

Article

Network Analysis of the Interaction between Different Religious and Philosophical Movements in Early Judaism

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Abstract: This paper presents an attempt to systematically describe and interpret the evolution of different religious and political movements in Judaea during the period of the Second Temple using the methods of the theory of social networks. We extensively analyzed the relationship between the main Jewish sects: Pharisees, Sadducees, Essenes (Qumranites), and later also Zealots. It is shown that the evolution of the relations between these sects agreed with the theory of social balance and their relations evolved toward more socially balanced structures.

Keywords: Judaeen sects; social networks; social network analysis; signed graphs; Essenes; Qumranites; Sadducees; Pharisees; Zealots



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1. Introduction

There has been a lot of interest in understanding and interpreting the evolution of Judaism during the early stage of Jewish history, in particular during the periods of the First and Second Temple. In this contribution, we consider the relations between different schools of Judaism during the period of the Second Temple. It is argued that the evolution of the relations between different schools of thought that existed in that time can be better captured and understood using the theory of social networks, in particular the theory of signed social graphs, which has proved to be very efficient in analyzing different historical, political, and social interactions (see Section 4.1 for a detailed introduction to the theory of signed networks and its applications).

In this contribution, we consider the following Jewish sects: Pharisees, Sadducees, Essenes (Qumranites), and Zealots. Those sects continuously interacted with each other, forming friendly ties, or developing animosity. Identifying the genesis, development, interactions, and relationships of Judaeen sects in the Hellenistic era and up to the destruction of the Second Temple poses a major challenge. This is due to the fact that their extant descriptions by their contemporaries are extremely scant and biased and are mostly directed at non-Jews; as for the rabbinic accounts of these Judaeen sects, they are recorded about two to five centuries after these sects left the historical scene. Moreover, the Essenes are not mentioned at all either in the New Testament or in the Talmud. The Qumran scrolls (2nd century BCE–1st century CE) shed a whole new light on the emergence of sectarian Judaism. Following most researchers, we identify the Qumran community as a congregation of the Essene trend (see Section 2 for a detailed account on the identification of Qumranites and their relation to Essenes). On the other hand, the esoteric nature of manuscripts from Qumran caves, the use of symbols, pejorative nicknames, ciphers, tendentious judgments, and direct language of hostility do not allow us to clearly restore the picture of the emergence, interactions, and relationships of key Jewish sects in the

Hellenistic era. In this regard, we find it promising to try to use the framework of signed social networks to better understand and visualize the processes in the development of sectarian Judaism that were taking place during those times.

The paper is organized as follows. In Section 2 we briefly introduce the main Judaeen sects and outline their origins and main features. We specifically consider Essenes and show that it can be identified with the sect of Qumranites. Section 3 is devoted to the analysis of the dynamics of interaction between the principal Judaeen sects: Sadducees, Pharisees, Essenes, and later also Zealots and Sicarii. Necessary facts about the signed graphs and respective signed networks theory are presented in Section 4. Finally, Section 5 provides an interpretation of the processes described in Section 5 in terms of the signed graphs theory. The paper concludes with a Discussion Section.

