CV of Yshai Avishai

PERSONAL DETAILS

date and place of birth: 1938 Afula, Israel.
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home address: Hagefen 3 Omer 84965 Israel, Tel. 972-8-6460401.
Language proficiency: Hebrew, English, French, German (fair), Japanese (fair), Russian (can read scientific papers).
Hobbies: Classical music, Jazz, piano playing, bicycling, skiing.

PERMANENT AFFILIATION

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EDUCATION

From-to	Institute	Degree	Area of specialization
1962-1964	Hebrew University	B.Sc	Physics
1964-1966	Hebrew University	M.Sc	Nuclear Physics
1966-1970	Weizmann Institute	Ph.D	Nuclear Physics

PREVIOUS EMPLOYMENT

From-to	Institute	Title	Research Area
1985-	BGU	Professor	Condensed Matter Physics
1990-1991	Saclay	Visiting Scientist	Condensed Matter Physics
1979-1985	BGU	Assoc. Professor	Nuclear Physics
1983-1984	Strasbourg	Visiting Professor	Nuclear Physics
1978-1979	Saclay	Visiting Scientist	Nuclear Physics
1977-1978	Lyon	Visiting Professor	Nuclear Physics
1974-1979	BGU	Sen. Lect.	Nuclear Physics
1972-1974	BGU	Lecturer	Nuclear Physics
1970-1972	Argonne Lab.	Postdoc	Nuclear Physics

OTHER ACADEMIC ACTIVITIES AND MEMBERSHIPS

Member of the Ilse Katz Center for Nanotechnology, Ben Gurion University.
Member of the American Physical Society.
Referee for numerous scientific journals including Phys. Rev. Lett. and Phys. Rev. B.
Occasional Divisional Associate Editor of Phys. Rev. Lett.
Many invited lectures in international conferences.
Member of Israel Prize Committee for Physics 2001.
Member of Emet Prize Committee 2003.

RECENT FIELDS OF INTEREST

Quantum dots: Non-linear transport, Transport through a single molecule, Kondo effect, Dynamical symmetries, Quantum dots between superconducting leads.
Quantum crossbars: Bosonization, response, infrared spectroscopy.
Quantum Hall effect: Localization, quantum Hall effect in disordered superconductors, spin Hall conductance, percolation approach to the integer quantum Hall effect, influence of spin-orbit interaction on the localization critical exponent.

RESEARCH HIGHLIGHTS

- **Dynamical symmetries in Kondo tunneling through composite quantum dots**.
  This research is devoted to a systematic exposure of the Kondo physics in quantum dots for which the low energy excitations consist of a few different spin multiplets. The effective spin Hamiltonian which couples the metallic electron spin with the operators of the dot then contains new exchange terms which generate a dynamical group. Experiments for realization of these new symmetries are suggested.

- **Quantum dots with even number of electrons: Kondo effect in a finite magnetic field**.
  This research focuses on a small spin-degenerate QD with even number of electrons, weakly connected by point contacts to the metallic electrodes, and subject to an external magnetic field. If the Zeeman energy is equal to the singlet-triplet level spacing in the dot, the ground state of the dot becomes doubly degenerate, and the system exhibits a Kondo effect, despite the fact that the magnetic field far exceeds the Kondo temperature. Possible realizations of this scenario in tunneling experiments are considered.

- **Kondo tunneling through real and artificial molecules**.
  When a cerocene molecule is chemisorbed on metallic substrate, or when an asymmetric double dot is hybridized with itinerant electrons, its singlet ground state crosses its lowlest triplet state, leading to competition between the Zhang-Rice mechanism of singlet-triplet splitting in a confined cluster and the Kondo effect (which accompanies the tunneling through quantum dot under a Coulomb blockade restriction). The rich physics of a Kondo impurity in the presence of low-lying triplet/singlet excitations is exposed. This research aims at evaluating the magnetic susceptibility and the electric conductance.

- **Double quantum dot as a spin rotator**.
  The low energy effective Hamiltonian of a double quantum dot (DQD) with even electron occupation number possess the symmetry SO(4) similar to that of a rigid rotator familiar in quantum mechanics (rotational spectra of Hydrogen molecule, electron in Coulomb field, etc). The "hidden symmetry" of the rotator manifests itself in the tunneling properties of the DQD. In particular, a Kondo resonance may arise under asymmetric gate voltage in spite of the even electron occupation of the DQD. The research exposes various symmetry properties of spin rotator in the context of the Kondo effect and suggests experimental realization of this unusual scenario.

