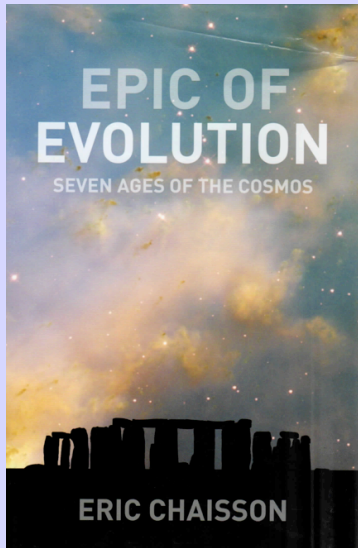




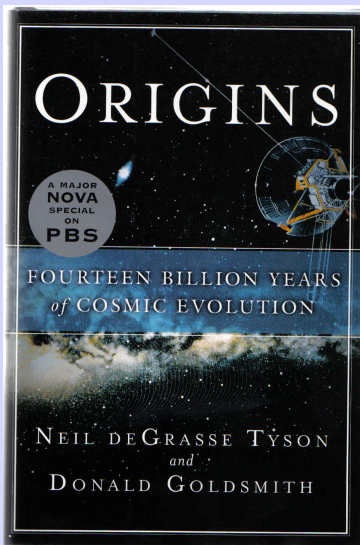
Cosmic Evolution
and
Human Destiny

STEVEN J. DICK

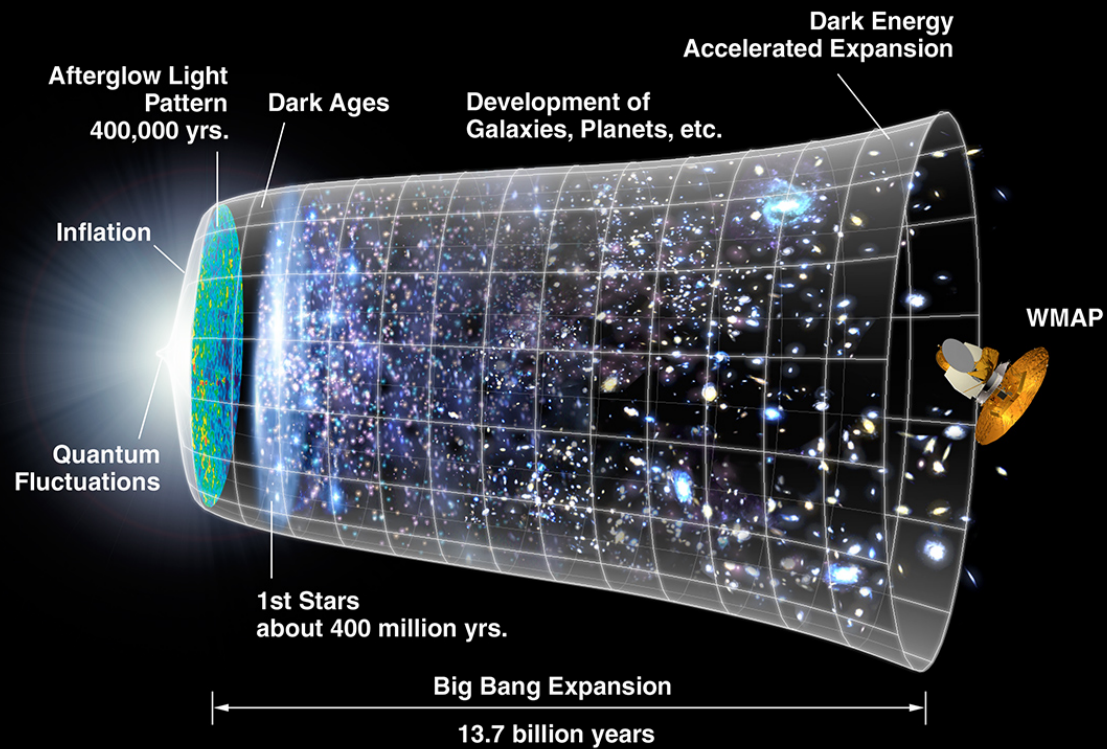
Cosmic Evolution



- The entire universe is evolving
- All its constituent parts are connected
- Applies to matter, life and culture
- But NOT Darwinian Evolution
(Transformational vs Variational Evolution)



The Master Narrative of the Universe





The New
Frontier

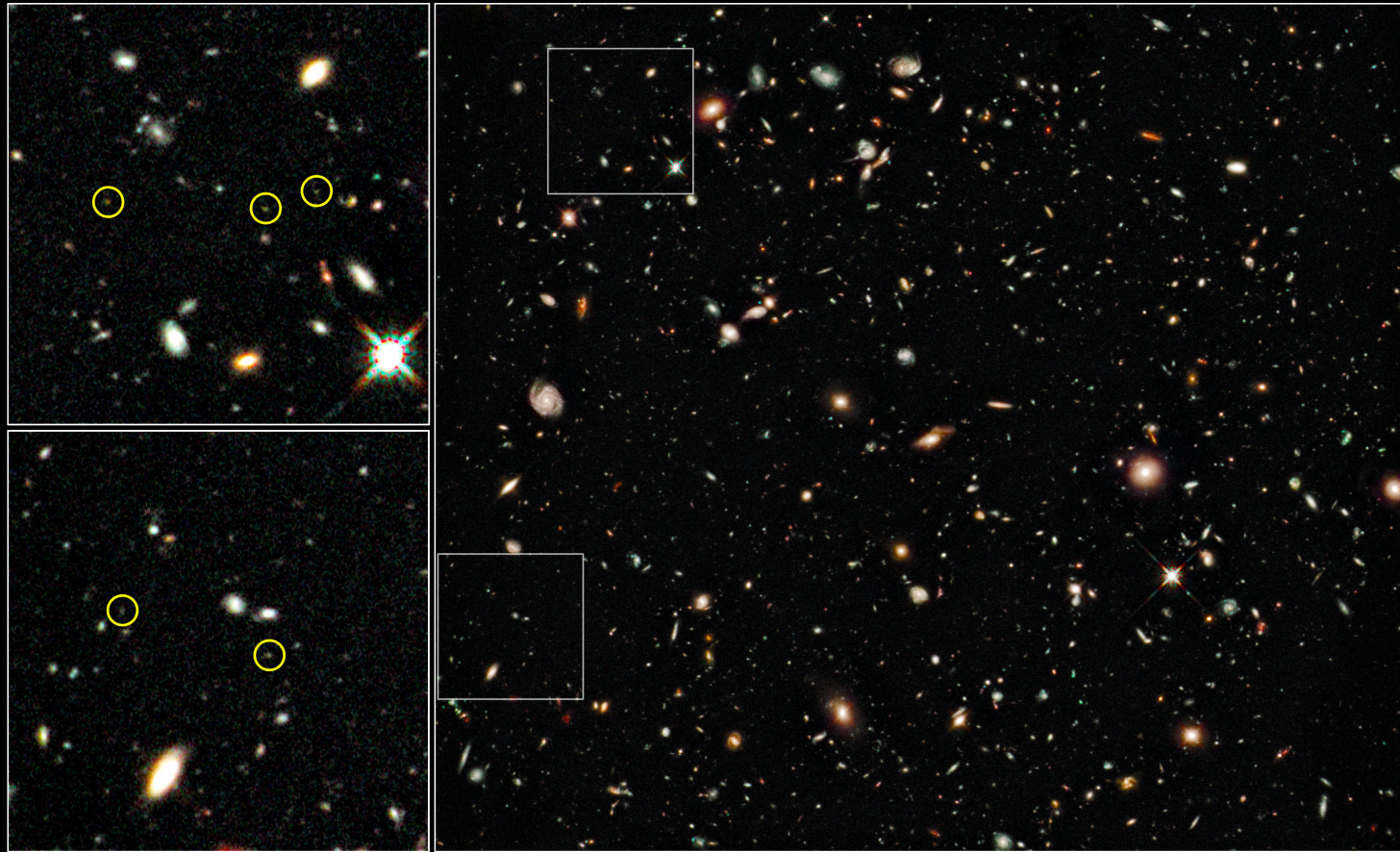
The Infinite
Ocean

13.7 Billion
Years Old

45 Billion
Light Years
Radius

Hubble Ultra Deep
Field, 2004

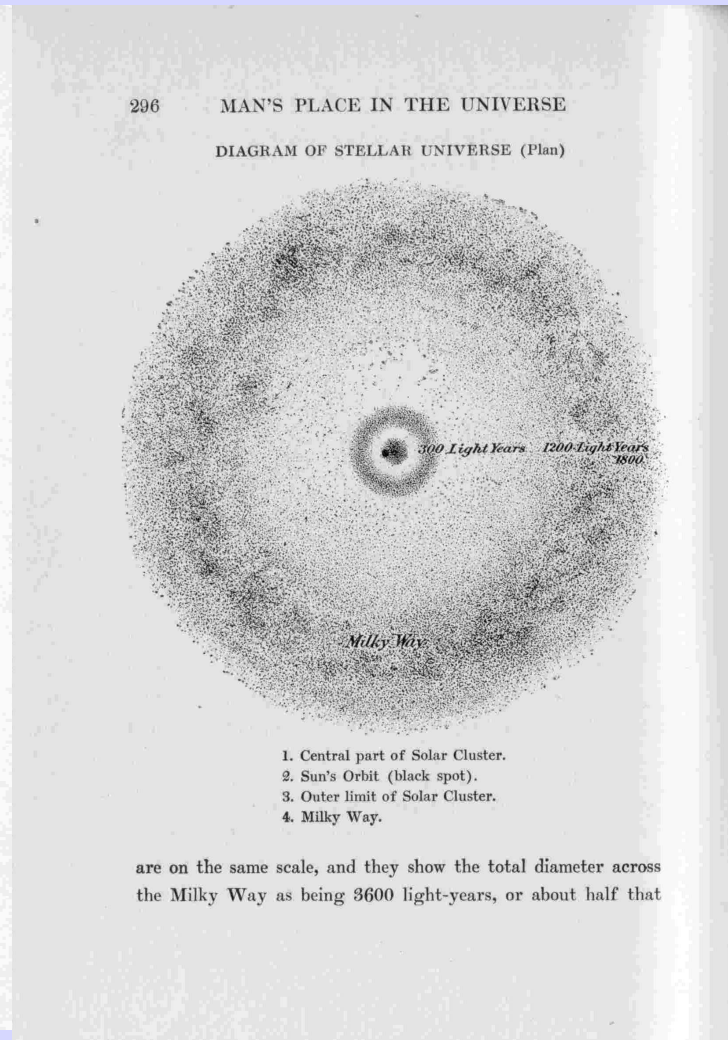
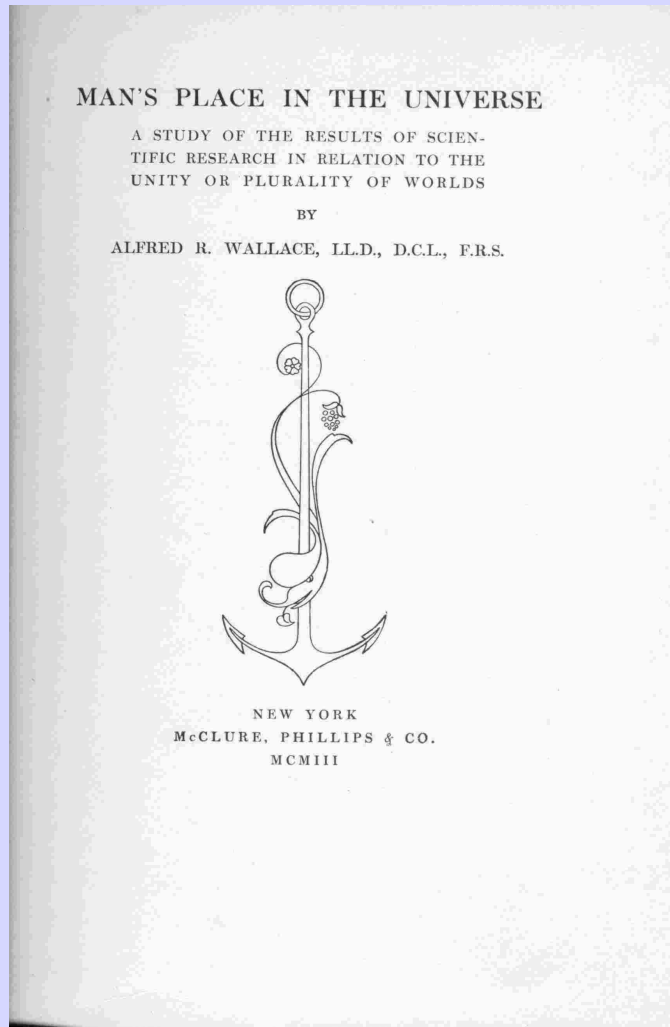
Billions of Light Years Distant



