Course Syllabus
«The Formal Ontology of the Natural Realism: The New Dual Paradigm in Natural Sciences»

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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 quantum field theory (QFT), interpreted as a thermal field theory, because of the "openness" of each quantum system to the irreducible quantum fluctuations of the quantum vacuum (QV). In this way, the Hamiltonian character of a quantum system is recovered, by including the thermal bath into the formalism, through the principle of the "doubling of the degrees of freedom" between the system and its thermal bath. Formally, this is elegantly obtained by G. Vitiello's modelling of the mirroring "system-thermal bath", through the duality – in category theory terms – between a q-deformed Hopf algebra, and the relative q-deformed Hopf coalgebra, where q is a thermal parameter. This is a functorial duality algebra-coalgebra, where the functor is the Bogoliubov creation-annihilation transform of QFT, and the "reversal of arrows and compositions" characterizing the duality, corresponds to the satisfaction of the energy balance constraint. This "populates" progressively the QV by physical particles and systems, through the "mechanism" of the Spontaneous Symmetry Breakdown (SSB) of the QV at the ground state, and of its "foliation". This is, of course, an alternative interpretation as to the "standard QFT" interpretation, based on quantum mechanics (QM), i.e., the QED and the QCD, and that uses systematically in QM the "glorious" perturbative methods of classical mechanics, as we discuss in the course.

Therefore, after an elementary introduction into such a QFT interpretation of fundamental physics in the online part of the course, we concentrate ourselves, during the onsite part of it, on the logical foundation of this interpretation, and of its ontological consequences. Indeed, from the standpoint of the philosophical logic, the functorial duality algebra-coalgebra, characterizing the mathematical logic of QFT, is able to suggest us an original solution of the secular problem of the justification of the "ontological bi-conditional" in the metaphysical theory of proof, in formal philosophy, as irreducible to the logical bi-conditional of the logical theory of proof. This is formally justified, on the coalgebraic, semantic side, through the use of Aczel's non-standard theory of sets, allowing by its "anti-foundation axiom" (AFA), the set self-inclusion (singletons), and hence an unbounded, branching succession of singleton set inclusions. Indeed, because of AFA, the transitivity of inclusions and hence the set total ordering do not hold in this semantics. On this way, it is possible to justify a generalization of this duality in terms of Rutten's Universal Algebra-Universal Coalgebra functorial duality, having in the pairs, congruence-bisimilarity, and induction-coinduction, its core notions. From the proof-theoretic standpoint, this allows NR to formalize Aquinas' suggestion of interpreting the onto/logical bi-conditional in terms of the arrow reversal between the logical entailment (among asserts) and the causal entailment (among the denoted entities), as far as based onto a more fundamental "functor" of efficient causality, from reality into the cognitive agent, sending the morphism (formal causality) from the former into the latter ("Not the stone is in mind, Aristotle said, but the form of the stone"). From the semantic standpoint, NR is thus able to formalize, in terms of a nested **KD45** modal logic, a nested branching of unbounded sequences of Kripke's models, as formalization of the ontology of the causal generation of nested natural kinds (i.e., the genera-species branched unfolding, by causal entailment from upper generating causes, till the first one) of ever more complex physical systems, so to demonstrate the compatibility between Aquinas' metaphysics and the evolutionary cosmology.

