GW and BSM

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Les Rencontres de Physique de la Vallée d'Aoste

La Thuile 2018

What did LIGO detect ?

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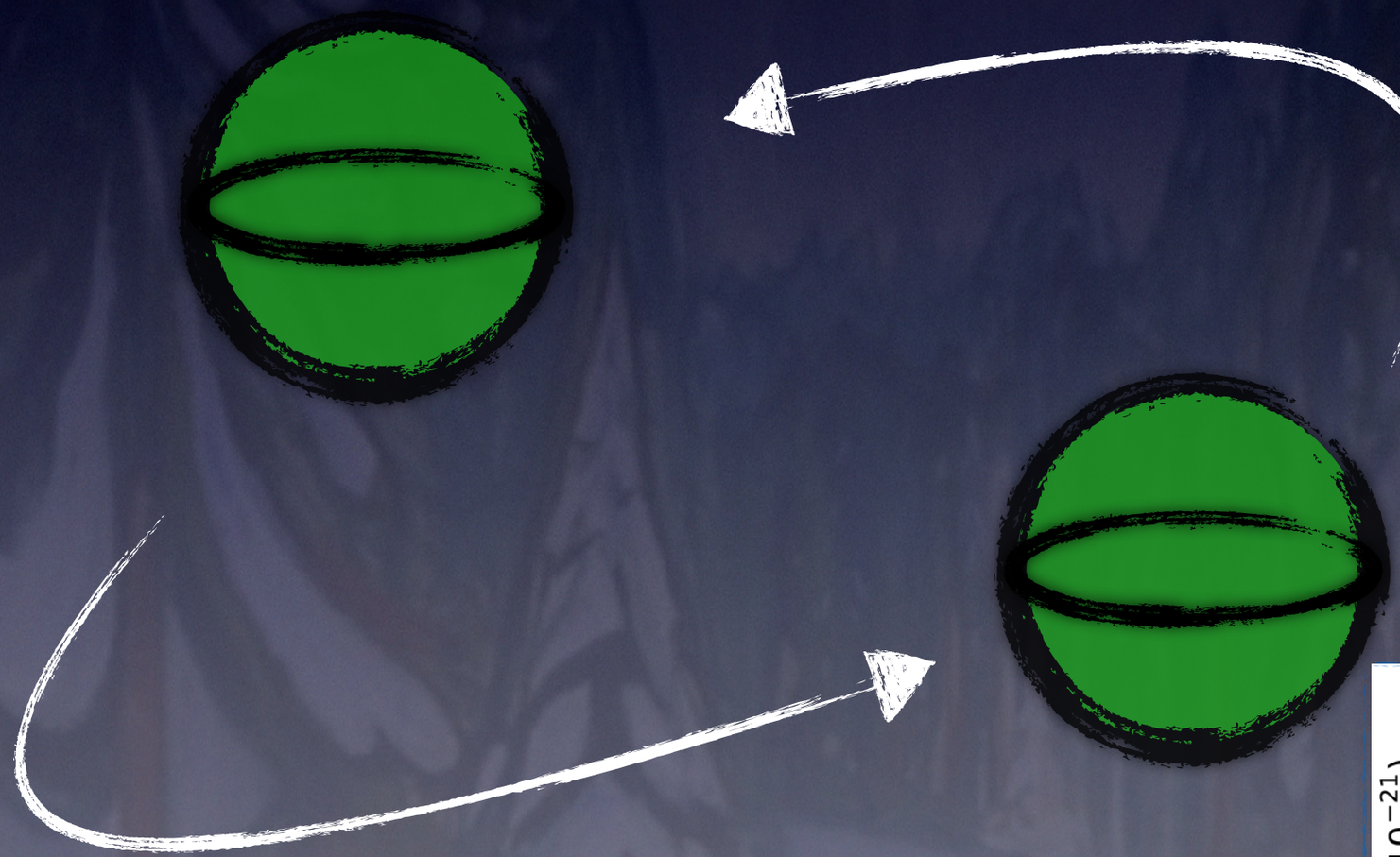
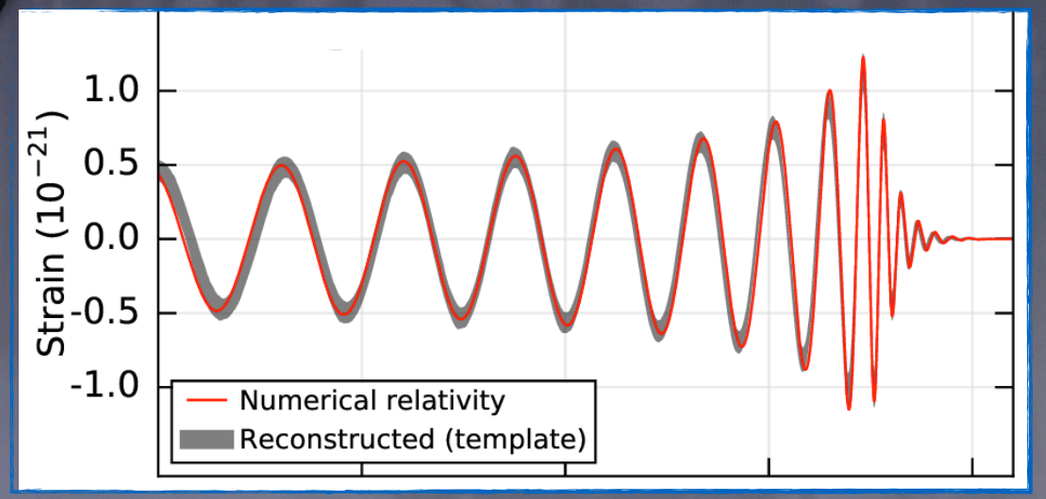


The GW signal emitted in the merger of compact objects with mass and compactness comparable to BH/NS



Matter of fact

Everything seems consistent with General Relativity

Motivation

General Relativity cries for a UV completion

... but I will not discuss GW beyond GR...

Motivation

And we need new particles beyond the Standard Model of particle physics... (isn't it?)

Pot at the end of the rainbow

Could they change standard GW signals ?

