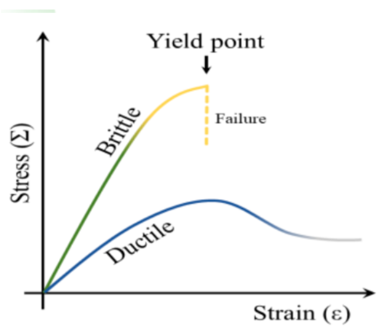
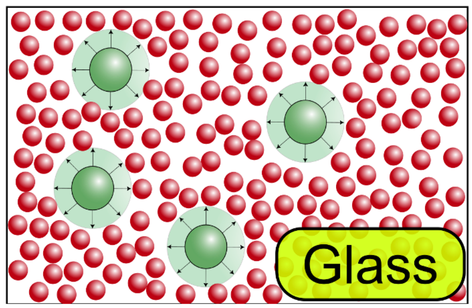
Brittle to Ductile transition in colloidal systems.

The mechanical response of amorphous solids remains one of the key open problems in condensed matter physics. When subjected to deformation, these materials may yield abruptly, leading to brittle failure, or deform progressively, exhibiting ductile behavior. Understanding the transition between these two regimes—the brittle-to-ductile transition (BDT) (see figure right)—is crucial both for fundamental physics and for applications in materials design, food science, and biophysics. While brittle and ductile behaviors have been reported in simulation in various amorphous materials, a clear observation of a BDT in a real experiment has not yet been achieved. Recent numerical studies have suggested that the BDT can be controlled by the degree of structural disorder frozen into the material during its preparation, but the microscopic origin of this transition and its dependence on preparation protocols remain open questions. To address these challenges, this internship will focus on numerical simulations performed in close collaboration with experimental teams working on colloidal systems, with the ultimate goal of identifying and characterizing the emergence of a BDT in a model amorphous material.





During this internship, the student will initiate numerical studies of the yielding transition in model colloidal glasses, with particular emphasis on the formation of glassy states via the 'expanding particle' protocol. In this approach, a system of interacting particles is gradually driven into a dense, glassy configuration by inflating a fraction of the particles over time (see figure left). This method allows precise control of the final density and of the rate of quench, which together determine the degree of disorder and the mechanical behavior of the glass. The student will use or particle-based simulations to explore how preparation conditions—such as the expansion rate or the particle-size ratio—affect the microscopic structure and mechanical response of the resulting amorphous solid. The work will involve setting up and running simulations of three-dimensional systems, analyzing local stress distributions and structural heterogeneity, and identifying microscopic precursors of yielding. This project will provide the student with a first-hand experience of modern computational physics approaches to soft matter and will form the foundation for future, more advanced studies on the brittle-to-ductile transition in amorphous solids.
Promising student will be considered to continue this investigation into a PhD, to this aim and ANR project has been submitted.

See H. Bhaumik, G. Foffi, & S. Sastry, *The role of annealing in determining the yielding behavior of glasses under cyclic shear deformation*, Proc. Natl. Acad. Sci. U.S.A. 118 (16) e2100227118, https://doi.org/10.1073/pnas.2100227118 (2021).

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