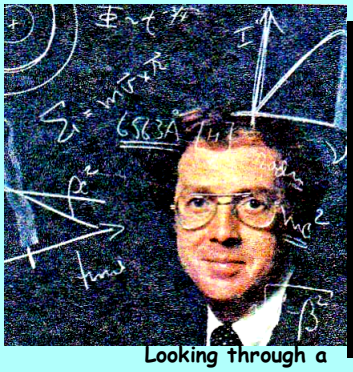
# Current Research



Looking through a superposition of his own calculations

**Eric Chaisson's current scientific research concerns the interdisciplinary subject of cosmic evolution—a grand synthesis of many varied changes from the big bang in the early Universe to humankind on Earth. He strives to use aspects of non-equilibrium thermodynamics to construct an all-inclusive scenario of evolution, broadly conceived, indeed applied to all known complex systems—physical, biological, and cultural. Some representative articles published during the past couple of decades along these lines include:**

**Chaisson, E.J., "The Rise of Information in an Evolutionary Universe," *World Futures: Journal of General Evolution*, v 50, pp 447-455, 1997**
http://www.cfa.harvard.edu/~ejchaisson/reprints/rise_of_info.pdf

**Chaisson, E.J., "Cosmic Age Controversy is Overstated," *Science*, v 276, p 1089, 1997**
http://www.cfa.harvard.edu/~ejchaisson/reprints/cosmic_age_overstated.pdf

**Chaisson, E.J., "The Cosmic Environment for the Growth of Complexity," *Biosystems*, vol. 46, pg. 13-19, 1998**
http://www.cfa.harvard.edu/~ejchaisson/reprints/cos_enviro_growth_complex.pdf

**Chaisson, E.J., "The Emerging Life Era: A Cosmological Imperative," in *Bioastronomy '99*, Lemarchand, G., Meech, K. (eds.), ASP Series, v 213, p 35, 2000**
http://www.cfa.harvard.edu/~ejchaisson/reprints/emerging_life_era.pdf

**Chaisson, E.J., "The Rise of Complexity in Nature," in *Bioastronomy '02*, Norris, R (ed.), ASP Series, p 531, 2004; Conf. Proc., Hamilton Island, Great Barrier Reef, 2002**
http://www.cfa.harvard.edu/~ejchaisson/reprints/rise_of_complexity_nature.pdf

**Chaisson, E.J., "A Unifying Concept for Astrobiology," *International Journal of Astrobiology*, v 2, pp 91-101, 2003; presented at Windsor Castle, UK, Sep, 2002**
http://www.cfa.harvard.edu/~ejchaisson/reprints/unifying_concept_for_astrobio.pdf

**Chaisson, E.J., "Complexity: An Energetics Agenda," *Complexity*, v 9, pp 14, 2004; DOI: 10.1002/cplx2009** http://www.cfa.harvard.edu/~ejchaisson/reprints/complexity_santafe_j.pdf

**Chaisson, E.J., "Non-equilibrium Thermodynamics in an Energy-rich Universe," in *Non-Equilibrium Thermodynamics and the Production of Entropy*, Kleidon, A. and Lorenz, R. (eds.), Springer, Berlin, 2005**
http://www.cfa.harvard.edu/~ejchaisson/reprints/nonequal_thermo_universe_2.pdf

**Chaisson, E.J., "Follow the Energy: Relevance of Cosmic Evolution for Human History," *Historically Speaking: Journal of the Historical Society*, v 6 #5, p 26, 2005**
http://www.cfa.harvard.edu/~ejchaisson/reprints/big_history.pdf

Speaking in Sydney, 2001

**Chaisson, E., "The Great Unifier," *New Scientist*, v 189, p 36, p 7, 2006**
http://www.cfa.harvard.edu/~ejchaisson/reprints/the_great_unifier.pdf

**Chaisson, E.J., "Cosmic Evolution: Synthesizing Evolution, Energy and Ethics", Filosofskie Nauki' (Philosophy, Science & Humanities), Moscow, v5, pp92-104, 2005**
http://www.cfa.harvard.edu/~ejchaisson/reprints/energy_evolution_ethics.pdf

**Chaisson, E.J., "Long-term Global Heating from Energy Usage," *Eos Transactions of American Geophysical Union*, v 89, no 28, p 253, 2008**
http://www.cfa.harvard.edu/~ejchaisson/reprints/Eos_AGU_Chaisson08.pdf

