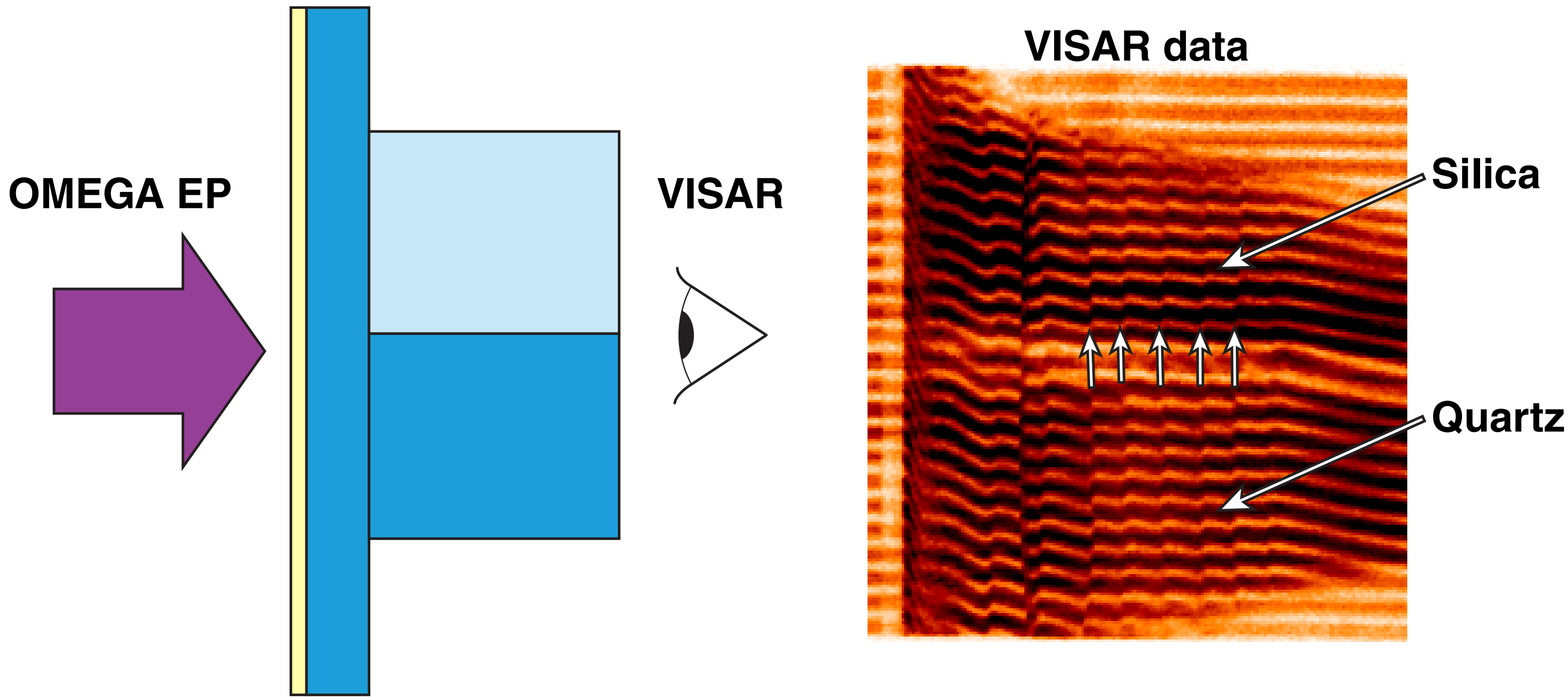
Measurements of the Sound Speed and Grüneisen Parameter with a Nonsteady Wave Correction



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The propagation of acoustic disturbances is used to measure the sound speed and Grüneisen parameter in fused silica and CH

- The temporal shift between perturbations provides information about the sound speed, while perturbation amplitude describes the Grüneisen parameter
- Sound-speed measurements are taken relative to a known standard
- Calibration of fluid silica as a sound-speed standard was done by comparing quartz and solid fused silica
- The measured sound speeds are consistent with existing equation-of-state (EOS) tables

