

## Understanding reactions at the heart of stars



**Sandrine Courtin is Director of the Hubert Curien Pluridisciplinary Institute (IPHC), under the auspices of the French National Centre for Scientific Research (CNRS) and the University of Strasbourg. She is one of the figureheads of French astrophysics,**

**and is known, inter alia, for her experimental initiatives and measurements of carbon combustion levels at stellar energies.**

In autumn 2023, she was awarded the Marguerite Perey Chair in the natural sciences at the University of Strasbourg Institute for Advanced Study (USIAS).

Sandrine Courtin is a renowned international nuclear physicist, whose first passion at a young age was for literature, writing and philosophy. But she was also attracted to science and had a talent for mathematics, interests that she was able to combine in physics. *"This discipline gave me an almost literary way to reason and explain the world that surrounds us",* she recalls.

She carried out a thesis on subatomic physics at the University of Paris-Sud, Orsay, under the direction of the British theorist, Neil Rowley. She was at that time interested in "sub-Coulombian"<sup>1</sup> nuclear reactions of medium-heavy nuclei, namely the phenomenon which takes place when nuclei fuse on collision with too low an energy for the fusion to take place according to the classical physics theory, but that can take place with the theory of quantum physics. It was at this very time that physicists also began to describe this phenomenon and Sandrine Courtin showed that the nuclei, when colliding at a low speed, are each sensitive to the structure of the other, that is to say the disposition of their neutrons and protons.

Her thesis director inspired her to develop her own ideas and to travel so, after receiving her doctorate in

1999, she went on numerous trips abroad, which included the USA, Canada, Australia, Italy and the United Kingdom. Over a period of time, she worked on experiments at the European Organisation for Nuclear Research (CERN) where she became familiar with the problematics of nuclear structure. She subsequently deepened her knowledge of the subject during the time she worked with Florent Haas, a specialist of molecular states in nuclei, identifiable due to gamma rays. In 2007, she prepared for her accreditation as director of research at the University of Strasbourg, which was an opportunity for her to show a certain maturity in her thinking and to set in motion her first work on nuclear astrophysics.

***"Every time I obtain a result, it's like a window that opens onto nature and reveals a glimpse of future questions. There is no price for the moment when we at last manage to characterise a phenomenon in the world that surrounds us. I have the same sense of amazement every time."***

She then became interested in the question of carbon. This constitutive element of living matter only exists in quantities that we know about because of the combinations it presents. Carbon is burned in the stars by very low-energy reactions, which would be impossible according to classical models but which is consistent with models of quantum mechanics on which Sandrine Courtin is an expert. After 2014, Sandrine Courtin formulated a new way of measuring carbon combustion in a laboratory, at the same energy level as in stars.



NASA's Webb Telescope Captures Rarely Seen Prelude to Supernova  
Credits: NASA, ESA, CSA, STScI, Webb ERO Production Team

<sup>1</sup> The Coulomb barrier is an energetic barrier resulting from the electrostatic interaction that two nuclei must cross to get close enough together to incur nuclear fusion.

She succeeded in obtaining research funding for different aspects of her idea – theoretical, practical, technical – at the national, European and international levels, including a USIAS Fellowship in 2015, which enabled her to put into practice her experiment and to measure the carbon combustion level in the stars with unparalleled precision.



Image: The STELLA experiment. © M. Heine, IPHC

As a result of this initiative and the discoveries that ensued, she established a collaboration between Europe and the United States and became a veritable initiator for the development of nuclear physics in Strasbourg, a discipline that hitherto had been absent from the scientific environment in the Alsatian capital. Since 2021, she is Director of the Hubert Curien Pluridisciplinary Institute, where over 400 researchers, teacher-researchers, engineers, technicians and doctoral students ponder over topics such as subatomic physics, analytical chemistry, ethology, physiology and the environment. In order to juggle between her new responsibilities and her desire to continue with her research, Sandrine Courtin, with her hands-on style, firmly believes in getting up before dawn, leaving her enough time to participate in discussions, interpretations and preparations of projects. As of today, she is also the author of 150 scientific publications, has given 50 presentations at international conferences, and has been invited to a number of residencies in foreign universities (USA, United Kingdom, and Australia).

One of the reasons she is keen to maintain close links with research is to foster the creativity of her collaborators.

***“My role consists in adapting the work environment to allow researchers to develop their ideas, she explains. So often we see the opposite in research, where ideas are suppressed in a context that is not favourable to them.”***

This is an approach in line with that of USIAS, whose philosophy is to encourage creative researchers to take risks – albeit measured – and to accompany them in this approach.

In 2023, Sandrine Courtin became the first holder of the USIAS Marguerite Perey Chair in the natural sciences, named in honour of the French scientist known for her discovery of francium, who was director of the department of nuclear chemistry at the University of Strasbourg and the first woman to be elected to the French Academy of Sciences in 1962. This two-year post will provide Sandrine Courtin the freedom to initiate future projects, in particular that of building up a solid link between the different players in her research field. Until now, their collaboration was very much based on the exchange of experimental data, with the nuclear physicists feeding calculations to the astrophysicists to determine the destiny of the stars. But Sandrine Courtin wants to go further and reinforce the transdisciplinarity of nuclear astrophysics. She predicts that

***“The next big step will be to reach a unified understanding of the evolution of the stars and nuclear reactions within them.***

***And this will lead to pluridisciplinary studies between astrophysics and nuclear physics that will drive their players, who use different languages, to find common ground and communicate better.”***

In addition to her research work and her role as institute director, Sandrine Courtin is involved in communicating scientific knowledge to a wide audience. She believes this to be one of the duties of a researcher and she addresses this responsibility in every possible manner: she writes articles in the scientific press for the general public, gives talks in schools, acts as moderator at evening events at Strasbourg’s “Jardin des Sciences” Planetarium, as well as at conferences in different universities over the world, and participates in mediation activities such as “Pint of Science.” She greatly enjoys this part of her work. *“I am convinced that everything can be explained, to all types of audiences, including children, she says. One just needs to find the right way of going about it.”*

*Interview by William Rowe-Pirra, science journalist*