

DRAFT VERSION MARCH 29, 2026  
Typeset using L<sup>A</sup>T<sub>E</sub>X **modern** style in AAS<sub>T</sub>eX61

# DOES THE GRAVITATIONAL-WAVE CANDIDATE S251112CM IMPLY A NEUTRON-STAR MOON?

ABRAHAM LOEB<sup>1</sup>

<sup>1</sup>*Astronomy Department, Harvard University, 60 Garden St., Cambridge, MA 02138, USA*

## ABSTRACT

I propose that the recent gravitational-wave candidate S251112cm involves a neutron-star moon around a black hole or a neutron star primary, formed through a head-on collision of two neutron stars.

## 1. INTRODUCTION

A giant impact of a Mars-size proto-planet named Theia with proto-Earth, 4.5 billion years ago, may have ejected debris that coalesced to form our Moon. Computer simulations support this giant impact hypothesis (cf. [Yuan et al. \(2023\)](#) and references therein). Could a moon form through a similar process when two neutron stars collide?

Globular clusters are known to host stellar remnants segregated near their centers. These remnants include stellar-mass black holes and neutron stars. They are typically more massive than the background stars and hence settle towards the cluster center through gravitational segregation (cf. [Teodori et al. \(2026\)](#) and references therein). Near the cluster center, these remnants find each other, creating pairs of black holes that coalesce through the emission of gravitational waves. This natural process could explain the origin of many of the gravitational wave sources detected by the LIGO-Virgo-KAGRA (LVK) collaboration over the past decade, as originally proposed by [Rodríguez et al. \(2015\)](#).

The cores of globular clusters are known to contain an abundant population of neutron stars which appear as pulsars or X-ray sources with a mass of up to  $2.1M_{\odot}$  ([Bagchi et al. 2025](#)). These dense environments can lead to the formation of pairs of black holes or neutron stars but also to three-body systems that are dynamically unstable, and can result in a head-on collision between two neutron stars under the Kozai-Lidov mechanism ([Naoz 2016](#)).

## 2. NEUTRON-STAR MOON

When two neutron stars collide head-on, their merger is expected to form a black hole or a massive neutron star carrying most of their combined masses. However, just as in the collision between Thea and Earth, a fraction of the mass might be ejected as debris that coalesces to form a moon made of neutron-star matter.

Equilibrium configurations of stable neutron stars exist down to  $0.09M_{\odot}$  ([Haensel et al. 2002](#)). Therefore, the debris from a head-on collision between two neutron stars could potentially lead to the formation of a central black hole or neutron star accompanied by a low-mass neutron-star moon. As a result of the emission of gravitational waves, the companion moon will ultimately merge with the central object over a timescale ([Peters 1964](#)),

$$t_{\text{coal}} = 63 \text{ yr} \left( \frac{a_0}{10^4 \text{ km}} \right)^4 \left( \frac{m_1}{1M_{\odot}} \right)^{-2} \left( \frac{m_2}{0.1M_{\odot}} \right)^{-1}, \quad (1)$$

where  $a_0$  is their initial separation,  $m_1$  is the mass of the primary object and  $m_2 \ll m_1$  is the mass of the neutron-star moon. An alternative channel for creating a black hole moon is from core collapse of a single progenitor star to a black hole and a debris disk that coalesces into a neutron-star moon ([Chen & Metzger 2025](#)).

## 3. S251112CM

On November 12, 2025, the LVK collaboration reported the detection of a gravitational wave signal from a compact merger candidate labeled S251112cm (Ligo Scientific Collaboration et al. 2025). This event is statistically significant due to its relatively low False Alarm Rate, estimated at about 1 per 6.2 years (as reported most recently by Vieira et al. (2026)). The source luminosity distance is estimated to be in the local Universe, measuring  $93 \pm 27$  Mpc, but a search for an electromagnetic counterpart did not yield a detection (Vieira et al. 2026). The analysis of the gravitational wave signal implies that the source chirp mass  $\mathcal{M} = (m_1 m_2)^{3/5} / (m_1 + m_2)^{1/5}$  falls mostly in the range of  $0.1\text{--}0.87 M_\odot$ , indicating a sub-solar mass object at the 99% confidence. The primary object mass  $m_1$  could be in the range of  $1\text{--}3.5 M_\odot$  (see Figure 1 of Vieira et al. (2026)). The inference of a low-mass compact object raises the possibility that S251112cm may have been produced by the coalescence of a neutron-star moon and a much more massive companion in the form of a black hole or a neutron star.

#### ACKNOWLEDGEMENTS

This work was supported in part by the Galileo Project and by Harvard’s *Black Hole Initiative*, which is funded by grants from JFT and GBMF.

#### REFERENCES

- Bagchi, M., Abbate, F., Balakrishnan, V., et al. 2025, *The Open Journal of Astrophysics*, 8, 54251, doi: [10.33232/001c.154251](https://doi.org/10.33232/001c.154251)
- Chen, Y.-X., & Metzger, B. D. 2025, *ApJL*, 991, L22, doi: [10.3847/2041-8213/ae045d](https://doi.org/10.3847/2041-8213/ae045d)
- Haensel, P., Zdunik, J. L., & Douchin, F. 2002, *A&A*, 385, 301, doi: [10.1051/0004-6361:20020131](https://doi.org/10.1051/0004-6361:20020131)
- Ligo Scientific Collaboration, VIRGO Collaboration, & Kagra Collaboration. 2025, *GRB Coordinates Network*, 42690, 1
- Naoz, S. 2016, *ARA&A*, 54, 441, doi: [10.1146/annurev-astro-081915-023315](https://doi.org/10.1146/annurev-astro-081915-023315)
- Peters, P. C. 1964, *Physical Review*, 136, 1224, doi: [10.1103/PhysRev.136.B1224](https://doi.org/10.1103/PhysRev.136.B1224)
- Rodriguez, C. L., Morscher, M., Pattabiraman, B., et al. 2015, *PhRvL*, 115, 051101, doi: [10.1103/PhysRevLett.115.051101](https://doi.org/10.1103/PhysRevLett.115.051101)
- Teodori, M., Straniero, O., Merafina, M., & Gianella, L. 2026, *A&A*, 707, 1, doi: [10.1051/0004-6361/202557469](https://doi.org/10.1051/0004-6361/202557469)
- Vieira, N., Franz, N., Subrayan, B., et al. 2026, arXiv e-prints, arXiv:2603.17009, doi: [10.48550/arXiv.2603.17009](https://doi.org/10.48550/arXiv.2603.17009)
- Yuan, Q., Li, M., Desch, S. J., et al. 2023, *Nature*, 623, 95, doi: [10.1038/s41586-023-06589-1](https://doi.org/10.1038/s41586-023-06589-1)