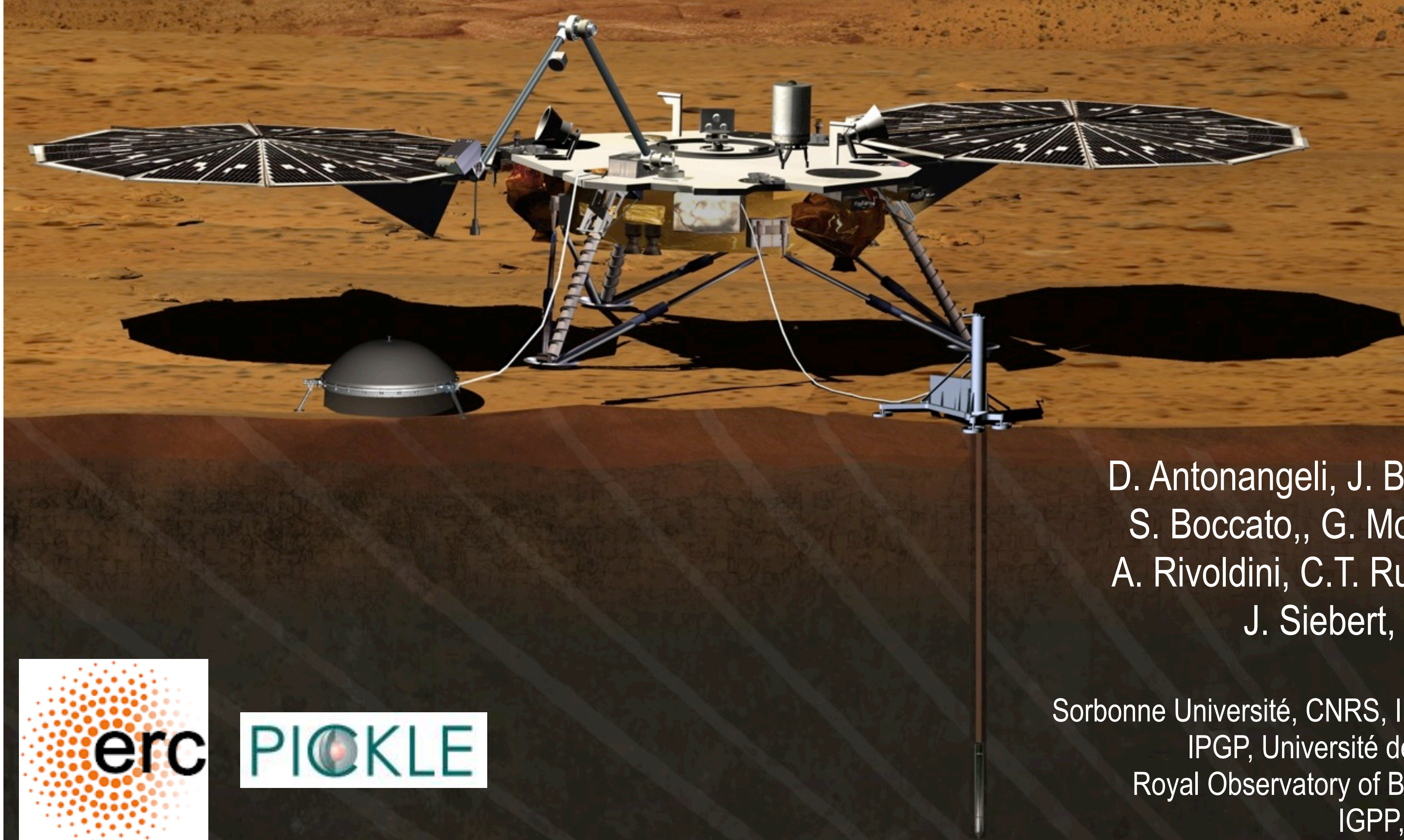
Constraints on Mars' core composition from a combined geochemical and mineral-physics approach

