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PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY

THEORY DIVISION
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I. Stochastic Alpha Loss by Magnetic Perturbations: Dangers and Possible Benefits

Harry E. Mynick

Two related transport issues, both of central importance for the successful operation of a tokamak reactor, are the good confinement of energetic alpha particles, and the removal of the helium ash. Low- n magnetic perturbations, either externally induced, or internally produced by MHD-activity, can induce transport analogous to the ripple transport due to TF coils. For highly energetic ions, the associated transport is the collisionless 'stochastic' mechanism originally considered for trapped particles perturbed by TF ripple.¹ More recent experimental observations have found a significant enhancement of MeV ion loss in the presence of low n MHD activity of passing as well as trapped particles, for modes of low frequency² ($\omega \lesssim 10$ kHz), moderate frequency³ ($\omega \sim 30$ kHz), and high frequency^{4,5} ($\omega \sim \omega_{TAE} \sim 100$ kHz). For low-frequency modes on TFTR, for example, for which some of the most detailed loss data is available, an MHD-enhancement of D-D fusion products near their birth energy of about a factor of 4 over its value in quiescent discharges is observed.² For the detectors well below the midplane most of this enhancement appears to be due to initially counter-going passing particles. Corresponding to these various cases, the theory of stochastic transport has been extended, to include trapped particles in finite- ω MHD,⁶ passing particles in low- ω ^{7,8} and in high- ω ⁹ perturbations, and to perturbations with multiple harmonics, and nontrivial radial structure.

An important lesson derived from consideration of the stochastic theory is the variety of energy scalings of the transport possible with differing choices of perturbations.⁸ While for some perturbations, the stochastic threshold of more energetic ions is below that of less energetic ones, consistent with observations of MHD-induced loss, it is not difficult to prescribe a perturbation for which the opposite is true, or even one for which particles at both high and low energy are below the threshold, but those in some intermediate energy range are above threshold. This last 'stochasticity profile' is what is needed for ash removal: one wants to confine both the energetic alphas and the thermal bulk, while inducing rapid alpha transport at some intermediate energy where most of an alpha's energy is spent, but it is still energetic

Figure 1.1: Analytic theory for island boundaries for a (2,1) perturbation versus η_1 , for $b_{21}^{max} = 4 \times 10^{-3}$.

enough to have transport characteristics distinguishable from the bulk. Thus, it may be possible to use the stochastic mechanism for beneficial purposes, by intentionally imposing perturbations of the appropriate structure for ash removal, burn control, or perhaps for compensating undesired transport effects of internally-generated perturbations.

We illustrate some of the possible transport scalings from differing perturbations. The analytic theory for passing particles is represented by plotting the island boundaries produced by a given perturbation, versus the parameter $\eta_1 \sim k_\perp \rho_b$, a measure of the amount of orbit-averaging a particle performs over the mode structure in the course of a bounce/transit period. Both ρ_b (the particle drift-orbit excursion) and η_1 have an energy scaling $E^{1/2}$. Stochasticity ensues when adjacent islands overlap. Figure 1.1 illustrates this for a single (2,1)-perturbation, with amplitude $b_{21}(r) \equiv \delta B_{21}^r/B_0$ peaking at $b_{21}^{max} \simeq 4 \times 10^{-3}$. The successive marks along the curves are at intervals of $E_0/10$, with the leftmost point at (near)-vanishing energy, and the rightmost at the alpha birth energy $E_0 = 3.5$ MeV. A single-harmonic perturbation b_{mn} produces a *sequence* of drift islands, labeled by bounce harmonic $l_b \equiv l - m$, with $l = 0, \pm 1, \pm 2, \dots$, and with island half-width $\delta r_d(l_b, n) \sim [b_{mn} J_l(\eta_1)]^{1/2}$. For the (2,1) case of Fig. 1.1 dominant islands are the (2,1) primary, and

Figure 1.2: Poincaré plots for passing alphas with (a) $E = .001E_0$ and (b) $E = .5E_0$ moving in the (2,1) perturbation of Fig. 1.1 but with $b_{21}^{max} = 8 \times 10^{-4}$.

the (3,1) sideband, which overlap above about $E = .45E_0$, yielding an island profile appropriate for burn control, where more energetic ions are more stochastic than less energetic ones. The island structure of Fig. 1.1 is corroborated numerically in Fig. 1.2, showing Poincaré plots for the same (2,1) perturbation, but at amplitude one fifth as large, at $E = .001E_0$ (a) and $E = .5E_0$ (b). One notes, as predicted by the analytic expression for δr_d , the emergence at high energy of a (3,1) sideband island.

