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General Relativity in Kraków 1945–1987

Abstract

We describe in what follows the development of general relativity in Kraków in the first four decades after the end of the Second World War in 1945. Professor Jan Weyssenhoff was the only theoretical physicist to survive the War. Most of his postwar Phd students started their scientific carreers from doing general relativity. In early 1960's emerged a group of young talented heoretical physicists that had been actively engaged in investigating modern at that time concepts of the theory. Almost all of them went later into other areas of physics. What was left from this period is the notable discovery of (2+1)- dimensional spacetimes (4-dimensional cosmic strings, in fact) by Andrzej Staruszkiewicz in 1963. Starting from the mid-1960's, only Staruszkiewicz had been actively researching relativity theory. He had many students and by 1985 we can observe the re-emergence in Kraków of a new generation of young researchers. The most significant result of that time – the uniqueness of the Kerr-Newman black hole – was proven by Paweł Oskar Mazur in 1982.

Keywords: *general relativity*, *Kraków*, *period 1945–1987*, *three-dimensional spacetimes*, *no hair hypothesis for black holes*, *history of science*

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Ogólna teoria względności w Krakowie 1945–1987

Abstrakt

Przedstawiamy poniżej rozwój ogólnej teorii względności w pierwszym czerdziestoleciu po zakończeniu w 1945 roku II wojny światowej. Profesor Jan Weyssenhoff był jedynym fizykiem teoretycznym, który przetrwał w Krakowie tę wojnę. Większość jego powojennych doktorantów zaczynała karierę naukową od badania ogólnej teorii względności. W początkach lat 60. pojawiła się grupa utalentowanych młodych fizyków teoretyków, którzy zaangażowali się w badanie nowych wówczas koncepcji. Prawie wszyscy przeszli później do uprawiania innych działów fizyki teoretycznej. Tym, co przetrwało próbę czasu, jest odkrycie (2+1)-wymiarowych czasoprzestrzeni (4-wymiarowych strun kosmicznych, jak się okaże) przez Andrzeja Staruszkiewicza w 1963 roku. Począwszy od połowy lat 60. jedynie Staruszkiewicz zajmował się badaniem teorii względności. Miał on wielu studentów i w roku 1985 odnotowujemy odrodzenie w Krakowie nowej generacji młodych badaczy. Najbardziej znaczący wynik uzyskany przez nich w tym czasie – jednoznaczność rozwiązania Kerra-Newmana – został dowiedziony przez Pawła Oskara Mazura w 1982 roku. Najbardziej znaczący wynik uzyskany przez nich w tym czasie – jednoznaczność rozwiązania Kerra-Newmana – został dowiedziony przez Pawła Oskara Mazura w 1982 roku.

Słowa kluczowe: *ogólna teoria względności*, *Kraków*, *lata 1945–1987*, *trójwymiarowe czasoprzestrzenie*, *hipoteza o braku włosów dla czarnych dziur*, *historia nauki*

1. Introduction: before 1945

Jan Weyssenhoff (27.11.1889–11.08.1972) obtained his PhD from the Zurich University in 1916, for the dissertation "Applications of quantum theory of rotating objects and theory of paramagnetism" (Średniawa 1985). He had an assistanship at ETH and the Zurich University in the period 1917–1919. After his return to Poland (in 1919) he obtained habilitation in 1921 at the Philosophical Faculty of the Jagiellonian University. Weyssenhoff had been appointed the associate professor at the Stefan Batory University at Vilnius in 1921 and then in 1935 he moved to Kraków, where he was nominated to associate professorship, and since 1938, full professorship at the Jagiellonian University.

He attracted to Kraków a group of physicists and mathematicians – Adam Bielecki, Józef Lubański and Myron Mathisson. They had been working mainly on the motion of test fluids in a given spacetime. That programme had been based on the idea of Myron Mathisson of describing the motion of test fluids using multipole expansions. It was published in 1937 in *Acta Physica Polonica* and again (in English translation) in 2010 in *General Relativity and Gravitation* (Mathisson 1937). W.G. Dixon commented on this work as follows:

> In 1937, Myron Mathisson published in this journal a paper entitled *A New Mechanics of Material Systems.* This showed for the first time how an extended body in general relativity could be described by an infinite set of multipole moments and how approximate equations of motion could be obtained by retaining only a finite number of these moments. He obtained such equations of motion when only the monopole and dipole moments are retained and also partial results when the quadrupole moment is also retained. This was the start of a programme of work that he continued until his death in 1940 (Dixon 2008).

The second world war led directly or indirectly to the destruction of the Weyssenhoff's group (Średniawa 1985). Mathisson left in 1939 to Cambridge (UK), where he died in 1940. Lubański had been from 1938 on a scholarship in Netherlands, where he died in 1946. Adam Bielecki had been imprisoned within the Sonderaktion Krakau and sent in 1940 to German concentration camps of Sachsenhausen and Dachau. After the war he worked at the Maria Curie-Skłodowska University in Lublin.

The Jagiellonian University had been closed during the German occupation, although there existed some forms of organized secret teaching, directed by professor Małecki (Średniawa 1985). Weyssenhoff collaborated with his students Antoni Raabe and Bronisław Średniawa for a few months

of 1941 and 1942. This work with Raabe was quite fruitful – it resulted in two papers that had been published after the war – but Bronisław Średniawa recalled that:

> in June 1942 Raabe was arrested by Germans in a man-hunt in a street of Cracow and sent to Auschwitz concentration camp, where he died four months later (Średniawa 1985).

