The interior structure of Mercury constrained by geodesy data

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New Geodesy data

- Margot et al. 2012
  Obliquity: 2.04 ± 0.08 arcmin ⇒ MOI=0.345 ± 0.014 (4%)
  Libration amplitude: 38.5 ±1.6 arcsec (4%)

- Stark et al. 2015
  Obliquity: 2.03 ± 0.09 arcmin ⇒ MOI=0.345 ± 0.014
  Libration amplitude: 38.9 ±1.3 arcsec

- Verma et al. 2016
  Tidal Love number: k_2=0.46 ± 0.02

OLD

- Genova et al. 2019
  Obliquity: 1.97 ± 0.009 arcmin ⇒ MOI=0.333 ± 0.0015 (0.5%)
  Libration amplitude: 40.0 ± 8.7 arcsec
  Tidal Love number: k_2=0.57 ± 0.03 (5.2%)

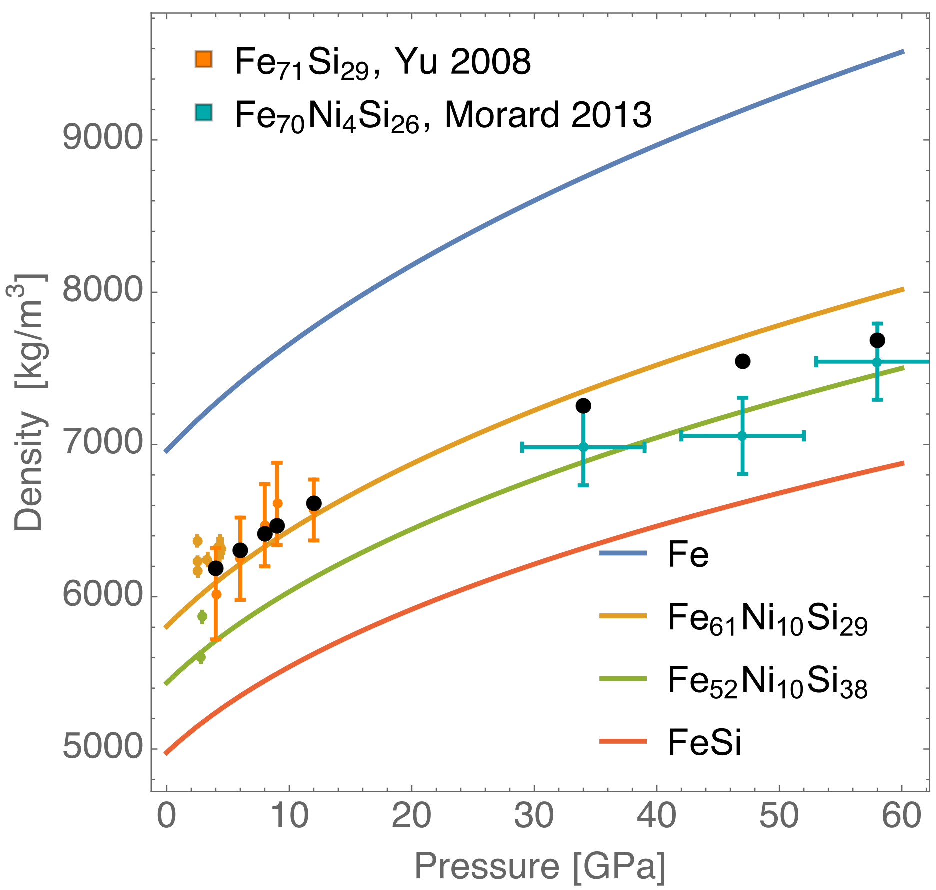
- Konopliv et al. 2020
  Obliquity: 1.99 ± 0.12 arcmin ⇒ MOI=0.337 ± 0.02 (~6%)
  Tidal Love number: k_2=0.53 ± 0.03 (5.6%)

