How slow is the glass flow?

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Glasses and the glass transition stand, in the much quoted estimate of a Nobel laureate, as “perhaps the deepest and most interesting unsolved problem in condensed matter physics”. One of the most provocative aspects, concerns the slowing down of the dynamics on decreasing the temperature of the melt. When a liquid is cooled below its melting temperature, it usually crystallizes. However, if the quenching rate is fast enough, the system may remain in a disordered state, progressively losing its fluidity upon further cooling. When the time needed for the rearrangement of the local atomic structure reaches approximately 100 seconds, the system becomes “solid” for any practical purpose, and this defines the glass transition temperature Tg. Approaching this transition from the liquid side, different systems show qualitatively different temperature dependencies of the viscosity, and accordingly they have been classified by introducing the
concept of “fragility.” In a highly cited paper appeared in SCIENCE magazine, we reported experimental observations that relate the microscopic properties of the glassy phase to the fragility. Based on that, we extend the fragility concept to the glassy state and indicate how to determine the fragility uniquely from glass properties well below Tg. More recently, by determining glass fragility for systems with different fictive temperature, we answer a question of of pivotal importance for glass formation theories: “Does the glass cease to flow at some finite temperature?” Our results, reported on PNAS, ultimately rules out the finite-temperature divergence of the molecular diffusion timescale in a glass.

Recent Inelastic X-ray Scattering (IXS) measurements of the dynamic structure factor have allowed the constitution of a sizeable library of high-frequency (THz) dynamical properties of glasses. These measurements allow, in particular, the determination of the nonergodicity factor, f(Q,T), i.e. the long time limit of the normalised density-density correlation function. This quantity represents the amount of decorrelation introduced by the vibrational dynamics, and it depends on both the (T-dependent) amplitude of the vibrations
and the degree of disorder of the glassy structure. We show that the low temperature dependence of the non ergodicity factor for several glasses stands in a fashion similar to the one exhibited by the Angell plot. It is indeed possible to define a glass fragility as the derivative of f(Q,T) in the T = 0 limit.