THE UNIVERSE

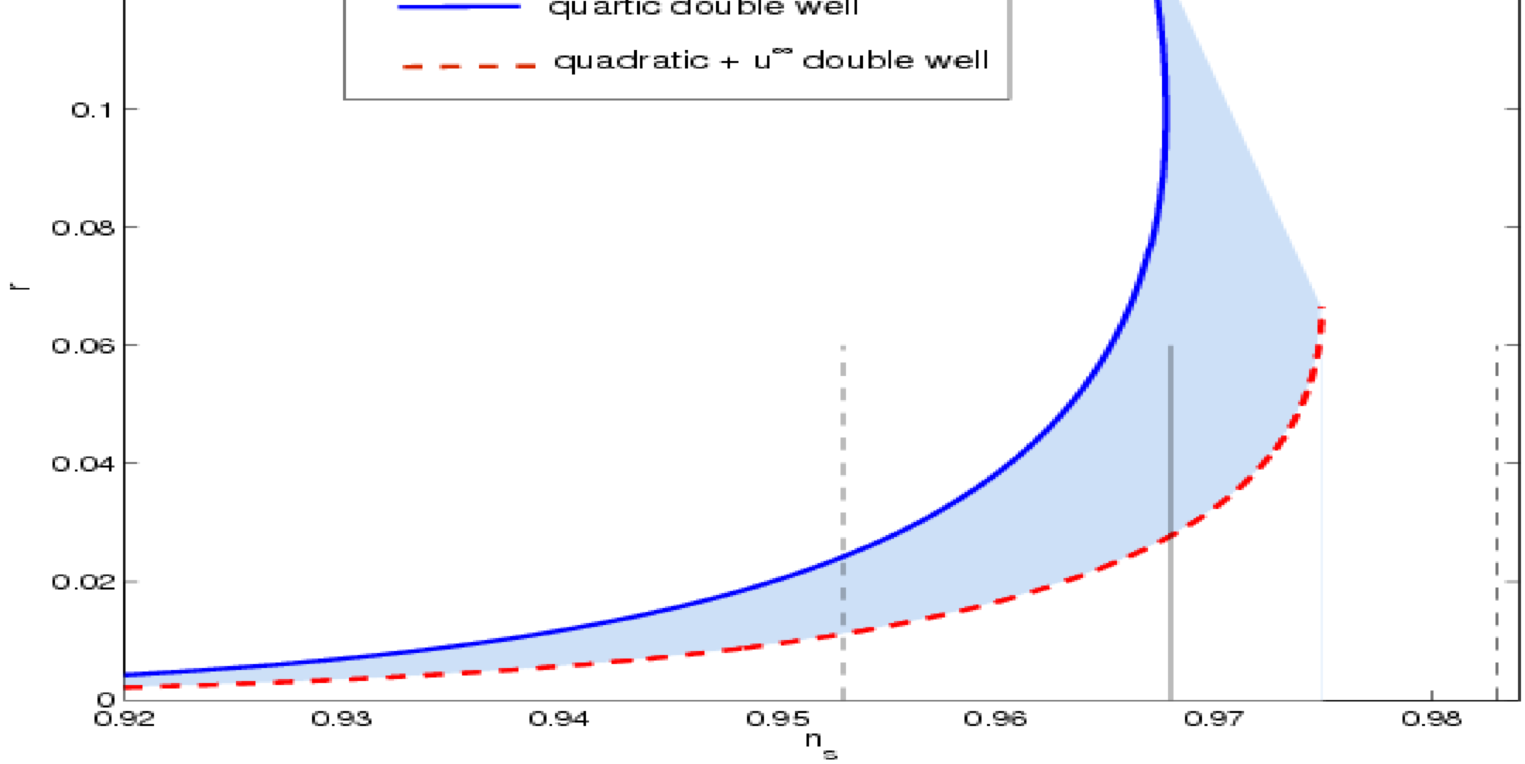
In the Scientific Programme 2012

of the Chalonge School

10 MAI 2012

Norma G. SANCHEZ

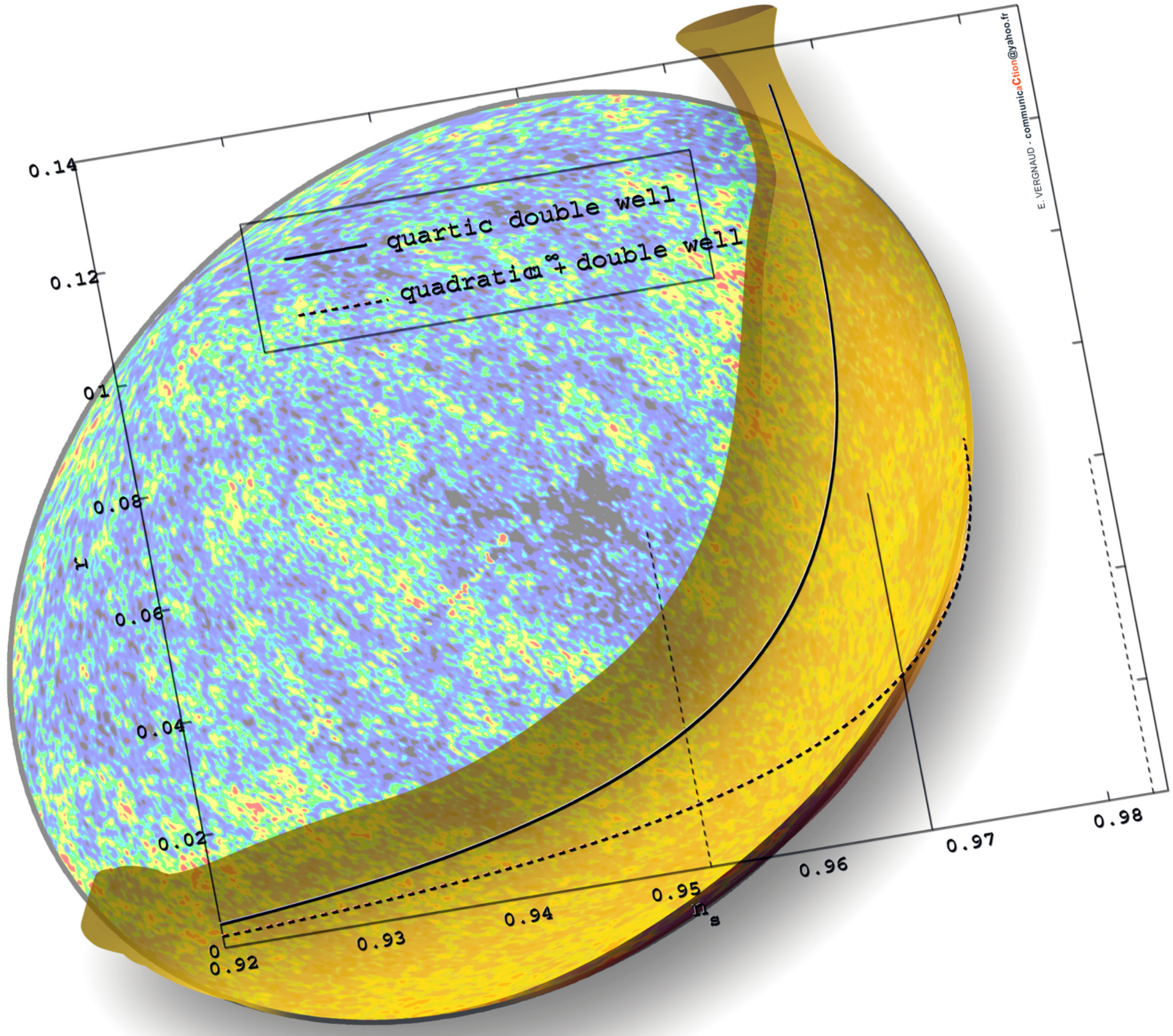
Observatoire de Paris & CNRS



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

