Master's Ceremony Physics 2023, ETH Zurich

Dear Masters of Physics

Dear guests!

You all know the famous words that Johann Wolfgang Goethe had Doctor Faustus proclaim:

Ah! Now I've done Philosophy,	***Habe nun, ach! Philosophie,***
I've finished Law and Medicine,	***Juristerei und Medizin,***
And sadly even Theology:	***Und leider auch Theologie***
Taken fierce pains, from end to end.	***Durchaus studiert, mit heißm Bemühn.***
Now here I am, a fool for sure!	***Da steh' ich nun, ich armer Tor,***
No wiser than I was before	***Und bin so klug als wie zuvor!***

(translation by A.S. Kline, poetryintranslation)

Even with a Master's degree in physics from ETH Zurich, you have probably often come to the realisation that your knowledge is limited. And that's a good thing!

Because this insight is at the beginning of your future activity, namely the ambition to learn, create or find out something new.

In Doctor Faustus' words:

To see if, through Spirit powers and lips,	***Ob mir durch Geistes Kraft und Mund***
I might have all secrets at my fingertips.	***Nicht manch Geheimnis würde kund;***
And no longer, with rancid sweat, so,	***Dass ich nicht mehr mit sauerm Schweiß***
Still have to speak what I cannot know:	***Zu sagen brauch', was ich nicht weiß;***
That I may understand whatever	***Dass ich erkenne, was die Welt***
Binds the world's innermost core together, ...	***Im Innersten zusammenhält, ...***

(translation by A.S. Kline, poetryintranslation)

As is well known, Doctor Faustus chooses the easy way and devotes himself to magic. Specifically, he makes an alliance with the devil in order to penetrate to deeper knowledge.

This leads me to formulate three topical questions that also pose themselves to me as a scientist:

1. How do I get to knowledge?

Today there are many possibilities – many more than back then, when we laboriously went through index cards in the ETH library until we finally found the desired work, only to discover that it was on loan and would not be available for another two weeks.

Soon Google came along, and with it we were able to get information at lightning speed. But we pay a price for this: whereas in the past reference works were checked for errors in several stages, the quality check is now our own responsibility. We have to maintain a healthy skepticism and keep checking the consistency of the information.

A completely new method has recently become available. It is seductively fast, even eloquent: ChatGPT. The software does amazing things. A kind of conversation with the machine seems possible.

So I asked the question whether perhaps humans might ***not*** be changing the climate. The answer appeared on my screen within seconds and really amazed me. It was not only linguistically convincing, but also correct.

And at that moment I felt like Doctor Faustus.

And no longer, with rancid sweat, so,	***Dass ich nicht mehr mit sauerm Schweiß***
Still have to speak what I cannot know	***Zu sagen brauch', was ich nicht weiß***

The temptation is indeed great to take this shortcut. But it is precisely this shortcut that prevents us from using the information we have gathered for the creative step, for the next question that opens our eyes to a new world. In short: the seemingly pleasant shortcut deprives us of the experience of being able to live the most beautiful moments of creativity ourselves.

Advancing to new knowledge is a creative process, and you have learned and practised this in your studies.

Do not let this be taken away from you. Society depends on physicists like you who have mastered the creative process!

2. How do I communicate new knowledge?

As part of your Master's degree, you have already taken the first step in scientific communication. You have written the thesis yourself, without a ghost writer, and without ChatGPT.

Master's theses, doctoral theses and articles in journals are the classic means of communication in science. If we make it into a so-called "high-impact journal", then perhaps the media and communication specialists of the house will help us to translate the complex results into digestible text, and then disseminate it on their channels.

In recent years, a very effective communication tool has been added: Twitter. Many scientists use it to draw attention to new findings or publications in short tweets. This is extremely effective, because journalists also follow these tweets. However, Twitter is a very short-lived medium and is used primarily as a manipulation tool in other areas.

Twitter is not suitable for disseminating scientific findings to society and achieving a long-term impact.

However, climate research already used a form of communication 44 years ago, which has since developed into an effective instrument: The report resulting from an assessment.

A handful of scientists first wrote a report for the US National Academy of Science in 1979, entitled *Carbon Dioxide and Climate: A Scientific Assessment*. In the summary they wrote in 1979:

> **We now have incontrovertible evidence that the atmosphere is indeed changing and that we ourselves contribute to that change. Atmospheric concentrations of carbon dioxide are steadily increasing, and these changes are linked with man's use of fossil fuels and exploitation of the land.**

The scientists go on to write about the possible consequences:

> **In order to address this question in its entirety, one would have to peer into the world of our grandchildren, the world of the twenty-first century.**
>
> - **Between now and then, how much fuel will we burn, how many trees will we cut?**
> - **How will the carbon thus released be distributed between the earth, ocean, and atmosphere?**
> - **How would a changed climate affect the world society of a generation yet unborn?**
>
> **A complete assessment of all the issues will be a long and difficult task.**

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was founded with the task of carrying out precisely this complete assessment. This was to provide scientific information on climate change for the Earth Summit in Rio de Janeiro in 1992. Based on this first IPCC report, the UN Framework Convention on Climate Change was adopted.

