IFIC'S JORNADAS CIENTÍFICAS — L5

# Gravity and the Dark Universe: Gravitational Waves and Black Holes

Jornadas Científicas - L5, Instituto de Física Corpuscular, April 28th 2022

# Today's AGENDA

| | |
|---|---|
| 09:30-09:35 | ..... Opening |
| 09:35-10:00 | ..... TALK 1 |
| 10:00-10:25 | ..... TALK 2 |
| 10:25-10:45 | ..... Break |
| 10:45-11:10 | ..... TALK 3 |
| 11:10-11:35 | ..... TALK 4 |
| 11:35-End | ..... Summary & Discussion |

# L5: GRAVITY & DARK UNIVERSE
# (Gravitational Waves & Black Holes)

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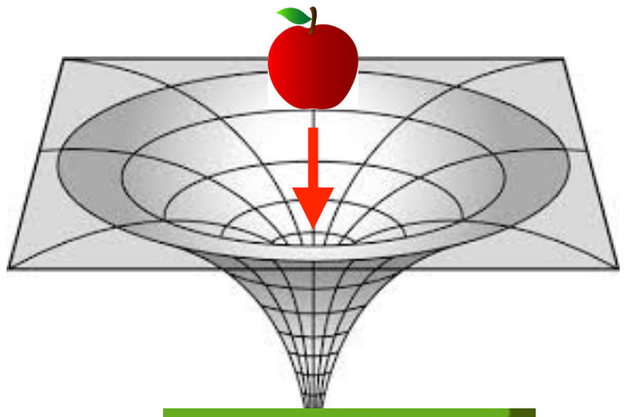

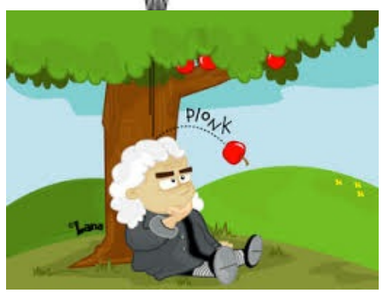

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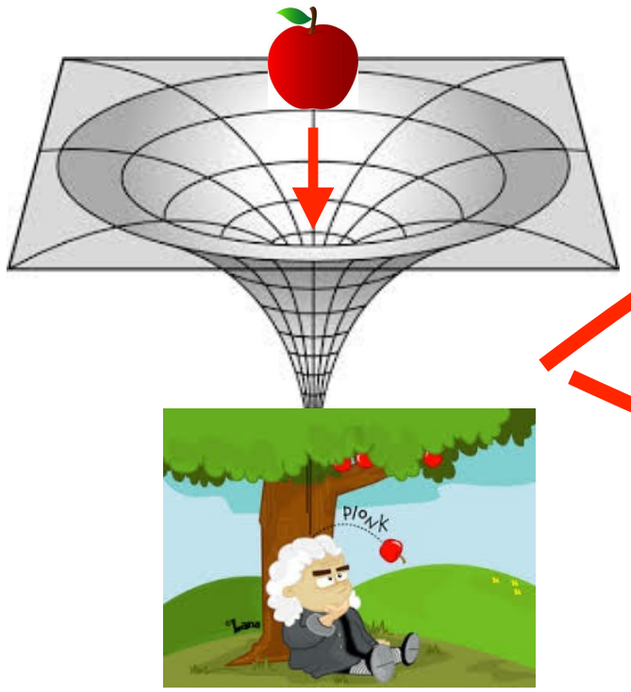




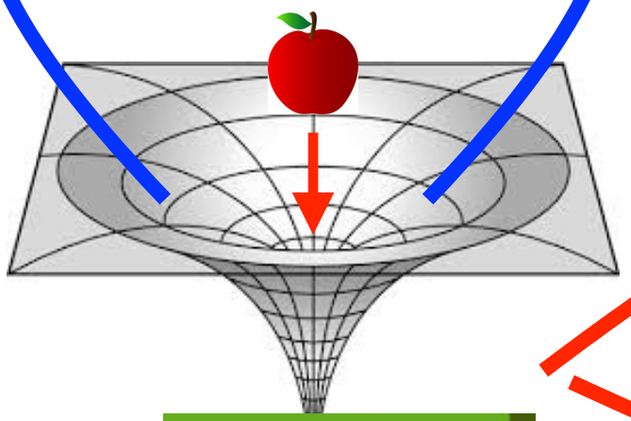

**Dark Matter**

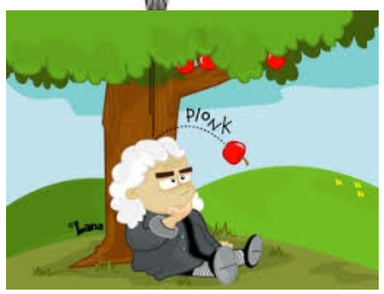
**Dark Energy**

# L5: GRAVITY & DARK UNIVERSE
# (Gravitational Waves & Black Holes)

**Gravitational Waves (GW)**

**Black Holes (BH)**






**Dark Matter**

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# L5: GRAVITY & DARK UNIVERSE
# (Gravitational Waves & Black Holes)

Gravitational Waves (GW)

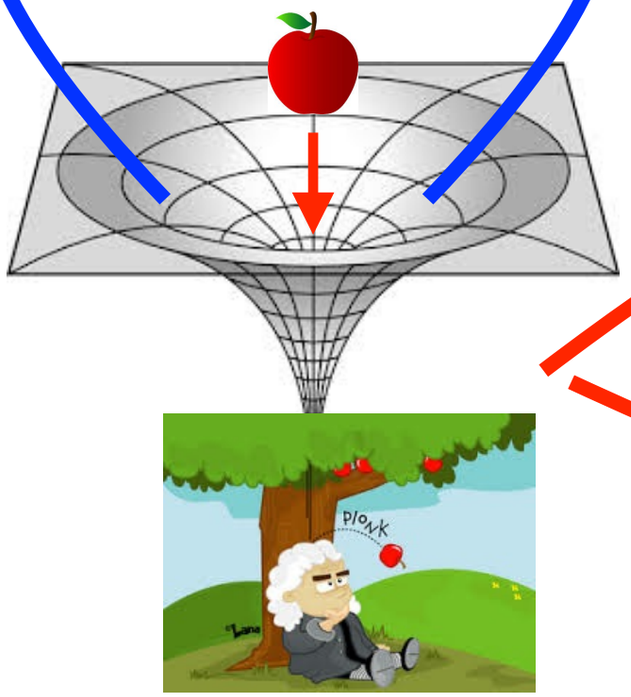
Black Holes (BH)

Initial Condition

Structure Formation

Dark Ages

Primordial Dark Ages



Dark Matter

Dark Energy

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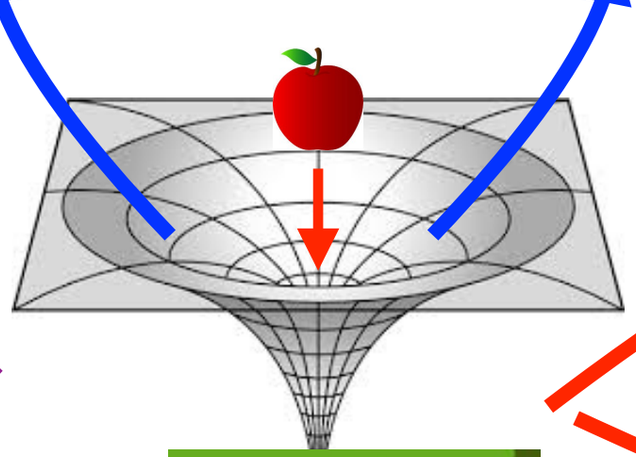

