Superflow in solid helium

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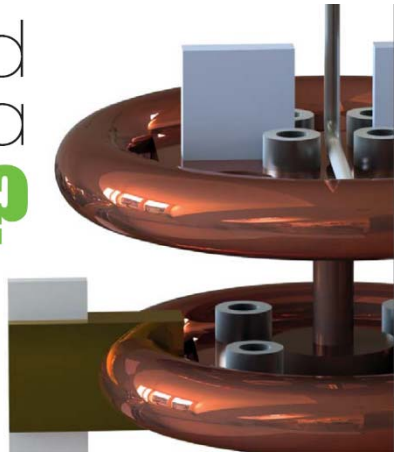
Is solid helium a SUPERSOLID?

Robert Hallock

Recent experiments suggest that helium-4 atoms can flow through an experimental cell filled with solid helium. But that incompletely understood flow is quite different from the reported superfluid-like motion that so excited physicists a decade ago.



Physics Today, May 2015

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Remarks on Solid Helium

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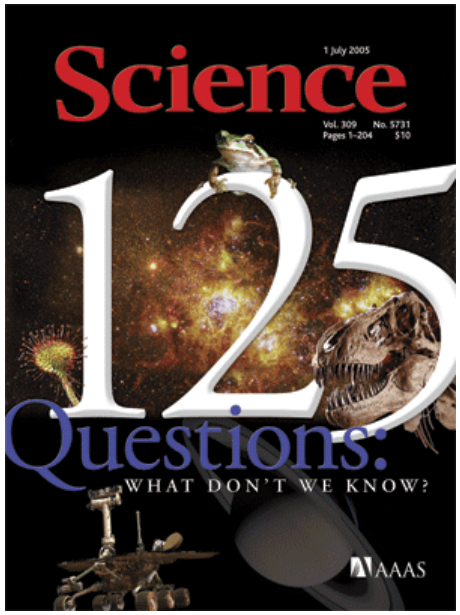
In this Special Issue, some of the fundamental and practical challenges and questions that appear to us to exist concerning the possibility of supersolidity or other unusual phenomena that may be present in solid helium are presented. The work of Kim and Chan stimulated a major rebirth of significant investigation of the properties and behavior of solid ^{4}He. In the intervening ten or so years, a number of discoveries have been made, but a number of early questions remain, and a number of new questions have emerged in recent years. Here, a number of issues that remain outstanding are presented. This list could no doubt be increased by other scientists active in these fields, but these ideas come to mind, stimulated by the recent work reported at LT27 and at this Workshop.

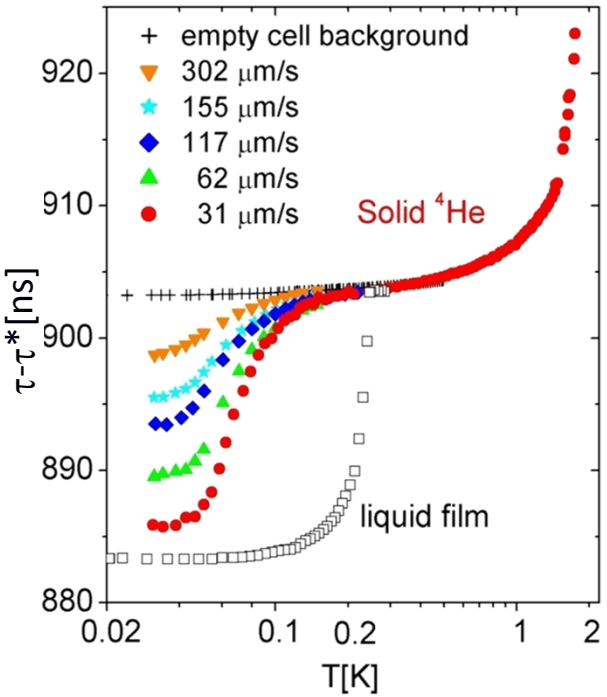


125 Questions :
what don't we know ?

Science (JUL, 2005)

