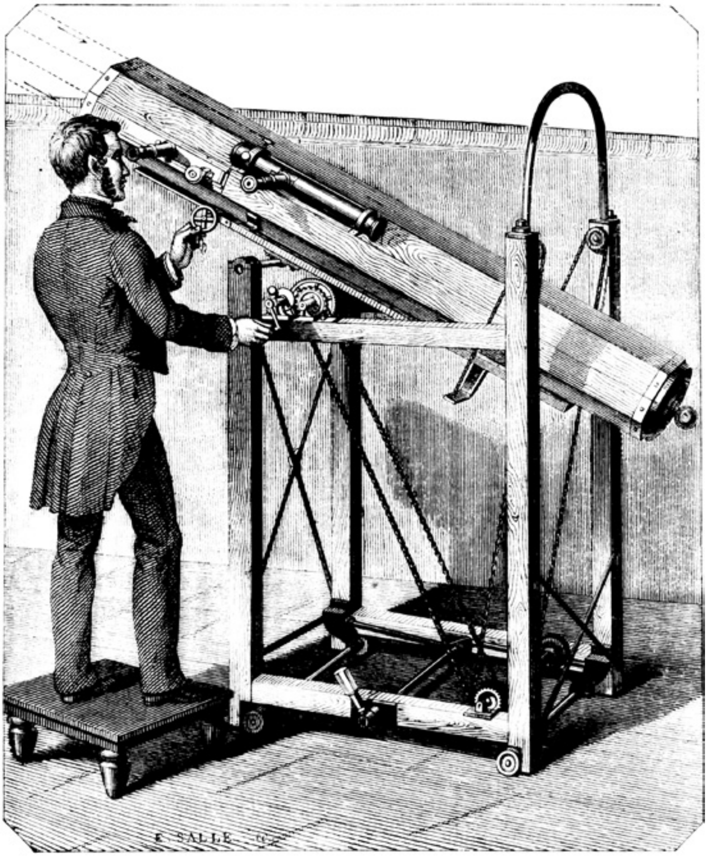
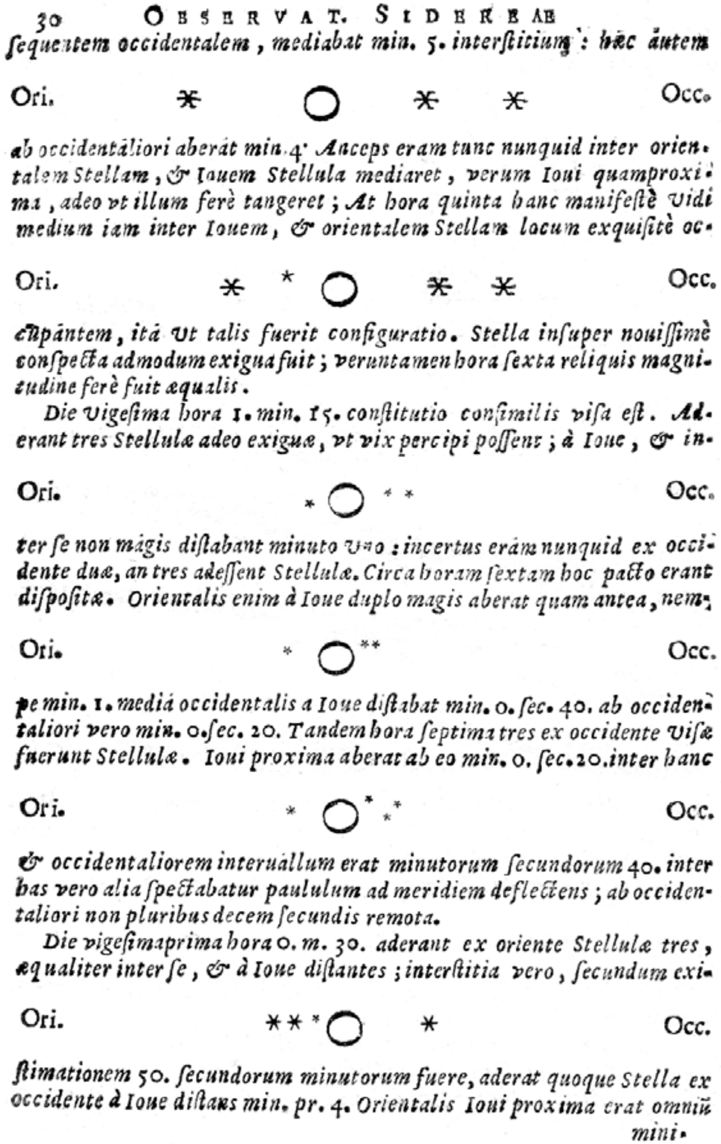
Observing the sky

