Revolution and the afterlife: a phylogenetic analysis of religious beliefs

Kiran Basava[1,2], Hanzhi Zhang[1*], and Ruth Mace[1]

Beliefs about the fate of humanity and the soul after death may structure behaviours of religious groups. Here we test theories from religious studies: that beliefs of an imminent apocalypse co-evolved with and facilitated revolutionary violence, while reincarnation beliefs cause people to acquiesce to existing social orders and withdraw from political activism. We test these hypotheses by building a cultural phylogeny of historical Islamic sects and schools from the 7-20th centuries and use phylogenetic comparative methods to show that these two beliefs display distinct relationships with intergroup violence. There is substantial evidence that apocalyptic beliefs co-evolved with revolutionary violence, while reincarnation beliefs were evolutionarily stable in peaceful groups. In both cases, violence precedes the emergence of beliefs, which suggests that conditions which generate revolutionary violence changed beliefs rather than beliefs generated violence. We also found that apocalyptic beliefs are associated with accelerated group extinction, although causal relationships cannot be determined.

[1] Dept of Anthropology, University College London, 14 Taviton St London, UK WC1E 6BT

[2] Institute of Cognitive and Evolutionary Anthropology, University of Oxford, 64 Banbury Road, Oxford, UK OX2 6PN

* E-mail: hanzhi.zhang.13@ucl.ac.uk

Afterlife belief, as manifested in ancestor worship, was present at the dawn of human religion[1]. Humans may have an innate inclination towards afterlife belief because we evolved theory of mind – the ability to perceive and simulate the intention of other individuals – which allows us to assign knowledge and concern for social behavior to supernatural agents[2]. Cultural evolutionary research on religion often emphasizes how identity markers and collective rituals can drive participation in violent conflict through engendering feelings of attachment and kinship among coreligionists[3-6]. Some researchers have also suggested the diversity of eschatological beliefs (relating to death and the fate of the soul) among religious groups may be causally related to forms and levels of religious intergroup violence[7,8]. There is experimental[9,10] and qualitative[11,12] evidence that the content of particular beliefs could influence levels of outgroup hostility and motivate violent acts. The promise of divine reward or the threat of divine punishment in the afterlife can alter the incentives of religiously-charged behaviours[13,14]. Here we apply phylogenetic comparative methods to a sample of historical Islamic sects to test social science theories that two eschatological beliefs – imminent apocalypse and reincarnation – served either to facilitate specific forms of intergroup violence or suppress political activism.

Apocalyptic ideologies are featured in all Abrahamic religions and some contemporary millennialist movements[15]. They commonly depict a catastrophic transition from the existing 'unjust' world into a blissful utopia of permanent well-being exclusively reserved for those following the "true faith". For instance, the New Testament book of Revelation depicts a violent imagery of battles between the Good and the Evil, which ends with the triumph of the Good who gained entrance to the utopian world[16]. These narratives can reify group boundaries and promote parochialism by emphasizing the irreconcilable conflicts between those acting in accordance with divine plans and all others obstructing the divinely-ordained course of events. Ingroup members exclusively possess the truth, with all

outsiders viewed as a collective enemy who needs to be purged before the arrival of the post-apocalyptic utopia[17].

Historians of religion argue that apocalyptic doctrines are particularly appealing to 'religions of resistance' and 'religions of revolution'[18]. Narratives of an immediate end time can attract individuals living under social and political oppression, and may be used to motivate revolutionary activism[19]. They often emphasise the moral decrepitude and injustice of 'status-quo' social orders, and an urgent need for renewal and purification. Islamic apocalyptic traditions have a history of links with anti-establishment movements[20,21]. Adopting beliefs and actions to bring about the apocalypse, in which the world order is destroyed and rebuilt, expresses dissatisfaction with the current system[17,22], so groups with these ideologies are often seen as threats by existing power structures. Forceful repression by such power structures can be interpreted as a sign of the impending apocalypse[15]. This may shift perceived agency from the divine to the human, driving believers to play an active role in fighting for the millennial kingdom rather than leaving this to God[15,23]. For instance, Aum Shinrikyō, a 20th century millennialist movement in Japan, when faced with divine inaction and increasing external opposition, resorted to violence in an attempt to bring about the millennial kingdom[22].

Apocalyptic ideologies may be interpreted as divine permission for violence to purify society and accelerate the end times[15,24,25]. In the book of Revelation, martyrdom following Jesus and resistance against enemies at all costs were encouraged. Apocalyptic rhetoric is often associated with a messianic figure believed to possess exclusive access to divine plans and the post-apocalyptic utopia. Such figures may claim to be imbued with divine authority and use this to redefine required beliefs and actions for salvation. This may include the use of apocalyptic imagery from sacred texts or earlier traditions to legitimize pre-emptive aggression against outgroups to ensure victory[26]. Many early Islamic sects used apocalyptic

imagery to mobilize revolutionary movements in the aftermath of Muhammad's death, with leaders taking on the title of mahdi to legitimate their authority[27,28].

The other ideology we examined is reincarnation belief. In religions such as Buddhism and Hinduism, reincarnation beliefs have been theorized to function as a system justification for a world filled with inequality and injustice[29-33]. In the sociological literature, reincarnation as expressed in the karmic Hindu system is an elegant, self-contained cosmic justification for the existence of castes[21]. Despite their unorthodoxy, ideas of reincarnation have emerged repeatedly among various Islamic groups, primarily heterodox Shi'i sects. Among such groups, misfortune and suffering among devoted, morally upstanding believers can be explained as the outcome of wrongs committed in past lives[34]. Some scholars have noted that beliefs associated with early Shiʿi sects in extant groups, including reincarnation, are present primarily among politically quietist populations[35]. While reincarnation beliefs have been present among groups that have engaged in violent activity (generally Kaysāni Shiʿi sects), they tend to emphasize the punishment of nonbelievers who fail to recognize internal spiritual knowledge through rebirth cycles and exclusion from the ascending hierarchy of souls. Theories about the pacifying function of reincarnation beliefs as system justification may therefore predict an inverse relationship between belief in reincarnation and political activism.

