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# POLISH PHYSICISTS AND THE PROGRESS IN PHYSICS (1870–1920)

# FIZYCY POLSCY I ROZWÓJ FIZYKI (1870–1920)

A b s t r a c t

The Polish-Lithuanian Commonwealth lost independence in 1795 and was partitioned among her three powerful neighbours: Austria, Prussia and Russia. The two old Polish universities in Cracow and Lvov enjoyed relatively liberals laws in the Austrian partition. It was there that Polish physicists (Karol Olszewski, Zygmunt Wróblewski, Marian Smoluchowski, Władysław Natanson, Wojciech Rubinowicz, Czesław Białobrzeski, and others) made most important discoveries and original contributions. There was no possibility of career for Poles living in the oppressive Russian and Prussian partitions where even the use of Polish language was forbidden in schools. Thus many bright Polish students such as e.g. Kazimierz Fajans, Stefan Pieńkowski, Maria Skłodowska, and Mieczysław Wolfke, went abroad to study in foreign universities. In spite of unfavourable conditions under which they had to live and act in the period 1870–1920, Polish scholars were not only passive recipients of new ideas in physics, but made essential contributions to several fields such as e.g. cryogenics, electromagnetism, statistical physics, relativity, radioactivity, quantum physics, and astrophysics.

*Keywords*: *cryogenics*, *statistical physics*, *electromagnetism*, *relativity*, *radioactivity*, *quantum physics*, *astrophysics*

S t r e s z c z e n i e

Rzeczpospolita Obojga Narodów straciła niepodległość w 1795 r. i została podzielona między trzech potężnych sąsiadów: Austrię, Prusy i Rosję. Dwa stare polskie uniwersytety w Krakowie i Lwowie mogły działać w stosunkowo liberalnych stosunkach w zaborze austriackim. Właśnie tam fizycy polscy (Karol Olszewski, Zygmunt Wróblewski, Marian Smoluchowski, Władysław Natanson, Wojciech Rubinowicz, Czesław Białobrzeski i inni) dokonali największych i najbardziej oryginalnych odkryć. W represyjnych zaborach pruskim i rosyjskim, w których język polski był nawet zabroniony w szkołach, nie było możliwości kariery naukowej dla Polaków. Z tego powodu wielu zdolnych polskich studentów, jak Kazimierz Fajans, Stefan Pieńkowski, Maria Skłodowska czy Mieczysław Wolfke emigrowało, by studiować zagranicą. Mimo niesprzyjających warunków, w jakich przyszło im żyć i działać w okresie 1870–1920, uczeni polscy nie byli tylko biernymi odbiorcami nowych idei w fizyce, ale wnieśli znaczący wkład do wielu dziedzin, jak np. kriogenika, elektromagnetyzm, fizyka statystyczna, teoria względności, promieniotwórczość, fizyka kwantowa i astrofizyka.

*Słowa kluczowe*: *kriogenika*, *fizyka statystyczna*, *elektromagnetyzm*, *teoria względności*, *promieniotwórczość*, *fizyka kwantowa*, *astrofizyka*

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## 1. Introduction

Poland, or more precisely, the Polish-Lithuanian Commonwealth, once a powerful country, the largest in Europe, became weakened by perpetual wars with Russia and Turkey. After losing independence in 1795 it was partitioned among the three powerful neighbouring empires: Austria, Prussia and Russia.

In the period (1870–1920) considered in this paper Poland still remained an occupied country. Cracow (Kraków) with the Jagellonian University, the oldest in Poland, founded in 1364 by the Polish king Casimir the Great, was included in the Austrian Partition, and so was the university in Lvov (Lwów), founded in 1661 by the Polish king Jan Casimir and later renamed Francis I$^{st}$ University by the Austrian authorities. There was also Lvov Polytechnic (founded in 1844 as a Technical School).

The revolutionary national movements during the "Springtime of Nations" in the years 1848–1849 were suppressed by the conservative forces. But not long afterwards the Habsburg Empire, weakened by military defeats, became a constitutional monarchy, and the nations which formed parts of it were granted certain freedoms and autonomy. The administration and education system in the Austrian Partition was re-polonized. Teaching and research in universities in Cracow and Lvov, and also at the Lvov Polytechnic could be carried out in the Polish language.

Physics departments existed in all three institutions. The best known physicists at the Jagellonian University at that time were Karol Olszewski, Zygmunt Wróblewski, August Witkowski, Władysław Natanson, and Marian Smoluchowski (after 1913). Those in Lvov were Oskar Fabian and Marian Smoluchowski (until 1913) at the university, and Kazimierz Olearski, Łukasz Bodaszewski, and Tadeusz Godlewski at the Polytechnic.

The Cracow Scientific Society, established in 1816, was transformed in 1873 into the Academy of Sciences (Akademia Umiejętności). In addition to ordinary members from the Austrian Partition it also elected foreign members who were in large part Polish scientists living elsewhere in Europe, including the Russian and Prussian Partitions. The Academy began publishing a number of periodicals in foreign languages, English, French, and German, to report the results of Polish scientists irrespective of where they were doing research. Thus, this institution played a very important role in maintaining links between scholars in the partitioned Polish lands.

Warsaw, the former capital of Poland, was situated in the most oppressive Russian Partition. The Imperial Warsaw University (Cesarski Uniwersytet Warszawski) founded by the Russians in 1869 had all teaching and research conducted in Russian, the use of the Polish language having been banned by law. Polish youth largely boycotted that institution, and so a large part of its students were Russians.

During the revolutionary period 1905–1907 the tsarist regime was forced to make certain concessions in the Russian Partition. For example, in 1907 permission was granted to form the Warsaw Scientific Society (Towarzystwo Naukowe Warszawskie – TNW in short). It began to play a role similar to that of the Academy of Sciences in the Austrian Partition.

No institution of higher education and/or research existed in the Prussian Partition which included Poznań (Posen), Toruń (Thorn), and Gdańsk (Danzig).