Gravitational Waves (GW)

Black Holes (BH)

Initial Condition

Structure Formation

Dark Ages

Primordial Dark Ages

Dark Matter

Dark Energy


QFT in Curved ST's

Modified Gravity

Quantum Gravity

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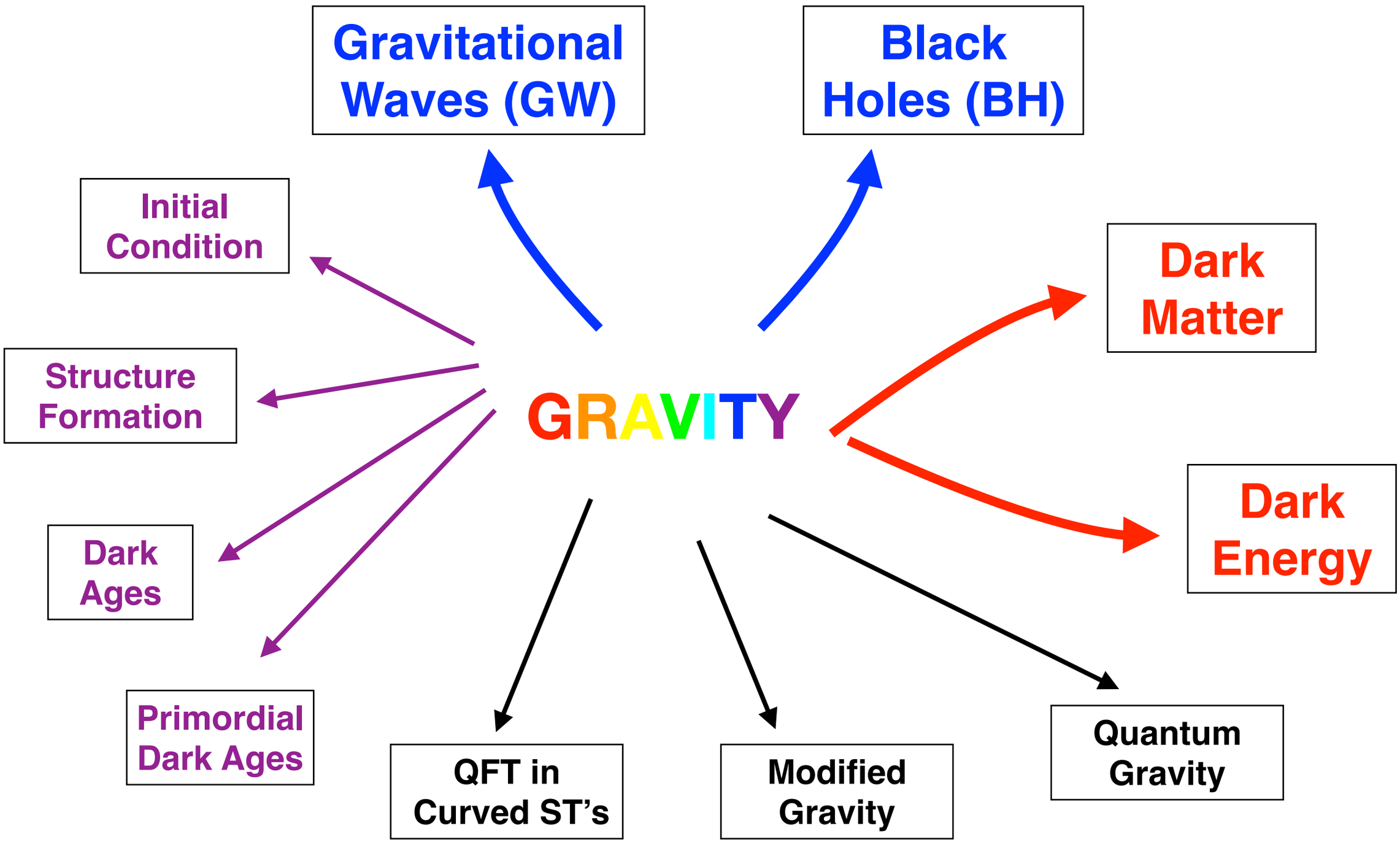

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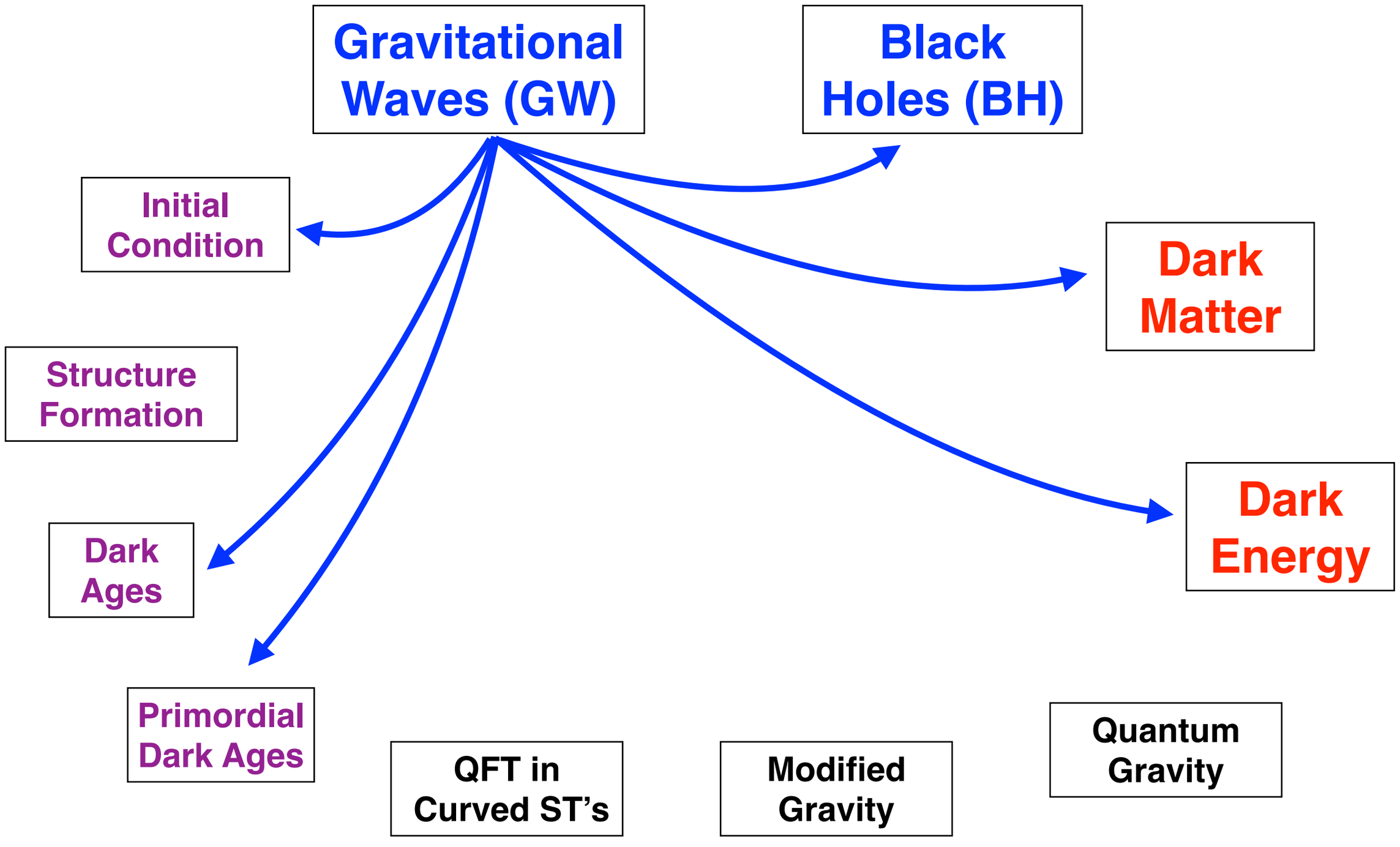

