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INTERVIEW WITH EDWIN F. TAYLOR, SENIOR RESEARCH SCIENTIST, EMERITUS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(***FSZ:*** Fizikai Szemle, ***EFT:*** Edwin F. Taylor)

FSZ: *Spacetime Physics*, the book you co-authored with John Archibald Wheeler, has many fans among physicists throughout the world, and Hungary is no exception. (The Hungarian edition was first published in 1974; the second printing of this edition came out in 2006 [1].) In 1972 you published an account of your collaboration with John Wheeler on the 1963 edition of *Spacetime Physics* and your personal impressions about John Wheeler (including his emotional reaction to the news of his mentor Niels Bohr's death in November 1962) [2]. Your collaboration and friendship with Wheeler started during your sabbatical at Princeton University in 1962. One of your assignments was to prepare lecture notes for a freshman physics course that Wheeler taught to a class of 35 students. He *started* the course with 6 weeks of relativity!
What had been your main areas of interest in physics before you met John Wheeler? Had you been particularly interested in relativity, or was it Wheeler's *presentation* of it during that introductory physics course in 1962 which made it a lifelong passion for you?

EFT: *My father, Lloyd W. Taylor, was a physics textbook writer, so it came naturally to me. My first book,* Introductory Mechanics*, arrived from the publisher when I was on a junior faculty sabbatical at Princeton University; that book included some chapters on special relativity. Wheeler arranged for me to assist him in this honors introductory class [3]. I was bowled over with his presentation of special relativity and immediately began to write up class notes, which one of the secretaries mimeographed and we handed out to the students at the end of the semester.* Spacetime Physics *grew from there.*

FSZ: Your collaboration on *Spacetime Physics* is told in fascinating detail in [2]. What was the initial reaction to the book among professionals and students? Was it an instant hit among physicists when it was published?

EFT: *The author is the wrong person to answer this question, because he receives a "skewed sample" of responses. Most people who dislike a textbook will not confront the author with their opinion. Wheeler's name was big enough to bring* Spacetime Physics *much attention, and it received good reviews.*

FSZ: In what pedagogical context was it published? That is, do you remember what standard university textbooks were used to teach undergraduate relativity in the late 1950's?

EFT: *Relativity was not included in my introductory physics text in college. I believe that only with the introductory textbooks from MIT and Berkeley in the 1960s was special relativity included, and has been ever since.*

FSZ: Could you say something about the worldwide reception of the book? How many languages has it been translated to? Do you remember in which country the first foreign edition appeared?

EFT: *Russian was first, in 1969, then French 1970, Polish 1972, and Hungarian 1974 (republished in 2006). Wheeler and I produced a second edition in 1992 that was published in German 1994, Italian 1996, and Slovak in 2012. In 2004 Japan published an edition of* Exploring Black Holes.

FSZ: Have you used *Spacetime Physics* as a textbook in your courses at MIT? Did Wheeler subsequently use it with his freshman students at Princeton?

EFT: *I do not think Wheeler taught an introductory course after the year we worked together. I used* Spacetime Physics *at MIT, but had the most fun teaching it, and later the black hole book, at Harvard University Extension School, a night school from which both my wife and daughter earned undergraduate degrees. Later I taught both special and general relativity online to small groups of students.*

FSZ: Can you give us a brief account of your work at MIT? How long have you taught there and what were your teaching obligations? [4]

EFT: *The innovator Jerrold Zacharias invited me to MIT to collaborate on an introductory quantum physics text that was part of the MIT Physics, A*

New Introductory Course project (whose acronym PANIC was recognized only after it was adopted). We tried out several drafts of the quantum book with second year physics majors, who are required to take this class; some students headed for other majors take it as well. The resulting text, An Introduction to Quantum Physics *[5], co-authored with A. P. French, came out in 1978 and, surprising to me, is still selling respectably.*

FSZ: In 2000, almost 40 years after your collaboration on the first edition of *Spacetime Physics*, you and John Wheeler published another relativity textbook, a sort of sequel to Spacetime Physics called *Exploring Black Holes: Introduction to General Relativity* [6]. Remarkably, that book is for undergraduates, and it gives a detailed analysis of the spacetime around non-spinning and spinning black holes, and of the universe. You derive light and particle trajectories and analyze in detail several cases that have a special practical or historical significance: the advance of Mercury's perihelion, gravitational lensing, the Penrose process for milking energy from a spinning black hole, and the relativistic aspects of the Global Positioning System.
Why do you think it is good to introduce General Relativity early in the university curriculum?

EFT: *Most science majors have played with special relativity before they come to the university; Big Bang, inflation, and red shift appear in the popular press. We live in a golden age of cosmology, described by general relativity, which fascinates students. The hero in our book is the metric, which expresses itself in calculus, the standard mathematical tool of undergraduate physics.*

FSZ: Did you and John Wheeler have an ongoing professional relationship during all those years between 1963 and 2000?