Thus there was not much chance for the Poles to pursue a scientific career in the Russian and Prussian Partitions. The number of positions for physicists in the liberal Austrian Partition was small and limited. Therefore many bright young people chose to find education and employment in other countries. Among those émigrés who later excelled in physical sciences were Maria Skłodowska, Czesław Białobrzeski, Jan Czochralski, Kazimierz Fajans, Józef Kowalski-Wierusz, Jakub Laub, Julian Lilienfeld, Stanisław Loria, Stefan Pieńkowski, Wojciech Rubinowicz, Ludwik Silberstein, Ludwik Wertenstein, and Mieczysław Wolfke. Not all of them returned to Poland when it again became an independent country in 1918.

In spite of unfavourable conditions under which they had to live and study, Polish scholars not only maintained close contact with the forefront of research in physics, but made essential contributions to several fields, such as e.g. cryogenics, statistical physics, electromagnetism, relativity, radioactivity, quantum physics, and astrophysics.

## 2. Cryogenics

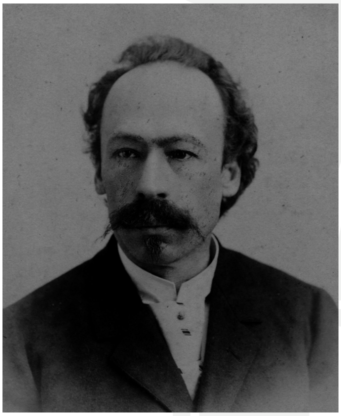


Fig. 1. Karol Olszewski

One of the “hot” subjects in physics in the second half of the XIX century was liquefaction of gases. Many gases could be obtained in a liquid form by simply cooling them and applying high pressure. However, several gases such as oxygen, nitrogen, carbon oxide, and hydrogen resisted liquefaction. Some scientists were even tempted to treat them as “permanent gases” which could not exist in a liquid state. However, in 1877 Louis Cailletet in Paris and Raoul-Pierre Pictet in Geneva, working independently and not knowing about each other, almost simultaneously achieved so-called dynamic liquefaction of oxygen, that is, they momentarily observed a short-lived fog in a container in which the gas, kept under high pressure, underwent rapid expansion caused by a sudden release. The observed fog was of course made up of minute drops of liquid gas which rapidly evaporated, and so there was no possibility for studying the properties of the liquid.

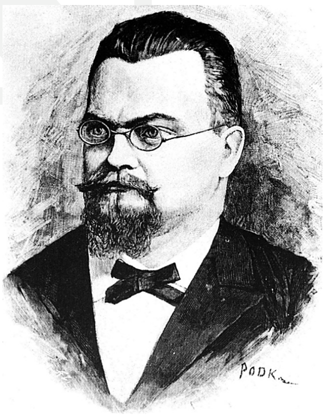



Fig. 2. Zygmunt Wróblewski

The groundbreaking static liquefaction of air and its components was achieved a few years later in Cracow by two scientists of the Jagellonian University, Zygmunt Wróblewski and Karol Olszewski. They made Cracow one of the world centres of low-temperature physics.

Zygmunt Wróblewski [1] (1846–1888) was born in Grodno (now in Belarus), went to schools there and in 1862 entered Kiev University to study physics. He became involved in conspiracy leading to the January Uprising of 1863, which was another desperate attempt by the Poles to regain independence from the Russians. Wróblewski was arrested by the Russian police and spent sixteen months in the Kiev prison. Afterwards he was transported to Siberia to serve the rest of his sentence. He was released in 1869, but as a former political prisoner he was barred from entering university anywhere in the Russian Empire.

Wróblewski went to Germany and studied physics in Berlin, Heidelberg, and Munich, where he obtained doctor's degree, and became *privatdozent* in Strasbourg. His experimental results on diffusion of gases were highly appraised by James Clerk Maxwell [2]. It resulted in an invitation from "Nature" to write a review article on this subject. Wróblewski's article appeared in that prestigious periodical in 1879 [3]. He published the same article also in Polish [4]. It helped to make his name as a scientist.

Wróblewski remained in Strasbourg until 1880. Then, with financial support from the Cracow Academy of Sciences, he visited several important physics laboratories in France and England. This experience helped him to decide on low temperatures as the domain of future research.

In 1882 the Jagellonian University appointed Wróblewski to the chair of experimental physics. In March of that year he came to Cracow bringing with him a Cailletet-type apparatus for attaining low temperatures which at that time had been already commercially produced in France.

Karol Olszewski (1846–1915) was born in Broniszów, a small village east of Cracow. He studied chemistry at the Jagellonian University. Then, in 1872, he went to Heidelberg to enrich his knowledge under Robert Bunsen and Gustav Kirchhoff. After return to Cracow he became first a *privatdozent* and in 1876 a professor of chemistry at the Jagellonian University. He also had in mind research of phenomena at low temperatures.

Wróblewski and Olszewski met and decided to join forces. They made two essential modifications of Cailletet's apparatus. Firstly, they replaced the original capillary tube with a wider one of a different shape, and secondly they used a new cooling container to lower the pressure over the boiling ethylene. In this way they were able to achieve temperatures as low as minus 135 degrees Celsius and finally, on March 29, 1883, succeeded to liquefy oxygen and a few days later also nitrogen and carbon monoxide in a static form, which enabled them to study the properties of these gases in a liquid state. The news about this important achievement were promptly communicated to the Academy of Sciences in Paris [5].

Sadly enough, after only a few months of successful collaboration the two scientists quarelled and separated. Since then they worked independently and later attempted to liquefy hydrogen. They could only claim dynamic liquefaction of that gas. Unfortunately Wróblewski died tragically on April 18, 1888, in consequence of heavy burns inflicted during the fire in his laboratory.

In 1894 William Ramsay and John William Rayleigh surprised the world by discovering a new gas, argon, the first of so-called inert gases. Ramsay did not trust his countryman John Dewar who had a cryogenic laboratory in London, so he sent samples of argon and also newly discovered helium to Olszewski's laboratory in Cracow to be liquefied and studied. Olszewski liquefied argon and examined its properties [6] but he failed to liquefy helium [7].

