

Siddheshwar Rameshwar Bhatt *Editor*

Quantum Reality and Theory of Śūnya

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New Delhi, Delhi, India

ISBN 978-981-13-1956-3 ISBN 978-981-13-1957-0 (eBook)
<https://doi.org/10.1007/978-981-13-1957-0>

Library of Congress Control Number: 2019933413

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The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

*Dedicated to
Seers, sages and thinkers
Who have shown the way to Reality*

Foreword

As I assumed the office of the President of the ICCR, I received a challenging letter from Dr. Peter Gobets to record concrete historic evidence on the precise genesis of the zero as a digit. The date of the origin of zero deserves study. Its presence in grammar and metrics as a semantic category goes far back in history. He sent a note of Dr. Elizabeth P. den Boer of the Leiden University on the uncanny convergence of the world views of Indian philosophies and quantum physics. The practical utility of the zero has been adopted in the West, but its deeper meaning remains to be grasped. As all signs refer both to a concrete presence and an intangible realm, the duality of the vestigial and ineffable is the reality of the *pūrṇa* and *śūnya*. Sanskrit stands out in having the dual number besides the singular and plural. Creation was viewed in India as a binary phenomenon, in consonance with the androgynous birth of humans and animals. The duality of consciousness and intellection was denoted by analogous verbal roots. The fundament of consciousness was the root *cit* and its nominal form *cetana*. It became the verb *cint* ‘to think’ with the addition of the infix *n* (from *cit* to *cint*) and the noun *cintana*. Creativity was binary and so was its grammatical expression in the dual number. The concept of empirical *pūrṇa* suggested the subtle *śūnya* ‘void’. The *nāsadīya* hymn of the Ṛgveda on creation speaks of sad ‘existence’ and a sad ‘non-existence’. The binary principle of India’s approach to reality, phenomena or vacuity induced the emergence of *śūnya* both as (i) zero and (ii) as a void vacuum where subatomic phenomena arise and decay.

The monocentric approach of Western philosophy, strengthened by monotheism, has led to the ontological quandary of quantum physics as to why subatomic phenomena arise and decay in an empty vacuum. The zero-based philosophy of nonism (no philosophy) has been missing in the West. The vast Buddhist literature of root texts and commentaries of the last two millennia on ‘negation’ and ‘*sūnyatā*’ can provide insights into the subatomic vacuum. Is this subatomic vacuum ‘empty’. No, it is a ‘creative void’.

The word *śūnya* goes back to the Ṛgveda where it means ‘emptiness, lack, want, absence’ from *śūna* ‘swollen’, or the state of hollowness. The verbal form *śvayati*

means ‘swells, increases and grows’ as both increase and emptiness are ingrained in the word *śūnya* itself. *Śūnya* means ‘sky’ in the Śabdacandrikā. Jaṭādhara’s lexicon translates *śūnyavādin* ‘one who propounds śūnya’ as a Buddhist. *Śūnya* developed as a philosophical term in Buddhism, e.g. *paribhāvitāśūnyatādīrgharātram* ‘we have meditated long on the void’ in the Lotus Sutra 117.7 (gāthā). There are different lists of *śūnyatā*: 18 in the Mahāvūyutpatti 933–951 and ŚatasāhasrikāPrajñāpāramitā and 20 in the Dharma-saṅgraha. The different śūnyayās have to be interpreted by physicists and mathematicians.

Buddhist thought was based on the negative concepts of *anātmavāda* denying the existence of soul and secondly the theory of *anityatā* ‘impermanence’ denying the eternal dimension. Laṅkāvatāra-sūtra 22.10 speaks of *śāśvatoccheda* ‘denying the eternal’. Both were to lead to śūnyatā. Nāgārjuna the founder of the Mādhyamikaschool was associated with the Prajñāpāramitā and gave rise to the doctrine of śūnyatā which should be translated as ‘Creative Void’. It is not emptiness related to the empirical volume. He defined śūnyatā as *pratītya-samutpāda* which can be rendered as ‘interdependent origination’ to state that things are not self-arisen but come into existence in mutual dependence on conditions. The conventional truth (*saṃvṛti-satya*) is a necessary means for the ultimate truth (*paramārtha-satya*), and the ultimate makes the conventional possible. The language of Buddhism and that of quantum physics have to overcome dualism of value and validity. Scientists have started to think more subtly than they had hitherto been accustomed. To cite Heisenberg, ‘Although I am now convinced that scientific truth is unassailable in its own field, I have never found it possible to dismiss the content of religious thinking as simply part of an outmoded phase in the consciousness of mankind’.