A brief introduction to astronomy and presentation of instruments from the first Geneva Observatory





30 OBSERVAT. SIDEREAE

ſequentem occidentalem, mediabat min. 5. interſtitium: hæc autem

Ori. * O * * Occ.

ab occidentaliori aberat min. 4. Anceps eram tunc nunquid inter orientalem Stellam, & Iouem Stellula mediaret, verum Ioui quamproxima, adeo vt illum ferè tangeret; At hora quinta hanc manifeſtè vidi medium iam inter Iouem, & orientalem Stellam locum exquiſitè oc-

Ori. * * O * * Occ.

cupantem, ita vt talis fuerit configuratio. Stella inſuper nouiſſimè conſpecta admodum exigua fuit; veruntamen hora ſexta reliquis magnitudine ferè fuit æqualis.

Die vigeſima hora 1. min. 15. conſtitutio conſimilis viſa eſt. Aderant tres Stellulæ adeo exiguæ, vt vix percipi poſſent; à Ioue, & in-

Ori. * O * * Occ.

ter ſe non magis diſtabant minuto vno: incertus eram nunquid ex occidente duæ, an tres adeſſent Stellulæ. Circa horam ſextam hoc pacto erant diſpoſitæ. Orientalis enim à Ioue duplo magis aberat quam antea, nem-

Ori. * O ** Occ.

pe min. 1. media occidentalis a Ioue diſtabat min. 0. ſec. 40. ab occidentaliori vero min. 0. ſec. 20. Tandem hora ſeptima tres ex occidente viſæ fuerunt Stellulæ. Ioui proxima aberat ab eo min. 0. ſec. 20. inter hanc

Ori. * O * * Occ.

& occidentaliorem interuallum erat minutorum ſecundorum 40. inter has vero alia ſpectabatur paululum ad meridiem deflectens; ab occidentaliori non pluribus decem ſecundis remota.

Die vigeſimaprima hora 0. m. 30. aderant ex oriente Stellulæ tres, æqualiter inter ſe, & à Ioue diſtantes; interſtitia vero, ſecundum exi-

Ori. * * * O * Occ.

ſtimationem 50. ſecundorum minutorum fuere, aderat quoque Stella ex occidente à Ioue diſtans min. pr. 4. Orientalis Ioui proxima erat omnium mini-

Observation of Jupiter's moons
Sidereus Nuncius, Galileo, Bologna 1655, Library of the Musée d'histoire des sciences

Cover : *Newton's telescope*
Cours de physique, Ganot, Paris, 1866, Library of the Musée d'histoire des sciences

Galileo, the Museum and the Observatory in Geneva

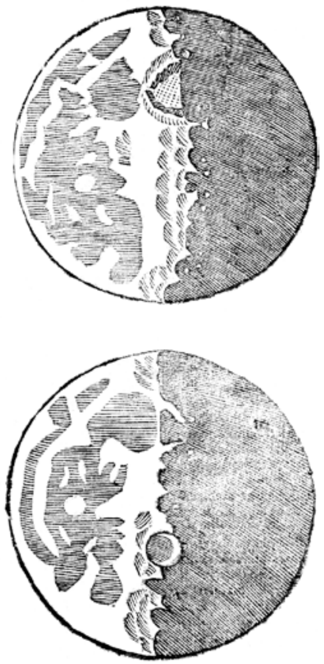
This booklet sets out to introduce and explain the functions of some of the instruments used in the first Geneva Observatory and now conserved in the Musée d'histoire des sciences of Geneva. It introduces the reader to some of the basic principles of astronomy, a subject which was in the spotlight in 2009, the International Year of Astronomy. Why 2009? It was the 400th anniversary of Galileo's first observations of the sky using a telescope.

Astronomical telescope
Cours de physique, Ganot, Paris, 1866, Library of the Musée d'histoire des sciences

The birth of modern astronomy

At the beginning of the 17th century, Dutch opticians invented the first telescope by mounting a corrective lens at each end of a tube, the length of which could be varied. The invention quickly spread through Europe. In 1609, in Padua, Italy, Galileo made his own telescope equipped with glass lenses which he had cut and polished himself. Rather than pointing his telescope to the earth, he raised it to the sky. In so doing, he made a series of discoveries which radically challenged the geocentric vision of the universe which prevailed at the time.

Galileo observed that the planet Jupiter is circled by four moons. He also noted that the appearance of Venus changes over time from a crescent to a full disc, as does the moon as it circles the earth. These two observations appeared to prove that other celestial bodies, namely Jupiter and the sun, around which Venus seemed to rotate, also had moons. Finally, by examining the moon, Galileo discovered that it was not as round and as smooth as had been thought. On the contrary, it appeared to be scattered with craters and steep ridges like many terrestrial landscapes.