The successor to Wróblewski in the chair of experimental physics was August Witkowski (1854–1913). He performed important experimental investigations of the properties of gases, especially at low temperatures. Due to his efforts a new larger physics building was constructed in 1911 (this building is now called Witkowski's Collegium). Witkowski is also remembered as the author of an excellent modern physics textbook *Zasady fizyki* (*Principles of physics*, in 3 volumes, 1892–1912).

## 3. Statistical physics

The chair of theoretical physics at Lvov University was created In 1872. Its first holder was Oskar Fabian (1846-1899). He wrote a textbook on analytical mechanics [8] and a number of papers on mathematics and physics. In 1898 the entire physics department consisting of chairs of experimental and theoretical physics was transferred to the specially constructed building at 8, Długosza Street.

Fig. 3. Marian Smoluchowski

After Fabian's death the chair of theoretical physics was filled by Marian Smoluchowski. He was born in 1872 in Vorderbrühl, a small village near Vienna where his family lived at that time. His father was a Cracow lawyer who became Secretary at the Court of Emperor Franz Joseph. Smoluchowski studied physics and mathematics at the University of Vienna under famous physicists Franz Exner and Joseph Stefan, and also listened to lectures given by Ludwig Boltzmann and Ernst Mach. In 1895 he graduated with honours and after that spent eight months in Paris in the laboratory of Gabriel Lippmann, then several months in Glasgow, where he studied radioactivity under Kelvin, and finally five months in the Berlin laboratory of Emil Warburg.

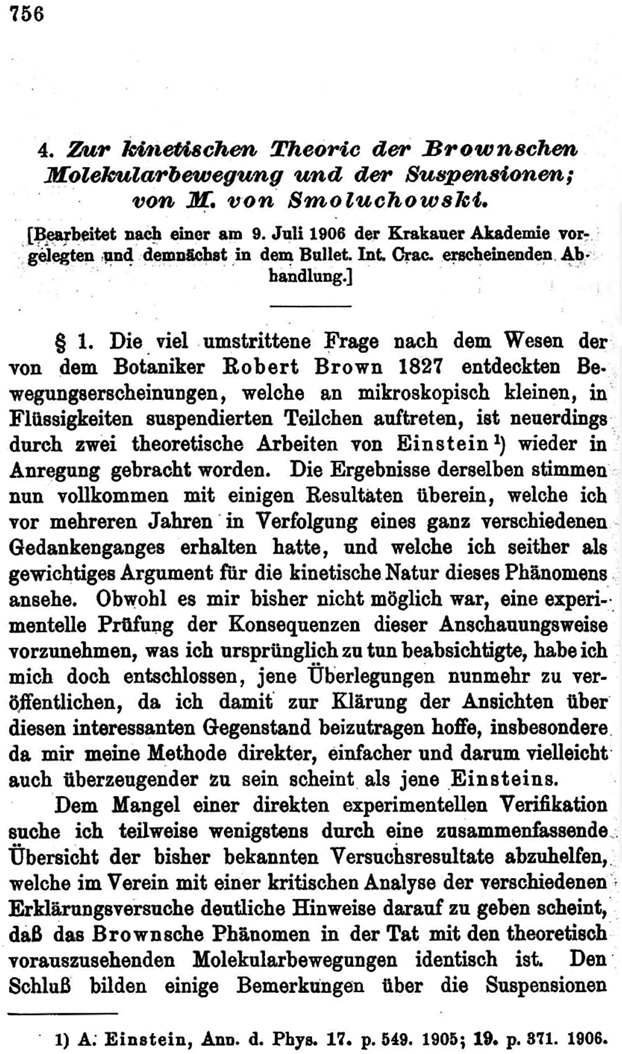
At the end of 1897 Smoluchowski returned to Vienna to become lecturer in the university of that city. However, already in May, 1899, he was invited to Lvov where at the age of twenty-eight he was promoted to the chair of theoretical physics, thus becoming the youngest professor in the Austro-Hungarian Empire.

During his work at Lvov between 1899 and 1913 Smoluchowski wrote several seminal papers on the theory of the Brownian motion, the kinetic theory of matter, the theory of fluctuations, and the theory of critical opalescence, to name a few.

In May, 1905, Albert Einstein, at that time still an unknown clerk in the Bern patent office, submitted to the "Annalen der Physik" the paper *On the motion of particles suspended in liquids at rest, required by the molecular-kinetic theory of heat* [9]. It contained an analysis of the Brownian motion. The same problem was independently investigated by Marian Smoluchowski. His results, obtained by a somewhat different method, were published in the following year [10].

Einstein and Smoluchowski have proved that irregular movement of particles suspended in a liquid results from their bombardment by molecules of the liquid. One may determine experimentally the mean-square displacement of the suspended particle in a given direction.

This quantity was found to be related to the Avogadro's number and the temperature of the liquid by a fundamental formula – now called the Einstein-Smoluchowski equation – which provided quantitative description of the Brownian motion. The discovery made independently by both scholars was an excellent confirmation of validity of the kinetic theory of matter and contributed to establishing atomistic concepts.



756

**4. *Zur kinetischen Theorie der Brownschen Molekularbewegung und der Suspensionen; von M. von Smoluchowski.***

**[Bearbeitet nach einer am 9. Juli 1906 der Krakauer Akademie vorgelegten und demnächst in dem Bullet. Int. Crac. erscheinenden Abhandlung.]**

**§ 1.** Die viel umstrittene Frage nach dem Wesen der von dem Botaniker Robert Brown 1827 entdeckten Bewegungserscheinungen, welche an mikroskopisch kleinen, in Flüssigkeiten suspendierten Teilchen auftreten, ist neuerdings durch zwei theoretische Arbeiten von Einstein [1]) wieder in Anregung gebracht worden. Die Ergebnisse derselben stimmen nun vollkommen mit einigen Resultaten überein, welche ich vor mehreren Jahren in Verfolgung eines ganz verschiedenen Gedankenganges erhalten hatte, und welche ich seither als gewichtiges Argument für die kinetische Natur dieses Phänomens ansehe. Obwohl es mir bisher nicht möglich war, eine experimentelle Prüfung der Konsequenzen dieser Anschauungsweise vorzunehmen, was ich ursprünglich zu tun beabsichtigte, habe ich mich doch entschlossen, jene Überlegungen nunmehr zu veröffentlichen, da ich damit zur Klärung der Ansichten über diesen interessanten Gegenstand beizutragen hoffe, insbesondere da mir meine Methode direkter, einfacher und darum vielleicht auch überzeugender zu sein scheint als jene Einsteins.

