New Quantum Phase of the Universe before Inflation: Its present day and Dark Energy implications

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Standard Cosmological Model:

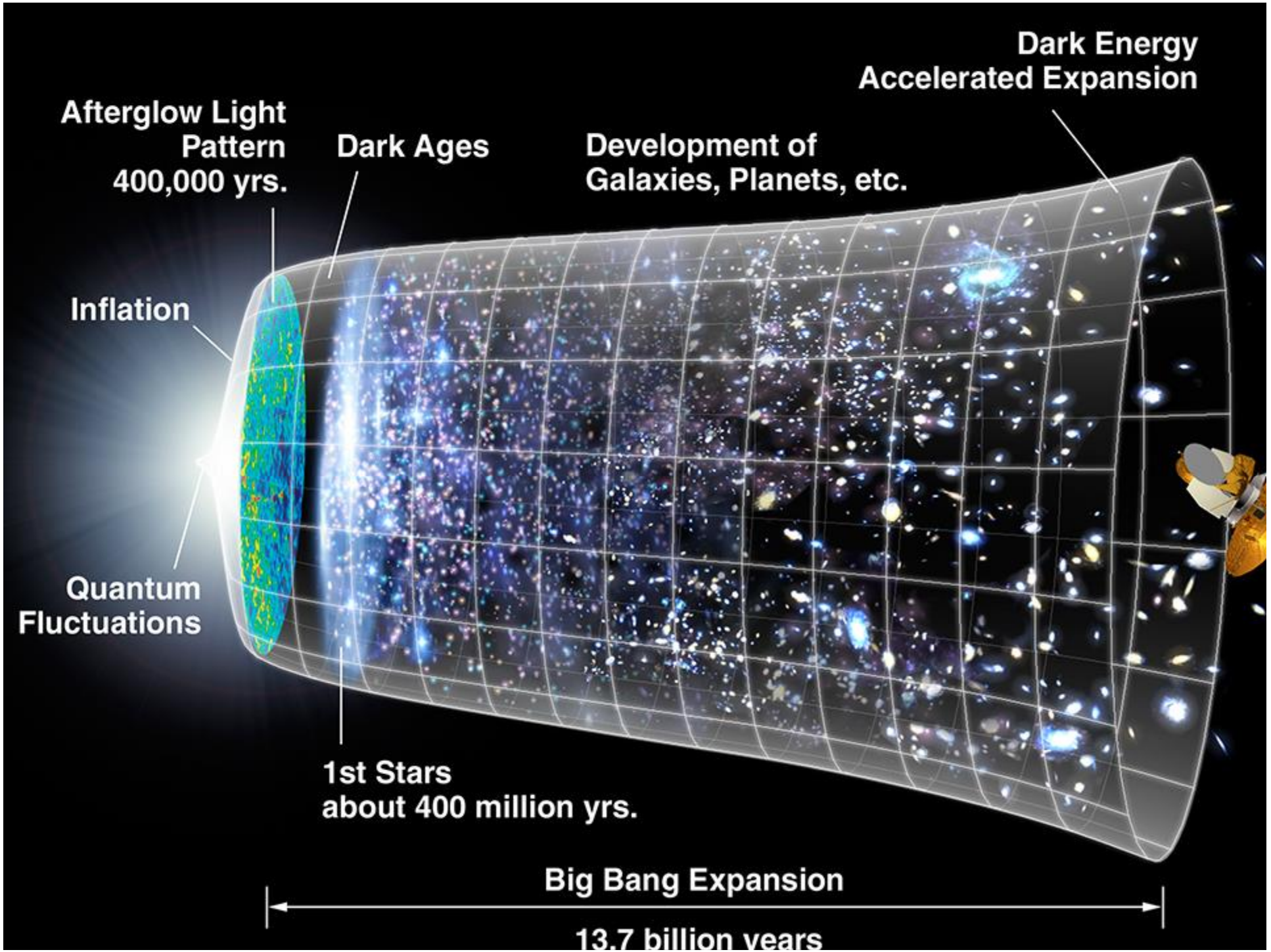
rdinary Matter + Dark Matter + Cosmological Constant

- 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 Λ

Standard Cosmological Model: ΛCDM $\Rightarrow$ ΛWDM

Dark Matter + Λ + 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 α Forest Observations
- Hubble Constant and Age of the Universe
  Measurements
- Properties of Clusters of Galaxies
- Galaxy structure explained by WDM


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

CONTENT

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, gravitational 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,*
  J. Grav & Cosmology 25, pp 91-102, (2019)
  https://link.springer.com/article/10.1134/S0202289319020142

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

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), June 2019

This Duality is Universal

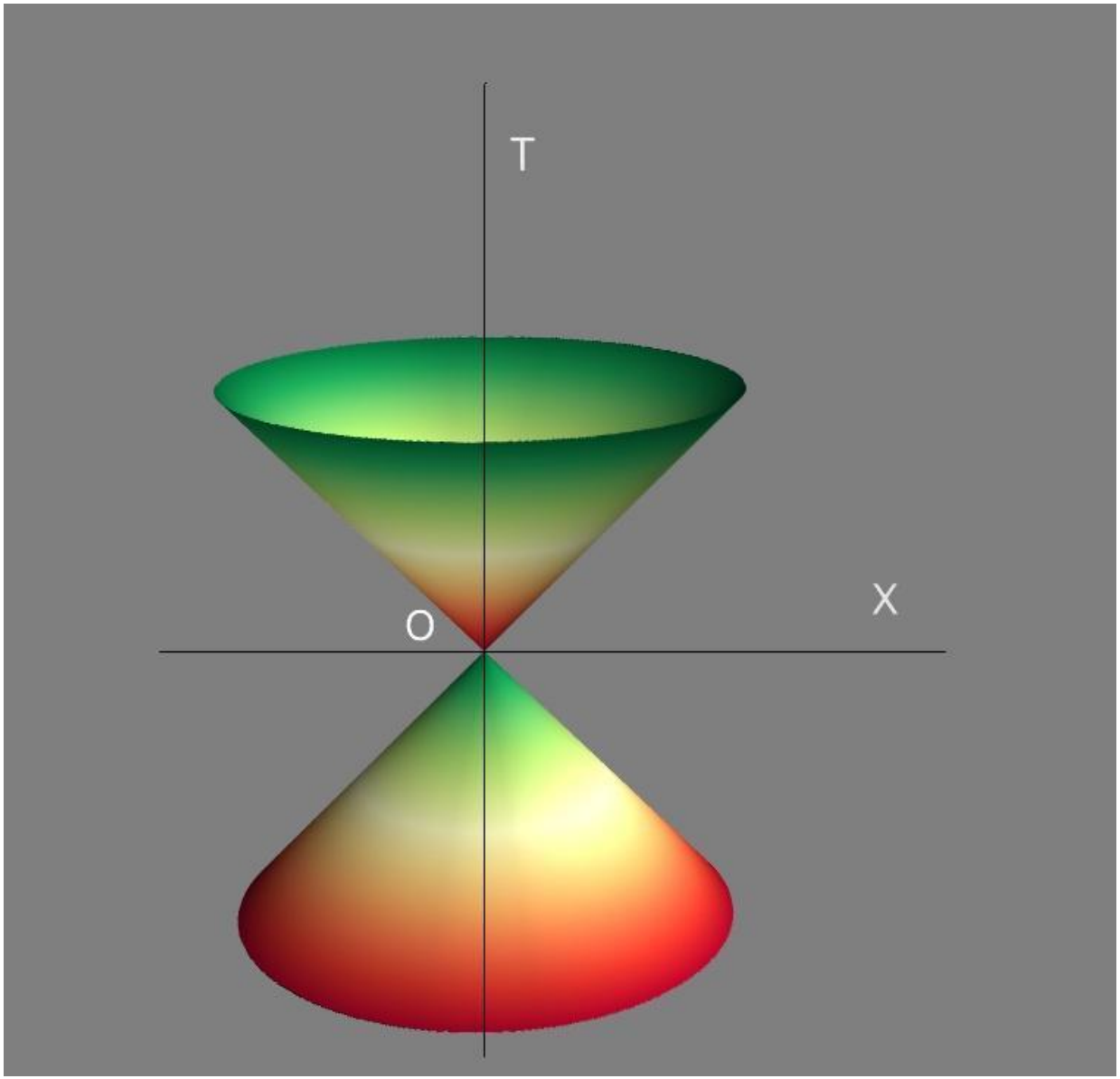
it includes the known duality and allows a general clarification and new results which reveal:

