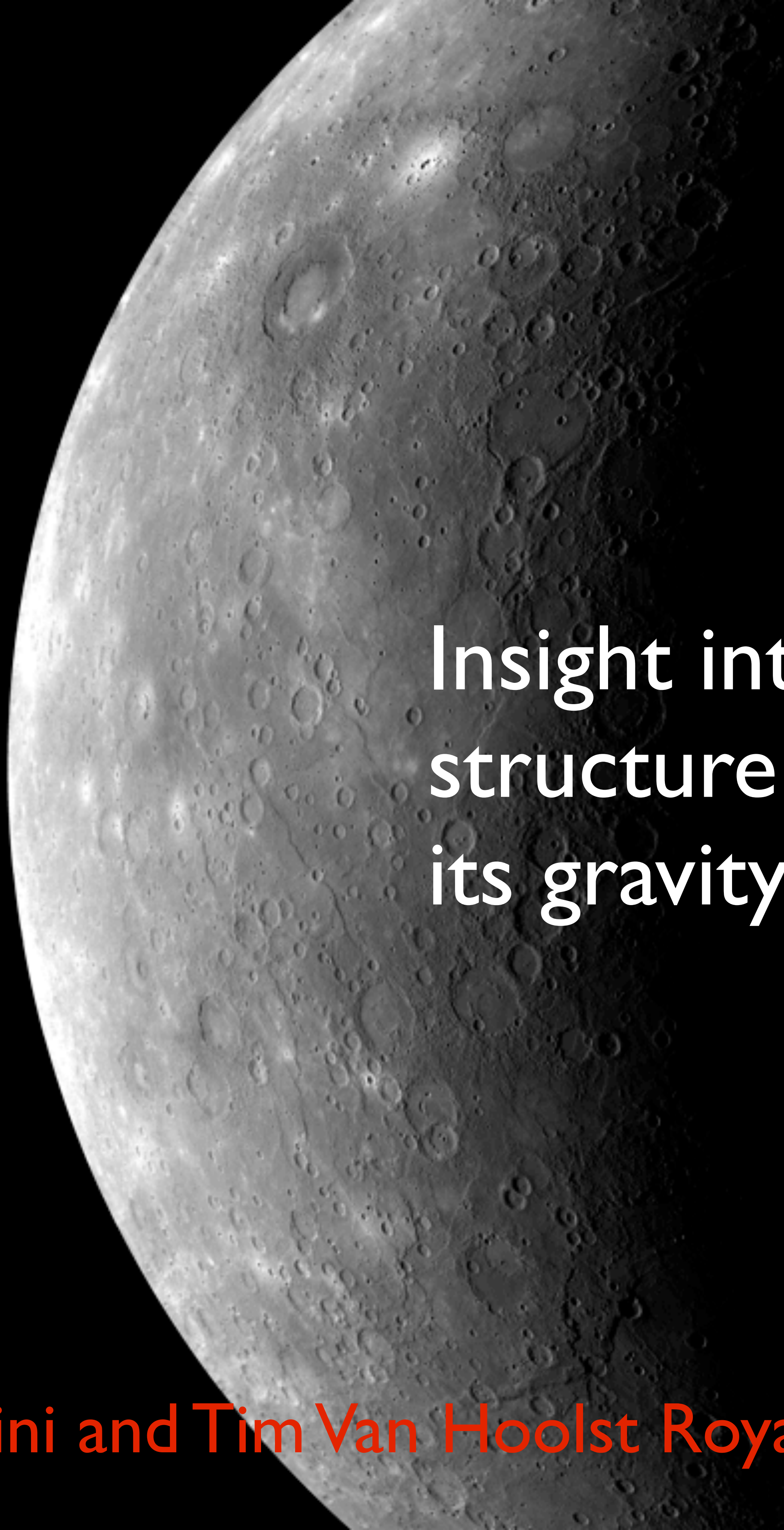

Insight into Mercury's interior structure from recent data on its gravity field and spin state

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Constraints on interior structure

- mass and radius constrain (composition and structure)
  - uncompressed average density 5300kg/m^3 (Earth 4400kg/m^3)
  - iron rich core >1800km
- surface spectrometry (bulk composition)(MESSENGER)
  (Nittler et al. 2011, Peplowski et al. 2011)
  - mantle has low Fe abundance (<~3wt% FeO)
  - mantle is volatile rich

  ⇒ Highly reduced precursor material

  - K/Th/U low ⇒ internal heating declined substantially
    ⇒ does the mantle still convect?
- internal magnetic field (core structure)(MESSENGER & Mariner 10)
  ⇒ liquid part in core and possible inner core
  ⇒ why is the field so small?

- spin rate (Earth-bound radar) (Margot et al. 2007, Smith et al. 2012)
  ⇒ 3:2 spin-orbit resonance (1965)
  - Mercury's equatorial moments of inertia (A,B) differ
    ⇒ Sun exerts torque on Mercury ⇒ longitudinal librations
    ⇒ core partially liquid
    88 day libration amplitude: $\gamma_{88} \sim \dfrac{B-A}{C_{\text{shell}}}$
  - rotation axes & orbit normal coplanar with normal to Laplace plane
    ⇒ Cassini 1 state, obliquity: $\varepsilon_C = f(A,B,C)$

- 2nd degree gravity field coefficient (MESSENGER):
  (Smith et al. 2012)

