# Investigación en objetos compactos y ondas gravitacionales.

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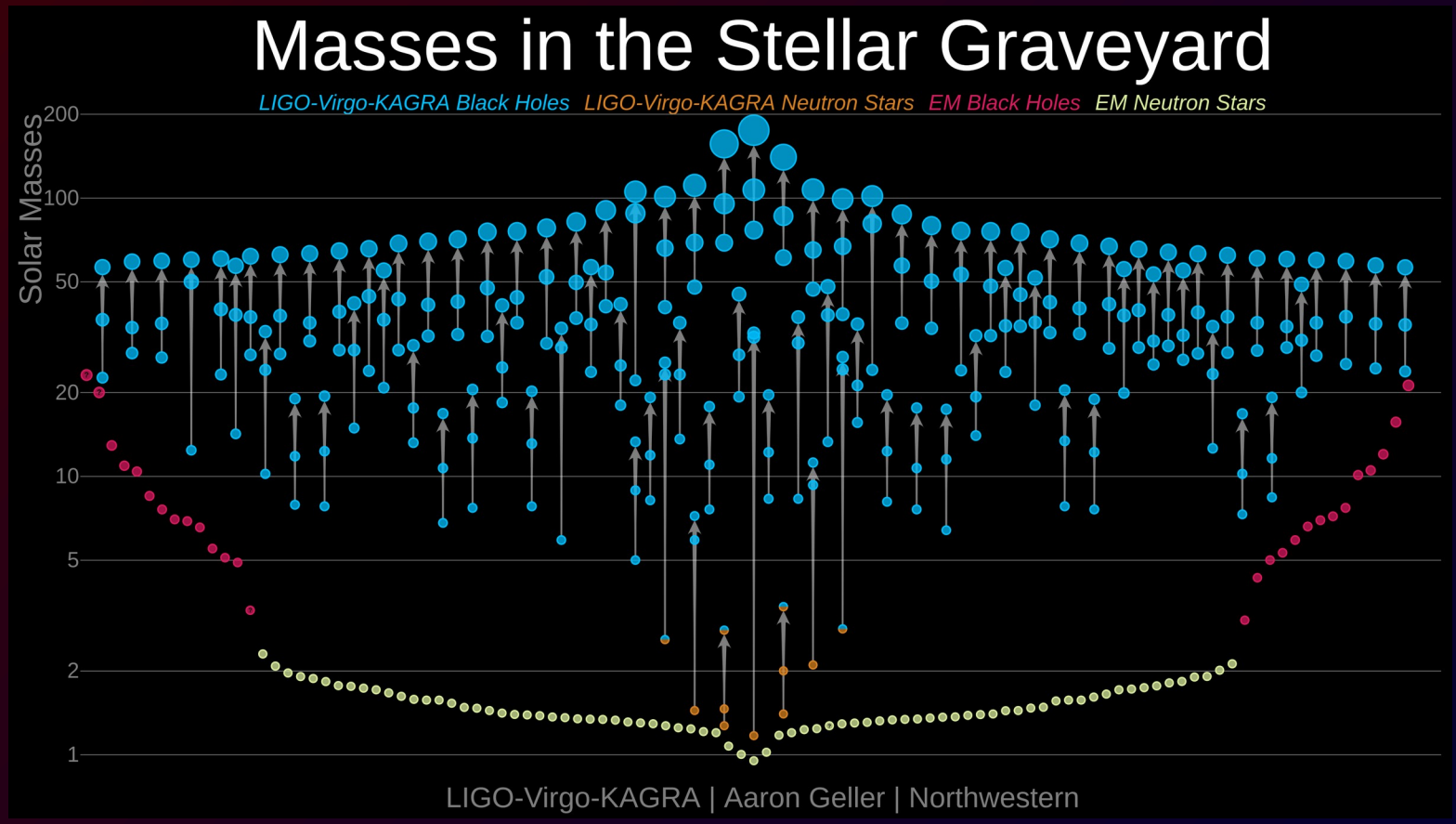
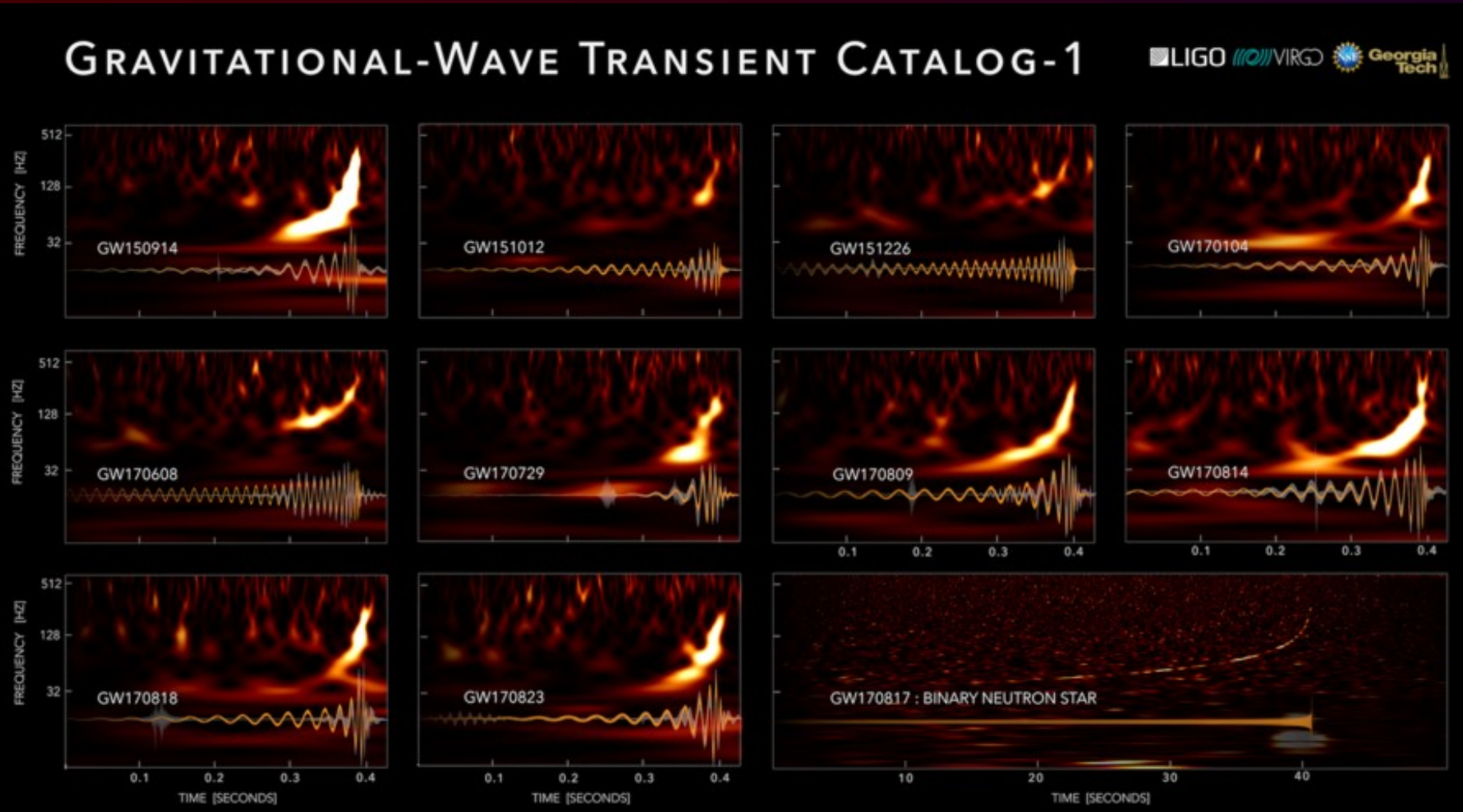