Dem Mangel einer direkten experimentellen Verifikation suche ich teilweise wenigstens durch eine zusammenfassende Übersicht der bisher bekannten Versuchsresultate abzuhelfen, welche im Verein mit einer kritischen Analyse der verschiedenen Erklärungsversuche deutliche Hinweise darauf zu geben scheint, daß das Brownsche Phänomen in der Tat mit den theoretisch vorauszusehenden Molekularbewegungen identisch ist. Den Schluß bilden einige Bemerkungen über die Suspensionen

1) A. Einstein, Ann. d. Phys. 17. p. 549. 1905; 19. p. 371. 1906.

Fig. 4. The beginning of Smoluchowski's paper on the Brownian motion

Some years later the French physicist Jean Perrin performed very precise experimental studies of the Brownian motion. He used a microscope to record successive positions and trace movements of individual particles (of a gum resin) suspended in a liquid. He checked that the mean square displacement in a given direction is indeed proportional to time, as predicted by the Einstein-Smoluchowski formula; from these observations he could calculate the value of the Avogadro's number.

After Witkowski's death in 1913 Smoluchowski was asked to fill the vacant chair and moved from Lvov to Cracow. He was elected rector of the Jagellonian University for the academic year 1917–1918 but unfortunately contracted dysentery and died on September 5, 1917, before taking office. Einstein, Sommerfeld and other eminent physicists of that time wrote commemorative articles expressing grief because of the premature passing away of the great physicist [11].

Marian Smoluchowski was indeed one of the most eminent scientists in Polish history. In addition to his 1906 work on the Brownian motion, he gave the explanation (1908) of critical opalescence, and in 1913 published an important statistical interpretation of the second law of thermodynamics. With the paper published in 1906 Smoluchowski originated the theory of stochastic processes [12].

It is worth to note that the first observation of the Brownian motion in gases has been made by another Lvov physicist, Łukasz Bodaszewski (1849–1908). He published his results in both German [13] and Polish [14]. This important discovery has been cited in several books and articles [15].

The properties of the distribution of colloidal particles have been studied experimentally by an Austrian chemist Richard Zsigmondy and also by a Swedish chemist Theodor Svedberg. They confirmed the formulae derived by Smoluchowski in 1904 [16].

Perrin became the recipient of the Nobel Prize for physics in 1926, whereas Zsigmondy and Svedberg received Nobel Prizes for chemistry in 1925 and 1926, respectively. Had Smoluchowski been alive at that time he would surely be a strong candidate for a Nobel Prize, too.

## 4. Electromagnetism

In 1864 James Clerk Maxwell announced his revolutionary electromagnetic theory. Its acceptance by physicists had been, however, quite slow.

On the experimental side the exciting discovery was that by Berend Feddersen who had proven in 1862 that the discharge of a Leiden jar (electric condenser) is an oscillatory process and consists of currents travelling in both directions between the plates. A number of authors engaged themselves in elaborating the theory of electric oscillations.

Kazimierz Olearski (1855–1936) was born in a small village near Cracow, went to schools in Cracow, and then studied at the Jagellonian University (1872–1876). Afterwards he completed his education in Leipzig and Berlin. He became *privatdozent* at the Jagellonian University and later went to Lvov Polytechnic where he took the chair of general and technical physics. Olearski published several papers on electromagnetism. His important article [17] on the theory of electrical oscillations published in the "Bulletin of the Cracow Academy of Sciences" has been noticed and cited e.g. by the eminent electrical scientist John Fleming [18].

Another Polish physicist who published papers on electromagnetism was Ludwik Silberstein (1872–1948). He was born in Warsaw, but studied first in Cracow, and afterwards

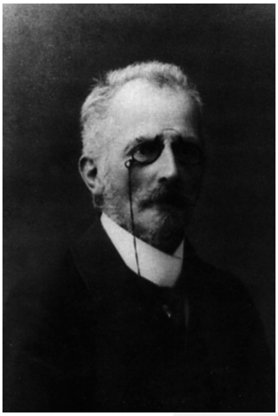


Fig. 5. Kazimierz Olearski

at Heidelberg and Berlin, where he got his Ph.D. In the years 1895–1897 Silberstein was assistant to Olearski at Lvov Polytechnic. That employment did not satisfy him and he returned to Warsaw. For a short period he earned his living by working in a private company. Since 1899 he was *privatdozent* in Bologna and Rome but stayed mostly in Warsaw and was very active in the Warsaw Scientific Society.

Silberstein was interested in mathematical physics, and electromagnetic theory and relativity in particular. Being a prolific author he published a few dozen papers in "Annalen der Physik", "Elektrochemische Zeitschrift", "Philosophical Magazine" and other foreign periodicals. He also published many articles in Polish, and also several books, including an excellent textbook of electric and magnetic phenomena [19]. In one of his papers he introduced a complex vector of the electromagnetic field (Riemann-Silberstein vector) [20]. In other papers he used quaternions to express relativity equations [21].

In 1913 Silberstein left Warsaw for good and lived first in Italy, then in London, and finally settled in the United States. In that later period he wrote several excellent books in English on special and general relativity and also on electromagnetism. According to Abraham Pais, "on several occasions, he was in dogged but intelligent opposition to relativity theory" [22].

