Descriptions of "Conceivable Governance" by Analogy with Physics:
Innovating a Paradigm of "Quantum Urban Governance" in Response to "Parallel Habitats"

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Contents

１．Introduction

According to an overview of the International Organization for Migration（IOM）, the number of people now living outside their birth-countries exceeds 200 million persons worldwide; thus, international migrants would compose the fifth most populous country in the world after China, India, the United States, and Indonesia. Moreover, in 2007, their remittances had already reached USD 337 billion, of which USD 251 billion flowed to developing countries（IOM, Global Estimates and Trends）.

For the sake of argument on future "development" and "urban" issues, especially in light of migratory movements, Tanimura（2005, 66–67; 2006, 276）discussed the importance of widening the scope further to the multilayered high mobility at national, urban-regional, and peripheral levels. Tanimura, on the basis of research projects at the Rector's Office, United Nations University（UNU）, and other academic institutions, also discussed the importance of considering that an increasingly mobile society does not come to simply multiply flows but to encompass "Parallel Habitats（synchronously 'inhabiting' *plural* territorial/non-territorial spaces that are arranged in parallel and shuttled back and forth between them so as to ensure adequate solutions）." Besides, logically, "there is an urgent need…to preliminarily explore an alternative 'urban governance' that is of a substantially different dimension from what conventional actors（including international organizations）have promoted on such assumption as 'sedentary society（fixing down to the domicile selected as only one most optimum solution）' and 'nation-state（a form of communities made up by inhabitants）' building. Furthermore, it is essential to work out new visions from the alternative standpoint," which Tanimura raised（2006, 275）.

In particular, "Beyond UN-Habitat's Classic Framework in Urban Development Strategies"（Tanimura 2006）looked into some concrete cases of "Parallel Habitats." In addition, as an innovative idea of governance in response to the *superposed* "living" states, it tentatively proposed

"Quantum Urban Governance," which was inspired by the "Many-Worlds Interpretation" of quantum mechanics. The new perspective was contrasted with "Governance in Solidity" and "Governance in Fluidity," which took a cue from a discussion of Tae-chang Kim et al. (2004), as follows.

［1］"Governance in Solidity" is grounded on such building blocks of modern nation-states as conventional communities and local/national governments that have territorially been woven by "sedentary" inhabitants. This perspective could also be shared by international organizations and global entrepreneurs attempting to reinforce/strengthen the territory-based logic. In consequence, migrants are treated within the framework of newly coming "permanent" residents, and for the sake of each individual, there is only one "most optimum" solution.

［2］"Governance in Fluidity" is a dynamic view of the peripatetic side as local communities are shaped from networked relationships of plural societies, including the idea of "transnationalism" woven by those globally mobile people that are "commuting" from permanent residents selected as the only one "most optimum" solution and those migratory population groups that are seeking to attain such a new "sedentary" home, considerably far beyond the static view of the above-mentioned "solidity."

［3］"Quantum Urban Governance" is an alternative viewpoint to the conventional fabric so as to more precisely figure out the real world—"uncertainty" and probabilistic "waves" (the individuals on the move) of human settlements implied by the concept of "Parallel Habitats"—by applying the "Many-Worlds Interpretation" in quantum physics [(mechanics)], far beyond the Newtonian paradigm for managing the aforementioned fictional "sedentary" society with approximate expressions (Tanimura 2006, 295).

For the international community, a critical challenge has been to effectively formulate schemes and policies of what is called "Globalization/Urbanization for All." Above all, there will soon be a grave need to devise "governance," which would be a foundation for that type of untiring dialogue and a piece of policy agenda, more flexibly. In view of the circumstances, this paper ventures away from conventional governance theories and, on the basis of the above thoughts as a clue, aims at building a theoretical framework of "conceivable governance," particularly in response to "Parallel Habitats," in paraphrase of discourses in physics much further. Naturally, through future phases of detailed study, those tentative concepts that are derivable from the analogy should be fearlessly edited and refined in light of the latest realities and theories, and such changes obviously would not be limited to cosmetic modifications.

This paper, which is based primarily on a literature review of contemporary physics (including quantum mechanics), begins by looking over respective paradigms of "classical physics" in the 17th century and "quantum physics" in the 20th century, when revolutionary worldviews had putatively emerged in the history of physics. Subsequent sections touch upon "weird" descriptions at the heart of quantum mechanics—the Schrödinger equation, Born's probabilistic interpretation, and Heisenberg's uncertainty relationship—and focus on discussions of so-called "interpretational problems of quantum mechanics"—Hugh Everett's "Many-Worlds Interpretation," which, among others, has attracted attention in recent years, in addition to the Bohr-led "Copenhagen Interpretation." On the basis of suggestive thoughts in classical and quantum physics, the last section compiles descriptions of "conceivable governance" by analogy—"Newtonian Urban Governance," which could be unquestionable for "sedentary inhabitants," and "Quantum Urban Governance" (Stochastic Interpretation and Many-"Habitats" Interpretation of "living" states), which must be seen as an extravagant notion for "sedentary inhabitants." At this point in the paper, definitions of "Parallel Habitats" and "Quantum Urban Governance" referred to above are altered slightly. Toward working out the theoretical framework of "Quantum Urban Governance," the very end of this paper summarizes future challenges.

2. Revolutionary Worldviews in the History of Physics

2-1. Classical Physics' Worldview that Began with Newton

In the history of physics, the 17th century is described as the era of scientific revolutions (Iyama 2000, 26). The Cartesian "mechanical view of the world," a thought that the whole universe is seen as ingenuities and ought to be governed by fundamental laws and rules—which differs substantially from the conventional ideas of Plato and Aristotle—was proven beyond a doubt by Isaac Newton's *The Principia* (*Philosophiae Naturalis Principia Mathematica*) in 1687. Over the ages, including until the edge of the 20th century, the dominant worldview had been the perspective and framework of mulling over things (Lindley 1996, 1; Wada 1997, 35; Laughlin 2005, 23-24). The work of physicists had been said to add "another cog" by elaborately probing causality, with the purpose of precisely depicting the clockwork universe (Lindley 1996, 1).

