Quantum Universe, H0 and Dark Energy

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CONTENTS

Planckian and transplanckian energies are **theoretically allowed, physically motivated too,**

the universe and its very early stages <u>have all the quantum conditions for such extreme quantum gravitational regimes and energies, the black hole interiors too.</u>

The truly quantum gravity domain is not reduced to be fixed at the planck scale or the neighborhoods of it, but extends deep beyond

Quantum theory is more complete than classical theory and tells us what value a classical observable should have.

<u>The classical-quantum (or wave-particle) duality is a robust and universal concept</u>

(It does not depend on the nature or number of space-time dimensions, compactified or not, nor on particular space-time geometries, topologies, symmetries, nor on other at priori condition.

Moreover, the quantum trans-planckian eras in the far past universe determine the observables of the post-planckian eras,

e.g. the inflation observables, CMB and the cosmological vacuum energy until today dark energy,

Namely the evolution from the quantum very early phases to the semi-classical and classical phases and the arrow of time as determined by the gravitational entropy.

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- [2] **N. G. Sanchez,** ***The Classical-Quantum Duality of Nature: New variables for Quantum Gravity,***
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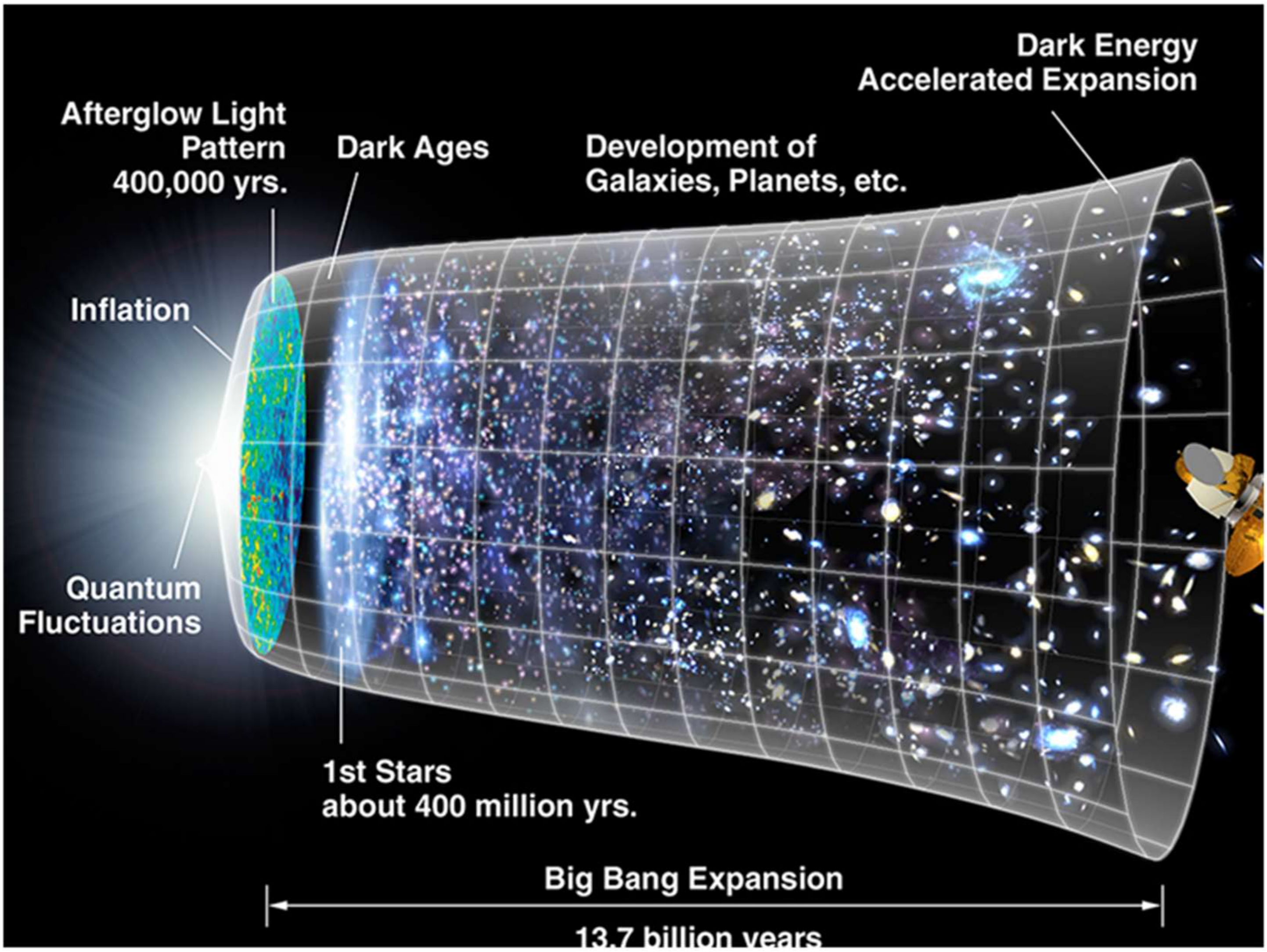
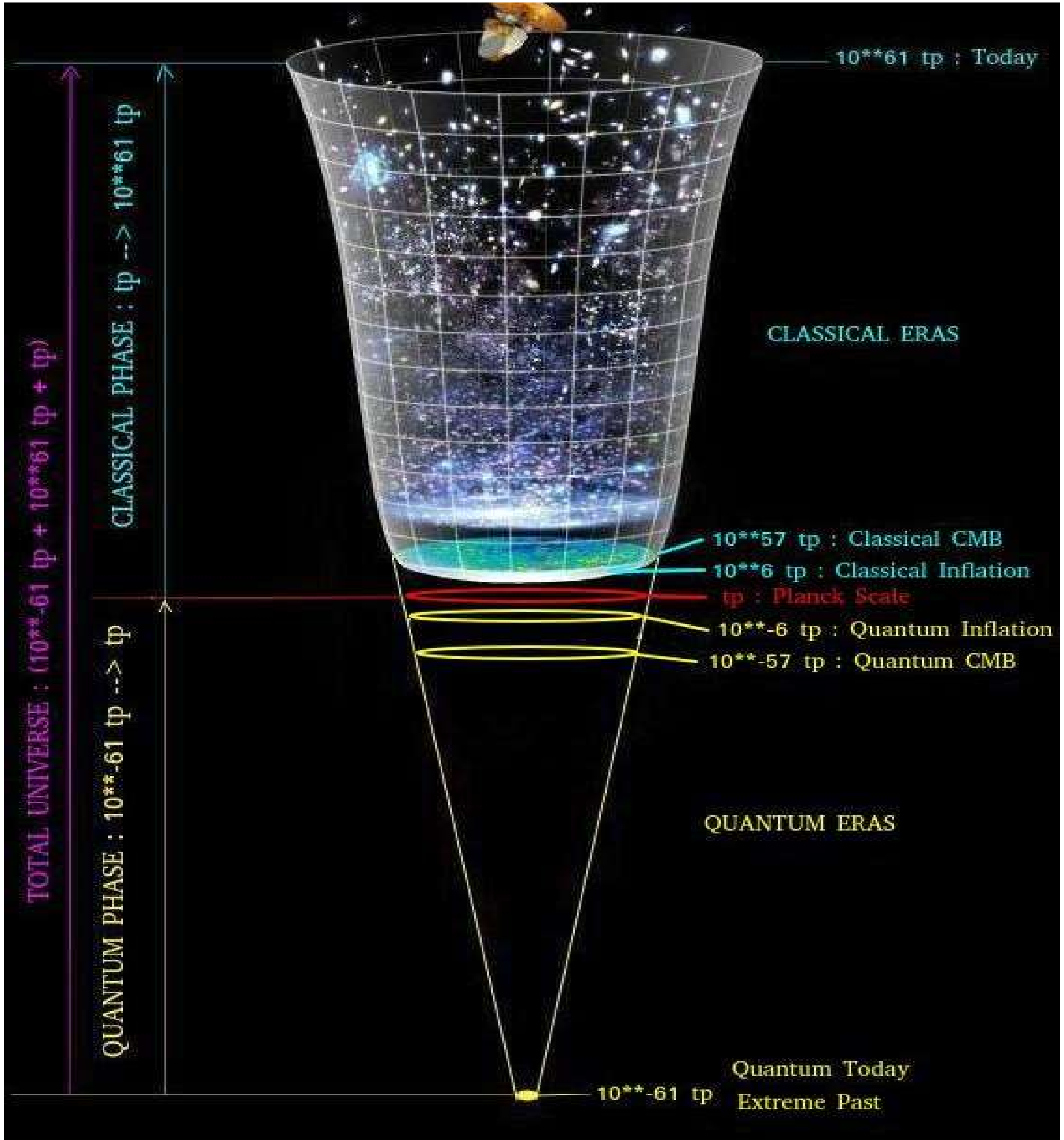
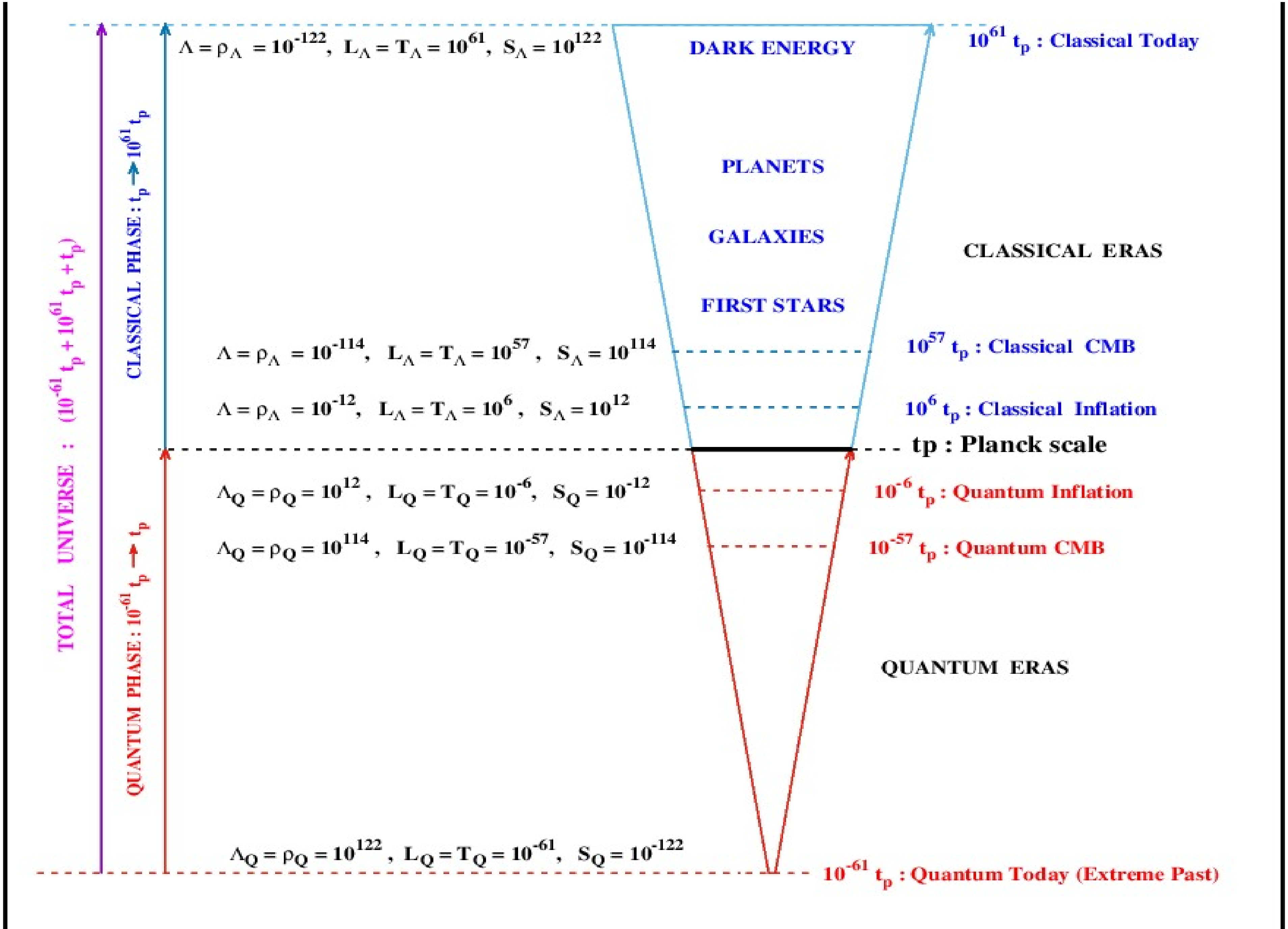

