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Foreword

Statistical Physics and Emergent Behaviour: From Spin Models to Cultural Complexity. In Memory of Ralph Kenna (27.08.1964–26.10.2023)

It's been sixty years since Ralph's birth day and soon it will be one year since he left us. Initially, this collection of papers was being prepared as a Festschrift — a birthday greeting, and now it is published in his memory. It is difficult to write this foreword, because Ralph is not only a fellow physicist and a close collaborator, he is a very close friend. It is also difficult to write because, in a short text, it is hard to reflect the versatility of his gifts: from statistical physics to field theory, from the science of complex systems to quantitative methods in social sciences and humanities, from scientometrics to history of physics. This is not a complete list of areas that he enriched thanks to his talent and hard work. What's more, his activities in scientific research are inseparable from his public activities, be it the protection of historical heritage or the restoration of historical memory in Ireland, his motherland, or the collection of funds for the fight against serious diseases in the UK, where he worked, or his participation in the organisation and evaluation of research work on a pan-European scale. The integrity of his personality is one of those features that first come to mind when we think about him, repeatedly.

Ralph Kenna (RK) was born in Athlone, on the border between counties Roscommon and Westmeath, Ireland, on 27 August 1964 as the first child of Pat Kenna and Irene Kenna (born Benson). He attended the Marist College in Athlone, having received the best Leaving Certificate. Afterwards, he studied at Trinity College Dublin and obtained there a B.A. degree in Theoretical Physics in 1985 and a M.Sc. in 1988. Having won a scholarship funded by the European Council for postgraduate studies in Austria, he did his doctoral studies at the University of Graz under the supervisorship of Prof. Christian B. Lang and completed his PhD (Dr. rer. nat.) with highest honours in 1993. Afterwards, RK was an EU Marie Curie Research Fellow at the University of Liverpool from 1994 to 1997 and at Trinity College Dublin

from 1997 to 1999. He lectured at Trinity from 1998 to 2002, when he moved to Coventry University. In 2005, he co-founded the Applied Mathematics Research Centre at Coventry and founded the Statistical Physics Group there. In 2018 these joined the Fluid and Complex Systems Research Centre, Coventry University, of which RK was Deputy Director. In 2016 he co-founded and was a co-director of the $\mathbb{L}^4$ Collaboration and Doctoral College for the Statistical Physics of Complex Systems that joins the Universities of Coventry, Leipzig, and Lorraine with the Institute for Condensed Matter Physics in Lviv. RK passed away on 26 October 2023 and is buried in the St. Kieran's Cemetery at Coosan, close to his home town Athlone.

Below we briefly mention RK's principal scientific interests and some of the important results that he obtained. Ralph was gifted with the ability to generate ideas, ask the right questions, and chart a path to finding answers to these questions. Moreover, he had a talent for motivating and inspiring people, as well as a rare ability to make others feel confident and important. He wasn't afraid to ask students questions when he didn't know something and was great at praising others for their achievements. Ralph could genuinely appreciate even seemingly simple things — perhaps this special trait also helped him be a true researcher.

In *statistical physics,* RK is famous for his studies of critical phenomena and phase transitions via the analysis of the zeros of the partition function in a complex plane, an approach introduced by T.D. Lee and C.N. Yang in the 1950s. Already during his doctoral studies RK mastered this theoretical approach, which is sometimes referred to as the fundamental theory of phase transitions. This method, alongside the field-theoretical renormalization group approach remained to be his favorite one and with the span of time he became a world-renowned expert in this field [1, 2, 5, 7, 12, 15, 17, 32, 55, 62].[1] RK also contributed to the connection between *information theory* and statistical mechanics. This work is another example of the inventiveness and open-mindedness that Ralph and his co-authors were capable of. Using the tools of differential geometry, the curvature of a metric was defined on the space of parameters of the considered model, providing information about its phase structure [9–11, 14].

