THE NEW UNIVERSE

A NEW QUANTUM WORLD

at and beyond the Planck Scale

$m_p = (hc/G)^{1/2}$

Norma G. Sanchez

CNRS LERMA OP PSL SU

Chalonge de Vega 27 juin 2019

THE FUNDAMENTAL PLANCK SCALE

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

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

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

$l_P = 10^{-33}$ cm, $\quad m_p = 10^{-5}$ gr, $\quad t_p = 10^{-44}$ 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 : $\quad L_{QG} = L_Q + L_G, \qquad O_{QG} = O_Q + O_G, \quad Q \leftarrow\!\!\!-\!\!\!\rightarrow G$

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

(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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I. Introduction and some Fundamentals

Classical - Quantum Duality
through the Planck scale

III. The Classical Universe and its Quantum Dual

IV Some Numbers and Cosmological Implications

. Implications for Inflation

. Implications for Dark Energy

V. The Cosmological Constant: Vacuum Energy,
Entropy and Temperature of the Universe

VI. Conclusions and Outlook

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.

<u>Whole unifying picture for the Universe epochs and their quantum precursors emerges</u>

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

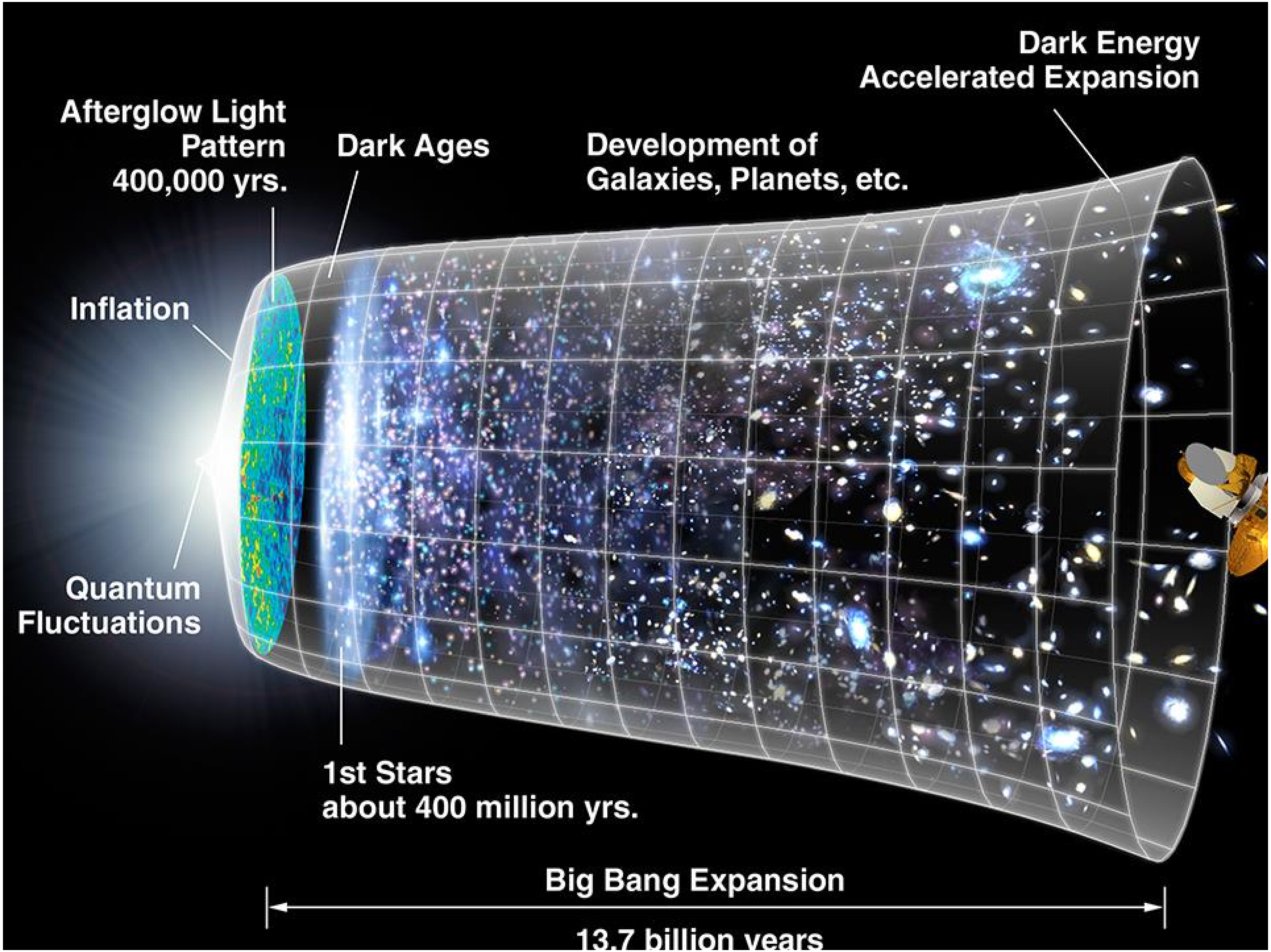
- [1] **N. G. Sanchez,** ***New Quantum Phase of the Universe before Inflation and its Cosmological and Dark Energy Implications***
  https://hal.archives-ouvertes.fr/hal-02048788

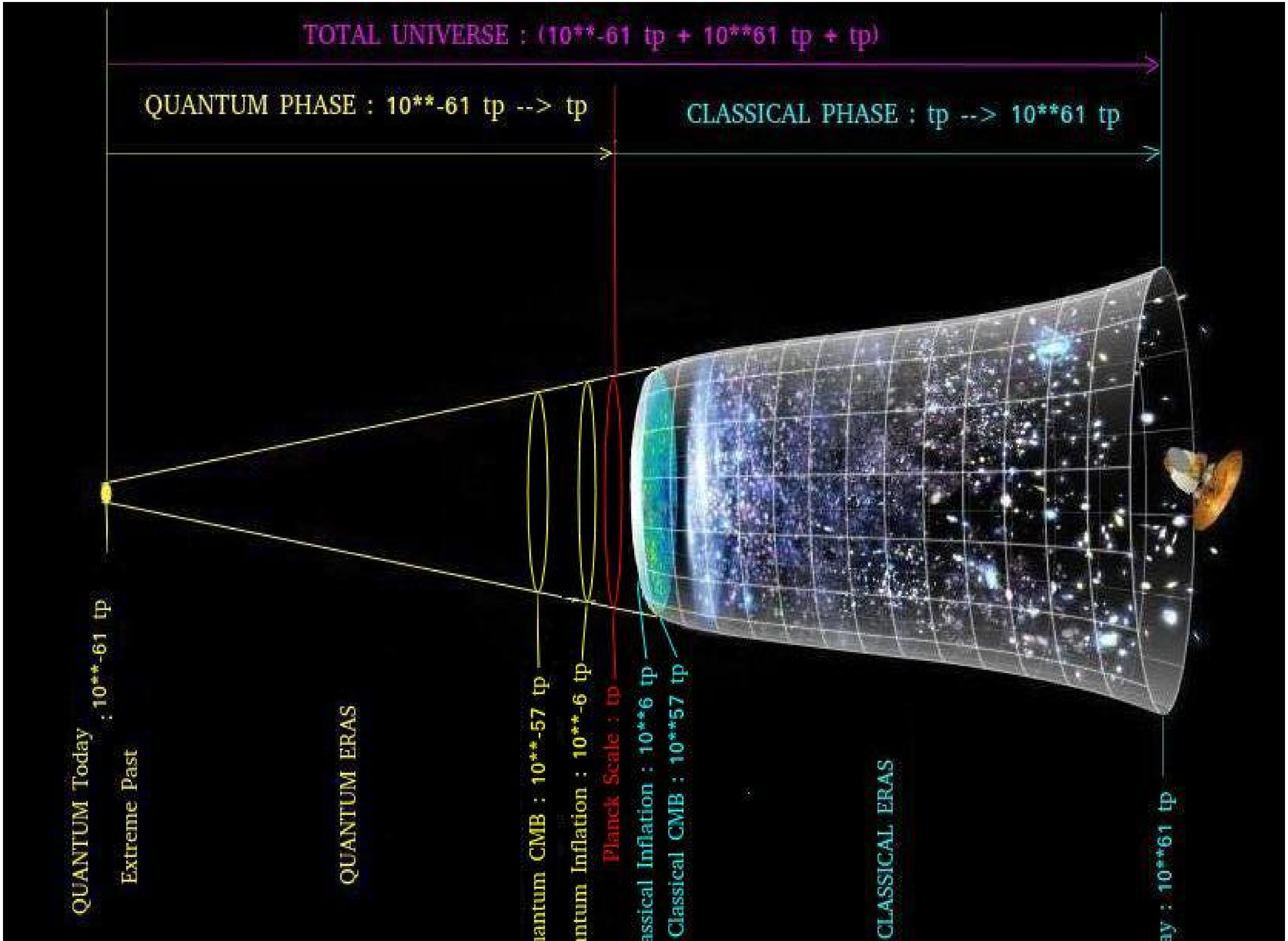
- [2] **N. G. Sanchez,** ***The Classical-Quantum Duality of Nature: New variables for Quantum Gravity,***
  arXiv:1803.04257, **Int Journal Mod Phys D18, 1950055 (2019)**

- [3] **N. G. Sanchez,** ***The New Quantum structure of the space-time, To appear in Grav & Cosmology vol 5, n.2, 99 (Springer, 2019)***
  https://hal.archives-ouvertes.fr/hal-01735421

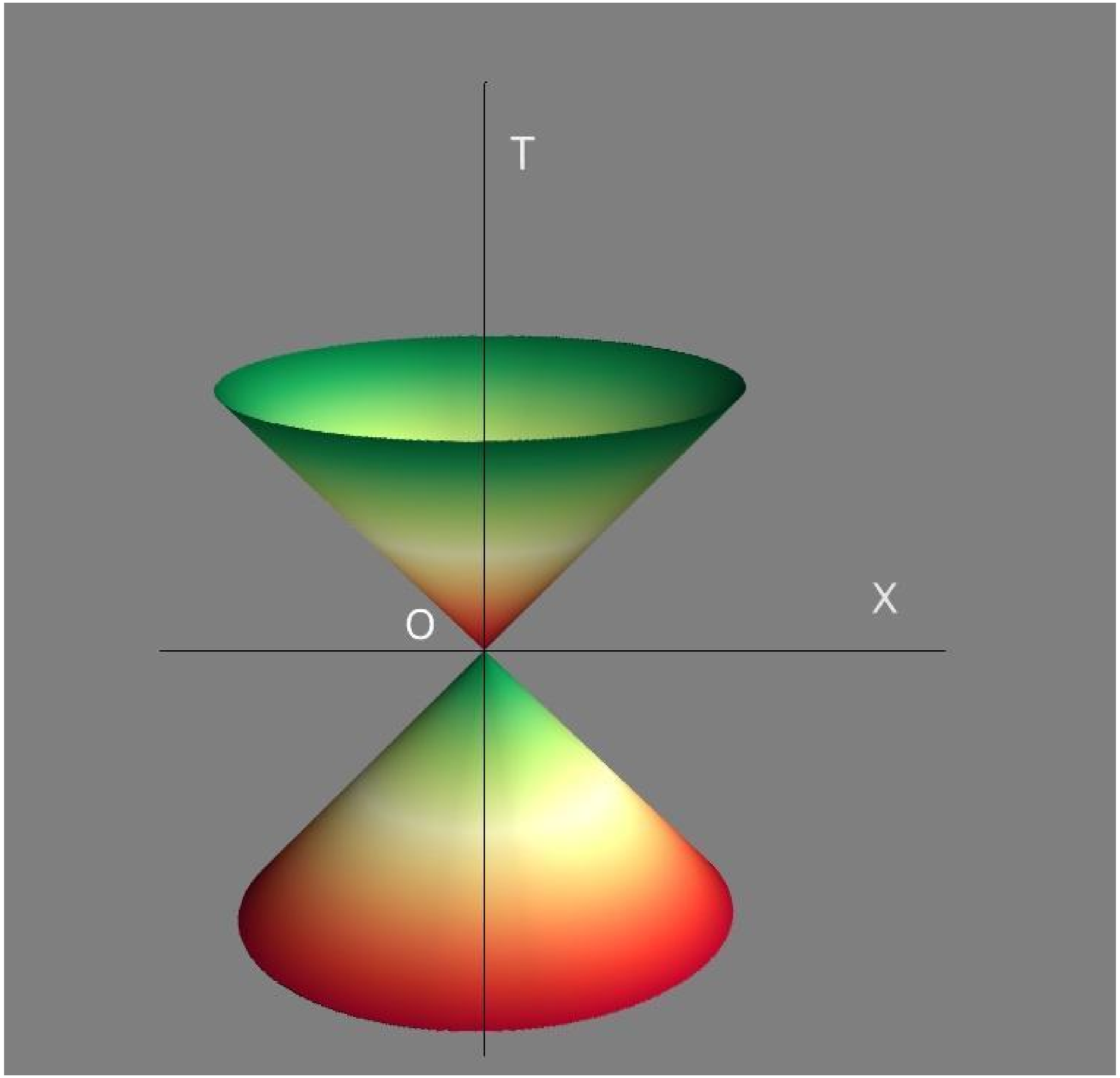
- Projects: **The New Universe , Dark Energy Programme, The Fractal Tree, Open Science & Open Access,**

