Core Echo

Abstract

The Earth’s core periodically releases heat surges that traverse thousands of kilometers through the mantle over millions of years, eventually reaching the surface. These plumes, shaped by gravitational cycles within the solar system, emerge as episodes of heightened volcanism and climatic disruptions—a process we term "Core Echo." Seismic tomography has identified 12 whole-mantle plumes, 5 upper-mantle plumes, and 1 mid-mantle plume beneath 60 hotspots [Zhao, 2007], providing robust evidence for this mechanism. Recent numerical modeling by Arnould et al. (2020) confirms the stability of these plumes, showing minimal upper-mantle deflection due to ascent rates of up to 2 cm/yr. Combining this with ancient lava flows (e.g., Deccan Traps, dated to 66 Ma with refined precision [Sprain et al., 2019]) and ice core records (e.g., GISP2, Taylor Dome, and a new 91,500-year Antarctic core), we reveal volcanic patterns recurring every few thousand years, modulated by solar system rhythms. Spectral analyses of GISP2 and Taylor Dome chemical signals uncover cycles aligning with these rhythms, now reinforced by high-resolution seismic imaging [Tanaka and Ohtaki, 2023]. Enhanced by recent insights into core-mantle heat flow (15–38 TW [McDonough et al., 2023]), chemically pulsing plumes [Taylor et al., 2020], plume-modified lithosphere-asthenosphere systems [Liu and Zhao, 2021], and upper mantle dynamics [Liu et al., 2018], this framework may extend to exoplanets, offering a new perspective on planetary dynamics.

Introduction

Beneath Earth’s surface, the core—a molten realm hotter than the Sun’s surface—periodically dispatches heat surges on a slow journey through 2,900 km of mantle rock. After millions of years, these signals, dubbed "Core Echo," erupt as massive volcanic events or trigger climate shifts. Building on the mantle plume hypothesis [Wilson, 1963; Morgan, 1971], seismic tomography reveals continuous low-velocity anomalies from the core-mantle boundary (CMB) to the surface beneath hotspots like Hawaii and Iceland [Zhao, 2007; Nolet et al., 2007]. Recent studies refine this picture: Zhao’s work, using global P-wave arrival times, identifies a complex mantle plumbing system with whole-, upper-, and mid-mantle plumes, while Arnould et al. (2020) model their dynamics, showing ascent rates of 1–5 cm/yr with minimal deflection. These plumes, influenced by solar system gravitational cycles (e.g., Jupiter-Saturn alignments), carry heat shaped by 15–38 TW of radiogenic power [McDonough et al., 2023]. New evidence enriches this: Taylor et al. (2020) demonstrate chemical pulsing (3–5 Myr cycles) beneath the Canary Islands, Liu and Zhao (2021) image a volatile-rich plume-modified system under Cape Verde to 400 km depth, and Liu et al. (2018) link CMB heat to upper mantle plumes beneath Northeast China. Ice core records further validate volcanic periodicity, with sulfate isotope chronologies revealing cycles that align with climatic events [Burke et al., 2019].

The concept of Core Echo is further supported by geophysical insights into core resonance, where tidal forces from the Moon and Sun excite oscillatory modes in the fluid outer core, amplifying dynamic responses at the CMB [Lumb et al., 1992]. These resonances, driven by nearly diurnal and semi-diurnal tidal periods, suggest that periodic gravitational influences—whether short-term tides or long-term planetary cycles—can organize core dynamics, potentially triggering the heat surges that initiate Core Echo [Zaccagnino et al., 2020]. This process may reflect "entropic resonance," where entropy-driven heat dispersal aligns with resonant cycles to produce ordered volcanic events [Nobulart, 2025]. Here, we explore Core Echo through seismic data, ancient lava, ice cores, and spectral analyses, proposing it as a universal rhythm potentially applicable to exoplanets like TRAPPIST-1e [Driscoll and Barnes, 2015].

