CLAVIUS AND THE JESUIT TRADITION

JOSEPH MACDONNELL, S.J.

Some time ago a New York Times front page story (July 6, 1979) related discoveries by astronomers that the sun is shrinking. Their evidence was a ring of light at total eclipse which had been meticulously recorded by the sixteenth century Jesuit astronomer Christopher Clavius, and today that ring is missing. It is this kind of periodic intrusion into the development of astronomy that has earned Clavius a place of esteem in every significant history of science for the past four centuries. His name is inscribed in stone on libraries and universities such as the Sorbonne and portraits of him hang in museums throughout the world. He appears on the tomb of Pope Gregory in the Vatican while one of the largest craters on the moon is named in his honor. His works are described in the earliest editions of the Philosophical Transactions of the Royal Society of London. Records of scientific correspondence, such as the twelve volume Mersenne collection have very many entries concerning him. Mathematicians such as Kepler, Descartes, and Leibniz acknowledged Clavius as a source of their inspiration. Pope Sixtus V said, and later historians have echoed the sentiment: "Had the Jesuit order produced nothing more than this Clavius, on this account alone the order should be praised." He was considered an illustrious mathematician and astronomer; one to whom scholars and potentates would entrust with the most sensitive scientific problems of the day. Even so, he has yet to be given full credit for all of his scientific accomplishments.

The reason so much attention has been given to this Jesuit mathematician-scientist lies in his teaching and publications, his mathematical innovations, his reform of the calendar and his contributions to astronomy during a period critical in the history of natural science—the time of Galileo. He was born in 1538, several years before the Jesuits began. He joined the Jesuits in 1555, taught at the Roman College for 45 years and died in 1612. It is impossible to verify the claim made by the Roman archives that he was trampled to death by an ox while visiting the seven churches.

Teaching and Publications

Very few books on mathematics and science appeared in the century that followed the printing of Gutenberg's bible in 1455. The Early Jesuits, however, realized the importance of the printed word and in the next few centuries they produced a flood of books. There would be 631 Jesuit authors of geometry books alone; and many of these men would author more than one book. Boscovich, for instance, wrote 151 books and treatises. One of the earliest of these authors was Clavius with nineteen publications, whose *Euclid elementorum* (Rome 1589), *Geometrica practica* (Rome 1604) and *Opera mathematica* (Rome 1611) went to many editions and remained in use until long after the suppression of the Society in 1773.

Date: July 31, 1988.

Clavius had an undoubted influence on mathematics. The historian of science George Sarton calls him "the most influential teacher of the Renaissance." His *Euclidis elementorum* contains all the known books of Euclid and a vast collection of comments and elucidations. This was not just a translation of Euclid, but a critical evaluation of Euclid's axioms. He noted the absence of an axiom guaranteeing the existence of a fourth proportional to three given magnitudes. He also showed his appreciation for Euclid's insight that the fifth postulate was necessary and his work on this troublesome postulate was continued by one of his successors, Girolamo Saccheri, S.J., who is listed as one of the founders of non-euclidiean geometry. Clavius used a first century method of proof which derives a proposition by assuming the contrary of the proposition to be proven. His *Euclidis* was called "a model text, perfect for its time" by historians Cantor and Kaestner who considered it indispensable for research in the history of mathematics. This work led to his being called the Euclid of the l6th Century.

The rigor in euclidean geometry that we take for granted today is due in part to the rigorous manner in which Clavius presented Euclid. Clavius' commentary on Euclid became the standard textbook for the 17th century and his books on arithmetic, geometry, algebra, harmonics and astronomy were used in all the European Jesuit schools, as well as many other schools. This made him the mathematics instructor of Catholic Europe as well as much of Protestant Europe. Evidence of how prevalent were his books is found in the number found extant today. Now it is possible to buy them for as little as 425 Marks. Some of Clavius' students spread this new emphasis abroad—men such as Matteo Ricci who translated Clavius' works into Chinese, giving China its first opportunity to enjoy Euclid.

The influence of Clavius was not limited to his teachings and his enduring books. His correspondence was enormous, and some of it has been collected and preserved in the archives of the Gregorian University in Rome. Since most of the 291 extant letters—some really treatises—in this collection are from correspondents writing to Clavius, it is like overhearing a telephone conversation and having to guess at what the other party is saying. The value of the correspondence is indicated by the addresses from all over the globe and by the number of persons of international reputation and influence. The correspondents include not only scientists and patrons of science, but also rulers of all kinds: kings, emperors, dukes, patriarchs, bishops and popes. The letters shed some light on famous personalities. Tycho Brahe chided Clavius for not writing more often. Another astronomer Francois Viete was concerned about Clavius criticism because it got him into trouble with Rome. Encyclopedias speak of Viete as a Protestant, a Huguenot, or an agnostic even though he was baptised and died a Catholic. His letters to Clavius show him a serious practicing Catholic.

