A Quantitative Approach to Comparative Mythology

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ABSTRACT. *A new, quantitative approach to comparative mythology is introduced using methods developed in theoretical physics. The broad concept of universality has long been relevant to comparative mythology, in a qualitative sense, and it has been claimed that narratives from a variety of cultures may share certain similarities in terms of structure. A notion of universality also lies at the heart of network theory, a relatively new branch of statistical physics with wide applicability. Network theory permits quantitative comparisons of the interconnectedness underlying a multitude of structures relevant to many disciplines, from biology, chemistry and physics to sociology, economics and the computer sciences. Here we apply this theory to comparative mythology and study interrelationships of characters appearing in three iconic epic narratives: Beowulf, the Iliad and the Táin Bó Cúailnge. By comparing these amongst each other, as well as to real, fictitious and random networks, we seek to introduce a new, quantitative approach to the humanities. We show that each of the three epics has, to varying degrees, properties akin to those of real social networks.*

KEYWORDS: *networks, epics, Beowulf, Iliad, Táin Bó Cúailnge, statistical physics, universality*

INTRODUCTION

In statistical mechanics, one studies how the large-scale, macroscopic properties of materials emerge from the interactions of basic components through the laws of physics. As such, it is a discipline which initially appears remote from the humanities in general and from comparative mythology in particular. However, in recent years interdisciplinary approaches have been become popular, especially as physicists turn their attention from fundamental to complex problems. Such ventures have led to mutual benefits in the pursuit of new insights, perspectives and knowledge in a variety of fields (see, e.g., Ausburg, 2006). Techniques of statistical physics, in particular, have increased quantitative understanding of multitudes of issues, including many of non-physical nature, especially where properties of complex systems emerge from the interactions between component parts in a non-trivial manner. In recent decades, applications of such techniques to social and economic systems have led to the emergence of new sub-disciplines, including *sociophysics* (Galam 2004) and *econophysics* (Mantegna and Stanley 2000).

In physics, one often has to deal with systems comprising large numbers of mutually interacting basic components such as the atoms or molecules in a material or fluid. Since it is impracticable to simultaneously track the location and movement of each individual component, physicists have developed a statistical approach (hence the term "statistical physics"). Such a methodology delivers average, global properties of macroscopic systems. Analogously, quantitative approaches to sociology frequently involve statistical investigations of entire societies rather than of the individuals they comprise. In recent decades, the emergent discipline of sociophysics has matured into an established academic area, which offers new perspectives on some aspects of such collective behaviour. Sociophysics is not intended as a replacement for traditional approaches to sociology; although sociophysics may bring a certain degree of mathematical robustness in answering specific questions, it cannot capture all of the broader dimensions of more holistic, traditional, qualitative approaches.

In a similar spirit, here we report an attempt to develop a new, quantitative approach to comparative mythology using network theory (Mac Carron and Kenna 2012). We attempt to bring to the field a new way to capture statistical information about how characters are interconnected in epic narratives. Because these characteristics are recorded through sets of numbers, quantitative comparisons are possible, and these may yield meaningful answers to certain questions. We stress that this approach cannot deliver information on events, emotions, meanings or other qualitative and holistic features which form the focus of traditional studies. The new approach can therefore at best be complementary to existing techniques and certainly cannot replace them.

Any pioneering application of a new method across disciplinary boundaries may be expected to entail caveats and limitations and these should be obvious in the present instance too. For example, a mathematical approach cannot hope to accurately or completely capture the subtleties of the interactions between characters. Therefore, for the bulk of the analysis presented here, we restrict our attention to whether or not an interaction or relationship between a given pair of characters exists without addressing the intensity of such interactions. Such a "crude" approach is quite common and quite successful, in the physical sciences, where ones and zeros may be used to represent the presence or absence of a given feature. We consider this reasonable as a first approximation. We may attempt to represent the intensity of relationships between individuals by recording how often they interact in the narrative. Although an improvement on our first approximation, this too lacks the subtleties of traditional approaches. However, since our approach is statistical, one may hope that the errors and inaccuracies inherent in this approach do not accumulate, as overestimations in some instances are balanced by underestimations in others. The reliability and accuracy of any statistical analysis is also dependent on the sample size, with smaller samples necessarily leading to less reliable results. Experience suggests that the statistical approach is most suitable if the narratives are extensive, with large numbers of characters and interactions between them.