InSight



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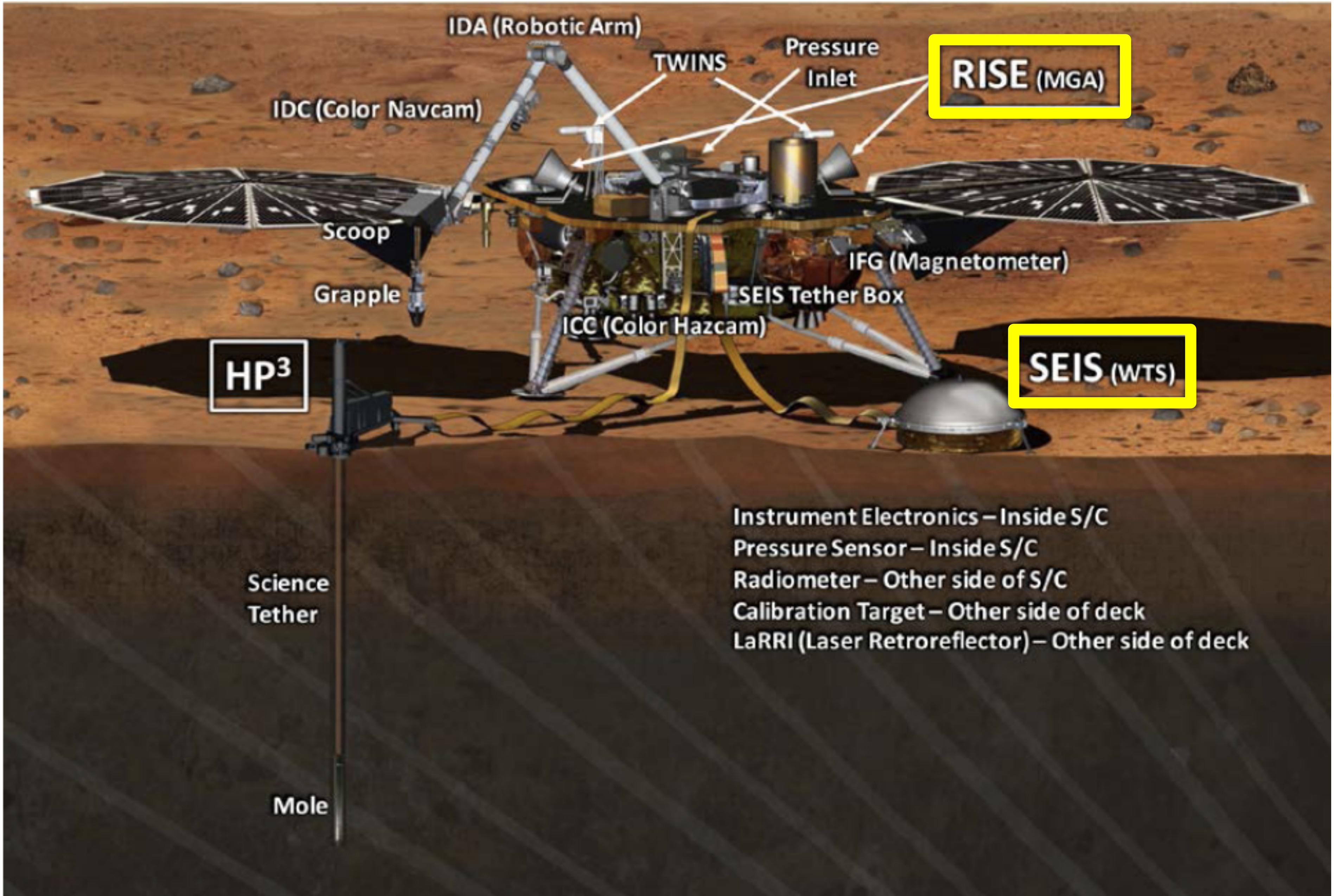
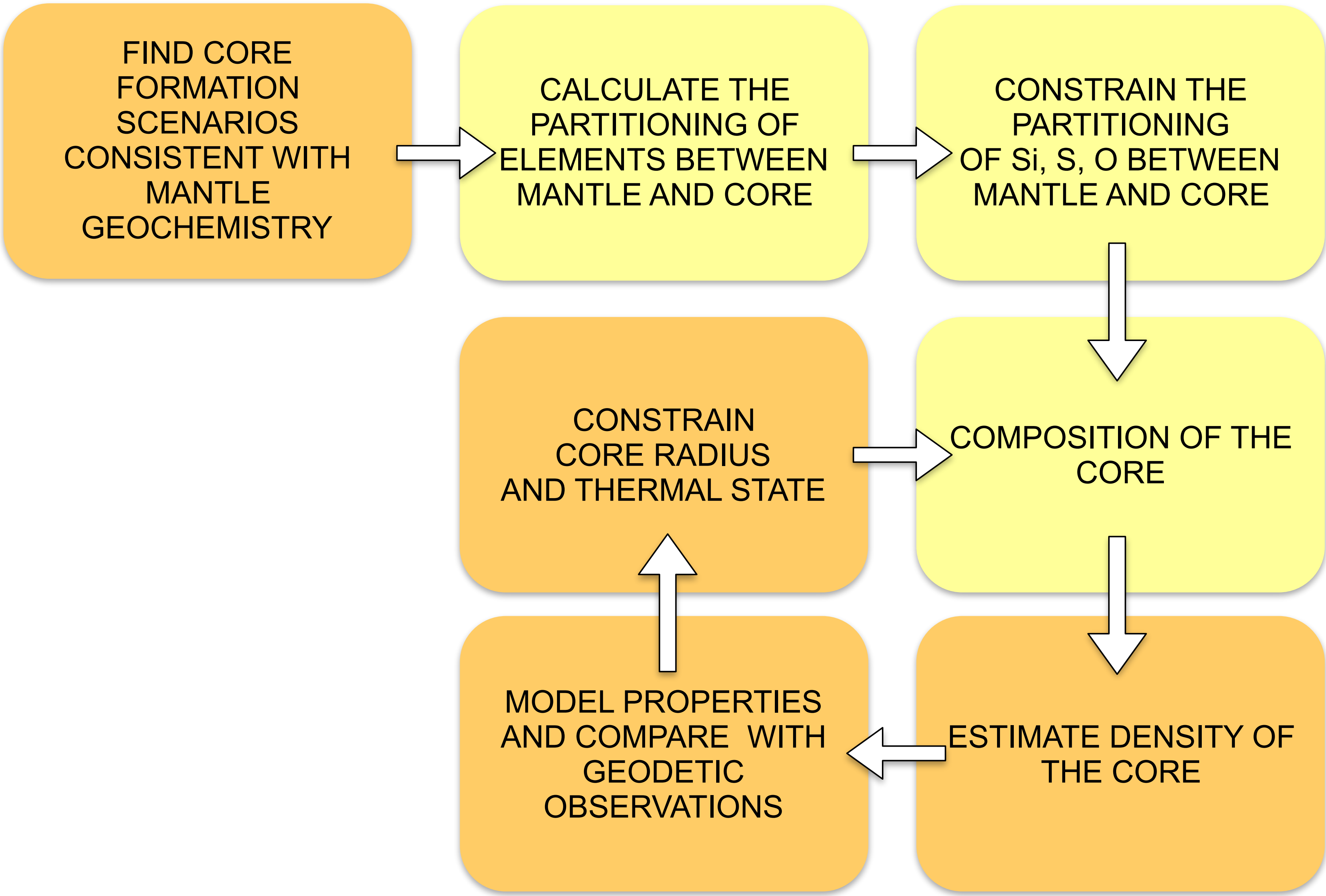
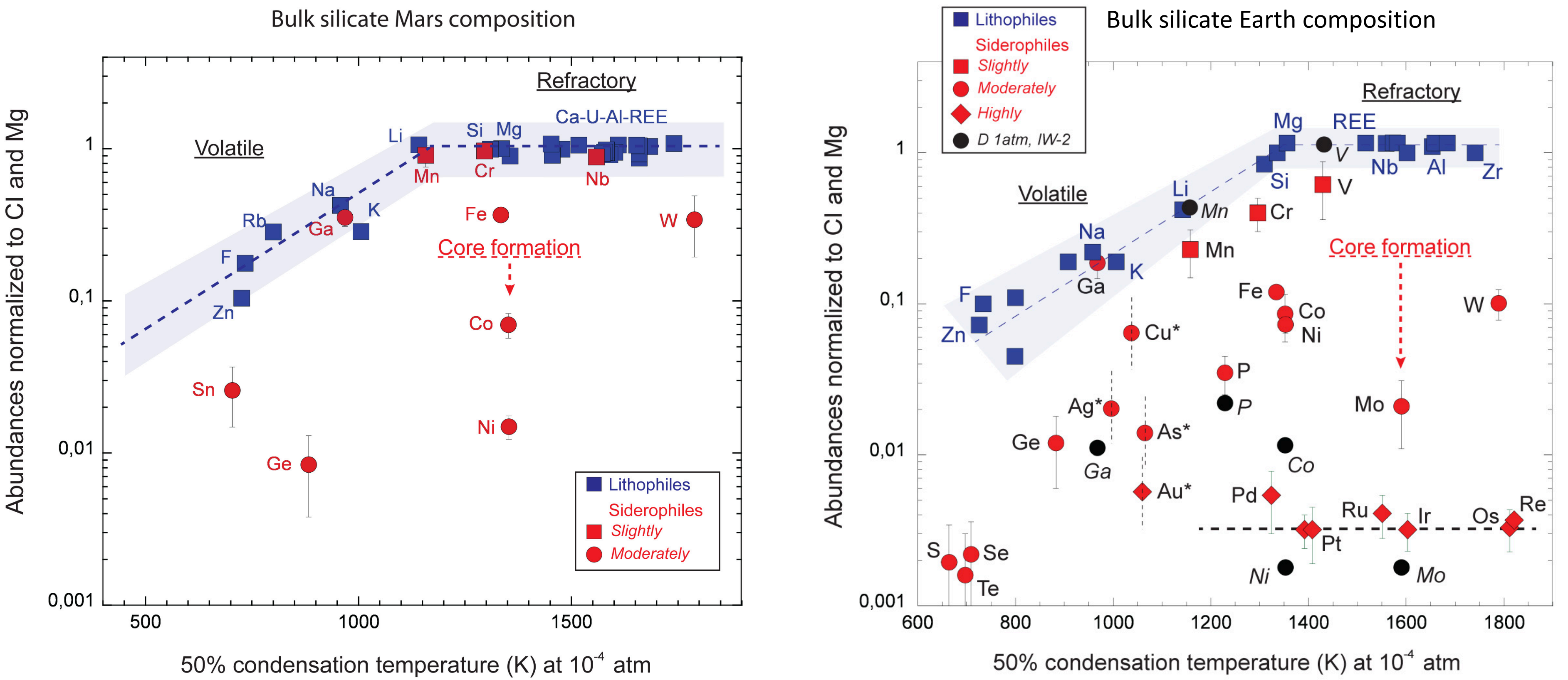
InSight: geophysical and geodetical constraints on Mars' core



