Coronal and Prominence Diagnostics based on Prominence Oscillations

Bojan Vršnak

Hvar Observatory, Croatia

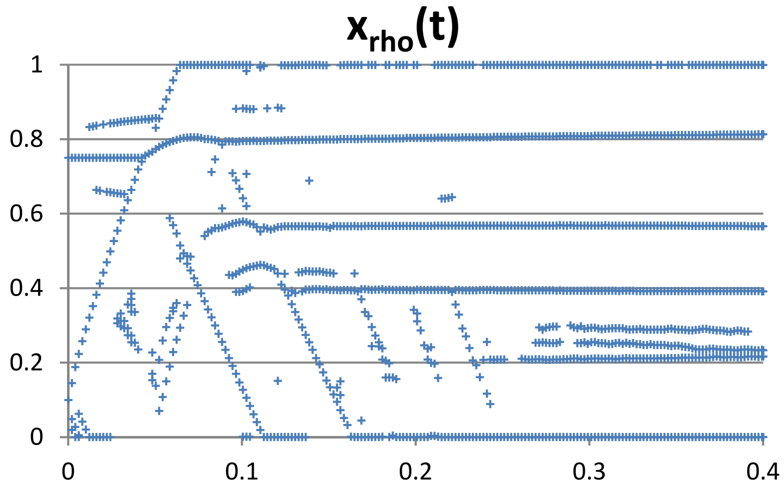
This work has been fully supported by *Croatian Scientific Fundation* under the project 6212 „*Solar and Stellar Variability*“ (**SOLSTEL**).

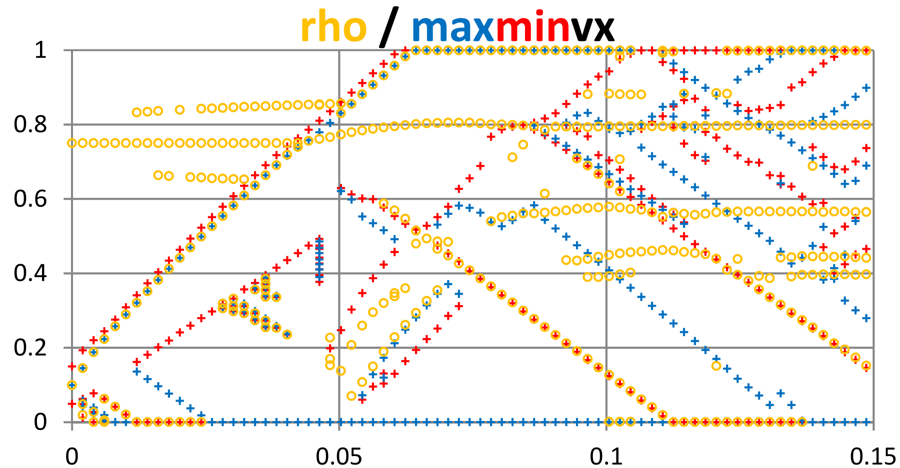
Simple Wave –> Dense Obstacle

(prominence, streamer, pseudo-streamer)