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

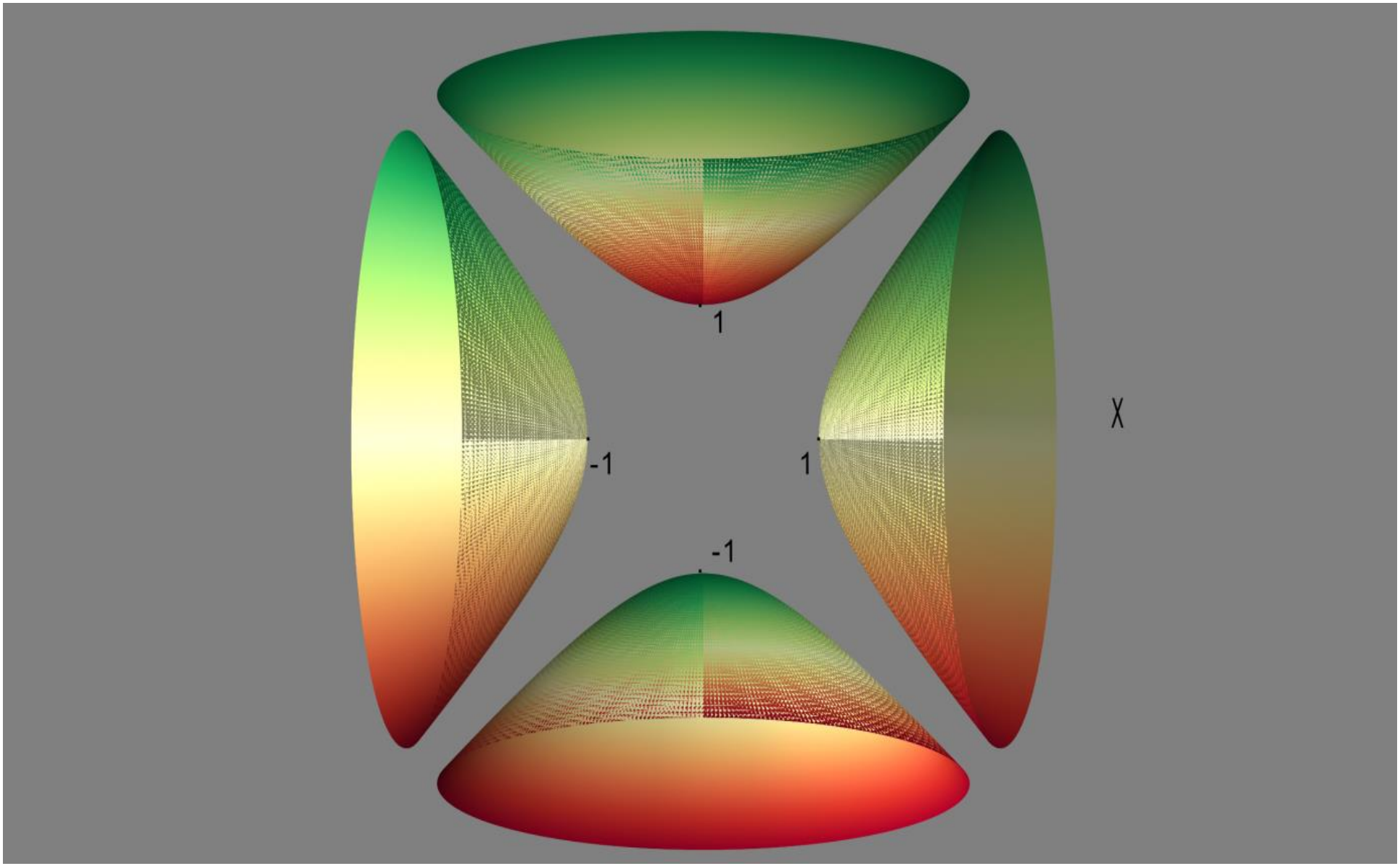
(ii) A new quantum domain not present in classical gravity does appear

(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).

The classical Universe today U_Λ: set of physical gravitational observables (age or size, mass, density, temperature, entropy) (L , M , ρ , 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

(h, c, G): $L_G = 2GM/c^2$, $L_Q = h/Mc$

$$l_P = (hG/c^3)^{1/2}, \qquad m_p = (hc/G)^{1/2}$$

$$G/c^2 = l_P/m_p, \quad l_P m_p = h/c$$

$l_P = 10^{-33}$ cm, $m_p = 10^{-5}$ gr, $t_p = 10^{-44}$ sec

$$L_Q = l_P^2 / L_G \ , \qquad M_Q = m_P^2 / M \ , \qquad O_Q = o_P^2 / O_G$$

New Variables : $L_{QG} = L_Q + L_G$, $O_{QG} = O_Q + O_G$, Q<--> G

N.G.S, Int J. Mod Phys D18, 1950055 (2019) $O_{QG} = o_P (O_G/o_P + o_P/O_G)$

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

$$[\,\Delta^{S}{}_{QH}\,] = [\,\Delta^{S}{}_{H}\,] \quad \frac{1}{[\,1 + (H/h_P)^2\,]} \quad \frac{1}{(\,1 - \delta\varepsilon_{QH})^{1/2}}$$

$$[\,\Delta^{T}{}_{QH}\,] = [\,\Delta^{T}{}_{H}\,] \quad \frac{1}{[\,1 + (H/h_P)^2\,]}$$

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:

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

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

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

fective 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 $dn_s/dlnk$	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 BICEF
inflaton potential curvature $V''(0)$	$V''(0) < 0$	$V''(0) < 0$

TI + WMAP+LSS means the MCMC analysis combining
ne ETI with WMAP and LSS data. Such analysis calls for
n inflaton potential with negative curvature at horizon
xit.The double well potential is favoured (new inflation).
). Boyanovsky, C. Destri, H. J. de Vega, N. G. Sanchez,
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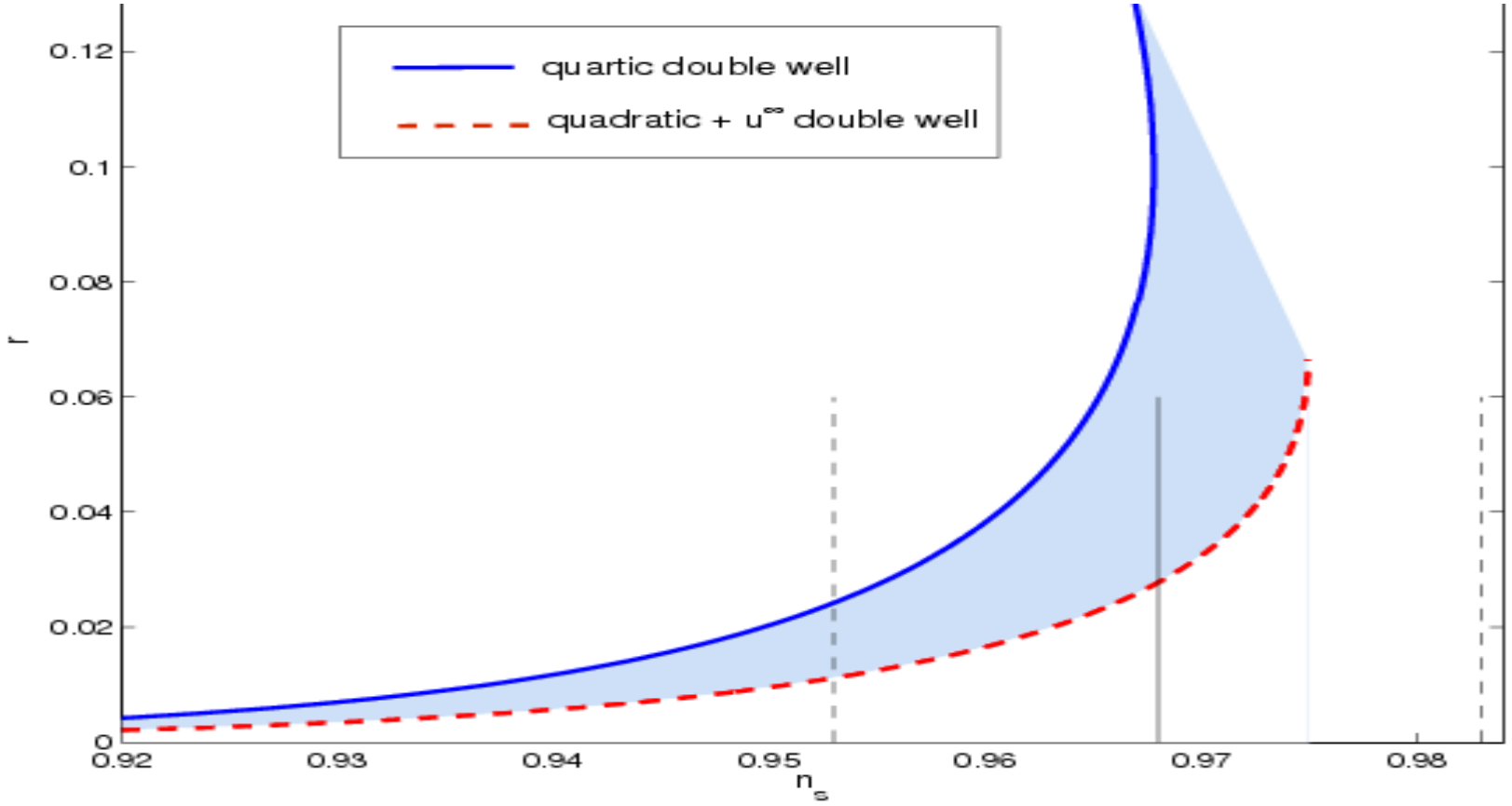


THE PRIMORDIAL COSMIC BANANA

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), PRD (2006), PRD 2008)

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 Bicep2 Keck : $r < 0.08$ (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 $\rho_H \equiv \rho_\Lambda$:

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

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

The last Planck satellite data yield the values: $H = 67.4 \pm 0.5\ Km\ se$

$$\Omega_\Lambda h^2 = 0.0224 \pm 10^{-4}, \quad \Omega_\Lambda = 0.6847 \pm 0.0073, \quad \Omega_\Lambda h^2 = 0.3107 \pm 0.0082,$$

which implies for the cosmological constant today:

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

The density ρ_Λ associated to Λ is precisely:

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

The Universe Today is Essentially Empty

Inter galactic distances $\sim$ Mpc. (pc = 3.0857×10^{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 galaxie

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

NEW RESULTS FOR DARK ENERGY

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

The classical Universe today U_Λ is precisely a *classical dilute gravity vacuum dominated by voids and supervoids as shown by observations:* The observed value of ρ_Λ or Λ today is *precisely the classical dual* of its quantum precursor values ρ_Q, Λ_Q in the quantum very early precursor vacuum U_Q as determined by our dual Equations.

