RADIOTELESCOPES AS PROBES OF HIGH-FREQUENCY GRAVITATIONAL WAVES

UNDARK WORKSHOP

INSTITUTO DE ASTROFÍSICA DE CANARIAS (IAC)

CAMILO GARCIA-CELY.

SEPTEMBER 30, 2025

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High-frequency gravitational waves

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

arXiv > gr-qc > arXiv:2501.11723

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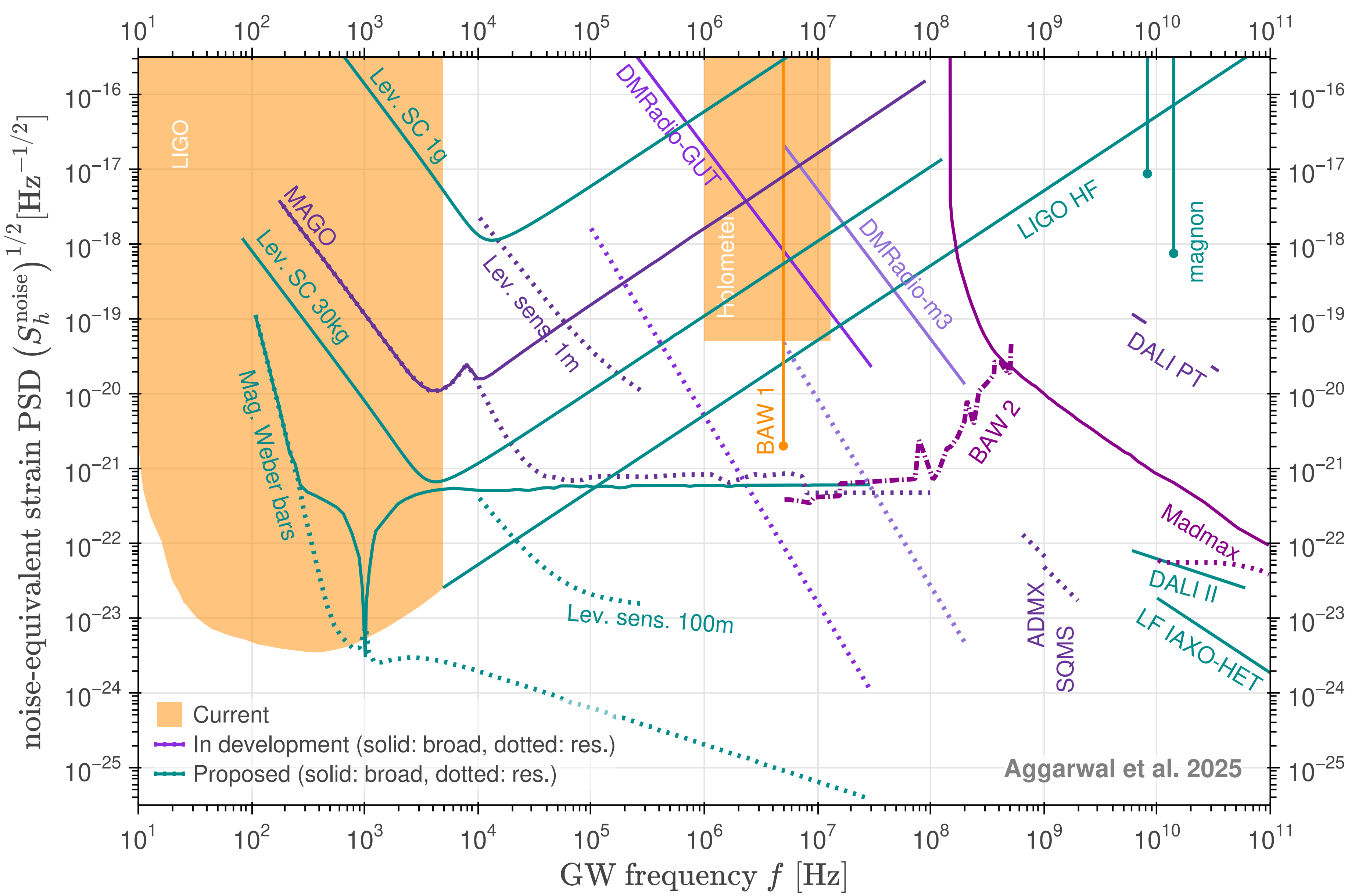
General Relativity and Quantum Cosmology

[Submitted on 20 Jan 2025]

Challenges and Opportunities of Gravitational Wave Searches above 10 kHz

Nancy Aggarwal, Odylio D. Aguiar, Diego Blas, Andreas Bauswein, Giancarlo Cella, Sebastian Clesse, Adrian Michael Cruise, Valerie Domcke, Sebastian Ellis, Daniel G. Figueroa, Gabriele Franciolini, Camilo Garcia-Cely, Andrew Geraci, Maxim Goryachev, Hartmut Grote, Mark Hindmarsh, Asuka Ito, Joachim Kopp, Sung Mook Lee, Killian Martineau, Jamie McDonald, Francesco Muia, Nikhil Mukund, David Ottaway, Marco Peloso, Krisztian Peters, Fernando Quevedo, Angelo Ricciardone, Andreas Ringwald, Jessica Steinlechner, Sebastian Steinlechner, Sichun Sun, Carlos Tamarit, Michael E. Tobar, Francisco Torrenti, Caner Ünal, Graham White



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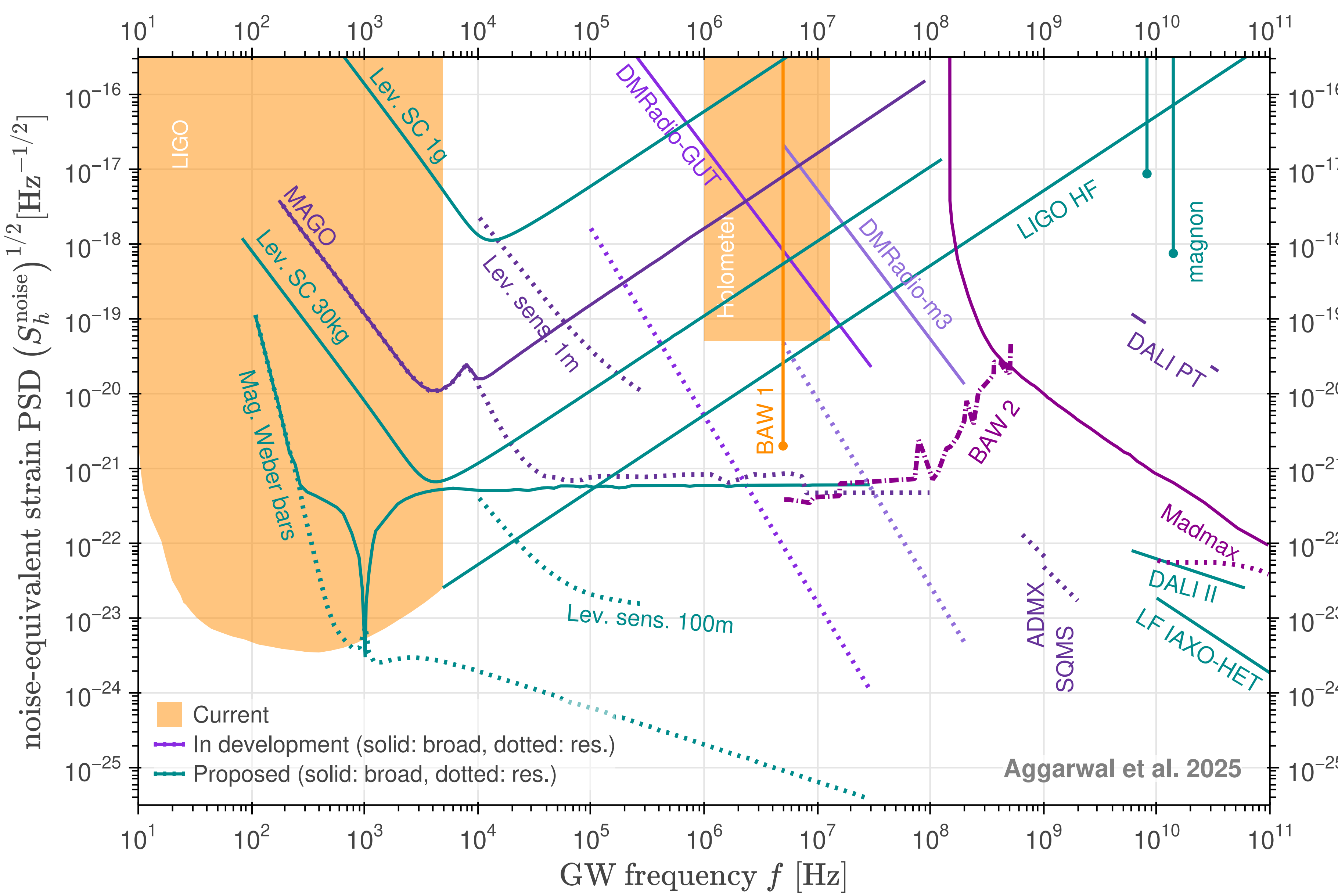
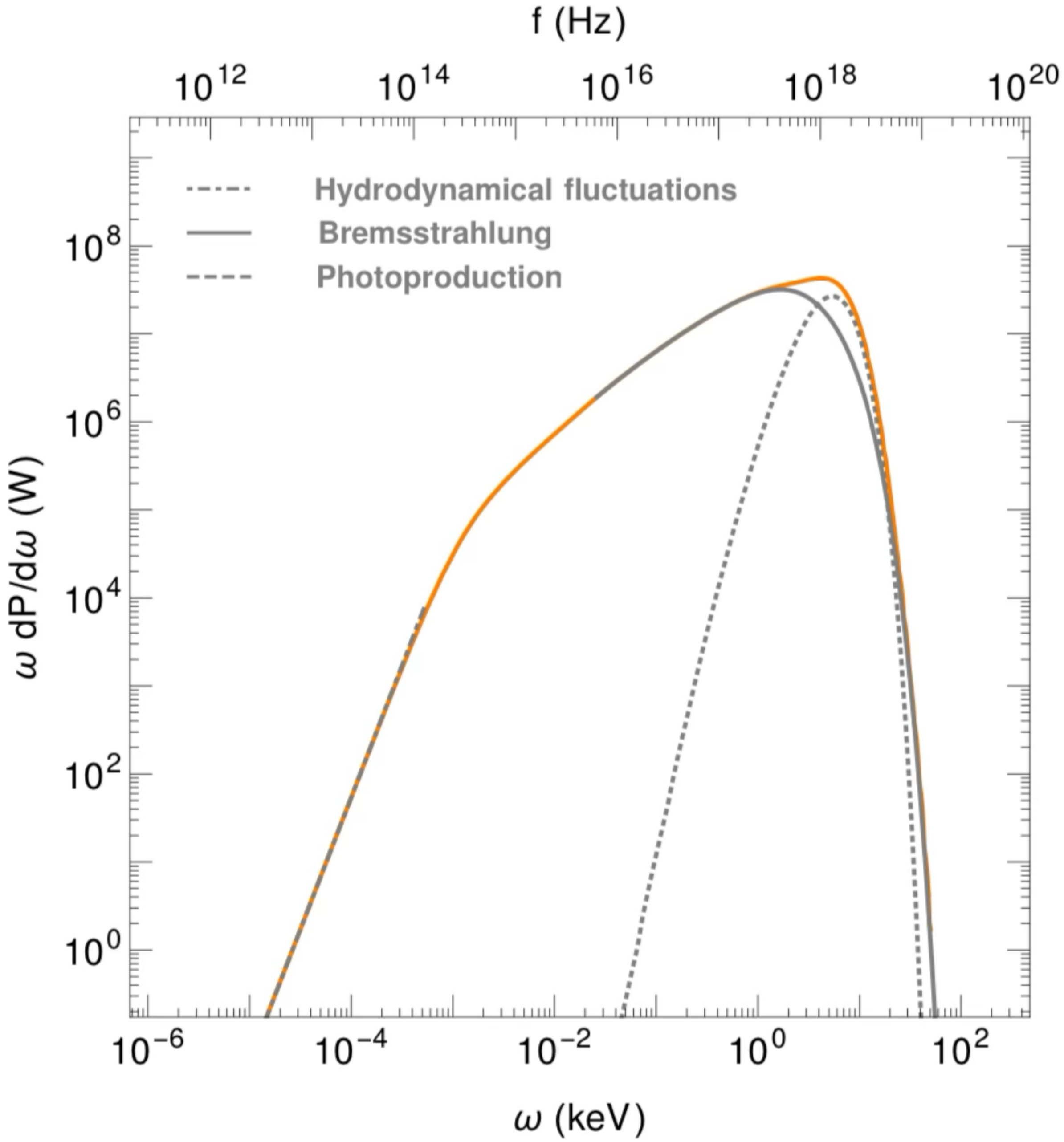


