Intergalactic Magnetic Field: a new probe of the Early Universe
FOCUS Week - IFPU. https://www.ifpu.it/focus-week-2025-02-10/

Links to the Forms: **1st.** https://forms.gle/hcWdtQS13H6Mi22k9 **2nd:** https://forms.gle/bsuCNoyegJFcwJ9j7 **3rd.** https://forms.gle/EFK8LMpuAuDwhj768

Shared Knowledge - Summary of responses

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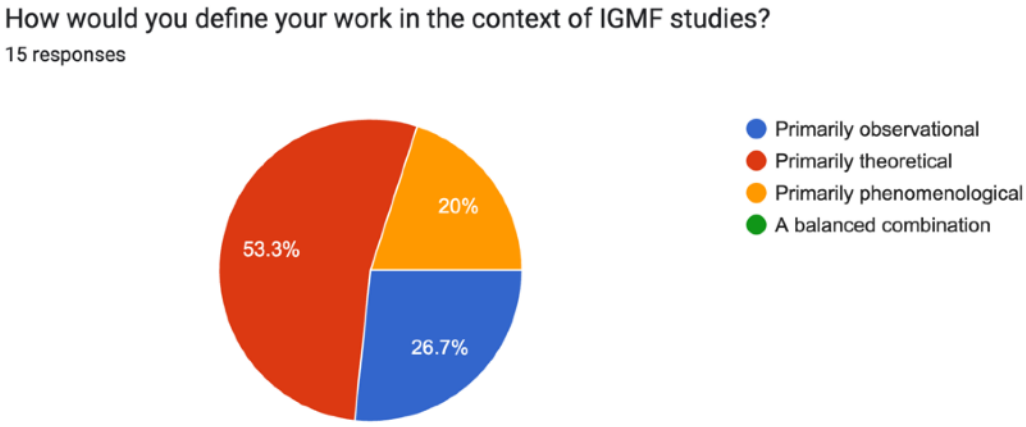
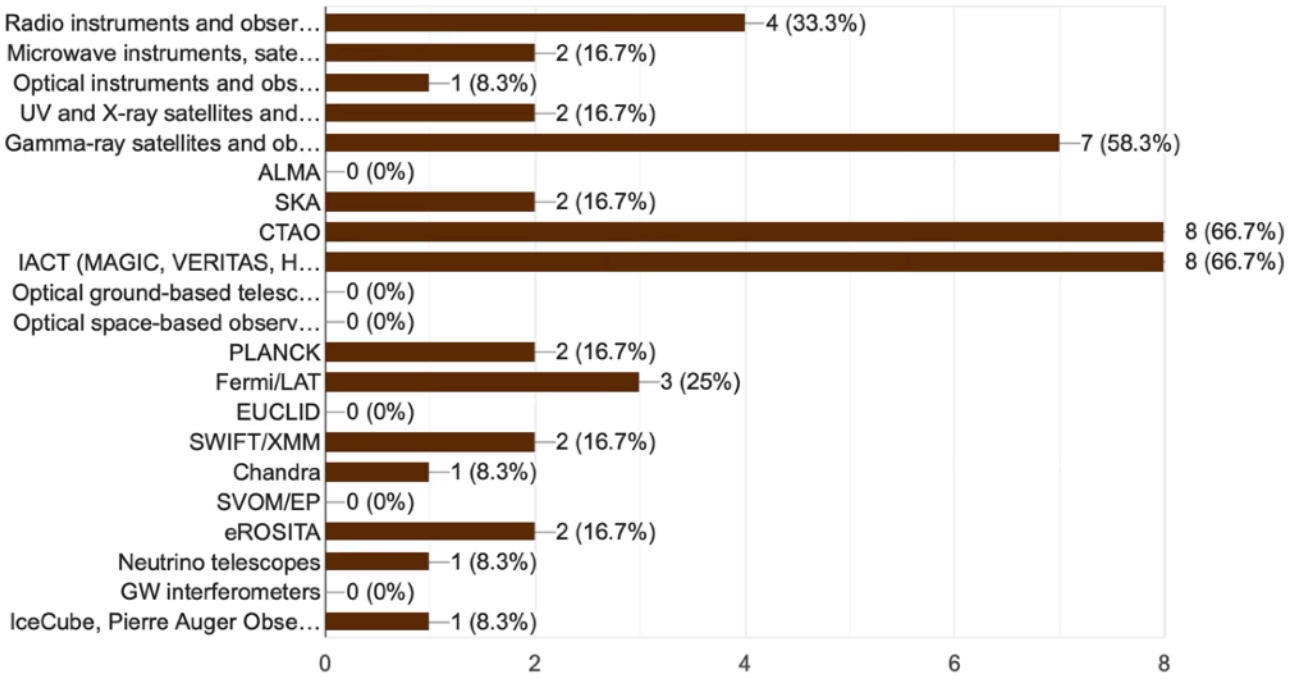
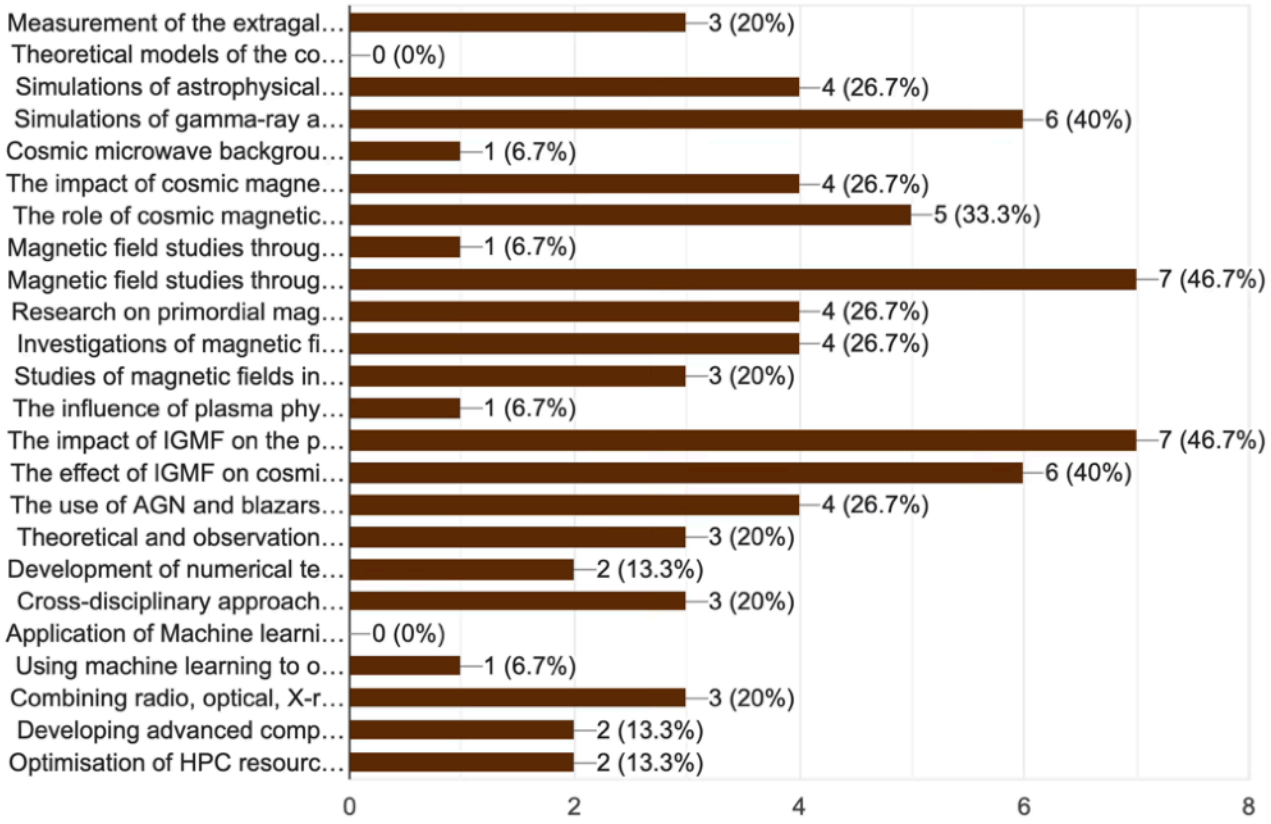
1. Understanding your work.



