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Experimental temperature measurements of Fe-bearing silicate minerals and glasses to 1.6 TPa

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Los Alamos NATIONAL LABORATORY

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Collaborators

Los Alamos National Laboratory

UC Davis

Lawrence Livermore National Laboratory

University of Rochester

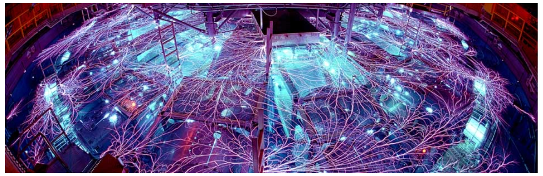
Institut de Physique du Globe de Paris (IPGP)

Sandia National Laboratories

Harvard University

Funding

MAP



Z FUNDAMENTAL SCIENCE

UR LLE

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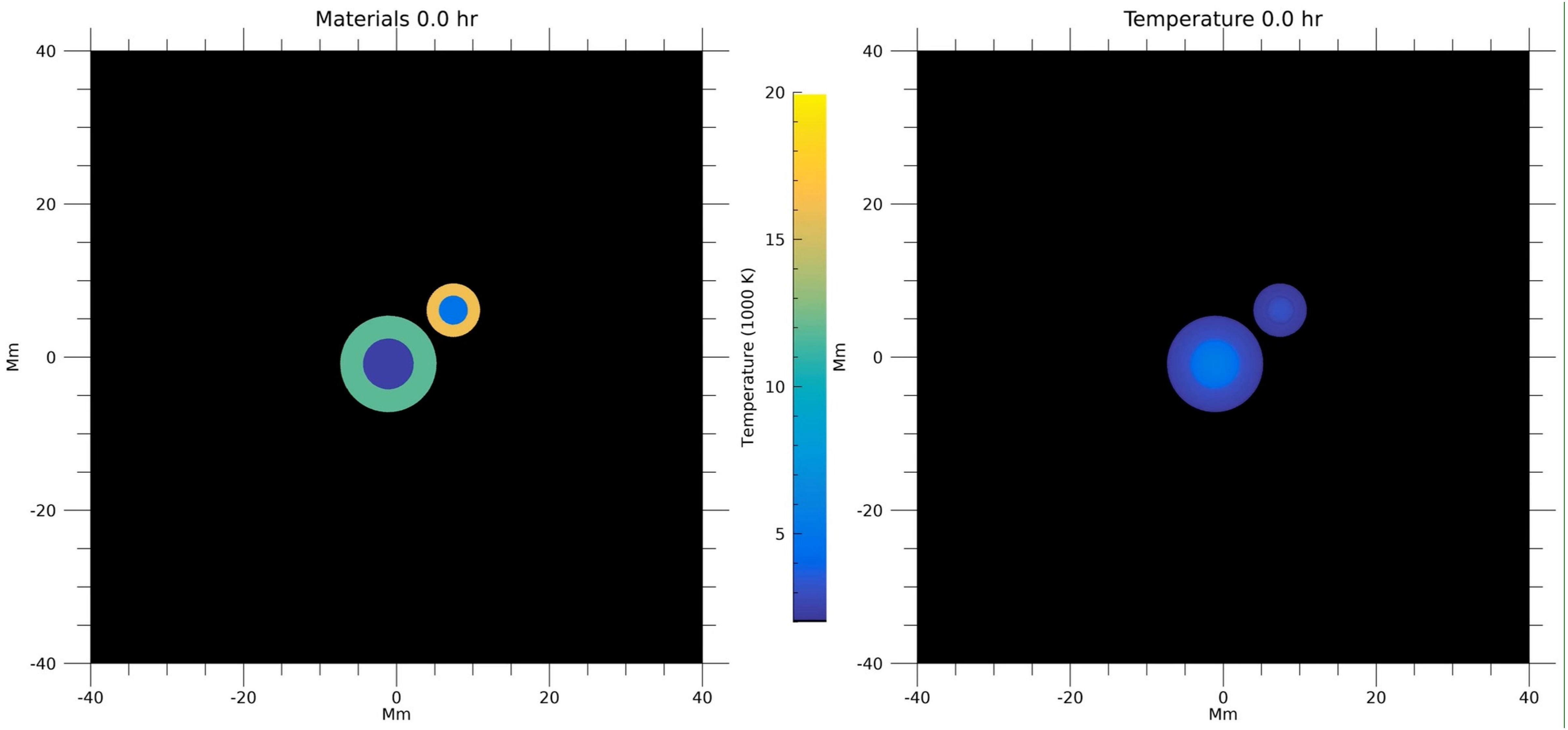
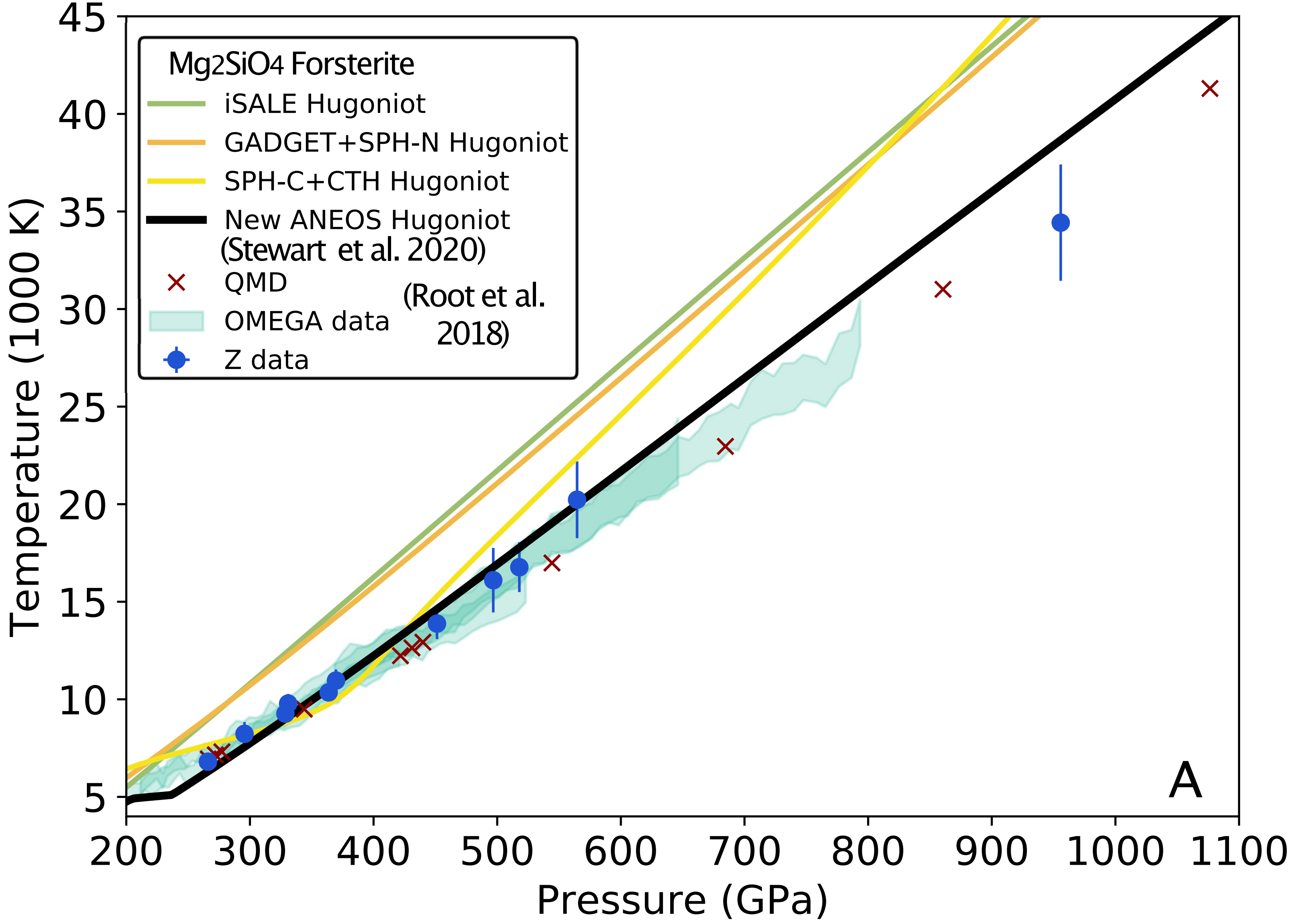
This work describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the work do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

Moon-forming giant impact



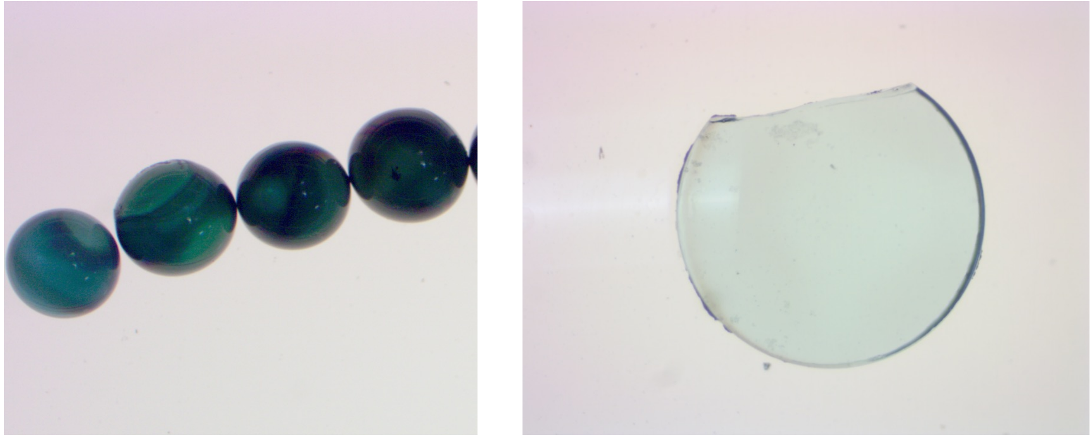
Shock temperatures are a particular problem



