Research on viscosity and dispersion relation in jamming sysytem

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Abstract

Computation is performed on jamming sysytem[1] under zero temperature to probe the viscosity and dispersion relation . We find that they behave differently in transverse vibration and longitudinal vibration . Boson peak is consistent with the Ioffe-Regal limit[2] condition of transverse vibration. The longitudinal vibration make great contribution to large vibration eigenmode. Further more, the viscosity in longitudinal vibration behave non-monotonicly when wave vector *k* increase .

Methods

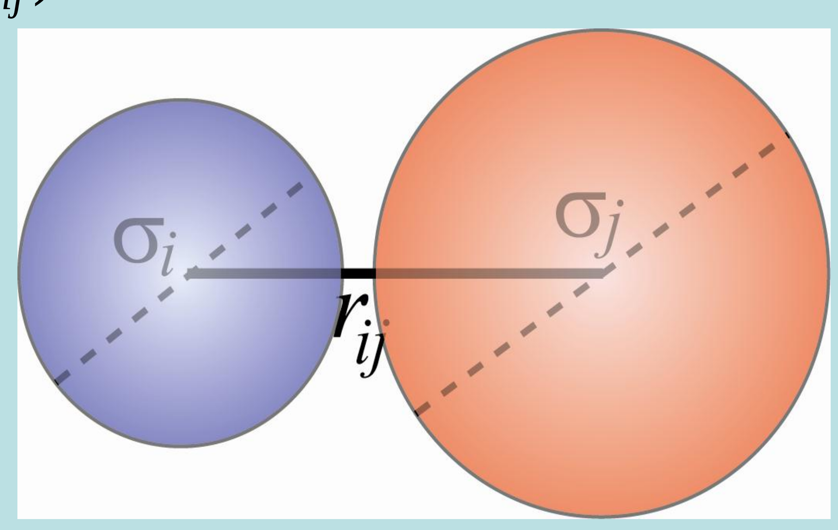
Purely repulsive interaction:

$$V(r_{ij}) = \frac{\varepsilon}{\alpha}(1 - r_{ij}/\sigma_{ij})^{\alpha}, \quad if\ (r_{ij} < \sigma_{ij})$$

$$V(r_{ij}) = 0, \quad if\ (r_{ij} > \sigma_{ij})$$

$$\sigma_{ij} = (\sigma_i + \sigma_j)/2$$

$$\alpha = 2$$



Condition: Zero Temperature and 3-D.

Dynamic structure factor

$$f_L(k,\omega) = \sum_i \left\langle \frac{1}{N} \left| \sum_j \hat{k} \cdot \hat{e}_{i\omega} \exp(i \hat{k} \cdot \hat{r}_j) \right|^2 \right\rangle \delta(\omega - \omega_i)$$

$$f_T(k,\omega) = \sum_i \left\langle \frac{1}{N} \left| \sum_j \hat{k} \times \hat{e}_{i\omega} \exp(i \hat{k} \cdot \hat{r}_j) \right|^2 \right\rangle \delta(\omega - \omega_i)$$

Response function

$$S_\alpha(k,\omega) = \frac{1}{\rho^2} \frac{\omega \eta_\alpha k^2}{(\omega^2 - \Omega_\alpha(k)^2)^2 + \omega^2 \Gamma_\alpha(k)^2}$$

$$\Omega_\alpha(k) = \sqrt{\frac{G_\alpha}{\rho}} k$$

$$\Gamma_\alpha(k) = \frac{\eta_\alpha}{\rho} k$$

$$\alpha = L, T$$

Ioffe-Regal limit condition

$$\Omega(k) = \pi \Gamma(k)$$

Results

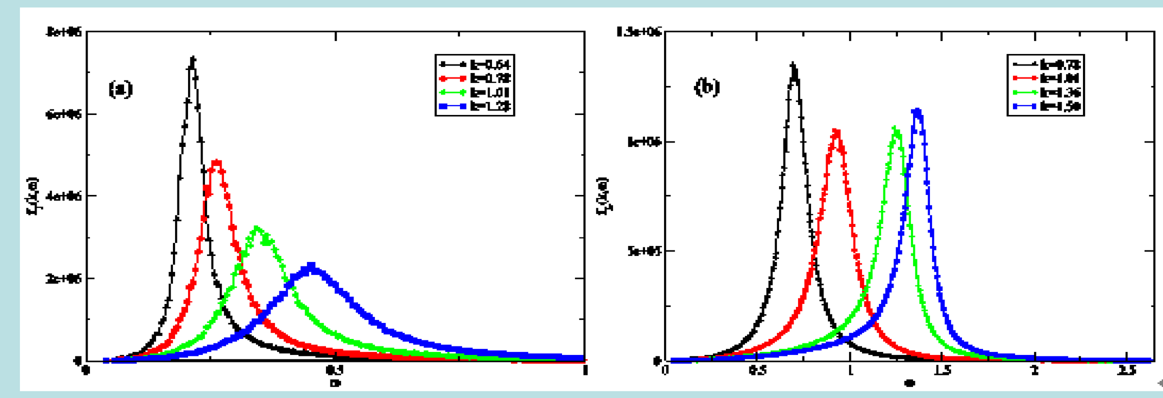


Fig. 1: dynamic structure factor dependence of vibration mode ω at constant pressure P=0.1 and varying wave vector k. (a) and (b) represent the dynamic structure factor in tranverse vibration and longitudinal vibration. In(a), k are 0.64, 0.78, 1.01 and 1.28, and in(b), k is 0.78, 1.01, 1.36, 1.50.

