

Supporting Information for "Thermal Conductivity of Iron at the Conditions of Small Planetary Cores"

Eric Edmund^{1,2}, Zachary M. Geballe¹, Attilio Rivoldini³, Nicola Tosi⁴, Stella Chariton⁵, Vitali B. Prakapenka⁵, Alexander F. Goncharov¹

¹Earth & Planets Laboratory, Carnegie Institution for Science, Washington, DC, USA

²Institut für Mineralogie, Universität-Münster, Münster, Germany

³Royal Observatory of Belgium, Brussels, Belgium

⁴Institute of Space Research, German Aerospace Center (DLR), Berlin, Germany

⁵GeoSoilEnviroCARS, University of Chicago, Chicago, IL, USA

Contents of this file

1. Supplemental Text S1
2. Supplemental Text S2
3. Supplemental Text S3
4. Figure S1
5. Figure S2
6. Figure S3
7. Figure S4
8. Figure S5
9. Figure S6
10. Figure S7
11. Figure S8
12. Figure S9
13. Figure S10

Additional Supporting Information (Files uploaded separately)

1. Supplemental Dataset S1

Supplemental Text S1: Thermal Conductivity and Lorenz number of Iron and Iron Alloys

The thermal conductivity of iron and iron alloys are generally determined experimentally by either indirectly from electrical conductivity measurements or through direct measurements of heat transfer. Estimates of thermal conductivity from electrical experiments commonly rely on the Wiedemann-Franz law:

$$k_{el} = L \cdot T \cdot \sigma \quad (1)$$

Where k_{el} is the electronic contribution to thermal conductivity in $W/m/K$, L is the Lorenz number of the material ($W\Omega/K^2$), T is temperature (K) and σ is the electrical conductivity ($1/\Omega/m$). As a result, thermal conductivity values derived from electrical measurements require accurate measurements of both electrical conductivity and temperature, and the assumed value for the Lorenz number. The Wiedemann-Franz relationship arises from the common role of conduction electrons in electrical and thermal transport in metals. In the simplest free-electron description, the Lorenz number is $L_0 = \frac{\pi^2}{3} \left(\frac{k_B}{e}\right)^2 = 2.445 \times 10^{-8} W\Omega/K^2$.

Although L_0 provides a useful reference value, the Lorenz number is not necessarily constant and can depend on temperature, pressure, composition, crystal structure, and the dominant electron-scattering mechanisms. Recent experimental work indicates that the Lorenz number of iron and iron alloys at high pressure can vary with pressure and composition (Hsieh et al., 2024), while theoretical studies suggest that variations in L under extreme conditions may be important for reconciling differences between thermal- and electrical-conductivity measurements of hcp iron (Pourovskii et al., 2017; Zhang et al., 2020). The distinction between total and electronic thermal conductivity is particularly important when comparing direct thermal-conductivity measurements with values inferred from electrical conductivity. In general,

$$k = k_{el} + k_{lat} \quad (2)$$

where k_{lat} represents the lattice (phonon) contribution. For cubic crystals, symmetry requires the thermal-conductivity tensor to be isotropic, so thermal conductivity can be described by a scalar quantity. In lower-symmetry structures, such as hcp iron, thermal conductivity is generally anisotropic and must be described by a tensor, with potentially different conductivities parallel and perpendicular to the crystallographic (c) axis. An apparent Lorenz number can also be defined from independently measured total thermal and electrical conductivities.

$$L_{app} = \frac{k}{T\sigma}. \quad (3)$$

Because k includes both electronic and lattice contributions, L_{app} can differ from the Lorenz number associated strictly with electronic transport. In particular, a value of $L_{app} > L_0$ may indicate a non-negligible lattice contribution, but deviations from L_0 can also arise from non-free-electron behavior and from energy-dependent or inelastic electron-scattering processes. Conversely, $L_{app} < L_0$ may result from inelastic scattering and other deviations from the assumptions underlying the conventional Wiedemann-Franz relation. Therefore, deviations of the apparent Lorenz number from L_0 should not be interpreted uniquely in terms of a single heat-transport mechanism without considering the relevant scattering processes. At ambient conditions, reported Lorenz numbers for iron can differ appreciably from the free-electron value. For example, values of approximately $2.8 \times 10^{-8} W\Omega K^{-2}$ have been reported for bcc iron, whereas values of approximately $2.1 - 2.4 \times 10^{-8} W\Omega K^{-2}$ have been proposed for fcc iron (Ho et al., 1972; Secco, 2017). These differences illustrate that the use of a fixed Sommerfeld value L_0 can introduce systematic uncertainties when thermal conductivity is inferred from electrical conductivity.

These differences illustrate that the use of a fixed Sommerfeld value L_0 can introduce systematic uncertainties when thermal conductivity is inferred from electrical conductivity. The lattice contribution to thermal conductivity is expected to decrease with increasing temperature approximately as $T^{-0.5}$ to T^{-1} in regimes dominated by phonon-phonon scattering, whereas the electronic contribution can exhibit a different temperature dependence depending on the dominant scattering mechanism (e.g. Pozzo et al., 2022; Yin et al., 2025; Ohta et al., 2016). Consequently, the phonon contribution to thermal conductivity in fcc iron at high temperatures is expected to be relatively small, but it need not be negligible. This distinction is important when comparing measurements performed using the two approaches: direct measurements determine the total thermal conductivity, whereas electrical measurements constrain the electronic contribution through the Wiedemann-Franz relation.

Accordingly, direct measurements of thermal conductivity can yield values substantially higher than those inferred from electrical conductivity if the lattice contribution is significant. Conversely, differences in the opposite direction, with directly measured thermal conductivity lower than the value inferred from electrical conductivity

using a fixed Lorenz number, can arise when the actual Lorenz number differs from the assumed value. Such discrepancies should therefore be evaluated by considering uncertainties in temperature and electrical and thermal conductivity measurements, as well as the possible pressure-, temperature-, composition-, and phase-dependence of the Lorenz number, rather than attributing them solely to experimental limitations.

Supplemental Text S2: System Timing and Streak Camera Calibration

Timing jitter of the pulsed heating laser, as estimated from a comparison of recorded emissions spectra from single event or multi-event heating, and from a comparison of single and time-averaged laser emissions recorded on an oscilloscope (tested for up to 40 collections) is negligible relative to the time resolution of the streak camera, thanks to the use of a Pockels cell to control the temporal shape of the laser pulse. The time-axis and wavelength-axis calibrations of the streak camera are determined using a SC laser, as this produces ns-width pulses of white light with a 1 μ s interval between successive pulses. These time-resolved pulses are recorded as intense streaks at regular intervals in time, which are used to calibrate the timing of the camera. Accumulations of the laser pulses recorded on the streak camera either as a single 10 μ s measurement, or as an average of up to 5000 repetitions (equivalent to a 5 s measurement in the standard configuration) are used to establish the timing calibration. Wavelength calibration is determined using two methods, first by passing a green continuous laser (VERDI) of wavelength 532 nm into the streak camera, and second by passing the SC laser through a colour wheel with wavelength centers at 488 nm, 532 nm, 632 nm, 694 nm and 780 nm. The system response of the optical system and streak camera are calibrated using thermal emissions from a tungsten lamp, leading to systematic uncertainties of ± 200 K when determining temperature from Planck fits to measured thermal emissions. This uncertainty comes from systematic effects due to uncertainties in the tungsten lamp temperature, the design of the collection optics (Giampaoli et al., 2018) and the differences in emissivity between DAC samples and devices for luminance calibration (Andrault et al., 2022). Systematic shifts of baseline temperature do not have a significant effect on the results of flash heating experiments (Geballe et al., 2020). Temperature fits are made to the time-varying thermal emissions recorded with the streak camera, binned in the time dimension over intervals of about 70 ns or 140 ns (equivalent to 5 or 10 pixels on the time axis of the streak camera image), depending on the signal to noise ratio of the measurement. The wavelength range of temperature fits is typically between 500 to 750 nm.

