Celebrating Professor K. R. Ito and Professor I. Ojima on their 60th birthdays

Tetsuya Hattori (Keio Univ.)

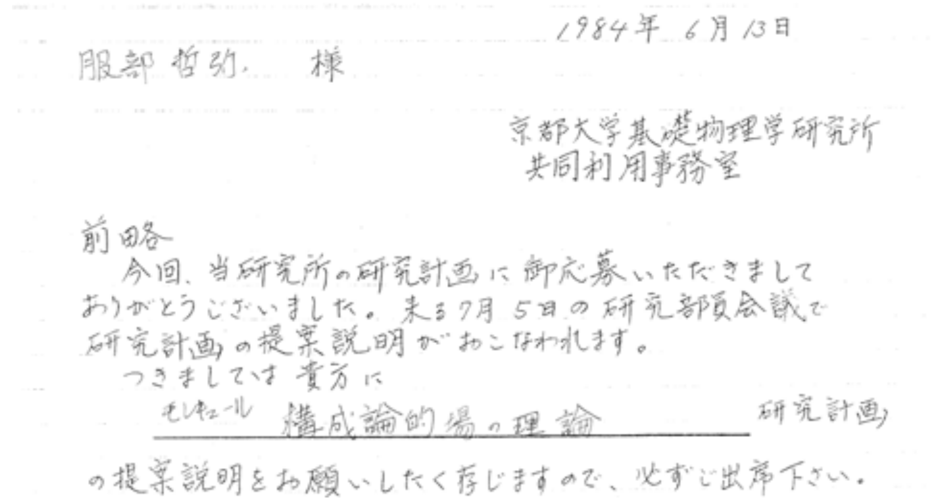
As a piece in the proceedings to the International conference at Kyushu University, Nov. 2009, held in honor of Professor K. R. Ito and Professor I. Ojima, celebrating their 60th birthdays, I would like to leave here a short personal note of how I came to know Professor K. R. Ito and Professor I. Ojima, a quarter of century ago.

Though I found that there are lots of potentially important historical background subjects, both social and scientific, necessary for present (or future) day young readers to understand why certain things could happen in a way recorded here, I gave up going into any depth. I apologize if this note is not clear or if there are misunderstanding on my side, in what follows.

Professor Kei-ichi R. Ito

In the year 1984, in the fourth year out of five years for my graduate study, I was among a group of a few graduate students who were making a research proposal to RIFP, Research Institute for Fundamental Physics, Kyoto University, now officially changed its English name to Yukawa Institute for Theoretical Physics. RIFP was then located at the next building to RIMS, the Research Institute for Mathematical Sciences, where Prof. Ito finished his graduate study.

RIFP had, and as I understand still has, a flexible fund for small size research proposals in physics. This meant something special in 20th century. At those time, Japan was about to have its best time in economy, but national budget for fundamental sciences had still been suppressed, and lack of flexibility made it even difficult to have official financial aid for graduate students. RIFP had been working hard on this problem, and was taking all possible measures to give small financial aid to encourage young physicists and improve their research environment. It was one of such funds from RIFP that we were applying in 1984.


Research Institute for Fundamental Physics
Kyoto University

1984年 6月 13日

服部哲弥 様

京都大学基礎物理学研究所
共同利用事務室

前略
今回、当研究所の研究計画に御応募いただきまして
ありがとうございました。来る7月5日の研究部員会議で
研究計画の提案説明がおこなわれます。
つきましては 貴方に
モレキュール 構成論的場の理論 研究計画
の提案説明をお願いしたく存じますので、必ずご出席下さい。

It was a coincidence that Prof. Ito returned to Japan from Europe in the same year 1984. As the budget situation for research was bad at those times in Japan, so was the job situation desperate for graduate students in physics. Japan was probably so 'advanced' a country in this problem, that we already long had had a Japanese-English word to describe the situation, the 'over-doctor' problem; the problem of large portion of PhDs without research job positions.

After completing graduate course program at RIMS, Prof. Ito remained at RIMS as a JSPS (Japan Society for the Promotion of Science) research fellow and then as a research fellow of the elemetary particle group Japan, before finding a three years SERC fellowship position at Bedford College, London University, where he stayed until 1983, and after visiting ZiF, Bielefeld University, for a year, he returned to Japan. He had to survive with a temporal position at Kyoto University, before he finally succeeded in finding a permanent position at Konan college, where he stayed from 1987 to 1993. He then moved to Setsunan University, where he is now.

