The Fraunhofer Refractor at Tartu Observatory

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Abstract We shall give a short overview of the Fraunhofer Refractor at Tartu Observatory. We shall also describe some significant astronomical observations made with this telescope. The 9.”5 Fraunhofer Refractor (also known as the Great Dorpat Refractor) was installed at Tartu Observatory at the end of 1824 by F. G. W. Struve. It was the best and the most modern refracting telescope built up to that time, and was for many years the largest achromatic refractor in the world. Tartu Observatory was also one of the best equipped observatory in Europe during the years 1825–1840. The most important work done by F. G. W. Struve with the Fraunhofer Refractor was detecting about 3100 double stars and measuring the stellar parallax of Vega. Nowadays, the Fraunhofer Refractor has been reconstructed and it stands as a museum piece at Tartu Old Observatory.

Keywords Fraunhofer Refractor · F. G. W. Struve · Tartu Observatory · Parallax of Vega

1 Some historical points about Tartu Observatory and astronomy in Estonia

Astronomy as a science has a long tradition in Estonia that goes back to the beginning of the 19th century. Recently, a list was published of the ten most famous scientists at Tartu University through time and two of them were astronomers.

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Fig. 1 Fraunhofer Refractor at Tartu Old Observatory nowadays

- When Tartu University was reopened in 1802, the first professional astronomer–observer (Ernst Knorre) started his work.
- In May, 1808 the construction of Tartu Observatory began and it was opened in 1812.
- In 1814 regular observations were started by F. G. W. Struve.
- In 1817 the first volume of the Tartu Observatory Publications was published.
- In 1824 F. G. W. Struve obtained the 9.5 inch refractor for Tartu Observatory.
- In 1837 F. G. W. Struve compiled a catalogue of binary stars. He was also the first who measured the distance of Vega.
- In 1922 E. J. Öpik determined accurately the distance of the Andromeda Galaxy.
- In 1964 the new observatory was opened in Tõravere (about 20 km away from Tartu). Nowadays, this is the main and only astronomical institution in Estonia. At present, the old observatory in Tartu is called Tartu Old Observatory.
- In 1975 the 1.5–m reflector started working. It is the largest telescope in Estonia and in the Nordic Countries.

2 F. G. W. Struve in Tartu

F. G. W. Struve arrived at Tartu (Dorpat) for the first time in summer 1808. He was then only 15 years old. It is symbolic that in the spring of that year the foundation stone of Tartu Observatory had been laid and the construction started. Struve started studying philology at Tartu University and graduated with a gold medal at the end of 1810.

Fig. 2 F. G. W. Struve

By recommendation of G. F. Parrot, the Rector of Tartu University, Struve continued his studies in the field of mathematics and astronomy. He obtained both his master's and doctor's degrees at the end of October 1813.

In December 1813 Struve was nominated for the chairr of mathematics and astronomy at Tartu University and also as astronomer–observer of the Observatory. The scientific activity of Struve had begun.

The instrumentation of the new observatory was very poor; the only modern instrument was the Dollond transit instrument. One of the main tasks and aims of Struve was to obtain some new instruments for Tartu Observatory. For this purpose, he made several trips to Europe. Especially important was the trip to Germany in 1820 where he became acquainted with Joseph Fraunhofer and his works. Struve was very inspired with the building of a large refractor and he decided that Tartu Observatory should obtain this telescope.

He made a corresponding proposal to the Rector of University, Gustav Ewers, whose attitude was very positive towards this matter. Therefore, it was decided that the largest refractor in the world at that time should be installed in Tartu.

F. G. W. Struve was connected with Tartu and Tartu Observatory until spring 1839 when he left Tartu and became the Director of Pulkovo Observatory.

3 The Great Dorpat Refractor

In September 1824 Struve received a letter that the refractor had been completed and sent out to Tartu. The telescope itself was packed into 22 boxes and the journey from Munich to Tartu took nearly two months.

The telescope reached Tartu in November 10, 1824 and during the next couple of days was installed in the west hall of Observatory (at that time there was no dome). The first observation with the new telescope was made during the night of 17th of November. Struve was ecstatic about the quality and power of the new telescope. He commented that upon seeing the instrument, he was unable to determine *"which to admire most, the propriety of its construction or the incomparable optical power, and the precision with which objects are defined."*

Table 1 Main parameters of the Refractor

Diameter of objective:	9.5 inches ≡ 24.4 cm
Focal length:	4.34 m
Relative aperture:	f/18
Mounting:	Equatorial

The Fraunhofer Refractor had a very good achromatic objective which was the best at that time. The Refractor was noted not only for the high quality of its lenses but also for its mounting. This was the first of what became known as equatorial mounting. The telescope had a polar axis which was accurately aligned with the rotational axis of the Earth. The great advantage of an equatorial mounting was that the polar axis was continuously rotated by a clock mechanism. It made it possible to observe objects in the sky for a long time without manual correction of the telescope position.