Supplemental Text S3: Finite-Element Modelling of Experimental Data

Finite-element models of time-dependent heat transfer are used in order to determine thermal conductivity values from a given measurement and their errors. The finite-element model calculates the temperature field which is generated by the continuous-wave lasers, as well as an additional time-dependent heating event generated by the pulsed laser. Models are calculated using the finite-element solver FlexPDE (PDE Solutions Inc.). The finite-element codes used in this study have been described previously (Montoya & Goncharov, 2012; McWilliams et al., 2015). Finite-element (FE) analysis of measured temperature histories requires 22 input parameters: k_{lat} , ρ and C_P of diamond, Fe and KCl, the geometrical parameters of the sample chamber, laser energies, pulsed and continuous heating spot sizes and the shape of the pulsed laser envelope. CW and pulsed laser energies, Fe and KCl thermal conductivity are treated as free parameters and varied until a good fit to the data is observed. Initially, CW laser energies are varied to match the baseline temperature of the experiments. After baseline temperatures are matched between model and experiment, the pulsed laser energy is varied to match the amplitude of the temperature rise on the DS side of the sample, and thermal conductivity values for KCl and Fe are varied to match the thermal evolution of the sample during the transient heating event. In our experiments we heat an iron foil embedded in KCl and watch the sample cool over time. As KCl does not absorb near-infrared laser light, we directly heat the iron sample. During this heating process, iron heats up first followed by the surrounding KCl. Consequently, the thermal conductivity of iron controls the heating process at shorter times (Figure S4), while the KCl thermal conductivity controls the cooling at longer timescales (Figure S5). Therefore a unique combination of iron and KCl thermal conductivity can be found by varying the thermal conductivity of iron against the temperature histories at short times ($t=2-4 \mu s$), and varying the KCl thermal conductivity to data at longer timescales ($t>4 \mu s$). Varying the thermal conductivity of KCl by a large amount will have a small effect on iron thermal conductivity - doubling the thermal conductivity of KCl in the model requires changing the thermal conductivity of iron by $\sim 15-20\%$ (Figure S5), however this would cause misfit to other parts of the measured temperature histories which are insensitive to iron thermal conductivity. The thermal conductivity of KCl can be constrained by literature values (Beck et al., 2007; McGuire et al., 2018), but it strongly covaries with other parameters which are directly determined in the experiment such as KCl thickness and laser spot size (Geballe et al., 2020).

Other parameters are either fixed to literature values or measured with independent diagnostics. The sample chamber geometry corresponds to the width of the Fe sample, and the thicknesses of each of the Fe and KCl plates sandwiched between the diamond anvils. Previous studies have shown that the physical properties of diamond and rhenium have little influence on calculated sample thermal conductivity (Geballe et al., 2020). As a result, we omit the Re gasket in the FE model, it is always much farther away from the heated spot than the diamond anvils (Edmund et al., 2024). ρ and C_P only appear in the heat diffusion equation together as ρC_P , and steady-state heat conduction is independent of density and heat capacity. It is observed in Figure S6a that KCl ρC_P varies little at high pressure and high temperatures, because the temperature range investigated here is above the Debye temperature of KCl, and density does not vary significantly because the thermal expansivity of KCl is low (Walker et al., 2002; Dewaele et al., 2012; Tateno et al., 2019). Figure S6b shows the results of finite-element models where the temperature dependence of KCl is explicitly taken into account. Using literature thermal equations of state, it is shown that accounting for temperature-dependent changes in KCl ρC_P has no effect on the finite-element model results. For simplicity, C_P of KCl has therefore been fixed as a constant. Where available, experimentally-determined densities have been used from either high temperature or ambient temperature X-ray diffraction at relevant pressures for Fe and KCl (Supplemental Dataset S1). Otherwise, measured pressures have been used to estimate density using literature equations of state (Dewaele et al., 2012; Komabayashi, 2014). The effect of temperature-dependent and temperature-independent models of Fe ρC_P are shown in Figures S7a and S7b. In Figures S7a and S7b, temperature-dependent models of Fe ρC_P are constructed using ρC_P values calculated from Komabayashi 2014. These temperature-dependent models are compared to simplified ones where ρ is determined using a literature equation of state at 300 K and 28 GPa, and C_P is fixed to the ambient pressure value of fcc-Fe, 650 J/Kg/K (Desai, 1986). Different assumptions for the value of C_P and its temperature dependence have a negligible effect on the model, justifying the use of a constant value in the present study.

One-colour pyrometry has been used to determine the spatial dimensions of the CW and pulsed heating lasers (Geballe et al., 2020). The pulse laser envelope is recorded using a photodiode and oscilloscope, and fit with a series of gaussians for the model input.

At the pressure range of interest, between 5 to 40 GPa, the primary sources of error for Fe thermal conductivity are uncertainties in baseline temperature, and uncertainties in thickness. Uncertainties in baseline temperature refer to the temperature of the sample prior to heating with the pulsed laser. Polarization control of the pulsed laser waveform is imperfect, resulting in a temperature rise of 5 K to 10 K prior to the arrival of the nearly-square wave output from the Pockels cell. This leads to intrinsic uncertainties in modelled thermal conductivities of 2-3

W/m/K which becomes comparable to other sources of uncertainty for the most precise measurements in the present study. In this pressure range, diamonds act as flat rigid bodies (Dewaele et al., 2003) which significantly reduces uncertainties when measuring sample chamber geometry with the WL technique, such that uncertainties in sample and KCl thickness are about 10% and 5% respectively. Uncertainties in sample thickness primarily relate to deformation of the sample during compression, decompression, and due to thinning of the sample during laser heating (Lobanov & Geballe, 2022). Laser thinning, the reduction in sample thickness over time during laser heating, is minimized by using short heating durations and few heating runs per sample position. The unit cell volume of iron increases by 7.5% when heating from 300 K to 2000 K at 30 GPa under isobaric conditions (Dewaele et al., 2006; Komabayashi, 2014), which corresponds to a 2.4% change in sample thickness. As thermal expansion is hindered by surrounding materials, thermal pressures of 2 GPa to 5 GPa can be expected which reduces linear expansion to between 2.2% and 1.8% during heating (Dewaele et al., 2012; Tateno et al., 2019). This effect is smaller than other sources of uncertainty and is neglected in the present study. The effect of thermal pressure on the results is negligible, because thermal pressure is too small at these conditions to significantly alter the density or heat capacity of iron (Morard et al., 2018).