When formulating an original mechanics, Newton had postulated the outer frame of fixed "absolute space" and uniformly flowing "absolute time" (Uchii 2007, 155). Soushichi Uchii (2007, 155-156), a philosopher of science who looked into the latest move in cosmology from the perspective of a conceptual clash between "expansile lines" and "austerity lines,"[1] found a similar collision of postures in history. Uchii sees Newton's approach with the premise of the "outer frame (background)" as a type of "expansile lines." He then attempts to look on Gottfried W. Leibniz's methods as opposite "austerity lines," primarily asserting that in a modern sense, the postulated outer frame (background) of absolute space and time is not appropriate to construct scientific theories, especially the ultimate ones, because the Newtonian way brings in unnecessary qualities not inhering in things of the world. Likewise, Colin Bruce (2004, 113), who has worked at the cutting-edge of research in quantum mechanics at Oxford University, alerts us to the situation that "the deceptively friendly Newtonian picture [of 'three fixed dimensions of space, and one of time'] actually robs us of something beyond price."

In addition, with regard to Newton's view of deliberating a change in natural phenomena, Takuji Tsuduki (2002, 143-144), well-known as an author of Blue Backs—popular science pocketbooks in Japan—and the like, described Newton's stance in the nature of a "spectator," as follows. [Tentative translation by Tanimura]

> .... Relationships between the measurer of *I* and the measured objects of the natural world were entirely left untouched. In other words, Newton looked squarely at the large *crucible* of nature from the outside. He treated all events in nature as phenomena on the other side of the river, and kept a close eye on it from this side of the river. It had *nothing to do with* the measurer, if there were any form of conflict in the melting pot, or any bustling circumstances on the opposite side of the river.
>
> A stance that completely turns down words such as *involvement* and *interaction* between the opposite shore (natural phenomena) and I (measurer).... This would be Newton's standpoint. [Emphases in original]

With reference to the above-mentioned Newton's viewpoint, Kaoru Takeuchi (2004, 98), a science writer, also ably depicted the relationship as the simple framework of "looking at a fixed stage from a fixed seat."

The Newtonian ideas of "absolute space" and "absolute time" concurrently had a theological meaning, and then, in the late 19th century, Ernst Mach's epistemology set up a viewpoint that absolute objectivity is nonsense and a configuration of knowledge per se is constrained by respective social forms in stages of development, which together with Marxism, attracted the radical's interest. In the midst of building up the idea that social reform triggered restructuring of knowledge, young Albert Einstein conducted his own research (Murakami 1998, 119-122, 127). David Lindley (2007, 5-6), a science writer who has been an editor at *Nature* and *Science*, touched the heart of the eminent theoretical physicist's intellectual endeavors as follows.

> .... In...1905, with his theory of relativity, [Einstein] had overthrown the old Newtonian idea of absolute space and time. ....
>
> But..., to Einstein, ... Relativity, to be sure, allowed for differing perspectives, but the whole point of his theory was that it allowed apparently contradictory observations to be reconciled in a way that all observers could accept.

Takuji Tsuduki (2002, 144-145), as referred to above, depicted Newton's stance as a "spectator" and determined that the basis of Newton's thought has not changed even with the advent of relativity, though Newtonian mechanics was modified to a certain degree. From the perspective of classical physics, more properly, its fundamental idea that the action of measurement produces no change in an object, he went straight to the point: the "theory of relativity is nothing more or less than classical physics."

2-2. Quantum Physics' Worldview that Highlights Even Particularity of Human Beings

What led the 20th century to a "Century of Physics" (Sato 1999) were the new discipline of "quantum physics"—nowadays in contrast with "classical physics"—and Einstein's theory of relativity (Tsuduki 1994, 16-17). Although the popular image of "Physics = Einstein = Relativity" has been persistent, Fumitaka Sato (1999, 71), a leading figure in the academic community, dispassionately described quantum mechanics, rather than relativity, as the star of 20th-century physics. Quantum mechanics mathematically unlocked the microworld, a result that has been widely used in many fields in contemporary society, such as nanotechnology; materials, electronic, and optical engineering; communications and computers; linear motors and nuclear energy; and explorations of nature from the root of matter to the origin of the universe (Sato 2005, 42).

Classic physics' causality, conventionally considering changes in nature as predictable, was substantially shaken by the advent of quantum mechanics, where "changes in nature are not continuous but probabilistic" (Machida 1994, 19). For comparison, Shigeru Machida (1994, 20), a specialist in elementary particle theory and the author of *Ryoshi-rikigaku no Hanran* [Backlash from Quantum Mechanics], indicated that the interesting phenomena of "chaos" spotlighted in recent years is fundamentally different from quantum mechanics' perception for nature, as follows. [Tentative translation]

> .... Chaos could be observed in every natural event.... However, because a natural phenomenon is engendered by complexly intertwined numerous elements, and an imperceptible change of a single element would have a profound influence on itself, the jargon merely indicates the impossibility of calculations in real life. On the condition that all the possible effects in the universe are considered, chaos theory must be able to make a prediction. In sum, this is not to say that chaos extends beyond classical physics' framework.

Transition from Newtonian mechanics to quantum mechanics is apt to give one the feeling that all of the conventional things were denied and everything new emerged. Hence, this transition could be hastily perceived as a paradigm change. However, Sumio Wada (1997, 38, 44), well-known as the author of quantum mechanics' worldviews and interpretational problems, articulated the thought that the transition should be seen as "paradigm deepening" rather than a so-called "paradigm shift"—albeit, the two are unquestionably different paradigms—as follows. [Tentative translation]

.... As long as treating macroscale objects, the truthfulness of Newtonian mechanics...is not at risk of being eroded even in the 20th century. Obviously, Newtonian mechanics still has been used publicly in the realm of not dealing with microscale objects as small as an atom.

.... It would be an accurate standpoint that the transition has not implied anything negative to the previous paradigm, but urged a need for reconsidering its meaning in more depth, and then revealed its limitations; in other words, the conventional paradigm was encompassed by a more comprehensive paradigm. As a result of the revolutionary view of nature in the 20th century, the old outlook on nature has just been deepened.

Kaoru Takeuchi (2001, 12), in his introductory book on quantum mechanics, said right from the start that the world could precisely be described by quantum mechanics, but there is no harm in regarding the approximate calculation as Newtonian or classical mechanics, when applicable.[2]

As for Mitteleuropa (Central Europe), where a skeleton of quantum mechanics had been made up in the 1920 s, coinciding with Germany's Weimar Republic (1918-1933) after it lost the First World War, Shigeru Machida (1994, 192-194) remarked that faith in deterministic causality must be daunted by the difficulties of a situation where the young were in anxiety, mad haste, and disappointment, and were going to work out their own guidelines without relying on the classical manner of thinking anymore. Likewise, Fumitaka Sato (1999, 81-82) indicated that the circumstances of the Weimar Republic nurtured an unstable but experimental and open atmosphere; there was a significantly growing trend among young researchers to defy the conventional views of naive reality, understandability, and causality prevailing in physicists.[3]

In a word, physics in the 20th century was sometimes talked about in terms of devotion to exploring "way of looking at things" rather than "things" per se (Sato 1999, 14).