In the next year (1825), a dome was constructed above the main building of the Observatory and at the end of November the Refractor was fitted into place below it where it remained until 1911. In 1825 Struve wrote a monograph about the Dorpat Great Refractor, as it was then called, where he described in details the refractor and its quality.

In 1993 the Fraunhofer Refractor was restored by Enno Ruusalepp, optician of Tartu Observatory. Since the restoration the Refractor is located in the east hall of Tartu Old Observatory where it stands as a museum piece.

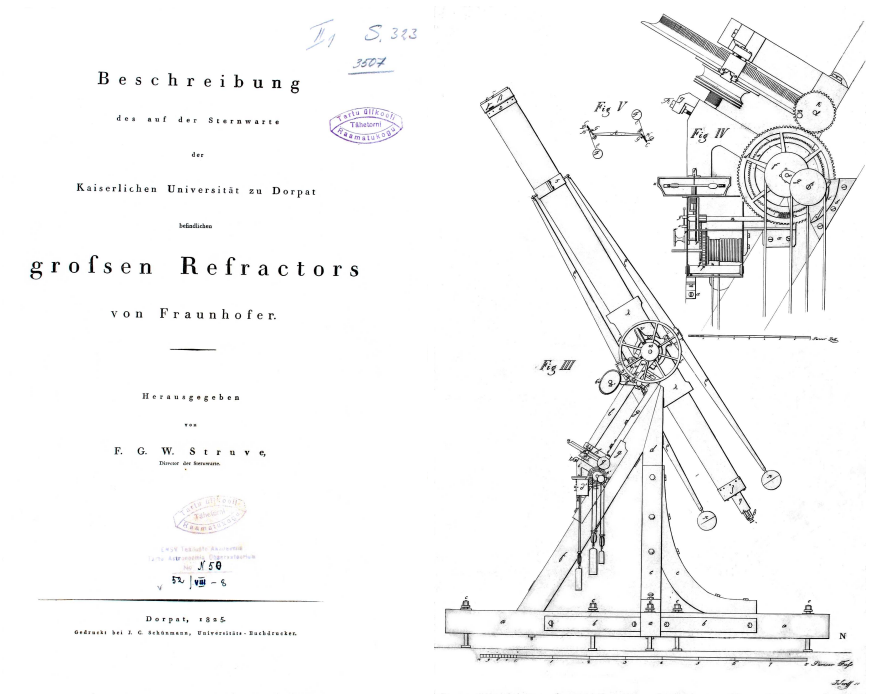
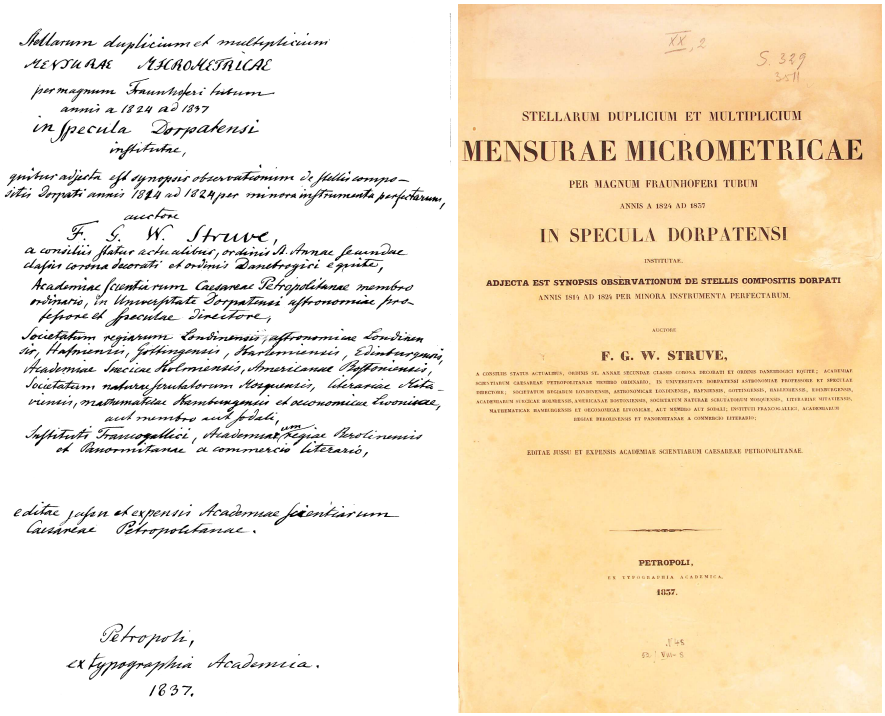


Fig. 3 The title page of Struve's book and figure of Fraunhofer refractor

Fig. 4 Some details and lenses of Fraunhofer Refractor during restoration

4 Observations with Fraunhofer Refractor

Let us see briefly which observations were made with the Fraunhofer Refractor. Since Struve had the best telescope of his time and he was an excellent observer, there were many very good observational results.