Hubble Ultra Deep Field • Infrared
Hubble Space Telescope • WFC3/IR

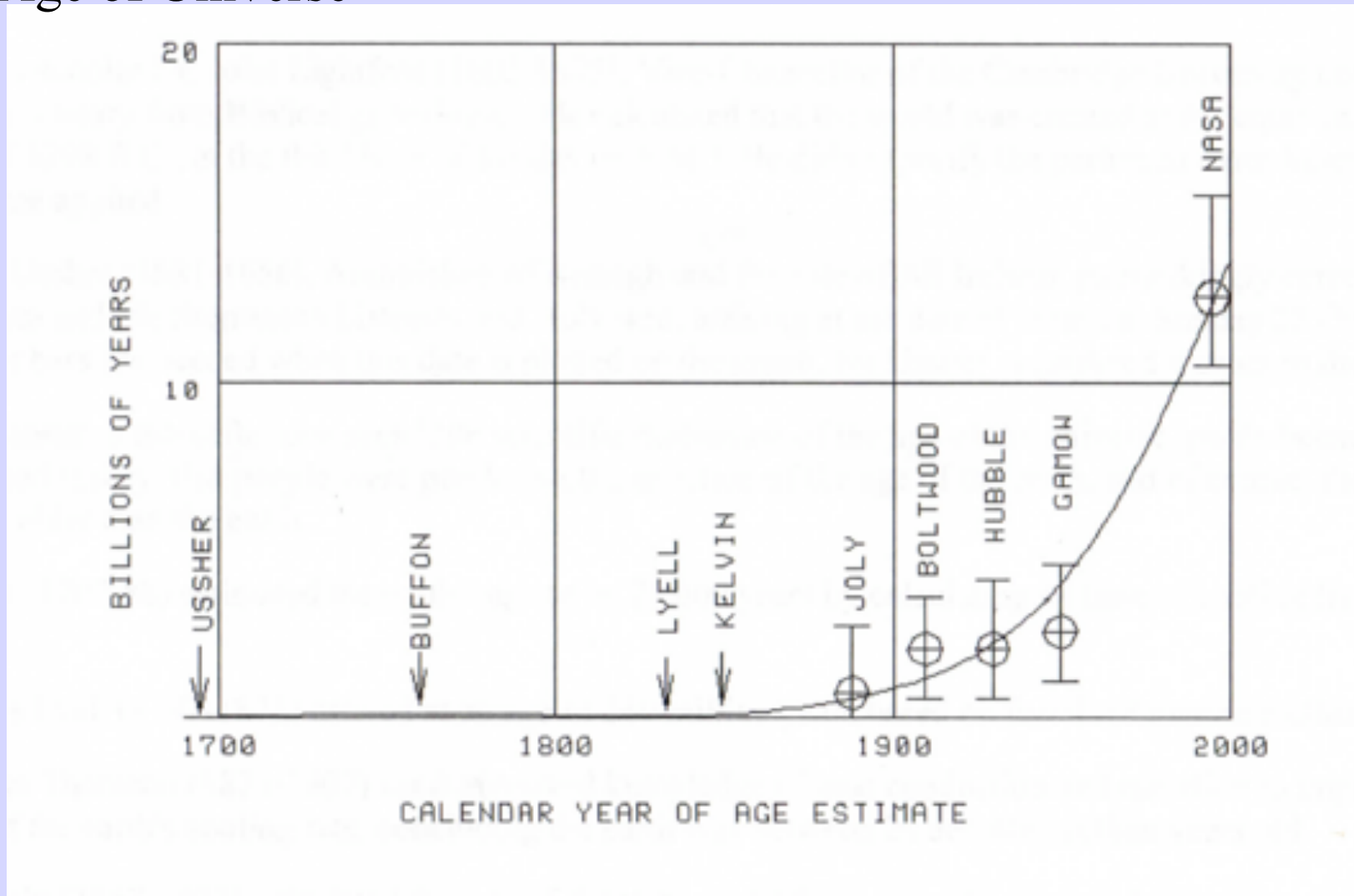
A Universe 3600 Light Years in Extent

A. R. Wallace, 1903



The Universe Acquires a History

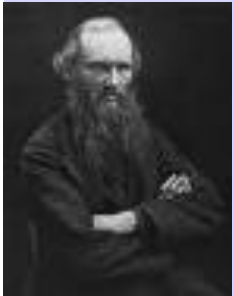
Age of Universe



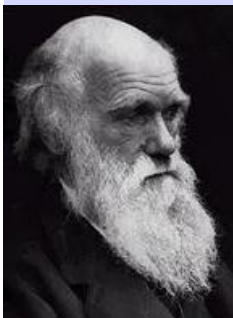
Simanek, 2001

The Universe Acquires a History

The 19th century Debate:



Lord Kelvin: constraints on the age of the Earth
= 20 million to 400 million years



Charles Darwin: evolution posits a very
long chronology



Not resolved until 20th century with
Radioactivity, Hubble, Big Bang

Sandage, 1958 = 13 to 25 billion years old

Antecedents

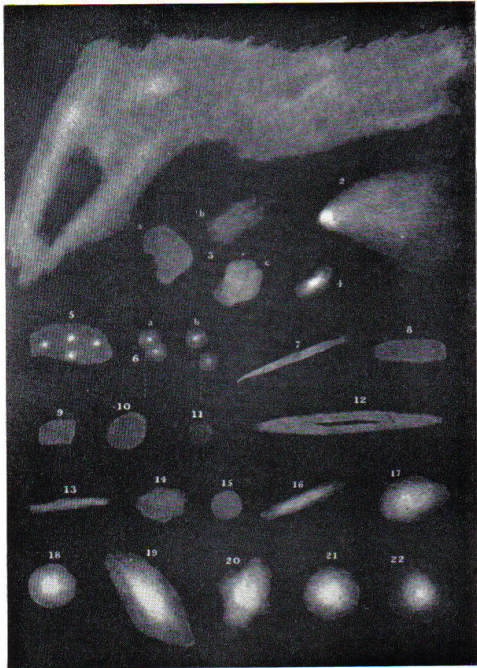


PLATE 6. Rough sketches by Herschel of 'nebulosities' and 'nebulae', illustrating his 1811 paper on the construction of the heavens (pp. 136-44).

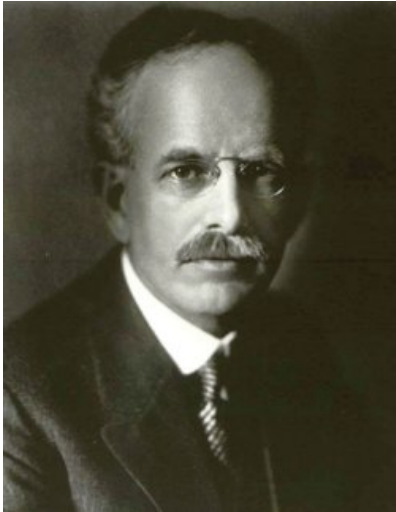
Laplace nebular hypothesis (1796)

W. Herschel, evolution of nebulae (1811)

Lowell, *The Evolution of Worlds* (1909)

Hale, *Study of Stellar Evolution* (1908)

These are only pieces of cosmic evolution

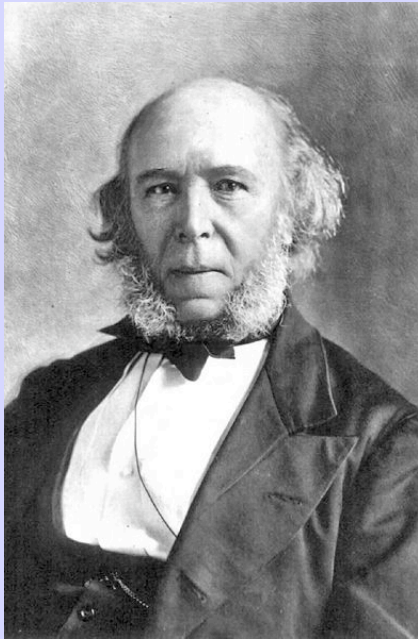


Cosmic Evolution, 1908

George Ellery Hale

“We are now in a position to regard the study of evolution as that of a single great problem, beginning with the origin of the stars in the nebulae and culminating in those difficult and complex sciences that endeavor to account not merely for the phenomena of life, but for the laws which control a society composed of human beings”

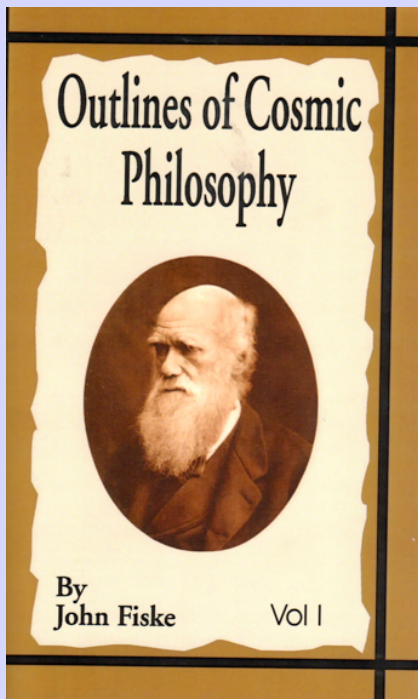
George Ellery Hale
The Study of Stellar Evolution, 1908



Herbert Spencer

Broader Precursors

- Robert Chambers, *Vestiges of the Natural History of Creation* (1844)
- Herbert Spencer – evolution guides every field (1862-97)
- John Fiske (1874)
- George Elery Hale (1908)
- Lawrence J. Henderson, *The Fitness of the Environment* (1913)



Cosmic Evolution, 1913

Lawrence J. Henderson

- Professor of Biological Chemistry, Harvard, & first president of History of Science Society
- *The Fitness of the Environment: An Inquiry into the Biological Significance of the Properties of Matter* (1913)
- See Iris Fry's detailed study "On the Biological Significance of the Properties of Matter: L. J. Henderson's Theory of the Fitness of the Environment," JHB, 29 (1996), 155-196

Cosmic Evolution, 1913

Henderson's Conclusion

There is ... one scientific conclusion which I wish to put Forward as a positive statement and, I trust, fruitful outcome Of the present investigation. The properties of matter and the Course of **cosmic evolution** are now seen to be intimately related To the structure of the living being and to its activities; they Become, therefore, far more important in biology than has been Previously suspected. For the whole evolutionary process, both Cosmic and organic, is one, and the biologist may now rightly Regard the universe in its very essence as **biocentric**.

Henderson, *The Fitness of the Environment* (1913)

Harlow Shapley (1885-1972)

- ❖ Globular cluster work determined solar system was far from galactic center
- ❖ Director Harvard College Observatory, 1921-1952
- ❖ Built strong graduate program
- ❖ Popularizer of science and its implications
- ❖ First sustained writer on cosmic evolution



See Jo Ann Palmeri dissertation: *An Astronomer Beyond the Observatory: Harlow Shapley as Prophet of Science*

Shapley on Cosmic Evolution, 1958



The Earth and its life are “on the outer fringe of one galaxy in a universe of millions of galaxies. Man becomes peripheral among the billions of stars in his own Milky Way; and according to the revelations of paleontology and geochemistry he is also exposed as a recent, and perhaps an ephemeral manifestation in the unrolling of cosmic time.”

Harlow Shapley
Of Stars and Men, 1958

Shapley on Cosmic Evolution

“Nothing seems to be more important
Philosophically than the revelation that the
Evolutionary drive, which has in recent years
Swept over the whole field of biology, also
Includes in its sweep the evolution of galaxies
And stars, and comets and atoms, and indeed
All things material.” (1967)

The Drake Equation

Astronomical Biological

Cultural

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Cosmic Evolution, NASA, 1979