Views raised by Géza Szamosi (1986, 130), the author of *The Twin Dimensions*, are sensational among others. With regard to classical mechanics' "mechanical universe," a cliché used by historians of science, the theoretical physicist ventured a remark that "[f]rom an evolutionary perspective, ...one could just as well call it a mammalian cosmology with a human face—a recreation of the built-in perceptual cosmology of the human brain within a mathematical framework," and then he stated:

When classical physics broke with the mythological and culturally determined worldviews of all prescientific and traditional societies, this was a radical enough enterprise. Twentieth-century physics, however, turned out to be far more audacious. Not only did it question the validity of earlier human ideas, [but also] challenged...the mammalian cosmology itself (145).

In the section of "More than One Picture of the World" within a chapter of fragmentary thoughts on quantum mechanics, Fumitaka Sato (1997, 104), who challenged *Ryoshi-rikigaku no Ideology* [Ideology of Quantum Mechanics], described the crux of quantum expression as the fact that a world portrayed in classical mechanics falls short of perfection, and, at the same time, a world depicted in quantum mechanics is not the entire picture of the world either. Likewise, in a later chapter on the formation of spacetime, he concluded, as follows. [Tentative translation] "In other words, we were always shown a special case in advance, and have continuously been taken in as though it had been the general, or rather, we have deceived ourselves" (261-262). In the subsequent book, *Butsurigaku no Seiki* [Century of Physics] (1999, 164), Sato also raised a question that if a set of self-righteous beliefs is an ideology, we are still wondering at quantum mechanics from the perspective of classical physics' ideology—if such preconceived ideas are required for intuitive understanding, we should ponder what an ideology of quantum mechanics is—and indicated that this mulling would highlight the peculiarities of human thought patterns.

3. "Weird" Descriptions in Quantum Mechanics

3-1. Imaginary in an Equation

Construction of quantum mechanics was undertaken from two different routes, namely, Werner Heisenberg's matrix mechanics and Erwin Schrödinger's wave mechanics (Machida 1994, 5). In a reprinted edition, *Heisenberg*, reviewing the physical revolution in the 20th century, Yoichiro Murakami (1998, 199-200), a prominent historian and furthermore philosopher of science, referred to Max Jammer (1966, 271-272), *The Conceptual Development of Quantum Mechanics* (*Ryoshi-rikigaku-shi* [History of Quantum Mechanics] *I* and *II*, the Japanese edition translated by Shoichiro Koide, Tokyo Tosho), as an outstanding description of contrasting those opposite approaches. The following paragraph is an excerpt of the key portion.[4]

> .... Heisenberg's [matrix mechanics]...defied any pictorial interpretation; it was an *algebraic* approach, which...emphasized the element of *discontinuity*; ...it was ultimately a theory whose basic conception was the *corpuscle*. Schrödinger's [wave mechanics], in contrast, was based on the familiar apparatus of differential equations...; it was an *analytical* approach, which...stressed the element of *continuity*; ...it was a theory whose basic conception was the *wave*. [Emphases in original]

Not long after, Schrödinger recognized that matrix mechanics and wave mechanics are mathematically equivalent. Many physicists applauded wave mechanics using their favorite differential equations (Machida 1994, 70). However, as this way has to deal with complex numbers (imaginary numbers in addition to real numbers), a question of growing concern was inevitably how to comprehend the implications. In Chapter 3 "Conspicuous World and Inconspicuous World," Shigeru Machida (1994, 56) discussed the problem as follows. [Tentative translation]

…. From the viewpoint of classical physics, there is only a phenomenal world represented as real numbers. …. Viewed from quantum mechanics, although there must be two different worlds—dual structure—in nature, classical physics is a theoretical framework merely looking at the conspicuous world, and failing to recognize the existence of the inconspicuous world far broader than the discernible counterpart.

…. Any terminology that human beings have ever constructed and fully utilized is entirely for representing the phenomenal realm, namely, the conspicuous world. To the contrary, in the realm of wave functions, or the inconspicuous world, it is still obscure what terms could be ready for use. For the time being, we have no choice but to grope to the behind-the-scenes world with conventional jargons. ….

Furthermore, Shigeru Machida (1994, 64-65) talked about the dual structure with an example of Plato's "The Allegory of the Cave." [Tentative translation]

Quantum mechanics' worldview might be comparable to Plato's Cave. A difference is that while people in the cave were merely passively shown shadowgraphs and forbidden from turning right around, modern people have obtained the tools for directly working on the behind-the-scenes and can cast a variety of shadows onto a wall in front, through knowing a mechanism—quantum mechanics—governing the rear world.

Meanwhile, Fumitaka Sato (1997, 61) tried to take a deeper perspective, as follows. [Tentative translation] "Then, why should we feel provocation, embarrassment, and adoration for setting into the imaginary? These feelings would intrinsically be based on the presupposition that there is no wonder as long as we stay within the domain of the real number. However, there is a need for looking into whether that is so true."

3-2. "Probabilistic Interpretation (Rules of Quantum Probability[5])"

Although Schrödinger tried to explain the microscopic world entirely in terms of a "wave," Max Born accepted an electron's dual nature, at once "particle" and "wave," and offered the amazing alternative perspective of "waves of probability" in lieu of "matter waves" as envisioned by Schrödinger (Sato 2001, 138-149; Bruce 2004, 58-59). Born's "probabilistic interpretation," which is nowadays confirmed by numerous experiments, is that in the case of measuring an electron's position, the probability that an electron will be found at a position is proportionate to the square of the absolute value of the amplitude of the electron wave (calculated from the Schrödinger equation) at the position (Wada 1997, 109-110, 118).

Now, as for the "probability," a brief description setting it out as an electron's "odds of existence" is still found in some introductory books. However, this idea has already been thrown out (Wada 2007, 330). Sumio Wada (1997, 111) raised caution about getting the meaning wrong, as follows. [Tentative translation]

> .... Probabilistic interpretation focuses on the probability that a particle will be found in a position at the point of measurement. We have to prevent it from being misconstrued as taking a look at the probability that "a particle will be present in a position." Simply, the upshot is looking at what happens to a particle at the point of measurement. The question at stake is not the probability of a particle's existence but the probability of finding a particle. ....
>
> A particle is present not in a given place but in places (in general, innumerable places) "at one time." It is not to say that a particle was actually more than one particle. A state in which a particle resides in one position, another state in which a particle has a different position, and the like...plural (by and large, infinite) states exist together.