One also has to be cautious about any attempt to interpret the quantitative outcomes of such an analysis. While we can certainly compare the statistical properties of the networks depicted in such narratives, both to random and real social networks, interpretations regarding the degree of historical reality behind mythological epics can only be speculative. These are obviously tempered by distortive political and religious forces which influenced their construction, as well as by the obvious enormous lapses in time between the creations of the medieval tracts in which they are recorded and the societies they purport to describe. Even the use of modern texts as proxies for, and translations of, the originals, presents another layer between this study and the ancient stories. Thus there are layers of obfuscation covering the material to be analysed. Nonetheless, speculation based upon sound scientific analysis is not unreasonable.

The reader should therefore keep in mind that any such analysis cannot offer proofs – only evidence and comparisons from new perspectives, which need to be combined with other approaches. With the above caveats in mind, and fully aware that we can only analyse the material which has come down to us in the form it has, and that we can only apply the techniques which we possess, we considered it worthwhile to examine what modern mathematical network techniques have to say on the matter on comparative mythology. The conclusions we draw here and speculations we offer, are "from a network-theoretic" point of view. A more complete picture would necessitate expertise from traditional comparative mythology and other fields (such as archaeology) to inform further. In non-exact disciplines, it is up to scholars to make informed judgements of their own. Our purpose is to help inform such judgements from a wholly new perspective.

This is, of course, not the first application of quantitative techniques in the humanities. For example, in the early part of the last century, Meillet (1925) pointed to the primarily statistical nature of linguistic reconstruction (in this instance in the Indo-European languages) while, at its end, Colarusso (1998) presented a probabilistic analysis of comparative techniques in linguistics and mythology.

For the benefit of readers unfamiliar with the mathematical technology, we begin our exposition with a brief picture of complex network theory. Then, following a reminder of the texts we seek to analyse, we report on the network analyses of *Beowulf*, the *Iliad* and the *Táin Bó Cúailnge* and a quantitative comparison between them. A more technical presentation, geared towards a mathematics/physics audience is contained in (Mac Carron and Kenna 2012).

COMPLEX NETWORKS

In recent years, many complexity theorists and statistical physicists have turned their attention and mathematical expertise to non-physical complex systems in attempts to understand how their macroscopic properties emerge from relatively simple interactions between component parts at a microscopic level. Applications include studies of complex networks in the natural, technological and social sciences as well as in the humanities. New impetus to network-theoretic, interdisciplinary studies came when similarities were noticed between the structure of an electrical grid, the neural wiring systems of nematode worms and social networks. Using network theory, one can classify and compare these (Watts and Strogatz 1998). The theory has since been extended to multitudes of areas including transport networks (von Ferber et al. 2012), food-webs (Dunne 2004), power grids (Buldyrev et al. 2010), the study of the structure of the internet (Cheswick and Burch 1999), and many more areas. Network theory is now a well-developed and useful tool to describe the interconnectivities of a vast variety of real-world systems (da F. Costa et al. 2007; Albert and Barabási 2001; Newman 2003).

Universality is an important notion in both comparative mythology and in statistical physics. In the former instance, Campbell (1949) maintained that mythological narratives from a variety of cultures share similar fundamental structures, a notion referred to as the *monomyth*. This is clearly a qualitative notion of universality. A quantitative version of a similar notion is of great importance in statistical physics.

There, the categorisation of different critical phenomena into so-called universality classes is an important theme. Such universality classes have the same or similar essential characteristics and, since these are quantified through numbers, it is relatively straightforward to gain an understanding of how similar or dissimilar different physical systems are. Our objective here is to use network theory to compare the statistics describing the interconnectedness underlying mythological narratives from three different cultures to each other as well as to real and imaginary networks.

A *network* (see figure 1) is a set or collection of *nodes* which are interconnected by *links* (also called *edges* in the technical literature). A *social network* is simply a network in which the nodes represent people and the links represent interactions between them (Wasserman and Faust 1994). Over the past years, a set of statistical tools has been developed to quantify various properties of networks. It has been observed that social networks have certain characteristics which distinguish them from other types of complex networks (Newman and Park 2003). We briefly outline some of the tools used in this type of analysis. The interested reader is referred to Mac Carron and Kenna (2012) and references therein for a greater level of mathematical detail.

