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Our Cosmos, from Substance to Process

Timothy E. Eastman
Plasmas International, Silver Spring, Maryland

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From Substance to Process

In its most successful results, research in physics and astronomy has led to perspectives that emphasize a "both/-and" character of systems: *both* continuity *and* quantization; *both* symmetry *and* asymmetry; *both* space *and* time, *both* substance *and* process, *both* reduction *and* emergence. This conceptual shift contrasts with common assumptions of a "substance universe," which gives priority to "things" or externally-related objects and spatialized representation. The latter likely derives from the dominance of vision for *homo sapiens*, along with apparent empirical validation by many classical systems and models, reinforcing a worldview of perceptual objects, reductionism, reversibility and possibilities of a "God's-eye" view that have become presuppositions of modernism. In contrast, quantum field theory shows the world as a plenum of events at multiple scales, now extended in networks of relationships to cosmic scales – a "process universe." Recent results in nonlinear dynamics and ecology, among other research fields, demonstrate emergence in multiply-interconnected systems. Undercutting global realism, certain limitations and approximations have been found to be fundamental and have contributed to the evolution of modern[1] physics, including relativity theory and quantum theory. Discoveries in space plasmas and other fields further illustrate limits of substance language and mere spatialized representation, and are steadily reinforcing processual aspects and both-and characteristics of physical systems.

Seeing is believing. For those of us blessed with sight, our experience of the world is vision-centric. This dominance of vision for humans often leads us to adopt a worldview of perceptual objects in which the world is simply constituted by a multiplicity of discrete objects, from atoms to galaxies, all of which are ultimately like classic substance, hence a "substance metaphysics" (see "Evolution in Metaphysics" below). Closely related concepts are simplistic forms of global realism in which some "God's eye view" allows for completely spatialized representation of systems at multiple levels and times. Global realism claims the natural actuality of non-perspectival surveys of the universe, which contrasts with Whitehead's denial of any genuinely non-perspectival surveying of the universe (*Whitehead*, 1929). Nevertheless, Whitehead was a nuanced realist with categorial obligations that had global implications.

[1] The term "modern physics" refers to quantum and relativity theories and their various developments and applications that have dominated much of 20th century physics. In contrast, "modernism" and "postmodernism" refer to cultural, philosophical and artistic movements. Griffin (1993) has developed a constructive postmodern framework that offsets the typical focus on deconstruction.

Prior to the space age, views of the cosmos from Earth's surface revealed a "steady" sun, planets, moons, stars and galaxies, all separated by the vast "emptiness" of space. Such presumption of separateness and discreteness, aided by the great 19th century advances in atomic theory, reinforced confidence in unlimited projections of substance thinking. When coupled with unlimited confidence in the new modernism, first introduced by Descartes [*Toulmin*, 1990], conditions were ripe for the *fin de siecle* certainties that led some to see an "end of science" in both the late 19th and late 20th century.

In contrast to such cosmic isolation and discreteness, recent research results (primarily within the past three decades) have dramatically shown how energetic particles, fields and space plasmas permeate the cosmos at all levels; i.e., there is no such thing as a pure "vacuum" anywhere. Further, the variable sun with all its planets and plasmas are imbedded in the heliosphere, which is part of the interstellar medium and our galaxy. These multiply-connected systems are analogous to the Earth system, which has been shown to be constituted by interconnected ecological systems including solid earth, oceans, atmosphere and geospace environments. Naturally, studies of the biosphere further demonstrate the importance of ecological perspectives [*Kauffman*, 1995]. Whitehead emphasized essentially the same point more than a half century earlier, and characterized his process philosophy as a "philosophy of organism" [*Whitehead*, 1929].

