Jacobus Cornelius Kapteyn (1851–1922)

Master of accuracy

Pieter C. van der Kruit
Jacobus C. Kapteyn Professor of Astronomy
Kapteyn Astronomical Institute, Groningen
www.astro.rug.nl/∼vdkruit

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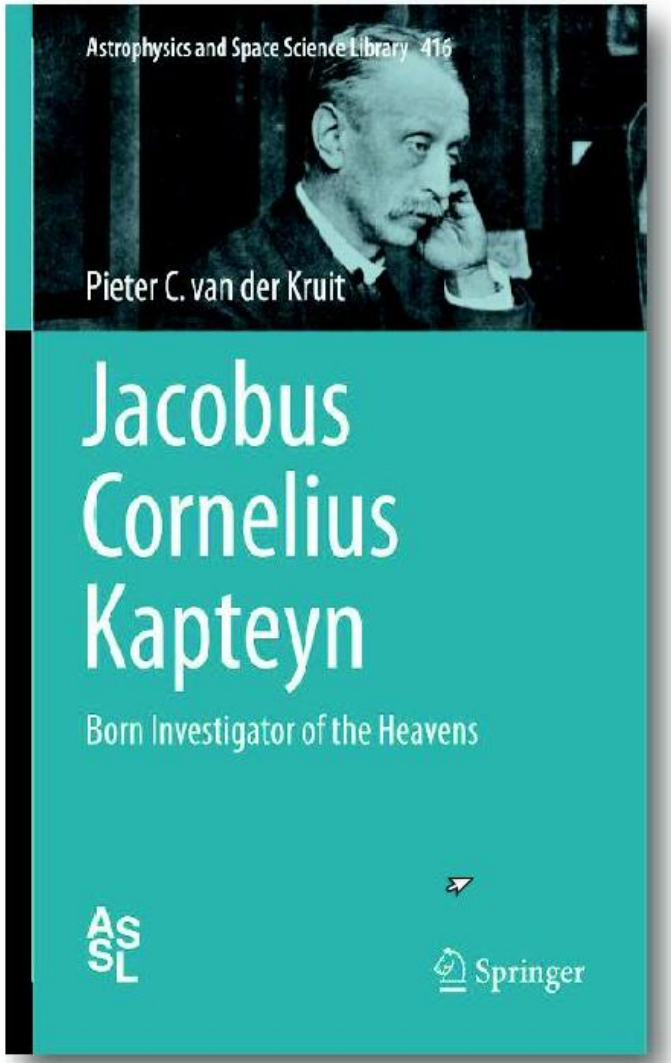
Background



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

- Based on my Kapteyn biography.
- I have designed a special Webpage accompanying 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**

- Kapteyn Astronomical Institute preprint series.
- Started around 1990.
- Cover showed Kapteyn (as on the left).
- Discrete criticism (*'Why Kapteyn? After all, he was wrong.'*).
- Regrettably replaced with a current IRAS result.

