PRIFYSGOL ABERYSTWYTH UNIVERSITY

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Flow-twist coupling in the solar atmosphere

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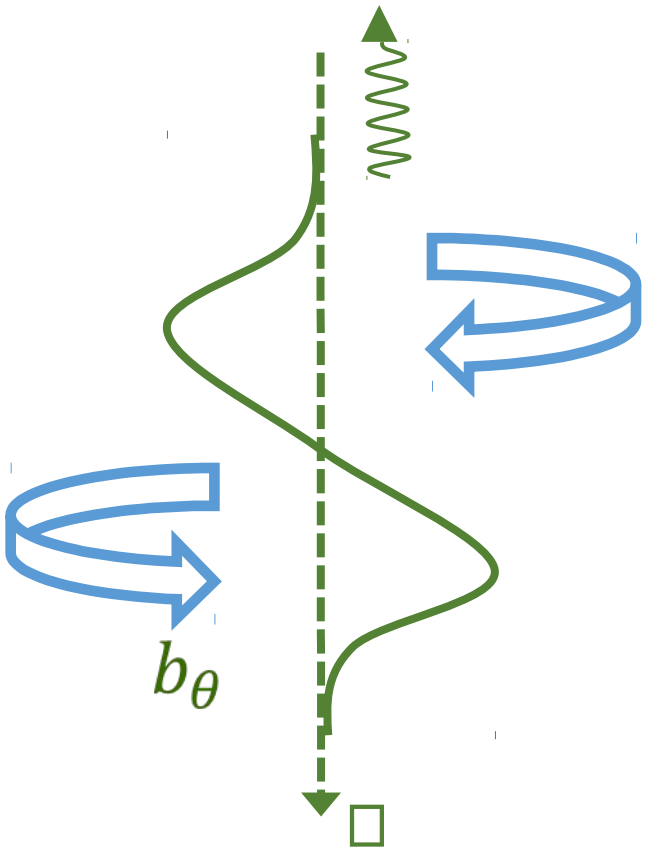
Propagation of Alfven waves in a stratified solar atmosphere

$$\frac{\partial^2 b_\theta}{\partial t^2} = \frac{\partial}{\partial z}\left(c_A^2 \frac{\partial b_\theta}{\partial z}\right)$$

Alfven speed (Ferraro 1954)

c_A = Alfven speed = e^{-z} (Ferraro 1954)



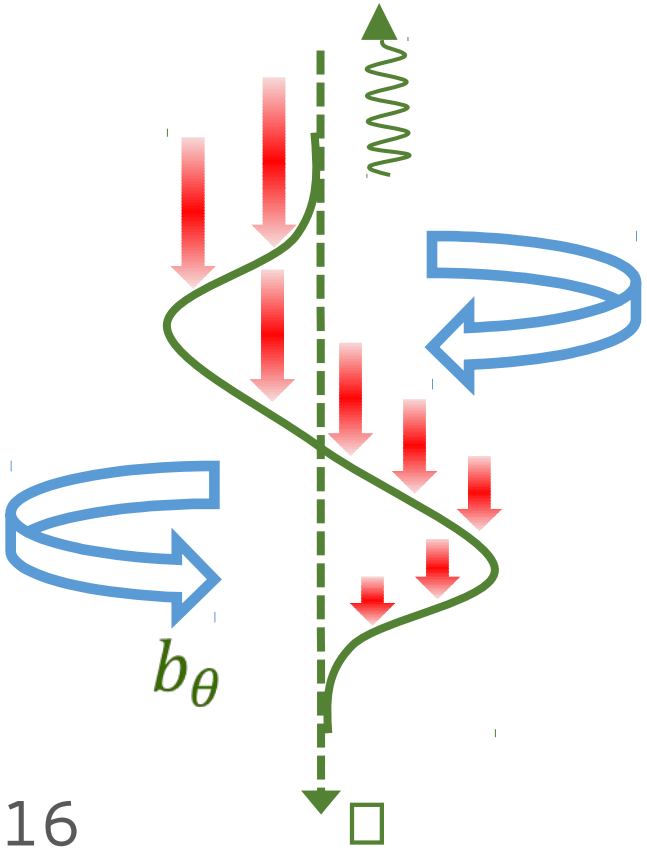
What happens in a non-static atmosphere?