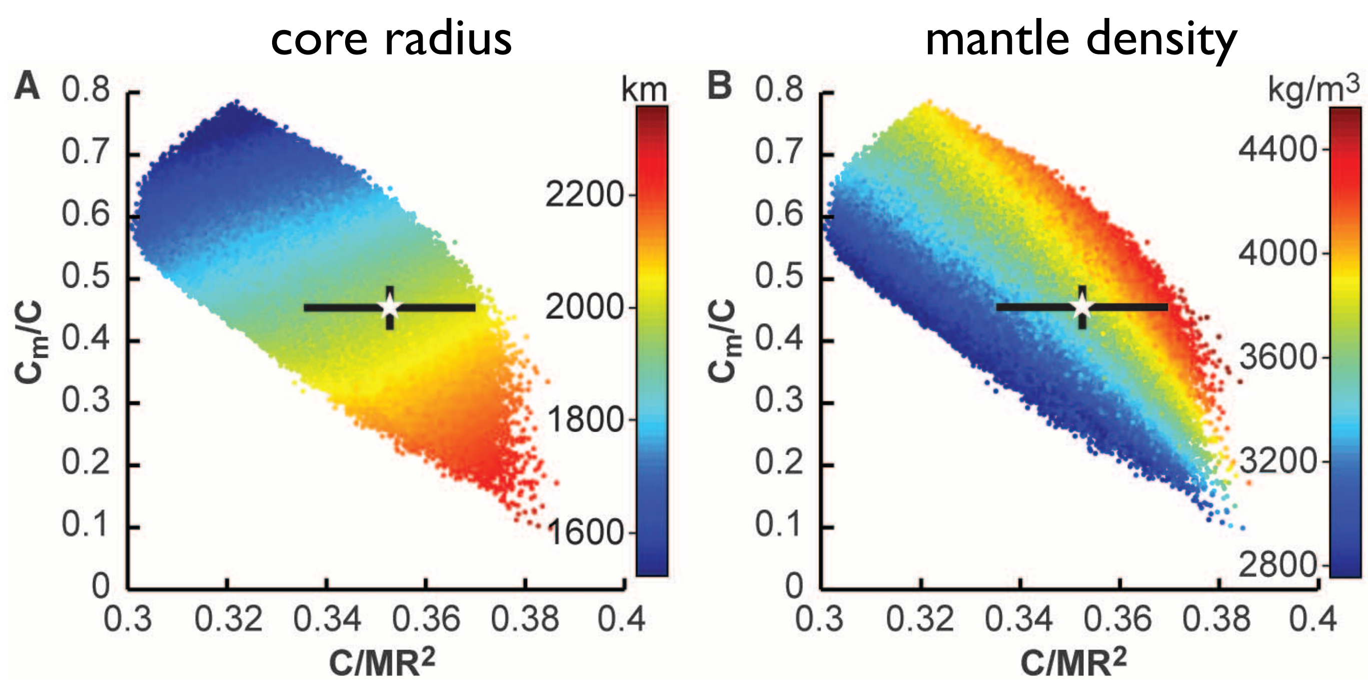
$$C_{20} = \frac{A+B-2C}{2m_a r_a^2}, C_{22} = \frac{B-A}{4m_a r_a^2}$$

$$\Rightarrow I = \text{MOI}\; m_a r_a^2 = \frac{A+B+C}{3} \sim \int_0^{r_a} r^4 dr\, \rho(r), \quad I_{\text{shell}} \sim \int_{r_{\text{cmb}}}^{r_a} r^4 dr\, \rho(r)$$

⇒ internal mass distribution

MESSENGER data interpretation

Smith et al. 2012

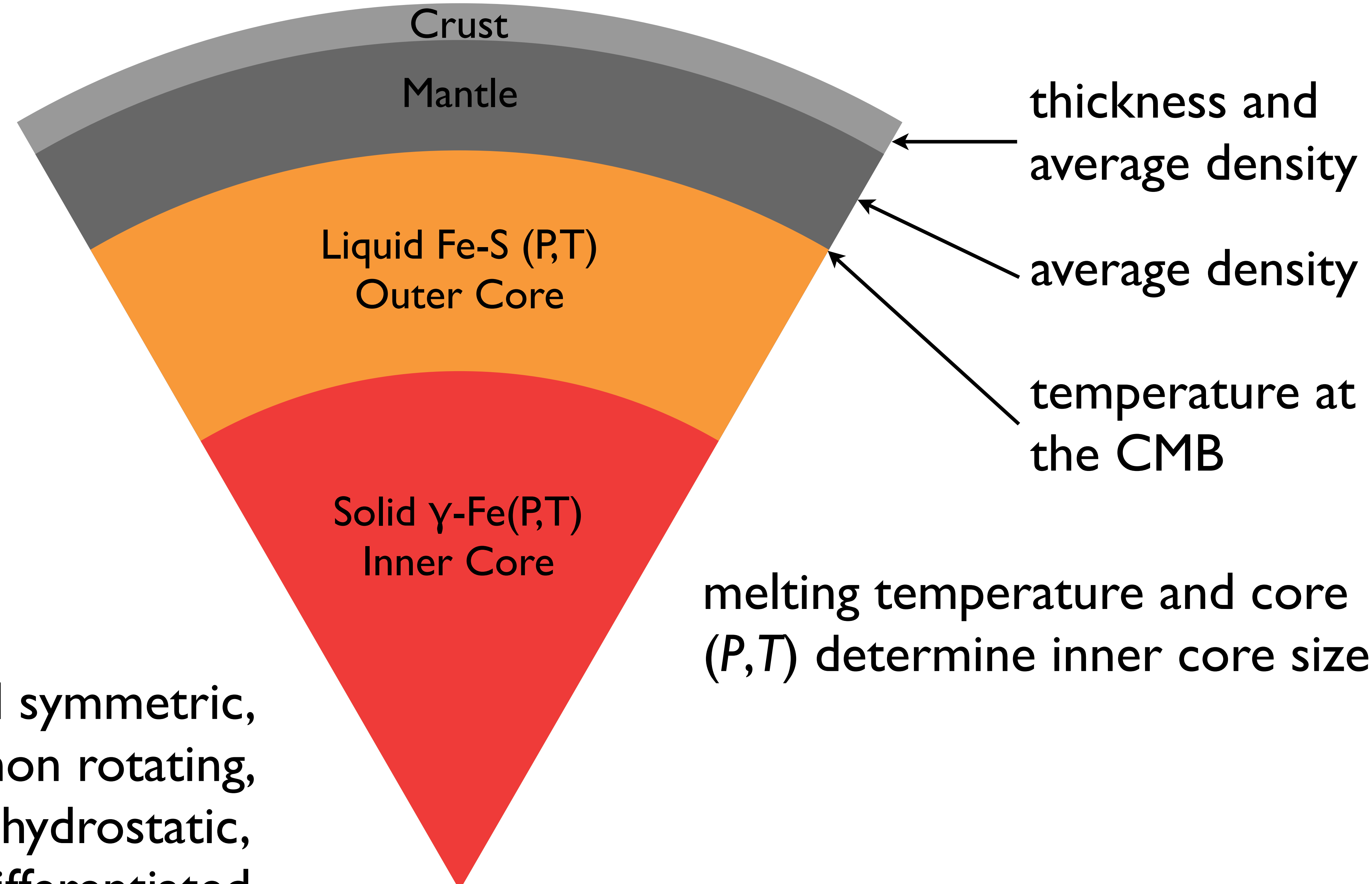


- large core: 2030±37km (silicate shell ~200km)
- dense mantle: 3650±225kg/m³
  ⇒ unlikely for Fe poor mantle and low pressure inside mantle
- previously published models do not fit data
- postulate: solid FeS layer (10-200km) at mantle bottom
  ⇒(maybe) thermodynamically possible (needs imiscible liquids & >1 light element inside the core)
  ⇒ could explain weak magnetic field (shielding)

This study

- infer knowledge about Mercury's interior from updated spin rate measurements and MESSENGER gravity field data
- determine if models with plausible silicate mantle densities and Fe-S cores can fit the new data
- assess if our previously published models fit the new data

