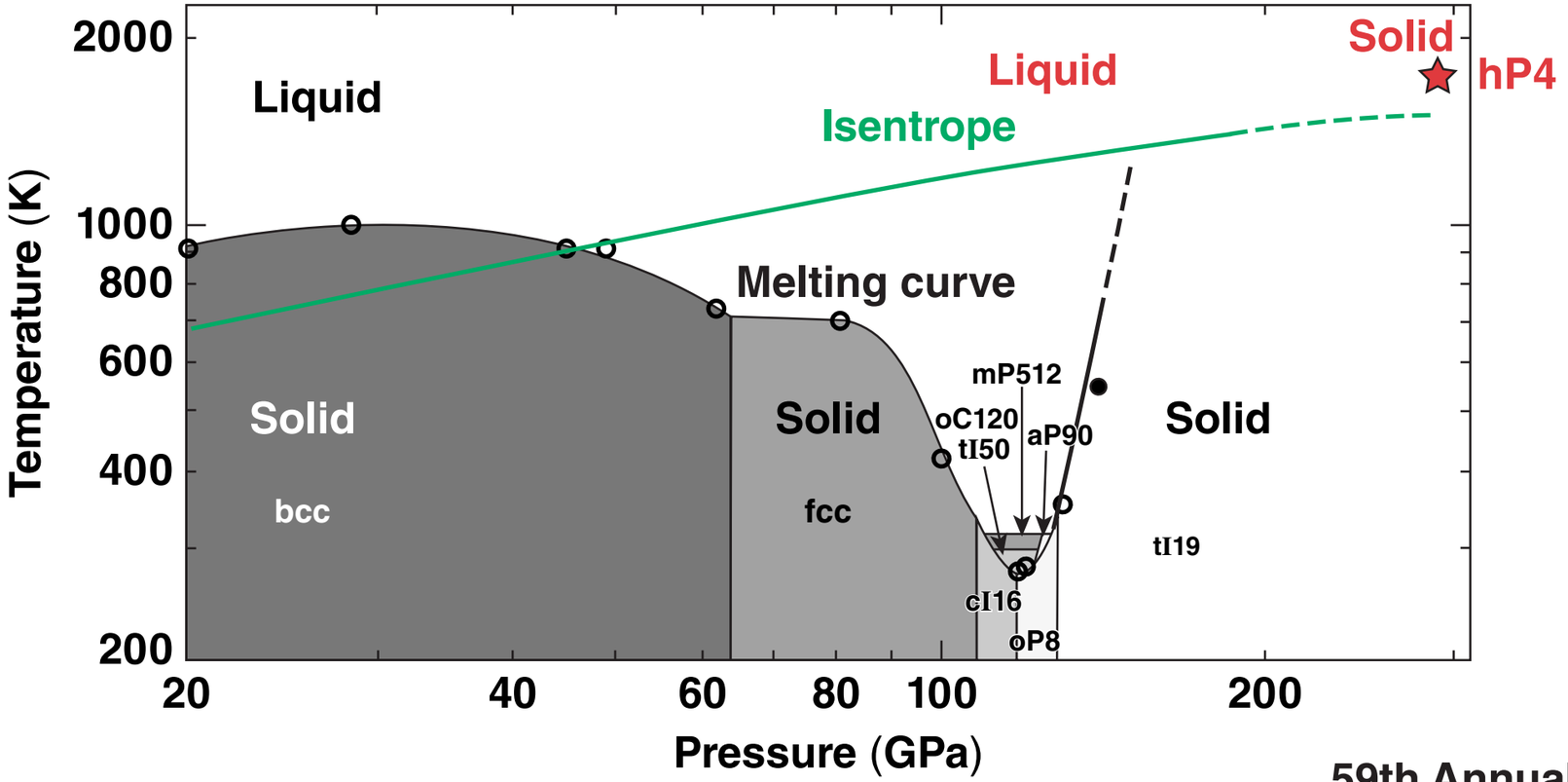
Sodium X-Ray Diffraction in the High-Pressure Regime



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American Physical Society
Division of Plasma Physics
Milwaukee, WI
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Summary

A solid hP4 phase of sodium has been observed at ~320 GPa

- Na has been previously observed to transform into an optically transparent phase at 200 GPa*
- The phase is predicted by simulation to be a structurally complex "electride" hP4 structure*
- Na was ramp compressed to ~320 GPa on the OMEGA EP Laser System and studied using *in-situ* x-ray diffraction
- The existence of the hP4 phase at ~320 GPa indicates that the rise of the melting temperature starting at 120 GPa continues even at higher pressures

*M. Marqués *et al.*, Phys. Rev. B 83, 184106 (2011).

Collaborators

D. N. Polsin, J. R. Rygg, T. R. Boehly, L. Crandall, B. J. Henderson, S. X. Hu, M. Huff, R. Saha, and G. W. Collins

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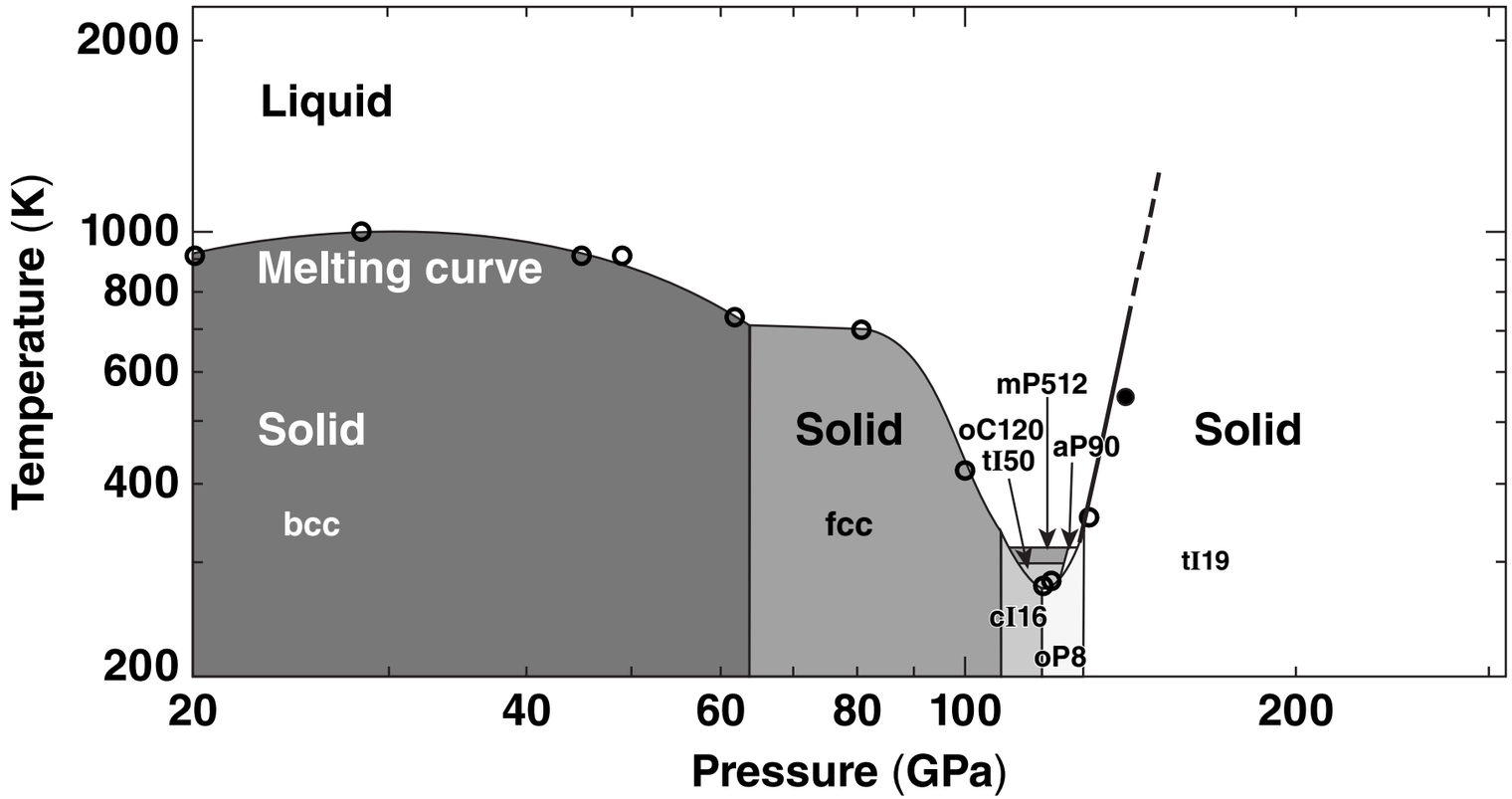
Lawrence Livermore National Laboratory

