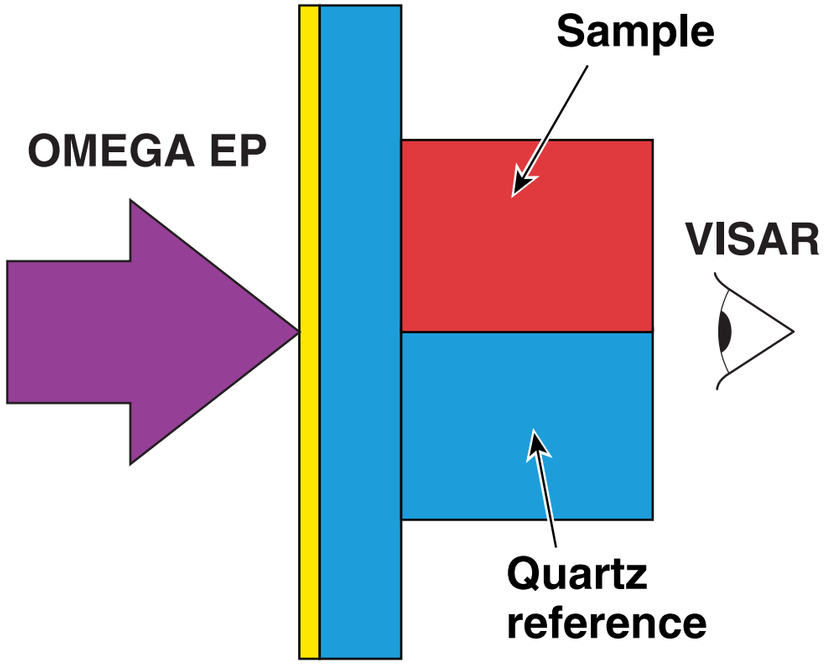
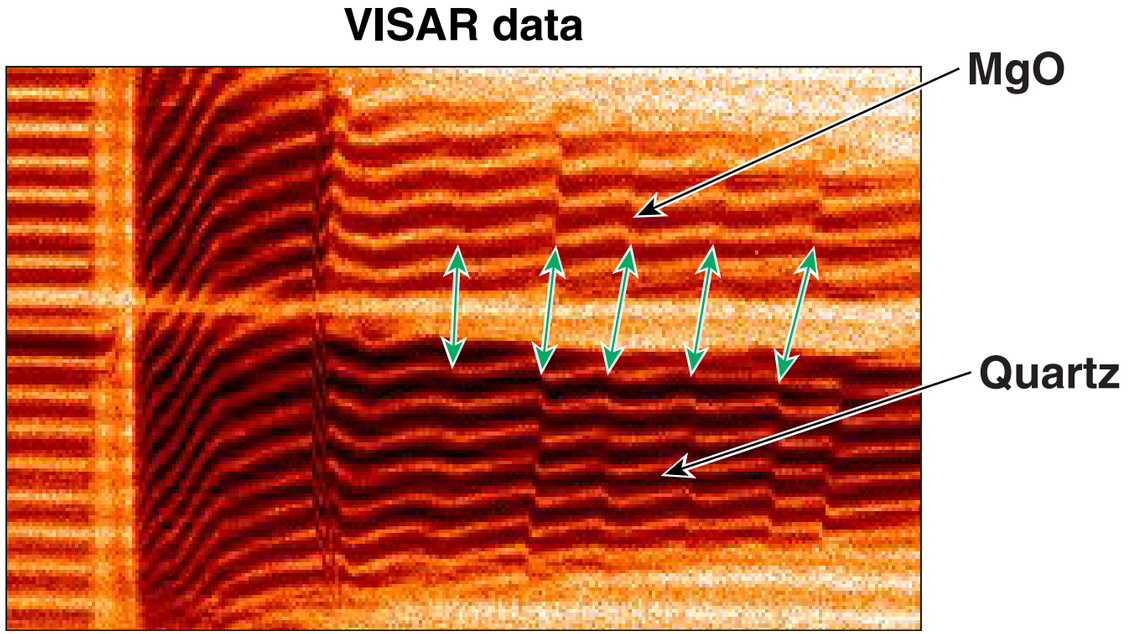
Measurements of Sound Velocity and Grüneisen Parameter in CH and MgO Shocked to TPa Pressures





