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Image Earth's Inner Core Fine-scale Heterogeneity and Temporal Changes using IMS arrays

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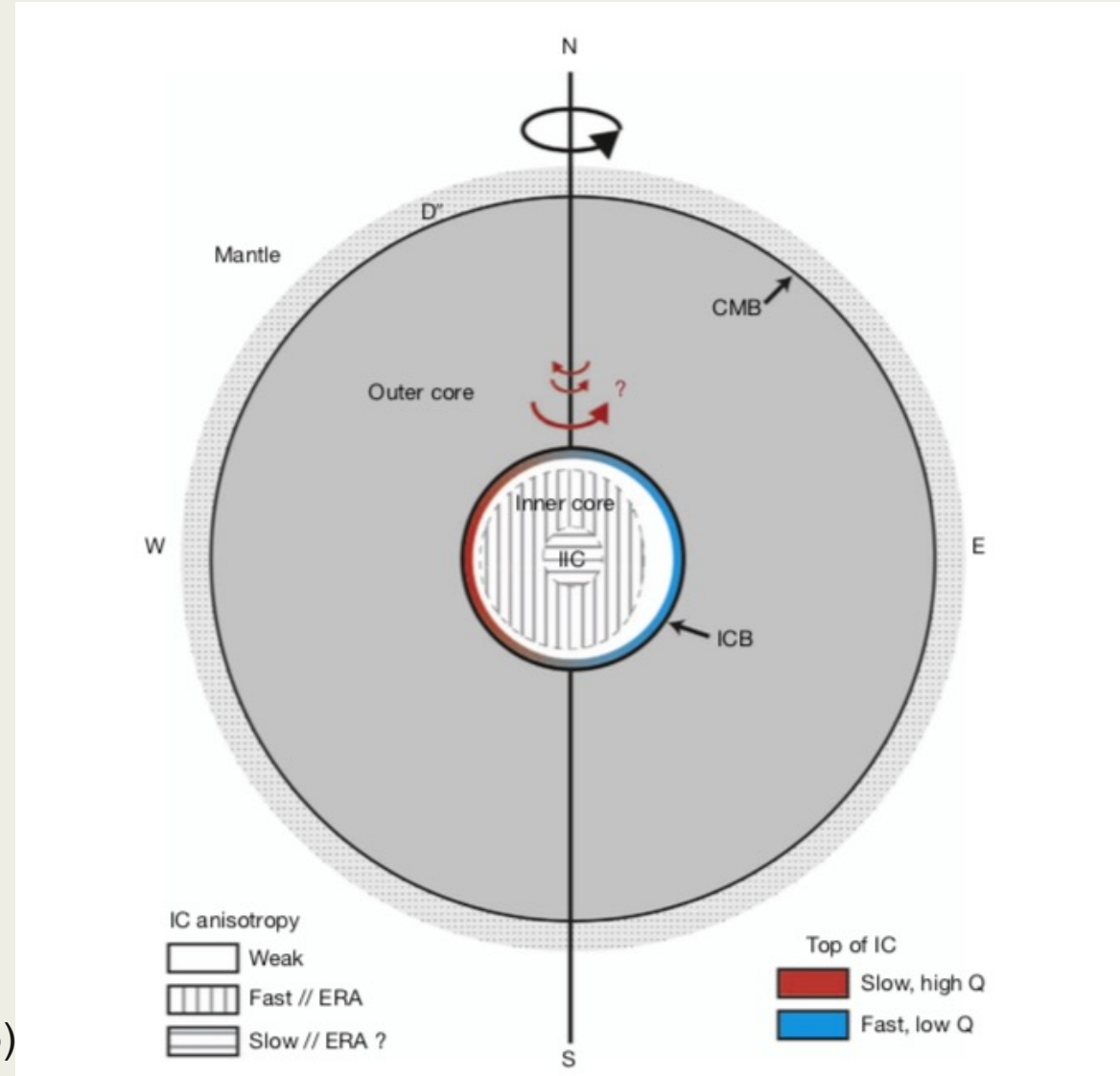
"Standard" Inner Core Model

- Solid-ish (viscosity of $10^{10\text{-}20}$ pas)
- Radius of 1221 km (bigger than Pluto)
- ~95% Fe/Ni, 5% (Si, S, ??)
- Elastically anisotropic (conductively too?)
- Hemispheric dichotomy
- Maybe rotating faster or slower than the rest of the Earth



Souriau & Calvet (2015)

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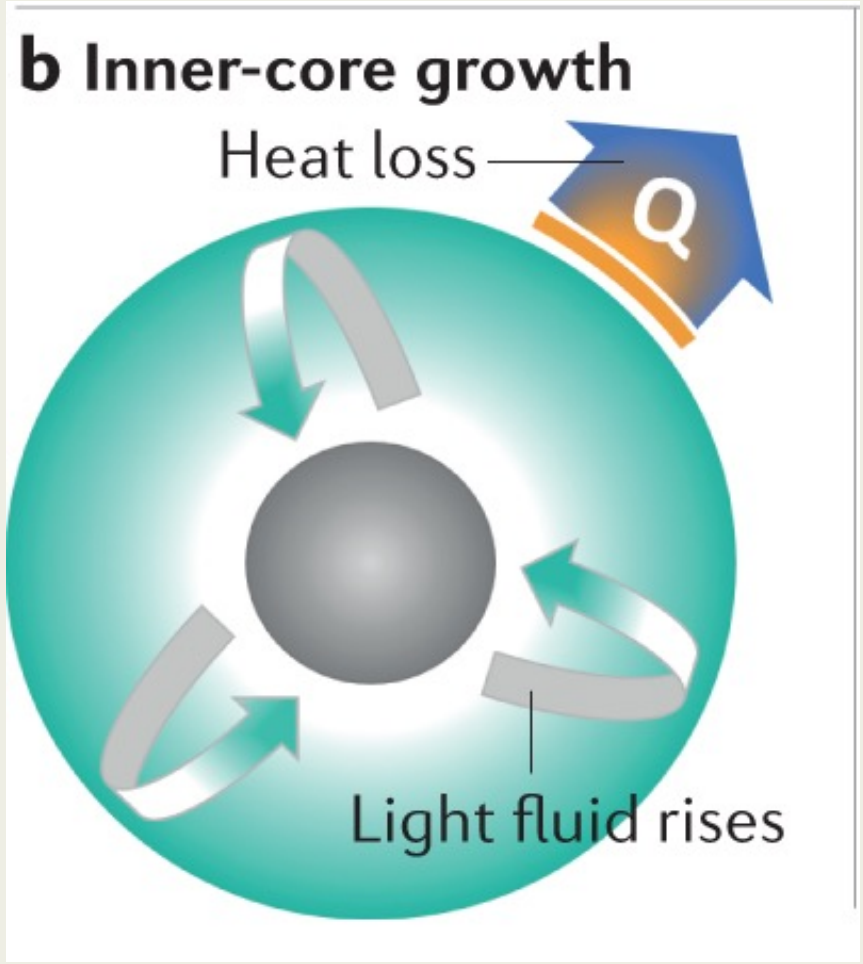
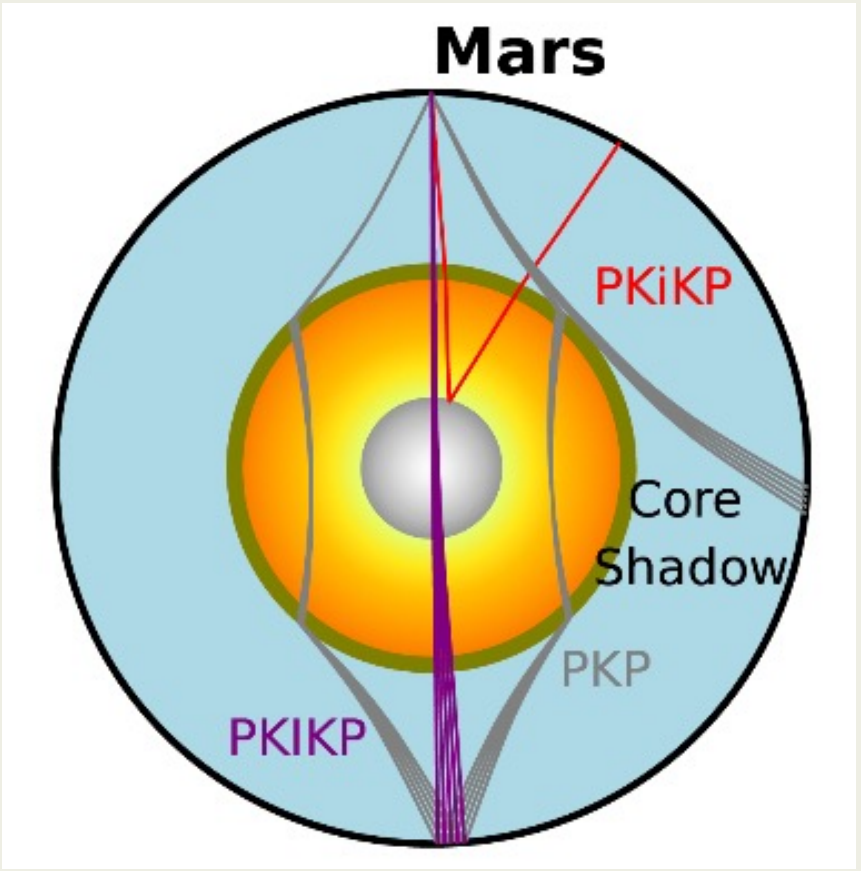
Importance of Inner Core

Generation of the geomagnetic field



Landeau et al. (2022)

Reference for terrestrial planets, e.g., Martian inner core



Bi et al. (in press)