2. Postwar activity: 1945–1963

The Jagiellonian University resumed its normal academic teaching in February 1945. Poland, devastated by the second world war, had been under a strict Soviet Russia control. The economic hardship had been combined with a strong ideological pressure. It is not my intention to give a detailed picture of these times; let me just refer the reader to reports of two lecturers from the Institute of Physics that started their academic carrer in the beginning of 1950's. Professor Antonina Kowalska describes in her memoirs (Kowalska 2021)[1] the removal of a philosopher Roman Ingarden from his university professorship in 1951. Ingarden had been chairing the Department of Christian Philosophy, that had been also liquidated at that time. Professor Kisiel (Kisiel 2024) in turn writes about preparation of various physical experiments, without access to modern specialist literature, no contacts with western scientific institutions and with rather limited financial resources. A visitor of the library of the Institute of FAIS Faculty of the Jagiellonian University, who read the preceding passage, might be surprised to see an almost complete edition of the Physical Review from 1950's; let me explain that this was due to the private initiative and contacts of professor Weyssenhoff (Białas 2024). No travel to the West was allowed in the first half of 1950's, when the oppression of the communist regime installed by Soviets culminated in Poland. In addition, the academic staff had been overloaded with teaching, since the number of students increased enormously.

Jan Weyssenhoff had been for many years the only professor of theoretical physics in Kraków. The other professor Jan Blaton, who had been elected in 1946 to chair Theoretical Mechanics, died tragically in May 1948. Professor Jerzy Rayski returned to Kraków from the Nicolai Copernicus University in Toruń as late as in 1957 roku, and in 1959 he replaced Jan Weyssenhoff (after his retirement) as the Chair of Theoretical Physics.

Thus it is not suprising that in the period 1945–1964 the activity of theoretical physicists in Kraków had been dominated by general relativity. I know nine doctoral dissertations that had been defended at that time; six of them dealt with general relativity or gravitation. Their topics had been usually close to scientific interests of Weyssenhoff.

Weyssenhoff and his students wished to find a classical counterpart of quantum spinning particles. The motivation and formalism had been explained in two publications in the *Acta Physica Polonica* (Weyssenhoff, Raabe 1947), that originated from the work that Weyssenhoff and Raabe did in 1942. The authors dealt with spinning particles within the special relativity theory – in Minkowski spacetime. Equations analyzed in their papers coincide with the special (dipole) case of Mathisson's construction described in the seminal paper (Mathisson 1937).

Weyssenhoff supervised three doctoral dissertations dealing with general relativity. I list them below after Bronisław Średniawa (Średniawa 1985; 1994).

[1] Short excerpts have been presented in Malec 2024.



Fig. 1. Diploma students and professors of Departments of Physics of Jagiellonian University. Professor Jan Weyssenhoff is seated second from the left, Professor Henryk Niewodniczański is fourth from the left. The picture was taken in early 1950's and it is reproduced here thanks to the kind agreement of Professor Kisiel – see the original in (Kisiel 2024).

Bronisław Średniawa (17.6.1917–10.8.2014) defended the thesis "Relatywistyczne równania ruchu cząstki dipolowej i kwadrupolowej swobodnej" (Relativistic equations of motion of free dipole and quadrupole particles) in 1947.

Zbigniew Borelowski (26.1.1933–5.8.2021) defended his dissertation "Jednorodna zasada wariacyjna z wyższymi pochodnymi w szczególnej teorii względności" (Homogeneous variational principle with higher derivatives in special relativity theory) in 1961.

Andrzej Białas defended his PhD thesis "Promieniowanie i ruch dipola magnetycznego" (Radiation and the motion of a magnetic dipole) in 1962.

Bronisław Średniawa changed his scientific interests in the middle of 1950's, in favour of quantum mechanics and nuclear physics. Zbigniew Borelowski stayed within the field, defined by his doctoral research, until the end of 1960's. Andrzej Białas decided to enter into the area of high energy physics – he had got a research grant in CERN starting from January 1964.

The end of 1950's and the beginning of 1960's had been a time of rapid developments in general relativity. We can observe the acceptance of the mathematical status of the Schwarzschild solution[2] and of the physical relevance of gravitational waves.[3] Brill[4] proved that gravitational waves possess a mass. Initial value formulations of Einstein equations had been proposed;[5] it became popular in the GR community. I find interesting that Choquet-Bruhat does not mention the work of Arnowitt, Deser and Misner in her short history of the Cauchy problem in General Relativity.[6] Penrose used

[2] Kruskal 1960; Szekeres 1960.
[3] Trautman 2015; see Kennefick 2007 for a thorough history.
[4] Brill 1959.
[5] Arnowitt, Deser, Misner 1959.
[6] Choquet-Bruhat 2014.

topological methods in his singularity theorems.[7] The rotating black hole had been found in 1963[8] and its charged counterpart in 1965.[9] The first astrophysical candidate for a black hole was detected (Cygnus X-1) in 1964.[10] We can notice the leading role in these developments of the Princeton relativity group centered around John Archibald Wheeler. Kip Thorne (a student of Wheeler at a time) describes this period as the beginning of the golden era of general relativity.[11]

The Stalinist epoch in Poland ended in 1956; after that year scientific travels to the West had been difficult but possible. New titles of western physical journals appeared in the Jagiellonian University Library. The Jagiellonian University had been awarded some funds in order to prepare for the 600th anniversary of its foundation which took place in 1364. The Institute of Physics of Jagiellonian University moved from Collegium Witkowskiego on Gołębia street to a new (much larger) building on Reymonta street in 1964. Information about new developments in general relativity certainly diffused to Kraków. It should come as no surprise that a group of young gifted theoreticians – Andrzej Białas, Elżbieta Białas, Bohdan Kozarzewski, Józef Namysłowski and Andrzej Staruszkiewicz – undertook investigation of modern topics of general relativity and gravitation in the beginning of 1960's. They worked independently on their own matters of interest. Private contacts and discussions had existed but there was no a formal forum (a seminar) for discussions (Białas, Staruszkiewicz 2024).

