Constraining gravitational parity violation

Mostly based on:
arXiv:2004.01253

Alejandro ***Cárdenas-Avendaño***

Programa de Matemática, Konrad Lorenz Fundación Universitaria
Illinois Center for Advanced Studies of the Universe, University of Illinois at Urbana-Champaign

in collaboration with
Hector **Silva**, Miguel **Holgado** and Nicolás ***Yunes***

KONRAD LORENZ FUNDACIÓN UNIVERSITARIA

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

09.23.2020
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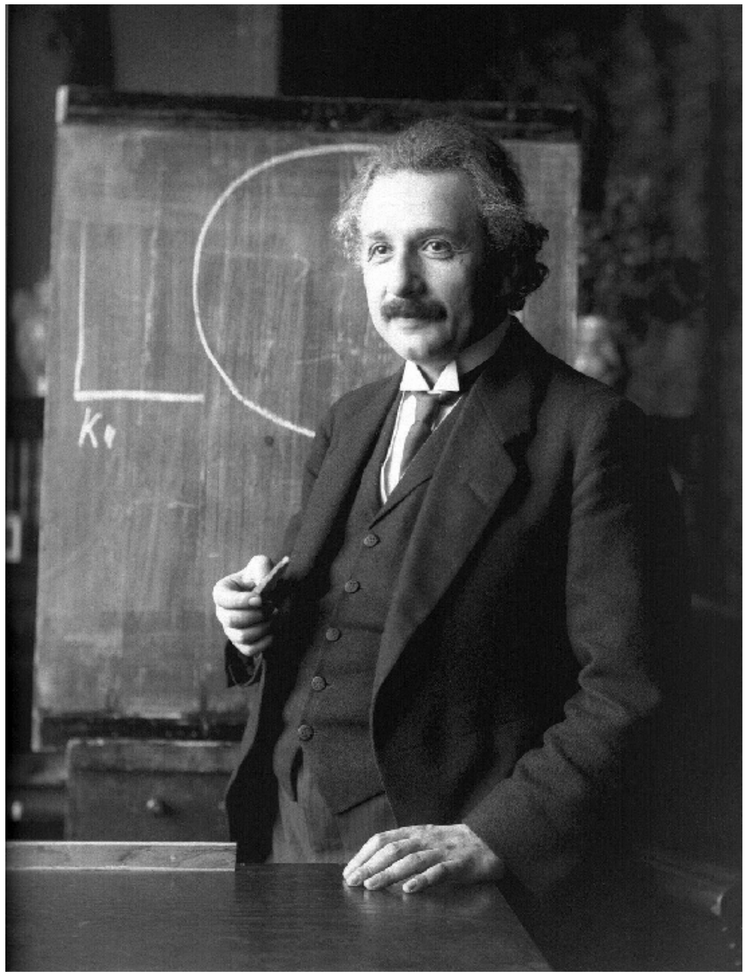
Was Einstein right or left handed?



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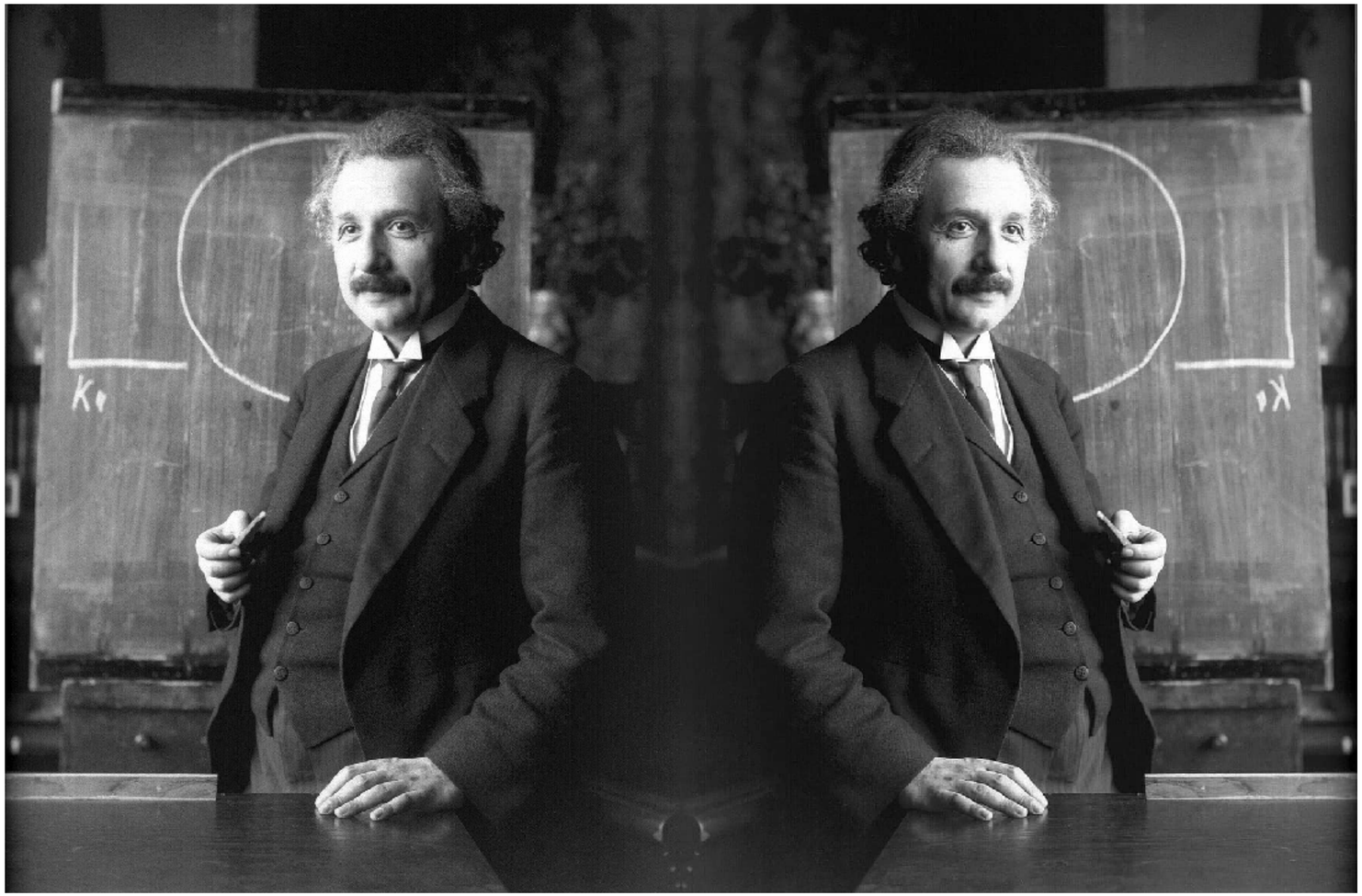

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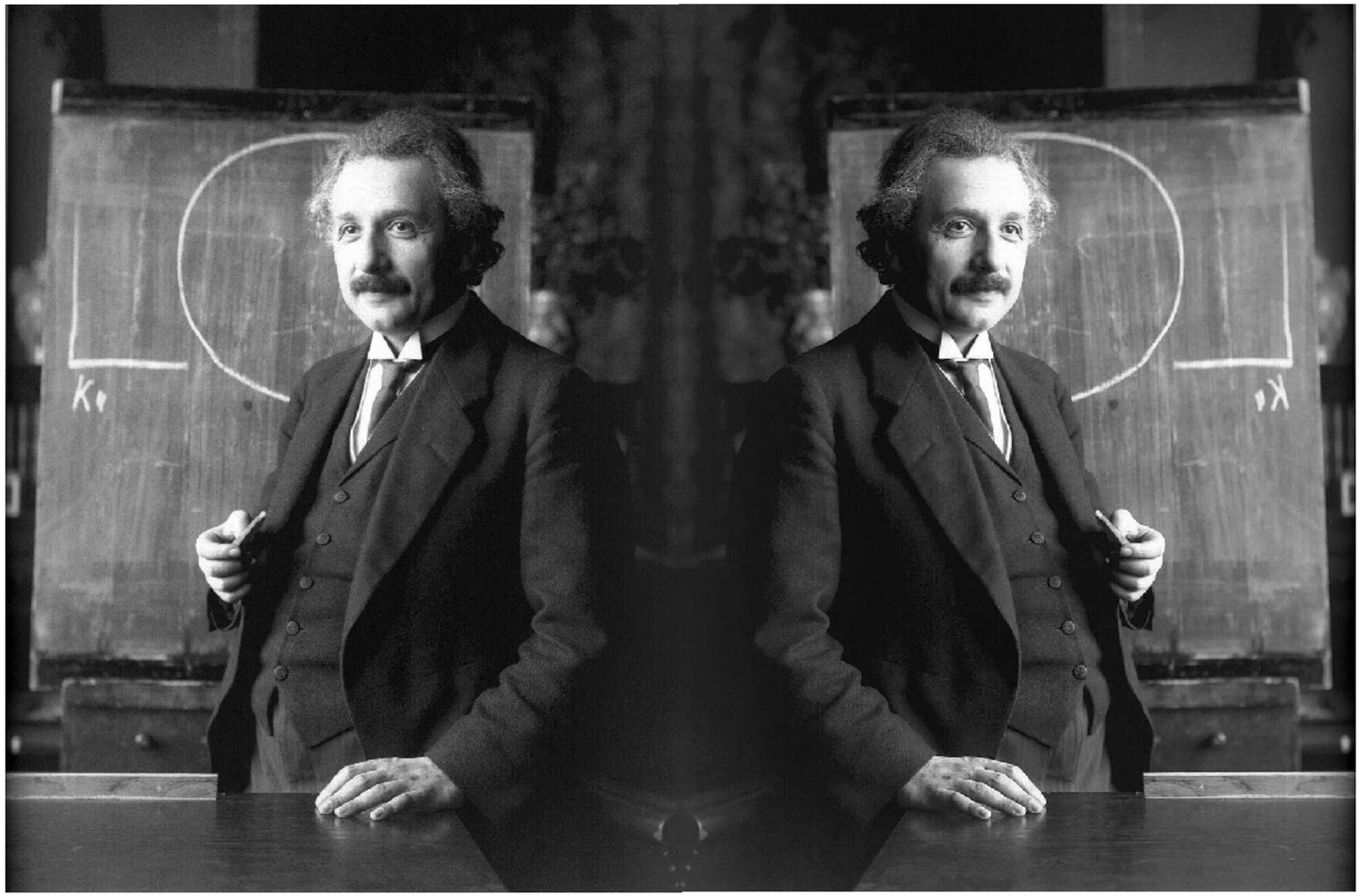

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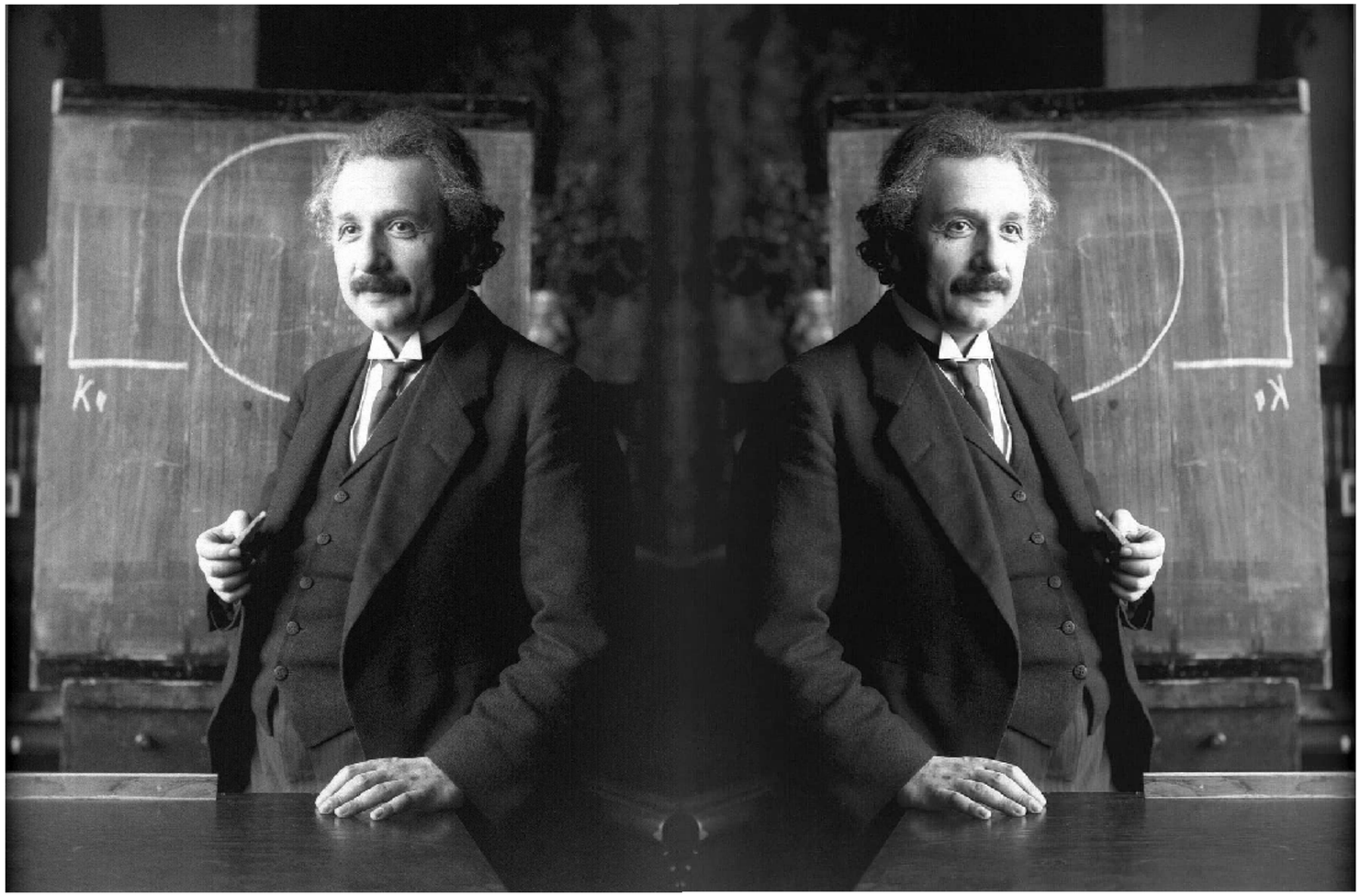

Jackiw & Pi (2003)

Dynamical Chern-Simons theory

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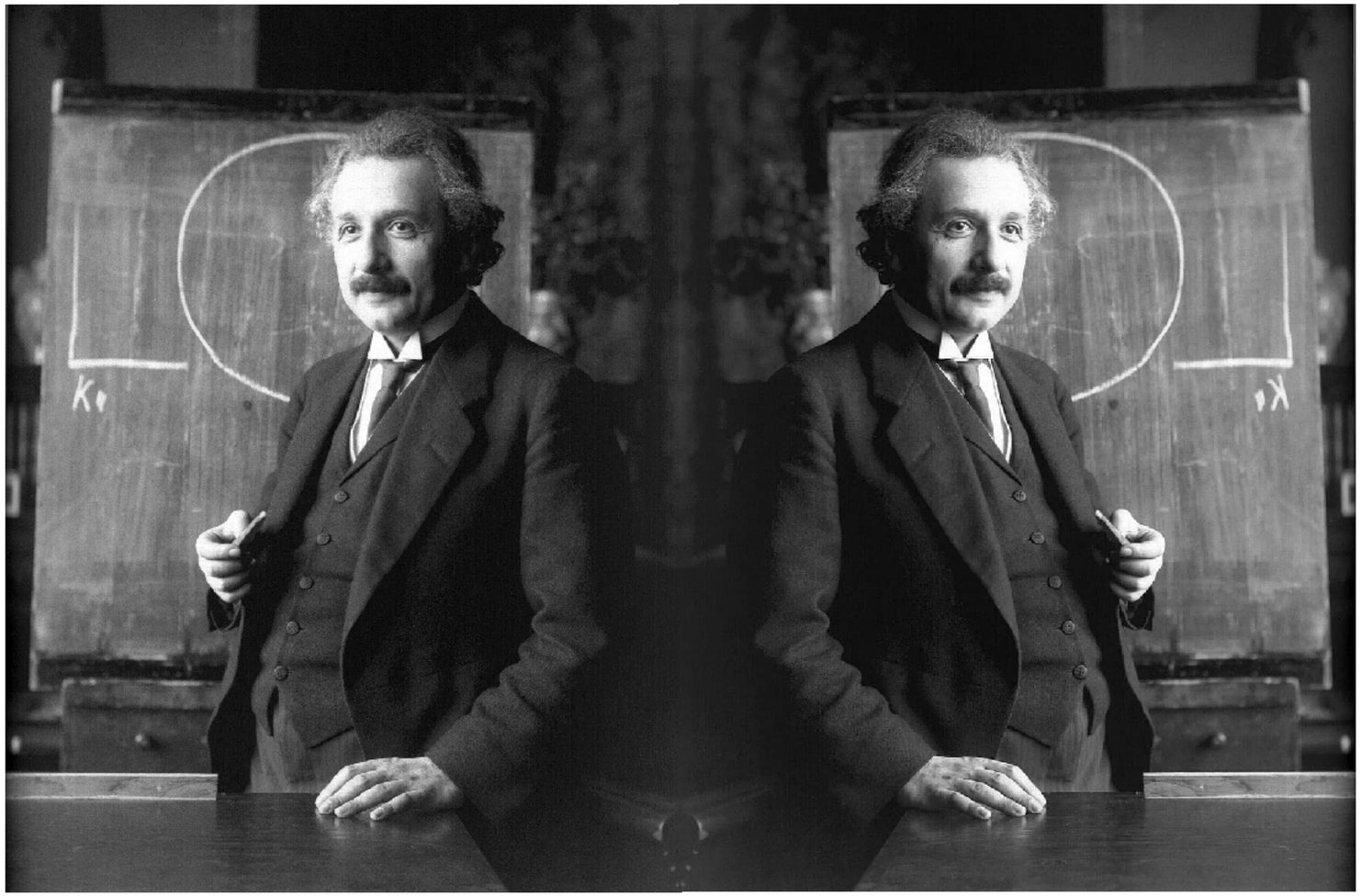

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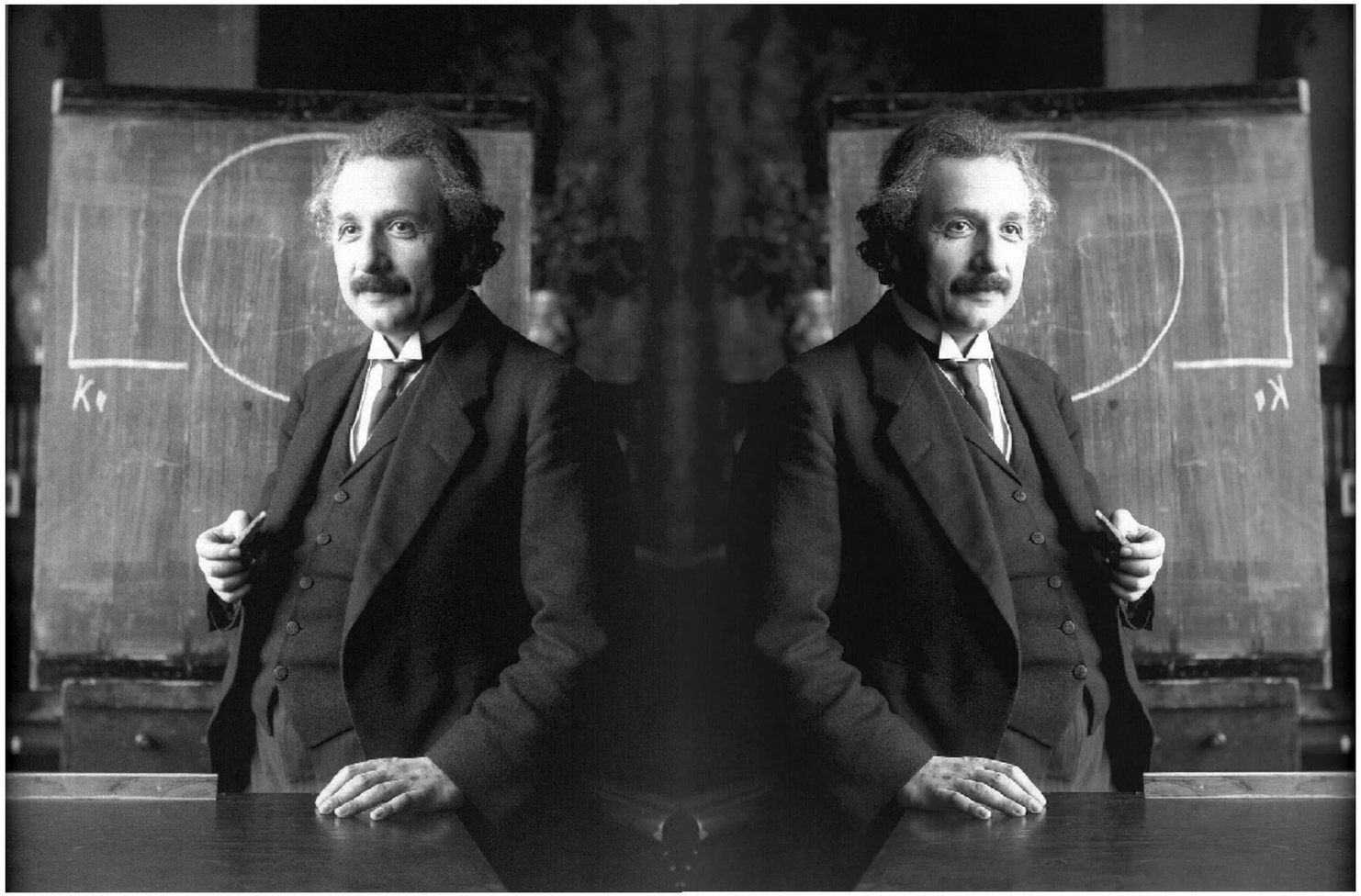

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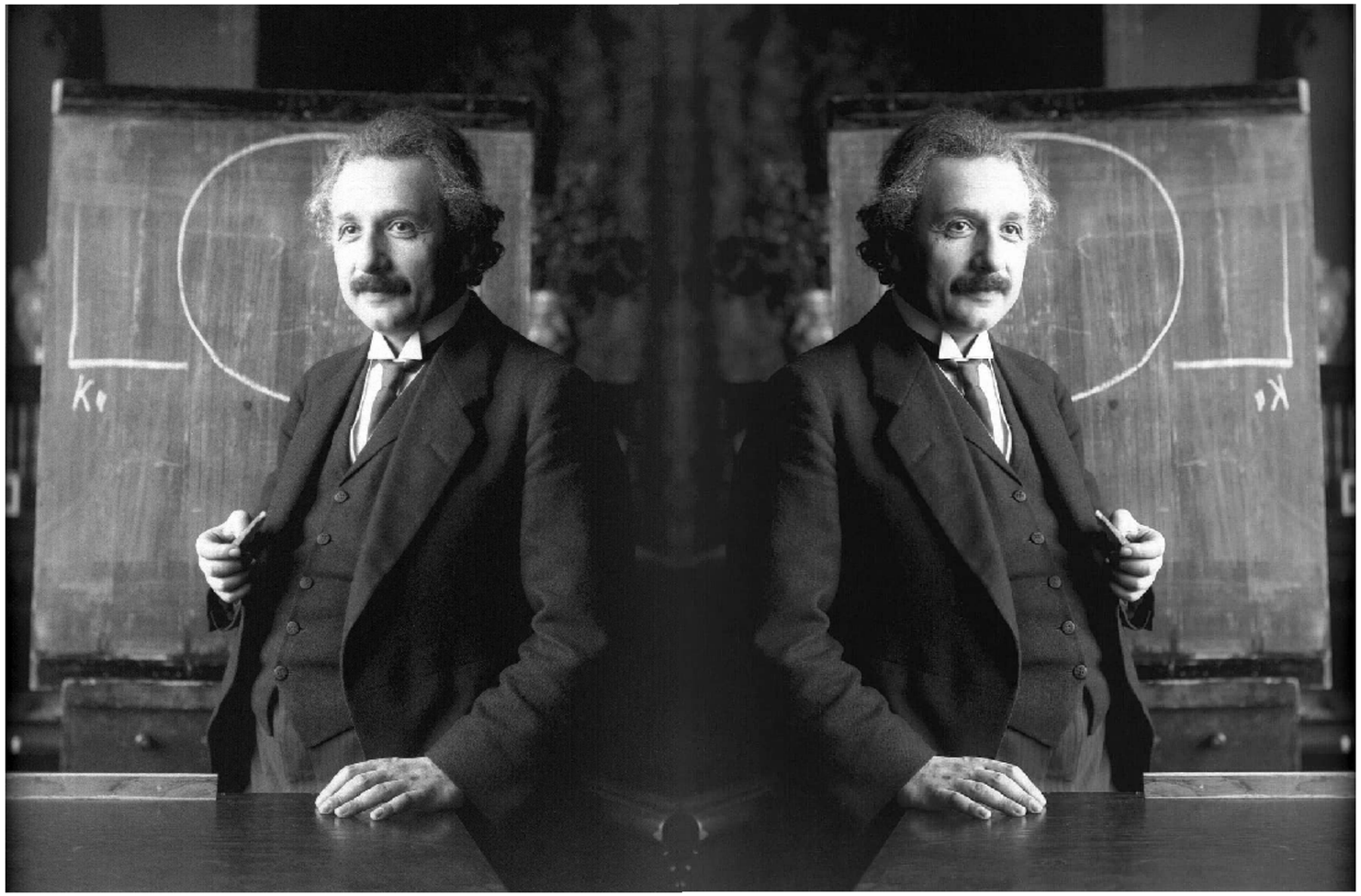

