Boson stars as black hole mimickers

Francisco Siddhartha Guzmán Murillo

Instituto de Física y Matemáticas,
Universidad Michoacana de San Nicolás de Hidalgo

ERE.2010 Granada

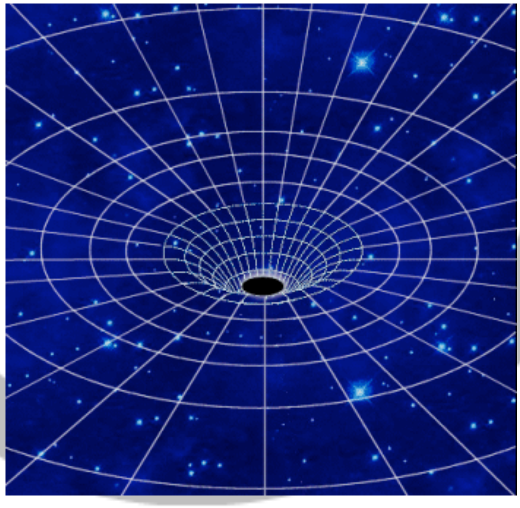
Plan

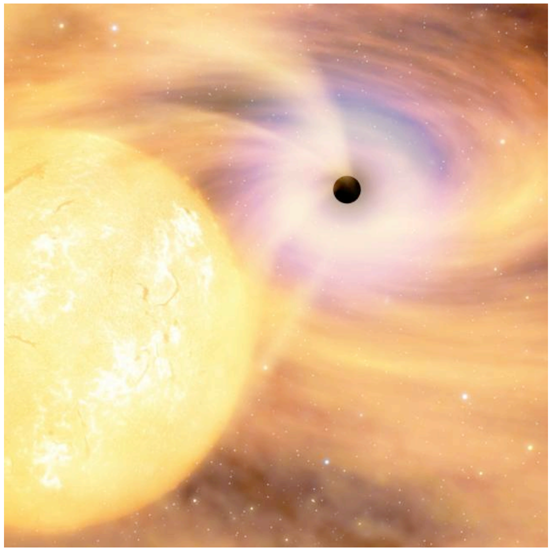
- Black holes
- What a mimicker needs to supplant a black hole
- Boson stars and a few motivations
- Supremacy of BSs over wormholes and gravastars
- Tests a BH mimicker has to sort out
- Work to be done on boson stars and other mimickers
- Final comments

INSTITUTO DE FÍSICA Y MATEMÁTICAS U M S N H

guzman@ifm.umich.mx

Schwarzschild's solution (a lot of symmetries)





$$ds^2 = -\left(1 - \frac{2M}{r}\right)dt^2 + \frac{dr^2}{\cdots} + r^2(d\theta^2 + sen^2\theta d\phi^2)$$

guzman@ifm.umich.mx

Black hole candaidates

Formally there is no way of seeing a BH directly, because of the arrangement of the light cones, which -at the horizon- point toward the inner region of the black hole.

In practice high energy observations are performed: accretion, gamma bursts, etc. Assuming there is a black hole provides a model.

The problem now is that it may or may not be a black hole solution, and then a variety of options arise: black holes, wormholes, gravastars, boson stars, etc.

guzman@ifm.umich.mx

What a mimicker needs to supplant a black hole

BHCs must satisfy a few conditions (not easy):

They have to catch up on black hole models, that is, they have to explain as many as possible phenomena related to BHs: accretion disc models, BHs as sources of high energy cosmic rays, gravitational lensing, etc, and BHs as sources of gravitaional waves [THIS IS KEY because it is related to a horizon].

THIS IS BAD, because all BHCs are asymptotically Schwarzschild (wehere asymptotically means not that far)

