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Citation inequity and gendered citation practices in contemporary physics

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The under-attribution of women's contributions to scientific scholarship is well known and well studied. One measure of this under-attribution is the citation gap between men and women: the under-citation of papers authored by women relative to expected rates coupled with an over-citation of papers authored by men relative to expected rates. Here we explore this citation gap in contemporary physics. We find a global bias wherein papers authored by women are significantly under-cited, and papers authored by men are significantly over-cited. Moreover, we find that citation behaviour varies along several dimensions, such that imbalances differ according to who is citing, where they are citing and what they are citing. Specifically, citation imbalance in favour of man-authored papers is highest for papers authored by men, papers published in general physics journals and papers for which citing authors probably have less domain or author familiarity. Our results suggest that although deciding which papers to cite is an individual choice, the cumulative effects of these choices needlessly harm a subset of scholars. We discuss several strategies for the mitigation of these effects, including conscious behavioural changes at the individual, journal and community levels.

The under-attribution of women's contributions to academic scholarship has been recognized for over 150 years[1,2]. A broad body of work has studied this 'Matilda effect'[2] of under-attribution using a variety of tools ranging from feminist theory[3] to statistics[4,5]. The devaluing of women's contributions manifests in a decremented interest in collaborating with women[6], the devaluation of women's contributions to research articles[7], a pervasive perception that women have less academic excellence[6,8–10] and a marked dearth of awards given to women[11,12]. Women also face longer publication processes[13], fewer paper invitations[14] and lower citation rates[4,15–24]. Moreover, the under-attribution of women's accomplishments represents a dangerous erasure of women from the collectively built story of the history and future of scientific progress. Exclusion of women from textbooks[3,25–27], for example, contributes to the construction of damaging stereotypes regarding who can be a good scientist[28,29]. Internalization of these stereotypes can impact scientific performance[30,31] and interest[31,32] among women and girls, leading to

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greater exclusion still. Each individual act of ignoring women's scientific achievements might be consciously or subconsciously performed, and may seem limited in effect on its own. However, small acts of bias have been shown to demonstrably and cumulatively harm members of structurally oppressed groups[33], and this harm is not necessarily related to the intent of the individuals performing those acts[34,35]. We advocate for a framework in which mitigation of cumulative harm is the responsibility of every individual who contributes to it, regardless of intent[36].

Our work focuses on the under-citation of woman authors as a particular means of erasure within academia. We quantify the extent of this phenomenon in physics, and discuss ways in which citation inequities might be mitigated by individuals and groups. Gender disparities in citation have previously been reported in astronomy[4], economics[19], neuroscience[17,22], medicine[24], communications[18] and international relations[20], spurring a range of positive responses from journals and individuals. Journals in these fields have published editorials[37,38] and commentaries[39], and even implemented policy changes[40–42] in response. Scholars have advocated for a range of actions including adding citation diversity statements (CDSs)[43] to their papers, shifting paradigms of scientific impact[44] and a variety of other strategies[45,46]. For the field of physics, there is an especially urgent need to quantify, discuss and mitigate citation disparities. Physics lags behind many other science, technology, engineering and mathematics (STEM) disciplines in numerous measures of gender equity, including undergraduate and doctoral degrees granted to women by US[47] and international[48] institutions, the proportion of women faculty in many countries[48] and global publication output by women[14]. Although previous work has explored publication[14,23] and citation[4,15,23] imbalances in datasets that include physics and astronomy papers, an analysis entirely focused on physics and its subfields can highlight discipline-specific drivers of citation imbalance and begin a conversation among physicists regarding how best to mitigate that imbalance.

In this work we analysed over 1,000,000 papers published in 35 physics journals between 1995 and 2020, and found that the under-citation of women does not exist diffusely as a background effect baked into the fabric of publication in physics, but instead depends on citation venue, citation actor and citation proximity. We used a proxy for author gender—namely, a statistical correlation between the forename under which an author publishes and gender identity, determined from two public databases—in all analyses. We utilized this proxy both because the data it relies on are immediately available and analysable via automated means and also (importantly) because names have a great deal of influence over individual perceptions of authors' gender identities[49] and thus over individual assumptions (implicit or explicit) regarding the merit of authors' scientific works. We found that citation inequity is especially strong for citing papers within the broad category of 'general' physics (citation venue). It is driven primarily by the citing behaviour of man authors, whose imbalanced citation practice remains stable over time (citation actor). Finally, global citation behaviour trends more towards the over-citation of man-authored papers when citations refer to work for which citing authors probably have less domain or author familiarity (citation proximity).

Our results underscore the complexity with which gender disparities manifest in scientific publishing, and identify correlates that could inform future actions by individuals, journals and collectives to mitigate inequity. For individuals, we advocate for thoughtful engagement with the gender make-up of every published reference list, and highlight an increasingly common accountability measure in the form of a CDS[43,50]. Our work indicates that special care must be taken when referencing work that lies outside one's primary area; in these cases, over-citation of man-authored papers can be especially high. We also show that longer reference lists tend to display less over-citation of man-authored papers, suggesting an implicit gendered meritocracy whereby man-authored papers are viewed as more deserving than woman-authored papers when resources (reference list length) are limited. While addressing this implicit gendered meritocracy, individual researchers might also choose to cite more papers (when allowed) to broaden engagement with other scientists and work towards citation equity. Publishing journals, similarly, can reconsider limitations on reference list lengths, recommend the inclusion of CDSs and work towards more equitable representation in their author pool, with the aim of mitigating citation imbalance in their current and future articles.