The high density ρ_Q and cosmological constant Λ_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 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: **Λ and Λ_Q, (or equivalently ρ_Λ and ρ_Q)** ,refer to the same concept or nature of Λ or ρ_Λ 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 Λ observed today**, and **quantum state and trans-Planckian very early universe epoch for the quantum mechanical super-Planckian value Λ_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 $L_Q = l^2_P\ /L_H\ = h\ /\ M_Hc$ which is *exactly the quantum dual of the classical horizon radius L_H***

$$\Lambda = 3H^2 = \hbar_P (H / h_P)^2 = \hbar_P (l_P / L_H)^2$$
$$= (2.846 \pm 0.076)\ 10^{-122}\ m_P^2$$

$$\Lambda_Q = 3H_Q^2 = \hbar_P (h_P / H)^2 = \hbar_P (L_H / l_P)^2$$
$$= (0.3516 \pm 0.094)\ 10^{122}\ m_P^2$$

$$\Lambda_Q \Lambda = \hbar_P^2 \quad , \quad \hbar_P = 3\ h_P^2 \ .$$

The quantum dual value Λ_Q is precisely the quantum value from particle physics:

$$J_Q = J_P\ (\Lambda_Q / \hbar_P) = J_P^2 / J_\Lambda = 10^{122}\ J_P$$

There is no problem between the two extremely different values Λ and Λ_Q or equivalently between ρ_Λ and ρ_Q, because the two values *do not refer to the same vacuum or eras:* *one* is exactly the *classical physics today vacuum energy density ρ, 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 Λ_Q value that is to say, the vacuum value computed from particle physics is exactly the quantum dual value of the classical Λ 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

$$\Lambda/\lambda_P = \rho_\Lambda/\rho_P = S_Q/s_P = \lambda_P/\Lambda_Q = (T_Q/t_P)^2 = 10^{-122}$$

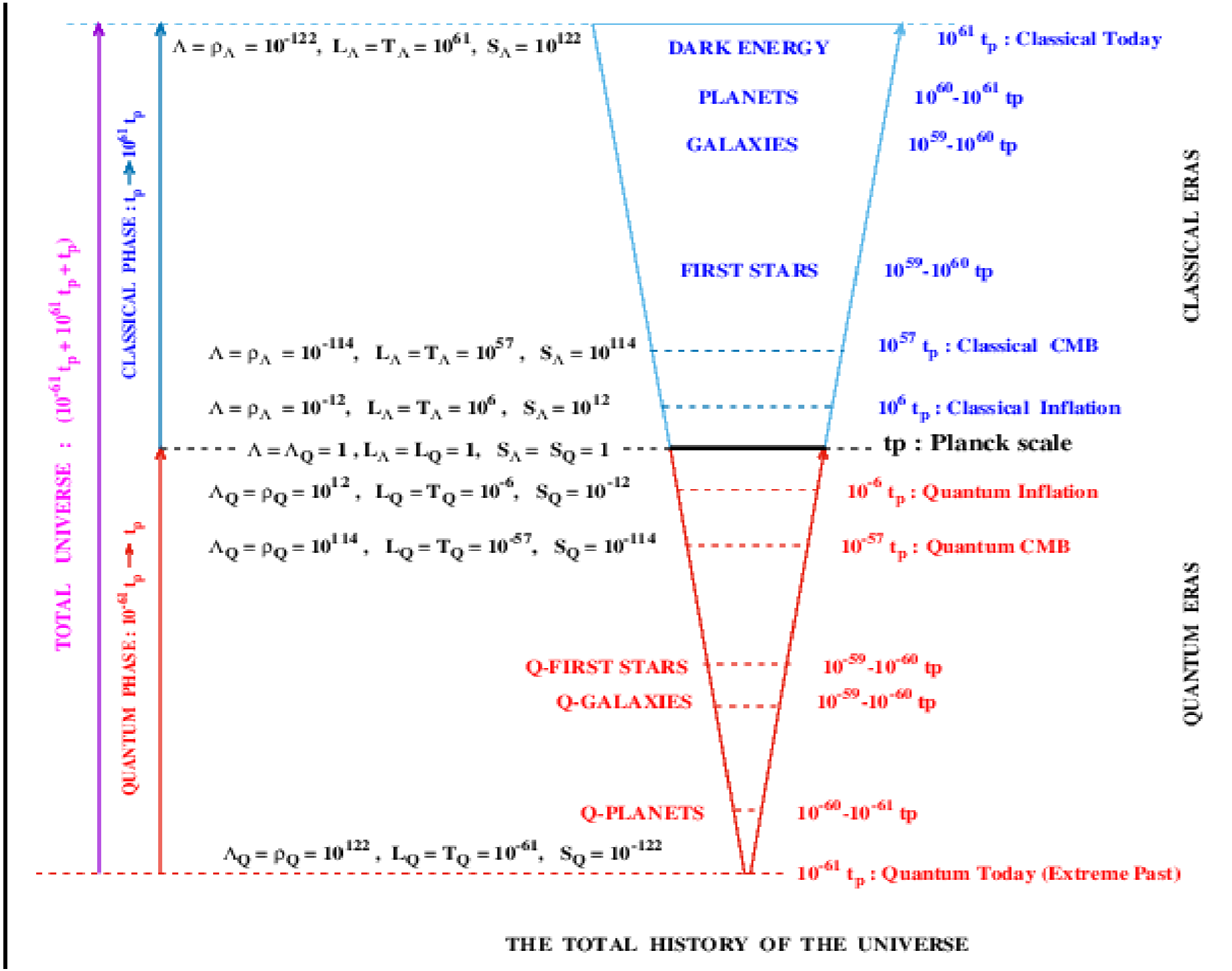
$$\Lambda_Q/\lambda_P = \rho_Q/\rho_P = S_\Lambda/s_P = \lambda_P/\Lambda = (T_\Lambda/t_P)^2 = 10^{+122}$$

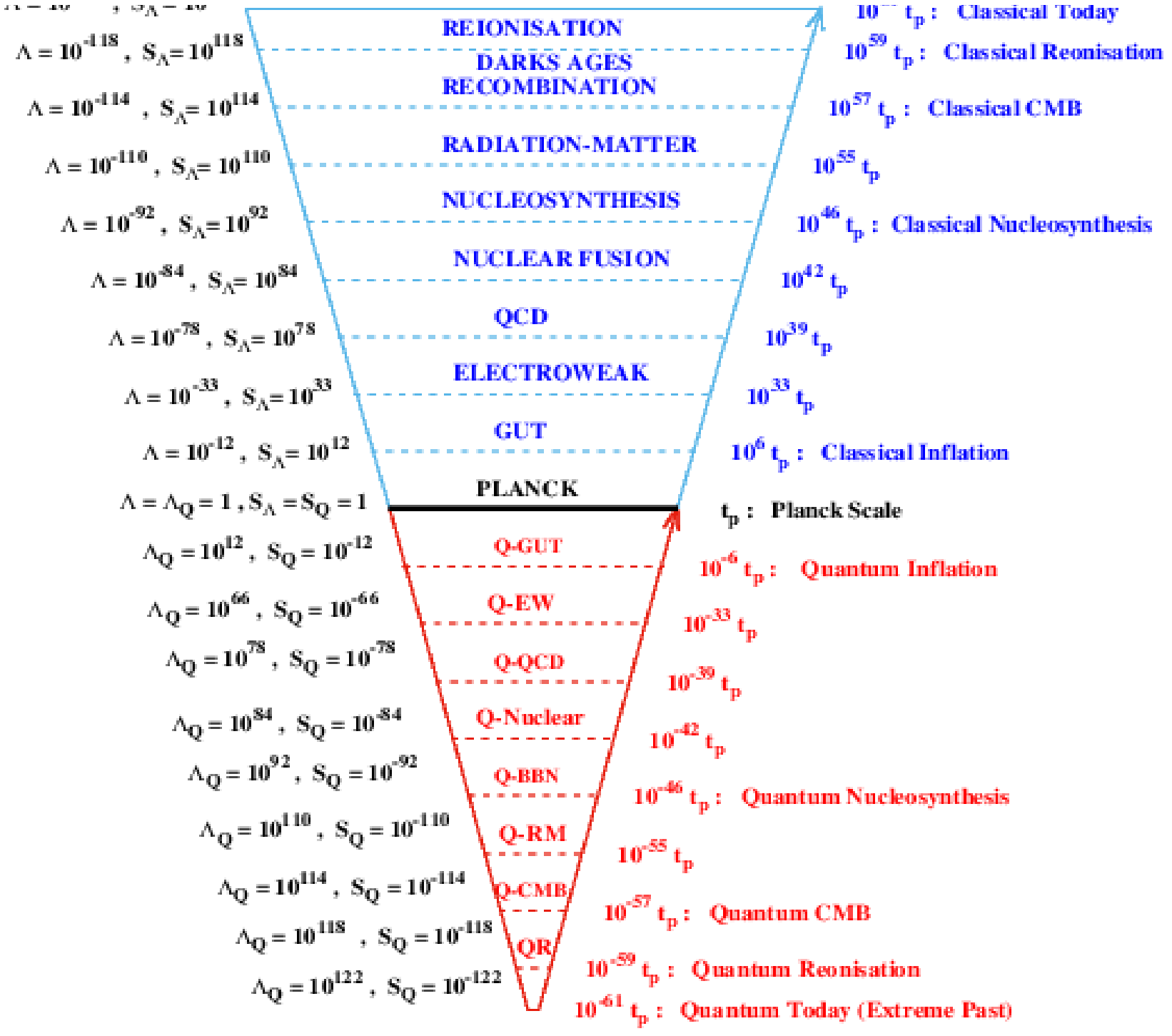
$$\Lambda_{\Lambda Q} = \Lambda + \Lambda_Q + \lambda_P = (\Lambda/\lambda_P + \lambda_P/\Lambda + 1)$$