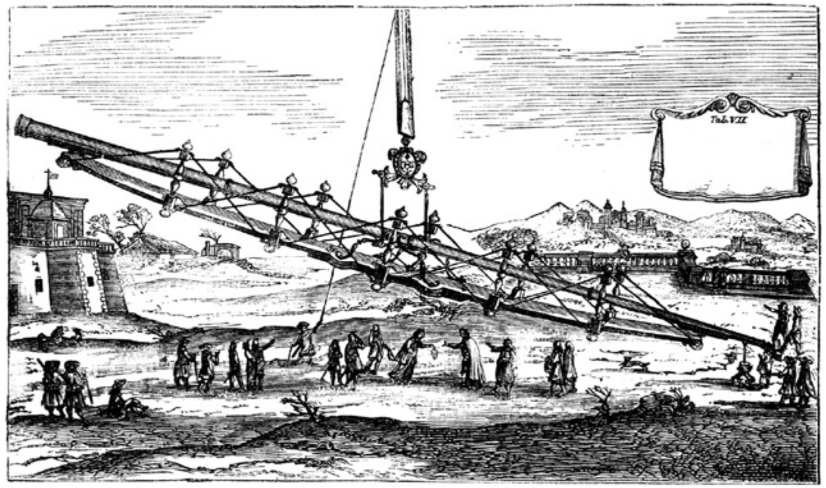


Drawings of the moon
Galileo, Sidereus Nuncius, Bologna, 1655
Library of the Musée d'histoire des sciences

Mirrors take the place of lenses

The astronomical telescopes available in the 17th century were difficult to use. While the stars were indeed magnified through the eyepiece, the image was often blurred and surrounded by a coloured halo. This was caused by light dispersion through the plain glass of the objective. In order to reduce distortion, makers were forced to construct tubes several metres long which were difficult to manipulate.

Scientists began to think about other techniques they might use for improving observations of the sky. In his 1611 work, Dioptrica, Johanes Kepler (1571-1630) suggested that one of the lenses could be replaced by a series of mirrors to avoid chromatic distortion. The first true telescope was constructed by Isaac Newton (1643-1727) and presented to the Royal Society in London in 1671. Barely 20 cms long, his instrument is fitted with a primary concave mirror and a second flat mirror set at 450 to the axis of the tube. The observer looks through the eye lens on the side of the tube.

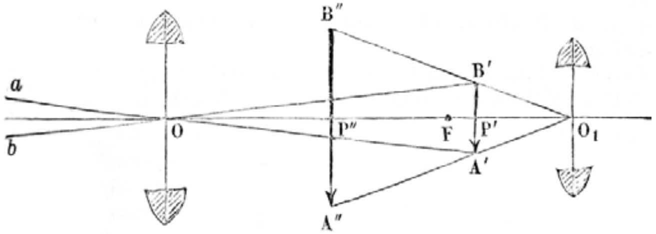


Large 17th century telescope
Astronomie populaire, Camille Flammarion, Paris, 1885,
Library of the Musée d'histoire des sciences

Optics

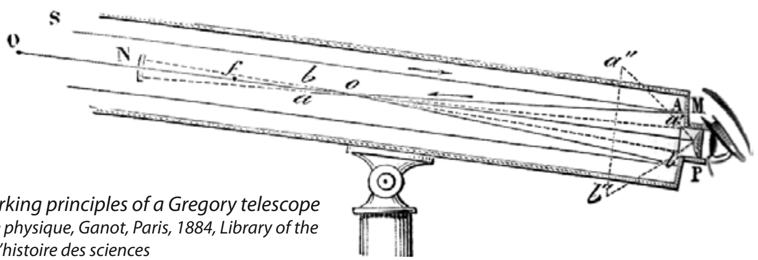
Refracting telescope and reflecting telescope

A schematic description of a refracting telescope: it consists of a closed tube equipped at each end with a glass lens (see sketch). The objective (O) collects the light emitted by the star and concentrates it as an image (A'B') which the eye piece (O) located close to the eye further magnifies into another image (A"B"). In telescopes used for terrestrial observation two other lenses are added to correct the image produced by the objective. Nowadays, lenses are usually made of several different types of glass to avoid the optical distortion resulting from chromatic aberration.



The working principles of a refracting telescope
Traité de physique, Ganot, Paris, 1884, Library of the Musée d'histoire des sciences

The reflecting telescope (a Gregory telescope is shown) is equipped with two mirrors. The first (M), mounted at the base of the tube next to the eye piece, receives light rays from the star and sends them to the second concave mirror (N) placed in the axis of the tube at the opposite end. The light, reflected a second time, returns towards the base of the tube where it forms an image (a'b') which is magnified by the eye piece (a"b").



