

Real-time latent heat emission during dynamic-compression freezing of water

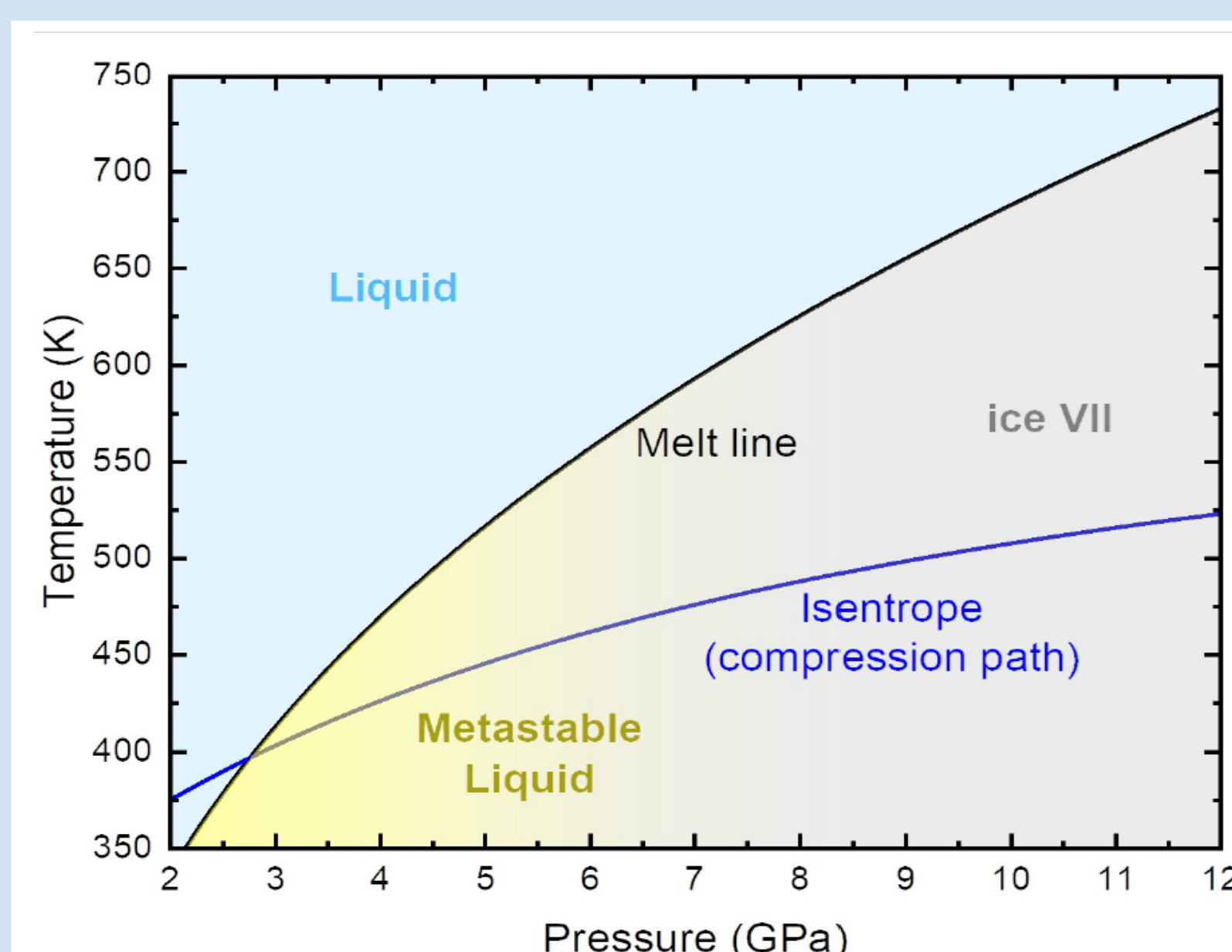


