NANOGrav Hints to Primordial Black Holes as Dark Matter

V. De Luca, G. Franciolini, and A. Riotto

Group 11 Presentation: James Oh, Kaitlyn Prokup, Matthew Nelson, Mohammad Saad, Sarah Rogers-Pastio

Editors' Suggestion

NANOGrav Data Hints at Primordial Black Holes as Dark Matter

V. De Luca,[1,*] G. Franciolini,[1,†] and A. Riotto[1,2,‡]
[1]*Département de Physique Théorique and Centre for Astroparticle Physics (CAP), Université de Genève, 24 quai Ernest Ansermet, CH-1211 Geneva, Switzerland*
[2]*INFN, Sezione di Roma, Piazzale Aldo Moro 2, 00185, Roma, Italy*

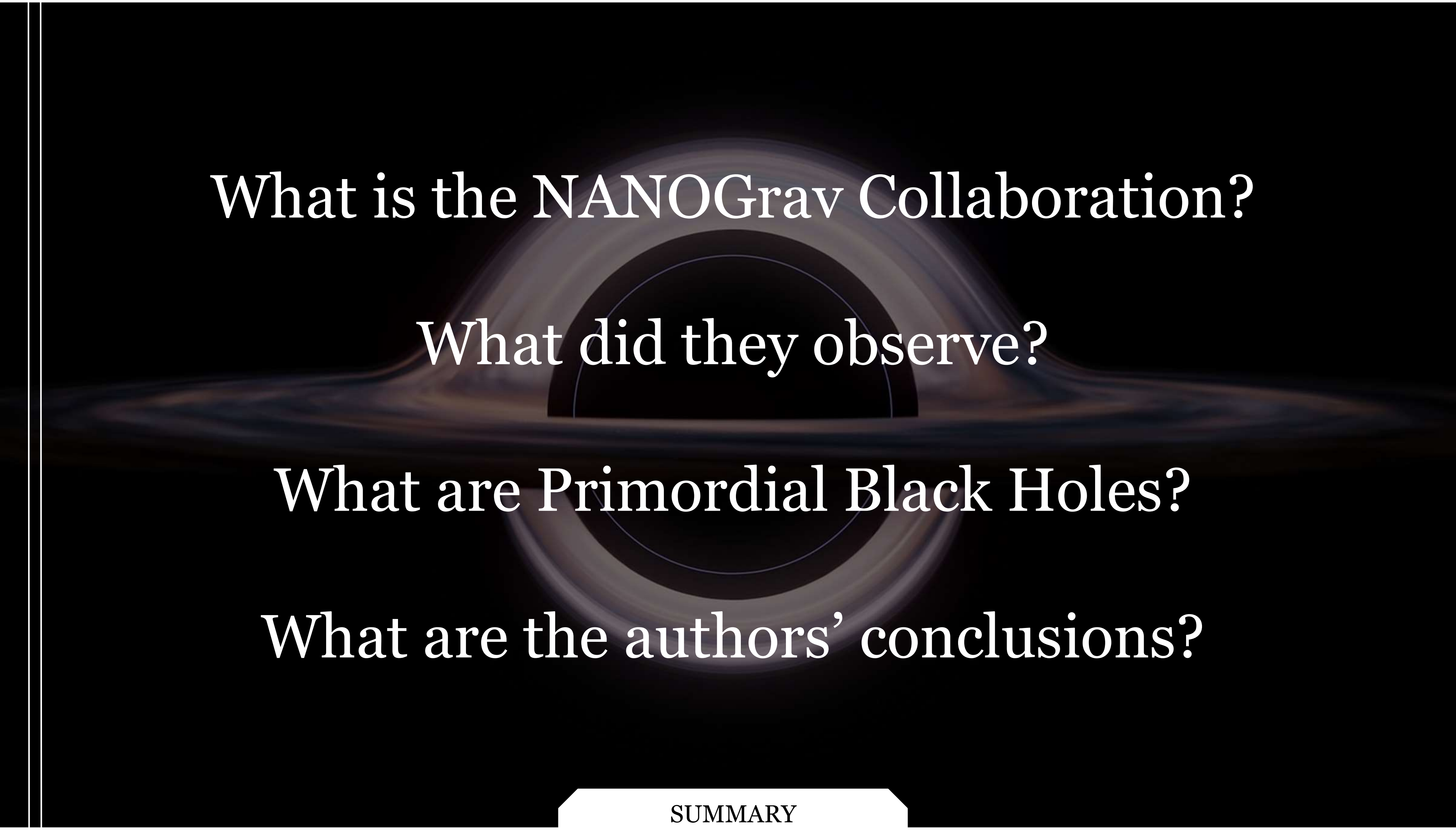
(Received 18 September 2020; accepted 23 November 2020; published 28 January 2021)

The NANOGrav Collaboration has recently published strong evidence for a stochastic common-spectrum process that may be interpreted as a stochastic gravitational wave background. We show that such a signal can be explained by second-order gravitational waves produced during the formation of primordial black holes from the collapse of sizeable scalar perturbations generated during inflation. This possibility has two predictions: (i) the primordial black holes may comprise the totality of the dark matter with the dominant contribution to their mass function falling in the range $(10^{-15} \div 10^{-11})M_\odot$ and (ii) the gravitational wave stochastic background will be seen as well by the Laser Interferometer Space Antenna experiment.

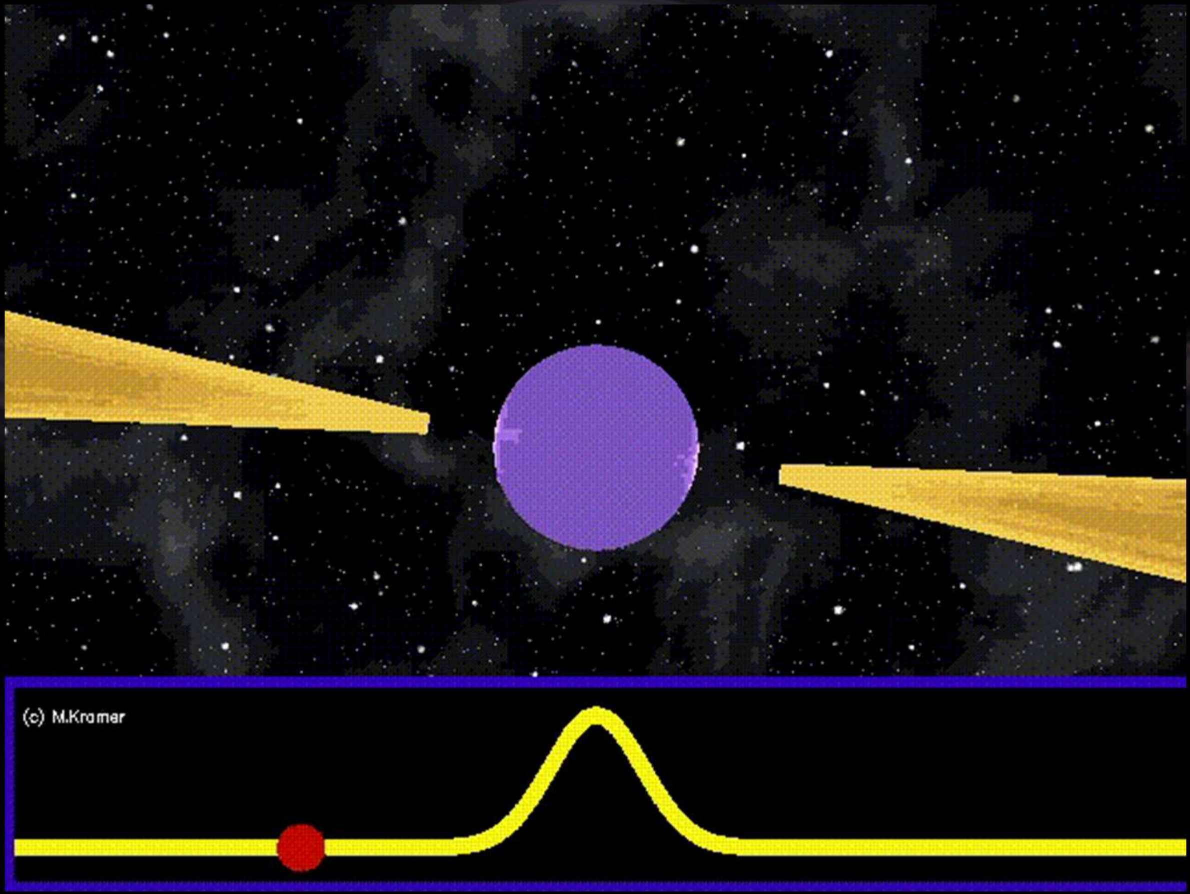
DOI: 10.1103/PhysRevLett.126.041303

Introduction.—The NANOGrav Collaboration has recently published an analysis of 12.5 yrs of pulsar timing data [1], reporting strong evidence for a stochastic common-spectrum process. The latter may be compatible with a gravitational wave (GW) signal with strain ampli-

The PBH abundance.—The most common formation scenario for PBHs is through an enhancement of the power spectrum of the comoving curvature perturbation ζ during inflation, at scales much smaller than those probed by cosmic microwave background (CMB) observations [6–8].