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

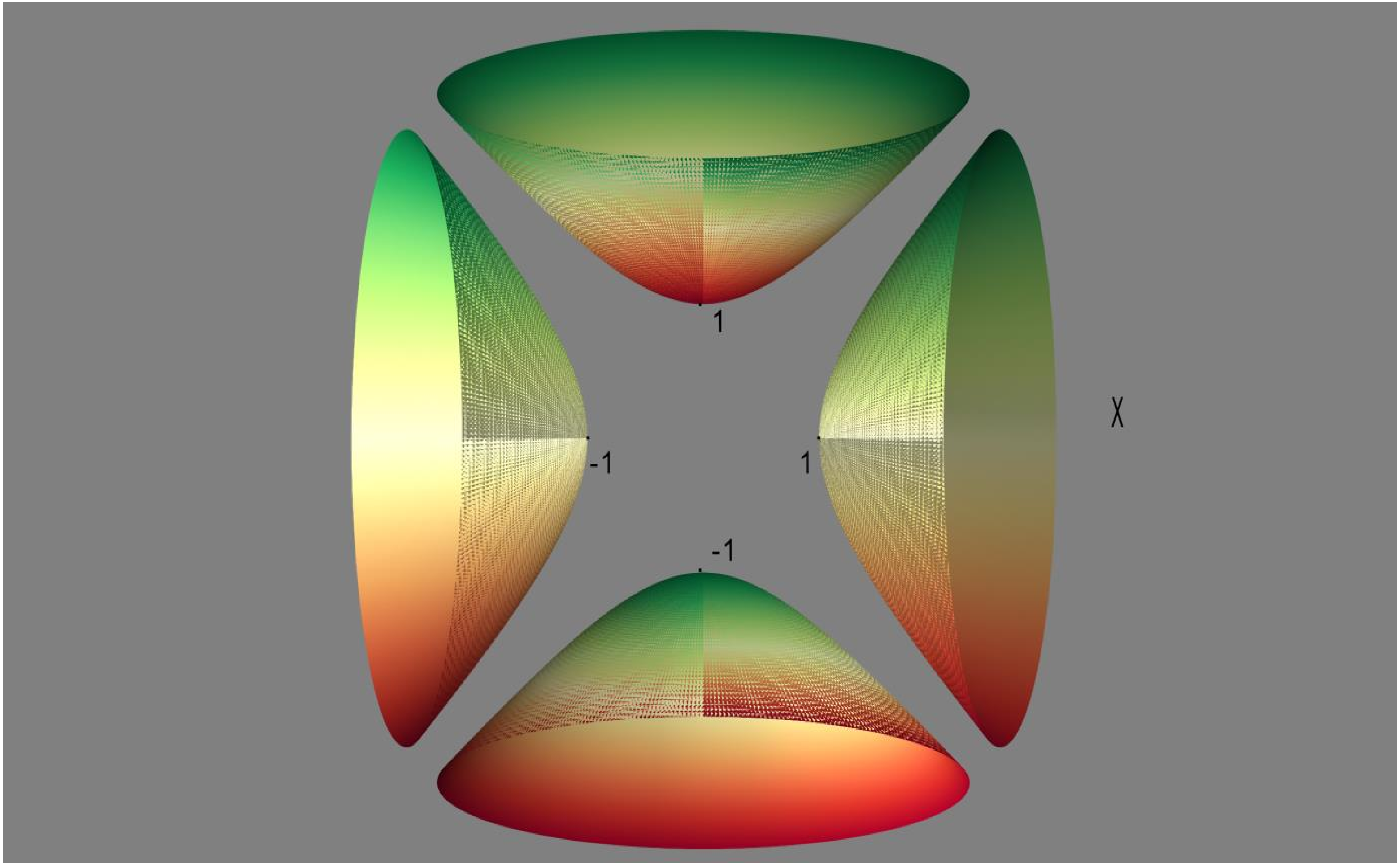

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years



THE TOTAL HISTORY OF THE UNIVERSE

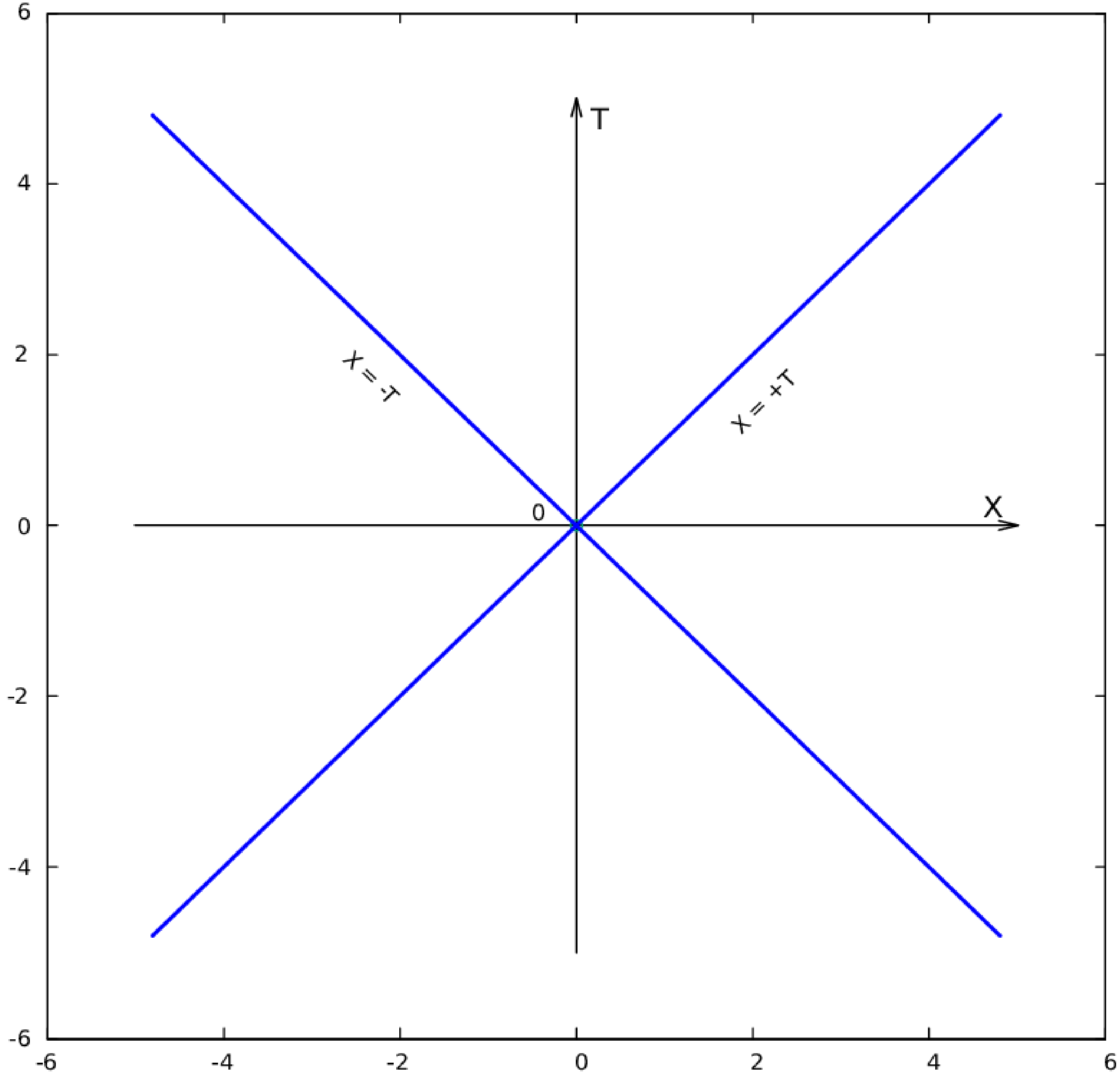


The known classical light-cone (future and past) of classical relativity in a space-time diagram is a special case of the Quantum light -cone

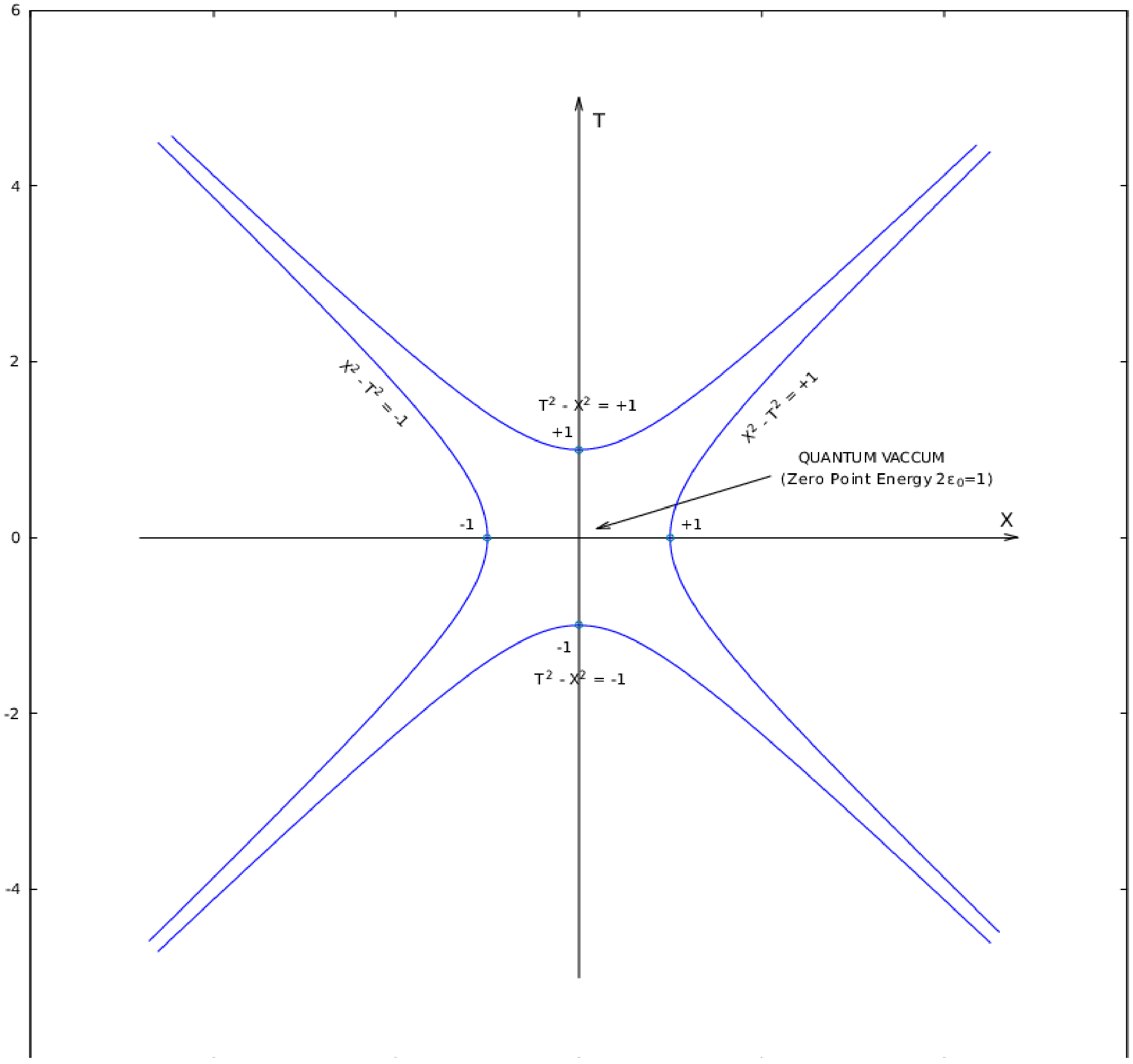


The quantum light-cone in a space-time diagram (time is the vertical axis).

