

# Inferring Mars' Internal Structure from a Probabilistic Inversion of Complementary Geophysical Data

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## Framework

- Which 1D interior structure models of Mars are compatible with different and complementary geophysical observables? What can we deduce about the evolution of Mars' interior?
- We adopt a synergetic strategy in which multiple types of geophysical data (body wave arrival times, electrical conductivity, Love number  $k_2$ , moment of inertia  $MoI$ ) are simultaneously inverted to infer the interior structure models of Mars.

## Method

- Our models depend on quantities that influence the thermo-chemical evolution of the planet (Samuel et al., 2019, Drilleau et al., 2022): The mantle rheology (effective activation energy, volume, reference viscosity), the initial thermal state (temperature below the lithosphere and core-mantle boundary temperature), the core radius, the equation of state of the core
- We assume Mg# dependent variations of the mantle composition models of Sanloup et al. (1999) [EH45], Taylor (2013) [TA], and Yoshizaki & McDonough (2020) [YM]
- The mantle mineral proportions and elastic properties are computed using Perple\_X (Connolly, 2005) employing the thermodynamic formulation and database of Stixrude & Lithgow-Bertelloni (2021)
- We consider models with and without a basal mantle layer (BML) (Samuel et al., 2023)
- Inversion scheme: Bayesian inversion using Monte Carlo Markov chains