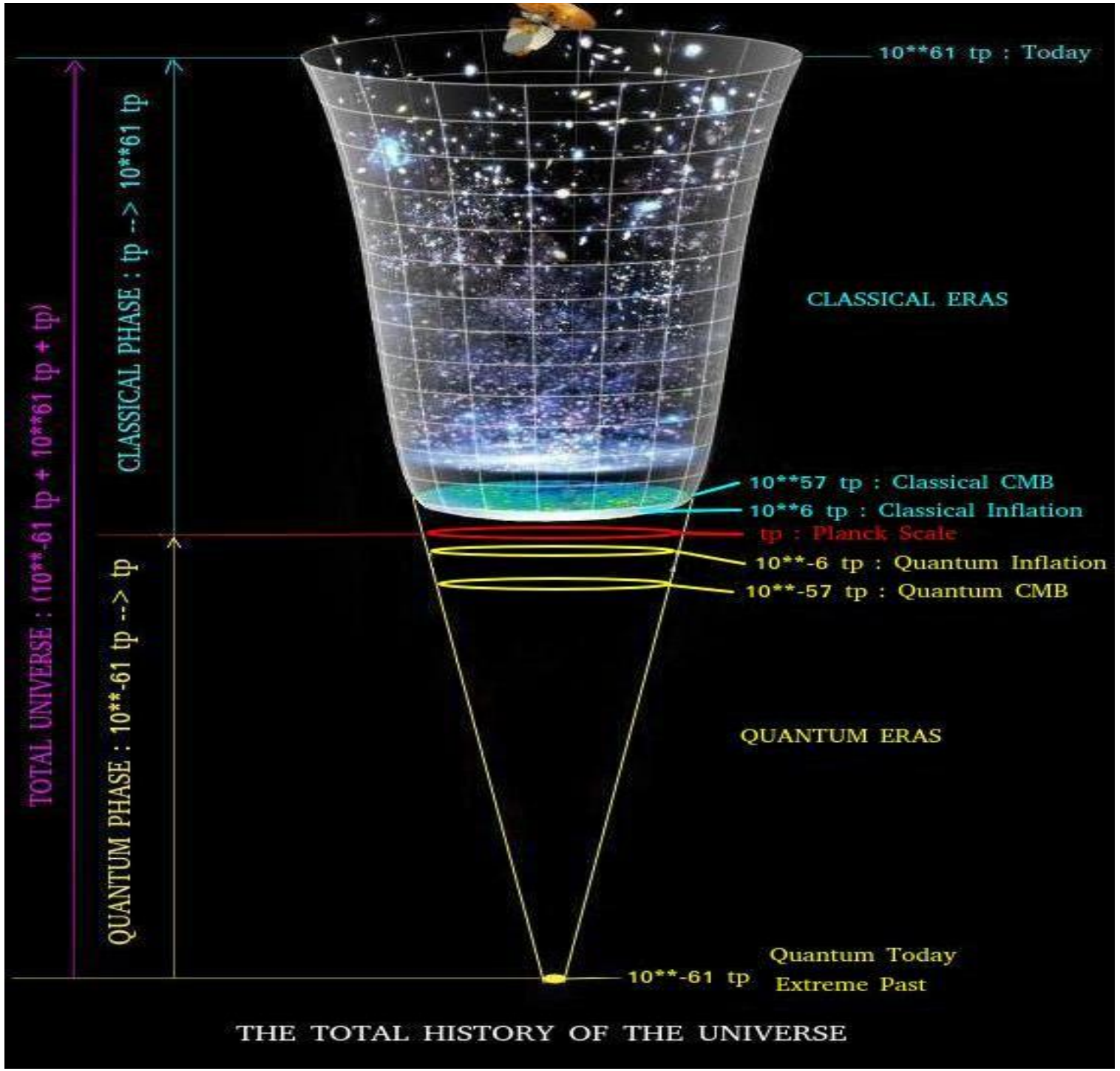
$$\Lambda_{\Lambda Q} = \lambda_P\,(10^{-122} + 10^{+122} + 1)$$

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	$3.5 \pm 1.7 \times 10^{78}$
Total	$\mathbf{2.6 \pm 0.3 \times 10^{122}}$


TOTAL UNIVERSE : $(10^{-61} t_p + 10^{61} t_p + t_p)$
CLASSICAL PHASE : $t_p \rightarrow 10^{61} t_p$
QUANTUM PHASE : $10^{-61} t_p \rightarrow t_p$
$\Lambda = \rho_\Lambda = 10^{-122}$, $L_\Lambda = T_\Lambda = 10^{61}$, $S_\Lambda = 10^{122}$
DARK ENERGY
PLANETS
GALAXIES
FIRST STARS
10^{61} t_p : Classical Today
10^{60}-10^{61} tp
10^{59}-10^{60} tp
10^{59}-10^{60} tp
$\Lambda = \rho_\Lambda = 10^{-114}$, $L_\Lambda = T_\Lambda = 10^{57}$, $S_\Lambda = 10^{114}$
10^{57} t_p : Classical CMB
$\Lambda = \rho_\Lambda = 10^{-12}$, $L_\Lambda = T_\Lambda = 10^{6}$, $S_\Lambda = 10^{12}$
10^{6} t_p : Classical Inflation
$\Lambda = \Lambda_Q = 1$, $L_\Lambda = L_Q = 1$, $S_\Lambda = S_Q = 1$
tp : Planck scale
$\Lambda_Q = \rho_Q = 10^{12}$, $L_Q = T_Q = 10^{-6}$, $S_Q = 10^{-12}$
10^{-6} t_p : Quantum Inflation
$\Lambda_Q = \rho_Q = 10^{114}$, $L_Q = T_Q = 10^{-57}$, $S_Q = 10^{-114}$
10^{-57} t_p : Quantum CMB
Q-FIRST STARS
Q-GALAXIES
10^{-59}-10^{-60} tp
10^{-59}-10^{-60} tp
Q-PLANETS
10^{-60}-10^{-61} tp
$\Lambda_Q = \rho_Q = 10^{122}$, $L_Q = T_Q = 10^{-61}$, $S_Q = 10^{-122}$
10^{-61} t_p : Quantum Today (Extreme Past)
CLASSICAL ERAS
QUANTUM ERAS
THE TOTAL HISTORY OF THE UNIVERSE


REIONISATION
DARKS AGES
RECOMBINATION
RADIATION-MATTER
NUCLEOSYNTHESIS
NUCLEAR FUSION
QCD
ELECTROWEAK
GUT
PLANCK
Q-GUT
Q-EW
Q-QCD
Q-Nuclear
Q-BBN
Q-RM
Q-CMB
QR
$\Lambda = 10^{-118}$, $S_\Lambda = 10^{118}$
$\Lambda = 10^{-114}$, $S_\Lambda = 10^{114}$
$\Lambda = 10^{-110}$, $S_\Lambda = 10^{110}$
$\Lambda = 10^{-92}$, $S_\Lambda = 10^{92}$
$\Lambda = 10^{-84}$, $S_\Lambda = 10^{84}$
$\Lambda = 10^{-78}$, $S_\Lambda = 10^{78}$
$\Lambda = 10^{-33}$, $S_\Lambda = 10^{33}$
$\Lambda = 10^{-12}$, $S_\Lambda = 10^{12}$
$\Lambda = \Lambda_Q = 1$, $S_\Lambda = S_Q = 1$
$\Lambda_Q = 10^{12}$, $S_Q = 10^{-12}$
$\Lambda_Q = 10^{66}$, $S_Q = 10^{-66}$
$\Lambda_Q = 10^{78}$, $S_Q = 10^{-78}$
$\Lambda_Q = 10^{84}$, $S_Q = 10^{-84}$
$\Lambda_Q = 10^{92}$, $S_Q = 10^{-92}$
$\Lambda_Q = 10^{110}$, $S_Q = 10^{-110}$
$\Lambda_Q = 10^{114}$, $S_Q = 10^{-114}$
$\Lambda_Q = 10^{118}$, $S_Q = 10^{-118}$
$\Lambda_Q = 10^{122}$, $S_Q = 10^{-122}$
$10^{\cdots} t_p$: Classical Today
$10^{59} t_p$: Classical Reonisation
$10^{57} t_p$: Classical CMB
$10^{55} t_p$
$10^{46} t_p$: Classical Nucleosynthesis
$10^{42} t_p$
$10^{39} t_p$
$10^{33} t_p$
$10^{6} t_p$: Classical Inflation
t_p : Planck Scale
$10^{-6} t_p$: Quantum Inflation
$10^{-33} t_p$
$10^{-39} t_p$
$10^{-42} t_p$
$10^{-46} t_p$: Quantum Nucleosynthesis
$10^{-55} t_p$
$10^{-57} t_p$: Quantum CMB
$10^{-59} t_p$: Quantum Reonisation
$10^{-61} t_p$: Quantum Today (Extreme Past)
CLASSICAL ERAS
QUANTUM ERAS


10**61 tp : Today
CLASSICAL ERAS
10**57 tp : Classical CMB
10**6 tp : Classical Inflation
tp : Planck Scale
10**-6 tp : Quantum Inflation
10**-57 tp : Quantum CMB
QUANTUM ERAS
Quantum Today
10**-61 tp
Extreme Past
TOTAL UNIVERSE : (10**-61 tp + 10**61 tp + tp)
CLASSICAL PHASE : tp --> 10**61 tp
QUANTUM PHASE : 10**-61 tp --> tp
THE TOTAL HISTORY OF THE UNIVERSE

$$M_{moon} = 7\,10^{25} gr = 7\,10^{20}\, m_P, \qquad M_{Q\,moon} = 0.14\,10^{-20}\, m_P$$

$$M_{asteroid,\,comet} = 10^{15} gr = 10^{20}\, m_P, \qquad M_{Q\,asteroid,\,comet} = 10^{-20}\, m_P$$

- For Human scales: $M_{human} = 10^{6} gr = 10^{13}\, m_P, \quad M_{Q\,human} = 10^{-15} gr = 10^{-10}\, m_P$

$$L_{human} = 1.7\,10^{2} cm = 1.7\,10^{35}\, l_P, \qquad L_{Q\,human} = 10^{-68} cm = 10^{-35}\, l_P$$

- For atomic scales: $L_{atom} = 10^{20}\, l_P, \qquad T_{atom} = 10^{20}\, t_P, \qquad M_{atom} = 10^{-20}\, m_P$

$$L_{Q\,atom} = 10^{-20}\, l_P, \qquad T_{Q\,atom} = 10^{-20}\, t_P, \qquad M_{Q\,atom} = 10^{20}\, m_P$$

- For elementary particles (ex. the electron mass): $M(eV/c^2) = 10^{-33} gr = 10^{-28}\, m_P, \quad M_Q(eV/c^2) = 10^{22} gr = 10^{28}\, m_P$

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 untill the present de Sitter era.

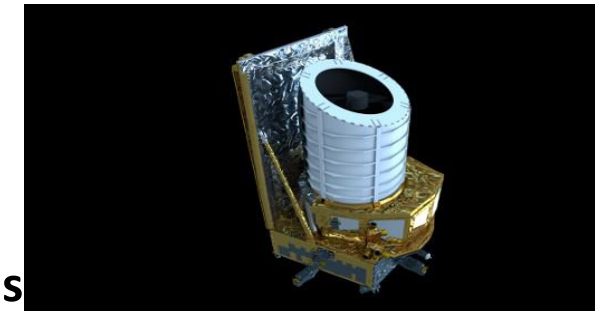
ÅThe wave-particle-gravity duality precisely manifests in this evolution, between the different gravity regimes : mapping between asymptotic (in and out) states characterized by the sets U_{Λ} (or U_{H}) and U_{Q}, and thus as a Scattering-matrix description: The Evolution of the Universe as a Scattering problem in time.

