

Lectures on Science and
Theology

Philosophical and Historical
Perspectives



Documentazione Interdisciplinare di
SCIENZA & FEDE

Lecture 7

The Place of the Human Being in the Cosmos. Unexpected Insights from the Anthropic Principle

Giuseppe Tanzella-Nitti

School of Theology and DISF Research Center
Pontifical University of the Holy Cross, Rome

Vatican Observatory



Pontificia
Università
della
**SANTA
CROCE**

Summary

**I. The position of the human being in the cosmos:
center or periphery?**

**II. The rise of the Anthropic Principle in the
context of modern science**

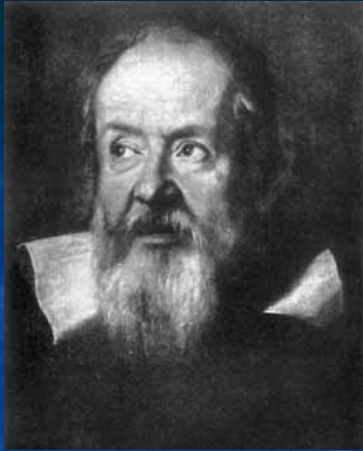
**III. The main cosmic "coincidences" underlying the
Anthropic Principle**

**IV. Philosophical implications and final theological
reflections**

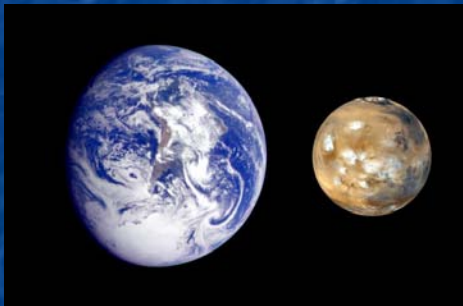


**I. The position of the human being in the cosmos:
center or periphery?**

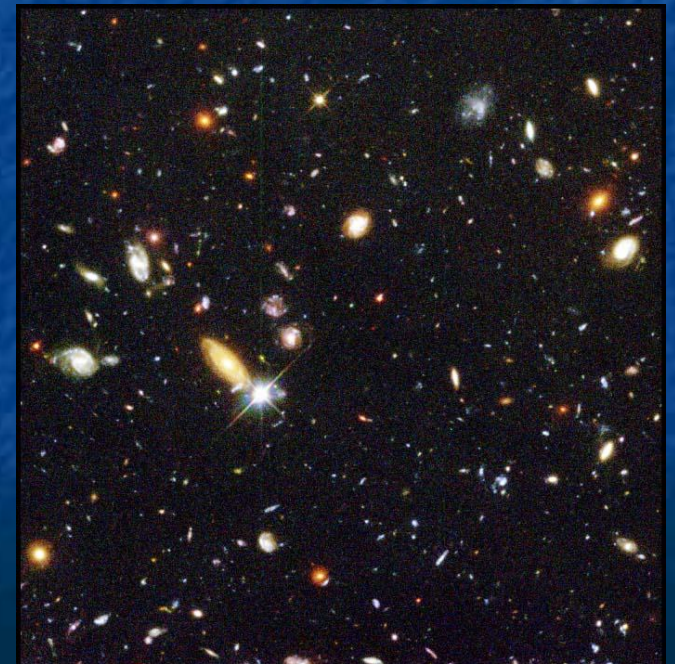
From Galileo (1609) to the James Webb Space Telescope (2022), the earth and its biosphere are comprehended within ever-widening horizons



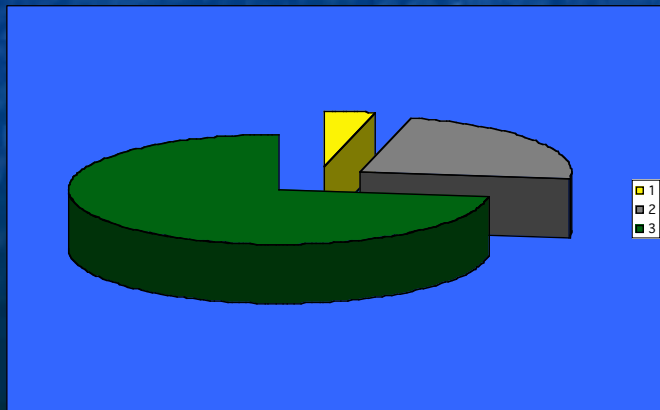
10^{11} stars



10^{12} galaxies

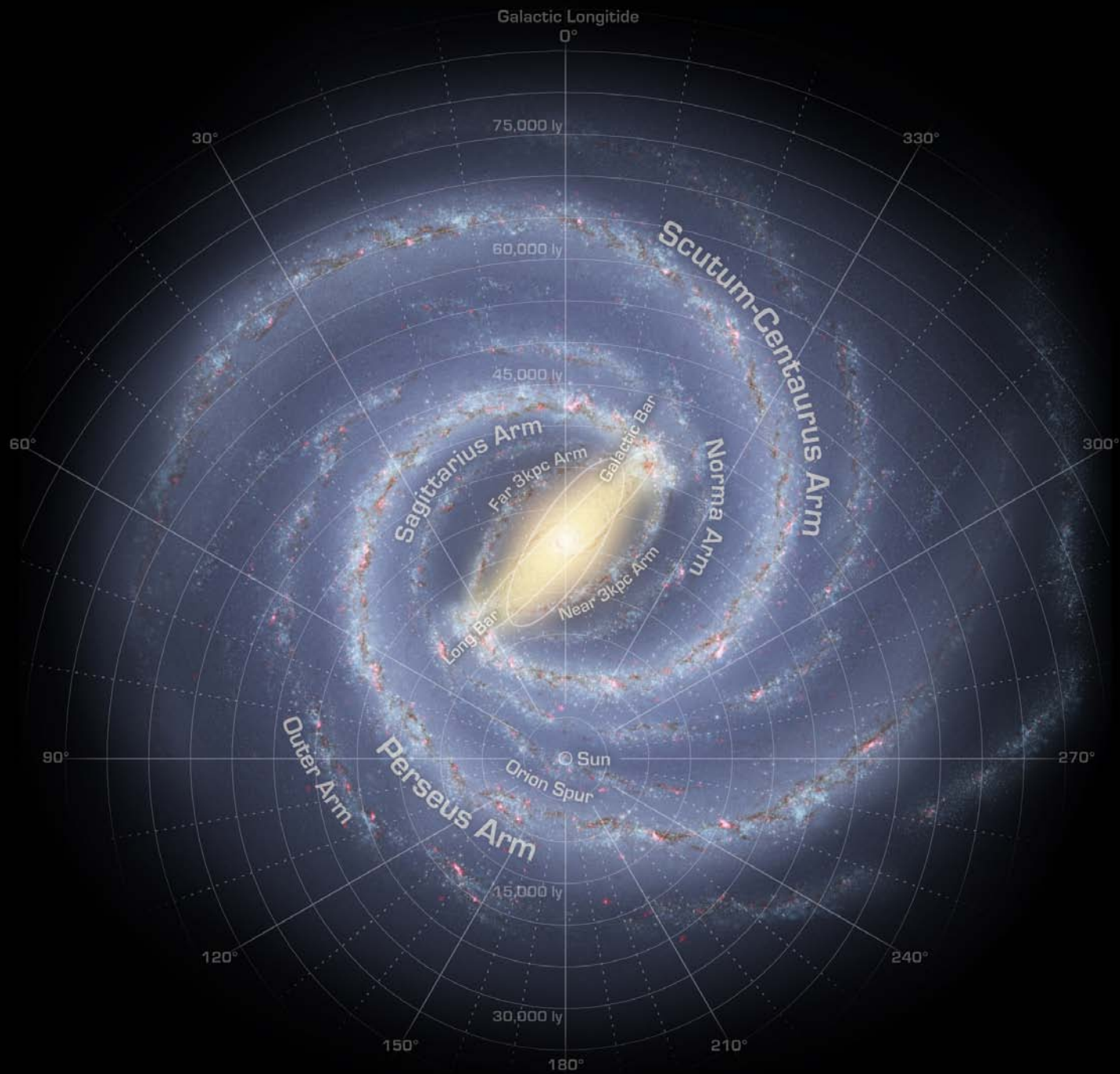


5.500 extrasolar planets



4% Visible Matter
23% Dark Matter
73% Dark Energy

Hubble Deep Field HST · WFPC2
PRC96-01a · ST ScI OPO · January 15, 1996 · R. Williams (ST ScI), NASA



■ Fragility and greatness of the human being, hanging between two infinities



Blaise Pascal
(1623-1662)

“Returning to himself, let man consider what he is in comparison with all existence; let him regard himself as lost in this remote corner of nature; and from the little cell in which he finds himself lodged, I mean the universe, let him estimate at their true value the earth, kingdoms, cities, and himself. What is a man in the Infinite?”

He who regards himself in this light will be afraid of himself, and observing himself sustained in the body given him by nature between those two abysses of the Infinite and Nothing, will tremble at the sight of these marvels

What is man in nature? A Nothing in comparison with the Infinite, an All in comparison with the Nothing, a mean between nothing and everything. Since he is infinitely removed from comprehending the extremes, the end of things and their beginning are hopelessly hidden from him in an impenetrable secret; he is equally incapable of seeing the Nothing from which he was made, and the Infinite in which he is swallowed up.”