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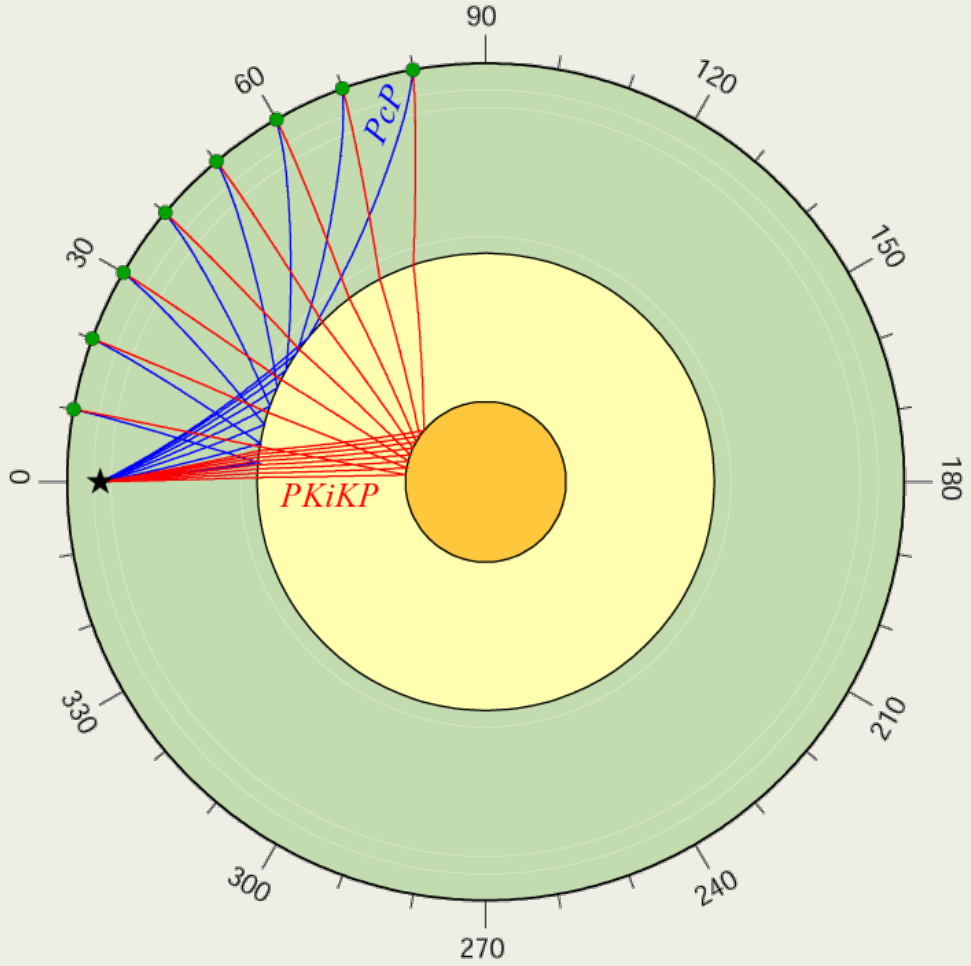
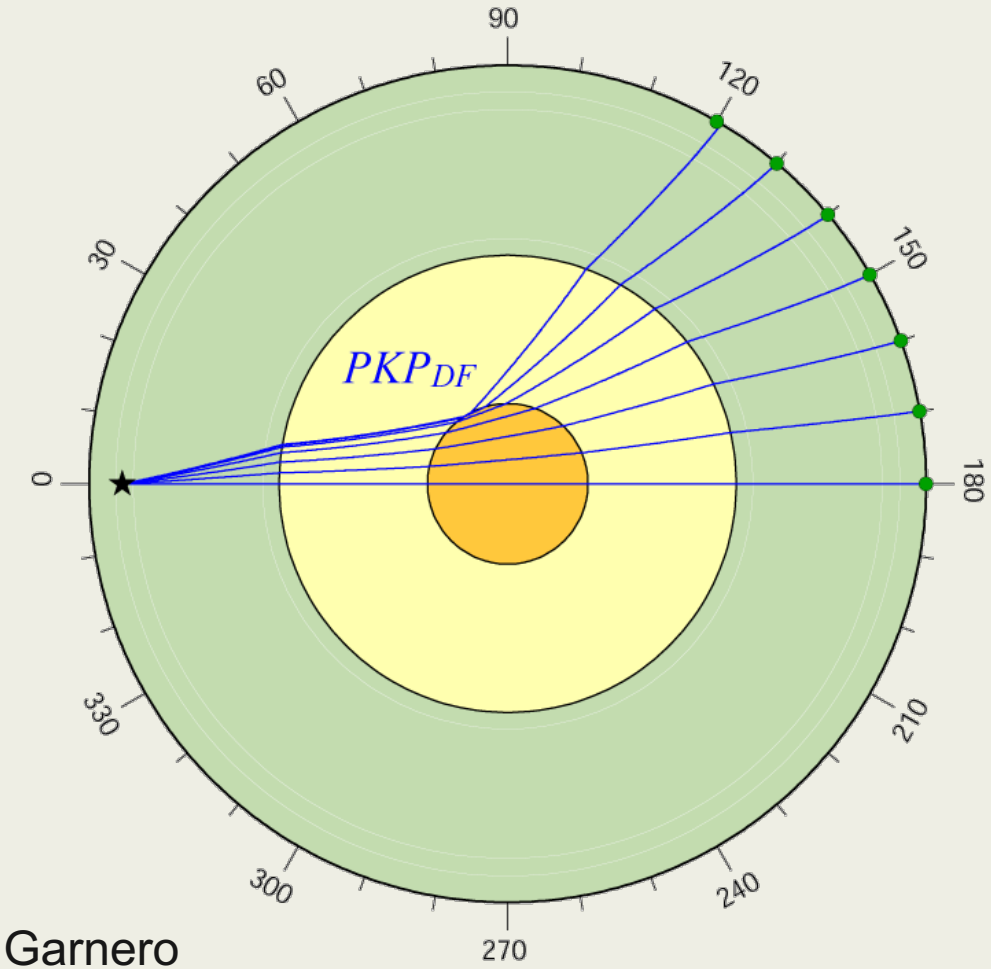
Seismic Core Probe

