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## The last paper by Ettore Majorana: An analysis

### (1) Introduction

Ettore Majorana was one of most great Italian physician of last century. He was born in a small town near Catania<sup>1</sup> the 5 of August 1906 into a family where studies were old friends, also if in economic more than in scientific field.

His grandfather, Salvatore, was a famous scholar of economy and society, and he was a deputy too. Several Ettore's uncles were scholar and politic men and, among them, Angelo was Minister of Finance in some Italian Government in 1905 and 1906 (prime Minister was the very famous Giovanni Giolitti). Another uncle, Quirino was, instead, a good experimental physician. Ettore Majorana, after to have attended secondary school in a college in Rome, entered university in that city but he didn't entered faculty of Physics but faculty of Engineering. He attended second class when a fact happened that had to modify his life, the life of many colleagues of him and whole history of Italian Physics.

Through Orso Mario Corbino's good offices was set up the chair of Theoretical Physics in Rome with professor Enrico Fermi, future Nobel Prize winner for the Physics in 1938. The presence of a so prestigious scholar in a so important University offered the possibility to create a real school of theoretical physics in Italy and Corbino invited those engineering students particularly good at Math and at theoretical study to move from Engineering to Physics.

Majorana was one of those, was able to resolve complex differential equations by heart, and together to other, among these future Nobel Prize winner in 1958 Emilio Segré and Giovanni Gentile ir. moved to Physics.

Enrico Fermi knew him as a true talent, was his supervisor and taught him in his team. Majorana published his first paper already in 1928 about some atomic spectroscopy questions.

The follow of his scientific activity is a part of history of physics. Majorana published few papers (just ten) but he broached and resolved in original manner some of the most important nuclear and sub-nuclear physics questions treated in whole last century. He became full professor of theoretical physics in Naples University in 1937 without to take examination because, as certified by official documents,<sup>2</sup> competition board suggested:

to appoint Majorana as full professor of Theoretical Physics in a University of the Italian kingdom, for high and well-deserved repute, independently of the competition rules.

Let's remind Majorana:

- studied the effect of an oscillating magnetic field over atomic spectrums discovering an effect, till today called Majorana–Brossel effect. An expansion of these studies, already indicated by Majorana himself, it's the base of every technique used for tipping atomic and neutron spins;
- studies the forces among nucleons and elaborated a model of them, based over exchange forces later on called Majorana forces, alternative and more efficient of another model developed by Heisemberg;
- studied a method to resolve Dirac equation, different respect to Dirac's one, forecasting the presence of so-called "Majorana neutrinos" or rather uncharged fermions coinciding with their antiparticles. These neutrinos have been never detected. but they are researched and studied till today;

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<sup>1</sup> See E. Recami, *Il caso Majorana (The Majorana affair)*, Di Renzo Ed., Roma, 2001.

<sup>2</sup> As written in competition board minutes reported in fn. 1.

- searched for an equation describing particles with spin greater than  $\frac{1}{2}$  and found an equation describing arbitrary high (also infinity) spin particles.

Then competition board suggestion was accepted and Majorana taught the chair of Theoretical Physics in Naples but, after few months of teaching, it started his more famous event.

## (2) The disappearance

The 25 of March 1938 Ettore Majorana sent letters<sup>3</sup> showing clear suicidal purposes to family and to Director of Physics Department. In the same day he taught ferry going from Naples to Palermo, but, here arrived, wrote another letter to Director telling he didn't kill himself (exact words "the sea didn't want me") but clearly stating to want once and for all to give up teaching. It seems, here hypothesizes start, that he taught ferry to return to Naples. Of course, since then Majorana is disappeared and found never any sign of him. Some people have affirmed to have seen him in Naples several days after disappearance<sup>4</sup>, others have seen him several weeks after to hide himself in the mountains of Cilento,<sup>4</sup> others have identified him in a person who presented himself in a monastery asking for doing "experiment of religious life".<sup>5</sup>

Several sources talked he was escaped in Argentina where he would be seen in Buenos Aires in 50's, others have spoken about his religious conversion and about his death in a monastery in Italy,<sup>6</sup> other have spoken about a failed kidnapping by a foreigner country<sup>7</sup> and so on.