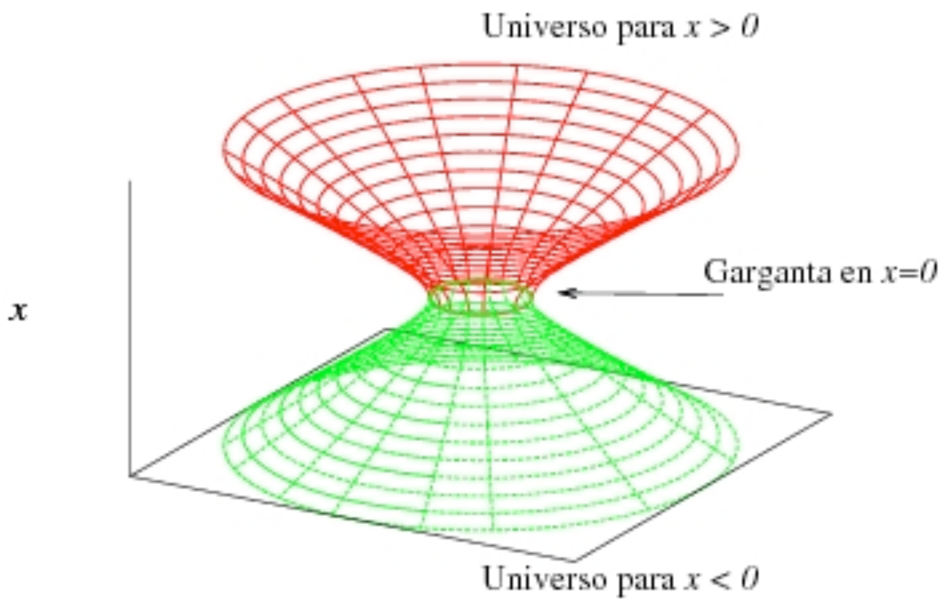
guzman@ifm.umich.mx

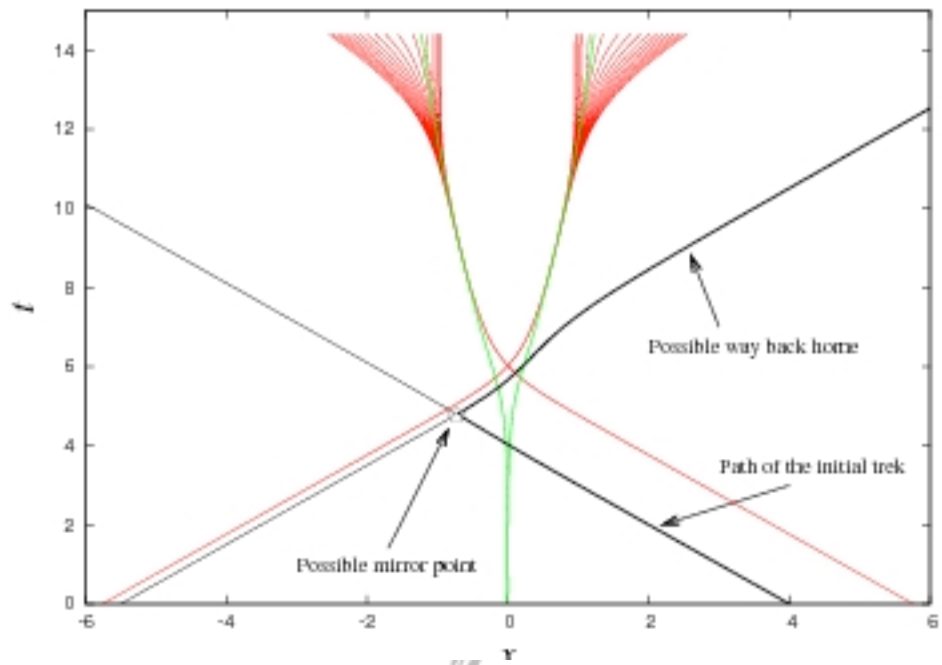
Black hole candidates one by one the most important mimickers

Wormholes

- Solutions of Eequations with exotic matter (ghost, phantom).
- No event horizon, but throat.
- Connects two assymptotic universes.
- Reproduce the strong gravity conditions, the motion of test particles outside the throat and according to new results strong lensing.
- Unfortunately: unstable

Final comments





guzman@ifm.umich.mx

Gravastars

Solution of Eequations suc
solution of de Sitter, c
Schwarzschild, and at th
of fluid.

Properties:

- no horizon
- all the outside proper
solution

Status:

- stability not yet completely established
- gravitational radiation in the far region studied and compared to that from Schwarzschild black holes.

guzman@ifm.umich.mx

Boson stars

Solution to Eequations with a matter source related to a T=0 Bose Condensate or a classical complex scalar field.

<u>**Properties**</u>:

- Stationary
- Regular everywhere
- No event horizon
- No singularities
- Asymptotically Schwarzschild
- Transparent to light
- STABLE-UNSTABLE branches

<u>**Status**</u>:

- this talk

guzman@ifm.umich.mx

Boson stars and a few motivations

$$L = -\frac{R}{\kappa_0} + g^{\mu\nu}\partial_\mu\phi^*\partial_\nu\phi + V(|\phi|^2)$$

$$G_{\mu\nu} = \kappa_0 T_{\mu\nu}$$

$$T_{\mu\nu} = \tfrac{1}{2}[\partial_\mu\phi^*\partial_\nu\phi + \partial_\mu\phi\partial_\nu\phi^*] - \tfrac{1}{2}g_{\mu\nu}[\phi^{*,\alpha}\phi_{,\alpha} + V(|\phi|^2)$$

$$(Dal\phi - \frac{dV}{d|\phi|^2})\phi = 0$$

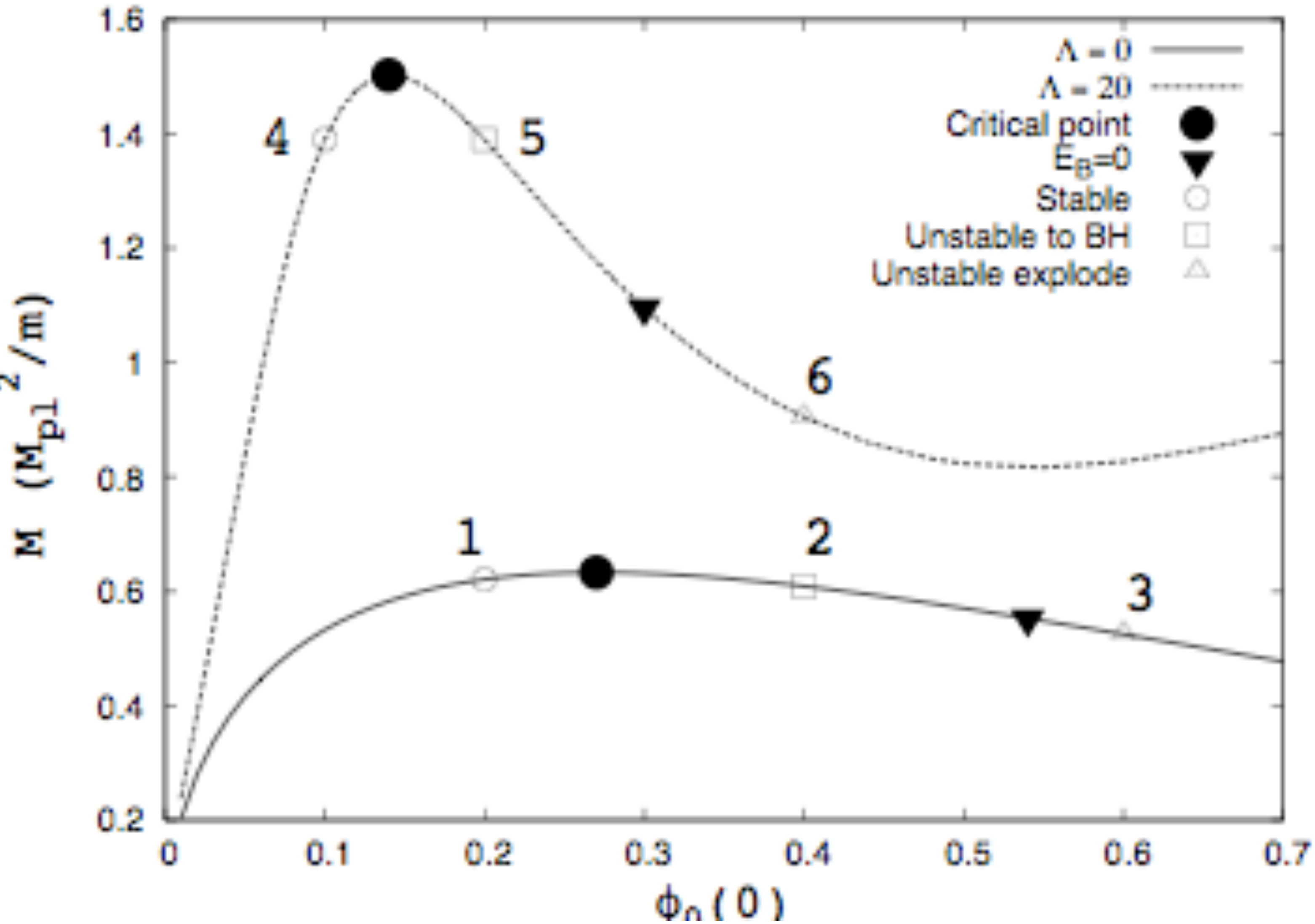
$$Dal\phi = \frac{1}{\sqrt{-g}}\partial_\mu[\sqrt{-g}\,g^{\mu\nu}\partial_\nu\phi]$$

