

WF-FI-BASTI2

Course Syllabus

«Towards a Contemporary Ontology: The New Dual Paradigm in Natural Sciences. Part II»

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Short Description

The course aims at presenting a first formalization of the natural realism (NR), as the formal ontology of the evolutionary cosmology based on QFT. Following Quine's remark that a theory of metaphysical deduction must include information about the ontic relations connecting the entities to which the asserts posed in direct implication relation are referring, NR follows Aquinas' suggestion that this relation connecting entities is the converse implication of the formal causality. We offer, firstly, a formalization of NR in terms of a nested KD45 modal logic, as ontology of the generation of ever more complex physical systems. However, coalgebra is the proper, complete, meta-language of modal logics, so the metaphysical double implication can have its proper formalization, in terms of Aquinas' "duality" (homomorphism), between the logical truth (algebra) and the ontological truth (coalgebra). Hence, NR is also a formalization of Aquinas metaphysics of participation of being.

Full Description

This course constitutes the formal logical-ontological counterpart of the WF-FI-BASTI1 course, representing the physical part of the present one, being the coalgebraic formalism underlying both perspectives, the strong theoretical link connecting the two parts, into one coherent framework.

The essential quantum field theory (QFT) notions in fundamental physics, analyzed in the WF-FI-BASTI1 complementary course, and constituting, with their Aristotelian ontological correspondences, its conclusions, will be summarized at the beginning of the present course, in its First Section. The other three Sections of the present course will be thus devoted to the modal and hence coalgebraic formalization of the Aristotelian ontology of the causal foundations of natural forms, in terms of Aquinas metaphysics of the participation of being.

In other terms, the rest of the course is devoted to the presentation of a formal treatment of the Natural Realism (NR), as the proper formal ontology of the actual evolutionary cosmology, just as R. Carnap's Logical Atomism (LA) is the formal ontology of the Newtonian atomism, and just as Cocchiarella's conceptual natural realism (CNR) is a candidate for representing the formal ontology of QM.

To summarize the core of NR formal ontology, we start from Quine's criticism against C. I. Lewis pretension that his theory of modal "strict implication" can constitute a theory of the ontological/metaphysical implication. Quine's remark is indeed that a theory of metaphysical deduction must include essential information about the ontic relations connecting the entities to which the asserts posed in direct implication relation are referring. NR follows thus Aristotle's and Aquinas' suggestion that this relation connecting entities in any ontological inference, to which the asserts posed in relation of implication are referring, is the converse implication of the formal causality. In such a way, the metaphysical double implication ("if and only if") consists of a logical (direct) direction (1011), and of an ontic (converse) direction (1101), so to be properly "ontological".

The ML of NR ontology is thus based on the theory of the classical "logical entailment": " q follows logically from p " (i.e., it is impossible p and not q), as "dual" of the "causal entailment": "(the referent of) p precedes causally (the referent of) q " (i.e., "it is impossible q and not p "), as basis of a proper modal semantics of the "onto-logical entailment" and hence of the metaphysical implication for ontological asserts "true in all possible worlds".

We offer, firstly, a formalization of such NR ontology, particularly suitable for being applied to an evolutionary cosmology based on QFT, in terms of a nested KD45 modal system. In this way, we propose an original ontological interpretation of it (till now there exist only deontic and doxastic interpretations of KD45 in intensional logics), with a "stratified rigidity" through an unbounded sequence of Kripke's models, as ontology of the cosmological generation of ever more complex physical systems and of the related physical mathematical laws, progressively ruling them as far as they are progressively causally unraveled. Indeed, the successors exist only "potentially" in the causal power of their ancestors, as their unpredictable effects. Recall, indeed, that in the truth table of the modal (strict) converse implication, both $(1,1 \rightarrow 1)$ and $(1,0 \rightarrow 1)$ are allowed, while only $(0,1 \rightarrow 0)$ is prohibited. So, the ancestors exist "virtually" in the actually existing successors, after that they are unraveled. Just as, for instance, the protons of our atoms, that existed as free particles (individuals) some billion years ago in the plasma of our sun, now exist virtually, with their causal power, as quanta of the relative force fields, in the nuclei of our atoms, proteins, tissues,... of our bodies that are the actually existing complex individuals, outcome of such an evolutionary history. This ontology depends strictly on the QFT interpretation of the uncertainty principle in quantum physics.