PREDICTIONS

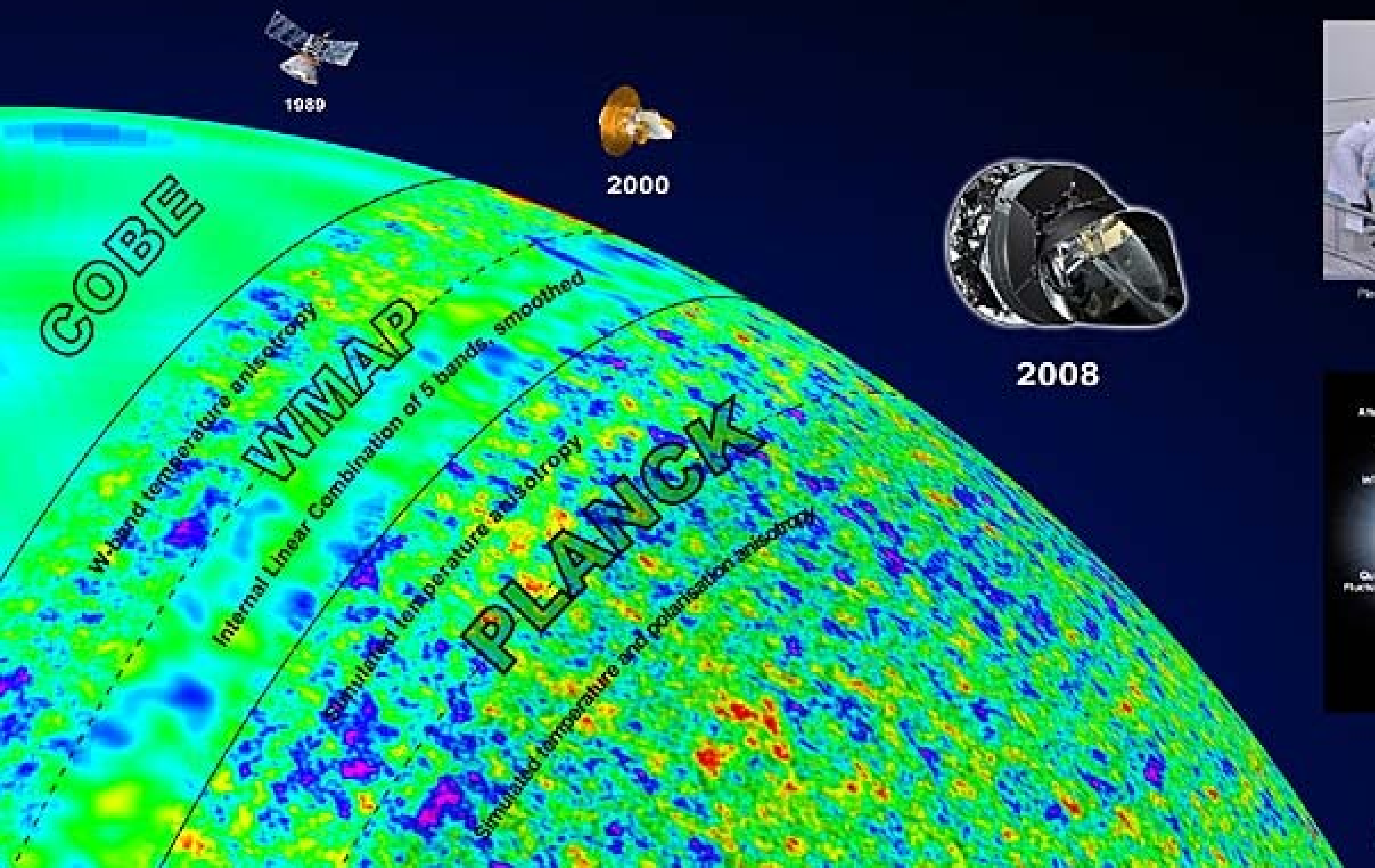
From the upper universal curve:
UPPER BOUND $r < 0.053$

From the lower universal curve:
LOWER BOUND $r > 0.021$

$$0.021 < r < 0.053$$

Most probable value: $r \sim 0.051$