Afterglow Light Pattern 400,000 yrs.
Dark Ages
Development of Galaxies, Planets, etc.
Dark Energy Accelerated Expansion
Inflation
Quantum Fluctuations
1st Stars about 400 million yrs.
Big Bang Expansion
13.7 billion years



THE TOTAL HISTORY OF THE UNIVERSE



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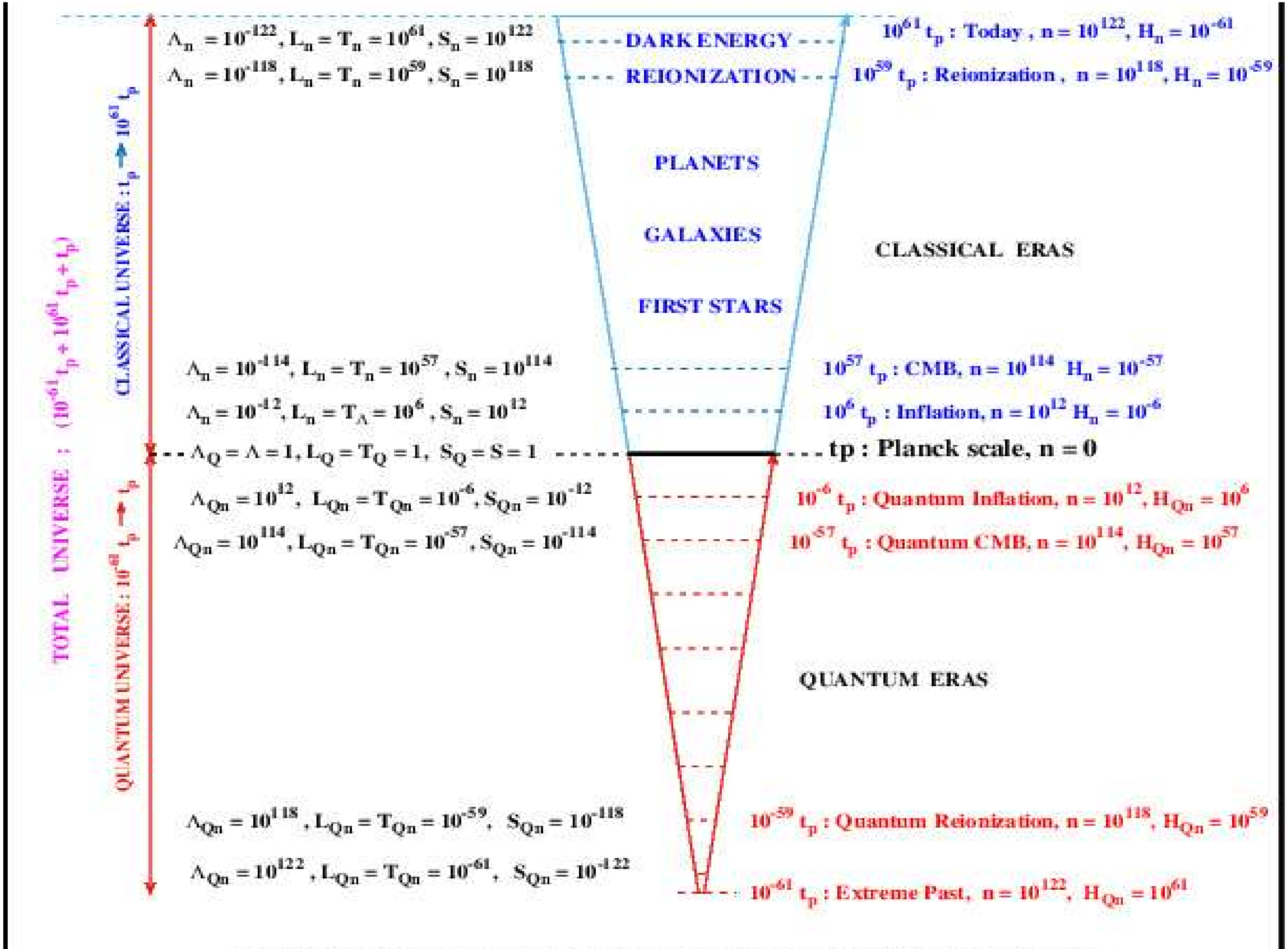


QUANTUM DISCRETE LEVELS OF THE UNIVERSE AND THEIR TOTAL HISTORY

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 FUNDAMENTAL PLANCK SCALE

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

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

$$G/c^2 = l_P/m_P, \qquad l_P\, m_P = h/c$$

$l_P = 10^{-33}$ 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 : $L_{QG} = L_Q + L_G$, $O_{QG} = O_Q + O_G$, $Q \text{<-->} G$

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

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

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

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

$$U_Q = (L_Q, M_Q, \rho_Q, T_Q, S_Q)\text{: Quantum Universe}$$

$$U_Q = u_P^{\,2} / U_\Lambda$$

$$u_P = (l_P, m_P, \rho_P, t_P, s_P)\text{: Planck Scale}$$

***The crossing scale** between the two gravity domains*

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

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

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

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:

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

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:*

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

NEW RESULTS FOR DARK ENERGY

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

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 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.

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

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

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

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

$$\rho_Q = \rho_P\, (\Lambda_Q / \lambda_P) = \rho_P^2 / \rho_\Lambda = 10^{122}\, \rho_P$$

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 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 transplanckian physics dual*** *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 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

$$\frac{\Lambda}{\lambda P} = \frac{\rho\Lambda}{\rho P} = \frac{SQ}{sP} = \frac{\lambda P}{\Lambda Q} = \left(\frac{TQ}{tP}\right)^2 = 10^{-122}$$

$$\frac{\Lambda Q}{\lambda P} = \frac{\rho Q}{\rho P} = \frac{S\Lambda}{sP} = \frac{\lambda P}{\Lambda} = \left(\frac{T\Lambda}{tP}\right)^2 = 10^{+122}$$

$$\Lambda_{\Lambda Q} = \Lambda + \Lambda_Q + \lambda P = \lambda P \left(\frac{\Lambda}{\lambda P} + \frac{\lambda P}{\Lambda} + 1\right)$$

$$\Lambda_{\Lambda Q} = \lambda P \left(10^{-122} + 10^{+122} + 1\right)$$

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	$\mathbf{2.6 \pm 0.3 \times 10^{122}}$

THE QUANTUM STRUCTURE OF THE SPACE-TIME

- **THE CLASSICAL - QUANTUM DUALITY OF NATURE :**
- $O_G = o_P^2 / O_Q$, $L_G = l_P^2 / L_Q$, $L_G = 2GM / c^2$, $L_Q = h / Mc$
- **THE SPACE TIME (X, T) Coordinates as**
- **QUANTUM NON COMMUTING OPERATORS :** $[X, T] = 1$

° THE SPACE-TIME AS a QUANTUM HARMONIC OSCILLATOR :

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

$P = iT$:

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

QUANTUM SPACE-TIME

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

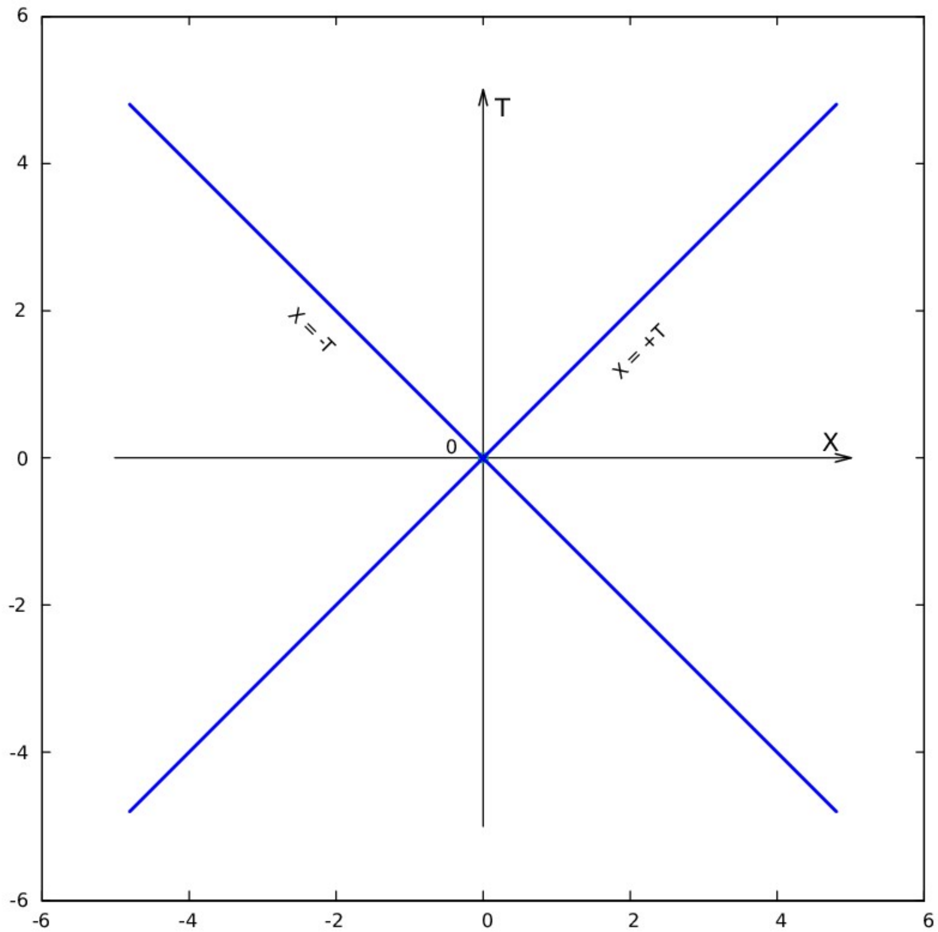
$$(X^2 - T^2)_n = 2n + 1$$ **: discrete levels**

