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What I wanted to convey in my closing speech

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Chairman, Program Committee,
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The international conference sponsored by N I F S (National Institute of Fusion Science: https://itc.nifs.ac.jp/) was over in the afternoon of November 11th. The conference was conducted via ZOOM using the Internet. The program was designed to take into account the local time of the invited speakers from Europe and the United States. The scope and report of the conference, an executive summary, will be written in a separate form. Here I reproduce the 20-minute message I delivered as the program committee chair at the closing ceremony. This is reproduced for the audience, especially, for students and junior researchers.

On the first day, Director-General Yoshida said, "We have to review the research accomplishment as an academic result. We will clarify the universality of the result and develop them in an interdisciplinary manner." He explained his thoughts on the new paradigm by showing **Fig. 1**. Don't be satisfied with the sweet taste of the fruits of your research. Behold the leaves, observe the branches. Think of the trunk from which academia branches out. The trunk is the origin of diverse sciences. Trace the results of your research to the trunk. For this purpose, interdisciplinary and international academic development is necessary. Take in the wisdom of other fields, develop it, and disseminate it to other fields. Instead of staying put, always ask yourself and your colleagues, "Where do we come from? What are we? Where are we going?".

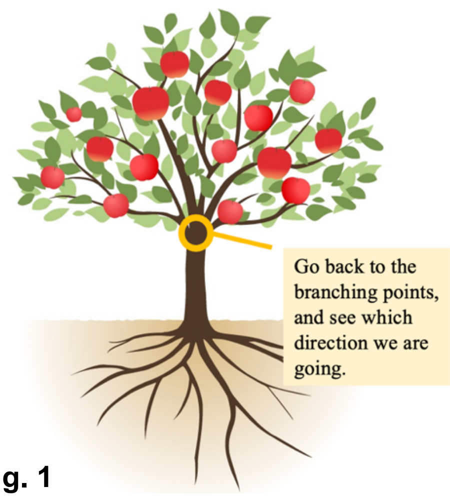
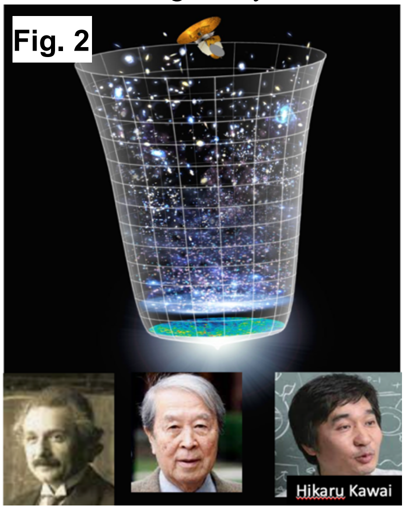


Fig. 1

One of my friends in physics at National Taiwan University is Prof. Hikaru Kawai. He is a particle theorist in string theory. We had a two-hour discussion about "What is science and academic?" In fact, every time we go out for dinner, we spend two hours discussing science-related topics. He is trying to create the universe mathematically using only the fundamental constants "c, $\hbar$, G" that govern light, quantum mechanics, and gravity (**Fig. 2**). Particle theory is mathematical and philosophical. I think his research method is "deductive". He is challenging to create everything in the universe. To do so, he investigates the structure of the space-time of the universe with the theory that seems to be behind the Lagrangian of **Fig. 3**, including the string theory. This is an attempt to get from the root to the trunk of **Fig. 1**.

Fig. 2



I thought about my case while discussing with Mr. Kawai. "How do I, as a plasma physicist, approach branching out? What is academic in my physics?". In my case, there are plasmas in front of me, though I cannot see them with my eyes. I see them as a phenomenology and wonder what kind of physics is woven into them. I measure them, analyze them, and write a paper with my thoughts. These days, simulation codes are freely available and anyone can use them. Today's computers are extremely faster than the supercomputers of the past. Simulations can be done on PCs as well. Then, the simulation and the experiment are compared, and if they agree, the results are happily published as a science paper. When I read many of the latest papers for writing textbooks, I encounter many such papers. Naturally, I don't read all of them, nor do I cite them. The question is, "What is the physics of the core?" There is no analysis, or rather no research, on this point. Occasionally, When I find a paper that talks about the physics of the core, it makes my heart sing.