## 5. Relativity

According to Leopold Infeld, a friend and collaborator of Albert Einstein, August Witkowski was the first Polish physicist who understood special relativity theory and saw in it the birth of a new science:

> "My friend Professor Loria told me how his teacher, Professor Witkowski (and a very great teacher he was!), read Einstein's paper and exclaimed to Loria: 'A new Copernicus has been born! Read Einstein's paper'. Later, when Professor Loria met Max Born at a physics meeting, he told him about Einstein and asked Born if he had read the paper. It turned out that neither Born nor anyone else had heard about Einstein. They went to the library, took from the bookshelves the seventeenth volume of Annalen der Physik and started to read Einstein's article. Immediately Born recognized its greatness and also the necessity for formal generalizations" [23].

Witkowski was indeed a critic of ether and a proponent of the principle of relativity which he described in his lectures.

However, the first Polish paper on relativity was published by Jakub Laub (1884–1962). He was born in Rzeszów, studied first at the Jagellonian University in Cracow, and then in Vienna and Göttingen. Afterwards Laub went to the University of Würzburg to study cathode rays under Wilhelm Wien. His Ph.D. thesis (1907) concerned secondary cathode rays. He published his dissertation both in German [24] and in Polish [25].

Wien asked Laub to read Einstein's special relativity paper [26] and give a talk about it at the physics institute colloquium. Laub at once became an ardent adherent of the theory of relativity and presented his calculations concerning the optics of moving bodies in two papers [27] in "Annalen der Physik". In July 1907 he reported his results at the $10^{th}$ Congress of Polish Physicians and Naturalists in Lvov [28] and later wrote a comprehensive article in Polish [29].

In February 1908 Laub wrote a letter to Einstein asking him about possibility of joint work on relativity. At that time Einstein, still an employee of the patent office in Bern, was known only to a few selected people, and he was glad to accept Laub's proposal. Thus Laub became the first collaborator of Albert Einstein. They published three joint papers [30] in "Annalen der Physik".

Following the advice of Einstein, Laub took the post of an assistant to Philipp Lenard in Heidelberg. At that time, however, Lenard became an enemy of Einstein's relativity theory, and ordered Laub to devise experiments which could give a definite proof of the existence of the ether. Laub wrote instead a splendid review of the special relativity theory [31]. Lenard became angry and promptly sacked Laub, who decided to accept the physics chair at the University of La Plata in Argentina. He arrived to Argentina in 1911. Some years later he entered the diplomatic service and was ambassador of Argentina in Germany and then in Poland (1936–1939).

A few other Polish physicists such as Wiktor Biernacki, Kamil Kraft (1873–1945), Henryk Merczyng (1860–1916), Ludwik Silberstein and Czesław Białobrzeski also published papers on the theory of relativity before 1920.

## 6. Radioactivity

Wiktor Biernacki (1869–1918) studied at the Imperial Warsaw University and was for six years an assistant to Peter Zilov, a Russian professor of physics there. He also simultaneously taught physics in a private Technical School in Warsaw and later at the Warsaw Polytechnic (founded in 1898).

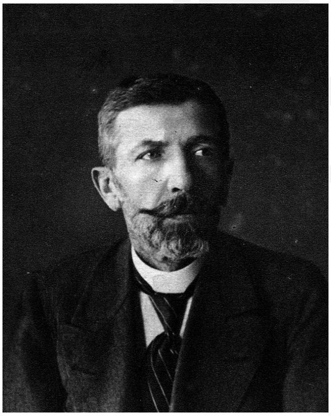
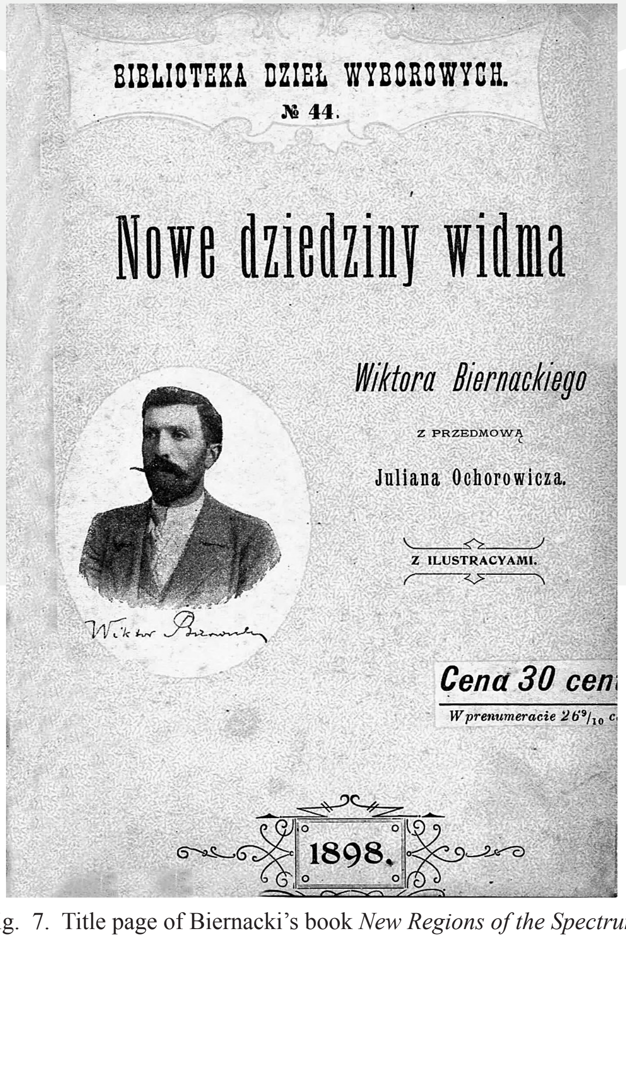


Fig. 6. Wiktor Biernacki

Biernacki published a number of articles on electromagnetism and also an excellent book on the newest discoveries in physics entitled *Nowe dziedziny widma* [32] (*New regions of the spectrum*). Large part of that book was devoted to the newly discovered electromagnetic rays but there was also detailed description of X-rays and "Becquerel rays". The book was published in Warsaw in the middle of 1898, but it had been written much earlier, probably at the time when Maria Skłodowska-Curie decided to study uranium rays.

