



2007 International Solvay Chair in Physics

Solvay colloquium

2 October 2007 at 4:00 pm in the Solvay Room

Michael Berry
(Physics Department, Bristol University)

"Making light of mathematics"

"Many 'mathematical phenomena' find application and sometimes spectacular physical illustration in the physics of light. Concepts such as fractals, catastrophe theory, knots, infinity, zero, and even when $1+1$ fails to equal 2, are needed to understand rainbows, twinkling starlight, sparkling seas, oriental magic mirrors, and simple experiments on interference, polarization and focusing. The lecture is strongly visual, and nontechnical, though the concepts are subtle."



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Lectures

Monday 15 October
4:00 pm to 6:00 pm
Solvay room

Lecture 1: *"Polarization fingerprints in the clear blue sky"*

Abstract : "Daylight is polarized, the strength being greatest at points in the sky at right angles to the sun, and zero at four points: above and below the sun and anti-sun. The zero-polarization points are 'fingerprint' singularities, around which the polarization direction makes a half-turn. Using elementary singularity theory, the polarization pattern across the whole sky can be described in a way that fits recent observations with an accuracy comparable to that of conventional elaborate multiple-scattering calculations. This recent work is a contribution to a story that started in 1817 and has been central to our understanding of polarized light."

Lecture 2: *"Tsunami asymptotics"*

Abstract: "For most of their propagation distance, tsunamis are linear dispersive waves whose speed is limited by the depth of the ocean and which can be regarded as a diffraction-decorated caustic in spacetime. For constant depth, uniform asymptotics gives a very accurate compact description of the tsunami profile generated by an arbitrary initial disturbance. Variations in depth can focus tsunamis onto cusped caustics, and this 'singularity on a singularity' constitutes an unusual diffraction problem, whose solution indicates that focusing can amplify the tsunami energy by an order of magnitude."



Tuesday 16 October
4:00 pm to 6:00 pm
Solvay room

Lecture 3: *"Optical vorticulture"*

Abstract: "After reviewing the history, beginning in the 1660s, of lines of phase and polarization singularity in light and other waves, I will describe our present understanding of their geometry, and several recent applications: to spiral phase plates (vortex choreography), vortex knots and links, ubiquity of vortices in interferometers, and quantum cores of the singularities."

Lecture 4: *"Physics of nonhermitian degeneracies"*

Abstract: "Decoherence makes quantum evolution nonunitary, and such systems, where some freedoms are ignored, can be described by nonhermitian hamiltonian operators. These differ most dramatically from hermitian operators in the neighbourhood of degeneracies. Several examples of non-hermitian degeneracy-dominated physical phenomena will be given, in laser physics, atom optics, and crystal optics."



Wednesday 17 October
4:00 pm to 6:00 pm
Solvay room

Lecture 5: *"Singularity-dominated strong fluctuations"*

Abstract: "The fluctuations of a physical quantity can be described by its moments. In many cases, these diverge as an asymptotic parameter becomes large (or small), through the influence of geometric singularities. These large moments are described by power laws whose exponents can be determined from a knowledge of the singularities. Examples are twinkling starlight, the sex life of moths, certain contour integrals, and several properties of spectra in quantum chaology."

Lecture 6: *"Three recent results on asymptotics of oscillations"*

Abstract: "The results are separate, and apparently paradoxical, and have implications for physics. First, when two exponentials compete, their interference can be dominated by the contribution with smaller exponent. Second, repeated differentiation of almost all functions in a wide class generates trigonometric oscillations ('almost all functions tend to $\cos x$ '). Third, it is possible to find band-limited functions that oscillate arbitrarily faster than their fastest Fourier component ('superoscillations')."



Thursday 18 October
4:00 pm to 6:00 pm
Solvay room

Lecture 7: *"Quantum mechanics, chaos, and the music of the primes"*

Abstract : "The Riemann hypothesis can be interpreted as stating that the prime numbers contain 'music', whose component frequencies are the Riemann zeros. The question "Frequencies of what?" leads to tantalizing connections with the energy levels of quantum systems whose corresponding classical motion is chaotic. At the level of statistics, predictions for the Riemann zeros based on semiclassical quantum asymptotics (with primes as periods of classical trajectories) have reached a high degree of accuracy and refinement. For the zeros themselves, the Riemann-Siegel formula and its improvements lead to new ways of calculating quantum levels."



Friday 19 October
4:00 pm to 5:00 pm
Solvay room

Lecture 8: *"Conical diffraction: imaging Hamilton's diabolical point"*

Abstract: "The transformation of a narrow beam into a hollow cone when incident along the optic axis of a biaxial crystal, predicted by Hamilton in 1832, created a sensation when observed by Lloyd soon afterwards. It was possibly the first prediction of a qualitatively new phenomenon using mathematics, the first application of the concept of phase space, and the prototype of the conical intersections now popular in quantum chemistry. But the fine structure of the light cone contains many subtle features, slowly revealed by experiment, whose definitive explanation, involving new mathematical asymptotics, has been achieved only recently, along with definitive experimental test of the theory. Radically different phenomena, being intensively studied now, arise when chirality and absorption are incorporated in addition to biaxiality."