JU Astronomers: it appears that we have just discovered the most widespread, regular magnetic field in the Universe

Magnetic field in the Space is nothing weird: its presence is detected on small, rocky planets, as well as in haloes enshrouding galaxy clusters that extend on millions of light years. Not only is this entity common, but it's also extremely important: while invisible to the naked eye, it is the magnetic field that has a dramatic impact on the galactic evolution, gives an onset – or the opposite, blocks! - stellar formation, or "keeps in line" charged particles ejected in the quasars' jets. Our knowledge of magnetic fields and their properties, despite being constantly broadened, still is relatively poor – in particular, when it comes to the structure of the Galactic magnetic field, or prospects for the further magnetisation of the seemingly empty space by objects already magnetised.

Cosmic magnetic field can be either regular, ordered, or chaotic. The last form is the most widespread one, without any preferred orientation. Such a field can encompass large areas, creating a form of a magnetic soup, in which particular galaxies, or even systems of them, are soaked. The ordered one is relatively rarer: they appear to have a preferred direction, but in fact the sign of the field can actually change from "+" to "-"; they are created when chaotic fields are squeezed, or stretched during galactic interactions. These fields can also grow vast: arch-like relics found in galaxy clusters are frequently as large as hundreds of thousands of kilometres. The least common one is the genuinely regular, unidirectional field. Creation of such an entity is not an easy task: usually the magneto-hydrodynamic dynamo has to take action. This one works effectively only for a small fraction of galaxies, mostly spiral ones (although not all of them; on the other hands, some of the irregulars can utilise it, too). A field created in such a way is hosted in the galactic disk, and can exit it only by the means of tearing the gas (into which it is frozen) away from the original location during interactions. Outside of the disk, however, the subtle regular structure of the field does easily deteriorate; henceforth, the only regularly magnetised structures found outside of galactic disks are narrow, elongated spiral arms. And even if they reach tens of thousands of light years of length, their width, or depth is not longer than a few thousands. Same applies to the tails created when matter is being expelled from the disks because of the supernovae feedback: this process does not create large intergalactic, regularly magnetised structures.

A team of scientists from the Jagiellonian University and CSIRO in Australia has just published an article that describes a vast, regularly magnetised structure found in a small, compact galaxy group – the Stephan's Quintet. This object is believed to be a model one for its class; galaxies that form it interact with each other, expelling the matter to the intra-group space, or even outside of it. Analysis of the regular magnetic field was done with the Rotation Measure Synthesis method that focuses on how does the polarisation angle vary in a broad, densely sampled fragment of the radio spectrum. A change in the angle means that the plane of polarisation of the incoming wave has changed – it happens in the presence of a regular magnetic field along the line of sight (Faraday's effect). Observations of the Quintet show that those radio sources that are inside the group, or shine through it, are immersed in one, consistent, regularly magnetised structure. Studies suggest that it is nearly impossible to explain the picture observed if that structure is placed inside our own Galaxy; that would contradict all known models of its magnetic field structure. Therefore, the only place where this structure can be located, is the vicinity of the Quintet. It seems that we are facing some kind of a magnetic „screen", with an extent of at least 200 000 on 130 000 on 65 000 light years. It is the largest known, regularly magnetised structure in the Universe, and the one and only object of this type found not in a single galaxy, or a galaxy pair. Moreover, there is no consensus on how was this structure created. While the most probable explanation is that it was torn from one of the member galaxies, it is hard to imagine the sequence of events that could led to a formation of such a vast entity.

An answer to these questions might possibly be revealed thanks to the already planned revisiting of the Quintet: thanks to the data from other instruments (including those from LOFAR, the state-of-the-art, Pan-European low frequency interferometer, to which a significant contribution is made by three Polish-owned stations), it will be possible to study the traces of the regular mangetic field in a much more detailed way. In particular, it might happen that either the source, or any hints on the nature of unexpected, magnetic "screen" will be found.