Evolution in Physics: Classical to Modern Physics

Classical Physics (19th century, see Figure 1) – Isaac Newton's revolutionary works of the late 17th century came to fruition in the 19th century through major mathematical and quantitative advances that completed this first major conceptual synthesis in physics. The Newtonian synthesis basically takes the inverse square law for gravity, so successful for the analysis of planetary motion, and applies it to any combination of discrete particles imbedded in pre-given space. Variables used in physical laws, including time (always an independent variable), are presumed to be continuous while all atoms are assumed to be perfectly rigid, simple bodies. In the 19th century, Hamilton and Lagrange constructed complementary and elegant theoretical frameworks of differential equations that provided conceptual and quantitative unity to classical physics [*Butterfield*, 2004]. This was extended in 1864 by James Clerk Maxwell to cover all of electricity and magnetism in Maxwell's great unification of electromagnetism.

Modern Physics (20th century, see Figure 1) – The second major conceptual and quantitative synthesis in physics, modern physics, arose near the turn of the 20th century with the advent of both quantum theory and relativity theory. Beginning in 1900, Max Planck, Albert Einstein, Niels Bohr and others, developed quantum theories with discrete energy levels to explain experimental results that were in conflict with classical physics, including the photoelectric effect and the black body spectrum. In 1925, Erwin Schrödinger and Werner Heisenberg developed quantitative theories that unified quantum theory; their alternative formulations were later shown to be equivalent. The fundamental equations of relativity theory, the Lorentz transformations, were formulated independently about 1900 by Joseph Larmor and Hendrik Lorentz. These transformations enabled Maxwell's equations of electromagnetism to remain the same (invariance) for different frames of reference. Einstein used the Lorentz transformations in his special relativity (1905) and general relativity theories (1915), providing for invariance of the laws of physics in constantly moving frames or accelerated frames, respectively.

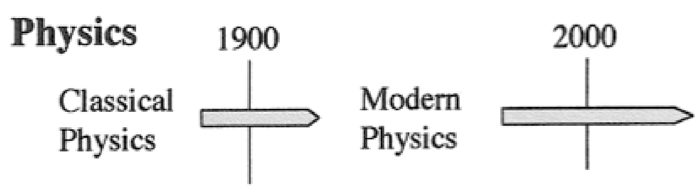

Figure 1. Timeline from Classical to Modern Physics.

Evolution in Metaphysics: Substance Metaphysics to Event Metaphysics

Substance Metaphysics (19^{th} and 20^{th} centuries, see Figure 2) – The metaphysical presuppositions that have generally accompanied classical physics include, among other, part-whole reductionism, "billiard-ball" atomism, strict determinism, and the ultimacy of continuity. This mechanistic-materialist framework derives partly from the worldview of perceptual objects discussed above because it always allows for, in some "God's eye view," exact modeling of any system by some mechanical model, however complicated. Given the world-shaking transformations made possible by industrial machines in the 19^{th} and early 20^{th} centuries, it is understandable that some considered their potential as unlimited. This Newtonian vision also portrays the world as fundamentally a collection of "things," or externally-related objects (albeit internally related in terms of symmetric and deterministic causal relations), and leaves little room for subjective beings. Following Descartes' approach, this presumption of "things" as ultimate, or substance metaphysics, is augmented by introducing subjects as another distinct ultimate notion. Thus, we have Descartes' classic subject-object dualism. The other option is to drop subjects altogether and hold to a consistent but value-less, radical materialism.

Event Metaphysics (late 20^{th} and 21^{th} centuries, see Figure 2) – The event metaphysics, or process framework, that has been rapidly gaining ground since the late 20^{th} century, provides a fundamental alternative to the substance metaphysics described above [*Clayton*, 2004; *Nobo*, 2004]. An event metaphysics treats events and processes as more fundamental than "things." An object or substance is not simply composed of more elemental objects (e.g., atoms or "elementary" particles). As found in quantum field theory, macroscopic objects are complex integrations of particles and fields, which in turn are constituted by a plenum of events at multiple scales [*Jungerman*, 2000]. All things are constituted ultimately by networks of relationships, from microscopic to macroscopic and cosmic scale.[2] Research in nonlinear dynamics and ecology also demonstrates the emergence of new structures and entities in multiply-interconnected systems [*Laszlo*, 2006]. Although elements of the new event metaphysics have been long present as emphasized by Whitehead and others, signatures of its presence in the new physics and other sciences have been primarily evident only within the past few decades [*Clayton*, 2004; *Eastman and Keeton*, 2004a,b].