See also the talk by Jamie McDonald

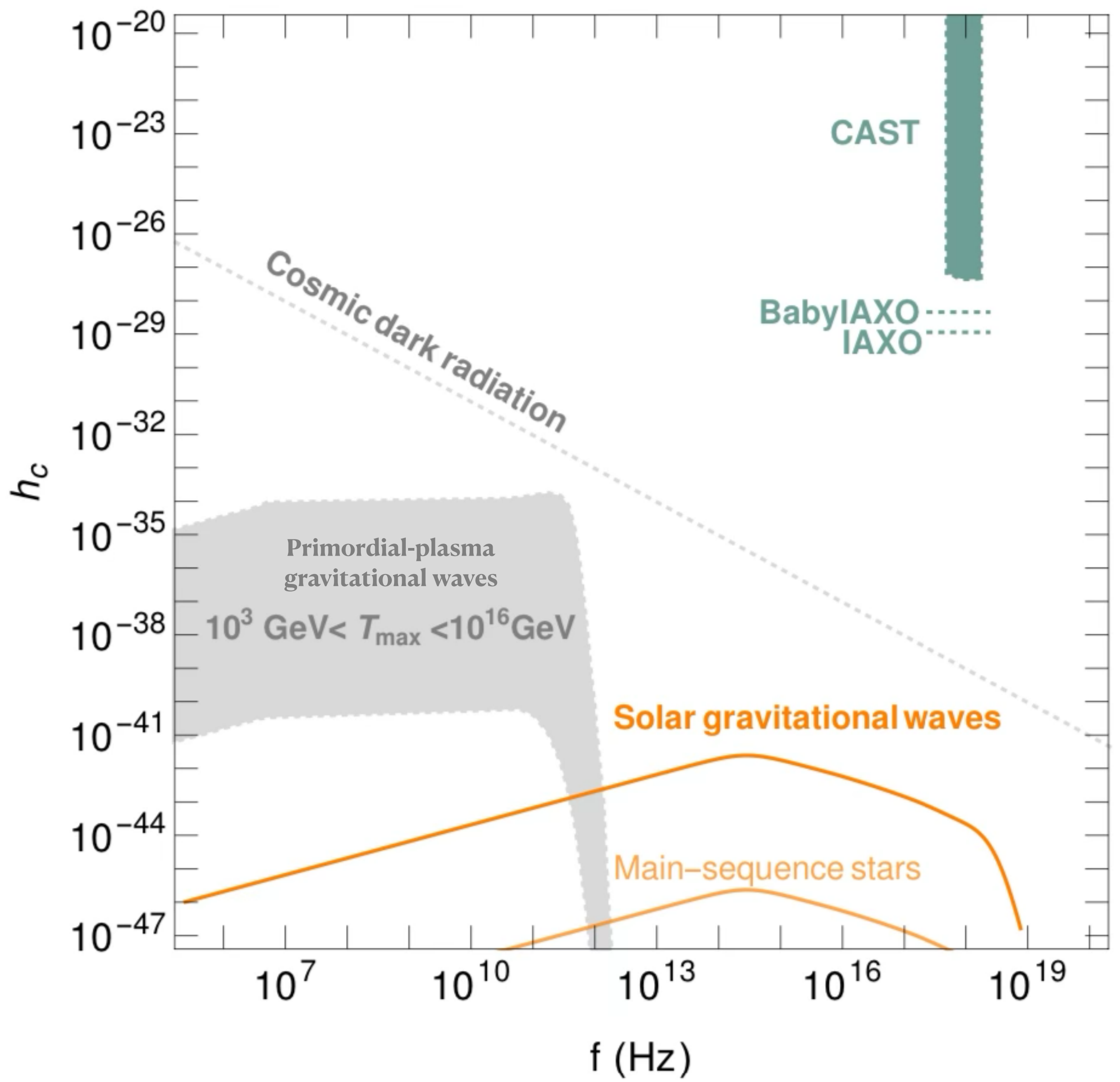
Sources within the Standard Model



PHYSICAL REVIEW LETTERS **135,** 061001 (2025)

Complete Gravitational-Wave Spectrum of the Sun

Camilo García-Cely[1] and Andreas Ringwald[2]



Gravitational waves as a big bang thermometer

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

Published 17 March 2021 • © 2021 IOP Publishing Ltd and Sissa Medialab

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

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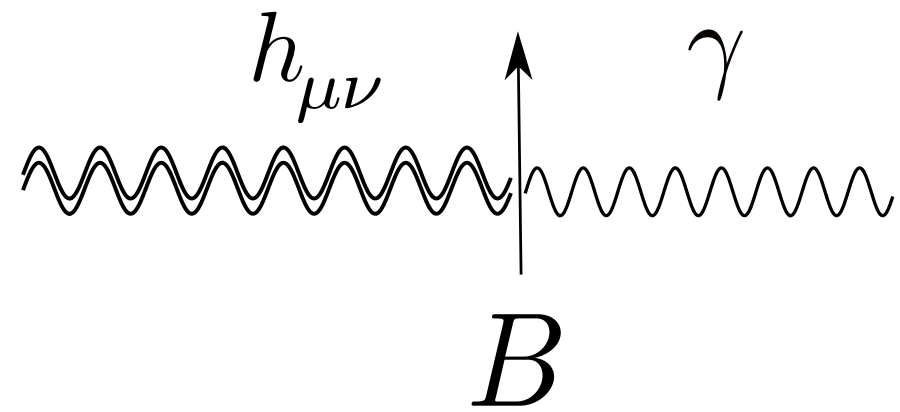
Revisiting Gertsenhstein's ideas

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

COSMIC MAGNETIC FIELDS AND RADIO ASTRONOMY

COSMIC MAGNETIC FIELDS

Durrer, Neronov, 2013

$$\langle \mathbf{B}_i(\mathbf{x})\mathbf{B}_j(\mathbf{x}')\rangle = \frac{1}{(2\pi)^3 a(t)^4}\int d^3k e^{i\mathbf{k}\cdot(\mathbf{x}'-\mathbf{x})}\left(\left(\delta_{ij}-\hat{k}_i\hat{k}_j\right)P_B(k) - i\epsilon_{ijk}\hat{k}_k P_{aB}(k)\right) ,$$

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$$\langle B^2\rangle = \frac{1}{\pi^2 a(t)^4}\int_0^\infty dk k^2 P_B(k) = \int_{-\infty}^{\infty} d\log\lambda\, B_\lambda^2$$

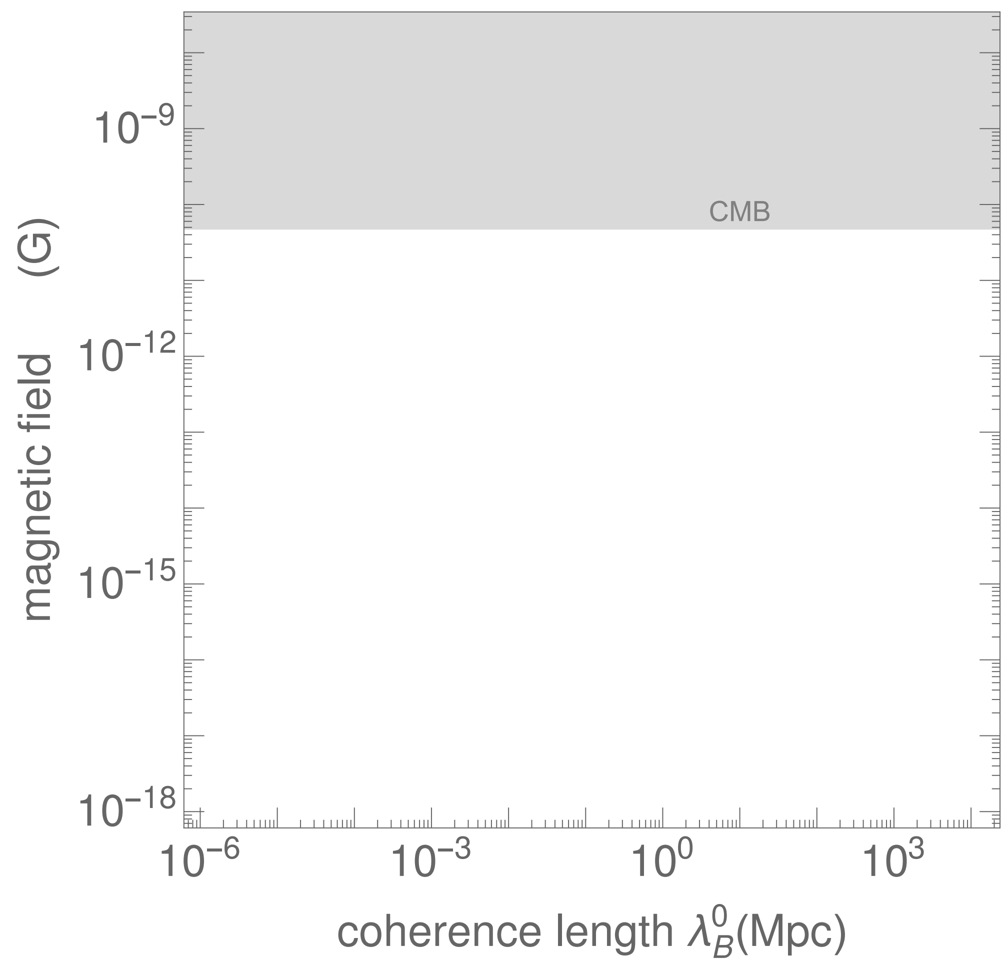
average magnetic field

where $B_\lambda^2 \equiv \frac{8\pi}{\lambda^3 a(t)^4} P_B\left(\frac{2\pi}{\lambda}\right) ,$

$$\lambda_B = \int_0^\infty d\lambda \frac{B_\lambda^2}{\langle B^2\rangle}$$

the coherence length

COSMIC MAGNETIC FIELDS



PHYSICAL REVIEW LETTERS **123,** 021301 (2019)

Stringent Limit on Primordial Magnetic Fields from the Cosmic Microwave Background Radiation

Karsten Jedamzik[1,*] and Andrey Saveliev[2,3,†]