With regard to this "superposition of probability waves" in the world of complex numbers, Kaoru Takeuchi (2004, 72-74) attempted to figuratively illustrate the configuration of a superposed quantum system, so to speak, as a state in which an electron is located in Tokyo and Osaka at the same time, and based on a mechanism wherein only probabilistic estimation is allowed for where the electron will be found; when measured by a detector, the superposition in the world of complex number disappears, and a state in the world of real number is fixed.

3-3. "Uncertainty Relationship"[6]

Another feature of quantum mechanics felt as weirdness is Heisenberg's "uncertainty relationship." Through the well-known thought experiment of measuring an electron by a gamma-ray microscope, it was indicated that an observer cannot identify the electron's position and momentum simultaneously—the more he/she tries to accurately measure any one of the two, the more uncertainty the other faces (Machida 1994, 69; Sato 1997, 32-33). David Lindley, in his recent publication, *Uncertainty: Einstein, Heisenberg, Bohr, and the Struggle for the Soul of Science* (2007, 2), discussed the physical revolution as follows: Although "uncertainty" had "always seemed a vanquishable foe," "[w]hat [Heisenberg] changed, and profoundly so, was its very nature and meaning."

With regard to this uncertainty relationship, Shigeru Machida (1994, 76, 79) described Heisenberg's approach as "extremely heuristic," "largely inappropriate at this moment," and suffering a "lack of universality," though showing his utmost respect for the great figure's achievements. Subsequently, he proceeded to the current knowledge that quantum mechanics can derive an uncertainty relationship from not only the old case between an electron's position and momentum but also from instances between two physical quantities in any complex object.

Likewise, Fumitaka Sato (1997, 32–33), who indicated the mix-up over an "uncertain part" of the uncertainty relationship back in those days, plainly reviewed the essential points in terms of measurement in the section of "Disturbance Caused by Intervention ?" [Tentative translation]

> …. In the…microscope-based thought experiments…, an observer has to shed light on a particle in order to measure its position. Shedding light means affecting the object to be measured. In other words, measurement inevitably sets off the observer's intervention in the object, resulting in no spectatorial measurement without intervention. …. As for an object in the microworld, the intervention causes a significant disturbance. This is a way to convince oneself.
>
> However, as the discussion progressed, it became clear that this understanding was not necessarily correct. Instead, the view was gaining ground that uncertainty must be attributed to the intention in itself of embracing a perception, in accordance with the determination of an object's state. In other words, although the object's state can be described by the wave function (or the "state vector" because wave is not necessarily exact), it is a superposition of the alternative states with respective positions and momenta. But measurement means fixing (picking) values. By arranging states of the same wave function and measuring them many times, an observer obtains various values each time. Dispersion of the data (their fluctuation range and frequency distribution) fulfills an uncertainty relationship.

Ideas on how to work out this puzzle, "a fixed state with a measured value is come out by the disturbance of measurement, which affects the wave function" (33), are finally in the area of "interpretational problems" of quantum mechanics.

In the subsequent section, among other thoughts, I will, together with the mainstream so-called Copenhagen Interpretation, direct a spotlight on an alternative perspective, the Many-Worlds Interpretation, which has tried to resolve the mainstream's contradiction with a bold mindset.

4. From "Interpretational Problems" of Quantum Mechanics

4-1. Copenhagen Interpretation

Quantum mechanics is a full-fledged theoretical system with no rough edges. Unquestionably, the physics is widely being utilized without any problem. Nevertheless, it is said that "nobody" knows exactly what this theoretical system describes. Even now it is controversial how we should “interpret” the “incomprehensible” points (Sato 1997, 14). It has often been said that going on the mainstream career path in physics means devoting yourself to becoming a “professional user” who does not explore fundamental implications (Sato 2007, 56)

This academic policy, recommending the idea of “habituating before deeply thinking,” primarily stemmed from a “containment strategy” worked out by Niels Bohr and his colleagues, who struggled to protect “still toddling” quantum mechanics from “reactionary” Einstein armed with a string of fundamental questions. Copenhagen-based Bohr tentatively set up “standard” interpretative instructions on quantum mechanics dubbed the Copenhagen Interpretation, that is, “interpretation of the theory” beyond the theory. He has been valued as a leading figure who effectively prevented younger researchers from being fascinated with superfluous puzzles and taking the wrong path (Machida 1994, 82, 87, 132; Sato 2005, 43; 2007, 58).

But it was reported that in reality, the Bohr camp internally had a wide range of opinions (Tsuduki 2002, 223; Lindley 2007, 156). In a situation where there is no explicit consensus concerning what the Copenhagen Interpretation is, Colin Bruce (2004, 63) indicated “the lowest common denominator.”

[1] The only real things are the results of experiments as measured by conscious, macroscopic observers; there is no deeper underlying reality.

[2] Experiments yield results consistent with either wavelike behavior or particle-like behavior, depending on the design of the experiment, but never both at the same time.

Taking the motion of an electron, for example, the positivism of the Copenhagen Interpretation does not consider the reality of unverifiable in-between routes. The motion is accounted for in terms of “only questioning what can stringently be verified” (Takeuchi 2004, 84–86, 92). In addition, it was Bohr’s “complementarity” that on the occasion of describing an observed object, the ideas of wave and particle were not contradictory but complementary—if an observer tries to measure a characteristic of a particle, he/she loses an opportunity to see a wave nature, and vice versa (Machida 1994, 132–33).

Now, in relation to the previous discussion in 3-3. on “Uncertainty Relationship,” the phenomenon that “a fixed state with a measured value is come out by the disturbance of measurement, which affects the wave function” has been called a “collapse of the wave function” in the Bohr-led Copenhagen Interpretation. Meanwhile, the process of this collapse cannot be described by the Schrödinger equation (Sato 1997, 33, 163). In other words, the collapse implies that at the moment of measurement, “coexistent states”—a superposed state of an electron that is positioned, for example, at point A as well as point B—disappear in a flash, and then only one state is left behind. That is to say, at the instant of measuring the electron’s position, the wave packet suddenly collapses, which has nothing to do with the Schrödinger equation, and the electron’s wave instantly concentrates on a single point (as a particle) (Wada 1998, 60–61, 66–67).