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[2] To say that "things are constituted ultimately by networks of relationships," however, does not here re-introduce some new reductionism with "nothing but" claims. The metaphysical basis for this arises from "the organic philosophy's reconciliation, at the metaphysical level, of two fundamental philosophic notions: individual absoluteness and individual relativity." [*Nobo*, 1986, p. 383; also see Lango, 2003]

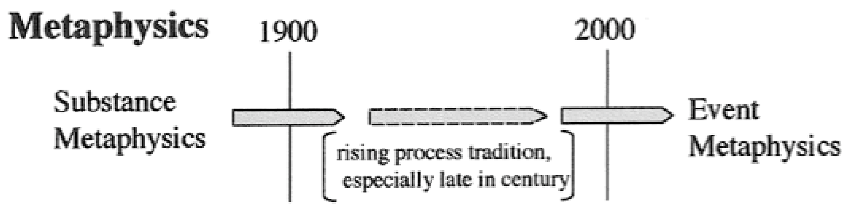

Figure 2. Timeline from Substance to Event Metaphysics.

Evolution in Philosophies of Nature: Classical –> Standard –> Process views

Philosophies of nature derive from a complex weaving of prevailing philosophical views at a given time along with concurrent understandings of the natural world, whether or not built on systematic sciences [*Leclerc*, 1986]. My hypothesis is that the two phases of physics since Newton's time [classical, modern] have been woven with the two principal metaphysical frameworks [substance, event], to create three distinct philosophies of nature.[3]

Building on the scheme of philosophical dualities laid out by *Hartshorne* [1970], Table 1 shows key dualities of modern physics and how they relate to classical physics concepts [*Eastman*, 2004a].

Table 1. Dualities in Classical and Modern Physics

Classical Physics	Modern Physics
Substance only; materialism	both substance and event-oriented descriptions
External relations for objects	both external and internal relations
Continuity only; no ultimate discreteness	both continuity and quantization
Symmetry only	both symmetry and asymmetry
Space only; time spatialized	both space and time; coupled space-time metric
Determinism only	both predictability/determination and indetermination
Particles only	both particles and waves
Parts only	both parts and wholes
External only (source for order)	both external and internal sources of order; self-organization
Efficient cause only	both efficient cause and other types

Classical View (19th century and earlier, see Figure 3) **–** In the schema used here, the classical view of nature is characterized by an *exclusive focus on the first of each duality pair* given in the Modern Physics column of Table 1 and also listed in the first, Classical Physics, column. The mechanistic-materialist framework of the classical view derives from a worldview of perceptual

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[3] Here I use "philosophy of nature" in Leclerc's broad sense as a blend of scientific interpretations and prevailing cultural frameworks. Whitehead characterized the philosophy of nature as necessarily abstracting from critical distinctions of perceived and perceiver, and thus being closed to mind (see Whitehead, 1919, 1920). Here, a process view of nature is envisioned that could overcome this limitation.

objects wherein things are precisely locatable in space ("simple location"), which encourages a simplistic part-whole reductionism. Spatialized representations at all levels combined with the assumption of global realism yielded strong claims of absolute determinism, the unlimited scope of mechanistic explanation, the ultimacy of continuity, and the ultimacy of "things." The new atomic theory of matter was interpreted in terms of the philosophical atom, being self-contained, absolutely rigid, and immutable.