M. McMahon

Department of Physics, University of Edinburgh

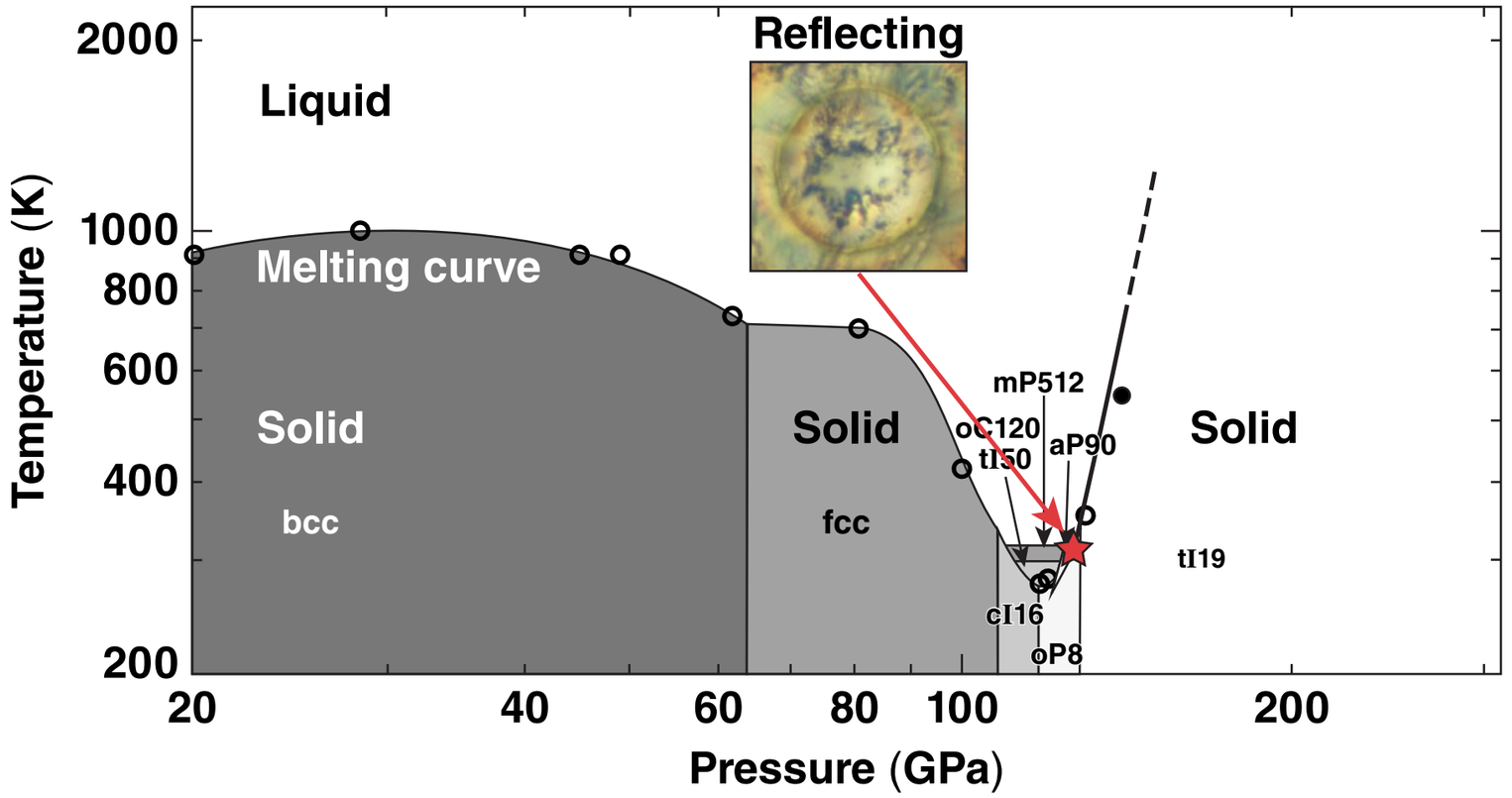
At high pressures, Na has a unique melting curve* that possesses a minimum at 120 GPa, then rises steeply



*M. Marqués *et al.*, Phys. Rev. B 83, 184106 (2011), and references therein.

TC13839

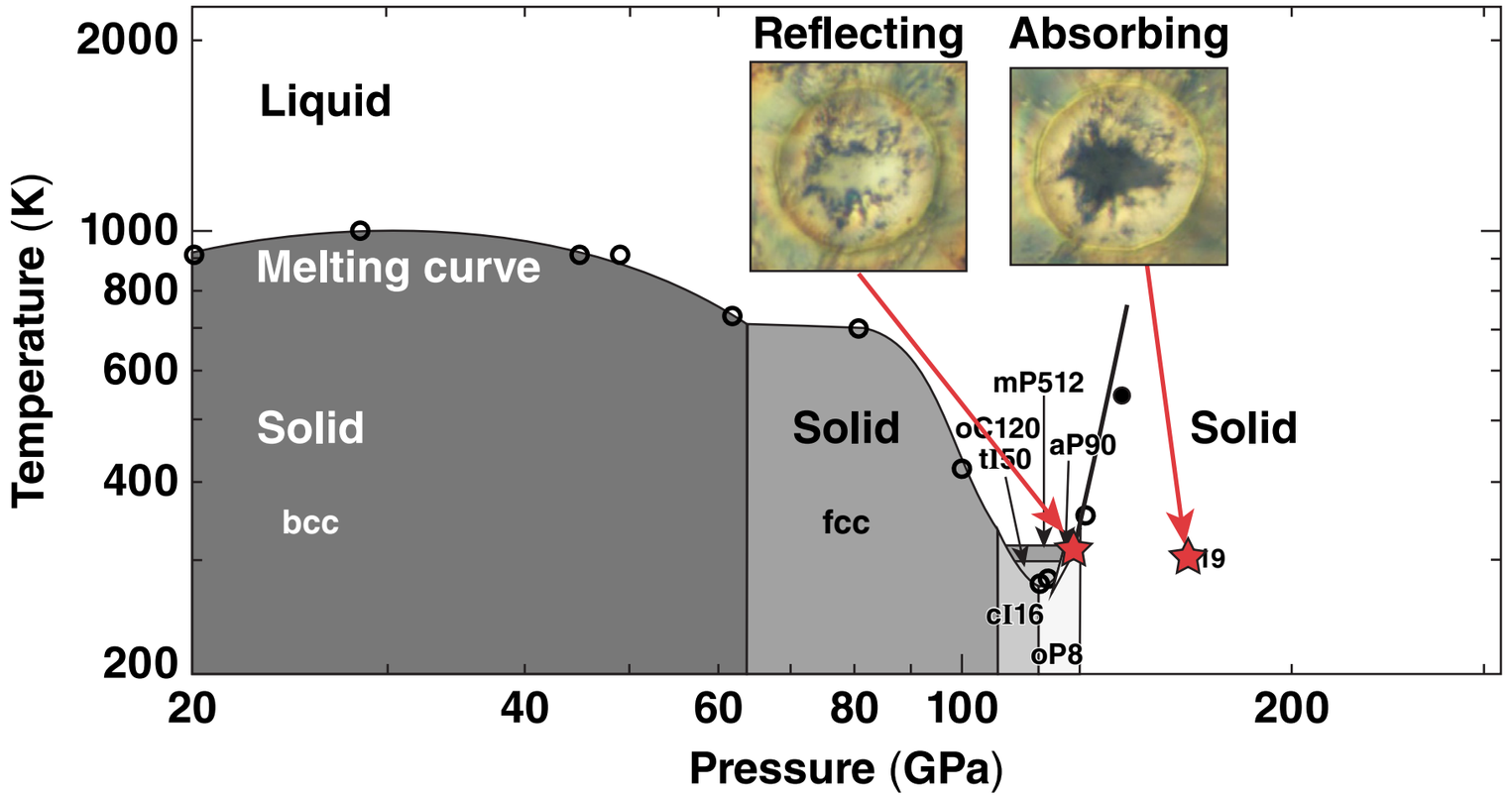
Diamond-anvil-cell (DAC) experiments* show that Na transforms into an optically transparent phase at 200 GPa



TC13840

*Y. Ma *et al.*, Nature 458, 182 (2009).