Reflected waves



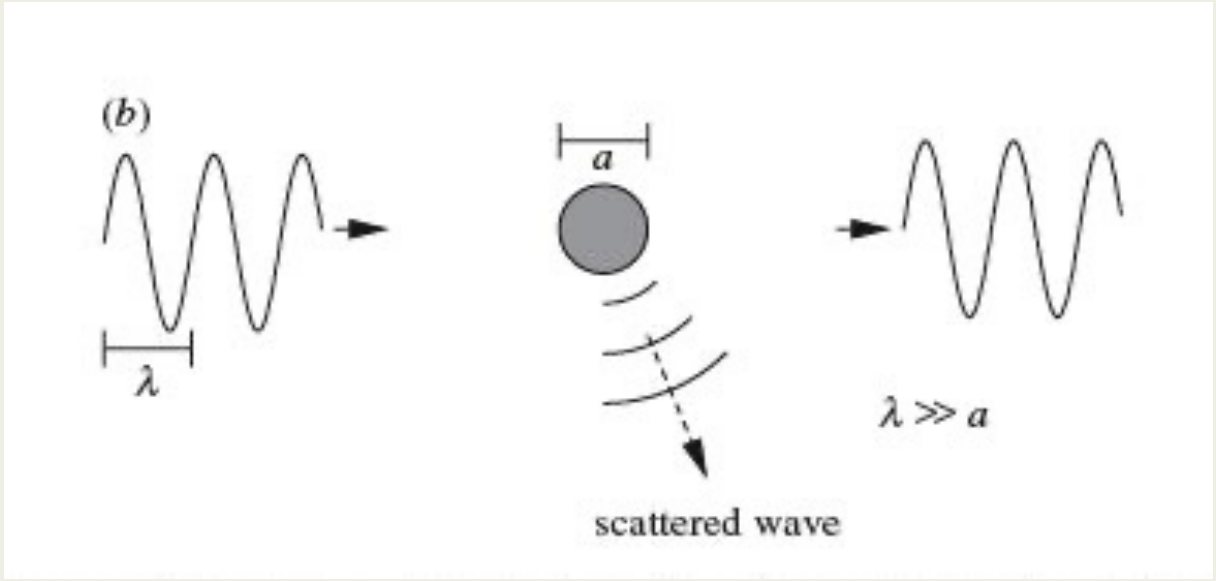
Refracted waves



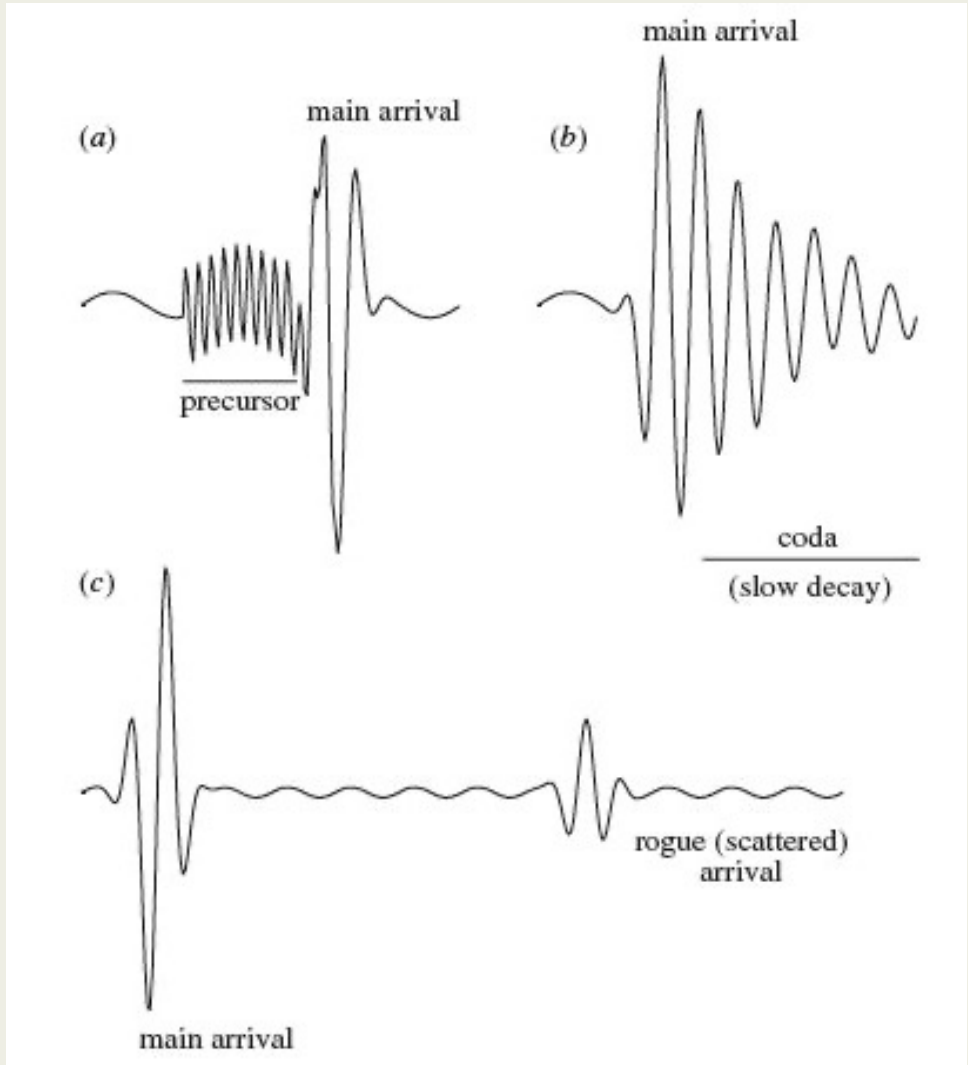
Figures from Ed Garnero

Scattered and Coda Waves

Density or Velocity anomalies



Helffrich (2002)



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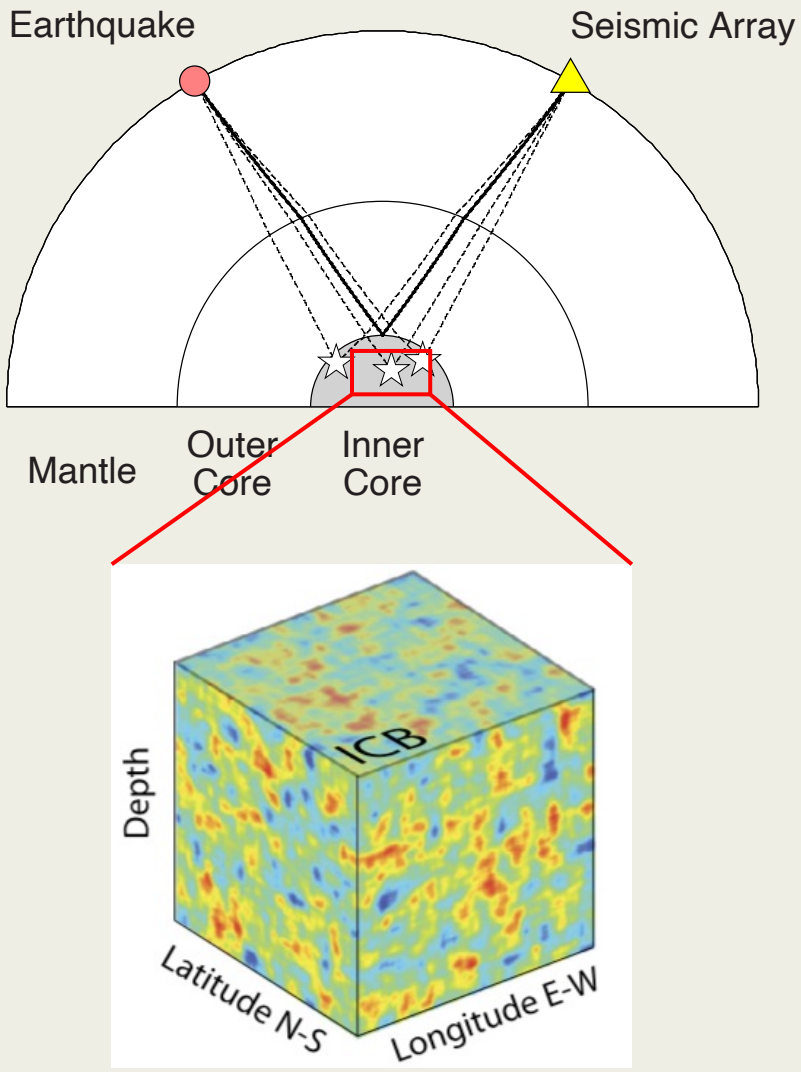
Inner Core is NOT homogeneous in 1–10 km scale

a

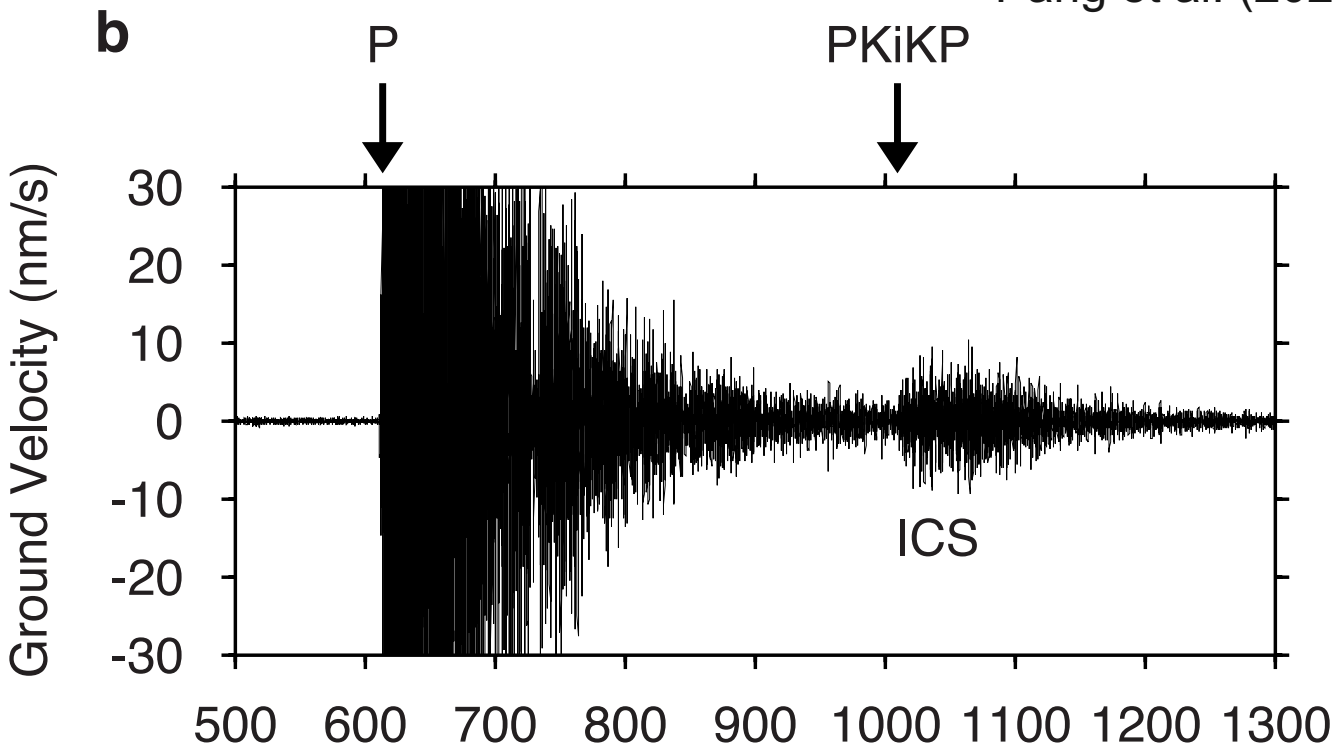


Calvet & Margerin (2018)

Tiny inner core scattered signal after PKiKP

Pang et al. (2023)