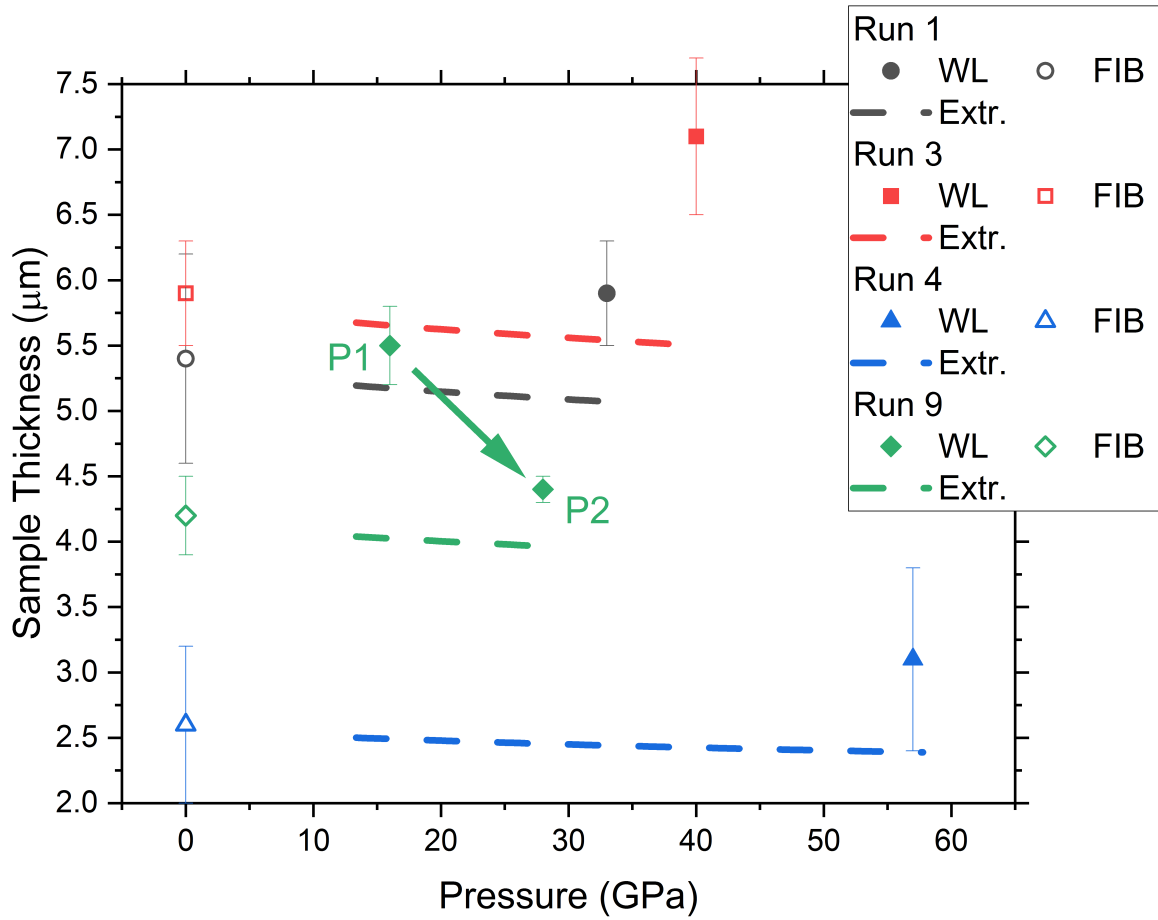


Figure S1. Iron sample thickness vs. pressure. Closed symbols indicate the results of *in situ* white light measurements at high pressure. Open symbols indicate thickness measurements from *ex situ* measurements of recovered samples. Dashed lines indicate the extrapolation of *ex situ* measurements to high pressure using an equation of state for iron (Dewaele et al., 2006). It is observed that *in situ* white-light measurements give systematically larger thicknesses than measurements on recovered samples, highlighting previous observations that decompression from high pressures involves significant plastic deformation of the sample (Dewaele et al., 2003; Lobanov & Geballe, 2022). Error bars reflect the variability of foil thickness over different measurement points within the heated regions of the sample. Thermal conductivity measurements were not successful for Run 3.

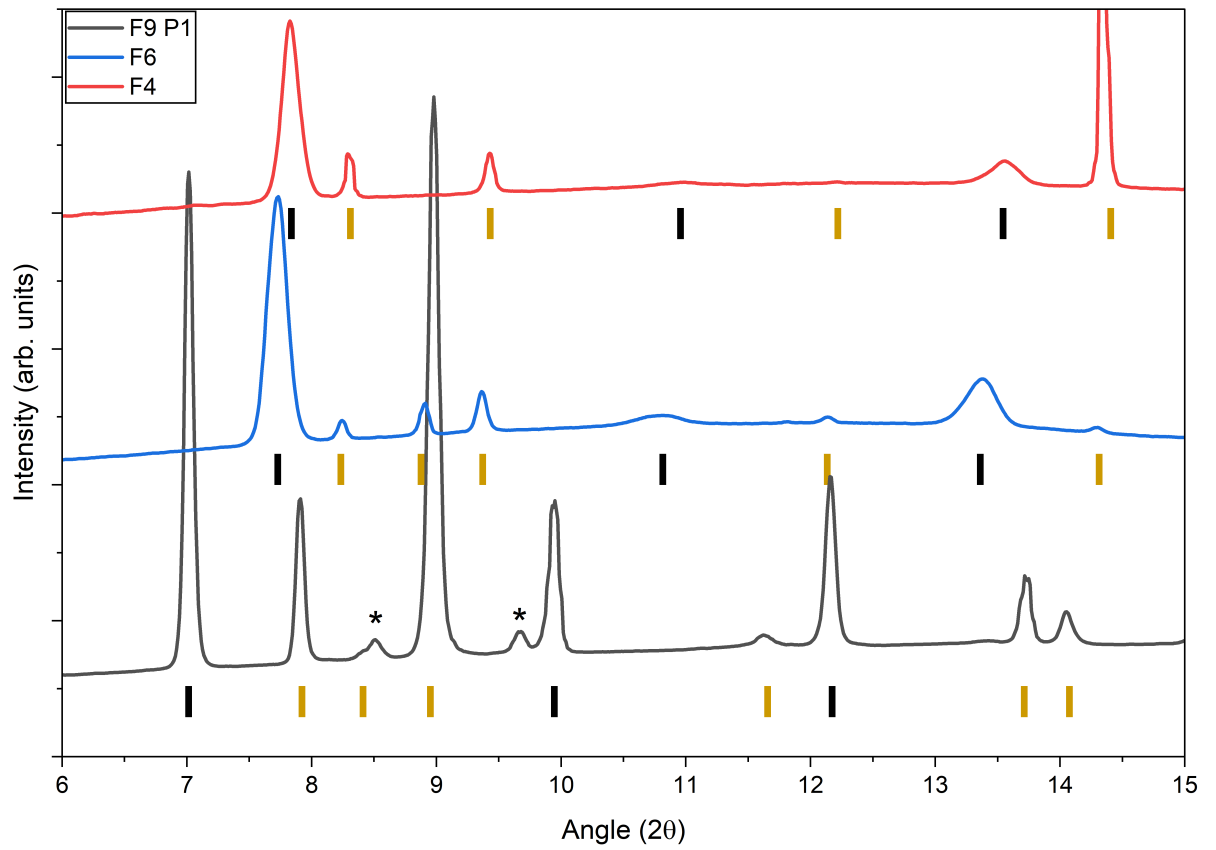


Figure S2. Diffraction of Fe samples from various experimental runs after heating. All reflections are attributed to Fe or KCl. Black ticks correspond to KCl reflections, gold ticks correspond to hcp-Fe reflections. Black asterisks indicate metastable quenched fcc-Fe, which is observed at low pressure.