Already his first publication [1] sets the basis of a very important progress on the onset of logarithmic corrections to the laws governing critical behaviour and finite-size scaling. The concepts of scaling and universality underlie the modern understanding of phase transitions. Significant successes were achieved in this area in the 60s and 70s of the last century, and seemingly, did not leave any opportunities for new important theoretical discoveries. However, RK had a chance to get involved in the creation of the theory of phase transitions and critical phenomena, and he duly took advantage of this chance! His analysis of the cases, when the scaling behaviour at second-order phase transition is modified by multiplicative logarithmic corrections, shed light on such effects for some basic models of statistical physics and field theory [3–5, 8, 13, 18, 23]. It was shown that the logarithmic corrections are also characterized by critical exponents, analogous to the standard ones, and RK defined the values of such exponents and established new scaling relations among them [16, 17]. These were totally unknown and unexpected relations which led to a major clarification of physics right at the upper critical dimension. These new scaling relations will surely find their place in future textbooks on critical phenomena [26].

RK was the first to apply the partition function zeros analysis to the study of critical behaviour on complex networks [20, 22, 37, 39, 53]. The analogies that he noticed in the appearance of logarithmic corrections to scaling observed on lattices and on scale-free networks have a deep physical meaning, and the study of phase transitions on networks itself has a number of interesting applications, in particular in the science of complex systems [45]. His research on the critical behaviour of complex networks was also continued in the analysis of the recently proposed spin models — such as the invisible states Potts model [30, 41, 49, 51, 59], or the analysis of resistor networks [33, 36].

Critical behaviour at high dimensions is another phenomenon, the study of which has found its new development thanks to the work of RK and his colleagues [25, 29, 40, 47, 57, 61]. It was believed that hyperscaling and finite-size scaling (FSS) fail above the upper critical dimension. Michael Fisher's concept of dangerous irrelevant variables partly explained the reason for such a failure, although, the introduction of the new pseudo-critical exponent koppa and its logarithmic counterpart koppa-hat [29] became a crucial step in the theoretical description of scaling in high dimensions. These exponents

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[1]We will not mention the dates and names of the co-authors, referring to the list of representative articles given at the end of the foreword.

govern the FSS of the correlation length and enter a new form for FSS, called QFSS, that replaces standard prescription above the upper critical dimension [57].

The breadth of RK's interests, his erudition in various areas of human knowledge and culture multiplied by his expertise in statistical physics and mathematical methods of analyzing collective phenomena in many-agent systems led to two more significant directions of his scientific research. These are *cultural complexity* and *scientometrics*. A deep interest in the history and culture of Ireland, which accompanied RK as we think from the time of youth, naturally led to the idea of applying mathematical methods, in particular the complex network science, to the analysis of Irish myths [24]. The very idea of forming a social network of characters of a narrative and applying exact methods of natural sciences to analyze it is ingenious in its simplicity. Moreover, such an analysis blurs the boundaries between social and natural sciences and humanities. So RK and the group led by him became the initiators of a new direction, for which RK was aptly called the 'father of mythematics'. The MMM (Mathematics Meets Mythology) workshops that he organized in Coventry became a meeting place for leading scholars in the field and a place for the emergence and discussion of a wide variety of ideas [44]. A further important feature of these studies is that they put the results obtained into the broader context of complex systems, where the social characteristics are seen as emergent features of a society and where quantitative characteristics of social relations are used to classify different groups according to their universal properties [45]. Over time, RK's ideas were extended to the analysis of narratives of other cultures as well [31, 42, 43, 50]. We are convinced that the mythematics, Ralph's legacy, will have a worthy continuation [54, 56, 58].

RK also contributed with important works in the field of *scientometrics*, numerous and diverse [21, 27, 28, 34, 35, 38, 46]. This is the theory of critical size (critical 'mass') of research groups [21], analysis of research evaluation systems in the UK [27, 28, 35], elaboration of a principled method for panel assessment [46], and many others. Despite their diversity, we think that the main motivation of these works was, according to RK 'a chasm between academics and professional services, bound into contact through competing targets' [52]. Current evaluation of the research work very often misuses quantitative methods, not all that counts can be counted — these calls of the academic community to policymakers and science managers found their background and support also due to RK's works. Moreover, work of his group contributed to halting the tide of metrics sweeping from the UK across the academic world.

