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Cosmic Priors: An Agent-Based Model of Civilizational Development under Solitude, Uncertainty, and Extraterrestrial Plurality

Daniel Ward

Department of Computer Science, Southern New Hampshire University, Manchester, USA
Email: d.ward@snhu.edu

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Abstract

Human societies have never developed under verified common knowledge that independently evolved extraterrestrial technological intelligence exists, or that humanity is cosmically alone. This study introduces Cosmic Priors, an agent-based model that treats solitude, persistent uncertainty, and extraterrestrial plurality as alternative epistemic genesis conditions rather than modern disclosure events. Identical synthetic populations coevolve cultural narratives and scientific, philosophical, educational, and political institutions across five matched worlds: solitude, uncertainty, plurality, uncertainty-to-solitude, and uncertainty-to-plurality. The primary experiment comprised 800 matched world histories, 1500 agents per world, and 90 generations, with common random numbers and a neutral fixed seed. Persistent uncertainty generated the greatest terminal narrative diversity (0.971) and inquiry investment (0.395). Plurality reduced species-uniqueness exceptionalism relative to solitude (0.445 versus 0.567) while increasing species-level identity (0.589 versus 0.444). Both late-resolution worlds experienced short-term worldview disruption despite converging toward genesis-world outcomes. The findings do not forecast actual civilizations; they demonstrate that cosmic knowledge can be modeled as a selection environment for cultural and institutional evolution, while separating the content of an answer from the historical cost of resolving foundational uncertainty.

Keywords

Agent-Based Modeling, Astrobiology, Cultural Evolution, Extraterrestrial Intelligence, Human Exceptionalism

1. Introduction

Whether humanity is alone, uncertain of its status, or one intelligent species among many is ordinarily treated as a question for astronomy, theology, or philosophy. It can also be treated as an initial condition of civilization. A society that has always known that extraterrestrial technological intelligence exists would not experience that fact as disclosure; its cosmologies, institutions, identities, and traditions of inquiry would form around that knowledge from the beginning. Conversely, a society that develops under uncertainty may build institutions around the unresolved question and incur transition costs when the answer becomes certain.

Existing empirical research provides little basis for assuming that extraterrestrial confirmation would automatically produce social collapse. Reactions to hypothetical or reported discoveries of extraterrestrial life have tended to be more positive than negative (Kwon et al., 2018), while studies of religious response do not support a general expectation of doctrinal disintegration (Peters, 2011). The broader post-detection literature instead emphasizes heterogeneous responses ranging from fear and threat appraisal to curiosity, equanimity, and delight (Harrison, 2011). These studies are informative but examine people socialized under present uncertainty; they cannot reveal how institutions would develop if certainty were present at cultural genesis.

This paper, therefore, shifts the unit of analysis from contemporary disclosure to epistemic genesis. It asks how otherwise identical civilizations diverge when common knowledge establishes cosmic solitude, leaves the question unresolved, or establishes extraterrestrial plurality. Two additional worlds begin under uncertainty and later resolve toward solitude or plurality. Their inclusion separates the content effect of the answer from the path-dependent effect of replacing a foundational cosmology.

The study contributes a transparent computational mechanism laboratory rather than a literal alternate-history forecast. The model integrates cultural inheritance, narrative competition, evidence sensitivity, meaning seeking, social conformity, institutional reinforcement, and environmental shocks. Its purpose is to derive conditional implications from explicit assumptions and to identify which findings persist under global sensitivity analysis.

2. Theoretical Background

2.1. Cosmic Knowledge as a Cultural Selection Environment

The central theoretical move is to treat cosmic status as common knowledge that changes the selection environment for narratives and institutions, not as a direct cause of predetermined outcomes. Solitude constrains extraterrestrial-pluralist claims but leaves supernatural, cryptoterrestrial, simulation, and other metaphysical narratives logically available. Uncertainty preserves a large unresolved question space. Plurality constrains strict species-solitude claims but does not determine how humanity interprets the other intelligence, its moral status, or human-

ity's own significance.

This narrow treatment is necessary because nonhuman-intelligence hypotheses differ in their relationship to humanity. Masters's extratempestrial model, for example, interprets at least some anomalous entities as future human descendants rather than independently evolved extraterrestrials (Masters, 2022). The model developed here does not adjudicate that hypothesis. It isolates independently evolved extraterrestrial technological intelligence so that later studies can vary whether the other intelligence is extraterrestrial, cryptoterrestrial, artificial, transcendent, or genealogically related to humanity.

Contemporary social-scientific research also shows why extraterrestrial confirmation should not be represented as a single undifferentiated event. In an online survey of 130 respondents, Döbler et al. (2023) found no confident, consistent relationship between loneliness or need for closure and belief in extraterrestrial life or intelligence. However, frequent religious activity was negatively associated with belief in extraterrestrial life. Schwarz and Seidl's (2023) analysis of 272 German news articles identified three distinct frames—beneficial space exploration, UAP/ETI, and SETI risk—demonstrating that public meaning depends in part on the communication context. Anton et al. (2024) develop differentiated first-contact scenarios, while Wisian and Traphagan (2020) and Wright et al. (2023) disagree about how strongly geopolitical monopoly and conflict risks should guide SETI policy after successful detection. Together, this literature supports treating remote, noncommunicating plurality separately from signal interpretation, direct contact, media framing, technology transfer, hostility, and state competition.

2.2. Awe, the Small Self, and Moral Identity

Awe research suggests one plausible but non-deterministic pathway from a cosmic perspective to social behavior. Awe can reduce the salience of the individual self and increase prosocial behavior (Piff et al., 2015); cross-cultural experiments have also linked the small-self experience with collective engagement (Bai et al., 2017). Accounts of the overview effect similarly connect perceptions of planetary smallness with self-transcendence and global identification (Yaden et al., 2016). Yet awe is generally a temporary state rather than a permanent civilizational trait. Accordingly, the model allows plurality-associated awe to decay unless educational, ritual, scientific, or philosophical institutions reinforce it.

2.3. Exceptionalism, Uncertainty, and Worldview Defense

Human exceptionalism is treated as a variable basis of identity rather than a binary belief. Research on mind perception shows that people attribute mental capacities unevenly across human and nonhuman targets (Gray et al., 2007). Knowledge of extraterrestrial intelligence may reduce claims of species uniqueness while preserving moral, spiritual, civilizational, or relational forms of exceptionalism. Persistent uncertainty likewise need not produce one response. Uncertainty-identity theory predicts that uncertainty can motivate stronger group identification and

adherence to meaning-providing systems, particularly when identity-relevant ambiguity is salient (Hogg, 2007). The model, therefore, assigns agents heterogeneous needs for meaning, evidence sensitivity, conformity, and cognitive flexibility.

2.4. Religion, Cooperation, and Institutional Coevolution

Religious and philosophical institutions serve explanatory, moral, coordinating, and identity functions. Empirical work has linked beliefs in moralizing supernatural agents to increased cooperation in some settings (Purzycki et al., 2016), but the causal sequence remains contested. Updated analyses using the Seshat Databank indicate that moralizing religions did not drive the rise of social complexity and instead developed alongside intergroup warfare and resource conditions (Turchin et al., 2023), while cross-cultural studies report substantial contextual variation in relationships between religious belief and cooperation (Lang et al., 2019). The model therefore rejects a one-way assumption that cosmology creates social complexity. Narratives and institutions coevolve with material conditions, conflict, population structure, and institutional performance.