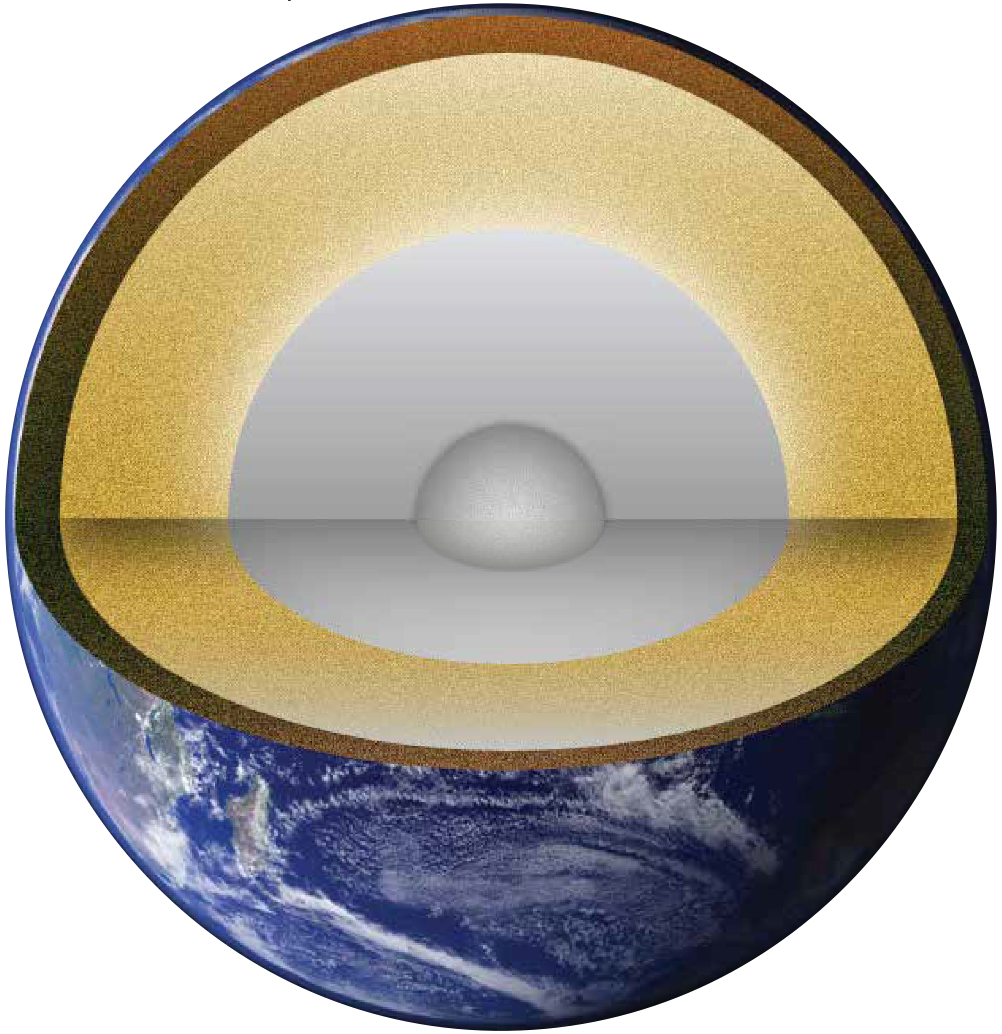
Fratanduono et al., *PRB*, 2018
Root et al., *GRL*, 2018
Chidester et al. *GRL*, 2021

$(Mg,Fe)SiO_3$
(Enstatite/Bronzite)

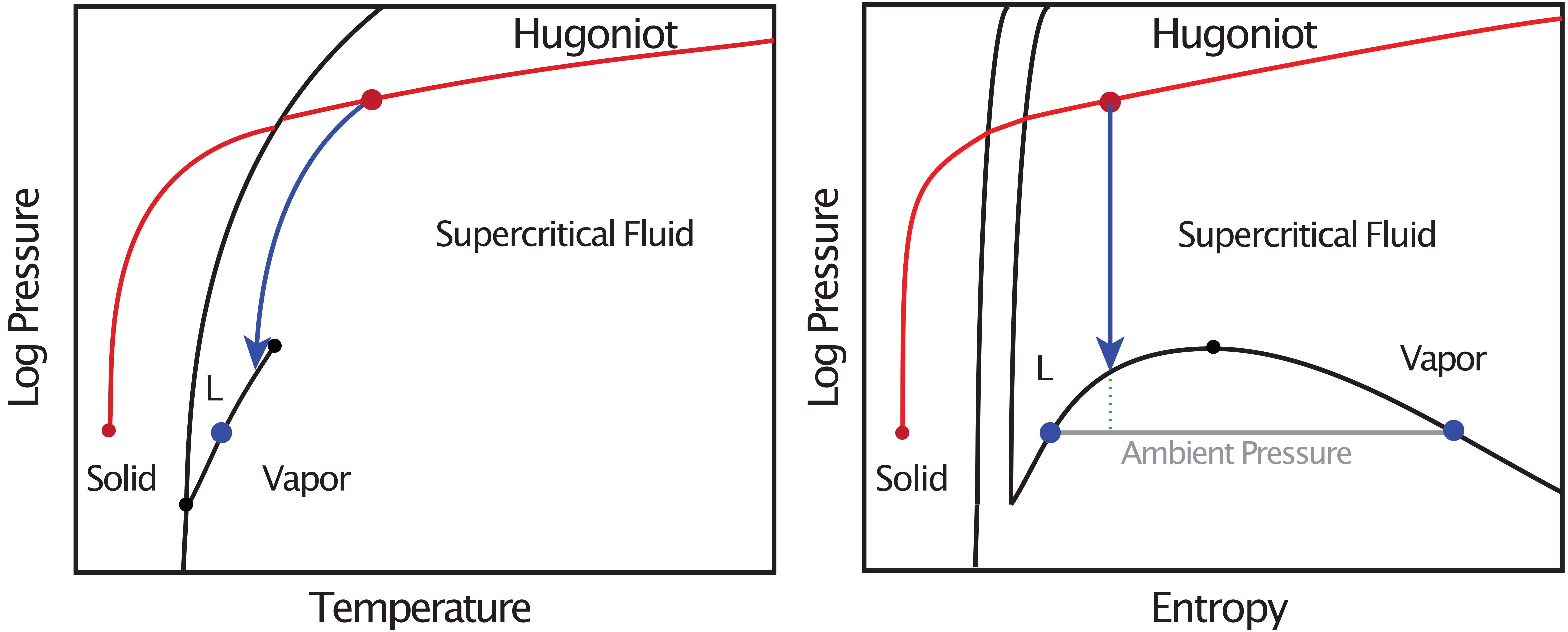
$(Mg,Fe)_2SiO_4$
(Forsterite/Olivine)