The only right thing can be said about Majorana after his disappearance is about work discussed in this paper (hereafter simply Work).

After few days from the disappearance, his brother Luciano found, among Ettore's papers, a hand-written ready for the publication whose title was *Il valore delle leggi statistiche nella fisica e nelle scienze sociali* (The value of statistical laws in physical sciences and in social sciences). Luciano Majorana showed it to Giovanni Gentile ir. who was the son of philosopher and Minister of Education Giovanni Gentile, but over all he was a great friend of Ettore and was a theoretical physician too (he taught in University of Milan).

Gentile recognized a work that would had to be presented to a journal of sociology (clearly Majorana have told him about Work) and, he made to publish it in journal "Scientia", an Italian review in issue 2 of 1942, few months before Gentile died.

The Work has been often cited by everyone who has been interested in Majorana affair but they haven't discussed it.

Among that have cited the Work there has been prof. R.N. Mantegna in a recent and famous introduction<sup>8</sup> to the new branch called Econophysics but we speak about it again.

The Work appears immediately different respect to everything Majorana had written before. Besides this work,

- it's popular;
- it has been written in conversational style with no mathematics;
- its matter, we are in the field of social-economic sciences; both Majorana and other people of Fermi's team, till then were never involved in such studies.

But overall the Work, being the last written paper, is the nearer work to time of disappearance and then it would be possible to know the psychological situation of Majorana in the moments immediately precedent to disappearance.

This last point is particularly important because the most presented hypothesis about disappearance has been the suicide. Edoardo Amaldi<sup>9</sup> thought that Majorana would have an existential crisis due to

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<sup>3</sup> This and other citation by Majorana's correspondence reported in fn 1.

<sup>4</sup> News reported in [http://italy.indymedia.org/news/2004/08/602181\\_comment.php](http://italy.indymedia.org/news/2004/08/602181_comment.php).

<sup>5</sup> From police transcript reported in fn. 1.

<sup>6</sup> L.Sciascia; *La scomparsa di Majorana (The disappearance of Majorana)*, Adelphi ed. 1975.

<sup>7</sup> U.Bartocci; *La scomparsa di Majorana: un affare di stato? (The Majorana disappearance :a state affair?)* ed. Andromeda, 1999.

<sup>8</sup> R.N.Mantegna and E.Stanley; *An introduction to Econophysics*, Cambridge edition, 2000.

lack of a partner (he was neither married nor been engaged) while other scholars have seen the start of a nervous breakdown in gastric problems which Majorana had until the beginning of 30 years.

So author has decide to do a meditate reading of Work.

### (3) The Work

The beginning of Work is similar to the start of notes, which Majorana had prepared for his course of Theoretical Physics. It starts from classical physics, with its great successes starting from explanation of movements inside solar system, and overall from its deterministic base. Practically Majorana reminds that “the movement of material body is fully determinated by initial conditions (position and speed) in which body is and by forces acting over it” and reasserts the Laplace principle according to which “the entire material universe takes place obeying inflexible law such a way that its state in a certain moment is fully determinated by state in which it was in previous moment”.

Majorana recognizes great charm of this capability of forecast respect to vagueness and to confusion of many philosophic visions of world and links up it to diffusion of mechanism, the conviction, very strong in the eighteenth and in nineteenth centuries, that every physical phenomena and other can be explained by mechanical phenomena and then that they can be explained with a precision limited only by technical capacity of instrumentations.

Majorana, however doesn't ignore the philosophical problems that this approach had and, in contrast to refusal towards philosophy of Fermi's team, cites the critiques that George Sorel, revolutionary trade-unionist and philosopher near to Marx and Nietzsche, then strongly critic towards science, addresses to mechanism, being inspiring also by certain ideas of G.B. Vico, Neapolitan philosopher of first seventeenth century. Majorana writes:

G. Sorel treats by deeply way the critique of determinism asserting this would concern only those phenomena called by him artificial nature phenomena characterized by not to be gone with a notable degradation of energy. Such phenomena happen sometimes spontaneously in nature, but more often are induced in laboratory by experimenters .... Other phenomena, that of ordinary experience or of natural nature ... wouldn't ruled by physical laws but, more or less strongly by chance.

