Gravitational wave spectrum of the Sun

Cosmic WISPers
WG3 seminar
Nov 5, 2024

IFIC INSTITUT DE FÍSICA CORPUSCULAR

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

VNIVERSITAT DE VALÈNCIA

Camilo García Cely

Based on 2407.18297, in collaboration with Andreas Ringwald

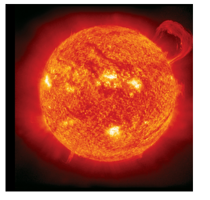
Outline

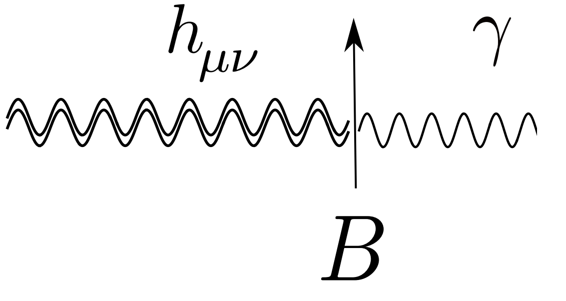
- Motivation: the Gertsenhstein effect

    Axions versus high-frequency gravitational waves

- Standard model backgrounds

    Solar gravitational waves





- Conclusions

Motivation

The Gertsenhstein effect

Axions versus high-frequency gravitational waves

High-frequency gravitational waves

Part of a collection:

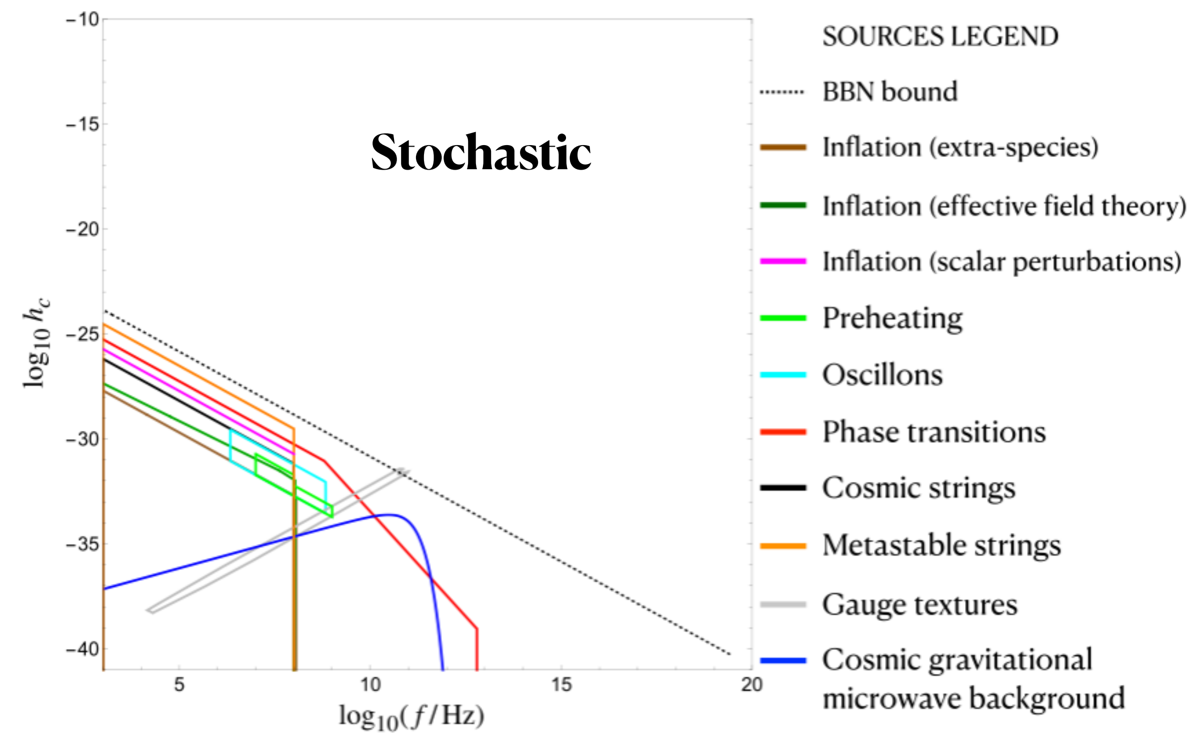
Gravitational Waves

Review Article | Open Access | Published: 06 December 2021

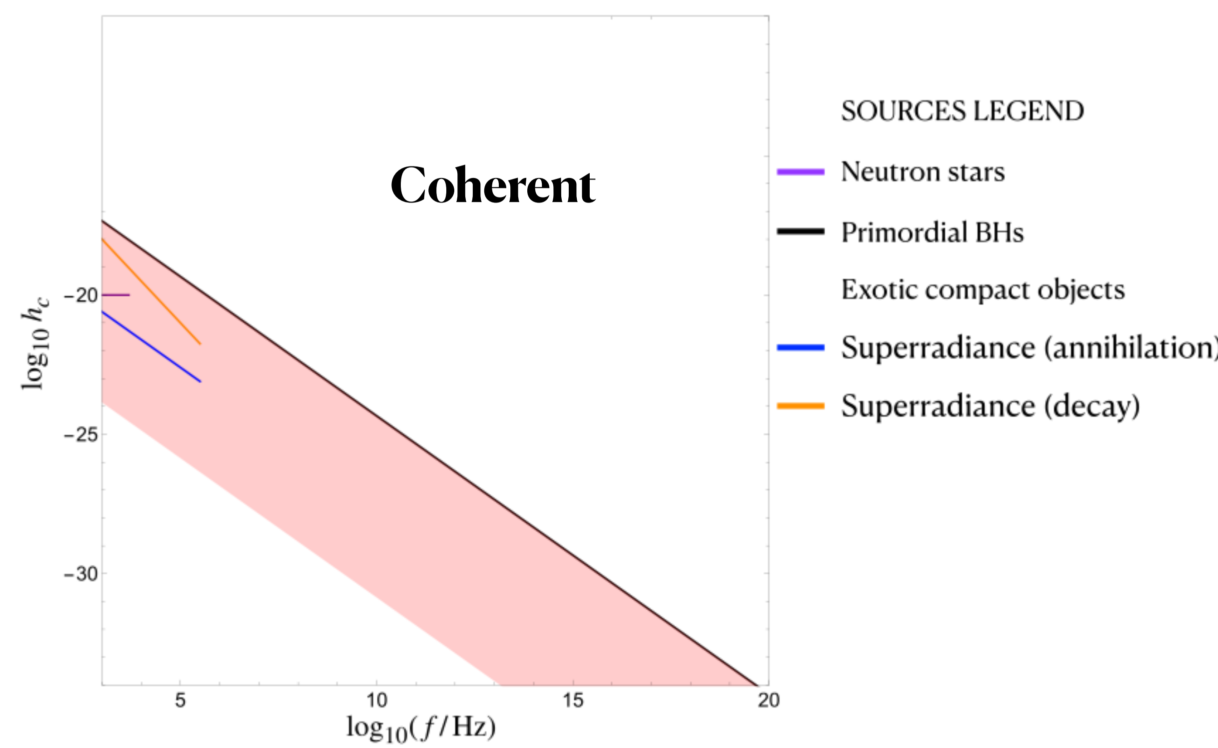
Challenges and opportunities of gravitational-wave searches at MHz to GHz frequencies

Nancy Aggarwal, Odylio D. Aguiar, Andreas Bauswein, Giancarlo Cella, Sebastian Clesse, Adrian Michael Cruise, Valerie Domcke, Daniel G. Figueroa, Andrew Geraci, Maxim Goryachev, Hartmut Grote, Mark Hindmarsh, Francesco Muia, Nikhil Mukund, David Ottaway, Marco Peloso, Fernando Quevedo, Angelo Ricciardone, Jessica Steinlechner, Sebastian Steinlechner, Sichun Sun, Michael E. Tobar, Francisco Torrenti, Caner Ünal & Graham White

Living Reviews in Relativity **24**, Article number: 4 (2021) | Cite this article

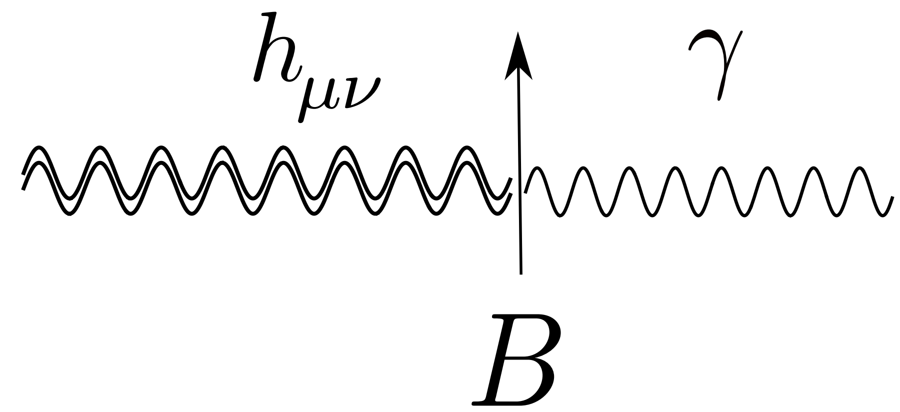


A growing community is seriously considering the search of high frequency gravitational waves



Revisiting Gertsenhstein's ideas

SOVIET PHYSICS JETP VOLUME 14, NUMBER 1 JANUARY, 1962



WAVE RESONANCE OF LIGHT AND GRAVITIONAL WAVES

M. E. GERTSENSHTEĬN

Submitted to JETP editor July 29, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **41**, 113-114 (July, 1961)

The energy of gravitational waves excited during the propagation of light in a constant magnetic or electric field is estimated.

