general and regional geology. For example, he was the first to investigate closely the evidence of the existence of diluvial moraines on the Bavarian plateau. Further, while participating in Gerhard Rohlf's expedition to the Libyan desert (1873–1874), he recognized that the desert sand was a product of wind erosion and did not originate in a Quaternary Sahara sea. (Some scientists had held that European Quaternary glaciation was influenced by the existence of such a sea.)

Zittel's mastery of geology and paleontology and of its history is reflected in his *Geschichte der Geologie und Paläontologie.* (As an encyclopedic historical survey it still remains an indispensable reference for the history of geology, being especially strong on Continental European developments of the nineteenth century. The English translation of 1901 is currently in print.) In this book he could proudly state that during his years at the University of Munich, it became "a center of paleontological and geological studies, where a considerable number of researchers from all parts of the world received their training."

Elected president of the Bavarian Academy of Sciences in 1899, Zittel was an honorary member of many scientific societies in Europe and elsewhere.

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HELMUT HÖLDER

ZÖLLNER, JOHANN KARL FRIEDRICH (*b.* Berlin, Germany, 8 November 1834; *d.* Leipzig, Germany, 25 April 1882), *astrophysics.*

Zöllner's father was a patternmaker and later a cotton printer. Although Zöllner had displayed outstanding talent for constructing instruments and conducting experiments by the age of sixteen, the death of his father (1853) obliged him to take over the direction of his factory. But Zöllner was not temperamentally suited to a business career: and shortly after assuming that post, he gave it up and resumed his education. He failed the final secondary-school examination, however, because of his poor marks in languages. In 1855 he began to study physics and other sciences at the University of Berlin, where his teachers included H. G. Magnus and H. W. Dove. While still a student Zöllner published "Photometrische Untersuchungen" in Poggendorff's *Annalen der Physik und Chemie*. He also worked on developing electric motors; but considering the great success later achieved in this area by Werner von Siemens, Zöllner's efforts proved to be of little significance.

Zöllner erected a small private observatory in the tower of his father's factory in Schöneweide (now part of Berlin), and thus was able to test his ideas concerning the photometry of celestial bodies. In 1857 Zöllner went to Basel, where his teachers included G. H. Wiedemann. He received the Ph.D. in 1859 for a work on photometric problems: "Photometrische Untersuchungen, insbesondere über die Lichtentwickelung galvanisch glühender Plantindrähte."

Exploiting a chance observation that he had made at Basel, Zöllner invented the astrophotometer, which was constructed in the Kern optical and mechanical workship in Aarau. (The accompanying drawing illustrates the instrument's operating principle.) Using this instrument, he investigated fundamental problems of photometry, made critical comparisons of other photometers, and soon

