Demetrios Christodoulou
Autobiography

I was born in Athens in October 1951. My father Lambros was born in Alexandria to Greek parents from Cyprus who had immigrated to Egypt. My paternal grandfather, Miltiades was from Agios Theodoros and my paternal grandmother Eleni was from Choirokoitia. My mother Maria was born in Athens to a family of Greek refugees from Asia Minor. When I was a child, I used to take long walks with my father in the environs of the ancient monuments and he used to inspire me with stories from the distant past when ancient Greece had made outstanding contributions to human civilization. My paternal grandparents left Egypt and settled in Greece in the 1950's, so I also had the opportunity to listen to many wonderful stories from my grandfather about his adventures as a youth in Cyprus during the last part of the 19th century. My father used to take me to a movie theater for children which showed documentaries. I still remember how impressed I was on seeing a documentary about Einstein. A problem in Euclidean geometry was the spark which initiated in me, at the age of 14, a burning interest in mathematics and theoretical physics. Within a couple of years I became fascinated with the concepts of space and time, with Riemann's geometry and Einstein's relativity. My case was brought to the attention of Achiles Papapetrou, a Greek physicist at the Institute Henri Poincare, who in turn contacted Princeton physics professor John Wheeler, on leave in Paris at that time. So in the beginning of 1968 I came to Paris and was examined by them. This led to my admission as a graduate student in the Princeton physics department in the fall of 1968, a month before my 17th birthday. In the fall of 1970, one month after my 19th birthday, I published my first paper "Reversible and irreversible transformations in black hole physics", which led to a new subject, the thermodynamics of black holes.

The fall of 1977 was very important for my career because at that time my scientific outlook was radically transformed. I had been since the previous year as a postdoctoral fellow at the Max Planck Institute in Munich, in the group of Jürgen Ehlers. Ehlers, though himself a physicist, recognized that I had mathematical talent which had not yet manifested itself. My knowledge of mathematics at that time was only at the undergraduate level. Ehlers was extraordinarily generous with me. He gave me a leave of absence with pay for an indefinite period in order to go to Paris to study mathematics under the guidance of Yvonne Choquet-Bruhat and in the period 1977-1981 I studied mathematical analysis in the French school. So with the encouragement of Ehlers I finally found my true calling, the development of mathematics for the solution of physical problems.

In 1981 I returned to the U.S. and one of the first scientists I met was the famous Chinese mathematician Shing-Tung Yau. I became closely associated with him for a period of 5 years, an association which played a decisive role in my mathematical makeup. From Yau I learned geometry and how to effectively combine geometry with analysis in what is today called geometric analysis, a field which Yau pioneered. My main mathematical contribution has been the extension of geometric analysis from the initial field of elliptic equations to the field of hyperbolic equations. My motivation for this extension was the study of the dynamical problems of continuum physics.

The first work of geometric analysis of hyperbolic equations was my work with Sergiu Klainerman on the stability of the Minkowski spacetime, the fruit of an intensive effort in the period 1984-1991. This work demonstrated the stability of the flat spacetime of special relativity in the framework of the general theory and gave a detailed description of the asymptotic behavior of the solutions. Basically, an initial disturbance in the fabric of spacetime propagates, like the disturbance in a quiet lake caused by the throwing of a stone, in waves, the gravitational waves. However, as I showed in a further 1991 paper entitled "The nonlinear nature nature of gravitation and gravitational wave experiments", there is subtle difference from the lake paradigm. For, whereas spacetime, becomes again, like the lake, flat after the passage of the waves, the final flat spacetime is related in a non-trivial manner to the initial flat spacetime and this leads to an observable effect, called "nonlinear memory effect", the permanent displacement of the test masses of a gravitational wave detector. There are currently ongoing efforts to detect this effect.

In the period 1988-1992 I was professor of mathematics at the Courant Institute. In 1992 I returned to my alma mater, Princeton University, as professor of mathematics. In 2001 I returned to Europe taking up my present position as professor of mathematics and physics at the ETH in Zurich.

The period 2001-2008 was for me one of most intense intellectual effort. I turned to the study of the formation of shocks in compressible fluids in the physical case of 3 spatial dimensions. My work in this topic resulted in a monograph "The Formation of Shocks in 3-Dimensional Fluids", which studies what happens after a long time when we have an arbitrary initial disturbance in a bounded region in a 3 dimensional fluid with a general equation of state. After a suitably long time, depending on the size of the initial disturbance, the wave fronts become infinitely densely packed along certain surfaces in spacetime, from which discontinuities develop, the shock waves. This problem was first studied by Riemann, in 1860, however only in the oversimplified case of one spatial dimension. My monograph treated the real physical problem and gave a complete picture of shock formation. The concept of spacetime played a central role here as well, however not the real spacetime but rather what I called "acoustical spacetime", which corresponds, so to say, to the experiences of a blind person, who can only hear. The analysis is more difficult technically than that of the work on the stability of the Minkowski spacetime, because of the fact that singularities appear in the geometric structure as shocks begin to form.

While working on the problem of shock formation, I was also thinking about a different problem. Penrose had introduced in 1965 the concept of a trapped surface on the basis of which he proved a remarkable theorem asserting that a spacetime containing such a surface must come to an end. A little afterwards it was shown that, under the same hypothesis of the presence of a trapped surface, there is a region of spacetime which cannot be observed from infinity, the black hole. A major challenge since that time had been to find out how trapped surfaces form by analyzing the dynamics of gravitational collapse. I was finally able to meet this challenge in May 2008 when I completed the monograph "The Formation of Black Holes in General Relativity". This monograph studies the formation of trapped surfaces in pure general relativity, that is, in the absense of matter, through the focusing of gravitational waves. My old physics professor, John Wheeler, had mentioned to me this problem back in 1968, but only as a dream, not something that I could start working on. The theorems which are proved in the monograph constitute the first foray into the long time dynamics of general relativity when the initial conditions are no longer confined to a suitably small neighborhood of the trivial initial conditions. The breakthrough on which the monograph is based came to me in 2004. It is a new method, which I call "short pulse method" and which capitalizes on the hypothesis that the initial data contain somewhere an abrupt change. This method allows us to study the long time behavior of the corresponding solution, illuminating a region of knowledge which had previously been considered inaccessible.