

# Dirac and Quantum Times

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*Abstract:* In 1926, Dirac attempted to give a relativistic generalization of his mechanics of  $q$ -numbers, defining a new "quantum time" starting from the relation:  $tW - Wt = -i\hbar$ . In the 1927 article, Heisenberg starts from this relationship by Pauli and Dirac which implies this new concept of quantum (relativistic) time. All the historical formulations of quantum mechanics were time irreversible. Time was a matrix in Heisenberg matrix mechanics and all the physical variables obeyed a matrix evolution, time irreversible equation. Schrödinger equation was written as representing the propagation of an irreversible physical wave. One has been able to state that quantum mechanics is time reversible only by defining the time reversal operator in a new way, involving also complex conjugation, just to obtain reversibility. This new formal insight was obtained for the first time only in 1932, in the paper *Über die Operation Zeitumkehr der in der Quantenmechanik* by Eugene Wigner. He introduced some sort of mathematical trick by defining the time reversal operator in a new way involving complex conjugation. Irreversibility of quantum mechanics is shown by giving a new insight into quantum time and motion.

*Keywords:* Quantum Time, Time Reversal Operator, Irreversibility; Quantum Mechanics

## 1. The Introduction of a *Quantum Time*

After the revolution of special relativity and general relativity, there was an unknown revolution in the concept of time also in quantum physics. It occurred very early, but was then denied and finally sent back to quantum gravity. At this level, it was then further denied, based on a classical idea of time. Quantum time is a discrete, discontinuous, multiple, irreversible time, linked to all the variety of processes and physical quantities that characterize them. It must not be identified with the idea of the existence of a minimum time, the so-called chronon (Kragh & Carazza, 1994). The concept of quantum time dates back at least to a work by Henri Poincaré (1854-1912) published in 1912 in which he presented an early form of quantum mechanics (Poincaré, 1912a, 1912b; Giannetto, 2005). The deepest recent search for a fundamental quantum time was done by David Finkelstein. It was through Dirac's work that in 1926 the concept of quantum time finally entered physics (Dirac, 1926). Dirac not only attempted to create a new mechanics as a synthesis of wave mechanics and matrix mechanics, but even before that Dirac had attempted to give a relativistic generalization of his  $q$ -number mechanics, defining a new quantum time starting from the relation:  $tW - Wt = -i\hbar$ , where  $W$  indicates the energy (Giannetto, 2005).

Quantum numbers,  $q$ -numbers, are indeed ordinal numbers, temporal numbers: they do not commute because of the temporal order: they indicate temporal irreversibility of measurement operations and general, temporal, physical processes.

Dirac, in his theory of transformations, had pointed out how the Schrödinger wave function corresponded to nothing other than a transformation from a scheme with diagonal position to one with diagonal energy in the language of matrices. That the system is described by a certain wave function means considering it as a process that can never be stationary in position energy or momentum or any other variable, except within the limits of a wave characterization.

This implied to Heisenberg that the fundamental concept of wave mechanics could be traced back to matrix mechanics. Matrices described temporal processes, thus wave functions did not describe states of a system, but temporal wave processes of some physical variable. Matrices, on the other side, were defined by Heisenberg in terms of a finite sum of Fourier analysis, which allows a decomposition of every physical variable change in terms of elementary sinusoidal and co-sinusoidal waves. Heisenberg considered the breakdown of the solar system model of the atom since Max Born has shown that an  $N = 2$  atom presented an unsolvable three-body problem (Born, 1924). Thus, Heisenberg thought to describe electron motions as planet motions in Babylon algebraic astronomy, where the problem was the irregularity of trajectories, or the non-existence at all of a definite trajectory because the planets have many retrograde motions: Heisenberg introduced ephemeris-like (sinusoidal) time tables (Heisenberg, 1925) for electron motions, then interpreted as matrices (Born & Jordan, 1925; Born, Heisenberg & Jordan, 1926).

The problem of the concept of time played a very important role in Heisenberg's uncertainty relations.

Pauli had already hinted at the idea of defining time in terms of energy in a letter to Bohr dated 17 November 1925 (Pauli, 1979, vol. I, pp. 257-261). In the 1926 encyclopedia article, he highlighted how energy transitions were not describable according to exact times, as there was an imprecision in the moment of the transition and a problem regarding its duration.

In response to a letter from Heisenberg dated 27 January 1926, Pauli, in a letter dated 31 January 1926 (Pauli, 1979 vol. I, pp. 281-288), gives a new physical definition of time through the relationship, in a matrix formalism,

$$Wt - tW = \frac{1h}{2\pi i} \quad (1.1)$$

where  $W$  indicates the energy.

The concept of quantum time was therefore already born in the context of a synthesis between quantum mechanics and special relativity: if the position is a  $q$ -number, the Lorentz transformations imply that time is also a  $q$ -number.

In the 1927 article, Heisenberg starts from this relationship by Pauli and Dirac which implies this new concept of quantum (relativistic) time (Heisenberg, 1927). Even if Heisenberg's indeterminacy relations do not contain all the relativistic implications, which make them even more limiting, they arise within a relativistic consideration.

