Proposed Nordita Program

“Cosmic Magnetic Fields: Primordial vs. Astrophysical Origins”

Proposed dates: May 31 — June 18, 2027

Organisers

- **Oindrila Ghosh** (***contact person***), The Oskar Klein Centre, Stockholm University; contact: oindrila.ghosh@fysik.su.se). Committed to being present for the full duration.
- **Manuel Meyer** (University of Southern Denmark, Odense; manuel.meyer@sdu.dk). Committed to being present for the full duration of the program.
- **Axel Brandenburg** (Nordita; brandenb@nordita.org). Committed for the full duration.

Abstract

Magnetic fields pervade the cosmic web, from cluster cores to filaments and voids; however, the nature of their origin remains debated: are the magnetic fields in the intergalactic space pristine fossils of the primordial seeds set before recombination, or are they built up by the cumulative contribution of astrophysical activity (active galactic nuclei, galaxies, shocks, ionization fronts, etc.) over cosmic time? This Nordita program will bring together theory, simulations, and multi-messenger observations to formulate and test discriminants between these histories. It also coincides with the beginning of a big in-house activity at Nordita related to the ERC Synergy Grant COSMOMAG using magnetic fields to probe the first microseconds of the Universe.

Week 1 will provide a common foundation for primordial and astrophysical magnetogenesis and their late-time evolution. Week 2 assembles constraints from radio observations focused on Faraday rotation measures, diffuse synchrotron, cosmic rays, and high-energy gamma rays across distinct environments (cluster cores and outskirts, filaments, circumgalactic space and the cosmic voids). Week 3 of the program will confront the measurements with the processes that can shape or obscure them, such as baryonic feedback, plasma instabilities, turbulence, and dynamos, leading to an understanding into projected observation benchmarks and jointly testable predictions for current and upcoming facilities. Expected outputs can take the form of a community white paper consisting of open benchmark datasets, with practical analysis and simulation guides for the evolution and observation of primordially and astrophysically generated magnetic fields.

1. Program Objective

Magnetic fields are pervasive across scales, from planets and stars to the large-scale magnetic fields detected in galaxies and galaxy clusters. Moreover, cosmic magnetism permeates beyond collapsed structures composed of gas and matter, i.e., cosmological filaments, into the vast expanse of underdense regions mostly devoid of structures, known as the cosmological voids. The exact nature and origin of these magnetic fields remain one of the most transcendental questions in astrophysics and cosmology, as they shape the formation and evolution of large-scale cosmological structures, including galaxies and galaxy clusters, as well as refine our understanding of fundamental physics.

Magnetic fields influence charged particles by bending their trajectories. High-energy photons (γ-rays) emitted from distant active galactic nuclei (AGNs), particularly blazars, which are AGNs with jets pointing directly toward us—provide a unique tool for probing these fields. As these γ-rays traverse space, they interact with background radiation, producing electron-positron pairs. These pairs scatter off the cosmic microwave background, undergoing inverse Compton scattering (ICS) and initiating electromagnetic cascades detectable in the giga-electronVolt (GeV) energy range [1]. The deflection of these charged particle pairs by cosmic magnetic fields results in measurable signals, either as spatially extended emissions known as "pair halos"[2] or as delays in photon arrival times [3]. The absence of expected GeV cascade halos around distant sources can directly translate into lower limits on the intergalactic magnetic fields (IGMF) [4].

Moreover, ultra-high-energy cosmic ray (UHECR) observations require that their extragalactic deflections be small enough to preserve the observed correlations with nearby galaxies, yet large enough to avoid excessive small-scale clustering and to reproduce the measured spectrum and composition, taking into account the galactic magnetic field and source environments, leading to an estimate of the extragalactic magnetic field in the local cosmic web up to 100 kpc.

Faraday rotation measures (RMs) have been historically used to measure the magnetization of galaxy clusters and the intracluster medium environments. In the current decade, on the one hand, foreground modelling has seen dramatic improvements. On the other hand, with further precision measurements such as residual rotation measures from radio observations, it has become possible to probe smaller structures such as galaxy groups. The main question this program seeks to address is:

➤ *Are cosmic magnetic fields astrophysical or primordial?*

There are two main hypotheses for the origin of cosmic magnetic fields.