Roughly speaking, because of the Third Principle of Thermodynamics, all the moles of matter, at whichever level of complexity, are oscillating, so that a force field can be associated to them. Hence, the intrinsic unity of each body at the macroscopic level depends on the phase coherence of the oscillations of these force fields at the microscopic level. The long-range correlations related with the instantaneous propagation of a phase coherence domain (the famous "quantum entanglement", but think also to the everyday phenomenon of the resonances) determines the emergence of coherent collective behaviors, and hence an intrinsic scale change from the micro- to the macro-level. In this way, the elements constituting the system lose their individuality, because of the emergence of a new collective behavior of the new complex individuality so emerged, so to be considered as quanta of the relative force fields. Effectively, they virtually (i.e., causally, by exerting a causal action: "virtus" means "force" in Latin) exist with their force fields in the new complex individual. This ontology, that is essentially the Aquinas one in his famous booklet "The Mixtion Elementorum", with the just described formalization in NR through the unraveling principle, is indeed the direct outcome of the duality particle-wave interpretation in QFT, versus its QM interpretation.

Namely, in QFT, the emergence of whichever physical system is related with some "spontaneous symmetry breakdown" of the quantum vacuum (QV), that is, it is related with the emergence of as many "phase coherence domains" in the QV by a spontaneous symmetry breaking (SSB) of it. In this way, the particles involved have to be considered as the quanta of the associated force field, just as photons are the quanta of the electromagnetic force field.

This formal ontology is indeed the outcome of the duality particle-wave interpretation, versus its QM interpretation.

Namely, in QFT, the emergence of whichever physical system is related with some "spontaneous symmetry breakdown" of the quantum vacuum, that is, it is related with the emergence of as many "phase coherence domains" characterizing the coherent behavior of the oscillating particles involved. In this way, particles are the quanta of the associated force field, just as photons are the quanta of the electromagnetic force field. This means rewriting, for large amplitude coherent states of phase θ , the uncertainty principle in QFT as the following:

$$\Delta n \Delta \varphi \geq f(\theta)$$

Where $f(\theta)$ is different from zero, n is the number of quanta of the force field, and φ is the field phase. If $(\Delta n = 0)$, φ is undefined so that it makes sense to neglect the waveform aspect in favor of the individual, particle-like behavior. On the contrary if $(\Delta \varphi = 0)$, n is undefined because an extremely high number of quanta are oscillating together according to a well-defined phase, i.e., within a given coherence domain. In this way, it would be nonsensical to describe the phenomenon in terms of individual particle behavior, since the collective modes of the force field prevail. Ontologically, a new more complex individual (physical system) emerged, of which the phase coherence is its "form", organizing in a new complex substance (individual) its "matter" elements, according to the language of hylomorphism, particularly adapted as a descriptive ontology of this physics.

We see during the course, that we can eliminate the quotation marks from "form", because in QFT a phase coherence is a condensate of Nambu-Goldstone bosons that are not gauge bosons, quanta of force field interactions like photons (i.e., quanta of energy even though in this case massless), but quanta of the modes of these dynamic interactions. So they have fundamentally an "immaterial", purely relational, ordering nature, though they can be indirectly detected and their density measured like the gauge bosons.

Coming back to the modal formalization in NR of such an ontology, because the modal relational semantics is logically incomplete, and coalgebra is the proper, complete, meta-language of modal logics ("modal logics are coalgebraic"), the

metaphysical double implication of NR can have its proper formalization only in the context of the duality algebra-coalgebra in category theory (CT). That is, in terms of Aquinas' intuition, at the basis of his masterpiece "De Veritate" (q.1, art.2 co), of the "duality" (homomorphism, with an inversion of arrows and of compositions), between the logical truth (algebra) and the ontological truth (coalgebra).

Indeed, the essential limit of a purely modal formalization of NR double implication is that the converse implication, also in its modal version as "strict converse implication" ("it is impossible that q and not-p"), is not "truth preserving" (i.e., $1,0 \rightarrow 1$ is allowed), so it cannot be used in dual composition with direct implication, for formalizing the double, "onto-logical", implication of the metaphysical deduction.

On the contrary, the "duality" between a category C and its opposite category Cop (in the case, between an algebra $(Ax \rightarrow A)$ and its coalgebra $(A \rightarrow Ax)$) is always "truth preserving", in the sense that every assert true in C, is true also in Cop, and vice versa, despite they belong to different categories, being the homomorphic functor relating them, bijective, without being isomorphic.