## Results: Correlation between Mg# and potential temperature

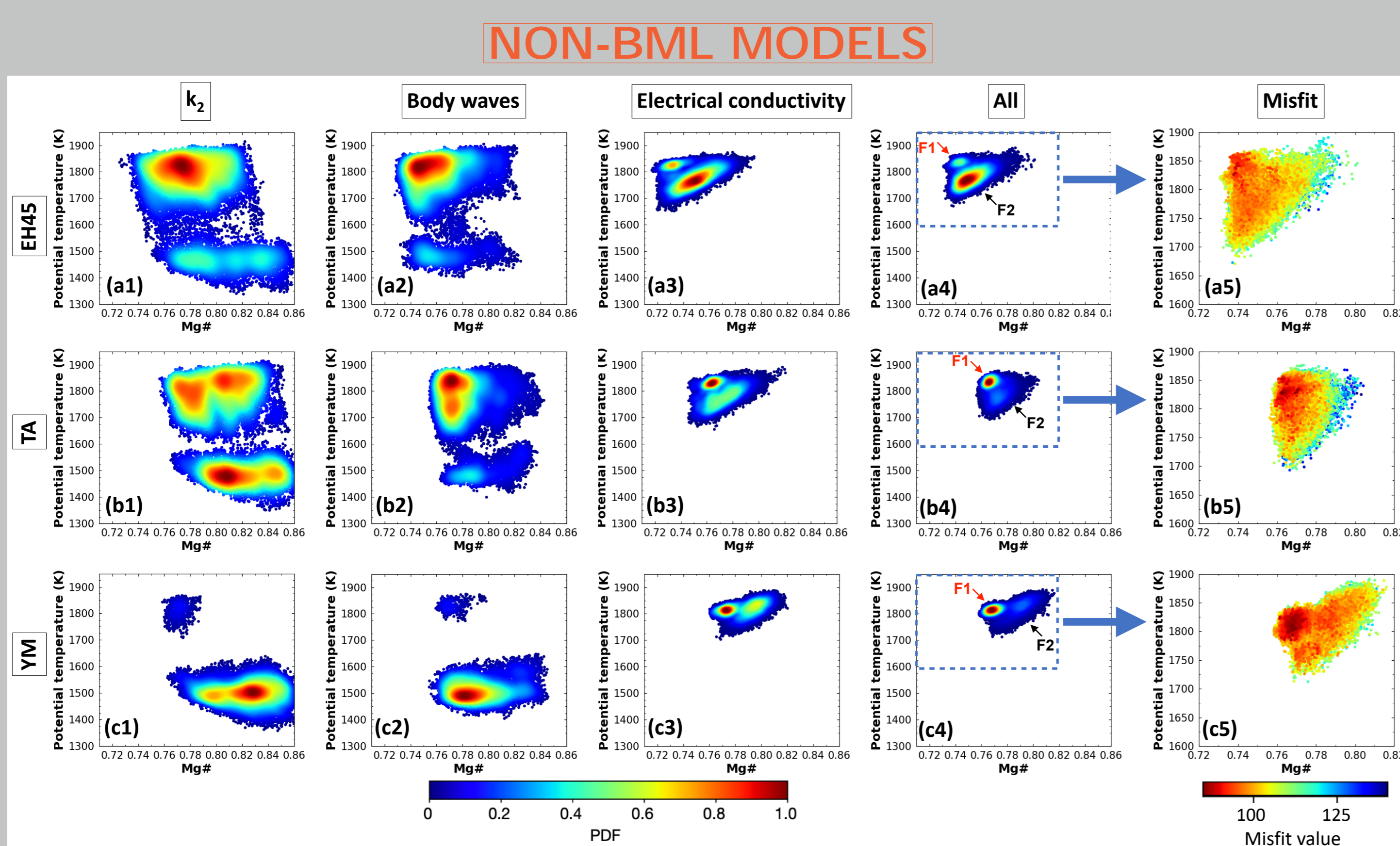


Figure 1: Correlations between Mg# and potential temperature, and data fit (last column) for non-BML models.