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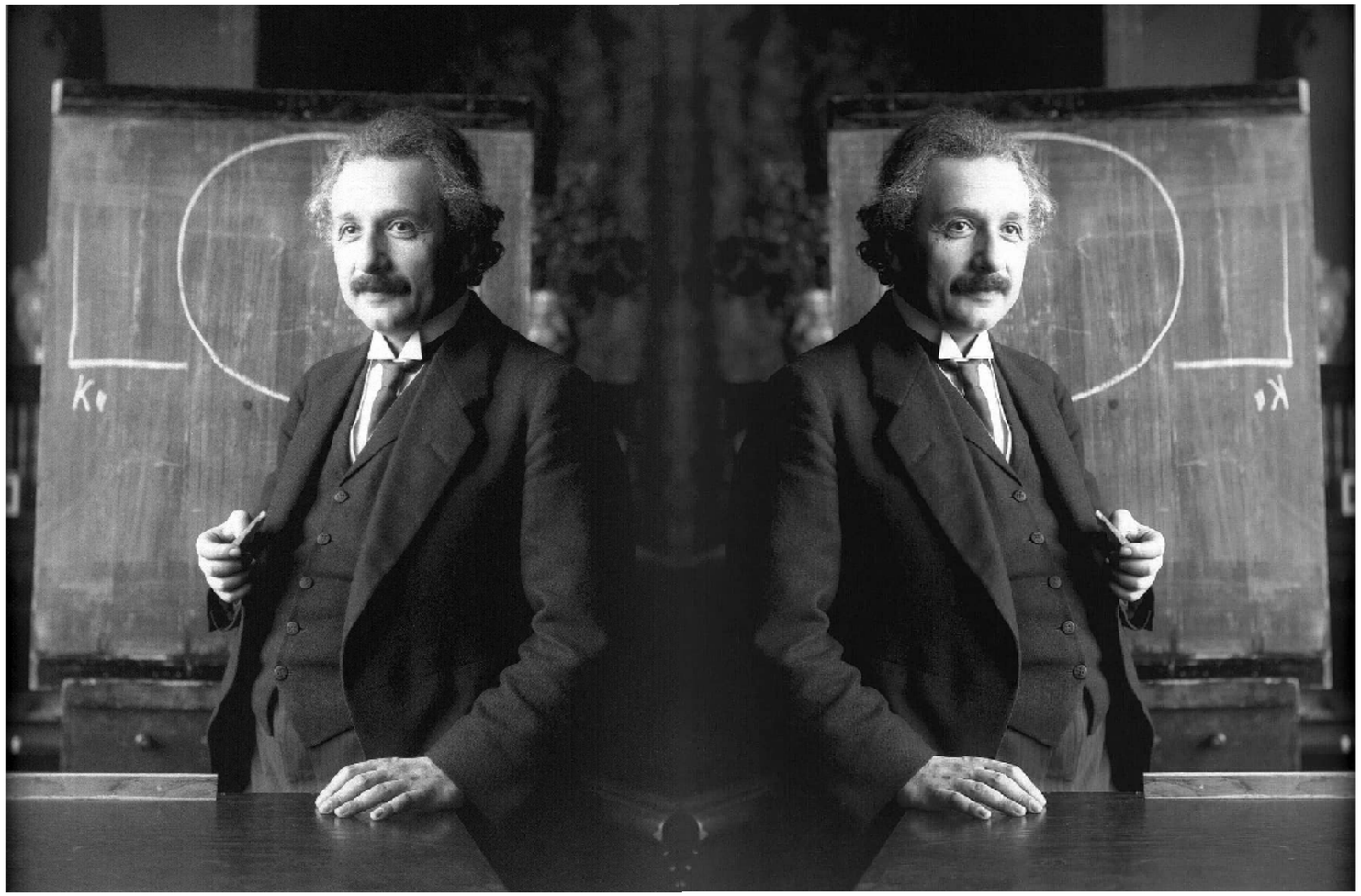

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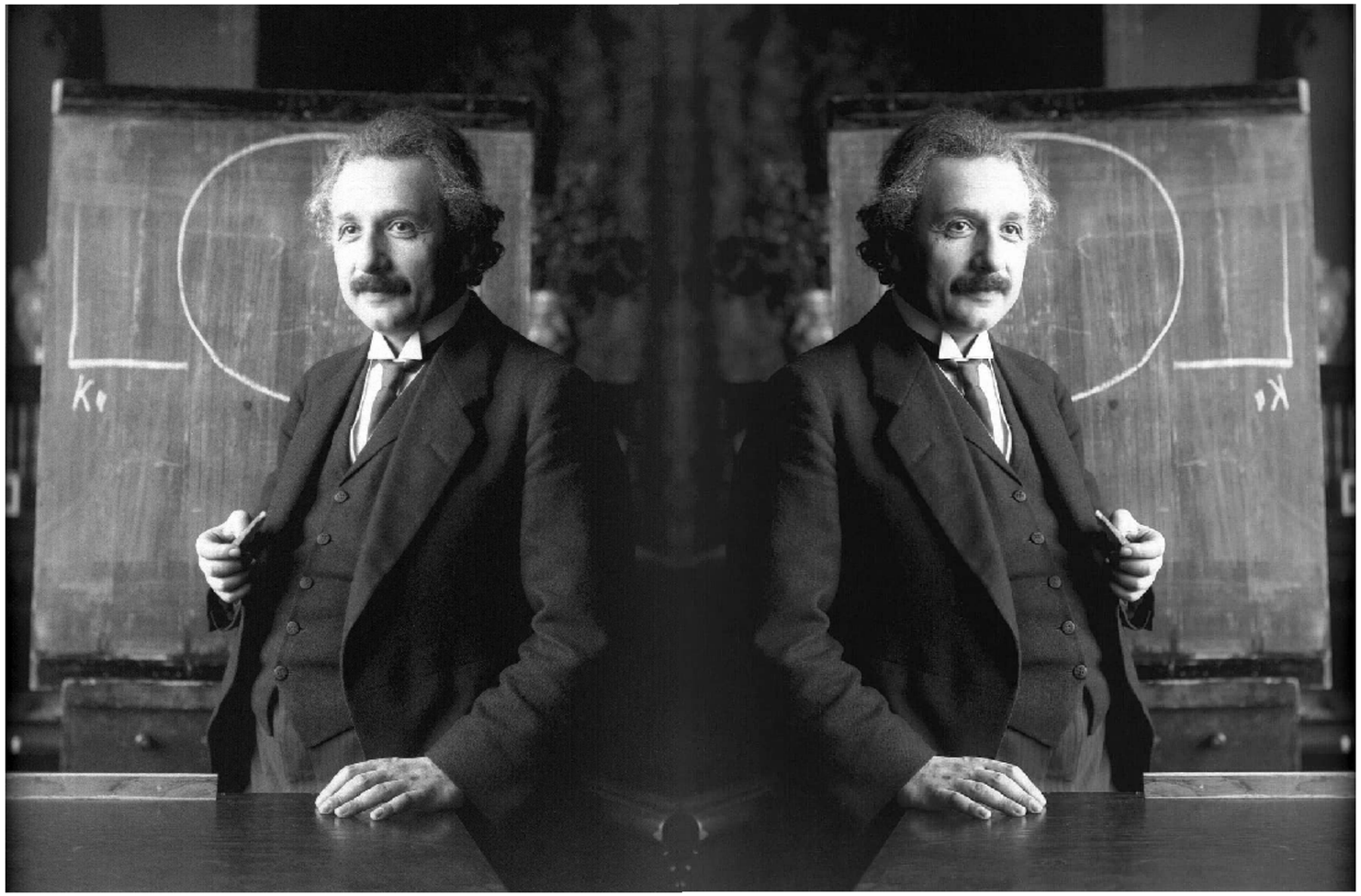

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Dynamical Chern-Simons theory (dCS)

The theory is defined through the action:

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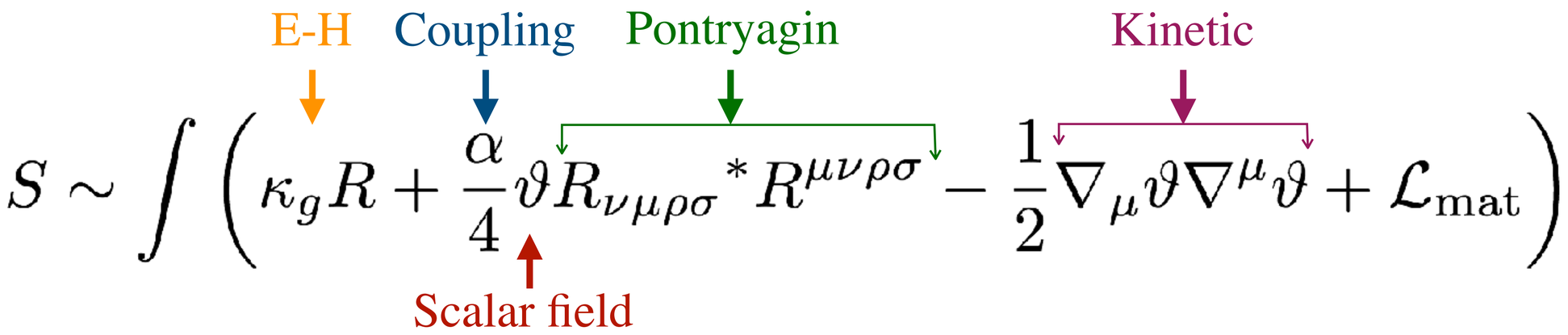

Solutions have only been found in the **slow-rotation** and in the **extremal approximations**:

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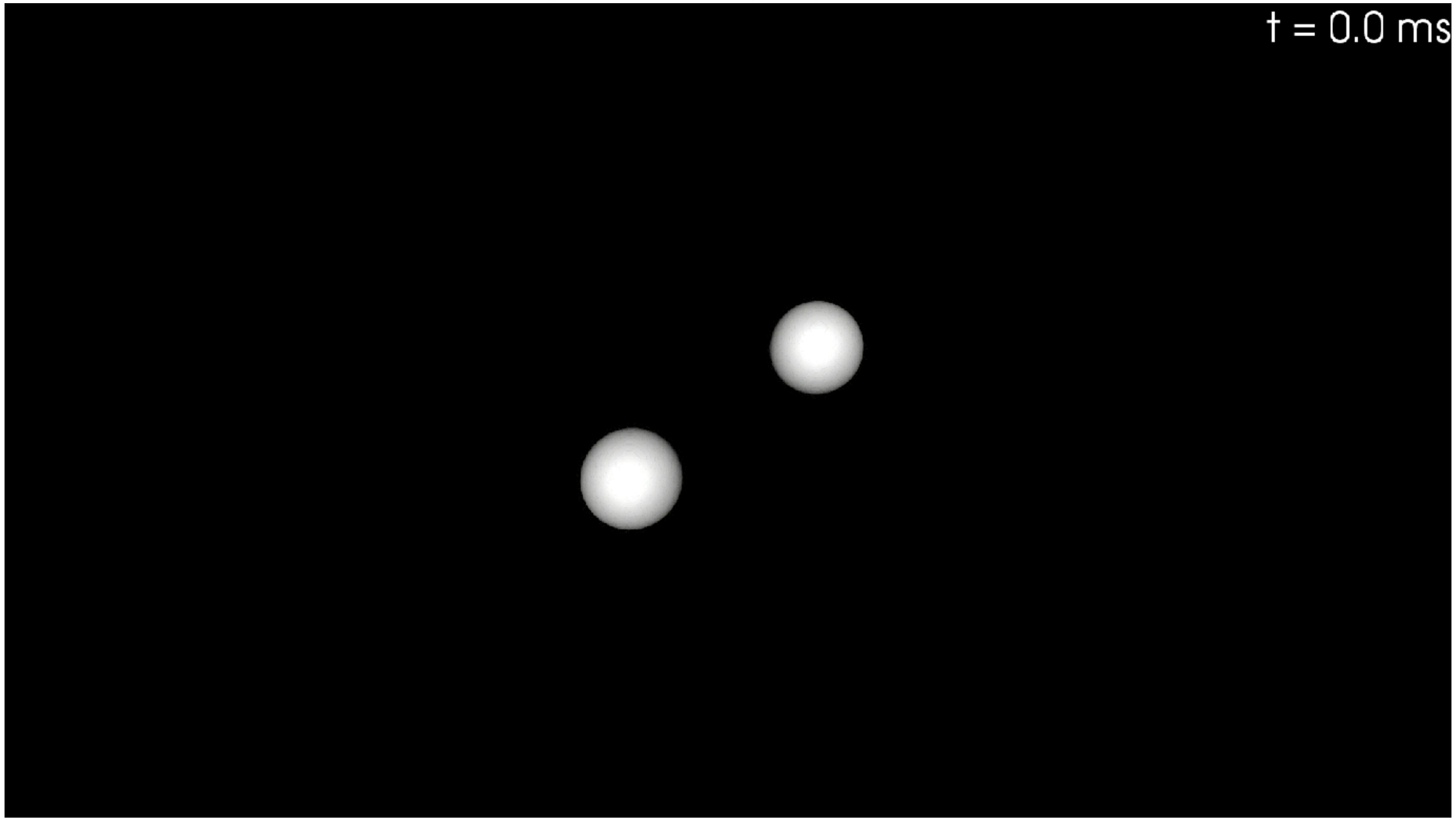
LIGO-VIRGO Collaboration (LVC): The last dance (GW170817)

The LIGO Scientific Collaboration and The Virgo Collaboration (2017)



Credit: W. Kastaun/T. Kawamura/B. Giacomazzo/R. Ciolfi/A. Endrizzi

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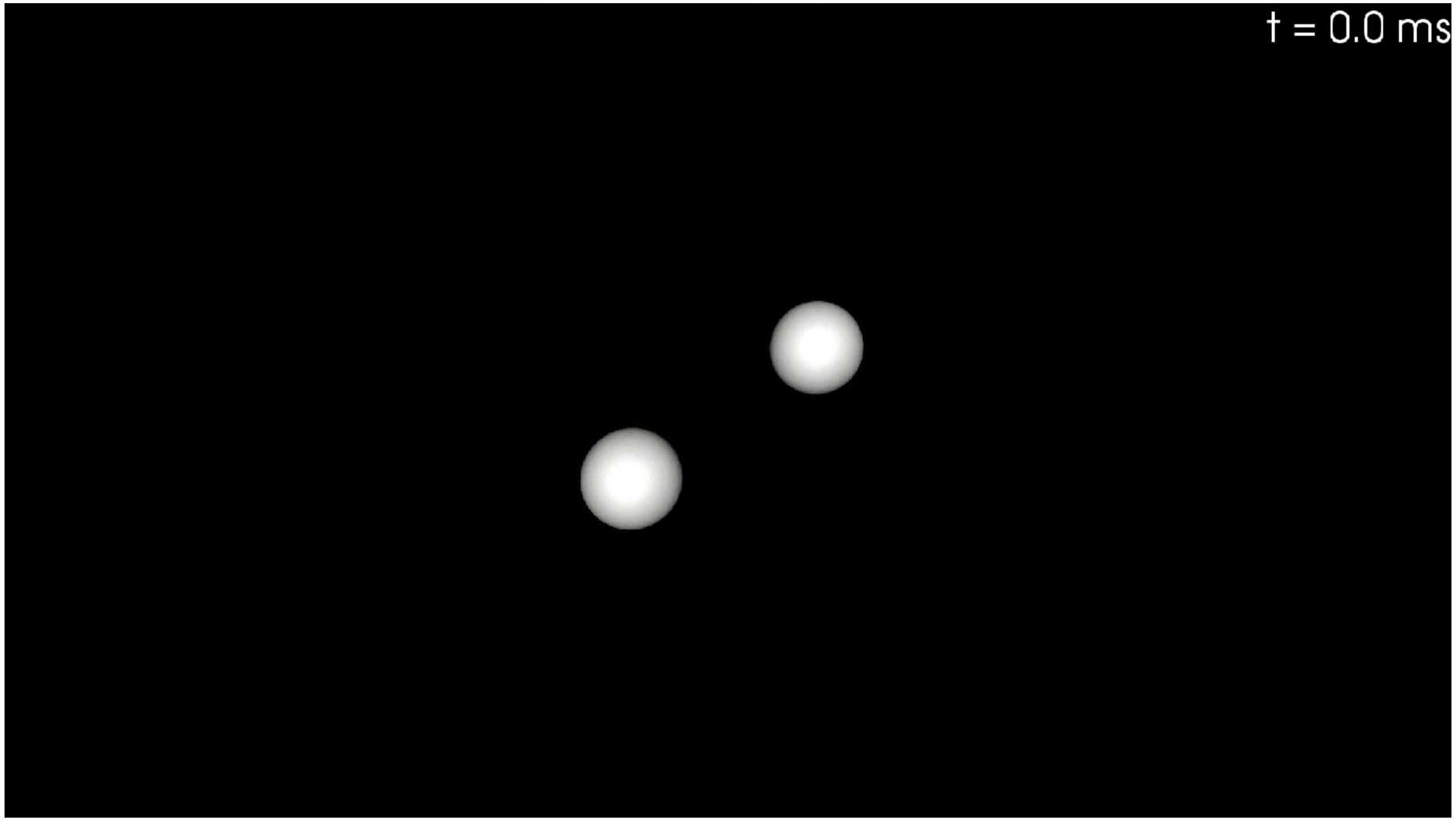

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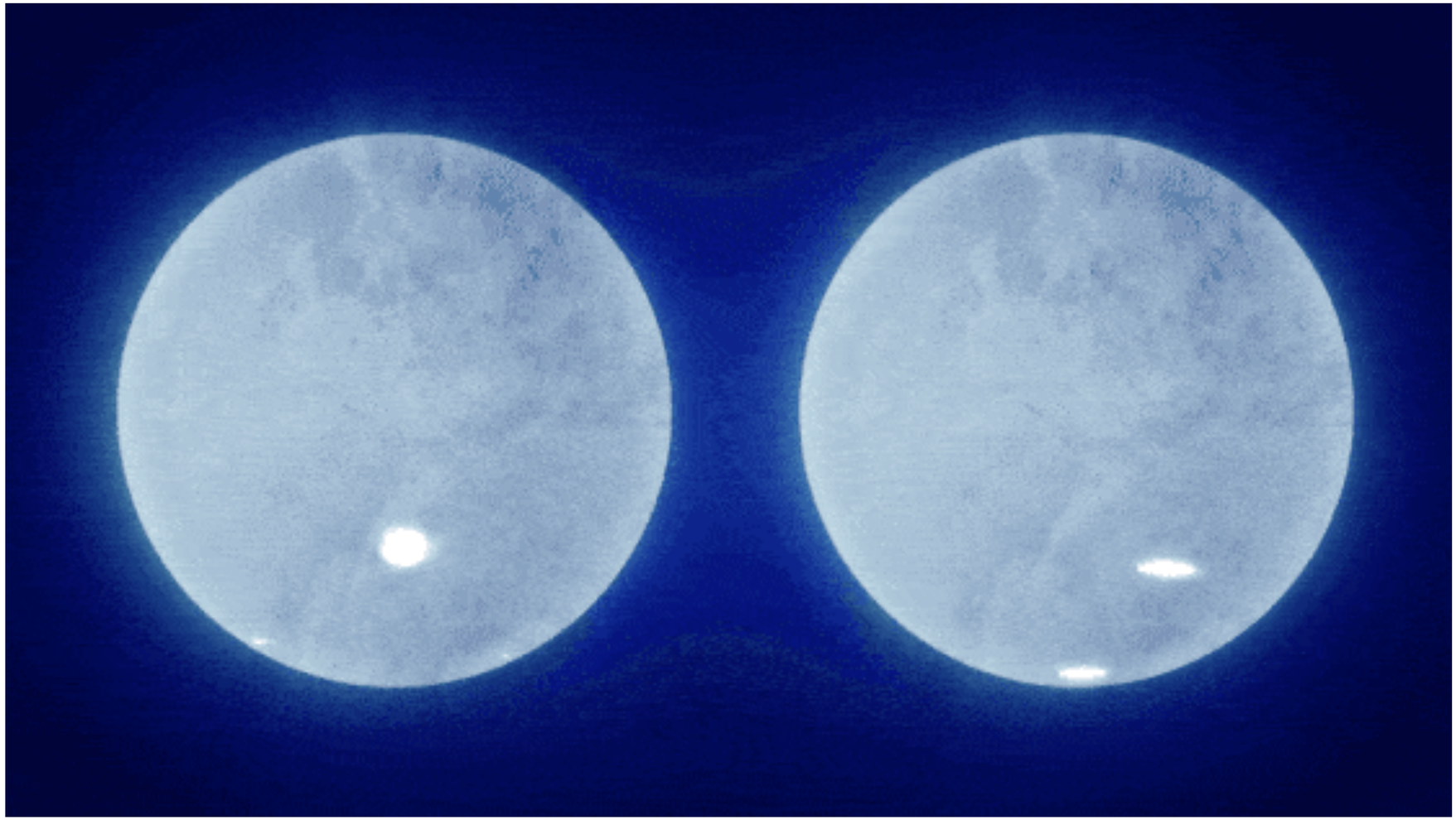

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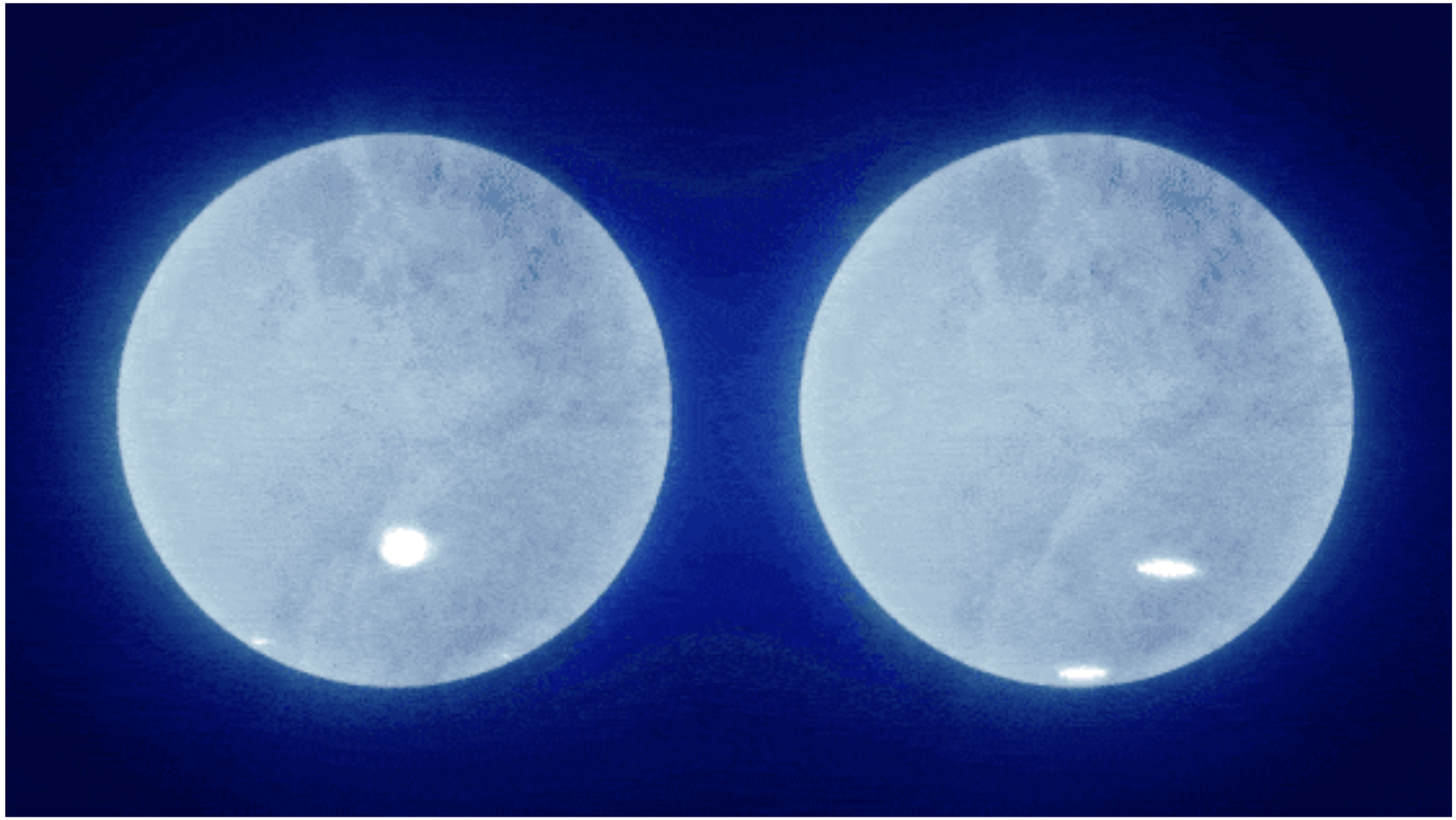