1. **Primordial magnetogenesis:** In such scenarios, the generation of the cosmic magnetic fields takes place in the early Universe through inflation or phase transitions [5], [6] with subsequent evolution concurrent with hierarchical structure formation at later times. Depending on the generation mechanism, magnetic fields have specific characteristic coherence scales and strengths imprinted in their magnetic power spectrum. Such primordially seeded fields can live in the cosmic voids away from bound structures such as galaxies and galaxy clusters. These are volume-filling weak fields with large coherence lengths.

2. **Astrophysical magnetogenesis:** In contrast to primordial fields, astrophysical processes create stronger but localized fields confined primarily to filaments and galaxy clusters. Seeding and amplification of magnetic fields through Biermann's battery mechanism or dynamo mechanisms in galaxies. In addition, magnetized winds from starburst events [7], and jets launched by AGNs, or radio-bright cavities of magnetized bubbles, shocks, and cosmic ray

transport can carry fields into the intergalactic medium. The extent and sustainability of such pollution of the cosmic voids is debated.

Status and gaps: Cosmological simulations and radio observations indicate cosmic filaments host magnetic fields around 0.1–10 nanoGauss (nG) [8], whereas fields in AGN-driven bubbles and galaxy clusters can reach μG levels [9]. When pair beams encounter such regions, stronger deflections can lead to broader angular halos and longer cascade delays than predicted for void fields alone. If unaccounted for, these magnetized structures can mimic the impact of a strong void field in cascade suppression, leading to lower limits on IGMF that actually reflect the astrophysical fields in filaments or AGN environments [10] rather than that on the PMFs. To tie the estimates of IGMF to a measurement of primordial magnetic fields (PMFs), it must be demonstrated that cascade suppression arises from truly underdense voids (filling factor ≳70–90%) [11], not from the magnetized cosmic structures with strong but localised magnetic fields experienced by the pair beams. Moreover, small-scale dynamos generated from turbulence driven by ionization fronts near filaments can magnetize the voids [12]. Furthermore, while the Mpc-scale Porphyrion jet observed can in principle magnetize intergalactic medium [13], they're thought to trace gamma-ray beams [14].

A further complication arises from other physical processes that could mimic or obscure the effects of magnetic fields. Depending on the activity time of a γ-ray source, charged e^+e^- pairs may lose energy through exotic particle production [15] or electromagnetic plasma instabilities [16],[17] which may suppress structure formation [18] in addition to synchrotron losses. At extremely weak magnetic fields (sub-fG), differentiating suppression effects due to IGMF from those caused by collective plasma phenomena becomes challenging [19]. This interplay remains poorly understood. In addition, stabilization and angular broadening of the pair beam due to momentum diffusion caused by tangled magnetic fields, plasma inhomogeneities [20], and nonlinear feedback of instabilities, can be important in both astrophysical pair-beam contexts [21] and laboratory astrophysics experiments [22]. These uncertainties hinder our ability to pinpoint the true origin, strength, and coherence scale of cosmic magnetic fields [23], highlighting the need for more sensitive observations and refined modeling.

Timeliness: Radio polarimetry has moved into a population regime with dense RM grids, Faraday tomography, and diffuse synchrotron beyond cluster cores. In parallel, high‑energy gamma-ray observations have strengthened constraints via cascade broadening and time delays. Over the coming years, existing and upcoming cosmic ray observatories are set to acquire order-of-magnitude larger exposures and near full-sky coverage, enabling much more precise anisotropy and source-correlation studies, such that constraints move beyond model-dependent bands.

Cosmological magnetohydrodynamic (MHD) simulations and semi‑analytic models are capable of mapping directly into observer data products. In particular, future extragalactic radio observations focused on individual galactic RMs can facilitate distinguishing between different genesis scenario benchmarks established by simulations, significantly cleaner than existing residual rotation measure from galaxy groups, in which additional correlations can obfuscate the topology of dynamo-generated galactic magnetic fields.

A coordinated effort bringing together complete multimessenger observational interpretations spanning radio, gamma, and CR analyses that probe coherence scales, topology, and helicity, not only upper or lower bounds. A focused, three‑week program will not only establish a synergy among these advances but also help build peer-guided reproducible pipelines spanning various wavelengths. In addition, we seek a community consensus on the role of astrophysical and plasma processes in void magnetization as well as their imprints in cosmic ray and gamma-ray observations.

