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To Hal with kindest regards

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Galileo's trial in the epistemology of einstenian physics

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GALILEO'S TRIAL IN THE EPISTEMOLOGY OF EINSTEINIAN PHYSICS

The circumstances of the last trial of Galileo, in 1633, have been extensively exploited by various vested interests. Now at the occasion of the quatercentenary jubilee, we will re-examine the struggle represented by the Ptolemaic and Copernican systems for a new scientific outlook. This will be developed from the position of a physicist and a philosopher. The historian may sometimes be subjected to various loyalties and is not always able to objectively analyze the nature of the impact of human thinking brought about by Copernicus or Galileo. This collision of ideas was so electrifying that it created conditions for the birth of a new science. The old speculative philosophy that started with the premise of aprioristic truth was to be progressively replaced by a new experimental, empirical science, based upon aposterioristic truth. In this new light even history may be interpreted as an experiment. Thus, Galileo's trial will not be considered as a controversial division between two ideological or political groups but will be observed as an experimental incident providing cumulative experience of a growing civilization. As such, it must remain as a beacon for guidance in our age.

For natural, chronological reasons historians will readily associate Copernicus with Galileo, Kepler or even Newton. The physicist and astronomer, however, will see Copernicus easily projected back no less than 1500 years, intellectually more closely linked with Ptolemy or even with Hipparchus or Aristarchus of Samos from the second and third century B.C. The question then arises, how much more advanced was the defense of the heliocentric system by Copernicus than by Aristarchus? (1) Was Galileo's defense of the Copernican system flawless as historians would have us presume from their traditional dramatic presentations of the trial? At first it may appear disconcerting or even absurd in this twentieth century to consider the defence of the Copernican or Ptolemaic system. Surely everyone knows that the earth turns and moves. Actually, this is only hazy information, imparted upon the mind much as a statement is impressed upon a phonograph record. As a valid scientific fact, it is not a direct, individual experience.

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(1) T. L. Heath, *Aristarchos of Samos*, Oxford 1943.

The immovable world, the earth at rest, still remains our only direct experience. Until the rotation and revolution of the earth become part of our direct sense perception, the problem of the motion of the earth from the empirical point of view will continue to exist.

So far, we have not adapted our colloquial habits to the Copernican scheme. Our dictionary remains Ptolemaic as we keep repeating « the sun is rising or the moon is setting. » Countless millenia of deeply ingrained tradition and direct evidence cannot be easily replaced by complicated, indirect proof of the earth's motion such as the popular Foucault's pendulum experiment. Copernicus merely justified the logic of his system in the realm of speculative philosophy. Half a century later, Galileo emerged as the first reasonable defender of the Copernican viewpoint in the domain of his new experimental science. Nor did he prove the heliocentric system in any experimental way. His various experiments, particualrly his impressive and sensational telescopic discoveries, offered only indirect evidence for the soundness of the Copernican scheme. Thus, he pleaded very eloquently for this system and the rotation of the earth, maintaining that the experiments intended in the realm of philosophical speculation. It is in this work however that Galileo appears as a great forerunner of modern relativistic physics. As Galileo attempts to confute the arguments brought against the heliocentric system and the rotation of the earth, maintaining that the experiments intended to demonstrate the absence of this movement had no importance, he draws a genial, relativistic picture of what goes on below the deck of an evenly moving vessel. (3)

The Foucault pendulum experiment performed as late as 1851 is usually considered a most excellent, objective and laboratory demonstration of the earth's rotation. In the language of relativistic reversibility of inertial systems, neither Bradley's discovery of the aberration of light in 1727 nor Bessel's measurement of the first stellar parallax in 1838 were experimental proofs of the earth's revolution around the sun. According to the relativity of motion, parallactic ellipses, the existence of which Tycho Brahe demanded as his condition for the acceptance of the heliocentric system, do not prove the earth's movement around its central luminary. In fact, this earth's movement, or rather just the movement through the « ether » which fills cosmic space, actually failed in the negative result of the famous Michelson-Morley's experiment in 1887. (4) A few years later, through the Lorentz-Fitzgerald contraction, Einstein followed up this « failure » and consequently opened

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(2) G. Galilei, *Dialogo sopra i due massimi sistemi del mondo Tolemaico e Copernicano*, Milano 1811.
(3) *Ibid. Second Day*, pp. 411-412.
(4) Michelson and Morley, Silliman Journal, Vol. 34, 1887, p. 333, 427; Phil. Magazine, Vol. 24, 1887, p. 449.

up the new vast realms of his revolutionary principle and new relativistic physics. Under these new conditions the problem of the earth's motion, with remarkable approximation, moves back into the field of philosophy and geometry, where it was in pre-Copernican years.

