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Network analysis reveals insights about the interconnections of Judaism and Christianity in the first centuries CE

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The development of the two religions: Christianity and Judaism, is a topic of much debate. Whereas Judaism and Christianity are known as separate religions, in fact, these two religions developed side by side. While earlier researchers conceptualized a “parting-of-the-ways,” after which the two religions evolved independently, new studies reveal a multi-layered set of interactions throughout the first several centuries CE. Until recently, this question was explored with the limited source material and limited tools to analyze it. While working on a limited set of data, from a specific corpus, this project offers a new set of methodological tools, borrowed from computer sciences, that could ultimately serve for understanding the connections between Jews and Christians in late antiquity. We generated models of inter-religious Christian–Jewish networks that demonstrate the scope, nature, and advantages of network analysis for revealing the complex intertwined evolution of the two religions. The Jewish corpora chosen for this research are rabbinic writings from late antique Babylonia and Palestine. Christian texts range from the first through sixth centuries CE. Instead of representing interactions between people or places, as is typically done with social networks, we model *literary interactions* that, in our view, indicate historical connections between religious communities. This novel approach allows us to visually represent sets of temporal-spatial-contextual relationships, which evolved over hundreds of years, in single snapshots. It also reveals new insights about the relationships between the two communities. For example, we find that rabbinic sources exhibit a largely polemical approach towards earlier Christian traditions but a non-polemical attitude towards later ones. Moreover, network analysis suggests a temporal-spatial familiarity correlation. Namely, Jewish sources are familiar with early, eastern Christian sources and with both Eastern and Western Christian sources in later periods. The application of network analysis makes it possible to identify the most influential texts—that is, the key “nodes”—testifying to the importance of certain traditions for both religious communities. Finally, the network approach is a tool for pointing scholarly research in new directions, which only reveals itself as a result of this type of mapping. In other words, the network not only describes the known data, but it is itself a way to enlarge the network and lead us down new and exciting paths that are currently unknown.

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Introduction

Network analysis has revolutionized our ability to analyze complex systems. Simply put, a network is a mathematical representation depicting connections between nodes, which could represent for instance biological cells, cities, individuals, or texts (Watts and Strogatz, 1998; Scott and Carrington, 2011; Collar et al., 2015; Finn et al., 2019). The connections between the nodes thus portray diverse systems of interactions such as biological organisms, transportation maps, or social communities. Among its advantages is the ability to represent a system visually facilitating our understanding of the effects of each set of interactions on the system as a whole.

Network analysis allows asking both quantitative and qualitative questions about the system. For example, network analysis allows detecting nodes that are key for information transfer through the network, allows identifying clusters of nodes that are strongly connected, and allows measuring information flow through the system. Moreover, network analysis allows running theoretical simulations to examine how the system operates under various conditions. Network analysis has been heavily used to describe gene and protein networks and their control over biological processes (Ma'ayan, 2011) as well as the effect of removal of a specific species from an ecological system or an individual from a social structure (Bellingeri et al., 2020).

Here, we propose to apply network analysis to a known scholarly question, namely the connections between Jews and Christians in late antiquity as they are revealed in the Babylonian Talmud, the major Jewish literary corpus of late antiquity composed in Babylonia (modern-day Iraq), as well as sources from the land of Israel. In this article, we limit our exploration to the smaller question of Jewish knowledge of Christian traditions but propose that our methodology can be expanded in future studies to address the larger question of Jewish-Christian interactions as a whole. We assume, for the purpose of this study, that textual connections between religious communities could testify to actual contacts between the composers of the texts and the communities that produced them (Bar-Asher Siegal, 2013, 2019). These connections, and specifically the ones discussed here from the Babylonian Talmud, are an essential part of the historical development of Judaism and Christianity, revealing the continuous dialog between the two religious communities in this crucial period.

“The parting of the ways” is often used as a metaphor to describe the separation of Judaism and Christianity into two distinct entities. It presumes a specific moment when this split occurred, leading scholars to describe and define an original, single “way” (the pre-split religious entity), a moment of separation, and then two separate “ways” that emerged from the “parting.” This prevailing assumption assumed the continuation of biblical Judaism in rabbinic Judaism and made sense as a way to describe the split between the two religions, when the Jesus movement appeared, creating Christianity as a separate entity without interaction between the two. However, as scholars have convincingly shown, a simplistic representation of the relationship between Judaism and Christianity as “ways that parted” does not adequately reflect the multifaceted evidence for the varied, ongoing relationships between the two religions and religious communities, nor does it recognize that the expression of religious identity is dynamic, changing depending on the historical context (Nicklas, 2018, 2019). In late antique Jewish and Christian texts, admonitions against following borrowed customs are preserved alongside casual references to joint religious practices, depicting a reality in which Jews and Christians lived in close proximity and engaged in a range of relationships (Becker and Yoshiko Reed, 2003; Schwartz, 2004a; 2004b; Zetterholm, 2005; Reinhartz, 2006; Boyarin, 2007; Lincicum, 2010; Stemberger,

2012; Nicklas, 2014, 2018, 2019; Berthelot, 2015; Grünstäudl, 2017; Baumgarten, 2017). These studies reveal much richer and more multi-layered models of interactions than previously thought (Albert, 1993; Baum and Winkler, 2003; Brock, 2006; Becker, 2006; Mustafa and Tubach 2007; Bernheimer and Silverstein, 2012; Pourshariati, 2013; Payne, 2016; Humphries, 2017; Meier, 2017; Teppler 2007; Daryae, 2021). This relationship also changed over time: Jewish-Christian interactions are manifested in various degrees and ways over the following centuries, from the middle ages to modern times, and in various geographical locations (Elukin, 2007).