free

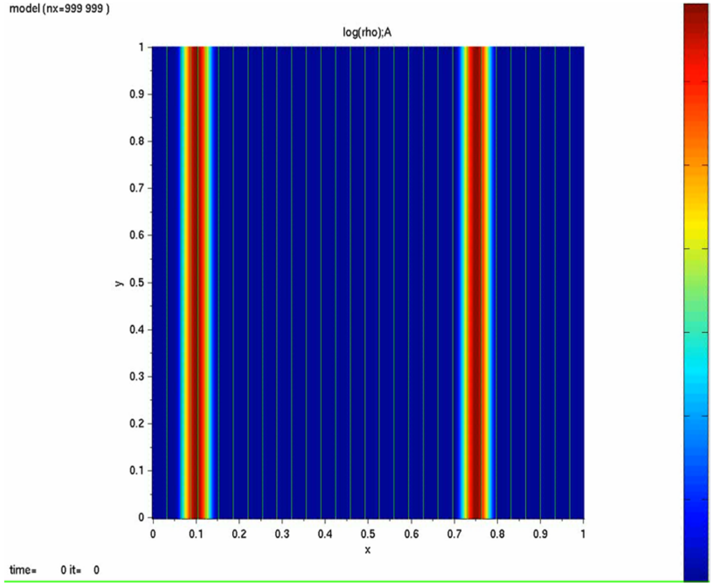
fixed



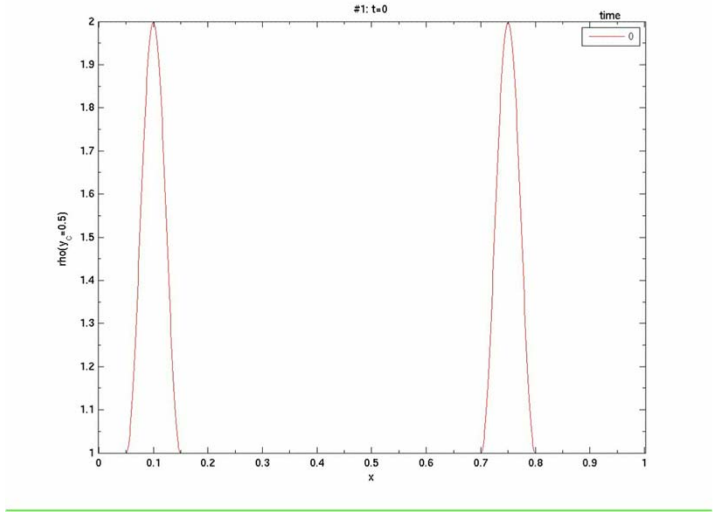


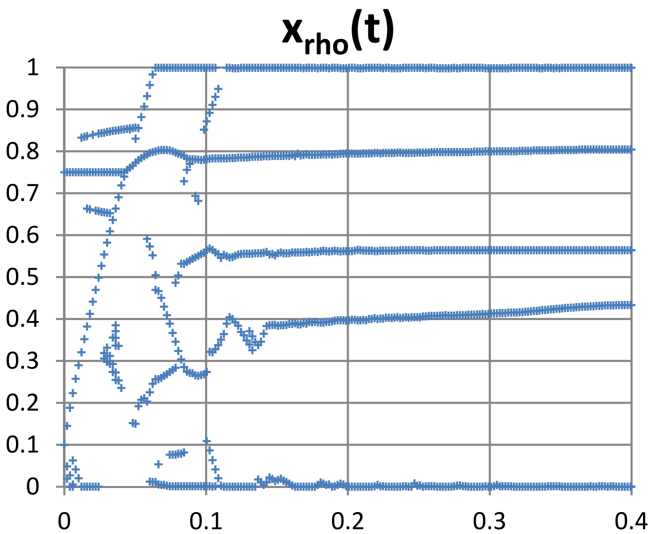
Simple Wave –> Dense Obstacle

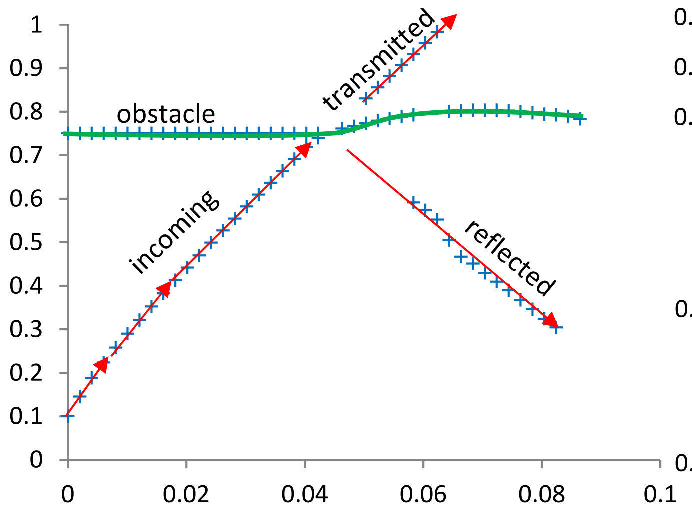
fixed

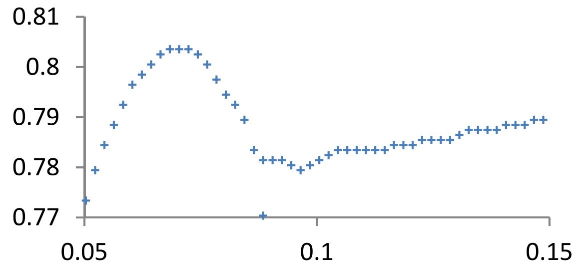


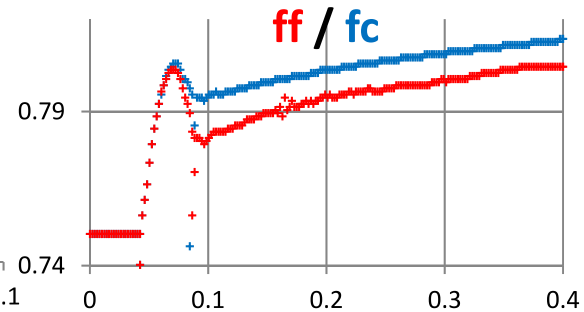
fixed



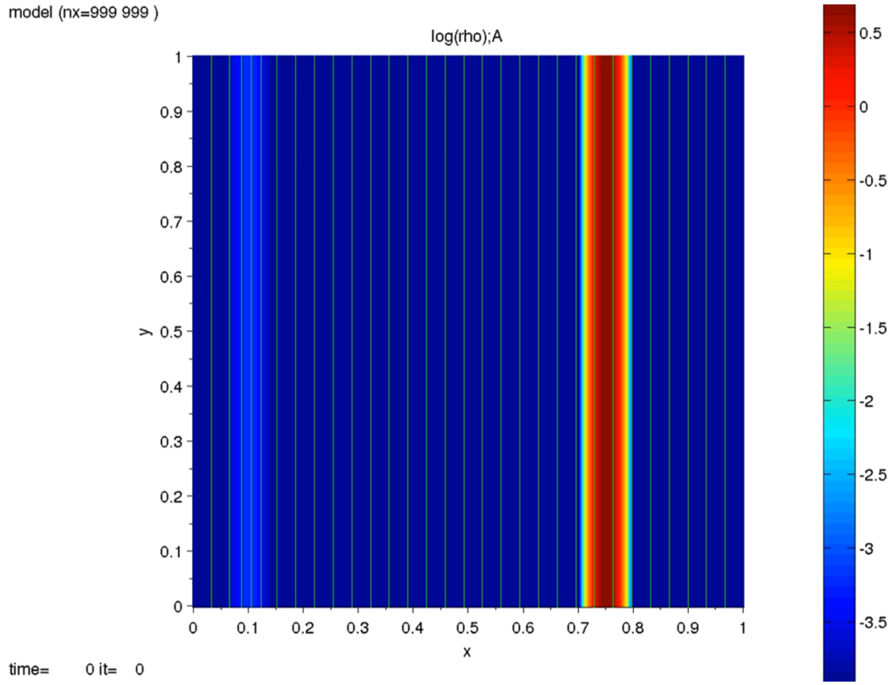