- **Two-channel Kondo tunneling in triple quantum dot**.
  In the strong coupling regime, a two-channel Kondo system exhibits a non-Fermi liquid behavior. Its experimental realization remains elusive. In our research we show that the effective spin Hamiltonian of a triple quantum dot with odd electron occupation weakly connected in series with left and right metal leads is composed of two-channel exchange and co-tunneling terms. The system can be mapped onto an anisotropic two-channel Kondo problem. The structure of the conductance as function of temperature and gate voltage implies that in the weak and intermediate coupling regimes, two-channel Kondo physics persists at temperatures as low as several times the Kondo temperature.

- **Non-linear response of a Kondo system: Perturbation approach to the time dependent Anderson impurity model**.
  This is one of the first studies the physics of nonlinear tunneling through a quantum dot (an Anderson impurity system) subject to both constant and alternating electric fields. A systematic diagram technique is developed for evaluating the current in physical systems out of equilibrium governed by time-dependent Hamiltonians of the Anderson and the Kondo models. Perturbation expansion of the current is carried out to third order in the Kondo coupling yielding a set of remarkably simple analytical expressions for the current. A zero alternating

bias anomaly is found in the alternating current differential conductance. The results pertaining to nonlinear response are shown to be valid also below the Kondo temperature.

- **Oscillatory instabilities in d.c. biased quantum dots**.
When a quantum dot in the Coulomb blockade regime is subject to a large source-drain voltage V (exceeding the Kondo temperature), the Kondo resonance splits into two components. It is shown in this research that interference between these two components results in spontaneous oscillations of the current through the dot. This is similar to what happens in Josephson junctions but here there is no superconductivity involved. The theory predicts the appearance of "Shapiro steps" in the current-voltage characteristics of an irradiated quantum dot; these would constitute an experimental signature of the predicted effect.

- **Interacting quantum dots between superconducting leads**.
This is a wide area of research which we have recently undertaken. The majority of research efforts pertaining to quantum dots refers to systems in which the quantum dot is attached to *normal* metallic leads. However, an interesting physics is exposed when the quantum dot is attached to *superconducting* leads. We were among the first to conduct a systematic investigation of this fascinating topics, and list below some of our main research directions.
1. **Subgap current**.
In this research we consider an Anderson impurity (A) weakly connected to a superconducting electrode (S) on one side and a superconducting or a normal metal electrode (N) on the other side. The response of SAN and SAS tunneling junctions to a constant (albeit large) voltage bias V is elucidated, using a combination of dynamical mean field approximation (to handle the repulsive Hubbard interaction) and the Keldysh close time path formalism (to handle non-equilibrium systems). An interesting physics is exposed at sub-gap bias $V < \Delta$. For an SAN junction, the (so called Andreev) conductance is calculated and exhibits a gap symmetry structure. For superconductors with p-wave symmetry it shows a remarkable peak at $V < \Delta$, while for superconductors with s-wave symmetric pair potential the peak is shifted to the gap edge $V = \Delta$ and strongly suppressed if the Hubbard repulsive interaction increases. The dynamics of tunneling between two superconductors (SAS junctions) is rather subtle. For s-wave superconductors the usual peaks in the conductance that originate from multiple Andreev reflections are shifted by interaction to larger values of V. They are also suppressed as the Hubbard interaction strength grows. For p-wave superconductors the subgap current is much larger and the $I - V$ characteristics reveals a new feature, namely, a midgap bound states which results in a peak in the current.
2. **Shot-Noise**.
In the second part of our research on the physics of quantum dot between superconducting leads we study shot noise in superconducting (SAS) and hybrid (SAN) junctions with singly occupied Anderson impurity (A) as a weak link. In particular, The zero-frequency *dc* component of the shot noise spectral density is calculated at zero temperature as a function of the bias at different Coulomb repulsion strengths (U), and show a remarkable structure resulting from combination of electron-electron interaction and Andreev reflections.
3. **p-wave superconducting leads**.
In this part of our research we investigate the physics of junctions containing p-wave superconducting and normal leads weakly coupled to an Anderson impurity in the Kondo regime. For p-wave superconducting leads, mid-gap surface states play an important role in the tunneling processes and help the formation of Kondo resonance. Calculations are carried out for the current, shot-noise power and Fano factor as functions of the applied bias voltage in the sub-gap region $eV < \Delta$ and for the Josephson current. The peculiar differences between the cases of s-wave and p-wave superconducting leads are pointed out.