The discoveries of new radioactive elements, polonium and radium, by Maria Skłodowska-Curie and Pierre Curie aroused great interest everywhere. The groundbreaking works of Maria Skłodowska-Curie, although done entirely in Paris, can be treated also as a part of Polish scientific heritage. The present text is, however, too short to allow for its full and detailed description. Thus we shall only stress that it is because of that great woman that Polish physicists played a significant role in the early history of radioactivity. Robert Lawson of Sheffield University published the following statistics [33]:

> "I have endeavoured to ascertain the numbers of authors in each country who have contributed four or more original papers on this subject. The result is embodied in what follows, the first numbers referring to those authors who have contributed four or more original papers and the numbers in brackets referring to the total number of authors who have made any noteworthy original contribution to radioactivity: British Empire 45 (171); Germany 28 (210); France 18 (70); Austria 10 (76); America 9 (89); Poland 4 (14); Switzerland 3 (19); Sweden 3 (9); Italy 2 (21); Norway 2 (20); Holland 2 (12); Hungary 2 (7); Russia 1 (13); Japan 1 (12); Denmark 1 (4), Roumania 0 (4); Spain 0 (1)".



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Nowe dziedziny widma

Wiktora Biernackiego

Z PRZEDMOWĄ

Juliana Ochorowicza.

Z ILUSTRACYAMI.

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Fig. 7. Title page of Biernacki's book *New Regions of the Spectrum*

Writing in 1921 Lawson apparently took note of the nationality of Polish physicists and not their citizenship imposed by the occupants, because he listed as Polish all those who were doing research in the Austrian and Russian Partitions. A few years later Stefan Meyer and Egon Schweidler [34] quoted as many as thirty Polish researchers, more than Lawson. Let us mention here several most important names.

Fig. 8. Tadeusz Godlewski

Tadeusz Godlewski (1978–1921) was born in Lvov and studied at the Jagellonian University in Cracow. He spent several months (1904–1905) in Rutherford's laboratory in Montreal and in that period published four papers on radioactivity. His most important paper concerned the discovery of a new radioactive substance called AcX (now $^{223}Ra$) [35]. After his return to Lvov Godlewski organized the first Polish laboratory devoted to the study of radioactivity. He originally served as an assistant to Olearski and since 1909 was professor of physics at the Lvov Polytechnic.

Kazimierz Fajans (1887–1975) was born in Warsaw and went to schools there. In 1904 he left the Russian Partition to study in Leipzig and Heidelberg. After obtaining his doctorate he spent some time (1910–1911) in Rutherford's laboratory in Manchester. In January 1913 Fajans formulated the "displacement law", which connected the type of radioactive decay with the shift of the product in the periodic system [36].

In February, 1913, Frederick Soddy, knowing already Fajans' papers, elaborated on the same topic; hence in the literature one finds the name "Fajans-Soddy displacement law". In the same year Soddy introduced the name "isotopes" for different radioactive substances which could not be separated by chemical means. Fajans noticed the same phenomenon but proposed to name such groups "pleiades", which was not accepted. For his important contributions Fajans got several nominations for the Nobel Prize in physics and chemistry [37].

Fig. 9. Kazimierz Fajans

In 1927 Fajans was invited to take the chair of physical chemistry at the University of Warsaw but it turned out that the authorities were not able to provide sufficient financial means for his laboratory. Thus he remained professor of chemistry in Munich. However, soon after the Nazi came to power in Germany, Fajans started looking for another employment. In 1935 the ultranationalistic and antisemitic attacks prevented him from accepting the chair of chemistry offered to him at the Lvov University. Finally he emigrated to USA and became professor of physics in Ann Arbor (Michigan).

### 6.1. Radiological Laboratory in Warsaw

Mirosław Kernbaum (1882–1911) was born in Warsaw, studied first in Charlottenburg and Zurich, and then physics in Geneva. He went to Paris and for three years (1908–1911) worked

Fig. 10. Mirosław Kernbaum

as an assistant to Maria Skłodowska-Curie. He published 10 important papers on radioactivity (and also 4 papers in Polish journals). But then, after returning to Poland, he unexpectedly developed a depression and committed suicide.

His father Józef, a rich Warsaw industrialist, decided to offer a large sum of money to the Warsaw Scientific Society (TNW) for establishing and maintaining a radiological physics laboratory in memory of Mirosław. The Warsaw Scientific Society accepted the offer and decided to invite Maria Skłodowska-Curie to take the direction of that laboratory. To that end a special TNW delegation, including Henryk Sienkiewicz (the 1905 winner of the Nobel Prize for Literature), was sent to Paris carrying that invitation.

However Maria Skłodowska-Curie was not able to return to Warsaw because of her involvement in the setting up of the Radium Institute in Paris. She decided instead to send to Warsaw two of her best Polish assistants, Jan Kazimierz Danysz and Ludwik Wertenstein, who were to run the radiological laboratory on her behalf and with her advice.

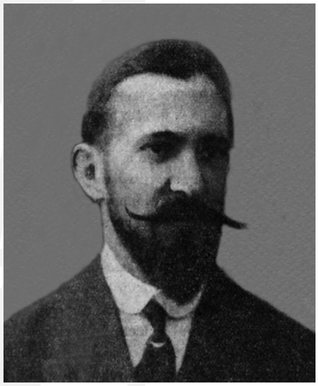


Fig. 11. Jan Kazimierz Danysz

Jan Kazimierz Danysz (1884–1914), known in the French sources as Jean Danysz, was born in Paris as son of Jan Danysz (1860–1928), a well-known Polish biologist who emigrated to France from the Prussian Partition, studied at the Sorbonne and later worked in the Pasteur Institute.

Jan Kazimierz Danysz served as an assistant to Pierre Curie and later to Maria Skłodowska-Curie. He studied radioactivity, in particular the beta radiation, and constructed the first beta spectrometer [38].

Ludwik Wertenstein (1887–1945) was born in Warsaw, finished schools there, and began studying physics at the Imperial Warsaw University. After a short time he was expelled for involvement in the students' protests. He then decided to emigrate to France, studied physics at the Sorbonne, and worked for five years (1908-1913) as an assistant to Maria Curie.

