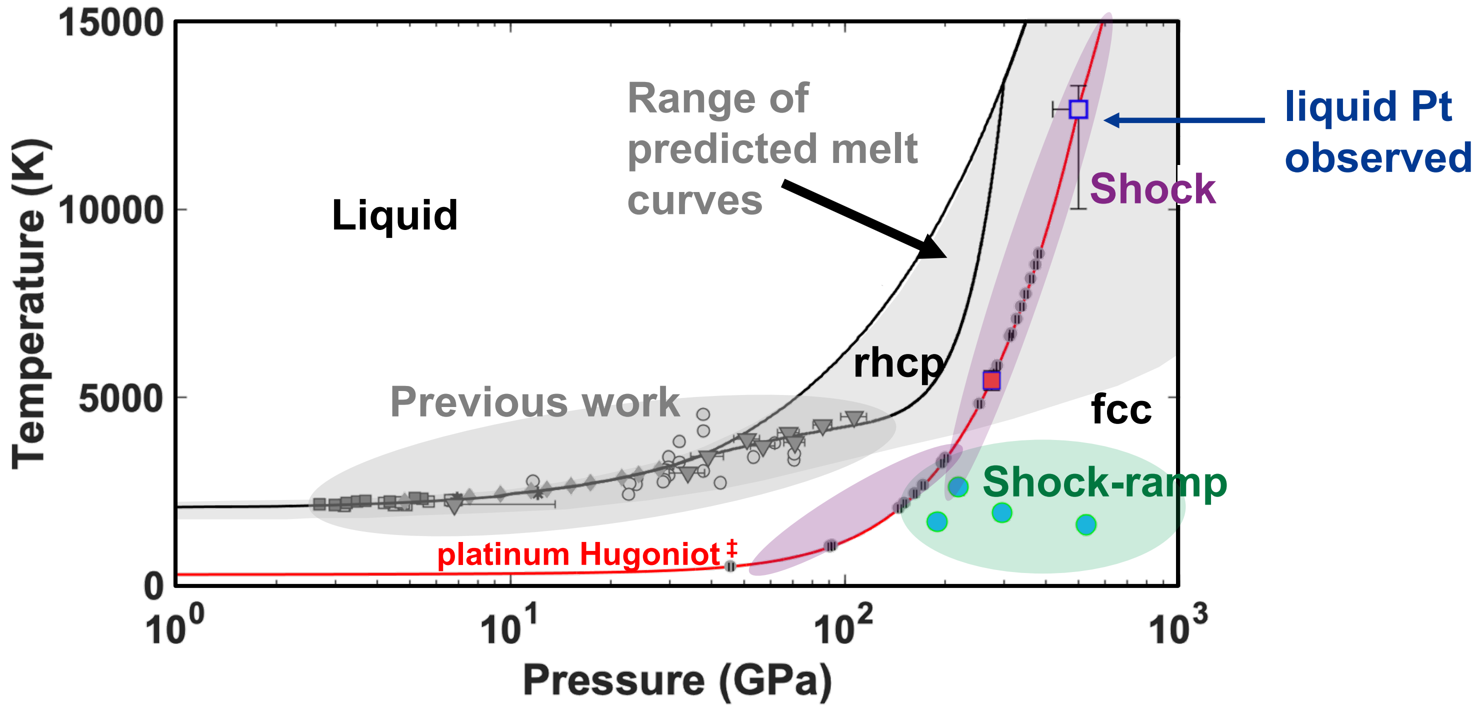
X-ray diffraction of shocked platinum



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Platinum remains face-centered cubic when shock-ramped to 530 GPa. Results of shock experiments agree with previous work* and further constrains shock-melting to 383 < *P* < 500 GPa.

- Platinum is used as a pressure standard in static and dynamic compression experiments due to its stability as a face-centered cubic crystal over wide pressure-temperature states.
- Recently, a solid-solid phase transformation was predicted to occur in platinum between 35 < *P* < 300 GPa. X-ray diffraction measurements observe platinum to remain in the face-centered cubic (*fcc*) phase when shocked ramped up to 530 GPa
- There are significant disagreements of the platinum melting curve that are magnified when extended to the Hugoniot. Solid *fcc* platinum was observed on the Hugoniot at 275 GPa and fully melted at 500 GPa, in agreement with previous work*.

*Sharma, S. M., *et al.* Rev. Lett.124, 235701. (2020).

Collaborators

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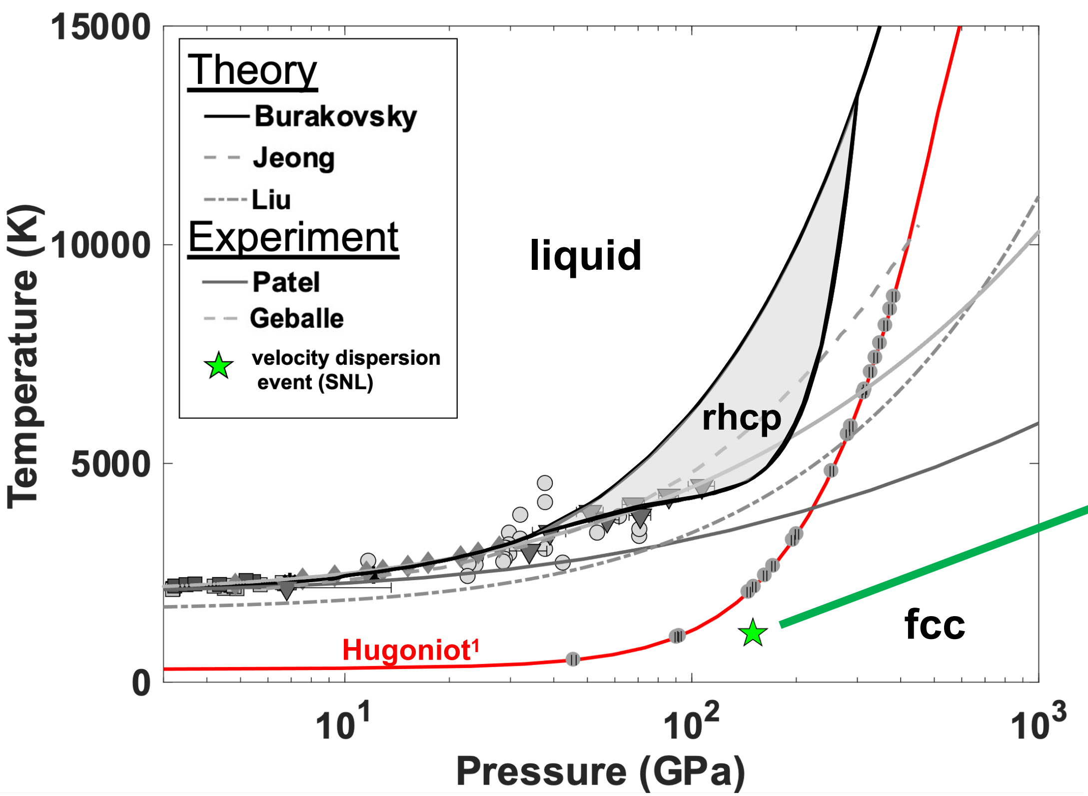
Lawrence Livermore National Laboratory