2.5. Agent-Based Cultural Evolution

Agent-based modeling is appropriate when macro-level patterns emerge from heterogeneous agents interacting under explicit rules. Generative social science emphasizes explaining a collective outcome by demonstrating how plausible local mechanisms can produce it (Epstein, 2006). Cultural evolution research likewise models transmission, selection, drift, mutation, and institutional inheritance across generations (Boyd & Richerson, 1985; Henrich, 2016; Mesoudi, 2011). The model follows the Overview, Design Concepts, and Details logic for transparent agent-based documentation (Grimm et al., 2020) and uses matched worlds, repeated runs, and global sensitivity analysis rather than a single illustrative trajectory.

3. Research Questions and Hypotheses

The study addresses four research questions:

RQ1. How do solitude, uncertainty, and plurality from genesis affect long-run narrative diversity, exceptionalism, moral identity, inquiry, cooperation, conflict, and existential coherence?

RQ2. Does late resolution of cosmic uncertainty produce disruption beyond the outcomes observed in civilizations born with the same answer?

RQ3. Are late plurality and late solitude symmetric, or does extraterrestrial plurality create an additional transition effect?

RQ4. Which behavioral and institutional parameters most strongly determine the direction and magnitude of divergence?

Eight hypotheses were preregistered within the executable model specification before the primary batch was run: persistent uncertainty would maximize narrative diversity (H1) and inquiry investment (H2); plurality would lower species-

uniqueness exceptionalism (H3) and increase species-level identity (H4); cosmological knowledge alone would not eliminate conflict (H5); plurality from genesis would avoid acute disclosure shock (H6); both late-resolution worlds would incur transition costs (H7); and any excess cost in late plurality relative to late solitude would isolate a plurality-specific effect (H8).

4. Materials and Methods

4.1. Evidence Synthesis and Model Scope

The mechanism corpus was assembled through searches in Elicit, Crossref, Google Scholar, and publisher databases. Searches combined the terms extraterrestrial life discovery, extraterrestrial intelligence and religion, cosmic awe and small self, human exceptionalism, uncertainty and worldview defense, moralizing gods and social complexity, cultural evolution, and agent-based social simulation. During revision, targeted searches were added for SETI societal response, technosignature detection, first-contact scenarios, SETI media framing, and the geopolitical consequences of successful detection. The primary window was 2000-2026, with older foundational works retained when they defined a theory or modeling method. Sources were included when they provided empirical findings, causal mechanisms, historical sequences, or reproducible computational methods relevant to at least one modeled process. Popular commentary, unsupported disclosure claims, and sources that could not be verified through a publisher or bibliographic record were excluded. The synthesis informed the mechanism direction and sensitivity ranges; it did not provide point estimates for forecasting actual civilizations. Table 1 summarizes the evidence domains and their roles in the model.

Table 1. Evidence domains and their roles in the model.

Evidence domain	Modeled mechanism	Use
ET discovery and post-detection research	Affect, religious accommodation, heterogeneous response	External plausibility constraints; no collapse assumption
Awe and overview-effect research	Temporary small-self and moral-circle effects	Plurality-associated state with institutional reinforcement and decay
Exceptionalism and mind perception	Species uniqueness and moral standing	Agent heterogeneity and narrative attributes
Uncertainty and identity	Worldview defense, group identification, closure seeking	Narrative switching and persistence
Religion and social complexity	Coordination, meaning, reciprocal institution formation	Bidirectional narrative-institution dynamics
Agent-based cultural evolution	Transmission, mutation, selection, emergence	Simulation architecture and validation

4.2. Counterfactual Worlds

The model contains five matched worlds, summarized in Table 2. Solitude, un-

certainty, and plurality are genesis worlds. The two resolution worlds remain uncertain through generation 44 and receive incontrovertible common knowledge at generation 45. The plurality condition specifies at least one independently evolved, remote technological civilization that is unmistakably real but not communicating, intervening, transferring technology, or displaying hostility. This isolates cosmic plurality from contact, threat, and competition for resources.

Table 2. Cosmic genesis and resolution worlds.

Symbol	World	Common-knowledge condition
S	Solitude from genesis	No independently evolved extraterrestrial technological intelligence exists.
U	Persistent uncertainty	The existence of extraterrestrial technological intelligence remains unresolved.
P	Plurality from genesis	At least one independently evolved extraterrestrial technological civilization exists.
$U \to S$	Late solitude	Uncertainty through generation 44; solitude becomes certain at generation 45.
$U \to P$	Late plurality	Uncertainty through generation 44; plurality becomes certain at generation 45.

The modeled world set is:

$$\mathcal{W} = \{S, U, P, U \to S, U \to P\}. \quad (1)$$

4.3. Agents, Narratives, and Institutions

Each world contains 1500 agents distributed across 20 communities. Agents vary in evidence sensitivity, need for meaning, conformity, inheritance weight, curiosity, cognitive flexibility, institutional trust, exceptionalism preference, moral openness, threat sensitivity, and agency attribution. Traits are initialized from beta distributions and transmitted imperfectly to replacement cohorts with Gaussian mutation. All matched worlds in a replication use the same synthetic population, initial narratives, communities, environmental shocks, and pseudo-random stream.

Five narrative archetypes compete: empirical inquiry, human uniqueness, cosmic pluralism, transcendent agency, and pragmatic agnosticism. They are analytical bundles rather than labels for existing religions or philosophies. Each carries normalized attributes for meaning, coordination, inquiry, exceptionalism, moral-circle radius, and adaptability. A separate evidence-fit matrix specifies compatibility with solitude, uncertainty, or plurality. Religious or metaphysical narratives remain possible in all worlds; only claims directly contradicting the common-knowledge condition receive a fit penalty. The complete numerical narrative-attribute matrix is provided in Supplementary Table S1, and the complete solitude-uncertainty-plurality evidence-fit matrix is provided in Supplementary Table S2. The executable model loads these values directly as NARR_ATTR and EVIDENCE_FIT.

Narrative institutions accumulate support from adherent share, coordination performance, and evidential alignment. The institutional layer represents the co-evolution of scientific, philosophical/religious, educational, and political author-

ity without assuming a fixed modern institutional structure. Institution support changes gradually, introducing path dependence and permitting late-resolution worlds to retain structures formed under uncertainty.

Figure 1 summarizes the model architecture and the reciprocal relationships among genesis conditions, agent traits, cultural narratives, institutions, social dynamics, and civilizational outcomes.

