Reprinted from AMERICAN JOURNAL OF PHYSICS, Vol. 23, No. 1, 51–54, January, 1955
Printed in U. S. A.

Sesquicentennial of Christian Doppler

KAREL HUJER
University of Chattanooga, Chattanooga 3, Tennessee
(Received March 26, 1954)

An account of some little-known phases of Doppler's struggling life is given at the occasion of his recent birthday anniversary. A brief analysis of Doppler's major work and its fundamental bearing upon modern astrophysics are also provided. Whether Doppler ever visited an astronomical observatory is not known. Spectroscopy and photography, which alone could prove Doppler's principle in astronomy, were still in their embryonic state during his productive years.

VARIOUS anniversaries of outstanding physicists pass by unnoticed. Yet the 150th anniversary of the birth of Christian Doppler deserves special mention. Today's astronomer is particularly indebted to him. While the well-known principle carries Doppler's name and its application is most extensive in modern astrophysics, little is to be found in English literature concerning his life. At the same time, few ideas in physics survive unchanged the vicissitudes of modern physics as did the original exposition of Doppler. Objective information continues to be revealed in the form of displacement of spectral lines as displayed for example in recent decades by the vastly consequential red shift associated with the expanding universe.

Christian Doppler was born of humble origin on November 29, 1803, the son of a stone-cutter in Salzburg, Austria. He attended the Lyceum of Salzburg, where he had an excellent teacher of mathematics, Simon Stampfer, who encouraged and supported the young talented student and facilitated his further studies at Vienna Polytechnic School. At this institute in 1829 he became assistant to Professor Hantschel. However, this position provided Doppler with but minimum subsistence. Unable to improve his situation, he planned to emigrate to America. Shortly before his projected departure, he was offered a teaching position in the School of Technology at Prague, Bohemia, where in 1835 he commenced the period of the most fruitful years of his life, continuing until 1847.

In Prague, Doppler accomplished his most notable works, principally his treatise of fundamental importance for modern astrophysics, *Über das farbige Licht der Doppelsterne und einiger anderer Gesstirne des Himmels.*[1] In this work, originally presented at the session of the Science Section of the Royal Bohemian Society at Prague, May 25, 1842, he first announced to the scientific world some significant and interesting results of his studies. He maintained, as is well-known today, that tone will appear higher the faster the source of sound approaches us, and reversely, it will appear lower with increasing speed of recession of the source. He derived his result mathematically and, as the title of this principal publication indicates, he proceeded at once to apply its consequences to optics. In fact, this publication deals primarily with the extension and applicability of the principle in the propagation of the waves of light. Thus, reasoning analogously upon light as a phenomenon of waves in the ether, he was first to perceive that the wave theory of light involved a change in the observed wavelength of light from a given source, corresponding to motion of the source relative to the observer. He concluded erroneously, however, that a rapidly approaching star would display a violet tinge whereas a swiftly receding star would display a redder tinge. The application he made of this idea to explain the color of stars was false in that light from a star extends on both sides of the visible range of the spectrum, and changes due to the motion of a star in the line of sight would take place simultaneously at both ends of the spectrum. Besides, the slight shift in the position of maximum intensity would lead to no appreciable color change for ordinary stellar velocities. Only

[1] Christian Doppler, *Über das farbige Licht der Doppelsterne und einiger anderer Gesstirne des Himmels,* Abhandlungen d.k. Bohmischen Gesellschaft d. Wissenschaften, II, 467 (1842).

in reference to the enigmatic high velocity of recession such as recorded in recent years by external galaxies did Hubble with others suggest a term of "tired light" of lowered energy.

We can visualize the experimental difficulties Doppler confronted in his time with spectroscopy in its infancy and photography practically nonexistent. There was no chance for any visual confirmation of Doppler's theory in his days of primitive spectroscopy. In the meantime however, the Doppler principle was impressively tested acoustically in Holland when, in 1845, a locomotive and a flat car secured for two days for this purpose were used in the experiment. Although erroneous, Doppler's assumption undoubtedly enabled Fizeau to make a further step in the optical interpretation of the principle. Lecturing to the little known Société Philomathique de Paris in 1848, Fizeau pointed out that the Doppler effect could be applied to the position of the line in the spectrum and that the motion of a source relative to the observer could be measured by the displacement of a spectral line from its normal position. Following this train of ideas, Fizeau mentioned in his original paper that the study of radial velocities for components of certain visual binaries would enable us to determine their parallaxes. Fizeau's remarkable paper did not arouse much excitement and it was saved from oblivion by belated publication in 1870.[2] Doppler's and Fizeau's ideas were, in turn, fully elaborated by Ernst Mach in his report to the Vienna Academy of Science.[3] In his paper Mach discussed the vast significance of the Doppler-Fizeau idea for astrophysics and for the determination of the radial motion of celestial objects that was heretofore considered unthinkable and completely impossible.

