

**New Planckian quantum phase of  
the Universe before Inflation:  
Its present day and Dark Energy  
implications**

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Chalonge de Vega 28 march 2019

## Standard Cosmological Model:

Ordinary Matter + Dark Matter + Cosmological Constant

- Begins by the **inflationary** era.
- Gravity is described by Einstein's General Relativity. Matter determines the spacetime geometry.
- **Ordinary Matter** described by the Standard Model of Particle Physics:  $SU(3) \otimes SU(2) \otimes U(1) =$  qcd+electroweak model. Strong, electromagnetic and weak interactions involving quarks, gluons, protons, electrons, photons and neutrinos.
- **Dark matter** plays a crucial role in galaxy and structures formation. DM could be a **sterile neutrino** which does not interact through the SM and has mass  $\sim$  keV.
- Dark energy uniformly distributed in space. **Repulsive** gravitational force. Described by the cosmological constant  $\Lambda$ .

## Standard Cosmological Model: $\Lambda$ CDM $\Rightarrow$ $\Lambda$ WDM

Dark Matter +  $\Lambda$  + Baryons + Radiation  
begins by the Inflationary Era. **Explains** the Observations:

- Seven years WMAP data and further CMB data
- Light Elements Abundances
- Large Scale Structures (LSS) Observations. BAO.
- Acceleration of the Universe expansion:  
Supernova Luminosity/Distance and Radio Galaxies.
- Gravitational Lensing Observations
- Lyman  $\alpha$  Forest Observations
- Hubble Constant and Age of the Universe  
Measurements
- Properties of Clusters of Galaxies
- Galaxy structure explained by WDM

## **(Pre) INTRODUCTION : A Word on Language**

***[Scientific developments incorporate new concepts and language, or assign new content to existing words. What is perceived at a given moment as "difficult" or not habitual, becomes thereafter "standard" and incorporated to the thought "habitual" by the use of these words in the current communications ....]***

***Les développements scientifiques incorporent des nouveaux concepts et langage, ou attribuent des nouveaux contenus à des mots existants . Ce qui est perçu à un moment donné comme "difficile" ou non habituel, devient par la suite "standard" et incorporé à la pensée "habituel" par l'usage de ces mots dans les communications courantes....]***

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**THE HISTORY OF THE UNIVERSE IS A HISTORY of EXPANSION  
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**THE EXPANSION OF THE UNIVERSE IS THE MOST POWERFUL  
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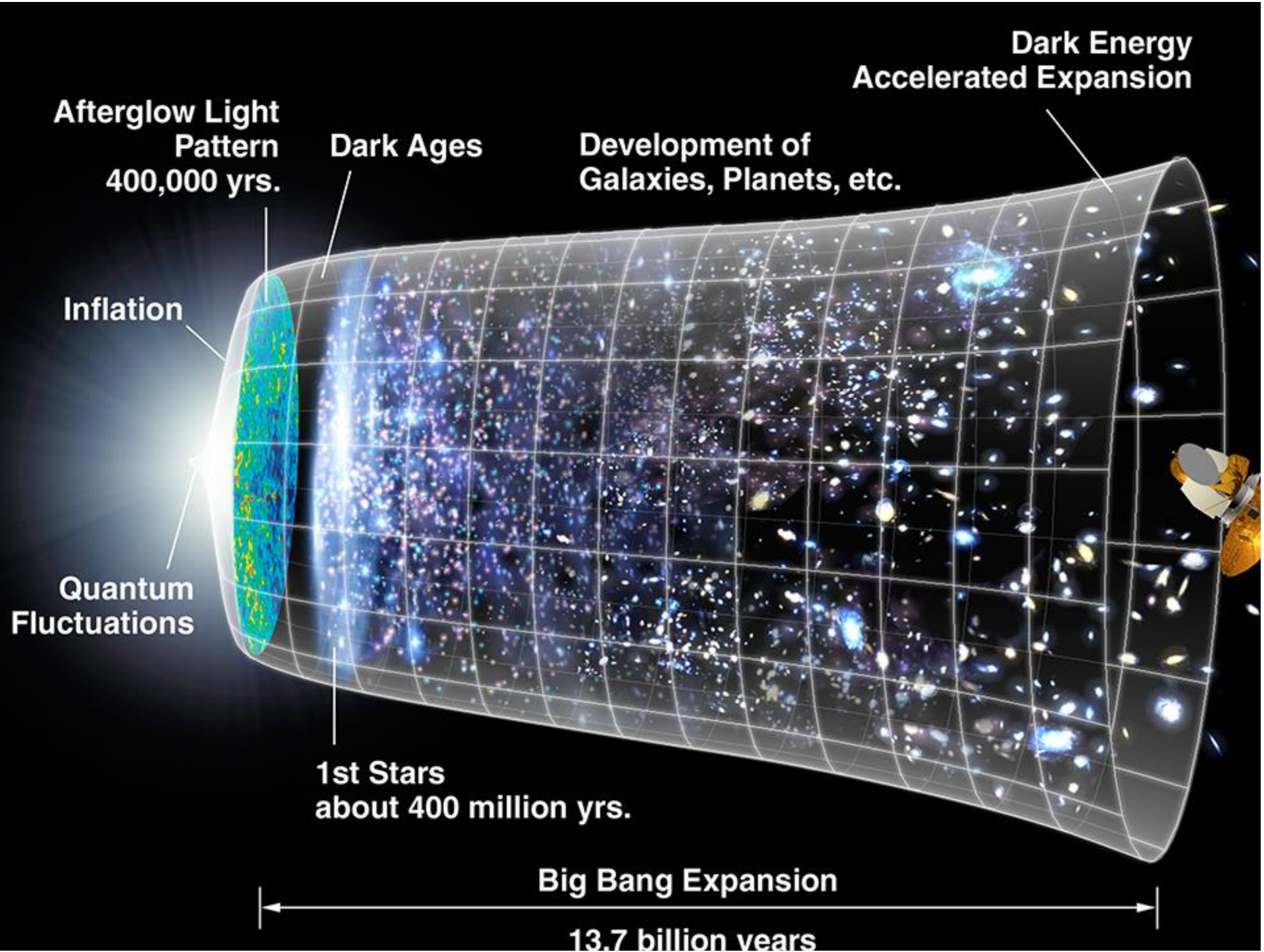
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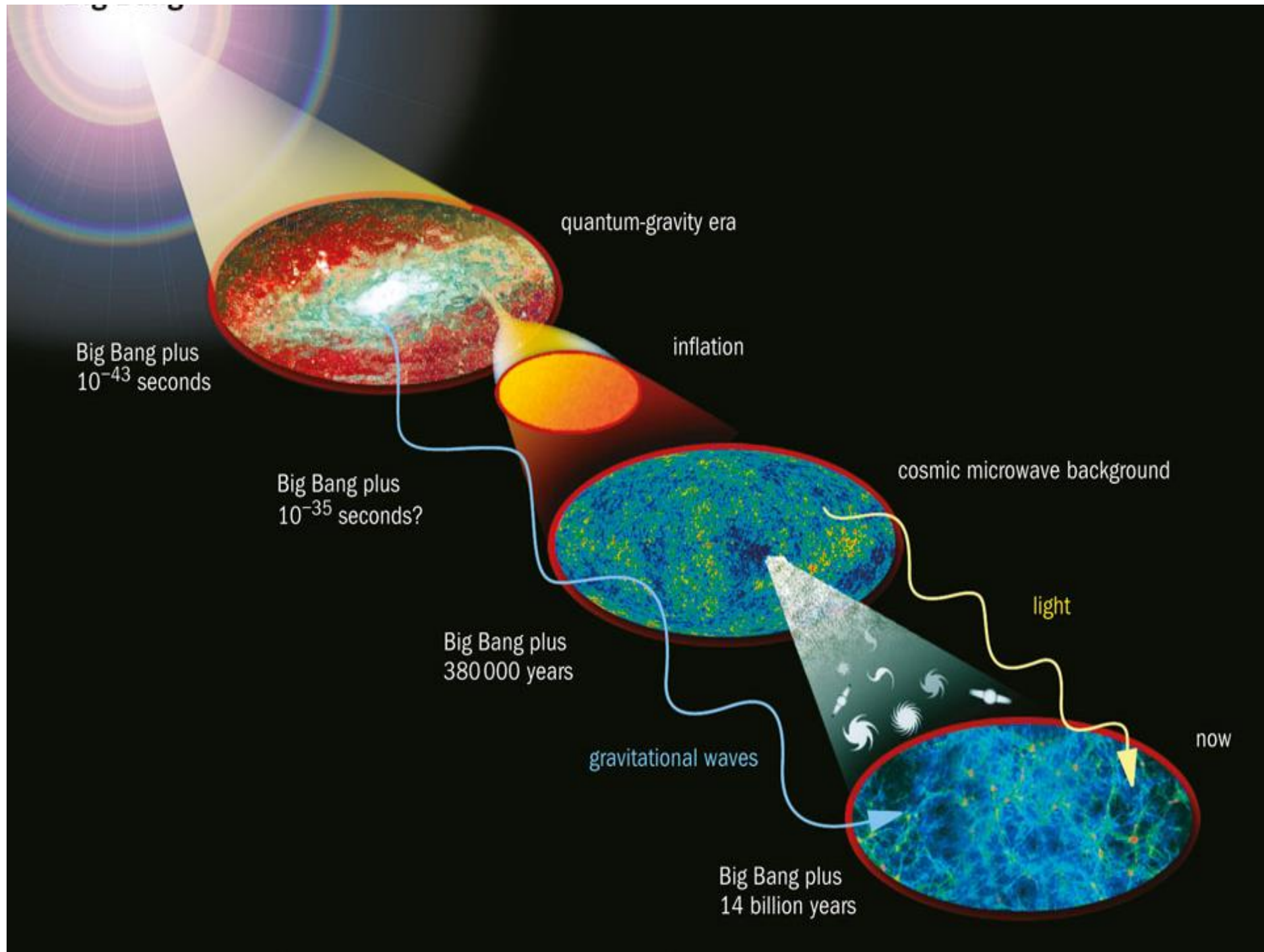
**THE EVOLUTION OF THE UNIVERSE IS FROM QUANTUM TO  
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**From Very Quantum (Quantum Gravity) stage to Semiclassical Gravity  
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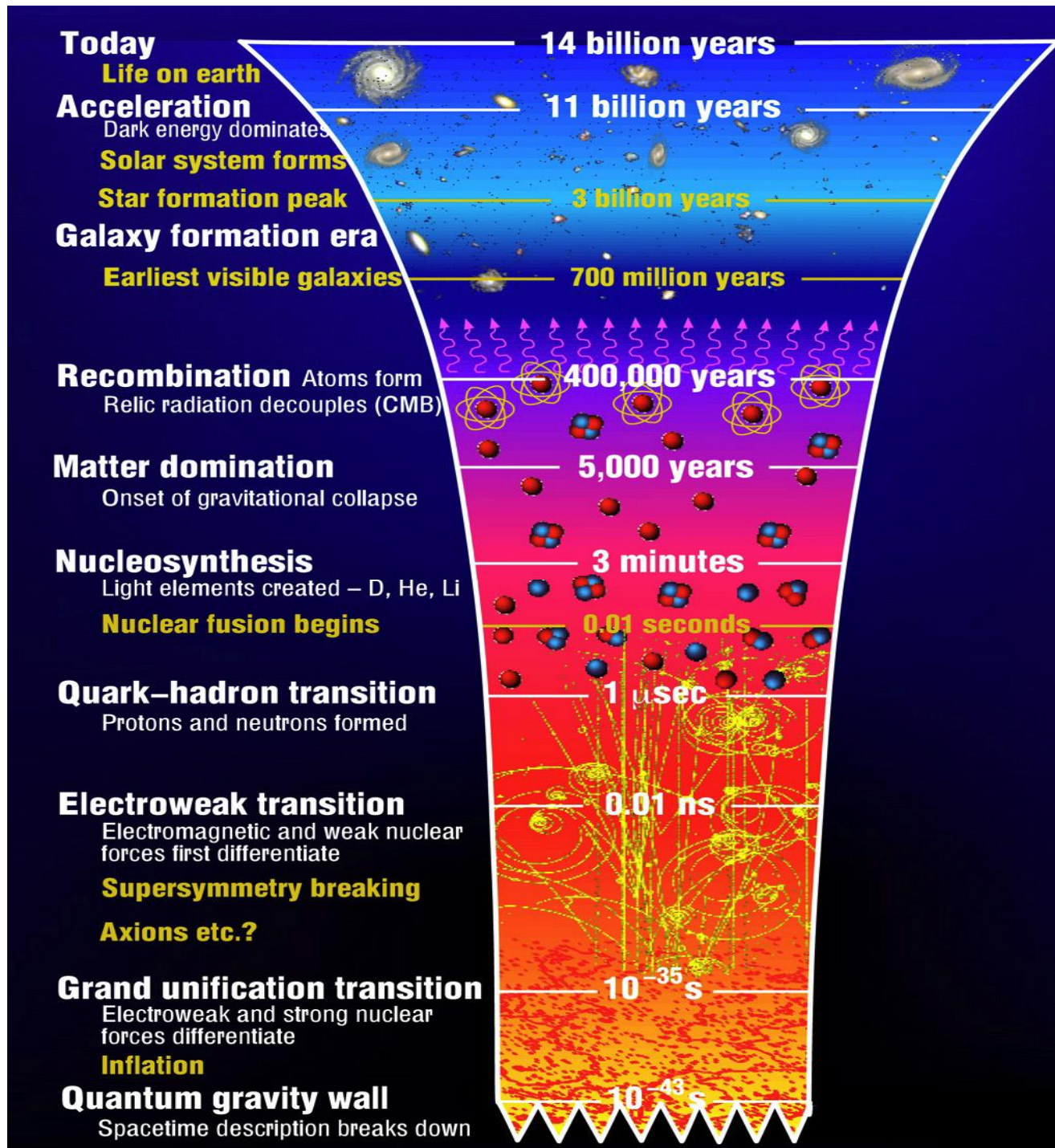
**THE EXPANSION CLASSICALIZES THE UNIVERSE**

**THE EXPANSION OF THE UNIVERSE IS THE MOST POWERFUL  
QUANTUM DECOHERENCE MECHANISM**









The physical history of the Universe is completed: quantum planckian and super-planckian phase before Inflation in **the Standard Model of the Universe in agreement with observations.** Quantum physics and its foundational milestone: **the universal classical-quantum (or wave-particle) duality**, which we extend to gravity and the Planck domain.