Quantifying citation imbalance

Our methods for citation data acquisition, preprocessing and analysis are detailed in the Supplementary Information. These methods draw from and build on the broad and growing body of literature on gendered citation bias throughout academia[4,15–22,24]; in particular, we have expanded on the methods used for a recent study of citation bias in neuroscience journals[17].

Time-varying demographics of published papers

We first present a demographic overview of the dataset. Our data consisted of approximately 1.07 million papers published between the years 1995 and 2020 in 35 representative and central journals (as measured by their 2018 Eigenfactor score) across a range of 8 physics subfields. Of these papers, 668,690 could be identified according to their name-based author gender category (see the Supplementary Methods for details). The proportions of papers in each author gender category are shown in Fig. 1a as a function of publication year. Note that although woman first- and/or last-authored (W||W) papers represent a small proportion of the total number of man first- and last-authored (MM) and W||W papers, that proportion has increased overall from 17% in 1995 to 33% in 2020. Individual journals vary markedly in that proportion and in its rate of change (Fig. 1b,c). The journals grouped into the general physics subfield—which includes many of the highest-impact journals in physics—and the high energy physics subfield collectively contain the lowest proportions of W||W papers. This pattern remains consistent over time. Conversely, journals grouped into the astronomy and astrophysics subfield generally contain the highest proportion of W||W papers over time, followed by the relatively young journals grouped into the nanoscience subfield (four of which were launched during the time period we analysed). See the Supplementary Results for more detail. Note that the high energy physics subfield is unique in that its paper authors tend to be ordered alphabetically, rather than according to author seniority or contribution (Supplementary Fig. 6). Thus, for high energy physics papers with more than one author, the assignment W||W is a broader designation than it is for multi-author papers in other subfields, reflecting only information related to the proportion of women in the paper's author list (see Supplementary Section 3D). It is therefore striking that demographic and citation imbalances (explored in the following sections) still exist for this broader category of high energy physics W||W papers.

Citation imbalance exists and varies by citing venue

The citation behaviour of the papers in our dataset is imbalanced with respect to the cited author gender category. In general, MM papers are cited more often than expected by approximately 1.06%, and W||W papers are cited less often than expected by approximately 3.17% (Fig. 2a,b). These results constitute an overall gender citation gap of roughly 4.23%. This gap varies markedly across subfields (Fig. 2c) and journals within those subfields (Fig. 2d and Supplementary Results). Papers published in journals grouped into the general physics subfield collectively show the widest citation gap, whereas papers in journals grouped into the astronomy and astrophysics subfield collectively show the narrowest citation gap. We defined over-/under-citation of an author gender category as the percent difference between the number of citations that papers in the category actually receive and their

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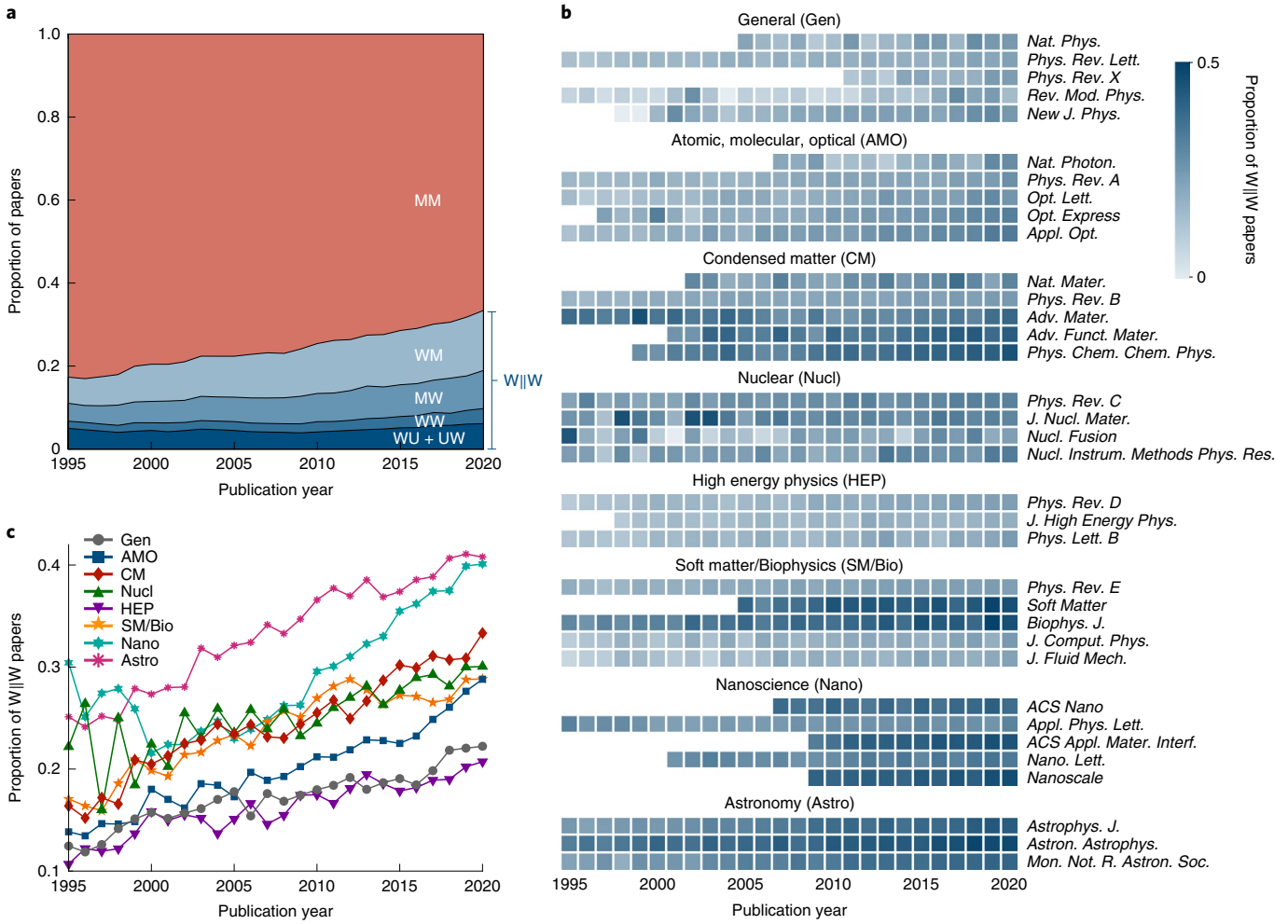

