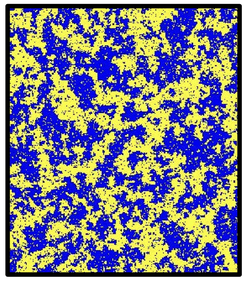
Motivation

We are searching for **new nanometer-scale forces** outside the Standard Model.

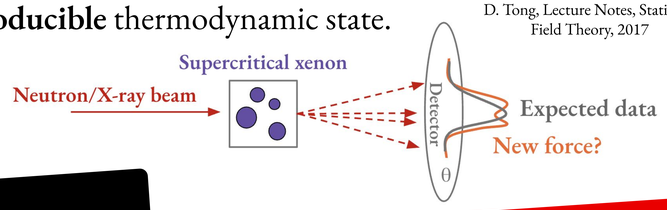
These should be visible using x-ray and neutron small-angle scattering off of cluster-like structure at 1-10 nm scales. Supercritical fluids have this structure.

To compare data between experiments, however, we need a **stable and reproducible** thermodynamic state.

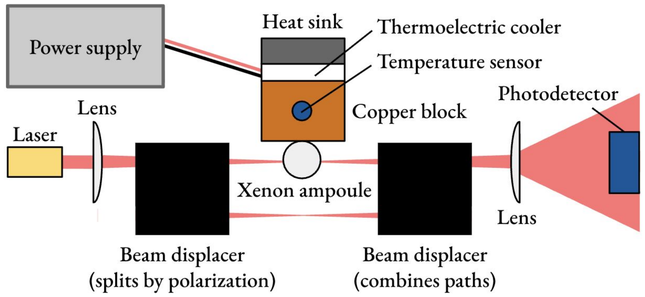


Fluid structure near the critical point.

D. Tong, Lecture Notes, Statistical Field Theory, 2017



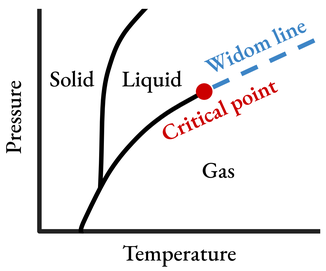
Setup



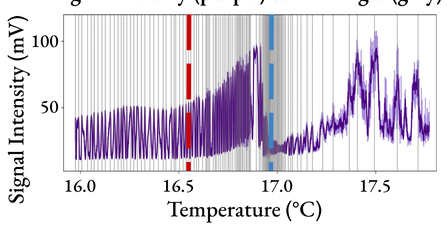
Changes in xenon density **affect the optical path difference between beams**, causing interference fringes to move.

Results

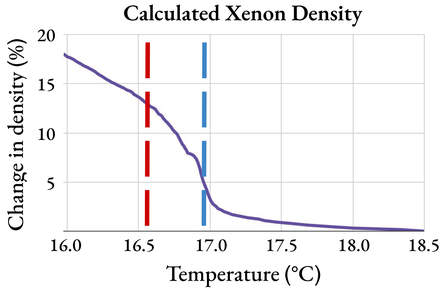
We tracked interferometer fringes across the **critical temperature** and the **Widom line**, an extension of the gas-liquid phase boundary into supercritical space.



Light Intensity (purple) with Fringes (gray)



Calculated Xenon Density



Interferometers can **precisely track density changes** in supercritical fluids.

We intend to use this setup for a xenon-based **new force search.**

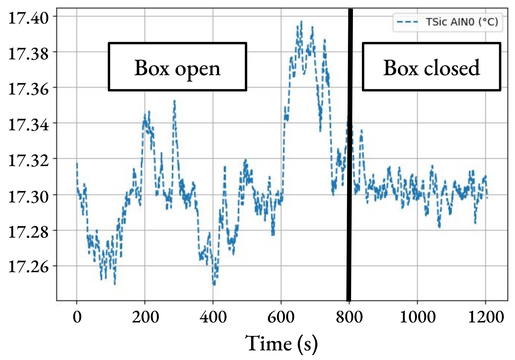
Presenter: Peter Bennett | Team: Soud Al Kharusi, Yan Sining, Giorgio Gratta

This research was supported by the DOE Office of Science.

Thermal Stability

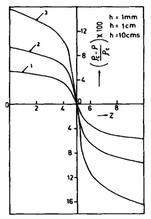
We use a thermoelectric cooler to control how much heat is pumped out of the ampoule.

With a proportional-integral-derivative controller and a box to block air currents, we achieve **±0.01°C stability** despite the ampoule being exposed to air.



Density Gradients

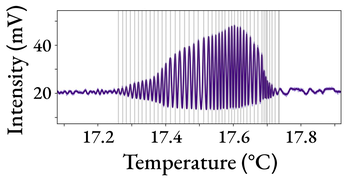
Isothermal compressibility is maximized at the Widom line, where gravity produces density gradients of up to ±10% at millimeter scales.



Chatterjee, S., et al. Pramana - J Phys 22, 203–212 (1984).

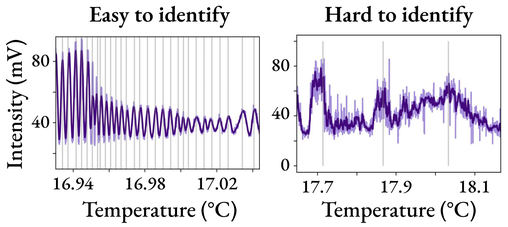
This gradient **causes our beam to bend**, with small fluctuations affecting the shape and intensity of the interference pattern.

Still, fringes are clearly visible in a focused temperature range.



Stability Tradeoff

Thermal noise, beam bending, scattering, and convection each produce noise and make gradual density changes hard to track.



Since we choose the conditions of our final experiment, we have a tradeoff to consider. **Moving closer to the critical point produces more interesting effects, but thermodynamic conditions become less reproducible.**