CMB Missions Revolutionise Our Understanding of the Universe



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 cosmological constant

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)

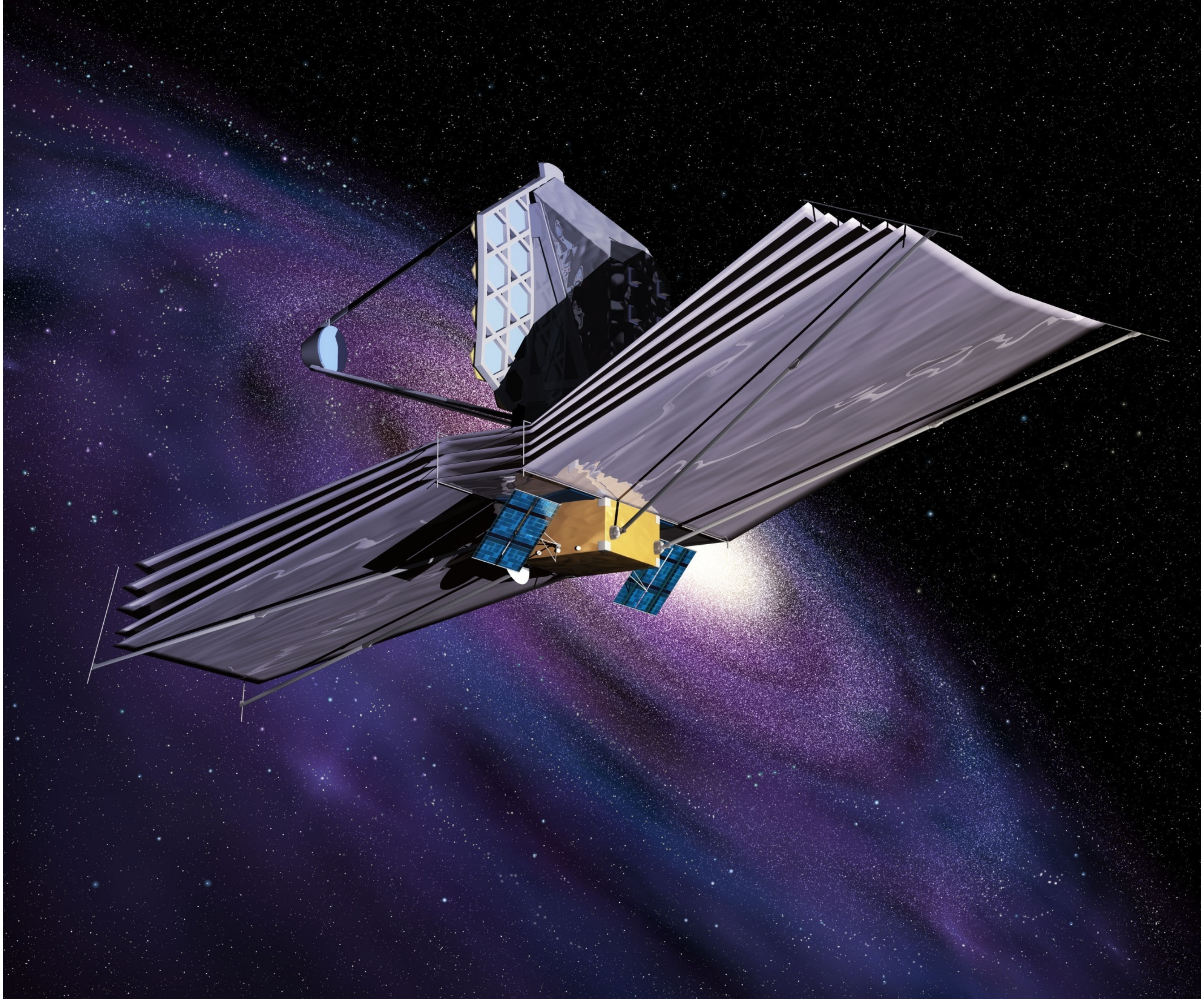
ΛWDM Concordance Model:

CMB + LSS + SSS Observations

DM is WARM and COLLISIONLESS

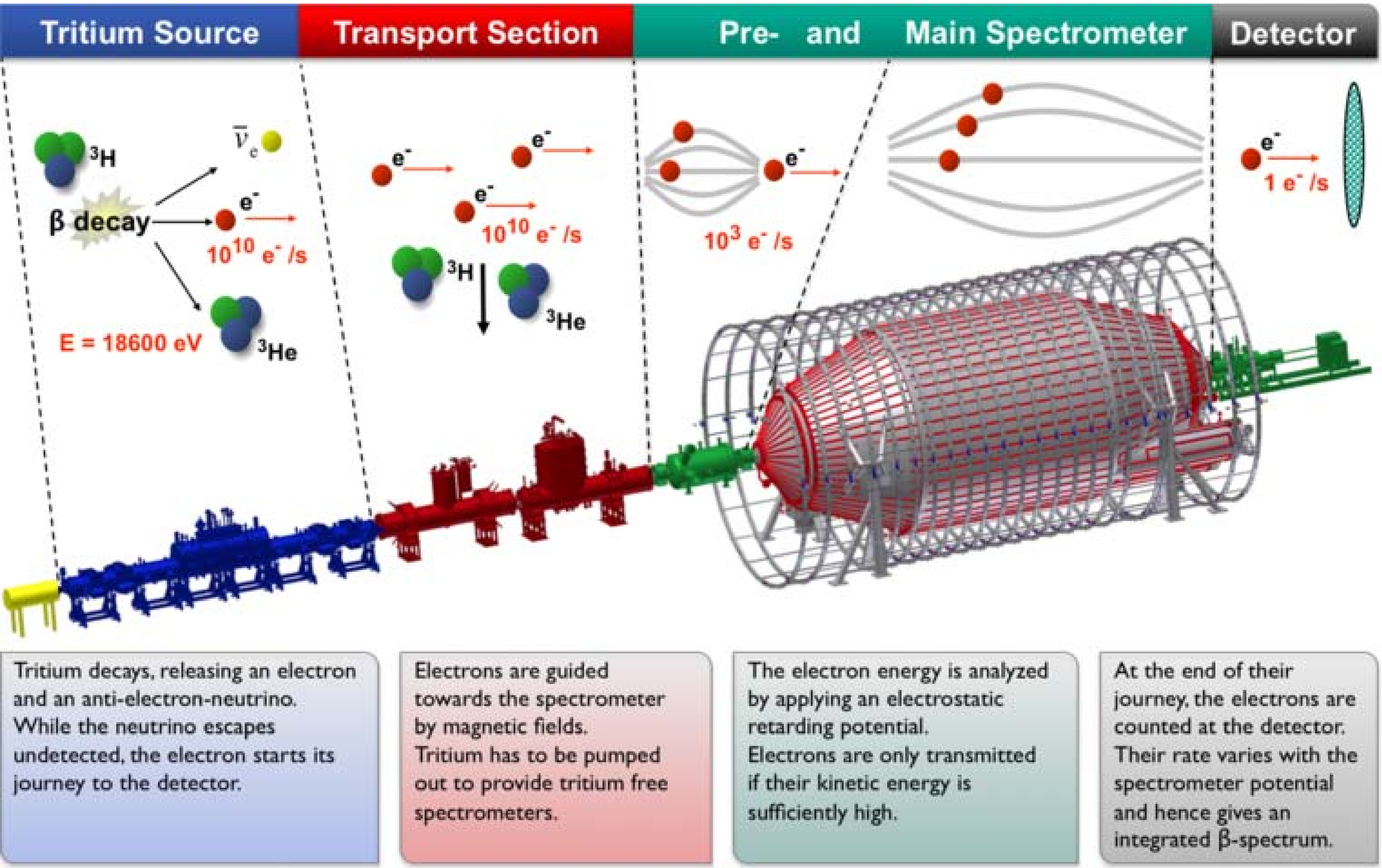
***CDM Problems*:**

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



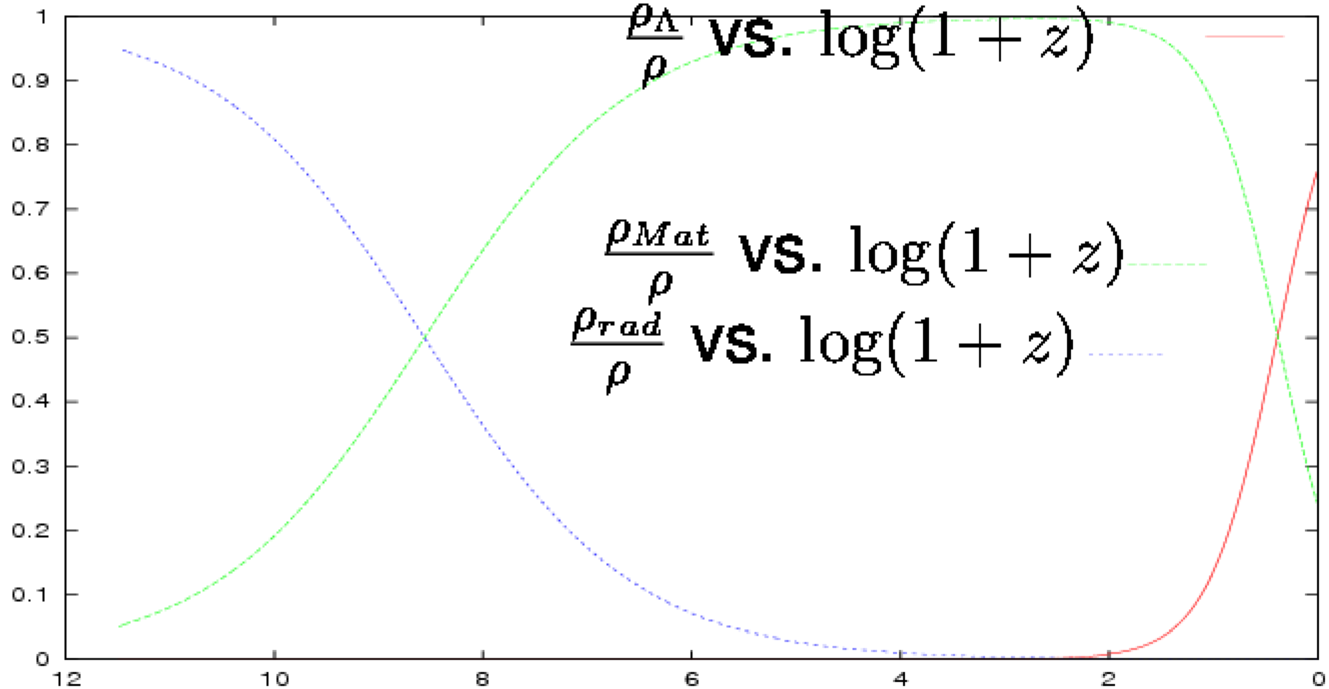
KATRIN

Karlsruhe Tritium Neutrino Experiment



Tritium Source
Transport Section
Pre- and Main Spectrometer
Detector
^{3}H
$\bar{\nu}_e$
β decay
e$^-$
10^{10} e$^-$ /s
E = 18600 eV
^{3}He
e$^-$
e$^-$
e$^-$
10^{10} e$^-$ /s
^{3}H
^{3}He
e$^-$
10^3 e$^-$ /s
e$^-$
1 e$^-$ /s
Tritium decays, releasing an electron and an anti-electron-neutrino. While the neutrino escapes undetected, the electron starts its journey to the detector.
Electrons are guided towards the spectrometer by magnetic fields. Tritium has to be pumped out to provide tritium free spectrometers.
The electron energy is analyzed by applying an electrostatic retarding potential. Electrons are only transmitted if their kinetic energy is sufficiently high.
At the end of their journey, the electrons are counted at the detector. Their rate varies with the spectrometer potential and hence gives an integrated β-spectrum.

