How can we define and quantify non-classicality?

Barbara Amaral

Instituto de Física da USP

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Outline

- When do we say that something is **classical**?

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- When do we say that something is **quantum**?

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- When do we say that something is **quantum**?
- When do we say that something is **non-classical**?

Outline

Strategy

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- Deduce conditions that must be satisfied by any theory adhering to these hypotheses;

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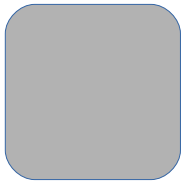
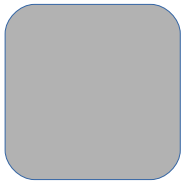
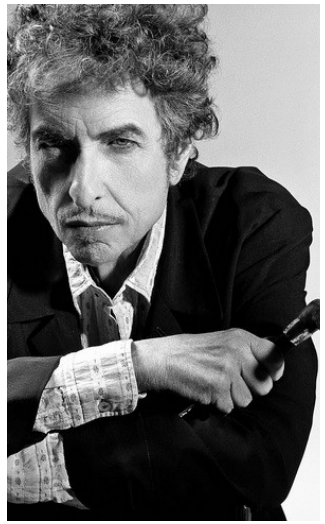
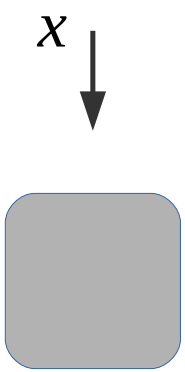
- Deduce conditions that must be satisfied by any theory adhering to these hypotheses;
- Show that these conditions are violated by the statistics obtained of an experiment.

Bell scenarios





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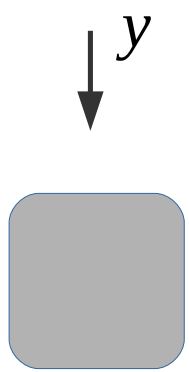
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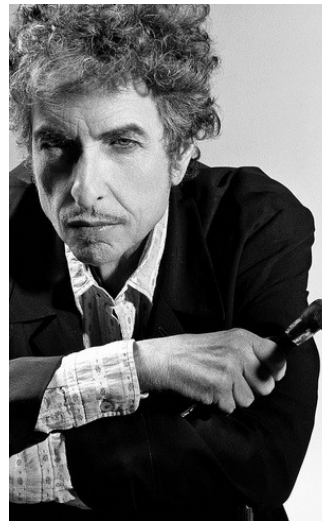

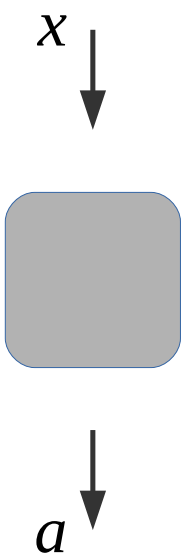
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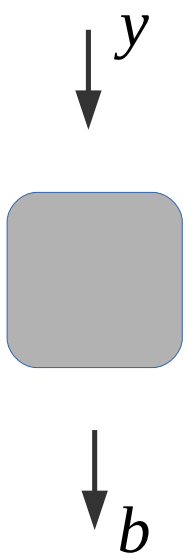
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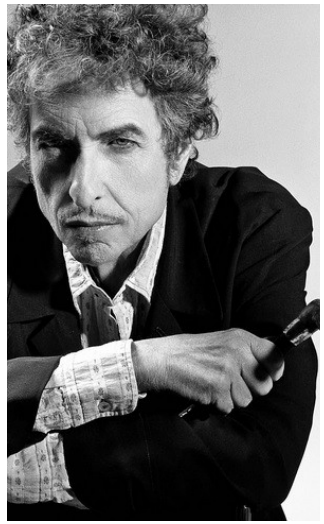

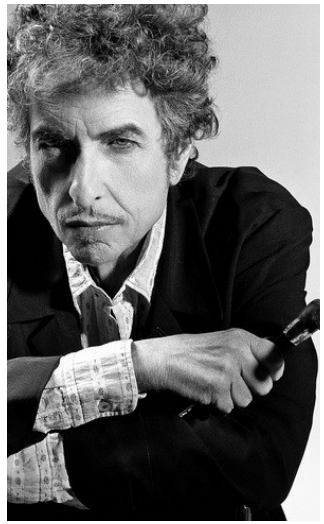

$$p(ab|xy)$$

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2. **Locality:** Alice's choices should not influence Bob's results and vice versa.
3. **Free will:** Alice and Bob can freely choose the experiments they will perform.