In the increasingly busy crossroads of artificial intelligence, neuroscience, consciousness, quantum physics and computing sciences, scientists have begun thinking deep below the level of consciousness, beyond the intellectual formalism of logic but with fluidity. The contemporary philosophy of science is becoming the spoilsport of modern logic, like Kurt Gödel’s incompleteness theorem which declares that any attempt to build a complete and consistent logical theorem will inevitably be ruined by undecidable proportions. Modern understanding of how the glories of the mind spring from pure matter is a challenge. The mind has been viewed as creative and self-aware, how can we think of it as nothing but electrical impulses and biological tissue.

Intuition gave rise to Vedic Mathematics and to the unique mathematical genius of Ramanujam at Cambridge who was hailed as the ‘man who knew infinity’. Semiotics, the science of signs and mathematical thought, invites us to study new realms of abstraction and meditational insights of Buddhist *śūnyatā* to co-contribute to progress, away from the deep-seated Greek aversion to the concept of emptiness. It will be *pāramitā* or trans-going to comprehend the universe.

These proceedings of the seminar on *śūnya* theory and quantum reality held in December 2016 are a milestone in the study of scientists. Philosopher and meditator Prof. S. R. Bhatt has provided insights into the India perceptions as well as put in

hard labour to edit the presentations. The *śūnya* and *pūrṇa* are the elemental binary eternal, and the dedicated efforts of Prof. Bhatt enshrined in this volume remind me of the words of Poet Rabindranath Tagore: 'The flower's sacrifice ripens in the sweetness of the fruit'.

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Cultural Relations, New Delhi, India

Lokesh Chandra

Preface

Quantum Reality and Intimations of *Śūnya*

The history of human kind reveals constant recurrence of some fundamental problems which have agitated reflective human mind right from the dawn of civilization. One of such perennial problems is the nature of Reality. The demand for some kind of universally acceptable conception of Reality is one which the rational human mind cannot help making. But no two minds have ever agreed with one another in their pronouncements. Another cognate problem which perplexes is ‘How and why the mutative world has come to exist?’ along with its corollaries of ‘whence’ and ‘whither’ of this universe.

There have been twofold approaches to Reality and hence to knowledge: the fundamental and the derivative, the ultimate and the proximate, the transcendental and the immanent, the ectype and the archetype and the *pāramārthika* and the *vyāvahārika*. There has been search for the transcendent and attempts to understand the immanent. For this, both the intuitive and the ratiocinative modes have been adopted. The inward exploration in the form of *pragyā* and outward observation in the form of *pratibhā* need to be taken as complimentary. It should be a synthesis of experience and expression, of course maintaining clear distinction between the two as Kaṭhōpaniṣad rightly emphasizes. This is the message of the Īsōpaniṣad also which talks of symbiosis (*ubhayosaha*) of *vidyā* and *avidyā*.

The subject matter of our deliberations consists of two subthemes, viz. search for the nature of quantum reality and the corresponding theory of *Śūnya* as a possible approach.

We begin with the Indian scene and expound the theory of *Śūnya* which is to be equated with Brahman, as the two have similar etymology and semantics. The roots *siv* and *bṛh* stand for ‘to manifest’ and ‘to grow’. *ParamaŚiva* or Brahman is regarded as the ultimate ontological substratum of the entire cosmos. It is at once both transcendent and immanent. It is unitary and unifying (*Tadekam*) and has a natural tendency to manifest and diversify (*Eko’hambahusyām*). It is

self-existing and self-sustaining (*svadhā*). It is luminous and illuminating (*Tasyabhasasarvamidamvibhāti*). It is peaceful and tranquil like deep sea and vibrant and turbulent like sea surface. It is to be noted that *Śūnya* is not void or vacuity but, in its original form, it means devoid of multiplicity, emptied of plurality. It is not absence of anything but abode of everything. It is self-luminous and therefore pure consciousness. It is fullness (*pūrṇa*) and therefore bliss (*Yadvābhūmotatsukham*). It is *Cidānandrūpa* but also *spandarūpa*. It is allogical, suprarational and intuitively realizable through *sādhanā*. It is comparable to 'quantum vacuum' of quantum physics.

