Impact angle of an academic journal

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Here we propose the metric of impact angle, a global scale-free dimension of the academic journal, to quantify its impact on the scientific community as a collection of citable items published in different years.

The academic journal is the main means of scholarly publishing, and thus evaluating the impact of academic journals is an integral part of the conduct of science. As the most influential tool in this area, the impact factor (IF) coined by Eugene Garfield in 1972, has incurred a flood of criticisms[1–4]. However, there still exists no established metric to rival the controversial IF. On the basis that the variation in the number of papers with their citations may follow the power-law distribution, here we propose the metric of impact angle, a global scale-free dimension of the academic journal, to quantify its impact on the scientific community as a collection of citable items published in different years.

The IF is the averaged citations in the current year of a citable item that the journal published during the two preceding years[5]. It was proposed to help libraries decide which journals to purchase and help authors decide where to submit their manuscripts[5,6]. Unexpectedly, over the years the IF is not only being used to evaluate journals, but has also evolved as a measure of the quality of individual papers, to help make decisions about evaluation, rewarding and recruitment of scientists[7]. The overemphasis of this limited assessment metric blocks innovation in risky and potentially groundbreaking areas of science, as Bruce Alberts, former Editor-in-Chief of *Science*, pointed out[4].

Academic administrations consider the IF as a measure of the typical citation rate for the journal, but in fact it is strongly influenced by a small minority of papers[8]. The IF of *Nature* in 2004 was 32.2, but 89% of that was generated by just 25% of the papers published in 2002 and 2003 (ref. 8). The statistics of citations are highly skewed[8,9]. Highly skewed data are scale-free, which means that they do not possess a typical scale. They usually follow power laws, and occur in many natural or man-made phenomena, such as the human populations of cities, the links to websites, and the species per genus of mammals, despite the fact that few empirical phenomena obey power laws for all values[10,11].

The characteristic feature of power laws is the straight line on the log–log plot. Let k be the number of citations in the current year and $p(k)$ the percentage of all items cited k times in the same year. Then the power-law distribution can be expressed as

$$p(k) \propto k^{-\gamma}, \text{ for } k \le k_0, \qquad (1)$$

where γ is a constant parameter that indicates the slope of the straight line on the log–log plot.

The citation rate of papers varies sharply between disciplines[8]. Here we select five representative academic physics journals: *RMP*, *NatP*, *PRL*, *SCPMA* and *AJP* (Table 1). By citable items we mean reviews, articles, and letters, and citations are only from these citable items. For a given journal, we collected

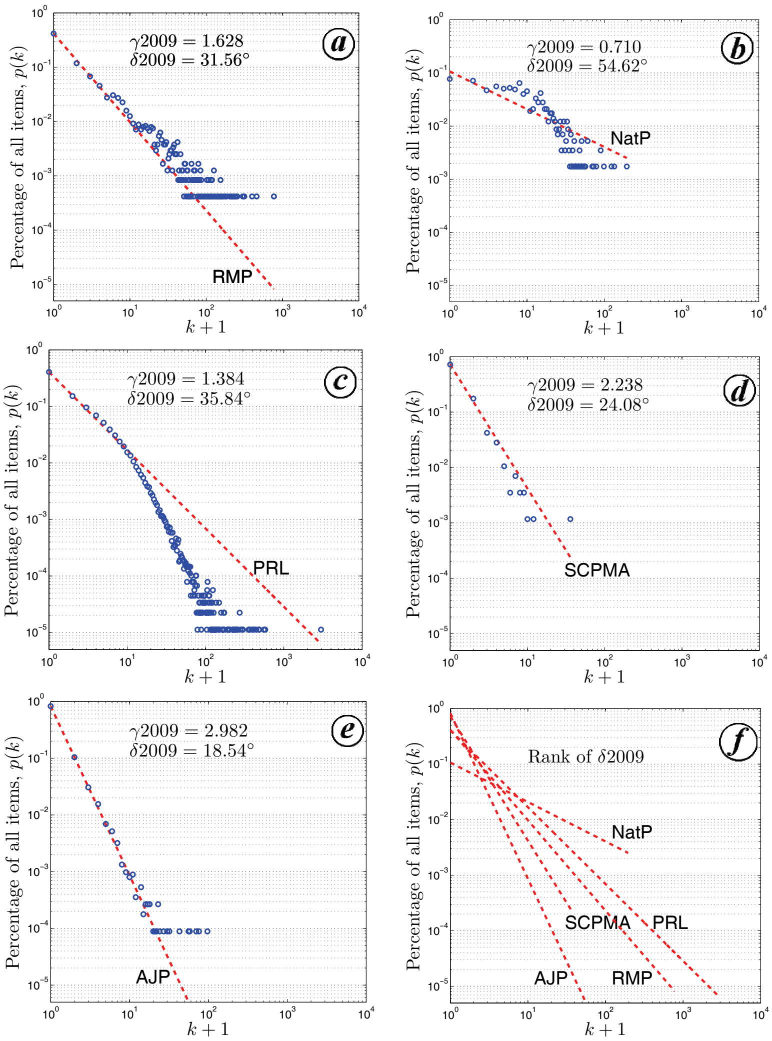

Figure 1. Citation data in 2009 and their power-law fitness of the five representative academic physics journals (Table 1). Note that the horizontal axis is actually $k + 1$, to avoid the singularity at zero on the log–log plot. (***a***) *RMP*; (***b***) *NatP*; (***c***) *PRL*; (***d***) *SCPMA*; (***e***) *AJP*; (***f***) five fitted straight lines on one subplot, which shows the impact-angle rank of *NatP* > *PRL* > *RMP* > *SCPMA* > *AJP* (Figure 2).