EFT: *We kept in touch. The Wheelers and their children owned an island, High Island, on the coast of Maine, and our family visited them there. And of course, we published a second edition of* Spacetime Physics *in 1992.*

FSZ: Whose idea was to write a separate volume on general relativity?

EFT: *I cannot remember, but Wheeler's office shelves on High Island were filled with drafts of his famous general relativity text GRAVITATION with*

Kip Thorne and Charles Misner, which came out in 1973 [7], so a less mathematical general relativity text for undergraduates was "in the air."

FSZ: In ref. [2] you describe in detail your working routine with John Wheeler on *Spacetime Physics*. Was your working routine on *Exploring Black Holes* different in any important respect?

EFT: *They were pretty much the same, and I think similar to Wheeler's routine with other collaborators: I would arrive at the Wheeler residence, in Princeton or on High Island, with a draft assembled from our previous interaction, and we would work through it. Wheeler made voluminous corrections, often cutting and pasting additions. Then I would go home and rewrite.*

FSZ: Here is an excerpt from ref. [2]: "One Saturday John came up to a motel in Cambridge, north of Harvard University. There we wrestled all day with the derivation of the relativistic expression for momentum. At the day's end we had forty handwritten pages full of diagrams, arrows, symmetry arguments – the heavy equipment of pedagogy. The next morning we decided to try summarizing the argument in a figure. As we worked, the structure erected the preceding day collapsed into a few simple statements. The upshot is the only derivation I know for the relativistic expression for momentum contained in a single figure and its caption (Figure 85 of *Spacetime Physics*, first edition). John told me with amusement how he and Richard Feynman once constructed a diagram so complicated that they were tempted to label it: 'For figure caption, see text,' thus making the entire article a caption for one figure!" Can you give us an example from your collaboration on *Exploring Black Holes* that stands out in your memory in a similar way?

EFT: *Oh yes! One time Wheeler and I met during an American Physical Society meeting in San Francisco. I had registered late, so had an expensive hotel room which was flooded with sunlight. There we struggled to find a simple derivation of the global energy of a particle falling into a black hole. As with Feynman, Wheeler engaged the problem fully, producing pages of diagrams and text. Then suddenly the entire structure collapsed into a simple deduction from what is called the Principle of Maximal aging, which grows simply from the famous Twin Paradox. That experience is as close as I have come to the ecstatic joy of sudden illumination. The Principle of*

Maximal Aging plus the metric are the two key tools in our treatment of general relativity.

FSZ: Can you describe in a few words your recent collaboration with cosmologist Edmund Bertschinger on the 2nd edition of *Exploring Black Holes*?

EFT: *Very similar and at the same time different. Both men are leaders with many competing responsibilities---in Bertschinger's case, running the MIT Department of Physics. Both collaborations involve intensive work together on drafts: for a couple of days with Wheeler every few months, for a couple of hours with Bertschinger every week or so. Like Wheeler, Bertschinger is an absolute master of the subject; I have watched fascinated as each of them poured his wide-ranging professional expertise into the funnel of the metric plus the Principle of Maximal Aging.*

FSZ: Why did you decide to write a 2nd edition of *Exploring Black Holes*? In what important respects will the 2nd edition be different from the 1st edition?

EFT: *Toward the end of collaboration on the first edition, Wheeler said to me, "Don't ask me, tell me." I realized this was a signal that he was beginning to decline, and he wanted me to take the initiative on* Exploring Black Holes*. So I finished the book mostly by myself. The result will not harm the reader, in my opinion, but it is not correct in some details. That's not the problem with the second edition! Ed Bertschinger has absolute integrity and is a martinet about accuracy of the theory and currency of the applications. In addition, of course, data pouring down from satellites have, in the meantime, revolutionized our knowledge of the cosmos.*

FSZ: One would think that a textbook author first has a clear concept in his mind about how his book will be structured, then sits down and writes it while trying to shut out any disturbing influence. Your working method on the 2nd edition of *Exploring Black Holes* seems quite unique. You frequently modify (sometimes just polish, sometimes rework entirely) your chapters and then upload *each new version* on the book's website [8] for anyone to see. On your personal website [9] you explicitly *invite* comments and criticisms from *anyone*. Can you explain why you chose this peculiar working method? Doesn't it slow down your work hopelessly?