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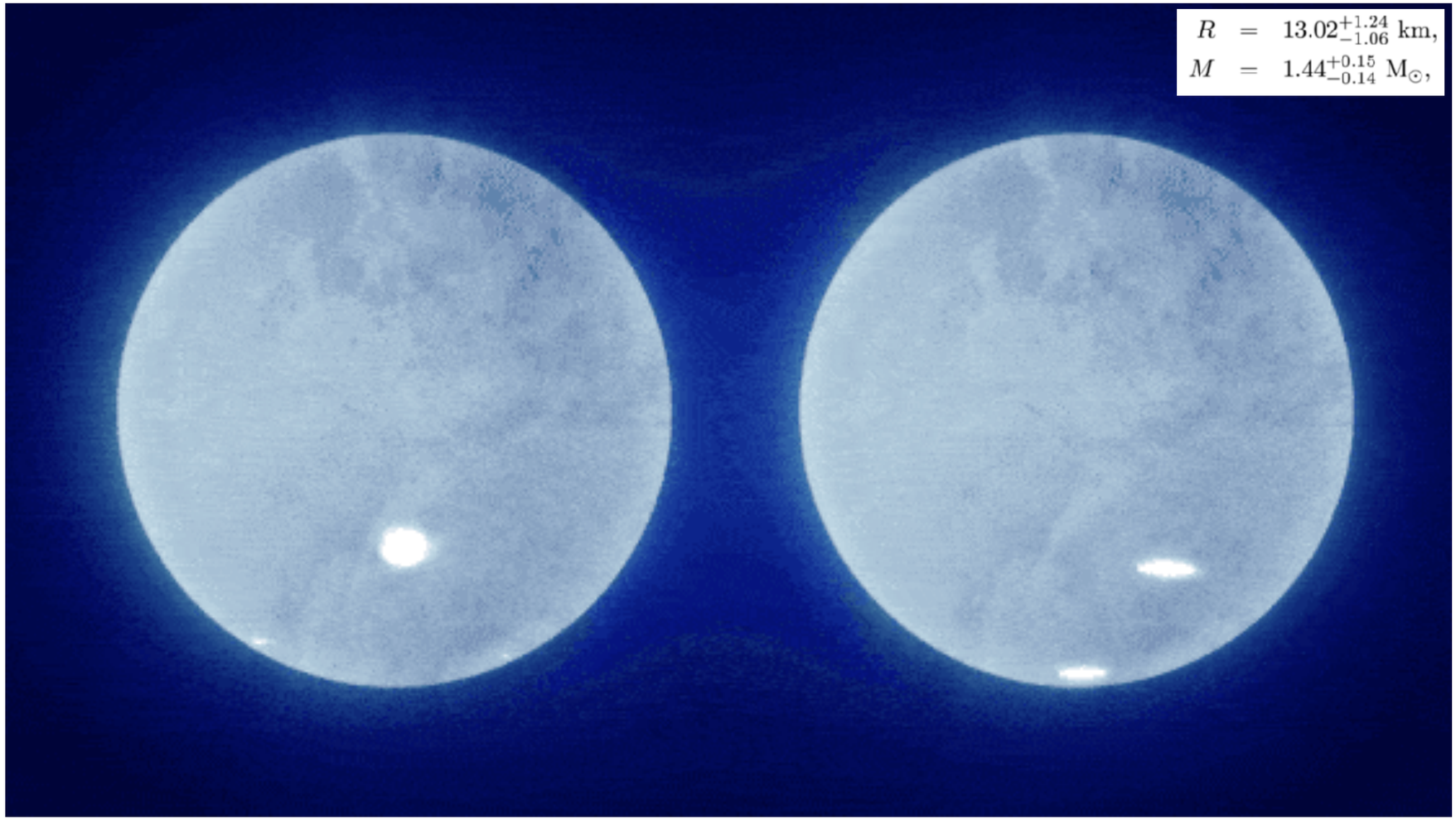
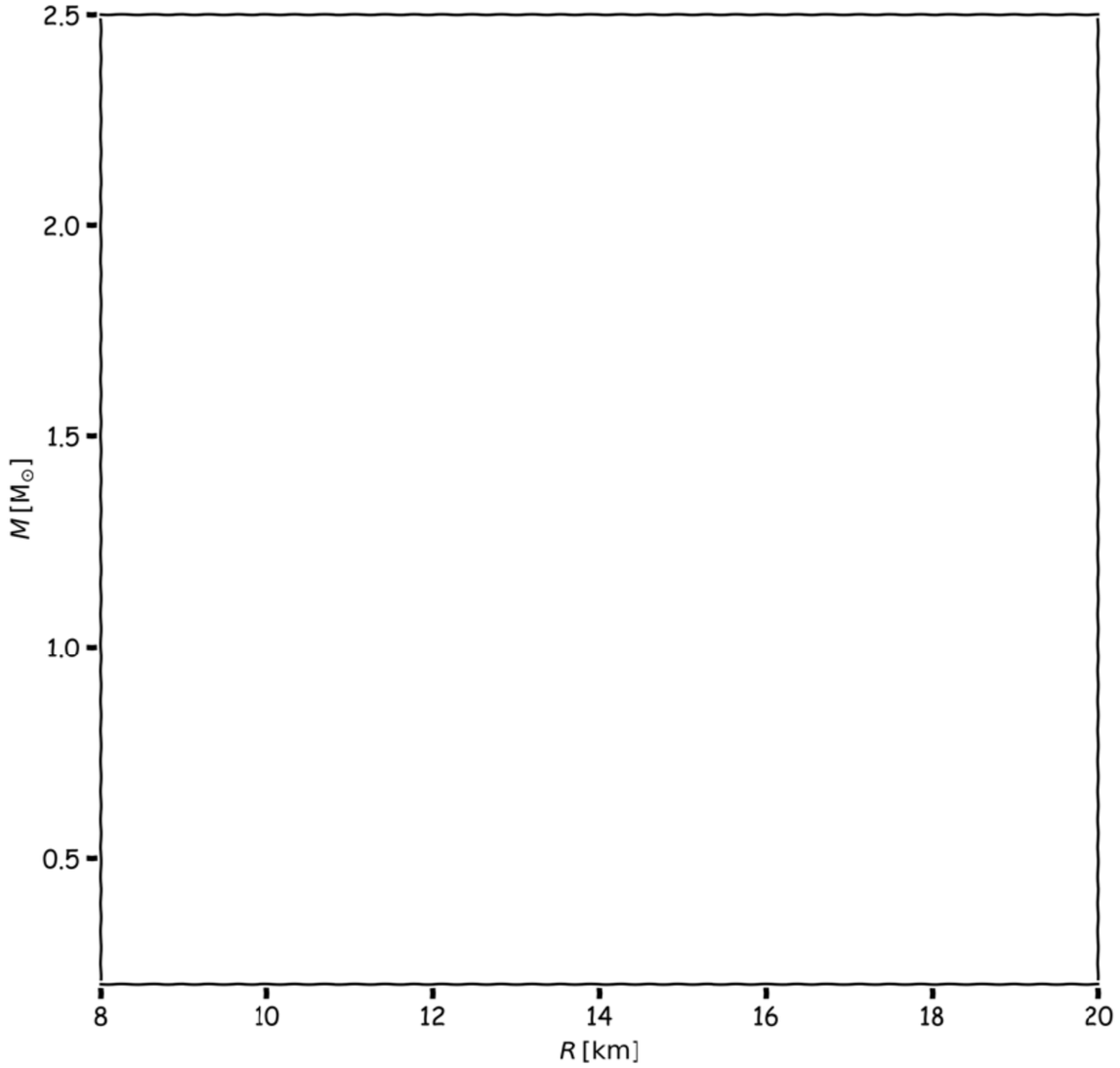


What is the equation of state of a neutron star?



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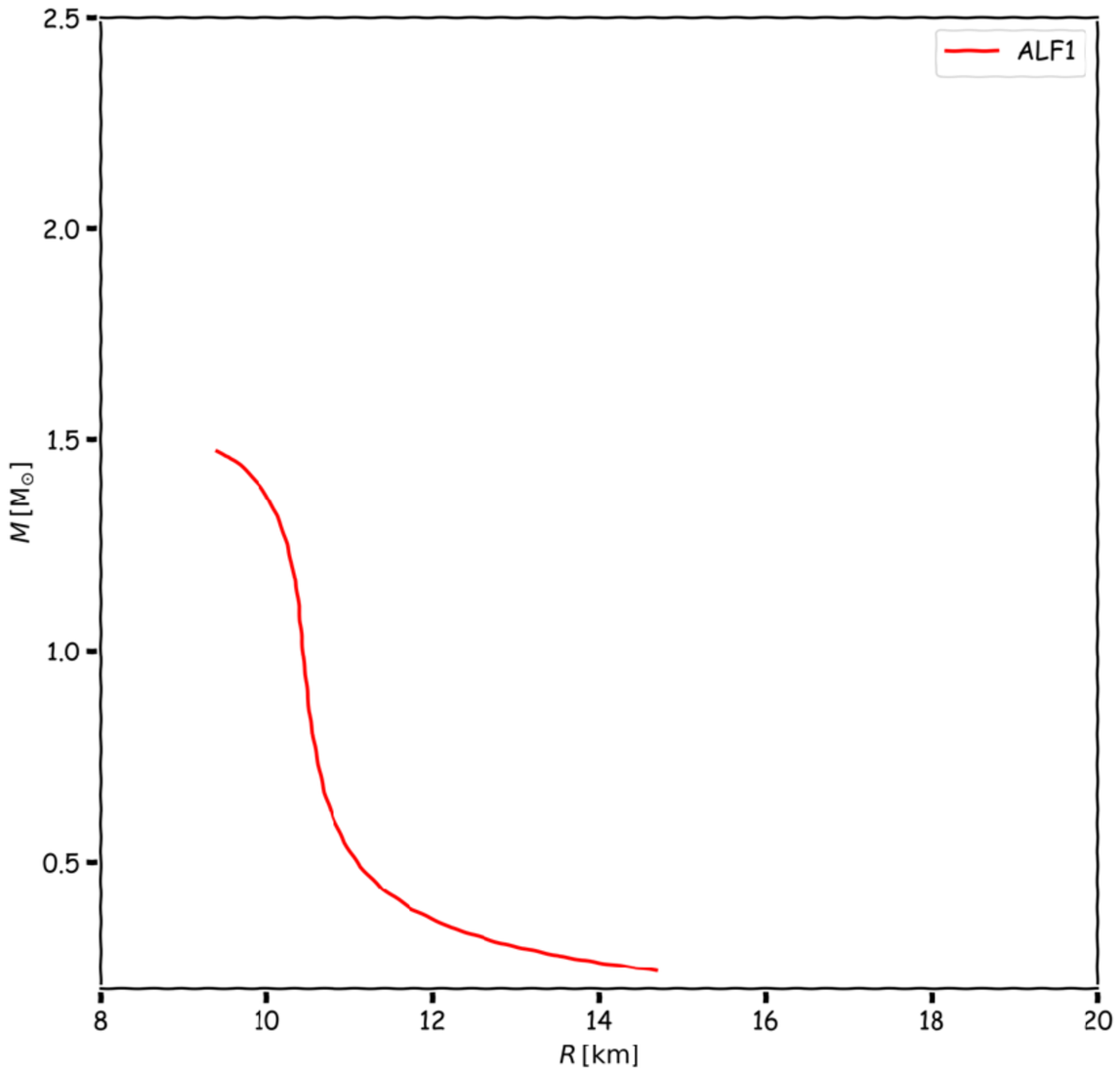

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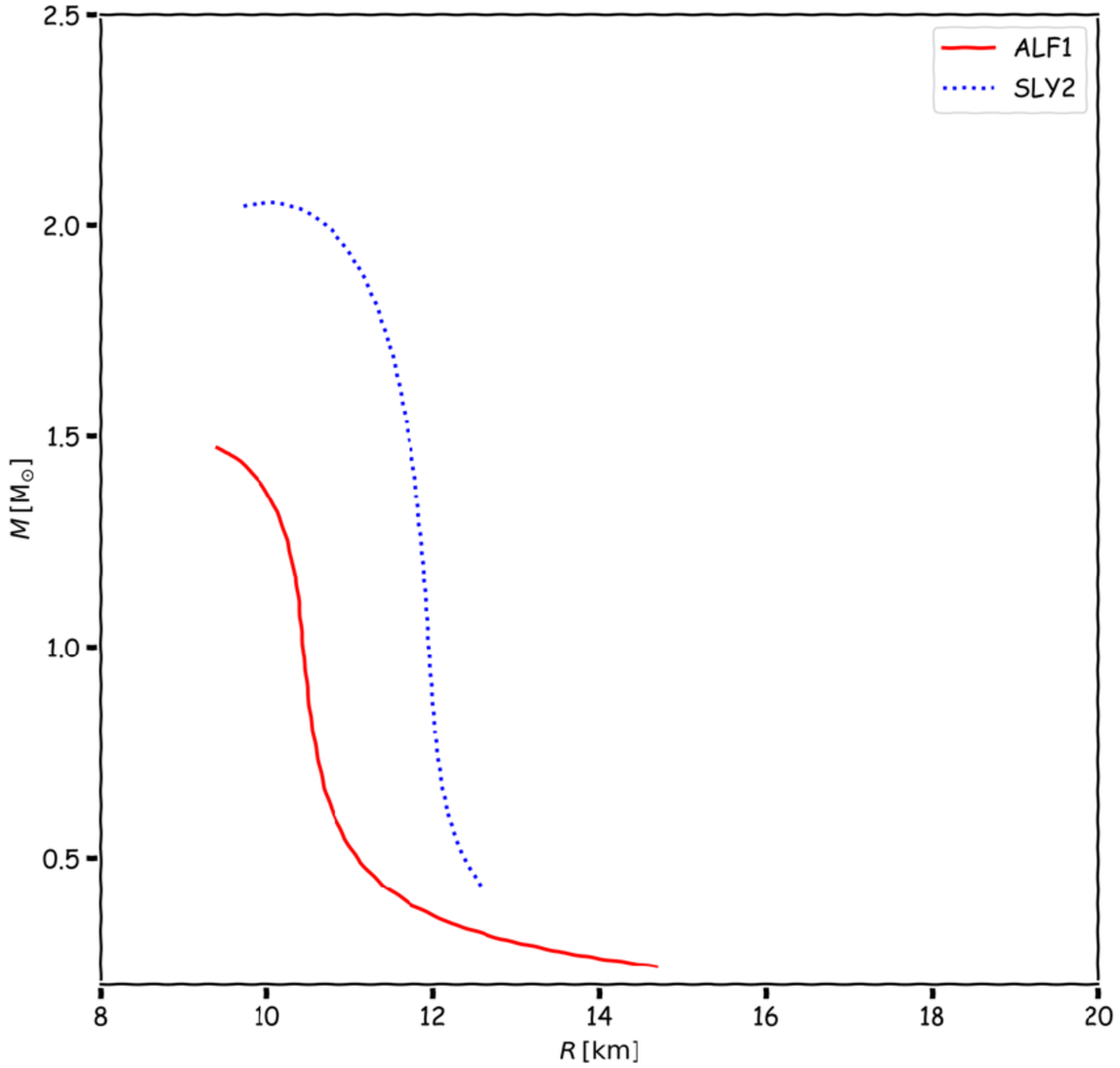

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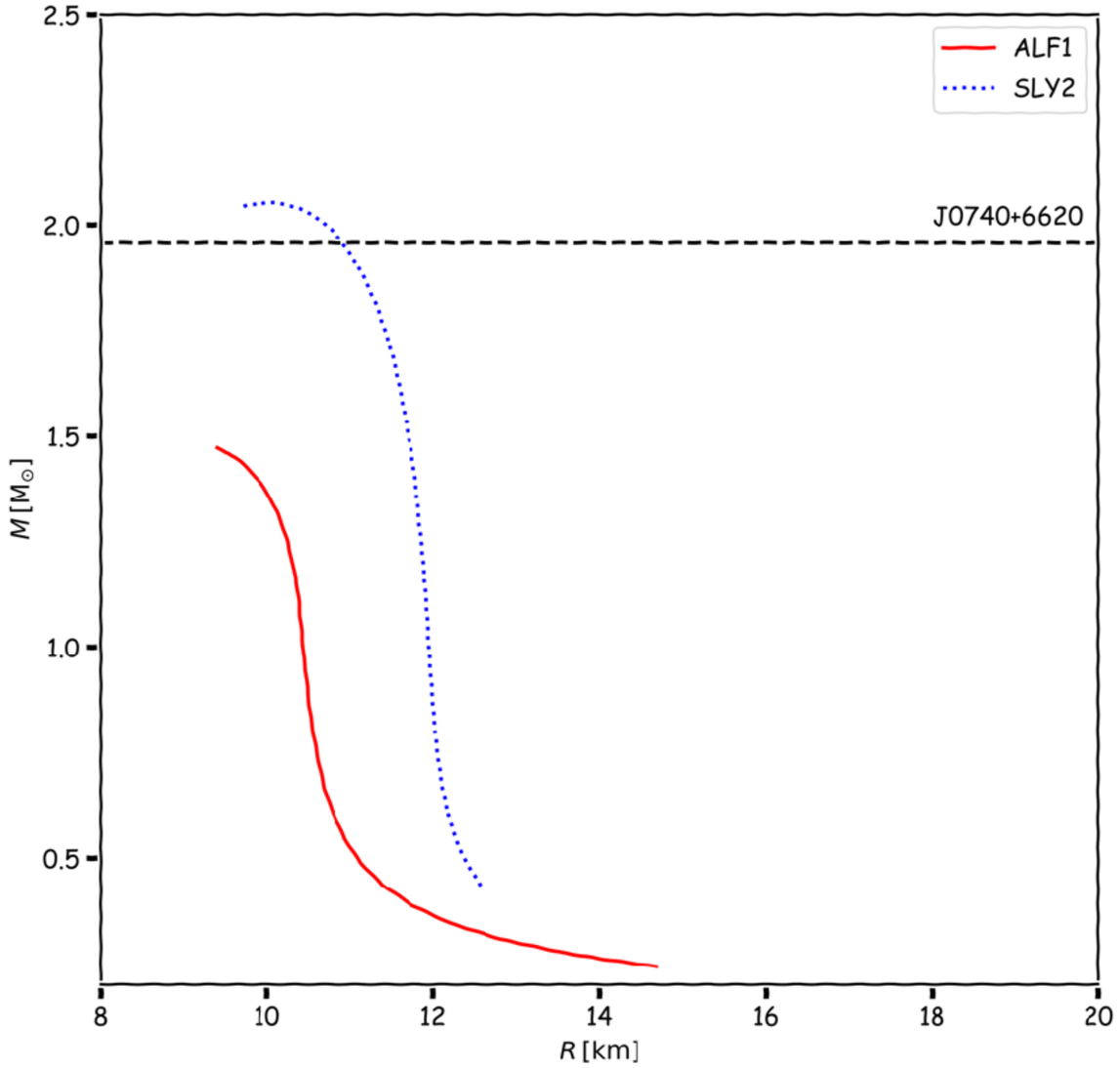

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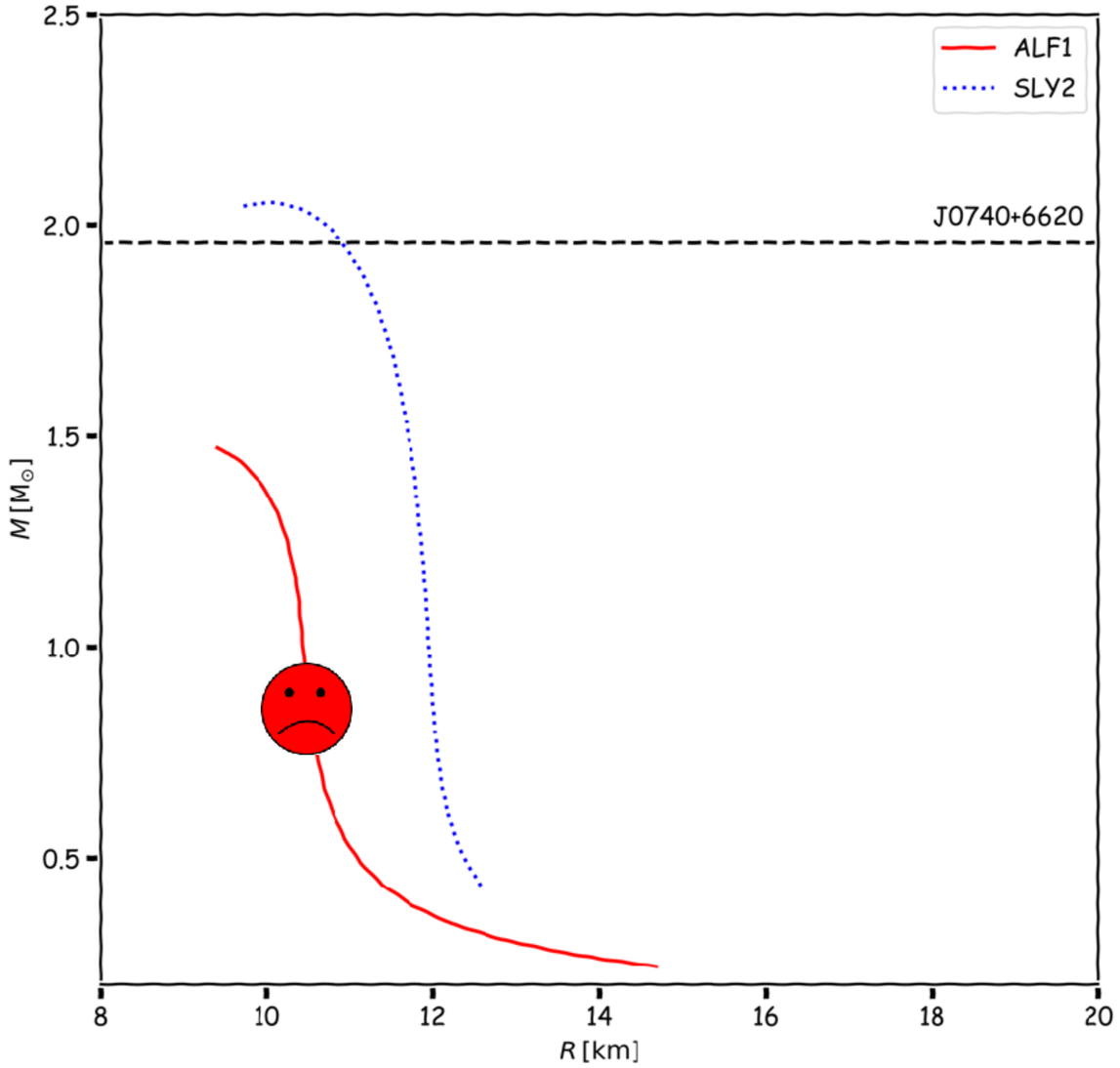