Fig. 1 | Time-varying demographics of published papers according to author gender category. a, Proportions of papers according to author gender category over time. Note that several author gender subcategories are grouped into the W||W category. The W||W category thus consists of all papers for which the first and/or last author's names were assigned to the woman gender category. The WU + UW subcategory consists of papers in which one of the (first or last) author's names was assigned to the woman gender category, and the other of the (first or last) author's names could not be assigned to a gender category (see the Supplementary Methods). **b**, Proportion of W||W papers published in all journals in our dataset over time. Journals are subdivided according to the subfield definitions used throughout this Perspective. Some journals were launched within the study period and lack squares for the preceding years. **c**, Proportion of W||W papers published within each subfield over time. All proportions shown here are with respect to the per-year sum of MM and W||W papers (that is, not including papers with authors whose names could not be assigned a gender category).

expected number of received citations according to a gender-blind model (Supplementary Methods). We also note that we chose to exclude self-citations from these and all subsequent analyses to better isolate the influence of gender perception on authors' citation engagement with the field around them (see Supplementary Sections 2E and 4H).

Citation imbalance varies by citing actor

We further separated citation behaviour according to the author gender category of citing teams (Fig. 3a), and found that MM papers tend to exhibit higher citation preference towards other MM papers (over-citing by 2.05%) and lower citation preference towards W||W papers (under-citing by 6.53%), whereas W||W papers tend to exhibit higher citation preference towards other W||W papers (over-citing by 3.56%) and lower citation preference towards MM papers (under-citing by 1.38%). The extent and existence of these citation preferences vary across subfield (Fig. 3c,d) and across journal (Supplementary Fig. 7). Both MM and W||W papers in the general physics subfield show the highest citation gaps, 16.5% and 8.8% respectively, in favour of MM papers. By contrast, W||W papers in the astronomy and astrophysics subfield exhibit the highest citation preference towards other W||W papers, resulting in a citation gap in favour of other W||W papers of 8.42%. See the Supplementary Results for more detail.

Stable and growing trends in citation imbalance over time

The overall citation gap between over-citation of MM papers and under-citation of W||W papers has remained relatively stable between the years of 2009 and 2020, and has even grown slightly. It is notable that this gap persists in the face of a growing fraction of published W||W papers (Fig. 1a) and a growing fraction of citations given to W||W papers by both MM and W||W teams (Supplementary Fig. 8) over the same time period. This trend is driven by the behaviour of MM citers, for which the citation gap in favour of MM papers is larger in 2020 than in 2009 (red lines in Fig. 3b and Supplementary Fig. 8a). By contrast, W||W citers show a citation gap in favour of other W||W papers that decreases between 2009 and 2020 (blue lines in Fig. 3b and Supplementary Fig. 8b). Citation trends also differ across the subfields and publishing journals of citing papers (Fig. 3e and Supplementary Figs. 9 and 10); the overall picture, however, is one of stagnant or worsening citation gaps over time, despite the relative growth of papers authored by W||W teams. See the Supplementary Results for more detail.

