Evaluation of the thesis "Simulating the Amplification, Saturation, and Structure of Turbulent Interstellar Magnetic Fields" by Neco Kriel

The thesis comprises original material from three first author papers by Kriel. The first two are concerned with the kinematic and saturated phases of the small-scale dynamo, respectively. The third paper deals with the MHD extension of the GPU-based QUOKKA code.

While small-scale dynamos play a role in many astrophysical environments, the application to the interstellar medium is particularly well motivated by the outstanding question how coherent large-scale magnetic fields can be generated sufficiently rapidly in very young distant galaxies. One additional clue comes from the fact that such environments are not only highly turbulent, but also supersonic. Another important application discussed by Kriel concerns galaxy mergers, where coherent fields are observed to be generated on short time scales. Kriel and collaborators therefore pose the interesting question whether large Mach numbers could potentially help producing large-scale fields sufficiently rapidly. This is a difficult question, because it requires careful convergence studies to disentangle physical from numerical effects. The answer to this question is *yes, shocks in supersonic turbulence can mediate the formation of larger scale structures.*

In this context, Kriel revises an old finding that strong magnetic field structures are more straight. He now finds that this result is restricted to low Mach numbers. At higher Mach numbers, or in more strongly supersonic turbulence, even strong magnetic field structures can be bent due to the overruling force exerted by shocks. This is not just a mathematical result that is reflected in just numbers, but it is also visually well displayed.

Kriel also revises our understanding of the relevant dissipative scales. He now identifies three distinct regimes that depend on the relative combination of Mach and Reynolds numbers. These are all quite pathbreaking discoveries that will have an impact on generations of future work in that field. Like with many other such results, Kriel displays them in clear and visually appealing form.

The second paper concerns the short but important stage just before the small-scale dynamo saturates. Between the exponential growth in the beginning and the saturated phase of a statistically constant magnetic field, there is an intermediate phase where the magnetic field appear to grow algebraically. This was known for some time, but conventional findings were restricted to small Mach numbers. They suggested that the magnetic energy grows linearly in time during this intermediate phase. There were some earlier theoretical studies that suggested a faster growth in the supersonic regime, but those results were never checked numerically. It now turns out that this intermediate phase is indeed Mach number-dependent and that the magnetic energy grows quadratically in the supersonic regime.

In the third paper, Kriel is concerned with an entirely new code that is GPU based, but where magnetic fields were not yet implemented. GPU based codes are the future of scientific computing, but most of the existing codes are only CPU-based, or they are still not very efficient when GPU-based acceleration is added. Therefore, there is a great need for new approaches. In his latest work, Kriel uses implemented the constrained transport algorithm into the GPU based code. Multiple tests are being described that confirm the validity and efficiency of the implementation.

The thesis papers are embedded in a pedagogical framework that gives insight into Kriel's broad understanding of the matter. Based on these displayed skills and the thoroughness and pathbreaking nature of the scientific results, it is very clear that Kriel has an excellent career ahead of him. There are no shortcomings in the thesis itself. I am therefore happy to give it my strongest possible recommendations.