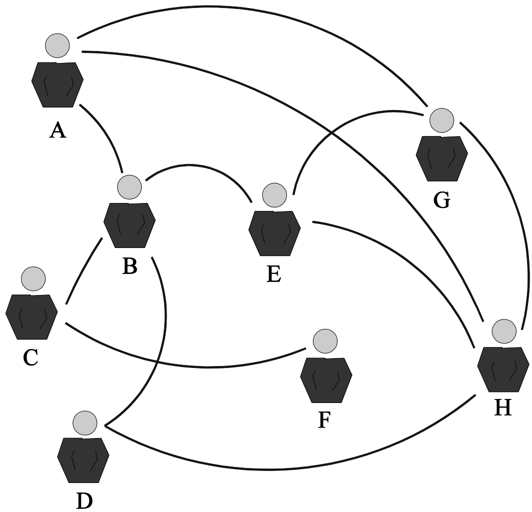

Fig. 1. Networks comprise both nodes and links which represent relationships between them. In network theory, we are interested in statistically capturing how these relationships are distributed.

Social networks are usually highly connected often referred to as being "*small world*" (Watts and Strogatz, 1998). *Connectivity* is measured quantitatively in at least two ways. The first measure is the *mean path length*, the average minimal number of steps linking pairs of individuals in the network. In figure 1 for example, while there are various routes by which individuals G and D may be connected (e.g., G to E to H to D), the shortest has only two steps (namely G to H to D). We say that the path length between G and D is 2 units long. If we then measure the (shortest) path lengths between all other pairs of nodes (e.g. A to B; A to C; ...; G to H), and then take the average of all of the resulting numbers, we obtain the mean path length of the network. This idea of mean path length was famously demonstrated in sociology through the notion of *six degrees of separation* (Milgram 1967), wherein, despite the world's population of over seven billion, everyone is, on average, only about six steps away from any other person when links are formed through chains comprising of "a friend of a friend of a friend of...".

Our second measure of connectivity is the *clustering coefficient*, which captures how cliqued a network is; if an individual knows two others, there is normally a relatively high probability that they are also acquainted. The clustering coefficient tends to be high in social networks compared to other networks. An example of how to calculate the clustering coefficient of an individual node is given in figure 2. The clustering coefficient for the entire network is determined simply by averaging over all nodes. In summary, real social networks tend to be characterised by small path length and a high clustering coefficient.

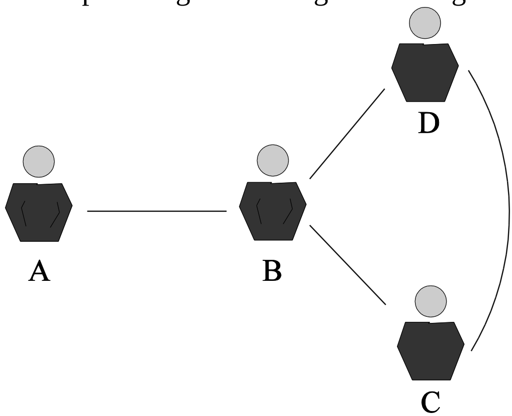

Fig. 2. To calculate the clustering coefficient for node B, one observes that of the three potential relationship-triads involving it (ABC, ABD, and BCD), only one is realised, namely BCD. The clustering coefficient of node B is therefore deemed to be 1/3.

The *degree* of a node is simply its number of links. In a social network the degree of a node is the number of acquaintances of that individual. Different individuals in the network have different numbers of acquaintances, so the degree varies from node to node. The *degree distribution* quantifies the spread of degrees across nodes throughout the entire network and its shape or mathematical form depends upon the type of network under discussion. Figure 3 contains schematic illustrations typifying three types of network. The first is a random network in the sense that the probability that any two nodes are joined by a link is random. This is very different in appearance to the regular, ordered network of the second figure (called a lattice). The third illustration is of a complex network, and is different to both previous types. Social networks are of this third, complex type. For such networks, the degree distribution tends to follow a so-called *power law* and is often called *scale free* (Amaral et al. 2000). The latter term implies that only a few people tend to form links with a large number of others.

Removal of the most connected nodes from the three networks depicted in figure 3 gives insight into the differences between them. In the random network and the lattice, removal of such a node has little effect – the remaining structure remains intact (connected). In the complex network, however, targeted elimination of the most important nodes quickly causes the network to fragment (become disconnected). However, for all structures depicted, random removal of nodes tends not to have a strong affect on the networks integrity.

In short, then, social networks usually have power-law degree distributions and are scale free. They are robust to random attacks and vulnerable to targeted attacks, and in the latter property they differ from random and regular networks (Albert et al. 2000).