Standard View (20th century, see Figure 3) – Along with the second major conceptual synthesis in physics, that of modern physics, it became recognized through the new quantum theory that discreteness is fundamental and that there is a basic duality of particles and waves. Secondly, the new relativity theory destroyed the notion of absolutely rigid bodies at any scale and put the focus on maintaining the invariance of physical relationships between different frames of reference. Through the Lorenz transformations, the special theory of relativity lays out constraints on temporal and spatial intervals for different events with only indirect dependence on "objects." What emerges in the standard view of nature, dominant throughout the 20th century, is an *emphasis on the first of each duality pair* shown in Table 1, but with increasing recognition of the importance of such dualities.

I propose that this emphasis on the substance metaphysics side of the duality pairings is a signature of the standard view being a hybrid combination of modern physics with substance metaphysics. One example of this is how substance-oriented interpretations dominated throughout most of the 20th century. However, discoveries in "particle" physics late in the century led many scientists to view the world as a plenum of events at multiple scales (Jungerman, 2000). Nevertheless, substance-oriented interpretations remain prominent due to a continuing presumption of metaphysical atomism and unlimited possibilities for spatialized representation. "Particle" physics is a prime exemplar of reductionistic science and the standard view even though, ironically, research results are forcing many interpreters to look beyond any simplistic substance metaphysics.

Process View (late 20th and 21st century, see Figure 3) – In this third major conceptual synthesis, currently in development, the *physical and philosophical implications of the duality pairings are becoming fully expressed*.

Recent work in nonlinear dynamics, quantum theory, superconductivity, space plasmas and other fields (*Kauffman*, 1995; *Goedbloed and Poedts*, 2004; *Laughlin*, 2005; *Levin and Wen*; 2005) point to ontological emergence, and not just epistemological emergence (*Silberstein and McGeever*, 1999). Thus, systems generally exemplify a combination of reduction (exclusively focused on efficient causes) and emergence with both top-down as well as bottom-up (efficient) causality. These new results suggest that all entities are constituted by networks of relationships, in contrast to substance views that ground all things in some type of immutable substance.

In a process universe, networks of relationship are generalized instead of discrete substance. Instead of 'things,' process or events and their processions are considered as fundamental – an event metaphysics. This process view emerges from the long-term evolution in philosophies of nature from Cartesian dualism to a "duality without dualism" or both-and descriptions as listed in Table 1 above.

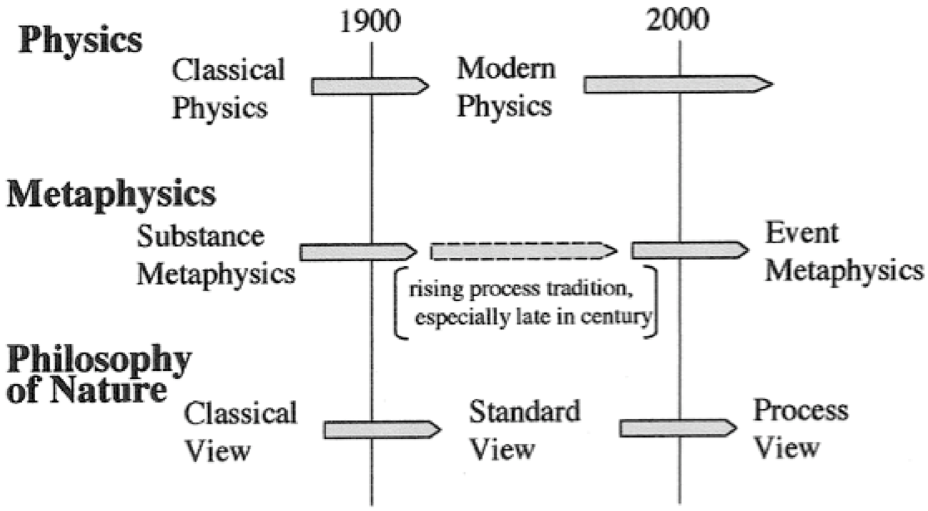

Figure 3. Timeline of Physics, Metaphysics, and Philosophies of Nature

Fin de Siècle Claims

By the late 19th century, the great success of Newtonian physics combined with the great success of the new atomic theory led Lord Kelvin to pronounce an "end of science" [*Kelvin*, 1900].