Stellarum duplicium et multiplicium
MENSURAE MICROMETRICAE
per magnum Fraunhoferi tubum
annis a 1824 ad 1837
in specula Dorpatensi
institutae,

quibus adjecta est synopsis observationum de stellis compositis Dorpati annis 1814 ad 1824 per minora instrumenta perfectarum,

auctore
F. G. W. Struve,
a consiliis status actualibus, ordinis S. Annae secundae classis corona ducorati et ordinis Danebrogici equite,
Academiae Scientiarum Caesareae Petropolitanae membro ordinario, in Universitate Dorpatensi astronomiae professore et specular Directore,
Societatum regiarum Londinensis, astronomicae Londinen sis, Hafniensis, Gottingensis, Karlsruhensis, Edinburgensis, Academiae Suecicae Holmiensis, Americanae Bostoniensis, Societatum naturae scrutatorum Norimbergensis, literariae Hatavicnsis, mathematicae Hamburgensis et oeconomicae Livonicae, aut membro aut sodali,
Instituti Francogallici, Academiarum Regiae Berolinensis et Panormitanae a commercio literario,

editae jussu et expensis Academiae Scientiarum Caesareae Petropolitanae.

Petropoli,
ex typographia Academica.
1837.

STELLARUM DUPLICIUM ET MULTIPLICIUM

MENSURAE MICROMETRICAE

PER MAGNUM FRAUNHOFERI TUBUM

ANNIS A 1824 AD 1837

IN SPECULA DORPATENSI

INSTITUTAE.

ADJECTA EST SYNOPSIS OBSERVATIONUM DE STELLIS COMPOSITIS DORPATI

ANNIS 1814 AD 1824 PER MINORA INSTRUMENTA PERFECTARUM.

AUCTORE

F. G. W. STRUVE,

A CONSILIIS STATUS ACTUALIBUS, ORDINIS ST. ANNAE SECUNDAE CLASSIS CORONA DECORATI ET ORDINIS DANNEBROGICI EQUITE; ACADEMIAE SCIENTIARUM CAESAREAE PETROPOLITANAE MEMBRO ORDINARIO, IN UNIVERSITATE DORPATENSI ASTRONOMIAE PROFESSORE ET SPECULAE DIRECTORE; SOCIETATUM REGIARUM LONDINENSIS, ASTRONOMICAE LONDINENSIS, HAFNIENSIS, GOTTINGENSIS, HASELTENSIS, EDINBURGENSIS, ACADEMIARUM SUECIAE HOLMIENSIS, AMERICANAE BOSTONIENSIS, SOCIETATUM NATURAE SCRUTATORUM NORIMBERGENSIS, LITERARIAE HATAVIENSIS, MATHEMATICAE HAMBURGENSIS ET OECONOMICAE LIVONICAE, AUT MEMBRO AUT SODALI; INSTITUTI FRANCOGALLICI, ACADEMIARUM REGIAE BEROLINENSIS ET PANORMITANAE A COMMERCIO LITERARIO;

EDITAE JUSSU ET EXPENSIS ACADEMIAE SCIENTIARUM CAESAREAE PETROPOLITANAE.

PETROPOLI,

EX TYPOGRAPHIA ACADEMICA.

1837.

Fig. 5 Title pages of "Micrometric Measurements of Double Stars"

4.1 Measurement of binary stars

No doubt the most important work of Struve was observations of binary stars. Observations of binary stars had already been started by Struve in 1814 using the Dollond transit instrument. Most observations were made with the Fraunhofer Refractor. Struve carried out a massive survey of binary stars from the north celestial pole to -15. He observed more than 120 000 stars up to magnitude 9. All these observations were carried out during 138 nights and 320 hours.

In 1827 he published the first catalogue consisting of 3112 binary and multiple stars. In 1837 he published a new catalogue (*"Micrometric Measurements of Double Stars"*) where the exact values of angular distances as well as magnitudes and colors for 2714 binary stars are given.

4.2 Parallax of Vega

Struve was also interested in the measurement of stellar distances. He spent a long time attempting to do this by using the Fraunhofer Refractor but the method of measurement of absolute coordinates of stars was not successful. In the middle of the 1830's Struve reached the idea that the best way to determine

the parallaxes is to measure the star position with respect to the very distant background stars.