SOVIET PHYSICS JETP VOLUME 16, NUMBER 2 FEBRUARY, 1963

ON THE DETECTION OF LOW FREQUENCY GRAVITATIONAL WAVES

M. E. GERTSENSHTEĬN and V. I. PUSTOVOĬT

Submitted to JETP editor March 3, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 605-607 (August, 1962)

It is shown that the sensitivity of the electromechanical experiments for detecting gravitational waves by means of piezocrystals is ten orders of magnitude worse than that estimated by Weber.[1] In the low frequency range it should be possible to detect gravitational waves by the shift of the bands in an optical interferometer. The sensitivity of this method is investigated.

Terrestrial interferometers

The (inverse) Gertsenhstein Effect

- The conversion of gravitational waves into electromagnetic waves is a classical process. Its rate does not involve $\hbar$

$$P \sim G B^2 L^2$$

- Cosmological conversion

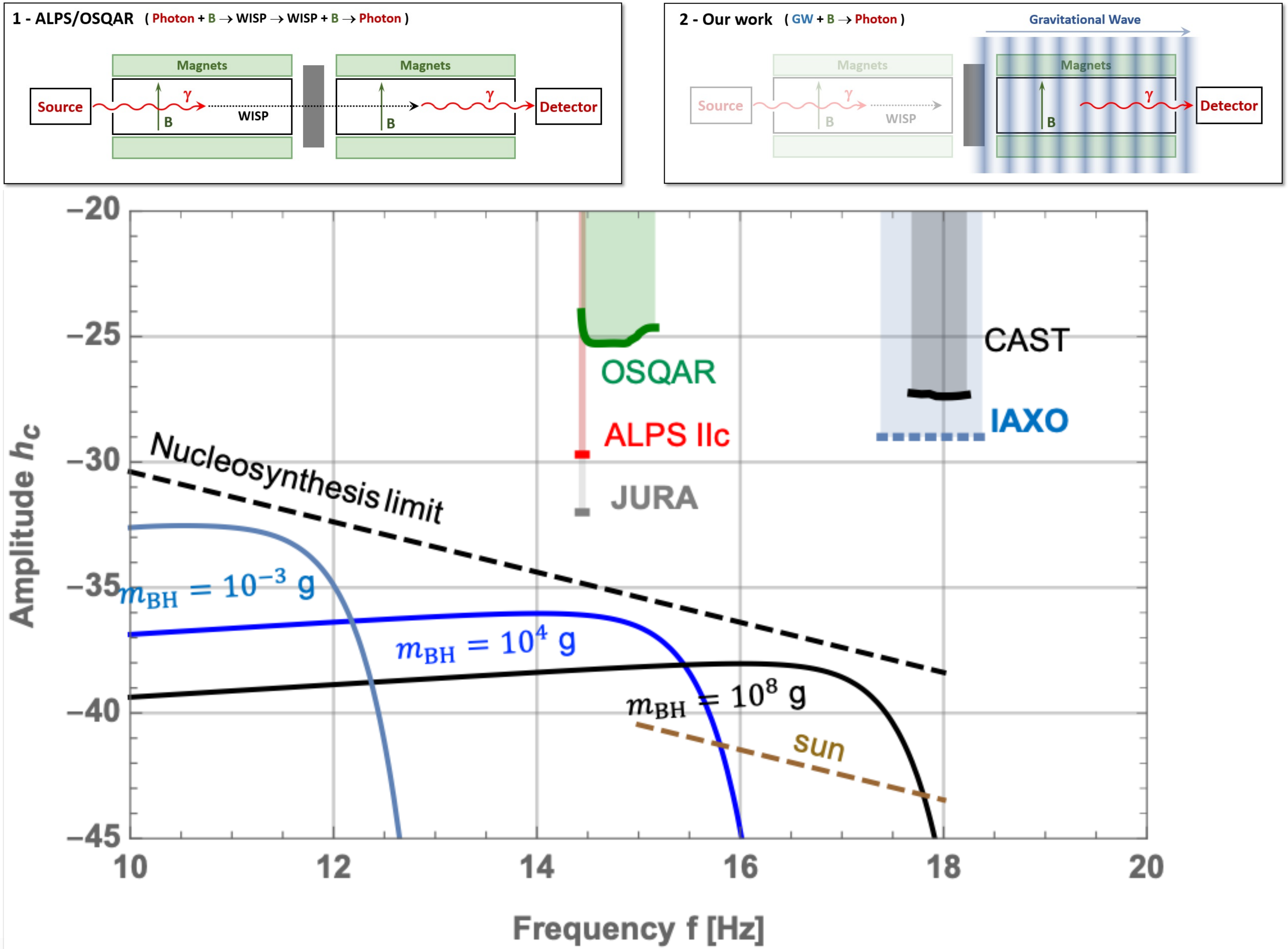
Potential of Radio Telescopes as High-Frequency Gravitational Wave Detectors

Valerie Domcke and Camilo Garcia-Cely
Phys. Rev. Lett. **126**, 021104 – Published 14 January 2021

- The process is strictly analogous to axion conversion.

Raffelt, Stodolski'89

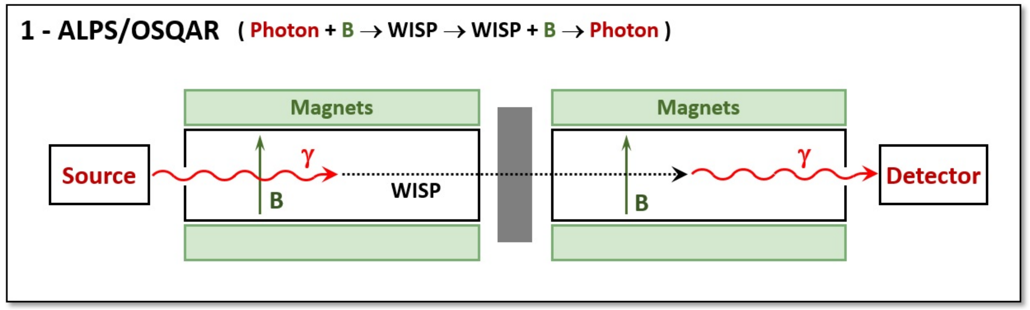
The (inverse) Gertsenhstein Effect

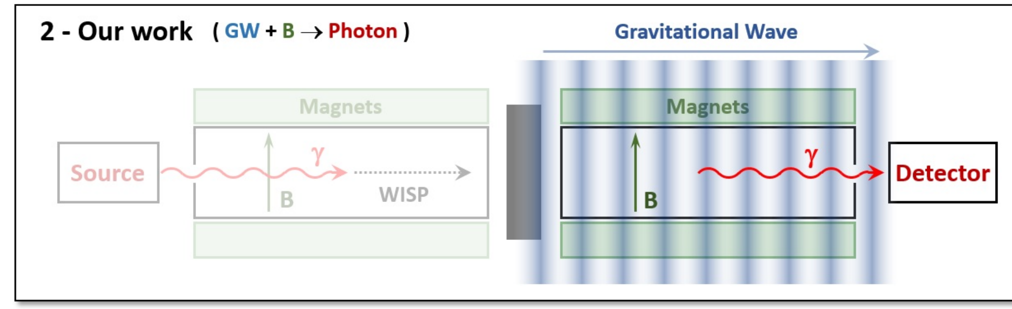


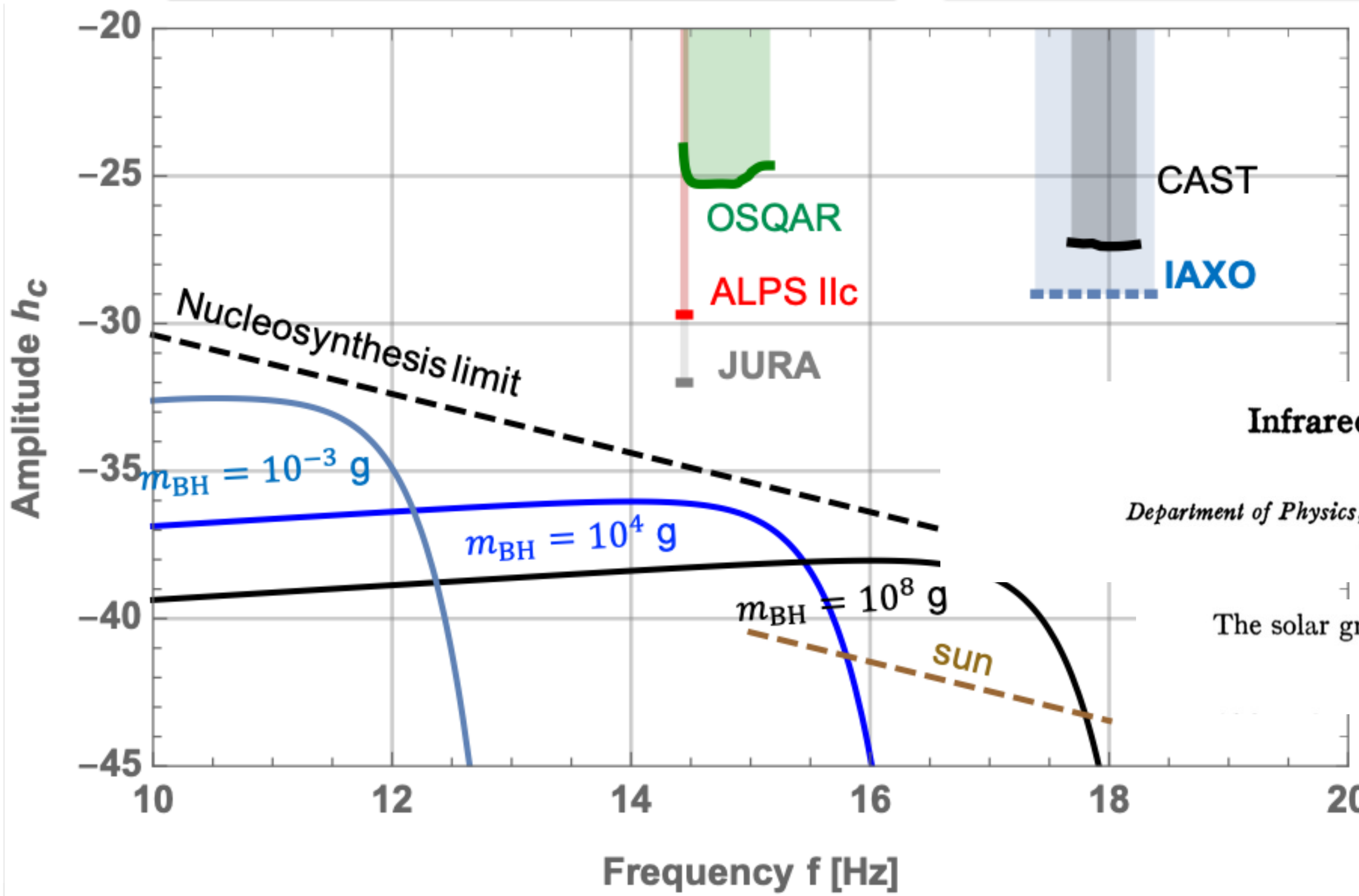
A. Ejlli, D. Ejlli, A. M. Cruise, G. Pisano & H. Grote