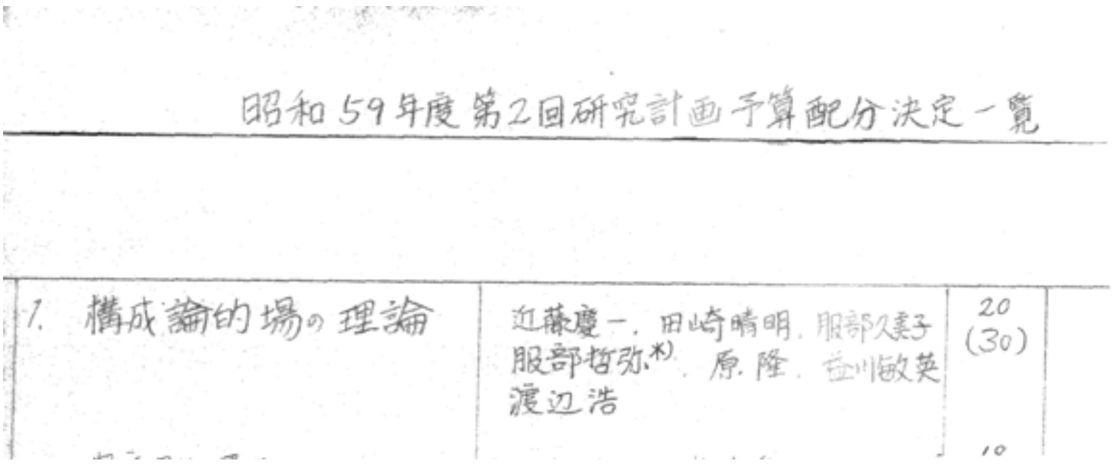
A main 'social' reason for the difficulty in winning permanent academic positions at those times was the 'over-doctor' problem. I would say that there must have been another reason for Prof. Ito's situation. At those time in Japan, a mathematical treatment of quantum field theory and statistical mechanics, or a study in quantum field theory and statistical mechanics as mathematical physics, which is Prof. Ito's main research concern to date, was thought to be mathematics from physicists, and physics from mathematicians. Few people could appreciate the importance of such studies, and very little number of academic positions could be expected for such approaches. I am confident about this, because a few year later, at around 1987 or 1988, I was personally warned from a very prominent senior professor, with such a strong word as 'You are strangling yourself'.

In fact, the situation partly motivated us in applying for a fund at RIFP. Though still graduate students, we somehow felt that not many physicists in Japan would like to be mathematically serious, and therefore, we felt a need to make an appeal to physics society, that we are interested in mathematical physics approach to quantum field theory and statistical mechanics. A particular topic which excited us then were the new approaches brought by people such as J. Fröhlich and M. Aizenman. The new ideas were to represent (Euclidean) quantum fields as random geometrical objects and use mathematically rigorous inequalities to prove physical intuitions on these random objects mathematically, resulting in interesting conclusions from quantum field theoretical point of view, such as the 'triviality' (non-renormalizability) of interacting scalar quantum field theories.

I wrote above that I felt an atmosphere in physics society against serious mathematical studies of physics. I should however add that scientific information was not blocked. In fact, the new results of J. Fröhlich and M. Aizenman were brought quickly to Japan, and the graduate students could know such latest results, even though the mathematical approach had not been appreciated widely. (This is not at all trivial, because we had another decade to go before the internet and web to prevail.) Scientists willingly accept information on new or even exotic ideas, which is good. Scientists are perhaps more conservative in evaluation, which may be reasonable, if it is not biased too much.

At the time we were applying to the RIFP funds, I did not know Prof. Ito: Much less did I know that he was returning to Japan. Anyway, on 5th July 1984, I attended a meeting at RIFP for proposal explanations, and explained our proposal with subject title 'Constructive quantum field theory'.