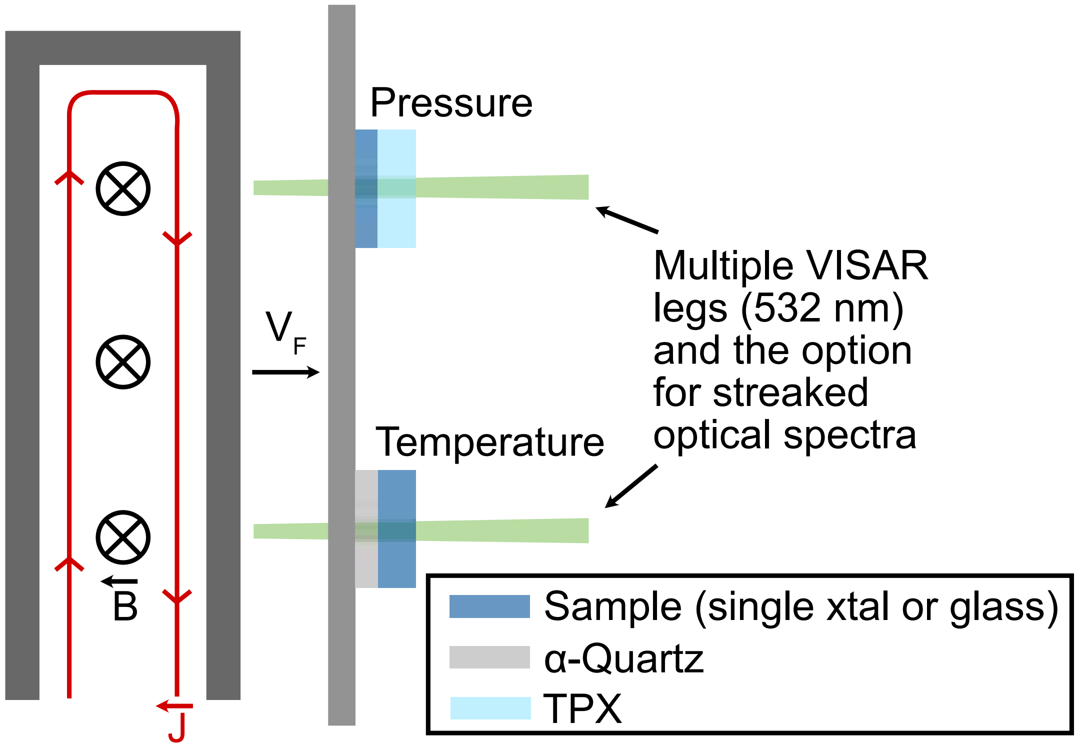
Pyrolite glass

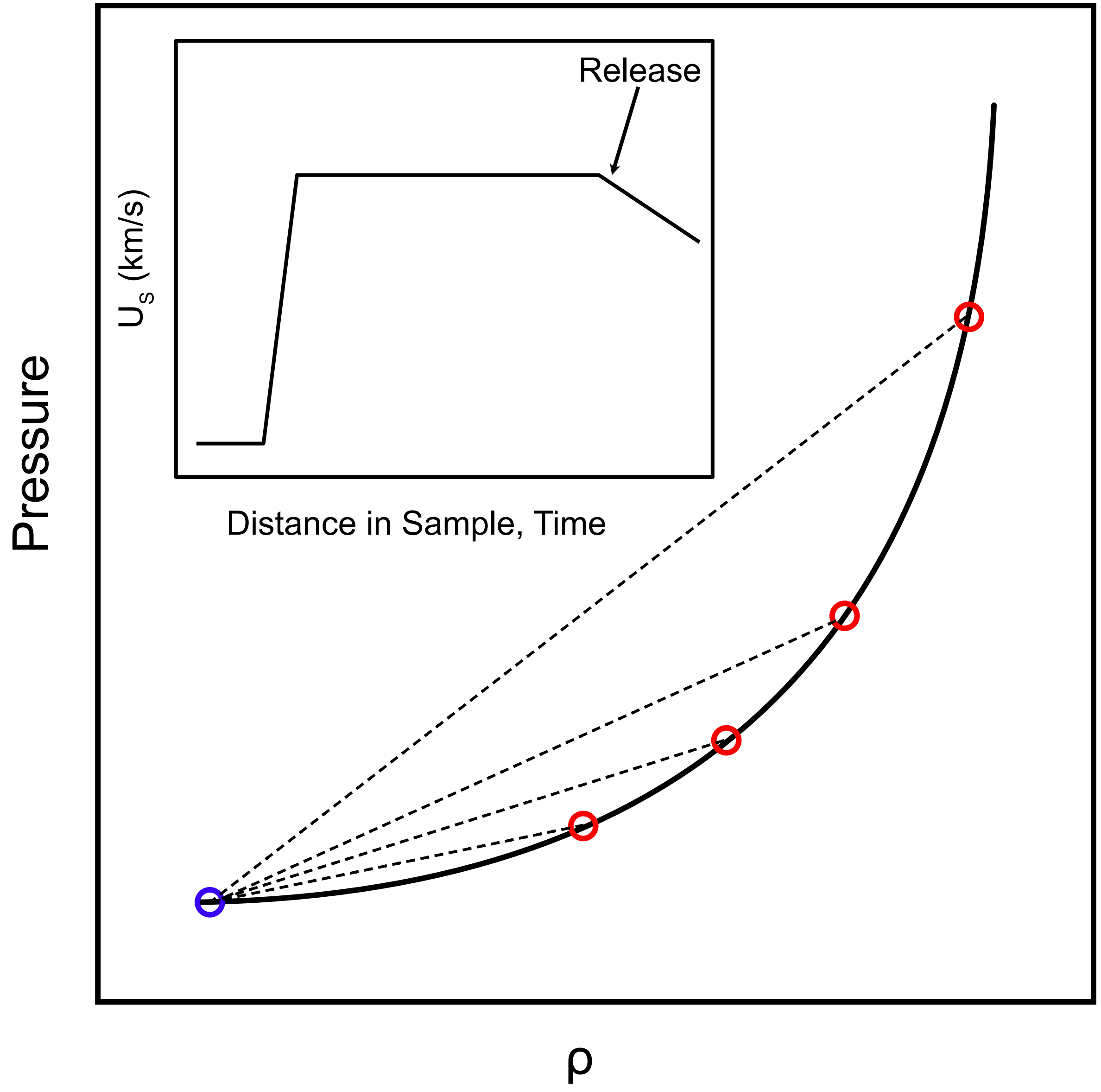


Shock Physics Experiments: Giant Impact P-T Paths



Shock compression experiments at Z Machine





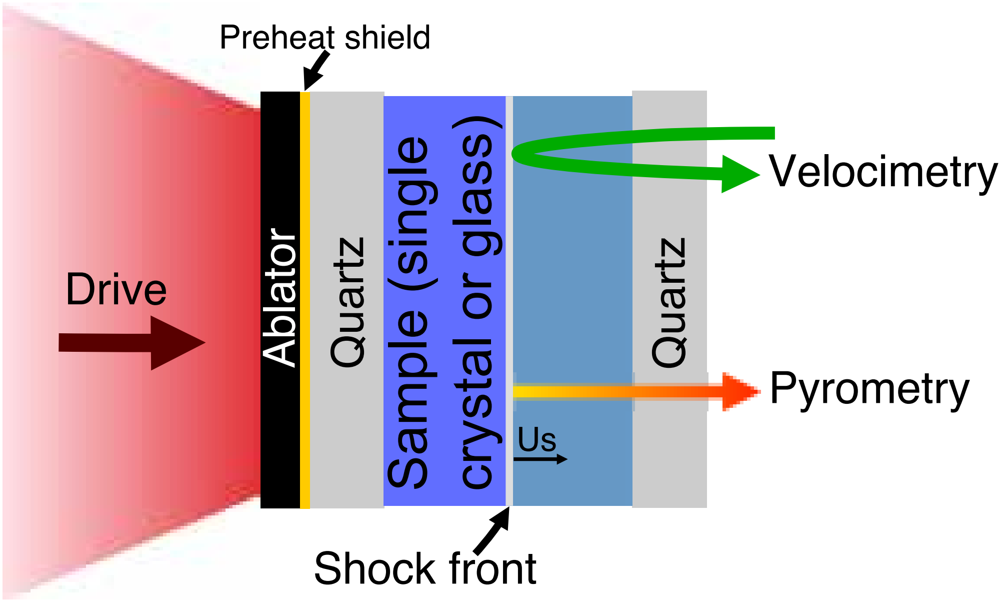
<u>Rankine-Hugoniot jump condition</u>

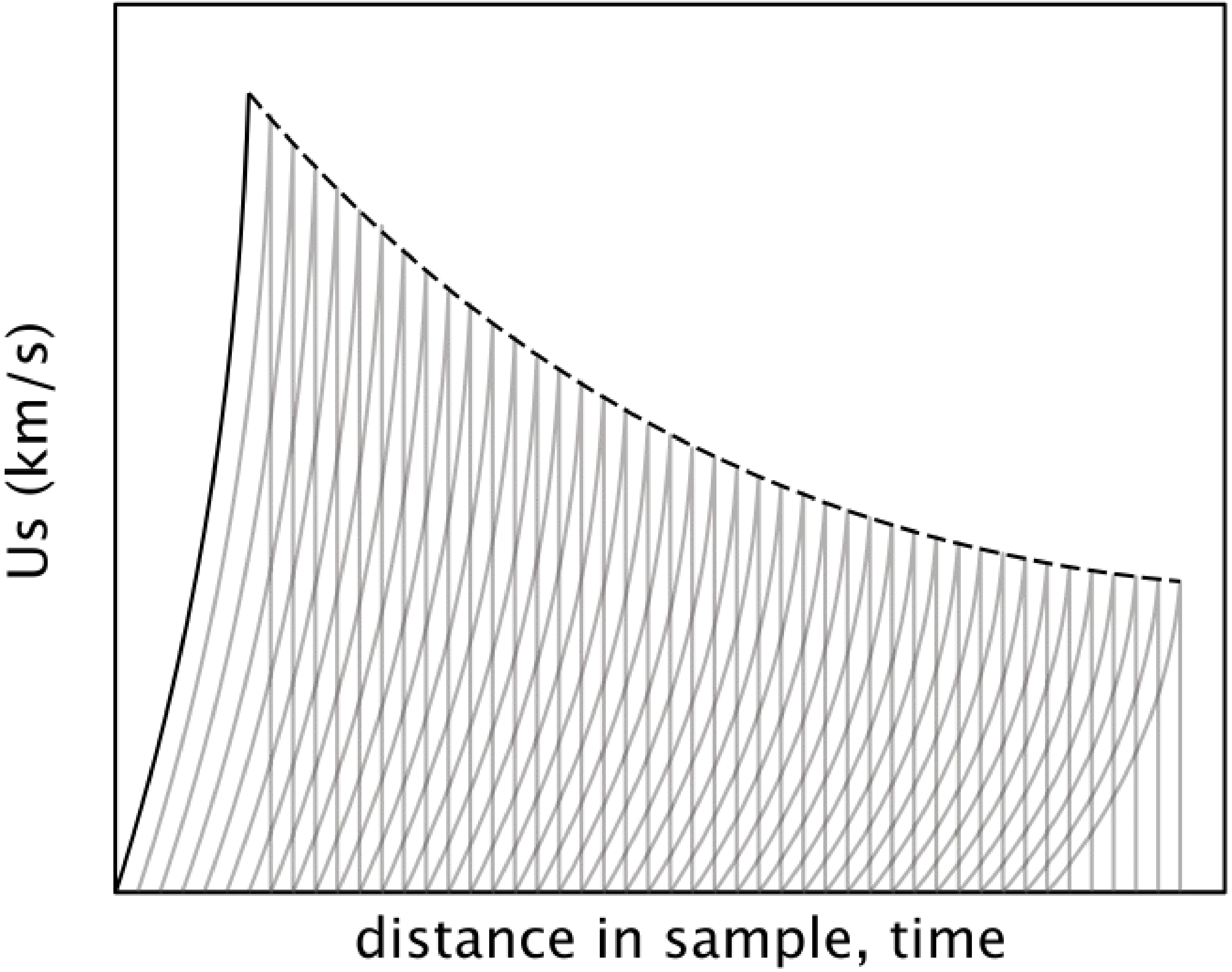
$$E - E_0 = \frac{1}{2}(P + P_0)(V_0 - V)$$