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Summary

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- Sound-velocity measurements are made using an unsteady wave analysis relating the temporal shift between acoustic perturbations
- The Grüneisen parameter of the material behind the shock front is determined from its sound velocity and the slope of its Hugoniot curve
- Sound-speed measurements are made relative to an α-quartz standard
- Results are compared to existing LEOS and *SESAME* equation-of-state (EOS) tables

Collaborators

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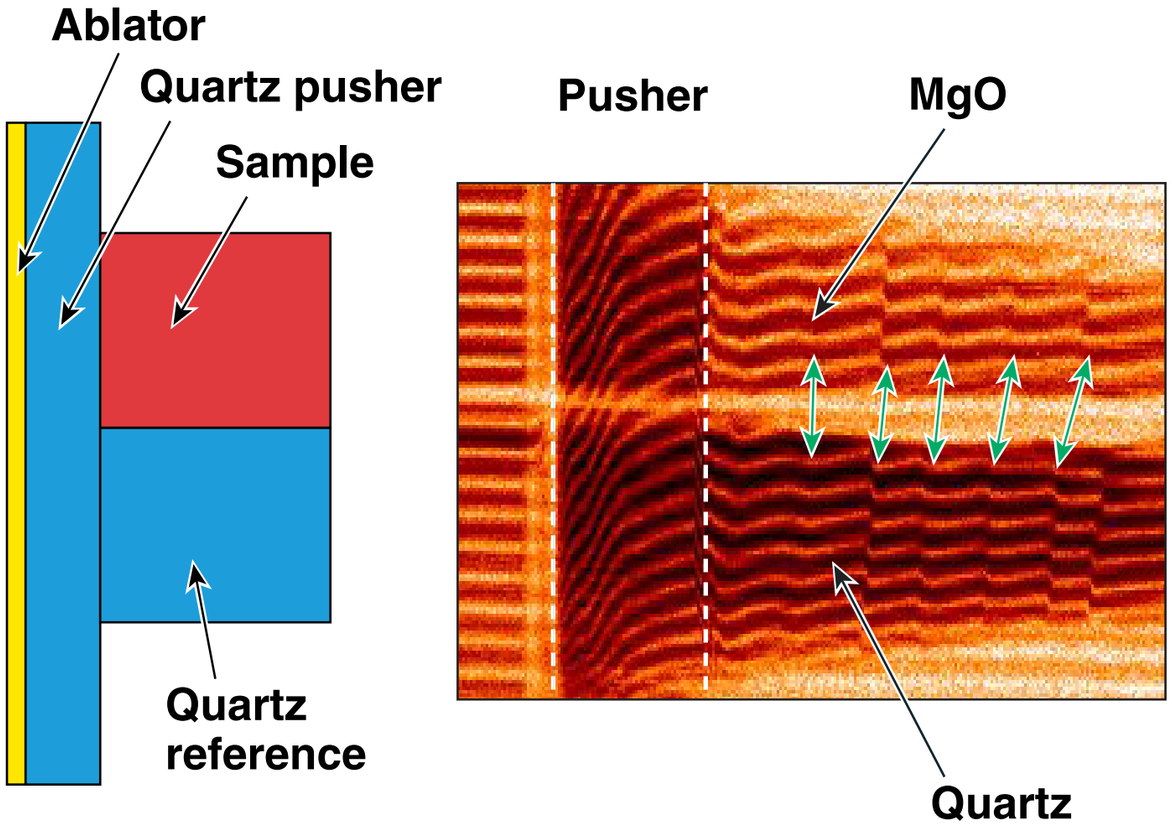
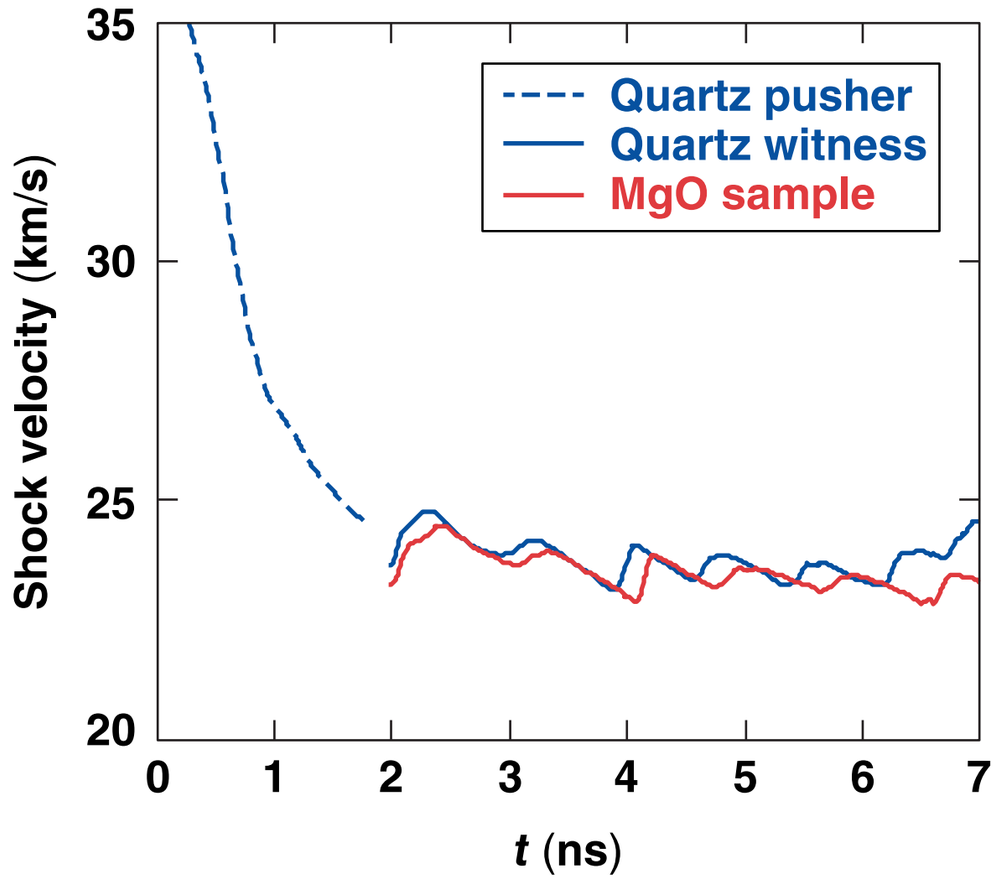
Motivation