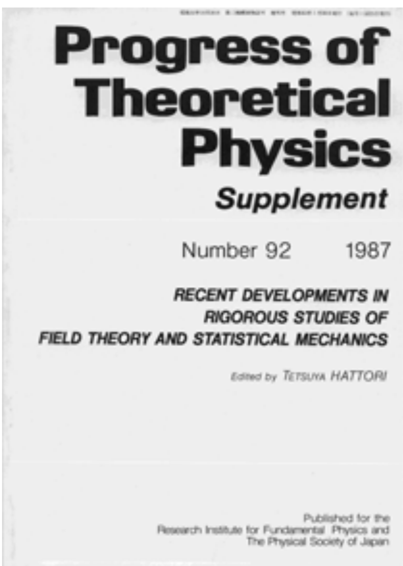
Guessing that the subject would not be welcome, and also having no senior professors joining the application, I anticipated that the proposal would be rejected, or at least, budget would be largely reduced. To my great surprise, the proposal was accepted with great encouragement, and with smallest decrease in rate among the proposals.


昭和59年度第2回研究計画予算配分決定一覧

1. 構成論的場の理論	近藤慶一，田崎晴明，服部久美子 服部哲弥*)，原隆，益川敏英 渡辺浩	20 (30)

Prof. T. Maskawa, a Nobel Laureate of 2008, who was at RIFP, apparently supported our proposal greatly. It turned out that he independently knew the works of J. Fröhlich and was interested in these approaches. The document says that he even ended up in joining our proposal as a member, though I don't remember how this was possible. (I think he was on the board of committee at RIFP, judging the proposals. Perhaps things were very flexible at those times.)

Approved as a RIFP project, we held a meeting at RIFP right away, which Prof. Ito noticed and, he reached us at the meeting room. I remember a tall person coming into the meeting room, with lively smile, as if he knew us for a long time. That was how I met him for the first time.


Progress of Theoretical Physics

Supplement

Number 92 1987

RECENT DEVELOPMENTS IN RIGOROUS STUDIES OF FIELD THEORY AND STATISTICAL MECHANICS

Edited by TETSUYA HATTORI

Published for the Research Institute for Fundamental Physics and The Physical Society of Japan

We applied successfully to the RIFP fund again the next year, this time with Prof. Ito in the list from the beginning. As an output of our two years activities,

昭和60年度第2回

研究計画提案申請書

せつめーつき！

昭和 60年 5月27日

京都大学基礎物理学研究所長　殿

所属 東京大学　理学部　物理学教室
（鈴木 研）

氏名 田崎　晴明

下記のとおり共同利用研究計画を提案します。

記

イ）研究テーマ　構成的場の理論 および 厳密統計力学

ロ）種別（○でかこむ）　1. 短期研究計画　2. 長期研究計画　③ モレキュール型研究計画　4. その他

ハ）開催希望時期・日数　'85年10月, '86年2月,6月 各2,3日　参加予定者数　10 人程度

ニ）予算希望額（○でかこむ）　第1希望　L・M・S・SS　第2希望　L・M・S・SS

ホ）世話人及び提案説明者

氏名	所属部局名	職名	氏名	所属部局名	職名
伊東恵一	京大・教	非常勤講師	益川敏英	京大・基研	教授
近藤慶一	名大・理	D.C.	渡辺 浩	東都大・理	D.C.
鈴木増雄	東大・理	教授			
田崎晴明	〃	D.C.			
服部燈子	〃	D.C.			
服部哲弥	学習院大・理	助手			
原 隆	東大・教	D.C.			

連絡責任者氏名 田崎 晴明　　提案説明者氏名 服部 哲弥

せずはちり

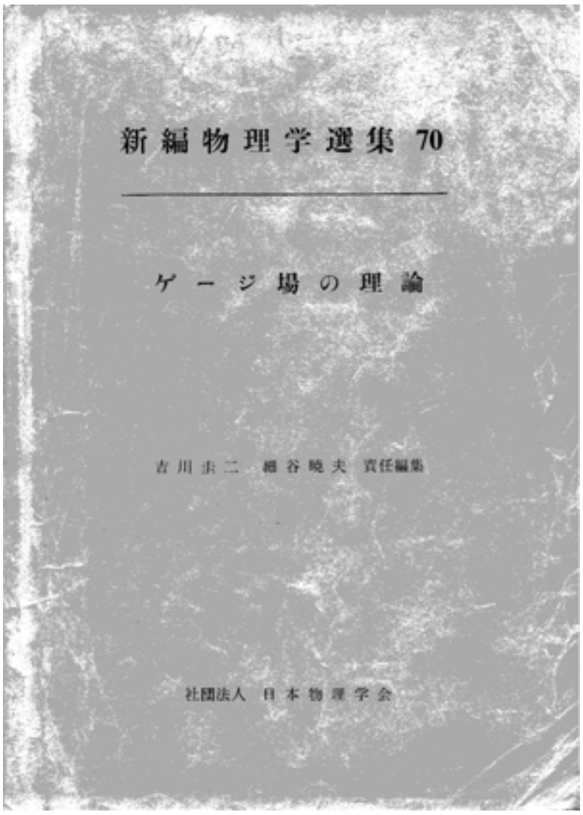
we were invited to publish a volume of Progress of Theoretical Physics Supplement, a review journal published by RIFP. Of course, Prof. K. Ito contributes a paper in the volume: K. R. Ito, 'Renormalization group methods on hierarchical lattices and beyond', Progress of Theoretical Physics Supplement **92** (1987) 46–71.