What is the NANOGrav Collaboration?
What did they observe?
What are Primordial Black Holes?
What are the authors’ conclusions?
SUMMARY

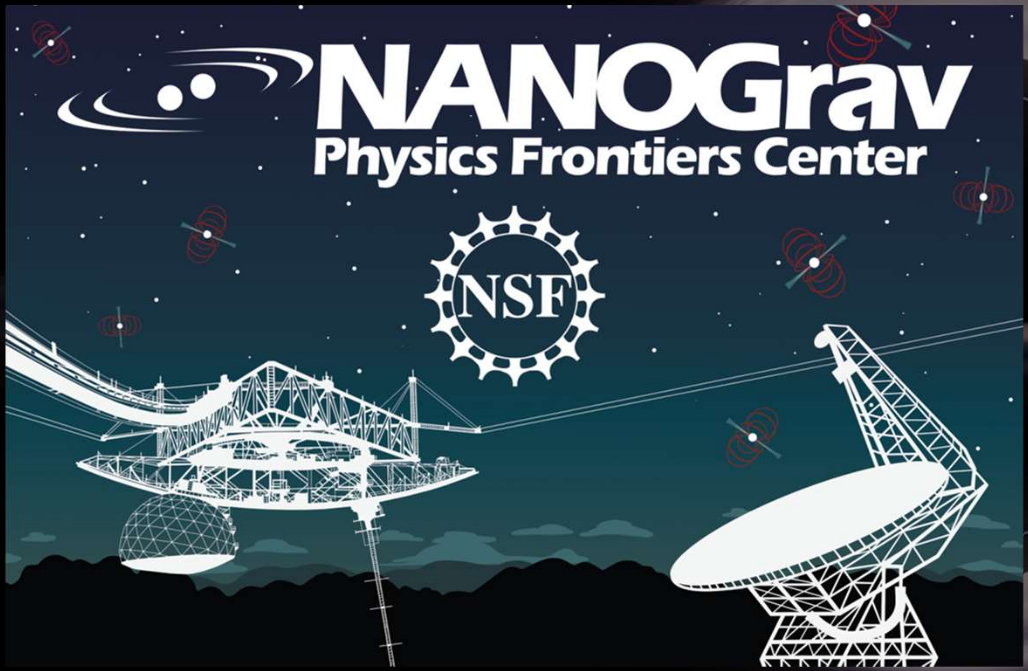
Model of a Pulsar and its Detected Intensity

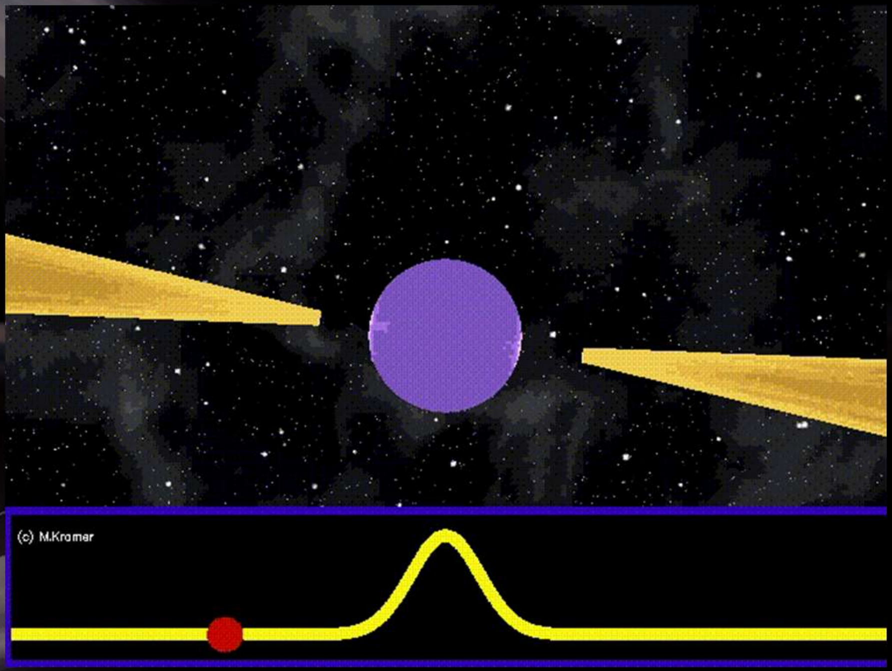


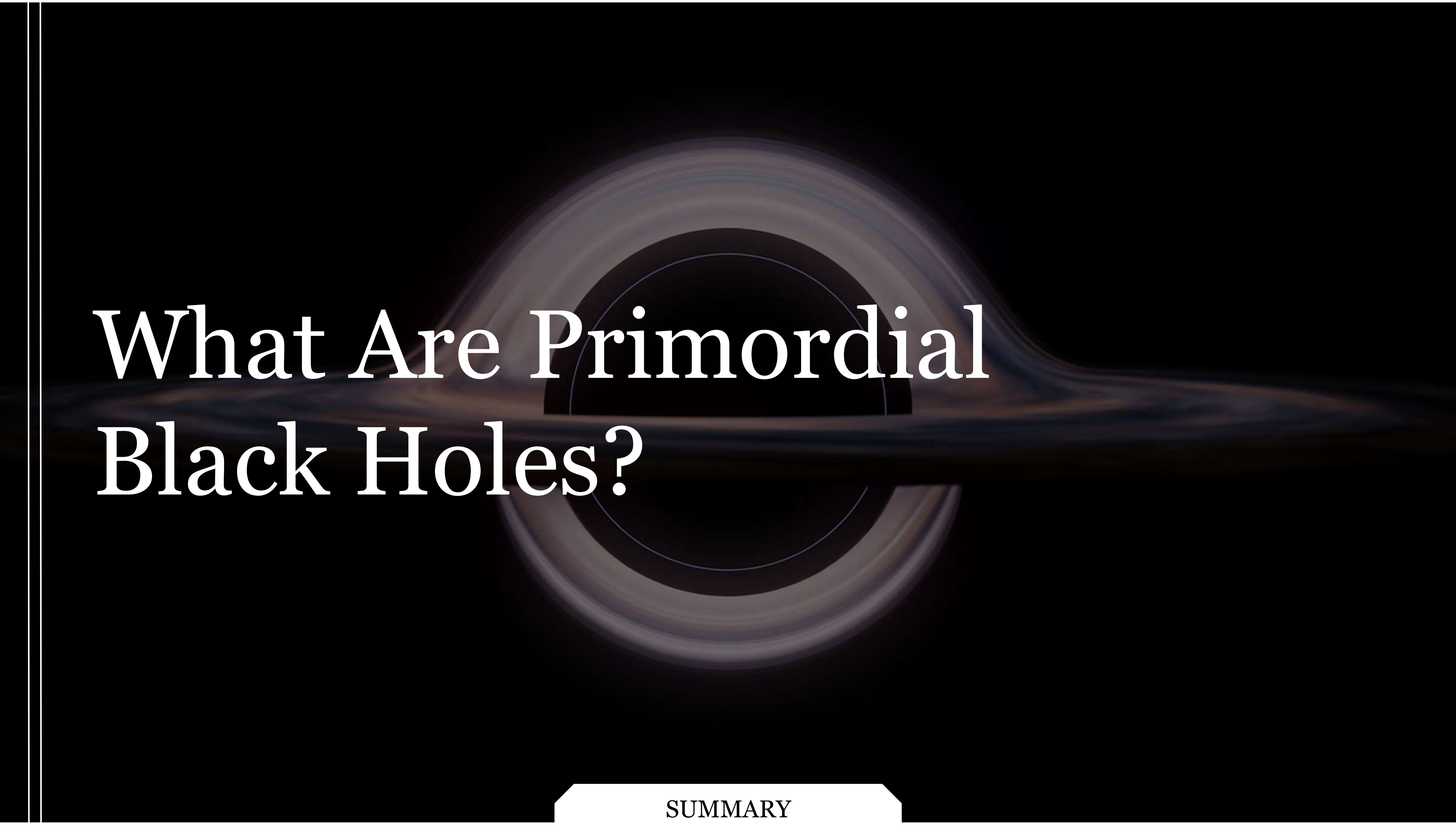
M. Kramer Animations

SUMMARY

NANOGrav Detects Deviations in Pulsar Timing



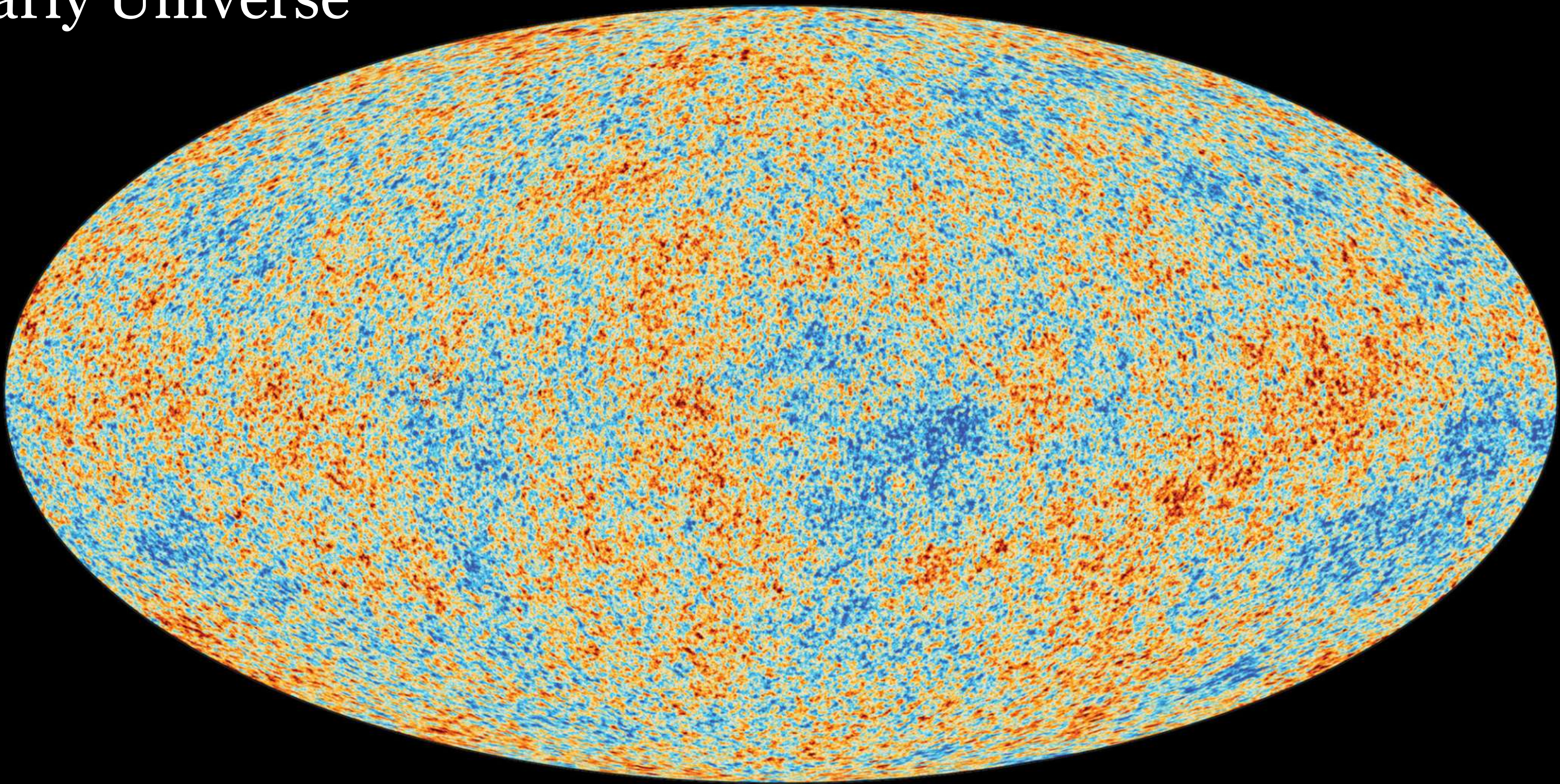




What Are Primordial Black Holes?