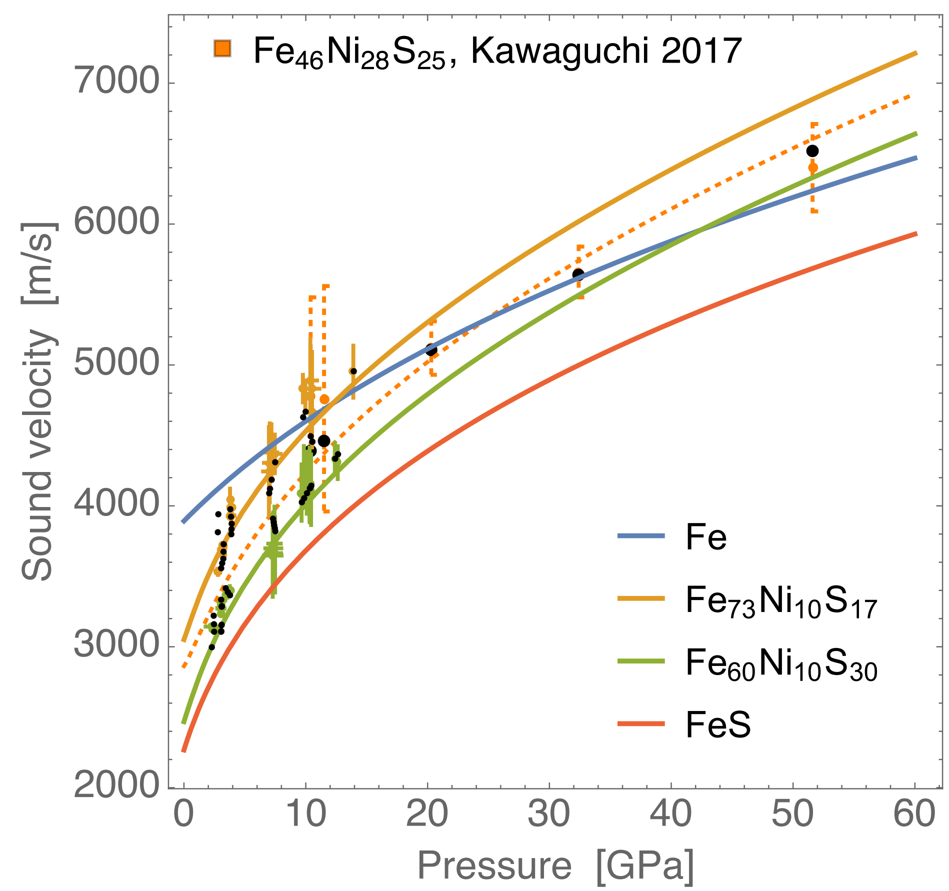
NEW

MOI ↓ and k_2 ↑

core radius ↓ **core radius ↑**

New thermoelastic data about l-Fe alloys





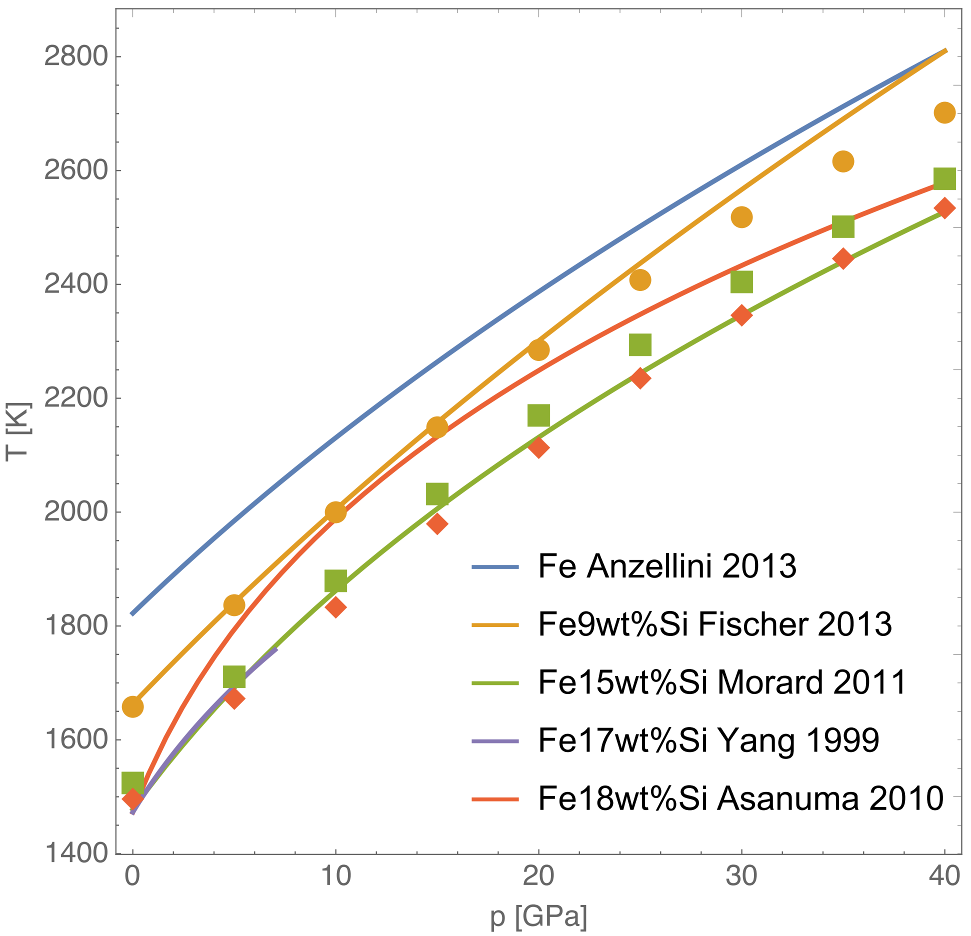
- Terasaki et. al 2019: densities (up to 5 GPa) and acoustic sound velocities (up to 14 GPa) of ($Fe_{73}Ni_{10}S_{17}$, $Fe_{60}Ni_{10}S_{30}$) and ($Fe_{61}Ni_{10}Si_{29}$, $Fe_{52}Ni_{10}Si_{38}$)
- non-ideal solution model required to summarize Fe-S and Fe-Si elastic data
- liquid solution model in agreement with low pressure and high pressure data