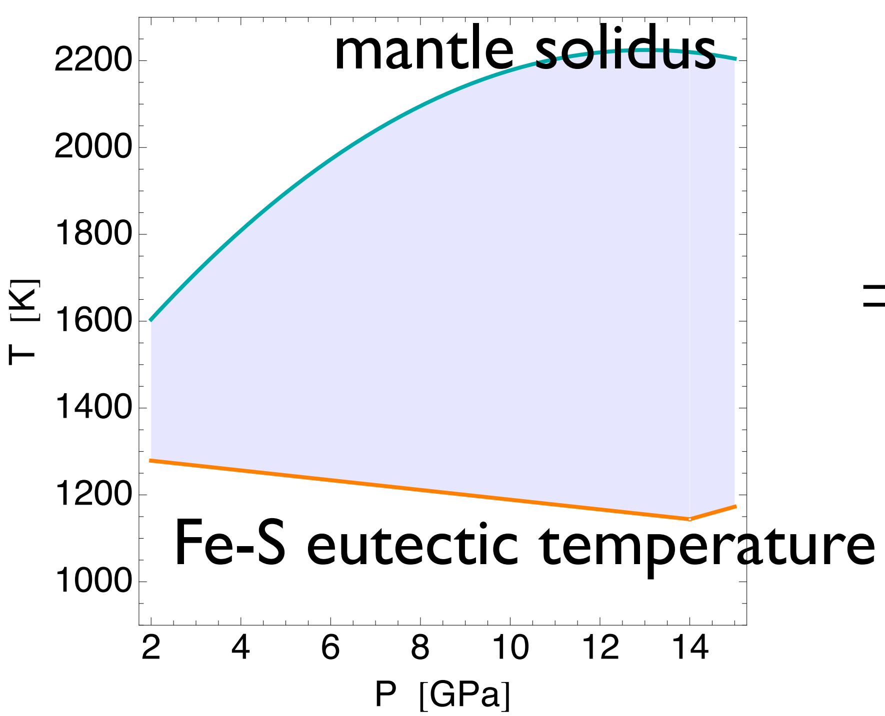
Interior structure model



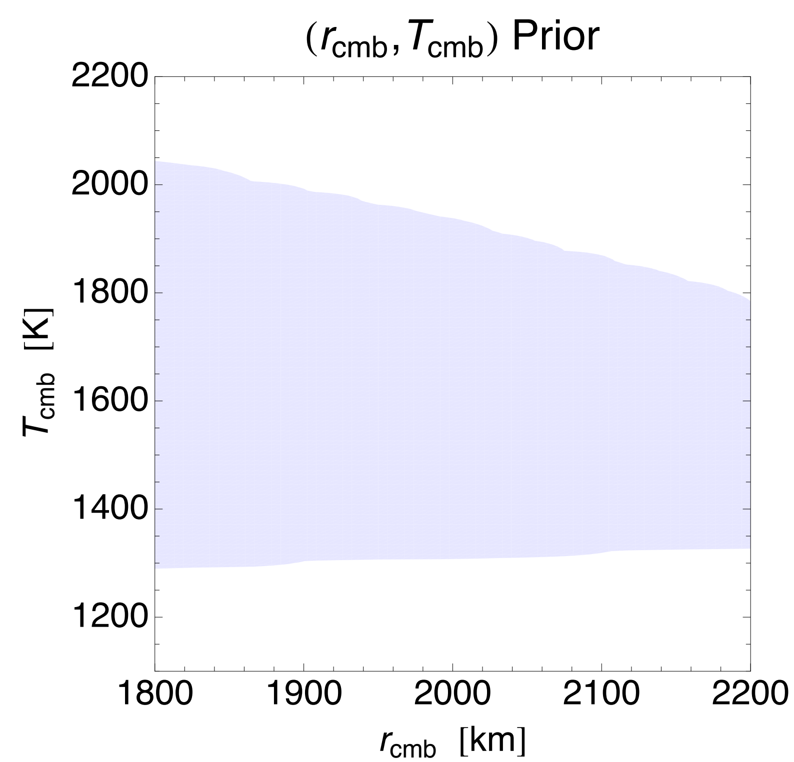
Spherical symmetric,
non rotating,
hydrostatic,
and differentiated

Parameter inference by Bayesian inversion

- non linear forward model
- 5 parameters (for given mass and radius of Mercury):
  - core: radius [1800,2200]km
  - mantle: average density [3100,3500]kg/m^3
  - crust: density [2700,3100]kg/m^3 and thickness [10,120]km
  - core mantle boundary temperature [1100,2100]K & >Fe-S eutectic temp. & < mantle solidus