The action is given schematically as follows:

$$S = \int d^4x \sqrt{-g}\,\mathcal{L}, \quad \mathcal{L} = \mathcal{L}_{GR} + \mathcal{L}_{SM},$$

$$\mathcal{L}_{GR} = -\frac{m_P^2}{2} R, \quad \longleftarrow \text{Planck mass}$$

$$\begin{aligned}\mathcal{L}_{SM} = &-\frac{1}{4} g^{\mu\nu} g^{\lambda\rho} F_{\mu\lambda} F_{\nu\rho} \\ &+ e_a^\mu \bar{\psi}\gamma^a D_\mu \psi + M\psi\psi + \text{c.c.} \\ &+ g^{\mu\nu}(D_\mu\phi)^*(D_\nu\phi) - m_H^2\,\phi^*\phi - \lambda(\phi^*\phi)^2 \\ &+ y\,\bar{\psi}\psi\phi + \text{c.c.}\end{aligned}$$

R : scalar curvature
F stands for field strengths of gauge fields.
ψ stands for fields of quarks and leptons.

Fig. 3

Plasma science approaches the physics of the core phenomenologically. It becomes a discipline by descending the branches and reaching the trunk. The methodology of academic research is rather "recursive". It is the search for truth by inductive method, and the study deepens empirically. If you reach the point of branching out, you will meet faces you will never forget. They can be Maxwell, Boltzmann and others (**Fig. 4**). By borrowing from their wisdom, we begin to see the "core of physics," and there we find universal truths. Sometimes it finally reduces to a simple mathematical model expressing our intuition. Once you find the law of the physical system that govern a complex system, it becomes a universal achievement.

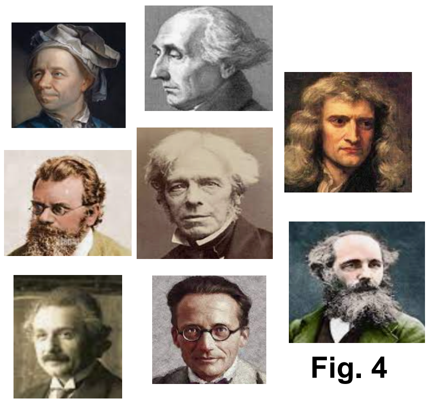


Fig. 4

Scientists who are exploring a different world will also come back to the trunk and perhaps create a new branch. At such a time, will particle theory, which attempts to imagine everything from the roots up, perhaps predict a "flattened" universe with no structure. A wonderful creation. But the universe has an extremely hierarchical and complex structure with large scale structures, galaxy clusters, galaxies, celestial bodies, planets, and the earth.

I do not believe in determinism like "Laplace's devil". I believe that the science of fluctuation, dissipation, instability, transport, turbulence, structure formation, and others having been challenged in plasma physics are essential to the connection between the magnificent universe that began with the phase transition of the vacuum and the diverse and profound science of today days.

When the plasma physics finds science in the trunk where various sciences and technologies that bear fruit in diverse branches branch out, we may encounter the science of cosmology and particle theory. There, we confirm that the science that has studied the universe deductively and the science that has arrived at the trunk inductively are "complementary" to each other. With mutual respect, the scientific community grows in the future. The science will deepen and broaden, and universal concepts will emerge. We have to hand them on to the next generation.

Fig. 5

I stopped composing simulation programs in the mid of my 40s. More than 20 years later, supercomputers are a 'billion times' faster. This is a revolution. The paradigm of my time would never have worked. So, I stopped computer programing. I decided to change generation and leave the younger generation to take over, as shown in **Fig. 5**. However, through my experience up to that time, I had come to see the core of the problem in a big picture. I have passed on that core to the younger generation and ask them to study it. I tasted a sense of defeat and encountered unexpected results.

At that time, I became a professor and tried to develop new research while I was busy for managing our research institute. It was truly the first attempt at 50 years old. Fortunately, with the help of talented young people and an international network of collaboration, we were able to achieve results that exceeded my expectations over a period of 10 years. I even received an award from the APS for our achievements. Still, I was not satisfied and kept asking myself in the corner of my mind what the "physical core" was. A quiet life in Germany began. In the midst of all this, I had a flash of inspiration. I came up with a simple mathematical model of a shock wave generated from turbulence. I think I have seen the core physics that governs the background of experiments and simulations. (To be published in Phys. Plasmas as an invited paper).