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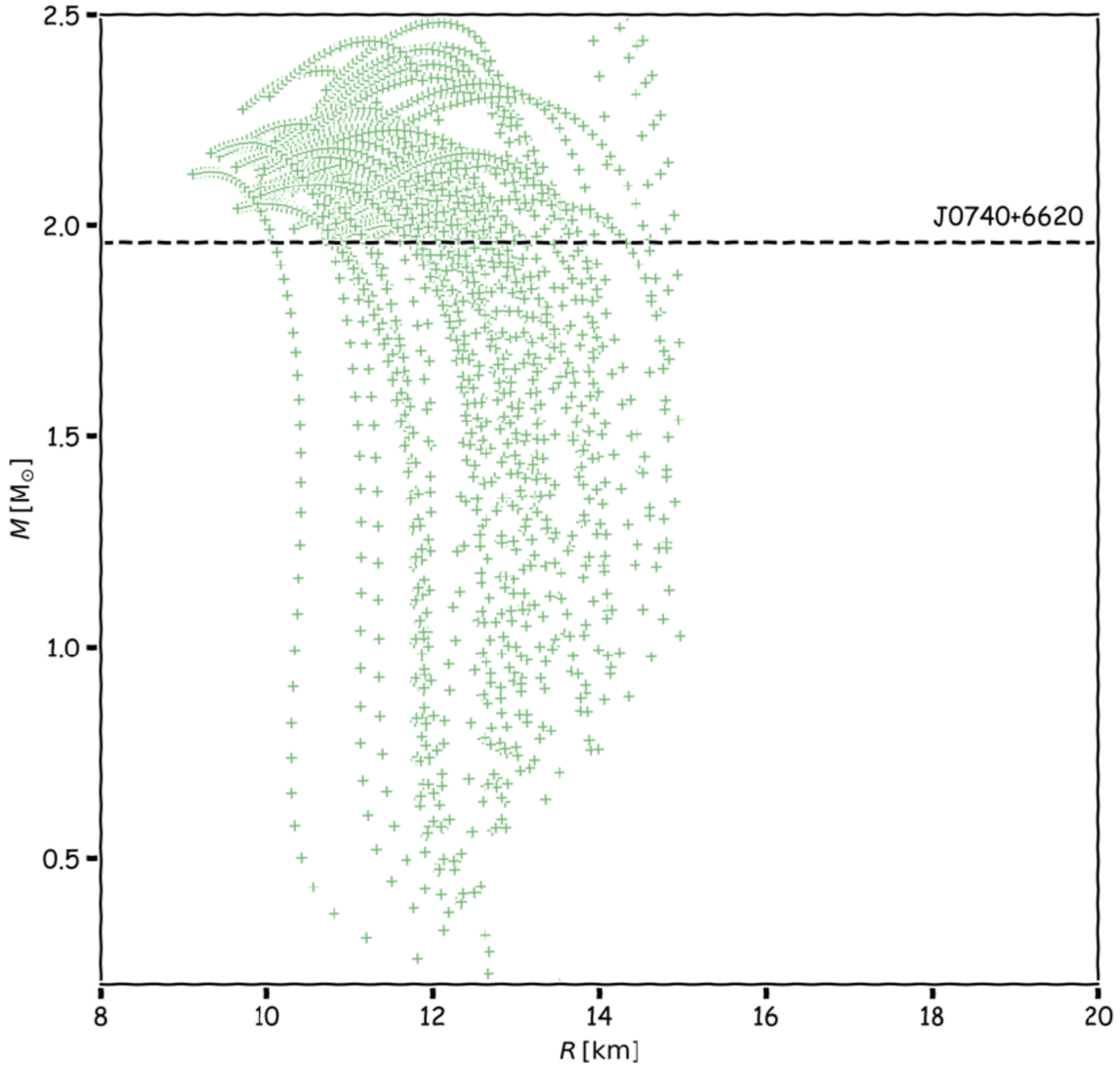

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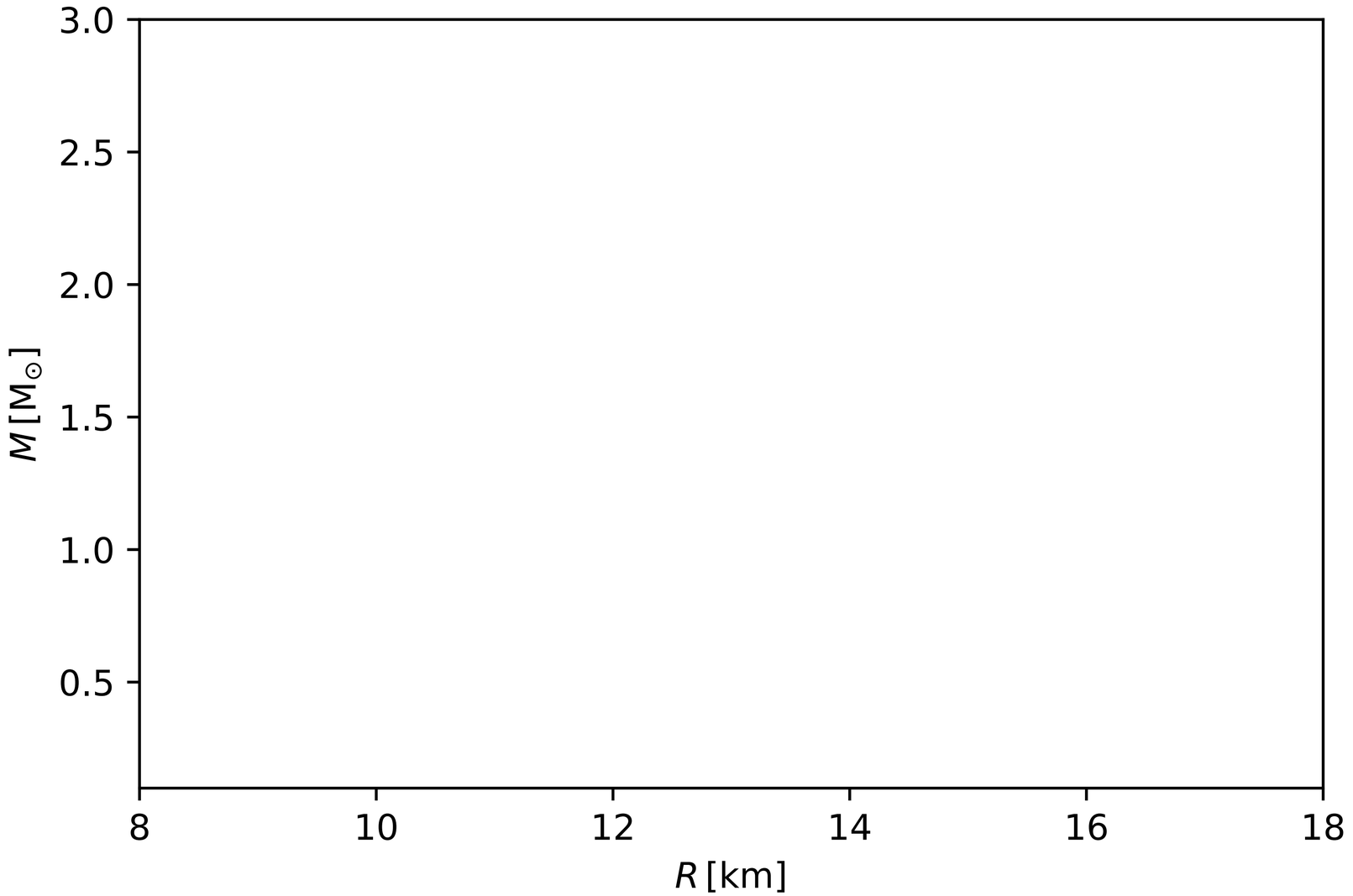

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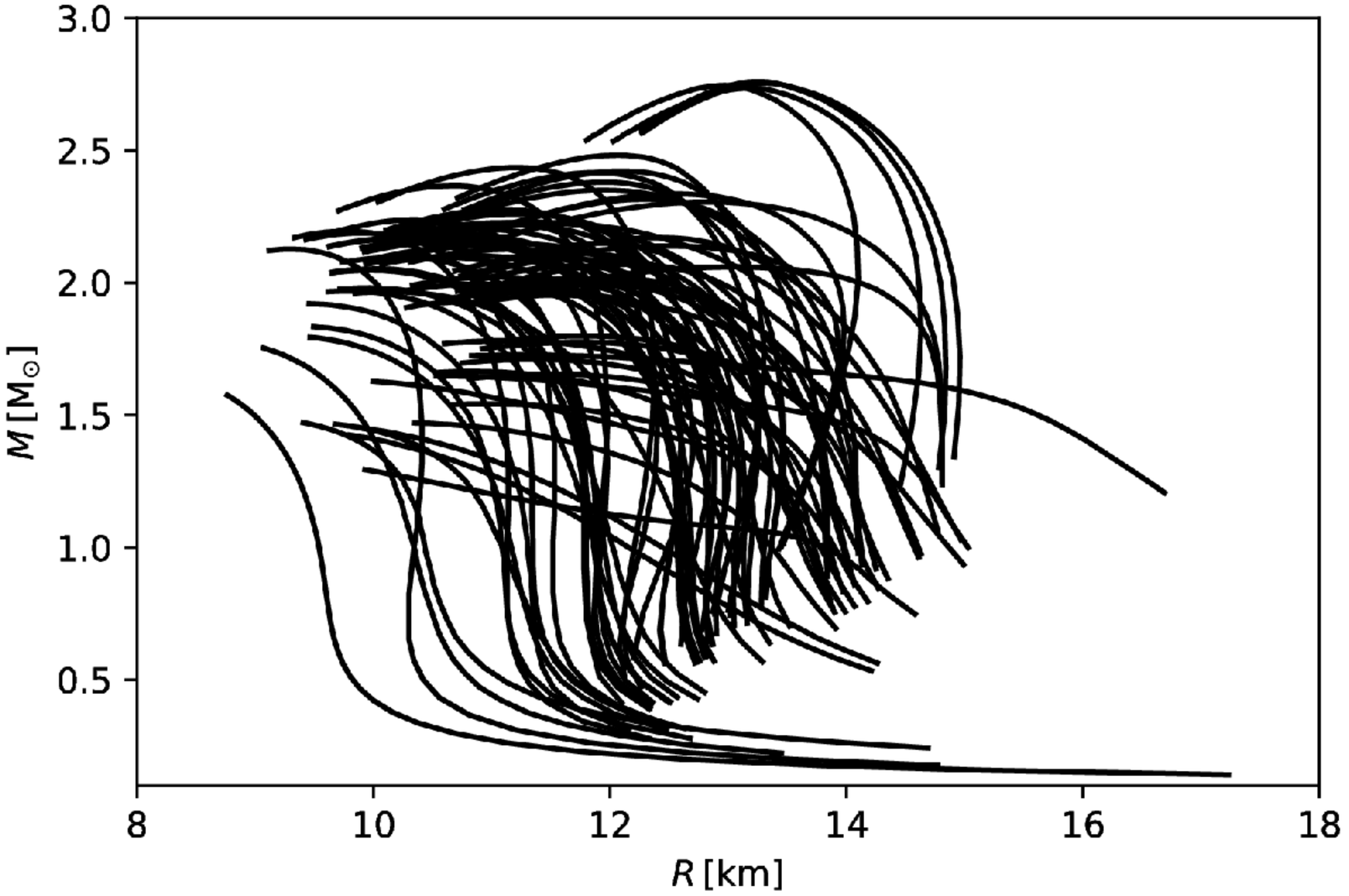

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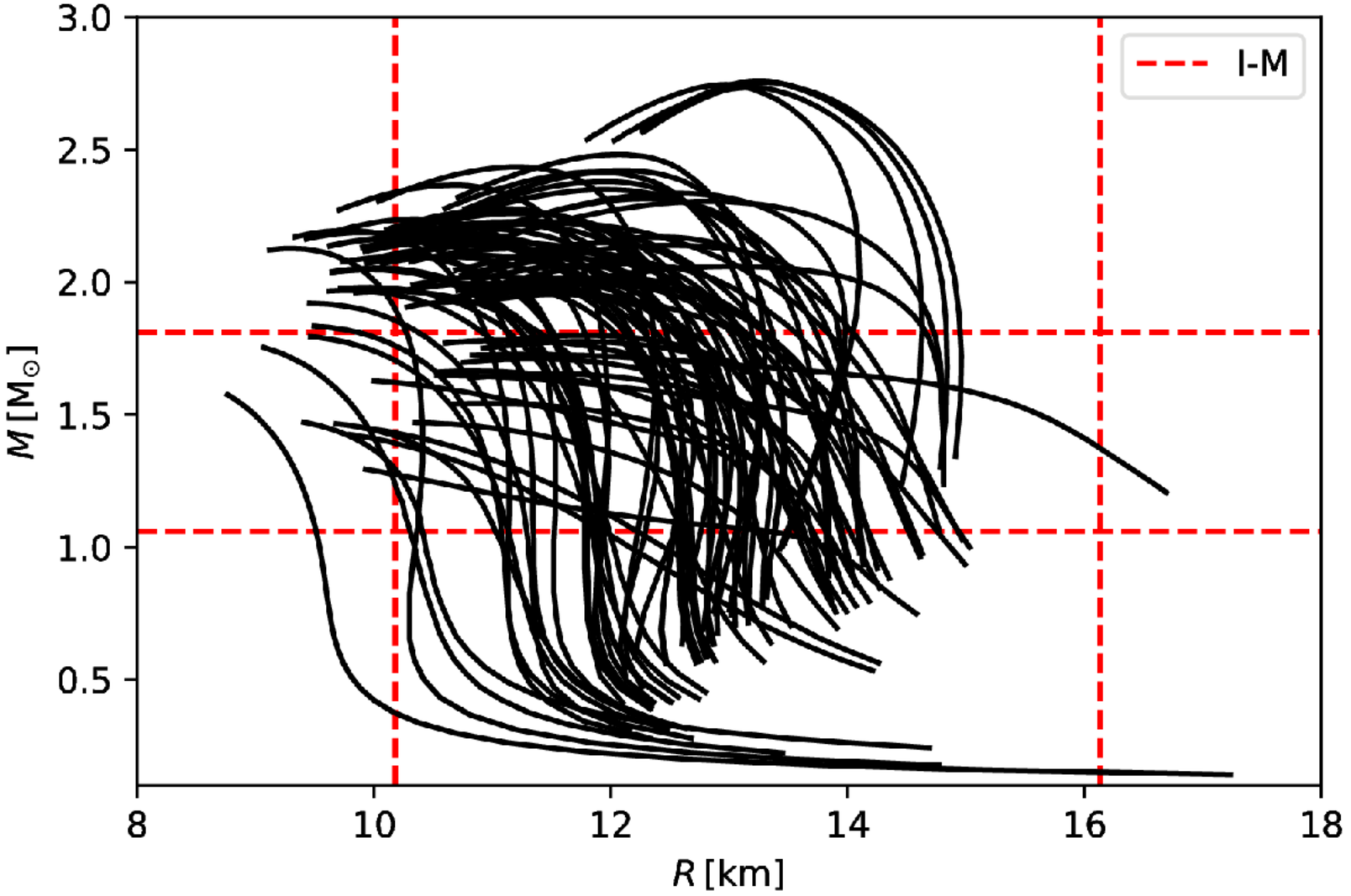

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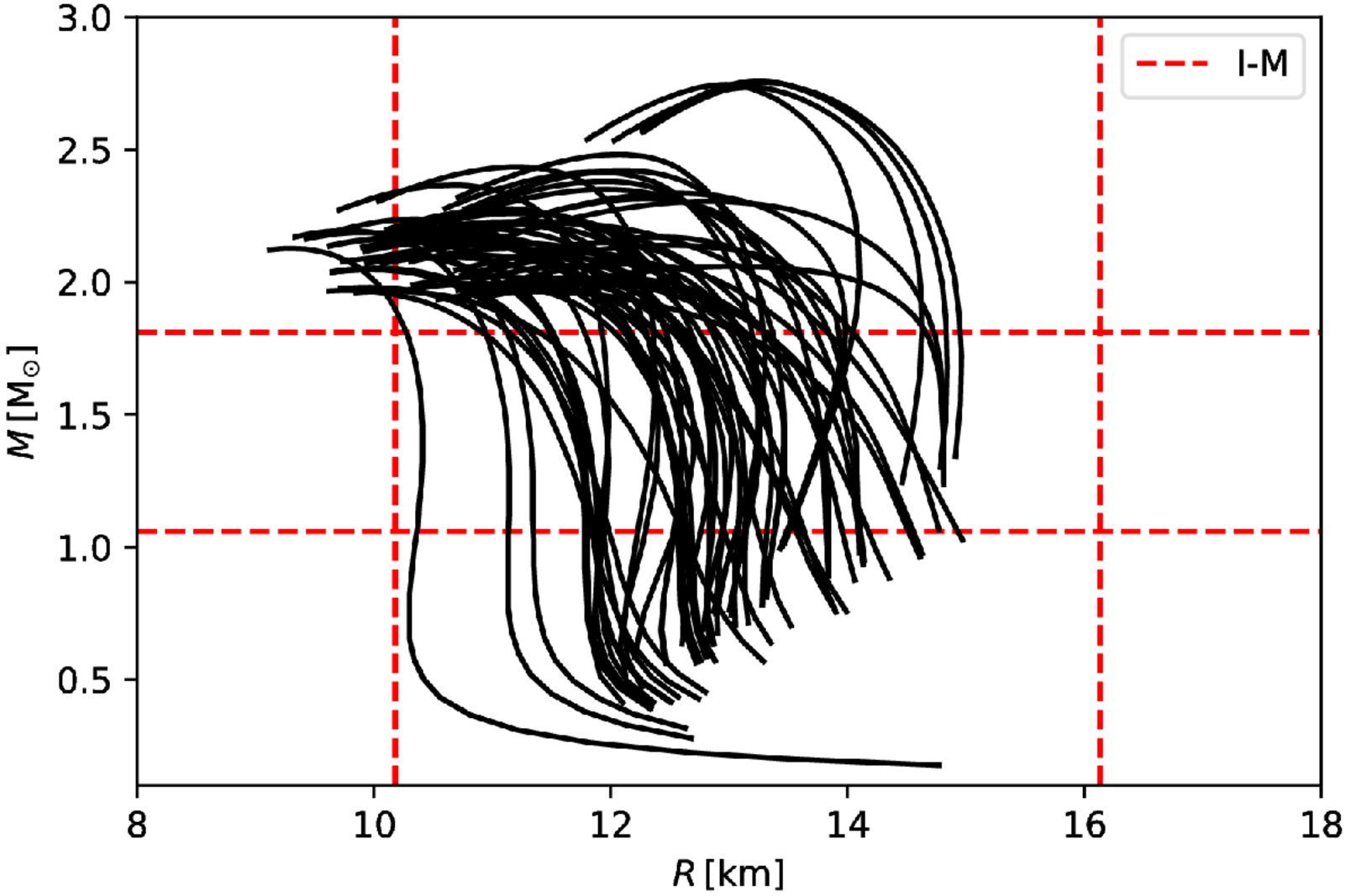

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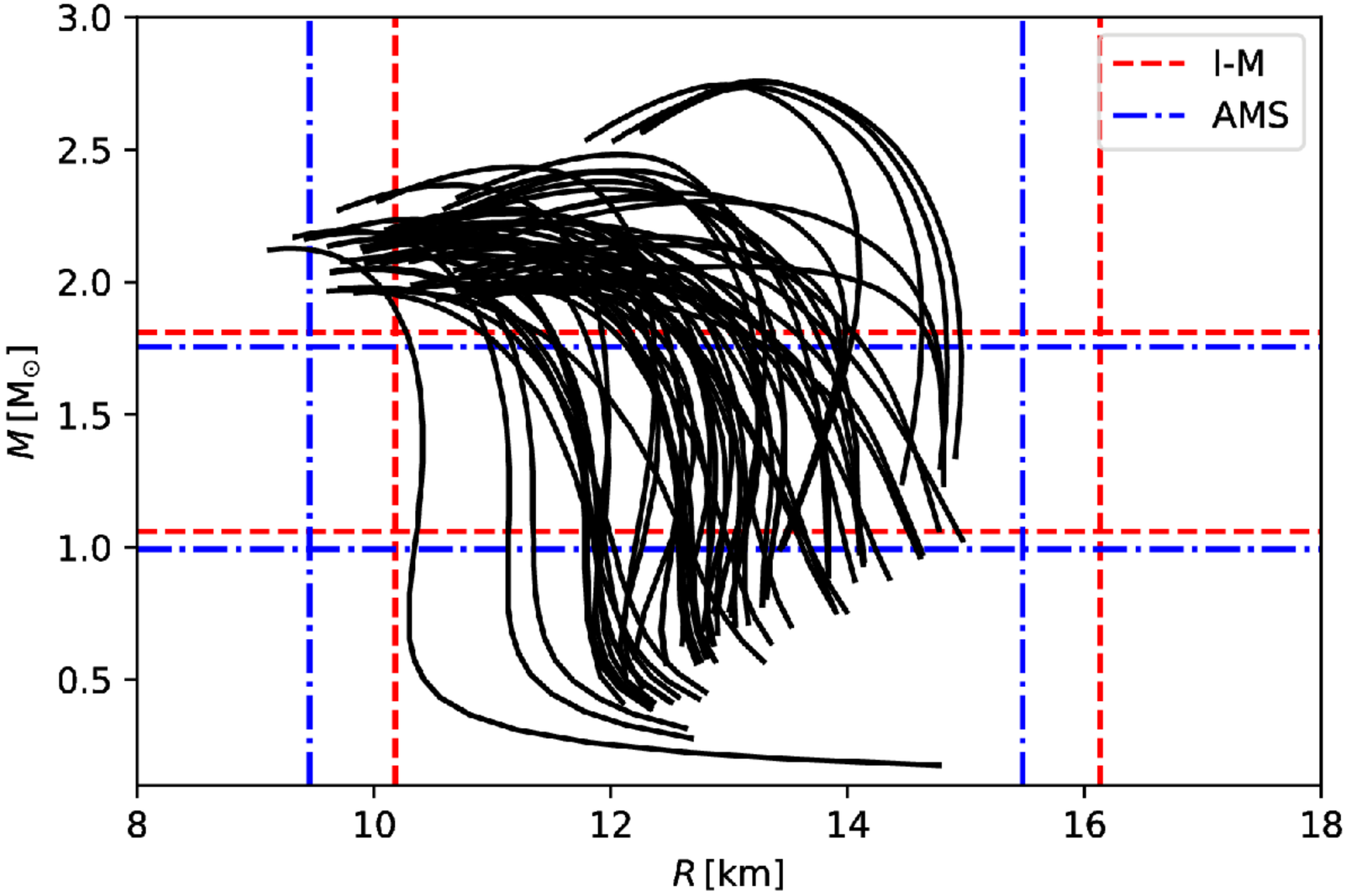

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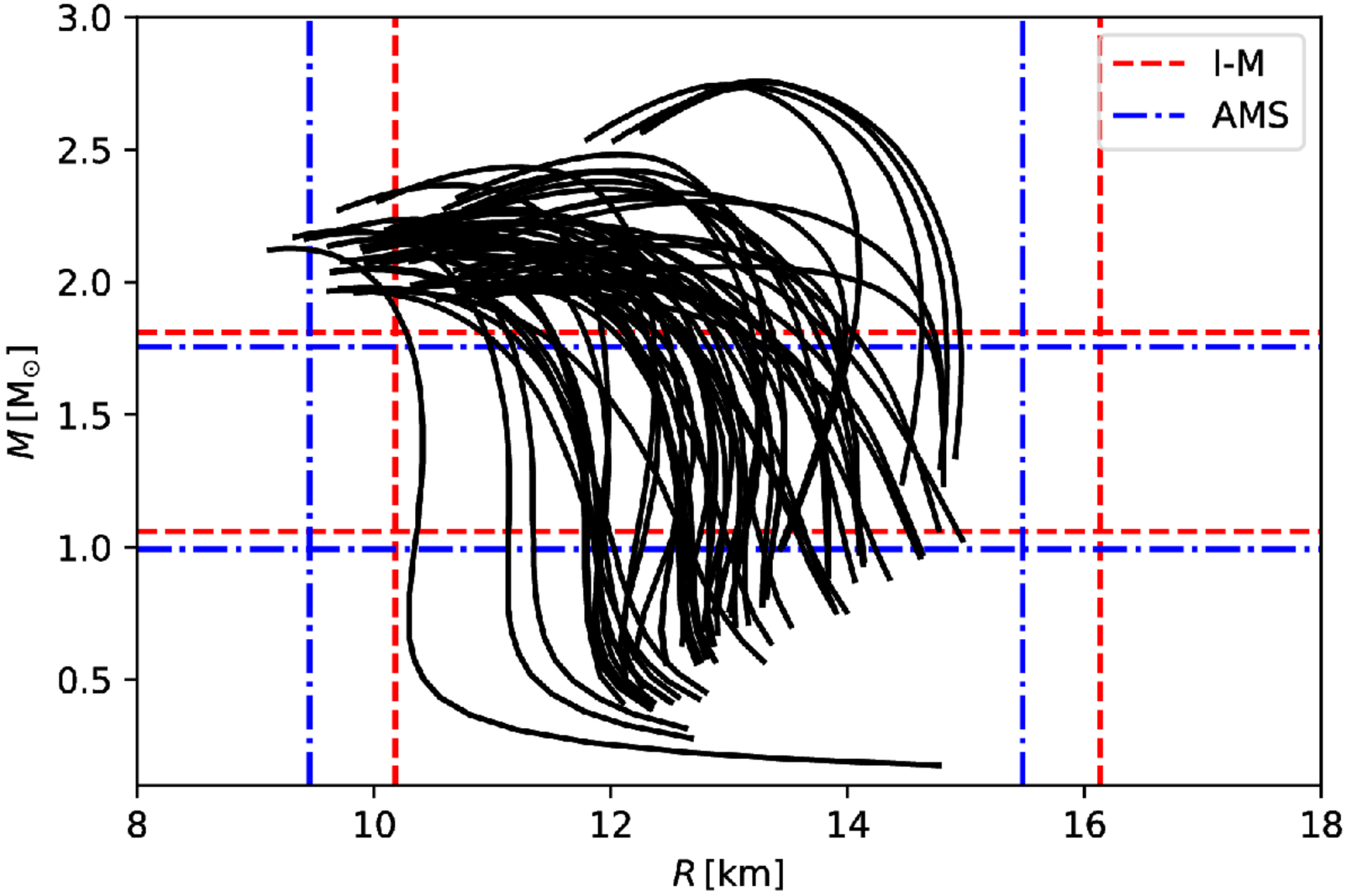

