Comments on The Alfven Wave Spectrum as Measured on The TCA Tokamak

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In Ref.1, the heating in the TCA tokamak is ascribed to a combination of compressional Alfven wave heating (CAW) and discrete Alfven wave (DAW) heating. In this communication we invoke an alternative plasma heating mechanism by the direct excitation of torsional Alfven waves (TAW) to account for the observed features of the TCA experiment.

Figure 1 shows the well known[2] Alfven wave dispersion characteristics. In the CAW heating scheme, the externally launched compressional wave excites the kinetic Alfven wave (KIN) in the plasma interior which is subsequently dissipated through electron Landau damping (ELD). The launching antenna is oriented azimuthally, perpendicular to B_0 so as to preferentially excite the compressional mode.

TAW is inadvertantly excited by an azimuthal antenna (for $m \neq 0$) used for CAW heating if there is no provision for Faraday shielding as in the case of TCA. This excitation would be further enhanced by the non-orthogonality of the magnetic field lines relative to the antenna orientation, *increasing monotonically with the plasma current* and would involve even the $m = 0$ mode. The TAW is dissipated by ELD in the region of

$$\varsigma = \frac{v_p}{v_e} = \frac{f\lambda_z}{v_e} \sim 1 , \tag{1}$$

where f is the frequency, λ_z is the parallel wavelength and v_e is the electron thermal speed. The antenna loading as well as the heating would not exhibit a rapid deterioration with the increase in the depth of the singular Alfven layer which no longer governs absorption. The dissipation will occur well in the plasma interior where the ELD conditions are met for the peaked electron temperature profiles of TCA *resulting* *in loading peaks resembling the DAW excitation* each time the singular layer crosses the plasma center. Due to the low edge temperature and the probable presence of neutral gas, significant collisional absorption is also likely to occur near the plasma edge with resultant density enhancement. The small wavelength TAW waves should be observable over a wide range extending up to the plasma edge instead of being confined to the propagating KIN inside the Alfven singularity.

These features are indeed observed in the TCA.[1] The presence of short wavelength waves practically throughout the plasma[3] would be much harder to explain with the conventional CAW model which precludes the occurance of propagating KIN outside the singular Alfven layer.

For a linear density profile, the TAW surface impedance is given by

$$-\frac{E_z}{H_y} = \frac{\Gamma(1/3)}{3^{1/3}\Gamma(2/3)} \frac{(n_z^2-1)^{2/3}}{|\epsilon_z'|^{1/3}} exp(\pi i/6) + i\frac{n_y^2}{|\epsilon_z{}'|} \,. \qquad (2)$$

In deriving (2) we assumed that $\epsilon_x \approx 1$, $\epsilon_y \approx 0$, while the reflected wave is absent because for TAW the WKB conditions are satisfied close to the plasma edge. The favorable coupling implied by (2) may be attributed to the absence of both the evanescent region and the inefficient wave conversions. This would cause significant coupling to TAW even for a relatively weak electric field E_z at the plasma edge.

For electron-ion collisions, the approximate damping length (n is the toroidal harmonic and R is the toroidal radius),

$$k_{xi}^{-1} = \frac{2}{n}\frac{\omega^2}{\nu_{ei}\omega_{pe}} R \,, \qquad (3)$$

of typically about 10 cm for the TCA parameters implies the likelihood of significant collisional heating which would help to explain both the observed density enhancement and the low electron temperature increase. The collisional damping would also explain the presence of broad plateaus in the antenna loading situated between the loading peaks where the ELD effects start to dominate.

By far the most convincing evidence for the dominant presence of TAW heating in the TCA is the *disappearance of heating effects upon the introduction of the Faraday* *screen.*[4] CAW heating, on the contrary, would not have been adversely affected by the presence of the Faraday screen as evidenced by the large number of ion-cyclotron heating experiments employing Faraday screen in conjunction with compressional Alfven wave heating.

In conclusion we believe that there is overwhelming evidence of TAW heating in the TCA and the observed results are more in accord with TAW than CAW heating.

References

[1] G. A. Collins, F. Hofmann, B. Joye, R. Keller, A. Lietti, J. B. Lister and A. Pochelon, Phys. Fluids (to be published); also Report LRP 265/85, Ecole Polytechnique Federale de Lausanne,1985.