Experimental verification of the Doppler-Fizeau principle in the realm of spectroscopy proceeded very slowly. Considerable impetus was given it with Kirchhoff's spectroscopic investigations by 1859. Somewhat unsuccessful efforts by Sir William Huggins, about 1866, to measure visually the predicted displacement of the stellar spectral lines were followed by positive results when H. C. Vogel at Potsdam Observatory applied improved photographic technique to the measurement of radial velocities of stars half a century after Doppler's original publication.[4] Besides the original pioneers, none of the eminent investigators realized fully the tremendous importance which the Doppler-Fizeau principle was later to attain in experimental astrophysics.

Indeed, the Doppler effect opened up an entirely new chapter in cosmic explorations. Its importance today is so universally established that it belongs to the most fundamental tools of modern astrophysics. It is an excellent example of complete cooperation between physics and astronomy. Neither Doppler nor Fizeau may ever have been in an astronomical observatory, yet outside spectroscopy, few discoveries have had more extensive application in astronomical investigation. Fundamentally, the Doppler principle permits determination of one of two components of the star's motion through space—radial velocity—information indispensable for the study of the structure of our galaxy, besides a number of other physical characteristics of individual stars and binaries. In addition, what is most important, this radial motion is completely independent of distance. The shift due to the motion in the line of sight will be measured with the same precision whether the source be one light year or a hundred million light years distant.

The early visual observations with the exception of Keeler's at Lick Observatory in 1890, proved unreliable.[5] Vogel and Scheiner at Potsdam Observatory and Belopolsky at Pulkowo Observatory were among the pioneers in photographic determination, their work dating from about 1890. It was only this photographic method that allowed increased accuracy in the application of the Doppler principle in the measurement of radial velocities of stars. In this connection, I recall an interesting story told by the late Dr. E. B. Frost at Yerkes Observatory in which he related an exciting experience with Dr. H. C. Vogel in the darkroom of Potsdam

[2] A. H. L. Fizeau, Ann. chim. et phys. **XIX**, 217–220 (1870).

[3] Ernst Mach, Sitzungsberichte d.k. Akademie in Wien, **XLI**, 543 (1860).

[4] H. C. Vogel, Astronomische Nachrichten, **123**, 289 (1890).

[5] J. E. Keeler, Pub. Lick Observatory, **III**, 195 (1894).

FIG. 1. Title page of the principal work of Christian Doppler originally presented at the session of the Science Section of the Royal Bohemian Society at Prague, May 25, 1842. Because of the subsequent importance of the work and the inaccessibility of the original copy in the files of the Society (5th Section, Volume II), the late Dr. F. J. Studnička sponsored a special publication (1903) at the occasion of the 100th anniversary of Doppler's birth. This is a photographic reproduction of the frontispiece of one of these copies, which itself is now very rare. The title is particularly interesting to the astrophysicist of today because Doppler may never have been at an observatory, nor could he possibly have realized ultimate photographic confirmation of his vision, with photography still unborn. The translation of the title reads: *Concerning the Colored Light of Double Stars and Other Celestial Constellations.*

Observatory as they were verifying the Doppler effect for the first time on the spectrogram of Algol, which was assumed to be an eclipsing variable, hence a double star displaying periodic oscillation of its spectral lines. Again at Lick Observatory, in the photographic application of the Doppler effect, a greatly increased accuracy in determination of radial velocities on the plates of the Mills spectrograph was first attained in America by W. W. Campbell. It was at this same observatory that Keeler's observation of the rings of Saturn became particularly famous for application of the Doppler principle, verifying spectroscopically Clerk Maxwell's theory of the meteoric nature of rings announced nearly half a century previously.

Doppler's work was recognized in Prague even before publication of his principal work above mentioned. He was elected member of the Royal Bohemian Society of Learning in 1840. When Prague University observed its 500th anniversary in 1848, while Doppler occupied the chair in physics and mechanics at the Imperial Mining Academy in Báňská Štávnica, today's Slovakia, he was proclaimed Doctor of Philosophy Honoris Causa. That same year he was appointed professor of practical geometry at the Vienna Polytechnic Institute, succeeding his old teacher Stampfer from Salzburg. Finally, in 1850, he was called to direct the new Physical Institute of the University of Vienna where he held the chair of experimental physics.

Doppler's life was not easy. In his astronomical essays entitled, *Bis an's Ende der Welt* (1903), F. J. Studnička, professor of mathematics at Prague University, gives a touching description of a small, gloomy classroom in the old Prague School of Technology at Jilska Street where Doppler taught for over 10 years. He ponders over the humble beginnings of his discovery, the fruit of which continues to grow in fertility and abundance with the development of modern astronomy. Doppler experienced his happiest years of creativity during this period while he resided in a modest room at house number 4, Karlovo Plaza. This house in Prague actually carried a memorial tablet dedicated to Doppler. After the war the house was demolished to make space for a new courthouse building.

The poverty and privations of Doppler's early years undermined his health. Searching for recuperation from protracted illness, he left for the Italian southland but too late. He passed away in his 49th year at Venice, May 17, 1853. The year 1953 was a double anniversary—commemorating the 150th year of Doppler's birth and the 100th year of his passing.