b



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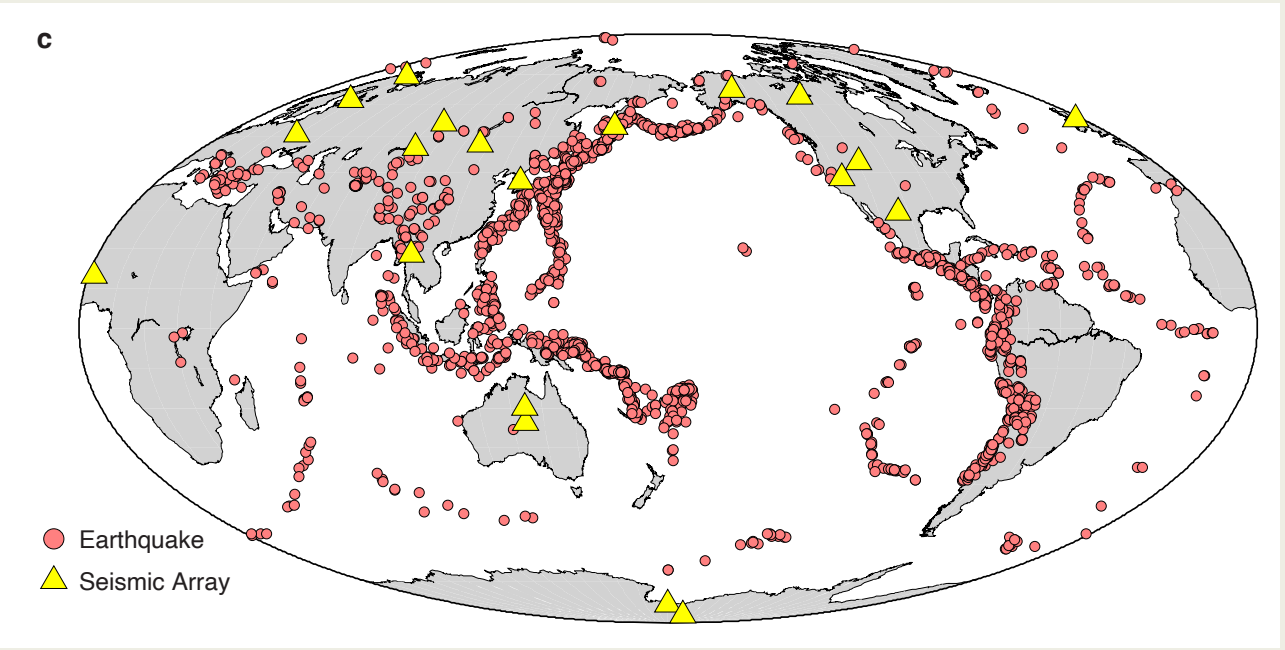
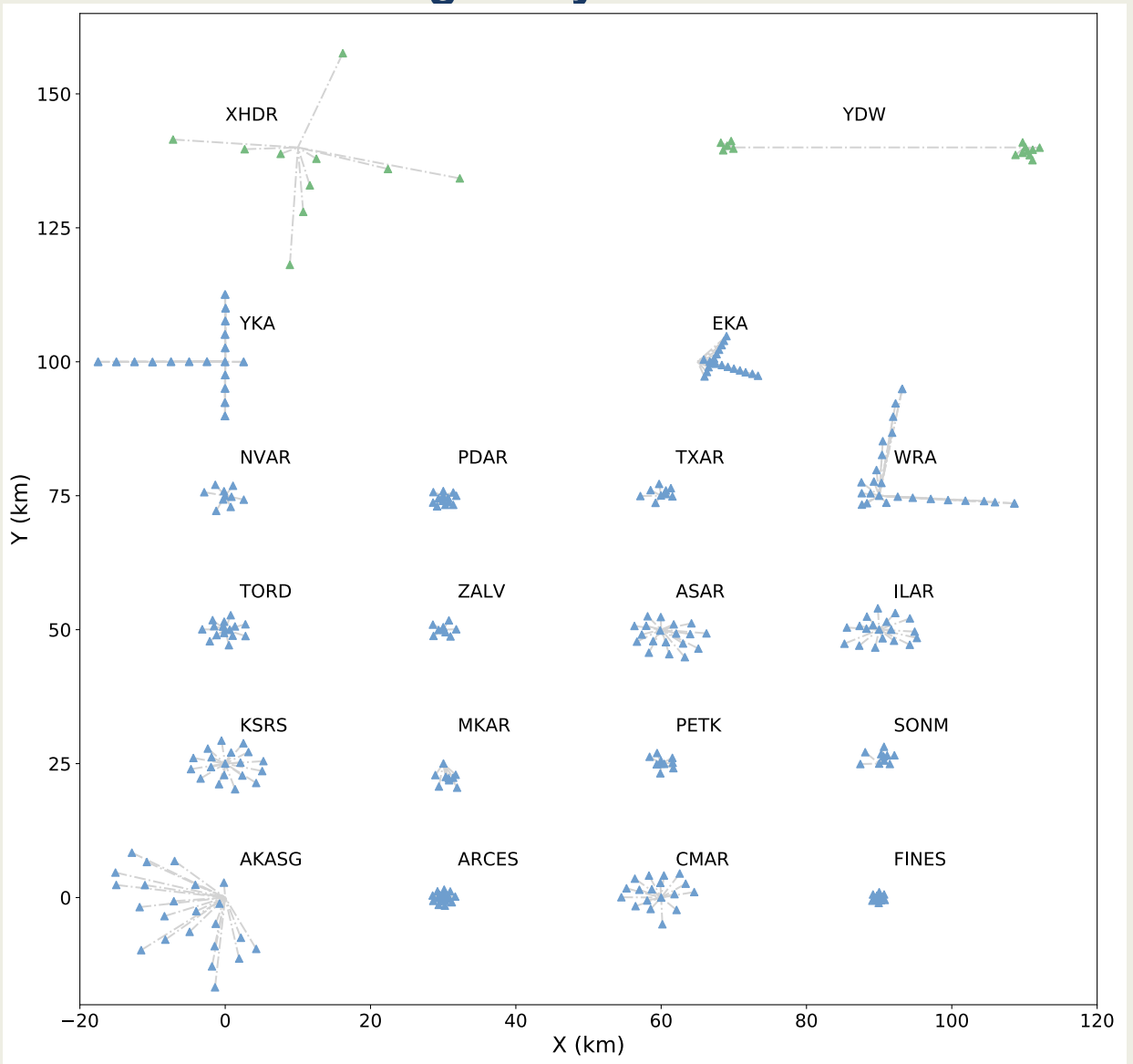
Global imaging of inner core fine-scale heterogeneity



Pang et al. (2023)



Global IMS small aperture arrays

Global PKiKP coda dataset

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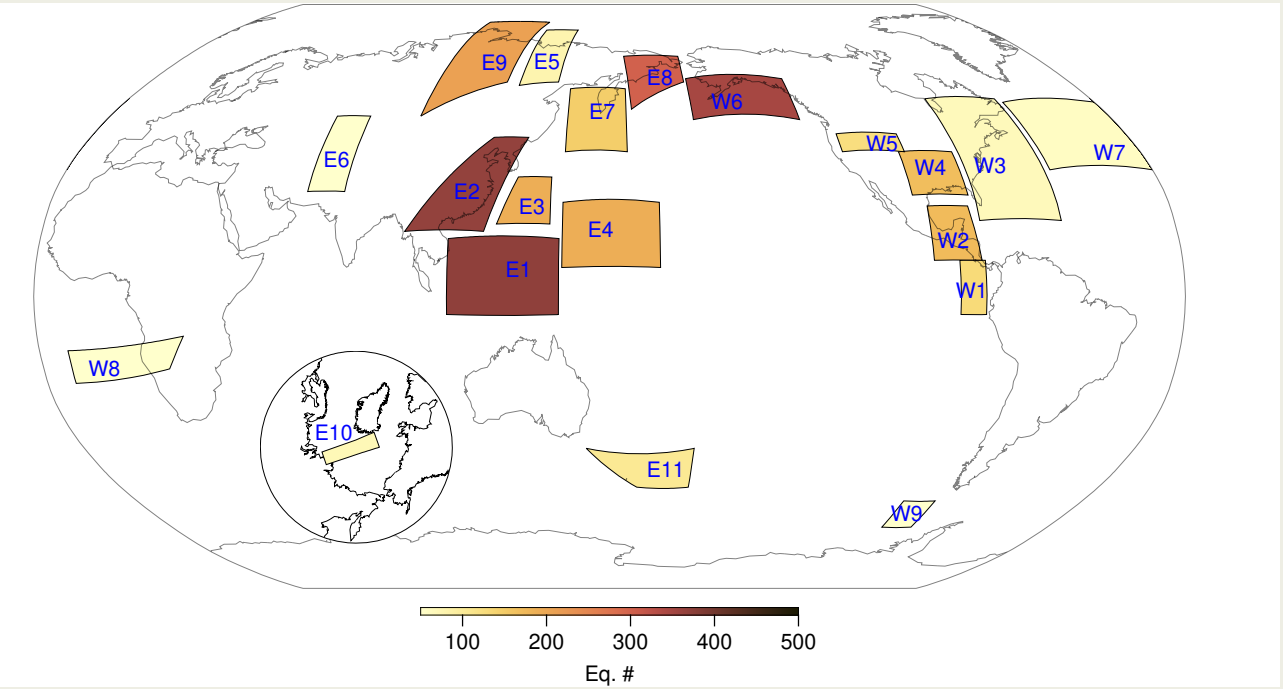
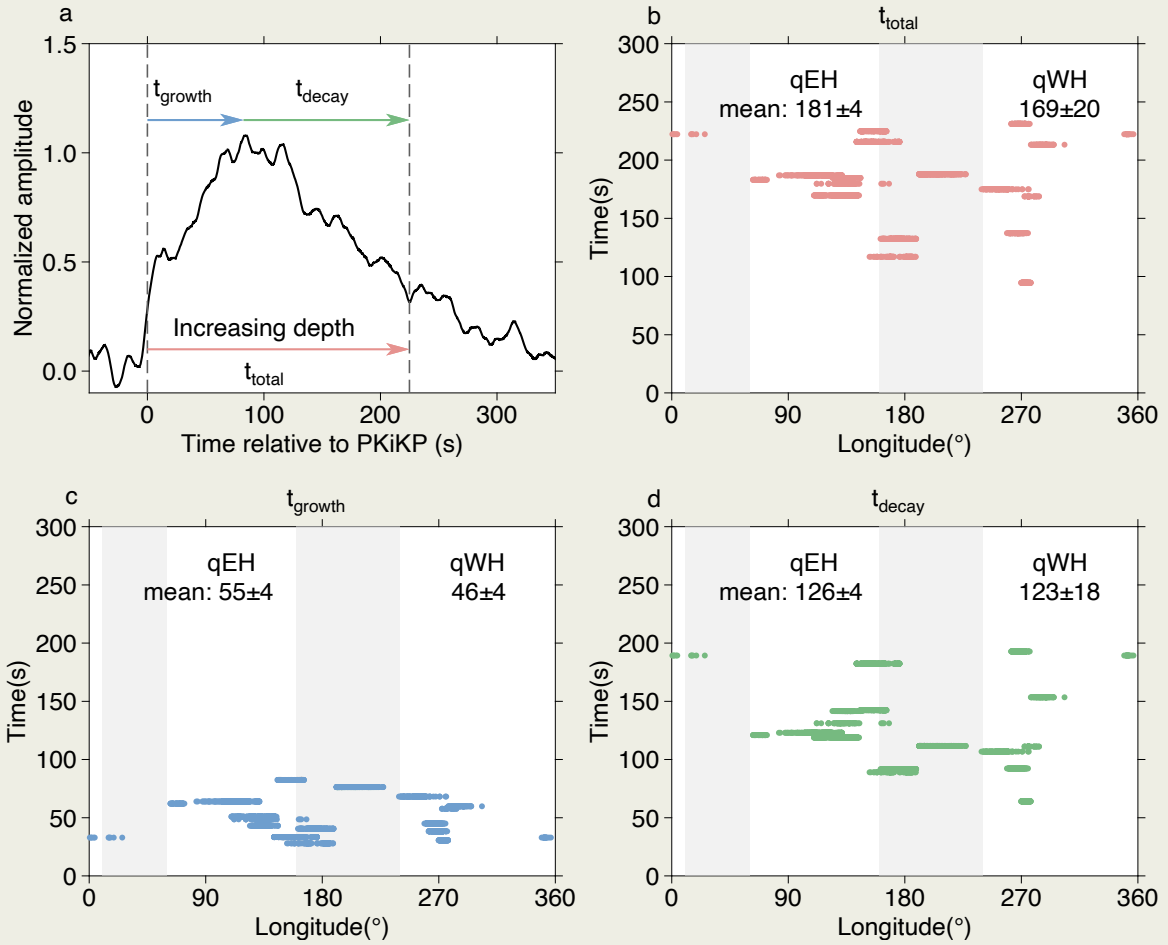
Global imaging of inner core fine-scale heterogeneity