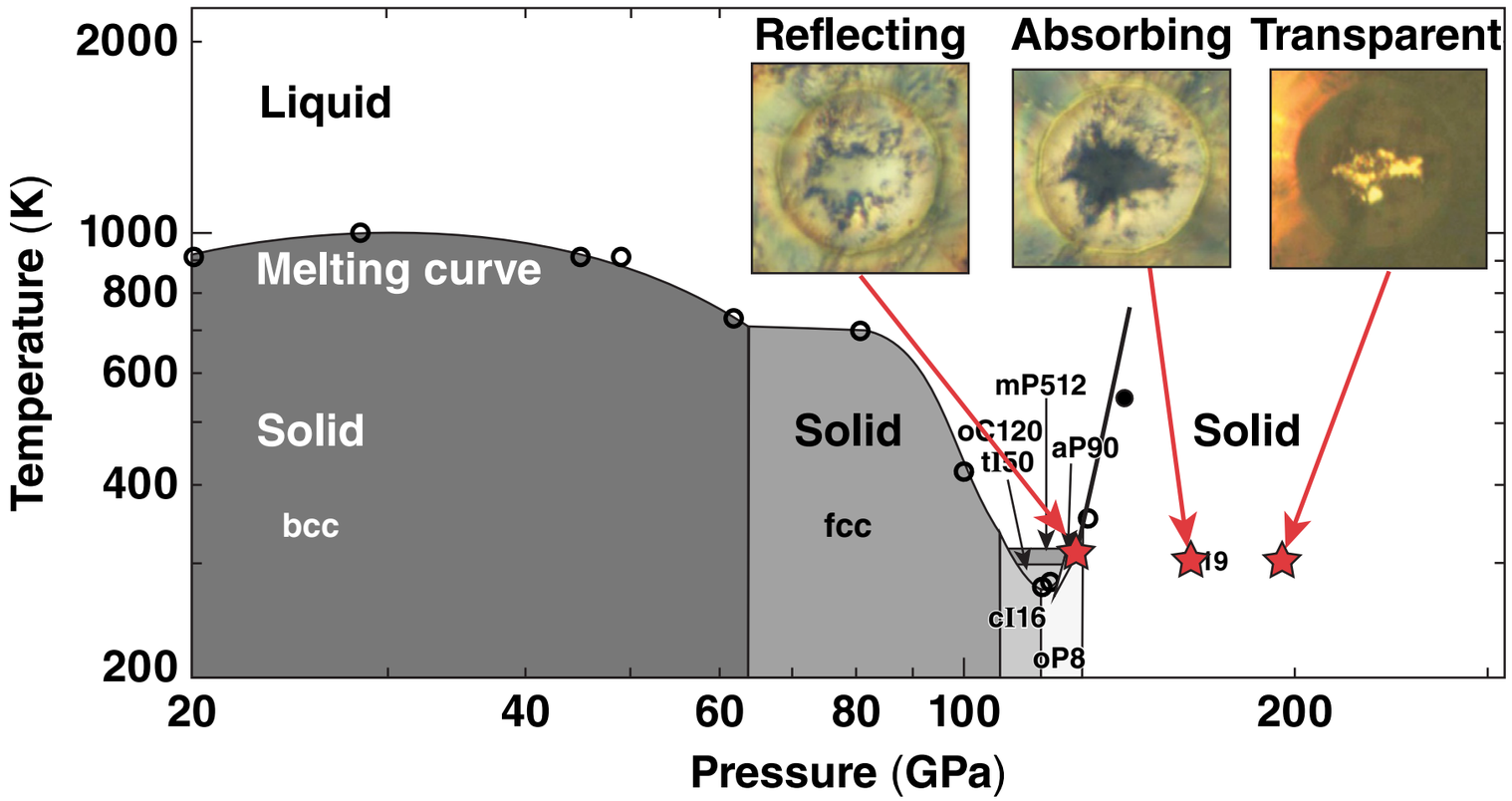
Diamond-anvil-cell (DAC) experiments* show that Na transforms into an optically transparent phase at 200 GPa



*Y. Ma *et al.*, Nature 458, 182 (2009).

TC13841

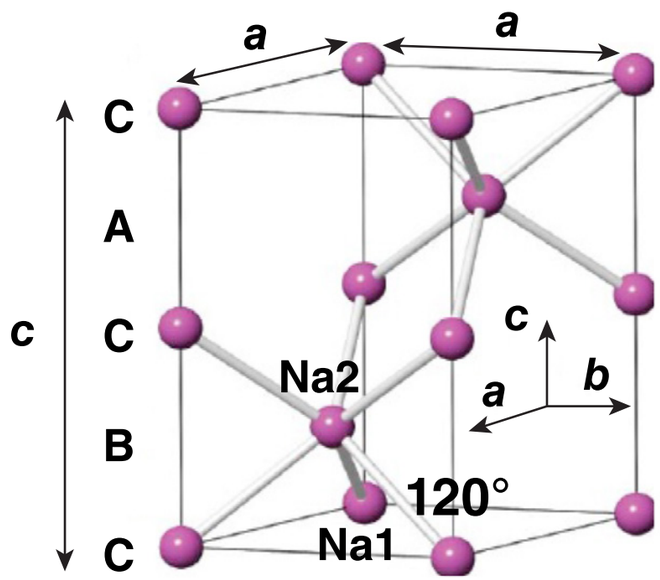
Diamond-anvil-cell (DAC) experiments* show that Na transforms into an optically transparent phase at 200 GPa



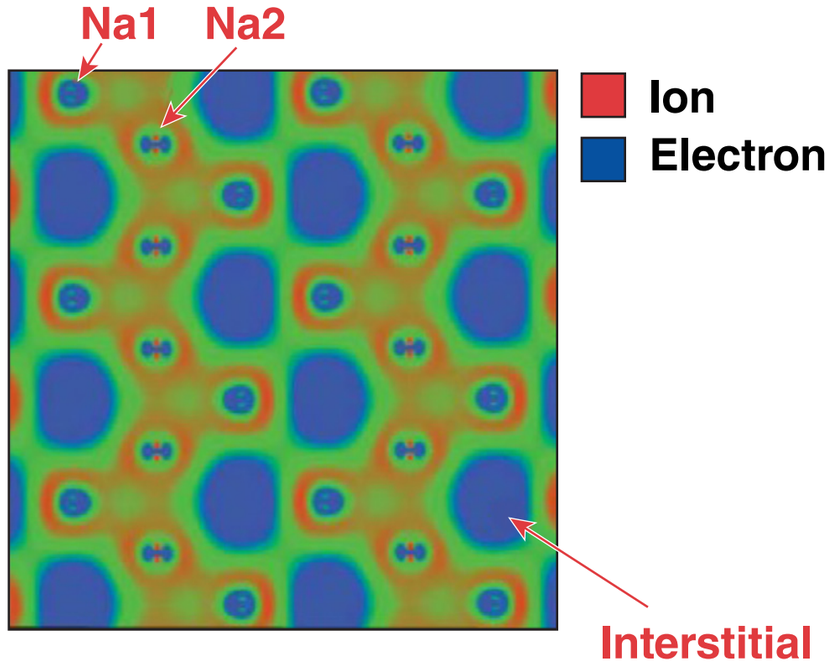
*Y. Ma *et al.*, Nature 458, 182 (2009).

TC13842

This phase is predicted* to be an “electride” hP4 structure, where conduction electrons are “trapped” in interstitial wells, producing an insulator



Electron localization function

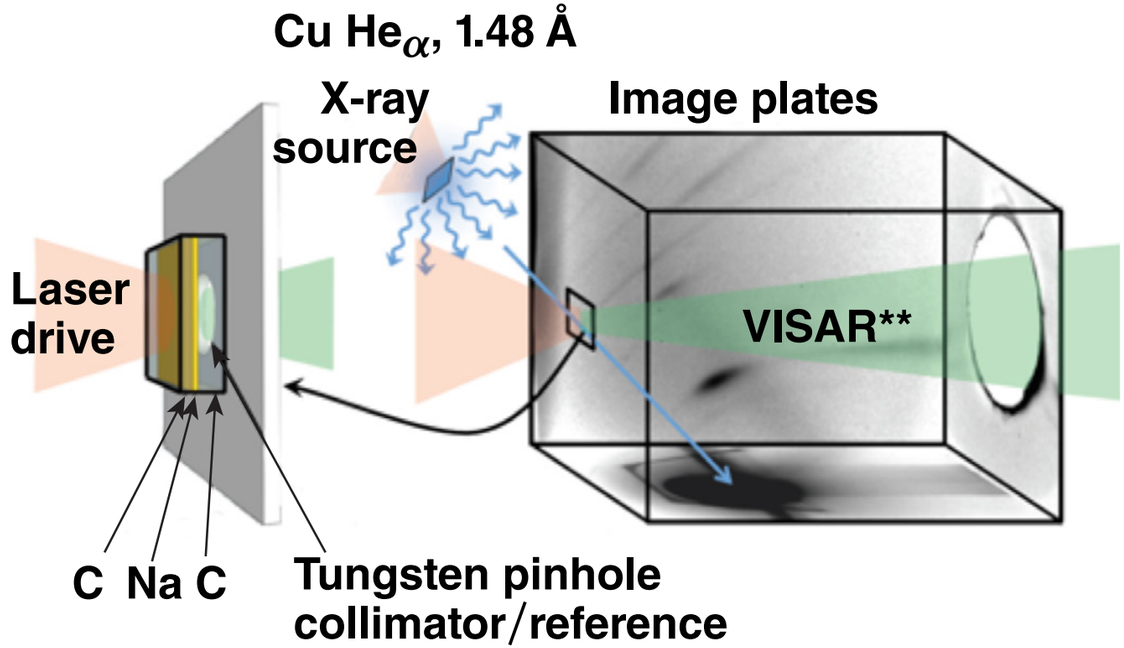


hP4: a double-hexagonal close-packed (dhcp) structure squeezed along the c axis.

*Y. Ma *et al.*, Nature 458, 182 (2009).