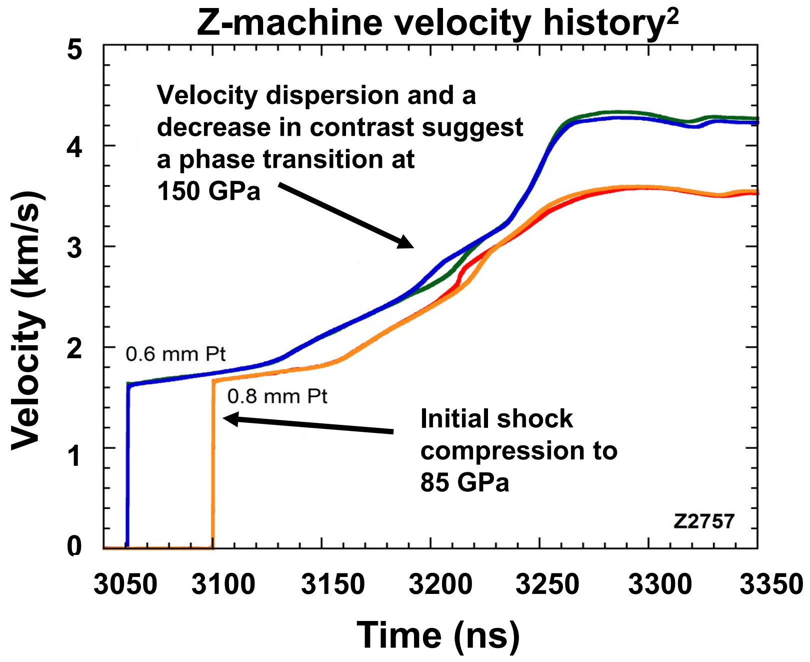
J.-P. Davis, C. A. McCoy, C. Seagle, S. Root

Sandia National Laboratories

Motivation

We investigated two aspects of the platinum phase diagram: the melt curve and a possible solid-solid phase transition





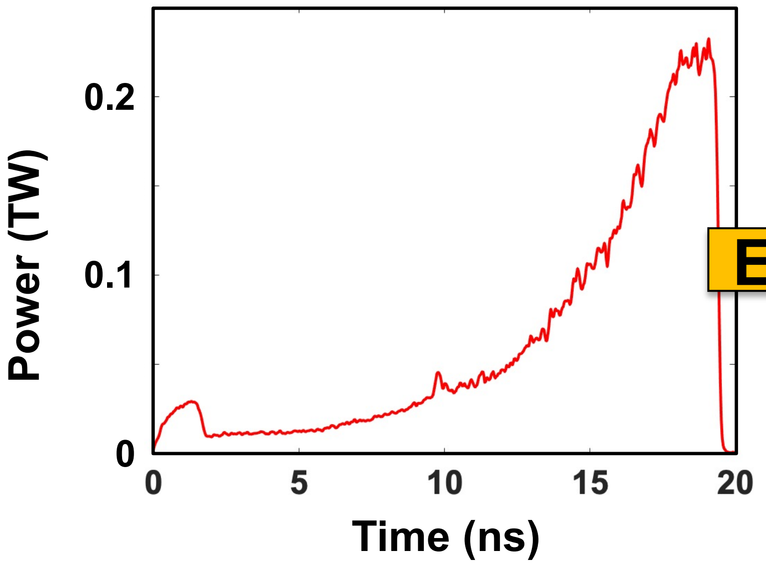
A velocity dispersion event was observed in platinum within the pressure region of a predicted solid-solid phase transition (35 < P < 300)

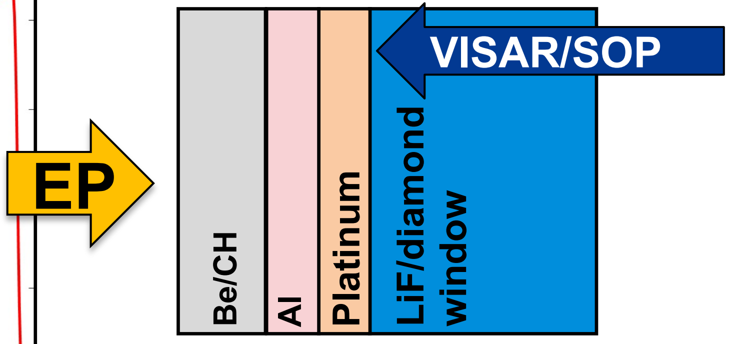
L. Burakovsky, *et al.*, *J. Phys.*: Conf. Ser. 500 162001 (2014)
J. Jeong and K J Chang 1999 *J. Phys.: Condens. Matter* 11 3799
Z.-L. Liu, *et al.*, *Phys. Lett. A* 374 (2010) 1579–1584
N. N. Patel and M. Sunder, in *DAE Solid State Physics Symposium 2017*, AIP Conf. Proc. No. 1942 (AIP, 2018), p. 030007.
Z. Geballe et al. Phys. Rev. Mat. 5, 033803 (2021)

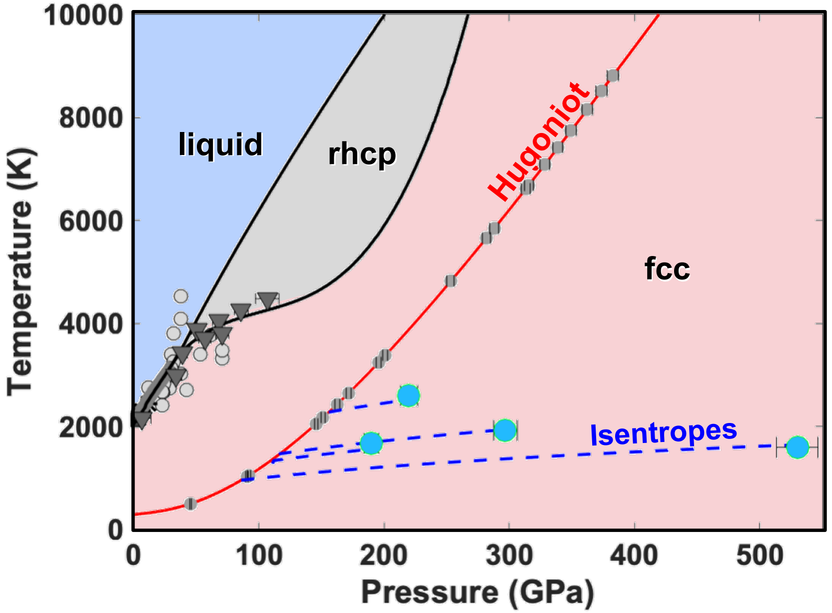
fcc: face-centered cubic
rhcp: randomly disordered hexagonal close packed
1. S. Crockett, LANL
2. C. Seagle, SNL

