Dr Nussinov and Dr Kelton are professors at Washington University in Saint Louis. Dr Weingarter recently completed his PhD studies in Dr Nussinov’s group. A shared passion of these three researchers concerns the nature of one of the most common states of matter – glass. A deeper theoretical understanding of glasses may, in turn, lead to numerous applications. Apart from improving age-old studied silicate glasses (such as those used in windows), an understanding of the structure and dynamics of glasses might also have profound ramifications to the many varied and far more recently discovered glass formers currently appearing across diverse arenas. These applications include those of bioactive materials, new drug design (organic glasses are more soluble than crystals), and various industries.

Understanding glassy dynamics

One of the most interesting, yet challenging issues in physics is the enigmatic behaviour of glasses. These complex systems can be contrasted with the far better understood ordered crystals. Glasses are rigid. However, unlike crystals, glasses are not neatly ordered.

The periodic, ordered structures of crystals have long captivated scientists. In the 17th century, long before the discovery of the atom, prominent scientists such as Robert Hooke (an astronomer, physicist and first biologist to coin the term “cell”), Christiaan Huygens (a mathematician, physicist, and inventor of the first reliable pendulum clock) and their contemporaries proposed that the sharp facets of single crystals resulted from recurrent fundamental unit cell configurations. Indeed, as we now know, in simple crystals, the structure of extremely small atomic unit cells is replicated to span the entire system. In essence, this replication endows large crystals with quantum mechanical behaviours.

Traditionally, quantum mechanics describes very small spatial scales (e.g., single atoms and molecules). However, thanks to the periodic locations of atoms in a crystal, quantum mechanics comes to life on the very large spatial scale of the entire crystal; the well known quantum energy levels of electrons in single atoms lead to an analogous “band structure” in crystals. Indeed, the invention of solar cells and the transistor was made possible by the understanding of these precise band structures.

Inspired by these and other well known successes, Dr Nussinov initially proposed that (like crystals) the behaviours of glass formers might also be more readily understood within a quantum mechanical framework and provided a prediction for their viscosity. An intense pursuit followed in which the combined theory-experiment team of the three researchers and their collaborators examined the viscosities of all known glass formers and, to their delight, found that these conform to the theory’s predictions. Additional aspects and new related ideas were introduced and critically studied by the team (many of which are detailed at length in Dr Weingarter’s recent PhD thesis).

WHAT, PRECISELY, ARE SUPERCOOLED LIQUIDS AND GLASSES?

In principle, and provided that they are sufficiently rapidly cooled (so-called supercooled liquids), liquids can be cooled to their glass transition temperature, below which they become amorphous solids. Glassy materials are typically amorphous, non-crystalline solids where the atoms are still in motion. The random nature of these materials makes them excellent insulators and good at trapping gases.

Understanding the nature of glassy dynamics is one of the few remaining unsolved and challenging issues in condensed matter physics, thus demonstrating the importance of the team’s research.
Providing a clear understanding of the true nature of glassy systems will revolutionise the way we look at and use glasses.