TC13843

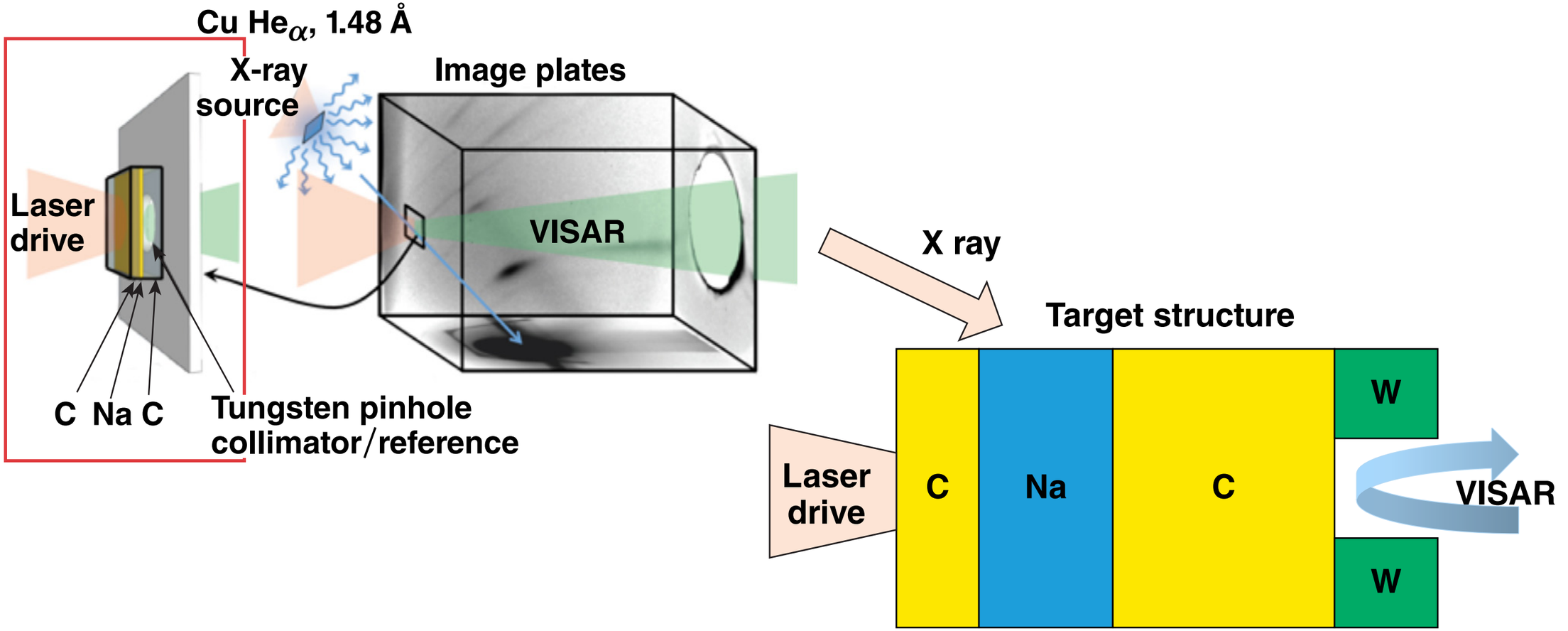
The powder x-ray diffraction image-plate (PXRDIP)* diagnostic is used to obtain diffraction data of a compressed powder Na sample



*J. R. Rygg *et al.*, Rev. Sci. Instrum. 83, 113904 (2012).
**VISAR: velocity interferometer system for any reflector

TC13844

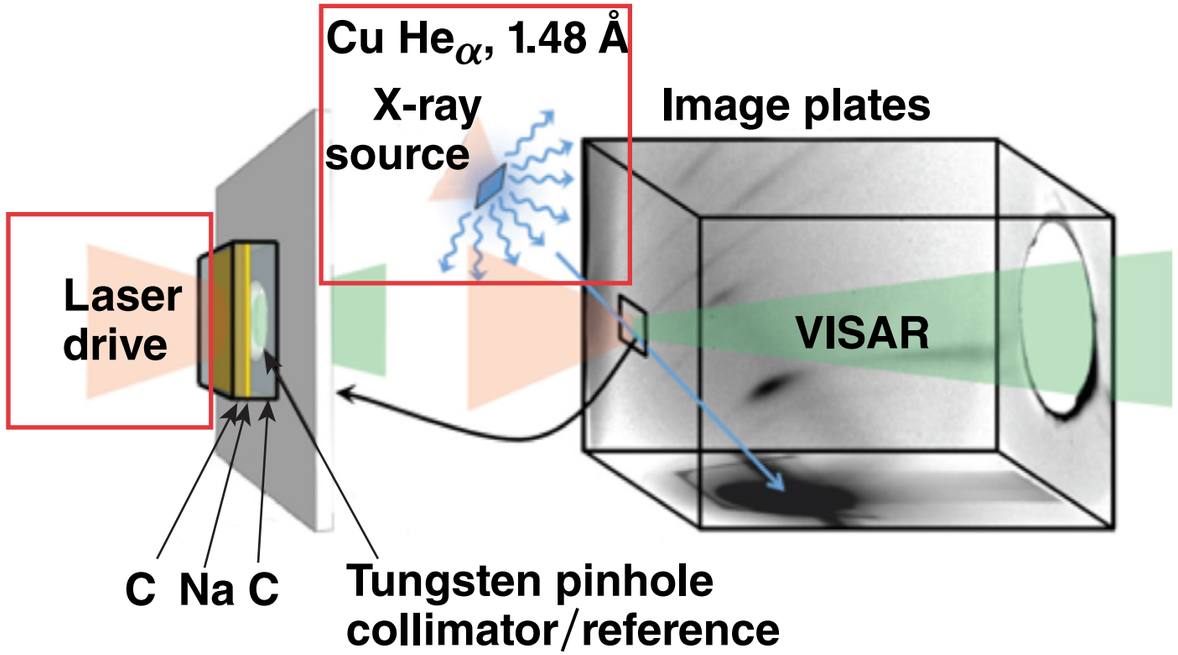
The powder x-ray diffraction image-plate (PXRDIP)* diagnostic is used to obtain diffraction data of a compressed powder Na sample

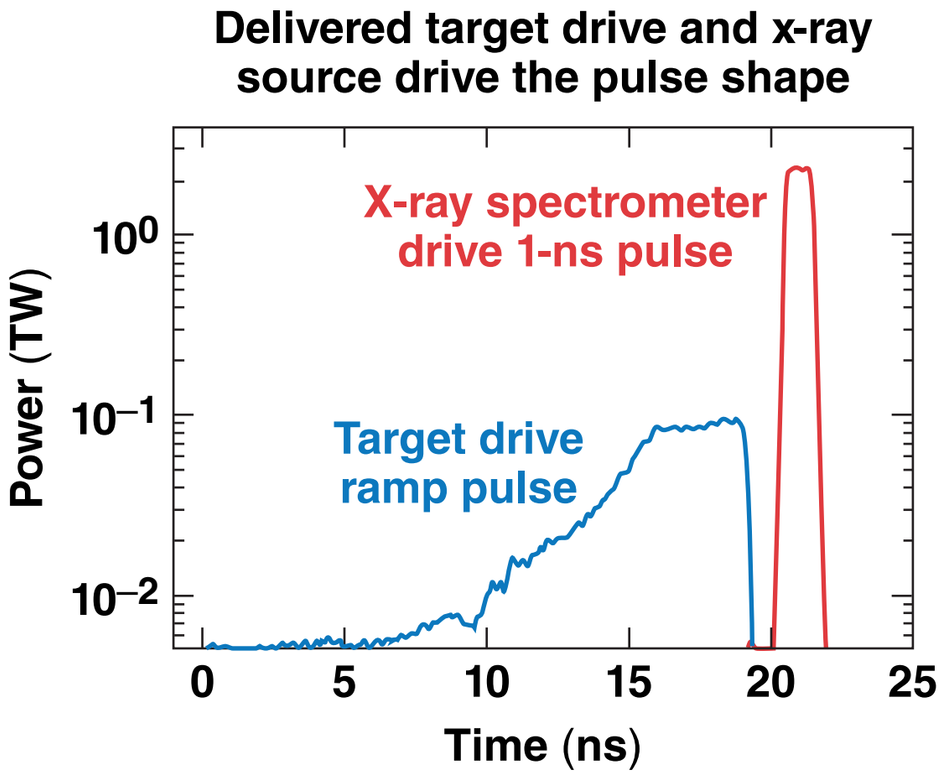


*J. R. Rygg *et al.*, Rev. Sci. Instrum. 83, 113904 (2012).

TC13845

The powder x-ray diffraction image-plate (PXRDIP)* diagnostic is used to obtain diffraction data of a compressed powder Na sample

