PROCEEDINGS OF SCIENCE

Remembering George Lazaridis

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This essay describes my long friendship and collaboration with George Lazarides, who passed away in March 2024. It is a tribute both to his extraordinary personality and accomplishments and to our enduring friendship and intuitive understanding of each other in all matters of research, which was truly unique. The essay details the different stages of George's career as well as his contributions to high energy physics and cosmology.

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[*] Speaker

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1. George Lazarides

In many ways, George Lazarides was a larger-than-life figure. An eminent theoretical physicist, an expert on Byzantine and Greek art, history and culture, and an exceptional human being, he was treasured and admired by his many friends and colleagues. George was a born leader who commanded authority and respect but whose company was also great fun. Accompanying him on one of his many walks in Mount Athos or sharing a meal in one of his favorite tavernas, let alone hear George tell a joke, was a unique and treasured experience.

Amfipoli,Greece, 2019

George was my closest friend and collaborator and throughout our long research partnership we had an intuitive bond and immediate understanding of how to approach and solve physics problems. We never argued but we laughed a lot, and our extraordinary partnership has been one of the greatest gifts of my career.

But where and how did it all start? George and I met at the ICTP in Trieste in the early 1970s. We were both students of the late Professor Abdus Salam and we instantly clicked and started discussing physics. In those days Professor Salam was interested, among other topics, in coming to grips with the so-called non-renormalizable theories including Einstein's theory of gravity. We certainly struggled to make meaningful progress with these topics. Yet, we also had a lot of fun being part of a tight group of friends that included Amin Patani, another close friend of George and me.

This initial phase lasted about a year because George was called back to Greece to complete his mandatory 18-months long military service. It was the time of the Junta and George had some truly harrowing experiences but he could also regale audiences with hilarious stories of his military days. One particularly memorable story involved target-shooting practice, and obviously this task was given to the guy with a PhD in physics. George computed the numbers but his unit ended up killing a few sheep and causing the wrath of the farmer.

After completing his service, George accepted a position at the University of Ioannina joined by his beloved wife Veta and soon their first-born son, Theo. Meanwhile, I had moved to the Albert Ludwigs University in Freiburg, Germany, and I encouraged George to apply for an Alexander von Humboldt fellowship, which he successfully did. George and Veta arrived in Freiburg in the late 1970s and after a few months George moved to Hamburg, to join the group of Professors Lehmann and Pohlmeyer. As it happened, the young family had to cope with one of toughest winters the city had ever experienced and daily life could be daunting. While in Germany we started our first serious discussion of gauge unified theories but our collaboration really took off when, most fortuitously, we both became CERN fellows at the same time, our families practically living next door to each other. We wrote papers on unified theories, topological defects, phase transitions, and the interface of particle physics and cosmology. These were very productive, very intense years, and one particularly exciting project that we completed with Mike Daniels

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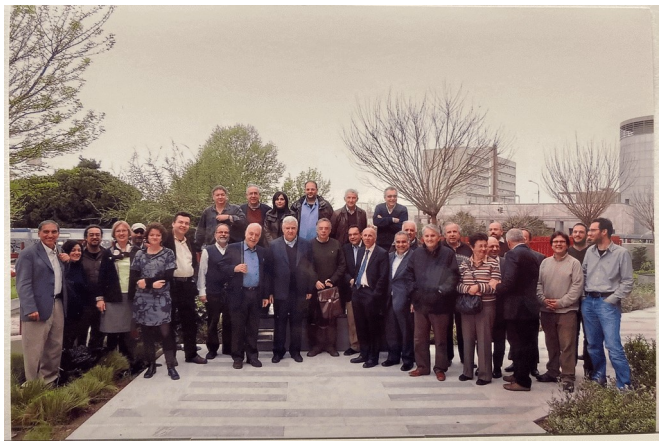
was to show that the SU(5) monopole carries a single unit ($2\pi/e$) of Dirac magnetic charge despite the presence of fractionally charged quarks.

The subsequent phase of George's career took him to the United States where he had accepted an assistant professorship at Rockefeller University, New York. Around the same time I also moved to America and, after a brief stint at NASA, joined the Bartol Research Institute at the University of Delaware. Professor Salam had also offered me a faculty position at the ICTP in Trieste, and the decision to remain in the US, partly influenced by my wife's academic career and my extended family living in Washington, DC, was not easy.

Early Universe Workshop, Cambridge

The 1980s saw George and his family return to Greece, where their second son, Philip, was born. George had accepted a professorship at the Aristotle University in Thessaloniki and the family made a home in their apartment in Kalamaria. Years of back and forth transatlantic visits followed, and I can still picture George working in our living room marveling at his unsurpassed power of concentration.



George Fest, Thessaloniki, 2013

So what did we work on during those years?

In the early 1980s, George and I joined the quest to explore whether topologically stable strings existed in grand unified theories, which led us to a pivotal collaboration with the late Sir Tom Kibble. Our inaugural paper introduced the discovery of a novel type of composite topological structures that we called "Walls Bounded by Strings" (WBS), and it became one of our all-time favorite papers. After all, how often can particle physicists claim that a theoretical prediction emanating from physics beyond the Standard Model is experimentally confirmed? More precisely, in 2019 an experimental group in Finland reported the discovery of precisely these structures in superfluid He3 phase transitions. These so-called KLS walls have subsequently also been found in liquid crystals and cold gases. As it turns out, these WBS structures are present in all axion models, and in a 1984 paper George and I described how their presence in the early universe might provide an additional source of density fluctuations for the formation of large scale structure in the universe.