2. A Brief Excursion into the Principal Judaeen Sects

Josephus Flavius (37/38–after 100 CE), describing the rise of three principal Judaeen sects—the Pharisees (lit. “set apart, separated”), the Sadducees (probably after Zadok, the first High Priest of the First Temple), and Essenes (according to *Vita*, II, 10–12, he studied these Jewish sects “in practice”), singles out the attitude towards predestination (εἰμαρμένη; lit. “lot”, “fate”, “destiny”, sc. Providence) as the main aspect of religious “schools” separation in Judaea in the middle of the 2nd century BCE (*Antiquitates Judaicae* [further–*Antt.*], XIII, 171–173). The historian notes that the very essence of the Essenes’ doctrine is “that all things are best ascribed to God” (*ib.*, XVIII, 18, see also: *ib.*, XIII, 172). Pliny the Elder (*Historia Naturalis*, V, 15, 73) asserts that the numbers of the Essenes “are fully recruited by multitudes of strangers that resort to them, driven thither to adopt their usages by the tempests of fortune”. The mention of *fortuna* (this term correlates with the εἰμαρμένη in Josephus’ account) in this context can imply the Essenes’ belief in predestination, according to which the sectarians, as they thought, found themselves in the community. Cf.: Solinus, *De mirabilibus mundi*, XXXV, 9, who used the word *providentia* (“providence”) in this connection. The widely spread Essene practice of the prediction of future events (including personal fates), well known to Josephus Flavius (see, e.g., *Bellum Judaicum* [further – *BJ*], I, 78–80; II, 111–113, 159; *Antt.*, XIII, 311–313; XVII, 346–348; XV, 371–379; XVII, 345–348; cf. also: Hyppolitus of Rome, *Philosophumena*, IX, 27), was likely to be based on their belief in predetermination. (In *Antt.*, III, 214–218, Josephus speaks of the Judaeen High Priest’s breastplate and describes its role in the process of predictions. He transcribes the Hebrew word *hōšēn* for a “breastplate” as ἐσσήν, and correlates the latter term with the Greek λόγιον, “oracle” (*ib.*, III, 163, 217; cf. the Septuagint’s correlate term λογιον). It is not impossible that Josephus perceived the implicit meaning “prediction” from the designation Ἐσσηνοί.) In the light of these considerations, it seems most natural to correlate the hitherto unclarified etymology of the term Ἐσσηνοί / Ἐσσηνοί with the Aramaic notion *hšy* / *hš* [1] (p. 508); cf.: [2] (p. 217), which is interpreted as “what man has to suffer, predestination, fortune” [1] (p. 508). The term *hšy* is attested in the Midrash on the Book of Lamentations, or *Eichah Rabbah* (89:14; *ib.* 20), which, along with the *Bereshith Rabbah* and the *Pesiqta de-Rab Kahana*, is the oldest composition of the Midrashic literature. It was written in the so-called Jewish Palestinian Aramaic, which continued, as opposed to the other Western Aramaic languages of the middle stage, one of the written Old Aramaic languages of the western branch. One can try to reconstruct a conjectural noun (*m. pl.*) of the same root after the model $C_1aC_2C_2aC_3$ (normally designations of persons by their profession, usual activity, etc. are formed after it) as *hššayyā* in *st. det.*, respectively *hš*(y)yn in *st. abs.* The etymology of the term Ἐσσηνοί / Ἐσσηνοί derived from this hypothetical term appears to be relevant not only semantically, but also linguistically. In connection with the correspondence of the beginnings in spelling, the following transcriptions are attested to in Hellenistic sources: *Hammoṭ* is normally rendered as Ἐμμοτ [3] (p. 108); *hōšēn*—as ἐσσήν (*Antt.*, III, 163, 217) (moreover, one should bear in mind that the original pronunciation of the sect’s name could begin with Ἐ-, not Ἐ-); as for the Greek “endings” -αῖοι/ -ηνοί, they can represent transcriptions of the Aramaic

endings *-ayyā' /-în* (pl. *m.* in *st. det.* and pl. *m.* in *st. abs.*, respectively) plus the Greek ending *m. pl. -οί* proper. So, if the suggested derivation of the Ἐσσαιῶν/Ἐσσηνοί's etymology from the reconstructed Aramaic term *ḥšy(y) /ḥš'(y)yn* is correct, then the "Essenes" are (1) *those, who believe in predestination*, that is to say, "fatalists", "determinists", or (2) *those, who predict fate*, the "foretellers". In connection with the latter interpretation, let us point out that in *Antt.*, XIII, 311 (cf. also: *BJ*, I, 78), Josephus Flavius even mentions a special school of the Essenes, who "learned the art of foretelling things to come" (it flourished at the very end of the 2nd century BCE), cf. also: *BJ*, II, 159; according to *Antt.*, XV, 373, the Essenes had the "foreknowledge (πρόγνωσιν; 'predetermination') of future events given by God"; cf. *ib.* 379: "... Many of these (Essenes) have, by their excellent virtue, been thought worthy of this knowledge of divine revelations". (On the other possible etymologies of the term "Essenes", see, e.g., [4] (II, 619f.); [5] (I, 262f.); [6] (pp. 61–75). The most widespread etymology is the derivation of the term Ἐσσαιῶν/Ἐσσηνοί from the Syriac word *ḥāsēn* (*st. abs.*) / *ḥāsayya* (*st. det. (emph.)*), "pious", but this etymology encounters a great phonological difficulty: in *1 Macc.* 2:42, 7:12–13, *2 Macc.* 14:6, its Aramaic equivalent—*ḥāsīdayya* (Heb. *ḥāsīdīm*), "pious", is transliterated as Ἀσιδαῖοι.)