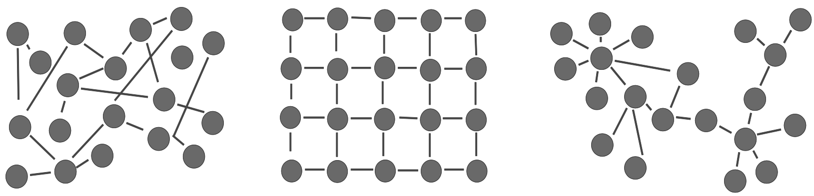

Fig. 3. Representations of three networks: a random graph (left), a regular lattice (middle) and a complex network (right).

In reality, people tend to have friends who are similar to themselves in the sense that popular people tend to be acquainted with other popular people. Networks in which this property features for most nodes are called *assortative* (Newman 2002). The opposite feature is called *disassortativity.* Figure 4 illustrates small networks with these characteristics. Assortativity is an important property which helps distinguish social networks from other networks. It is now known that most non-social networks are disassortative (Newman and Park 2003). For our analysis of mythological networks, assortativity will also play a key role. The assortativity properties of a network are studied by comparing the degrees of nodes to the degrees of their neighbours.

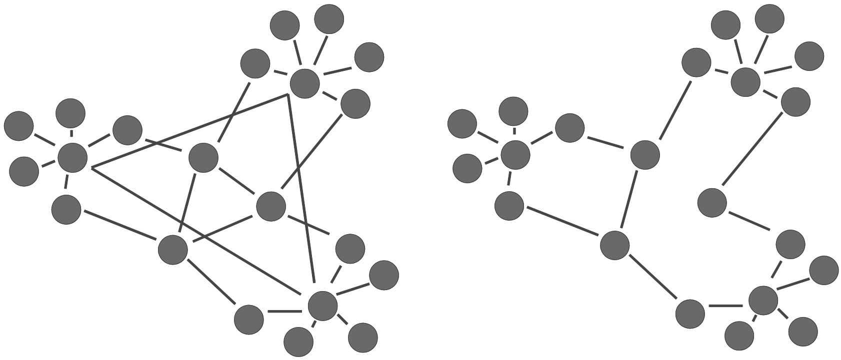

Fig. 4. The network on the left illustrates assortativity because nodes of similar degree tend to be linked to each other. E.g., the three highest-degree nodes are themselves linked. The network on the right, which has the same distribution of nodes, illustrates disassortativity and the three most linked nodes are not intra-connected.

Assortativity is the tendency for similar nodes to be connected (as in the maxim "birds of a feather flock together") and social networks tend to be assortative, while most other networks tend not to have this property.

In the past decade, many different types of social networks have been studied and many of their properties have been catalogued. Examples of real social networks include those formed by actors appearing in the same movies (Amaral 2000), musicians in Jazz bands (Gleiser and Danon, 2003), users of online forums (Kujawski and Abell 2011), scientific co-authors collaborating on research papers (Newman 2001) and directors of companies (Davis et al. 2003). In each of these, a "link" or relationship may have different meanings. For example, Newman (2001) argues that the link between two scientists who collaborate on an academic paper together may be stronger than the link deemed to exist between two actors who appear together on a film set. Notwithstanding these differences, the general properties of a variety of real-life social networks are by now well established.

The *Marvel Universe* is the collection of characters which have appeared in Marvel comics throughout the years. The relationships between them form an obvious example of a fictional social network and this has been studied by Alberich et al. (2002) and by Gleiser (2007). In the Marvel network, characters are considered linked if they appear in the same comic book. Unsurprisingly, the analyses showed that although the Marvel Universe does have some aspects of a real social network, it has tell-tale sign of artificiality. In particular, although it is highly connected, it is also highly disassortative – the superheroes are too highly connected to be realistic.

Besides Marvel Comics, there are few analyses of other artificial or fictional networks, and for this reason we also examined a selection. These included Larsson's *Girl with the Dragon Tattoo*, Rowling's *Harry Potter*, Tolkien's *Lord of the Rings*, Shakespeare's *Richard III* and Hugo's *Les Misérables*. We certainly do not claim that this limited set of narratives embody all of the features of the network structures of the entire corpus of world fiction. Rather, some of these are chosen because they are examples of clear works of fiction – works involving fabulous characters, which make no attempt to emulate reality. For others, the data were readily available, facilitating a speedy study. We hope that, in the future, other researchers will analyse other works of fiction, so that an extensive list of typical features of fictional social networks will ultimately be built, just as has been achieved for real social networks. We found that each of the admittedly limited number of fictional networks analysed are small world - just like real social networks. However, none of their degree distributions are well described by power laws and they are all disassortative. Moreover, unlike real social networks, the fictional ones are very robust upon targeted removal of the most connected nodes. This initial research indicates that degree distributions, disassortativity and robustness may be suitable indicators to distinguish some fictional social networks from real ones.