Experiment

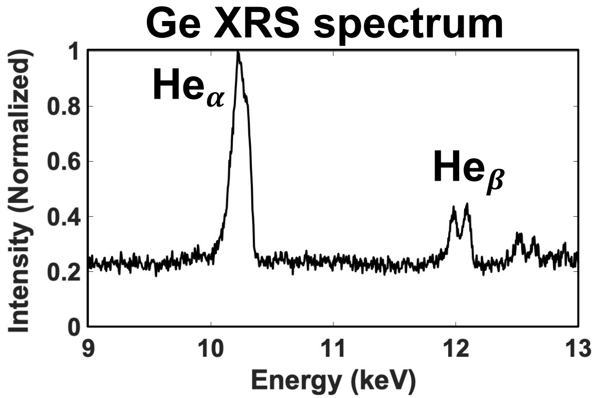
Platinum was compressed using specifically designed laser pulses and targets to access different *P-T* states

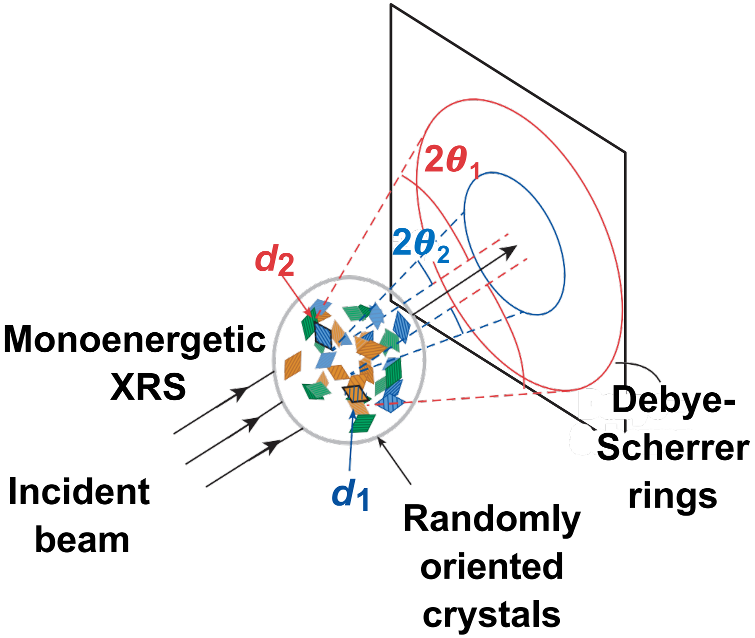


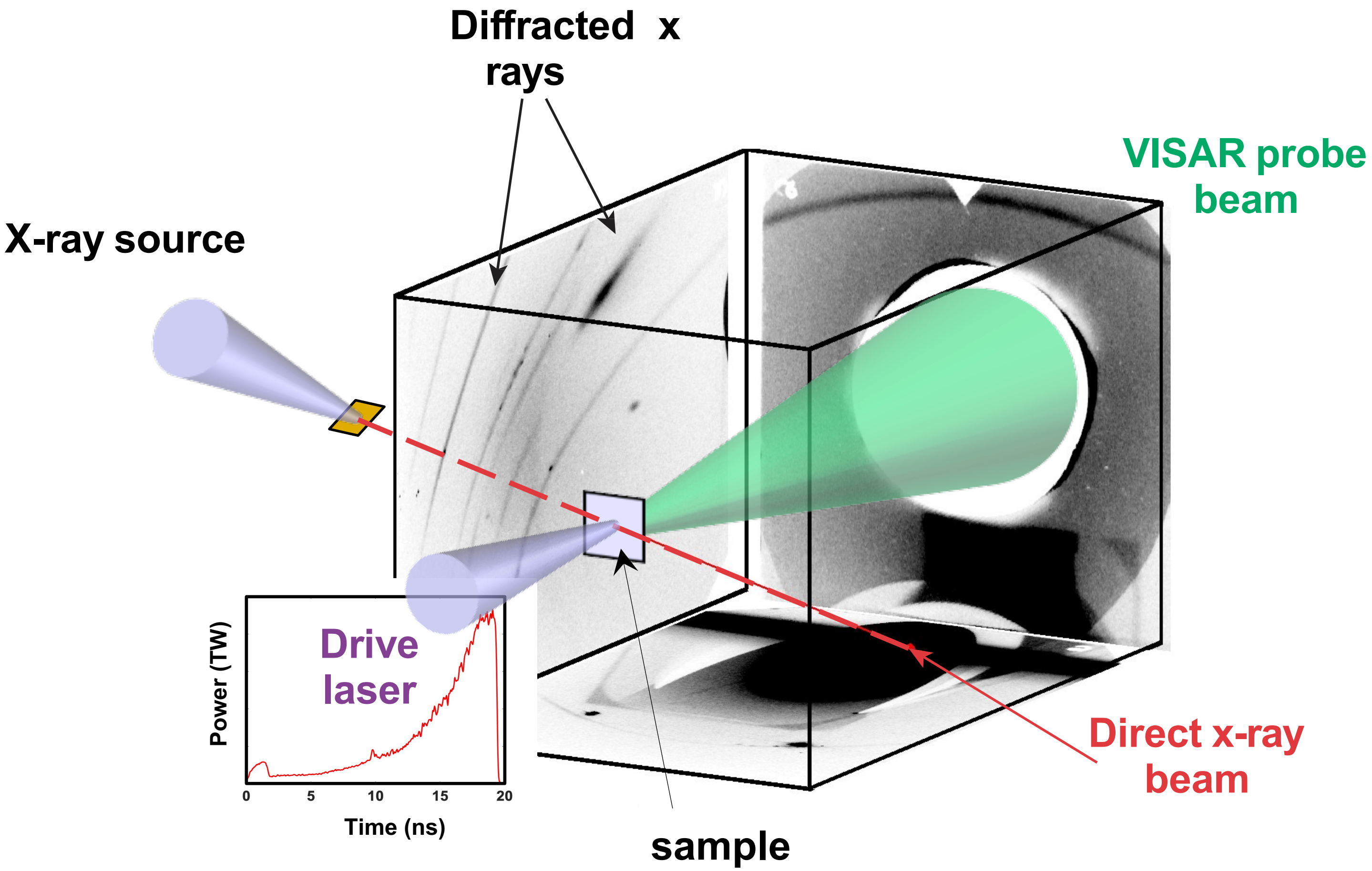




The powder x-ray diffraction image plate platform (PXRDIP*) records the diffraction pattern of the compressed sample