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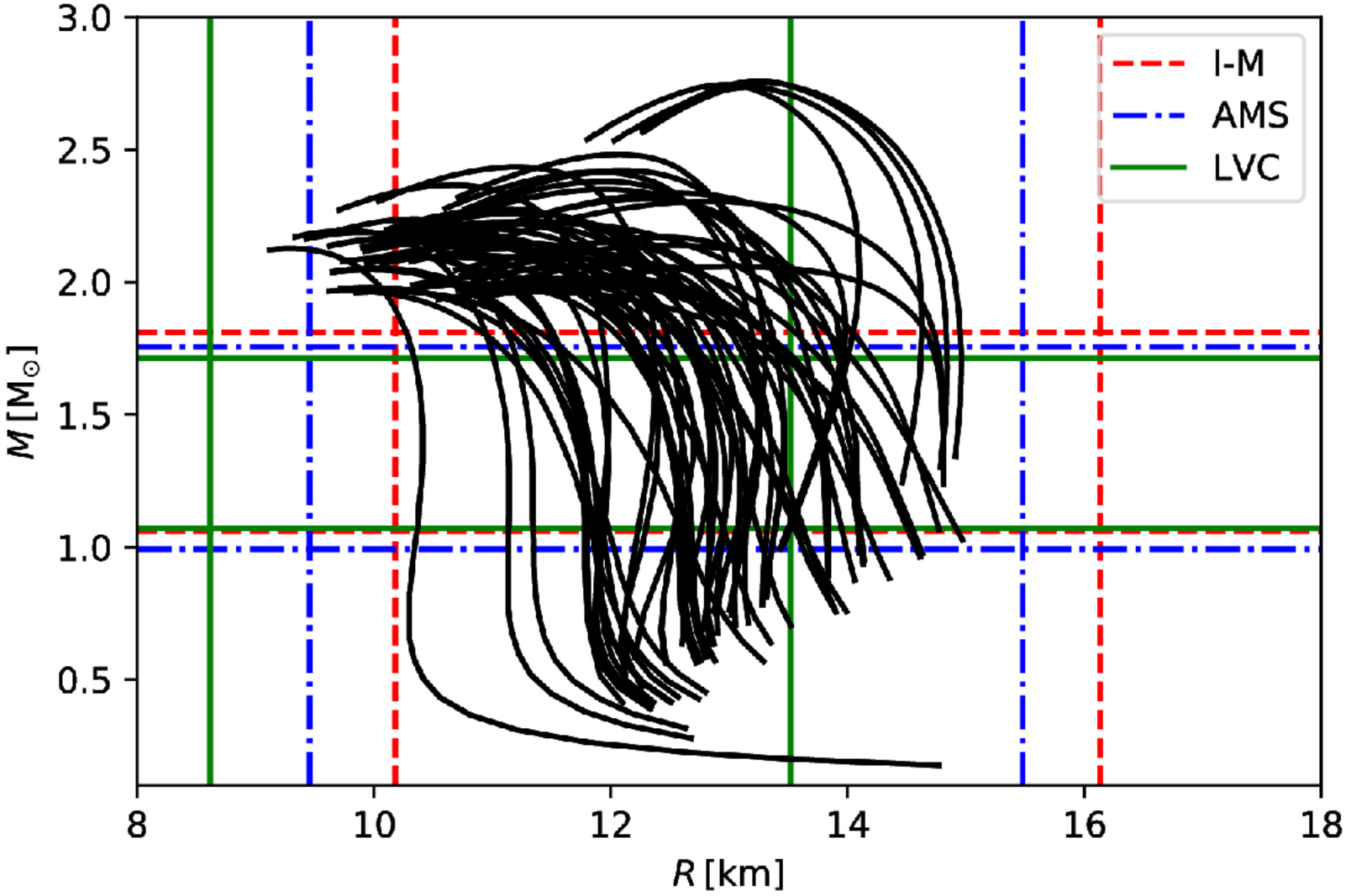

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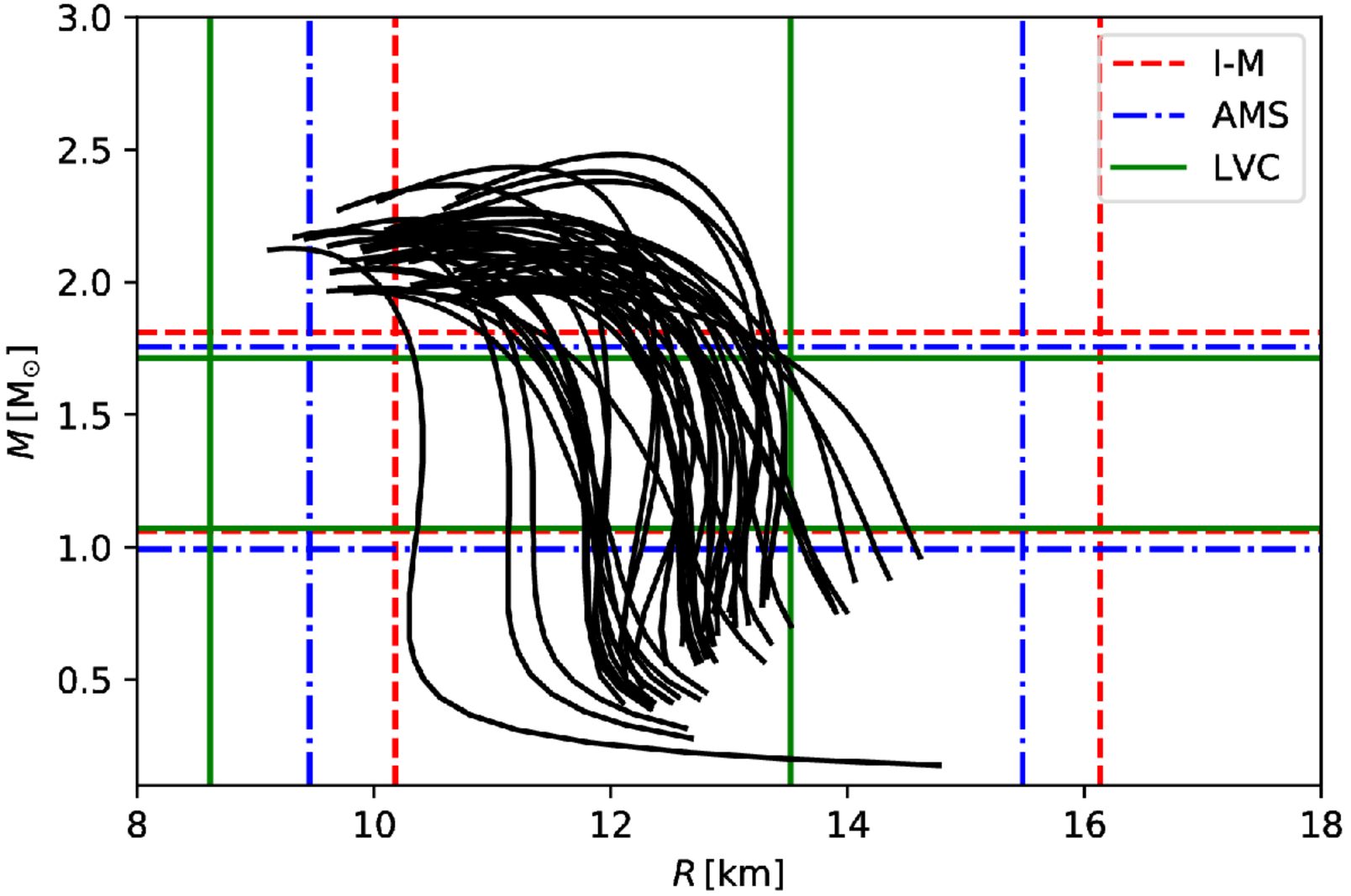

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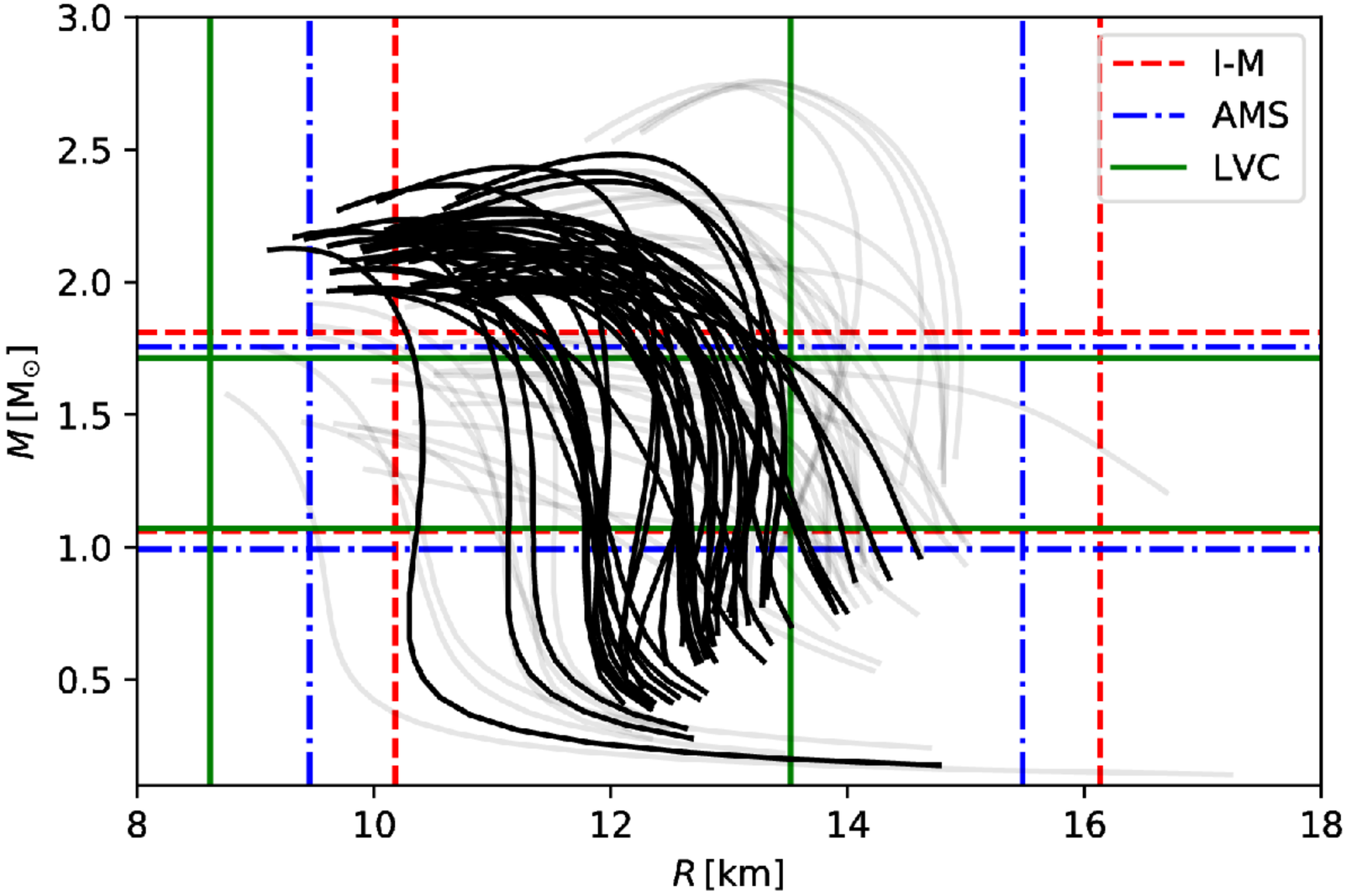

(Quasi) Universal relations

Yagi & Yunes (2013)

(Quasi) Universal relations

I

Moment of inertia

Yagi & Yunes (2013)

(Quasi) Universal relations

I ***LOVE***

Moment of inertia Love Number

Yagi & Yunes (2013)

(Quasi) Universal relations

I	***LOVE***	***Q***
Moment of inertia	Love Number	Quadrupole

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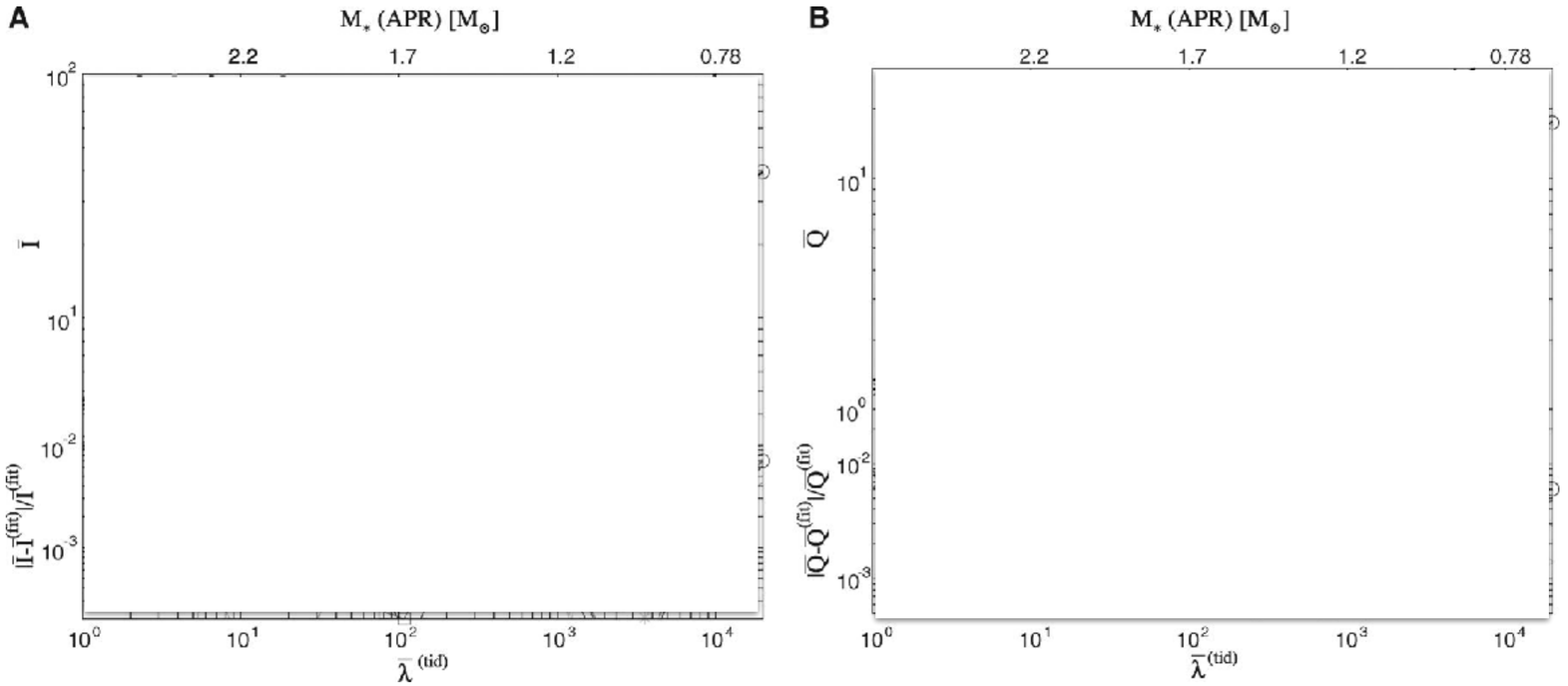

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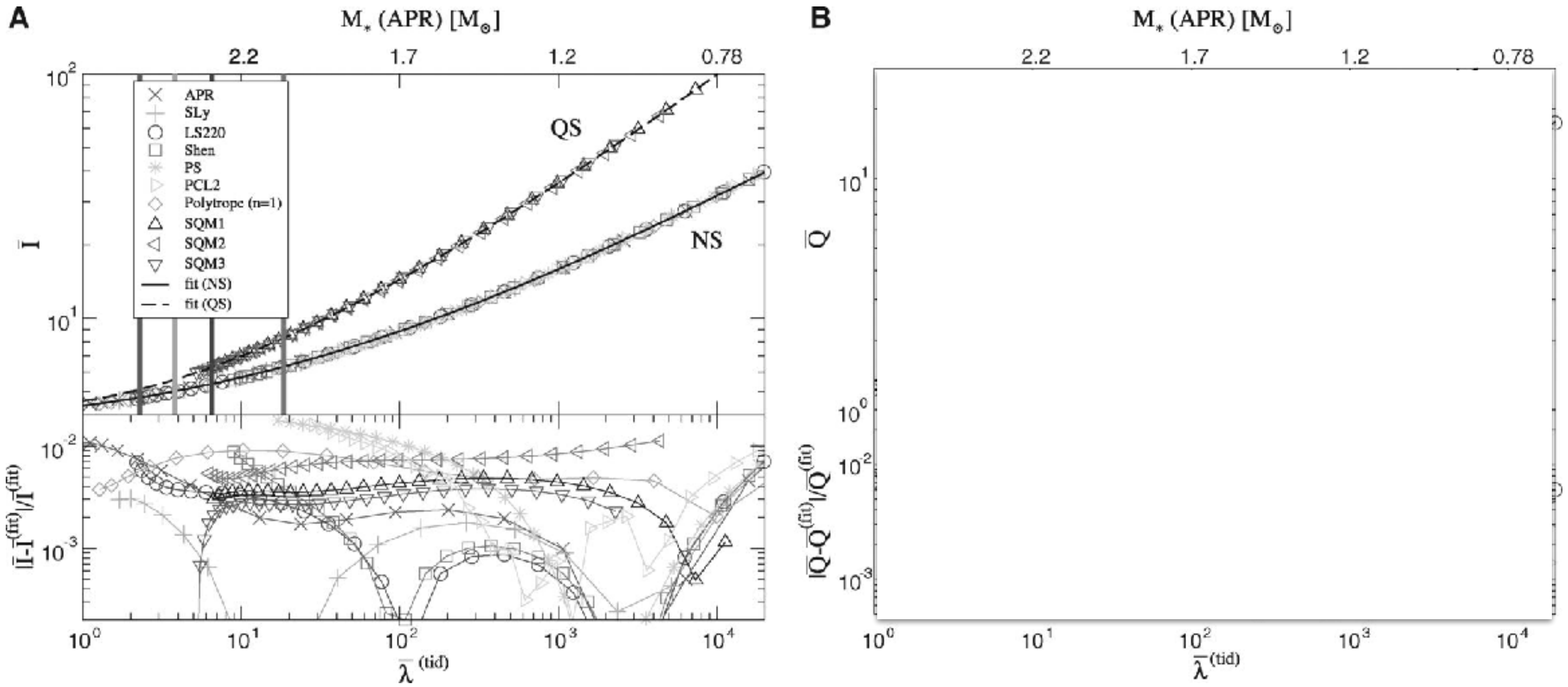

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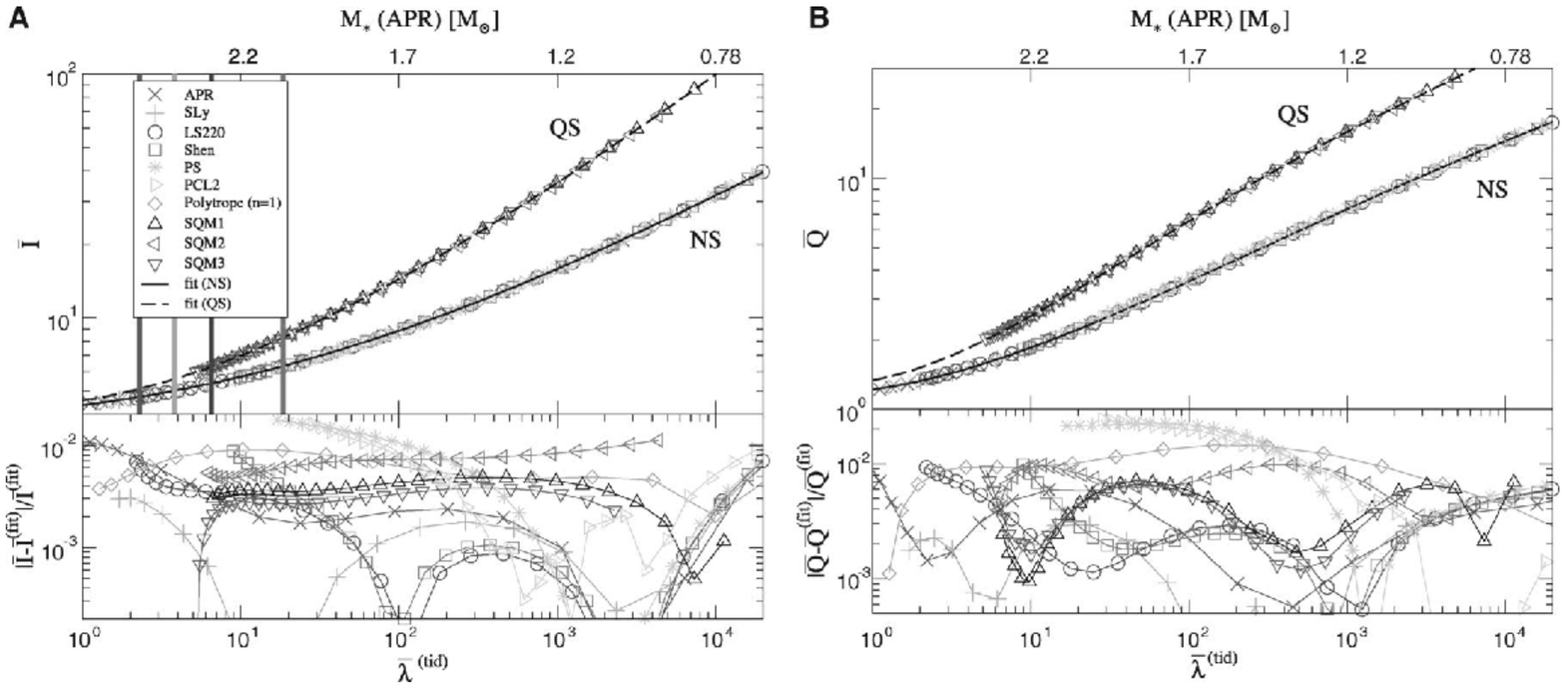


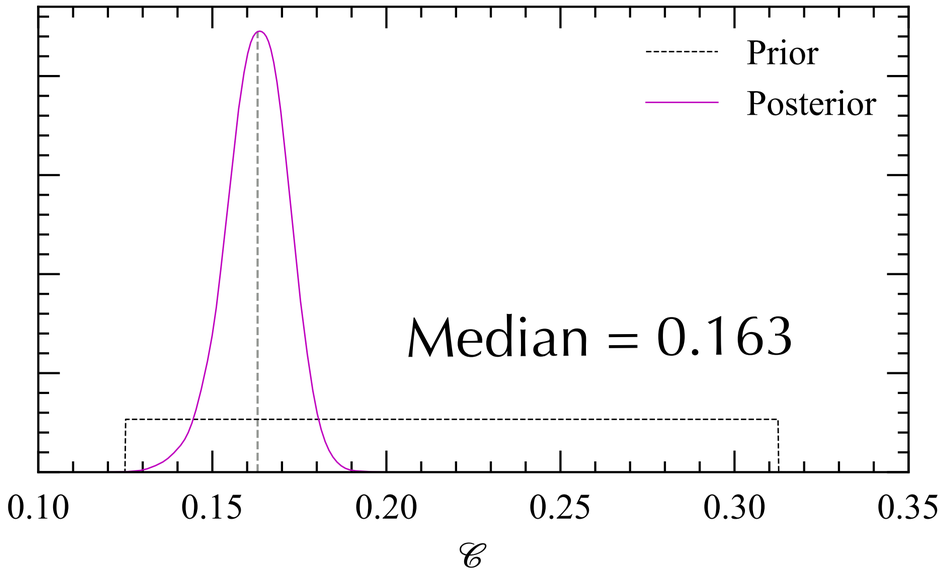
Yagi & Yunes (2013)

An inference scheme to get astrophysical properties

Landry & Kumar (2017)
Silva, Holgado, **ACA** & Yunes (2020)

An inference scheme to get astrophysical properties

$$P(GM/Rc^2 \mid \text{NICER})$$



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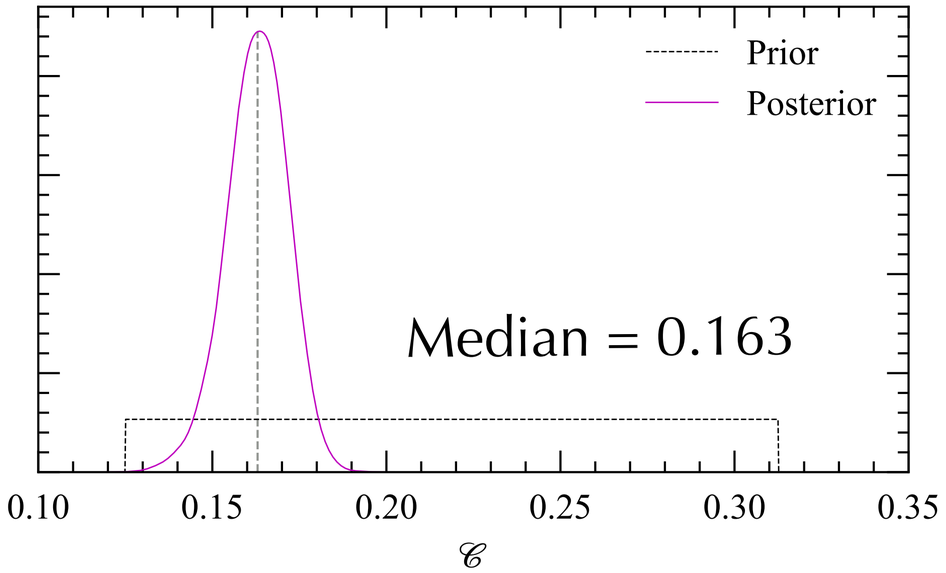