Collaborators

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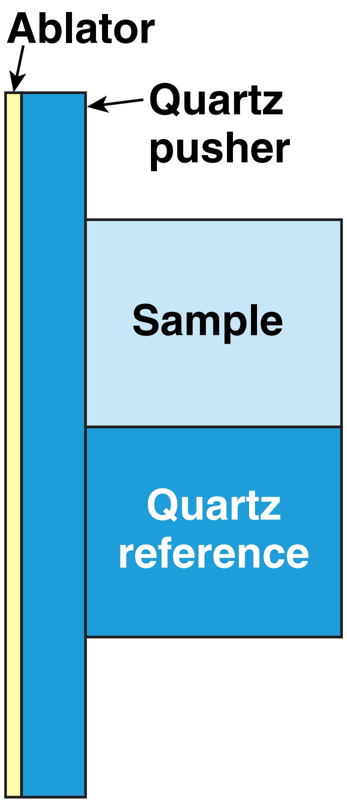
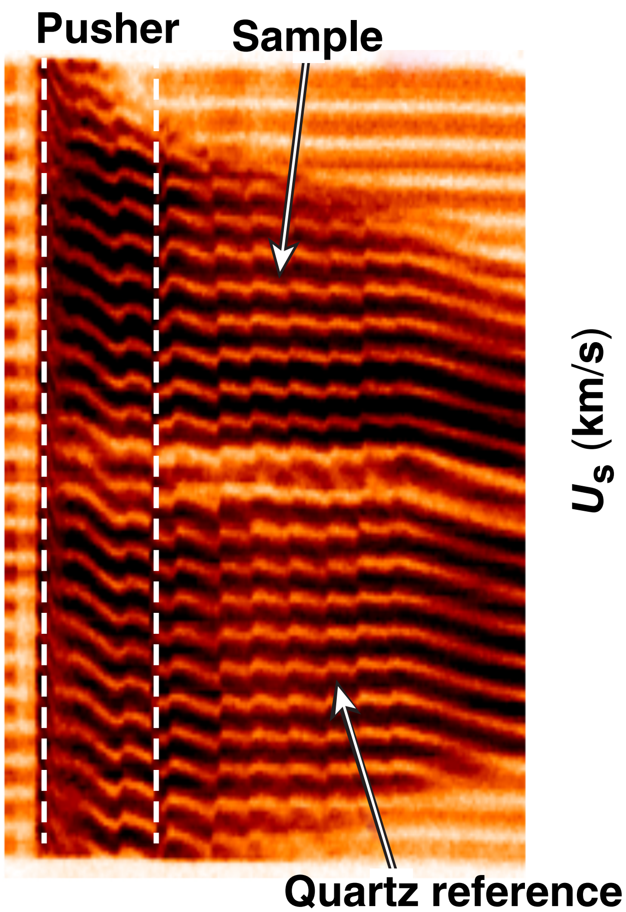
Motivation

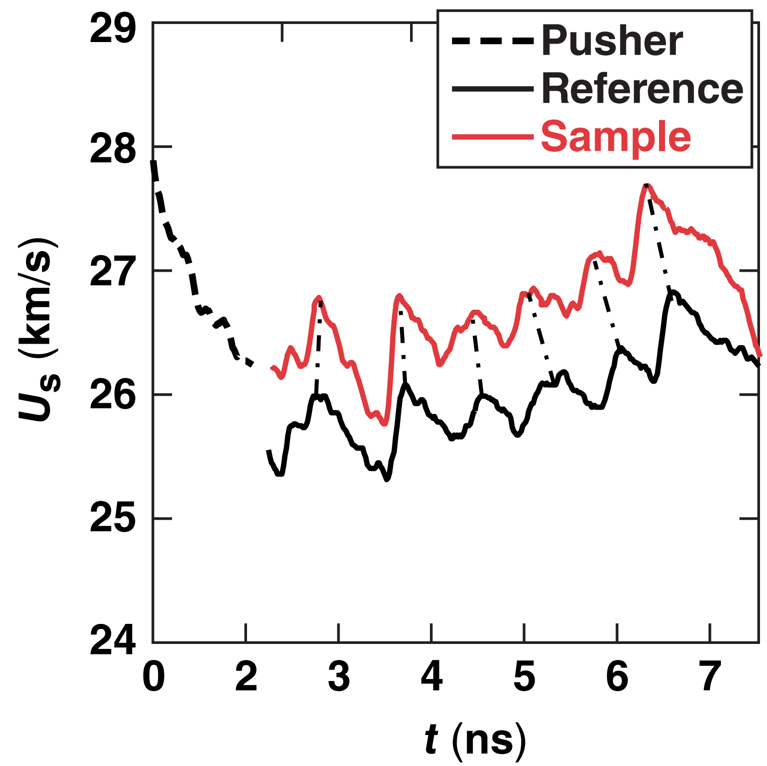
Experimental measurements of the sound speed and Grüneisen parameter are difficult for laser-driven shocks