Global Inner core sampling of IMS arrays



PKiKP coda characterizations



Pang et al. (2023)

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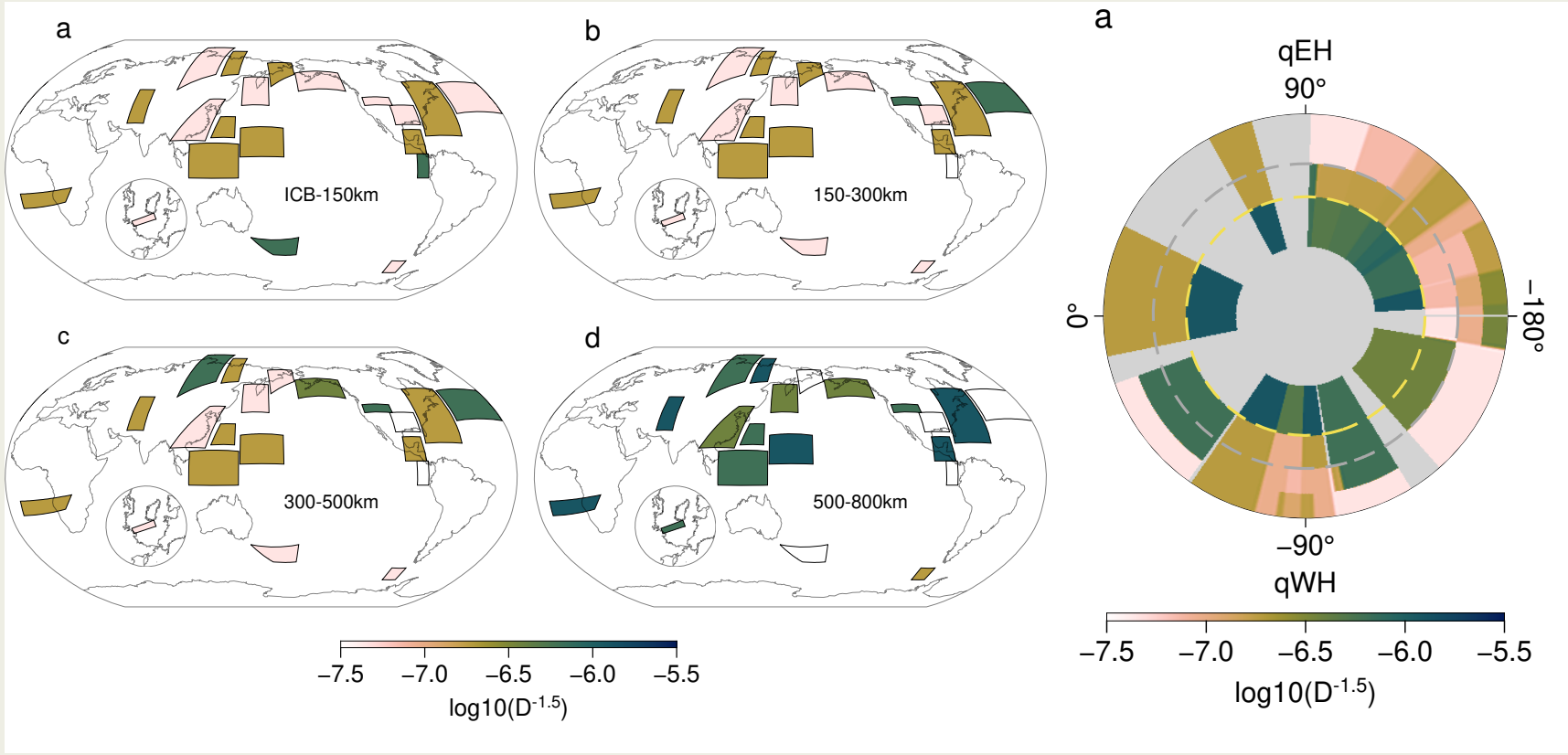
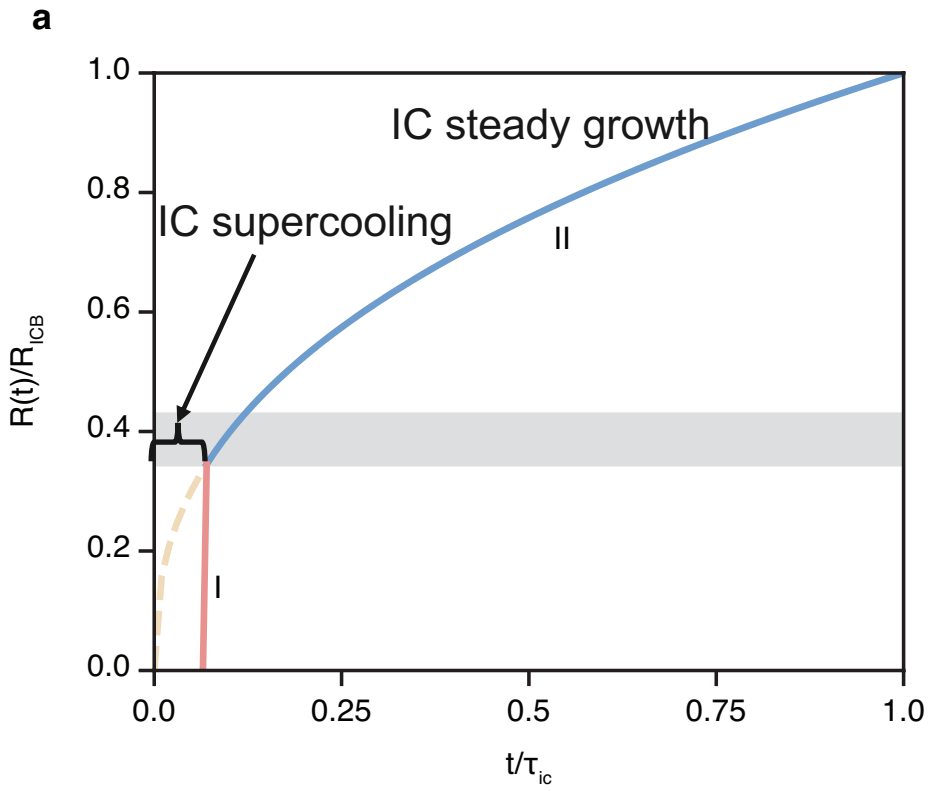
Global imaging of inner core fine-scale heterogeneity

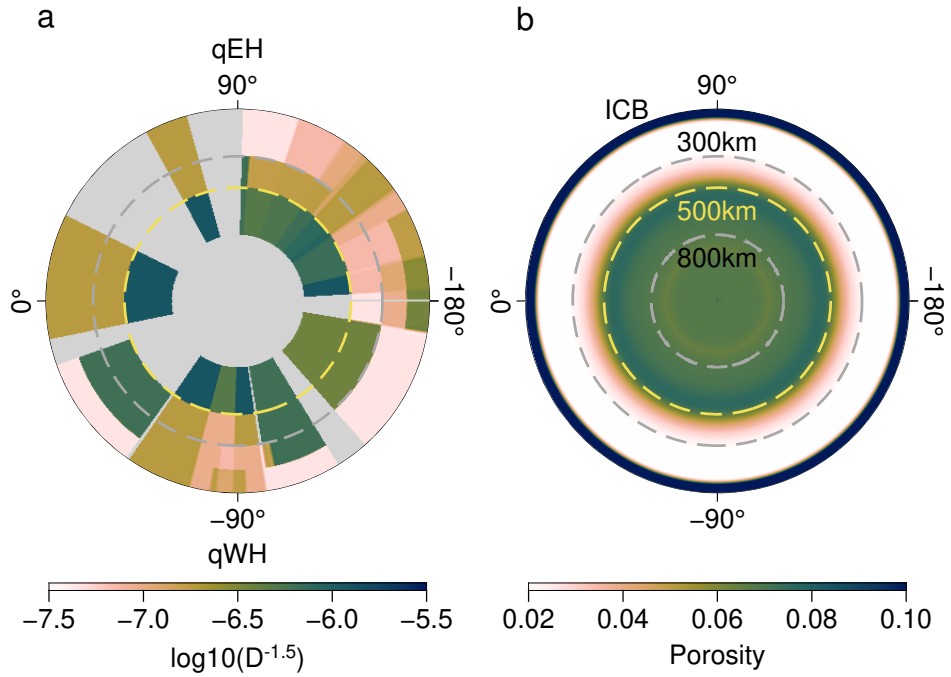
- Ubiquitous heterogeneity
- No hemispheric dichotomy
- Regional variations
- Stronger in the equator region
- Increasing strength with depth