THE CLASSICAL LIGHT CONE



THE QUANTUM LIGHT CONE



QUANTUM SPACE-TIME

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

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

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

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

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

the quantum light cone

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

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 :** $[X, T] = 1$

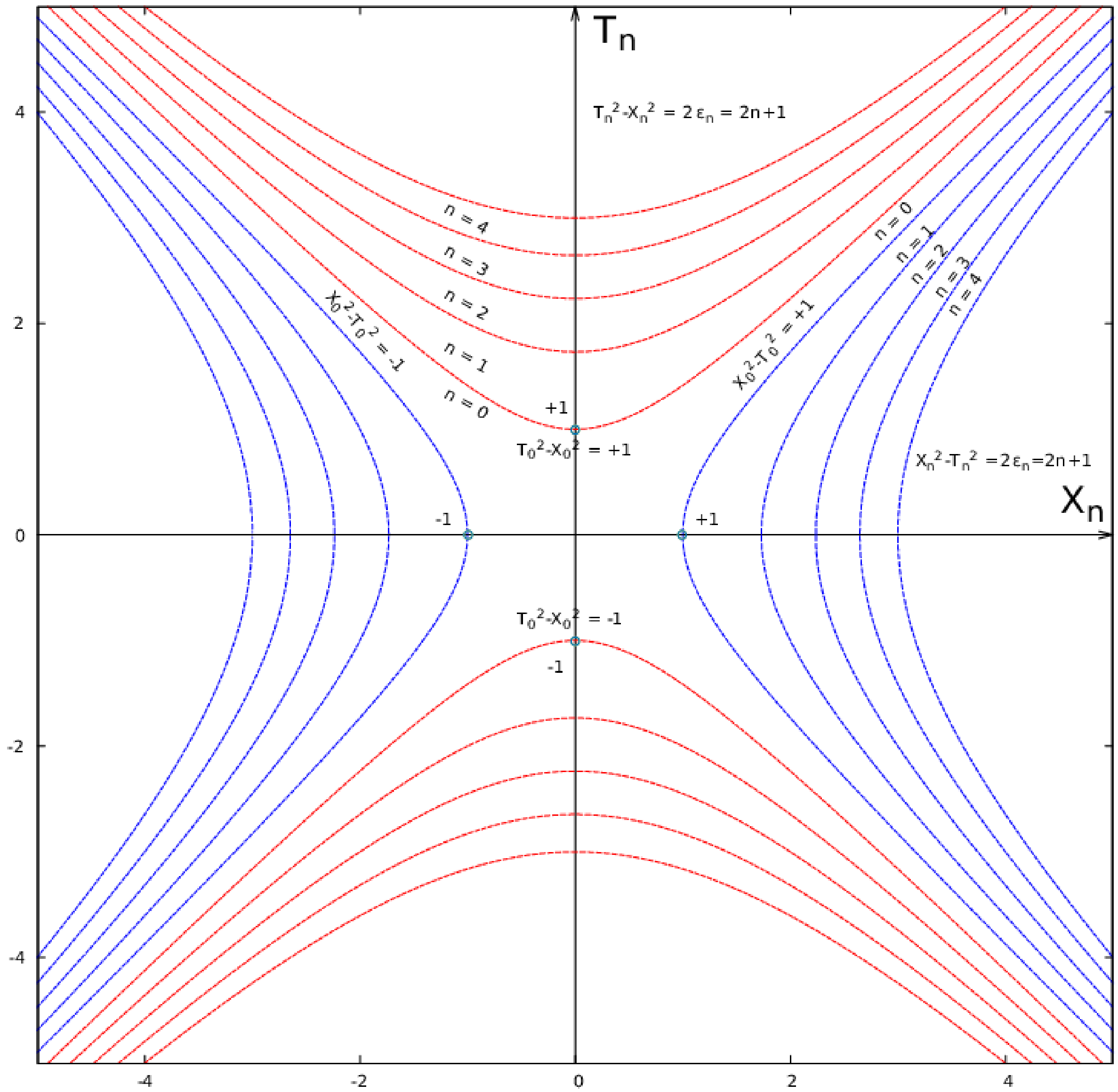
° **THE SPACE-TIME AS a QUANTUM HARMONIC OSCILLATOR :**

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

$P = iT$:

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

QUANTUM SPACE-TIME STRUCTURE



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

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

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 $(L_Q, M_Q, \rho_Q, T_Q, S_Q)$:

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

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

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

***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:

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

The QH factor covers

the FULL CLASSICAL and QUANTUM RANGE, namely:

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

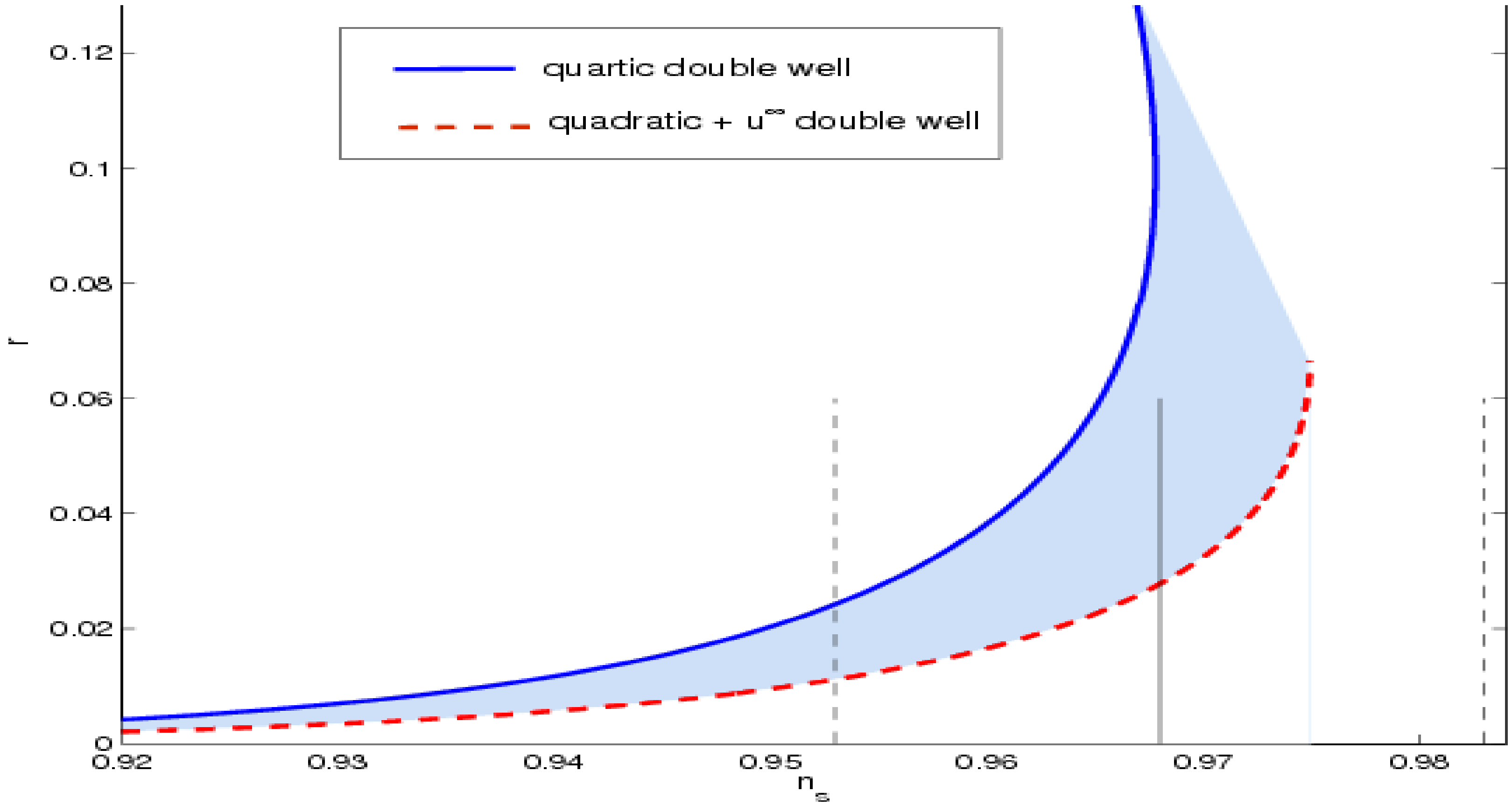
If $H >> h_P$, Eq.(1) precisely *changes to the quantum regime*, **ie to the quantum Hubble rate H_Q, which is the** *super-Planckian domain:*

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

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,
rXiv: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), 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 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 the following 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) <u>The discrepancy is correct and must be be in that way.</u>

(vi) The true problem.

(vii) Not trivial. Deep and Consistent. A General framework

The two huge different values: $\mathbf{10^{-122}}$ **and** $\mathbf{10^{122}}$ 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.**

$$ş = 3H^2 = \text{ə̃}_P\,(H/h_P)^2 = \text{ə̃}_P\,(\ell_P/L_H)^2$$
$$= (2.846 \pm 0.076)\, 10^{-122}\, m_P^2$$

$$ş_Q = 3H_Q^2 = \text{ə̃}_P\,(h_P/H)^2 = \text{ə̃}_P\,(L_H/\ell_P)^2$$
$$= (0.3516 \pm 0.094)\, 10^{122}\, m_P^2$$

$$ş_Q\, ş = \text{ə̃}_P^{\,2}\,, \qquad \text{ə̃}_P = 3\, h_P^2\,.$$

The quantum dual value $ş_Q$ is precisely the quantum vacuum value obtained from particle physics:

$$Ɉ_Q = Ɉ_P\,(ş_Q/\text{ə̃}_P) = Ɉ_P^{\,2}/Ɉ_ş = 10^{122}\, Ɉ_P$$

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

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

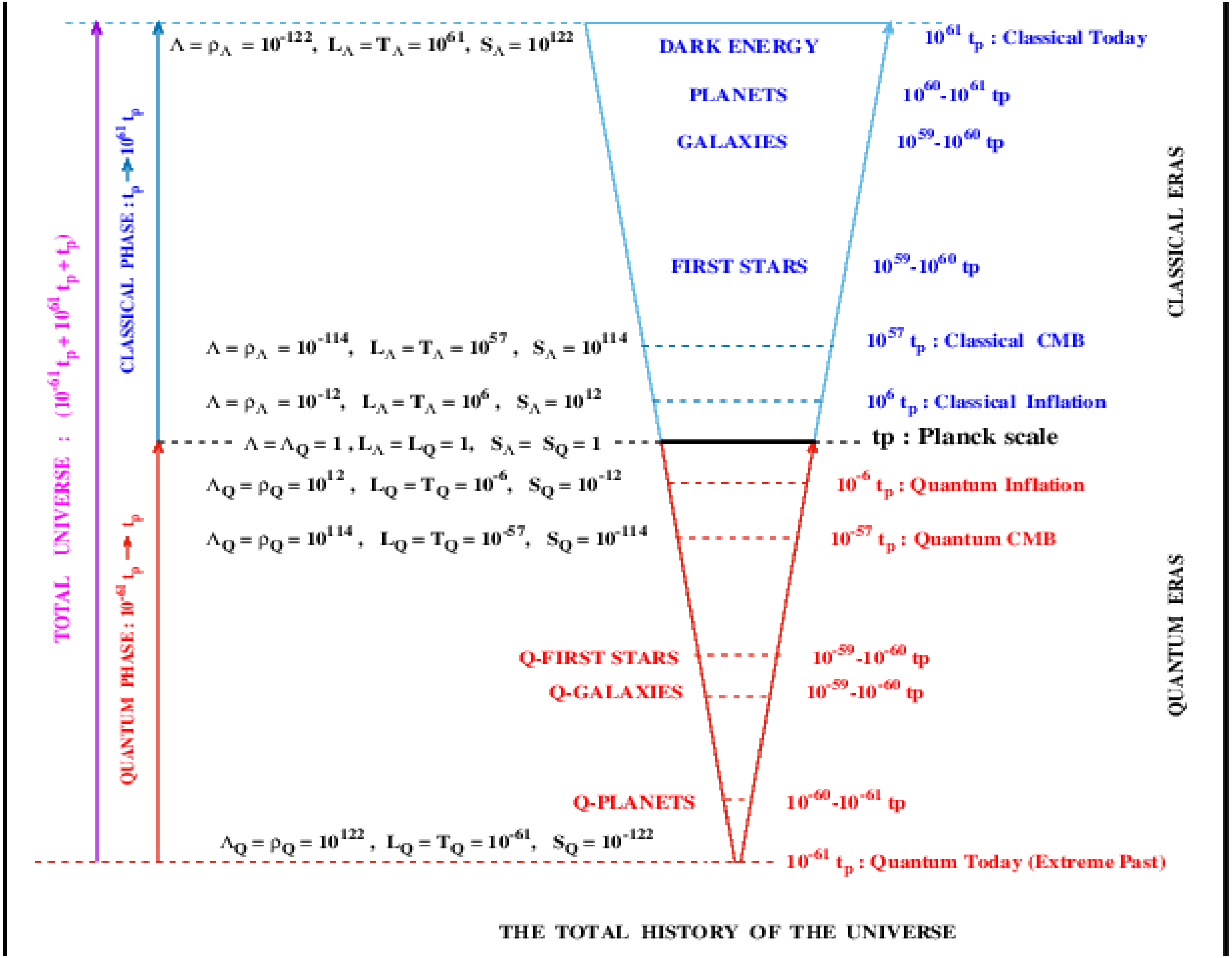
$$\Lambda_Q/\lambda_P = \rho_Q/\rho_P = S_\Lambda/s_P = \lambda_P/\Lambda = (T_\Lambda/t_P)^2 = 10^{+122}$$