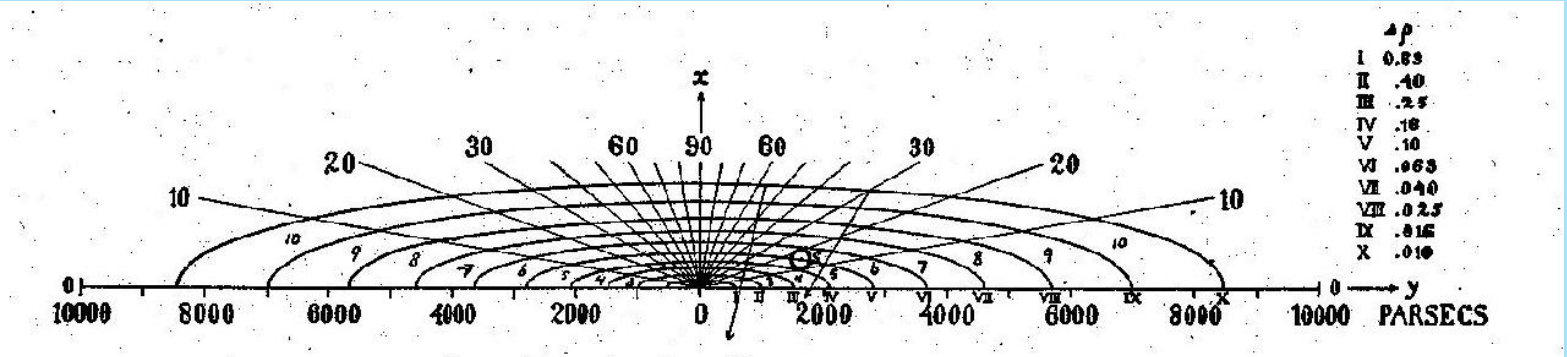


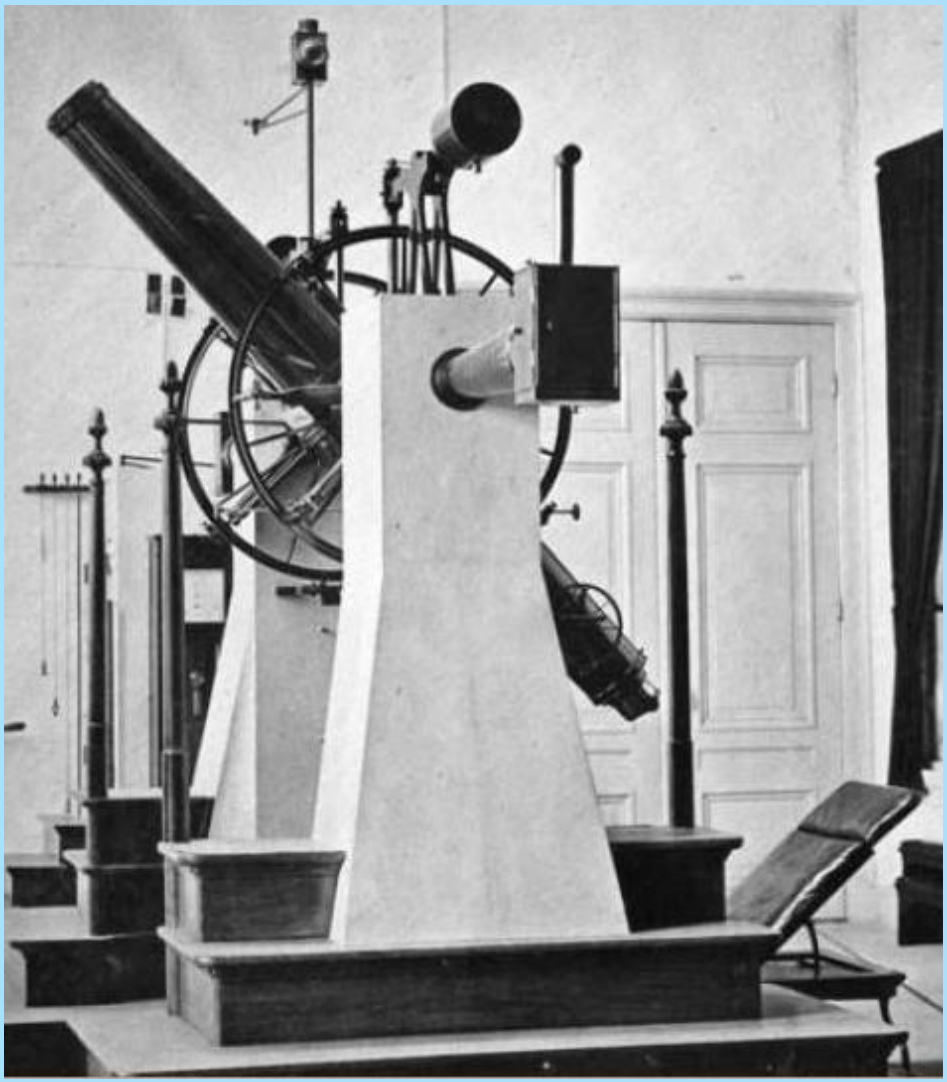
FIG. 1

- Kapteyn's aim was the distribution of stars in the Sidereal System from star counts and proper motions (secular parallaxes).
- Required three assumptions:
  - Uniform Luminosity Function,
  - No systematic motions,
  - No interstellar absorption.
- Kapteyn developed all mathematical tools required together with his brother Willem Kapteyn.