2. Program Structure and Schedule

Week 1 — Primordial and Astrophysical Magnetogenesis & Evolution

New advances in the simulations of primordial genesis scenarios such as inflation and phase-transition. In the same week, talks on astrophysical seeding by galactic dynamo mechanism, Biermann's battery mechanism and starburst winds. Dedicated discussions on how amplitudes, coherence lengths, topology, and helicity evolve through structure formation, and what the major obstacles are.

Week 2 — Observations Across Environments and Messengers

Overview talks on radio observations detailing extragalactic Faraday rotation measures; diffuse synchrotron emission in halos, relics, and filaments; constraints from gamma-ray cascades and time delay observations; and cosmic-ray deflections. Emphasis on environment-by-environment comparisons and discussion on source specifications, details of gamma-ray source population, redshift dependence, and foreground modelling.

Week 3 — Interpreting Measurements: Feedback, Plasma Physics, and Turbulence

Various talks on how baryonic feedback, AGN outflows, turbulence, small-scale dynamos, reconnection, and plasma instabilities shape observables. Discussion sessions to guide connections between simulations and analyses to RM statistics, polarization morphology, and high-energy signatures in gamma-ray and UHECR cross-correlations.

Typical day:

- 10:00–12:30 Two long talks (45–60 minutes + 15 minutes Q&A each)
- 14:00–15:30 Long talk (45–60 minutes + 15 minutes Q&A each)
- 15:30–17:00 Free discussion / working groups

Participation is primarily by invitation to keep the room focused (~25 on site at any given time, with rotation), but we also allow for open applications. At the end of each week, a moderated panel discussion will be convened to stimulate the development of new ideas and to advance ongoing debates.

Output: We envision (a) a possible **whitepaper or review** (arXiv preprints and special issue in a journal) for future probes discriminating magnetogenesis in the late Universe, organized by environments, messengers, and analysis recipes, with (b) formation of new collaborations and **working groups** within the scope of the conference.

3. Participants and Community

We plan to host 35–40 researchers over the three weeks of the program. 20 participants have already committed to attending the program, out of which 6 are Nordic participants and 33% are women. We have invited ~20 more people out of which 50% are women, but did not receive a response at the time of submission of the proposal. Out of the total number of invitations and expected participants, approximately half are early-career researchers (ECRs).

The confirmed list of speakers is as follows.

Tim Linden, Associate Professor, Department of Physics, Stockholm University, Sweden.
Carlos Blanco, Assistant Professor of Physics, Pennsylvania State University, USA.
Milena Crnogorcevic, Postdoctoral Fellow, Department of Physics, Stockholm University, Sweden.
Franco Vazza, Associate Professor, University of Bologna, Italy.
Chiara Caprini, Professor, University of Geneva and staff in Theoretical Physics, CERN
Andrii Neronov, Director, LASTRO, EPFL; Professor at Paris U. and Researcher, APC Paris, France.
Oksana Iarygina, Postdoctoral Fellow, Nordita, Sweden.
Michael Kachelriess, Professor, Norwegian University of Science and Technology (NTNU) Trondheim.
Federico Urban, Senior Researcher, CEICO, Czech Academy of Sciences, Prague, Czechia.
Carmelo Evoli, Associate Professor, Gran Sasso Science Institute (GSSI), L'Aquila, Italy.
Arjen van Vliet, Assistant Professor of Physics, Khalifa University, UAE.
Martin Pohl, Leading Scientist at DESY Zeuthen and Professor, University of Potsdam, Germany.
Deepen Garg, Postdoctoral Researcher, University of Bonn, Germany.
Rafael Alves Batista, Junior Professor, Institut d'Astrophysique de Paris, Sorbonne Université, France
Jonathan Biteau, Researcher at IJCLab, Université Paris-Saclay, CNRS/IN2P3, Orsay, France
Foteini Oikonomou, Associate Professor, NTNU Trondheim, Norway
Subir Sarkar, Professor Emeritus, Rudolf Peierls Centre for Theoretical Physics, University of Oxford.
Jennifer Schober – Associate Professor, University of Bonn, Germany.
Muni Zhou, Assistant Professor of Physics and Astronomy, Dartmouth College, USA
Cathy Horellou, Professor, Chalmers University of Technology & Onsala Space Observatory, Sweden

In addition, people who have been invited and whose participation is anticipated.