Propagation of Alfven waves in a stratified solar atmosphere

$$\frac{\partial^2 b_\theta}{\partial t^2} = \frac{\partial}{\partial z}\left(c_A^2 \frac{\partial b_\theta}{\partial z}\right) + \boldsymbol{flow\ terms}$$

Alfven speed (Ferraro 1954)

c_A = Alfven speed = e^{-z} (Ferraro 1954)

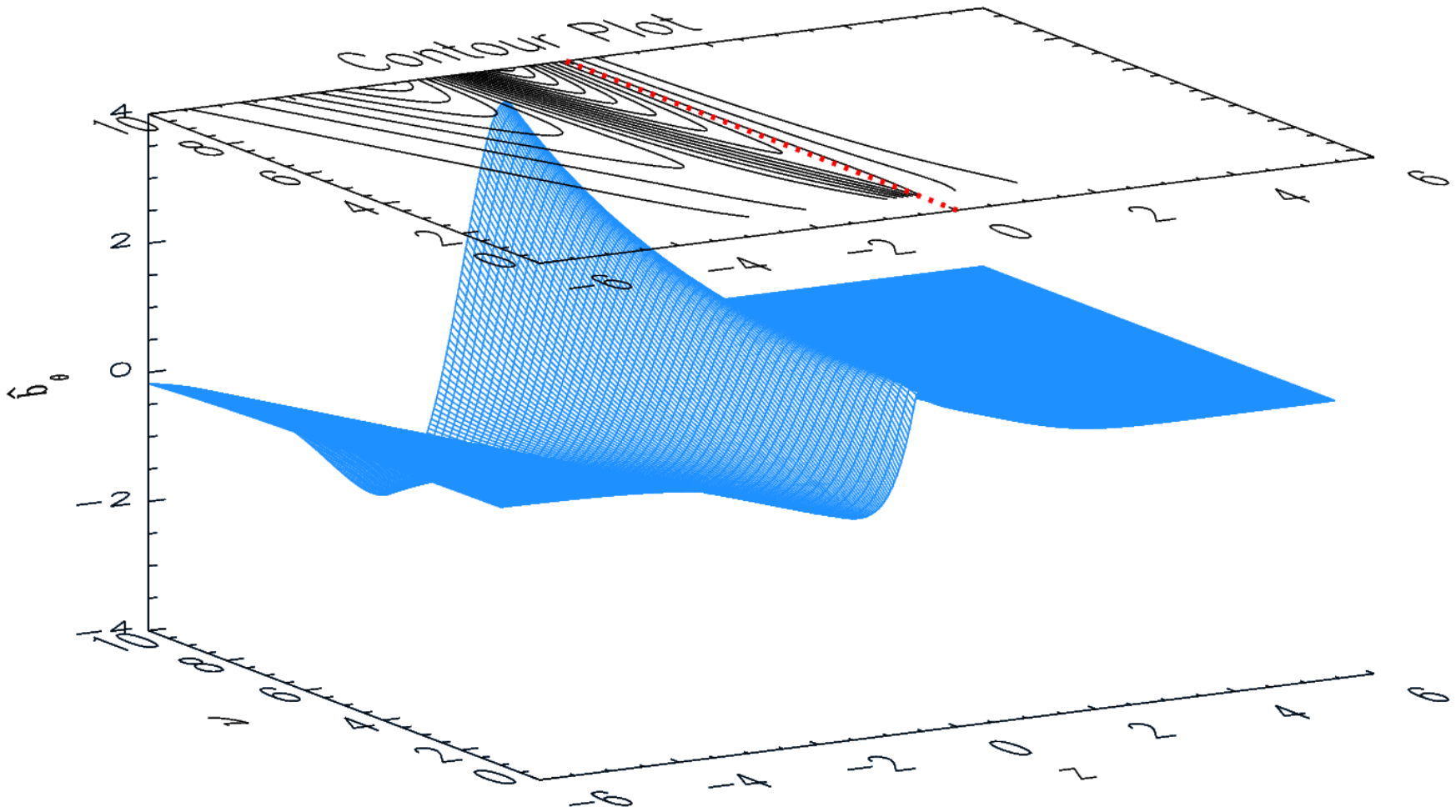