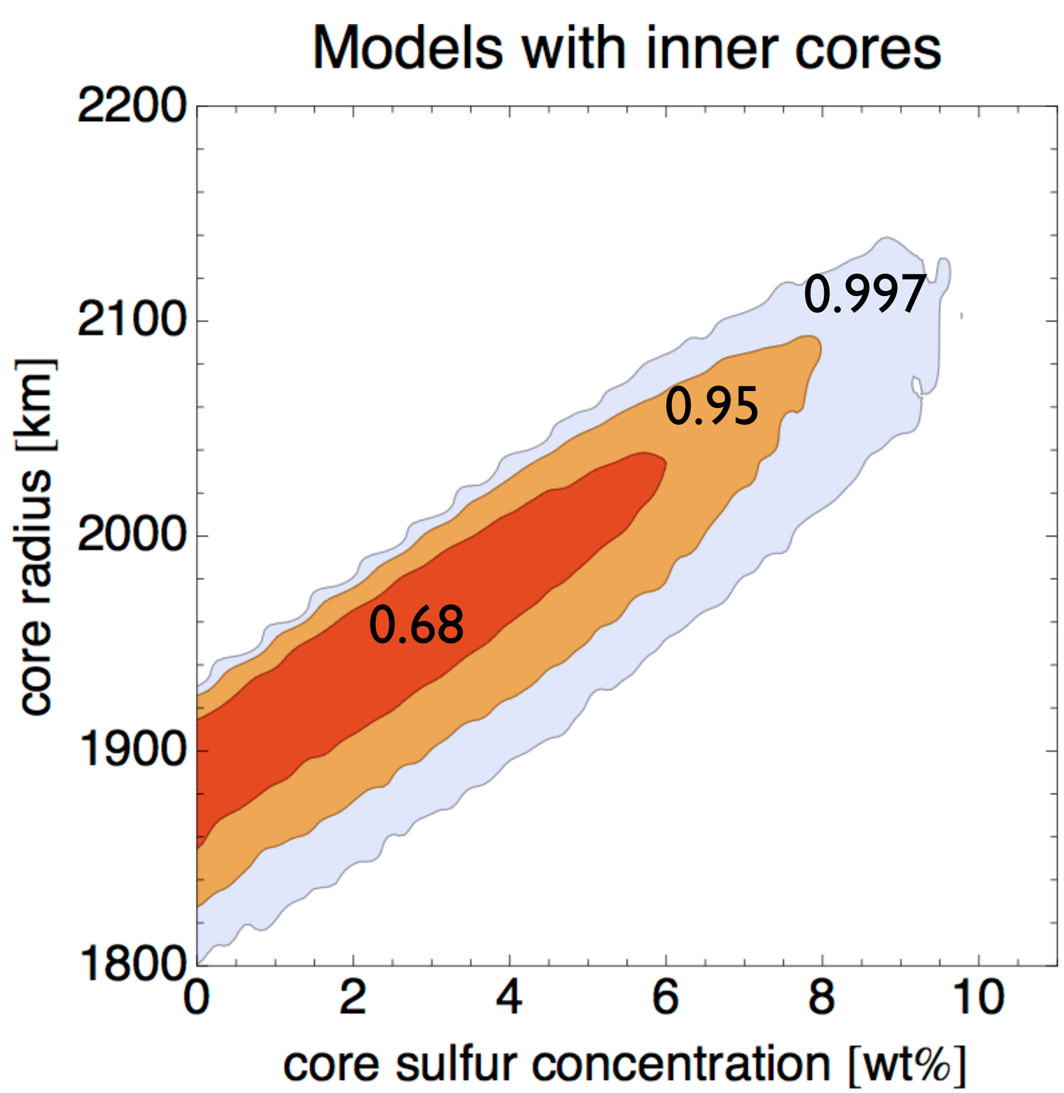


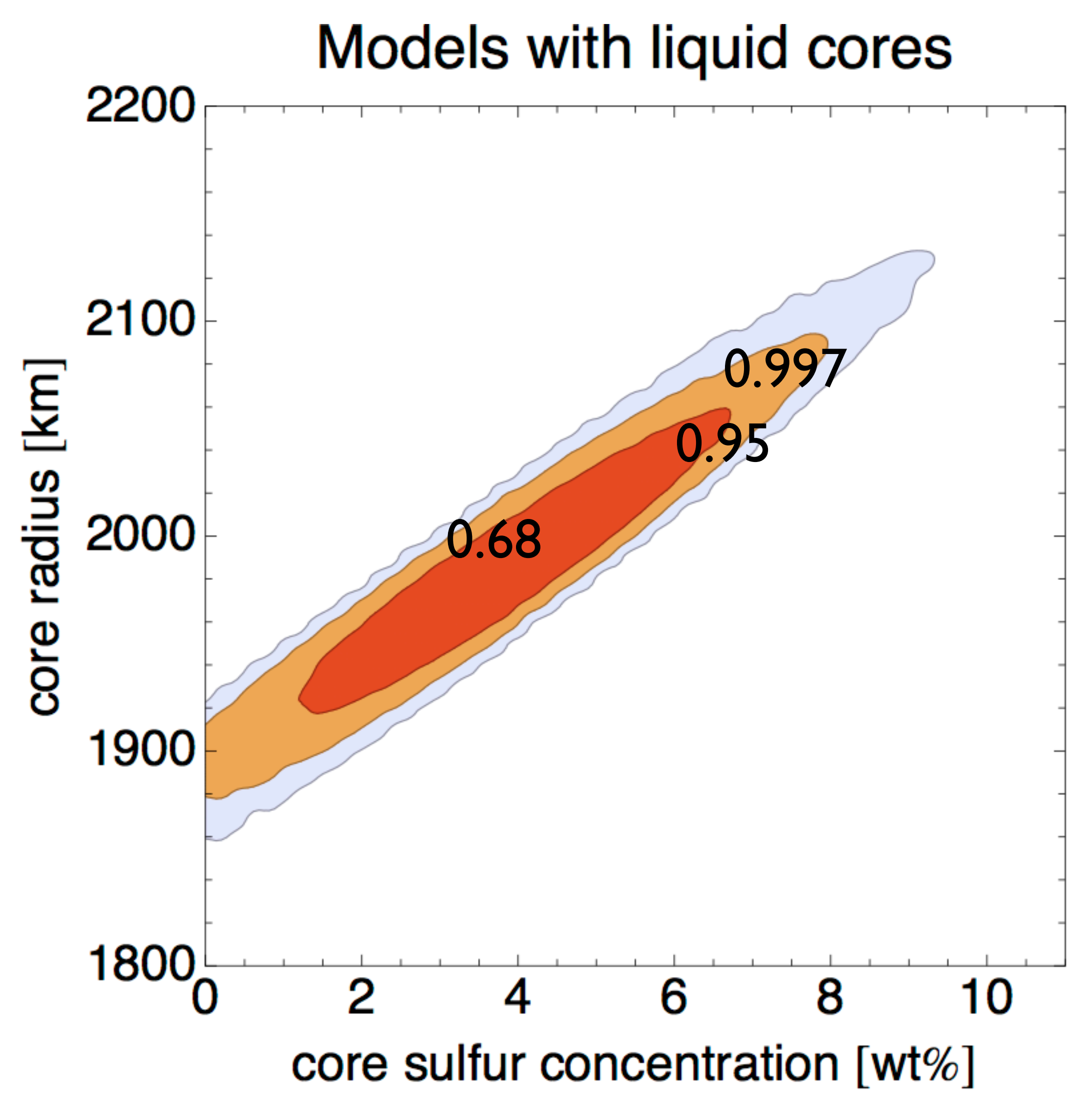
⇒



- 2 data: MOI and moment of inertia of shell (I_{shell})