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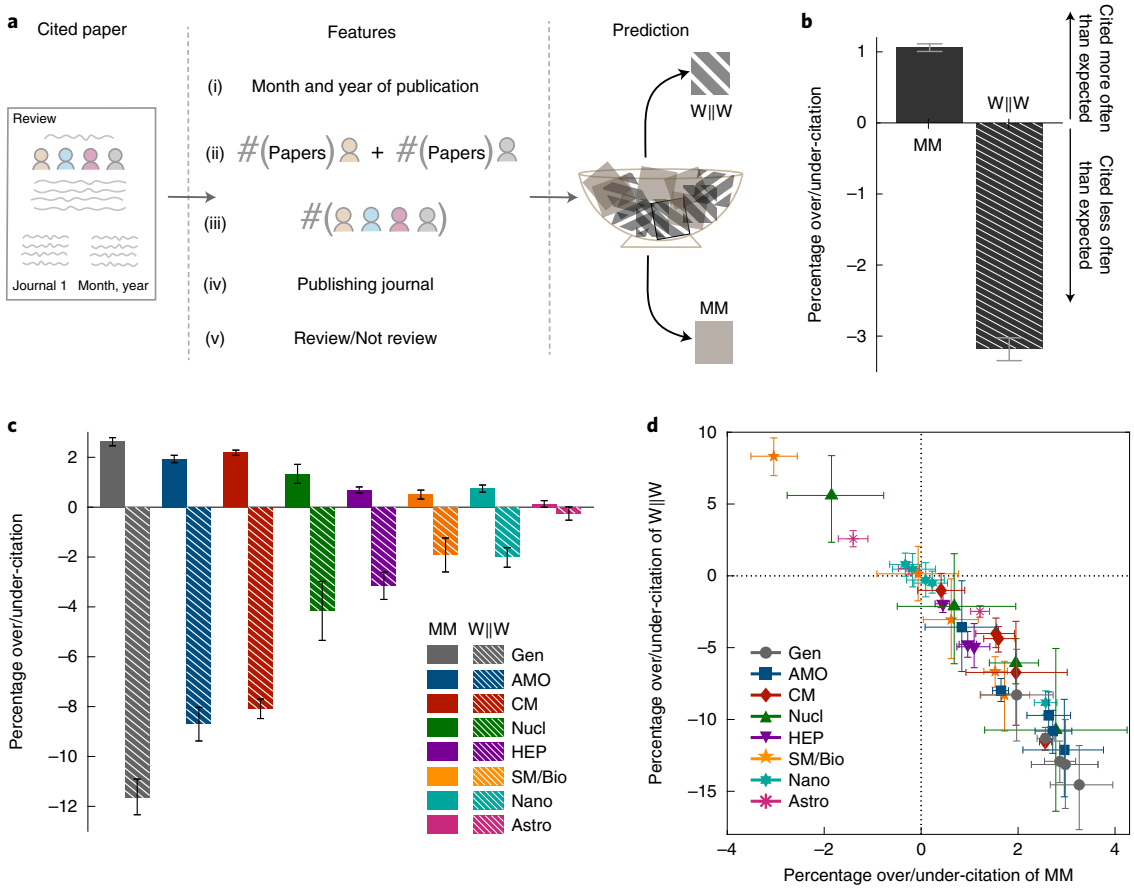

Fig. 2 | Over-/under-citation of physics papers is imbalanced with respect to author gender category. a, Illustration of the statistical model used to estimate over/under-citation of MM or W||W papers according to paper characteristics. **b**, Over-citation of MM papers and under-citation of W||W papers is exhibited in aggregate over all citing papers in our dataset published between 2009 and 2020. **c**,**d**, Over/under-citation varies when the citing papers are grouped according to their subfield (**c**) and journal (**d**). Each marker in **d** reflects an individual journal coloured according to subfield. In all panels the reported over/under-citation values utilize the reference lists of all relevant citing papers, including those of unknown author gender category, to increase statistical power. Error bars representing the 95% confidence interval (CI) of each over/under-citation calculation were computed via 500 bootstrap resampling iterations.

Citation imbalance varies by citation proximity

The citation behaviours exhibited by MM and W||W teams vary significantly in magnitude according to whether or not their citations reference proximal work with which they are likely to be familiar. We categorized proximity along two dimensions: (1) domain and (2) co-authorship. We defined domain proximity between citing and cited papers according to whether they are published in journals that fall within the same subfield (left diagram in Fig. 4a). We defined co-author proximity between citing and cited papers according to whether the cited paper lies within the local co-authorship neighbourhood $\mathcal{C}_2$ of the citing paper (left diagram in Fig. 4b). The neighbourhood $\mathcal{C}_2$ is defined in Supplementary Section 3E, and consists of the set of papers written by the authors of the citing paper and their co-authors. With both definitions of proximity, we found similar results regarding the total citation gap between MM and W||W authored papers: for the set of more distant (less familiar) citations, the citation gap is larger than it is for closer (more familiar) citations, with greater over-citation of MM papers and greater under-citation of W||W papers (black symbols in Fig. 4a,b). The suppression of the familiar citation gap and the enhancement of the unfamiliar citation gap together arise from the cumulative effects of two very different citation behaviours according to citing author gender category. Across domain- and co-author-proximal citations, both MM (red symbols in Fig. 4a,b) and W||W (blue symbols in Fig. 4a,b) citing teams show enhanced citation preferences for their respective author gender categories. Across domain- and co-author-distant citations, however, MM and W||W teams differ in their citation behaviour. For W||W teams, the citation preference for W||W papers is approximately erased. By contrast, for MM teams, the citation preference for MM papers is not erased. Instead, this preference is enhanced for domain-distant citations, and slightly reduced but still significant for co-author-distant citations. The overall result is a smaller familiar citation gap in favour of MM papers due to the competing citation behaviours of W||W and MM citing teams, and a larger unfamiliar citation gap in favour of MM papers due to the MM citing papers' persistent citation preference for other MM papers even when citing domain- or co-author-distant references. Given that domain proximity and co-author proximity do not measure identical aspects of cited papers, the similarity of these broad trends is striking. See the Supplementary Results for more detail.