This is a mindset of a juggling act to fit the facts, applying technical terms of quantum mechanics to the microworld and those of classical mechanics to measured results, respectively (Wada 2007, 330-331). Shigeru Machida (1994, 147) also indicated that Bohr's key concepts, seemingly "innovative," were actually "patchworks of quantum mechanics and classical physics," and he contrasted Bohr with Einstein, an antagonist in theoretical debates over quantum mechanics. [Tentative translation]

> Although Einstein aimed at developing a totally new theory far beyond viewpoints in quantum mechanics..., Bohr tentatively preserved ideas in classical physics and limited himself to raising the reservation of complementarity in the context of newborn quantum mechanics. With regard to the development of quantum mechanics, ... Bohr and Einstein are largely positioned as representatives of progressive and conservative, respectively. In reality, however, in terms of their attitudes toward fundamental conceptions grasping the essence of nature, it was Bohr that belonged to the conservative wing (88-89).[7]

Based on a work for a conference in Oxford, Colin Bruce (2004, 63-66), who sided with this view—Bohr was a "cautious agnostic"—discussed the positivism and the complementarity of the Copenhagen Interpretation, as stated below.

> .... [U]ntil the Copenhagen interpretation came along, the whole *point* of doing experiments was to formulate a picture of an underlying reality. Why, exactly, are we being forbidden to speculate further in this instance ? Surely the idea that there are questions that must not be asked is contrary to the whole spirit of scientific endeavor. .... [Emphasis in original]
>
> Nowadays, we can do experiments involving behavior that is intermediate between particle-like and wavelike. We are beginning to understand a process called decoherence [loss of interference caused by interaction with the environment], which is arguably the real mechanism of quantum collapse [the wave packet collapse] and is in some ways quite analogous to turbulence. .... Agnosticism is perhaps an intellectually respectable position, but it does not lead to progress. Bohr had not so much an interpretation of quantum mechanics as an absence of one.

In any event, it was also underscored that "the conscious-observer-collapse hypothesis," namely, "the idea of a conscious observer with a mysterious power to collapse systems by looking at them," is superfluous (Bruce 2004, 68-69).

4-2. Many-Worlds Interpretation

In the mid-1950s, an extravagantly unique view for unlocking quantum mechanics was raised by Hugh Everett III, who was a Princeton University graduate student at that time. In 2007, fifty years after his article on the idea of Many-Worlds was printed in *Reviews of Modern Physics*, *Nature* (July 5, 2007), put the groundbreaker's interpretation on the front cover (Byrne 2007, 79)—it could be speculated that the science journal attempted to show its "sensibility for enterprise" (Sato 2007, 59–60).

Peter Byrne, an investigative journalist and science writer, aptly illustrated the gist of the Many-Worlds Interpretation in his article, "The Many Worlds of Hugh Everett" (2007, 74–75), as follows.

> .... [Everett] made the observer an integral part of the system observed, introducing a universal wave function that links observers and objects as parts of a single quantum system. He described the macroscopic world quantum mechanically and thought of large objects as existing in quantum superpositions as well. ....
>
> Consider a person measuring a particle that is in a superposition of two states, such as an electron in a superposition of location A and location B. In one branch, the person perceives that the electron is at A. In a nearly identical branch, a copy of the person perceives that the same electron is at B. Each copy of the person perceives herself or himself as being one of a kind and sees chance as cooking up one reality from a menu of physical possibilities, even though, in the full reality, every alternative on the menu happens.

The Copenhagenists expressed the feeling of "discomfort" over Everett's views at that time. This innovative researcher had argued hard against the criticism that "[t]he Copenhagen Interpretation is hopelessly incomplete because of its a priori reliance on classical physics…as well as philosophic monstrosity with a 'reality' concept for the macroscopic world and denial of the same for the microcosm." However, as early as the end of the 1950s, he left the arena of quantum physics in frustration. Byrne elaborately traced the entire story (76–77).

As for the differences between the Everett-minted Many-Worlds Interpretation and the Copenhagen Interpretation, Table 1 summarizes the key points based on Sumio Wada's excellent introductory books on the Many-Worlds Interpretation in quantum mechanics (1994, 1997, 1998, 2002).

Now, with regard to these interpretations, Sumio Wada (2002, 13–14) indicated that from the viewpoint of Ockham's razor (a principle that asks for a much simpler explanation without bringing in unverifiable assumptions), because the existence of many worlds introduced into the Many-Worlds Interpretation is unverifiable and undeniable in principle, it would be a commonplace to say that the introduction of the "unnecessary object" should be excluded from the discussions. The physicist also indicated that on the contrary, supporters of the Many-Worlds Interpretation would assert that the existence of many worlds is an inevitable conclusion, once quantum

Table 1　Major Differences between Copenhagen Interpretation and Many-Worlds Interpretation

	Copenhagen Interpretation	Many-Worlds Interpretation
Epistemologically, the viewpoint is…	positivism. probabilistic logic.	realism. determinism in accordance with the uncertainty relationship.*1
Coexistence states are…	not real but fictional for convenience of calculation.	beyond realism in the classical theory (by emancipating realism from human consciousness), able to be understood from the viewpoint that entire many-worlds—overall coexistence states—represented by quantum mechanics are real.
Measurement is…	the process that an observer standing outside, like classical mechanics, selects a state among coexisting numerous ones.	carried out in respective states wherein an observer and measuring equipment are also conceived as essential components.
Regarding which of the states is selected, …	the probability (as an abstract concept) is proportional to the square of the wave height representing each state—with indifference toward why that is so.	namely, which of the worlds is shared with the observer, it is dependent on the degree of coexistence of respective worlds. the probability is the frequency as a result of numerously repetitive measurements.*2
At the moment of measurement, …	it is assumed to be the wave packet collapse, which has nothing to do with the Schrödinger equation, artificially discarding anything but the selected state.	there is no need to consider the wave packet collapse. there is also no interference from other states, which are still coexistent with the observed one.

(Based on Wada 1994, ch. 4, 7, 12; 1997, ch. 5; 1998, phase 3-a b, 5-b, 6-a b, 7-b; 2002, introduction, ch. 1, 3, 7)

*1 "Determinism" (the doctrine that all events are founded on the principle of causality) is used in light of the context that the distribution of coexistence degrees complies with the Schrödinger equation. However, the fact remains that a human being cannot predict a measurement result. Hence, it is also noted that those people who are bound by the perspective of "one world" have to think of the above in terms of the theory of probability (as an abstract concept) (Wada 1997, 139-140; 1998, 160-161).