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

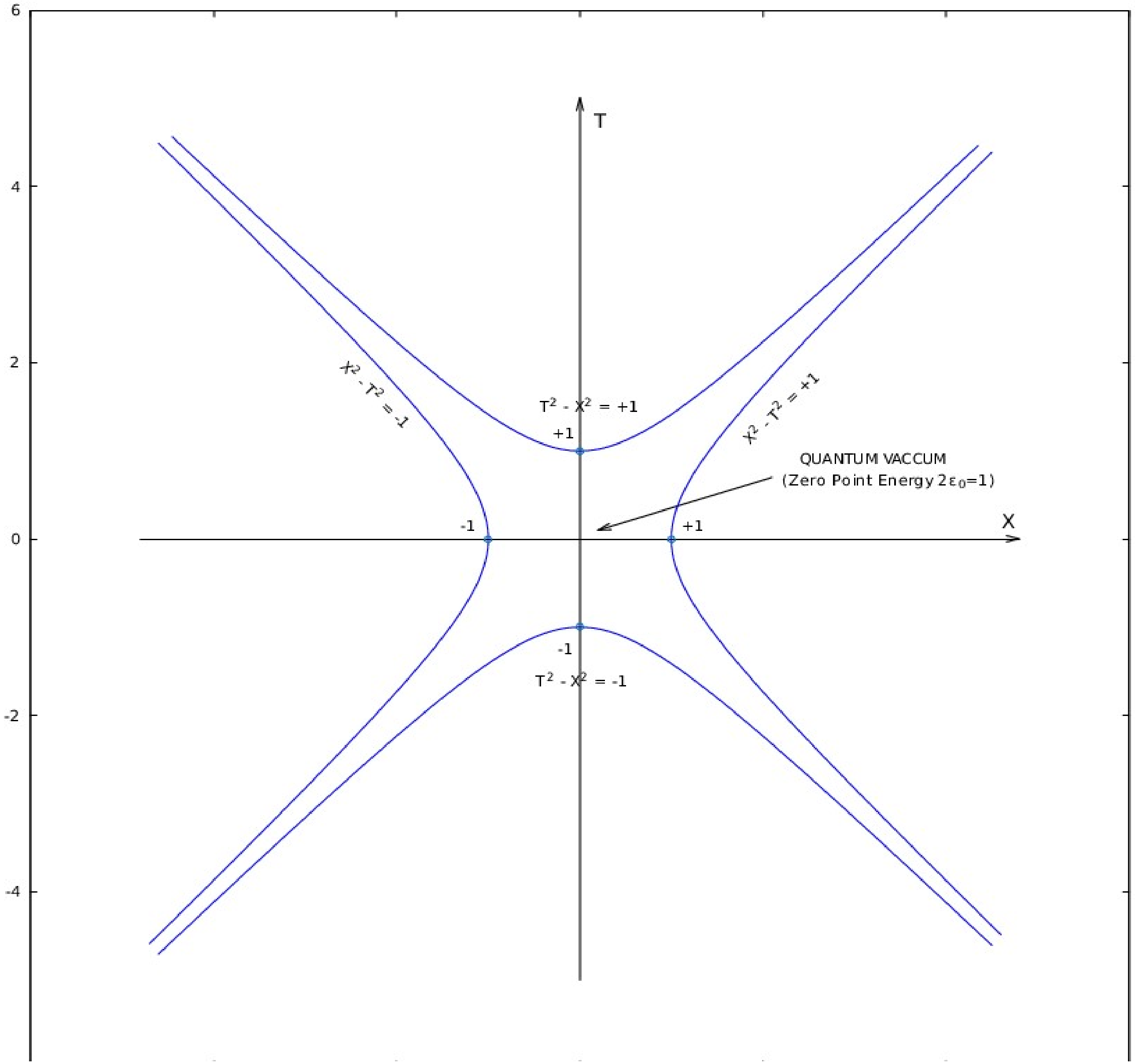
the quantum light cone

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

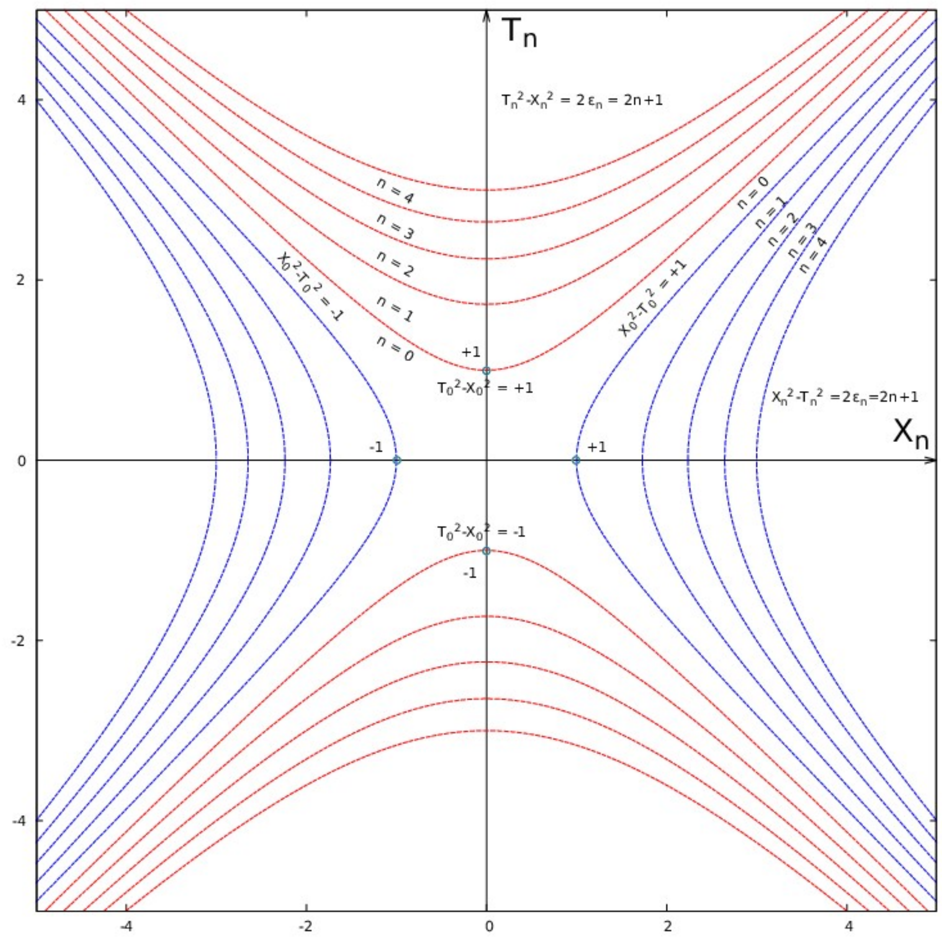
THE CLASSICAL LIGHT CONE

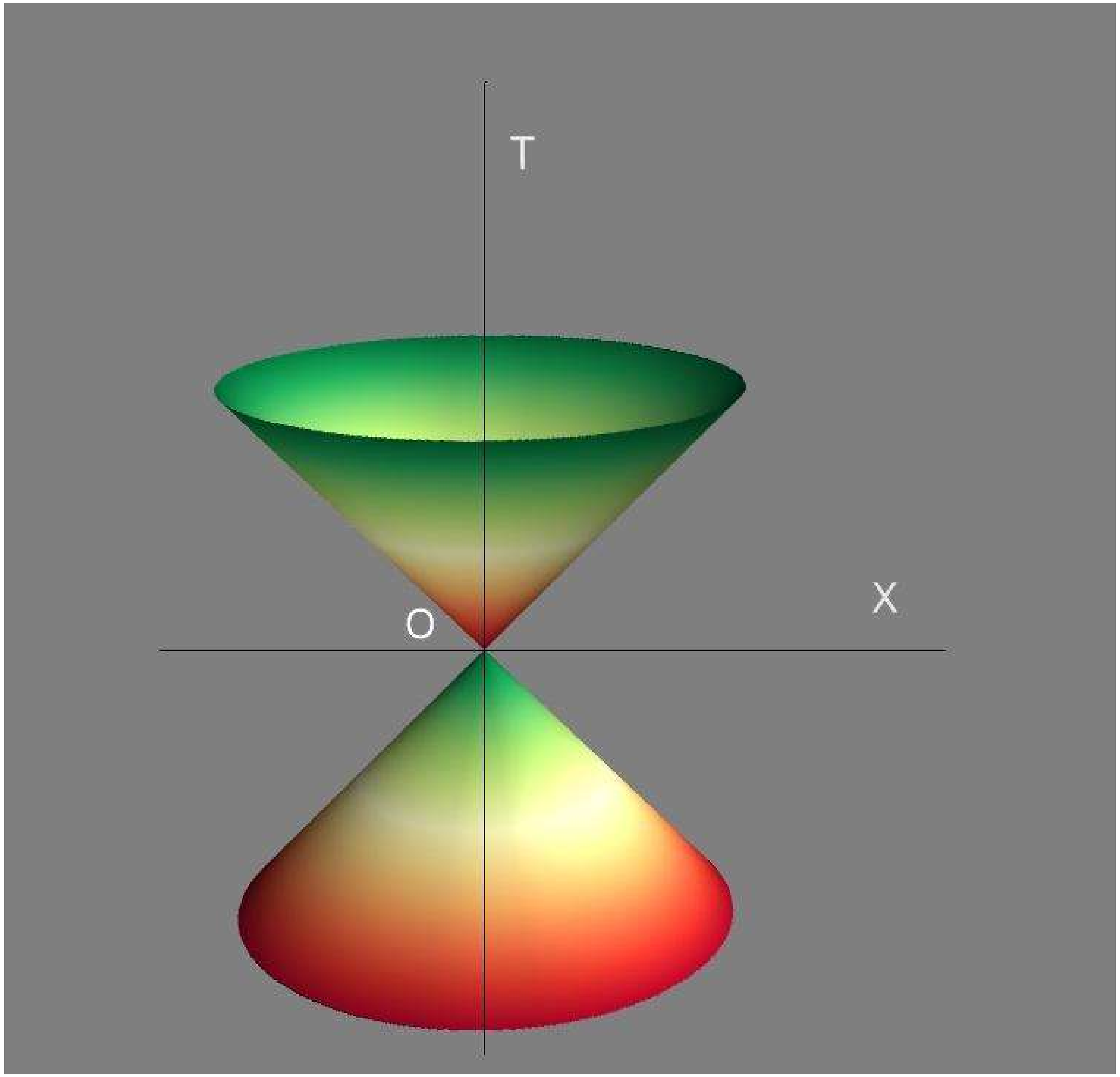


THE QUANTUM LIGHT CONE

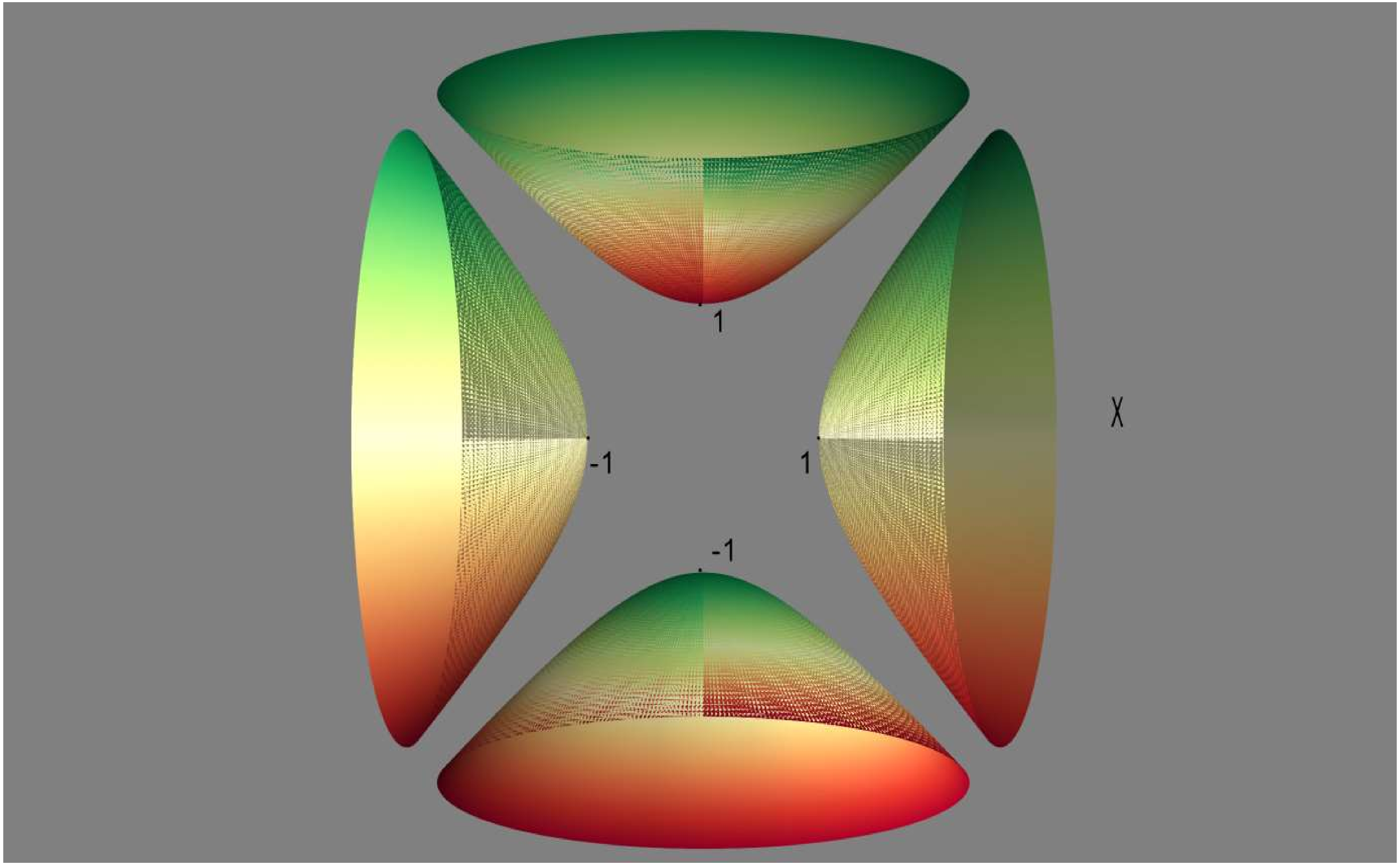


QUANTUM SPACE-TIME STRUCTURE





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).

$(X_n^2 - T_n^2) = \pm 1$, $(n = 0)$ and the quantum levels (low n) until the quasi-classical and classical ones (intermediate and large n), tend asymptotically (very large n) to a continuum classical space-time. In the trans-planckian domain: times and lengths smaller than the planck scale, the (X_n, T_n) levels are $1/(2n+1)$, the most higher n being the more excited quantum and transplanckian ones.

For each level $n = 0, 1, 2, ...,$ the two: post and pre (trans) - planckian phases are covered: In the post-planckian universe $t_P \equiv t_{planck} < t \leq t_{today} = 10^{61} t_P$ the levels (in planck units) for the Hubble constant H_n, vacuum energy Λ_n, and gravitational (Gibbons-Hawking) entropy S_n are