**New quantum precursor phase of the Universe beyond the Planck scale.**

Cosmic Microwave Background, Inflation and Dark Energy have their precursors in this era.

Whole unifying picture for the Universe epochs and their quantum precursors emerges

with the **cosmological constant as the vacuum energy, entropy and temperature of the Universe**, clarifying the so called cosmological constant problem which once more in its rich history needed to be revised.

The consequences for the deep universe surveys, and missions like Euclid will be outlined.

# REFERENCES

- [1] N. G. Sanchez, *New Quantum Phase of the Universe before Inflation and its Cosmological and Dark Energy Implications*  
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- [2] N. G. Sanchez, *The Classical-Quantum Duality of Nature: New variables for Quantum Gravity*,  
arXiv:1803.04257, *Int Journal Mod Phys D18*, 1950055 (2019)
- [3] N. G. Sanchez, *The New Quantum structure of the space-time*,  
*To appear in J. Grav & Cosmology (Springer, 2019)*  
<https://hal.archives-ouvertes.fr/hal-01735421>
- **Projects:** The New Universe , Dark Energy Programme, The Fractal Tree, Open Science & Open Access,

[https://www.researchgate.net/profile/Norma\\_Sanchez12](https://www.researchgate.net/profile/Norma_Sanchez12)

# **Nature is Quantum.**

**That means that the real and complete laws of nature are those of quantum physics. Classical behaviours and domains are particular cases, limiting situations or approximations.**

**Classical gravity, and thus successful General Relativity are incomplete (non quantum) theories and must be considered as a particular approximation from a more complete theory yet to achieve.**

**A complete quantum theory should include and account for the physics at the Planck scale and domain.**

**(i) Instead of starting from gravity, that is General Relativity and quantize it (by applying the different quantization -perturbative and non perturbative- procedures, with the by now well known shortcomings and developpements and its rich bibliography (is not our aim here to review it),**

**(ii) I start from Quantum theory and try to extend it to the Planck scale domain. (instead of going from classical gravity to quantum gravity, I go from quantum physics to quantum gravity). Of course, in constructing the road (ii) many of the lessons from**

**RECALL:** One tractable and well posed piece of work is **SEMICLASSICAL GRAVITY** :  
**Quantum fields** in **classical General Relativity**

Examples are the Hawking radiation,  
**the early universe inflation and the primordial quantum fluctuations**, seeds of the structure in the Universe **imprinted in the CMB temperature anisotropies and polarization.**

Moreover, as a result of **quantum theory**, the **quantum cosmological vacuum** could be the **source** of the present acceleration of the universe (**dark**

# The Wave-Particle Duality of Quantum Physics Including Gravity

**Nature has a dual behavior of wave and corpuscle:**  
*this is the well known*  
***classical-quantum duality or wave-particle duality***

*of quantum physics (as the light and its photons, the microscopic world of elementary particles, ultradense plasmas, the laser, macroscopic quantum states (as compact stars, dwarfs , black holes), and many other examples).*

**I generalized this duality to gravity**

**by including its three regimes: classical, semiclassical and quantum, together with the Planck regime and the elementary particles domain: namely the**

***wave-particle-gravity duality or the classical-quantum gravity duality.***

***NGS, IJMPD18, (january 2019).***

# **This Duality is Universal**

**it includes the known duality and allows a general clarification and new results which reveal:**

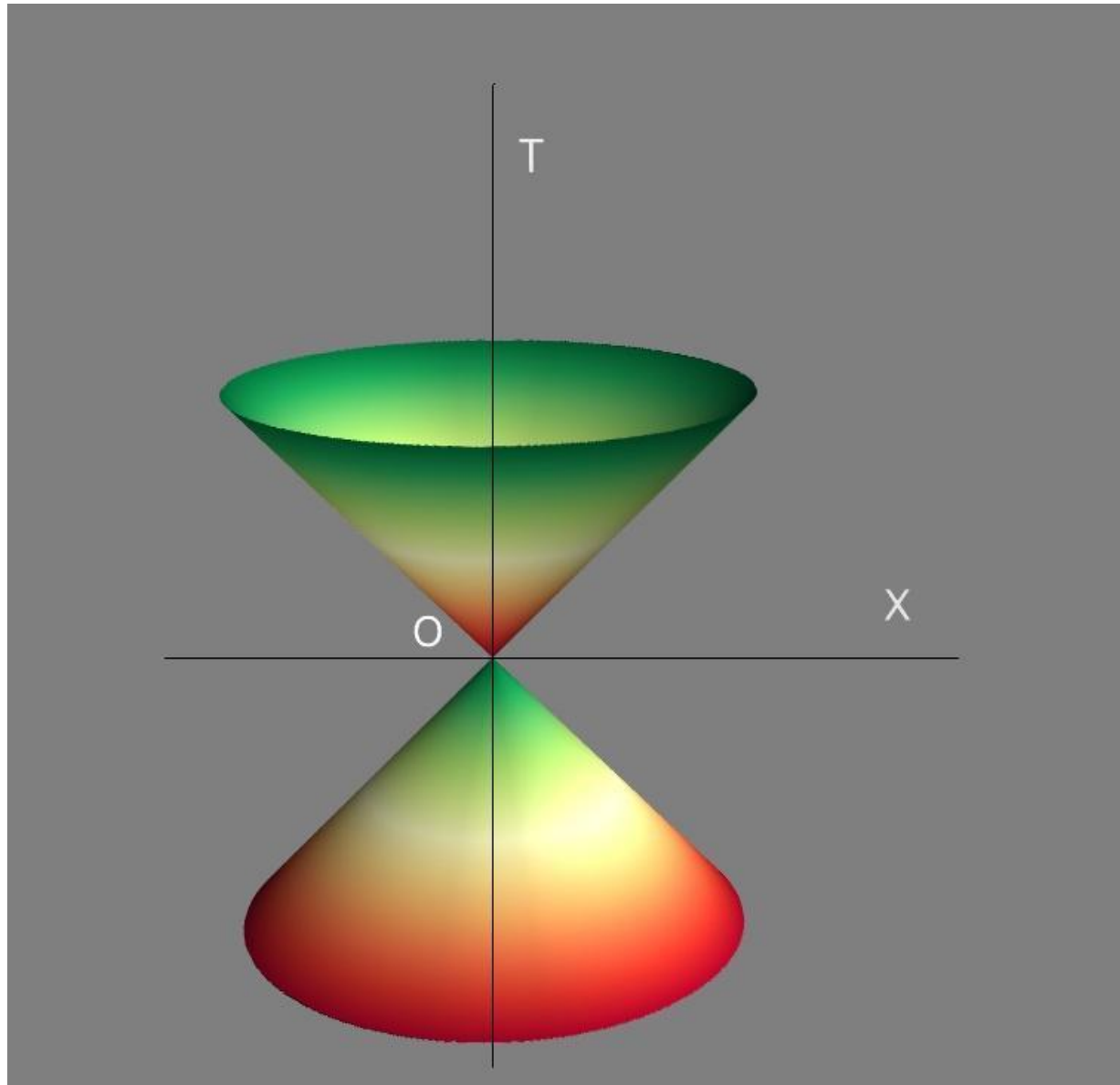
**(i) The classical-quantum duality of the space-time and black holes**

**(ii) A new quantum domain not present in classical gravity does appear**

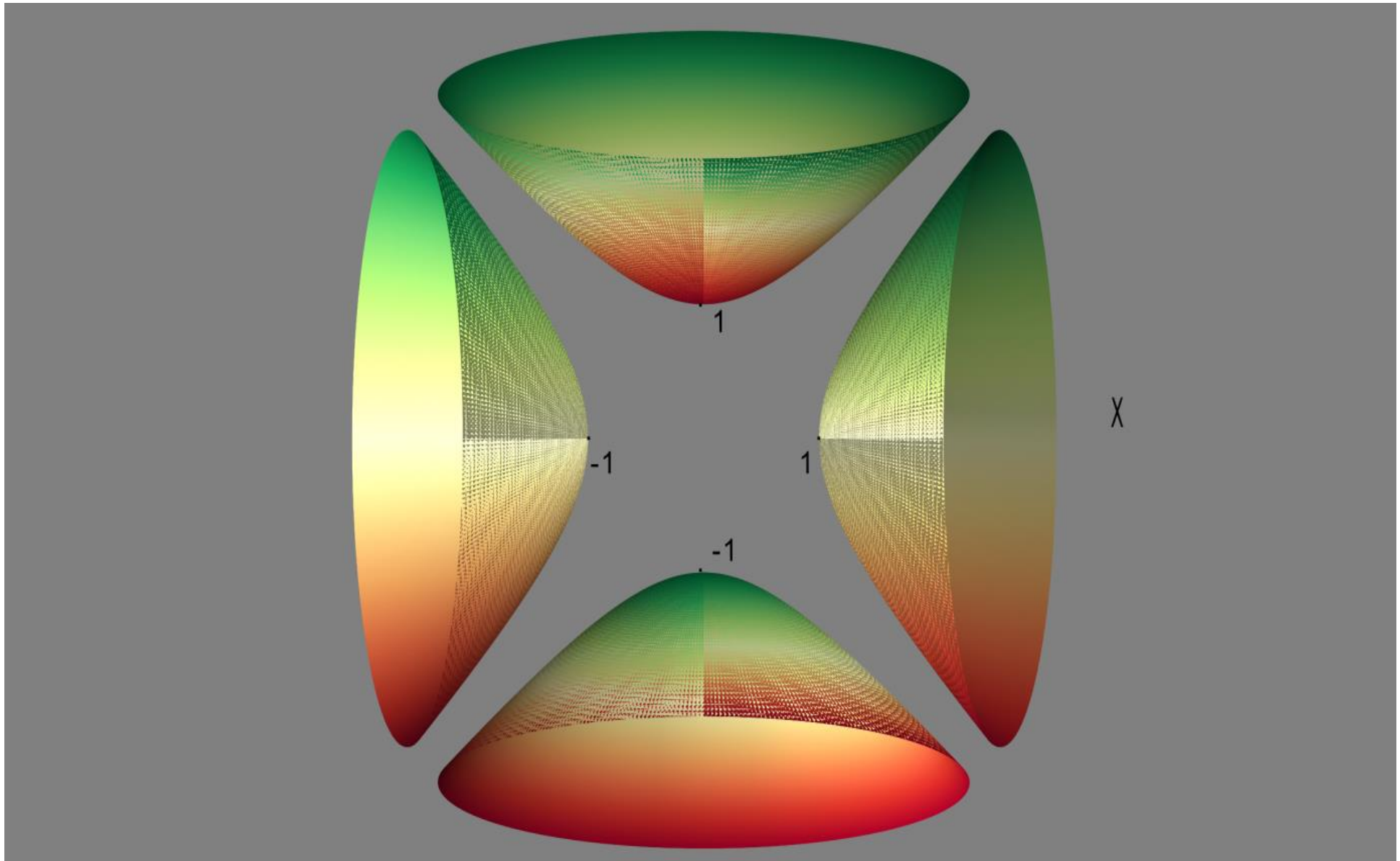
**(iii) The quantum light-cone from which the known classical light-cone of relativity and the classical universe are a special case.**

**A more complete vision of space-time does**





**The known classical light-cone (future and past) of classical relativity in a space-time diagram is a special case of the Quantum light -cone**



**The quantum light-cone in a space-time diagram (time is the vertical axis).**

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**The classical Universe today  $U_{\Lambda}$** : set of physical gravitational observables (age or size, mass, density, temperature, entropy) ( $L, M, \rho, T, S$ )

**$U_{\Lambda} = (L_{\Lambda}, M_{\Lambda}, \rho_{\Lambda}, T_{\Lambda}, S_{\Lambda})$ : Classical Universe**

**The very early quantum Universe  $U_Q$** : set of corresponding quantum dual physical quantities ( $L_Q, M_Q, \rho_Q, T_Q, S_Q$ ):

**$U_Q = (L_Q, M_Q, \rho_Q, T_Q, S_Q)$ : Quantum Universe**

$$U_Q = u_p^2 / U_{\Lambda}$$

$u_p = (l_p, m_p, \rho_p, t_p, s_p)$ : Planck Scale

*The crossing scale between the two gravity domains*

# THE FUNDAMENTAL PLANCK SCALE

$$(\mathbf{h}, \mathbf{c}, \mathbf{G}): \quad \mathbf{L}_G = 2\mathbf{GM}/\mathbf{c}^2, \quad \mathbf{L}_Q = \mathbf{h}/\mathbf{Mc}$$

$$\mathbf{l}_P = (\mathbf{hG}/\mathbf{c}^3)^{1/2}, \quad \mathbf{m}_p = (\mathbf{hc}/\mathbf{G})^{1/2}$$

$$\mathbf{G}/\mathbf{c}^2 = \mathbf{l}_P/\mathbf{m}_p, \quad \mathbf{l}_P \mathbf{m}_p = \mathbf{h}/\mathbf{c}$$

$$\mathbf{l}_P = 10^{-33} \text{ cm}, \quad \mathbf{m}_p = 10^{-5} \text{ gr}, \quad \mathbf{t}_p = 10^{-44} \text{ sec}$$

$$\mathbf{L}_Q = \mathbf{l}_P^2 / \mathbf{L}_G, \quad \mathbf{M}_Q = \mathbf{m}_p^2 / \mathbf{M}, \quad \mathbf{O}_Q = \mathbf{o}_P^2 / \mathbf{O}_G$$

$$\text{New Variables : } \mathbf{L}_{QG} = \mathbf{L}_Q + \mathbf{L}_G, \quad \mathbf{O}_{QG} = \mathbf{O}_Q + \mathbf{O}_G, \quad \mathbf{Q} \leftrightarrow \mathbf{G}$$

$$\text{N.G.S, Int J. Mod Phys D18, 1950055 (2019)} \quad \mathbf{O}_{QG} = \mathbf{o}_P (\mathbf{O}_G/\mathbf{o}_P + \mathbf{o}_P/\mathbf{O}_G)$$

**A Precursor Quantum phase** of the known **Classical Inflation era** does appear as well as the precursors for the classical standard eras and today Dark Energy era.