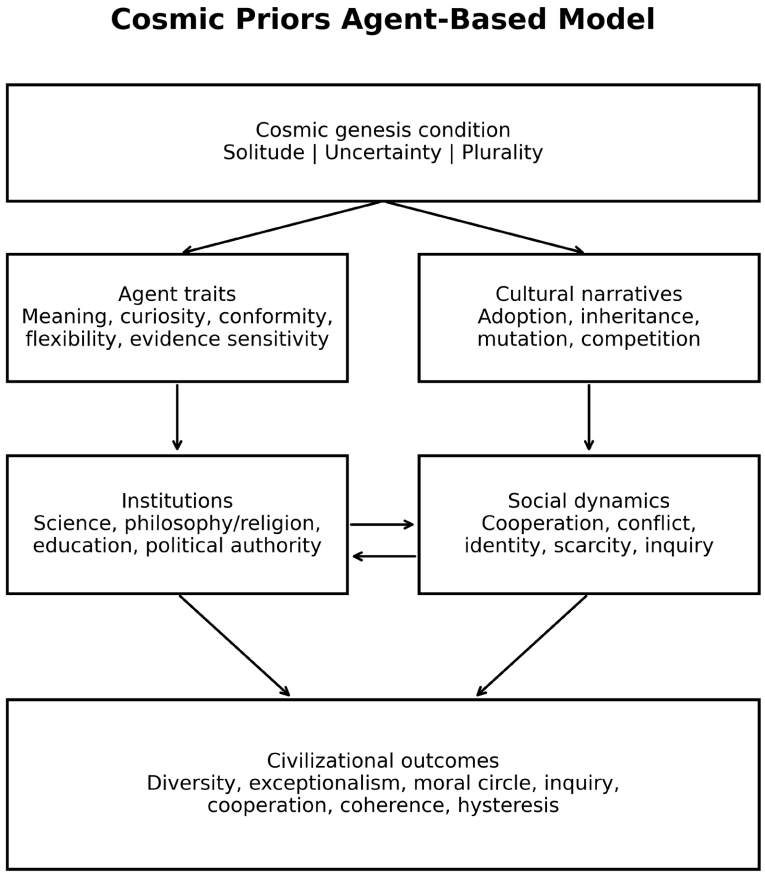

Figure 1. Architecture of the Cosmic Priors agent-based model. Cosmic knowledge constrains narrative evidence fit, while agents, narratives, institutions, and social dynamics co-evolve.

4.4. Narrative Adoption and Institutional Updating

For agent i, narrative n, world w, and generation t, narrative utility combines evidential fit, meaning utility, local social prevalence, inherited attachment, institutional support, inquiry return, identity compatibility, and idiosyncratic noise:

$$F_{inwt} = \omega_E e_i E_{nw} + \omega_M m_i M_n + \omega_S c_i S_{inwt} + \omega_H h_i H_{in,t-1} + \omega_I \tau_i I_{nwt} + \omega_Q q_i Q_n R_w + \omega_X X_{in} + \varepsilon_{inwt}. \quad (2)$$

The probability of adopting narrative n follows a multinomial logit rule:

$$\Pr\left(N_{i,t} = n\right) = \frac{\exp\left(F_{inwt}/\theta\right)}{\sum_{k=1}^{5} \exp\left(F_{ikwt}/\theta\right)}. \quad (3)$$

Institutional support is updated through inertia and a softmax transformation of adherent share, coordination performance, and evidential alignment:

$$I_{n,t+1} = \phi I_{nt} + (1-\phi)\frac{\exp(\kappa P_{nt})}{\sum_{k=1}^{5}\exp(\kappa P_{kt})}. \quad (4)$$

During resolution generation, agents incur a contradiction cost proportional to the decline in the fit of their inherited narrative and inversely proportional to cognitive flexibility. The cost decays over subsequent generations. Plurality-associated awe is modeled as a temporary state and as a culturally reinforced state proportional to support for empirical inquiry and cosmic pluralist institutions.

4.5. Generation Sequence and Social Dynamics

Each generation proceeds in a fixed sequence documented in Supplementary Table S7. The world condition first selects the appropriate evidence-fit vector. Each matched replication also receives one environmental-scarcity sequence drawn from a lognormal distribution (meanlog = −2.0, σ = 0.55), clipped to [0, 0.65], and reused across all five matched worlds. This scalar scarcity state enters the conflict function but does not alter the narrative evidence fit. The shared draw ensures that counterfactual differences do not arise from different external scarcity histories.

Local social influence relies on community block mixing rather than on an explicit dyadic network. At the start of each generation, narrative shares are calculated separately in 20 communities, and each agent's social utility depends on the share of each narrative in that agent's community. Replacement agents copy a randomly selected parent's traits with Gaussian mutation (SD = 0.035); 90% inherit the parent's community, and 10% migrate uniformly. The model therefore represents local clustering and migration but does not represent degree distributions, hubs, tie strengths, or network rewiring.

After condition-specific contradiction and awe are updated, agents propose narratives through the multinomial-logit rule in Equations (2) and (3), selectively switch, reproduce culturally, and experience worldview-shock decay. Outcomes are then calculated, followed by the institutional update. For narrative n, coordination performance is the mean normalized coordination attribute among its current adherents, and institutional performance equals 0.55 times the adherent share plus 0.25 times the mean coordination plus 0.20 times the mean evidence alignment. Target support is softmax (3.3 times performance), and new support equals 0.84 times prior support plus 0.16 times target support, renormalized to sum to one. The only modeled resource-allocation variable is inquiry investment: a normalized propensity to allocate attention to inquiry, not a finite economic resource stock, budget, or production function.

4.6. Outcome Construction and Counterfactual Contrasts

Let $s_n(t)$ denote the global share of narrative n, $I_n(t)$ institutional support before the current-generation update, $q_{gn}(t)$ narrative n's share in community g, $z_i(t)$

agent i's current narrative, $A(t)$ the common awe state, $W_i(t)$ agent i's recorded post-decay worldview shock, clip(x) truncation to [0, 1], and logistic(x) = 1/(1 + exp(-x)). Narrative diversity is $-\sum_n s_n(t)\ln\left[s_n(t)\right]/\ln(5)$. Institutional diversity uses the same normalized Shannon formula over $I_n(t)$, and epistemic concentration is $\sum_n I_n(t)^2$. These definitions and all coefficients are also provided in machine-readable Supplementary Table S6.

Species-uniqueness exceptionalism is clip{mean$_i$[0.72$E_z(i, t)$ + 0.28e_i] − 0.08$A(t)$}, where E_z is the adopted narrative's exceptionalism attribute and e_i is the agent's exceptionalism preference. Moral-circle radius is clip{mean$_i$[0.72$M_z(i, t)$ + 0.28m_i] + 0.10$A(t)$}, where M_z is the adopted narrative's moral-circle attribute and m_i is moral openness. Species-level identity is clip[0.48 moral-circle + 0.34(1 − exceptionalism) + 0.18$A(t)$]. Inquiry investment is clip{mean$_i$[curiosity$_i$ × narrative-inquiry$_z(i, t)$] × R_c}, with R_c = 0.66 under solitude, 1.00 under uncertainty, and 0.86 under plurality.

Community fragmentation is $F(t)=\text{mean}_g\left\{0.5\sum_n\left|q_{gn}(t)-s_n(t)\right|\right\}$. With scarcity $R(t)$, exceptionalism $X(t)$, and moral-circle radius $M(t)$, conflict is logistic[−2.2 + 2.8(0.82)$F(t)$ + 2.2(0.62)$R(t)$ + 1.4(0.42)$X(t)$ − 1.15$M(t)$]. Cooperation is clip[0.43$C(t)$ + 0.31$M(t)$ + 0.18(1 − conflict) + 0.08(1 - epistemic concentration)], where $C(t)$ is the mean coordination attribute of agents' adopted narratives.