Which data or simulations from current or future instruments are you using in your studies?



Which of the following themes related to IGMF are you presently working on.



Which of the following themes related to IGMF and magnetic fields are you interested in but feel you lack expertise in and would like to collaborate on?

In progress. Currently Collecting data

2. Introductory resources

If you were to recommend a text or article to introduce a student to IGMF studies, which one would you suggest?

- Neronov et al. 2009 "Sensitivity of gamma-ray telescopes for detection of magnetic fields in intergalactic medium"
- Alves Batista et al. 2021 "The Gamma-Ray Window to Intergalactic Magnetism"
- Subramanian 2016. https://ui.adsabs.harvard.edu/abs/2016RPPh...79g6901S/abstract ; Neronov et al. 2025 https://ui.adsabs.harvard.edu/abs/2024arXiv241214825N/abstract
- https://ui.adsabs.harvard.edu/abs/2001PhR...348..163G/
- Durrer & Neronov 2013
- https://arxiv.org/abs/2105.12020
- https://ui.adsabs.harvard.edu/abs/2013A%26ARv..21...62D/abstract
- No text comes to mind, but I'd recommend they look at Caretti et al. 2023, Vernstrom et al. 2021, Vazza et al. 2017 and references.
- Origin of galactic and extragalactic magnetic fields (by Widrow)
- For gamma-ray studies related to the IGMF:
- Neronov & Semikoz (2009): https://ui.adsabs.harvard.edu/abs/2009PhRvD..80l3012N/abstract
- Biteau & Meyer (2022): https://ui.adsabs.harvard.edu/abs/2022Galax..10...39B/abstract
- Alves Batista & Saveliev (2021): https://ui.adsabs.harvard.edu/abs/2021Univ....7..223A/abstract
- 2105.12020, 1303.7121
- https://arxiv.org/abs/2402.14079
- https://arxiv.org/abs/1303.7121
- https://ui.adsabs.harvard.edu/abs/2013A%26ARv..21...62D/abstract
- Batista&Savaliev 2021, "The Gamma-ray Window to Intergalactic Magnetism", https://www.mdpi.com/2218-1997/7/7/223

Which of your papers would you recommend to describe your work related to magnetic fields and IGMF?

- Miceli et al. "Prospects for detection of the pair-echo emission from TeV gamma-ray bursts"
- Vazza et al. 2021 https://ui.adsabs.harvard.edu/abs/2021Galax...9..109V/abstract
- https://ui.adsabs.harvard.edu/abs/2023PhRvD.107f3030D/
- CTAO Consortium, JCAP 2021; Fermi-LAT Collaboration, 2018; Marafico+, 2024
- https://arxiv.org/abs/1911.06680
- I'd say the most relevant are Ntormousi et al. 2022, Brandenburg & Ntormousi 2023 (review)
- arXiv:1408.4141, 1808.08237, 2401.00560
- Aharonian et al. (2023): https://ui.adsabs.harvard.edu/abs/2023ApJ...950L..16A/abstract Tjemsland et al. (2024): https://ui.adsabs.harvard.edu/abs/2024ApJ...963..135T/abstract
- 2401.00560
- Constrained simulations of the magnetic field in the local Universe and the propagation of ultrahigh energy cosmic rays, JCAP 2005
- https://arxiv.org/abs/2501.06299
- https://arxiv.org/pdf/2307.10744
- https://ui.adsabs.harvard.edu/abs/2024A%26A...687A.186B/abstract
- https://doi.org/10.1051/0004-6361/20224412 "A lower bound on intergalactic magnetic fields from time variability of 1ES 0229+200 from MAGIC and Fermi/LAT observations"

What are the key papers or observational/theoretical results that have significantly changed our understanding of magnetic fields in the Universe, both on local and cosmological scales?