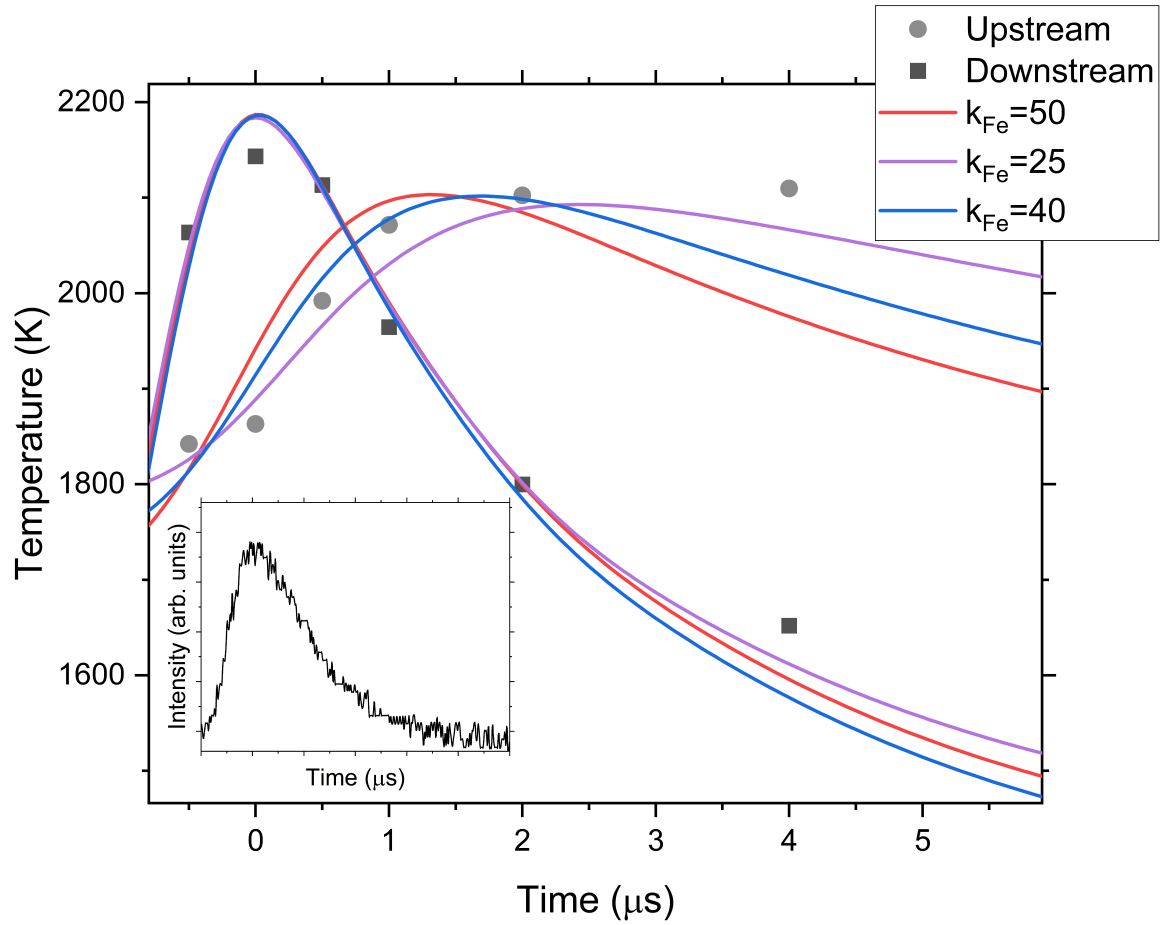


Figure S3. Temperature vs. time as measured during Mixed Mode (MM) heating, Run 9 P2 APS in Table 1, and its comparison to a finite element model with $k_{Fe} = 40$ and $k_{KCl} = 8$. Models with $k_{Fe} = 50$ and $k_{KCl} = 8$ and $k_{Fe} = 25$ and $k_{KCl} = 8$ are shown for comparison, which more poorly fit the dataset. Inset: Pulse shape of the pulsed laser used to generate the transient heating event. The present results demonstrate that thermal conductivity measurements can be directly implemented on synchrotron beamlines.

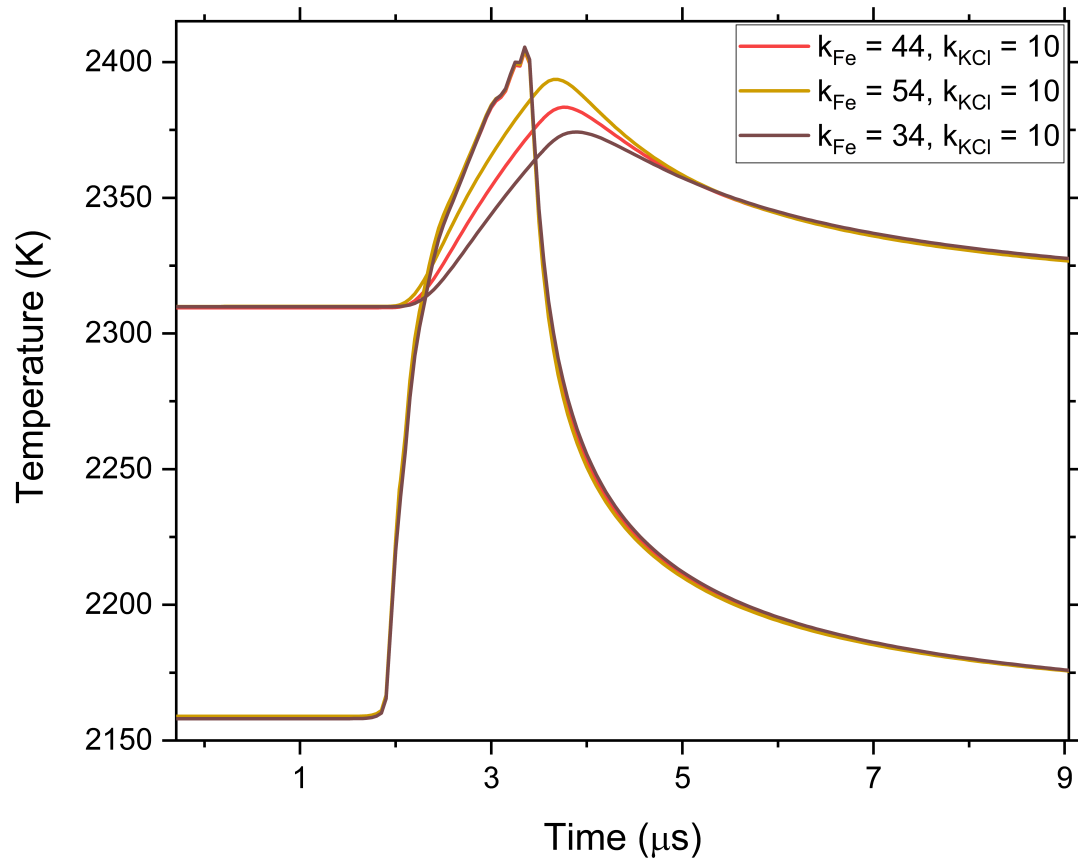


Figure S4. Effect of varying thermal conductivity of iron (k_{Fe}) at constant KCl thermal conductivity (k_{KCl}) on modelled temperature histories. k_{Fe} influences the change in temperature of the sample during and shortly after heating.