Core composition from combined min-φ and geo-χ



Depletion of siderophile elements: Imprint of core formation



→ Ni and Co as tracer of P and T (*i.e.* magma ocean depth)

→ Cr as tracer of silicate composition (*i.e.* magma ocean composition)

→ Nb/Ta as tracer of silicate & metal composition (*i.e.* core composition)

Metal-silicate partitioning experiments

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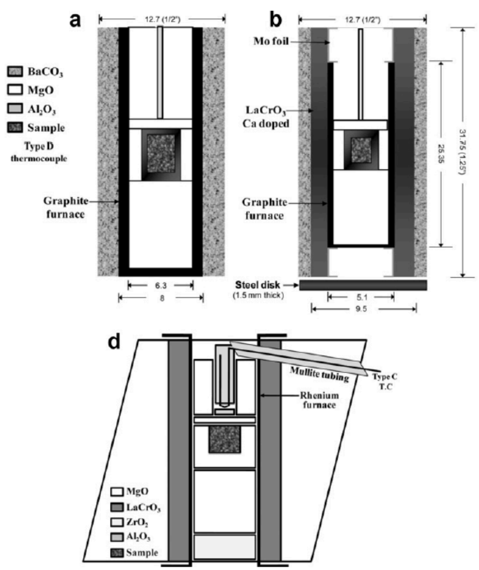
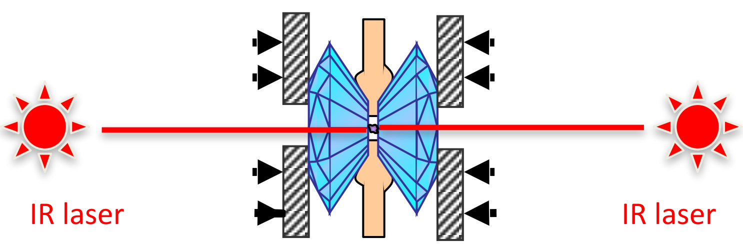
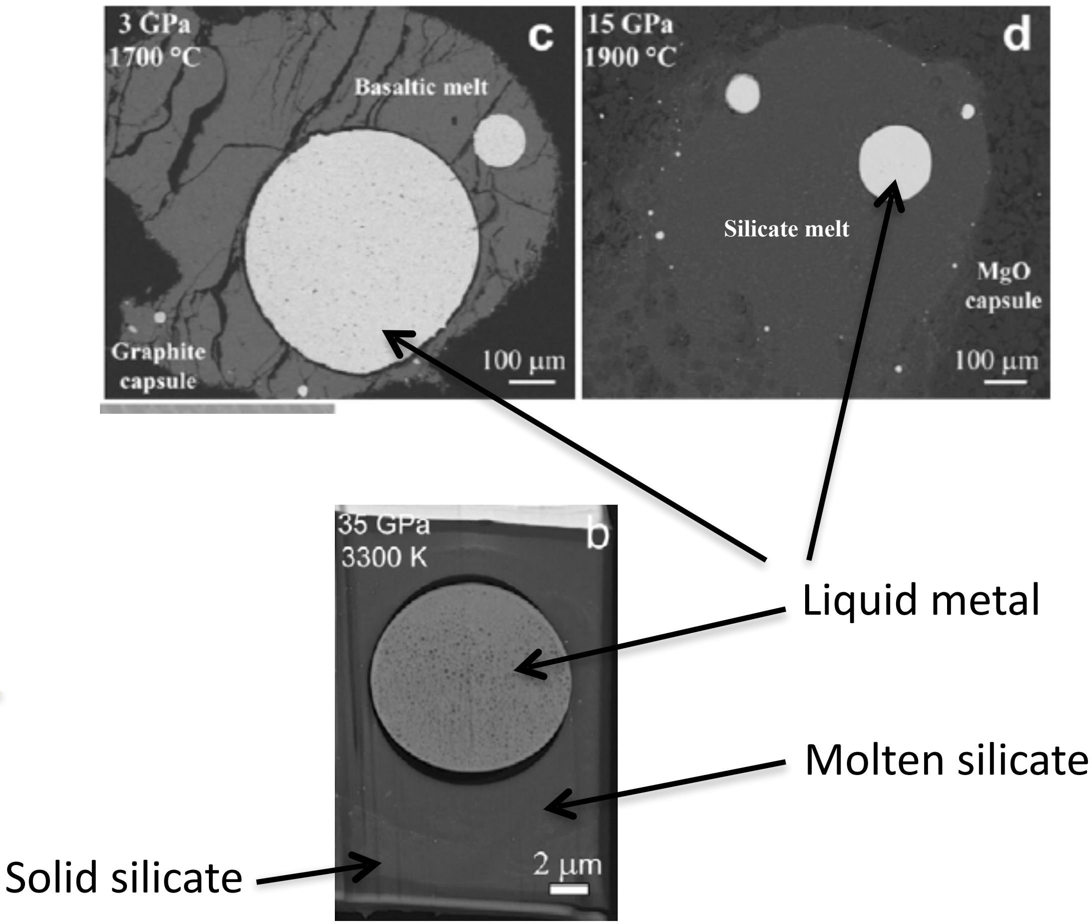
Experiments in piston-cylinder press, multi-anvil apparatus and laser-heated DAC
+ chemical analysis of recovered samples

→ Partitioning coefficients over large P-T range

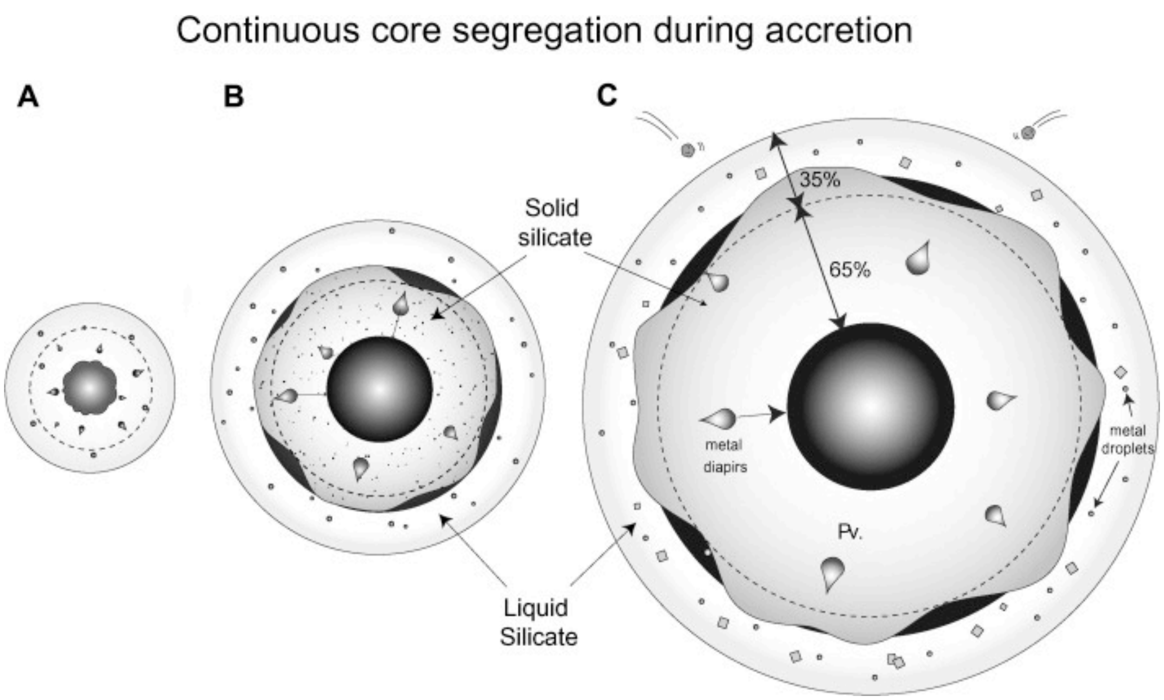
→ Exchange coefficiens as a function of P, T and X