Thus, in the age of Einsteinian physics, the defence of either of the two world systems is not an anachronism, for it still remains more a question of philosophy in addition to that of experiment. Relativistic physics tempered the controversy between the Copernicans and Ptolemaists which once shook the foundation of the intellectual world. From this new point of view, the challenge of some of Galileo's scholastic opponents was not unreasonable whether or not they were aware of it and the state of Galileo's physics did not always place him in position to face his adversaries forthrightly.

The first who confronted the problem seriously was the intellectual giant, Ernst Mach. He maintained that only observable phenomena should enter into the laws of an empirical science such as physics. Thus, if you consider the earth in the state of rest or in the state of motion, the observable phenomena will be exactly the same. When Newtonian mechanics was in position to explain Foucault's pendulum and the flattening of the earth at the poles but not the revolution of the heavens, Mach saw in it a defect in Newtonian dynamics. Mach, as a serious critic of Newtonian mechanics, advocated that empirical science should not contain a metaphysical assumption which can never be proved or disproved by observation, and by observation we can never distinguish the rotation of the earth from the revolution of the heavens.

It was only with the beginning of the twentieth century, when with Einstein new light was shed upon the relativity of motion, that the Copernican system was revised by penetrating minds to a degree of shocking radicalism and heresy. In 1906, the respected mathematician-astronomer, Henri Poincaré, wrote in his « La science et l'hypothèse »: ([5])

> « Let use resume our fiction: thick clouds hide the stars from men, who cannot observe them and are ignorant even of their existence; how shall these men know the earth turns around? Even more than our ancestors, no doubt, they will regard the ground which bears them as fixed and immovable; they will await much longer the advent of a Copernicus. But in the end the Copernicus would come — how? »

This statement was evidently an aftermath of a much heated discussion in 1904 when Henri Poincaré was compelled to reply to press attacks in a letter to Camille Flammarion, editor of the Bulletin of the French Astronomical Society. ([6]) Here he asserted that the rotation of the earth is not a

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([5]) H. Poincaré, *La science et l'Hypothèse*, Paris 1933, p. 139.
([6]) H. Poincaré, *La Terre tourne-t-elle*, « Bulletin de la Societé astronomique de France », Vol. XVIII (1904), p. 216.

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fact because, according to definition, « un fait est le résultat brut de l'experience. » Only a few years before this incident Ernst Mach stated: (7)

> « The movements in the world system are relatively the same according to both, the Ptolemaic or the Copernican conception, if we do not consider the unknown medium of cosmic space. Both interpretations are equally correct, only the Copernican is more simple. »

These considerations, illustrating the character of the rising relativistic physics, bring us to such serious opponents of Galileo as Riccioli. Actually Copernicans did not try to prove the movement of the earth neither by mathematics nor by physical reasons but merely by the fact that their hypothesis better explained celestial phenomena. In fact, after its publication in 1543, Copernicus' work « De orbium » was not placed on the Prohibitory Index until 1616, and then principally because of Galileo's outspoken public defence of heliocentric ideas. By Bellarmine's reproach, the inquisitorial congregation made more or less discreet demand on Galileo to forsake the Copernican system as a reality. Indeed, Galileo in this case over-rated his telescopic observations of celestial phenomena in submitting them as popular proof of the reality of the heliocentric world system. This gave the wiser members of the Holy Office grounds for serious objections. What Riccioli wrote during Galileo's time is really significant and epistemologically does not differ from such contemporary statements as those of Mach or Poincaré: (8)

> « If we consider celestial phenomena, we can explain both hypotheses equally well on mathematical and astronomical grounds, and so far proof pertaining to celestial phenomena has not been found which would safely demonstrate either the veracity of the one or the falsity of the other. »

Likewise, again more recently, Rudolf Wolf raises a similar objection: (9)

> « The Copernican system lacked the fundamental proofs; moreover direct sense experience even opposed it, after all, the explanation of the celestial phenomena from this new point of view was not more precise. »

These statements in no way oppose the new physic point of view and therefore, today, we realize that particularly for its own age, the Copernican view could only be an hypothesis.