Judging by the accounts of some ancient authors (first of all, Philo of Alexandria [ca. 25 BCE–before 50 CE], Josephus Flavius, Pliny the Elder [23/24–79 CE], see, e.g., [7]), the distinctive features of the Essenes were the following: common property, collective labor and meals, preferably observance of celibacy; it is most likely that the Essenes used the solar calendar. According to Pliny the Elder (*Historia Naturalis*, V, 15, 73; cf. also: Solinus, *De mirabilibus mundi*, XXXV, 9, 12; see further, e.g., [8] (pp. 133–137); [9] (I, pp. 480–481); [7] (3, n. 9); [4] (II, p. 620); cf.: [10] (pp. 6–8)), their central settlement (Dio Chrysostom called it "a whole happy city by the dead water in the interior of Palestine"; see: Synesius of Cyrene, *Dio*, 3, 2) was apparently located northwest of the Dead Sea coast. It was in this region—in the Khirbet Qumran area near the northwest coast of the Dead Sea—that the manuscripts were discovered in the middle of the 20th century, belonging to the Judaean community (official publication of the full corpus of the Dead Sea scrolls was completed relatively recently; see: [11]), which the vast majority of researchers identify with the Essenes (see, e.g., [12,13]); as for the Qumran settlement itself, these researchers consider it to have been the main center of the Essenes. The fact is that the doctrine of absolute predestination played a key role in the religious outlook of the Qumran community (see, e.g., *1QH^a* IX (= 4Q432 2), 7–34; *1QS* IX, 24–25; *1QpHab* VII, 13–14, etc.; cf., e.g., *1QH^a* IX, 23–24: "Everything is engraved before You ... for all the periods of eternity, for the numbered seasons of eternal years in all their appointed times". See further, e.g., [14] and [15] (pp. 184–189)), and this aspect is considered to be one of the most important arguments in favor of the Qumranites' identification with the Essenes (cf., e.g., [16] (pp. 71–74)). A Qumran Hebrew etymological and semantic equivalent of the term εἰμαρμένη, used by Josephus Flavius, is the notion *gōrāl*, "lot", "share", sc. destiny, which is frequently attested to in the scrolls (cf. also the Hebrew notions *ḥēleq* in the meaning "share", "portion", "lot" (e.g., CD-B XX, 10, 13) and *tē'udāh*, "destiny", "predestination" (e.g., *1QH^a* IX, 19)). Judging by the sectarian manuscripts, mainly the so-called *Pesharim* (i.e., Commentaries on the Latter Prophets and Psalms), the members of the Qumran community, like the Essenes (in this connection cf. especially Josephus' *BJ*, II, 159), predicted the fates of the whole world, as well as of certain individuals.

According to the Rule of the Qumran community (*1QS*; *4QS^{a-j}*, *5QS* (= *5Q11*)) and a number of documents related to it (see, e.g., [17]), the Qumranites were characterized by the same rare socio-economic characteristics as the Essenes in the descriptions of ancient authors—above all, common ownership, collective work, and way of life; the Qumran sectarians observed celibacy (perhaps, with rare exceptions in some historical periods (cf., e.g., [18] and [19] (p. 111)) and kept the solar calendar (of 364 days), cf. [20]. Thus, using Ockham's razor—*not sunt multiplicanda entia praeter necessitatem*—it is hard not to agree with the Essene identification of the Qumran community.

3. Evolution of the Relations between Judean Sects

The Qumran community was headed by the priests of the Zadokite lineage (“the sons of Zadok (that is, the descendants of the High Priest Zadok), the priests who keep the Covenant”), who went from Jerusalem to the Judean Desert to an area northwest of the Dead Sea around the middle of the 2nd century BCE (or slightly later) and organized the congregation there. The leader of the community, called the Teacher of Righteousness in the Qumran scrolls, was probably a major priest in the Jerusalem Temple, perhaps even serving as the High Priest during the *Intersacerdotium* (159–152 BCE), see: [17] (p. 15). This probably explains the fact that a number of Qumran “halakhic” regulations, as described in early Qumran works—the Temple Scroll (11QT^{a-c}) and the Halakhic Letter (4QMMT^{a-f})—largely coincide with the ritual regulations attributed to the priestly sect of the Sadducees in rabbinic compositions ([21] (pp. 157–170), [22] (pp. 27–36), [23] (pp. 11–79), [24] (pp. 179–200), [25] (pp. 35–49), [26] (pp. 123–147)). On the other hand, the Halakhic Letter—which is probably a letter of the Qumran Teacher of Righteousness and his followers to the Judean High Priest (*ex hypothesi* Jonathan I Hasmoneus (152–142 BCE), apparently standing mainly in the Pharisaic positions, cf.: 4QpPs37 4:7–10)—contains a rigid polemic with the Pharisaic halakhah. It should be also noted that, based on the content of this document, the separation of Jewish sects was not primarily due to disagreements on issues of worldview, theology, soteriology, etc. (see, for example, Acts 23:6–8), but on halakhic regulations and calendar (lunar or solar) issues.