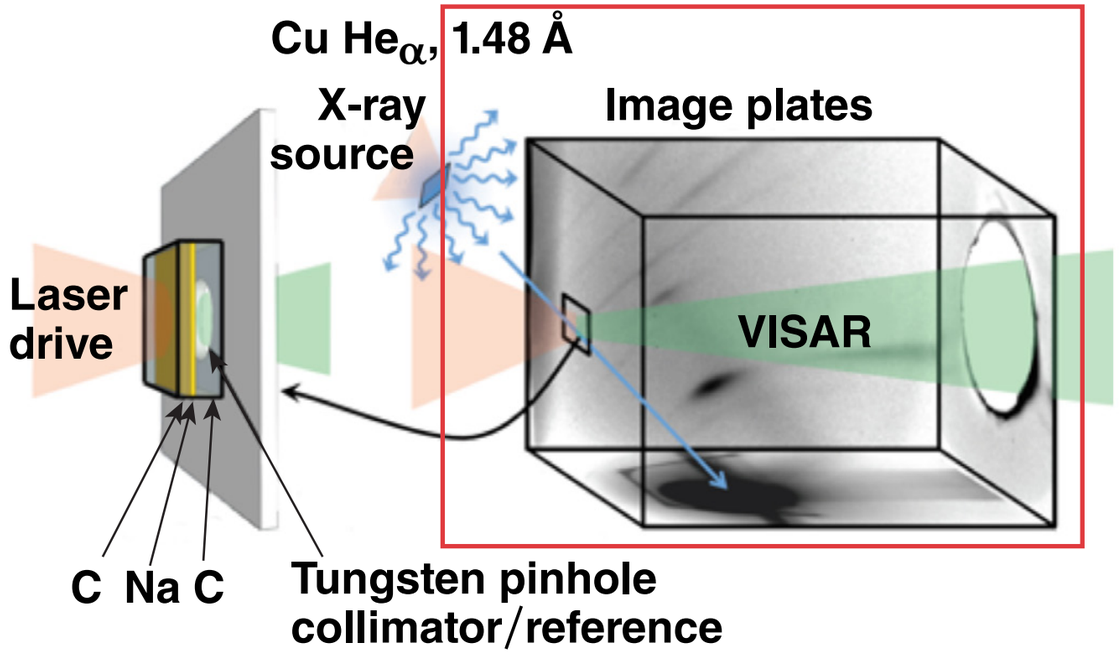


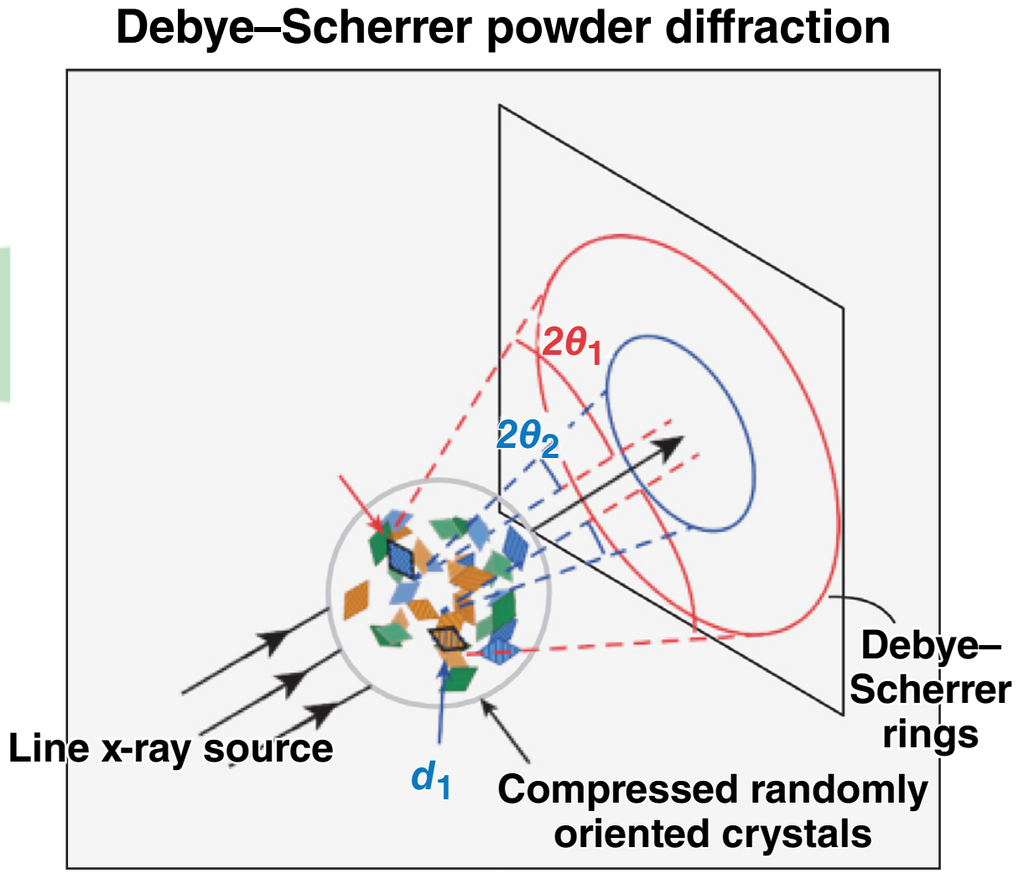


*J. R. Rygg *et al.*, Rev. Sci. Instrum. 83, 113904 (2012).

TC13846

The powder x-ray diffraction image-plate (PXRDIP)* diagnostic is used to obtain diffraction data of a compressed powder Na sample

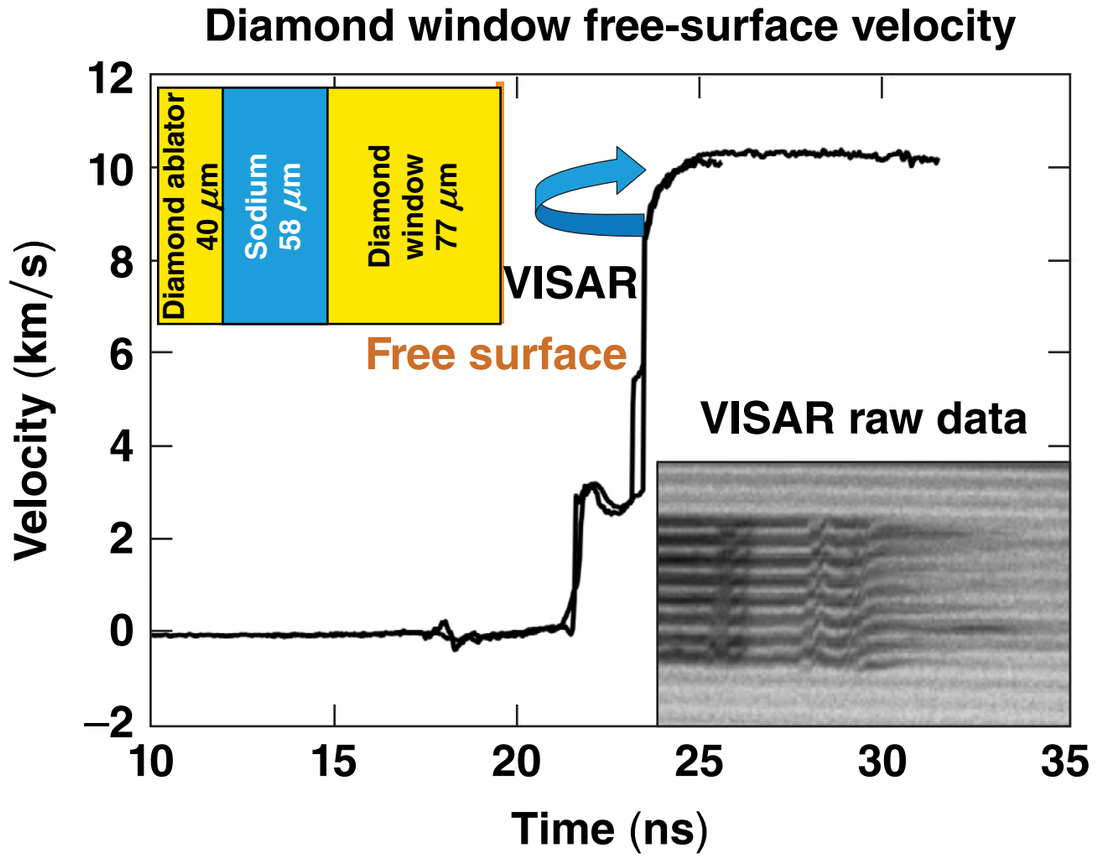


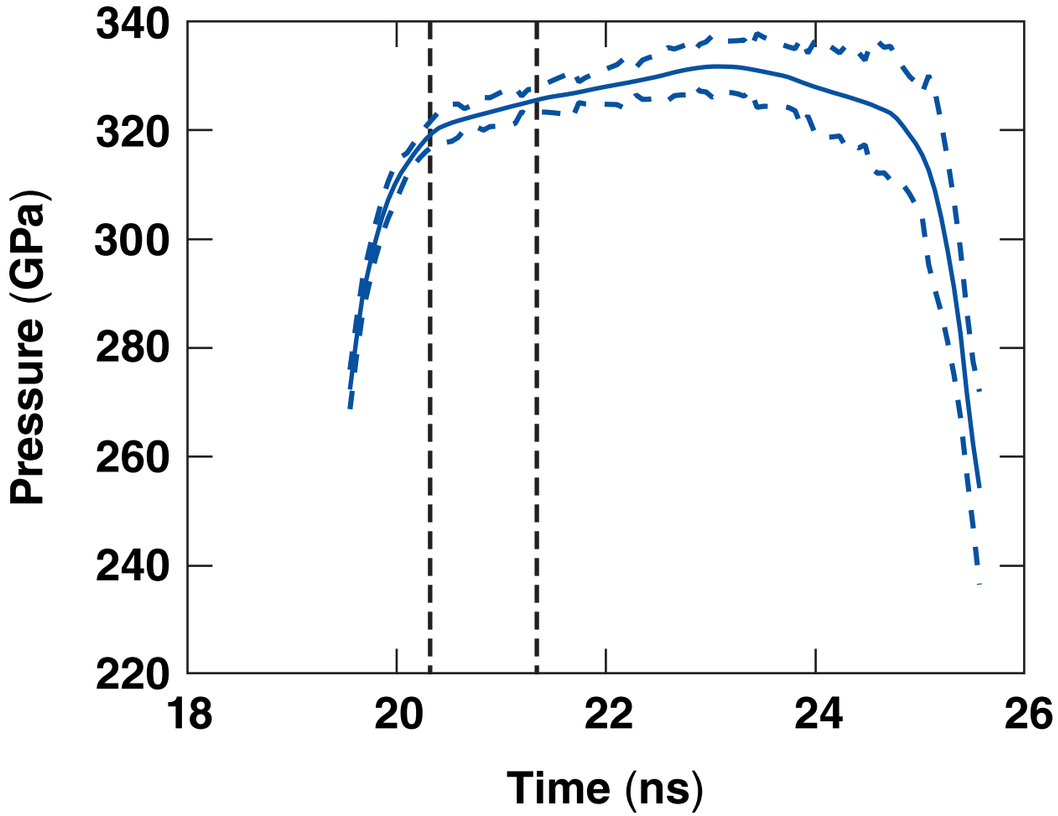


*J. R. Rygg *et al.*, Rev. Sci. Instrum. 83, 113904 (2012).

