



DO BLACK HOLES HAVE HAIR ?!



Hugo CANDAN



Black holes are the simplest object in the
Universe !

Yes they are ...



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Universe !

Yes they are ...

→ **No-hair** theorem



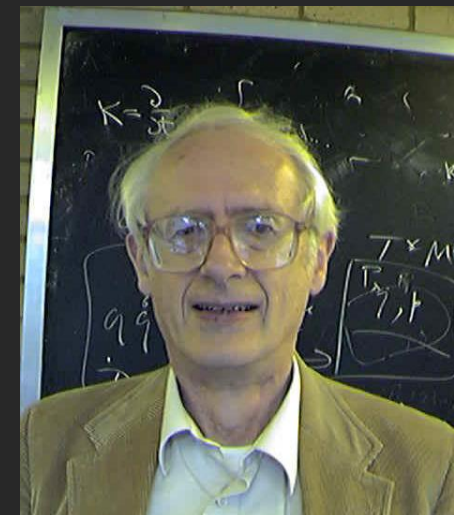
« Black holes have no hair » - John Wheeler



Stephen Hawking



Brandon Carter



David Robinson



What is this supposed to mean ????????



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It's a metaphor !! (phew) :

• **hair = characteristics of the black hole**





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✦
No-hair theorem :

Black holes described by only **3 parameters** !

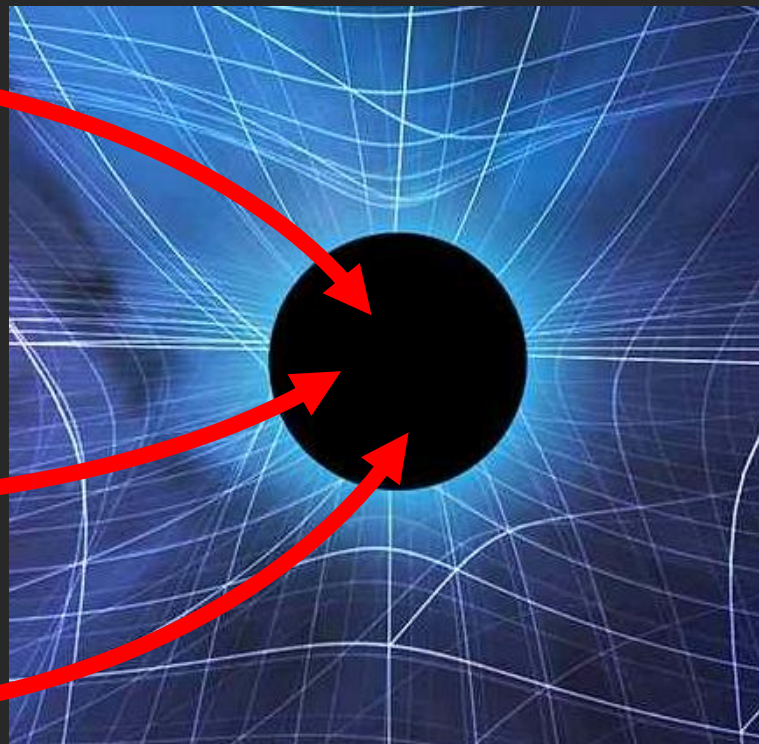
- Mass M
- Angular momentum J
- Electric charge Q



No other parameter => "no hair"



Information paradox !

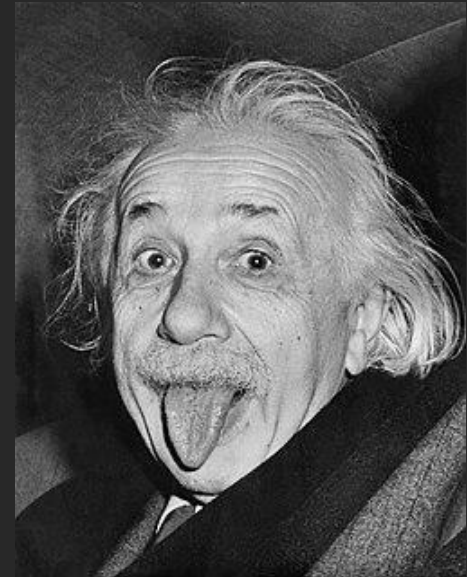


→ M, J, Q

Where is all the
information gone ??



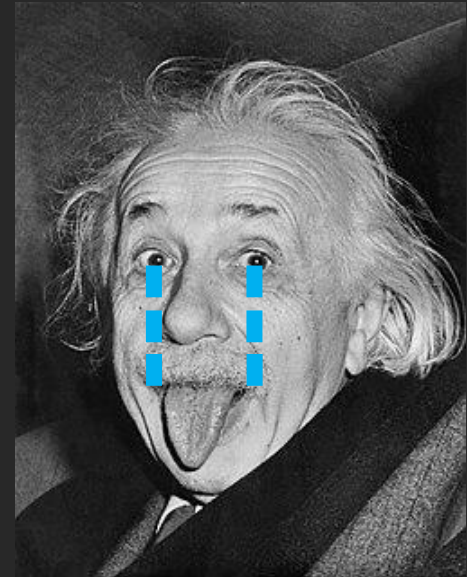
But this is according to Einstein ...





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What if Einstein is wrong ?!





My work !



Studying black holes in modified theories of gravity !