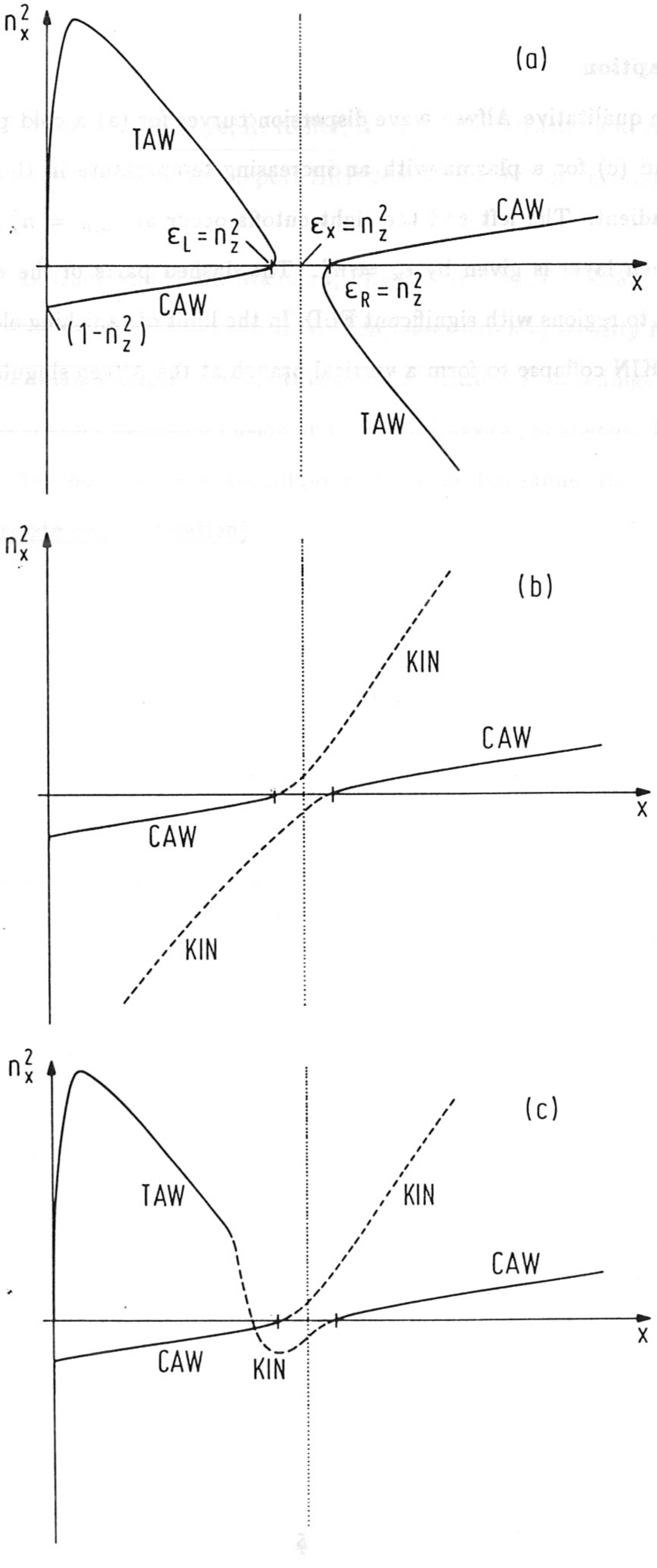
[2] D. W. Ross, G. L. Chen and S. M. Mahajan, Phys. Fluids **25**, 652(1982).

[3] R. Behn, G. A. Collins, J. B. Lister and H. Weisen,*Observation of Density Fluctuations localized at the Resonance Layer During Alfven Wave Heating*, Proceedings of the 13th European Conference on Controlled Fusion and Plasma Physics , Schliersee, FRG(1986); also Report LRP 289/86, Ecole Polytechnique Federale de Lausanne, 1986.

[4] J. B. Lister (private communication)

Figure Caption

Fig. 1 The qualitative Alfven wave dispersion curves for (a) a cold plasma, (b) a hot plasma, and (c) for a plasma with an increasing temperature in the direction of the density gradient. The left and the right cutoffs occur at $\epsilon_{L,R} = n_z^2$ and the position of the Alfven layer is given by $\epsilon_x = n_z^2$. The dashed parts of the dispersion curves correspond to regions with significant ELD. In the limit of vanishing electron mass both TAW and KIN collapse to form a vertical branch at the Alfven singularity.



n_x^2
(a)
TAW
$\varepsilon_L = n_z^2$
$\varepsilon_x = n_z^2$
CAW
x
CAW
$\varepsilon_R = n_z^2$
$(1-n_z^2)$
TAW
n_x^2
(b)
KIN
CAW
x
CAW
KIN
n_x^2
(c)
TAW
KIN
CAW
x
CAW
KIN