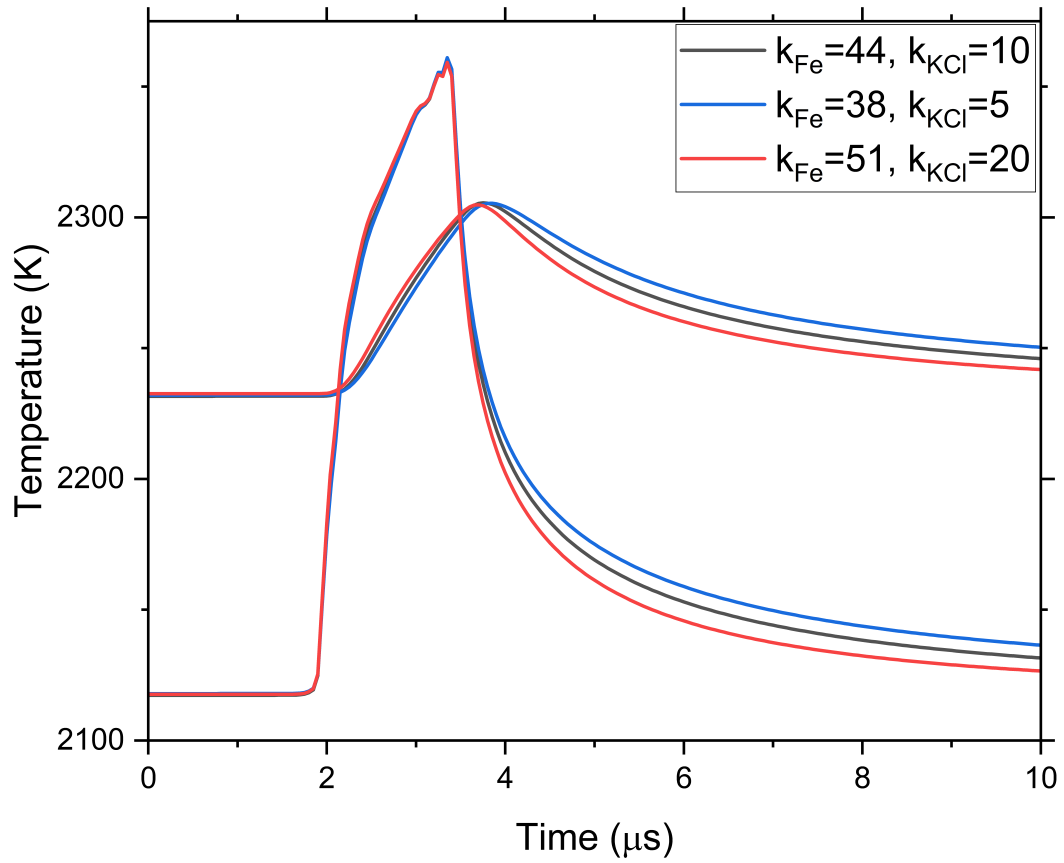


Figure S5. Effect of varying thermal conductivity of iron (k_{Fe}) and KCl (k_{KCl}) on modelled temperature histories. k_{Fe} is varied to keep the amplitude ratio between the DS and US temperature maxima the same, the primary observable used to determine k_{Fe} . Changing k_{KCl} by a factor of two is compensated by changes in k_{Fe} of $\sim 15\text{-}20\%$.

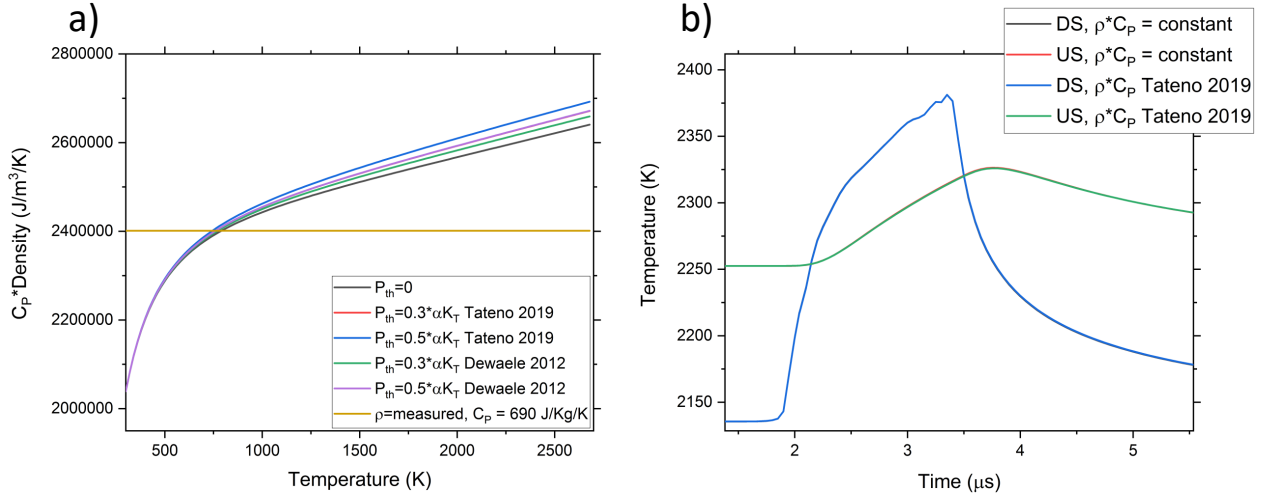


Figure S6. a) ρC_P for KCl vs. temperature at pressures near 28 GPa. Gold line indicates the model value of ρC_P used in finite-element modelling for Run 9 P2, where the measured 300 K density is used, multiplied by the ambient P-T C_P value for KCl. Other lines show ρC_P values as a function of temperature, calculated from Tateno et al. (2019). P_{th} indicates the assumed thermal pressure in the model, the change in pressure of the sample with a change in temperature. As pressure can vary during heating, different ρC_P models are shown using different thermal pressure assumptions. b) Results of finite element model calculations using the geometry of Run 9 P2. Black and red lines indicate downstream and upstream sides of the Fe foil using the ρC_P model used in the manuscript. Blue and green lines show results where the temperature-dependence of KCl ρC_P is explicitly incorporated into the model ($P_{th} = 0.5\alpha K_T$, Tateno 2019). Differences in temperature histories are less than 1 K.

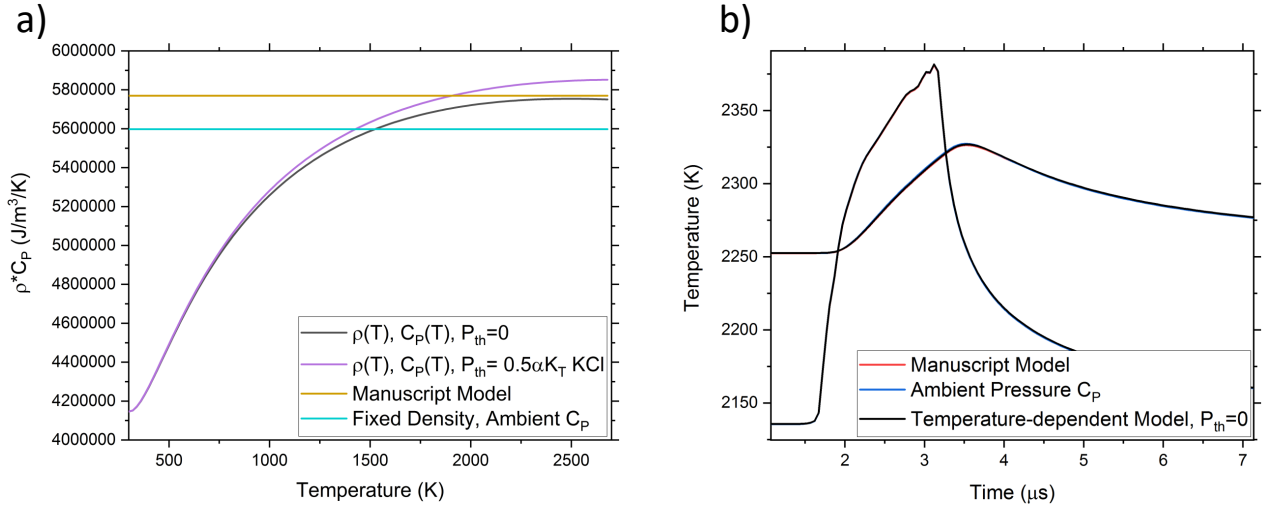


Figure S7. a) ρC_P for Fe vs. temperature at pressures near 28 GPa. Gold line indicates the model value of ρC_P used in finite-element modelling for Run 9 P2, where the measured ~ 1500 K density of Fe is used, multiplied by C_P calculated at the baseline temperature of the experiment using the thermodynamic model of Komabayashi (2014). P_{th} indicates the assumed thermal pressure in the model, the change in pressure of the sample with a change in temperature. Black and magenta lines show ρC_P values as a function of temperature, calculated from Komabayashi (2014) using different thermal pressure assumptions. The black line indicates isobaric heating, while the magenta line uses the upper limit on the thermal pressure of KCl at these conditions, about 6 GPa at 2500 K (Tateno et al., 2019). Cyan line shows ρC_P where the density is the same as the model used in the present study, while C_P is fixed to the ambient value for fcc Fe. b) Results of finite element model calculations using the geometry of Run 9 P2. Differences between parametrizations of ρC_P are less than 1 K, irrespective of the parametrization used from Figure S2a, indicating that this is not a significant source of error in the present experiments.