(*Pensées*, n. 72, transl. by W.F. Trotter, Christian Classics Ethereal Library)

Fragility

- **peripheral location** of our planet and the enormous space-time dimensions of the cosmos
- kinship of the human being with the **higher primates**, to whose evolutionary phylum he belongs
- **fragility** of the human body, in solidarity with the corruptible and ever-changing **matter** of the cosmos



Greatness

- the extraordinary **scientific-technological progress** achieved by the human beings
- **complexity** of their brain and their neuro-physiological functions
- **self-transcendence of *H. sapiens***, well beyond the goals of nutrition, conservation and reproduction



■ Earth's *déplacement*: a broken harmony?

- The **rise of scientific thought**, particularly the shift from the geocentric to the heliocentric system, would have caused the **breakdown of the previous harmony** between man and the cosmos, proper to the classical and medieval ages.
- The **balance point** between the two infinities would collapse, leaving the human beings **to fall into nothingness** – that nothingness from which they had appeared by chance.
- An **evolving nature**, subject to continuous transformations and dramatic struggles, is **no longer a harmonious and hospitable scenario**, crowned by the appearing of man
- A definite change would have occurred: from the closed universe of **predictable regularities**, ruled by the **laws of nature**, to the open universe characterized by **unpredictable complexity** and **indeterminism**
- with repercussions in **philosophy, ethics, law, art...**

John Donne (1572-1631) abandons the ordered cosmos of Dante's *Commedia* to sing now, in *An Anatomy of the World* (1611), about the collapse of the Ptolemaic system, which drags behind it the loss of all certainty and of firm landmarks



“So did the world from the first houre decay,
the evening was beginning of the day,
And now the Springs and Sommers which we see,
Like sonnes of women after fifty bee.
And new Philosophy cal's all in doubt,
The Element of fire is quite put out;
The Sunne is lost, and th'earth, and no mans wit
Can well direct him where to looke for it.
And freely men confesse that this world's spent,
When in the Planets, and the Firmament
They seek so many new; they see that this
Is crumbled out againe to his Atoms.
It's all in pieces, all cohaerence gone;
All just supply, and all Relation:
Prince, Subiect, Father, Sonne, are things forgot [...].
The art is lost, and correspondence too.”

■ ... However, for a correct assessment of the changes about man's position in the cosmos, it is also necessary to ask oneself..

- whether the classical universe, later forged by Christian inspiration, was indeed a human-centered universe
- with respect to what "geometry" such centrality was lost? (how far away was the sphere of the "fixed stars"?)
- why those who provoked such decentralization (Cusanus, Copernicus, Kepler, etc.), and developed a scientific method without any privilege for the man-observer (Galileo, Descartes, etc.), maintained a Judeo-Christian understanding of the human being as the image of God?
- whether the modern age actually proposed new forms of centrality for man (humanism, Enlightenment, idealism, etc.)?
- why the "religious" understanding of the human being continued to hold the two infinities in balance (sacred Scripture, Christian Cathedrals, man as microcosm...)



“Lord, our Lord, how majestic is thy name in all the earth!

Thou whose glory above the heavens is chanted by the mouth of babes and infants, thou hast founded a bulwark because of thy foes, to still the enemy and the avenger.

When I look at thy heavens, the work of thy fingers, the moon and the stars which thou hast established;

what is man that thou art mindful of him, and the son of man that thou dost care for him?

Yet thou hast made him little less than God, and dost crown him with glory and honor.

Thou hast given him dominion over the works of thy hands;

thou hast put all things under his feet, all sheep and oxen, and also the beasts of the field, the birds of the air, and the fish of the sea, whatever passes along the paths of the sea.

O Lord, our Lord, how majestic is thy name in all the earth!”

Psalm 8

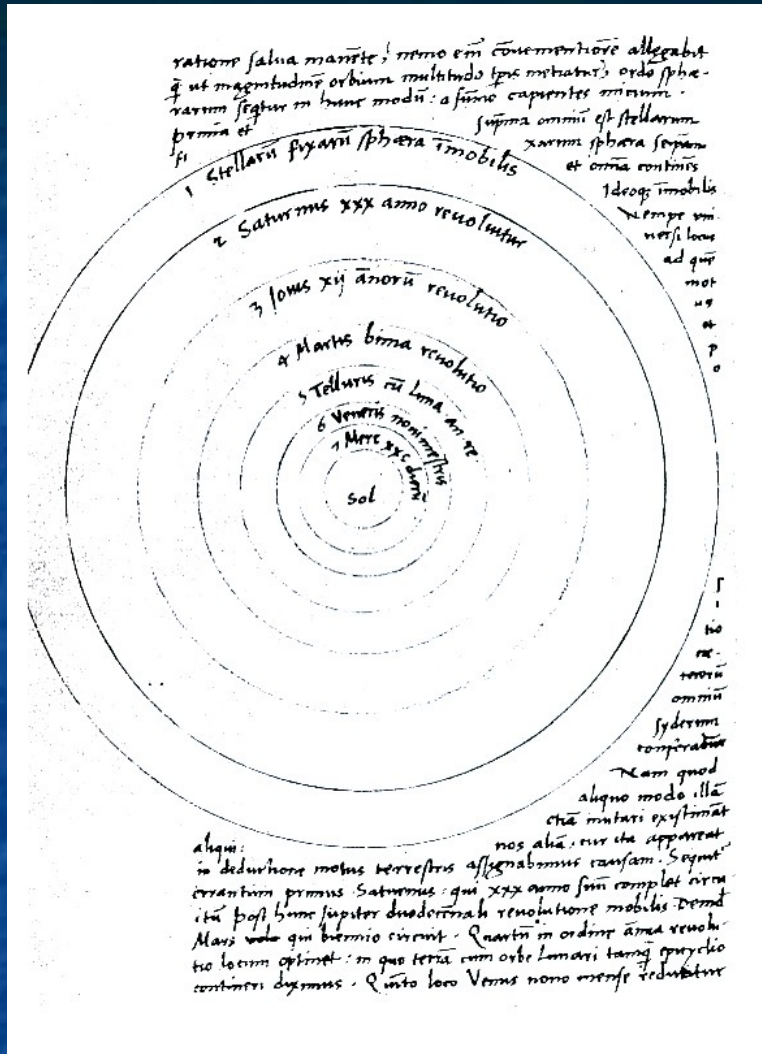


“The logos [creator] created man, a single living being formed from the two substances, that is, from the invisible and the visible nature: from the matter already created before He took the body, from Himself He took the breath which He inserted into matter [...].

Man was like a second world, a large world in a small being, [...] overseer of the visible creation and initiate of the intelligible creation; king of all things that are on earth, but subject to the realm of the supernal realities; an earthly and heavenly being, ephemeral and immortal, visible and intelligible, placed somewhere between greatness and humility, simultaneously spirit and flesh.”

Gregory of Nazianzus, *Homilies on the Nativity*,
Discourse 38, no. 11.

Nicholas Copernicus
De Revolutionibus Orbium Coelestium,
1543



II. The rise of the Anthropic Principle in the context of modern science

■ Methodological principles that deny any observer's privilege

- Copernican principle or principle of mediocrity

The earthly observer has no longer a privileged place

- Principle of covariance

The laws of nature and the principles of science must be valid for every observer

- Principle of relativity (Galilean, Einsteinian)

There must be transformations that allow different observers, to describe a phenomenon in equivalent terms (Cartesian, Lorentz transformations)

- Cosmological principle

Every point in the universe is adequate to describe the whole physical universe, its structure and laws, in a universally valid way (homogeneous and isotropic universe, inhomogeneities on a local scale have no influence on medium and large scales)

- Perfect cosmological principle

The characters and laws of the universe should be identical when observed both at any point in space and at any instant in time.

■ The "Anthropic Principle" is the first attempt, arisen within the sciences, to employ the position of the observer as a significant element in understanding the cosmos.

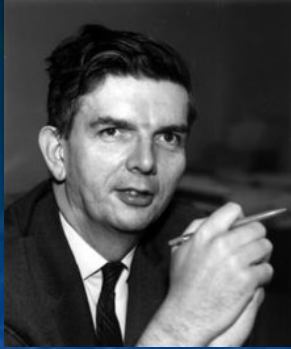
From the fact that intelligent life has developed in the universe, the following characteristics of the physical universe can be predicted:

age
dimensions
chemical composition
...

Thus, precise "anthropocentric conditions" were unexpectedly discovered:

☞ the **constants of nature** that govern the physics and chemistry of the universe have precisely those numerical values that enable the universe **to have a structure and a history adequate to host life.**





Robert Dicke (1961):

some cosmological values, "as observed," depend on the presence of life and of the intelligent human being.

Brandon Carter (1974)

for the first time proposed to collect all these observations using the term "Anthropic Principle."



Weak version: the measurements of some specific cosmological parameters can only be those which are compatible with the existence of observers;

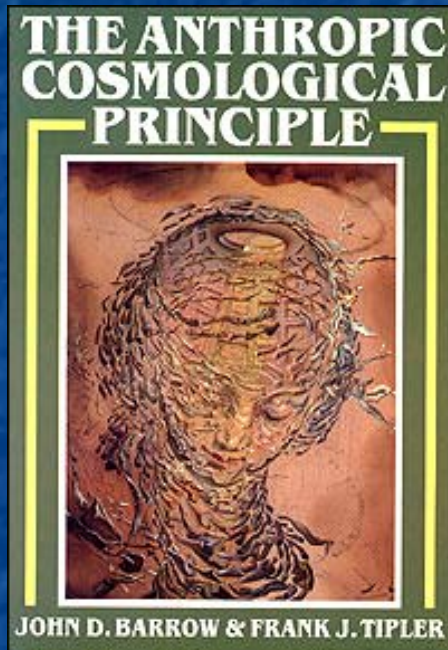
strong version: the universe must possess only those properties and parameters whose values actually give rise, at some stage of its development, to the presence of observers.



