Yuri Cavecchi

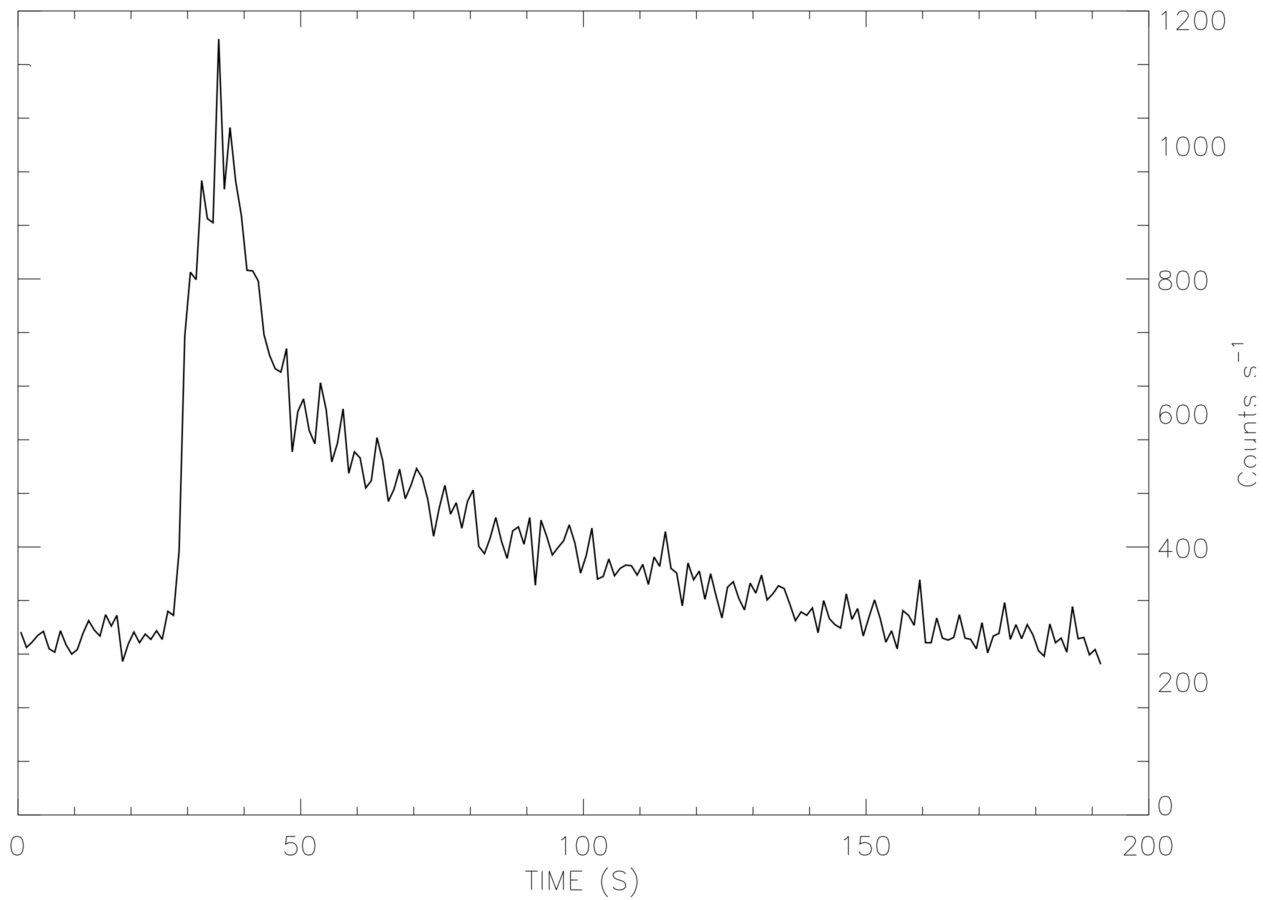
Thermonuclear flame propagation

during accreting neutron star Type I Bursts

In collaboration with
Y. Levin, A. Watts, J. Braithwaite

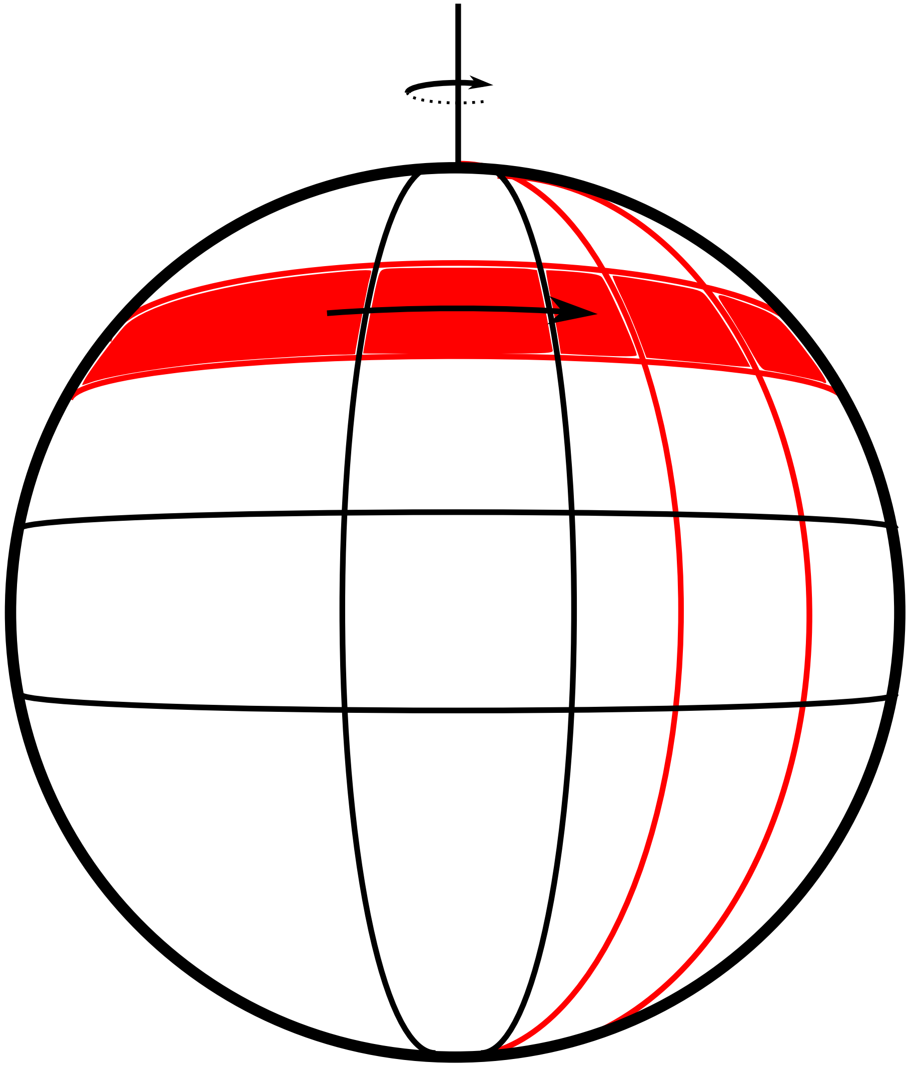
NewCompStar NS Oscillations 2016

Type I burst light curve (example)