Śūnya/Brahman is vibration-less vibration, unmoved mover. In the cosmic process, the *ParamaŚiva/Śūnya Brahma* assumes the role of *Śiva-Śaktisāmarasya* (symbiosis of pure consciousness and consciousness in manifestation). Then its dynamism gets manifested. This is known as *unmeṣa* (fulguration) or *spandana* (vibration). This is the process of stir of consciousness, the *vimaśa of prakāśa*. *Śiva* is *asti* (being), and *Śakti* is *bhavati* (becoming). When *Śakti* is in action from here, individuation and multiplication get manifested. It is not creation but manifestation. But it should be remembered that in this kinetic process the *ParamaŚiva/Brahman* is not affected. *That is why it is described as vibration-less vibration*. In this process, there is dependent origination and interdependent existence of all phenomena. This is comparable to principles of interconnection, entanglement, implicate and explicate orders, exclusion principle, etc. of quantum mechanics. This is how phenomenon of teleportation, non-locality, etc. can be understood.

There is a very poignant word for the start of cosmic process which is rich in meaning. This is an adjective of *Śūnya/ParamaŚiva/Brahman*. It is characterized as *svātantrya*. It means (a) *svamtanute* (manifests itself), (b) *svasmāttanute* (manifests from within itself), (c) *svecchayātanute* (out of one's sweet will), (d) *svaśaktyātanute* (from its own power without being controlled by anyone outside as there is nothing outside), (e) *svacchnadatayātanute* (without any causal constraint) and (f) *svasmintanute* (manifests within itself as it is second to none, *advaya* or *advaita*).

It is to be emphasized that all manifestations here are of the same nature of perfection as from perfection only perfection can arise (*pūrṇādpūrnamudachyate*). Due to improper understanding and due to individuation and consequent 'I-ness' or egoity, we feel separated and limited. So there is a need for self-recognition (*Pratyabhijñā*) or ātmalābha (self-realization). For this, the material world which is also a part and parcel of the same ultimate Reality provides an arena. This is the implication of the prayer *Mrtyorma'mṛtamgamaya*. This is how we can have symbiosis of Vedanta and Tantra.

The multifaceted concept of *Śūnya* has been an ingenious thought of fertile and innovative Indian mind. It has been a unique contribution of India to world culture and civilization. This seminal and pivotal concept has its ramifications in various fields like metaphysics, cosmology and cosmogony, physics, mathematics, religion, yoga, etc. There are several implications of the theory of *Śūnya*. Some of them are philosophical (Vedanta and Buddhism), mathematical (concept of zero, decimal system, etc.), spiritual (concept of *Pūrṇa*), religious (Mahimā cult), in *sādhanāpakṣa* (in Yoga and Tantra), in astrophysics (pertaining to *Ākaśa* or *loka*), etc. Several new

dimensions can also be discerned. In different contexts, it has different meaning. It would be a worthwhile and rewarding exercise if its different facets are attended to and analysed. They are all correlated, and only a holistic and integral approach can bring out their significance and value.