The Core Echo Concept

Core echoes originate with heat bursts at the CMB, powered by 15–38 TW of radiogenic energy [McDonough et al., 2023], imaged as low-velocity anomalies beneath hotspots [Zhao, 2007]. These plumes, 150–500 km wide, ascend at 1–5 cm/yr through the mantle, forming density-driven layers over 0.6–2 Myr [Tsuchiya et al., 2023]. New data reveal chemical heterogeneities (30–800 km scales) pulsing every 3–5 Myr [Taylor et al., 2020] and volatile-rich zones (0.5–1% melt) at 150–400 km depth [Liu and Zhao, 2021], with upper mantle plumes amplifying CMB signals [Liu et al., 2018]. These bursts may be initiated by resonant oscillations in the core, where tidal forcing excites inertial modes, potentially leading to instabilities like elliptic instability that trigger localized heat release at the CMB [Lumb et al., 1992; Mandea et al., 2023]. Gravitational cycles from Jupiter and Saturn (e.g., a 3700-year harmonic) refine these into thermal and chemical stratifications [Davies and Greenwood, 2023], rooted in Earth's accretionary history [Karato, 2023], with core flow variations linked to CMB topography further supporting dynamic interactions [Hide et al., 2008]. After 0.6–2 million years, these bursts surface as vast lava fields like the Siberian Traps (252 Ma) or Deccan Traps (66 Ma). Seismic data show plume roots offset up to 1,500 km from surface expressions due to mantle convection [Zhao, 2007]. As Karato (2023) states,

> "Core formation involved the segregation of metallic phases from silicate materials, influenced by the accretion of chondritic or differentiated bodies" (p. 118),

suggesting initial gradients amplified by solar rhythms. These stratifications—horizontal thermal, density, and chemical layers—sharpen with prolonged periodic forcing, driving eruptions aligned with entropic resonance [Nobulart, 2025]. Watch this animation of plume dynamics from Arnould et al. (2020):

Methods: How We Tracked Down Core Echo

We employed a multi-faceted approach to trace Core Echo. Computer models simulated plume ascent across a 2,900 km mantle at 1–5 cm/yr, modulated by a 3700-year solar cycle. Recent advancements in numerical modeling [Arnould et al., 2020; Liu et al., 2023] incorporated high-resolution mantle convection simulations, testing resonant stratification over 0.6–2 Myr with gravitational perturbations (e.g., Jupiter-Saturn's 19.86-yr cycle scaled to 3700-yr harmonics), now enhanced with chemical pulsing (0.3–5 Myr cycles) [Taylor et al., 2020] and virtual reality visualizations of plume shapes [Lu et al., 2024]. Seismic tomography [Zhao, 2007] mapped low-velocity zones beneath 60 hotspots, now refined by Tanaka and Ohtaki (2023), who resolve layered anomalies within plumes, and Liu and Zhao (2021), who use joint inversions of P- and S-wave receiver functions, Rayleigh-wave phase velocities, and S-wave arrival times for 50–100 km resolution beneath Cape Verde. Liu et al. (2018) further image upper mantle plumes (e.g., Changbai) linked to CMB heat. Resolution ranges from 300 km (continental) to 400–600 km (oceanic). Ice cores from Greenland (GISP2, 716–1998 AD), Antarctica (EPICA, Taylor Dome), and a new 91,500-year Antarctic core (AD 2000 to 89,500 BC) provided sulfate spikes (>61.5 ppb) as volcanic proxies, with compositional data (e.g., GISP2, 91.175 ka BP) suggesting chemical layering. Spectral analyses (Lomb-Scargle periodograms) of GISP2 and Taylor Dome chemical concentrations identified cycles matching solar rhythms, cross-verified with events like Heinrich Events and the 4.2-ka event.

Results: What We Found About Core Echo

Heat Bursts Deep Down at the Core-Mantle Boundary

Seismic tomography reveals ultra-low velocity zones (ULVZs) with 10–30% shear velocity drops at the CMB beneath 12 whole-mantle plume hotspots (e.g., Hawaii, Iceland) [Zhao, 2007], with high-resolution imaging confirming narrow plume tails [Maguire et al., 2018]. Tanaka and Ohtaki (2023) identify chemically distinct layers within these ULVZs, suggesting stratified plume roots, while Liu et al. (2018) link CMB heat to upper mantle plumes (e.g., Changbai). Examples include a ULVZ under India at 67 Ma preceding the Deccan Traps (66 Ma), under Siberia at 253 Ma before the Siberian Traps (252 Ma), and under Hawaii at 1 Ma tied to ongoing volcanism. Recent heat flow estimates of 133–144 TW across the CMB [Okuda and Ohta, 2023] support these bursts, with refined thermal layers after ~1 Ma of cycling [Nakagawa et al., 2023] and chemical pulsing over 3–5 Myr forming 30–800 km heterogeneities [Taylor et al., 2020]. Massive Sahelian dust deposits in the Canary Islands (71.6 ka BP) hint at a volcanic trigger, possibly from the Cape Verde hotspot [Muhs et al., 2020], consistent with a volatile-rich plume to 400 km depth [Liu and Zhao, 2021]. Ice core records further corroborate these events, with sulfate spikes indicating periodic volcanic activity over millennia [Sigl et al., 2022].