Sharp anti-Pharisee attacks are also present in the so-called Thanksgiving Hymns of the Teacher (1QH^a X–XVIII) as well as in some other Thanksgiving Hymns (1QHodayot^{a-b}, 4QHodayot^{a-f}). Severe criticism of the Pharisees (= the “interpreters/expounders of smooth things (slippery)”, “Ephraim”) and “their false teaching (*tālmūd*) (4QpNah, fr. 3–4, 2:8–10) is present in the Qumran *Pesharim*, i.e., special “commentaries” on books of the Latter Prophets and Psalms, which reflect historical events in Judaea in the first half of the 1st century BCE ([27,28] (pp. 329–338), [29]). At the same time no direct anti-Sadducee polemics are found here (at least it does not seem to be explicitly expressed), only their failures are stated (cf., e.g., 4QpNah, fr. 3–4, 4:1–4).

The Hasmonean High Priest and ethnarch John Hyrcanus I (134–104 BCE) started to move away from the Pharisees, and his son, High Priest and King of Judaea Alexander Jannaeus (= Jonathan II; 103–76 BCE) abandoned the Pharisaic regulations openly and aligned himself with the Sadducees (cf.: Josephus Flavius, *Antt.*, XIII, 293–298, see also: [22] (pp. 30–31)). By the end of the 2nd century BCE, the Essenes appeared in Jerusalem (*BJ*, I, 78–80; *Antt.*, XIII, 311–313, also cf.: B.T. *Kiddushin*, 66a and *Antt.*, XIII, 290–292). As for the Sadducees, they actively supported Alexander Jannaeus during the uprising against him in 94/93–88 BCE, which was led by the Pharisees and which Alexander suppressed in the most brutal way, including the crucifixion of the Pharisees who did not have time to flee the country (*BJ*, I, 92; *Antt.*, XIII, 376–379; see also: 4QpNah and in more detail: [30] (pp. 221–231)). However, the Pharisees, led by Shimon ben Shetakh, brother of Alexander Jannaeus’ widow, Queen of Judaea Alexandra Salome (76–67 BCE), recovered under her reign: Josephus Flavius claims that “the Pharisees governed” the queen and were “the real administrators of the public affairs” (*BJ*, I, 110).

Ideology in Judaea changed dramatically with the arrival of the Romans in 63 BCE. According to Josephus Flavius (*BJ*, I, 204–212; II, 56; *Antt.*, XIV, 158–179; XVII, 271–272; see further: *BJ*, I, 304–316; *Antt.*, XIV, 415–433), a powerful armed rebel movement emerged in Galilee in the early 40s of the 1st century BCE. At a certain stage, Yehuda from Gamala took over the leadership of the uprising (cf.: *BJ*, II, 56; *Antt.*, XVII, 271–272). According to Josephus’ account (*BJ*, II, 56, 118, 433; *Antt.*, XVIII, 4–10, 23–25, XX, 102, cf. also: Acts 5:37; Lk. 13:1–3), when Judaea was incorporated into the Syrian province in 6 CE, i.e., at the beginning of direct Roman rule, Yehuda, together with the Pharisee Zadok, founded the “fourth philosophical school” (after the Pharisees, the Sadducees, and the Essenes), and thus consolidated the movement of the Zealots, who “in all other things are quite adjacent to the teaching of the Pharisees, but they are distinguished by an unconstrained love of

freedom: They consider God to be their only Ruler and Lord". In 66 CE, Yehuda's youngest son, Menachem, proved to be one of the most powerful leaders of the rebellion against Rome in its early days and would take over power in Jerusalem for a short time (see: *BJ*, II, 433–449; *Vita*, I, 21, 46); as for Menachem's relative, Eleazar ben Yair, he led the patriot detachment in Masada, the last stronghold of the rebellious Jews, which fell in 73/74 CE.