George and I wrote a second paper with Tom Kibble, which successfully accomplished the goal that had initiated our collaboration. After some input from Steve Hawking, we had persevered with our investigations and finally discovered the first grand unified, and so far only grand unified model that predicts the existence of topologically stable cosmic strings. The discrete gauge symmetry tied to the topological stability of this string also plays a critical role in explaining how a dark matter candidate particle can be stable. These two papers identified for the first time the two important discrete symmetries in SO(10) grand unification. Indeed, quite

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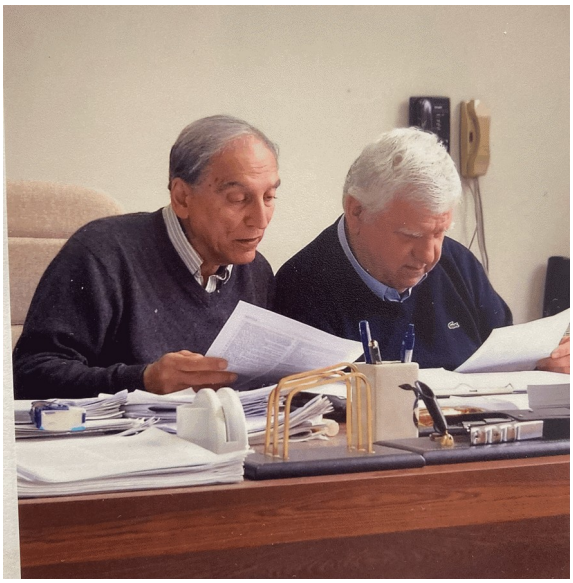
recently, George and I together with our young collaborator Rinku Maji published a paper demonstrating how the unique gravitational wave spectrum generated by the WBS structures can be used to search for their presence in the early universe.



George's office, Thessaloniki, 2019

The 1980s and beyond were very productive decades for George who wrote major papers on grand unified theories and cosmology, supersymmetric theories, superstring and Calabi-Yau phenomenology, origin of the matter in the universe, and dark matter physics. During these years he published papers describing the salient features of so-called 'thermal' inflation, origin of matter–antimatter asymmetry via non-thermal leptogenesis, superconducting axion strings, origin of 'matter' parity in Calabi-Yau compactification, and type II neutrino see-saw mechanism, which we discovered with Christoph Wetterich.

Another influential paper by George, Anananthanarayan Balasubramaniam and me was on third family Yukawa unification and top quark mass prediction in supersymmetric models, which appeared in the early nineties, just a couple years before the experimental discovery of the top quark. George, Mario Gomez and Costas Pallis did significant work on dark matter candidates in Yukawa unified supersymmetric models, and George also published important papers on inflation and unified theories with Costas Panagiotakopoulos.

For many years, George also lectured on topics in particle physics and cosmology at the Corfu Institute organized by George Zoupanos and his team. George was an inspiring speaker, clear and comprehensive, and his lectures were keenly appreciated not only by the conference attendees but a worldwide physics audience.

George always was a formidable presence at conferences, and especially at the one he organized in 1985 commemorating the founding of Thessaloniki 2300 years earlier. He had also invited Professor Salam who canceled at the last moment. George quipped to me: "Tell him we'll invite him for the next millennial."

George retired in 2013 and in the subsequent years he continued to make important contributions to sparticle spectroscopy, dark matter physics, inflationary cosmology and topological structures in gauge theories. We would continue to regularly meet at conferences in Greece as well as quite a few times at the annual summer schools in High Energy Physics and Cosmology held at the ICTP in Trieste. Much of our work also took place via email and phone calls. George's retirement, the George Fest, a one-day conference, beautifully organized by his many colleagues and spearheaded by George Leontaris and Nikos Vlachos, was a great tribute to this exceptional physicist and a fun experience that ended close to dawn in a well-known bouzouki place. By the way, George had started learning how to play the bouzouki in his retirement and one time I recorded him practicing. Not surprisingly, he had become quite good in a fairly short time.

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While George enjoyed retirement, he was especially happy to be relieved of grading duties, he never stopped doing physics. He very much enjoyed meeting our new collaborators, and I particularly recall his interaction with my current PhD student Amit Tiwari, to whom he became a second mentor. In one of George's last papers the three of us uncovered a number of new composite topological structures, with George carefully guiding Amit through the research, explaining critical steps and teaching him a great deal of physics in the process.

George together with Rinku Maji and I completed our last paper, in February 2024, less than a month before he passed away.

Thinking about George, this extraordinary person and scientist, it still seems unfathomable that we will never again hear his beautiful voice or his roaring laughter. His was a life well lived, imbued with intellectual rigor and passion and lovingly shared with Veta, Theo, Philip, and their beautiful families.

On one of his many visits to Delaware George gave me a collection of poems by Constantine P. Cavafy, which he treasured and spent hours explaining, "You really need to read them in Greek, Qaisar, no translation can do justice". So it seems fitting to conclude with a quote from Cavafy's most famous poem "Ithaka", which explores life as a journey and the pursuit of goals.

"Ithaka gave you the marvelous journey.
Without her you wouldn't have set out.
She has nothing left to give you now. […]
Wise as you will have become, so full of experience,
you'll have understood by then what these Ithakas mean."

George understood and found his Ithakas. And more than that, he generously shared them and thus made the lives of those who loved him infinitely more meaningful.

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