Measurements of the sound speed and Grüneisen parameter are necessary to determine off-Hugoniot states

- The off-Hugoniot behavior is important to impedance matching experiments, inertial confinement fusion, and geophysical properties
- The sound velocity $c_s^2 = \left(\frac{dP}{dV}\right)_V$ and Grüneisen parameter $\Gamma = V\left(\frac{dP}{dE}\right)_V$ define derivatives across the Hugoniot curve
- Knowledge of the Grüneisen parameter and principal Hugoniot enables creation of the full *P-V-E* thermodynamic plane

Pressure perturbations propagate at different speeds between the quartz witness and MgO sample





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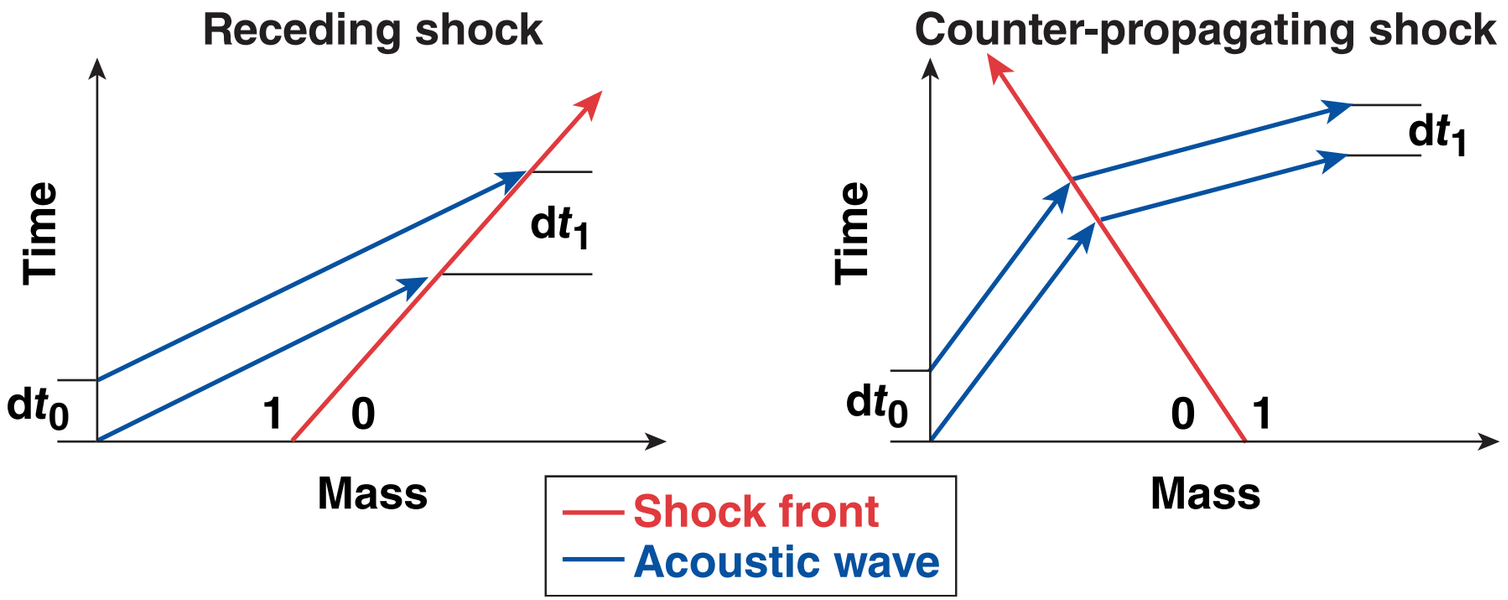
Unsteady wave analysis* is used to propagate acoustic waves through samples