Existential coherence is clip{mean$_i$[0.54 meaning-need$_i$ × narrative-meaning$_z(i, t)$ + 0.46 evidence-sensitivity$_i$ × evidence-fit$_z(i, t)$, $c(t)$] - mean$_i$[$W_i(t)$]}. At a late-resolution generation, W_i receives 0.80 × max(old fit − new fit, 0) × (1 − 0.55 flexibility$_i$) before multiplicative decay; the reported worldview-shock outcome is its post-decay population mean. Consequently, coherence responds to both current meaning/evidential alignment and residual transition shock rather than to certainty alone.

$$CE_k = Y_{P,k}(T) - Y_{S,k}(T). \tag{5}$$

The persistent-uncertainty effect is:

$$UE_k = Y_{U,k}(T) - \frac{Y_{P,k}(T) + Y_{S,k}(T)}{2}. \tag{6}$$

The path-dependent resolution cost compares a late-resolution world with the genesis world that possesses the same final knowledge:

$$RC_{g,k}(t) = Y_{U\to g,k}(t) - Y_{g,k}(t),\ \ g \in \{S, P\}. \tag{7}$$

4.7. Experimental Design and Reproducibility

The primary experiment used 160 matched replications across all five worlds, 90 generations, and 1,500 agents per world, resulting in 108,000,000 agent-generation updates. NumPy's PCG64 generator used the arbitrary, non-date seed 271828; the sensitivity analysis used seed 271829. Within each replication, common random numbers ensured that world differences were attributable to the cosmic condition rather than different external shocks or initial populations. Termi-

nal world means use normal-approximation 95% confidence intervals across independent matched replications. Late-versus-genesis contrasts and the H8 acute-shock comparison use 95% t intervals over within-replication paired differences; a paired t test, paired standardized effect d_z, and Wilcoxon signed-rank check are supplied for H8 in Supplementary Table S3. The primary acute-shock window is generations 45 - 50 inclusive. For exact reproducibility, the original reduced-sensitivity experiment retains its five-generation window, inclusive of generations 33 - 37.

Table 3 lists the principal baseline parameters and the ranges used for robustness testing.

Table 3. Principal simulation parameters.

Parameter	Baseline	Robustness treatment
Population per world	1500	Fixed
Communities	20	Fixed
Generations	90	Fixed
Resolution generation	45	Fixed
Matched replications	160	Fixed
Replacement rate	0.11	Fixed
Evidence weight	1.25	Sensitivity range 0.75 - 1.70
Meaning weight	0.82	Sensitivity range 0.45 - 1.20
Social-influence weight	1.08	Sensitivity range 0.55 - 1.55
Institutional inertia	0.84	Sensitivity range 0.68 - 0.94
Resolution-shock penalty	0.80	Sensitivity range 0.35 - 1.25
Awe reinforcement	0.45	Sensitivity range 0.05 - 0.90

The global sensitivity experiment used 96 Latin-hypercube parameter sets over eight theoretically important parameters. Each set used eight paired replications with a reduced population of 600 agents and 65 generations. Spearman rank correlations were calculated between parameters and five contrasts: uncertainty's entropy advantage, plurality's exceptionalism difference, plurality's species-identity difference, plurality-resolution shock, and shock asymmetry. Source code, parameter files, full trajectories, terminal outcomes, narrative shares, and sensitivity results are supplied as supplementary materials.

The study did not involve human participants, private records, or live interventions. Ethical review was therefore not required.

5. Results

5.1. Narrative Diversity and Inquiry

As shown in Figure 2, persistent uncertainty maintained the highest narrative diversity throughout most of the modeled history, ending at 0.971 [0.970, 0.971],

compared with 0.948 [0.947, 0.950] under solitude and 0.929 [0.928, 0.930] under plurality. This result supported H1 in the baseline model. The uncertainty world preserved evidential space for mutually incompatible narratives, whereas both certainty conditions imposed stronger selection against claims contradicting common knowledge.

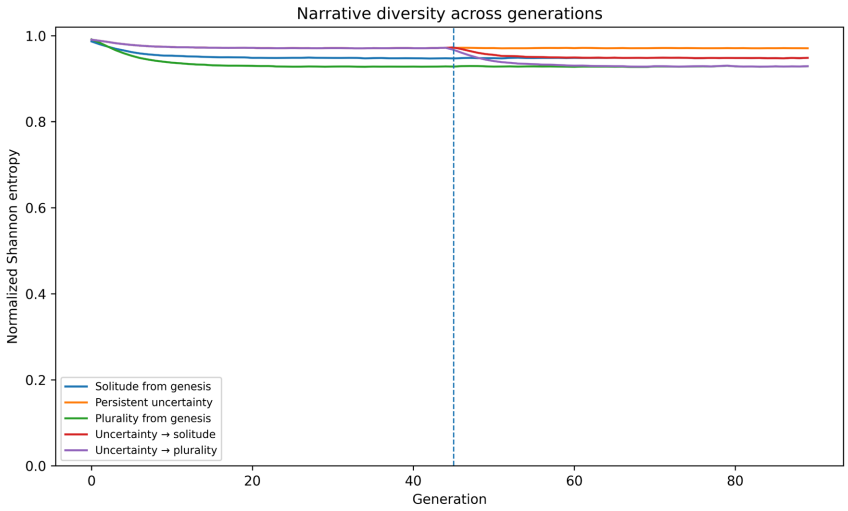

Figure 2. Mean narrative diversity across matched worlds. Shaded bands show 95% confidence intervals; the dashed line marks late resolution.

Figure 3 shows that inquiry investment was also highest under persistent uncertainty, ending at 0.395 [0.392, 0.398]. The plurality world ended at 0.341 [0.338, 0.343], and solitude at 0.235 [0.233, 0.237]. H2 was therefore supported under the baseline parameterization. The model distinguishes inquiry into whether another intelligence exists from inquiry into the consequences of a known answer; certainty redirects rather than eliminates curiosity.

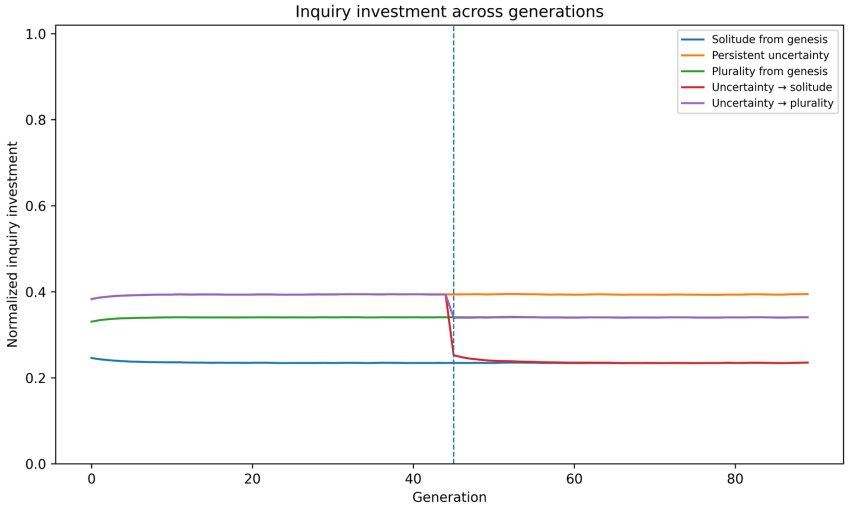

Figure 3. Mean normalized inquiry investment across generations. The dashed line marks the resolution generation for the two transition worlds.

5.2. Exceptionalism, Moral Circle, and Species Identity

Terminal outcomes are summarized in Table 4 and Figure 4. Plurality from genesis produced lower species-uniqueness exceptionalism than solitude (0.445 [0.444, 0.447] versus 0.567 [0.565, 0.568]) and higher species-level identity (0.589 [0.588, 0.590] versus 0.444 [0.443, 0.445]). These results supported H3 and H4 under the baseline mechanism set. The change did not eliminate exceptionalism; human-uniqueness narratives lost evidential fit while moral, civilizational, and transcendent narratives remained viable.

Table 4. Terminal outcomes by world, mean [95% confidence interval].