SUMMARY

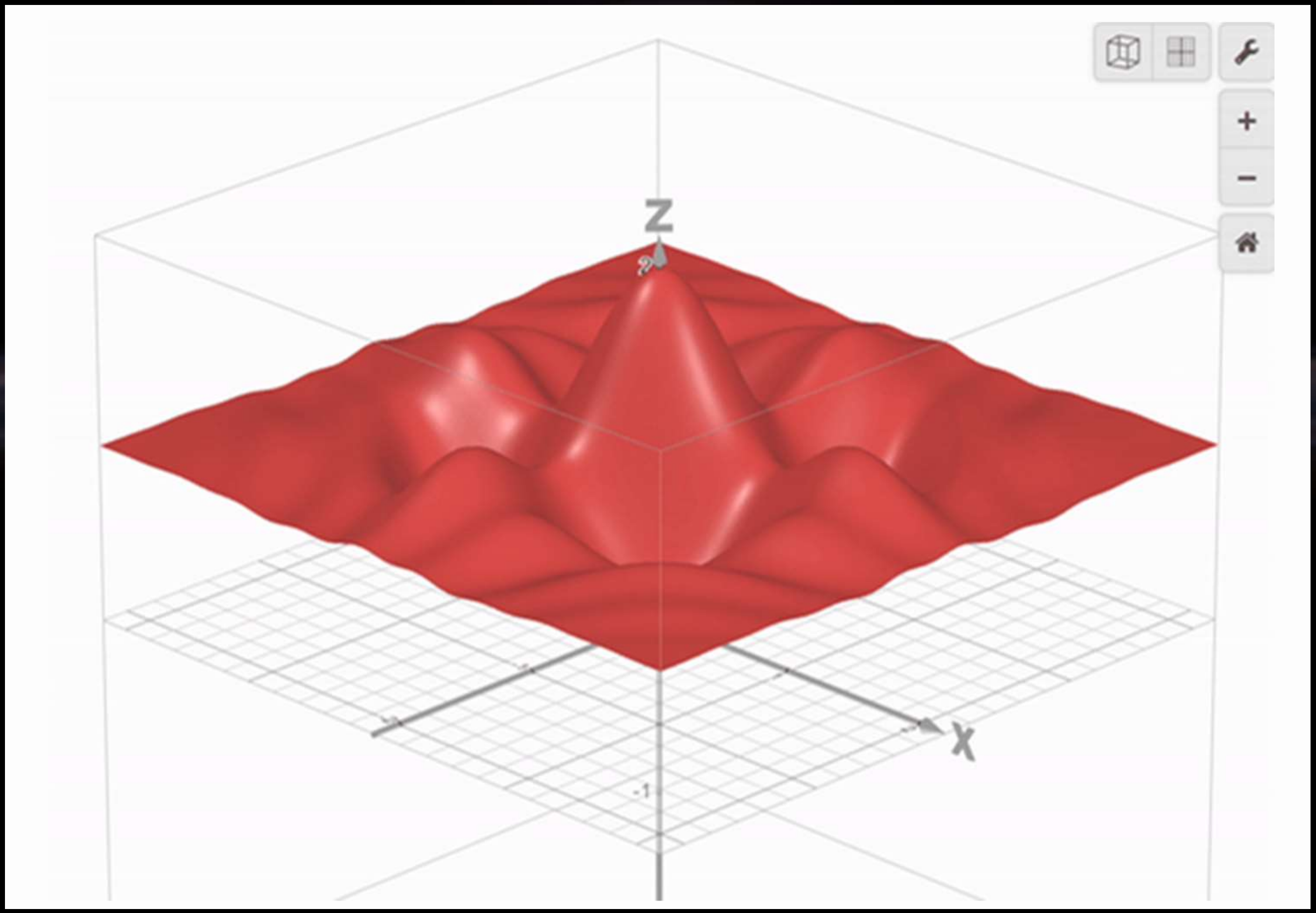
Cosmic Microwave Background Indicates Variation in the Early Universe