Additional correlates of citation imbalance

Our dataset revealed additional correlations between citation behaviour and citing actor, venue and form, each of which might be useful considerations for developing individual and institutional strategies to mitigate citation imbalance in the future. In particular, we found that citation behaviour varies on the journal level according to the relative proportion of W||W published papers, generally showing increased time-aggregated citation preference for W||W papers (and decreased time-aggregated citation preference for MM papers) with increased

time-aggregated fraction of W||W papers published (Fig. 5a and Supplementary Fig. 14). These results are not unexpected given the tendency of W||W papers to cite other W||W papers to a greater extent than MM citing papers do (Fig. 3a–d), and demonstrate that representation within journal authorship pools is a meaningful correlate of citation imbalance.

For individual citing papers, we also found a collective trend whereby papers with longer reference lists tend to exhibit increased citation preference for W||W papers. Figure 5b demonstrates this phenomenon for papers published in 2019. Papers are grouped according to author gender category and reference list length, and linear fits to the data for each author gender category show the upward trend of W||W citation preference with reference list length. The slopes of these linear fits, averaged over the years between 2009 and 2020, suggest that reference lists gain approximately 1.5% in W||W citation preference when they add ten citations (Supplementary Fig. 18). The conceptual significance of this effect is notable when considered in light of the global rate of MM over-citation (1.06%) and W||W under-citation (−3.17%) for all (2009–2020) papers (Fig. 2b). See the Supplementary Results for more detail.

Towards citation equity

Immediate actions

Taking action in response to inequities requires effort. Gender-bias research is generally underappreciated in academia[51], and viewed less favourably by men—especially men faculty in STEM[52]. This is an unfortunate irony given that bias tends to be preferentially perpetuated by those who think it is not happening[53]. Action can be guided by detailed assessment of the existing inequities, such as that we provide here. At the individual level, our work underscores the critical need for self-education, particularly focused on the work published in general physics and in fields outside the author's primary area, where we find the greatest disparities. We suggest that authors consider including CDSs in their published papers, which state the importance of citation diversity, the percentage breakdown of citations, the method (and its limitations) used to assess percentages and a commitment to equity[43,50]. Thus far, papers published with a CDS display more equitable citation practices[54,55], underscoring the efficacy of the CDS in mitigating disparities. Several journals support the use of CDSs, including the *Journal of Cognitive Neuroscience*[40] and those affiliated with the Biomedical Engineering Society[41], and journal-specific (ref. [22] and https://postlab.psych.wisc.edu/gcbialyzer/) and journal-general[56] tools exist to aid in the calculation of citation diversity statistics of individual papers. Cell Press also now uses a form (https://els-jbs-prod-cdn.jbs.elsevierhealth.com/pb/assets/raw/shared/forms/IandDstatement_form.pdf) in their more than 50 journals to assess how the values of diversity and inclusion were evinced in the performance of the work being published[42].

At the journal level, our work raises the possibility that increasing the number of women authors a journal publishes could lead to a decrease in gender citation imbalance. This causal hypothesis derives from our non-causal observation that journals publishing a higher fraction of papers authored by women tend to show less under-citation of women. For example, journals focusing on non-primary content could solicit reviews from under-represented authors to increase their fraction of W||W papers. Efforts to increase the number of women authors in a journal would also serve to combat (1) the higher writing standards for women than for men[13] and (2) the tendency for submitted work to be perceived as better when it is associated with a man's name compared with a woman's name[6,57]. Our results also suggest the possibility that removing length limits on reference lists may be beneficial to gender equality, as papers with longer reference lists tended to display less disparity. However, we note that this recommendation does not condone the implicit notion that man-authored papers are of greater value and more deserving when resources (reference entries) are limited.

Homophilic behaviour and its drivers

Throughout our analyses, we observed homophilic citation behaviour for both MM and W||W teams, with MM citing teams tending to devote more of their reference lists to papers published by other MM teams than predicted by our model, and W||W citing teams tending to devote more of their reference lists to papers published by other W||W teams than predicted by our model. For MM citing teams, this homophilic behaviour was persistent over time, pronounced across subfields and present for both more familiar and less familiar citation types. For W||W citing teams, homophilic behaviour lessened in magnitude over time, varied according to subfield (with some subfields not showing homophily) and was significant only for more familiar citations.

The presence of gendered homophilic citation behaviour throughout our dataset is not surprising; indeed, homophily along numerous dimensions of similarity is a well-studied and prominent driver of human activity and social system development[58]. In academia, gender homophily influences patterns of co-authorship and collaboration[59–61], citations[62,63], invitations to give colloquia and other talks[64,65], networking[66,67], the nomination of Nobel laureates[68] and peer-reviewer selection[69]. However, we stress that although homophilic behaviours of majority and minority populations in any context (here, men and women in physics) might seem similar on the level of quantitative analysis, they need not be driven by similar factors. Members of a minority population may choose to take part in 'activist choice homophily', built on the perception of shared structural barriers (rather than similar attributes) and a desire to help overcome those barriers[70]. We found that women in physics take part in the homophilic practice of citing other women and thereby permanently embedding them into the scientific canon. This practice, if driven by activist choice, could thus be argued to be a form of resistance against a scientific narrative dominated by men.