Local distributions

$$\underbrace{p\left(a|x,\lambda\right)}_{0 \text{ or } 1}$$

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$$\underbrace{p\left(a|x,\lambda\right)}_{0 \text{ or } 1}\underbrace{p\left(b|y,\lambda\right)}_{0 \text{ or } 1}$$

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Local distributions

$$p\left(ab|xy\right) = \sum_{\lambda} p\left(\lambda\right) p\left(a|x,\lambda\right) p\left(b|y,\lambda\right)$$

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Another Strategy

- Find sets of measurements with a certain structure that can be performed on the system.

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- Show that such structures are not compatible with theories adhering to reasonable **classical** hypotheses.

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1. **Realism:** Measurements only reveal pre-defined results. The hidden variables determine what that value is.

2. **Non-contextuality:** The value assigned to a test A does not depend on which compatible tests are performed alongside A.

3. **Free will:** The experimenter can freely choose the experiments to perform.

Bell-Kochen-Specker Theorem

There is no theory satisfying conditions 1, 2, and 3 that is consistent with the predictions of quantum physics.

Scenario

It consists of a set $\mathcal{X}$ of measurements on a physical system and a set $\mathcal{C}$ of subsets of $\mathcal{X}$.

The subsets of $\mathcal{X}$ contained in $\mathcal{C}$ are called **contexts**.

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They represent subsets of variables in $\mathcal{X}$ for which a joint probability distribution is known.

Non-contextual distributions

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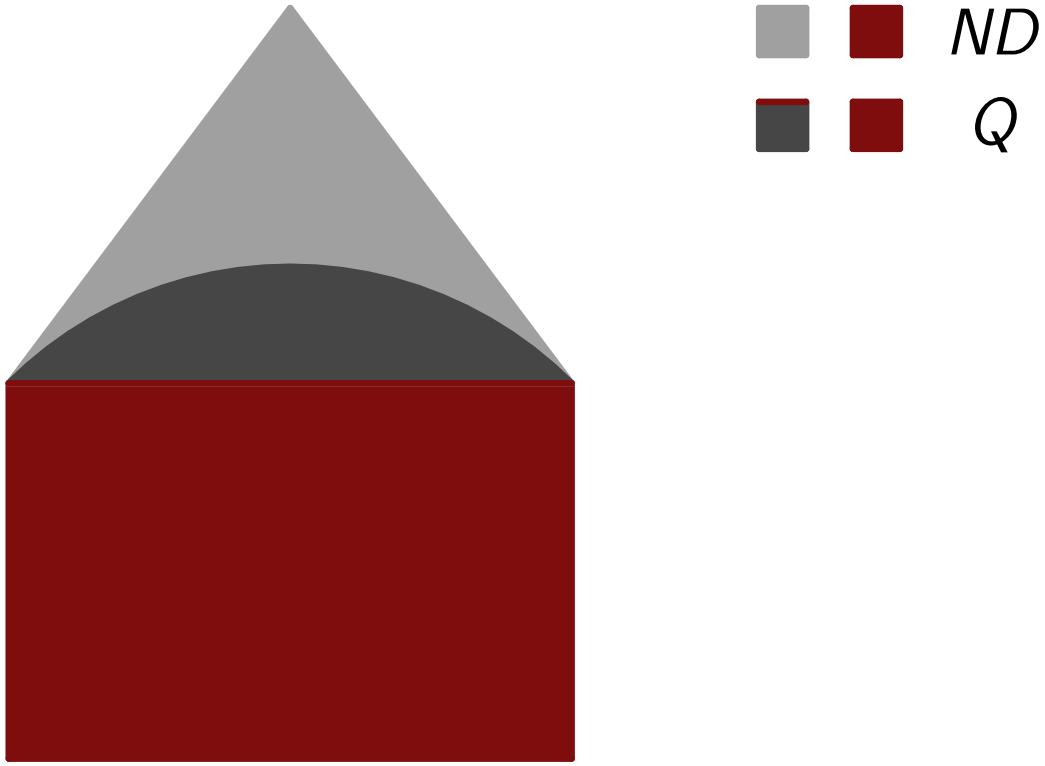
$$p\left(ab|xy\right) = \sum_{\lambda} p\left(\lambda\right) p\left(a|x,\lambda\right) p\left(b|y,\lambda\right)$$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Outline

Why do we care?

