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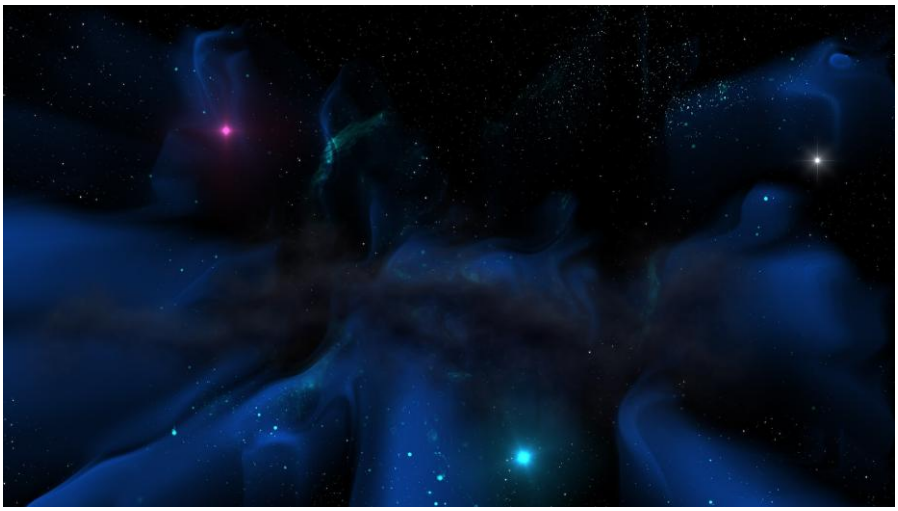
PRESS RELEASE

Magnetic fields in the infant Universe may have been billions of times weaker than a fridge magnet

This has been established by a new piece of research published in Physical Review Letters, based on 250,000 simulations and confirmed by observations. The cosmic web still carries traces of their existence. The study was conducted by an international team led by SISSA in Trieste.



Trieste, 2 September 2025

The magnetic fields that formed in the very early stages of the Universe, may have been billions of times weaker than a small fridge magnet, with strengths comparable to magnetism generated by neurons in the human brain. Yet, despite such weakness, quantifiable traces of their existence still remain in the cosmic web, the visible cosmic structures connected throughout the Universe. These conclusions emerge from a study using around a quarter of a million computer simulations, conducted by a team from SISSA (the International School for Advanced Studies based in Trieste) in collaboration with the Universities of Hertfordshire, Cambridge, Nottingham, Stanford, and Potsdam. Observational data were subsequently used to validate these findings. The research, recently published in Physical Review Letters, specifies both possible and maximum values for the strengths of primordial magnetic fields. It also offers the possibility of refining our knowledge of the early Universe and the formation of the first stars and galaxies.

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A magnetic cosmic web

“The cosmic web, of which much remains to be discovered, is a filamentary structure connecting the galaxies that permeates the Universe. One of its many unsolved mysteries is why it is magnetised, not only near galaxies, where this might be expected, but also in distant regions that are sparsely populated and constitute the bulk of the cosmic web. This is harder to explain”. These comments come from Mak Pavičević, a SISSA PhD student and lead author of the research, and Matteo Viel, his supervisor and co-author of the study. "Our hypothesis was that this could be a legacy of events occurring in cosmic epochs during the birth of the Universe, and that magnetism was linked essentially to physical processes in the primordial Universe. For example, the filaments would have become magnetised during the inflation process before the so-called "Big Bang" or through events in later epochs, called phase transitions. This is what we sought to ascertain with our work. We also wished to assess the magnitude of these primordial magnetic fields through our investigations, establishing an upper limit and attempting to measure their strengths."

At the origin of the Universe with a quarter of a million simulations

The international team used over 250,000 computer simulations to study the cosmic web and better understand the influence of primordial magnetic fields. Vid Iršič from University of Hertfordshire, and a co-author of the study, emphasises that “these are the most realistic and largest suite state-of-the-art simulations of the influence of primordial magnetic field on the intergalactic cosmic web.” Pavičević and Viel explain: "By comparing these simulations with observational data, we saw that our hypotheses were correct. When the influence of primordial fields is included in the picture, the cosmic web looks different and more in agreement with observed data. In particular, we can say that a standard model of the Universe with a very weak magnetic field of around 0.2 nano-gauss actually fits experimental data much better."

The magnitude of primordial magnetic fields: a new upper limit

The scientists have derived a particularly low value for the magnitude of the primordial magnetic fields, establishing a new upper limit several times lower than previously estimated. Pavičević and Viel continue: "Our research thus places strict limits on the intensity of magnetic fields formed in the very early moments of the Universe and is consistent with recent results obtained in independent data and studies on the cosmic microwave background. The two scientists explain: "This evidence will help us to improve our understanding of events in the early Universe. The magnetic field would have increased the

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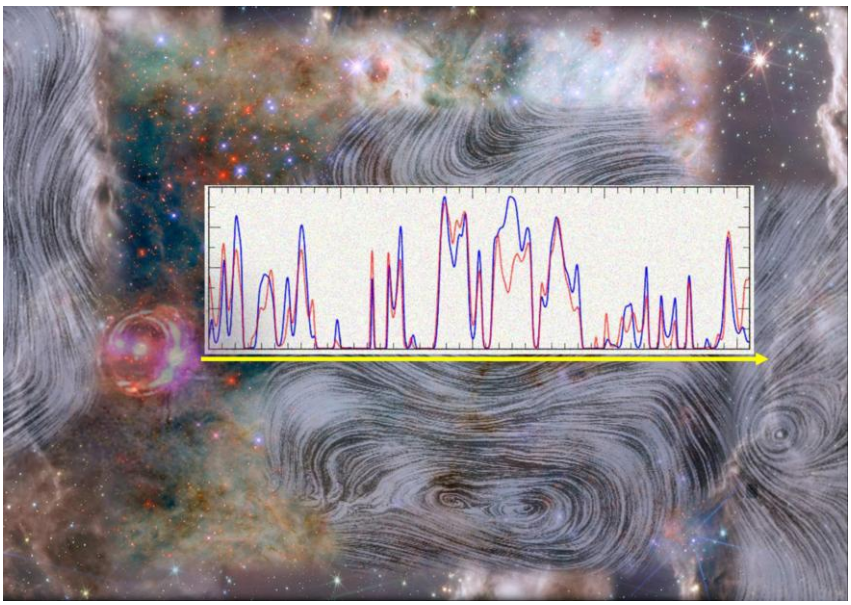
density of the cosmic web, in turn accelerating the process of star and galaxy formation. It will be possible to further validate our results through observations made by the James Webb Space Telescope." Vid Iršič concludes: “Not only will these new limits help us understand the impact of the primordial magnetic fields on the evolution of the Cosmo, but they also hold important implications for other theoretical models that enhance structure formation”.



The figure shows simulated Lyman-alpha spectrum, comparing the standard ΛCDM universe (red) and addition of Primordial Magnetic Fields (blue). Image by Mak Pavicevic.

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