Chemical Composition of the Lower Mantle: Constraints from Elasticity

Motohiko Murakami

Tohoku University

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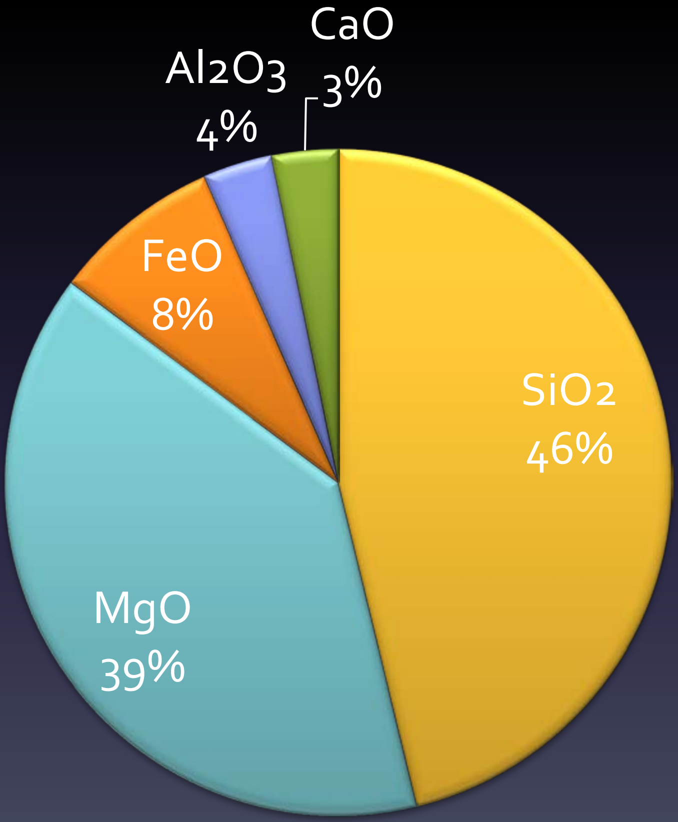
Mineralogical model of upper mantle

"Peridotitic" upper mantle

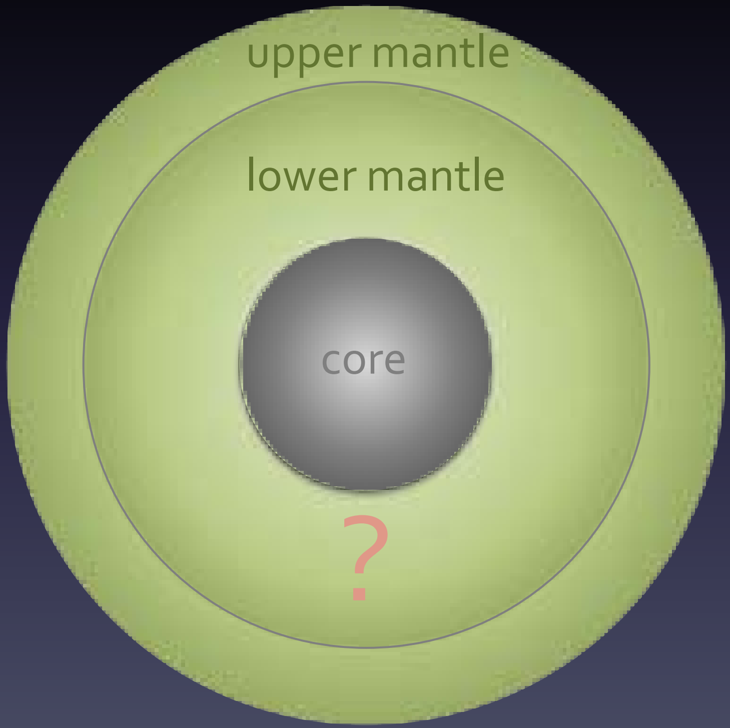
http://www.lpl.arizona.edu/grad/fieldtrips/2007f-southernnewmexico/



wt%

Is Earth's mantle chemically homogeneous?

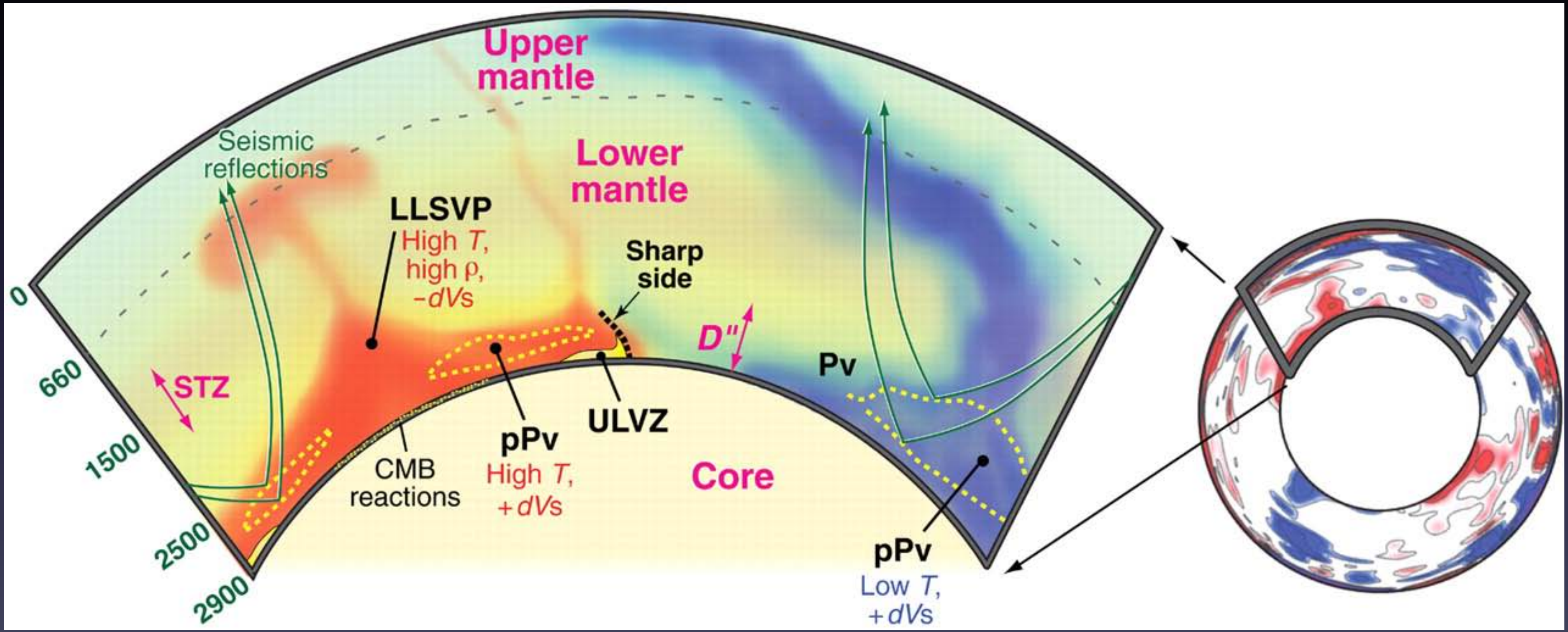
Homogeneous mantle
(Pyrolitic)



Heterogeneous mantle
(Si-rich lower mantle?)

Recent seismological views in Earth's deep interior

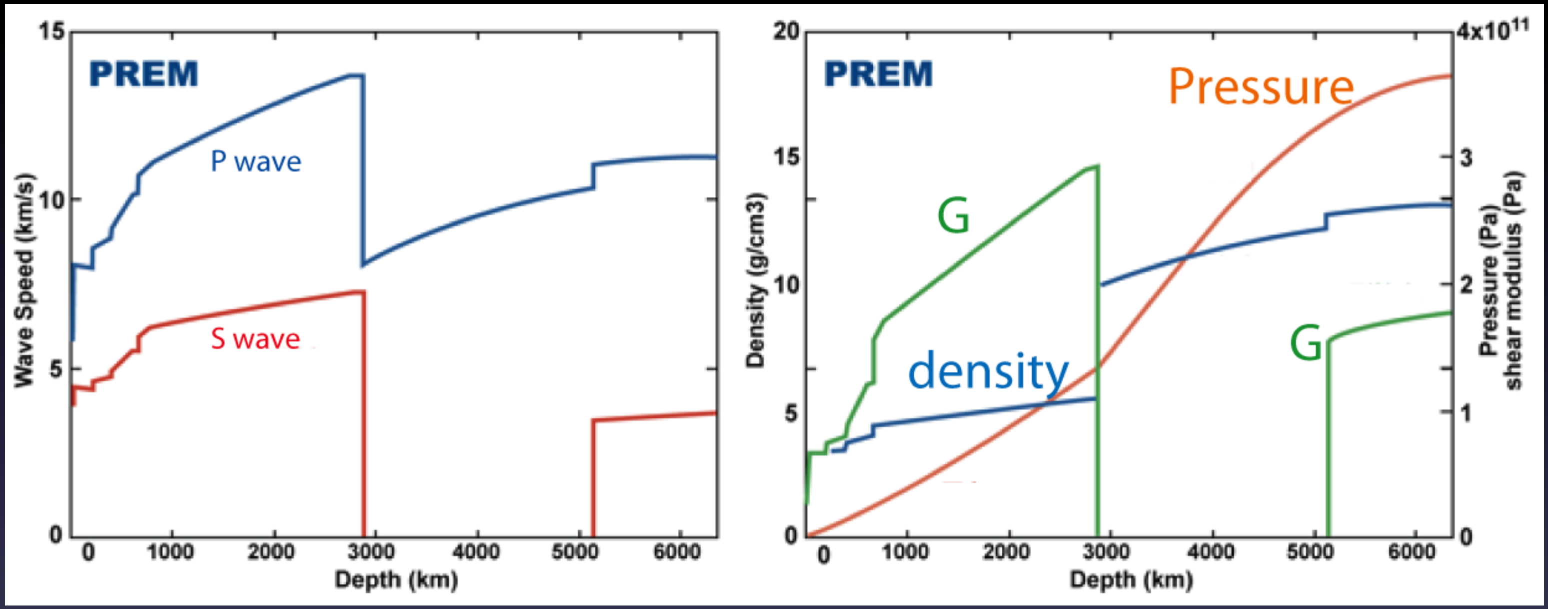
Large Low-Shear-Velocity Provinces (LLSVPs)
Ultra Low Velocity Zones (ULVZs)



(Garnero & McNamara, 2008)