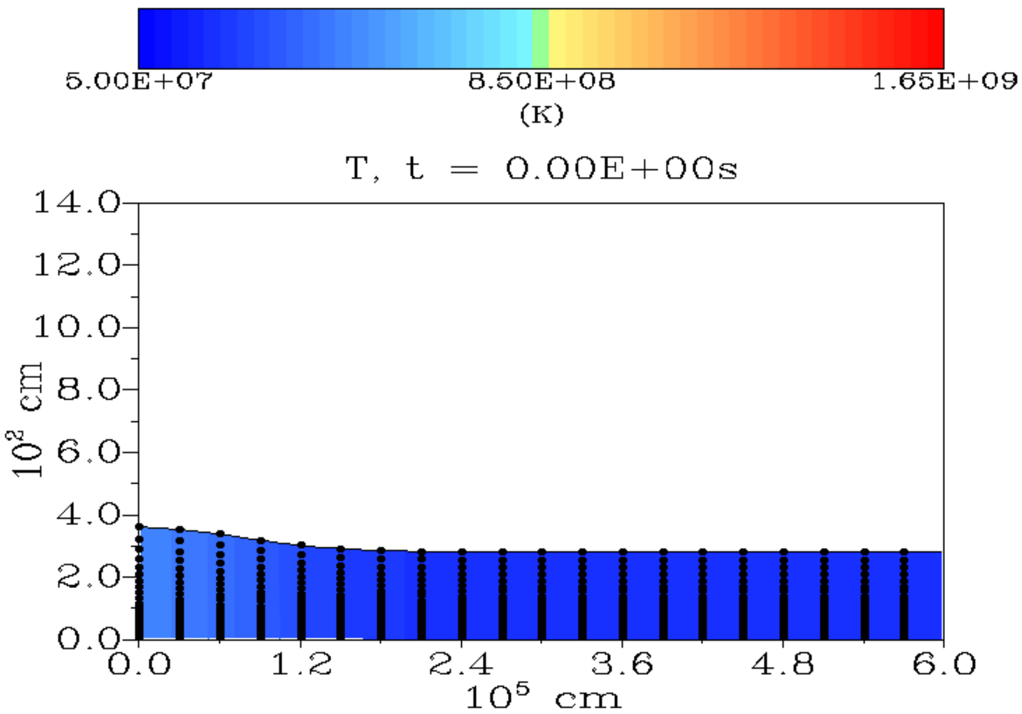


(Cavecchi et al., 2011)

Direction - Longitudinally

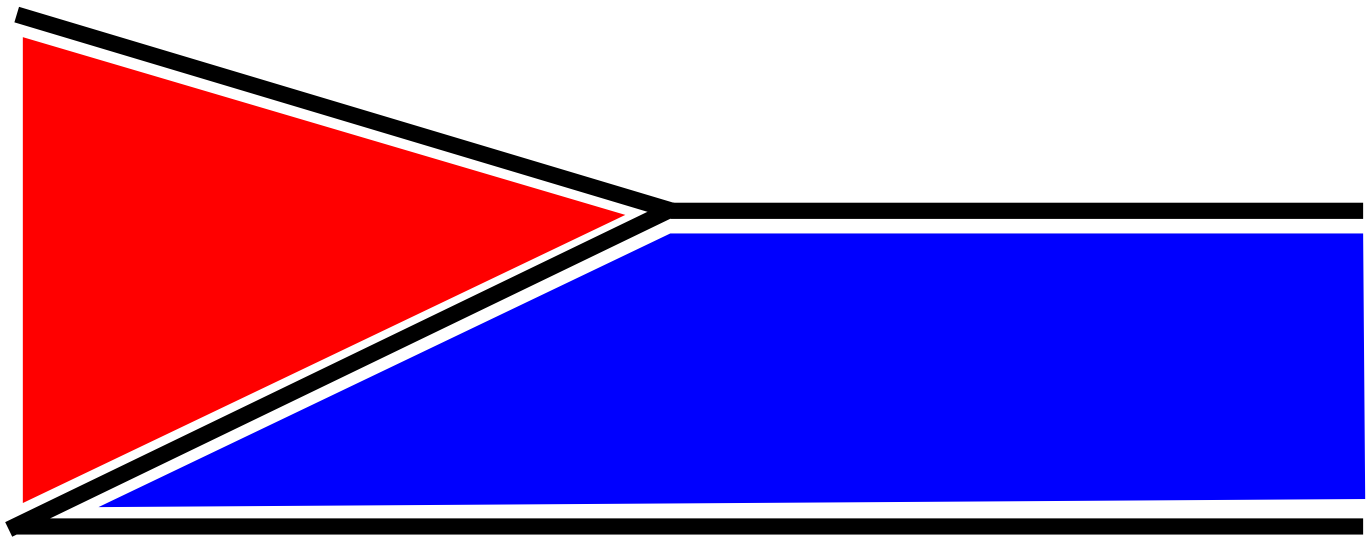


$\nu_0 = 450$ Hz



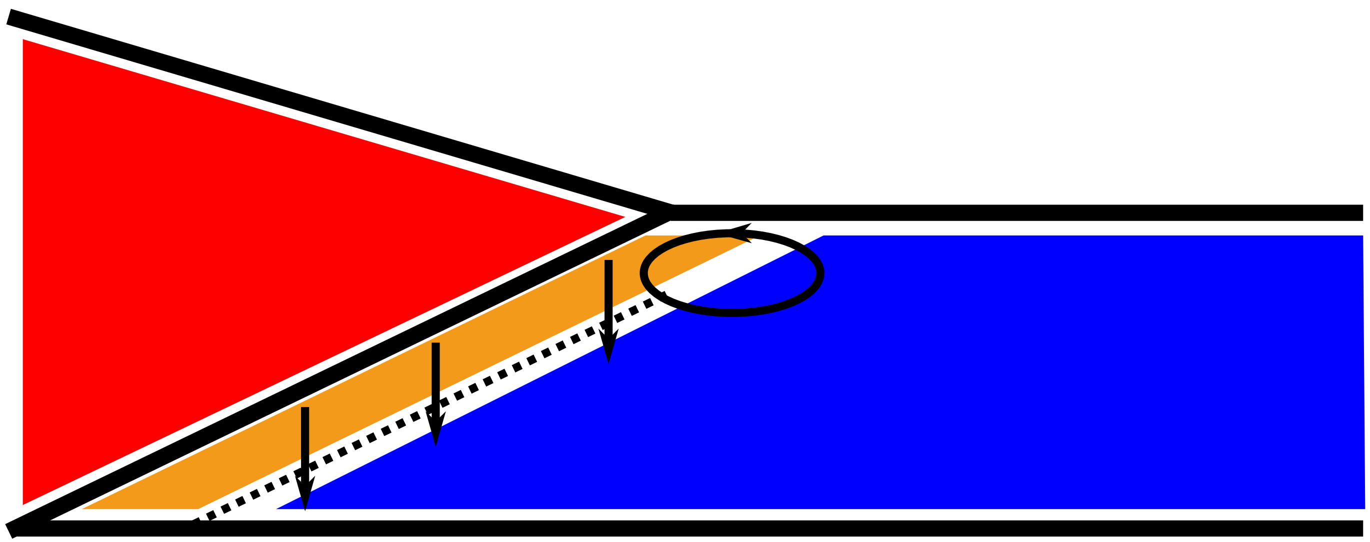
(Cavecchi et al., 2013)