Quantum-relativistic complete implications indeed amount to the fact that it is no longer possible to obtain measurements relating to momentum and energy in an instant or in a short time since their accuracy would require an infinite amount of time (as regards momentum, the indeterminacy is around  $\frac{h}{c}$  for the inverse of temporal indeterminacy,  $\Delta p \Delta t \sim \frac{h}{c}$ . The error on the position of a particle can end up coinciding with the De Broglie wavelength,  $\Delta x \sim \frac{h}{mc}$  or  $\frac{h}{p}$ , which implies that the photon is never localizable) (Landau & Lifshitz, 1958).

It follows that uncertainty relations cannot be formulated in terms of simultaneous measurements of conjugated variables, as simultaneity is relativistically dependent on the reference system and can be rigorously defined only for events that occur at the same spatial point. The wave function of a certain size at a given instant is not definable, it does not correspond to observable and physically available information: it must be interpreted in terms of a space-time process, that is of an actual (ontological) finite, discontinuous multiplicity of quantum physical wave fields. The indeterminacies on the momentum and energies correspond to those of possible processes of creation and destruction of a particle-antiparticle pair  $\Delta p \sim mc$  and  $\Delta E \sim mc^2$ , which means that the possibility of attributing them to a specific material particle is no longer valid, which means that particles can no longer be considered isolated and localizable objects, but waves.

In Heisenberg's 1927 formulation, which took Dirac's quantum time into account, the two indeterminacy relations,  $\Delta q \Delta p \sim \hbar$  and  $\Delta E \Delta t \sim \hbar$  were interpreted symmetrically. The  $\Delta t$  was not interpreted as a simple duration of the process but as an effective error on a quantum variable that can only be known probabilistically (Heisenberg, 1927).

In the letter to Pauli dated November 23, 1926 (Pauli, 1979, vol. I, pp. 357-360), Heisenberg wrote that "it is completely impossible for the world to be continuous" and "what the word 'wave' or 'particle' means is no longer known". And he added: "if space-time is discontinuous, the velocity in a defined point cannot have any meaning, because, to define the velocity in a point, there is a need for a second point infinitely close to the first: that is impossible in a discontinuous world".

Mathematically, Heisenberg's reflection can be translated as follows:  $v = \frac{ds}{dt}$  and this also makes the definition of the momentum impossible, and being  $E = h \frac{\omega}{2\pi} = \frac{d\theta}{dt} \cdot \frac{h}{2\pi}$  that is, since the pulsation  $\omega$  is associated with an angular velocity, even the definition of energy becomes impossible if space-time is discontinuous. It is not possible to calculate the limit of the incremental ratio that defines the speed: time intervals, such as spatial or angular ones, cannot tend to zero, and mathematical discontinuities correspond to finite and irreducible experimental indeterminacies of physical quantities. Quantum time means discontinuous time, linked to discontinuous physical processes of change. Indeterminacy and discontinuity imply irreversibility. Usually, however, this irreversibility has been confined to the act of measurement. In classical mechanics, motion is considered reversible and so is time, as a spatial trajectory can be traveled in both directions. In quantum mechanics, it is not possible to trace a motion trajectory linked to a motion time law that gives the position as a continuous function of time. In the matrix mechanics of Heisenberg, Bohr, and Jordan, time is a matrix, and the matrices representing the physical processes of change (transition) are linked to temporally irreversible equations.

In any case, since Dirac's, Pauli's, and Heisenberg's works the concept of quantum time changed the concept of time: while, before them, it was connected to space and therefore to the process which, from Aristotle onwards, is called local motion, Heisenberg, under the suggestion of Pauli and Dirac, with the relations of indeterminacy, defines quantum time by connecting it to more general energetic processes of energy change. And here an irreversible, discontinuous, quantum time emerges. It was not discontinuity, discreteness of time to be not accepted. Now, the concept of an irreversible quantum time encountered very strong opposition when one wanted to consider quantum mechanics as temporally reversible like classical mechanics. Reversibility prepares a return to a time that can only be classical, like a simple mathematical parameter, to which no reality of irreversible change corresponds.

From a Heraclitean vision in which time was the constitutive foundation of *Physis*, we returned to a Parmenidean timeless vision also in quantum physics (Prigogine & Stengers, 1979).

## 2. The transformation of the time reversal operator

Quantum mechanics is usually considered as time reversible (Messiah, 1961, vol. II, pp. 664-675; Landau & Lifshitz, 1958), even if sometimes this "axiom" has been challenged (Racah, 1937; Schrödinger, 1950; Watanabe, 1955, 1965; Jauch & Rohrlich, 1955, pp. 88-96; Costa de Beauregard, 1980; Healey, 1981; Callender, 2000). Schrödinger's wave mechanics is considered as time-reversible and the other (Heisenberg's or Dirac's) formulations of quantum mechanics are considered as equivalent to wave mechanics (Giannetto, 1999). Quantum time asymmetry is so usually limited to the act of measurement (Reichenbach, 1956; Davies, 1974; Sachs, 1987; Zeh, 1989). However, it is not clear at all that this property of quantum mechanics is a theoretical or better an epistemic postulate. The deep reason for this postulate is related to the continuity (analogy) with classical mechanics. Quantum mechanics should be

time-reversible because classical mechanics is time-reversible. In classical mechanics, motion should be time-reversible because a spatial trajectory is time-reversible.