[1] *Laboratoire Univers et Particules de Montpellier, UMR5299-CNRS, Université de Montpellier, 34095 Montpellier, France*
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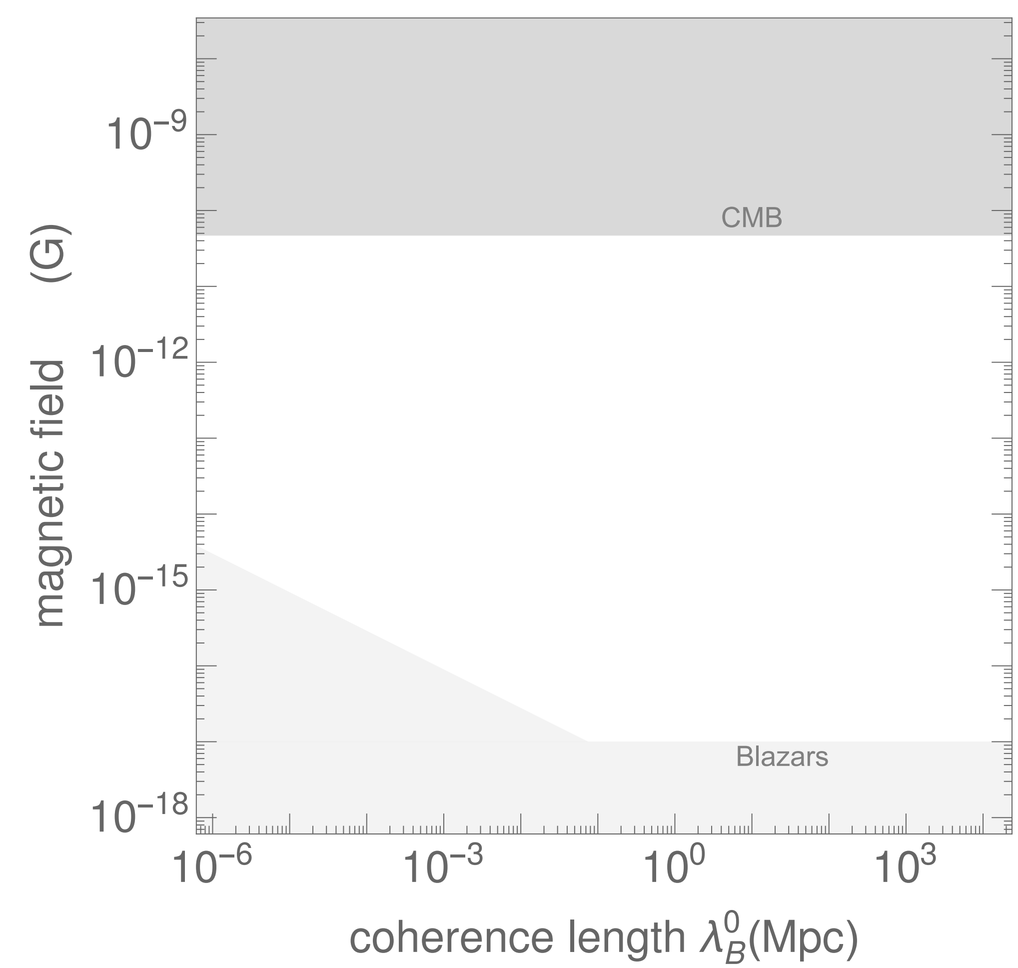
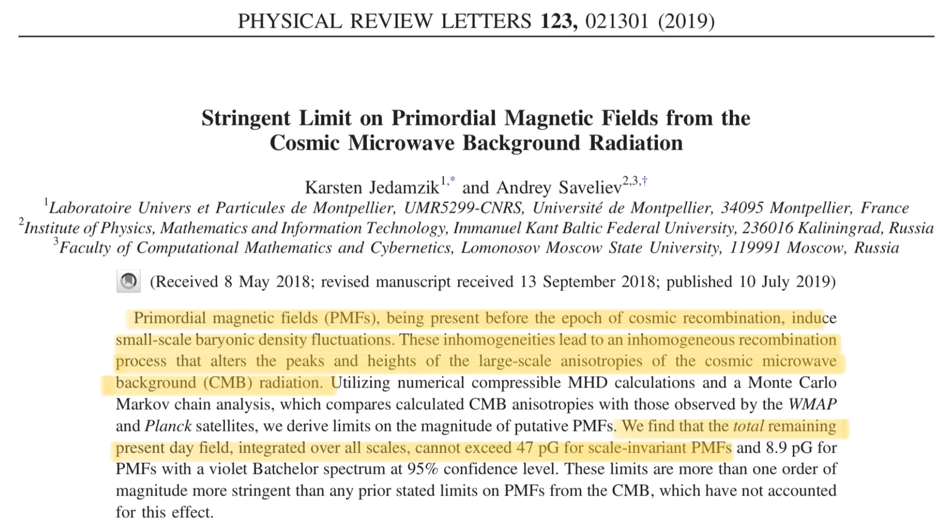
EVIDENCE FROM TEV BLAZARS



Durrer, Neronov, 2013



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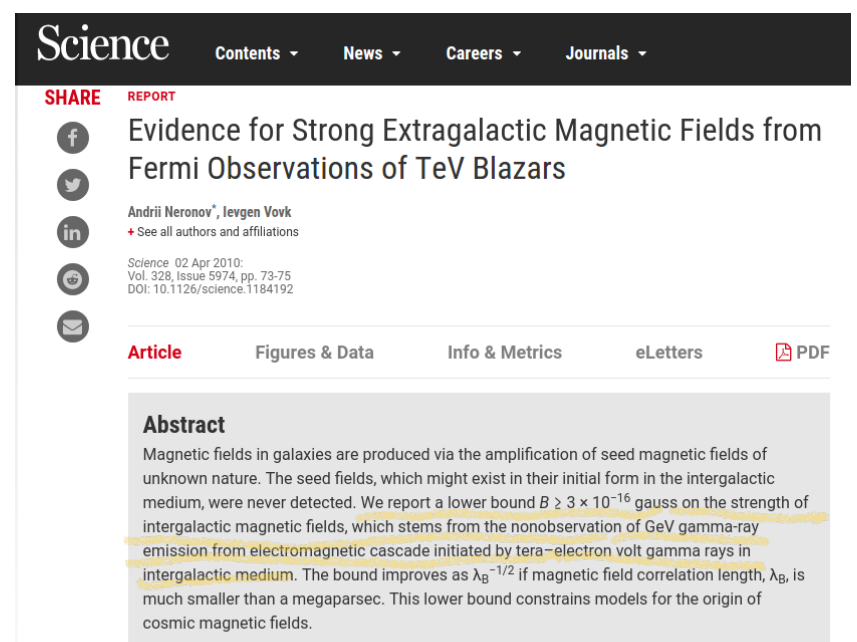

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REPORT

Evidence for Strong Extragalactic Magnetic Fields from Fermi Observations of TeV Blazars

Andrii Neronov*, Ievgen Vovk
+ See all authors and affiliations

Science 02 Apr 2010:
Vol. 328, Issue 5974, pp. 73-75
DOI: 10.1126/science.1184192

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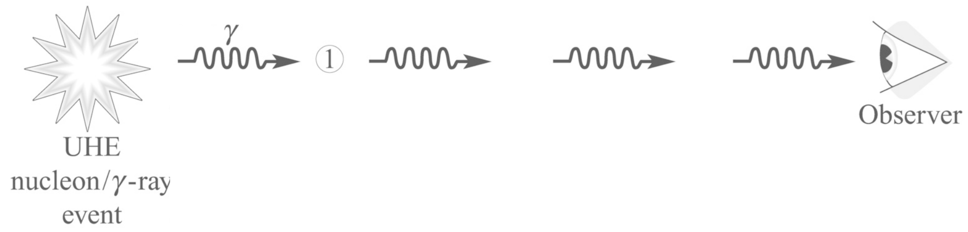
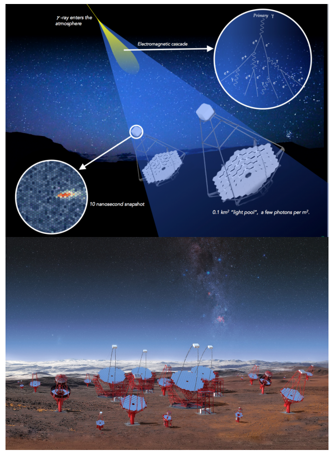
Kronberg , 2016
Cambridge University Press





EVIDENCE FROM TEV BLAZARS

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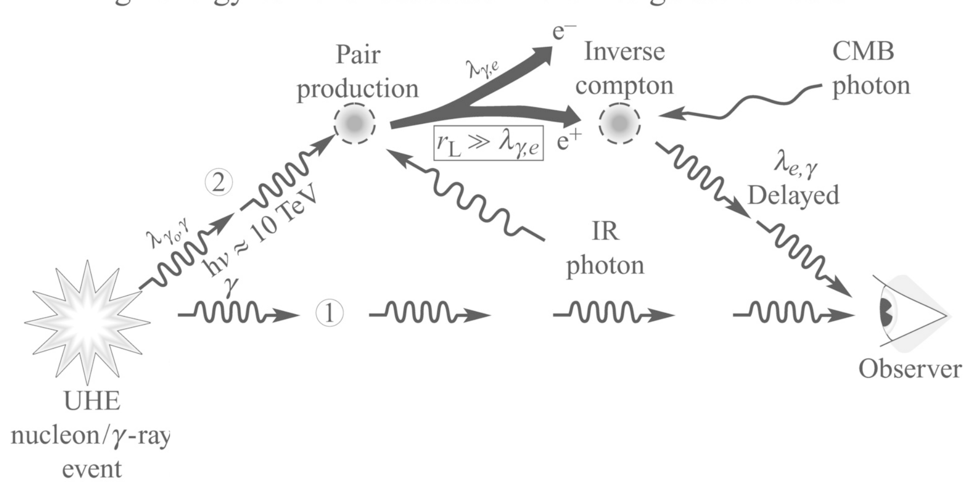
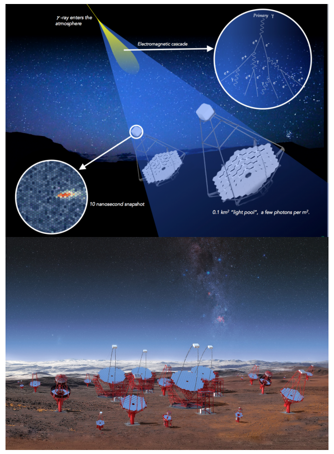
High energy $h\nu$ –e^+e^- cascades in the intergalactic medium





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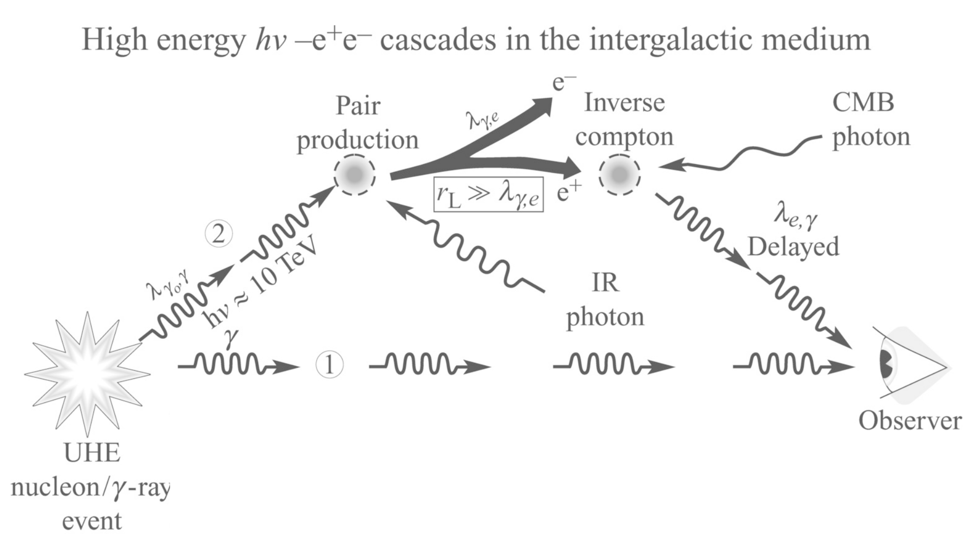