Outline

I Correction to observable quantities

aka "direct detection"

II Statistical effects

aka "indirect detection"

III Additional material I will not cover:
BH superradiance and PBHs

Correction to obs quantities

I.a) Change in the waveform
during the inspiral phase

I.b) Change in the waveform
during the ringdown phase

I.c) Change in the frequency evolution
during the inspiral phase
(but I do not have time to discuss)

Correction to obs quantities

I.a) Change in the waveform during the inspiral phase

Goal: Highlight the presence of "new physics corrections" compared to what we expect in standard General Relativity

Correction to obs quantities

I.a) Change in the waveform during the inspiral phase

In this example I will consider the merger of two black holes.

And what new physics you have in mind ?

Simple U(1) dark QED

$$\mathcal{L}_V = -\frac{1}{4} V_{\mu\nu} V^{\mu\nu} + \frac{1}{2} m_V^2 V$$
$$\mathcal{L}_\chi = \bar{\chi} \left[\gamma^\mu \left(i\partial_\mu - g' V_\mu \right) -$$

Correction to obs quantities

I.a) Change in the waveform during the inspiral phase

In this example I will consider the merger of two black holes.

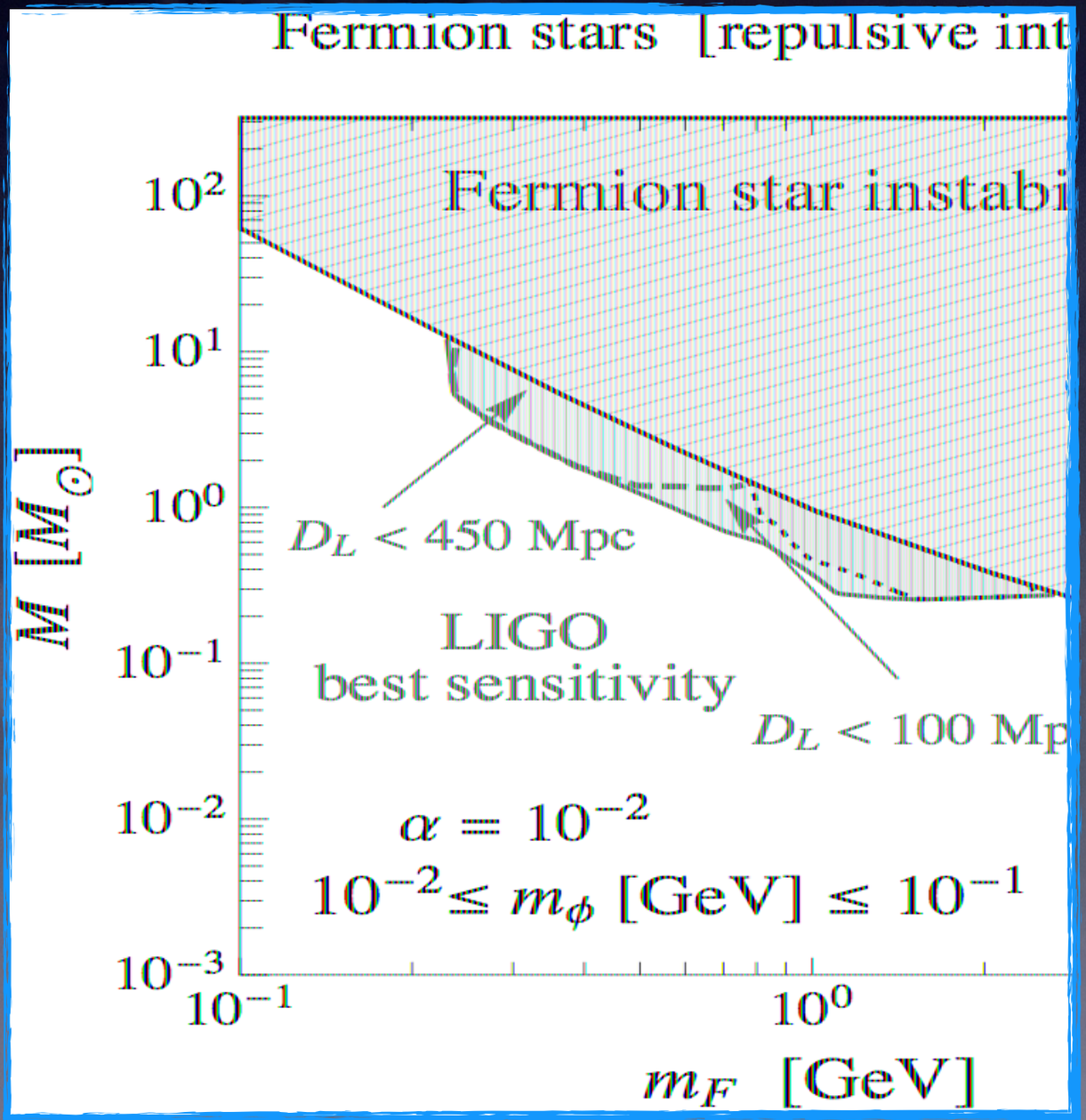
ASSUMPTION

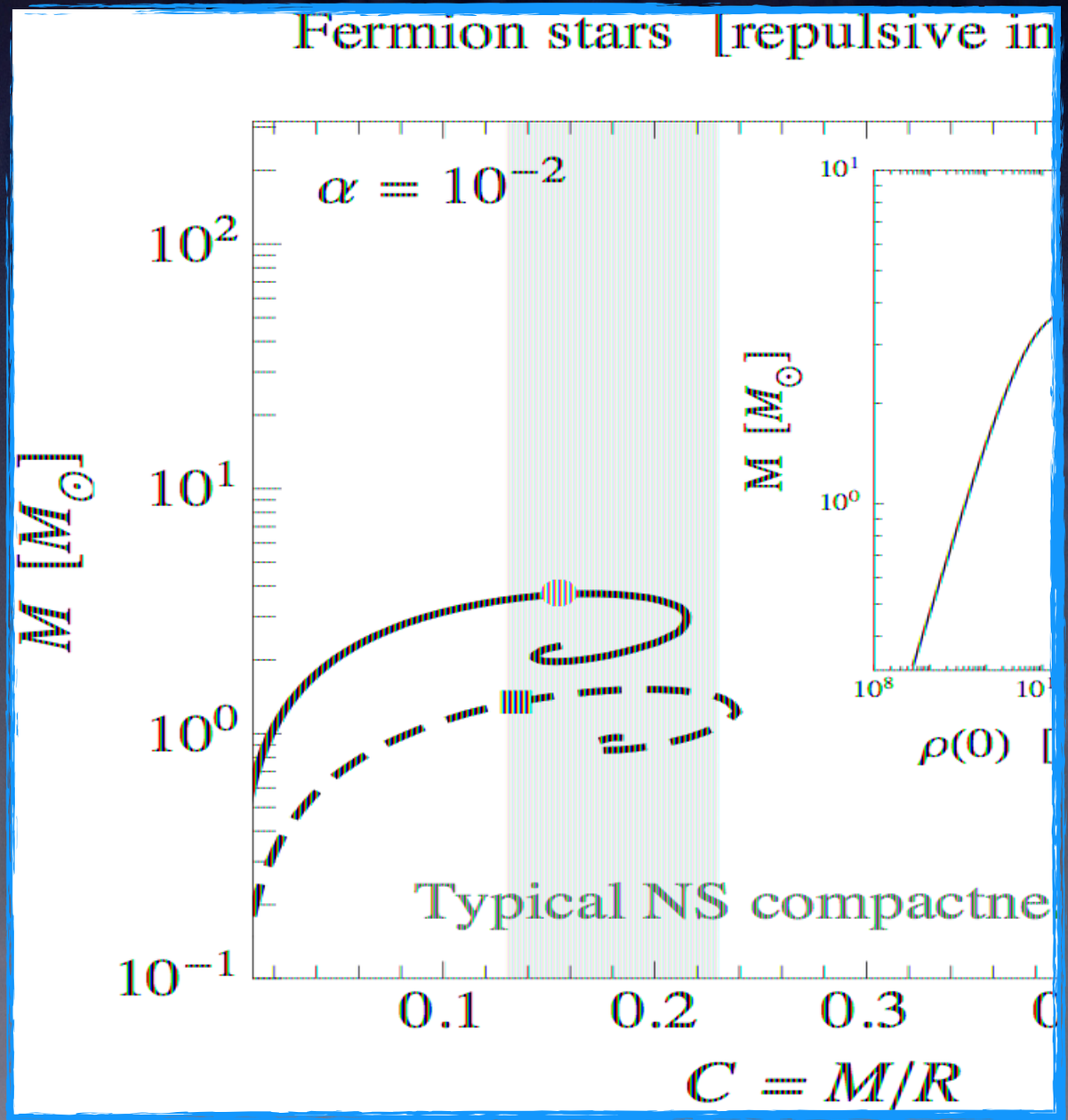
The new fermions condensate to form a "dark neutron star"

$$\mathcal{L}_V = -\frac{1}{4} V_{\mu\nu} V^{\mu\nu} + \frac{1}{2} m_V^2 V$$
$$\mathcal{L}_x = \bar{x} \left[\gamma^\mu \left(i\partial_\mu - g' V_\mu \right) -$$

Correction to obs quantities

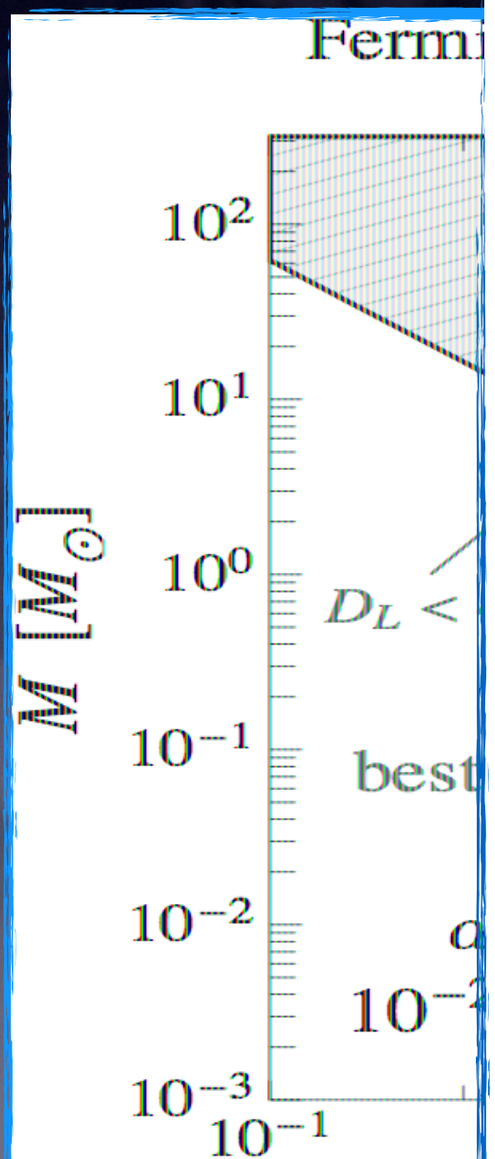
I.a) Change in the waveform during the inspiral phase