However, all the historical formulations of quantum mechanics were time irreversible. Time was a matrix in Heisenberg matrix mechanics and all the physical variables obeyed a matrix evolution, time irreversible equation. Schrödinger equation was written as representing the propagation of an irreversible physical wave (Giannetto, 1999).

One has been able to state that quantum mechanics is time reversible only by defining the time reversal operator in a new way, involving also complex conjugation, just to obtain reversibility. This new formal insight was obtained for the first time only in 1932, in the paper *Über die Operation Zeitumkehr der in der Quantenmechanik* by Eugene Wigner. It must be remembered that the time reversal operator must be defined in a new way to yield a time-symmetrical quantum mechanics. This was realized for the first time by Eugene Wigner (1931, 1932). Time reversal  $\tau$  is defined an antiunitary operator, associating the transformation  $\theta$  of  $t$  into  $-t$  with a conjugation operation  $*$  changing  $i$  into  $-i$ , in such a way that

$$\tau = \theta^* \quad (2.1)$$

$$\tau[\psi(x, t)] = \psi^*(x, -t) \quad (2.2)$$

where  $\psi$  is the wave function of a quantum mechanical system.

This definition is such that Schrödinger equation

$$H\psi(x, t) = i\hbar \frac{\partial \psi(x, t)}{\partial t} \quad (2.3)$$

where  $H$ , the Hamiltonian operator, is invariant under  $\tau$  transformation.

For a free particle

$$H = \frac{p^2}{2m} = \frac{\hbar^2}{2m} \nabla^2 \quad (2.4)$$

and

$$p = -i\hbar \nabla \quad (2.5)$$

is invariant under  $\tau$  transformation and the change in  $i$  is counterbalanced by the change of sign in  $t$  and the temporal partial derivative. This corresponds to the requirement that momentum changes its sign and energy does not change under time reversal as in classical mechanics and the canonical commutator between  $x$  and  $p$  is invariant:  $[x, p] = i\hbar$ .

However, these requirements are related to the classical concepts of momentum and energy and one cannot neglect that within quantum mechanics momentum and energy are no more classical variables but are associated with operators, which has no intrinsic physical meaning.

Within quantum mechanics, in the usual representation of eq. 2.5 momentum does no more depend on time, and so it does not change by changing  $t$  into  $-t$ . And even if one does not associate energy to an operator  $i\hbar \frac{\partial}{\partial t}$ , Schrödinger equation is not invariant by changing  $t$  into  $-t$  by transformation  $\theta$  and makes energies change into negative values.

From

$$\theta[H\psi(x, t)] = \theta\left[i\hbar \frac{\partial \psi(x, t)}{\partial t}\right] \quad (2.6)$$

it follows:

$$H\psi(x, t) = -i\hbar \frac{\partial \psi(x, -t)}{\partial t} \quad (2.7)$$

that is,  $\psi(x, -t)$  does not obey the same equation.

However, this result cannot be a reason to change the definition of time reversal operator into an antiunitary operator. On the contrary, this must be taken as proof that quantum mechanics is not invariant under time reversal, just because a time inversion would change energies to negative values. Evolution operator  $e^{-iHt/\hbar}$  under time reversal would imply negative energy values. For a  $\theta$  time reversal transformation there is no probability ( $P$ ) conservation and so no information conservation:  $\frac{\partial P(x, -t)}{\partial t} = \nabla J(x, -t)$ . Thus, time inversion cannot have any physical meaning.

This does not allow any dualism between a time-reversible, quantum dynamics and an irreversible quantum measurement.

### 3. Pauli against Dirac's Quantum Time

The need for classical time, as a parameter and not as a quantum operator, was due to the maintenance of temporally reversible quantum mechanics.

The main argument against quantum time is paradoxically due to Wolfgang Pauli:

In the older literature on quantum mechanics, we often find the operator equation  $Ht - tH = \frac{\hbar}{i}I$ . It is generally not possible, however, to construct a Hermitian operator (e.g. as a function of  $P$  and  $Q$ ) which satisfies this equation.

This is so because, from the C.R. written above, it follows that  $H$  possesses all eigenvalues from  $-\infty$  to  $\infty$  whereas on the other hand, discrete eigenvalues of  $H$  can be present. We therefore conclude that the introduction of an operator  $t$  is basically forbidden and the time  $t$  must necessarily be considered an ordinary number ("c-number") in Quantum Mechanics. (Pauli, 1980, p. 63)

Pauli's objection to the possibility of a time operator was linked to the fact that since energy is classically the generator of (continuous) time translations, every time operator must be conjugated to an energy operator (Hamiltonian) that has a spectrum unlimited continuum, a property which is not satisfied by the Hamiltonian of typical systems and which also leads to negative energy values.

However, Pauli presupposed here the continuity of time and the connection to energy. Paradoxically, the attempt to avoid quantum time linked to energy opens the way to a new concept of a multiplicity of quantum times linked to the rates of variation of each physical quantity.