$$\boxed{H_n = 1/\sqrt{(2n+1)}, \;\; \Lambda_n = 1/(2n+1), \;\; S_n = (2n+1), \; n = 0, 1, 2, ...} \tag{1.1}$$

As n increases, radius and mass increase, H_n and Λ_n decrease, S_n increases and *consistently* the universe *classicalizes*. In the pre-planckian (trans-planckian) phase $10^{-61} t_P \leq t \leq t_P$, the quantum trans-plankian levels (Q denoting quantum) are:

$$\boxed{H_{Qn} = \sqrt{(2n+1)}, \;\; \Lambda_{Qn} = (2n+1), \;\; S_{Qn} = 1/(2n+1), \; n = 0, 1, 2, ...} \tag{1.2}$$

The scalar curvature levels in the respective phases being $R_{Qn} = (2n+1)$ and $R_n = 1/(2n+1)$

Hawking) entropy S_n are

$$H_n = 1/\sqrt{(2n+1)}, \;\; \Lambda_n = 1/(2n+1), \;\; S_n = (2n+1), \; n = 0, 1, 2, ... \tag{1.1}$$

As n increases, radius and mass increase, H_n and Λ_n decrease, S_n increases and *consistently* the universe *classicalizes*. In the pre-planckian (trans-planckian) phase $10^{-61} t_P \leq t \leq t_P$, the quantum trans-plankian levels (Q denoting quantum) are:

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The scalar curvature levels in the respective phases being $R_{Qn} = (2n+1)$ and $R_n = 1/(2n+1)$. The n-levels cover *all* scales from the remote past highly excited trans-planckian level $n = 10^{122}$ with maximum curvature $R_Q = 10^{122}$, vacuum $\Lambda_Q = 10^{122}$ and minimum entropy $S_Q = 10^{-122}$, n decreases passing the planck level $n = 0$: $H_{planck} = 1 = \Lambda_{planck} = S_{planck}$ and enters the post-planckian phase: $n = 1, 2, ...n_{infl} = 10^{12}, ...n_{cmb} = 10^{114}, ...n_{reion} = 10^{118}, ...n_{today} = 122$ with the most classical value $H_{today} = 10^{-61}$, $\Lambda_{today} = 10^{-122}$, $S_{today} = 10^{122}$.

The space-time (the arena of events) in the quantum domain is described by *a quantum algebra* of space-time position and momenta: We implement the *Snyder-Yang* algebra in the cosmological context thus yielding a consistent group-theory realization of quantum discrete de Sitter space-time, classical-quantum gravity duality and its symmetry with a clarifying

$$H_{Qn} = \sqrt{(2n+1)}, \quad \Lambda_{Qn} = (2n+1), \quad S_{Qn} = 1/(2n+1), \; n = 0, 1, 2, ... \tag{1.2}$$