Prior assumptions, modeling, and data

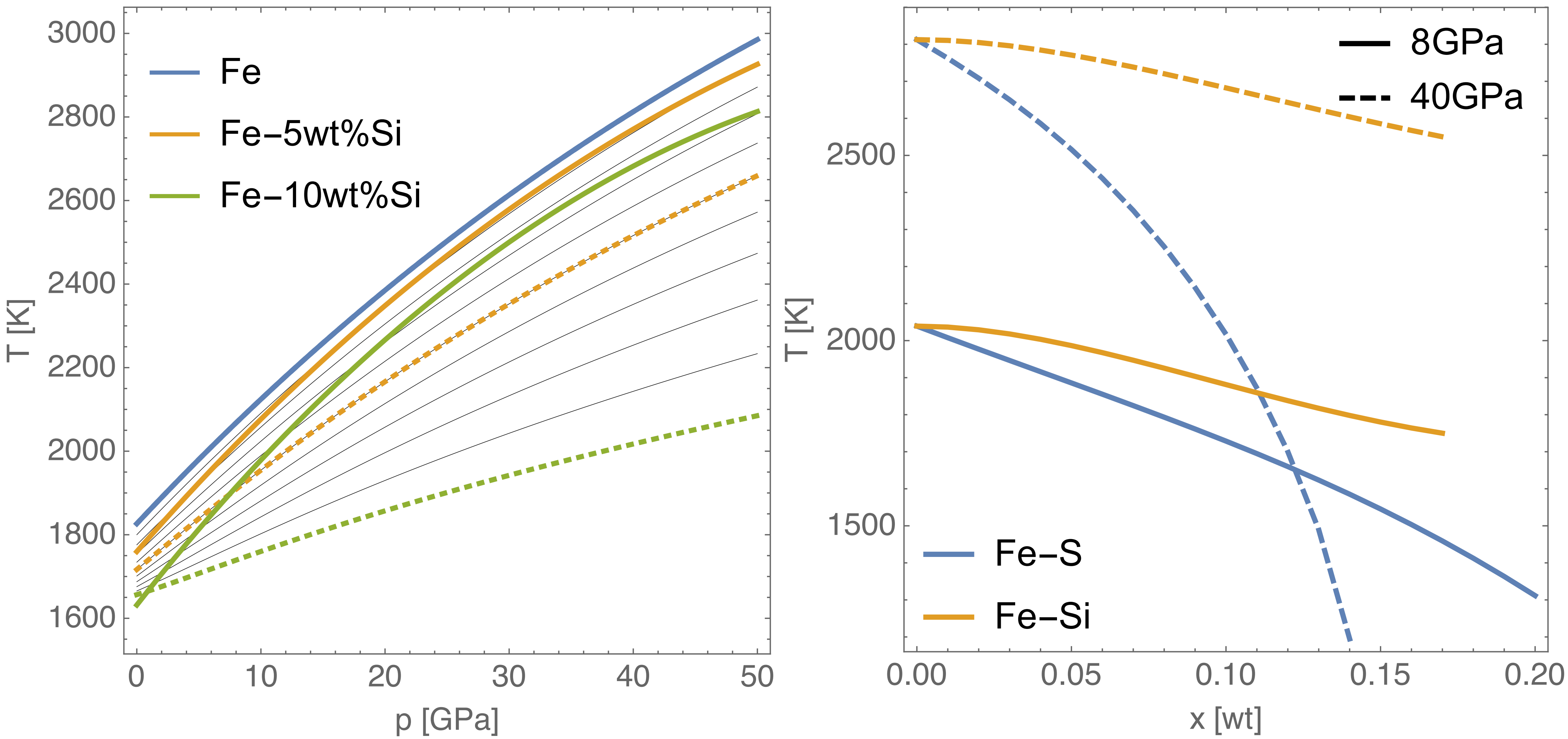
- crust: density [2700, 3100]kg/m^3 and thickness [15,120]km
- mantle elastic properties compatible with forsterite-enstatite mixture; corresponds to a prior mantle density [3150, 3400]kg/m^3
- inner core radius and light element fraction in agreement with liquidus; assume Si concentration in liquid below eutectic composition (because of unknown liquidus at those compositions); core radius prior [1800, 2200]km
- prior core-mantle boundary temperature between eutectic temperature and (very likely too warm!) mantle solidus
- libration amplitude calculated by taking into account gravitational core-mantle coupling and mantle induced core density stratification (Dumberry et al., 2013)
- geodesy data: MOI and k_2 from Konopliv 2020 and libration amplitude Margot et al. 2012