Continuous core differentiation models



- Final equilibration depth 0 to 25 GPa (0 to 2080 km depth)
- Temperature between mantle solidus and liquidus
- Varying magma ocean composition, final FeO concentration given by mantle composition

Core differentiation models without sulfur – constant mantle FeO

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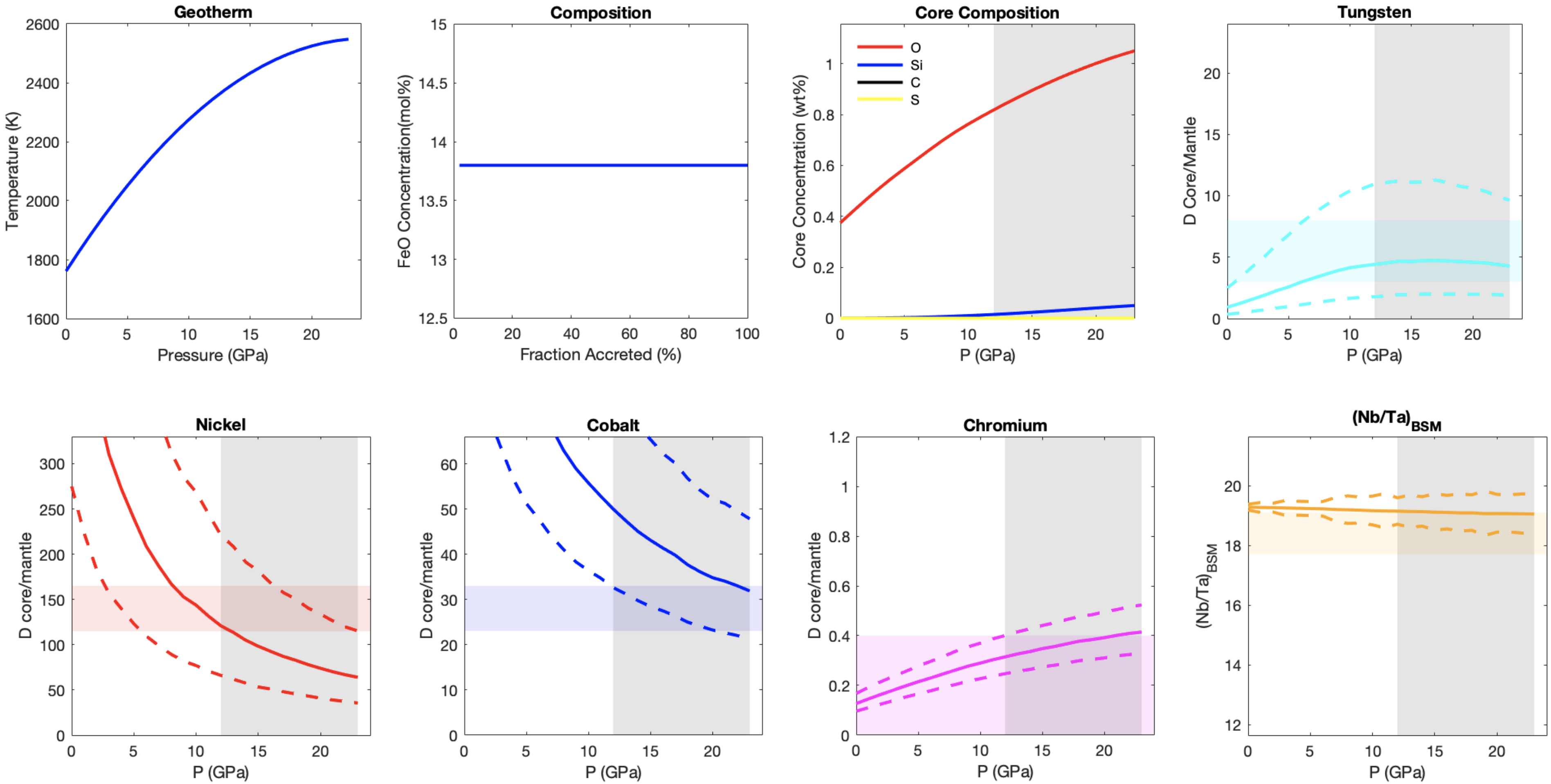
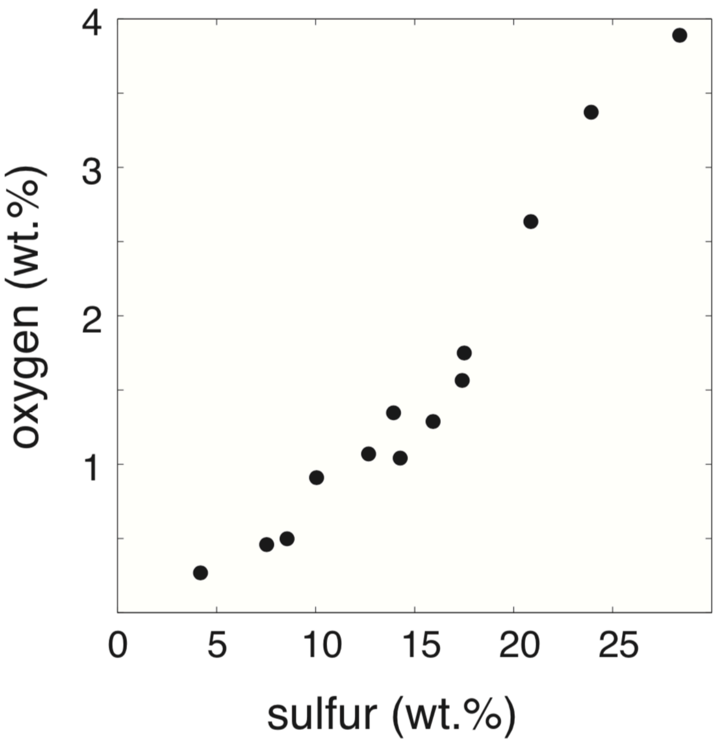