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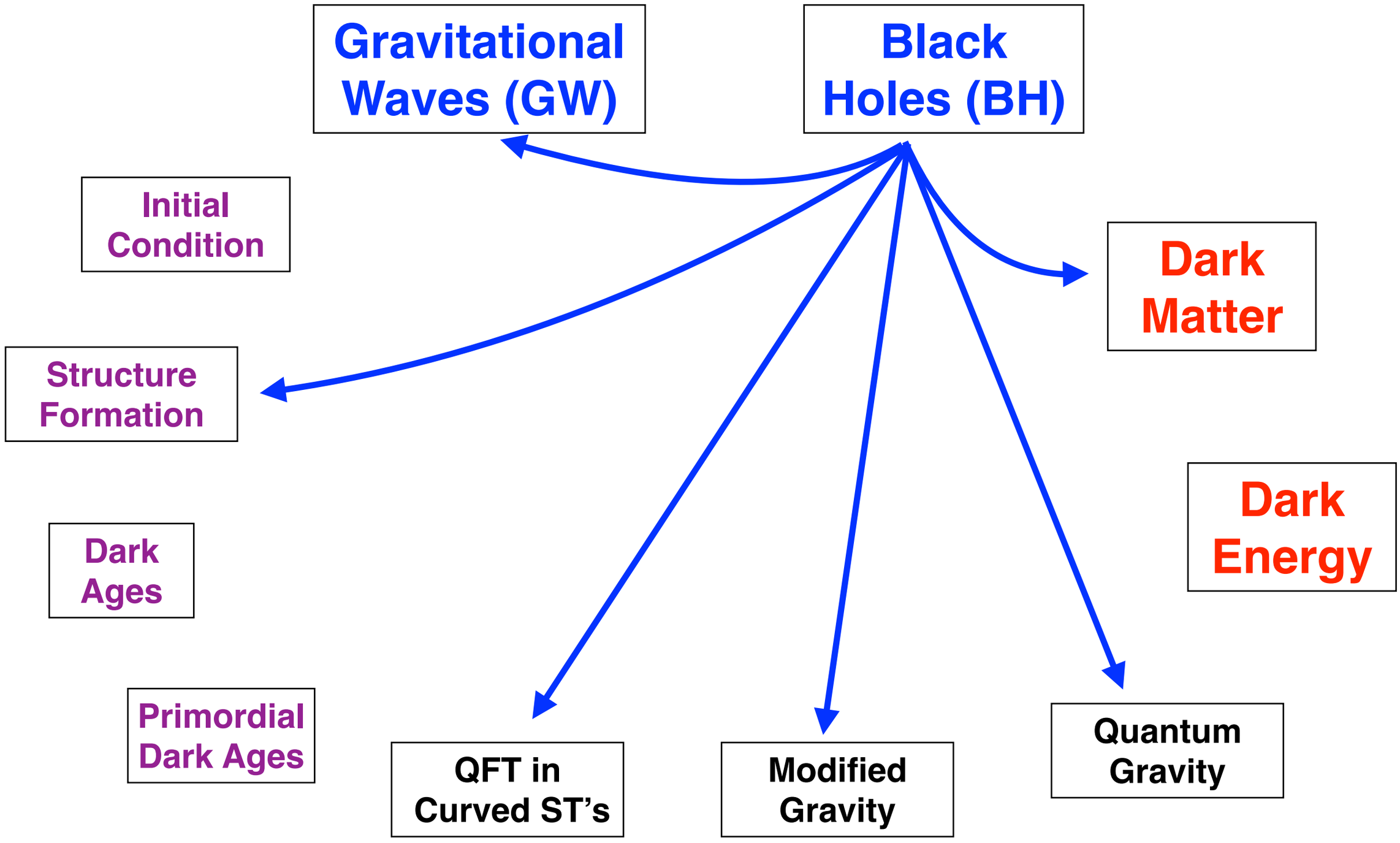

# L5: GRAVITY & DARK UNIVERSE
# (Gravitational Waves & Black Holes)

Gravitational Waves (GW)

Black Holes (BH)

+ 21cm Cosmology

Initial Condition

Dark Matter

Structure Formation

Dark Energy

Dark Ages

Primordial Dark Ages

QFT in Curved ST's

Modified Gravity

Quantum Gravity

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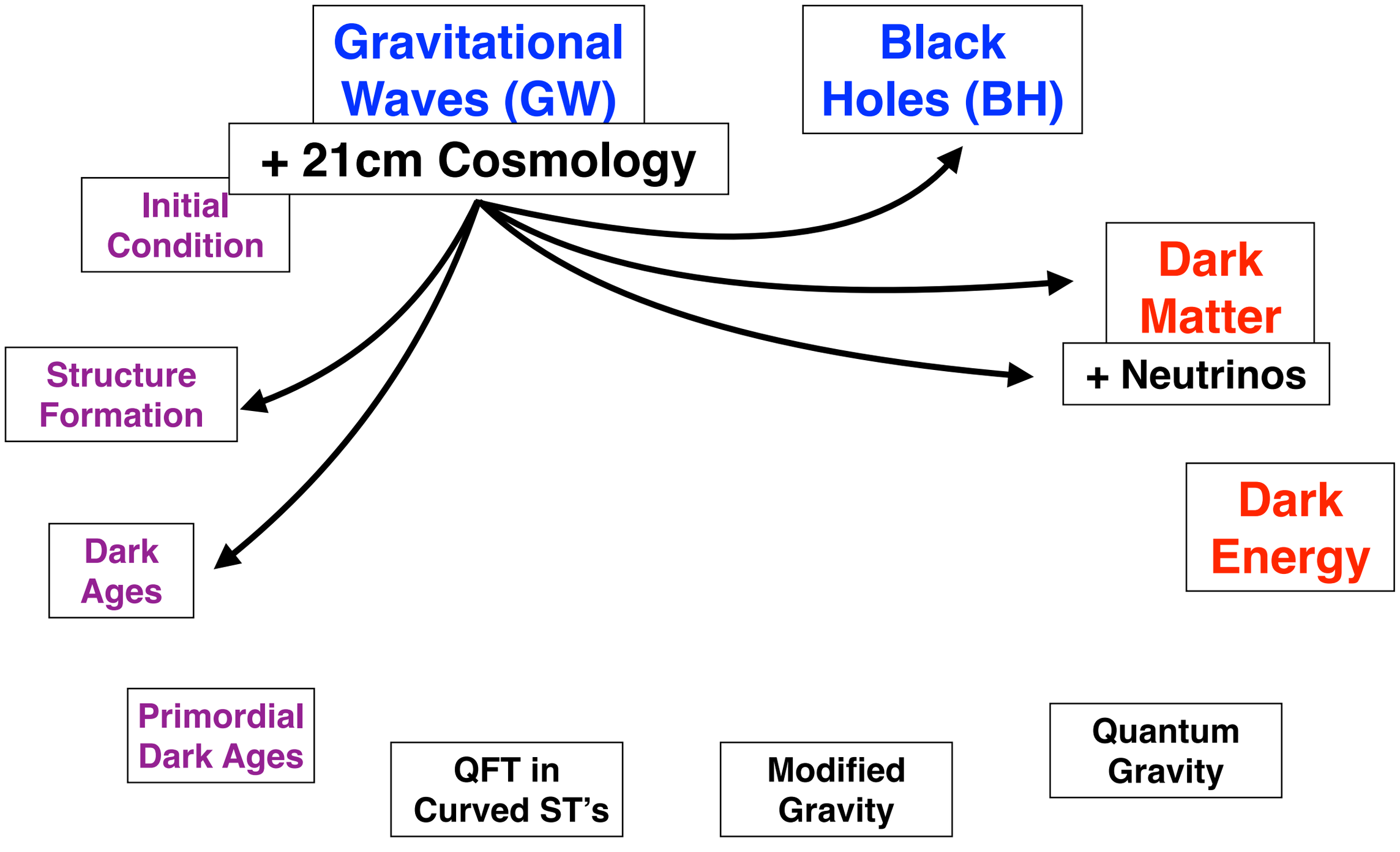