Andrzej Białas inspired the creation of Summer Schools of Theoretical Physics in Zakopane. The first conference took place in 1961. During the second conference (Kalatówki 1962) Andrzej Białas gave a talk on "O klasyfikacji algebraicznej pól grawitacyjnych" (On algebraic classification of gravitational fields). His wife Elżbieta Białas talked on "Inwariantne sformułowanie teorii promieniowania grawitacyjnego" (Invariant formulation of the theory of gravitational radiation). Andrzej Staruszkiewicz lectured on "O pomiarach i wielkościach mierzalnych w ogólnej teorii względności" (On measurements and measurable quantities in general relativity theory). I refer here only to lectures dealing with general relativity – the list of talks was much longer. All presentations had been published in *Prace Fizyczne* – a bulletin published by the Jagiellonian University (*Prace Fizyczne* 1963).[12]

The Third Summer School in Theoretical Physics (June 10–22 of 1963 in Dolina Chochołowska) had been dominated by general relativity. I list below titles of some of relevant lectures (see also *Prace Fizyczne* 1965).[13]

Thus, Halina Światak talked on "Fizyczne i grawitacyjne własności pól grawitacyjnych dopuszczających grupy ruchów (Physical and gravitational properties of gravitational fields that admit group of motions). Bohdan Kozarzewski lectured on "Asymptotyczne własności pola grawitacyjnego" (Asymptotic properties of gravitaional fields). Elżbieta Białas dealt with "Pola grawitacyjne dopuszczające promienie geodezyjne" (Gravitational fields that admit geodesic rays). Andrzej Białas lectured on "Fale grawitacyjne w ogólnej teorii względności" (Gravitational waves in general relativity. Finally, Andrzej Staruszkiewicz gave a lecture on "Teoria grawitacji w przestrzeni trójwymiarowej" (Three-dimensional spacetime). Józef Namysłowski, who 2 months earlier obtained his PhD degree (for a thesis written under Jerzy Rayski, entitled "Wpływ pola grawitacyjnego i elektromagnetycznego na pole spinorowe" – Impact of gravitational and electromagnetic field onto spinorial fields) decided to talk on a different topic. He soon left the field of general relativity.

The official conference picture of the participants of this 1963 conference, published in *Prace Fizyczne* 1965, is shown below (Fig. 2).

[7] Penrose 1965.
[8] Kerr 1963.
[9] Newman et al. 1965.
[10] Bowyer et al.1965.
[11] Thorne 1994.
[12] I quote after Pawłowska, Dobija 2024.
[13] *Ibidem*.



Fig. 2. Participants of the Summer School of Theoretical Physics in Zakopane (strictly saying, in Chochołowska Valley), 1963. After Pawłowska, Dobija 2024. Standing from the the left: Prof. Jerzy Gierula, Prof. Jan Weyssenhoff and Prof. Marian Mięsowicz, X, Prof. Jan Łopuszański, Romuald Wit, Halina Światak, Dr. Zbigniew Borelowski, Andrzej Staruszkiewicz, Dr. Jan Olszewski, Dr. Antonina Kowalska, X, Kinga Eskreys. Seated in the upper row: X, Prof. Bronisław Średniawa, X, Dr. Kacper Zalewski, X, Dr. Józef Namysłowski, Dr. Andrzej Białas, X, X, X. Seated in the lower row: X, X, Jędrzej Śniatycki (?), Elżbieta Białas, X, X, Andrzej Eskreys. Several participants are not identified in this picture, including Uhlmann, Maksymowicz, Umiastowski, Kozarzewski, Bochnacki and Tulczyjew.

3. Three-dimensional spacetimes of Andrzej Staruszkiewicz and their reception: John Wheeler in Les Houches 1963 and further developments

Leopold Infeld had been the most influential Polish relativist in early 1960's. He had been interested in the relation between gravitational field and matter (Einstein-equations and equations of matter). Field equations had been expected to dictate the motion of material fields. We should add that this difficult question had been investigated by many other researchers of that time.

Andrzej Staruszkiewicz told me at various occasions in 2024 that he was aware of Infeld's problem. He decided that the easiest way to tackle the issue is to investigate Einstein equations in 3 dimensions. He finished his work in May 1963 – the article "Gravitation theory in three-dimensional spacetime" had been submitted to *Acta Physica Polonica* on Friday 31st of May and it had been published in December of 1963 (Staruszkiewicz 1963). Staruszkiewicz gave also a talk during the Third Summer School in Theoretical Physics (at Dolina Chochołowska 1963), published two years later (Staruszkiewicz 1965). The contents of the paper (Staruszkiewicz 1963) and of the talk (Staruszkiewicz 1965) are similar. He states in that the external metric generated by a single body can be written in cylindrical coordinates as follows (Staruszkiewicz 1965):

$$ds^2 = -dt^2 + adr^2 + r^2\, d\varphi^2,$$

where the angle variable φ satisfies inequalities $0 < \varphi \leq 2\pi$ and the coefficient a is constant. He presented an argument that the positiveness of mass requires that $a \geq 1$. Take the hypersurface of constant time t. It is locally flat outside regions filled with matter. It is easy to see that the

circumferential radius of a circle labelled by *r* reads *r* while its geodesic radius reads $r\sqrt{a}$; thus their ratio is $1/\sqrt{a}$ – there appears the angle deficit $2\pi\,(1-1/\sqrt{a}\,)$ for a positive mass. Thus the hypersurface $t = const$ has the cone geometry and there can appear non-Euclidean effects. This is described by the following statement that ends the *Acta Physica Polonica* paper:

> As a result in the sense of *integral* geometrical properties the trajectories of the particles are not of Euclidean character. In particular there can occur twice intersecting trajectories as is easily found on a cone (trajectories of test particles). Clearly, such particles cannot exist within the framework of Euclidean space (Staruszkiewicz 1963).

In the same paper it is stressed that in a similar way one can find the external geometry for an arbitrary number of bodies of compact support. The external geometry of two massive bodies in rest had been also presented. It reads, in the notation of the paper published in *Acta Physica Polonica* (Staruszkiewicz 1963), as follows:

$$ds^2 = dt^2 - |c|^2 \frac{dx^2 + dy^2}{[(x-a)^2 + y^2]^{\frac{\alpha}{\pi}} [(x-b)^2 + y^2]^{\frac{\beta}{\pi}}}.$$

The two massive bodies are located on the x-axis at points a and b respectively. 2α and 2β are angle deficits in regions close to the bodies.