## NEW RESULTS FOR INFLATION

$$[\Delta^S_{QH}] = [\Delta^S_H] \frac{1}{[1 + (H/h_p)^2]} \frac{1}{(1 - \delta\epsilon_{QH})^{1/2}}$$

$$[\Delta^T_{QH}] = [\Delta^T_H] \frac{1}{[1 + (H/h_p)^2]}$$

**H:** classical known Inflation (**classical H**) era,

**Q:** stands for its **Quantum dual precursor**,

**QH** stands for the Complete Inflation era : **classical known Inflation** and **its Quantum precursor Inflation**.

The QH factor modifying the Hubble constant and the inflationary spectra can be written

as the summation of the series:

$$QH \equiv \frac{H}{[1 + (H/h_P)^2]} = H \sum_{n=0}^{\infty} (-1)^n \left( \frac{H}{h_P} \right)^{2n} \quad (1)$$

The QH factor covers

the **FULL CLASSICAL** and **QUANTUM RANGE**, namely:

If  $H < h_P$ , Eq.(1) yields the usual corrections in  $(H/h_P)^2$ .

If  $H \gg h_P$ , Eq.(1) precisely changes to the quantum regime, ie to the quantum Hubble rate  $H_Q$ , which is the *super-Planckian domain*:

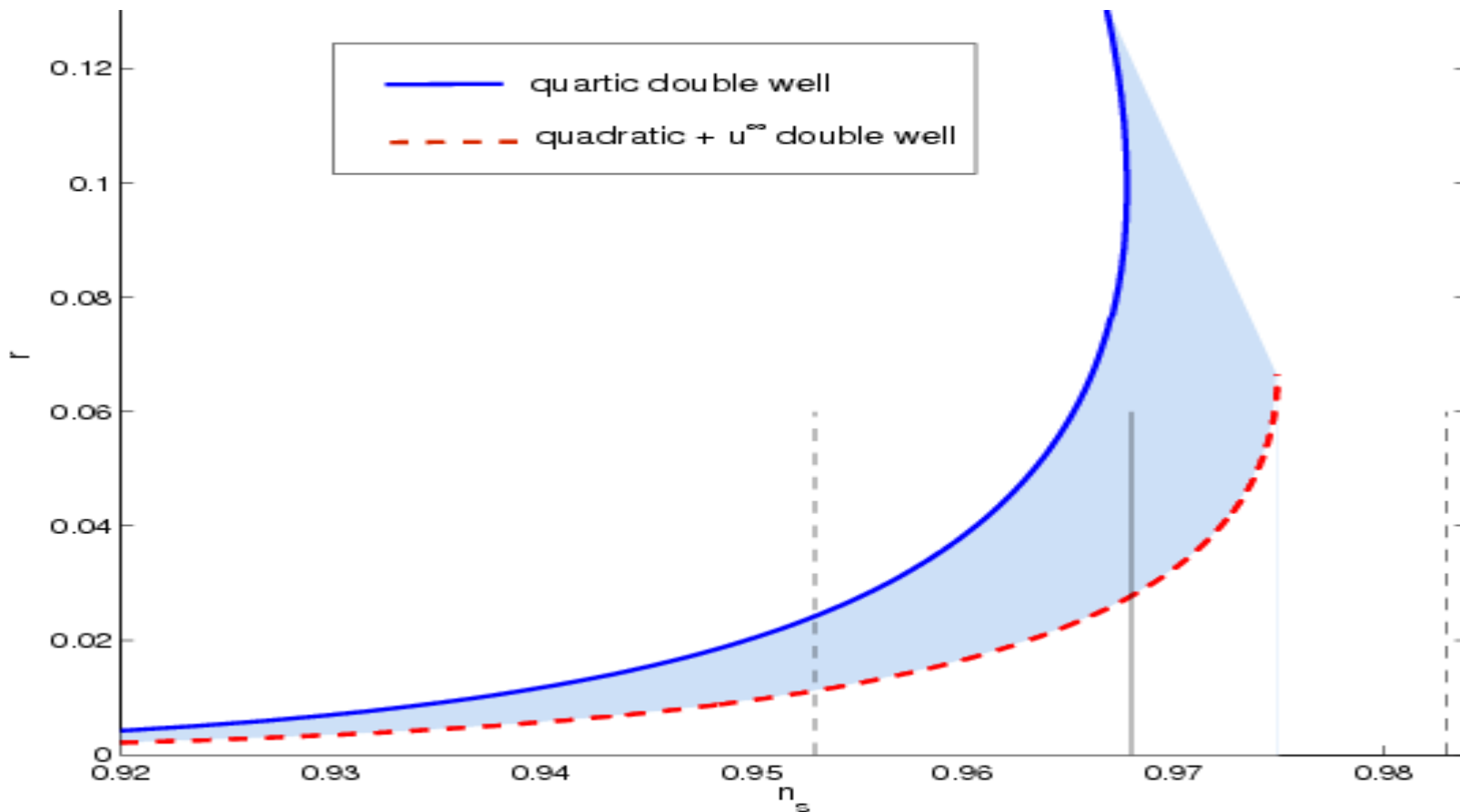
$$HQ \equiv \frac{H_Q}{[1 + (H_Q/h_P)^2]} \quad (2)$$

## Efficient Theory of Inflation (ETI) confirmed by Planck

Quantity	ETI Prediction	Planck 2013
Spectral index $1 - n_s$	order $1/N = 0.02$	0.04
Running $dn_s/d\ln k$	order $1/N^2 = 0.0004$	$< 0.01$
Non-Gaussianity $f_{NL}$	order $1/N = 0.02$	$< 6$
	ETI + WMAP+LSS	
tensor/scalar ratio $r$	$r > 0.02$	$< 0.11$ see BICEP
inflaton potential curvature $V''(0)$	$V''(0) < 0$	$V''(0) < 0$

ETI + WMAP+LSS means the MCMC analysis combining the ETI with WMAP and LSS data. Such analysis calls for an inflaton potential with negative curvature at horizon exit. **The double well potential** is favoured (new inflation).

I. Boyanovsky, C. Destri, H. J. de Vega, N. G. Sanchez, arXiv:0901.0549, IJMPA 24, 3669-3864 (2009).



## THE PRIMORDIAL COSMIC BANANA

The tensor to scalar ratio  $r$  (primordial gravitons) versus the scalar spectral index  $n_s$ . **The amount of  $r$  is always non zero**  
H.J. de Vega, C. Destri, N.G. Sanchez, *Annals Phys* 326, 578(2011)



**Two key observable numbers :**  
**associated to the primordial density and**  
**primordial gravitons :**

### **PREDICTIONS**

$$n_s = 0.9608 , \quad r \sim 0.04$$

$$0.021 < r < 0.059$$

**Destri, de Vega, Sanchez (PRD 2008): WMAP**

**Burigana, Destri, Mandolesi, Natoli, de Vega,**

**Sanchez ApJ 2010**

**Planck BICEP2Keck :  $r < 0.08$  (2015)**

**$r < 0.064$  (2018)**

# **NEW RESULTS FOR DARK ENERGY**

**Dark energy and its more direct candidate, the cosmological constant, [Supernova (1998, 1999, 2001), WMAP (2003, 2008, 2013), Planck sat.(2018), DES (2018), DES/LIGO, (2019)] is relevant to both modern cosmology and particle physics.**

**The value of the observed dark energy density today  $\rho_H \equiv \rho_\Lambda$ :**

$$\rho_\Lambda = \Omega_\Lambda \rho_c = 3.28 \cdot 10^{-11} (eV)^4 = (2.39 \text{ meV})^4, \quad \text{meV} = 10^{-3} eV$$

**corresponding to  $h = 0.73$ ,  $\Omega_\Lambda = 0.76$ ,  $H = 1.558 \cdot 10^{-33} eV$ .**

**The last Planck satellite data yield the values:  $H = 67.4 \pm 0.5 \text{ Km sec}^{-1} \text{ Mpc}^{-1}$ ,  $\Omega_\Lambda h^2 = 0.0224 \pm 10^{-4}$ ,  $\Omega_\Lambda = 0.6847 \pm 0.0073$ ,  $\Omega_\Lambda h^2 = 0.3107 \pm 0.0082$ ,**

**which implies for the cosmological constant today:**

$$\Lambda = (4.24 \pm 0.11) \cdot 10^{-66} (eV)^2 = (2.846 \pm 0.076) \cdot 10^{-122} m_P^2$$

**The density  $\rho_\Lambda$  associated to  $\Lambda$  is precisely:**

$$\rho_\Lambda = \frac{\Lambda}{8\pi G} = \rho_P \left( \frac{\Lambda}{\lambda_P} \right), \quad \rho_P = \frac{\lambda_P}{8\pi G} \quad \lambda_P = 3h_P^2$$

## The Universe Today is Essentially Empty

—Inter galactic distances  $\sim$  Mpc. (pc =  $3.0857 \times 10^{13}$  kms.)

Galaxy sizes  $\sim$  0.0001 – 0.1 Mpc. (pc = 3.262 light years.)

99.9 % of the universe volume is the intergalactic space with an average energy density of 5 proton masses per m (cosmological constant).

**Galaxy masses:**  $10^6 - 10^{12} M_{\odot}$  from dwarf compact galaxies to (diluted) big galaxies spirals.

**Galaxy density:**

$\sim$  4000 – 40000 proton masses per  $m^3$  for big galaxies.

$\sim 4 \times 10^6$  proton masses per  $m^3$  for small compact galaxies

For comparison: air density at the atmospheric pressure and  $0^{\circ}$  C  $\sim 3.9 \times 10^{26}$  proton masses per  $m^3$ .

# NEW RESULTS FOR DARK ENERGY

This framework reveals enlightening for the issue of *Dark Energy*, and allows clarification into *the cosmological constant problem*.

The classical Universe today  $U_{\Lambda}$  is precisely a *classical dilute gravity vacuum dominated by voids and supervoids as shown by observations*: The observed value of  $\rho$  or  $\Lambda$  today is *precisely the classical dual of its quantum precursor values  $\rho_Q, \Lambda_Q$  in the quantum very early precursor vacuum  $U_Q$  as determined by our dual Equations*.

The high density  $\rho_Q$  and cosmological constant  $\Lambda_Q$  are *precisely the quantum particle physics superplanckian value  $10^{122}$* . This is precisely expressed by our dual Equations.

The enormous discrepancy between the large theoretical value expected from **microscopic particle physics for the vacuum energy density  $10^{122}$**  and the **small cosmological value observed today  $10^{-122}$**  is largely known as the cosmological constant problem.

*However, several clarifications are in order here:*

- (i) The classical gravity vacuum.
- (ii) **The quantum gravity vacuum.**
- (iii) Two extremely different physical gravity regimes.
- (iv) The classical and **quantum dual values.**
- (v) The discrepancy **is correct and** must be in that way.
- (vi) The true problem.
- (vii) Not trivial. Deep and Consistent. **A General framework**

The two huge different values:  $10^{-122}$  and  $10^{+122}$  refer to *two huge physically different vacuum states* of the Universe corresponding to **two huge different eras**, to two huge different physical cosmological conditions (**present time and very early eras**), and consistently, they *must be different*. Such enormous difference must be in such way and is **not a problem or inconsistency**.

Moreover and consistently, one value is the **quantum physics dual** of the other -**or the quantum precursor** of the other- **as exactly** expressed by the dual Equations.

**This is not fortuitous**, that is to say, this is not pure chance or unexplained coincidence. This is not trivial, that is to say, this is simple, deep and robust.

The two values:  $\Lambda$  and  $\Lambda_Q$ , (or equivalently  $\rho_\Lambda$  and  $\rho_Q$ ), refer to the same concept or nature of  $\Lambda$  or  $\rho_\Lambda$  as **a vacuum energy density or cosmological constant** but they are in **two huge different vacuum states or two huge different cosmological epochs**: **Classical state and classical epoch today for  $\Lambda$  observed today**, and **quantum state and super-Planckian very early universe epoch** for the quantum mechanical super-Planckian value  $\Lambda_Q$ .