- Traditional measurements of the Grüneisen parameter compare the Hugoniots of a given material from different starting states
  - Γ is derived from multiple measurements (Hugoniots) potentially resulting in large errors
- Sound-speed measurements traditionally use overtaking rarefaction or edge-rarefaction methods
  - these are nonviable for laser-driven shocks (steadiness/time scale)
- Choose to establish quartz as a standard for reference because of good optical properties and existing high-pressure data

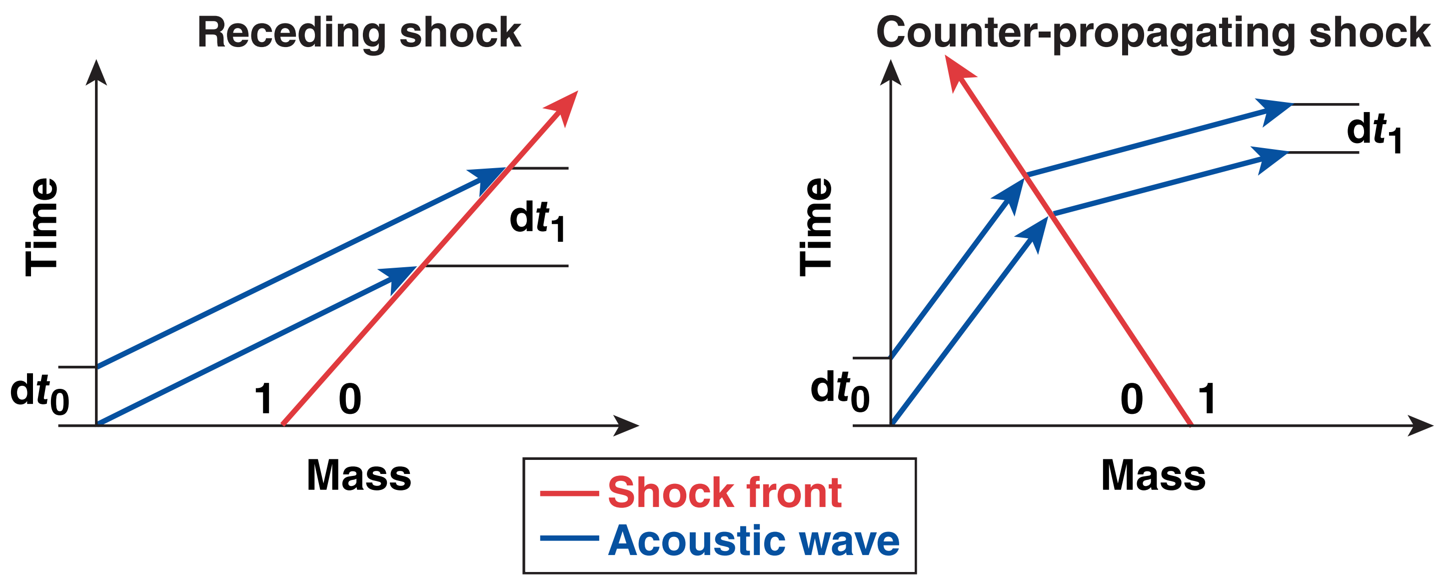
Modulations in pressure, exerted by pusher, propagate at different speeds through the reference and sample