It is the basis for global climate protection, as its Article 2 states, in abbreviated form:

> **The ultimate objective of this Convention [...] is to achieve [...] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.**

Without this formalised way of communication from science to society, the Framework Convention would not exist. Without the climate research of the last three decades, and four other IPCC reports, the Paris Agreement would not have come into being.

This agreement requires that global warming be kept well below 2°C compared to pre-industrial levels. Each country should do their part to reduce greenhouse gas emissions according to the principle of common but differentiated responsibility. Switzerland, as a highly industrialised and one of the richest countries, clearly has a special responsibility.

To my great relief, the Climate Protection Act was adopted last Sunday with 59.1% in favour. This was despite the fact that one political party used a well-financed campaign of lies to carry out a nationwide propaganda campaign.

The level of information and social participation of the population in the democratic process is an important element in determining which political and social decisions are taken.

Therefore: Get involved as trained physicists to develop and communicate solutions to the current challenges of our society.

Who, if not you, will provide the facts!

And that brings me to the last question:

3. What happens with the new knowledge?

The basis of physical climate models are partial differential equations. The Navier-Stokes equations describe the currents in the atmosphere and in the ocean. Energy fluxes in the atmosphere are calculated from the sum of the spectral absorptions and emissions of all main and trace gases – essentially quantum physics and thermodynamics. Cloud formation is approximated based on the dynamics and state of the atmosphere. These models simulate the climate of today and provide us with explanations for the signals from past climate that we measure from ice cores, marine sediments, tree rings and other archives.

But these models are also the basis for scenarios of the future:

- What happens if greenhouse gas emissions are not reduced to net zero?
- What effects would that have on the frequency of heat waves and on our well-being?
- What if part of the Antarctic ice sheet melts?

From these scenarios, we scientists already drew the following conclusion in 2013:

> **Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.**

This clear statement is in the Summary for Policymakers of the IPCC's 5th Assessment Report and was accepted by consensus by 195 countries. The statement forms the scientific basis for net zero.

Models are an instrument of climate physics. With physics, you can develop pacemakers to combat heart insufficiencies, but you can also build bombs. This is the age-old dilemma of physics, indeed of the natural sciences generally.

The dilemma is already visible in the sketches of Leonardo da Vinci, whose creativity produced war machines as well as depicted the inside of the human body to help cure diseases.

Climate models do not escape this dilemma either. A whole branch has been dealing with the question for some time:

Couldn't we artificially cool the atmosphere without giving up the convenient technology of burning coal, oil and gas?

With geoengineering, we would have to put several million tonnes of sulphur dust into the lower stratosphere every year, which reduces solar radiation. Climate models are supposed to show that this experiment could work and would thus provide the scientific arguments for a second global climate experiment with an uncertain outcome. Another experiment with risks and consequences for future generations.

Geoengineering is the ChatGPT of climate protection. A shortcut, a fake solution. Nevertheless, some scientists seriously propagate this strategy and justify its feasibility with results from climate models. But these models also show that geoengineering could neither stop the acidification of the ocean nor the global shifts in the water cycle.

But what is ignored: Geoengineering is another global-scale intervention in nature. Just as Article 2 of the UN Framework Convention on Climate Change applies to the emissions of greenhouse gases into the atmosphere, it also applies to the dumping of sulphur dust in the stratosphere. A dangerous human impact on the climate system must be prevented.

Johann Wolfgang Goethe also thought about this as early as 1797 in his Sorcerer's Apprentice:

Off they run, till wet and wetter	***Und sie laufen! Naß und nässer***
Hall and steps immersed are lying.	***wirds im Saal und auf den Stufen.***
What a flood that naught can fetter!	***Welch entsetzliches Gewässer!***
Lord and master, hear me crying! -	***Herr und Meister! hör mich rufen! –***
Ah, he comes excited.	***Ach, da kommt der Meister!***
Sir, my need is sore.	***Herr, die Not ist groß!***
Spirits that I've cited	***Die ich rief, die Geister***
My commands ignore.	***werd ich nun nicht los.***

(translation E. Zeydel, babelmatrix)

During the last quarter of an hour, the global sea level has risen by another 0.13 micrometres. Per decade that makes 4.6 cm, by the end of the 21st century a total of over half a metre since the beginning of the 20th century. Under business-as-usual, however, a metre or more!

Therefore, dear physics masters:

Work to ensure that your findings are beneficial and do not create ghosts that you will never get rid of.

In any case, do what inspires you!

I wish you all the best on your future paths, personally as well as professionally!

Thomas Stocker
Bern, 23. June 2023