- Equations describing time dilation of acoustic disturbances across regions of flow are dependent on Mach numbers
- For example, a counter-propagating shock is given by: $\frac{dt_1}{dt_0} = \frac{(1+M_1)}{(1+M_0)}$

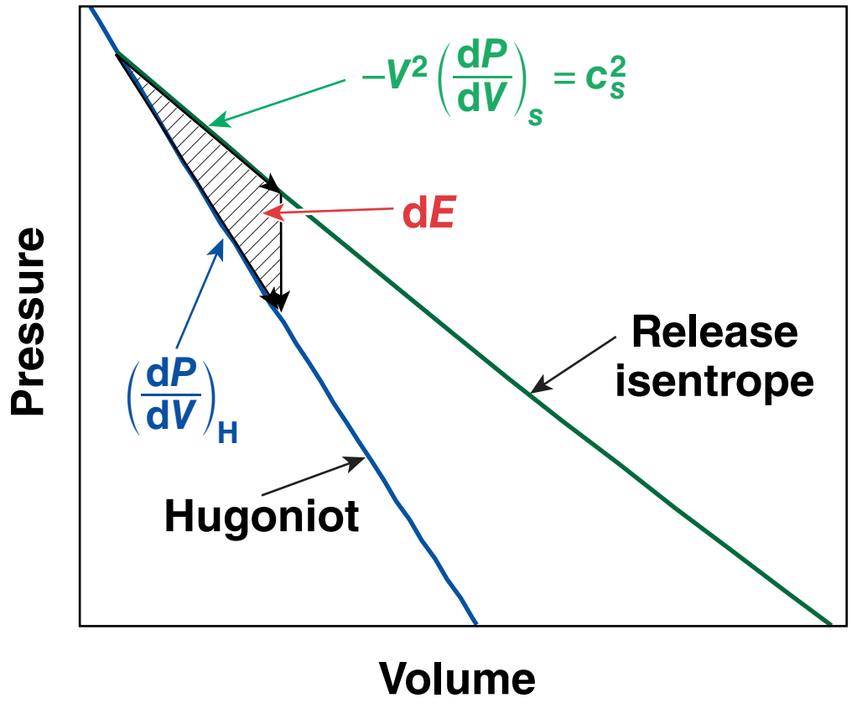
*D. E. Fratanduono *et al.*, J. Appl. Phys. 116, 033517 (2014); D. E. Fratanduono, JI3.00006, this conference.

E23514a

The Grüneisen parameter is determined from the sound velocity and the slope of the Hugoniot curve

- The Hugoniot curve is easy to measure using direct impact or impedance-matching techniques
- Sound velocity c_s gives the slope of an isentrope at a point where it intersects the Hugoniot curve
- The two slopes define an infinitesimal area in the pressure–volume plane, allowing for the energy difference between curves
- From the definition of the Grüneisen parameter:

$$\Gamma = \frac{2\left[V\left(\frac{dP}{dV}\right)_H + \frac{c_s^2}{V}\right]}{P_H + \left(\frac{dP}{dV}\right)_H (V_0 - V_H)}$$