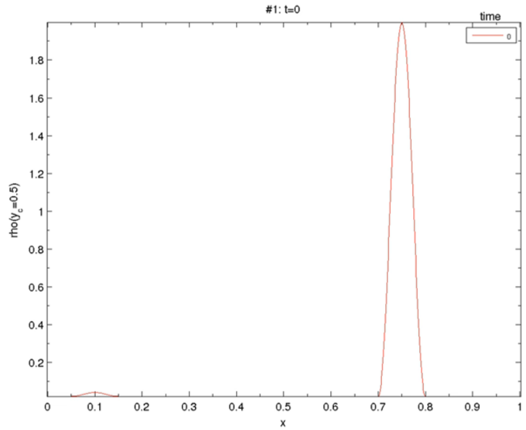


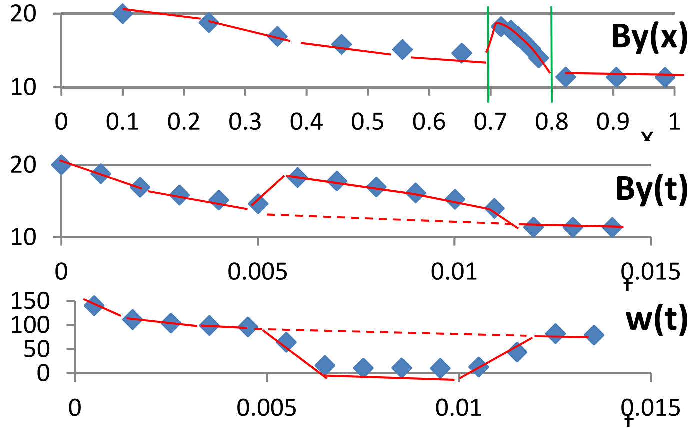


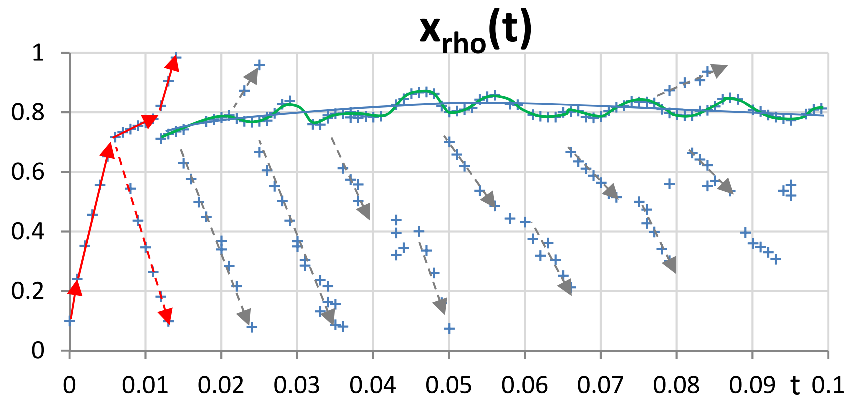


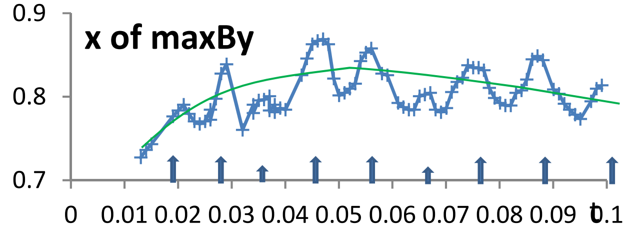
Dense Obstacle

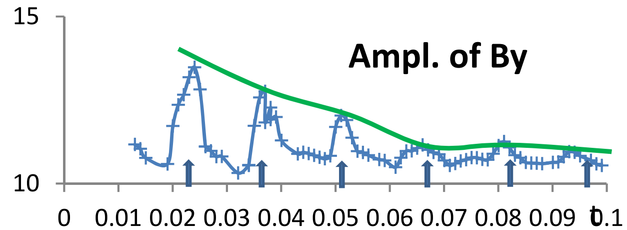










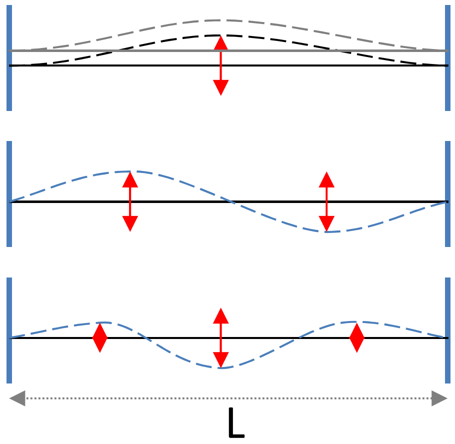


Analytical Model: Basic Modes

$$a(x,t) = -c_1 x + c_2 f(t) - c_3 v$$

