Física del Universo

El Universo desde sus Origenes Cuánticos hasta Nuestros Dias

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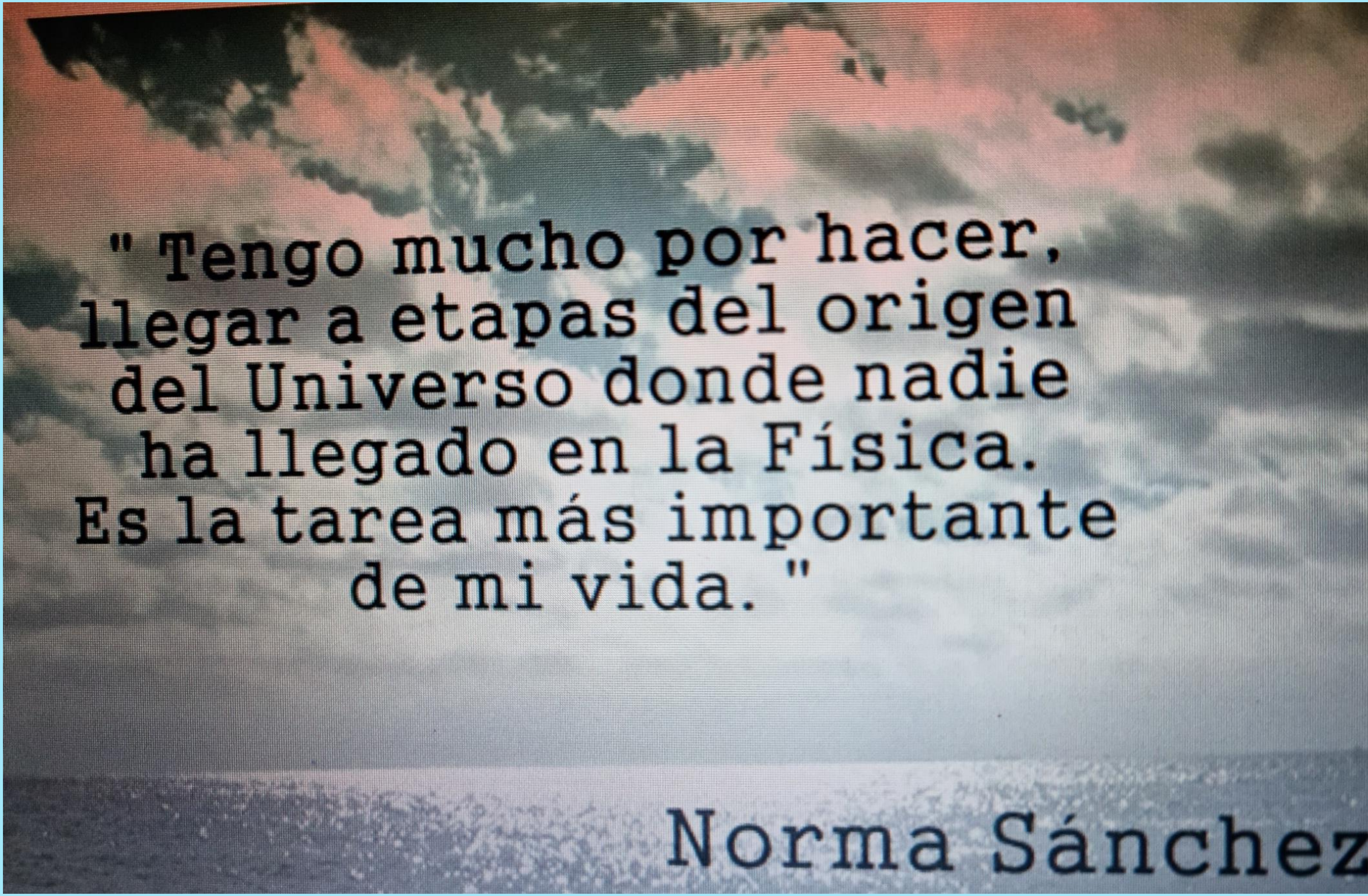
Communication Publica CyT,

Buenos Aires, Argentina

A Word on Language

[Los desarrollos científicos incorporan nuevos conceptos y lenguaje, o asignan nuevos contenidos a las palabras existentes. Lo que se percibe en un momento dado como "difícil" o no habitual, se convierte posteriormente en "estándar" y se incorpora al pensamiento "habitual" mediante el uso corriente o repetido de estas palabras en las comunicaciones actuales ......mismo si no los entandamos totalmente…]

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....meme si nous comprenons pas….]


" Tengo mucho por hacer, llegar a etapas del origen del Universo donde nadie ha llegado en la Física. Es la tarea más importante de mi vida. "
Norma Sánchez

EL UNIVERSO CONOCIDO (EL VIEJO UNIVERSO)

→ (i) La teoria efectiva de la Inflación cósmica compatible con las observaciones y sus predicciones .

→ (ii) La naturaleza de la materia oscura compatible con las observaciones cosmológicas y de grandes y pequeñas structuras, incluyendo los agujeros negros.

→ (iii) La naturaleza de la energía oscura compatible con la energia de vacío y su clarificación.
→(iv)Mi visión conclusiones sobre el estado actual de la investigación en el tema y las direcciones a seguir.

→ (iv) EL NUEVO UNIVERSO: La nueva etapa cuántica transplanckiana precursora del Universo y sus implicaciones, BHs, S-T Cuantico, Q Light-cone, NEW

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[1] **N. G. Sanchez,** *Quantum Discrete Levels of the Universe from the early trans-planckian vacuum to the late dark energy ,*
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- **2019 Trilogy**

- [2] **N. G. Sanchez,** ***New Quantum Phase of the Universe before Inflation and its Cosmological and Dark Energy Implications***
Int Journal Mod Phys A34, No.27, 1950155 (2019)

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

- [4] **N. G. Sanchez,** ***The New Quantum structure of the space-time,***
J. Grav & Cosmology 25, pp 91-102, (2019) (Springer)

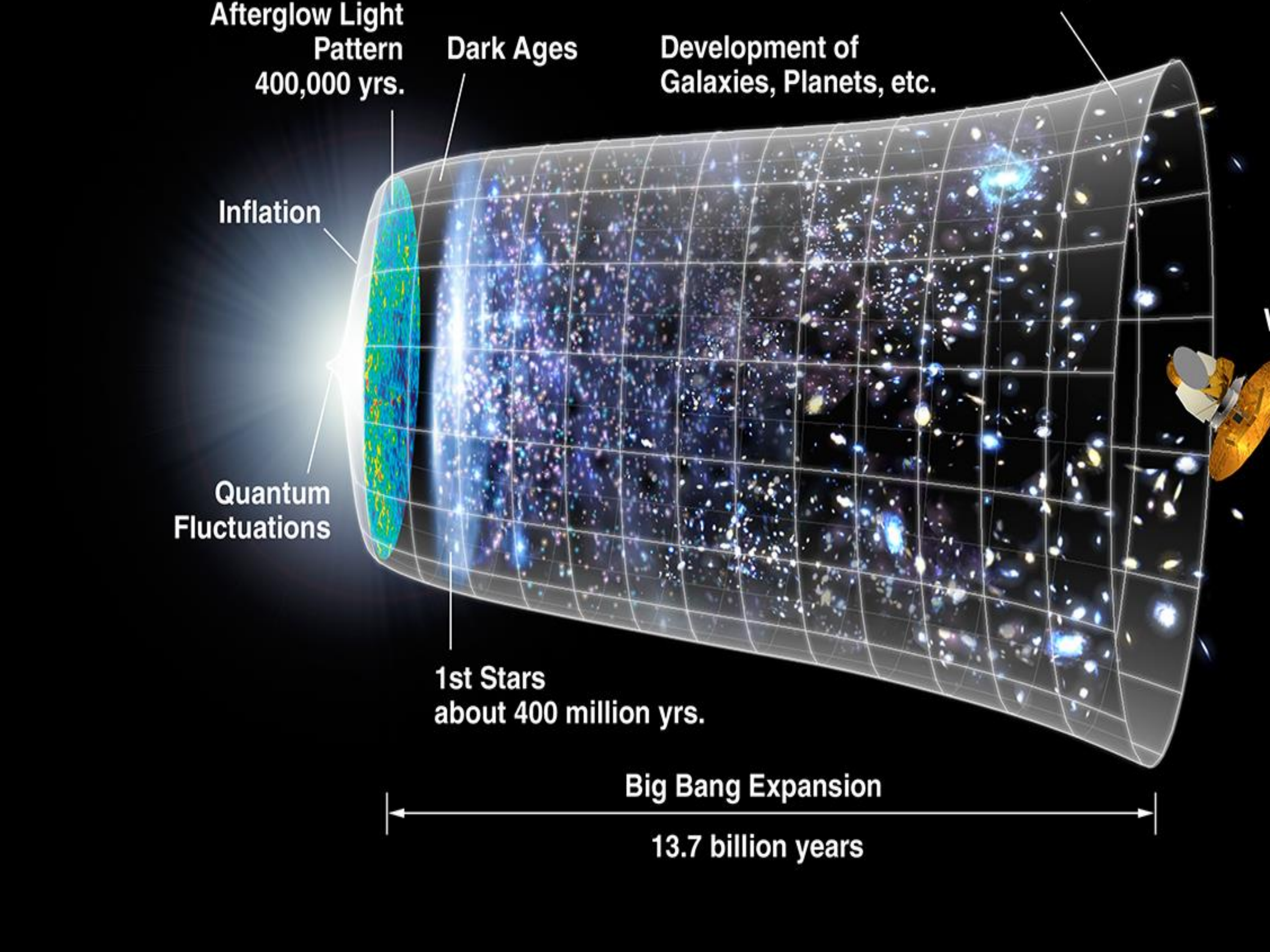
- https://www.researchgate.net/profile/Norma_Sanchez12