- Device independent approach;

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- Theory independent: test generalized probability theories;

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- Device independent approach;
- Theory independent: test generalized probability theories;
- Certification of states and measurements.

Non-locality x contextuality

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- Simulating contextuality requires memory.

Non-locality x contextuality

- Non-locality requires multipartite spatially separated systems (not expected in gravity experiments);

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- Non-locality requires multipartite spatially separated systems (not expected in gravity experiments);
- Contextuality allows for much more possibilities.

Non-locality x contextuality

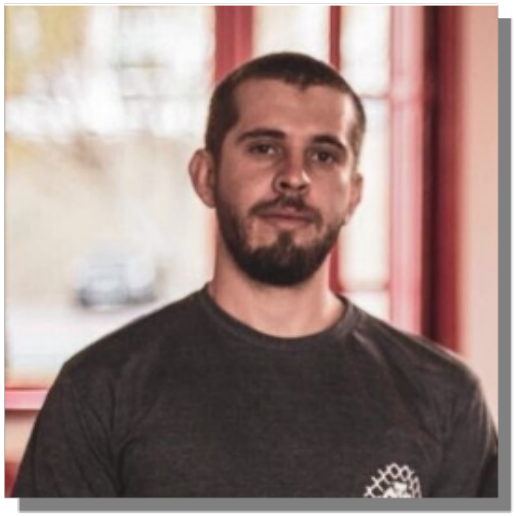
Loophole-free experiment is unlikely with interactions mediated by gravity.

Outline

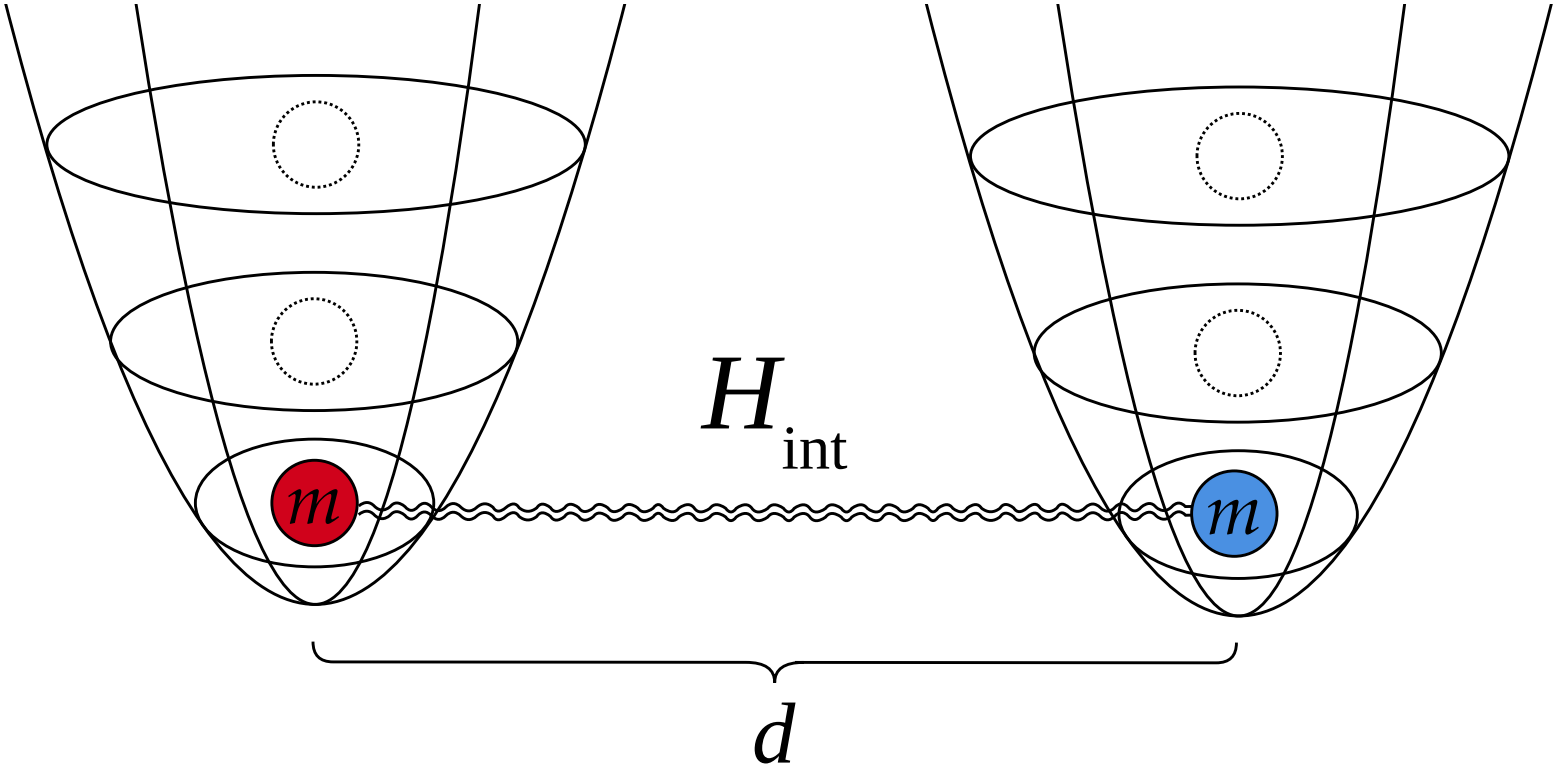
Testing contextuality in gravity experiments: is it possible?