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

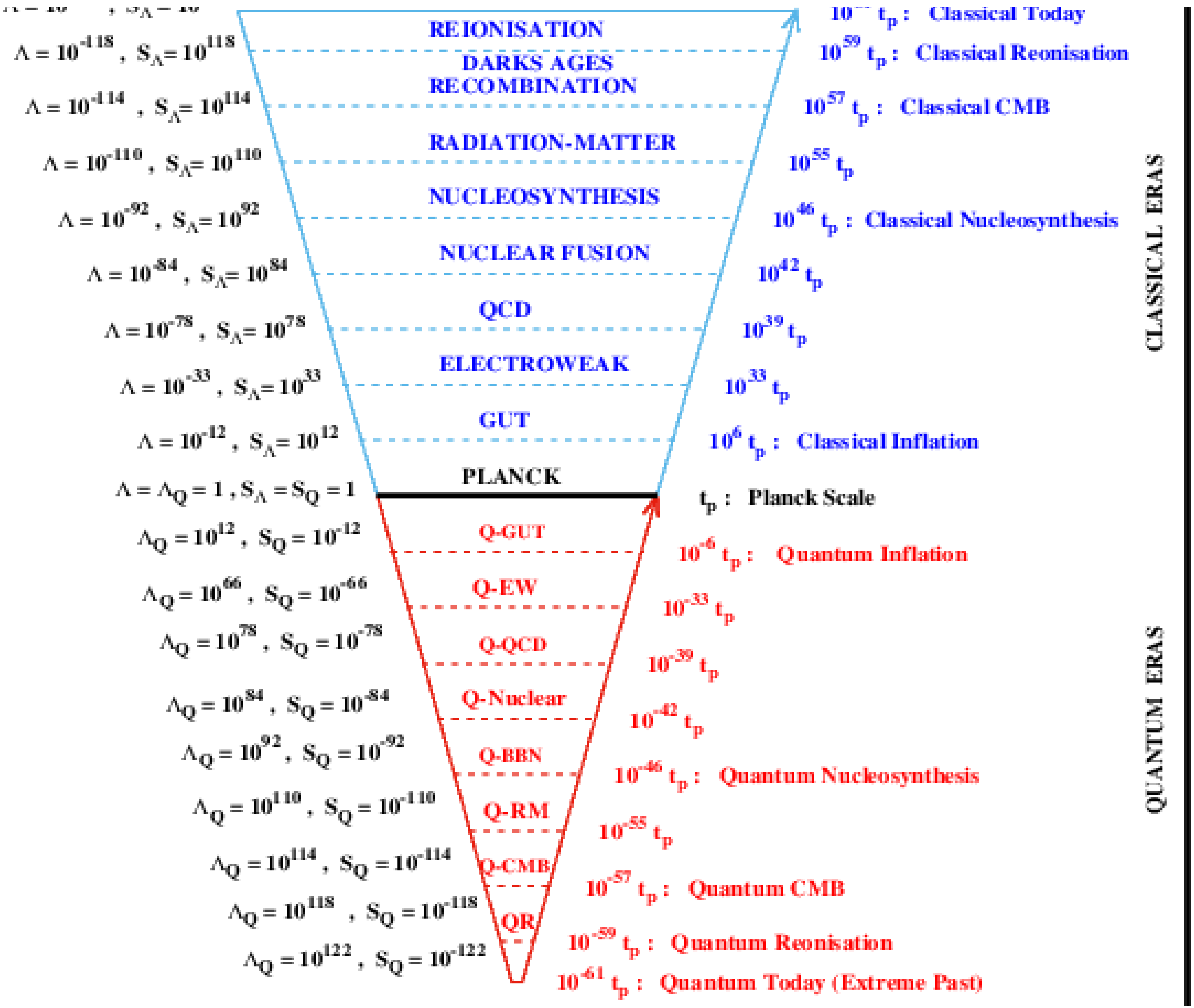
$$\Lambda_{\Lambda Q} = \lambda_P\,(10^{-122} + 10^{+122} + 1)$$

THE ENTROPY OF THE UNIVERSE

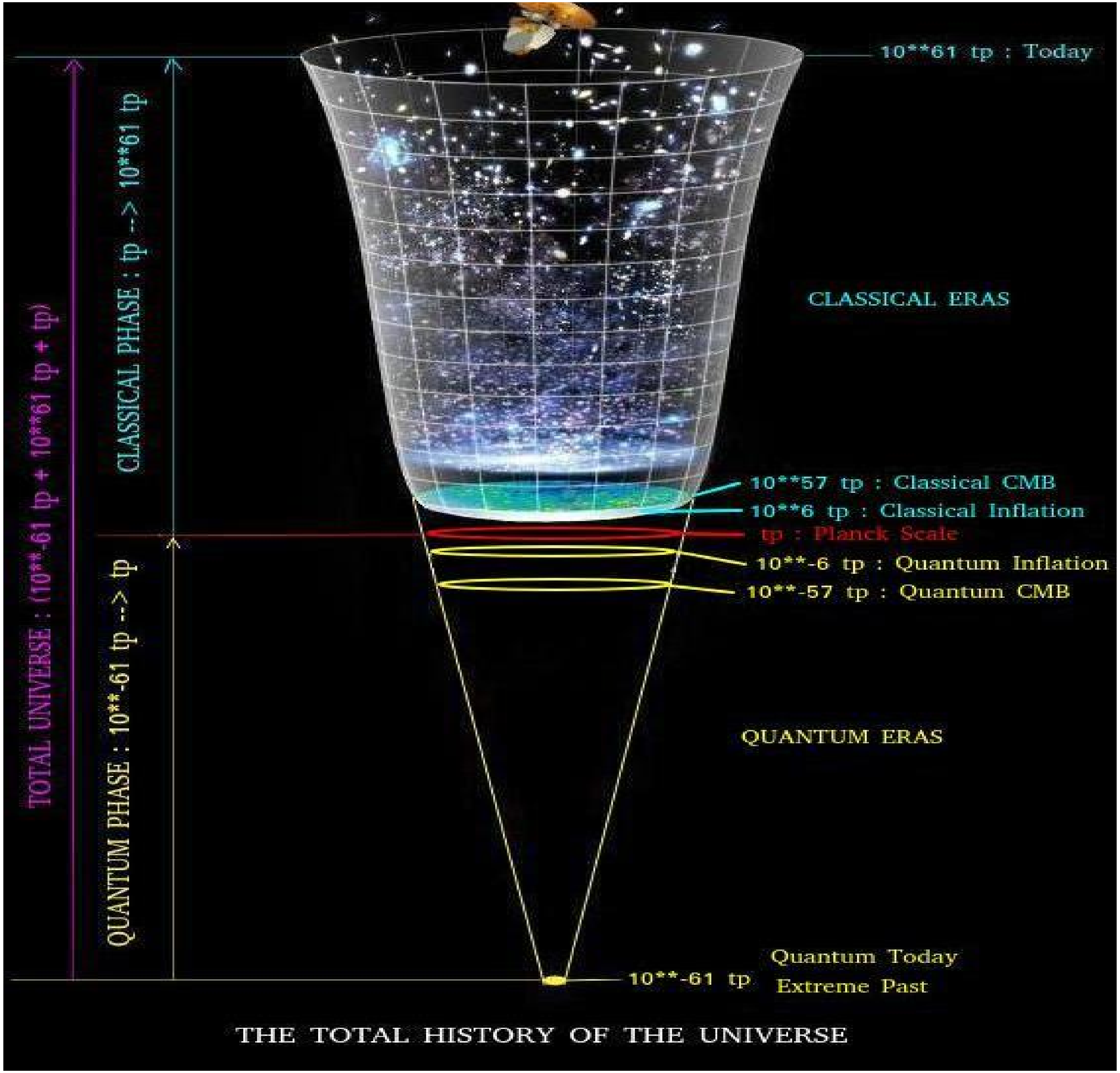
Component	Entropy S [k]
Cosmic Event Horizon	$2.6 \pm 0.3 \times 10^{122}$
SMBHs	$1.2^{+1.1}_{-0.7} \times 10^{103}$
$*$Stellar BHs ($42 - 140\ M_{\odot}$)	$1.2 \times 10^{98^{+0.8}_{-1.6}}$
Stellar BHs ($2.5 - 15\ M_{\odot}$)	$2.2 \times 10^{96^{+0.6}_{-1.2}}$
Photons	$2.03 \pm 0.15 \times 10^{88}$
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	$\mathbf{2.6 \pm 0.3 \times 10^{122}}$



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


10**61 tp : Today
CLASSICAL PHASE : tp --> 10**61 tp
TOTAL UNIVERSE : (10**-61 tp + 10**61 tp + tp)
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 PHASE : 10**-61 tp --> tp
QUANTUM ERAS
Quantum Today
10**-61 tp
Extreme Past
THE TOTAL HISTORY OF THE UNIVERSE

$$M_{moon} = 7\,10^{25} gr = 7\,10^{30}\, m_P, \qquad M_{Q\,moon} = 0.14\,10^{-30}\, m_P$$

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

- For Human scales: $M_{human} = 10^{5} gr = 10^{10}\, m_P, \quad M_{Q\,human} = 10^{-15} gr = 10^{-10}\, m_P$

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

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

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

- For elementary particles (ex. the electron mass): $M(eV/c^2) = 10^{-33} gr = 10^{-28}\, m_P, \quad M_Q(eV/c^2) = 10^{23} gr = 10^{28}\, m_P$

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.**

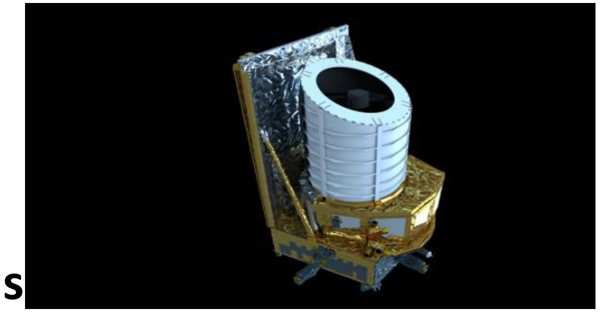
ÅThe wave-particle-gravity duality precisely manifests in this evolution, between the different gravity regimes : mapping between asymptotic (in and out) states characterized by the sets U_{Λ} (or U_{H}) and U_{Q}, and thus as a Scattering-matrix description: The Evolution of the Universe as a Scattering 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 curvature and therefore without singularity.

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 $z \sim 2$, look-back time of about 10 billion years, thus covering the dark energy accelerated period.

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:

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

(Reiss et al, 2018, 2019)

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

THEORY & OBSERVATIONS

The direction in which data and Theory are pointing:

ÅStandard Model of the Universe and

its Quantum Precursor

ÅStandard Single field Inflation: Double Well

År ~ 0.04 - 0.02

ÅPRIMORDIAL GAUSSIANITY

Å NO RUNNING of the Primordial Spectral Index

Å ABSENCE of PRIMORDIAL NON GAUSSIANITY

Å DARK ENERGY= VACUUM ENERGY = Λ

DARK MATTER = WARM DARK MATTER = keV

NO CUSP/CORE Problem, Profiles are Cored

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  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 Grav & Cosmology vol 5, n.2, 99 (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

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).