$$P - P_0 = \rho_0(U_s - u_{p,0})(u_p - u_{p,0})$$

$$\rho_0/\rho = 1 - (u_p - u_{p,0})/(U_s - u_{p,0})$$

Shock compression experiments at OMEGA EP





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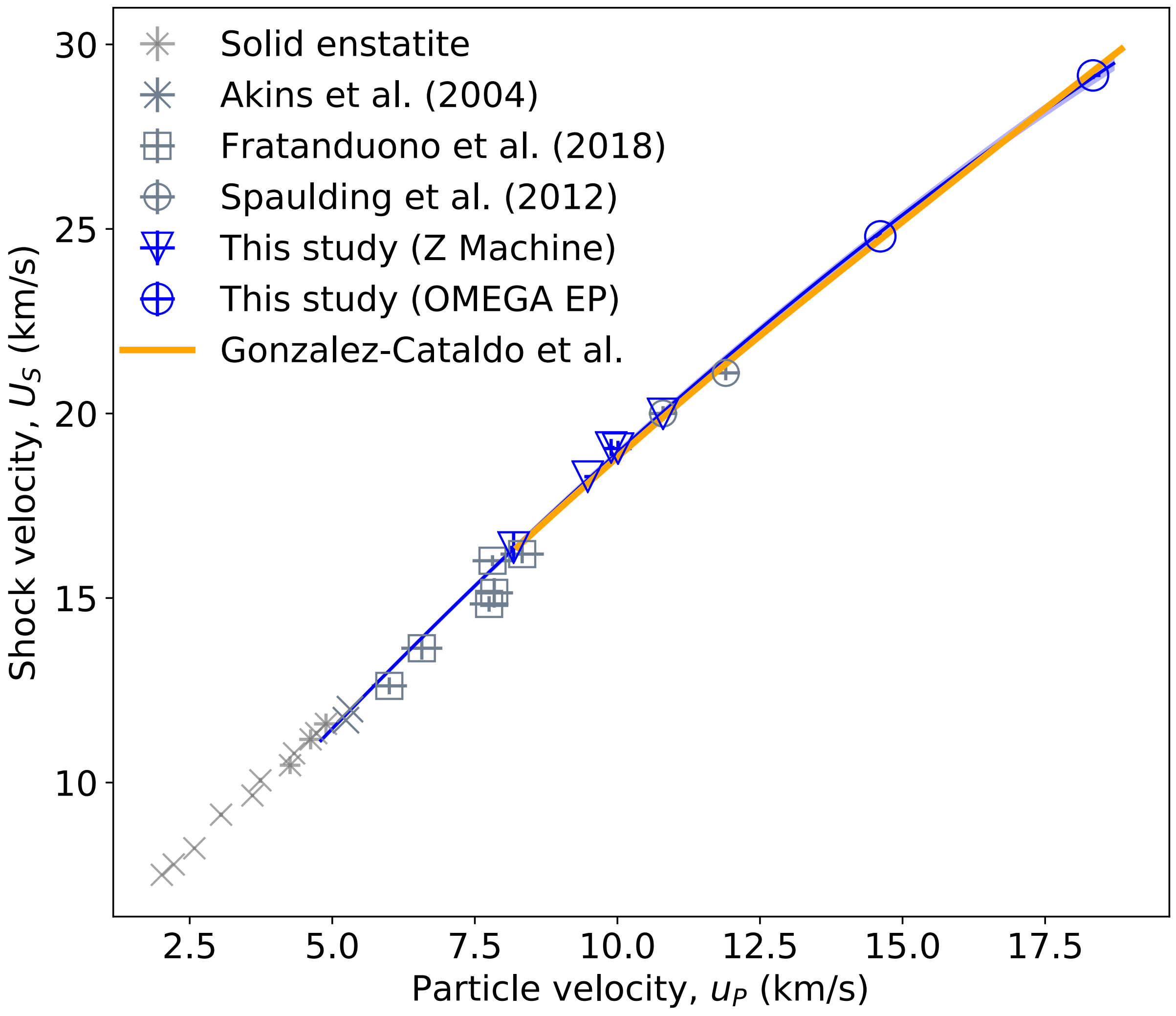
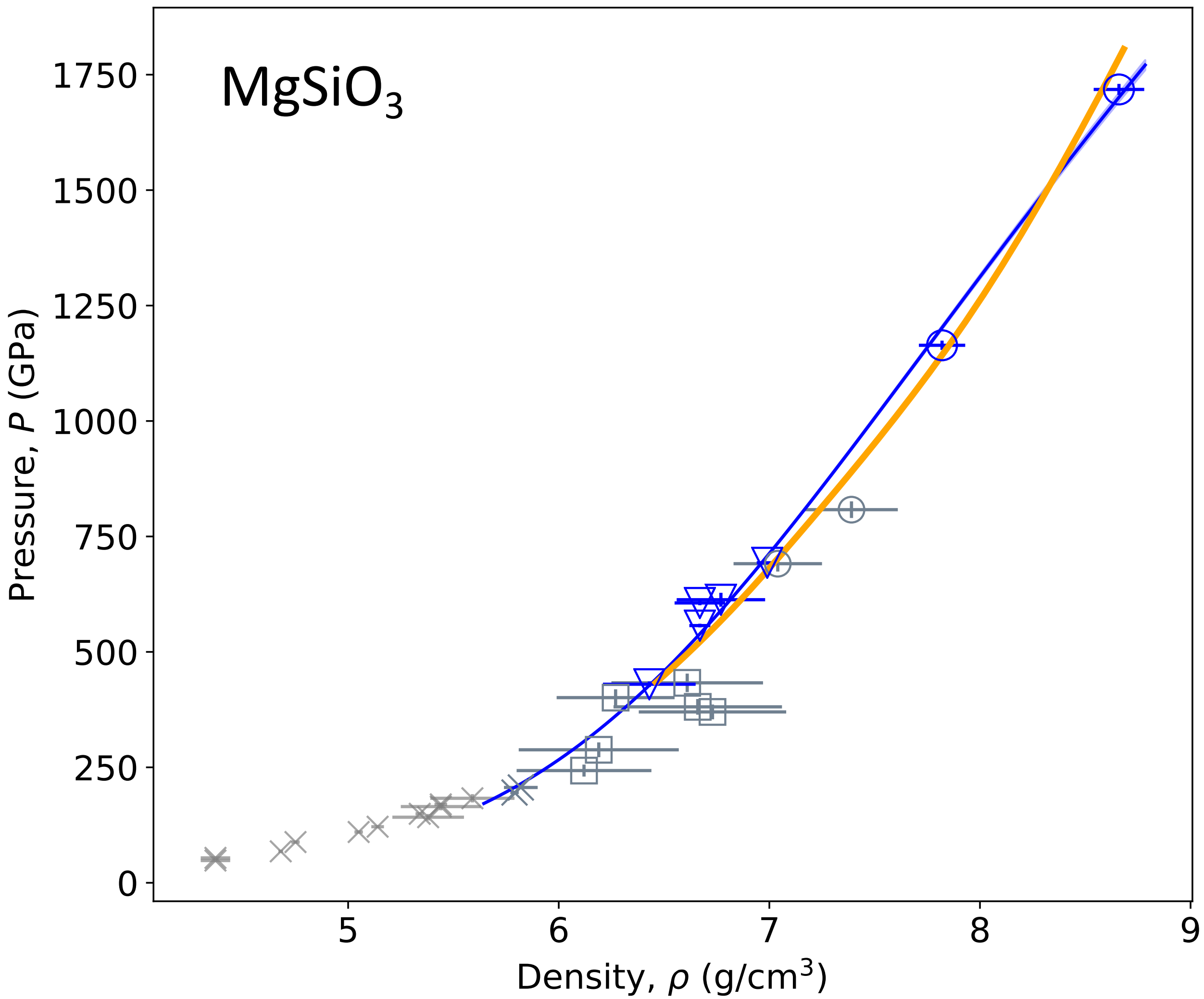
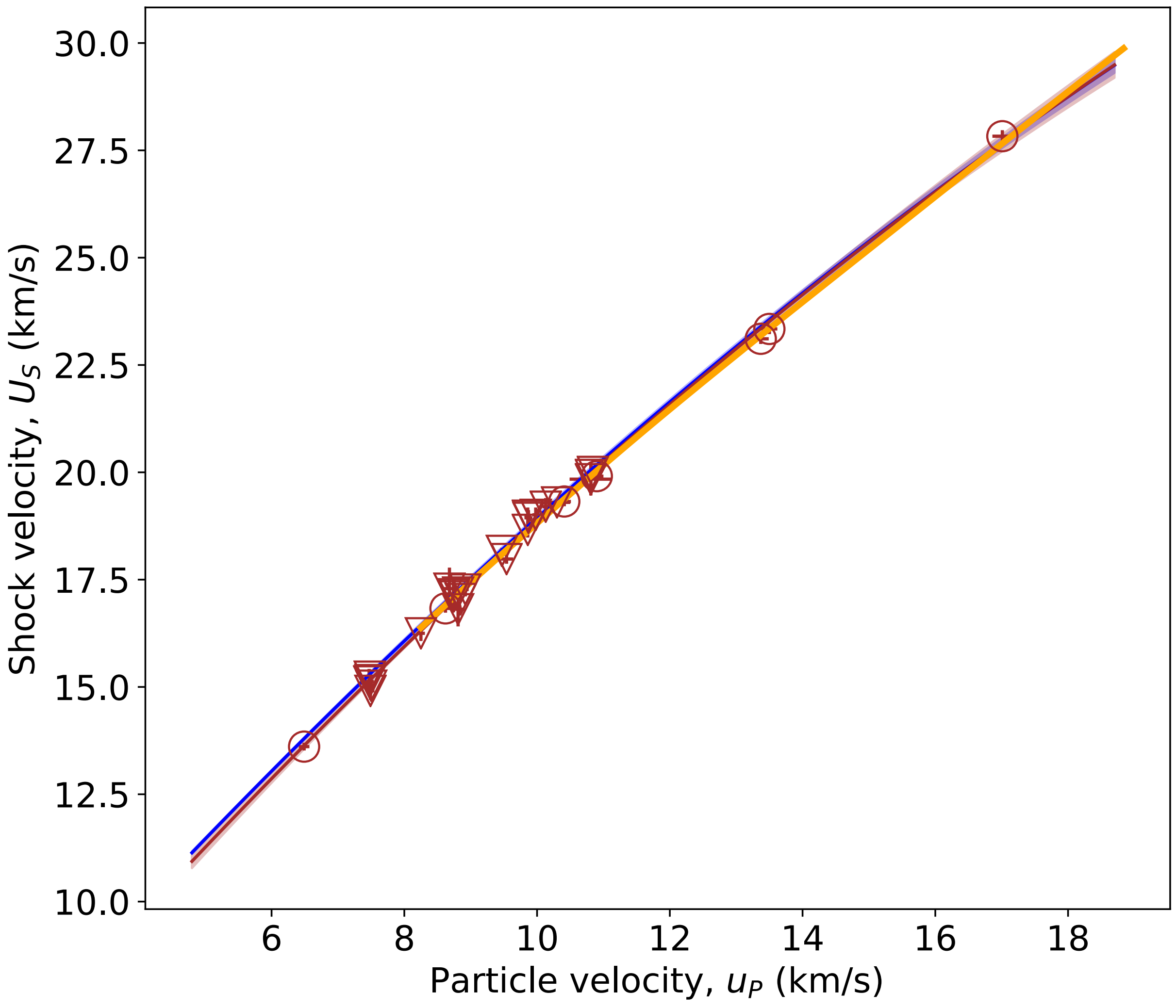
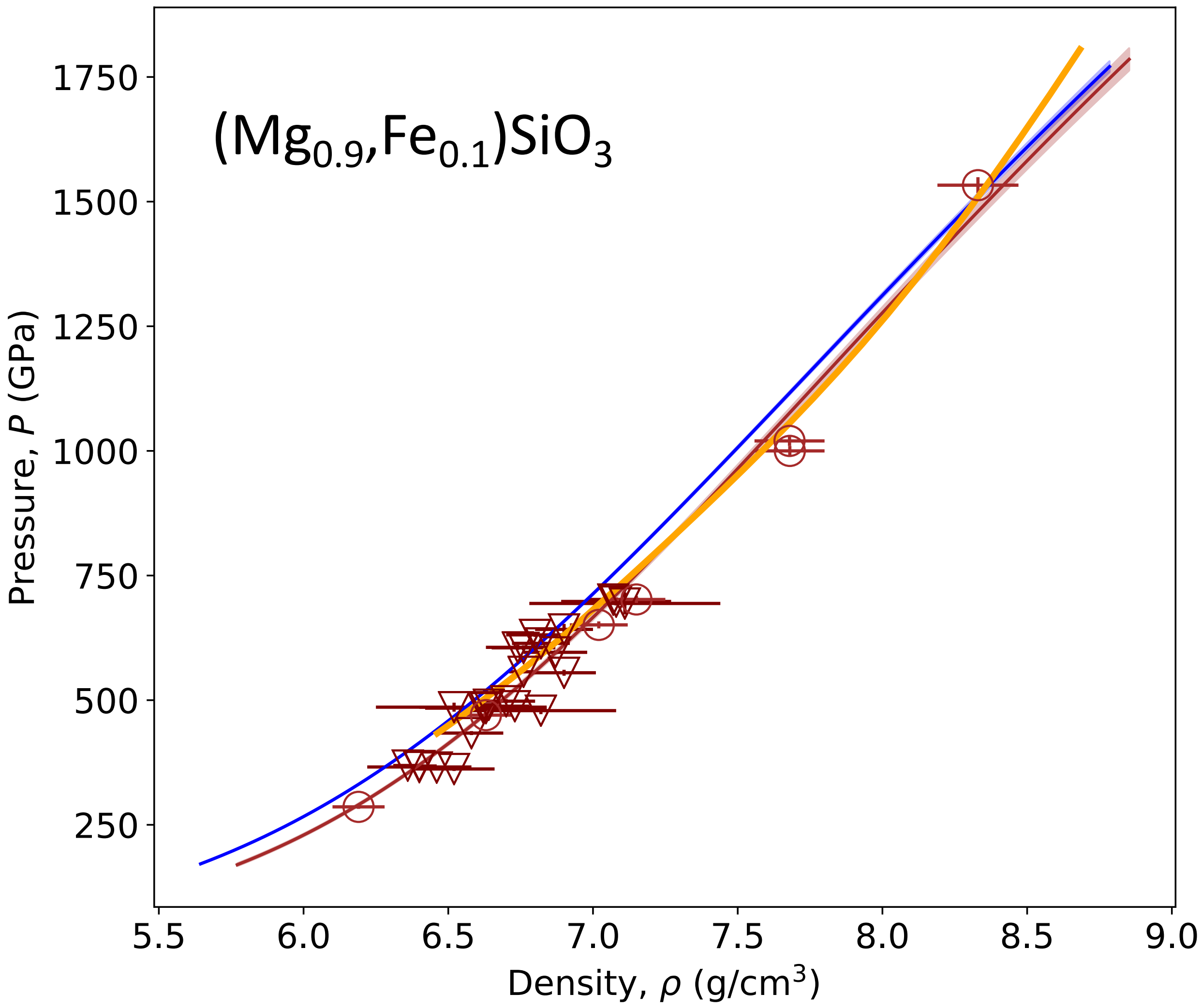
Enstatite compressibility results