Salome Mtchedlidze, Research fellow, University of Bologna, Italy.
Ruth Durrer, Professor, University of Geneva, Switzerland.
Dmitri Semikoz, Researcher, APC (Astroparticle and Cosmology), Université Paris Cité, CNRS/IN2P3.
Pallavi Bhat, Faculty member, International Centre for Theoretical Sciences (ICTS-TIFR), Bengaluru.
Elisabete M. de Gouveia Dal Pino, Professor, Institute of Astronomy, University of São Paulo, Brazil.
Andrew Taylor, Staff scientist, DESY Zeuthen, Germany.
Alexander Korochkin, Postdoctoral fellow, Université Libre de Bruxelles, Brussels, Belgium.
Annalisa Bonafede, Professor, University of Bologna, Italy.
Valentina Vacca, Researcher in radio astronomy, INAF, Osservatorio Astronomico di Cagliari, Italy.
Ettore Carretti, Senior Research Scientist, INAF, Istituto di Radioastronomia (IRA), Bologna, Italy.
Federica Govoni, Director, INAF, Osservatorio Astronomico di Cagliari, Italy.
Luigina Feretti, Astrophysicist at INAF, Istituto di Radioastronomia, Bologna.
Walter Winter, Senior scientist, Theoretical Astroparticle Physics group, DESY Zeuthen, Germany.
Karsten Jedamzik, Professor, Université de Montpellier, France.
Deborah Sijacki, Professor, Inst. of Astronomy, Kavli Institute for Cosmology, Cambridge University.
Marcus Brueggen, Professor, Department of Physics & Hamburg Observatory, University of Hamburg.
Chiara Stuardi, Researcher, INAF and Istituto di Radioastronomia (IRA), Bologna.
Elena Moretti, Researcher, INAF-Osservatorio Astronomico di Brera, Italy
Ievgen Vovk, Research Associate, University of Tokyo, Japan

Moreover, we expect several more PhD and postdocs from these groups to attend some weeks.

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4. Nordic Relevance

The relevance of the topic of this program is high in the Nordic region.

The Oskar Klein Centre hosts a strong group on cosmic rays which includes researchers actively working on constraining the intergalactic magnetic fields using gamma-ray observations [4], such as Tim Linden, Oindrila Ghosh (one of the organisers), and Milena Crnogrcevic at the Physics Department of Stockholm University (SU). Both T. Linden and M. Crnogrcevic have committed to attend the program and give talks. In addition, we anticipate interests from Garrelt Mellema (SU Astronomy) and Ariel Goobar (OKC, SU Physics) as well as from the galaxy group in Uppsala University and the IRF Uppsala plasma astrophysics group.

Axel Brandenburg at Nordita (one of the organisers) has made pioneering contributions in the fields of astrophysical dynamos [24] with applications in stellar and galactic environments, in addition to his expertise in magnetogenesis from turbulence in the early Universe [25] as well as the evolution of primordial fields owing to turbulence [26]. He has also developed the PENCIL code [27] which is a leading finite-difference MHD code, which has recently been used in my joint work with him [28][29] in the context of magnetization of cosmic voids owing to fields generated by galactic dynamos. A recent implementation of the dark matter module into the PENCIL code also makes it possible to perform large-scale structure simulations incorporating astrophysical processes in terms of baryonic feedback, which is to be explored in our future works. In addition, Oksana Iarygina at Nordita who has significant expertise on inflation, relevant to primordial magnetogenesis, has committed to attending the program.

The University of Southern Denmark (SDU) has a gamma-ray group led by Manuel Meyer (one of the organisers) who is an internationally known expert on gamma-ray astronomy [30] have derived leading constraints on intergalactic magnetic fields and analysed distinctions on astrophysical vs primordial magnetogenesis scenarios based on their specific volume-filling fractions compared with gamma-ray observations of blazars [31]. He is a member of the CTA, H.E.S.S. and Fermi-LAT collaboration. His group is also an active contributor to the cosmic-ray propagation software CRPropa and he has prepared a python wrapper of the software called simCRPropa in addition to his well-known VHE gamma-ray propagation software for axion-like particle detection using GammaALPs [32].