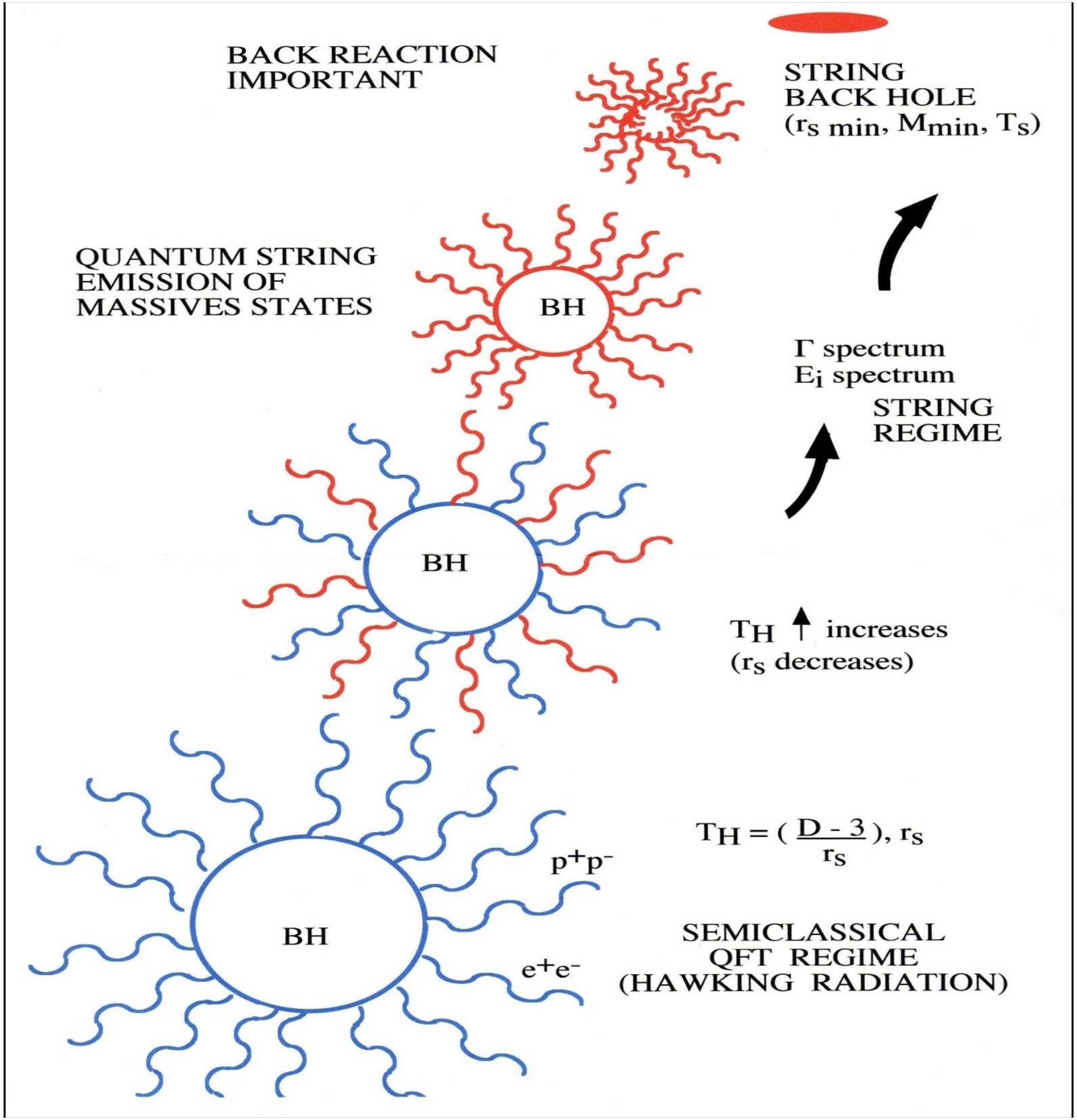
Conceptual unification of quantum black holes, elementary particles and quantum states

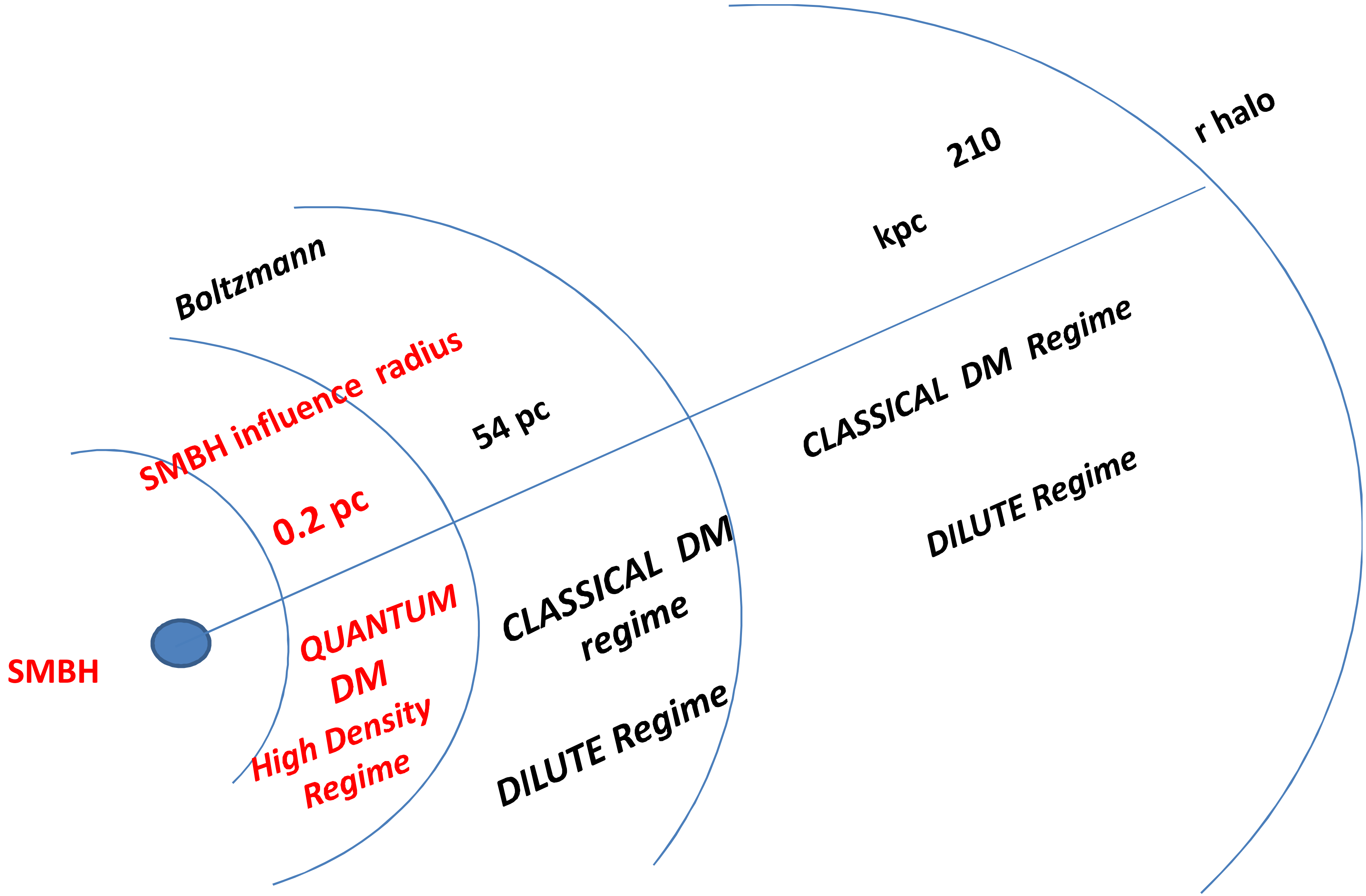
CONCEPTUAL UNIFICATION

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



WDM Thomas-Fermi Galaxy Theory with SMBH

de Vega & Sanchez, 2017

LYON

Les commerçants de la Presqu'Île tirent la sonnette d'alarme

PAGE 19

LE PROGRÈS
Édition Lyon - Villeurbanne - Caluire 69X
Jeudi 11 avril 2019 - 1,10 €

INTELLIGENCE ARTIFICIELLE

ROBOT pour être VRAI ?

Des robots "empathiques", de plus en plus "humains" : à Lyon, un laboratoire a dévoilé ses travaux ce mercredi. Photo Progrès/Maxime JEGAT

PAGES 10 ET 11

MUSIQUE

Un album hommage à Hubert Mounier (*L'Affaire Louis'Trio*)

PAGE 33

Photo Progrès/Joël PHILIPPON

LYON MÉTROPOLE

Le périphérique passera à 70 km/h le 29 avril

PAGE 12

re image du trou noir : l'univers se dévoile

…ille de la Terre.
…rvations ont eu lieu en
…quand huit télescopes
…ux trous noirs : Sagit-
…ucentre de notre voie
…a supergéante de la ga-
… dont la photo a été

…ité ? Huit mois de
…n de ce type d'opéra-
…pées, les observations
…l'ouvrage, les astrono-
…aucun moyen de sa-
…a fonctionné. Il aura
…ée de débarquer un
…nan à tous les télesco-
…t dire dans l'Univers,
…e dans une boîte de

… an de travail a été
… pour reconstituer les
…a photo. « Pour plus de
…travail a été fait quatre
…uatre équipes différen-
…cie Frédéric Gueth,
…e deux des études.

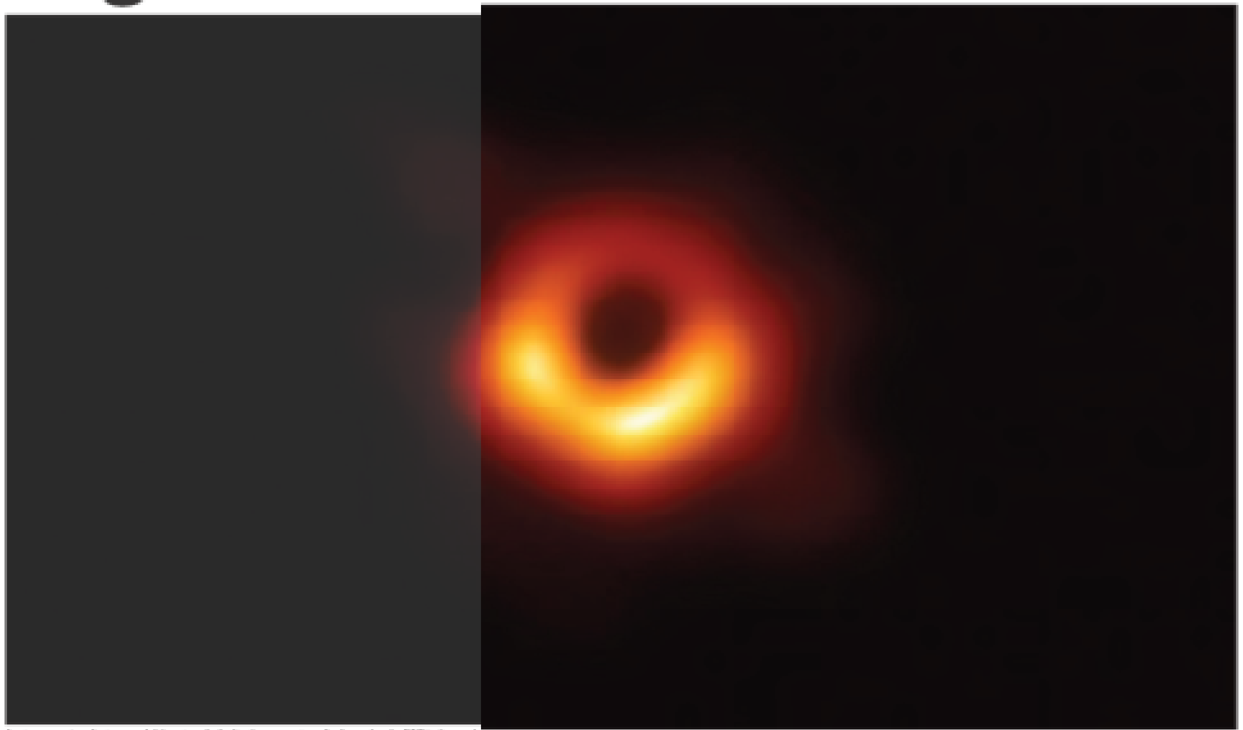
…uron du « Seigneur
…ux »
…ge du trou noir, depuis
…ps recherché, si sou-
…lisé - et aussi fantasmé
… l'objet de six articles
…urnal dans la revue
…cal Journal Letters. Et
…ment le même image,
…mbre sur un halo écla-
…e du trou noir sur la
…atière qui l'entoure.
… révélation, cette pho-
…ntrement parler. Beau-
…onomes s'amusent à
…s trou noir avec l'œil
…nt du « Seigneur des
…, l'ignoble Sauron.
…53 millions d'années-
…univers continue de
…er…

T. L. (avec AFP)

…angeté

…rmes, ce que vous
…t pas forcément ob-
…e. Un objet peut ap-
…formé ou dédoublé.
…marée est tellement
…'un astronaute qui
…vers l'horizon d'un
…erait transformé en
…es pieds accélérant
…e tête. Il s'est ain-
…temps qui se dilate, et
…qui se déroule vers le
…'il devient invisible.
…teur lointain qui re-
… chute de ce même
…ssant l'impression
…ntinuellement puisse
…le s'effacer progres-

J.-M. L.