$$V = m^2|\phi|^2 + \frac{1}{2}\lambda|\phi|^4$$

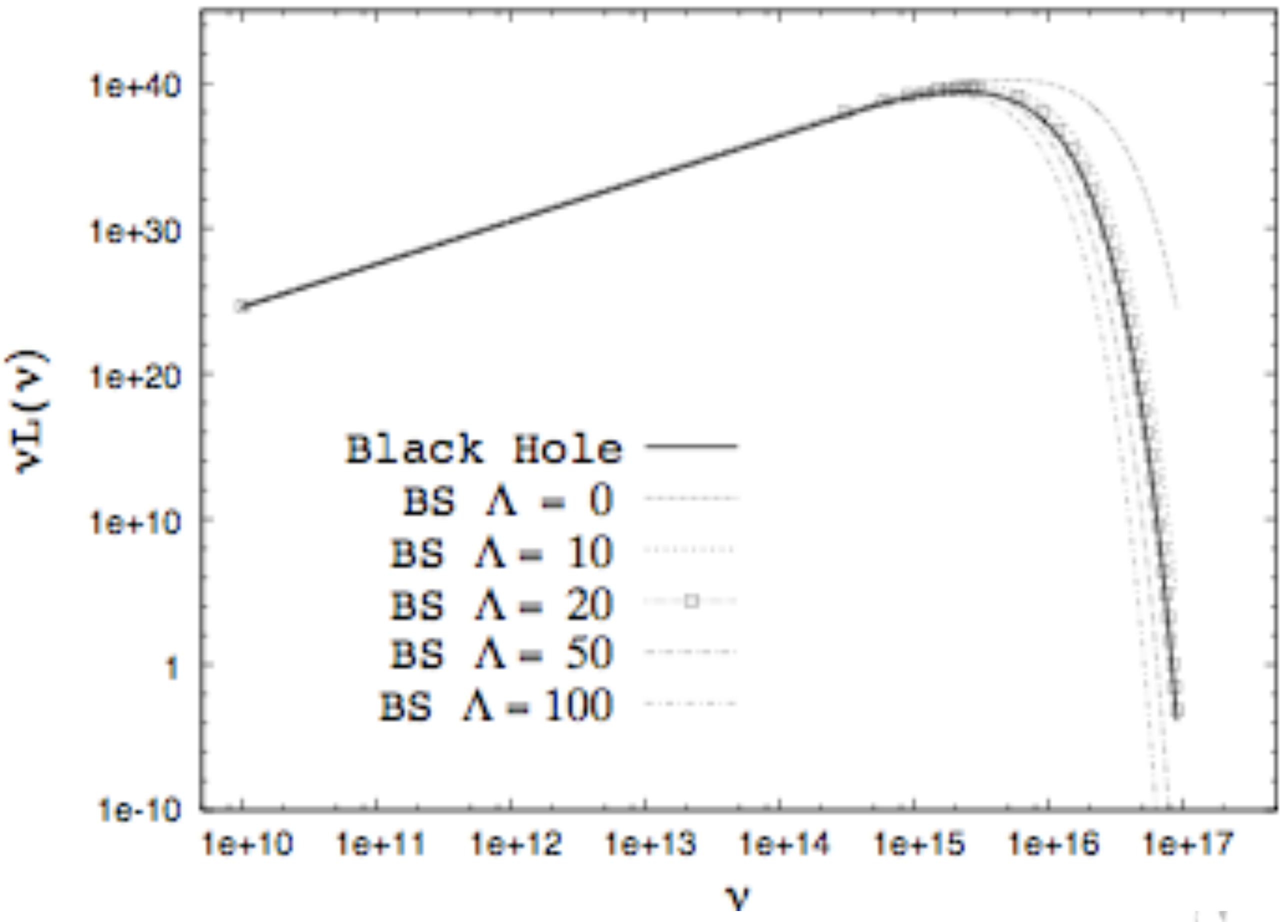
guzman@ifm.umich.mx

Boson stars

1. Three dynamical fates of these solutions