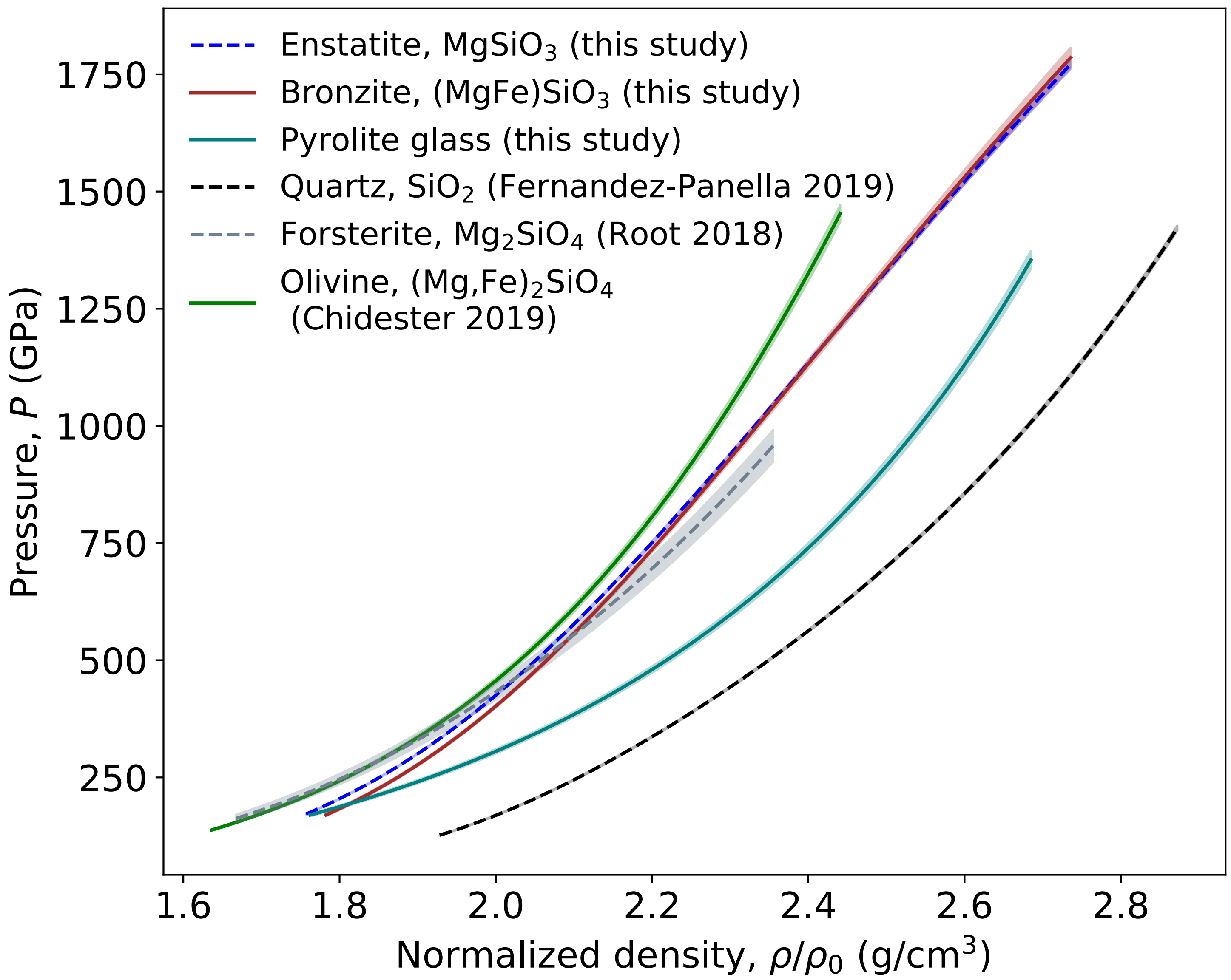


Bronzite compressibility results

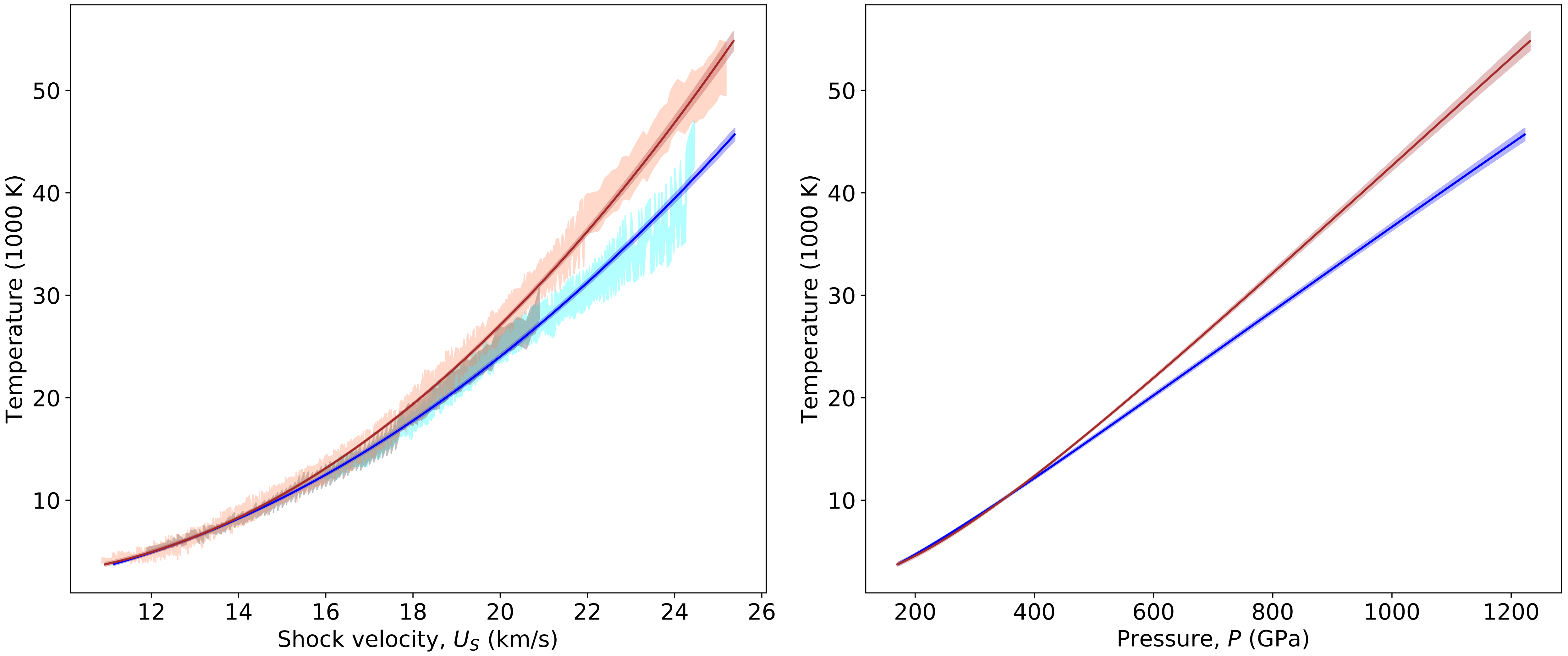




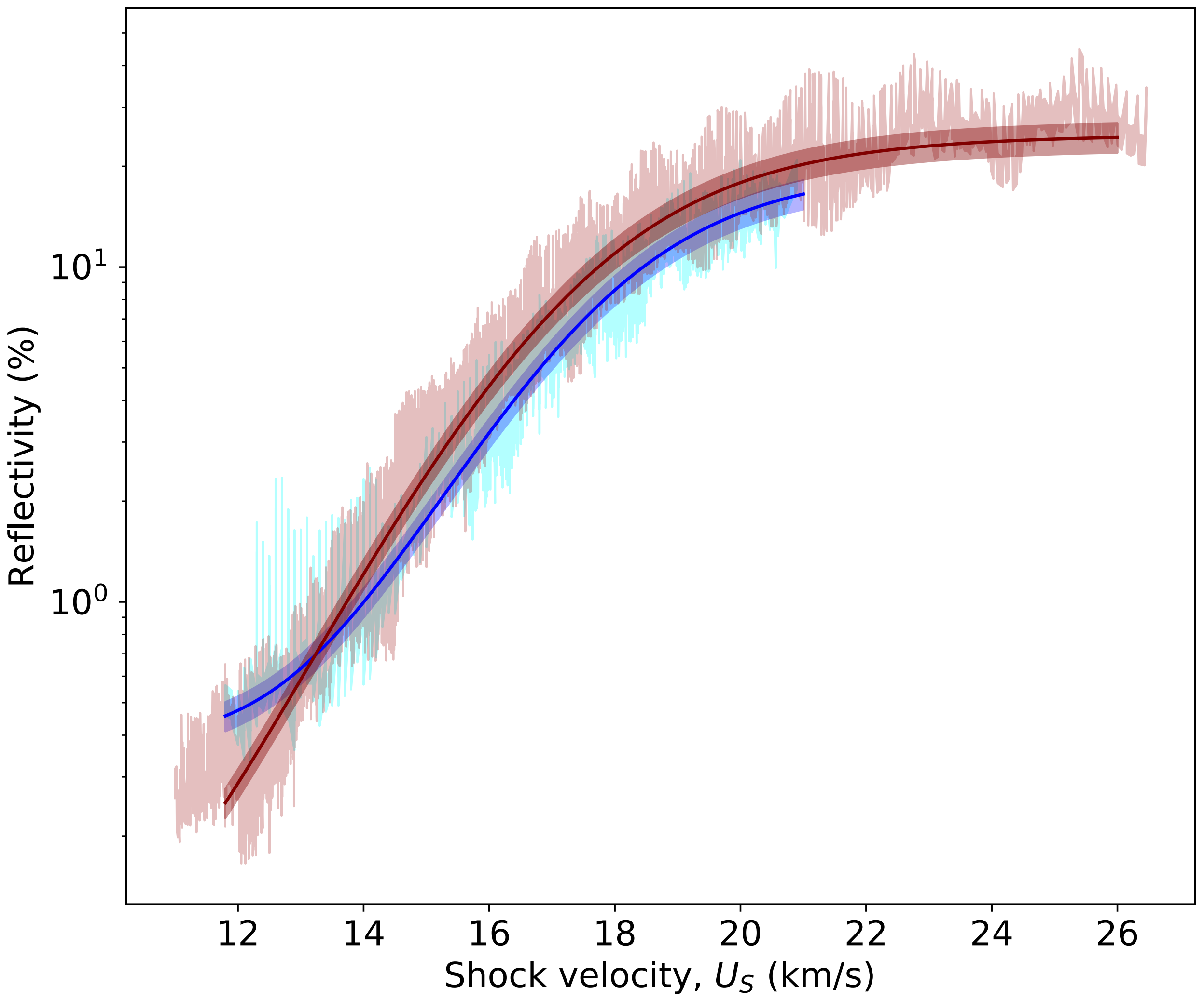
Comparison to other silicates



Temperature



Reflectivity



Silicates become conductive at high temperatures!

