SEMICLASSICAL and QUANTUM BLACK HOLES

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Open Session 19 MAI 2016

Observatoire de Paris

Macroscopic black holes → gravitational collapse of astrophysical bodies

Microscopic Black Holes

→ **Could arise from high density concentrations (of the order of the Planck energy scale) in the early universe, as well as from the collisions of particles at such energy scales.**

→ **Are necessarily quantum and their properties governed by quantum or semi-classical gravity, evaporation through Hawking radiation is a typical effect of these black holes.**

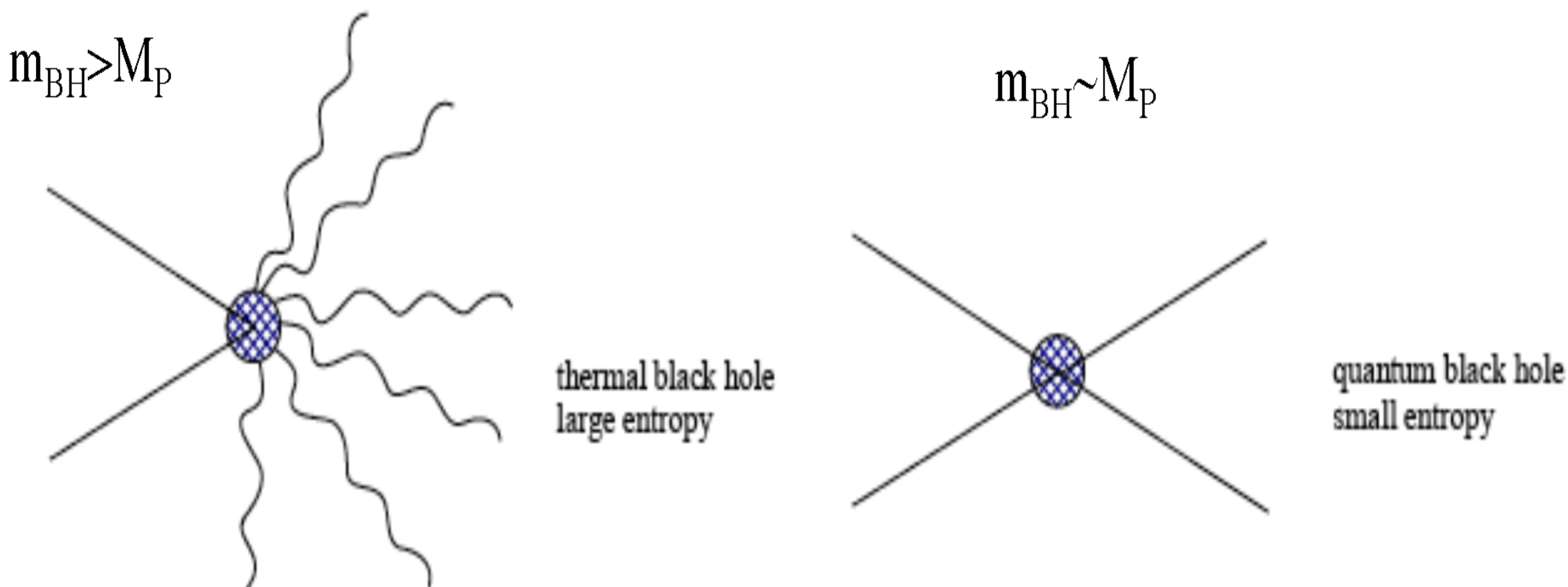
→ **Share in some respects analogies with elementary particles, and on the other hand, show many important differences.**

→ **A theory of quantum gravity, or "theory of everything" should account for an unified and consistent description of both black holes and elementary particles, and the physics of the early universe as well.**

TROUS NOIRS SEMICLASSIQUES
(thermiques, emission de Hawking)

TROUS NOIRS QUANTIQUES
(non thermiques, avec masses de Planck,

Semi-classical versus quantum non-thermal black hole:



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)