Pang et al. (2023)

Inner core delayed nucleation and two-step growth





- Inner core nucleation was delayed by **~0.07–0.12 τ_{ic}**, supercooling **20–30 K**

Pang et al. (2023)

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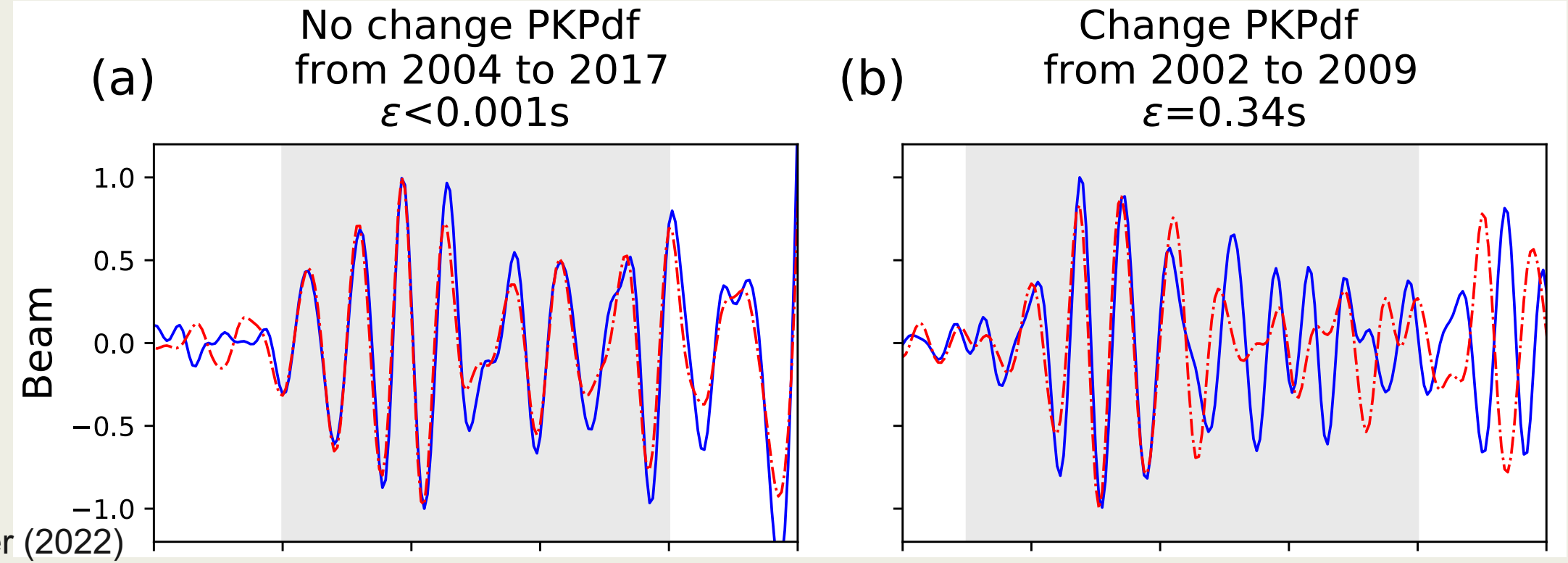
Inner core temporal change

- Decadal-scale changes have been observed in the inner core seismic waveform
- Inner core superrotation Vs. Non-rotational changes

Intermittent changes in inner core PKIKP coda



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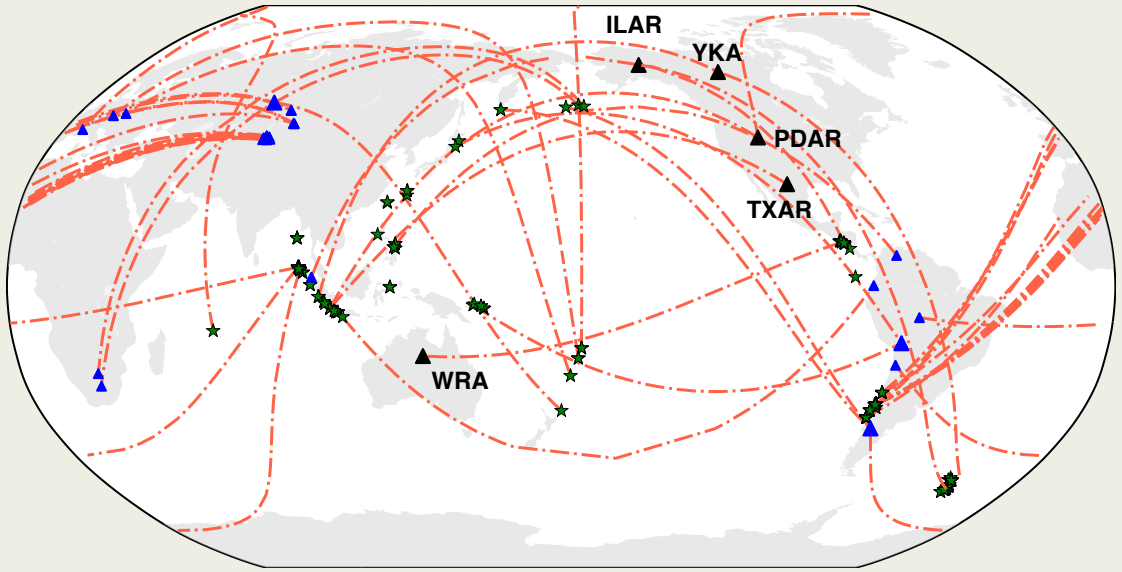
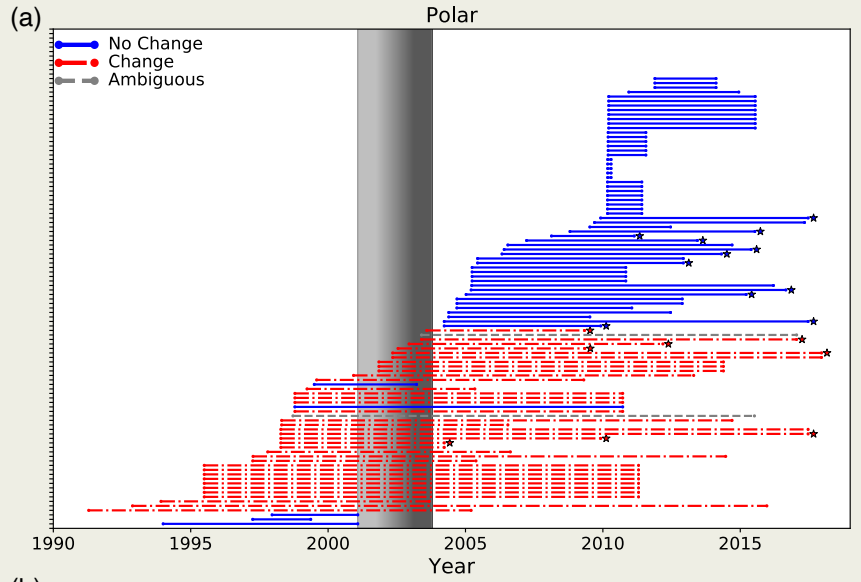
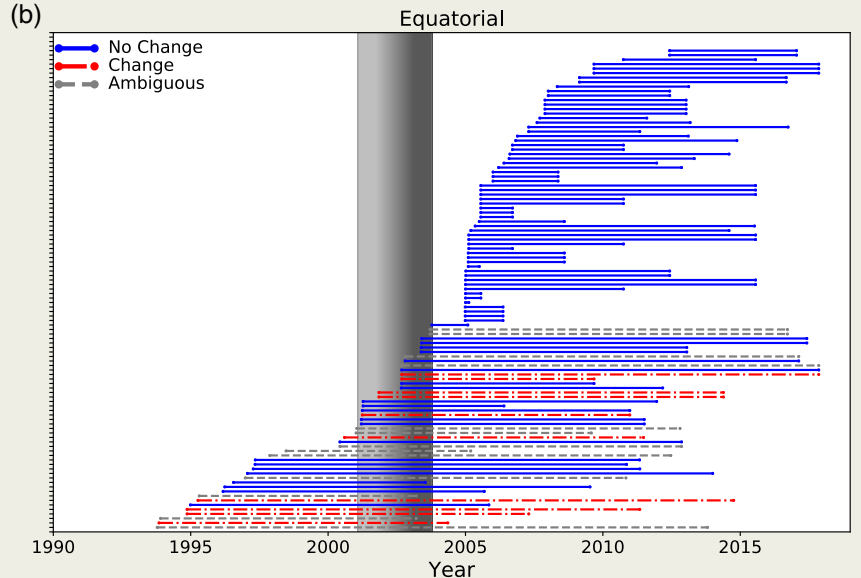
Inner core changed only in 2001–2003