Nonsteady wave correction* is used to propagate acoustic waves through samples



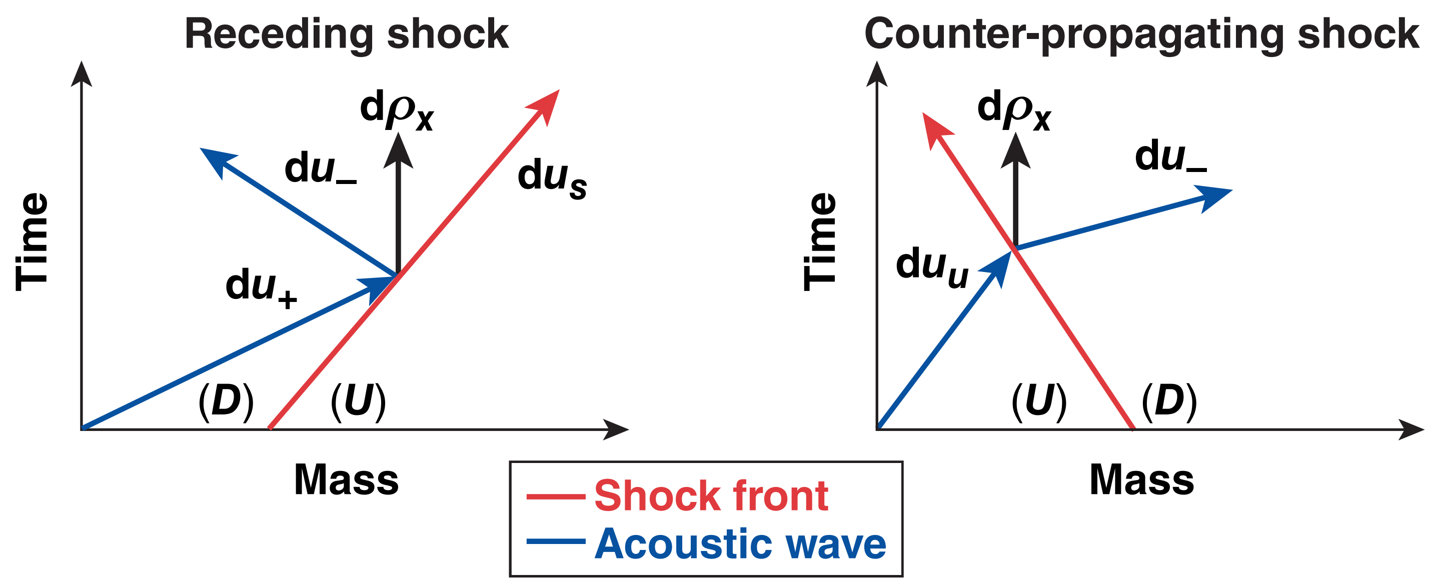
- Equations describing time dilation of acoustic disturbances across regions of flow are dependent on Mach numbers
- For example, a counter-propagating shock is given by: $\frac{dt_1}{dt_0} = \frac{(1+M_1)}{(1+M_0)}$

E23514

*D. E. Fratanduono *et al*., J. Appl. Phys. 116, 033517 (2014); D. E. Fratanduono *et al*., JO7.00008, this conference.