Big Bang

Galaxies

Stars

Biogenic Elements

Planets

Chemical Evolution

Origin of Life

Precambrian Biology

Complex Life

Intelligent Life

Cultural Evolution

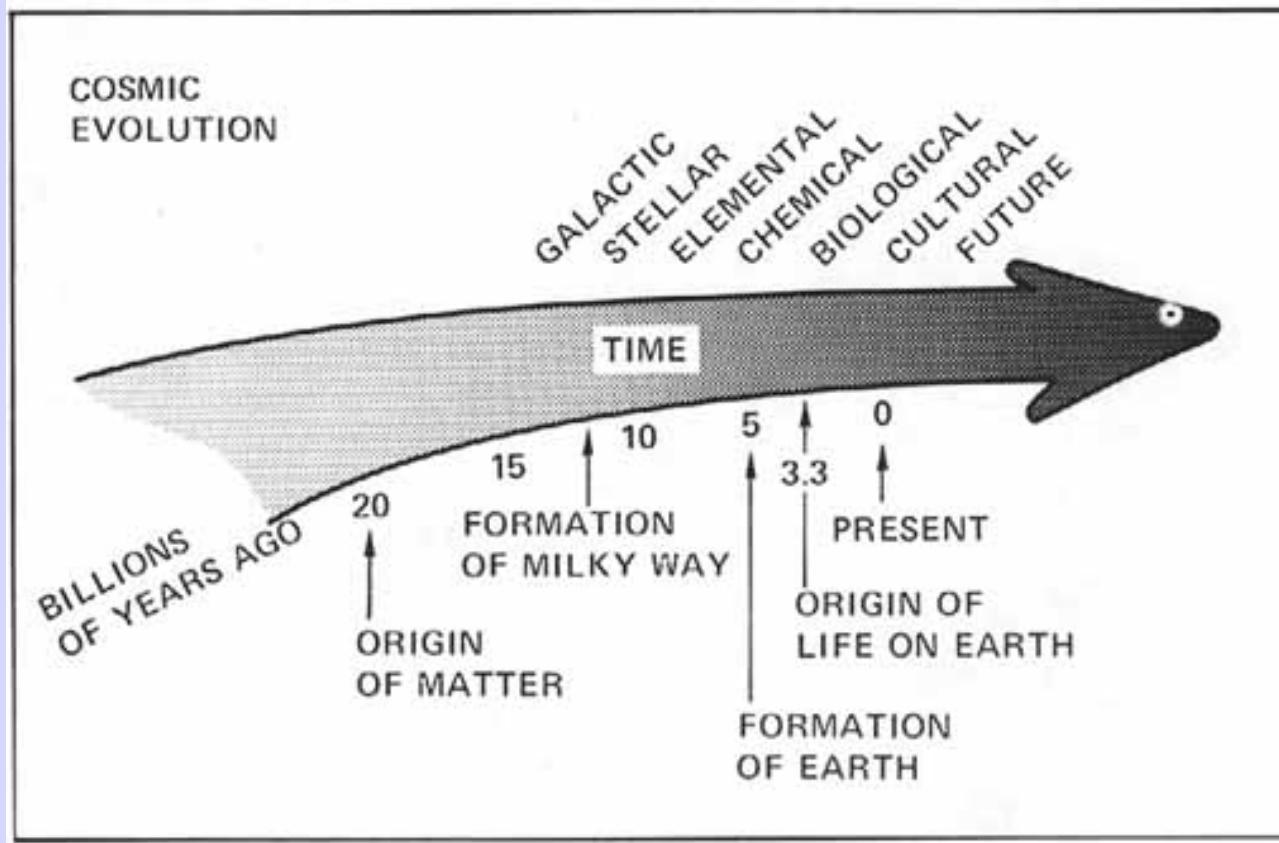
Civilizations

Science and Technology

Study of Life in the Universe

Source: NASA SETI Program, 1979

Cosmic Evolution, 1979



Eric Chaisson, "Three Eras of Cosmic Evolution"
From NASA Ames Conference on Life in the Universe,
Ed. John Billingham (MIT Press, 1981)

Cosmic Evolution, 1986

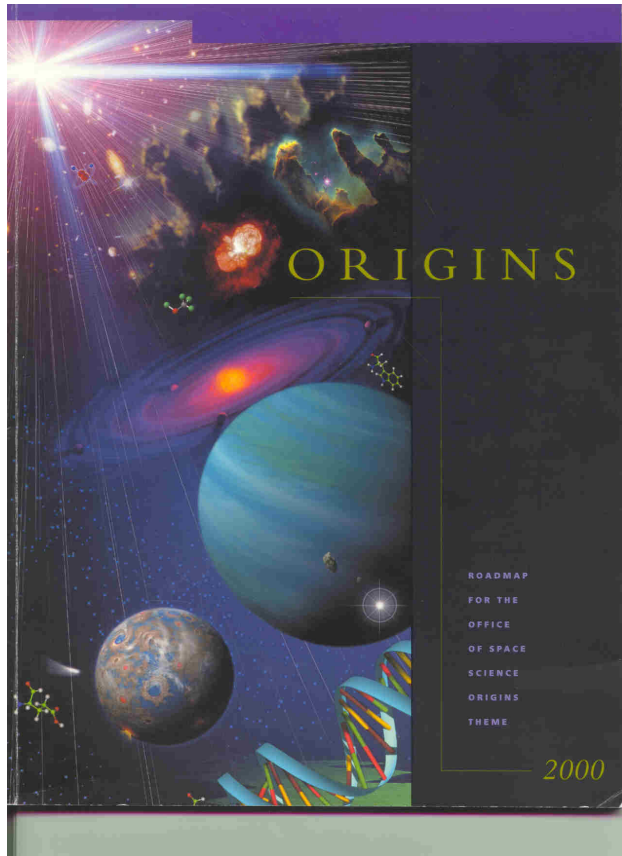


David DesMarais, Thomas Scattergood and Linda Jahnke/ NASA Ames, 1986, reissued 1997.

Cosmic Evolution, 1997



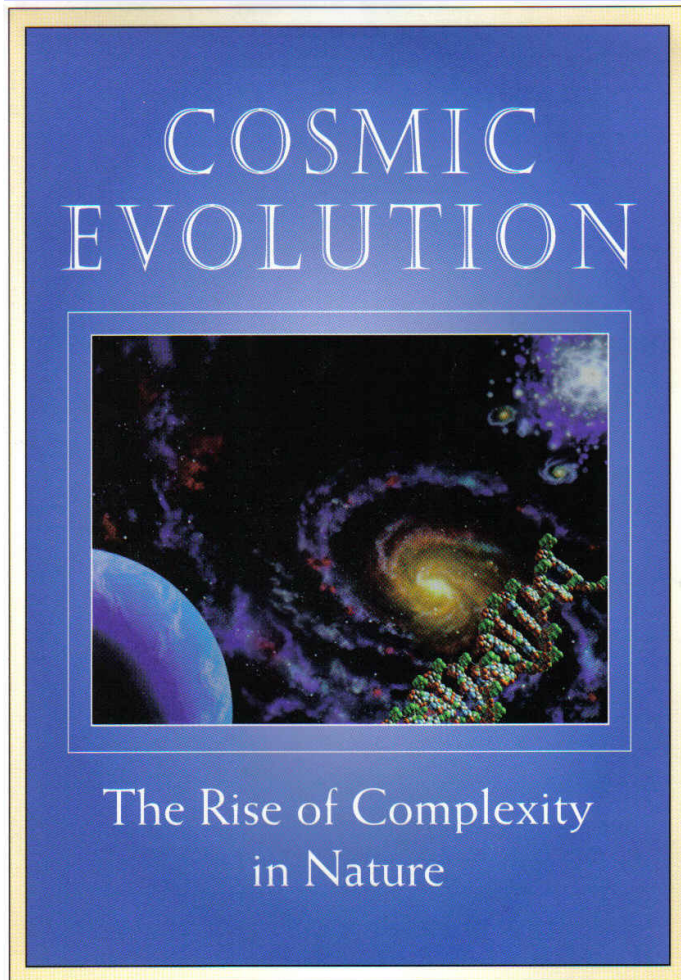
From NASA's Roadmap for Office of Space Science Origins Theme, 1997



NASA and Cosmic Evolution

Following the 15 billion year long chain of events from the birth of the universe at the Big Bang, through the formation of chemical elements, galaxies, stars, and planets, through the mixing of chemicals and energy that cradles life on Earth, to the earliest self-replicating organisms – and the profusion of life

The Rise of Complexity



ERIC J. CHAISSON

How to Quantify Complexity?

- Energy
- Energy Flow
- Energy Rate Density
- Energy rate per unit time per unit mass = Ergs per second per gram

Energy Rate Density: One Quantitative Measure

Credit: Eric Chaisson

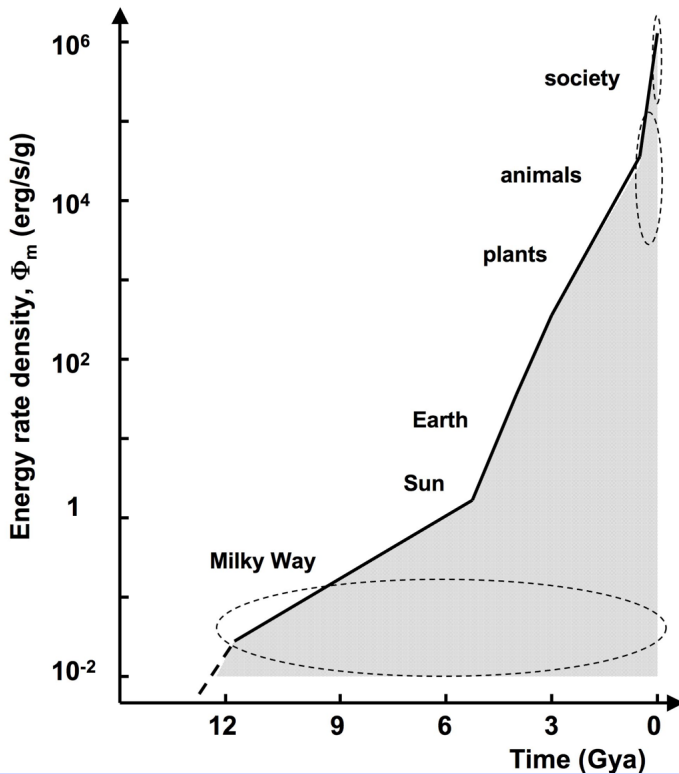


TABLE 1

Average Energy Rate Densities

System	Age (Gya)	Φ_m [erg/s/g]
Human society	0	500,000
Animals, generally	0.5	40,000
Plants, generally	3	900
Earth's geosphere	4	75
Sun	5	2
Milky Way	12	0.5

FIGURE 1— Energy rate densities, Φ_m , for a variety of open, organized, non-equilibrium systems, plotted here semi-logarithmically at the time of their origin, display a clear increase during the ~14 Gy history of the Universe. The shaded area includes a huge ensemble of changing Φ_m values as systems evolve and complexify. The three dashed ovals from bottom to top outline parts of this graph that are explored in greater detail for physical, biological, and cultural systems in Figures 2, 3, and 4, respectively.

Energy Rate Density for our Milky Way Galaxy

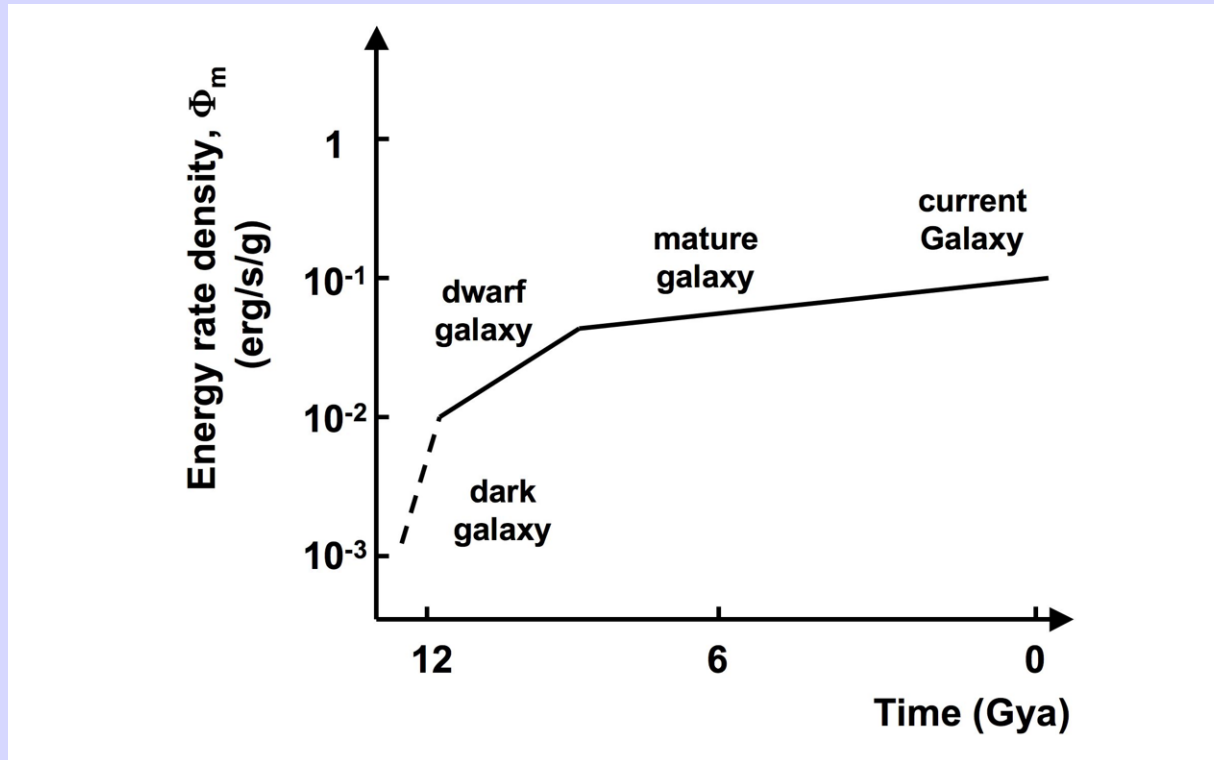


FIGURE 2—The growing complexity of the Milky Way Galaxy, expressed in terms of Φ_m and plotted within the bottom oval of Figure 1, is shown here in greater detail rising slightly over its ~12 Gy existence to date during the physical-evolutionary phase of cosmic evolution. According to the hierarchical theory of galaxy construction, dwarf galaxies and pregalactic clumps of gas merged relatively rapidly in the earlier Universe, such that within several Gy after the big bang our Galaxy had matured to nearly its present size and scale. The value of Φ_m for the Galaxy has continued rising ever since and will likely continue doing so, though only slightly, slowly, and episodically, as more galaxies (mostly dwarfs) collide and merge with our parent Galaxy.