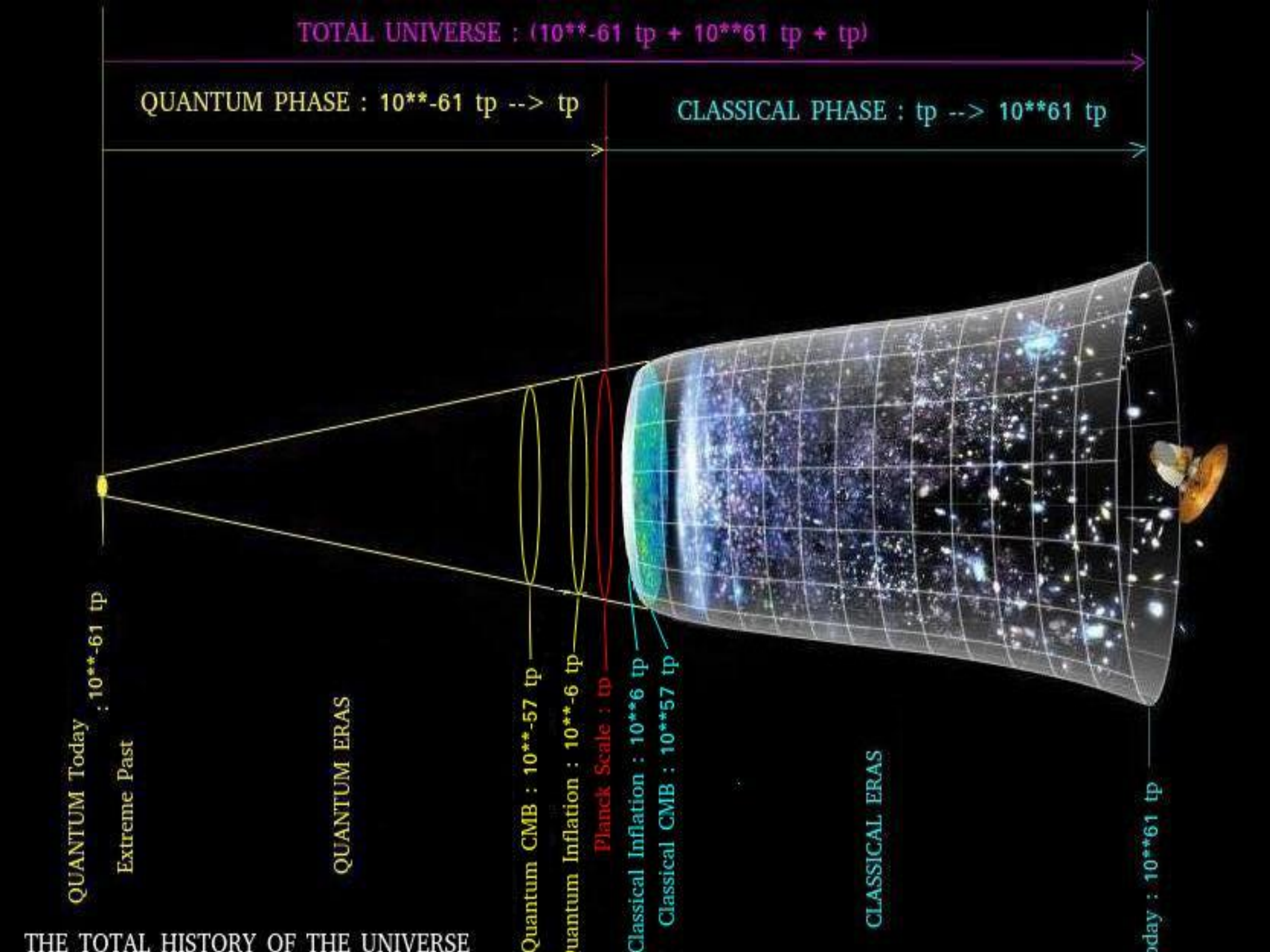
LE TIEMPO: CONCEPTOS

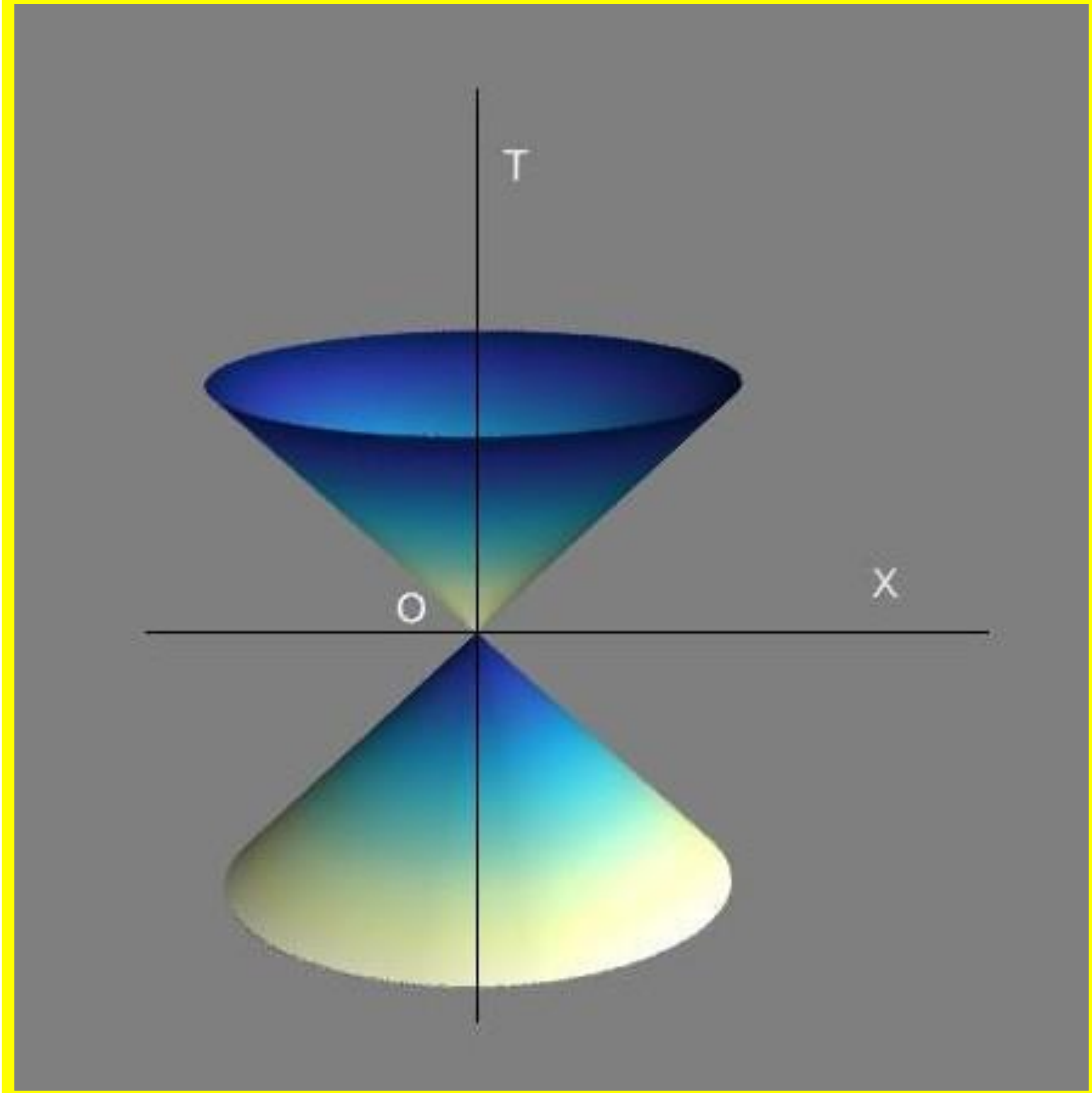
- CAUSALIDAD, VELOCIDAD MAXIMA: c
- PASADO, PRESENTE, FUTURO: CONO DE LUZ
- IRREVERSIBILIDAD : LA FLECHA DEL TIEMPO →→→
- EVOLUCION, ELUNIVERSO évoluciona DEL DESORDEN HACIA EL ORDEN

(DEL CAOS HACIA LA ESTRUCTURACION): => ENTROPIA, Siempre CRECE

- LA GRAVITACION, ESPACIO-TIEMPO, CLASSICA vs CUANTICA
- EL TIEMPO es un concept CLASICO, SemiCl, Cuantico
- EMERGE a partir du QUANTIQUE
- ORIGIN DU TEMPS : VACIO (« NADA ») : VIDE QUANTIQUE ==>
- TIEMPO QUANTICO ==> Niveles Discretos del Tiempo


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


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


T
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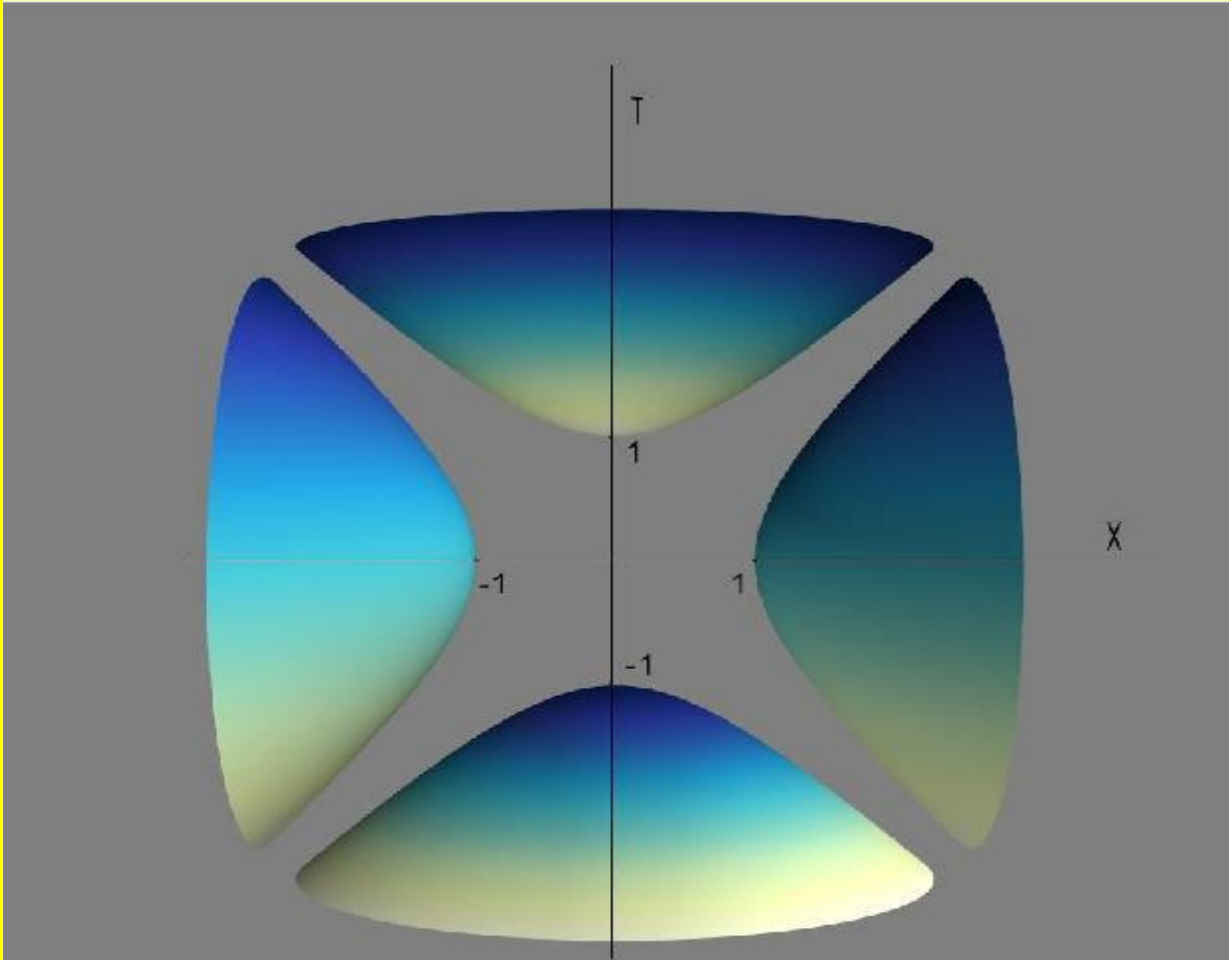

T
1
X
-1
1
-1

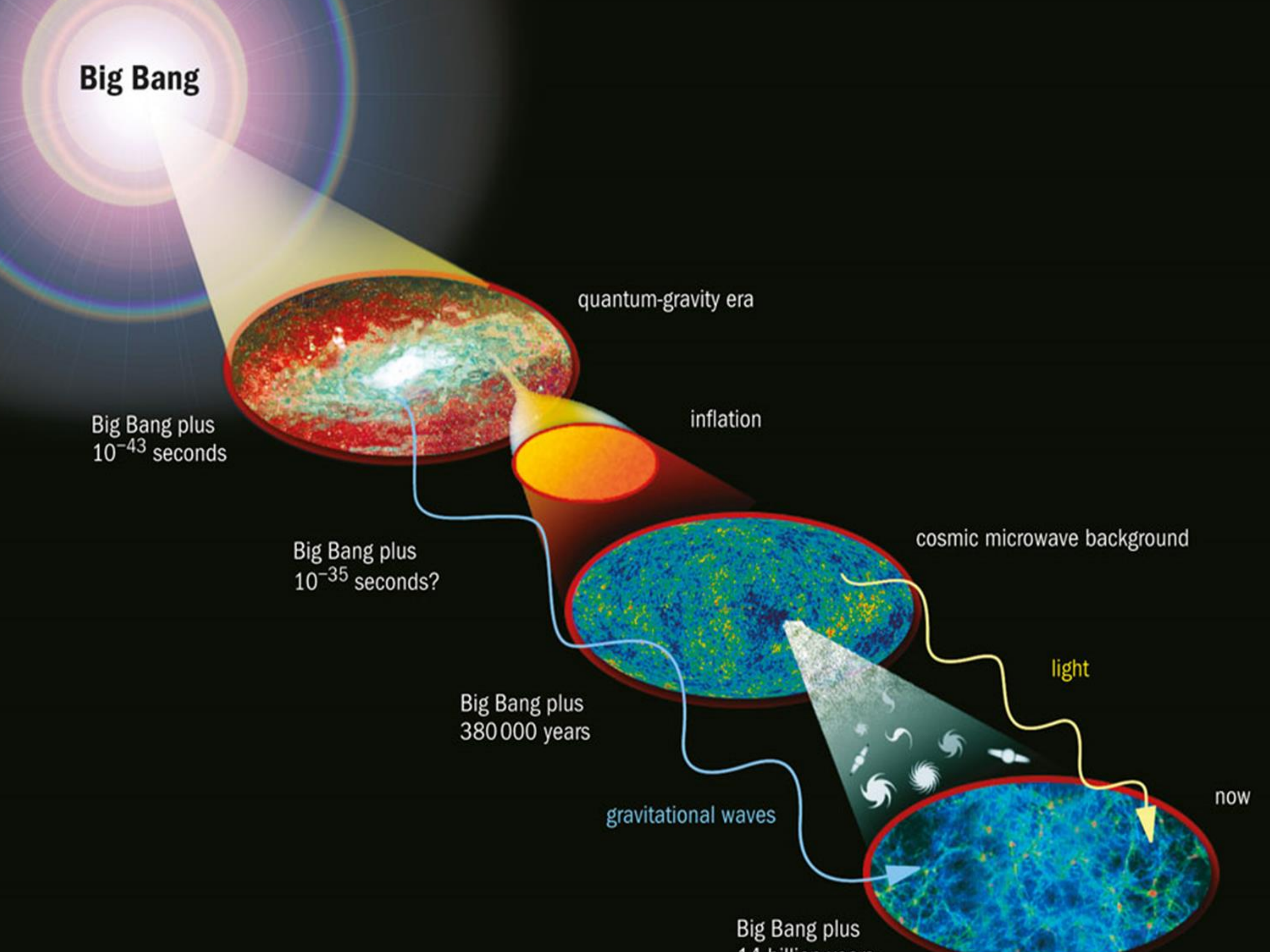
A NEW QUANTUM WORLD

From the Planck Scale

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

10^{-5} gr, 10^{-33} cm, 10^{-44} sec, 10^{19} GeV

To The Trans-Planckian Physics Domain



Big Bang
quantum-gravity era
Big Bang plus
10^{-43} seconds
inflation
Big Bang plus
10^{-35} seconds?
cosmic microwave background
light
Big Bang plus
380 000 years
gravitational waves
now
Big Bang plus

CONTENT OF THE UNIVERSE

ATOMS, the building blocks of stars and planets: represent only the 4.6%

DARK MATTER comprises 23.4 % of the universe. This matter, different from atoms, does not emit or absorb light. It has only been detected indirectly by its gravity.