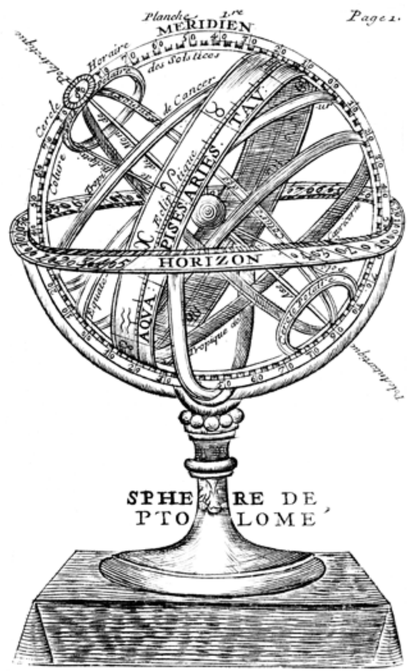
The working principles of a Gregory telescope
Traité de physique, Ganot, Paris, 1884, Library of the Musée d'histoire des sciences

Coordinates of a location

Positioning on the earth and in the sky

We can locate our position on the earth with the help of two geographical coordinates: latitude and longitude. **Latitude** indicates the angular distance (north or south) of a point from the terrestrial equator. **Longitude** describes the angular distance (east or west) between a point and the reference meridian. The reference meridian is an imaginary line joining the two poles and passing through Greenwich near London.

In order to find the position of stars in the sky, astronomers use a similar system of celestial coordinates founded on the ancient geocentric vision of the world in which the sky is seen as a transparent sphere turning around a fixed point (the Polar star), the interior surface of which is encrusted with stars. The angle between the direction of a star on the sphere and the celestial equator (the projection of the terrestrial equator onto the celestial sphere) is called the **declination** (equivalent to terrestrial latitude). Similar to terrestrial longitude, the **right ascension** is the angular distance between a star and a celestial reference meridian.



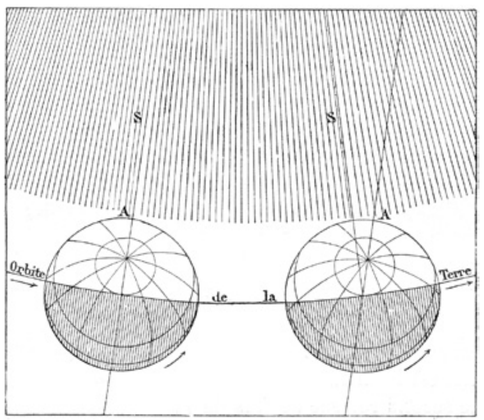
The Ptolemy Sphere, a geocentric universe
L'usage des globes céleste et terrestre et des sphères, Bion, Paris, 1717, Geneva Library

Sun time and star time

Our daily life is based on a 24-hour day, that is, the duration between two consecutive middays, or the time taken by the sun to apparently make one full passage around the earth. In reality, however, it is the earth which rotates and it does so irregularly. It accelerates and decelerates with such frequency that a solar day is rarely equal to 24 hours (see page 12).

The star day, invariably 23 hours, 56 minutes and 4 seconds, is much more precise and consistent. It is the length of time which separates two consecutive passages of a star (other than the sun) over the meridian of the observation point.

That 4-minute difference between the solar and star day is explained by the fact that the earth rotates on itself but also around the sun. The diagram below showing the earth in orbit around the sun explains this. To the left, it is midday at the terrestrial meridian (A) which directly faces the sun's light (S). The following day, after a complete rotation of the earth, (A) is no longer directly facing the sun which appears to have retreated. This is because of the movement of the earth on its orbit. In order to be midday again at (A), the earth must turn for about another 4 minutes.



The difference between the length of a day and the time taken to complete one rotation of the earth
Astronomie populaire, Camille Flammarion, Paris, 1885, Library of the Musée d'histoire des sciences

Observatories for sailors

Towards the end of the 17th century the first large-scale astronomical observatories were built in Europe, notably in Paris, France and in Greenwich, England. Their construction was partly motivated by an urgent need : the problem of identifying longitude at sea. At the time, ships could not calculate their location with precision because they were not able to determine their longitude. This lead to great loss of both ships and human lives.

Astronomers embarked on a review of phenomena which were easy to observe from the bridge of a ship : eclipses of Jupiter's moons, the position of the moon in relation to certain prominent stars, etc. They then produced ephemerides, tables showing the hours at which selected events occur in relation to a given reference point (Paris for the French, London for the English). By noting the local time at which the events occurred and comparing them with the reference hours in the tables, sailors were finally able to calculate the longitude of their position.

As the calculations involved were time-consuming and tedious, celestial navigation did not survive the invention of an instrument in the 18th century which accurately measured longitude and revolutionised the sailor's life : the marine chronometer.