TC13847

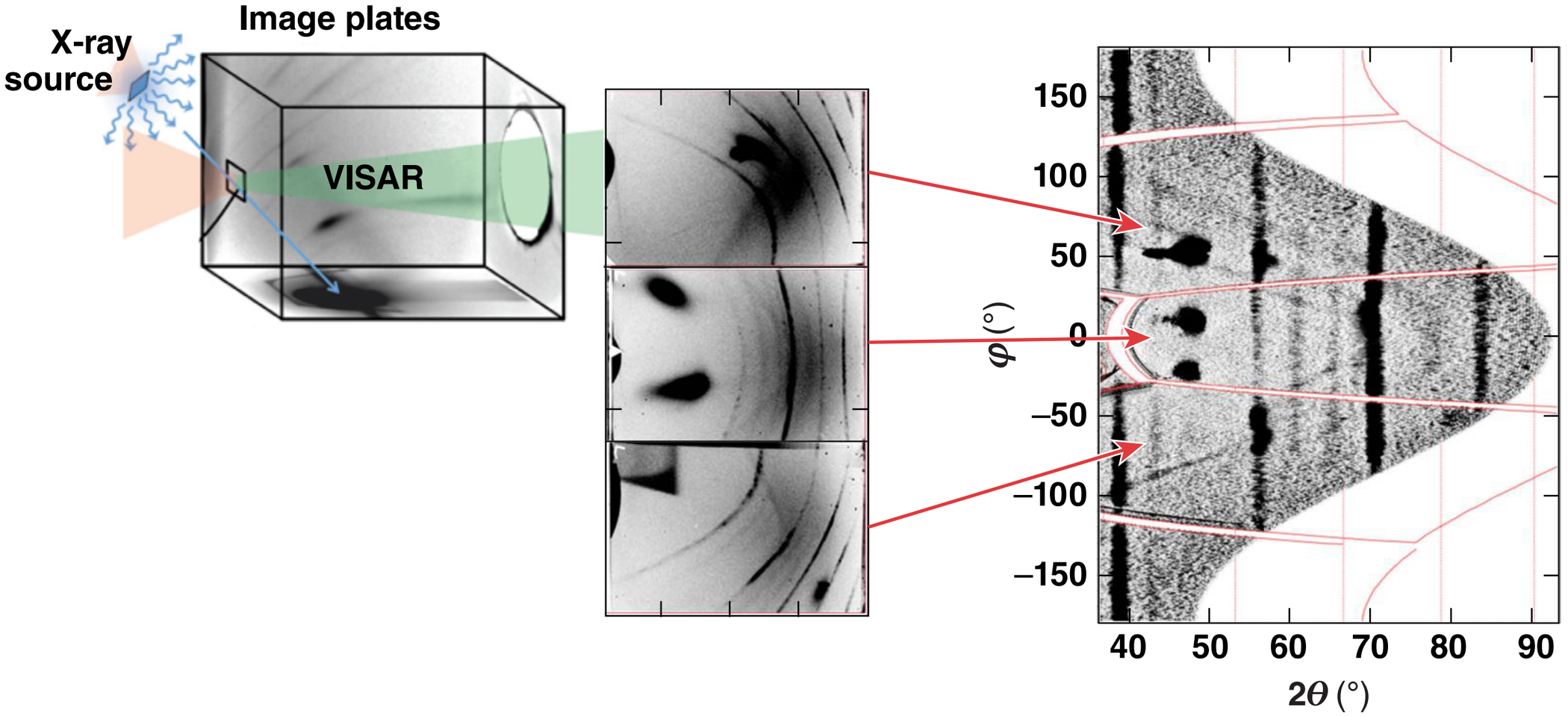
VISAR data are used to determine the velocity of the diamond free surface, which is back-propagated to determine the pressure in the Na sample





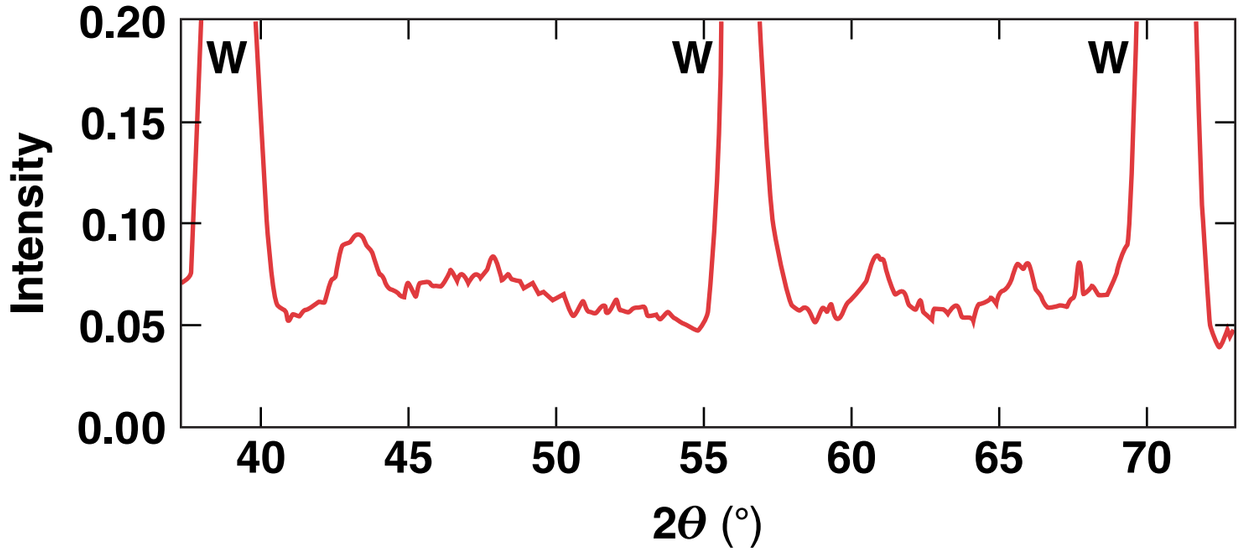
TC13848

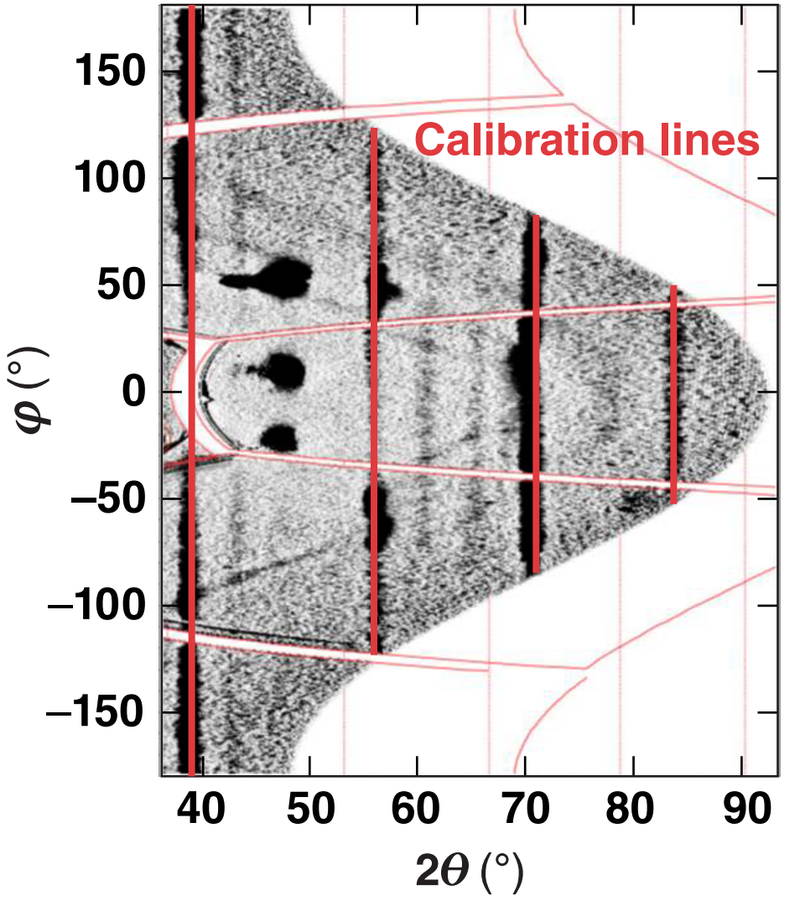
Raw diffraction data are scanned from image plates on five sides of the box and projected onto a φ–2θ plane



TC13849

The four brightest lines are tungsten bcc* diffraction signals, which are used for calibration