2. They scale with the Planck mass

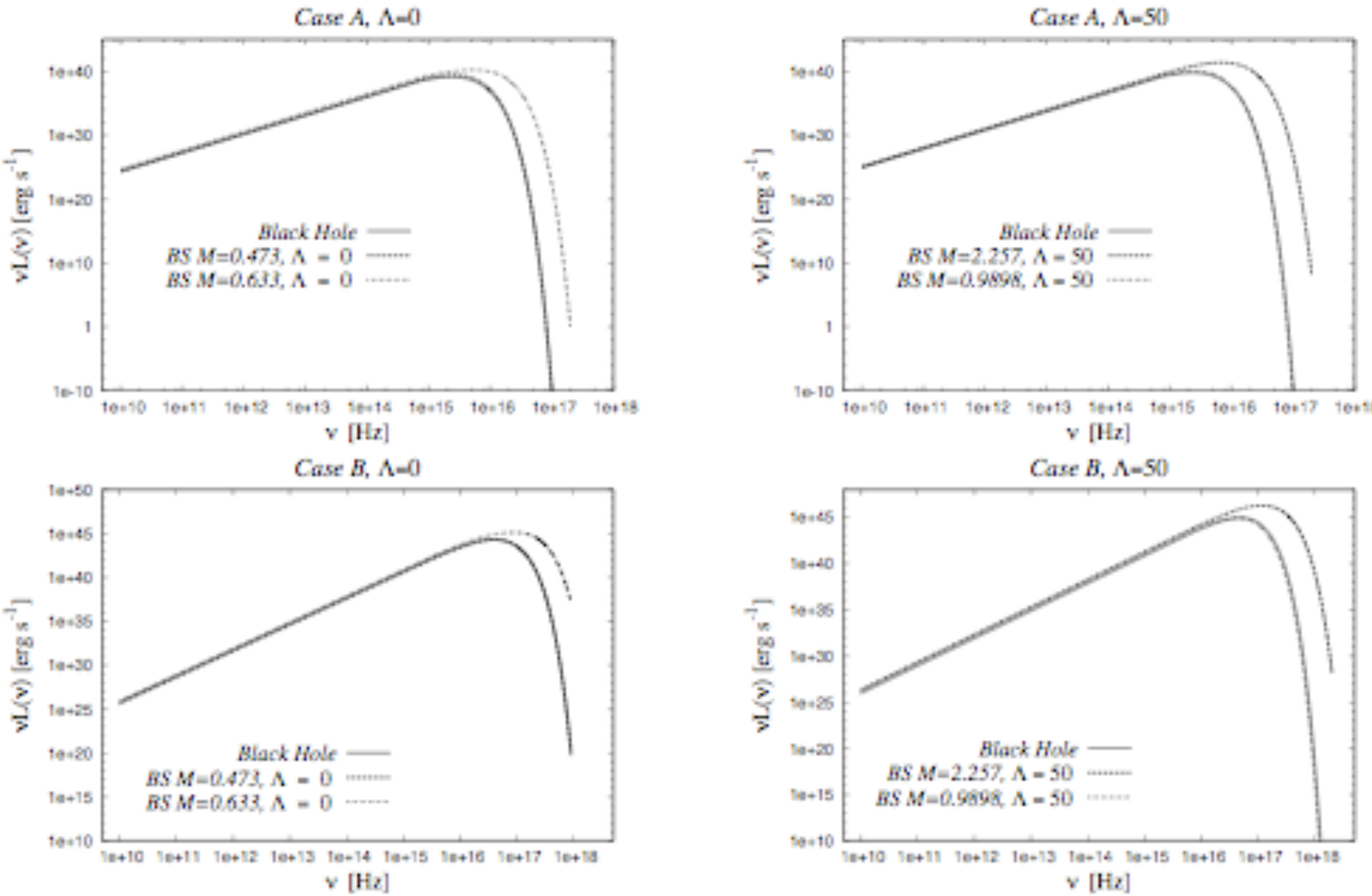


Boson stars (the mimickers)



guzman@ifm.umich.mx

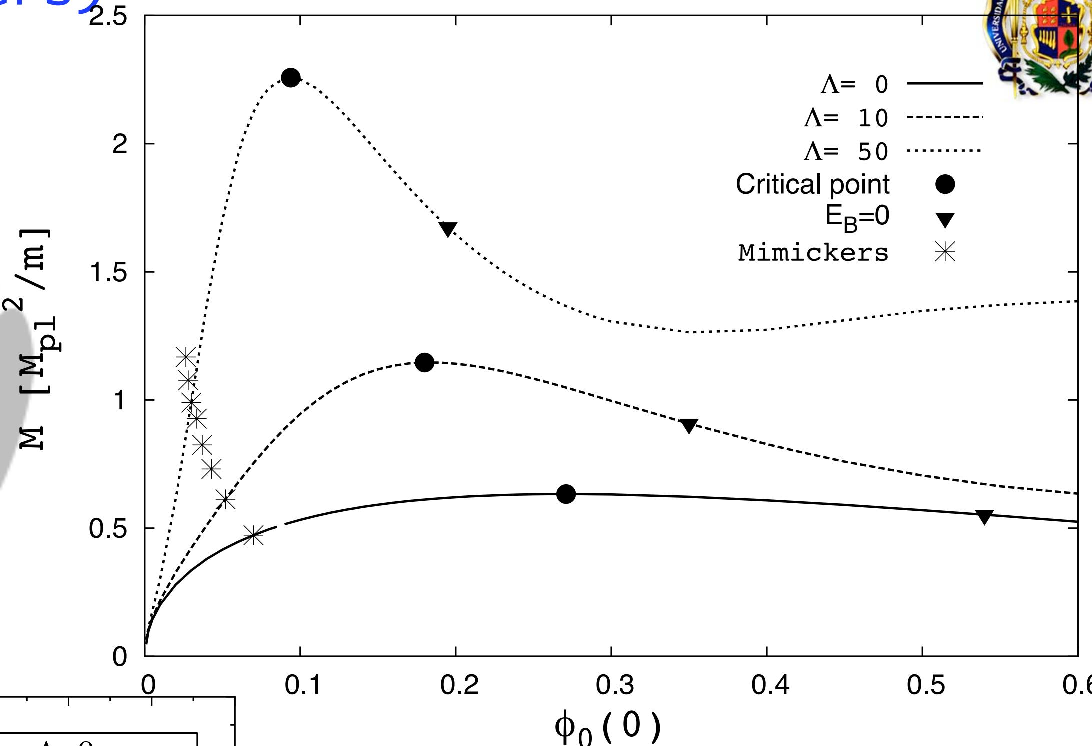
Boson stars (the mimickers)