The European Physical Journal C **79**, Article number: 1032 (2019)

The (inverse) Gertsenhstein Effect







Infrared Photons and Gravitons*

Steven Weinberg†
Department of Physics, University of California, Berkeley, California
(Received 1 June 1965)

The solar gravitational radiation power is then

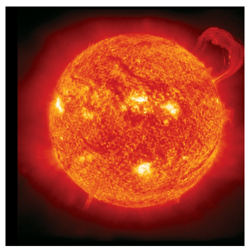
$$P_{\odot} \simeq 6 \times 10^{14} \text{ erg/sec}. \quad (4.24)$$

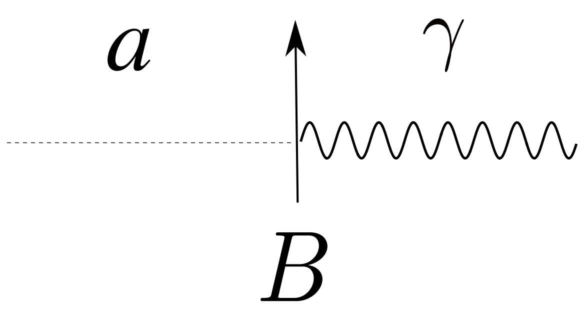
A. Ejlli, D. Ejlli, A. M. Cruise, G. Pisano & H. Grote

The European Physical Journal C **79**, Article number: 1032 (2019)

Solar emission of axions

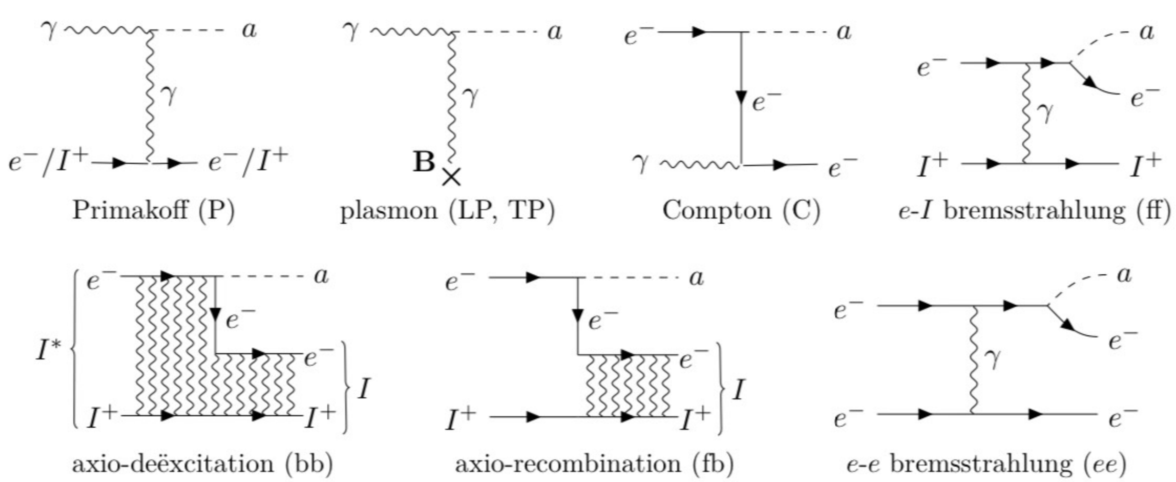
- Helioscopes

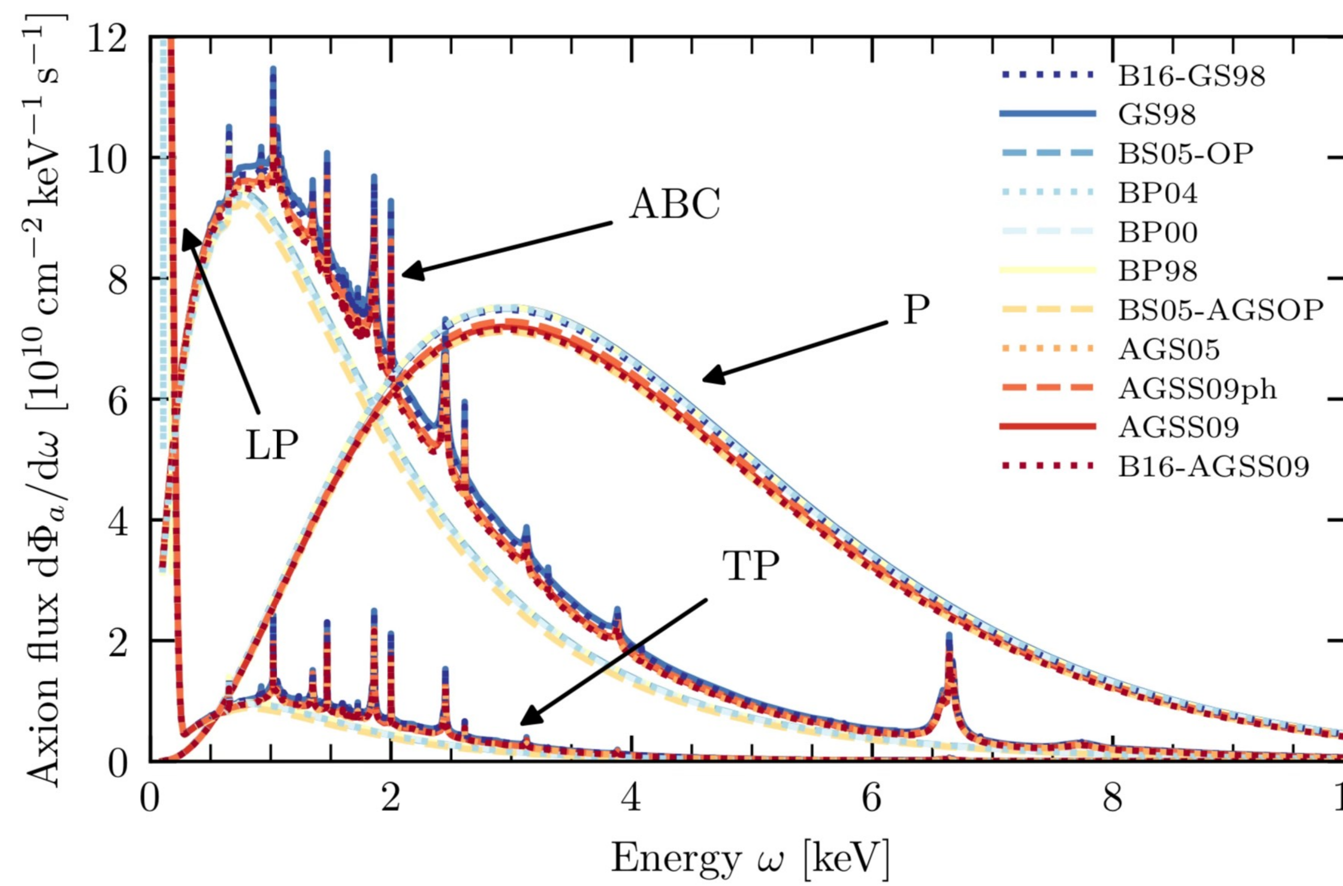




- CAST
- IAXO
- .....