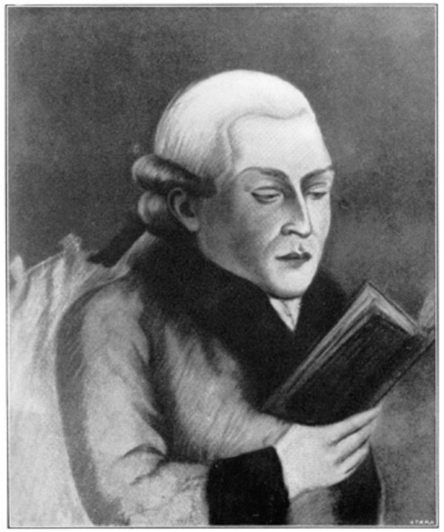
Sailor using a sextant
The applications of Physical Forces, Guillemin, London, 1877, Library of the Musée d'histoire des sciences

The distance between the earth and the sun

Mallet and the transit of Venus

Born in 1740 in Geneva, Jacques-André Mallet, the founder of the Geneva Observatory, studied mathematics in Geneva and then in Basel where he was a student of Daniel and Jean Bernoulli. In 1765 he travelled to England and France and became a friend of Lalande and Maskeline who introduced him to astronomy. Under their patronage, he took part in the observations of the transit of Venus on 3 June 1769. This extremely rare event mobilised scholars worldwide. According to the calculations of the great astronomer Halley in 1716, the time taken for the passage of Venus across the sun from different terrestrial observation points, should lead to the accurate determination of the earth-sun distance, the fundamental unit of measurement of the solar system.

Commissioned by Catherine II of Russia and the St Petersburg Academy of Sciences, Mallet left Geneva in 1768 to observe the transit in Russian Lapland in the company of his friend and colleague, Jean-Louis Pictet. The expedition was dogged by bad luck: Pictet's observations were washed out by rain while Mallet only saw part of the event because of cloud cover. Other astronomers were luckier. Thanks to their measurements, the distance between the earth and the sun was estimated to be 150 million kilometres, not far off the official figure of 149, 597, 870.691 applied today.



Jacques André Mallet (1740-1790)
Collection Musée d'histoire des sciences

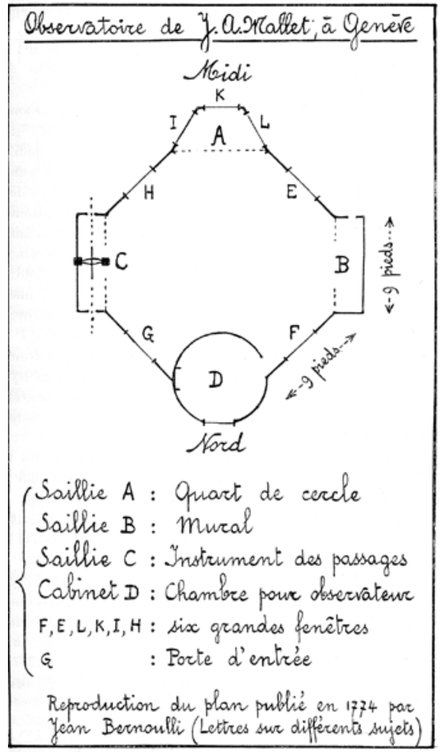
The birth of astronomy in Geneva

The first observatory

In 1772, after returning to Geneva from his Russian expedition, Mallet received permission to build an observatory (octagonal in form) in the Old Town opposite the College and Academy of Geneva (now Calvin College). Mallet installed his own instruments some of which are on display at the History of Science Museum. He spent the rest of his life examining the sky and sending his observations to the Academies of Science in Paris and London for which he had become a correspondent. Mallet died at the end of 1790.

Mallet's successor, the Geneva physicist Marc-Auguste Pictet, extended the activities of the Observatory to include chronometry and meteorology. In particular, he contributed to the establishment of the meteorological station at the Grand Saint-Bernard where measurements were taken by the monks of the hospice.

By 1830, the observatory was in a dilapidated state and was demolished and reconstructed a few hundred metres away opposite the Art and History Museum. After modernisation, it was moved to its current location in Sauverny in the north of the canton in 1966.