Le trou noir photographié est celui situé au centre de la galaxie M87, à environ 50 millions d'années-lumière de la Terre. Photo EUROPEAN SOUTHERN OBSERVATORY/AFP

REPÈRES

Une existence théorique

Dès la fin du XVIIIe siècle, l'astronome anglais John Michell et le marquis de Laplace avaient eu l'intuition de l'existence des trous noirs. Mais il aura vraiment fallu attendre le début du XXe siècle et la théorie de la relativité générale d'Einstein pour que les trous noirs rejoignent le bestiaire cosmologique. Le chemin de la reconnaissance a toutefois été long. Einstein lui-même n'y croyait pas. C'est à un autre astrophysicien allemand, Karl Schwarzschild qu'on doit la démonstration de leur existence. Le terme de « trou noir » n'est toutefois apparu que tardivement, au milieu des années 1960. Pour autant, faute d'observation directe, leur existence restait jusqu'à présent purement théorique.

Des preuves indirectes

Depuis une trentaine d'années, les progrès technologiques ont permis de multiples observations de trous noirs. Mais toujours indirectes. Heureusement, dans l'univers, beaucoup de trous noirs sont aussi discrets qu'un éléphant dans un magasin de porcelaine. Lorsqu'ils « avalent » une étoile voisine, d'immenses jets de matière peuvent se produire. Les plus gros sont entourés de disques de matière tournoyant à des vitesses vertigineuses, et d'où s'échappent latéralement de gigantesques jets de radiations. Leur présence peut également être trahie par l'effet de lentille gravitationnelle, qui peut déformer ou déformer l'image d'un objet lointain. Et ne mentionnons même pas le cas de la collision de deux trous noirs : c'est un événement de ce type qui a permis de détecter pour la première fois les ondes gravitationnelles en 2015.

6,5

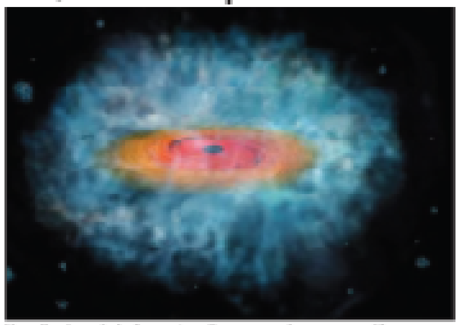
MILLIARDS de fois la masse du Soleil, telle est le poids du trou noir dont la photo a été observée ce mercredi. Pour quantifier, la masse du Soleil équivaut à 333 000 fois la masse de la Terre. Notre planète pèse environ 6 000 quadrillions de kilogrammes. En masse, un quadrillion, c'est au-delà de mille milliards de milliards de kg.

Un trou noir, c'est quoi ?

Pour comprendre ce qu'est un trou noir, imaginez que vous deviez envoyer une fusée dans l'espace. Pour y parvenir, il vous faudra évidemment atteindre une certaine vitesse. C'est ce qu'on appelle la vitesse de libération, qui permet de s'échapper du champ gravitationnel.

Pour la Terre, cette vitesse est de 11,2 km/s. Vous savez désormais pourquoi les fusées ont de gros moteurs. Si vous décollez d'un corps plus léger, évidemment, pas besoin d'aller aussi vite : les astronautes d'Apollo 11 n'ont eu besoin que d'atteindre 2,4 km/s pour quitter la Lune.

Et si vous vous trouvez à la surface d'un corps plus lourd ? C'est logique, la vitesse de libération augmente. Sur Neptune, elle s'élève à 23,6 km/s, sur Jupiter 59,5 km/s… Mais il y a une limite : la vitesse de la lumière. Que se passe-t-il lorsque le corps est tellement lourd, qu'il faudrait atteindre les 300 000 km/s pour échapper à son attraction ? Eh bien, rien. Rien, car rien ne peut atteindre une telle vitesse, pas même un photon. Si un corps est tellement massif que la vitesse de libération atteint celle de la lumière, rien ne pourra jamais s'en échapper. De l'extérieur, vous ne verrez qu'une sphère obscure. Un trou noir, dont la frontière est baptisée « horizon des événements ».



Vue d'artiste de la formation d'un trou noir supermassif. Nasa/CXC/M. Weiss

Des nains et des géants

Contrairement à une idée reçue, tous n'ont toutefois pas une densité gigantesque. Ce n'est le cas que pour les trous noirs stellaires, nés de l'effondrement d'une étoile, et dont le diamètre peut être ridiculement petit. Dans ces derniers, une masse équivalente à celle de la Terre tiendrait dans le volume d'une cacahuète.

D'autres trous noirs auraient une densité proche de celle de l'eau, mais compenseraient par une taille gigantesque : certains de ces géants pourraient faire plusieurs fois la taille de notre système solaire. Ce sont ces trous noirs dits « supermassifs » qui se trouveraient au centre des galaxies, à l'image de Sagittarius A*. Ils sont même suspectés d'être les véritables architectes de l'Univers, à l'origine de la création des étoiles et des galaxies.

Jean-Michel LAHIRE

QUESTIONS À

Norma G. Sanchez Physicienne théoricienne, directrice de recherche au CNRS et directrice de l'École internationale d'astrophysique Daniel Chalonge

Le prochain défi est d'aller voir à l'intérieur

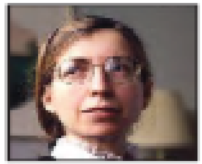


Photo DR

La première image du trou noir vient d'être dévoilée. Quelles sont vos impressions ?

Il y a l'exploit scientifique d'avoir assemblé cette image, de reconstituer ce puzzle grâce aux huit télescopes du réseau Event Horizon Telescope. Après, sur l'image en elle-même, à savoir un puits noir entouré de matière qui émet de la lumière, cela n'est pas surprenant. Cette image était pressentie, mais elle reste importante aussi bien pour l'observation de la galaxie que pour la physique théorique.

Quelle est la prochaine étape ?

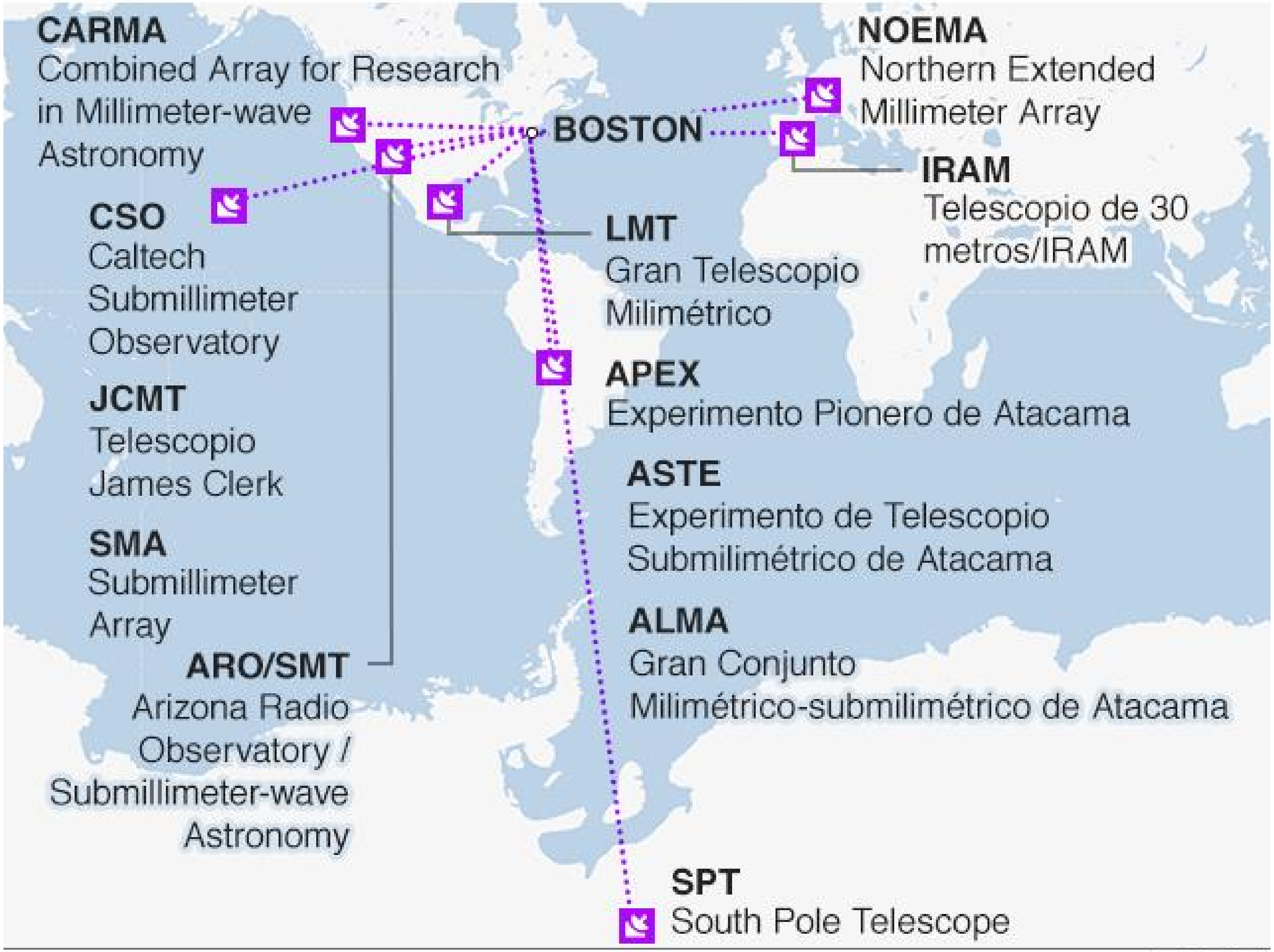
Depuis Stephen Hawking, on sait que les trous noirs rayonnent, et donc émettent des informations. Désormais, le prochain défi est d'aller voir à l'intérieur d'un trou noir en allant capter ces informations. La première étape sera d'intégrer les nouvelles connaissances scientifiques. Jusqu'à présent, toutes les observations de trous noirs, y compris cette photographie, sont basées sur la théorie d'Albert Einstein sur la relativité générale qui date de 1915 ! Pour comprendre ce que contient un trou noir, il va falloir aller au-delà d'Einstein, et ce, même si sa théorie a été magnifique pour la communauté scientifique, même un siècle plus tard. Nous avons fait des progrès, heureusement !

Peut-on s'attendre à des surprises ?