Hoof et al, 2021





PHYSICAL REVIEW D VOLUME 33, NUMBER 4 15 FEBRUARY 1986

Astrophysical axion bounds diminished by screening effects

Georg G. Raffelt

PHYSICAL REVIEW D VOLUME 37, NUMBER 6 15 MARCH 1988

Plasmon decay into low-mass bosons in stars

Georg G. Raffelt

PHYSICAL REVIEW D **102**, 043019 (2020)

Axion helioscopes as solar magnetometers

Ciaran A. J. O'Hare,[1,*] Andrea Caputo,[2,†] Alexander J. Millar,[3,4,‡] and Edoardo Vitagliano[5,§]

PHYSICAL REVIEW D **101**, 123004 (2020)

Revisiting longitudinal plasmon-axion conversion in external magnetic fields

Andrea Caputo,[1,*] Alexander J. Millar,[2,3,†] and Edoardo Vitagliano[4,‡]

PHYSICAL REVIEW D **102**, 123024 (2020)

Production of axionlike particles from photon conversions in large-scale solar magnetic fields

Ersilia Guarini,[1] Pierluca Carenza,[1,2] Javier Galán,[3] Maurizio Giannotti,[4] and Alessandro Mirizzi[1,2]

Axion emission by magnetic-field induced conversion of longitudinal plasmons

N. V. Mikheev
Department of Theoretical Physics, Yaroslavl State University, Sovietskaya 14, Yaroslavl 150000, Russia

G. Raffelt
Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Föhringer Ring 6, 80805 München, Germany

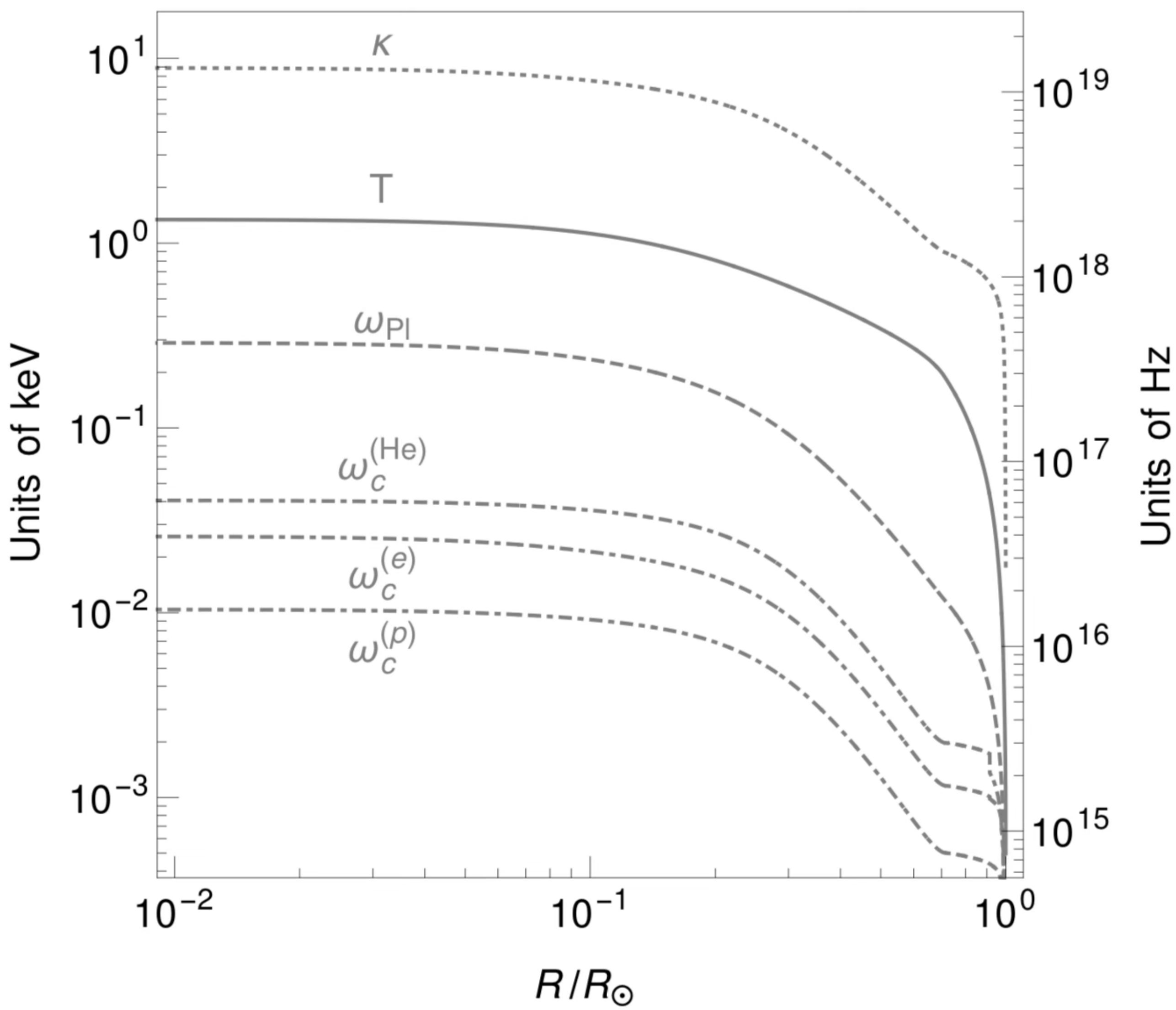
L. A. Vassilevskaya

Solar axion flux from the axion-electron coupling

Javier Redondo (Munich U., ASC and Munich, Max Planck Inst.)
Oct 2, 2013

Solar emission of gravitational waves

García-Cely, Ringwald, 2024



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Department of Physics, University of California, Berkeley, California

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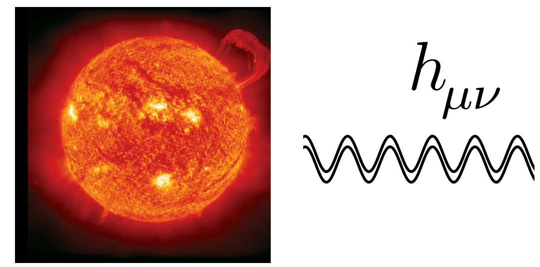
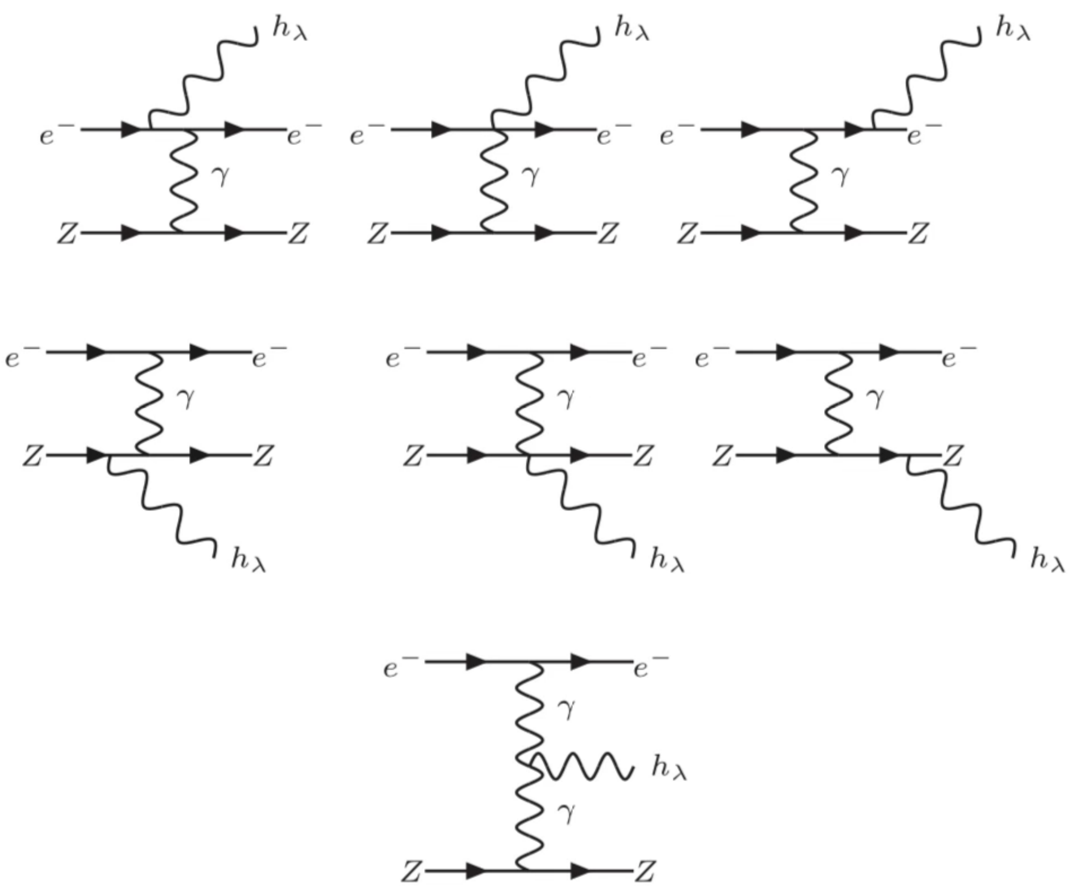
Solar emission of gravitational waves

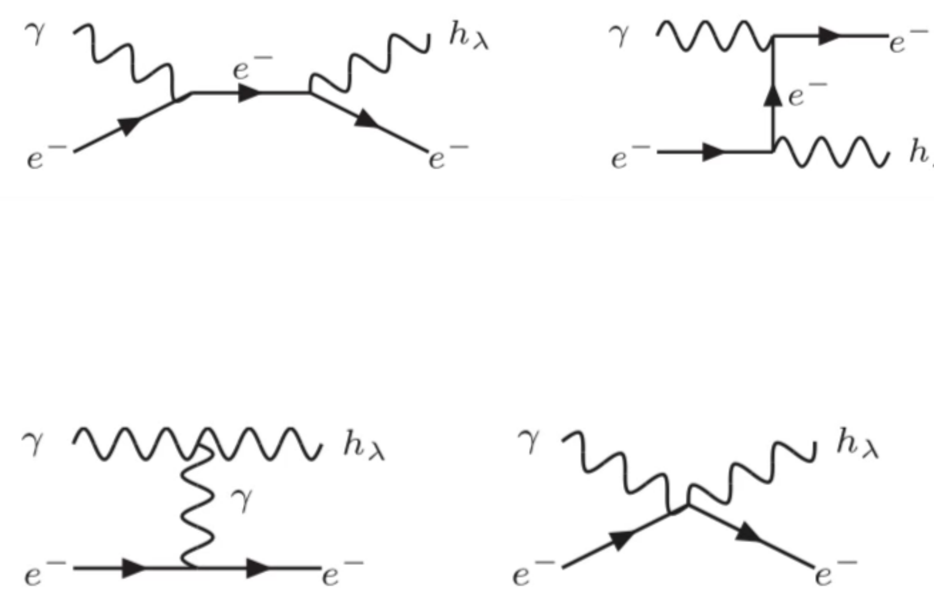
Microscopic contribution: graviton emission