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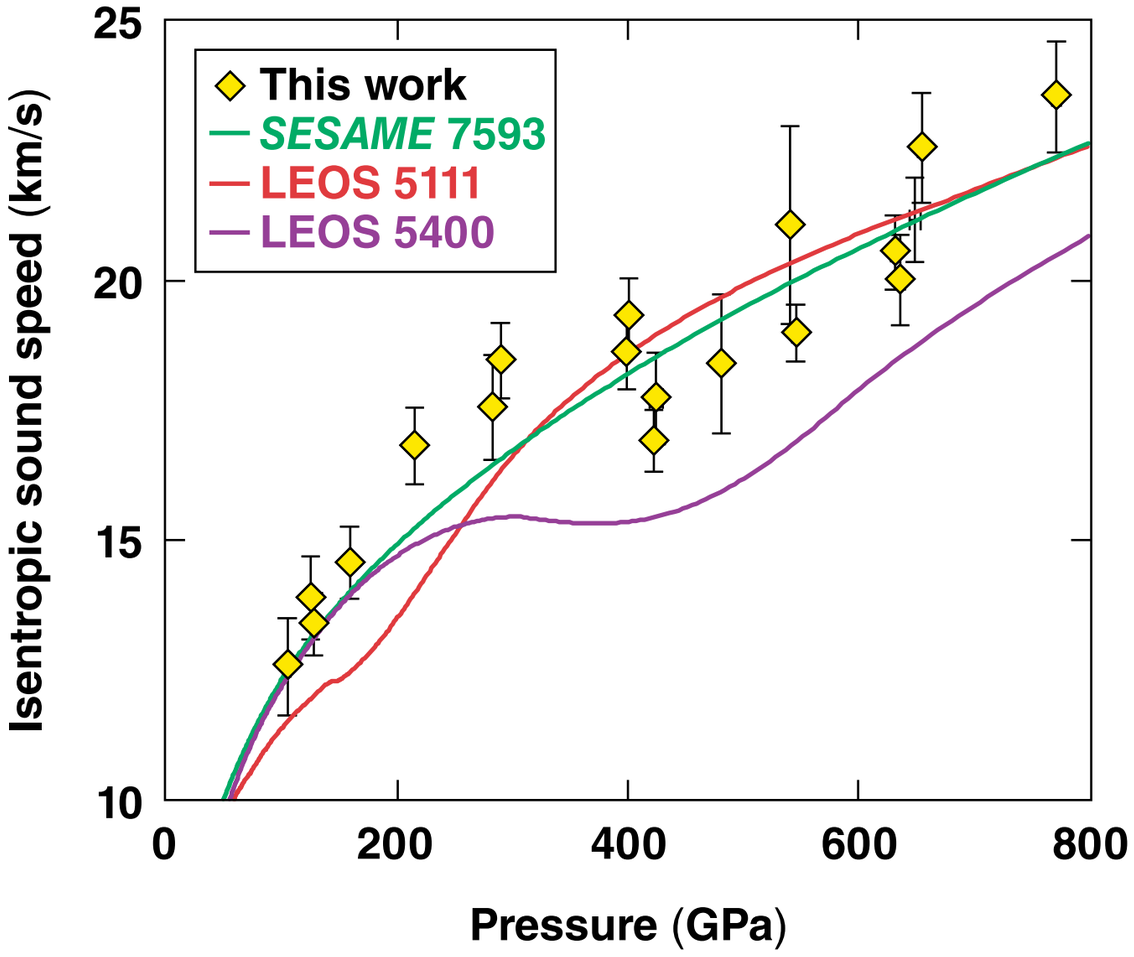
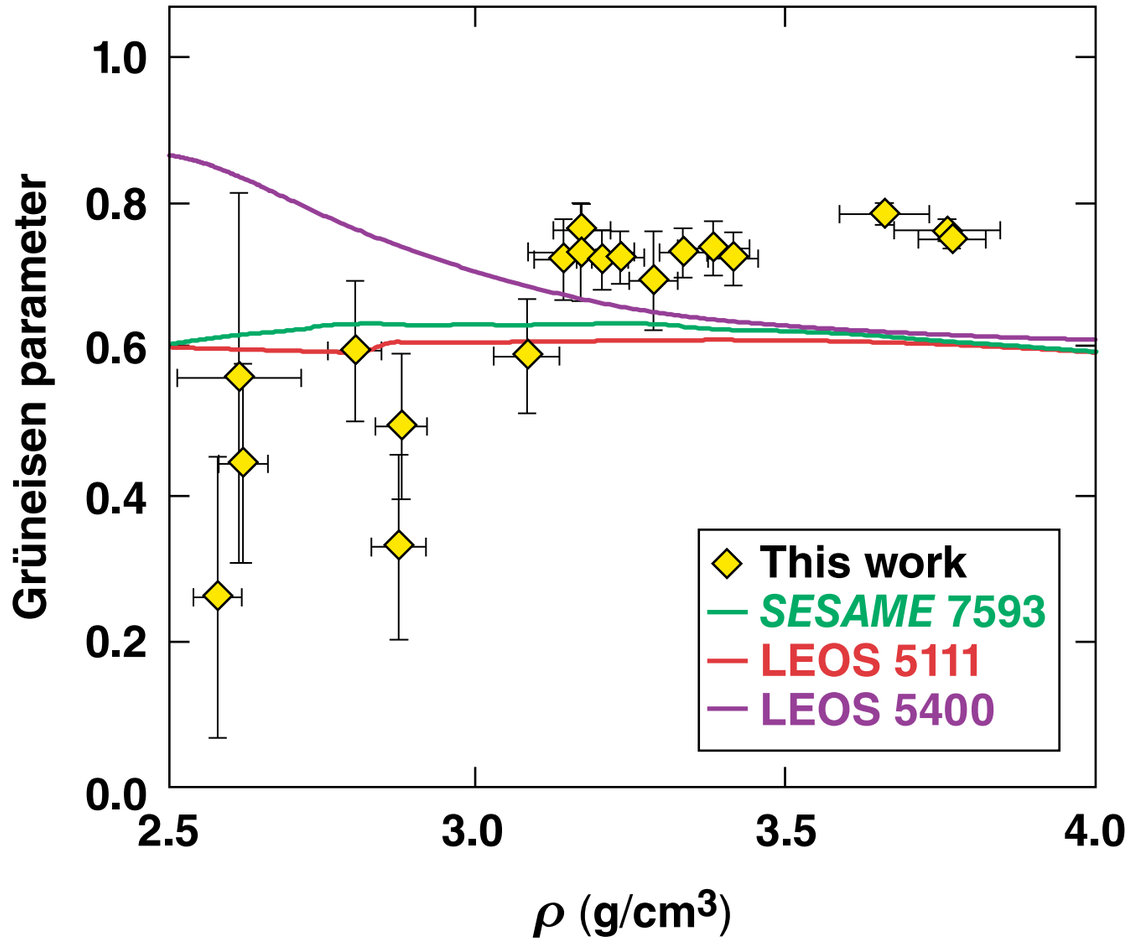
Sound speed and Grüneisen parameters measured in polystyrene favor *SESAME* 7593 table in this region





