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Statistical Analysis on Simulated Polarization Angle Data of M31

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We introduce a statistical measure of the effective model complexity, called Bayesian complexity[1], to find how many effective parameters a data can support using simulated polarization angle data of Andromeda galaxy, M31. This model selection approach can be used in the selection of Fourier modes for observed radio data[2]. The evidence or the marginal likelihood is the most general way to select the best model, but it is difficult to calculate. We find that the Bayesian complexity is a useful complement to that and can be used as the model selection method for polarization angle data that can help infer the magnetic field structure of the galaxy.

Magnetic fields can be small-scale turbulent or large-scale coherent, depending on what physical processes are occurring. Polarized synchrotron radio emission allows us to study the strength and orientation of the ordered magnetic field in the sky plane. Also, the Faraday rotation of the polarization angle, along with the density of thermal electrons, gives information about the line of sight component of the regular magnetic field. Combining these two, one can find the 3D magnetic field structure of the galaxy.

For simulation, we use M31, the nearest spiral galaxy with 780 kpc of distance and 75° inclination angle, which allows us to get a large angular size to study in great detail. Previously analysis with multiwavelength polarization data suggested an axisymmetric field (Fourier mode, m=0) for radial range of 8-14 kpc from the center of the galaxy[3]. So, we take a similar radial ring, ie, 8-10 kpc and use a mixed field of axisymmetric, bisymmetric and quadrisymmetric (m=0+1+2) to simulate polarization angle data. Then we use Monte Carlo Markov Chain using the *cobaya* package for *Python* to fit the simulated data for 16 different combinations of models including mode 0 to 4. We take m=0 to always be there, as the axisymmetric mode is the dominant in spiral galaxies like M31. Then we calculate the log likelihood and model complexity (in terms of effective number of parameters) and find that the model with m=0+1+2 performs best. This validates our modeling method as well as the model selection criteria that can be used to analyze the observed polarization angle data for other spiral galaxies.

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