RK was not only interested in the *history of physics*, but also conducted specific research in this area. His doctoral studies in Graz began with the field-theoretical treatment of critical phenomena related to the Ising model. Later, RK returns to the very origins of experimental and theoretical studies of critical phenomena, writing a beautiful essay about Cagniard de la Tour and his discovery of critical phenomena [19] and a biography of Ernst Ising together with the analysis of the historical development of the Ising model [48]. This latter analysis formed the basis of a project involving a bilingual annotated edition of Ernst Ising dissertation, a project that is now being worked on without Ralph. Already in 2000, RK contributed to the Irish scientist Millenium Yearbook 2000 [6]. The purpose of the book was to provide an overview of Irish science and to inspire young people to pursue scientific activities. Therefore, Ralph was intrigued when, in his final years, he studied Ising's dissertation with us and realized that the roots of the Ising model might have been in the work on magnetism by Richard Kirwan, the Irish scientist from the end of the 18th century, whose work is mentioned in Ising's dissertation. In [60] he summarised his view: 'one of Kirwan's many contributions was to teach us that if there were no interactions between atoms there'd be no magnetism. Likewise, a society is formed by interactions.'

Professor Ralph Kenna has achieved significant success during his professional career. This is the initiation and lead of research in the field of statistical physics and complex system science at Coventry University. This is the establishment and management of the $\mathbb{L}^4$ Collaboration and International Doctoral College for the Statistical Physics of Complex Systems (Leipzig-Lorraine-Lviv-Coventry). This is his membership in the supervisory board of the Middle European Collaboration in Statistical Physics (MECO) and on the editorial boards of several international journals (along with Condensed Matter Physics, RK was the editor in Entropy and Advances in Complex Systems). It is the management of international collaborative projects that have linked Coventry University with numerous research centers around the world. Especially close ties connected him with Ukraine (the title of Doctor honoris causa of the ICMP, Lviv, was conferred on RK for his pioneering research and for his personal initiative in different forms of collaboration with Ukraine) and Armenia. These initiatives started and supported by him will definitely have a proper continuation.

However, we believe that not only his professional activities will be continued by his students and colleagues. Those who knew RK closer admire his attentiveness to people and readiness to help, his excitement by new ideas and his engagement in their realization, his broad erudition, and his active position in different situations. A tireless champion of his historical and cultural traditions, he desperately fought for the preservation of these traditions in the modern world. We add to this foreword one of his articles, 'When Will Our Rivers Run Free?' which together with the article [60] enables one to understand the scale of these activities of his and the amazing combination of his professional knowledge, his personal convictions, and his nonconformism. As RK once wrote, he tried 'holding the anti-ferromagnetic line in a ferromagnetic world' [52]. His constant open attitude towards people and desire to help them led to incredible manifestations of the strength of his will and spirit. After an out-of-hospital cardiac arrest in 2017, despite being 30 minutes gone, he made a full recovery and became fund raiser for the air ambulance who aims to help people in similar situations. In the last years of his life, struggling with another disease, he tried and did everything possible to support those around him — both with advice, for now, and for the future, and with concrete work, and with his wisdom and kindness. We believe that those who knew him will be grateful to him for this and will continue his work in different ways. Among these people are the authors of this collection — they are only a small part of the scientific environment of Professor Ralph Kenna — who, together with the CMP Editorial board, devote this special issue to his memory.

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Nancy-Linz-Lviv

Ralph Kenna: When Will Our Rivers Run Free?[2]

I lived in Dublin's docklands in the early days of the Celtic Tiger. It was a handy location — just a hop across the Liffey to Trinity College where I worked as a theoretical physicist. Something between curiosity and aggrievement greeted me as I passed the Custom House each day on my way to work. Once you've noticed it, it's hard to "un-see" the Crown of England perched superior to the Harp of Ireland on that grand building's ornamentation.

But this was Dublin and I am an Athlonian. Dublin is not my city; who am I to question its iconography? Besides, the Custom House dates from 1791 and I am a physicist, not a historian.

Anyway, whinging about our difficult past was not always welcome. My letter in the *Irish Times* about Sheela-na-Gig sculptures from my native Westmeath being locked away in London met a swift rebuke. "During many centuries of British exploration and conquest" went the reply:

> they brought things with them: law, the conventions of civilised conduct and, perhaps most importantly, the language in which Mr Kenna expresses his opinions — let us hope they do not come looking for these things back.