Fe-Si melting

- based on 1 bar Fe-rich liquidus, and melting data of: Fe9wt%Si, Fe15wt%Si, Fe15wt%Si, Fe18wt%Si
- assume equipartitioning of Si in solid and liquid Fe
- Margules model with pressure dependent interaction coefficients

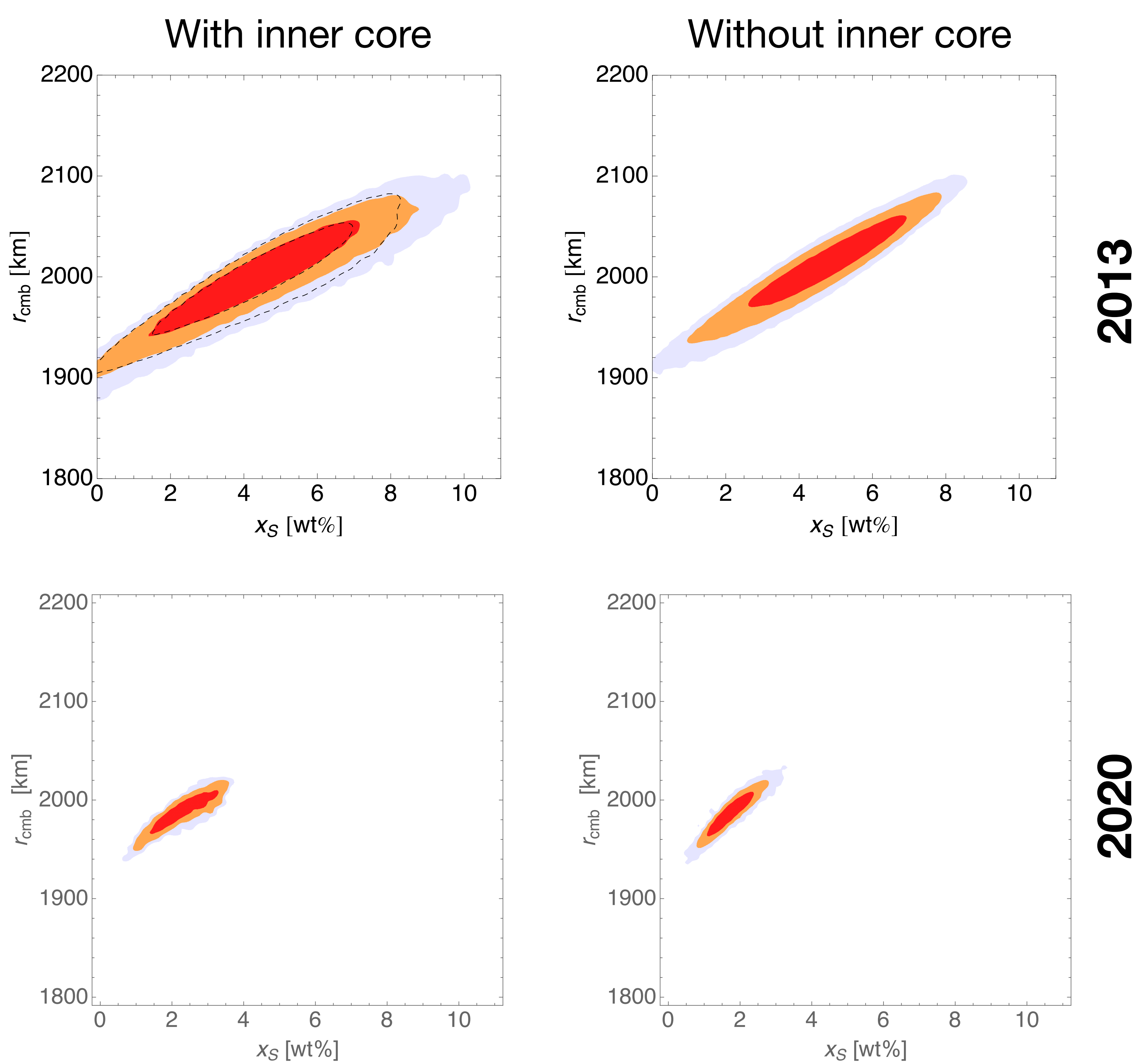


Fe-Si melting compared to Fe-S



⇒ **5wt%Si decrease Fe liquidus by about as much as 1wt%S**

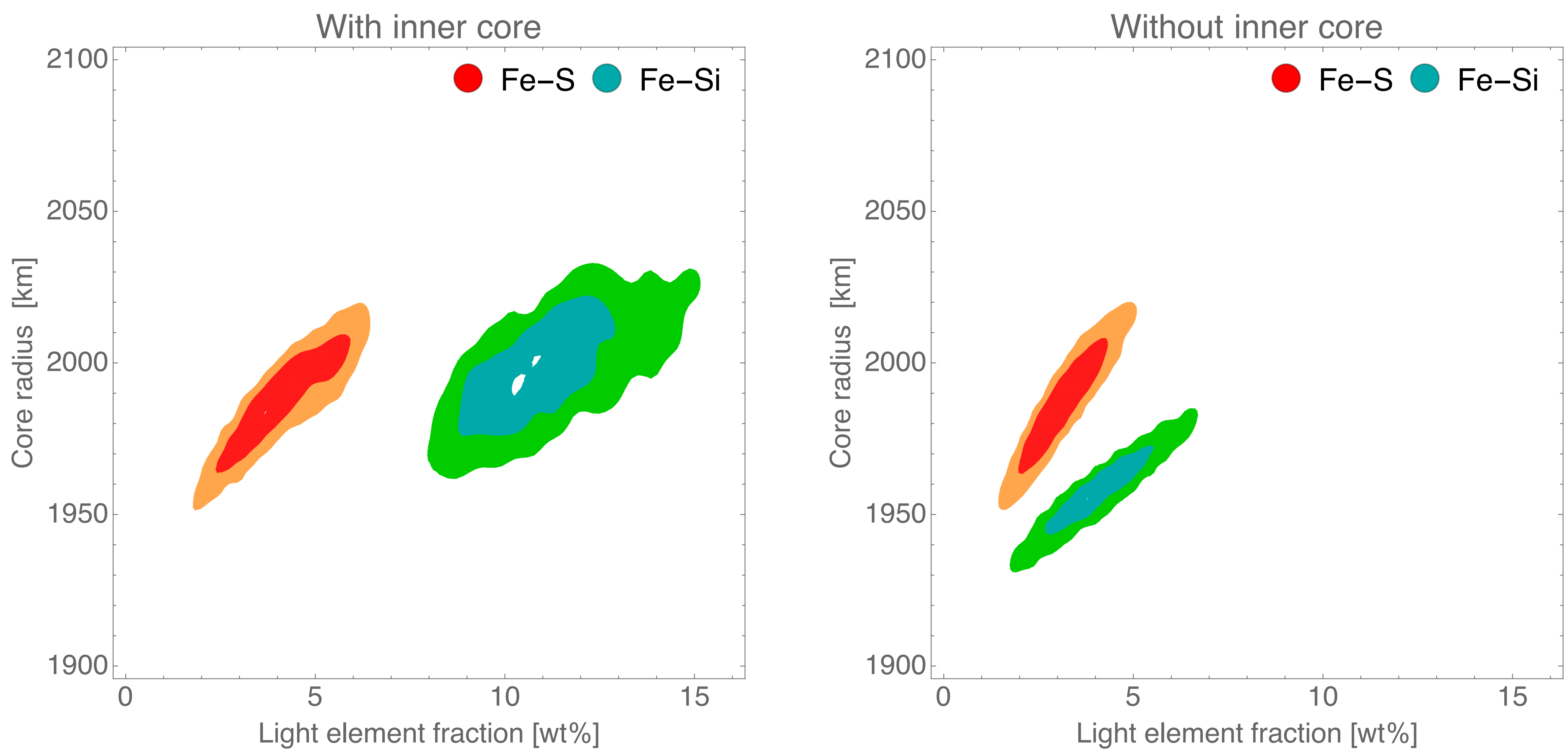
Results: Fe-S models compared to Rivoldini et al. 2013