Here we offer a set of computational tools that can be used to describe and analyze the range of literary interactions between the Jewish and Christian communities. In this article, we limit our exploration to examples preserved in late antique Christian writers as well as the Babylonian Talmud and parallel Palestinian sources. But these findings support and advance the larger scholarly goal of understanding this complex inter-religious relationship and can be applied to wider sets of data in future studies.

The primary Jewish corpus chosen for this research, the Babylonian Talmud, was produced by Babylonian Jewish sages called rabbis in the Sasanian East beginning in the third century CE and finally redacted around the seventh century (Stemberger, 2011; Vidas, 2014; Bar-Asher Siegal, 2020). The choice of this corpus for the proposed study has to do, *inter alia*, with its authoritative status as the definitive work of rabbinic culture. By the 11th century, the Babylonian Talmud was the dominant source for legal decision-making throughout the Jewish world and had a strong impact on the Christian world, as well as representing “the face of Judaism” to non-Jewish communities. In addition to the Talmud, we include several textual parallels from rabbinic sources compiled in the land of Israel, including the Palestinian Talmud (redacted around the 5th century CE) and works of biblical exegesis such as *Avot deRabbi Natan* (redacted around the 8th or 9th century CE).

The Christian traditions that we analyzed are drawn from texts as early as the first-century writings of the first communities of Jesus' followers, including the New Testament, as well as from later writers of the second through sixth centuries, self-identified Christians from both Western and Eastern communities.

Broadly speaking, earlier generations of scholars fall into one of two camps on the question of Christian traditions in the Babylonian Talmud. Those in the first group, which includes the majority of earlier scholars, were not concerned with rabbinic literature's relation to Christian source material. This lack of interest was due in large part to their conception of the rabbinic corpus as distinct from all other contemporary bodies of literature. In the other camp were those few scholars who did explore the relationship between rabbinic literature and its Christian parallels. However, these scholars focused on rabbinic works produced in the land of Israel, under the pagan or Christian Roman Empire. In recent years, owing to the above-mentioned advances in the study of Christianity, scholars of rabbinic texts have begun to explore the Babylonian Talmud in light of Christian sources. They have found a number of examples attesting to different types of literary interactions ranging from fierce polemics to analogies, shared theological concepts, appropriation, and parody (Brock, 1979; Boyarin, 1999, 2007; Kalmin, 1994, 2006; Rouwhorst, 1997; Stökl Ben Ezra, 2003; Schäfer, 2007; Zellentin, 2011; Frey, 2017; Bar-Asher Siegal, 2013, 2019, among others). The methods these scholars used have been philological in nature and based on a comparison of textual passages in Jewish and Christian texts. The passages were found in manual searches in databases, and analyzed by scholars based on their vast historic

and textual background. The results have no doubt revolutionized the study of Jewish–Christian relations as seen in literary sources. However, the limitations of these methods are apparent. They do not allow discussion of quantitative nature. Specifically, the study of local anecdotal cases does not facilitate the understanding of the effects of each set of interactions on the system as a whole. The anecdotal approach makes it difficult to identify the most influential texts and traditions, that is, the key “nodes,” and to seek to quantify the importance of each node in the Jewish–Christian or in other inter-religion literary networks of interaction.

As we will see below, our small-scale networks, using examples from the corpora chosen showcase possible uses of network analysis to illuminate broader issues.

Network analysis has already been adopted in literary sciences, and even within the realm of religious texts (Collar, 2015; Elwert, 2021). For instance, Clark (1991) created hand-drawn networks relating to the Origenist controversy. Adam Schor (2011) used social network theory to demonstrate the complex “doctrinal coalitions” of fifth-century religious clashes involving Theodoret the bishop of Cyrhus and his Syrian allies and opponents. The GEHIR is an interdisciplinary research initiative at Masaryk University, Brno, which applies selected methods of formalized modeling to the study of the diffusion dynamics of specific religious ideas such as the spread of the Isiac cults (<https://gehir.phil.muni.cz/> and see Fousek et al., 2018; Glomb et al., 2018; Chalupa et al., 2021)

In the case of the Judaism of our period, Hezser (1997) suggested that rabbinic social circles might be understood with the help of network analysis as applied in sociological studies. Lapin (2001) took an important step forward by creating visual representations of networks in rabbinic literature on matters such as geography and economy. Satlow and Sperling (forthcoming) created citation networks within the rabbinic texts, and Lapin (forthcoming) used rabbinic case narratives to examine the question of social networks. We should note, however, that while rabbinic figures are mentioned by name throughout the rabbinic corpus, new scholarship doubts the historical reliability of the attribution of statements and stories to particular individuals, making network analysis methodologically problematic (but see Satlow and Sperling (forthcoming) on this issue). Elwer (2021) surveys the use of networks in the study of religion, primarily to model networks of individual persons and their interactions, but he also moves from a social network to a semantic-based network to suggest automatic topic modeling of words and their interactions, in the case of Ancient Egyptian texts. Although these studies and others have used names of persons or places to model social networks, and even specific words to create literary networks based on linguistic criteria, to the best of our knowledge, no previous study has used networks to represent and analyze literary interactions between religious communities based on *textual parallels* between them.