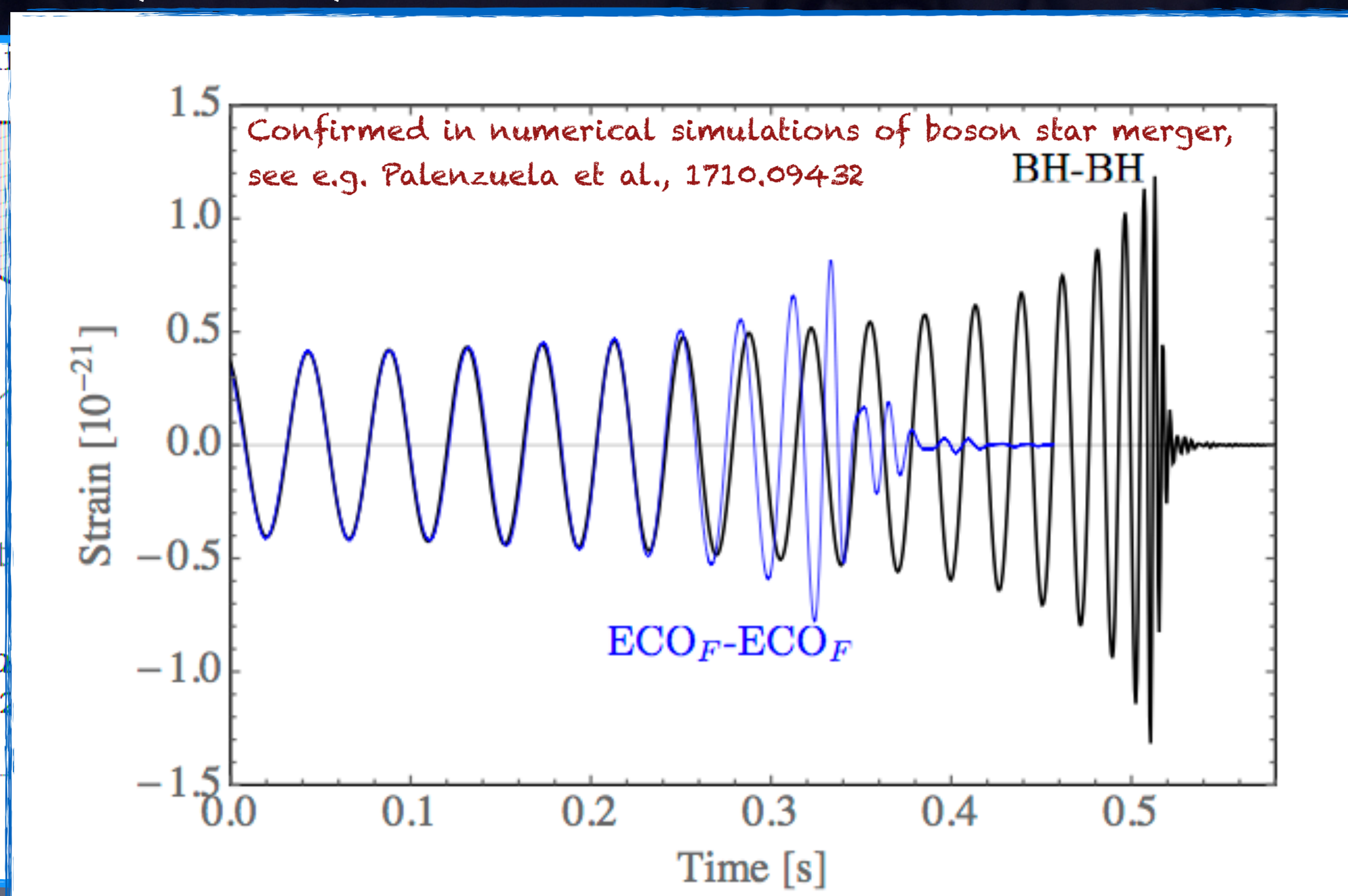




Correction to obs quantities

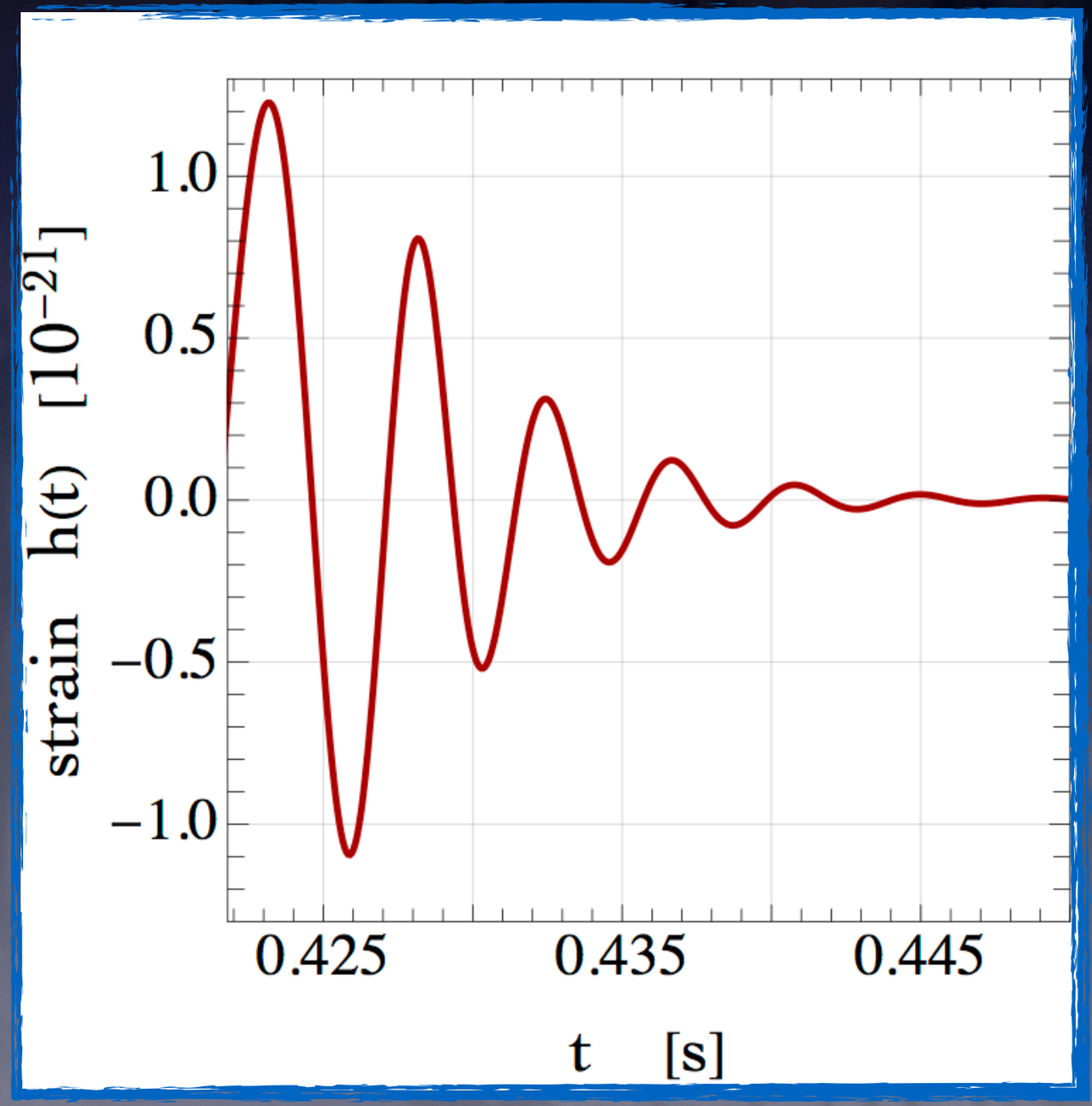
I.a) Change in the waveform during the inspiral phase