Chalmers University of Technology in Gothenburg hosts a strong radio polarimetry group led by Cathy Horellou who has committed to give a talk on Faraday rotation measure grids as a tool to probe magnetized media in the foreground of polarized radio sources.

At NTNU Trondheim, Michael Kachelriess who has committed to attending the program has developed the ELMAG code for cosmic ray propagation and is one of the leading experts in the field of UHECR generation and propagation. In addition, Foteini Oikonomou who is an expert on ultra-high-energy neutrinos and cosmic ray correlations has also committed to attending the program.

Mark Hindmarsh and David Weir at the University of Helsinki hold long-term expertise on phase transition, whose field-plus-fluid simulations and sound-shell model established the acoustic origin of the gravitational-wave signal and delivered practical templates used across the community. We expect to provide tools to probe primordial magnetogenesis, complementary to the PENCIL code.

The program consolidates these strengths into a visible Nordic contribution to extragalactic magnetism and forge a topical roadmap into the coming decades, with enhanced collaboration and envisioned core working groups. We will use the Nordic infrastructure for open science (code/data curation) and coordinate with informal networking to maximize opportunities for ECRs.

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5. Budget: ~550 kSEK [Nordita] + 110 kSEK [co-funding]

With the requested budget, we will be able to cover the accommodation costs of 25 participants for the duration of three weeks at Biz apartment. We assume ~25 on-site participants at any time, with typical ~3-week stays. In addition, we will be able to provide travel support to ECRs and for low-carbon travel modes such as trains for participants travelling from within the Nordic region, and broadly Europe budget permitting, with priorities towards those from historically underrepresented communities. For attendees with children, we will seek to provide the cost of childcare. In addition to women scientists, our program aims to improve accessibility by providing an online component to the program, making it hybrid. This ensures participation beyond immigration/visa barriers, as well as promotes inclusivity towards attendees with disabilities. In addition, we seek funding to cover social events. We plan a workshop social dinner for each week of the program, as well as a reception each week on Mondays. We are planning to contribute an additional ~110,000 SEK from external grants: Vetenskapsrådet (VR) grant no. 2025-05957 and the European Research Council (ERC) Synergy grant COSMOMAG (2026-2032). If matched by Nordita, this will cover the costs listed below.

- **Accommodation:** ~1,000 SEK/night × 25 participants × 20 nights → **500,000 SEK**
- **Travel support (ECR/under-represented):** 3,000 SEK × ~20 → **60,000 SEK**
- **Low-carbon travel (train where feasible):** 2,000 SEK × ~5 → **10,000 SEK**
- **Budget for social dinner:** 1000 sek (/person/week) × 25 × 3 weeks → **75,000 SEK**
- **Budget for reception: 5000 SEK** × 3 weeks → **15,000 SEK**

- **Total request: 660,000 SEK (including co-funding)**

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6. Relation to Previous and Complementary Programs

In 2023, the program titled *“Generation, evolution, and observations of cosmological magnetic fields”* was hosted for 6 weeks at the Bernouille Centre, Lausanne. While early universe simulations of phase transitions and inflation which are related to PMF generation have been discussed in part in the 2025 Nordita program on *“Numerical simulations of early Universe sources of gravitational waves”*, several issues regarding the interpretation of the observation of cosmic magnetic fields came to the forefront. In particular, distinction between the two broad classes of genesis scenarios led to multiple unresolved debates, specifically on the role of plasma processes, turbulence, the extent and volume filling fractions of astrophysically generated magnetic fields, all of which are largely unaddressed and constitute enormous gaps on the topic of extragalactic magnetic fields as cosmic ray, gamma-ray, and radio telescopes enter their next-generation precision era.

A closely named but distinct Nordita program ran in April 2023, *“Towards a Comprehensive Model of the Galactic Magnetic Field”* which focused on the Milky Way’s galactic magnetic field (GMF) using Faraday tomography, starlight polarization and CR propagation in the interstellar medium with completely separate communities of researchers involved. This is in contrast to our proposed program focusing on a completely different environment constituting underdense plasma of the intergalactic medium, making the overlap minimal. Moreover, one of the focal points of our program is high-energy gamma-ray observations, which have never been discussed in any of the Nordita programs to date.

