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A Galilean Answer to the Needham Question

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Résumé : Pour pouvoir la résoudre, nous généralisons la question posée par Needham : *Qu'est-ce qui a empêché la science gréco-romaine et médiévale de franchir la prochaine grande étape après Archimède, et qu'est-ce qui a empêché les savants orientaux de contribuer à la physique moderne des siècles encore après Galilée ?* Pour répondre à cette question, on propose comme distinction-clef entre physique moderne et science néo-galiléenne le droit d'inventer des concepts fondamentaux « illogiques », vérifiables par expérimentation. Ce droit se fonde sur la croyance en un univers régi par des lois fondamentales cachées, mais accessibles à la connaissance humaine. Cette croyance prend sa source dans la vision biblique du monde, qui devint le socle des cultures européennes à l'époque de la révolution scientifique à l'occasion de l'invention de l'imprimerie et de la Réforme.

Abstract: To make the Needham question answerable it is extended thus—*What hindered Greco-Roman and Medieval science from making the next major step after Archimedes, and what hindered Eastern scientists from contributing to modern physics for centuries after Galileo?* To answer this question the key distinction between modern physics and pre-Galilean science is suggested: the right to invent "illogical" fundamental concepts which can be verified by experiments. This right is based on the belief that the Universe is governed by hidden fundamental laws which Man is capable of knowing about. The source of this belief was the biblical worldview which became the basis for European cultures by the time of the Scientific Revolution thanks to book printing and the Reformation.

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1 Introduction

The strongest question on Galileo's role in history was put by the British biochemist and sinologist Joseph Needham:

> Why did modern science, the mathematization of hypotheses about Nature, with all its implications for advanced technology, take its meteoric rise only in the West at the time of Galileo? Why modern science had not developed in Chinese civilization [which in the previous centuries] was much more efficient than occidental in applying human natural knowledge to practical human needs? [Needham 1969, 16, 190]

Evidently he had in mind physics, since in his view

> [...] the birth of the experimental-mathematical method, which appeared in almost perfect form in Galileo, [...] led to all the developments of modern science and technology. [Needham 1959, 156]

So, Needham's "Grand Question" is to be coupled with the question: *What was the actual innovation of Galileo, that had changed science so much, accelerated its progress a hundredfold, though only in the West?* Hence, hereafter the term "*modern science*" means "*modern physics*".

2 An extended Needham question

By the time when Needham came to his heuristic question, the birth of modern science had already been named "the Scientific Revolution" and explained in a few ways: by needs of capitalist economy, by Protestant ideology, by "mathematization of nature", by contacts between scholars and craftsmen facilitated by the capitalist economy, etc. [Cohen 1994], but none of those explanations satisfied Needham [Needham 2000].

Indeed, all the achievements of the new physics had no economic value in the 17th century. All the greatest "revolutionaries"—Copernicus, Galileo, Kepler, and Newton—used both empirical and mathematical tools. Only two of them were Protestants. And in China contacts between scholars and craftsmen did not result in modern physics.

While the discussion about the Scientific Revolution continues with no consensus in sight [Cohen 2010], [Huff 2011], the Needham question was sometimes dismissed as a counterfactual question about a unique event [Sivin 1982]. However, Needham didn't ask why modern physics emerged in Italy rather than in England, and he would hardly have been so puzzled if Eastern scientists had contributed into modern physics in the 19th century. Anyway,

the Needham question is debated in China and in the West [Dun 2000], [Ducheyne 2008].

To make this question historically answerable, I will extend it in cultural time and space. Indeed, refuting Aristotelian physics, Galileo relied on "superhuman", "the most divine" Archimedes [Galilei 1590]. The new Galilean science was eagerly accepted in France, Holland, England, and even in backward Russia, but failed to reach beyond Europe for centuries, although medieval Europeans used to assimilate important Eastern innovations like Hindu-Arabic numerals. Arabic science adopted Greek science much earlier than the Europeans, advanced optics and astronomy, but did not contribute into post-Galilean science.

The real question is not why modern science emerged in the West at the time of Galileo but why it took so long since the time of Archimedes and why after the birth of modern science it was not adopted in Eastern civilizations for so long. So, an extended Needham question is:

> What hindered Greco-Roman and Medieval scientists from making the next major step after Archimedes, and why didn't Easterners contribute into modern science for centuries after Galileo?

