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MAGNETIC RECONNECTION BY ALFVÉN WAVES

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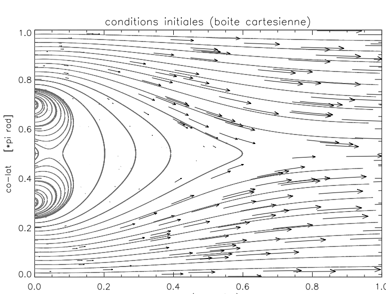
Abstract. We investigate the effects of the injection of alfvén waves into the solar corona using an axisymmetric 2.5 MHD numerical model extending from the top of the transition region up to about 15 solar radii. Transparent boundary conditions are applied at the top and bottom of the numerical domain and waves are injected by perturbing the alfvénic characteristic at the bottom boundary. We study two kinds of magnetic configuration: a) a quadrupolar region inside an equatorial streamer and b) a small bipole within an unipolar flux polar coronal hole region. In configuration a), waves generate a pattern of convective flows ($10 - 50$ km/s) inside the streamer and simultaneously slow reconnection around the magnetic null point, which continuously rises upwards (≈ 25 km/s). In configuration b), we observe an increase in density, wind speed and mass flux along its central axis in a behaviour which resembles that of polar plumes in coronal holes. Current density accumulates around the magnetic null point.

1 Introduction

The understanding of the destabilisation of magnetised coronal structures and of the subsequent dynamical events (CMEs, plumes, jets, inflows, etc) relies on the correct assessment of the energy transport mechanisms taking place from down below the photosphere up to the corona. Numerical models need to make use of simple approximations to such transport phenomena. Most often, the coronal plasma is assumed to be "line-tied" to the photosphere, which translates into setting the horizontal velocities at the photosphere as rigid lower boundary conditions (footpoint shearing), neglecting any feedback from the coronal dynamics over the photosphere; energy flows upwards through the photosphere (e.g, Aulanier et al. 2005) but not downwards (being reflected there, instead). Grappin et al. (2008) show this approximation severely overestimates the magnetic energy and velocity shear transmitted to coronal loops, unless for rather short timescales. We search for destabilisation methods which do not rely on linetied footpoint shearing. We use an axisymmetric MHD numerical model of an isothermal ($\gamma = 1$) corona starting from just above the TR. We inject alfvén waves through the transparent lower boundary by perturbing the alfvénic characteristic there. We test two magnetic configurations: a) quasi-quadrupolar system with a magnetic null point within an equatorial streamer (Fig. 1); b) magnetic bipole in polar coronal hole ("plume-like" configuration, Fig. 2).



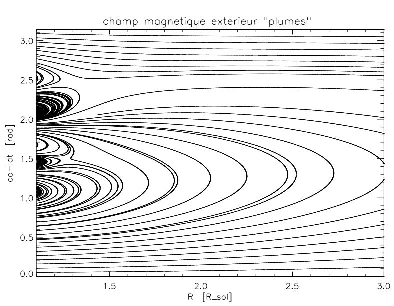


Fig. 1. Magnetic configuration a) in a cartesian representation of the numerical domain; x-axis is R from 1 to 15 $R_\odot$ in log-scale, y-axis is co-latitude from 0 to 2π.

Fig. 2. Magnetic configuration b) in a cartesian representation of the numerical domain; x-axis is R from 1 to 3 $R_\odot$, y-axis is co-latitude from 0 to 2π.

2 Results

Figure 3 shows the flow pattern which forms within the equatorial streamer shown in Fig. 1 at about 5 h after the wave injection starts. A stagnation point forms over the magnetic null point as in classical 2D reconnection, but

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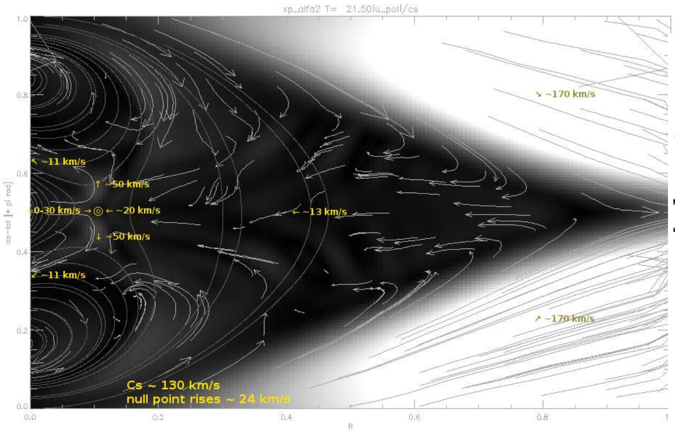