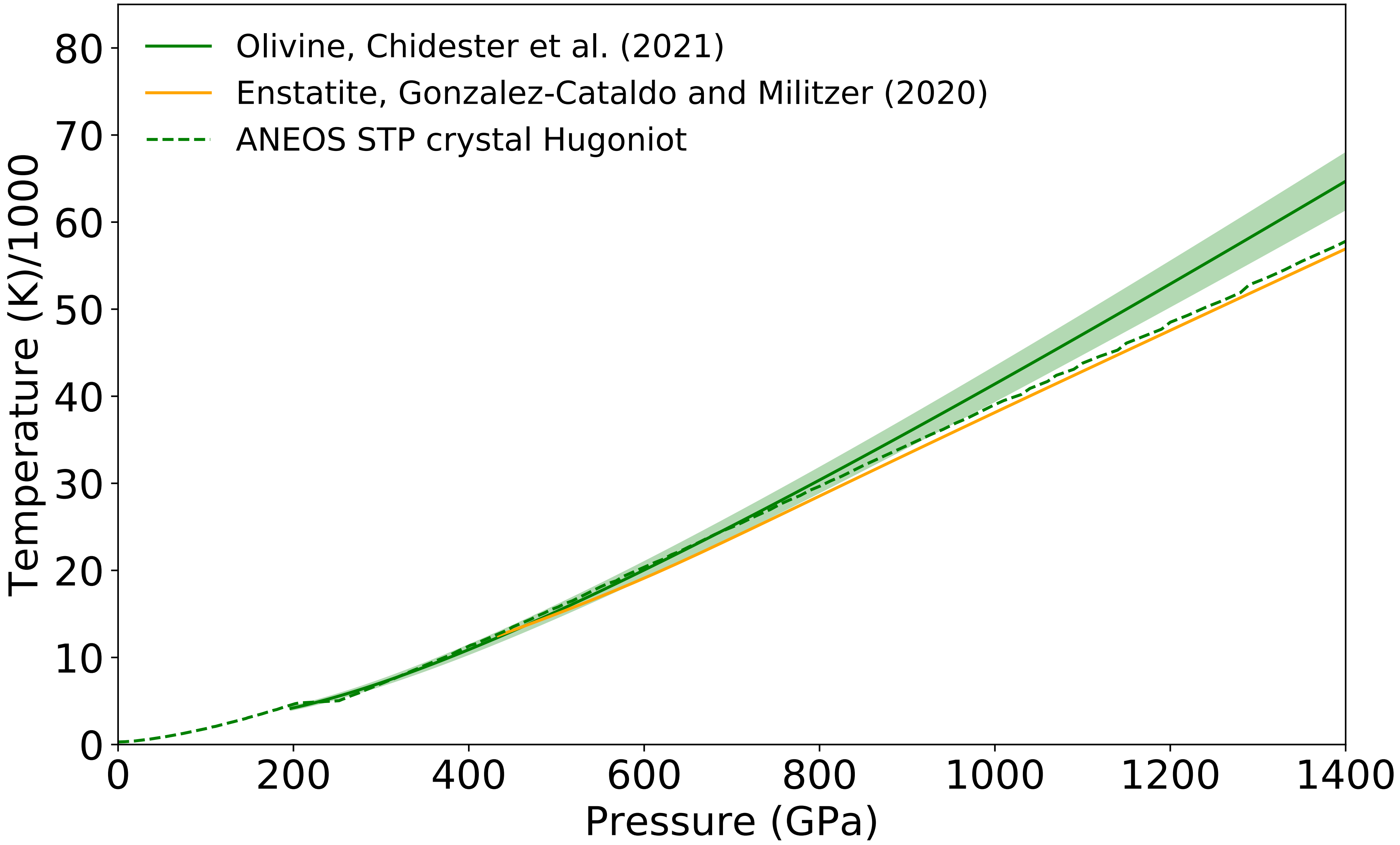
Fe atoms likely increase the effect.

Conclusions

- Fe-bearing silicates seem to shock to higher temperatures than their Fe-free endmembers
- This is related to the change in reflectivity, likely a different electronic contribution to the heat capacity as the material becomes more conductive

Might stop here, but if I have time I’ll continue on to other slides

Analytical EOS constrained by experimental results



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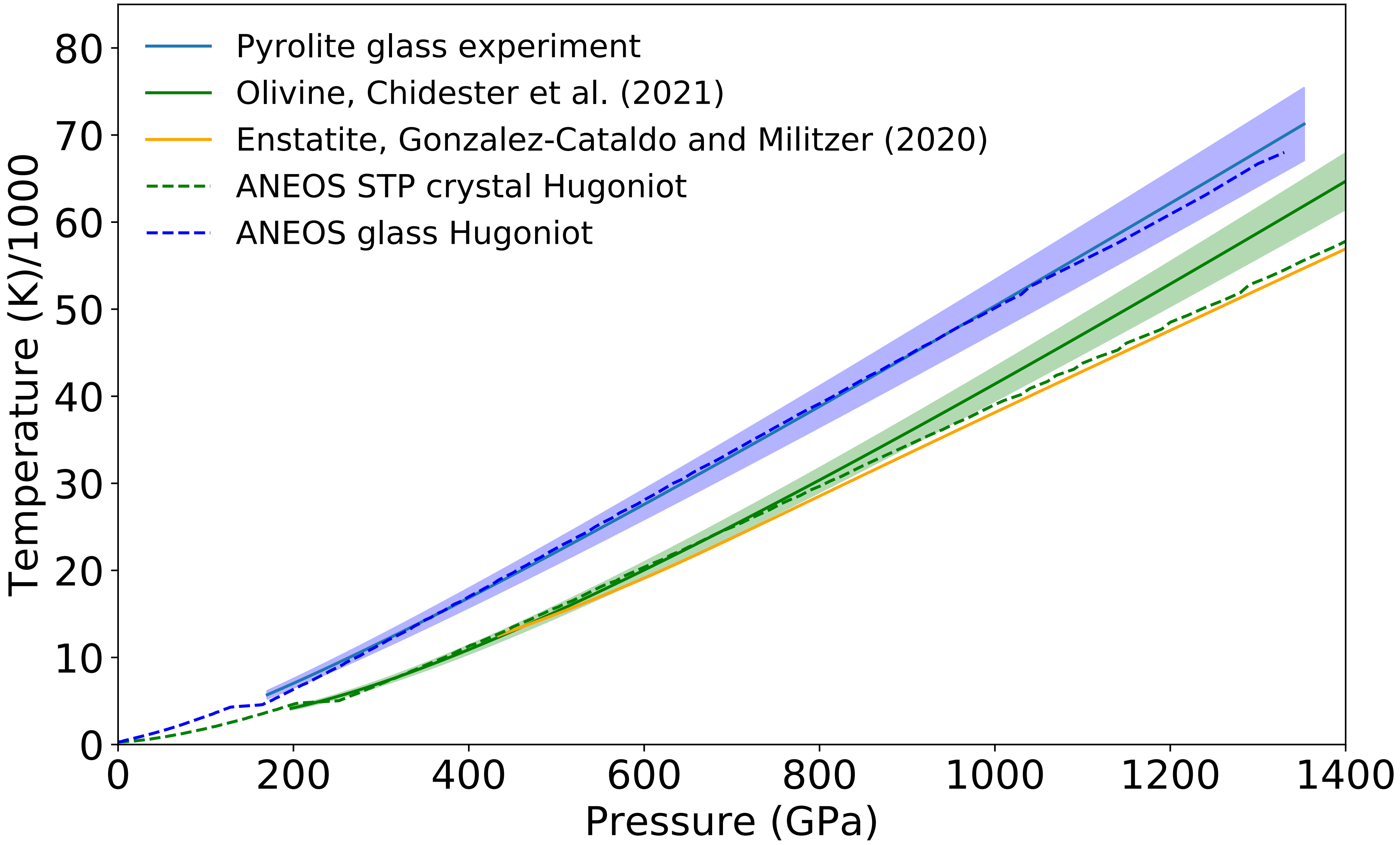