- Aharonian, F.A., Coppi, P.S., Voelk, H.J. 1994, ApJL, 423, L5. doi:10.1086/187222
- Plaga R., Nature (London), 1995, 374, 430
- Neronov, A. and Vovk, I. 2010, Science, 328, 73. doi:10.1126/science.1184192
- Simulations of the Small-Scale Turbulent Dynamo, https://ui.adsabs.harvard.edu/abs/2004ApJ...612..276S/abstract, Schekochihin et al. 2004
- Polarized accretion shocks from the cosmic web, https://ui.adsabs.harvard.edu/abs/2023SciA....9E7233V/abstract, Vernstrom et al. 2023
- Evidence for Strong Extragalactic Magnetic Fields from Fermi Observations of TeV Blazars https://ui.adsabs.harvard.edu/abs/2010Sci...328...73N/abstract Neronov & Vovk 2010
- Neronov & Vovk (2010): https://ui.adsabs.harvard.edu/abs/2010Sci...328...73N/abstract
- A. Neronov and I. Vovk, Evidence for strong extragalactic magnetic fields from Fermi observations of TeV blazars, Science 328 (2010) 73; .
- Govoni, E. Orr`u, A. Bonafede, M. Iacobelli, R. Paladino, F. Vazza et al., A radio ridge connecting two galaxy clusters in a filament of the cosmic web, Science 364 (2019);
- T. Vernstrom, G. Heald, F. Vazza, T.J. Galvin, J. West, N. Locatelli et al., Discovery of magnetic fields along stacked cosmic filaments as revealed by radio and X-ray emission, Mon. Not. Roy. Astron. Soc. 505 (2021) 4178/
- J.M. Quashnock, A. Loeb and D.N. Spergel, Magnetic Field Generation During the Cosmological QCD Phase Transition, Astrophys. J. Lett. 344;
- B. Ratra, Cosmological 'seed' magnetic field from inflation, Astrophys. J. Lett. 391 (1992);
- Grasso and H.R. Rubinstein, Limits on possible magnetic fields at nucleosynthesis time, Astroparticle Physics 3 (1995) 95;
- J.D. Barrow, P.G. Ferreira and J. Silk, Constraints on a primordial magnetic field, Phys. Rev. Lett. 78 (1997) 3610; A. Lewis, CMB anisotropies from primordial inhomogeneous magnetic fields, Phys. Rev. D 70 (2004) 043011;
- F. Finelli, F. Paci and D. Paoletti, The Impact of Stochastic Primordial Magnetic Fields on the Scalar Contribution to Cosmic Microwave Background Anisotropies, Phys. Rev. D 78 (2008) 023510;
- D. Paoletti, F. Finelli and F. Paci, The full contribution of a stochastic background of magnetic fields to CMB anisotropies, Mon. Not. Roy. Astron. Soc. 396 (2009) 523 https://www.science.org/doi/10.1126/sciadv.abq7623
- blazar implications on IGMF, e.g., Neronov and Vovk 2010
- Bonafede+ 2010; Vernstrom+ 2021; Carreti+ 2022; Pshirkov+ 2016, O' Sullivan+ 2020; Jedamzik & Saveliev 2019; Vazza+ 2017. https://cds.cern.ch/record/457096/files/0009061.pdf

What is the most interesting, ingenious, or captivating paper and/or book (from any field in Physics or Astrophysics) that you have ever read?

- Hard question. I recently read a paper that I believe is a perfect example of how different areas of expertise can find common ground to produce interesting and valuable scientific results:
- Tjemsland, J., Meyer, M. and Vazza, F.\ 2024, ApJ, 963, 135. doi:10.3847/1538-4357/ad22dd
- Chaos: Making a New Science by Gleick, James
- Such a tough question! I go for these two classics:
  - https://ui.adsabs.harvard.edu/abs/1970RvMP...42..237B/abstract
  - https://ui.adsabs.harvard.edu/abs/1988PhRvD..37.1237R/abstract
- Scott Dodelson, Modern Cosmology, not captivating but the base for every calculation in CMB/ totally off topic but very fascinating "The Life and death of Planet Earth" Donald E. Brownlee and Peter Ward.

- https://arxiv.org/abs/astro-ph/9711251
- Longair
- "The quark and the jaguar: Adventures in the Simple and the Complex" by Murray Gell-Mann
- Too general question (at least for me)
- I think that a very good recent book on the Astroparticle field is 'Probes of Multimessenger Astrophysics. Charged cosmic rays, neutrinos, γ-rays and gravitational waves' by Maurizio Spurio (https://inspirehep.net/literature/1707916)
- Theoretical Understanding in Physics by Longair

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3. Challenges, opportunities and goals

What specific goal do you believe you can achieve in IGMF studies this year?