To answer this question we are to find commonality among the cultures where the new (modern) science took roots and fructified, and to explain the timing of the Scientific Revolution and the social forces, which brought it about. We are to look not for a single cause, but for the decisive one. Some contributory causes—a system of higher education and Greco-Roman intellectual tradition—were present in Islamic civilization but it did not adopt the science of Galileo. And European universities had been around for four centuries before modern science was born.

3 Modern physics as a fundamental science

First of all, what is the key distinction between modern physics and pre-Galilean science? The scientific tools of experiment and mathematics are vital but not uniquely modern, since back in the 13th century Roger Bacon stated that "without experiment it is impossible to know anything thoroughly" and "no science can be known without mathematics" [Bacon 1268]. In fact, both of the tools were used by Archimedes, who was not only the first real physicist but also a great engineer and mathematician. Galileo's experiments and mathematics didn't go beyond what was feasible for Archimedes.

Of course measuring experiment and mathematics are indispensible tools to verify or disprove a theory expressed in quantitative language. But in modern physics no less important is the third tool, described by Einstein as "the boldest speculation [to] bridge the gaps between the empirical data"

[Einstein 1953]. Such a speculation results from inventive imagination rather than from mathematical or empirical inferences [Cohen 1995].

The real novelty of modern physics can be seen in the scheme depicted by Einstein in his letter of 1952 [Einstein 1993, 137] (cf. Fig. 1).

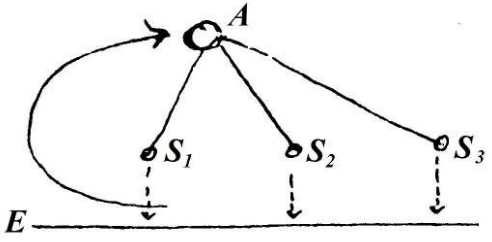

FIGURE 1. Einstein's explanation how modern physics works

In Fig. 1, *axioms* A—the fundamental concepts of theory—are invented by intuition taking off from the ground of experience E: the fundamentals are "free inventions of the human spirit (not logically derivable from what is empirically given)" [Einstein 1949]. Then some statements S_n derived from A are to be verified by landing in the E. And if the landing is soft, the theory is endorsed.

There is the key difference between Galileo's science and Archimedes' one and the principal similarity between Galileo's and Einstein's. In Archimedean physics all the notions are visible and tangible (weight, density, geometrical form), whereas in modern physics fundamentals do not have to be evident, and their validation is a result of the whole scientific enterprise joining theory and experiment. Einstein emphasized, that "concepts can never be derived logically from experience [...]. Unless one sins against logic, one generally gets nowhere" [Einstein 1993, 147], apparently meaning "against the logic of previous theory or common sense", since there is no other logic when a theorist's inventive intuition is just taking off.

The first "illogical" fundamental notion invented by Galileo was "vacuum", or rather "motion in vacuum". He defied the authority of Aristotle, who, as philosophers believed, had "logically proved" the nonexistence of void, or the vacuum [Galilei 1590, 34]. Galileo introduced "vacuum" as a *physical* notion, rather than a logical one. In logic, a notion is validated by pure reason, whereas in physics it is validated by *reason coupled with experience.*

To invent a new fundamental notion, a scientist has to believe that:

The Universe is governed by profound exact laws which are hidden like the foundation of a building [in Latin, *fundamentum*], but humans are able to probe into and comprehend these fundamental laws by inventing new concepts to be validated empirically.

Such a belief is the prerequisite, or *the postulate, of modern—fundamental—science*.

Human ability to comprehend the working of the Universe was a "miracle" for Einstein although he himself took part in such miracles. All the boldest inventions of modern science were encouraged by *fundamental* worldview coupled with *cognitive optimism*. It was the key novelty which let Copernicus initiate the Astronomical Revolution and Galileo invent modern physics [Gorelik 2012].

The boldest idea of Copernicus, which, in his words, "seemed absurd" [Copernicus 1543, 5], was to take a careful look at the planetary motions from the Solar point of view. Kepler's boldest idea was that all the planetary motions are governed by a fundamental law. For both of them, fundamental cognitive optimism supported laborious mathematical processing of their astronomical data, and they could be named *fundamental astro-mathematicians*.