This course presents the formal ontology of the Natural Realism (NR) as the ontology of the quantum field theory (QFT) interpretation of the fundamental physics, 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, both in the microscopic relativistic realm of Standard Model, and in the macroscopic realm of condensed matter physics, biological matter included, together with their Aristotelian ontological interpretation, 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 NR as formal ontology of QFT, and as well of the Aristotelian ontology of the causal foundations of the natural forms of ever more complex natural kinds of physical systems, in terms of Aquinas metaphysics of the "participation of being". QFT indeed, just as the Aristotelian ontology of nature, constitute a different paradigm as to the Newtonian one of the classical and quantum mechanics (formally based on the use of perturbative methods, for "cutting" the interactions of a physical system, so to study it as an isolated one), both reducing in such a way dynamics to kinematics, and hence inverting the Aristotelian foundation of the mathematical and physical laws on the causal relation between things (science as *cognitio certa per causas*), to the Newtonian and Kantian reversal of such a relationship (causal necessity is founded on the logical necessity) and hence to the notion of science as *cognition certa per leges*. "Explaining" in science means exclusively to find a mathematical relationship linking variable quantities, so to make their variations predictable in time, without any reference to "causes" and "essences", left to the elucubrations of philosophers. The actual cosmology and the related QFT interpretation of fundamental physics are emphasizing that "physics is legislated by cosmogony" (Wheeler) and/or the "'causality is without law', so revising our modern vision of causality and of its relation to laws of nature" (Mangabeira Unger). These are the emerging ontological and epistemological challenges emerging from the contemporary physics. NR formal ontology want to suggest a first answer to this challenge in a post-modern way,connecting the best of the classical tradition (metaphysics), with the best of the modern one (science) for a new interdisciplinary, but rigorous research program.

The course consists therefore of four sections and several modules. The first two modules (module 0 and module 1) of the first section are in distance learning (e-learning) modality, the rest is given in onsite modality through eight classes, supposing the study of the previous e-learning part. All the slides, both for the e-learning and the onsite parts of the course are available online with many texts of the suggested bibliography.

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. This is true, even though, as Van Benthem recently emphasized, mathematical logic, philosophical logic, and computational logic are today intercommunicating, given that the coalgebraic interpretation of modal logics, per se developed in computational logic, allows by bisimilarity and observational equivalence a non-extensional notion of equivalence. 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 a conceptualist formalization of

the Aristotelian ontology of nature. Apart from some undoubtable contact points with NR, NCR's 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, so confusing modeling in science and formal ontology.

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 QML 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 suitable notion of ontological/metaphysical implication. In the last module, we summarize all the theoretical itinerary, characterizing our course.

General Bibliography.

Many of these texts are available online for the course, by clicking on the relative active link, if present, of this list. Other texts are suggested (and linked) in the bibliography slide(s) of each lecture.

0. MAIN TEXTS:
    - G. BASTI, "From formal logic to formal ontology. The new dual paradigm in natural sciences," in: *Proceedings of 1st CLE Colloquium for Philosophy and History of Formal Sciences, Campinas, 21-23 March 2013*, F. M. Bertato (Ed.), Campinas, 2015 (In Press)
    - G. BASTI, *Lecture notes of the course on the QFT in fundamental physics.*
1. M. BLASONE, P. JIZBA, G. VITIELLO, «Preface», in: *Quantum field theory and its macroscopic manifestations. Boson condensations, orderd patterns and topological defects*, Imperial College Press, London, 2011, pp. vii-xii.
2. G. VITIELLO, «Links. Relating different physical systems through the common QFT algebraic structure», *Lecture Notes in Physics*, 718 (2007), 165-205.
3. E. DEL GIUDICE & G. VITIELLO, «The role of the electromagnetic field in the formation of domains in the process of symmetry breaking phase transitions», *Phys. Rev.*, A74 (2006), 022105.
4. E. DEL GIUDICE, R. PULSELLI, E. TIEZZI, «Thermodynamics of irreversible processes and quantum field theory: an interplay for understanding of ecosystem dynamics», *Ecological Modelling*, 220 (2009), 1874-79.
5. W. J. FREEMAN & GIUSEPPE VITIELLO, «Nonlinear brain dynamics as macroscopic manifestation of underlying many-body field dynamics», *Physics of Life Reviews*, 3 (2006), 93-118.
6. G. BASTI, *Philosophy of Nature and of Science. Vol.I: The Foundations*, Rome 2002 (English translation for student use only)
7. G. BASTI, «Intelligence and reference. Formal ontology of the natural computation». In: *Computing Nature*, G. DODIG-CRNKOVIC AND R. GIOVAGNOLI (Eds.), Springer-Verlag, Berlin Heidelberg, 2013, pp. 139-159 (Sapere, 7).
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9. A. CHURCH, *Introduction to mathematical logic*, Princeton UP, 1996, Princeton, NJ (1956[1]).
10. *Formal philosophy*, V. F. Hendricks e J. Symons (Eds.), Automatic Press/VIP, Copenaghen, 2005.
11. J. P. BURGESS, *Philosophical logic (Princeton foundations of contemporary philosophy)*, Princeton UP, Princeton NJ, 2009.
12. M. J. CRESSWELL & G. E. HUGES, *A new introduction to modal Logic*, Routledge, London, 1996.