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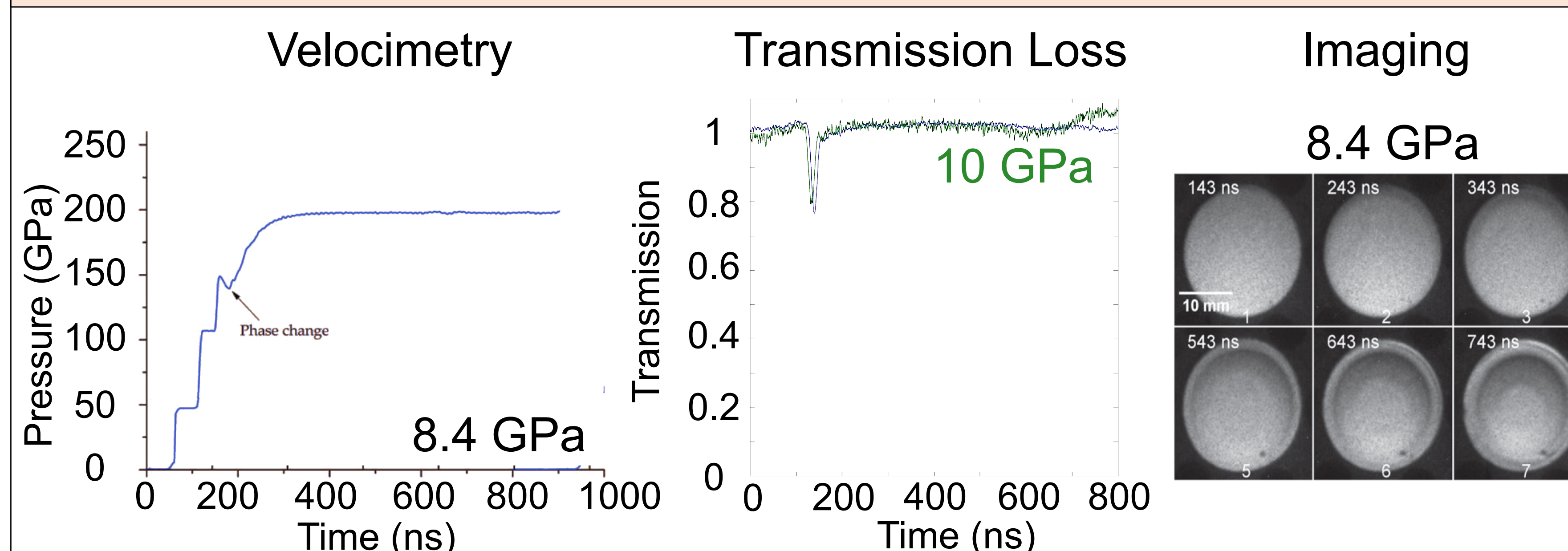
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Motivation