World	Narrative diversity	Exceptionalism	Moral-circle radius	Species identity	Inquiry investment	Cooperation	Conflict	Existential coherence
Solitude from genesis	0.948 [0.947, 0.950]	0.567 [0.565, 0.568]	0.618 [0.617, 0.620]	0.444 [0.443, 0.445]	0.235 [0.233, 0.237]	0.734 [0.733, 0.735]	0.107 [0.105, 0.109]	0.413 [0.410, 0.415]
Persistent uncertainty	0.971 [0.970, 0.971]	0.514 [0.512, 0.515]	0.642 [0.641, 0.643]	0.473 [0.473, 0.474]	0.395 [0.392, 0.398]	0.734 [0.733, 0.735]	0.101 [0.099, 0.103]	0.415 [0.413, 0.417]
Plurality from genesis	0.929 [0.928, 0.930]	0.445 [0.444, 0.447]	0.710 [0.708, 0.711]	0.589 [0.588, 0.590]	0.341 [0.338, 0.343]	0.769 [0.769, 0.770]	0.091 [0.089, 0.093]	0.427 [0.425, 0.429]
Uncertainty to solitude	0.948 [0.947, 0.950]	0.567 [0.565, 0.568]	0.618 [0.617, 0.620]	0.444 [0.443, 0.445]	0.235 [0.233, 0.237]	0.734 [0.733, 0.735]	0.107 [0.105, 0.109]	0.413 [0.410, 0.415]
Uncertainty to plurality	0.929 [0.928, 0.930]	0.445 [0.444, 0.447]	0.710 [0.708, 0.711]	0.589 [0.588, 0.590]	0.341 [0.338, 0.343]	0.769 [0.769, 0.770]	0.091 [0.089, 0.093]	0.427 [0.425, 0.429]

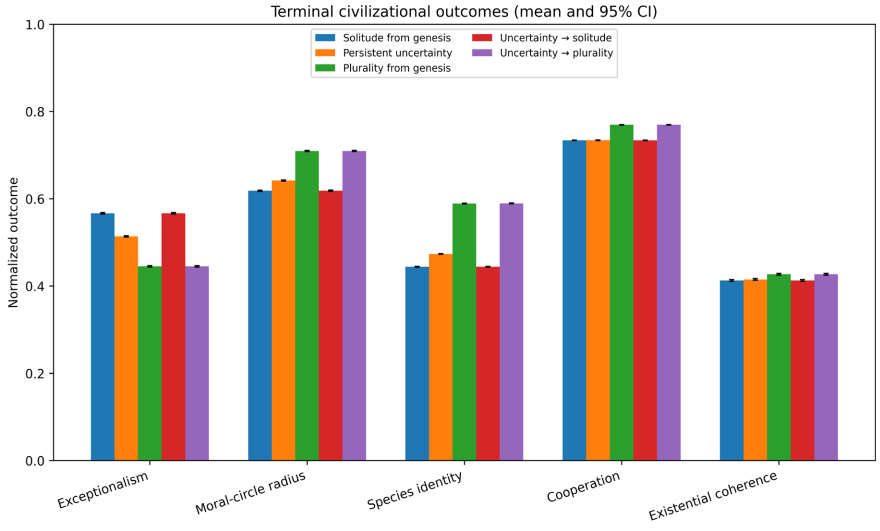

Figure 4. Selected terminal outcomes by world. Error bars show 95% confidence intervals across matched replications.

5.3. Cooperation, Conflict, and Existential Coherence

Differences in cooperation were smaller than differences in cosmological diversity or identity. Cooperation at the terminal generation ranged from 0.734 to 0.769,

while conflict remained above zero in every world (0.091 - 0.107). H5 was therefore supported: common knowledge about cosmic status altered the cultural landscape but did not remove scarcity, community fragmentation, or status competition. Existential coherence was similarly produced by the interaction of meaning utility, evidential fit, institutional reinforcement, and transition shock rather than by certainty alone.

5.4. Resolution Cost and Hysteresis

Late resolution generated a short-term disruption absent from genesis worlds. Across the first six post-resolution generations, mean worldview shock was 0.04539 [0.04499, 0.04579] for uncertainty-to-plurality and 0.05522 [0.05480, 0.05564] for uncertainty-to-solitude. The paired difference (late plurality minus late solitude) was -0.00983, 95% CI [-0.01012, -0.00954], t(159) = -66.03, $p < 0.001$, $d_z = -5.22$; all 160 matched replications were negative. The Wilcoxon check reached the same directional conclusion ($W = 0$, $p < 0.001$). Figure 5 compares existential coherence in each resolution world to that of the corresponding genesis world. H6 and H7 were supported, whereas H8 was not merely unsupported: its predicted plurality-greater-than-solitude direction was reversed in the baseline model. Complete statistics are reported in Supplementary Table S3.

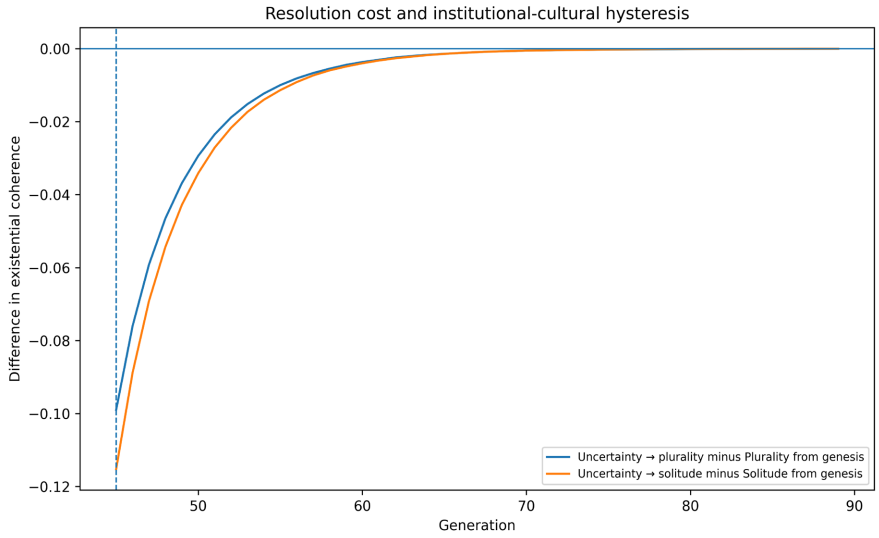

Figure 5. Difference in existential coherence between each late-resolution world and the genesis world with the same final cosmic knowledge. Zero indicates convergence.

The late-resolution rows in Table 4 appear identical to their corresponding genesis rows because the table rounds the means to 3 decimal places. No terminal value is copied from a genesis world. At full precision, the maximum absolute mean late-versus-genesis difference among the outcomes reported in Table 4 is 0.000248. The near-convergence is an emergent result strongly induced by the update rules: after generation 45, each late world uses the same final evidence-fit condition as its matching genesis world; contradiction shock and acute awe decay;

and the baseline model contains no permanent historical-memory state. Common random numbers also allow narrative arrays to resynchronize, while small institutional and state residues can persist. Supplementary Table S4 reports every full-precision paired terminal difference and interval. The current model, therefore, represents transient hysteresis, not guaranteed permanent path dependence.