THREE EPIC NARRATIVES

Beowulf is an Old English heroic epic, set in Scandinavia, which has survived as a single codex estimated to date from between the 8th and 11th centuries. The story tells of the coming of the Gaetish hero Beowulf to the assistance of Hrothgar, king of the Danes. After slaying two monsters, Beowulf returns to Sweden and becomes king of the Geats. Following another fabulous encounter many years later, he is fatally wounded. Although the poem is embellished with obvious fiction and fantasy, archaeological excavations in Denmark and Sweden offer support for historicity associated with some of the human characters in the tale (Anderson 1999). The character Beowulf himself is, however, mostly believed not to have existed (Klaeber 1950; Chambers 1959). We base our analysis on Heaney's translation (1999).

The *Iliad* is an epic poem attributed to Homer and is dated to the 8th century BC. It takes place during the final year of the Trojan War and tells of a quarrel between Agamemnon, king of Mycenae and leader of the Greeks, and Achilles, their greatest hero. Whether or not it is based upon real events has been much debated (Wood 1998). While some evidence suggests the story may be based on a historical conflict around the 12th century BC, interwoven with elements of fiction (Kraft et al. 2003; Korfmann 2004; Papamarinopoulos et al. 2012), some maintain that the *Iliad* is entirely fictional (Finley 1954). Our analysis is based upon the translation by Rieu (2003).

The *Táin Bó Cúailnge (Cattle Raid of Cooley)* is the most well-known epic of Irish mythology. It describes the invasion of Ulster in the north of Ireland by the armies of queen Medb of Connacht in the west and feats and exploits of Cúchulainn, Ireland's most famous hero. Related to the Táin itself are a number of pre-tales and tangential tales (*remscéla*) which give the backgrounds and exploits of the main characters. The Táin survives in three recensions. The first has been reconstructed from partial texts contained in *Lebor na hUidre* (the Book of the Dun Cow, dating from the 11th or 12th century) and *Lebor Buide Lecáin* (the Yellow Book of Lecan, a 14th century manuscript) and other sources. The second, later recension is found in *Lebor Laignech* (the Book of Leinster, a 12th century manuscript formerly known as the *Lebor na Nuachongbála* or Book of Nuachongbáil). A third recension comes from fragments of later manuscripts and is incomplete. Two popular English translations of the Táin (Kinsella 1969; Carson 2007) are mainly based on the first recension, although they each include some passages from the second. While the analysis which we present here is based on the Kinsella version, we also examined Carson's to check that the two translations give similar networks. For the purposes of this analysis then, Kinsella's translation serves as a proxy for what is commonly understood as the Táin Bó Cúailnge.

The Táin was dated by medieval scholars to the first centuries BC, but this may have been an attempt by Christian monks to artificially synchronise oral traditions with biblical and classical history. Of the three narratives we study, the historicity of the Táin is most questioned. O'Rahilly (1946) asserts that it has no historical basis whatsoever. While Jackson (1964) argues that, such narratives corroborate Greek and Roman accounts of the Celts and offer us a "window on the iron age", he states that "the characters Conchobar and Cúchulainn, Ailill and Medb and the rest, and the events of the Cattle Raid of Cooley, are themselves entirely legendary and purely un-historical". On the other hand, Lynn (2003) has claimed some evidence that the landscape reflected in the story may be based on reality.

NETWORK ANALYSES OF THE THREE NARRATIVES

Instead of using a computer to "read" the texts and generate the networks, we constructed the databases "by hand". We carefully read each of the three narratives and entered each character's name into databases, meticulously listing interactions between them. In an attempt to increase consistency, we separately built the Beowulf network first. Comparing our individual interpretations allowed us to formulate a set of rules for network construction and to satisfy ourselves that this could be done in a reasonably objective manner. Heaney's Beowulf has 165 links linking 74 unique characters; Kinsella's Táin has 1,233 links between 404 characters; and Rieu's version of the Iliad has 2,650 links between 716 characters. Two distinct types of interactions were defined, with links designated as "friendly" if they know each other, are related to each other, speak to one another, or appear in a small congregation together. If two characters meet in combat, the corresponding links was deemed "hostile". The number of encounters between characters constitutes a "weight". For example, in The Táin, the relationship between the king and queen of Connaught (Ailill and Medb) is more strongly weighted than that between Ailill, for example, and the Ulster hero Cúchulainn.

