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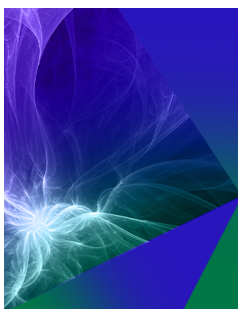
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ABSTRACT

The plasma physics community mourns the loss of Professor Fernando Haas, a distinguished Brazilian physicist, who passed away on December 2, 2024. For the last 25 years, Fernando was a highly active researcher in the field of theoretical quantum plasma physics, where he was recognized as an authority by his colleagues.

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I. LIFE AND SCIENCE OF FERNANDO HAAS

Fernando was born on November 19, 1970, in Brazil. He pursued his undergraduate and graduate studies at the Universidade Federal do Rio Grande do Sul (UFRGS), where he obtained his PhD in physics in 1998, under the supervision of Dr. Joao Goedert. His original field of studies was in the area of dynamical systems and their symmetries and invariants, particularly for the family of Ermakov equations, which was the topic of Fernando's PhD thesis.

Over the course of his career, Fernando worked as a guest scientist in several European universities, where he met and started productive collaborations with some of us. As a young postdoc, he spent 1 year at the University of Nancy in France (2000), funded by a grant of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). He was later a guest scientist at the Ruhr-Universität Bochum in Germany (2007–2009), having earned a prestigious grant from the Alexander von Humboldt Foundation. In 2009, he was invited to Umeå University in Sweden in the framework of a European Research Council project. Back in Brazil, Fernando was a researcher at the National Laboratory for Scientific Computing (LNCC) from 2000 to 2003 and a professor at the Universidade do Vale do Rio dos Sinos (Unisinos) from 2003 to 2011. From 2011 to 2014, he was based at the

Federal University of Paraná, before returning to his *alma mater* UFRGS in 2014.

Fernando was an internationally recognized researcher in the field of quantum plasmas, where he made several foundational contributions through the development of quantum hydrodynamic (QHD) and quantum magnetohydrodynamic (QMHD) models. These models provide a fluid-based description of quantum plasmas, incorporating essential quantum effects, such as the Bohm potential, Fermi pressure, and spin dynamics.¹ Fernando's work was instrumental for the study of nonlinear wave propagation and collective modes in high-density, low-temperature plasmas, where classical models fail to capture quantum coherence and degeneracy effects. His monograph *Quantum Plasmas: An Hydrodynamic Approach*² offers a systematic derivation of the QHD equations and has become a cornerstone in the field. Building on these foundations, Fernando explored quantum plasmas with arbitrary degeneracy, deriving quantum versions of the Korteweg–de Vries and Zakharov–Kuznetsov equations to describe nonlinear ion-acoustic and magnetosonic waves.³ Fernando contributed to the rigorous derivation of exchange-correlation potentials in the framework of quantum kinetic theory, ensuring that QHD models respect the Pauli exclusion principle and maintain consistency with

quantum statistics.^{4,5} He also extended QHD models to the relativistic regime.⁶ Based on the QHD equations, Fernando further developed a variational technique to study monopole (breathing) and dipole modes in a quantum electron gas confined in a parabolic well.⁷

One of the most original aspects of Fernando's work concerned neutrino physics and its interplay with plasma dynamics.^{8,9} In a series of works with his colleague Tito Mendonça, Fernando extended the standard MHD to include the weak interaction, which describes the coupling between neutrinos and plasma particles. This results in a more powerful model that allows to explore new neutrino beam driven instabilities. These studies revealed that neutrinos can prevent magnetic field lines from freezing, even in an ideal plasma, which challenges a foundational assumption of classical MHD. Fernando and his collaborators also derived a new, neutrino-driven plasma instability that should play a central role in a supernova's strongly magnetized environment.

The scope of Fernando's work was very vast, ranging from dynamical systems to classical and quantum plasmas and neutrino physics and would be hard to summarize in a short article. Readers interested in exploring Fernando's achievements may refer to his full list of publications.¹⁰

Beyond his research contributions, Fernando was deeply invested in mentoring and education. He guided numerous students, supervising many master and doctoral dissertations and several postdoctoral researchers. His death represents a great loss for the international scientific community working on quantum plasmas (Fig. 1).

II. PERSONAL RECOLLECTIONS

In the following paragraphs, we report a few recollections, both personal and professional, by some of his closest colleagues in Europe.