The Universe is made of radiation, matter and dark energy



End of inflation: $z \sim 10^{29}$, $T_{reh} \lesssim 10^{16}$ GeV, $t \sim 10^{-36}$ sec.

E-W phase transition: $z \sim 10^{15}$, $T_{\rm EW} \sim 100$ GeV, $t \sim 10^{-11}$ s.

QCD conf. transition: $z \sim 10^{12}$, $T_{\rm QCD} \sim 170$ MeV, $t \sim 10^{-5}$ s.

BBN: $z \sim 10^9$, $T \simeq 0.1$ MeV, $t \sim 20$ sec.

Rad-Mat equality: $z \simeq 3200$, $T \simeq 0.7$ eV, $t \sim 57000$ yr.

CMB last scattering: $z \simeq 1100$, $T \simeq 0.25$ eV , $t \sim 370000$ yr.

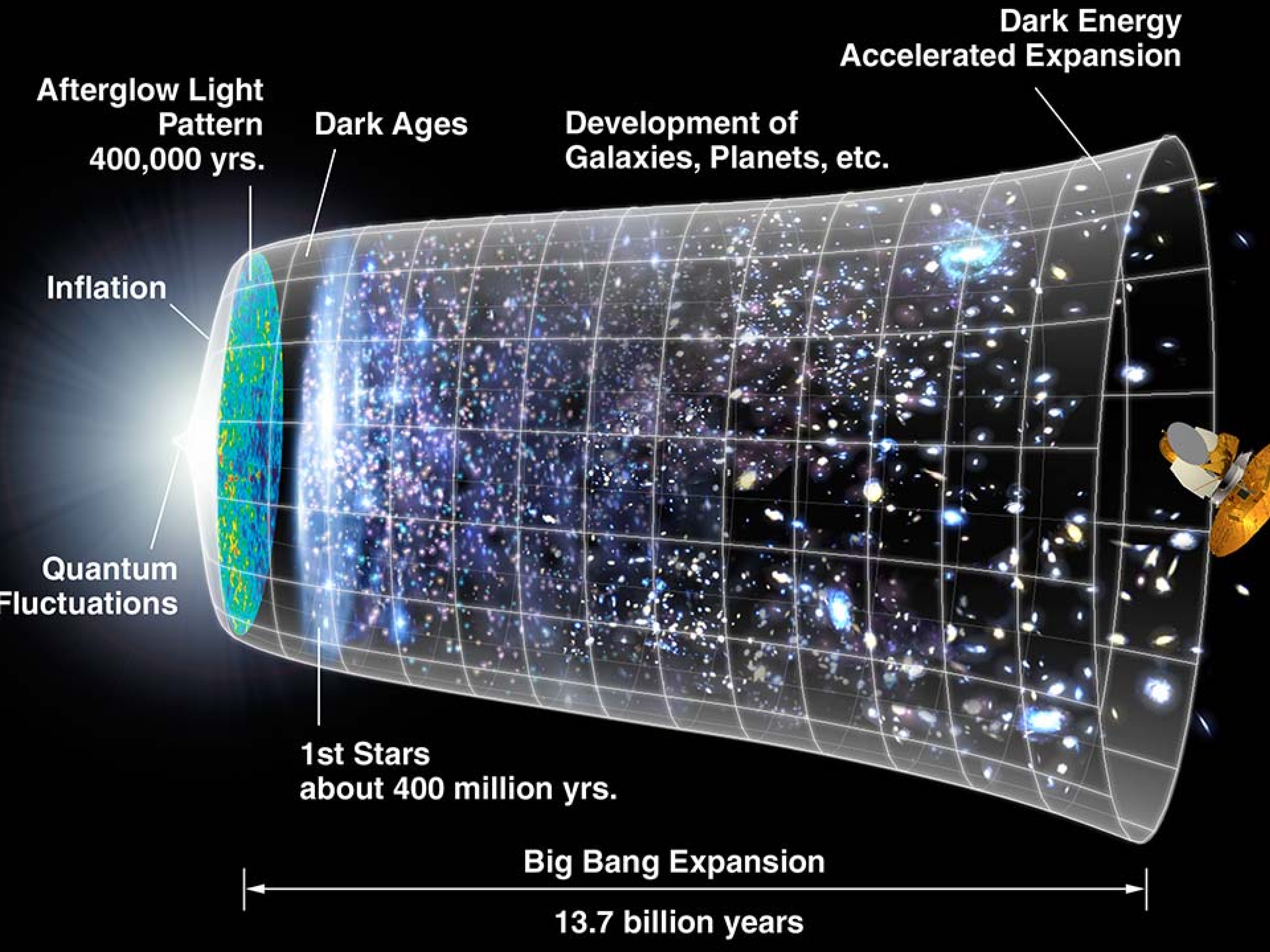
Mat-DE equality: $z \simeq 0.47$, $T \simeq 0.345$ meV , $t \sim 8.9$ Gyr.