### 4. A Plurality of Quantum Times

One has to consider also Dirac's Heisenberg operator equation for every operator  $A$ :

$$[A, H]_- = i\hbar \frac{\partial A}{\partial t} \tag{4.1}$$

that is not invariant for  $\theta$  time reversal:

$$\theta[A, H]_- = \theta\left[i\hbar \frac{\partial A}{\partial t}\right] \tag{4.2}$$

implies

$$[A(-t), H]_- = -i\hbar \frac{\partial A(-t)}{\partial t} \tag{4.3}$$

Indeed, indeterminacy relations take the form:

$$\langle \Delta A \rangle \langle \Delta H \rangle \geq \frac{1}{2} |[A, H]_-| \tag{4.4}$$

so that

$$\langle \Delta A \rangle \langle \Delta H \rangle \geq \frac{1}{2} |[A, B]_-| \quad (4.5)$$

and

$$\langle \Delta A \rangle \langle \Delta H \rangle \geq \frac{\hbar}{2} \frac{\partial A}{\partial t} \quad (4.6)$$

In general, indeterminacy relations define a new concept of quantum time as a function of quantum operators: it can be associated with any change of physical variable that is irreversible by the Heisenberg equation. There is a multiplicity of quantum times (operators): there is no single temporal order. It is no longer necessary or possible to define time in terms of uniform spatial variation, but there is a different type of quantum time internal (proper) to each type of physical process. Due to the indefinability of a trajectory, local motion is also quantum unpredictable and an irreversible process (it is not possible to define a state of motion, i.e. motion as a state).

Therefore, we have that the energy-time indeterminacy relations are:

$$\langle \Delta E \rangle \langle \Delta t \rangle = \frac{\langle \Delta E \rangle \langle \Delta A \rangle}{\frac{\partial A}{\partial t}} \geq \frac{\hbar}{2} \quad (4.7)$$

and the quantum time for each A is defined:

$$\tau_A = \frac{\partial A}{\partial t} \quad (4.8)$$

Thus, if we carry out a time reversal transformation  $\theta$ , we obtain

$$\langle \Delta E \rangle \langle \Delta t \rangle = \langle \Delta E \rangle \langle \Delta A(-t) \rangle > \frac{\partial A(-t)}{\partial t} \leq \frac{\hbar}{2} \quad (4.9)$$

which cannot be accepted because there is a violation of indeterminacy relations.

In this new definition of a multiplicity of quantum times linked to the variations of physical quantities, the time derivative is calculated in relation to a classical macroscopic time which acts as a reference sample. The quantum time of Heisenberg's uncertainty relations is therefore no longer directly connected to energy processes, but intrinsically to all physical variations in their discontinuity and irreversibility and is a further generalization of the concept of time. The attempt to maintain a reversible and continuous classical time has meant that the issue of a quantum time has been postponed until quantum gravity where it is unavoidable for space-time quantization, and here too the obsession with the classical concept of time does not allow it to emerge: it is said that time cannot be defined. However, if one accepts the rigorous original formulation of quantum mechanics, one has to deal with a plurality of discontinuous, discrete, finite, and irreversible quantum times.

## Bibliography

- Born, M. (1924). "Über Quantenmechanik", *Zeitschrift für Physik*, 26, pp. 379-396
- Born, M. & Jordan, P. (1925). "Zür Quantenmechanik I", *Zeitschrift für Physik*, 34, p. 858.
- Born, M., Heisenberg, W. & Jordan, P. (1926). "Zür Quantenmechanik II", *Zeitschrift für Physik*, 35, pp. 557-615;
- Callender, C. (2000). "Is Time Handed in a Quantum World?", *Proceedings of Aristotelian Society*, 121, pp. 247-269.