$[\ c_1 = \omega^2\ ;\ \ c_3 = 2\gamma\ ]$

“kink” mode



$\omega_0 = \omega_k$

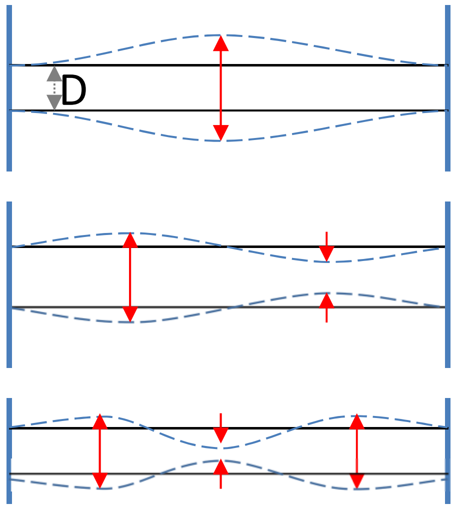
$\omega_{k2} = \omega_k/2$

$\omega_{k3} = \omega_k/3$

$c_1 \sim B^2/\mu_0 \rho R \sim 2xB^2/\mu_0 \rho \lambda^2$

$\omega_k \sim v_{A0}/\lambda \quad \rightarrow \quad T_k \sim 2\pi\lambda/v_{A0}$