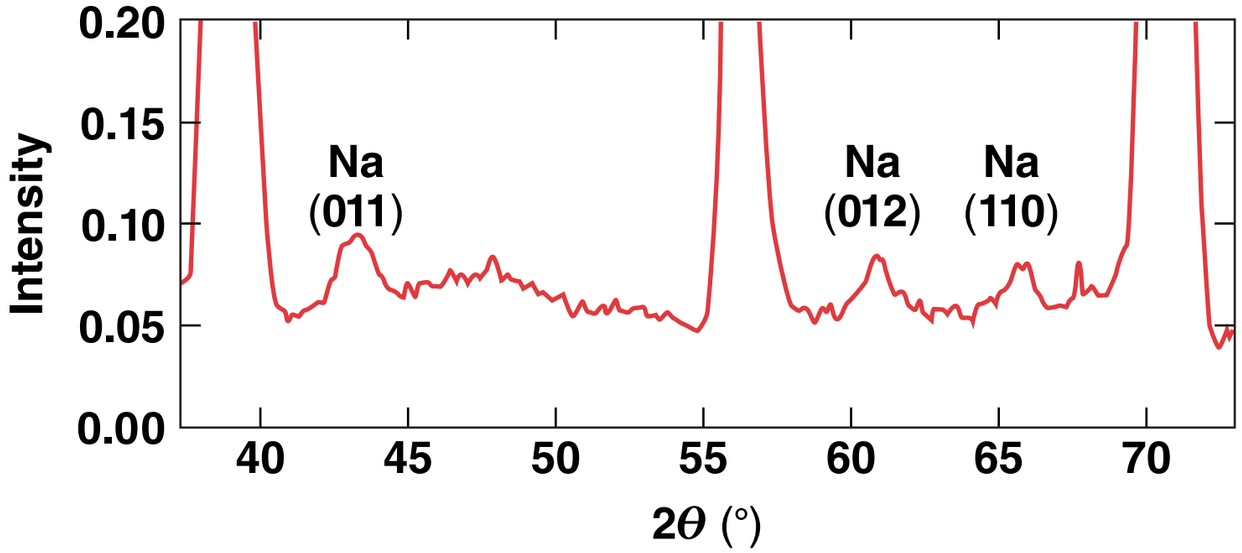


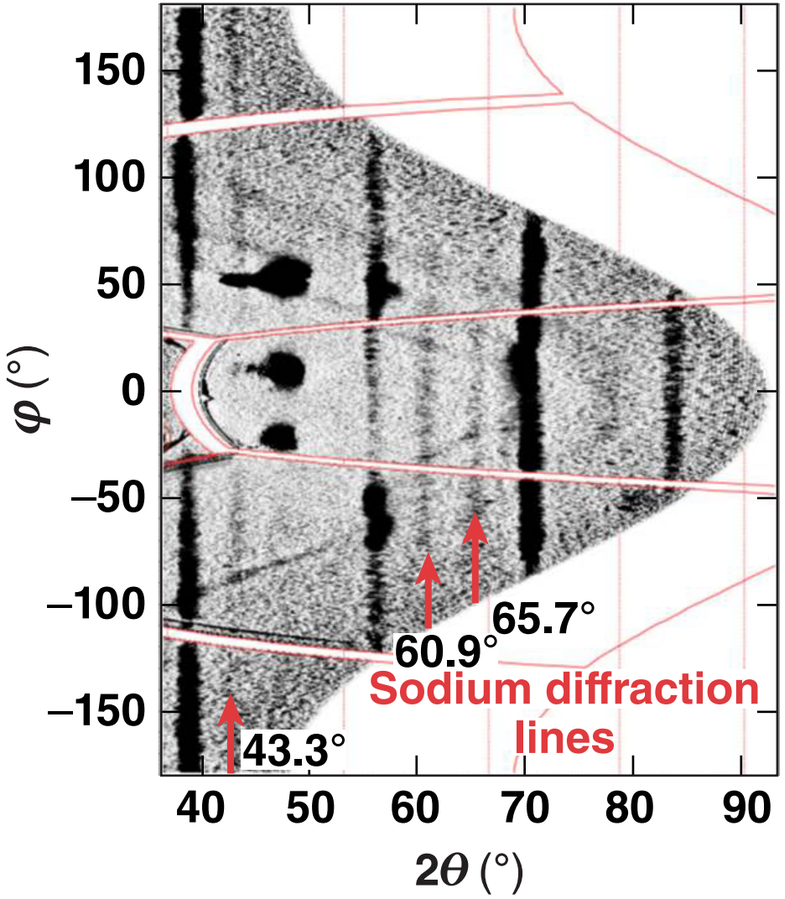


TC13850

*bcc: body centered cubic

The three weaker lines are sodium diffraction lines, consistent with hP4 structure

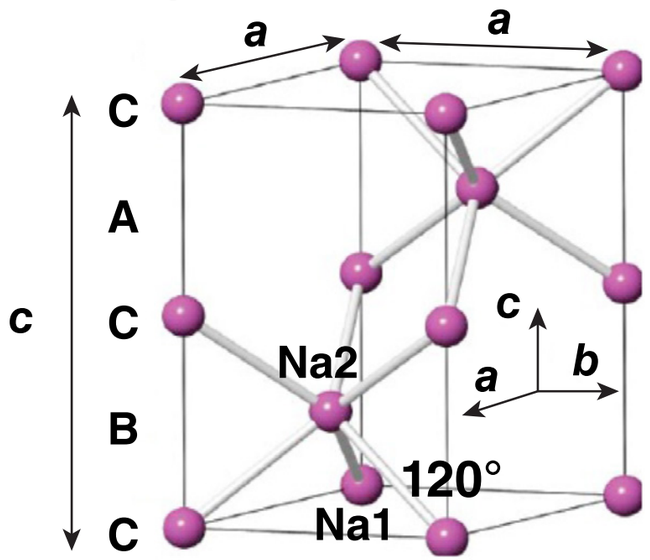


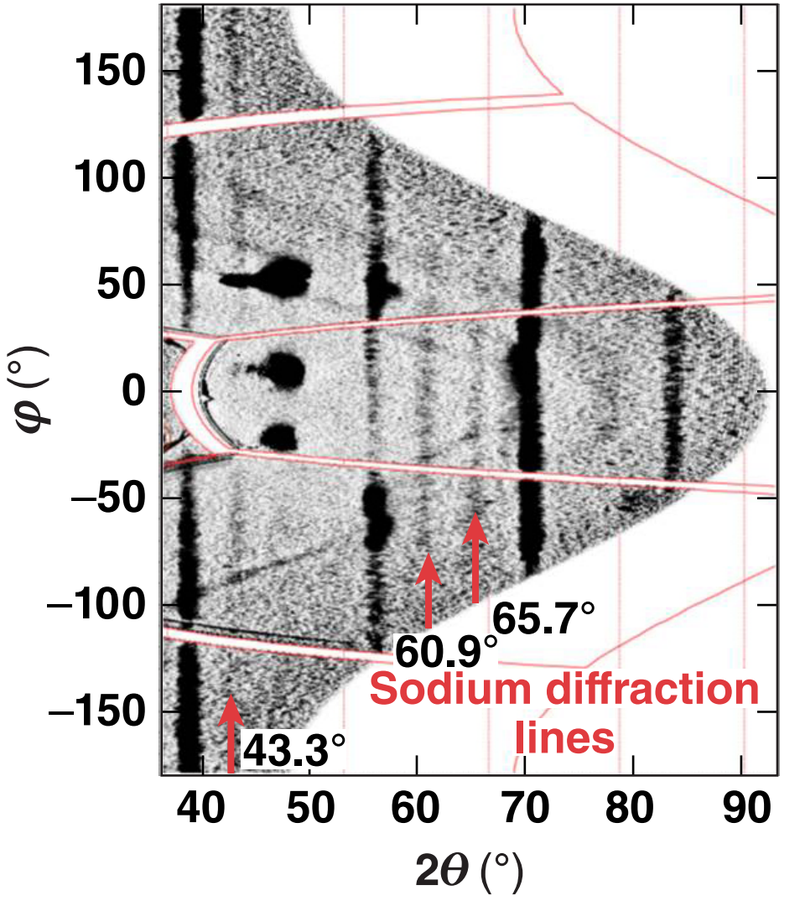


TC13851

The three weaker lines are sodium diffraction lines, consistent with hP4 structure