Bremsstrahlung



Photoproduction



García-Cely, Ringwald, 2024

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Solar emission of gravitational waves

Macroscopic contribution: Hydrodynamical fluctuations

García-Cely, Ringwald, 2024

Gravitational wave background from Standard Model physics: qualitative features

J. Ghiglieri[1] and M. Laine[1]

Published 16 July 2015 • Journal of Cosmology and Astroparticle Physics, Volume 2015, July 2015

Citation J. Ghiglieri and M. Laine JCAP07(2015)022

DOI 10.1088/1475-7516/2015/07/022

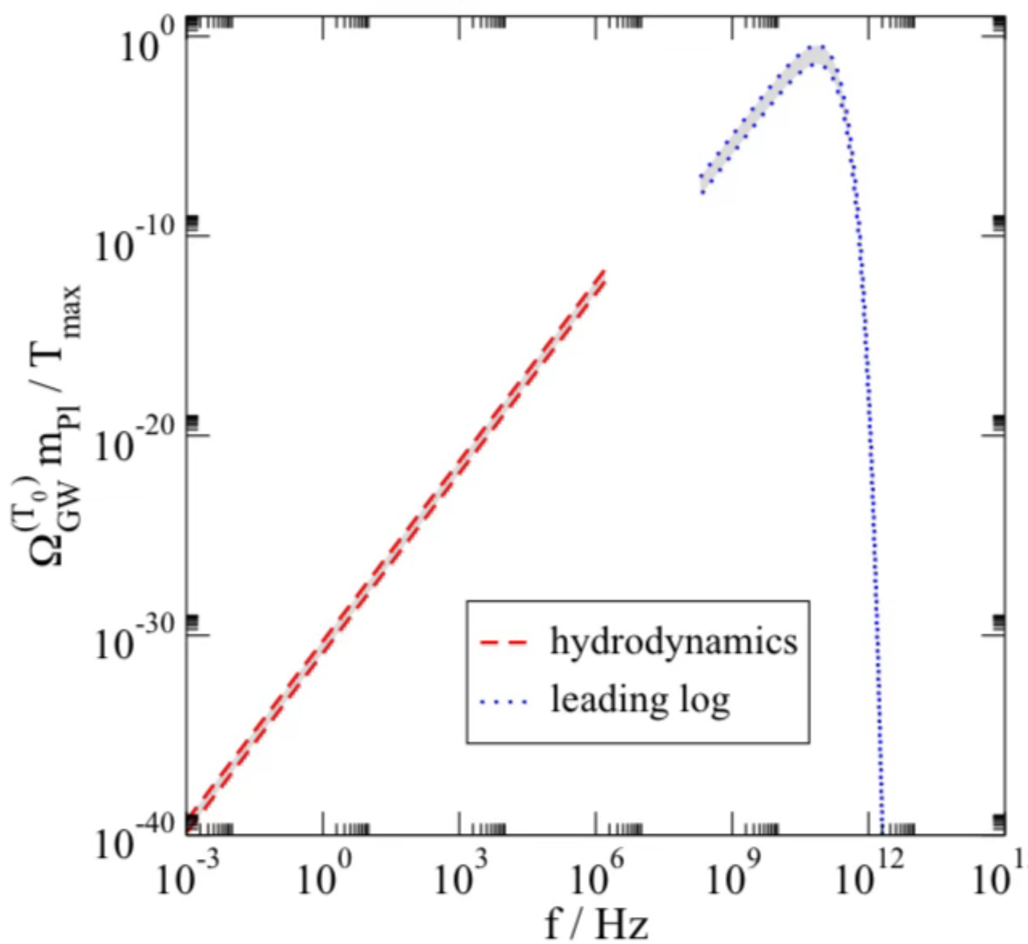
Article PDF

References

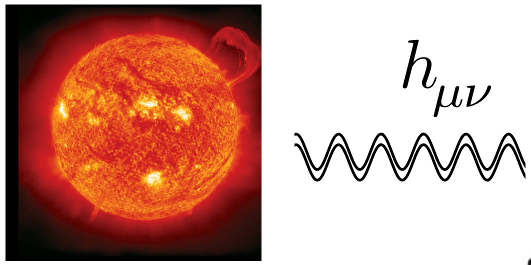
+ Article and author information

Abstract

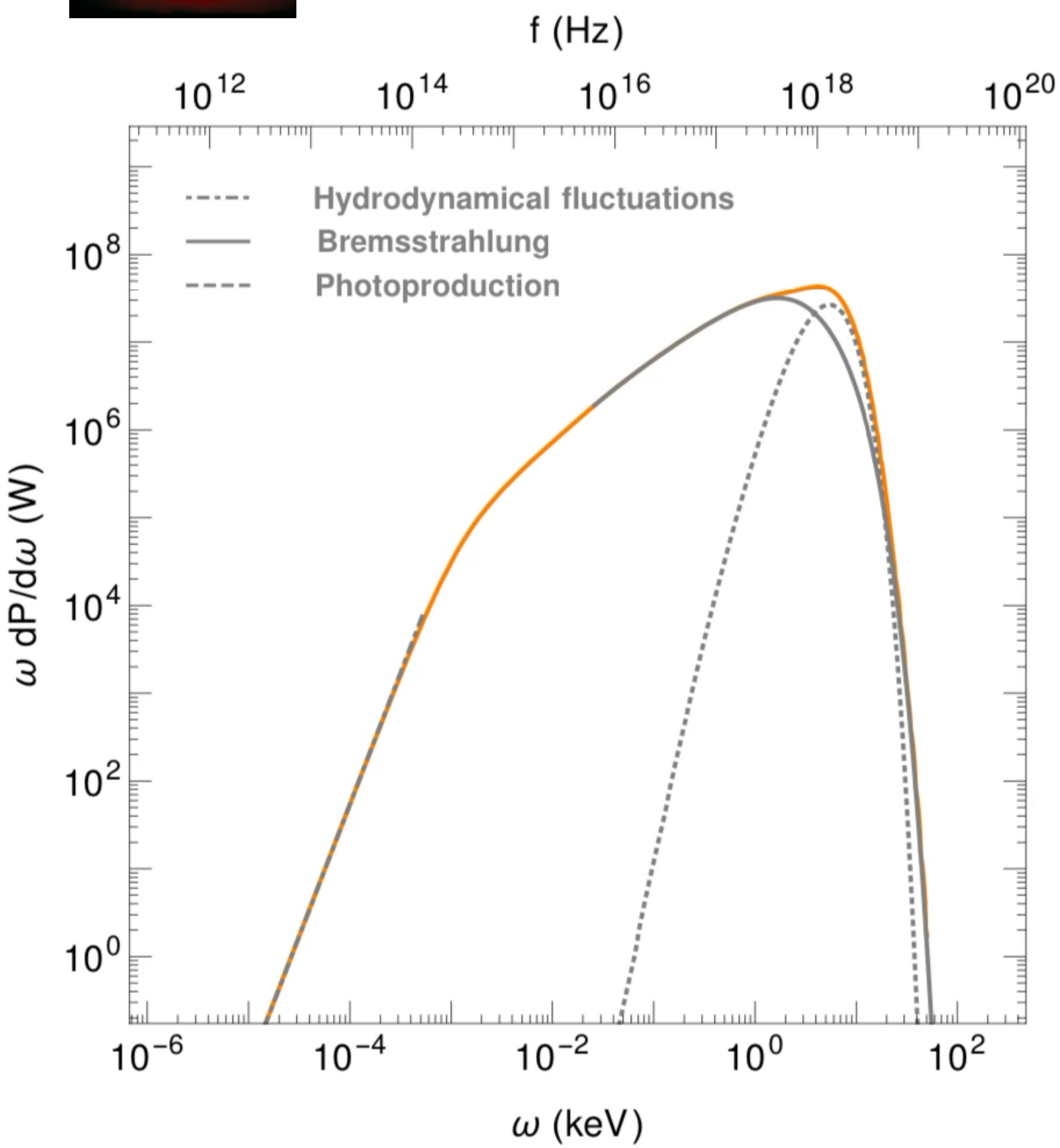
Because of physical processes ranging from microscopic particle collisions to macroscopic hydrodynamic fluctuations, any plasma in thermal equilibrium emits gravitational waves. For the largest wavelengths the emission rate is proportional to the shear viscosity of the plasma. In the Standard Model at