	2013	2020
MOI	0.346±0.014	0.337±0.02
g_{88}	38.5”±1.6”	38.5”±1.6”
C_m	0.148±0.006	0.148±0.006
k_2	-	0.53±0.03

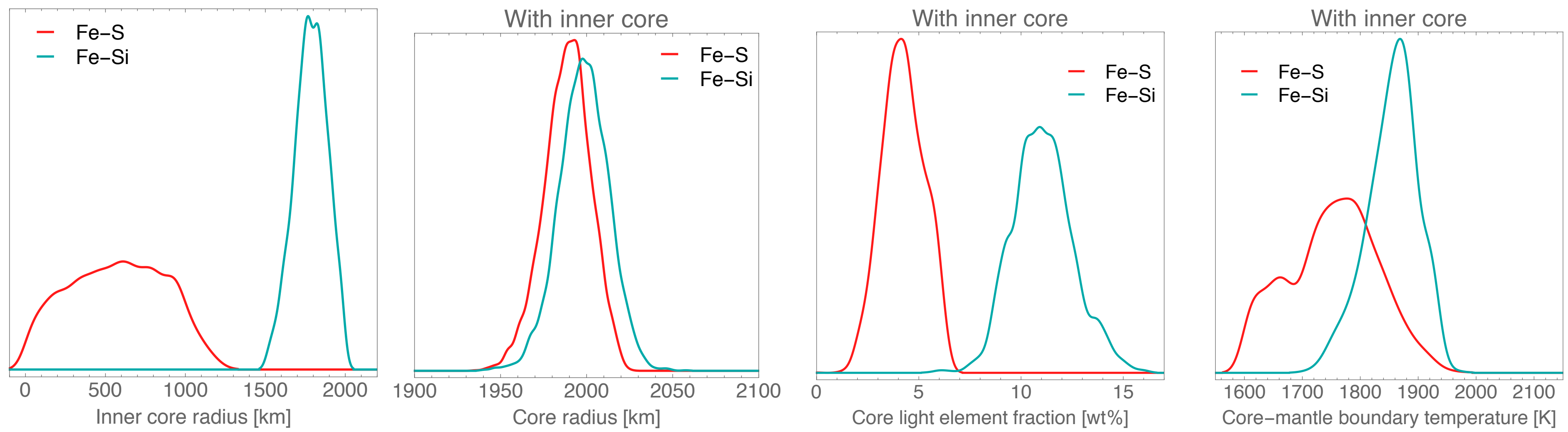
	2013	2020
r_{cmb} [km]	1965-2043	1974-2003
r_{icb} [km]	345-1430	246-899
x_S [wt%]	2.8-6.2	2.7-5.3
ρ_{Mantle}[kg/m³]	3163-3449	3110-3180