In Fig. 1.3 we show how perturbations with multiple harmonics can radically alter an island profile. Added to the (2,1) perturbation of Fig. 1.1 is an additional (3,1) harmonic, with $b_{31}^{max} = 1.5 \times 10^{-3}$. The half-width expression is the sum over contributions from the magnetic harmonics, $\delta r_d(l_b, n) \sim [\sum_m b_{mn} J_{l_b+m}(\eta_1^{mn})]^{1/2}$. Thus, the contribution from one magnetic harmonic can cancel that from another, resulting in, for example, the null at about $E = .5E_0$ in the (3,1) island.

Fig. 1.4 shows an island profile with the general features appropriate to ash removal, generated by a single (6,3) harmonic. The higher (m, n) values

Figure 1.3: Same as Fig. 1.1, but for a superposition of the same (2,1) mode of Fig. 1.1 with an additional (3,1) perturbation with $b_{31}^{max} = 1.5 \times 10^{-3}$.

Figure 1.4: Same as Fig. 1.1, but with a (6,3) perturbation having $b_{63}^{max} = 1.7 \times 10^{-3}$.

permit a larger η_1 , which allows more use to be made of the Bessel functions. Now, one is below threshold as $E \rightarrow 0$ (because of the null in the $J_{\pm 1}$ of the sideband islands) and also at $E = E_0$ (because of the null in J_0 of the primary), but above threshold for a range of intermediate energies. As above, Poincare plots provide numerical corroboration of this behavior. This scheme, producing radially local stochasticity may be extended to be radially global by radial 'stacking' of perturbations, producing a similar pattern over the entire minor radius. To produce a profile acceptable for ash removal, this preliminary scheme must be refined to be above threshold over a narrower range in energy, and starting at lower values. Various methods of accomplishing this, involving additional components of yet higher (m, n) -perturbations, making more use of the different energy scaling of magnetic *ripple* perturbations (instead of the magnetic 'braiding' perturbations b_{mn} focussed on here), and using perturbations with time-varying frequencies to 'sweep' particles radially, are now being studied.

Bibliography

- [1] R. J. Goldston, R. B. White and A. H. Boozer, Phys. Rev. Lett. **47**, 647 (1981).
- [2] S.J. Zweben, et al., **Proceedings of the Fourteenth International Conference on Plasma Physics and Controlled Nuclear Fusion Research** (Wurzburg, Germany, September, 1992) (International Atomic Energy Agency, Vienna), Paper IAEA-CN-56/A-6-3.
- [3] H.H. Duong and W.W. Heidbrink, General Atomics Technical Report GA-A20923, (1992) (to appear in Nucl. Fusion).
- [4] K.L. Wong, et al., Phys. Rev. Lett. **66**, 1874 (1991).
- [5] W. Heidbrink, E.J. Strait, E. Doyle, G. Sager, R.T. Snider, Nucl. Fusion **31**, 1635 (1991).
- [6] H.E. Mynick, R.B. White, in **Theory of Fusion Plasmas**, edited by J. Vaclavik, F. Troyon, and E. Sindoni, **Proceedings of the Joint Varenna-Lausanne International Workshop**, Chexbres, Switzerland October 1988, Editrice Compositio, Bologna, 1989) pp.385-400.

- [7] S.V. Konovalov, S.V. Putvinskii, Fusion Technol. **18**, 397 (1990).
- [8] H.E. Mynick, (a) Phys. Fluids B **5**, 1471 (1993), (b) Phys. Fluids B **5**, 1471 (1993), and Princeton University Report PPPL-2856 (1992).
- [9] H.L. Berk, B.N. Breizman, and H. Ye, IFS Report IFSR-566 (Sept., 1992).