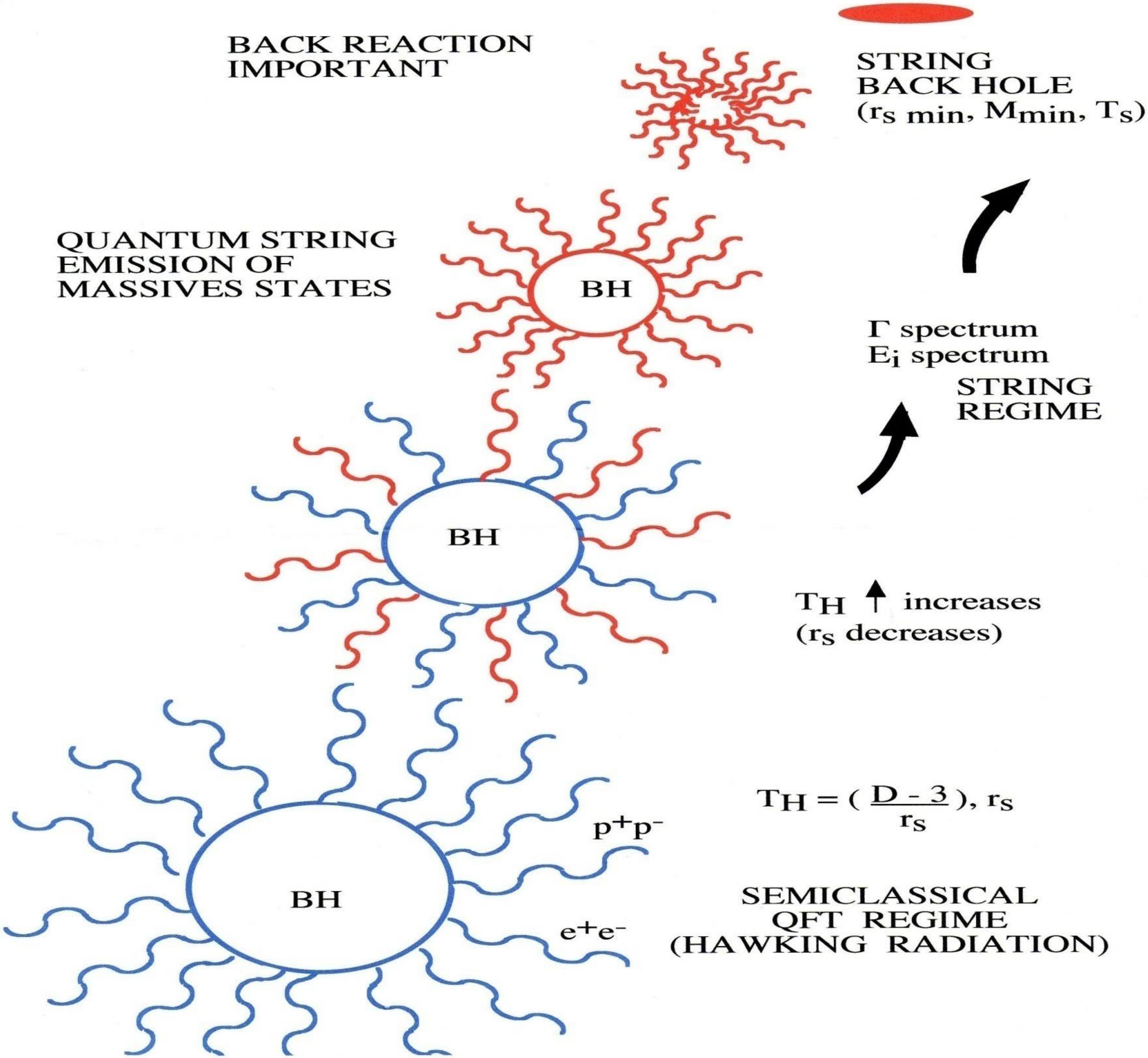
The CMB allows to observe it
(while is not possible to observe for Black Holes)

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


BACK REACTION
IMPORTANT
STRING
BACK HOLE
(rs min, Mmin, Ts)
QUANTUM STRING
EMISSION OF
MASSIVES STATES
BH
Γ spectrum
Ei spectrum
STRING
REGIME
BH
TH ↑ increases
(rs decreases)
TH = (D - 3 / rs), rs
p+p-
BH
e+e-
SEMICLASSICAL
QFT REGIME
(HAWKING RADIATION)

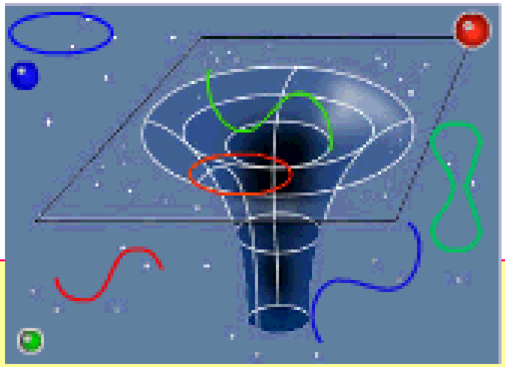
CONCEPTUAL UNIFICATION

- 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.

Conceptual unification of elementary particles, black holes and the primordial states of the universe



Unification of black holes and elementary particles is proposed in a conceptual way.