**Chaisson, E.J., "The heat to come...," *New Scientist*, v202, p 24, 2009**
http://www.cfa.harvard.edu/~ejchaisson/reprints/newscientist_galley1.pdf

**Chaisson, E.J., "Cosmic Evolution—State of the Science," in *Cosmos and Culture*, S. Dick and M. Lupisella (eds.), NASA Press SP-4802, pp 3-23, Washington, 2009**
http://www.cfa.harvard.edu/~ejchaisson/reprints/nasa_cosmos_and_culture.pdf

With his PhD student, Aaron Price, commencement 2011

**Chaisson, E.J., "Exobiology and Complexity," a review article in 11-volume *Encyclopedia of Complexity and Systems Science*, R. Myers (ed.), pp 3267-3284, Springer, Berlin, 2009**
http://www.cfa.harvard.edu/~ejchaisson/reprints/Springer_complexity_exobio_final_review.pdf

**Chaisson, E.J., "Energy Rate Density as a Complexity Metric and Evolutionary Driver," *Complexity*, v 16, pp 27-40, 2010; DOI: 10.1002/cplx.20323**
http://www.cfa.harvard.edu/~ejchaisson/reprints/EnergyRateDensity_I_FINAL_2011.pdf

**Chaisson, E.J., "Energy Rate Density II: Probing Further a New Complexity Metric," *Complexity*, v 17, pp 44-63, 2011; DOI: 10.1002/cplx.20373)**
http://www.cfa.harvard.edu/~ejchaisson/reprints/EnergyRateDensity_II_galley_2011.pdf

**Chaisson, E.J., "Cosmic Evolution—More than big history by another name," in *Evolution: A Big History Perspective*, a Euro/Russian journal/almanac, L. Grinin, A. Korotayev, B. Rodrigue (eds.), pp 37-48, Uchitel Publishing House, Volgograd, 2011**
http://www.cfa.harvard.edu/~ejchaisson/reprints/EuroRussian_galley_2011.pdf

**Chaisson, E.J., "A Singular Universe of Many Singularities: Cultural Evolution in a Cosmic Context," in *"Singularity Hypotheses: A Scientific and Philosophical Assessment*, Eden, Moor, Soraker, and Steinhart (eds.), pp 413-439, The Frontiers Collection, Springer, Berlin, 2012**
http://www.cfa.harvard.edu/~ejchaisson/reprints/Springer_Frontiers.pdf

**Chaisson, E.J., "Using Complexity Science to Search for Unity in the Natural Sciences," in *Complexity and the Arrow of Time*, C. Lineweaver, P. Davies and M. Ruse (eds.), pp 68-79, Cambridge Univ. Pr., 2013**
http://www.cfa.harvard.edu/~ejchaisson/reprints/ASUessay_revised_for_CUP.pdf

**Chaisson, E.J., "The Natural Science Underlying Big History," *Scientific World Journal*, v 2014, 41 pages, article ID 384912, 2014; DOI: 10.1155/2014/384912**
http://www.cfa.harvard.edu/~ejchaisson/reprints/big_history_review_Chaisson_TSWJ2014.pdf

**Chaisson, E.J., "Practical Applications of Cosmology to Human Society," *Natural Science*, v 6, pp 767-796, 2014; DOI: 10.4236/ns.2014.610077**
http://www.cfa.harvard.edu/~ejchaisson/reprints/cosmic_evolution_apps_Chaisson_NS2014.pdf

**Chaisson, E.J., "Big History's Risk and Challenge," *Expositions*, v 8.1, pp85-95, 2014**
https://www.cfa.harvard.edu/~ejchaisson/reprints/Expositions_BH.pdf

**Chaisson, E.J., "Internalizing null extraterrestrial 'signals': An astrobiological app for a technological society," in The Impact of Discovery Life Beyond Earth, S.J.Dick (ed.), Cambridge Univ. Press, 2015.**
https://www.cfa.harvard.edu/~ejchaisson/reprints/NASA_LoC_galley_Chaisson.pdf

**Chaisson, E.J., "Energy Flows in Low-entropy Complex Systems," *Entropy*, v 17, pp 8007-8018, 2015; DOI:103390/e17127857**
https://www.cfa.harvard.edu/~ejchaisson/reprints/entropy_2015_FINAL.pdf

**Chaisson, E.J., "Relating Big History to Cosmic Evolution," in *From Big Bang to Global Civilizations: A Big History Anthology*, Vol II, B. Rodrigue, L. Grinin, and A. Korotayev (eds.), pp 17-30, Primus Books, Delhi, 2016.**