Constraints on core radius and core sulfur concentration

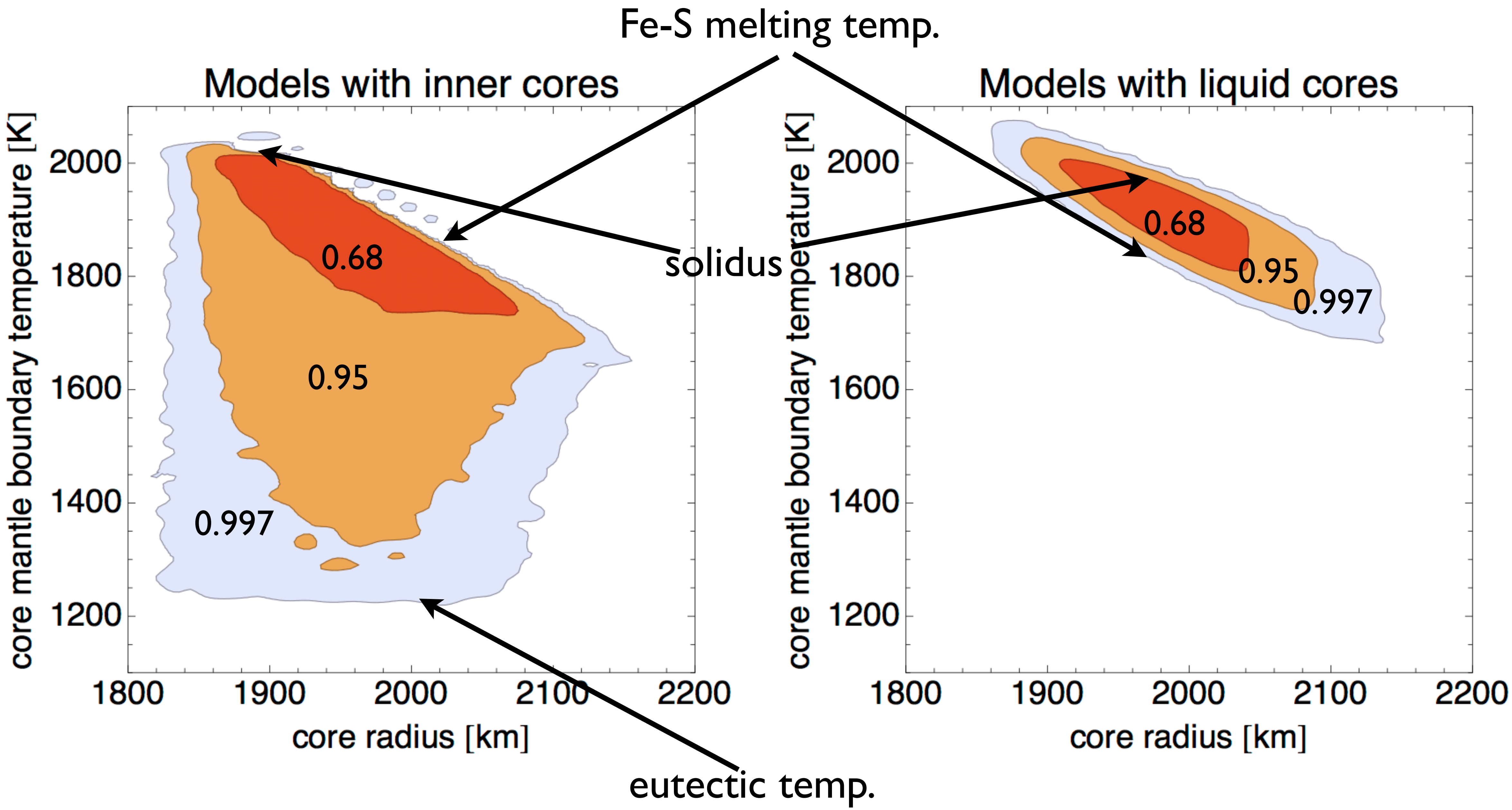




core radius: 1969±64km (0.68)
core sulfur concentration: 1.-6.wt% (0.68)

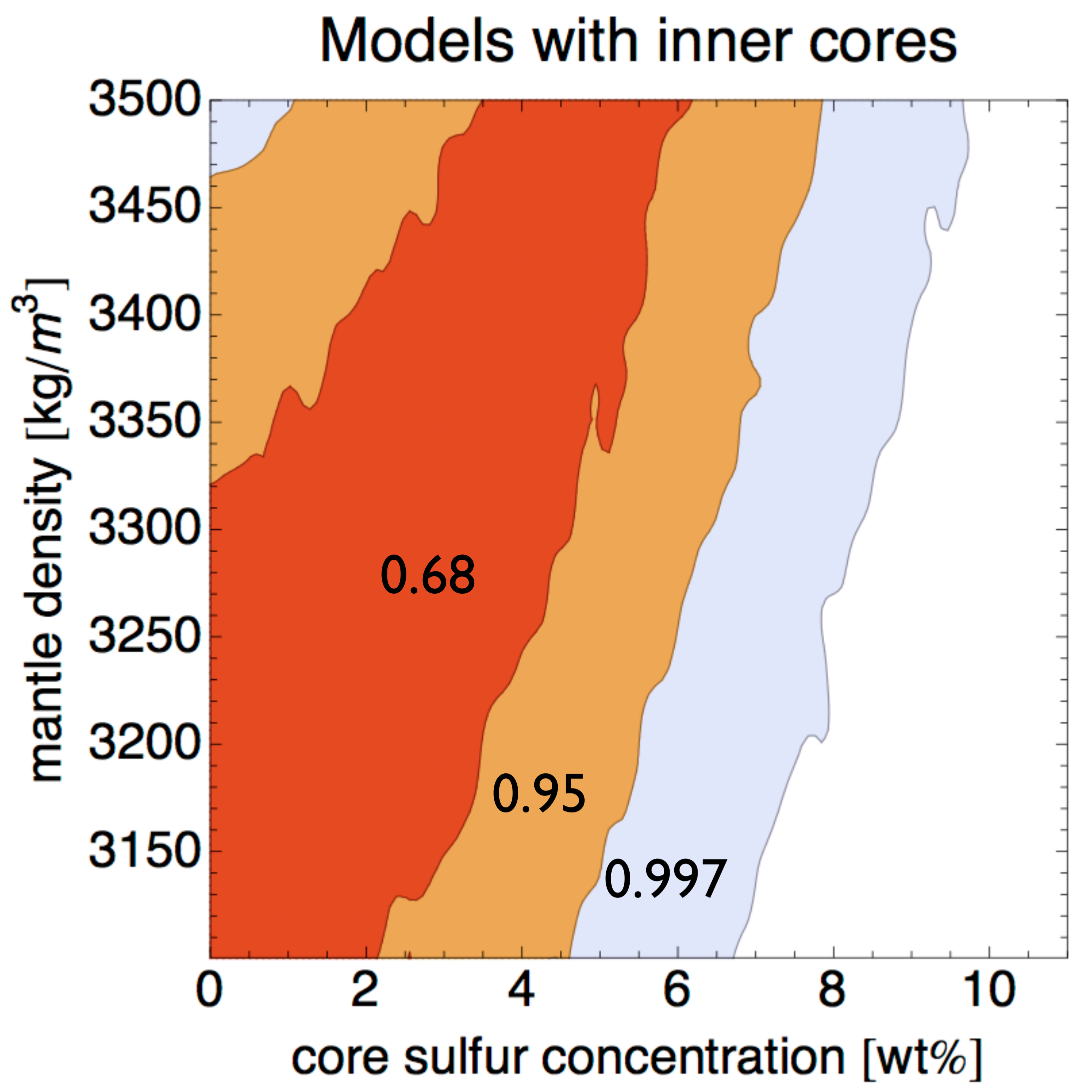
Smith et al. 2012 : core radius 2030±37km