Time Dilation

First-order hydrodynamics* determine transmission coefficients for the propagation of pressure disturbances



- Equations describing pressure fluctuations of accoustic disturbances across regions of flow are dependent on Mach numbers and the Grüneisen parameter
- For example, a counter-propagating shock is given by:

$$\frac{du_1}{du_0} = \frac{M_1(1+M_0)}{1+M_1} \frac{1+1/M_0-(\rho_1/\rho_0-1)M_1^2\Gamma_1}{1+M_1-(\rho_1/\rho_0-1)M_1^2\Gamma_1}$$

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Standard

Quartz sound speed and Grüneisen parameter were obtained from impedance matching with fused silica

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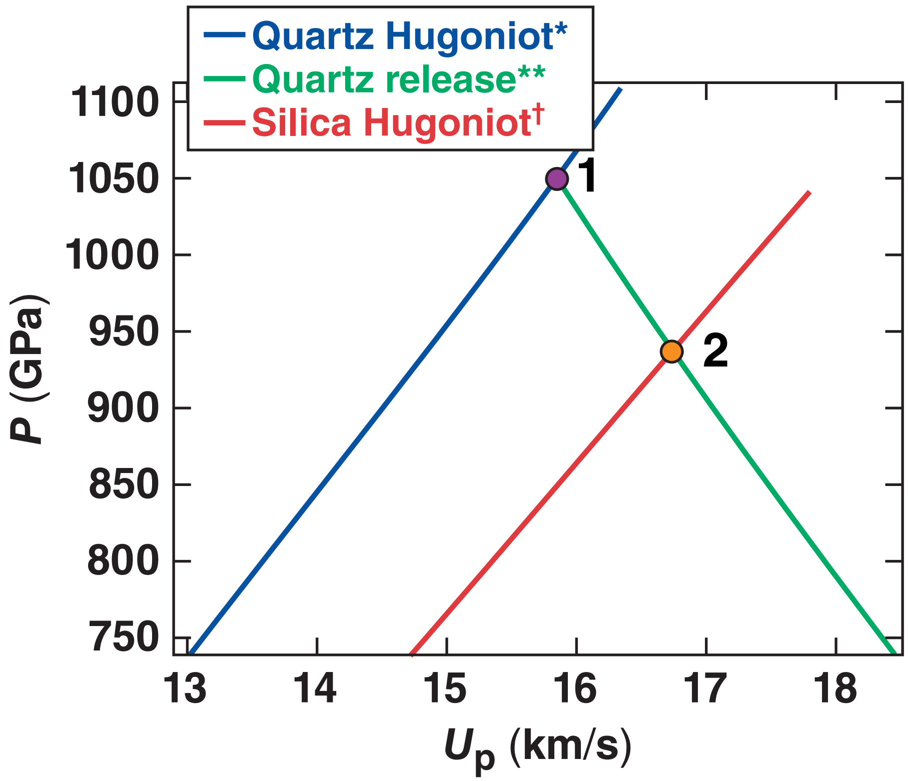

- Pressure known from impedance match
  - need specific volume and energy
- Specific volume given by

$$V_2 = V_1 - \int_{P_1}^{P_2} \left(\frac{du}{dP}\right)^2 dP$$

- Energy given by

$$E_2 = E_1 + \int_{P_1}^{P_2} P\left(\frac{du}{dP}\right)^2 dP$$

- Sound velocity

$$c_s = \sqrt{-V\left(\frac{dP}{dV}\right)_s}$$

- Grüneisen parameter

$$\Gamma = V\left(\frac{dP}{dE}\right)_V$$

*M. D. Knudson and M. P. Desjarlais, Phys. Rev. Lett. 103, 225501 (2009).
**M. D. Knudson and M. P. Desjarlais, Phys. Rev. B 88, 184107 (2013).
†Special thanks to M. D. Knudson for fit to Z data for fused silica.