72% of the Universe, is composed of DARK ENERGY that acts as a sort of an anti-gravity.
This energy, distinct from dark matter, is responsible for the present-day acceleration of the universal expansion, compatible with a cosmological constant

Standard Cosmological Model:

Ordinary Matter + Dark Matter + Cosmological Constant

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

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^3 (cosmological constant).

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

Galaxy density:

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

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

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

How the Universe took its present aspect?

The Universe was homogeneous and isotropic after inflation thanks to the fast and gigantic expansion stretching lenghts by a factor $e^{64} \simeq 10^{28}$.

The universe by the end of inflation is a extraordinarily hot plasma at $T \sim 10^{14}$ GeV $\sim 10^{27}$ K.

However, small ($\sim 10^{-5}$) quantum fluctuations were of course present.

These inflationary quantum fluctuations are the seeds of

- the structure formation in the universe: galaxies, clusters, stars, planets (and all on them), ...
- the CMB anisotropies today.

That is, our present universe (including ourselves) was built out of inflationary quantum fluctuations.

Two key observable numbers :

associated to the primordial density and primordial gravitons :

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

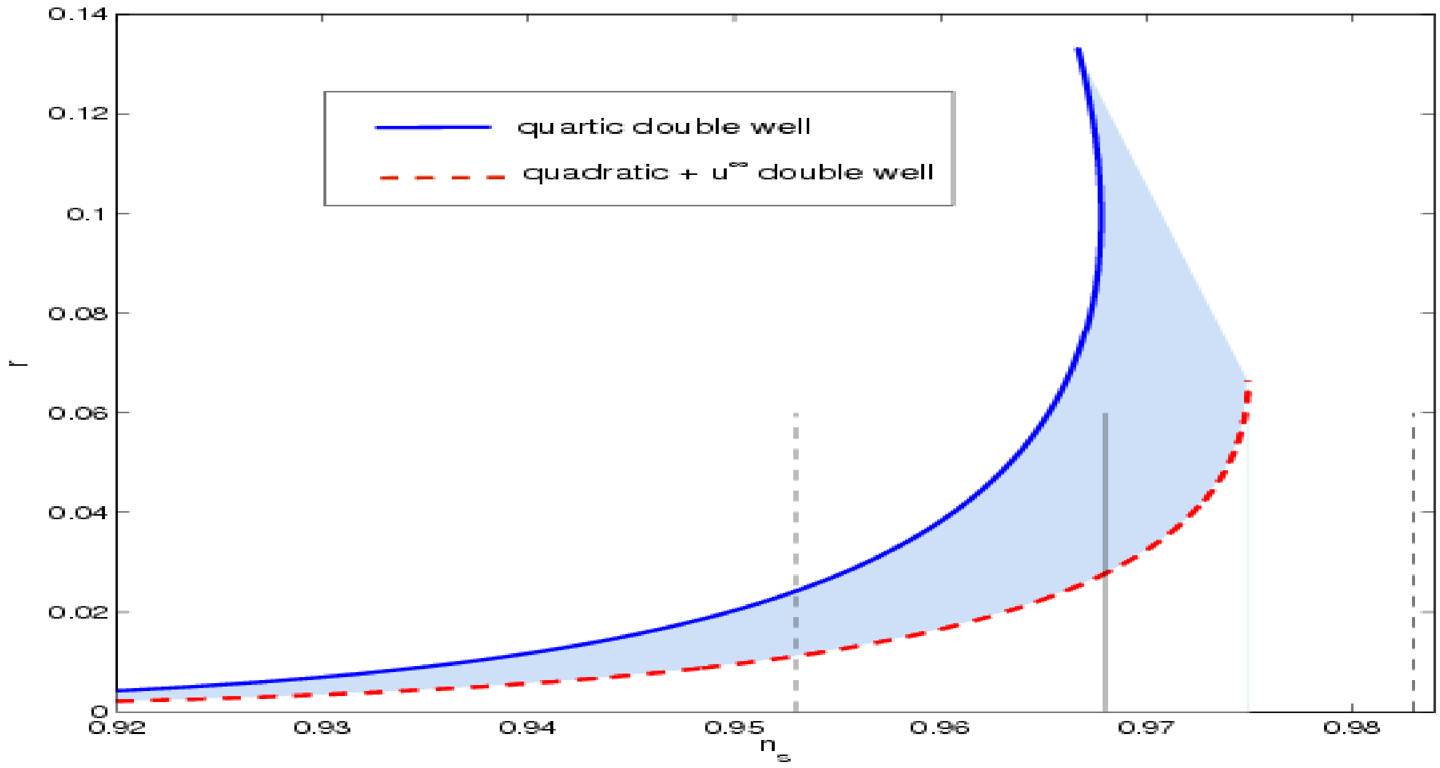
PREDICTIONS

$r < 0.030$

$r > 0.016$

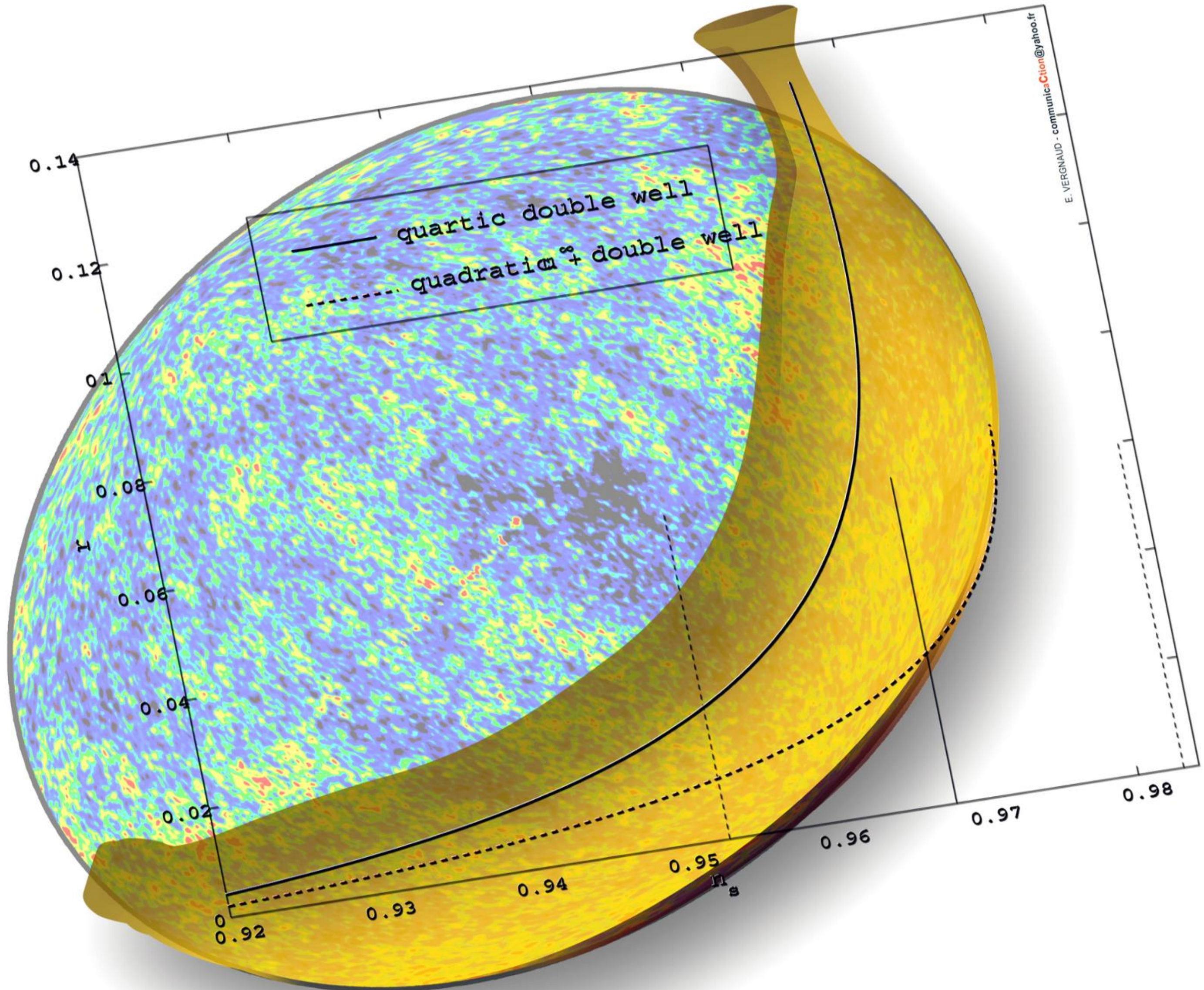
$0.016 < r < 0.030$

Most probable value: $r \sim 0.02$



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)



quartic double well
quadratic + double well
r
n_s
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.92
0.93
0.94
0.95
0.96
0.97
0.98
E. VERGNAUD - communicaCtion@yahoo.fr

Dos pioneros argentinos que predijeron los nuevos datos

Dos científicos argentinos más cerca del origen del cosmos

Dos científicos argentinos más cerca del origen del cosmos

El satélite Planck de la ESA permitirá a Norma Graciela Sánchez y Héctor José de Vega probar sus teorías sobre el universo temprano

https://www.dicyt.com/noticias/dos-cientificos-argentinos-mas-cerca-del-origen-del-cosmos

AGENCIA IBEROAMERICANA PARA LA DIFUSION DE LA CIENCIA Y LA TECNOLOGIA, DICYT

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

FECYT FUNDACIÓN ESPAÑOLA PARA LA CIENCIA Y LA TECNOLOGÍA

THE ENERGY SCALE OF INFLATION

is The

THE SCALE OF GRAVITY IN ITS SEMICLASSICAL REGIME

(OR THE SEMICLASSICAL GRAVITY TEMPERATURE)

(EQUIVALENT TO THE HAWKING TEMPERATURE)

The CMB allows to observe it

(while is not possible to observe for Black Holes)

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).