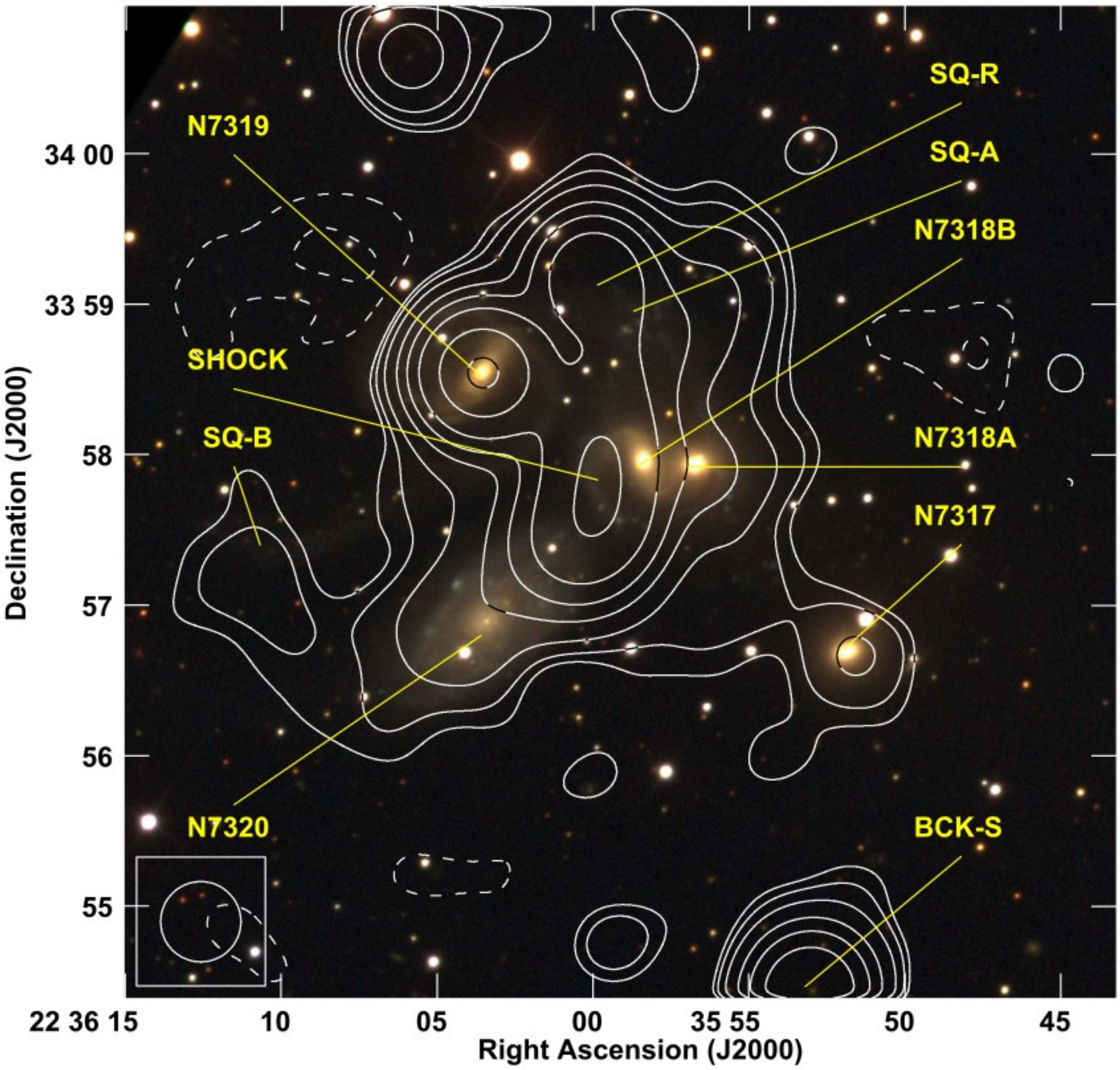

Figure 1. The Stephan's Quintet in all its glory. Discovered in 1877, it was once demoted to a quartet, and later promoted back. Out of five galaxies visible in the picture, only four actually belong to the group; the southernmost one lies approximately 8 times closer than the rest, while the actual fifth member of the Quintet is located a bit more left to the image boundary. The contours superimposed show the extent of the radio halo of the group: it is even larger than the "screen" and hosts mostly chaotic and ordered fields, remnants of the tempestuous history of this object.