B.J. Carr and Martin Rees (1979)

systematize a dozen of physical and cosmological "numerical coincidences" that must occur in order for the universe to have adequate physics and chemistry to host life.

John Barrow and Frank Tipler (1986) study in depth the major anthropocentric conditions of the universe, methodologically and philosophically contextualized, proposing three versions of the Principle:



Weak Anthropic Principle (WAP):

“the observed values of all physical and cosmological quantities are not equally probable, but are constrained by the condition that there should be places in which carbon-based life can evolve, as well as by the condition that the Universe is old enough to have given rise to such life forms.”

Strong Anthropic Principle (SAP):

“the Universe must possess those properties that allow life to develop within it, at some stage in its history.”

Final Anthropic Principle (FAP):

“information produced and developed by intelligent life *must come into being* in the Universe, and once it comes into existence, it will last forever.”

■ The **constants of interaction of the four fundamental forces** (namely, strong nuclear, weak nuclear, electromagnetic and gravitational), which govern the mutual relationship of these forces, so determining the structure and evolution of the cosmos, **do not take random values, but rather “special” values**, showing a sort of ***fine tuning***. Actually, they:



- determine a proper **rate of expansion of the universe**, one that is suitable for galaxy formation;
- regulate the **stability of atomic nuclei** heavier than hydrogen, allowing the short-range nuclear force to prevail over electrical repulsion;
- allow stars, formed by gas contraction, to **reach temperatures sufficient to be able to trigger thermonuclear reactions**, and this precisely just before a gravitational collapse irreversibly occurs;
- allow stars to form having a sufficient **variety of thermodynamic properties**, including **sun-like** stars;
- allow **supernovae** explosions at the end of massive stars evolution, enabling **interstellar diffusion of carbon** and the **formation of elements heavier than iron**

■ Think about the different scientific and philosophical value the WAP and SAP have

The Weak AP:

- is based on scientific observations, that is, on experimental measurements and grounded theoretical frameworks
- is philosophically poor: it could admit a tautological reading or just express a *de facto* situation.

The Strong AP:

- has poor scientific bases, but it states a strong philosophical view

■ Fallout of the AP in philosophy and natural theology

It has been employed at the same time:

- to show the existence of a deterministic, **immanent** cosmic evolution, one which necessarily leads to the existence of intelligent observers
- to show the existence of a “Design” that **transcends the cosmos**, and then as a possible reference to a God Creator.

■ The topic is **subject to misunderstandings** or improper deductions because of its **dual sides**, philosophical and scientific.



It becomes necessary, then:

- to separate the **scientific data** from its extra-scientific extrapolations
- to assess the **different philosophical import** of the strong and weak versions
- to critically examine whether **it is really a Principle** and whether is **it correct to call it Anthropic**.

☞ Before evaluating any philosophical implication, it is therefore necessary, to first analyze what the “anthropic conditions” are...

M20 Triphid Nebula
Sagittarius
Constellation

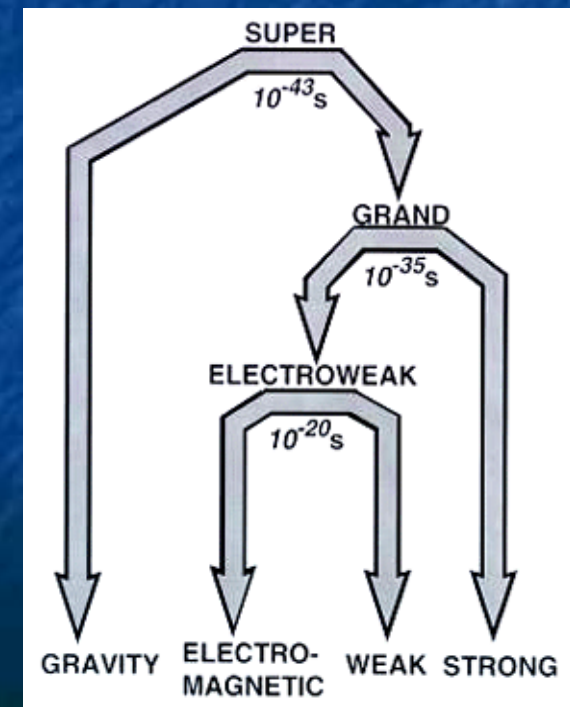


**III. The main cosmic “coincidences”
underlying the Anthropic Principle**

Role of the interaction constants of the 4 fundamental forces

Interaction	constant	numerical value	formula
strong nuclear	α_s	15	$2 \pi g_s / hc$
weak nuclear	α_w	$3.1 \cdot 10^{-12}$	$8 \pi^3 m_e^2 c g_w / h^3$
electromagnetic	α	$7.3 \cdot 10^{-3}$	$2 \pi e^2 / hc$
gravity	α_g	$5.9 \cdot 10^{-39}$	$2 \pi G m_p^2 / hc$

- govern their *mutual relationship* when structuring the evolving cosmos
- originated in the very first moments of the expansion of the universe, as the 4 forces gradually differentiated, when energy density and temperature decreased
- were all determined within 10^{-20} sec after the *Big Bang* (beginning of the expansion)



1. The "miracle" of the expansion of the cosmos...

The value of the gravitational interaction constant

α_g

determined a mode of expansion of the universe

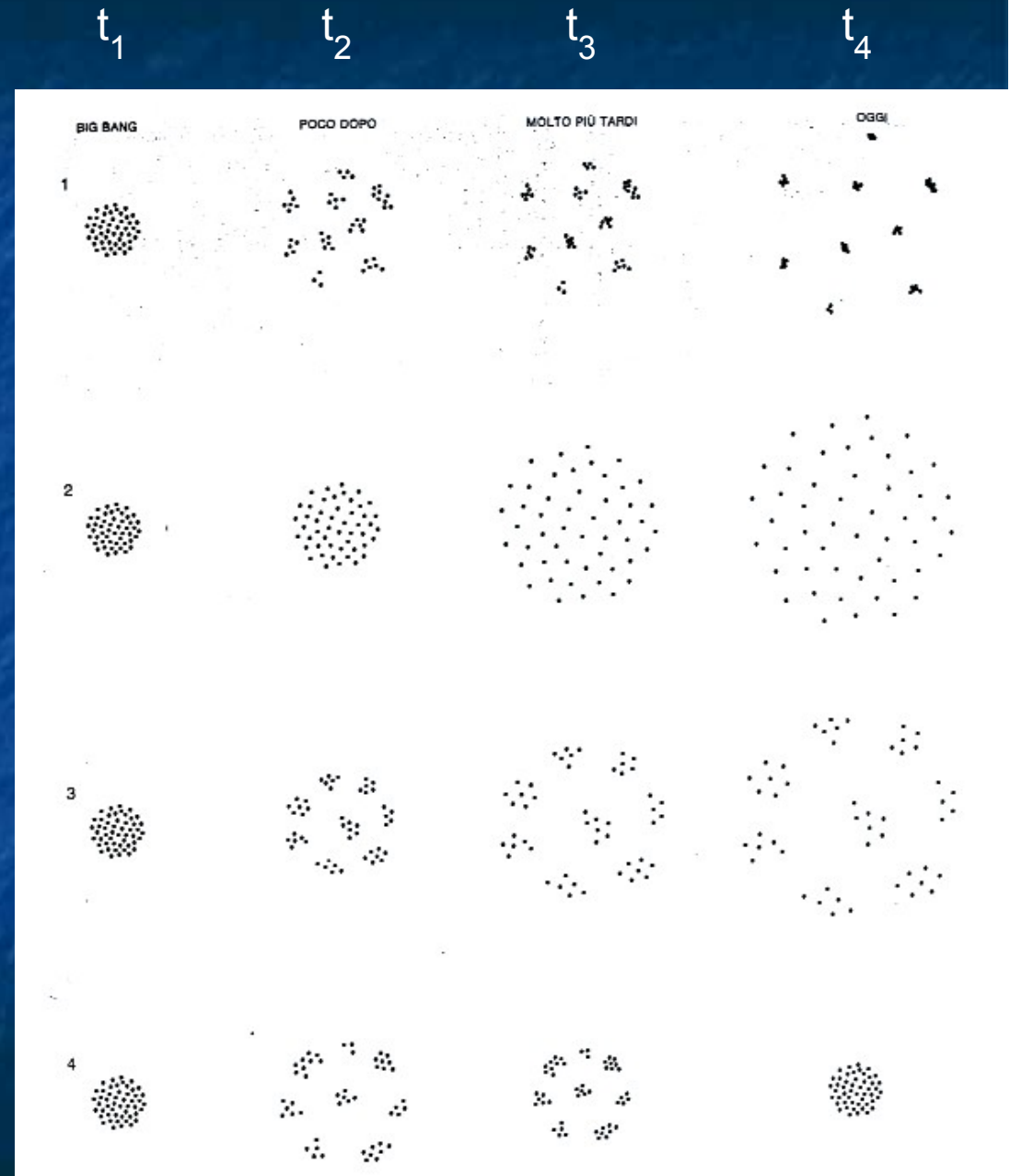
that was suitable for the formation of galaxies and then of stars, a necessary condition for the later formation of planets