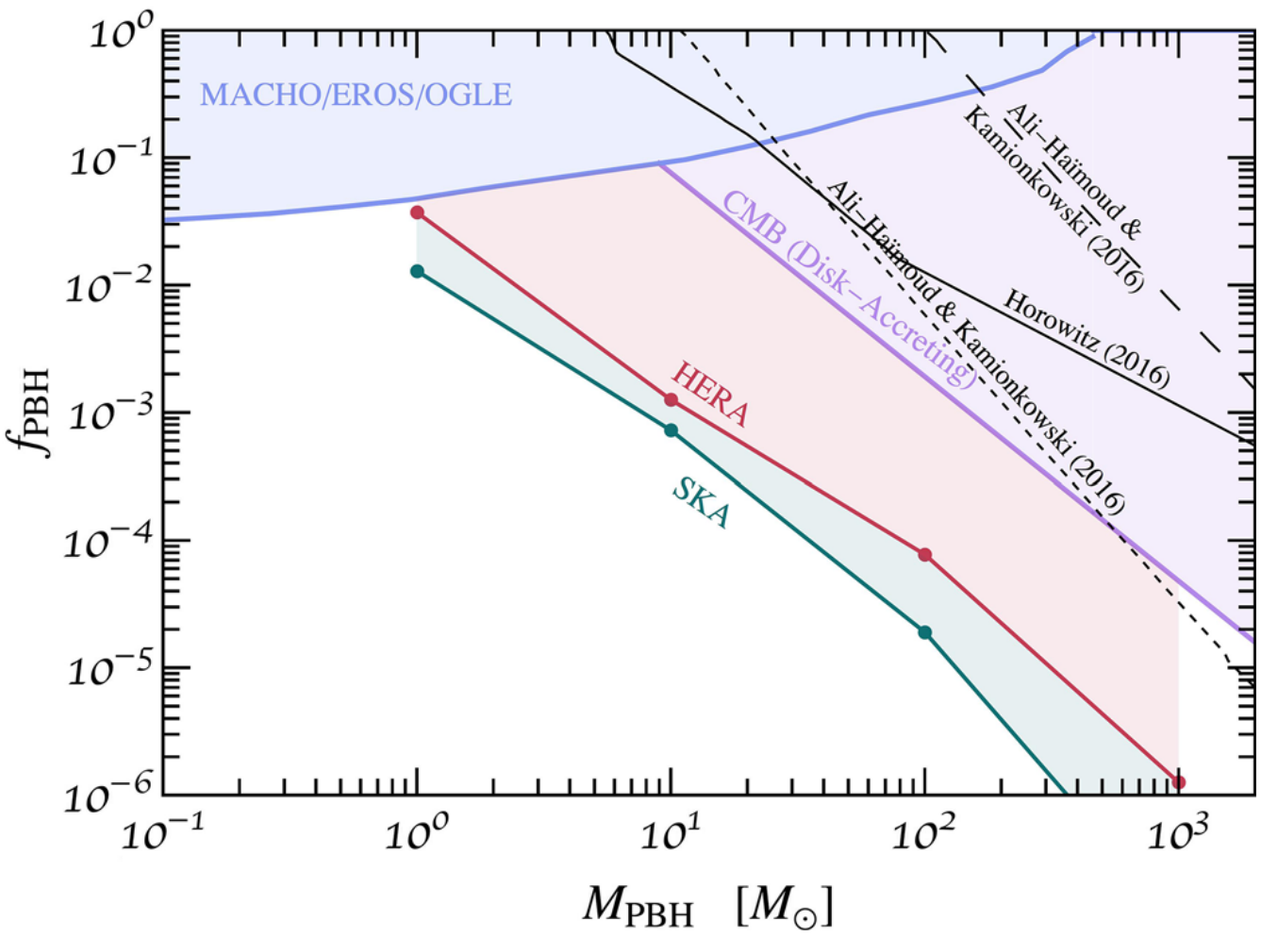
# Detailed Cases

# (selected works)

**Olga Mena, Sergio Palomares-Ruiz,**
Pablo Villanueva-Domingo and Samuel J. Witte

O. Mena, S. Palomares-Ruiz, P. Villanueva-Domingo and S. J. Witte, Phys.Rev.D 100 (2019) 4, 043540

# Primordial black holes as dark matter




Accretion of gas onto PBHs leads to emission of X-rays that would affect intergalactic medium → modification of the ionization and thermal evolution of the Universe