A. Gert Brodin and Mattias Marklund

We both met Fernando for the first time at a conference in Trieste almost 20 years ago. At the time, we had recently become interested in quantum plasmas and realized that Fernando had made important contributions to the field. When the conference ended, we had several interesting discussions and even mentioned ideas for future collaboration, although the plans did not materialize immediately.

A few years later, however, Fernando moved to Umeå for a couple of years. We got to know Fernando better, both through work and social events. His soft-spoken and thoughtful personality was much appreciated, as was his sense of humor, which became apparent once you got to know him. The years in Umeå were productive, and when he left for Brazil, we stayed in contact, occasionally discussing possibilities for further collaboration. Practical matter prevented that from happening, but Fernando's work always had a personal touch and was a pleasure to read. He will be sorely missed—not only by us but also by all the friends and colleagues he met during his years in Umeå.

B. Antoine Bret

Fernando was not only a brilliant plasma physicist but also a kind individual. Our common interest in quantum plasmas brought us together, leading to five peer-reviewed articles between 2009 and 2014. Working with Fernando was always a stimulating experience. Beyond the science, I will cherish the memory of our long, late-night conversations, particularly during a conference in Faro, Portugal, in 2012, where we even shared a hotel room.

Fernando possessed a unique blend of intellectual curiosity and genuine camaraderie. His dedication to exploring the frontiers of quantum plasma physics was evident in every project we undertook,



FIG. 1. Fernando in Graça (old part of Lisbon, Portugal) in November 2022.

and he leaves a lasting legacy in the field. His gentle spirit and sweet disposition set him apart. He was the kind of colleague who became a dear friend. I will deeply miss his presence.

C. Tito Mendonça

With his soft talk and gigantic figure, Fernando was a strange Brazilian-German blend. Brazilian in his easy-going and emotional approach; German in his search for rigor and precision. Also a Gaúcho, a Brazilian from the South, a man of large horizons. However, above all, a scientist, a man obsessed with knowledge and discovery. A bright and creative theoretician, a complex and disquiet person.

I first met Fernando in Trieste, during a topical conference. At that time, he was a visiting fellow at Bochum University, in the group of Padma Shukla, a long-time friend and collaborator, who also disappeared a few years ago. Great theoreticians have the tendency to leave too early. Fernando was soon to become an important name in Quantum Plasmas. For some time, I used to visit the University of São Paulo, Brazil, three or four times a year. I would stay one month, and during my stays, I would travel to the South and visit Fernando for a couple of days. First in Curitiba and then in Porto Alegre, his birthplace. We then started collaborating on a regular basis, with no budget and no big project, just for the fun of doing science.

If I am not wrong, our first paper concerned the problem of neutrino oscillations, when they mix with plasma oscillations.⁸ That led us to explore novel territories in neutrino-plasma physics, which culminated in the formulation of the Neutrino-MHD.⁹

In more recent years, we moved to other topics, and our last paper was devoted to the nonlinear version of Quantum Landau Damping.¹¹ This work, with Hugo Terças as a coauthor, was published in 2023. This paper had been prepared during his three-month visit to Lisbon, the last time I met him in person. We had some nice walks and good talks. Many drinks, talks, and papers were still in project, when he suddenly left us.

D. Giovanni Manfredi

I first met Fernando in the year 2000, when he came to the University of Nancy, France, as a young postdoc, shortly after I got my first permanent research position there. It was obvious from the start that Fernando was a brilliant mathematical physicist. We soon started working together on quantum effects in plasmas. I had always been interested in quantum physics, and particularly in Wigner functions, but it was during Fernando's stay that the study of quantum plasmas really took off.

I still remember the intensity of our collaboration and the pleasure of discovering new things (some of which were already known, but that is how one learns in science!) almost daily. I guess it worked so well because our skills were nicely complementary: Fernando was very strong on the mathematical and analytical aspects, whereas I was more at ease with the numerical simulations and the general background in plasma physics. Our collaboration culminated with three papers that laid the bases of quantum hydrodynamics for plasmas.^{1,12,13} It was certainly one of the most productive times in my whole career, and it had a long-lasting influence on my future research trajectory, which progressively shifted from plasma physics to condensed matter and nano-physics.

Fernando was a complex character—he took his work very seriously but, at the same time, displayed an almost childish innocence in his approach. He will be missed not only as a person but also as an example of playful, yet rigorous, scientist.

E. Hugo Terças

My first contact with Fernando was in 2008, when I first became interested in quantum plasmas. Inevitably, his work popped up before my eyes at a time when literature on quantum plasmas was still scarce. I decided to send him a message asking for good references, and without hesitation, he pointed me to Giovanni Manfredi's beautiful notes, "How to Model Quantum Plasmas." He did not direct me to his own work but rather to a colleague's. This immediately revealed his humility, his impeccable work ethic, and his generosity toward others.