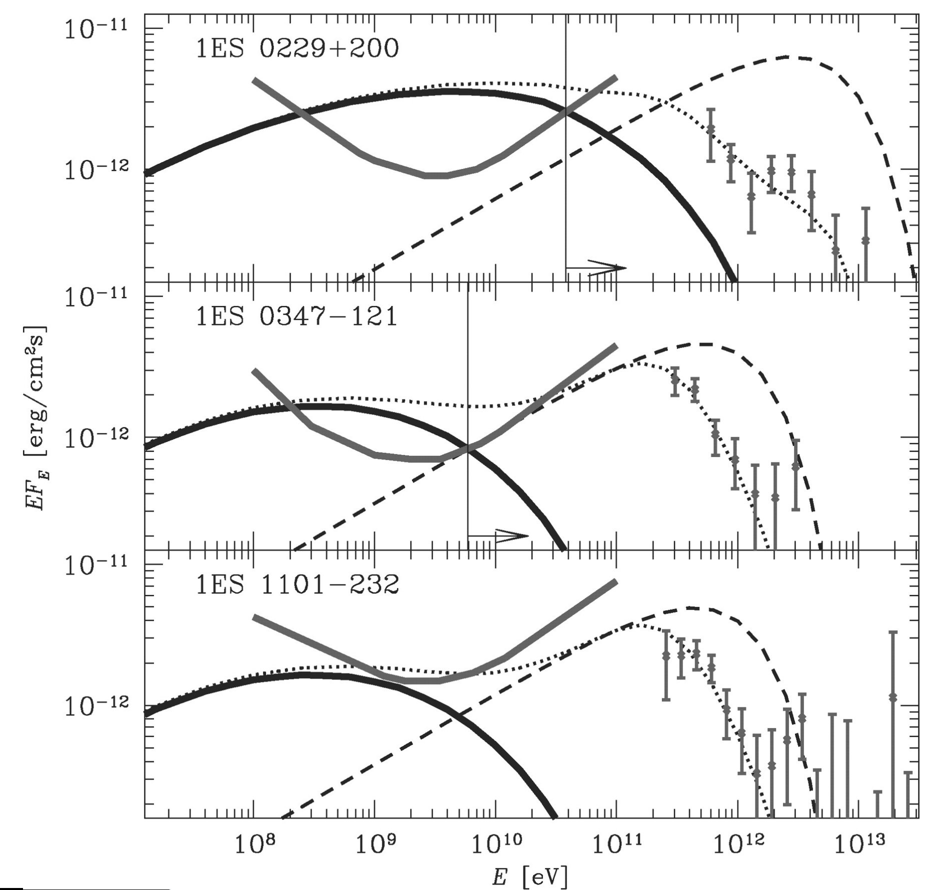

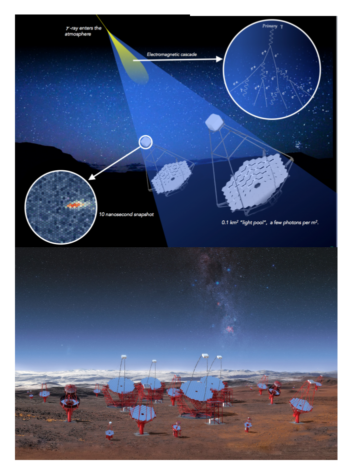

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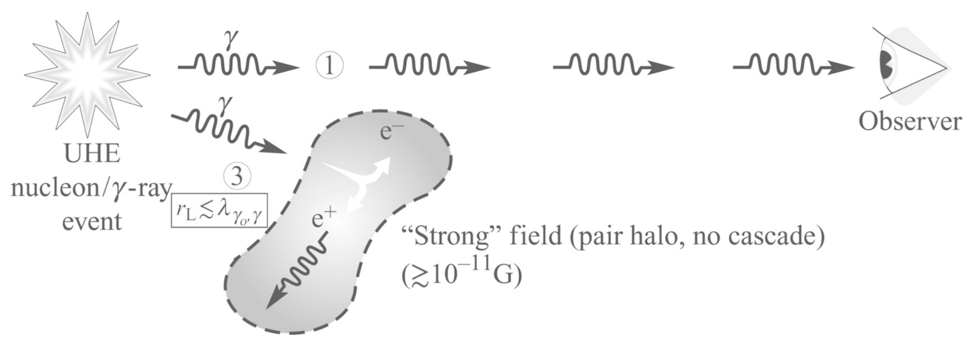

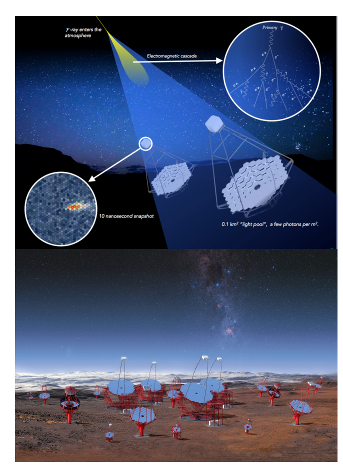

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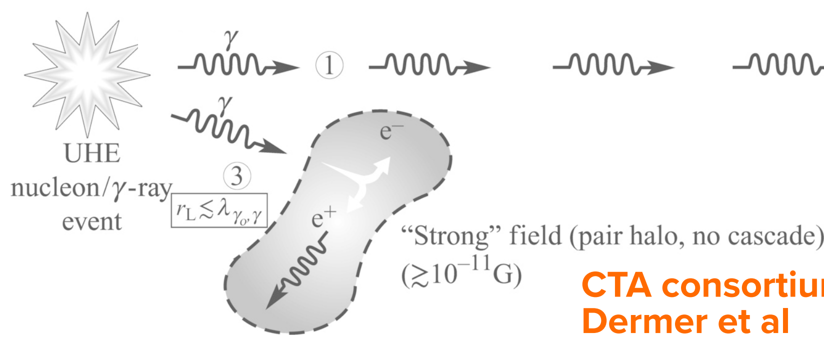
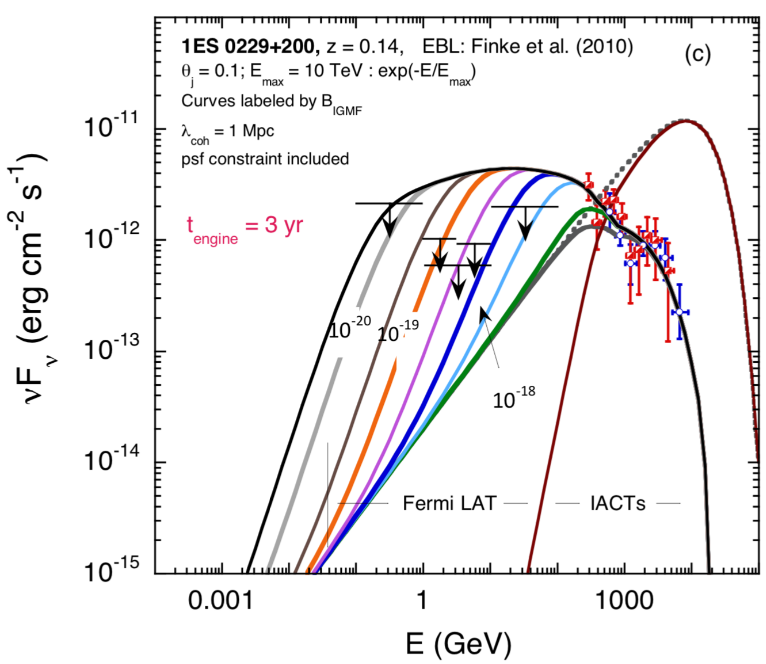
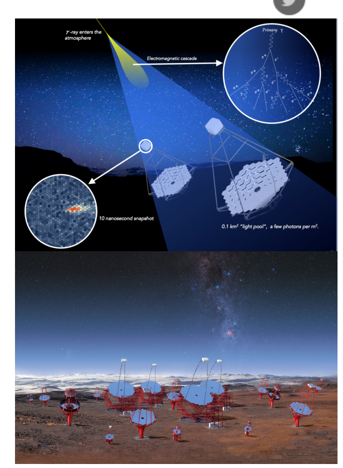
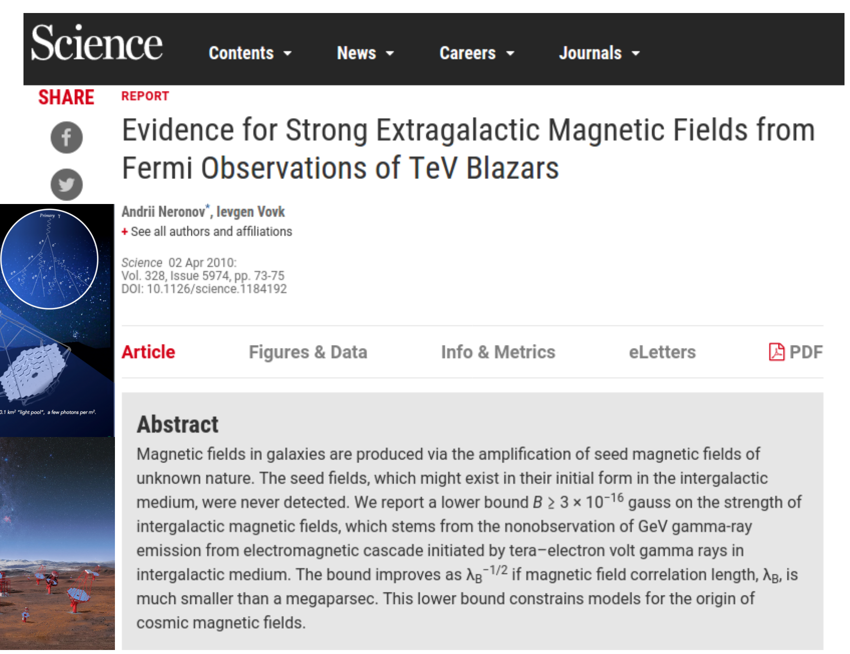


CTA consortium 2017
Dermer et al



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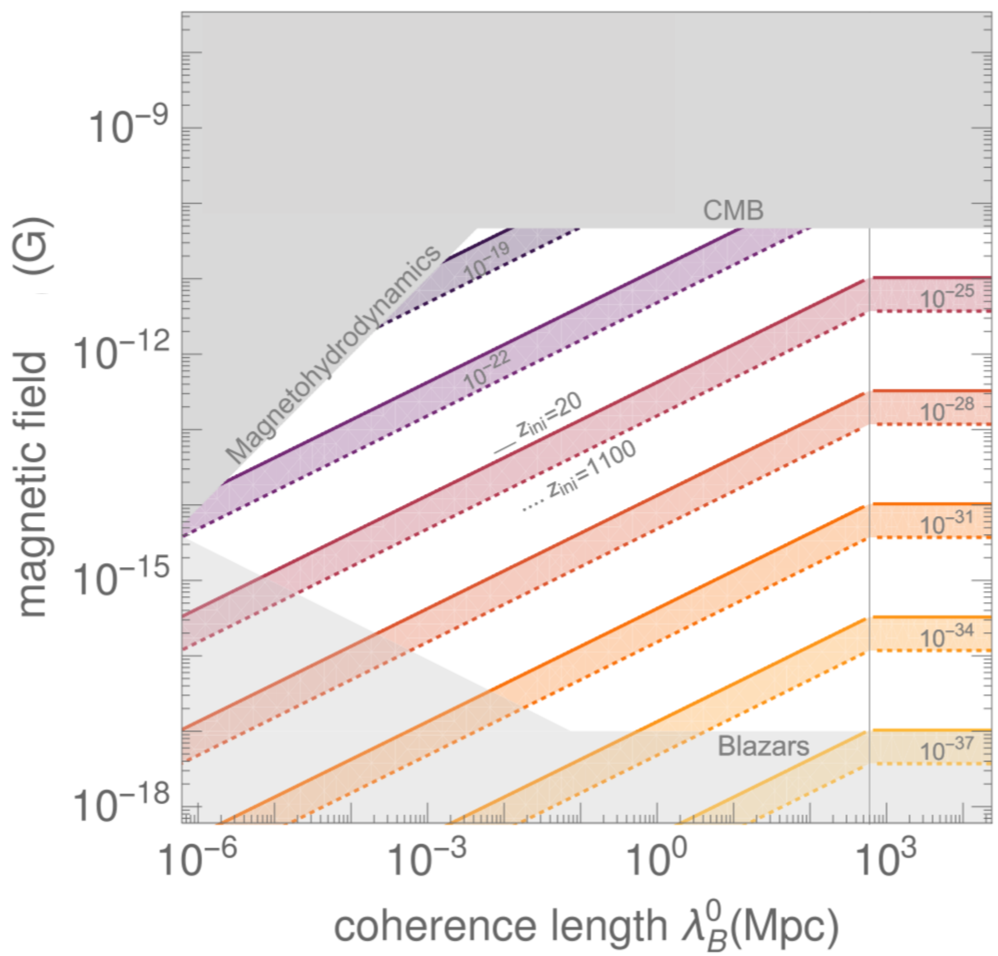