Today: $z = 0$, $T = 2.725$K $= 0.2348$ meV $t = 13.72$ Gyr.

Standard Cosmological Model: ΛCDM

ΛCDM = Cold Dark Matter + Cosmological Constant begins by the Inflationary Era. Explains the Observations:

- Seven years WMAP data and further CMB data
- Light Elements Abundances
- Large Scale Structures (LSS) Observations. BAO.
- Acceleration of the Universe expansion: Supernova Luminosity/Distance and Radio Galaxies.
- Gravitational Lensing Observations
- Lyman α Forest Observations
- Hubble Constant (H_0) Measurements
- Properties of Clusters of Galaxies
- Measurements of the Age of the Universe



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

Quantum Fluctuations During Inflation and after

The Universe is homogeneous and isotropic after inflation thanks to the fast and gigantic expansion stretching lenghts by a factor $e^{62} \simeq 10^{27}$. By the end of inflation: $T \sim 10^{14}$ GeV.

Quantum fluctuations around the classical inflaton and FRW geometry were of course present.

These inflationary quantum fluctuations are the seeds of the structure formation and of the CMB anisotropies today: galaxies, clusters, stars, planets, ...

That is, our present universe was built out of inflationary quantum fluctuations. CMB anisotropies spectrum:

3×10^{-32}cm $< \lambda_{begin\, inflation} < 3 \times 10^{-28}$cm

$M_{Planck} \gtrsim 10^{18}$ GeV $> \lambda^{-1}_{begin\, inflation} > 10^{14}$ GeV.

total redshift since inflation begins till today $= 10^{56}$:

0.1 Mpc $< \lambda_{today} <$ 1 Gpc , 1 pc = 3×10^{18} cm $= 200000$ AU

THE HISTORY OF THE UNIVERSE IS A HISTORY of EXPANSION and COOLING DOWN

THE EXPANSION OF THE UNIVERSE IS THE MOST POWERFUL REFRIGERATOR

INFLATION PRODUCES THE MOST POWERFUL STRETCHING OF LENGTHS

THE EVOLUTION OF THE UNIVERSE IS FROM QUANTUM TO SEMICLASSICAL TO CLASSICAL

From Very Quantum (Quantum Gravity) state to Semiclassical Gravity (Inflation) stage (Accelerated Expansion) to Classical Radiation dominated Era followed by Matter dominated Era (Deccelerated expansion) to Today Era (again Accelerated Expansion)

THE EXPANSION CLASSICALIZES THE UNIVERSE

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

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,

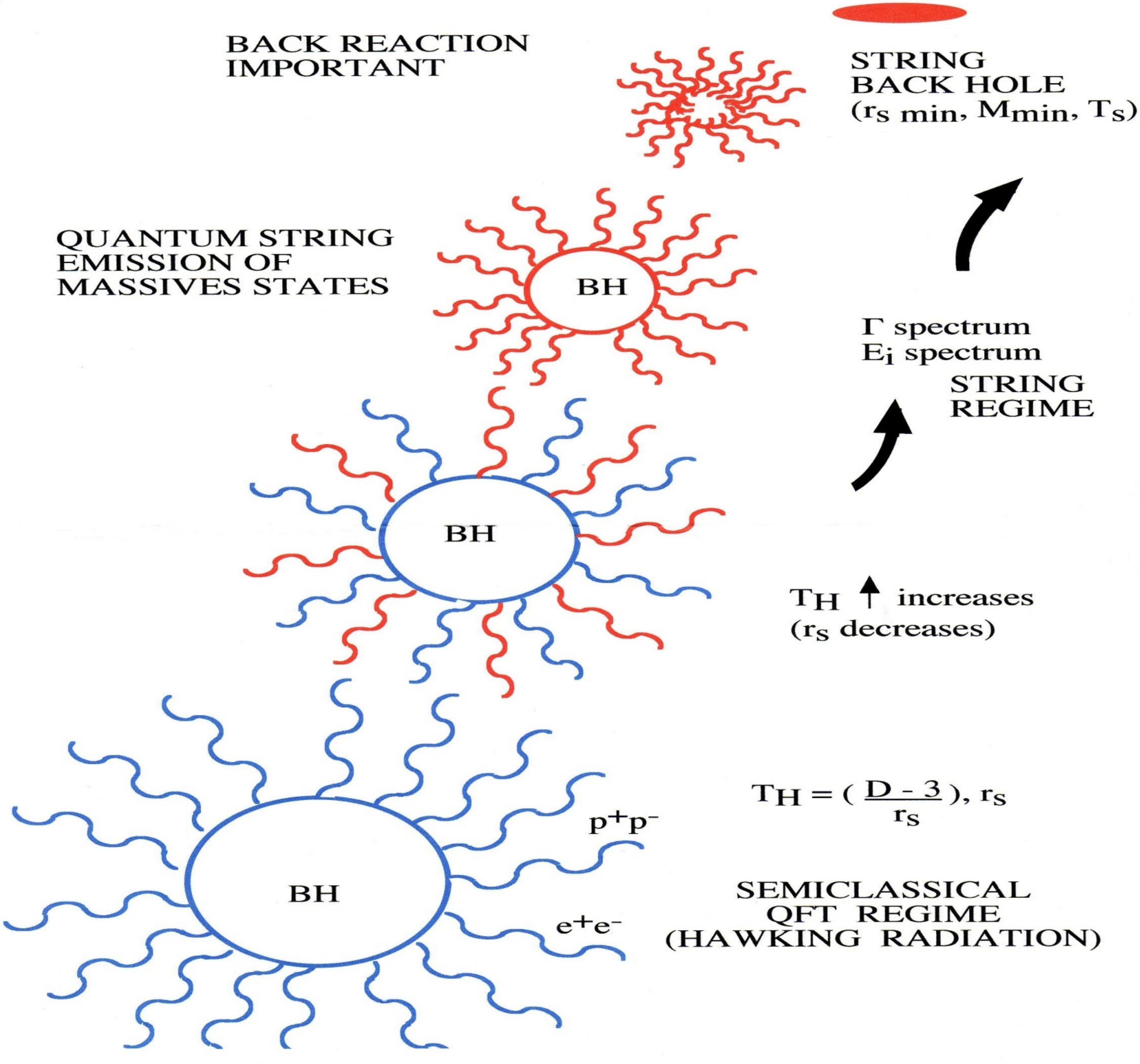
Through this evolution, the Black Hole temperature goes from the semiclassical gravity temperature (Hawking Temperature) to the usual temperature (the mass) and the quantum gravity temperature (the Planck temperature).