“sausage” mode



$\omega_0 = \omega_s$

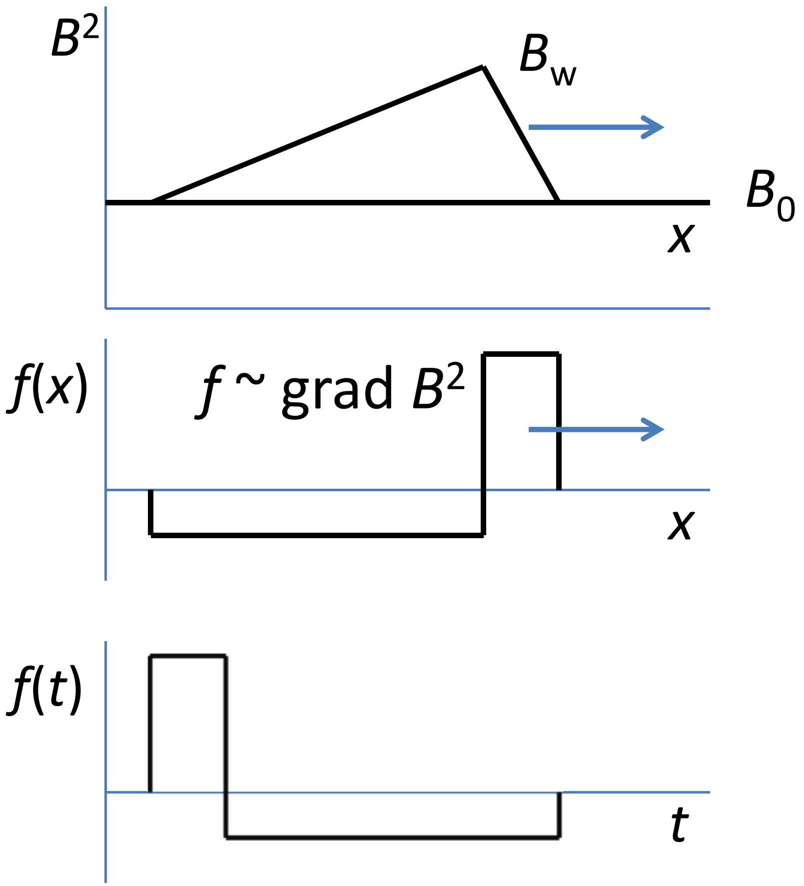
$\omega_{s2} = \omega_s/2$

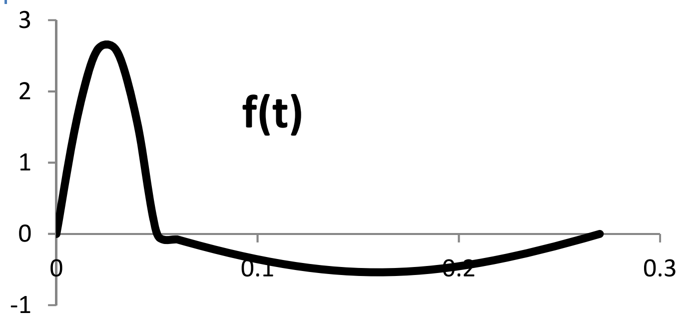
$\omega_{s3} = \omega_s/3$

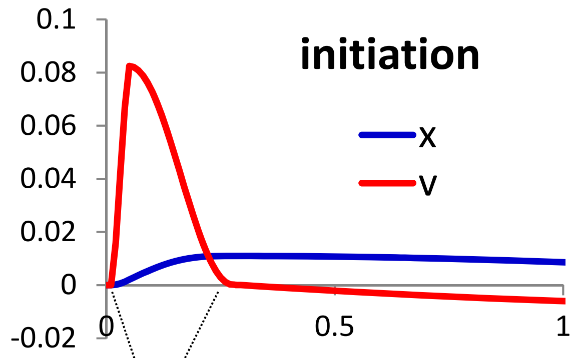