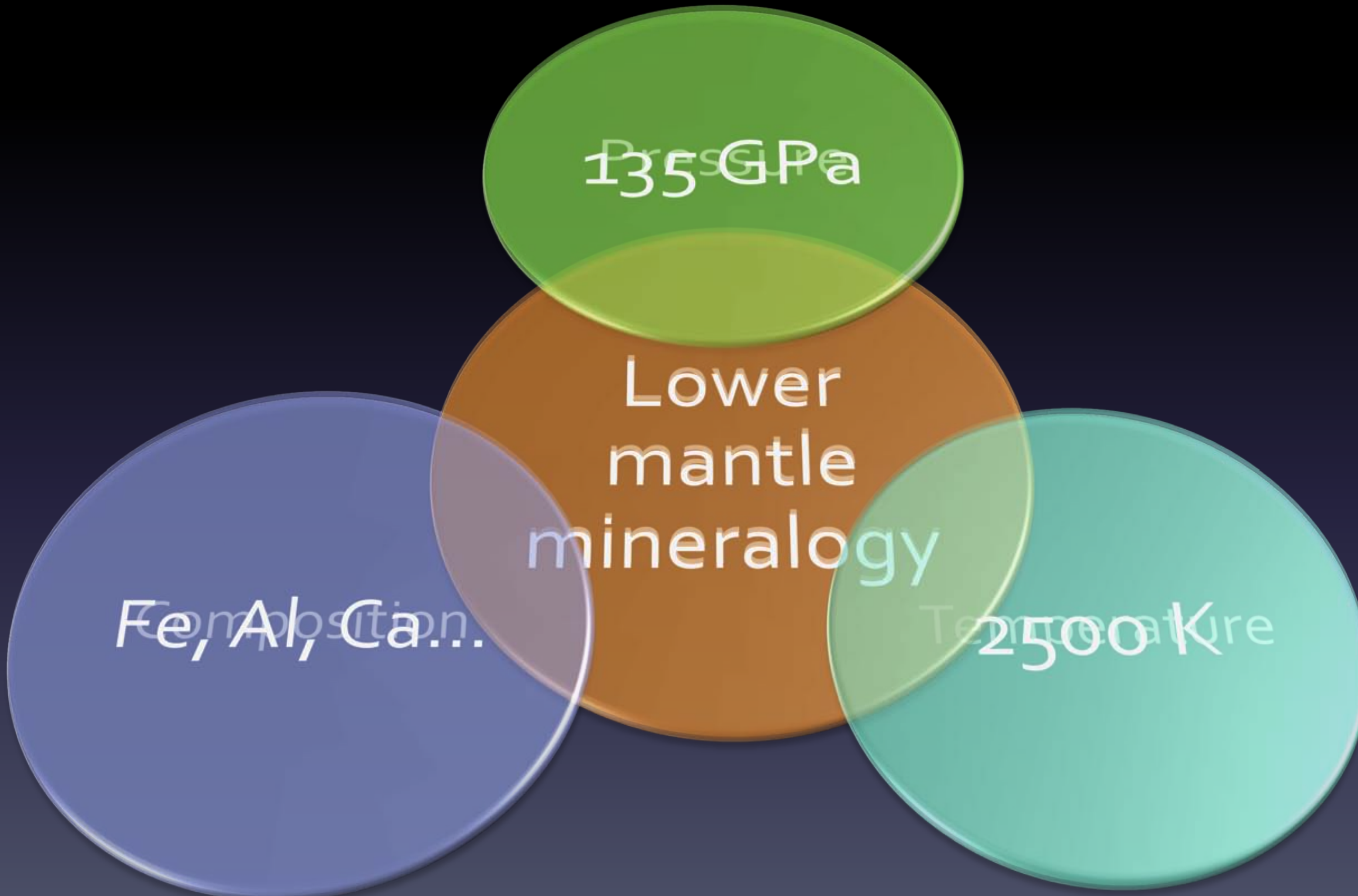
1D seismological model in Earth's interior

PREM



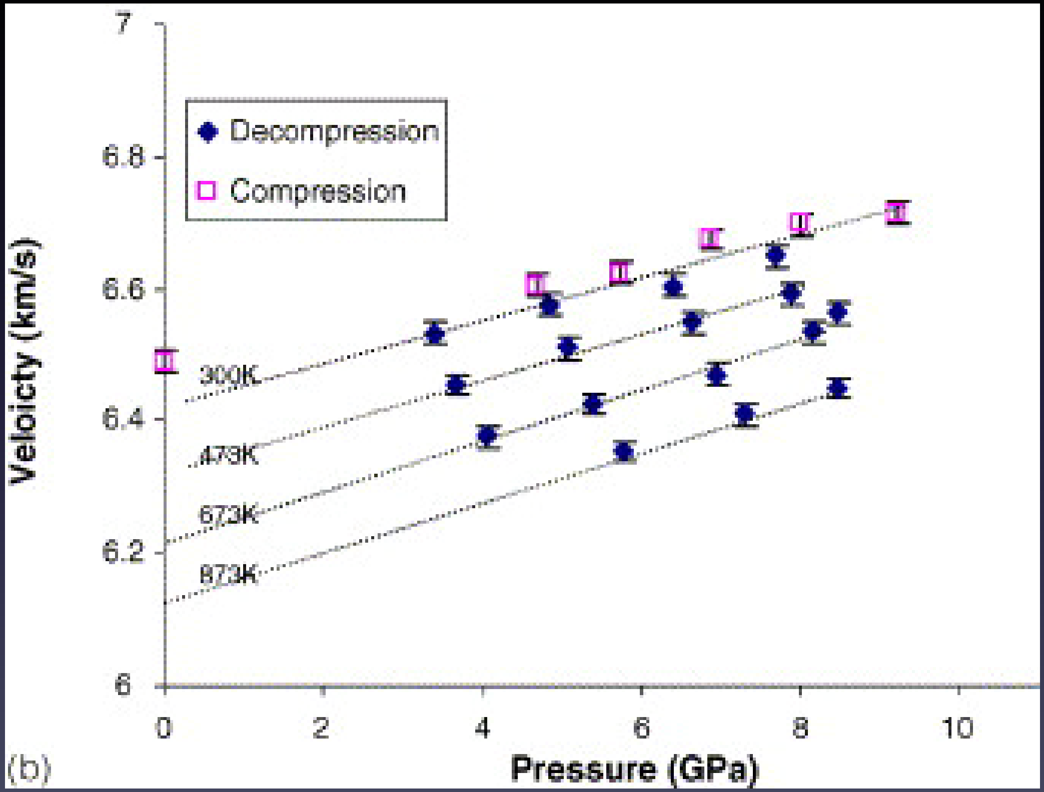
Mineralogical modeling of deep mantle

Challenges for sound velocity measurements



Previous work on MgSiO3 pv

up to ~9 GPa by ultrasonic measurement

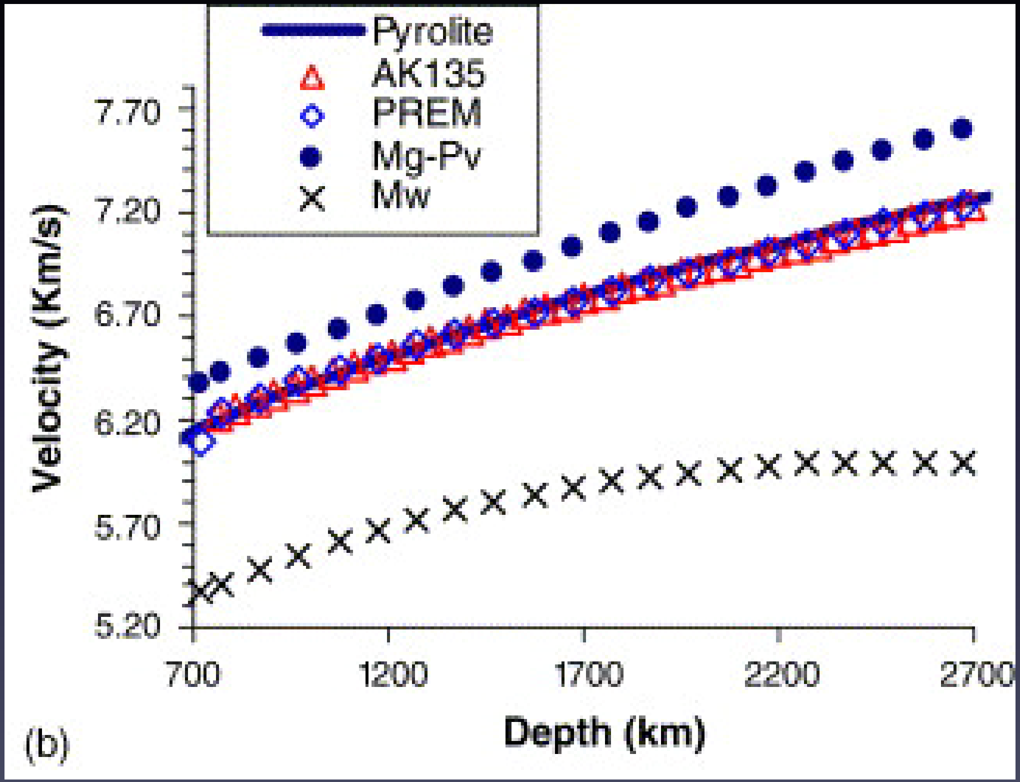


(Li & Zhang, 2005)

Previous work on $MgSiO_3$ pv

dG/dP (G'o) =2.0

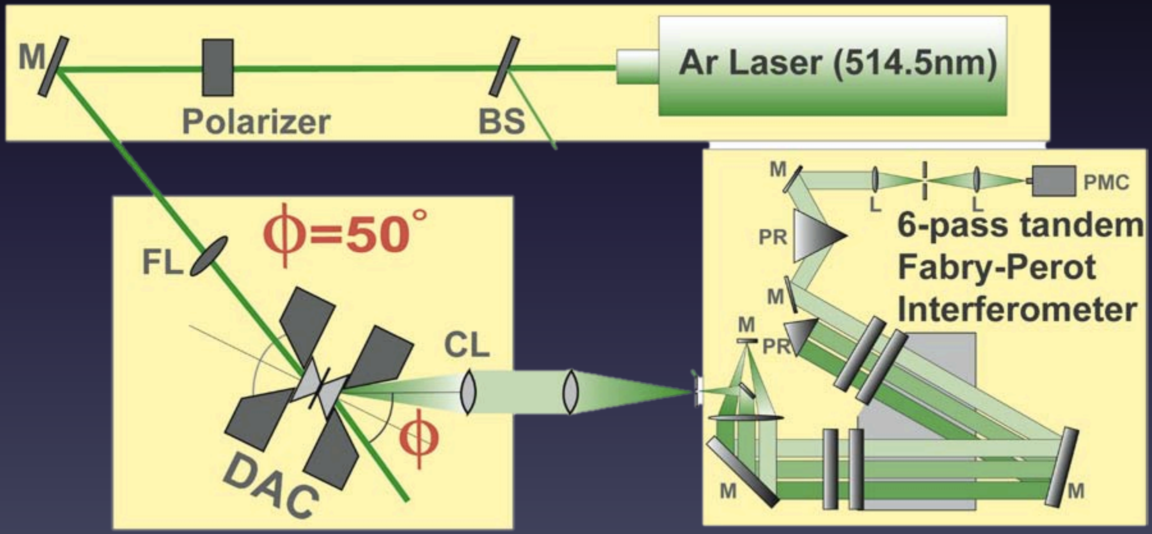
➔ pyrolitic lower mantle



(Li & Zhang, 2005)

High-Pressure sound velocity

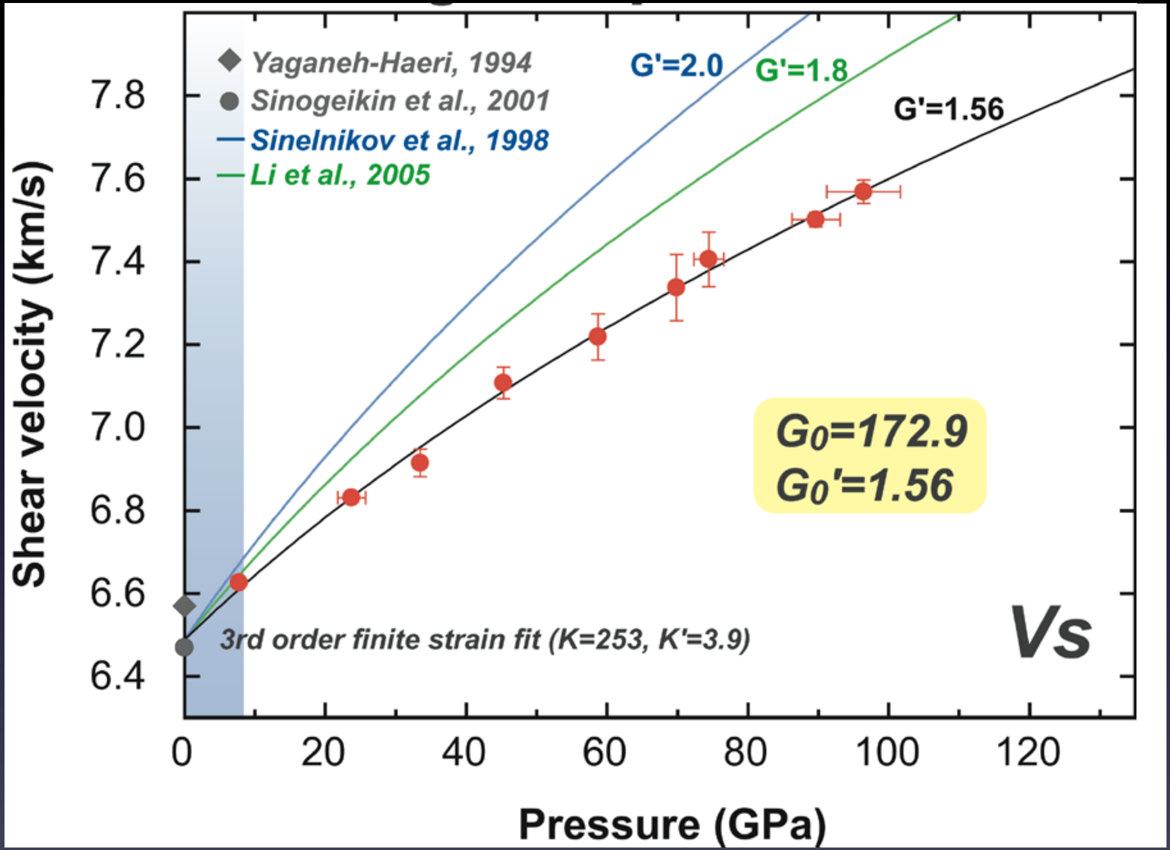
Diamond Anvil Cell (DAC) apparatus
Probe laser (514.5 nm, 532 nm)
6-pass tandem Fabry-Perot interferometer