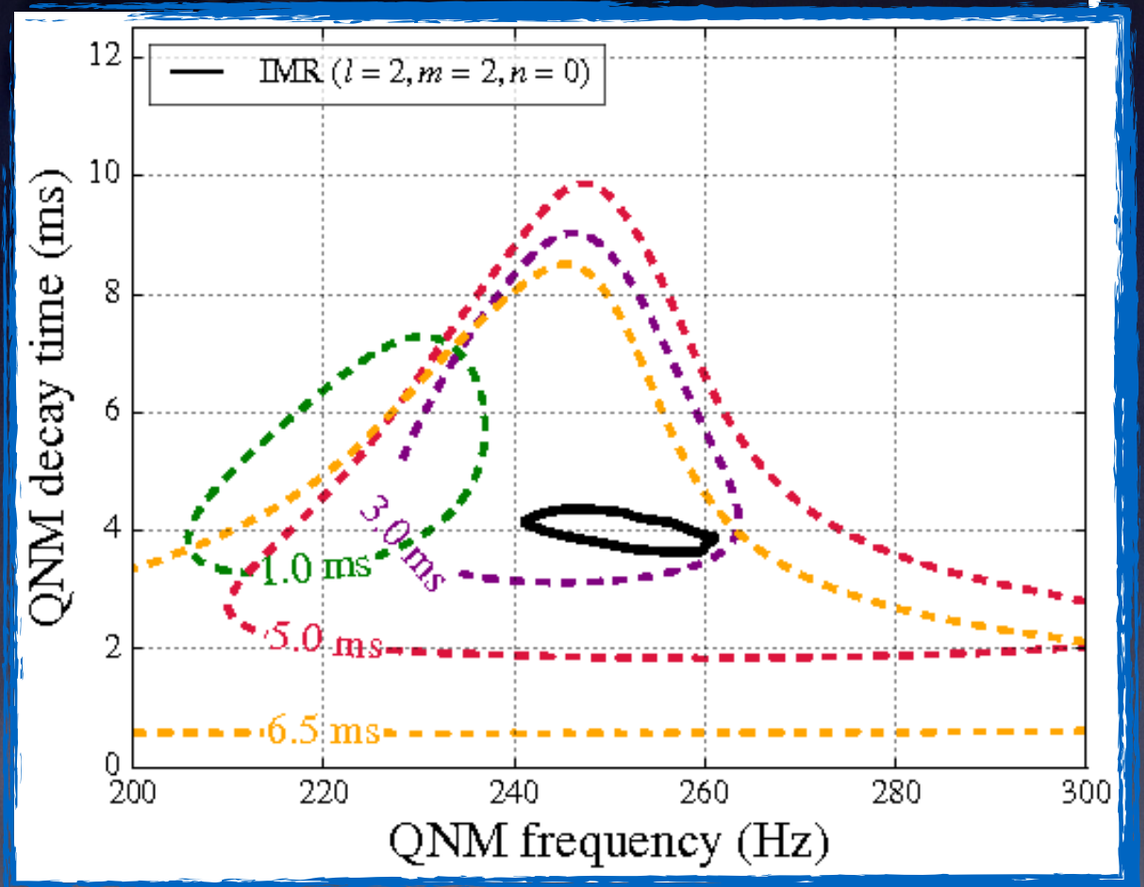
Correction to obs quantities

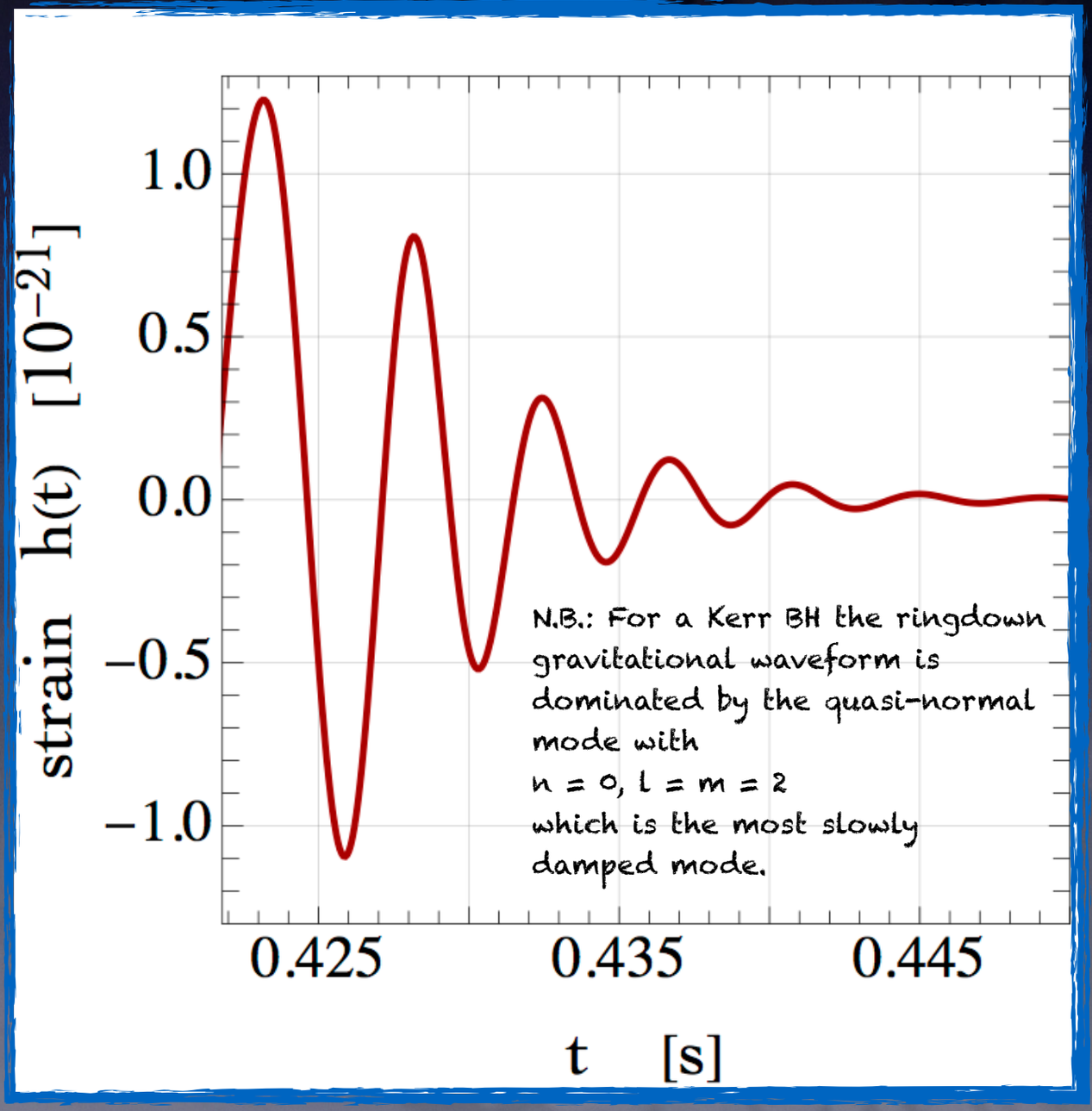
I.b) Change in the waveform during the ringdown phase