Staruszkiewicz explicitly states in his conference talk that "trójwymiarowa teoria Einsteina nie może reprodukować w przybliżeniu klasycznym dwuwymiarowej teorii Newtona" (Staruszkiewicz 1965). Here is the English translation of this statement: "three-dimensional Einstein gravitation cannot give in the classical limit the two-dimensional Newtonian gravity".

Staruszkiewicz wrote his doctoral thesis in 1964. Comparing it to the former publications (Staruszkiewicz 1963; 1965) , we notice two new important elements.

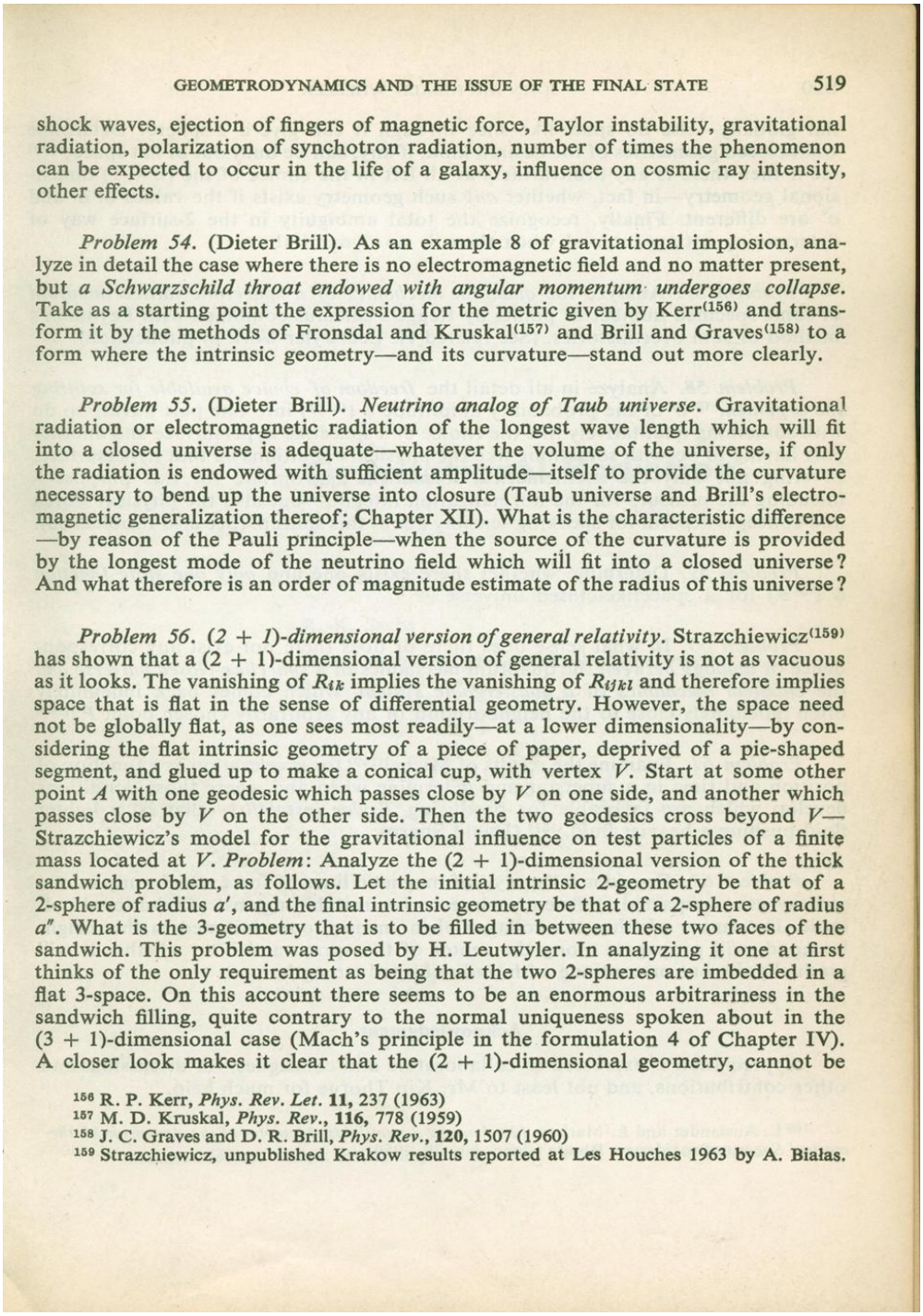
First, the three-dimensional spacetime Σ seems to be interpreted – I use the conditional phrase, since this is not explicitly explained by Staruszkiewicz – as a submanifold of a 4-dimensional spacetime that exhibits translational invariance in the spatial direction orthogonal to the hypersurface Σ – say in the z-th direction. The angle deficits μ are now related to the two-dimensional integrals $\mu = \int dx^1\, dx^2\, T_{00}\, \sqrt{\det(g)}$ – the mass line densities dm/dz – of sources at rest. T_{00} is now the mass volume density of a source. Notice that the mass line density μ is dimensionless. In the case of a single static source the angle deficit is equal to 4π μ. Thus there appears for the first time (to my knowledge) the concept of the cosmic string solution, formulated explicitly twenty years later (in 1980's), albeit I have to stress that Staruszkiewicz does not use this terminology.

Second, the doctoral thesis contains also a proposal for a geometric definition of point-like sources in 3-dimensional spacetimes; it is shown that there is no need to use the concept of Dirac δ functions.

In the same 1963 year the Les Houches Summer School of Theoretical Physics: Relativity, Groups and Topology took place, between July 1st and August 24th. There was one participant from Kraków, Dr. Andrzej Białas and at least three relativists from Warsaw (including Dr. Stanisław Bażański and Marek Demiański – see Communication 2024).