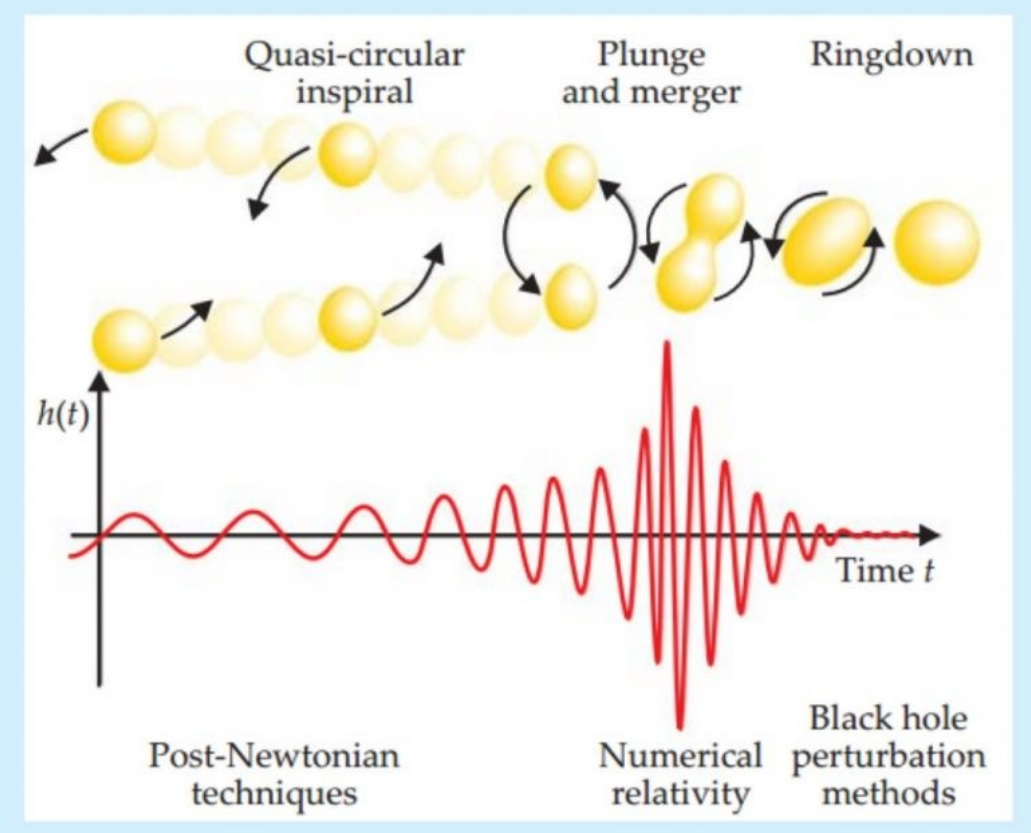
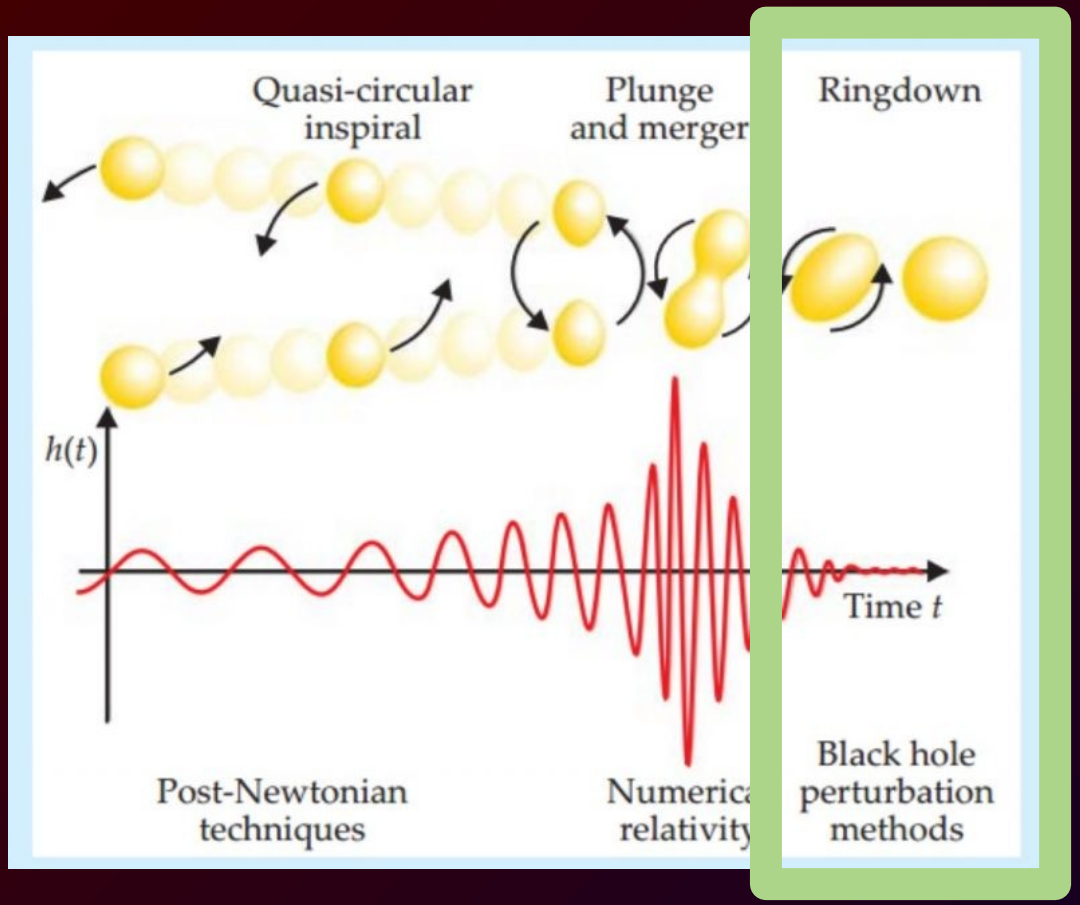