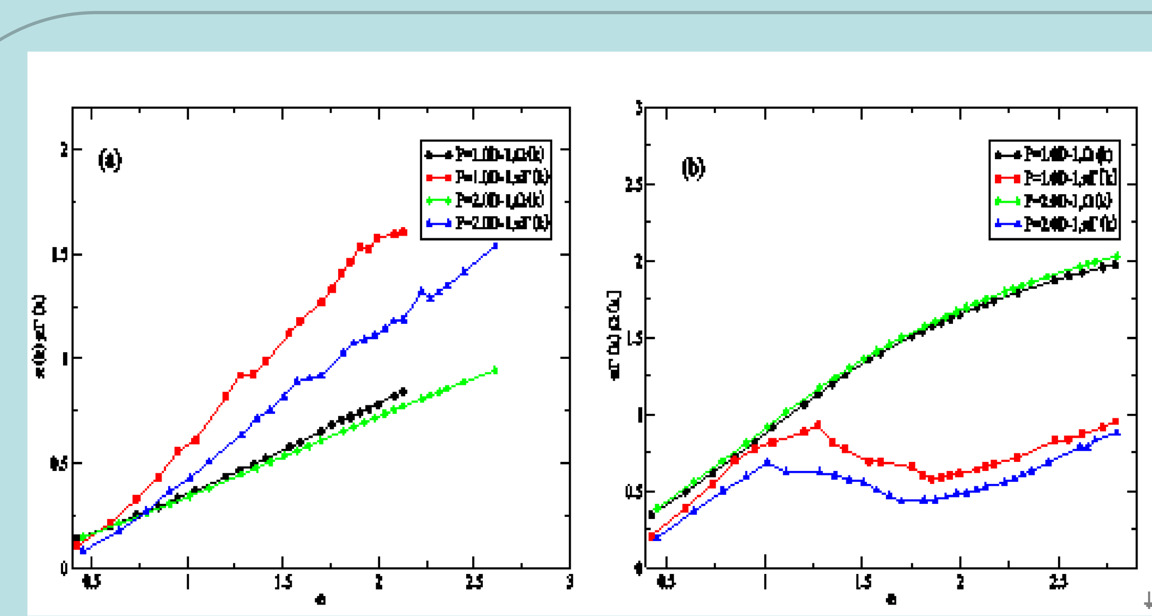


Fig. 2: Viriable $\pi\Gamma$, Ω in dynamic structure factor $f(k,\omega)$ are fitted by response function at pressure P=1.0D-1,2.0D-1. As showed in (a) that $\pi\Gamma$, Ω as function of ω in tranverse vibration interact, Ioffe-Regal limit condition obvious exists,.However, $\pi\Gamma$, Ω in longitudinal vibration do not interact,which means the Ioffe-Regal do not exist.

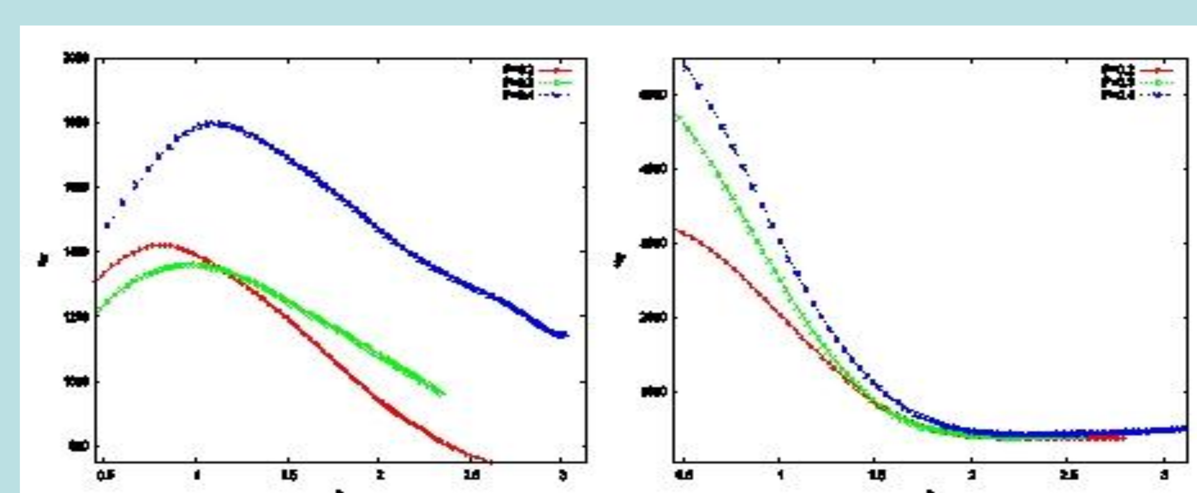


Fig. 3: The viscosity in tranverse vibration(left) and longitudinal vibration(right) dependent on wave vector(scale),the pressure P are at P=0.2, 0.3, 0.4. As showed in the curve, the viscosity in tranverse vibration behave nonmonotonously when k increase, however, it decreasese monotonously when k increases.

Conclusion

1, For dynamic structure factor in longitudinal vibration, the full-width at half-maximum is non-monotonicly as function of k which is due to its great contribution to large vibration eigenmode.
2, The Loffe-Regal limit condition only exists in transverse vibration.
3, The viscosity behave non-monotonicly in transverse vibration while it behave monotonicly in longitudinal vibration.

References

[1] Zhao Cang., Tian Kaiwen. and Xu Ning., New Jamming Scenario: From Marginal Jamming to Deep Jamming, Phys. Rev. Lett. , 106 (2011) (125503).
[2]Hiroshi Shintani., Hajime Tanaka., Universal Link Between the Boson Peak And Tranverse Phonons in glasses, Nature Material, 7(2008)870