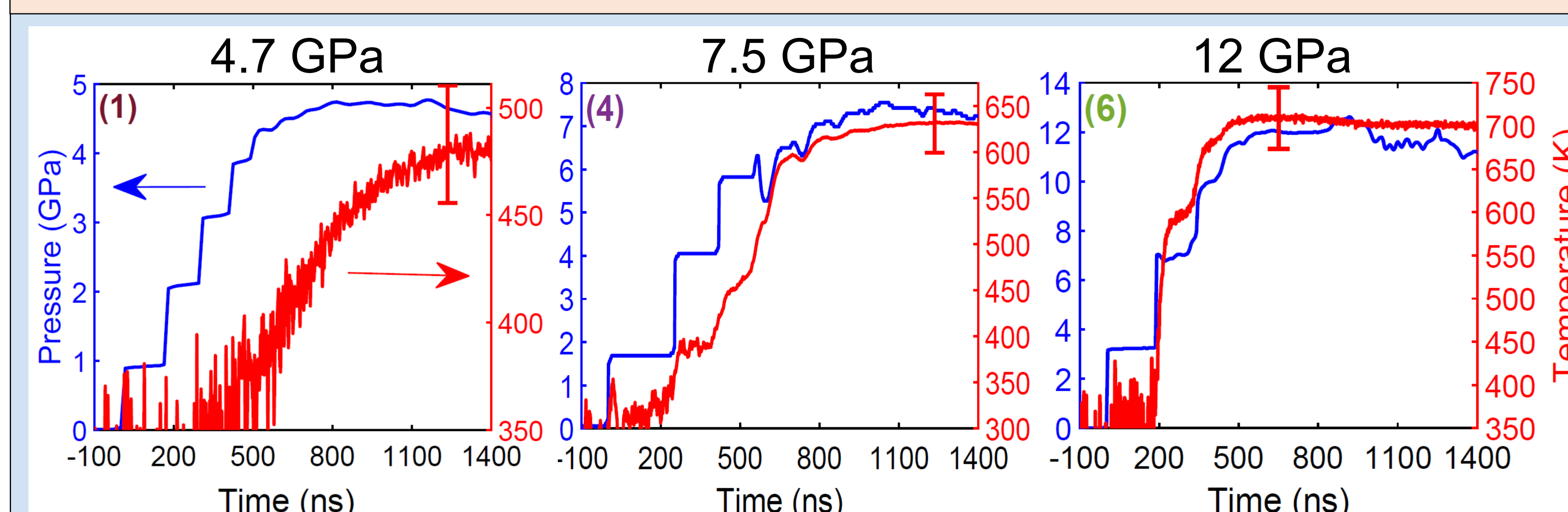
Advanced knowledge on the mechanism of freezing during isentropic compression is important for our nation's understanding of materials in extreme conditions. Water is one of the few materials known to freeze on nanosecond timescales during dynamic compression, and thus has been used to design classic nucleation theory (CNT) based models. We performed the first temperature measurements to better constrain those models.