Correction to obs quantities

I.b) Change in the waveform during the ringdown phase



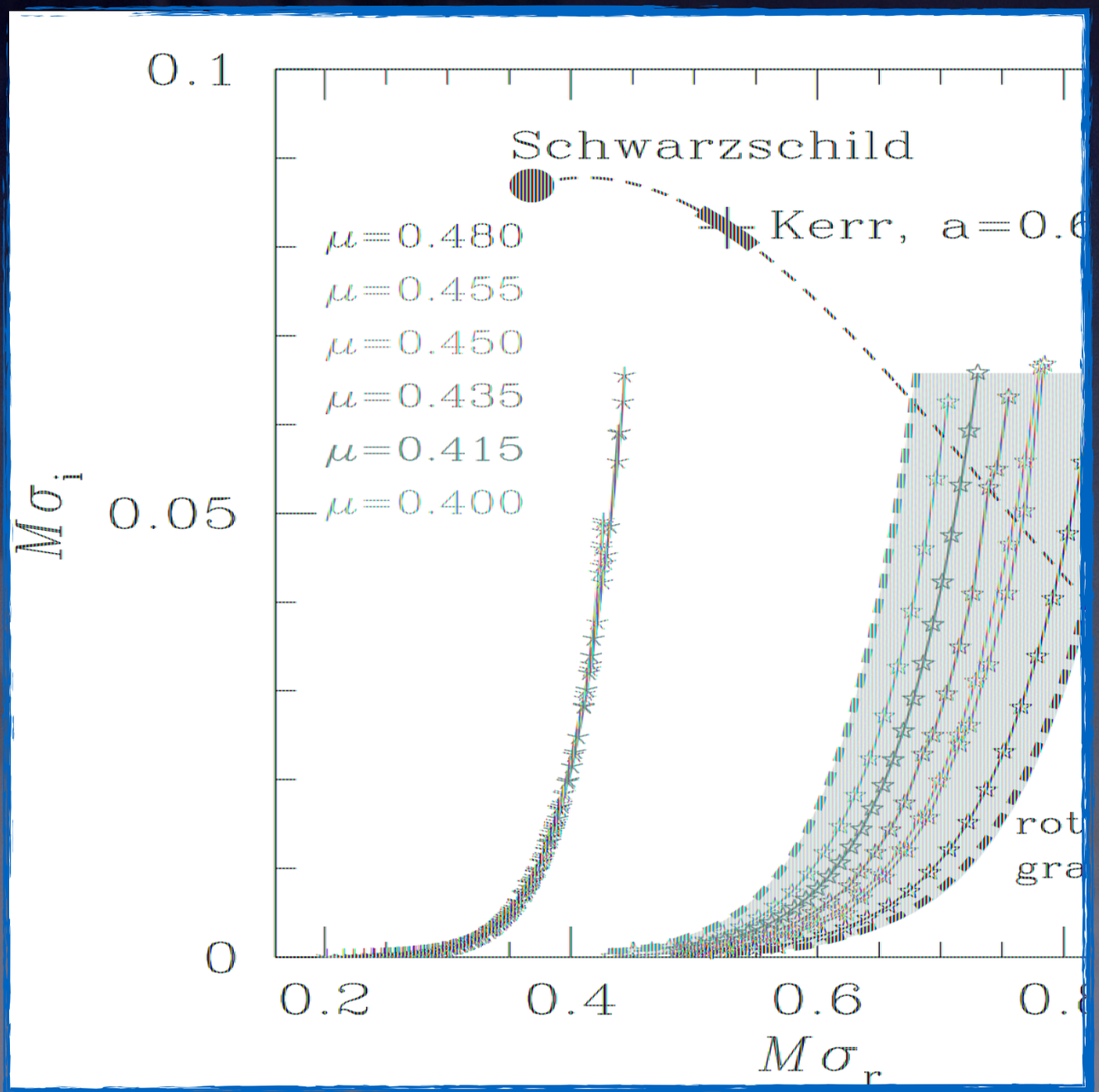


For any spherically symmetric asymptotically flat space-time the real and imaginary part of the QNMs are given by the frequency and instability timescale of the unstable circular null geodesics (the "light ring")

