Biography of Ole Rømer
(1644–1710)

Ole Rømer. Courtesy Rundetårn, the observatory and museum in Copenhagen.

Ole Christensen Rømer was a Danish astronomer who in 1676 made the first quantitative measurements of the velocity of light. In scientific literature alternative spellings, such as "Roemer", "Römer", and "Romer", are common.

Ole Rømer was born 25 September 1644 in Århus to a merchant and skipper Christen Pedersen and Anna Olufsdatter Storm, daughter of an alderman. Christen Pedersen had taken to using the name Rømer, which means that he was from Rømø, to disambiguate himself from a couple of other people named Christen Pedersen [1]. There are few sources on Ole Rømer until his immatriculation in 1662 at the University of Copenhagen, at which his mentor was Rasmus Bartholin who published his discovery of the double refraction of a light ray by Iceland spar (calcite) in 1668 while Rømer was living in his home. Rømer was given every opportunity to learn mathematics and astronomy using Tycho Brahe's astronomical observations, as Bartholin had been given the task of preparing them for publication [2].

Rømer was employed by the French government: Louis XIV made him teacher for the Dauphin, and he also took part in the construction of the magnificent fountains at Versailles.

In 1681, Rømer returned to Denmark and was appointed professor of astronomy at the University of Copenhagen, and the same year he married Anne Marie Bartholin, the daughter of Rasmus Bartholin. He was active also as an observer, both at the University Observatory at Rundetårn and in his home, using improved instruments of his own construction. Unfortunately, his observations have not survived: they were lost in the great Copenhagen Fire of 1728. However, a former assistant (and later an astronomer in his own right), Peder Horrebow, loyally described and wrote about Rømer's observations.

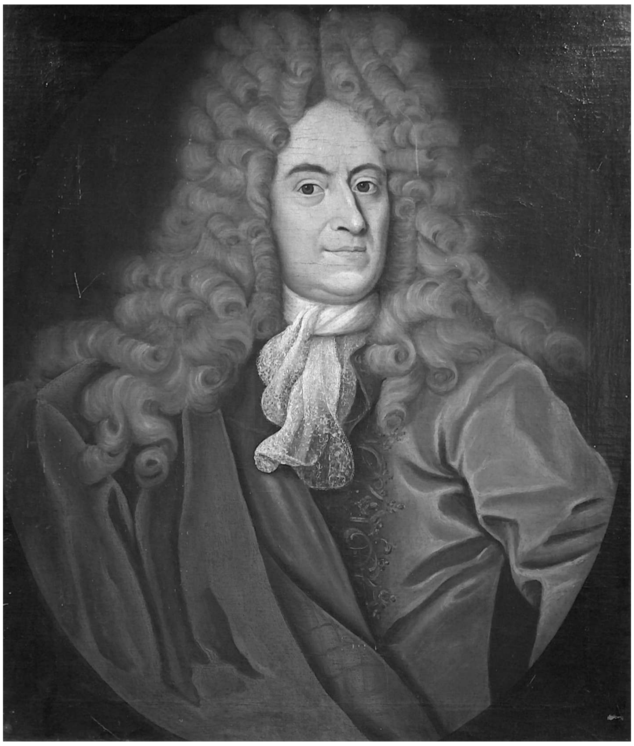
In Rømer's position as royal mathematician, he introduced the first national system for weights and measures in Denmark in May 01, 1683. Initially based on the Rhine foot, a more accurate national standard was adopted in 1698. Later measurements of the standards fabricated for length and volume show an excellent degree of accuracy. His goal was to achieve a definition based on astronomical constants, using a pendulum. This would happen after his death, practicalities making it too inaccurate at the time. Notable is also his definition of the new Danish mile. It was 24,000 Danish feet, which corresponds to 4 minutes of arc latitude, thus making navigation easier. In Norway and Sweden, this 4 minute geographical mile was mainly used at sea (sjømil), up to the beginning of the 20th century.

In 1700, Rømer managed to get the king to introduce the Gregorian calendar in Denmark-Norway — something Tycho Brahe had argued for in vain a hundred years earlier.

Rømer also developed one of the first temperature scales. Fahrenheit visited him in 1708 and improved on the Rømer scale, the result being the familiar Fahrenheit temperature scale still in use today in a few countries.