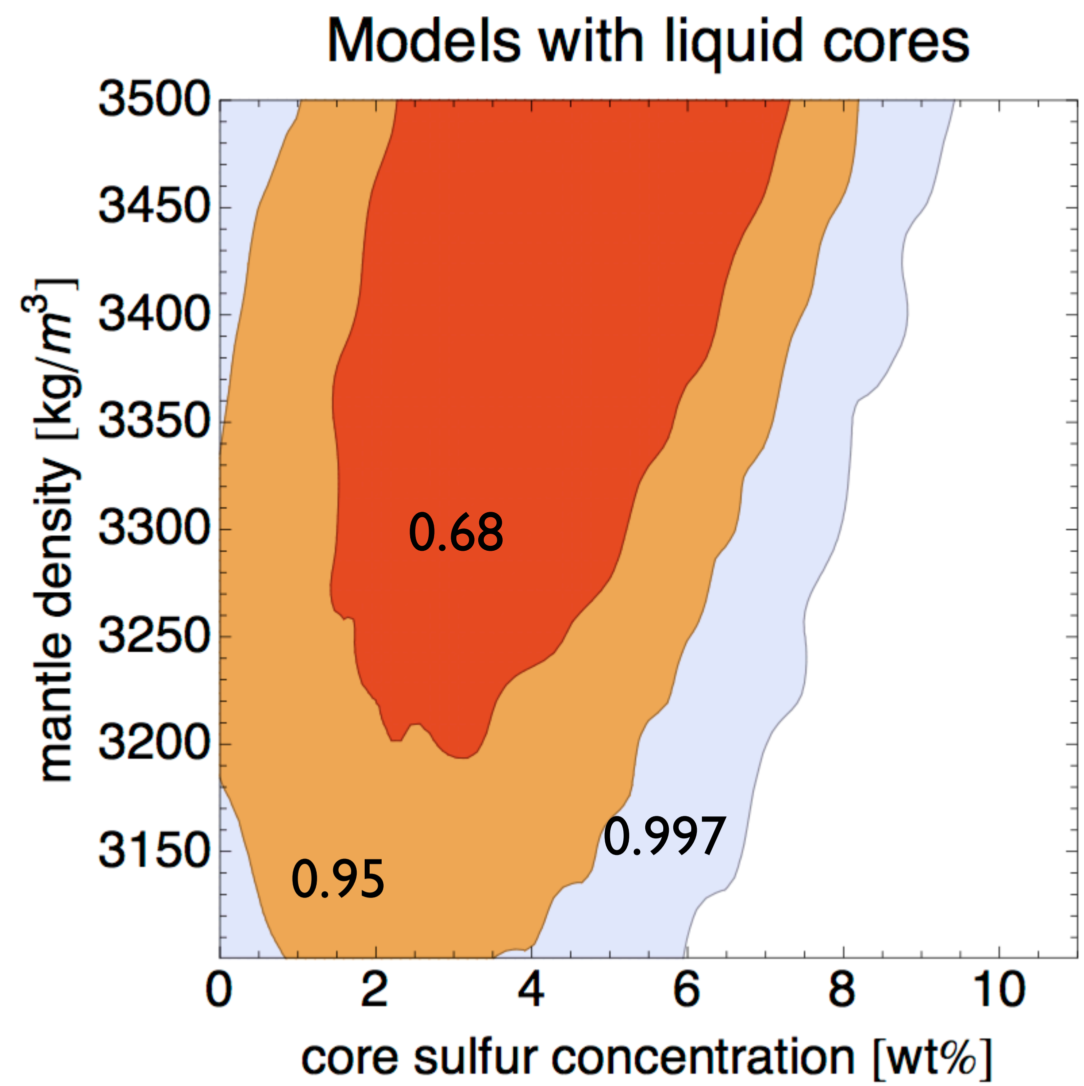
Core mantle boundary temperature



⇒ core mantle boundary temperature prior (Fe-S melting temp., mantle solidus, & eutectic temp.) determine model