Similarly: $T_s \sim 2\pi D/v_{A0}$

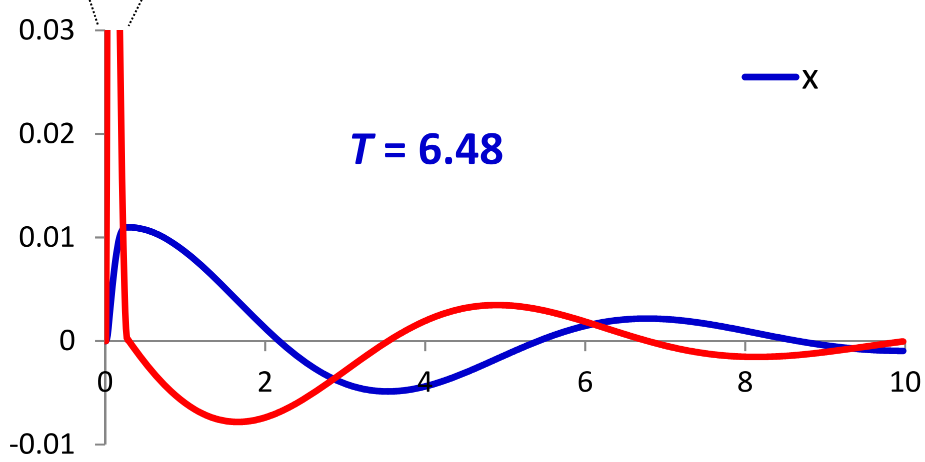
$$T_k/T_s \sim L/D$$

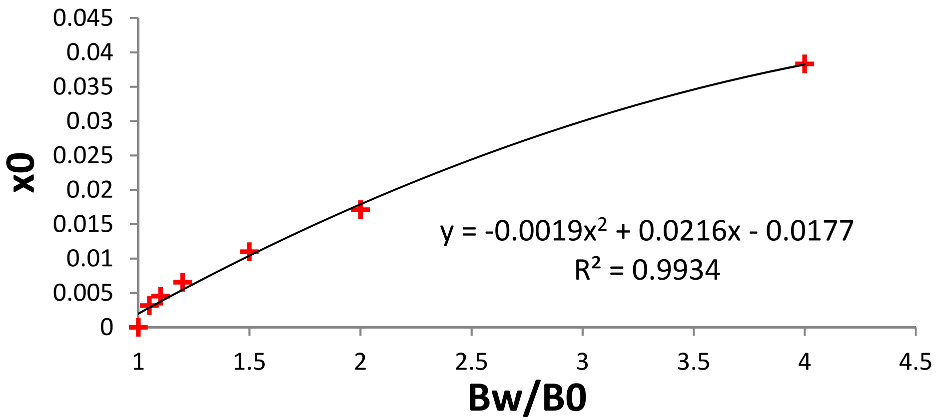
Analytical model: Oscillation Triggering