downflow Taroyan & Williams ApJ 2016

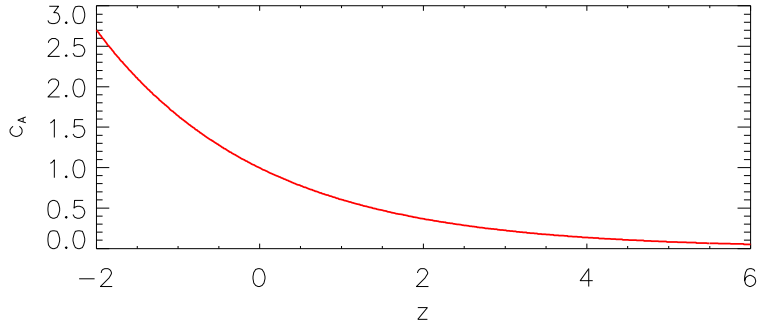
$\boldsymbol{u_0 = e^{-2z}}$ – downflow Taroyan & Williams ApJ 2016

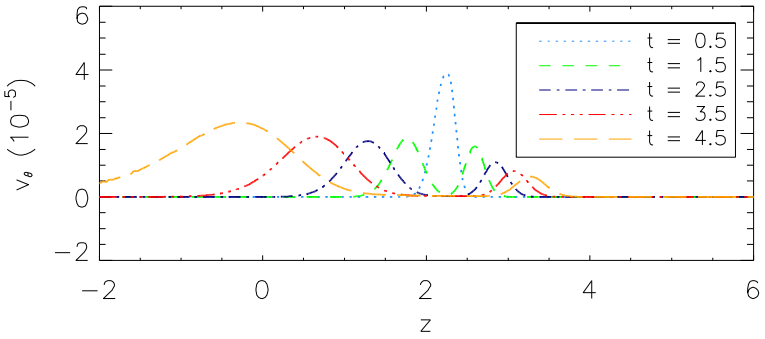
Analytical Results

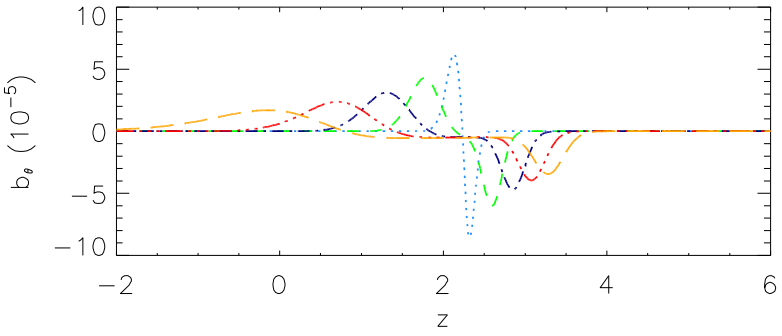
$$\Im(\omega) = -\frac{1+\Re(\nu)}{2}\left[\frac{du_0}{dz}\right]_{z=0}$$ – growth rate