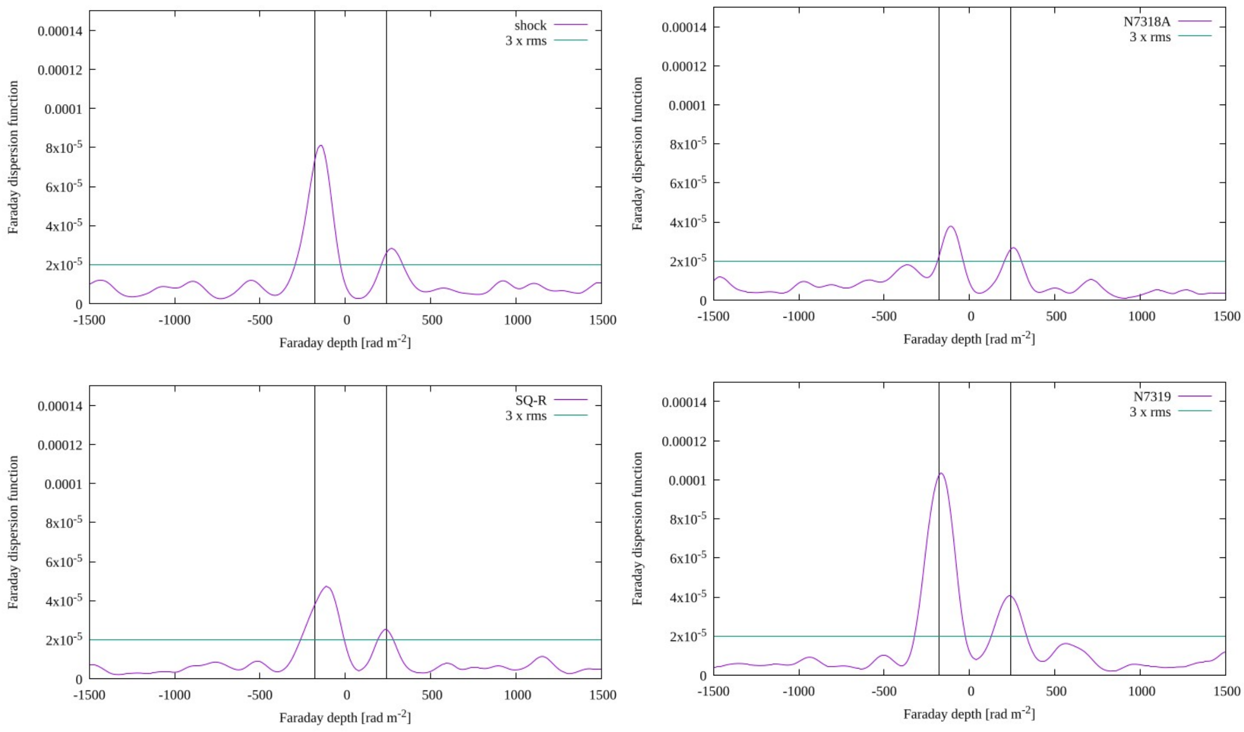

Figure 2. These unimposing plots are, actually, the most important part of the paper: a visual proof that a single, vast, regularly magnetised structure exists inside the Quintet. They represent the signal level vs. the so-called Faraday Depth (FD). The peak located below the zero on the horizontal axis represents the signal originating in the Milky Way, the one above – the signal that is believed to come from the Quintet's vicinity. Estimation of (some of) the parameters of the detected, regular magnetic field is possible thanks to the analysis of the distance between the particular peaks (the larger it is, the stronger the field is), location below/above the FD axis null point (orientation towards/outwards the observer, or its possible change), or association with one particular structure (this happens if plots made for a subset of points close to each other show a similar configuration of peaks: similar distance between the peaks, or position in the Faraday space). Only those objects that are located within the Quintet, or shine through exhibit a concordant peak configuration; those outside the group's area show much different ones.

Original paper: A Large-scale, Regular Intergalactic Magnetic Field Associated with Stephan's Quintet?, Błażej Nikiel-Wroczyński[1], Marian Soida[1], George Heald[2], Marek Urbanik[1], *The Astrophysical Journal*, 2020, 898, 110, https://doi.org/10.3847/1538-4357/ab9d89

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