- **Electronic properties of quantum bars**.
Interacting electrons in one dimensional quantum wires form a Luttinger liquid. The possibility of spin-charge separation in one dimensional systems enables the use of a powerful method for treating such systems, namely, bosonization. What happens if we form a grid of one dimensional quantum wires? (referred to as quantum crossbar). This is experimentally relevant because quantum crossbars can be fabricated from Carbon nano-tubes. The main question is whether bosonization techniques are still applicable and what are the experimental signatures. Our research focuses on the spectrum of boson fields and two-point correlations in a system of crossed arrays of quantum wires. It is conjectured that Bosonization procedure is valid at least within the two-wave approximation. The system behaves as a sliding Luttinger liquid in the vicinity of the Γ point, but its spectral characteristics may have either 1D or 2D character depending on the direction of the

wave vector in the rest of Brillouin zone.

- **Infrared Spectroscopy of Quantum Crossbars**.
In continuation of our research on quantum crossbars the present research focuses on optical response. In particular, infrared (IR) spectroscopy can be used as an important and effective tool for probing periodic networks of quantum wires or nano-tubes at finite frequencies far from the Luttinger liquid fixed point. Plasmon excitations may be involved in resonance diffraction of incident electromagnetic waves and in optical absorption in the IR part of the spectrum. Direct absorption of external electric field strongly depends on the direction of the wave vector. This results in two types of $1D \to 2D$ dimensional crossover with varying angle of an incident wave or its frequency. It is shown that when a quantum crossbar interacts with a semiconductor substrate, the capacitive contact between them does not destroy the Luttinger liquid character of the long wave excitations. However, the dielectric losses on a substrate surface are significantly changed due to appearance of additional Landau damping. The latter is initiated by diffraction processes and manifests itself as strong but narrow absorption peaks lying below the damping region of an isolated substrate.

- **Quantum Hall effect - Spin-orbit interaction and localization exponent**.
Spin-orbit scattering is known to give rise to pronounced effects in some disordered systems. In three dimensions, its presence changes the universality class of the metal-insulator transition. For a system consisting of non-interacting electrons in two dimensions, it leads to a metal-insulator transition, which does not exist in its absence. In this research we investigate the effect of spin-orbit scattering on the localization exponent in the quantum Hall effect. Using heuristic arguments and numerical simulations it is argued that the critical exponent describing the localization length divergence at the integer quantum Hall transition is modified in the presence of spin-orbit scattering with short range correlations. The exponent is very close to $\nu = 4/3$, the percolation correlation length exponent, consistent with the prediction of a semi-classical argument. In addition, a band of weakly localized states is conjectured.

- **Quantum Hall effect in disordered superconductors**.
In 1997, Altland and Zirnbauer have shown that besides the six known random matrix ensembles there are four new ones corresponding to the physics of disordered superconducting grains. However, a realistic physical system in which one of this new ensembles can be realized is not known. This is the motivation for the present research. It is focused on a delocalization transition for non-interacting quasiparticles moving in two dimensions, which belongs to the C type symmetry class. This symmetry class can be realized in a dirty, gapless superconductor in which time reversal symmetry for orbital motion is broken, but spin rotation symmetry is intact. We find a direct transition between two insulating phases with quantized Hall conductances of zero and two for the conserved quasiparticles. The energy of quasiparticles acts as a relevant, symmetry-breaking field at the critical point, which splits the direct transition into two conventional plateau transitions.

Yshai Avishai: LIST OF PUBLICATIONS

1. W. Ebenhöh Y. Avishai and A. Rinat, *Dispersion relations in elastic proton deuteron scattering.* Phys. Lett. **29B**, 638, (1969).

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Z. Phys. **A282**, 347 (1977).

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