ÅThere 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

Euclid Consortium

A space mission to map the Dark Universe



Euclid is primarily a cosmology and fundamental physics mis
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 ~ 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.**

Important: H_0 value

Important: H(z) Measurements

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

We already know from Observations:

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

(Reiss et al, 2018, 2019)

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

THEORY & OBSERVATIONS

The direction in which data and Theory are pointing:

A Strategy for discoveries:

Å Standard Model of the Universe and its Quantum Precursor

Å Standard Single field Inflation: Double Well

Å r ~ 0.04 - 0.02

Å RUNNING of the Primordial Spectral Index 10^-4

Å SMALL PRIMORDIAL GAUSSIANITY : f_NL ~ 0.02

Å DARK ENERGY= VACUUM ENERGY = Λ

DARK MATTER = WARM DARK MATTER = keV

NO CUSP/CORE Problem, Profiles are Cored

And more in this direction….

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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- [3] N. G. Sanchez, *The New Quantum structure of the space-time,*
  J. Grav & Cosmology 25, pp 91-102, (2019)
  https://link.springer.com/article/10.1134/S0202289319020142

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

https://www.researchgate.net/profile/Norma_Sanchez12

THE NEW QUANTUM STRUCTURE OF THE SPACE-TIME

Å **THE CLASSICAL - QUANTUM DUALITY OF NATURE :**

Å $O_G = o_P^2 / O_Q$, $L_G = l_P^2 / L_Q$, $L_G = 2GM/c^2$, $L_Q = h/Mc$

Å **THE SPACE TIME (X, T) Coordinates as**
Å **QUANTUM NON COMMUTING OPERATORS :** $[X, T] = 1$

° **THE SPACE-TIME AS a QUANTUM HARMONIC OSCILLATOR :**

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

P = iT :

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

QUANTUM SPACE-TIME

$$Å\,(T^2 - X^2) - 1 \geq 0 : \textit{timelike}$$

$$Å\,(X^2 - T^2) - 1 \geq 0 : \textit{spacelike}$$

$$Å\,(T^2 - X^2) - 1 = 0, \textit{ null : the "quantum light- cone".}$$

$$\mathbf{(X^2 - T^2)_n = 2n + 1 : \text{discrete levels}}$$

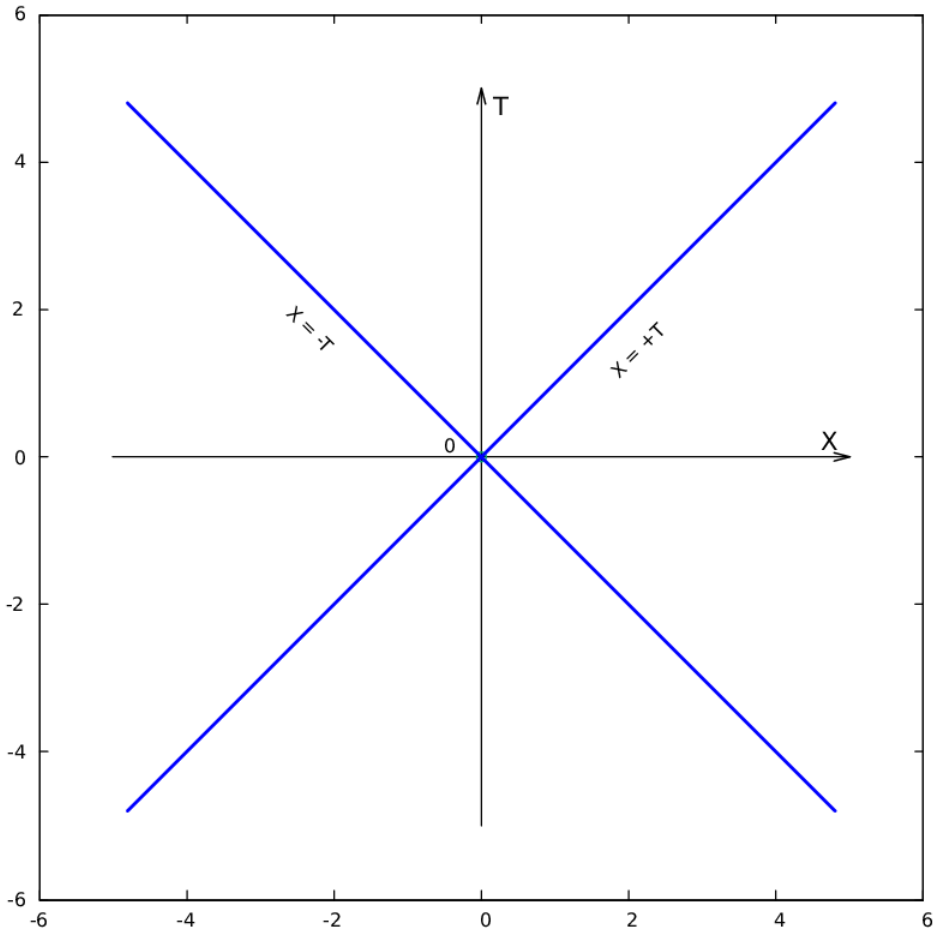
$$(X^2 - T^2) = \pm[X, T] = \pm 1, \quad 1 = 2\varepsilon_0, \quad (n = 0)$$

the quantum light cone

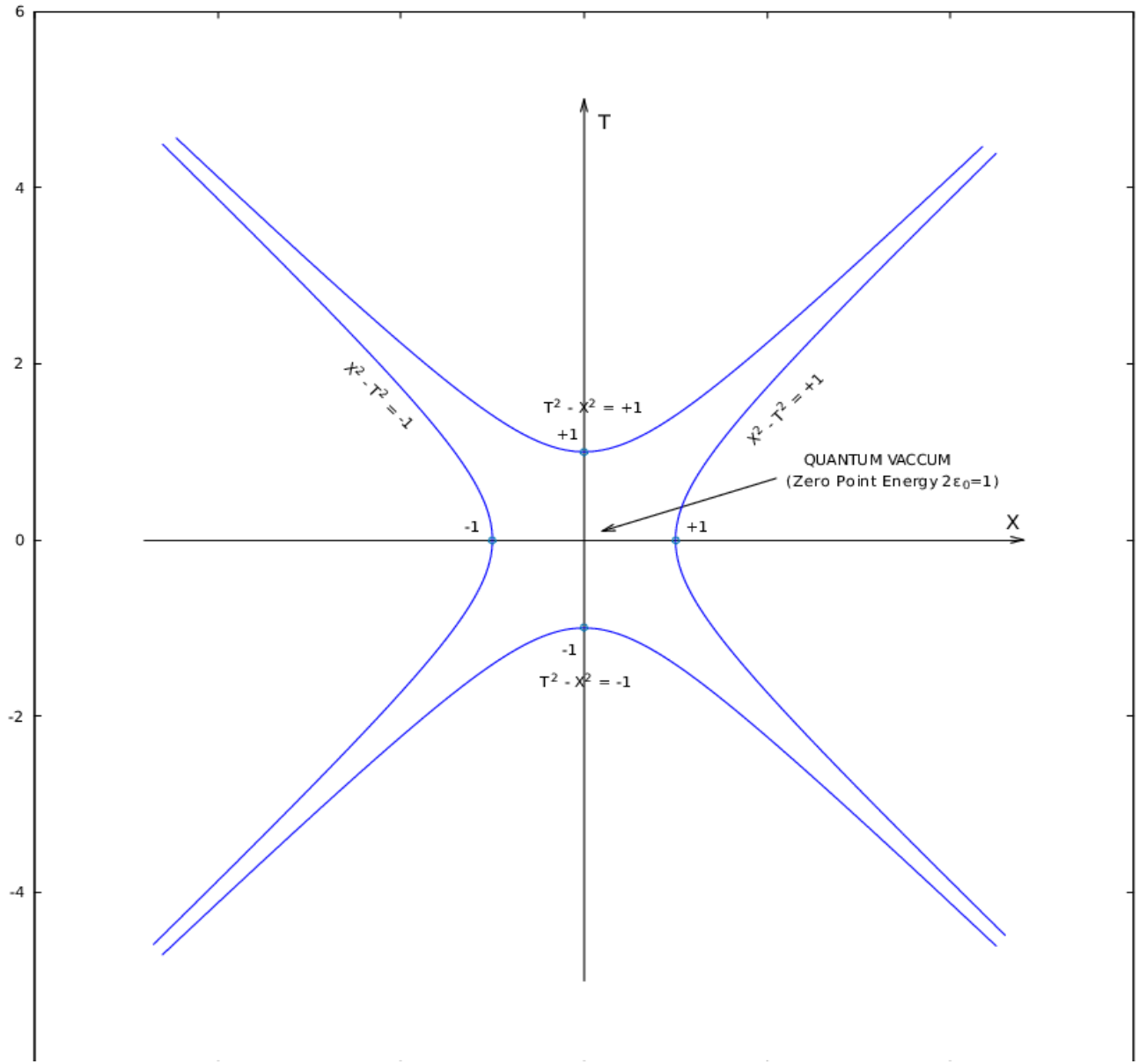
$$Å\,[X, T] = 0 : \quad X = \pm T$$

the classical light cone.