=

<<

<

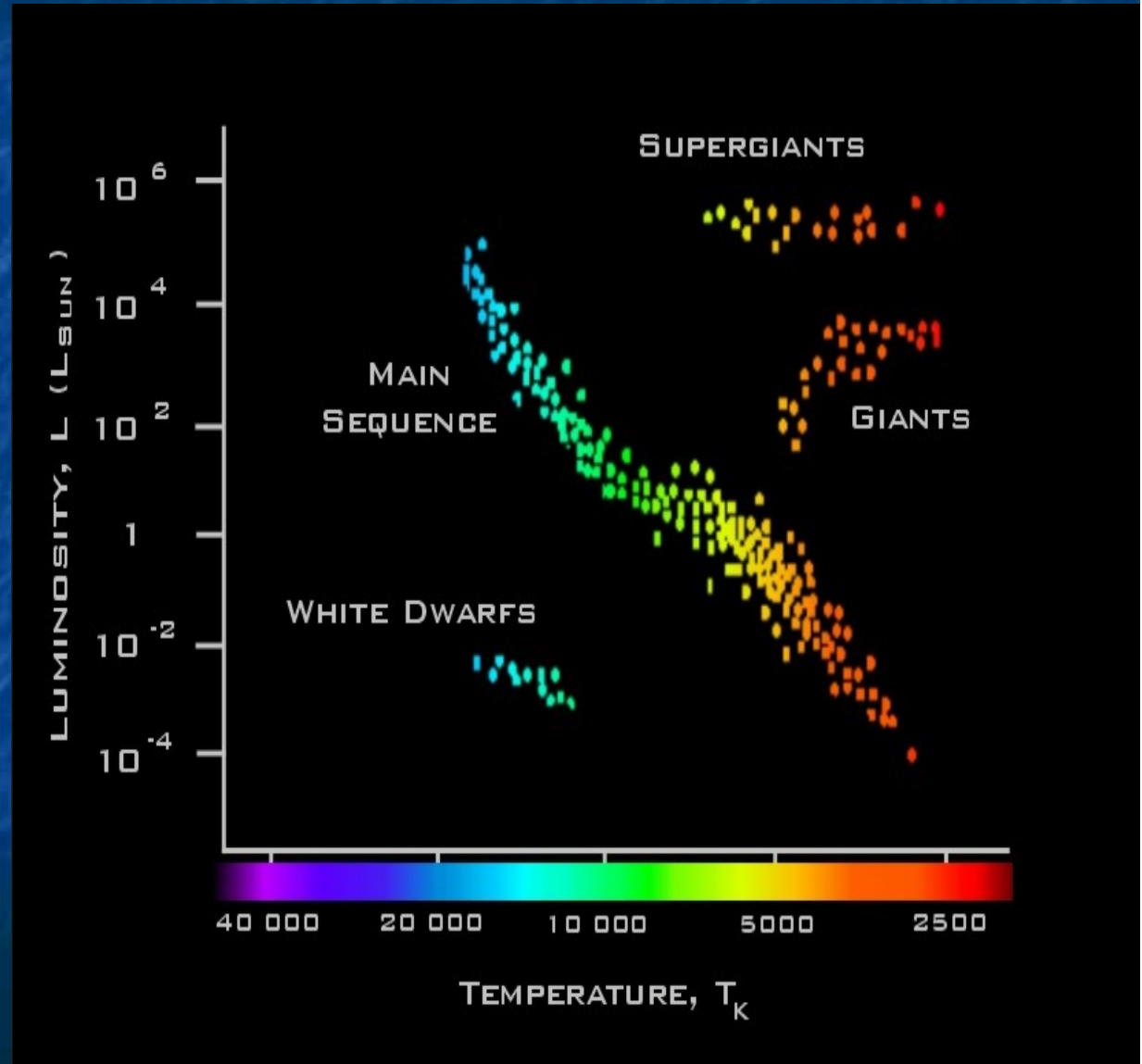
>



2. The "miracle" of the formation of a right sequence of stellar masses...

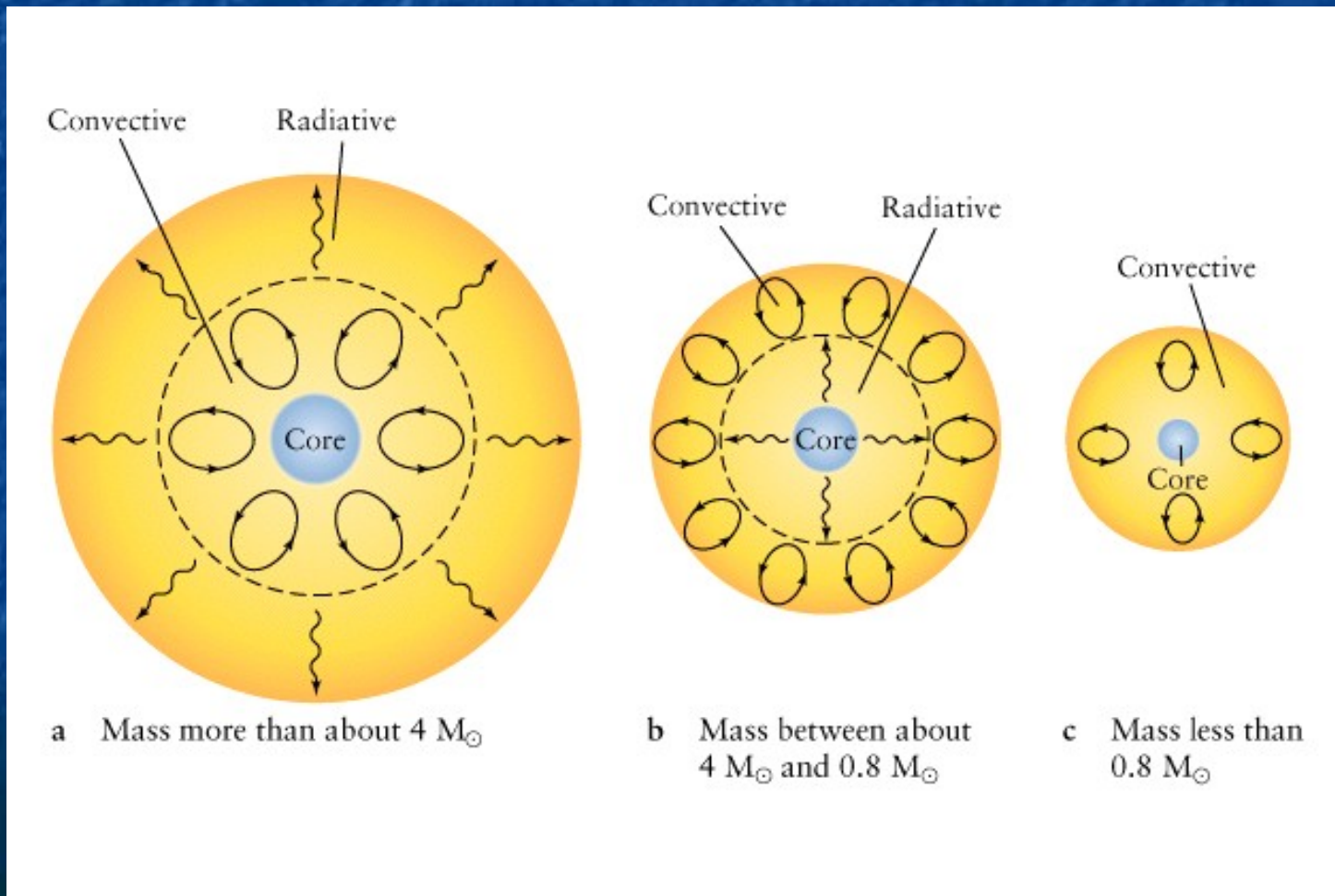
The very specific ratio existing between the gravitational and the electromagnetic interaction constants α_g / α

allows the formation of stars with a sufficient variety of thermodynamic properties, giving rise to the "main sequence" dwarf stars, in the Temperature-Brightness diagram.