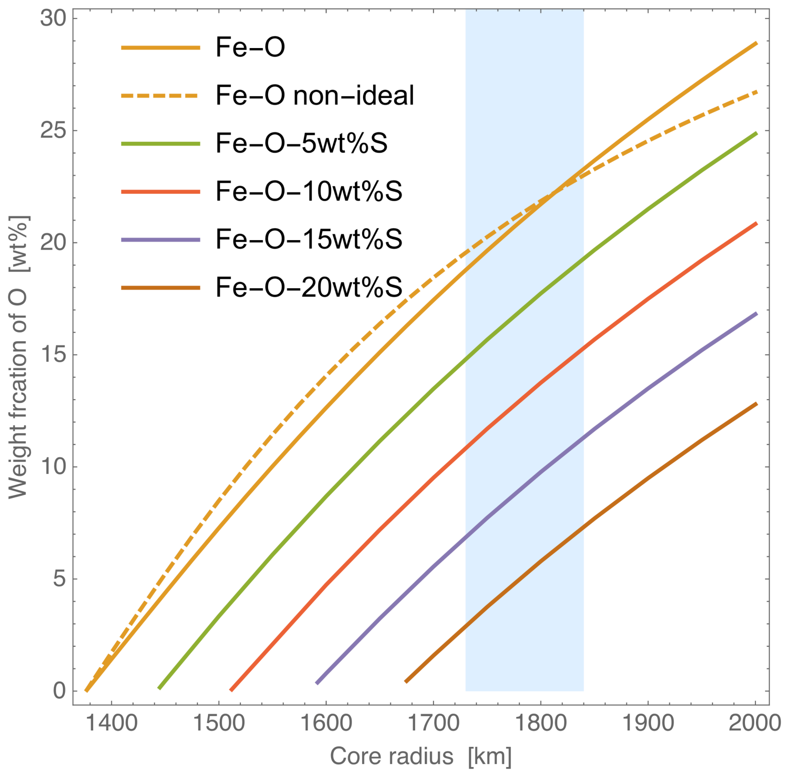
Ni, Co → final equilibration depth > 14 GPa

Cr, Nb/Ta → constant FeO concentration, high T

→ No significant Si in the core, some O (0.5-1 wt.%), agreement with Brennan 2019 but not as much as predicted by single-stage models (Steenstra 2018, Tsuno 2011)

Interaction between elements





Core differentiation models with 7 wt.% sulfur

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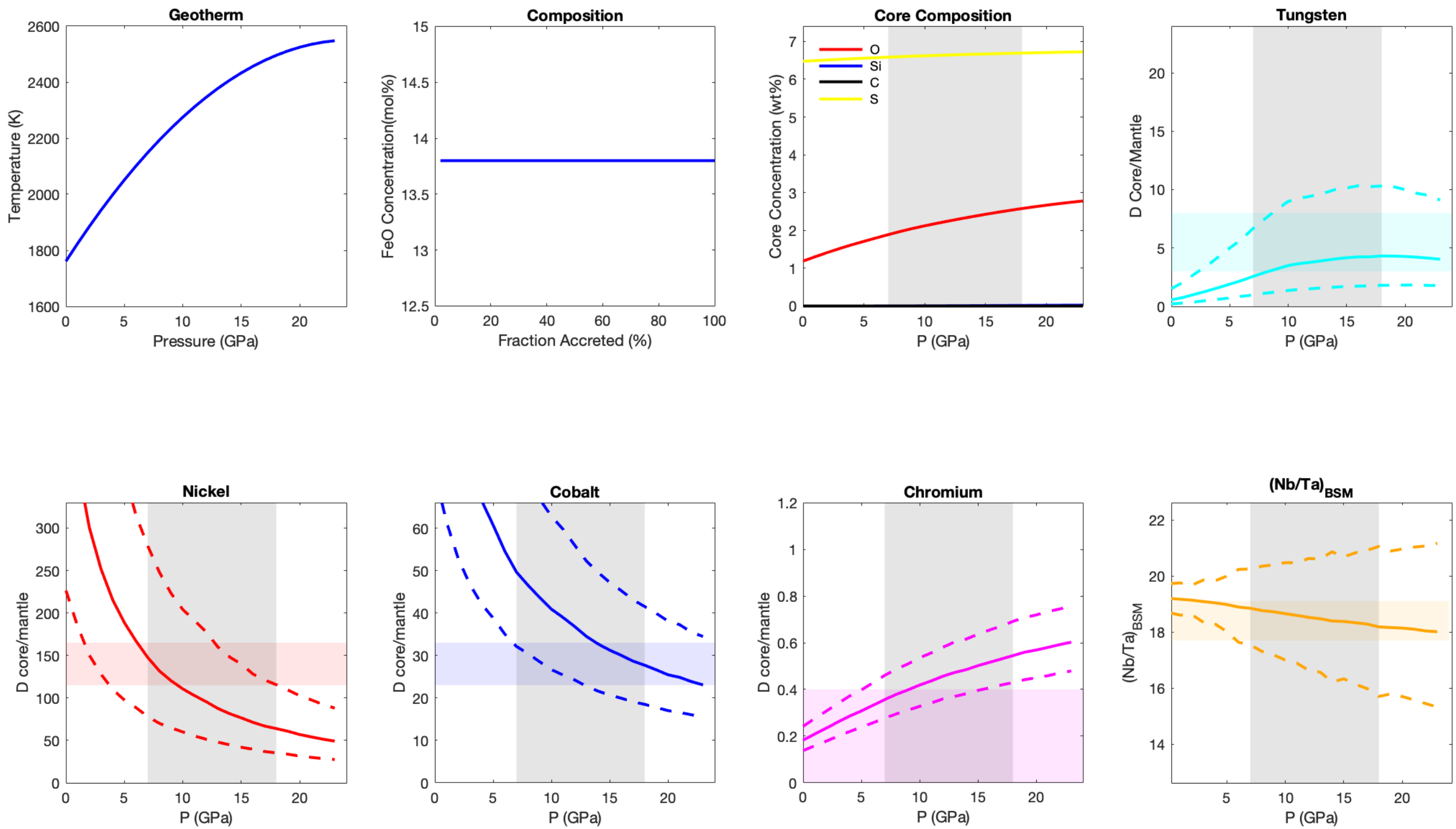

S in the core increase O significantly: 7 wt.% S → 2-3 wt.% O

Core differentiation models with 12 wt.% sulfur

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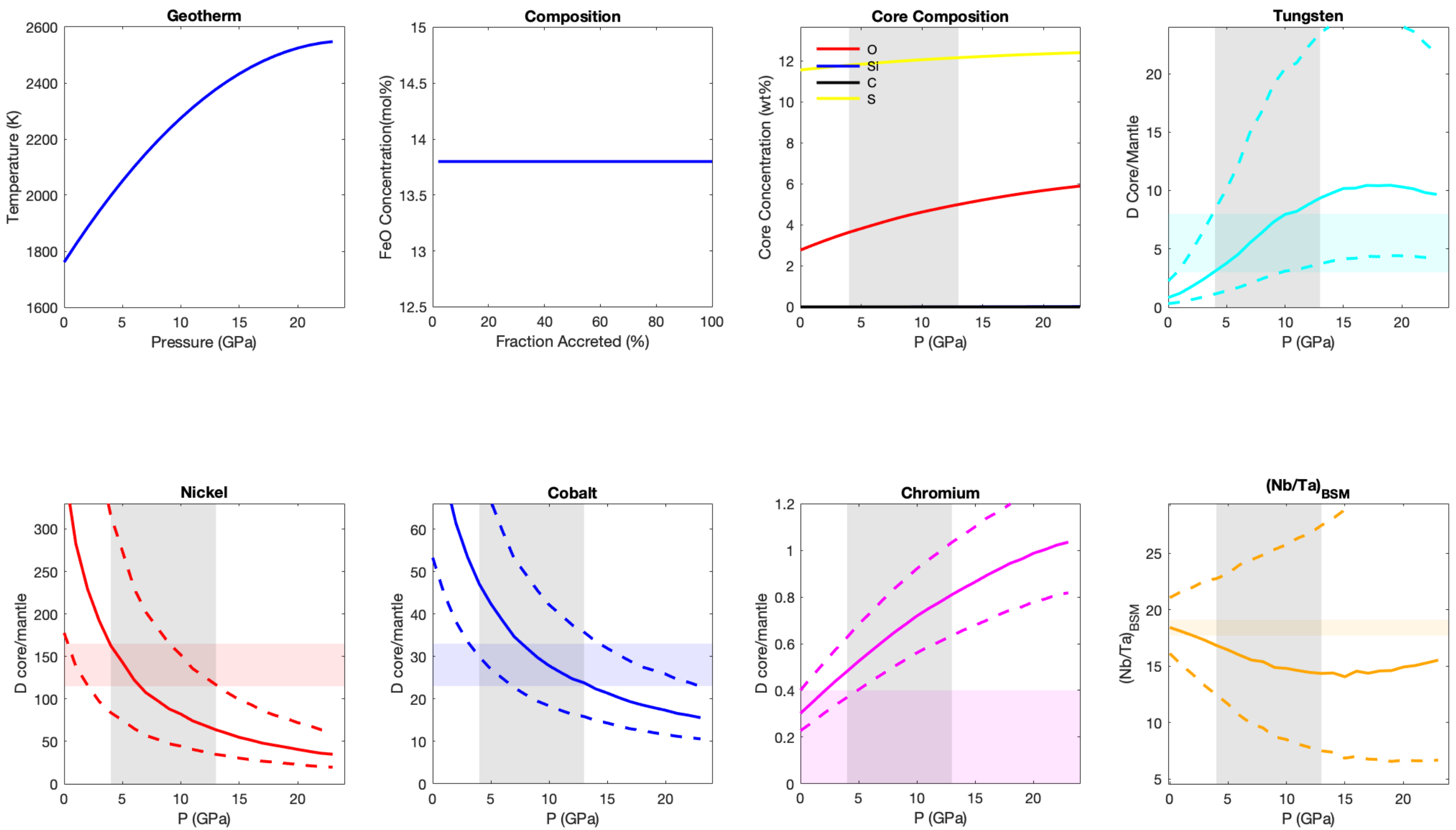