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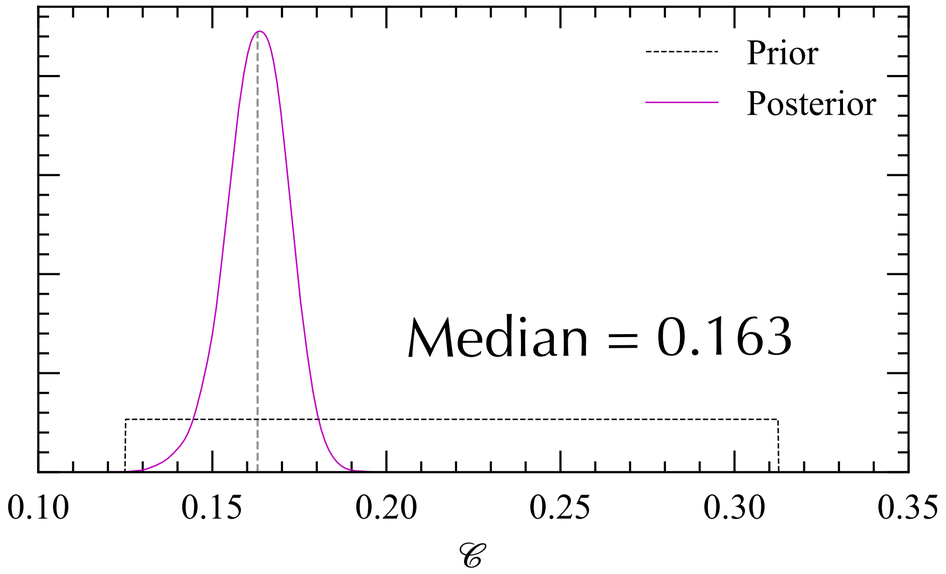

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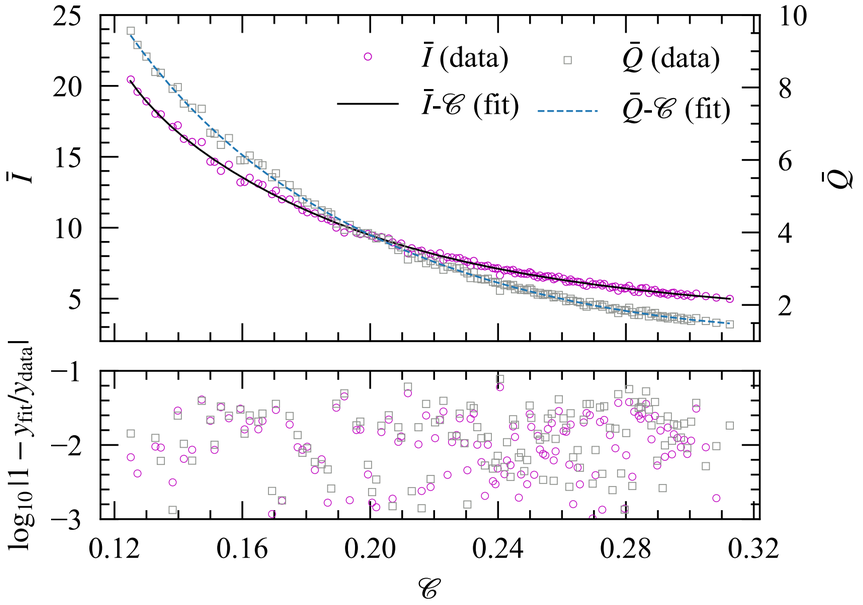
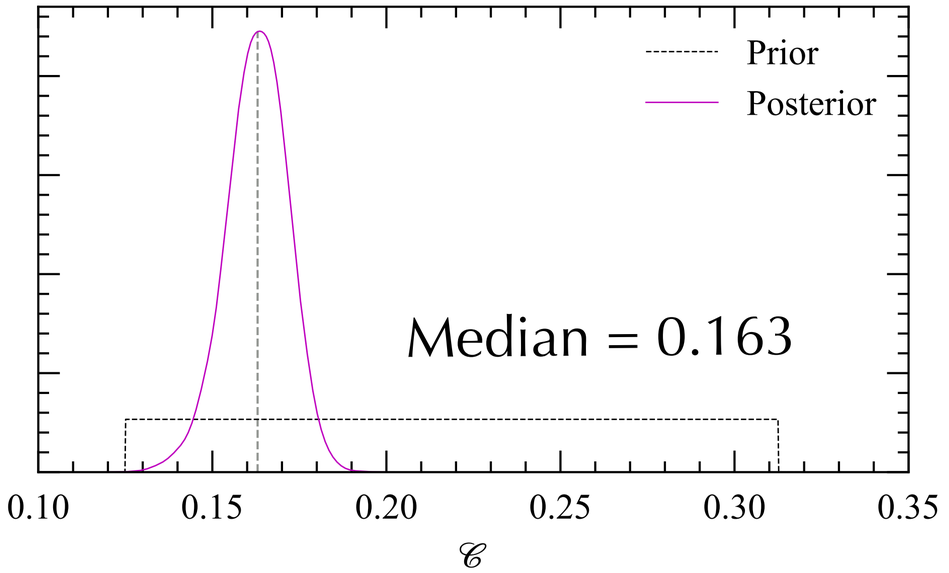
An inference scheme to get astrophysical properties

$$P(y \mid \mathscr{C}) \equiv (2\pi\sigma_y^2)^{-1/2}\left[-\frac{(y-y_{\rm fit})^2}{2\sigma_y^2}\right] \quad \times \quad P(GM/Rc^2 \mid \text{NICER})$$

$$\sigma_y \equiv \epsilon_y^{\rm max} y_{\rm fit}/1.645$$





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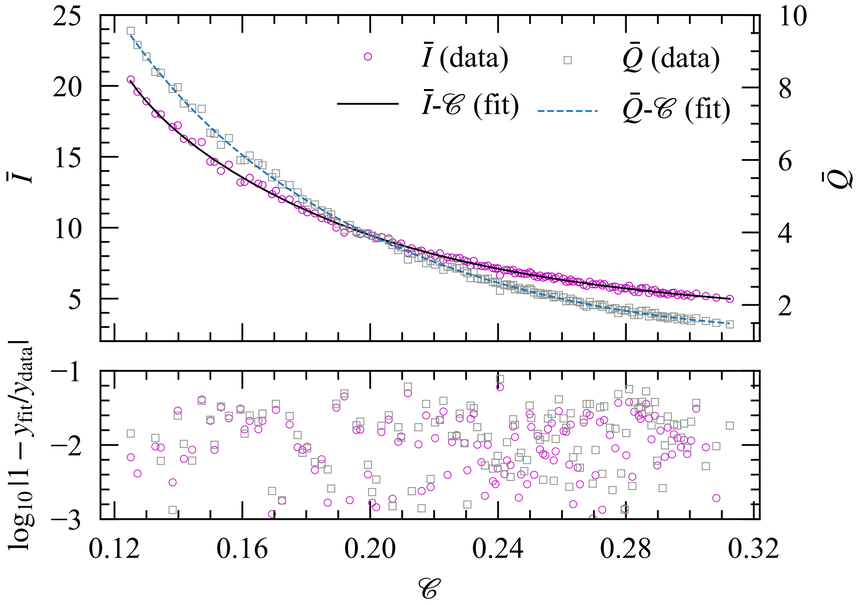

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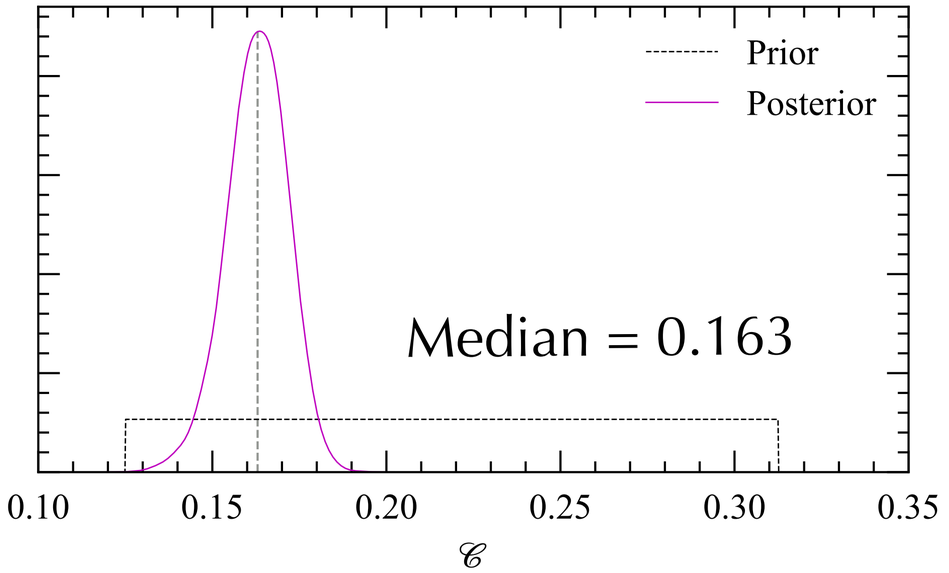

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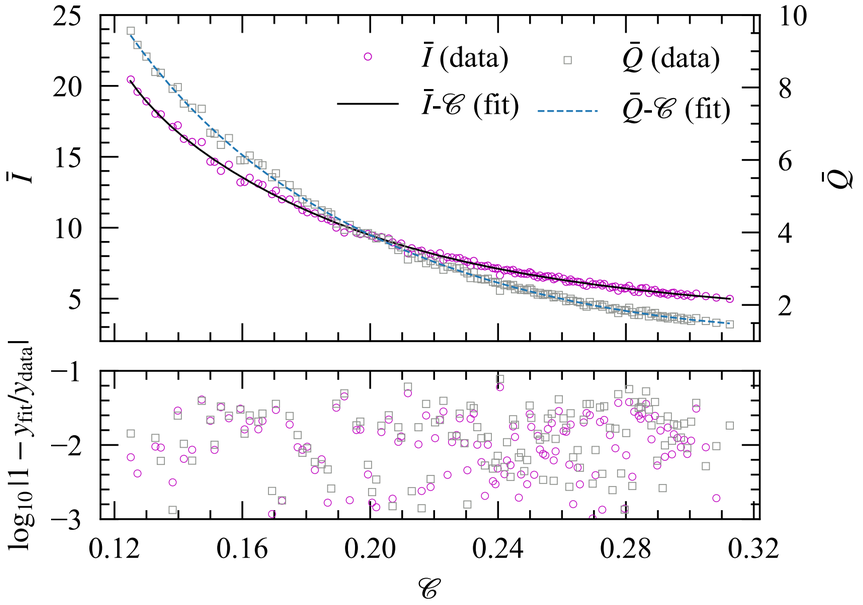

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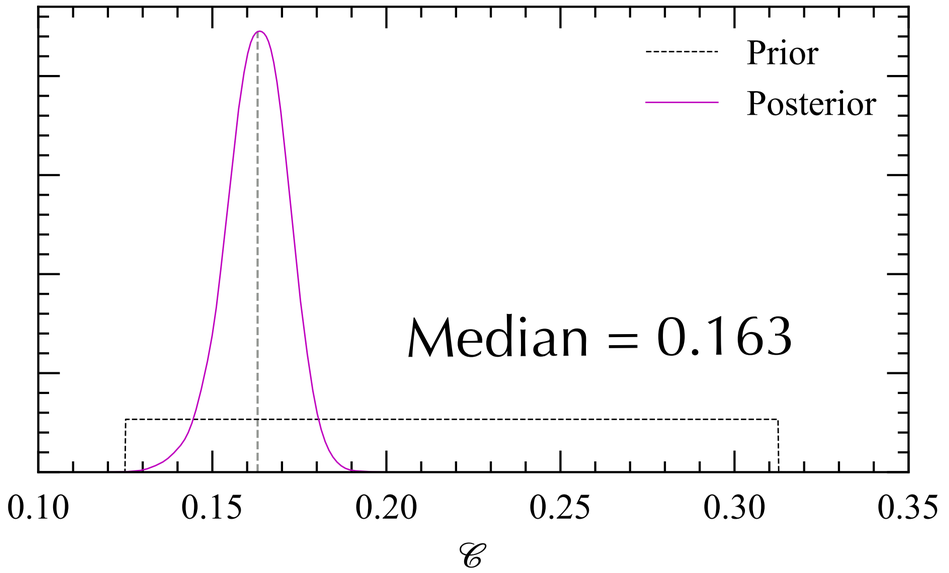

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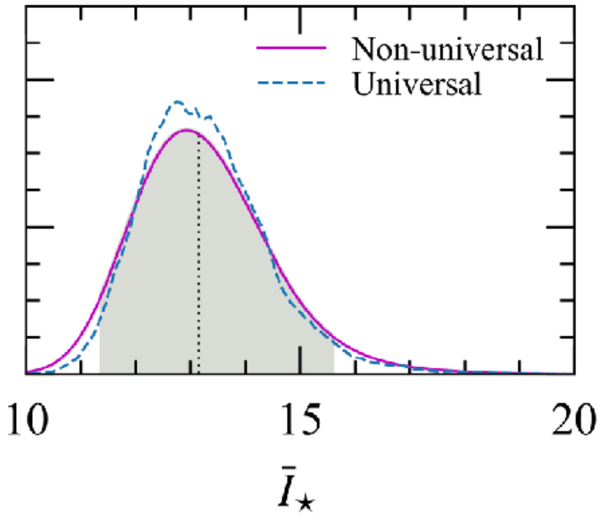

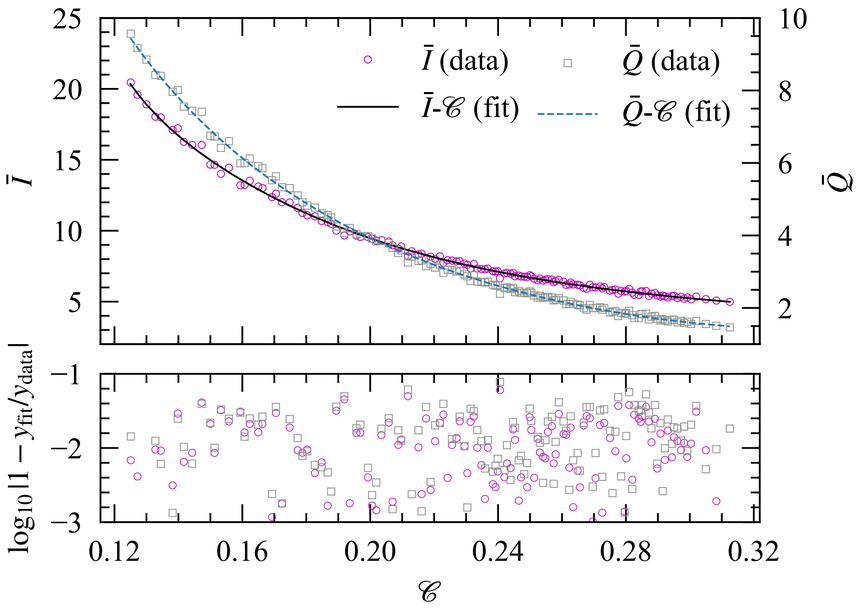

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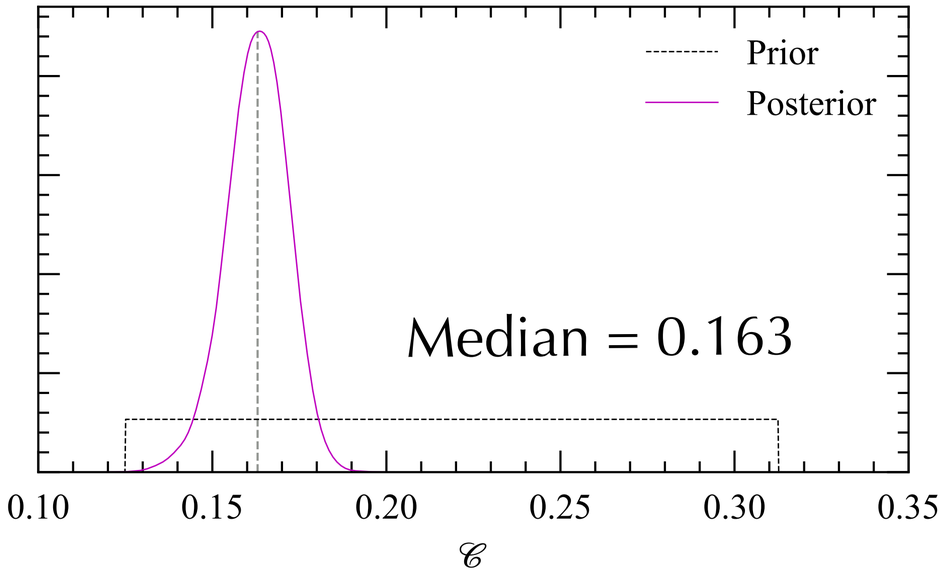

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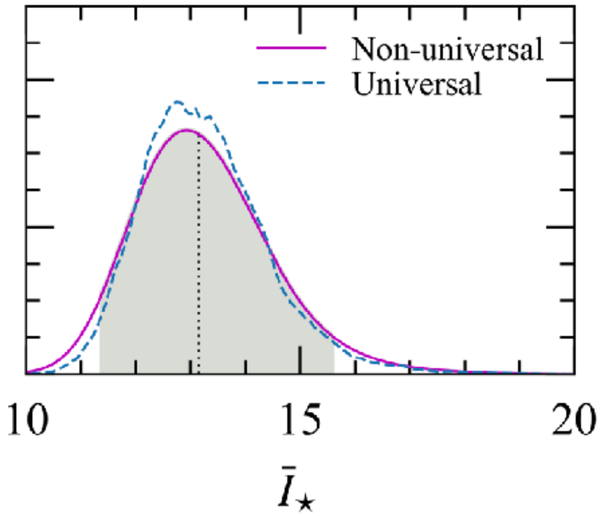

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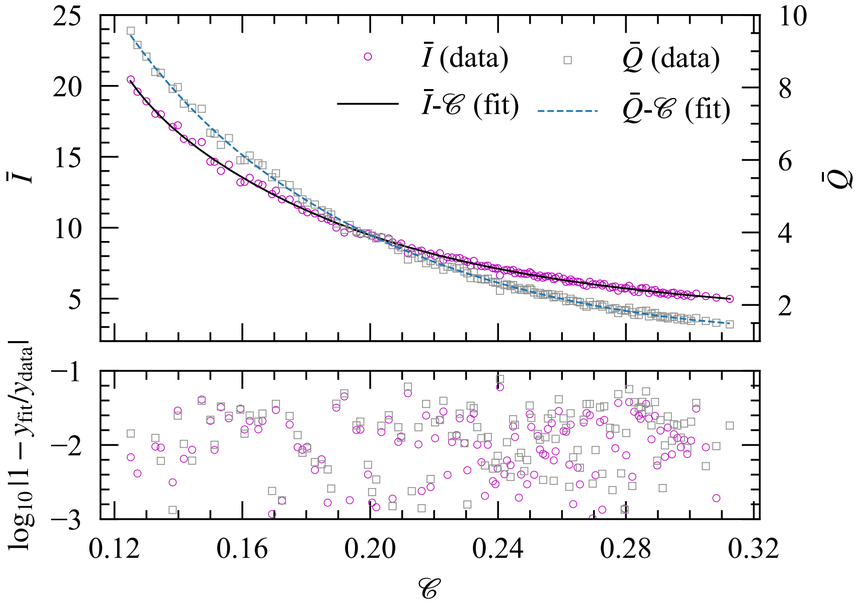

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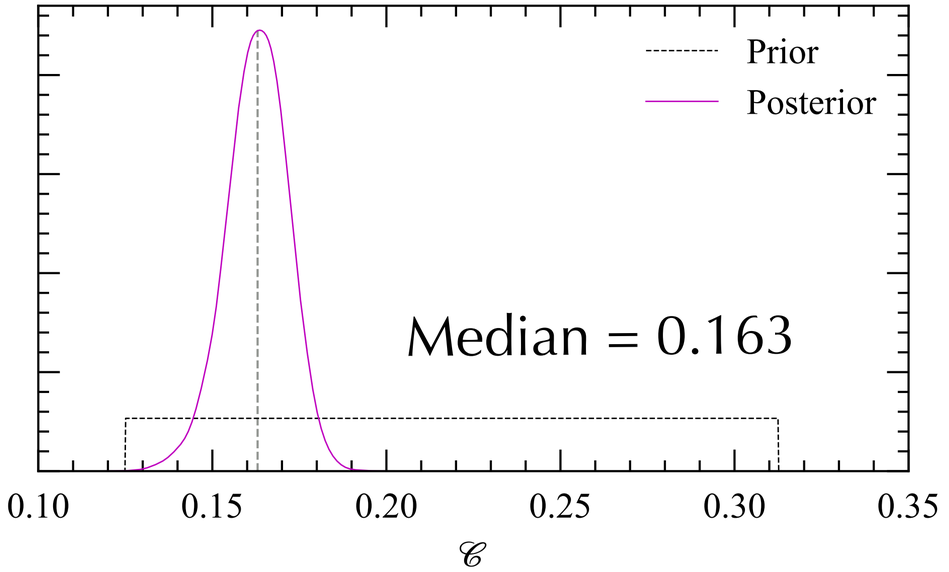

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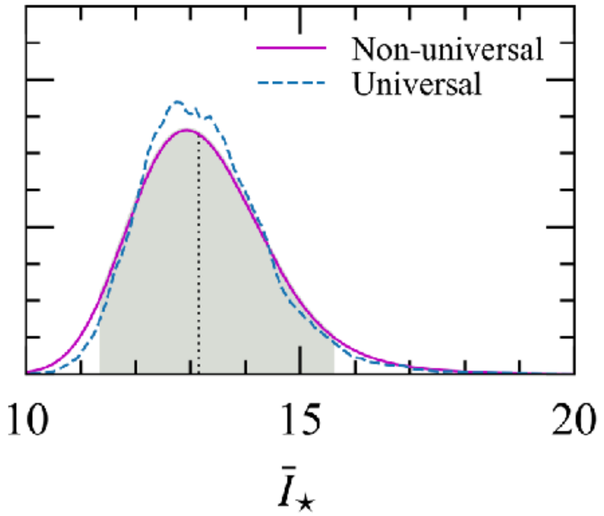

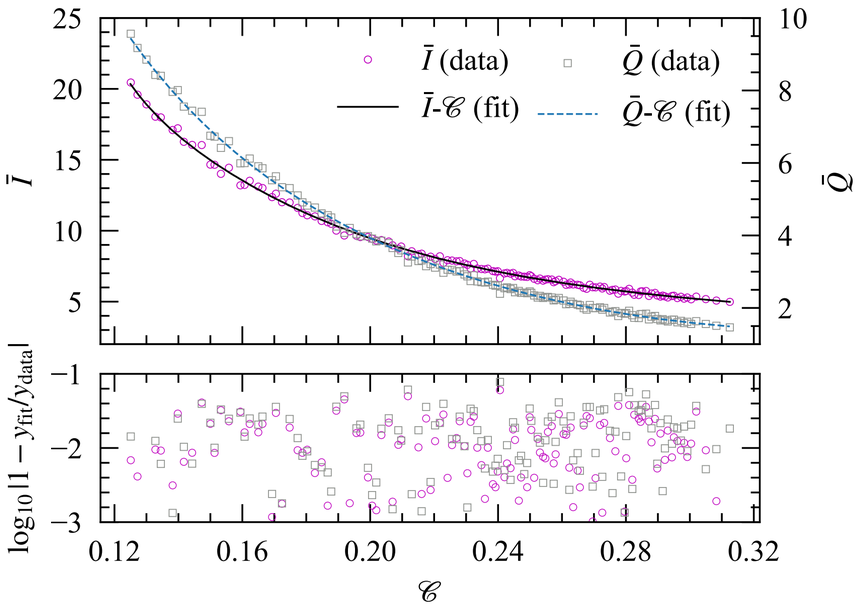

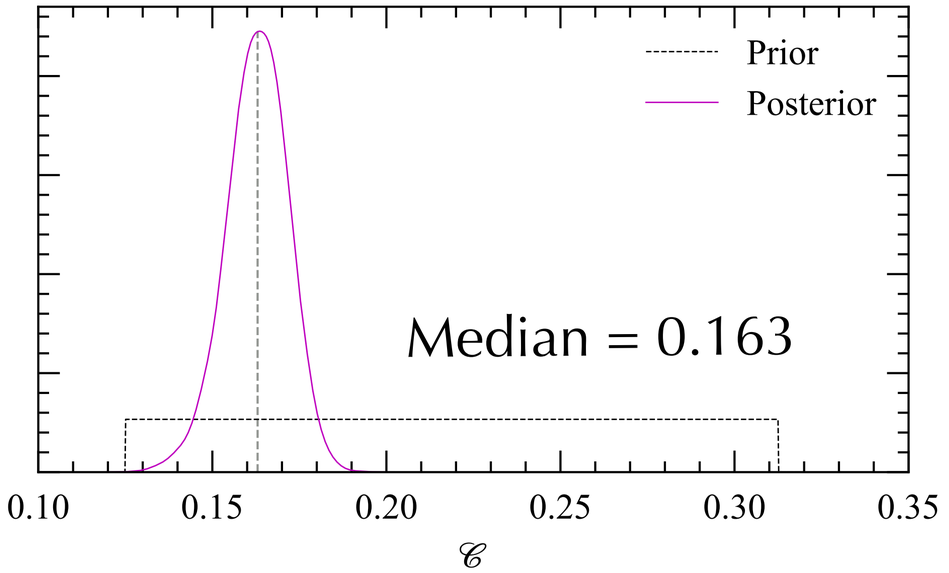

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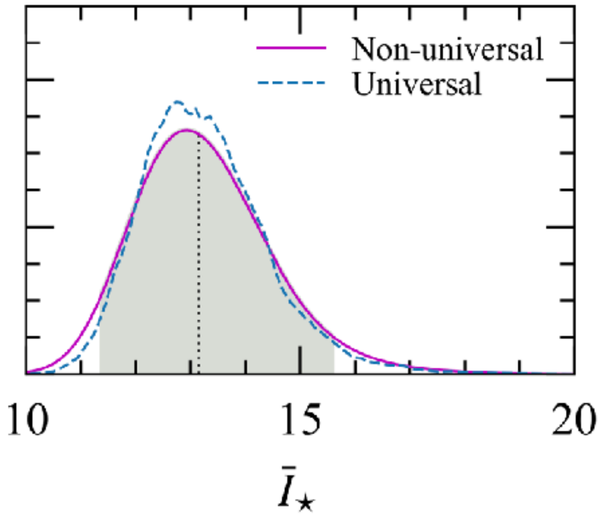