Einstein's equations of GR

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi T_{\mu\nu}$$

Some modified theory equations

$$\begin{aligned} G_4(X) \left(R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} \right) + G'_4(X) \left(-\frac{1}{2}R \phi_\mu \phi_\nu - \square \phi \phi_{\mu\nu} + R_{\mu\alpha} \phi^\alpha \phi_\nu + R_{\alpha\nu} \phi^\alpha \phi_\mu \right. \\ \left. + \phi_{\mu\alpha} \phi^\alpha{}_\nu + \frac{1}{2} \square \phi^2 g_{\mu\nu} - R_{\alpha\beta} \phi^\alpha \phi^\beta g_{\mu\nu} + R_{\mu\alpha\nu\beta} \phi^\alpha \phi^\beta - \frac{1}{2} \phi_{\alpha\beta} \phi^{\alpha\beta} g_{\mu\nu} \right) \\ + G''_4(X) \left(-\frac{1}{2} \square \phi^2 \phi_\mu \phi_\nu + \square \phi \phi^\alpha \phi_{\alpha\mu} \phi_\nu + \square \phi \phi^\alpha \phi_{\alpha\nu} \phi_\mu - \phi^\alpha \phi^\beta \phi_{\alpha\mu} \phi_{\beta\nu} + \phi^\alpha \phi^\beta \phi_{\alpha\beta} \phi_{\mu\nu} \right. \\ \left. - \phi^\alpha \phi_\alpha{}^\beta \phi_{\beta\mu} \phi_\nu - \phi^\alpha \phi_\alpha{}^\beta \phi_{\beta\nu} \phi_\mu + \frac{1}{2} \phi_{\alpha\beta} \phi^{\alpha\beta} \phi_\mu \phi_\nu - \square \phi \phi_{\alpha\beta} \phi^\alpha \phi^\beta g_{\mu\nu} + \phi_{\alpha\beta} \phi^\beta{}_\gamma \phi^\alpha \phi^\gamma g_{\mu\nu} \right) \\ - \frac{1}{2} G_2(X) g_{\mu\nu} - \frac{1}{2} G'_2(X) \phi_\mu \phi_\nu = 0 \end{aligned}$$





Few results

- Some theories give black holes with **1 additional parameter !!**



Black holes with one hair !

- Some theories give black holes **without singularities**





More hair ???



Future (and a lot of work) will tell !!

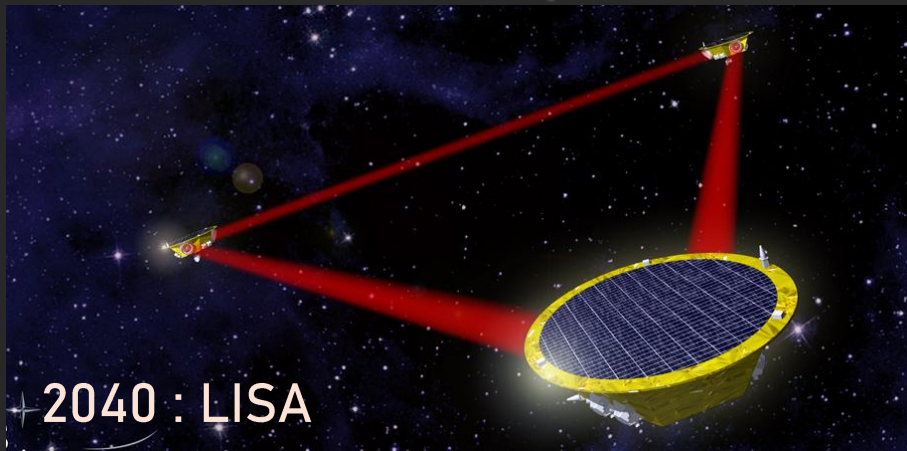
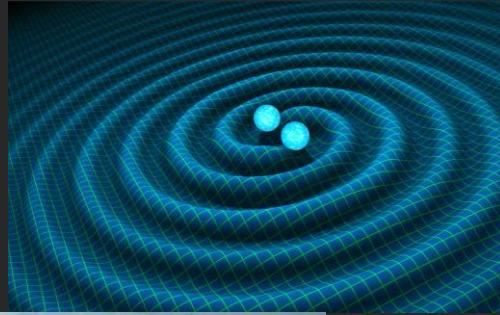


Thanks for listening !

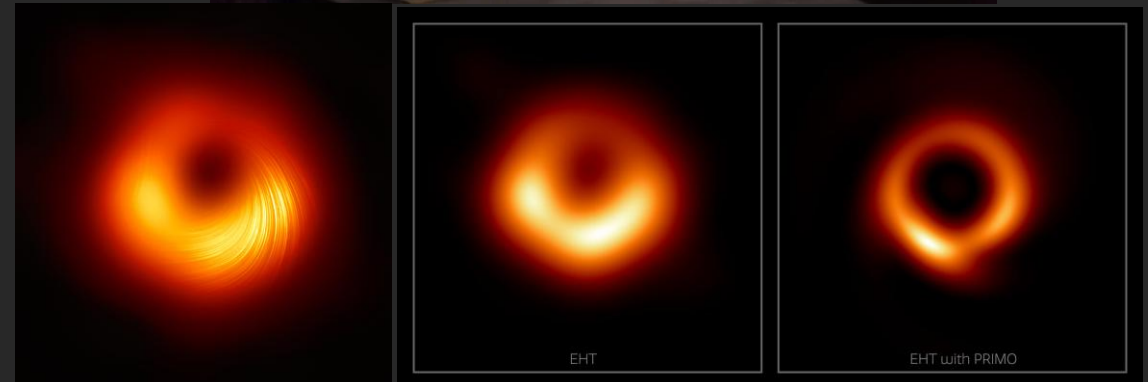


Black hole observations

Gravitational waves



Photos



→ Check the no-hair