S in the core increase O significantly: 12 wt.% S → 4-6 wt.% O

Structural and thermo-elastic properties of liquid Fe-S alloys

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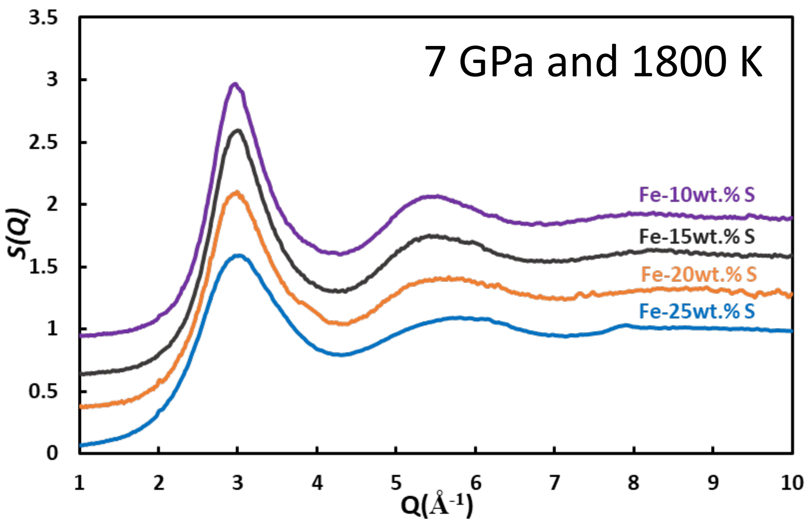
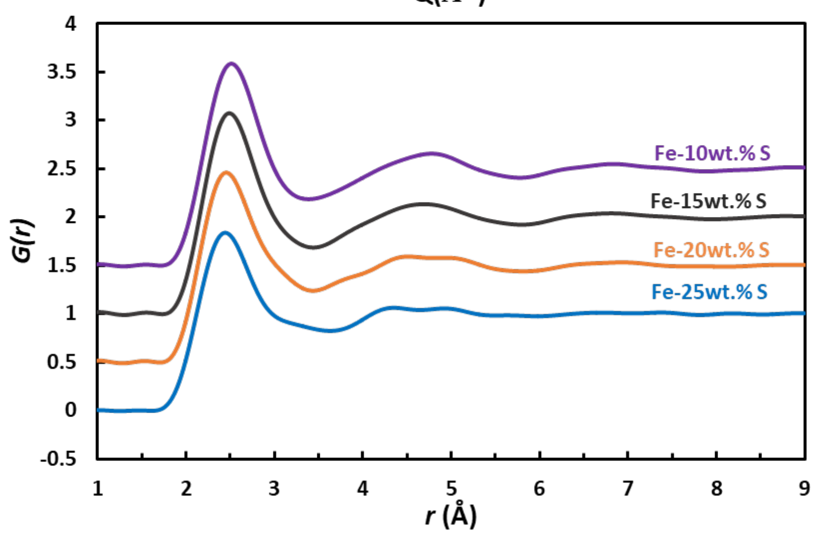
XRD experiments on liquid Fe-S alloys at high pressure and high temperature
6 GPa < P < 14 GPa; 1200 K < T < 2500 K; 0 wt.% < S < 25 wt.%