Wave -> Obstacle

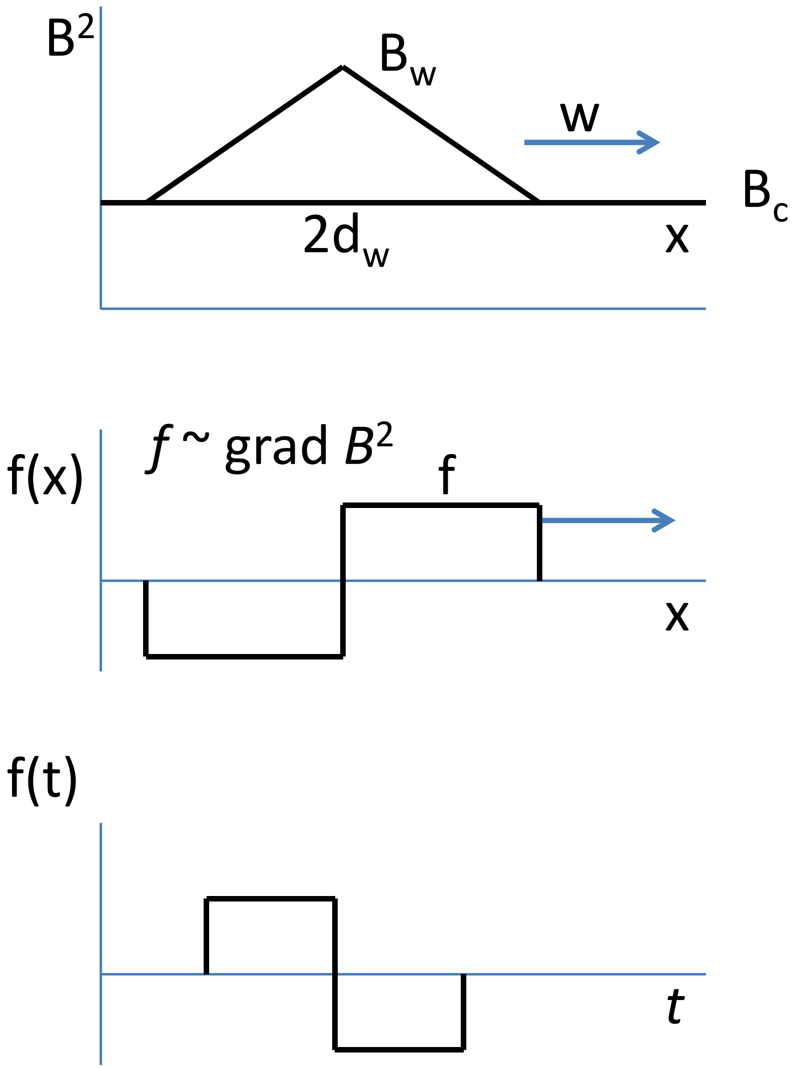
Damped Oscillator:

$$\ddot{x} + \omega^2 x + 2m\delta\dot{x}(t) + f(t) = 0$$

Key parameters:

- maximum speed v_m
- acceleration length: $x(v_m) = x_1$
- acceleration time t_1
- initial acceleration a_0
- period: P
- amplitude x: $x_m = x_2$
- [damping: δ]

Analytical model: Oscillation Triggering



(neglecting damping)

Eq 1a: $\rho_p v_m^2/2 = \int_0^{x1} (f+\rho_p\omega^2 x)dx$

[Eq 1b: $\rho_p v_m^2/2 = \int_{x1}^{x2} (f-\rho_p\omega^2 x)dx$]