To our knowledge, a program titled *“Future of ultra-high-energy cosmic ray studies”* is being proposed at the same time by Ralph Engel, Kohta Murase, Foteini Oikonomou, and Michael Unger, with which one of the topics we cover during the second week of our program has a minor overlap. Unlike this program, our proposed program is geared specifically towards understanding the origin and evolution of the extragalactic magnetic fields using UHECR in addition to gamma-ray and radio observations, which we plan to discuss during week 2 and 3.

The topic has been of interest for and will guide future editions of internal collaboration meetings and workshops on high-energy gamma-ray telescopes such as the Cherenkov Telescope Array (CTA), MAGIC, the Fermi-Large Area Telescope, H.E.S.S. and VERITAS, as well as UHECR observatories such as Pierre Auger (PAO), Telescope Array (TAO), and radio observatories such as LOFAR and Square Kilometre Array (SKA). The topic has been of great interest in regular conference series such as the biennial International Cosmic Ray Conference (ICRC) and Rencontres de Moriond: Very High Energy Phenomena in the Universe, and the annual TeV Particle Astrophysics (TeVPA). Other events that have addressed cosmic magnetism in the recent past are “Cosmic Magnetism in Voids and Filaments” (Bologna, January 2023) and “Primordial Magnetic Fields Workshop” (Leiden, August 2023).

Therefore, this program is highly complementary to the previous events mentioned above. Given the strong interest in the community, as well as borne out of the need of the hour to address these gaps. Our emphasis is on both simulation of various astrophysical environments and observational discriminants across radio, gamma, and CR data and an improved understanding of astrophysical processes that may obscure signatures of primordially seeded fields. What sets this program apart is its timeliness and the clear objective to address the debate between two distinct classes of magnetogenesis scenarios.

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7. Inclusivity, Accessibility, and Research Culture (EDI)

We will actively integrate equity, inclusion, and accessibility into the scientific programme and its practical organization, rather than treating them as afterthoughts. This includes careful planning of invitations and speaker slots, transparent and fair allocation of financial support, and concrete steps to support participants with caring responsibilities. These measures are intended both to broaden participation, especially of early-career, under-represented, and international colleagues, and to foster a working atmosphere in which scientific disagreement is encouraged but conducted in a respectful and constructive manner.

In addition, we will design the workshop format and logistics to reduce barriers related to geography, disability, and family situation. Hybrid participation, where feasible, will allow colleagues who cannot travel to engage meaningfully, while also helping to limit the carbon footprint of the meeting. Clear communication of expectations (e.g. via a code of conduct and accessible information about childcare and family-friendly options) will ensure that participants know what support is available and what standards of behaviour are expected.

- **Balanced representation across gender, geography, and career stage.**

  Invitations to speakers, panelists, and discussion leaders will be made with explicit attention to diversity in gender, geographical background, and career stage. We will keep a running overview of the programme (e.g. plenary vs. contributed talks, panel memberships, session chairs) to avoid systematic under-representation of any group and to ensure that early-career researchers and researchers from under-represented regions are visible in prominent roles. Where possible, we will consult existing networks (e.g. diversity initiatives in European astronomy and astroparticle physics) to broaden the pool of potential invitees.

- **Prioritized support for early-career and under-represented researchers.**

  Subject to available funding, we will reserve a portion of travel and local support specifically for PhD students, postdocs, and researchers from under-represented groups or institutions with limited resources. Calls for financial support will clearly state eligibility criteria, evaluation principles (e.g. scientific relevance, career stage, equity considerations), and deadlines. Decisions and allocations will be communicated early enough to allow participants to plan travel, and we will prioritize support that makes participation possible for those who would otherwise be unable to attend.

- **Childcare and family-friendly arrangements.**

  In collaboration with Nordita, we will explore concrete options for childcare support, such as on-site childcare during core meeting hours, negotiated rates or partial subsidies for external childcare providers, and the identification of family-friendly accommodation options. We will also aim to schedule the main scientific programme within predictable daytime hours, avoiding unnecessary evening sessions where possible. Information on available childcare support, facilities suitable for accompanying family members, and local family-friendly infrastructure (e.g. nearby playgrounds, supermarkets, healthcare) will be collected and circulated well in advance so that participants with caring responsibilities can plan accordingly.