The appearance of the Romans in Judaea in 63 BCE probably radically changed the Qumranites' ideology as well. It seems that it was during this period that the Qumran so-called War Scroll (*1QM*, *4QM^{a-h}*, *4Q285(?)*; see, e.g., [31]) and related documents were created, the central idea behind which was the liberation war with the Romans ("the *kittim*" in the scrolls) to the victorious end. (In the Qumran *Pesharim*, the appearance of the Romans in Judaea was most likely still expected; see, e.g., our works listed in References.) Starting from 6 CE, these moods seem to be only getting stronger. Let us also mention ad hoc that judging from *BJ*, II, 111–113 and *Antt.*, XV, 371–379, XVII, 346–348, the Essenes lived in Jerusalem under King Herod (37–4 BCE), whose respect and patronage they enjoyed, and probably under his son, ethnarch Herod Archelaus (4 BCE–6 CE). It seems that the emergence of the Essenes in Jerusalem in this period correlates with the fact that the Qumran settlement was destroyed by an earthquake in 31 BCE (cf.: *BJ*, I, 370; *Antt.*, XV, 121) and was left by its inhabitants for a time (the end of archeological period Ib). But Qumran again settles down at around 6 CE (the beginning of archeological period II). It cannot be ruled out that the restoration of the Qumran settlement was somehow connected with the introduction of direct Roman rule in Judaea.

A number of sources suggest that the Qumranites, like some other communities of the Essene trend, took part in the patriotic movement for the liberation of Judaea from Roman rule and even in the armed uprising of 66–73/74 CE. Hippolytus of Rome (ca. 170–235 CE) in *Philosophumena*, IX, 26, 2 and John Chrysostom (344/354–407 CE) in *Homilies on the Acts of the Apostles* (400/401 CE), 46, 3 (to *Acts* 21:38) directly identified the Essenes with the Zealots and their radical wing, the Sicarii (from Latin *sica* – "crooked dagger"), cf.: Philo of Alexandria, *Quod omnis probus liber sit*, 75, 91; *Id.*, *Apologia*, (I); *Josephus Flavius*, *BJ*, II, 119. We see an implicit indication to the accession of a patriotic grouping of the Essene-Qumran trend to the Zealots and the Sicarii around 55 CE in *BJ*, II, 254–265. This grouping is referred to by Josephus Flavius as *στύφος*, "body of men in close array", "battle array", i.e., the term equivalent to the Hebrew *מַעְרָכָה* (*ma'ārākāh*; "array", "row", "battle-line" (perhaps this term means a "row of worshippers" in *1QS* X, 14; see further: [32] (pp. 413–415)), which is repeatedly used in the Qumran War Scroll to refer to the combat orders of the "sons of the Light" fighting the "*kittim*"—the Romans. The fact that Josephus Flavius does not explicitly refer to the sectarian affiliation of this group can be explained by his explicit sympathy for the Essenes and his desire to disguise their direct mass participation in the anti-Roman movement.

Indirect evidence in favor of the fact that at least part of the Essenes participated in the uprising against Rome in 66–73/74 CE can be found in the text of *BJ*, II, 152, where Josephus Flavius spoke about the terrible tortures to which the Romans subjected the sectarians. In the same work, the Jewish historian says that the commander of the Tamna district was the Essene Johanan during the Jewish War (II, 566–568; III, 9–12). Judging from the archeological findings, the Qumran settlement was attacked by the Roman troops (probably by the tenth legion from Caesarea—*Legio X Fretensis*) and completely destroyed (the end of the Qumran archeological period II). This likely happened in the summer of 68 CE as most researchers believe, following R. de Vaux ([8]; cf.: [33], also: *Josephus Flavius*, *BJ*, IV, 449–450, 477, 486), but perhaps later, in 73 CE (see, e.g., [34] (19–23); [35] (pp. 121–165)). The numismatic evidence of Qumran closely resembles that of Masada. Some Qumranites apparently managed to escape to the fortress of Masada, the last stronghold of the rebellious Jews controlled by the Sicarii. This seems to be evidenced by the discovery of fragments of the Qumran text *Songs of the Sabbath Sacrifice* in Masada (*MasShirShabb*) during excavations of this fortress (see, e.g., [36] (pp. 120–132)).

Thus, it seems reasonable to assume that the military and political situation that developed in Judaea since the appearance of the Romans in Jerusalem in 63 BCE and especially after the introduction of direct Roman rule in Judaea in 6 CE brought the communities of the Essene-Qumran trend closer to the Pharisees, especially to their radical anti-Roman groupings. Eventually, all three major Jewish sects—the Pharisees (including the Zealots), the Essenes, and the Sadducees—perished in the fire of the First Jewish War with Rome in 66–73/74 CE.

4. Social Balance in Signed Networks

4.1. *The History of Social Balance Analysis for Signed Social Networks*

When people (groups, countries) interact, they form a structure called a social network. Typically, a network is represented as a set of vertices corresponding to different actors and a set of edges, i.e., the links connecting these actors. The theory of graphs offers a natural framework for studying such systems. During most of the 20th century, such social graphs were studied by both sociologists and mathematicians, but the field of their application did not go beyond rather specific sociological problems. However, the advent of modern age social networks such as Facebook, Twitter, etc. has led to a surge of interest in the theory of complex networks—an extension of the classical theory of social graphs that takes into account the inherent complexity and somewhat vague character of the problems studied.