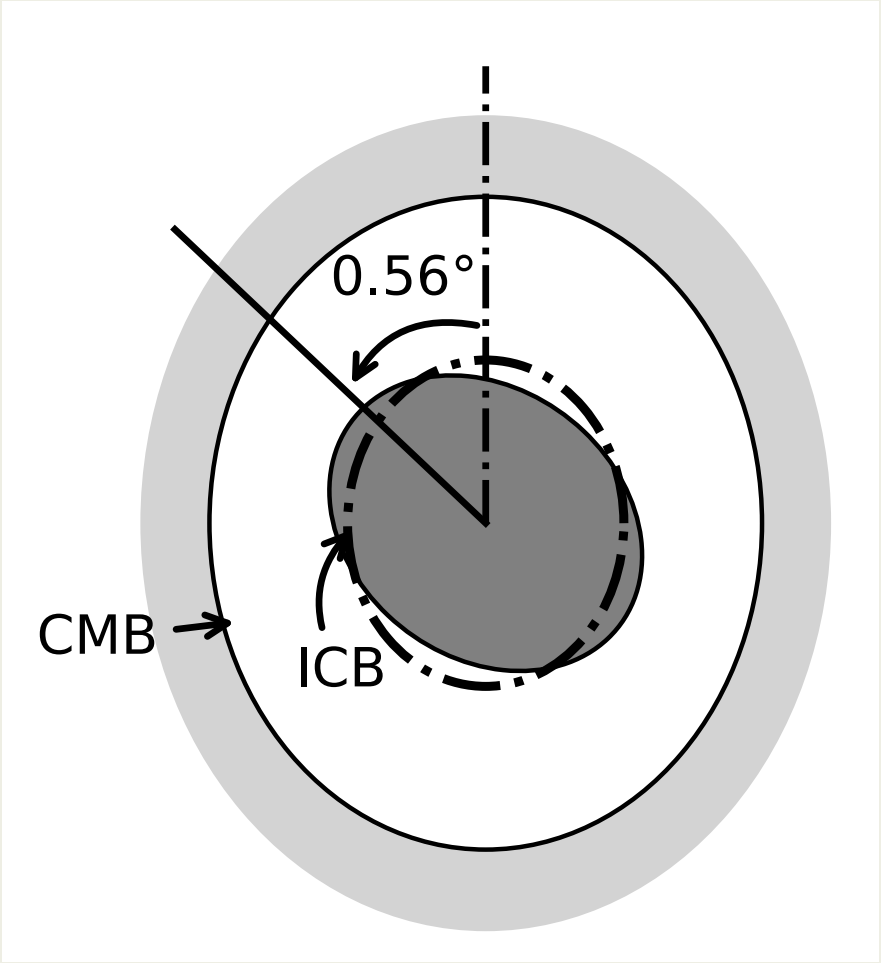
- PKIKP coda only changes if the earthquake doublets cross 2001–2003
- Polar seismic ray paths have more significant changes, expected from inner core differential rotation

Pang & Koper (2022)

Inner core burst of differential rotation

- A burst of differential rotation of ~0.5° during 2001–2003
- Relatively small differential rotation during 1991–2001 and 2003–2017

What is happening after 2003?



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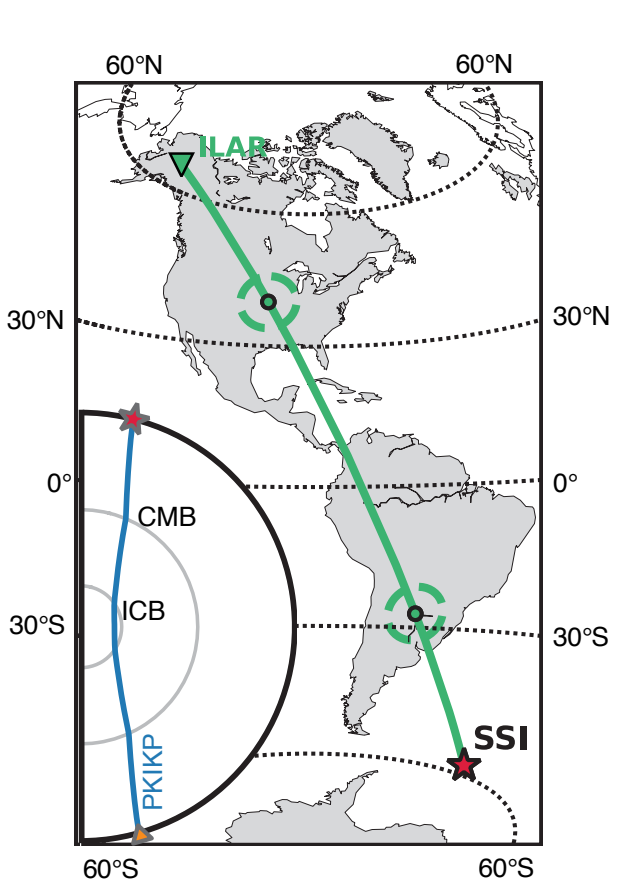
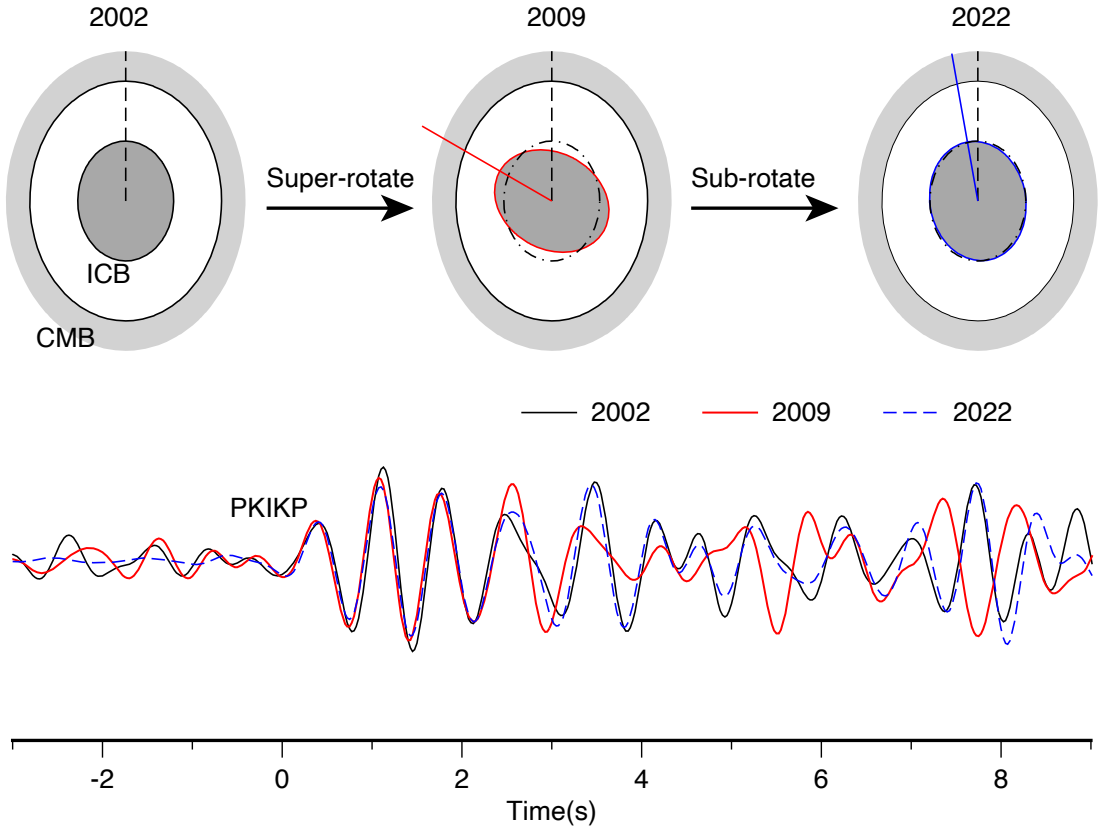
Inner core backtracking





- Focus on SSI–ILAR & YKA and expand earthquake doublet to 2023
- PKIKP changes between 2002–2009, but match up again between 2002–2022

Wang et al., (2024)

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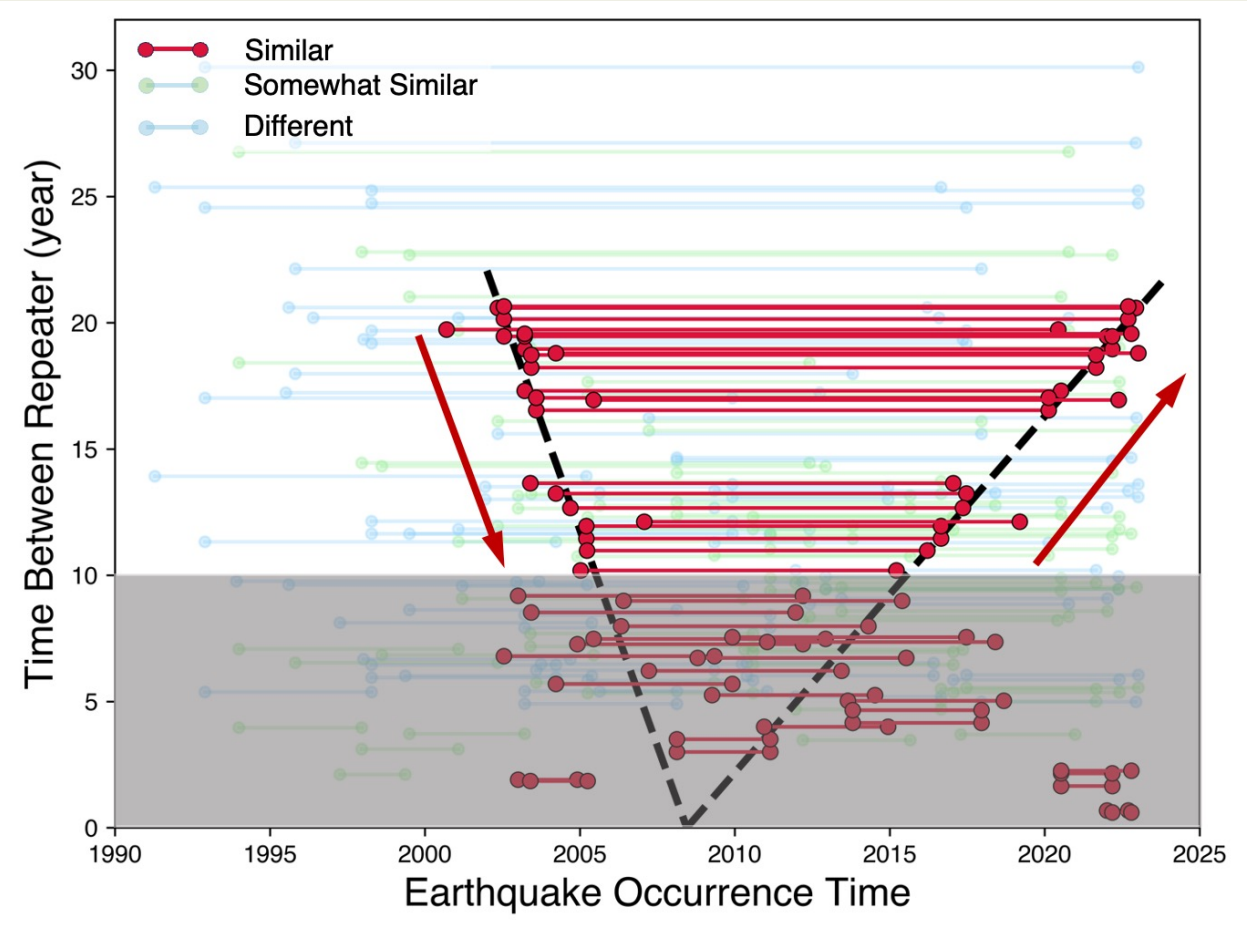
Inner core backtracking