The standard view yielded problematic "end of science" claims in the 1990s [e.g., *Hawking*, 1996] analogous to comparable claims by Lord Kelvin in the 1890s – errors incurred by such *fin de siècle* claims have a common root in substance metaphysics and part/whole reductionism. These claims are all the more representative because they were both made by physicists of the very highest achievement and standing in the scientific communities of their time. Stephen Toulmin (1990) argues that certain claims for certainties, illustrated by *fin de siècle* claims, reflect extra-scientific motivations like those associated with Descartes and the birth of modernism.

Some interpretations of modern physics, especially in the popular literature, exemplify this hybrid mix of modern physics and substance metaphysics. For example, physicist Julian Barbour (2000) argues that time does not exist and that it is all an illusion; what exists are only static containers of records associated with abstract configuration spaces. Such elimination of time and process is common in formulations depending on substance metaphysics and commits Whitehead's "fallacy of misplaced concreteness" (*Griffin*, 1986). Butterfield (2002) along with Griffin demonstrate how problematic such a claim is on both scientific and philosophical ground.

In these issues, one needs to distinguish the evolution of science from that of the underlying metaphysics. There has been a continuing evolution of scientific observation, experimentation, theory and modeling for more than 300 years. However, the underlying metaphysical frameworks have not similarly evolved because they reflect historical, cultural, and religious factors that cannot be easily falsified, if at all.

Both Reduction and Emergence

With continuing progress in new observation and experiments, a really new physics is steadily emerging that is less dependent on the unstated substance metaphysics that infects the standard view. For example, it is ironic that the rigor of controlled laboratory experiments and constant, evolving interplay between theory and experiment has led particle physics to seeing the world not just as "particles" but as a plenum of events; thus, both "particles" and events. Feynman recognized the reality as both/and, and simply suggested the "particle" label for physics as a convenient convention. Unfortunately, many others have had much deeper substance metaphysics commitments. Feynman's path integral approach is recognized by many physicists today as being an important key towards new developments, and this approach is much more compatible with a process view than with any type of substance view. There are many examples of process trends in modern science with even greater presence in the research literature than in popularizations, although not as accessible. The process-oriented scholarly and scientific communities have documented many such examples in *Process Studies* and other journals and books that highlight the interface of process thought and modern science [see compilation in *Eastman and Keeton*, 2004a,b].

Ours is a multiply-interconnected, processual universe in which any finite actuality is necessarily constituted by some unifying response to the plenum of events constituting its local world (*Hartshorne*, 1979). Concepts may be global but concrete facts are local, not global (*Hansen*, 2004). The essential character of concrete facts denies the universality of claims for global realism, or God's-eye-view claims. Recent developments indicate a need to go beyond forms of modernism that presuppose a substance universe and move on to a more integrated, ecological worldview, or process view of nature. And this is best done through the reinforcement of sound scientific methodology and the application of careful science-philosophy distinctions.

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References

Barbour, Julian, *The End of Time*, Oxford: Oxford University Press, 2000

Butterfield, Jeremy, 2002. "Critical notice," *The British Journal for the Philosophy of Science*, Vol. 53 (no. 2), pp. 289-330.

Butterfield, Jeremy, 2004. "On Hamilton-Jacobi Theory as a Classical Root of Theory" and "Between Laws and Models: Some Philosophical Morals of Lagrangian Mechanics," available from http://users.ox.ac.uk/~alls0074/

Clayton, Phillip, 2004. "Introduction to Process Thought," in *Physics and Whitehead: Quantum, Process, and Experience*, Albany: State University of New York Press (pp. 3-13).

Eastman, Timothy E., and Hank Keeton, editors, 2004a. *Physics and Whitehead: Quantum, Process, and Experience*, Albany: State University of New York Press.

__________, 2004b. Resource Guide to Physics and Whitehead, *Process Studies Supplement*, Issue 4.

Eastman, Timothy, 2004. "Duality without Dualism," in *Physics and Whitehead: Quantum, Process, and Experience*, Albany: State University of New York Press (pp. 14-30).