Struve decided to measure the parallax of Vega which was quite bright and very well visible from Estonia. He measured the position of Vega with respect to the 11-magnitude star located within 43″ from Vega. Between November 1835 and December 1836 the position of Vega was measured 17 times. From these measurements Struve found that the parallax of Vega is $0''.125 \pm 0''.055$. This result is published in the monograph *"Micrometric Measurements of Double Stars"* (1837) and it was **the first time** that the parallax of star was accurately determined. Next year, in 1838, Bessel published his parallax measurements of 61 Cygni.

Unfortunately, some years later Struve had doubts about his results. He continued the observations and in 1840 he announced that the parallax is $0''.2613 \pm 0''.0254$. This result was twice the correct value.

4.3 Diameters of Jupiter satellites

Besides the binary stars observations Struve measured the diameters of four Jupiter satellites. In March 1826 Jupiter was in opposition to the Sun and it was a suitable time for the observations. Between March 7 and April 20, Struve observed the Jupiter satellites during eight nights.From these observations he determined the diameters of satellites. Note that his values correspond very well to currently known values, especially accurate was the diameter of Callisto. Furthermore, during the next century nobody managed to measure the diameters more exactly than Struve!

Table 2 Diameters of Jupiter Satellites (in km)

	Io	Europa	Ganymede	Callisto
Current value:	3643	3122	5262	4821
Struve's value:	3830	3437	5615	4803

4.4 Halley's comet

When Halley's comet was at its minimum distance from the earth in autumn 1835, it was very well visible from Tartu. From August 20 up to November 15, Struve observed Halley's comet during 36 nights. He measured the positions of the comet and the dimensions of its tail. Struve even saw the nucleus of comet through his Fraunhofer Refractor. In 1839 he published a special monograph which was dedicated to Halley's comet. This monograph also contained 9 illustrations about the comet as Struve saw it through the telescope.

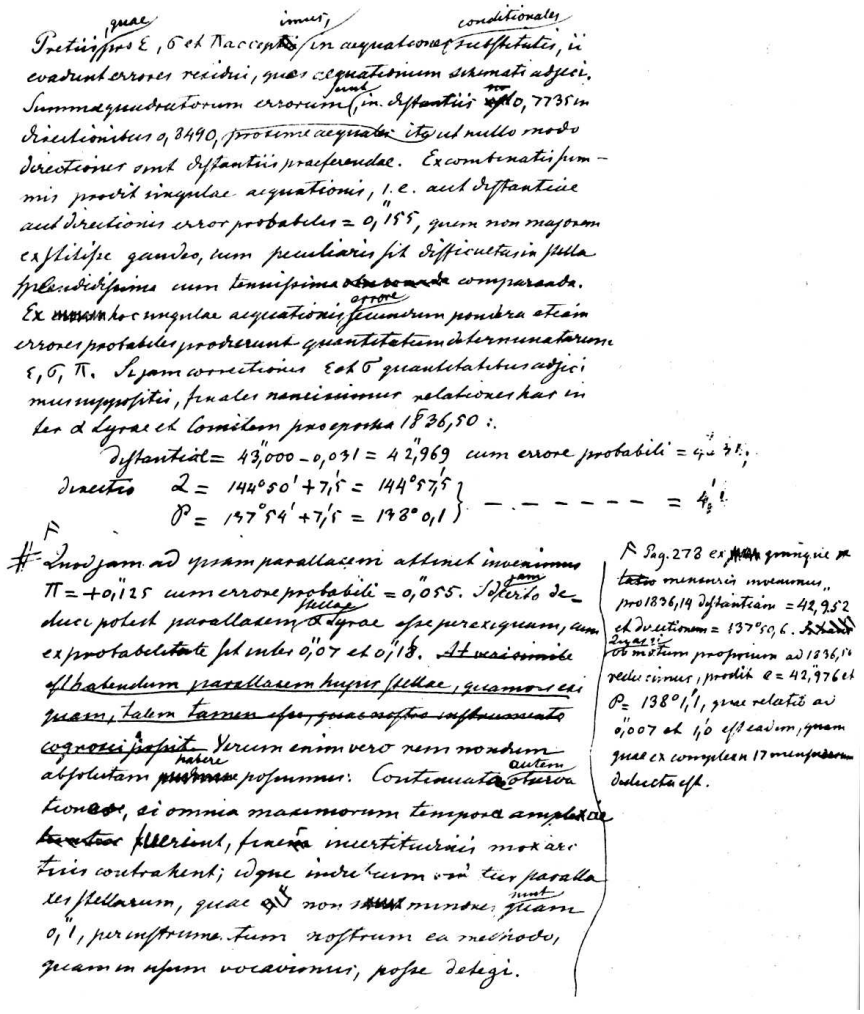


Fig. 6 The manuscript page about Vega parallax

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