MHD wave propagation in the neighbourhood of coronal null points

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Coronal null points are locations where the magnetic field, and hence the local Alfven speed, is zero. The behaviours of all three MHD wave modes, i.e. fast and slow magnetoacoustic waves and the Alfven wave, have been investigated in the neighbourhood of 2D, 2.5D and (to a certain extent) 3D magnetic null points, for a variety of assumptions, configurations and geometries. These studies contribute to our understanding of MHD wave propagation in inhomogeneous media, and this poster will detail some specific findings in this area, in particular the results that have led to critical insights into mode-coupling, mode-conversion, reconnection, and quasi-periodic pulsations.

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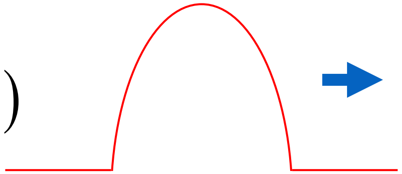
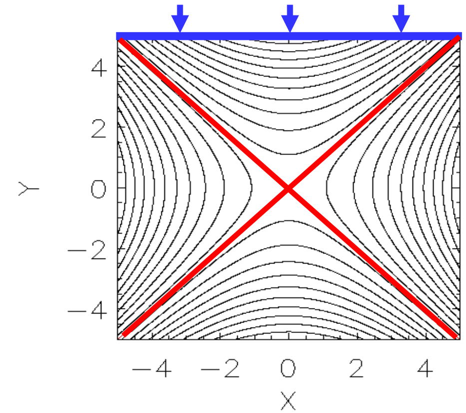
McLaughlin & Hood (2004, *A&A*, **420**, 1129)

Consider wave propagation near to equilibrium magnetic field – simple 2D X-point.

$$\mathbf{B}_0 = \frac{B_0}{L}(y, x, 0)$$



Idea is to send in wave pulse from top boundary, and see (and explain!) what happens.

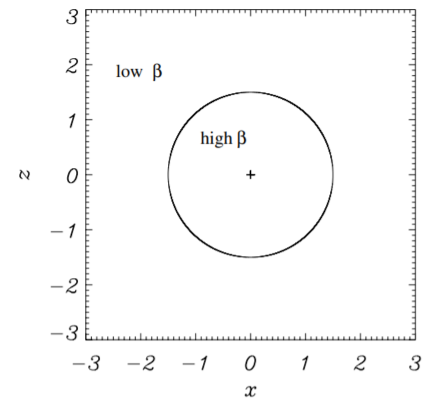


For zero-β system, we find that:

- Linear, fast magnetoacoustic wave travels towards the vicinity of the X-point and bends around it.
- Alfvén speed spatially varying: travels faster further away from the null.
- Wave demonstrates *refraction* – wraps wave around null
- **Key feature of fast wave propagation** (linear + cold plasma).

McLaughlin & Hood (2006, *A&A*, **459**, 641)