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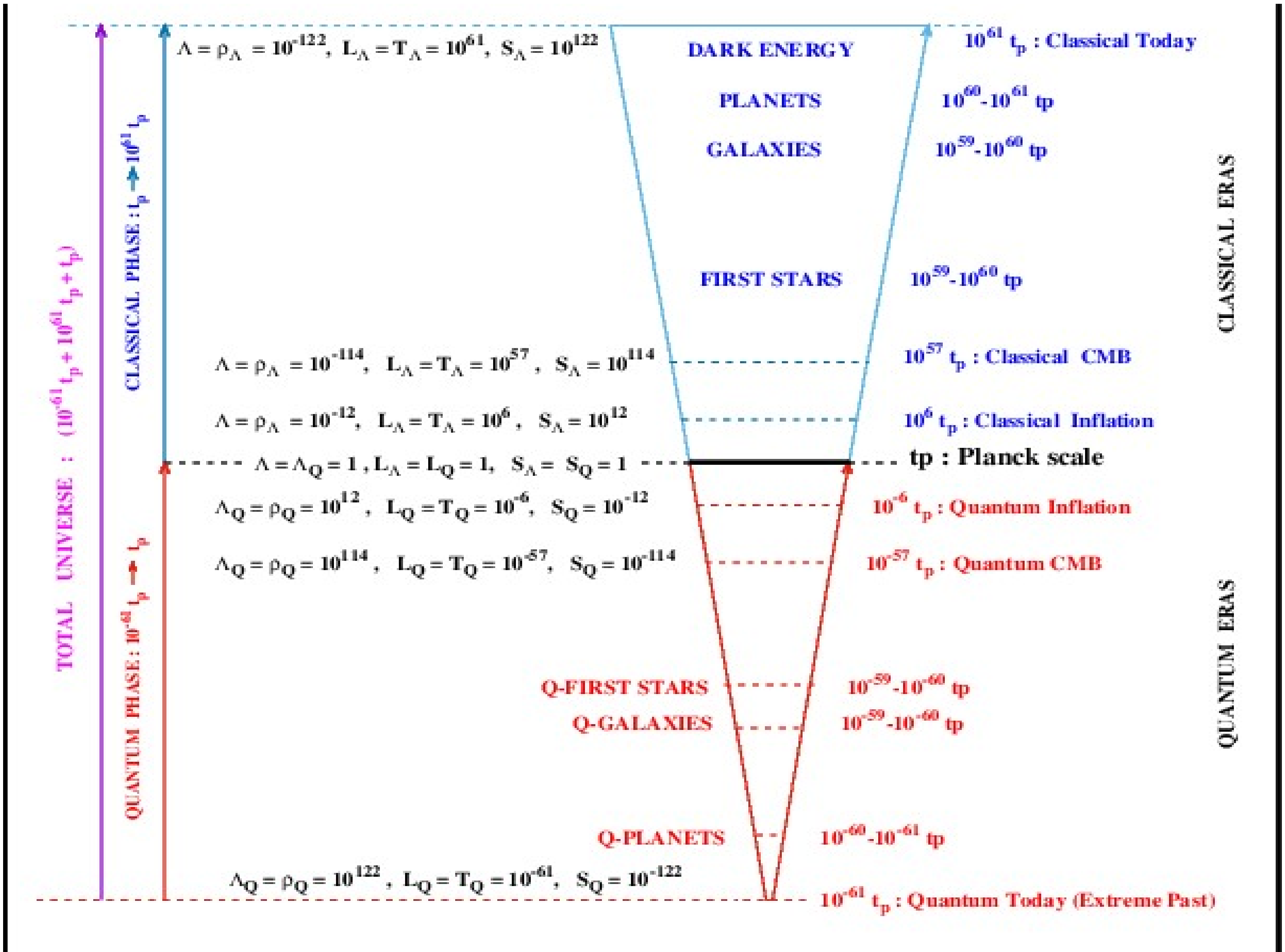
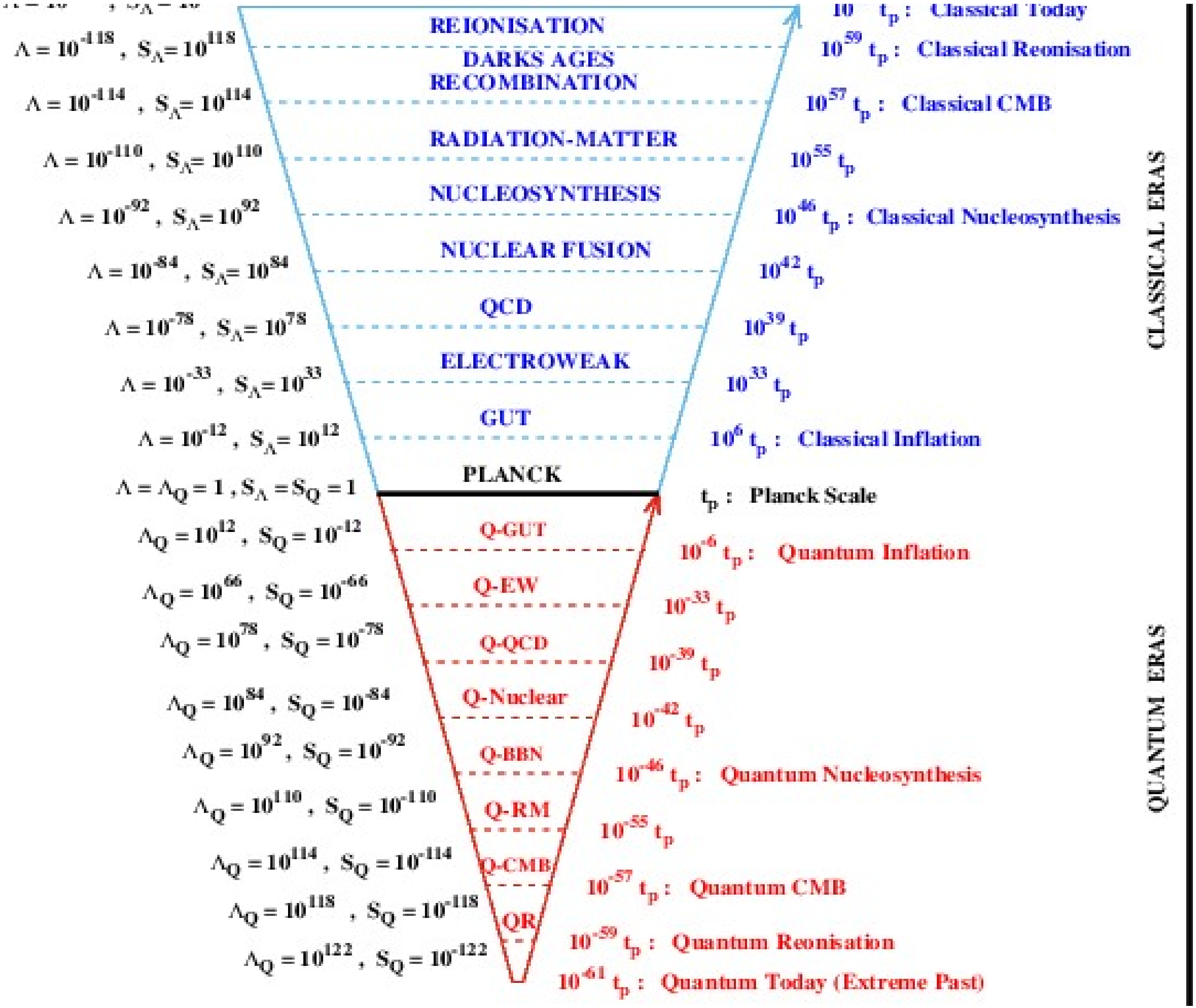
The space-time (the arena of events) in the quantum domain is described by *a quantum algebra* of space-time position and momenta: We implement the *Snyder-Yang* algebra in the cosmological context thus yielding a consistent group-theory realization of quantum discrete de Sitter space-time, classical-quantum gravity duality and its symmetry with a clarifying unifying picture: Our complete (classical and quantum) length $L_{QH}(l_P, L_H) = L_Q + L_H = l_P(L_H/l_P + l_P/L_H)$, L_H being the classical universe radius, $L_Q = l_P^2/L_H$ being its quantum size (the compton length), turns out to be the appropriate length for the two-parameter Snyder-Yang algebra, thus providing a quantum operator realization of the complete de Sitter universe including the quantum trans-planckian and classical late de Sitter phases.



