W. HERSCHEL, MAKER OF TELESCOPES

S. Mancuso
Università di Napoli
Dipartimento di Scienze Fisiche
Mostra d'Oltremare, Pad. 19
80125 Napoli

Abstract. After a short biographical notice the scientific activity of. W. Herschel is considered in relation to his work as inventor and maker of telescopes of his own, which he employed for his observations. Subsequently are discussed the reflecting telescopes which were brought back to use by Herschel by improving the models previously developed by Gregory, Cassegrain and Newton.

Later on are described the reflecting telescopes constructed by Herschel with conic sections mirrors (parabola and hyperbola) in order to eliminate the spherical aberration which had been the main defect of reflecting telescopes, as well as chromatism of lenses had been, before Dollond, a considerable limitation for refracting telescopes.

Frederick William Herschel was born in Hannover in a numerous family. His father had no luck as musician. The young Herschel studied fine arts, French and metaphysics before going to England, aged 21, engaged as music teacher of an English regiment's band. In 1765, he obtained an employment as organist in Halifax and having solved the problem of survival, he improved his education by studying Italian, geometry and mathematics (in order to understand the mathematical theory of music by R. Smith). He became chapel master in Bath. In spite of his artistic activity he studied optics, started the observation of the heavens by a small telescope and not having enough money he himself constructed a telescope with 1.50 m focal length, starting in 1774 the observation of heavens. By a larger telescope he succeeded to discover Uranus (1781) winning great fame. King George III grante to him a pension of 300 goldenguineas and a dwelling near Windsor; in 1786 Herschel got another residence in Alough where he founded an observatory.

Herschel studied with assiduity the brightness variations of some stars. In 1780 and 1791 he devoted himself to Mira Ceti (o Ceti, discovered by Fabricius in 1796) and fixed its orbital period in 331 days (fixed variable star). Since 1795 to 1796 he observed α-Hercules, variable star with orbital period of about 60 days.

In 1783 Herschel had noted (as Halley and Cassini II) the displacement of some stars and made the important discovery of the translation motion of our solar system towards a point of the heavens which he called APEX. From his observations he came to the conclusion that APEX is the star λ of the Hercules constellation. Mayer and others had already put forwartd the hypothesis of the Sun displacement.

From the study of Mars white polar spots he deduced, since 1779 to 1784, the rotation axis obliquity to the plane of its orbit.

By means of one of his telescopes he discovered in 1789 two another satellites of Saturn, Mimas and Enceladus.

He also discovered, by Saturn ring observation, its orbital period.

He was the first to ascertain that the Moon has no atmosphere and, by improving the Hevelius method, he measured the height of lunar mountains.

Contribution of Herschel to the development of reflecting telescope

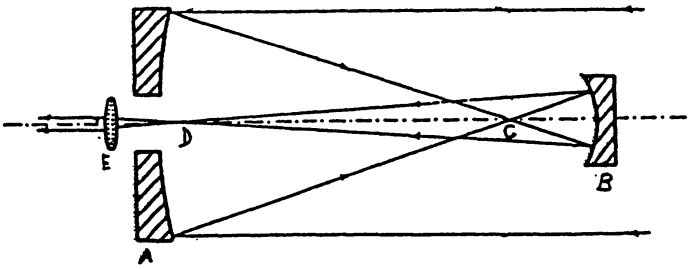
The invention of the reflecting telescope, as we know, follows the invention of the refracting telescope.

Nicolò Zucchi, Jesuit father, seems to be the first to have made use of an eyepiece so as to observe an image formed by reflection by a concave metallic mirror (optica philosophica, Lyon, 1652).

J. Gregory (1638-1678) describes his reflecting telescope in the work "Optica promota, seu abdita radiorum reflexorum et refractorum mysteria geometrice enucleata", London 1663.

This is made by two metallic concave mirrors: one parabolic, is placed at the end of the tube, the other,

smaller and with elliptic section, as in figure



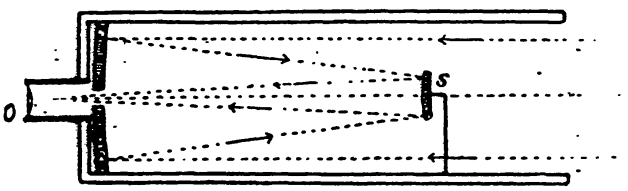
Gregory reflector

A primary perforated paraboloid mirror
B secondary concave ellipsoid mirror
C biconvex eyepiece

The light coming from a star is reflected in C, focus of mirror A and mirror B and is sent back to D, the other focus of the ellipsoid and the image is observed by eyepiece E.

In 1762 Cassegrein, professor of physics of the college of Chartres, replaced the concave mirror by a small convex mirror.

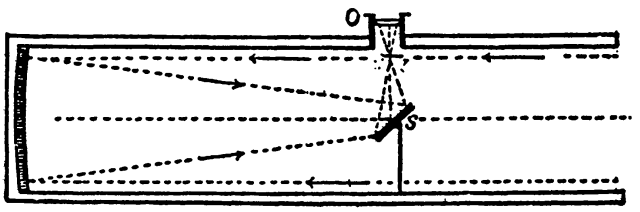
By this artifice the telescope became shorter because the small mirror intercepts the luminous cone, coming from the concave mirror before the formation of the focal image.