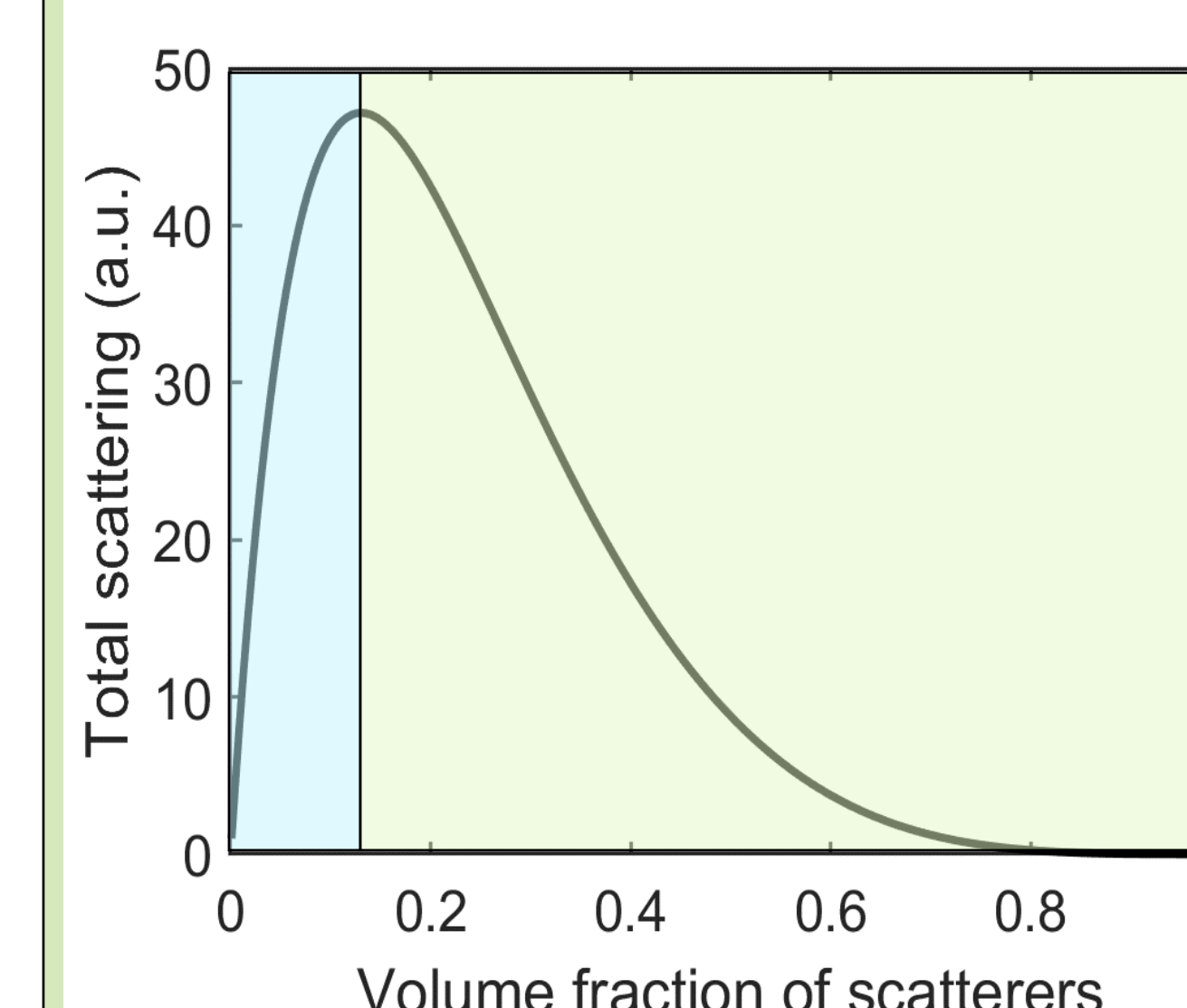
Background: Homogeneous Nucleation



Pressure & Temperature vs. Time Profiles



Does Dynamically Compressed Water have to be Completely Frozen to be Optically Transparent?

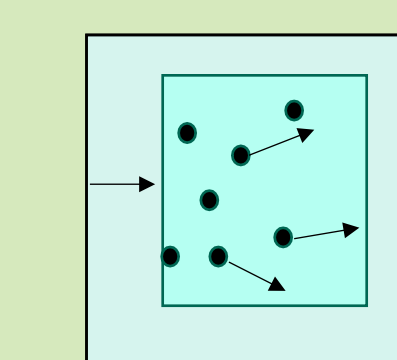


$$C_{total} = NC_{sca} S(\phi)$$

$$S(\phi) = \frac{(1 - \phi)^4}{1 + 4\phi + 4\phi^2 - 4\phi^3 + \phi^4}$$

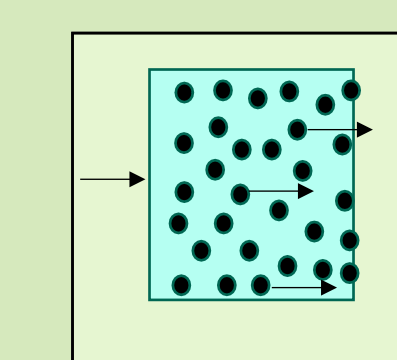
As the concentration of scatters increases, there are more scattering events, but also more destructive interference. The maximum total scattering occurs around 13% and decreases beyond this concentration.