Credit: Eric Chaisson

Energy Density Rate for Complex Technology

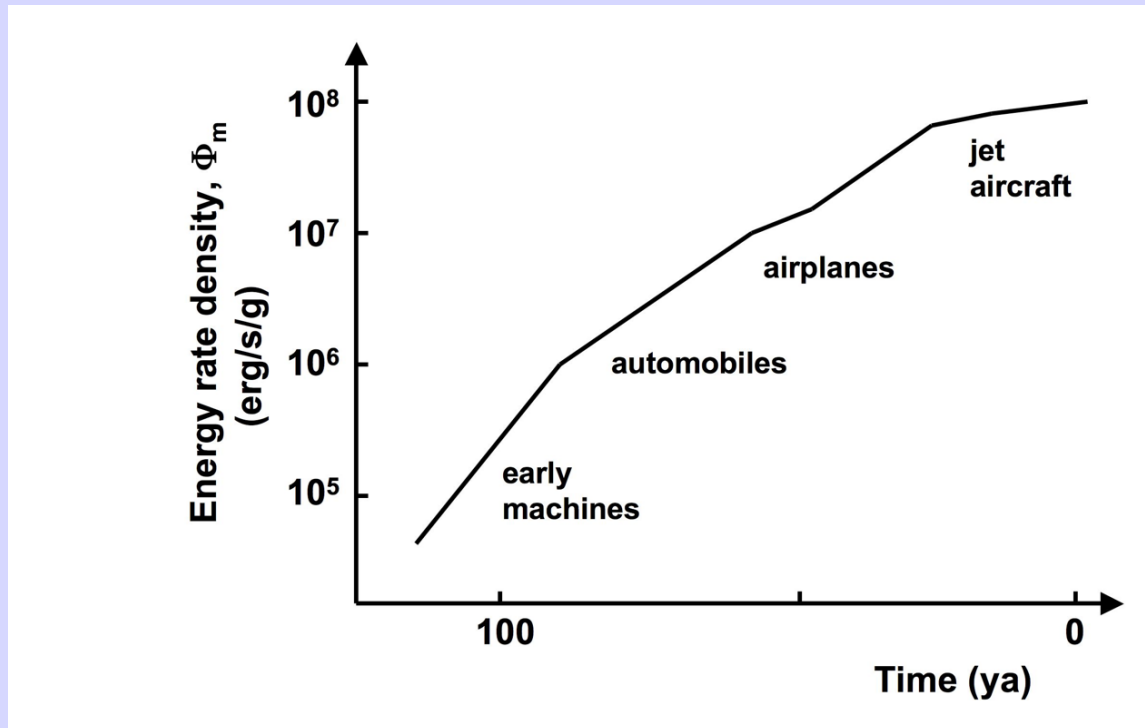
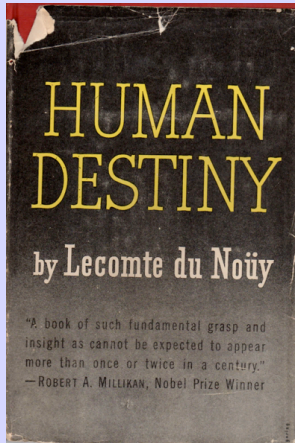
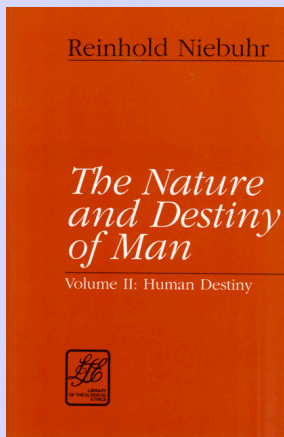


FIGURE 4—The complexity of technological devices, expressed in terms of Φ_m , rises to illustrate increased utilization of power density by invented machinery during the cultural-evolutionary phase of cosmic evolution. That rise has been dramatic within the past few generations as contemporary civilization has become so heavily dependent upon energy. Note that the timescale over which these curves are plotted is much shorter than for any other graph in this article or in Paper I—roughly the past century of natural history—so it represents only a minute part of the curve in the top oval at upper right in Figure 1.



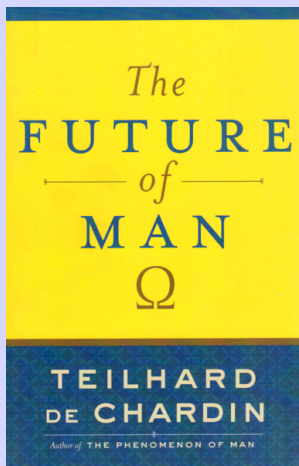
FROM DENSITY TO DESTINY

- Human Destiny Normally Discussed in Religious Terms



MAYBE

- **The Outcome of Cosmic Evolution will Affect Human Destiny**



DEFINITELY

Possible Outcomes of Cosmic Evolution

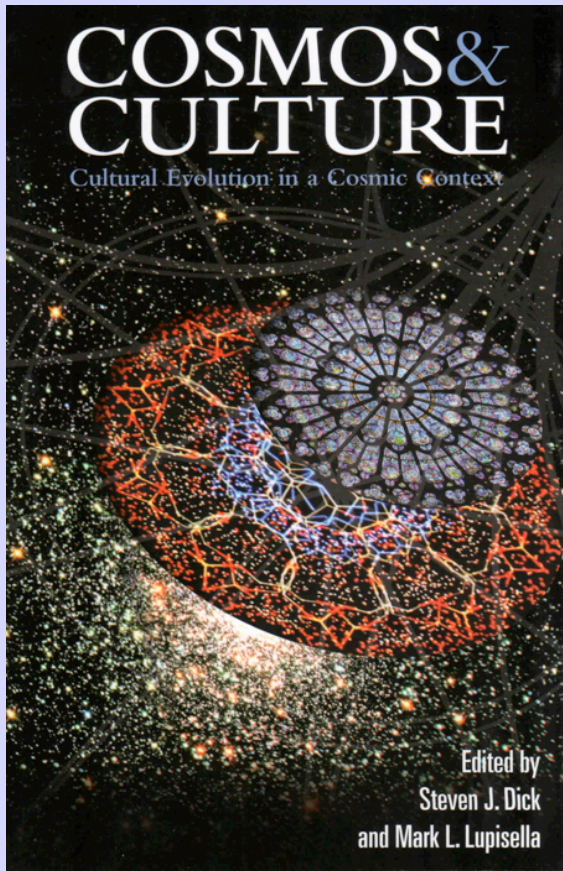
The background of the slide is a vibrant, multi-colored cosmic scene. It features a large purple and blue galaxy on the left, a bright yellow star with a lens flare in the upper right, and various smaller celestial bodies and molecular models scattered throughout. Several red arrows point in different directions, suggesting a path or flow of evolution. The overall aesthetic is that of a deep space exploration or a scientific visualization of the universe's evolution.

1. Astronomical Evolution = Physical Universe
2. Biological Evolution = Biological Universe
3. Cultural Evolution = Postbiological Universe

Definitions

- **Physical Universe: Cosmic Evolution Ends with Planets, Stars and Galaxies: We Are a Fluke**
- **Biological Universe: Cosmic Evolution Commonly Ends with Intelligent Carbon-based Life**
- **Postbiological Universe: Cultural Evolution Has Replaced Carbon-based Intelligence with Artificial Intelligence**

Human Destiny and the Cosmos



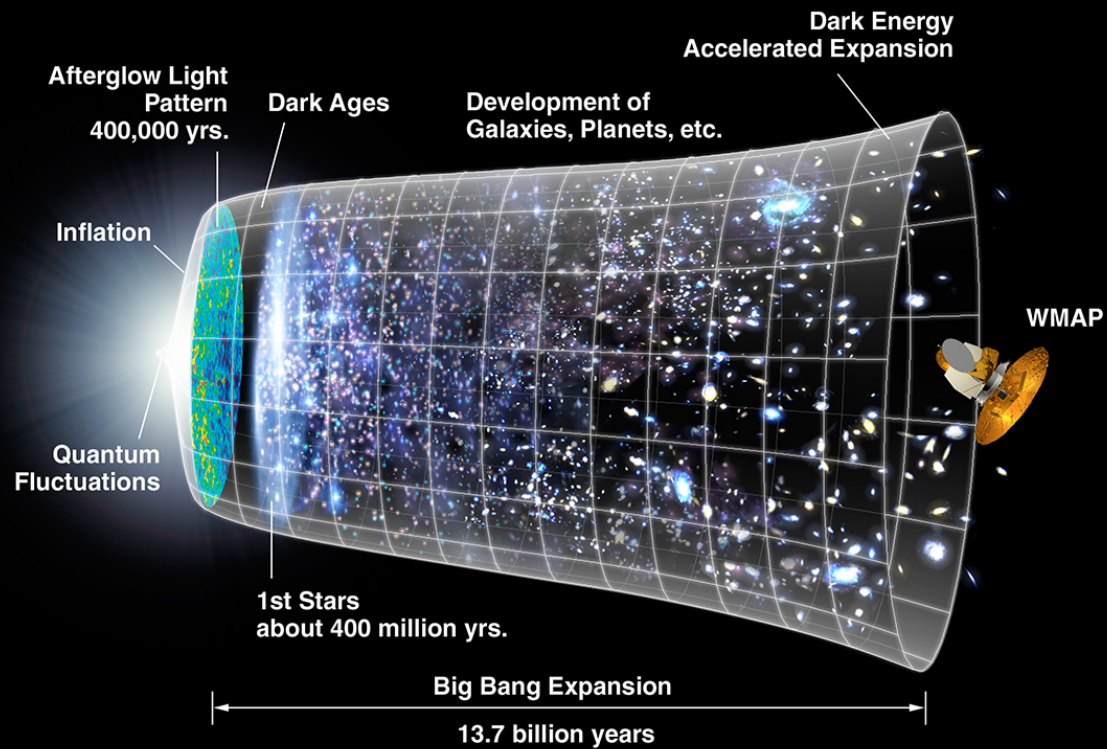
- In a Physical Universe the Universe is Ours to Populate
- In a Biological Universe Our Destiny is to Interact with ETs, Perhaps Join the Galactic Club
- In a Postbiological Universe we Will Interact with Artificial Intelligence