Now Majorana feels for these critiques nether scandal nor irritation, on the contrary he seems to share them and states, in this part of Work, determinism “doesn't leave any place to human freedom” asking himself, also if tacitly, whether, in a world fully regulated by deterministic laws, it would have meaning to say about free will of man.

It's important Majorana asked himself this question for two reasons.

First of all this fact informs us he didn't have a narrow-mindedness towards philosophy, also towards that philosophy criticizing science, very positive attitude but attitude rare also among present day physicians, besides the citation of free will, and then the positive opinion about it informs us Majorana didn't have Nazis fancies that have been attributed to him.

These fancies would be deducted by a letter written to Emilio Segrè the 22 may of 1933 when Majorana was in Germany. In this letter several considerations were justifying an hard policy, but not violent, against Jewish. However this letter can be different respect to Majorana thought, anyway the tacitly but positive valuation of free will does justice of these suppositions.

In the second part of Work Majorana reminds the needed of a statistical description of some system belonging to macroscopic world, and then being in the field of classical physics, but that are made by objects so little than it isn't possible to observe them directly and so numerous than it isn't possible to made calculations of their position and speed.

Majorana distinguishes macroscopic state of a system from microscopic states of particles forming it, with reference to gases theory and he introduces entropy as a measure of number of accessible states of a system, a way to introduce this concept present in many famous textbooks<sup>10</sup> but, in that time a novelty overall in popular texts.

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<sup>9</sup> E.Amaldi, *Ricordo di Ettore Majorana (Remind of Ettore Majorana)*, *Giornale di fisica*, 9, 1968, pag 300.

<sup>10</sup> Kittel, *Statistical Physics* vol 5 of *The Berkeley Physics course*.

To the end of this exposition Majorana summarizes the statistical tractation in classical physics saying that:

1) natural phenomena obey to an absolute determinism; 2) ordinary observation doesn't permit to recognize exactly the internal state of a body but only to establish a countless sum of undistinguishable. Possibility; 3) established plausible hypotheses about probability of different possibility; the probability calculus permits a more or less secure forecast of future phenomena.

It's in these lines that Majorana introduces the first comparison between natural sciences and social sciences saying: we can describe the state of a gas knowing its temperature without knowing the state of individual molecules so as we can know the wedding rate of European peoples (and here he cites data taken by real statistics) without to know what happens in single marriages.

This example is original, apt and also accurate, he uses the Italian word "nuzialità" that is a technical term of demographical statistic.

The mention of marriages could remind the loneliness of Ettore Majorana above reminded but perhaps it would imputes an excessive importance to a citation.

It's more important the fact Majorana, not only does the comparison but also comments it as if he would eliminate some objections due to draw near two so apparently different things.

A first objection could be physics laws are expressed in analytical form by precise mathematical formulas while statistical social laws are empirical and Majorana answers with two counter-objections. First phenomena described by empirical laws there are in Physics too (i.e. friction phenomena and ferromagnetic materials phenomena), second this difference can be explained by a greater complexity of social phenomena that hasn't yet allowed to write in analytical form the laws regulating them.

It' to note that, by this second claim, Majorana admits tacitly the possibility social phenomena obey to laws similar to which regulating natural phenomena.

Another objection could be that, to determinate the statistic of marriage was needed long surveys while measure of temperature is prompt but Majorana reminds in Physics not every measures are so simply and immediate.

To this point of Work Majorana introduces contemporary physics or rather quantum physics.

He doesn't make an historical introduction as that till today used in the great majority of textbooks, but confine himself to a short mention of wave-particle dualism, or rather, of fact to have to admit certain systems (as light with diffraction and photo electronic effect) have both a wave-like behaviour and a particle-like behaviour, besides he emphasizes every quantum system description is a statistical description due to their very nature and here he does another comparison between, more explicit than previous one, natural sciences and social sciences.