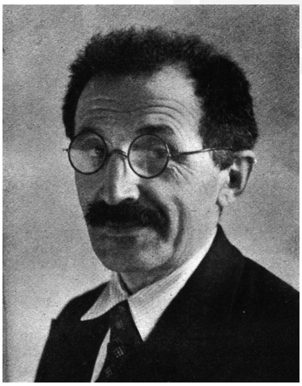


Fig. 12. Ludwik Wertenstein

In the summer of 1913 Jan Kazimierz Danysz and Ludwik Wertenstein arrived in Warsaw to organize and run the Radiological Laboratory of the TNW. The official inauguration of the laboratory took place on November 13, 1913, in presence of Maria Skłodowska-Curie who arrived from Paris. Unfortunately Danysz's stay in Warsaw was short. Being a French citizen, he returned to Paris after the outbreak of World War I, was drafted to the army, and killed in action already in November 1914.

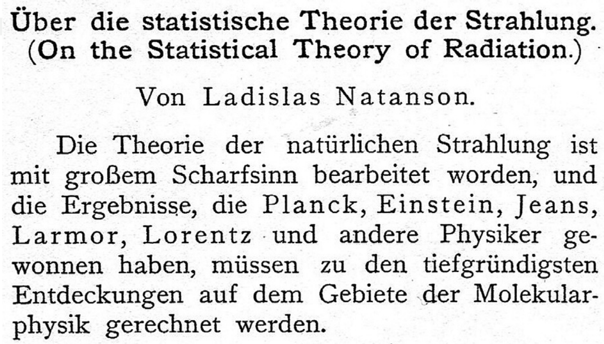
After 1914 the Radiological Laboratory of the TNW was directed by Wertenstein, who became also professor of physics at the Free Polish University (Wolna Wszechnica Polska) in Warsaw. In spite of poor financing the Radiological Laboratory of the TNW became an important research institution. It is worth adding that much later, in 1934, new radioactive isotopes of fluorine and scandium were discovered there by Marian Danysz (the son of Jan Kazimierz Danysz) and Michał Żyw.

## 7. Quantum physics

Fig. 13. Władysław Natanson

Władysław Natanson (1864–1937) was born in Warsaw, and studied in St. Petersburg, Dorpat and Graz. In 1890 he published the first Polish textbook of theoretical physics *Wstęp do fizyki teoretycznej* [39] (*Introduction to theoretical physics*). In 1891 he became a *privatdozent* at the Jagellonian University and stayed in Cracow ever since. In 1894 he became professor of theoretical physics. Natanson's interest was initially in thermodynamics and the kinetic theory of gases. He published several important papers on irreversible thermodynamics, and later on optical properties of matter. In 1911 he performed a pioneering analysis of radiation and derived the statistics of indistinguishable particles. His paper [40] was much ahead of the time and was not properly recognized. Thirteen years later the statistics of indistinguishable particles was rediscovered by Satyendra Nath Bose and improved by Einstein. Nevertheless, Natanson's priority has been recognized by historians of quantum physics. Thus Friedrich Hund wrote [41]:

> „This method of counting events for indistinguishable particles, which had already been perfectly clearly recognized by Natanson in 1911, was subsequently to be called Bose statistics (Natanson's work had of course been forgotten by 1924)".



**Über die statistische Theorie der Strahlung.**
**(On the Statistical Theory of Radiation.)**

Von Ladislas Natanson.

Die Theorie der natürlichen Strahlung ist mit großem Scharfsinn bearbeitet worden, und die Ergebnisse, die Planck, Einstein, Jeans, Larmor, Lorentz und andere Physiker gewonnen haben, müssen zu den tiefgründigsten Entdeckungen auf dem Gebiete der Molekularphysik gerechnet werden.

Fig. 14. The beginning of Natanson's paper *On the statistical theory of radiation*

According to Abraham Pais [42]:

„Ladislas Natanson from Cracow (1911) was the first to state that distinguishability has to be abandoned in order to arrive at Planck's law".

Similar statements may be found in several other books on the history of quantum physics [43].

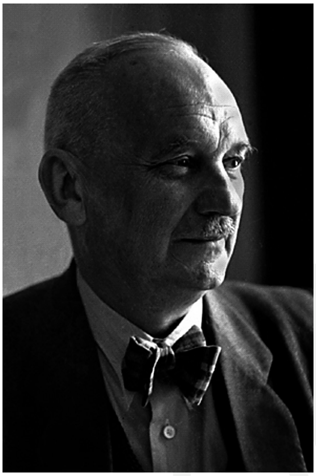


Fig. 15. Wojciech Rubinowicz

Wojciech Rubinowicz [44] (1889–1947) was born in Sadogora, and studied at the University of Czernowitz, where he obtained his doctor's degree. He later spent two years (1916-1918) as an assistant to Arnold Sommerfeld in Munich. It was there that Rubinowicz discovered selection rules for atomic transitions [45].

„At roughly the same time (1918) A. Rubinowicz in the Sommerfeld school and Bohr gave a selection rule for the angular momentum quantum number, which, following Bohr, was mostly called $k$ and $l$. Rubinowicz showed that an electromagnetic spherical wave can only transfer an angular momentum of 0 or $\pm h/2\pi$ when it receives or gives up an energy $h\nu$. He deduced from this that the angular momentum quantum number could only vary as between 0 and ±1" [46].

Using modern language we may say that it was the first estimate of the photon spin.

Later Rubinowicz was for a short time professor at the University of Ljublana in Yugoslavia, and since 1922 he was professor of physics at the Lvov Polytechnic. He has published a number of important papers on diffraction of light (1916, 1924, 1938), forbidden transitions in atoms (1929, 1930) and quadrupole radiation (1932). In 1933 he was invited to co-author the *Quantentheorie*, vol. 24/1 of the famous *Handbook der Physik*. The other five authors of that volume were: Wolfgang Pauli, Hans Bethe, Friedrich Hund, Gregor Wentzel, and Nevil Mott – all top physicists of that time (three of them: Pauli, Bethe, and Mott later received the Nobel Prize for physics).