Solar gravitational waves



García-Cely, Ringwald, 2024



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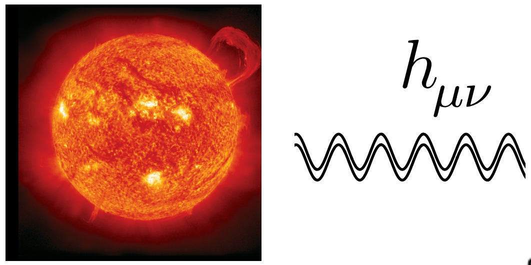
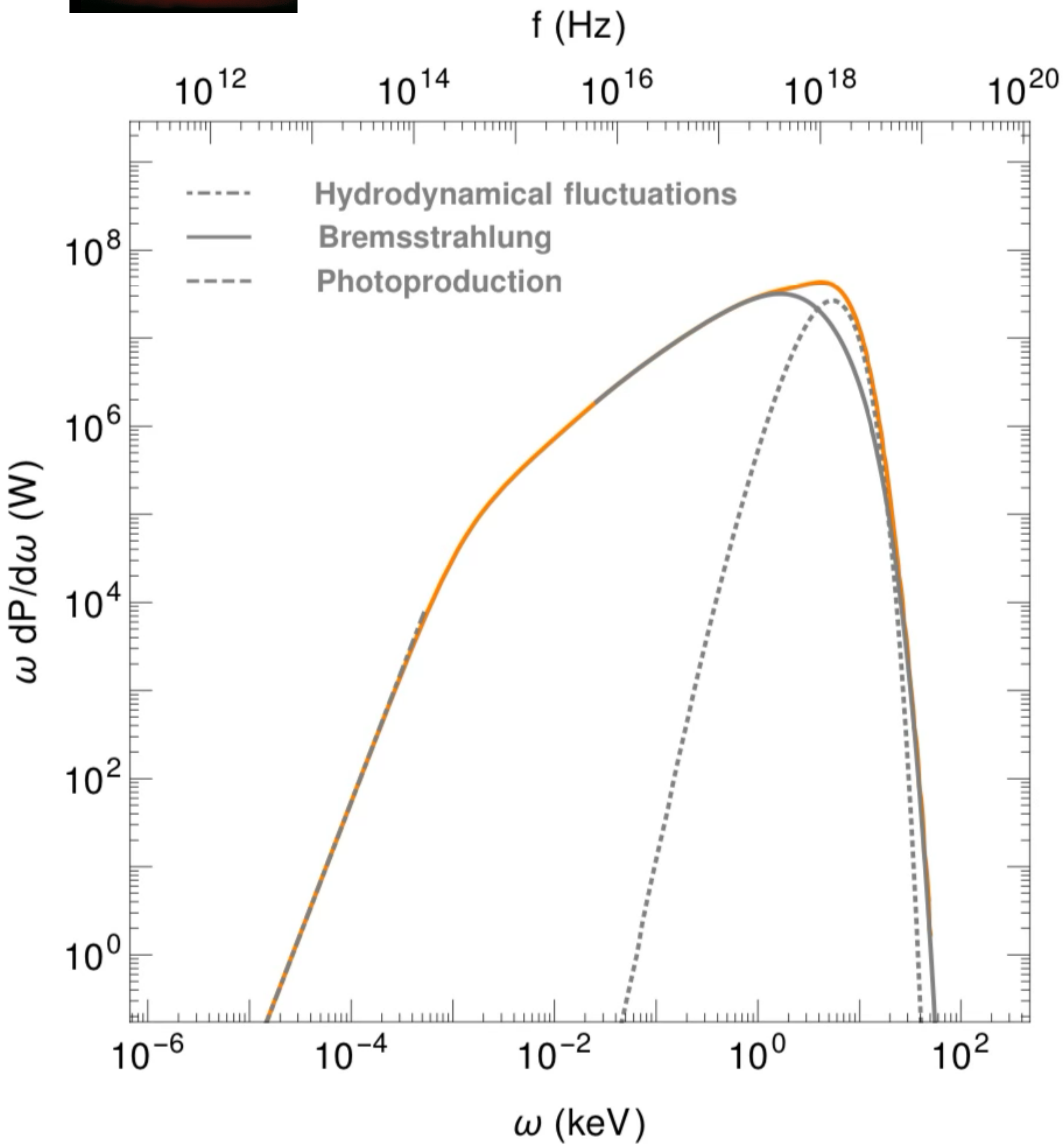
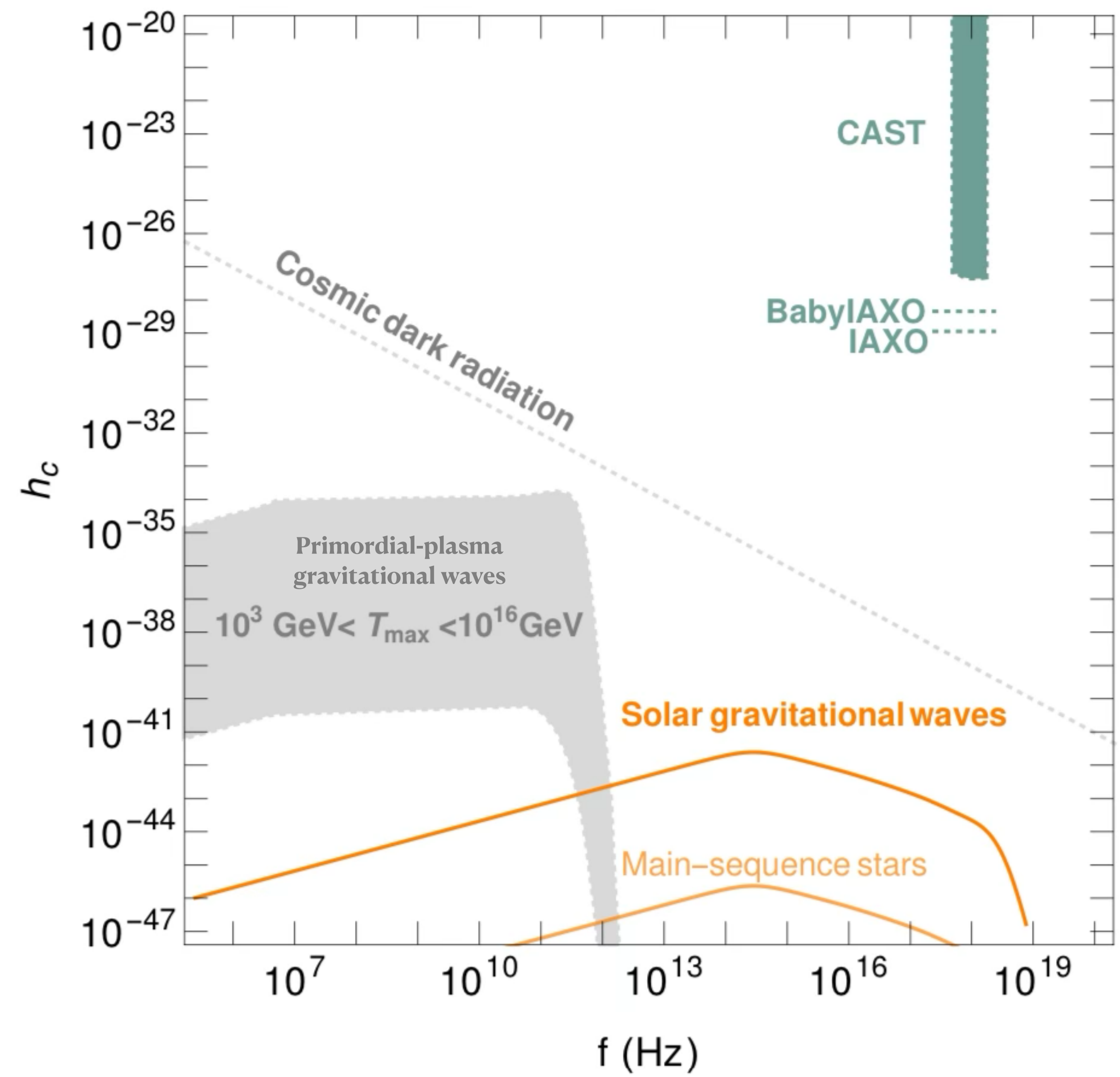
Solar gravitational waves