The concept of *Śūnya* has a profound metaphysical connotation which stands for the totality of Reality. In this sense, it is equated with *Pūrṇa* (completeness, infinitude and boundlessness). The Reality is a Whole which comprehends all iota of the universe as its intrinsic parts. But each part (*kośa* or *khaṇḍa*) is also a Whole (*piṇḍa*) within this widest Whole (*brahmāṇḍa*). It is represented as a Supreme Circle, and in the cosmos, there are circles within circles presenting a picture of concentric Wholes. The ultimate reality is full circle, an overarching circle. The invocation of *ĪśaUpaniṣad* remarkably puts forth this intuitive vision. It states that the Reality is a Whole or totality comprising all that was, that is and that will be, an idea available in the *PuruṣaSūkta* of the Ṛgveda. From this Whole, only Whole can spring forth even though we may not be aware of it. This Whole is infinite. Infinite cannot be *finitized*, and therefore the Advaita Vedanta regards all differentiations as finite appearances which are in ultimate analysis infinite only. Bhaskaracharya, a later mathematician, also avers the same. He opines that no change takes place in the infinite and immutable Brahman when worlds are evolved or withdrawn even though in these processes numerous orders of beings are put forth and absorbed. The equation of *Śūnya* and *pūrṇa* was a wonderful feat of Indian logical acumen which could be apprehended only by a *mantradṛṣṭāriṣi*. This concept of *Śūnya* is not emptiness or voidness but 'devoidness' in the sense that in its proto-nature the Reality is devoid of all differentiations. In itself, it is emptied of all manifest diversity. It is a non-dual realm, a quantum vacuum. In logical terms, it is referred to as 'null set', but this null set is not devoid of membership but only devoid of manifest membership. It is not to be regarded as 'nothingness' as nothing can come out of nothing. The *NāsadīyaSūkta* of the Ṛgveda begins with this intuitive realization. All quantum phenomena arise within it and get dissolved in it. The modern quantum physics endorses this understanding, and it is struggling to explain how this cosmic event takes place. The Big Bang theory is only an indication of this. The search for 'God-particle' or 'Boson' seems to be a futile exercise of the Western scientists. The *impartite* approach to Reality is a unique and ingenious gift of the Indian mind, and Western scientist should pay heed to it.

Deriving inspiration from this intuitive realization the Indian mathematicians like Bodhāyana, Brahmagupta, and many others have invented the idea of zero (cipher) and the decimal system. The mathematical zero has its obverse as infinity. All numbers or numerical signs act as tangible reference to finite, but zero represents the non-dual realm, the infinity. The Western mind has adopted zero only functionally for practical utility; it could not grasp its deeper metaphysical meaning. The concept of zero did have tremendous impact on Western science and mathematics in terms of 'decimal system' and 'quantum vacuum', but they could not reach to its metaphysical heights and depths because of the limitations of their empirical methodology. Only through *ṛtambharāpragyā* (to use Indian terminology) this realization is possible in a state of *samādhi*.

Apart from metaphysics, physics and mathematics, this concept of *Śūnya* has been profitably utilized by schools of Śaivism wherein Lord *ParamaŚiva* is referred to as *Śūnya* or *Bindu*. The *Śūnya* is described as *Aśūnya* which means that it is beyond one and many but supreme source of one and many. The worship of Lord Jagannātha in Puri and the text *ŚūnyaSamhitā* followed by the Mahimā school advocated by Pañcasakhas of Orissa are the elaborations of this idea synthesizing it with the Buddhist concept of *Śūnyata*. Their concept of *Śūnya Brahma* or *ŚūnyaPuruṣa* is a remarkable idea, the implications of which need to be brought out shorn of its religious connotation. *ŚūnyaPuruṣa* is *Anādimaṇḍala*, also described as *ŚūnyaMaṇḍala* which is the source of all creation. It is proto cause as well as the effects. The Buddhist concepts of ‘dependent origination’ and ‘interdependent existence’ coupled with this idea of *Śūnya* can help in revealing the nature of empirical and trans-empirical Reality as Nāgārjuna has pointed out. Nāgārjuna averred that there are two levels of approaching Reality. There is transcendental Reality underlying the world of phenomena.

A depth analysis of this seminal concept of *Śūnya* can open up new horizons and intellectual vistas and help in enriching improvised Western science and mathematics. Indian contributions in terms of place value decimal system, domestication of fire, invention of wheel and original gifts to science and mathematics are certainly recognized, but they have not been adequately utilized. Now that Indian contributions are gradually appreciated and the saturated Western mind is looking towards India for newer insights and fresh approaches, in-depth delineation of this concept will go a long way in spiritualizing science and making Indian spirituality more scientific.

Coming to Western scenario with this background, we may begin with the Greek and medieval periods to trace the development of scientific thought. There has been separation between physics and metaphysics after Aristotle resulting in divorce between science and spirituality. These days a need is being felt to reconcile the findings of the two for their mutual benefit. It seems that a holistic approach may be more rewarding and fruitful. In post-Newtonian physics, there is a transition from solid state to quantum. Limitations of classical physics have been realized. It is a good development. It is hoped that this may lead to the twofold approaches referred to earlier. Of course, some hard scientists may not find it easy or convenient to reach to the transcendent. However, in modern times, there is gradual realization of primacy of consciousness which transcends matter. Studies have been undertaken both in space-time bound local communication and also non-local communication independent of space and time. Non-local communication may be characterized by super non-locality and super-super-non-locality (David Bohm). The space-time bound local communication is measurable in terms of speed of light (and we are now celebrating 340 anniversary of determination of speed of light in the west), but non-local communication is not so measurable. So in this respect, the present science has to go beyond the recourse to measurability.