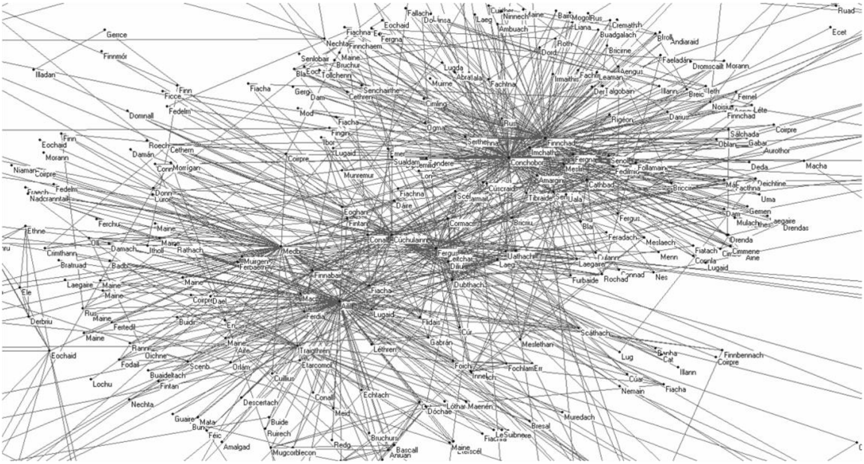

Fig. 5. The Táin friendly network. Three main clusters are identifiable by eye. The right upper cluster is that of Ulster, with Conchobor at its centre. The lower left cluster is that of Connacht, centred on Medb and Ailill. The middle cluster centres on Cúchulainn, Fergus mac Roich and other warriors (mostly the Ulster exiles).

The friendly network for the Táin is depicted in figure 5. Groups of characters clustering into communities is obvious, reflecting the fact that characters from Ulster more frequently associate in a friendly manner with other characters from Ulster, and similar for Connaught. The opposite occurs for the hostile network (not shown) as the conflict is between the two provinces. This suggests that only in the friendly networks may disassortativity be a potential signal of artificiality.

Each of the three networks has a low average path length and high clustering coefficients relative to random networks of the same size and mean degree. This means that each of them is small world. When the most connected 5% of characters in each epic are removed the corresponding networks become disconnected. However, if 5% of nodes are removed at random, the networks remain intact. Of the three narratives, only the Iliad turns out to be assortative. Beowulf was found to be mildly disassortative and the Táin very much so. These results indicate that only the social-network properties of the Iliad are similar to those of real social networks. Moreover, its properties are dissimilar to random networks and to the fictitious social networks listed above. This is what one may expect if the Iliad contains a reasonable portrayal of a realistic societal network. As cautioned in the introduction, this certainly does not *prove* that the Iliad is based on reality. It merely *supports* the case for historicity (Kraft et al. 2003; Korfmann 2004; Papamarinopoulos et al. 2012).

Beowulf has many of the properties of real social networks, but its disassortativity could be interpreted as a signal of artificiality (Gleiser 2007). However widespread belief amongst experts is that, while the society in Beowulf may be based on reality, the eponymous character is believed fictitious. To make use of this information we remove the character Beowulf from the network and redo the entire analysis. It turns out that the remaining network is assortative. So the social network depicted in Beowulf (without the character Beowulf) has *all* of the features which characterise real social networks.

The initial analysis indicates that the Táin Bó Cúailnge is strongly disassortative, a feature which may signal artificiality (Gleiser 2007). With the mathematical and statistical tools at hand, it is relatively easy to investigate wherein this artificiality lies. We ask: does the social network depicted in the Táin appear fictional in its entirety or is its apparent artificiality localised in a few characters, as we found in the Beowulf case? To gain insight into how to answer this question, we first analyse the degree distributions of all three networks. Each is reasonably well described by a power law, which is manifest as a straight line on a double-logarithmic scale, as used in figure 6. (As with many statistical approaches, one cannot expect the data to be perfectly aligned. At best, the fitted curve captures an essence or average feature of the underlying distribution.) In this regard, the narrative societies are quite like real social networks. The degree distributions for Beowulf and the Táin are given in figure 6 and one observes a remarkable similarity between them. This similarity extends up to, but not including, the six rightmost data points coming from the Irish narrative, data which correspond to the six most connected characters in The Táin.