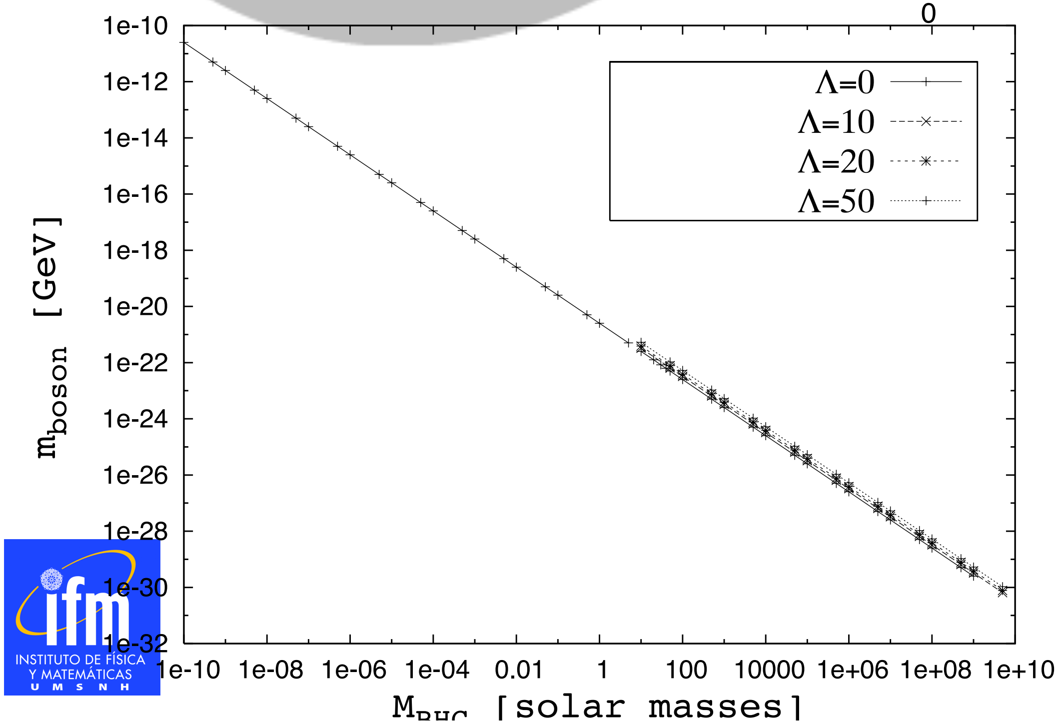


INSTITUTO DE FÍSICA Y MATEMÁTICAS U M S N H

guzman@ifm.umich.mx

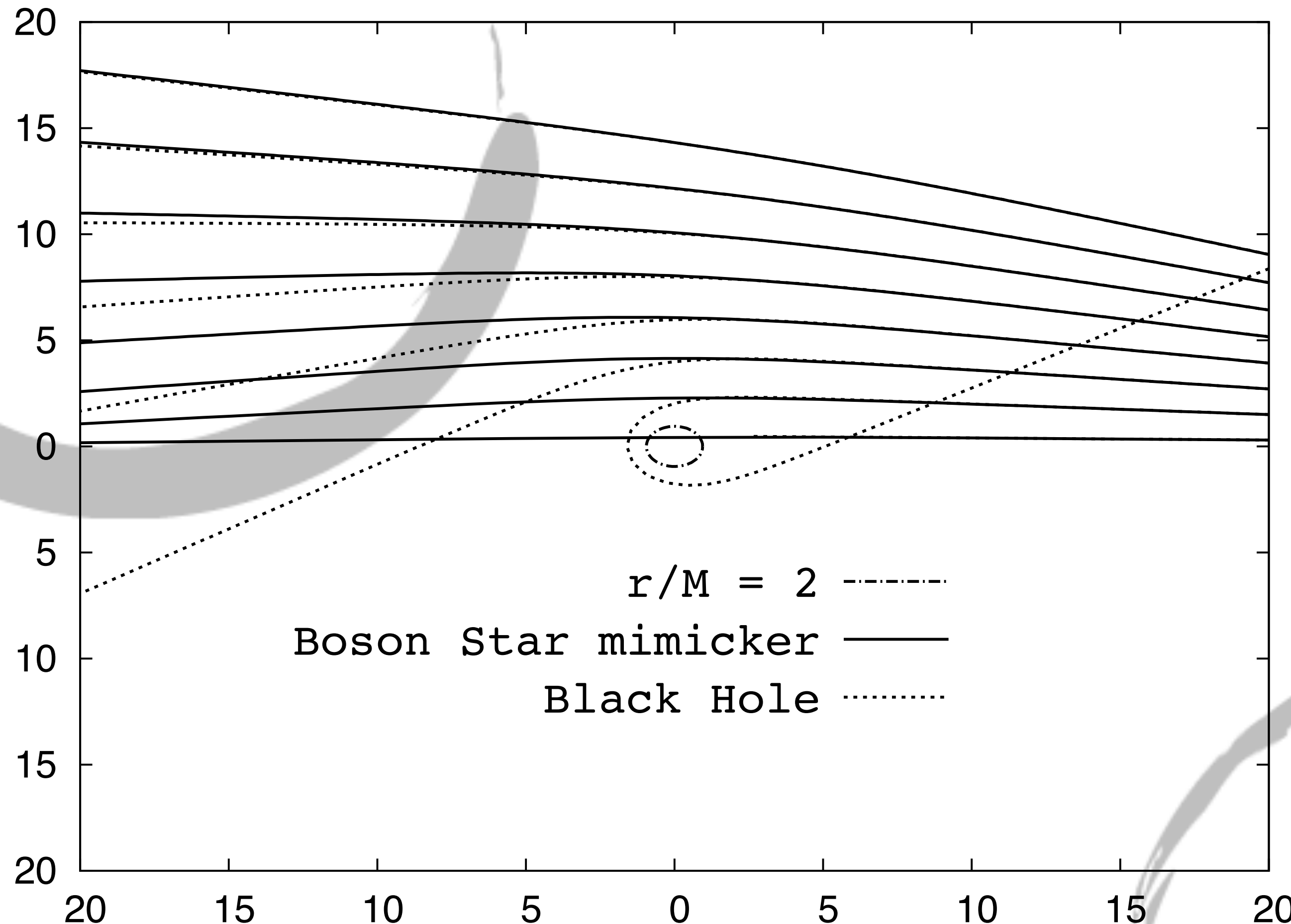
Boson stars (the mimickers)