Drawing on social sciences and religious studies literature, we hypothesized that the belief in an imminent apocalypse serves to inspire revolutionary action[20,21,26] while the belief in reincarnation serves to suppress political activism[29,30,36]. We coded three types of intergroup relations – religious violence, revolutionary violence (a specific form of religious violence), and political quietism – among historical Islamic sects. Religious violence refers to a broad range of religiously-motivated, preemptive aggression towards the outgroup that are not for defense purposes. Revolutionary violence refers to a specific type of group-level

violence that involves a revolt or rebellion to overthrow an existing power structure. Political quietism is defined as no participation in significant political events, including non-violent political activism (See SI for detailed coding criteria). Neither apocalyptic or reincarnation beliefs are expected to have a positive relationship with religious violence generally as they do not contain elements that would independently promote religiously motivated violence against outgroup members. As is the case with injunctions in other religious traditions and/or systems of moral thought, statements in Islamic texts related to violence and intergroup relations have been interpreted across space and time in a multitude of ways heavily contingent on the relevant historical and social context, regardless of sectarian identity[37-40].

Similar to biological species, religious groups evolve by *descent with modification*[41]. They inherit ideologies and practices from their ancestral groups and occasionally modify their content before passing them on to descendent groups[42,43]. Variation in these beliefs and practices contribute to differential abilities of religious groups to compete with one another by gaining new members and maintaining existing members. Failure to compete often results in group dissolution, a process comparable to species extinction[44]. Disputes over ideology or practices can lead to the splitting of one group into multiple lineages, a process parallel to cladogenesis in biological evolution. It is therefore possible to represent the evolutionary history of Islamic sects by reconstructing a phylogeny calibrated by timings of splitting and extinction events that were recorded in written history. We reconstruct a phylogeny using written historical records in a bottom-up way (rather than the top-down approach using contemporary linguistic or genetic data to infer unknown evolutionary history). In cases of overlaps in group memberships and ideologies, some groups were not explicitly represented on our phylogeny, such as some early theological schools which overlapped in adherents and doctrines with the legal schools included as taxa on the current tree.

Cultural evolutionary studies have provided key insights into the diversity of religious and political systems that we observe nowadays. Phylogenetic comparative methods have been applied to examine the signaling functions of religious practices[44], the transmission patterns of violent ideologies[45], the evolutionary relationship between human sacrifice and social stratification[46], and conversion rates to Christianity[47]. Previous studies suggest the transmission of violent religious ideologies tend to be inherited from ancestral groups rather than borrowed from neighbouring groups[45]. Although religious beliefs are shaped significantly by context and are susceptible to horizontal borrowing from surrounding traditions, the two beliefs we examined here lie at the core of sect identities and can be traced along the vertical trajectory of Islamic history. Islamic scholars also recognize the significance of historical continuity. One scholar of Ibāḍi Islam even compares studying contemporary Wahbi Ibāḍi thought to gain insight into classical Khārijte beliefs with studying modern bird species to better understand extinct dinosaurs[48].

Based on secondary literature of written historical records, we reconstructed a phylogeny representing the evolutionary history of Islamic sects and mapped the presence or absence of eschatological beliefs to all contemporary and historical sects at its tips (Figure 1). To build the phylogeny, information on the formation of Islam into separate schools and sects from its inception in 610 CE to 2000 CE was taken from secondary sources, generally books and peer-reviewed journal articles, as well as reference works with entries by scholars of Islamic studies. Islamist (political Islamic) groups formed after 1900 CE were excluded, due to their discontinuity with previous phylogenetic history and difficulty in being clearly designated as religious groups, as they frequently encompass political parties and/or militias and have varying levels of theological cohesion.

Groups included as taxa were compiled from multiple sources (see SI). The starting points were the four Sunni legal schools and three main branches of Shiʿism as described in

reference sources and secondary sources on Islamic history[20,49,50]. With these forming the basic structure of the tree, research was conducted into further branches such as the Nizāris, Karramis, and Ibāḍis. The words most closely reflecting a reasonable unit of analysis to serve as taxa on the tree - "sect" and "school" - were searched primarily through the Brill Encyclopaedia[51] online entries . Group names were also searched in the main reference sources used and in additional academic papers. During this process, the information found in these sources on the formation and evidence for distinct doctrines, the context in which they were formed, and, if applicable, context of extinction or splitting into further groups, was documented to decide whether and where to include them in the phylogeny (for instance, some were argued to be fabrications by medieval scholars, or too similar to parent groups in doctrine to fully count as a separate group). The reconstructed phylogeny has 55 tips and 56 internal nodes. 20 of the 56 internal nodes correspond to identifiable historical sects, so the phylogeny represents 75 Islamic sects overall. Presence of eschatological beliefs and violence were coded independently by two researchers (Cohen's kappa $\kappa = 0.662$, $p < 0.001$. See Table S8 for intercoder agreement rates for each trait). We then used Bayesian phylogenetic inferences to test for correlated evolution between these beliefs and three types of intergroup relations: religious violence, revolutionary violence, and political quietism.

Figure 1. Time-Calibrated Reconstruction of the Phylogeny of Islamic Sects. Horizontal axis indicates Years-before-present. Topology based on historical records of the splitting events of Islamic sects from its inception circa. 610 CE to 2000 CE. The reconstructed phylogeny is fully bifurcating. 20 internal nodes with known character states were identified and fixed using the "Fossil" command in *BayesTraits v3* to inform ancestral state reconstruction and co-evolutionary analyses. See Supplementary Datasheet for sources of tree-building and time calibrations.