Our networks visually represent Jewish–Christian literary interactions, occasions where a source from one religious tradition shows familiarity with one or more sources from the other religious tradition. The anthological nature of the rabbinic sources incorporates almost no source attributions, making it very hard to prove literary borrowing or references to parallel sources. This makes our networks unique in the sense that they depict, for the first time, connections between religious traditions. They allow us to understand the movement of theological concepts, stories, biblical interpretations, and more, from one community to the other. In other words, we offer a new approach by using textual interactions to model social ones.

In short, the unique nature of this project lies in the application of a new methodology to the subject of Jewish-Christian relations

in the formative period of both religions, aimed not only at identifying and collecting the relevant sources but also at mapping them. Moreover, while taking into account that parallel textual traditions can stem from various reasons: literary borrowing, common source, or independent parallel developments; our approach to connecting rabbinic and Christian literary sources makes possible also the in-depth investigation of the complex system of possible actual historical interactions between the two religious communities that produced these texts. As a result, we will be able to offer tools to address the question: how much did Jews know about Christians and Christianity in this formative period?

Methods

Our research is based on a qualitative approach grounded in the philological study of texts. We generated several exemplary inter-religious Christian–Jewish networks. In our context, the nodes of the network are literary traditions found either in rabbinic or Christian sources, while the edges depict that the two nodes are both familiar with a specific tradition within the literary corpus of the other religious community. We use the term “traditions” to describe literary motifs, describing, among others, theological, practical, or hagiographical aspects; which in turn are analogous to parallel theological, stylistic, and lexical features of the other religion. In other words, each node is a literary tradition, and each edge represents a literary interaction between the sources based on the shared tradition. We also annotated our networks according to several salient contextual factors such as their geographical and chronological backdrop of the literary traditions. Note that literary traditions that we refer to could have been known to the rabbinic authors either through textual or oral transmission, but we must rely on texts to find evidence for their existence.

Data collection methods: The two main Talmudic passages we chose to use in this research represent examples of two types of texts used to demonstrate Jewish–Christian literary interactions. The first comes from a Talmudic corpus of stories about heretics discussing biblical verses with rabbinic figures (Bar-Asher Siegal, 2019); the second comes from a recently recognized Talmudic corpus of traditions engaging with contemporary Christian monastic traditions (Bar-Asher Siegal, 2013). By using two exemplary, well-studied passages, we demonstrated the proposed method, to show how even from these two test cases, one can draw conclusions that might not have been apparent without applying network analysis.

In addition to the Talmudic passages, we include several textual parallels from rabbinic sources: the Palestinian Talmud and Avot deRabbi Natan. The choice of the addition of these rabbinic parallels was made due to the analogous literary topoi found in them, suggesting a literary connection between the traditions. These few passages suggest the existence of possible connections between the Christian authors and the rabbinic ones. We do not, at this point, claim that the networks we analyze represent the full picture revealed by the Jewish–Christian literary network.

We generated weighted directional networks (connectivity matrices).

The edges between the nodes in our networks were weighted according to the level of certainty regarding the connection between the sources. In total, in our data set, we identified three levels of certainty in the knowledge of the shared tradition (visualized in solid, dashed, and finely dashed lines). Note, however, that we do not quantify the difference between these levels of certainty. For example (see supplementary text 1 for the details), our network shows a literary connection regarding a theological dispute about the status of the Holy Spirit and its

