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Fluctuation dynamos and their Faraday rotation signatures

Pallavi Bhat and Kandaswamy Subramanian
IUCAA, Post Bag 4, Ganeshkhind, Pune 411007, India.
email: `palvi@iucaa.ernet.in`, `kandu@iucaa.ernet.in`

We study fluctuation dynamo (FD) action in turbulent systems like galaxy-clusters focusing on the Faraday rotation signature. This is defined as $\mathrm{RM} = K \int_L n_e \mathbf{B} \cdot \mathbf{dl}$ where n_e is the thermal electron density, $\mathbf{B}$ is the magnetic field, the integration is along the line of sight from the source to the observer, and $K = 0.81$ rad m^{-2} cm^{-3} μG^{-1} pc^{-1}. We directly compute, using the simulation data, $\int \mathbf{B} \cdot \mathbf{dl}$, and hence the Faraday rotation measure (RM) over $3N^2$ lines of sight, along each x, y and z-directions. We normalise the RM by the rms value expected in a simple model, where a field of strength B_{rms} fills each turbulent cell but is randomly oriented from one turbulent cell to another. This normalised RM is expected to have a nearly zero mean but a non-zero dispersion, $\bar{\sigma}_{RM}$. We show in Fig. 1a and 1b, that a suite of simulations, on saturation, obtain the value of $\bar{\sigma}_{RM} = 0.4 - 0.5$, and this is independent of P_M, R_M and the resolution of the run. This is a fairly large value for an intermittent random field; as it is of order 40%–50%, of that expected in a model where B_{rms} strength fields volume fill each turbulent cell, but are randomly oriented from one cell to another. We also find that the regions with a field strength larger than $2B_{rms}$ contribute only 15–20% to the total RM (see Fig. 1a). This shows that it is the general 'sea' of volume filling fluctuating fields that contribute dominantly to the RM produced, rather than the the high field regions.

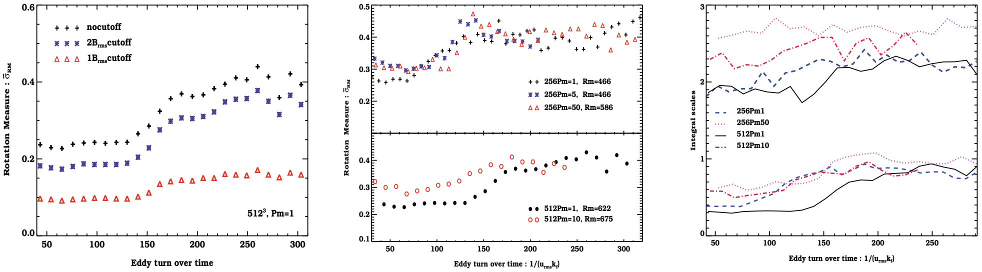

Figure 1. Figure (a) on the left shows the effective RM after removing the regions with $|\mathbf{B}| > 2B_{rms}$ and $1B_{rms}$ fields. Fig. (b) in the middle shows RM evolution for runs with different R_M and P_M. Fig (c) on the right shows magnetic integral scales in the lower half and velocity integral scales in the upper half.

Interestingly, the magnetic integral scale, L_{int} (see Fig. 1c) starts to increase in all the runs, as Lorentz forces become important to saturate the dynamo. It appears that on saturation, the magnetic integral scale, L_{int} tends to a modest fraction $1/2 - 1/3$ of the integral scale of the velocity field for all our runs. Finally, we find that $\bar{\sigma}_{RM} \sim 0.4 - 0.5$ obtained, implies a dimensional $\sigma_{RM} \sim 180$ rad m^{-1}, for parameters appropriate for galaxy clusters. This is sufficiently large to account for the observed Faraday rotation seen in these systems.