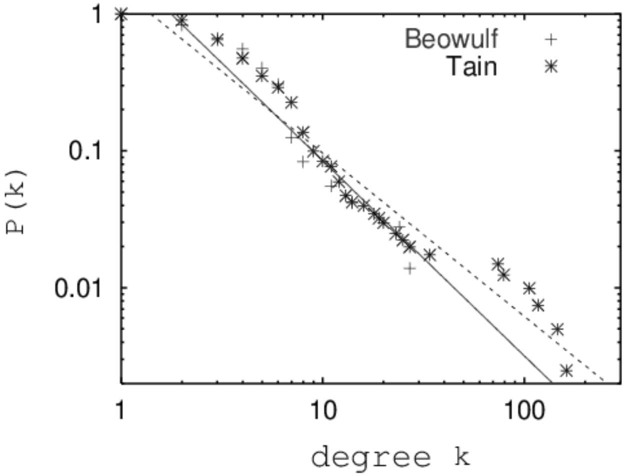

Fig. 6. The degree distributions of Beowulf and the Táin on a double logarithmic scale. Notice the strong overlap except for the six characters with the highest degree for the Táin offsetting the best-fit line (dashed line). Here, P(k) represents the cumulative probability of a character having a specific degree k (number of people a character knows).

The two lines depicted in figure 6 represent power laws fitted to the Beowulf data (yielding the solid line) and the Táin (dashed line). The six rightmost data points of the latter are offset relative to the rest. This means that the degrees of these Táin characters are out of sync with the remaining characters of both the Táin and Beowulf. Indeed, the dashed Táin line is "pulled" upwards on the right relative to the solid Beowulf line by these anomalous six characters. The overall impression is that the network structure of the Táin may be rather similar to that of Beowulf, but for the six anomalous characters in the Irish narrative. We interpret this as a potential indicator that the artificiality of the Táin is located in these six characters. The six anomalous Táin characters in figure 6 are, in order of decreasing degree, Conchobor Mac Nessa (king of Ulster), Cúchulainn (Ulster warrior), Ailill Mac Mágach (king of Connacht), Medb (queen of Connacht), Finnchad Fer Benn (son of Conchobor) and Fergus Mac Roich (a former king of Ulster exiled to Connacht). The first four of these were identified by Jackson (1964) as unhistorical.

Unlike in the Beowulf case, we have no basis to remove these six characters from the Táin network. Instead, we recognise that their anomalous nature is due to them being over-connected or "exaggerated" relative to the remaining characters in the narrative and relative to the characters of Beowulf. Therefore, reduction in their degrees should be sufficient to synchronise them with the remaining Táin society. To achieve this in a simple manner, we bring weighting into the analysis. We first define a *weak link* as one that occurs when two characters meet only once in the entire narrative. We next remove the weak links associated with the six anomalous Táin characters. This process of reducing their degrees does *not* remove them from the tale and preserves their important relationships. It is as if we are reducing some of the elements of exaggeration associated with these individuals. The degree distribution for the adjusted Táin network is depicted in figure 7. As expected, the top six data points are no longer strongly offset and all the data points are reasonably close to the best-fit line.