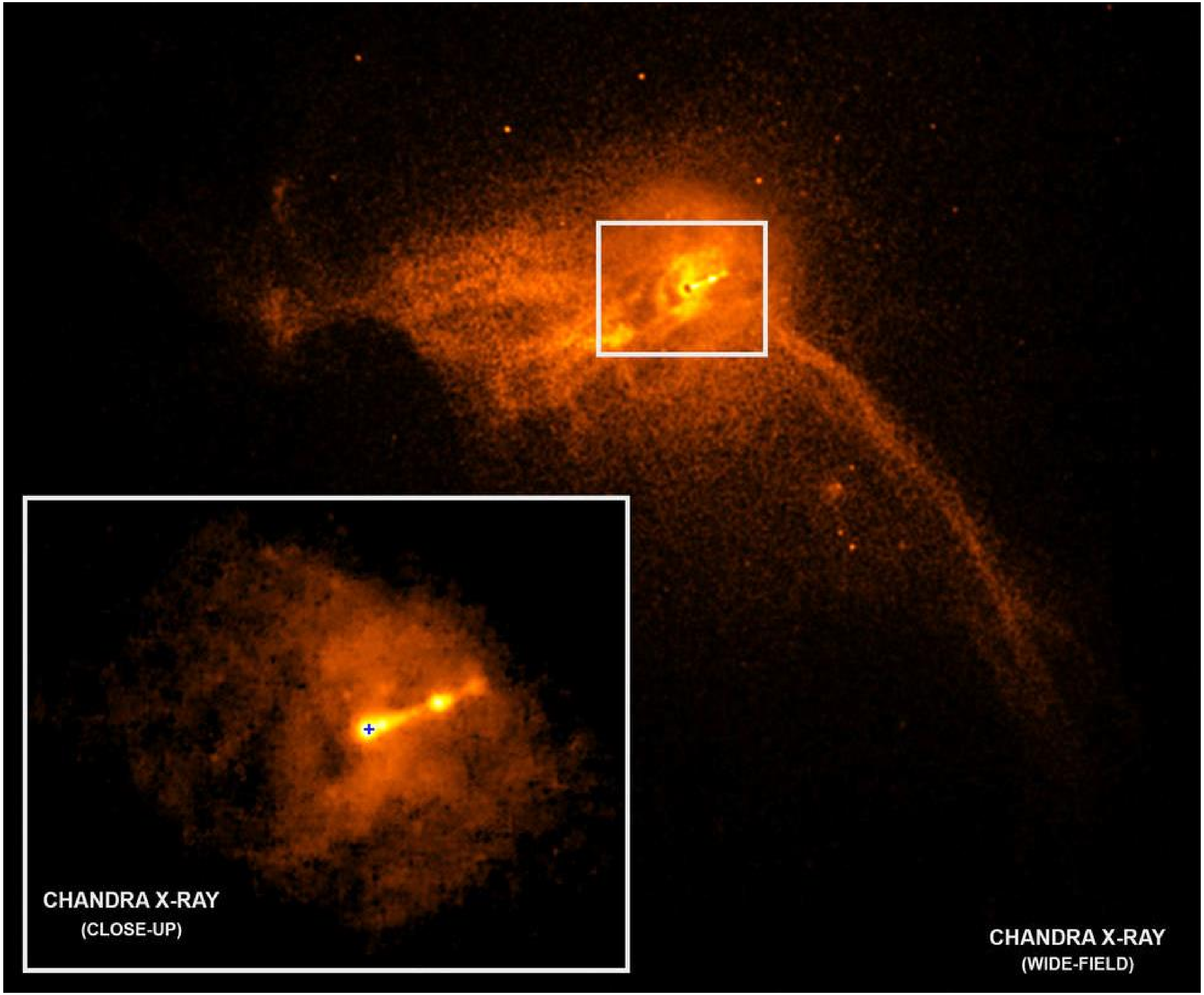
Je ne pense pas. Ce qui paraissait étrange pour Einstein ou même Hawking devient plus simple au fur et à mesure des nouvelles connaissances. D'où l'intérêt de les intégrer.

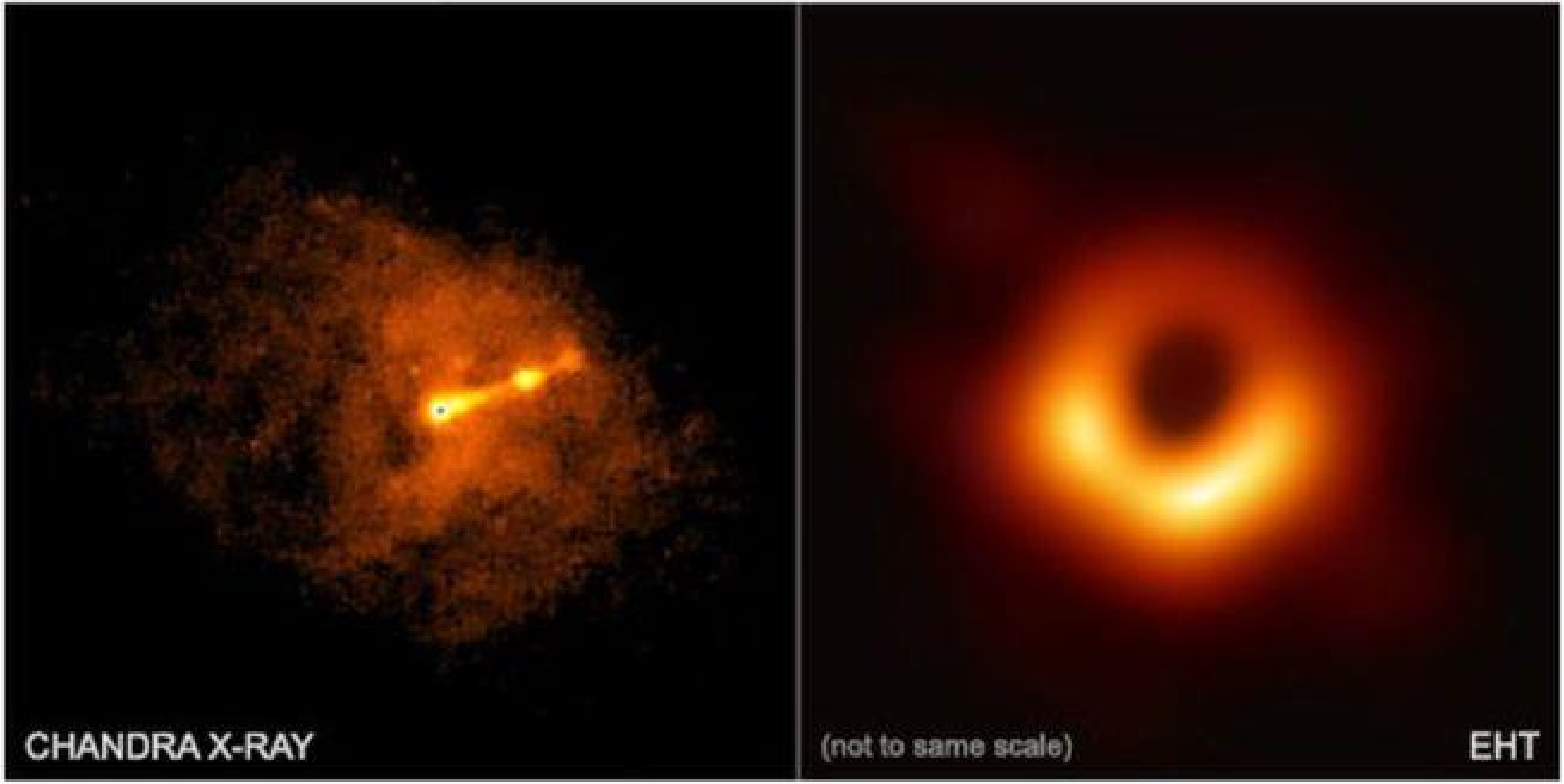
Recueilli par Thibault LIESSI

Telescopio del Horizonte de Sucesos (EHT)



BBC


CHANDRA X-RAY
(CLOSE-UP)
CHANDRA X-RAY
(WIDE-FIELD)


CHANDRA X-RAY
(not to same scale)
EHT

For a static black hole, the **quantum particle emission rate $H(k)$** and the **classical wave absorption cross section $\sigma_A(k)$**
are related by the Hawkingôs formula (1975)

$$H(k) = \frac{\sigma_A(k)}{e^{8kM} - 1}$$

the factor relating them being a Planckian factor. Here **k** and **M** stands for the **frequency of waves** and for the **mass of the black hole** respectively.

We see the role played by **the absorption in the emission.**

In spite of the extensive litterature discussing about the interaction of

In fact, the complexity of analytic solutions of the perturbation fields equations made this problem very difficult.

We have studied in detail the absorption spectrum of the black hole and we have found the total absorption cross section $\sigma_A(k)$ obtaining a very simple expression (N. S´anchez, 1978), which is valid to very high accuracy over the entire range of k, namely

$$\sigma_A(k) = 27\pi M^2 - 2\sqrt{2}\, M \,\frac{\sin[(\sqrt{27})\,\pi k M]}{k}\,, \quad kM \geq 0.07$$

$$\sigma_A(0) = 16\,\pi M^2$$

The **absorption** spectrum presents, as a function of the frequency, a remarkable oscillatory behaviour characteristic of a **diffraction pattern .** It oscillates around its constant geometrical optics value $\sigma_A(\infty)$ **= 27pM²** with decreasing amplitude as **1/(√2 kM)** and constant period **2 (√3/3) .**

The computation of the Hawking radiation shows that it is only important in the interval 0 ≤ k ≥ 1/M .

The **emission spectrum does not show** any of the interference oscillations characteristic of the absorption cross section, because the contribution of **the S-wave (partial wave l=0) dominates the Hawking radiation.**

The rapidly decrease of the Planck factor for kM ≥ 1 supresses the contribution of the higher partial waves.

Thus, for a black hole the emission follows a **planckian spectrum**, given by eq. (1), (Fig.1), and the absorption follows **an oscillatory spectrum**, given by eq.(2), (Fig.2).