High-pressure Brillouin scattering system

Shear velocity of $MgSiO_3$ pv

dG/dP (G'o) = 1.56

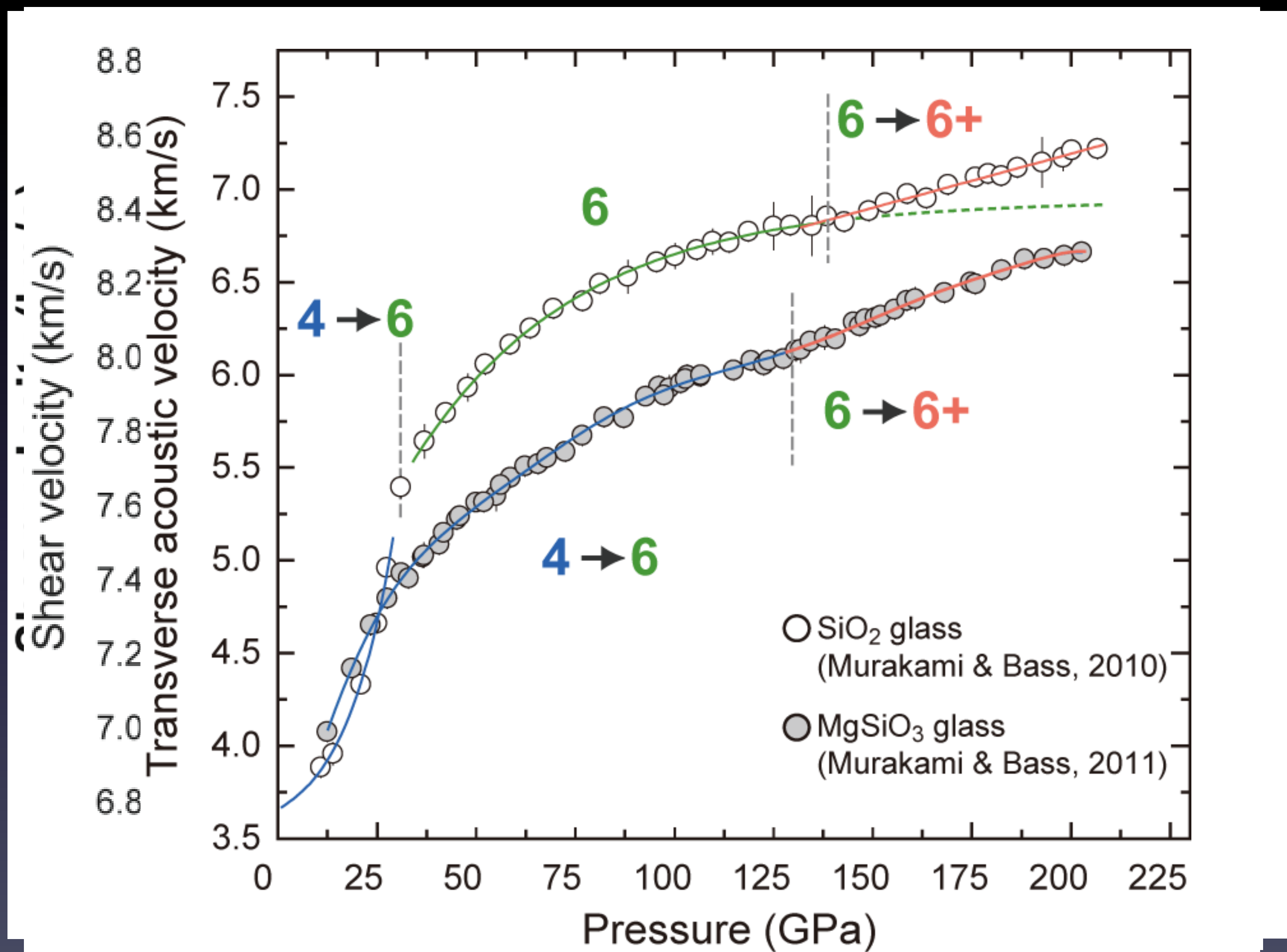


(Murakami et al., 2007)

Pressure

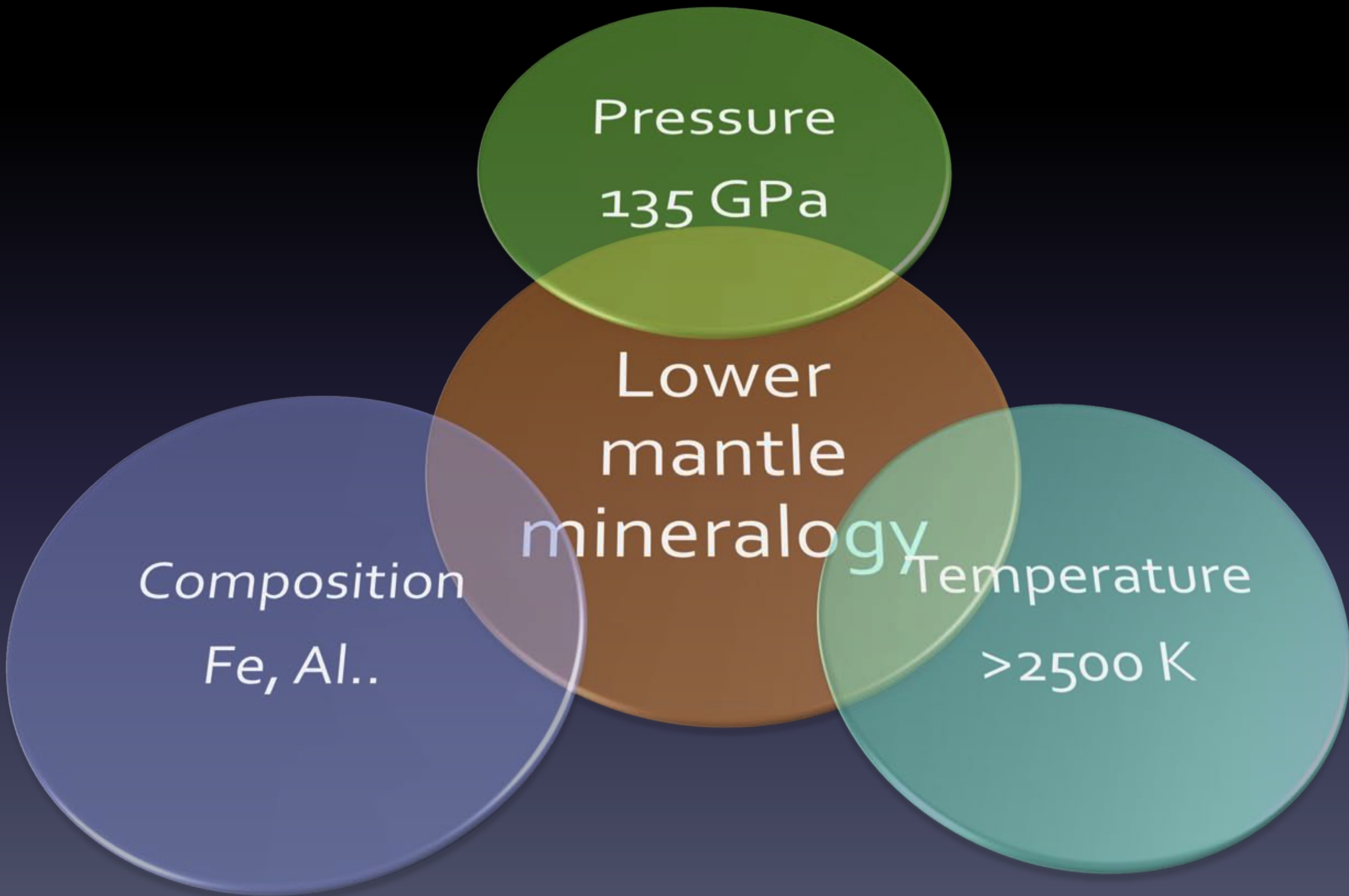
High-Pressure sound velocity

SiO_2 & $MgSiO_3$ glasses to 200 GPa



(Murakami & Bass, PRL, 2010)
(Murakami et al., EPSL, 2007)
(Murakami & Bass, PNAS, 2011)

Challenges for sound velocity measurements



Effect of chemistry

Composition

Fe, Al...

(Mg,Fe)O fp

Crowhurst et al. 2008
Marquardt et al., 2009

Al-$MgSiO_3$ pv

Jackson et al. 2005

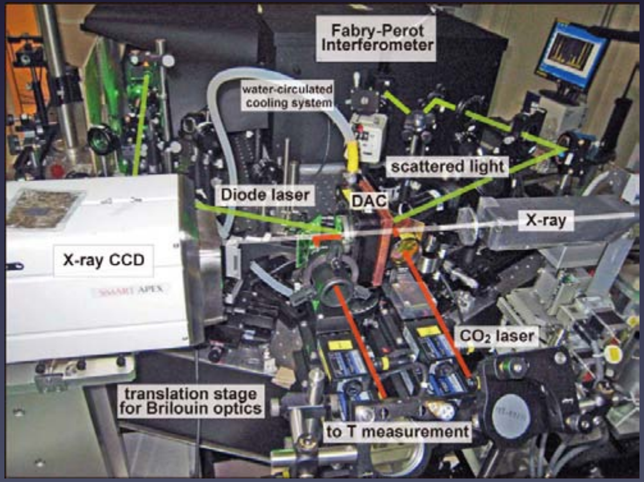
High-pressure data are still limited

Shear wave velocity measurements for fp and Al-pv

$(Mg_{0.92}Fe_{0.08})O$: 120 GPa, 300 K

Al-$MgSiO_3$ pv: 124 GPa, 300 K

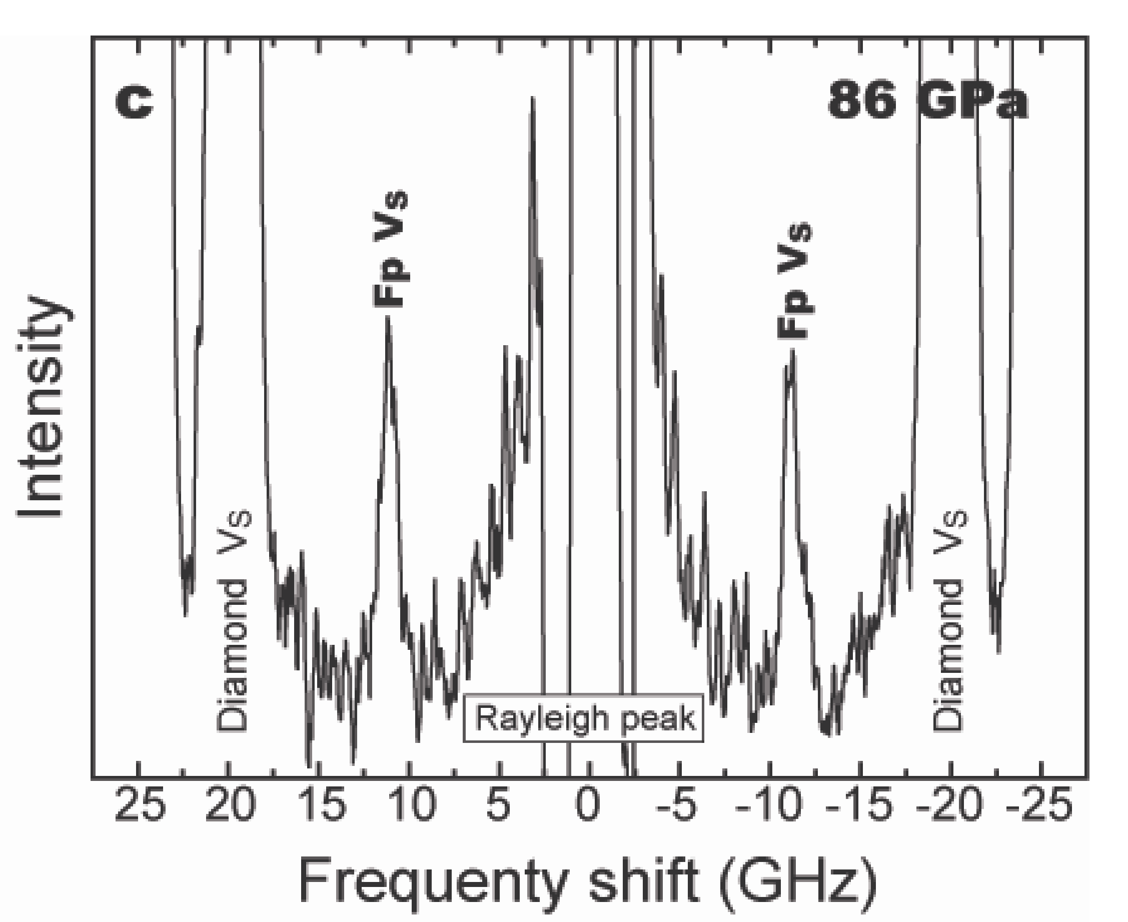
(4 wt% Al_2O_3)



