The Wigner Medal 2014

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1. Introduction

The Wigner Medal was established in 1977/78 and is administered by the Group Theory and Fundamental Physics Foundation. The first Wigner Medal was awarded to Eugene P. Wigner and Valentine Bargmann at the Integrative Conference on Group Theory and Mathematical Physics / VIIth International Group Theory Colloquium in 1978 in Austin, Texas, U.S.A.

The purpose of the Wigner Medal is to recognize outstanding contributions to the understanding of physics through group theory.

The Medal is in principle awarded every two years and the awarding ceremony is held at the colloquium on Group Theoretical Methods in Physics. The previous recipients of the Wigner Medal are:

1978	E.P. Wigner	1996	V. Kac and R.V. Moody
1978	V. Bargmann	1998	M. Moshinsky
1980	I.M. Gel'fand	2000	L. O'Raifeartaigh
1982	L. Michel	2002	H.J. Lipkin
1984	Y. Ne'eman	2004	E. Inönü
1986	F. Gürsey	2006	S. Okubo
1988	I.M. Singer	2010	M. Jimbo
1990	F. Iachello	2012	C.A. Mead
1992	J. Wess and B. Zumino		

The winner of the Wigner Medal is chosen by the Selection Committee which consists of five members. The chairman of the Group Theory and Fundamental Physics Foundation is the member ex officio. The remaining members are assigned for a four year term: two by the Standing Committee of the Group Theory Colloquia and two by the Board of the Group Theory and Fundamental Physics Foundation.

The 2014 International Selection Committee consisted of: Alden Mead (Chairman), Arno R. Bohm, Mo-Lin Ge, Michio Jimbo and Lawrence S. Schulman.

The 2014 Wigner Medal was awarded to:

Joshua Zak
Technion, Haifa, Israel
FOR HIS DISCOVERY OF THE MAGNETIC TRANSLATION GROUP
AND THE PHASE AND TRANSFORM THAT BEAR HIS NAME

The ceremony for the Wigner Medal took place on July 16, 2014 in the Aula Academica of Ghent University, a historical building dating from 1826. The ceremony was graced by the saxophone quintet, "Sax Obsession", playing music from Gershwin, Shostakovich and more. The participants were welcomed by Debora Van Durme, master of ceremonies, who welcomed the awardees, committee members and the invitees. She gave a brief presentation on the history of the university and the Aula building, and on Adolphe Sax and the instruments that bear his name. The Hermann Weyl Prize was also presented during this ceremony.

The Wigner Medal was presented by Arno Bohm (University of Texas at Austin) after a short picture show of the history of the Medal. The laudatio for Professor Joshua Zak was delivered by Lawrence Schulman (Clarkson University). The full text of the laudatio is given in the following pages.

The ceremony was concluded by a reception with drinks and cocktail snacks in the adjacent Peristylium.

In figure 1 the front and back face of the 2014 Wigner Medal are shown. Figure 2 shows some pictures taken at the ceremony.

Figure 1. The 2014 Wigner Medal

2. Laudatio for Professor Joshua Zak

It is a pleasure and an honor to deliver the laudatio for Professor Joshua Zak, the 2014 Wigner medal Laureate.

As I will recount below, besides Joshua's scientific achievements, there has been a thread through much of his life connecting him to the person implicitly also honored at this ceremony, Eugene Wigner. But before I get serious let me mention one tiny strand of that thread. For many years, when I was on the faculty of the Technion, Joshua's office was down the hall from mine and we'd often chat in front of the blackboard. He would ask me some "simple" question, as if I were the real authority. So I'd give him the benefit of my wisdom, but then he'd have one "little" question, and pretty soon my glib answer was completely unraveled and I'd appreciate that there was a really deep issue involved. Now I ask those of you who knew Wigner: is this man his disciple or not?

Let me begin then with Joshua's personal history.

Joshua Zak was born in 1929 in Wilno, Poland, now Vilnius, capital of Lithuania, where he went to a Hebrew grammar school. The Molotov-Ribbentrop pact of 1939 partitioned Poland between Germany and the USSR. Teaching Hebrew was forbidden once the Red army took over

Figure 2. Arno Bohm presenting the Medal to Professor Joshua Zak (left). Lawrence Schulman delivering the Laudatio (right). Professor Joshua Zak at the reception, together with friends and relatives (bottom).

in Wilno, and the 10-year old Joshua switched to Yiddish. He was 12 when the German army invaded Vilnius and for the next two years Joshua lived in Vilnius Ghetto (1941-1943). At age 14 he was taken to a labor camp in Estonia and at 15 to the Stutthof concentration camp (1944-1945). At 16 he participated in the Death Marches from Stutthof to the West. While still 16 he was liberated by the Red Army, only to be drafted into that same army for the next three years (until April 1948).

At age 19 Joshua returned to Vilnius and resumed his schooling. Two years later he graduated from high school with a silver medal. He then went on to study physics in the University of Vilnius.

In 1950 the Korean war started and Joshua was again drafted into the Red Army. He was on the train to go to war, when he heard his name on the loudspeaker. He was taken off the train and allowed to resume his studies. Whence this miracle? It was the successful intervention of his brother, Benzion, who later became a well-known physician in Tel Aviv.

The interest of Joshua in group theory started early. As an undergraduate he studied Wigner's book on symmetries in German, since the English or Russian translations of the book were yet to be made. You can now count how many languages Joshua speaks.

In 1953 Joshua won the championship of Lithuania in 1000m singles in kayaking.

In 1955 Joshua got his Master's degree from the University of Vilnius and applied to the Graduate School of Herzen University in Leningrad. In the Soviet Union after graduating one had to perform three years of national service, and Joshua was assigned to a military school in the Latvian Republic. He was relieved from this obligation by being accepted as a graduate student in the group of Professor Lev Emanuilovich Gurevich. A second miracle.