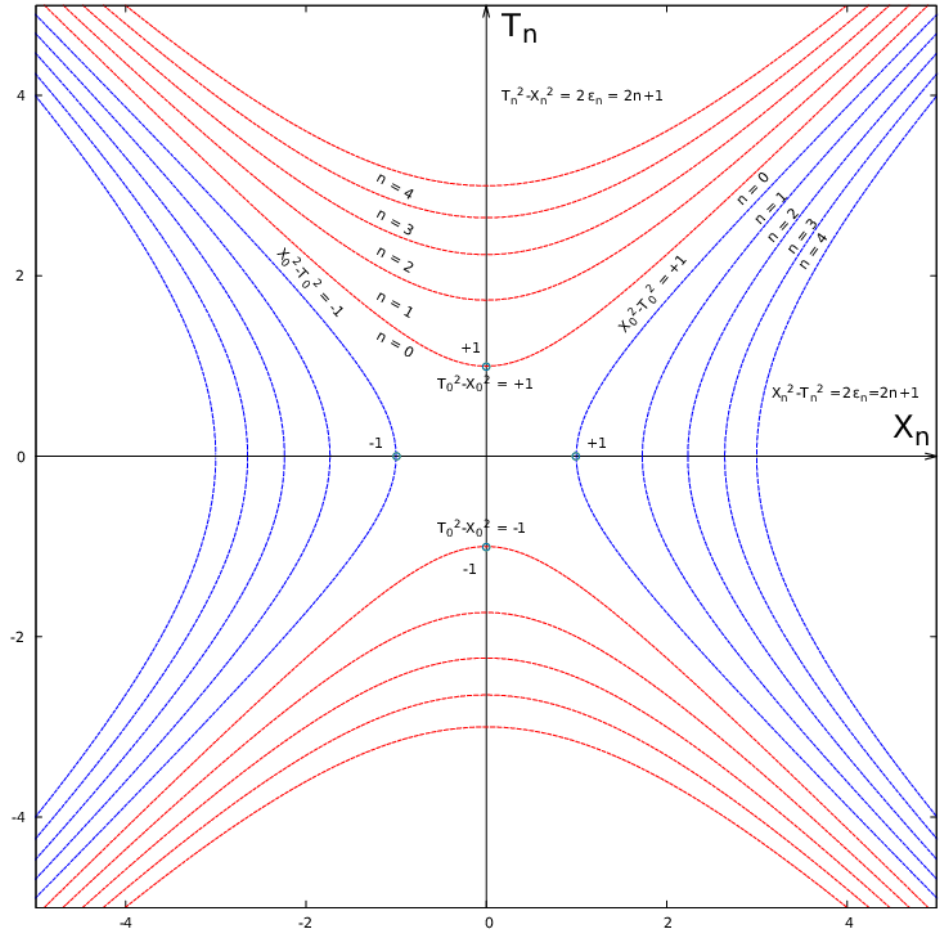
THE CLASSICAL LIGHT CONE

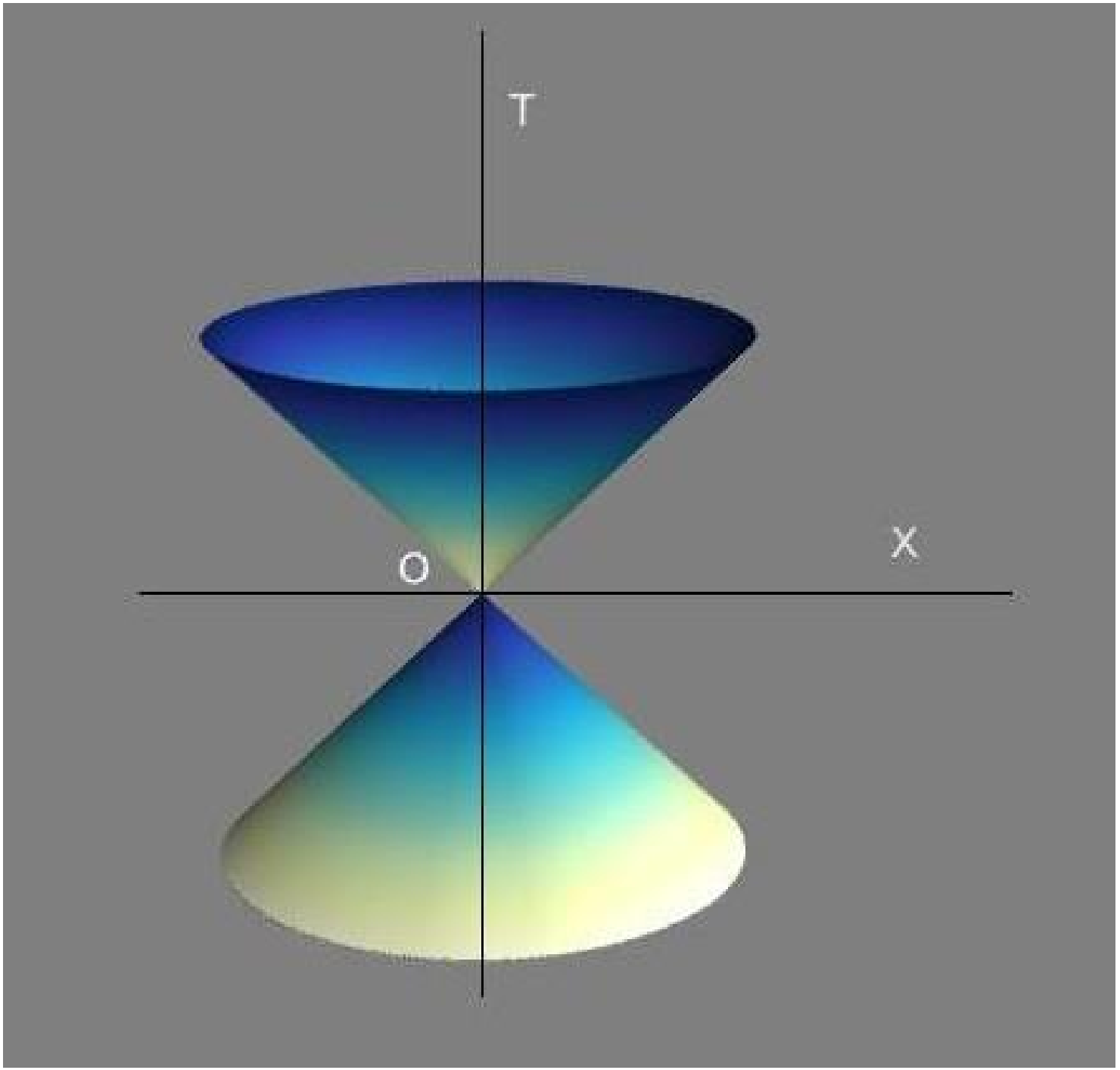


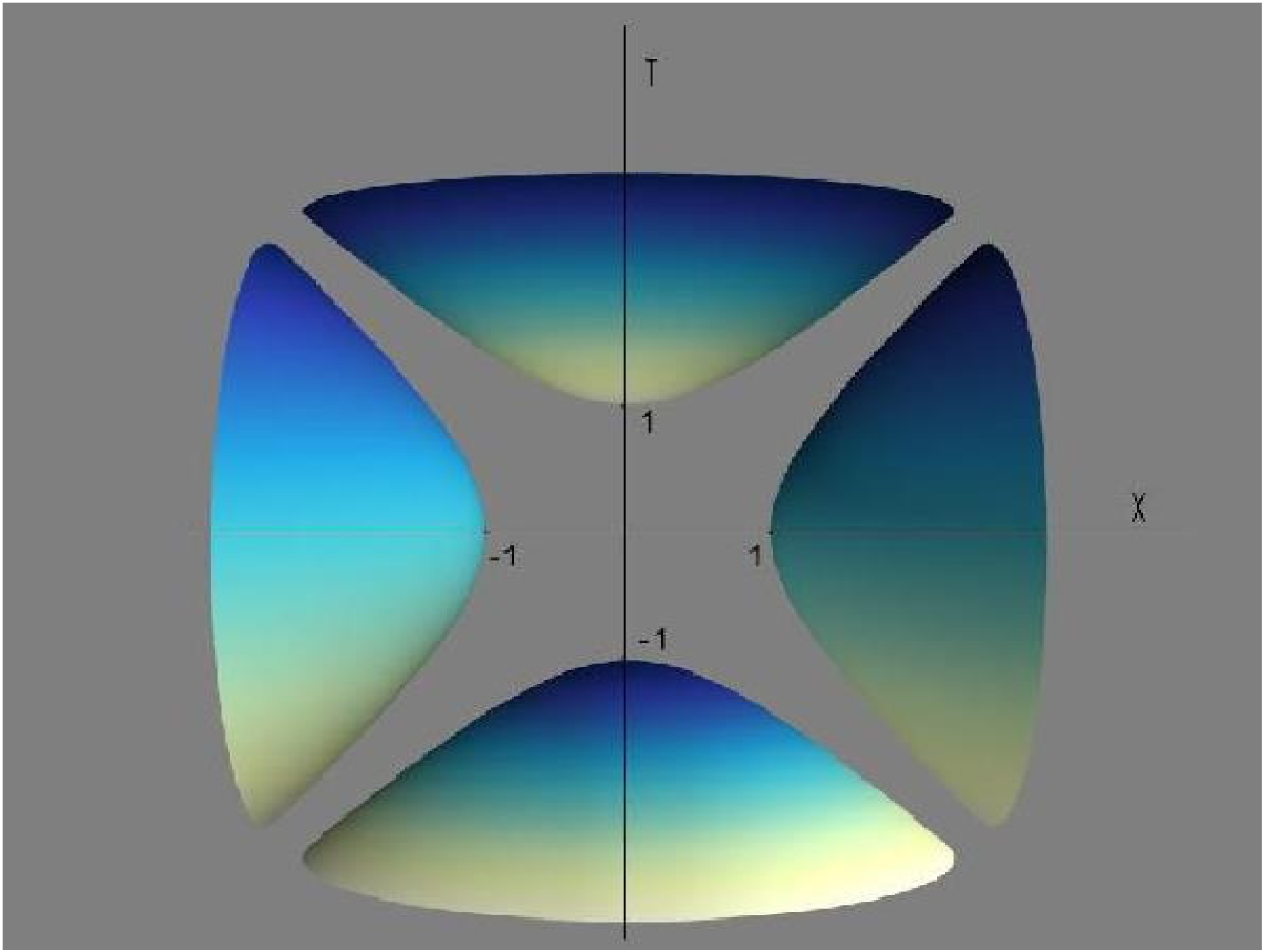
THE QUANTUM LIGHT CONE



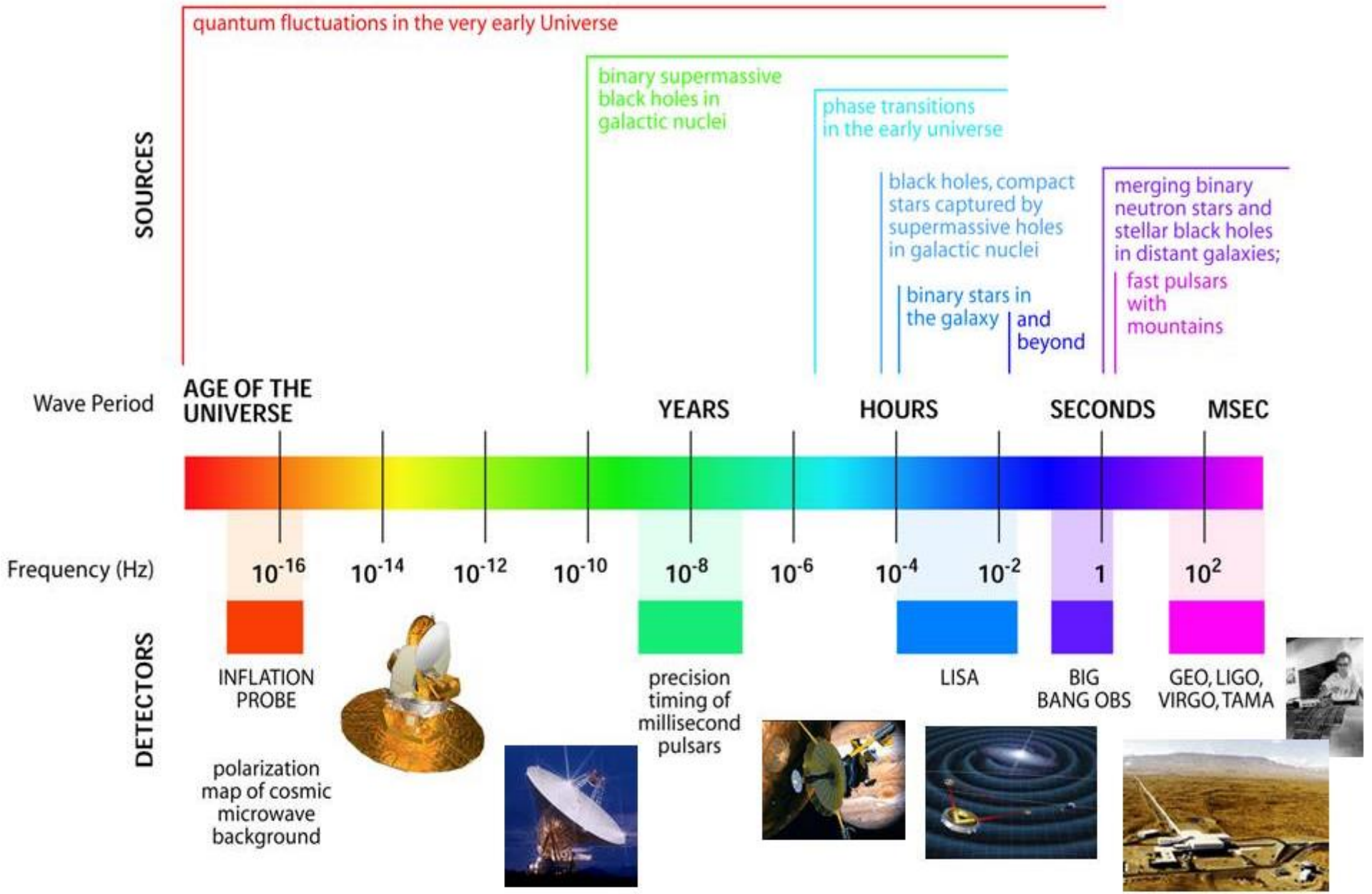
QUANTUM SPACE-TIME STRUCTURE



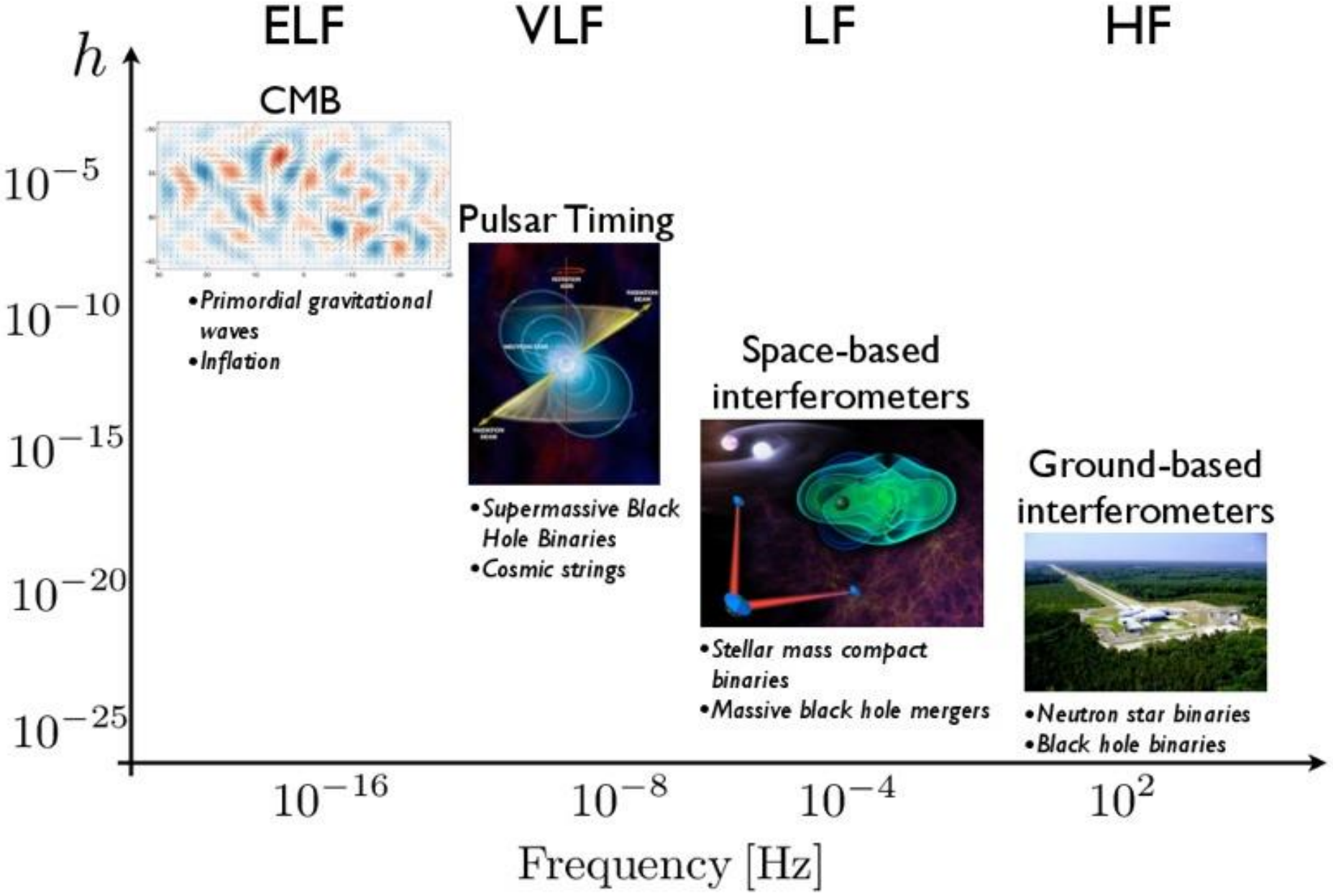

T
X
O


T
1
-1
1
X
-1

THE GRAVITATIONAL WAVE SPECTRUM



The big picture of gravitational wave astronomy



Å ***Science is built up with facts,***