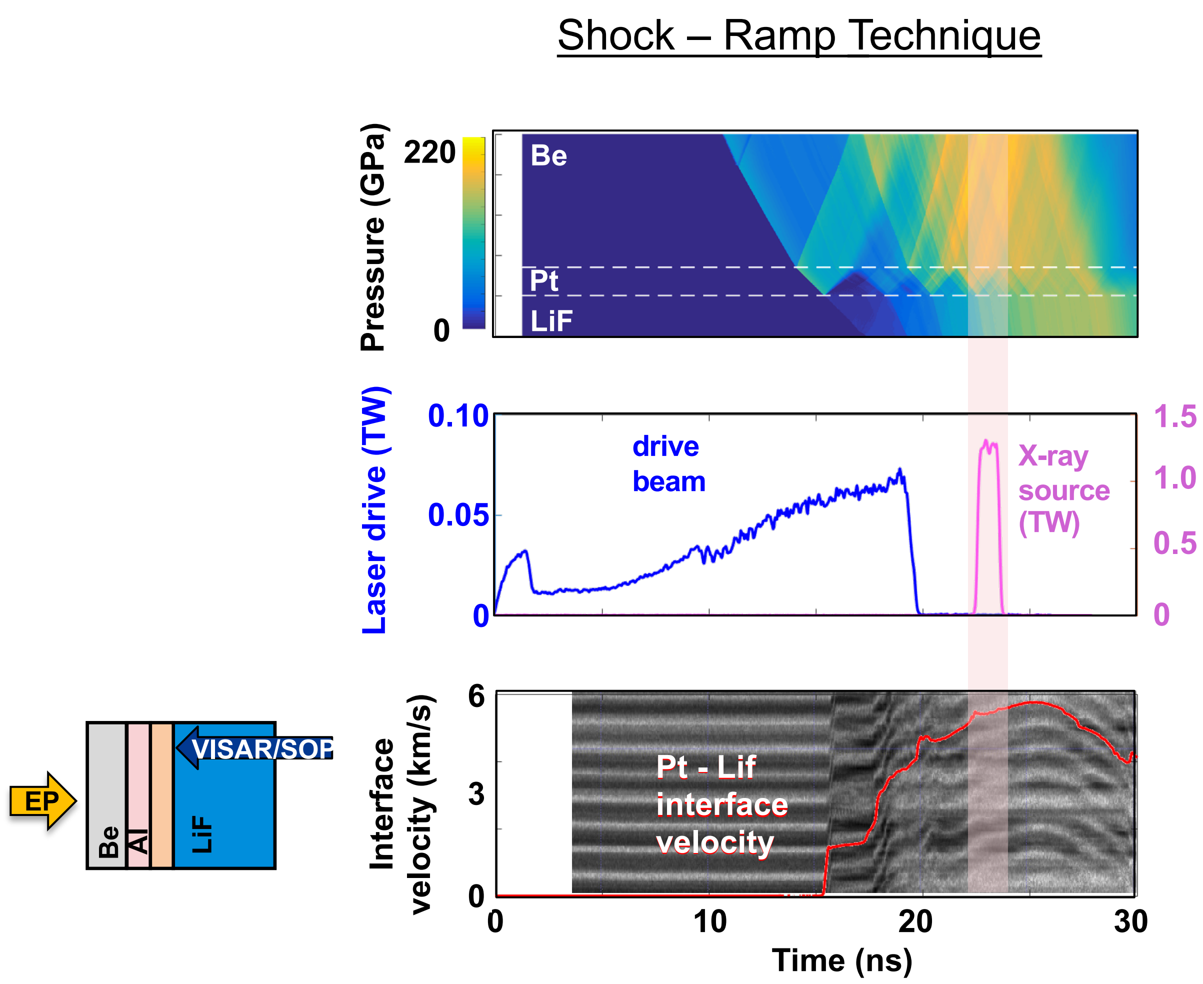


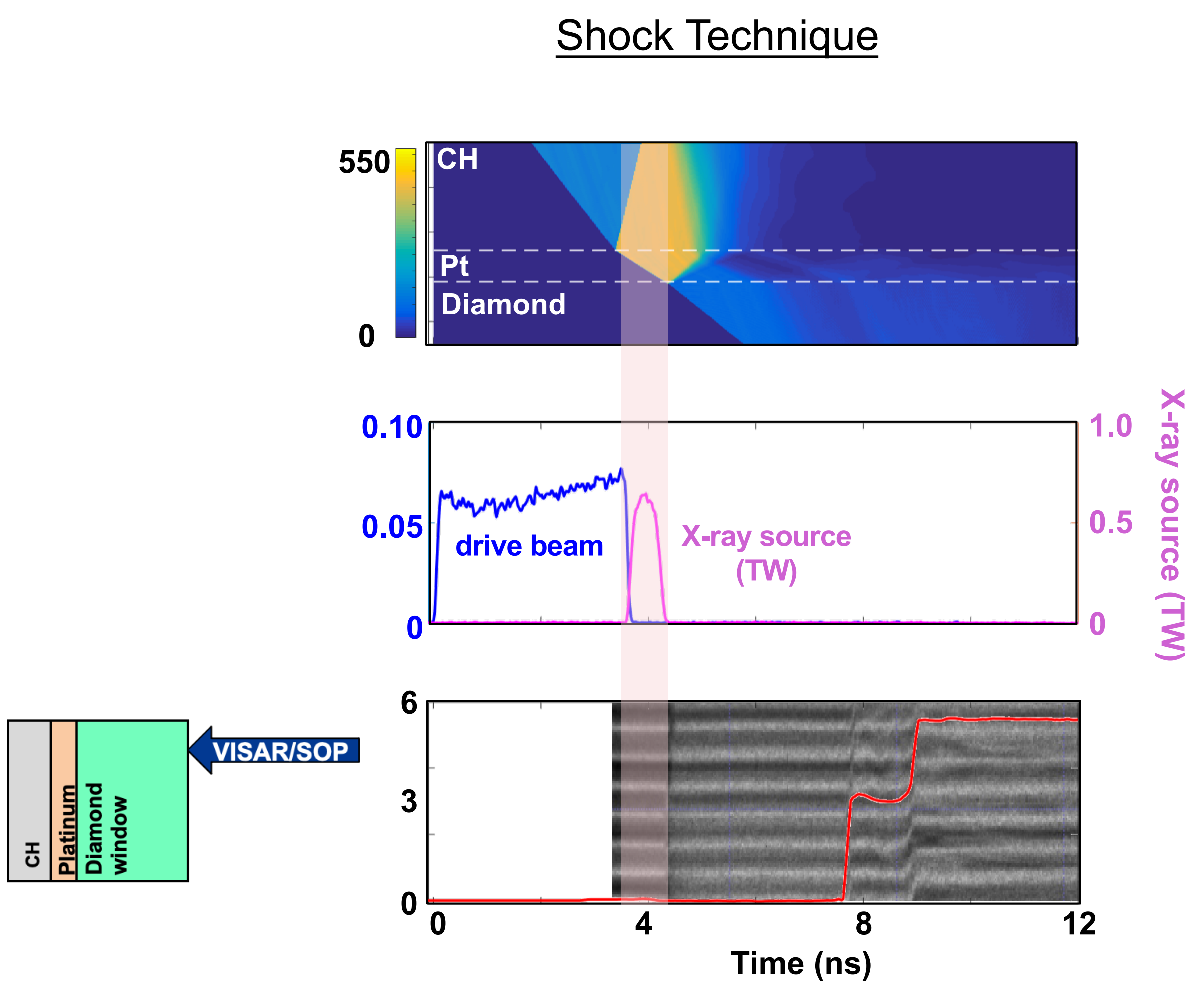


* J. R. Rygg *et al.*, Rev. Sci. Instrum. 83, 113904 (2012).

VISAR* tracks a particle or free surface velocity to infer the pressure in the sample at the time it is probed with x-rays