Rømer also established several schools for marine navigation in many Danish cities.

In 1705, Rømer was made the second Chief of the Copenhagen Police, a position he kept until his death in 1710. As one of his first acts, he fired the entire force, being convinced that the morale was alarm-



The second of two portraits of Rømer painted during his lifetime. Courtesy Rundetårn, Copenhagen.

ingly low. He was the inventor of the first street lights (oil lamps) in Copenhagen, and worked hard to try to control the beggars, poor people, unemployed, and prostitutes of Copenhagen. This was the start of a social reform.

In Copenhagen, Rømer made rules for building new houses, got the city's water supply and sewers back in order, ensured that the city's fire department got new and better equipment, and was the moving force behind the planning and making of new pavement in the streets and on the city squares.

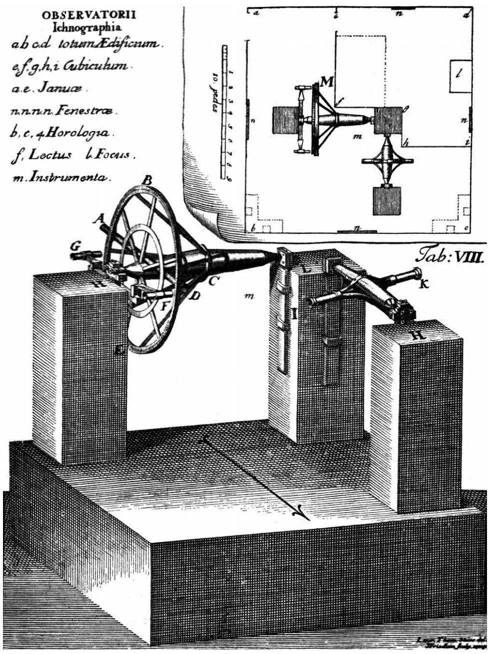
The determination of longitude is a significant practical problem in cartography and navigation. Philip III of Spain offered a prize for a method to determine the longitude of a ship out of sight of land, and Galileo proposed a method of establishing the time of day, and thus longitude, based on the times of the eclipses of the moons of Jupiter, in essence using the Jovian system as a cosmic clock; this method was not significantly improved until accurate mechanical clocks were developed in the eighteenth century. Galileo proposed this method to the Spanish crown (1616–1617) but it proved to be impractical, because of the inaccuracies of Galileo's timetables and the difficulty of observing the eclipses on a ship. However, with refinements the method could be made to work on land.

After studies in Copenhagen, Rømer travelled to the observatory of Uraniborg, then in ruins, on the island of Hven, near Copenhagen, in 1671. Over a period of several months, Jean Picard and Rømer observed about 140 eclipses of Jupiter's moon Io, while in Paris Giovanni Domenico Cassini observed the same eclipses. By comparing the times of the eclipses, the difference in longitude of Paris to Uranienborg was calculated.

Cassini had observed the moons of Jupiter between 1666 and 1668, and discovered discrepancies in his measurements that, at first, he attributed to light having a finite velocity. In 1672 Rømer went to Paris and continued observing the satellites of Jupiter as Cassini's assistant. Rømer added his own observations to Cassini's and observed that times between eclipses (particularly those of Io) got shorter as Earth approached Jupiter, and longer as Earth moved farther away. Cassini published a short paper in August 1675 where he states [3]:

> "This second inequality appears to be due to light taking some time to reach us from the satellite; light seems to take about ten to eleven minutes to cross a distance equal to the half-diameter of the terrestrial orbit."

Oddly, Cassini seems to have abandoned this reasoning, which Rømer adopted and set about buttressing in an irrefutable manner, using a selected number of observations performed by Picard and himself between 1671 and 1677. Rømer presented his results to the French Academy of Sciences, and it was summarized soon after by an anonymous reporter in a short paper, *Démonstration touchant le mouvement de la lumière trouvé par M. Roemer de l'Académie des Sciences*, published on December 7, 1676, in *Journal des Sçavans.* Unfortunately the paper bears the stamp of the reporter failing to understand Rømer's presentation, and as the reporter resorted to cryptic phrasings to hide his lack of understanding, he obfuscated Rømer's reasoning in the process [4]. However only interpretation of the presented numbers makes sense: As forty orbits of Io — each of 42.5 hours — observed as the Earth moves towards Jupiter are in total 22 minutes shorter than forty orbits of Io observed as the Earth moves away from Jupiter, and Rømer