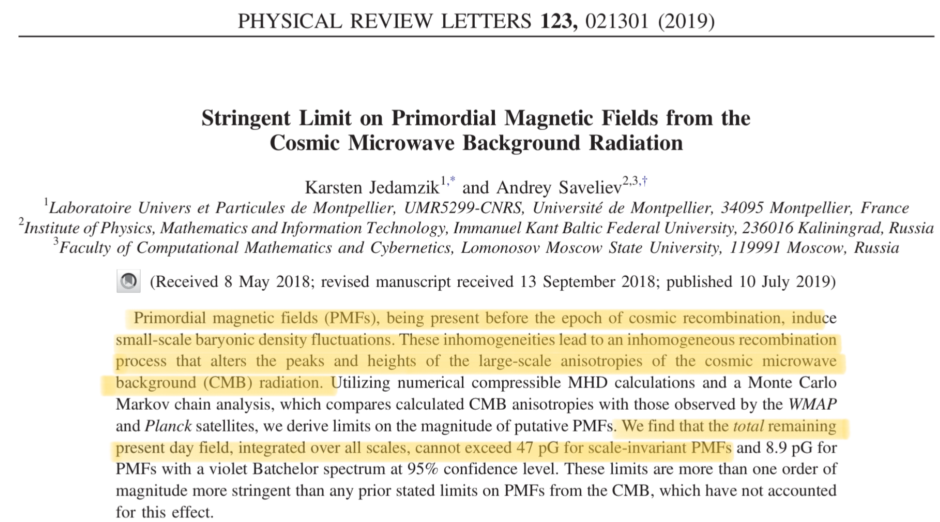

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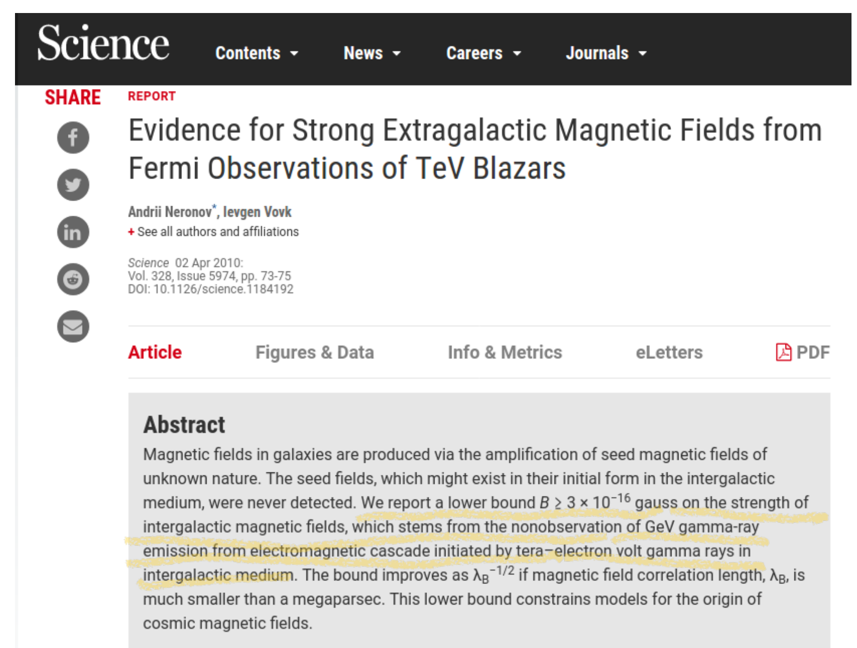

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EFFECT AFTER RECOMBINATION

$$\left(\Box + \omega_{\rm pl}^2\right) A_\lambda = - B\partial_\ell h_\lambda$$

$$\Box\, h_\lambda = 16\pi G B\, \partial_\ell A_\lambda$$

$$\omega_{\rm pl} = \sqrt{e^2 n_e / m_e}$$

The plasma frequency acts as an effective mass term

$$\ell_{\rm osc} \simeq 4\omega/\omega_{\rm pl}^2$$

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Although cosmic magnetic fields are not expected to be perfectly homogeneous, coherent oscillations take place in highly homogeneous patches.

$$\ell_{\text{osc}} = 4\omega/(1+z)^2 X_e(z)\omega_{\text{pl},0}^2 \ll 1\ \text{pc}$$

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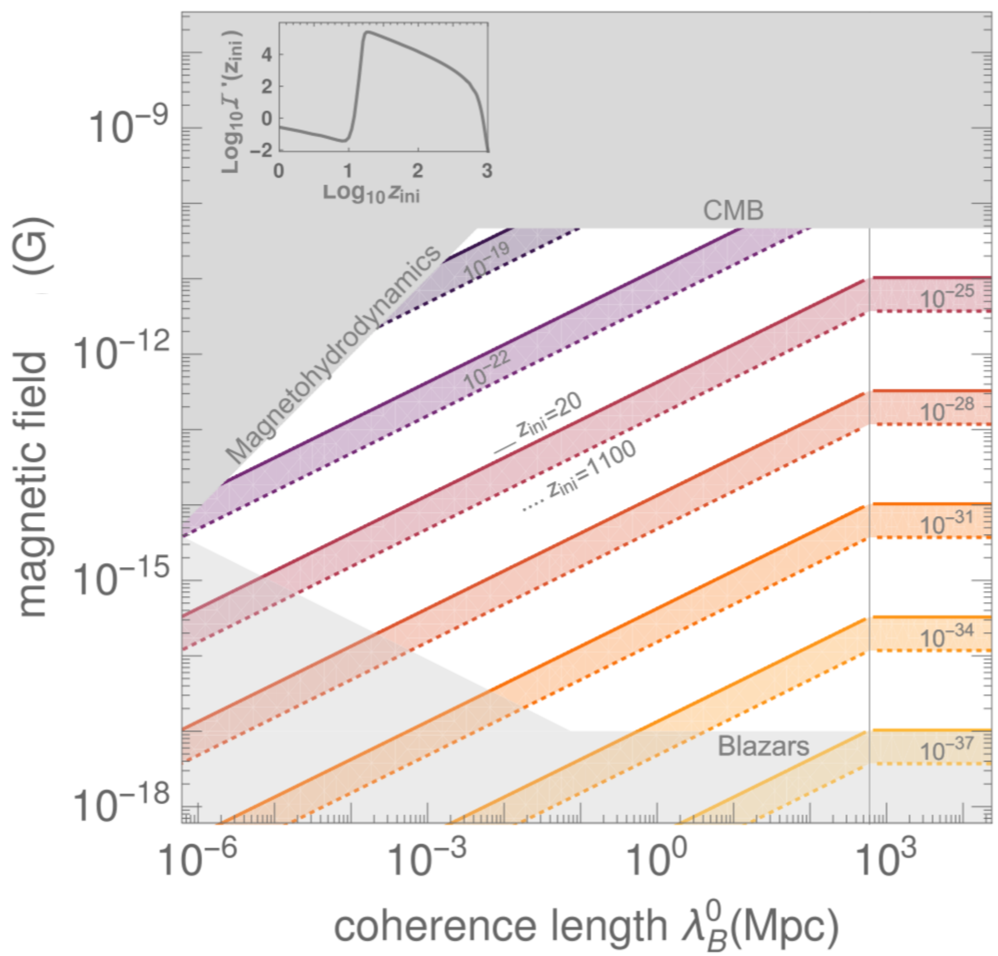
COSMIC MAGNETIC FIELDS