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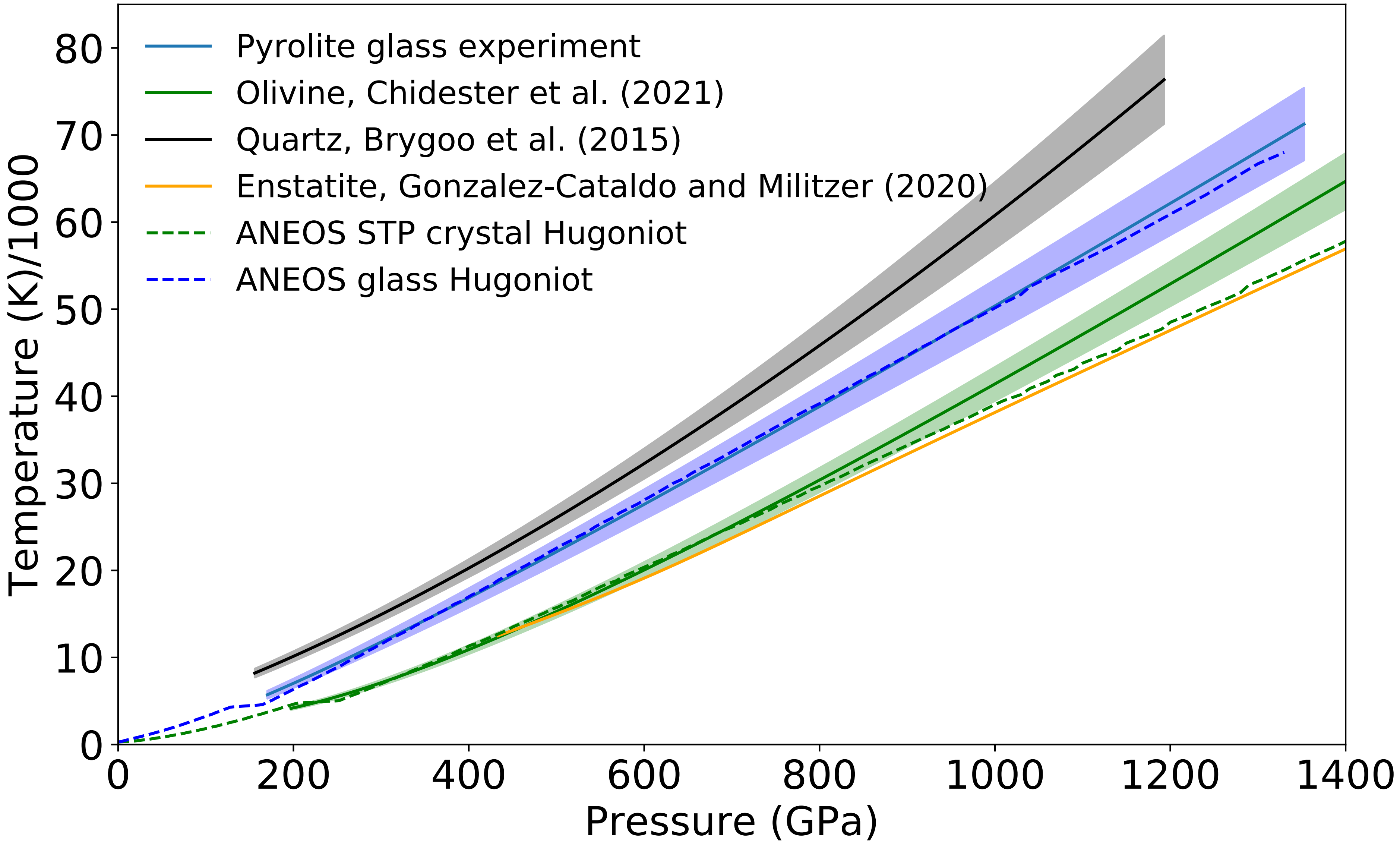
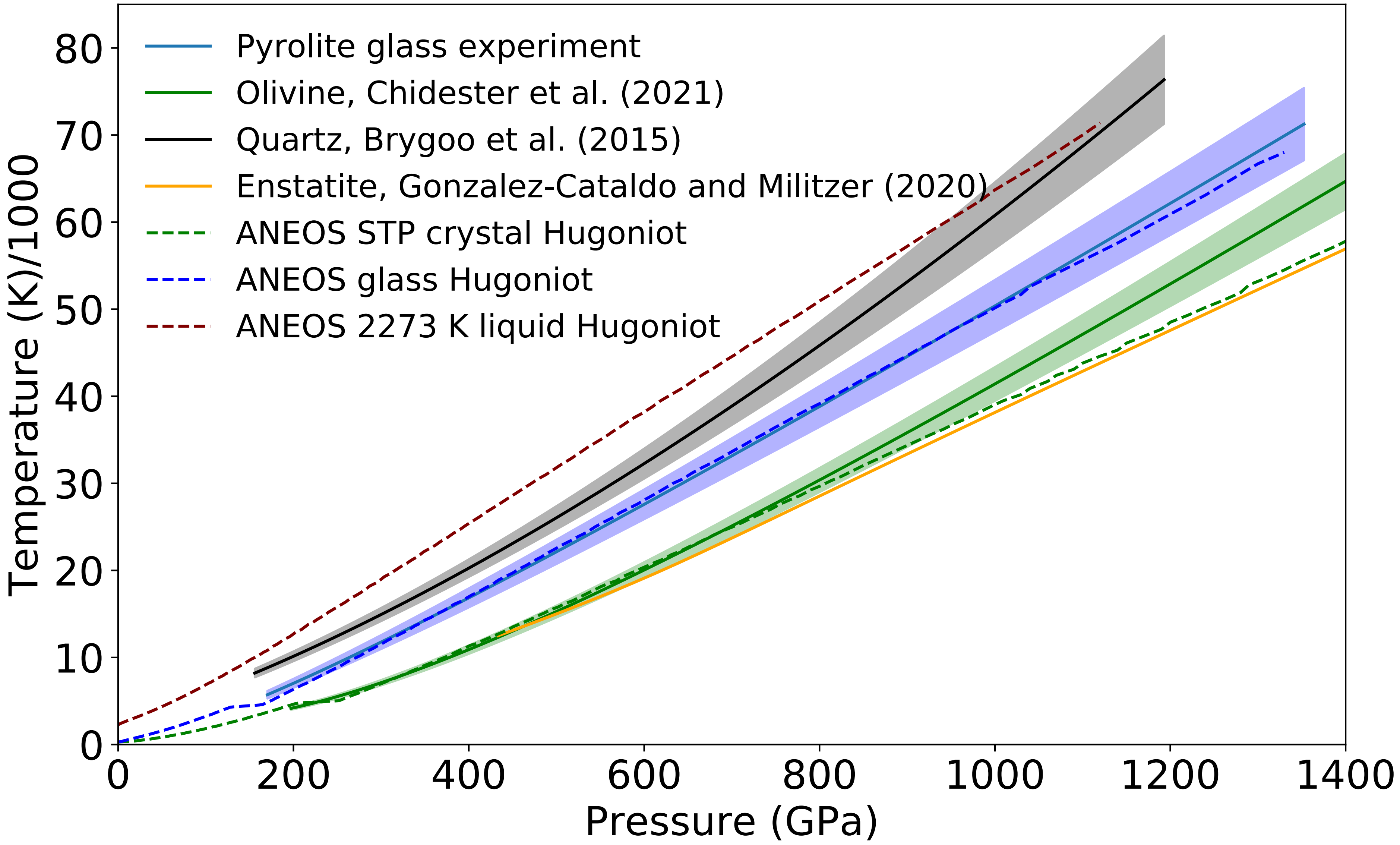
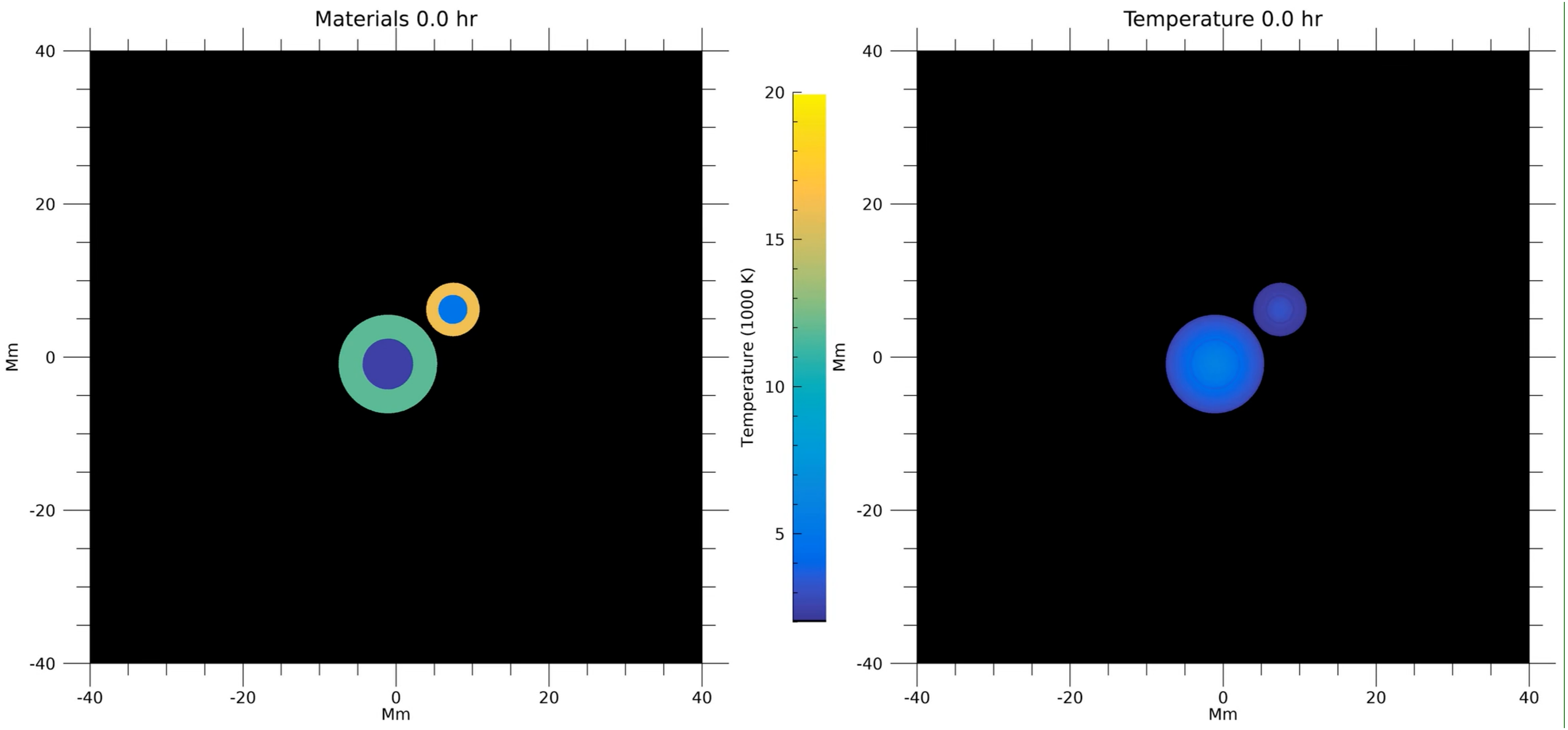


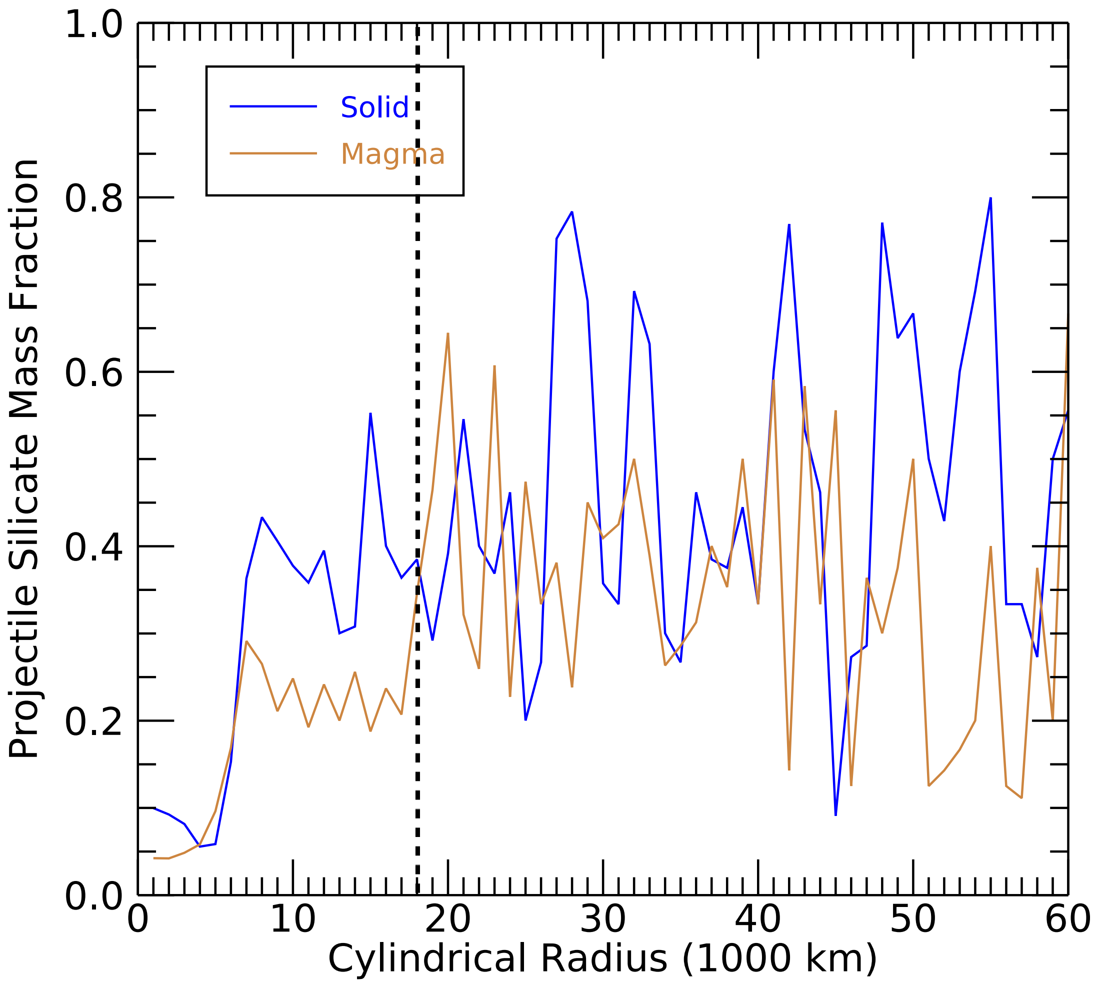
Analytical EOS constrained by experimental results

