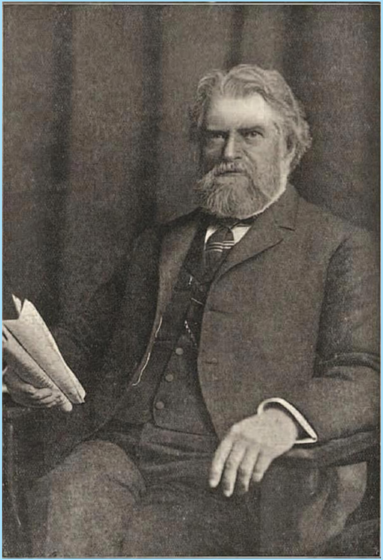


- Kapteyn collected as much proper motions as he could find.

FIG. 1



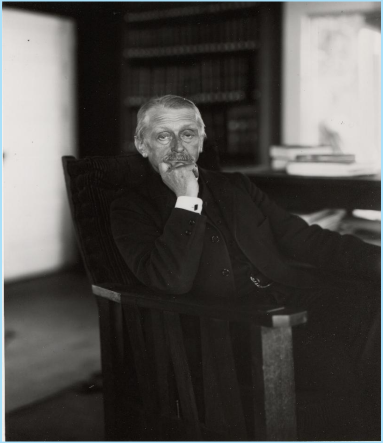
- However, then he discovered the Two Star Streams, showing two opposite, preferred directions.

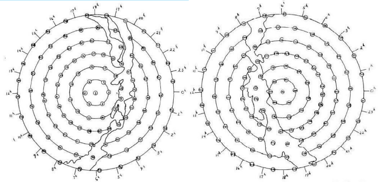


- He first presented that at the St. Louis Congress during the 1904 Louisiana Purchase Exposition.
- This was organized by Simon Newcomb of U.S. Naval Observatories, who had visited Kapteyn in Groningen.
- This introduced him to American astronomy, particularly Hale at Mount Wilson and Pickering at Harvard.

- The concept of Star Streams was quickly confirmed, a.o. by Arthur Eddington (1882–1944).
- However, Karl Schwarzschild (1873–1916) proposed an anisotropic velocity ellipsoid.
- Kapteyn, and for a long time Eddington, did not accept this, as the properties of stars in both streams were different.

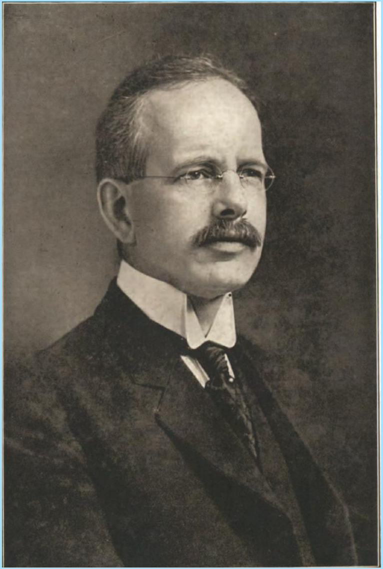
Plan of Selected Areas





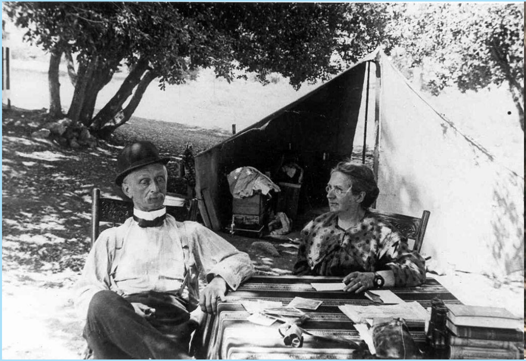
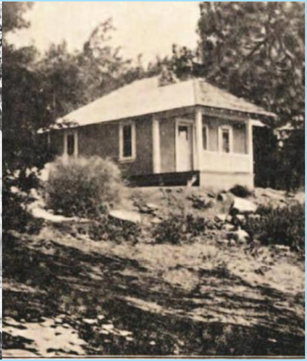
- He devised the Plan of Selected Areas, which he discussed with many colleagues, starting in St. Louis and later in Capetown.
- Eventually it became 120 areas across the sky (+46).
- All measurable properties of stars should be determined.

- Edward Pickering took plates of all Areas.
- Plates were measured in his Astronomical Laboratory; an *'observatory without a telescope'*.
- The Harvard–Groningen Durchmusterung was published between 1918 and 1924.
- It contained 231,118 stars in all S.A.'s down to $m \sim 16$.



- In St. Louis Kapteyn met George E. Hale and must have impressed him.
- Hale adopted the 'Plan' as prime program for his new Mt. Wilson 60-inch telescope.
- Much help from Frederick Seares.
- The Mount Wilson-Groningen Catalogue down to $m \sim 19$ in all northern Areas was published in 1930.
- Walter Adams studied radial velocities.

- Kapteyn was appointed part-time staff associate.
- He went to Mt. Wilson each year from 1908 to 1914.
- Kapteyn lived on Mount Wilson, first in a tent, later in the Kapteyn Cottage.