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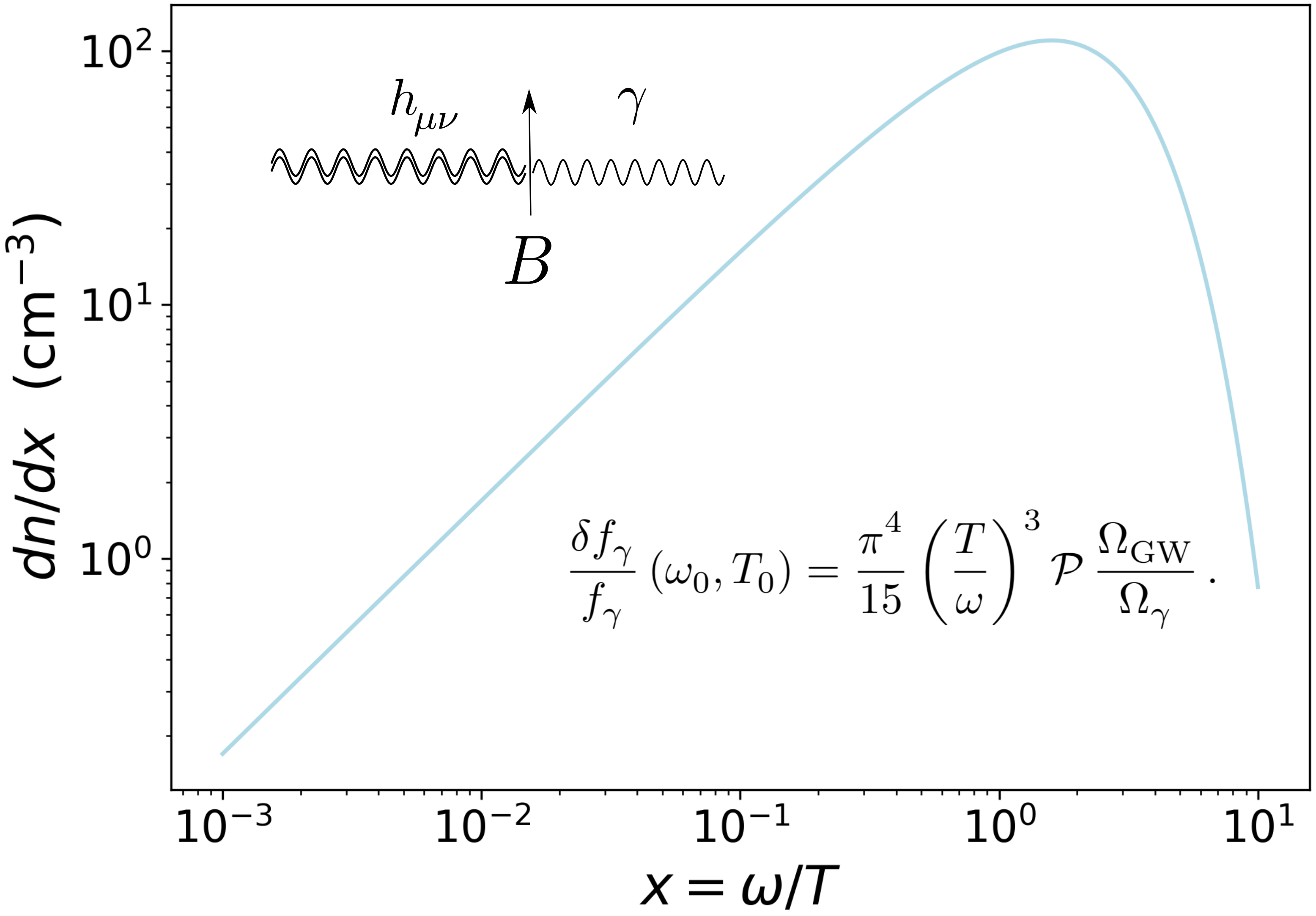
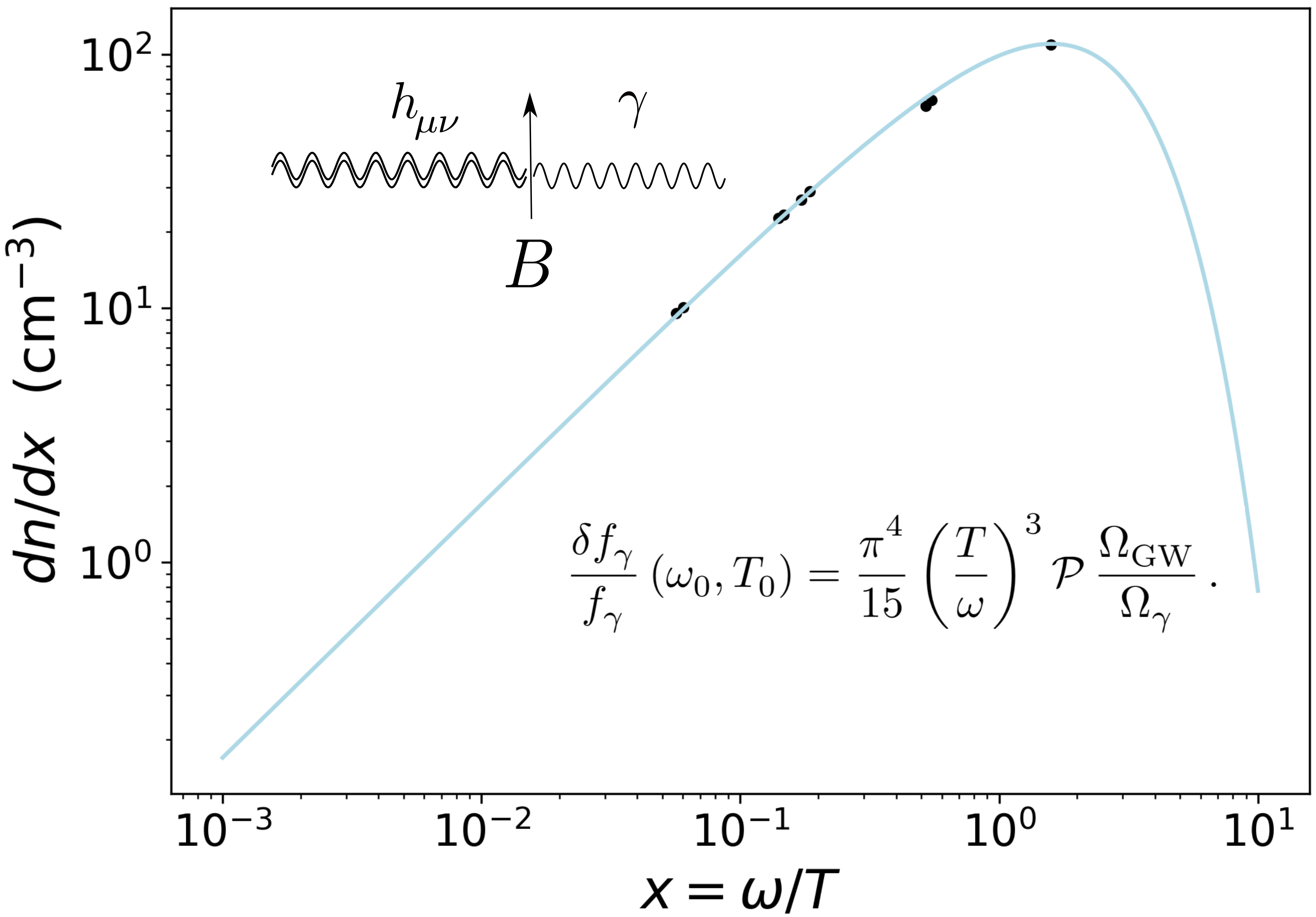
RADIO OBSERVATIONS



RADIO OBSERVATIONS



THE ASTROPHYSICAL JOURNAL

ARCADE 2 MEASUREMENT OF THE ABSOLUTE SKY BRIGHTNESS AT 3-90 GHz

D. J. Fixsen[1], A. Kogut[2], S. Levin[3], M. Limon[4], P. Lubin[5], P. Mirel[6], M. Seiffert[3], J. Singal[7], E. Wollack[2], T. Villela[8] + Show full author list

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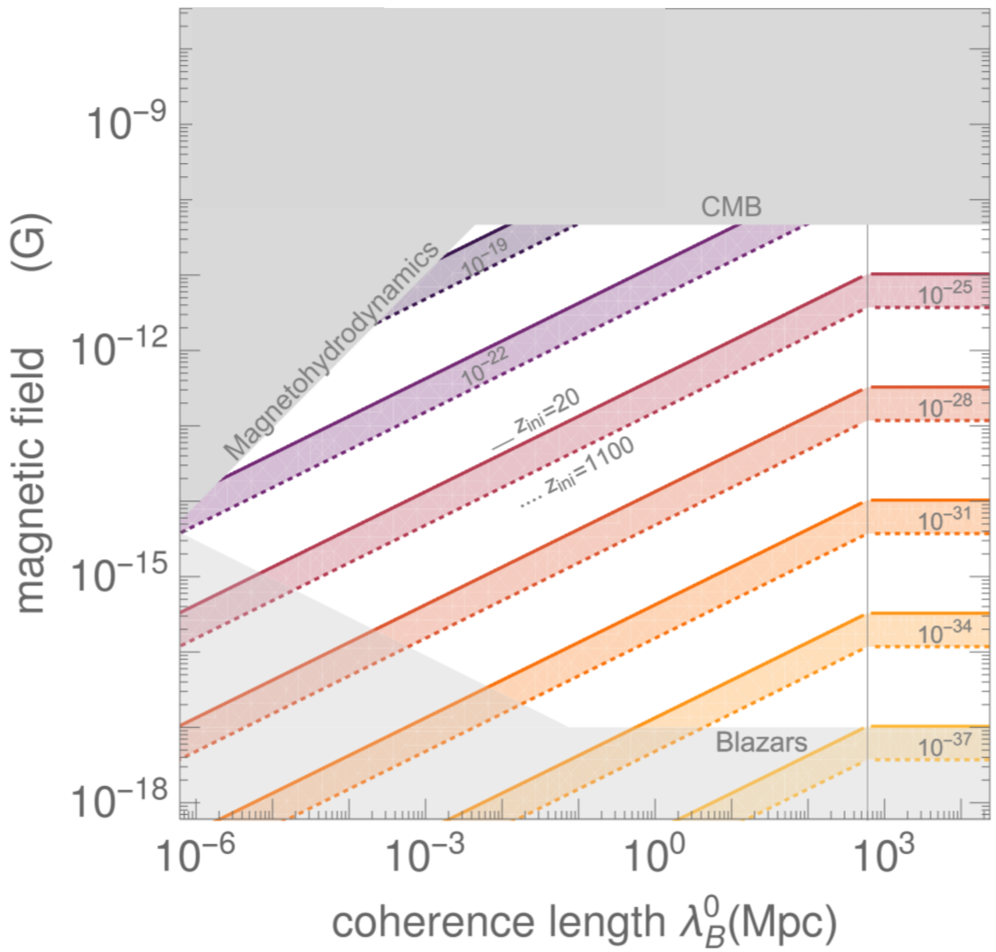
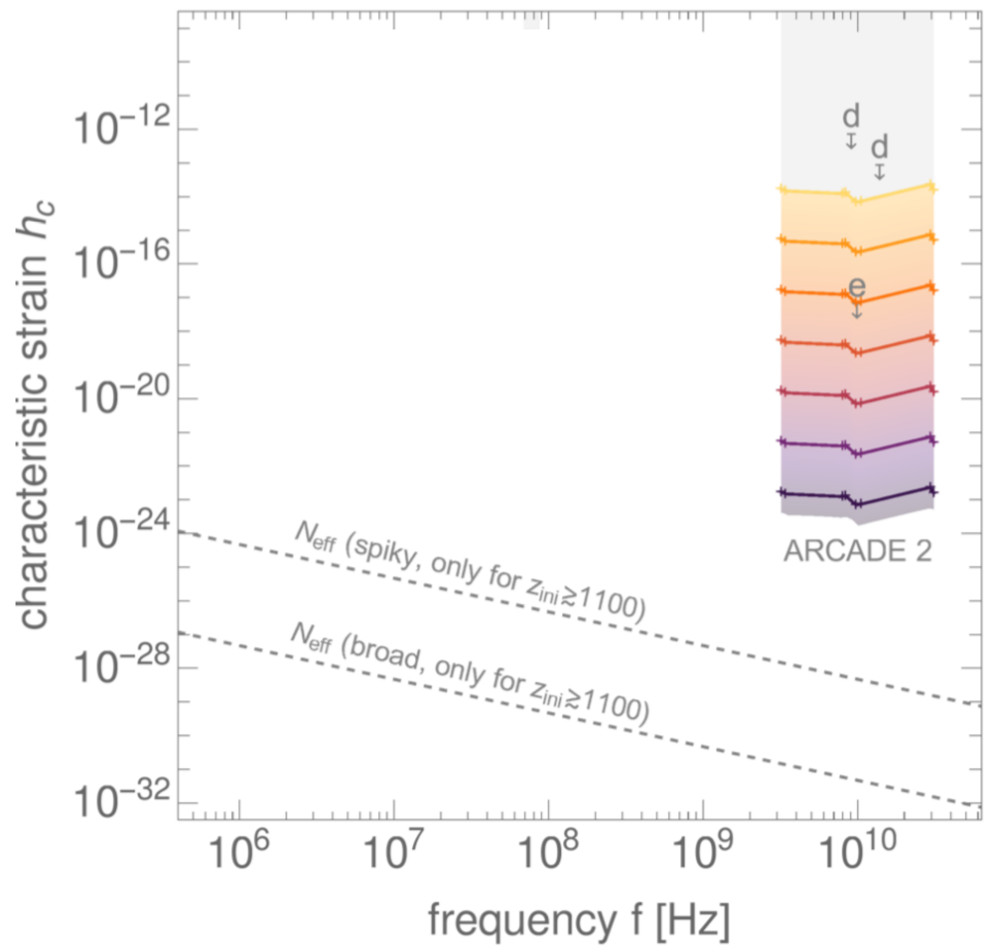
BOUNDS ON STOCHASTIC GRAVITATIONAL WAVES

PHYSICAL REVIEW LETTERS **126,** 021104 (2021)

Potential of Radio Telescopes as High-Frequency Gravitational Wave Detectors

Valerie Domcke[1,2,3,*] and Camilo Garcia-Cely[1,†]