The Physical Universe

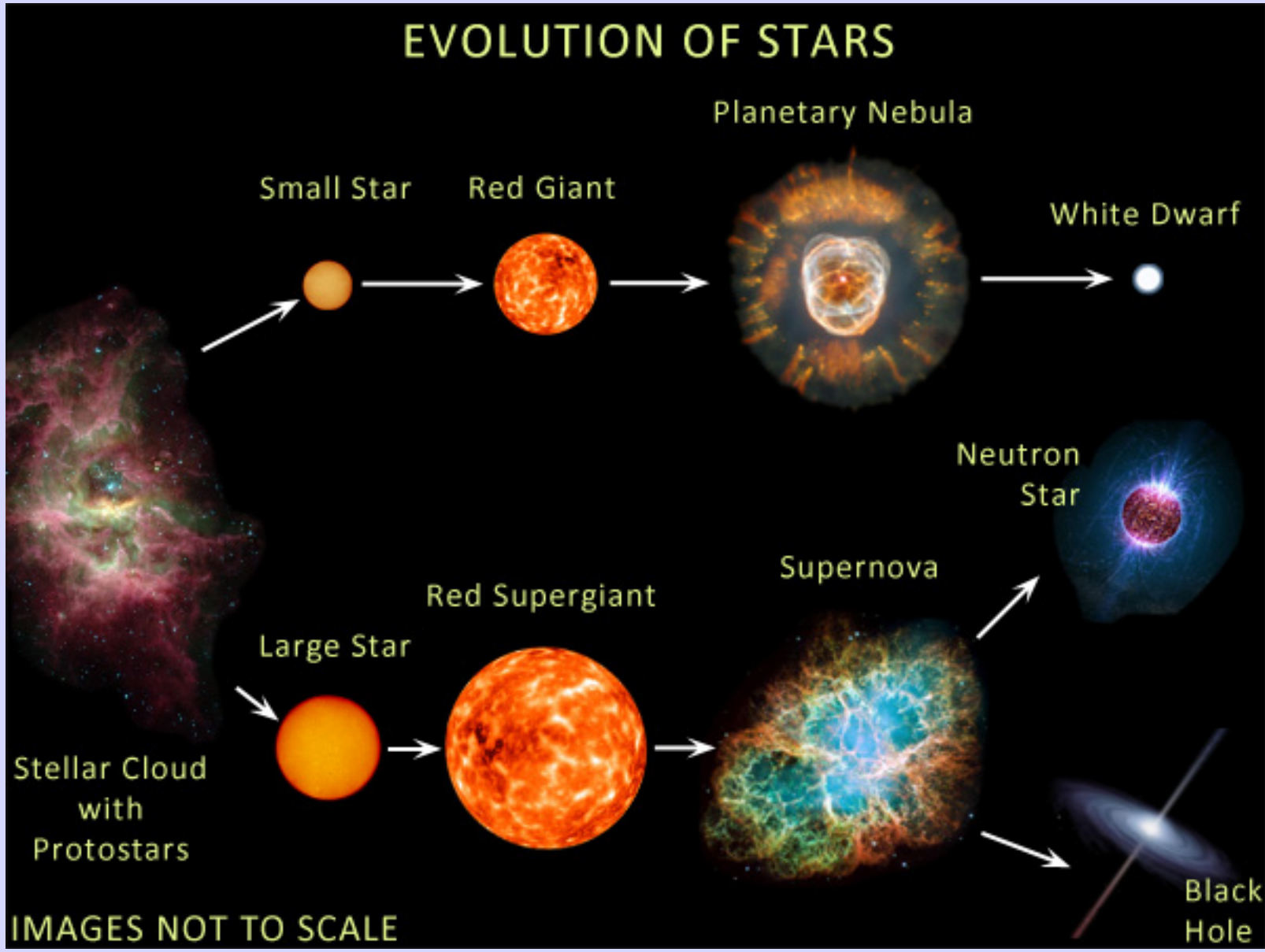


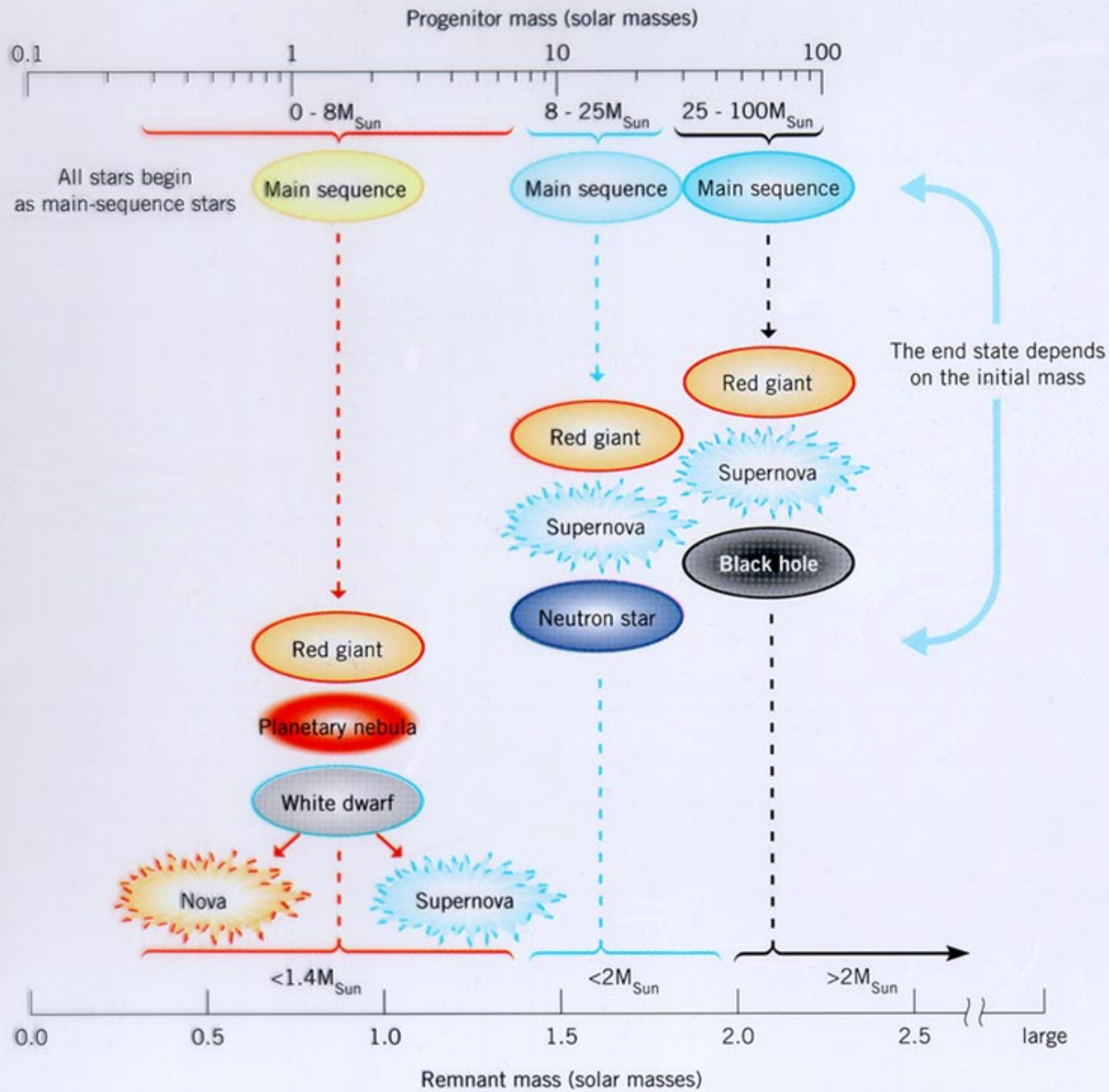
M 31/ Gendler

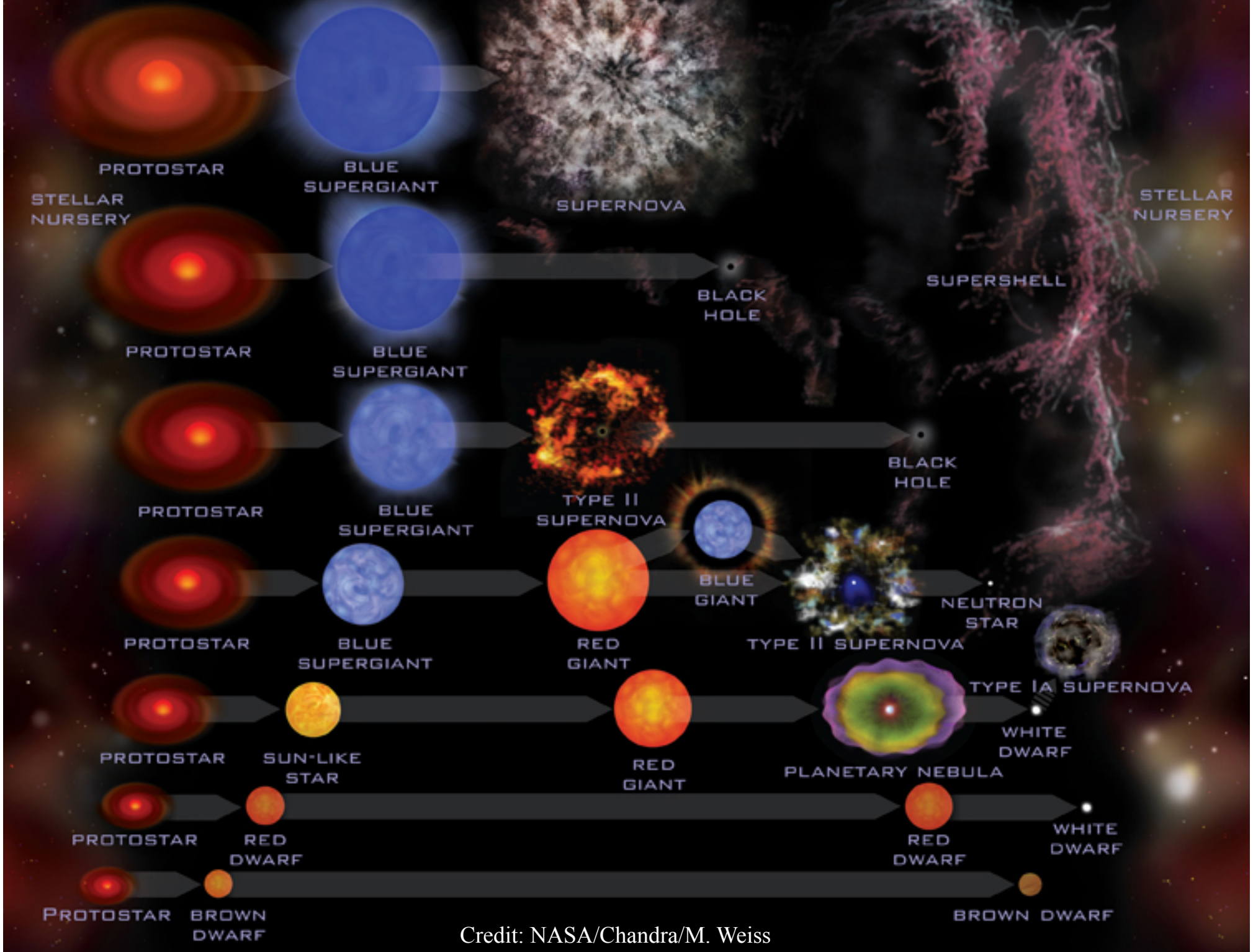
WMAP Spacecraft - 2003



EVOLUTION OF STARS

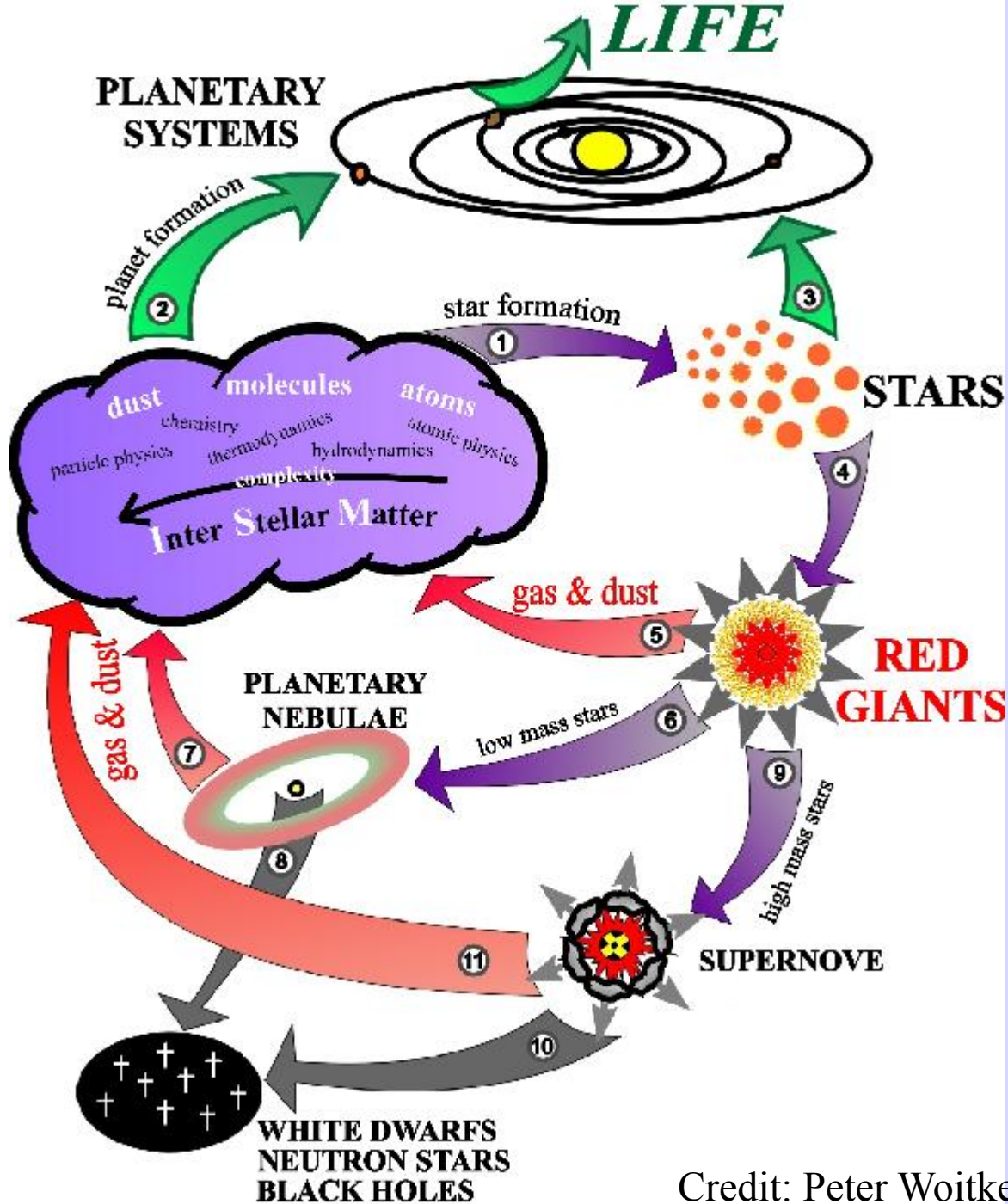




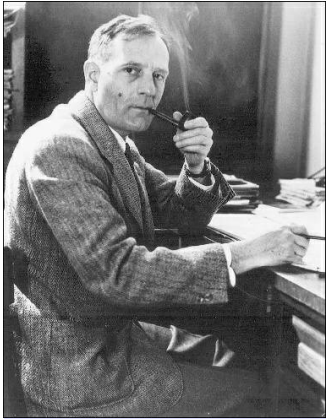


Credit: NASA/Chandra/M. Weiss

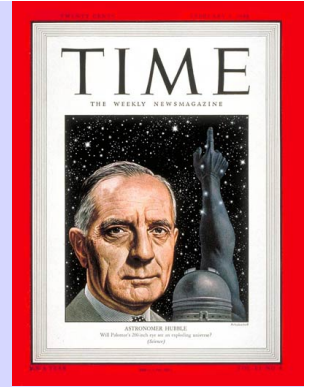
Cosmic Ecology



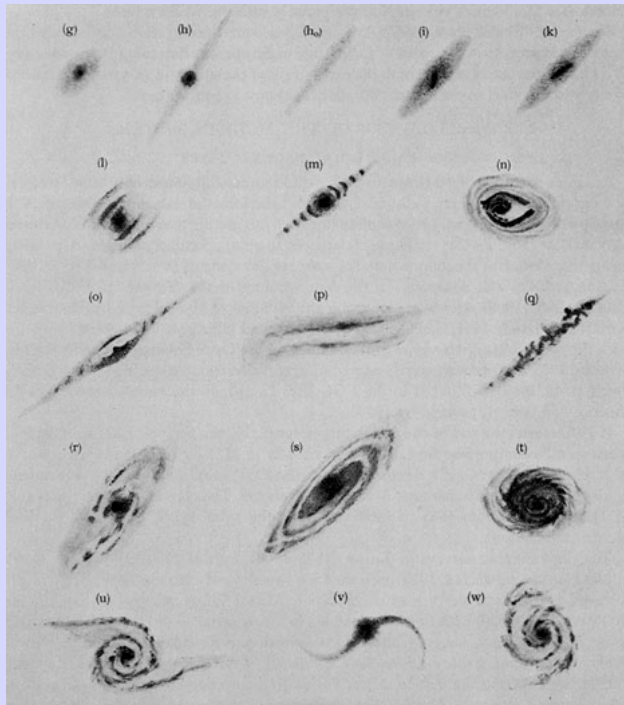
Credit: Peter Woitke: Sterrewacht Leiden