"Let us hope so indeed" went a third letter:

> In all the excitement and pride over our prosperous, modern nation, we tend to forget what a thick, filthy, ill-mannered, poverty-stricken, pig-ignorant crowd of bog-trotters we were just a few short centuries ago, before the British Empire took us under its kindly and cultured wing.

The letter-writer's sarcastic style was as effective as his knowledge of the past: "Brehon Law ... appeared to work quite well", he said — "the brehons (judges) themselves maintained that the system represented the law of nature."

Physics is not just about laws of nature; "physics is what physicists do late at night" said Nobel-Prize winning physicist Richard Feynman. As atoms, electrons or quarks interact with each other, so too do people or characters in a story — be they now or in the distant past. And that was my conduit into the days of yore — my route back to Ireland after emigrating to Coventry, where late at night I lay thinking about the Brehon laws of old. All I had to do was to take the maths developed for physics and apply it to old stories.

Surrounded by a vibrant team of mathematicians in Coventry, we analysed a medieval Irish text, telling how an army under the leadership of Brian Boru challenged Viking invaders, culminating with the Battle of Clontarf in 1014. Despite centuries of lore, revisionists of late told us that it wasn't an Irish-versus-Viking conflict at all! It was the Irish at it again — fighting against each other while the more sophisticated Vikings just helped out.

But mathematics combined with the annals told us otherwise. We developed a way to measure war on spectrum between either side of a binary debate. With an Irish-versus-Viking conflict at one end, and civil war at the other, the annals deliver a score a third of the way along — a predominantly Irish-Norse conflict but not wholly so.

Athlone plays an important role in the story of Viking Age — it sits on Ireland's longest river, the Shannon — a natural defensive line between the eastern and western provinces. It was at Athlone in 1002 that the king of Meath (which included Westmeath), submitted to Brian Boru, an act that opened the way for Brian's dominion over all of Ireland. And the importance of Athlone to all of Ireland endured. In 1607 the Flight of Earls had marked the end of the old Gaelic Order and a sad story of emigration started. One Irish soldier returned from Spain in 1626 as a Franciscan friar on a mission to rescue Ireland's ancient manuscripts — to preserve her identity. It was at a meeting in Athlone in 1630 that they started compiling what would become the **Annals of the Four Masters** — chronicles of our history and mythology.

Athlone's role in history continued. It was in 1691 that Sergeant Custume and his stalwart band stood fast against Williamite invasion. It was at Athlone that the "unforgettable fire" decommissioned Moydrum Castle during the War of Independence. It was there that Radio Éireann broadcast to the world from the 1930s. Athlone stood alongside capital cities such as Vienna and Helsinki, embraced as it was between them on the old radio dials. It was at Custume Barracks in Athlone that the 26-county government built a nuclear bunker during the Cold War — a new capital they could decamp to should the missiles fly. It is Athlone that would be capital of a federal reunited Ireland under the Éire Nua ("New Ireland") proposal.

Thus Athlone is not only the physical centre of Ireland; it is central to her mythology, her history, her identity — no matter where on the political spectrum you find yourself. So imagine my consternation when I arrived home in Spring 2019 and saw in the local newspaper how a statue from the Custom House had been selected to represent my town.

Two years ago, Westmeath County Council called for a new sculpture for Athlone. It was to be "uniquely 'of' the town" and address its "heritage, memory and environment." And "in particular", it should address the town's "location in relation to the River Shannon." To my dismay the Council decided on a replica of Custom-House iconography! It is not a crown but a neo-classical Neptunesque figure — a "river god of the Shannon", claimed to "hark back to Irish mythology."

Why is this so very, very wrong? And why should you care?

In 2016 we published further mathematical investigations into the past. In the 1760's, shortly before John Beresford had the idea to build the Custom House, James Macpherson published what he claimed were translations from Scottish-Gaelic sources of a third-century bard named Ossian. He tried to align his work with the Classics as, during the Imperial Era, British administrators viewed themselves as inheritors of the torch of civilization-passed on from ancient Greece and Rome. Conquest and colonization were justified if a devalued, inferior and even expendable Gaelic culture was replaced by something that emulated the eminence of the Classics. So, positioning the epic poems of Ossian within a classical context would add legitimacy and authority to the new Scottish epic.