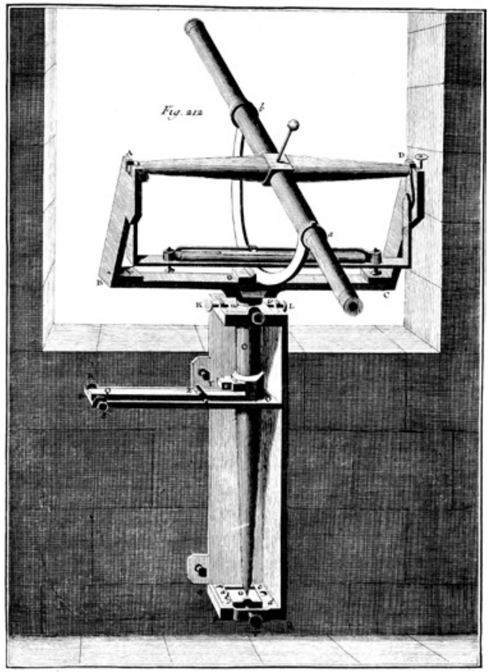


The plan of the first Observatory
Lettres sur différents sujets, Bernoulli, Berlin, 1777, Geneva Library

Meridian telescope
Mapping the sky

Mallet took advantage of his visit to England, which was renowned for the quality of its scientific instruments, to acquire celestial mapping equipment (the positions of stars and planets) for the Geneva Observatory. He installed a meridian (or transit) telescope in the east wing of the building in order to capture the moment when a star crossed the meridian. This type of telescope could only view the meridian of the location in a north-south plane.

The duration of the passage required to calculate the right ascension (celestial longitude) of the star, is given by an astronomical clock (Shelton's transit clock, or Lepaute's pendulum which is exhibited at the Museum). The declination (celestial latitude) of the star is measured with the help of two quadrants (quarts-de-cercle), a telescope with instruments attached and a quadrant (secteur) scaled in 900 degrees



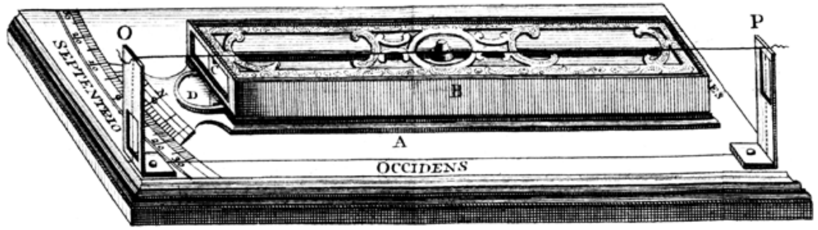
Lunette méridienne ou instrument des passages
Diderot et Alembert, Encyclopédie, Paris 1767, Geneva Library of Art and Architecture

Declination compass
Magnetic north and geographical north

From the end of the 16th century it was known that magnetic north and geographical north were rarely the same. At sea, sailors noticed that the compass hand did not always point north-south along the meridian where the ship was located. The difference between the two, also called the declination, may even vary widely from place to place. During the 17th century sailors produced marine charts showing longitude and variations of declination in order to determine their position.

In Europe, the first systematic measurement of declination began in the 18th century under the aegis of Prince-Elector Karl Theodor de Hesse, Duke of Bavaria and founder of the first International Meteorological Society. From 1780, he sent free compasses manufactured in Germany with identical declinations to various European institutes and academies of science including the Geneva Observatory.

The compass must first be oriented north-south with the help of a wire (no longer attached) which links the tops of the two metal sighting plates. At the solar midday, the shadow cast by the wire falls over the line engraved between the two plates.



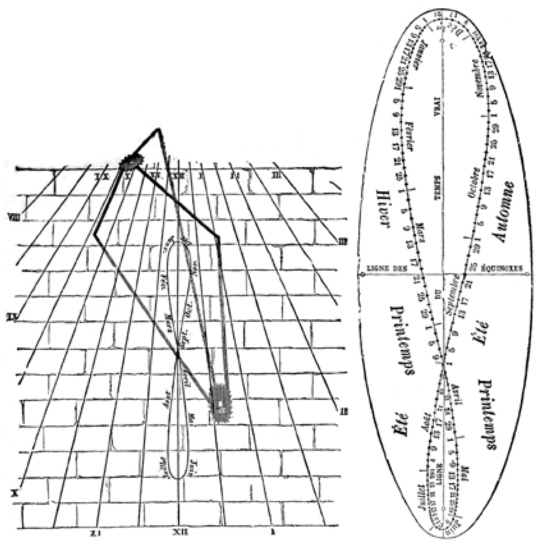
Declination compass
Brander, Beschreibung eines magnetischen declinatorii …., Augsburg, 1779, Library of the Musée d'histoire des sciences

Apparent midday and mean midday

Solar time and mechanical time

By the end of the 18th century, clocks had become precise enough to show that the length of a solar day (based on the apparent movement of the sun in the sky) varied over a year and that it rarely equalled 24 hours. However, until the beginning of the 19th century, the only way of adjusting watches and clocks was based on observation of the sun's passage over the local meridian at the real solar mid-day. As the length of time between successive real mid-days fluctuated, watches and clocks had to be adjusted daily.