While reincarnation beliefs may have originally been transferred through contact with surrounding non-Islamic traditions like Manichaeism[27,52], Shi‘i Islamic traditions in particular exhibit vertical transmission pattern beginning with early Shiʿi sects which deified ʿAli and some imams[27]. They appear among some groups of Ismāʿīli Shiʿi Muslims, and today are present among Ismāʿīli Tayyibis, ʿAlawites, Druze, and Alevis. Continuity in cosmological thought between early and later Shiʿi groups are often cited as examples of historical relatedness[52]. Though apocalyptic beliefs are more common and diffusely distributed, they often contain recurring motifs drawn from Islam's origin as an expectant apocalyptic movement such as the Greater and Lesser signs of the Hour from the Ḥadīth [57]. In Shiʿi Islam, the mahdi or Qā'im ("the one who rises") abolishes injustice and establishes a long-lasting messianic kingdom, reflecting a history of social and political oppression due to its minority status[25,58]. Vertical transmission of such narratives through Islamic sects is evident in Shi‘i groups, with sects deriving their names from their respective recognized imams, and with expectant messianism emerging from Uṣūli Twelver Shi‘ism in the form of the Shayki, Bābī, and Bahai' movements one millennium after the occultation of the twelfth imam. Our phylogenetic signal analyses also indicate vertical transmission of these beliefs (See Table S1).[18]. Our phylogenetic signal analyses also indicate vertical transmission of these beliefs (See Table S1).

Figure 2. Inferred transition rates between states of eschatological belief and intergroup violence. Using BayesTraits DISCRETE program[53] Arrow widths proportional to inferred transition rates. Dashed arrows indicate transition rates not statistically significantly above zero. See Table S7 for estimated log marginal likelihoods of dependent and independent models of correlated evolution. There is no evidence for correlated evolution between apocalyptic and reincarnation beliefs (logBF=1.731).

By comparing the marginal likelihoods of dependent and independent transition models, we found statistically-significant evidence for correlated evolution of apocalyptic beliefs and revolutionary action (Figure 2 and Table S7) which is consistent with theories in religious studies literature noting the political potential of apocalyptic ideas. There is evidence that apocalyptic beliefs co-evolved with religious violence in general; however, the association is much weaker compared to co-evolution with revolutionary action. The different relationships displayed between apocalypticism and the two forms of violence examined here could indicate how a specific variant of afterlife beliefs (the idea of the immediate end time) is associated with a particular group-level action (violence aimed at overthrowing the political order). Inferred transition rates suggest that revolutionary action preceded apocalyptic beliefs rather than the other way around, contradicting our first hypothesis.

Scholars of religion have emphasized the importance of political and social context in engendering political activism and revolutionary behaviour. For instance, Lincoln writes that "millennial expectations alone ... do not lead inevitably to revolution, as history abundantly documents" (2003: 87). He argues that this is more likely to occur when the ruling class loses legitimacy with the majority of society, and that such "religions of resistance" promote millenarian worldviews to advance anti-authority campaigns "in which the world of the present is condemned as decadent or senescent, while a radically different mode of being is expected in the immediate future in the wake of an apocalyptic struggle" (1985: 277). It is therefore possible that these narratives become more tenable at times of political instability conducive to intergroup violence[15,26], rather than being a causal force.

Our co-evolutionary analyses of reincarnation beliefs suggest that the presence of both reincarnation beliefs and violence was an unstable state (Fig 2). The state with reincarnation belief present and religious violence absent is evolutionarily stable; transitions away from this state are all inferred to be zero. This suggests sects which acquired reincarnation belief following religious violence but subsequently lost religious violence tend to stay non-violent. However, the results of the correlation analysis did not indicate that groups were more likely to transition to politically quietist states after acquiring reincarnation beliefs. It is possible reincarnation beliefs in Islam do not serve the same functions as they are hypothesized to in karmic religions.

There are a multitude of doctrines in Islam that more directly support politically quietist and/or nonviolent behaviour, including among more orthodox sects that do not have any reincarnation beliefs. These include the concept of *taqiyya* (precautionary dissimulation), as well as obedience to rulers or delegation of political authority to occulted figures. There are also countless examples, both throughout history and in the present day, of individuals professing belief in religious doctrines espousing reincarnation participating in violence. The finding that groups with both reincarnation beliefs and violence were unlikely to retain both traits could point to a possible relationship between these beliefs and the presence or absence of group-level violence. However, we caution overgeneralization of these results to non-Islamic religious groups beyond our sample. Evolutionary researchers have recently begun to extend theories of prosocial religions to karmic religious traditions, including those where reincarnation beliefs are central[31]. Comparative work on reincarnation beliefs among Muslims and followers of religions such as Hinduism and Buddhism could shed further light on how the social functions of this belief may differ with those of other afterlife beliefs across and within religious traditions.

Religion has been a vital part of our social life for a long time in our evolutionary history[54,55]. How religion persisted in our lineage, despite the energetic costs of religious practices, poses an evolutionary puzzle[56]. Some argue that religious beliefs and practices that increased the fitness of individuals or cultural groups were positively selected for and assembled into functional religious systems over time[57-60]. Sufficiently intense violence between religious groups could serve as a form of cultural group selection, which would favour cultural phenotypes promoting success in intergroup conflict[61]. Psychological and anthropological studies have shown costly behaviours that enhance credibility of sincere beliefs and group loyalty are more likely to be copied and transmitted[58,59]. Costly requirements placed on community members also promote the survival and longevity of religious communes[62]. If apocalyptic belief serves to mobilise collective action against the outgroup while reincarnation belief serves to suppress political activism, we would expect apocalyptic beliefs to promote the survival of cultural groups and reincarnation beliefs to be selected against under prolonged periods of intense cultural-group competition.

