Growth and decay of scalar clouds outside (rotating) black holes

Vítor Cardoso

(CENTRA/IST & Perimeter)

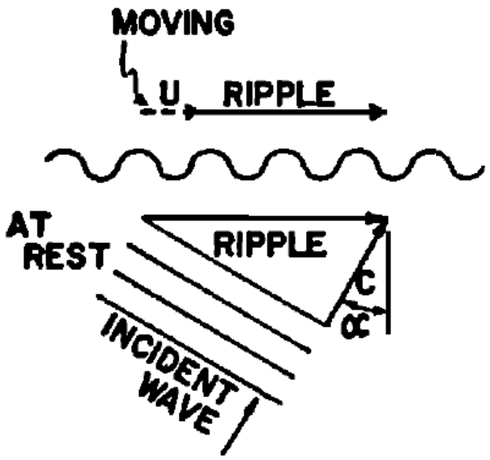
BHs7 Aveiro

TÉCNICO LISBOA | More at http://blackholes.ist.utl.pt | erc supports this project

Berti, Brito, Carucci, Gualtieri, Ishibashi, Okawa, Pani, Sotiriou, Sperhake, Witek

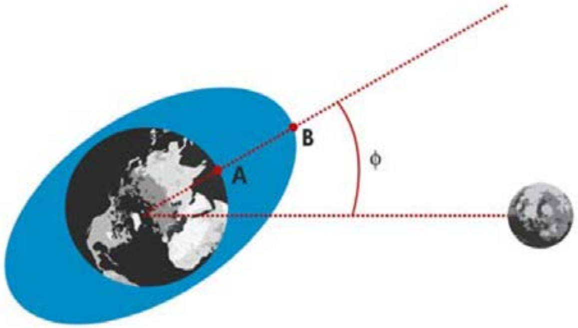
Brito, Cardoso, Pani, Superradiance in Black Hole Physics 2015

Friction & superradiance



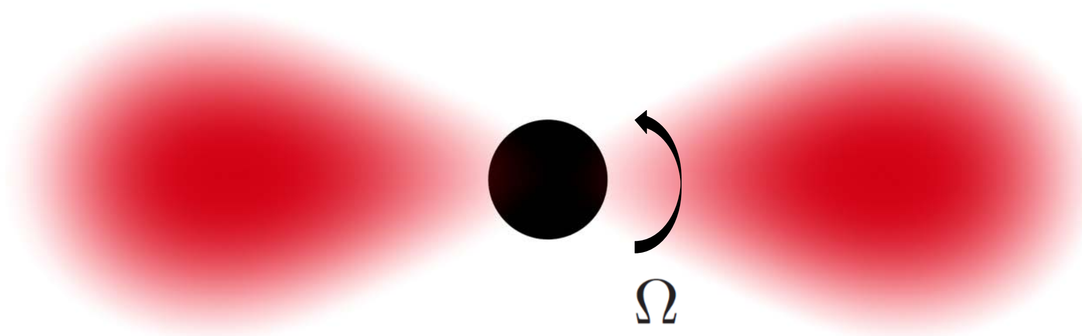
Ribner, J. Acous. Soc. Amer.29 (1957)

Tamm & Frank, Doklady AN SSSR 14 (1937)



G. H. Darwin, Philos. Trans. R. Soc. London 171 (1880)

$$\Phi \sim e^{-i\omega t + im\phi} \;\rightarrow\; (Angular)\, phase\, velocity = \frac{\omega}{m}$$



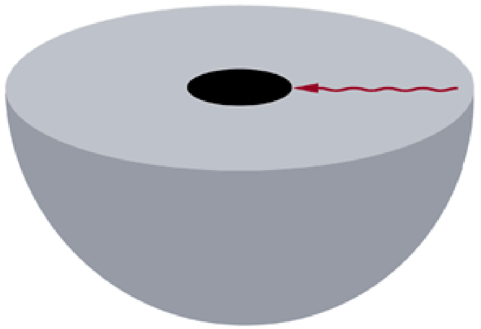
$$\omega < m\Omega$$

Zel'dovich, Pis'ma Zh. Eksp. Teor. Fiz. 14 (1971)

Black holes and superradiance

Friction built-in through one-way membrane (horizon)