Prof. Ito has continued to study quantum field theory and statistical mechanics as mathematical physics. In 1970s his main concern was in quantum electro dynamics in 2 space-time dimensions, in 1980s he turned to the renormalization group theories, and in 1990s he focused more on polymer expansions.

Besides these original studies, he continues to organize a series of RIMS Symposium 'Applications of Renormalization Group Methods in Mathematical Sciences' starting in 1999 and held every two years (`http://www.setsunan.ac.jp/mpg/`). In this series of symposium, Prof. Ito invites foreign speakers who he finds at meetings abroad. I suspect that he intentionally does this, as a responsibility of a senior leader of the field in Japan, to keep introducing to Japan up-to-date research progress of the rest of the world, to stimulate younger generation, and hopefully, persuade them to go beyond.

Professor Izumi Ojima

The educational background and job situation for Prof. Ojima is very different from those for most of us. The way how I came to know the name is also very different from how I came to know Prof. Ito.

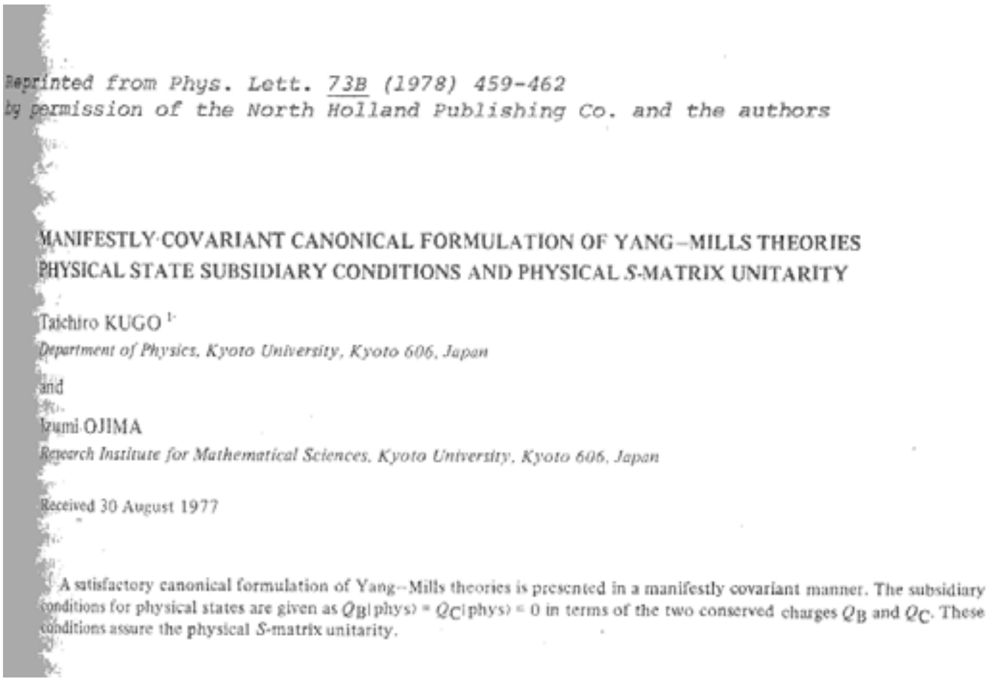


Prof. Ojima graduated Faculty of Medicine, Kyoto University, and has a doctor's licence. He however did not choose the field of medicine as his professional career.

Instead he went to Graduate school of Science, Kyoto University, and received his PhD in 1980.