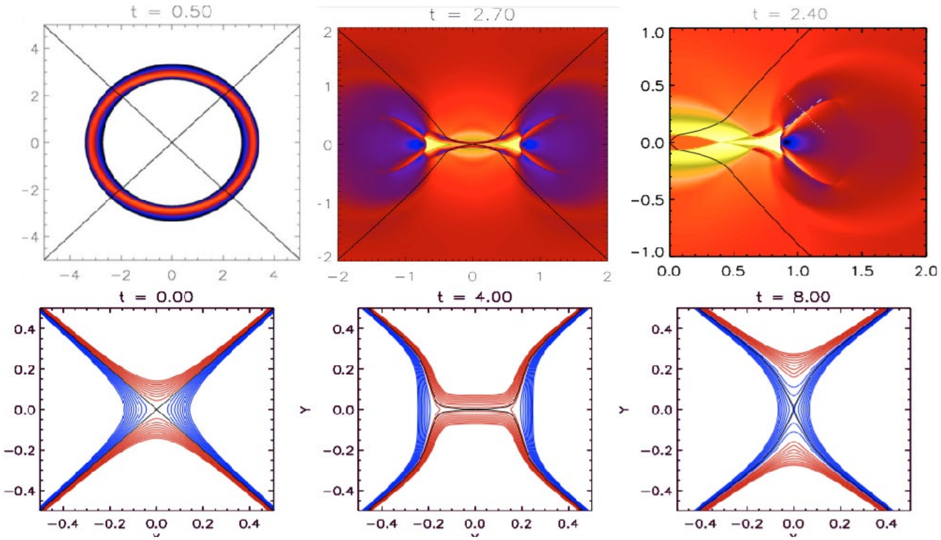
- There does not exist a robust set of rules connecting low-β and high-β waves across the equipartition layer (where sound speed is equal to Alfvén speed).
- It was found that when a finite gas pressure is included in a magnetic equilibrium containing an X-type null point, a (low-β) fast wave is attracted towards the null by a refraction effect and that *both* a high-β fast wave and a high-β slow wave are generated as the wave crosses the equipartition layer.
- Current accumulation occurs close to the null and along nearby separatrices. The fast wave can now pass through the null due to the non-zero (sound) speed there.
- We conclude that there are two competing phenomena; the refraction effect (due to the variable Alfvén speed) and the contribution from the non-zero sound speed.



Regions of high-β and low-β in our equilibrium magnetic field, where β is inversely proportional to x^2+z^2 . The black circle indicates the position of the equipartition layer and the cross denotes the null.

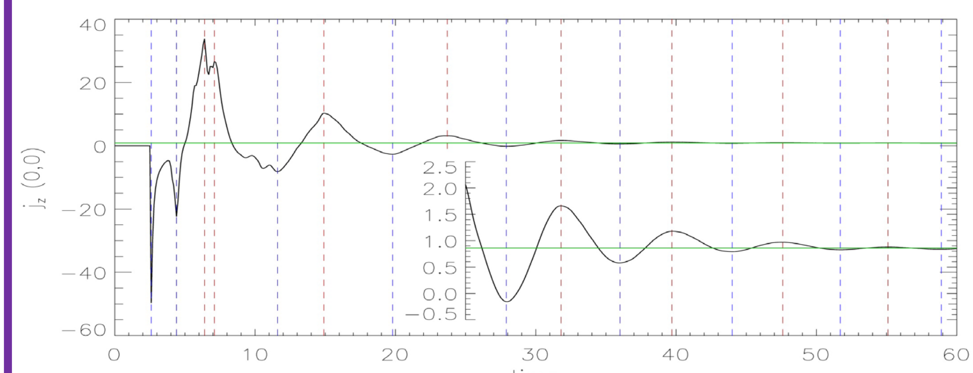
McLaughlin, De Moortel, Hood & Brady (2009, *A&A*, **493**, 227)

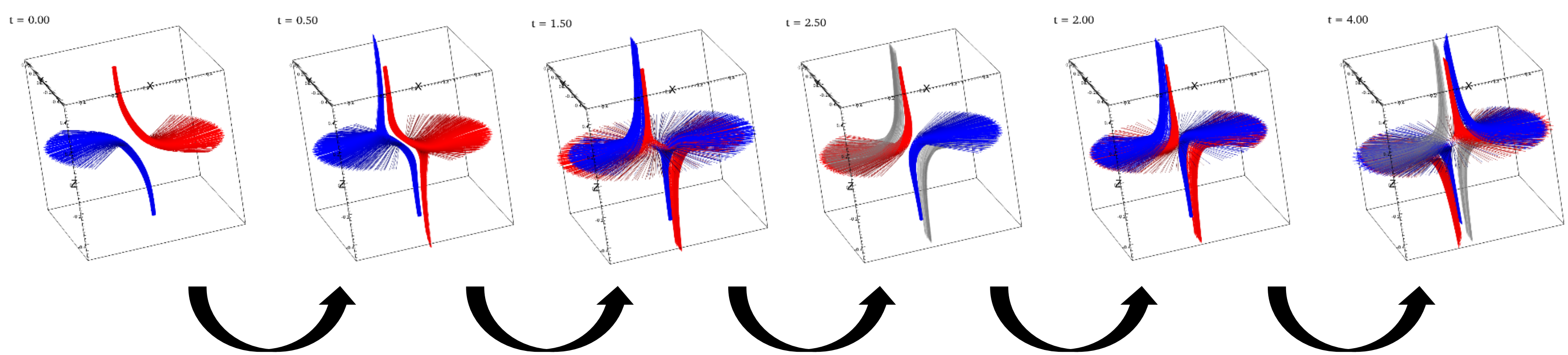
- Investigate the nature of nonlinear fast magnetoacoustic waves about a 2D magnetic X-point.
- The nonlinear wave deforms the X-point into a “cusp-like” point which in turn collapses to a current sheet.
- The system then evolves through a series of horizontal and vertical current sheets, with associated changes in connectivity: the system exhibits oscillatory reconnection.