The basic mechanism

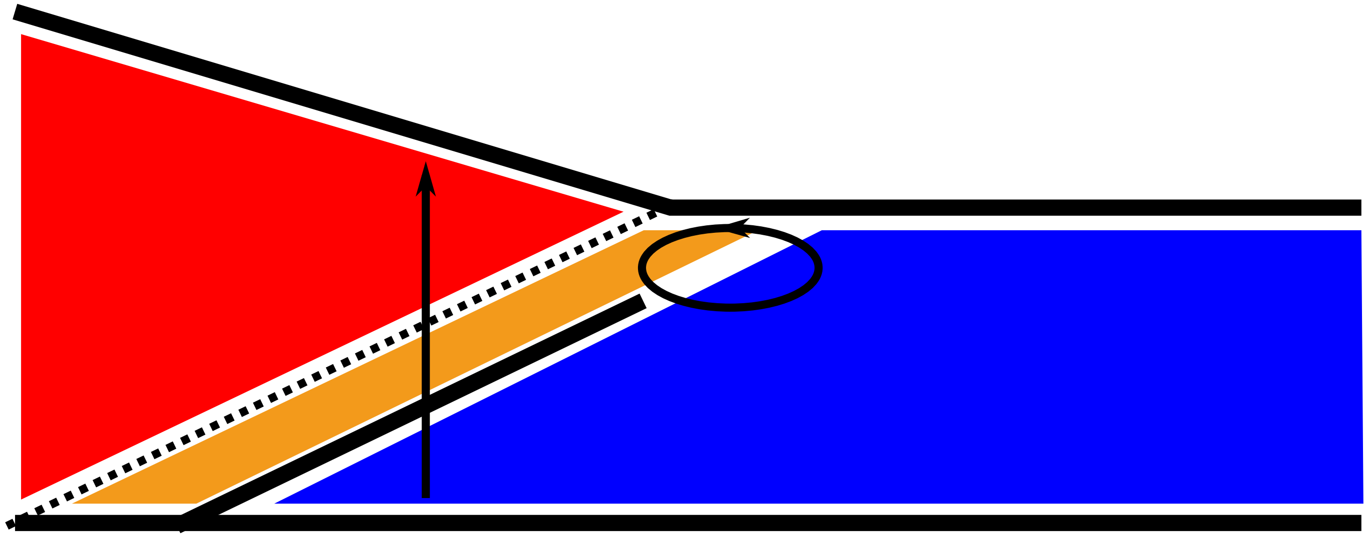


(Spitkovsky et al., 2002; Cavecchi et al., 2013)