Incoherent Scattering



Reduces Optical Transparency

Coherent Scattering

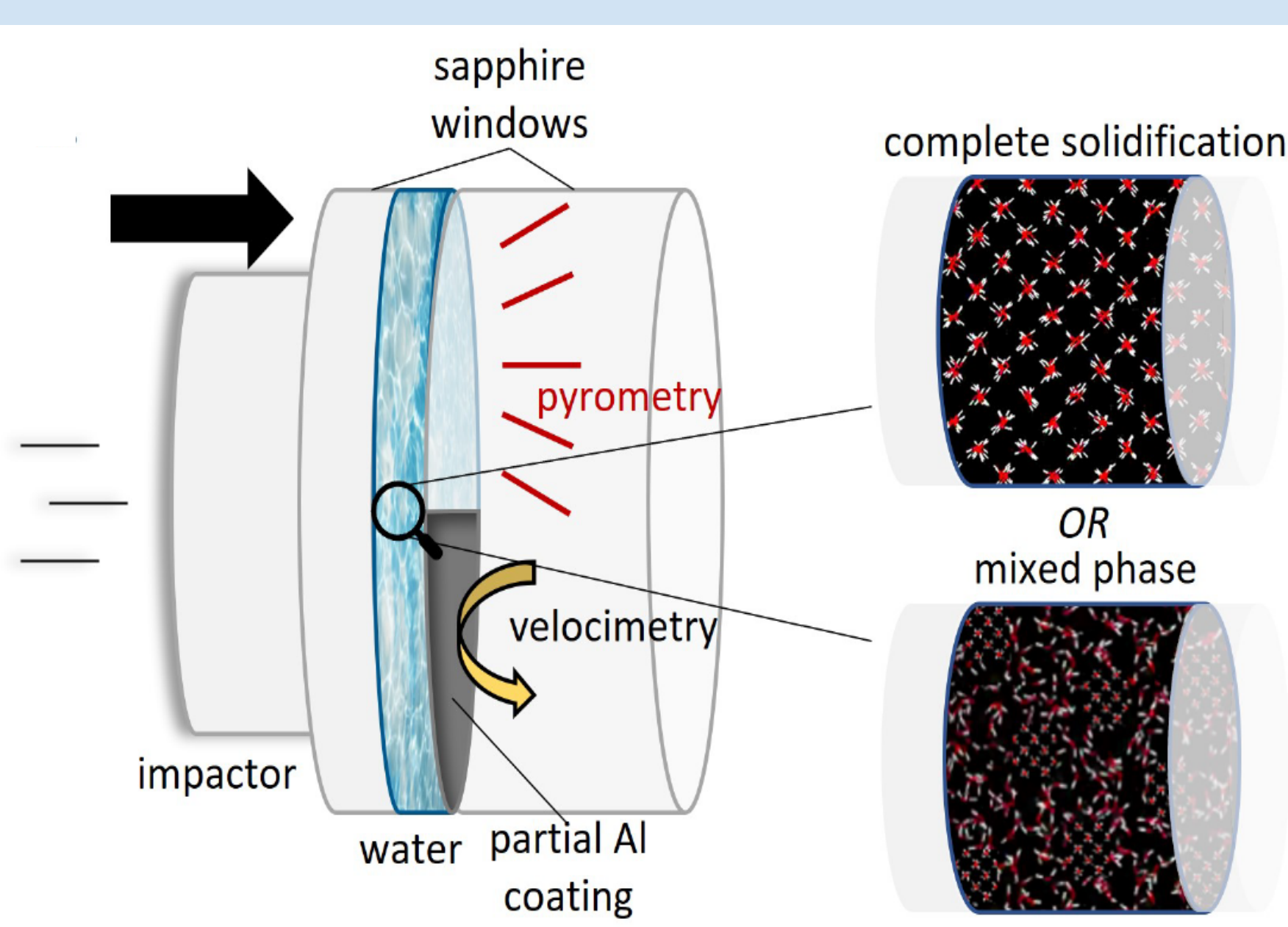


Appears Transparent

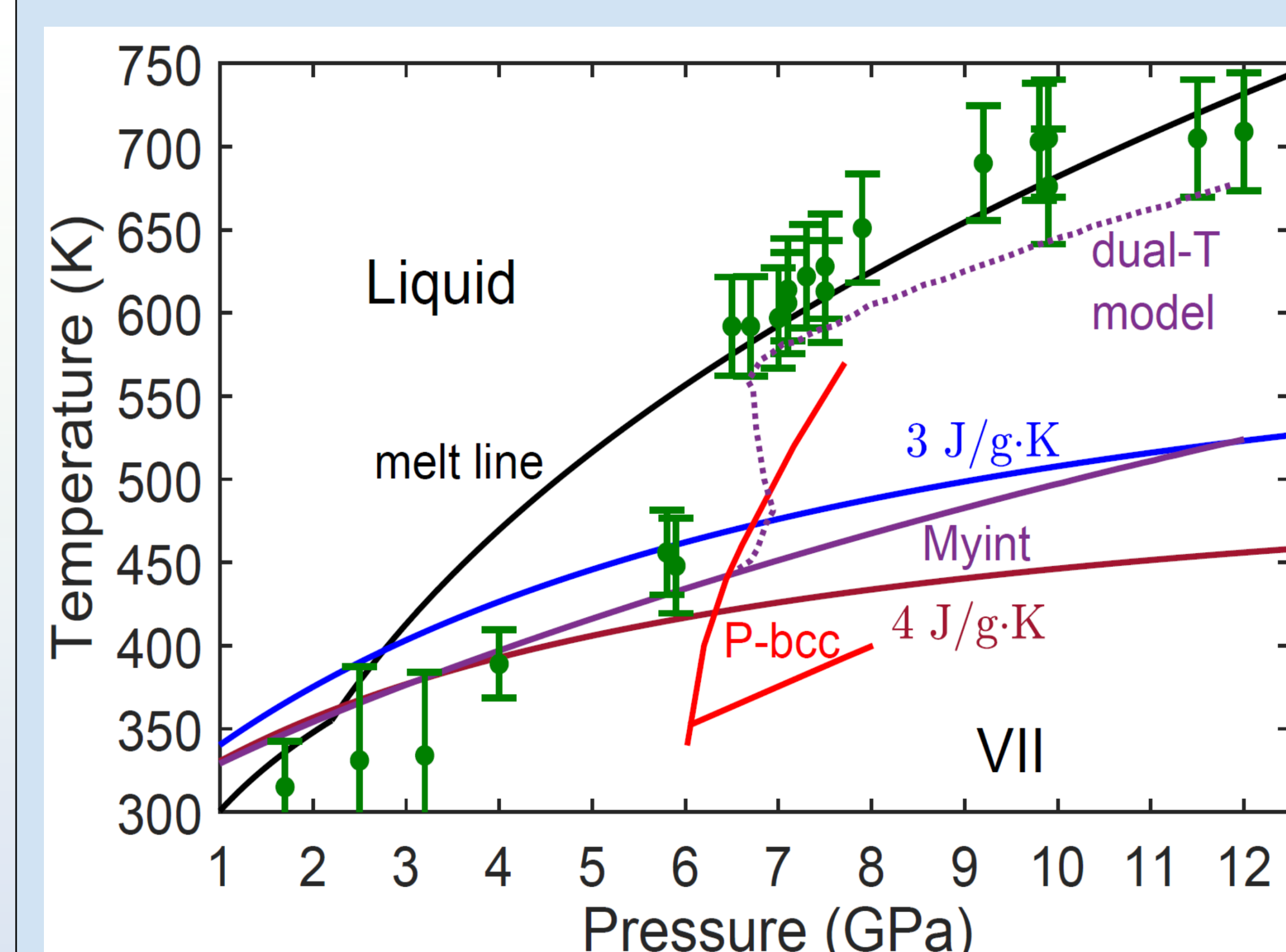
1% volume ice > 2000 scatters in a 500 nm cube

A similar argument explains transparency of the mammalian cornea and lens

Experimental Configuration



Phase Diagram for Water with Measured P-T States



Measured P-T states (green circles) compared to three calculated isentropic compression paths, the dual-temperature model derived from coupling CNT and growth with hydrodynamic simulations, and predicted plastic ice phase from molecular dynamics using TIP4P/2005 models.

Future Plans & References

E.J. Nissen, B.M. La Lone, J.G. Mance, E. Larson, and D.H. Dolan, *Communication Physics*, 6, 156 (2023).

Explore pressure & temperature of heavy water – does heavy water completely freeze, why?

LDRD on pressure shear plate impact (PSPI) of water and heavy water – can PSPI define phase changes?

Develop fluorescence anisotropy technique and apply it to water – can anisotropy define viscosity?