The European Space Agency

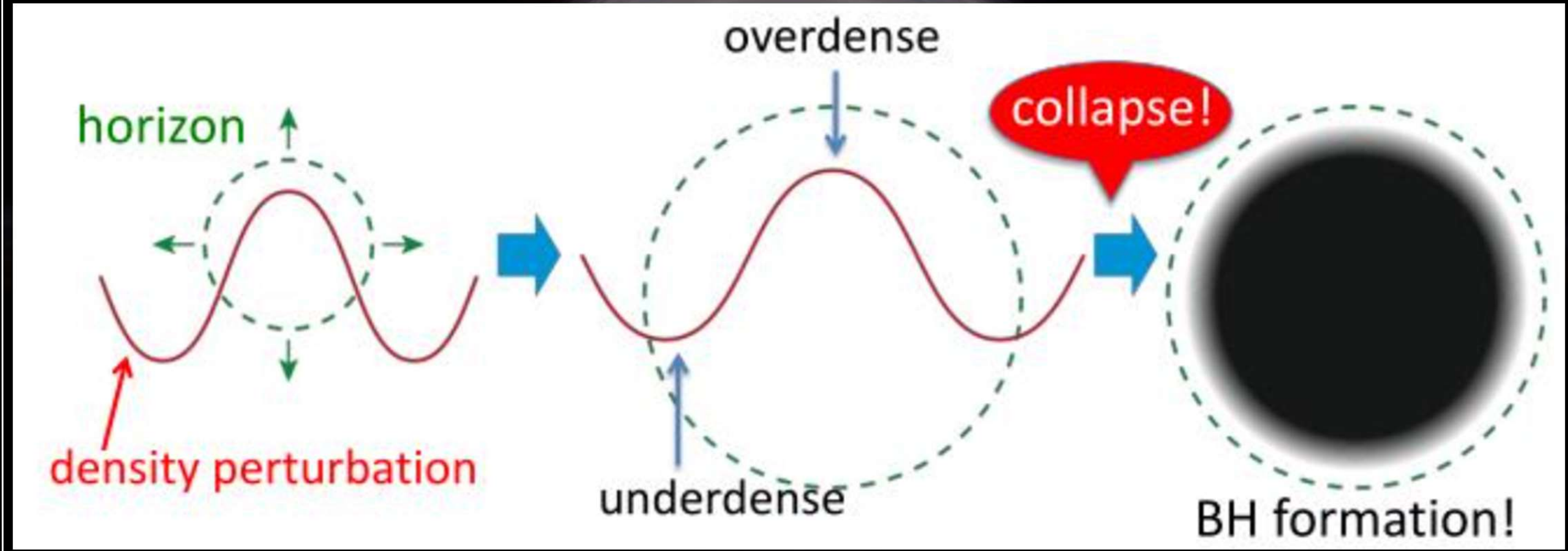
SUMMARY

Regions of High Density Could Cause a Primordial Black Hole

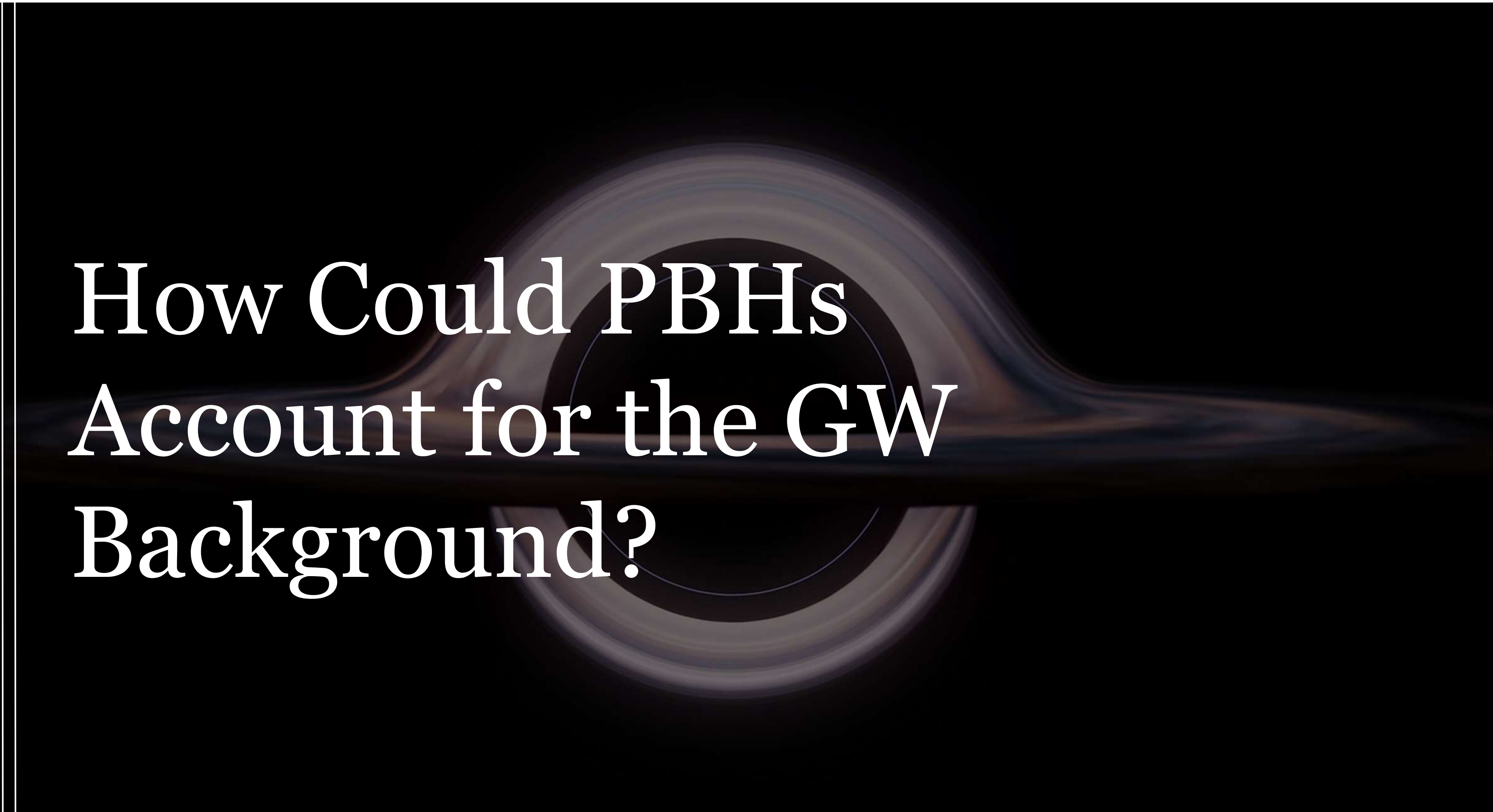


SUMMARY

Primordial Black Hole Formation by Collapse of Overdense Regions in the Early Universe



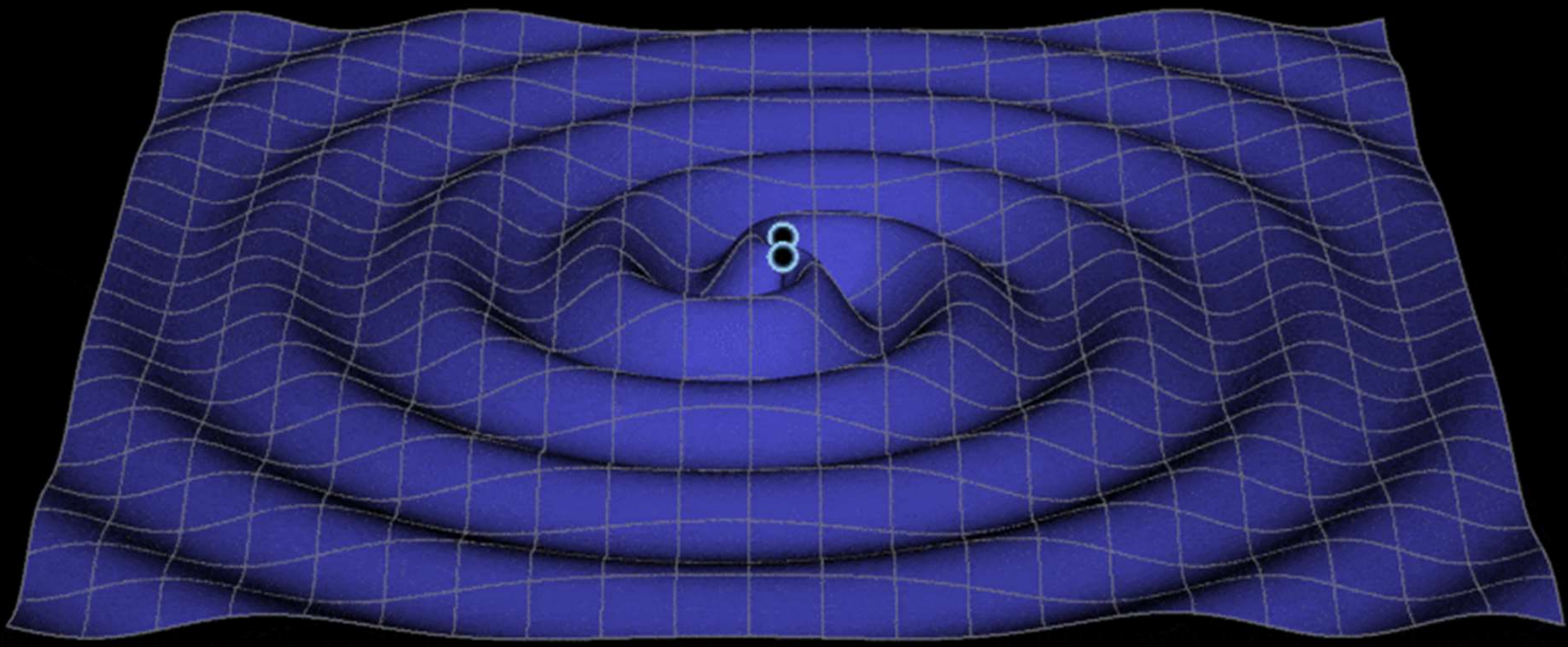
Gema White



How Could PBHs Account for the GW Background?

SUMMARY

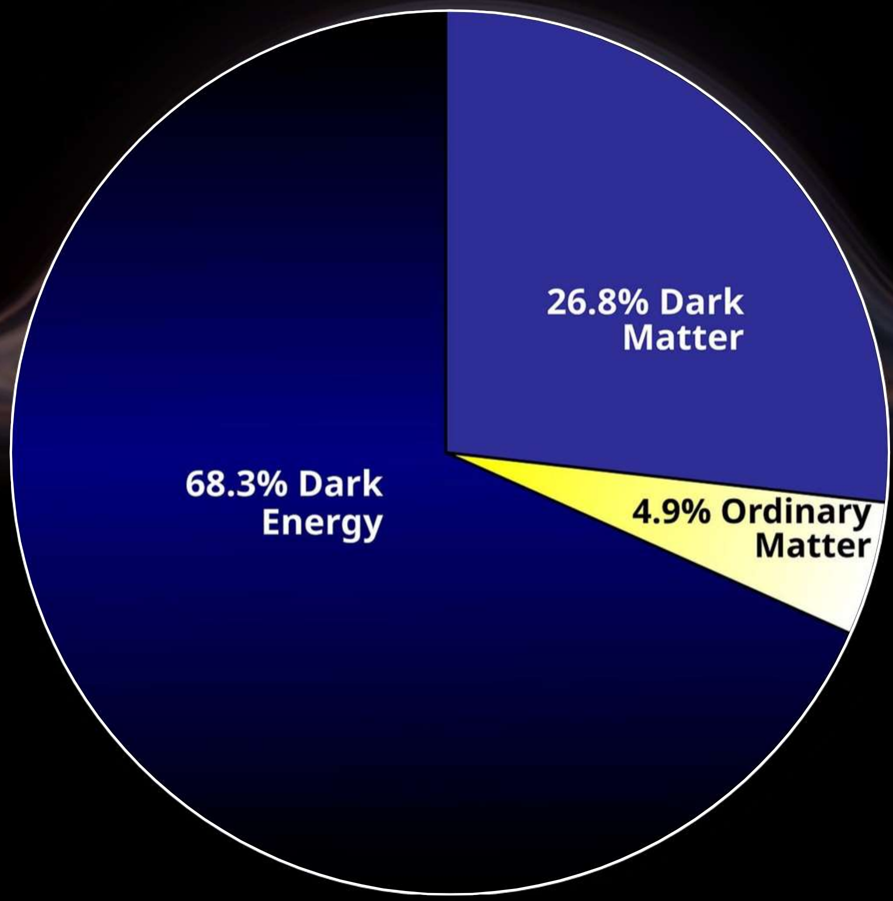
The Formation of Primordial Black Holes Could Cause Gravitational Waves