*2 As for "probability," in particular, there are a variety of viewpoints and no conclusions among advocates of the Many-Worlds Interpretation. In this table, the standpoint of "frequentism," which is able to prove Born Rules without introducing superfluous concepts, is exemplified with reference to "Afterword by the Translator" (Wada, 317-318) in Colin Bruce (2008), *Ryoshi-rikigaku no Kaishaku-mondai* (Schrödinger's Rabbits: The Many Worlds of Quantum).

mechanics is embraced as it is. Indeed, to deny the corollary, quantum mechanics is forced to incorporate an "unnecessary principle" (the wave packet collapse). Consequently, the immediate need is to exclude this "unnecessary principle."

Although the Copenhagen Interpretation is still dominant over the Many-Worlds

Interpretation, Everett's thoughts have recently been reevaluated (Byrne 2007, 78–79). A prominent example would be “Tasekai kara Umareta Keisanki” [Computing Machinery Derived from the Many-Worlds] (Furuta 2008), namely, the “quantum computers” (computing machines with the help of parallel universes) studied by David Deutsch,[8] Oxford University, on the basis of Everett's outrageous ideas (Bruce 2004, 155; Furuta 2008, 54). Aya Furuta (2008, 54–55), a science and technology journalist, touched the heart of Deutsch's intellectual endeavors as follows. [Tentative translation] “The difference in interpretations is the one in worldviews. A distinct worldview will create different awareness of the issue, and sometimes trigger alternative scientific intuitions.” Furthermore, under the present situation where mainstream physicists have raised voices saying “quantum computers can be perfectly understood from the Copenhagen Interpretation,” she asked a question, “But when there was no concept of such a quantum computer, can they come up with it from the standpoint of the Copenhagen Interpretation ?” (65).

5. Descriptions of Governance by Analogy with Physics

Some important perspectives highlighted in the previous discussions of both Newtonian mechanics and quantum mechanics provide helpful clues particularly to ponder the possibility of the innovative concept “Quantum Urban Governance” in response to “Parallel Habitats.” Once apart from conventional arguments about governance, this section attempts to tentatively set up alternative views of governance by analogy with discourses in physics—the two interpretations of the “Newtonian Urban Governance” and the “Quantum Urban Governance” by “paraphrasing” the earlier key discussions.

5-1. Analogy from Reflections on Newtonian Mechanics

“Newtonian Urban Governance” that Sounds Reasonable to “Sedentary Inhabitants”

“Newtonian Urban Governance” would be the urban governance encompassing the thoughts of “Governance in Solidity” and “Governance in Fluidity” in terms of its visions mentioned in the beginning. A depiction of the worldview, taking a cue from the dimension of Newtonian thoughts, could be a conception in which “the outer framework of fixed absolute nation-states” is set up in advance, and fundamental laws sustaining people's “sedentary” states govern such a complex world as the “ingenious mechanical society” composed of international organizations, civil society organizations, corporate citizens, and the like. This paradigm—even if the necessity of reforms is from time to time brought up within the framework—might be a “deceptively friendly picture” for not only literally sedentary inhabitants but also those globally mobile people who are “commuting” from permanent residences selected as the only one “most optimum” solution and those migratory population groups that are seeking to attain such a new “sedentary” home.

It would also be an imaginable analogy that even under today's expanding globalization in a wide variety of aspects, this Newtonian paradigm is still applicable to the real world, if dealt with approximately. Moreover, one might assume that its interest in public policy is in precisely depicting mechanical motions of the "sedentary society," and to counter issues that impede sustainable development, for instance, the role of leading actors should be properly finding out an "alternative vital actor" who can be a "new cog" essential for project management and trumpeting the engagement as global partnership. Then the stance of a spectator who sees the target population and its livelihood as affairs on "the opposite side of the river" could be a distinct feature.

Meanwhile, unique perspectives, such as a chaos-based (chaotic "living" states) analytical approach for people's livelihood in which a wide range of elements are complexly intertwined and relativistic study methodology on global issues/actors inspired by Einstein's theory of relativity, have occasionally been brought out. However, there is a possibility that in light of the earlier discussions in physics, those endeavors are, from the standpoint of "paradigm," fundamentally seen as thoughts within the mindset of the "Newtonian Urban Governance."

Incidentally, Leibniz's line in opposition to Newton's line suggests that the postulated outer frame of the "nation-states" is inappropriate on the grounds that the approach brings in an unnecessary notion not inhering in human institutions per se. This is reminiscent of the importance of radical thinkers' advocating self-governance free from any forms of authority and power even within classical approaches.

5-2. Analogy from Reflections on Quantum Mechanics

"Quantum Urban Governance" that Highlights Even Particularity of "Sedentary Inhabitants"

It might be said that conventional actors, such as nations, international institutions, civil society organizations, and corporate citizens, have always been shown the special "Newtonian Urban Governance" in advance. In addition, they have been taken in as though a world depicted in this light had just been the general one, or rather, have deceived themselves and others. Then "Quantum Urban Governance" as a more comprehensive paradigm would highlight particularity of "sedentary inhabitants' thought patterns."

From the above discussions in physics, the definition of "Parallel Habitats" raised in the beginning could be finely tuned as "a quantum-mechanical superposition of an individual's two or more 'living' states, 'inhabiting' territorial/non-territorial spaces, so as to ensure adequate solutions." In this instance, the individual synchronously "inhabits" plural places. This is not to say that the individual was actually *plural* individuals. Plural "living" states are coexistent.

Likewise, "Quantum Urban Governance" could be revised as "a proposal of urban governance that makes a Many-'Habitats' Interpretation of the superposition of *plural* 'living' states (on the basis that overall coexistence 'living' states are real), implied by the concept of 'Parallel Habitats'—by taking a cue from the Many-Worlds Interpretation in quantum mechanics, deepening the Newtonian paradigm for managing the fictional 'sedentary' society with approximate expressions." Together with the "Stochastic Interpretation" of "living" states (on the assumption that at the moment of a survey, only one "living" state is left behind) hammered out by analogy with the Copenhagen Interpretation, which was pointed out to be a patchwork of quantum mechanics and classical physics, I analogically sketch out the key elements of the two interpretations.

