Multi-temperature equilibria for plasma in complex stellar magnetic fields

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1.Observing prominences and motivation

Our knowledge of distant stars often relies on observed values of stellar luminosity.

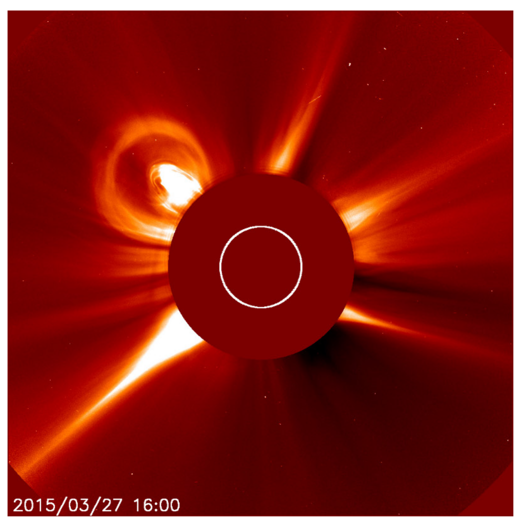

Figure: CME from 27.03.15 [1].

Prominences, cool condensations of stellar plasma, lie along the magnetic field lines and thus these features could prove very useful in understanding the processes that occur in these stars. Ejected prominences could also impact on nearby planets, influencing ability to harbour life.

2. Loop buoyancy

Using force balance:

$$\mathbf{0} = -\nabla \boldsymbol{p} + (\mathbf{j} \times \mathbf{B}) + \rho \mathbf{g} \quad (1)$$

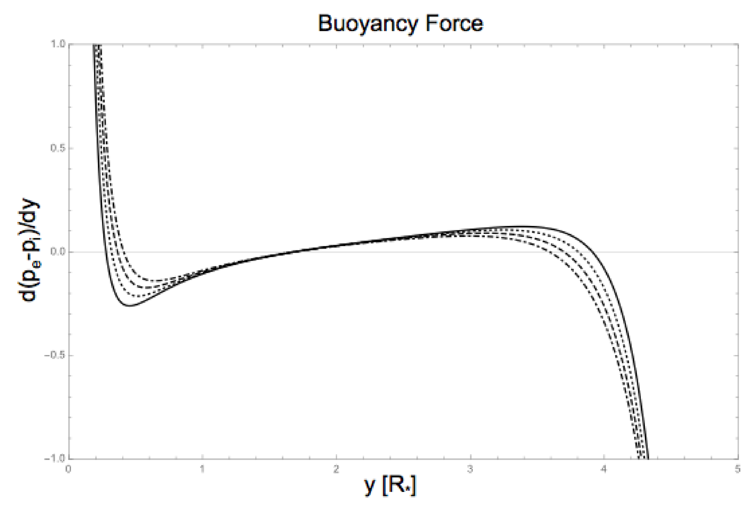

Figure: Buoyancy force ($(\rho_e - \rho_i)\boldsymbol{g}$) with height from stellar surface.

Buoyancy force depends on if the loop is under or over dense but also on the sign of $\mathbf{g}$, the effective gravity. Below the co-rotation radius effective gravity acts inwards and above co-rotation it acts outwards.

3. Available equilibria

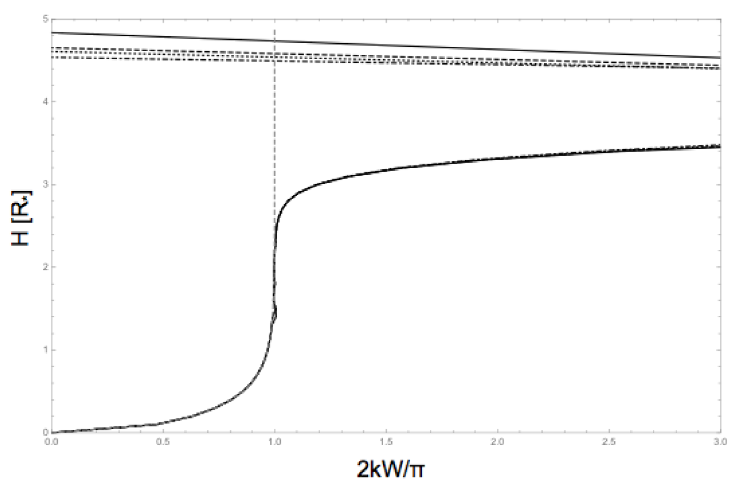

Figure: Grey dashed line: external field. Black, dashed, dotted dot-dashed: $T_i = 0.07T_e, 0.08T_e, 0.09T_e, 0.1T_e$ respectively.

Can plot the Heights of the loop against Width.

4. Loop shape

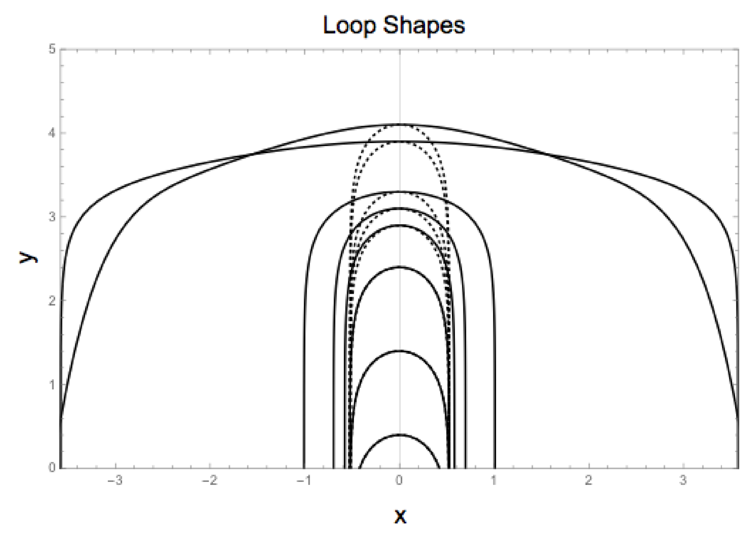

Figure: Dotted lines show the external field whilst the full lines show the internal loop shapes.