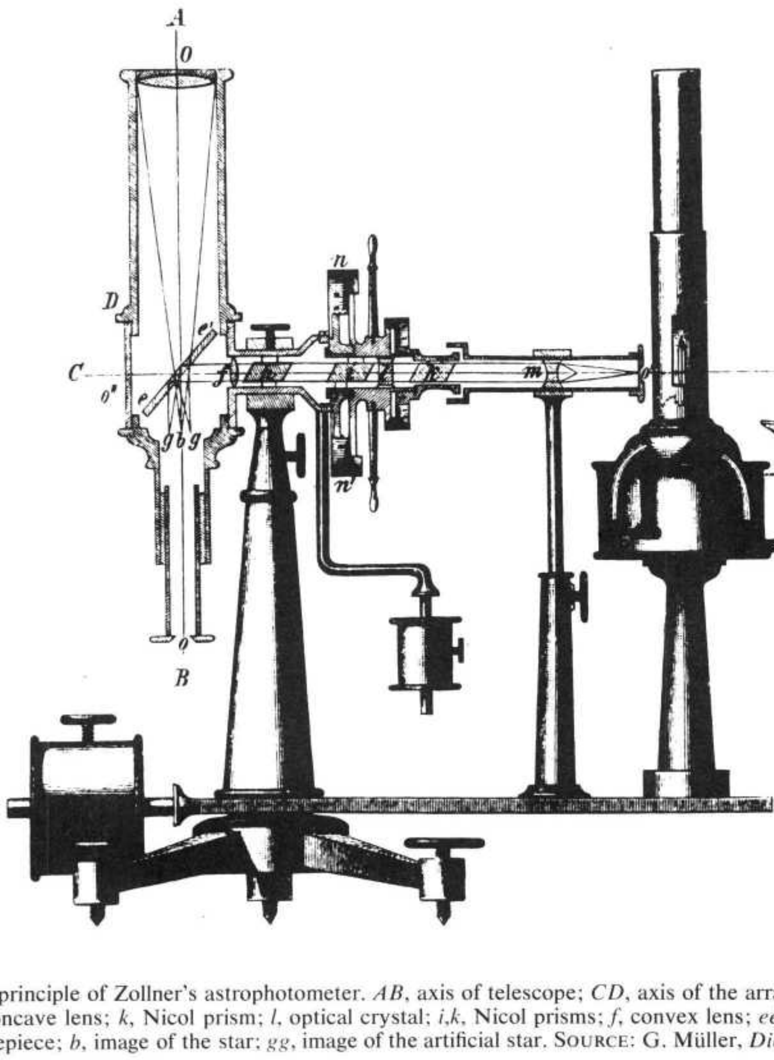

FIGURE 1. Operating principle of Zollner's astrophotometer. *AB*, axis of telescope; *CD*, axis of the arrangement for production of the artificial star; *m*, biconcave lens; *k*, Nicol prism; *l*, optical crystal; *i,k*, Nicol prisms; *f*, convex lens; *eé*, glass plate; *F*, petroleum lamp; *O*, objective; *o*, eyepiece; *b*, image of the star; *gg*, image of the artificial star. SOURCE: G. Müller, *Die Photometrie der Gestirne* (Leipzig, 1897), p. 247.

amassed a considerable body of material. On the advice of Mitscherlich and Wiedemann, Zöllner decided to compete for a prize offered by the Vienna Academy of Sciences. The jury found that Zöllner had not measured the brightness of enough stars to receive the prize. (The other two papers submitted were also found not to merit the prize, and thus none was awarded.) Zöllner's entry, which he published in 1861, is a classic of astrophysics. The photometer described in it far surpassed all its predecessors and, in a modified form, found wide application. The Potsdam observatory used it to obtain data of unsurpassed precision for its *Photometrische Durchmusterung des nördlichen Himmels*, the publication of which was begun at Zöllner's suggestion.

In 1862 Zöllner moved to Leipzig and published *Photometrische Studien mit besonderer Rücksicht auf die physische Beschaffenheit der Himmelskörper* (1865), which contains his *Habilitationsschrift*, "Theorie der relativen Lichtstärken der Mondphasen." With his appointment as professor at the University of Leipzig in 1866, Zöllner's financial situation was sufficiently improved for him to resume important experimental research.

Among Zöllner's main achievements was the design of the reversion spectroscope (1869), another instrument that demonstrates his experimental ingenuity. It is based on the principle of the heliometer: two beams of rays are conducted through two direct-vision prism systems arranged so that the dispersion within them occurs in mutually opposed directions. With this device Zöllner intended to improve the precision of measurements of Doppler shifts in the spectra of objects with velocities having a high radial component. Hermann Vogel used the instrument to determine the rotational velocity at the solar equator. The reversion spectroscope later lost its importance with the adoption of more exact methods.

Another important device designed by Zöllner is the horizontal pendulum, which in improved form was widely used in geophysical research. Inspired by the attempts of Janssen and Lockyer to observe solar protuberances, Zöllner devised the first method that made these phenomena easily amenable to study. These inventions, which make Zöllner a pioneer in astrophysics, brought him membership in the Saxon Academy of Sciences at Leipzig.

Zöllner also made an intensive study of theoretical questions, including solar theory, sunspots, and solar rotation, and Olber's paradox. One product of these rather speculative inquiries was especially important for the development of spectroscopy, the memoir "Über den Einfluss der Dichtigkeit und Temperatur auf die Spektra glühender Gase" (1870). Also of far-reaching significance was Zöllner's theory of comets, in which he correctly assumed that elements of the nucleus of a comet gradually vaporize as it nears the sun. Beyond this, the book on comets contains a wealth of penetrating remarks on the subject announced in the subtitle, *Beiträge zur Geschichte und Theorie der Erkenntnis*. This portion of the book is notable for a number of at least partly original ideas and critical comments. Attacking abuses in the scientific profession of his time, Zöllner lashed out with great vehemence against the vanity of scientists, ridiculing scientific careerism and contending that these vices are harmful to the progress of science.