Goedbloed, Johan Peter, and Stefaan Poedts, 2004. *Principles of Magnetohydrodynamics: With Applications to Laboratory and Astrophysical Plasmas*, Cambridge University Press.

Griffin, David Ray, 1986. “Introduction: Time and the Fallacy of Misplace Concreteness,” in *Physics and the Ultimate Significance of Time*, ed. D. Griffin, Albany: State University of New York Press (pp. 1-48).
Griffin, David Ray, 1993. “Introduction: Constructive Postmodern Philosophy.” In David R. Griffin, et al., *Founders of Constructive Postmodern Philosophy: Peirce, James, Bergson, Whitehead, Hartshorne*. Albany: State University of New York Press, pp. 1-42.
Hansen, Niels Viggo, 2004. “Spacetime and Becoming: Overcoming the Contradiction Between Special Relativity and the Passage of Time,” in *Physics and Whitehead: Quantum, Process, and Experience*, Albany: State University of New York Press (pp. 136-163; especially p.150).
Hartshorne, Charles, 1979. Whitehead’s revolutionary concept of prehension, *International Philosophical Quarterly*, Vol. 19, pp. 253-264.
Hartshorne, Charles. 1970. *Creative Synthesis and Philosophic Method*. La Salle: Open Court.
Hawking, Stephen W., *The Theory of Everything: The Origin and Fate of the Universe*, New Millennium Press, 2002 (first published as *The Cambridge Lectures: Life Works*, Dove Audio, Inc., 1996).
Jungerman, John A., 2000. *World in Process: Creativity and Interconnection in the New Physics*, Albany: State University of New York Press.
Kauffman, Stuart, 1995. *At Home in the Universe*. Oxford University Press.
Kelvin (Lord Kelvin), or William Thomson, "There is nothing new to be discovered in physics now, All that remains is more and more precise measurement." spoken in an address to the British Association for the Advancement of Sciences, 1900 [also see Quotations from Lord Kelvin available at http://zapatopi.net/kelvin/quotes/]
Lango, John W., 2003. Relational Particulars and Whitehead’s Metaphysics, in *Process and Analysis: Whitehead, Hartshorne, and the Analytic Tradition*, George Shields, editor, Albany: State University of New York Press.
Laszlo, Ervin, 2006. *Science and the Reenchantment of the Cosmos: The Rise of the Integral Vision of Reality*, Rochester, Vermont: Inner Traditions, 2006.
Laughlin, Robert, 2005. *A Different Universe*. New York: Perseus Books.
Leclerc, Ivor, 1986. *The Philosophy of Nature*, Washington, D.C.: Catholic University of America Press.
Levin, Michael and Xiao-Gang Wen, Photons and electrons as emergent phenomena, *Reviews of Modern Physics*, Vol. 77, July 2005.
Nobo, Jorge, 1986. *Whitehead’s Metaphysics of Extension and Solidarity*, Albany: State University of New York Press.
__________, 2004. “Whitehead and the Quantum Experience,” in *Physics and Whitehead: Quantum, Process, and Experience*, Albany: State University of New York Press (pp. 223-257).
Silberstein, Michael, and John McGeever, “The Search for Ontological Emergence,” *The Philosophical Quarterly*, Vol. 49, No. 195, April 1999, pp. 182-200.
Toulmin, Stephen, 1990. *Cosmopolis: The Hidden Agenda of Modernity*, Chicago: The University of Chicago Press.
Whitehead, Alfred North, 1919. *An Enquiry Concerning the Principles of Natural Knowledge*, Cambridge: Cambridge University Press.
________, 1920. *The Concept of Nature*, Cambridge: Cambridge University Press.
________, 1929. *Process and Reality*, New York: Macmillan Publishing Co.
[see Corrected Edition,   D. Griffin and D. Sherburne, editors, New York: The Free Press, 1978].