

**COSTANZA TONINELLI:**

"Quantum mechanics comes into your life like a huge surprise and turns everything upside down. You have the feeling that everything you have known up to that point was only partially true or just a veil over a much richer world".

Lydia González Orta: Why choose the quantum field. Who/what can provide inspiration:

Costanza Toninelli: I think quantum mechanics comes into your life like a huge surprise, something that really surprises you and turns everything upside down. You have the feeling that everything you have known up to that point was only partially true or just a veil over a much richer world.

It was during the course of my studies

when I had this feeling for the first time. Then, during my Erasmus exchange in 2001, I went to Paris where I had the opportunity to take courses by Claude Cohen-Tannoudji – a Nobel Prize-winner in the field – who made me fall in love with atomic physics. I suppose that those days shaped my career. The fact that quantum systems are always surprising moved me a lot. What can be observed goes against intuition and common perception, thereby unveiling a hidden world that I did not know about.

L.G.O.: The reasons to take part in the QuantERA call:

C.T.: Actually, I had tried other calls before and we always got very good scores but never got funded. Then I had the opportunity to apply to QuantERA. There was a little reduction in the budget but the amount of work was reasonable and the reporting was convenient. So, we decided to give it a go. I like the idea of having some dedicated funding for fundamental research.

L.G.O.: The content of the funded research project for non-specialised audiences: impacts on technology and society:

C.T.: The ORQUID project is about an unconventional platform for quantum technologies. In our vision we believe that organic materials will play a major role in quantum technologies, pretty much the same way they have had a strong impact in other disciplines; i.e., the development of optoelectronic devices or flat-panel displays.

Organic materials have a number of advantages due to the flexibility of the synthesis process. You can start from solution, mix things and obtain tailored results.

Most people in quantum technologies work with semi-conductor inorganic materials. Therefore, **we wanted to bring this shift to quantum technologies. The challenge was essentially to develop interfaces to control the interaction between organic molecules and light.** Our project aimed to develop a toolbox for organic materials, a nanophotonic toolbox tailored to organic materials to show and prove their advantage.

To tell the full truth, I am interested in the physics of what is going on, on the fundamental aspects of light matter interaction with single molecules and single photons. I also believe it is very important to think about application of project's result, because this is the way to have an impact on society and the world we live in.

One thing that we are currently investigating is the development of single photon sources. Those non-classical sources of light are a crucial resource in quantum communications, for quantum key distribution (QKD) protocols, for instance: in order to exchange the key between two users in a way that is physically secure. This is something that is really happening and application of this research will have a huge impact on society.

The secure exchange of data is crucial, especially nowadays, as the amount of exchanged information is growing steadily to unprecedented numbers. This communication will be threatened also by the development of a quantum computer that will be able to decrypt keys much more easily than a classical computer. **The development of quantum secure communication will probably balance this threat due to quantum computers. I think this is a major challenge for our society.**

We also have in mind sensing applications that have been partially developed during the project and that might become actual devices at some point.

Interestingly, you typically access an extreme regime with single molecule sensors. For instance, we have developed a sensor that is able to optically detect a single electron charge. This type of sensitivity was achieved in the characterisation of the electronic noise in graphene and there is no alternative way to do that optically. Now we are working on the development of a temperature sensor in the range of 3 Kelvin, like minus 270 Celsius degrees. The possibility of mapping the thermal profile of a material with high accuracy and temperature resolution is something that is not available at the moment. **Measurements like these can be relevant for thermal management strategies at room temperature also, and hence are appealing within the framework of a sustainable society.**

L.G.O.: The role of coordinator: opportunities, challenges and gender issues:

C.T.: I tried to give soft guidance... soft in the sense of letting people express themselves. I like the idea of being a facilitator, oiling the engine.

Everyone was working nicely, mostly not in competition and it was a very good collaboration. I tried to keep track of what was going on and to make sure that possible exchanges were taking place, to make sure that no one spends time and energy on a matter that has been already solved by someone else. It was the first time that I had to coordinate such a consortium. **At the beginning I felt a lot of pressure because I was coordinating very highly-renowned scientists. Did I have to know everything? I did not! So, I decided to be honest about it** and if something was not really within my expertise, I asked someone else: “what do you think about this?”, “can you help me with that?”; I wanted to be honest about my expertise and competence and I think it went pretty well.

Unfortunately, among the group leaders, I was the only women. However, the rest of the consortium included women PhD students and postdocs.

At the level of coordination of a project I did not realise gender issues. I think one important point concerning the role of a project leader is to make sure that people are given the same credit.

It is important to avoid a situation when one person performs the work but then only the professor attends the meetings and gives the speeches, for instance.

L.G.O.: The main challenges for more gender balance in the quantum field: QuantERA’s first steps, promising measures, the most popular topics in the community’s discussions:

I have been discussing discrimination issues more often for the last 5 years. Nowadays we can hear and read about gender balance all the time, as the topic becomes more relevant. Whether is this proportional to the success of real inclusiveness, I do not know. Definitely, due to the public discussions the general awareness about the changes in language and gender balance increases. It is important to start from little things, like paying attention to the way in which debates are organised. Sometimes, during discussions, you can very quickly give credit to someone while not giving credit to someone else, in a way that unfortunately degrades the perception of the woman’s contribution.

It is really a question of sensitivity to the topic and awareness. I think this is a cultural aspect that needs to be seriously taken into account because it has an impact at such a deep level that is then reflected in decisions taken later on or in the very performance of people.