Jeffrey Bryant, Wolfram|Alpha, LLC

SUMMARY

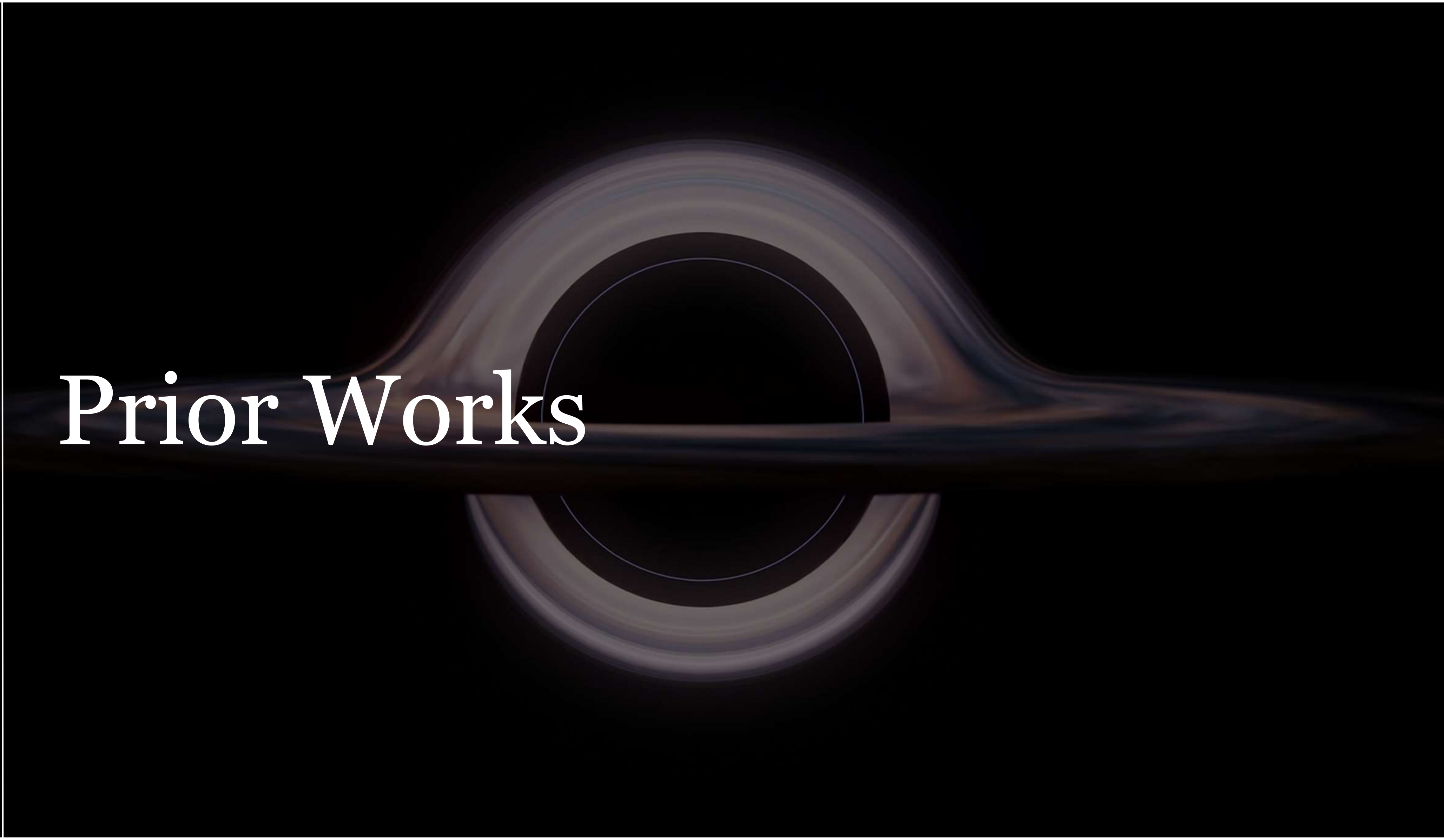
Primordial Black Holes Could Account for All Dark Matter



Szczureq

SUMMARY

Prior Works



The following papers are

Highly Cited

Referenced Multiple Times

PRIOR WORKS

Gravitationally Collapsed Objects of Very Low Mass

AUTHOR	YEAR	CITATIONS
S. Hawking	1971	1315

Black Holes in the Early Universe

AUTHOR	YEAR	CITATIONS
S. Hawking	1974	1083

PRIOR WORKS

Gravitational Wave Spectrum Induced by Primordial Scalar Perturbations

AUTHOR

—

Takahashi et al.

YEAR

—

2007

CITATIONS

—

477

PRIOR WORKS

Primordial Black Holes- Perspectives in Gravitational Wave Astronomy

AUTHOR

—

Yokoyama et al.

YEAR

—

2018

CITATIONS

—

701

PRIOR WORKS

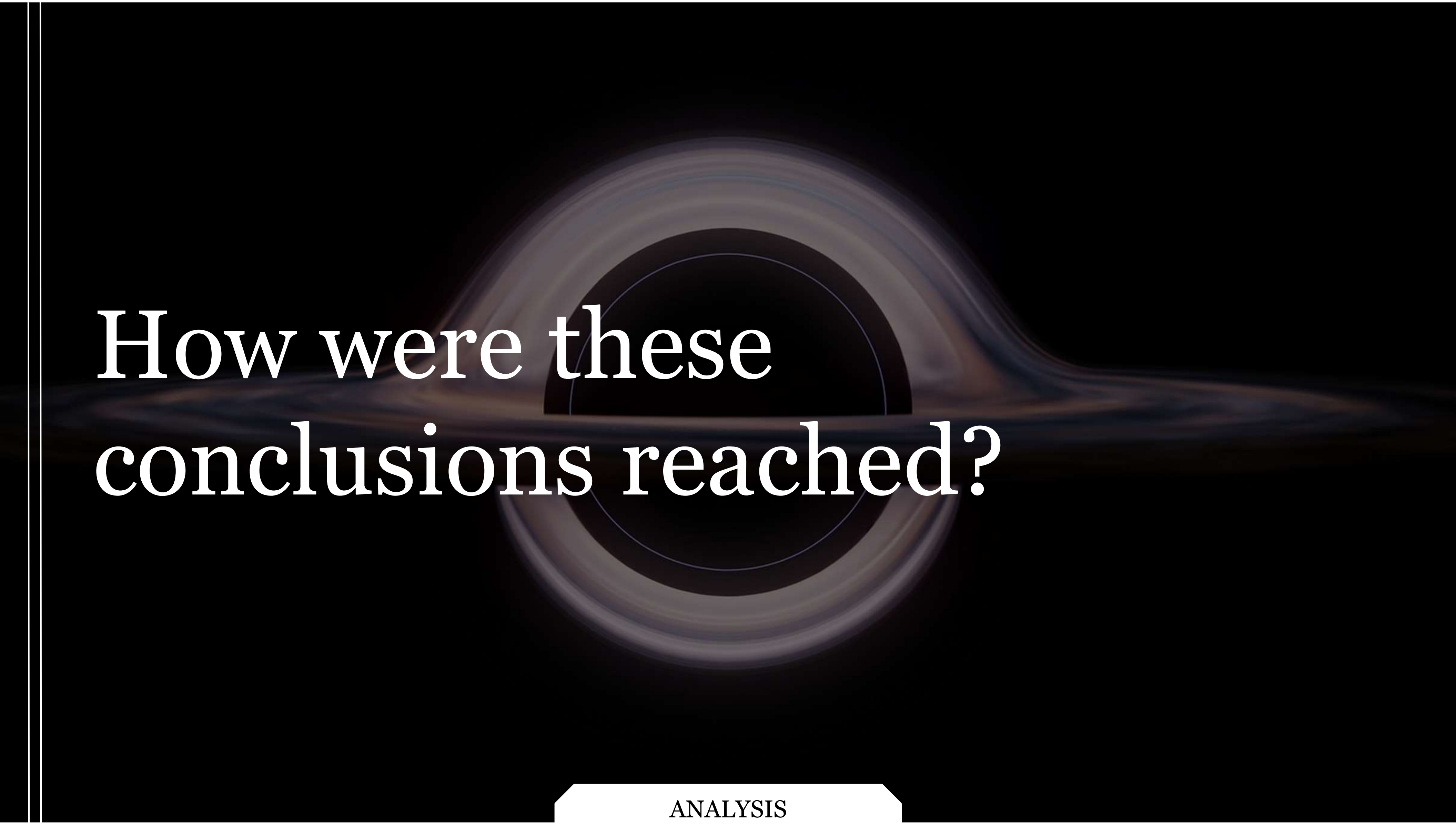
Analysis of Results & Conclusions

Key Conclusions

PBHs can explain **NANOGrav data**

PBH mass range explains **dark matter**

PBH GW spectrum will be **detectable by LISA**

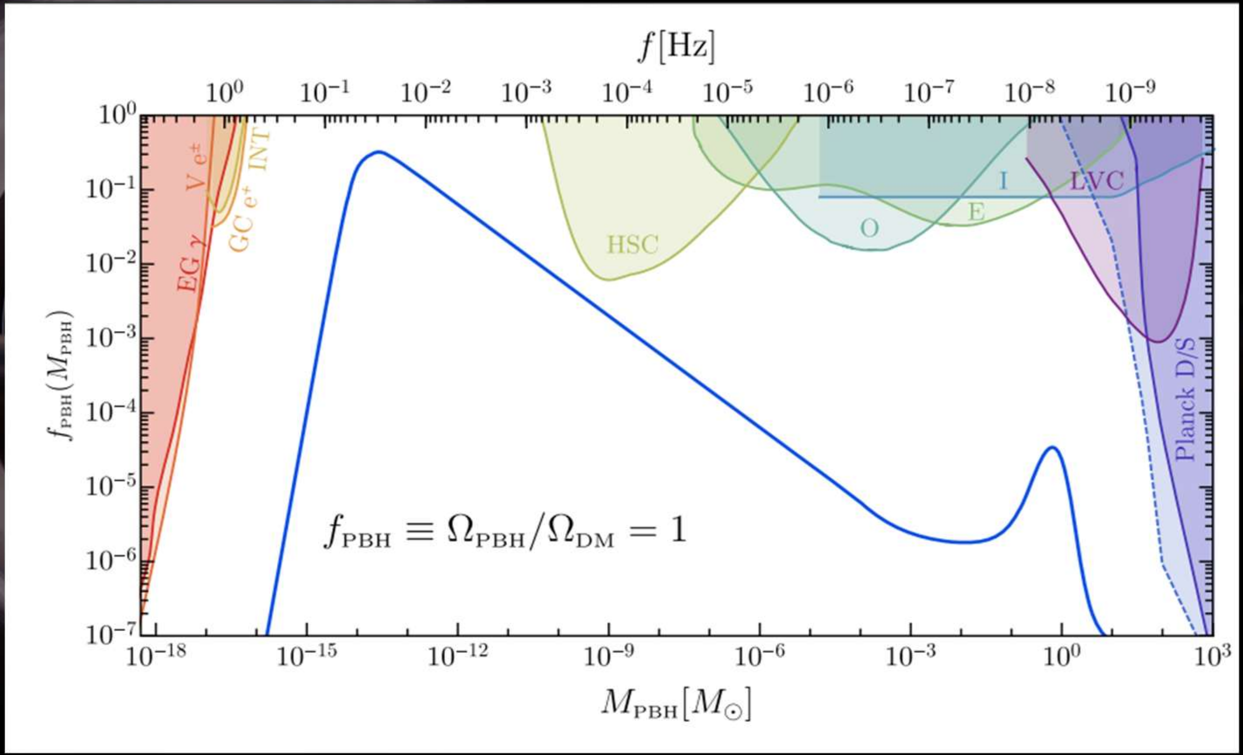


How were these conclusions reached?