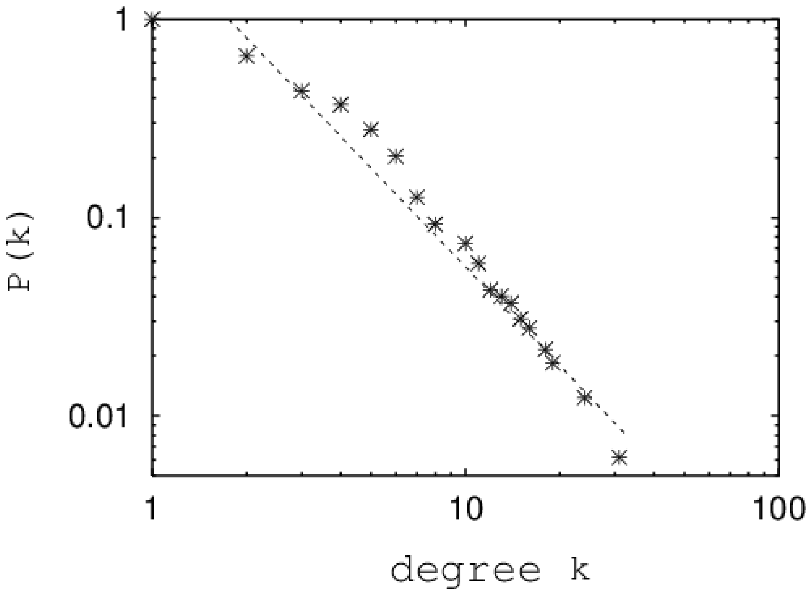

Fig. 7. The degree distribution of the adjusted Táin network, the dashed blue line is the best-fit line. Note the top six characters no longer offset the fit.

A remarkable outcome of this adjustment is that the resulting Táin social network is assortative. This means that it has all of the characteristics of a real social network. This observation reaffirms our hypothesis that the bulk of the artificiality of the network is localised, in the sense that it is associated with just six of the 404 characters. We may speculate that these six characters may be amalgams of numbers of entities and proxies whose collective degrees are large but whose individual degrees are reduced. For example, the many single encounters described in the text between queen Medb of Connacht and her warriors may instead represent encounters between Medb and a small number of proxies, and subsequent interactions between the proxies and those warriors. This new interpretation would render the network properties of the Táin society similar to that of real social networks, while maintaining the integrity of the narrative.

CONCLUSIONS

We have introduced a new quantitative approach to comparative mythology by borrowing modern mathematical tools from theoretical physics. Instead of focusing on individual characters or events depicted in epic narratives, the new methodology is appropriate to investigate the totality of *relationships* that underpin the societies depicted in such stories. The statistical approach allows us to capture certain aspects of the structures of these societal networks and to make numerical comparisons between them.

We chose to analyse three iconic European narratives in this initial investigation. Each of the networks underlying the societies depicted is dissimilar from random and regular networks. Of the three, the society depicted in the Iliad has properties most similar to those of real social networks. One may speculate that the source of this similarity may be a degree of historicity underlying the narrative. This speculation is corroborated by recent evidence suggesting a historical basis for the story while acknowledging it is interwoven with elements of fiction (Kraft et al. 2003; Korfmann 2004; Papamarinopoulos et al. 2012).

There is even stronger material evidence suggesting some of the characters in Beowulf may be historically based (Anderson 1999;

Chambers 1959; Klaeber 1950) although the events described contain obvious elements of fantasy associated with the eponymous protagonist. Indeed, although the social network in Beowulf has many of the properties of real social networks, it is disassortative – a feature also exhibited by fictional narratives studied. However, removal of the main character from the network renders the remaining society assortative. Therefore the speculation that assortativity is a signal of artificiality aligns our network analysis with conclusions of independent approaches for both the Iliad and Beowulf. In other words, both societies (with the main character excluded from Beowulf) have properties akin to real social networks.

The analyses of Iliad and Beowulf provide a guide to the quantitative study of the Táin, for which there is the least amount of material evidence and which is mostly believed to be fanciful. Although the Táin network initially appears disassortative (and hence indeed artificial), one may legitimately inquire what it would take to render that social network realistic. In particular, would it necessitate dramatic alteration of the entire society or would local adjustment to a small number of characters suffice? Our analysis indicates that the apparent artificiality in the Táin network is essentially contained within its six most connected characters. Similar to the heroes of Marvel Comics, they are too highly connected (in a sense, too super-human) to be realistic. We think it is remarkable that a minimal alteration – removal of their direct weak social ties – is sufficient to render the network assortative. On the basis of this observation we speculate that the six anomalous Táin characters may be based on amalgams of a number of entities and proxies. The adjusted Táin network is similar to that of Beowulf, the Iliad and to real social networks and very different to random networks and those of certain works of fiction. On this basis we suggest that, if one believes that the social network depicted in the Táin has some basis in reality, then one should consider that the six most interactive characters are amalgams that likely became fused as the narrative was passed down orally through the generations.

Finally, we re-emphasise that our new approach is no substitute for traditional approaches to comparative mythology. Rather, it is hoped that this quantitative approach may complement qualitative ones e.g., it is encouraging that four of the six characters which we identified in the Táin as being anomalous were also identified by the Celticist Kenneth

Jackson through traditional, qualitative studies. Indeed, while cautioning against interpretations in terms of historicity of persons and events, Jackson also indicates that mythological narratives may offer a window on ancient societies.

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