- Costa de Beauregard, O. (1980). "CPT Invariance and Interpretation of Quantum Mechanics", *Foundation of Physics*, 10(7/8), pp. 513-531.
- Davies, P.C.W. (1974). *The Physics of Time Asymmetry*. Guildford: Surrey University Press.
- Dirac, P.A.M. (1926). "Relativity quantum mechanics with an Application to Compton Scattering", *Proceedings of Royal Society of London A*, 111, pp. 405-423.
- Giannetto, E. (1999). "La rivoluzione della meccanica delle matrici di Heisenberg, Born e Jordan", in Gambillo, G. & Giannetto, E. (eds), *Heisenberg, W.: Lo sfondo filosofico della fisica moderna*. Palermo: Sellerio, pp. 25-37.
- Giannetto, E. (2005). *Saggi di storie del pensiero scientifico*. Bergamo: Sestante.
- Healey, R. (1981). "Statistical Theories, Quantum Mechanics and the Directedness of Time". in Healey, R. (ed.), *Reduction, Time and Reality*. Cambridge: Cambridge University Press, pp.99-127.
- Heisenberg, W. (1925). "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen", *Zeitschrift für Physik*, 33, pp. 879-893.
- Heisenberg, W. (1927). "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik", *Zeitschrift für Physik*, 43, pp. 172-198.
- Jauch, J.M. & Rohrlich, F. (1955). *The Theory of Positrons and Electrons*. New York: Addison-Wesley.
- Kragh, H. & Carazza, B. (1994). "From Time Atoms to Space-Time Quantization: The Idea of Discrete Time, ca 1925-1936". *Studies in History and Philosophy of Science*, 25(3), pp. 437-462.
- Landau, E.M. & Lifshitz, L. (1958). *Course of Theoretical Physics*, vol. III, *Quantum Mechanics: Non-Relativistic Theory*. New York: Pergamon Press.
- Messiah, A. (1961). *Quantum Mechanics*. Amsterdam: North Holland.
- Pauli, W. (1979). *Wissenschaftlicher Briefwechsel mit Bohr, Einstein, Heisenberg*, (von Meyenn, K., ed). Berlin: Springer.
- Pauli, W. (1980). *General Principles of Quantum Mechanics*. Berlin: Springer.
- Poincaré, H. (1912a). "L'hypothèse des quanta", *Revue Scientifique*, 50, pp. 225-232.
- Poincaré, H. (1912b). "Sur la théorie des quanta", *Comptes Rendus de l'Académie des Sciences*, 153, pp. 1103-1108.
- Prigogine, I. & Stengers, I. (1979). *La Nouvelle Alliance. Métamorphose de la Science*, Paris : Gallimard.
- Racah, G. (1937). "Sulla Nascita di Coppie per Urti di Particelle Elettrizzate", *Nuovo Cimento*, 14, p. 93.
- Reichenbach, H. (1956). *The Direction of Time*. Berkeley: University of California Press.
- Sachs, R. G. (1987). *The Physics of Time Reversal*. Chicago: University of Chicago Press.
- Schrödinger, E. (1950). "Irreversibility", *Proceedings Royal Irish Academy*, 53, pp 189-195.
- Watanabe, S. (1955). "Symmetry of Physical Laws. Part 3. Prediction and Retrodiction", *Review of Modern Physics*, 27(1), pp. 179-186.
- Watanabe, S. (1965). "Conditional Probability in Physics", *Progress Theoretical Physics, Supplement*, pp. 135-167.
- Wigner, E. (1931). *Gruppentheorie und ihre Anwendungen auf die Quantenmechanik der Atomspektren*. Braunschweig: Vieweg Verlag.
- Wigner, E. (1932). "Über die Operation der Zeitumkehr in der Quantenmechanik", *Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse*, 31, pp. 546-559.
- Zeh, H.D. (1989). *The Physical Basis of the Direction of Time*. Berlin: Springer.





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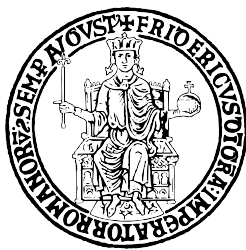
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## Introduzione

Il XLIV Congresso nazionale della nostra Società ha avuto il privilegio di svolgersi nella suggestiva cornice di Firenze, presso l'edificio Garbasso del dipartimento di Fisica e Astronomia dell'Università di Firenze e presso la Biblioteca dell'INAF-Osservatorio Astrofisico di Arcetri, ospitato dalla effervescente comunità scientifica che opera sul Colle di Arcetri. Non poteva esserci sede più adatta, per la SISFA, per celebrare i 100 anni che hanno segnato sia la nascita della statistica di Bose-Einstein che della moderna cosmologia, tenuto conto che proprio nel 2024 ricorrevano anche i 100 anni dalla fondazione dell'Università di Firenze.

Questo importante anniversario, che ha rappresentato anche un'occasione per sottolineare l'importanza dell'intero Colle di Arcetri nello sviluppo scientifico della fisica e dell'astronomia italiana dell'ultimo secolo, è stato efficacemente illustrato dagli interventi di Daniele Dominici, Simone Bianchi, Marco Ciardi e Alessandro Farini. Particolarmente significativa è stata anche la commemorazione di Giuseppe Occhialini (1907-1993) tracciata da Pasquale Tucci, che ha messo in luce l'influenza che l'ambiente fiorentino esercitò su Occhialini e la connessione con i più importanti contributi allo studio dei raggi cosmici che lo scienziato italiano diede prima a Cambridge e poi a Bristol. A questa è seguita la proiezione del documentario "Giù nell'abisso, fino alle stelle - Le scoperte di uno scienziato, le esplorazioni di uno speleologo", che ha messo in evidenza un aspetto poco noto del fisico di Fossombrone.

La sessione "Dalla Statistica Quantistica alla Fisica della Materia Condensata" ha visto tra i relatori di spicco gli esperti del settore Joseph Martin e Giuseppe Giuliani, mentre la sessione "1924-2024: Edwin Hubble e la Nascita della Cosmologia Moderna" ha commemorato la pubblicazione dell'articolo di Hubble che sanciva la scoperta epocale compiuta grazie alle Cefeidi classiche nella galassia di Andromeda (M31), dimostrando che la 'nebulosa' di Andromeda non era parte della nostra Galassia. La presentazione di Edvige Corbelli ha illustrato efficacemente come questa scoperta abbia modificato il nostro concetto di Universo e abbia segnato l'inizio dell'astronomia extragalattica e dell'esplorazione dello spazio oltre la Via Lattea.

Un'altra sessione tematica di grande rilievo è stata "Dall'informazione all'intelligenza artificiale: oltre 100 anni di comunicazione e computazione", che ha celebrato i 150 anni dalla nascita di Guglielmo Marconi e i 100 anni dalla pubblicazione del fondamentale articolo di Harry Nyquist (1889-1976). Gli interventi di Giovanni Paoloni e Francesco Bianchini, assieme a quelli di Benedetta Campanile e Niccolò Covoni, hanno offerto una riflessione storica e critica sull'evoluzione dei concetti di informazione, comunicazione e calcolo, fino alle attuali sfide poste dall'intelligenza artificiale.