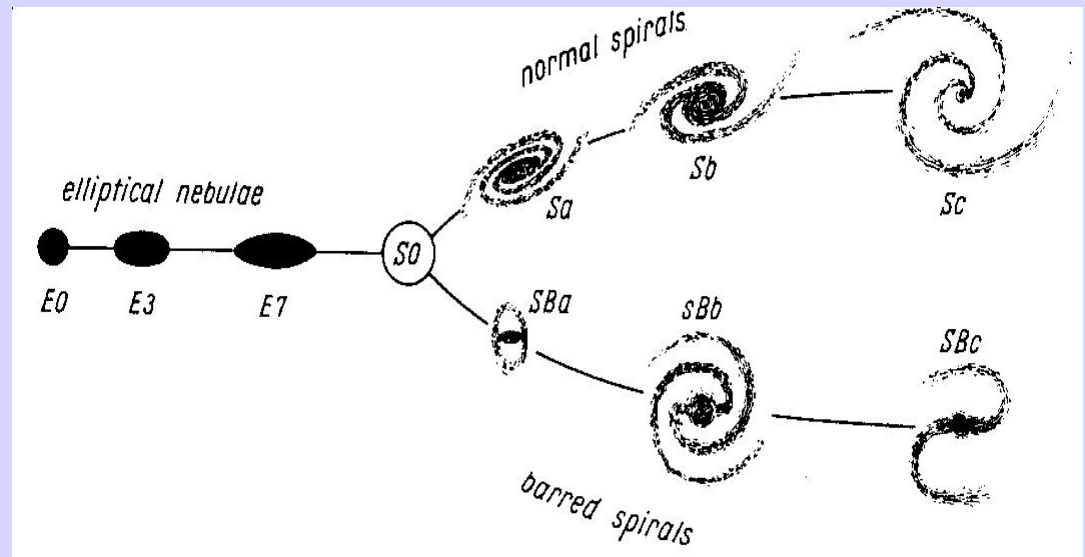
Galaxies – Hubble Sequence is NOT an Evolutionary Sequence



February 9, 1948

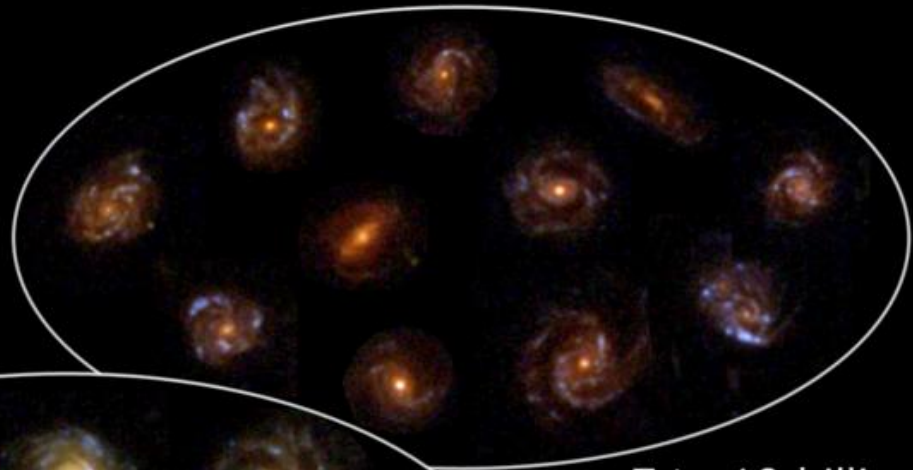


Wolf's system, 1908



Hubble 'tuning fork' classification
From Realm of the Nebulae (1936)

Evolution of Spiral Galaxies



7 to 10 billion
years ago



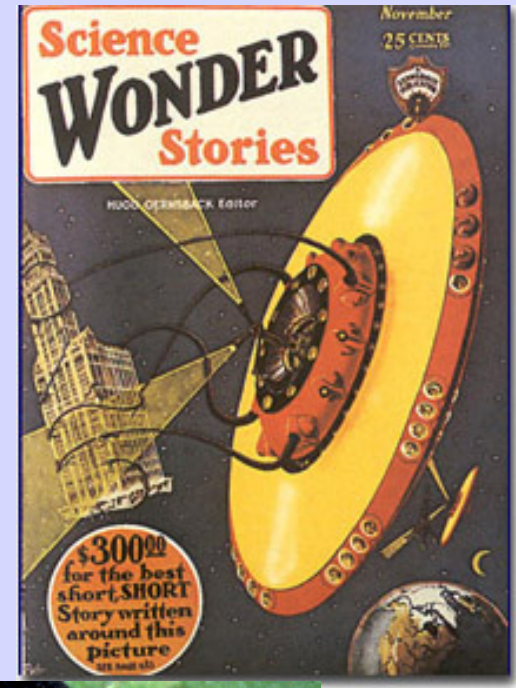
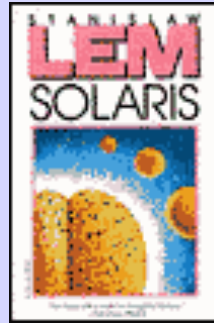
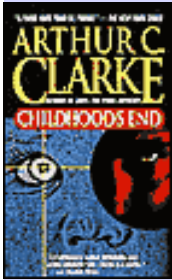
3 to 7 billion
years ago



Present to
3 billion years ago

The Biological Universe

The Biological Universe in Popular Culture



Coalescence of a New Discipline

Planetary Systems

Circumstellar Disks
Extrasolar Planets
Kepler, SIM, TPF
Biosignatures
Theoretical studies

Origins of Life

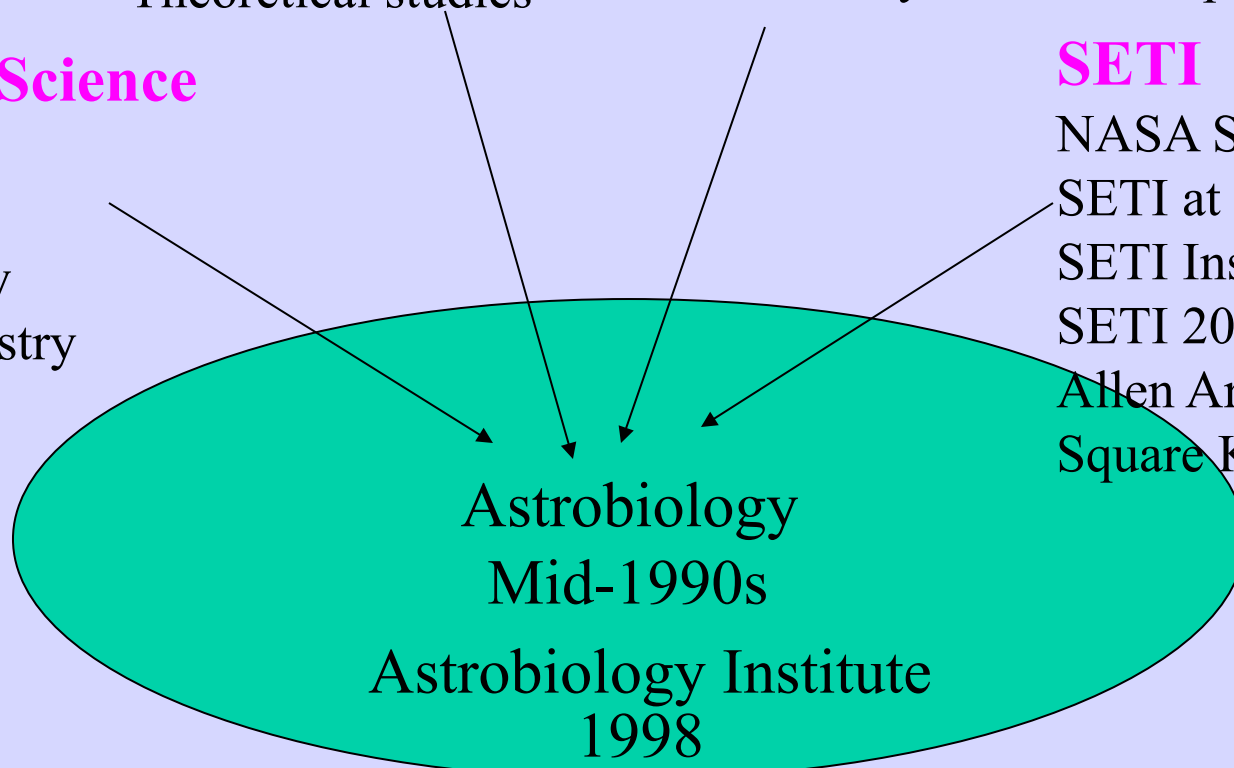
Genomics/Phylogenetic relationships
Life in Extreme Environments
Complex Organics Simulations and Obsns
Laboratory Prebiotic Experiments

Planetary Science

Mars Rock
Europa
Geochemistry
Biogeochemistry

SETI

NASA SETI
SETI at Home
SETI Institute
SETI 2020 Roadmap
Allen Array
Square Kilometer Array



IAU Bioastronomy Commission 51 Triennial Meetings, 1984-

The Postbiological Universe

Cultural Evolution

Cultural Evolution must be seen as an Integral Part of Cosmic Evolution and the Drake Equation.

It Dominates all other Forms of Evolution.

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$



Astronomical

Biological

Cultural

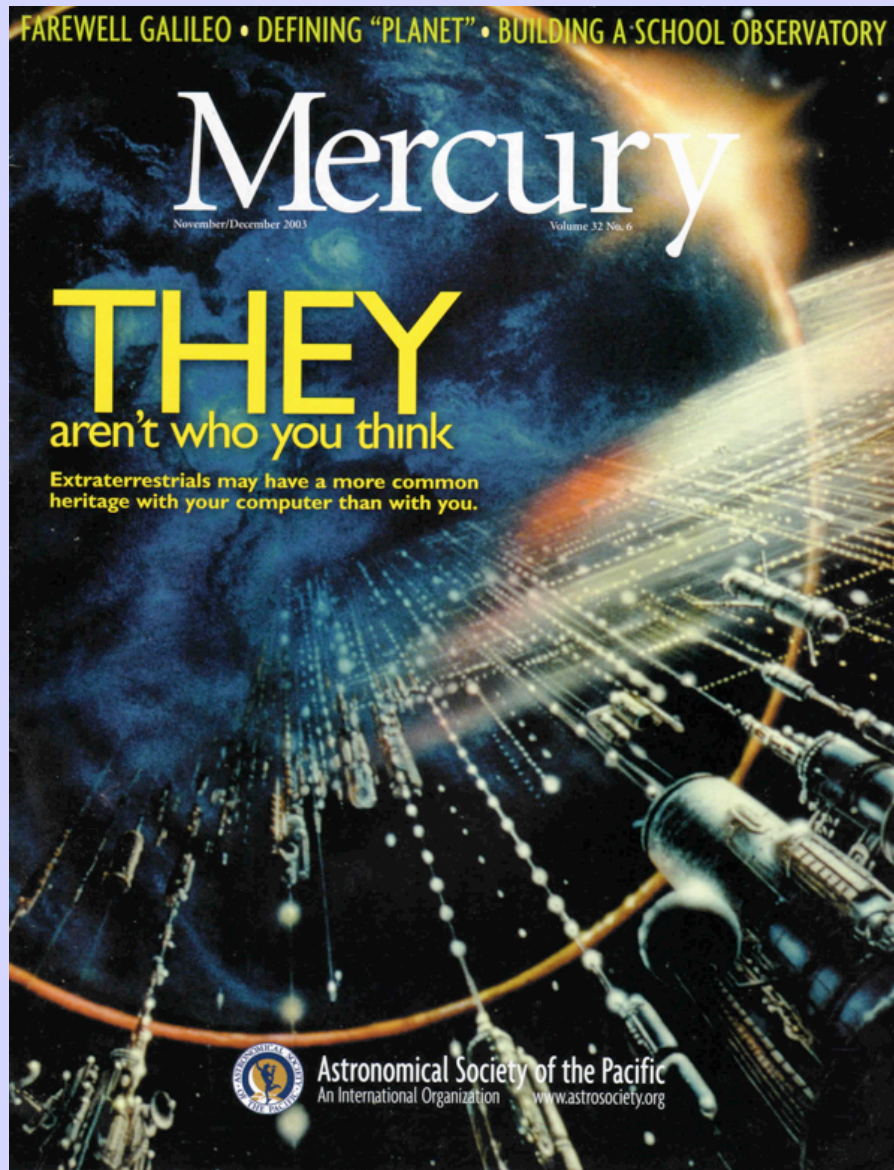
Stapledon- Think Long-Term!