There is a welcome shift from Newtonian to quantum physics as it enlarges our vision, but it has to join hands with spirituality. Max Plank in 1900 and Einstein in 1905 spearheaded this movement, and this revolutionized our understanding of the

basic nature of Reality. Subsequently, Niels Bohr, Heisenberg, Schrodinger, Pauli, David Bohm and many others have developed this. Many of them have acknowledged Indian and Chinese influences on their thinking. Apart from the famous 'Exclusion' principle, Pauli discovered the existence of 'Neutrino', an uncharged particle. Niels Bohr, Heisenberg and Schrodinger advanced ideas of complementary opposites and acausality. Synchronicity as an acausal connecting principle was recognized. The dual descriptions of subatomic micro-entities in terms of waves and particles were accepted. Schrodinger's theory of oneness of all existences is an outstanding contribution. In spite of controversy between 'Copenhagen interpretation' and EPR thought experiment regarding the nature of quanta, the Wholeness and implicate order and interconnectedness of all phenomena remain undisputed. There may be difference of opinion about 'uncertainty principle', 'collapse of wave function', etc., but the 'non-locality' and 'entanglement' at the quantum level, verified and established by Bell's theorem, find general acceptance. The same is the case with the theory of overcoming 'viewing subject'-'viewed object' distinction at this level. The point is that space-time-causality operation is applicable only at the physical level, and at the deep down transcendental level, non-locality prevails. There are no 'basic building blocks' of the universe but only complicated web of relations deeply interconnected between various parts of the Whole.

To conclude, contemporary quantum physics is driven to posit dual levels of reality, the empirical and the trans-empirical, and yet many theoretical scientists do not take this seriously. They still cherish the idea of ultimate state of matter. But no account of any reductionism—behaviourist or naturalistic or any sort of physicalism—can be free from logical flaws and therefore untenable. There is incurable limitation of theoretical reason, and the trans-empirical is not accessible to current positivistic methodologies.

New Delhi, Delhi, India

Siddheshwar Rameshwar Bhatt

Acknowledgements

This book comprises papers presented in an international seminar jointly organized by the Indian Council for Cultural Relations and Indian Council of Philosophical Research. Scholars from different parts of the world participated in the deliberations on behalf of these two organizations. We extend our heartfelt thanks for their erudite contributions.

Ms. Shinjini, Ms. Priya Vyas and other staff have graciously undertaken its publication. I express my gratitude to them.

The theme is of topical interest and significance. It is hoped that it will be useful to enlightened readers.

Contents

Part I Theory of Quantum Reality

- 1 **Quantum Reality, Spiritual Concepts, and Modern Optics Experiments** 3
Devulapali V. Rao and Lalitha D. Rao
- 2 **Can A Quantum Field Theory Ontology Help Resolve the Problem of Consciousness?** 13
Anand Rangarajan
- 3 **Emergent Reality in Quantum from Classical Transition** 27
Tabish Qureshi

Part II Concept of Śūnya

- 4 **Śūnya and Pūrṇa** 39
S. S. Rama Rao Pappu
- 5 **Quantum Reality and the Theory of Śūnya** 47
Amalkumar Mukhopadhyay

Part III Comparative Analysis of Nature of Quantum Reality and Theory of Śūnya

- 6 **Two Aspects of Śūnyatā in Quantum Physics: Relativity of Properties and Quantum Non-separability** 93
Michel Bitbol
- 7 **Śūnya, Śūnyatā, and Reality in Modern Physics** 119
Herbert J. Bernstein
- 8 **Quantum Reality and the Concepts of Infinity, Infinitesimal, and Zero in Mathematical and Vedic Sciences** 143
Radhey Shyam Kaushal