Wheeler gave one of the main courses in this school. His lecture notes that had been published in proceedings of this school (Wheeler 1964) show that he had been impressed by the work of Staruszkiewicz. Notice, that Wheeler mispells the name of Staruszkiewicz – in his article appears "Strazchiewicz". Further, he says in a footnote that the work of Staruszkiewicz was reported at Les Houches 1963 by A. Białas. I asked Andrzej Białas whether he gave a seminar. He answered that he did not give any seminar during the school, but certainly talked privately to Wheeler (Białas 2024).
Wheeler proposes many open problems within his course. In one of them, in the first part of Problem 56, he describes basic properties of 3-dimensional spacetimes. He stresses, in particular, that locally

flat geometries can be non-Euclidean globally. We reproduce below the relevant part of Wheeler's lecture notes containing the Problem 56.



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shock waves, ejection of fingers of magnetic force, Taylor instability, gravitational radiation, polarization of synchotron radiation, number of times the phenomenon can be expected to occur in the life of a galaxy, influence on cosmic ray intensity, other effects.

Problem 54. (Dieter Brill). As an example 8 of gravitational implosion, analyze in detail the case where there is no electromagnetic field and no matter present, but *a Schwarzschild throat endowed with angular momentum undergoes collapse.* Take as a starting point the expression for the metric given by Kerr[156] and transform it by the methods of Fronsdal and Kruskal[157] and Brill and Graves[158] to a form where the intrinsic geometry—and its curvature—stand out more clearly.

Problem 55. (Dieter Brill). *Neutrino analog of Taub universe.* Gravitational radiation or electromagnetic radiation of the longest wave length which will fit into a closed universe is adequate—whatever the volume of the universe, if only the radiation is endowed with sufficient amplitude—itself to provide the curvature necessary to bend up the universe into closure (Taub universe and Brill's electromagnetic generalization thereof; Chapter XII). What is the characteristic difference —by reason of the Pauli principle—when the source of the curvature is provided by the longest mode of the neutrino field which will fit into a closed universe? And what therefore is an order of magnitude estimate of the radius of this universe?

Problem 56. (2 + 1)-dimensional version of general relativity. Strazchiewicz[159] has shown that a (2 + 1)-dimensional version of general relativity is not as vacuous as it looks. The vanishing of R_{ik} implies the vanishing of R_{ijkl} and therefore implies space that is flat in the sense of differential geometry. However, the space need not be globally flat, as one sees most readily—at a lower dimensionality—by considering the flat intrinsic geometry of a piece of paper, deprived of a pie-shaped segment, and glued up to make a conical cup, with vertex V. Start at some other point A with one geodesic which passes close by V on one side, and another which passes close by V on the other side. Then the two geodesics cross beyond V— Strazchiewicz's model for the gravitational influence on test particles of a finite mass located at V. *Problem*: Analyze the (2 + 1)-dimensional version of the thick sandwich problem, as follows. Let the initial intrinsic 2-geometry be that of a 2-sphere of radius a', and the final intrinsic geometry be that of a 2-sphere of radius a''. What is the 3-geometry that is to be filled in between these two faces of the sandwich. This problem was posed by H. Leutwyler. In analyzing it one at first thinks of the only requirement as being that the two 2-spheres are imbedded in a flat 3-space. On this account there seems to be an enormous arbitrariness in the sandwich filling, quite contrary to the normal uniqueness spoken about in the (3 + 1)-dimensional case (Mach's principle in the formulation 4 of Chapter IV). A closer look makes it clear that the (2 + 1)-dimensional geometry, cannot be

[156] R. P. Kerr, *Phys. Rev. Let.* **11,** 237 (1963)
[157] M. D. Kruskal, *Phys. Rev.*, **116,** 778 (1959)
[158] J. C. Graves and D. R. Brill, *Phys. Rev.*, **120,** 1507 (1960)
[159] Strazchiewicz, unpublished Krakow results reported at Les Houches 1963 by A. Białas.

Fig. 3. This scan shows Wheeler's description of basic properties of 3-dimensional spacetimes. He credits their discovery to Staruszkiewicz, mispelled as "Strazchiewicz" (Wheeler 1964)

Information about Wheeler's enthusiastic reaction probably reached the Warsaw community of general relativists – as we already know, at least 3 participants of this Les Houches school came from Warsaw. A few weeks (or perhaps months) later Staruszkiewicz had been invited by Andrzej Trautman – a young (30 years old) docent (meaning a scientist with a doctorate and habilitation) at the Institute of Theoretical Physics of the Warsaw University – in order to give a talk on 3-dimensional

spacetimes in the seminar led by Leopold Infeld. Infeld had been present during Staruszkiewicz's lecture and asked several questions.

Somewhat later Trautman wrote to Jerzy Rayski, who had been heading the Chair of Theoretical Physics of the Jagiellonian University, that in his opinion the work of Staruszkiewicz suffices for a PhD thesis and that he – Trautman – can be one of the referee's. That was quite important for the young (barely 24 years old!) assistant. The thesis "Trójwymiarowy model teorii grawitacji" (Three-dimensional gravity model) had been written in 1964 and defended on May 27th of 1965. Professor Jerzy Rayski had been the (purely nominal) supervisor while Trautman and Weyssenhoff refereed the thesis.

The 1963 paper on three-dimensional spacetimes of Staruszkiewicz had been virtually unknown for two decades. In 1984 Deser, Jackiw and 't Hooft published "Three-dimensional Einstein Gravity: Dynamics of Flat space" (Deser, Jackiw, 't Hooft 1984) where they quote (actually wrongly – they refer to the page number 734 of (Staruszkiewicz 1963), while the correct page is 735) the work of Staruszkiewicz. Obviously, they were not aware about those new elements that had been present in his PhD thesis (see my comments above), because it was written in Polish. They obtain, in a different way, some results of (Staruszkiewicz 1963); they got also new results in the case of a nonzero angular momentum. They point also that in the case of a single body a conical spacetime had been obtained in 1958 by Marder (Marder 1958). I checked that the journal *Proceedings of the Royal Society Ser. A*, in which Marder published his article, was not available in Kraków at that time. Staruszkiewicz told me that he was not aware about Marder's work. Anyway, the publication of Deser, Jackiw and 't Hooft in 1984 marks the beginning of the world-wide interest in the paper of Staruszkiewicz (Staruszkiewicz 1963) – the Science Citation Index registers in the first half of the year 2025 more than two hundred citations, almost all coming after the year 1983.