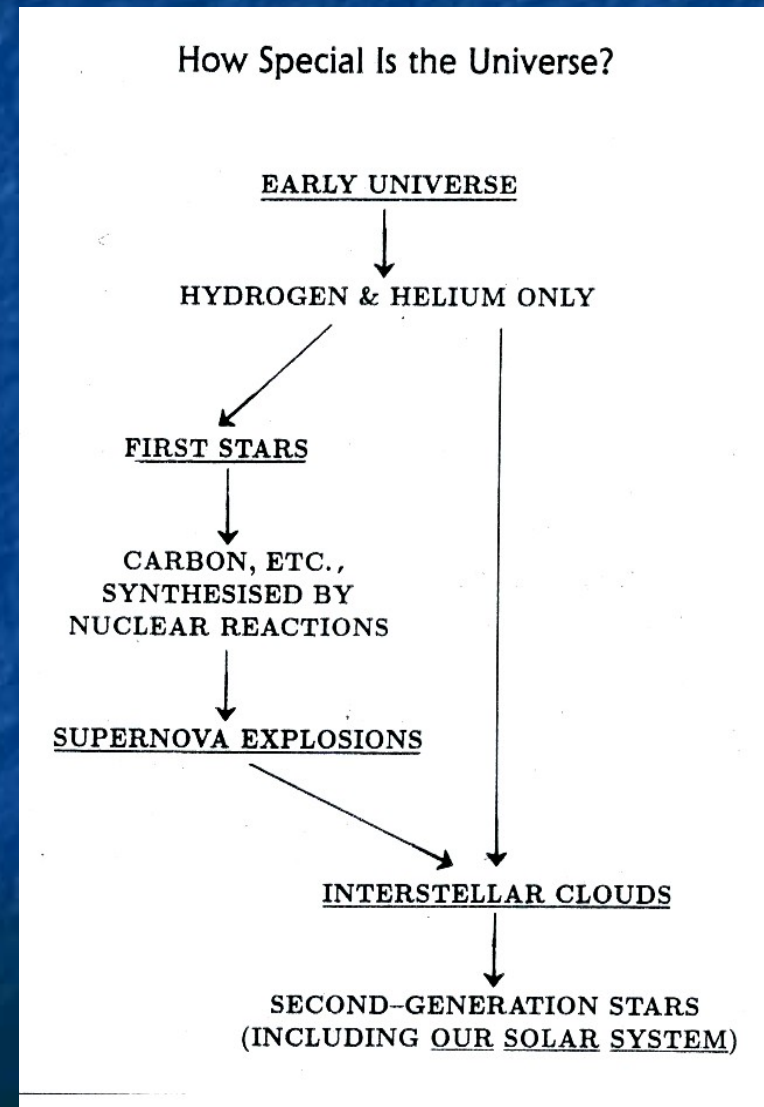
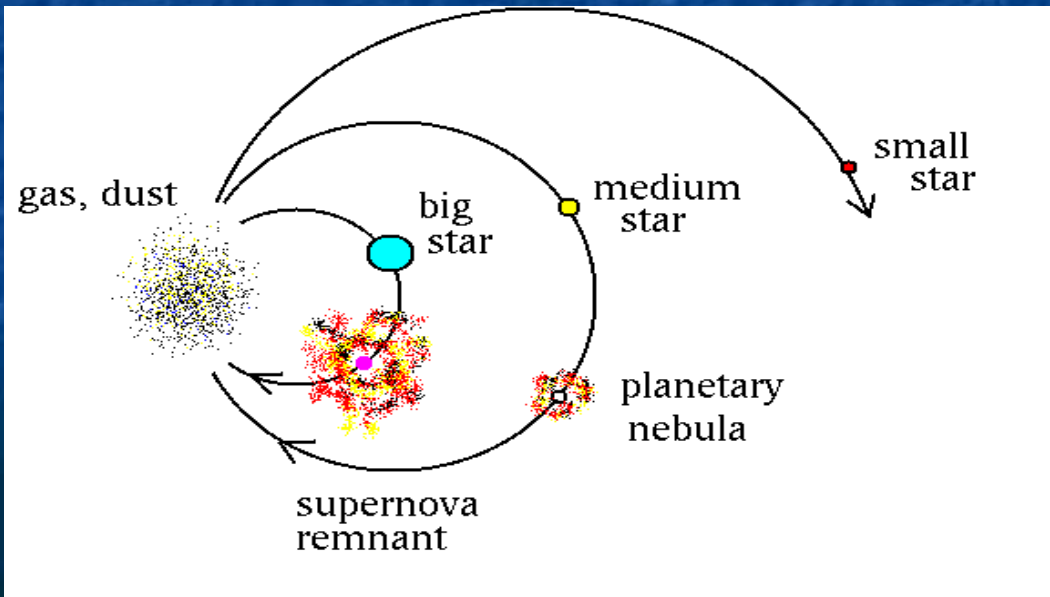
The simultaneous need for both radiative equilibrium giants and convective equilibrium dwarfs

A chemistry adequate for life needs both convective equilibrium dwarf stars (having planets around them) and radiative equilibrium giants (rapidly evolving and producing heavy chemical elements)

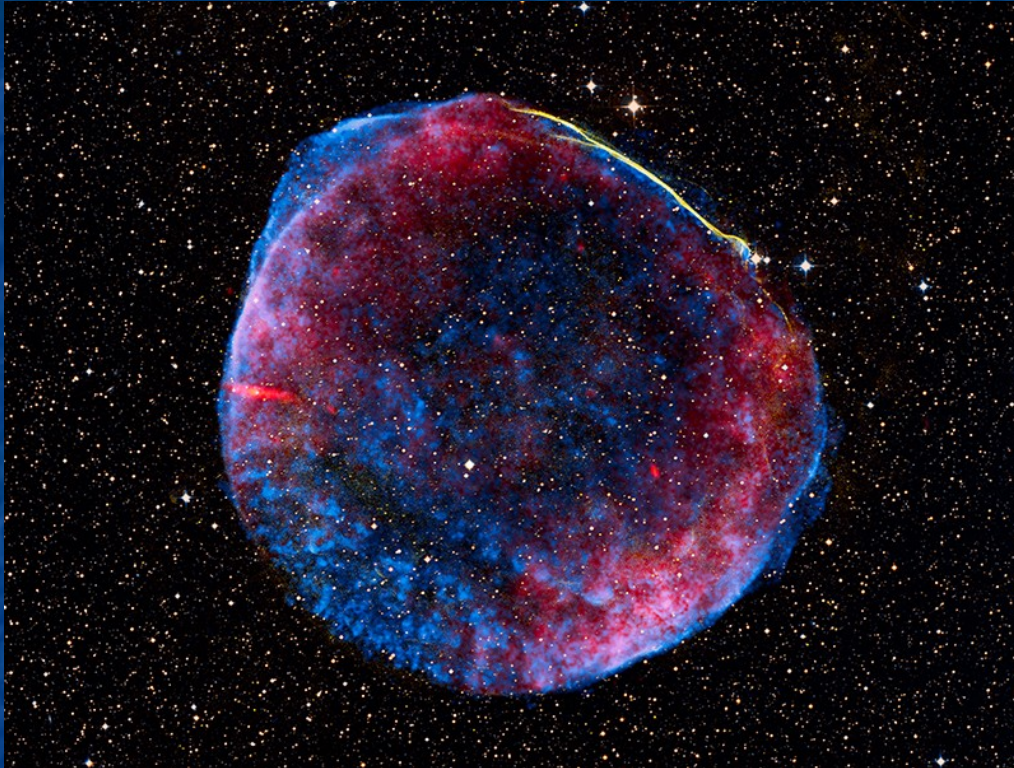


3. Thanks to *Supernovae*: the interstellar diffusion of carbon and the production of chemical elements heavier than Iron ($Z > 26$)

The very specific value of the ratios α_g / α and α_s / α_w allow *Supernovae* explosions to occur, with the consequent ejection into the interstellar medium of carbon and other elements; during the high temperatures developed, chemical elements heavier than iron can be synthesized.



Supernovae remnants

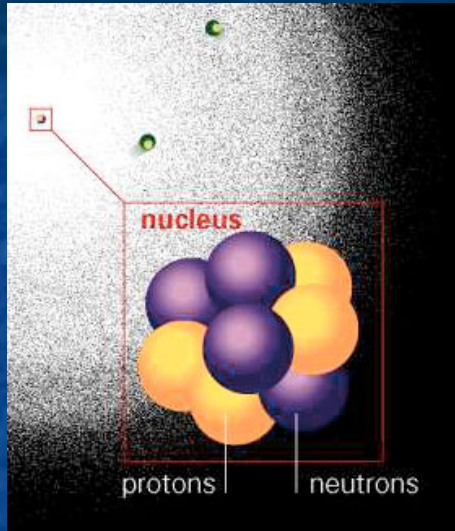


SN 1006c (Lupus constellation)
exploded in 1006



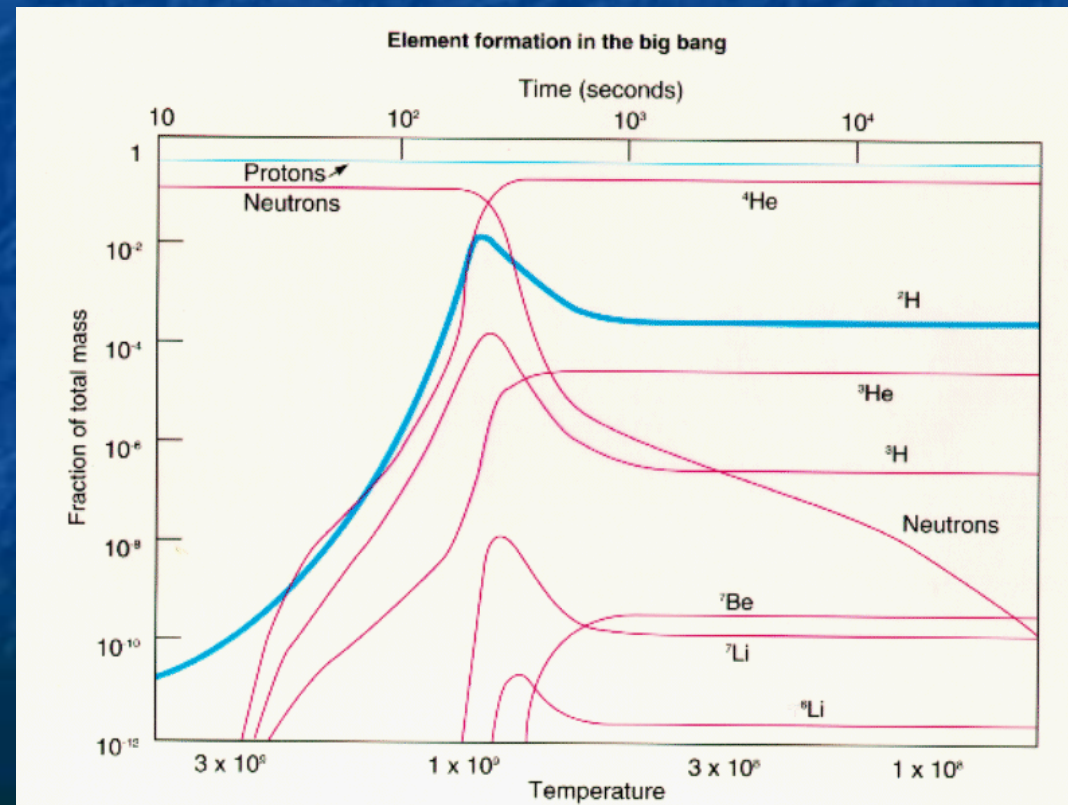
Crab Nebula M1 NGC 1952
(Taurus constellation)
exploded in 1084

4. The “unexpected” stability of atomic nuclei and the formation of cosmological helium...



The precise value of the ratio α_s / α allows the short-range nuclear force to prevail over electrical repulsion, enabling the formation and stability of atomic nuclei

The value of the ratio α_g / α_w prevents cosmological hydrogen from being transformed entirely into helium. Hydrogen is the most important stars fuel, and a necessary component of water molecule.