Prof. Ojima won Nishina Prize in 1980 for a joint study with Prof. T. Kugo: 'Theory of covariant quantization of non-abelian gauge fields', which was accomplished in their graduate studies. I learned their name instantly as I became a graduate student in 1980. In the weekly seminar for graduate students, my thesis adviser chose, as a textbook for the seminar, a volume in the series of collected papers in physics, edited by the Physical Society of Japan.

Volume 70 of the 'new series' is devoted to the theory of gauge fields, and in the volume, a summary of Kugo and Ojima's results published in Physics Letters 73B is included.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MANIFESTLY COVARIANT CANONICAL FORMULATION OF YANG–MILLS THEORIES
PHYSICAL STATE SUBSIDIARY CONDITIONS AND PHYSICAL S-MATRIX UNITARITY

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and

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Received 30 August 1977

A satisfactory canonical formulation of Yang–Mills theories is presented in a manifestly covariant manner. The subsidiary conditions for physical states are given as $Q_B|\mathrm{phys}\rangle = Q_C|\mathrm{phys}\rangle = 0$ in terms of the two conserved charges Q_B and Q_C. These conditions assure the physical S-matrix unitarity.

Nishina Prize was then the only prize in physics society in Japan, so winning the prize meant being noticed by all the physicists at the time in Japan. It is no wonder that after being in a research position at Princeton IAS for a year, Prof. Ojima won a permanent position at RIMS in 1981, where he is now.

I hear that, nowadays, in the applications for job positions or for promotions especially in smaller universities, one has to compete with candidates from other fields of study of very wide range, and also has to explain one's academic accomplishments. Such a kind of social pressure resulted in creating more and more prizes in physics, with a reason that it makes it easier to explain to non-specialists. In contrast, in the good old days, Japanese physics society preferred to doubt authority, and moreover, kept the physics society itself from being an authority. I heard that it was from these basic idea that the Japanese physics society kept the number of prizes to minimum, in those days when Prof. Ojima won Nishina Prize.

The study of covariant quantization of non-abelian gauge fields, for which Prof. Kugo and Prof. Ojima won Nishina Prize, gives a clear algebraic structure of the reason why the physical states of non-abelian gauge theories, such as QCD, are positive metric, in spite of the fact that in the covariant formulations of the theories, negative metric states are inevitable. The problem was known as the unitarity problem of

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$$(P^{(n)})^2 = P^{(n)} = P^{(n)\dagger}\,, \tag{11}$$

$$P^{(n)}P^{(m)} = P^{(m)}P^{(n)} = \delta_{mn}P^{(n)}\,, \tag{12}$$

where $P^{(0)}$ is defined as the projection operator onto the Hilbert subspace $\mathcal{H}_{\mathrm{phys}}$ consisting solely of the physical particles. The eqs. (11) and (12) indicate the following *orthogonal* decomposition of the total space $\mathcal{V}$:

$$\mathcal{V} = \mathcal{H}_{\mathrm{phys}} \oplus \bigoplus_{n\geqslant 1} (P^{(n)}\mathcal{V})\,. \tag{13}$$

Next we turn into the most important problem, that is, the subsidiary conditions for selecting the physical state subspace $\mathcal{V}_{\mathrm{phys}}$. We impose two subsidiary conditions:

$$Q_{\mathrm{B}}|\mathrm{phys}\rangle = 0\,, \tag{14}$$

$$Q_{\mathrm{c}}|\mathrm{phys}\rangle = 0\,. \tag{15}$$

By the conservation of these charges, the second of the two physical state conditions (1) follows trivially: $\mathcal{V}^{\mathrm{in}}_{\mathrm{phys}} = \mathcal{V}^{\mathrm{out}}_{\mathrm{phys}}$. In what follows we only have to prove the first of conditions (1), the positive semi-definiteness of the metric in $\mathcal{V}_{\mathrm{phys}}$.