II. Energetic Particle Effects: Tapping Alpha-Particle Energy with Waves

Nat Fisch

Thermonuclear fusion appears to be a promising avenue for new energy resources, but the physics and the technology of magnetic confinement do not yet point to a reactor that is by a wide margin both economical and feasible. If the fusion cross-section were slightly larger, or if the maximum cross-section were reached at lower temperatures, or if the cross-section for Coulomb collisions were smaller, one could easily imagine a very cheap, realizable and economical source of energy processed by tokamak or other fusion reactors. But these cross-sections are given. One might ask, however, where might significant improvement be possible in tokamak operation if only some strongly held belief turned out to be untrue.

One *law* that is not quite inviolable and that might be "violated" usefully is the law that the energetic charged fusion products (α -particles in the cast of D-T reagents) slow down primarily on bulk electrons. The consequence of this law is that electrons must be hotter than the reacting ions, because the ion source of heat is only through the electrons. But electron heat is not really useful, except for heating ions, and the electrons lose part of this heat through radiation, radiative transfer and heat transport before transferring this energy to the reacting ions. This is the case particularly in advanced fuel reactors, probably making most of them impractical.

While it is obviously impossible to tamper with the cross-section for energetic α -particles to slow down on electrons, it may be possible to extract the energy of the energetic α -particles first by some collisionless means, for example, if the α -particles were to interact with an intense wave, possibly

a wave deliberately injected into the tokamak. If the α -particles slow down collisionlessly, then their energy will not be available to heat electrons collisionally. Instead, in amplifying the wave, the α -particle energy is converted to wave energy. The wave energy is then available for uses other than simple direct heating of the electrons.

There are two very good things that might be done with the wave energy: One, to channel the wave energy into fast electrons traveling in one direction - this accomplishes the current-drive effect.¹ Two, to channel the energy into the tail of the ion distribution: this increases the fusion reactivity.² It turns out that one plausible wave intermediary for both of these effects is the lower-hybrid wave.

Lower hybrid waves are a demonstrated, continuous means of driving toroidal current in a tokamak. When these waves propagate in a tokamak fusion reactor, in which there are energetic α -particles, there is, in fact, a concern that these waves may be absorbed, rather than amplified, by the α -particles, and not absorbed, for example, by the electrons. In fact, for heating by very intense waves, the α -particles tend to absorb more wave power than do the electrons, because the electron interaction exhibits quasi-linear saturation, i.e., the electron velocity distribution flattens in the region where the wave phase velocities are finite. The α -particle interaction exhibits no saturation, because once in resonance, the α -particle remains in resonance even as it gains energy. In such a case the current-drive efficiency would diminish greatly.

What we can show, however, is that there are conditions under which the α -particles do not appreciably damp, and may even amplify, the wave, thereby enhancing the current-drive effects when the power is eventually absorbed by electrons, or the fusion reactivity if the waves interact with the ion tail. Waves traveling in one poloidal direction, in addition to being directed in one toroidal direction, are shown to be the most useful in accomplishing these effects.

The waves are to be absorbed in the region of the largest density gradient to the energetic α -particles, as the lower-hybrid rays circle the magnetic axis. The amplification occurs at the expense of the free expansion energy of the α -particles, and if this happens, there would be favorable side effects, in that less of the α -particle energy would then be available to fuel unwanted instabilities, and some helium ash would be transported to the tokamak

periphery. It turns out that the free expansion energy is limited by theorems other than the conventional theorem associated with plasma free energy, because of the constraint that the expansion occur as a result of a diffusive process.³

It should be noted that the extraction of energy envisioned here is essentially an *in situ* direct conversion method. Fusion products are used not just to heat, but to perform useful work. A further advantage over even the direct conversion of this energy to work is that, since it is converted *in situ* and directly to the end use, the inefficiencies associated with intermediate stages, such as generating waves and delivering the wave power to the tokamak, are also avoided.

