Discussion: Tests of the Kerr nature of BHs and new physics

Observables

1. Location-specific observables
    - BH shadows
    - QNMs
    - Isolated QPO detections
2. Integrated effects (~depend on ISCO)
    - Continuum spectrum
    - Iron line profile
    - Jet power
3. Spacetime tomography
    - Iron line reverberation
    - Ryan style tomography/EMRIs
    - wide range of QPO detections from different regions of the disc

Questions

- How generic are the different spacetime parameterisations?
- Can we get around the degeneracies?
- Are the tests that we have independent/complementary?
- How important is the structure/properties of the central object and do the above approaches capture that?
    - Or, are these tests sensible if they disregard internal structure and properties?
- Can we distinguish *theories* using bumpy spacetimes?
- Astrophysics is messy. Will we be able to go around it?
- Is there anything in the literature to fit something very exotic?
    - A very hairy BH, or a rotating boson star?
- Is it possible/likely that waveform degeneracy exists, between a binary of two exotic compact objects in GR (say two rotating boson stars) and two non-GR black holes?
- Can we probe quantum corrections to Kerr?
    - What are appropriate observables?

Open issues

Black holes as particles detectors:

1) End-state of the superradiant instability?

2) Can we distinguish bosonic fields with different spins?

3) Can non-linearities change the picture (e.g. mixing between modes, bosenova, …)?

Exotic compact objects (ECOs):

1) Ultra-compact objects likely to be unstable and formation channels are hard to conceive. How seriously should we take them?

2) Does the echo picture remains the same for collisions of ~equal-mass ECOs?

3) Sistematic study of waveforms from collisions of bosonic stars is needed.

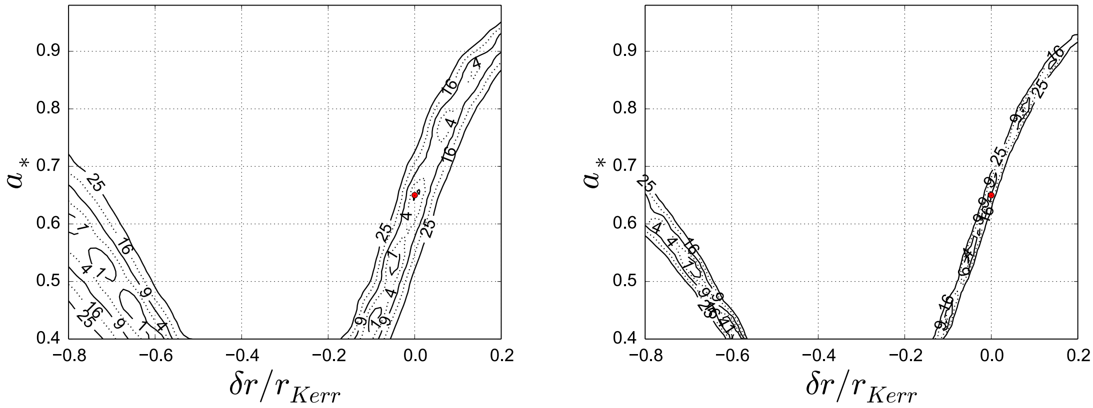

FIG. 1. $\Delta\chi^2$ contours with $N_{\rm line} = 10^4$ (left panel) and 10^5 (right panel) from the comparison of the iron line profile of a Kerr black hole simulated using an input spin parameter $a'_* = 0.65$ and an inclination angle $i' = 45°$ vs a set of non-Kerr black holes with spin parameter a_* and deformation parameter $\delta r/r_{\rm Kerr}$. The red dot indicates the reference black hole. See the text for more details.

Alejandro Cardenas-Avendano, Jiachen Jiang, Cosimo Bambi

Phys.Lett.B760:254-258,2016

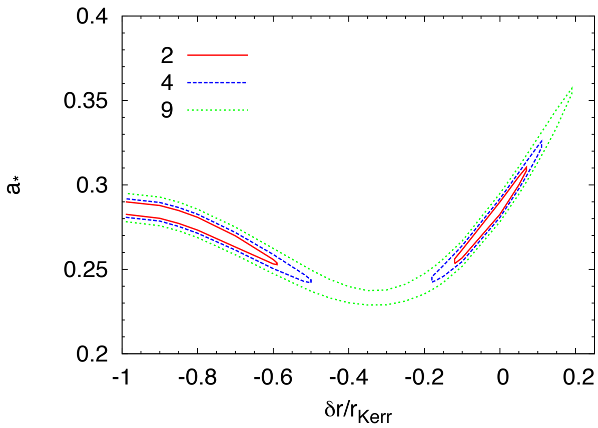

FIG. 1. Constraints on the spin parameter a_* and the deformation $\delta r/r_{\rm Kerr}$ for the black hole candidate in GRO J1655-40 from current observations of QPOs within the relativistic precession model. The red-solid line, blue-dashed line, and green-dotted line represent, respectively, the contour levels $\Delta\chi^2 = 2$, 4, and 9. See the text for more details.

Cosimo Bambi, Sourabh Nampalliwar

Europhys.Lett. 116: 30006, 2016

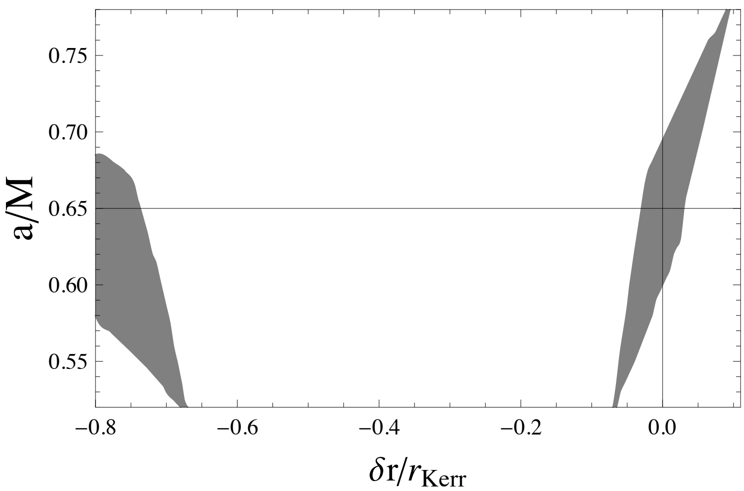

FIG. 1. Parametric region (gray) of possible deformations $\delta r/r_{\rm Kerr}$ leading to the ringdown frequency $\omega M = 0.635 - 0.0901i$ (which corresponds, according to the WKB formula for the Kerr metric with $a/M \approx 0.65$) within 3% accuracy.

Roman Konoplya, Alexander Zhidenko

Phys.Lett.B756:350-353,2016

Probing Kerr with tidal Love number

[Cardoso et al. (2017)]

Can we probe exotic compact objects whose surface is just Planck length outside the Schwarzschild radius?

		Love number k_2^E
NSs		210
ECOs	Boson star	41.4
	Wormhole	$\frac{4}{5(8+3\log\xi)}$
	Perfect mirror	$\frac{8}{5(7+3\log\xi)}$
	Gravastar	$\frac{16}{5(23-6\log 2+9\log\xi)}$
BHs	Einstein-Maxwell	0
	Scalar-tensor	0
	Chern-Simons	0

$$\xi = \frac{R}{2M} - 1$$

$$k_2 \sim 10^{-3} \quad \text{for} \quad R = 2M + l_P$$

Quantum effect is not Planck suppressed!!