Within just two decades, the theory of complex networks has become a well-established area of research. Dozens of monographs have been published on the subject (see, e.g., [37–39]), and a wealth of papers have been devoted to this topic (see, for instance, [40] and [41] for a good overview and introduction). The scope of classical complex network theory is mostly restricted to the study of statistical properties of undirected and/or unweighted graphs. However, there are numerous applications that cannot be considered within this framework and require the use of more general graph structures. In particular, there has been a growing interest in studying signed networks, i.e., the networks where two nodes are connected by a signed relation.

The idea of a systematic study of positive and negative interpersonal relations was initiated by Heider [42] and further developed by Cartwright and Harary [43] within a graph-theoretic framework. In that setup, one considers different individuals as vertices of a (large) network, whereas the interpersonal relations are represented by edges (or links) that can be either positive (which corresponds to friendship, trust, esteem, etc.) or negative (enmity, distrust, disrespect, etc.) The elementary building blocks of such a network are the triangles, i.e., the groups of three individuals (vertices) that are mutually connected by edges of either sign. It had been postulated that the distribution of edges' signs determines whether the considered triple is balanced or not. For instance, if Mary is friends with Mike and Zoe, but Mike and Zoe hate each other, such a group will not likely be balanced. More formally, a triangle is said to be balanced if the product of edges' signs is positive and unbalanced otherwise. In Figure 1, all possible interrelation structures (up to an edge relabeling) within a triangle are shown. The balanced triangles are drawn in blue, while the unbalanced ones are drawn in red. More complex structures, e.g., consisting of 4, 5, or more individuals, can be classified along this line, but the interpretation of the results is not that straightforward. Since the seminal work by Harary [44], many results aimed at formally characterizing and measuring the extent of balance in a given signed network have been presented. See, e.g., [45] for an overview and [46] for recent results.

The theory of structural balance can be naturally generalized to the case when we consider various social groups instead of individuals: religious communities, political parties, or countries. In [47], a signed social network describing the relational structure of tribes, living in the Eastern Central Highlands of New Guinea, was presented. This network contains 16 tribes connected by friendship (“rova”) and enmity (“hina”) relations. It had been shown that all tribes can be separated into two groups such that the respective tribes are connected by the friendship relation within each group, while the tribes from different groups are set against each other. In the paper by Kropivnik and Mrvar [48], a similar

analysis was performed for the parliamentary parties in Slovenia in 1996. It turned out that all parties could be divided into two groups such that parties within one group were close to each other and the parties from different groups were far apart. It is interesting to note that the relations of closeness (or similarity) and distance (or dissimilarity) were estimated according to several criteria however, the results remained the same. We also mention a recent paper [49], where the dynamics of the international relations of nations within the period from 1946 through 1999 were studied within the framework of signed networks.

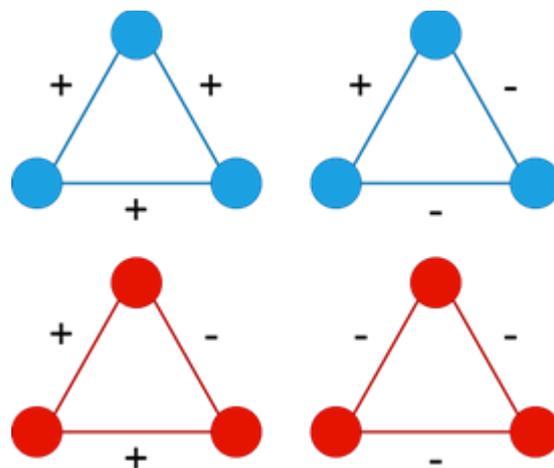


Figure 1. All possible signed triangles. The blue triangles (**above**) are balanced, while the red ones (**below**) are unbalanced.

While the examples described above study the static structure of signed social networks, it is of interest to analyze the temporal evolution of such networked structures. In the paper [50], the authors used signed social networks to describe the evolution of the political relations between leading European countries within the period from the establishment of Three Emperors' League in 1872 to the beginning of World War I. The authors showed that the development of international relations had led to the emergence of a balanced structure comprised of two antagonist groups. While being inherently balanced, such a structure turned out to be unstable at a meta-level: two alliances clashed in a global conflict, now known as the First World War. Further along this line, it has been argued in [51] that the notion of structural balance must be refined to satisfy a number of additional requirements (see [45] for an overview of different notions of balance and partial balance in signed networks). Using the introduced formulation, the author showed that some social networks that were previously declared balanced turned out to be highly imbalanced, which indeed agreed with the empirical evidence. However, it remains an open question whether the formulated set of conditions does indeed ensure that the balanced network remains stable.