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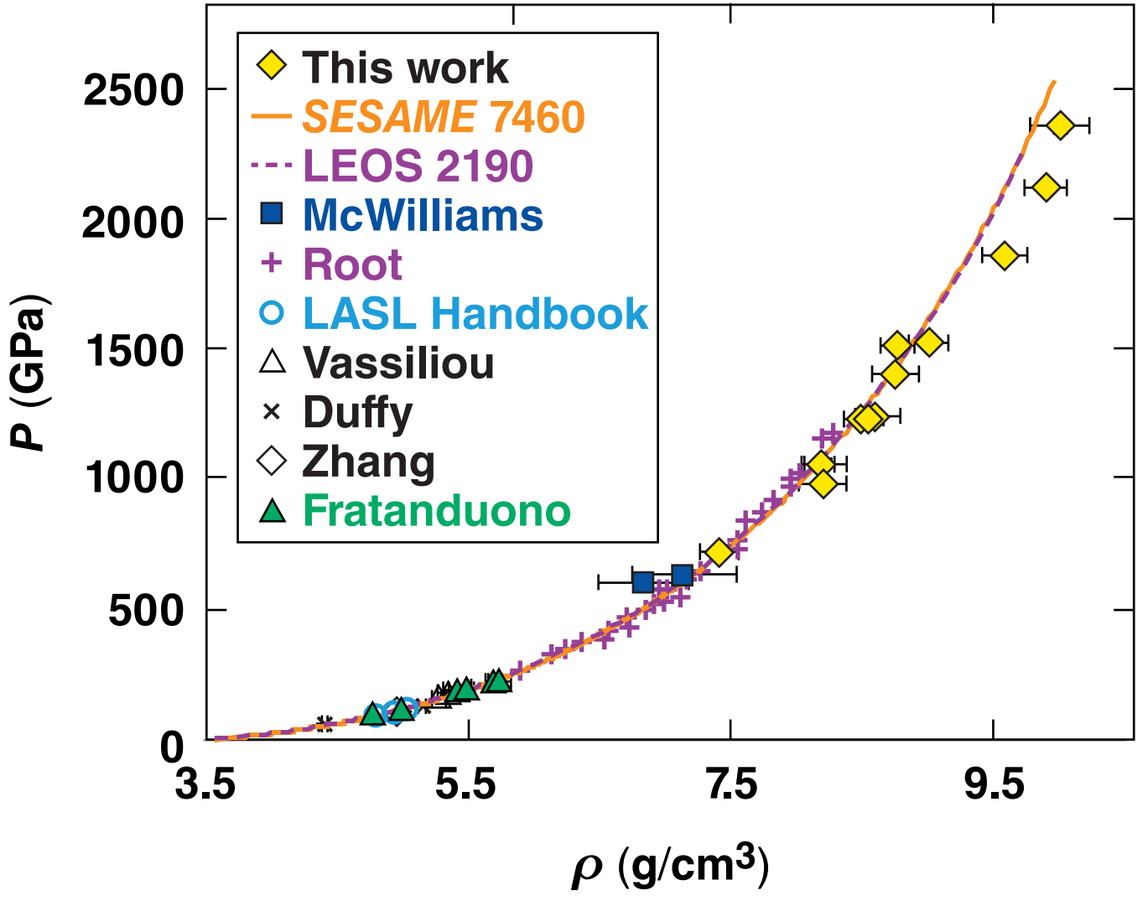
The MgO Hugoniot was extended to 2.4 TPa to enable sound velocity and Grüneisen parameter measurements