4. General relativity in Kraków 1965–1978

As we have noticed, before 1963 existed a group of young relativists at the Institute of Physics of the Jagiellonian University. Andrzej Białas, Elżbieta Białas and Józef Namysłowski decided to abandon general relativity in favour of high energy physics. Bronisław Średniawa had already been active in nuclear physics. Zbigniew Borelowski continued for some time investigation of Weyssenhoff spin particles, but in 1972 he left the Jagiellonian University and had been employed by the Pedagogical University in Kraków. Bohdan Kozarzewski defended his PhD thesis "Asymptotyczne własności pól: grawitacyjnego i elektromagnetycznego" (Asymptotic properties of fields: gravitational and electromagnetic). The public defense took place on 27.05.1965 (the date is the same as in the case of Staruszkiewicz's public defense), the advisor had been Bronisław Średniawa. Kozarzewski analyzed the Newman-Penrose equations, written down only three years earlier (Newman, Penrose 1962). Soon later he went to investigate solid state physics.

Staruszkiewicz had spent the academic year 1965/1966 in the Syracuse University, in the group led by Peter Bergmann; that sabbatical had been arranged by Leopold Infeld and Andrzej Trautman. At that time Polish scientists could travel abroad, but that was usually difficult, because of the pressure or obstacles put by the communist party and/or secret service. Staruszkiewicz, however, did not experience any difficulties – one can guess, that this was because he was under the political umbrella of Infeld, who had good contacts with top communist officials. Staruszkiewicz had been later active in relativity theory and in quantum field theory (with the focus on explaining the numerical value of the fine structure constant); he (briefly) returned to general relativity much later, at the turn of 20th and 21st centuries. He was very succesful as a teacher and almost all modern general relativists in Kraków descend – directly or indirectly – from him.

In 1973 Staruszkiewicz had been awarded third prize in the competition organized by the Gravity Research Foundation, for the essay entitled "Retardation effects in the planetary system" (Staruszkiewicz 1973). He has shown that a finite speed of propagation of perturbations can lead to the appearance of instabilities. At that time the Gravity Research Foundation competition had been quite respectable. In the same decade Stephen Hawking and Roger Penrose obtained their prizes

(in 1971 and 1975, respectively). James York and Niall O'Murchadha had been third in 1975, for their important analysis of initial constraints of Einstein equations.

A cosmological conference "Confrontation of cosmological theories with observational data" had been organized in September 1973 in Kraków; it was a part of widespread celebrations in Poland of the 500th birth anniversary of Nicolai Copernicus. We should add here that Nicolai Copernicus studied at the Jagiellonian University from 1491 until probably the summer of 1495. John Archibald Wheeler, who attended the conference, still remembered about the work on three-dimensional spacetimes; he found Staruszkiewicz in the audience after one of the lectures. Staruszkiewicz recalled that they had a pleasant conversation (Staruszkiewicz 2025).

Doctoral studies in physics at the Institute of Physics of the Jagiellonian University have been founded around 1965. They have been actually quite important, since they opened a regular route for getting a doctoral degree. PhD students of physics had been getting a stipend – modest but sufficient (at that time) to survive the three to four year period of studies. In 1970's circa 10 to 20 physics or astronomy graduates would annually enter those studies. Janusz Garecki had been the first student to get PhD in general relativity for the thesis "Odstępstwa od euklidesowych praw zachowania w rozmaitości czasoprzestrzennej ogólnej teorii względności i uogólnione euklidesowe prawa zachowania" (Deviations from Euclidean conservation laws in spacetimes of general relativity and generalized euclidean conservation laws); the public defense took place in 1974. He in fact worked under direction of Andrzej Staruszkiewicz but the nominal advisor had been Jerzy Rayski. At that time it was demanded that a supervisor should have a habilitation, a condition that Staruszkiewicz satisfied in fall of 1973 – too late to be a formal advisor of Garecki. Janusz Garecki later had been employed by the University in Szczecin.

Leszek Sokołowski was the first formally accepted PhD student of Staruszkiewicz. His thesis "Geometria hiperpowierzchni zerowych i powierzchniowe równania Einsteina" (Geometry of null hypersurfaces and surface Einstein equations) had been defended in May 1975. Sokołowski worked later as an assistant and associate professor in the Astronomical Observatory of Jagiellonian University. He was a member of the Cracow Cosmological Group that was founded in early 1970's, with Michał Heller as one of its founding members. Heller, who has been ordained as a catholic priest, obtained his PhD in 1966 under supervision of professor Stanisław Mazierski from KUL (the Catholic University in Lublin). The PhD thesis "Koncepcja seryjnych modeli Wszechświata i jej filozoficzne implikacje'" (The concept of serial models of the Universe and its philosophical implications) had been defended in KUL. Strictly saying, Michał Heller had been connected to Tarnów (a city near Kraków) – he had been a professor in a local theological seminar (later also in the The Pontifical University of John Paul II in Kraków) – but he became the unquestionable leader of the Cracow Cosmological Group, although majority of its members consisted of employees of the Astronomical Observatory of the Jagiellonian University. Members of the Cracow Cosmological Group often published in their own journal *Acta Cosmologica*, that had existed for more than 20 years thanks to donations of the Astronomical Observatory.