4.2. The Dynamics of Achieving Social Balance

Since most real signed networks are to some extent unbalanced, it is natural to consider the process of balancing. By balancing, we understand the gradual change of the parameters and structure of a network aimed at increasing its balance. The most natural model of balancing consists of "flipping" the signs or even breaking certain edges in order to get rid of "dissenting" relations.

We believe that such actions might be too radical within the context of social relations. Indeed, in real life we often observe the people tend to change their attitudes rather than completely breaking relations with each other. Following this line, we consider a signed network as a dynamic system, in which the attitudes tend to change in a way that leads to a more balanced network. To illustrate this idea, let us assume that the weights of the edges may take values within an extended set $\{-2, -1, 0, 1, 2\}$, where the respective attitude ranges

from -2 (very negative) through 0 (neutral) to 2 (very positive). Consider two triangles shown in Figure 2: it is intuitively clear that the left triangle is more unbalanced than the central one even though both are formally equally unbalanced, as the product of the weights of the edges is negative in both cases.

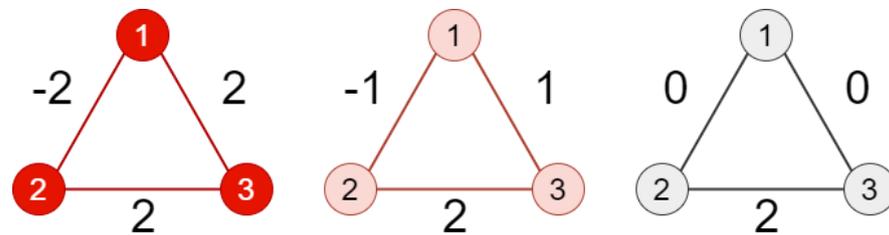


Figure 2. An example of re-balancing in a signed triangle.

Let us dwell a while upon the two left triangles. We can give the following interpretation to the evolution depicted therein. The structure of interaction presented in the most left triangle is clearly unbalanced. Each actor experiences a tension: actor 3 is friends with actors 1 and 2 which, in turn, hate each other. On the other hand, actors 1 and 2 are stressed by the fact that their friend (actor 3) has great relations to their enemy. None of the actors is ready to break the respective positive connection (and it is not clear at all how to break a negative tie). This seems to be a stalemate. But in real life, there is seldom a stalemate. Typically, the situation evolves according to the following scenario: one of the actors starts to rethink the respective relations by either impairing their positive tie(s) or improving the negative one(s). In the described case it was actor 1 who yielded to the pressure by impairing the tie with actor 3 and improving the tie with actor 2. While it is not necessary the case, it seems conceivable that such a re-balancing is likely to be symmetric: deteriorating one tie is accompanied by improving the other one. Such dynamics are to some extent profitable for the respective actor as their loss is (at least partially) compensated for by the gain. In this case, actor 3 is in the worst position as the only option that is left is to deteriorate some of their ties without a chance to get compensation. This suggests that actors 1 and 2 are most likely candidates for playing a pivotal role in the re-balancing procedure.

Now assume that actor 1 continues rethinking their relations and becomes neutral with respect to both other actors, as shown in the most right triangle in Figure 2. There is no longer an imbalance in the system. One might say that the respective triangle is now neutral. In fact, there are only two befriended actors and a third one that is no longer involved in the respective intergroup relations.

To formalize the preceding observations, we introduce several definitions.

Definition 1. We say that a network is an extended signed network if the set of weights contains zero: $W = \{-1, 0, 1\}$. Furthermore, we call a signed network weighted if its set of weights contains more than one positive (or negative) weight.

Clearly, the signed network shown in Figure 2 is an extended weighted signed network. In the rest of the paper, we only consider such networks without explicitly mentioning this.

Next, we defined the notion of the degree of social balance. We formulated the definition for a triangle, but it can readily be extended to a general (extended, weighted) signed network.

Definition 2. Given an extended weighted signed network with 3 vertices (a triangle), the degree of social balance is defined as the average of absolute values of all weights (that is the sum of all absolute values of the weights divided by the number of weights, i.e., by 3) multiplied by 1 if the product of all weights is positive (the network is balanced), by 0 if the product of all weights is equal to 0 (the network is neutral), and by -1 if the product of all weights is negative (the network is imbalanced).