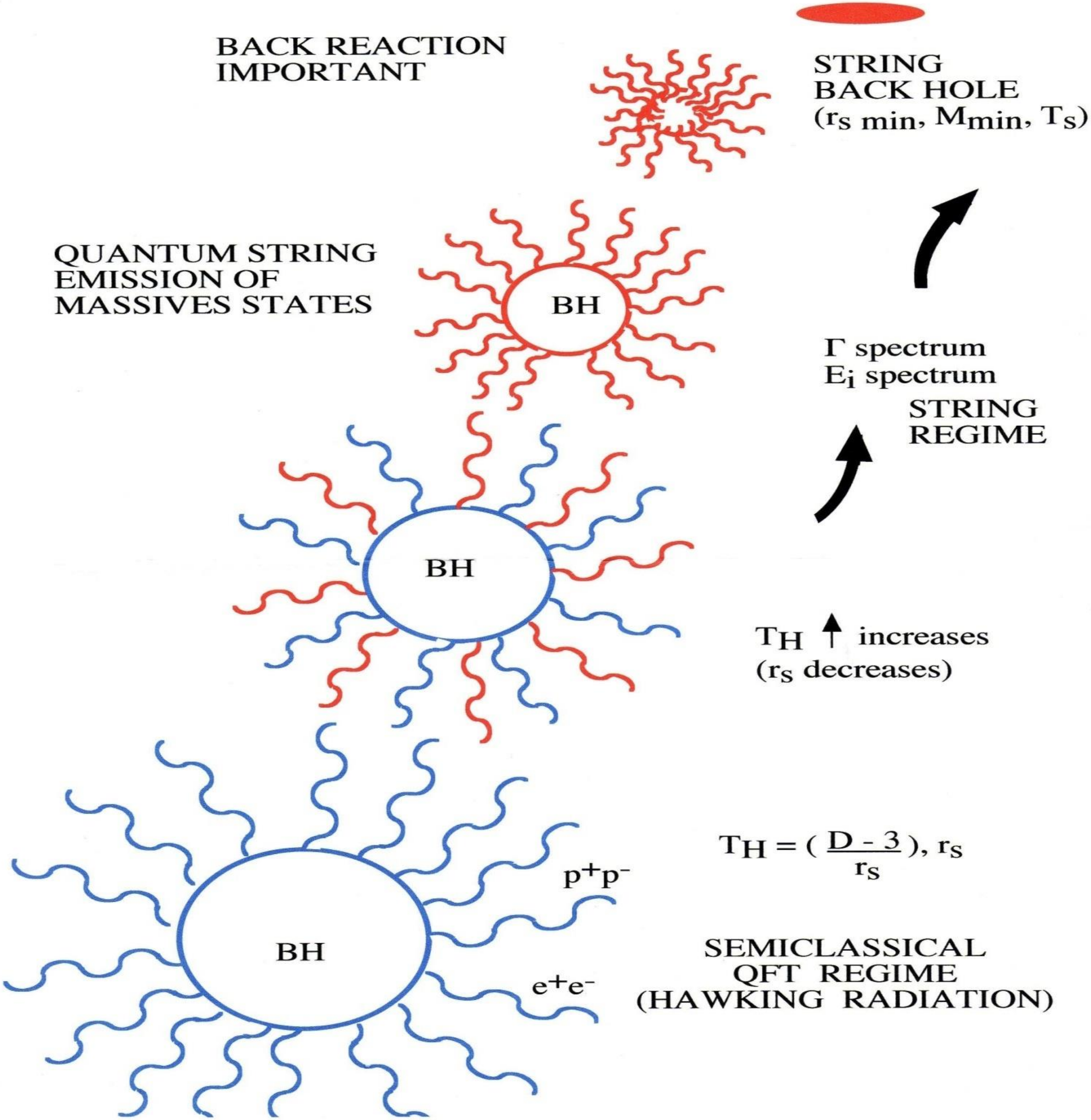
Conceptual unification of quantum black holes, elementary particles and quantum states

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)

Unifying quantum mechanics with Einstein's general relativity. The quantum nature of gravity is an enigma which has eluded even the brightest of physicists for many decades.

Now, Dr Norma G. Sanchez at the French CNRS describes a possible solution. Her approach takes the form of a general theory, incorporating both quantum mechanics and Einstein's theory of general relativity.

Her results could bring researchers a step forward in their knowledge of how the physics which plays out on the very smallest of scales can be compatible with that which occurs on the very largest cosmological scales.

Unifying quantum mechanics with Einstein's general relativity - Research Outreach DOI: 10.32907/RO-111-138141 2020

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-
u centre de notre voie
n congénère de la ga-
, dont la photo a été

ite ? Huit mois de
n de ce type d'opéra-
pées, les observations
l'aveugle, les astrono-
aucun moyen de sa-
a fonctionné. Il aura
dre de débusquer un
mun à tous les télesco-
t dire, dans l'Univers,
le dans une botte de

an de travail a été
pour reconstruire les
photo. « Pour plus de
travail a été fait quatre
uatre équipes différen-
cine 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
ercredi dans la revue
cal Journal Letters. Et
nent la même image,
mbre sur un halo scin-
e du trou noir sur le
matière qui l'entoure.
révélation, cette pho-
rrément parler. Beau-
ernautes s'amusent à
ce trou noir avec l'œil
nt du « Seigneur des
, l'ignoble Sauron.
50 millions d'années-
univers continue de
ner...

T. L. (avec AFP)

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

angeté

rmes, ce que vous
t pas forcément où
ez. Un objet peut ap-
formé ou dédoublé.
marée est tellement
'un astronaute qui
vers l'horizon d'un
erait transformé en
ses pieds accélérant
e sa tête. Et c'est sans
temps qui se dilate, et
qui se décale vers le
'à devenir invisible.
ateur lointain qui re-
chute de ce même
aurait l'impression
ernier silence puisse
de s'effacer progres-

J.-M.L.

REPÈRES

Une existence théorique
Dès la fin du XVIII[e] 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 XX[e] 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 d'accrétion 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 dédoubler 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.

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

6,5

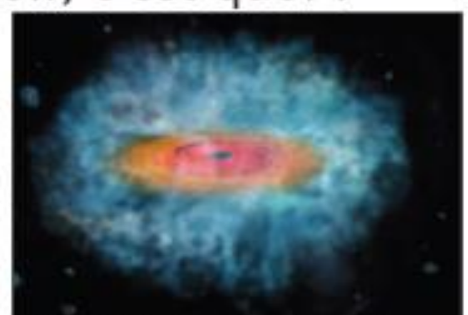
**MILLIARDS
de fois la masse du Soleil, telle est le poids du trou noir dont la photo a été observée ce mercredi.
Pour quantifier, la masse du Soleil équivaut à 333 000 fois la masse de la Terre.
Notre planète pèse environ 6 000 quadrillions de kilogrammes.
En masse, un quadrillion, c'est au-delà de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


MOËT & CHANDON
Fondé en 1743

What is the nature of the Dark Matter?

83% of the matter in the universe is Dark.

Only the DM gravitational effects are noticed and they are necessary to explain the present structure of the Universe.

DM (dark matter) particles are neutral and so weakly interacting that no effects are so far detectable.

Theoretical analysis combined with astrophysical data from galaxy observations as:

- Observed galaxy densities and velocity dispersions.
- Observed galaxy density profiles are cored.
- Acceleration of gravity in the surface of DM dominated galaxies is universal
  $g \simeq 1.7 \times 10^{-11}\, m/s^2 \ = 540 \text{ kpc}/(\text{Gyr})^2.$

points towards a DM particle mass in the keV scale called warm dark matter (WDM). 2 keV = 1/250 electron mass.

Dark Matter: from primordial fluctuations to Galaxies

❖ Cold (CDM): small velocity dispersion: small structures form first, bottom-up hierarchical growth formation, *too heavy (GeV)*

❖ Hot (HDM) : large velocity dispersion: big structures form first, top-down, fragmentation, ruled out, *too light* (eV)

Warm (WDM): ``in between", *right mass scale,* (keV)

ΛWDM Concordance Model:

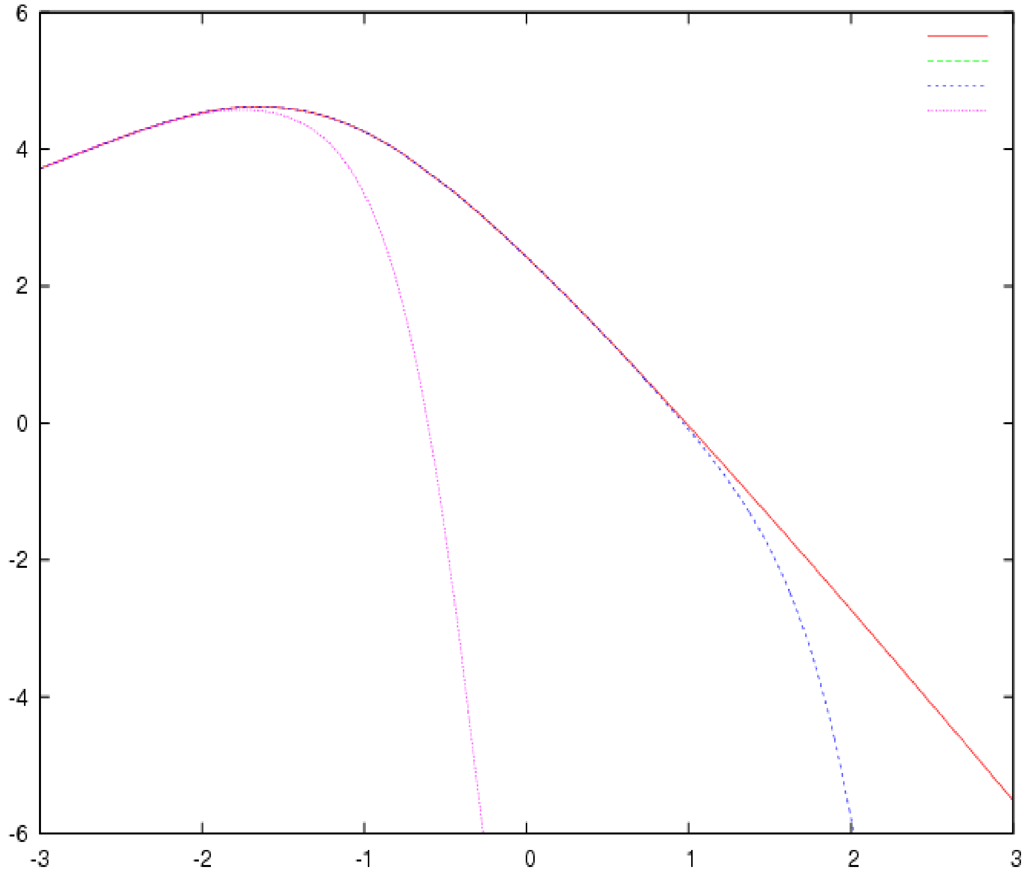
CMB + LSS + SSS Observations

DM is WARM and COLLISIONLESS

CDM Problems:

- "clumpy halo problem", large number of satellite galaxies
  "satellite problem", overabundance of small structures
- ρ (r) ~ 1 / r (cusp)
- And other problems…..

Linear primordial power today $P(k)$ vs. k Mpc h



$\log_{10} P(k)$ vs. $\log_{10}[k \text{ Mpc } h]$ for WIMPS, 1 keV DM particles and 10 eV DM particles. $P(k) = P_0 \, k^{n_s} \, T^2(k)$.

$P(k)$ cutted for 1 keV DM particles on scales $\lesssim 100$ kpc.

Transfer function in the MD era from Gilbert integral eq

ΛWDM Cosmology

(I) The Standard Model of the Universe Includes Inflation

(II) DARK MATTER IN GALAXIES from Theory and Observations: Warm (keV scale) DM

(III) NOVEL: THE ESSENTIAL ROLE OF QUANTUM PHYSICS IN WDM GALAXIES: Semiclassical framework: Analytical Results and Numerical (including analytical) Results

Observed Galaxy cores and structures from Fermionic WDM and more results.

(IV) NEW: The generic Galaxy types and properties from a same physical framework: From quantum (compact, dwarfs) to classical (dilute, large) galaxies. Equation of state. Generalized Eddington approach to galaxies

DARK MATTER UPDATE

- THERE IS NO CUSP/CORE problem:
- Observed Galaxy density profiles are cored.
- WDM Galaxy density profiles are cored

- THERE IS NO satellite problem
- WDM abundance of structures agrees with observations
- In addition, these are not fundamental problems.