guzman@ifm.umich.mx

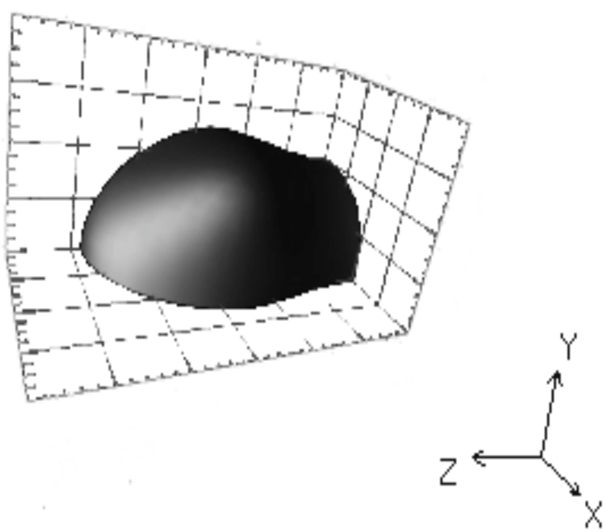
Boson stars (a way out)

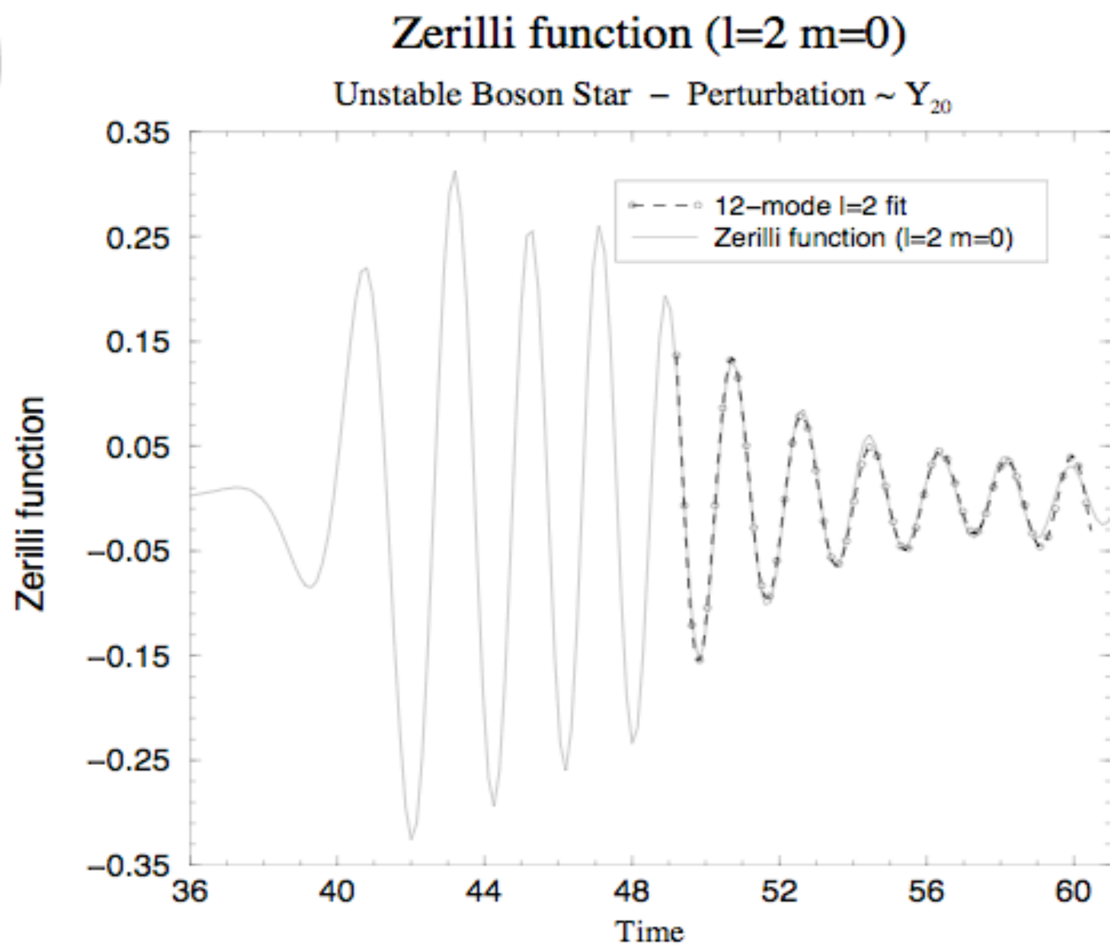


guzman@ifm.umich.mx

Boson stars (gravitational radiation)