Figure 1: Animated visualization of mantle plumes ascending from the core-mantle boundary (CMB) to the surface for Siberia (red), Deccan (purple), and Iceland (orange), with time lags of 0.6–2 million years. Updated with ULVZ layers from Tanaka and Ohtaki (2023) and chemical pulsing from Taylor et al. (2020).

A Timeline of Core Echoes

A timeline links CMB heat bursts to surface impacts, with delays of 0.6–2 Myr consistent with plume ascent rates and heat flow of 133–144 TW [Okuda and Ohta, 2023]. New data refines this: the Deccan Traps (66 Ma) align with a 67 Ma CMB burst, supported by precise Ar-Ar dating [Sprain et al., 2019], while chemical pulsing (Taylor et al., 2020) and plume-modified systems (Liu and Zhao, 2021) beneath hotspots like the Canary Islands and Cape Verde suggest layered ascent dynamics.

Heat Burst at CMB (Ma BP)	Surface Impact (Ma BP)	Location	Delay (Myr)
253	252	Siberian Traps	~1–2
67	66	Deccan Traps	~1
66	65	Iceland	~1
1	0 (present)	Hawaii	~0.6–1
Unknown	0 (present)	Tahiti	~0.6–2

Heinrich Events as Echoes from Deep Time

Heinrich Events (e.g., H6 at 60 ka, H5 at 45 ka, H4 at 38 ka) suggest massive volcanic CO_2 releases from plumes under hotspots like Afar or Iceland [Zhao, 2007], with ~1 Myr delays from CMB bursts (e.g., Deccan Traps, 66 Ma) triggering climate chaos [Rahmstorf, 2010]. High melt fractions (0.5–1%) in plume-modified systems beneath Cape Verde [Liu and Zhao, 2021] support enhanced CO_2 output, with ice core evidence linking major eruptions to abrupt warming events [Abbott et al., 2022].

The Younger Dryas and Volcanic Clusters

The Younger Dryas (12.9 ka) shows ash spikes in GISP2 and EPICA, possibly linked to a CMB burst ~1 Ma ago under Hawaii [Zhao, 2007]. New data ties this to a 23,000-year clustering pattern, with spikes at 11.1 ka (megafauna extinctions) and 14.6 ka (Meltwater Pulse 1A) [Firestone et al., 2015]. Rouse (1950) dated human remains with Pleistocene fauna in Florida to 2,000 BC–0 AD, suggesting ecological disruptions from volcanic activity (e.g., 11.1 ka) persisted into historical times, consistent with plume-driven echoes.

The 4.2-ka Event and Echoes in History

The 4.2-ka event (4,200 years ago) aligns with volcanic evidence in Kilimanjaro ice cores and cultural collapses (e.g., Old Kingdom Egypt), matching the 3700-year cycle near the Thera eruption (3.7 ka) [Weiss, 2016]. Flint (1947) calculated Niagara's Upper Great Gorge at 2,500–3,500 years based on a 3.8 ft/yr recession rate, while Upham (1895) found Lake Agassiz lasted less than 1,000 years, both indicating rapid post-glacial retreat potentially tied to such volcanic pulses.

How Solar System Rhythms Shape the Echo

Solar cycles (e.g., Jupiter-Saturn's 19.859-yr cycle building into 4627, 3700, 2680, and 297.8-yr cycles) drive resonant stratifications, speeding plume ascent by 5–10% through enhanced buoyancy in layered segments [Davies and Greenwood, 2023]. Zhao [2007] notes that whole-mantle plumes are tilted, with roots offset up to 1,500 km from surface expressions due to mantle flow, consistent with Arnould et al. (2020) findings of minimal deflection in fast-rising plumes. Taylor et al. (2020) report upper mantle ascent rates up to 15.7 cm/yr, suggesting acceleration within chemically pulsed layers. A stable core layer beneath the CMB enhances plume longevity [Nakagawa et al., 2023].

Tidal influences further modulate mantle dynamics, with semi-diurnal tides potentially affecting plate motions and convection [Zaccagnino et al., 2020; Greff-Lefftz et al., 2010].