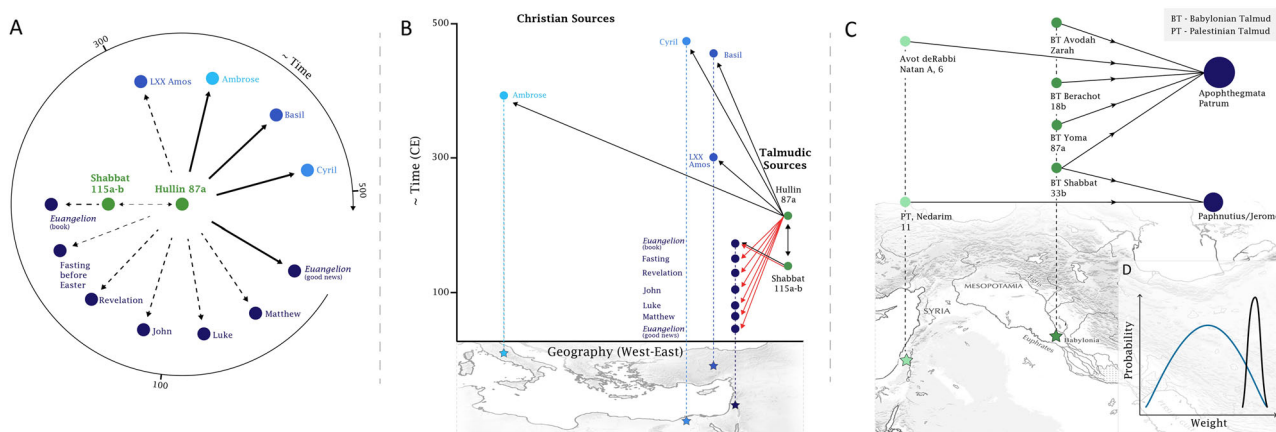


Fig. 1 Inter-religious literary networks. **A** The Hullin network in a polar representation. Nodes are color-coded according to their religious origin. The thickness of the edges represents their certainty. Specifically, solid lines represent the highest certainty, thick dashed lines represent less certainty and thin dashed lines represent the least certain connections. The angle on the circle depicts a time on a non-linear scale. **B** The Hullin network in spatial-temporal representation. Edges are color-coded according to their type (polemic or non-polemic), and nodes are color-coded according to their religious origin (green or blue) and according to their geographical location (in shades of blue). Nodes are distributed in space according to their temporal and geographical relations. Arrows with varying thickness depict the direction and weight of the edge. **C** The Monastic network is represented according to the same schematic as the Hullin network (see **B**) only that geography is represented in shades of green. The size of the nodes is scaled according to Google’s page ranking algorithm. Specifically, the nodes ranked as follows: 0.3683, 0.1737, 0.0763, 0.0763, 0.0763, 0.0763, 0.0763, 0.0763, for the following nodes respectively: Apophthegmata Patrum, Paphnutius/Jerome, BT Avodah Zarah, Avot deRabbi Natan, BT Berachot 18b, BT Yoma 87a, BT Shabbat 33b, PT Nedarim 11. **D** Edge-weight distributions of the Hullin (blue) and the Monastic (black) networks. Because of their small size, we could not estimate the actual distribution and we draw an estimate.

connection to a verse in Amos. This connection provides clear evidence for a shared tradition between the Talmudic authors and the traditions mentioned in the writings of Cyril, Ambrose, and Basil. However, other shared traditions such as the literary topos of the three days fast of the rabbi found in the Talmudic story, and its connection to the Christian costume to fast for 3 days before Easter is less certain. In another example, the edge between two rabbinic nodes, Hullin and Shabbat, receives low certainty because they both refer to the Christian use of the Greek word *euangelion*, but to different meanings of the term. These weights are obviously debatable, reconstructed based on human expertise, previously published in an already established research (Bar-Asher Siegal 2013, 2019). Each node in our small-scale network is based on extensive research, on each case individually and its probability takes into account the overall findings regarding the specific edge. Note that the exact scale of the weights is arbitrary and does not influence any of our results (more information about the weights of specific edges can be found in the supplementary text 1). Note that the weights of all edges in the monastic network are equal. This is due to the certainty of the connections between the sources, and is easier to demonstrate than in the case of the Hullin network: The later time and geographical spread of the Christian monks (not earlier than the 4th century), as well as their unique literary characteristics (for example stories about people staying in caves) makes the case for shared knowledge of literary traditions about them, by the rabbinic authors, much more likely and equally likely (see Bar-Asher Siegal, 2013).

Notice that the level of certainty of the connections between the nodes in our networks relates to the *knowledge* of the content by the Rabbinic authors, but they do not presume to represent the certainty about the actual contact between the authors of these specific texts (see results and discussion). The directionality was based on which resource was familiar with the other (i.e. whether the Christian relies on the Jewish source or vice versa). Each connection in our connectivity matrix is based on vast historical philological research done by the human hand. A list of the connections with brief explanations can be found in Supplementary

text 1 (based on fuller descriptions found in Bar-Asher Siegal, 2013, 2019). We annotate the edges according to type: polemic or non-polemic (Fig. 1B). Literary relationships which express a literary attack on Christian tradition, often using literary devices such as satirical language, were classified as polemic; while others that lack a negative tone were classified as non-polemical, and seen Bar-Asher Siegal (2013, 2019) for a more detailed discussion.

We used several graphical representations to present and analyze these networks: (1) we color-coded the edges according to type (polemic or non-polemic), and the nodes according to their religious origin and geographical location; (2) we distributed the nodes in space according to their temporal and geographical relations; and (3) we depicted the direction and weight of each edge using arrows of varying type thicknesses. All of the above has allowed us to interpret the networks, providing new insights into the early relations between Judaism and Christianity.

We further used Google’s node ranking algorithm (applied in Matlab) to rank the nodes of the Monastic network.

Because of the small scale of our networks, all of the data necessary to reconstruct them is available in the networks themselves.

Results

(1) The first analysis we present is based on a story found in the Babylonian Talmud tractate *Hullin 87a*, and we thus refer to this network as the Hullin network. The story tells of an interaction between Rabbi Yehuda Hanasi and a *min* (literally, “a heretic”). The heretic poses a question about a biblical verse from the book of Amos to the rabbi who answers the heretic, who then commit suicide, and whose death is mocked by the rabbi and a second heretic. The story is part of a larger corpus of such rabbis-heretics stories, a corpus which we accept, based on scholarly findings, as a literary representation of contemporaneous Jewish-Christian literary dialogs (Bar-Asher Siegal, 2019). We mapped the connections between this Talmudic story and various Christian sources from different periods and geographical areas. We used

these connections to present two different representations of the Hullin network.