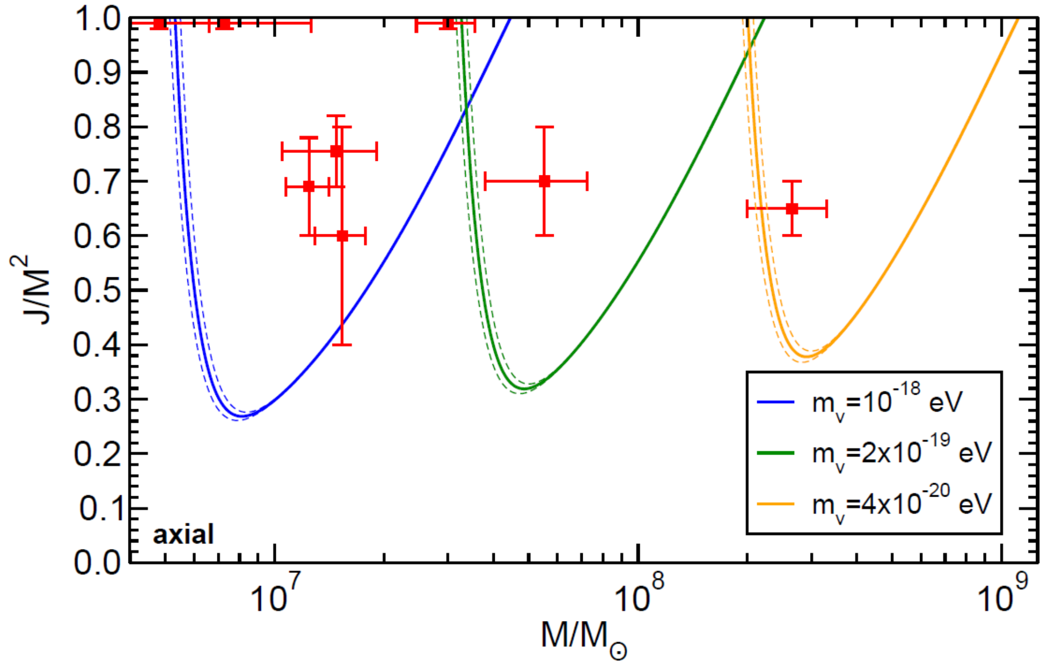
Can construct unstable states by forcing wave to bounce back



Zel'dovich, Pis'ma Zh. Eksp. Teor. Fiz. 14 (1971), *Damour et al*, Lett.Nuovo Cim. 15 (1976) ;
Cardoso and Dias, Phys.Rev. D70 (2004) ; *Brito, Cardoso and Pani*, in preparation (2015)

Bounding the "photon" mass

Pani et al PRL109, 131102 (2012)



Depend very mildly on the fit coefficient and on the threshold

✸

$\tau_{Salpeter}$ → timescale for accretion at the Eddington limit

Bounding the graviton mass

Brito et al PRD88, 023514 (2013)

Bound on photon mass is model-dependent: details of accretion disks or intergalactic matter matter...but gravitons interact very weakly!