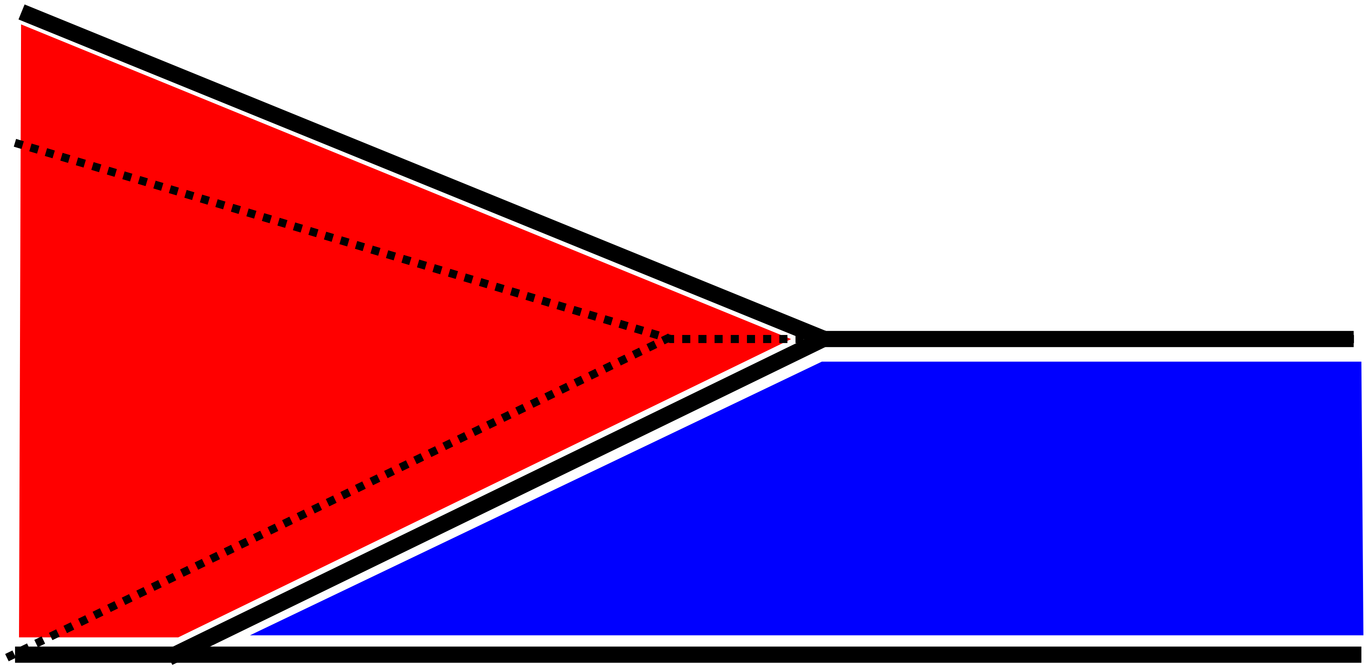
The basic mechanism



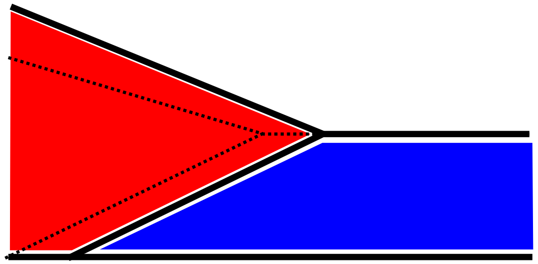
The basic mechanism

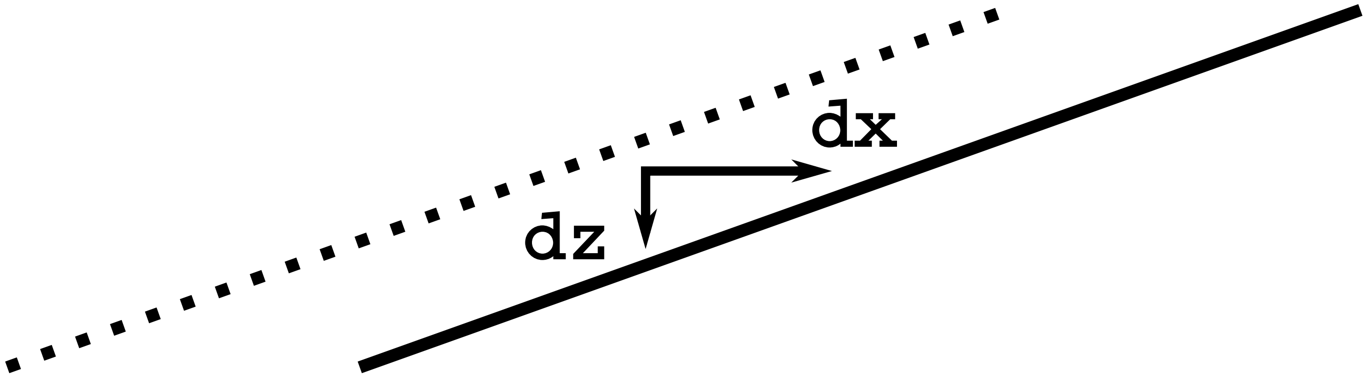


The basic mechanism

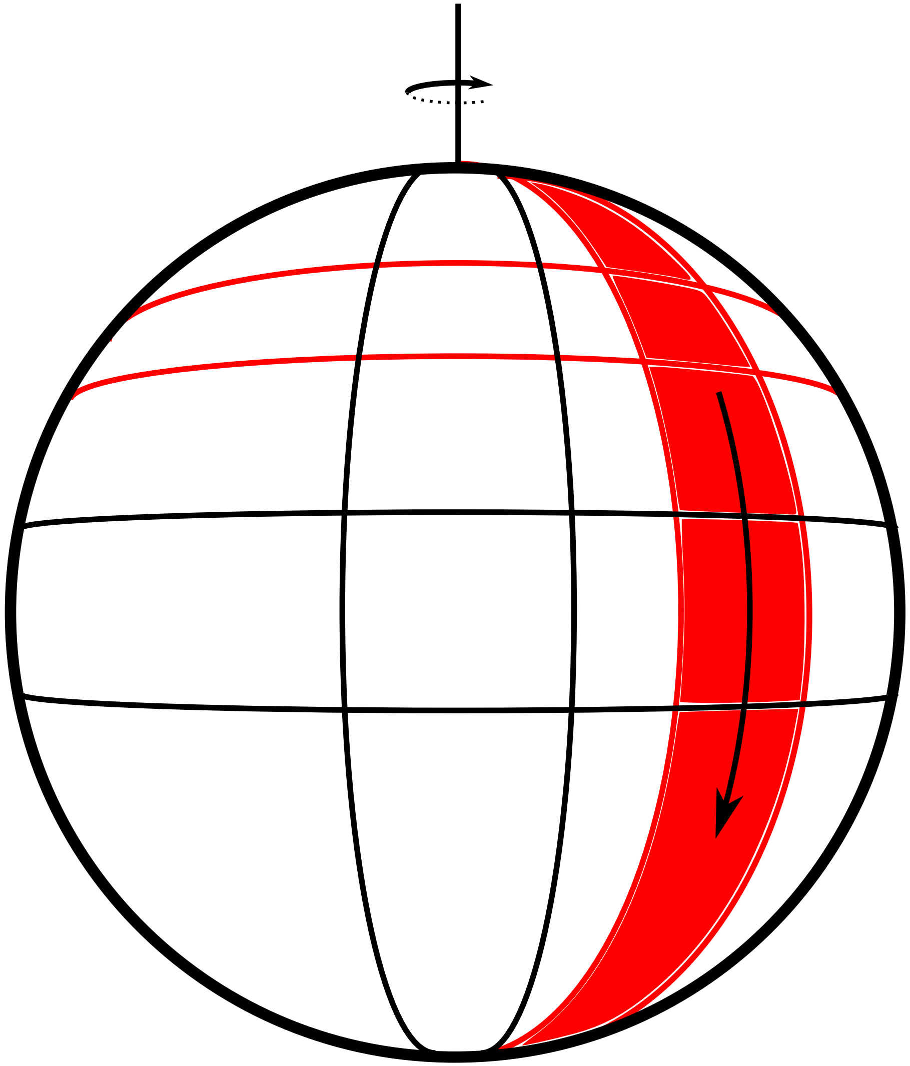


The basic mechanism

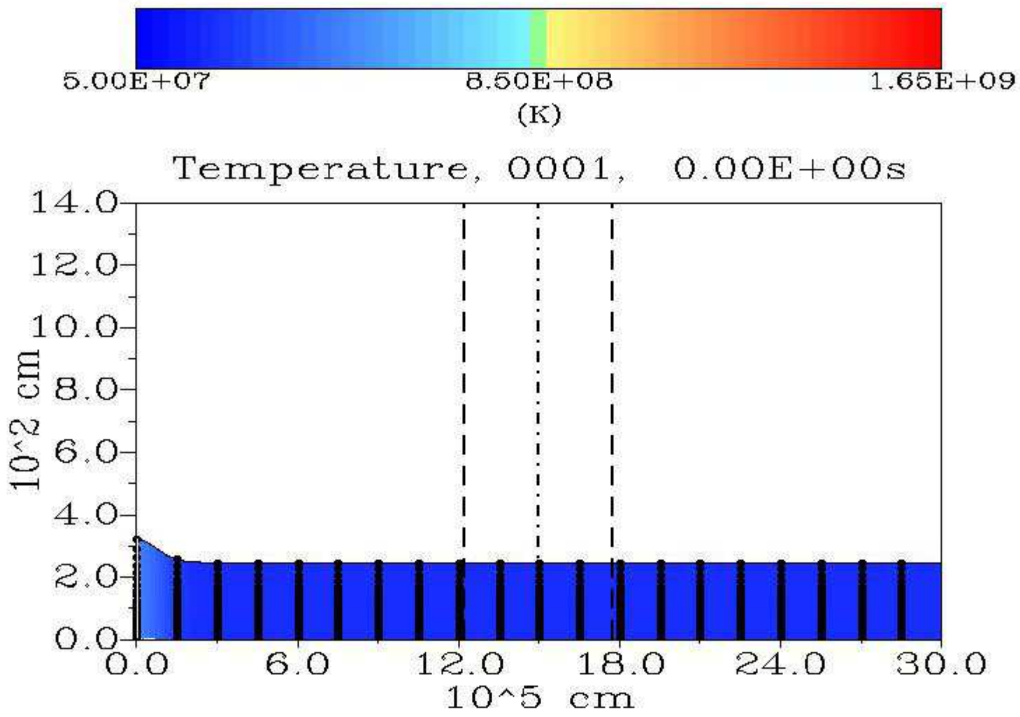




Direction - Latitudinally



$\nu_0 = 450$ Hz

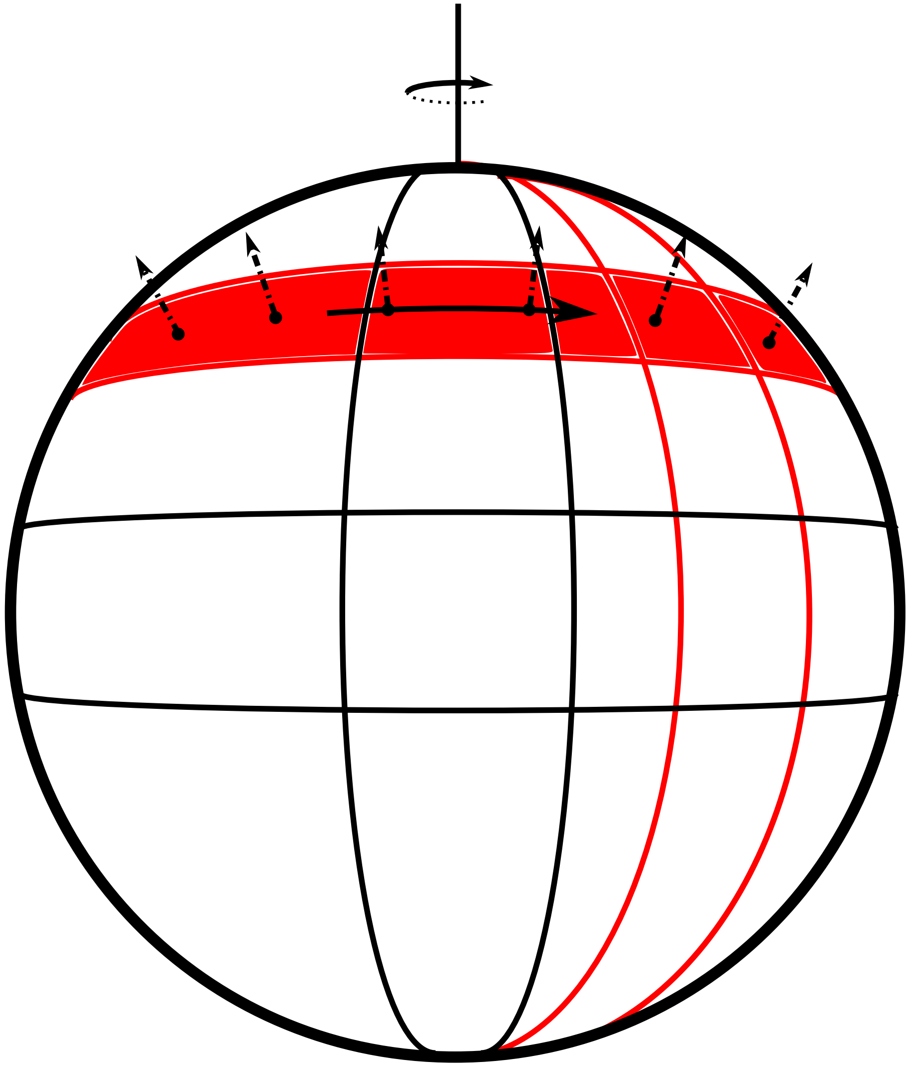


(Cavecchi et al., 2015)