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 (standard Friedman-Robertson-Walker) phases
- 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)
$T_H = (\frac{D-3}{r_s}), r_s$
p^+p^-
BH
e^+e^-
SEMICLASSICAL
QFT REGIME
(HAWKING RADIATION)

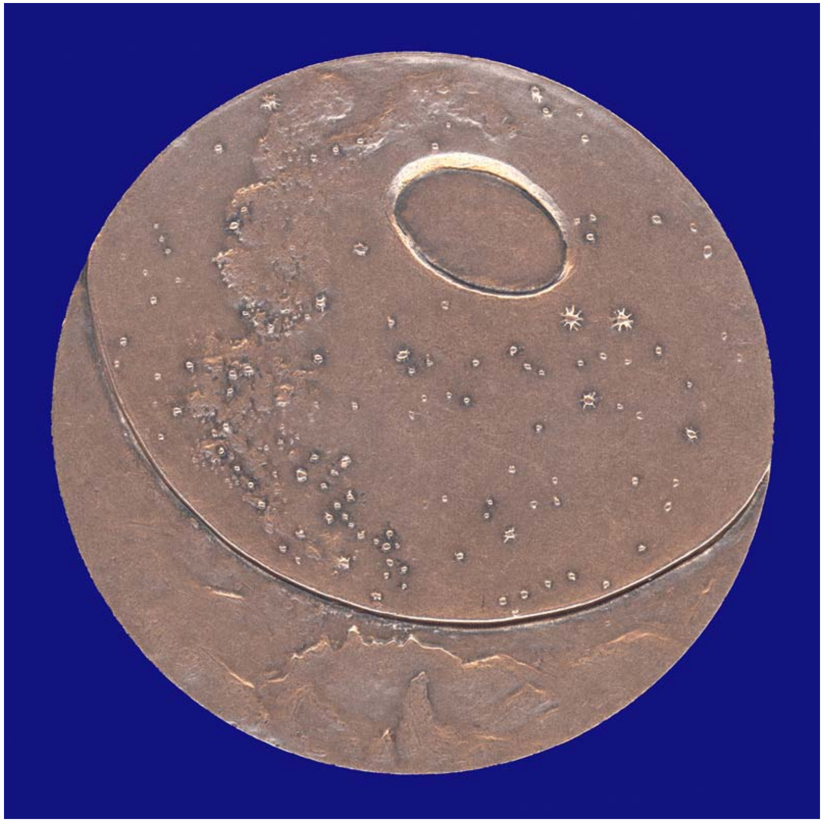
Ecole Internationale
Daniel Chalonge

The 16th Paris Cosmology Colloquium 2012

25-27 July, Observatoire de Paris

http://chalonge.obspm.fr

The Daniel Chalonge Medal



Edited and Coined Specially for the School by the Maison de la Monnaie de Paris (The French Mint)

END

THANK YOU FOR YOUR ATTENTION