Because of early successes the Society of Jesus was asked to open many schools throughout Europe, and it was evident that some standard process was needed. A committee which included Clavius completed the proposed plan, called the *Ratio Studiorum*, which was promulaged in 1599 by the Jesuit General Acquavia. Because of Clavius mathematics would be a regular part of the curriculum in all Jesuit schools from then on.

Clavius made the following observations about training Jesuit mathematics teachers "to the end that mathematical studies be held in higher esteem. Many a professor of philosophy has made no end of mistakes because of his ignorance of mathematics. Once a month scholastics should be gathered to hear original demonstrations of the propositions of Euclid. That the Society may be able always to have capable teachers of mathematics, a number of men fit and able to undertake such positions ought to be chosen and organized in a private academy for the study of mathematics." His desire for Jesuit mathematicians to cooperate and support each other is realized today through the efforts of 24 Jesuit and lay mathematicians from nine countries and twenty universities, known as the Clavius Group, who engage in mathematical research on some university campus each summer.

Mathematical Innovations

Clavius anticipated a number of mathematical developments. The details of some of his discoveries are found in he Dictionary of Scientific Biography. In his *Astrolabium* (Rome,1593) he uses a dot to separate whole numbers from decimal fractions, but it would be 20 more years before the decimal point would be widely accepted. Carl Boyer mentions "the Jesuit friend of Kepler" who was the first to use the decimal point with a clear idea of its significance. In the same work, Clavius originated a way of dividing a scale for precise measurements. His idea was adopted by Vernier 42 years later. Some historians state that the Vernier scale would more properly be called the Clavius scale. In his *Algebra* (Rome, 1608) Clavius was the first to use parenthesis to express aggregation and the first to use a symbol for an unknown quantity. Other innovations were also seen in the symbols attributed to him by Florian Cajori such as the radical sign, plus and minus signs.

Clavius proposed a proof that there can be no more than three dimensions in geometry, based on the fact that only three concurrent lines can be drawn from a point so that they are mutually perpendicular. He discovered and proved a theorem for a regular polygon with an odd number of sides which two centuries later enabled Carl Friedrich Gauss to construct a 17-sided polygon by ruler and compass.

In his *Triangula sphaerica* (Mainz 1611) Clavius summarized all contemporary knowledge of plane and spherical trigonometry. His prostlaphaeresis, the grandparent of logarithms, relied on the sine of the sum and differences of numbers. In this way he was able to substitute addition and subtraction for multiplication, by solving the identity with which we are familiar today: $2\sin x \sin y = \cos(x-y) - \cos(x+y)$. D.E. Smith gives the details of the proof and emphasizes the impact Clavius' work had on the discovery of logarithms. Smith also underlines the modesty of Clavius in generously giving to one of his contemporaries more credit than is due for his own prostlaphaeresis.

Calendar

Were it not for Christopher Clavius we would be celebrating Christmas on 12 December solar time. In 1582, the Julian calendar ended on a Thursday, 4 October, with the promulgation of the papal bull *Inter gravissimas* so that the next day, the "Gregorian" calendar began on a day named Friday, 15 October (after the arbitrary fashion in which mathematicians define objects and use axioms). October was chosen by Clavius for the conversion because it was the month with the fewest number of feast days.

The change was the result of the work of a commission appointed by Pope Gregory XIII and led by Christopher Clavius to correct the Julian calendar. For centuries, it was known that Easter was being celebrated on the wrong day, sometimes a month late, and was gradually becoming a summer feast. For 800 years many scholars had failed to identify the correct date for Easter, and also correct the Julian calendar for the future.

The problem with the Julian calendar was partly astronomical and partly arithmetic. A year (the time for a complete transit of the earth around the sun) is shorter now than it was in 45 B.C., when the Julian calendar was adopted. Then the transit-time was 365.2422 days; now it is 365.2419 days (a day being the time required for the sun to return to a fixed meridian). Neither of these numbers is an integer, so a year does not have an integral number of days. If a year were divided up into a number of equal days, there would be no 23rd day of the year; it would be, for instance, the 23.4368... day of the year. No one wanted this, especially printers of calendars!

Clavius' task, to calculate the time of the vernal equinox and to correct the shift, was monumental considering the meager astronomical and mathematical resources available at the time. This was long before the invention of most of the mathematical tools we take for granted today. It was a time that preceded the common use of a decimal point and long division was considered a college course! The accuracy of his calculations have earned Clavius historical fame. Clavius found the correct date for Easter and that 97 days had to be added every 400 years. The wonder is that he was able to measure the year length so accurately: to this day no one knows how he accomplished this. The fact that there exists a unique sequence of 400 calendars is another indicator of the complications involved. A cursory review of the extensive "calendar" literature over the years illustrates that the calender was a non-trivial problem. It is comforting to know that, using his plan, the next time an extra full day will have to be added will be the year 4317. It took Clavius 800 pages to explain and justify his results.