Ireland's antiquarians were aghast! They protested at attempts to misappropriate Ireland's heroes and identified thinly veiled characters from the Irish epic tradition. Ossian, an illiterate Bard of an illiterate age in Macpherson's work, was Oisin, the warrior-poet of the Fenian Cycle in Irish mythology. Ossian's father, Fingal, a Scottish king for Macpherson, was Fionn mac Cumhaill, leader of the Fianna. They accused Macpherson of lacking decency in the illiberal abuse of all ancient and modern writers who endeavored to throw lights upon the ancient state of Ireland. In our paper, we analysed Ossian in a similar

manner to how we had previously analysed the Fenian Cycle and indeed the Viking age. Again, the mathematics gave a clear answer — quantifiable structural affinities with the Irish texts and a dissonance from the Classics.

In Irish mythology the personification of the Shannon is Sinann. She is a woman not a hairy man. She is the granddaughter of Lir (of the Children of Lir fame) and her story is as beautiful as it is inspiring. As Athlonian, Celtic scholar and linguist Maud Joynt wrote in 1912: "To the Boyne as well as the Shannon among Irish rivers was attributed the gift of inspiration."

Whatever about Macpherson's inspiration, we certainly know what inspired Beresford. He was the first commissioner of revenue for Ireland and his world was one of privileged nobility. Beneath it lay the impoverished underclass struggling for basic civil rights who should be kept down by a policy of unyielding repression. Of the 14 river heads on the Custom House only the Liffey is female a quite conceivable eighteenth-century misunderstanding of Anna Liffey as personification of Abhainn na Life. The river heads represent commerce and profit hence their appearance on reverse of old bank notes. They have nothing to do with Irish mythology. The prime position of the Custom House is still held by a crown perched superior to the harp which is surrounded by the lion and unicorn. Just in case anyone is in doubt as to what they celebrate, the hairy-faced neo-classical river head concocted to represent the Boyne has the inscription 1690.

Athlone's unfortunate sculpture is therefore neither "uniquely 'of' the town" nor does it address its "heritage, memory and environment." Its claim to "hark back to Irish mythology" in relation to the Shannon represents ignorance at best — or triumphalist colonial misappropriation of identity and gender in a town devoid of secular female iconography. It stands for profit and domination not for curiosity and education that Sinann inspires.

Ossian provoked the greatest literary controversy of all time. Athlone's new statue is controversial too. It initially found favour when Westmeath County Council put a model up for public viewing in January 2019. But the Council — ranked worst in country for transparency, accountability and ethics — failed to share its symbolism or to explain that in Irish mythology the river takes the female form of the goddess Sinann. When informed of our paper, people rejected the statue. Peaceful street activities, art, poetry, newspaper items, radio broadcasts, an open lecture and a petition followed. But these failed to convince the Council of their folly and Athlone's mayor proudly declared they are not for turning. They erected the statue in the dark of night at the darkest time of year (19.12.2020) at Custume Place, named for Ireland's defenders and directly outside the Williamite HQ where the grim Dutch gunners eyed them well. Over 90% of a thousand comments posted online in the days after erection of the statue shared my dismay.

So, this is an Athlone issue — why should you care? What has it to do with your identity? If issued in the last few years, perhaps you should look at your passport — it may well contain the same symbolism:

> Half-form images of 14 different river gods — like those on the Custom House and Liffey bridges, in Dublin city centre — are at the edge of each page.

Historians say that myths tell us more about the society who told, recorded or created them than it does about anyone who went before. The Athlone statue and our passports are of our time. Do we wish to adorn them with colonial money-gods of a privileged nobility — at a time when the rest of the world is taking theirs down? Or do we prefer more noble concepts our ancestors sought to communicate to us through our myths, our tales, our stories — concepts that more inclusively span our complex identity spectrum? Surely there is room on our iconography for female as well as male? Surely there is room for curiosity, enlightenment and hope, and all that Sinann inspires?

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Ralph Kenna is an Athlone native and Professor of Theoretical Physics at Coventry where his research includes mathematical investigations into epic narratives, especially those from Ireland.

List of representative publications of Professor Ralph Kenna:

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