NO CDM Wimps, NO DM annhilation,

The Total DM cannot be bosons (Axions)

UPDATE and CLARIFICATIONS

→ΛCDM agrees with CMB + LSS **BUT**

ΛCDM **DOES NOT agree with SSS (GALAXIES)**

ΛWDM agrees with CMB + LSS + SSS (GALAXIES)

→ **The Standard Model of the Universe is LWDM =**

{GR, Newtonian Gravity, Field Theory, QFT}

Sentences like « CMB confirms the ΛCDM model … »

Must be completed by adding: « in the large scales” »

and must be updated with the sentence:

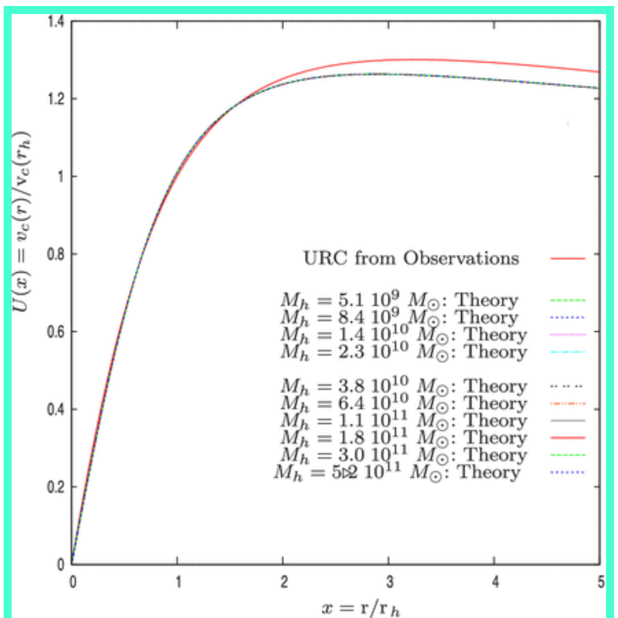
CMB confirms the ΛWDM model in large scales

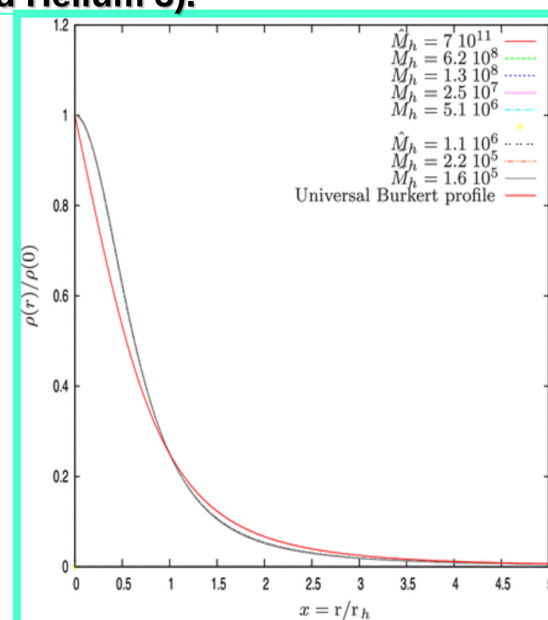
→ **NEW: Gravity and Quantum Mechanics in Galaxies. Newton, Fermi and Dirac meet together in Galaxies because of keV WDM**

Newton, Fermi and Dirac, meet together in Galaxies through keV Warm Dark Matter

Rotation curves (left panel): The theoretical curves for 10 different galaxy masses all fall one into each other providing an Universal Rotation Curve (URC) which remarkably coincides with the observed universal curve (displayed in red) . Small deviations show up only at distances outside twice the *radius.*

The right panel the density profiles for the 10 galaxy masses: All fall into the same and universal density profile which reproduces the observed universal density profile and its size (in red). Interestingly enough, small deviations show up for compact dwarf galaxies as a manifestation of the quantum macroscopic effects predicted in these galaxies, and which can be further tested observations. (Examples of other macroscopic objects in nature are dwarf stars, neutron stars and the liquid Helium 3).





Universal rotation curves and Universal density profiles: The same for all large galaxies

The theoretically obtained galaxy rotation curves and density profiles reproduce extremely well the observational curves from
ten different and independent sets of data for galaxy
Masses from 5×10^{9} Msun till 5×10^{11} Msun.

Remarkably enough, the normalized circular velocities and density profiles are universal (URC): they are the same for all galaxies of different types, sizes and masses, and agree extremely well with the observational curves described by cored profiles (flat smooth profiles at the center) and their sizes.

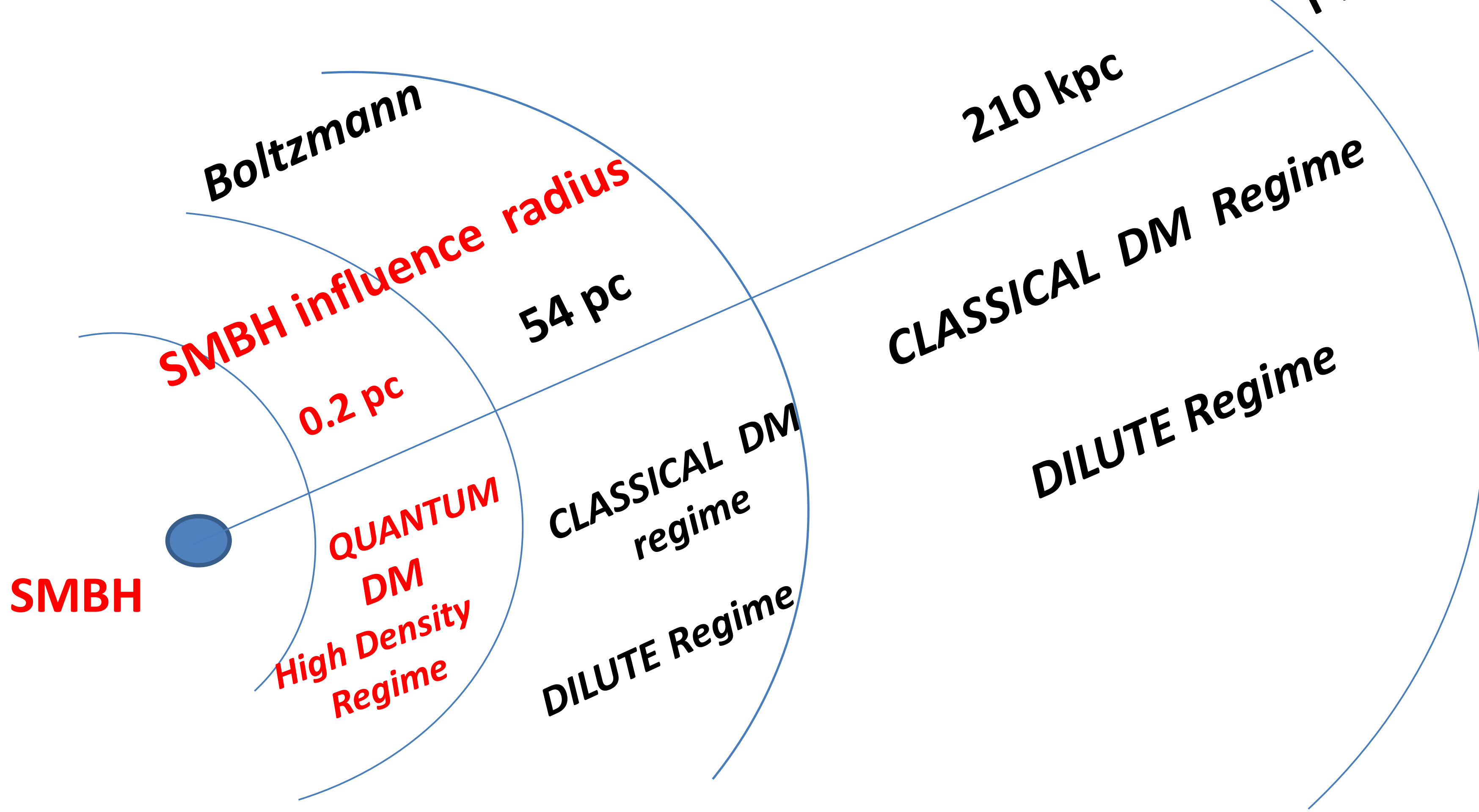
Interestingly enough, small deviations from the exact scaling relations show up for compact dwarf galaxies as a manifestation of the quantum macroscopic effects present in these galaxies.

Robust Results

independent of any particular WDM particle physics model, they only follow from the self-gravitation of the WDM particles and their fermionic nature. Ability of this approach to describe the galaxy structures. Baryonic corrections are not very important to WDM, consistent with the fact that DM is in average at least six times more abundant than baryons.

Reference:

H.J. de Vega; P. Salucci; N. G.Sanchez MNRAS 442 (2): 2717 (2014)



WDM Thomas-Fermi Galaxy Theory with SMBH

SMBH: Super Massive Black holes

H.J. de Vega & N.G. Sanchez

Universe, 8(3), 154 (2022)
https://doi.org/10.3390/universe8030154

$$M_h^{min} = 6.892 \times 10^7 \left(\frac{2\,\text{keV}}{m}\right)^{\frac{16}{5}} \left(\frac{\Sigma_0\,\text{pc}^2}{120\,M_\odot}\right)^{\frac{3}{5}} M_\odot\ , \text{ with central black hole.}$$

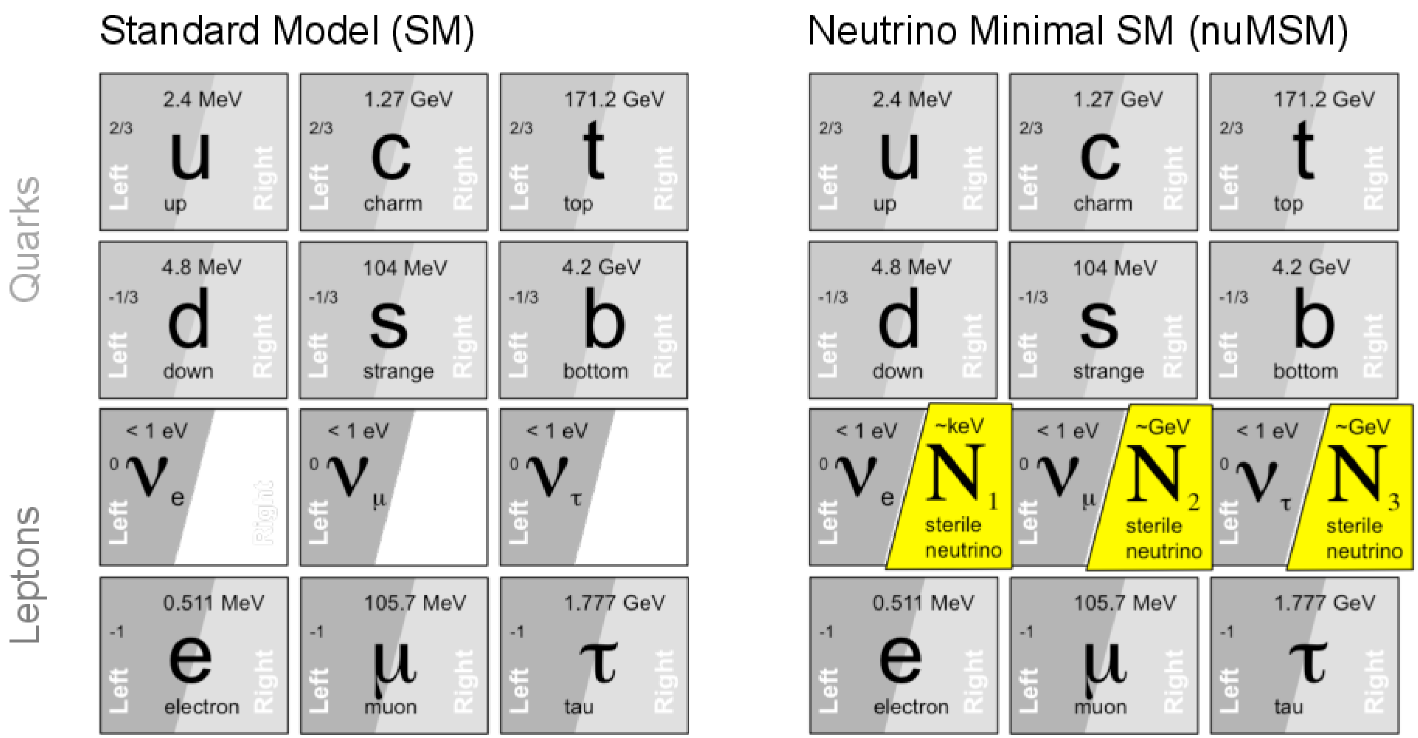
$$M_h^{min} = 3.0999 \times 10^4 \left(\frac{2\,\text{keV}}{m}\right)^{\frac{16}{5}} \left(\frac{\Sigma_0\,\text{pc}^2}{120\,M_\odot}\right)^{\frac{3}{5}} M_\odot\ ,\ T_0^{min} = 0\ , \text{ without central black hole}$$

Mh min with BH = 2.2233 × 10^3 times Mh min without BH

Galaxies with a central BH are in the classical dilute Boltzmann regime: large mass: Mh > 10^6 M⊙ > Mh min.