Results



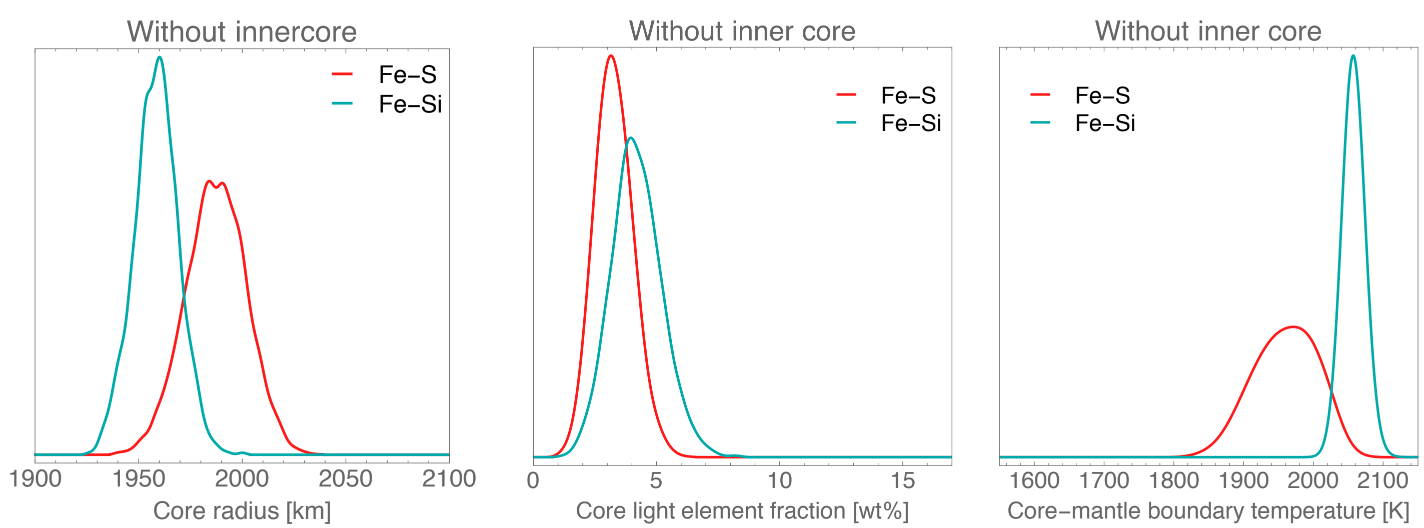
- core radius between ~1926 and 2030km
- Fe-Si models require more light elements since Fe-Si alloys are denser than Fe-S alloys

Results



With inner core

	Fe-S	Fe-Si
r_{cmb} [km]	1975-2002	1984-2012
r_{icb} [km]	236-896	1673-1892
x_S [wt%]	3.2-5.3	9.6-12.5
T_{cmb} [K]	1664-1831	1814-1892



Without inner core

	Fe-S	Fe-Si
r_{cmb} [km]	1973-2002	1948-1968
x_S [wt%]	2.5-4.0	3.2-5.2
T_{cmb} [K]	1913-2006	2051-2064

- models with and without inner core have a comparable core radius range with the exception of the liquid Fe-Si models
- liquid Fe-Si models only possible for high $T_{cmb} \gtrsim 2037$K (3σ) (implying molten lower mantle?) and inner core models with Fe-Si only possible if $T_{cmb} \gtrsim 1718$K (3σ)
- Fe-S models r_{icb}~[0,1214]km and Fe-Si r_{icb}~[1507,2000] km (3σ)
- mantle density ~[3100,3310]kg/m^3 (3σ)
- almost no constraints on crust thickness and density

Conclusions

- models with and without an inner core agree with the new geodesy data (liquid Fe-Si models only possible if $T_{cmb} \gtrsim 2037K$)
- new smaller MOI value favors models with smaller core radii Fe-S [1975,2003]km (old [1965,2043]km) and FeSi [1950-2012]km as well as a smaller mantle density (<3310 kg/m^3)
- Fe-S models have an inner core radius below about 1300km and for Fe-Si models the inner core radius is ~[1500,2000]km
- new MOI value favors models with smaller cores but those models are somewhat at odds with the large k_2 value suggesting that the mantle in the models is too stiff