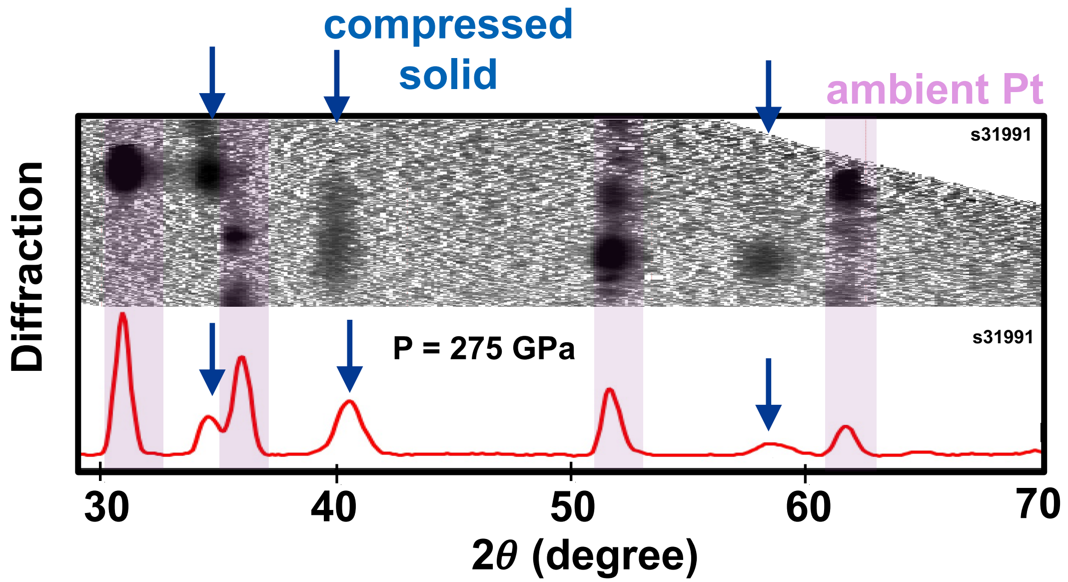
UR LLE

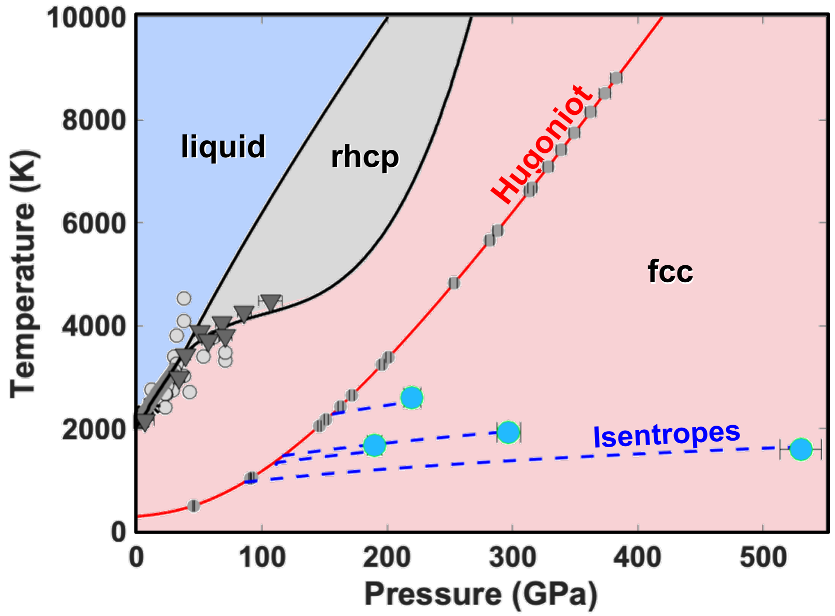




* Velocity Interferometer System for Any Reflector

The crystal structure and density of the compressed solid platinum is obtained from the x-ray diffraction pattern