Find loop shapes by taking the equation of motion parallel to the field:

$$\frac{2B_i[y]^2 y''[x]}{(1 + y'[x]^2)} = \frac{\partial B_i[y]^2}{\partial y} \quad (3)$$

and solving for y[x] (the field line path), or equally the equation can be solved for x[y].

5. Thermally driven wind (Parker wind)

$$\frac{v^2}{c^2} - ln\frac{v^2}{c^2} = 4ln\frac{r}{r_c} + 4\frac{r_c}{r} - 3 \quad (2)$$

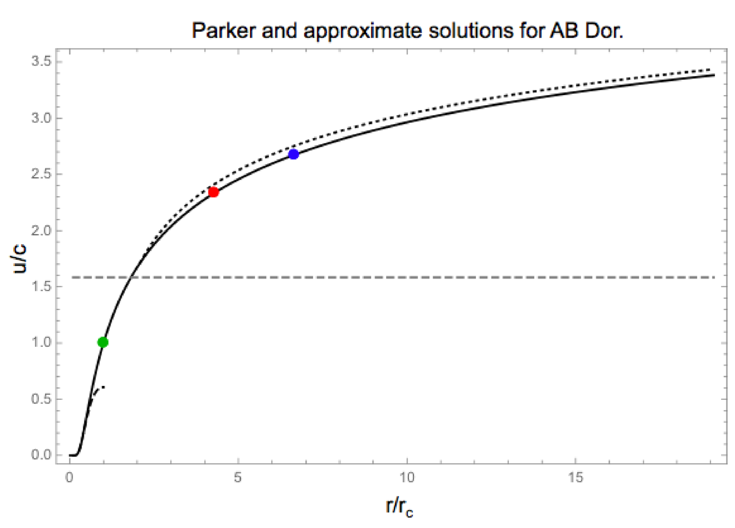

Figure: Solid, dashed and dotted lines: Parker solution, low and high r/rc approximations. Green, red and blue dots: sonic, co-rotation and Alfvenic points, respectively.

The Parker wind solution is used to calculate $\boldsymbol{u}_*$ and estimate a lifetime for the prominences.

6. Timescales

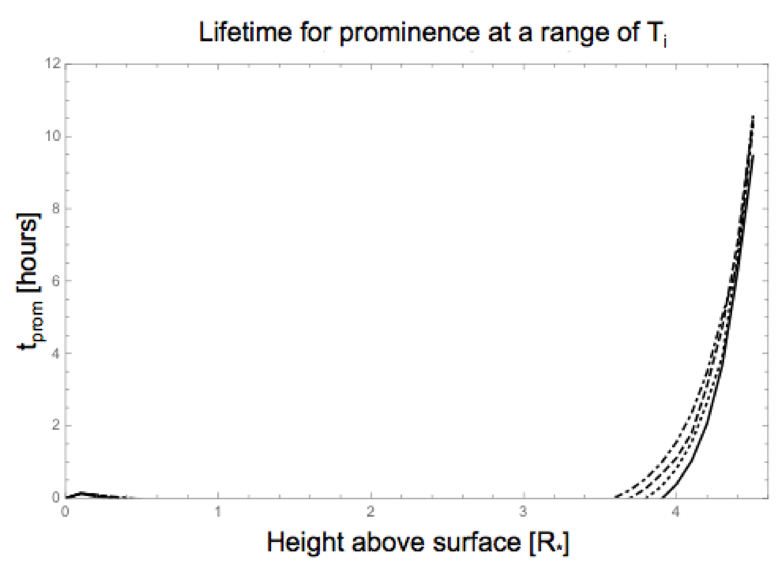

Figure: Lifetime for a prominence for a range of equilibria.

7. Future work

Extend to a cylindrical geometry, still in the equatorial plane, using a dipole field as a background field.

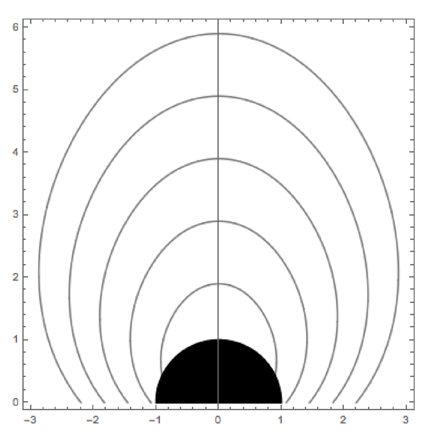

Figure: Dipole field

8. Conclusions

Find τ on the order of 10hours which is the same order of magnitude as expected. This predicts an ejection frequency of 10 hours - this would effect surrounding planets.
Are not finding prominences at co-rotation from our timescales as we would expect - could be due to choice in parameters, could be limitations of the model.

9. References

[1] Picture credit: ESA/NASA SOHO, LASCO coronograph
[2] M. Jardine and A. Collier Cameron, Solar Phys. **131**: 269-289, 1991
[3] M. Jardine and A.A. van Ballegooijen, MNRAS, **361**, 1173–1179, 2005

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