There are obviously many different levels of this painful lack of equity and inclusivity, starting from what I have just mentioned, then accounting the impact of unconscious bias in the hiring processes, the problems we have in the family-work balance during maternity leave, culminating in the cases of sexual harassment. We have to work on all of them in order to be effective.

Actually, not very concrete actions tend to be taken. We always hear very nice words but the problem is that no action follows. I would prefer to discuss taking real steps. The question is: which concrete action would play a major role? For instance, what we are doing now in this interview, I guess, is to try to give visibility to positive cases. This is a concrete action that could help, and not because of myself. **Definitely, showing good examples is a positive practice, this definitely makes sense.** On the contrary, just to write in a call announcement that it is good to have women PIs or to have women

as a part of the team – does it have any real meaning in the end?

For instance, we could consider allocating a small budget for the childcare or caring in general during participation in workshops or conferences. This is something concrete that would help women during special moments such as maternity leave or when they look after small kids. The other thing is to **require the participation in unconscious bias training for all the PIs. If you really want to be the leader in a European project, you have to know how to deal with these things.** You would have to participate and receive a certificate that confirms a basic knowledge of the subject. Another idea to implement could be **to make sure that there is a balanced audience or balanced panel of speakers at project meetings and conferences.** It could help to create a standard and to spread the message, like: "If you do not follow this rule, you cannot have the QuantERA stamp".

We are having these discussions and these are action points within the working group of the CSA of the Quantum Flagship.

As I said before, there are different levels of actions. Some of them are related to local situations and you have to act locally. Some are at the level of the QuantERA call or of the funding organisation. Some are at an even higher political level, in relation to the political situation in a single country. The paternity leave that exists in Spain and Sweden, for instance, is something that we can only dream about in Italy. And this is not related to QuantERA. But indeed, there are matters that can be controlled.

L.G.O.: Facing specific challenges for being a woman in the field?

C.T.: I certainly faced a lot of challenges. Some of them I am aware of, while others not. It is very important to recognize that something is so much embedded in stereotypes that you are not even aware of the impact your gender has on your working experience.

On QUANTERA's first steps toward contributing to a more gender-balanced field:

To promote equal opportunity and gender balance, QuantERA II encourages the participation of consortia with a fair representation of female researchers both as PIs and in the research team (2021 call)

2021 call peer review guidelines encouraged all panel members to recognise and challenge “unconscious bias”

The Gender Equality Statement as Annex II of the 2021 call recognised the key role of RFOs while calling on physics institutes and the physics community to:

- Create a gender-sensitive environment and organisational culture
- Create an equality standard regarding the management structure
- Acknowledge that diversity is beneficial for science
- Encourage all women PhDs in physics and in QTs and provide them with the adequate career support
- Acquaint STEM students with role models of women researchers in QTs

The other thing I have to say is that I have been lucky because I am the daughter of a woman who has invested a lot in her professional career and she has been working as a professor. Since I never really felt an abandoned child, I am kind of doing the same with my kids without much feeling of guilt. But some other people ask me “how do you feel?”. Fortunately, my mother was such a good parent and such a good physicist at the same time that I have always understood that I could do both at the same time.

However, for instance, I remember perfectly **when I was pregnant with my second child and at the coffee machine a full-time professor asked me: “but now, you have to really choose if you want to be a good scientist or a good mother”**. This is one of the things you are regularly confronted with. The stereotype is so transversal, left-wing and right-wing, that people ask such questions with no shame. This hurts me. **In many other circumstances I simply had the feeling that I had to be twice as good to prove that I am worthy. And this is really annoying...** There are also different dimensions in different moments of your life. As a student student, you probably don't feel it

so much. **However, even the feeling of “not being adequate” (that is something very common in the academic world), is certainly more often and more firmly experienced by women.**

When you are at the age when you want to have children, this matter starts to have a huge impact. Trying to balance the two aspects of your life, makes you feel vulnerable and fragile. I would love to have had more support from my colleagues back then. Since it is a “structural” moment and you know that it is going to happen, you have to deal with it in such a way that doesn't make you feel bad. Yet, you still feel bad at that moment. It should be clear from the beginning that you will do everything to make things happen as smoothly as possible. And this is not happening in any way. Now I am facing different circumstances because I am in a position that I can access a certain level of power in the sense of decision-bodies and there **I see other mechanisms: you are a good scientist and you are a woman, so I would like to use your face to create an inclusive image of the field.**

I am invited to many conferences that is even too much because I cannot travel that often. **But when it is time to make the decisions, it is still an “old-men club”.** Then there is no space for me there.

L.G.O.: On the usefulness of these visibility actions targeting women researchers:

C.T.: I am happy to be interviewed and I am happy to discuss these things but it would be nice if these interviews were also extended to male coordinators. This would be highly relevant as it is not just a problem for women!

Moreover, the topic of inclusion is far broader than just a question of men and women; there are different gender perceptions and fluid situations and I think in general these types of actions would be beneficial for everyone. When you are trained to identify mechanisms and patterns during discussion that automatically tend to prioritise a certain type of person, you will recognize it in all contexts. We have to train our brains in order to avoid this and I also have to get this training. Women are not exempt from having biases.

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Costanza Toninelli is a researcher from the National Institute of Optics (INO-CNR) and group leader at LENS – Florence, working on the enhancement and control of light-matter interaction through the coupling of single quantum emitters to photonic structures. Her main focus are: quantum science and technologies.

*A series of interviews with female coordinators of QuantERA co-funded projects is a part of Task 5.4 Towards a more gender balanced quantum field, i.e. “Highlighting the presence of female researchers among the Coordinators of the QuantERA-funded projects in QuantERA communication and PR materials”.