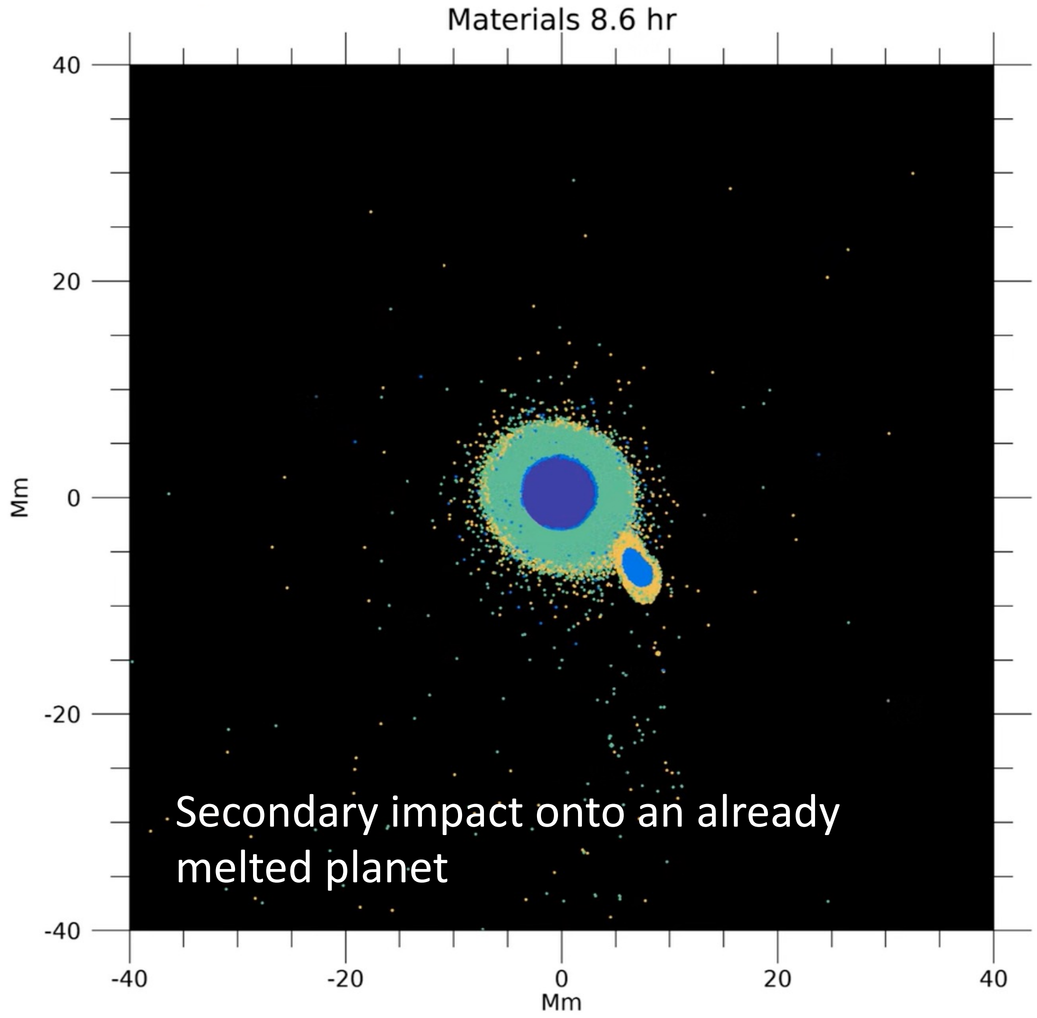


Magma ocean proto-Earth



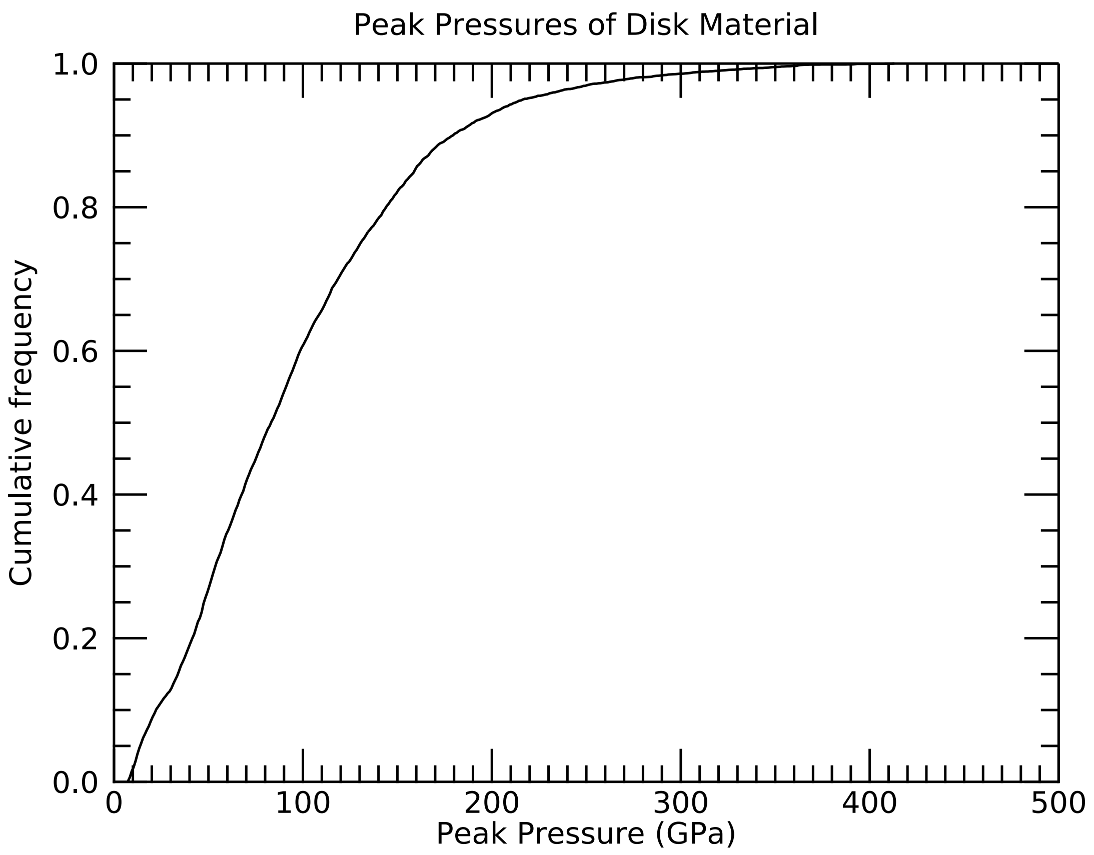
Result 1: Giant impacts onto a magma ocean are not different than giant impacts onto a solid planet



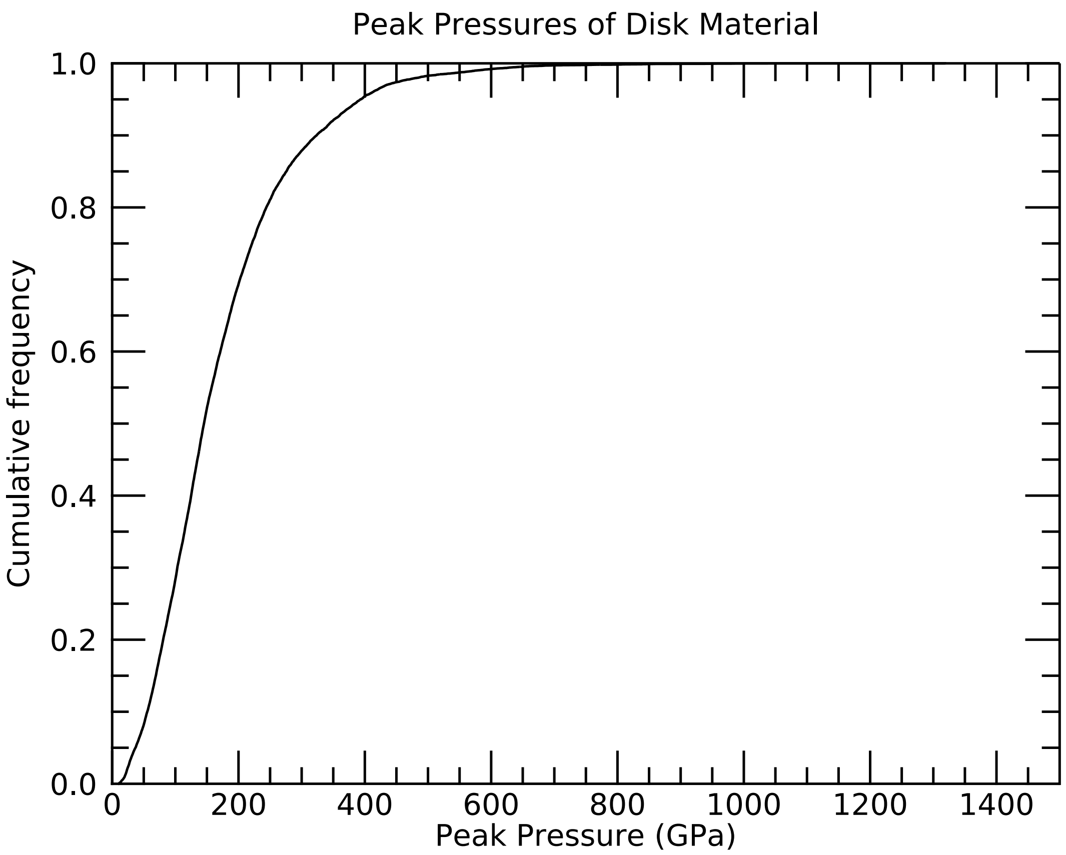


Result 2: The disk is heavily shocked

Mars-Mass Giant Impact



Two Half-Earths Colliding



Conclusions

- Experimentally-constrained EOS are needed for accurate planet formation models
- Shocked pyrolite glass is very similar to known crystalline silicates.
- The canonical giant impact model provides the same results if the planet is entirely solid or has a magma ocean
- These experiments provide information on the pressures and temperatures reached in giant impacts, which is important for chemistry