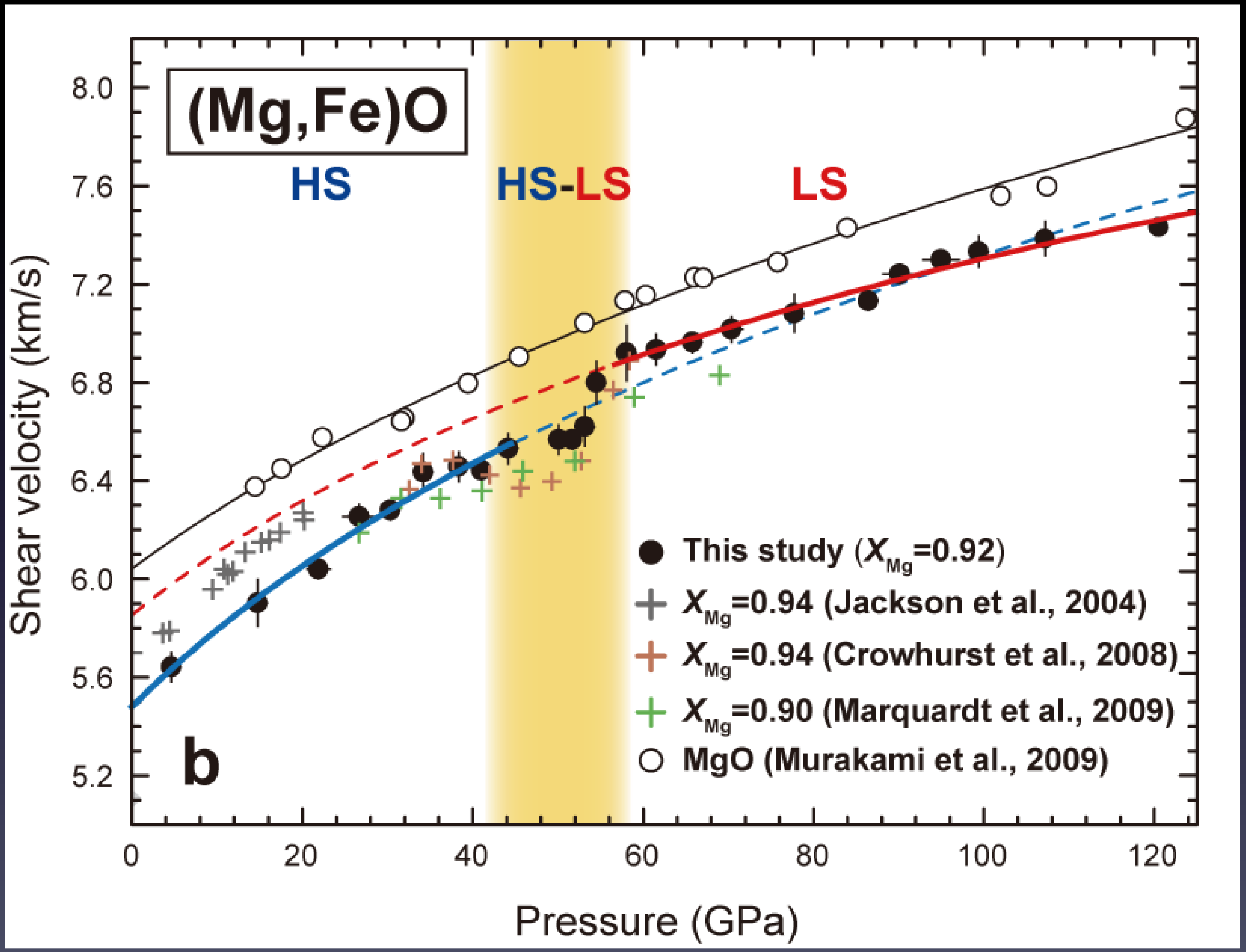
Brillouin System at SP8

Brillouin data $(Mg_{0.94}Fe_{0.08})O$

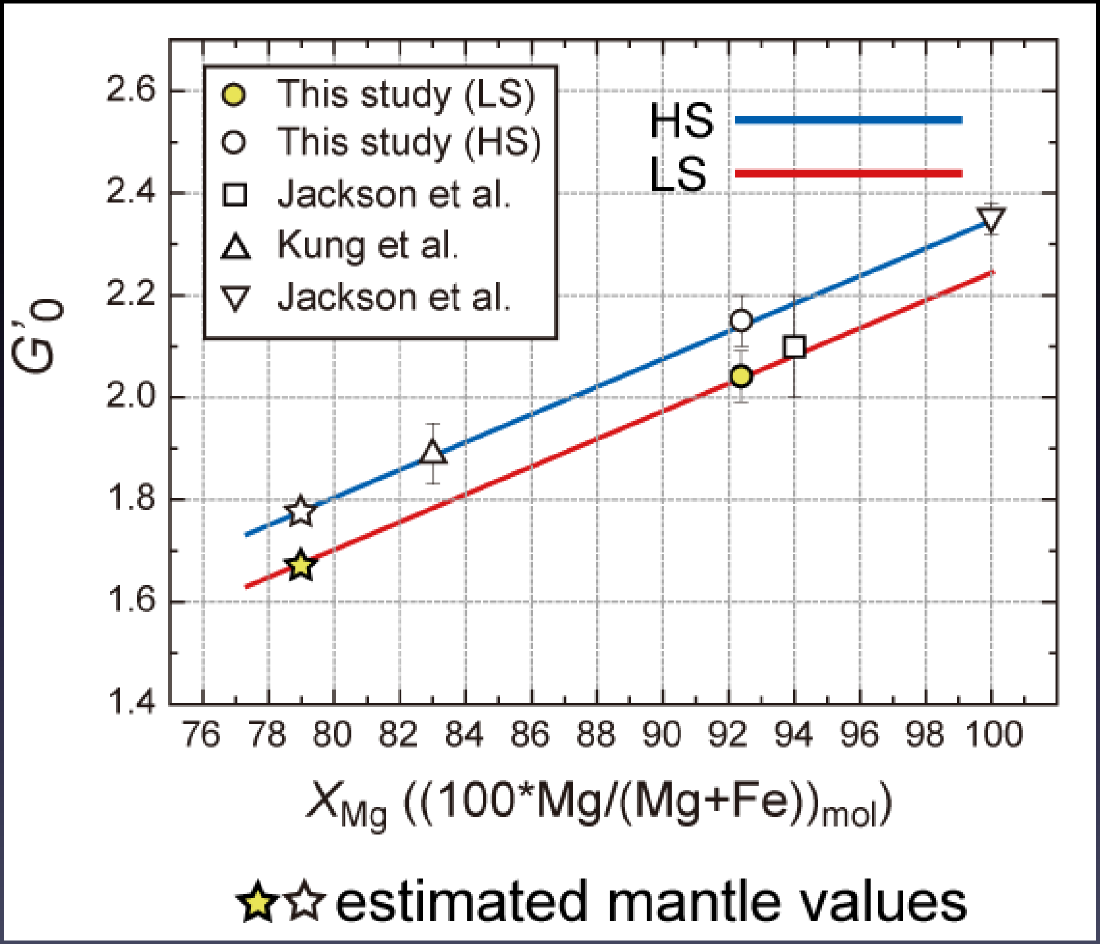
86 GPa



Shear velocity of (Mg,Fe)O



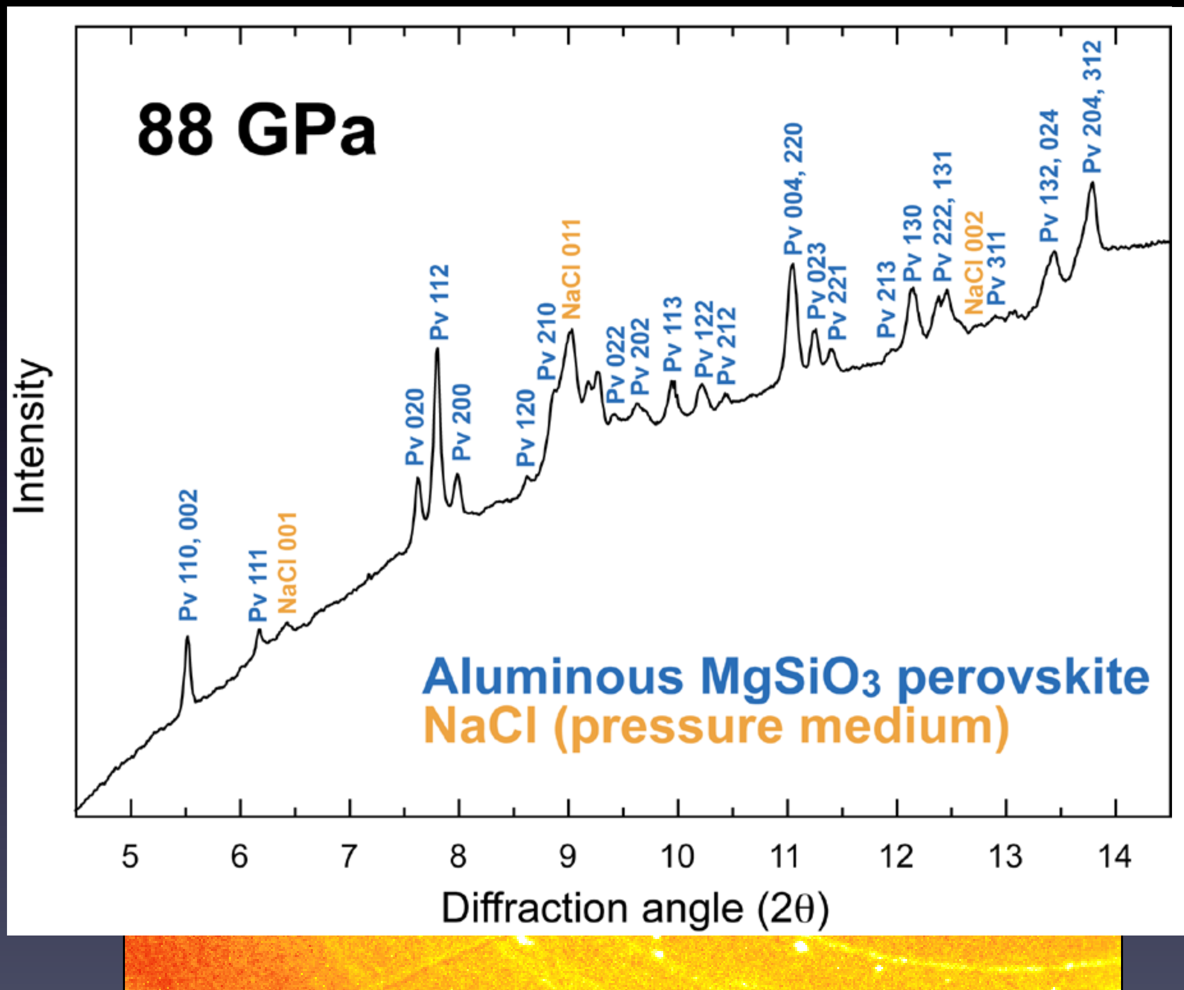
Effect of spin transition on the elasticity