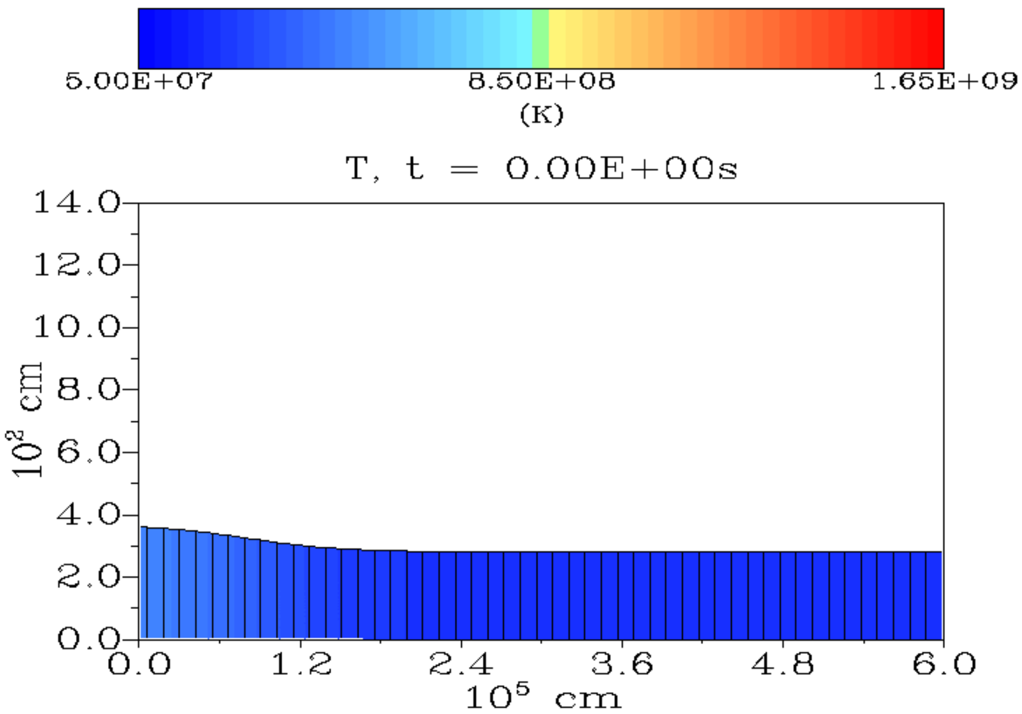
Problem

Propagation time scales are still slower than needed.

Direction - Longitudinally + Magnetic Field

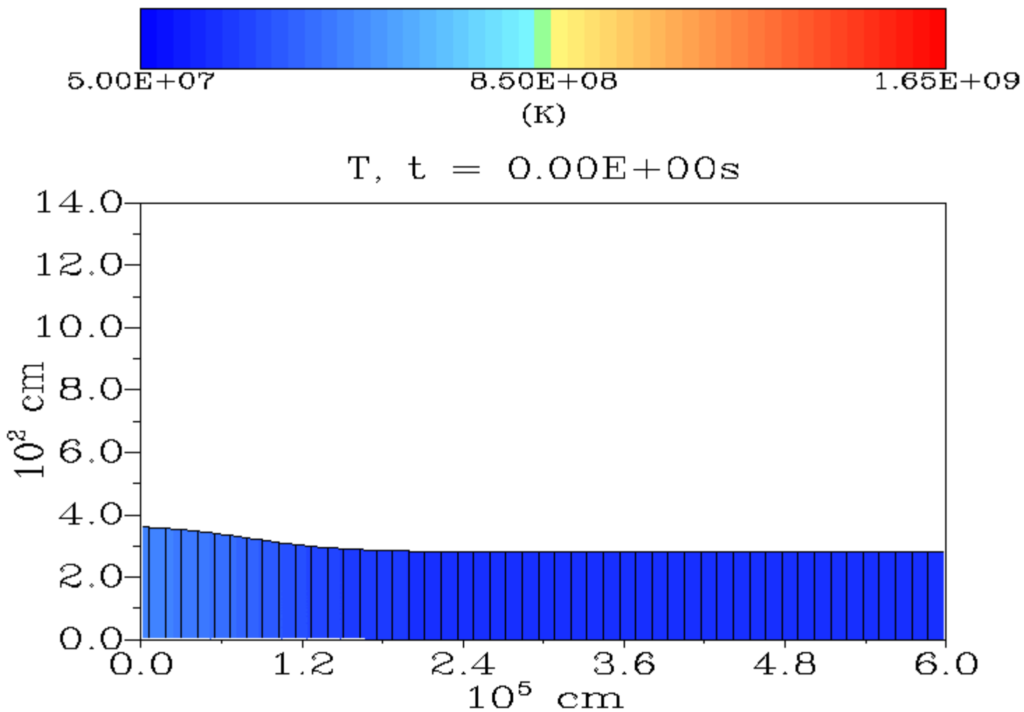


$\nu_0 = 450$ Hz; $\tilde{B} = 10^7$ G



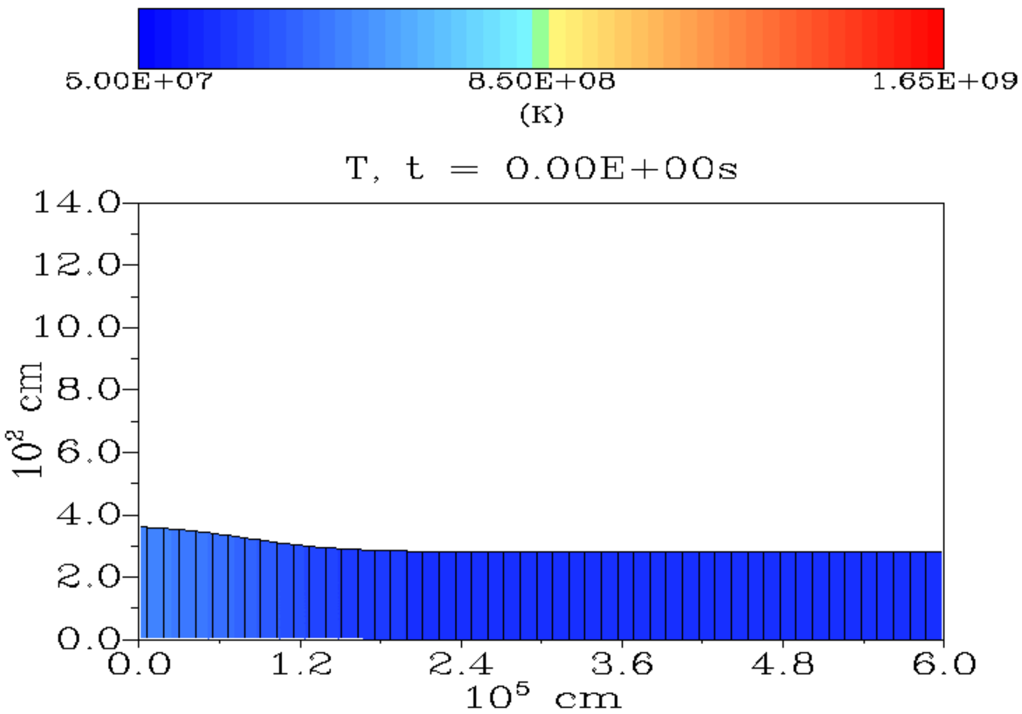
(Cavecchi et al., 2016)