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
$\Lambda = 10^{-118}$, $S_\Lambda = 10^{118}$
$\Lambda = 10^{-114}$, $S_\Lambda = 10^{114}$
$\Lambda = 10^{-110}$, $S_\Lambda = 10^{110}$
$\Lambda = 10^{-92}$, $S_\Lambda = 10^{92}$
$\Lambda = 10^{-84}$, $S_\Lambda = 10^{84}$
$\Lambda = 10^{-78}$, $S_\Lambda = 10^{78}$
$\Lambda = 10^{-33}$, $S_\Lambda = 10^{33}$
$\Lambda = 10^{-12}$, $S_\Lambda = 10^{12}$
$\Lambda = \Lambda_Q = 1$, $S_\Lambda = S_Q = 1$
$\Lambda_Q = 10^{12}$, $S_Q = 10^{-12}$
$\Lambda_Q = 10^{66}$, $S_Q = 10^{-66}$
$\Lambda_Q = 10^{78}$, $S_Q = 10^{-78}$
$\Lambda_Q = 10^{84}$, $S_Q = 10^{-84}$
$\Lambda_Q = 10^{92}$, $S_Q = 10^{-92}$
$\Lambda_Q = 10^{110}$, $S_Q = 10^{-110}$
$\Lambda_Q = 10^{114}$, $S_Q = 10^{-114}$
$\Lambda_Q = 10^{118}$, $S_Q = 10^{-118}$
$\Lambda_Q = 10^{122}$, $S_Q = 10^{-122}$
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

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 vacuum energy 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.

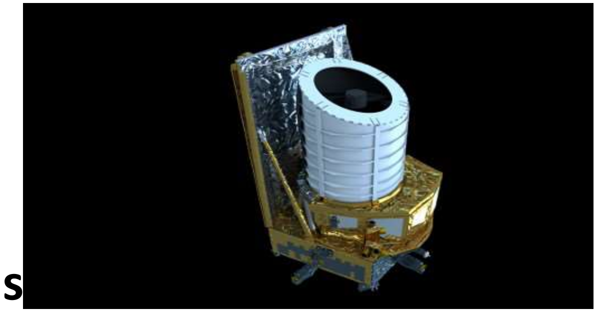
• The wave-particle-gravity duality precisely manifests in this evolution, between the different gravity regimes : mapping between asymptotic (in and out) states characterized by the sets U_{Λ} (or U_{H}) and U_{Q}, and thus as a Scattering-matrix description: The Evolution of the Universe as a Scattering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

• 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 trans-planckian 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:

- **Standard Model of the Universe and its Quantum Precursor**
- **Standard Single field Inflation: Double Well**
- **$r \sim 0.04 - 0.02$**
- **RUNNING of the Primordial Spectral Index 10^{-4}**
- **SMALL PRIMORDIAL NON GAUSSIANITY : $f_{NL} \sim 0.02$**
- **DARK ENERGY= VACUUM ENERGY = Λ**

DARK MATTER = WARM DARK MATTER = keV

NO CUSP/CORE Problem, Profiles are Cored

And more in this direction....

BLACK HOLE EVAPORATION DOES THE INVERSE EVOLUTION:

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

Through its 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 and trans-Planck temperatures).

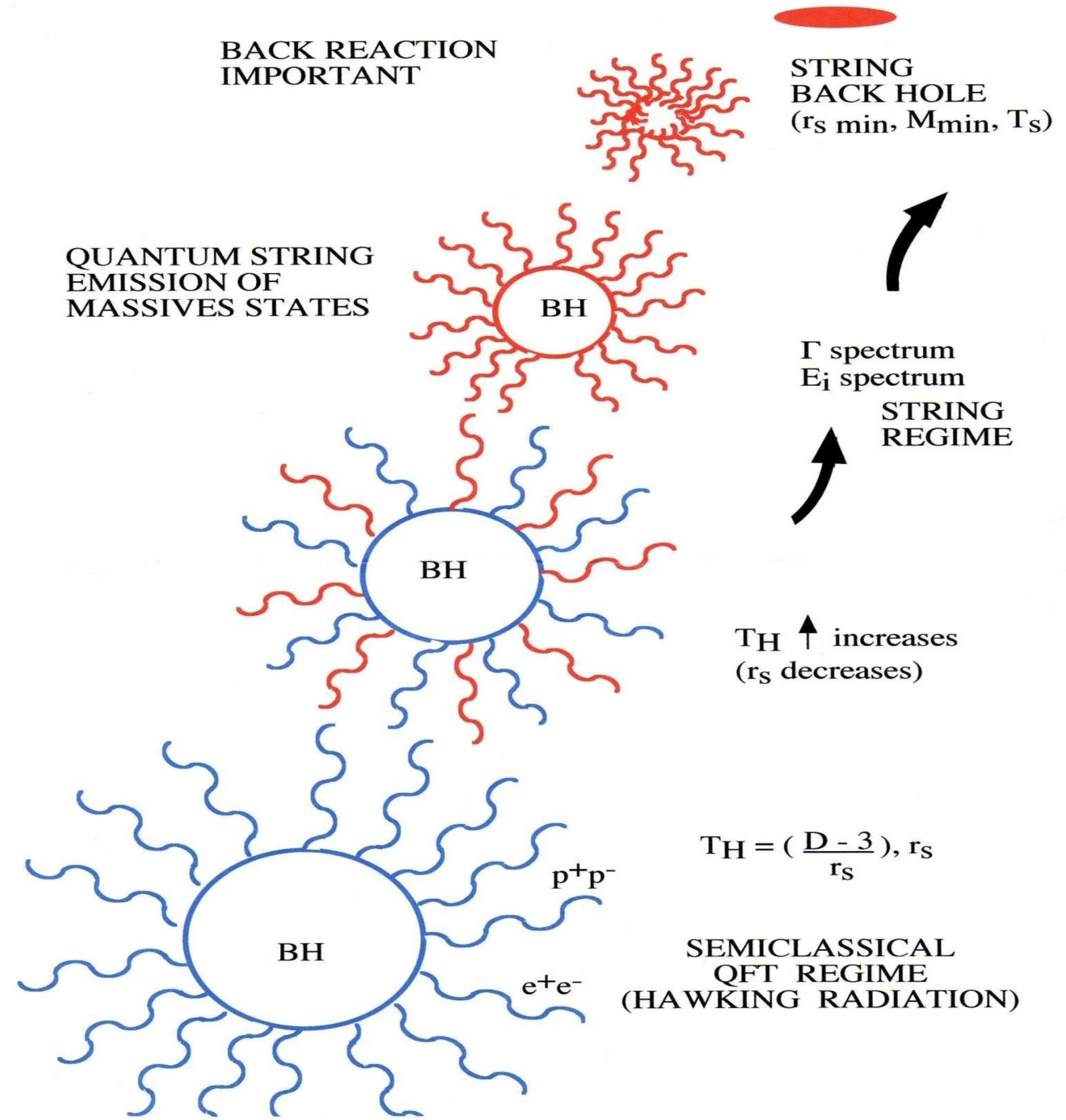
Conceptual unification of quantum black holes, elementary particles and quantum states

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
Γ spectrum
E_i spectrum
STRING REGIME
BH
T_H ↑ increases
(r_S decreases)
BH
p^+p^-
e^+e^-
$T_H = \left(\frac{D-3}{r_S}\right), r_S$
SEMICLASSICAL QFT REGIME (HAWKING RADIATION)

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MERCI BEAUCOUP !!

THANK YOU VERY MUCH

FOR YOUR ATTENTION!!