In the first network (Fig. 1A) we show a typical graphical representation, where the central node (tractate Hullin 87a) appears as a hub aggregating connections with multiple Christian sources. We color-code the nodes according to source—Christian or Jewish, and we use a directional representation: the connections between nodes are arrows pointing in the direction of the information transfer, i.e., from the Christian to the Jewish literary corpus. Note that in our work, networks are based on searching Christian traditions within rabbinic sources, and thus all arrows point in the same direction. Future work will generate bi-directional networks. We also use a weighted representation in which the type and thickness of the connections represent our level of certainty regarding the connection. We arrange the nodes along a circular time axis and color-code them according to their geographical origin (in shades of blue).

In the second representation (Fig. 1B), we present the same data, but this time we distributed the Christian sources (blue nodes) along a temporal vertical axis and their geographical origin along a spatial horizontal axis. This literary–temporal–spatial representation reveals the spatial–temporal dynamics of the inter-religious interactions. For example, the fact that BT Hullin 87a refers to Christian sources created as a result of a theological debate about the status of the Holy Spirit taking place in the fourth and fifth centuries CE, suggests that it could not have been written before that period (see discussion and Supplementary text 1). Moreover, in this example, we also color-coded the edges according to their type, in this case, either polemical edges, implying a theological argument with the Christian tradition (red), or non-polemical edges, simply showing familiarity with Christian traditions (black). Color-coding the edges provides new insight, allowing us to assess the proportion of different types of inter-religious connections.

Color-coding the edges, also led, thanks to this visualization of the data, to the understanding that, at least in this case, rabbinic engagement with earlier Christian sources (such as the New Testament) is typically polemical while engagement with later Christian authors is not. One edge (between an additional Talmudic passage from BT Shabbat 115a and the term *Euangelion* for book), includes materials of both types and is thus color-coded in both red and black. Note that temporally, this double-colored edge fits the hypothesis above regarding early vs. late types of content: It shows the liminal time period where the polemical attitudes towards early Christian sources turn to non-polemical ones. This provides independent support for our analysis: specifically, it contains polemical content about the New Testament traditions, but also simple awareness of the later non-polemical meaning of the term *Euangelion* to indicate the books themselves.

Furthermore, distributing the nodes and color-coding them according to their geographic origin (in shades of blue from east to west), reveals that the earlier Christian traditions referred to in the Talmud are primarily Eastern traditions while later traditions arrive both from east and west.

Note that the geographical identities depict the location where the texts were composed, but they do not necessarily indicate the location from which they were known to the Jewish authors. Thus, the connections between the nodes in our networks are certain because they relate to the knowledge of the content, but they do not presume to depict actual contact between the authors of these specific texts. Generally speaking, the earlier the tradition and the more it was widespread, the harder it is to pinpoint the location from which it was adopted in later years. The New Testament traditions provide a clear example of this issue: composed in the first century CE and widespread by the time they were incorporated into the rabbinic texts, it is hard to determine

in what way they were made known to the Jewish authors. In other words, the nodes represent the geographical “identity,” of a Christian tradition, but not the source’s geographical origin at the time of its incorporation into the Jewish sources.

Together, these two findings, namely the change over time in the nature of the rabbinic attitude towards Christian traditions, from polemical to non-polemical; and the temporal–geographical patterns of the literary contacts between the two religious communities; both demonstrate how our network approach can reveal new insights about scholarly topics that were already studied using traditional methods, which in turn, did not offer these insights.

(2) The second analysis examines literary analogies between Christian monastic texts (e.g., the *Apophthegmata Patrum* and other monastic writers) and rabbinic traditions. We shall refer to this as the Monastic network. The *Apophthegmata Patrum* or *Sayings of the Desert Fathers* is a set of early monastic literary traditions anonymously edited in Palestine in the second half of the fifth century. It was later enlarged, re-organized and re-edited in all the languages of early Christianity testifying to their widespread popularity (Rubenson 2007). The importance of the monastic movement in the Persian Empire, during the time of the composition and redaction of the Babylonian Talmud fostered a literary connection between the two religious populations, manifested in the literary traditions found in the Talmud (Bar-Asher Siegal, 2013). We also find traditions in Palestinian rabbinic sources that parallel these Christian monastic traditions. We present and analyze a graphical representation of the Monastic network (Fig. 1C). As in the previous network, we color-code the nodes according to their religious origin. We also distribute the nodes along the horizontal axis according to their geographic origin, but in this case, we do so only for the Jewish sources to demonstrate the benefits of focusing on even one of the two. In this case, all connections were equally probable and therefore the network is not weighted. The network analysis reveals clearly that the literary traditions of the *Sayings* feature in multiple rabbinic passages. The high degree of the *Apophthegmata* node indicates that it is a particular Christian literary hub for the Talmudic authors. Moreover, to quantify the relative importance of the nodes, we used Google’s page ranking algorithm to rank the importance of different nodes as sources of inter-religious literary connection. In brief, this algorithm ranks websites as more important if many other websites contain links directing to these sites. Moreover, unlike simply using the in-degree of the node, the page rank algorithm also takes into account the importance of the nodes pointing towards the node whose rank is being assessed. However, in our case, the two are identical as the pointing nodes all have the same rank. We chose to use it in order to highlight its potential for future use. In our case, higher-ranked nodes are nodes that many other nodes are connected to them, demonstrating the shared literary tradition of this node.