Following this line of thought, the prudential introduction Osiander wrote for the first edition of Copernicus' « De orbium » most appropriately coincides. Preferably quoted in its original, it states:

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(7) E. Mach, *Die Mechanik in ihrer Entwickelung, historisch-kritisch dargestellt.* Leipzig, F.A. Brockhaus, 1901, p. 343.

(8) A. Linsmeier, Riccioli's Stellung im Galileistreit, Natur und Offenbarung, 1901, 47 Bd.

(9) Wolf, Rudolf, *Geschichte der Astronomie*, München, R. Oldenburg, 1877.

« Neque enim necesse est, eas hypotheses esse veras, imo ne verosimiles quidem, sed sufficit hoc unum, si calculum observationibus congruentem exhibeant. »

Osiander thus reveals a very important as well as an entirely modern view, both pragmatic as well as relativistic, that it is neither necessary an hypothesis be true nor even probable but that it is sufficient if it renders calculation consistent with observation. Indeed, this is a remarkable idea although highly premature for the trend of the first Copernicans. If we substantiate the motion of the earth today, we include into our consideration the principle of economy and simplicity of nature. Reference to this simplicity in support of the Copernican view as an hypothesis was made in Ptolemy's as well as in Galileo's time. Therefore, Osiander's words are unusually interesting, and, as A. Dittrich points out: (10)

« Osiander anticipates the standpoint, which we today call pragmatic according to the synonymous philosophy of American origin. At the present time, however, under the influence of the special theory of truth which pragmatism has secured, it is to the very hypothesis 'si calculum observationibus congruentem exhibeant' that we attach the honorary assignment of being 'veracious'. »

Hence, we can maintain that both systems are of relatively equal value, the Ptolemaic pragmatically conforming instantly to direct observation and sense perception. In the time of Copernicus and Galileo, the geocentric system was even more acceptable, when not only Newton's works were non-existent, but Kepler's discoveries were only slowly infiltrating, and Galileo, although in personal correspondence with Kepler, evidently was not aware of the great importance of his famous introduction of elliptical orbits.

There is another relativistic angle of significant interest in the Ptolemy-Copernicus transition. When Copernicus moved the sun into the center of the system, he discarded the principal epicycle of each planet but had to keep the remaining epicycles primarily because he adhered exclusively to circular motions as did the ancient philosophers. Therefore, with this expression of movements, Copernicus got no farther than did Ptolemy. Copernicus tentatively explained these movements from the eccentric deferents around which one epiycle rotated in the case of a planet and two in the case of the Moon. From this it is evident that he displayed a tendency to divide celestial movement into its epicyclic components, known today as Fourier's series. It was indeed a genial idea for Copernicus to seek the exact spatial definition of celestial orbits, later attained by Kepler. Copernicus desired to do this by means of the resolution of a given movement into a

(10) A. Dittrich, Geometrická rovnocennost svetové soustavy Ptolemaiovy, Kopernikovy a Tychonovy. Rozhledy matematicko-prírodovědecké, Praha 1923.

series of circular motions, in which Fourier also later succeeded. Consequently A. Dittrich is able to state: ([11])

> « If our intellect, according to Fourier, were able to decompose periodical movements as automatically as the hearing does the sound, then no one should complain about the complexity of epicycles. Under these circumstances, celestial movements would be as well 'explained' as they were by the Greeks who called the resolution into a few epicycles as 'the saving of appearances' (Diasozein ta fainomena). »

This indicates we cannot overlook the explanation of celestial phenomena by means of epicycles, especially from the point of view of relativistic ideas on movement, according to which movements of both systems are equivalent.