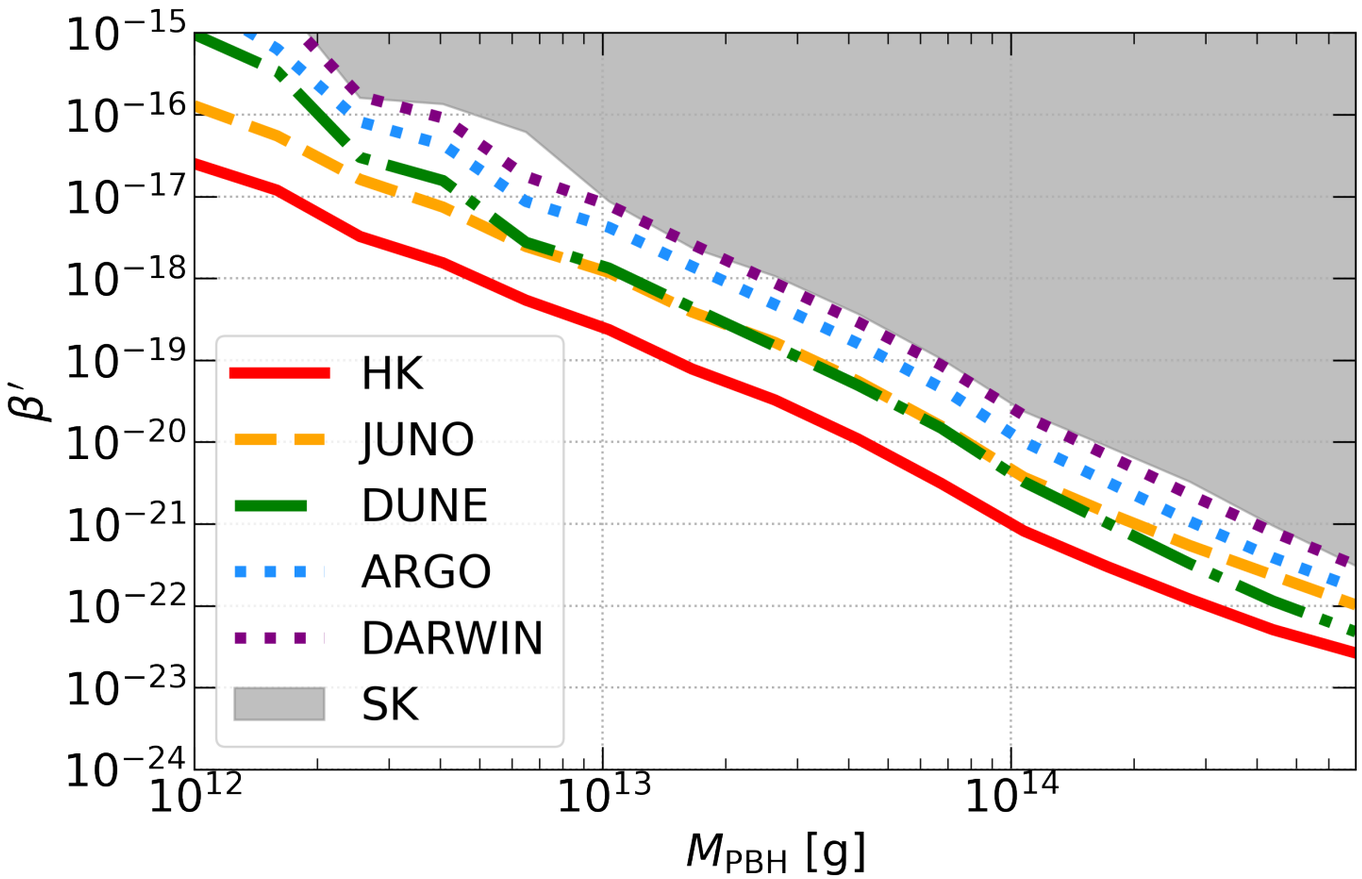
21cm experiments like SKA and HERA could potentially **improve** upon existing constraints from observations of the CMB by **more than one order of magnitude**

**Valentina De Romeri, Pablo Martínez-Miravé and Mariam Tórtola**

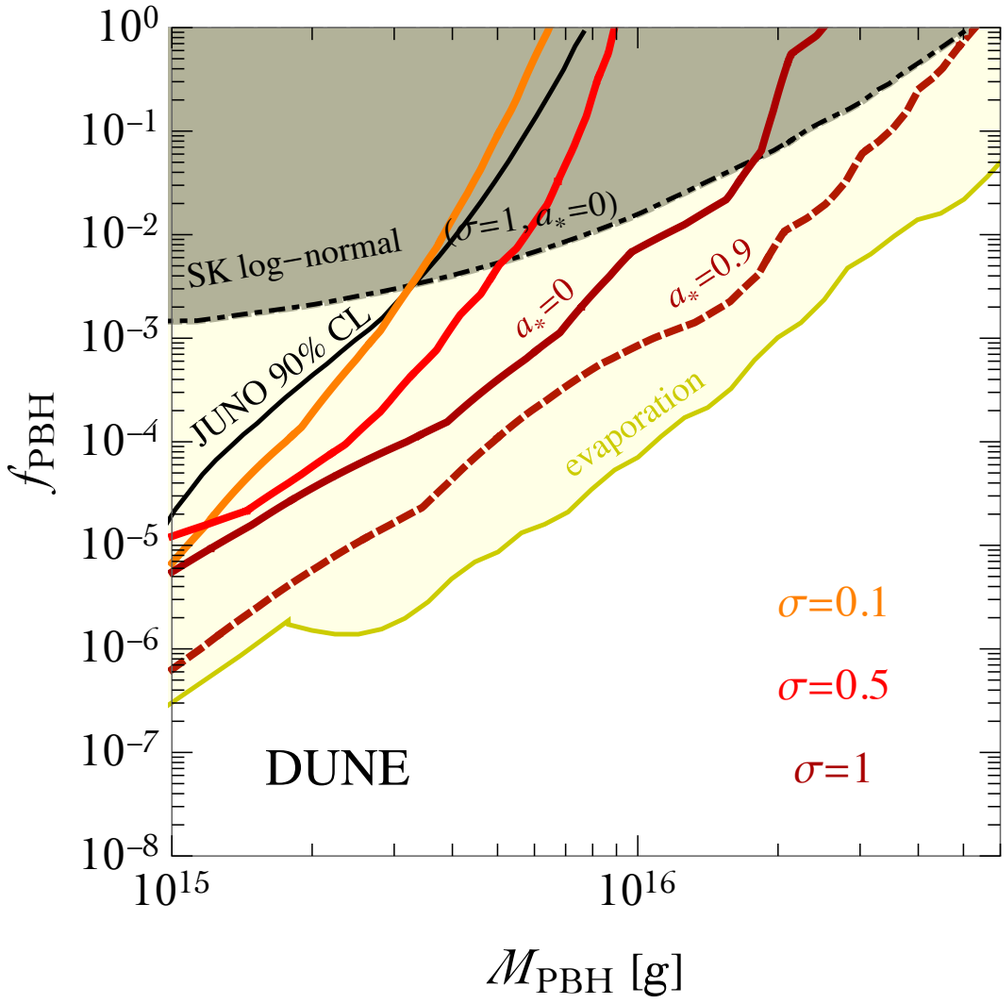
Nicolás Bernal, **Víctor Muñoz-Albornoz**, **Sergio Palomares-Ruiz** and Pablo Villanueva-Domingo