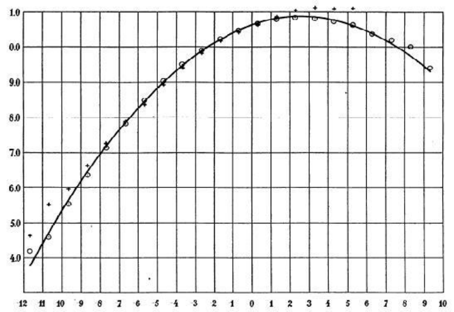
Absorption and the Kapteyn Universe

- Kapteyn worried very much about extinction, and wrote four papers on this (1 in A.J. and 3 in Ap.J.)
- In 1904 George Comstock had deduced from the star ratio that absorption was very strong.
- He deduced 0.18 mag per unit distance (corresponds to parallax of $0\farcs1$).
- Kapteyn agreed there was extinction, but much less than Comstock.
- Sun in special position (local minimum) if Comstock were right.
- In 1909 Kapteyn proposed that scattering means reddening.
- Deduced 0.01 mag per unit distance in photographic band.
- Actually not too bad compared to present.

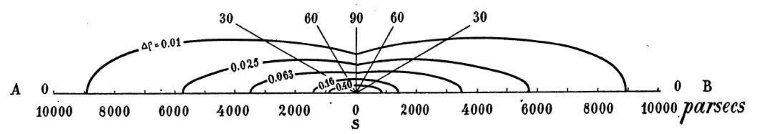
- The turning point came with Shapley's 1916 work on M13.
- If Kapteyn were correct, the stars should be 2.5 magnitudes redder than observed.
- Shapley concluded that space was transparent.
- This was widely accepted as the final word.

- Kapteyn & van Rhijn (1920):
  'Now that, after so many years of preparation, our data seem at last to be sufficient for the purpose, we have been unable to restrain our curiosity and have resolved to carry through completely a small part of the work ...'

- First determined the luminosity curve.



Kapteyn hated the term parsec, but did adopt it and redefined absolute magnitude to distance of 1 pc.



- Kapteyn & van Rhijn (1920):
- Solved counts for star density as function of distance from Sun, using analytical methods developed by Schwarzschild.
- Performed this process for latitudes 0°, 30°, 60° and 90°.
- Resulting system had radius of 9 kpc, but based on extrapolations..

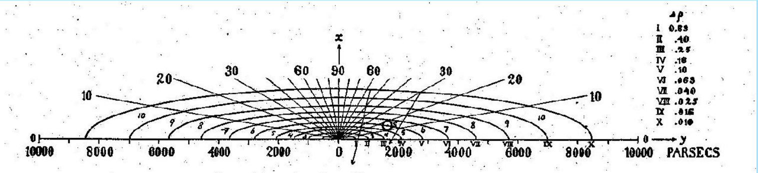


FIG. I

- Kapteyn's (1922) *'First attempt at a theory of the arrangement and motion of the Sidereal System'*:
- First he fitted ellipsoids and then calculated gravitational potential.
- In the vertical direction assumed hydrostatic equilibrium with velocity dispersion 12 km/s
- *'Mass of dark matter' in the Universe' ... 'cannot be excessive'.*
- Fit Kapteyn data with isothermal sheet: $z_\circ = 650$ pc.
- Modern: $z_\circ \sim 700$ pc and velocity dispersion about 17 km/s.

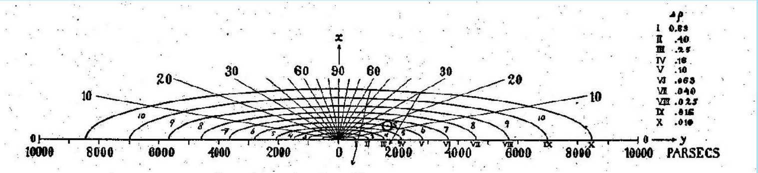


FIG. I

- Kapteyn (1922) in the horizontal direction.
- Add centrifugal force: between 0.5 and 1.5 kpc from center rotation of 20 km/s required.
- That meant that the rotation was seen in the Star Streams!
- Sun cannot be in center; chose 650 pc radial displacement.
- From (son-in-law) Ejnar Hertzsprung from distribution of Cepheids: vertical displacement 38 pc.

- Kapteyn's Universe was a consistent, dynamical system.
- It explained both the distribution and the motions.
- What was wrong were two parts:
  1. Transparency of space – Observational evidence was Shapley's colors of M13 stars.
  2. Star Streams versus velocity ellipsoid – Observational evidence was very different make-up in terms of spectral types.
- Kapteyn constructed his model just before retirement and died soon afterwards,
- Important developments occurred only a few years later.

Kapteyn's Legacy

- Developed statisical astronomy[1]
- First modern study of the 'Structure of the Sidereal System'.
- First consistent dynamical study.
- International collaboration, Plan of Selected Areas.
- Ensured future for Dutch astronomy and left his protogé's in key positions:.
  - Reorganisation of Leiden Observatory in 1918:
  - de Sitter (theory), Hertzsprung (astrophysics), Pannekoek (astrometry) failed, but went to Amsterdam.
  - Astronomical Laboratory in Groningen with van Rhijn.
- Turned Oort to astronomy, who subsequently
  - Suspected interstellar absorption.
  - Discovered Galactic rotation.
  - Established Stellar Dynamics.

[1] Some of this independently by von Seeliger.

That's all folks