Å ***as a house is with stones.***

Å ***But a collection of facts is no more a science***

Å ***than a heap of stones is a house.***

-- **Henri Poincaré**

Å ***La science est construit avec des faits,***

Å ***ainsi comme une maison est construite***

Å ***avec des pierres.***

Å ***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).

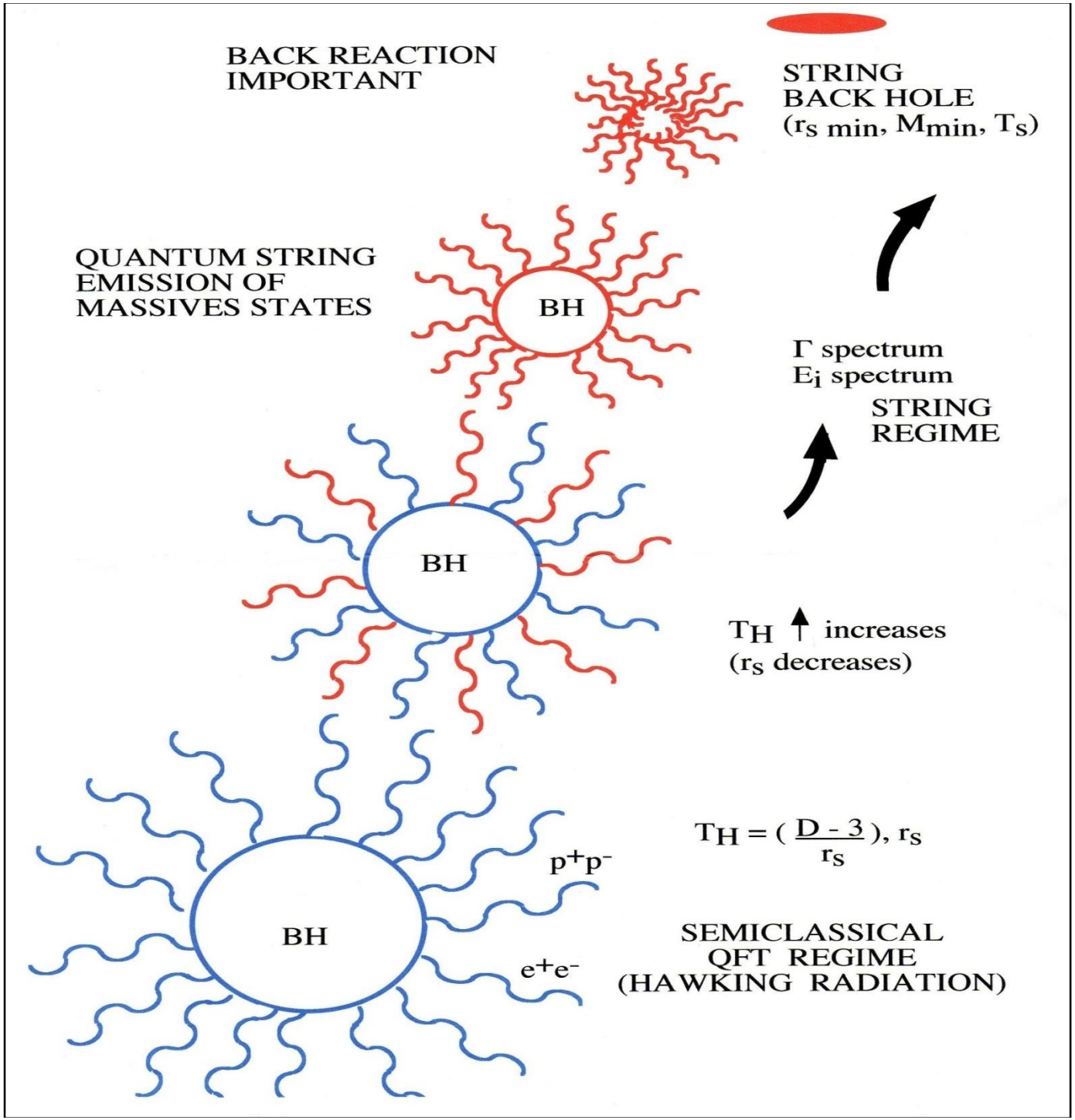
Conceptual unification of quantum black holes, elementary particles and quantum states