# Neutrinos from evaporation of primordial black holes

N. Bernal, V. Muñoz-Albornoz, S. Palomares-Ruiz and P. Villanueva-Domingo, arXiv:2203.14979




V. De Romeri, P. Martínez-Miravé and M. Tórtola, JCAP 10 (2021) 051



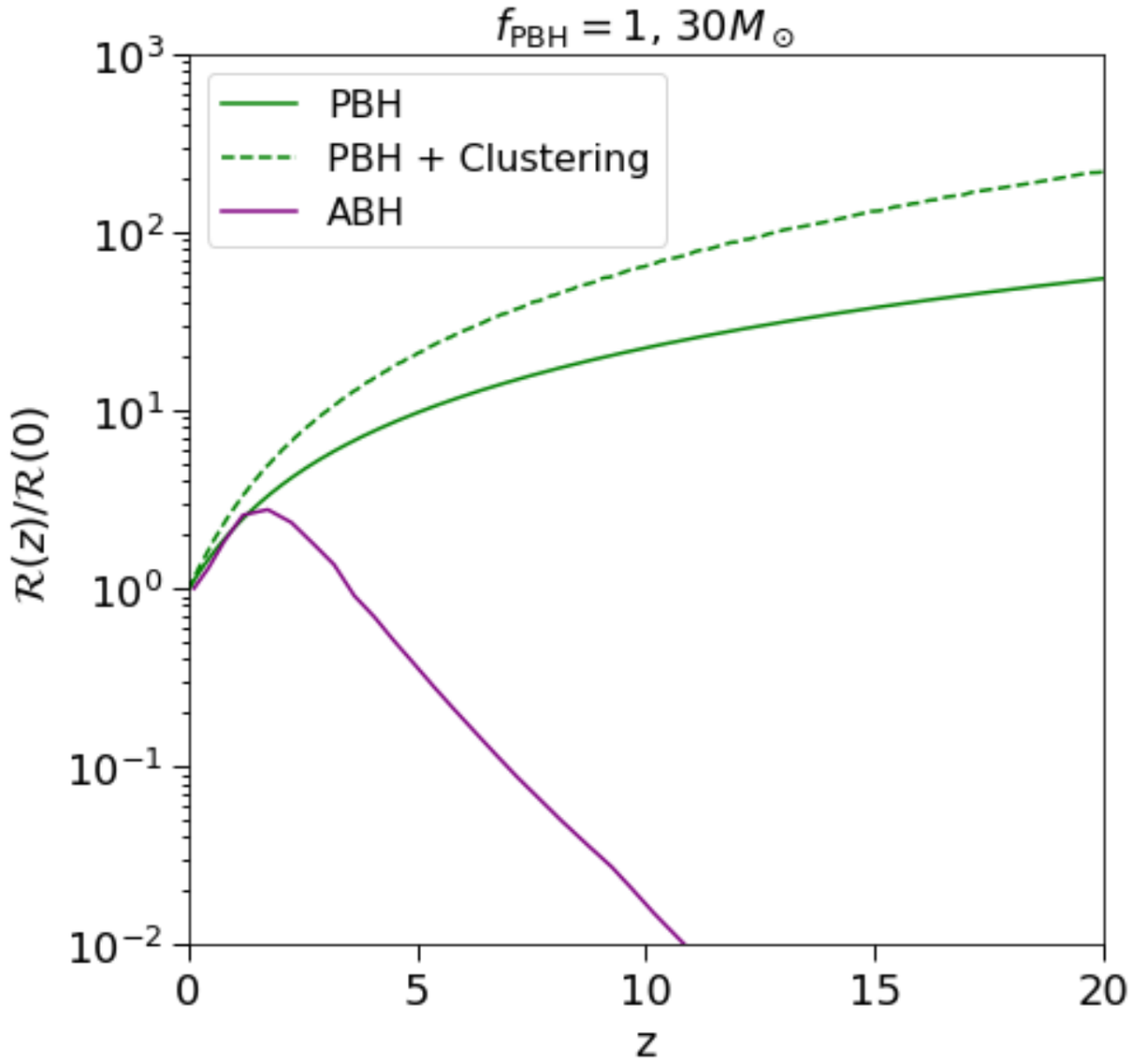

Neutrinos emitted as Hawking radiation from PBHs could be detected with energies >10 MeV at current and future neutrino detectors → constraints on the PBH abundance

# High-redshift merger rate

- **High-redshift merger events** may reveal the presence of a (possibly sub-dominant) population of **Primordial Black Holes**

- **Very different behavior** of the merger rate as a function of redshift for **Primordial** and **Astrophysical** Black Holes

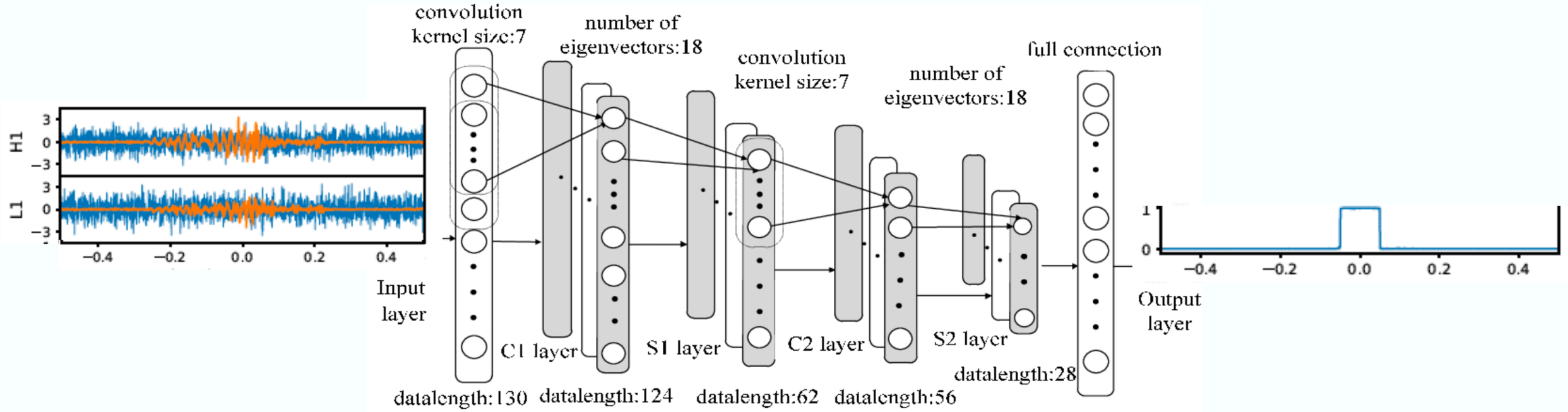
- **Modeling Challenges:**
  - *Effect of clustering*
  - *Impact of different mass functions*
  - *Uncertainties in the astrophysical rate*




C. Fernández, P. Fleury, **D. Gaggero**, B.J. Kavanagh, M. Martinelli, F. Scarcella, *in preparation*

Roberto Ruíz de Austri and collaborators

# Anomaly detection in time-series with Deep Learning




## Supervised

- Data are labeled (signal and noise)
- 1D Convolutional Networks give impressive results: train on LIGO and Virgo O1 data and predict all events observed in O2

## Unsupervised

- Source agnostic
- Train just on noise
- Signal leads to high scores compared to noise in the reconstruction (ie. autoencoders)
- Potential to find departures from GR

Physics Letters B

Volume 807, 10 August 2020, 135577

# Gravitational footprints of massive neutrinos and lepton number breaking

Andrea Addazi [a, b] ✉, Antonino Marcianò [a, g] ✉, António P. Morais [c] ✉, Roman Pasechnik [d] ✉, Rahul Srivastava [e, f] ✉, José W.F. Valle [e] ✉

Show more



https://doi.org/10.1016/j.physletb.2020.135577

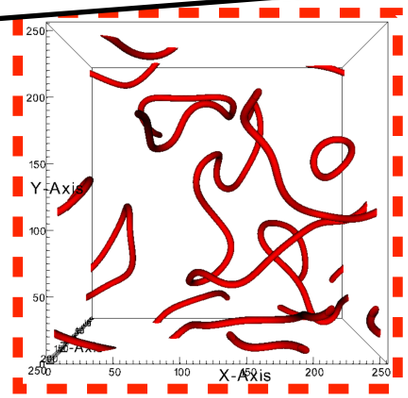


We investigate the production of primordial Gravitational Waves (GWs) arising from First Order Phase Transitions (FOPTs) associated to neutrino mass generation in the context of type-I and inverse seesaw schemes. We examine both “high-scale” as well

# Daniel G. Figueroa + { Jorge Baeza, Nico Loayza, Catarina Cosme

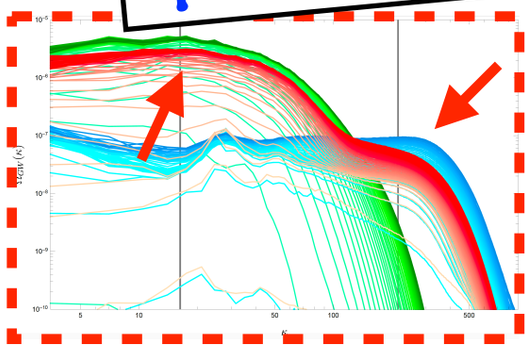
## GW backgrounds from the early Universe