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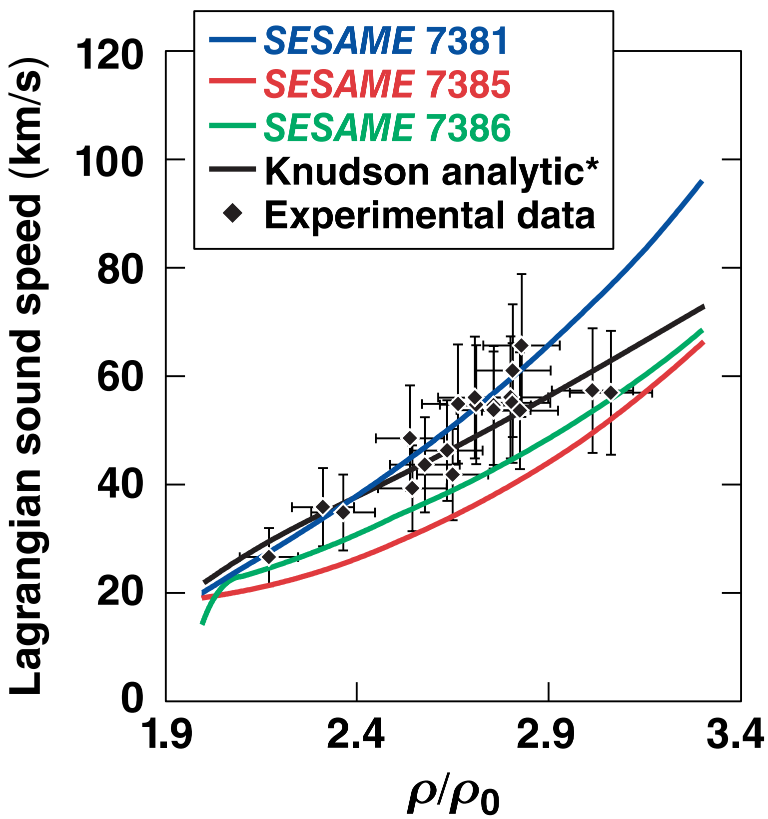
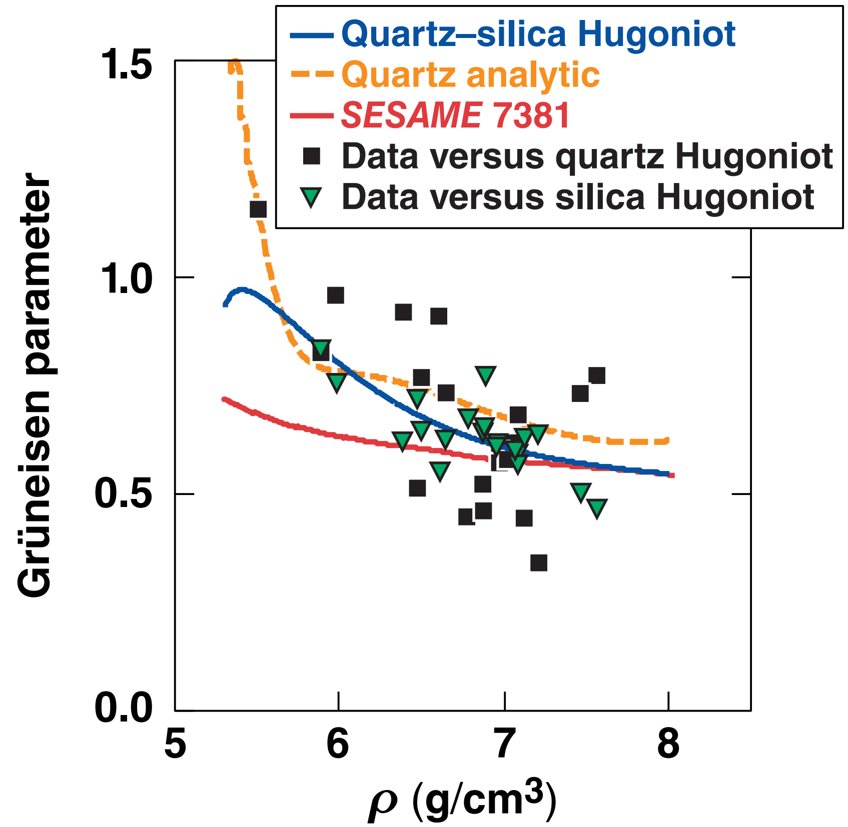
Quartz–silica impedance match results favor the analytic-release construct developed by Knudson *et al.**