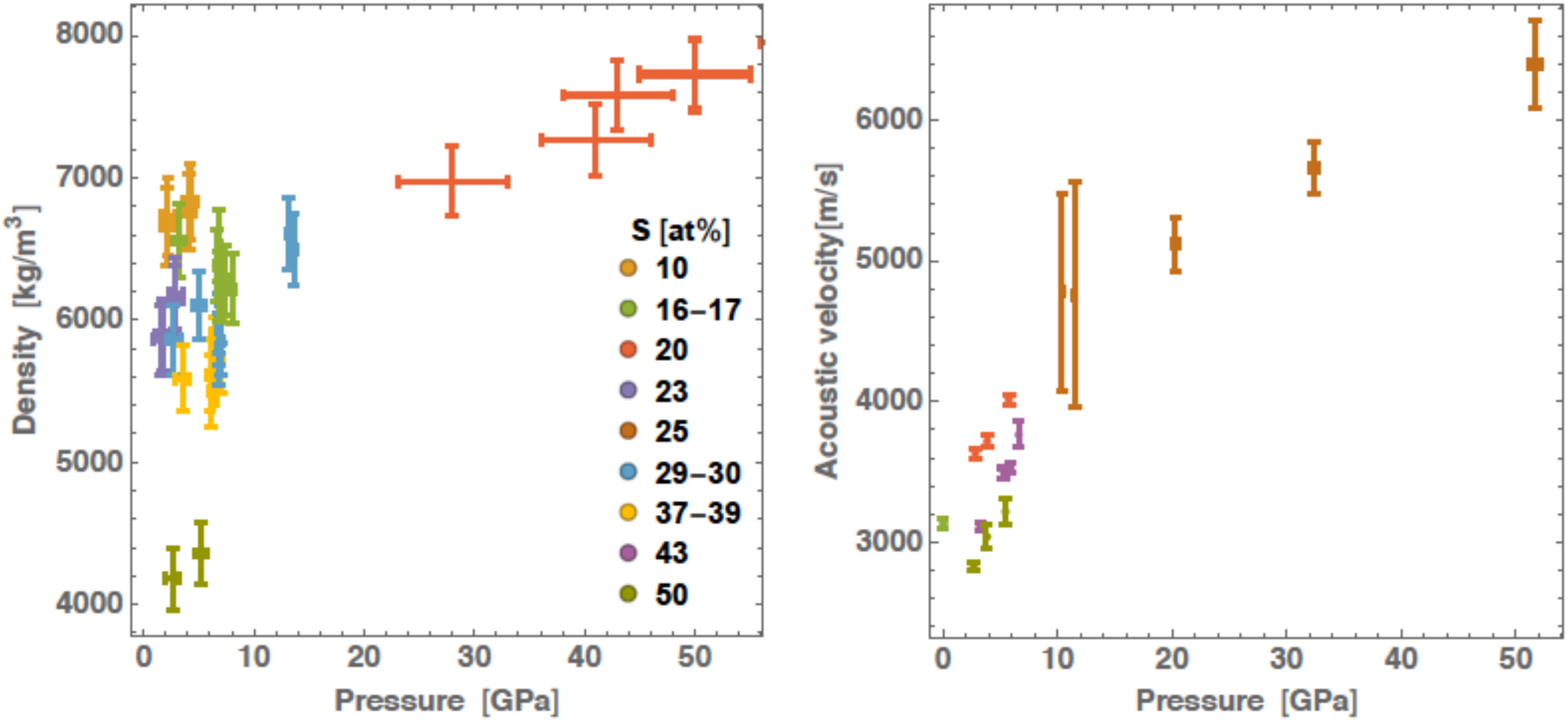
Density vs. P → compressibility

Density vs. T → thermal expansion

MR51D-0088

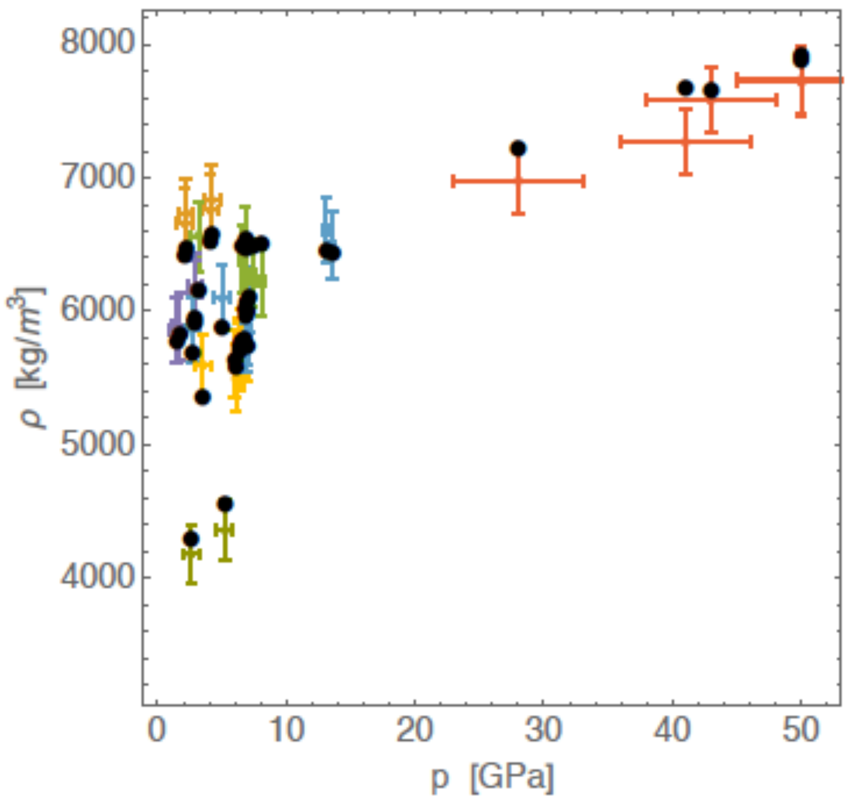
Xu et al., in prep.

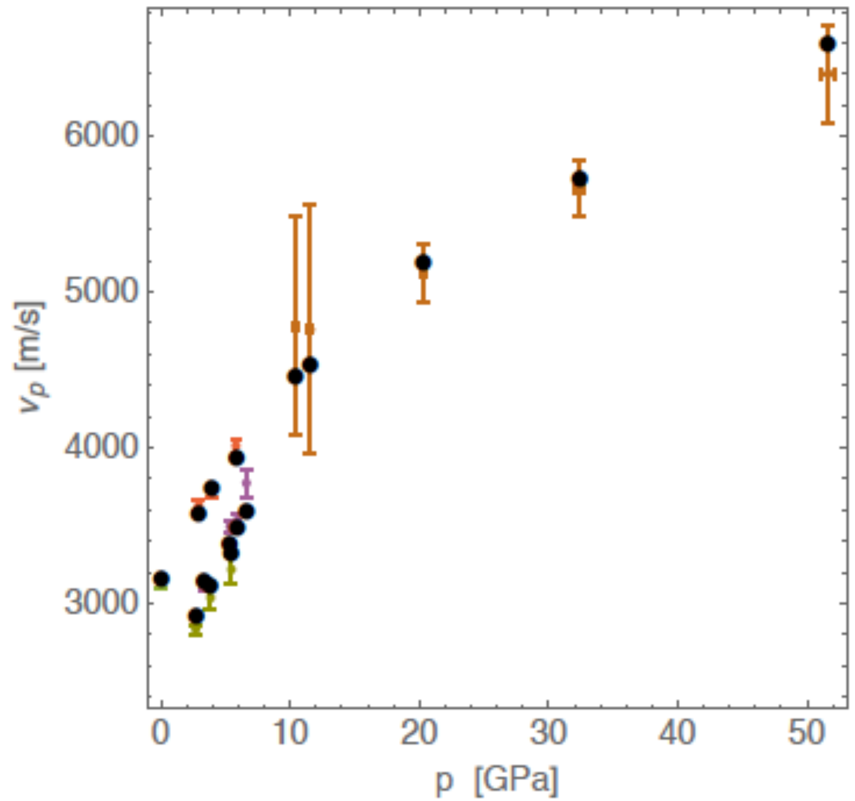
Liquid Fe-S data set



density: Morard 2013; Morard 2018; Xu in prep.
velocities: Nishida 2017; Kawaguchi 2017