This network also goes a step further in demonstrating the potential of these graphs to represent complex structures, in which multiple sources are familiar with each other. Here, different corpuses edited in the land of Israel (the Palestinian Talmud and Avot deRabbi Natan nodes) show engagement with eastern and western Christian traditions, as does the Babylonian Talmud. To exemplify this, we color-code the Jewish nodes according to their geographic origin (i.e. Palestine or Babylonia) and locate them accordingly along the horizontal axis. Moreover, these Jewish Palestinian sources also show shared knowledge of the same Christian traditions, suggesting possible connections between the authors of the rabbinic texts.

In both networks, the Christian sources serve as an Archimedean point allowing new information to shed light on contacts between existing sources and the historical connections between

the communities that produced them. In other words, the network allows us to represent the complex literary relationships between sources eastern and western, Jewish and Christian, and even between the rabbinic sources themselves. This network reveals the potential of studying intra-religious literary interactions between Jewish communities spread out geographically (in Babylonia and Palestine) and even how Christian traditions can teach us about these internal rabbinic connections.

Finally, to exemplify the potential of the network analysis approach, we compare the weight distribution of the two networks mentioned above (Fig. 1D). The weight distribution of a network describes the strengths of connections between its nodes, and is often used to characterize a network as it has implications regarding network connectivity. The two networks are characterized by very different weight distributions, one of which (Hullin) is much wider than the other. To some extent, this difference reflects the difference in our knowledge about the sources (which is much more variable in the case of Hullin).

Discussion

The primary advantage of analyzing these textual connections between Jews and Christians as networks are that it provides an intuitive picture of this complex inter-communal relationship, the nature of which is still the subject of much scholarly debate. This tool enables the presentation of a great quantity of data in one clear snapshot, and it allows us to identify the most influential texts and traditions in the network—the key “nodes”—and to quantify the importance of each node. At a glance, one can identify various patterns, different types of connections, and the importance of each.

The complexity of the picture revealed by this network analysis is important in and of itself for an additional reason. For many years, the scholarly consensus that ruled the field of Jewish–Christian relations was a simplistic one: Judaism and Christianity developed along separate paths, meeting only sporadically in polemical encounters. This prevailing assumption limited scholarly analysis of Jewish–Christian relations primarily to questions of who influenced whom in reference to specific theological similarities (Schäfer, 2010, pp. 1–31). We now know that this earlier consensus ignored vast fields of interactions between Jews and Christians and largely ignored the complicated state of human inter-relations.

In fact, while it is now agreed that the simplistic model of “parting of the ways” is not adequate, scholars are still debating which alternative descriptive models *are* reflective of a complicated and nuanced historical reality. Our networks, we offer, are a way to visually represent what a limited verbal metaphor will never be able to achieve: a snapshot of a multi-facet reality spread over many decades and thousands of kilometers in which Jews and Christians interact in various ways with one another. The network analysis approach is thus not only a mathematical tool to analyze the system, but it is a conceptual tool allowing researchers to grasp its complexity.

Indeed, the main idea that these networks convey at a glance is complexity: they uncover a complicated set of data with many different interconnections. This is visually apparent from the thickness and colors of the connections; the timeline, as well as the geography. The compilation of all of this data in a visual form is a new contribution to the field. Note that our approach is limited in size and thus serves as a proof-of-concept for the potential of using network analysis in this field. However, even with such a limited data set our analyses revealed new insight into a long-standing open question. We are obviously aware that our results may not reflect the overall picture of the Jewish–Christian literary relationship, and can be misleading based on the small

scale and local findings. But the findings at least raised, several so far unnoticed, possible patterns worth examining on a larger scale.

As part of the proof-of-concept, we demonstrate two types of network analysis: (1) we compare the edge weight distribution of our two networks. Such comparisons can shed light on the differences between networks, and accordingly on the differences between inter-religion interactions as they are reflected in different literary sources. (2) We use a common node ranking algorithm to demonstrate how the connections between literary sources could be quantitatively ranked.

Some additional analyses that should be performed (on larger, more comprehensive, networks include: (1) Various centrality analyses to reveal which nodes serve as connectivity hubs. (2) Cluster analysis which allows to detect sets of sources that more often refer to each other. (3) short-path analyses to reveal which nodes might be indirectly connected with one another.

Creating inter-religious literary networks is a complicated and challenging task. It requires knowledge of a vast amount of written material, comparison of sources in different languages, and, more than anything, the painstaking work to uncover the textual parallels that testify to shared knowledge of traditions. Notably, networks that are based on names of people or places appearing together might be easier to create, but not necessarily more reliable when considering the dubious historical reliability of named sages in rabbinic sources. Though more complicated to create, literary networks are probably a more reliable tool for representing actual connections between two religious communities, suggesting that authors in both communities knew and used the same traditions, testifying to a shared tradition between them. Therefore, developing a methodology for mapping literary networks using new computational tools, will be a game changer in our ability to understand the complex historical relations between religious communities to a degree on par with the revolution that systems biology underwent through the use of gene networks (Ma’ayan, 2011; Jingwen et al. 2018).