9	Concepts of Reality and Śūnya from the Perspective of a Physicist	159
	Kashyap Vasavada	
10	Intrinsic Property, Quantum Vacuum, and Śūnyatā	173
	Sisir Roy	
11	Beyond Vedānta: Speculations of a Quantum Realist	185
	Rajendra Prasad Bajpai	
12	Quantum Vacuum and Beyond: An Exegesis in the Light of the Concept of Śūnya	199
	Rajeshwar Mukherjee	
13	How to Approach Śūnyatā as the Quantum Reality Through Biological Consciousness?	211
	Bal Ram Singh	
14	Quantum Physics, Consciousness and Śūnya	229
	S. Rammohan	
15	The Concept of Reality in Quantum Mechanics and Śūnyavāda: From the Perspective of Yoga	241
	Geo Lyong Lee	
16	Quantum Mechanics Shows the Limit of Naïve Realism	249
	Bhakti Vijnana Muni	
17	Subjective Evolution of Consciousness in Modern Science and Vedāntic Philosophy: Particulate Concept to Quantum Mechanics in Modern Science and Śūnyavāda to Acintya-Bhedābheda-Tattva in Vedānta	271
	Bhakti Niskama Shanta	
18	Is Nāgārjuna's Śūnyavāda Complimentary to Quantum Field Theory?	283
	Shreekala Nair	
19	Quantum Reality and Concept of Śūnya: Need for an Integrative Approach	291
	Surendra Singh Pokharna	
20	The Concept of Śūnya with Reference to the Pañcasakhās, the Mahimā, and the Modern Quantum Reality	325
	Bijayananda Kar	
21	Quantum Reality and Śūnya	335
	Jayant Burde	

22	Ontological Reality: Quantum Theory and Emptiness in Buddhist Philosophy	345
	Geshe Dorji Damdul	
23	Logical Interface Between Quantum Physics and Śūnyatā with Special Reference to Theravāda and Mādhyamika Philosophy	351
	Rana Purushottam Kumar Singh	
24	How the Pañcakośa Model of Experience Fits the Understanding of Śūnya and Helps Explain Quantum Reality?	359
	Rashmi M. Shetkar, Alex Hankey, and H. R. Nagendra	
25	How Physics Would Look Like <i>If Based</i> on the Metaphysical Guidelines of Śūnyavada?	369
	Debajyoti Gangopadhyay	
26	A New Information Theory Explains Śūnya in Samādhi	379
	Alex Hankey	

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Table of Diacritical Marks

Key to Transliteration (Using Diacritical Marks)

	अ	इ	उ	ऋ				
	a	i	u	r̥				
आ	ई	उ	ए	ऐ	ओ	औ	अं	अःa
ā	ī	ū	e	ai	o	au	am	aḥ

Classified Consonants

क	ख	ग	घ	ङ	
k	kh	g	gh	ṅ	
च	छ	ज	झ	ञ	
c	ch	j	jh	ñ	
ट	ठ	ड	ढ	ण	
ṭ	ṭh	ḍ	ḍh	ṇ	
त	थ	द	ध	न	
t	th	d	dh	n	
प	फ	ब	भ	म	म् (intermidate)
	p	ph	b	bh	m ṃ

Part I
Theory of Quantum Reality

Chapter 1

Quantum Reality, Spiritual Concepts, and Modern Optics Experiments



Devulapali V. Rao and Lalitha D. Rao

Abstract Truth is One; wise men call it by various names. Both religious/spiritual philosophers and modern scientists have the same goal – pursuit of the ultimate truth. Science looks at “objective reality” independent of the human observer, whereas old Indian mystics adopted a holistic approach involving the observer and the observed – isolating the two is arbitrary. In terms of basic concepts, quantum theory contains some parallels to Hindu scriptures – the fuzzy and nebulous world of atoms sharpens into the world of reality only when an observation is made, similar to the Hindu concept of *Aham Brahmasmi* (I am Brahman). The well-known Schrodinger’s cat is a thought experiment illustrating this bizarre concept. The famous physicist John Wheeler’s thought experiment about the observer creating even retroactive reality is spectacularly confirmed by recent experiments on helium atoms scattered by laser light. Abstract concepts in Hindu scriptures are getting translated to real-world objective demonstrations in modern science and technology. For example, the Sanskrit sloka “*Om Pūrṇamadaḥ, Pūrṇamidam, Pūrṇāt Pūrṇamudacyate, Pūrṇasya Pūrṇamādāya, Pūrṇamev āvaśiṣyate*” can be illustrated by a hologram (Pūrṇa or Whole) recorded by coherent light generated by lasers. The *śloka* implies: That (pure universal consciousness) is full (perfect); this (manifest universe of matter, individual consciousness) is full. This fullness has been projected from that fullness; what remains is fullness. When the hologram is illuminated by light, the whole event is displayed as virtual reality, close to the concept of *Māyā*. One can cut the hologram into any number of small pieces; each piece contains the whole information and displays the event sharply.