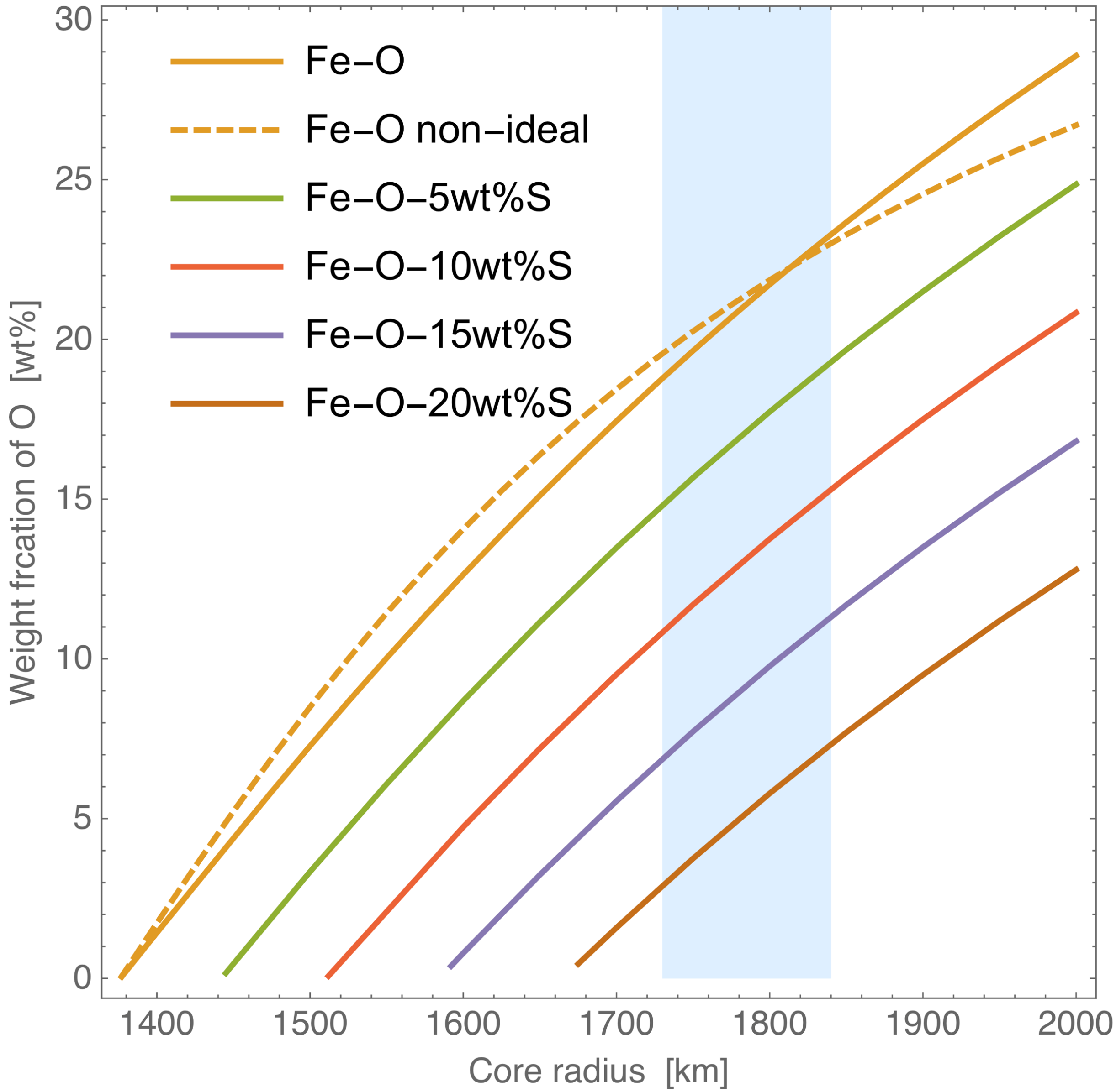
Thermodynamical model and data fit



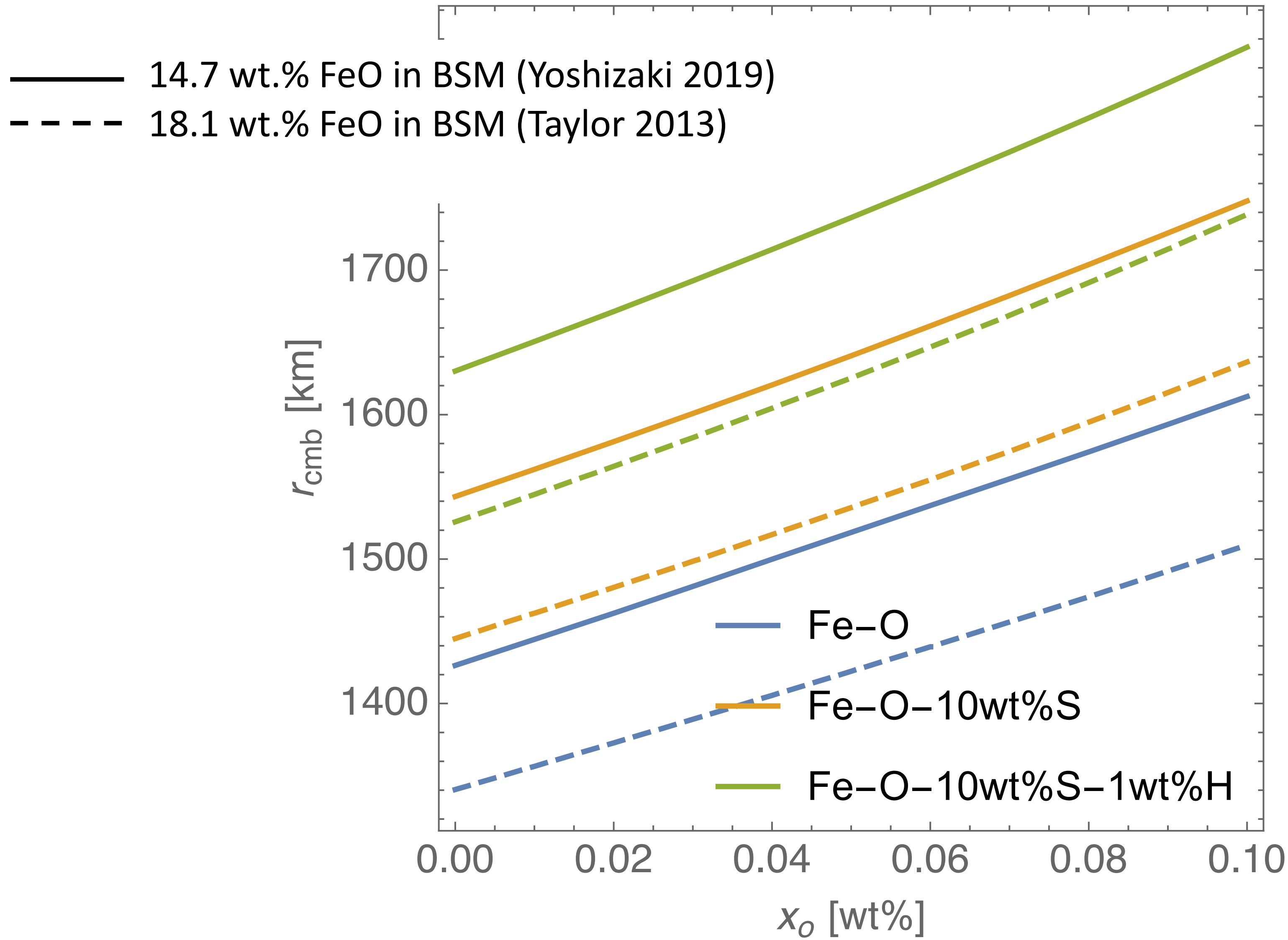


- both density and velocity data accurately described by non-ideal solution model with pressure-dependent excess volume
- Liquid FeS end-member EoS and excess volume from the data
- Liquid Fe end-member EoS from Komabayahsi 2018

Core compositions matching geodesy constraints



Different compositional models



Conclusions

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- Model core composition of Mars while matching the geochemistry of the Martian mantle (Ni, Co, Cr, Nb/Ta, W)
- Accreting with low FeO content not consistent with Cr abundances
- Mars' core cannot contain Si (< 0.2%)
- Core is too dense if S not present (Si and O not sufficient)
- S in the core increases O significantly:
  - 7 wt% increases O from 1 to 3 wt%
  - 12 wt% increases O to 6-7 wt%
- HP-HT experiments on liquid Fe-S, Fe-O and Fe-S-O alloys to build a reference data set (thermo-elasticity and melting)
- Thermodynamic models accounting for data

→ Ready once constraints on Mars' core radius will come from InSight

Acknoledgments

InSight

- Nicolas Guignot (Synchtrotron SOLEIL)
- Steeve Greaux (GRC, Ehime University)