Citation inequities along dimensions of difference

Under-attribution, bias and discrimination are faced by individuals of many—and intersecting—identities. Future work would do well to unpack citation practices not just along the (cisgender) man/woman binary, but also along other dimensions of difference including race, ethnicity, class, sexual orientation and disability. For example, previous work in several areas of science provides evidence for under-attribution according to race and ethnicity; scholars of colour are broadly under-cited by their academic communities[71,72]. These effects compound known intersecting gender and class inequalities in hiring at all levels in academia[73–75]. Furthermore, sexual orientation is a

Fig. 3 | Citation behaviour varies across time and according to citing author gender category. a, Over/under-citation of MM and W||W papers published between 2009 and 2020 calculated separately for MM and W||W citing teams. Each team category exhibits citation preference towards their own author gender category. **b**, Citation behaviour of each citing author gender category varies over time. MM citing teams exhibit a higher citation preference towards other MM papers and a lower citation preference to W||W papers, resulting in a citation gap that is widening over time. W||W citing teams exhibit lower citation preference toward other W||W papers, and that preference decreases over time. **c**,**d**, Citation imbalance exhibited by MM teams and W||W teams varies according to subfield. In both types of teams, papers in the general physics category exhibit the highest over-citation in favour of MM papers. The legend in **d** also applies to **c**. **e**, The overall citation imbalance within subfields is relatively stable over time. The values reported in **e** incorporate the reference lists of all relevant papers, including those of unknown author gender category, to increase statistical power. In all panels error bars representing the 95% CI of each over/under-citation calculation were computed via 500 bootstrap resampling iterations.

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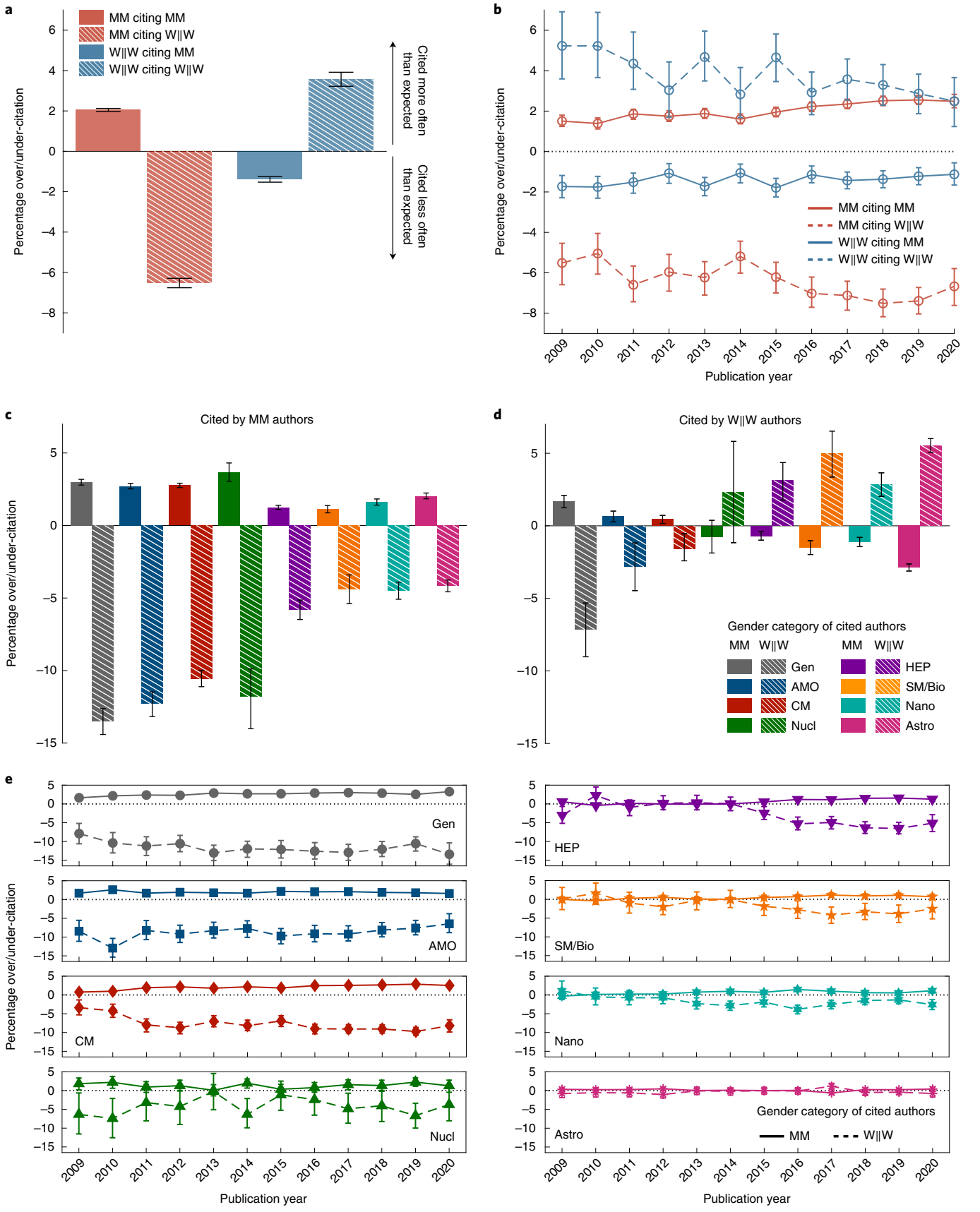
proven axis of inequality in STEM[76,77]: lesbian, gay, bisexual, transgender and queer (LGBTQ) STEM professionals are more likely to experience career limitations, harassment and professional devaluation than their non-LGBTQ peers[78,79]. Because sexual orientation is not reflected in a scholar's name, self-attestation will be critical to future evaluations of citation practices along this dimension[80,81]. Similarly,