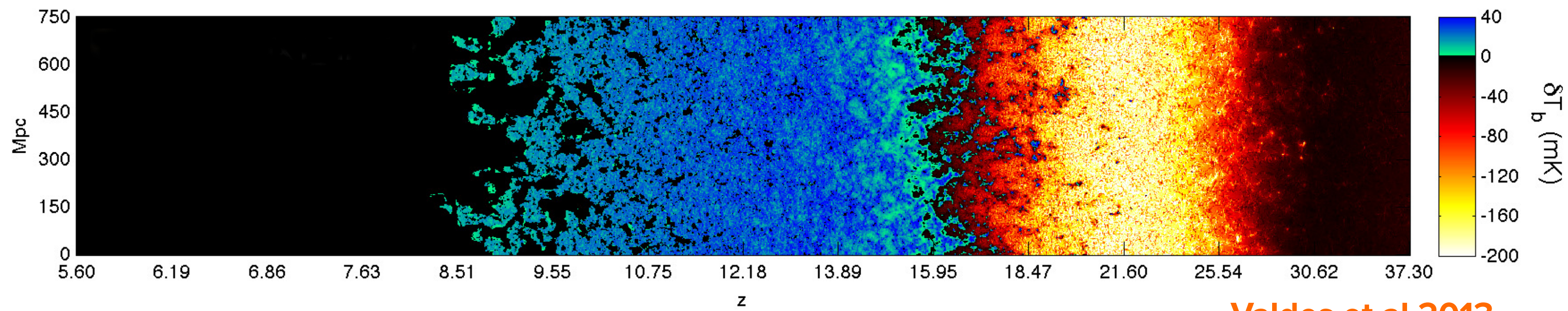


existing laboratory bounds from

$$\mathscr{P} \equiv \int_{l.o.s.} \langle \Gamma_{g\leftrightarrow\gamma} \rangle dt = \int_0^{z_{\rm ini}} \frac{\langle \Gamma_{g\leftrightarrow\gamma} \rangle}{(1+z)\,H} dz$$

d) magnon detector Ito, Soda '04
e) magnetic conversion detector Cruise et al '12

BOUNDS ON STOCHASTIC GRAVITATIONAL WAVES



Valdes et al 2013

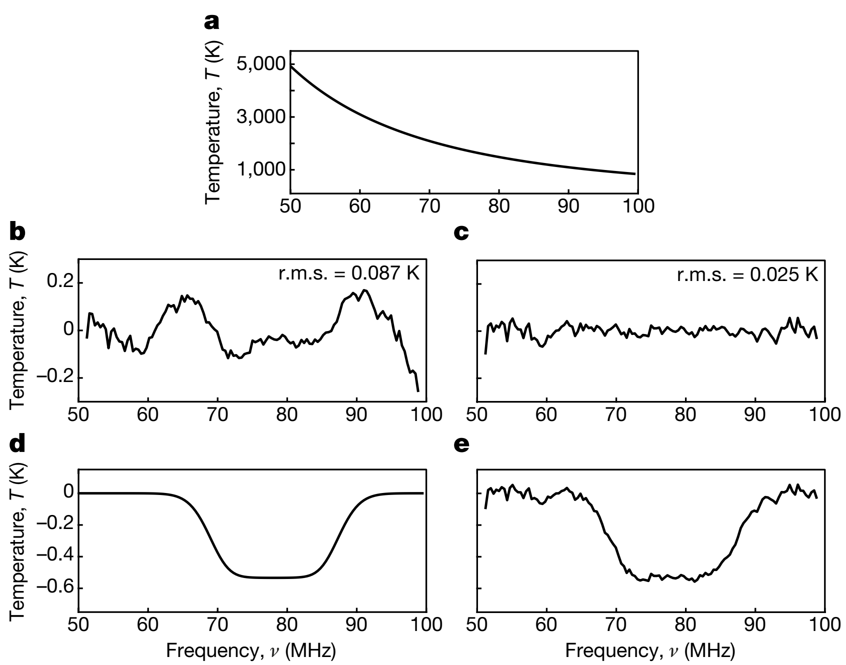


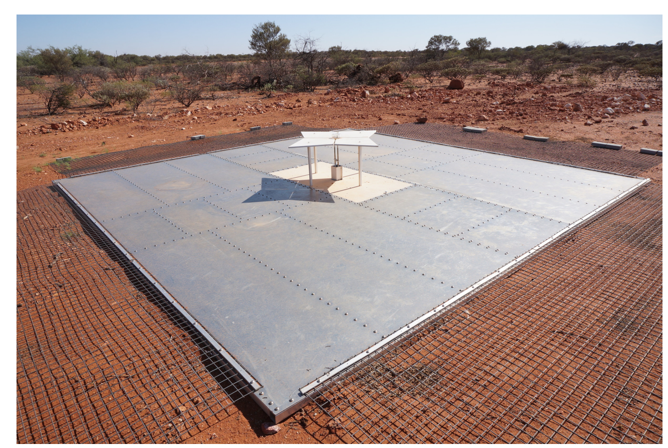
Figure 1 | Summary of detection. a, Measured spectrum for the reference dataset after filtering for data quality and radio-frequency interference. The spectrum is dominated by Galactic synchrotron emission. **b**, **c**, Residuals after fitting and removing only the foreground model (**b**) or the foreground and 21-cm models (**c**). **d**, Recovered model profile of the 21-cm absorption, with a signal-to-noise ratio of 37, amplitude of 0.53 K, centre frequency of 78.1 MHz and width of 18.7 MHz. **e**, Sum of the 21-cm model (**d**) and its residuals (**c**).

nature

An absorption profile centred at 78 megahertz in the sky-averaged spectrum

Judd D. Bowman, Alan E. E. Rogers, Raul A. Monsalve, Thomas J. Mozdzen & Nivedita Mahesh

Nature **555**, 67–70(2018) | Cite this article



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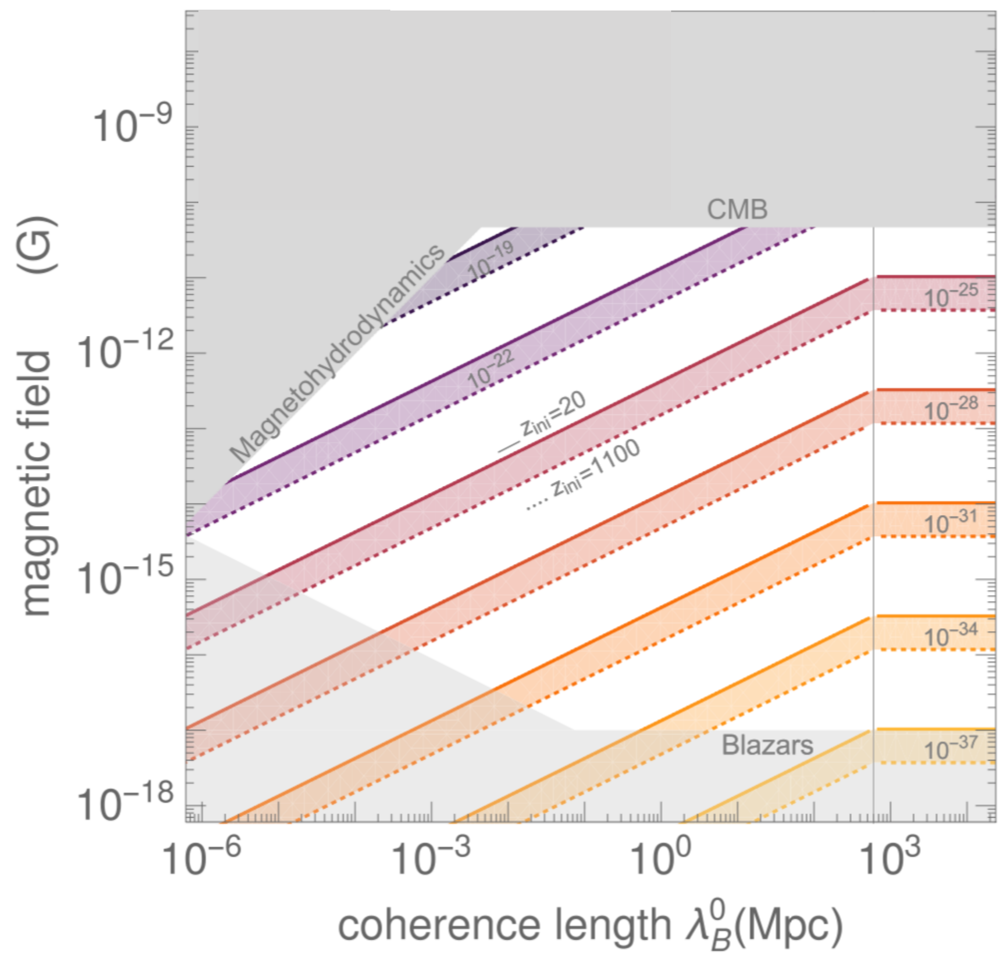
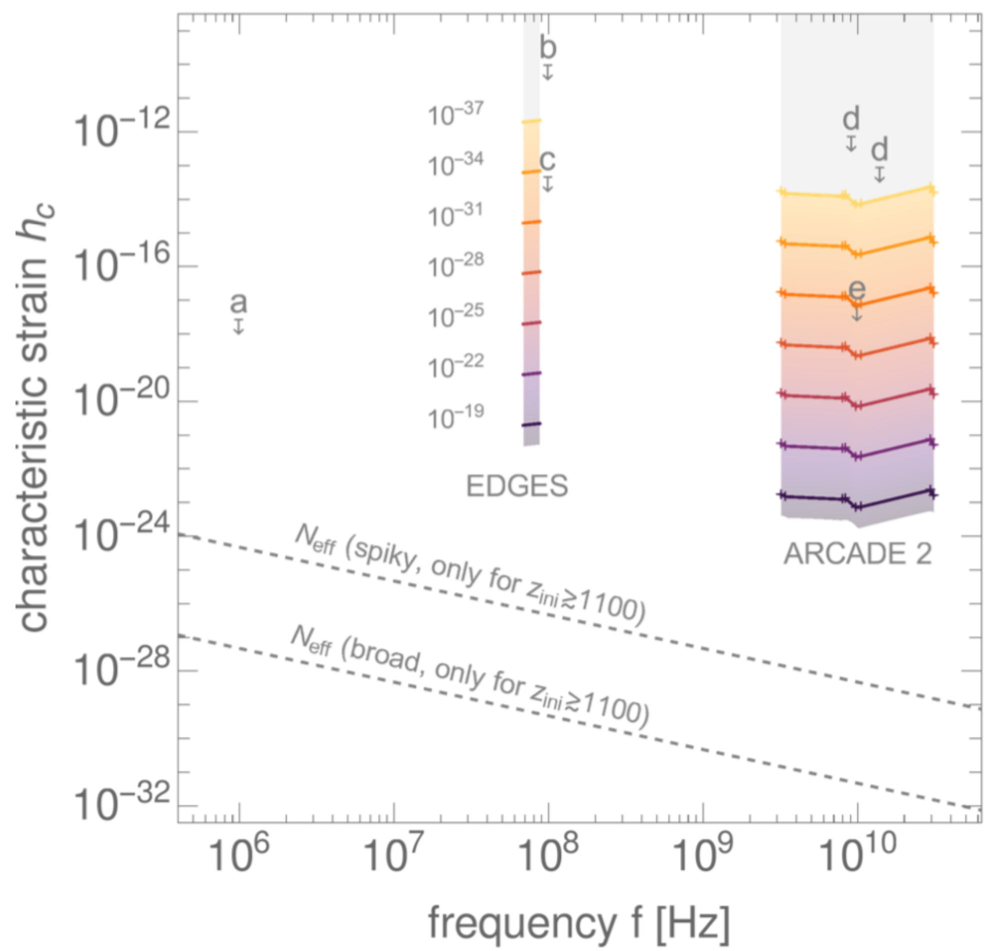
Potential of Radio Telescopes as High-Frequency Gravitational Wave Detectors

Valerie Domcke[1,2,3,*] and Camilo Garcia-Cely[1,†]





existing laboratory bounds from

a) superconducting parametric converter Reece et al '84
b) waveguide Cruise Ingley '06
c) 0.75 m interferometer Akutsu '08
d) magnon detector Ito, Soda '04
e) magnetic conversion detector Cruise et al '12

$$\mathscr{P} \equiv \int_{l.o.s.} \langle \Gamma_{g\leftrightarrow\gamma} \rangle dt = \int_0^{z_\text{ini}} \frac{\langle \Gamma_{g\leftrightarrow\gamma} \rangle}{(1+z)\,H} dz$$