In-situ synthesis of Al-$MgSiO_3$ pv

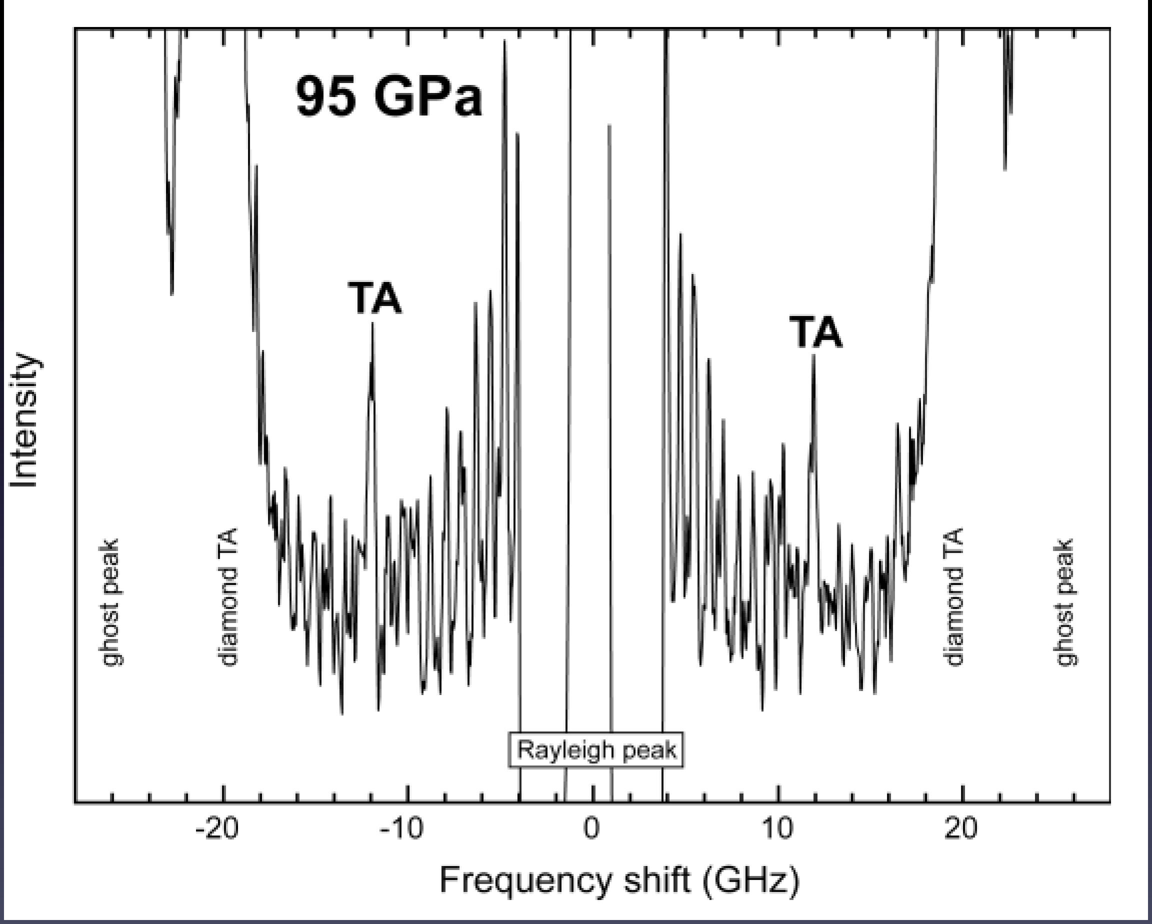
XRD pattern at 88 GPa

XRD image at 88 GPa

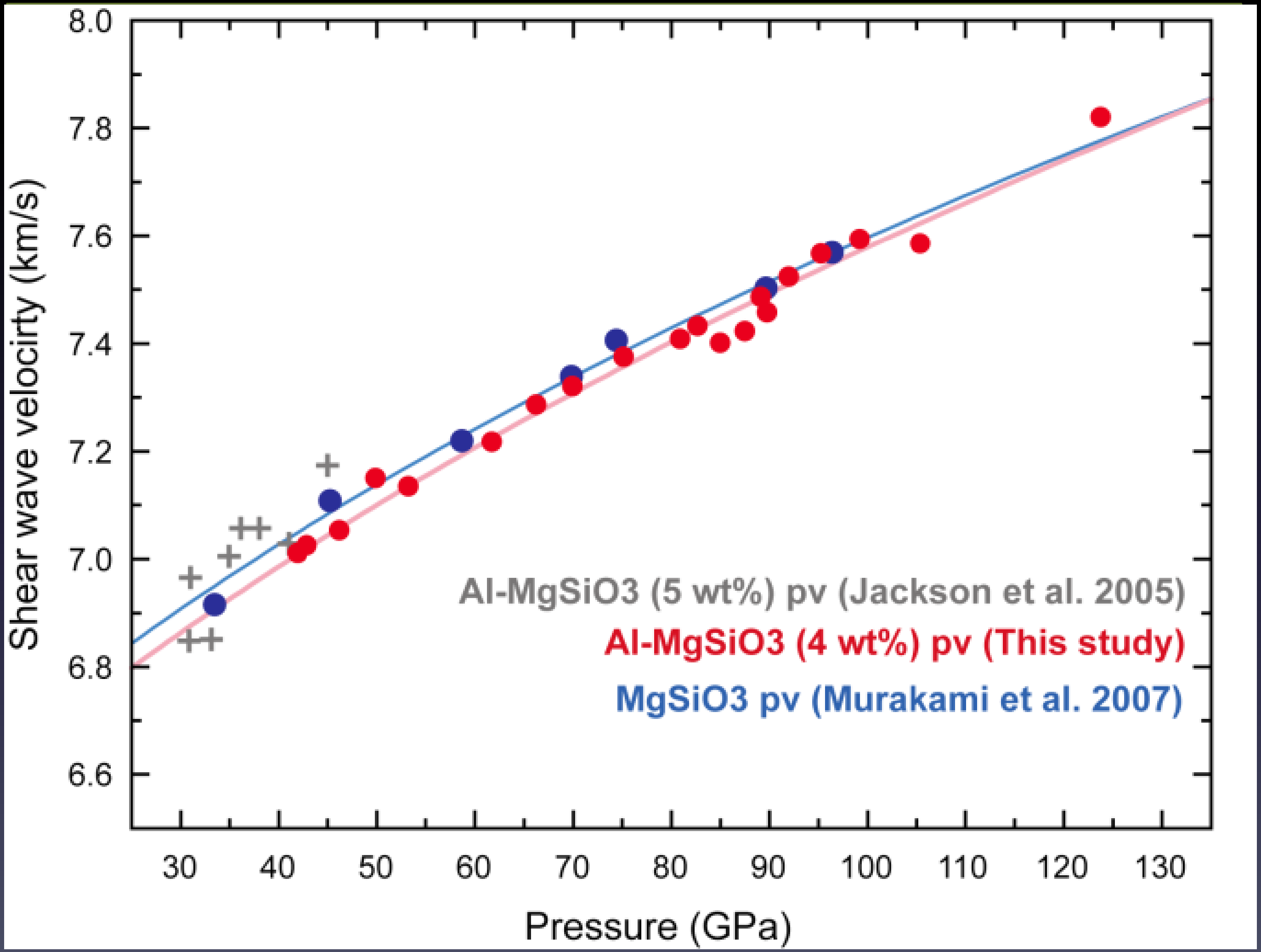


Brillouin data of aluminous MgSiO3 pv

95 GPa



Shear velocity of Al-MgSiO3 pv



Effect of Al on the elasticity of pv

composition	Go (GPa)	G'o	pressure	reference
Al-MgSiO3 (4 wt%)	166(1)	1.57(5)	124 GPa	This study
Al-MgSiO3 (5 wt %)	165(2)	1.7(2)	45 GPa	Jackson et al. 2005
MgSiO3	173(1)	1.56(4)	96 GPa	Murakami et al. 2007

Composition

MgO-SiO_2-FeO-Al_2O_3

$MgSiO_3$ pv, 96 GPa

(Murakami et al. 2007)

MgO, 130 GPa

(Murakami et al. 2009)

(Mg,Fe)O, 120 GPa

(Murakami et al. 2012)

Al-$MgSiO_3$ pv, 124 GPa

(Murakami et al. 2012.)

Modeling of lower mantle mineralogy

System

(Mg,Fe)O, 120 GPa (Murakami et al. under review)

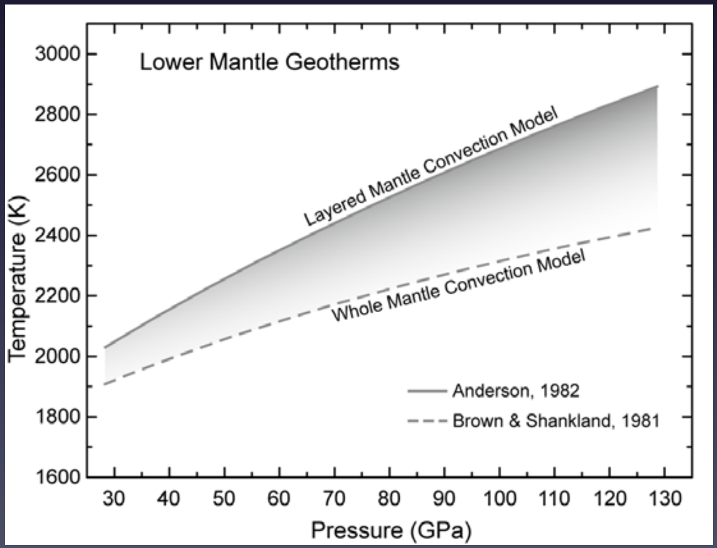
Al-$MgSiO_3$ pv, 124 GPa

(Murakami et al. in prep.)