EFT: *I often joke that no one who understands a subject should be allowed to write a textbook about it, because the expert has mastered the details and forgotten the parts that are hard for the beginner. We paid our students with credit toward their grade to submit a weekly Reading Memo that told us what they found difficult or confusing in each assigned chapter [4]. Some of their comments appear in the text as objections, which we sharpen into confrontative statements: "Baloney! No one can believe . . ." to which we respond politely. Readers have remarked that such an objection/response often appears at the moment they are having difficulty with the presentation. Several instructors have used current drafts in their classes and provided feedback themselves and from their students. Finally, a small group of advisors has appeared out of the woodwork to read drafts and help us with corrections and suggestions. As a result, I believe that our text presents general relativity as an intensely human enterprise. This whole process does take a lot of time, but I enjoy every minute of it.*

FSZ: Recently published excellent undergraduate general relativity textbooks include James Hartle's *Gravity* [10] and Thomas Moore's *General Relativity Workbook* [11]. (The influence of *Spacetime Physics* in exemplified in Moore's dedication in the latter book "... for Edwin Taylor, whose book with Wheeler set me on this path decades ago"). Where do you position your and John Wheeler's *Exploring Black Holes* in the literature of recent undergraduate general relativity textbooks?

EFT: *Both Hartle and Moore are excellent and use a mixed strategy: applications of the metric plus gradual introduction of tensor notation. For us the central question is: How do you want the student to spend his or her limited time? We choose to spend essentially all student time and effort on powerful applications of the metric plus the Principle of Maximal Aging, following the Biblical book of Ecclesiastes 9:10, "Whatsoever thy hand findeth to do, do it with thy might, . . ." With some exceptions, the metric is all you need until the last four chapters of the book. There the power of tensors would be useful, and our text admits this lack. In the final chapter we present and solve Einstein's equations for symmetrical cases.*

FSZ: As John Wheeler put it, "Everything important is, at bottom, utterly simple". Can you summarize in a sentence or two the basic ideas of special relativity and general relativity, as laid out in *Spacetime Physics* and in *Exploring Black Holes*?

EFT: *The back cover of Exploring Black Holes has four descriptive slogans which, of course, make sense only in the context of an entire book:*

1. *The metric describes spacetime.*
2. *The Principle of Maximal Aging describes motion.*
3. *Make* every *measurement and observation in an inertial frame*
   ---a local *inertial frame when in curved spacetime.*
4. *Global coordinates connect local inertial frames.*

Special relativity depends on the first two of these slogans and the first line of the third.

FSZ: Is there any other area of physics, besides relativity, which you would teach – or, in fact, have taught – with a drastically different approach than what is customarily used nowadays?

EFT: *The quantum book with French used polarized photons to illustrate quantum principles, which allowed students to investigate results with an inexpensive kit containing small sheet polarizers and a tiny calcite crystal. Other than that, my professional life has been absorbed in learning and teaching special and general relativity.*

FSZ: In 1998, you received the Oersted Medal, a prestigious award from the American Association of Physics Teachers [12]. It is awarded annually for "notable contributions to the teaching of physics." The list of those honored includes Robert Millikan, Arnold Sommerfeld, George Uhlenbeck, Richard Feynman, Isaac Rabi, John Wheeler, Hans Bethe and Carl Sagan. Can you tell us about your how you received the Oersted Medal?

EFT: *I assumed this award would never come to me, because my professional accomplishments were mostly collaborations. Perhaps five years as editor of the* American Journal of Physics *helped; who knows? To be mentioned in the same breath with some of these demi-gods is truly humbling. My present goal in life is to become retroactively worthy of this honor.*

References:

[1] Edwin F. Taylor and John Archibald Wheeler, *Spacetime Physics*, W. H. Freeman 1966.

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Edwin F. Taylor – John Archibald Wheeler, *Téridőfizika*, Typotex 2006.

[2] *Magic Without Magic: John Archibald Wheeler, A Collection of Essays in Honour of His Sixtieth Birthday*, John R. Klauder, Editor, W. H. Freeman, 1972. Taylor's essay in this volume, "The Anatomy of Collaboration," is available at exploringblackholes.com/AnatomyOfCollaboration.pdf

[3] An honors class is for a small *select* group of first-year students with advanced background, such as college-level courses in high school or high grades in a national advanced placement exam.

[4] For a hint at Edwin F. Taylor's teaching philosophy, see: Edwin F. Taylor, „Csak a diák tudja" (Only the Student Knows), *Fizikai Szemle* 2008/10, pp. 345-347.

[5] A. P. French and Edwin F. Taylor, *An Introduction to Quantum Physics (M.I.T. Introductory Physics)*, CRC Press 1978.

[6] Edwin F. Taylor and John Archibald Wheeler, *Exploring Black Holes: Introduction to General Relativity*, Addison-Wesley-Longman 2000.

[7] Charles W. Misner, Kip S. Thorne and John A. Wheeler, *Gravitation*, W. H. Freeman 1973.

[8] exploringblackholes.com

[9] eftaylor.com

[10] James Hartle, *Gravity: An Introduction to Einstein's General Relativity*, Addison-Wesley 2003.

[11] Thomas Moore, *A General Relativity Workbook*, University Science Books, 2012.

[12] en.wikipedia.org/wiki/Oersted_Medals