The classical value today  $\Lambda = 3H^2$  corresponds to **the classical Universe today of classical rate  $H$  and classical cosmological radius  $L_H = c/H$** . The quantum mechanical value  $\Lambda_Q = 3 H_Q^2$  corresponds to **the early quantum Universe of quantum rate  $H_Q$  and quantum radius  $L_Q = l_p^2 / L_H = h / M_H c$  which is exactly the quantum dual of the classical horizon radius  $L_H$**



$$\begin{aligned}
 &= 3H^2 = \rho_P (H/h_P)^2 = \rho_P (\ell_P/L_H)^2 \\
 &= (2.846 \pm 0.076) 10^{-122} m_P^2
 \end{aligned}$$

$$\begin{aligned}
 \rho_Q &= 3H_Q^2 = \rho_P (h_P/H)^2 = \rho_P (L_H/\ell_P)^2 \\
 &= (0.3516 \pm 0.094) 10^{122} m_P^2
 \end{aligned}$$

$$\rho_Q = \rho_P^2, \quad \rho_P = 3 h_P^2.$$

**The quantum dual value  $\rho_Q$  is precisely the quantum vacuum value obtained from particle physics:**

$$\rho_Q = \rho_P \left( \rho_Q / \rho_P \right) = \rho_P^2 / \rho_P = 10^{122} \rho_P$$

There is no problem between the two extremely different values  $\Lambda$  and  $\Lambda_Q$  or equivalently between  $\rho_\Lambda$  and  $\rho_Q$ , because the two values *do not refer to the same vacuum or eras: one is exactly the classical physics today vacuum energy density  $\rho$ , the other is its quantum dual value in the planckian and superplanckian very early phase :*  $10^{-61} t_p < t < t_p$

*This early phase of the Universe is exactly **the quantum precursor** of the **today classical era** in the precise meaning of the **wave-particle (or classical-quantum) duality including gravity.***

The two huge different values  $10^{+122}$  and  $10^{-122}$  are explained by the fact that they are exactly, mathematically and physically, the classical-quantum dual of each other:

*The  $\Lambda_Q$  value that is to say, the vacuum value computed from particle physics is exactly the quantum dual value of the classical  $\Lambda$  value observed today*

**THE COSMOLOGICAL CONSTANT:**

**GRAVITATIONAL ENTROPY**

**AND TEMPERATURE**

**OF THE UNIVERSE**

# GRAVITATIONAL ENTROPY AND TEMPERATURE

$$S = (\text{Area} / 4 a_p) s_p, \quad s_p = \pi k_B$$

$$T = (\text{Area} / a_p)^{1/2} t_p = L t_p = M t_p$$

**Classical: CLASSICAL Lengths,**

**Quantum: QUANTUM Lengths**

# **THE COSMOLOGICAL CONSTANT: VACUUM ENERGY, ENTROPY AND TEMPERATURE OF THE UNIVERSE**

$$\Lambda/\lambda_p = \rho_\Lambda/\rho_p = S_Q/s_p = \lambda_p/\Lambda_Q = (T_Q/t_p)^2 = 10^{-122}$$

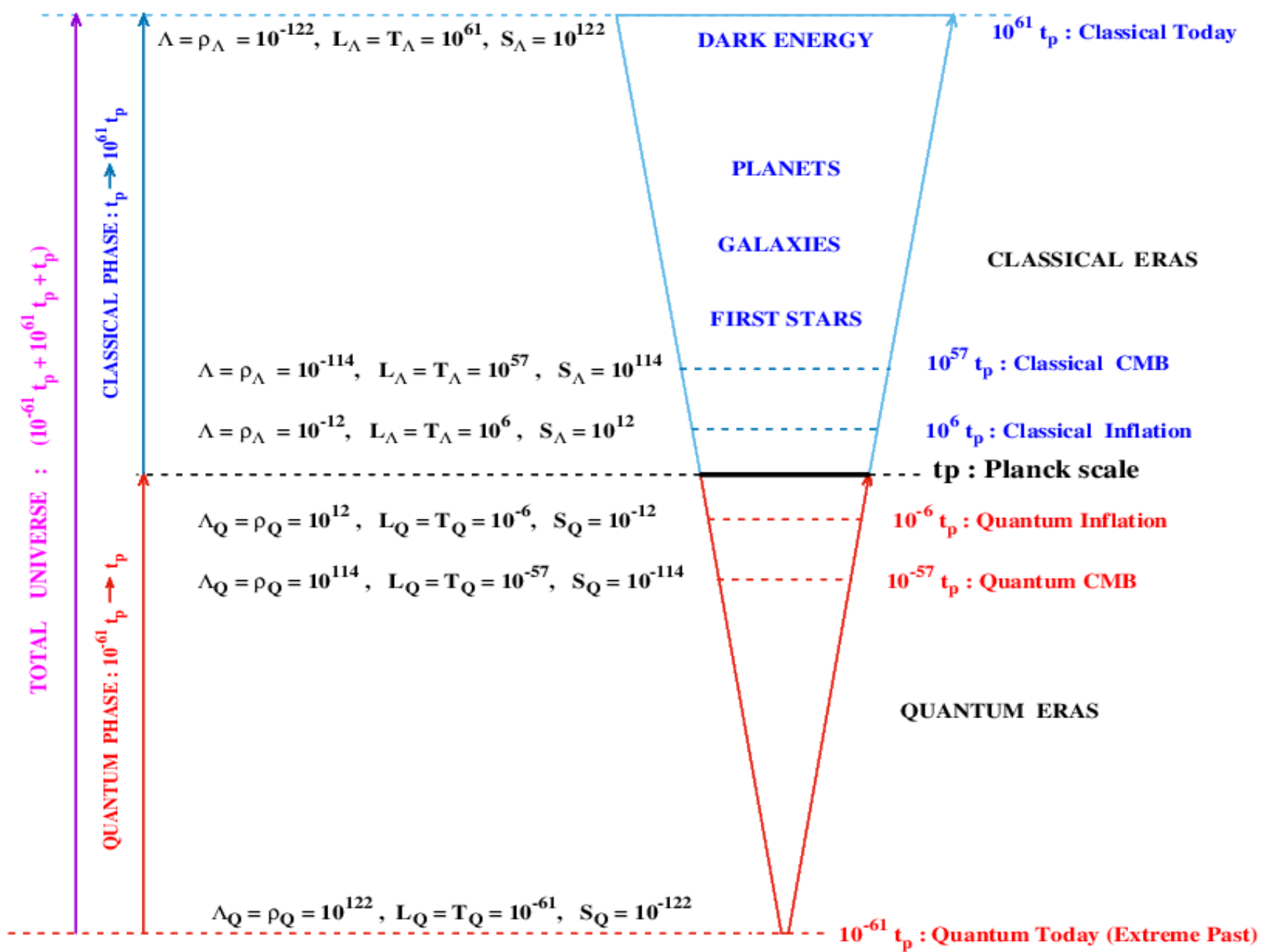
$$\Lambda_Q/\lambda_p = \rho_Q/\rho_p = S_\Lambda/s_p = \lambda_p/\Lambda = (T_\Lambda/t_p)^2 = 10^{+122}$$

$$\Lambda_{\Lambda Q} = \Lambda + \Lambda_Q + \lambda_p = (\Lambda/\lambda_p + \lambda_p/\Lambda + 1)$$

$$\Lambda_{\Lambda Q} = \lambda_p (10^{-122} + 10^{+122} + 1)$$

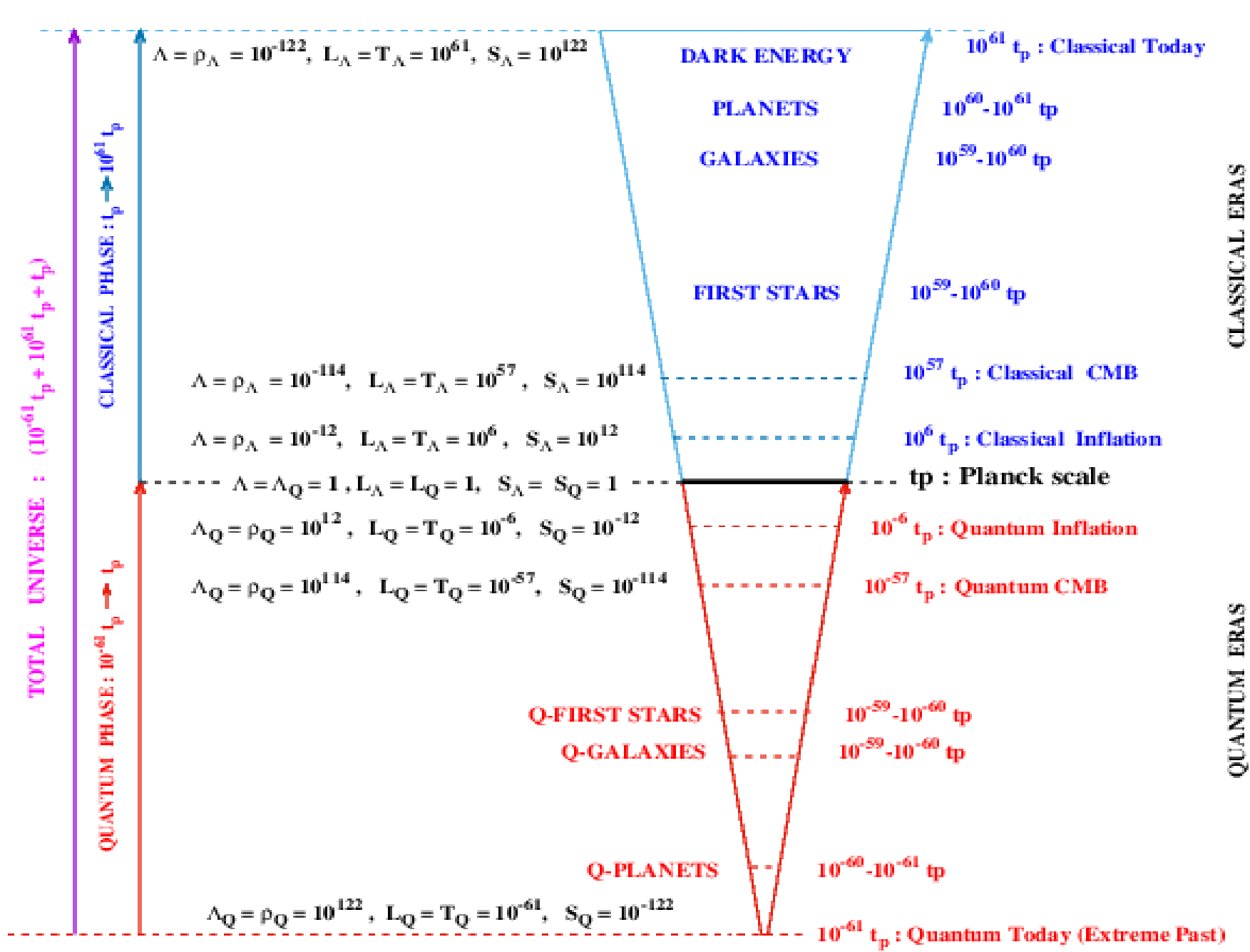
# THE ENTROPY OF THE UNIVERSE

Component	Entropy $S$ [ $k$ ]
Cosmic Event Horizon	$2.6 \pm 0.3 \times 10^{122}$
SMBHs	$1.2^{+1.1}_{-0.7} \times 10^{103}$
*Stellar BHs ( $42 - 140 M_{\odot}$ )	$1.2 \times 10^{98^{+0.8}_{-1.6}}$
Stellar BHs ( $2.5 - 15 M_{\odot}$ )	$2.2 \times 10^{96^{+0.6}_{-1.2}}$
Photons	$2.03 \pm 0.15 \times 10^{88}$
Relic Neutrinos	$1.93 \pm 0.15 \times 10^{88}$
Dark Matter	$6 \times 10^{86 \pm 1}$
Relic Gravitons	$2.3 \times 10^{86^{+0.2}_{-3.1}}$
ISM & IGM	$2.7 \pm 2.1 \times 10^{80}$
Stars	$3.5 \pm 1.7 \times 10^{78}$
<b>Total</b>	<b><math>2.6 \pm 0.3 \times 10^{122}</math></b>