Formalism

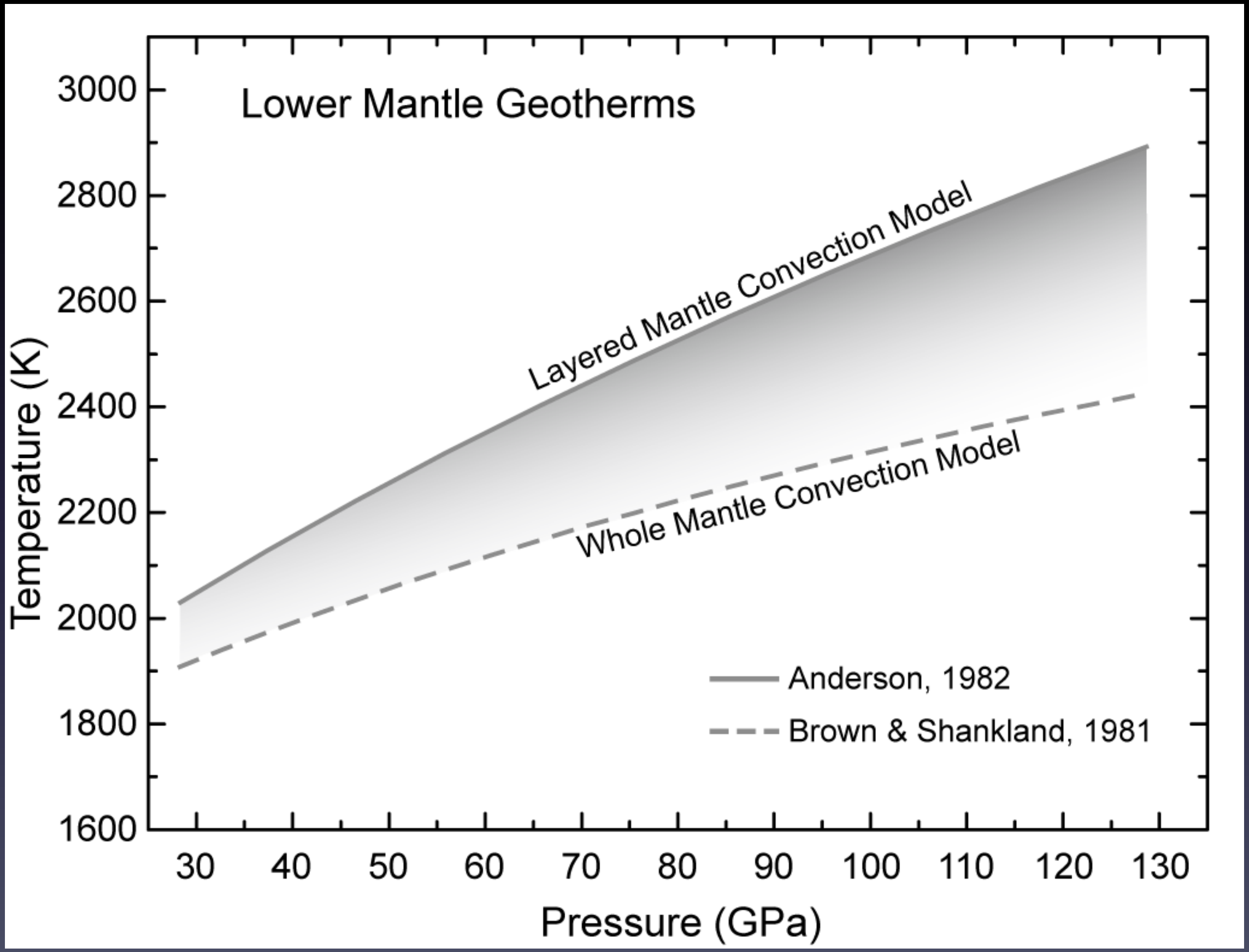
Stixrude & Lithgow-Bertelloni, 2005

Geotherm



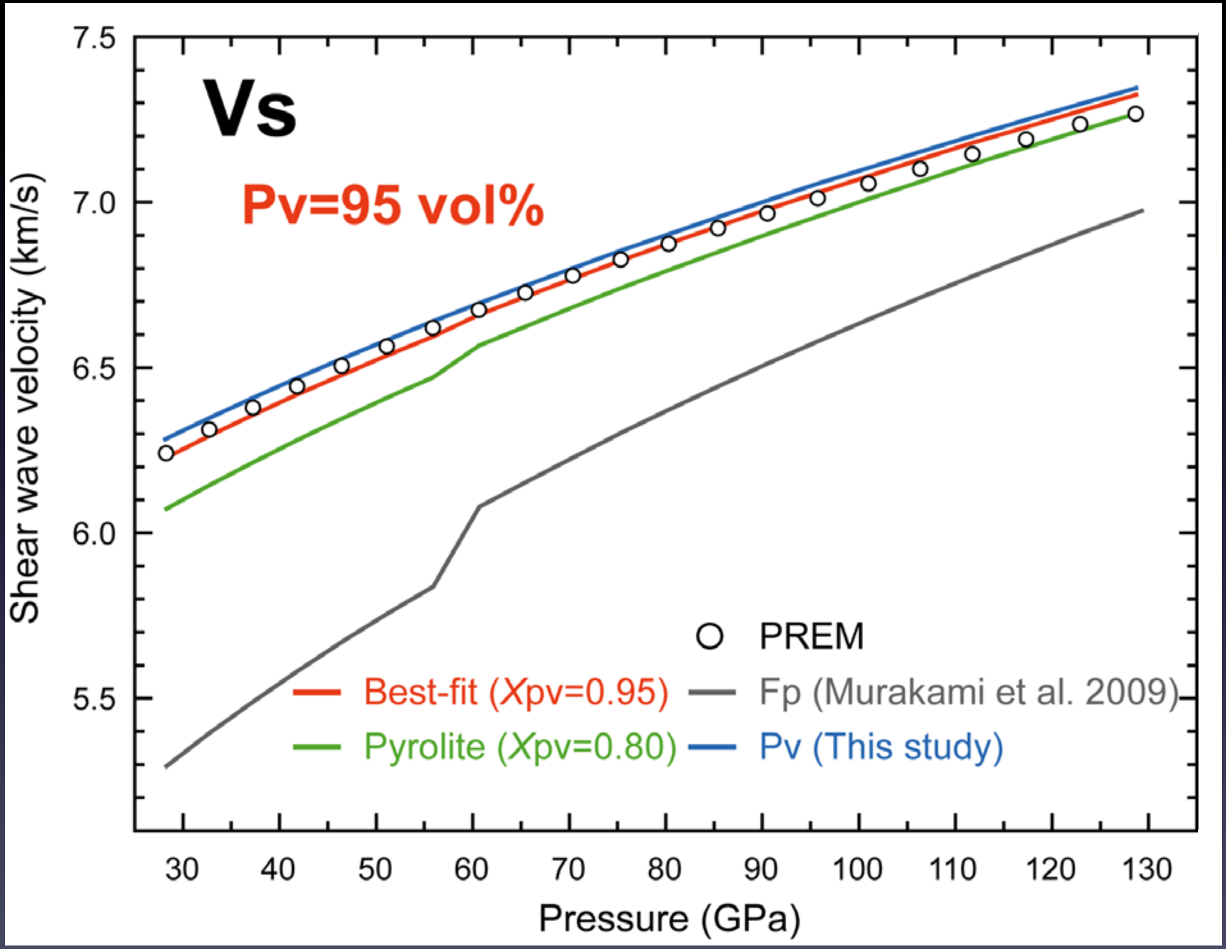
Lower mantle geotherms

Two extreme models



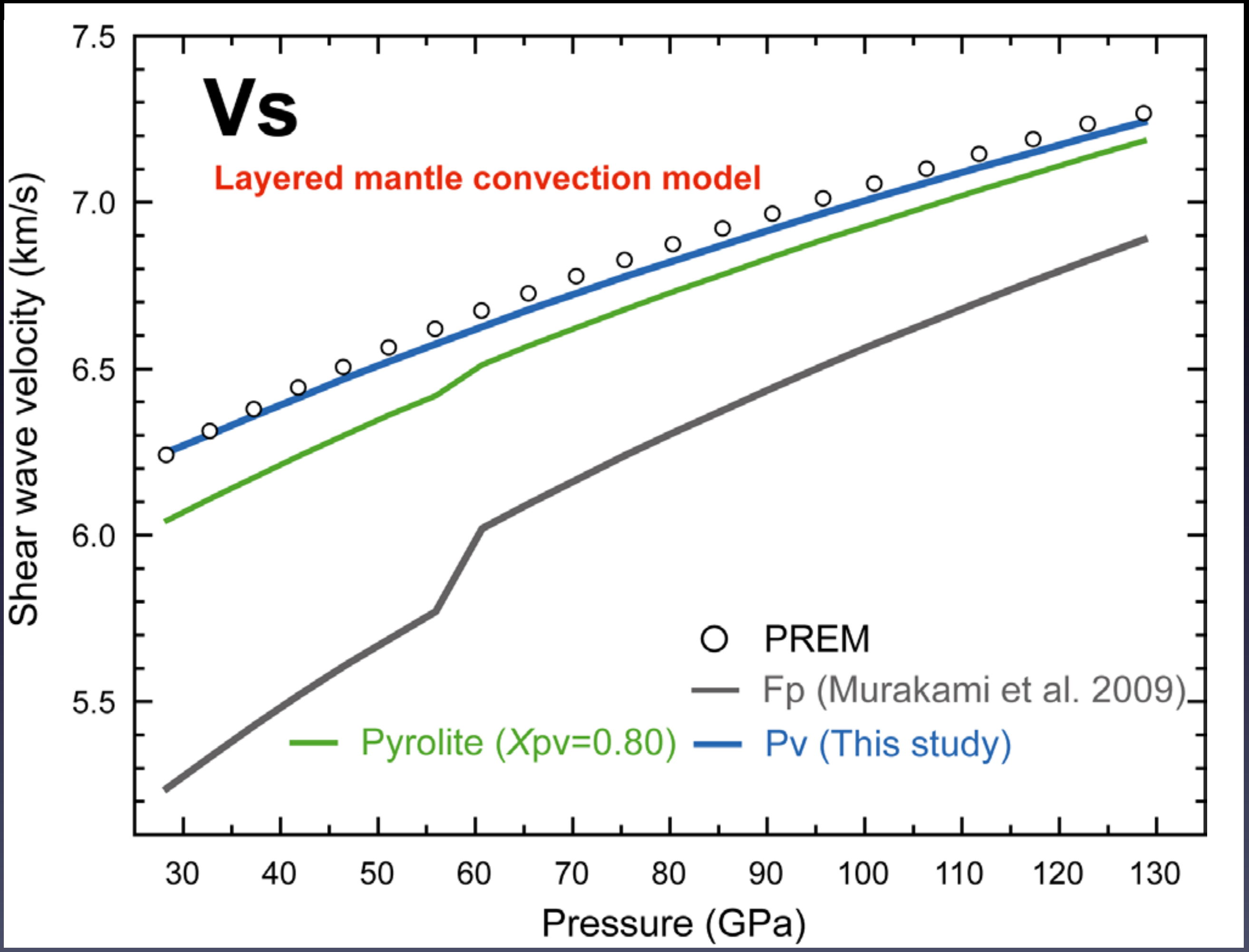
Modeling of lower mantle mineralogy

Whole mantle convection geothermal model



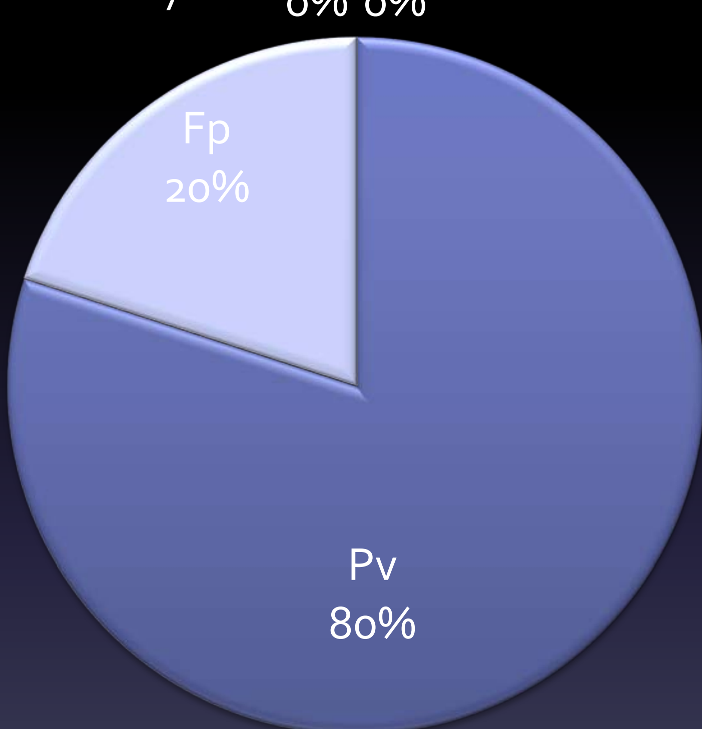
Modeling of lower mantle mineralogy

Layered mantle convection geothermal model



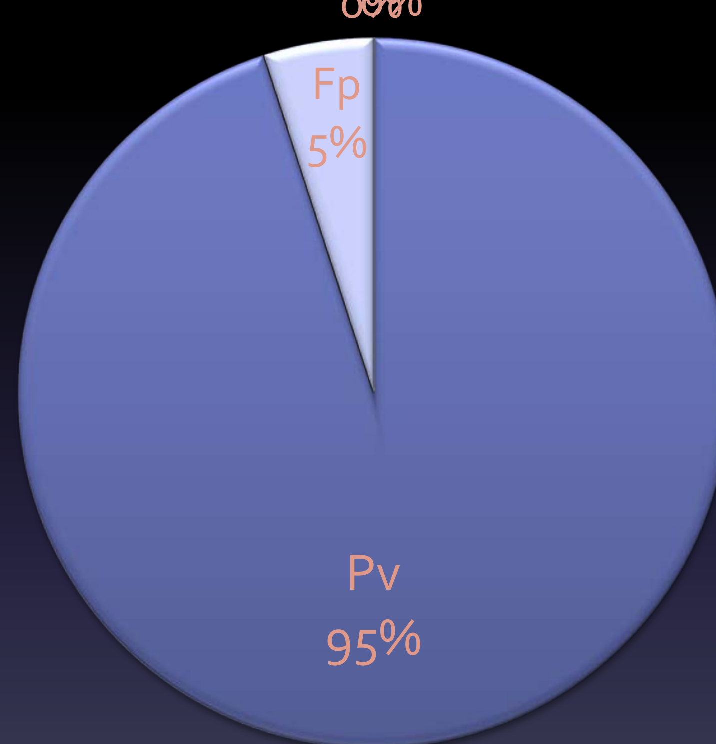