Bibliography

- [1] N.J. Fisch and J-M. Rax, *Interaction of Energetic α -Particles with Intense Lower hybrid Waves*, Phys. Rev. Lett. **69**, 612-615 (July, 1992).
- [2] N.J. Fisch and J-M. Rax, *Diffusion of Energetic Alpha Particles by Intense Lower Hybrid Waves*, to appear in Plasma Physics and Controlled Nuclear Fusion Research, Wurzburg, Germany, September 30 - October 7, 1992 (IAEA, Vienna, 1993).
- [3] N.J. Fisch and J.M. Rax, *Free Energy in Plasmas under Wave-induced Diffusion*, Phys. Fluids B **5** (6), 1754-1759 (1993).

III. Theory Publication List for July 1992 – March 1993

Artun, M., and W.M. Tang, *Gyrokinetic Analysis of Ion Temperature Gradient Modes in the Presence of Sheared Flows*, Phys. Fluids B 4, 1102 (1992).

Chance, M.C., et al., *MHD Stability of Tokamak Plasmas*, in Conference Proceedings of Second Symposium on Plasma Dynamics, Trieste, Italy, July 8-10, 1992.

Cowley, S.C., *Neoclassical Transport in High- β Tokamaks*, PPPL Report 2866 (December 1992).

Cowley, S.C., F.W. Perkins, E.J. Valeo, *Generation of High Intensity RF Pulses in the Ionosphere by Means of In Situ Pulse Compression*, submitted to Geophys. Res. Letts. and PPPL Report 2899 (April 1993).

Fisch, N.J., *Review of Current Drive Theory Selected Topics*, Proceedings of the Europhysics Topical Conference on RF Heating and Current Drive of Fusion Devices, Brussels 7-10 July, 1992. (Satellite Meeting of 1992 International Conference on Plasma Physics, Innsbruck, Austria).

Fisch, N.J., and J-M. Rax, *Interaction of α -Particles with Intense Lower Hybrid Waves*, submitted to Phys. Rev. Letts. and PPPL Report 2846 (July 1992).

Hahm, T.S., *Atomic Physics Effects on Tokamak Edge Drift-Tearing Modes*, submitted to Phys. of Fluids B and PPPL Report 2877 (March 1993).

Johnson, J.L., D.A. Monticello, A.H. Reiman, and C.Y. Wang, *Applications of the PIES Code to the ATF Stellarator*, Proceedings of the 9th IAEA International Workshop on Stellarators, Garching, May 10-14, 1993 (IAEA, Vienna, 1993).

Krommes, J.A., *Equilibrium Statistical Constraints and the Guiding-Center Plasma*, Phys. Fluids B 5, 650 (1993).

Krommes, J.A., *Dielectric Response and Thermal Fluctuations in Gyrokinetic Plasmas*, Phys. Fluids B **5**, 1066 (1993).

Krommes, J.A., *Advances in Gyrokinetic Fluctuation Theory: The Gyrokinetic Fluctuation-Dissipation Theorem and Dielectric Function*, Phys. Fluids B **5**, 2405 (1993).

Lee, W.W., T.S. Hahm, et al., *Kinetic Studies of Microinstabilities in Toroidal Plasmas: Simulation and Theory*, **Proceedings of IAEA 14th International Conference of Plasma Physics and Controlled Nuclear Fusion Res.** Würzburg, September 30 - October 7, 1992 and PPPL Report 2865 (December 1992).

Monticello, D.A., *Advances in Simulation and Modeling Thermonuclear Plasmas*, Nucl. Fusion **33**, 359 (1993).

Monticello, D.A., A.H. Reiman, and C.Y. Wang, *The PIES Code: Three-dimensional Equilibria with Pressure, Islands, and Stochastic Regions*, **Proceedings of the 9th IAEA International Workshop on Stellarators**, Garching, May 10-14, 1993 (IAEA, Vienna, 1993).

Mynick, H.E., *Transport of Energetic Ions by Low- n Magnetic Perturbations*, Phys Fluids B **5**, 1471 (1993) and PPPL Report 2856 (October 1992).