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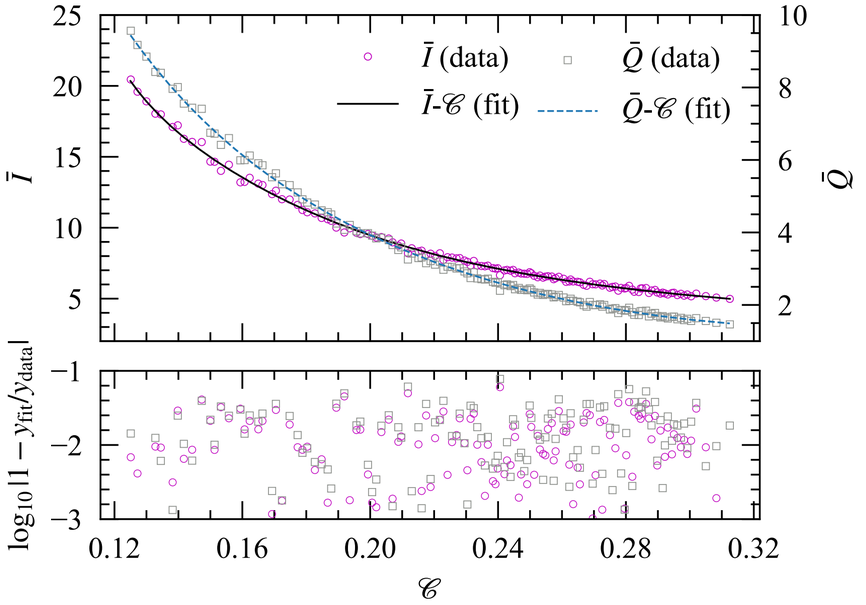

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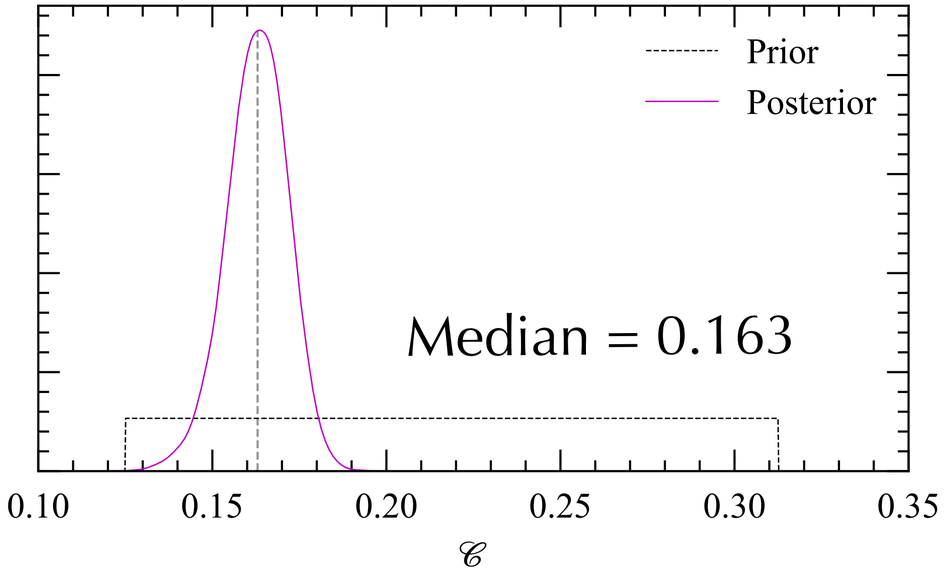

Parameter	Median	PSR J0030+0451	
$\bar{I}_\star$ (10)	1.31	$I_\star$ (10^{45} g cm^2)	1.71
$\bar{\lambda}_\star$ (10^2)	4.97	$Q_\star$ (10^{43} g cm^2)	1.49
$\bar{Q}_\star$	5.92	$e_\star$ (10^{-1})	1.56

Landry & Kumar (2017)
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A multimessenger test of general relativity

Courtesy of Hector Silva

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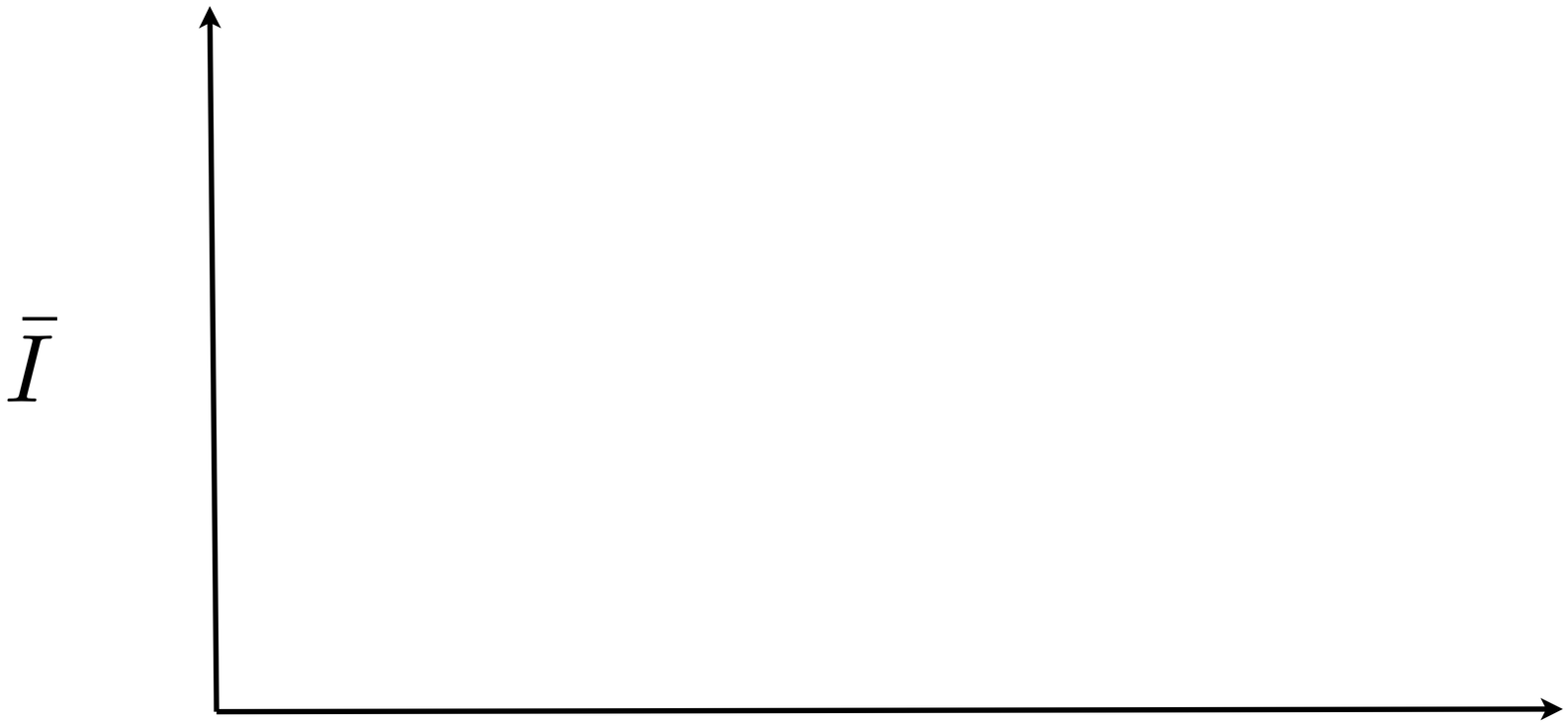

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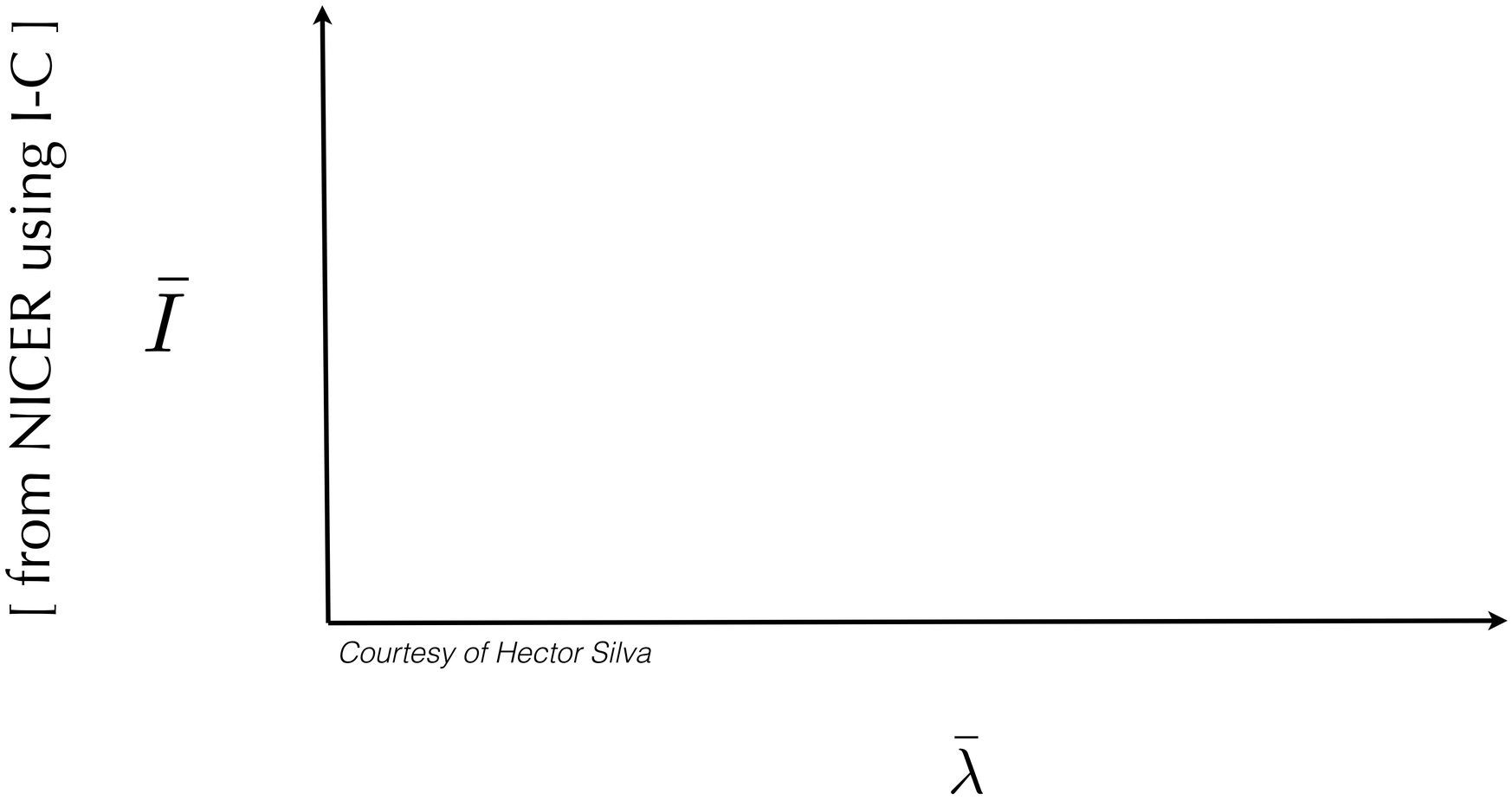

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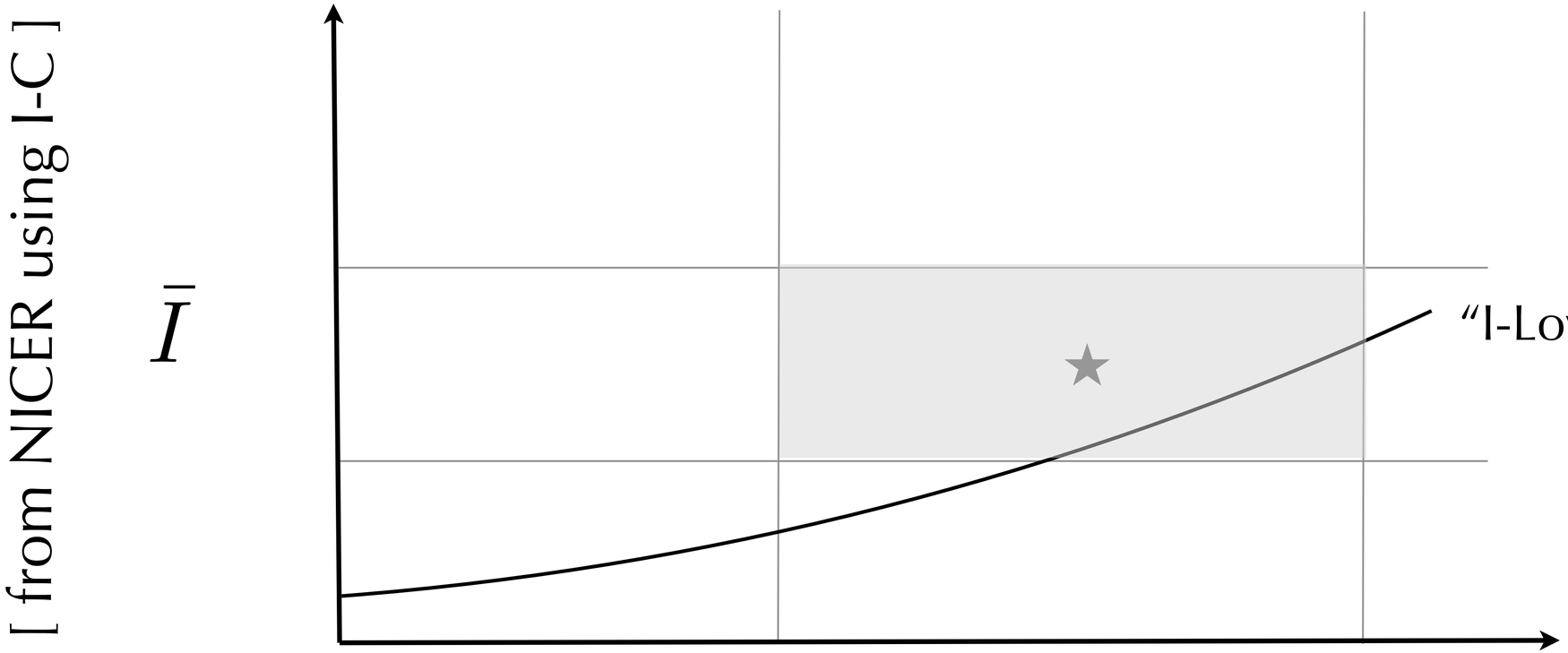

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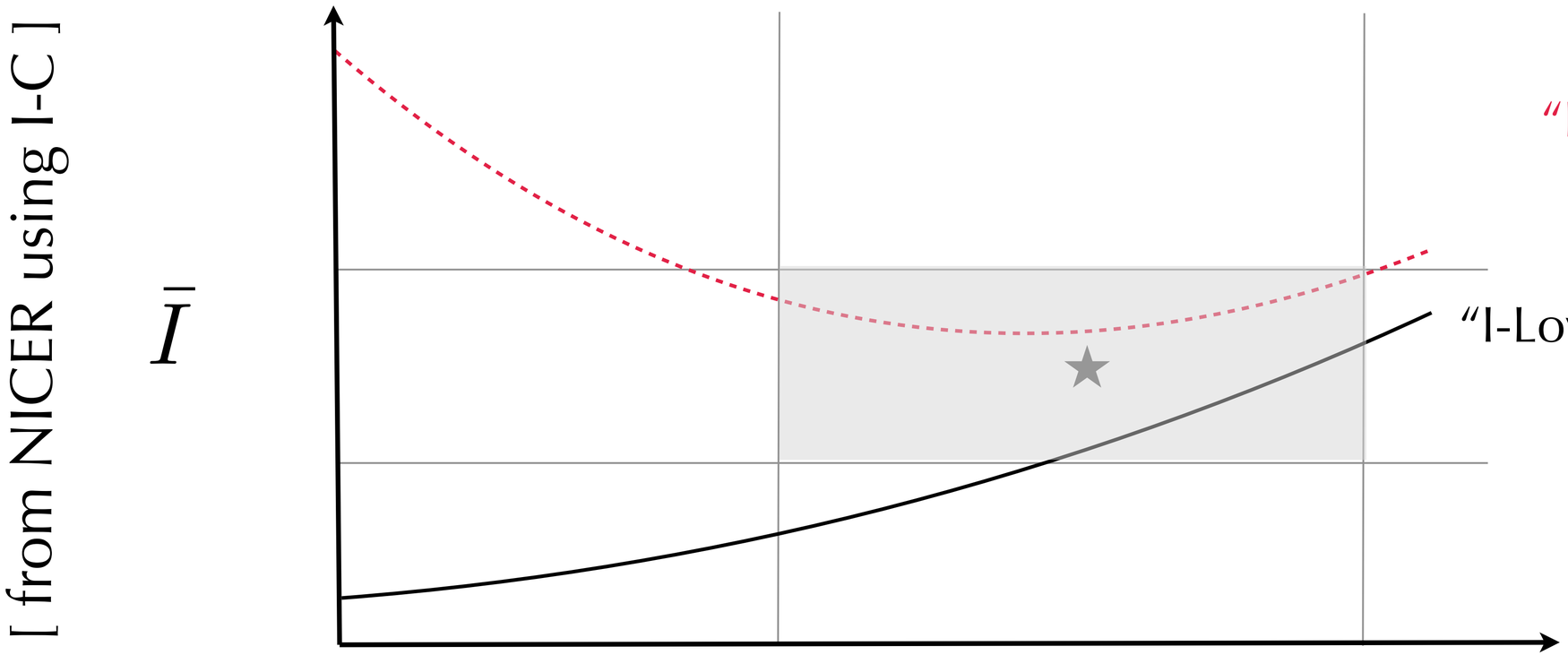

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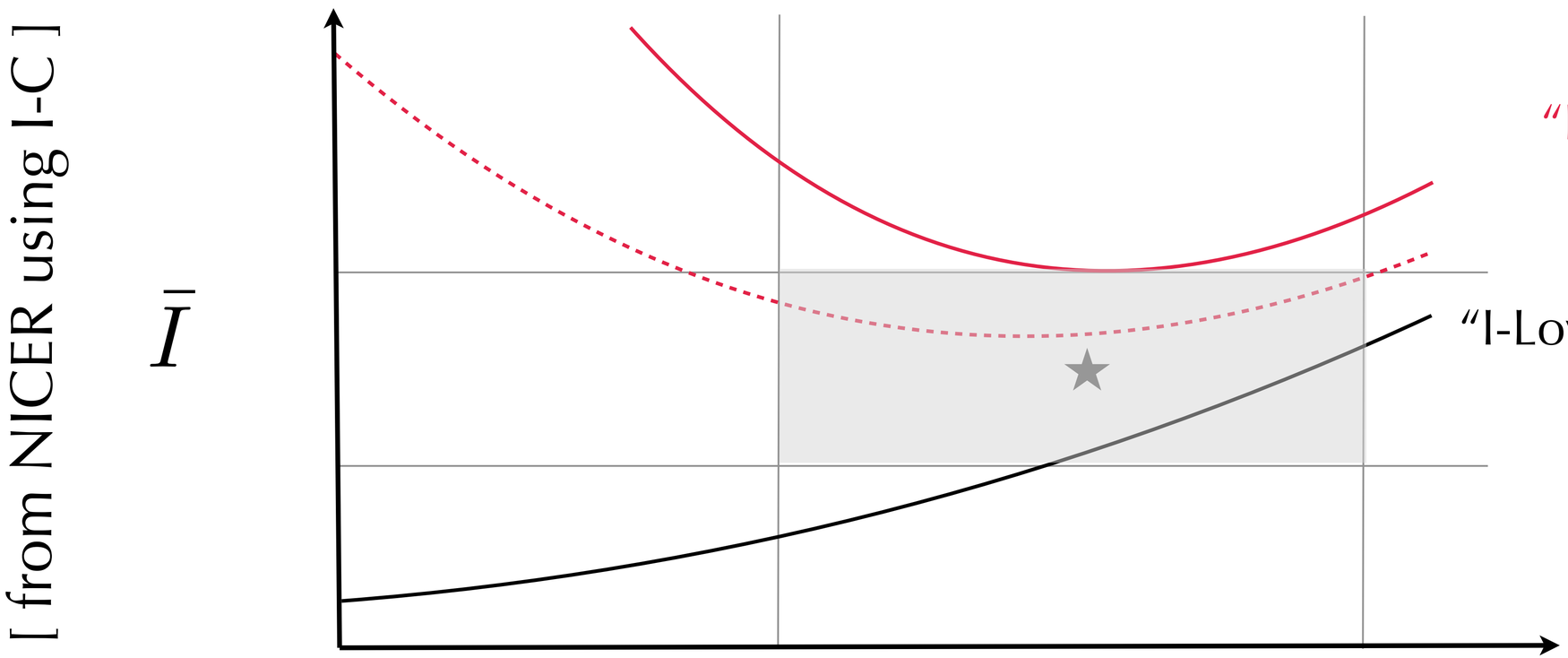

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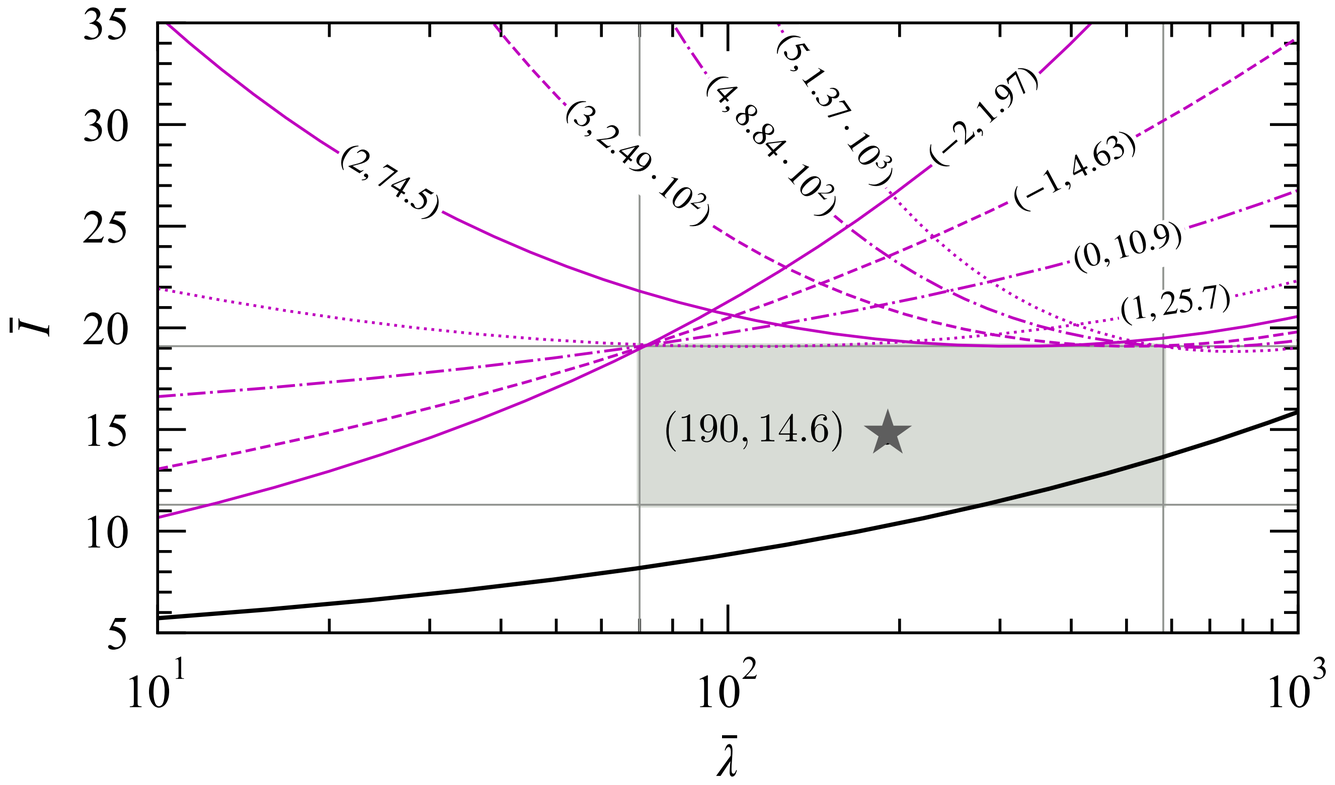

