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Cheung, M. C. M.; **Moreno-Insertis, F.**; **Schüssler, M.**

Moving magnetic tubes: fragmentation, vortex streets and the limit of the approximation of thin flux tubes. (English) Zbl 1096.85505

Astron. Astrophys. 451, No. 1, 303-317 (2006).

Summary: Aims. We study the buoyant rise of magnetic flux tubes in a stratified layer over a range of Reynolds numbers ($25 \preceq \mathrm{Re} \preceq 2600$) by means of numerical simulations. Special emphasis is placed on studying the fragmentation of the rising tube, its trailing wake and the formation of a vortex street in the high-Reynolds number regime. Furthermore, we evaluate the relevance of the thin flux tube approximation with regard to describing the evolution of magnetic flux tubes in the simulations.

Methods. We used the FLASH code, which has an adaptive mesh refinement (AMR) algorithm, thus allowing the simulations to be carried out at high Reynolds numbers.

Results. The evolution of the magnetic flux tube and its wake depends on the Reynolds number. At Re up to a few hundred, the wake consists of two counter-rotating vortex rolls. At higher Re, the vortex rolls break up and the shedding of flux into the wake occurs in a more intermittent fashion. The amount of flux retained by the central portion of the tube increases with the field line twist (in agreement with previous literature) and with Re. The time evolution of the twist is compatible with a homologous expansion of the tube. The motion of the central portion of the tube in the simulations is very well described by the thin flux tube model whenever the effects of flux loss or vortex forces can be neglected. If the flux tube has an initial net vorticity, it undergoes asymmetric vortex shedding. In this case, the lift force accelerates the tube in such a way that an oscillatory horizontal motion is super-imposed on the vertical rise of the tube, which leaves behind a vortex street. This last result is in accordance with previous simulations reported in the literature, which were carried out at lower Reynolds number.

MSC:

85A30 Hydrodynamic and hydromagnetic problems in astronomy and astrophysics

83C50 Electromagnetic fields in general relativity and gravitational theory

Cited in **1** Document

Keywords:

magnetohydrodynamics (MHD); Sun: magnetic fields; Sun: interior

Software:

FLASH Code

Full Text: DOI

Edited by FIZ Karlsruhe, the European Mathematical Society and the Heidelberg Academy of Sciences and Humanities
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