- Experiments reached highest shock pressures to date in MgO
- Grüneisen parameter measurements require the slope of Hugoniot curve
  - used fit to these results and historical data for pressures of 0.6 to 2.4 TPa



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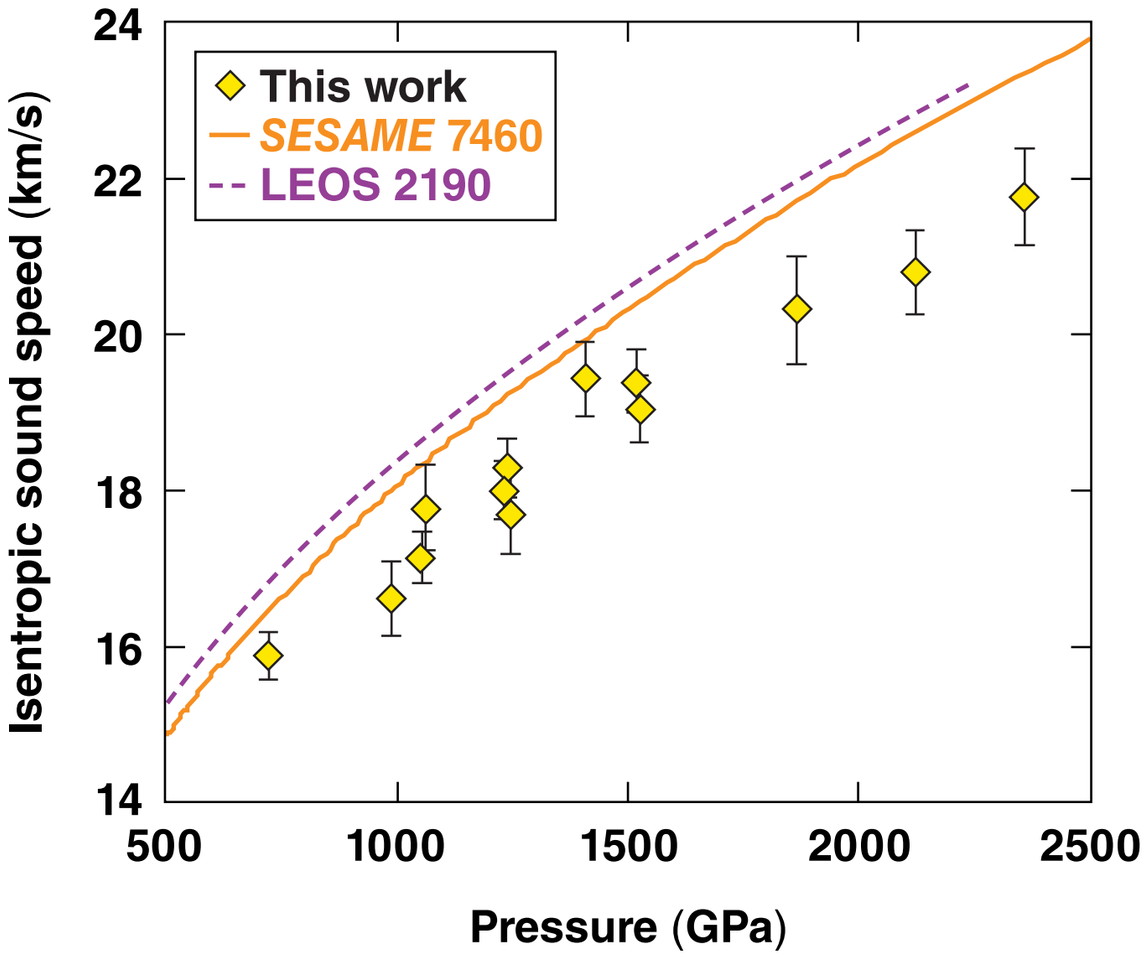