Because the "De Veritate" is universally known as the semantics of Aquinas metaphysics of the participation of being, hence NR, as far as completely formalized in a coalgebraic modal logic, can be trustworthy considered, not only as a formal ontology of the evolutionary cosmology based on QFT in the physical realm, but also – at the most fundamental level – as a formalization of Aquinas metaphysics and logic of the participation of being – evidently including also "a non-evolutionist evolutionary theory" of the universe such as QFT (see below).

More deeply, the coalgebraic modal logic depends strictly on the development of the Universal Coalgebra (UC), as "dual", in CT sense, of the Universal Algebra (UA), and as general theory of dynamic systems and of computing systems as state transition systems (STS). In this way, the unbounded sequences of Kripke models can be formalized as the progressive "unfolding" of all the infinite possible combinations of elements (states) from the carrier set of a final coalgebra $(A \rightarrow Ax)$ as the semantics of the syntactic formulas (effectively, the translation of propositional calculi formulas into formulas of a Boolean algebra (equation logic)) of the dual initial algebra $(Ax \rightarrow A)$. "Semantics" in the sense that the algebraic formulas are satisfied by a subset of the possible states/behaviors of the computing systems. In this way it becomes possible to define formally, in theoretical computer science, also the semantics of infinite data sets (data streams). On the other hand, the UC theory, as general theory of dynamic systems, is able also to give the proper strong, universal theoretical framework in which interpreting the formalism of QFT, having in the duality algebras-coalgebras - in terms of q-deformed Hopf algebras/coalgebras dualities - its core notion. Finally, the UC theory is able also to give the same universal theoretical framework in which formalizing also the NR formal ontology, so to justify formally the continuity we have envisaged between QFT - at the physical-mathematical level - and NR at the logical-ontological level.

Particularly, in such a context, the key notions of NR, such as: 1) "the reversal of the arrows and of the compositions" between the direct (logical necessity) and the converse (causal necessity) implications, and hence 2) between the bottom-up logical induction and the top-down ontological co-induction (corresponding to the unraveling of unbounded sequences of model domains/subdomains in ML), can find their proper formalism in terms of the "duality", in the category theory (CT) sense, between UA and UC in its application to the metaphysical deduction.

Indeed, the invariance of the "truth/falsehood" operators in a coalgebra as to their dual algebraic counterpart by the "inversion of arrows and of compositions", can give a strong formal foundation to the NR theory of the duality between logic "direct implication" and the ontic "converse implication", in the theory of the metaphysical implication, which cannot have otherwise a justification in the context of the logical formalism. The intrinsic reference-to-object of any ontological and/or applied (usage of) a language (ordinary languages before all) can have indeed a justification, if and only if we attain at the deep "structural" (i.e., algebraic/coalgebraic) character of any articulated language, and hence of any grammar, and, finally, of any logic. The abstract logical distinctions between syntax, semantics and pragmatics of logic are indeed a superstructure over the fundamental dual structure algebra-coalgebra where they are intimately fused, even though not confused. Hence, intractable problems in logic, such as the reference problem and the metaphysical/ontological implication, for limiting ourselves to those discussed in our course, can have a solution only by attaining at the fundamental structure of logic and thought, disclosed by CT and the duality theory.

To conclude, such a renewed emphasis over the algebraic structure of ontology and even metaphysics, certainly supports, after three centuries, a similar emphasis in G. Leibniz work, at the beginning of the modern era. He, indeed, with his theory of a *Characteristica Universalis*, for the first time proposed the idea of a UA. Nevertheless, such a reproposal emphasizes also the limit of Leibniz interpretation in metaphysics. His truth functor T is essentially an endofunctor over the Divine Intellect $(A \times$

A \rightarrow A), making of each thing a “monad” – in the algebraic proper sense – and hence a “representation” internal (self-dual as) to the Divine Intellect. For this reason, Leibniz ontology – i.e., his “Monadology”, as he rightly defined it – makes of him the maximal expression of the “pre-established harmony” theory, i.e., of the onto-theological principle in its modern version.

What is lacking at his time was the coalgebraic “dual” of UA, that is UC. By UC and the implied coalgebraic ML, we can vindicate the genius of Aquinas in defining his metaphysics and semantics – with the homomorphism relating the logical and the ontological truth – of “the participation of being”, of which the NR constitutes thus a formalization.