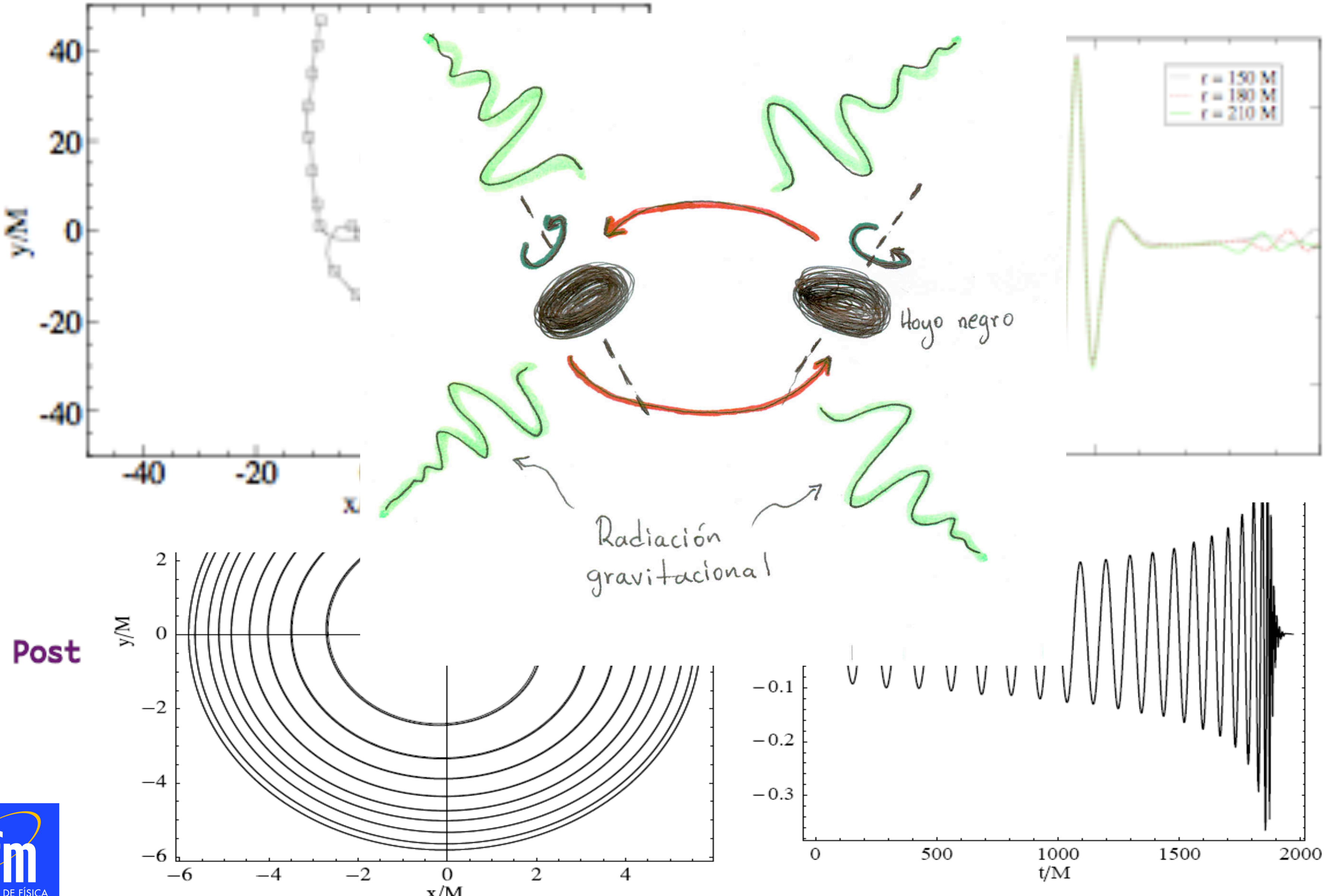
A single object perturbed





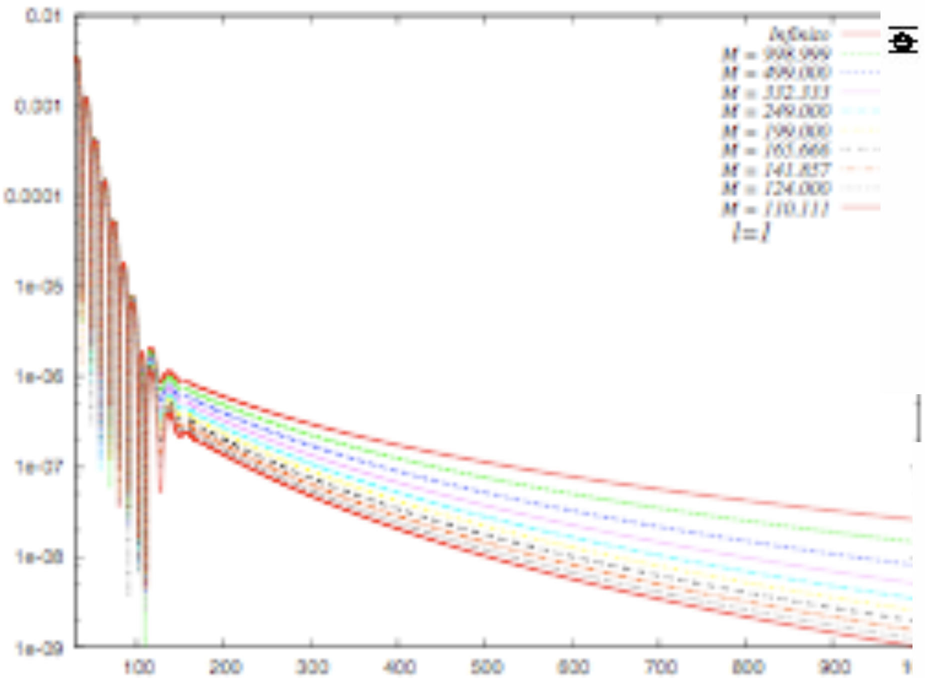
guzman@ifm.umich.mx

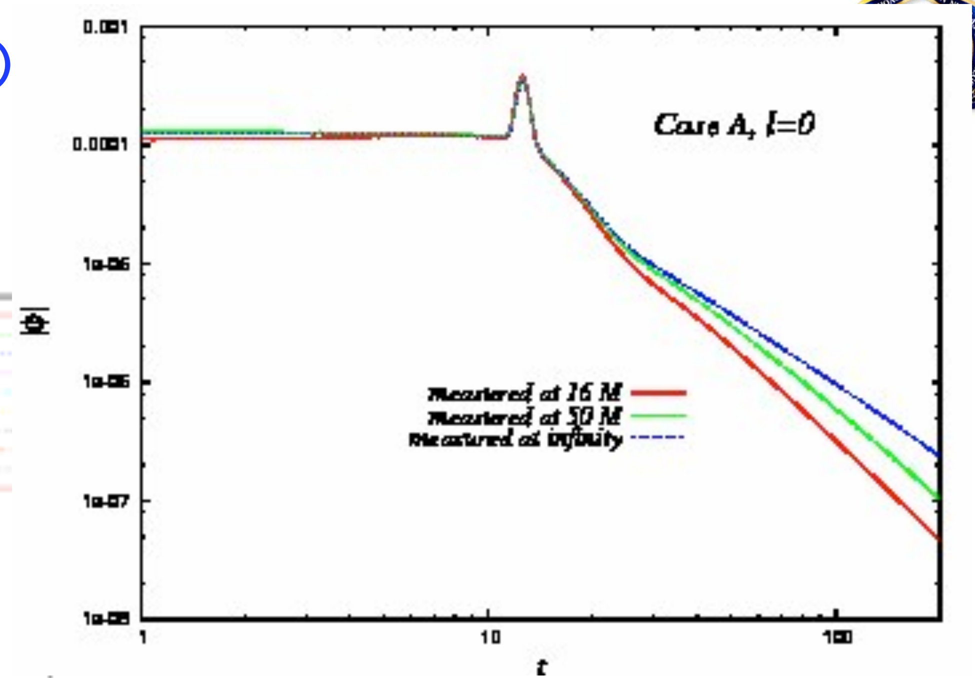
Boson stars (gravitational radiation)

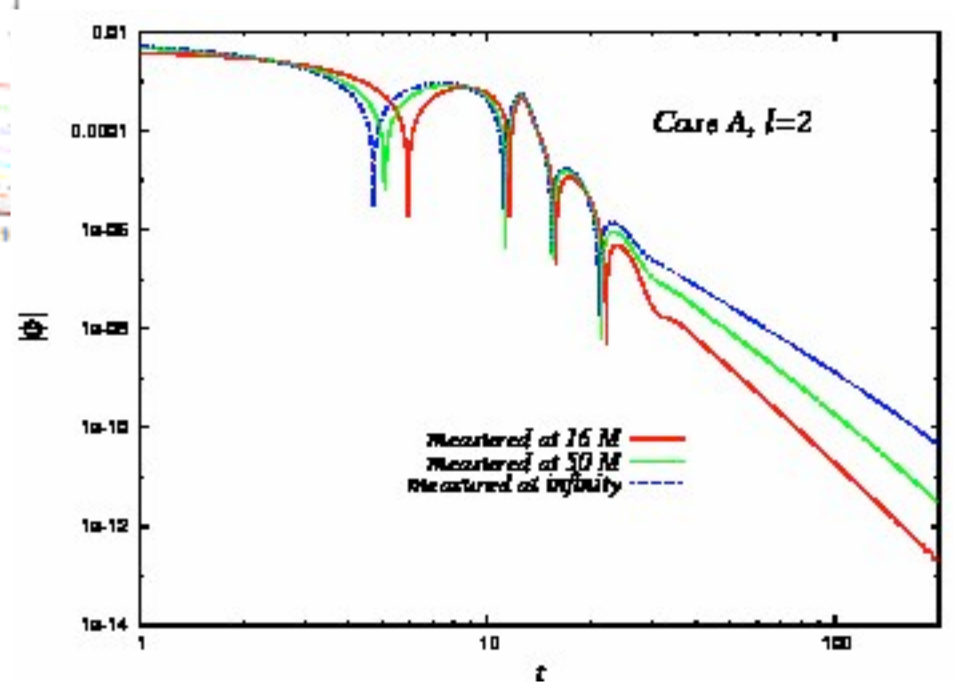


Post

Boson stars (QNM and tails)







INSTITUTO DE FÍSICA Y MATEMÁTICAS
U M S N H

Work to be done and being done on BSs

QNM at future null infinity and at far time-like detectors and quantitative measurable tail parameters and QNM frequencies.

Binaries that coalesce from far apart.

Quantitative measurable predictions on high resolution lenses.

Quantitative differences in waveforms.

guzman@ifm.umich.mx

Final comments

- We are not at scri+
- Why not surface candidates…
- Why not gravastars
- Why not wormholes
- Why Boson Stars
- Why NOT Boson Stars (2 free parameters?)
- Why BLACK HOLES (vac)
- The best experiment to distinguish between a NH and a BS is GW related: tails, merger of binary systems, Quasi-Normal-Modes.

INSTITUTO DE FÍSICA Y MATEMÁTICAS U M S N H
guzman@ifm.umich.mx