5.5. Sensitivity Analysis

The global sensitivity analysis showed that several directly tested directions were fully stable across the 96 Latin-hypercube parameter sets, although their magnitudes varied. Uncertainty's terminal entropy advantage was positive in 96/96 sets (100%; range 0.00210 - 0.04568); plurality's exceptionalism difference was negative in 96/96 (range −0.16111 to −0.07689); and plurality's species-identity difference was positive in 96/96 (range 0.06192 - 0.23569). Acute shock was positive in 96/96 sets for both late plurality (0.02212 - 0.08359) and late solitude (0.02699 - 0.09988). H8's predicted positive asymmetry occurred in 0/96 sets; the reverse direction occurred in 96/96, with late-plurality-minus-late-solitude shock ranging from −0.02002 to −0.00461. Figure 6 presents the Spearman correlation matrix; Table 5 lists the strongest parameter associations for each principal contrast; and Supplementary Table S5 provides exact counts and proportions. The sensitivity design did not directly test H2 inquiry dominance, H5 conflict persistence, or the direction of terminal cooperation and existential coherence; no full-sensitivity robustness claim is made for those outcomes.

5.6. Hypothesis Evaluation

Table 6 reports the baseline-model evaluation of all eight preregistered hypotheses.

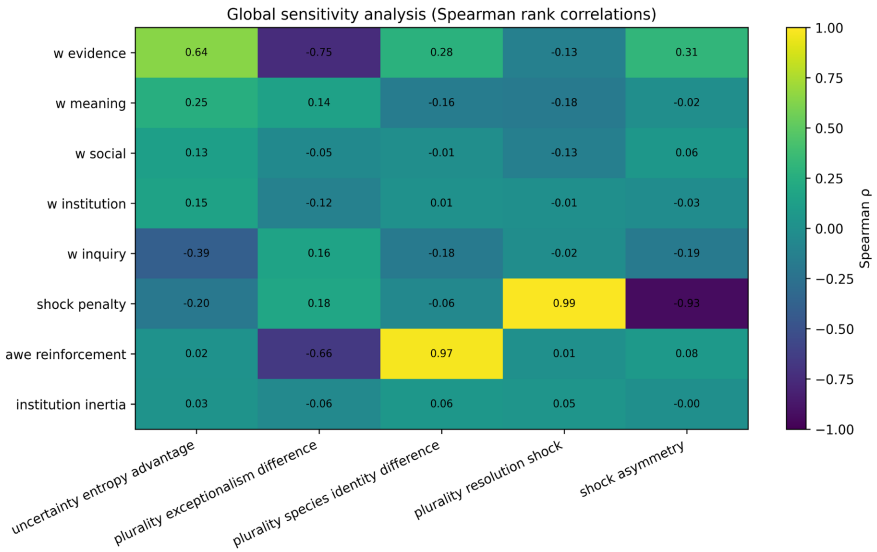

Figure 6. Spearman rank correlations between varied model parameters and selected counterfactual contrasts across 96 Latin-hypercube parameter sets.

Table 5. Strongest global sensitivity associations.

Outcome contrast	Strongest parameter	Spearman ρ
Uncertainty Entropy Advantage	W Evidence	0.64
Plurality Exceptionalism Difference	W Evidence	−0.75
Plurality Species Identity Difference	Awe Reinforcement	0.97
Plurality Resolution Shock	Shock Penalty	0.99
Shock Asymmetry	Shock Penalty	−0.93

Table 6. Baseline hypothesis evaluation.

Hypothesis	Claim	Result	Effect/threshold
H1	Persistent uncertainty has the greatest terminal narrative diversity	Supported	0.022
H2	Uncertainty sustains the greatest inquiry investment	Supported	0.054
H3	Plurality lowers species-uniqueness exceptionalism relative to solitude	Supported	−0.121
H4	Plurality yields higher species-level identity than solitude	Supported	0.145
H5	Cosmological condition alone does not eliminate conflict	Supported	0.091
H6	Plurality from genesis avoids the acute transition shock observed after late resolution	Supported	0.045
H7	Both late-resolution worlds experience nonzero acute transition cost	Supported	0.045
H8	Late plurality creates additional acute shock beyond late solitude	Not supported	−0.010

6. Discussion

6.1. Cosmic Priors Alter Selection, Not Destiny

The primary finding is that cosmic knowledge acts as a constraint and incentive structure for cultural evolution rather than a deterministic script. Uncertainty favored a broader ecology of narratives because no empirical answer could decisively exclude solitude, plurality, or agnosticism. Solitude and plurality narrowed some explanatory possibilities but left meaning, moral regulation, transcendence, and institutional authority as persistent social functions. The model, therefore, does not predict the disappearance of religion or philosophy under extraterrestrial certainty; it predicts pressure to reinterpret claims directly contradicted by common knowledge.

6.2. Genesis and Disclosure Are Distinct Problems

A civilization born into plurality did not experience the acute transition cost observed when an uncertainty-based civilization received the same answer later. This supports a crucial distinction: disruption associated with disclosure may reflect the replacement of inherited narratives and institutions rather than the final cosmic condition alone. In the current finite-memory model, however, that path dependence is transient. Once the contradiction and acute-awe states decay, late-resolution worlds approach the matching genesis attractor and differ only slightly at full precision. The finding supports short-run hysteresis rather than irreversible

civilizational lock-in. Models with durable institutional memory, intergenerational trauma, constitutional constraints, or non-ergodic identity commitments are needed to test permanent divergence.

6.3. Exceptionalism Is Reconstructed Rather Than Eliminated

Plurality reduced species-uniqueness exceptionalism but did not create a non-exceptionalist civilization. Narrative competition shifted toward claims that humanity is morally distinctive, developmentally young, spiritually significant, or uniquely responsible for terrestrial life. This is consistent with the broader observation that evidence can change the content of identity without removing the social need for identity. Future models should distinguish biological uniqueness, moral status, civilizational rank, spiritual importance, and perceived destiny.

6.4. Implications for Alternative NHI Models

The model's narrow extraterrestrial treatment is a starting point, not a claim that all anomalous-intelligence hypotheses are equivalent. The extratempestrial model (Masters, 2022), cryptoterrestrial hypotheses, artificial-intelligence hypotheses, and supernatural interpretations imply different genealogical, moral, and temporal relationships between humanity and the other intelligence. A future factorial model could vary origin, kinship, proximity, agency, technological asymmetry, contact, and intervention. Such extensions would reveal whether the strongest civilizational effects arise from nonhuman intelligence as such or from the relationship between that intelligence and human identity.

6.5. Implications for Post-Detection Research

The results caution against transferring modern survey reactions directly into claims about civilizational development. Current respondents have been socialized under uncertainty and within existing scientific, religious, political, and media institutions. Their reactions are therefore most relevant to late-resolution worlds. The contemporary literature added in revision further shows that belief correlates, media frames, first-contact scenarios, and geopolitical risk assessments vary with the form and institutional handling of evidence (Döbler et al., 2023; Schwarz & Seidl, 2023; Anton et al., 2024; Wisian & Traphagan, 2020; Wright et al., 2023). Genesis-world analysis instead requires cultural transmission and institutional emergence. The approaches are complementary: empirical and post-detection studies can calibrate short-term transition mechanisms, while generative models can test whether the same factual condition produces different societies when present from the beginning.