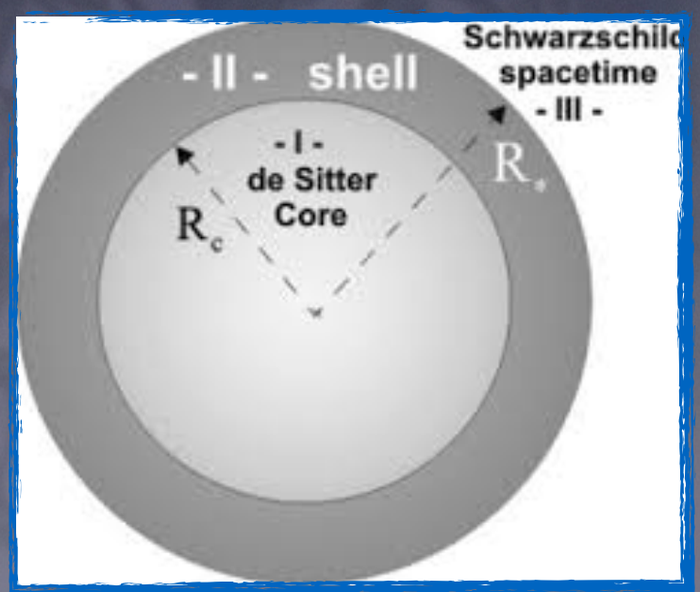
Correction to obs quantities

I.b) Change in the waveform during the ringdown phase

Chirenti and Rezzolla, 1602.08759



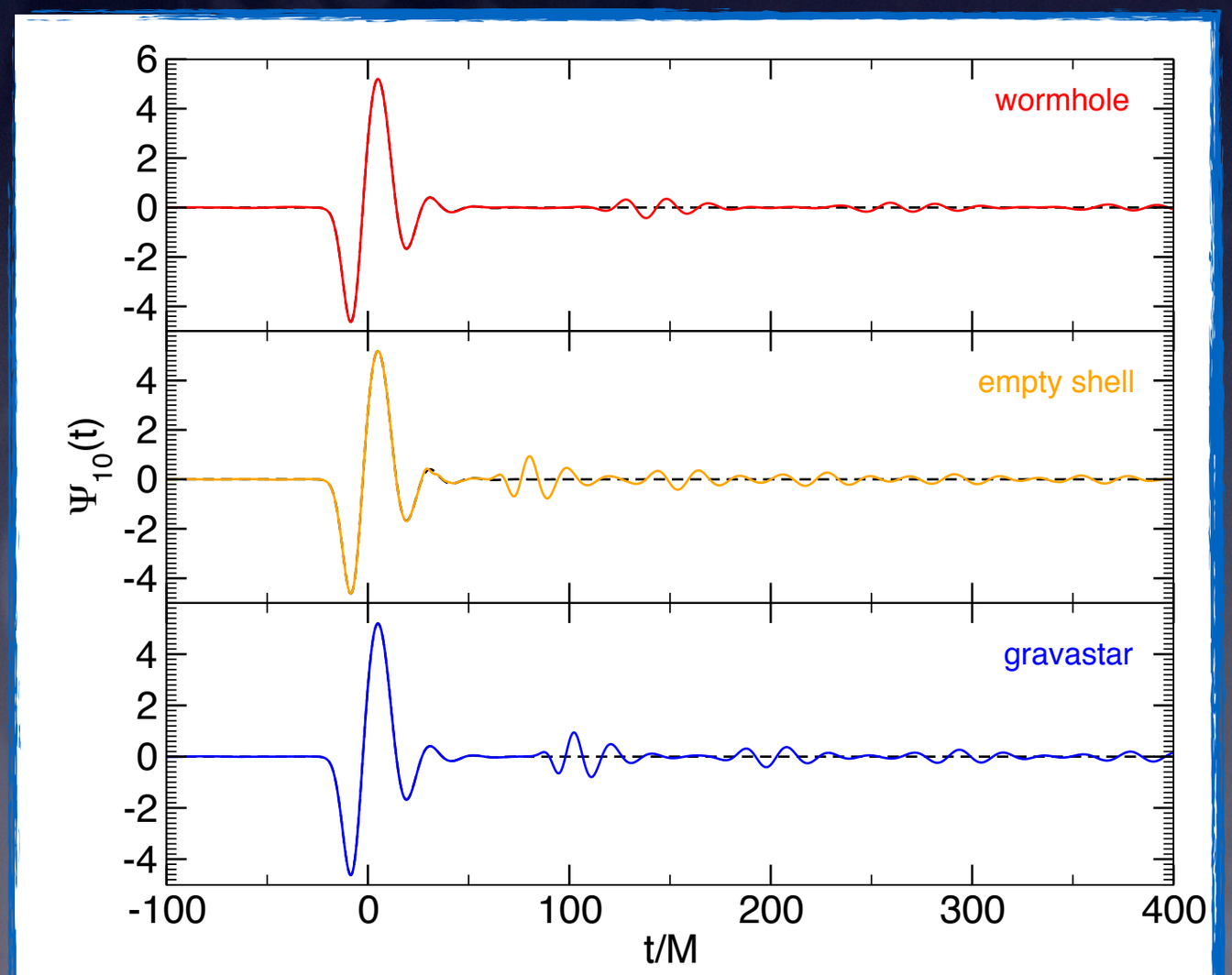
Gravastars are a toy model for the so-called "black-hole mimickers", objects that can be almost as compact as a black hole but without an event horizon.



Correction to obs quantities

I.b) Change in the waveform during the ringdown phase

V. Cardoso et al., 1608.08637



Even in the limit in which the ECO is as compact as a black hole, we can still distinguish the former from the latter because of the presence of additional pulsations ("echoes" of ECOs) in the ringdown phase.

Statistical effects

Simulations from "The Synthetic Universe project",
http://www.syntheticuniverse.org/