Long-term “Stapledonian” Thinking may be Necessary To Understand the Nature of Intelligence In the Universe Today, if it is Indeed Widespread

Humans not Accustomed to Thinking on Cosmic Time Scales for Biology and Culture.



Effects of Cultural Evolution

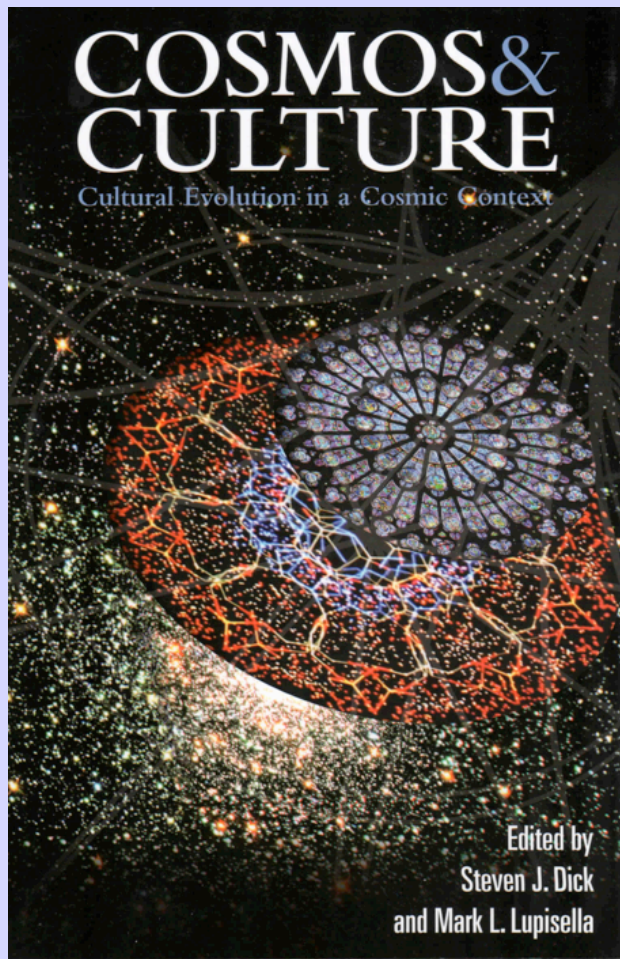


Cultural Evolution Has Resulted in a Postbiological Universe, with Implications for SETI Strategies

S. J. Dick, "Cultural Evolution, the Postbiological Universe and SETI," *International J. of Astrobiology*, 2 (2003), 65-74

Mercury, November-December, 2003

Bringing Culture to Cosmos – A Postbiological Universe?

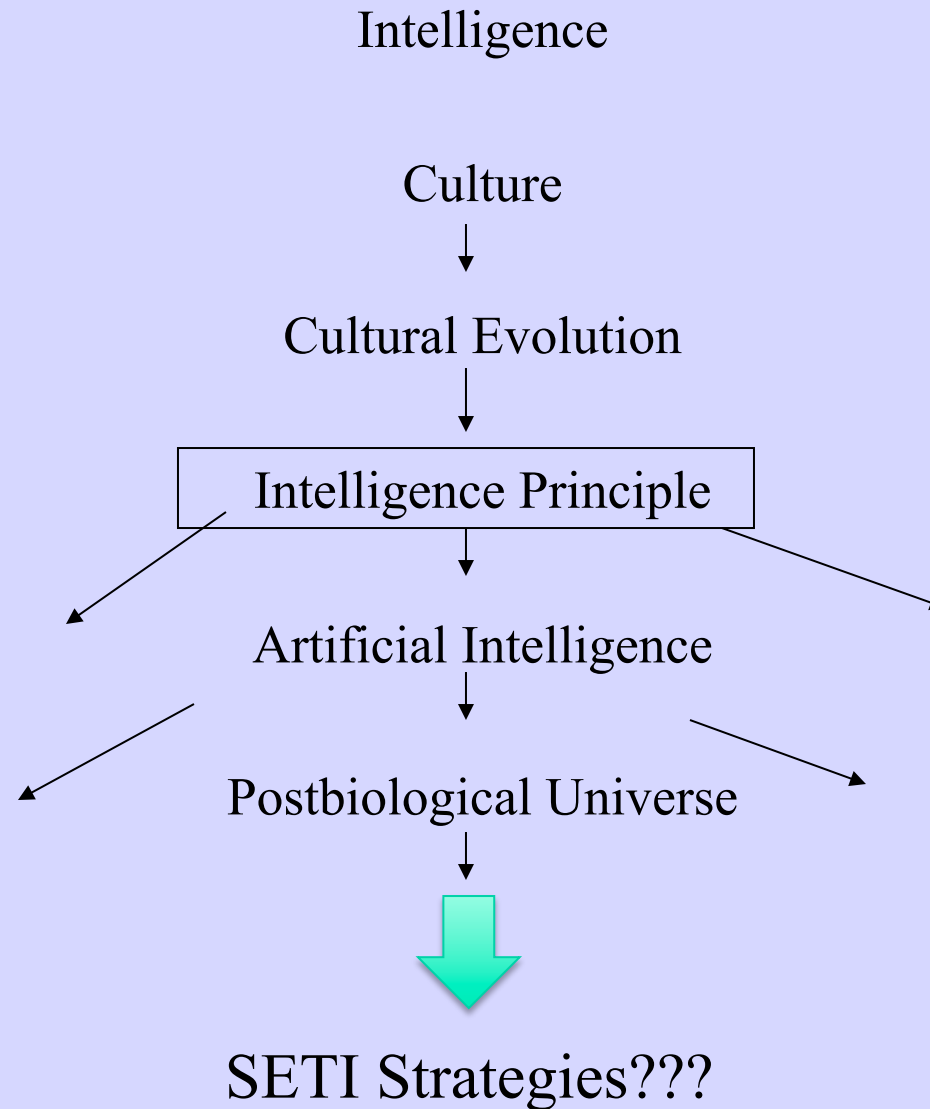


- 1) **The Maximum Age (A) of ETI is Several Billion Years**
- 2) **The Lifetime (L) of a Technological Civilization is > 100 Years and Probably Much Larger**
- 3) **In the Long Term Cultural Evolution Supersedes Biological Evolution, and Would Produce Something Far Beyond Biology**

Maximum Age of ETI

- Kardashev (1997): 6-8 Billion Years based on Cosmology and Cosmic Evolution
- Livio (1999): 3 Billion Years Based on Peak Carbon Production Rate
- Norris (1999): 1.7 Billion Year [median age]
- Bottom Line: ETI Could be Billions of Years Old

The Main Argument



Intimations of A Postbiological Universe

“There are a number of arguments which suggest that biological intelligence may be but a transitory phase in the evolution of conscious intelligence in the universe . . . Even if alien biological entities have, here and there, attempted interstellar radio communication, it is overwhelmingly probable that the machines, with their greater resourcefulness and unlimited patience, will dominate the airwaves.”

Davies, *Are We Alone?* (1995)

“But What if ET isn’t Biological . . . ?

Shostak, *Sharing the Universe* (1998)

Artificial Intelligence - The Outlook

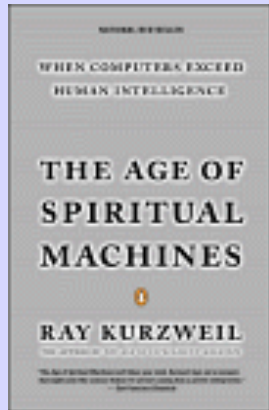
Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (1988)



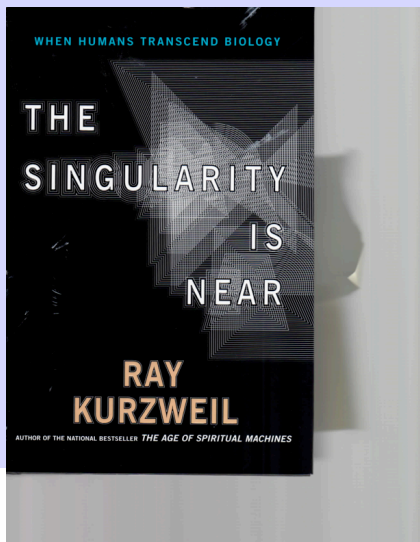
“What awaits is not oblivion but rather a future which, from our present vantage point, is best described by the words ‘postbiological’ or even ‘supernatural.’ It is a world in which the human race has been swept away by the tide of cultural change, usurped by its own artificial progeny . . . Unleashed from the plodding pace of biological evolution, the children of our minds will be free to grow to confront immense and fundamental challenges in the larger universe.”

Artificial Intelligence: The Outlook

Ray Kurzweil: *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999)



Sees takeover of biological intelligence by AI, not by hostility, but by willing humans who have their brains scanned, uploaded to a computer, and live their lives as software running on machines. Human intelligence will be left behind.



Central Principle of Cultural Evolution

The Intelligence Principle:

The Maintenance, Improvement and Perpetuation Of Knowledge and Intelligence is the Central Driving Force of Cultural Evolution. To the Extent that Intelligence Can be Improved, It Will be Improved

Bottom Line: The Individual and the Culture will do Whatever They Must to Perpetuate and Improve Themselves. Lacking this Principle, Cultural Evolution Ceases to Exist

Artificial Intelligence

Artificial Intelligence (AI) is a Striking Example of the Intelligence Principle at Work

AI Dominates all other Developments in the Sense that Other Fields are Subservient to Intelligence:

- **Biotechnology is a Step on the Road to AI**
- **Nanotechnology will help Construct Efficient AI**
- **Space Travel will Spread AI**

Artificial Intelligence: A Cautionary Note

**Assumes Strong AI Position that an Intelligence
Can be Constructed Equivalent to or Superior to
Human Intelligence**

Not Everyone Agrees!

**Are Computers Tools for Studying the Mind . . .
or Can They Be Minds Themselves?**

Dennett vs Searle

Implications for SETI

Moravec (speaking of Earth):

“A postbiological world dominated by self-improving, thinking machines would be as different from our world of living things as this world is different from the lifeless chemistry that preceded it. A population consisting of unfettered mind children is quite unimaginable.”

Implications for SETI

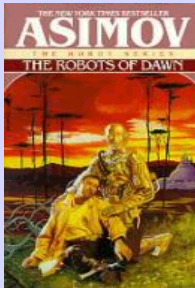
- Postbiologicals need not be confined to a Sun-like Star
- Postbiologicals are Immortal - Travel is as Good as Communication
- Postbiologicals will have Capacity for Good and Evil: Asimov's Robots vs. Saberhagen's Berserkers
- Implications for Message Construction?

Postbiological Universe

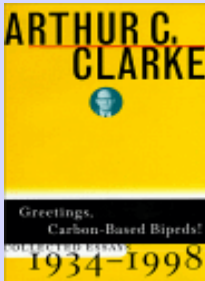
- Long-term Thinking Essential to Understand the Nature of Intelligence
- Cultural Evolution an Integral part of Cosmic Evolution - - The Most Important Part!
- Assume Strong AI
- Adopt Intelligence Principle of Cultural Evolution
- If $L > 1000$ years, we (may!) live in a Postbiological Universe

Chief Weakness: The Claim is not Bold Enough

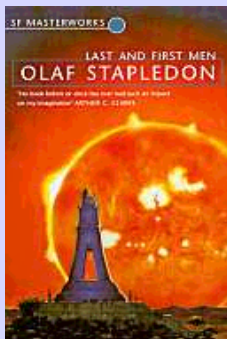
Whose Universe?



The Universe of Asimov with Robot-Human Interaction and the Three Laws of Robotics?