Galileo became the first *fundamental physicist* by establishing the method of modern physics: believing in fundamental unity of terrestrial and celestial phenomena, he launched his boldest speculations by taking off from terrestrial physical experiments, invented the concept of "*motion in vacuum*", employed mathematical language and landed his speculations in the empirical reality of both terrestrial and celestial phenomena. He never experienced vacuum by his senses, but having compared motions in air and water, he felt free to invent the notion of vacuum as a "medium totally devoid of resistance" and came to the idea that in such a medium "all bodies would fall with the same speed" [Galilei 1914, 72]. It was the notion of invisible vacuum that helped Galileo to discover the law of free fall, the law of inertia, and the principle of relativity.

According to Needham, Galileo's "experimental-mathematical method" included, as a key element, "formulation of a hypothesis involving a mathematical relationship", and—just in a footnote—Needham mentioned "concepts of the unobserved and the unobservable" [Needham 1959, 156]. However, at the turning points in history of modern science, to formulate a new hypothesis a theorist had to invent a "concept of the unobservable" [Needham 1959, 156]. To formulate a rational hypothesis and to invent a somewhat "irrational" fundamental concept are quite different acts.

The next fundamental concepts invented in Galilean way were *universal gravity, electromagnetic field, quanta of energy, photons, curved space-time*, etc. Introducing a new fundamental notion a theorist usually has to dismiss some of the old ones, and it could be no easier than to accept the new notions. It was the Galilean way of making physics that became the main engine to propel the whole of science.

4 The source of fundamental cognitive optimism

Reflecting on making science, Einstein remarked: "one cannot build a house or construct a bridge without using a scaffolding which is really not one of its basic parts" [Einstein 1993, 147]. What kind of scaffolding did the first constructors of modern science use?

Copernicus began his heliocentric thinking being

> [...] annoyed that the movements of the world machine, created for our sake by the best and most systematic Artisan of all, were not understood with greater certainty by the philosophers". [Copernicus 1543, 4]

A half-century later, when Kepler was thinking about the same machine,

> [...] the very existence of general lawfulness of natural processes was not assured at all. How great must his faith in such lawfulness have been to give him the strength to devote decades of patient hard work to the empirical investigation of planetary motion and to formulate its mathematical laws! [Einstein 1930b]

To Kepler's mind

> [...] astronomers are priests of the highest God with respect to the Book of Nature, [they] do not promote the praise of the intellect but above all behold the glory of the Creator. He who is convinced of this does not easily bring to light anything other than what he himself believes, nor does he abruptly alter anything in [astronomical] hypotheses unless he hopes that from them the phenomena can be demonstrated with greater certainty. [Boner 2013, 40]

All the originators of modern science shared the faith in fundamental lawfulness and intelligibility of Nature, and it was this faith, as cognitive optimism, that encouraged their research and resulted in brand new scientific knowledge.

What was that encouragement? An inkling of the answer was found by Edgar Zilsel, who traced the usage of the phrase "physical law" and discovered that it emerged in the 17th century within biblical worldview as a transformation of the idea of the Nature governed by God's laws. Earlier, the notion "law" had only juridical and theological meanings [Zilsel 1942]. Galileo did not use the phrase "physical law" in his books. Instead, he used (Italian) words *ragione* [reason, ratio, proportion] or *principio* [principle]. The transformation began in Galileo's theological letters of 1613-1615, and here is a summary of his views:

> The Scripture and Nature both derive from God, the Scripture as His dictation, the Nature as the obedient executrix of His orders. The purpose of the Scripture is to persuade humans of those propositions which are necessary for service of God and salvation. To adapt to the understanding of unlearned people, the Scripture speaks many things which differ from the bare meaning of words, and it would be blasphemy to accept them literally by attributing to God human feelings like anger, regret, or forgetfulness. Nature, on the other hand, never transgresses the laws imposed upon her, or cares a whit whether her recondite reasons and ways of operating are understandable to men. God has endowed us with senses, language, and intellect not to bypass their use and give us by other means the knowledge we can obtain with them. Therefore, whatever sensory experience and necessary demonstrations prove to us concerning natural phenomena, it should not be questioned on account of Scripture's words which appear to have a different meaning. This is especially so for those sciences about which we can read only very few words in the Scripture which does not contain even the names of all the planets, and so it was not written to teach us astronomy. [Galilei 1613-1615]

In short, there are unbreakable laws of the abstruse reasons in Nature, and humans are able to comprehend them. This is actually the postulate of the fundamental science (formulated in chap. 2).