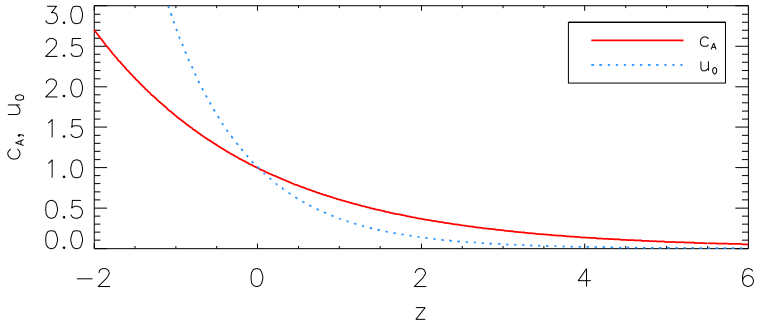
zero flow

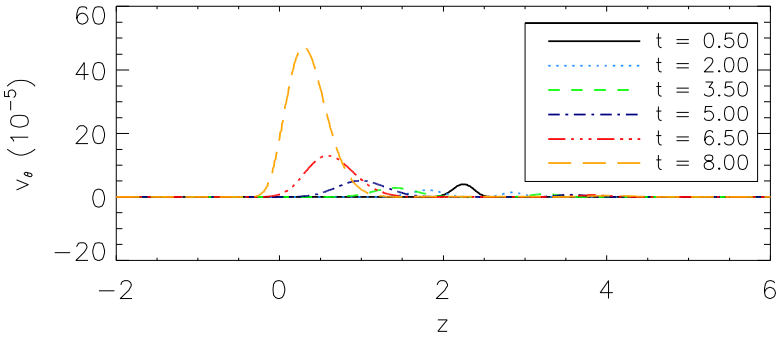


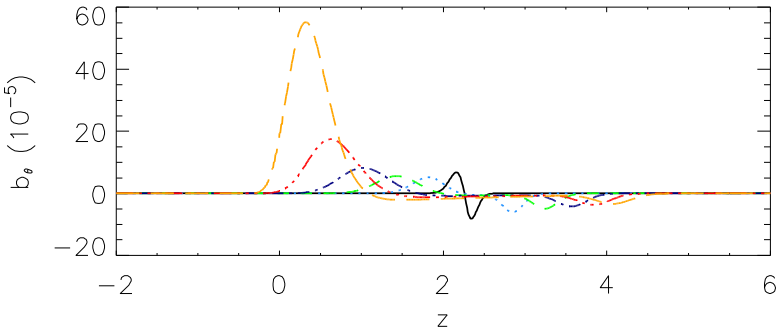




with flow







Wave Energy

$$\frac{\partial W_T}{\partial t} + \frac{\partial F_W}{\partial z} = -\frac{\partial u_0}{\partial z} W_m,$$

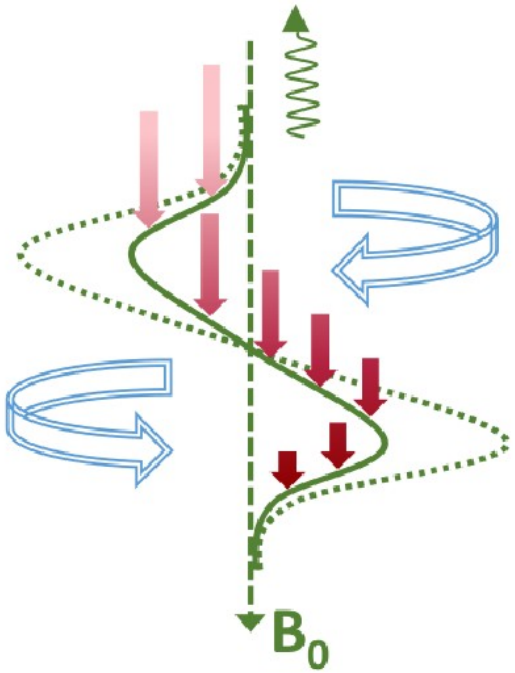
W_T – sum of kinetic and magnetic energy densities,