GRAVITATIONAL-WAVE TRANSIENT CATALOG-1
LIGO VIRGO Georgia Tech
FREQUENCY [HZ]
512
128
32
GW150914
GW151012
GW151226
GW170104
GW170608
GW170729
GW170809
GW170814
GW170818
GW170823
GW170817 : BINARY NEUTRON STAR
0.1
0.2
0.3
0.4
10
20
30
40
TIME [SECONDS]
LIGO-VIRGO DATA: HTTPS://DOI.ORG/10.7935/82H3-HH23
WAVELET (UNMODELED)
EINSTEIN'S THEORY
S. GHONGE, K. JANI | GEORGIA TECH


Quasi-circular inspiral
Plunge and merger
Ringdown
h(t)
Time t
Post-Newtonian techniques
Numerical relativity
Black hole perturbation methods




Fase de **“Ringdown”**:
Frecuencias de resonancia y amortiguación exponencial

“Quasinormal modes”
Modos cuasinormales

**Relatividad General:** el espectro depende de la **masa**, el **momento angular**, la **carga**, y la composición de la **materia** (ecuación de estado...)

**Teorías Alternativas:** constantes de acoplo, parámetros de la teoría, cargas de campos exóticos (campos escalares, gauge, etc)

**¿Por qué modificar la teoría de la gravedad?**

- Energía oscura, materia oscura  - Teoría de la gravedad cuántica

Numerosas teorías efectivas de la gravedad propuestas más allá de RG:

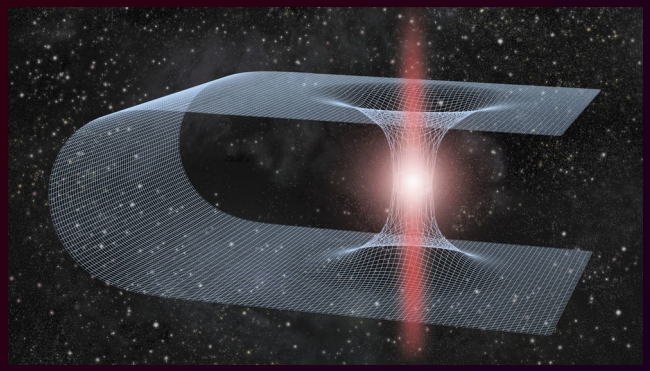
Horndeski gravity, Scalar-tensor theory, f(R), altas dimensiones, ...

Modificación a la gravedad de Einstein en regímenes de alta gravedad: **Objetos compactos**


**Agujeros negros**

**Estrellas de neutrones**

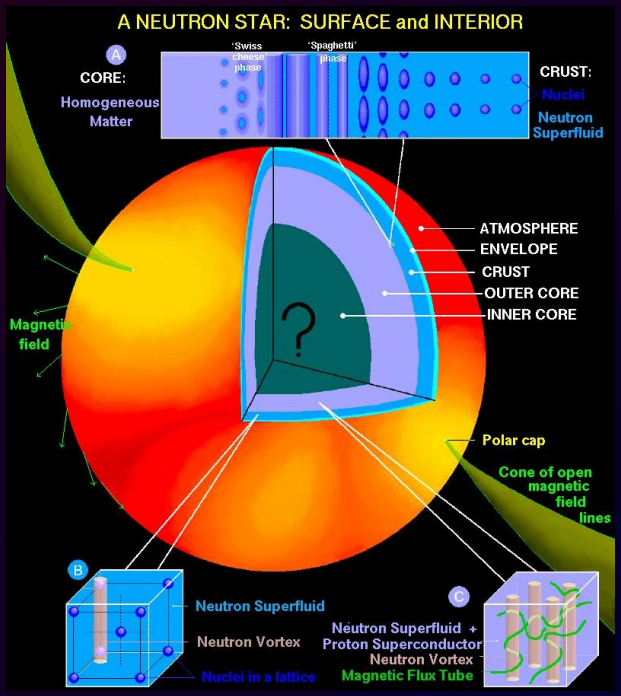
**Agujeros de gusano**



**Estrellas de bosones**

**Solitones**

**...**



# Research Activity

Black holes:

Construction of solutions in alternative theories or matter content beyond the standard model.