Inclusion of the primordial states of the universe: the states describing ***inflation*** (whose existence is supported by the recent cosmic microwave background observations) and the states describing an ***earlier (microscopic or quantum***) ***phase*** for which is predicted a discrete spectrum and a new phase transition.

This ***phase transition*** would be the quantum gravity counterpart of the (non linear) Jeans instability with cosmological constant and with a more complex and richer structure.

The classical-quantum (de Broglie) duality at the basis of quantum mechanics is here extended to the ***quantum gravity or string regime*** (that is, wave-particle-string duality for gravity,).

This ***classical-semiclassical-quantum gravity duality*** precisely describes the whole history of black hole evaporation and the universe evolution.

de Sitter states

Describe the inflation era of the early universe and most probably, the acceleration of the present universe

They correspond to a positive cosmological constant.

Anti de Sitter states (negative cosmological constant)

They appear in particle unification models and allow interesting comparison between the positive and negative cosmological constant effects.

The conducting line of argument

The ***classical-quantum*** (de Broglie, Compton) duality, at the basis of quantum mechanics, here extended to the ***quantum gravity (string) regime*** (that is, wave-particle-string duality). The semi-classical and quantum (string) gravity regimes are thus respectively characterized and related: sizes, masses, accelerations and temperatures.

Set of quantities

Classical / semi-classical gravity regime $O_{cl,sem} = \left(L_{cl}, M_{cl}, \kappa_{cl}, T_{sem}\right)$

- Length
- Mass
- Gravity Acceleration
- Hawking Temperature

Quantum gravity regime $O_q = \left(L_q, M_q, \kappa_q, T_q\right)$

Duality

$$O_{cl,sem} = o_{Pl}^{2} \; O_q^{-1} \quad \Longleftrightarrow \quad O_{cl,sem} = o_s^{2} \; O_s^{-1}$$

String theory

$$O_s = \left(L_s, M_s, \kappa_s, T_s\right)$$

$$o_{Pl}^{2} \, (\hbar, G, c) \quad \Longleftrightarrow \quad o_s^{2} \, (\hbar, \alpha', c)$$

Unified quantum decay of QFT elementary particles, black hole and strings

Quantum decay rate of unstable particles → $\Gamma = \frac{g^2\, m}{numerical\ factor}$

String decay rate → $\Gamma_s = \frac{G}{n^o} T_s^3 \sim \frac{G}{l_s^3}$ or $\Gamma_s = \frac{g^2}{n^o} m_s$ $\left(\text{with } g \equiv \sqrt{\frac{G}{\alpha'}}.\right)$

Semi-classical black Hole decay ('grey body at Hawking Temperature') →

Loss mass rate :

$$\left(\frac{dM_{cl}}{dt}\right) = -\sigma L_{cl}^2 T_{sem}^4 \sim T_{sem}^2$$

Semi-classical black Hole decay rate →

$$\Gamma_{sem} = \left|\frac{d}{dt} \ln M_{cl}\right| \sim \frac{G}{n^o} T_{sem}^3 \sim \frac{G}{L_{cl}^3}$$

Evaporation ⇒ Black hole enters its string regime : $T_{sem} \to T_s$, $L_{cl} \to L_s$

with decay rate → $\Gamma_{sem} \to G T_s^3 \sim \frac{G}{l_s^3} \to \Gamma_s$

The semiclassical black hole decay rate Γ_{sem} tends to the string decay rate Γ_s.

Concluding Remarks

- The Hawking temperature, elementary particle temperature and quantum gravity temperature are shown to be the same concept in different energy regimes and turn out to be the precise classical-quantum duals of each other.
- This result holds for the black hole decay rate, heavy particle and string decay rates; black hole evaporation ends as quantum string decay into pure (non mixed) non thermal radiation.
- Microscopic density of states and entropies in the two (semi-classical and quantum) gravity regimes are related, an unifying formula for black holes, de Sitter and anti-de Sitter states is provided in the two regimes.
- A phase transition towards the de Sitter string temperature (which is shown to be the precise quantum dual of the semi-classical (Hawking-Gibbons) de Sitter temperature) is found.
- Cosmological evolution goes from a quantum gravity phase to a semi-classical phase (inflation) and then to the classical (standard Friedman-Robertson-Walker) phase.
- The wave-particle- duality, ie the classical-quantum duality precisely manifests in this evolution, and can be viewed as a mapping between asymptotic states and so as a scattering -matrix description.

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And recent implications and elaboration..... (irrespective of string theory) supported by this work

New perspectives from past work do appear ......