Finally, a corollary of this theory as to the problem of the false dualism “creationism” “evolutionism”. The connotation of QFT as a “non-evolutionist evolutionary theory of the universe” I suggested at the beginning, can have in NR formal ontology a rigorous definition, since the “q-deformed Hopf algebras/coalgebras” of QFT formalism are not “self-dual” w.r.t. classical Hopf bialgebras in QM. Now, as the Polish mathematician and philosopher M. Heller emphasized, in a paper written ten years ago and devoted to emphasize, by commenting the work of S. Majid, the potentialities of CT duality theory in the philosophy of physics, there are in QM at least two, even though highly controversial, ways for supposing that Hopf self-duality could play a role in fundamental physics, for giving a physical significance to A. Connes’ non-commutative geometry. I.e., for giving a physical significance to the most fascinating theory till now proposed (and this is true also ten years) for connecting gravitation and quantum physics into one only geometrical formalism. If this QM application was true – this is Majid’s fundamental thesis – such an algebraic self-duality could play also the role of the “ultimate explanation” of a “self-explaining universe”. On the contrary, as Vitiello and his colleagues recently proposed, the q-deformed algebras-coalgebras of QFT can endow Connes’ non commutative geometries – effectively Connes’ “non-commutative spectral geometries” applied to a purely geometric explanation of the standard model of electroweak and strong interactions – with a much more physically significant algebra doubling, than the Hopf self-duality in its QM interpretation. That is, “the unfulfilled dream of any geometry”, and of Connes’ non-commutative geometry in species, of a bijective correspondence between a non-commutative doubled algebra and a given space, is satisfied in a very elegant way with the correspondence between each of the infinitely many non-commutative, doubled q-deformed Hopf algebras – one for each different q-deformation parameter (effectively a “temperature”) – and its representations into one of the infinitely many inequivalent Hilbert spaces, into which the unique Hilbert space of QM (because of Stone-Von Neumann theorem) can be “foliated” in QFT (where this theorem cannot hold). Effectively, each of these bijection between a doubled q-deformed Hopf algebra/coalgebra and its representation in one inequivalent Hilbert space foliation, corresponds to one of the infinitely many inequivalent representations of the canonical commutation relations, made available by the spontaneous symmetry breakdowns, in the QV ground state. It is evident that, in such a way, the q parameter is the “evolution parameter” of the universe(s) according to QFT, which in this way appears to be a “complete” evolutionary theory of the universe – in the physical and in the formal sense. On the physical side, QFT is complete because the QV, and the consequent intrinsic “openness” of each quantum system to QV fluctuations, is not a “boundary condition”, but an intrinsic ingredient of the theory, according to the physical sense of the third principle, interpreting the QV as the inner reservoir of energy of each physical system, the whole universe included. On the other side, in CT formalism, QV is nothing but an implementation, at the cosmological level, of the final UC of all the QFT dynamic systems, w.r.t. which each q-deformed Hopf algebra and its “dual” q-deformed coalgebra - physically satisfying (making physically true the formulas of) its algebraic partner -, are as many sub-algebras/sub-coalgebras. Effectively, the q-deformed Hopf sub-coalgebras, are as many topologies, dynamically designed as partial ordering on the (infinite) carrier of clopen sets of UC in its QV implementation. At the same time, although QFT is a complete (in a CT and not logical sense: there are no “mathematical laws of everything” at its footing, so that Gödel theorems are not violated) explanatory theory of the universe evolution, nevertheless it is not a “self-explanatory” theory of the universe, because its underlying dual structure is not self-dual. All the dualities characterizing it are homomorphisms between different categories – the logical necessity among representations (algebraic: $Ax_A \rightarrow A$ endomorphisms) vs. the causal necessity among states/phases/behaviors (coalgebraic: $A \rightarrow Ax_A$ morphisms), included. For this, intrinsic, non self-dual character, QFT is an ultimate (fundamental) theory of universe evolution, granting no self-explanatory character to its existence. For this reason, I connoted QFT as an evolutionary, but non-evolutionistic theory.

The course consists thus of four sections, each of two modules. We give the first two sections in online modality, while we give the second ones by at-place classes.

In the FIRST SECTION, after a course introduction and overview, in the first module we summarize in a descriptive way the new evolutionary vision of nature related to QFT as a quantum thermal field theory, as distinct and irreducible to QM, with its applications, both in the relativistic realm (microphysics) and in many body physics (macrophysics), from cosmology, to standard model of quantum physics, to the physics of condensed matter, biological and neurophysiological application

included. In the second module we discuss the ontological interpretation of QFT, suggesting that the Aristotle and Aquinas natural ontology and metaphysics constitute the proper ancestor of such a vision of nature, given that it implies a new paradigm in physical sciences opposed to the modern mechanistic one of the Newtonian physics and QM.