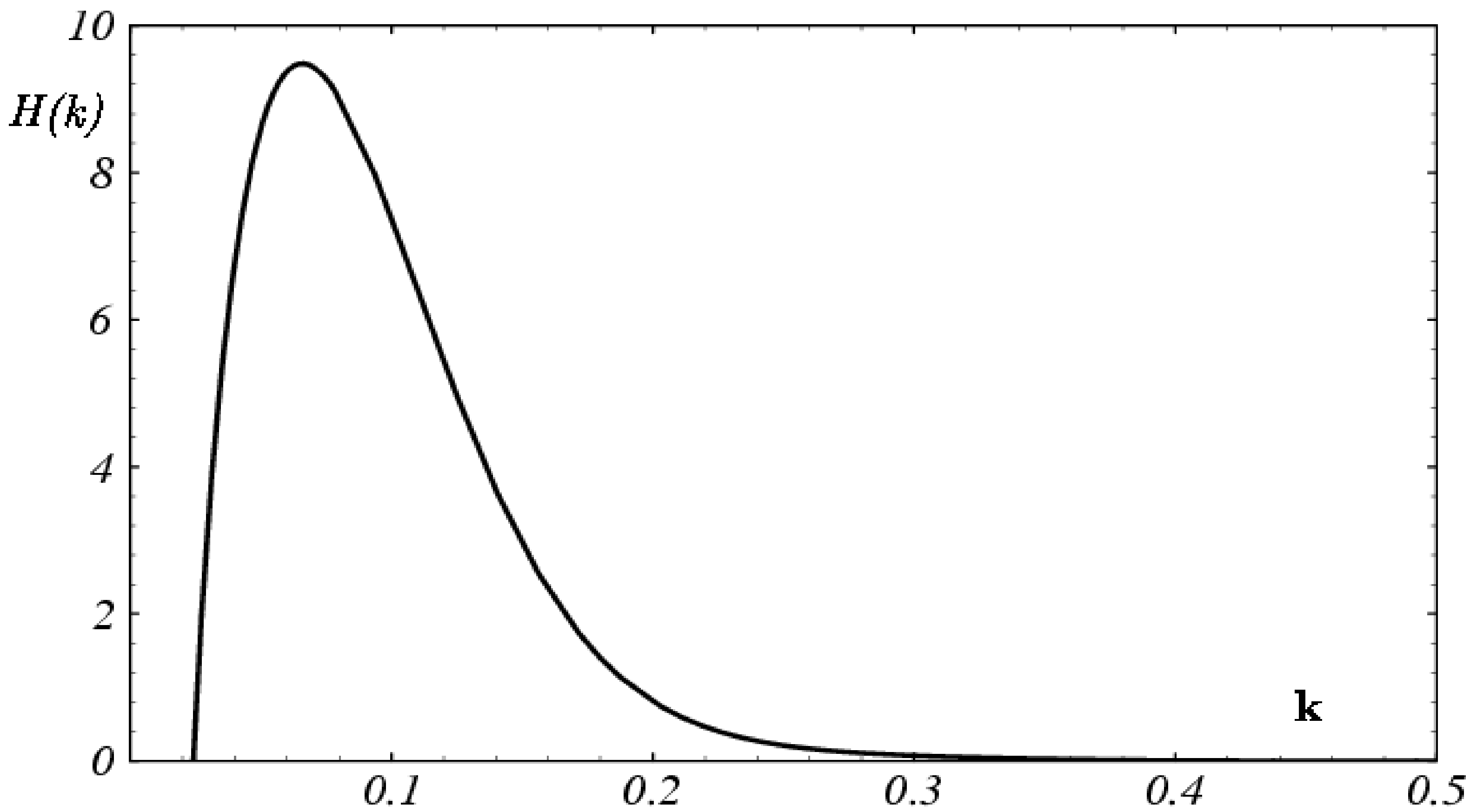


Figure 1: EMISSION BY A BLACK HOLE

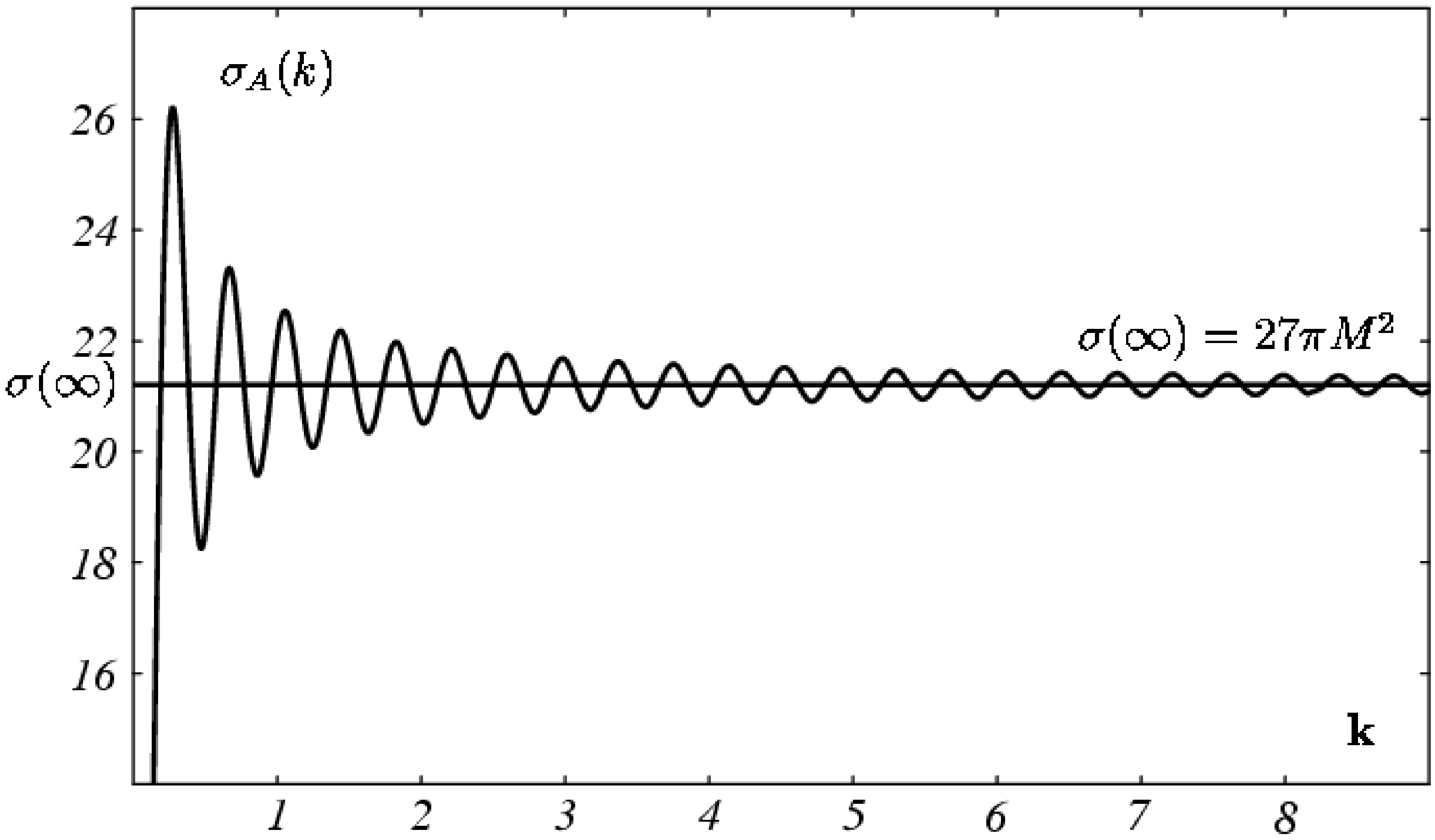


Figure 2: ABSORPTION BY A BLACK HOLE

It is interesting to compare the absorption by a black hole with that of other physical systems. Fig.3 shows the total absorption cross section for an ordinary material sphere with a complex refraction index. It is a monotonically increasing function of the frequency. It attains its geometrical optics limit without any

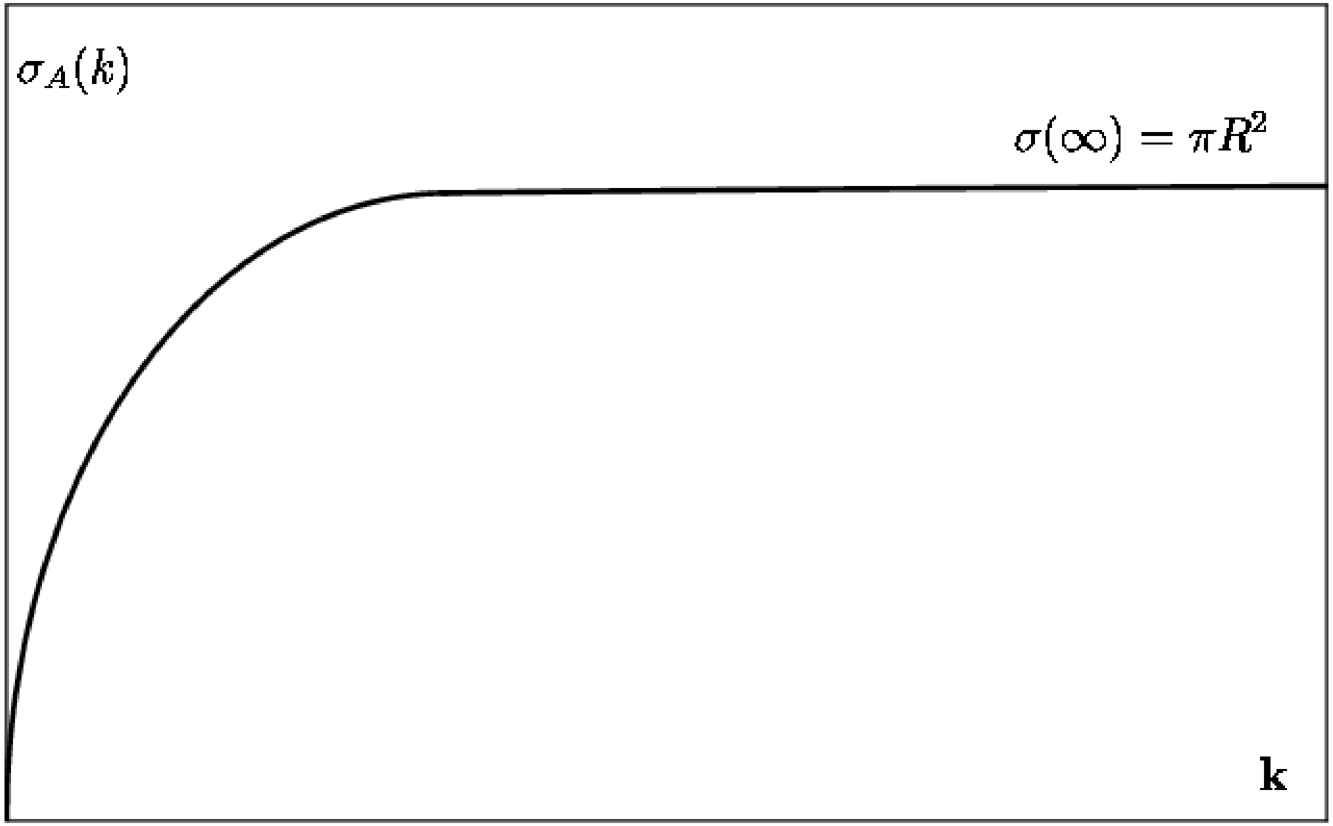


Figure 3: ABSORPTION BY A MATERIAL SPHERE WITH A COMPLEX REFRACTION INDEX

Usually, in scattering theory, absorption processes are related to complex (and non-singular) potentials. On the contrary, in the black hole case, the potential is real and singular at the origin. All partial absorption amplitudes have

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.***

MERCI BEAUCOUP

POUR VOTRE ATTENTION !!

THANK YOU VERY MUCH

FOR YOUR ATTENTION !!

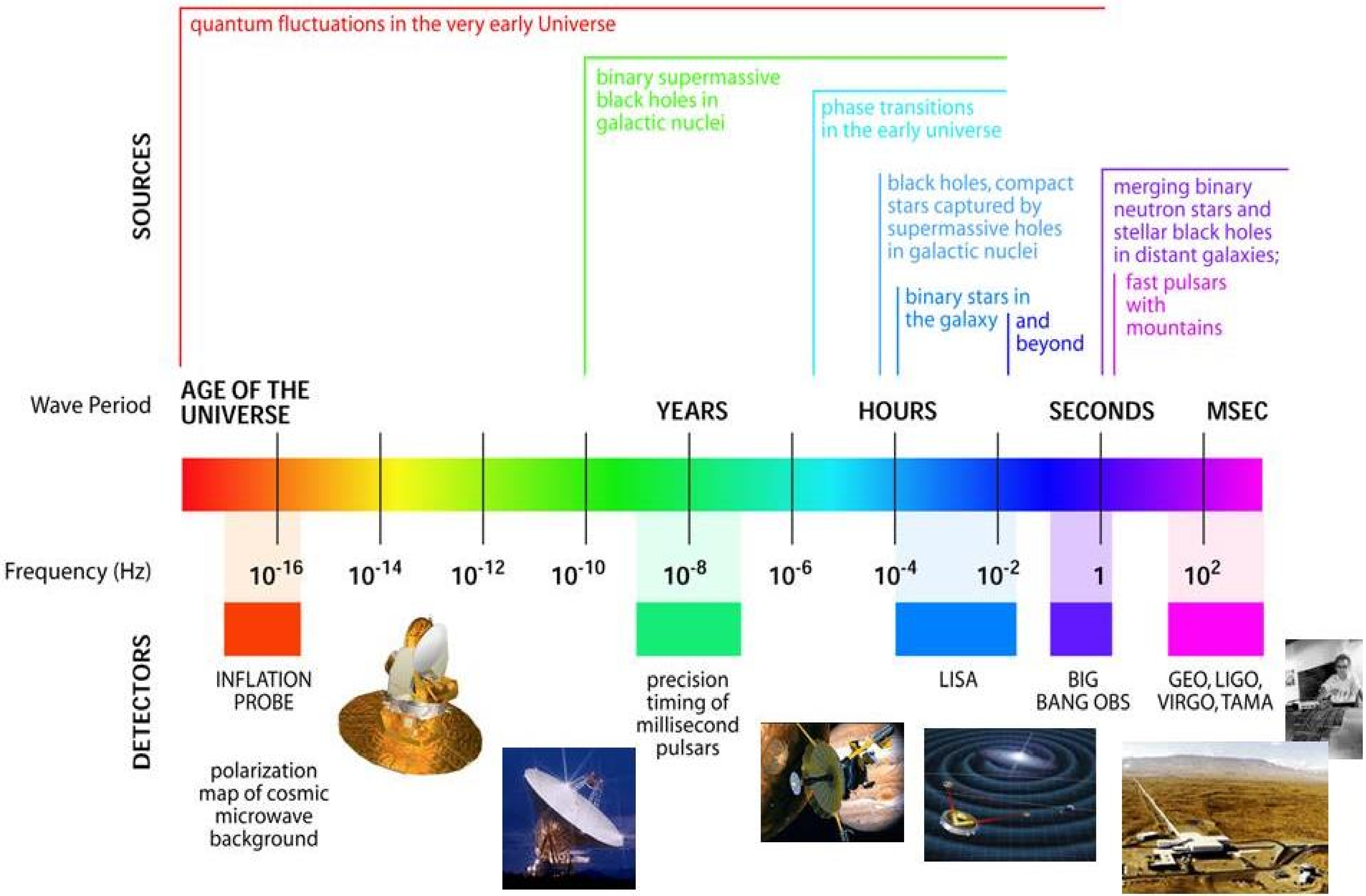
MUCHAS GRACIAS

POR VUESTRA ATENCION !!

MOLTE GRAZIE

PER LA VOSTRA ATTENZIONE !!

THE GRAVITATIONAL WAVE SPECTRUM



The big picture of gravitational wave astronomy