Fig. 3. The convective flow pattern inside the equatorial streamer (cf. Fig. 1) at time $\delta t \approx 5$ h ($\approx 20\ \tau_{alfven}$ for the internal loops). Only the sub-domain $1 < r/R_\odot < 2.5$, $0.17\ \pi < \theta < 0.83\ \pi$ is shown. Grayscale represents $|u|/c_s$. A stagnation point forms over the null point, its position being indicated by a yellow circle.

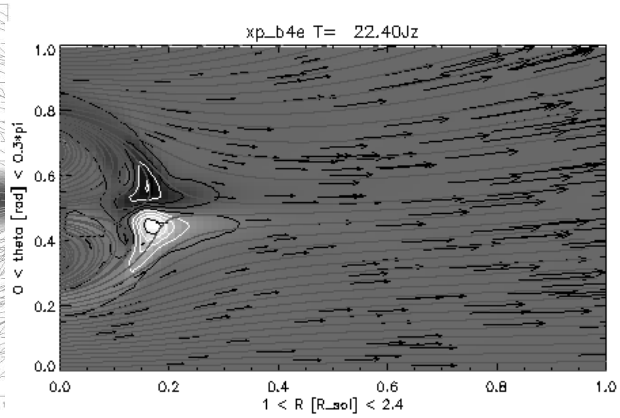
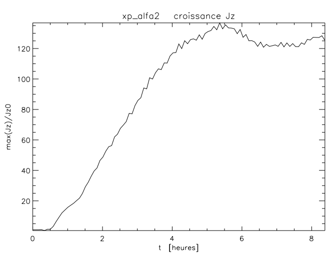


Fig. 4. Snapshot of the accumulation of current density around the null point above the dipole in the configuration in Fig. 2. Only the sub-domain $1 < r/R_\odot < 2.4$, $0 < \theta < 0.3\ \pi$ is shown. Grayscale represents J_Z, grey lines are magnetic fieldlines and black arrows show the local flow velocity. An overdense jet forms along the magnetic axis, above the null point.



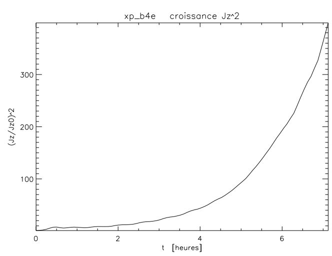


Fig. 5. Current density accumulation around the null point in figs. 1 and 3, which seems to saturate after $\approx 20\ \tau_{alfven} \approx 5$ h. The reconnection do not stop, though.

Fig. 6. Current density accumulation around the null point in figs. 2 and 4. $|J_z|$ seems to grow without bound, for at least $\approx 50\ \tau_{alfven} \approx 7$ h.

here the null point moves upwards at a nearly constant velocity 24 km/s without any signs of deceleration. Wave injection is restricted to zones not directly connected to the neighbourhood of the null point. The reconnection process is triggered by a re-arrangement of the magnetic and gas pressures after the wave propagation pattern occupies a large portion of the streamer. Figure 5 shows the accumulation of current density around the null point as a function of time. As we use transparent boundaries the accumulation of energy in the system cannot be a trivial consequence of footpoint shearing as when using linetying conditions, because here there is a well defined upper limit for the energy added (see Grappin et al. 2008).

Figure 4 shows the formation of a coronal jet along the magnetic axis of a magnetic bipole within a unipolar flux region. Unlike in the previous case, the topology is stationary. There is, however, reconnection going on around the null point. Also here, a pattern of convective flows with a stagnation point coincident with the magnetic null settles in. Density, velocity and mass flux build up in the vicinity of the bipole axis, making up a small coronal jet. Current density accumulates; its spatial distribution is shown in Fig. 4 and the peak density is shown as a function of time in Fig. 6.

References

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