In the SECOND SECTION, in its first module, we illustrate the notion of formal philosophy as a result of applying the formalization typical of the axiomatic method of theoretical and applied mathematical science also to philosophy. What we stress, however, is the different logic used for such a type of formalization : the philosophical logic as opposed to mathematical logic. We insist particularly on the intensional logics, as the core of the philosophical logic, because they are formalizations of the logical structures of "first (plural and singular) person" thought and language – effectively the intentional jargon common to all the natural languages –, they are effectively different semantics, each characterized by different truth conditions of the very same modal logic. This emphasizes the core difference between intensional (philosophical) and extensional (mathematical) logic: all intensional logics are not truth-functional because the extensionality axiom and the existential generalization rule do not hold in them. Effectively, however, there is a way for integrating, at the meta-language level, these two perspectives: they share the same (co)algebraic structures because it is possible to offer a coalgebraic formalization of the modal logic structures and semantics: "modal logics are coalgebraic", indeed. These last developments of formal philosophy, however, will be the object of the last section of our work. In the second module we discuss an intermediate step toward NR, that is the conceptualist natural realism (CNR) of N. B. Cocchiarella as a conceptualist formalization, alternative to Carnap's logical atomism, of the ontology of QM and at the same time as a proposal of formalizing the Aristotelian ontology of nature. Apart from some undoubtable contact points with NR, its weakness for constituting a valuable formalization of a realistic ontology is precisely its "conceptualist" bias. In it the existence of physical beings is based not on an "onto-logical calculus" but on hypotheses waiting for an empirical confirmation.

In the THIRD SECTION we present, in the first module, our ML formalization of NR. We start from Quine's criticism w.r.t. early Lewis' pretension of giving through the notion of "strict implication" a sufficient definition of the metaphysical implication. This criticism is useful because it emphasizes that a suitable theory of the metaphysical implication must give information also about the relationship relating the beings to which the statements posed into a metaphysical implication relationship refer. We already emphasized at the beginning of this description the main points of the ML formalization of NR, with its potentialities and criticalities. In the second module we introduce some elements of CT, as far as useful for justifying a coalgebraic ML for our NR system, in view of solving the main critical points of our NR modal formalization.

In the FOURTH SECTION, we present in the first module, in the context of the CT "duality" between UA and UC, a coalgebraic ML and its applicability both to a general theory of dynamic systems (QFT dynamic systems, in particular), and to a metaphysics of being such as Aquinas' one, founding the existence of all beings in their double, hylomorphic constitution on the efficient causality from a "Primary Cause". Particularly, we emphasize that QFT theory, as far as based on q-deformed algebras that are not self-dual, is a complete theory of our evolutionary universe, without granting it a "self-explanatory" character of its existence. Finally, in the second module of this section, we illustrate the metaphysical and the theological implication of Aquinas theory of the "duality", in CT sense, between the logical truth and the ontological truth, so to satisfy Quine's requirement about a satisfying notion of metaphysical implication. In the last module, we summarize all the theoretical itinerary, characterizing our course.

[Bibliography \(many of these texts and other texts \(lecture notes\) will be made available online\):](#)

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Course Schedule (every module corresponds to 4 classes, except those in italic font (1 class):

Modules	Topic	Suggested Reading
SECTION ONE		
0.	<i>Introduction & Course Overview</i>	
1.	QFT: an evolutionary interpretation of nature from cosmology to neuroscience	References: 1-5
2.	QFT in fundamental physics and the Aristotelian-Thomistic ontology of nature	References: 6, chs. 5-6; 7-8
SECTION TWO		

Modules	Topic	Suggested Reading
3.	Formal philosophy and formal ontology	References: 9-11
4.	The formal ontology of the conceptual natural realism (CNR)	References: 12-15
SECTION THREE		
5.	The formal ontology of the natural realism (NR)	References: 16-18
6.	The duality algebras/coalgebras in CT and the notion of Universal Coalgebra (UC)	References: 19-24
SECTION FOUR		
7.	"Modal logics are coalgebraic": an application to NR and to the duality logical/ontological truth	References: 24-28
8.	<i>Conclusions: from ontology, to metaphysics, to theology</i>	

Examinations:

Evaluation of an examination paper prepared by the student about some topics developed in the course.