$\nu_0 = 450$ Hz; $\tilde{B} = 10^8$ G



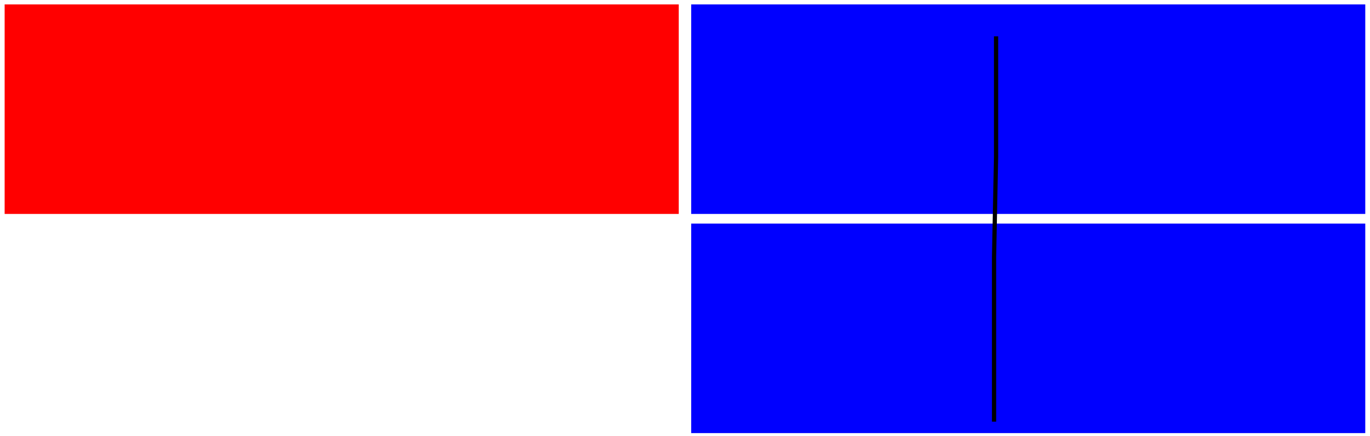
(Cavecchi et al., 2016)

$\nu_0 = 450$ Hz; $\tilde{B} = 10^{10}$ G



(Cavecchi et al., 2016)

The basic mechanism + mechanical friction



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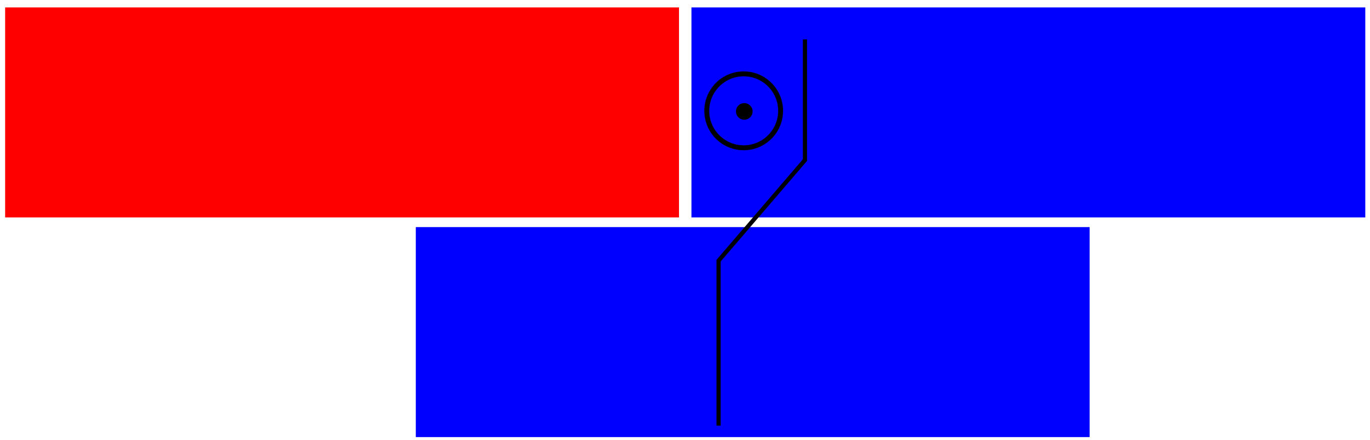

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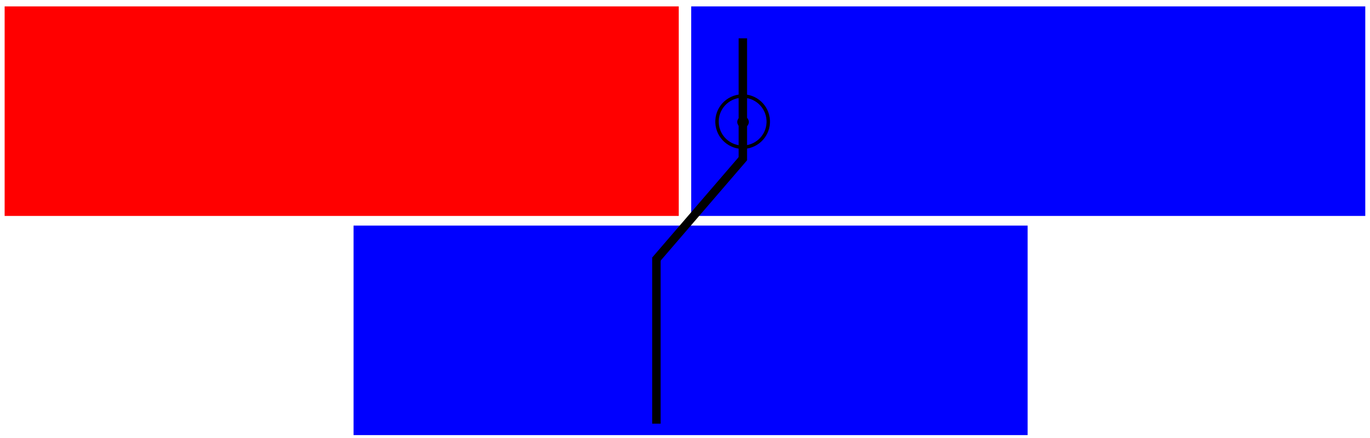