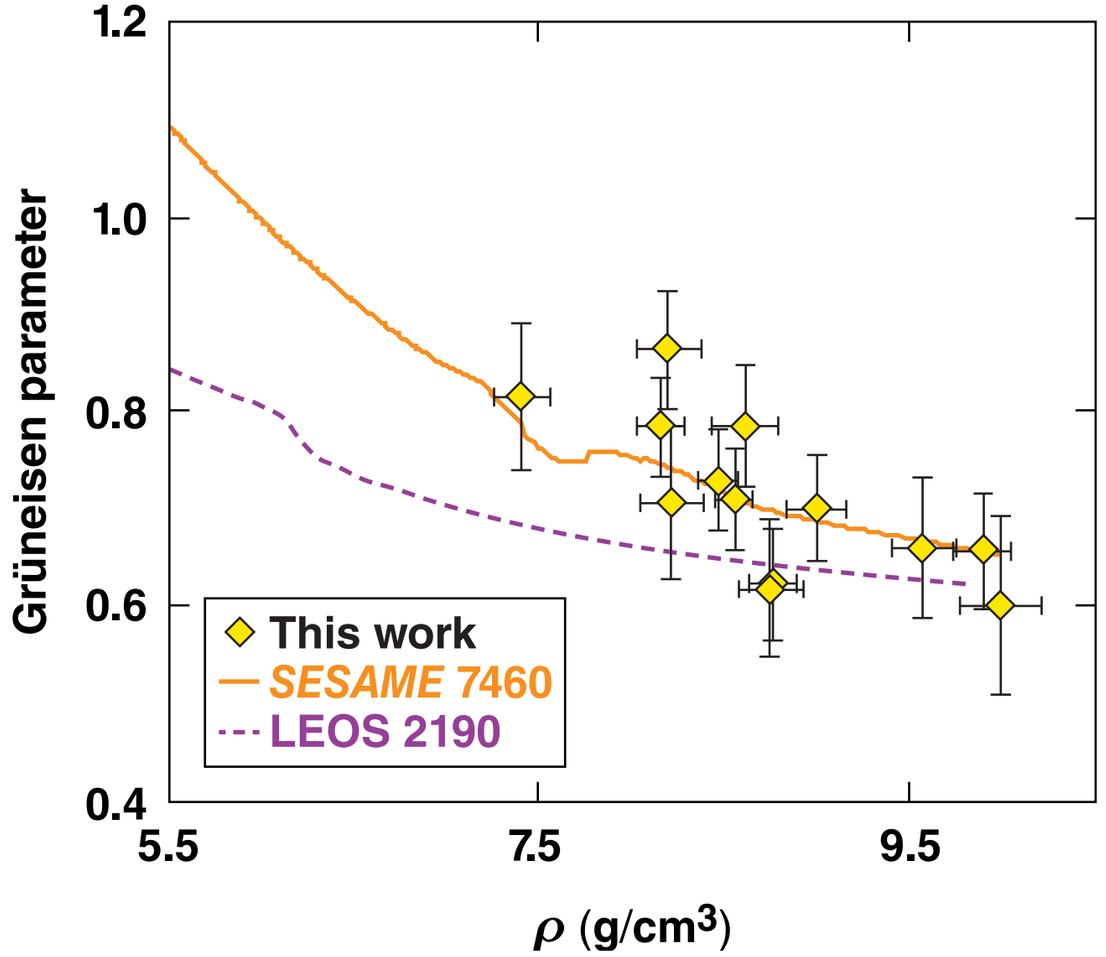
The Grüneisen parameter agrees with the *SESAME* 7460 table but both tables overestimate the sound velocity





E24601

Summary/Conclusions

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