By the end of the 17th century Galileo's "laws imposed upon Nature by God" transformed into seemingly secular "laws of Nature", due to influential writings of Descartes and Newton. Since then the term was used by both believers and nonbelievers, and by the 20th century its biblical origin had been forgotten.

For a Marxist atheist, Zilsel, "the law-metaphor originates in the Bible", but for the theistic originators of modern science most ways to talk about God were metaphorical. The origin of the expression "physical law" reveals the role of biblical worldview in their mentality and hints at the connections between the postulate of fundamental science and the basic biblical ideas/images of God who created the lawful Universe for the humankind, and of humans made as His likeness with the purpose to rule over all the Earth.

Such supernatural wording sounded quite natural for the originators of modern science, all of whom were true believers: Copernicus was a cleric, Galileo and Kepler in their adolescence intended to become clerics, and Newton wrote about the Bible more than about physics. All of them were profound biblical theists, thought in religion as freely and boldly as in science, and felt free to interpret the Bible by themselves. Basing their religious thinking on their understanding of the Bible, they came to be at odds with Church canons:

Galileo could not accept the Pope's opinions as final truths; Newton could not accept the doctrine of the Trinity.

The faith in the Creator-Lawgiver and in humanity as His purpose, together with experience of faith as "the conviction of things not seen", encouraged the originators' "*boldest speculations*" to invent new invisible fundamentals to gain the knowledge about "all the Earth" to be able to rule over it.

The same faith was expressed by the third great inventor of invisible fundamental (electromagnetic field), Maxwell, who wrote to his friend:

> [...] Christianity—that is, the religion of the Bible—is the only scheme or form of belief which [makes an explorer free indeed]. You may search the Scriptures and not find a text to stop you in your explorations.[1] [Campbell & Garnett 1884, 96]

The fourth fundamental inventor was an openly religious person [Planck 1950], and according to the fifth one:

> Our moral leanings and tastes, our sense of beauty and religious instincts, are all tributary forces in helping the reasoning faculty toward its highest achievements. [Einstein 1930a, 375]

Of course, there were atheists back in the time of Archimedes, as well as in the 17th century (an atheist, astronomer E. Halley, was a colleague and friend of Newton), but there were no atheists among the originators of modern science.

5 Modern science in the biblical civilization

Returning to the extended Needham question, we can see the commonality between the countries where Galilean science did take roots, or, rather, the commonality between these countries' sociocultural minorities from which the future scientists emerged. All the would-be scientists had to be readers. By the 17th century, the most widely read book in Europe was the Bible, as a result of Gutenberg's invention, Reformation, and the print explosion. Since then the Bible became the most influential text for European cultures as different as Italian and Scandinavian, British and Russian. It was the main common factor uniting all these cultures into modern European civilization, which therefore could be called *the biblical* one.

1. A prayer found in Maxwell's papers reads: "Almighty God, who hast created man in Thine own image, and made him a living soul that he might seek after Thee and have dominion over Thy creatures, teach us to study the works of Thy hands that we may subdue the Earth to our use, and strengthen our reason for Thy service [...]" [Campbell & Garnett 1884, 160].

There were a few correlations between the history of modern science and the sociocultural role of the Bible. The first correlation between religious and scientific postulates was revealed back in the late 16th century by missionaries who brought to China both the Bible and European science. The Chinese emperor welcomed missionaries, but they failed to implant the European science into Chinese soil. One of the later missionaries explained:

> The Chinese atheists are not more tractable with relation to Providence, than with regard to the Creation. When we teach them that God, who created the universe out of nothing, governs it by general Laws, worthy of his infinite Wisdom, and to which all creatures conform with a wonderful regularity, they say, that these are high-sounding words to which they can affix no idea, and which do not at all enlighten their understanding. As for what we call laws, answer they, we comprehend an Order established by a Legislator, who has the power to enjoin them, to creatures capable of executing these laws, and consequently capable of knowing and understanding them. If you say that God has established Laws, to be executed by Beings capable of knowing them, it follows that animals, plants, and in general all bodies which act conformable to these Universal Laws, have a knowledge of them, and consequently that they are endowed with understanding, which is absurd. [Needham 1969, 308]