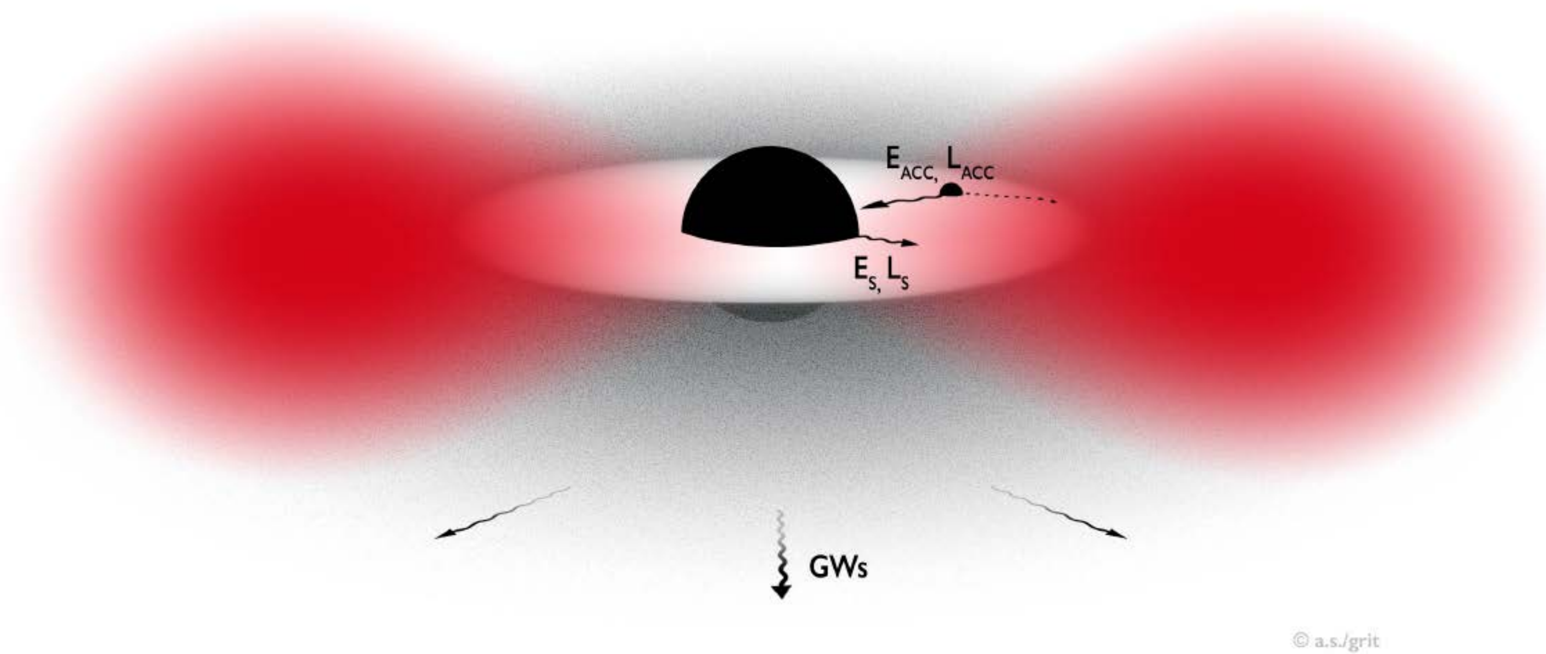
$$\bar{\Box} h_{\mu\nu} + 2\bar{R}_{\alpha\mu\beta\nu} h^{\alpha\beta} - \mu^2 h_{\mu\nu} = 0$$

VALUE (eV)	*DOCUMENT ID*		*COMMENT*
$<6 \times 10^{-32}$	[1] CHOUDHURY	04	Weak gravitational lensing
• • • We do not use the following data for averages, fits, limits, etc. • • •			
$<5 \times 10^{-23}$	[2] BRITO	13	Spinning black holes bounds
$<4 \times 10^{-25}$	[3] BASKARAN	08	Graviton phase velocity fluctuations
$<6 \times 10^{-32}$	[4] GRUZINOV	05	Solar System observations
$>6 \times 10^{-34}$	[5] DVALI	03	Horizon scales
$<8 \times 10^{-20}$	[6,7] FINN	02	Binary pulsar orbital period decrease
	[7,8] DAMOUR	91	Binary pulsar PSR 1913+16
$< 2 \times 10^{-29}\ h_0^{-1}$	GOLDHABER	74	Rich clusters
$<7 \times 10^{-28}$	HARE	73	Galaxy
$<8 \times 10^{4}$	HARE	73	2γ decay

Review of Particle Physics 2014 (PDG, 2014)

Nonlinear effects are expected to be negligible!

Gravitational-wave emission and accretion?



E_{ACC}, L_{ACC}
E_S, L_S
GWs
© a.s./grit

Accretion:

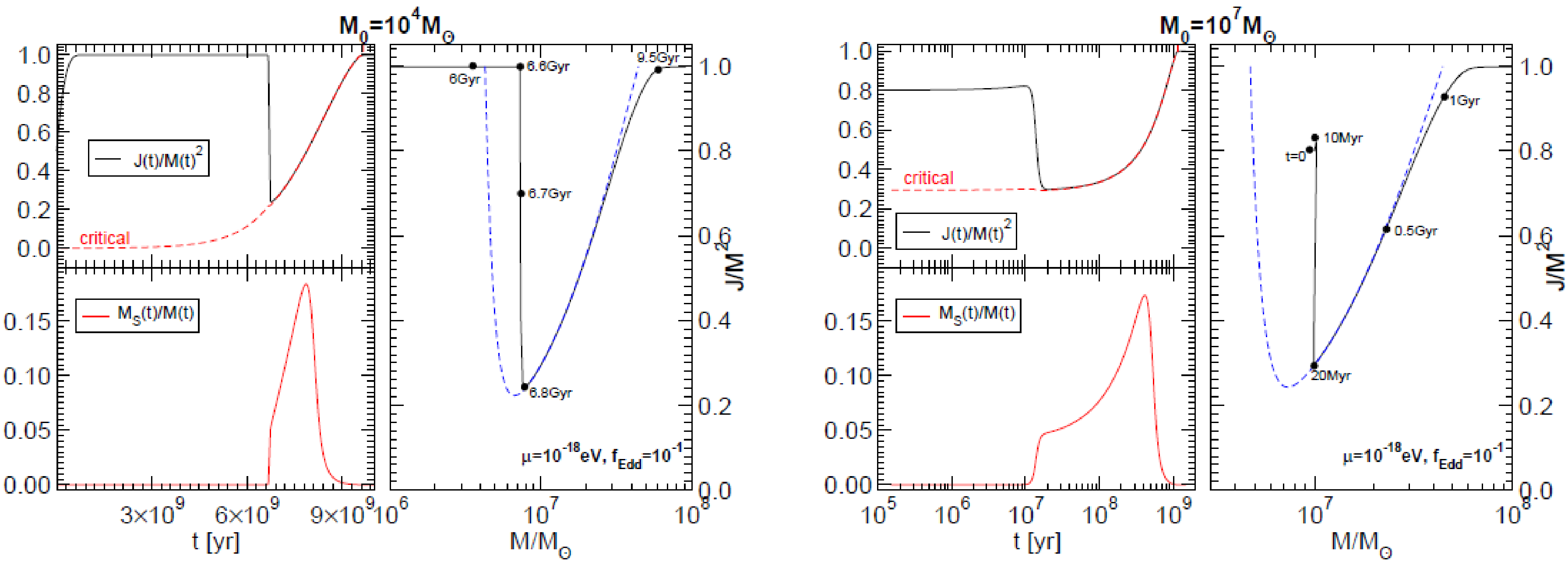
$$\dot{M}_{\rm ACC} \equiv f_{\rm Edd}\dot{M}_{\rm Edd} \sim 0.02 f_{\rm Edd}\frac{M(t)}{10^6 M_\odot} M_\odot {\rm yr}^{-1}$$