We say that a triangle is balanced if the respective degree of social balance is positive, neutral if it is equal to zero, and unbalanced otherwise. We say that one triangle is more imbalanced than the other if its degree of balance is less than the respective degree of the other triangle.

To illustrate this definition, let us consider the triangles shown in Figure 2. The degrees of balance of the respective triangles are (from left to right): -2 , $-4/3$, and 0 . We thus immediately observe that the left triangle is most imbalanced, while the right one is neutral.

Remark 1. Note that the definition of the degree of social balance agrees with the conventional characteristic that is defined as a product of all the weights of a triangle.

4.3. Balancing through Splitting

While the balancing process described above reflects many real-life processes, we suggest one more possible scenario of balancing evolution. This scenario is restricted to the case when the actors are not individuals, but rather are groups of people, schools of thought, countries, etc. In this case, there is another possible reaction to the pressure imposed by social imbalance: when an actor feels “stretched” between two mutually exclusive tendencies, one possible response would consist of splitting into two. This is the scenario that we observe when countries divide over religious or nationalistic tensions, when religious movements split over different interpretation of certain dogmas, and so on.

To illustrate the described scenario, let us consider the situation depicted in Figure 3. Consider a triangle describing the relations between three different parties. We assume that parties A and B enjoy good relations with party C, while A and B oppose each other. This forms a tension within this system. One possible way to relax this tension would be to change the attitude of either the first or the second party. However, in practice it is often impossible for the whole party to change its attitude. Rather, the party gets increasingly divided into those who seek to normalize their relations with their opponents and those, who do not wish to do so. This division is indicated by a dashed line that goes through vertex A. As this division grows and gets deeper, it becomes increasingly difficult to maintain the integrity of the party. So, at some point the party splits into two parts: B-phobes (A1) and B-philes (A2). Now the A1 wing gets even more opposed to B, while A2 seeks to improve its relations with B. Also, the relations between A1 and A2 sour as it often happens after a split.

Will the new pattern of relations be more stable than the old one? To check that we compute the degrees of balance for both triangles shown in the right part of Figure 3. Indeed, the degree of balance of the triangle A1–A2–B is $4/3$, while for the triangle A2–C–B this characteristic is equal to $5/3$. Both numbers are positive, thus implying that the new structure of relations is structurally balanced.

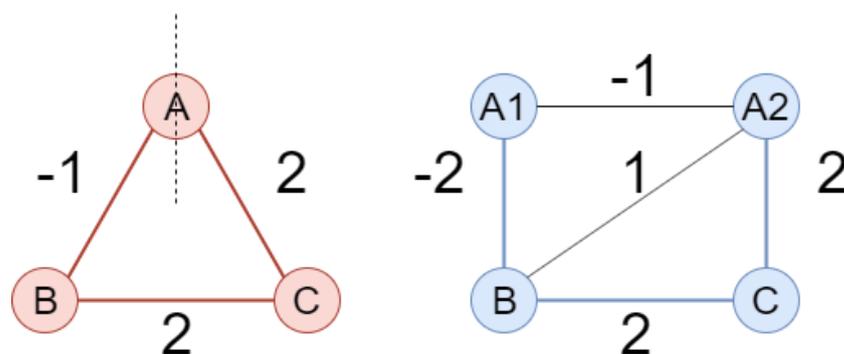


Figure 3. Rebalancing an unbalanced triangle by splitting one vertex.

opposed to direct Roman rule. This movement joined parts of both the Pharisees and Essenes and thus it enjoyed relatively good relations with both sides. On the other hand, the relations between the Essenes and Sadducees continued to worsen. The structure of relations at the first half of the 1st century CE is presented in Figure 4c. We note that the resulting structure is completely balanced. We might also conjecture that—as the theory of social balance predicts—the relations between Zealots and Sadducees should be rather negative, than positive. However, there is not enough historical evidence to conclude this with certainty.

6. Discussions

In this contribution, we have shown that while the relations between different Jewish sects were determined by different factors, both of local and global nature, the overall evolution of their relations developed toward more socially balanced structures. It is interesting to observe that during this evolution, we observed different scenarios aimed at achieving social balance: redistribution of the weights between different edges (i.e., rethinking the relations between different sects) and splitting of a single agent into two, thus relieving the tension within the respective group.

This paper does not present an ultimate answer to the problem of relations between different Jewish sects, but it can point towards different aspects that require additional attention from researchers. Our future work will concentrate on considering the described problem within a more general framework and finding further evidence reinforcing the formulated results.

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