Mineralogical Model of Lower Mantle

Pyrolitic lower mantle



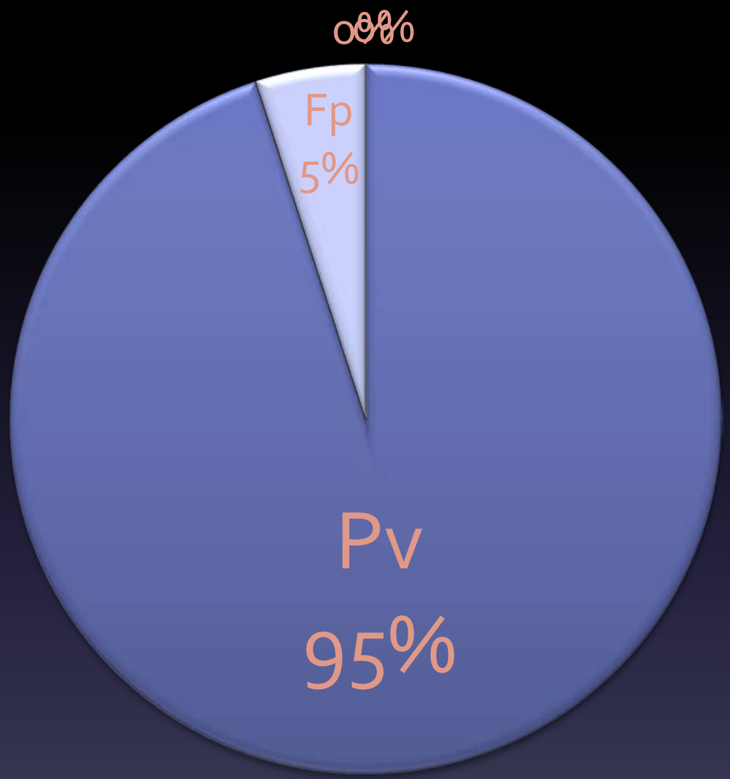
Mineral proportion (vol%)

Perovskititic lower mantle



Mineral proportion (vol%)

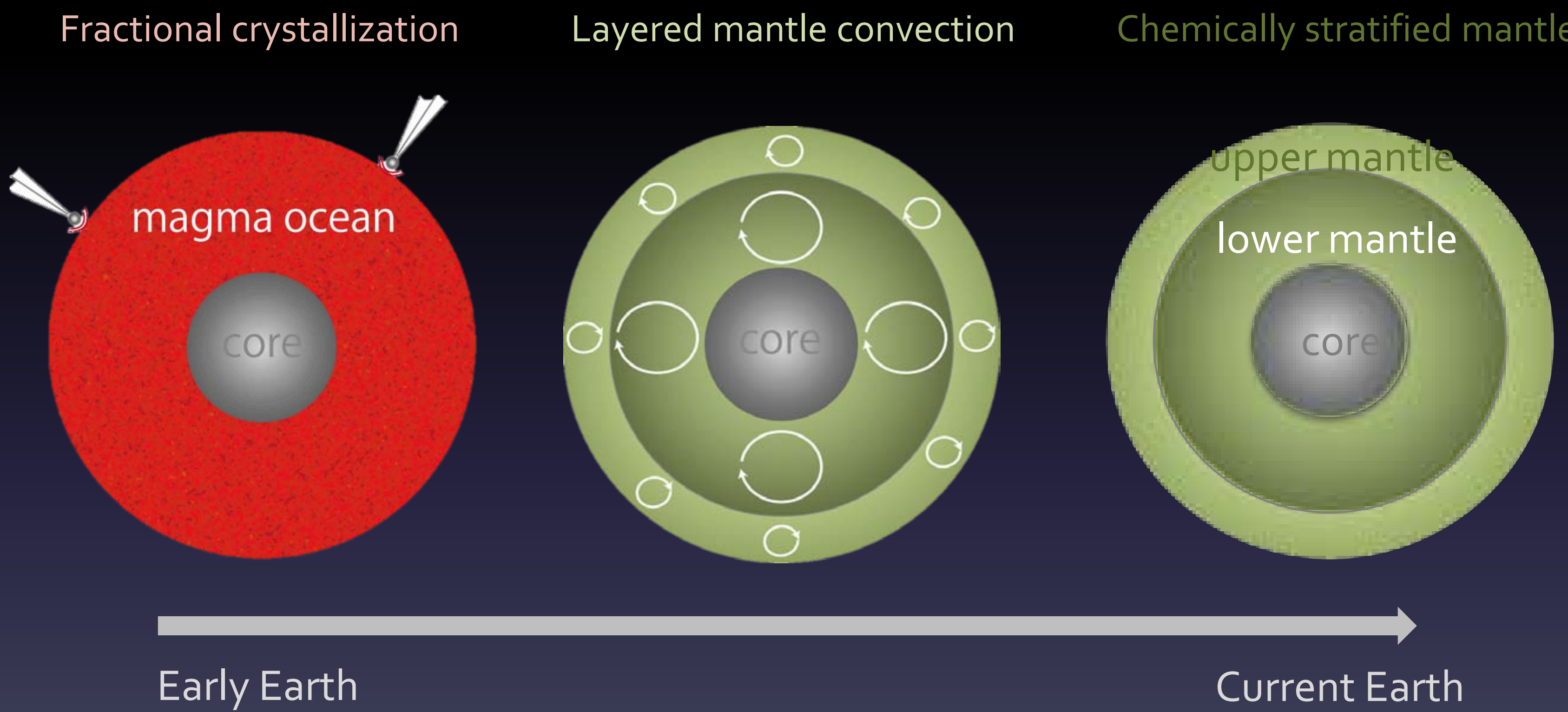
Perovskititic lower mantle



Mineral proportion (vol%)

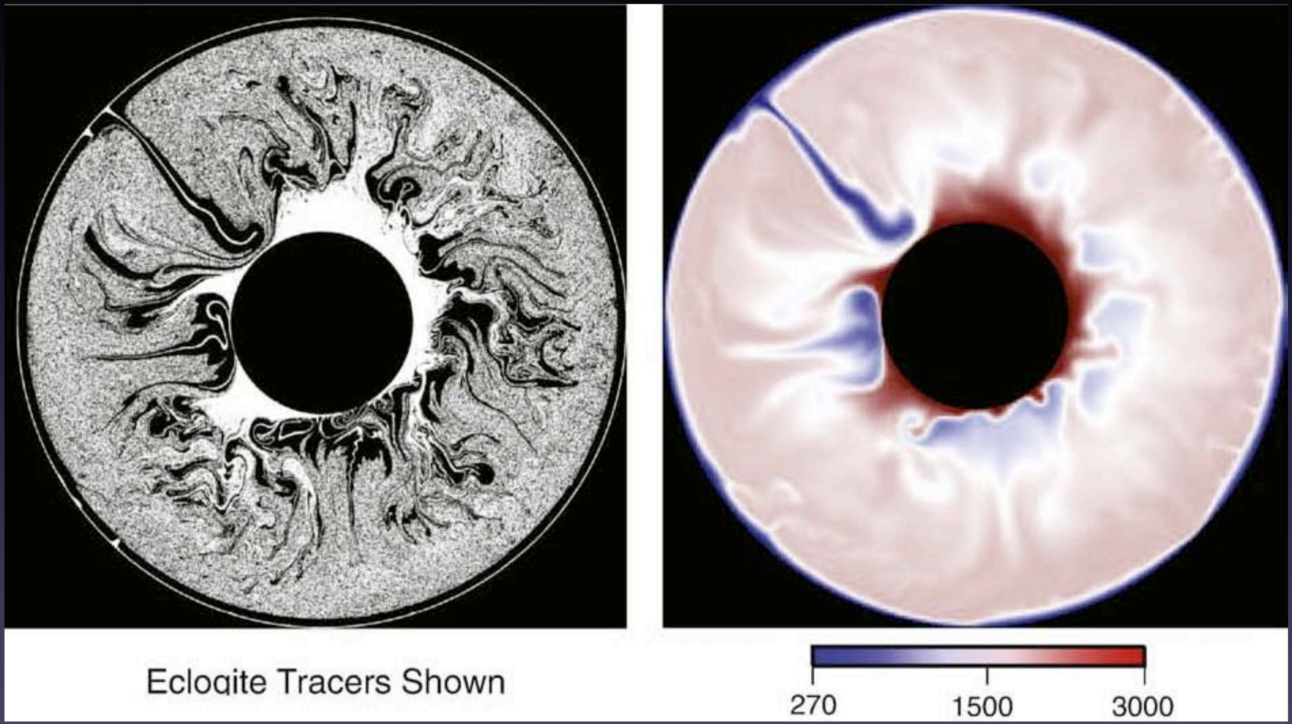
SiO_2-enriched lower mantle

Evolution history of the mantle



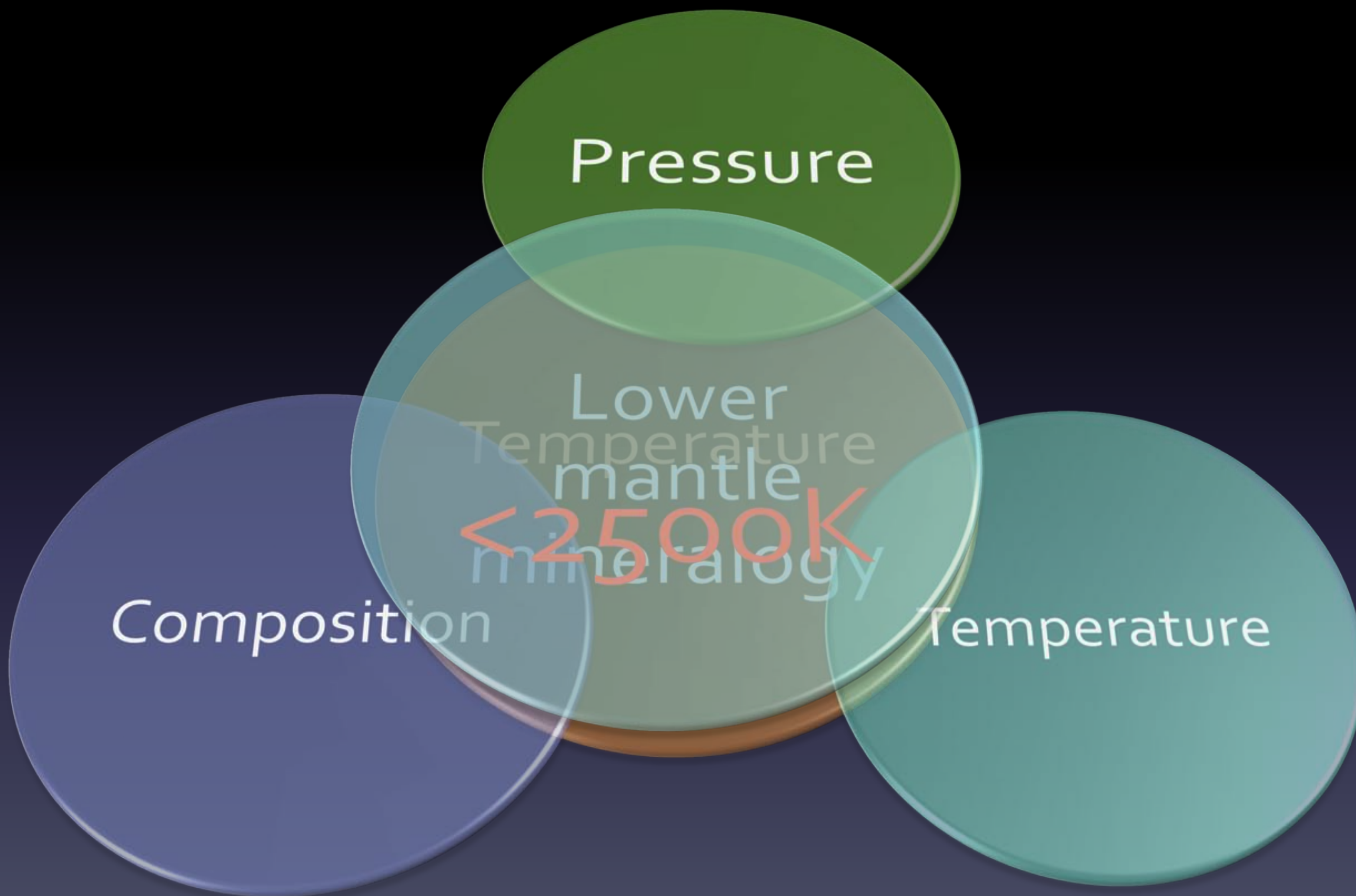
Big question/problem

How to maintain such chemical stratification?