It was only a matter of time before we reconnected. In 2019, Fernando invited me to join the jury for one of his students, and from then on, we grew closer and closer. Fernando would write to ask about my research, to check whether I was on track for a permanent position, or simply to see how I was holding up amid the struggles. We shared songs, film critiques, and thoughts about society. Fernando was not only a brilliant scientist but also an acutely aware person — aware of the deceptive world we live in, critical of his own limitations and gaps in knowledge. He was deeply politically engaged, often sharing insightful, humanistic perspectives on politics. For that very reason, Fernando was not always easy—his personality inevitably clashed with mainstream norms.

I met a kinder, more tender side of Fernando, when he finally visited Lisbon in 2023. Together with Tito Mendonça, we decided to work on a topic that fascinated all three of us: quantum kinetic theory. Fernando was incredibly generous, leading the mathematical aspects of the paper, but we found a sweet balance between his rigorous mind and our more intuitive, physical approach. His perseverance and respect for precision sometimes made him hesitant to share incomplete results, but we eventually discussed everything openly. Of course, we occasionally had to navigate his fiery temperament during technical debates—but it was a joy to see the work flourish.

I take comfort in knowing that Fernando was, in the end, truly happy in Lisbon. It may have been one of the happiest periods of his later life: his smile, his constant good mood, and the spontaneous way he struck up conversations. One memory in particular, stands out—a dinner in Lisbon's lively Bairro Alto. Without warning, Fernando started talking to a tourist couple sitting nearby, and we ended up sharing a bottle of wine with them. I was surprised to witness such a kind, spontaneous, and relaxed moment from him. I hold that memory close. Now, all I can do is thank him—for the joy of chasing the true spirit of physics, for his sharp critical mind and refusal to conform, and for his profound cultural depth. I hope to see you again one day, Fernando.

F. Ioannis Kourakis

Fernando Haas's unexpected passing, at a relatively young age, represents a significant loss to the plasma community as well as to all who knew him as a reliable colleague, a good scientist, and a cherished friend. Over the past three decades, Fernando and I collaborated in various capacities—initially as research colleagues, later as academic

partners, and eventually as close friends who frequently exchanged both professional and personal updates.

I first met Fernando in Bochum, Germany, where he held an Alexander Von Humboldt fellowship. We shared an office while working as postdoctoral researchers with the late Padma Shukla. As our careers progressed, our collaboration evolved into a productive partnership, culminating in a successful EU Marie Curie project on quantum plasmas with researchers from the UK, Brazil, Portugal, and Sweden. This partnership allowed for several exchanges between the Federal University of Rio Grande do Sul (UFRGS) in Porto Alegre, Brazil, and Queen's University Belfast (QUB) in Northern Ireland, enriching both of our careers and contributions to the field.

Fernando was one of the leading figures worldwide in modeling quantum plasmas. His expertise, combining solid foundations in dynamical systems and refined over the years to incorporate many-body systems modeling and plasma physics, was embodied in his well-known monograph on quantum hydrodynamics.² Fernando's analytical rigor and passion for research were evident in how he would be eager to discuss science impromptu, *entre la poire et le fromage*, both praising outstanding work and at the same time rigorously criticizing papers with logical inconsistencies, always striving to find solutions. Our own collaboration grew casually and spontaneously from such a critique, where we recognized the need for a rigorous relativistic fluid model for electrostatic waves in quantum plasmas. This work led to several published papers, also forming the foundation of two PhD theses at QUB.

On a personal level, Fernando was a unique individual—sort of an introvert yet a bon vivant, with a love for electric guitar, beat generation literature, poetry, and hard-rock music. I already miss with nostalgia those long evenings in Porto Alegre, enjoying Brazilian churrasco and local beer as well as our lively bar hopping sessions among various Kneipen in Bochum and pubs in Belfast.

Fernando will be deeply missed, both as a scientist and as a dear friend.

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AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

Author Contributions

G. Manfredi: Writing – original draft (equal); Writing – review & editing (equal). **A. Bret:** Writing – original draft (equal). **G. Brodin:** Writing – original draft (equal). **I. Kourakis:** Writing – original draft (equal). **M. Marklund:** Writing – original draft (equal). **J. T. Mendonça:** Writing – original draft (equal). **H. Terças:** Writing – original draft (equal).

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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