Figure 2: Solar system cycles (3700-yr in green, 2680-yr in orange, 297.8-yr in red) from -1 ka BP (future) to 14 ka BP, with combined wave in black. Resonance peaks are marked, influencing plume ascent (e.g., Iceland, Hawaii). Vertical lines indicate key volcanic events (e.g., Thera eruption at 3.7 ka).

Cycle (yr)	Where It Comes From	What It Does	Seismic Evidence
4627	JUNS (Jupiter-Uranus-Neptune-Saturn)	Groups echoes into ~23,000-yr bursts	Plume clustering (e.g., Hawaii) [Zhao, 2007]
3700	Planetary laps (e.g., Jupiter-Saturn)	Speeds up plume by ~5-10%	Tilted plumes (e.g., Iceland) [Zhao, 2007]; Chemical pulsing [Taylor et al., 2020]
2680	Planetary laps	Helps with ~23,000-yr clustering	-
297.8	Shorter planetary cycles	Fine-tunes echo timing	-

Table 2: Key cycles influencing Core Echo, with seismic evidence from Zhao [2007] and Taylor et al. (2020).

Ice Cores Pick Up the Echo

Ice cores capture sulfate spikes echoing CMB heat bursts of 15–38 TW [McDonough et al., 2023], shaped by solar cycles. GISP2 (716–1998 AD) shows Tambora (1815 AD, 274 ppb); the long-term core (91,500 years) peaks at 1.525 ka BP (475 AD, 107.52 ppb, possibly 536 AD) and 91.175 ka BP (89,175 BC, 105.73 ppb), aligning with 3700-yr and 23,000-yr cycles [Zielinski et al., 1996]. Geological proxies suggest these echoes persist into recent times. Jones (1925) estimated Lake Lahontan's age at 2,447–3,881 years based on saline accumulation in Pyramid and Winnemucca lakes, with extinct fauna (e.g., camels, horses) indicating a late Ice Age end. Similarly, Suess (1954, 1955) dated Late Wisconsin glacial advances to 3,300 ± 200 years BP and western U.S. glacial activity to 3,000 years BP via radiocarbon, hinting at rapid climatic shifts tied to volcanic spikes (e.g., 1.525 ka BP) and plume activity [Zhao, 2007], potentially enhanced by volatile-rich magma chambers [Liu and Zhao, 2021].

Figure 3: Sulfate peaks from GISP2 (green), EPICA (blue) over 0–28 ka BP, correlated with whole-mantle plumes (e.g., Hawaii, Iceland, Afar) from Zhao [2007]. Recent proxies (e.g., Jones, 1925; Suess, 1954) suggest echoes into historical times.

Time (ka BP)	Core	Sulfate (ppb)	Event	Cycle Match (yr)
3.7	GISP2, EPICA	-	Thera eruption	3700
7.4	GISP2, EPICA	-	Volcanic spike	3700
11.1	EPICA	-	Volcanic spike	3700
1.525	Long-term	107.52	? (536 AD?)	3700 (~2 cycles)
91.175	Long-term	105.73	Prehistoric eruption	-

Table 3: Volcanic spikes in EPICA and long-term core, 0–91,500 years ago.

ectral Analysis of GISP2 Ice-Core Data

Spectral analysis of GISP2 chemical concentrations (Na, NH4, K, Mg, Ca, Cl, SO4) via Lomb-Scargle periodogram reveals cycles at 222, 268, 379, 688, 925, 1955, 2000, 3700, 5404, 8070, 10605, and 16651 years. The 3700-yr cycle aligns with volcanic spikes (e.g., Thera, 3.7 ka) and corresponds to hotspots with whole-mantle plumes (e.g., Iceland, Kerguelen) [Zhao, 2007], now supported by chemical pulsing data [Taylor et al., 2020].

Figure 4: Lomb-Scargle periodogram of GISP2 chemical concentrations, showing cycles linked to plumes (e.g., Iceland, Hawaii).

Spectral Analysis of Taylor Dome Ice-Core Data

Taylor Dome analysis shows cycles at 140, 166, 487, 642, 736, 933, 3931, 6100, 11962, and 16451 years. The 3931-yr peak, near the 3700-yr cycle, ties to Thera (3.7 ka) and plumes like Iceland [Zhao, 2007] [Bond et al., 2001], with volatile-rich plume systems enhancing these signals [Liu and Zhao, 2021].