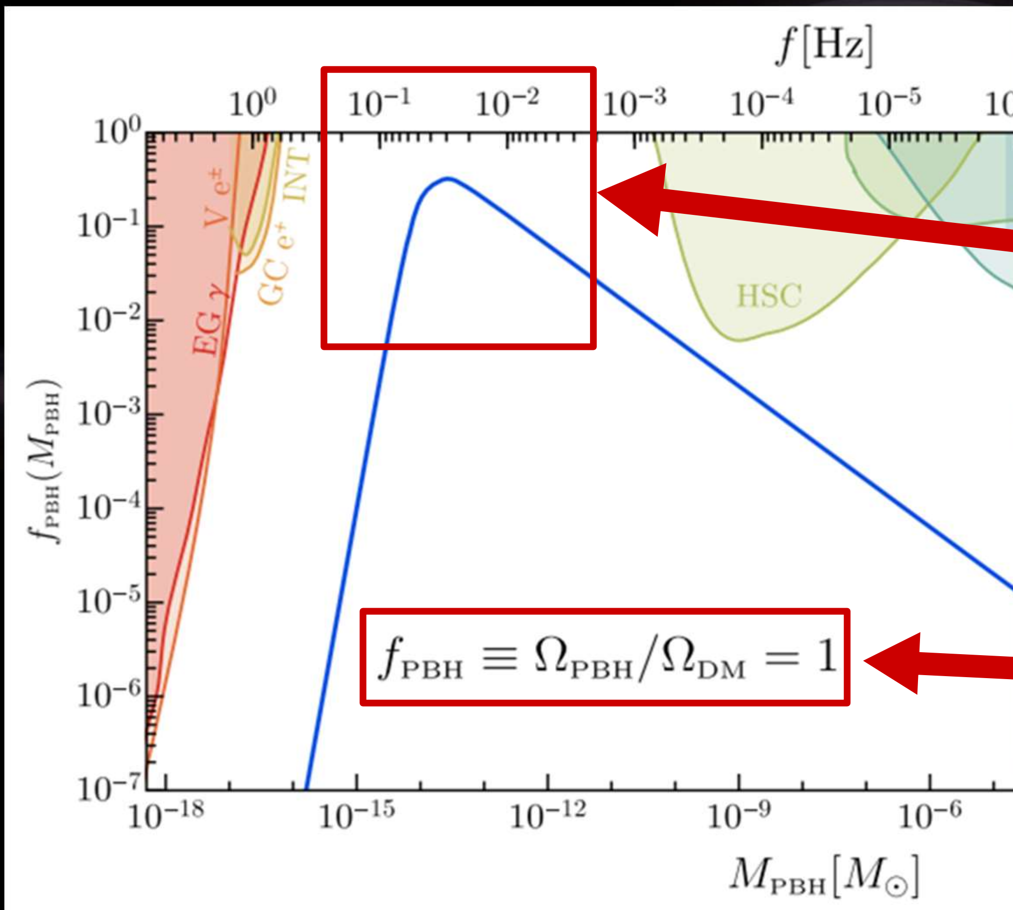
ANALYSIS

Primordial Black Hole Mass Distribution Model

Authors derived a model for the **PBH mass distribution** from *early universe perturbations*



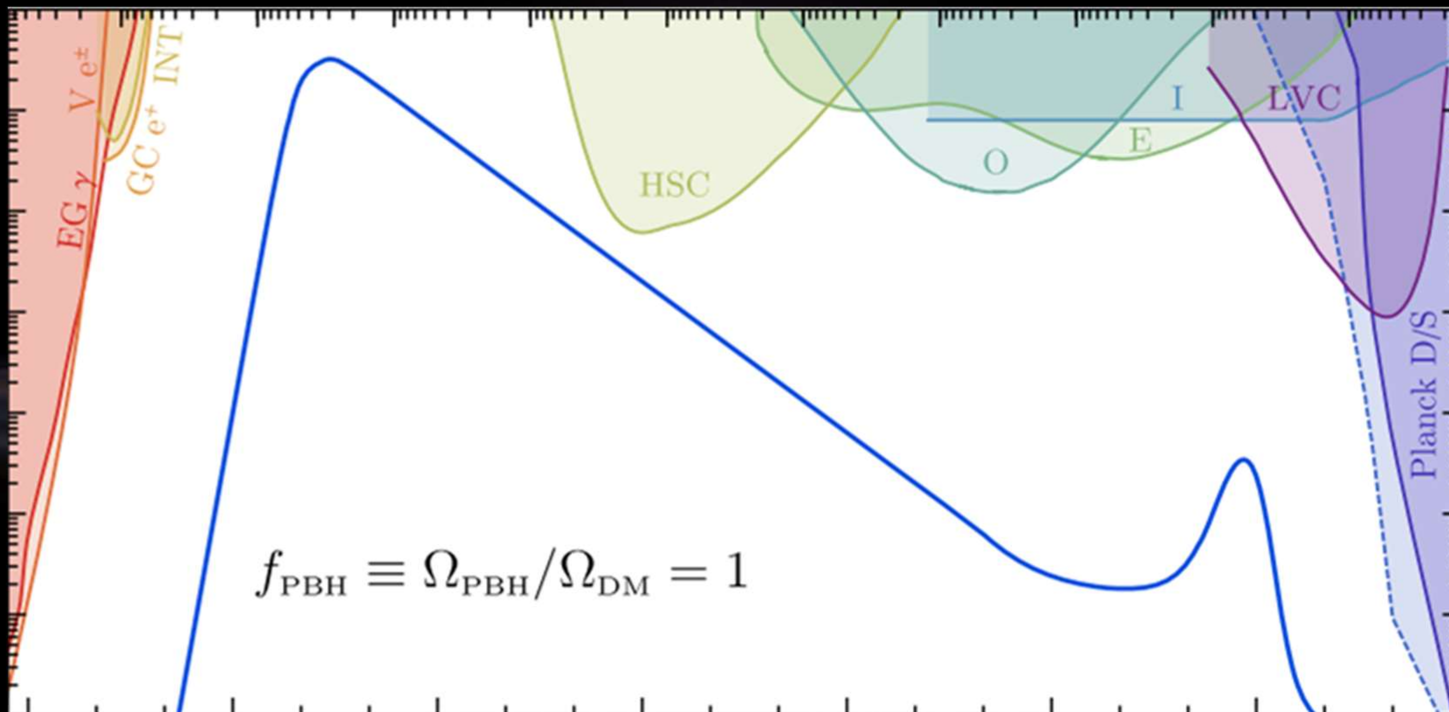
Mass Model Relation to Dark Matter



Mass distribution peaks in **dark matter range**

Fraction of *dark matter* consisting of primordial black holes is **fixed to one**