It was absurd for those who did not believe in the biblical Creator-Lawgiver. The most alien for non-biblical cultures is the notion of Man made as God's likeness to rule over all the Earth. Islam, being the closest to biblical tradition historically and geographically, rejects the biblical status of Man, since the Quran states: "Nothing is as God's likeness" [Michot 2005]. On the other hand, in mainstream Islam, after Al-Ghazali's "renewal of the faith" in the 12th century, the very idea of unbreakable fundamental laws of Nature was considered incompatible with the omnipotence of God, and the decline of the Islamic Golden Age of science followed [Hoodbhoy 1991, 105].

In the time of the quote about the "Chinese atheists" (1737), a young Russian, Mikhail Lomonosov, a fisherman's son, after having graduated from the Slavic-Greek-Latin Academy in Moscow, was getting education in Germany. Then he returned to Russia and became the first prominent native Russian scientist. On his path to science he overcame many barriers, but among them there were no Chinese or Islamic ones. Like Galileo and Newton, Lomonosov was a biblical theist and happened to be at odds with clerical officialdom. He greatly contributed into higher education in Russia and European ways to do science. A result was the first Russian world-class achievements like Lobachevskian geometry and Mendeleev's periodic table. Thus, modern science took roots in Russia with no native scientific tradition, but failed in China, India and the Islamic world, whose innovations in science and technology Europe assimilated up until the 16th century.

To explain the European birthplace of modern science, the factor of Christian culture was employed more than once. However, by the time of the Scientific Revolution Christianity had been around for sixteen centuries. The medieval Church taught mainly about the corrupted state of humanity after the Fall of Man, rather than about human dignity and freedom endowed by God. The key new factor of modernity emerged in the 16th century due to book printing and Reformation, when the Bible became socially much more accessible and a very powerful guide. This guide made clear that human fallibility was an element of divinely endowed freedom of Man. So, this social factor correlated with post-Gutenberg time and European space of the Scientific Revolution.

Another correlation manifested in the shifting of leading role in modern science from scientists of Catholic background to those of Protestant one. This shift, discovered by A. de Candolle in 1870s and emphasized by R. Merton in the 1930s [Cohen 1990], could be explained by quite different roles of the Bible in cultures of the two denominations, rather than by theological differences. The principle "*Sola Scriptura*" made the reading of the Bible the central factor in Protestant culture, whereas Catholic Church discouraged the laity to read the Bible on their own. In the 20th century, de Candolle's disparity is supported by the statistics of Protestant *vs.* Catholic backgrounds of Nobelists, about 8:1 *per capita*.

Some pre-Guttenberg clerics who did read the Bible, such as Robert Grosseteste and Roger Bacon, manifested that biblical theology was quite compatible with a genuine interest in natural sciences, though it was too much for a cleric to concentrate on physics.

Any belief is a preconception, but it can be more or less influential, helpful or harmful. The biblical preconceptions, inculcated by accessible vernacular translations of the Bible, proved to be very helpful for exploring Nature (as well as for advancing technology and economy).

The key factor was the basic belief in divine human purpose in the divinely lawful Universe, rather than the array of theological subtleties, different in Christian denominations. Of course, just reading the Bible didn't make a scientist out of any person, but for *religious* adolescents amply endowed with pro-scientific abilities—intellectual curiosity, independent insight and persistence (like the pioneers of modern science)—the key biblical preconception informed their cognitive optimism. At the same time, laconic biblical stories provoked questions in truth seeking, even if led to question the Church's canons. That was why medieval churches stood against making vernacular translations accessible to laity.

Thus, the biblical answer to the Needham question explains also other factual correlations: the time and space of the Scientific Revolution, theism of its originators, and the disproportion of scientists of different religious backgrounds.

There is, however, another important fact—prevailing atheism of scientists in the 20th century [Larson & Witham 1998].

6 Scientific thinking and religious feeling

In Einstein's words, "In the temple of science are many mansions, and various indeed are they that dwell therein and the motives that have led them thither" [Einstein 1918]. Different also are the types of problems that attract theorists of different mental styles, such as "birds" and "frogs" [Dyson 2009].