Patrick Andriolo

Naim Comar



Danilo Cius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Outline

Conclusion

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- Non-locality unlikely to be the most suitable for gravity experiments.
- Testing contextuality in gravity experiments: it is possible?

Thank you!
Questions?

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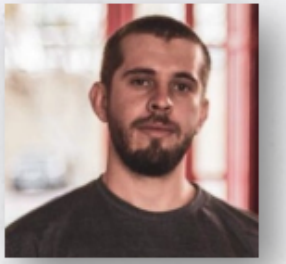
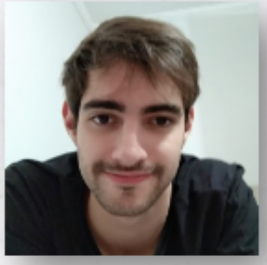
RESEARCHERS

Naim Comar

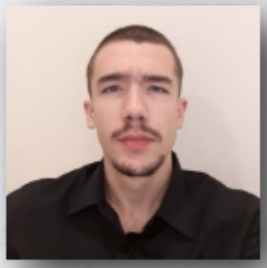


Danilo Cius

PHD STUDENTS



Alisson Tezzin



Gabriel Muniz

Luis Silva

MSC STUDENTS

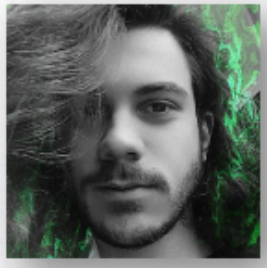
Amanda Fonseca

Lucas Ribeiro

Felipe Barreto

Gustavo Balvedi

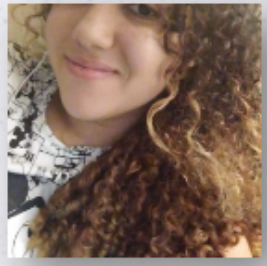
Mikael Alcântara



Patrick Andriolo

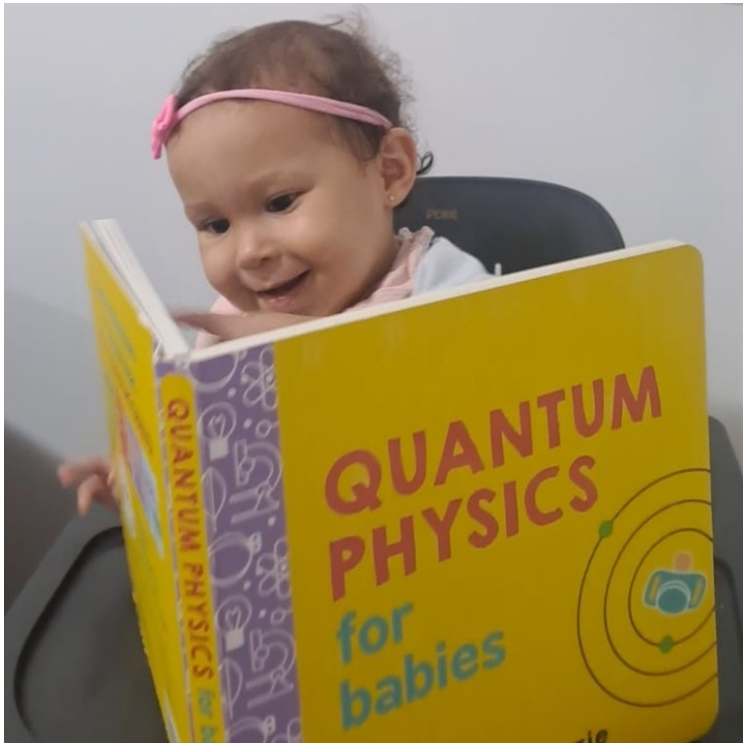
Sílvio Jr.