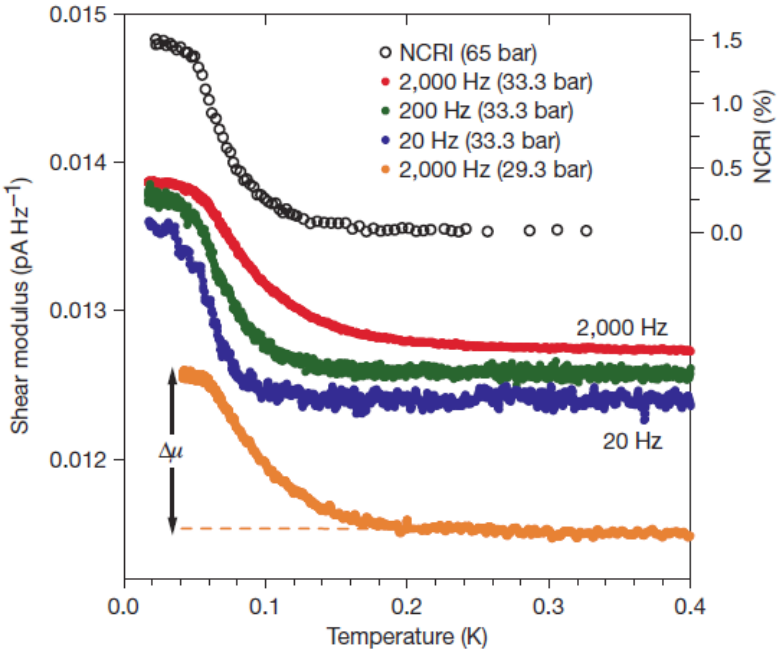
Is superfluidity possible in a solid? If so, how?
Despite hints in solid helium, nobody is sure whether a crystalline material can flow without resistance. If new types of experiments show that such outlandish behavior is possible, theorists would have to explain how.

Response of TO Containing Solid ^{4}He



E. Kim and MHW Chan, Nature **427**, 225 (2004).

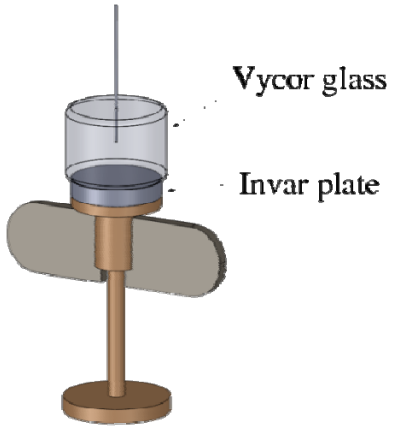
Shear Modulus Increase in Solid ^{4}He



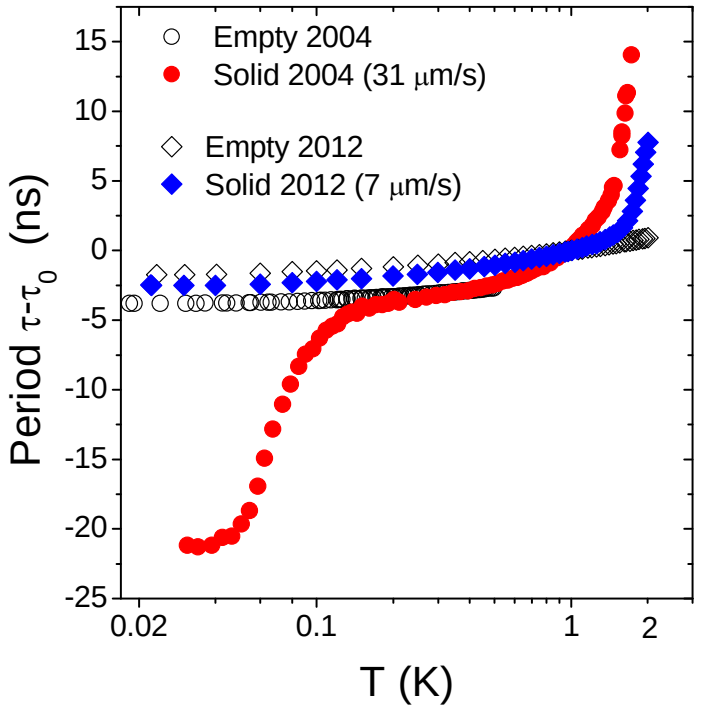
J. Day and J. Beamish, Nature **450**, 853 (2007).