Majorana compares tables of mortality used by insurances and tables of average life of radioactive nucleus, or rather between probabilistic of radioactive decay (passage from one nucleus to another) and the statistical nature of passage of a man from life to death.

This example remembers Schrödinger's cat but it proves the good knowing Majorana had about techniques used by insurance companies too, this knowing that often, till today, isn't need of which do life insurance and it doesn't turn out Majorana had taught out a policy.

Immediately after this second comparison, Majorana faces up another objection because the decay of an individual nucleus is a sudden, fully unforeseeable event that can happen also after billion of years and that cannot be spoken about the death of a people or about social phenomena.

Majorana doesn't answer directly to this observation but, starting from the fact that an individual decay can be recorded by a macroscopic object and then can have macroscopic effects says:

There is nothing ... that prevents to consider plausible that a vital, simple, invisible and unforeseen fact is to origin of human event. If it is so .... The statistical laws of social science have increased their duty .... Above all to give a prompt representation of reality. The interpretation of which needs an special art not last help to the art of government.

Reading these lines (the last of Work) isn't possible not to think to those models that describe financial crashes or similar phenomena as effects of chain reactions produced by individual facts i.e. diffusion of lying news.

#### (4) Comment about the Work

The first thing sticks out is the expanse of interests and of culture of Ettore Majorana. Elements of very different disciplines, from philosophy to insurance technique are cited, and the mentions are always exact and pertinent.

It's difficult to determine if these mentions come from readings or from contacts with people not belonging to circle of physicians, i.e. when Majorana was lecturer in Rome, mathematician De Finetti one of founders of actual financial mathematics was full professor in that university. On the other part letters to mother and to friends documents the expanse of Majorana's interest too.

In some of these letters observation about German and international economic situation (that seem done by an economic commentator more than by a physician) there are, and there is also a letter to friend Giovanni Gentile jr. dated 25 august 1937 in which Majorana affirm "I can establish every day as weather forecasts fail" as if he was interested also in meteorology. Besides many people have affirmed his readings went from philosophy (Schopenhauer) to literature (Pirandello). He had a religious sensibility too such that he wrote, in another letter, dated 21 November 1937 in a tone between serious and humorous "whether they elect me Pope in next conclave for exceptional merits I accept certainly".

But the most important aspect of Work is the conviction, never made clear, but that makes out, of the possibility to study social phenomena by methods typical of physics, a conviction that does him to be part of Econophysics' fathers according to the very famous book above mentioned.

In author's opinion (author is an Econophysics scholar too), Majorana could be considered not one of fathers but "the father" of it, being the first physician of a certain stature to affirm the possibility to do certain studies.

It's notorious that Econophysics studies, starting from 70', have reached interesting results.<sup>11</sup> Among these it's possible to reminder: Blach-Schoes-Merton theory of options pricing and more generally of financial markets (Blach and Schoes were Nobel prize Winner for Economy in 1990), the discovery of an universal laws of incomes distributions, several recent physical models proposed to explain such distribution,<sup>12</sup> the discovery of scaling laws for the distribution of very many social phenomenon, successes in simulating temporal evolution of many social phenomena by physical models as agent Brownian model,<sup>13</sup> cellular automata model and other.

Also the Majorana's hope that econophysics studies or rather the interpretation of their results could help political classes, it could seem a naive hope, is linked with recent studies as those underlining a deep similarity between born of "opinions clusters" in an electorate, influencing results of political elections, and physics phenomenon as percolation.<sup>14</sup>

It's to note every these studies have started tenth years after the disappearance if Majorana.

For example, a mathematical physics theory of wedding rate there isn't yet and author knows only few recent papers about automata cellular models explaining unions of people, studies nearer to job market than wedding.<sup>15</sup>

Another comment: Majorana spoke about an "art of government" and then, in his opinion politics isn't a "science" or a "philosophy" or a "culture" but it's a practical thing. Then a politician hasn't to be an "intellectual" and a scientist hasn't to take the place of politician.

Another important thing about Work: it doesn't seem absolutely a spiritual will or the work of an aspirant suicide. Work seems the program of researches to be done in a future time and then it would be very important to establish with precision the date in which it has been written, to see how much is near to the date if disappearance. In author's opinion there are at least three elements to think Work has been written near 1938.