To this effect, analyzing relative and absolute movement, Henri Poincaré raises the question as to how Copernicus would confront the case, were our sky continually covered with clouds and we knew nothing of the stars. He states: ([12])

> « And just as our Copernicus said: It is more suitable to assume the rotation of the earth because we thus can formulate much more simply the laws of astronomy, so even today he would tell us: It is more convenient to assume the rotation of our earth because in this way we are able to express the laws of mechanics in much more simple language. »

Then to say « the earth rotates » and « it is more convenient to assume that the earth rotates » is one and the same thing. If there is a question of the absolute movement of the earth, there is no preference in the movement of either the first or the second systems.

Consequently, from these considerations in terms of the theory of knowledge of relativistic physics, Galileo's trial appears in an entirely new light. Some objections raised against Galileo's standpoint, particularly those of Riccioli, were entirely reasonable. Neither side, however, had really solid foundation, yet both had their justifications and fallacies. The real point of dispute concerned not so much the novelty of the Copernican system as it did the more serious danger arising from Galileo's experimentation which menaced the authority of scholastic philosophy. In this Galileo founded an inseparable bond between reason and observation and made it subject to strict positive rules. Similarly, Alexander Koyré advocates that the real controversy was not so much between Ptolemy and Copernicus as was the

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([11]) A. DITTRICH, Epicyl jako prostredek k ovládnutí libovolného pohybu periodického. Časopis pro pěstování Matematiky a fysiky, Praha, vol. IV, 1924.
([12]) H. POINCARÉ, *La Science et l'Hypothèse*, Paris 1923.

justification of a mathematical over a non-mathematical physics. ([13]) To a considerable extent, the Copernican revolution and its defence by Galileo played a role similar to that now being performed by Einstein's principle of relativity — it shattered the ancient conceptions of the world, thus creating an impression of refuting traditional scientific thought as now conceived in the form of classical Newtonian physics. It demonstrated primarily that sense perception was misleading in the most common astronomical phenomena.

In conclusion, reviewing the panorama of the most dramatic chapter in the history of the evolution of physics once enacted around the difference between two world systems — Ptolemaic and Copernican — culminating in Galileo's trial, that difference has now vanished in the language of the epistemology of modern physics. As schools of thought, both doctrines are evolutionally blended and inseparably wedged, one with the other, with no trace of any definite boundary existing between them. If we enjoy the benefit of calm examination of the once heated dispute, it is because we are able to emphasize conclusively that the Copernican system is merely the Ptolemaic doctrine nurtured in the soil of the heliocentric idea. Above all, however, it is Ernst Mach, direct forerunner of relativistic physics, who, with his phenomenological point of view and with his empiriocriticism has created a bridge that transformed the conflict into a magic stepping stone in the growth of our physical science and man's understanding of the nature of the universe. Thus, the principal experience acquired from the study of the motion of the earth has taught us among other things to be critical of direct sense perception, now especially facing the vast new continent of microcosmos of relativistic physics. Or, as Philipp Frank, the outstanding student of Ernst Mach stated, ([14]) the Copernican doctrine and the Galileo conflict give us an excellent opportunity to teach the student the distinction between statements which are descriptions of observable facts and statements which describe a way of speaking.

Ernst Mach's philosophy which consisted in the denial of any other reality apart from our sensation leads us back through Berkeley to Protagoras. We can at will observe nature, measure it, ponder it, but it always remains our impression. Perhaps that is why Henri Poincaré maintains that the earth's motion is not a scientific fact because it is inobservable. Hence, Galileo's arguments are a matter of philosophy. In Protagoras' words, man is the measure of all existing things. ([15]) Thus, even natural science was unable to overcome enduring anthropomorphism.

([13]) A. Koyré, *Galileo and Plato.* Roots of Scientific Thought. Ed. by P.P. Wiener and A. Nolan, New York 1957, pp. 147-175.

([14]) P. Frank, *Intercommunication Between Science and Philosophy.* From the address in the Conference on Science, Philosophy and Religion, New York 1945

([15]) L. Diogenes, IX, 51.