A rather lengthy proof using the GLZ formula [8] gives expressions for Q_{B} and Q_{c}:

$$Q_{\mathrm{B}} = \int \mathrm{d}^3x \,:B^{\mathrm{as}}\overleftrightarrow{\partial}_0 c^{\mathrm{as}}: = \mathrm{i}\sum_k (c_k^\dagger B_k - B_k^\dagger c_k)\,, \tag{16}$$

$$Q_{\mathrm{c}} = \int \mathrm{d}^3x \,:\bar{c}^{\mathrm{as}}\overleftrightarrow{\partial}_0 c^{\mathrm{as}}: = -\mathrm{i}\sum_k (c_k^\dagger \bar{c}_k + \bar{c}_k^\dagger c_k)\,, \tag{17}$$

in terms of the asymptotic (in or out) fields, where $Q_{\mathrm{B}} = \tilde{Z}_3^{1/2} Z_{\mathrm{B}}^{-1/2} Q_{\mathrm{B}}^0$. The assumption of asymptotic completeness and the WT identities as results of symmetries generated by Q_{B} and Q_{c}, are the essential ingredients to prove eqs. (16) and (17). Eqs. (16) and (9) say

$$[Q_{\mathrm{B}}, P^{(0)}] = 0\,, \tag{18}$$

$$Q_{\mathrm{B}}^2 = 0\,, \tag{19}$$

$$\begin{aligned} &[Q_{\mathrm{B}}, B_k] = \{Q_{\mathrm{B}}, c_k\} = 0\,,\\ &[Q_{\mathrm{B}}, \chi_k] = -\mathrm{i}c_k\,, \quad \{Q_{\mathrm{B}}, \bar{c}_k\} = \mathrm{i}B_k\,, \end{aligned} \tag{20}$$

and their hermitian conjugates. The physical subspace $\mathcal{V}_{\mathrm{phys}}$, including the Hilbert subspace $\mathcal{H}_{\mathrm{phys}}$ by eq. (18), is orthogonally decomposed corresponding to eq. (13) as

$$\mathcal{V}_{\mathrm{phys}} = \mathcal{H}_{\mathrm{phys}} \oplus \mathcal{V}_0\,, \quad \mathcal{V}_0 \equiv \bigoplus_{n\geqslant 1} (\mathcal{V}_{\mathrm{phys}} \cap P^{(n)}\mathcal{V})\,. \tag{21}$$

Therefore, the positive semi-definiteness of metric in $\mathcal{V}_{\mathrm{phys}}$ can be shown by proving the zero-norm property of $\mathcal{V}_0$. This is proved by using only the subsidiary condition (14). Noting eq. (18), it is an easy task to show inductively

$$[Q_{\mathrm{B}}, P^{(n)}] = 0\,, \quad n = 0, 1, 2, \ldots, \tag{22}$$

by the help of eqs. (10) and (20). Next, let $|f_m\rangle$ and $|g_n\rangle$ be arbitrary states containing m and n unphysical particles, respectively, and satisfying the subsidiary condition (14): $Q_{\mathrm{B}}|f_m\rangle = Q_{\mathrm{B}}|g_n\rangle = 0$. Then, by using this and eq.(20),

$$\begin{aligned} \langle f_m|g_n\rangle &= \langle f_m|P^{(n)}|g_n\rangle \\ &= (1/n)\sum_k \langle f_m|-\mathrm{i}\bar{c}_k^\dagger[Q_{\mathrm{B}}, P^{(n-1)}]\chi_k \\ &\quad -\mathrm{i}\chi_k^\dagger[Q_{\mathrm{B}}, P^{(n-1)}]\bar{c}_k|g_n\rangle \\ &\quad -(1/n)\sum_k \langle f_m|\bar{c}_k^\dagger Q_{\mathrm{B}} P^{(n-1)} Q_{\mathrm{B}}\bar{c}_k|g_n\rangle\,. \end{aligned} \tag{23}$$

The first two terms of eq. (23) vanish by eq. (22). The second term also vanishes by eqs. (22) and (19). Thus we have proved $\langle f_m|g_n\rangle = 0$ for $n \geqslant 1$. This completes the proof of the zero-norm property of $\mathcal{V}_0$, and therefore of the physical S-matrix unitarity:

$$S^\dagger_{\mathrm{phys}} S_{\mathrm{phys}} = S_{\mathrm{phys}} S^\dagger_{\mathrm{phys}} = P^{(0)}\,, \tag{24}$$

where $S_{\mathrm{phys}} \equiv \mathcal{P}^\dagger S \mathcal{P}$ and $\mathcal{P}$ is a projection operator onto $\mathcal{V}_{\mathrm{phys}}$.