The difference between "intuitive" and "analytical" styles helps to understand the role of theists in originating modern physics and to see a room for atheists' contributions. The quoted Einstein's scheme of making modern science includes three phases of scientific enterprise, or three kinds of problems to solve:

1. to invent new fundamentals-axioms ($E \Rightarrow A$),
2. to derive from them specific testable statements ($A \Rightarrow S$), and
3. to test these statements empirically ($S \Rightarrow E$).

Only the first phase requires an intuitive "leap of faith". The other two phases require creative using of the new fundamentals and devising new experiments. So, atheists, like L. Boltzmann, P. Dirac, S. Weinberg, have enough room for creativity. In fact, this room is much bigger than one for the first phase: it takes just one or very few persons to blaze a new trail into unexplored territory, but it takes many people to develop a trail into a highway (of applied science and technology).

All the three phases are necessary to accomplish a cycle of establishing a new fundamental theory. To start a new cycle in the expanding spiral of quest in modern science, a new leap of inventive intuition is necessary. However, in the very first cycle, in the 17th century, when inventing new fundamentals had no precedent, the Einsteinian "free inventive spirit" needed unprecedented support, which was provided by scientists' spiritual/religious faith.

According to Harvard psychologists, personal theistic belief correlates with intuitive (*vs.* analytic) cognitive style rather than with such factors as education level, IQ, and familial religiosity [Shenhav, Rand *et al.* 2012]. So, the power of a physicist's intuition could be responsible both for his theism and for his type of creativity.

An additional source of creative successes in modern physics was the paradoxical combination of cognitive audacity and personal humility.

Exploring Nature's "recondite reasons", Galileo found himself in a sea "with vacua and infinities" and questioned his ability to reach dry land. He believed, nevertheless , that it was "possible to arrive at the true and primary causes" of natural phenomena and perceived his work as "merely the beginning,

ways and means by which other minds more acute than [his] will explore remote corners" of the "vast and most excellent science" he had just opened up [Galilei 1953, 485], [Galilei 1914, 44, 153–154]. The same humble audacity could be seen in Newton who likened himself to a boy on the seashore, who had found a few smooth pebbles, with the sea of undiscovered truths before him.

Such a combination of bold creativity and personal humility in Galileo and Newton stemmed apparently from their belief in biblical connection between Almighty Creator of the whole World and mortal humans made as His likeness to rule over all the Earth. To be able to rule over the world, humankind has to explore the world to understand how it works. It was the occupation of Galileo's successors, who invented new fundamentals of science. Even in the 20th century the effectiveness of physics seemed miraculous to Einstein and unreasonable to E. Wigner [Einstein 1993, 131], [Wigner 1960]. It was much more unreasonable four centuries ago, when no fundamental law of physics had been discovered.

Well known are both Einstein's credo: "Subtle is the Lord, but malicious He is not" and Bohr's apparently secular saying that a new fundamental theory which is not crazy enough has no chance of being correct. Both ways to encourage a theorist are based on the *belief* in the right to invent "crazy" fundamentals to comprehend the lawful Universe.

Cognitive optimism complemented by personal humility corresponds to the golden mean between a belief in Full and Final theory of Everything and the disbelief in the fundamental lawfulness of the world. As F. Dyson put it:

> If it should turn out that the whole of physical reality can be described by a finite set of equations, I would be disappointed. I would feel that the Creator had been uncharacteristically lacking in imagination. [Dyson 1988]

Einstein had

> [...] found no better expression than "religious" for confidence in the rational nature of reality insofar as it is accessible to human reason. Wherever this feeling is absent, science degenerates into uninspired empiricism. [Einstein 1993, 119]

If, in the 20th century, eloquent and religiously unaffiliated physicists choose theistic wording to express their cognitive belief, apparently it is the most adequate wording, and the root of this belief was indeed theistic. It is supported by theism of all the founders of modern physics. Their preconception of personal freedom and cognitive optimism of Godlike creative creatures—an idea of biblical descent—transformed into a "self-evident" secular worldview.