Hairy black holes: scalar hair ...

Ringdown phase and gravitational wave emission.

Stability analysis.

New development of analytical and numerical techniques: Quasinormal modes of rotating configurations via perturbative methods, spectral methods...

Neutron stars:


Neutron stars beyond GR:

- f(R), STT, ...

Universal relations in alternative theories

Gravitational waves: long-lived quasinormal modes, scalar radiation ...

Inverse problem: reconstruction of the equation of state from potential ringdown measurements.

Stability and maximum mass.

Wormholes:

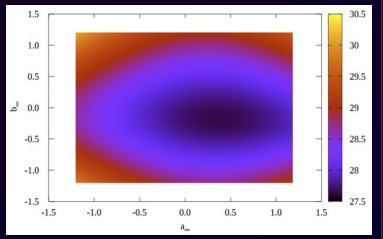
Discovery of new models with Dirac fields

Stability analysis: evidence for the stabilization of the throat because of rotation

First calculation of the ringdown spectrum for fully rotating solutions

Comparison with black holes: (non-)isospectrality, ...

Other exotic objects:




Higher dimensional black holes:

- Chern-Simons theory, supergravity, ...

Solitonic solutions: vortices, Skyrmions, …

Stability

$$S_{\rm EGBd}(g,\Phi)=\frac{1}{16\pi}\int d^4x\sqrt{-g}\Big(R-\frac{1}{2}\partial_\mu\Phi\,\partial^\mu\Phi+\frac{1}{4}\alpha e^{\gamma\Phi}R^2_{\rm GB}\Big)$$

Field equations of Einstein-Gauss-Bonnet-dilaton gravity

$$G_{\mu\nu}=\frac{1}{2}\,T_{\mu\nu}$$

$$\nabla^2\Phi=\frac{1}{4}\alpha\gamma e^{\gamma\Phi}R^2_{\rm GB}$$

$$T_{\mu\nu}=T^{(\phi)}_{\mu\nu}+\frac{1}{4}\alpha e^{\gamma\Phi}T^{(\rm GBd)}_{\mu\nu}$$

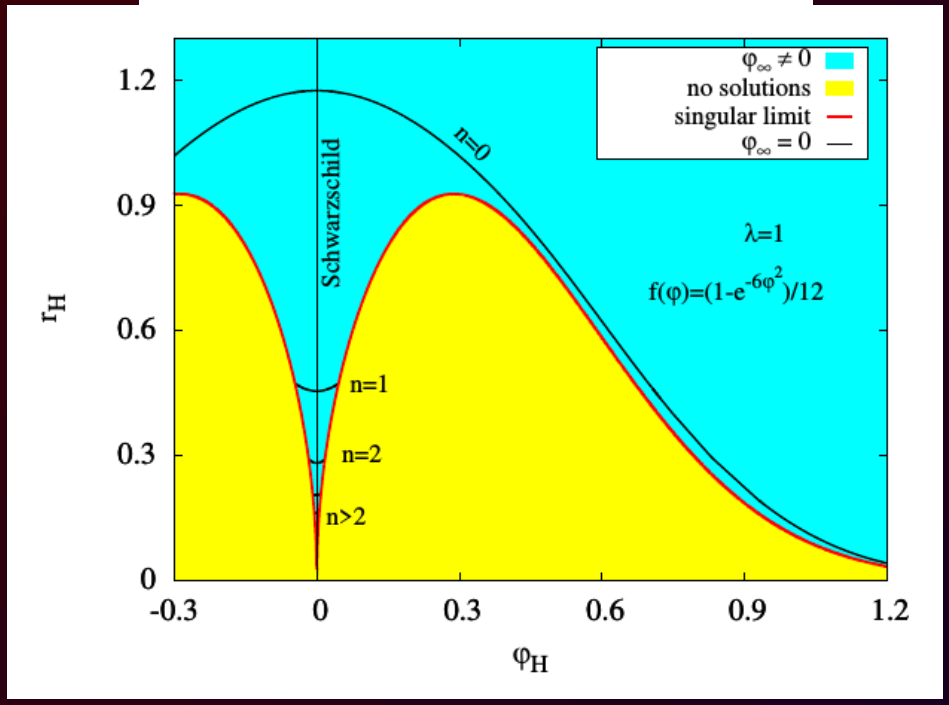
$$T^{(\phi)}_{\mu\nu}=\partial_\mu\Phi\,\partial_\nu\Phi-\frac{1}{2}g_{\mu\nu}\partial_\rho\Phi\,\partial^\rho\Phi$$