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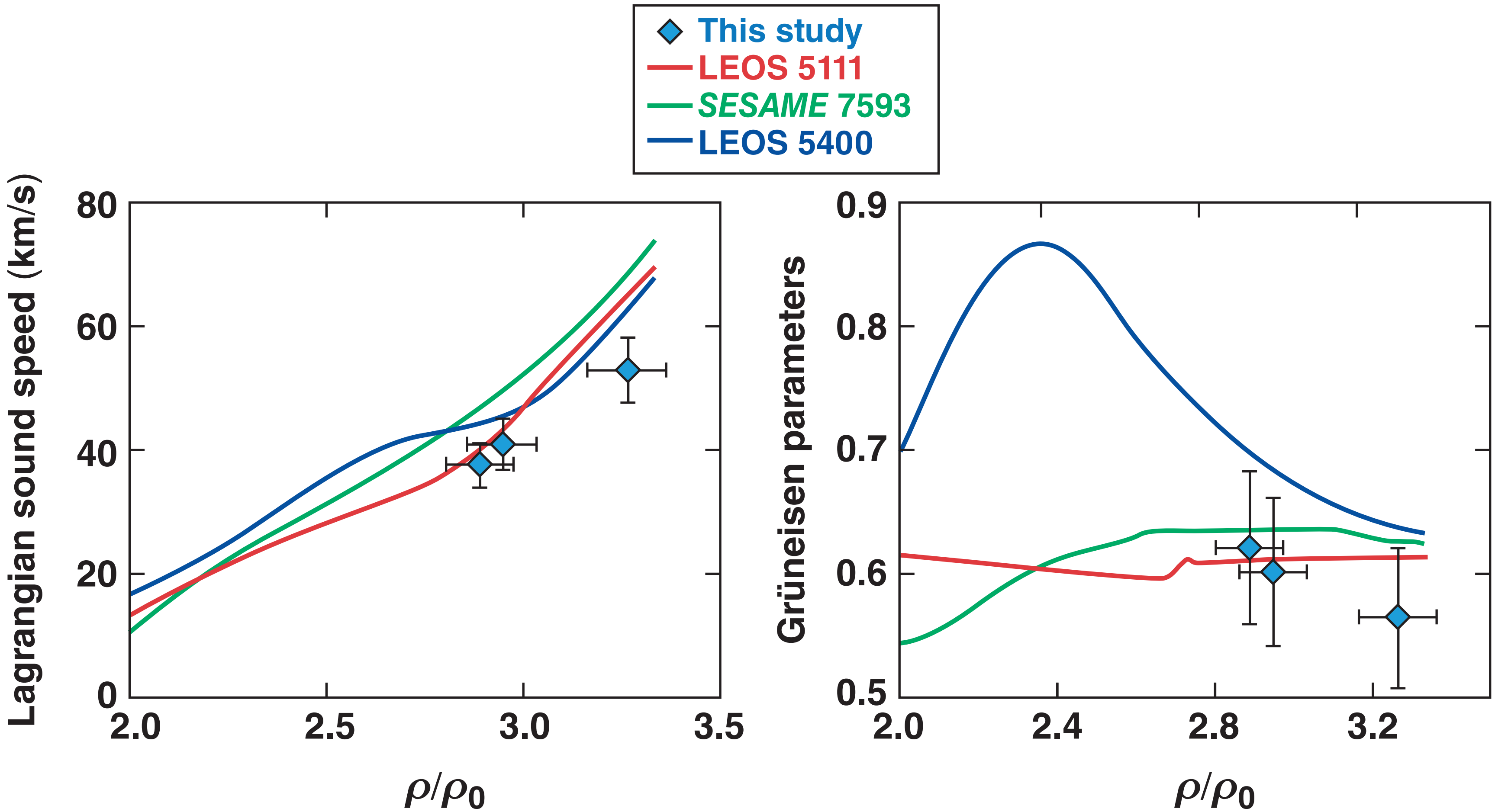
*M. D. Knudson and M. P. Desjarlais, Phys. Rev. B 88, 184107 (2013).