Analogy from the Copenhagen Interpretation: "Stochastic Interpretation" of "Living" States

The "Stochastic Interpretation" of "living" states only questions what can stringently be verified and could be explained as a viewpoint that looks on the superposition of *plural* "living" states as "fictional" for the convenience of estimation. Furthermore, it perceives a survey as the process that an observer standing outside, such as "Newtonian Urban Governance," stochastically selects one of the "living" states. This interpretation assumes the "Quantum Collapse" of "living" states—namely, in the case of an individual's superposition of two "living" states at location A and location B, at the moment of a survey on the respondent's "living" place, any one of the "living" states is merely identified—and artificially discards anything but the selected "living" state. The mindset could be said to be an ad hoc modification approach only aiming to make use of "Quantum Urban Governance," an extension of the conventional paradigm under de facto "lack of interpretation."

Analogy from the Many-Worlds Interpretation: "Many-'Habitats' Interpretation"

In the "Many-'Habitats' Interpretation" looking on the overall many-"habitats"—the whole of coexistence "living" states—that "Quantum Urban Governance" considers real, and assuming that at the instant of a survey, an observer is all together in each "living" state, the question, "Which of the 'living' states is shared with the observer ?" would depend on the degrees of coexistence of respective "living" states. This interpretation never supposes "Quantum Collapse" of "living" states and sees other "living" states as consistently existent together. For example, in the case of surveying "an individual in a superposition of location A's 'living' state and location B's 'living' state," it could analogically be said that in one branch, an observer obtains a result that the individual is in location A's "living" state. Moreover, in a nearly identical branch, a copy of the observer obtains a result that the same individual is in location B's "living" state. Each copy of the observer perceives herself or himself as being one of a kind and sees chance as cooking up one reality from a menu of the individual's possible "living" states, even though, in the full "reality," every alternative "living" state on the menu happens.

In order to build up the theoretical framework of "Quantum Urban Governance" (Many-"Habitats" Interpretation), which would be needed to deepen conventional theories of governance, this paper has touched upon conceivable conceptions and points by analogy with deliberations in classical physics and quantum physics. In the next phase, in light of cases in the real world, I will consider necessary conceptual modifications of the above-mentioned view to be applicable as the alternative governance in response to "Parallel Habitats." In addition, the proposal must be further reviewed and expounded in the context of well-accepted theories on population migration, cities, governance, development cooperation, and other related areas, and then, should be developed as a standpoint working out tomorrow's global public policies.

For instance, from the perspective of "Quantum Urban Governance," I will aim to work out the next level of urban governance-related policy studies, through revisiting some influential theories on space in the area of urban and regional development. Furthermore, I will also be adding an idea of a "superposition of 'living' states" in a view of "spanning divides of actors, sectors, and/or levels" and other current terms of development management.

Finally, a "paraphrase" of the above-referenced article on the "quantum computer" could imply the following lines. "The differences in interpretation is the one in governance-views. A distinct governance-view will create different awareness of the issue, and sometimes trigger alternative policy intuitions." This could be an impetus that I further promote in a study on "Globalization/Urbanization for All."

Notes

1 Soushichi Uchii (2007, 154-155) took up "superstring theory" as a prime example of the "expansile lines," and the "theory of loop quantum gravity" as that of "austerity lines," respectively. In particular, the "theory of loop quantum gravity" takes an approach aiming to quantize the structure of spacetime itself, integrating the general theory of relativity and quantum theory, and studying the structure of spacetime, which is a framework of physics, without the premise of the higher dimensional outer frame.

Interestingly, in studies on loop quantum gravity, the spacetime of the Newtonian "fixed-stage" is erased. On the basis of spin—an attribute of quantum theory—quantum states of "space" are illustrated as diagrams of lines and nodes called spin networks, and quantum states of "spacetime" are depicted in abstract diagrams of "spin forms" (Smolin 2004, 58, 60-63; Takeuchi 2004, 198-206).

2 Robert B. Laughlin (2005, 31-32), a theoretical physicist, voiced objections to this viewpoint, as follows. "[Many physicists]…routinely speak about Newton's laws being an approximation for quantum mechanics, valid when the system size is large—even though no legitimate approximation scheme has ever been found. …. [T]he correspondence principle remains mathematically unprovable."

3 As for building up quantum mechanics, there were those lopsided arguments that placed undue importance on external influences. A case in point was frequently quoted Paul Forman, a historian of science.

Roger G. Newton (1997, 27), distinguished professor emeritus of physics at Indiana University, took the following extravagant assertion of Paul Forman as an example.

> [S]uddenly deprived by a change in public values of the approbation and prestige, which they had enjoyed before and during World War I, the German physicists were impelled to alter their ideology *and even their science* in order to recover their favorable public image. In particular, many resolved that one way or another, they must rid themselves of the albatross of causality. [Emphases in original]

Among recently published books, David Lindley (2007, 179) summarily introduced Paul Forman's shocking discussion, as follows.

> …. If history, like science, was deterministic, and if that determinism had resulted in Germany's downfall, then evidently some other kind of history was urgently required. Therefore, scientists too, to avoid being associated with the discredited past and to curry favor in the new intellectual climate, likewise abandoned

determinism and marched under the banner of chance, probability, and uncertainty.

4 Subsequently, Yoichiro Murakami (1998, 210) also showed the following view. [Tentative translation by Tanimura]

…. Heisenberg had gracefully broken away from the classical view of continuous causality or classical determinism. However, to put it the other way around, it could be said that the attitude had been rooted in sticking to the classical image of the physical particle that cannot be completely denied. In the meantime, Schrödinger had gracefully broken away from the classical image of the physical particle, and started to take the extremely innovative view of the matter waves. However, conversely, it might be attributed to clinging to the classical view of causal determinism.

5 Although the term of Born's “Probabilistic Interpretation” has been well-accepted, Shigeru Machida (1994, 51) advocated an alternative description of “Rules of Quantum Probability,” because what Born put forward were rules that connected the wave function with a complex number representing states under study in a microworld to probabilities of real phenomena, and that are distinct from the unresolved “interpretational problems” in the area of quantum mechanics.

6 The uncertainty relationship is a conclusion derived from quantum mechanics. It is pointed out that the well-used term of the “uncertainty principle” is inappropriate (Machida 1994, 69; Wada 1998, 143). Hence, in this paper, I make use of the “uncertainty relationship,” instead of “uncertainty principle,” which has often been found in introductory books on quantum theory.

7 As for the terms “progressive” and “conservative,” Shigeru Machida (1994, 89) added that these modifying words simply point out the leading physicists' stances in relation to classical physics and have nothing to do with rightness or usefulness of their views for the further progress of physics.