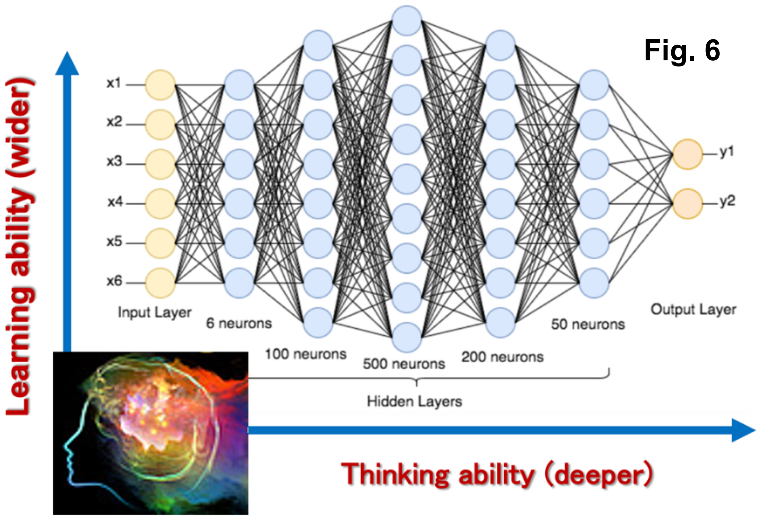


Fig. 6

With the background of progressing computing power, I found many presentations to use the artificial intelligence (AI), such as "machine learning, neural networks, big data, and statistical modeling," to conduct research wisely and to develop science in greater depth. Plasma physics is also the frontier of physics discovery with AI [1, 2].

Artificial intelligence is modeled on the structure of the human brain; as shown in **Fig. 6,** humans have a hierarchical brain that thinks deeply and a brain that stores broad knowledge, connected vertically and horizontally by neural networks. What this suggests is interesting. When the human brain digs deep into research, it does not function well when it is the only thing it can see, like an octopus pot. What we see, hear, and learn are accumulated as information, and ideas are "spontaneously" generated when unrelated things are connected. From there, they are able to progress to even deeper insights.

Let us compare such a human being to a tree, as shown in **Fig. 7**, which is a street tree taken in Tokyo. The tree's trunk grows taller and taller with a goal-oriented approach, saying, "Cut waste, don't go sideways, cut off the branches and leaves”. In some cases, I have seen a slogan“develop energy” written at the end of the trunk. Some organizations seem to deny academia in universities. I believe that purpose-oriented research doesn't fit well at universities. I believe that a university should be an organization that supports academia, basic academic activities. To use a metaphor, university research is like a "big tree" with leaves growing on large branches like the one in **Fig. 8** (the photo shows a famous big tree in Taiwan, visited by young people). The spreading leaves receive a lot of solar energy and grow further through photosynthesis.


Fig. 7


Fig. 8

The title of this conference is "Expanding Academic World Emerging from Fusion Science". Some young participants may not know how to deepen their academic world through international conferences and discussions. Therefore, I would like to conclude by explaining three things that I have learned from my experience (or rather, my way of life itself).

(1) Honesty, Openness

Science is an activity in pursuit of truth. Science does not demand lies, deception, or power. We just want scientists to look at facts, accumulate facts, and find the truth. To do this, they need to be open-minded, honest in their explanations, and open to discussion with others. Show your weaknesses, too. If you are honest, if you say what you think, there will be no contradiction. Distinguished researchers see and appreciate such a way of life. This is because they have the moral code. Honesty is the first step to expand your network.

(2) Fairness

International conferences are not one-way meetings where you just listen to presentations. Speakers are waiting for questions and comments from the audience, even some new ideas. You should be inspired to find your questions. A meeting without questions is "unfair" and unacceptable. The value of "gain and loss" is not acceptable. Sports are possible because there are rules. Scientists have rules of ethics. It is self-evident whether it is ethical or avaricious.

(3) Respect

When talking with children, bend your knees and keep your eyes at the same level. Look them in the eyes when you talk to them. This is to respect the other person. The same goes for eye-contact. It is an evidence that you are listening seriously. Meeting people at an international conference is a real pleasure that you cannot experience at a ZOOM conference. A friendly update with an old acquaintance. When you find an interesting talk, you start the conversation with questions any chance after the talk. It's great if you can continue the conversation over a meal or something. Poster session. Respect and question junior scientists from the same perspective as you do. Getting to know someone means asking them about their scientific stance. It is important to know the differences from your own ideas. Find out what you don't have. This leads to new discoveries. “Humanity”. Respect humanity in any case in one’s life.

After reading this message, some people will surely scoff and say that it is idealistic and difficult. However, my own argument is that "university people should present an ideal image to society". Now in abroad, I can freely do the research I want to do, because I am free. I also write textbooks while enjoying traveling and other activities abroad. I also enjoy meeting new people from different fields. My wife and I are enjoying a fulfilling post-retirement life that I could never have imagined if I had stayed in the octopus pot until retirement.

References

1. Brian K. Speasr et al., *Deep learning: A guide for practitioners in the physical sciences*, Phys. Plasmas 25, 080901 (2018).
2. Peter W. Hatfield et al., *The data-driven future of high-energy-density physics*, Nature, Vol 593, 351 (2021).

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