### Cosmic Strings



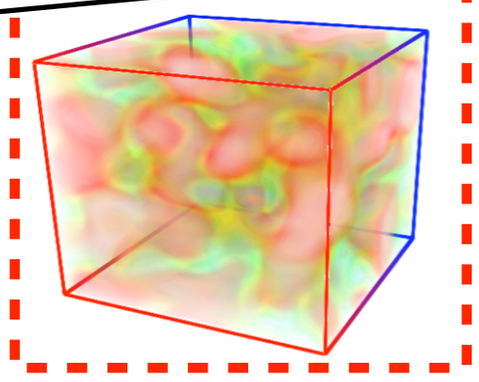

**Field Th & Nambu-Goto**
(Baeza, DGF, …)

### (p)Reheating



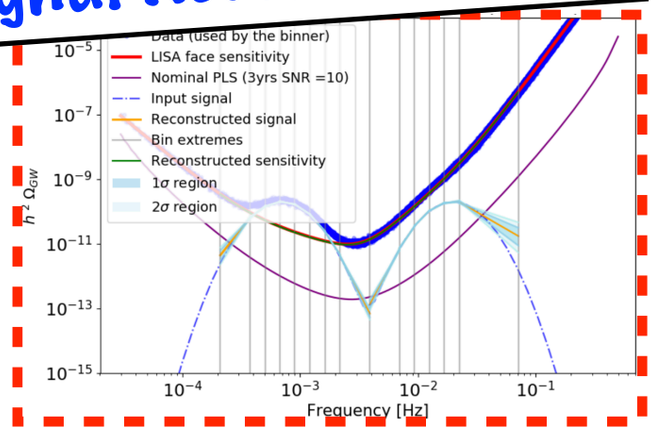
**Spectroscopy of particle couplings**
(DGF, Loayza, …)

### Higgs Excitation



**BSM Symm. Breaking**
(Cosme, DGF, Loayza)

### Signal Reconstruction

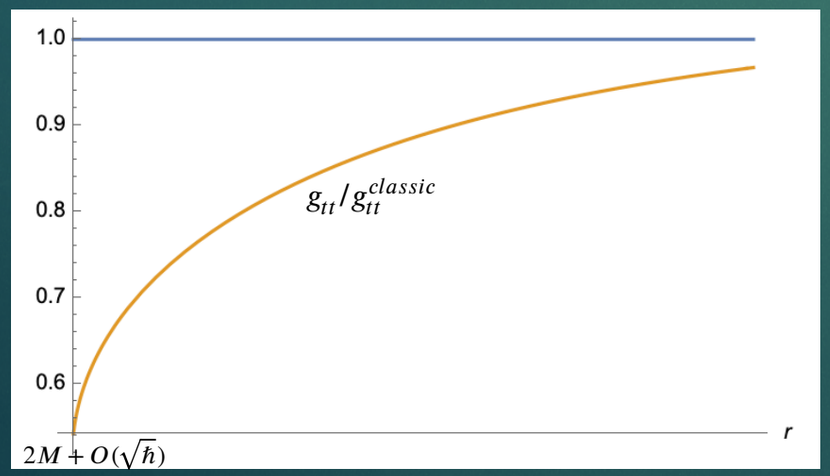


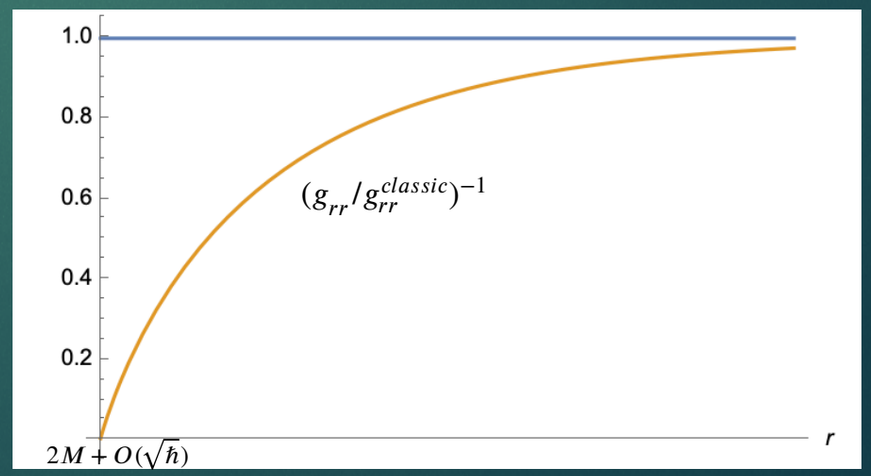

**ML + MCMC + …**
(Dimitriou, DGF, Zaldívar, …)

# Quantum corrections to the Schwarzschild metric

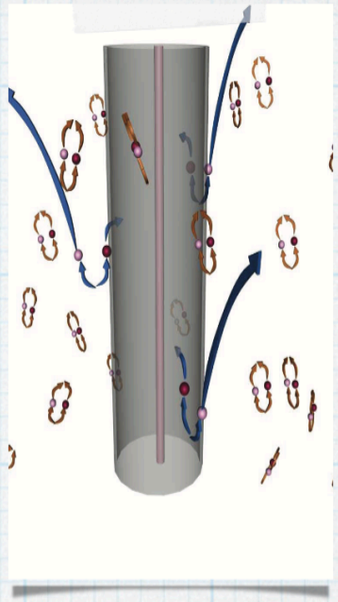
- We consider the semi-classical Einstein equation: $G_{\mu\nu} = 8\,\pi < T_{\mu\nu} >$
- Vacuum polarization $< T_{\mu\nu} >$ introduces static quantum corrections to the Schwarzschild metric proportional to $\hbar$ that are not negligible near the horizon
- We consider conformal matter fields and take advantage of the well-known trace anomaly to define an effective equation of state: $-<\rho> + 3 <p> = <T^{\mu}_{\mu}>$
- We study the possibility of obtaining horizonless geometries from vacuum polarization.

Pau Beltrán-Palau, Adrián del Río and José Navarro Salas

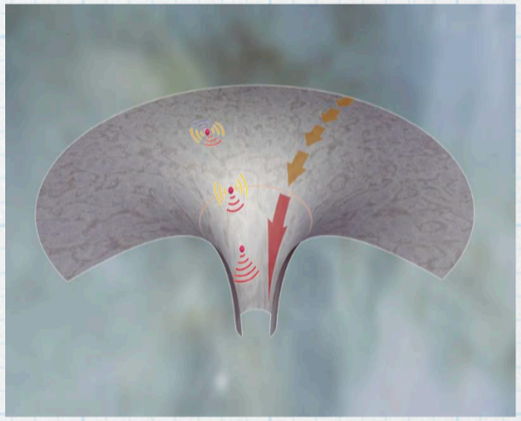


# Hawking radiation

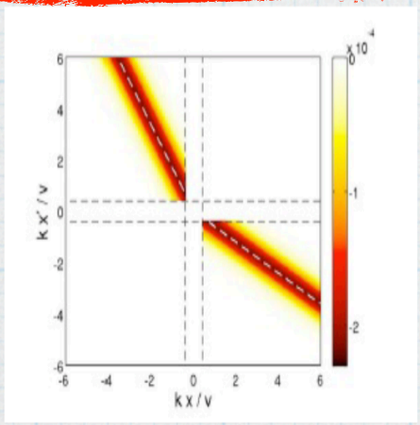


* Hawking '74: conversion of quantum fluctuations into on shell particles by the the black hole horizon ( $T_H \sim 10^{-7} \frac{M_{Sun}}{M}\ K \ll T_{CMB} \sim 3\ K$ too small to be detected ) Fabbri, Navarro-Salas, ICP/World Scientific 2005