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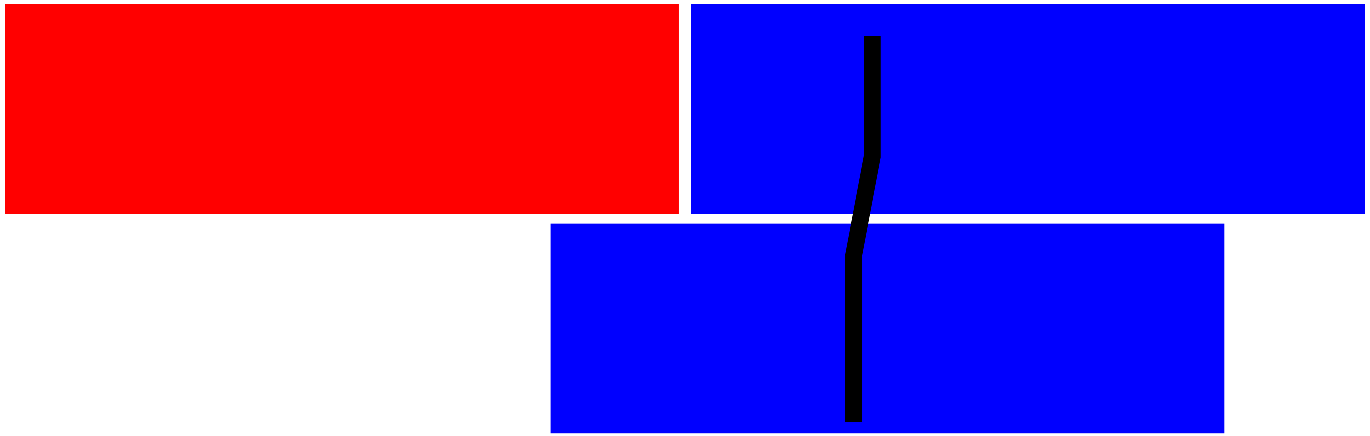

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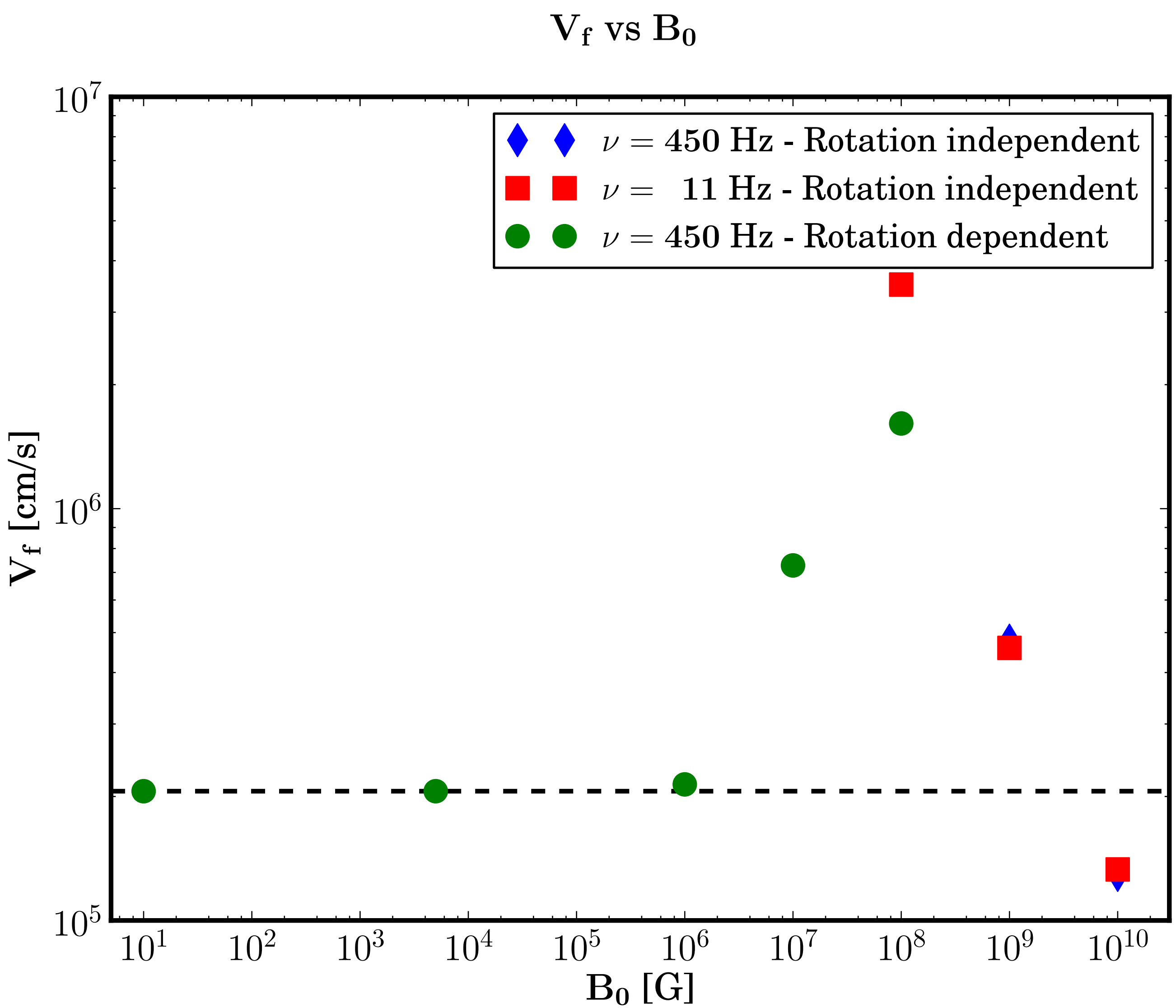
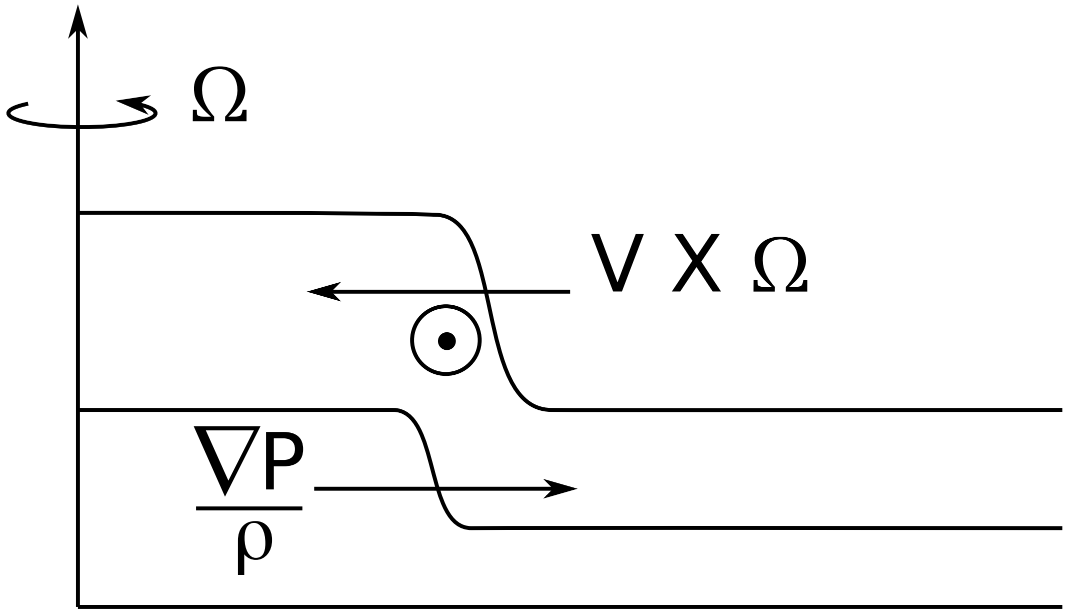


Conclusions

- Flame propagates mainly via conduction.
- But it is Hydro Dynamics that makes propagation fast!
- However, it is not fast enough.
- Magneto Hydro Dynamics makes propagation faster, by providing mechanical coupling!