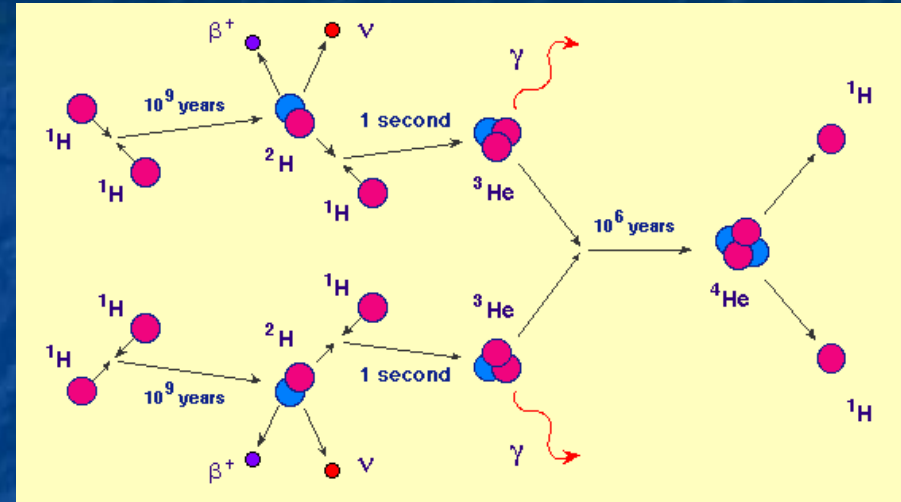


5. During the process of stars formation, the thermonuclear reactions ignite just before the star collapses irreversibly...

Stars are formed by gravitational contraction of hydrogen gas clouds. As the gas heats up, thermonuclear reactions begin.

The value of the ratio of α_g / α_s is such that the temperature able to “turn on” stars is reached *just shortly before* the gravitational contraction of the cloud becomes irreversible.

If the values of these constants were not favorable, the protostars would collapse, ending their lives before they ever began to shine.





James Webb - Hubble photo-composition of M74.

Young stars in formation can be recognized by the blue dots on the spiral arms

Image credit: NASA / ESA / CSA / Webb / Hubble / J. Lee / PHANGS-JWST Team / R. Chandar / J. Schmidt

■ Summary of the main anthropocentric conditions related to the values of the constants of interaction

	had it been less	had it been greater
gravitational interaction	the "Main Sequence" would consist only of hot, blue giant stars Interstellar gas aggregations would not form	the "Main Sequence" would consist of cold, red dwarfs stars only During the initial expansion, the universe would have collapsed on itself
ratio between gravitational and weak nuclear	No cosmological Helium: stars would evolve too rapidly to give rise to planet formation	All Hydrogen would turn into Helium No water: no physical and biochemical scenarios suitable for life
ratio between electromagnetic and weak nuclear	No physical conditions to lead some stars to become SN. No chemical elements heavier than Fe. No dispersing of C-N-O into the interstellar medium.	

One among many other coincidences: “anthropocentric” water conditions

The molecule of H_2O has an angle of 104.5° , very close to that of a tetrahedron (109.5°).

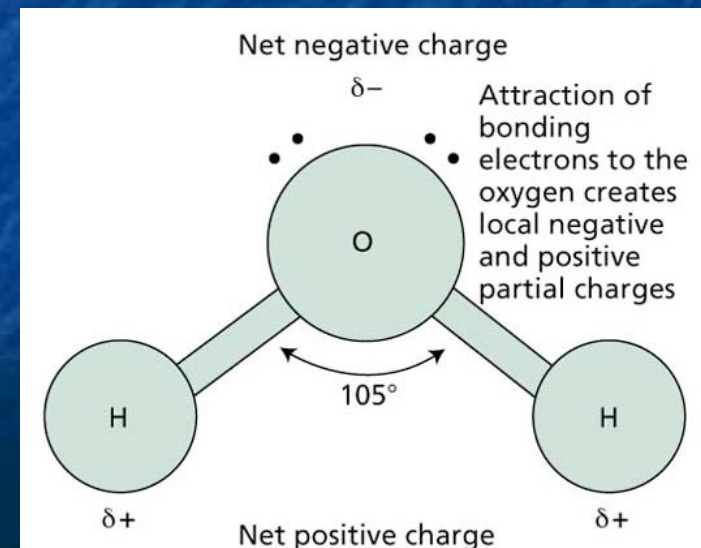
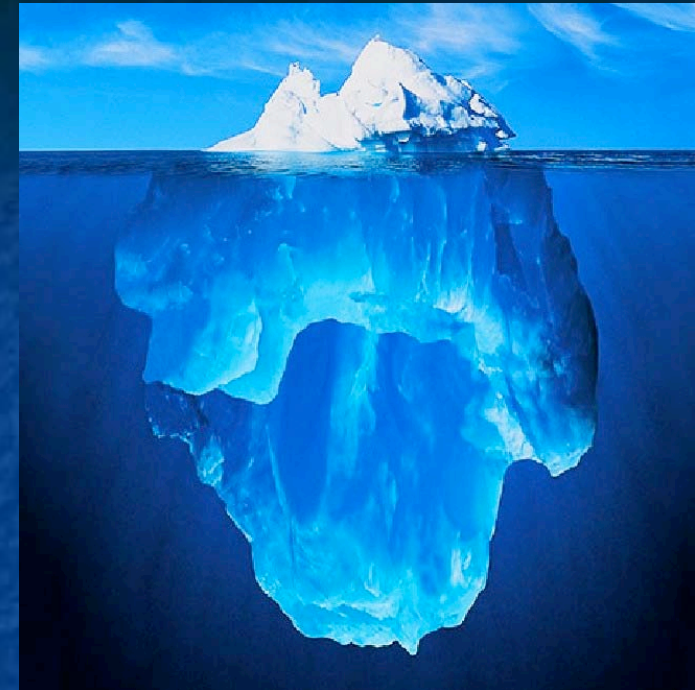
For this reason, water can freeze into loosely packed structures.

In the tetrahedron (4 spikes) the molecules are spaced far apart, unlike other crystal lattices, such as cubes (6), dodecahedron (12), etc., which house closely packed molecules.

This makes the *ice lighter than water*.

Were the ice heavier, it would go down and **surface solidification would be continuous**.

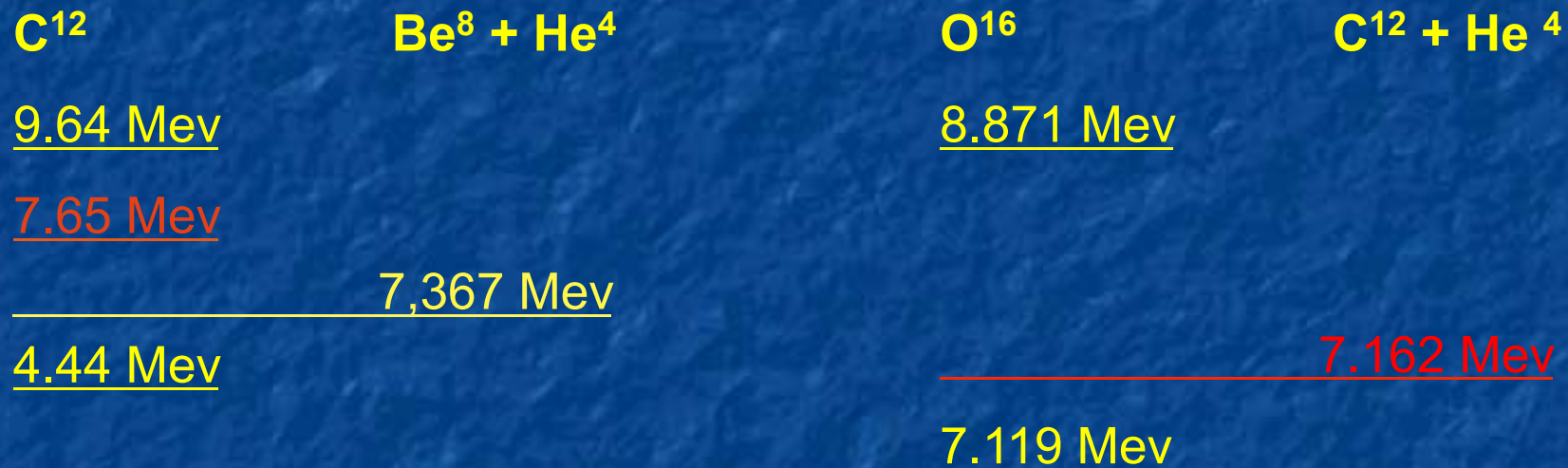
The angle of 104.5° , far from the flat angle (180°), generates an **electric dipole**, which which causes the solvent action of water and the effectiveness of many bio-chemical processes.