**Chaisson, E.J., "Energy Budgets of Evolving Nations and Their Growing Cities," *Energies*, v 15, article 8212, 50 pages, 2022; DOI: 10.3390/en15218212**
https://www.cfa.harvard.edu/~ejchaisson/reprints/Energies_nation-states_2022.pdf

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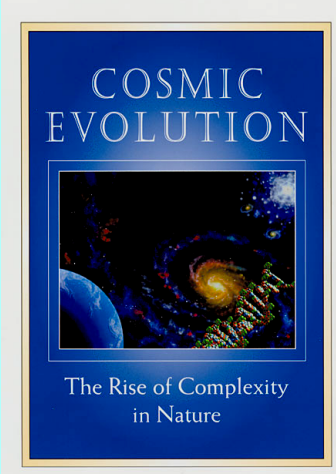
**In addition, the interdisciplinary subject of cosmic evolution is addressed in a monograph, *COSMIC EVOLUTION: The Rise of Complexity in Nature* ( www.hup.harvard.edu/catalog.php?isbn=9780674009875&content=reviews ), written under contract with Harvard University Press. What follows, by way of a brief description, is the book's preface (© President and Fellows of Harvard College):**




**Using astronomical telescopes and biological microscopes, among a virtual arsenal of other tools of high technology, modern scientists are weaving a thread of understanding spanning the origin, existence, and destiny of all things. Now emerging is a unified scenario of the cosmos, including ourselves as sentient beings, based on the time-honored concept of change. From galaxies to snowflakes, from stars and planets to life itself, we are beginning to identify an underlying, ubiquitous pattern penetrating the fabric of all the natural sciences—a sweepingly encompassing view of the order and structure of every known class of object in our richly endowed Universe. We call this subject "cosmic evolution."**

**Recent advances throughout the sciences suggest that all organized systems share generic phenomena characterizing their emergence, development and evolution. Whether they are physical, biological or cultural systems, certain similarities and homologies pervade evolving entities throughout an amazingly diverse Universe. How strong are the apparent continuities among Nature's historical epochs and how realistic is the quest for unification? To what extent might we broaden conventional evolutionary thinking, into both the pre-biological and post-biological domains? Is such an extension valid, merely metaphorical, or just plain confusing?**

**For many years at Harvard University, starting in the 1970s and continuing to the present, I have taught, initially with George B. Field, an introductory course on cosmic evolution that explores common denominators bridging a wide variety of specialized science subjects—physics, astronomy, geology, chemistry, biology, anthropology, among others. The principal aim of this interdisciplinary course creates a universal framework against which to address some of the most basic issues ever contemplated: the origin of matter and the origin of life, as well as how radiation, matter, and life interact and change with time. Our intention was to help sketch a grand evolutionary synthesis that would better enable us to understand who we are, whence we came, and how we fit into the overall scheme of things. In doing so, my students and I gained a broader, integrated knowledge of stars and galaxies, plants and animals, air, land, and sea. Of paramount import, we learned how the evident order and increasing complexity of the many varied, localized structures within the Universe in no way violate the principles of modern physics, which, prima facie, maintain that the Universe itself, globally and necessarily, becomes irreversibly and increasingly disordered.**

**Beginning in the late 1980s while on sabbatical leave at MIT, and continuing for several years thereafter while on the faculty of the Space Telescope Science Institute at Johns Hopkins University, I occasionally offered an advanced version of the introductory course. This senior seminar attempted to raise substantially the quantitative aspects of the earlier course, to develop even deeper insights into the nature and role of change in Nature, and thus to elevate the subject of cosmic evolution to a level that colleague scientists and intelligent lay persons alike might better appreciate. This brief and broadly brushed monograph—written mostly in the late 1990s during a stint as Phi Beta Kappa National Lecturer, and polished while resuming the teaching at Harvard of my original course on cosmic evolution--is an intentionally lean synopsis of the salient features of that more advanced effort.**