Figure 3. Survival Probability of sects with belief/violence versus sects without belief/violence against Time (years). Cox Proportional Hazard Regression for Duration of Group Survival showed no statistically-significant correlation between the states of reincarnation beliefs and the duration of group survival (extinction risk coefficient = 0.9053, 95%CI = 0.3378 - 2.426, p = 0.843). Apocalyptic beliefs (**b**) (coefficient = 4.043, 95%CI = 1.683 - 9.712, p = 0.0018), religious violence (**d**) (coefficient = 3.532, 95%CI = 1.289 - 9.673, p = 0.0141), and revolutionary violence (**c**) (coefficient = 3.071, 95%CI = 1.191 - 7.916, p = 0.0202) are statistically significant predictors of group longevity.

We found no significant correlation between sect survival and the states of reincarnation beliefs. However apocalyptic beliefs, religious violence, and revolutionary violence all predicted a shorter duration of Islamic sects on our reconstructed phylogeny (Figure 3). It appears that apocalyptic beliefs and religious violence were selected against in the long term. However, these characters all correlate with the phylogeny and we cannot distinguish their effect from the effect of other factors passed down by descent. For instance, some sects could have inherited the socioeconomic circumstances of their parental group as well as afterlife beliefs. Certain socioeconomic circumstances on their own are sufficient to trigger intergroup violence when violence is perceived as a cost-effective way to improve living conditions and social status[63-65]. We performed multi-level Cox regression which controls for phylogenetic non-independence at the clade level, and found that religious violence and revolutionary violence no longer predict the duration of sects; however, presence of apocalyptic belief is still a significant predictor of shorter sect survival (See Table S10). This is consistent with historical records that indicate how rebellion attempts against rulers (generally the ‘Abbāsids and Umayyads) led to the demise of various Kaysāni groups including the Mughīriyya, Khattābiyya, and Mansūriyya[27,52]. Nevertheless, we cannot affirm a causal relationship between apocalyptic belief and group survival without controlling for a wide range of socioecological factors.

Past research has indicated that the group-delineating and ritual aspects of religion, which increase identity salience and strengthen within-group bonds, are integral to cooperation and conflict. Here we demonstrate the two categories of Islamic eschatological beliefs examined in this paper displayed distinct relationships with various forms of group-level violence and political behaviour. Our analysis of evolutionary models indicates that apocalyptic beliefs have a stronger evolutionary relationship with revolutionary violence than with religious violence. While reincarnation beliefs did not appear to coevolve with

politically quietist behaviour, they are evolutionarily stable when religious violence is absent. The presence of collective violence preceded the appearance of both apocalyptic and reincarnation beliefs. These results support the idea that sociopolitical context is likely to encourage both certain forms of political action, as well as the use of ideologies to justify and mobilize them. Actions and beliefs may then reinforce one another, rather than a simplistic model in which religious (or other) beliefs cause violence. Additional data and analyses are needed to support evidence for any effects of religious beliefs on group survival.

Our study illustrates how quantitative, phylogenetic methods can be applied to questions about the transmission and social functions of religious beliefs, as well as some avenues and challenges in using religious groups as units of analysis. It fits within broader efforts to build historical databases to scientifically examine questions of human social evolution[66-68]. By focusing on the diversity of religious beliefs over time and across different Islamic groups, our research attempts to incorporate expertise and subject-specific scholarship from the humanities in order to take account of historical contexts, and avoids problematic assumptions of homogeneity or essentialism. With such a synthesis, research in this area can contribute to better understandings of how religious groups interact with their natural and social environments, and how variation in the content of religious beliefs may co-evolve with group-level cooperation and conflict in specific ways. Overall, we found no evidence that particular afterlife beliefs drove violent collective action. Instead, our results indicate that these beliefs tend to follow rather than create violent circumstances.

Methods

Tree building and taxa definition

The tree was written in Newick format, with branch lengths calibrated in Mesquite[69] and R. Further details on the tree construction are provided in the Supplementary Information. Polytomies where orders of splitting events could not be ascertained from historical records were resolved using the *multi2di* function in the *ape* package which breaks polytomies in random order so the final tree is fully bifurcate with minimum branch length of 1e-07. Qualitative findings of co-evolution analyses were replicated on five phylogenies with alternative polytomy resolutions (see Table S9). The final tree has 52 tips, of which, 30 are extant, and 51 internal nodes. Nodes represent known extinct groups ancestral to contemporary sects and splitting events. The datings of some of these splits were exact, generally when there were schisms over the succession of a group and the death date of the last agreed-upon leader was known, while others were much more approximate, such as the coalescence of doctrines into a legal school. Splits were dated using information from secondary scholarly sources (See Supplementary Datasheet).

Defining the unit of analysis referred to as a species or cultural group is a challenge in the study of both biological and cultural evolution, and for phylogenetic representations specifically[70]. An attempt was made to classify these groups as such consistent with how they are considered in scholarly works on Islam, with source-critical studies used to make informed decisions on which groups to include in the final phylogeny[71,72]. In general, a group was included if sources provided evidence of distinct theological doctrines that could be effectively coded under characters of interest. Further details are provided in the SI.

Dataset and character coding

Data was coded using secondary historical and reference sources. While a dataset is obviously static, in comparison with the dynamic nature of beliefs and practices within cultural groups, characters were coded at their states either at the time of a group's extinction, or for extant groups, the state for the majority of the date range 1900-2000 CE. The characters used in the analyses were religious and revolutionary violence, apocalyptic beliefs, belief in reincarnation, and political quietism. All these variables were coded as a binary character, for presence (1) or absence (0) in each group. See Table S8 for intercoder agreement rates for each trait. The supplementary dataset includes the positive and negative character codings for each group, specific evidence for positive trait codings for violence characters, and references. For implications of potential coding errors, see imputation output in Figure S5.