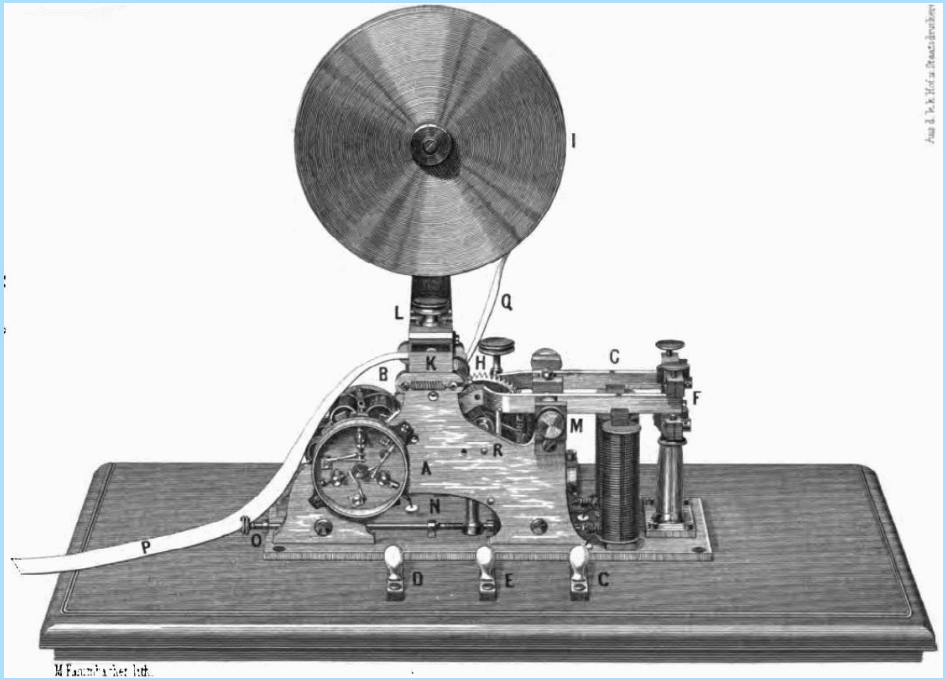
- Kapteyn collected data to check his second and third assumptions:
  - proper motions to check on the uniform, random motions.
  - colors and spectra to check on the absence of extinction.
- Kapteyn was an exceptionally careful and accurate observer and reducer/interpreter of data.

Illustration I:

Trigoniometric parallaxes



- Kapteyn started a program to measure annual parallaxes by differential meridian timing measurements.
- This was felt to be too difficult.
- If parallax is 0.1 arcsec and its declination 50°, then parallax corresponds to time difference of 0.02 seconds of time.



- Kapteyn had no access to a telescope in Groningen.
- Kapteyn used a 'Registrir-Apparat' or strip recorder on the Leiden meridian circle (spring 1885, Christmas 1885 and 1886, and in spring 1887).

- He selected 15 stars with high proper motion that were probably not too distant.
- Results published in Astronomische Nachrichten (preliminary) in 1889 and in Annalen van de Sterrewacht te Leiden in 1891.

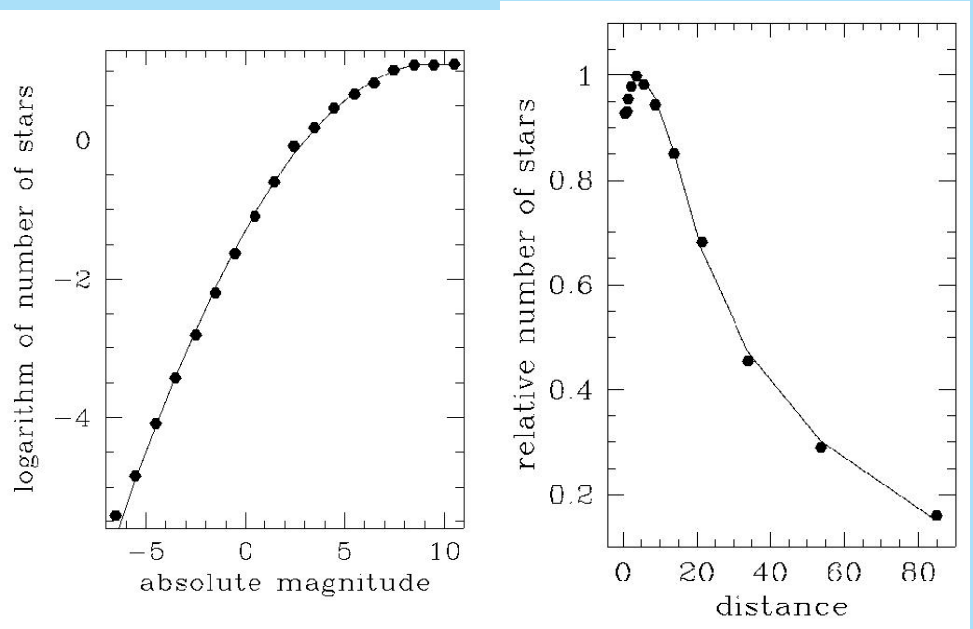
Star	$p_{\rm Kapteyn}$ milli-arcsec	HD	$p_{\rm modern}$ milli-arcsec	Remarks
BB VII 81 (pr.)	74 ± 27	79210	172.06 ± 6.31	Flare star; binary
		79211	156.45 ± 8.58	Flare star; binary
θ Ursa. Maj.	52 ± 26	82328	74.19 ± 0.16	Spectroscopic binary
BB VII 85	64 ± 22	84031	54.89 ± 0.92	Variable star
20 Leon. 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 amazingly good!!