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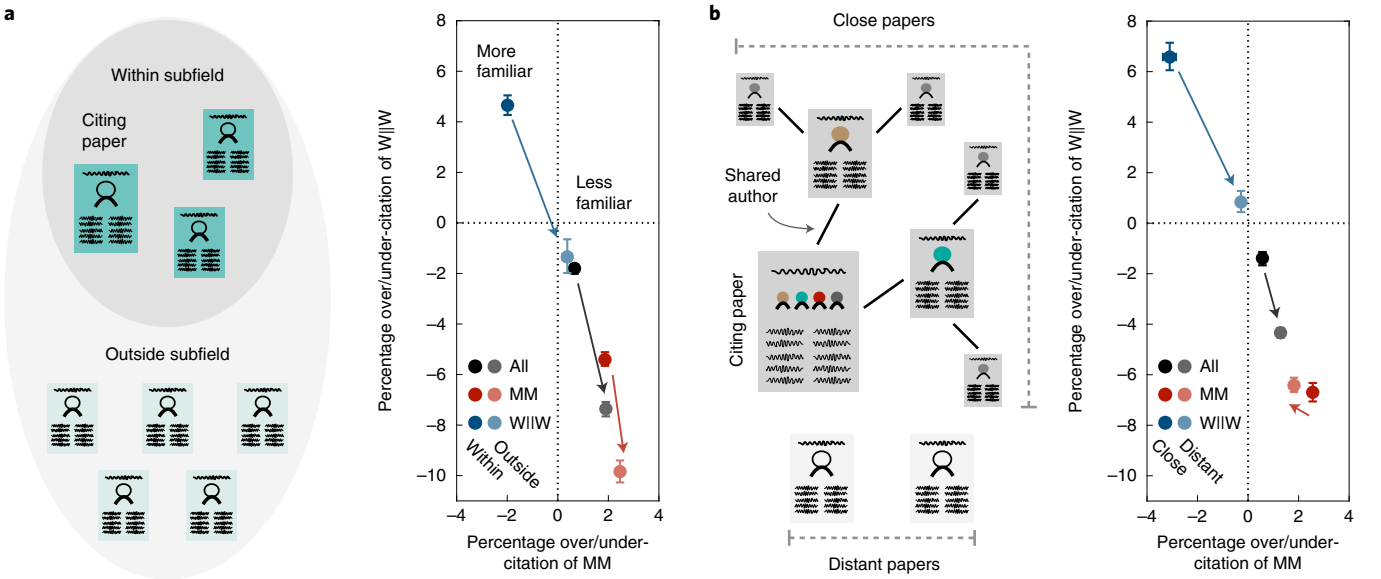

Fig. 4 | Citation behaviour varies according to citer proximity to cited work. **a**,**b**, Proximity as defined by whether the publishing journals of cited and citing papers fall within the same subfield (domain proximity/familiarity; **a**) and whether cited papers lie within the local co-authorship neighbourhood of citing papers (co-author proximity/familiarity; **b**). In each panel, a schematic of the proximity definition is shown on the left, and citation behaviour according to that definition is shown on the right. Symbols show the citation behaviour of all papers written between 2009 and 2020, including those with unassigned author gender categories, the subset of papers in the MM author gender category and the subset of papers in the W||W author gender category. Arrows point from over/under-citation when considering only close (familiar) citations to over-/under-citation when considering only distant (unfamiliar) citations. Overall, over-citation of MM papers and under-citation of W||W papers are more marked for unfamiliar citations, although this effect is due to differing behaviours of MM and W||W citing teams. In both panels, error bars representing the 95% CI of each over/under-citation calculation were computed via 500 bootstrap resampling iterations.