The secular nature of scientific knowledge was most clearly expressed by a Catholic priest and astrophysicist Georges Lemaître, who discovered the expansion of the Universe and suggested that it began with the explosive birth. Thirty years later (and two years before becoming the President of the

Pontifical Academy of Sciences) this astrophysicist in soutane, at a conference on astrophysics, stated that the theory of Big Bang

> [...] remains entirely outside any metaphysical or religious question. It leaves the materialist free to deny any transcendental Being. [...] For the believer, it removes any attempt at familiarity with God [...]. It is consonant with the wording of Isaiah speaking of the "Hidden God", hidden even in the beginning of creation [...]. There is no natural limitation to the power of mind. The Universe does not make an exception, it is not outside of its grip. [Lemaître 1958, 7]

Whereas the results of scientific quest are indeed metaphysically neutral, the motive vigor of research results from specific metaphysics, or, rather, from pre-physical belief that "there is no natural limitation to the power of mind", that the Universe is fundamentally lawful, and that free humans are capable of discovering those laws. Lemaître's religious feeling was as compatible with his scientific thinking as it was for Einstein and Galileo.

7 Secular fruits of religious culture

Compatibility, however, is too weak a word to describe the connection between modern science and biblical metaphysics/prephysics. Dignity of free Man as the purpose of God's creation was the basis for the manifesto of early modern humanism "On the dignity of Man" (1486) by Pico della Mirandola. He put the following words into the mouth of "God the Father, Supreme Architect of the Universe" after his "last creative act":

> We have placed you [Man] at the world's center so that you may survey everything else in the world. [Pico della Mirandola 1486, 261]

This manifesto as well as Pico's critique of astrology had been published before Copernicus started to think about astronomy.

Just like the European arts and humanities owe so much to biblical images, stories and ideas, the most rational and empirical domain of human knowledge—modern physical science—also appears to have biblical roots. Due to the Printing Revolution and the Reformation, the Bible informed the cultural background of the modern Western civilization, including atheists, who relied on their *self-evident* personal freedom secured by law. In fact, they assimilated their cultural postulates in their cultural upbringing, even if in their adulthood, they believed they needed no metaphysical—or, rather, pre-physical and pre-ethical—support. Those *biblical atheists* could hardly see the biblical stories as the reason to accept any belief but they could appreciate the Bible as a *historical* source of humanitarian postulates. These atheists may

be the most selfless children of the biblical civilization, since they adhere to the central biblical tenet without rational natural substantiation and without irrational hope for supernatural approval. Religion used to be instrumental in changing culture to be later shared by both believers and unbelievers.

The biblical view on human freedom developed into the idea of freedom of conscience via separation of Church and state and into the notion of unalienable human rights, which was constitutionally self-evident to the founders of the United States. One of them, Thomas Paine, rejected all the churches as tools to enslave mankind, but, in his book *The Rights of Man*, to answer the question "What are those rights?" he referred to "the Mosaic account of the creation, whether taken as divine authority or merely historical" [Paine 1791, 49]. This argument, however, could be strong only for those whose upbringing was as biblical as it was for founders of the United States.

The history of modern Western view on human rights is similar to the transformation of Galileo's "laws imposed by God upon Nature" into the secular "laws of nature". Biblical preconception of unalienable rights of Man resulted in the Universal Declaration of Human Rights (1948) which became a social framework for all cultural traditions compatible with human dignity.

Western civilization was open to Eastern cultural innovations since premodern time. As to openness of other civilizations, exemplary was the medieval Islamic Golden Age when actual separation of science/philosophy and mosque let adherents of various faiths to freely cooperate. In the 20th century, a few Far-Eastern countries assimilated Western technological and social innovations.

8 Conclusion

In the 21st century two Chinese historians have made an assessment:

> Compared with the huge system of universities and research institutes and the large number of researchers in contemporary China, the quantity of original scientific work accomplished is embarrassingly small

and asked: "What is responsible for this situation?" [Hao & Cao 2009]. It looks like a sign of intellectual freedom, which is indispensable for advancing science. If China is to catch up with the West in fundamental science without assimilating the idea of unalienable human rights, it will invalidate the suggested answer to the Needham question. And there is a real problem waiting for invention of new fundamental concepts,—the problem of quantum gravity. It remains unsolved a century after Einstein had discovered it, 80 years after Matvei Bronstein (1906-1938) predicted that its solution might require "the rejection of our ordinary concepts of space and time, replacing them by some much deeper and nonevident concepts" [Gorelik 2005], and after thousands of articles on the subject in the last fifty years.

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