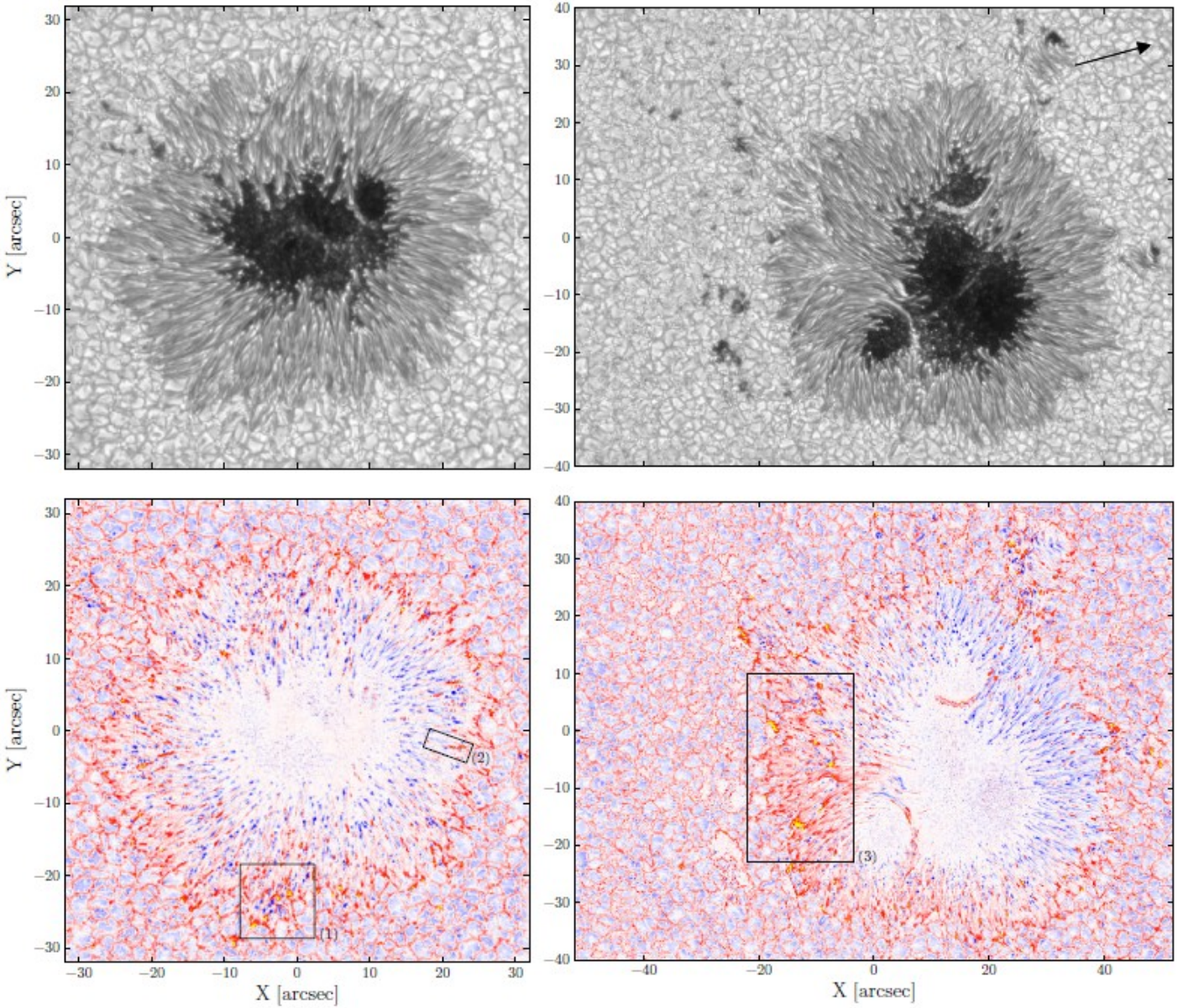
F_W – wave energy flux.

$$\frac{\partial}{\partial t}\int_{-\infty}^{\infty} W_T \, dz = -\int_{-\infty}^{\infty} \frac{\partial u_0}{\partial z} W_m dz$$