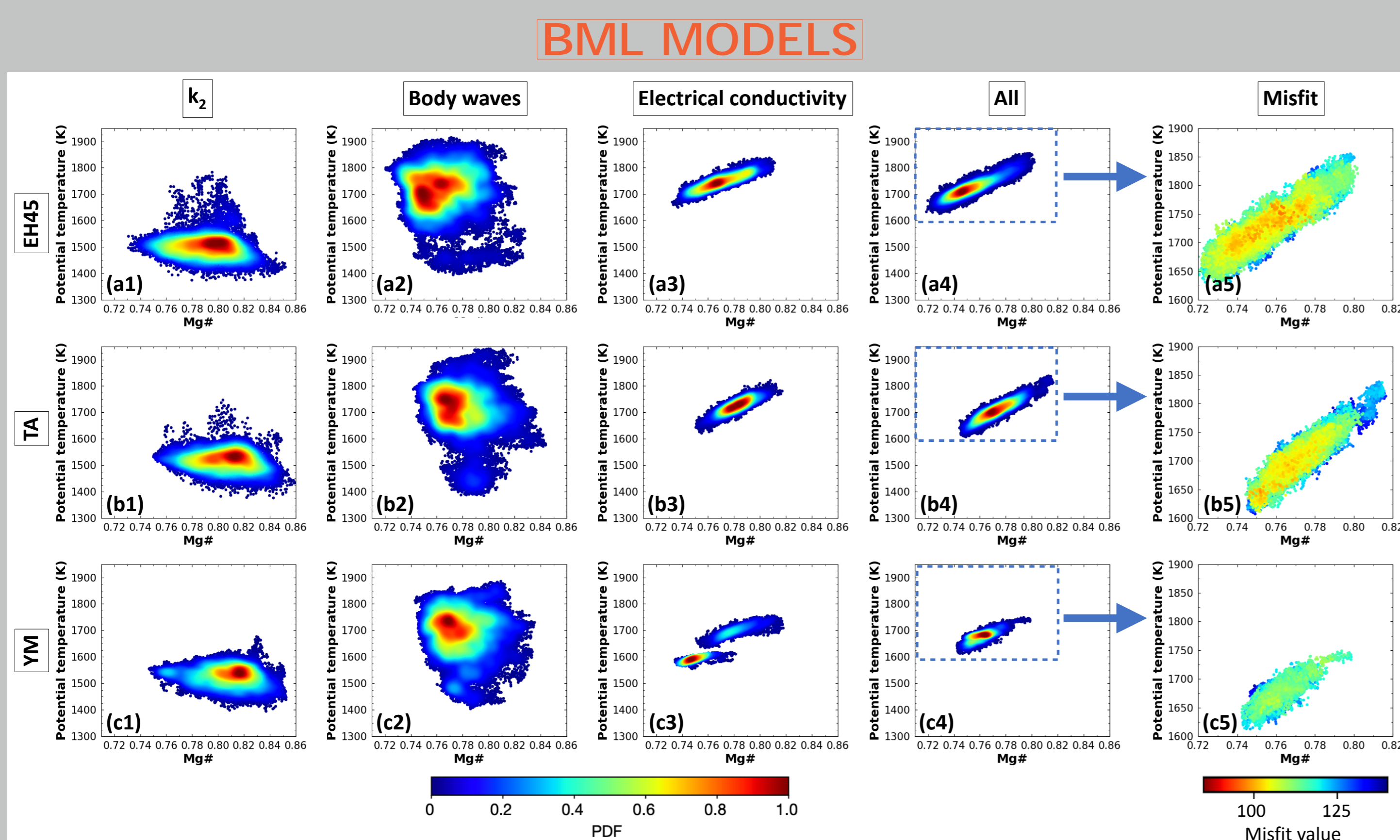


Figure 2: Correlations between Mg# and potential temperature, and data fit (last column) for BML models.

- Models with  $Mg\# < 0.72$  are not compatible with the  $MoI$
- Models inferred with mantle electrical conductivity data favour larger potential temperatures
- Non-BML:** Models based on either of the considered mantle composition with  $Mg\# > 0.72$  agree with the geophysical data at the same level
- BML:** Models based on the [YM] mantle composition are less compatible with seismic data
- BML:** The models agree less with electrical conductivity data

## Data

- Body waves data set of 31 seismic events: P, S, PP, SS, PPP, SSS, pP, sP, sS, ScS, SKS, Pdi or Pbd, PcP (Samuel et al., 2023, Drilleau et al., 2024)
- $k_2$  Love number and moment of inertia  $MoI$  (Konopliv et al., 2020)
- 1D electrical conductivity profile (Civet & Tarits, 2014)

## Results: Inferred seismic velocity and electrical conductivity profiles



Figure 3: Output profiles of temperature, electrical conductivity, and  $V_p$ , considering the [TA] mantle composition.

- non-BML:** The mantle electrical conductivity profile of Civet & Tarits (2014) favours models with thick thermal lithospheres (>800 km)
- BML:** Models have colder present-day mantle temperatures and thinner lithospheres, and agree less well with the mantle electrical conductivity profile of Civet & Tarits (2014)
- Models inferred from electrical conductivity data favour larger mantle temperatures than those inferred by body wave arrival times only
- The seismic velocity profiles are shifted toward smaller values