Vycor TO - revisited

- Sealed by painting epoxy
- Tiny drilled fill line
- Mounted on a Invar plate

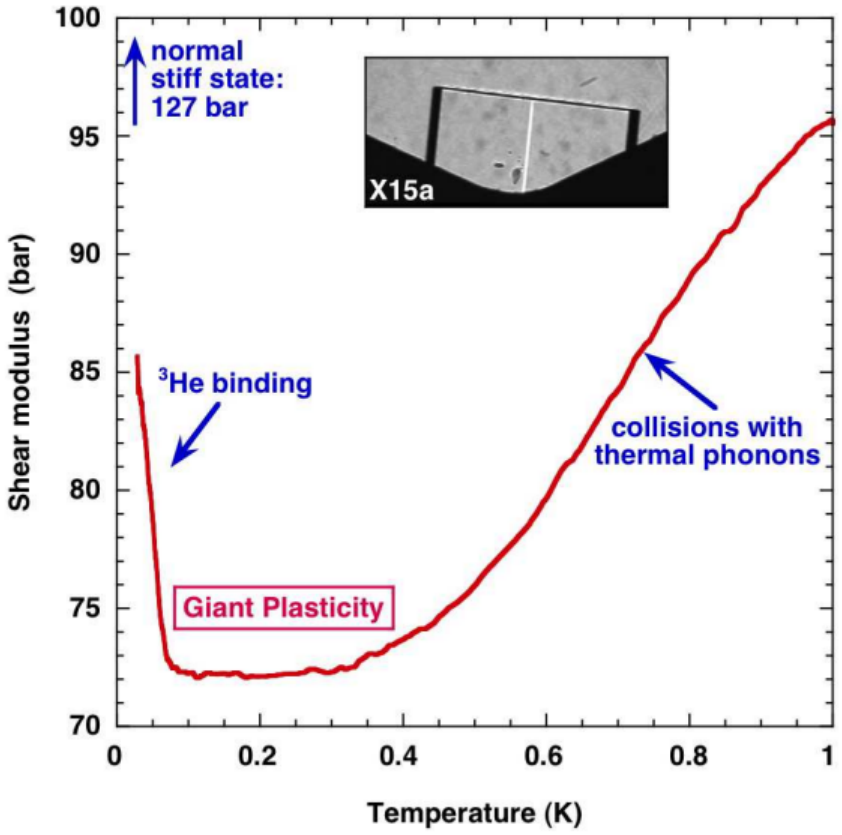


- Mass loading : 5100 ns
- Resolution : 0.1 ns (NCRI < 2×10^{-5})



D.-Y. Kim and MHW Chan PRL 109, 155301(2012)

Role of defects (Alberta/ ENS)



- Giant plasticity

Helium can be a unique model system for studying fundamental material science issues of dislocation creation, structure, motion, etc.

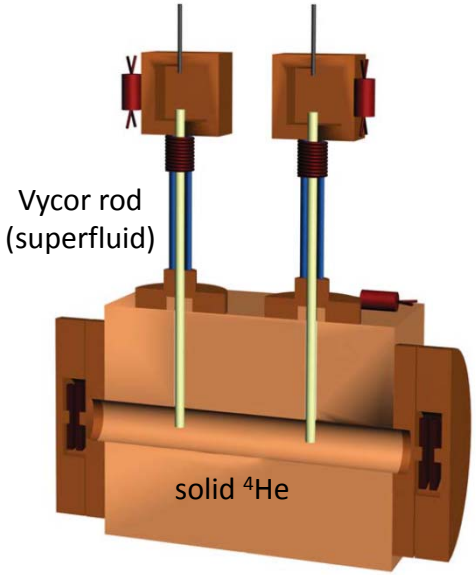
A. Haziot et al., PRL 110 035301 (2013)

Supersolid coming to an end?

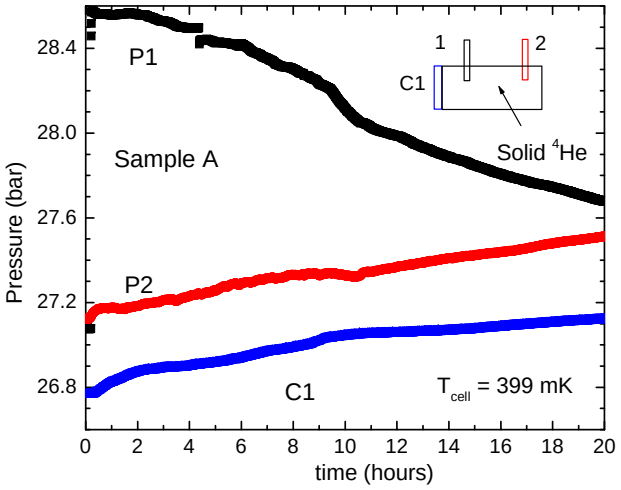
- Rotation Experiment? H. Choi et al, Science 2010
- Heat Capacity Experiment? X. Lin et al, Nature 2007
- Elusive supersolidity in double freq. TO (Reppy Group)