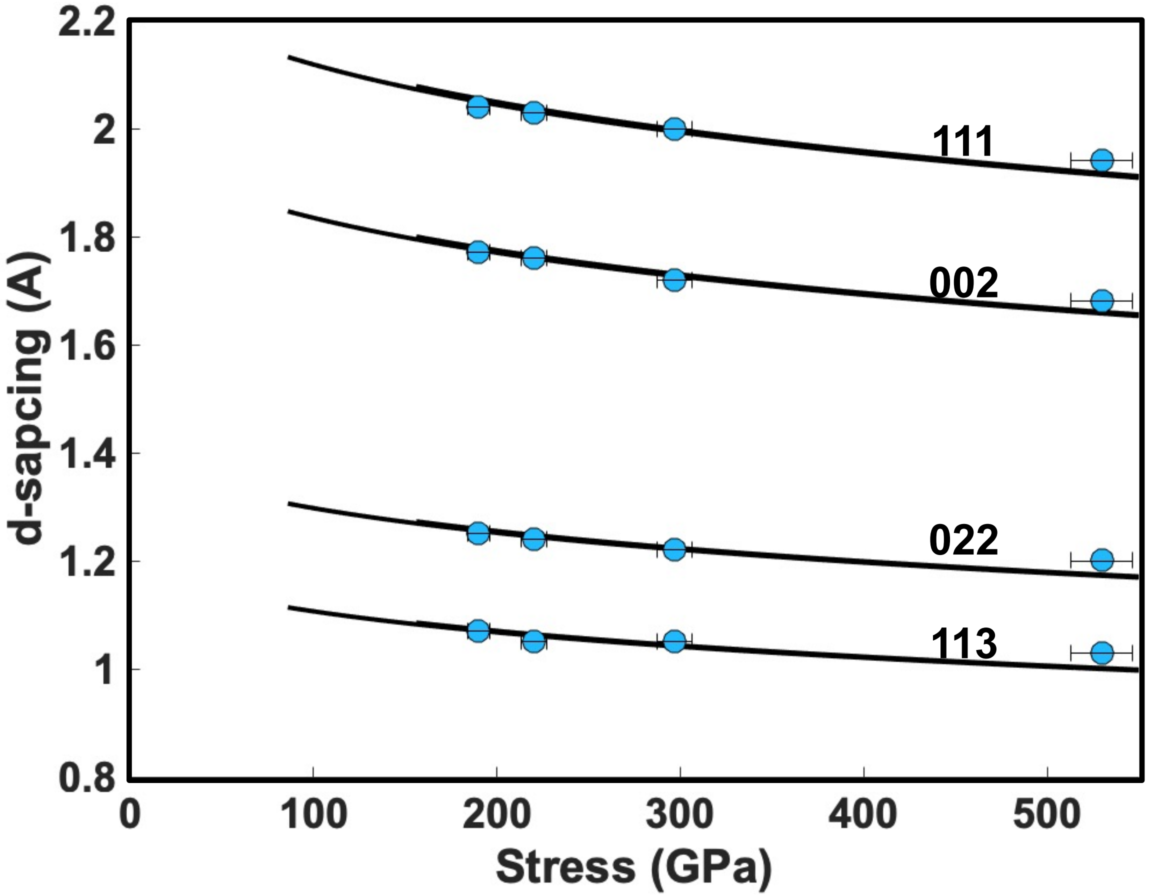
- Ambient Pt diffraction from the pinhole provides geometric calibration of the image plates
- Compressed Pt that remains solid produces a shift in the fcc pattern

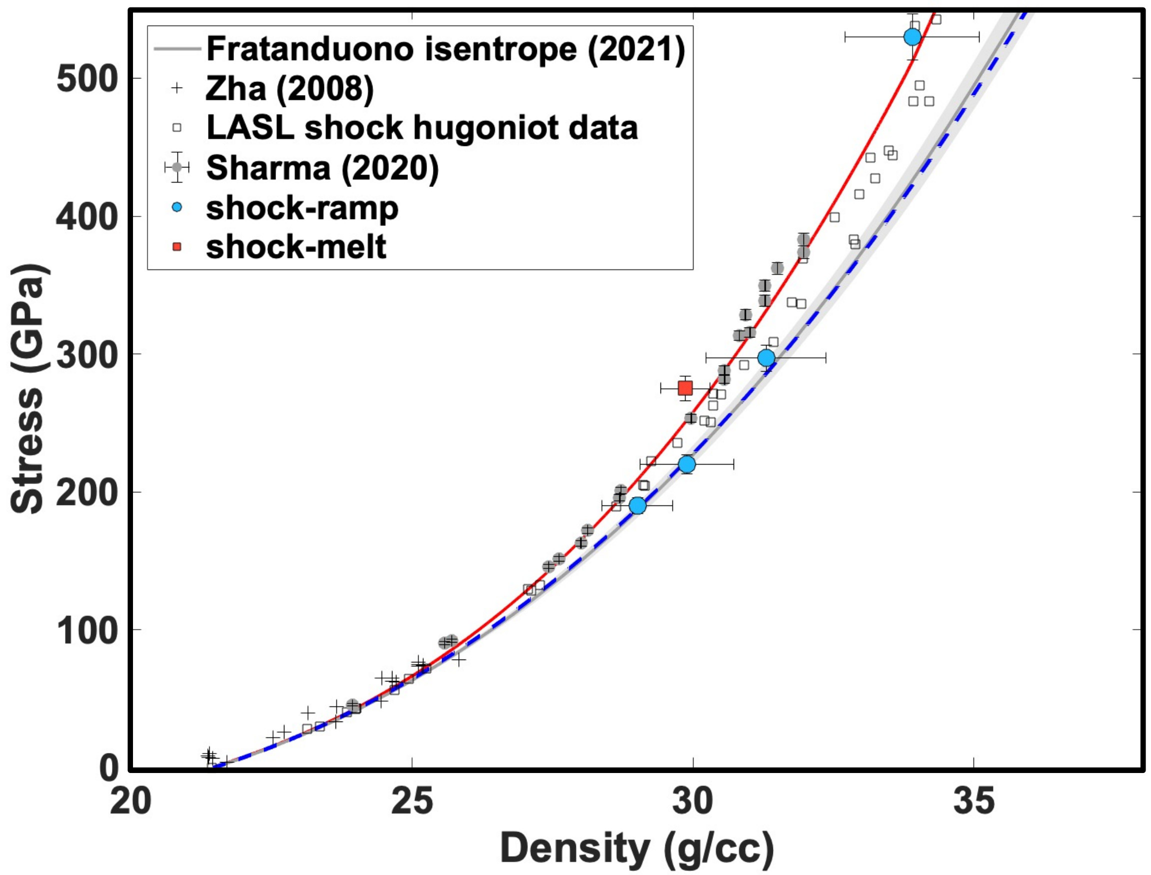
- Temperature is obtained from the tabular EOS[1] isentrope at the pressures inferred from velocimetry measurements

fcc: face-centered cubic
rhcp: randomly disordered hexagonal close packed
1. S. Crockett, LANL