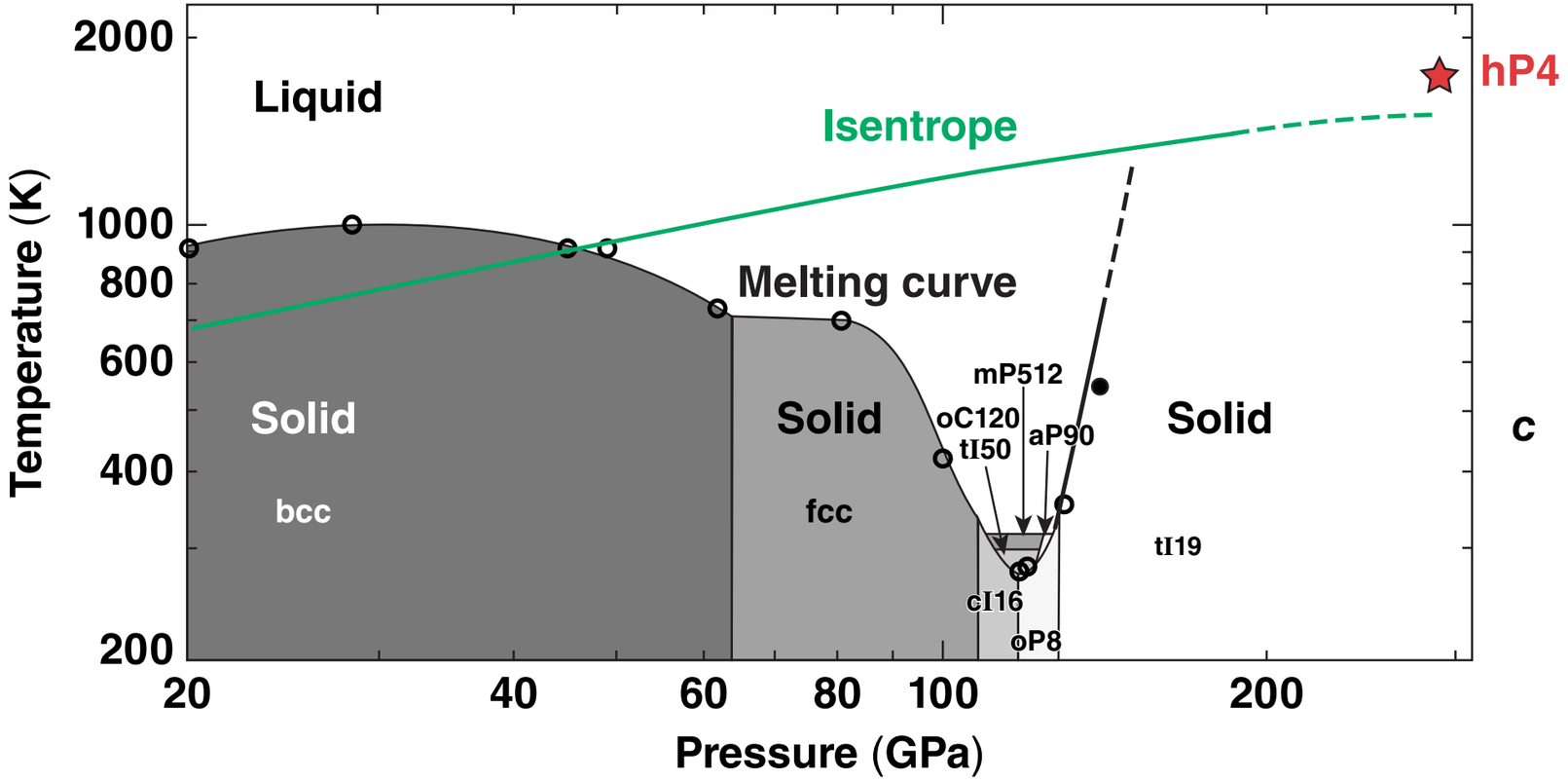
$a = 2.73$ Å
$c = 3.72$ Å
$c/a = 1.36$
$\rho = 6.36$ g/cm^3
$\rho/\rho_0 = 6.57$

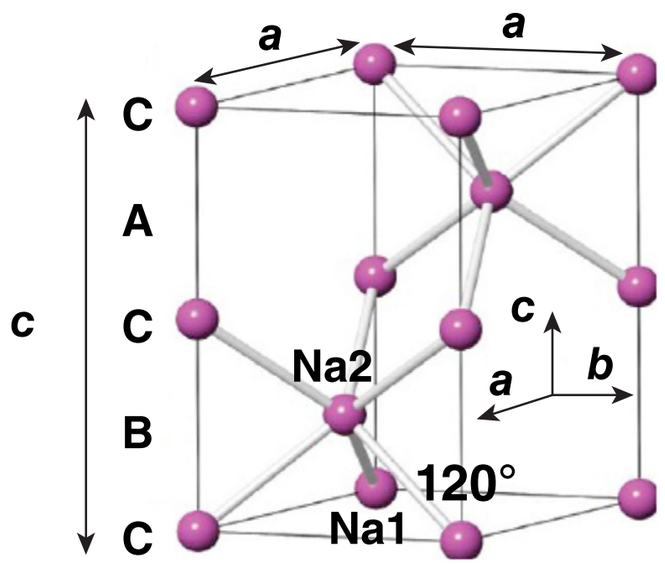




TC13852

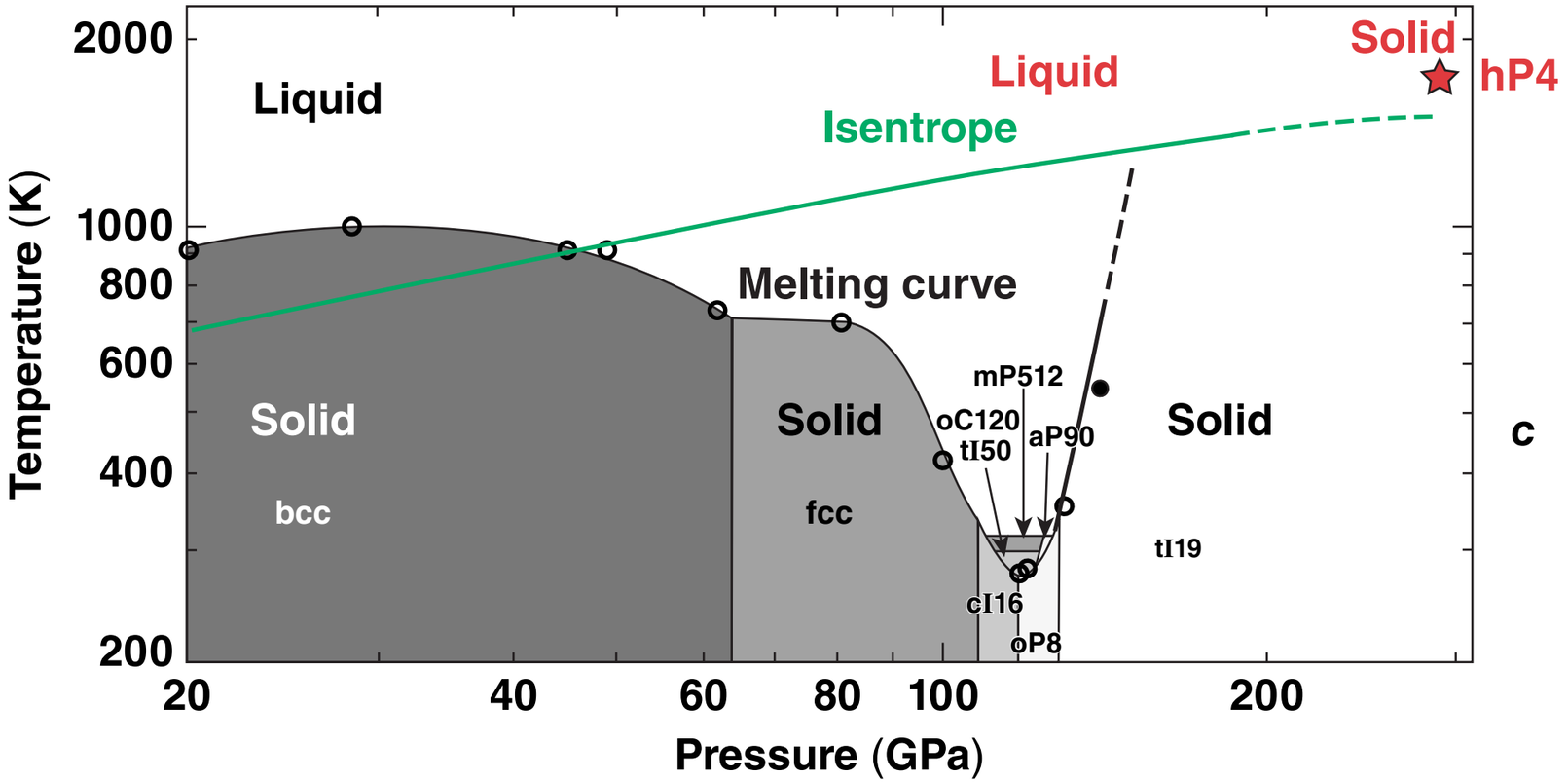
Sodium has a solid phase at ~320 GPa, which is consistent with hP4 structure

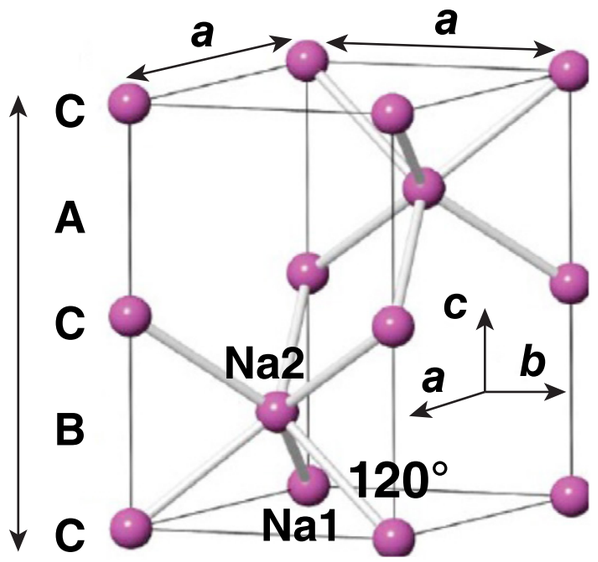




TC13853

The melting temperature rises at >120 GPa





TC13854

Summary/Conclusions

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