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Biocomplexity Faculty Search Committee
c/o Prof. Rob de Ruyter
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Dear Colleagues,

I am writing on behalf of Leonardo E. Silbert, who has applied to your department for a tenure-track faculty position. Leo went to the University of Chicago as a postdoc a year and a half ago with a rather unusual arrangement: he is working jointly with Sid Nagel, at the James Franck Institute, and with me (we each pay half his salary). Although I do not see Leo very often, we talk frequently, both one-on-one and also in conference calls with Sid. I have come to know him well and recommend him to you highly.

Leo's work is entirely numerical. As a graduate student, he worked on simulations of colloids with John Melrose at Cambridge University, and before coming here, he worked with Gary Grest at Sandia National Labs, developing a tour-de-force code for granular materials. Sid and I were therefore excited to have him join us in working on jamming.

Jamming occurs when a system develops a yield stress or extremely long stress relaxation time in the disordered state. According to this definition, many different systems jam—supercooled liquids jam as the temperature is lowered towards the glass transition, colloidal suspensions jam as the density is raised towards the colloidal glass transition, and elastoplastic materials such as foams or emulsions jam as an applied shear stress is lowered towards the yield stress. Leo's work has been directed at understanding a very special point (Point J) in parameter space at zero temperature and zero applied shear stress, which represents the onset of jamming with increasing density. This point exists for particles with repulsive potentials that go to zero at a well-defined distance (which defines the particle diameter), and is at the random-close-packing density (in fact, Point J provides a clean definition of random close-packing). Static granular packings necessarily exist near this point because they are effectively at zero temperature (i.e. the thermal energy is small compared to the energy needed to lift a grain by its own diameter) and the particles are quite hard.

In earlier work, our previous postdoc Corey O'Hern found that Point J is very similar to a critical point—there is power-law scaling of quantities such as the pressure and the shear modulus and there is no self-averaging at the point. However, the exponents depend on potential but not on dimensionality and there are no fluctuations around the point--on the unjammed side, there are no fluctuations at all, even infinitesimally close to the point. This is very different from an ordinary critical point. Thus, the onset of jamming with density is not a critical point, but has very special properties.

Leo's work focuses on two aspects of Point J. I will first describe them, and then explain why Leo's results are so interesting. First, the point differs from an ordinary critical point in that there is an important length scale that vanishes there; this is the overlap distance between neighboring particles. Below Point J, none of the particles overlap but just above Point J, there is an average of $2d$ overlapping neighbors per particle, where d is the dimensionality. As a result, the first peak of the pair correlation function $g(r)$ diverges at Point J. Leo showed that the peak height diverges as a power-law as Point J is approached from the high-density side. Additionally, Leo showed that the width of the peak on the small r side vanishes with the same power-law, so that the area under the peak remains constant at 2d. Finally, the large-r side of the peak obeys a separate power-law that reflects the fact that increasing numbers of particles are poised to become neighbors as the system is compressed beyond Point J.

The second part of Leo's work concerns the density of vibrational modes of the system, as Point J is approached from the high-density side. It is well-known that glasses have anomalous low-frequency modes, in excess of the Debye expectation. Leo finds that as the density decreases towards Point J, these anomalous low-frequency modes proliferate, so that the density of vibrational modes actually approaches a constant, independent of frequency, at Point J. He has shown that these modes are primarily transverse in character.

Leo's results are important because they suggest a connection between Point J and glasses. Glassforming liquids have attractions and Point J only exists for systems with finite-range repulsive interactions. However, the attractive interactions in liquids mainly serve to hold the system at a high enough density so that the short-ranged repulsive interactions come into play. Leo's results allow us to take this argument further. It is well-known that as supercooled liquids are cooled towards the glass transition, the first peak of $g(r)$ becomes higher and narrower. Leo showed that the first peak becomes infinitely high and narrow at Point J. It is also well-known that many of the unusual low-temperature properties of glasses stem from anomalous low-frequency vibrational modes. Leo showed that these anomalous modes are most abundant at Point J. Thus, his results are suggestive of a very important idea, namely that Point J might control the glass transition.

Leo is affable and outgoing; he enjoys giving talks and telling people about his results. He has attended several conferences on his own initiative. As a result, his work has had significant impact (he will be giving an invited talk on his results at the APS March meeting this year). He is a very able simulator and he has a good nose for problems. He would be an excellent colleague and teacher. All in all, he has the important qualities for success in the academic world. I strongly urge you to take a look!

Sincerely,

Andrea L

Andrea J. Liu
Professor