García-Cely, Ringwald, 2024





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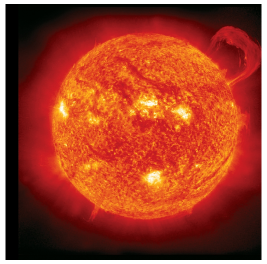
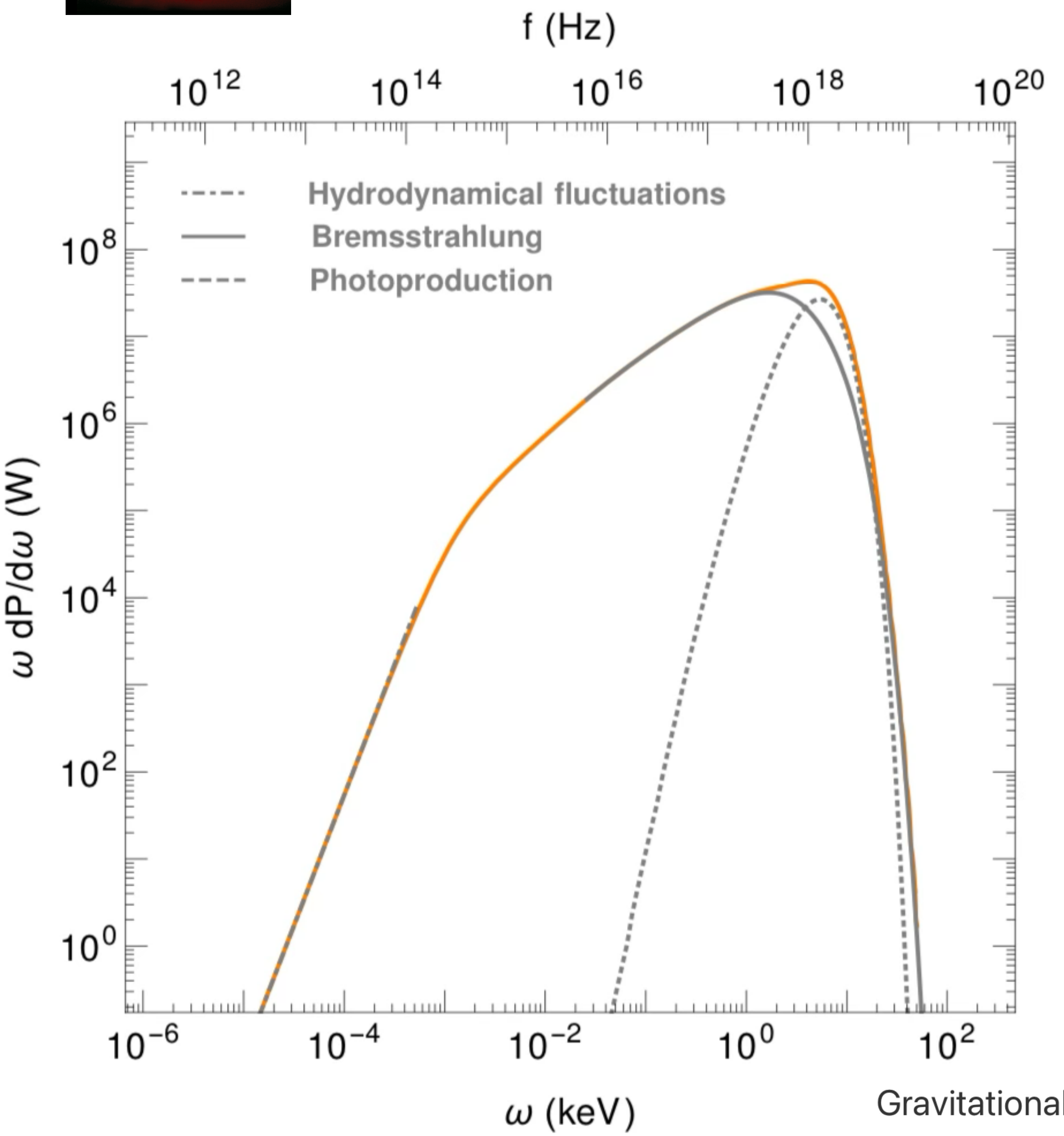
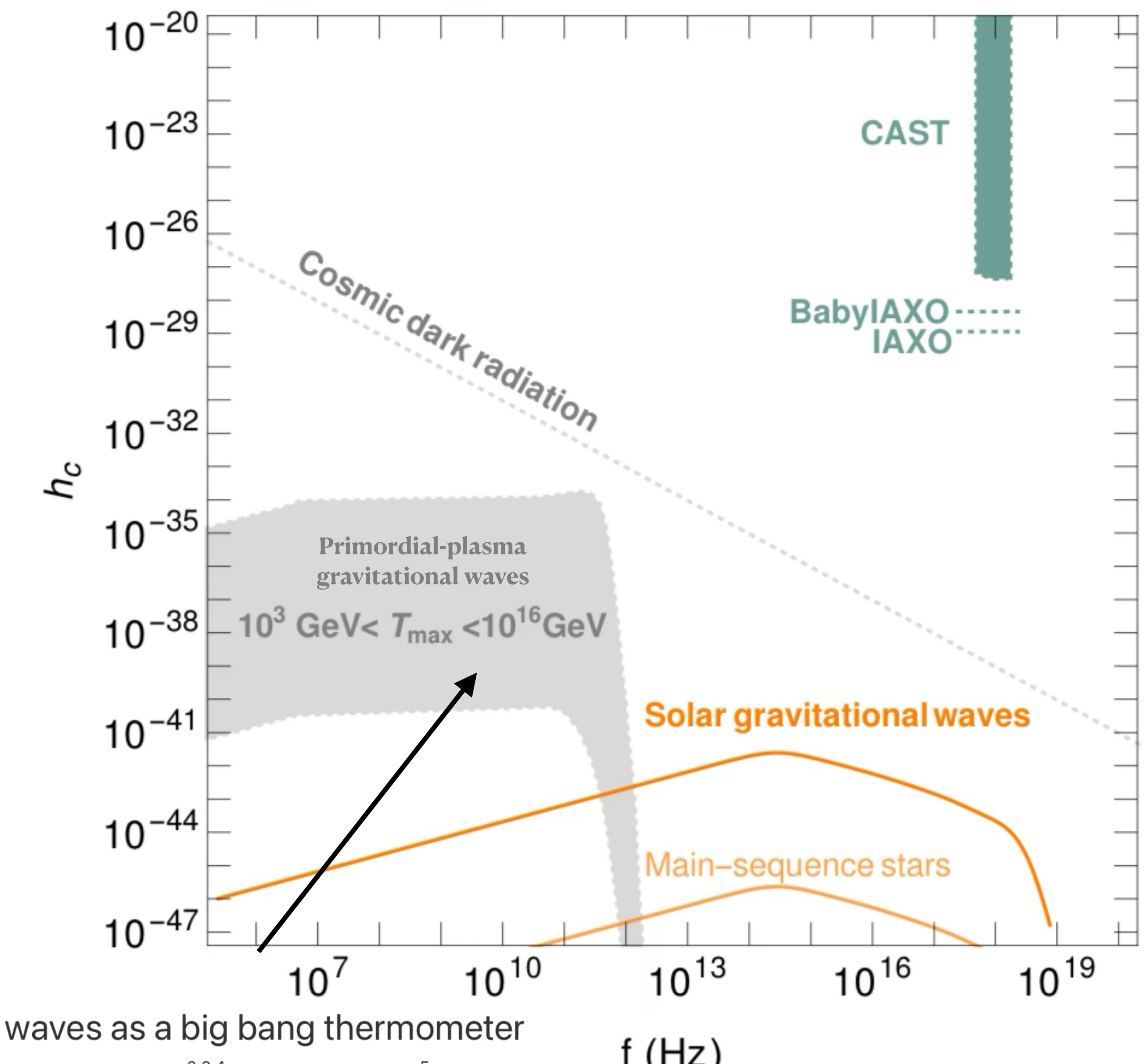
Solar gravitational waves



García-Cely, Ringwald, 2024





Gravitational waves as a big bang thermometer

Andreas Ringwald[1], Jan Schütte-Engel[2,3,4] and Carlos Tamarit[5]

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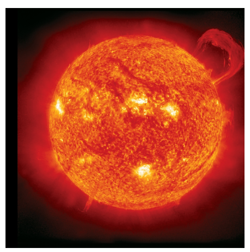
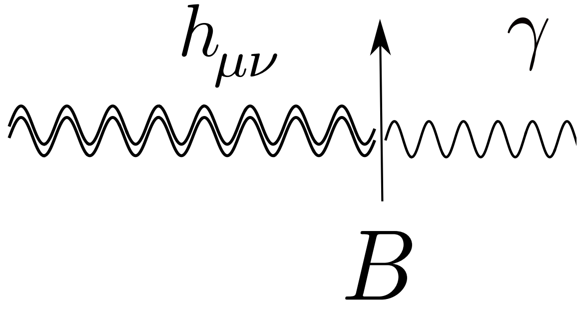
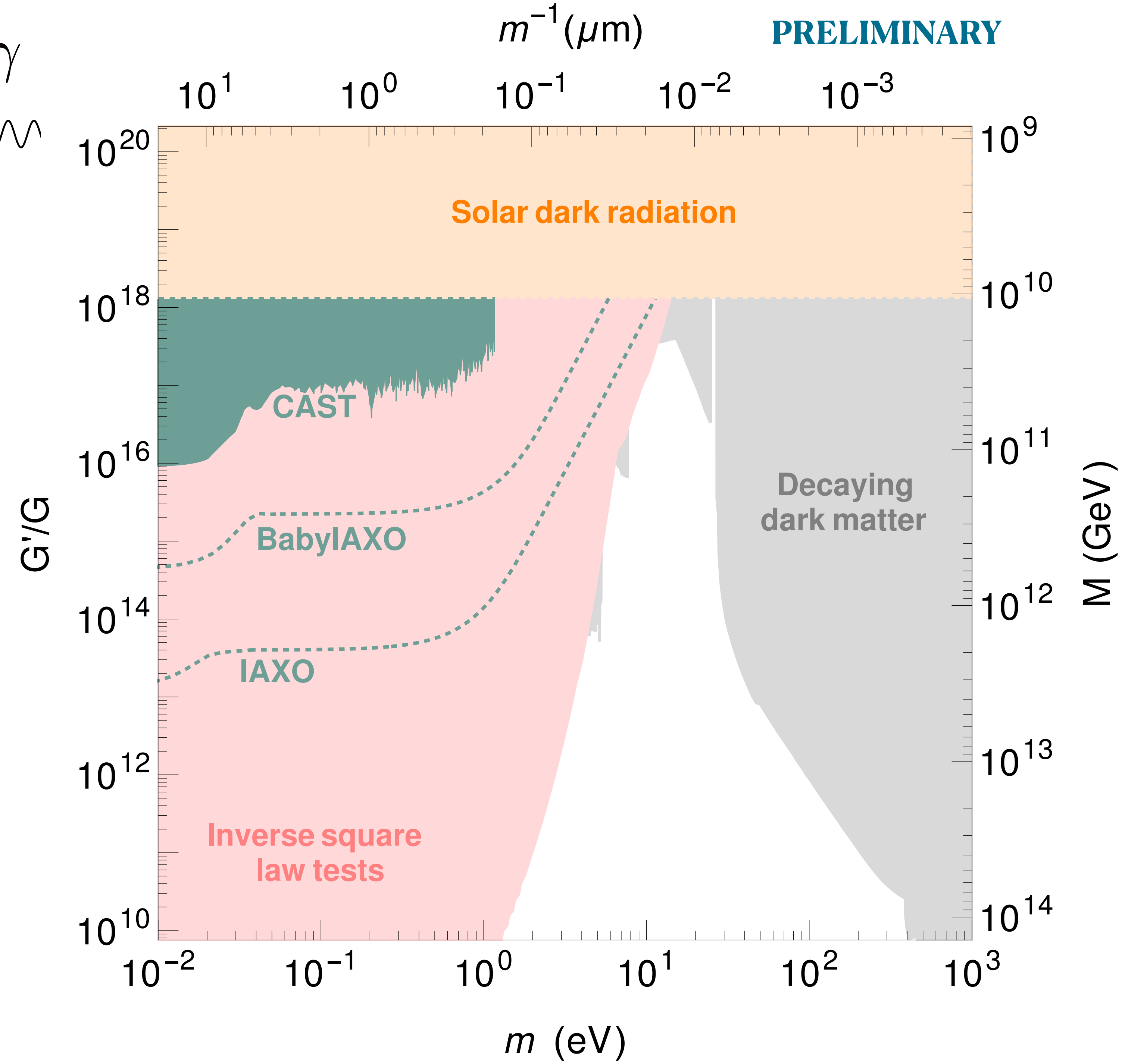
Journal of Cosmology and Astroparticle Physics, Volume 2021, March 2021