UNDERGRAD STUDENTS



Letícia Lima

FAÇA CIÊNCIA COMO UMA GAROTA!



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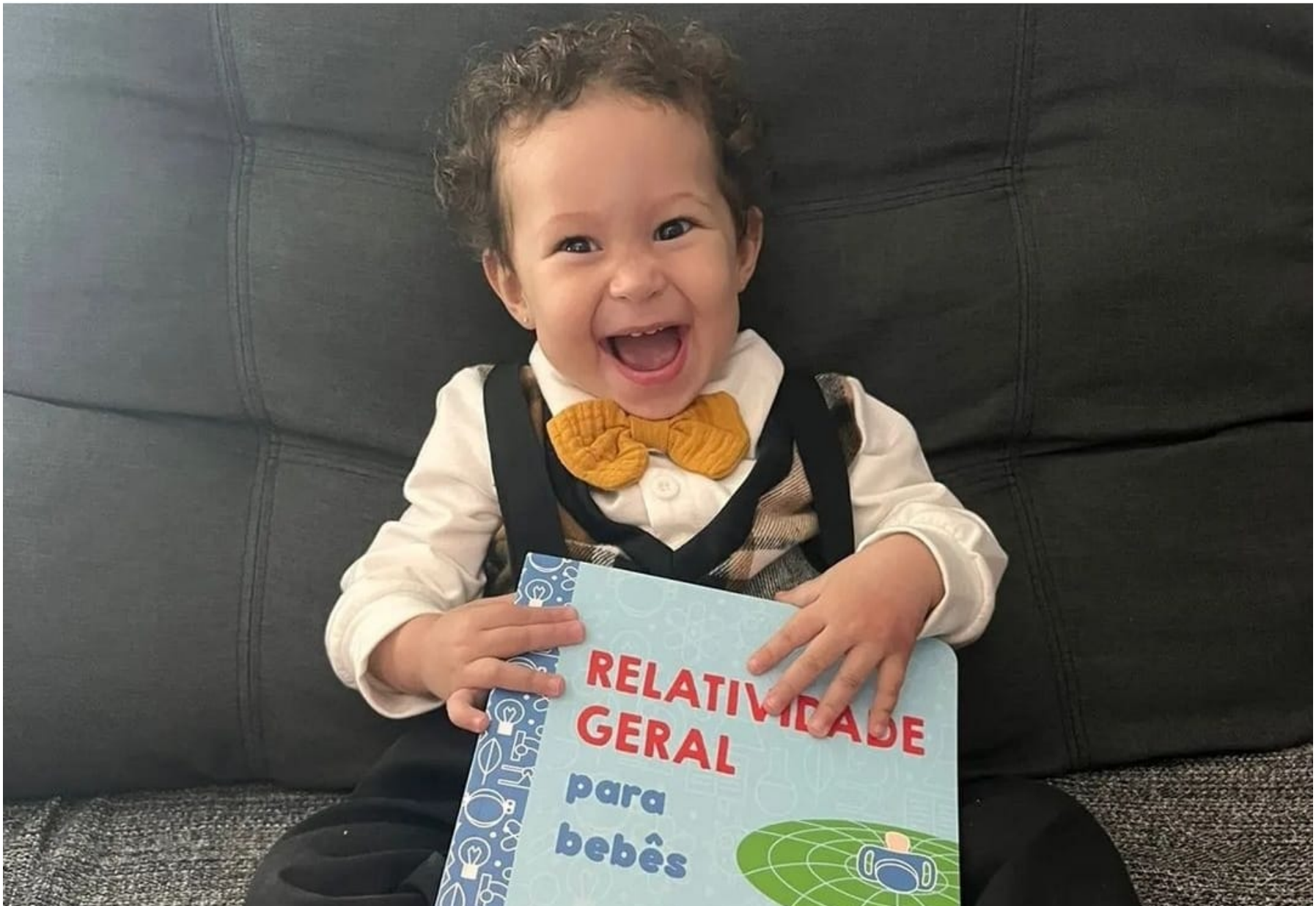
FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO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