- **Code of conduct and confidential contact persons.**

  A concise code of conduct will be adopted and shared on the workshop website, in registration materials, and at the opening session. It will explicitly prohibit harassment and discrimination, emphasize respectful, evidence-based disagreement, and set expectations for behaviour in talks, discussions, and social events. One or more confidential contact persons (ideally of different genders and career stages) will be designated and clearly identified; they will be available during the event for informal advice and, where appropriate, to help initiate formal procedures through the host institutions. Participants will be reminded that critical scientific debate is welcome, but personal attacks and exclusionary behaviour are not.

- **Hybrid and accessible participation, and archiving of materials.**

  Where technically feasible, we will offer remote participation via videoconferencing for selected talks and discussions, with the aim of enabling involvement by colleagues who cannot travel due to caregiving duties, visa constraints, health, cost, or climate considerations. We will encourage speakers to allow recording of their talks and tutorials, and with their permission archive these materials in a restricted or open format to extend the impact of the meeting. We will also take basic accessibility measures (such as providing slides in advance where possible, using microphones consistently, and avoiding highly cluttered visuals) so that both in-person and remote participants can follow the scientific content effectively.

References

[1] Alves Batista, R., & Saveliev, A. (2021). The γ-ray window to intergalactic magnetism. Universe, 7, 223.
[2] Broderick, A. E., Tiede, P., Chang, P., Lamberts, A., Pfrommer, C., Puchwein, E., … & Werhahn, M. (2018). Missing gamma-ray halos and the need for new physics in the gamma-ray sky. Astrophys. J., 868, 87.
[3] Neronov, A., & Vovk, I. (2010). Evidence for strong extragalactic magnetic fields from Fermi observations of TeV blazars. Science, 328, 73-75.
[4] Neronov, A., & Semikoz, D. V. (2009). Sensitivity of γ-ray telescopes for detection of magnetic fields in the intergalactic medium. Phys. Rev. D—Particles, Fields, Gravitation, and Cosmology, 80, 123012.
[5] Brandenburg, A., Kahniashvili, T., Mandal, S., Roper Pol, A., Tevzadze, A. G., & Vachaspati, T. (2017). Evolution of hydromagnetic turbulence from the electroweak phase transition. Phys. Rev. D, 96, 123528.
[6] Mtchedlidze, S., Domínguez-Fernández, P., Du, X., Brandenburg, A., Kahniashvili, T., O'Sullivan, S. et al (2022). Evolution of primordial magnetic fields during large-scale structure formation. ApJ, 929, 127.
[7] Brandenburg, A., & Subramanian, K. (2005). Astrophysical magnetic fields and nonlinear dynamo theory. Phys. Rep., 417, 1-209.
[8] Vazza, F., Ferrari, C., Brüggen, M., Bonafede, A., Gheller, C., & Wang, P. (2015). Forecasts for the detection of the magnetised cosmic web from cosmological simulations. Astron. & Astrophys., 580, A119.
[9] Vachaspati, T. (2021). Progress on cosmological magnetic fields. Rep. Prog. Phys., 84, 074901.
[10] Arámburo-García, A., Bondarenko, K., Boyarsky, A., Neronov, A., Scaife, A., & Sokolenko, A. (2023). The contribution of magnetized galactic outflows to extragalactic Faraday rotation. MNRAS, 519, 4030-4035.
[11] Tjemsland, J., Meyer, M., & Vazza, F. (2024). Constraining the astrophysical origin of IGMF. ApJ, 963, 135.
[12] Cain, C., McQuinn, M., Scannapieco, E., D'Aloisio, A., & Trac, H. (2025). Kiloparsec-scale turbulence driven by reionization may grow intergalactic magnetic fields. arXiv preprint arXiv:2504.21082.