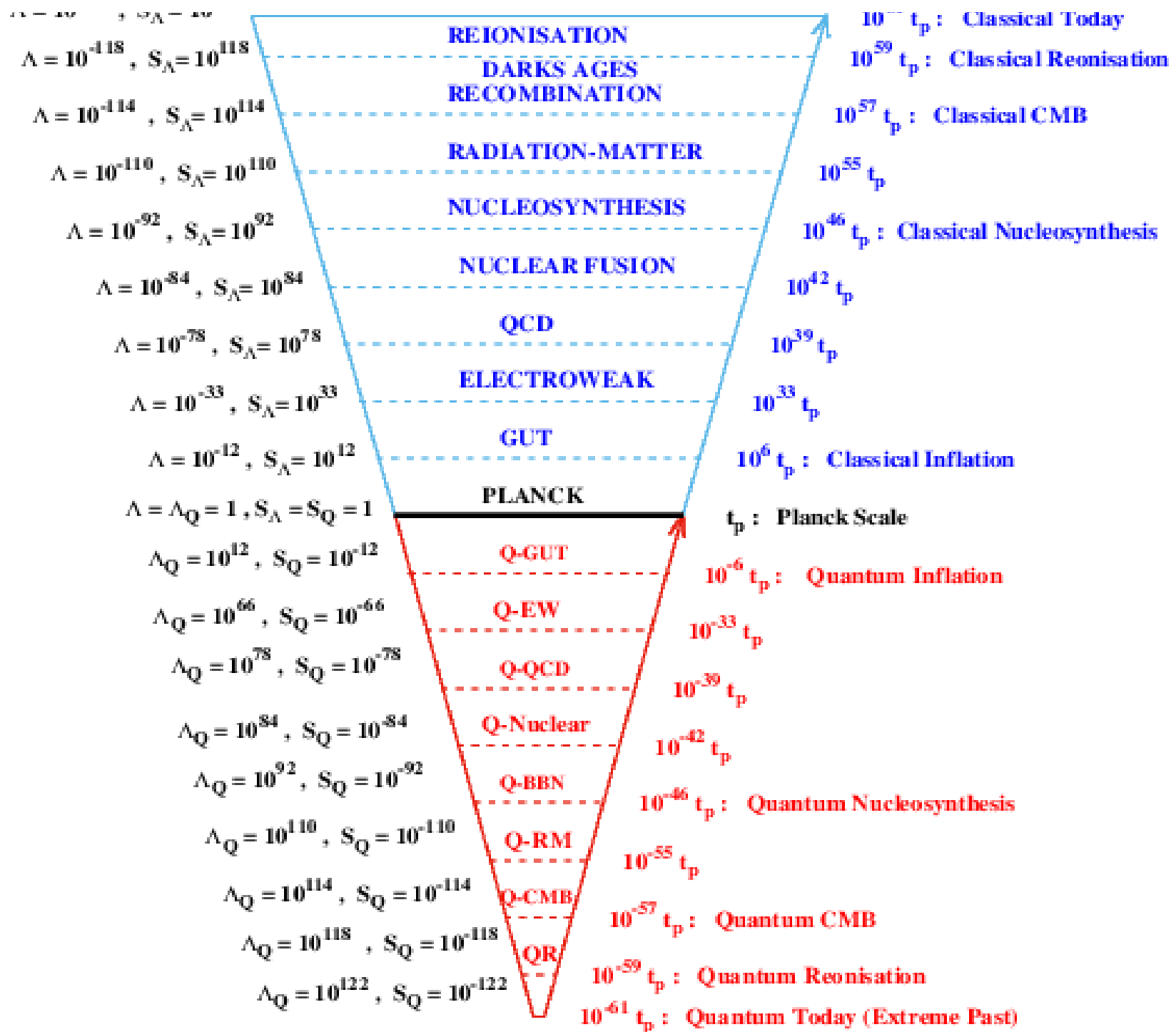


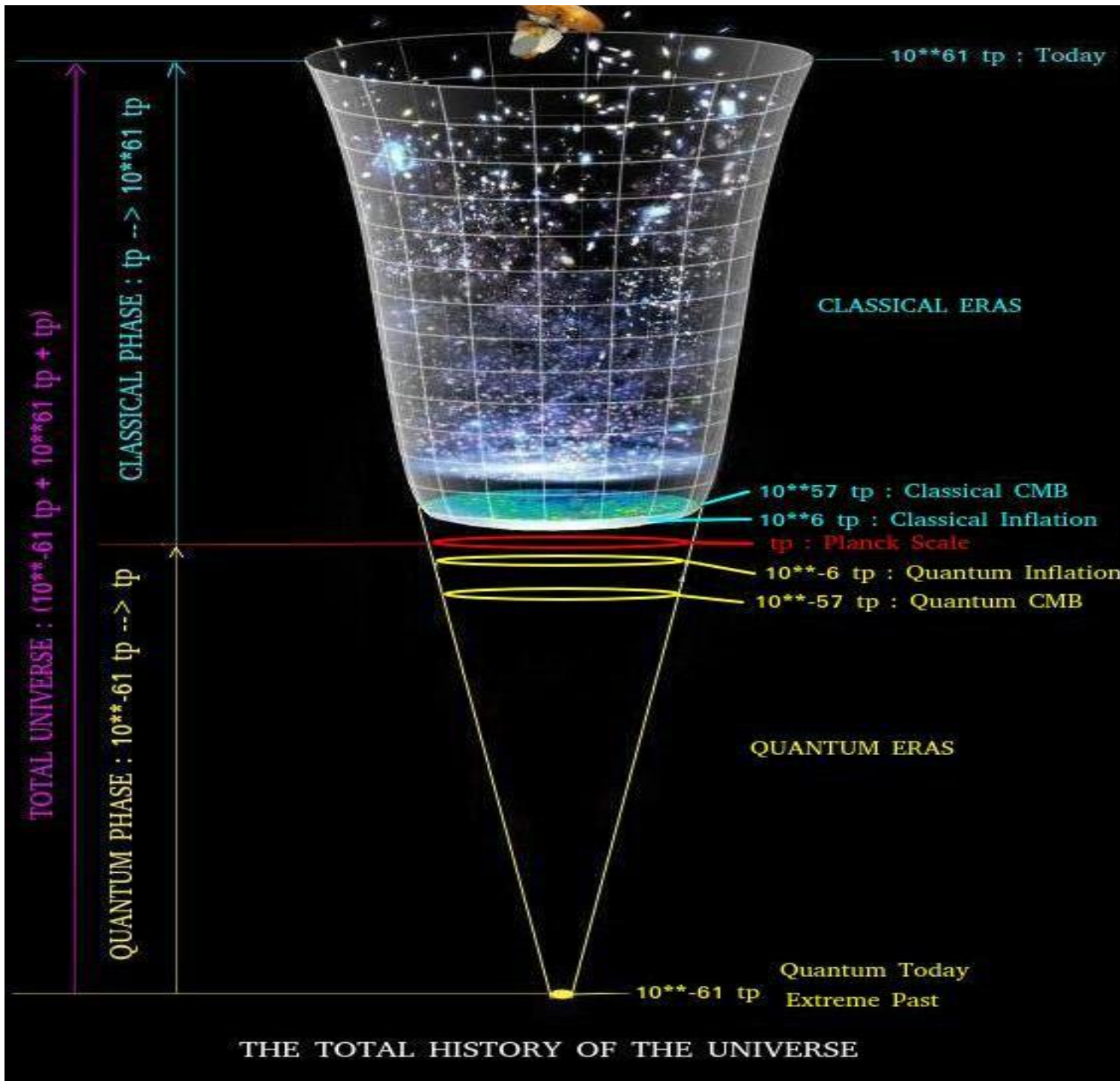
THE TOTAL HISTORY OF THE UNIVERSE





THE TOTAL HISTORY OF THE UNIVERSE





THE TOTAL HISTORY OF THE UNIVERSE

# CONCLUSIONS and IMPLICATIONS

- Concepts as the **Hawking temperature** and the **usual (mass) temperature** are shown to be precisely the same concept in the different **classical** and **quantum gravity** regimes respectively. Similarly, it holds for the Bekenstein-Gibbons and Hawking entropy.
- **Unifying and clarifying picture** : main physical gravitational intrinsic magnitudes of the Universe: age, size, mass, vacuum density, temperature, entropy, in terms of **the cosmological constant** covering the relevant gravity regimes or cosmological stages: **classical**, **semiclassical** and **quantum-planckian and superplanckian**- eras.

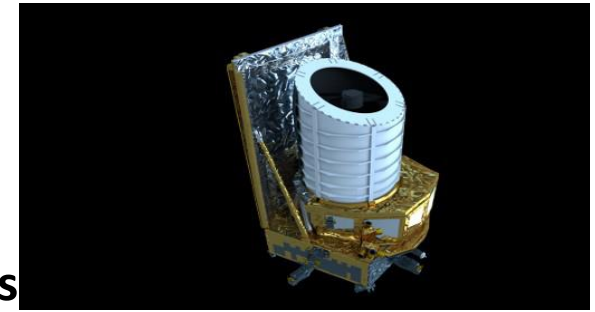
- Cosmological evolution goes from a **quantum precursor phase** to a **semiclassical accelerated de Sitter era (field theory inflation)**, then to the **classical phase until the present de Sitter era**.

“ The **wave-particle-gravity** duality precisely manifests in this evolution, between the different gravity regimes : mapping between asymptotic (in and out) states characterized by the sets  $U_{\Lambda}$  (or  $U_H$ ) and  $U_Q$ , and thus as a Scattering-matrix description: **The Evolution of the Universe as a Scattering problem in time.**

“ **There is no singularity at the Universe's origin.** Because the more earlier known stages of the Universe are de Sitter (or quasi de Sitter) eras : The extreme past (at  $10^{-61} t_P$ ) is a quantum state of high bounded superplanckian constant curvature and therefore **without singularity.**

# Euclid Consortium

## A space mission to map the Dark Universe



Euclid is primarily a cosmology and fundamental physics mission. Its main scientific objective is to understand the source of the accelerating Universe and discover the very nature of dark energy. It will measure galaxies out to  $z \sim 2$ , look-back time of about 10 billion years, thus covering the dark energy accelerated period.

### PRIMARY SCIENCE

What is the nature of Dark Energy? What are the nature and properties of dark matter? What are the initial conditions which seed the formation of cosmic structure? What will be the future of the Universe over the next ten billion years?

The imprints of dark energy and gravity from their signatures on **the expansion rate of the Universe and the growth of cosmic structures** (Baryonic Acoustic Oscillations and Redshift Space Distortion). Baryon acoustic oscillations provide a direct distance-redshift probe **to explore the expansion rate of the Universe.**

Weak lensing provides an almost direct probe of dark matter but combines together angular distances that probes the expansion rate and the mass density contrast that probe the growth rate of structure and gravity. In contrast, redshift space distortion probes the growth rate of cosmic structures and gravity. **Combined together these three probes are solid and complementary probes of the effects of dark energy.**

**Need  $H_0$  value**

**Need  $H(z)$  Measurements**

$$E(z) = H(z) / H_0$$

**We already know from Observations:**

$$H(z=1.5) = 2.69 H_0$$

$$H(z=1.5) \sim 3 H_0$$

# **THEORY & OBSERVATIONS**

The direction in which data and Theory are pointing:

- “ **Standard Model of the Universe and its Quantum Precursor**
- “ **Standard Single field Inflation: Double Well**
  - “  **$r \sim 0.04 - 0.02$**
  - “ **PRIMORDIAL GAUSSIANTY**
  - “ **ABSENCE of PRIMORDIAL NON GAUSSIANTY**
  - “ **NO RUNNING of the Primordial Spectral Index**
  - “ **DARK ENERGY = VACUUM ENERGY =  $\Lambda$**
  - DARK MATTER = WARM DARK MATTER = keV**
  - NO CUSP/CORE Problem, Profiles are Cored**



**MERCI BEAUCOUP  
POUR VOTRE ATTENTION !!**

**THANK YOU VERY MUCH  
FOR YOUR ATTENTION !!**

**MUCHAS GRACIAS  
POR VUESTRA ATENCION !!**

**MOLTE GRAZIE  
PER LA VOSTRA ATTENZIONE !!**

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- **Projects:** The New Universe , Dark Energy Programme, The Fractal Tree, Open Science & Open Access,

[https://www.researchgate.net/profile/Norma\\_Sanchez12](https://www.researchgate.net/profile/Norma_Sanchez12)

# THE NEW QUANTUM STRUCTURE OF THE SPACE-TIME

” THE CLASSICAL - QUANTUM DUALITY OF NATURE :

$$” O_G = O_P^2 / O_Q , \quad L_G = I_P^2 / L_Q , \quad L_G = 2GM / c^2, \quad L_Q = h / Mc$$

” THE SPACE TIME (X, T) Coordinates as

” QUANTUM NON COMMUTING OPERATORS : [ X, T ] = 1

° THE SPACE-TIME AS a QUANTUM HARMONIC OSCILLATOR :

$$[X, P] = i, \quad 2H = X^2 + P^2 = 2N + 1, \quad [2H, X] = -iP, \quad [2H, P] = iX$$

**P = iT :**

$$[X, T] = 1, \quad 2H = X^2 - T^2 = 2N + 1, \quad [2H, X] = T, \quad [2H, T] = X$$

# QUANTUM SPACE-TIME

“  $(T^2 - X^2) - 1 \geq 0$  : *timelike*

“  $(X^2 - T^2) - 1 \geq 0$  : *spacelike*

“  $(T^2 - X^2) - 1 = 0$ , *null : the "quantum light- cone".*

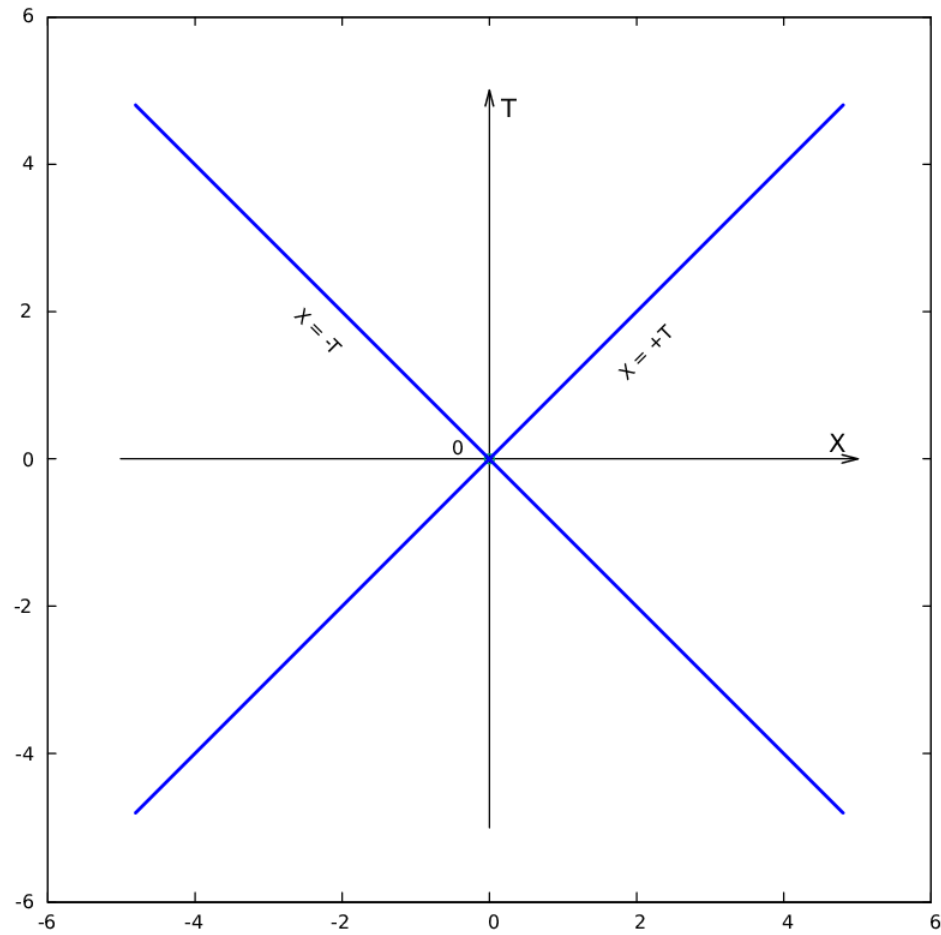
$(X^2 - T^2)_n = 2n + 1$  : **discrete levels**