Table 1. Five representative academic physics journals

Journal	ISSN	IF2012	Since	Items	Data years
RMP[a]	0034-6861	44.982	1929	2,553	1929–2012
NatP[b]	1745-2473	19.352	2005	1,086	2005–2012
PRL[c]	0031-9007	7.943	1958	88,998	1958–2009
SCPMA[d]	1674-7348	1.169	2003	960	2003–2012
AJP[e]	0002-9505	0.782	1945	11,771	1945–1954 1961–2012

[a]*Reviews of Modern Physics*; [b]*Nature Physics*; [c]*Physical Review Letters* (the citation data in 2010–2012 incomplete at Thomson Reuters); [d]*Science China Physics, Mechanics & Astronomy* (formerly *Science in China Series G: Physics, Mechanics & Astronomy*); [e]*American Journal of Physics*.

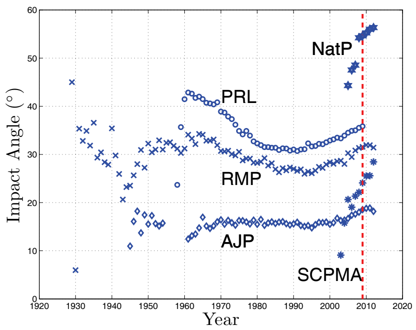

Figure 2. Evolution of the impact angles of the five representative academic physics journals since their first issues (Table 1). Around World War II, *RMP* experienced a valley of impact angles. Amazingly, the impact angles of the three mature journals, *RMP*, *PRL* and *AJP*, seem to evolve in a similar pattern since 1960s, which is supposed to reflect the evolutionary trend of the discipline of physics during this period. In contrast, the two young journals, *NatP* and *SCPMA*, are in a phase of fast growth, and they are supposed to experience a small drop in the impact angles in the near future with the accumulation of relatively-less-cited items. The dashed line shows that the impact-angle rank in 2009 is *NatP* > *PRL* > *RMP* > *SCPMA* > *AJP* (Figure 1).

the citation data in the current year of all citable items published since its first issue. Figure 1 shows that the citation data of four out of the five aforementioned journals can be fitted well by the power-law distribution roughly when $k \leq 10$, which covers the absolute majority of all citable items.

NatP is an exception that is not fitted that well by the straight line (Figure 1). Actually its citation data are fitted far better by the exponential distribution. The main reason is that *NatP* is a relatively young journal with relatively high citation rate, which does not cumulate enough low citation items. The power-law fitness is expected to become better and better as time passes.

Here we define the impact angle $\delta \in [0°, 90°]$ of an academic journal by

$$\delta = \arctan(-\gamma) \times 180°/\pi + 90°, \qquad (2)$$

which indicates the angle between the vertical axis and the fitted straight line on the log–log plot (Figure 1). For example, the impact angles in 2009 of *PRL*, *RMP* and *AJP* are 35.84°, 31.56° and 18.54° respectively (Figure 1). A journal with a larger impact angle is supposed to have a more extensive impact on the scientific community. The impact-angle rank in 2009 is *NatP* > *PRL* > *RMP* > *SCPMA* > *AJP* (Figures 1 and 2).

We have to emphasize that the straight line on the log–log plot is necessary, not sufficient, for the power-law distribution[10,11]. However, for our purpose to describe the global property of a journal, it is sufficient that the citation data can be fitted well by the straight line. Whether these citation data really follow power laws or not is not an important issue.

Note that the impact angle of *RMP* is less than that of *PRL*. However, as a mature journal which publishes a small number of reviews, *RMP* always got an IF far larger than *PRL* (Table 1). The latter annually publishes about 4,000 letters in recent years in all fundamental areas of physics. Hence, the metric of impact angle may relieve the concern of the editors of *PRL*, that they might publish too many items to have an impact[8], and of Philip Campbell, Editor-in-Chief of *Nature*, that worrying about maximizing the IF renders journals consider publishing more good papers as a burden, because the larger the number of papers, the lower the IF[3].

Scale-free citation data do not process a typical citation rate, and thus the IF is doomed to frailty. The catch-on *h*-index and its numerous variants focus on a rather small portion of highly-cited items and are subject to arbitrariness[12,13]. They provide little information for a collection of skewed data. High citation is supposed to be the property of those highly cited papers, not that of the journal. In contrast, the impact angle we proposed here focuses on the scale-free statistical property of the absolute majority of relatively-less-cited items, and thus it is supposed to reflect the global property of a journal. This feature is the defining advantage of the metric of impact angle, which is no doubt a perfect complement to those established metrics such as IF and *h*-index.

The overemphasis of IFs entices editors to inflate them through coercive self-citation with the acquiesce of authors[14], who would benefit from the high IFs of journals. The global nature of the metric of impact angle makes harder this disgraceful practice, and might thus inhibit the coercive motive that deteriorates the situation.

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