Other favorable anthropocentric “coincidences”

The reaction that from helium leads to carbon through beryllium has a very low cross section ($\text{Be}^8 + \text{He}^4 \Rightarrow \text{C}^{12}$).

However, thanks to the unexpected existence of a C excited level resonant with the energy level resulting from the sum of Be and He nuclei, the reaction can occur. **Otherwise, the amount of the carbon produced would be negligible.**



The reaction that from C leads to O through He capture ($\text{C}^{12} + \text{He}^4 \Rightarrow \text{O}^{16}$) is such that the energy level of O is just slightly less than the sum of the energy levels of C plus He. Would it be only a bit higher, **all the C would be entirely burned into O.**



Bible Moralisée, XIII century's miniature.
God measures the size of the cosmos

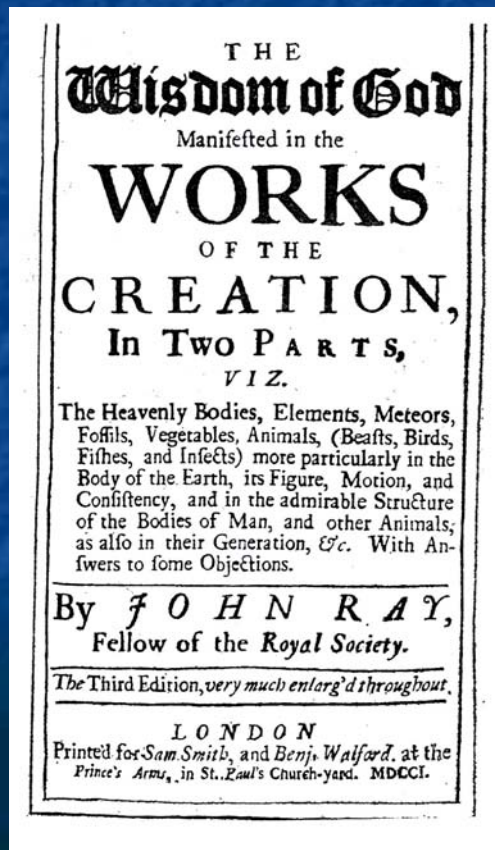
IV. Philosophical implications and final theological reflections



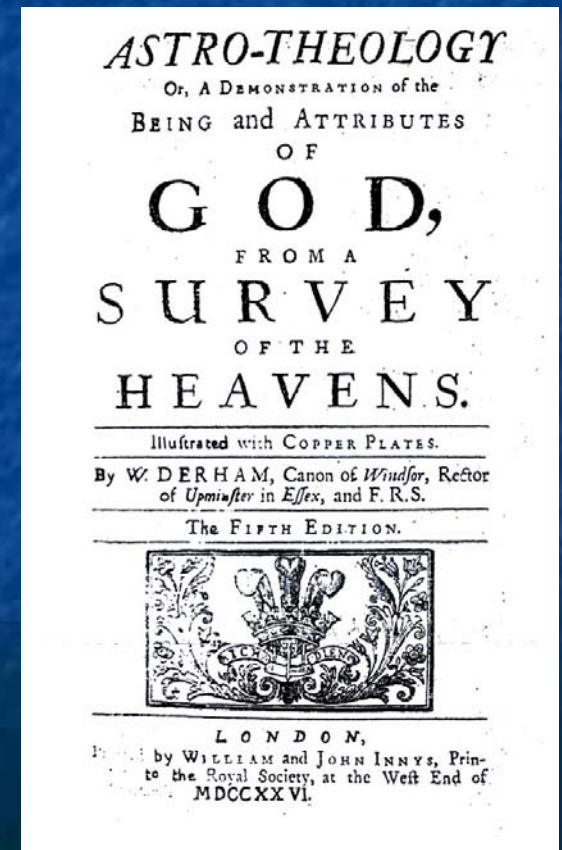
- Do suggestions coming from the Anthropic Principle bring about new insights about the position of human beings in the cosmos?
- Are the Anthropic coincidences a “scientific” evidence of some purpose in the physical and biological evolution of the universe?

■ Anthropropic Principle and Argument from Design

Deducing the existence of a Creator from the existence of an “intentional design” in nature was a classic argument in natural theology: patristic and medieval theology, Anglican apologetics of the 17th-18th centuries, etc. This argument was interrupted with the philosophy of Kant and Hume and, in the sciences, with the rise of Darwinism.



William Derham, *Astro-Theology:
or a demonstration of Being and
Attributes of God from a Survey of
the Heavens* (1715)




John Ray, *The Wisdom of
God manifested in the Works
of Creation* (1691)



■ Some necessary clarifications

- The only formulation of the Anthropic Principle which originated by strictly scientific data is the so-called **weak AP**: many cosmic parameters assume only **those values which give rise** to a physics and a chemistry **compatible with the existence of life**
- **No purpose corresponds to** that formulation: compatibility is a **necessary, but not a sufficient condition** to cause the phenomenon of life
- Strictly speaking, scientific observations related to the weak AP do not concern human life as such, but rather the existence of **habitats suitable for hosting life**
- Scientific method **cannot conclude the existence of an intentional purpose** in the cosmos: other methods are needed to acknowledge the existence of some “finalism” caused by a personal being’s will



■ **Weak AP brings about some real implications about our view of the cosmos and man's place in it**

a) The cosmos possesses a **strongly unified character**: the 4 fundamental constants of interaction determine the evolution of the universe far more than all the individual events occurring after the Big Bang

b) The universe seems to be something “**thought as a whole**” and “**from the very beginning.**” The fine tuning between life and matter, between cosmic and biological evolution, is a kind of primeval “set up”

c) Life – including human life – strongly depends **on the entire history of the universe.**

d) Starting from a set of **scientific** observations, we can now address philosophical questions, and provide existential reflections, about our **place in the cosmos.**

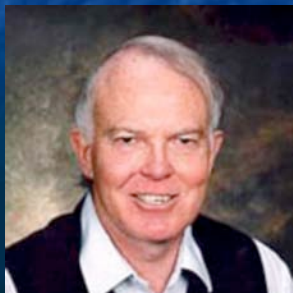
■ Several possible explanations have been suggested for the various anthropocentric “coincidences”...



Perhaps someday we will have a sophisticated physical way to explain why all the relationships discussed here, which appear now as mere coincidences, are so. However, even if all these apparent anthropic coincidences were explicable in such a way, it would still remain quite remarkable that the relationships dictated by a physical theory are also those propitious to life. (Martin Rees)

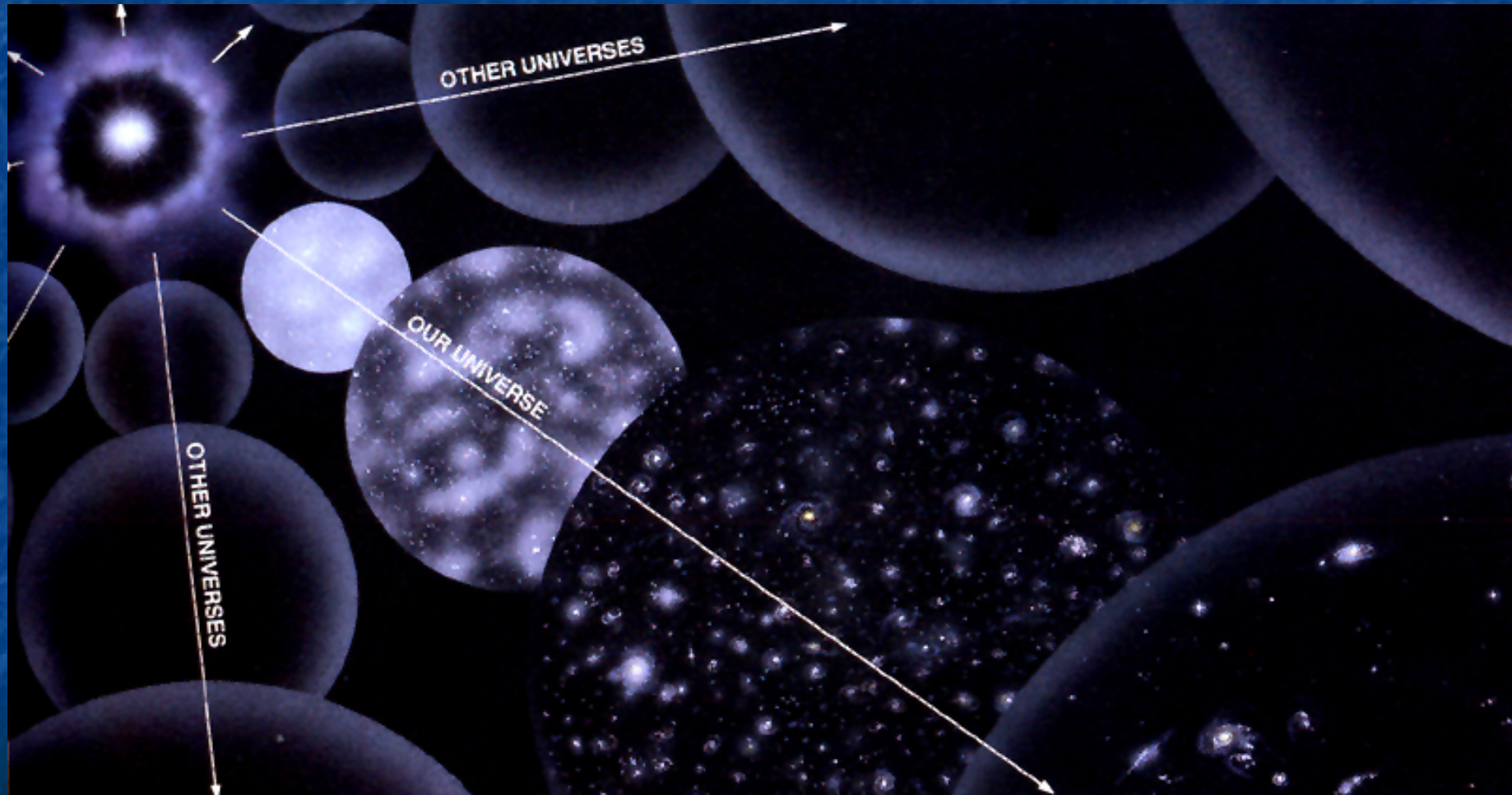


Should our attempts to derive those coincidences from more general and fundamental mathematical structures fail, this would represent evidence that the philosophy of the set of worlds should be taken seriously, even if we did not like it... (Brandon Carter)