Il Congresso fiorentino ha voluto porre anche una attenzione particolare al tema degli strumenti scientifici e delle collezioni museali, archivistiche e bibliografiche, vero patrimonio per la storia della fisica e dell'astronomia. Oltre alle consuete apposite sessioni, dedicate agli strumenti e alle collezioni scientifiche, arricchite dagli interventi di elevata caratura scientifica di Peter Plassmeyer, Anna Giatti, Emilia Olostro Cirella e Fausto Casi, il Congresso ha ospitato anche una appassionante tavola rotonda sul tema della valorizzazione e della conservazione, con particolare attenzione agli aspetti giuridici e normativi, argomenti che certamente coinvolgeranno nuovamente la SISFA nei prossimi anni.

Le visite organizzate dal LOC alle collezioni dell'Istituto Nazionale di Ottica, dell'INAF - Osservatorio Astrofisico di Arcetri, e a quelle del Dipartimento di Fisica e Astronomia dell'Università di Firenze conservate presso il Garbasso, hanno rappresentato un ulteriore esempio virtuoso e una fonte preziosa di spunti per riflettere sul valore e sulla conservazione di questi preziosi manufatti, capaci di raccontare la storia del pensiero scientifico.

Il ricco programma fiorentino non ha naturalmente trascurato il consueto dialogo tra storia, didattica e divulgazione, che è stato affrontato nelle comunicazioni di Francesco Longo, Andrea Battocchio, Pietro Cerreta, Salvatore Ganci, Marco Giliberti e Luisa Lovisetti.

Un momento particolarmente emozionante è stato il concerto del giovedì sera, tenuto dall'astronomo e Maestro Marco Padovani nella biblioteca dell'Osservatorio Astrofisico di Arcetri. Il concerto ha visto protagonista il celebre pianoforte Blüthner del 1899, donato da Albert Einstein alla sorella Maja nel 1931 e oggi noto come il pianoforte di Einstein. Il programma musicale, che ha incluso brani di Mozart, Beethoven e Castelnuovo-Tedesco, ha creato un ponte ideale tra musica, scienza e storia, incarnando perfettamente lo spirito del Congresso.

In generale tutto il Congresso ha dato ampio spazio alla fondamentale interazione tra i soci SISFA e gli studiosi italiani e internazionali di storia della fisica e dell'astronomia. Le numerose comunicazioni presentate, che da sempre costituiscono l'anima dei congressi SISFA, hanno evidenziato la vivacità, la profondità e la varietà delle ricerche in questo campo. Un significativo spazio è stato riservato ai giovani ricercatori, la cui vitalità e qualità degli studi sono state testimoniate anche dal consolidato Premio di Laurea SISFA.

È doveroso sottolineare come l'ottima riuscita sia stata frutto di un lavoro corale. Un ringraziamento sentito va al Comitato Organizzatore Locale, in particolare ad Antonella Gasperini e Samuele Straulino, che con dedizione e competenza hanno curato ogni dettaglio, assicurando il perfetto svolgimento dell'evento. La loro abnegazione, unita alla partecipazione entusiasta di tutti i loro colleghi, ha reso possibile una nuova, significativa tappa nella storia dei congressi SISFA. A loro, che assieme a Mauro Gargano sono anche i curatori del presente volume che vede ora la pubblicazione, va la più profonda gratitudine dell'intera Società, del Consiglio Direttivo e mia personale.

Valeria Zanini  
Presidente SISFA

# 44th National Congress of the Italian Society for the History of Physics and Astronomy

Florence, 17-20 September 2024

## Programme

# 17

 SEPTEMBER

8.30-9:00 - REGISTRATION

Department of Physics and Astronomy, Garbasso Building

9:00-9:30 - CONGRESS OPENING

Department of Physics and Astronomy, Garbasso Building

**Salvatore Esposito** – *President of SISFA*

**Marco Pierini** – *Vice Rector for Technology transfer, cultural activities and social impact, University of Florence*

**Guido Risaliti** – *Vice Director, Physics and Astronomy Department, University of Florence*

**Simone Esposito** – *Director, INAF - Arcetri Astrophysical Observatory*

**Giovanni Passaleva** – *Director, Division INFN - Florence*

9.30-10:30 - 100 YEARS SINCE THE BIRTH OF THE UNIVERSITY OF FLORENCE

Department of Physics and Astronomy, Garbasso Building

**Dominici D.** – *The history of Florence Institute of Physics from the 1920s to the end of the 1960s*

**Bianchi S.** – *Waiting for another centennial: first ideas for Astrophysics at the Arcetri Astronomical Observatory (1872-1921)*

10.30-11:00 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

11.00-12:00 - 100 YEARS SINCE THE BIRTH OF THE UNIVERSITY OF FLORENCE

Department of Physics and Astronomy, Garbasso Building

**Jafrancesco D. & Farini A.** – *La storia dell'Istituto Nazionale di Ottica di Arcetri - Firenze*

**Ciardi M.** – *La città delle stelle: Astronomia e comunicazione scientifica a Firenze tra Ottocento e Novecento*

12:00-13:00 - IN MEMORY OF GIUSEPPE OCCHIALINI AND BRUNO ROSSI

Department of Physics and Astronomy, Garbasso Building

**Bonolis L.** – *Bruno Rossi and the magical years in Arcetri: 1929-1932*

**Tucci P.** – *L'influenza dell'ambiente fisico e astrofisico di Firenze sui contributi di Occhialini allo studio dei raggi cosmici*