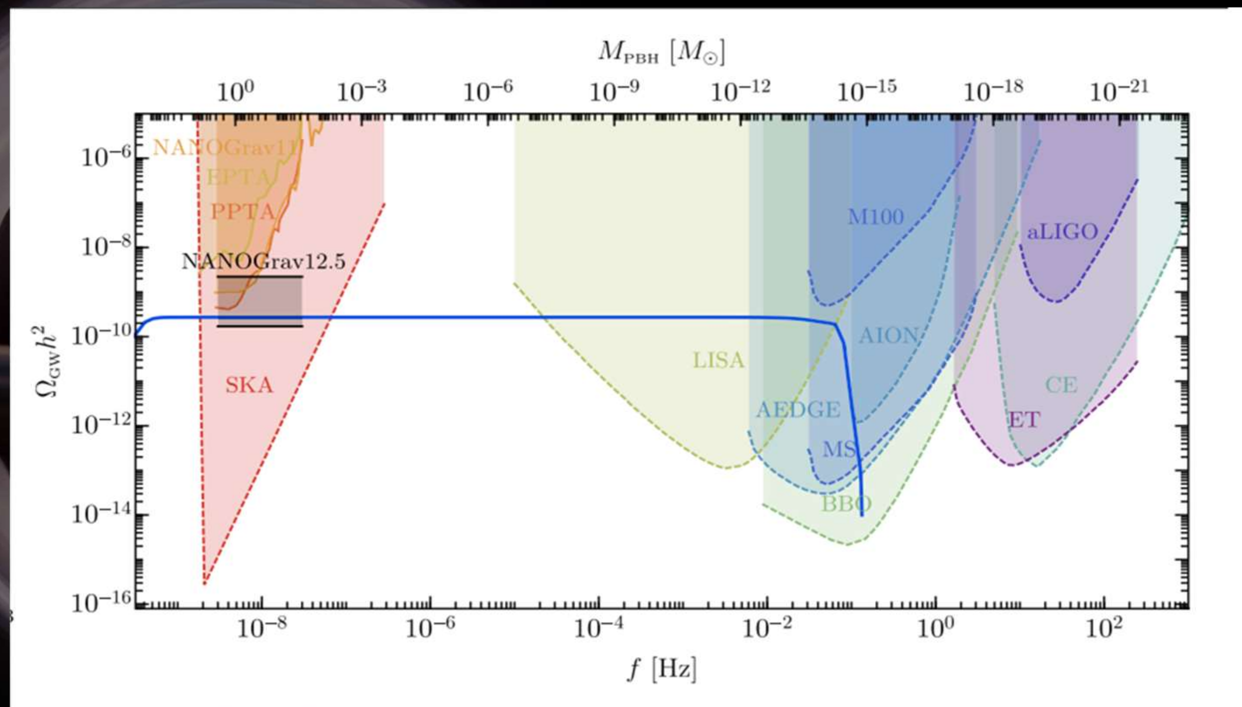
Detection of Mass Distribution Model



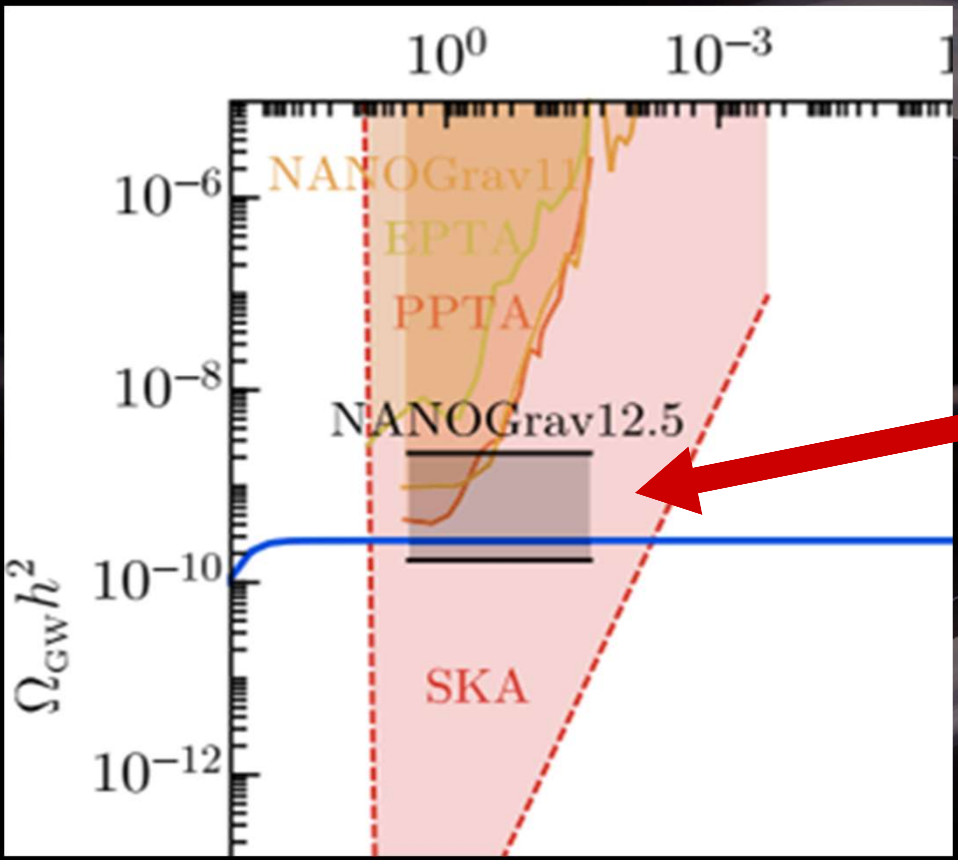
Model falls into **a gap in current observations and constraints**

Gravitational Wave Spectrum of Primordial Black Holes

Mass distribution corresponds to a **gravitational wave spectrum**



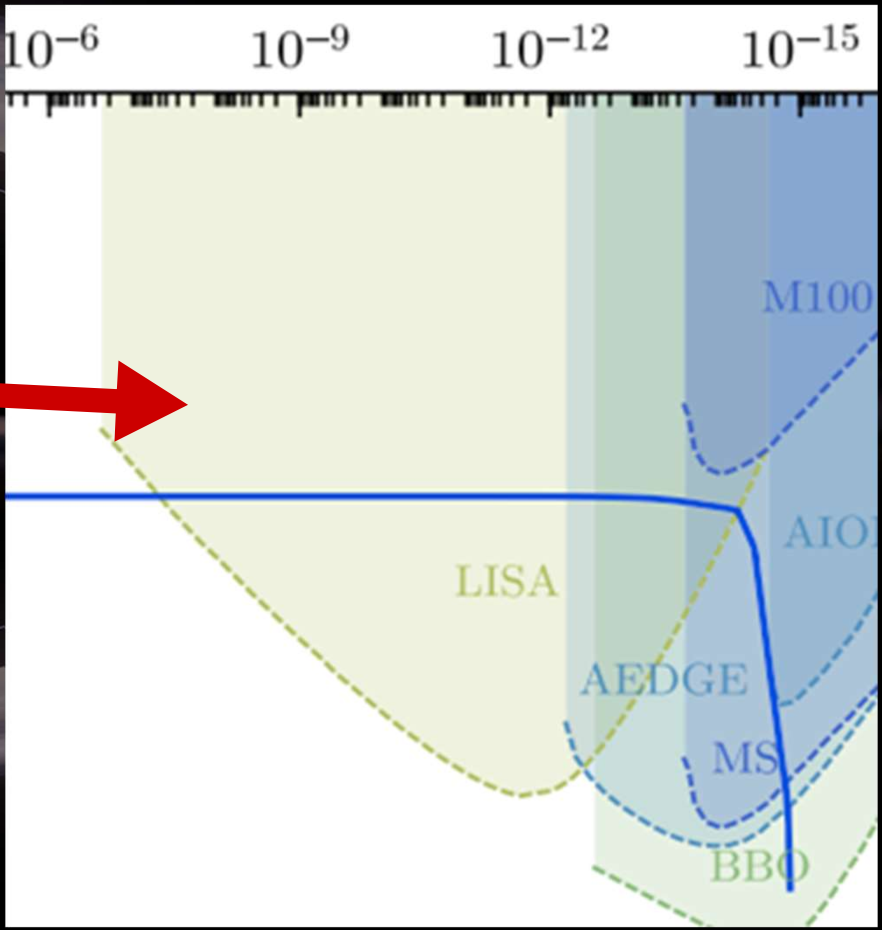
Gravitational Wave Spectrum Relation to NANOGrav

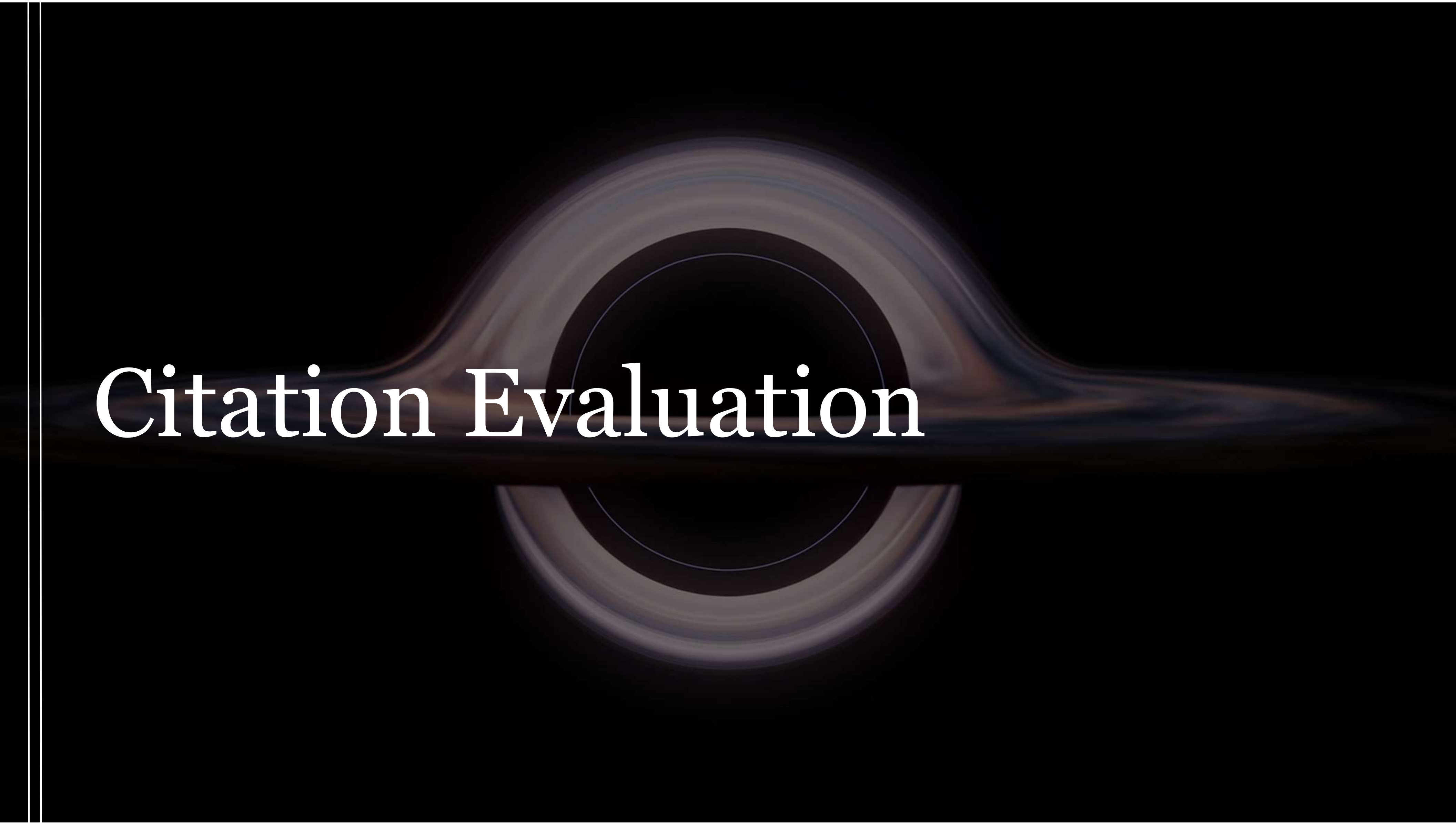


Gravitational wave spectrum falls in **95% confidence interval of NANOGrav data**

Gravitational Wave Spectrum Relation to NANOGrav

Gravitational wave spectrum is in range **detectable by LISA**





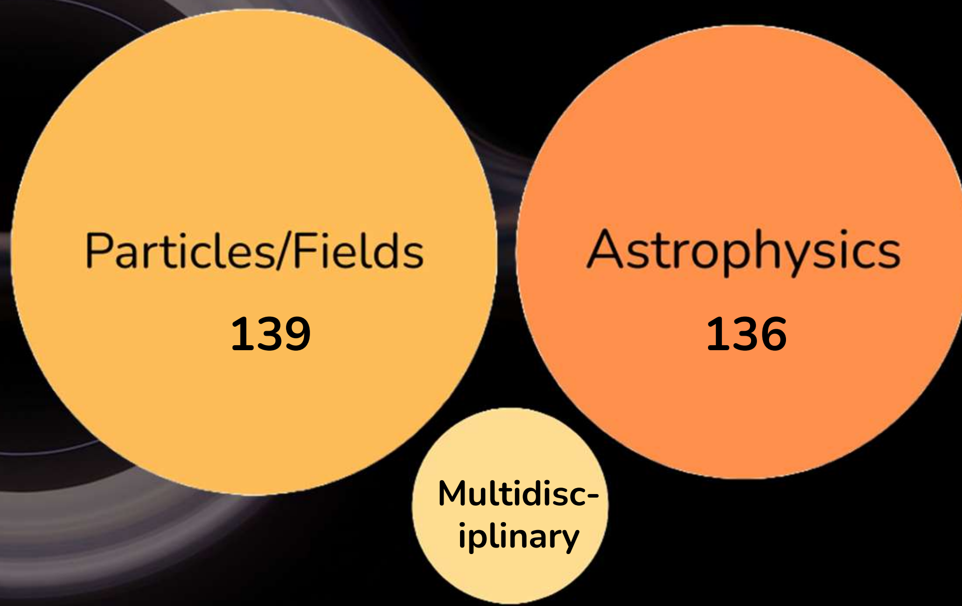
Citation Evaluation

The paper boasts of a good citation record! Since its publication in 2021:

215 Total Citations

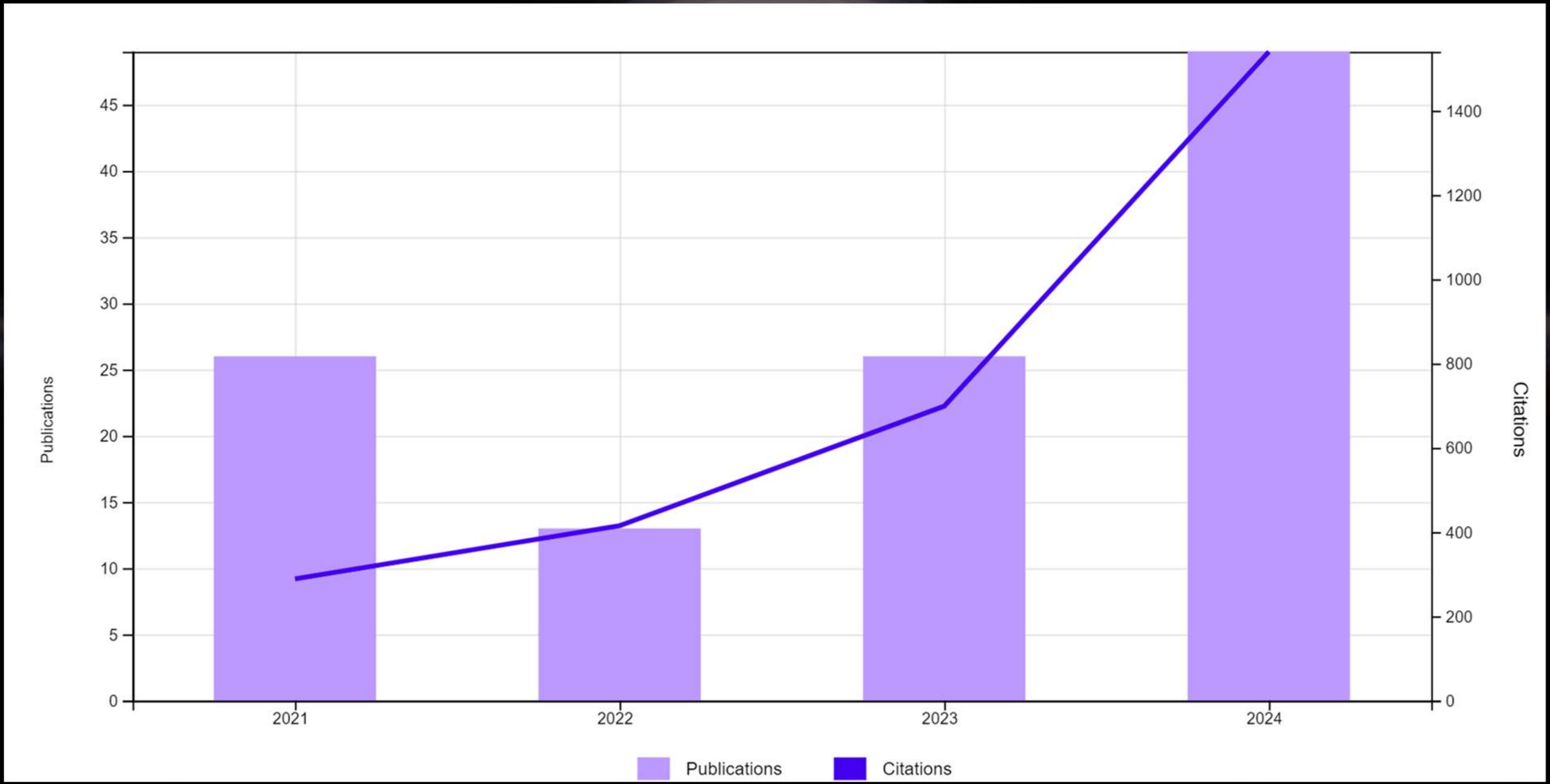
96 Citations in the last 2 years

94.74 Times more citations than average



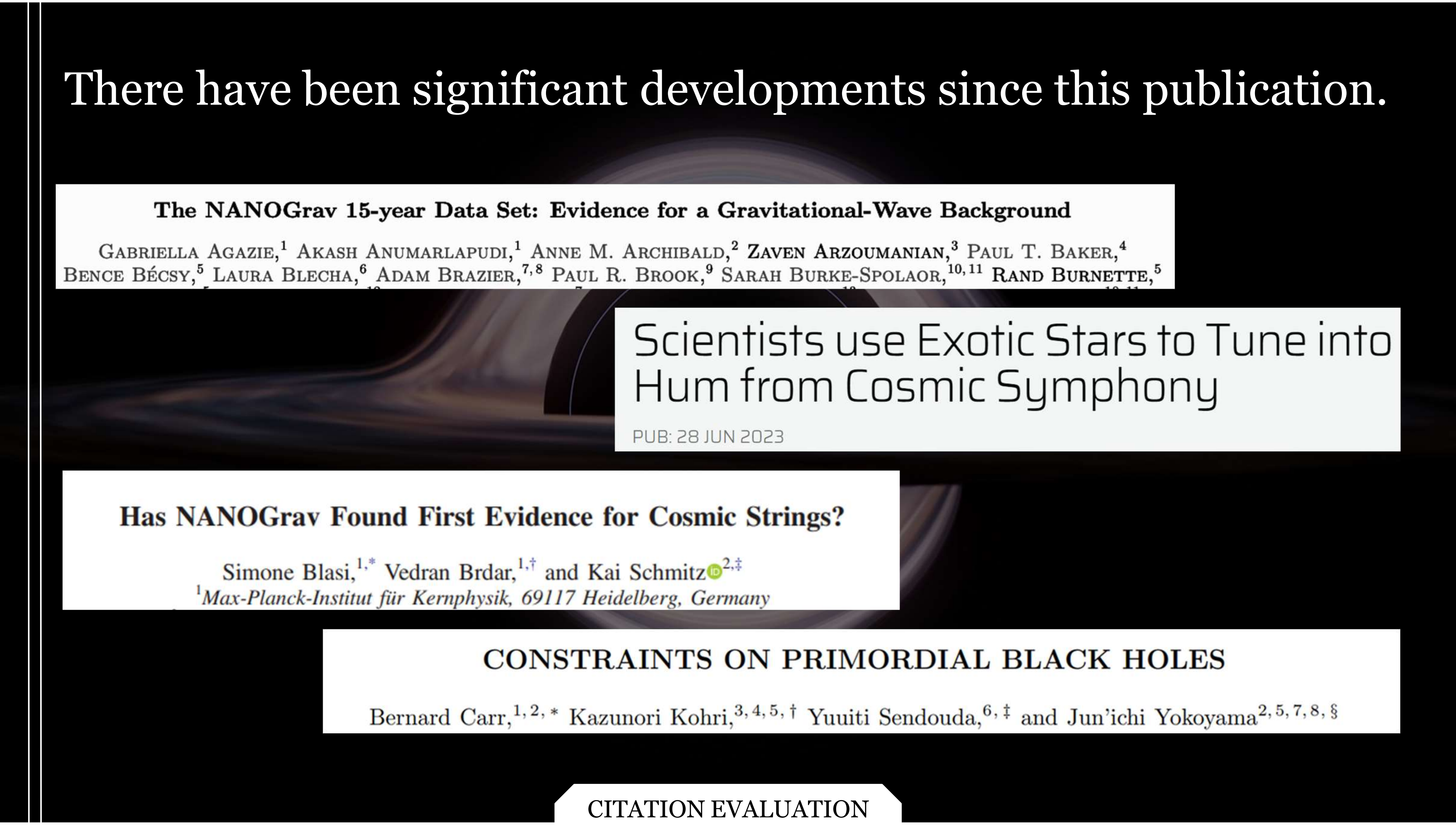
Source: Dimensions; Web of Science

This paper has been increasingly cited since its publication



Web of Science

CITATION EVALUATION


There have been significant developments since this publication.
The NANOGrav 15-year Data Set: Evidence for a Gravitational-Wave Background
Gabriella Agazie,[1] Akash Anumarlapudi,[1] Anne M. Archibald,[2] Zaven Arzoumanian,[3] Paul T. Baker,[4]
Bence Bécsy,[5] Laura Blecha,[6] Adam Brazier,[7,8] Paul R. Brook,[9] Sarah Burke-Spolaor,[10,11] Rand Burnette,[5]
Scientists use Exotic Stars to Tune into Hum from Cosmic Symphony
PUB: 28 JUN 2023
Has NANOGrav Found First Evidence for Cosmic Strings?
Simone Blasi,[1,*] Vedran Brdar,[1,†] and Kai Schmitz[2,‡]
[1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
CONSTRAINTS ON PRIMORDIAL BLACK HOLES
Bernard Carr,[1,2,*] Kazunori Kohri,[3,4,5,†] Yuuiti Sendouda,[6,‡] and Jun'ichi Yokoyama[2,5,7,8,§]
CITATION EVALUATION

References

Background Image: Alexander Antropov