$$T^{(\rm GBd)}_{\mu\nu}=H_{\mu\nu}+4(\partial^\rho\Phi\,\partial^\sigma\Phi+\partial^\rho\partial^\sigma\Phi)P_{\mu\rho\nu\sigma}$$

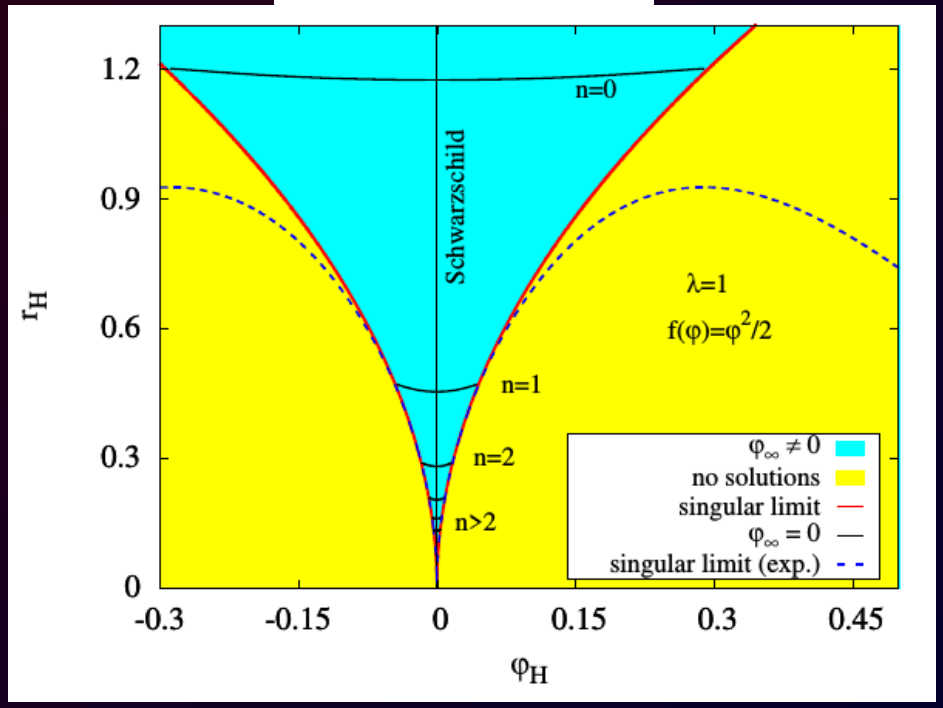
$$H_{\mu\nu}=2(RR_{\mu\nu}-2R_{\mu\alpha}R^{\alpha}_{\ \nu}-2R_{\mu\alpha\beta\nu}R^{\alpha\beta}+R_{\mu\alpha\beta\delta}R_{\nu}^{\ \alpha\beta\delta})-\frac{1}{2}g_{\mu\nu}R^2_{GB}$$

$$P_{\alpha\beta\gamma\delta}=R_{\alpha\beta\delta\gamma}+g_{\alpha\gamma}R_{\delta\beta}-g_{\alpha\delta}R_{\gamma\beta}+g_{\beta\delta}R_{\gamma\alpha}-g_{\beta\gamma}R_{\delta\alpha}+\frac{1}{2}Rg_{\alpha\delta}g_{\gamma\beta}-\frac{1}{2}Rg_{\alpha\gamma}g_{\delta\beta}$$