Fig. 16. Mieczysław Wolfke

Another Polish physicist who worked on early quantum theory was Mieczysław Wolfke (1883–1947). He was born near Łódź, and studied in Liège, Paris and Breslau. During World War I he was a *privatdozent* at the Eidgenössische Technische Hochschule (ETH) in Zurich, and in 1921 got the appointment to the chair of experimental physics at the Warsaw Polytechnic. Wolfke published several interesting papers on localized light-atoms [47].

It is worth noting that in 1920 Wolfke proposed the principle of holography. Although his paper [48] was published in a well-known physics journal, the idea was not appreciated and was forgotten.

The principle of holography has been rediscovered much later by Dennis Gabor, who mentioned Wolfke in his Nobel Lecture (11 December, 1971) [49]:

> "(…) I did not know at that time (…) that Mieczislav Wolfke had proposed this method in 1920, but without realising it experimentally".

## 8. Other areas

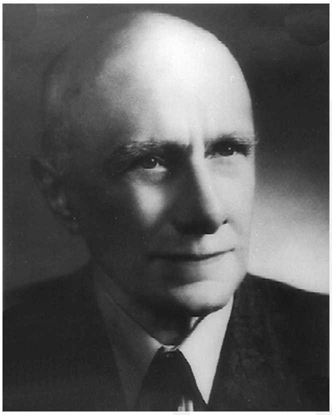


Fig. 17. Czesław Białobrzeski

Czesław Białobrzeski [50] (1878–1953) was born near Yaroslavl in Russia, where his father, a physician, was employed. He went to schools in Kiev and then studied physics at Kiev University. He spent two years (1908–1910) in Paris, working in the laboratory of Paul Langevin. After returning to Kiev we was appointed (1913) professor of physics at the university. When Poland regained independence Białobrzeski left Kiev and after a short stay in Cracow he became professor of theoretical physics at the University of Warsaw (1921).

In 1913 Białobrzeski published a pioneering work [51] on the physics of stars. He gave the proof that radiation pressure was an important factor in maintaining the internal equilibrium within stars. A similar theory was proposed three years later by the English astrophysicist Arthur Eddington [52]. These were World War years, so that he was ignorant of Białobrzeski's paper and did not cite it. Similarly, Białobrzeski had learned about Eddington's paper only after the war had ended. He then sent a copy of his 1913 paper to Eddington, who answered (1922) in a polite letter:

> "I congratulate you on having been apparently the first to point out the large share of radiation pressure in the internal equilibrium of a star".

Unfortunately, it was the only instance of Eddington's acknowledgment of Białobrzeski's paper which he later never cited in his books and articles. There is no doubt that Eddington was by far a better-known and more famous scientist than Białobrzeski. Thus, with years Białobrzeski's priority has been largely overshadowed by Eddington's accomplishment, although he had been quoted in a number of books [53].

The Białobrzeski-Eddington affair is a good example of so-called "Matthew Effect" introduced by R. K. Merton [54]:

> "For unto every one that hath shall be given, and he shall have abundance; but from him that hath not shall be taken away even that which he hath" (St. Matthew 25:29)

*O równowadze termodynamicznej kuli gazowej swobodnej. — Sur l'équilibre thermodynamique d'une sphère gazeuse libre.*

Mémoire

de M. **TCHESLAS BIALOBJESKI,**

présenté, dans la séance du 5 Mai 1913, par M. Lad. Natanson m. t.

Je me propose dans ce mémoire de mettre en lumière l'importance de la pression de radiation pour l'équilibre thermodynamique des sphères gazeuses de grandes dimensions. Les corps célestes, le soleil en particulier et les étoiles, peuvent être considérés comme de telles sphères isolées dans l'espace.

§ 1. *Système: gaz, énergie de radiation.*

Examinons un des systèmes les plus simples de la Thermodynamique. Soit un corps de pompe muni d'un piston mobile et ren-


Fig. 1.

fermant un gaz quelconque (fig. 1). On fournit au gaz une quantité de chaleur infiniment petite $dQ$. Lorsque le gaz se dilate, la

Fig. 18. The beginning of Białobrzeski's paper on radiation pressure

Fig. 19. Julian Lilienfeld

Julius Edgar Lilienfeld (1882–1963) was born in Lvov. In 1899 he began studies at the Technische Hochschule in Charlottenburg, but quickly decided on physics and chemistry at Berlin University; in 1905 he obtained doctor's degree for his studies of application of spectral analysis. He then went to Leipzig, where he was a *privatdozent* and a professor (since 1916). After World War I Lilienfeld paid several visits to the United States and in 1927 settled there for good. In 1930 he obtained a patent for the field--transistor effect [55]. The device was never constructed, but the patent had serious consequences, since because of its existence William Shockley's patent claim (1948) for a field transistor was rejected. Lilienfeld had also several other patents for electronic devices. He always stressed his

Polish background and nationality, and has been remembered as a Polish-American scientist and inventor.

Jan Czochralski (1885–1953) was born in Kcynia, a small town in the Prussian Partition. He initially worked in a pharmacy but in 1901 left to Berlin. He worked there in various industrial firms, and also studied chemical engineering at the Technische Hochschule in Charlottenburg. He specialized in metallurgy and worked in several industrial companies. In 1916 he invented a method of growing large monocrystals (his paper [56] was published only in 1918). Since 1929 Czochralski was professor of metallurgy and physics of metals at the Warsaw Polytechnic. After World War II "the Czochralski method" was found to be the most efficient way for producing crystals required by modern electronics, and Czochralski became the most often cited Polish scientist.

Fig. 20. Jan Czochralski

## 9. Conclusion

In the period 1870–1920 Polish physicists were not only passive recipients of new ideas in physics, but made essential contributions to several fields, such as e.g. cryogenics, electromagnetism, statistical physics, relativity, radioactivity, quantum physics, and astrophysics.

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