7. Limitations and Future Research

The model is intentionally abstract. Narrative archetypes compress diverse traditions; agent traits are synthetic; parameter values are theoretically informed rather than estimated from a nonexistent population; and institutional categories do not

reproduce any specific historical society. The remote plurality condition excludes communication, hostile behavior, technology transfer, and geopolitical competition. Certainty of cosmic solitude is an axiomatic counterfactual and not an achievable conclusion from finite astronomical search. Local influence is implemented as community-block mixing rather than as an explicit dyadic network, and inquiry investment is a normalized allocation proxy rather than a finite economic resource budget. The model also omits biological evolution, population growth, detailed economics, state formation, and technological innovation beyond the allocation of inquiry. Finally, its finite-memory shock and institution rules permit late-resolution worlds to approach the matching genesis attractor; the model can demonstrate transient hysteresis but not irreversible historical lock-in.

These limitations define the next research agenda. Structural robustness should be tested with alternative narrative sets, explicit network topologies, finite resource budgets, Bayesian evidence updating, reinforcement learning, explicit demography, durable institutional-memory variables, non-ergodic lock-in mechanisms, and independently implemented models. Subsequent experiments should vary proximity, communication, hostility, technology transfer, signal ambiguity, media framing, and ontological relationship. The contemporary disclosure module can then introduce concealment, institutional betrayal, contested evidence, state competition, and media dynamics without allowing those present-day mechanisms to dominate the genesis question.

8. Conclusion

Cosmic Priors provides a computational framework for comparing civilizations formed under solitude, uncertainty, and extraterrestrial plurality. In the baseline model, uncertainty sustained greater narrative diversity and inquiry; plurality reduced species-uniqueness exceptionalism and increased species-level identity, and neither certainty condition guaranteed social unity nor eliminated conflict. Late resolution produced a disruption that genesis certainty did not, demonstrating why disclosure and discovery should not be treated as the same causal event. The model does not forecast humanity's future. Its contribution is a falsifiable, reproducible mechanism laboratory for asking how common knowledge about humanity's cosmic status can shape cultural selection, institutional development, and historical path dependence.

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Declarations

Funding: This research received no external funding.

Ethics Statement: The study used no human participants, animals, private records, or live interventions; ethical review was not required.

Data and Code Availability: The submission includes the executable simulation, parameter file, primary trajectories, narrative shares, terminal outcomes, resolution differences, hypothesis summary, and global-sensitivity outputs. Supplementary Table S1 and Table S2 provide the complete narrative-attribute and evidence-fit matrices; Table S3 provides paired acute-shock statistics; Table S4 provides full-precision terminal convergence differences; Table S5 provides exact sensitivity direction counts; Table S6 defines every reported outcome from model states; and Table S7 documents the generation-level update sequence and mechanisms.

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Author Contributions

The author conceived the study, designed the model, implemented the simulation, analyzed the outputs, and wrote the manuscript.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendixes

Table S1. Narrative-attribute matrix.

Narrative	Meaning	Coordination	Inquiry	Exceptionalism	Moral Circle	Adaptability
Empirical inquiry	0.56	0.66	1	0.44	0.68	0.91
Human uniqueness	0.82	0.78	0.32	0.96	0.46	0.36
Cosmic pluralism	0.8	0.82	0.78	0.22	0.9	0.76
Transcendent agency	0.94	0.84	0.46	0.6	0.71	0.56
Pragmatic agnosticism	0.5	0.56	0.86	0.5	0.63	0.86

Table S2. Evidence-fit matrix by cosmic condition.

Narrative	S	U	P
Empirical inquiry	0.92	0.91	0.92
Human uniqueness	0.96	0.56	0.16
Cosmic pluralism	0.1	0.56	0.99
Transcendent agency	0.72	0.76	0.77
Pragmatic agnosticism	0.46	0.97	0.46

Table S3. Paired acute-shock statistics for late-resolution worlds.

Comparison	Window generations	n matched replications	Mean	SD	SE	CI 95% low	CI 95% high	Paired t	Paired t df	Paired t p	Paired dz	Wilcoxon statistic	Wilcoxon p	Negative pairs	Positive pairs	Zero pairs
Late plurality acute shock	resolution through resolution + 5 (6 generations)	160	0.045391	0.002547	0.000201	0.044993	0.045788									
Late solitude acute shock	resolution through resolution + 5 (6 generations)	160	0.055221	0.002705	0.000214	0.054799	0.055644									
Paired difference: late plurality minus late solitude	resolution through resolution + 5 (6 generations)	160	−0.00983	0.001883	0.000149	−0.01012	−0.00954	−66.0279	159	1.76E−117	−5.21996	0	5.24E−28	160	0	0

Table S4. Full-precision paired terminal convergence differences.

Late world	Genesis world	Metric	n matched replications	Mean late minus genesis	SD paired difference	CI 95% low	CI 95% high	Paired t	Paired t df	Paired t p	Maximum absolute replication difference	Exact zero pairs
Uncertainty to Solitude	Solitude	narrative entropy	160	1.50E−05	0.000313	−3.38E−05	6.38E−05	0.608834	159	0.543503	0.001775	98
Uncertainty to Solitude	Solitude	exceptionalism	160	−2.02E−05	0.00023	−5.61E−05	1.57E−05	−1.11175	159	0.267925	0.001066	98

Continued

Uncertainty to Solitude	Solitude	moral circle	160	1.11E−05	0.000125	−8.45E−06	3.07E−05	1.122577	159	0.26331	0.000634	98
Uncertainty to Solitude	Solitude	species identity	160	1.22E−05	0.000138	−9.29E−06	3.37E−05	1.121744	159	0.263663	0.000666	98
Uncertainty to Solitude	Solitude	inquiry investment	160	1.09E−05	0.000111	−6.47E−06	2.83E−05	1.240365	159	0.216668	0.000596	97
Uncertainty to Solitude	Solitude	institutional diversity	160	5.20E−05	6.89E−05	4.12E−05	6.27E−05	9.549107	159	2.31E−17	0.000226	0
Uncertainty to Solitude	Solitude	epistemic concentration	160	−3.14E−05	4.05E−05	−3.77E−05	−2.51E−05	−9.81936	159	4.39E−18	0.000131	0
Uncertainty to Solitude	Solitude	cooperation	160	5.44E−06	5.13E−05	−2.56E−06	1.34E−05	1.342626	159	0.181307	0.000249	0
Uncertainty to Solitude	Solitude	conflict	160	−4.46E−06	8.49E−05	−1.77E−05	8.80E−06	−0.66447	159	0.507355	0.000331	97
Uncertainty to Solitude	Solitude	existential coherence	160	−1.39E−05	0.000112	−3.14E−05	3.54E−06	−1.57477	159	0.117298	0.000643	0
Uncertainty to Solitude	Solitude	mean worldview shock	160	7.65E−06	2.49E−06	7.26E−06	8.04E−06	38.90206	159	3.79E−83	1.86E−05	0
Uncertainty to Plurality	Plurality	narrative entropy	160	7.68E−05	0.000387	1.64E−05	0.000137	2.510779	159	0.013046	0.001939	73
Uncertainty to Plurality	Plurality	exceptionalism	160	−2.14E−05	0.000257	−6.15E−05	1.87E−05	−1.05364	159	0.293648	0.001169	0
Uncertainty to Plurality	Plurality	moral circle	160	6.28E−05	0.000142	4.07E−05	8.50E−05	5.599275	159	9.24E−08	0.000626	0
Uncertainty to Plurality	Plurality	species identity	160	0.000248	0.000164	0.000222	0.000274	19.16286	159	3.60E−43	0.000677	0
Uncertainty to Plurality	Plurality	inquiry investment	160	−6.91E−06	0.000159	−3.17E−05	1.79E−05	−0.55018	159	0.582971	0.000487	73
Uncertainty to Plurality	Plurality	institutional diversity	160	0.000155	9.94E−05	0.000139	0.00017	19.70585	159	1.57E−44	0.000534	0
Uncertainty to Plurality	Plurality	epistemic concentration	160	−0.00011	6.81E−05	−0.00012	−0.0001	−20.7703	159	3.73E−47	0.000372	0
Uncertainty to Plurality	Plurality	cooperation	160	1.42E−05	5.86E−05	5.04E−06	2.34E−05	3.063188	159	0.002573	0.000192	0
Uncertainty to Plurality	Plurality	conflict	160	−8.13E−06	0.000109	−2.51E−05	8.88E−06	−0.94415	159	0.346525	0.000411	0
Uncertainty to Plurality	Plurality	existential coherence	160	−3.33E−05	9.29E−05	−4.78E−05	−1.88E−05	−4.5377	159	1.12E−05	0.000454	0
Uncertainty to Plurality	Plurality	mean worldview shock	160	6.21E−06	1.93E−06	5.91E−06	6.51E−06	40.77764	159	4.18E−86	1.35E−05	0