Illustration II:

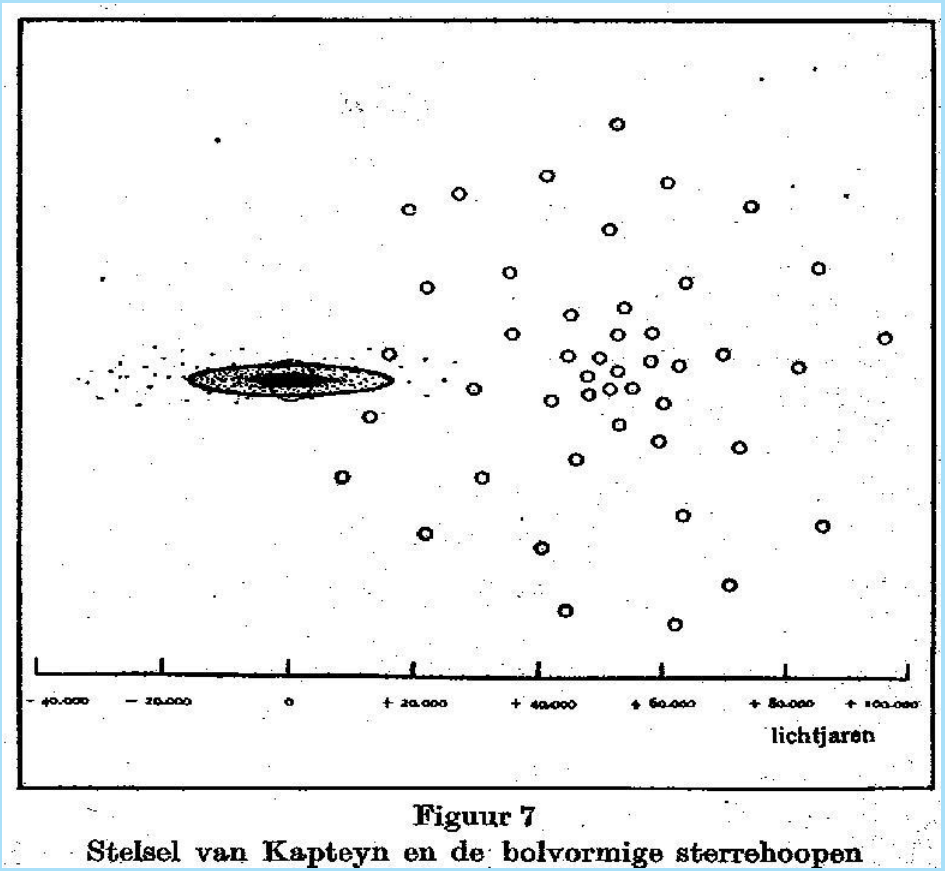
Interstellar absorption

- Kapteyn worried very much about extinction, and wrote four papers on this (1 in A.J. and 3 in Ap.J.).
- Edward Pickering used the theoretical star ratio (uniform distribution of stars of equal luminosity) is 3.981.
- Data showed 3.28 to 2.31 at faintest magnitudes.
- In 1904 George Comstock had deduced from the star ratio that absorption was very strong:
- 0.18 mag per unit distance (parallax of $0''.1$), or 18 mag/kpc.
- Sun in special position (local minimum).



- Kapteyn (1904) presented model calculations, that showed that the effect could be (partly) due to decreasing star density.
- From luminosity curve change of slope with distance he found much less than Comstock.