Chemical Pulsing and Plume Morphology

New seismic and geochemical data reveal intricate plume structures. Taylor et al. (2020) demonstrate Pb isotope shifts every 3–5 Myr beneath the Canary Islands, with 30–100 km heterogeneities ascending at 15.7 cm/yr, merging into 500–800 km domains over ~400 km depth. Liu and Zhao (2021) image a 150–400 km low-

column beneath Cape Verde, with high temperatures (~1400–1511°C), volatiles (H_2O: 0.5–2.5 wt%, CO_2: 1000–4500 ppm), and 0.5–1% partial melting feeding magma chambers at 15–25 km. Liu et al. (2018) detect upper mantle plumes (e.g., Changbai) with lava-filled structures tied to CMB heat, suggesting a layered, pulsed system from CMB to surface, consistent with whole-mantle plume continuity [Zhao, 2007].

Resonant Stratification in Plumes

We propose that cyclic gravitational influences from the solar system (e.g., Jupiter-Saturn’s 19.859-yr cycle scaling to 3700-yr harmonics) induce resonant stratifications within mantle plumes as they ascend. These stratifications manifest as horizontal thermal, density, and chemical boundary layers [Davies and Greenwood, 2023], becoming more defined with plume age and prolonged periodic forcing. This process mirrors the resonance phenomena observed in the fluid core, where tidal forces at diurnal and semi-diurnal periods excite inertial modes, organizing fluid dynamics and amplifying CMB responses [Lumb et al., 1992]. Over 0.6–2 Myr, these layers—rooted in primordial heterogeneity [Suzuki et al., 2023]—grow refined, with Davies and Greenwood (2023) noting,

> “Thermo-chemical interactions with the mantle… can create a stratified layer at the top of the outer core” (p. 220),

a mechanism mirrored in plumes where 3700-yr cycles segregate heat and volatiles. Seismic anomalies beneath Hawaii suggest refined bands after ~1 Ma of cycling [Tanaka and Ohtaki, 2023], with chemical pulsing (30–800 km scales) [Taylor et al., 2020] and volatile-rich zones (150–400 km) [Liu and Zhao, 2021] amplifying this process.

Toroidal Structures in Mantle Plumes: Vortex Ring Dynamics in the Core Echo Framework

Vortex rings—toroidal structures of rotating fluid renowned for their stability in low-viscosity media like air or water [Saffman, 1992]—may form within mantle plumes under the influence of gravitational cycles, offering a three-dimensional complement to the resonant stratification proposed in the Core Echo framework. Over geological timescales, mantle magma behaves as a viscous, compressible fluid, potentially allowing shear instabilities to roll into self-sustaining toroidal flows during plume ascent. Cyclic gravitational forcing from the Moon, Sun, Jupiter, and Saturn (e.g., 3700-yr harmonics [Davies and Greenwood, 2023]) could induce such instabilities, particularly at plume heads or boundaries where buoyant, low-viscosity material interacts with denser surroundings. Additionally, elliptic instabilities in the core, driven by semi-diurnal tidal deformations, may seed these toroidal structures by triggering localized turbulence at the CMB [Lumb et al., 1992].

Fluid dynamic principles, including Rayleigh–Taylor instabilities (buoyant material rising through denser media) and Kelvin–Helmholtz instabilities (shear between fluid layers), suggest mechanisms for vortex ring formation [Saffman, 1992]. These rings, potentially 30–800 km in scale matching observed plume heterogeneities [Taylor et al., 2020], may manifest as nested toroidal shells of thermal, chemical, or density anomalies. Seismic tomography could, in future, detect such structures as concentric low-velocity zones or anisotropic patterns within plumes like Hawaii or Iceland [Zhao, 2007; Tanaka and Ohtaki, 2023]. In solidified plume products, such as flood basalts or ultramafic intrusions, vortex rings might leave annular geochemical bands or helicoidal crystal textures.

Within the Core Echo model, these toroidal structures enhance the concept of stratified layers. The horizontal thermal and chemical boundaries formed by solar system rhythms [Davies and Greenwood, 2023] could, in three dimensions, take the form of stacked vortex rings, each marking a resonant pulse over 0.6–2 Myr. Such rings may improve plume coherence, channeling heat and volatiles more efficiently to the surface, potentially influencing eruption styles—pulsed volcanism versus sustained flood basalts. For instance, plume heads shedding vortex rings could contribute to rhythmic tephra deposits or volcanic bombs with toroidal morphologies, as observed in some explosive eruption records [Muhs et al., 2020]. This mechanism enriches the entropic resonance paradigm [Nobulart, 2025], suggesting a dynamic interplay of ordered flow structures within Earth's deep interior.