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<sup>11</sup> For an overview see V. M. Yakovenko; *Research in Econophysics*, arXiv, cond-mat/0302270).

<sup>12</sup> B.K.Chakrabarti, Achatterjee, "Pareto law in a kinetic model of market with random saving propensity", *Physica A*, 335, pp. 155-163, (2004).

<sup>13</sup> F.Schweitzer; *Brownian agents and active particles*, Springer ed. (2003).

<sup>14</sup> A.T.Bernades et al. Election results and the Sznajd model on Barabasi network arXiv:cond-mat/0111147; 8 Nov 2001.

<sup>15</sup> Michael Dzierzawa, "Statistics of stable marriages"; arXiv:cond-mat/0007321; 20 Jul 2000.

1) The fact it has been written for a journal of sociology which would have accepted a paper of a physician only if he was been a famous scholar, also outside his circle and Majorana become such after 1933.

2) The very strong similarity between beginning of Work and beginning of lessons of Theoretical Physics course, Majorana knew to be become full professor only in 1937.

3) The fact that Majorana decided to publish his works only after a very deep control of them, control needing many times. It's to remind Work was found ready for publication.

It's possible also to think a Majorana farer and farer from fundamental physics and moved closet to econophysics interests and researches programs.

The famous phrase "physics is going in a wrong direction" that his sister Mary would have to hear told by him can be interpreted as a critique to a physics "getting stuck in mud" in detailed researches and not seeing the very large field of applications statistical nature of fundamental physics offered for an absolutely new kind of study of society.

In fact also Franco Rasetti, close aid of Enrico Fermi and valued an experimental physics perhaps better than Fermi himself, after the explosion of first atomic bomb, leaved physics and continued studies, until 80 years in palaeontology and in botanic.

Perhaps Majorana wanted to do same choose of Rasetti but directed towards social studies and perhaps he did it if he didn't suicide but escaped in Argentina.

Returning to true things, it can have an educational importance the fact Majorana identified as separating element between classical and quantum physics the passage from determinism to probabilism as he did in the beginning of notes for his theoretical physics course.

Now it could be an excellent idea to introduce contemporary physics also in High school because of, at least in Italy, almost every textbook follows an approach with a long historical introduction starting from Planck's hypothesis about blackbody radiation till Schrodinger's equation, introduction that requires many times and that is much unsystematic for student. A valid alternative could be a discussion, also epistemological, about determinism followed by a critique of concept of trajectory, with immediate attach to indetermination principle, and to wave-particle dualism (clearly reminded by Majorana in Work) and author had proposed something similar some years ago.<sup>16</sup>

The work, besides, is an example of speaking to public about the most recent discoveries of physics informally, there is only a very simple formula, going straight fundamental concepts of scientific theories and using a language with the least possible number of technical terms (words as wavefunction or dualism or quantum states have never been used) but in the same time accurate.

To make an example entropy is introduced as measure of microscopic states accessible to a macroscopic system and not as measure of a generic "disorder" (using a word having in the common language meanings having nothing to do with entropy).

## (5) Conclusions

In the future other things will be written and told about Ettore Majorana also because many scholars, also till today, continue to work in the fields of researches open by his works as demonstrate by very recent papers, some of these with his name even in their title.<sup>17</sup>

It's clear, besides, that it's to have to study in depth both the psychology of Majorana for example by expert opinion on a sample of his handwriting, and those unpublished paper of him concerning arguments studied till today.

In author's opinion it would be useful to try some econophysics works in 50's and 60's traced back to an activity of a Majorana hide in Argentina.

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<sup>16</sup> C.Artemi, "Il dualismo onda corpuscolo" ("The wave-corpuscular dualism"); *La didattica delle scienze*, 182 (1996), pp. 22-24.

<sup>17</sup> *Majorana representation of the Lorentz group and infinite component field*; D.I. Stoyanov "J.of Mathematical Physics", ott. 2003, and *Scales of mass generation for quarks, leptons, and Majorana neutrinos*; D.A.Dicus "P.R.L." 9, 4-6-2005.