- In 1909 Kapteyn proposed that scattering means reddening.
- Used 1433 stars in Draper Catalogue and Harvard Extension with spectral types, colors (Phot.-Vis.) and proper motions.
- Deduced 0.003 mag per unit distance in photographic band.
- Actually not too bad compared to present!



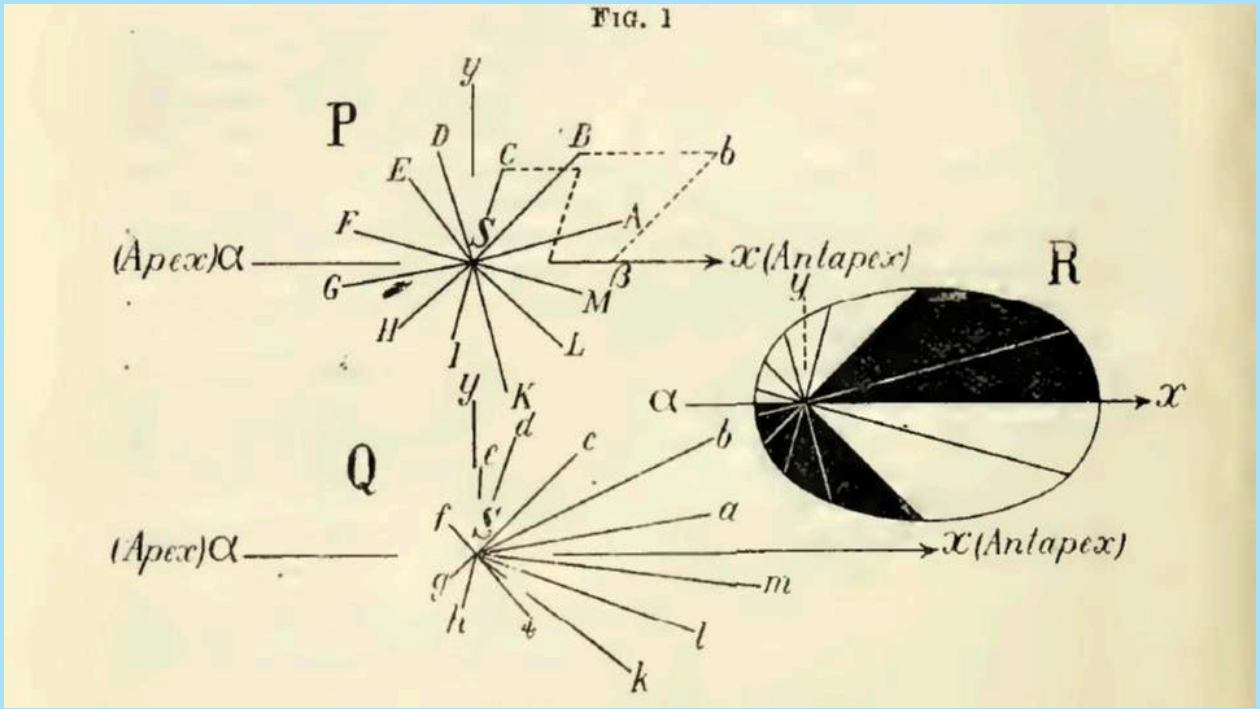
Figuur 7
Stelsel van Kapteyn en de bolvormige sterrehoopen

- However, Kapteyn worried about systematic changes of color with distance.
- The turning point came with Shapley's 1916 work on M13.
- If Kapteyn were correct, the (giant) stars should be 2.5 magnitudes redder than observed.
- Shapley concluded that space was transparent and this was widely accepted.