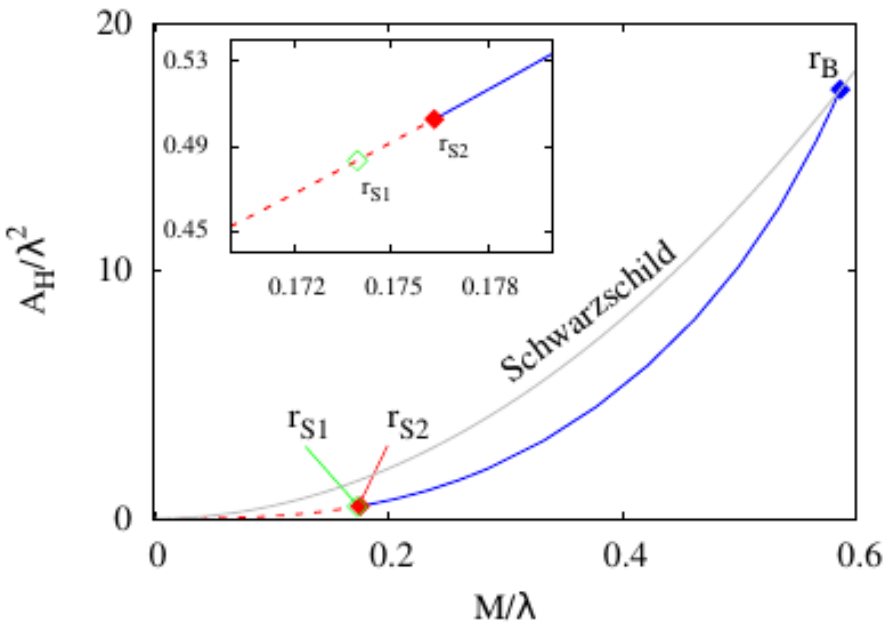
$$f(\varphi) = \frac{1}{12}\left(1 - e^{-6\varphi^2}\right)$$