Testing for phylogenetic signal of characters

Phylogenetic signal for apocalypticism, reincarnation beliefs, and revolutionary and religious violence as binary variables were tested with Fritz and Purvis' D statistic[73] in the caper package in R[74]. The D statistic measures the number of state changes needed for the observed distribution at the tips of the phylogeny, scaled by the expected distribution under a Brownian motion model of evolution and the expected distribution if the trait is random with respect to phylogeny[73]. A D statistic close to or below 0 indicates that a trait is phylogenetically patterned, while a D close to 1 indicates no phylogenetic pattern. This was calculated with 1000 permutations across the known tree. Additional details of technical aspects of tree construction are in SI.

Phylogenetic Comparative analyses

We used 'Multistate' algorithm as implemented in the software *BayesTraits v3*[75] to fit continuous-time Markov models of trait evolution to the observed character states (i.e. presence vs. absence) on the reconstructed tree[76]. For discrete traits with binary states, there are three possible models of evolution: one with gain and loss rates, one with loss rates only (gain rates equal to zero), and one with gain rates only (loss rates equal to zero). The rate parameters of the model record transitions to and from the two character states of each trait. We employed the "reversible-jump MCMC" (RJ-MCMC) implementation of this model[53], available in *BayesTraits v3*. For a given character state, the RJ-MCMC model visits the posterior distribution of different models of evolution, as well as the posterior distributions of the parameters of these models, in proportion to their probabilities of describing the observed data. We rescaled the branch lengths by a factor of 0.001 and used a hyper prior drawing from a uniform 0 – 10 to seed the distributions of transition rate priors. Each RJ-MCMC chain was run for 5050000 iterations (including the first 50000 iterations of burn-in period) and sampled every 1000th iteration, to produce a posterior sample of 5000 of most likely models and their corresponding rate parameters.

Ancestral State Reconstruction

Based on information from historical records (See Supplementary Data), we identified 20 internal nodes with known character states which we fixed using the "Fossil" command in *BayesTraits v3* (See Figure S1 in SI). To estimate the character states of unknown internal nodes, we employed the 'most-recent-common-ancestor' method[76] which identifies the reconstructed node in the posterior sample with a set of descendant taxa. The estimated ancestral state of each unknown node is a probability distribution of the posterior sample. We report the posterior mean for each node in Figure S1-4. Figures are produced with ape[77] and ggplot2[78] packages in *RStudio* (http://www.rstudio.com/) software.

Testing for Coevolution

We used 'Discrete' algorithm as implemented in the software *BayesTraits v3* to analyse correlated evolution between pairs of discrete binary traits[76,79]. We ran RJ-MCMC analyses for dependent evolution and independent evolution models separately. In the dependent model, transition rates of the first trait are dependent on states of the second trait. In the independent model, transition rates of one trait are independent of those of the other. We rescaled the branch lengths by a factor of 0.001 and used an exponential distribution (mean = 10) for priors. Following the first 50000 iterations of burn-in period, the RJ-MCMC chain was run for another 5000000 iterations and sampled every 1000th iteration, to produce a posterior sample of 5000 of most likely models and their corresponding rate parameters. For likelihood ratio test, we calculated the log Bayes Factors[80] (log-BF) between models using the log-marginal likelihood of each model, estimated with the "stepping stone" method in *BayesTraits v3*. A log-BF larger than 2 is indicative of 'positive' evidence for supporting one model over the other. A log-BF larger than 5 indicates 'strong' evidence that one model is better than another.

Directions of trait evolution

We tested the significance of transitions by restricting individual transition rates to zero and comparing the likelihood of the reduced model with that of the unrestricted model. In a MCMC framework, we computed the Bayes Factors (posterior-to-prior-odds) for each model based on the frequency with which a model occurs in the posterior sample compared to our prior expectation of observing that model[81].

To compute the prior odds, we calculate the total number of potential evolution

models (i.e. possible combinations of transition-rate values). For the unrestricted dependent model with 8 non-zero parameters, we used the binomial theorem to calculate the number of possible transition rates between character states (n=4,140). For restricted dependent models with at least one zero-rate, we calculate the total number of evolution models using Stirling numbers[53] multiplied by the number of possible positions that zero-rate can take and obtain a sum of 17,006. These combine to give the total of 21,146 potential evolution models (See Table S2-6).

Bayes Factors were compared to assess whether transition rates were significantly above zero. Bayes Factors values less than 1 are evidence against the model, values between 1 and 3 provide positive support, 3 to 10 are substantial, 10 to 30 are strong, 30 to 100 are very strong and values greater than 100 are decisive.

Time-to-Extinction Analyses

To assess the potential impact of beliefs and violence on the longevity of Islamic sects, we conducted time-to-event analyses of tree branches. For each trait, we fitted proportional hazards regression models to assess whether the ending state of a branch predicts its length (i.e. group duration in history). We chose the branches' ending states and not beginning states as the predictor for two reasons: (1) Extinction events coincide with the ending node/tip; (2) Most ending states are tips with known state but most beginning states are internal nodes with unknown states. It does not imply that character states remain constant along branches. The end of a branch may be a bifurcating node, a contemporary taxon/tip, or an extinct taxon. Branches leading to an extinct taxon were recorded as an event. Branches leading to a bifurcating node or a contemporary at the tips were recorded as right-censored, as extinction events may take place at times beyond their endings (See Figure S1-

4).