8 With regard to Everett's interpretation, Deutsch made such slight changes that there are countless worlds from the outset, and these worlds are not increased by branching. According to Deutsch's view, it is not “a world” that is being divided into branches, but “many worlds.” It is the many worlds having traced the same history that branch into and set off on their respective paths (Furuta 2008, 58).

Bibliography

Bruce, Colin 2004, *Schrödinger's Rabbits: The Many Worlds of Quantum*, Washington, D. C., Joseph Henry Press.

Bruce, Colin (Translator: Sumio Wada) 2008, *Ryoshi-rikigaku no Kaishaku-mondai* (Schrödinger's Rabbits: The Many Worlds of Quantum), Tokyo, Kodansha.

Byrne, Peter 2007, “The Many Worlds of Hugh Everett,” *Scientific American*, Vol. 297, Issue 6, pp. 72–79. (http://www.SciAm.com)

Furuta, Aya 2008, “Tasekai kara Umareta Keisanki” [Computing Machinery Derived from the Many-Worlds], in Nikkei Science Henshubu ed. *Fushigina Ryoshi wo Ayatsuru* [Manipulating the Weird Quantum World], Nikkei Science separate Vol. 161, pp. 54–65, Tokyo, Nikkei Science.

International Organization for Migration (IOM) website, “Global Estimates and Trends.” (http://www.iom.int/)

Iyama, Hiroyuki et al. 2000, *Gendai Kagaku-ron* [Contemporary Science Studies], Tokyo, Shinyosha.

Jammer, Max 1966, *The Conceptual Development of Quantum Mechanics*, New York, McGraw-Hill Book Company.

Kim, Tae-chang et al. 2004, “Hatsudai IV wo Ukete no Toron” [Discussion on the Basis of Presentation IV], in Takatoshi Imada et al. eds., *Toshi kara Kangaeru Kokyosei* [Publicness from the Perspective of the City], pp. 138–151, Tokyo, University of Tokyo Press.

Laughlin, Robert B. 2005, *A Different Universe: Reinventing Physics from the Bottom Down*, New York, Basic Books.

Lindley, David 1996, *Where does the Weirdness Go ?: Why Quantum Mechanics is Strange, but not as Strange as You*

Think, New York, Basic Books.

Lindley, David 2007, *Uncertainty: Einstein, Heisenberg, Bohr, and the Struggle for the Soul of Science*, New York, Random House, Inc. (Anchor Books Edition, 2008).

Machida, Shigeru 1994, *Ryoshi-rikigaku no Hanran* [Backlash from Quantum Mechanics], Tokyo, Gakushu-kenkyusha.

Murakami, Yoichiro 1998, *Heisenberg* (Werner Karl Heisenberg), Tokyo, Kodansha.

Newton, Roger G. 1997, *The Truth of Science: Physical Theories and Reality*, Cambridge, Harvard University Press.

Sato, Fumitaka 1997, *Ryoshi-rikigaku no Ideology* [Ideology in Quantum Mechanics], Tokyo Seidosha.

Sato, Fumitaka 1999, *Butsurigaku no Seiki* [Century of Physics], Tokyo, Shueisha.

Sato, Fumitaka 2005, "Ryoshi-rikigaku wa Nani no Riron ka ?" [What is Quantum Mechanics for ?], in *Gendai-shiso*, Vol. 33 No. 11, pp. 42–58, Tokyo, Seidosha.

Sato, Fumitaka 2007, "Ryoshi-rikigaku no Mibun" [Quantum Mechanics in Perspective], in *Gendai-shiso*, Vol. 35 No. 16, pp. 54–67, Tokyo, Seidosha.

Sato, Katsuhiko ed. 2001, *Ryoshi-ron* [Quantum Theory], Tokyo, Natsumesha.

Smolin, Lee 2004, "Atoms of Space and Time," *Scientific American*, Vol. 290, Issue 1, pp. 56–65. (http://www.SciAm.com)

Szamosi, Géza 1986, *The Twin Dimensions: Inventing Time & Space*, New York, McGraw-Hill Book Company.

Takeuchi, Kaoru 2001, *Zero kara Manabu Ryoshi-rikigaku* [Quantum Mechanics Starting from Zero], Tokyo, Kodansha.

Takeuchi, Kaoru 2004, *Sekai ga Kawaru Gendai Butsurigaku* [Contemporary Physics with an Alternative View of the World], Tokyo, Chikuma Shobo.

Tanimura, Mitsuhiro 2005, "Development and Urban Futures," *The Journal of Social Science*, No. 54, pp. 49–72, Tokyo, International Christian University.

Tanimura, Mitsuhiro 2006, "Beyond UN-Habitat's Classic Framework in Urban Development Strategies," *The Journal of Social Science*, No. 57, pp. 275–304, Tokyo, International Christian University.

Tsuduki, Takuji 1994, *Nattoku suru Ryoshi-rikigaku* [Understanding of Quantum Mechanics], Tokyo, Kodansha.

Tsuduki, Takuji 2002, *Shinso-ban Fukakuteisei Genri* [The Uncertainty Principle (Renewed Edition)], Tokyo, Kodansha.

Uchii, Soushichi 2007, *Ryoshi-juryoku to Tetsugaku* [Quantum Gravity and Philosophy], in *Gendai-shiso*, Vol. 35 No. 16, pp. 152–165, Tokyo, Seidosha.

Wada, Sumio 1994, *Ryoshi-rikigaku ga Kataru Sekaizo* [The Worldview Derived from Quantum Mechanics], Tokyo, Kodansha.

Wada, Sumio 1997, *20 seiki no Shizenkan Kakumei* [Revolutionary View of Nature in the 20th Century], Tokyo, Asahi Shimbunsha.

Wada, Sumio 1998, *Schrödinger no Neko ga Ippai* [Schrödinger's Cats], Tokyo, Kawade Shobo Shinsha.

Wada, Sumio 2002, "Ryoshi-rikigaku no Tasekai Kaishaku" [Many-Worlds Interpretation in Quantum Mechanics], in Yoshihiko Ohtsuki ed. *Gendai Butsuri Saizensen 6* [Frontiers of Contemporary Physics 6], pp. 3–60, Tokyo, Kyoritsu Shuppan.

Wada, Sumio 2007, "Ryoshi-rikigaku towa Nani ka" [What is Quantum Mechanics ?], in Seiya Abiko et al. *Hajimete Yomu Butsurigaku no Rekishi* (A History of Physics), pp. 328–339, Tokyo, Beret Shuppan.