Zöllner continued this polemic in such works as *Das deutsche Volk und seine Professoren. Eine Sammlung von Citaten ohne Kommentar* (Leipzig, 1880). The scientific community responded with counterattacks, and there began a long period of controversies that drove Zöllner into ever greater isolation. The excessive irony and somewhat biased approach of which he was guilty were, however, only partially responsible for this isolation. In 1875 Zöllner had met William Crookes in London and begun an intensive study of Spiritualism, to which he ultimately became a convert. In the following years some scientists did not hesitate to attribute Zöllner's views to an increasingly serious mental illness. Even sympathetic friends, such as Otto Struve, were much dismayed by his adherence to this doctrine, and W. Foerster termed this change in his life both remarkable and painful. Zöllner, however, refused to be dissuaded from pursuing his unscientific speculations; and he saw in his supposed proofs of the existence of a "transcendental world" a support for theology. In the last years of his life he produced little work of scientific significance. He died—presumably of a stroke—while preparing the preface to the third edition of his book on comets.

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DIETER B. HERRMANN

ZOLOTAREV, EGOR IVANOVICH (*b.* St. Petersburg, Russia [now Leningrad, U.S.S.R.], 12 April 1847; *d.* St. Petersburg, 19 July 1878), *mathematics.*

Zolotarev was the son of a watchmaker. After graduating in 1863 with a silver medal from the Gymnasium, he enrolled at the Faculty of Physics and Mathematics of St. Petersburg, where he attended the lectures of Chebyshev and his student A. N. Korkin. He graduated with the candidate's degree in 1867 and the following year became assistant professor there. In 1869 he defended his master's dissertation, on an indeterminate third-degree equation; his doctoral dissertation (1874) was devoted to the theory of algebraic integers. In 1876 he was appointed professor of mathematics at St. Petersburg and junior assistant of applied mathematics at the St. Petersburg Academy of Sciences.

On two trips abroad Zolotarev attended the lectures of Kummer and Weierstrass, and met with Hermite. He shared his impressions of noted scholars and discussed mathematical problems with Korkin, whose collaborator he subsequently became. Zolotarev died at the age of thirty-one, of blood poisoning, after having fallen under a train.

The most gifted member of the St. Petersburg school of mathematics, Zolotarev produced fundamental works on mathematical analysis and the theory of numbers during his eleven-year career. Independent of Dedekind and Kronecker, he constructed a theory of divisibility for the whole numbers of any field of algebraic numbers, working along the lines developed by Kummer and elaborating the ideas and methods that now comprise the core of local algebra. He operated with the numbers of the local ring Z_p and its full closure in the field $Q(\theta)$ and, in essence, brought under examination the semilocal ring O_p. In modern terminology Zolotarev's results consisted in proving that (1) the ring O_p is a finite type of Z_p-modulus and (2) O_p is a ring of principal ideals. In his local approach to the concept of a number of the field $Q(\theta)$ Zolotarev demonstrated that the ring O of the whole numbers in $Q(\theta)$ is the intersection of all semilocal rings O_p. Zolotarev defined ideal numbers in O as essentially valuations and found the simple elements of O_p with the aid of a lemma that is the analog of the theory of expansion into Puiseux series.

Zolotarev employed a theory that he had constructed for determining, with a finite number of operations, the possibility of selecting a number, A, such that the second-order elliptical differential $(x + A)\, dx / \sqrt{R(x)}$, where $R(x)$ is a fourth-degree polynomial with real coefficients, can be integrated in logarithms. Abel demonstrated that for an affirmative solution it is necessary and sufficient that $\sqrt{R(x)}$ be expandable into a periodic continuous fraction; but because he did not give an evaluation of the length of the period, his solution was ineffective. Zolotarev provided the required evaluation, applying the equation of the division of elliptic functions.

With Korkin, Zolotarev worked on the problem posed by Hermite of determining the minima of positive quadratic forms of n variables having real coefficients; they gave exhaustive solutions for the cases $n=4$ and $n=5$.

Among Zolotarev's other works are an original proof of the law of quadratic reciprocity, based on the group-theoretic lemma that Frobenius had called "the most interesting," as well as solutions of difficult individual questions in the theory of the optimal approximation of functions. Thus, Zolotarev found the nth-degree polynomial, the first coefficient of which is equal to unity and the second coefficient of which is fixed, that deviates least from zero.

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