Setting out to help watchmakers, in 1778 Mallet recalculated and redesigned the meridian trace (a kind of metal sighting attachment which allowed the sun's rays to pass through at mid-day). He placed the instrument on the facade of St Pierre's cathedral so the daily local mean mid-day (accurate to within 4 seconds) was shown and not the apparent mid-day. Solar time was finally abandoned in Geneva on 15 April 1821. On that date, the official mean hour was applied and became the standard for all the clocks in the town.



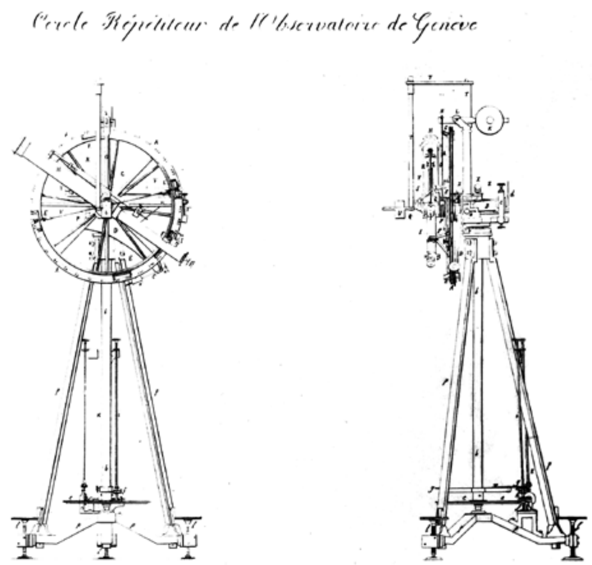
Sundial showing mean time meridian
Astronomie populaire, Camille Flammarion, Paris, 1885
Library of the Musée d'histoire des sciences

Repeating meridian circle

Fixing Geneva's latitude

Between 1825 and 1828, Jean-Alfred Gauthier, astronomer and director of the Geneva Observatory, carried out a series of measurements of the altitudes of the meridians of a variety of stars. This work led to the calculation of Geneva's latitude, matching the definitive figure very closely (46011'59".4) and laying the basis for map making. The previous calculations of latitude from astronomical observations made by Jacques Mallet and Marc-Auguste Pictet, had given a latitude range of 46°12' to 46°11'32".

Gauthier achieved his results by using a repeating meridian circle, newly acquired from the well-known Parisian maker Henri-Prudence Gambey. The instrument, 20-inches in diameter (about 50 centimetres) was much more efficient than the quadrant used by Mallet and Pictet. It consisted of a scaled circle equipped with an astronomical telescope with a viewing lens. The repeating circle allowed several readings of the height of the same star without having to return to zero each time. This also helped to reduce measurement errors.



Repeating circle from the Geneva Observatory
Anonymous, Geneva 19th century

The Observatory, the time keeper

At the Geneva Observatory, as at other observatories in the world, clocks have always been part of the basic equipment along with telescopes. Some of them measured sidereal time, that is the time according to the apparent movement of stars in the sky, which is necessary for pinpointing the position of a star in the celestial sphere. Other clocks calibrated with the mean time (the time shown on watches) supplied the reference hour to the public and particularly to clock and watch makers who could thus check the accuracy of their timepieces.

One of the Observatory's tasks was to contribute to the development of Geneva precision watch making, a pillar of the local economy. From 1842, the Observatory made available a depot for monitoring precision clocks and watches. Their performance was compared with a reference clock. Competitions were organised to identify the most accurate pieces produced.

22

1er prix. Chronomètre n° 64025 : MM. J.-M. BADOLLET & Ce. Régleur : M. F. VIDONNE

Température.	Date. 1872	État du chronomètre sur le temps moyen.	Marche diurne.	Variation.
		Plat.		
°		s	s	s
+19,9	Sept. 2	−1m 4,0		
20,0	3	4,3	−0,3	+1,0
20,5	4	3,6	+0,7	0,0
21,4	5	2,9	+0,7	−0,1
22,1	6	2,3	+0,6	+0,1
22,5	7	1,6	+0,7	−0,1
22,6	8	1,0	+0,6	−0,1
22,5	9	0,5	+0,5	0,0
22,5	10	0,0	+0,5	−0,2
22,5	11	−0m 59,7	+0,3	+0,2
22,2	12	59,2	+0,5	−0,2
22,4	13	58,9	+0,3	0,0
22,4	14	58,6	+0,3	0,0
22,3	15	58,3	+0,3	−0,6
22,7	16	58,6	−0,3	
+21,90				
		Pendu.		
+22,0	17	−0m 59,3		
21,8	18	59,4	−0,1	0,0
22,2	19	59,5	−0,1	0,0
20,8	20	59,6	−0,1	+0,5
19,4	21	59,2	+0,4	+0,8
17,5	22	58,0	+1,2	−0,7
16,5	23	57,5	+0,5	−0,4
16,5	24	57,4	+0,1	+0,4
16,7	25	56,9	+0,5	−0,3
15,7	26	56,7	+0,2	+0,3