We checked whether the proportional hazard assumptions of Cox regression models were valid using *cox.zph* command in *'survival'* package in R[78]. Given that assumptions were valid, we used *coxph* command in package '*survival'* to fit a proportional hazards regression model predicting each branch's length with its ending state[82]. Figures of survival curves are produced using the'*survminer'* package[83] in R. We fit multi-level frailty Cox model for sect duration which controls for clade-level variance. . See Supplementary Datasheet for clade-grouping details.

Model inferences such as the Binary State Speciation Extinction Model (BiSSE)[84] and its extensions[85] are commonly adopted to estimate binary traits' effect on extinction rates. However, these methods show limited statistical power under small sample size[86] and do not accommodate fossil branches, hence are not appropriate for the phylogeny in this study.

Data Availability: All codes and sources can be found in Supplementary Datasheet. Nexus file of the reconstructed phylogeny is available in Supplementary Materials.

Code Availability: Source code for BayesTraits software is available on the website (http://www.evolution.rdg.ac.uk/BayesTraitsV3.0.1/BayesTraitsV3.0.1.html) and is released under GNU General Public License V3.

References

1 Peoples, H. C., Duda, P. & Marlowe, F. W. Hunter-gatherers and the origins of religion. *Human Nature* **27**, 261-282 (2016).

2 Purzycki, B. G. *et al.* Moralistic gods, supernatural punishment and the expansion of human sociality. *Nature* **530**, 327 (2016).

3 Ginges, J., Hansen, I. & Norenzayan, A. Religious Belief, Coalitional Commitment, and Support for Suicide Attacks: Response to Liddle, JR, Machluf, K., and Shackelford, TK (this issue). Understanding suicide terrorism: Premature dismissal of the religious-belief hypothesis. *Evolutionary Psychology* **8**, 147470491000800303 (2010).

4 Ginges, J., Hansen, I. & Norenzayan, A. Religion and support for suicide attacks. *Psychological science* **20**, 224-230 (2009).

5 Whitehouse, H. Dying for the group: Towards a general theory of extreme self-sacrifice. *Behavioral and Brain Sciences* **41** (2018).

6 Sosis, R., Kress, H. C. & Boster, J. S. Scars for war: Evaluating alternative signaling explanations for cross-cultural variance in ritual costs. *Evolution and Human Behavior* **28**, 234-247 (2007).

7 Ginges, J. & Shackleford, C. Self-sacrifice for a cause: The role of ideas and beliefs in motivating human conflict. *Behav Brain Sci* **41**, e203, doi:10.1017/S0140525X18001693 (2018).

8 Johnson, D. D. The wrath of the academics: criticisms, applications, and extensions of the supernatural punishment hypothesis. *Religion, Brain & Behavior* **8**, 320-350 (2018).

9 Bushman, B. J., Ridge, R. D., Das, E., Key, C. W. & Busath, G. L. When God sanctions killing: Effect of scriptural violence on aggression. *Psychological Science* **18**, 204-207 (2007).

10 Rothschild, Z. K., Abdollahi, A. & Pyszczynski, T. Does peace have a prayer? The effect of mortality salience, compassionate values, and religious fundamentalism on hostility toward out-groups. *Journal of Experimental Social Psychology* **45**, 816-827 (2009).

11 Graham, J. & Haidt, J. in *Herzliya series on personality and social psychology. The social psychology of morality: Exploring the causes of good and evil* (eds M. Mikulincer & P. R. Shaver) (American Psychological Association., 2012).

12 Juergensmeyer, M. *Terror in the mind of God : the global rise of religious violence*. (University of California Press, 2000).

13 Juergensmeyer, M. The logic of religious violence. *The Journal of Strategic Studies* **10**, 172-193 (1987).

14 Sosis, R., Phillips, E. J. & Alcorta, C. S. *Sacrifice and sacred values: Evolutionary perspectives on religious terrorism*. (New York: Oxford University Press, 2012).

15 Wessinger, C. in *The Oxford Handbook of Apocalyptic Literature* (2014).

16 Walliss, J. & Aston, J. Doomsday America: The pessimistic turn of post-9/11 apocalyptic cinema. *The Journal of Religion and Popular Culture* **23**, 53-64 (2011).

17 Bromley, D. G. & Wessinger, C. in *The Oxford Handbook of Millennialism* (2011).

18 Lincoln, B. À la recherche du paradis perdu. *History of religions* **43**, 139-154 (2003).

19 Cook, D. *Studies in Muslim apocalyptic*. (Darwin Press, 2002).

20 Bowering, G. *et al. The Princeton Encyclopedia of Islamic Political Thought*. (Princeton University Press, 2013).

21 Kenney, J. T. in *The Oxford Handbook of Millennialism* (2011).

22 Gallagher, E. V. in *The Oxford Handbook of Millennialism* (2011).

23 Juergensmeyer, M. *Global religions: An introduction*. (Oxford University Press, 2003).

24 Wojcik, D. in *The Oxford handbook of millennialism* (2011).

25 Ellwood, R. S. UFO Religious Movements. *America's Alternative Religions* (1995).

26 Velji, J. in *The Oxford Handbook of Religion and Violence* (2012).

27 Daftary, F. *The Ismāʿīlīs : their history and doctrines*. Second edition. edn, (Cambridge University Press, 2007).

28 Tucker, W. F. & ProQuest. *Mahdis and millenarians : Shi'ite extremists in early Muslim Iraq*. (Cambridge University Press, 2008).

29 Mahalingam, R. Essentialism, culture, and power: Representations of social class. *Journal of Social Issues* **59**, 733-749 (2003).

30 Jost, J. T. *et al.* Belief in a just God (and a just society): A system justification perspective on religious ideology. *Journal of Theoretical and Philosophical Psychology* **34**, 56 (2014).