- Predict the impact of GRB properties on IGMF studies in current and future gamma-ray astronomy
- Bracketing to a robust level the maximum possible seeding of magnetic fields by galaxy activity in voids & filaments
- IGMF UL with gamma-rays
- Target selection for CTAO
- New constraints from 1. deep TeV observation of a hard TeV blazar; 2. monitoring of a variable hard TeV blazar
- Study the connection between galactic and inter-galactic magnetic fields in zoom-in cosmological simulations
- Clarification of how IGMFs can be used to constrain properties of magnetic monopoles, and vice versa.
- Improved constraints on IGMF from GRB221009A, using MHD simulations of the IGMF in gamma-ray constraints.
- Improve predictions on lower limits
- Check if the excess of power seen at small scales in the flux lyalpha power is a physical effect of systematic error
- I would like to work on baryon clumping induced by primordial magnetic fields at recombination
- Improve modeling and understanding of effects of photon drag on present day magnetic field.
- Simulation studies and data analysis to set limits on IGMF using a morphological study on blazars/ GRB on the expected GeV-TeV halo emission (including the highest values >1e-12G)
- Test the impact of stochastic primordial magnetic fields on the formation of small-scale baryon fluctuations and cosmological recombination

What do you consider the most critical open question in IGMF and/or primordial magnetic field research?

In progress. Currently Collecting data

Are there any widely accepted statements, plots, or assumptions in IGMF studies that you believe should be revisited or revised? Which?

In progress. Currently Collecting data

What is the primary technical challenge (e.g., simulations, theoretical computations, computational resources, sensitive precision measurements, dedicated instruments, etc) that limits your work in this area?

- sensitive precision measurements
- simulations
- sensitivity of instruments
- Impact on the cosmic-web along the line of sight, namely how well using tracers of filaments & sheets can we determine the impact of the cosmic web on the propagation of gamma-rays and cosmic rays from specific sources (out to z~0.1-0.2).
- Probably theoretical computations
- Definitely computational resources!
- (1) Lack of communication between the IGMF and particle communities. (2) I would also like to understand the current status of astrophysical generation of IGMFs.
- I'm extensively using CRPropa for my work. Especially with GRB221009A, it became obvious that the code does not perform well for high time resolution. It shows numerical errors and becomes very slow. However, I still prefer this code due to its 3D nature and the possibility to not only inject gamma rays but also cosmic rays.
- Precision measurements
- HPC challenges
- CPU time and high-signal to noise observation of Lyman-alpha forest spectra
- capability of running simulations
- Both physical detail in simulations and their dynamical range.
- 1. Computational limits on simulations strong magnetic fields 2. PSF resolution of IACTs to disentangle halo emiission.
- Analytical and semi-analytical computations, linear Einstein-Boltzmann codes

Are there areas of expertise or skills that you or your group currently lack but believe would significantly enhance your ability to reach your goals?

- Implementation of realistic magnetic field models in the intergalactic medium to properly propagate the VHE photons from extragalactic sources
- CRPROPA simulations of UHECR propagation and Inverse Compton Cascade for large cosmological simulations
- Writing our own / improving existing codes for the propagation of high energy gamma rays and cosmic rays over cosmological distances.
- Expertise in Anisotropic Universes
- yes
- Propagation of cosmic ray
- I need to improve my expertise in the VHE data analysis

- Radio-astronomy constraints on the magnetism of the sub-structures of the cosmic web.
- critical approach to simulations
- Theoretical developments
- How magnetic field models and their evolution impact results in the gamma-ray domain

Are there any commonly cited ideas or methods that you think are not properly addressed or justified and should be investigated further?