Keywords Quantum and reality · Quantum mechanics · Hologram · *Śūnyāta* · *Pūrṇata* · *Brahman*

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1 Introduction

The two revolutionary theories of relativity and quantum mechanics provide the framework for all modern physics. In terms of some of the basic concepts, they can be compared to the Hindu scriptures Bhagavadgītā and Yogavāśiṣṭha. Max Planck suggested in 1900 that heat is radiated from any hot body as small discrete packets or quanta. Einstein considered particles of light called photons. On the other hand, physicists were already familiar with the wave nature of electromagnetic radiation such as light and heat. A few years later, experiments indicated that particles of matter such as electrons also display wavelike behavior. In the microscopic atomic world, physicists encountered the bizarre behavior of wave-particle duality. One cannot clearly say whether any basic elementary particle, photon, electron, proton, or neutron, is actually a wave or a particle. Heisenberg's uncertainty principle is also a basic tenet of quantum mechanics. It states that at a given time, the position and momentum (velocity times mass) cannot both be determined precisely; if one is known exactly, then there is more uncertainty in the other parameter to compensate so that the product of the two cannot be below a fixed value equal to Planck's constant h . One can experimentally determine the value of this constant in the lab. This quantum uncertainty is not due to lack of sophisticated instrumentation but is intrinsic in the very nature of things. Quantum tunneling is a well-known phenomenon where moving particles suddenly disappear at one place and appear at another place. They can cross barriers, swerve around corners, and exist in many places at once. There is experimental evidence for this peculiar behavior. In fact it has many applications in technology, for example, in transistors. In the macroscopic world, this is similar to a Yogi confined to a locked room appearing elsewhere transcending all barriers.

According to Niels Bohr, one of the founders of quantum mechanics, the fuzzy and nebulous world of the atom sharpens into concrete reality only when an observation is made. In the absence of an observation, the atom is a ghost. It only materializes when you look for it and you can decide what to look for! Further the reality that the observation sharpens into focus cannot be separated from the observer and his choice of measurement strategy. If all this seems paradoxical or mind-boggling to accept, Einstein would have agreed with you. The classic remark "anyone who is not shocked by quantum theory means he has not understood it" is attributed to Niels Bohr (Fig. 1.1).

The well-known Schrödinger's cat is an interesting thought experiment illustrating the weirdness of the quantum mechanical concepts. The cat is in a sealed box which contains a bottle of cyanide poison. There is also a radioactive source in the box which radiates particles at random. When a particle is emitted, it triggers a mechanism to break the poison bottle and the cat dies. This is an absolutely random process. According to the tenets of quantum mechanics, the cat should exist in both the possible states, live or dead, until an observer opens the door and looks for it.