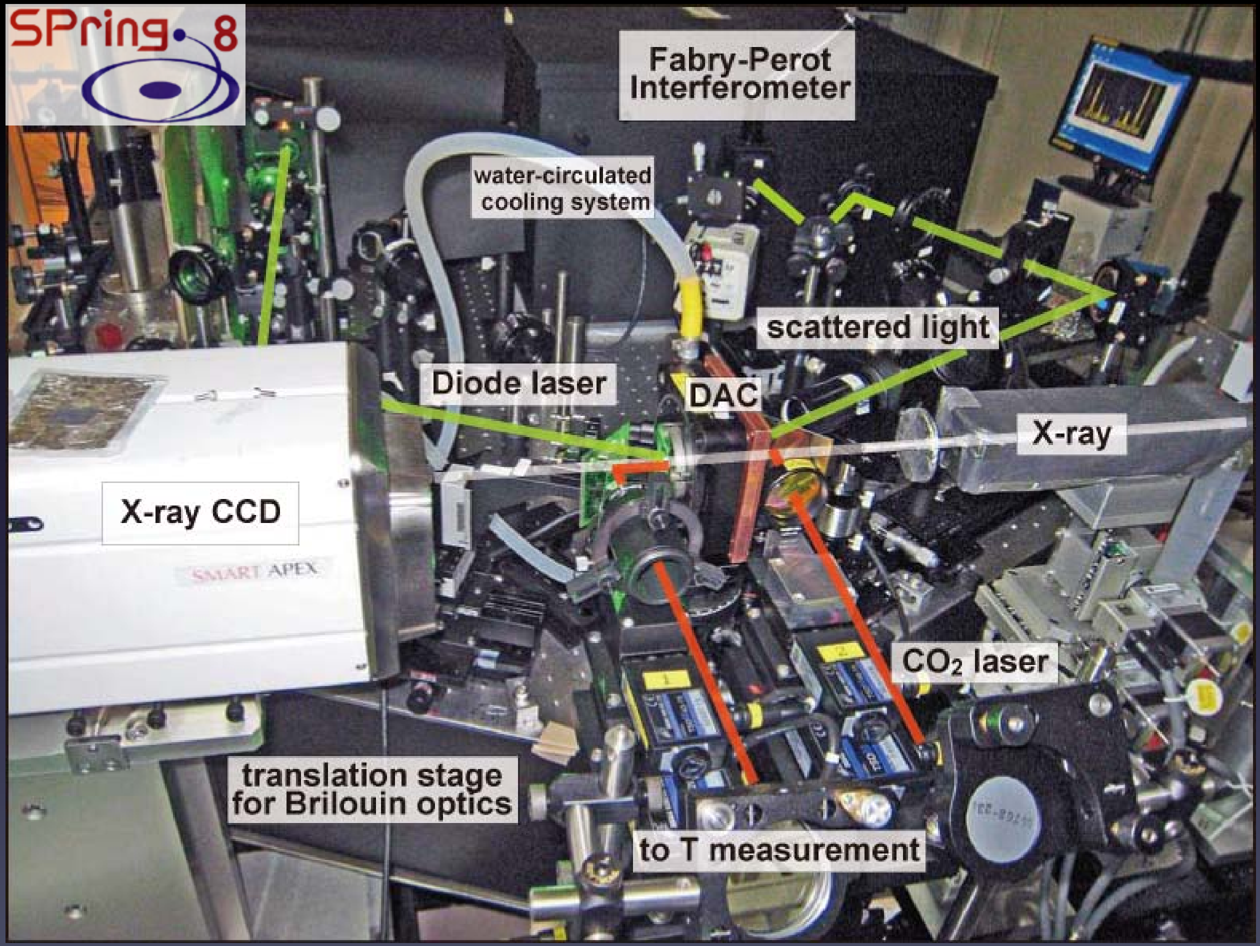
(Brandenburg et al., 2008)

Challenges for sound velocity measurements
Effect of temperature



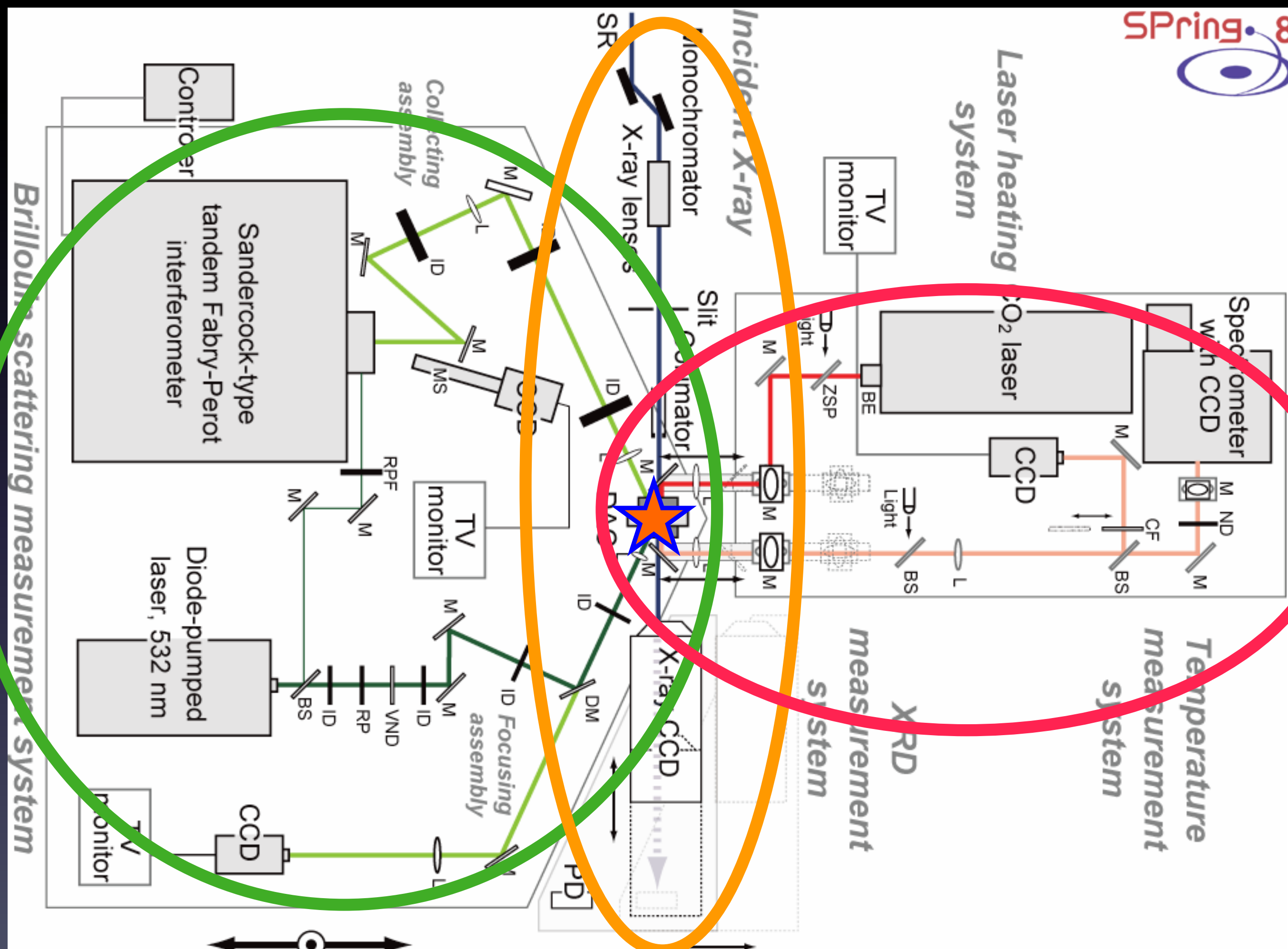
Technical development for sound velocity measurements under H-T

Temperature



Simultaneous measurement system for Vs,p, V and T

Brillouin scattering + XRD + Laser heating

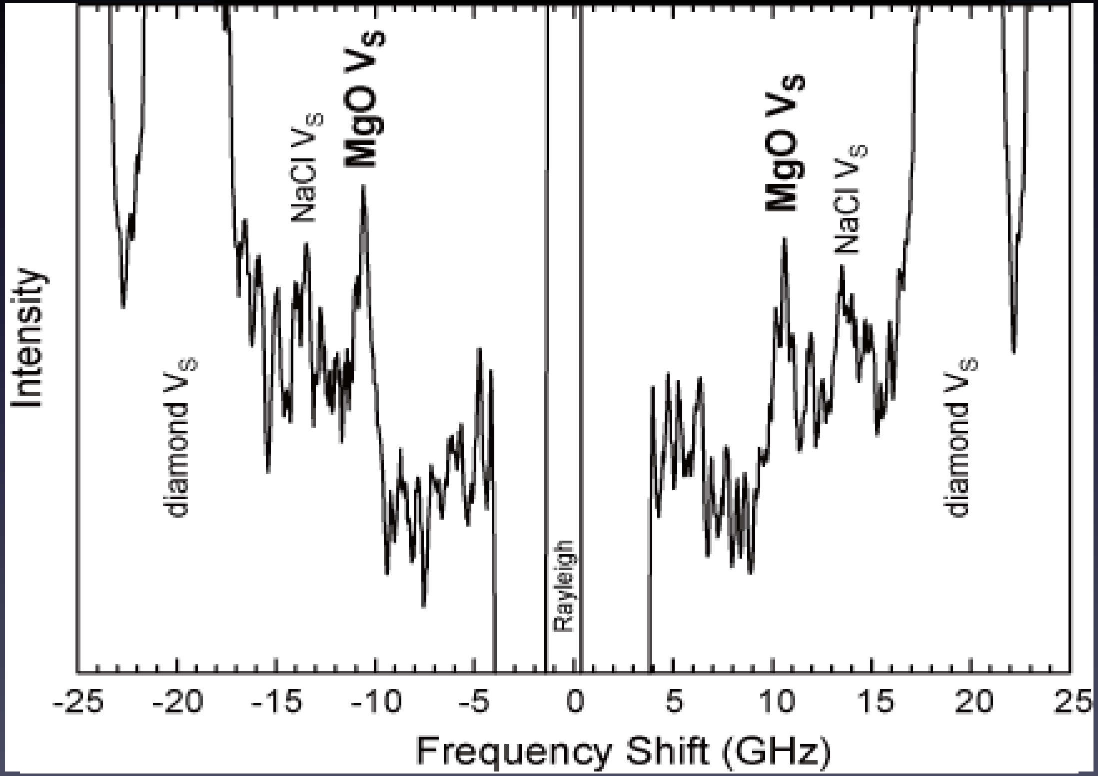


(Murakami et al. 2009)

Sound velocity under high P-T

MgO at 50 GPa, 2500 K

Brillouin spectrum



Toward better understanding..

*Effect of spin-transition of iron in Pv on the elasticity

*Combined effect of Fe & Al on the elasticity of Pv

*Data quality improvement of the high-T data

Summary

We have determined the sound velocities of $MgSiO_3$ perovskite, MgO, (Mg,Fe)O and Al-MgSiO3 perovsktie under lower mantle pressure conditions

Mineralogical modeling using obtained results strongly indicates the perovskitic lower mantle.

Development of new Brillouin spectroscopy at high PT enables us to explore the sound velocities under lower mantle condition.