**Some will see this work as reductionistic, with its analytical approach to understand all material things. Others will regard it as holistic, with its overarching theme of the whole exceeding the sum of Nature's many fragmented parts. In the spirit of complementarity, I offer this work as an evolutionary synthesis of both these methodologies, integrating the deconstructionism of the former and the constructivist tendencies of the latter. Openly admitted, my inspiration for writing this book has been Erwin Schroedinger's seminal little tract of a half-century ago, *What is Life?,* yet herein to straighten and extend the analysis to include all known manifestations of order and complexity in the Universe. No attempt is made to be comprehensive in so far as details are concerned; much meat has been left off the bones. Nor is this work meant to be technically rigorous; that will be addressed in a forthcoming opus. Rather, the intent here is to articulate a skeletal précis—a lengthy essay, really—of a truly voluminous subject in a distilled and readable manner. To bend a hackneyed cliché, although the individual trees are most assuredly an integral part of the forest, in this particular work the forest is of greater import. My aim is to avoid diverting the reader from the main lines of argument, to stay focused on target regarding the grand sweep of change from big bang to humankind.**

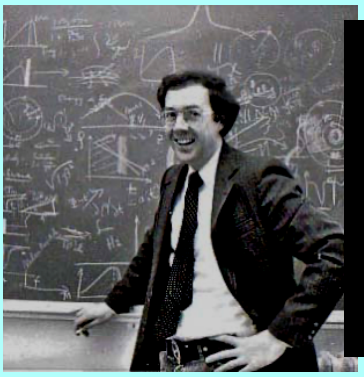
**Of special note, this is not a New Age book with mystical overtones however embraced or vulgarized by past scholars, nor one about the history and philosophy of antiquated views of Nature. It grants no speculation on the pseudo-science fringe about morphic fields or quantum vitalism or interfering dieties all mysteriously affecting the ways and means of evolution; nor do we entertain epistemological discussions about the limits of human knowledge or post-modernist opinions about the sociological implications of science writ large. This is a book about mainstream science, pure and simple, outlining the essence of an ongoing research program admittedly multidisciplinary in character and colored by the modern scientific method's unavoidable mix of short-term subjectivity and long-term objectivity.**

**In writing this book, I have assumed an undergraduate knowledge of natural science, especially statistical and deterministic physics, since as we shall see, much as for classical biological evolution, both chance and necessity have roles to play in all evolving systems. The mathematical level includes that of integral calculus and differential equations, with a smattering of symbolism throughout; the units are those of the centimeter-gram-second (cgs) system, those most widely used by practitioners in the field, editorial conventions notwithstanding. And although a degree of pedagogy has been included when these prerequisites are exceeded, some scientific language has been assumed. "The book of Nature is written in the language of mathematics," said one of my two intellectual heroes, Galileo Galilei, and so are parts of this one. Readers with unalterable math phobia will benefit from the unorthodox design of this work, wherein the "bookends" of Prologue-Introduction and Discussion-Epilogue, comprising more than half of the book, can be mastered without encountering much mathematics at all.**

**What is presented here, then, is merely a sketch of a developing research agenda, itself evolving, ordering and complexifying—an abstract of scholarship-in-progress incorporating much data and many ideas from the entire spectrum of natural science, yet which attempts to surpass scientific popularizations (including some of my own) that avoid technical lingo, most numbers, and all mathematics. As such, this book should be of interest to most thinking people—active researchers receptive to an uncommonly broad view of science, sagacious students of many disciplines within and beyond science, the erudite public in search of themselves and a credible worldview—in short, anyone having a panoramic, persistent curiosity about the nature of the Universe and of our existence in it.**

## Summary Abstract of This Work

**The essence of this book outlines the grand scenario of cosmic evolution by qualitatively and quantitatively examining the natural changes among radiation, matter, and life within the context of big-bang cosmology. The early Universe is shown to have been flooded with pure energy whose radiation energy density was initially so high as to preclude the existence of any appreciable structure. As the Universe cooled and thinned, a preeminent phase change occurred a few hundred centuries after the origin of all things, at which time matter's energy density overthrew the earlier primacy of radiation. Only with the onset of technologically manipulative beings (on Earth and perhaps elsewhere) has the energy density contained within matter become, in turn, locally dominated by the rate of free energy density flowing through open organic structures.**




At ease at a blackboard, either researching or teaching . . . .

**Using non-equilibrium thermodynamics at the crux, especially energy flow considerations, we argue that it is the contrasting temporal behavior of various energy densities that have given rise to the environments needed for the emergence of**

**galaxies, stars, planets, and life forms. We furthermore maintain that a necessary (though perhaps not sufficient) condition—a veritable prime mover—for the emergence of such ordered structures of rising complexity is the expansion of the Universe itself. Neither demonstrably new science nor appeals to non-science are needed to explain the impressive hierarchy of the cosmic-evolutionary scenario, from quark to quasar, from microbe to mind.**

**Eric J. Chaisson**
**Concord, Massachusetts**