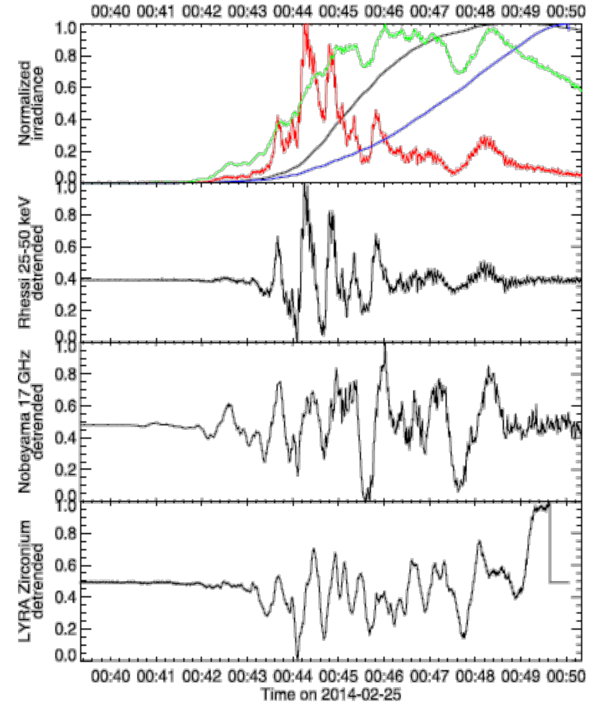


Thurgood, Pontin & McLaughlin (2017, *ApJ*, **844**, 2)

- Oscillatory Reconnection works in 3D as well!
- Detailed the dynamic evolution of localized reconnection regions about 3D magnetic null points.
- We demonstrate for the first time that reconnection triggered by the localized collapse of a 3D null point that is due to an external MHD wave involves a self-generated oscillation, whereby the current sheet and outflow jets undergo a reconnection reversal process.







McLaughlin, Nakariakov, Dominique, Jelínek & Takasao (2018)
Modelling Quasi-Periodic Pulsations in Solar and Stellar Flares
Space Science Reviews, **214**, 45

- Solar flare emission often shows a pronounced oscillatory pattern, with characteristic periods (Quasi-Periodic Pulsations)
  => currently a mystery, but may be the key to unlocked solar flare physics!

- The underlying physical mechanism(s) still unknown, but oscillatory reconnection is an excellent candidate: the **advantage** of the time-dependent reconnection model is the natural explanation of the simultaneity of QPPs in different bands (as they are produced by the same cause: the time-varying rate of the electron acceleration).

Zimovets, McLaughlin, et al. (2021)
Quasi-periodic pulsations in solar and stellar flares: a review of underpinning physical mechanisms and their predicted observational signatures
Space Science Reviews, **accepted**

- At least fifteen mechanisms/models have been developed to explain QPPs in solar and stellar flares, and this paper reviews all these mechanisms and – crucially – **we present the predicted and prominent observational signatures of each of the fifteen mechanisms**.

For more information on any of these results, contact me via *james.a.mclaughlin@northumbria.ac.uk*