The third miracle was the political upheaval in Poland and the rise of Gomulka in 1956. Among the reforms Gomulka introduced was allowing Jews born in Poland to emigrate to Israel. This was done partly to relieve anti-Semitic pressures in Poland. Joshua and his two brothers seized the opportunity and in March 1957 moved to Wałbrzych, where Joshua worked in a book store for nine months. He and his brothers arrived in Haifa, Israel in December 1957 and Joshua became a graduate student of Professor Nathan Rosen, the R of EPR, at the Technion.

Nathan Rosen was mostly interested in general relativity while Joshua wanted to apply group theory to solid state physics. So Joshua was on his own and as a topic for his thesis he chose *Irreducible Representations of non-Symmorphic Space Groups*. There was nobody in the Technion who was expert in this area, but Joshua did have Giulio Raccah, at the Hebrew University in Jerusalem with whom he would consult on a weekly basis. Joshua finished his Ph.D. thesis in 1960 with George Koster of MIT as referee.

When Wigner visited Israel for the first time, he also visited the Physics Department of the Technion. It was a small department and Rosen introduced all its members to Wigner. When Joshua's turn came Wigner asked him what was the subject of his thesis. Joshua told him. Wigner's reaction was, "Oh really, I had a student, Frederick Seitz, who also did some work on representations of Space Groups." It was well known that after Seitz there was very little left to do in this field.

In 1961 Benjamin Lax, Director of the National Magnet Laboratory (NML) at MIT, invited Joshua for the academic year 1963-64. It was at there that Joshua discovered the Magnetic Translation Group. He then returned to the Technion as a faculty member, where he has remained ever since. In 1967 Joshua was invited again to MIT as visiting professor. During that year he discovered the kq representation, also known as the Zak Transform. The Zak phase was invented at the Technion in 1989.

Let me now turn to the scientific side, with a short description of Zak's main discoveries.

First the kq representation. Weyl recognized that the canonical commutation relations between position and momentum cannot be implemented by finite dimensional matrices: P and Q are necessarily unbounded operators. As we all know, Q can be implemented as multiplication by the coordinate on the line and P as a first order differential operator. By a theorem of Stone and von Neumann all other representations of the canonical commutation relations are unitarily related to this one. For example, the momentum representation, where P is a multiplication and Q a first order differential operator is unitarily equivalent by the Fourier transform. The kq representation is a representation of the canonical commutation relations which maintains the PQ symmetry. Actually, kq is a one parameter family of representations parametrized by a period. The q of the kq is associated with the position Q modulo the period and the k is associated with P modulo the dual period in momentum space. The two periods define a lattice in phase space whose area is one Planck unit. In the kq representation both P and Q are first order differential operators acting on functions on a compact two-dimensional cell in phase space. The boundary conditions need to be twisted so that P and Q are self-adjoint and have the correct spectrum.

The kq representations are universal, and like the position representation, can be used to

study any quantum problem. However, they are naturally tailored to situations with discrete translational symmetry where the Schrödinger equation retains its form as a differential operator, rather than a pseudo-differential operator. The kq representation has the Bloch theorem built in and gives elegant proofs of fundamental results in the dynamics of Bloch electrons. It also has applications to condensed matter physics and to signal processing. Google gives more than 640,000 entries under the entry "Zak transform." It is recognized by Mathematica, Wolfram alpha, and MATLAB. A 2012 US patent makes practical use of the Zak transform and books have been written about it.

The magnetic translation group: Emmy Noether taught us that each continuous symmetry in the Lagrangian implies a conservation law. Bloch then found that in quantum mechanics the discrete symmetry of translations also leads to a conserved momentum. An interesting situation arises when translations in different directions fail to commute. This happens for translations in phase space, but, surprisingly, it can also happen for translations in coordinate space in the presence of a constant magnetic field. Since the vector potential associated with a homogenous magnetic field is a linear function, it is translation invariant up to a gauge transformation. The magnetic translations introduced by Zak are translations accompanied by a gauge transformation. They do not commute in general but rather satisfy the same Weyl algebra as translation in phase space. This observation is fundamental to the modern theory of the quantum Hall effect and is at the root of Chern-Simons theory. Another important application is to periodic Schrödinger operators with a magnetic field and in particular the Hofstadter model where the symmetry and spectral properties are sensitive to the rationality of flux per unit cell. When Joshua studied this problem in the 1960's it looked like a mathematical delicacy, with little relation to observable physical phenomena. Fifty years later, experimental work on the quantum Hall effect demonstrates this sensitivity to the flux. This work now has the fetching name, "moiré butterflies" (see [1]).

The Zak phase: In 2005 Kane and Mele discovered that there are distinct topological classes of insulators labeled by integers. These phases are characterized by non-dissipative chiral edge currents. The subject of topological insulators is arguably one of the hottest topics in condensed matter physics today. The Zak phase, which Joshua found in 1989, is the one-dimensional granddaddy of topological insulators. It associates a parity index with insulators in one dimension. (There are no edge currents in one dimension, unfortunately). The Zak phase is a close relative of the Mead-Truhlar phase in the adiabatic pseudo-rotations of molecules. The Zak phase has been measured in recent experiments by Immanuel Bloch (Max Planck Institute) and Eugene Demler (Harvard) on cold atoms.

This brings my laudatio to its end. Eugene Wigner was the scientific hero of Joshua Zak. If Wigner could be watching this ceremony, I am sure he would be pleased to see his disciple, Joshua Zak, honored with the medal that bears his name.

References

[1] Dean C R *et al* 2013 *Nature* **497** 598