However, we argue that fully automated text-mining algorithms will not be able to replace human philological expertise and scholarly judgment in the near future for a number of reasons: (1) One of the major obstacles such a project faces is the level of certainty ascribed to these textual connections. These textual parallels are notoriously hard to find and hard to establish (Sandmel, 1962). In some instances, we may find a strong similarity that nevertheless does not necessarily point to a connection between the authors, while in other cases two traditions are so uniquely similar that the connection is obvious to almost every reasonable reader. Often a shared tradition can be found in multiple Christian literary sources testifying to its widespread availability. It is important to stress that our network does not attempt to find the exact Christian source for a tradition found in rabbinic sources. Rather, it depicts literary connections suggesting knowledge of a tradition that can be confined in time and space. For this reason, in our monastic network, we combine two Christian Palestinian 3–4 century monastic sources (i.e., Jerome and Paphnutius nodes), because we cannot determine whether the Rabbinic nodes BT Shabbat 33 and PT Nedarim 11 are familiar with either of them (or with a similar monastic source). For this reason, we could have united, in the Hullin network, the three nodes of Cyril, Ambrose, and Basil. However, we left them as separate nodes to show their tradition’ geographical spread, and possible transmission routes to the Talmudic text.

These challenges make any attempt to describe the specific connection between the religious communities complicated and multi-layered. Despite decades, even centuries of religious studies scholarship, researchers still debate the best way to determine whether a specific textual connection testifies to an actual

interaction. In our case, in the Hullin network, we weighted the connections according to our understanding of their strengths in order to show that not all connections were born equal (see Supplementary Text 1). The visualization of these weightings in a network model is in fact a way to deal with differing levels of certainty, which are harder to demonstrate and compare using standard narrative descriptions.

(2) In addition, while some sources can be dated, we often do not know when the authors of a Jewish tradition came into contact with an earlier Christian tradition that found its way into the rabbinic corpus. For example, a New Testament tradition dating to the end of the first century CE and found in the Talmud could have been incorporated into a very early rabbinic tradition that was preserved in the later source, or it could have been known to the authors of the Talmud via later Christian writers all the way to the time of the redaction of the Talmud around the seventh century CE. In some cases, however, the use of a Christian tradition can be dated more specifically, giving us a narrower window through which the writers of the Talmudic texts could have drawn their knowledge of that tradition. For example, in the case of BT Hullin 87a, even though this text refers to traditions from a wide range of periods, spanning several centuries, we find a discussion of the status of the Holy Spirit (the Basil, Cyril, and Ambrose nodes in our Hullin network). This discussion does not appear in Christian sources before the fourth century CE, proving that this Talmudic text must post-date the emergence of Christian debate in the fourth or fifth century CE. Similarly, BT Shabbat uses the term *Euangelion* as a physical book, a use that is only found from the second century onwards, setting a lower bound on the time of its composition. In the future, when many more such connections, with multiple nodes, are mapped, such a representation will enable quick detection of other hubs as well as the timing of nodes.

We envision that a combination of computational tools and human analytical skills will allow us, for the first time, to achieve a comprehensive overview of this intriguing and emerging field of study: Jewish knowledge of and interactions with different forms of Christianity.

Another limiting factor of the literary network approach is the sampling strategy. In the natural sciences, it is common practice to sample the data independently (and randomly). Obviously, this cannot be the case in our type of study where the search for inter-religion textual interactions is based on philological and theological clues such as terminology or literary topoi, analyzed in light of a huge background of literature. To a certain extent, the obtained results could be biased by our specific selection procedure. For example, past research has tended to stress the polemical side of Jewish-Christian relations because it focused on passages with explicit mentions of Jesus (see Schäfer, 2007). Adding to the dataset examples which show literary interactions, that revolve around non-Jesus related themes such as repentance and asceticism, revealed a much more nuanced picture of the nature of the literary relationship including rabbinic passages that, on the contrary, appropriated Christian concepts (Bar-Asher Siegal, 2013).

However, in our case, we propose that the current state of scholarship (alongside better philological tools such as searchable digital databases, access to manuscripts versions, and more) allows for a more bias-conscious choice of textual parallels, correcting past biases which more severely influenced the results of the examination.

And lastly, the bigger the dataset, the less bias the results of our findings. In the future, we hope to employ computational methods for the systematic collection and organization of a massive quantity of new data on the literary parallels between the two religious communities. Harnessing existing computational methods in the search for similarities between texts, the project will create a computing interface that will allow us to view and

navigate through N-grams in the rabbinic and Christian texts. Such methods of “distant reading,” using the terminology employed in digital humanities, have focused on identifying phrases or letter sequences in multiple locations that are exactly identical, or nearly so (Coffee et al., 2012; Shmidman et al., 2018).

Despite the small scale of our networks, they do demonstrate both the potential for future collection and analysis of data as well as newly discovered insight. For example, in the Hullin network (Fig. 1A, B), we distributed the Christian sources along vertical and circular temporal axes. This literary-temporal network, used to our knowledge for the first time, has allowed us to date Talmudic texts based on their references to Christian sources. In addition, in the second representation of the Hullin network (Fig. 1B) color-coding the connections in this network according to their content, i.e. polemical or non-polemical, has led to the new realization that polemical connections are generally earlier than non-polemical connections. The Babylonian Talmud’s authors thus tend, at least in the cases examined here, to polemicize against earlier sources, such as New Testament traditions, while they treat later sources in non-polemical fashion. This discovery would have been harder to reach without a visual representation that immediately demonstrated the change over time, through placement on the temporal axis and color-coding of the edges. Another such discovery was the realization that distributing and color-coding the nodes according to their geographic origin reveals that earlier Christian traditions referenced in the Talmud are mainly eastern traditions, while later traditions arrive both from east and west, at least in the small sample examined in this study. This is another novel insight revealed by our visualization.