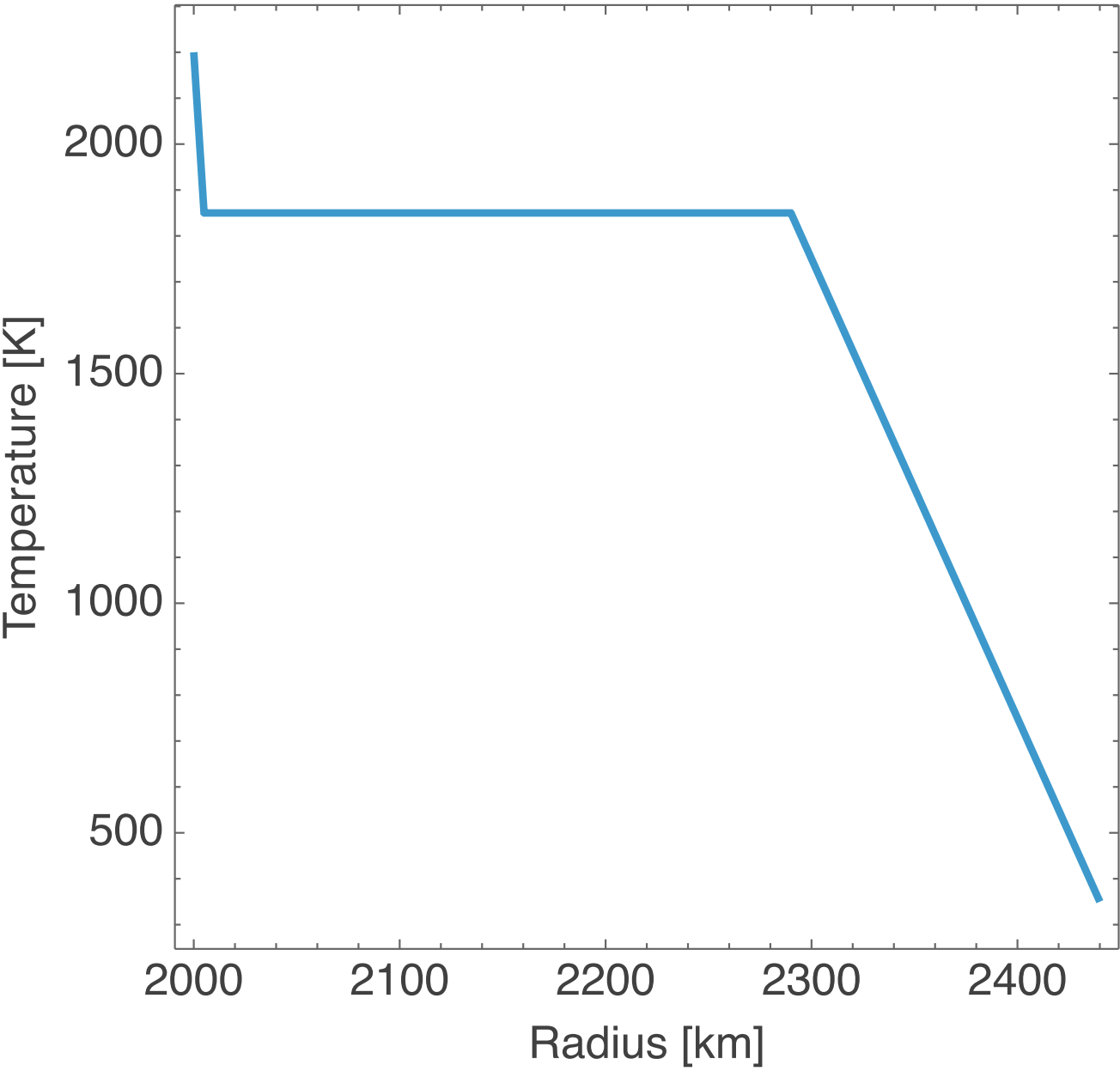


Figure S8. Initial temperature distribution from the core-mantle boundary to Mercury’s crust.

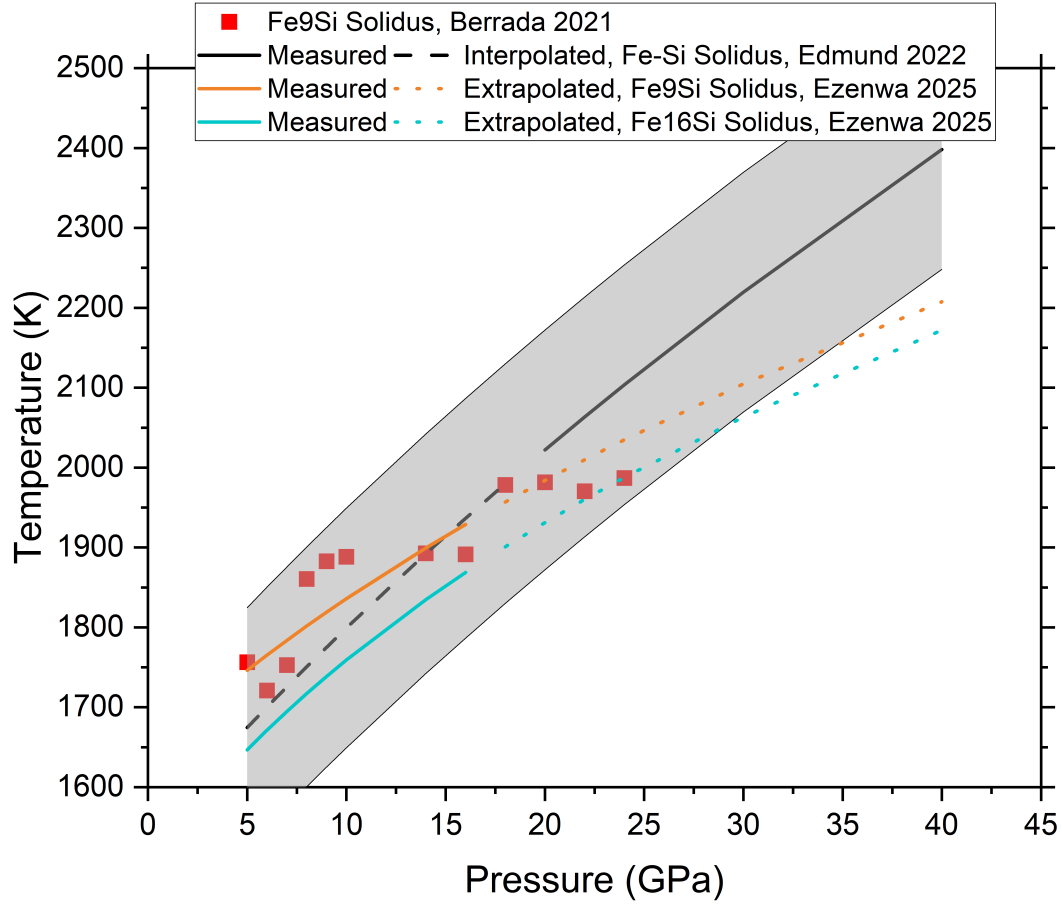


Figure S9. Solidus melting of iron-silicon alloys vs. pressure based on diamond anvil cell (DAC) and large-volume press literature at the pressures of Mercury's core (Berrada et al., 2021; Edmund et al., 2022; Ezenwa et al., 2024). Grey bands indicate the uncertainty in temperature associated with spectroradiometric methods in DAC experiments. Solid lines indicate P-T regions where experiments were conducted, dashed and dotted lines indicate regions not covered by experiments in each study. Data agrees where coverage overlaps, but studies disagree on the slope of the melting line. Our thermal evolution models assume the solidus curve of Edmund et al. (2022) and a eutectic composition of 12.5 wt%Si. The study of Ezenwa et al. (2024) shows that melting curves for Fe-9wt%Si and Fe-17wt%Si converge above 20 GPa within experimental uncertainties, consistent with this eutectic composition.