Eq 2: $w_m = V_{Ap} + 3v_m/2$

$\omega = 2\pi/P = 2\pi V_{Ap} / \lambda$

$f = \rho_p a = (B_{wp}{}^2 - B_p{}^2) / 2\mu d_{wp}$

Results: Prominence

(a = const.): $v_m = 2x_1/t_1$; $a = 2x_1/t_1^2$

$\omega = (2\pi/P)$, $V_A = 2L/P$

Eq.1&2: $\omega^2 = (2ax_1 + v_m^2)/x_1^2$ & $w_m = V_A + 3v_m/2$

Eq.2 (for $d_{wc} >> d_p$): $d_{wp} = w_m t_1/2 = (V_A + 3v_m/2)\, t_1/2$

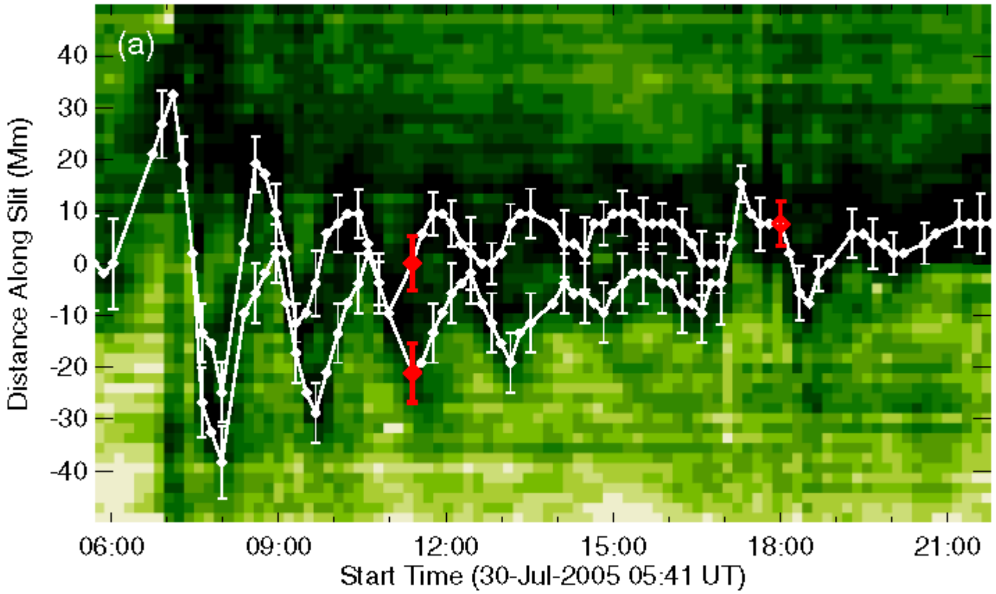
$B = V_A (\mu\rho)^{1/2}$ & $f = \rho a$

$f = (B_w^2 - B^2) / 2\mu d_{wp} = (X^2 - 1)\, B^2 / 2\mu d_{wp}$

$B_w^2 = B_p^2 + 2\mu f d_{wp}$ i.e., $X^2 = 1 + 2\mu f d_{wp}/B^2$

Example:

Transversal LAO of 30 July 2005
(Hershaw et al. 2011 A&A 531, A53)

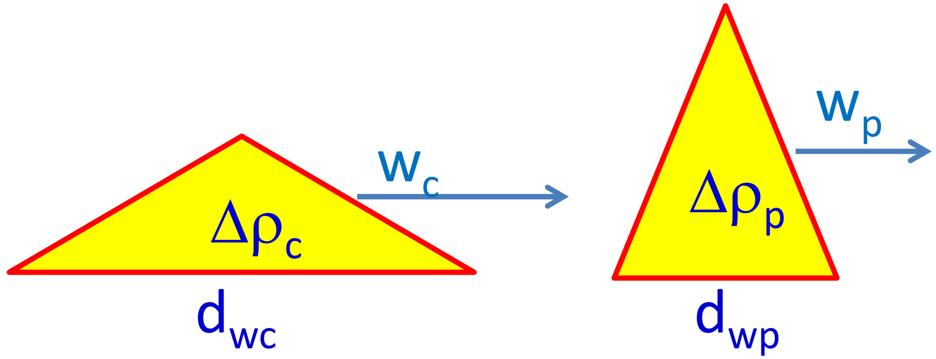


t_1 (min)	x_1 (Mm)	P (min)	L (km)	t_1 (s)	x_1 (km)	P (s)	a (km/s^2)	v_m (km/s)
38	30	90	212132	2280	30000	5400	0.0115	26.3
42	40	100	212132	2520	40000	6000	0.0126	31.7

ω (s^{-1})	v_A (km/s)	w_m (km/s)	d_{wp} (Mm)	ω^* (s^{-1})	$\Delta\omega$ (%)
0.0012	78.6	118.0	135	0.001241	6.6
0.0010	70.7	118.3	149	0.001122	7.2

n (cm^{-3})	B (G)	f (N/m^3)	X
1E+11	11.4	1.93E-09	1.50
1E+11	10.2	2.10E-09	1.75

Results: Corona



$\Delta t_c = \Delta t_p$

$d_{wp}/w_p = d_{wc}/w_c$ i.e., $d_{wc} = d_{wp} w_c / w_p$

$\Delta\rho_p \, d_{wp} = \Delta\rho_c \, d_{wc}$ i.e., $(\rho_c/\rho_p)(X_c - 1)/(X_p - 1) = w_p/w_c$

$(w_c{}^2 - V_{Ac}{}^2) = (w_p{}^2 - V_{Ap}{}^2)\, w_p/w_c$ i.e.,

$(V_{Ac}/V_{Ap})^2 = (w_c/V_{Ap})^2 - [(w_p/V_{Ap})^2 - 1]\,(w_p/w_c)$

&

$\rho_c/\rho_p = (V_{Ac}/V_{Ap})^2$

&

$B_c = V_{Ac}\,(\mu\rho_c)^{1/2}$