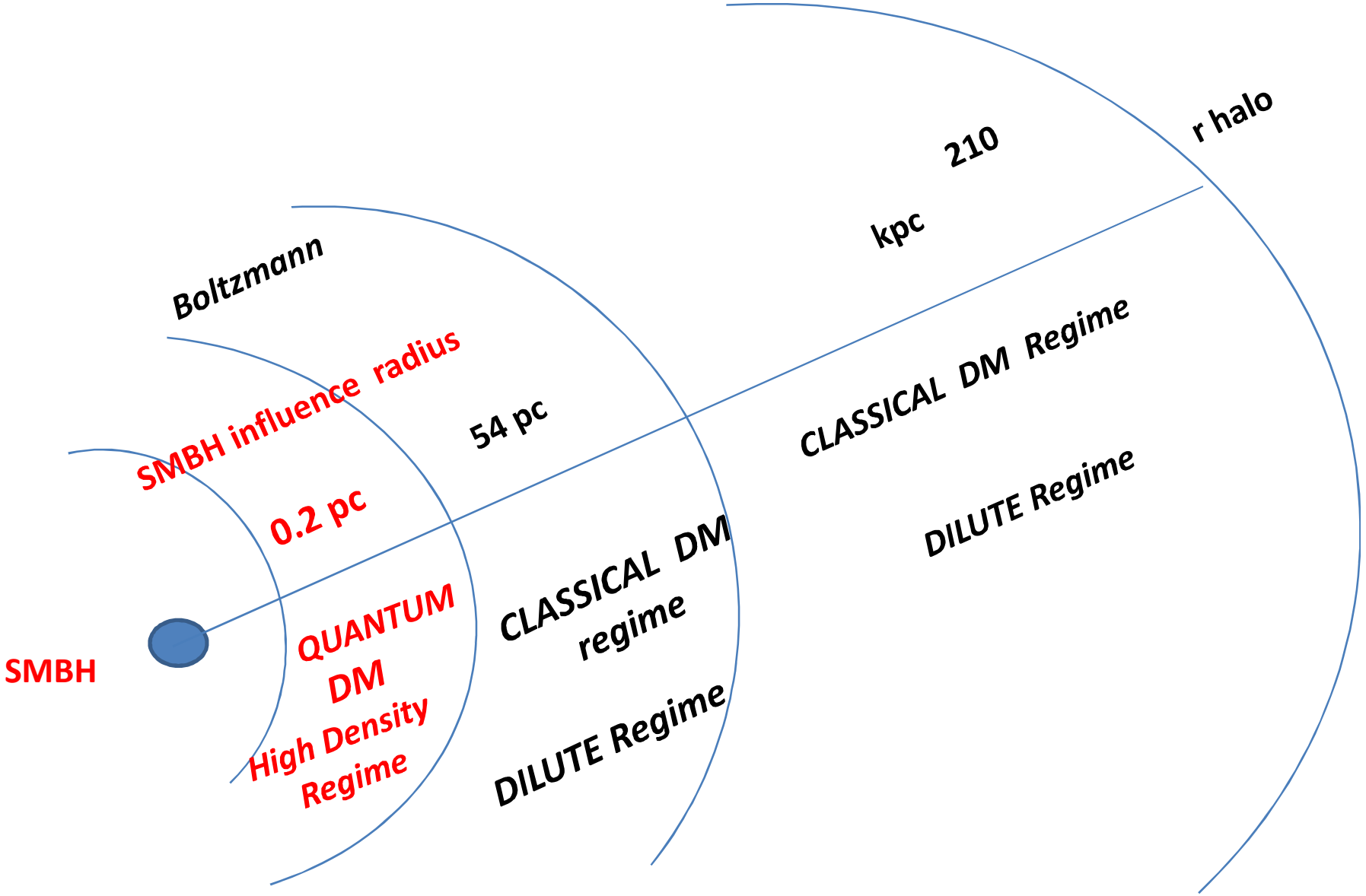
CONCEPTUAL UNIFICATION

- **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.**

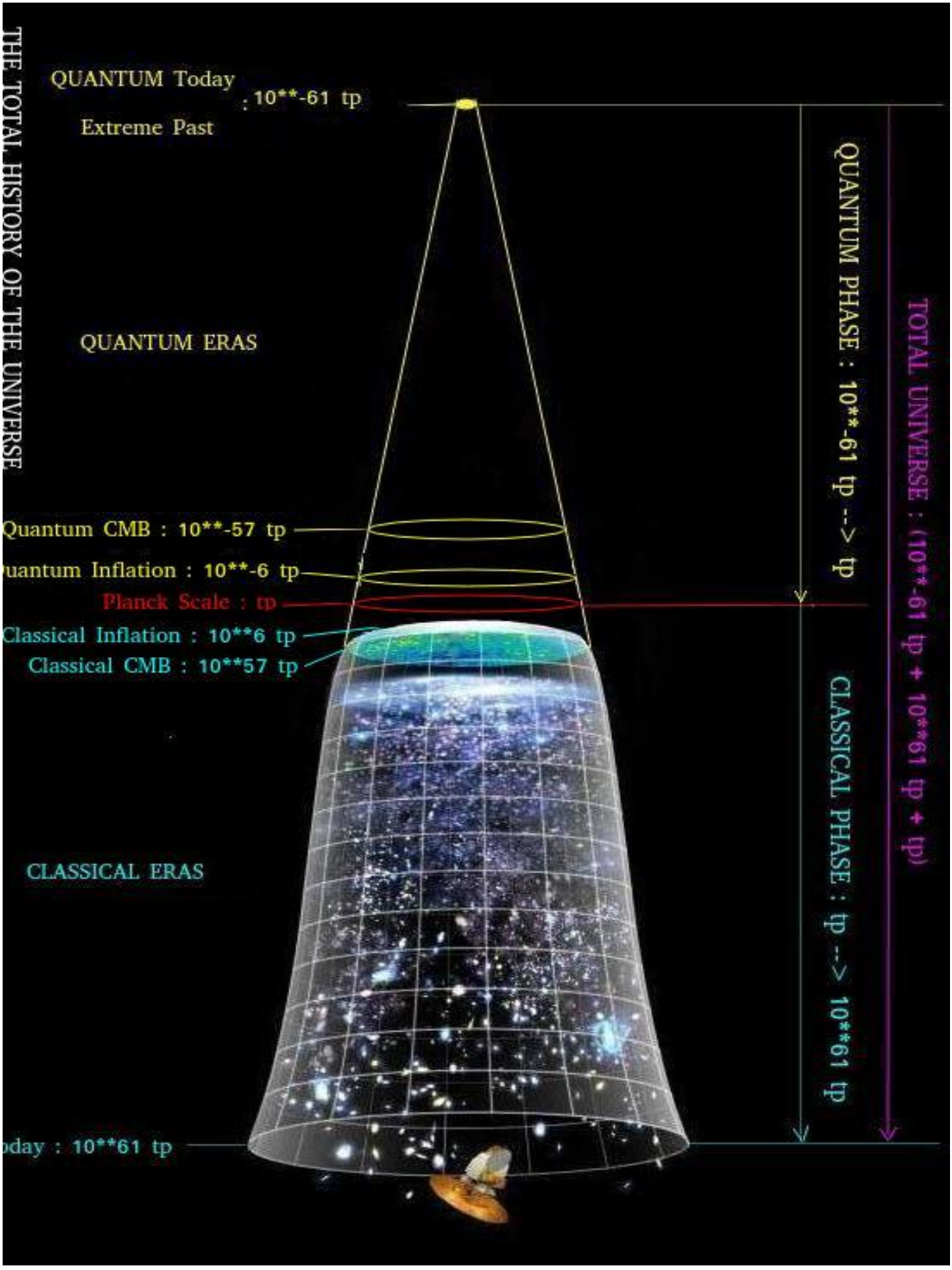
- **The Hawking temperature, elementary particle and Hagedorn (string) temperatures are the same concept in different gravity regimes (classical, semiclassical, quantum) and turn out to be the precise classical-quantum duals of each other.**


BACK REACTION
IMPORTANT
STRING
BACK HOLE
($r_{S\,min}$, M_{min}, T_S)
QUANTUM STRING
EMISSION OF
MASSIVES STATES
BH
BH
BH
Γ spectrum
E_i spectrum
STRING
REGIME
T_H ↑ increases
(r_S decreases)
$T_H = \left(\frac{D-3}{r_S}\right), r_S$
p^+p^-
e^+e^-
SEMICLASSICAL
QFT REGIME
(HAWKING RADIATION)



WDM Thomas-Fermi Galaxy Theory with SMBH

de Vega & Sanchez, 2017


THE TOTAL HISTORY OF THE UNIVERSE
QUANTUM Today
: 10**-61 tp
Extreme Past
QUANTUM ERAS
Quantum CMB : 10**-57 tp
uantum Inflation : 10**-6 tp
Planck Scale : tp
Classical Inflation : 10**6 tp
Classical CMB : 10**57 tp
CLASSICAL ERAS
oday : 10**61 tp
QUANTUM PHASE : 10**-61 tp --> tp
CLASSICAL PHASE : tp --> 10**61 tp
TOTAL UNIVERSE : (10**-61 tp + 10**61 tp + tp)

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

ñé nature isnôt classical, dammit, and if you want to make a simulation of nature, youôd better make it quantum mechanical, and by golly itôs a wonderful problem, because it doesnôt look so easy.ò

Feynman again:

ñIt doesnôt matter how beautiful your theory is, it doesnôt matter how smart you are. If it doesnôt agree with experiment, itôs wrong.

THANK YOU VERY MUCH
FOR YOUR ATTENTION!!