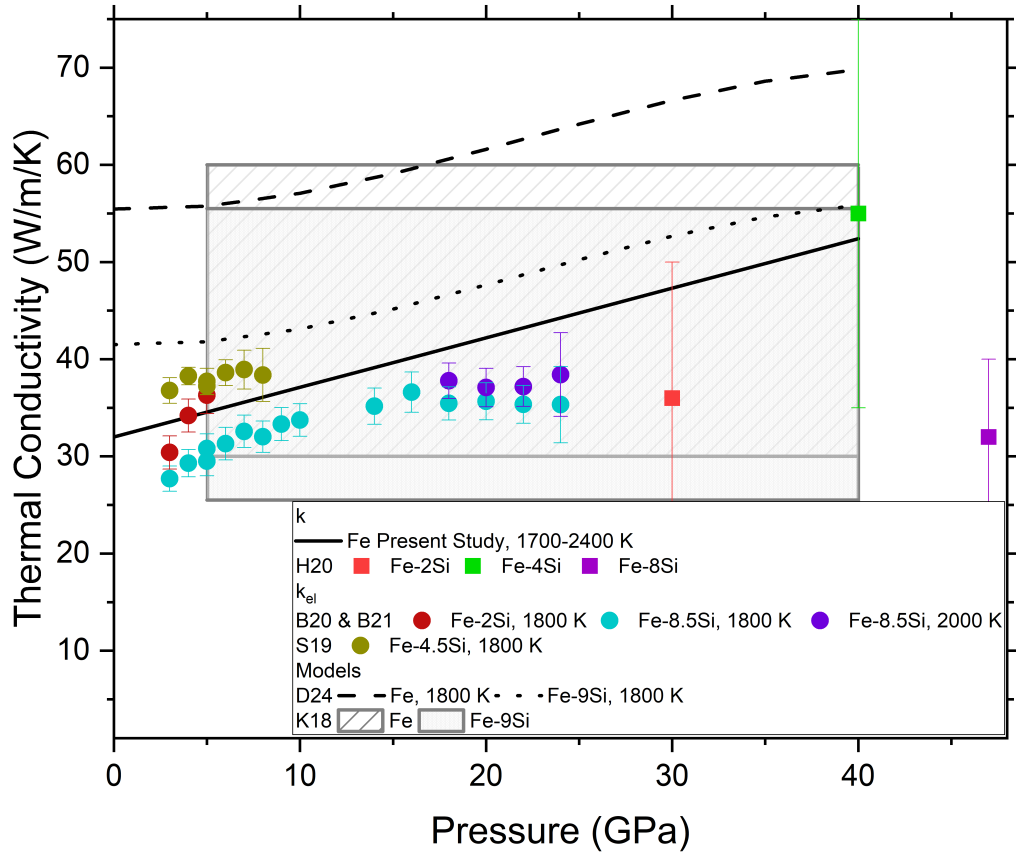


Figure S10. Pressure dependence of iron-silicon alloy thermal conductivity at Mercury's core pressures. Grey boxes as well as dashed and dotted lines indicate different thermal conductivity models used in previous thermal evolution studies for Mercury (K18: Knibbe and van Westrenen (2018), D24: Davies et al. (2024)). Studies which report k_{el} values for Fe-Si alloys show that the effect of composition is small with respect to pure iron, but the pressure dependence becomes smaller with increasing Si content (S19: Silber et al. (2019), H20:Hsieh et al. (2020), B20: Berrada et al. (2020), B21: Berrada et al. (2021)).

References

- Andraut, D., Pison, L., Morard, G., Garbarino, G., Mezouar, M., Bouhifd, M. A., & Kawamoto, T. (2022). Comment on: Melting behavior of SiO_2 up to 120 gpa (andraut et al. 2020). *Physics and Chemistry of Minerals*, 49(2), 3. Retrieved from <https://doi.org/10.1007/s00269-021-01174-2> doi: 10.1007/s00269-021-01174-2
- Beck, P., Goncharov, A. F., Struzhkin, V. V., Militzer, B., Mao, H.-k., & Hemley, R. J. (2007, 11). Measurement of thermal diffusivity at high pressure using a transient heating technique. *Applied Physics Letters*, 91(18), 181914. Retrieved from <https://doi.org/10.1063/1.2799243> doi: 10.1063/1.2799243
- Berrada, M., Secco, R. A., & Yong, W. (2021). Adiabatic heat flow in mercury's core from electrical resistivity measurements of liquid $\text{Fe-8.5 wt\%Si}$ to 24 gpa. *Earth and Planetary Science Letters*, 568, 117053. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0012821X21003083> doi: <https://doi.org/10.1016/j.epsl.2021.117053>
- Berrada, M., Secco, R. A., Yong, W., & Littleton, J. A. H. (2020). Electrical resistivity measurements of Fe-Si with implications for the early lunar dynamo. *Journal of Geophysical Research: Planets*, 125(7), e2020JE006380. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020JE006380> (e2020JE006380 2020JE006380) doi: <https://doi.org/10.1029/2020JE006380>
- Davies, C. J., Pommier, A., Greenwood, S., & Wilson, A. (2024). Thermal and magnetic evolution of mercury with a layered Fe-Si(-S) core. *Earth and Planetary Science Letters*, 641, 118812. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0012821X24002450> doi: <https://doi.org/10.1016/j.epsl.2024.118812>
- Desai, P. D. (1986, 07). Thermodynamic Properties of Iron and Silicon. *Journal of Physical and Chemical Reference Data*, 15(3), 967-983. Retrieved from <https://doi.org/10.1063/1.555761> doi: 10.1063/1.555761
- Dewaele, A., Belonoshko, A. B., Garbarino, G., Occelli, F., Bouvier, P., Hanfland, M., & Mezouar, M. (2012, Jun). High-pressure-high-temperature equation of state of KCl and KBr . *Phys. Rev. B*, 85, 214105. Retrieved from <https://link.aps.org/doi/10.1103/PhysRevB.85.214105> doi: 10.1103/PhysRevB.85.214105
- Dewaele, A., Eggert, J. H., Loubeyre, P., & Le Toullec, R. (2003, Mar). Measurement of refractive index and equation of state in dense He , H_2 , H_2O , and Ne under high pressure in a diamond anvil cell. *Phys. Rev. B*, 67, 094112. Retrieved from <https://link.aps.org/doi/10.1103/PhysRevB.67.094112> doi: 10.1103/PhysRevB.67.094112
- Dewaele, A., Loubeyre, P., Occelli, F., Mezouar, M., Dorogokupets, P. I., & Torrent, M. (2006, Nov). Quasihydrostatic equation of state of iron above 2 mbar. *Phys. Rev. Lett.*, 97, 215504. Retrieved from <https://link.aps.org/doi/10.1103/PhysRevLett.97.215504> doi: 10.1103/PhysRevLett.97.215504
- Edmund, E., Bi, T., Geballe, Z., Brugman, K., Lin, J.-F., Chariton, S., ... Goncharov, A. (2024). Structure and transport properties of FeS at planetary core conditions. *Earth and Planetary Science Letters*, 646, 118959. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0012821X24003923> doi: <https://doi.org/10.1016/j.epsl.2024.118959>
- Edmund, E., Morard, G., Baron, M. A., Rivoldini, A., Yokoo, S., Boccato, S., ... Antonangeli, D. (2022). The Fe-FeSi phase diagram at mercury's core conditions. *Nature Communications*, 13(1), 387. Retrieved from <https://doi.org/10.1038/s41467-022-27991-9> doi: 10.1038/s41467-022-27991-9
- Ezenwa, I. C., Fei, Y., Hrubiak, R., & Kenney-Benson, C. (2024). High pressure melting curve of Fe-Si : Implication for the thermal properties in mercury's core. *Journal of Geophysical Research: Planets*, 129(12), e2024JE008353. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2024JE008353> (e2024JE008353 2024JE008353) doi: <https://doi.org/10.1029/2024JE008353>
- Geballe, Z. M., Sime, N., Badro, J., van Keken, P. E., & Goncharov, A. F. (2020). Thermal conductivity near the bottom of the earth's lower mantle: Measurements of pyrolite up to 120 gpa and 2500 k. *Earth and Planetary Science Letters*, 536, 116161. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0012821X20301047> doi: <https://doi.org/10.1016/j.epsl.2020.116161>
- Giampaoli, R., Kantor, I., Mezouar, M., Boccato, S., Rosa, A. D., Torchio, R., ... Pascarelli, S. (2018). Measurement of temperature in the laser heated diamond anvil cell: comparison between reflective and refractive optics. *High Pressure Research*, 38(3), 250-269. Retrieved from <https://doi.org/10.1080/08957959.2018.1480017> doi: 10.1080/08957959.2018.1480017
- Ho, C. Y., Powell, R. W., & Liley, P. E. (1972, 10). Thermal Conductivity of the Elements. *Journal of Physical and Chemical Reference Data*, 1(2), 279-421. Retrieved from <https://doi.org/10.1063/1.3253100> doi: 10.1063/1.3253100
- Hsieh, W.-P., Goncharov, A. F., Labrosse, S., Holtgrewe, N., Lobanov, S. S., Chuvashova, I., ... Lin, J.-F. (2020). Low thermal conductivity of iron-silicon alloys at earth's core conditions with implications