Finally we add two comments. (i) If we had adopted the usual hermitian conjugation assignment $\bar{c} = c^\dagger$, we would have failed in proving the zero-norm property of $\mathcal{V}_0$ for lack of the relation $\langle f_m|Q_{\mathrm{B}} = \langle g_n|Q_{\mathrm{B}} = 0$, because we would not have $Q_{\mathrm{B}}^\dagger \propto Q_{\mathrm{B}}$ in the usual assignment [6,9]. In fact this can be seen in a more concrete example. For usual ghosts, denoted by the capital letters C, $\bar{C}$ for distinction, we would have (symbolically)

$$\begin{aligned} &C(x) \sim C_k + \bar{C}_k^\dagger\,, \quad \bar{C}(x) \sim \bar{C}_k + C_k^\dagger\,,\\ &\{\bar{C}_k, \bar{C}_l^\dagger\} = -\{C_k, C_l^\dagger\} = \delta_{kl}\,,\\ &Q_{\mathrm{B}} = \mathrm{i}\sum_k (\bar{C}_k^\dagger B_k - B_k^\dagger C_k)\,, \end{aligned} \tag{25}$$

non-abelian gauge theories and is also related to the (perturbative) renormalizability of the theories. The unitarity problem was first solved by t'Hooft and Veltman using perturbation theories, and the Kugo–Ojima theory gives an algebraic interpretation of why the diagrammatic cancellation worked in t'Hooft–Veltman results: A graded Lie algebra structure of the field operators, now known as the BRST-symmetry, implies the consistency of the restriction to the positive metric states, namely, the consistency of the Kugo-Ojima physical state condition. A page in Kugo and Ojima's Physic Letters paper shows all these theoretical structure in a compact and clear way, just like what one would see in the present day textbooks, which shows the perfectness of Kugo-Ojima theory well ahead of time. The theory is also described in full detail and in an utmost clarity in T. Kugo, I. Ojima, *Local Covariant Operator Formalism of Non-Abelian Gauge Theories and Quark Confinement Problem,* Progress of Theoretical Physics Supplement **66** (1979) 1–130. The name BRST-symmetry is due to an independent work published a year earlier than Kugo and Ojima Physics Letters paper. But the full algebraic theory, including the definition of physical states using the BRST-charge, the Kugo-Ojima condition, and the mechanism that the symmetry implies the consistency of the condition, is the discovery of Kugo and Ojima.

After the accomplishment of his graduate study, Prof. Ojima gradually moved to philosophically deeper problems of mathematical and information theoretical foundation of quantum physics through thermodynamic and statistical physics. Symmetry breaking and micro-macro duality are among the key words of his study. These key words suggest me that Prof. Ojima is trying to give an answer to a question: 'What is the mathematical structure in quantum physics which intellectually attracts people (in particular, its relation with classical physics)?'

Quantum phenomena are very different from macroscopic phenomena explained by classical physics. For example, it is well-known that Albert Einstein, who played a leading role in the construction of quantum physics, could not accept probabilistic interpretation of quantum fields. A classical phenomena, on the other hand, is theoretically a many body problem of the quantum physics, so at least theoretically it is a logical consequence of quantum physics. All these thoughts enchant people. It seems to me that Prof. Ojima is trying to find out precisely which aspect of the mathematical (or intellectual, if 'mathematics' is too restrictive a word) structure in quantum physics attracts people. We say that a theory explains a reality only if we are convinced that the theory reflects some essential aspect of the reality, and we cannot be convinced by an unattractive theory. Therefore a theoretical essence must be at the part where people are intellectually attracted most. That is perhaps what Prof. Ojima is now trying to find out.

Professor Ito and Professor Ojima

I have been a lazy student all my life, trying to learn neither in depth nor in width. I still have lot to learn both from Prof. Ito and Prof. Ojima. But I think I unconsciously learned one common lesson from the two professors: Be absolutely sincere to one's own scientific interest, and be proud enough to stick to unpopular field of research.

The two professors perhaps are examples from good old days when there were people who studied what they thought are important, in spite of (perhaps) authorities' warning that they are wasting their academic talent and career. A new direction, invention or discovery, means important and not standard. We always need a new direction to push forward our intellectual frontier. I hope we continue to have a few, non-zero good young people in the future, following the examples of Prof. Ito and Prof. Ojima, who would stick to their own scientific interest, to surprise the scientific community with new ideas, and eventually persuade the community to move on to new research directions.

A happy 60th birthday to Professor Ito and Professor Ojima!