$(X^2 - T^2) = \pm[X, T] = \pm 1, \quad 1 = 2\varepsilon_0, \quad (n = 0)$

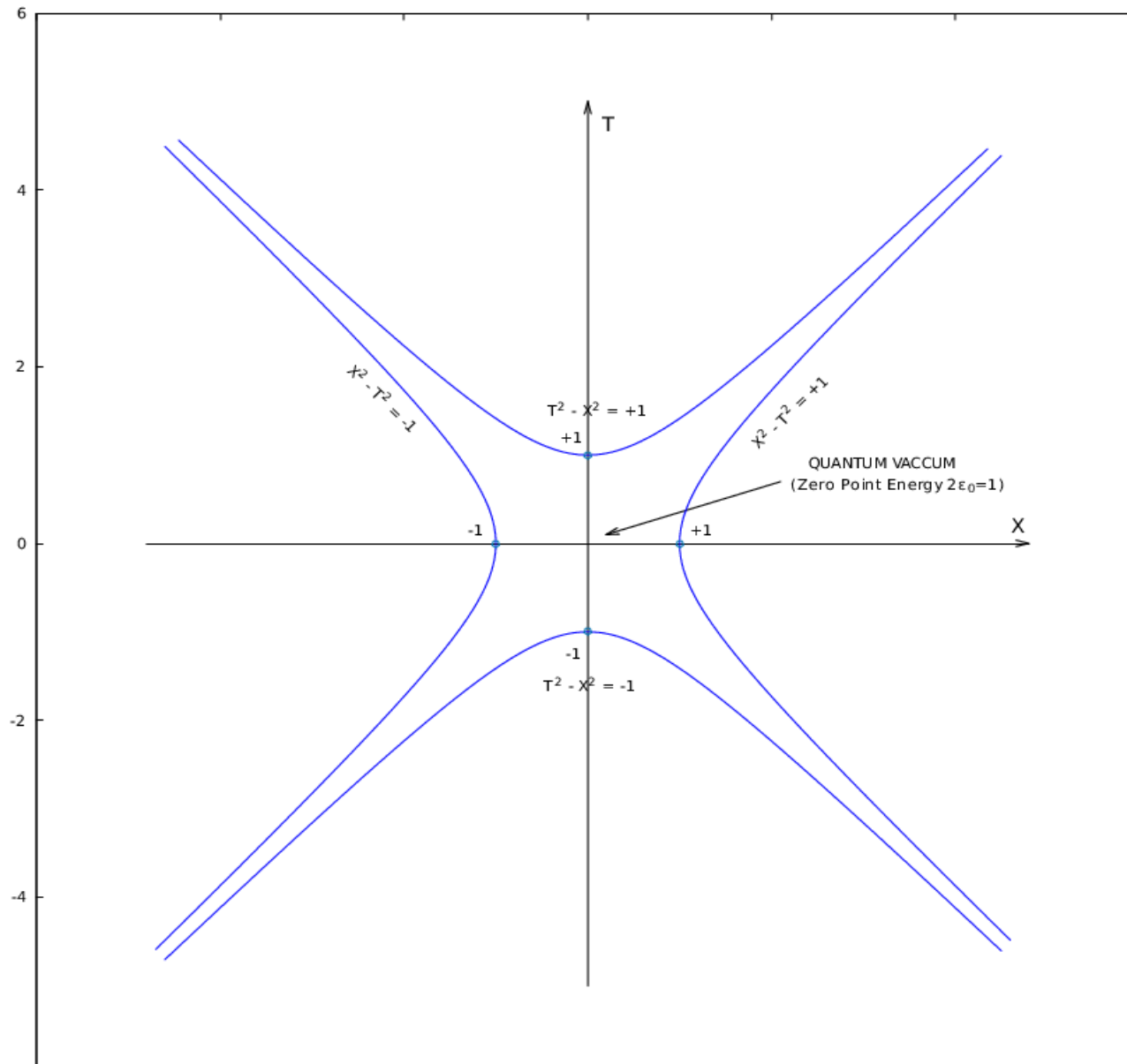
**the quantum light cone**

“  $[X, T] = 0$  :  $X = \pm T$  **the classical light cone.**

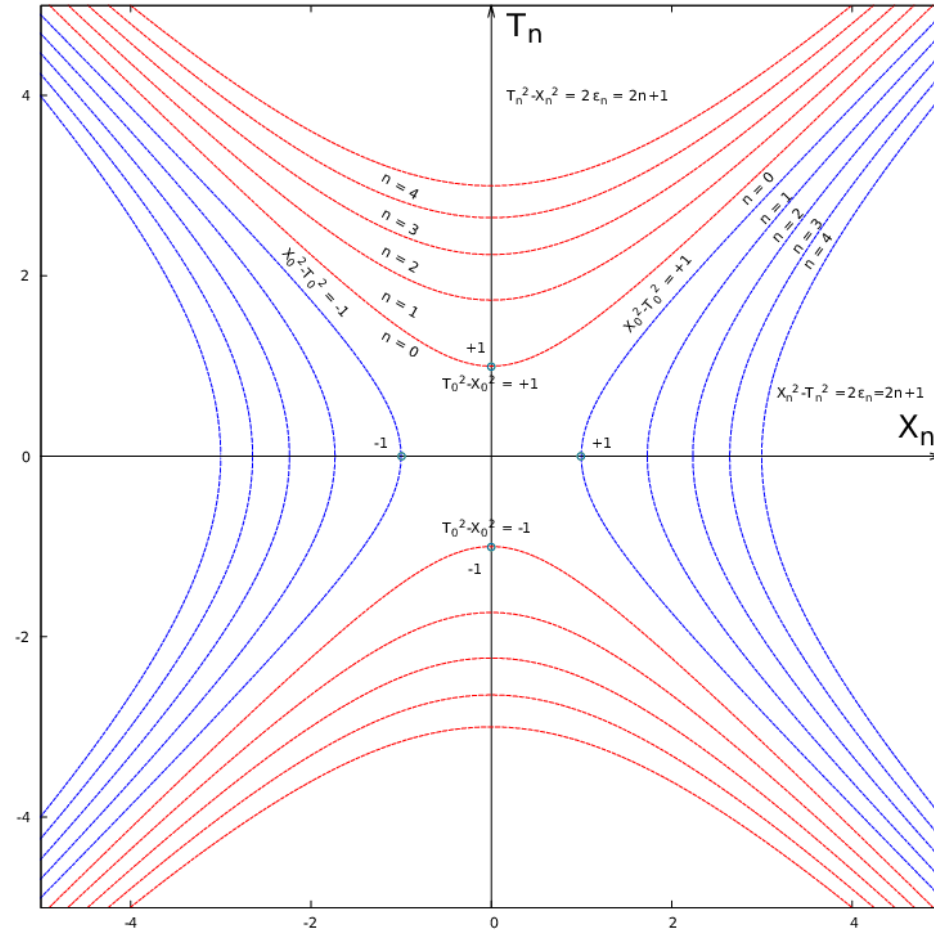
# THE CLASSICAL LIGHT CONE

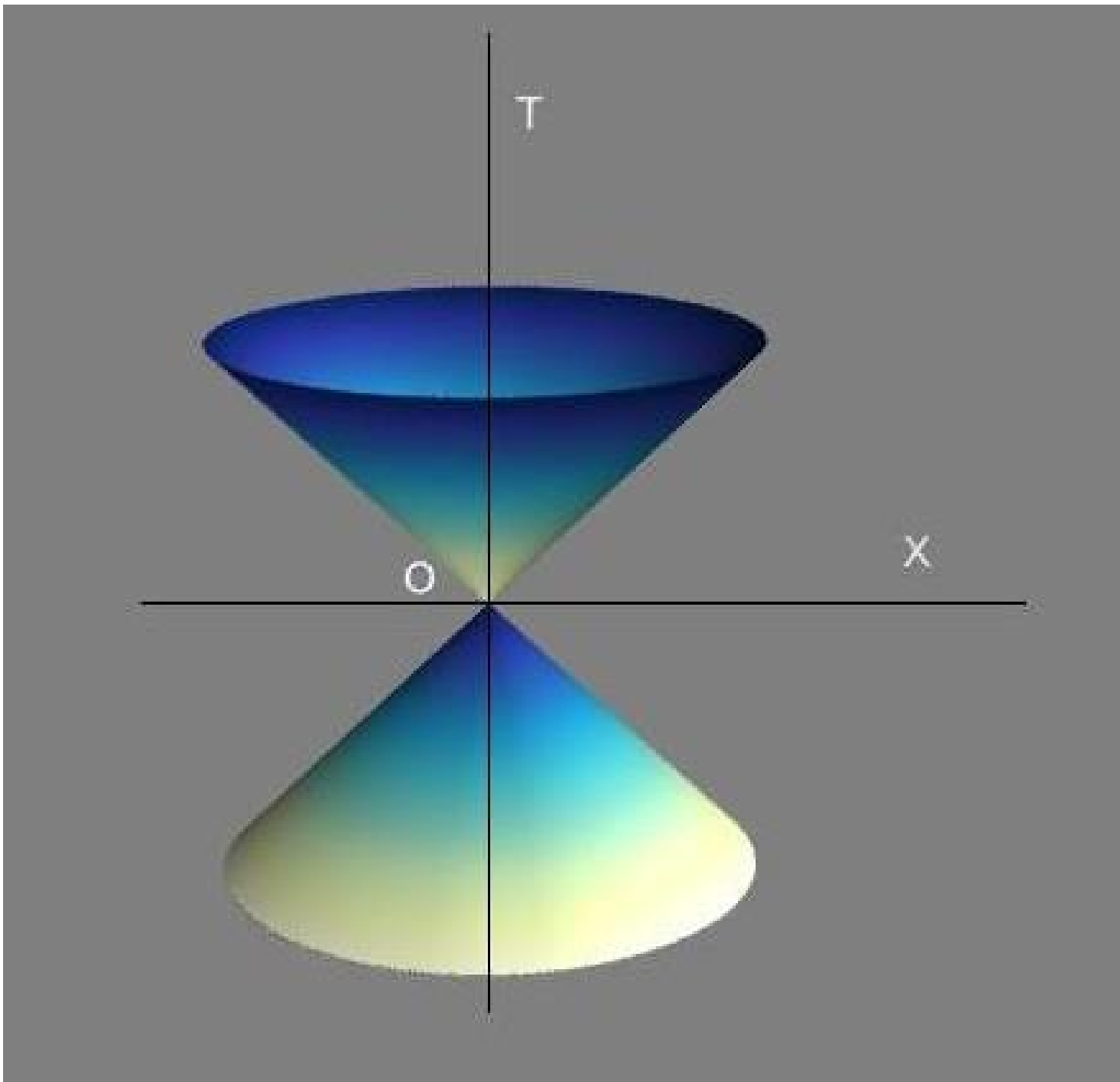


# THE QUANTUM LIGHT CONE

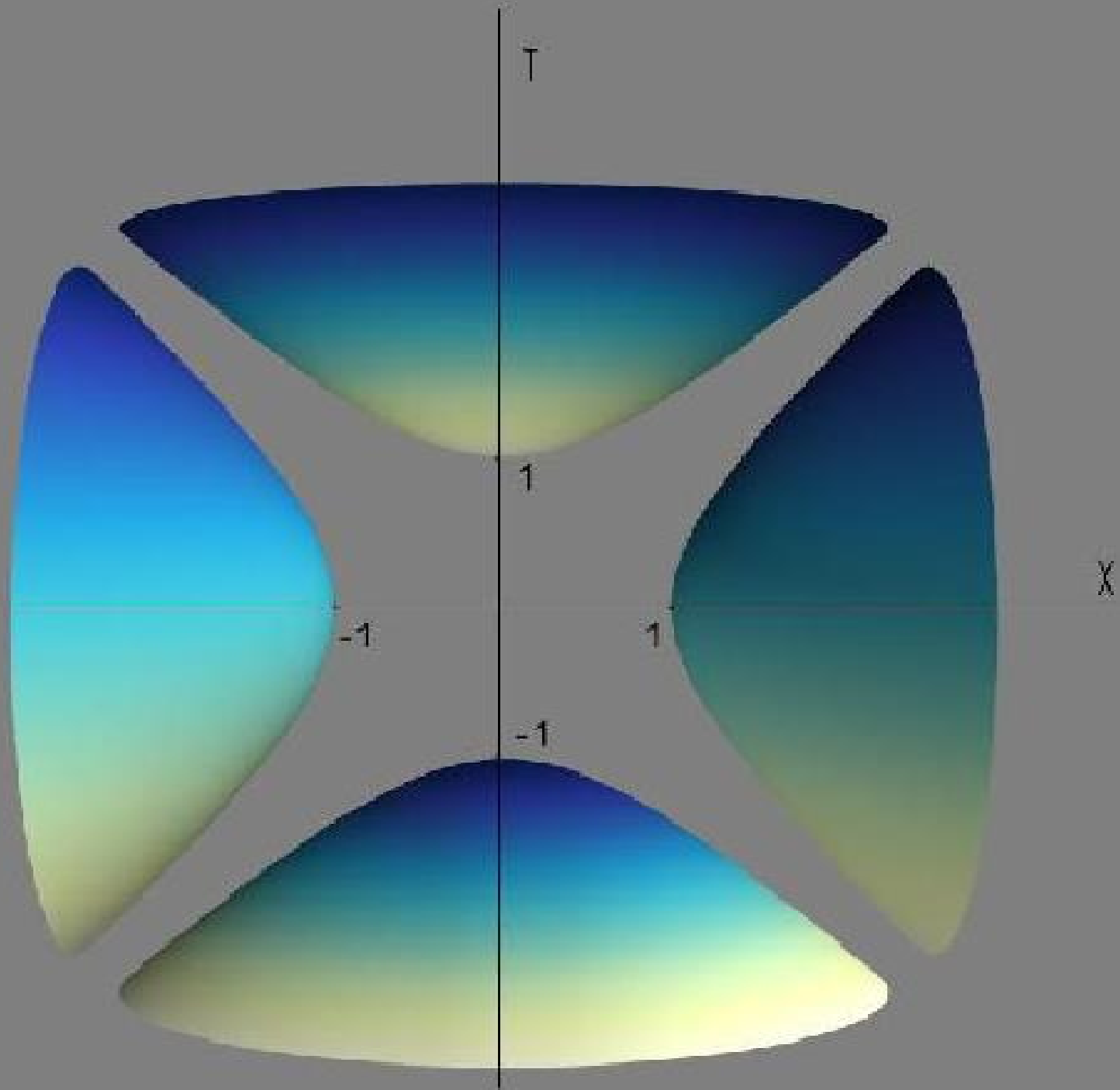


# QUANTUM SPACE-TIME STRUCTURE

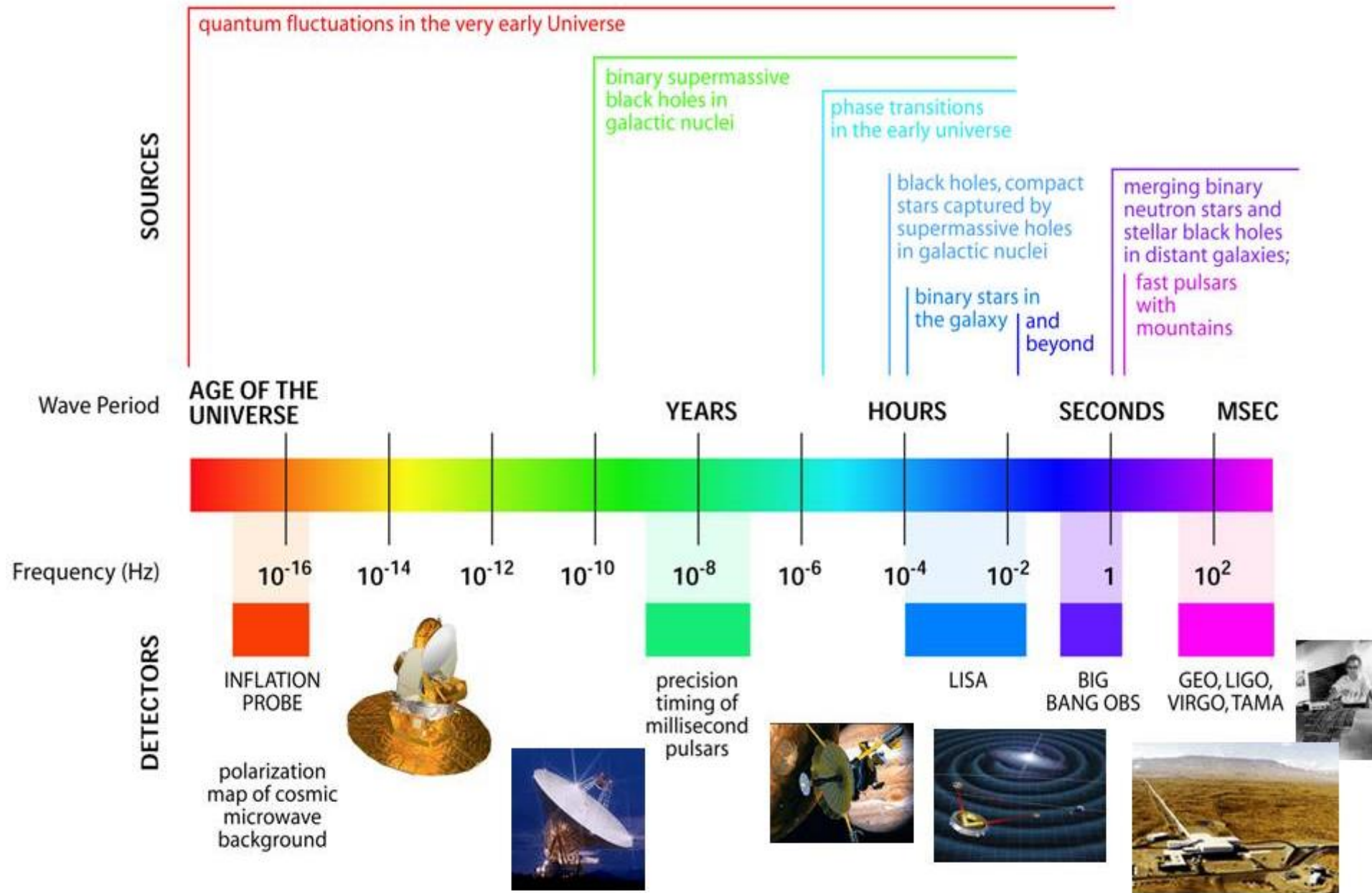




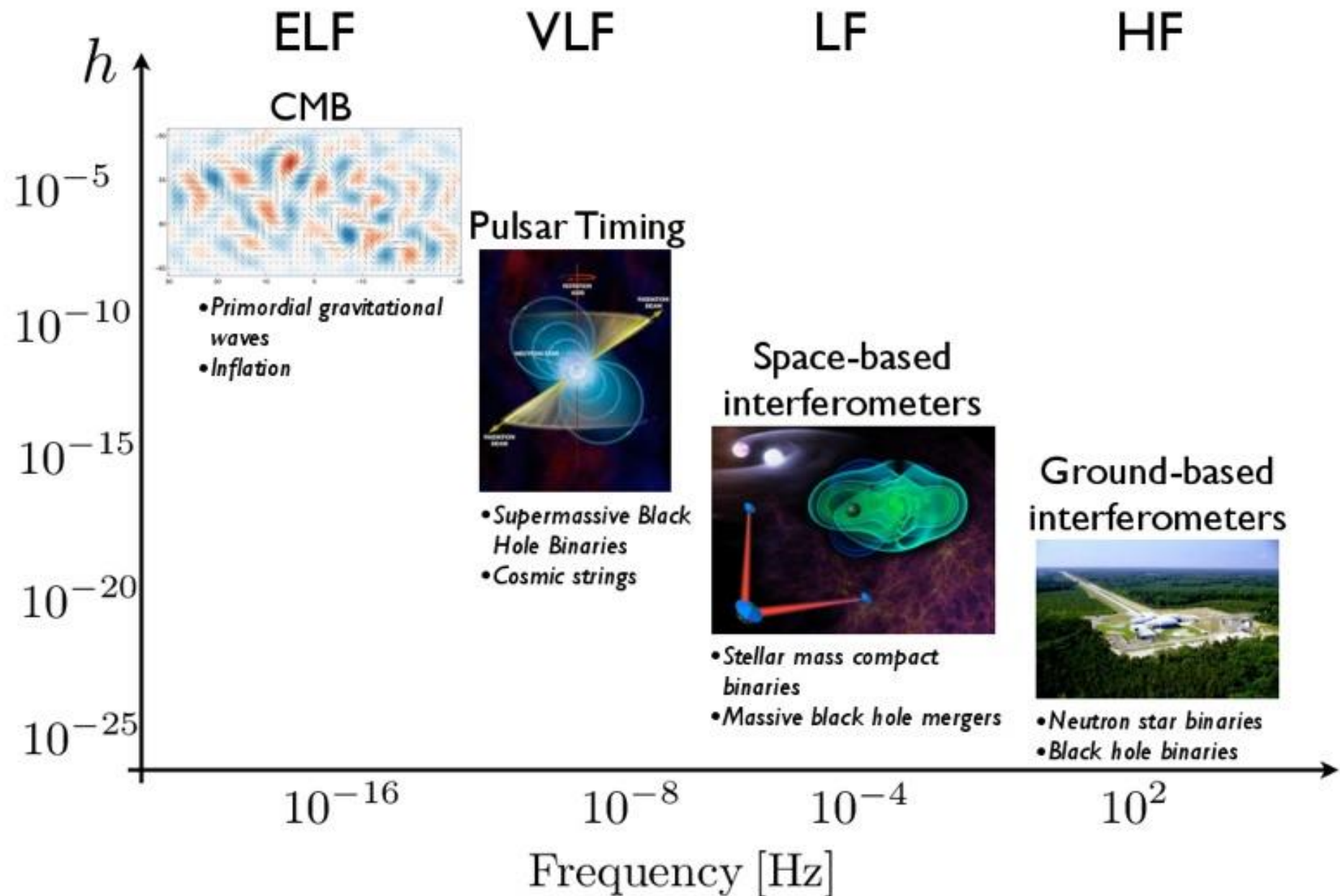




# THE GRAVITATIONAL WAVE SPECTRUM



# The big picture of gravitational wave astronomy



*“ Science is built up with facts,  
“ as a house is with stones.*

*“ But a collection of facts is no more a science  
“ than a heap of stones is a house.*

**-- Henri Poincaré**

*“ La science est construit avec des faits,  
“ ainsi comme une maison est construite  
“ avec des pierres.*

*“ Mais une collection de faits n'est pas une  
science, ainsi comme un tas de pierres n'est  
pas une maison.*



# **BLACK HOLE EVAPORATION DOES THE INVERSE EVOLUTION :**

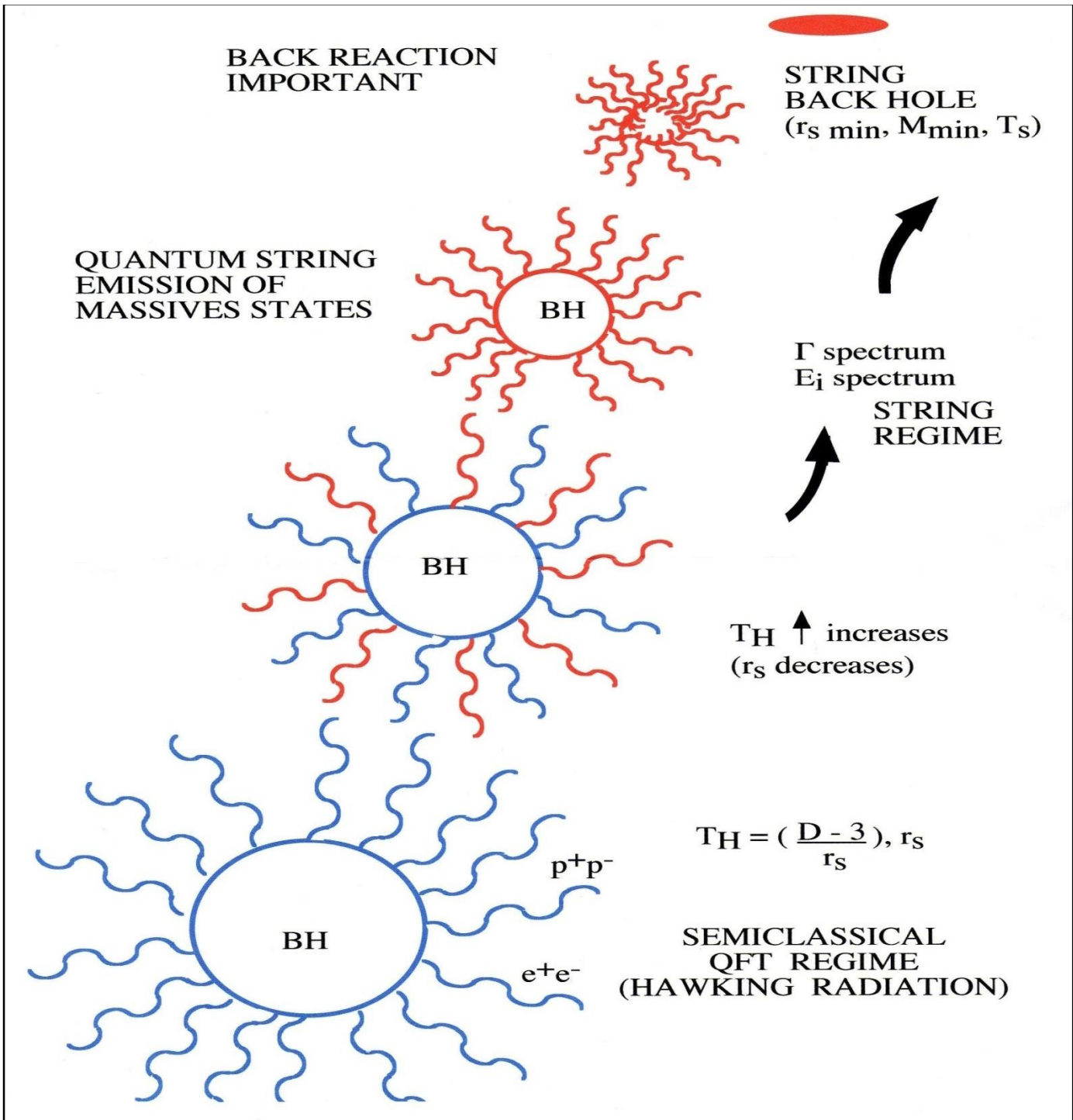