13. P. Blackburn, M. De Rijke, Y. Venema, *Modal logic. Cambridge tracts in theoretical computer science* , Cambridge UP , Cambridge, UK, 2002.

14. N. B. Cocchiarella, «Logic and ontology», *Axiomathes*, 12 (2001), 117-50:

15. Nino B. Cocchiarella, *Formal Ontology and Conceptual Realism* , Springer Verlag , Berlin-New York, 2007.

16. J. W. Garson, «Quantification in modal logic», in *Handbook of Philosophical Logic. Second Edition, Vol. III*, D. Gabbay e F. Guenthner (ed.), Springer , Berlin-New York, 2001, pp. 267-324.

17. R. Hayaki, «Actualism and higher-order worlds», *Philosophical studies*, 115 (2003), 149-78

18. G. Basti, «From formal logic to formal ontology. The new dual paradigm in natural sciences», in *Proceedings of 1st CLE Colloquium for Philosophy and History of Formal Sciences, Campinas, 21-23 March 2013*, Fabio M. Bertato (ed.), Campinas UP , Campinas, 2014.

19. Jean-Pierre Marquis, «Category Theory», in *Stanford Encyclopedia of Philosophy* <http://plato.stanford.edu/archives/sum2013/entries/category-theory/> [accessed 13 September 2014]

20. Jap Van Oosten, «Basic Category Theory. 2002 Ed.» <http://www.staff.science.uu.nl/~ooste110/syllabi/catsmoeder.pdf> [accessed 13 September 2014]

21. P. Aczel, «Non-well-founded sets», *CLSI Lecture Notes, vol.14*, 1988.

22. P. Aczel & N. P. Mendler, «A Final Coalgebra Theorem», in *Category Theory and Computer Science*, Lecture Notes in Computer Science , Springer , London, UK, 1989, CCCLXXXIX, 357-65.

23. J. J. M. Rutten, «Universal coalgebra: a theory of systems», *Theoretical computer science*, 249 (2000), 3-80.

24. Y. Venema, «Algebras and co-algebras», in *Handbook of modal logic*, P. Blackburn, J. F.A.K. van Benthem. and F. Wolter (Eds.) , Elsevier , Amsterdam, 2007, pp. 331-426.

25. C. Cirstea et al., «Modal logics are coalgebraic», *The computer journal*, 54 (2011), 31-41.

26. P. Blackburn, M. De Rijke and Y. Venema, *Modal logic. Cambridge tracts in theoretical computer science* , Cambridge UP , Cambridge, UK, 2010 (2002[1]).

27. M. Heller, «Algebraic sef-duality as the "ultimate explanation"», *Foundations of science*, 9 (2004), 369-85.

28. M. Sakellariadou, A. Stabile & G. Vitiello, «Noncommutative spectral geometry and the deformed Hopf algebra structure of quantum field theory», *Journal of Physics: Conference Series*, 442 (2013), 012016.

29. R. Mangabeira Unger & L. Smolin, *The singular universe and the reality, of time. A proposal in natural philosophy*, Cambridge UP, Cambridge UK, 2015.

Course Program

Modules	Topic	Suggested Reading
	SECTION ONE	
0.	*Introduction & Course Overview*	
1.	QFT: an evolutionary interpretation of nature from cosmology to neuroscience	References: 1-5. 29
2.	QFT in fundamental physics and the Aristotelian-Thomistic ontology of nature	References: 6, chs. 5-6; 7-8
	SECTION TWO	
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) I: logical vs. causal inference	References: 16-18

Modules	Topic	Suggested Reading
6.	The formal ontology of the natural realism (NR) II: Aczel sets and coalgebraic modal logic	References: 19-24
	SECTION FOUR	
7.	The formal ontology of the natural realism (NR) III: the duality logical/ontological truth	References: 24-28
8.	*Conclusions: from ontology, to metaphysics, to theology*	