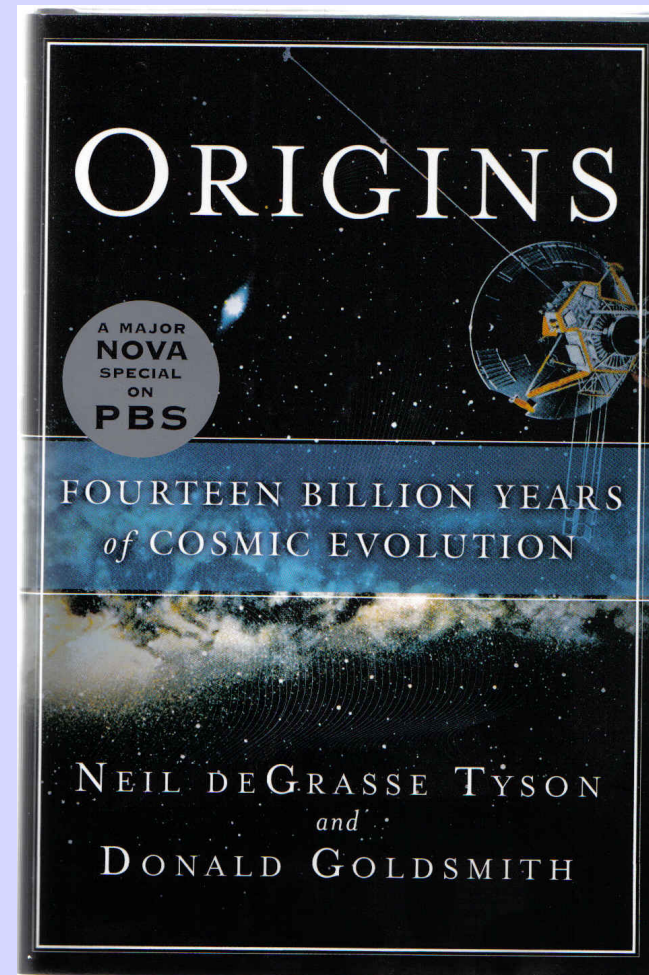
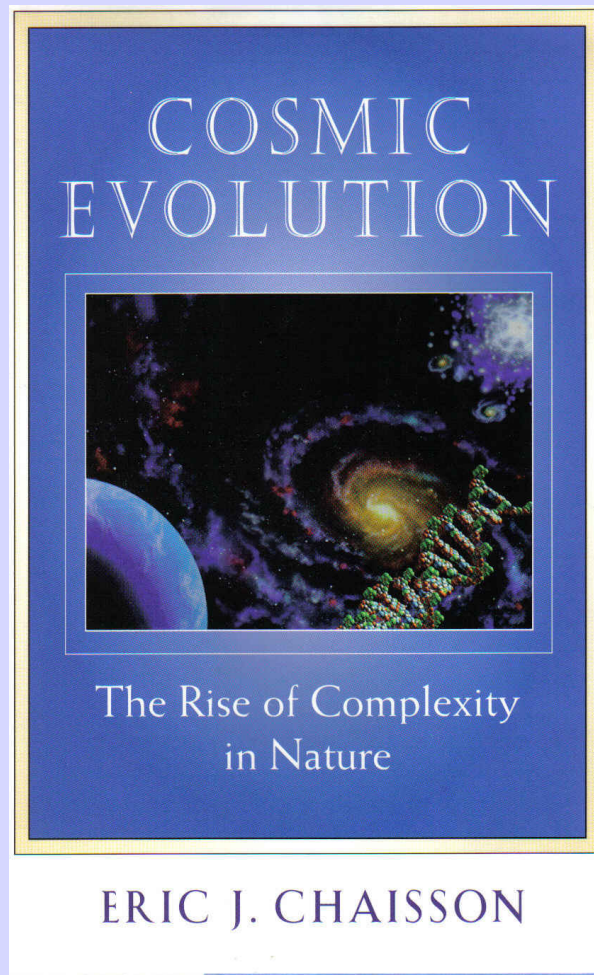
The Universe of Clarke Full of Carbon Biped?



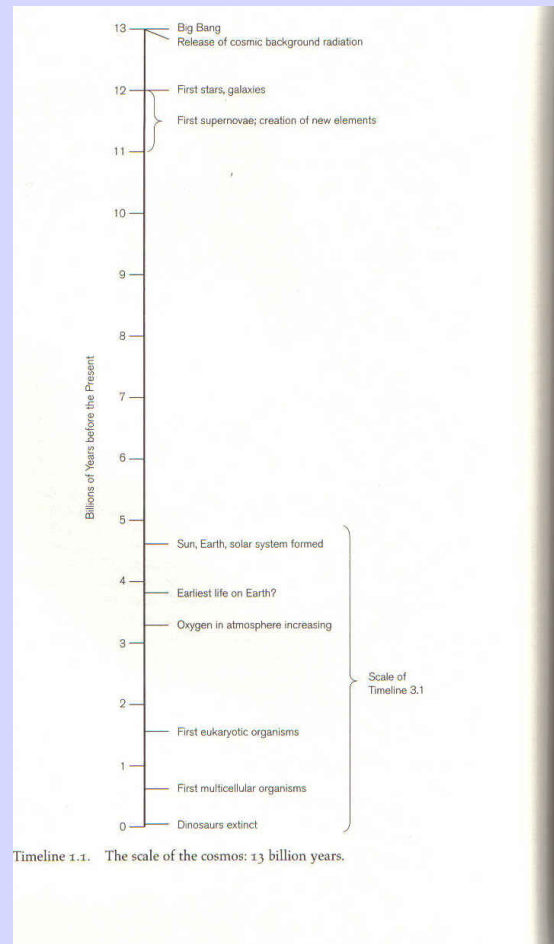
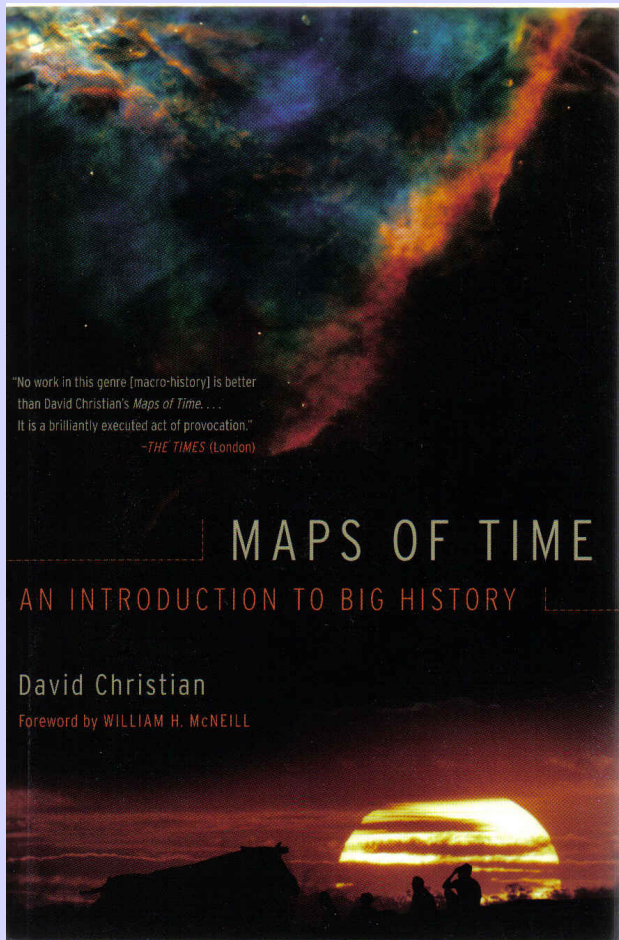
Stapledon's Universe (If he had known about AI): Extraterrestrials are Intelligent Robots

“Last Men” Takes on New Meaning!

Uses of Cosmic Evolution: Science



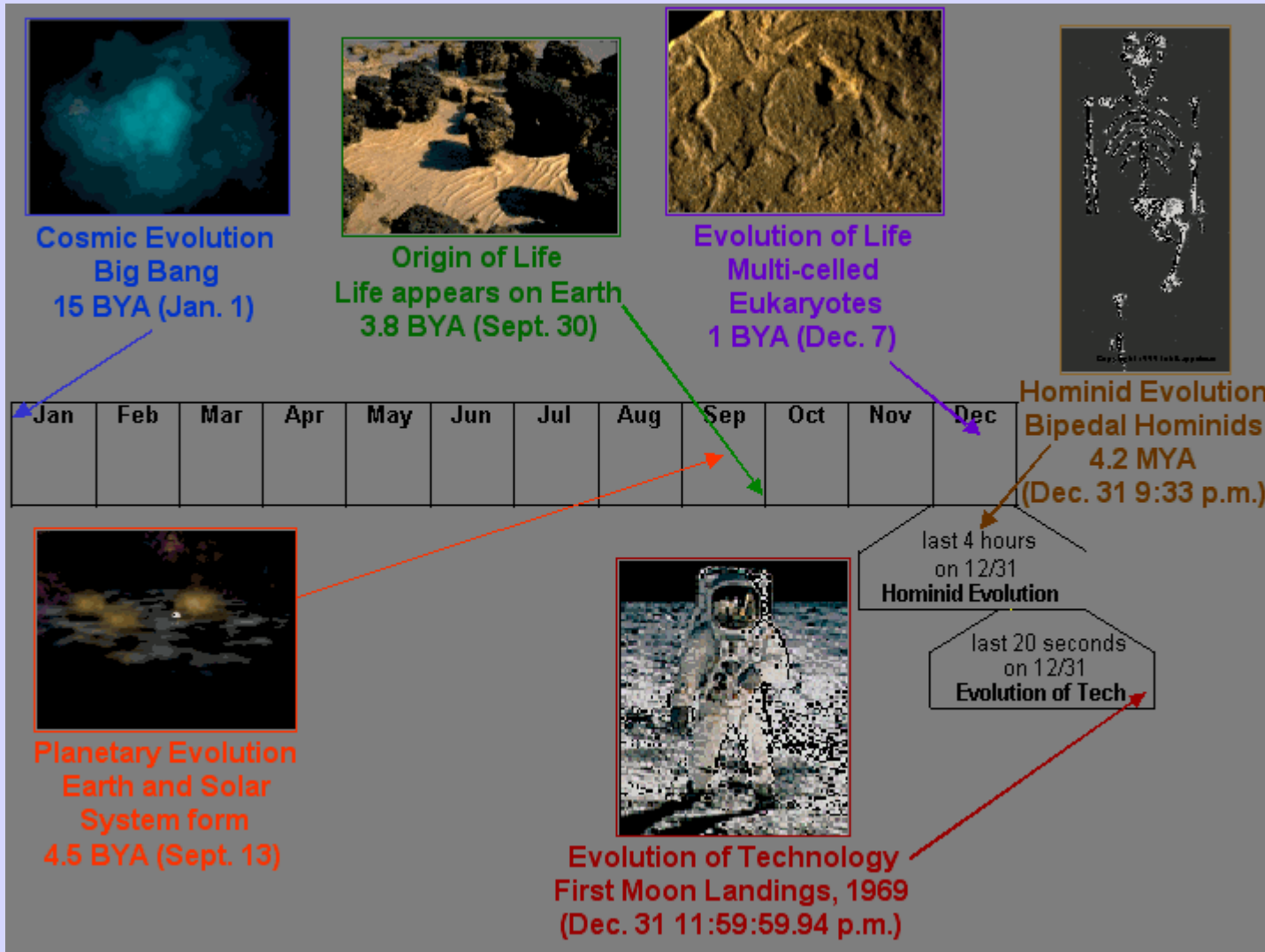
Uses of Cosmic Evolution: History



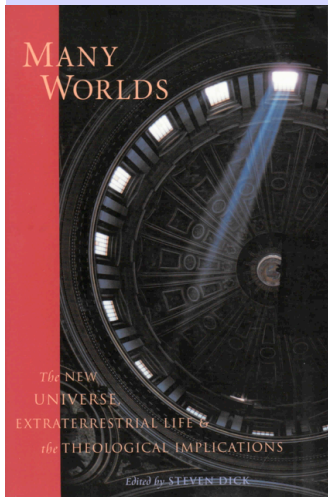
The ultimate
Master Narrative

The ultimate in Braudel's
longue duree history

The Cosmic Calendar

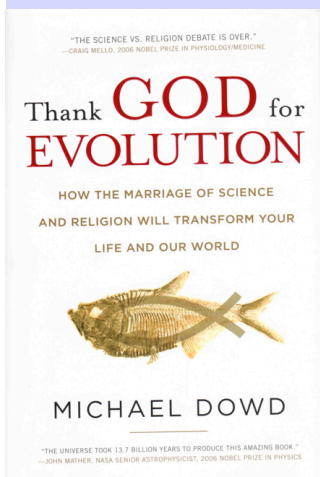


Uses of Cosmic Evolution: Religion



Sir Arthur Peacocke – Biochemist and Anglican Priest

“The Challenge and Stimulus of the Epic of Evolution To Theology,” in Dick, *Many Worlds*



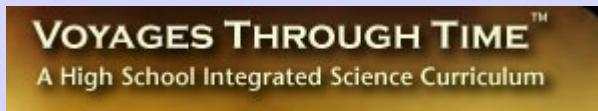
“Any theology – any attempt to relate God to all-that-is – Will be moribund and doomed if it does not incorporate this Perspective [of cosmic evolution] into its very bloodstream.”

- Michael Dowd – Cosmic Evolution evangelism

Uses of Cosmic Evolution: Education

SETI Institute (Drake, Tarter, et al., CA)

<http://www.seti.org/>



Wright Center for Science Education (Tufts)

http://www.tufts.edu/as/wright_center/

Summary



- **Cosmic Evolution is the Key to Cosmological World Views**
- **We are on the Brink of Deciding Between Two World Views:
The Physical Universe or the Biological Universe**
- **The Postbiological Universe is a Third Possible Outcome**
- **Astrobiology is the Science that will Provide the Critical Data**
- **These World Views will Determine Human Destiny
in the Long Term**

Cosmic Evolution according to NASA (1997)

Thank You!