- Inner core super-rotation from 2003–2008
- From 2008–2023, sub-rotate 2–3 times more slowly back to the same path



Wang et al. (2024)

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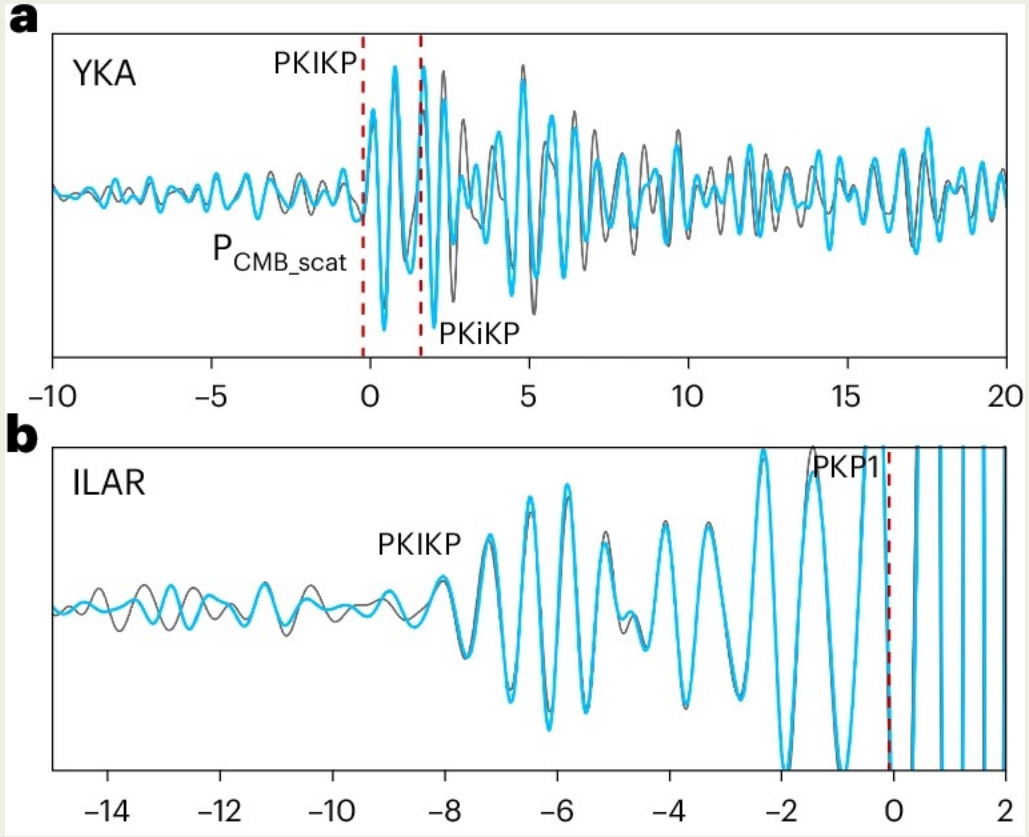
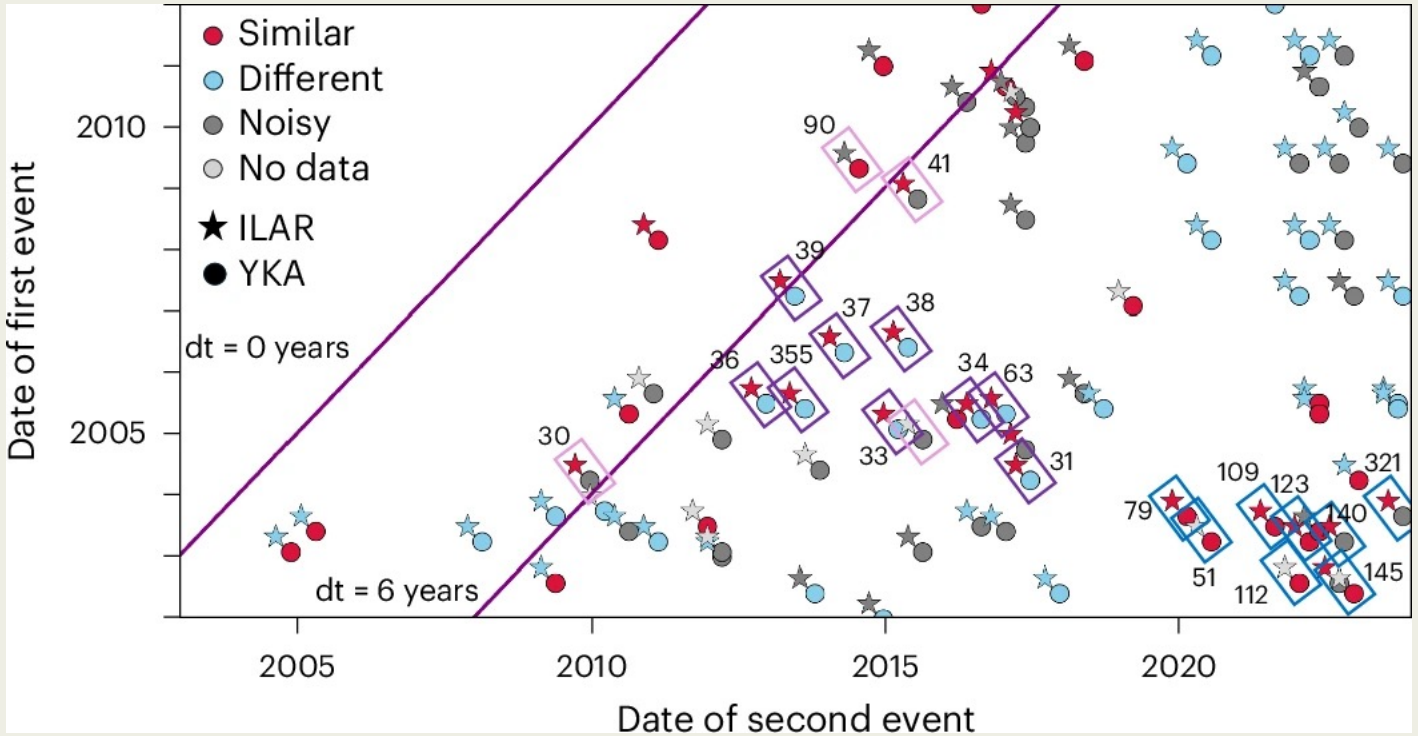
More than rotation: Changes in Inner core's shape





- Tiny changes in waveform in YKA but not ILAR
- Changes in Inner core's shape that only change the shallow ray paths at YKA

Vidale et al. (2025)

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All works are published

Article | Published: 05 July 2023

Enhanced inner core fine-scale heterogeneity towards Earth's centre

Guanning Pang, Keith D. Koper, Sin-Mei Wu, Wei Wang, Marine Lasbleis & Garrett Euler

Nature **620**, 570–575 (2023) | Cite this article

JGR Solid Earth

RESEARCH ARTICLE
10.1029/2022JB024420

Key Points:
- *PKiKP* coda waves recorded by seismic arrays at distances of 50°–75° are used to observe and model inner core scattered energy
- Significant scattering is observed on both sides of the Pacific

A Search for Large-Scale Variations in the Fine-Scale Structure of Earth's Inner Core

Sin-Mei Wu[1,2], Guanning Pang[1,3], Keith D. Koper[1], and Garrett Euler[4]

[1]Department of Geology and Geophysics, University of Utah, Salt Lake City, UT, USA, [2]Now at Swiss Seismological Service (SED), ETH Zurich, Zürich, Switzerland, [3]Now at Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA, [4]Los Alamos National Laboratory, Los Alamos, NM, USA

Excitation of Earth's inner core rotational oscillation during 2001–2003 captured by earthquake doublets

Guanning Pang [a b], Keith D. Koper [a]

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Wei Wang, John E. Vidale, Guanning Pang, Keith D. Koper & Ruoyan Wang

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Annual-scale variability in both the rotation rate and near surface of Earth's inner core

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