Statistical effects

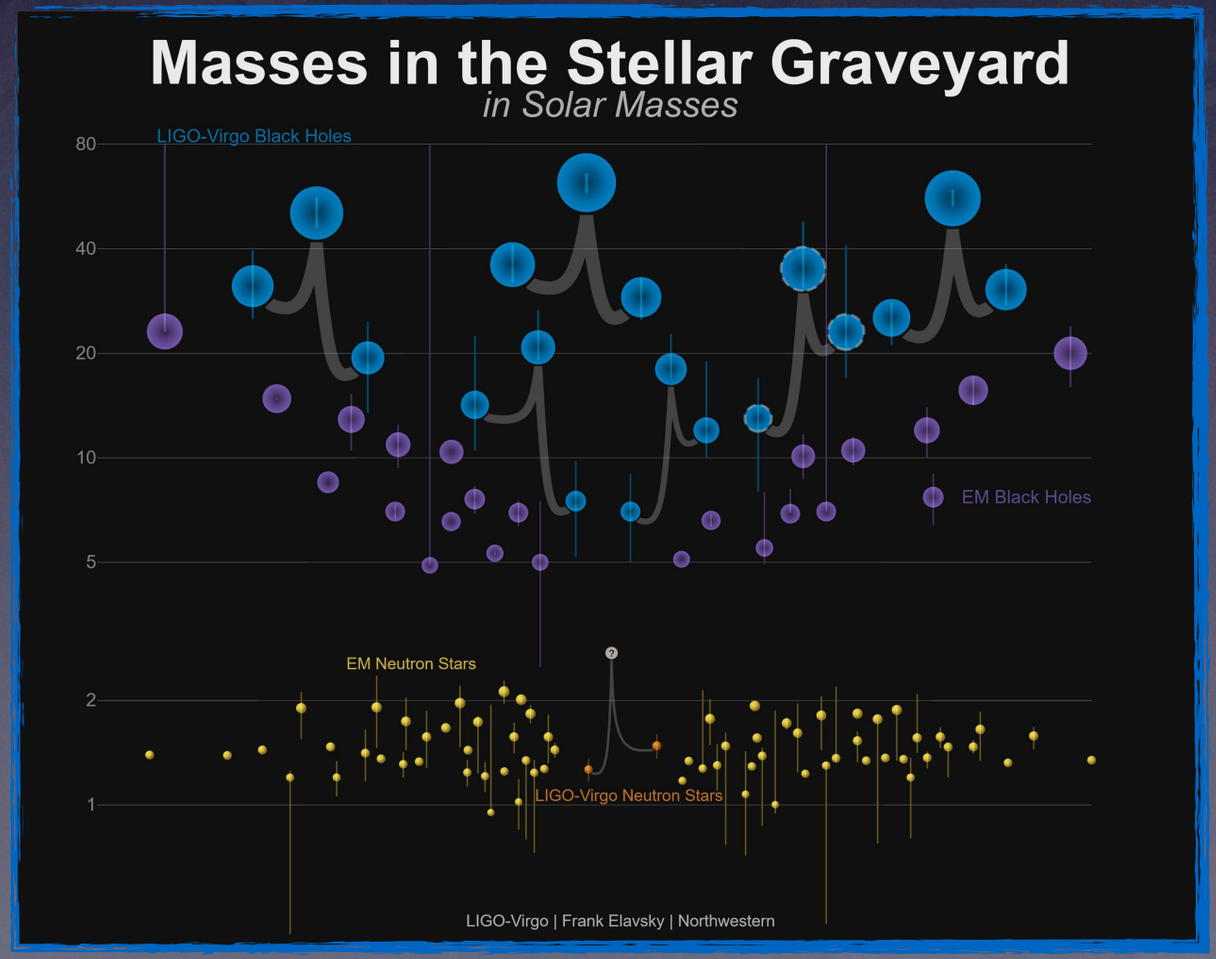
Neutron stars

Black holes

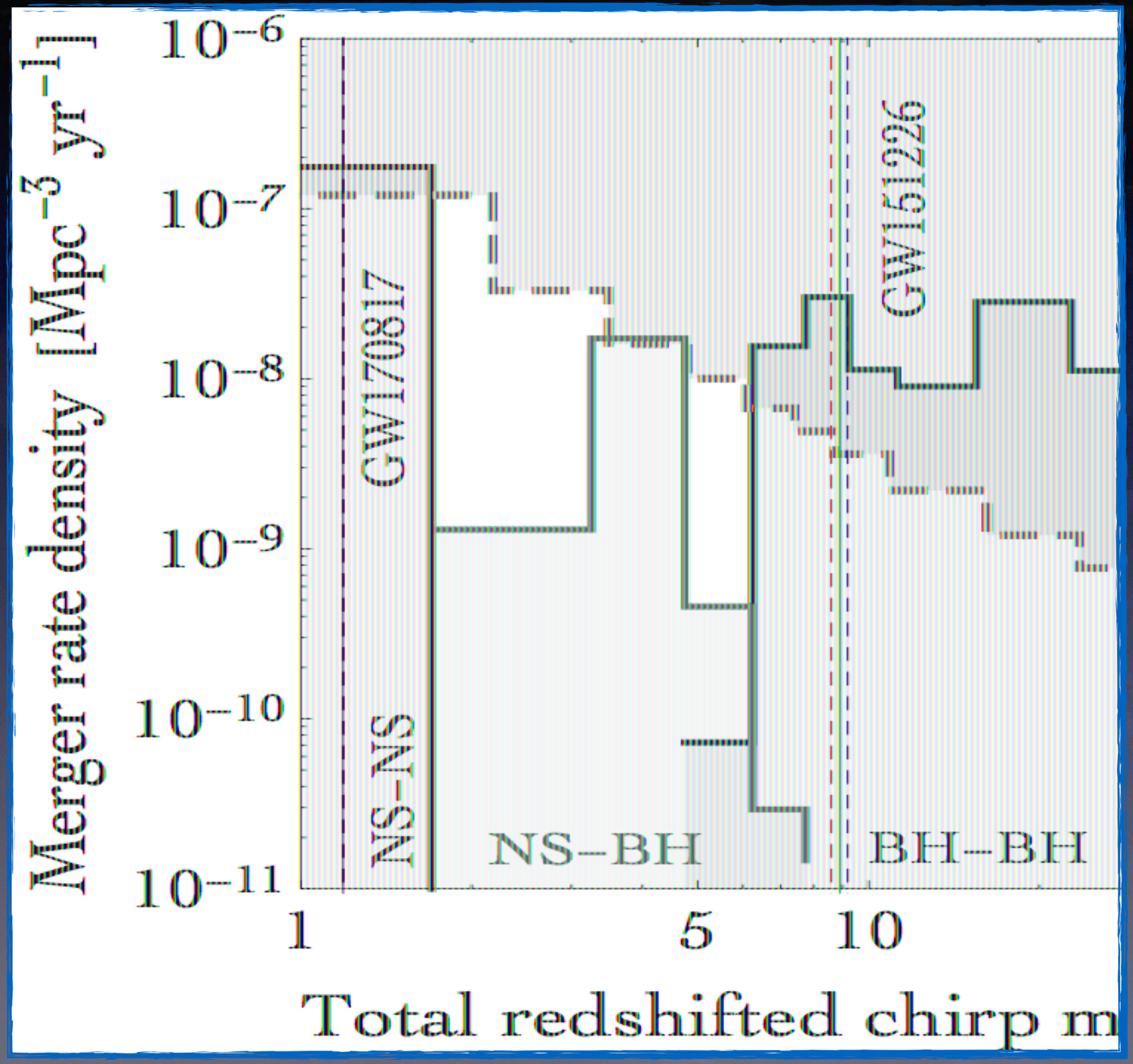
~2

~5

Mass



Statistical effects



Conclusion/Open questions

Conclusion/Open questions

i) The hunting season is now open

ii) ECOs: formation and stability + numerical simulations

iii) Many things I didnt have time to discuss... (BH superradiance, PBHs, et cetera...)

Backup

Correction to obs quantities

I.c) Change in the frequency evolution during the inspiral phase

$$f_{\rm GW}(t) \sim \frac{1}{\pi}\left(\frac{G_N M_C}{c^3}\right)^{-5/8}\left(\frac{}{t}\right.$$

$$\begin{aligned} m_V^{-1} &= \mathcal{O}(10 - 1000) \\ m_V &= \mathcal{O}(10^{-11} - 10^{} \end{aligned}$$

ASSUMPTION

The charged DM particles are trapped by a NS during its lifetime

The NS carries a net "dark charge"