In other words, this small-scale network is a good example of how many layers of information can be added to a visualization and read together, in concert, to illuminate unseen phenomena and patterns unknown to previous researchers. However, the networks are also based on, thus far, limited scholarly knowledge of the sources, or manual searches. The creation of broader networks in the future must necessarily be based on human-machine combined approaches which will produce high throughput information in a shorter time and provide a broader image of the complex interactions. This more complete network would also map the Christian sources’ literary connections to Talmudic traditions, creating a bi-directional network of interactions as opposed to the one-directional networks we created.

Thus, this future, more comprehensive, network analysis will finally allow us to navigate the mosaic landscape of late antique religious encounters in new and exciting ways.

Alongside the primary goal of mapping connections between religions, these network models can also reveal new insights about the Talmud’s redaction, which is currently a topic of great scholarly interest but little certainty (Vidas, 2014). Knowing the extent of Talmudic authors’ interactions with non-Jewish traditions, their timing, geographic location, and whether the interactions were polemical in nature; all of this data can enrich our understanding of the raw literary material from which the Talmud was created. But even more than that, our ability to visualize connections between passages *within* the rabbinic corpus is itself a remarkable feat. The fact that two different rabbinic texts are aware of the same Christian tradition (e.g. the two Talmudic passages in BT Shabbat and Hullin (Fig. 1A, B); or the passages in BT Shabbat and PT Nedarim 11 (Fig. 1C)) is a sign of shared knowledge. This kind of information—that the authors of two different rabbinic passages shared knowledge of a non-rabbinic tradition and are therefore connected in some ways in their editorial processes—is novel and only available to us via the use of network visualization.

Importantly, by pointing us to new scholarly questions, the analysis of the assembled data and network visualizations gives us

the tools to answer the fundamental question: “How much knowledge of Christianity did late antique Jews possess?” The application of network analysis will make it possible to start asking: what is each component’s degree of influence, each parallel text and tradition, within the network? For example, how many connections involve rabbinic familiarity with the New Testament? Which parts of the New Testament? Are there connections to writings by later Christian authors? From which geographical areas and in which languages?

All of the above then allows us to ask what the network shows us about the levels of connectedness? What are the “hubs” in the newly created network? Are there specific Christian texts that are connected to a large number of different Talmudic passages, whereas others are only seldom or never connected? Are authors and traditions from within the Roman and Early Byzantine realm relevant to the Talmudic authors, or only traditions belonging to eastern Christianity? Is the divide between the Churches within and outside the Sasanian Empire relevant? Why are certain expressions of Christian belief, certain Christian practices, and certain Christian writings of interest to the rabbis while others are not? Do most cases present polemical attitudes toward the Christian traditions, or do they display shared motifs and theological ideas? Are the literary parallels centered around late antique realia, religious praxis, rhetorical devices, or other areas of social interaction? An interaction map will create a picture of the “Christian library,” or rather the multiple different “Christian libraries,” be they virtual or physical, to which the rabbis had access, as well as a list of each library’s “best sellers.”

After identifying the Christian texts that serve as “hubs,” those that are most often linked to rabbinic passages, we will be able to examine whether new patterns emerge. What kind of new questions that we did not even know to ask will present themselves as a result of this mapping? In other words, the network is not only a tool for describing its own data, but it is itself a way to enlarge the network and to lead us to new and exciting currently-unknown scholarly paths.

Finally, our use of networks thus far is aimed at observing and interpreting known connections, but networks can also be used as generative models, that is, models that allow predicting unknown and even non-existing connections. For example, our networks reveal two types of interactions: (1) of one rabbinic source showing familiarity with many other Christian traditions (Hullin network) and (2) of many rabbinic traditions showing familiarity with one Christian source (the monastic network). Larger data sets together with network analysis tools could allow to infer whether these are general patterns in Jewish–Christian literary tradition flow and perhaps even in other inter-religious literary interactions. Network analysis allows additional types of inference. For instance, if two Jewish sources are both familiar with a Christian source this might imply that they are familiar with each other. And—if we can demonstrate that these two sources shared knowledge of two or more Christian traditions, that would strengthen the prediction that they are familiar with each other. Such analysis can become quantitative when using network models. In the future, with more comprehensive networks, we could even use them to simulate knowledge transfer. For instance, we could ask what is the probability that a specific Jewish source (and accordingly community) knew about a specific Christian tradition (and community), even without such a tradition being explicitly mentioned. And lastly, we could even ask hypothetical questions such as how would Jewish rabbinic tradition change if a specific Christian source was unknown to Jewish sages.

Summary

Our paradigm, new to the field of religious studies, is relevant for the study of inter-religious contacts as it creates a “panoramic

view,” which can account for the richness and complexity of the contacts between two religious communities: The ancient sources, in this case, do not offer us the “easier” way of pinpointing mentioned names and meetings between the communities, for the simple reason that these do not exist. We used new findings of Jewish-Christian interactions, as revealed in *literary* sources, to create such a network, demonstrating how this approach can advance our understanding of the complex relationship between the communities, in ways that make up for such a crucial lacuna.

Data availability

All data generated or analyzed during this study are included in this published article.

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Michal Bar-Asher Siegal and Yossi Yovel contributed equally to this work.

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The authors declare no competing interests.

Ethical statements

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Informed consent

No informed consent was needed for this article.


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