R.A.S.C. PAPERS

CHRISTIAN DOPPLER IN PRAGUE*

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Christian Doppler, the discoverer of Doppler's principle, the most powerful tool in the hands of the modern astrophysicist, represents an example of a relatively little-known life of incomparable privations which pioneers of science had to experience as late as the nineteenth century. The one hundred and tenth anniversary of Doppler's passing offers an opportunity to reconsider some aspects of his struggling life which should be known particularly to astronomers of today.

Like the great, tragic composer Mozart, Doppler was born in Salzburg, Austria, and both, by misery, were driven out of their native town. Again, like Mozart, Doppler found his happiest and most productive years in Prague, in that meagreness which the conditions of the time afforded. In his astronomical essays entitled "Bis an's Ende der Welt," written for the centenary of Doppler's birth, F. J. Studnička (1903), professor of mathematics at Prague University, gives a touching description of a small, gloomy classroom in the old Prague School of Technology at Jilská Street where Doppler taught for over ten years. Studnička ponders over the humble beginnings of Doppler's discovery, the fruit of which expands in fertility and abundance with the rise of modern astronomy. Indeed, with the Einsteinian gravitational red shift and the phenomenon of receding galaxies, Doppler's principle revealed most far-reaching consequences unforeseen half a century ago. During these best years of creativity while teaching in Prague, Doppler resided in a modest room at house number 4, Karlovo Plaza. This house in Prague actually carried a memorial tablet dedicated to Doppler, but the house was demolished after the war and replaced by a new courthouse building.

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

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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. Here commenced the period of the most fruitful years of his life, continuing until 1847.

In Prague Doppler accomplished his most notable works, above all, his treatise of fundamental importance for modern astrophysics, "Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels" (Doppler 1843). In this work on the coloured light of double stars, 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. As is well known today, he maintained that tone will appear higher the faster the source 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, first advocated, as he states, by Euler and Huygens, Doppler was first to apprehend that the wave theory of light involved a change in the observed wave-length of light from a given source, corresponding to motion of the source in the line of sight 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 colour 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 colour change for ordinary stellar velocities. Only in reference to the enigmatic high velocity of recession, such as recorded in recent years by external galaxies, did Hubble, as well as others, suggest the term "tired light" for lowered energy.

It is not easy to visualize the experimental difficulties Doppler confronted in his time with spectroscopy in its infancy and photography practically non-existent. 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. Here, in 1845, a locomotive and a flat car were secured especially for this purpose for two days and used in the experiment.

Doppler's erroneous assumption in his original paper concerning the change of colour of the stars due to the radial motion evidently enabled Fizeau to make a further step in the optical interpretation of the principle. Lecturing to the little known Société Philomatique 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 the 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 this original paper of 1848 that the study of radial velocities for components of certain visual binaries would enable us to determine their parallaxes. This remarkable paper did not arouse much excitement and it was saved from oblivion by belated publication (Fizeau 1870). Doppler's and Fizeau's ideas were, in turn, fully corroborated by Ernst Mach (1860) in his report to the Vienna Academy of Science. In his paper Mach discussed the vast significance which he foresaw in 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 provided with Kirchhoff's spectroscopic investigations by 1859. Half a century after Doppler's original publication and after somewhat unsuccessful efforts by Sir William Huggins, about 1866, to measure visually the predicted displacement of the stellar lines, H. C. Vogel (1890) at Potsdam Observatory achieved positive results by applying improved photographic technique to the measurement of radial velocities of stars. Outside the original pioneers, it is significant that none of the eminent investigators fully realized 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 exploration. 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 co-operation between physics and astronomy. Neither Doppler nor Fizeau may ever have entered an astronomical observatory, yet outside spectroscopy, few discoveries have had more extensive application in astronomical investigation. Fundamentally, the Doppler principle permits the determination of one of two components of a star's motion through space—radial velocity—an information indispensable for the study of the structure of our galaxy. 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 those of Keeler (1894) at Lick Observatory in 1890, proved unreliable. Vogel and Scheiner (1892) at Potsdam Observatory and Belopolsky at Pulkovo Observatory were among the pioneers in photographic method that allowed increased accuracy in the application of the Doppler principle in the measurement of radial velocities of stars. A greatly increased accuracy in determination of radial velocities on the plates of the Mills spectrograph of Lick Observatory was first attained in America by W. W. Campbell. It was at this same observatory that the observation of the rings of Saturn by Keeler (1895) became particularly famous for application of the Doppler principle, verifying spectroscopically James Clerk Maxwell's theory of the meteoric nature of rings announced nearly half a century earlier.

Doppler's work was recognized in Prague even before publication of his principal paper previously mentioned. He was elected a member of the Royal Bohemian Society of Learning in 1840. When Prague University observed its five-hundredth anniversary in 1848, at the time Doppler occupied the chair in physics and mechanics at the Imperial Mining Academy in Báňská Št'ávnica, 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. But the poverty and privations of Doppler's early years had undermined his health. Searching for recuperation from protracted illness, he left for the Italian southland but too late. He passed away in his forty-ninth year at Venice, March 17, 1853. In his latter years of recognition, Doppler always cherished the memory of his years in Prague where a new chapter of his life unfolded.

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