5. Department of General Relativity and Astrophysics 1979–1987

The Institute of Physics of the Jagiellonian University had been reorganized several times after 1962. For many centuries the main element of the traditional university structure had been the Chair. Thus in 1960's we have, in the case of theoretical physics: the Chair of Theoretical Physics (led by Jerzy Rayski) and the Chair of Theoretical Nuclear Physics (chaired by Bronisław Średniawa). Each of two Chairs comprised two departments. They had been dissolved in 1970 – that was enforced by a decree coming from the communist government which for some (political) reasons did not like Chairs at Polish universities – and replaced by one big Department of Theoretical Physics, headed by Jerzy Rayski. This in turn had been partitioned into 4 smaller departments on January 2nd of 1979 – one of them was Department of General Relativity and Astrophysics (Zakład Teorii Względności

i Astrofizyki – ZTWiA). Professor Bronisław Średniawa had become the first head of this new department.

Staruszkiewicz supervised in early 1980's two PhD students working in general relativity. One of them had been Paweł Oskar Mazur, the other Jacek Gruszczak. Staruszkiewicz suggested Paweł Mazur investigating black hole thermodynamics; Paweł actually complied and wrote with Sokołowski the article "Second-order phase transitions in black-hole thermodynamics" that appeared in the *Journal of Physics A* in 1980. The authors are not listed in the alphabetic order, which suggests that Sokołowski was the main contributor.

I remember Paweł Mazur from that time. My advisor docent Jan Olszewski worked at the Pedagogical Academy in Kraków. I found a topic in mathematical physics, not related to general relativity. Once a week I would visit Olszewski and the remaining weekdays I had spent in the room 421 which I shared with two other colleagues Jacek Szmigielski and Andrzej Górski (if my memory is correct) or in the library of the Institute of Physics on 4 Reymont Street. Occasionally I would meet Paweł and those encounters often would turn into long discussions or even lecture sessions. I learned at that time terms like "no hair conjecture", "naked singularities", "Hawking radiation" and many others. That was not only the question of stating a physical problem, but also of its history, proponents and opponents, validity of their arguments and even critically assessment of the cohesion of their scientific personalities. There was one meeting that continued for four hours. We started at the Institute of Physics on Reymonta 4 and then slowly walked, visiting on the way several bookshops in the Main Market Square, to 15 Grudnia Street (nowadays Rev. Franciszek Blachnicki Street) in Grzegórzki, where I lived with my family. We finally parted after a small lunch. I remember of being overwhelmed by scientific information and related (purely scientific!) gossip.

Paweł Mazur found his own research project – investigation of stationary and axially symmetric solutions of Einstein equations. Andrzej Staruszkiewicz always stressed, that Paweł had been independent in his work and that he had been the factual supervisor of his other student Jacek Gruszczak. Jacek Gruszczak defended his PhD thesis "Całkowalność równań Einsteina dla pól grawitacyjnych stacjonarnych i aksjalnosymetrycznych" (Integrability of Einstein equations for stationary and axially symmetric gravitational field) in 1982. He worked in the Pedagogical Academy (later known as the Pedagogical University and, finally, the University of KEN in Kraków). Paweł Oskar Mazur defended his doctoral thesis "Metody całkowania równań Ernsta" (Methods of integration of Ernst equations) later than Jacek Gruszczak but also in the year 1982.

The most interesting achievement of Mazur during his Kraków episode of life is, in my opinion, the proof of uniqueness of the Kerr-Newman black hole solution (published in *the Journal of Physics A* – see Mazur 1982). The author shows there that a rotating and charged black hole is unique in electrovacuum. The proof had been surprising – it appealed to axially symmetric Einstein equations written in the form of Ernst equations. I asked (in November 2024) Paweł how he arrived to this idea. He answered that it came to him while reading an article by Brandon Carter published in 1979 (Carter 1979). Yet in Mazur 1982 is quoted an earlier paper of Carter (1973) and there was no even a mention about (Carter 1979). The uniqueness of black hole solutions of Einstein equations had been intensively studied in the last quarter of 20^{th} century. The result of Mazur had been anticipated – in accordance to the J.A. Wheeler hypothesis that black holes do not have hair – but his method had been surprising. I should add in this place that independently (but somewhat later) Bunting proved (but never published) a similar result (Bunting 1983). Bunting and Masood-ul-Alam extended later this into the case of multiple black holes.

Paweł Mazur obtained the third prize of the Gravity Research Foundation in 1983 (Mazur 1983) for his essay on the uniqueness of the Kerr-Newman black holes, that based on the paper (Mazur 1982). Mazur had been formally employed in the Institute of Physics of the Jagiellonian University until 1989, but he had been on a long-term holliday of leave. He worked at various scientific and university institutions in USA. Since the beginning of 1990's he has been employed in the South Carolina State University in Columbia, from 2001 as a full professor.

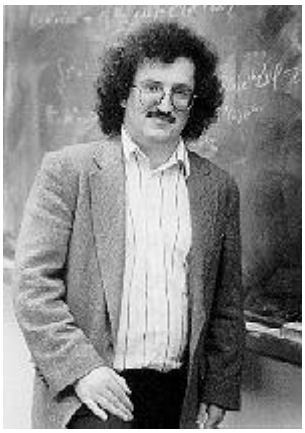


Fig. 4. Professor Paweł Oskar Mazur before 1982,
picture is taken from his homepage in USC.

Paweł Mazur left Kraków in 1984 as a fully accomplished theoretical physicist. He demonstrated earlier his independence and scientific prowess by choosing his own research project as the theme of the PhD thesis. Yet he returned later to his scientific heritage – he published in 1985 and 1986 two papers (Deser, Mazur 1985; Mazur 1986) dealing with three-dimensional spacetimes discovered two decades earlier by his advisor Andrzej Staruszkiewicz.

The next PhD student of Staruszkiewicz had been Piotr Bizoń, who defended his PhD thesis "Global conserved charges in theories with long-range fields" in 1985. He has been employed in the Department of General Relativity and Astrophysics since October 1985.