## Results: Influence of the thermodynamical database

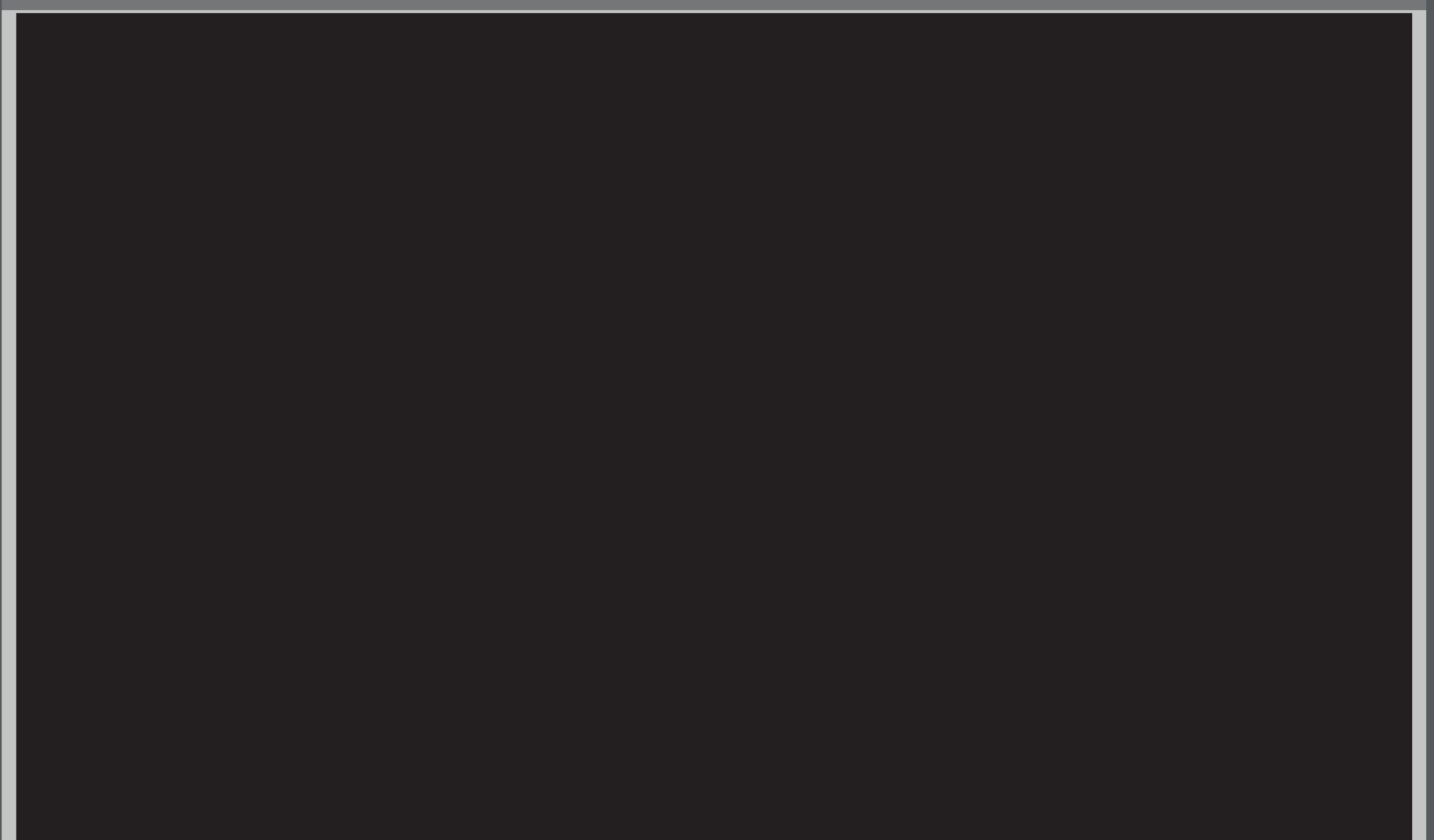


Figure 4: Comparison of seismic velocities and mineralogical phase diagrams between SLB11 and SLB21 (Stixrude & Lithgow-Bertelloni, 2011, 2021), considering the [TA] mantle composition for non-BML models.

- All the published models using InSight data rely on the thermodynamical database of SLB11
- The use of SLB21 introduces several differences:
  - An additional discontinuity appears below the Moho (~80 km depth)
  - The location/amplitude of seismic discontinuities or velocity gradients associated with mineralogical phase transitions are significantly modified in the lower part of the mantle
- The data fit is comparable between SLB11 and SLB21!

## Main findings and discussion

- By using electrical conductivity data, the range of plausible mantle temperature profiles is reduced and hot mantle profiles are favoured
- For BML models, whose temperature at the top of the convecting mantle is close to the solidus, a good estimation of the solidus is critical
- The ambiguity in the interpretation of the slope of the Civet & Tarits (2014)'s profile can significantly influence model selection
- A better knowledge of the depth of the seismic discontinuities in the mantle associated with mineralogical phase transitions could further help discriminate between competing interior models