Mantle density

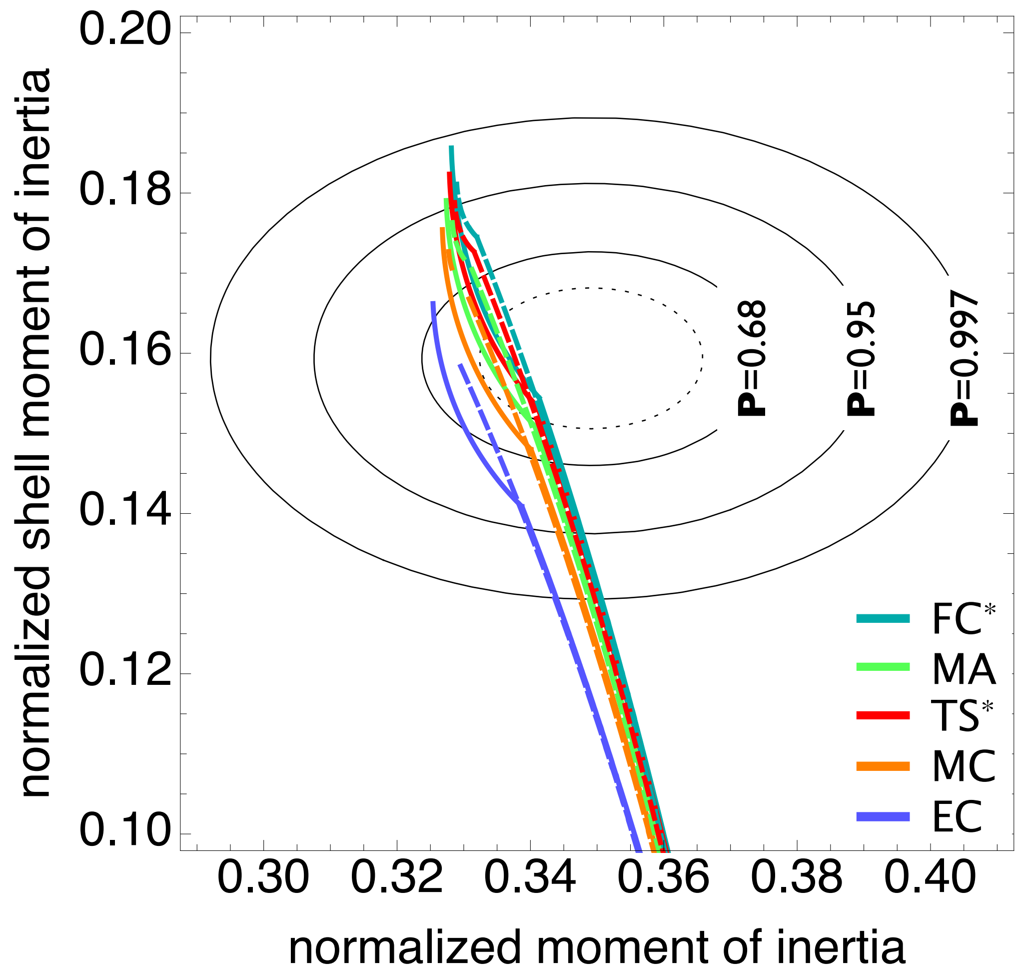


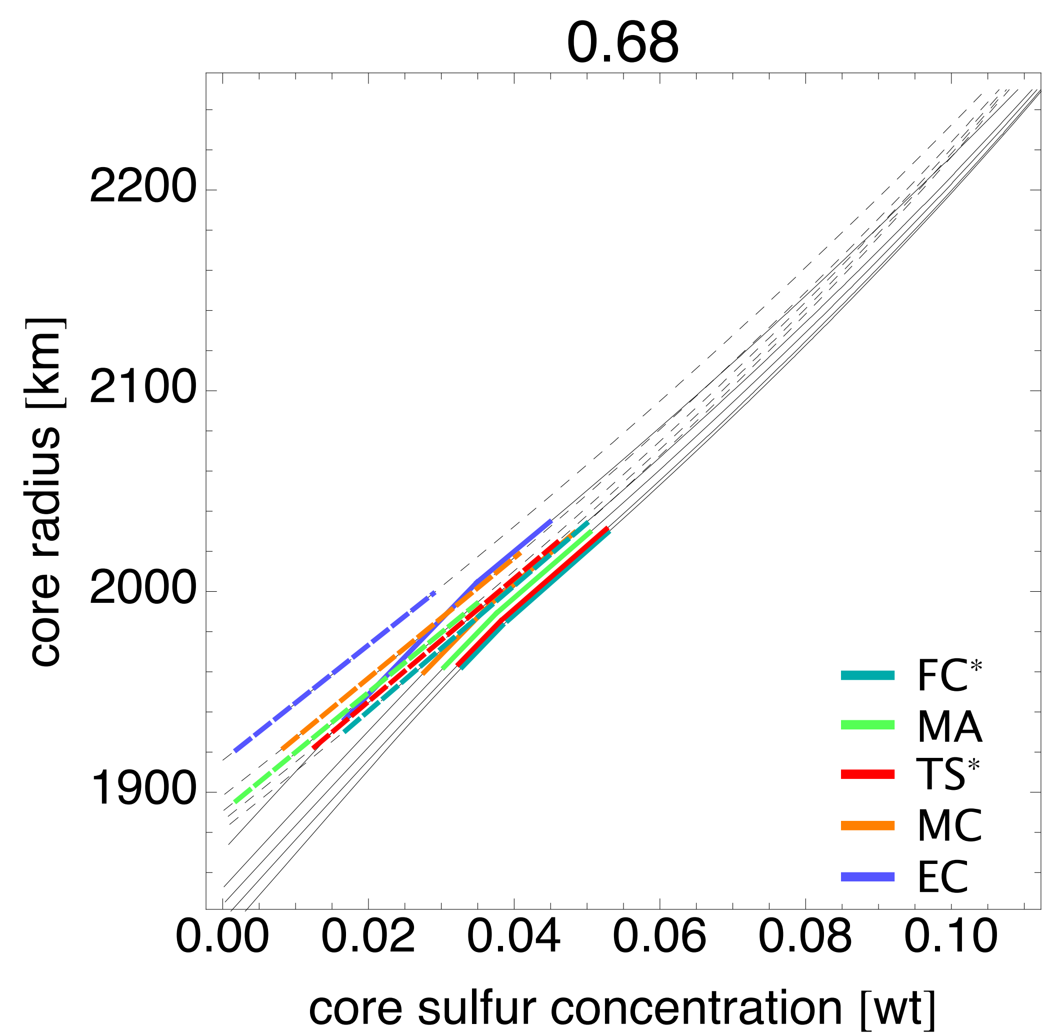


⇒ an exceptionally dense mantle layer at the core mantle boundary is not required in order to fit the data

Fixed crust and given mantle mineralogies

- 5 mantle mineralogies, crust thickness 100km, crust thickness 2700kg/m^3, 2 end-member mantle temperatures profiles (T_{cmb}=1850K, T_{cmb}=2000K) (Rivoldini et al. 2009)
- parameter: core radius