On the contrary, compact galaxies, eg, ultracompact galaxies in the quantum regime Mh < 2.3×10^6 M⊙ ,
cannot harbor central BH :
Mh min with BH is always > 2.3 × 10^6 M⊙.
→ ***Ultra compact dwarfs*** **Mh < Mminh,**
***necessarily do not possess central* BH**

Sterile Neutrinos



L. Canetti, M. Drewes, and
M. Shaposhnikov, PRL **110** 061801 (2013)

Sterile Neutrinos ν

Rhenium and Tritium beta decay (MARE, KATRIN).
Theoretical analysis: H J de V, O. Moreno, E. Moya de Guerra, M. Ramón Medrano, N. Sánchez,
Nucl. Phys. B866, 177 (2013).

[Other possibility to detect a sterile ν_s: a precise measure of nucleus recoil in tritium beta decay.]

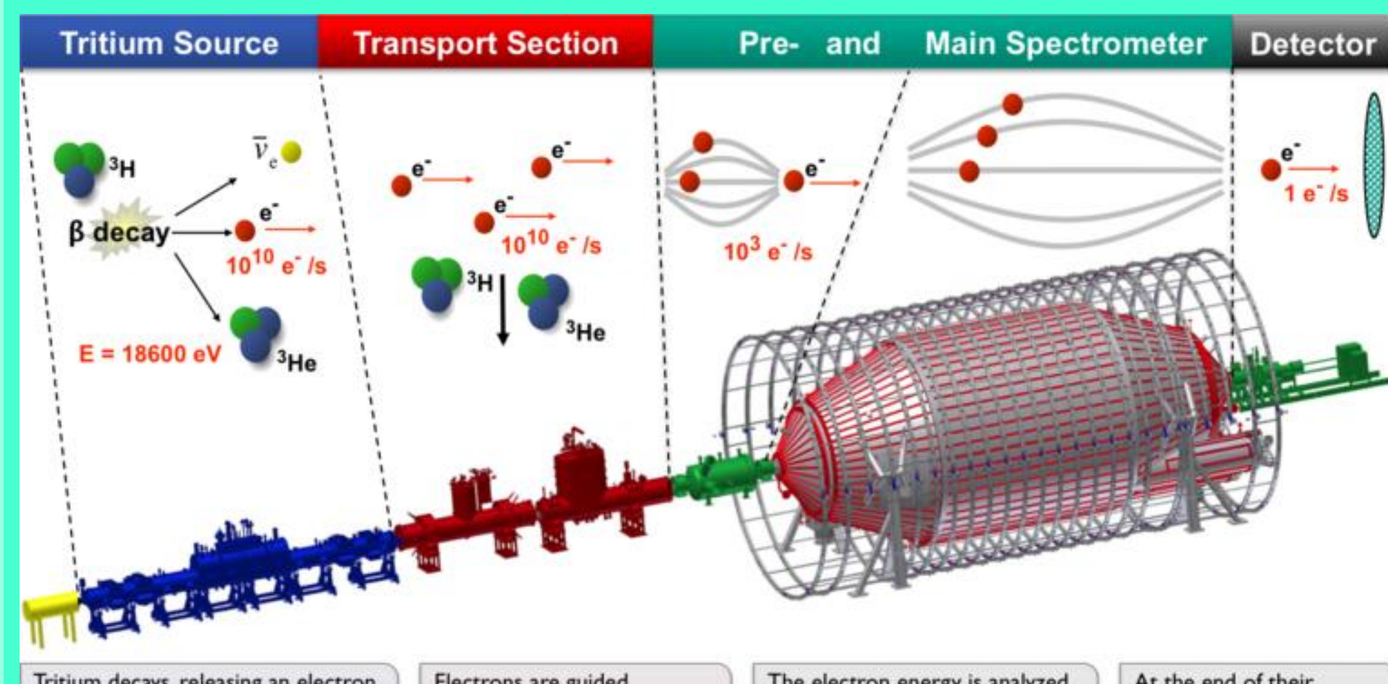
Conclusion: the empty slot of right-handed neutrinos in the Standard Model of particle physics can be filled by keV-scale sterile neutrinos describing the DM.

An appealing mass neutrino hierarchy appears:

- Active neutrino: $\sim$ mili eV
- Light sterile neutrino: $\sim$ eV
- Dark Matter: $\sim$ keV
- Unstable sterile neutrino: $\sim$ MeV....

KATRIN

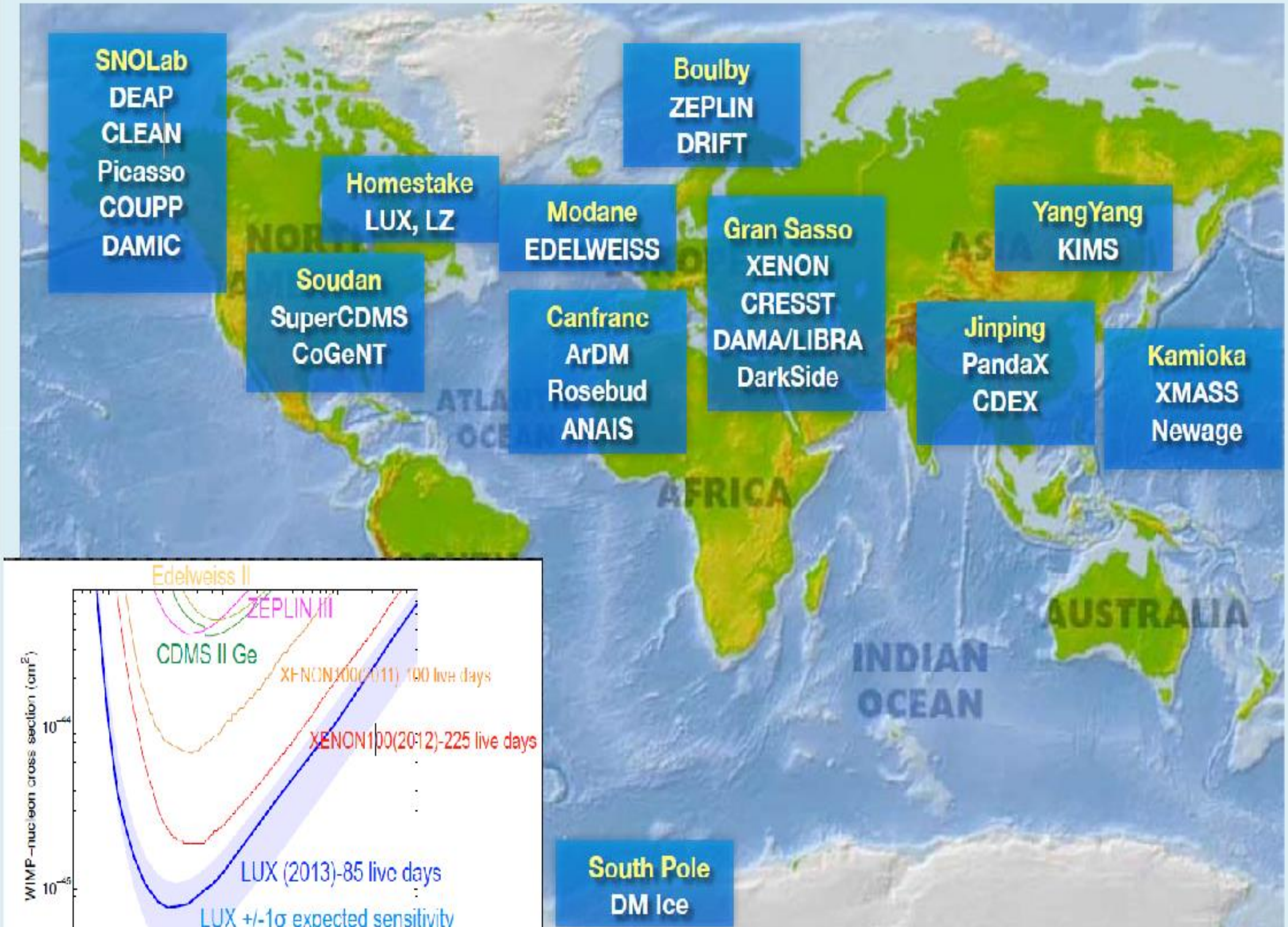
Karlsruhe Tritium Neutrino Experiment



• Why No Experimental Detection of the DM particle has been reached so far ? Because:

- All experimental searches for DM particles are dedicated to CDM: wimps of m > 1 GeV,
- While the DM particle mass is in the keV scale .
- Moreover, past, present and future reports of signals of such CDM experiments <u>cannot be due</u> to DM because of the same reason.
- The inconclusive signals in such experiments should be originated by phenomena of other kinds.
- In addition, such signals contradict each other supporting the idea that they are <u>unrelated to any DM</u> detection.

Dans le monde entier



Future Perspectives: Detection!

Sterile neutrino detection depends upon the particle physics model. There are sterile neutrino models where the keV sterile is stable and thus hard to detect.

Astronomical observation of steriles:
X-ray data from galaxy halos.

Direct detection of steriles in Lab:

Bounds on mixing angles from
Mare, Katrin, ECHo, Project 8 and PTOLEMY are expected.

For a particle detection a dedicated beta decay or electron capture experiment looks necessary to search sterile neutrinos with mass around 2 keV.

Calorimetric techniques seem well suited.

Best nuclei for study:

Electron capture in ^{163}Ho, beta decay in ^{187}Re and Tritium.

The Standard Model of the Universe and its Extension

→The Standard Model of the Universe: Inflation, General Relativity, Quantum Field Theory, Dark Matter (outside of the Standard Model of Particle Physics, Warm Dark Matter), Dark Energy (Vacuum Energy).

→As in Particle Physics : The Standard Model of Cosmology needs to be Extended or Completed:

And also: Some pieces (eg CDM: recurrently do not agree with observations at galactic and smaller scales , or recurrently not detected in the dedicated energy range with the right detectors) call for a changement.

WDM It yields the same LSS results as CDM and CMB and also agree with SSS and Galaxy observations .

→ Extending / Completing the Universe History Before Inflation requires Quantum Physics at and beyond the Planck scale.

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 the domain beyond it.

(i) Instead of starting from Gravity, that is General Relativity and quantize it (by applying the different quantization procedures, with the by now well known problems and its rich bibliography),

(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 road (i) are most useful.

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, IJMP19, GraCosm2019, PhyRevD Dec 2021

This Duality is Universal

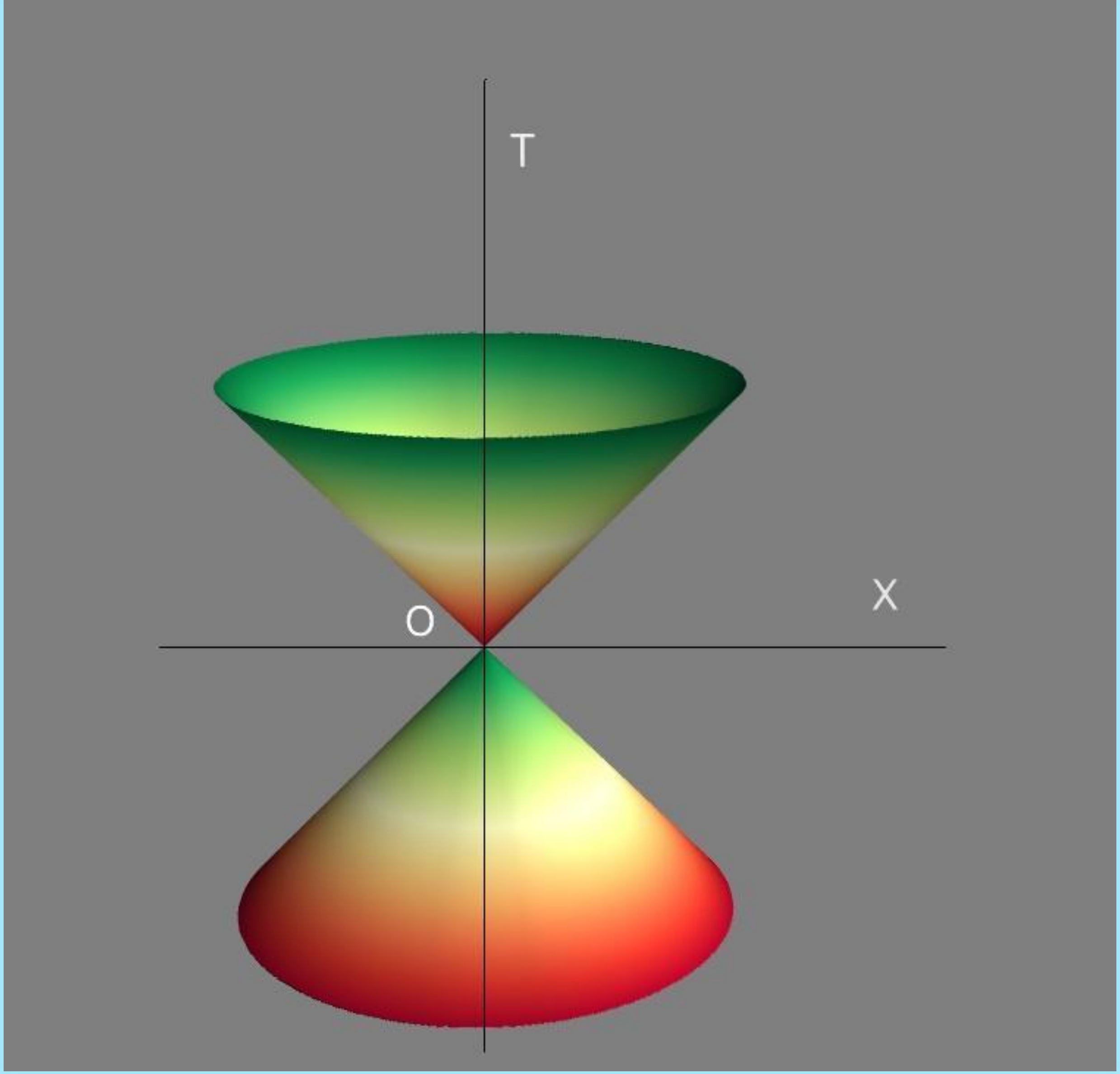
it includes the known duality and allows a general clarification and new results which reveal:

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

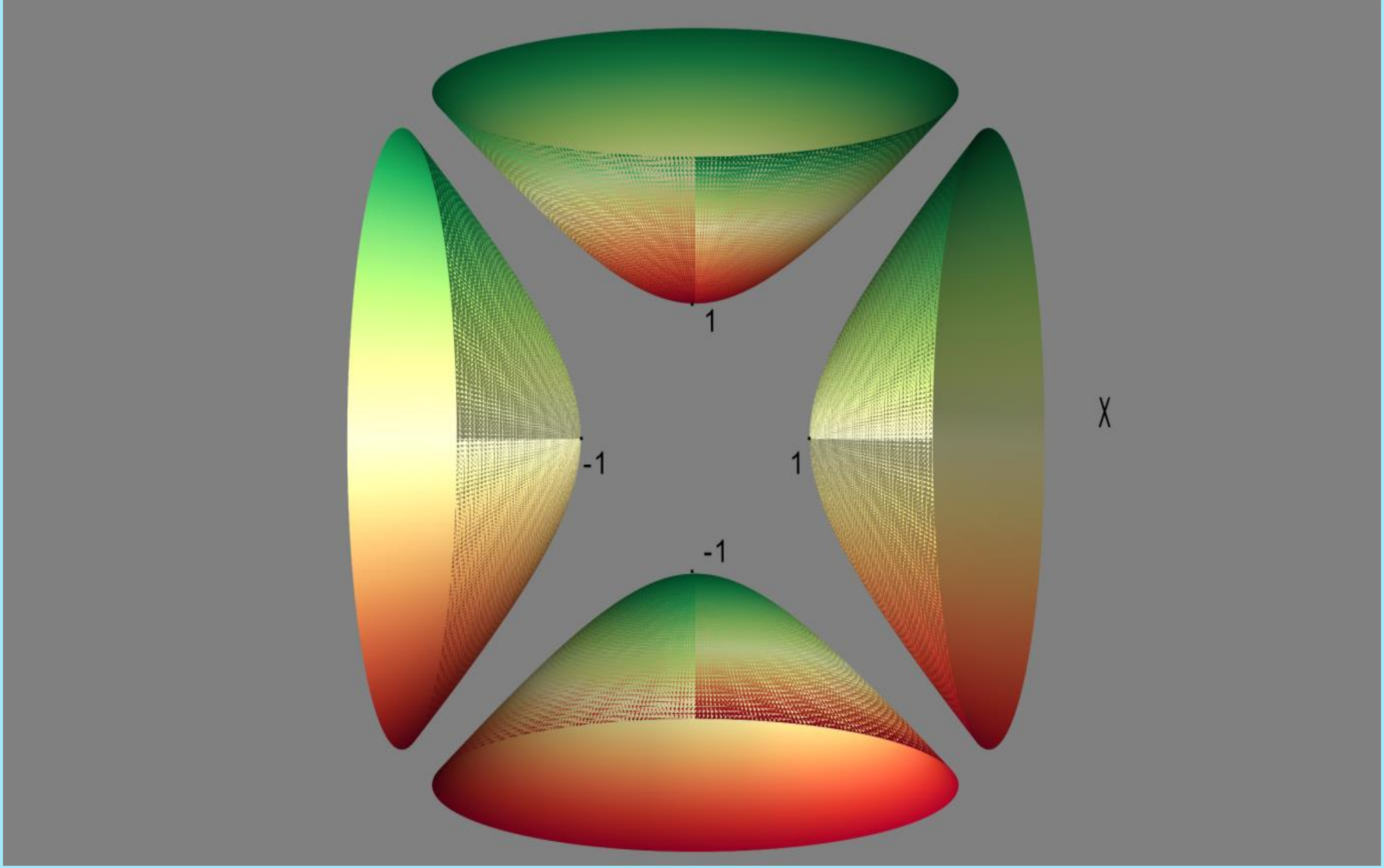
(ii) A new quantum domain not present in classical gravity does appear

(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 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

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

New Variables : $L_{QG} = L_Q + L_G$, $O_{QG} = O_Q + O_G$, $Q \Longleftrightarrow G$

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)

$U_\Lambda = (L_\Lambda, M_\Lambda, \rho_\Lambda, T_\Lambda, S_\Lambda)$: 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*

Precursor Quantum phase of the known Classical Inflation era and of the classical standard eras and today Dark Energy

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.

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.

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, 2018-2021)

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

THE COSMOLOGICAL CONSTANT:

GRAVITATIONAL ENTROPY

AND TEMPERATURE

OF THE UNIVERSE

GRAVITATIONAL ENTROPY AND TEMPERATURE

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

$$T = (\text{Area} / a_P)^{1/2}\, t_P = L\, t_P$$

Classical: CLASSICAL Lengths

Quantum: QUANTUM Lengths

NEW 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".***

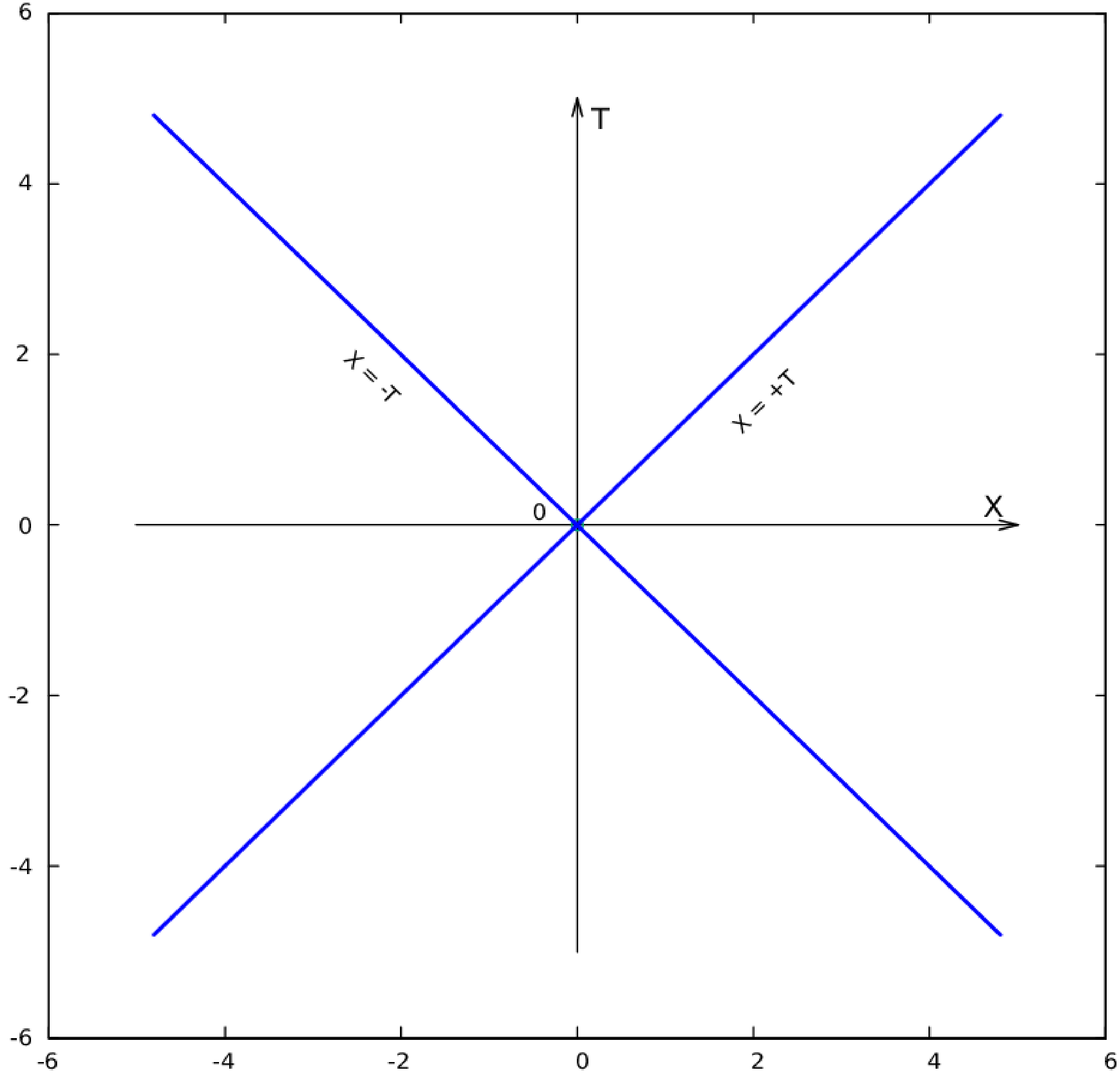
$$\mathbf{(X^2 - T^2)_n = 2n + 1}$$ **: discrete levels**