Thanks!!!



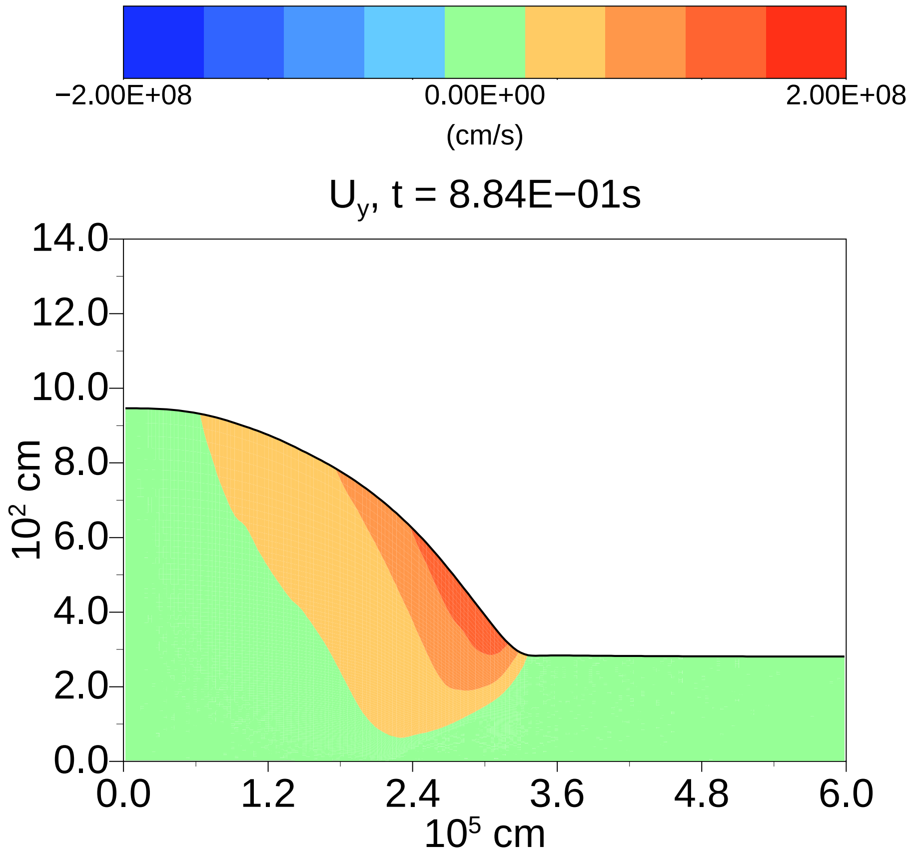
$$2\vec{v} \times \vec{\Omega} = \frac{\vec{\nabla} P}{\rho}$$

$$v \sim R\,\Omega$$

$$2R\,\Omega^2 = \frac{gH_P}{R}$$

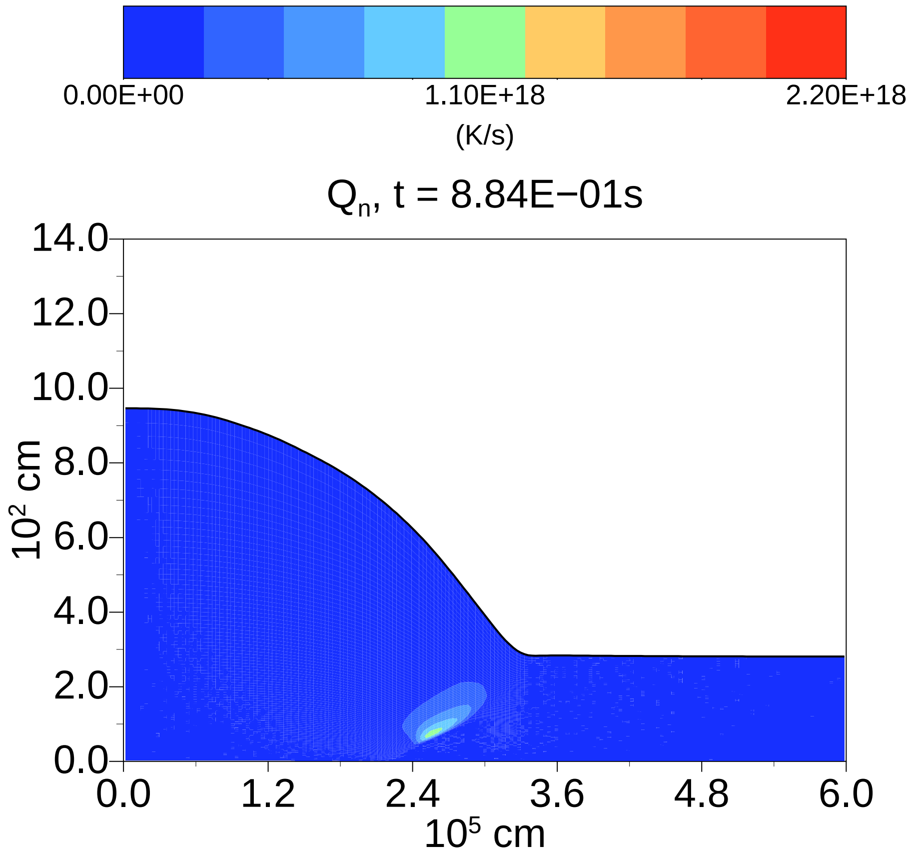
$$R \sim \frac{\sqrt{gH_P}}{\Omega}$$

$\nu_0 = 450$ Hz



−2.00E+08
0.00E+00
2.00E+08
(cm/s)
U$_y$, t = 8.84E−01s
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10^2 cm
0.0
1.2
2.4
3.6
4.8
6.0
10^5 cm

$\nu_0 = 450$ Hz


0.00E+00
1.10E+18
2.20E+18
(K/s)
Qn, t = 8.84E−01s
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10² cm
0.0
1.2
2.4
3.6
4.8
6.0
10⁵ cm

It’s all a matter of geometry and hydrodynamics

$$v_{\mathrm{f}\perp} \propto \frac{1}{\sqrt{\kappa_{\mathrm{c}}}} \sim 10^2 - 10^3\ \mathrm{cm/s}$$

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$$\frac{dx}{dz} \propto \frac{R_{\mathrm{Ro}}}{H} = \frac{\sqrt{gH}}{4\pi\nu} \quad \frac{1}{H} \sim 10^2 - 10^3$$

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$$v_{\mathrm{f}\perp} \propto \frac{1}{\sqrt{\kappa_{\mathrm{C}}}} \sim 10^2 - 10^3 \text{ cm/s}$$

$$\frac{dx}{dz} \propto \frac{R_{\mathrm{Ro}}}{H} = \frac{\sqrt{gH}}{4\pi\nu} \quad \frac{1}{H} \sim 10^2 - 10^3$$

$$v_{\mathrm{f}} \propto \frac{1}{2\pi\nu\sqrt{\kappa_{\mathrm{C}}}} \sim 10^4 - 10^6 \text{ cm/s}$$

ν changes with latitude

$$\nu_{\mathrm{f}} \propto \frac{1}{2\pi\nu_0 \cos\theta \sqrt{\kappa_{\mathrm{c}}}}$$

It’s all a matter of timescales

$$\tau_{\rm R} = 1/4\pi\nu$$

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$$\tau_{\rm R} \text{ vs } \tau_{\rm fric}$$

$$\tau_{\rm fric} = \tau_{\rm A}^2/\tau_{\rm burn} \propto B^{-2}$$

The basic mechanism + mechanical friction