[13] Oei, M. S., Hardcastle, M. J., Timmerman, R., Gast, A. R., Botteon, A., Rodriguez, A. C., … & Djorgovski, S. G. (2024). Black hole jets on the scale of the cosmic web. Nature, 633(8030), 537-541.
[14] Neronov, A., Vazza, F., Brandenburg, A., & Caprini, C. (2025). Intergalactic magnetism in a γ-ray beam as a model of Porphyrion. Astron. & Astroph., 696, L8.
[15] Ghosh, O., Jacobsen, S., & Linden, T. (2025). Heavy Axions Can Disrupt γ-ray Bursts. arXiv:2501.08978. Published in Phys. Rev. D
[16]Broderick, A. E., Chang, P., & Pfrommer, C. (2012). The cosmological impact of luminous TeV blazars. I. Implications of plasma instabilities for the IGMF and extragalactic γ-ray background. Astrophys. J, 752, 22.
[17] Alves Batista, R., Saveliev, A., & de Gouveia Dal Pino, E. M. (2019). The impact of plasma instabilities on the spectra of TeV blazars. MNRAS, 489, 3836-3849.
[18] Ghosh, O., & Bhattacharyya, S. Light Dark Matter in a Blazar-heated Universe. PoS ICRC2023 (2023), 1448
[19] Blanco, C., Ghosh, O., Jacobsen, S. & Linden, T. Where are the Cascades from Blazar Jets: An Emerging Tension in the γ-ray sky. arXiv preprint:2303.01524 (2023). PoS ICRC2023 (2024) 1446
[20] Perry, R., & Lyubarsky, Y. (2021). The role of resonant plasma instabilities in the evolution of blazar-induced pair beams. MNRAS, 503, 2215-2228.
[21] Alawashra, M., & Pohl, M. (2024). Nonlinear feedback of the electrostatic instability on the blazar-induced pair beam and GeV cascade. ApJ, 964(1), 82.
[22] Beck, M., Ghosh, O., Grüner, F., Pohl, M., Schroeder, C. B., Sigl, G., Stark, R. D., & Zeitler, B. Evolution of Relativistic Pair Beams: Implications for Laboratory and TeV Astrophysics. arXiv preprint:2306.16839 (2023)
[23] Christensson, M., Hindmarsh, M., & Brandenburg, A. (2001). Inverse cascade in decaying three-dimensional magnetohydrodynamic turbulence. Phys. Rev. E, 64, 056405.
[24] Brandenburg, A., & Ntormousi, E.: 2023, ``Galactic Dynamos," Annu. Rev. Astron. Astrophys. 61, 561-606
[25] Brandenburg, A., Kahniashvili, T., & Tevzadze, A. G.: 2015, ``Nonhelical inverse transfer of a decaying turbulent magnetic field," Phys. Rev. Lett. 114, 075001
[26] Brandenburg, A., Enqvist, K., & Olesen, P.: 1996, ``Large-scale magnetic fields from hydromagnetic turbulence in the very early universe," Phys. Rev. D 54, 1291-1300
[27] Pencil Code Collaboration: Brandenburg, A. *et al*: 2021, ``The Pencil Code, a modular MPI code for partial differential equations and particles: multipurpose and multiuser-maintained," J. Open Source Softw. 6, 2807
[28] Ghosh, O., Brandenburg, A., Caprini, C., Neronov, A., Vazza, F. (2025). Can galactic magnetic fields diffuse into the voids? arXiv:2510.26918, submitted to Phys. Rev. D.

[29] Brandenburg, A., Caprini, C., Ghosh, O., Neronov, A., Vazza, F. (2025). Magnetic Field Spreading from Stellar and Galactic Dynamos into the Exterior. To be submitted to Astrophys. J. Nordita preprint: NORDITA-2025-054 https://norlx65.nordita.org/~brandenb/tmp/Astrophysical-field-in-voids/notes.pdf
[30] Biteau, J., Meyer, M. (2022), Gamma-Ray Cosmology and Tests of Fundamental Physics. Galaxies, 10, 39.
[31] Meyer, M., Conrad, J., Dickinson, H. (2016), Sensitivity of the Cherenkov Telescope Array to the Detection of Intergalactic Magnetic Fields. Astrophys. J., 827, 147.
[32] Meyer, M., Davies, J., Kuhlmann, J., (2021), gammaALPs: An open-source python package for computing photon-axion-like-particle oscillations in astrophysical environments. arXiv: 2108.02061