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

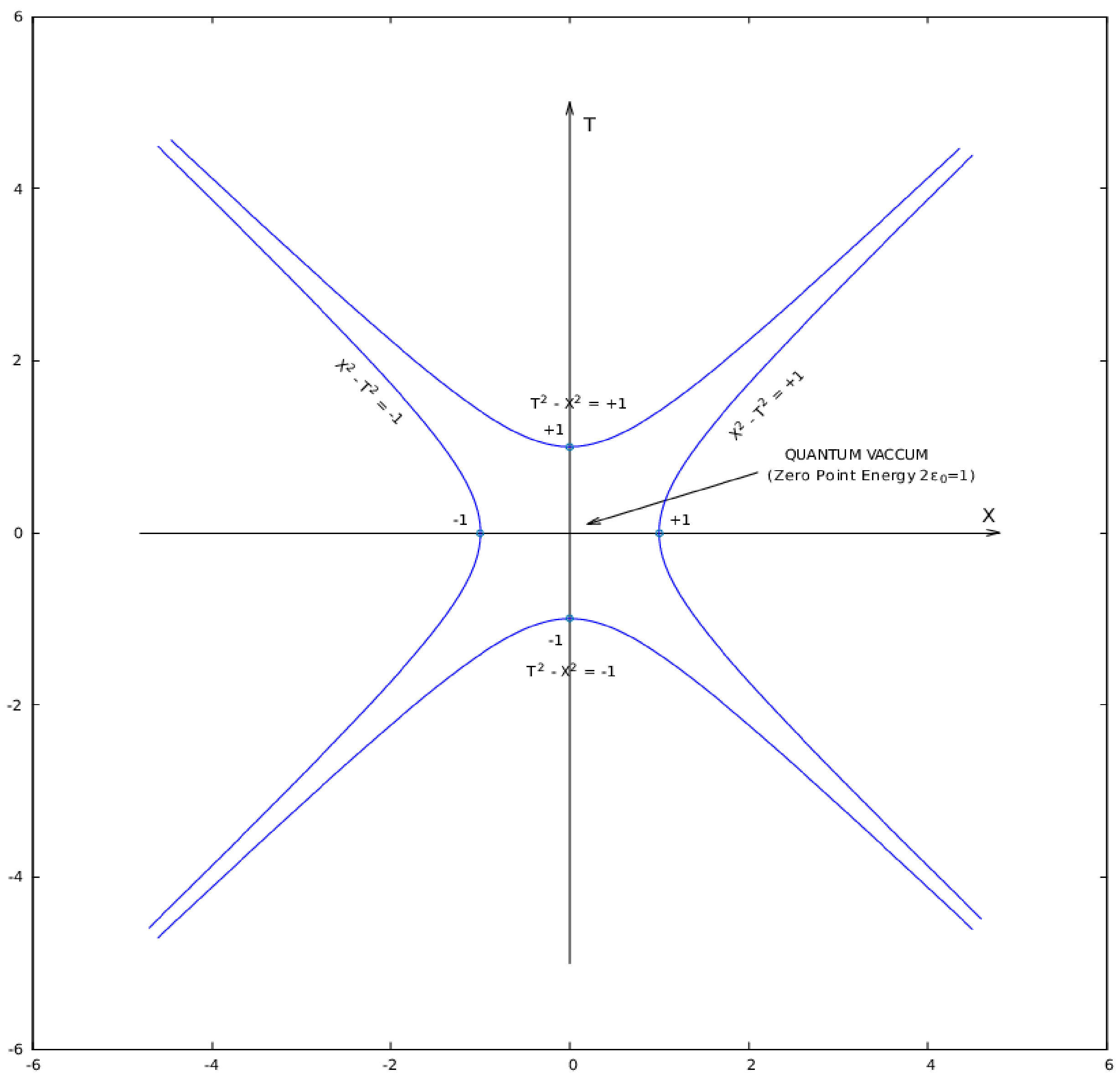
the quantum light cone

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

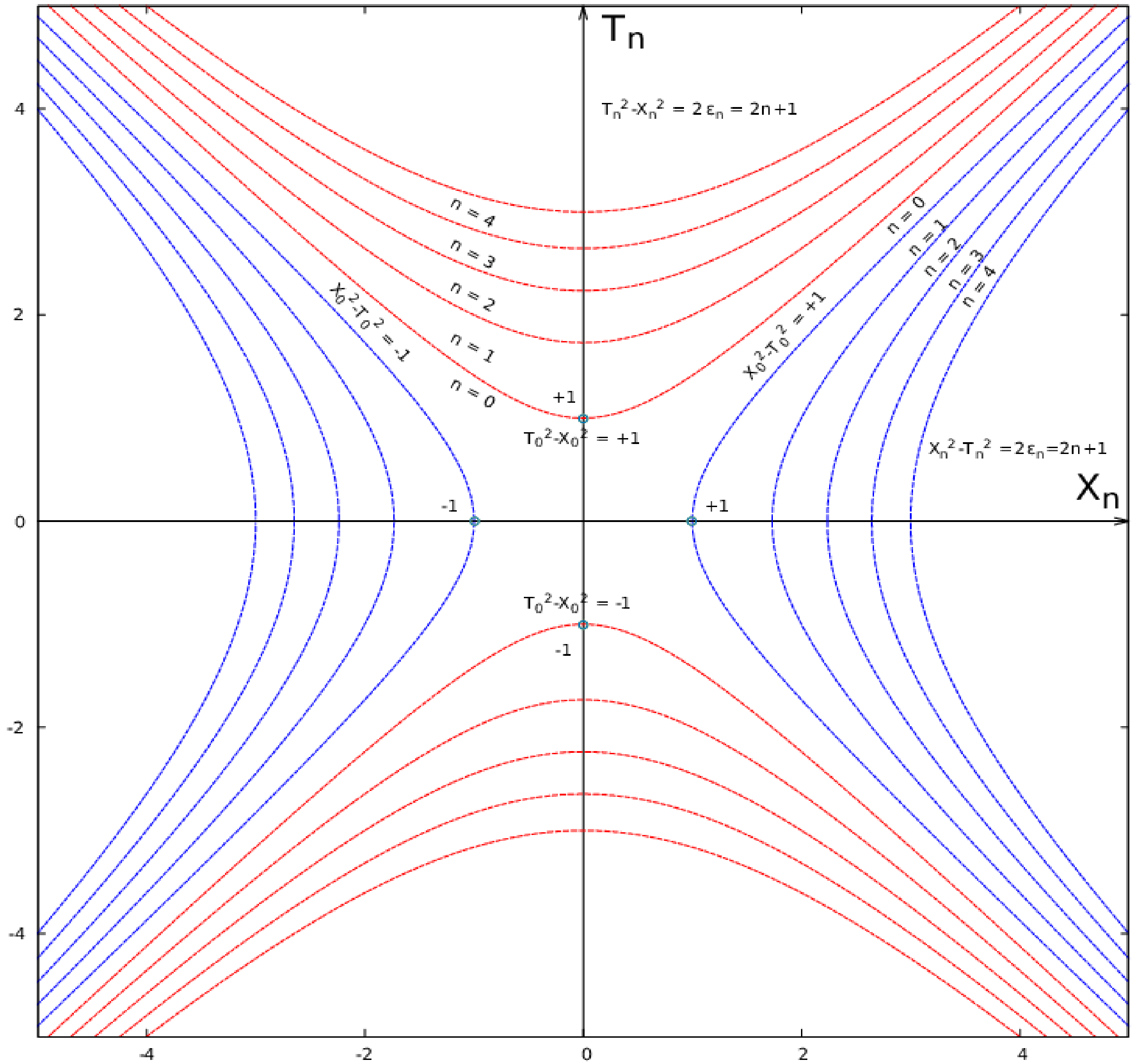
THE CLASSICAL LIGHT CONE



THE QUANTUM LIGHT CONE



QUANTUM SPACE-TIME STRUCTURE



In the pre-planckian (trans-planckian) phase,
the quantum levels are:

$H_{Qn} = \sqrt{(2n+1)}$, $\Lambda_{Qn} = (2n+1) = \mathcal{R}_{Qn}$, $S_{Qn} = 1/(2n+1)$

Q denoting quantum. The n - levels cover *all* scales
from the far past highest excited trans-planckian level
n = 10^[122} with finite curvature,
H_Q = 10^{61}, Λ_Q = 10^{122} and S_Q = 10^{−122} ,
n decreases till the planck level (n=0)
H planck = 1, Λ planck = 1, S planck = 1
and then enters the post-planckian phase e.g:
n = 1, 2,..., n inflation = 10^{12},..., n cmb = 10^{114},...,
n reoin = 10^{118},..., n today = 10^{122}:
H today = 10^{−61}, Λ today = 10^{-122}, S today = 10^{122}

Quantum discrete cosmological levels

size, time, vacuum energy, Hubble constant and gravitational (Gibbons-Hawking) entropy.

For each level $n = 0, 1, 2, \ldots$,

All phases are covered:

post-planckian universe levels: (in planck units):

Hubble constant $H_n = 1/\sqrt{(2n+1)}$

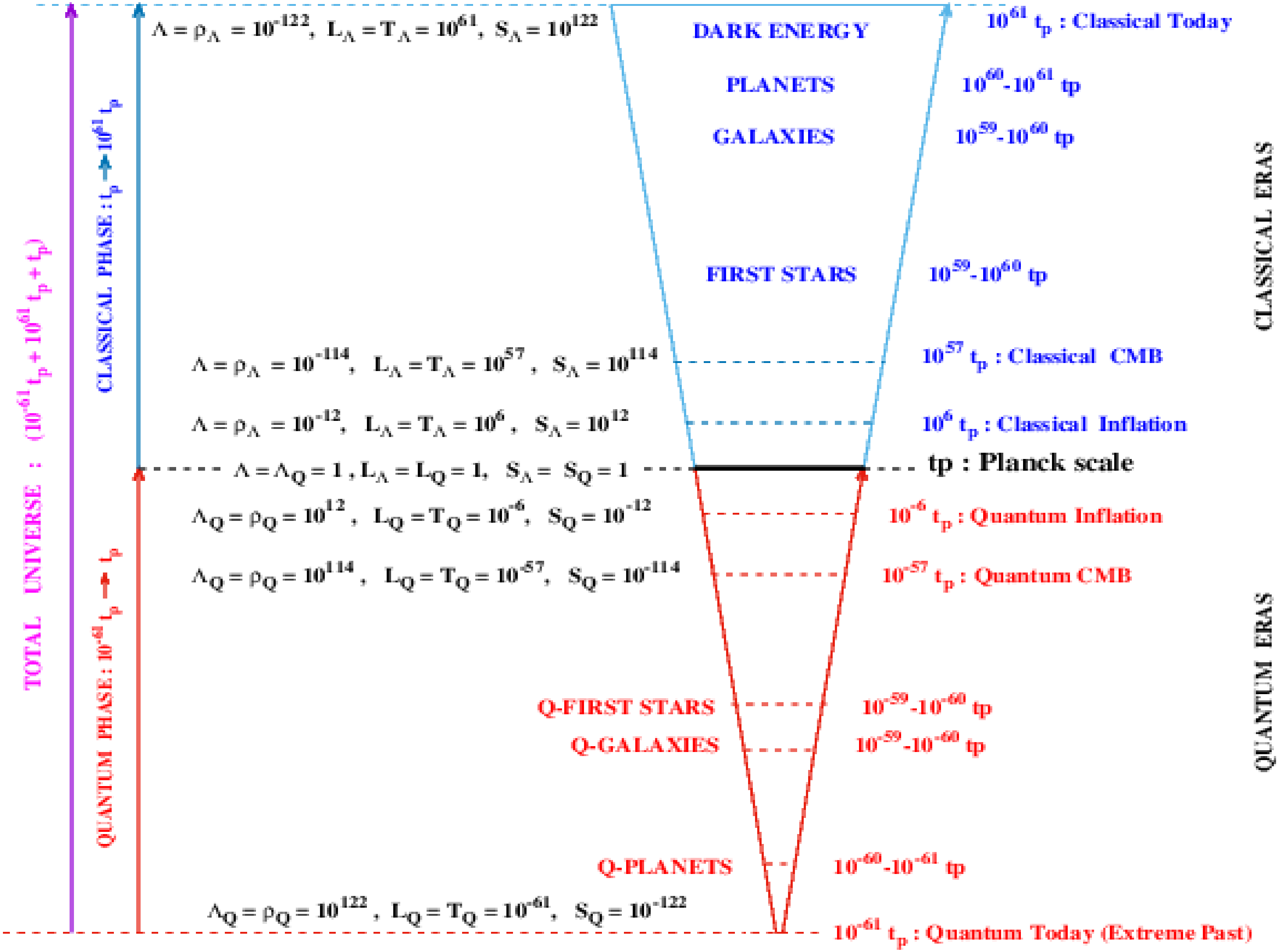
Vacuum energy $\Lambda_n = 1/(2n+1)$

Entropy $S_n = (2n+1)$

As n increases, radius, mass and S_n increases, H_n and Λ_n decreases and *consistently* the universe *classicalizes*:

$n = 10^{122}$: H today $= 10^{-61}$

Λ today $= 10^{-122}$, S today $= 10^{122}$



THE TOTAL HISTORY OF THE UNIVERSE

QUANTUM DECAY RATES

Unifying formula : $\Gamma = \dfrac{g^2\ m}{\text{numerical factor}}$

g = coupling constant, m = typical mass in the theory (mass of the unstable particle or quantum object) and the (numerical factor) often contains relevant mass ratios for the decay process.

All decays, whatever the objects: heavy relics from the early universe, topological and non-topological solitons, black-holes, microscopic fundamental strings, ($g^2 = G/\alpha'$), as well as heavy particles in the standard model (muons, Higgs, etc)

$\Gamma_n = m\,n$, $\Gamma_n = (2n+1)$,

$\Gamma_{Q\,n} = 1/(2n+1)$: des-excitation: $\exp(-\Gamma)$

• **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 : 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} tP) is a quantum state of high bounded trans-planckian constant curvature and therefore without singularity.

CONCLUSIONS and IMPLICATIONS

- The Hawking Temperature and 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 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.

MUCHAS GRACIAS
por vuestra Atencion !!

MERCI BEAUCOUP !!
pour votre Atention

THANK YOU VERY MUCH
for your Attention!!