31 White, C., Baimel, A. & Norenzayan, A. What are the causes and consequences of belief in karma? *Religion, Brain & Behavior* **7**, 339-342 (2017).

32 White, C. J. & Norenzayan, A. in *Advances in experimental social psychology* Vol. 60 1-63 (Elsevier, 2019).

33 Willard, A. K., Baimel, A., Turpin, H., Jong, J. & Whitehouse, H. Rewarding the good and punishing the bad: The role of karma and afterlife beliefs in shaping moral norms. *Evolution and Human Behavior* (2020).

34 Procházka, S. in *Oxford Research Encyclopedia of Religion* (2015).

35 Obeyesekere, G. & American Council of Learned, S. *Imagining karma : ethical transformation in Amerindian, Buddhist, and Greek rebirth*. (University of California Press, 2002).

36 Crone, P., American Council of Learned Societies. & ACLS Humanities E-Book (Organization). xvii, 566 p (Cambridge University Press,, New York, NY, 2012).

37 Abouheif, E. A method for testing the assumption of phylogenetic independence in comparative data. *Evolutionary Ecology Research* **1**, 895-909 (1999).

38 Kelsay, J. in *The Oxford Handbook of Religion and Violence* 306 (Oxford University Press, 2013).

39 Syed, M. Jihad in Classical Islamic Legal and Moral Thought. *Just War in Religion and Politics, ed. Jacob Neusner, Bruce Chilton, and RE Tully*, 135-162 (2013).

40 Firestone, R. *Jihād : the origin of holy war in Islam*. (Oxford University Press, 1999).

41 Collard, M., Shennan, S. J. & Tehrani, J. J. Branching, blending, and the evolution of cultural similarities and differences among human populations. *Evolution and Human Behavior* **27**, 169-184 (2006).

42 Sosis, R. & Alcorta, C. Signaling, solidarity, and the sacred: The evolution of religious behavior. *Evolutionary Anthropology: Issues, News, and Reviews: Issues, News, and Reviews* **12**, 264-274 (2003).

43 Sterelny, K. Cultural evolution in California and Paris. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* **62**, 42-50, doi:10.1016/j.shpsc.2016.12.005 (2017).

44 Wilson, D. S. *Darwin's cathedral : evolution, religion, and the nature of society*. (University of Chicago Press, 2003).

45 Matthews, L. J., Edmonds, J., Wildman, W. J. & Nunn, C. L. Cultural inheritance or cultural diffusion of religious violence? A quantitative case study of the Radical Reformation. *Religion, Brain & Behavior* **3**, 3-15 (2013).

46 Watts, J., Sheehan, O., Atkinson, Q. D., Bulbulia, J. & Gray, R. D. Ritual human sacrifice promoted and sustained the evolution of stratified societies. *Nature* **532**, 228, doi:10.1038/nature17159 (2016).

47 Watts, J., Sheehan, O., Bulbulia, J., Gray, R. D. & Atkinson, Q. D. Christianity spread faster in small, politically structured societies. *Nat Hum Behav* **2**, 559-564, doi:10.1038/s41562-018-0379-3 (2018).

48 Gaiser, A. *Muslims, Scholars, Soldiers: the origin and elaboration of the Ibadi Imamate traditions*. (Oxford University Press, 2010).

49 Lapidus, I. M. *Islamic societies to the nineteenth century : a global history*. (Cambridge University Press, 2012).

50 Cook, M. A. *Commanding right and forbidding wrong in Islamic thought*. (Cambridge University Press, 2001).

51 Bearman, P. J. *Encyclopaedia of Islam*. (Koninklijke Brill NV, 2012).

52 Tucker, W. F. *Mahdis and millenarians : Shī'ite extremists in early Muslim Iraq*. (Cambridge University Press, 2008).

53 Pagel, M. & Meade, A. Bayesian analysis of correlated evolution of discrete characters by reversible-jump Markov chain Monte Carlo. *The American Naturalist* **167**, 808-825 (2006).

54 Renfrew, C., Zubrow, E. B. & Audouze, F. *The ancient mind: elements of cognitive archaeology*. (Cambridge University Press, 1994).

55 McBrearty, S. & Brooks, A. S. The revolution that wasn't: a new interpretation of the origin of modern human behavior. *Journal of human evolution* **39**, 453-563 (2000).

56 Powell, R. & Clarke, S. Religion as an evolutionary byproduct: A critique of the standard model. *The British Journal for the Philosophy of Science* **63**, 457-486 (2012).

57 Johnson, D. & Krüger, O. The good of wrath: Supernatural punishment and the evolution of cooperation. *Political theology* **5**, 159-176 (2004).

58 Norenzayan, A. *et al.* The cultural evolution of prosocial religions. *Behav Brain Sci* **39**, e1, doi:10.1017/S0140525X14001356 (2016).

59 Power, E. A. Discerning devotion: Testing the signaling theory of religion. *Evolution and Human Behavior* **38**, 82-91 (2017).

60 Sosis, R. Religious behaviors, badges, and bans: Signaling theory and the evolution of religion. *Where God and science meet: How brain and evolutionary studies alter our understanding of religion* **1**, 61-86 (2006).

61 Turchin, P. *Ultrasociety : how 10,000 years of war made humans the greatest cooperators on Earth*. (Beresta Books, 2016).

62 Sosis, R. & Bressler, E. R. Cooperation and commune longevity: A test of the costly signaling theory of religion. *Cross-cultural research* **37**, 211-239 (2003).

63 Atran, S. Genesis of suicide terrorism. *Science* **299**, 1534-1539, doi:10.1126/science.1078854 (2003).

64 Kalyvas, S. N. *The logic of violence in civil war*. (Cambridge University Press, 2006).

65 Berman, E. *Radical, religious, and violent: The new economics of terrorism*. (MIT press, 2011).

66 Kirby, K. R. *et al.* D-PLACE: A global database of cultural, linguistic and environmental diversity. *PloS one* **11**, e0158391 (2016).