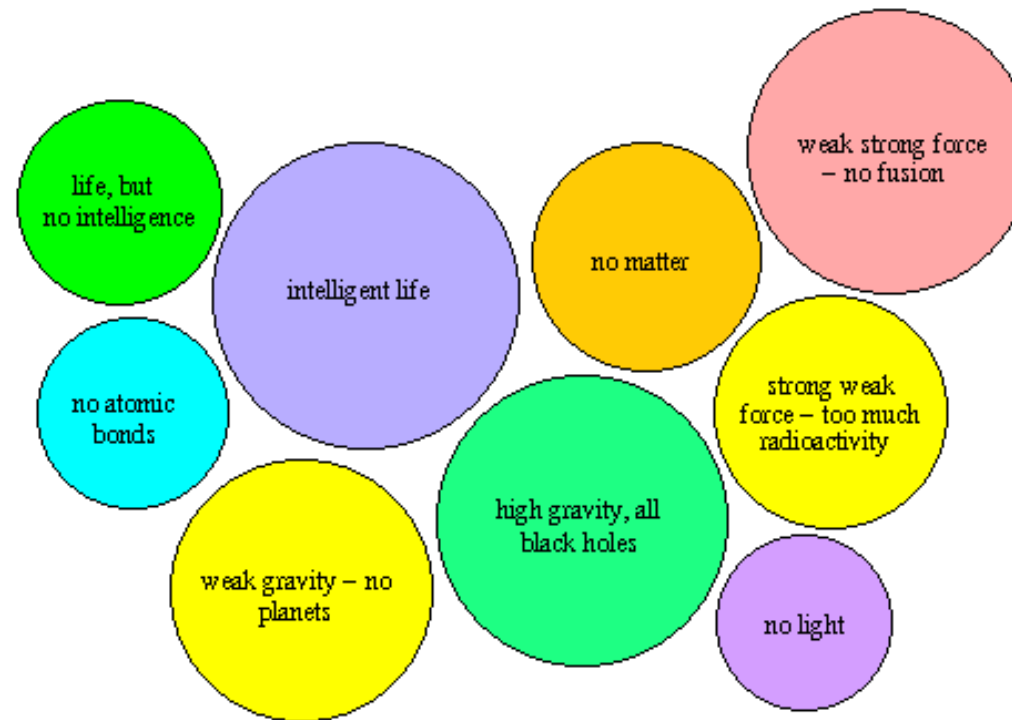
*Accurate tuning (fine tuning) is evidence, genuine evidence, of the following fact:
That God is something real and/or there are many different universes. (John Leslie)*

■ The Many-Worlds Hypothesis as the main *philosophical* criticism to AP suggestions



Anthropic Bubbles

one possible solution to the anthropic dilemma is the numerous bubble universes produced by inflation. Each bubble universe may have its own physical constants, which determine the evolution within the bubble



the evolution of intelligent life is extremely sensitive to the initial conditions, but since number of bubble universes is also large, the possibility is finite and our existence is not a big mystery

■ The weak points of the Many-Worlds Hypothesis

- **Lack of empirical evidence:** the hypothesis is **untestable** in the frame of observational cosmology
- **Ockham's Razor violation** (*entia non sunt multiplicanda*): the hypothesis adds unnecessary complexity without solid empirical grounding
- Gravitational constant and other cosmic parameters **already set before** the formation of many independent and causally disconnected space-time regions
- Even in a multiverse scenario, the **basic philosophical relationship** between a Creator and a created universe **still hold**
- To be accepted, the many-worlds model hypothesis should generate some testable **empirical consequences to be observed in our universe.**



Through my scientific work I have come to believe more and more strongly that the physical universe is put together with an ingenuity so astonishing that I cannot accept it merely as a brute fact.

There must, it seems to me, be a deeper level of explanation. Whether one wishes to call that deeper level 'God' is a matter of taste and definition.

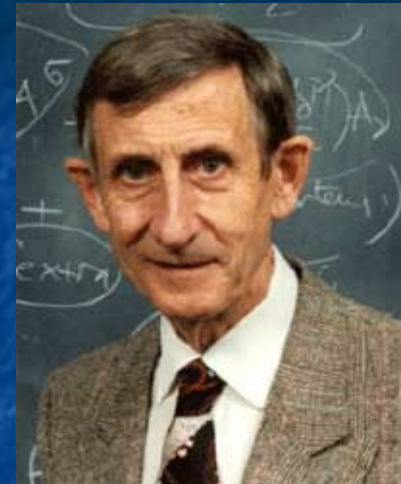
*P. Davies, *The Mind of God. Science and the Search for Ultimate Meaning* (New York: Simon and Schuster, 1992), p. 15*

I conclude from the existence of these accidents of physics and astronomy that the universe is an unexpectedly hospitable place for living creatures to make their home in.

Being a scientist, trained in the habits of thought and language of the twentieth century rather than the eighteenth, I do not claim that the architecture of the universe proves the existence of God.

I claim only that the architecture of the universe is consistent with the hypothesis that mind plays an essential role in its functioning.

F. Dyson, *Disturbing the Universe*, Harper & Row, New York - London 1979, p. 251



■ The new insights brought about by AP only suggest a *meaningful consonance between scientific and theological perspectives*



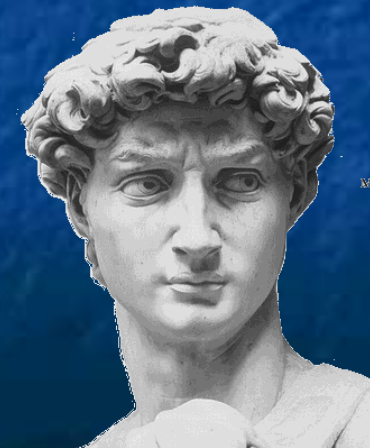
"You have disposed all things by measure and number and weight"
(*Book of Wisdom* 11:20)

"He who made the earth by his power,
established the world by his wisdom,
and stretched out the heavens by his skill."
(*Jeremiah* 10:12)

"The designer and maker of the earth who established it, not
creating it to be a waste, but designing it to be lived in."
(*Isaiah* 45:18)

"Through his bodily composition the human being
gathers to himself the elements of the material world;
thus they reach their crown through him, and through
him raise their voice in free praise of the Creator ."

Second Vatican Council, *Gaudium et spes*, no. 14.



... we could conclude our journey investigating Man's place in the cosmos and the insights brought about by the AP, using Chesterton's words:



*“This world does not explain itself.
It may be a miracle with a supernatural
explanation;
it may be a conjuring trick with a natural
explanation [...].*

*There is something personal in the world, as
in a work of art; whatever it means it means
violently.”*

G.K. Chesterton, *Orthodoxy* (1908) (Garden City
NY: Doubleday, 1959), p. 65

Selected bibliography

Scientific aspects:

P.A.M. Dirac, *The Cosmological Constants*, "Nature" 139 (1937), p. 323

R.H. Dicke, *Dirac's Cosmology and Mach's Principle*, "Nature" 192 (1961), pp. 440-441

B. Carter, *Large Number Coincidences and the Anthropic Cosmological Principle*, "Confrontation of Cosmological Theories with Observational Data," edited by M.S. Longair, Reidel, Dordrecht 1974, pp. 291-298

B. Carr, M. Rees, *The Anthropic Principle and the Structure of the Physical World*, "Nature" 278 (1979), pp. 605-612;

J. Barrow, *Anthropic Definitions*, "Quarterly Journal of the Royal Astronomical Society" 24 (1983), pp. 146-153;

J. Barrow, F. Tipler, *The Anthropic Cosmological Principle*, Clarendon Press, Oxford 1986.

Interdisciplinary reflections:

J.D. Barrow et al, *Fitness of the cosmos for life. Bio-chemistry and fine-tuning*, Cambridge University Press, New York 2008.

J. Demaret, D. Lambert, *Le principe anthropique. L'homme est-il le centre de l'Univers?*, Armand Colin, Paris 1994

W.L. Craig, J. Barrow, F. Tipler, *On the Anthropic Principle vs. Divine Design*, "British Journal of Philosophy of Science" 39 (1988), pp. 389-395

E. Harris, *Cosmos and Theos: Ethical and Theological Implications of the Anthropic Cosmological Principle*, Humanity Press, London 1992

G. Tanzella-Nitti, *Anthropic Principle*, "Interdisciplinary Encyclopedia of Religion and Science," at inters.org