**BLACK HOLE EVAPORATION GOES FROM CLASSICAL/SEMICLASSICAL STAGE TO A QUANTUM (QUANTUM GRAVITY) STATE,**

**Through this evolution, the Black Hole temperature goes from the semiclassical gravity temperature (Hawking Temperature) to the usual temperature (the mass) and the quantum gravity temperature (the Planck temperature).**

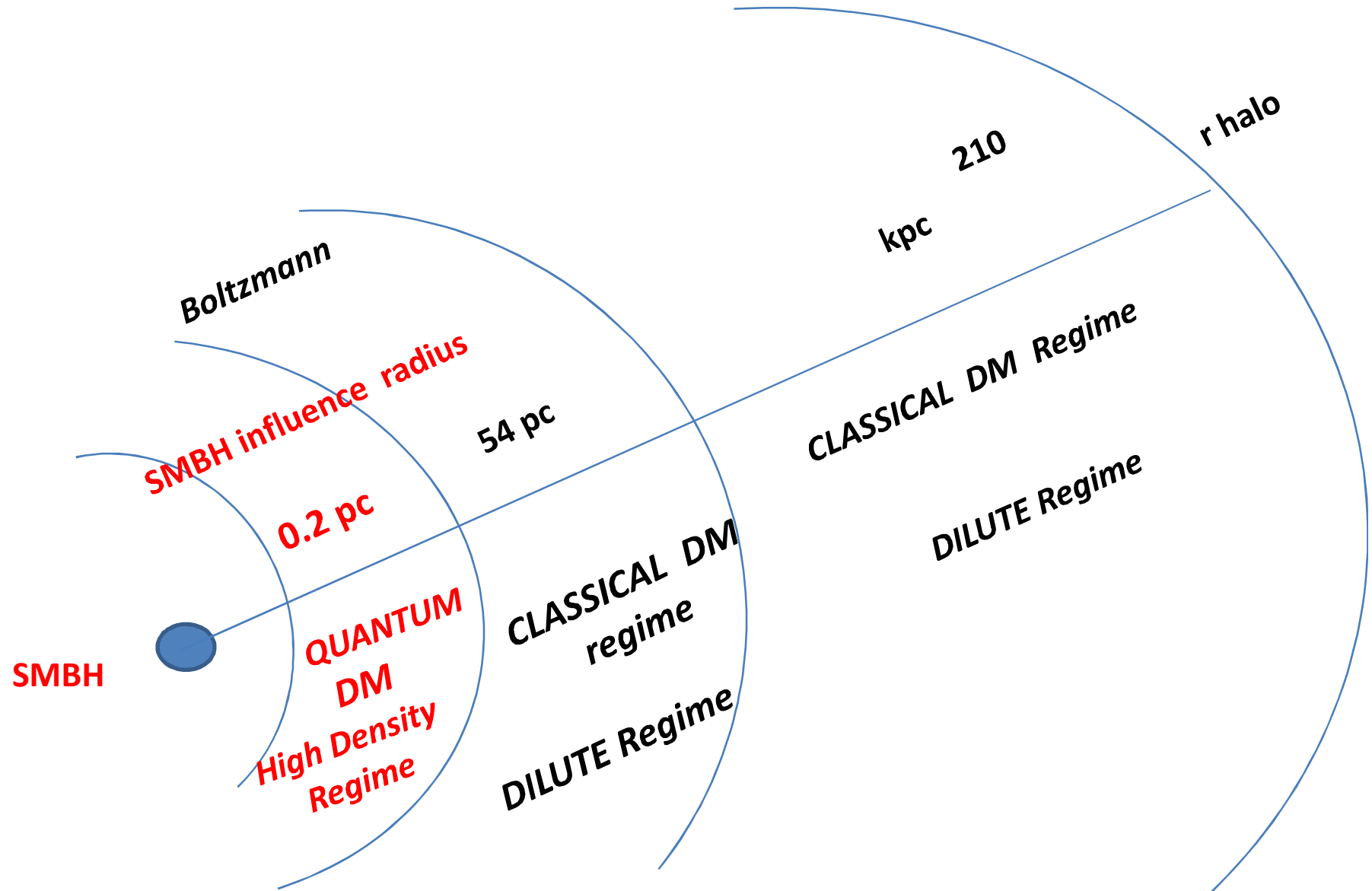
**Conceptual unification of quantum black holes, elementary particles and quantum states**

# CONCEPTUAL UNIFICATION

- **Cosmological evolution** goes from a quantum gravity phase to a semi-classical phase (inflation) and then to the classical (present cosmological) phase.
- **Black Hole Evaporation** (BH hole decay rate), heavy particles and extended quantum decay rates; black hole evaporation ends as quantum extended decay into pure (non mixed) non thermal radiation.
- The Hawking temperature, elementary particle and Hagedorn (string) temperatures **are the same concept in different gravity regimes (classical, semiclassical, quantum)** and turn out to be the precise classical-quantum duals of each other.