Flow through SF-Solid-SF Junction

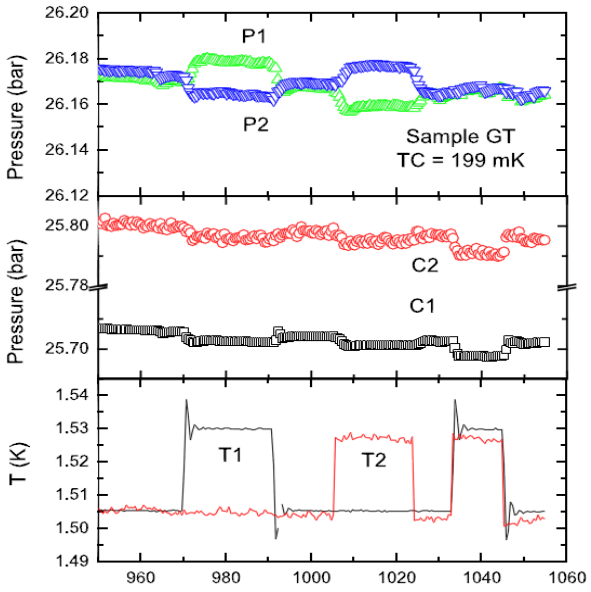
Hallock et. al, University of Massachusetts



The first sample that showed evidence for flow:

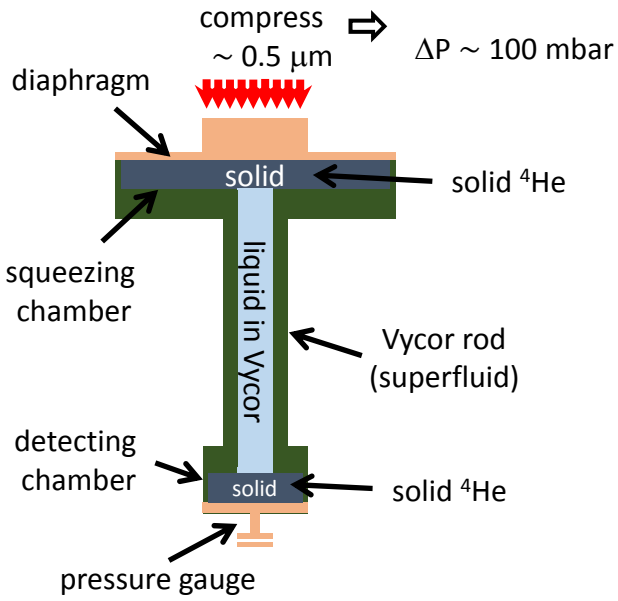


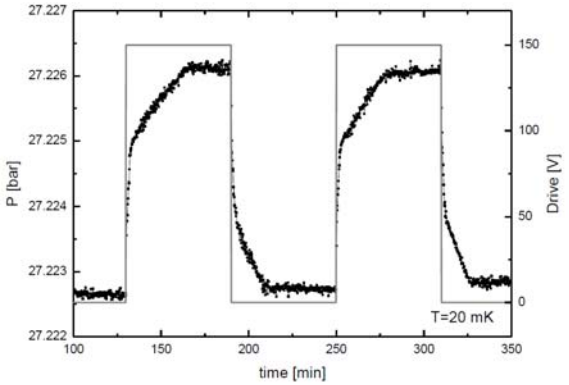
Chemical potential driven flow in UMass Sandwich



Flow through a solid-superfluid-solid junction

(Z Cheng et al. UAlberta/ENS PRL 2015)





P = 27.3 bar, 120 ppb ^{3}He

"squeeze" and "unsqueeze"

constant flow (linear) regions

Narrow gap (50μm)Junction in PSU