Solar emission of light spin-2 particles







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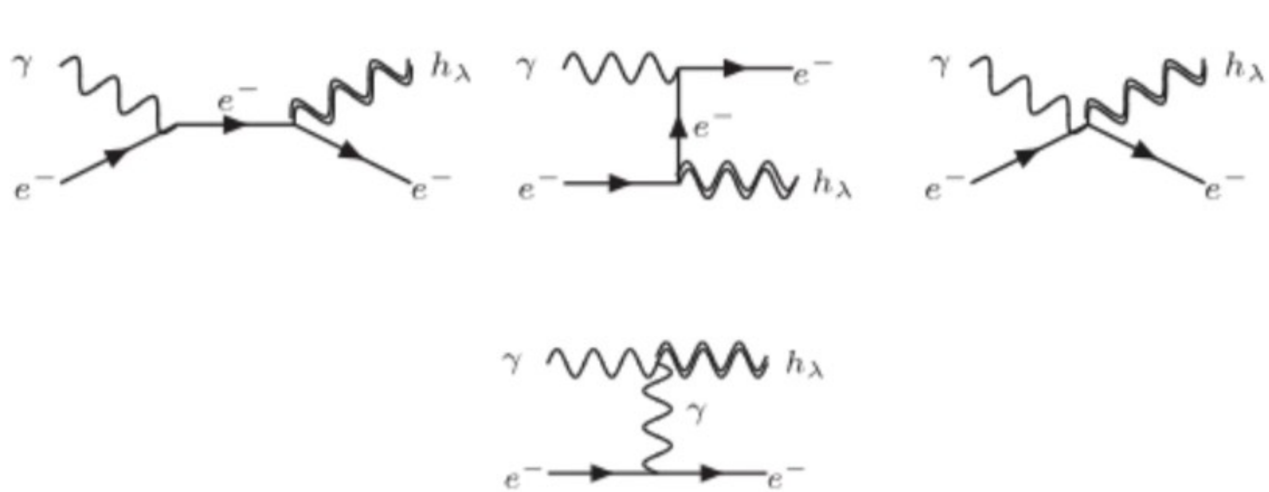
Solar emission of light spin-2 particles

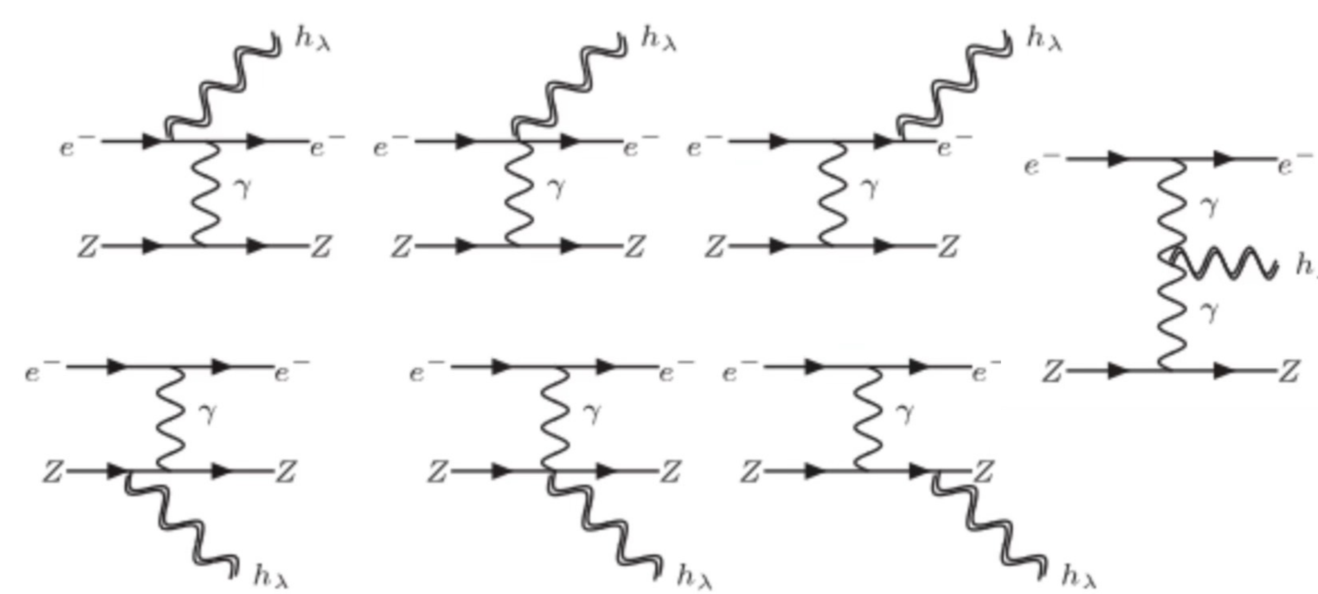
PRELIMINARY

Collision	λ	$\frac{d\Gamma}{d\omega dV}$	
Photo-production $\gamma Z \to Z\, h_\lambda$	± 2	$n_\gamma n_Z G' Z^2 \alpha\pi\, \delta(\omega - p_i) \int \mathrm{d}\cos\theta \cot^2\frac{\theta}{2}[1+\cos^2\theta]F(\theta)$	$F(\theta) = \frac{\left(2\omega\sin\frac{\theta}{2}\right)^2}{\kappa^2 + \left(2\omega\sin\frac{\theta}{2}\right)^2}$
	± 1	0	
	0	$\frac{4}{3} n_\gamma n_Z G' Z^2 \alpha\pi\, \delta(\omega - p_i) \int \mathrm{d}\cos\theta \cot^2\frac{\theta}{2} \sin^4\frac{\theta}{2} F(\theta)$	
Bremsstrahlung $eZ \to eZ\, h_\lambda$	± 2	$\frac{32 n_e n_Z G' Z^2 \alpha^2 p_i}{15\omega}\left(\frac{1}{m_e} + \frac{1}{m_Z}\right)\left(3(1+\xi^2)L + 10\xi + \mathcal{O}(\xi_s^2)\right)$	$\xi = \frac{p_f}{p_i}, \quad \xi_s = \frac{\kappa}{p_i}$
	± 1	0	
	0	$\frac{16 n_e n_Z G' Z^2 \alpha^2 p_i}{45\omega}\left(\frac{1}{m_e} + \frac{1}{m_Z}\right)\left((1+\xi^2)L + 30\xi + \mathcal{O}(\xi_s^2)\right)$	$\omega = E_i(1-\xi^2)$
Bremsstrahlung $ee \to ee\, h_\lambda$	± 2	$\frac{16 n_e^2 G' \alpha^2 p_i}{15\omega m_e}\left(\left(6(1+\xi^2) - \frac{3(1-\xi^2)^4 + 7(1-\xi^4)^2}{2(1+\xi^2)^3}\right)L + 20\xi - \frac{6\xi(1+\xi^4)}{(1+\xi^2)^2} + \mathcal{O}(\xi_s^2)\right)$	$L = \log\sqrt{\frac{(1+\xi)^2+\xi_s^2}{(1-\xi)^2+\xi_s^2}}$
	± 1	0	
	0	$\frac{16 n_e^2 G' \alpha^2 p_i}{15\omega m_e}\left(\left(\frac{1}{3}(1+\xi^2) - \frac{(1-\xi^2)^4 + 29(1-\xi^4)^2}{12(1+\xi^2)^3}\right)L + \frac{29\xi}{3} + \frac{2\xi^3}{3(1+\xi^2)^2} + \mathcal{O}(\xi_s^2)\right)$	

1. Photoproduction



2. Bremsstrahlung



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Conclusions

- The high-temperature plasma within the solar interior generates stochastic gravitational waves.
- We reexamined this phenomenon due to its significance as the primary source of high-frequency gravitational waves in the solar system.
- Our analysis builds upon existing studies of axion emission from the Sun, particularly regarding the treatment of plasma effects.
- Similar to several well-motivated signals from the Early Universe, we find that the resulting gravitational wave spectrum is several orders of magnitude below the current sensitivity of axion helioscopes, such as (Baby)IAXO.
- This study represents a step toward establishing a multi-frequency gravitational wave background from Standard Model processes, analogous to that of neutrinos.
- Our approach can be extended to other stellar plasmas, such as those in white dwarfs and neutron stars, as well as to early Universe stages following nucleosynthesis, where plasmas are also non-relativistic.
- Whether future advancements will enable the necessary sensitivity to probe these signals remains an open question.