Shock-ramp Results

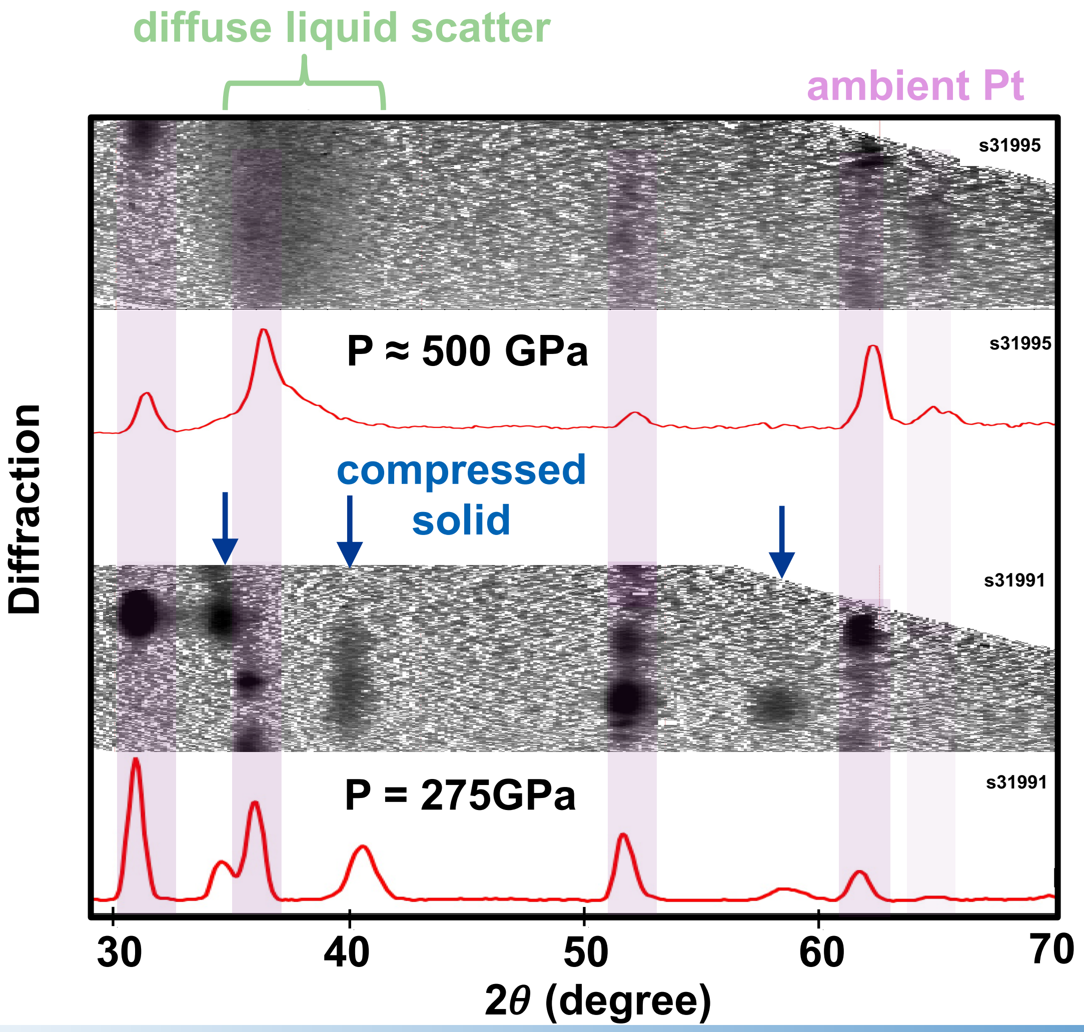
We observed face-centered cubic platinum in the region of the Sandia experiment and no evidence of other solid structures

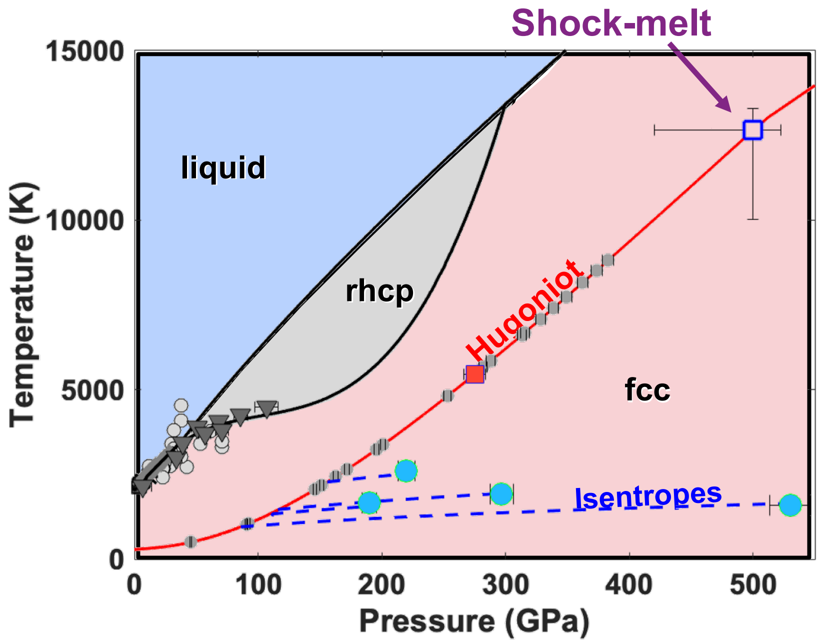




[1] S. Crockett, LANL
[2] Zha, *et al.*, J. Appl. Phys. 103, 054908 (2008)
[3] Marsh, S. P. *LASL Shock Hugoniot Data*. 5 Univ of California Press, (1980).
[4.] D. E. Fratanduono et al., Science 372, 1063 (2021).
[5] Sharma, S. M., *et al.* Rev. Lett.124, 235701. (2020).

A single broad diffraction line, seen among the ambient platinum, is the signature of diffuse scattering from a liquid