# WDM Thomas-Fermi Galaxy Theory with SMBH

de Vega & Sanchez, 2017

TOTAL UNIVERSE :  $(10^{-61} \text{ tp} + 10^{61} \text{ tp} + \text{tp})$

QUANTUM PHASE :  $10^{-61} \text{ tp} \rightarrow \text{tp}$

CLASSICAL PHASE :  $\text{tp} \rightarrow 10^{61} \text{ tp}$

QUANTUM Today :  $10^{-61} \text{ tp}$   
Extreme Past

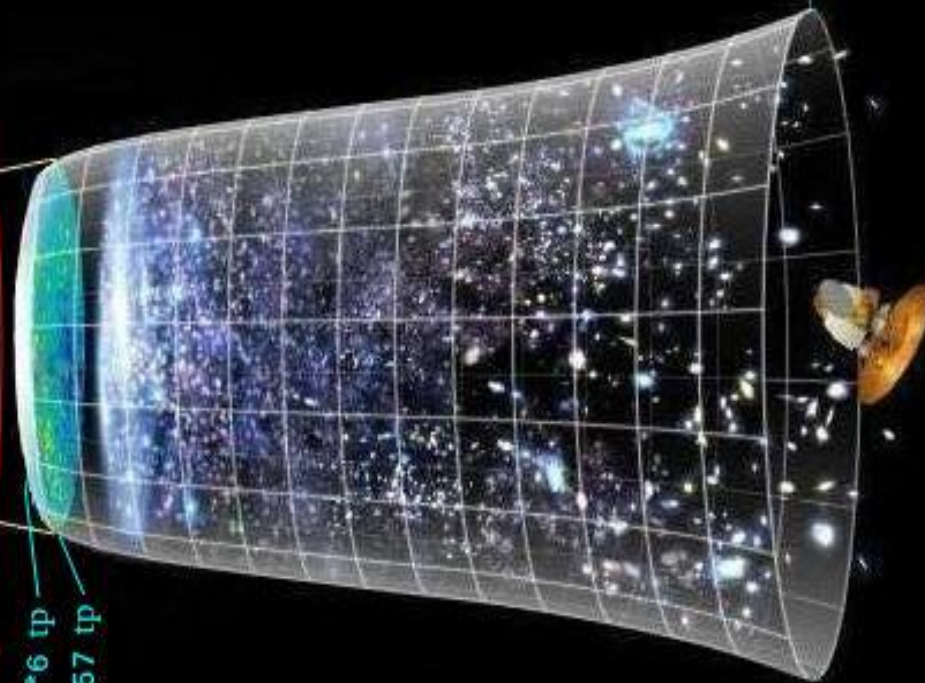
QUANTUM ERAS

Quantum CMB :  $10^{-57} \text{ tp}$   
Quantum Inflation :  $10^{-6} \text{ tp}$   
Planck Scale :  $\text{tp}$   
Classical Inflation :  $10^6 \text{ tp}$   
Classical CMB :  $10^{57} \text{ tp}$

CLASSICAL ERAS

Today :  $10^{61} \text{ tp}$

THE TOTAL HISTORY OF THE UNIVERSE



## Dark Energy

76 ± 5% of the **present** energy of the Universe is Dark !

Current observed value:

$$\rho_\Lambda = \Omega_\Lambda \rho_c = (2.39 \text{ meV})^4, \quad 1 \text{ meV} = 10^{-3} \text{ eV}.$$

Equation of state  $p_\Lambda = -\rho_\Lambda$  within observational errors.

Quantum zero point energy. Renormalized value is finite.

Bosons (fermions) give positive (negative) contributions.

Mass of the lightest particles  $\sim 1 \text{ meV}$  is in the right scale.

Spontaneous symmetry breaking of continuous symmetries produces massless scalars as Goldstone bosons. A small symmetry breaking provide light scalars: axions, majorons...

Observational Axion window  $10^{-3} \text{ meV} \lesssim M_{\text{axion}} \lesssim 10 \text{ meV}$ .

Dark energy **can be** a cosmological zero point effect. (As the Casimir effect in Minkowski with non-trivial boundaries).

We need to learn the **physics of light particles** ( $< 1 \text{ MeV}$ ), also to understand dark matter !!

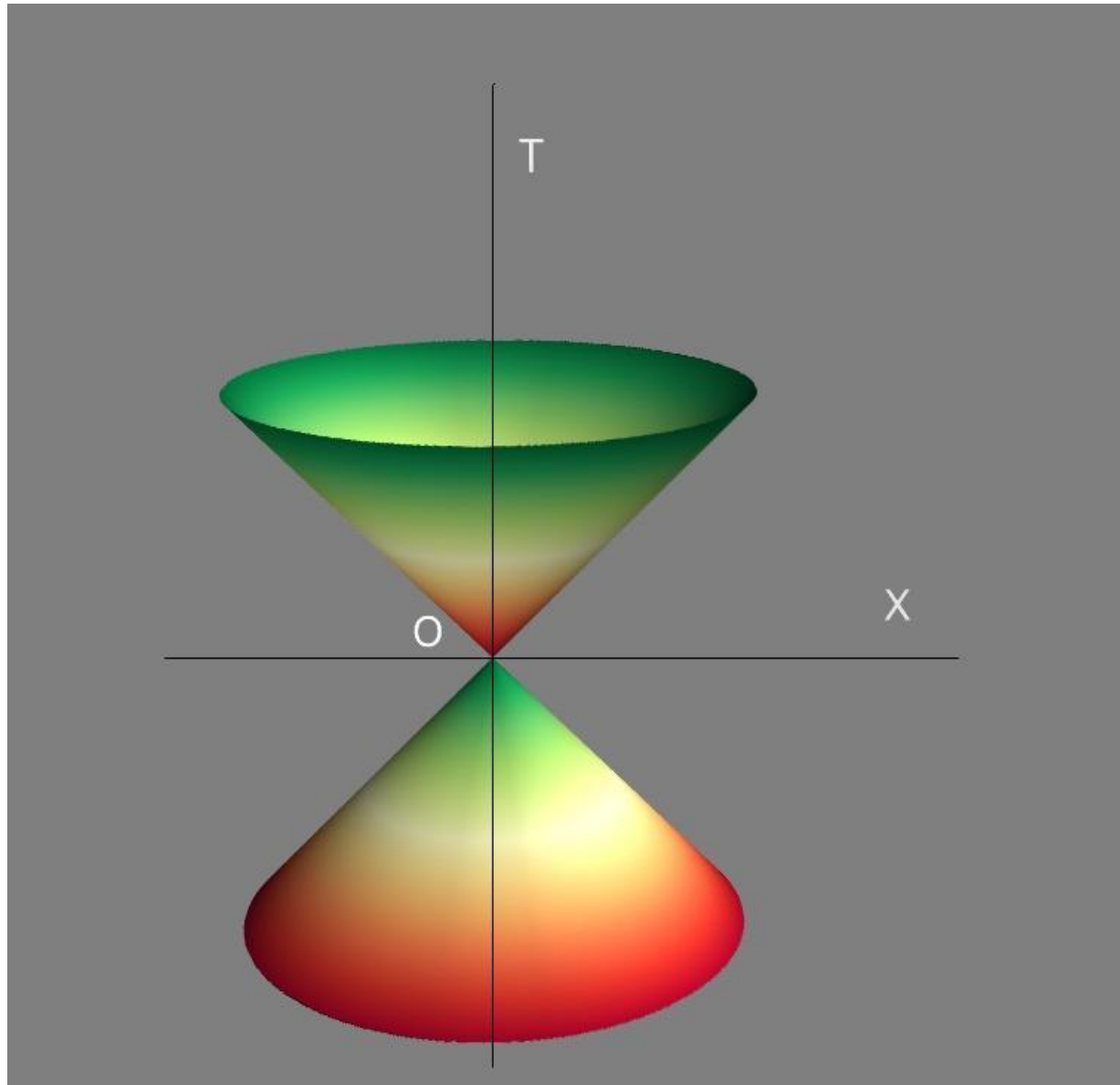
**Richard P. Feynman foresaw the necessity to include quantum physics in simulations in 1981**

**Í Å nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy.Í**

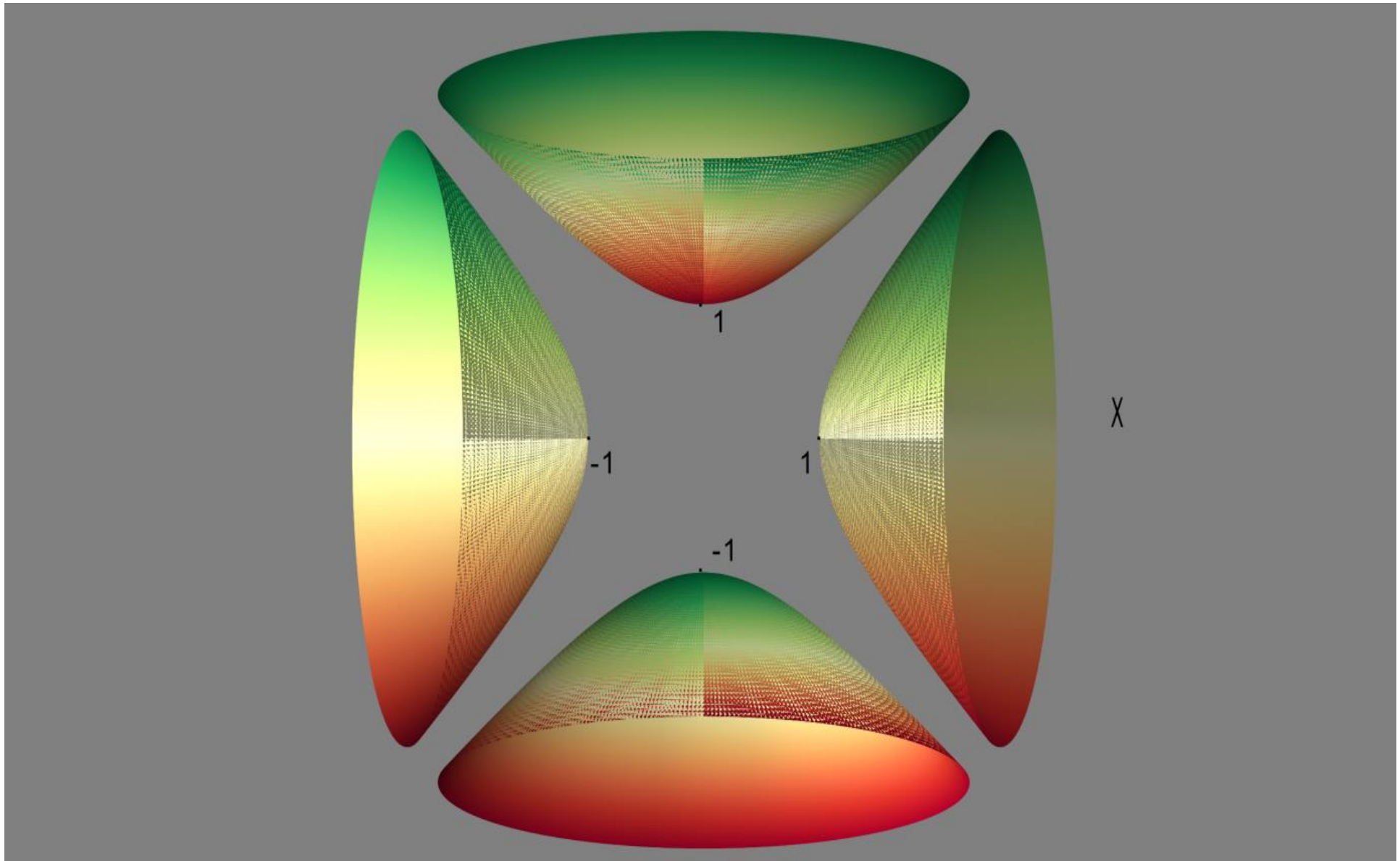
**Feynman again:**

**Í It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong.**

**THANK YOU VERY MUCH  
FOR YOUR ATTENTION!!**



**The known classical light-cone (future and past) of classical relativity in a space-time diagram is a special case of the Quantum light -cone**



**The quantum light-cone in a space-time diagram (time is the vertical axis).**

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