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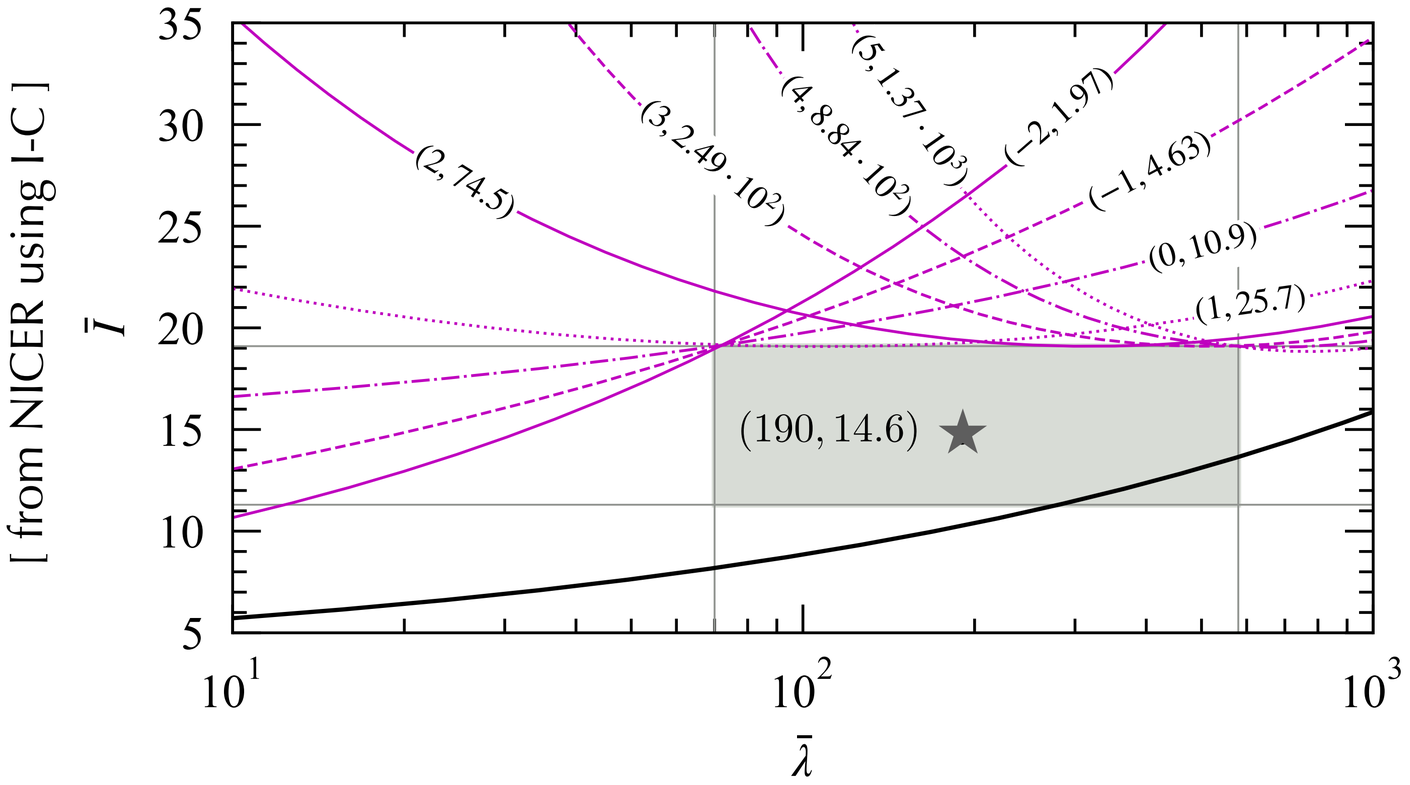
Newtonian | post-Minkowskian | non-GR



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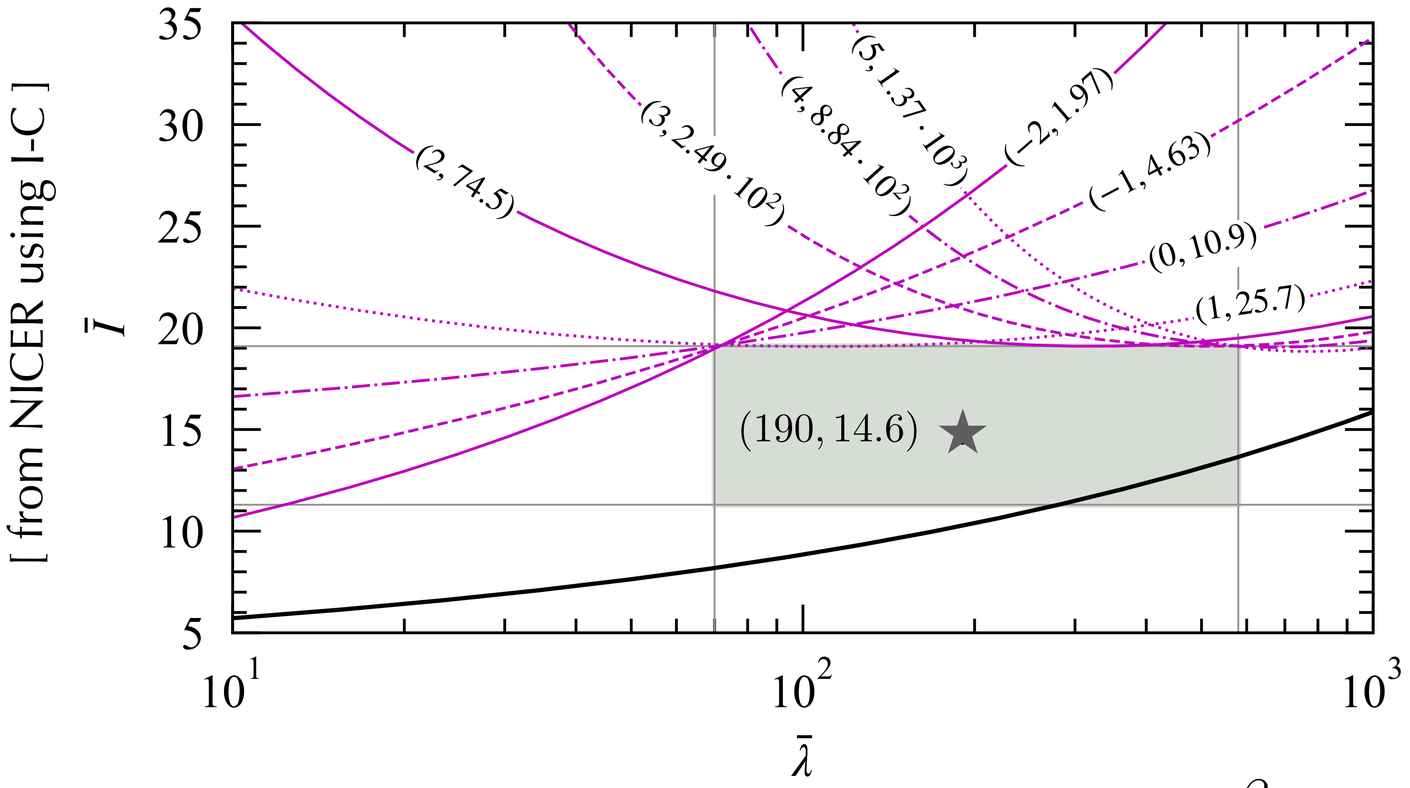

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$$\beta_{\rm CS} \approx 3\,(\alpha_{\rm CS}/M^2)^2\,,\ b_{\rm CS} = 4$$

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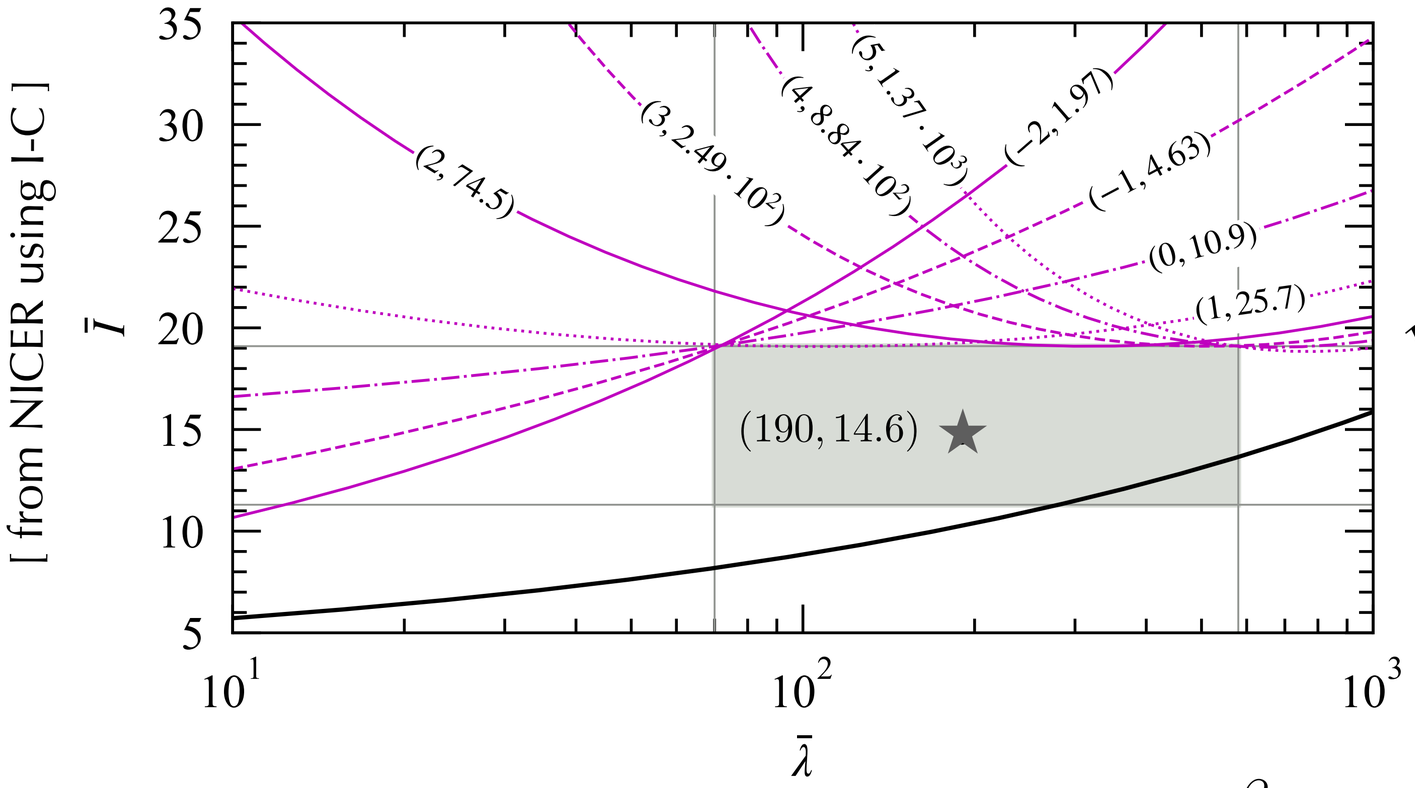

$$\sqrt{\alpha_{\rm CS}} \leqslant 8.5\,{\rm km} \ll 10^8\,{\rm km}$$

$$\beta_{\rm CS} \approx 3\,(\alpha_{\rm CS}/M^2)^2\,,\ b_{\rm CS} = 4$$

Silva, Holgado, **ACA** & Yunes (2020)

Conclusions

- We derived the first measurements of the **moment of inertia**, the **quadrupole moment**, the **surface eccentricity** and the **Love number** of an isolated neutron star.

- We performed the first **theory-agnostic** and **equation-of-state independent** test of general relativity

- Consistency with general relativity places the **most stringent constraint** on **gravitational parity violation** to date

Thank you!

More details: arXiv:2004.01253

Backup

Precision Tests of General Relativity

Theory-Specific:

Theory-Agnostic:

Precision Tests of General Relativity

Theory-Specific:

- e.g., *Extra Scalar Field, Lorentz-violating, Massive Gravity, Nondynamical fields*

c.f., Berti, et. al., CQG Topical Review (2015)
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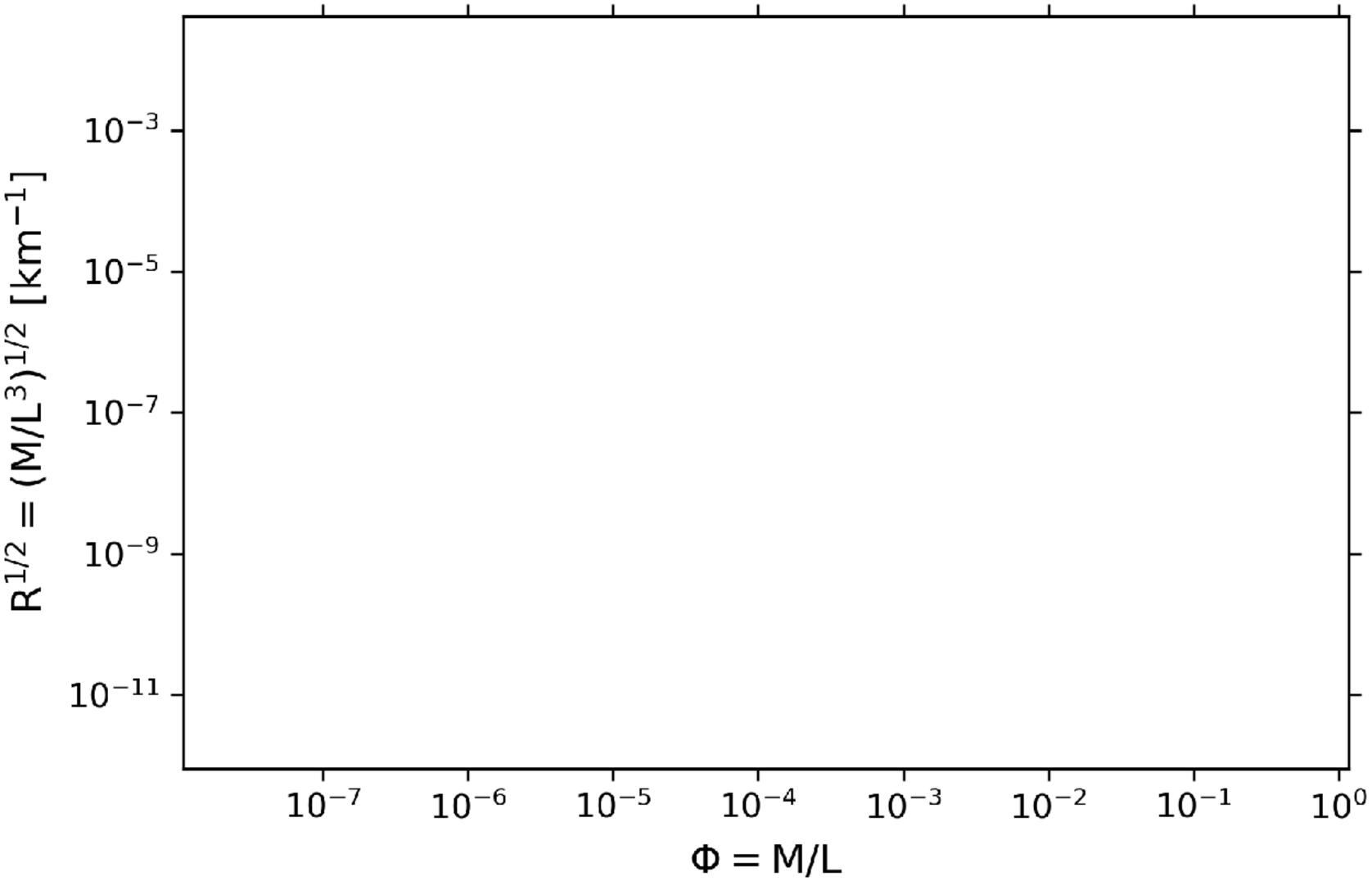
Theory-Agnostic:

Will & Nordtvedt (1972)

- Parameterized post-Newtonian (PPN)
- **Bumpy BHs** *Ryan (1995); Collins & Hughes (1995)*
- Parameterized Post-Einsteinian (PPE)

Yunes & Pretorius (2009)

The strong-field regime



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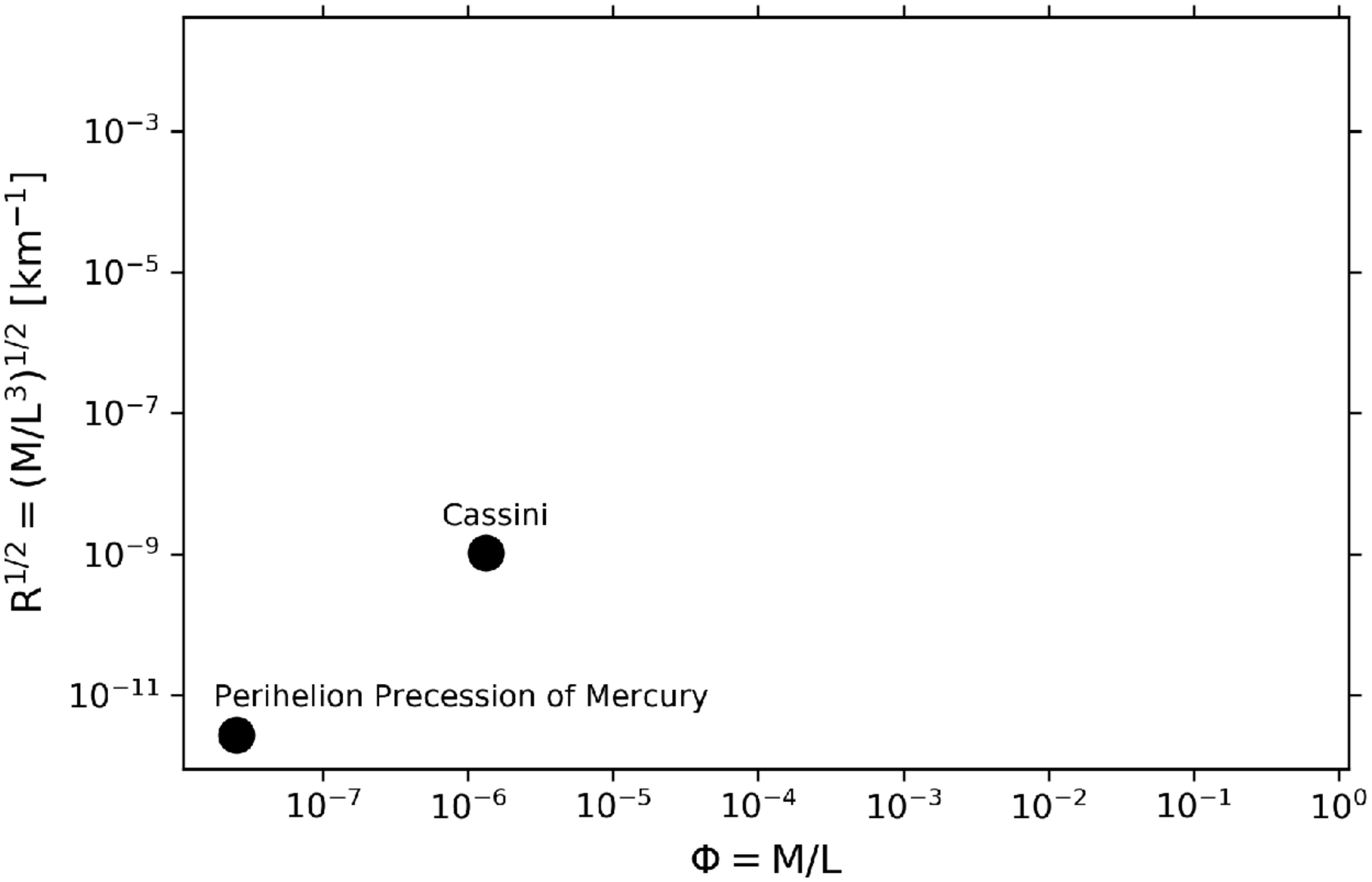

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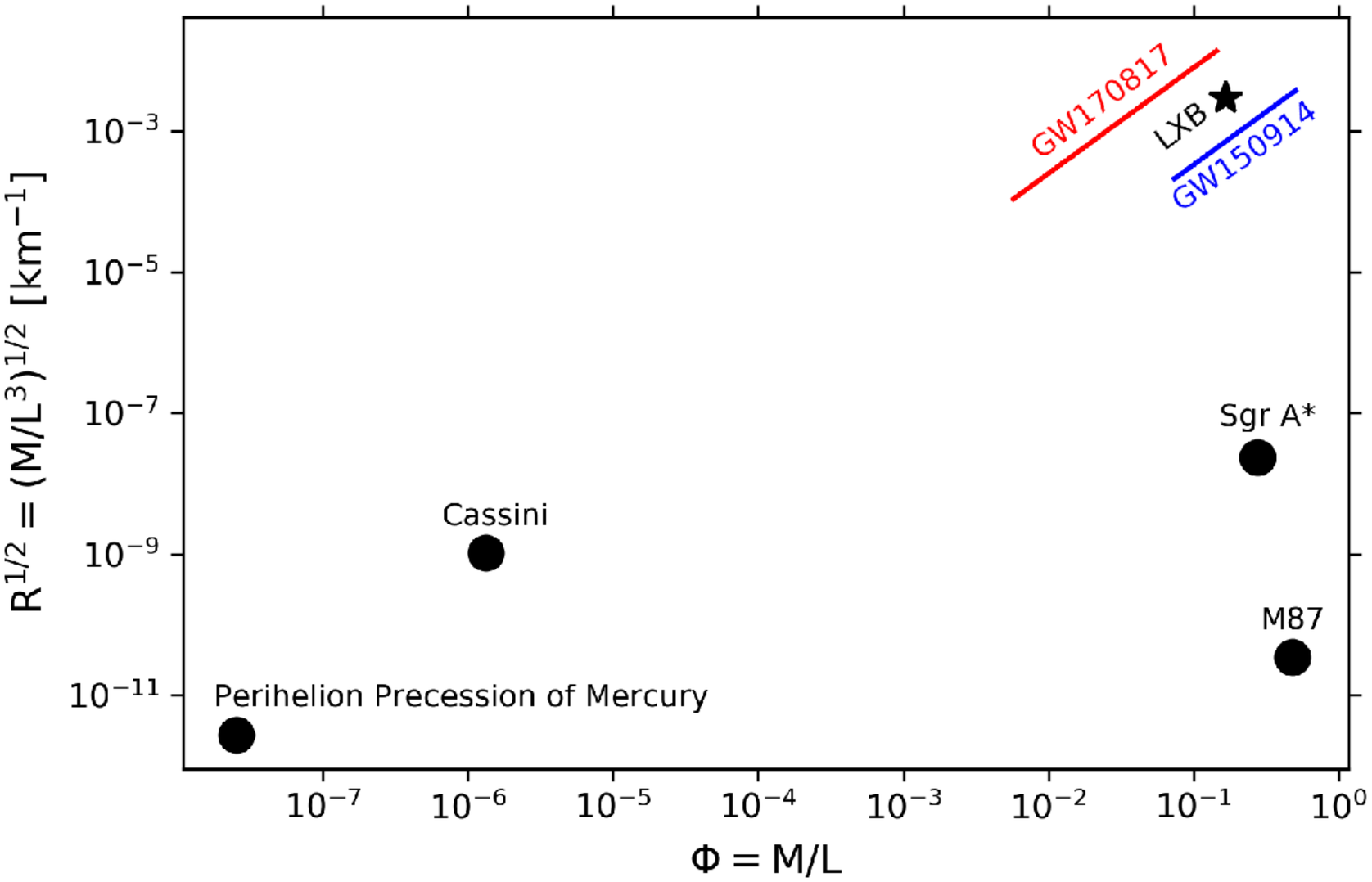

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