13:00-14:00 - LUNCH

Department of Physics and Astronomy, Garbasso Building

14:00-15:00 - 1924–2024: FROM QUANTUM STATISTICS TO CONDENSED MATTER PHYSICS

Department of Physics and Astronomy, Garbasso Building

**Martin J.** – *When condensed matter physics became king*

15:00-15:40 - SISFA PRIZE 2024 & CARTACCI PRIZE 2024

Department of Physics and Astronomy, Garbasso Building

15.40-16:00 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

16:00-17:00 - DOCUMENTARY

Department of Physics and Astronomy, Garbasso Building

**Tronconi R.** – *Giù nell'abisso, fino alle stelle – Le scoperte di uno scienziato, le esplorazioni di uno speleologo*



# 18 SEPTEMBER

## 9.00-10:40 - FROM INFORMATION TO AI: MORE THAN 100 YEARS OF COMMUNICATION AND COMPUTATION

Department of Physics and Astronomy, Garbasso Building

**Paoloni G.** – *Il ‘sistema Marconi’ e il suo sviluppo, fra scienza, società e politica*

**Bianchini F.** – *Information transmission as artificial intelligence*

**Campanile B.** – *The art of communicating: from the theory of information transmission to the Shannon-Fano Code*

**Covoni N.** – *From Shannon to Von Neumann: a partial understanding of information*

## 10.40-11:10 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

## 11:10-13:10 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 19TH CENTURY)

Arcetri Astrophysical Observatory

**Amabile A.** – *William Rowan Hamilton, poet and mathematician*

**Esposito S. & Naddeo A.** – *Earliest meteorological observations in Naples in the 18th century*

**De Frenza L.** – *The first meteorological series of southern Italy. Report on a rediscovered archive*

**Del Monte R.** – *On the “last discovery of Cavalier Melloni”*

**Macaluso T.** – *The passage of the Comet C/1861 J1 in 1861. Angelo Secchi’s drawings and the Cometa San Pietro tempera, history and restoration*

**Sanchini G.** – *Enrico Dal Pozzo, a physicist of the Risorgimento between heresy and innovation*

## 11:10-12:50 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 20TH CENTURY)

Dept. of Physics and Astronomy, Garbasso Bld

**Guzzardi L.** – *Theoretical patterns for understanding scientific collaborations*

**Furlan S. & Puleio D.** – *At home in a Super-Copernican Cosmos: the nature of the observer and Wheeler’s “It from Bit”*

**Lalli R.** – *Fusing Europe from EURATOM to ITER: A network analysis of European techno-scientific cooperation in controlled thermonuclear research*

**Bassanelli S.** – *The diplomacy of standardization: how the SUN commission negotiated electrical units during the interwar period*

**Maragno A.** – *Percepire, comprendere e comunicare i luoghi storici della meteorologia ferrarese attraverso la multisensorialità. A public engagement project of the University of Ferrara*

## 13:10-14:00 - LUNCH

Department of Physics and Astronomy, Garbasso Building

14:00-15:40 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 19TH CENTURY)

Arcetri Astrophysical Observatory

**Leone M., Monti F. & Robotti N.** – *The first electron charge measurement: status, meaning and implications of J.J. Thomson's and R. Millikan's respective research*

**Giannetto E.** – *Dirac's quantum time*

**Rossi P.** – *La corrispondenza italiana di Bruno Pontecorvo dal 1945 al 1950*

**Di Mauro M., Esposito S. & Naddeo A.** – *Exchanges in the nucleus in the 1930s: Werner Heisenberg and Ettore Majorana*

**Carlà M., Poggi G., Righi T. & Straulino S.** – *Revisiting Bruno Rossi's experiment on cosmic rays showers: comparison with the original results*

14:00-16:00 - DIALOGUE BETWEEN HISTORY, TEACHING AND DISSEMINATION IN PHYSICS AND ASTRONOMY

Dept. of Physics and Astronomy, Garbasso Bld

**Mantovani R.** – *The Belli-Babinet tap: an innovation in pneumatic technology in the first half of the 19th century*

**Rossi E.** – *Hidden treasures: The tale of Florentine thermometers 150 years after their crafting*

**Giatti A., Gurioli M. & Cattaneo B.** – *Lippmann: history, art and science in one photo*

**Spinazzè E.** – *Sacred alignments of early christian churches and baptisteries in Ravenna, Italy*

**Giatti A.** – *The celestial Weigel Globe in the Stibbert Museum: restoration and valorisation*

**Tuscano M.L.** – *Un quadrante lunare, forse cosmologico, nell'Abbazia di San Martino delle Scale*

16:00-16:30 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

16:30-17:00 - REMEMBERING GIORGIO DRAGONI

Department of Physics and Astronomy, Garbasso Building

**Bevilacqua F.**

**Tucci P.**

17:00-18:30 - SISFA GENERAL ASSEMBLY

Department of Physics and Astronomy, Garbasso Building

20:30-22:30 - SOCIAL DINNER



# 19 SEPTEMBER

## 9.00-11:00 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 19TH CENTURY)

Department of Physics and Astronomy, Garbasso Building

**Gargano M.** – *Angelo Catone and the comet of 1472*

**Gambaro I.** – *Astronomical observations and scientific practices between Cayenne and Paris*

**Wartenberg I.** – *A Hebrew witness of the Theorica Planetarum from 1492 Naples*

**Bercigli E.** – *E noi uscimmo a riveder le stelle: the Medici family and the scientific patronage in Florence*

**Capecchi D. & Capecchi G.** – *Joseph Sauveur and the fixed sound*

**Drago A.** – *The history of the many versions of the “Curie’s Principles”. A comparative study of their versions and their ranges of validity*