Table S5. Global sensitivity direction counts and observed ranges.

Hypothesis or contrast	Directional claim	Sensitivity output	Direction test	Supporting parameter sets	Total parameter sets	Supporting proportion	Minimum observed value	Maximum observed value	Mean observed value
H1	Uncertainty terminal entropy exceeds both certainty worlds	uncertainty entropy advantage	>0	96	96	1	0.002101	0.045677	0.02115
H3	Plurality exceptionalism is lower than solitude	plurality exceptionalism difference	<0	96	96	1	−0.16111	−0.07689	−0.12108
H4	Plurality species identity is higher than solitude	plurality species identity difference	>0	96	96	1	0.061922	0.235687	0.148373
H7-P	Late plurality acute shock is nonzero	plurality resolution shock	>0	96	96	1	0.022119	0.083588	0.049686
H7-S	Late solitude acute shock is nonzero	solitude resolution shock	>0	96	96	1	0.026985	0.099878	0.060596
H8	Late plurality acute shock exceeds late solitude	shock asymmetry	>0	0	96	0	−0.02002	−0.00461	−0.01091
H8-reverse	Late plurality acute shock is lower than late solitude	shock asymmetry	<0	96	96	1	−0.02002	−0.00461	−0.01091

Table S6. Definitions and exact calculations for reported outcomes.

Metric	Construct	Exact calculation	State interpretation	Range
narrative entropy	Normalized Shannon entropy	-sum_n(s_n * ln(s_n)) / ln(5)	s_n is the global share of narrative n; zero shares are omitted.	[0, 1]
exceptionalism	Species-uniqueness exceptionalism	clip(mean_i(0.72 * narrative_exceptionalism[z_i] + 0.28 * exceptionalism_preference_i) - 0.08 * awe_t)	z_i is agent i's current narrative; awe_t is the common plurality-associated state.	[0, 1]
moral circle	Moral-circle radius	clip(mean_i(0.72 * narrative_moral_circle[z_i] + 0.28 * moral_openness_i) + 0.10 * awe_t)	Narrative and agent-level openness are combined; awe expands the modeled radius.	[0, 1]
species identity	Species-level identity	clip(0.48 * moral_circle_t + 0.34 * (1 − exceptionalism_t) + 0.18 * awe_t)	Higher moral-circle radius, lower uniqueness exceptionalism, and awe strengthen species identity.	[0, 1]
inquiry investment	Normalized inquiry allocation	clip(mean_i(curiosity_i * narrative_inquiry[z_i]) * inquiry_return[condition_t])	This is the model's only resource-allocation proxy; no finite economic budget is simulated.	[0, 1]
institutional diversity	Institutional support diversity	-sum_n(I_n * ln(I_n)) / ln(5)	I_n is institutional support for narrative n before the current-generation institutional update.	[0, 1]
epistemic concentration	Institutional support concentration	sum_n(I_n^2)	Herfindahl-style concentration over the five institutional-support shares.	[0.2, 1]
community fragmentation	Community narrative fragmentation (internal state)	mean_g(0.5 * sum_n(abs(q_gn - s_n)))	q_gn is narrative n share in community g; this total-variation distance enters conflict.	[0, 1]
conflict	Conflict propensity	logistic(−2.2 + 2.8*w_fragmentation*fragmentation_t + 2.2*w_scarcity*scarcity_t + 1.4*w_exceptionalism *exceptionalism_t − 1.15*moral_circle_t)	Baseline weights are 0.82, 0.62, and 0.42 for fragmentation, scarcity, and exceptionalism.	(0, 1)
cooperation	Cooperation propensity	clip(0.43*mean_narrative_coordination_t + 0.31*moral_circle_t + 0.18*(1−conflict_t) + 0.08*(1−epistemic_concentration_t))	Mean narrative coordination is the average coordination attribute of current adherents.	[0, 1]
existential coherence	Existential coherence	clip(mean_i(0.54*meaning_need_i*narrative_meaning[z_i] + 0.46*evidence_sensitivity_i* evidence_fit[z_i,condition_t]) − mean_i(worldview_shock_i,t))	Meaning and evidential alignment raise coherence; residual contradiction shock lowers it.	[0, 1]
mean worldview shock	Worldview shock	mean_i(W_i,t) after the end-of-generation decay step	At resolution, W_i receives shock_penalty * max(old_fit-new_fit,0)*(1-0.55*flexibility_i); it then decays multiplicatively.	[0, 1]

Table S7. Generation-level update sequence and modeled mechanisms.

Update order	Mechanism	Implementation
1	Cosmic condition and evidence fit	Set S, U, or P for the world and generation; load the matching five-element evidence-fit vector.
2	Environmental scarcity shock	For each matched replication, draw one length-T sequence from Lognormal (meanlog = −2.0, sigma = 0.55), clip to [0, 0.65], and reuse the same sequence in all five worlds.
3	Local interaction structure	Use community block mixing rather than an explicit dyadic graph. Each agent observes the current narrative shares of its assigned community. There are 20 communities in the primary experiment.
4	Resolution contradiction and awe	At the resolution generation, add fit-loss shock scaled by inflexibility. In late plurality, add a decaying acute-awe term; all plurality worlds also receive institutionally reinforced cultural awe.
5	Narrative proposal and adoption	Compute five utilities, add Normal (mean = 0, SD = 0.08) idiosyncratic noise, transform by softmax with temperature 0.72, draw a proposed narrative, and switch according to replacement or 0.08 + 0.42 * flexibility + 0.28 * shock.
6	Replacement, inheritance, and migration	Replace agents independently at rate 0.11. Replacement agents copy a randomly selected parent's traits plus Normal (mean = 0, SD = 0.035) mutation clipped to [0, 1]; 90% inherit the parent's community and 10% migrate uniformly.
7	Worldview-shock decay	Multiply each agent's shock by clip (1 − shock_decay * (0.45 + flexibility_i), 0.50, 0.98), with baseline shock_decay = 0.23.
8	Outcomes and conflict	Compute narrative shares, institutional metrics, fragmentation, exceptionalism, moral circle, inquiry allocation, logistic conflict, cooperation, species identity, and coherence using Supplementary Table S6.
9	Institutional performance and update	For narrative n, performance = 0.55 * adherent_share + 0.25 * mean_coordination + 0.20*mean_evidence_alignment; target support = softmax(3.3*performance); new support = 0.84*old + 0.16*target, renormalized.