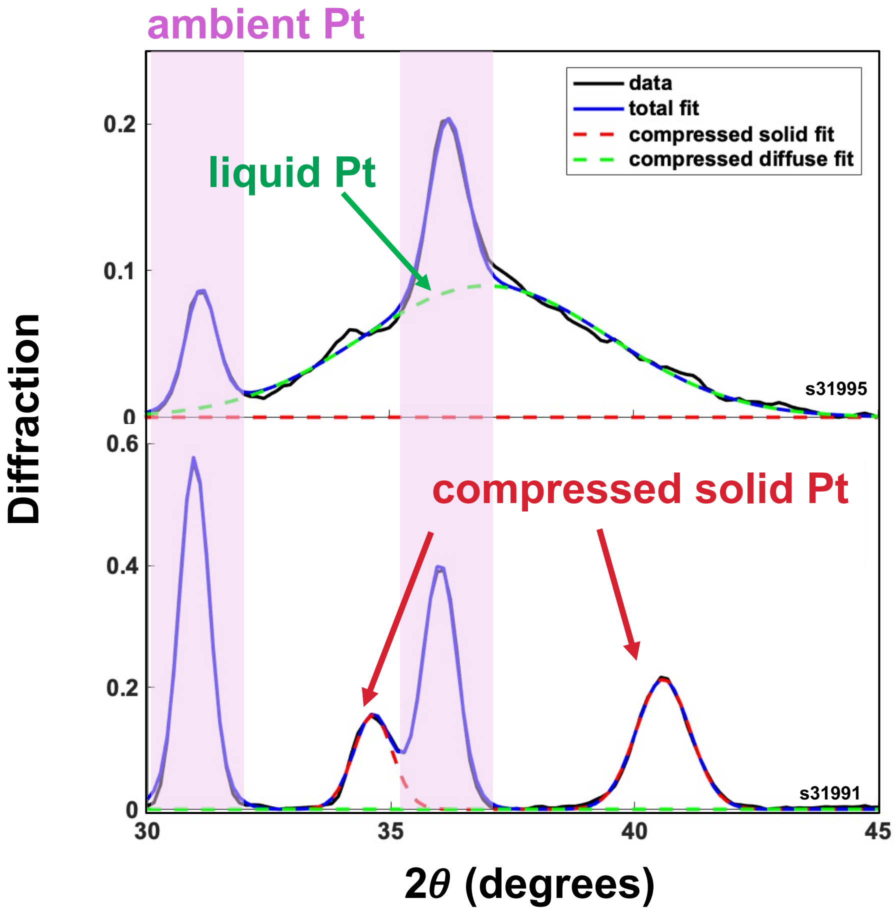




- Analysis of the liquid structure can provide density and coordination number of the liquid phase

fcc: face-centered cubic

The data was fit to a series of Gaussian functions to identify liquid scattering*



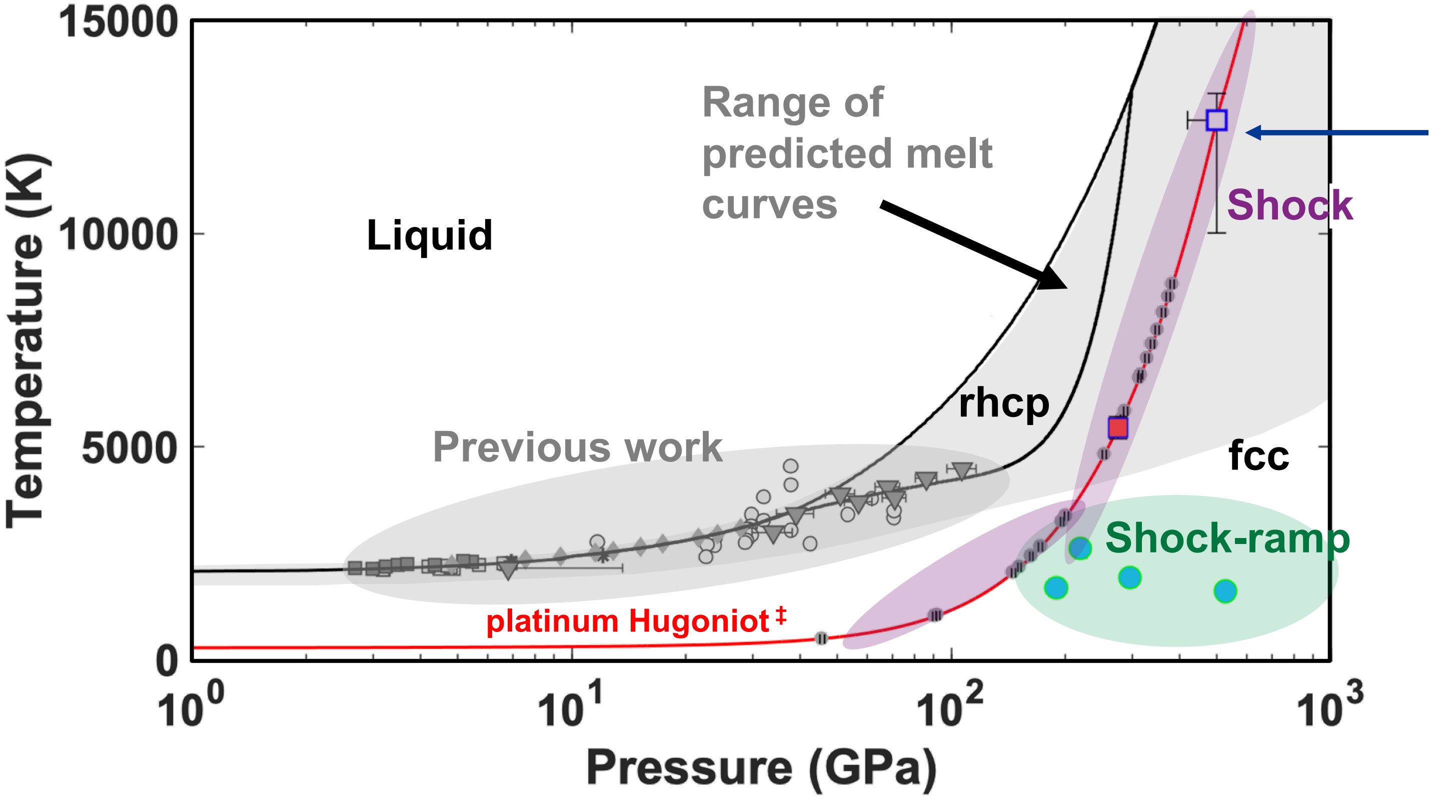
- Each solid peak can be described as two Gaussians with three free parameters: amplitude, centroid location, and width.

$$I = a_1 e^{-(x-a_2)^2/2a_3^2} + 0.2 a_1 e^{-(x-a_2)^2/2(0.5)^2}$$

- A single Gaussian is used to fit the liquid scattering feature

* R. G. Kraus, *et al.* Phys. Rev. Lett. 126. 255701 (2021)

Observation of Pt melt at 500 GPa extend previous Hugoniot measurements at 380 GPa of *fcc* platinum



P **≈ 500 GPa was determined with hydrodynamic simulations.**

A lower pressure estimate of 420 GPa was obtained using the transit time of elastic and plastic waves at the free surface of the diamond window (McWilliams)

McWilliams *et al.* Phys Rev B **81**, 014111 (2010)

S. Crockett, LANL
L. Burakovsky, *et al.*, *J. Phys.*: Conf. Ser. 500 162001 (2014)
H. M. Strong and F. P. Bundy, Phys. Rev. 115, 278 (1959)
N. R. Mitra, D. L. Decker, and H. V. Vanfleet, Phys.Rev.B 161, 613 (1967)
A. Kavner & R. Jeanloz, *J. Appl. Phys.*, 83(12), 7553-7559 (1998)
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R. Boehler, in Recent Trend in High Pressure Research, edited by A. K. Singh, Proc. of AIRAPT XIII (International Science, New York, 1992), p. 591
Zha, *et al., J. Appl. Phys.* 103, 054908 (2008)
Sharma, S. M., *et al.* Rev. Lett.124, 235701. (2020)
Z. Geballe *et al.* Phys. Rev. Mat. 5, 033803 (2021)

Summary/Conclusions

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