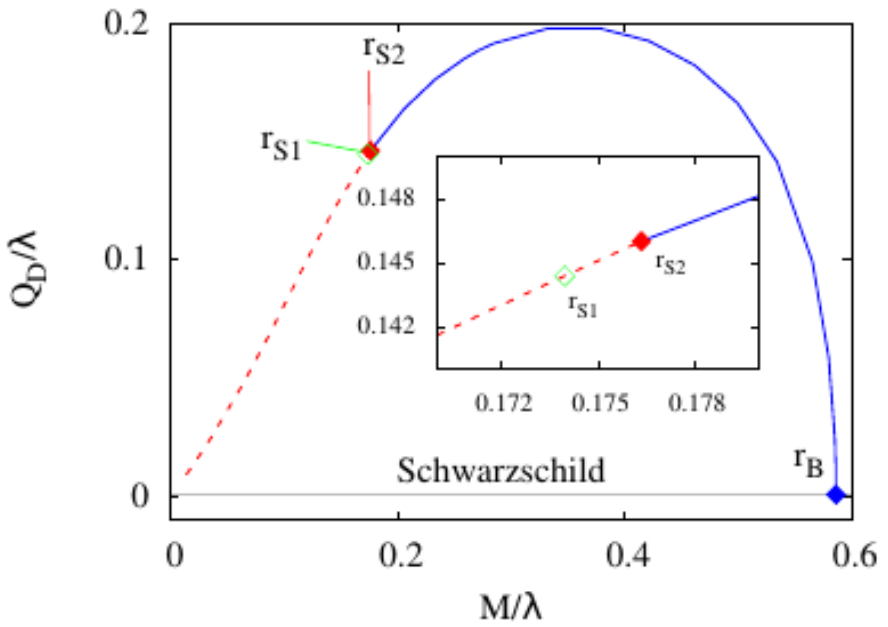



$$f(\varphi) = \frac{1}{2}\varphi^2$$



$$f(\varphi) = \frac{1}{12}\left(1 - e^{-6\varphi^2}\right)$$



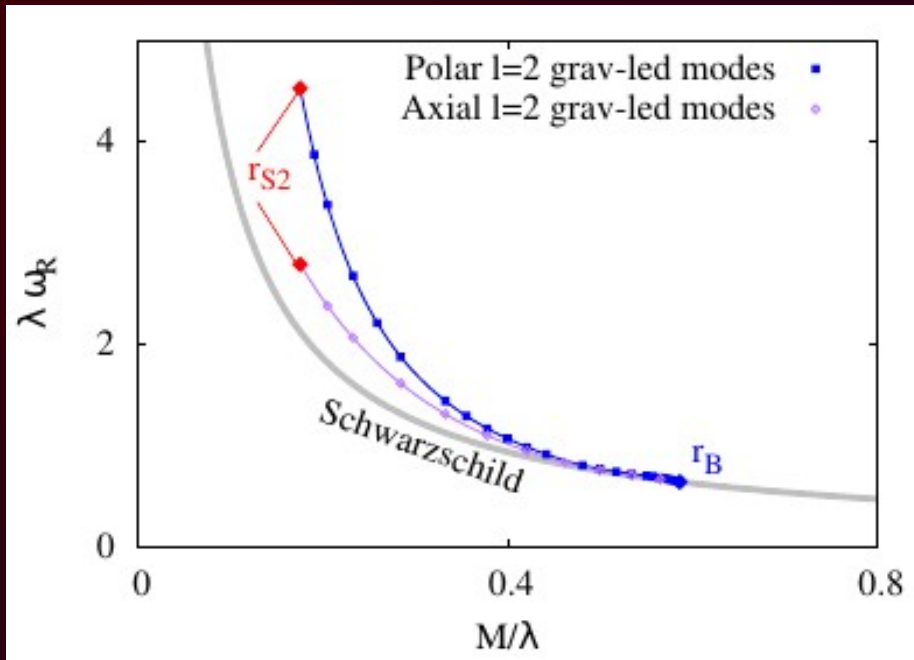

Técnicas analíticas + métodos numéricos

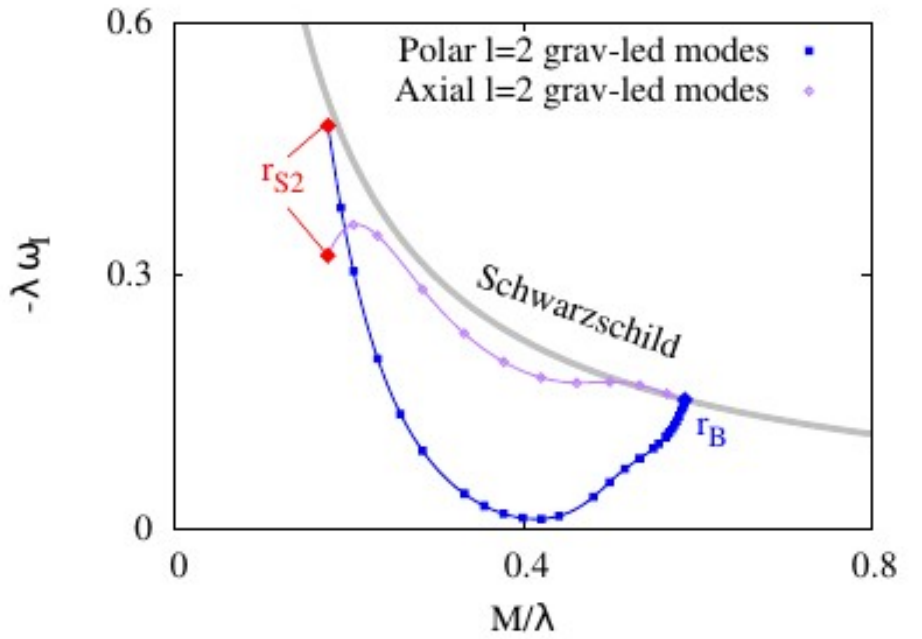
(Maple, Mathematica + Fortran, Python, Matlab ...)

Modos quasinormales:

Teoría de perturbaciones → ecuación de ondas

Problema de autovalores → espectro



## Nuestro grupo UCM: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## Colaboradores internacionales:

**Alemania: Jutta Kunz, Burkhard Kleihaus, Daniela Doneva, ...**
**Portugal: Carlos Herdeiro, Eugen Radu, Vitor Cardoso, …**
**Bulgaria: Stoytcho Yazadjev, Petya Nedkova, …**
**Irlanda: Tigran Tchrakian**
**y más...**

## Publicaciones e impacto:

**+30 publicaciones en los últimos 5 años**
**Physical Review Letters, Physics Letters B, Physical Review D, …**
**Entrevistas en Órbita Laika, RTVE, CNN, Amautas...**
**Cobertura en prensa y blogs internacionales**

## Proyectos, financiación:


**“QuasiMode”: MICINN PID2021-125617NB-I00.**
**Santander-UCM PR44/21-29910.**
**JLBS: Consolidación investigadora CNS2023-144089.**
**FSK: Programa Atracción de Talento “César Nombela” 2024.**
**PNM: Contratos Predoctorales UCM 2024.**


**Alemania: collaboration in DFG projects with Jutta Kunz, Burkhard Kleihaus, Bahareh Azad.**
**Portugal: FCT “Testing the Kerr hypothesis with gravitational waves and lensing"**
**Research Unit de la colaboración Einstein Telescope**
**Grupo IPARCOS-UCM (Ayudas TFM y PhD)**