- for the geodynamo. *Nature Communications*, 11(1), 3332. Retrieved from <https://doi.org/10.1038/s41467-020-17106-7> doi: 10.1038/s41467-020-17106-7
- Hsieh, W.-P., Lin, C.-H., Chen, C.-C., & Chang, J.-W. (2024, 12). Testing the validity of the wiedemann–franz law for metals and alloys at high pressures. *Applied Physics Letters*, 125(25), 252201. Retrieved from <https://doi.org/10.1063/5.0234126> doi: 10.1063/5.0234126
- Knibbe, J. S., & van Westrenen, W. (2018). The thermal evolution of mercury’s fe–si core. *Earth and Planetary Science Letters*, 482, 147–159. doi: 10.1016/j.epsl.2017.11.006
- Komabayashi, T. (2014). Thermodynamics of melting relations in the system fe–feo at high pressure: Implications for oxygen in the earth’s core. *Journal of Geophysical Research: Solid Earth*, 119(5), 4164–4177. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2014JB010980> doi: 10.1002/2014JB010980
- Lobanov, S. S., & Geballe, Z. M. (2022). Non-isotropic contraction and expansion of samples in diamond anvil cells: Implications for thermal conductivity at the core–mantle boundary. *Geophysical Research Letters*, 49(19), e2022GL100379. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2022GL100379> (e2022GL100379 2022GL100379) doi: <https://doi.org/10.1029/2022GL100379>
- McGuire, C., Sawchuk, K., & Kavner, A. (2018, 09). Measurements of thermal conductivity across the b1–b2 phase transition in nacl. *Journal of Applied Physics*, 124(11), 115902. Retrieved from <https://doi.org/10.1063/1.5042407> doi: 10.1063/1.5042407
- McWilliams, R. S., Konôpková, Z., & Goncharov, A. F. (2015). A flash heating method for measuring thermal conductivity at high pressure and temperature: Application to pt. *Physics of the Earth and Planetary Interiors*, 247, 17–26. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0031920115000916> (Transport Properties of the Earth’s Core) doi: <https://doi.org/10.1016/j.pepi.2015.06.002>
- Montoya, J. A., & Goncharov, A. F. (2012, 06). Finite element calculations of the time dependent thermal fluxes in the laser-heated diamond anvil cell. *Journal of Applied Physics*, 111(11). Retrieved from <https://doi.org/10.1063/1.4726231> (112617) doi: 10.1063/1.4726231
- Morard, G., Boccato, S., Rosa, A. D., Anzellini, S., Miozzi, F., Henry, L., ... Torchio, R. (2018). Solving controversies on the iron phase diagram under high pressure. *Geophysical Research Letters*, 45(20), 11,074–11,082. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018GL079950> doi: <https://doi.org/10.1029/2018GL079950>
- Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K., & Ohishi, Y. (2016). Experimental determination of the electrical resistivity of iron at earth’s core conditions. *Nature*, 534(7605), 95–98. Retrieved from <https://doi.org/10.1038/nature17957> doi: 10.1038/nature17957
- Pourovskii, L. V., Mravlje, J., Georges, A., Simak, S. I., & Abrikosov, I. A. (2017, jul). Electron–electron scattering and thermal conductivity of ϵ -iron at earth’s core conditions. *New Journal of Physics*, 19(7), 073022. Retrieved from <https://doi.org/10.1088/1367-2630/aa76c9> doi: 10.1088/1367-2630/aa76c9
- Pozzo, M., Davies, C. J., & Alfè, D. (2022). Towards reconciling experimental and computational determinations of earth’s core thermal conductivity. *Earth and Planetary Science Letters*, 584, 117466. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0012821X22001029> doi: <https://doi.org/10.1016/j.epsl.2022.117466>
- Secco, R. A. (2017). Thermal conductivity and seebeck coefficient of fe and fe–si alloys: Implications for variable lorenz number. *Physics of the Earth and Planetary Interiors*, 265, 23–34. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0031920116301832> doi: <https://doi.org/10.1016/j.pepi.2017.01.005>
- Silber, R. E., Secco, R. A., Yong, W., & Littleton, J. A. H. (2019). Heat flow in earth’s core from invariant electrical resistivity of fe–si on the melting boundary to 9 gpa: Do light elements matter? *Journal of Geophysical Research*, 124(6), 5521–5543. doi: 10.1029/2019JB017375
- Tateno, S., Komabayashi, T., Hirose, K., Hirao, N., & Ohishi, Y. (2019). Static compression of b2 kcl to 230 gpa and its p–v–t equation of state. *American Mineralogist*, 104(5), 718 – 723. Retrieved from <https://www.degruyter.com/view/journals/ammin/104/5/article-p718.xml> doi: <https://doi.org/10.2138/am-2019-6779>
- Walker, D., Cranswick, L. M., Verma, P. K., Clark, S. M., & Buhre, S. (2002, 07). Thermal equations of state for B1 and B2 KCl. *American Mineralogist*, 87(7), 805–812. Retrieved from <https://doi.org/10.2138/am-2002-0701> doi: 10.2138/am-2002-0701
- Yin, Y., Liu, C., Zhai, S., Liu, Y., & Fei, Y. (2025). Lattice thermal conductivity of hcp fe–si alloys determined by machine learning potentials. *Geophysical Research Letters*, 52(17), e2024GL111953. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2024GL111953> doi: <https://doi.org/10.1029/2024GL111953>

Zhang, Y., Hou, M., Liu, G., Zhang, C., Prakapenka, V. B., Greenberg, E., ... Lin, J.-F. (2020, Aug). Reconciliation of experiments and theory on transport properties of iron and the geodynamo. *Phys. Rev. Lett.*, 125, 078501. Retrieved from <https://link.aps.org/doi/10.1103/PhysRevLett.125.078501> doi: 10.1103/PhysRevLett.125.078501