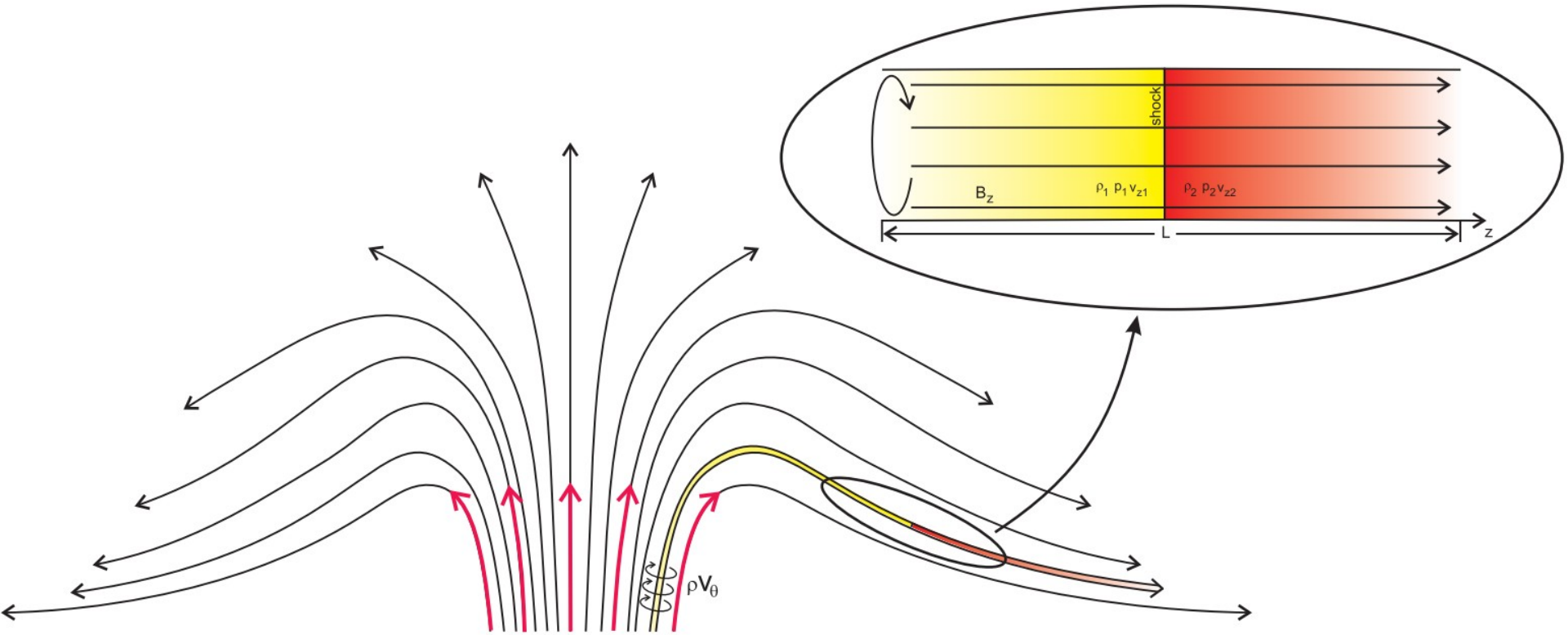
Energy growth

Twist-flow coupling



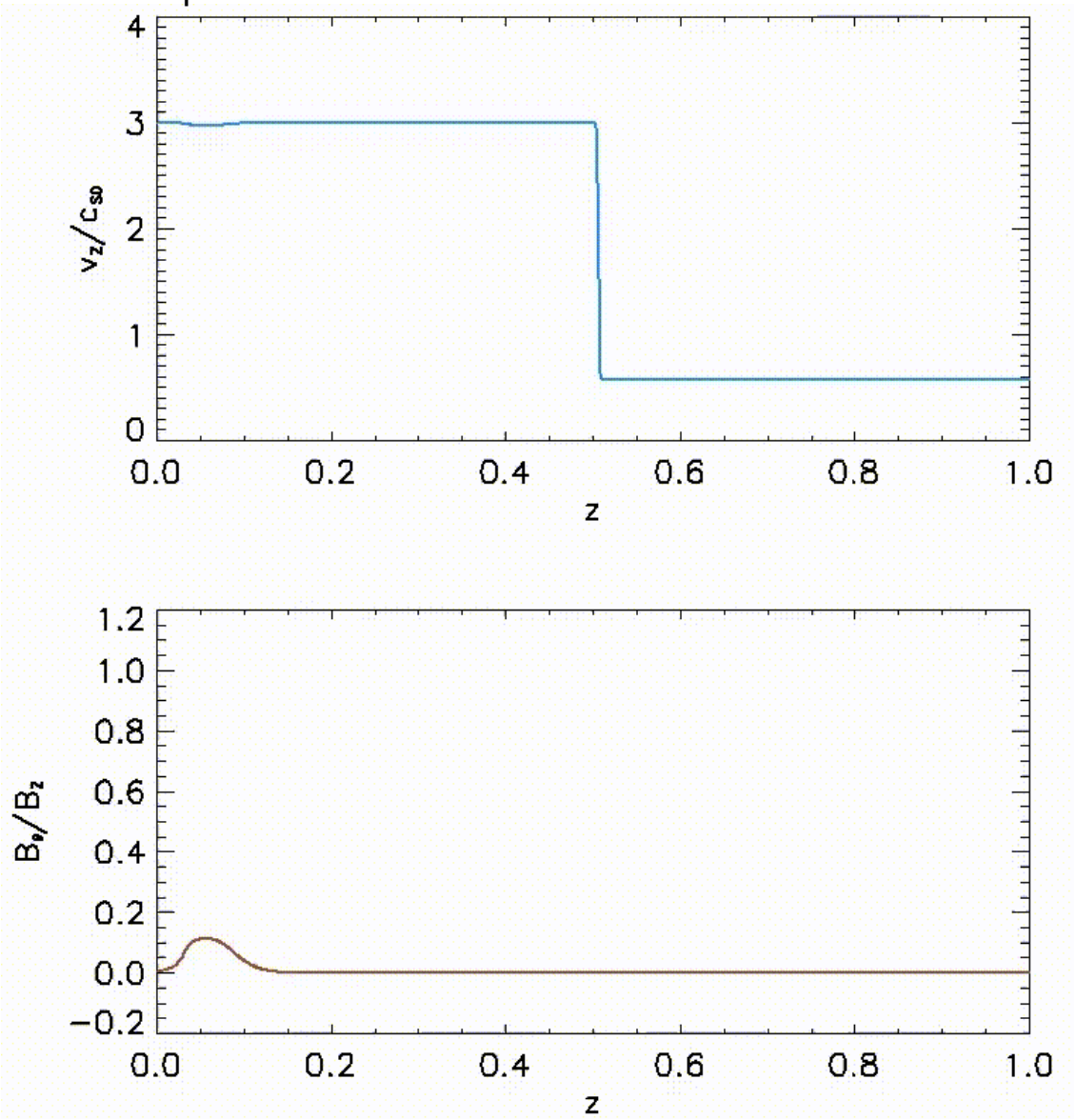


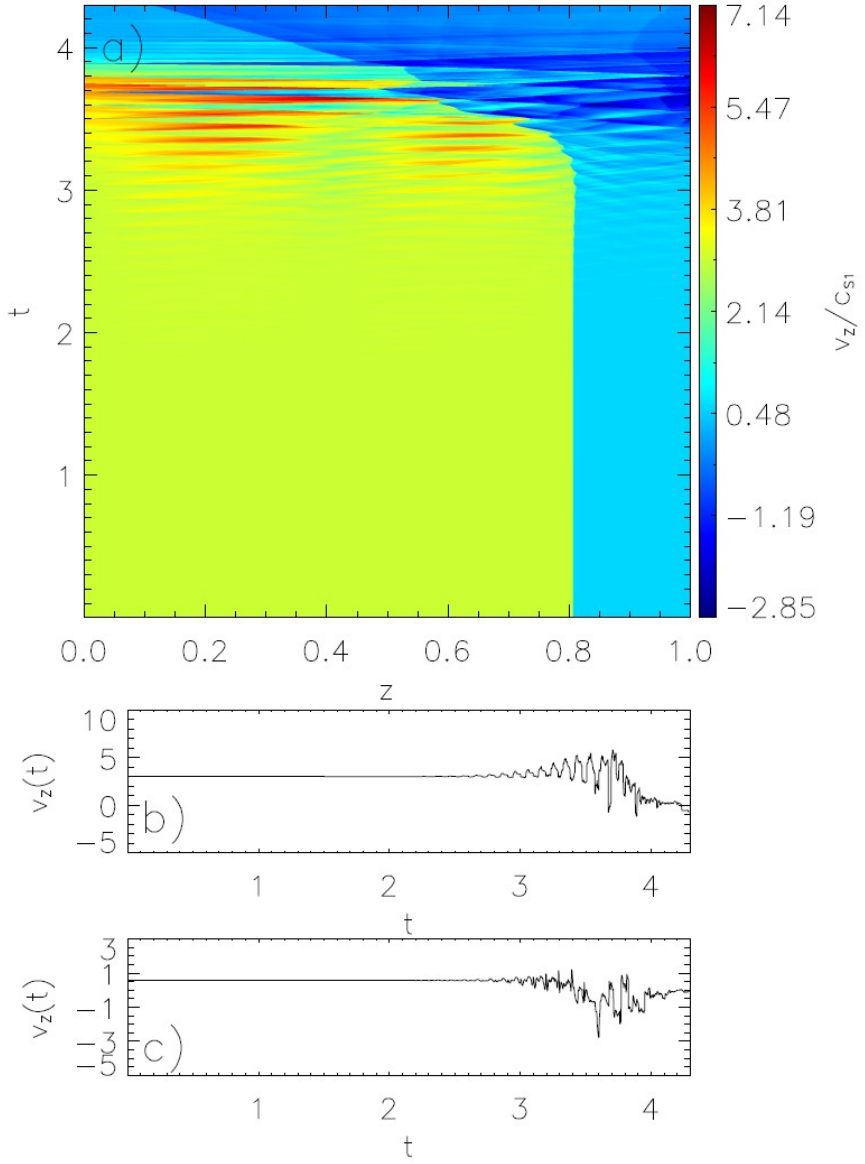
Van Noort et al., A&A
2013

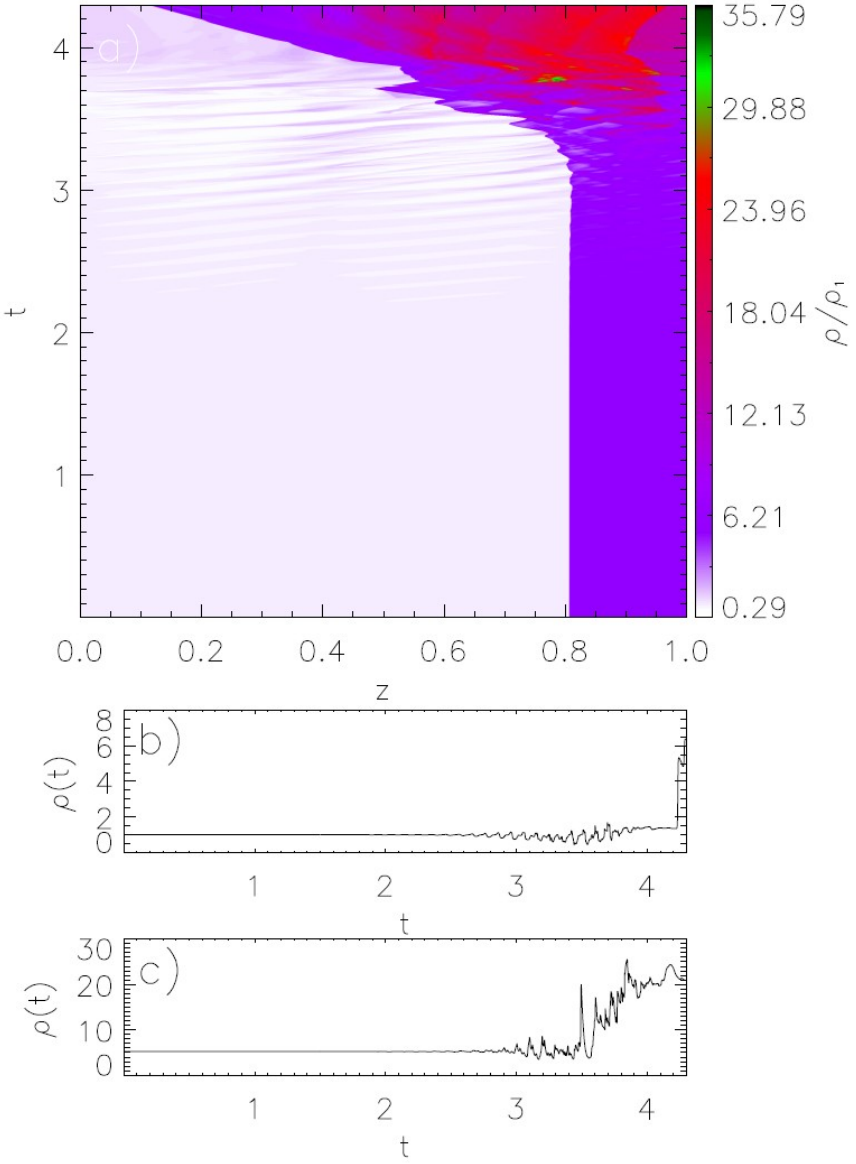


Williams, Taroyan, Fedun, ApJ 2016

Simulation of a magnetic (Alfvén) wave interacting with a sonic shock above a sunspot.







Williams & Taroyan, ApJ 2018

Summary

- Efficient mechanism of coupling between decelerating (and accelerating!) flows and magnetic twists occurs both in the linear and nonlinear regimes.
- Large amplitude Alfven waves generated
- Shocked siphon flows are unstable
- A shock tube becomes globally twisted
- The shock is swept away by the increasing magnetic pressure gradient
- Future work will focus on transient flows