Jacobus Cornelius Kapteyn (1851–1922)
Master of accuracy

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Background

Trigoniometric parallaxes

Interstellar Absorption

Star Streams

Conclusions
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.
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 1:

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 Streams

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

This really is amazingly good!!

Piet van der Kruit  
The Born Investigator of the Heavens
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!
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 absence 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 $125^\circ$ apart and *not* in the Milky Way.

After correction for solar motion, the vertices were $180^\circ$ apart and *in* the Milky Way.
▶ Star Stream vertices at $l = 20^\circ$ and $l = 200^\circ$.
▶ 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.
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 transparent 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.