$$\dot{J}_{\rm ACC} \equiv \frac{L(M,J)}{E(M,J)}\dot{M}_{\rm ACC}$$

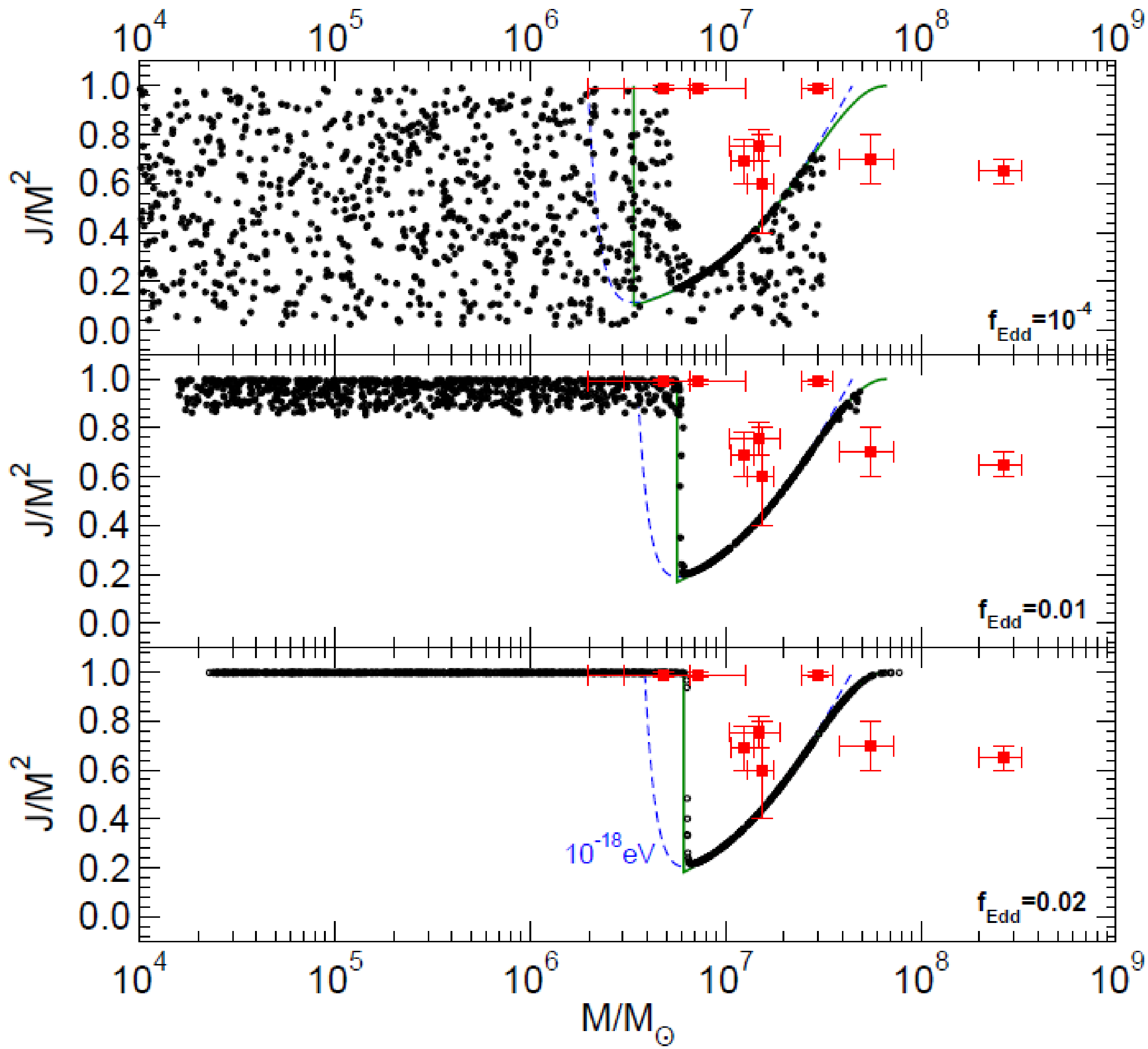
Gravitational-wave emission:

$$\dot{E}_{\rm GW} = \frac{484+9\pi^2}{23040}\left(\frac{M_S^2}{M^2}\right)(M\mu)^{14}$$

$$\dot{J}_{\rm GW} = \frac{1}{\omega_R}\dot{E}_{\rm GW}$$



M0=10^4 M⊙
J(t)/M(t)^2
critical
Ms(t)/M(t)
t [yr]
6Gyr
6.6Gyr
6.7Gyr
6.8Gyr
9.5Gyr
μ=10^-18eV, fEdd=10^-1
M/M⊙
J/M^2
M0=10^7 M⊙
J(t)/M(t)^2
critical
Ms(t)/M(t)
t [yr]
t=0
10Myr
20Myr
0.5Gyr
1Gyr
μ=10^-18eV, fEdd=10^-1
M/M⊙
J/M^2



$\mu = 10^{-18}\mathrm{eV}$

Random distributions 1000 BHs, with initial mass between $\log_{10} M_0 \in [4, 7.5]$ and $J_0/M_0^2 \in [0.001, 0.99]$ extracted at $t = t_F$, with t_F distributed on a Gaussian centered at $\bar{t}_F \sim 2 \times 10^9$yr with width $\sigma = 0.1\bar{t}_F$.

Strong field gravity is a fascinating topic

***

Fundamental fields, either in form of minimally coupled fields or under curvature couplings have a very rich and unexplored phenomenology: condensates outside BHs and compact stars act as gravitational-wave lighthouses, but can also act as dark matter.

***

Superradiant instabilities can provide strong constraints on masses of ultra-light bosons, turning black holes (and stars with dissipation channels) into effective particle detectors.

***

New BH solutions are possible stationary end-state of superradiant instability (see Herdeiro and Benone). Our results show that BHs grown out of Kerr are Kerr to a good precision

Thank you