## 11.00-11:30 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

## 11.30-12:40 - 1924–2024: EDWIN HUBBLE AND THE EVOLUTION OF MODERN COSMOLOGY

Department of Physics and Astronomy, Garbasso Building

**Corbelli E.** – *Beyond the Milky Way: an historical perspective*

**Adamo A.** – *A semi-Malthusian analysis of the possible social and cultural causes behind Hubble’s discovery of the law of recession of galaxies*

**Macchia G.** – *Hubble did not discover the expansion of the universe: observation versus discovery*

## 12.40-13:10 - 1924–2024: FROM QUANTUM STATISTICS TO CONDENSED MATTER PHYSICS

Department of Physics and Astronomy, Garbasso Building

**Giuliani G.** – *The origins of solid state physics in Italy: 1945-1960 circa*

## 13:10-14:00 - LUNCH

Department of Physics and Astronomy, Garbasso Building

## 14:00-15:40 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 19TH CENTURY)

Arcetri Astrophysical Observatory

**Serra L.** – *Insegnamento scientifico nel Seminario Vescovile di Bergamo tra XVIII e XIX Secolo*

**Loviseti L.** – *The two transits of Venus of 1874 and 1882: or the greatest astronomical events of the 19th century*

## 14:00-15:20 - DIALOGUE BETWEEN HISTORY, TEACHING AND DISSEMINATION IN PHYSICS AND ASTRONOMY

Dept. of Physics and Astronomy, Garbasso Bld

**Bologna V, Longo F., Parmigiani F. & Poli V.** – *Photon or light quantum?*

**Battocchio A.** – *The Lorentz force and transformations: an example of how the history of physics can simplify teaching*

**Zanini V. & Gasperini A.** – *The Lorenzoni-Abetti correspondence: insights into Italian astronomy and social context post-unification*

**De Piccoli L. & Carpino M.A.** – *Friendly Stilbon, fraudulent Hermes. Giovanni Virginio Schiaparelli and the rotation of Mercury*

**Sasso C., Gargano M. & Olostro Cirella E.** – *Solar storms that enchant and frighten: a historical-artistic journey among the aurorae boreales appeared in the sky of Naples over the last two centuries*

**Cerreta P.** – *From Faraday's candle to today's STEM: some suggestions for teachers*

**Giliberti M. & Lovisetti L.** – *Cultural understanding of physics: quantum mechanics a century later*

15.40-16:10 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

16.10-18:00 - ROUND TABLE ON INSTRUMENTATION

Department of Physics and Astronomy, Garbasso Building

**Mauro O.**

18:00-21:00 - SOCIAL ACTIVITIES

*Visit to the Research Institutes located on the Arcetri hill*

**Padovani M.** - *Piano Concert*

*Light dinner and astronomical observations*



# 20 SEPTEMBER

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## 9.00-11:30 - MUSEUMS, ARCHIVES, AND SCIENTIFIC COLLECTIONS OF PHYSICS AND ASTRONOMY IN ITALY AND ABROAD

Department of Physics and Astronomy, Garbasso Building

**Plassmeyer P.** – *The Mathematisch-Physikalischer Salon in Dresden. A princely collection of scientific instruments*

**Verduci D.** – *Il Museo Enrico Fermi di Roma apre le porte ai più giovani: metodi e strumenti per raccontare la scienza alle nuove generazioni*

**Casi F.** – *Il Mondo in Tasca MUMEC Museum celebrations 2024*

**Mortellaro R.** – *The Archimedes Institute for the manufacture of scientific-educational materials: the role of school museums in tracing the history of disciplines*

**Olostro Cirella E.** – *Gli incunaboli e le cinquecentine dell'INAF: un catalogo a stampa per scoprire il patrimonio bibliografico antico degli Osservatori italiani*

**Faustini L.** – *The astronomy books of the former Istituto Tecnico of Florence*

**Mauro O.** – *Le città del tempo delle Marche*

## 11.30-12:00 - COFFEE BREAK

Department of Physics and Astronomy, Garbasso Building

## 12.00-12:40 - HISTORY OF PHYSICS AND ASTRONOMY (UNTIL 19TH CENTURY)

Department of Physics and Astronomy, Garbasso Building

**Schiavon M.** – *Astronomical sciences and scientific diplomacy: Giuseppe Lorenzoni (1843-1914) and the International Geodesic Association during the second half of the 19th Century*

**Corradini E.** – *The Italian Society of Sciences known as the Society of XL in Modena in the late 18th and 19th centuries*

## 12.40-13:20 - CONCLUSIONS





## ATTI \ PROCEEDINGS

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