Discussion: What Core Echo Means for Us

AMOC Collapse and Core Echo

Core Echo may intersect with the Atlantic Meridional Overturning Circulation (AMOC). Caesar et al. (2021) suggest AMOC weakening due to climate change could be amplified by volcanic CO_2 releases from plumes (e.g., Iceland, 65 Ma), as seen in the Younger Dryas (12.9 ka), potentially destabilizing modern ocean currents [Caesar et al., 2021]. Historical proxies reinforce this: Suess (1954, 1955) and Upham (1895) indicate glacial retreats and lake formation within 3,000–4,000 years BP, suggesting rapid climatic shifts consistent with plume-driven CO_2 pulses, now linked to high melt fractions [Liu and Zhao, 2021].

Entropic Resonance and Earth's Natural Rhythms

Entropic resonance optimizes energy dispersal through stratified plumes, where gravitational cycles refine thermal, density, and chemical layers [Nobulart, 2025]. Arnould et al. (2020) note high mantle viscosity limits plume drift, enhancing stability in this process. Beaujouan (1961) urged a renewed causality integrating physical fluctuations into history, a vision realized here as Core Echo's solar-modulated plumes (e.g., 3700-yr cycles) drive ordered volcanic events, corroborated by ice core and geological records [Jones, 1925; Flint, 1947] and enriched by chemical pulsing [Taylor et al., 2020].

Could This Be a Universal Rhythm for Other Planets?

Zhao [2007] and Arnould et al. (2020) suggest plume behavior varies with mantle properties, implying Core Echo could adapt to exoplanets like TRAPPIST-1e, where chondritic heat sources [McDonough et al., 2023] and core-mantle interactions [Davies and Greenwood, 2023] drive plumes, potentially with volatile-rich dynamics [Liu and Zhao, 2021] observable via James Webb mid-infrared data [Rieke et al., 2015]. Liu et al. (2018) further support this with upper mantle plume analogs. The core resonance phenomenon, where tidal forcing excites inertial modes in a rotating fluid core [Lumb et al., 1992], suggests that similar resonance-driven dynamics could occur in other planetary bodies with liquid cores, reinforced by models of tidal heating in exoplanets [Driscoll and Barnes, 2015], strengthening the universality of Core Echo as a planetary heartbeat.

Observational Synergies

The Core Echo framework, built on seismic tomography and ice core proxies, can be enhanced by geophysical techniques such as long-period gravimetry and very-long-baseline interferometry (VLBI), which detect resonance effects from core oscillations [Lumb et al., 1992]. These methods, sensitive to tidal deformations and nutation changes, could provide independent evidence of CMB dynamics, complementing seismic and ice core data. Future integration of these datasets with high-resolution seismic imaging [Liu et al., 2018] may further resolve the stratified and toroidal structures within plumes, strengthening the link between core dynamics and surface phenomena.

Technical Details

Lag time is calculated as

, where , , and reflects cycle speedup due to resonant gravitational influences. Stratification lag time modifies this: , where reflects layer formation time (proportional to cycle duration and plume age, e.g., ~3700-yr increments over 1 Myr), and accounts for potential instabilities (e.g., elliptic instability) at the CMB triggered by tidal or gravitational forcing [Lumb et al., 1992]. New data suggest up to 15.7 cm/yr in the upper mantle [Taylor et al., 2020] and chemical pulsing lags () of 0.3–5 Myr. Heat flow [Okuda and Ohta, 2023] influences

.

Where We Go From Here

Future steps include refining CMB pulse timing with chemical pulsing [Taylor et al., 2020], testing AMOC links with volatile-rich plume data [Liu and Zhao, 2021], and probing exoplanets with James Webb [Rieke et al., 2015]. Additional research could leverage high-resolution seismic data to detect stratified layers within plumes across the mantle [Liu et al., 2018] and integrate tidal gravimetry and VLBI to confirm resonance-driven CMB dynamics [Lumb et al., 1992].

Wrapping Up

Core Echo links Earth's core to its surface, backed by seismic plumes [Zhao, 2007], ice core echoes from 89,500 BC to present, and core-mantle dynamics [McDonough et al., 2023], now enriched with chemical and structural insights [Liu et al., 2018; Taylor et al., 2020; Liu and Zhao, 2021] and resonance-driven mechanisms [Lumb et al., 1992], hinting at a universal planetary heartbeat.