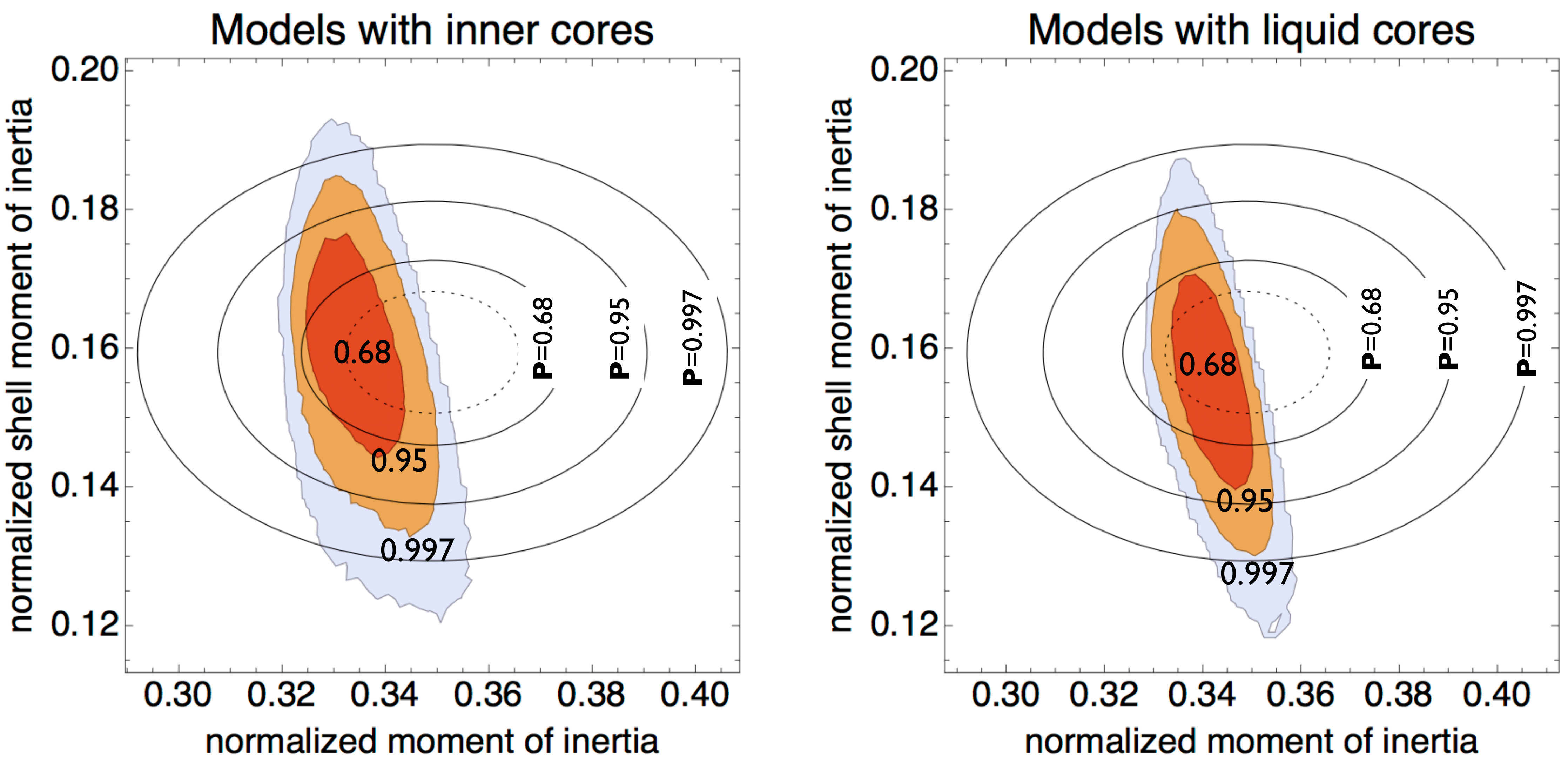


⇒ evaporation model (**F**egley & **C**ameron, 1987) and refractory-volatile mixture model (**T**aylor & **S**cott, 2005) incompatible with measured abundance of surface volatiles (Nittler et al. 2011, Peplowski et al. 2011)

Conclusions

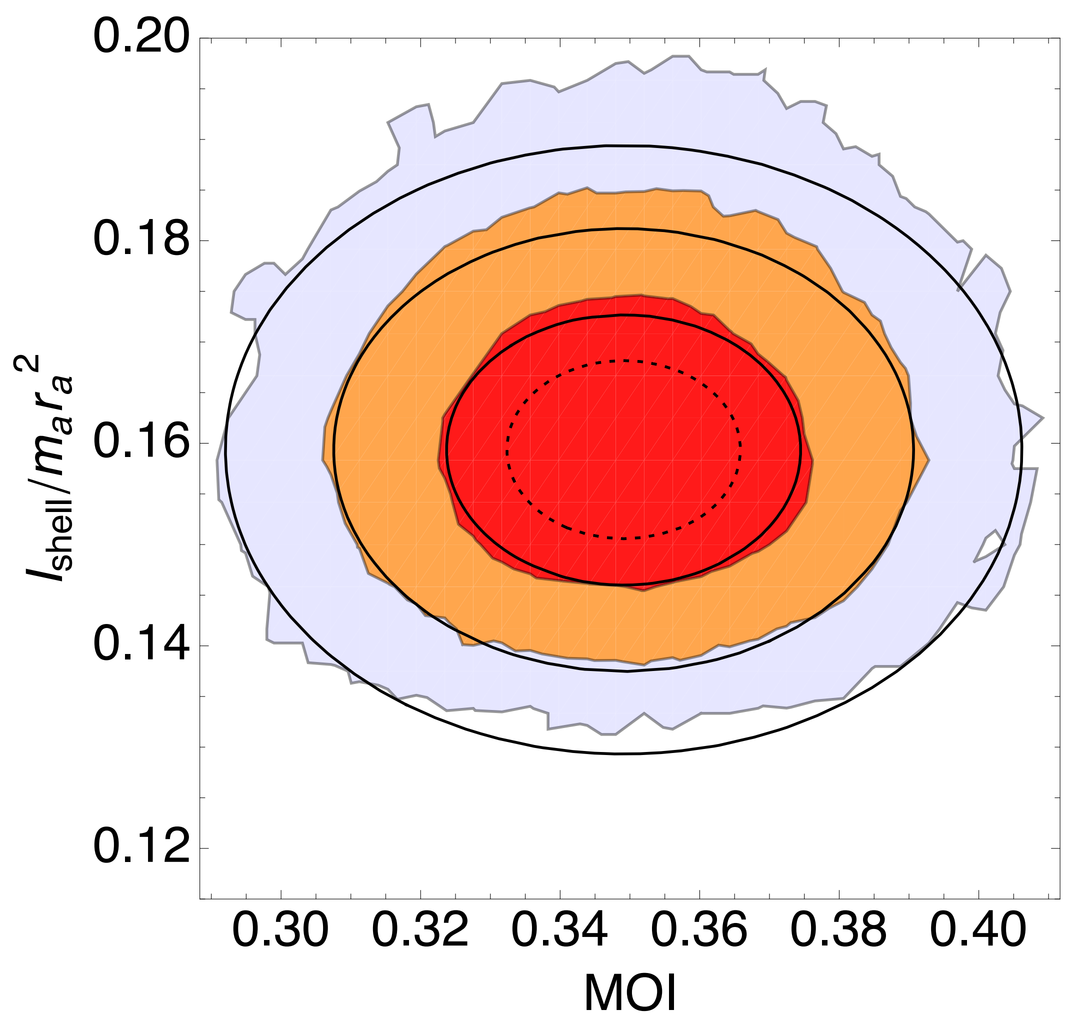
- models with and without inner cores are possible
- core radius: 1969±64km (0.68)
- core sulfur concentration: [1,6]wt% (0.68) (if S is the only light element in the core)
- data provide few constraints on core mantle boundary temperature, on the mantle density and on the crust density and thickness
- models with an Fe-S core do not require an exceptionally dense layer at the bottom of the mantle or top of the core in order to agree with the data
- models with fixed crust parameters and given mantle mineralogies of Rivoldini et al. (2009) are compatible with the data

Data fit



Models with inner cores
Models with liquid cores
normalized shell moment of inertia
normalized moment of inertia
0.20
0.18
0.16
0.14
0.12
0.30
0.32
0.34
0.36
0.38
0.40
0.68
0.95
0.997
P=0.68
P=0.95
P=0.997

Moments of inertia



	$A/ma\ ra^2$	$B/ma\ ra^2$	$C/ma\ ra^2$	$C_m/ma\ ra^2$	MOI	C_m/C
Mean	0.349245	0.349278	0.349312	0.160105	0.349278	0.459434
Median	0.349213	0.349245	0.34928	0.159657	0.349246	0.457578
std	0.0169458	0.0169458	0.0169458	0.0091	0.0169458	0.0344986
68%	{0.332248, 0.366164}	{0.332281, 0.366197}	{0.332315, 0.366231}	{0.151046, 0.169161}	{0.332281, 0.366197}	{0.425169, 0.493673}
95%	{0.315549, 0.383092}	{0.315581, 0.383124}	{0.315615, 0.383158}	{0.143424, 0.179606}	{0.315582, 0.383125}	{0.396116, 0.534211}
99.7%	{0.299479, 0.399659}	{0.299511, 0.399691}	{0.299546, 0.399725}	{0.136816, 0.191655}	{0.299512, 0.399692}	{0.369798, 0.579013}