My PhD thesis (under supervision of Jan Olszewski, 16.12.1926–12.9.2007) "Struktura przestrzeni rozwiązań klasycznych równań Yanga-Millsa"' (Structure of solution's space of classical Yang-Mills equations) was defended on December 9th of 1981. The next years in Poland had been politically turbulent (including martial law imposed by the communist government on December 13th of 1981), which had negative impact on my professional carrier. I had been involved in illegal at that time political activity – mainly in "Solidarność Walcząca". I worked for two and half years at the Silesian University in Katowice, then in the Institute of Nuclear Physics in Kraków and at the Pedagogical University in Kraków. Finally I had been employed in the Department of General Relativity and Astrophysics since January 1st 1986 – Staruszkiewicz had been a dean of the Faculty of Mathematics and Physics at that time and it was his personal decision to hire me. I had at that time one publication related to general relativity – a proof that small (in a suitable functional norm) static solutions are absent in Einstein-Yang-Mills equations (Malec 1984). This implies the absence of perturbative solutions. McKinnon and Bartnik found numerically static solutions of Einstein-Yang-Mills equations in 1988; they are nonperturbative (Bartnik, McKinnon 1988).

Professor Średniawa retired in 1987 and professor Andrzej Staruszkiewicz had replaced him as the head of the Department of General Relativity and Astrophysics. For the next two decades the core of the Department had consisted of Andrzej Staruszkiewicz, Piotr Bizoń and Edward Malec. Staruszkiewicz organized the departmental seminar always on Wednesdays, at 10.15 in the morning – attended by the whole general relativistic community of Kraków.

6. General relativity and cosmology at Astronomical Observatory of Jagiellonian University in 1979–1987

The only relativists at Astronomical Observatory in 1979 had been Dr. Leszek Sokołowski (23.01.1948–6.11.2024)[14] and MSc Andrzej Woszczyna. They both belonged to the Department of Theoretical Astronomy and Astronomical Geophysics, and later (after 1984) to its successor, the

[14] Informacja uzyskana od dr. hab. Krzysztofa Maślanki, prof. PAN.

Department of Radioastronomy and Cosmic Physics (Mietelski 1992)[15]. Andrzej Woszczyna obtained his PhD in 1984 for the thesis "Wpływ warunków energetycznych na dynamikę jednorodnych, izotropowych modeli wszechświata" (The influence of energy conditions onto dynamics of homogeneous and isotropic models of Universe). His formal advisor had been Prof. Józef Masłowski.

Marek Szydłowski (13.03.1952–8.10.2020),[16] who had been employed in the Observatory since 1983, graduated from the Catholic University of Lublin. His PhD thesis "Problem ensemble'a wszechświatów w kosmologii relatywistycznej" (The problem of ensemble of universes in relativistic cosmology) had been done in 1982 under a formal supervision of professor Stanisław Mazierski, but the factual advisor was Associate Professor (*docent*) Michał Heller, PhD, DSc.

Andrzej Kułak wrote PhD thesis "Elektromagnetyczne detektory promieniowania grawitacyjnego" (Electromagnetic detectors of gravitational field). His advisor had been Marek Demiański. He had been employed by AGH University of Science and Technology in Kraków.

Zdzisław Golda defended his PhD thesis entitled "Proces dynamicznej redukcji wymiarowej anizotropowych modeli wszechświata w teorii Kaluzy-Kleina" (Dynamical dimensional reduction of anisotropic universes in Kaluza-Klein theory) in 1987; he was supervised by professor Marek Demiański. Subsequently he had been employed in the Astronomical Observatory of the Jagiellonian University.

Sokołowski, Woszczyna and Golda collaborated within an informal research group – Krakowska Grupa Kosmologiczna (Cracow Group of Cosmology). As we already know, it was led by Michał Heller. Marek Demiański from Warsaw and several younger members (Dr. Jacek Gruszczak and students or PhD students at that time – Marek Biesiada, Krzysztof Maślanka, Paweł Turkowski, Tadeusz Stawicki, Jerzy Szczęsny, Piotr Multarzyński) also participated in this activity. This group organized several conferences in 1980's and edited the journal *Acta Cosmologica* (Golda 2024). It ceased to exist in the middle of 1990's.

7. Concluding remarks

Professor Jan Weyssenhoff created a group of relativists in Kraków two years before the second world war. The group had been dispersed and destroyed during the war. Myron Mathisson left in 1939 to UK, where he died a year later, Adam Bielecki was imprisoned in a German concentration camp and after the war moved to Lublin, Józef Lubański went to the Netherlands, where be died in 1946. Weyssenhoff survived the war and dedicated himself mainly to teaching of theoretical physics, including general relativity. He had many good students. The last generation of his students, taught by him around the time of official retirement in 1959, went beyond the Weyssenhoff's themes of research – investigation of spinning fluids. They investigated modern at that time topics in general relativity. I would like to stress that this was essentially impossible during the earlier (stalinist) period, without access to western literature and with virtual embargo onto travel to the West. The political climate of early years of the next epoch in the history of communist Poland – gomułkowszczyzna – was more friendly for keeping international relations in science, but there still existed economic restraints. It is remarkable that in those circumstances these young theoretical physicists had been able to keep contact with new ideas that been abundant in the "golden era" of general relativity. This relativistic group disappeared after 1965.

Twenty years later Andrzej Staruszkiewicz, the discoverer of three-dimensional gravity, had been the main figure in forming a new group of researchers in general relativity and gravitation. They had been employed mainly in the Jagiellonian University – in the Department of General Relativity and Astrophysics (headed by Staruszkiewicz) or in the Astronomical Observatory.

[15] Mietelski writes that cosmologists belonged to the Department of Theoretical Astronomy and Astronomical Geophysics, and later (after 1984) to its successor, the Department of Radioastronomy and Cosmic Physics. In 1984 the group of cosmologists consisted of L. Sokołowski, M. Szydłowski and A. Woszczyna.

[16] Biesiada 2025. Informacja uzyskana od dr. hab. Krzysztofa Maślanki, prof. PAN.

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