Of the many attempts to solve the problem, some were more precise, but required a thorough knowledge of astronomy to compute a date. Kepler, defending Clavius' simple plan, said: "After all, Easter is a feast, not a planet!" Joseph Scaliger, author of a competing plan, took the rejection of his plan less than gracefully and referred to Clavius as nothing more than a "German potbelly." Scaliger later, in a cheerier mood, acknowledged his esteem for Clavius saying: "a censure from Clavius is more palatable than the praise of other men."

Implementation of the plan was not an immediate and universal success. It had a fate similar to the adoption of the metric system in America today. The populace became disoriented and windows were broken in the houses of the European Jesuits who were blamed for the change. The Orthodox Church saw it as a Roman intrusion (which it was), and Protestant countries were reluctant to accept any decree from a pope. England did not adopt Clavius' calendar until 1751, while Orthodox Russia would require the Bolshevik revolution before it changed.

Astronomy and Galileo

His book *Gnomonices* (Rome 1602) contains every then known principle concerning the measurement of time. His *In sphaeram Joannis de SacroBosco* (Rome 1581) on the famous book of John Halifax (Holiwood) was called the best commentary on the *Spheres* ever written. In this Clavius shows that initally he held the Ptolemaic system. In later years, however, he taught and supported the heliocentric system.

When Galilei Galileo invited Cardinal Bellarmine to see the new-found wonders of the sky in his telescope, Bellarmine's gratitude led him to write Galileo: "your affection will be reciprocated if I ever get an opportunity of doing you a service." Soon the opportunity came and it was to Clavius that Bellarmine turned to confirm the findings of Galileo, which resulted in Bellarmine's gentle treatment of Galileo.

Galileo was a rather celebrated and frequent visitor to the Jesuit Roman College. His friendship with members of the Society of Jesus started in 1587, when, at the age of 23, he met Clavius, and continued for the rest of his life. The number and contents of Galileo's letters to Clavius show that he was a good friend of Clavius. The latter was able to needle Galileo about seeing Jupiter's four moons only because Galileo drew them on the lens of his telescope. Other letters demonstrate the fact that Clavius' support for the heliocentric teaching was the preponderant reason for its acceptance among the learned. In the time of his distress it was to Jesuits like Clavius that Galileo turned. At one point the Jesuits of the Roman college having confirmed his discoveries of the motion of the earth honored Galileo with a three day celebration.

The Dominican scholar William Wallace, O.P., in his book *Galileo's Early Notebooks* (Notre Dame 1977) has demonstrated, by using the internal evidence of terminology, word order, symbols, and authorities quoted, that much of Galileo teachings came from nine Jesuits teaching at the Roman College. After studying Galileo's manuscripts for fifteen years, he found that all Galileo's notebooks show considerable evidence of copying. Practically all of the material derives from texbooks and lecture notes which were being used by Clavius and eight other Jesuits. Though his Latin prose is more simple than Clavius' sophisticated style, the parallels between Galileo and Clavius are unmistakable. Galileo's mathematical organization was not original. It occurred to him through contact with *reportationes* of the Roman College. A mathematical approach to nature was indelibly etched in his Jesuit colleagues' mindset by Clavius. It was Clavius who supplied the formal apparatus for "geometrical philosophy," and his influence on Galileo through his commentary on Sacrobosco is apparent. Clavius knew every technique for handling motion which had been invented since the fourteenth century. The Roman Jesuits were the immediate source of a number of Galileo's leading mathematical concepts. Galileo is still considered the father of modern science, but now there is evidence that there was a grandfather as well. The grandfather which Wallace has been able to establish is a collection of Clavius and eight other Jesuit teachers of "natural philosophy."

A wonderful encomium was paid to Clavius after he died. Clavius' chair was filled by one of his pupils, Christopher Grienberger, S.J., inventor of the equitorial mount, still in use today. The Jesuit general Mutius Vitelleschi, S.J., assigned him the difficult task of judging a controversial book by Gregory Saint Vincent, S.J., (a forerunner of the calculus). After a year Grienberger threw up his hands in despair and said: "If only Clavius were alive now! How I miss his counsel!" All Jesuits would appreciate this accolade for themselves, many deserve it, but few earned it as did the "greatest teacher of the Renaissance," Christopher Clavius, an embodiment of the Jesuit tradition of scholarship, dedication and service. His influence on our culture was monumental. His birth preceded the birth of the Society, and from his perch he has witnessed four and a half centuries of fluctuating Jesuit enthusiasm for the apostolate of scholarship. In fact this special Jesuit charism has declined in recent decades. Like Grienberger we wistfully might cry: "How we miss his council."