Camilo García-Cely

CSIC Consejo Superior de Investigaciones Científicas

Vniversitat de València

THREE DIMENSIONAL EFFECTS

THREE DIMENSIONAL EFFECTS

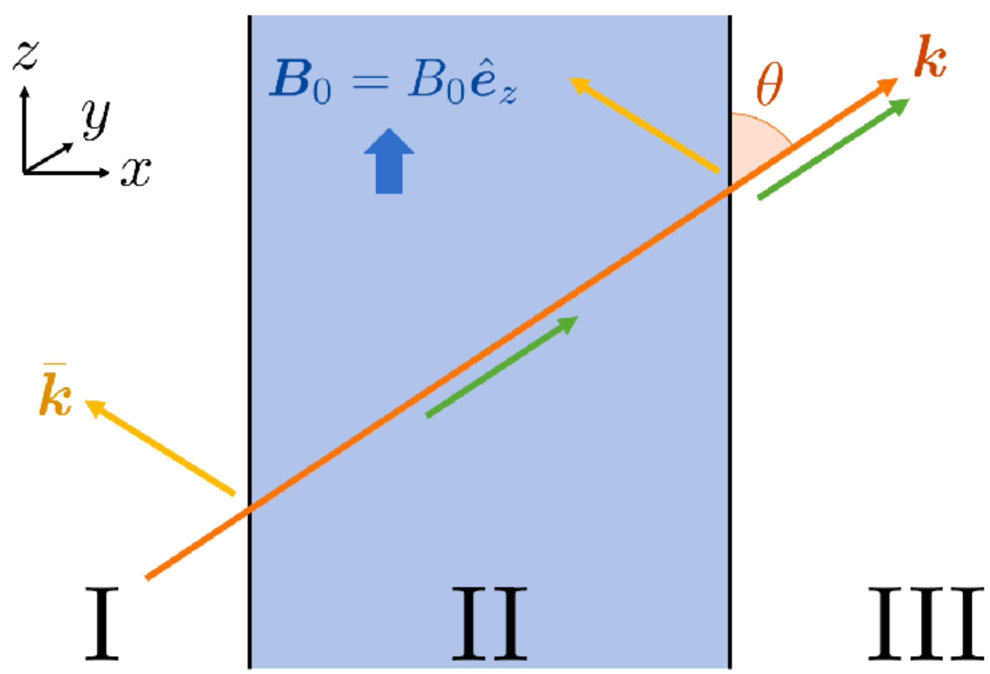
arXiv > gr-qc > arXiv:2507.16609

General Relativity and Quantum Cosmology

[Submitted on 22 Jul 2025]

Gravitational Wave Scattering on Magnetic Fields

Valerie Domcke, Camilo Garcia-Cely, Sung Mook Lee



- Realistic three-dimensional settings.
- The geometry and the magnetic-field structure imprint polarization on the converted signal (even for unpolarized GW backgrounds)
- For instance, the GW analogue of the optical Brewster angle allows a magnetic domain to act as an ideal polarizer.
- Guidance for experiments and multi-messenger observations aiming to detect GW–EM conversion.

STOKES PARAMETERS

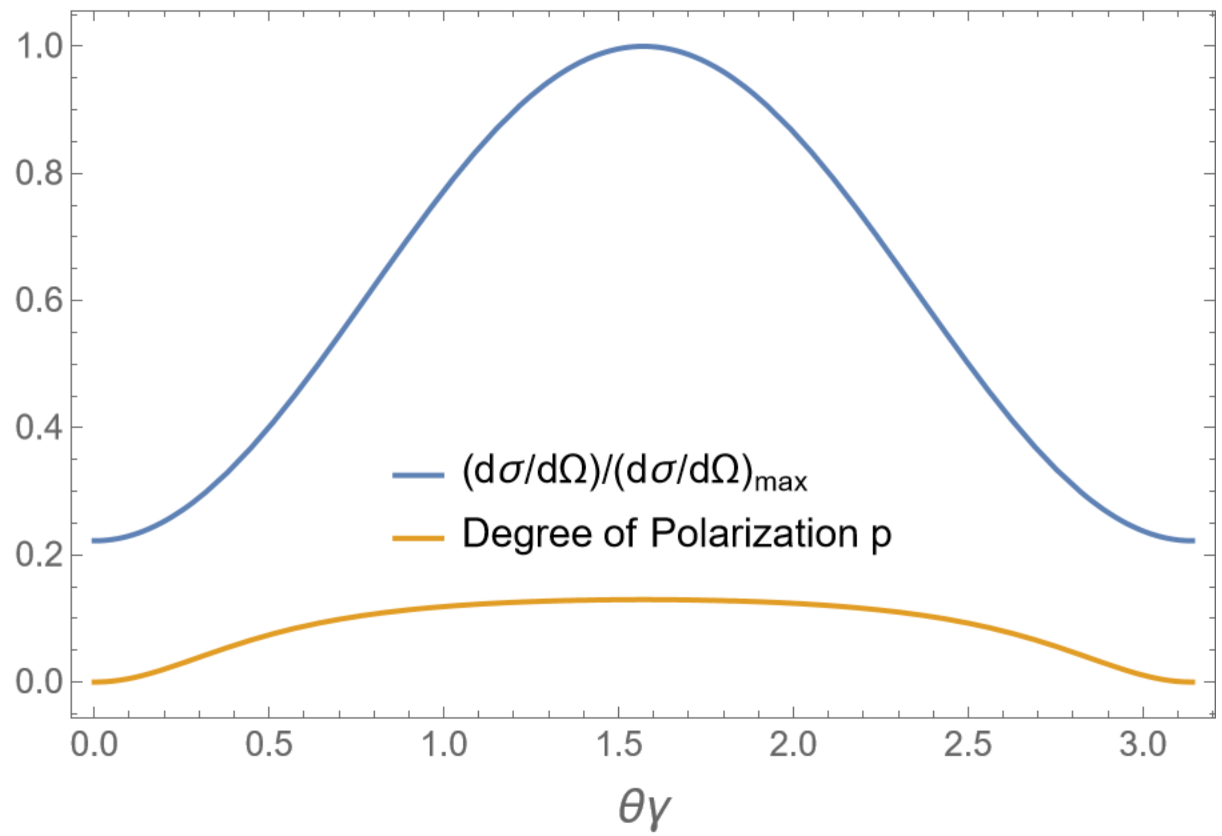
$$\xi_3^{\mathrm{GW}} = \frac{\langle |h_+|^2\rangle - \langle |h_\times|^2\rangle}{\langle |h_+|^2\rangle + \langle |h_\times|^2\rangle}, \qquad \xi_1^{\mathrm{GW}} + i\xi_2^{\mathrm{GW}} = \frac{2\langle h_\times h_+^*\rangle}{\langle |h_+|^2\rangle + \langle |h_\times|^2\rangle}.$$

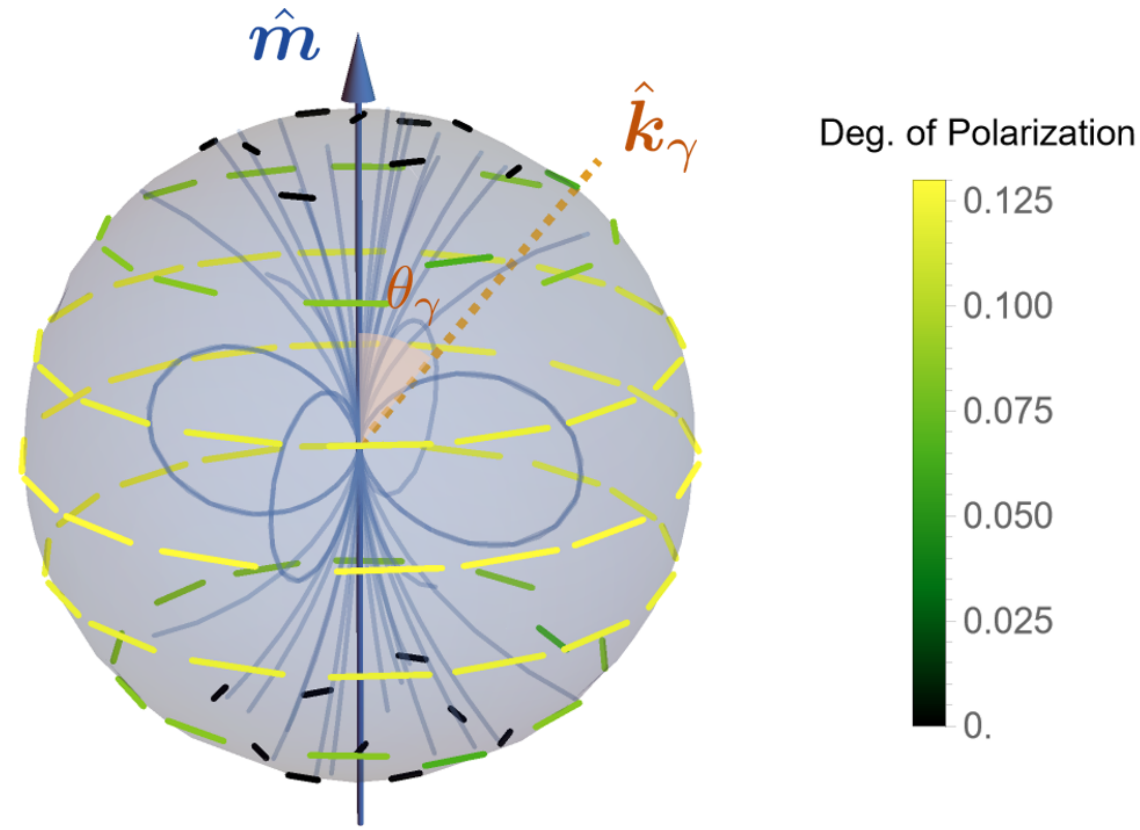
GW State	$\langle \lvert \boldsymbol{h}_+ \rvert^2\rangle$	$\langle \lvert \boldsymbol{h}_\times \rvert^2\rangle$	$\boldsymbol{\xi}^{\mathrm{GW}}$
Linear $\times$ (pure)	$\neq 0$	0	$(0,0,1)$
Linear $+$ (pure)	0	$\neq 0$	$(0,0,-1)$
Unpolarized (mixed)	$\langle \lvert h \rvert^2\rangle$	$\langle \lvert h \rvert^2\rangle$	$(0,0,0)$
EM State	$\langle \lvert \boldsymbol{A}_h \cdot \boldsymbol{u}_\gamma \rvert^2\rangle$	$\langle \lvert \boldsymbol{A}_h \cdot \boldsymbol{v}_\gamma \rvert^2\rangle$	$\boldsymbol{\xi}$
Linear vertical (pure)	$\neq 0$	0	$(0,0,1)$
Linear horizontal (pure)	0	$\neq 0$	$(0,0,-1)$
Unpolarized (mixed)	$\langle \lvert A \rvert^2\rangle$	$\langle \lvert A \rvert^2\rangle$	$(0,0,0)$

See also Wataru Chiba, Jinno and Nomura, 2025

and Kushwaha and Jain, 2025

UNPOLARIZED STOCHASTIC GWS ON A MAGNETIC DIPOLE





Potential consequences for neutron stars

CONCLUSIONS

- Gravitational waves can convert into photons in magnetic fields (inverse Gertsenshtein effect).

- Radio observations (EDGES, ARCADE 2) already set strong bounds on high-frequency gravitational waves.

- Polarimetry in three-dimensional magnetic fields can reveal signatures of gravitational wave–photon conversion.

- Different experimental proposals have coalesced on a strain sensitivity of 10^(-22) for MHz GWs, still orders of magnitude away from signals of the early Universe. Whether we can hope to probe such strain sensitivities remains to be determined.