Cassegrain Reflector

S small convex mirror
O eyepiece lens

In the same year, in which Cassegrein modified the instrument of Gregory, Newton presented in the day of his election in the Royal Society of London a reflecting telescope which he made by his own hands. This instrument is exhibited in London by the Academy of Royal Society with the inscription: Invented by Sir Isaac Newton and made with his own hands in the year 1677



Newtonian reflector

S small plane mirror at 45°
O side eyepiece in which the real image is observed

In the newtonian telescope the image formed in the focus of a large concave mirror, is laterally reflected by a small mirror at 45°. The direct observation of an object in the direction of view explains why the gregorian telescope is preferred to the newtonian one.

The modification of Cassegrain improved, as we said, the telescope of Gregory.

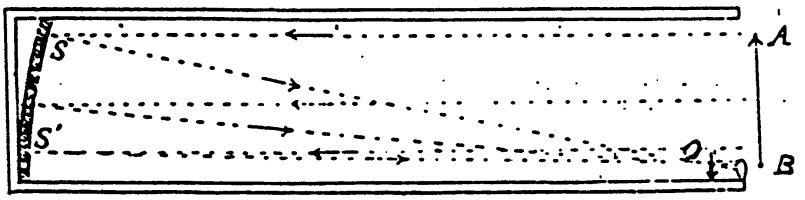
This kind of telescopes has the defect that the mirror central part is not used, owing to mirror perforation and plugging of the small mirror.

We have here to emphasize that a remarkable improvement of the refracting telescopes (which had been hindered by Newton's convinction according to which it would have been not possible to get achromatic lenses) is due to J. Dolland who in 1758, resuming some experiments of Klingenstierna, was able to construct the first refracting telescope with achromatic lenses of flint glass and crown glass.

The reflectig telescopes were brought back to use by William Herschel, the founder of modern astronomy.

Herschel was a great explorer of the heavens and constructed his instruments by his own hands (his financial conditions did not allow him to buy them). He thought to improve the previous telescopes of Gregory, Newton and Cassegrain. Particularly he constructed a telescope which is

reported in the following figure.



Herschel telescope

the mirror SS' (paraboloid) is inclined to the axis of the tube and the parallel incident rays AS and BS', after reflection, converge at the side of the tube, forming an image which can be observed by the lens O. The drawbacks are therefore eliminated which are due to the perforation of the main mirror and to the interception caused by the secondary mirror. Herschel designated this instrument «front view telescope» because the heavenly body is observed at the front side of the telescope. The secondary mirror of the Gregory's telescope is eliminated and the image is formed close to the tube's circumference.

The design of this construction, which recalls the experiments described in 1732 in the VI book of the work «Machines et inventions approvees par l'Academie des Sciences de Paris», was realized by Herschel in 1776. He applied it earlier unsuccessfully on a 10 feet focal length telescope and later on a 20 feet one.

These first failures draw his attention to the construction of mirrors. Herschel knew that the smallest curvature inequalities of mirrors, which are difficult to be avoided, especially those at the borders of the reflecting surface, can form a confused image: this defect is the spherical aberration. Herschel devoted himself then to construct reflecting mirrors with shapes of conical sections (parabola and hyperbola) in order to eliminate the spherical aberration which was at that time the main defect of reflectors, as well as chromatism had been, before Dollond, the main defect of refracting telescopes.

The largest telescope which was constructed by Herschel, about 40 feet in length (12 m) and 4 feet in diameter (1.47 m), was started in 1785 and completed in 1789. King George III bore its cost. It was made by a big iron tube and only the mirror's weight was more than 1000 kg.

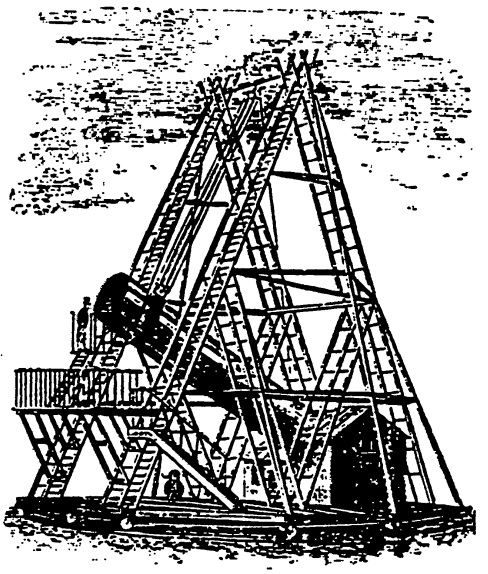
Contrary to the opinion of many astronomers this huge

instrument was not at all useless to Herschel. It was employed by him to discover the sixth satellite of Saturn, to see distinctly the seventh and to observe better the stains of this planet.

Herschel did not use frequently this instrument, because in spite of its admirable mechanism three persons were required to operate it.

Moreover, for fast temperature changes, the telescope, owing to its mass, reached very slowly the ambient temperature and this impaired the quality of images.

The instruments could be displaced in height and rotate in azimuth and we can say that Herschel, in spite of the limits of the technical means of that epoch, was a forerunner of the present large altazimuthal telescopes.



Herschel altazimuthal telescope