

Noise effects in PIC simulations relevant to the ECDI

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Outline

1. Collisional effects & sub-Debye resolution
2. Noise estimate from fluctuation/dissipation
3. Excitation of normal modes due to fluctuation
4. Conclusions

PIC noise can affect results in various ways

- artificial collisionality introducing spurious damping.
- sampling-noise driven fluctuations interacting with physical modes.
- exists mostly in accessible physical modes of the system.

Collisions with finite-sized particles

- Particle size limits interaction due to screening. For sub-Debye ranges collisions can occur.
- Okuda & Birdsall (PoF 13 8 2123): $\nu \approx nv_t\sigma = \frac{\pi\omega_{pe}}{16N_D}$
for Janhunen et al. PoP 2018: $\nu = 5 \cdot 10^{-6}\omega_{pe}$
for Croes et al. 2017: $\nu = 4.5 \cdot 10^{-5}\omega_{pe}$
- Turner (PoP 13 033506):
 - “... kinetic properties of the simulation are appreciably degraded when the $\nu \geq 10^{-4}\omega_{pe}$, ...”

Noise spectrum due to (thermal) fluctuations

- Langdon (PoF 22 163), Krommes, Nevins, Decyk:

$$L|E(k, \omega)|^2/8\pi = -\frac{T}{\omega} \Im\left(\frac{1}{\varepsilon(k, \omega)}\right)$$

$$\left\langle \frac{E_k^2 L}{8\pi} \right\rangle = \frac{T_p}{2} \left(1 + \frac{k^2 \lambda_{De}^2}{S^2(k) W^2(k)} \right)^{-1}$$

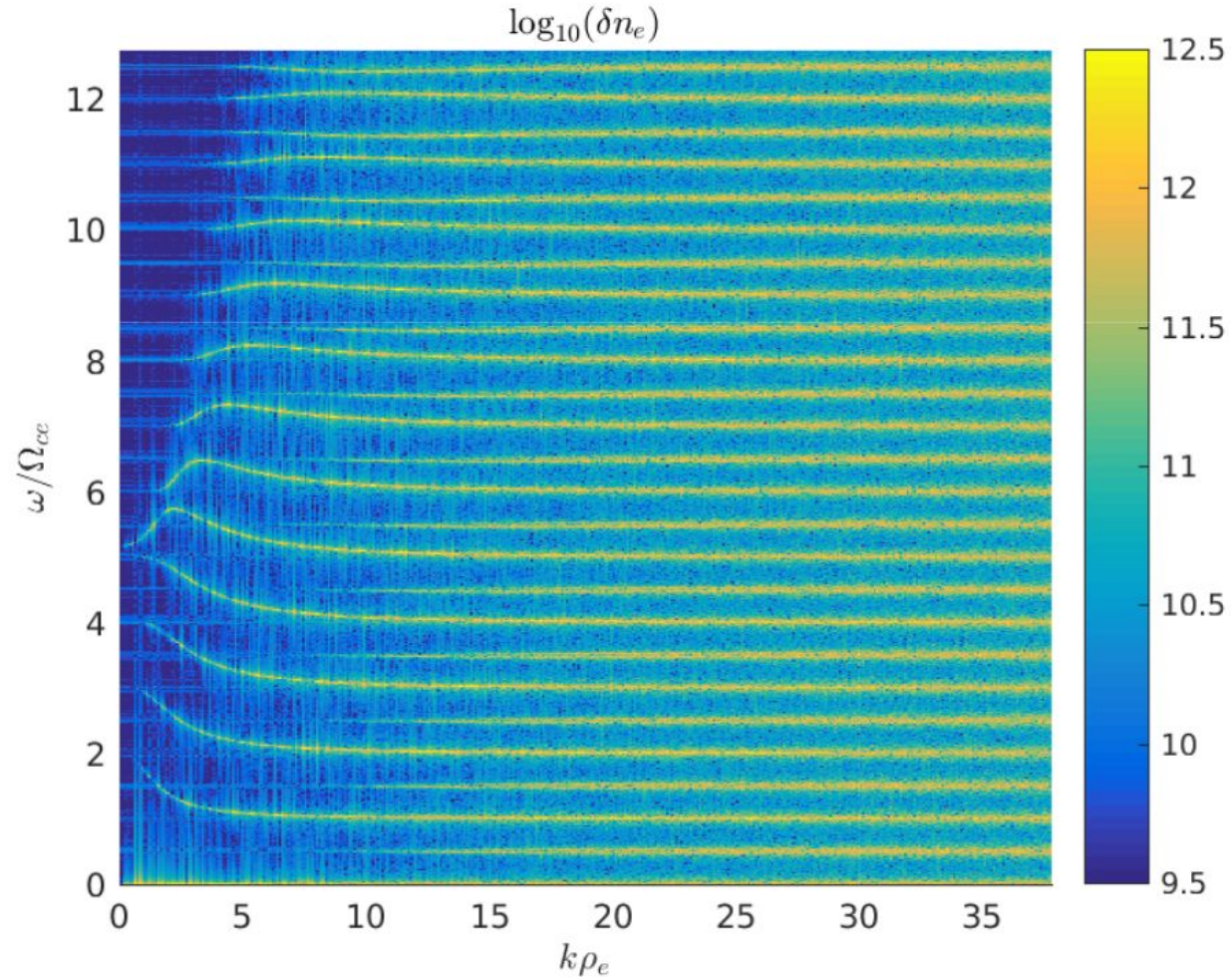
- Limiting cases:

$$|e\phi(k, \omega_{pe})/T_e| = \frac{1}{\sqrt{N} k \lambda_{De}} \quad |e\phi(k, \omega_s)/T_e| = \frac{1}{\sqrt{N}}$$

Plasma waves

IAW

Noise in a stable system exists in the normal modes of the plasma.



$B=200$ G, $T_e=20$ eV, $T_i=1$ eV, $n_0=10^{17}$ 1/m³.

Conclusions

- Particle noise influences through:
 - effective collisionality (helped by finite sized particles).
 - fluctuations induced by thermal noise.
- Noise appears to exist in physical modes.
- ECDI exists in a regime of intermediate frequency (in the electron frame) and intermediate wavelength. Noise could be a problem.