The first Meridian Circle constructed by Rømer in 1704 at his Countryside Observatory near Copenhagen. Courtesy Rundetårn, Copenhagen.

concluded from this that light will travel the distance, which the Earth travels during eighty orbits of Io, in 22 minutes [4]. This makes it possible to calculate the strict result of Rømer's observations: The ratio between the velocity of light of the velocity with which the Earth orbits the Sun, which becomes 80×42.5 hours / 22 minutes $\approx$ 9,300. In comparison to the result of Rømer's calculation, the modern numerical value is circa 299,792 km $\times$ sec^{-1} / 29.8 km $\times$ sec^{-1} $\approx$ 10,100 [5].

Rømer neither calculated this ratio, nor did he give a value for the velocity of light. However, many others calculated a velocity from his data, the first being Christiaan Huygens; after corresponding with Rømer and eliciting more data, Huygens deduced that light travelled $16\frac{2}{3}$ Earth diameters per second, misinterpreting Rømer's value of 22 minutes as the time in which light traverses the diameter of the Earth's orbit [6].

Rømer's view that the velocity of light was finite was not fully accepted until measurements of the so-called aberration of light were made by James Bradley in 1727.

In 1809, again making use of observations of Io, but this time with the benefit of more than a century of increasingly precise observations, the astronomer Jean Baptiste Joseph Delambre reported the time for light to travel from the Sun to the Earth as 8 minutes and 12 seconds. Depending on the value assumed for the astronomical unit, this yields the velocity of light as just a little more than 300,000 kilometres per second.

A plaque at the Observatory of Paris, where the Danish astronomer happened to be working, commemorates what was, in effect, the first measurement of a universal quantity made on this planet.

In addition to inventing the first street lights in Copenhagen, Rømer also invented the Meridian circle, the Altazimuth and the Passage Instrument.

The Ole Rømer Museum is located in the municipality of Høje-Taastrup, Denmark, at the excavated site of Rømer's observatory Observatorium Tusculanum at Vridsløsemagle. The observatory operated until about 1716 when the remaining instruments were moved to Rundetårn in Copenhagen. There is a large collection of ancient and more recent astronomical instruments on display at the museum. Since 2002 this exhibition is a part of the museum Kroppedal at the same location.

Rundetårn (spelled as Rundetaarn), or the Round Tower, is the observatory and museum for astronomical artifacts at the historical centre of Copenhagen, built in 1637–1642. The currently working observatory there was equipped in the 20th century. The author is thankful to Rundetårn, where he maintains the Rømer memorial exhibition and the artifacts, for the permission to use the portraits of Rømer and the lithograph showing his Meridian Circle, in this publication.

Erling Poulsen

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1. Friedrichsen P. and Tortzen C. G. Ole Rømer — Korrespondance og afhandlinger samt et udvalg af dokumenter. C. A. Reitzels Forlag, Copenhagen, 2001, page 16.
2. Friedrichsen P. and Tortzen C. G. *Ibidem*, pages 19–20.
3. Cassini G. D. Cette seconde inégalité paraît venir de ce que la lumière emploie quelques temps à venir du satellite jusqu'à nous, et qu'elle met environ dix à onze minutes à parcourir un espace égal au demi-diamètre de l'orbite terrestre. *Journal des Sçavans*, tome 4, August, 1675.
4. Teuber J. Ole Rømer og den bevaegede Jord — en dansk førsteplads? In: *Ole Rømer — videnskabsmand og samfundstjener*, edited by Friedrichsen P., Henningsen O., Olsen O., Thykier C., and Tortzen C. G., Gads Forlag, Copenhagen, 2004, page 218.
5. Knudsen J. M. and Hjorth P. G. Elements of Newtonian mechanics. 2nd edition, Springer Verlag, Berlin, 1995, page 367.
6. Huygens C. Treatise on light. January 08, 1690. Translated into English by Silvanus P. Thompson, stored at *Project Gutenberg*.

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