Mynick, H.E., *Stochastic Transport of MeV Ions by Low- n Magnetic Perturbations*, Phys. Fluids B **5**, 2460 (1993).

Nagayama, Y., S.A. Sabbagh, J. Manickam, et al., *Observation of Ballooning Modes in High-Temperature Tokamak Plasmas*, Phys. Rev. Letters **69**, 2376 (1992) and PPPL Report 2850 (August 1992).

Okuda, H., *Numerical Simulation of the Subsolar Magnetopause Current Layer in the Sun-Earth Meridian Plane*, J. Geophys. Res. **98**, 3953 (1993).

Parker, S.E., and W.W. Lee, *A Fully Nonlinear Characteristic Method for Gyrokinetic Simulation*, Phys. of Fluids B **5**, 77 (1993) and PPPL Report 2851 (July 92).

Rax, J-M., and N.J. Fisch, *Phase-Matched Third Harmonic Generation in a Plasma*, IEEE Trans. on Plasma Science **21, 105 (1993).**

Tang, W.M. and G. Rewoldt, *Long-Wavelength Microinstabilities in Toroidal Plasmas*, Phys. Fluids B **5, 2451 (1993) and PPPL Report 2872 (January 1993).**

White, R.B., and Yanlin Wu, *Collisionless Transport in a Stochastic Magnetic Field*, Plasma Physics and Control. Fusion **35, 595 (1993) and PPPL Report 2857 (September 1992).**

White, R.B., J-M. Rax, and Yanlin Wu, *Transport Near Stochastic Threshold*, submitted to Phys. Rev. Lett. and PPPL Report 2870 (December 1992).

White, R.B., J-M. Rax, and Yanlin Wu, *Transport in a Stochastic Magnetic Field*, in **Conference Proceedings of Second Symposium on Plasma Dynamics, Trieste, Italy, July 8-10, 1992.**

Zakharov, L., S. Migliuolo, and B. Rogers. *The Theory of the Early Nonlinear Stage of $m=1$ Reconnection in Tokamaks*, Phys. Fluids B **5, 2498 (1993).**

Zweben, S.J., D.S. Darrow, E.D. Fredrickson, and H.E. Mynick. *Anomalous Delayed Loss of Trapped D-D Fusion Products in TFTR*, submitted to Nucl. Fusion and PPPL Report 2864 (February 1993).

IV. Theory Visitors for July 1992 – March 1993

Azumi, Masafumi, JAERI, Ibaraki, Japan, November 8 – 10, 1992.

Braams, Bastiaan, Courant Institute, New York University, 1 day per week in 1992 and 1993.

Brizard, Alain, Lawrence Berkeley Laboratory, University of California at Berkeley, July 27 – August 28, 1992.

Hayashi, Takaya, NIFS, Nagoya, Japan, December 6 – 18, 1992.

Heikkila, Walter, University of Texas at Dallas, September 25 – 28, 1992.

Lanzotti, Lou, AT&T Bell Labs, January 5 – 9, 1993.

Lukash, Victor, Troitska Inst. of Innov. and Fusion Res., Moscow, Russia, January 15 – February 28, 1993.

Maurice, Sylvestre, Observatoire Midi – Pyrenees, France, October 2 – November 15, 1992.

Rayevski, Dimitri, Courant Institute, New York University, one day per week in 1992 and 1993.

Romanelli, Francesco, Centro Ricerche Energia, Frascati, Italy, January 4, 1993.

Salas, Angel, CIEMAT, Madrid, Spain, June 9 – August 7, 1992.

Song, Paul, National Center for Atmospheric Research, Boulder, CO, September 9 – 10, 1992.

Tessarotto, Massimo, Department of Mathematics, University of Trieste, Trieste, Italy, August 20 – October 21, 1992.

Tsai, S.T., Institute of Physics, Chinese Academy of Science, Beijing, China, July 13, 1992 – January 13, 1993.

Wang, Caiyi, Columbia University, February 1992 – May 1993.

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