67 Turchin, P. *et al.* Seshat: the global history databank. *Cliodynamics: The Journal of Quantitative History and Cultural Evolution* (2015).

68 Gray, R. D. & Watts, J. Cultural macroevolution matters. *Proceedings of the National Academy of Sciences* **114**, 7846-7852 (2017).

69 Maddison, W. & Maddison, D. Mesquite 2. *A modular system for evolutionary analysis* (2007).

70 Slingerland, E. *et al.* Coding culture: challenges and recommendations for comparative cultural databases. *Evolutionary Human Sciences*, 1-20 (2020).

71 Gaiser, A. Source‐Critical Methodologies in Recent Scholarship on the Khārijites. *History Compass* **7**, 1376-1390 (2009).

72 Lewinstein, K. Making and unmaking a sect: the heresiographers and the Ṣufriyya. *Studia Islamica*, 75-96 (1992).

73 Fritz, S. A. & Purvis, A. Selectivity in mammalian extinction risk and threat types: a new measure of phylogenetic signal strength in binary traits. *Conserv Biol* **24**, 1042-1051, doi:10.1111/j.1523-1739.2010.01455.x (2010).

74 Orme, D., Freckleton, R., Thomas, G. & Petzoldt, T. The caper package: comparative analysis of phylogenetics and evolution in R. *R package version* **5**, 1-36 (2013).

75 Meade, A. & Pagel, M. (2017).

76 Pagel, M., Meade, A. & Barker, D. Bayesian estimation of ancestral character states on phylogenies. *Syst Biol* **53**, 673-684, doi:doi:10.1080/10635150490522232 (2004).

77 Paradis, E. & Schliep, K. ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. *Bioinformatics* **35**, 526-528, doi:10.1093/bioinformatics/bty633 (2019).

78 Wickham, H. *ggplot2: elegant graphics for data analysis*. (Springer, 2016).

79 Pagel, M. Detecting correlated evolution on phylogenies: a general method for the comparative analysis of discrete characters. *Proc. R. Soc. Lond. B* **255**, 37-45 (1994).

80 Kass, R. E. & Raftery, A. E. Bayes factors. *Journal of the american statistical association* **90**, 773-795 (1995).

81 Currie, T. E., Greenhill, S. J., Gray, R. D., Hasegawa, T. & Mace, R. Rise and fall of political complexity in island South-East Asia and the Pacific. *Nature* **467**, 801-804, doi:doi:10.1038/nature09461 (2010).

82 Therneau, T. M. & Lumley, T. Package 'survival'. *Survival analysis Published on CRAN* (2014).

83 Kassambara, A., Kosinski, M., Biecek, P. & Fabian, S. Package 'survminer' *Published on CRAN* (2017).

84 Maddison, W. P., Midford, P. E. & Otto, S. P. Estimating a binary character's effect on speciation and extinction. *Systematic biology* **56**, 701-710 (2007).

85 Beaulieu, J. M. & O'Meara, B. C. Detecting Hidden Diversification Shifts in Models of Trait-Dependent Speciation and Extinction. *Syst Biol* **65**, 583-601, doi:10.1093/sysbio/syw022 (2016).

86 Davis, M. P., Midford, P. E. & Maddison, W. Exploring power and parameter estimation of the BiSSE method for analyzing species diversification. *BMC Evol Biol* **13**, 38, doi:10.1186/1471-2148-13-38 (2013).

Acknowledgements: This research received no specific grant from any funding agency. We thank Professor Luke Matthews for his advice on defining religious taxa and Professor Mairaj Syed for his helpful comments on the manuscript and the dataset.

Author Contributions: Conception: BK, MR; Data collection: BK, ZH; Data analyses and visualisation: ZH; Writing: BK, ZH, MR; Editing: BK, ZH, MR.

Competing Interests statement: The authors declare no competing interest.

Figure Legends

Figure 1. Time-Calibrated Reconstruction of the Phylogeny of Islamic Sects. Horizontal axis indicates Years-before-present. Topology based on historical records of the splitting events of Islamic sects from its inception circa. 610 CE to 2000 CE. The reconstructed phylogeny is fully bifurcating. 20 internal nodes with known character states were identified and fixed using the "Fossil" command in *BayesTraits v3* to inform ancestral state reconstruction and co-evolutionary analyses. See Supplementary Datasheet for sources of tree-building and time calibrations.

Figure 2. Inferred transition rates between states of eschatological belief and intergroup violence. Using BayesTraits DISCRETE program[53] Arrow widths proportional to inferred transition rates. Dashed arrows indicate transition rates not statistically significantly above zero. See Table S7 for estimated log marginal likelihoods of dependent and independent models of correlated evolution. There is no evidence for correlated evolution between apocalyptic and reincarnation beliefs (logBF=1.731).

Figure 3. Survival Probability of sects with belief/violence versus sects without belief/violence against Time (years). Cox Proportional Hazard Regression for Duration of Group Survival showed no statistically-significant correlation between the states of reincarnation beliefs and the duration of group survival (extinction risk coefficient = 0.9053, 95%CI = 0.3378 - 2.426, p = 0.843). Apocalyptic beliefs (**b**) (coefficient = 4.043, 95%CI = 1.683 - 9.712, p = 0.0018), religious violence (**d**) (coefficient = 3.532, 95%CI = 1.289 - 9.673, p = 0.0141), and revolutionary violence (**c**) (coefficient = 3.071, 95%CI = 1.191 - 7.916, p = 0.0202) are statistically significant predictors of group longevity.