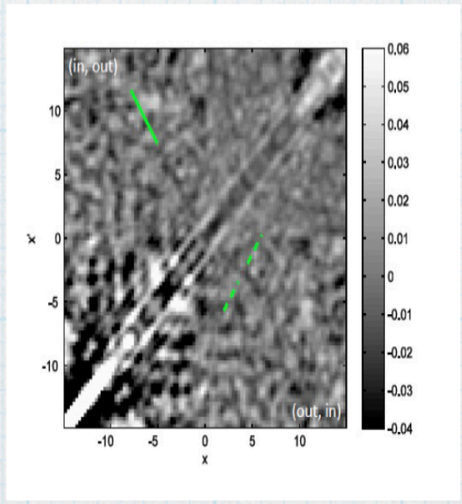


* Unruh '81: An analog of this effect is present in the lab, by considering transsonic flows (acoustic black holes)

* J. Steinhauer 2016, 2019 : Experimental evidence of quantum analog Hawking radiation the density-density correlator in Bose-Einstein condensates




Balbinot, Fabbri, Fagnocchi, Recati, Carusotto, 2008

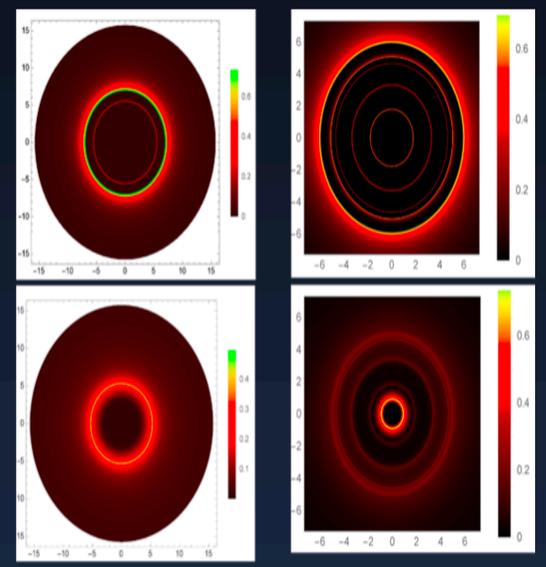



Experimental results

**G.J. Olmo, Andreu Masó, Gerardo Mora, Gonzalo Gurrea, Azmat Rustam, Flavio Bombacigno, Fabio Moretti, Florencia A. Teppa Pannia**

1. Singularities in gravitation: causes, implications, and how to avoid them.

2. Stars and compact astrophysical objects: BHs, BH mimickers, and their observable features (shadows and gravitational waves).



3. Beyond the SM of gravity: non-Riemannian geometry, quantum aspects, and beyond.

4. Solution generating methods, symmetries, mathematical aspects ...

5. The dark side of the Universe and nonsingular cosmologies from the perspective of non-standard gravity.

UV QG

**New website!!!**
(with videos!)

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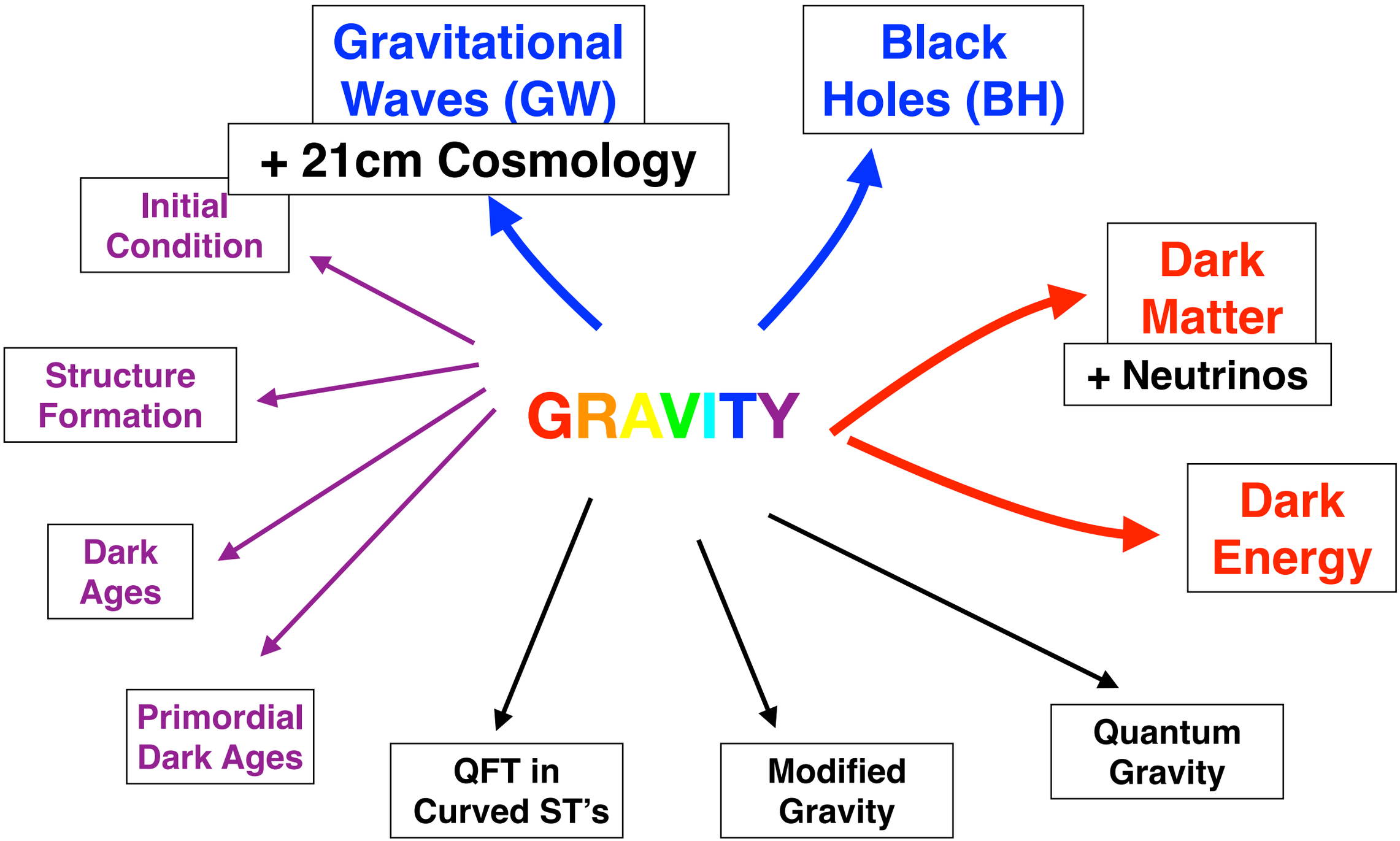

# Thanks for your attention !

# Questions?

# Comments?

# Back

# Slides

# Cosmic Strings (a la Nambu-Goto)