Température.	Date. 1872	État du chronomètre sur le temps moyen.	Marche diurne.	Variation.
		Pendu.	(suite)	
°		s	s	s
+14,8	Sept. 27	−0m 56,2	+0,5	+0,1
14,8	28	55,6	+0,6	−0,7
15,6	29	55,7	−0,1	+0,3
16,7	30	55,5	+0,2	−0,2
17,0	Octob. 1	55,5	0,0	+0,4
17,6	2	55,1	+0,4	
+17,85				
		Plat.		
+17,2	3	−0m 55,4		
16,9	4	55,6	−0,2	0,0
15,7	5	55,8	−0,2	0,0
15,2	6	56,0	−0,2	0,0
14,2	7	56,2	−0,2	0,0
13,9	8	56,4	−0,2	
+15,52				
+31,52		**Étuve.**	−1,0	
13,9	9	−0m 57,4		
13,6	10	57,6	−0,2	−0,3
13,2	11	58,1	−0,5	−0,1
13,0	12	58,7	−0,6	+0,5
12,4	13	58,8	−0,1	−0,5
12,0	14	59,4	−0,6	−1,3
10,8	15	−1m 1,3	−1,9	+0,4
10,2	16	2,8	−1,5	
+12,39				

1re période du 2 au 16 septembre 1872, température +21,90 plat. Marche moyenne +0s,39
2me » du 17 sept. au 2 octob. » » 17,85 pendu. » +0,28
3me » du 3 au 8 octobre » » 15,52 plat. » −0,20
4me » du 8 au 9 octobre » étuve 31,52 plat. » −1,00
5me » du 9 au 16 octobre » température 12,39 plat. » −0,77

4me période — (3e + 5)/2 périodes ; différence tempér. +17°,57 ; différence de marche −0s,515
Erreur de compensation à ± 1° ∓0s,03

1re période, marche réduite à +17°,0 plat. Marche moyenne +0,53
2me » » » » » pendu. » +0,31
3me » » » » » plat. » −0,24
5me » » » » » plat. » −0,91
Marche moyenne, plat (périodes 1, 3 ,5) −0s,31. Marche moyenne, pendu (période 2) +0s,31
Différence de marche, pendu − plat + 0s,62
» » » après et avant pendu − 0s,77
» » » après et avant l'étuve − 0s,57
Variation moyenne de marche du 2 septembre au 16 octobre ± 0s,28

First prizes from 1876-1877
Coucours de chronométrie,
Observatoire de Genève,
1891, Library of the Musée d'histoire des sciences

Exoplanets and quasars

Installed since 1966 at Sauverny in the north of the Canton of Geneva, the Geneva Observatory has made a name for itself over recent years through its frequent discoveries of extra solar planets. The first was identified in 1995 by Michel Mayor and Didier Queloz. Research at Sauverny also includes other areas of contemporary astrophysics such as the evolution of stars and galaxies, the study of quasars (nuclei of distant galaxies) and the development of measuring instruments for use on the earth or in space.

The two telescopes installed in the domes are now only used for teaching or for calibrating measuring instruments. All the data analysed at Sauverny comes from observatories in Chile, the Canaries, Provence and the Swiss Alps and from telescopes on satellites orbiting the earth, for example, the European Integral satellite observatory specialised in the spatial observation of gamma rays.

The European Integral satellite observatory, launched in 2002
European Space Agency

Astronomy worldwide and in Geneva

Some key dates

1543 Copernicus publishes *De revolutionibus orbium coelestium* which puts forward the hypothesis of a heliocentric universe.
1609 Galileo is the first to point an astronomical telescope towards the sky.
1610 Publication of Sidereus Nuncius *(Celestial Messenger)* in which Galileo describes his astronomical observations offering many proofs of a heliocentric universe.
1667 Establishment of the Paris Observatory, the oldest in Europe.
1671 Newton presents the first telescope to the Royal Society in London.
1675 Establishment of Greenwich Observatory in London.
1769 The Geneva astronomers, Mallet and Pictet, observe the Venus transit from Russian Lapland.
1772 Establishment of the first Geneva Observatory by Mallet.
1830 Reconstruction and transfer of the Observatory within the Old Town.
1966 Move of the Observatory to Sauverny.
1995 Discovery of the first exoplanet by Michel Mayor and Didier Queloz of the Geneva Observatory.

Further reading

- L'Astronomie, les yeux de la Découverte, Gallimard, Paris, 1995-2001
- L'Encylopédie de l'Univers, Delachaux et Niestlé, Lausanne-Paris, 1999
- L'Observatoire de Genève 1772-1830-1930, Gautier, Tiercy, Observatoire de Genève, 1930

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