- The role of the plasma instabilities in the context of transient VHE events such as GRBs
- Ideal MHD should at some scale/epoch/environment be gradually replaced with a kinetic model of plasma physics, and embedding this in large simulations is far from easy
- We still use chi^2 statistics way too often.
- PMF effects on very small scales
- yes
- Impact of the magnetized cosmic web on the propagation of gamma rays and cosmic rays, in particular sheets and walls whose volume filling fraction is expected to less negligible than clusters and filaments.
- from the gamma-ray perspective, the identification of blazars as good probes
- gamma-ray halos for instrument with big PSF
- Spectral and temporal variability of gamma-ray sources

What recent advancements or discoveries in related fields (e.g., observational tools, computational techniques) or methodologies or insights from other fields (e.g., AGN physics, dark matter studies, GW observations, or plasma physics) do you think could have a transformative impact on IGMF research? ("none", is also a possible answer!)

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Would you be interested in contributing to a perspective paper that collects the views, questions, and proposals from this meeting?

In progress. Currently Collecting data

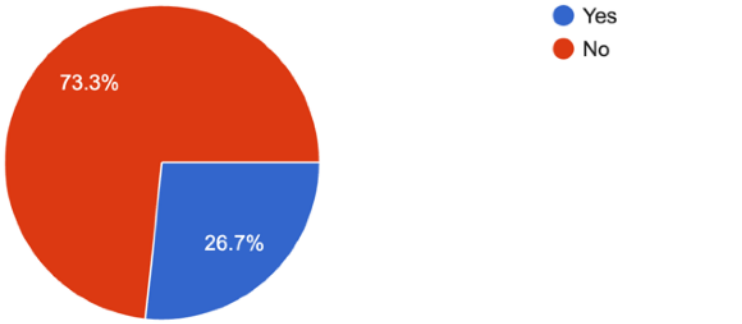
Are there specific institutions, research groups, or people with which increased collaboration could accelerate progress in your area of study? If you want, list them here.

In progress. Currently Collecting data

3. Fun, Culture and diversity also matters!

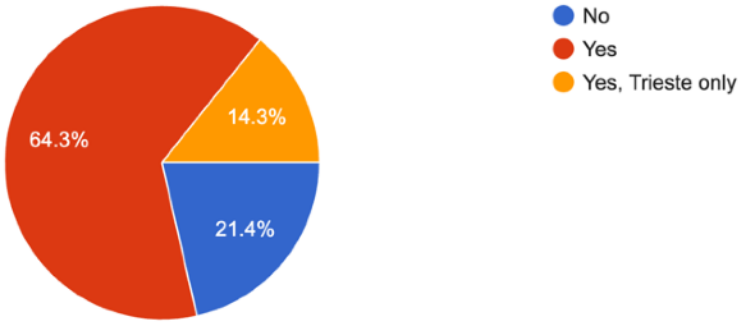
Is this your first time at SISSA/ICTP in Trieste?

15 responses



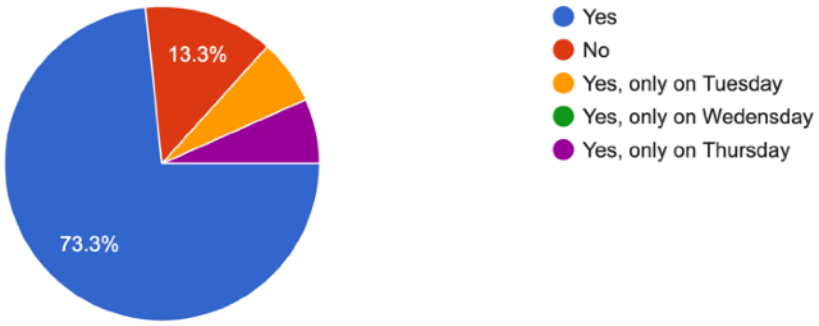
Have you already visited Trieste and its surroundings?

14 responses



Would you be interested in joining a group dinner in downtown Trieste? (Self-paid)

15 responses



Would you be interested in developing interdisciplinary workshops or educational programs to train young researchers, or creating public outreach materials to communicate the significance of cosmic magnetism to broader audiences? Any other suggestion is welcome!

- In principle yes, it's a bit of a question of available time...
- Outreach is my third job (the second is art) so sure!
- Why not
- In principle yes, also sharing with my team this duty. I think that the interdisciplinarity approach to this complex theme should be highlighted when communicating it to the public.
- yes I am very interested

Which book, movie, or piece of art has been particularly inspiring for your work?

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There is a plot, a result, an instrument that sparkle(d) your imagination or that moves you?

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