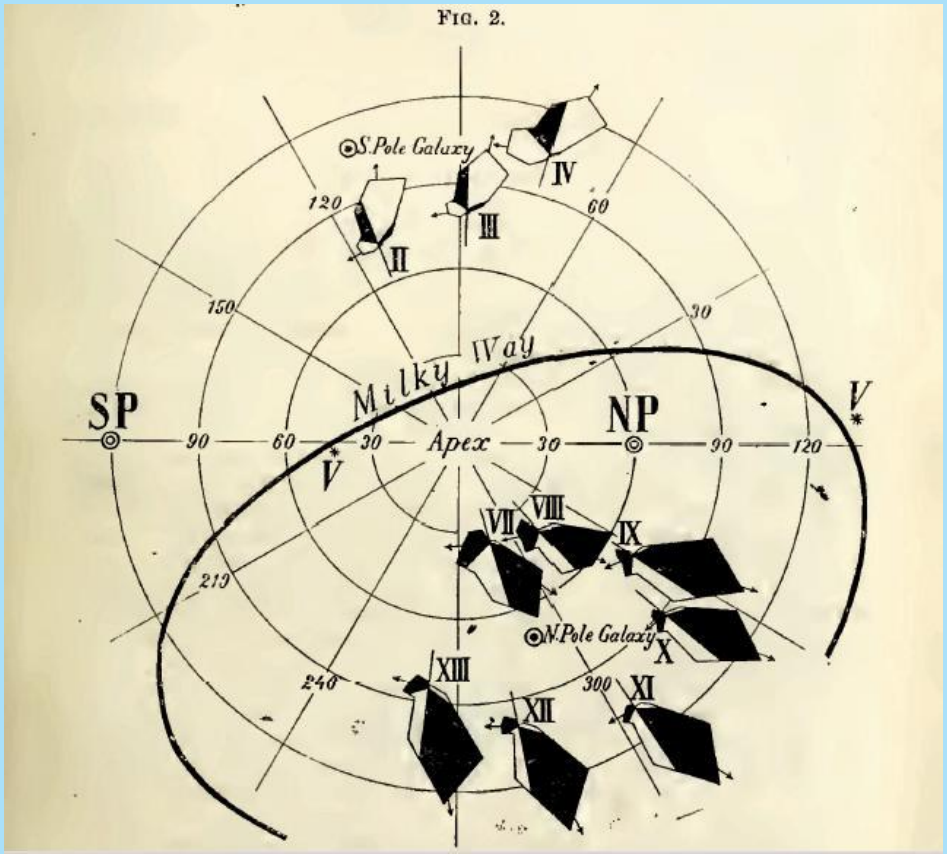
- Kapteyn Universe factor 2-3 too small, Shapley globular cluster system factor 2 too large.

Illustration III:

Star Streams



- In order to test the assumption of absense of preferred motions Kapteyn used proper motions.
- The sample was that of the 2400 Bradley stars, which covered 2/3 of the full sky.
- Kapteyn analysed these in 28 areas.



- Results plotted for 10 areas.
- Kapteyn found two streams with two vertices.
- These were about 125° apart and *not* in the Milky Way.
- After correction for solar motion, the vertices were 180° apart and *in* the Milky Way.

- Star Stream vertices at $l = 20°$ and $l = 200°$.
- From radial velocities 40 km/s relative to each other.
- He first presented that at a Congress during the 1904 Louisiana Purchase Exposition.
- The concept of Star Streams was quickly confirmed, a.o. by Arthur Eddington (1882–1944).
- However, Karl Schwarzschild (1873–1916) proposed the explanation by an anisotropic velocity ellipsoid.

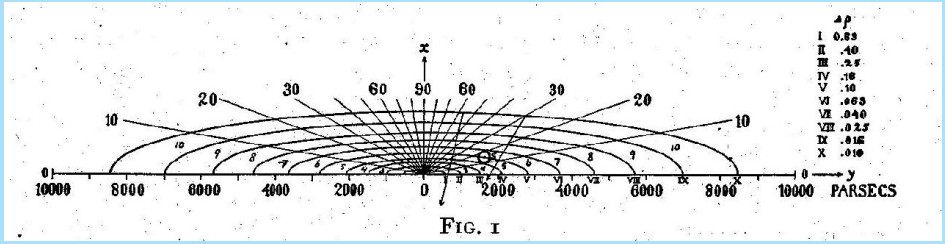


FIG. 1

- Kapteyn interpreted Star Streams as two opposite rotations in the Sidereal System.
- Vertical fit gave 'M/L', rotation then 20 km/s and Sun 650 pc from center.
- Stellar dynamics predicts velocity ellipsoid points to center-anticenter.
- Difference is exactly the Vertex Deviation!

Conclusions

- Kapteyn's parallax methods through meridian passage timing were amazingly accurate.
- Kapteyn's determinations of interstellar absorption from change of slope of luminosity function and of average colors of stars (reddening) with distance were close to the truth. However, Shapley's observations of globular clusters were believed to show that space was transparant everywhere.
- Kapteyn's determination of the vertices of the Star Streams were very accurate and consistent with later determinations of the Vertex Deviation.
- See www.astro.rug.nl/∼vdkruit.