Sound speed and Grüneisen parameters measured in plastic favor the LEOS 5111 table in this region



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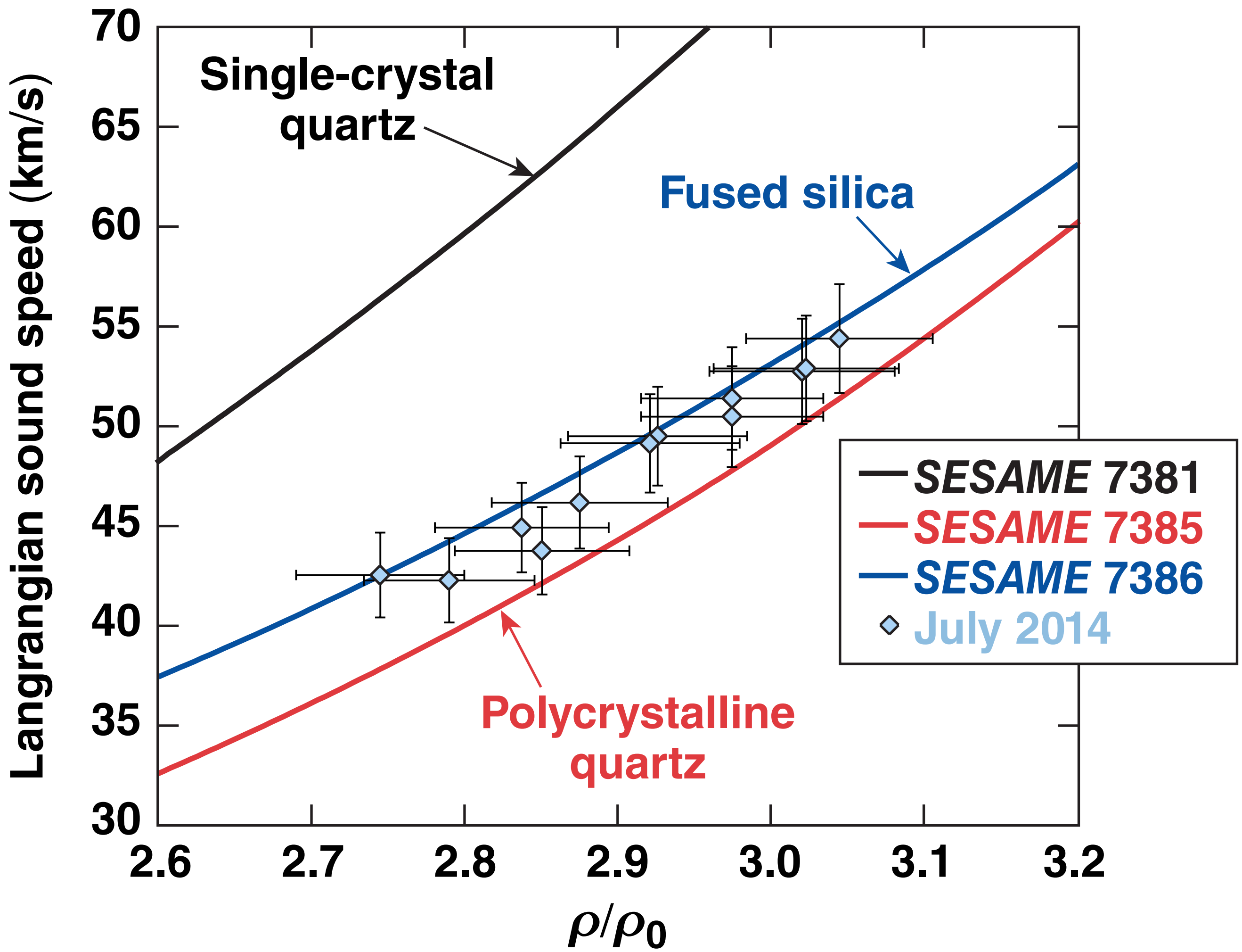
Sound-speed measurements made for fused silica agree well with the *SESAME* 7386 table



Summary/Conclusions

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