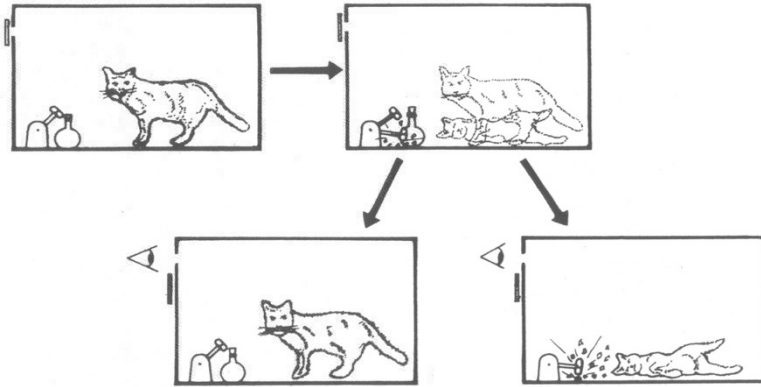


Fig. 1.1 Schrodinger’s cat

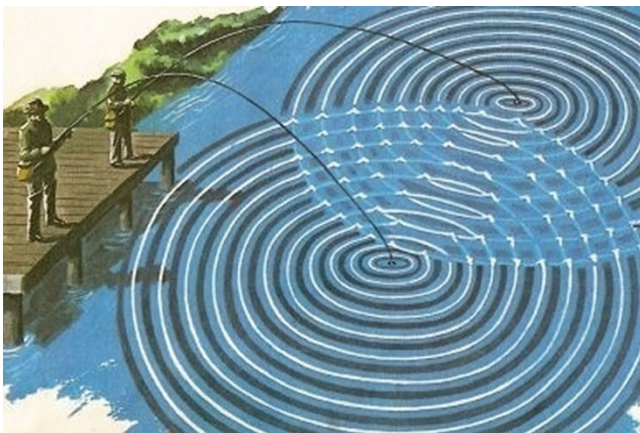


Fig. 1.2 Wave interference – whenever a crest coincides with a trough, the water surface is flattened (decrease in amplitude). A crest coinciding with a crest yields a double crest (increase in amplitude)

The study of hybrid states of the quantum world, “entangled states,” is a hot topic of current interest in basic research and also for potential applications in quantum computation and communications.

Let us now look at a few simple experiments in optics which a college student carries out in introductory physics course. Everybody is familiar with waves in a pond (Fig. 1.2), when a stone is dropped and the interference of two waves causes enhanced crests and troughs.

In the classical interference experiment in the lab (Fig. 1.3), a laser beam illuminates the two narrow vertical slits A and B, and the pattern is observed on screen C. The experiment can also be done using a mercury lamp as a source with the light confined to a pinhole going through a narrow band color filter, but with a laser

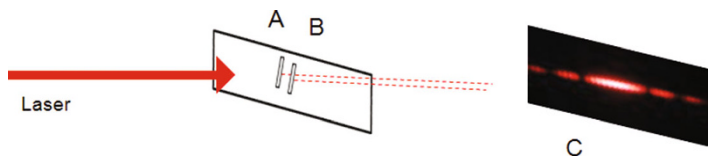
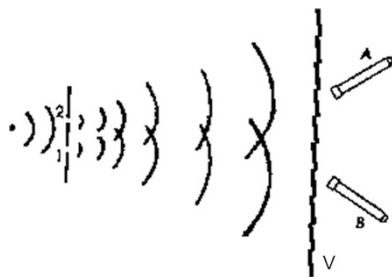


Fig. 1.3 Experimental arrangement for double-slit interference. A, B, narrow vertical slits; C, screen showing the interference pattern

Fig. 1.4 Delayed choice experiment. A, B, photodetectors; V, venetian blind



which is highly monochromatic (sharp in color), bright, and highly directional, the experiment is easy and the picture is sharp. The pattern observed contains a series of bright and dark bands called interference fringes. Depending on the light from the two sources arriving at the screen in-step or out-of-step at the location of the screen, we see a bright or dark band, thus demonstrating the wave nature of the light.

This is not the whole story. When the intensity of the laser is turned down so low that only one photon at a time is radiated, given long enough time, the same interference pattern is observed. The weirdness is obvious, any particular photon can pass through only one hole, but interference requires two overlapping waves one from each slit. Experiments with other quantum particles like atoms, electrons, or neutrons yield the same kind of interference pattern. In terms of the photon model, this looks bizarre. A wave can go through both the slits and recombine generating interference, but how can a particle go through both slits, sometimes expressed by saying that the photon went through both the slits – it was in two places at the same time! Bohr's interpretation goes like this. Think of the case when the photon goes through slit A as one possible world A and when it goes through B, world B. Both these worlds A and B have to be presently superimposed. We cannot say that the world of our experience is either A or B but is a genuine hybrid of the two. A significant factor to be mentioned is that the interference pattern is observed only if no attempt is made to determine which slit the photon has gone through. If this is done in the experimental arrangement, no interference is observed. This is illustrated in Fig. 1.4 for the delayed choice experiment where the screen is replaced with a venetian blind and two detectors A and B behind.

When the blind is closed, the detectors are not operative, and there is no way to know which slit the photon has gone through, and the usual interference pattern is observed. When the blind is open, the detectors can see the path of the photon, and