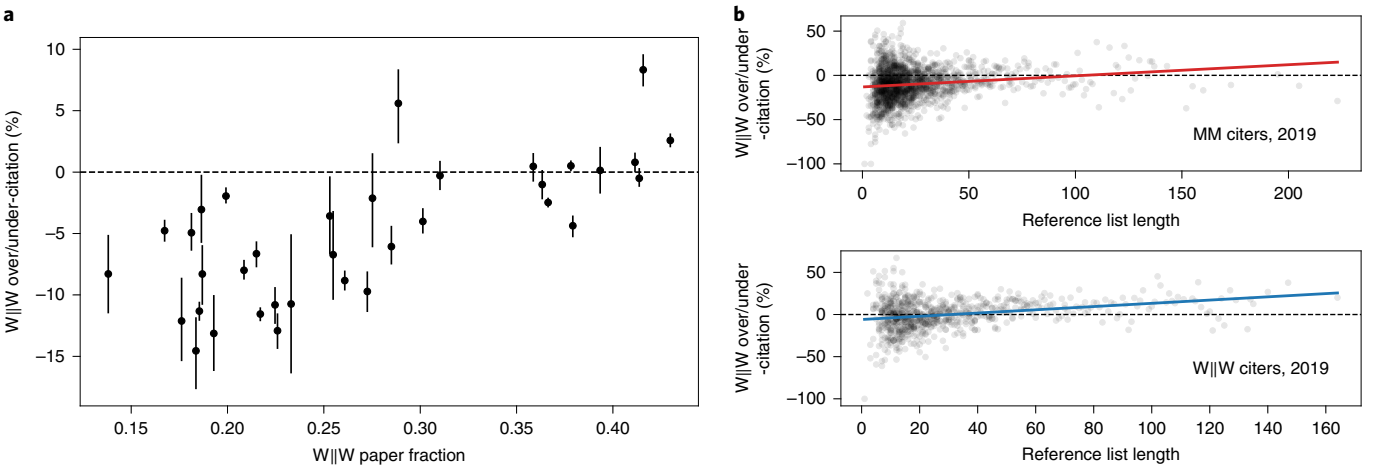

Fig. 5 | Additional correlates of citation behaviour. **a**, Journals that published a higher proportion of W||W papers between 2009 and 2020 generally exhibited higher citation of W||W papers. Each data point represents a journal; error bars representing the 95% CI of each over/under-citation value (calculated across all citing papers published in each journal between 2009 and 2020) were computed via 500 bootstrap resampling iterations. The proportions of W||W papers are reported with respect to total MM and W||W papers published in each journal between 2009 and 2020. **b**, Papers with longer reference lists tend to exhibit higher citation of W||W papers. This trend is consistent for MM papers published in 2019 (top) and W||W papers published in 2019 (bottom). Each data point shows over/under-citation aggregated over paper subsets of a maximum size of ten at each reference list length (see the Supplementary Information for details). Linear fits to the data via ordinary least-squares regression are also shown, expressed approximately by $y = 0.126x - 13.095$ (top) and $y = 0.192x - 5.911$ (bottom).

transgender and non-binary status cannot be predicted from names, and hence name-based assessments cannot reveal specific discrimination faced by these individuals. Nevertheless, transgender and non-binary individuals exist in our dataset, and their name–(binary) gender associations are part of the probabilistic databases we employ. At the population scale, these individuals face the same name-based citation costs and pay-offs as a cisgender scholar, which could be compounded by other costs and pay-offs not accessible to our analysis. Of course, all scholars with marginalized intersecting identities are likely to face compounded citation costs, as is supported by a recent study that evaluated the intersection of gender and race/ethnicity[71]. We hope that further work could complexify our understanding of citation practices, and their ethics, along these diverse lines of difference.

Citation equity in broader context

Gender disparities exist throughout the discipline, performance and processes of science. Accordingly, calls to citation equity are multifaceted and often involve assessing research ethics at more than one level[82–85]. Scientometricians have increasingly advocated for citation equity at both the reference and index levels of citation[86,87], as well as for equitable practices in broader systems of science communication. Citation equity at the reference level, for example, might involve thoughtful evaluation of 'citances', or the textual context in which references occur[88]. Recent work has discerned differences in citance sentiment according to paper field, journal venue and author gender, with more positive sentiment occurring in citances to men's scholarship than women's scholarship[89,90]. Citation equity at the index level involves reflection on citation indices and their use in the field. Scholars across the natural sciences, social sciences and humanities call for a careful re-evaluation of how citations are used in academic economies, given the limited capacity of citations to reliably indicate scholarly impact, quality, creativity or importance[85,91,92]. Such a re-evaluation might include expanding and equalizing the avenues through which scholarship is recognized and rewarded[91], as well as practicing engagement with and stewardship of minority scholarship beyond mere citation[85,92].

Finally, citation equity is related to a larger culture of science communication, which involves formal and informal mention across social media, curricula, organizational meetings and conversations among editorial staff. While the presence of gender disparities in STEM syllabi, at conferences and among journal editors is well-established, recent work finds similar disparities in social media metrics[93]. However, awareness of these problems is, and must be, paired with innovative solutions. Important initiatives to improve women's representation in STEM are many: the Cite Black Women collective (https://www.citeblackwomencollective.org), American Physical Society-sponsored Conferences for Undergraduate Women in Physics (https://www.aps.org/programs/women/cuwip) and the BiasWatchNeuro group (https://biaswatchneuro.com) are but a few examples.

Future research along all these vectors would be valuable, as well as individual and collective reflection not only on how citation imbalances and other dynamics explored in this Perspective might appear within and beyond our reference lists, but also on how they might be addressed by different actors, venues and networks[94–96]. We invite readers to consider these and other ways we can all make visible the contributions of all scholars to the scientific endeavour.

Abbreviated CDS

In writing this Perspective we sought to proactively consider choosing references that reflect the diversity of the field in thought, form of contribution, gender and other factors. We used databases that store the probability of a name being carried by people of different genders to mitigate our own citation bias at the intersection of name and identity. On the basis of the databases used, the set of names assigned the 'woman' label will contain a predominance of women and the set of names assigned the 'man' label will contain a predominance of men, but both sets may also contain other genders. By this measure (supplemented by manual research of some individual authors and excluding self-citations to the first and last authors of this Perspective, and papers whose authors' first names could not be determined), our references contain 43% W||W, 20% MW, 16% WM and 21% MM papers. This method is limited in that the names, pronouns and social media profiles used to construct the databases may not, in every case, be indicative of gender identity. Furthermore, probabilistic studies of names cannot be used to detect citation costs that are specific to intersex, non-binary or transgender people who are out to a large number of their colleagues. We look forward to future work that could help us to better understand how to support equitable practices in science.

Data availability

The data generated and analysed for this study are available in an Open Science Framework repository and can be accessed at https://osf.io/p5cb7/.

Code availability

The code used to generate Figs. 1–5 can be accessed at https://osf.io/p5cb7/, and the code used for the data processing and analyses presented in this study can be accessed at https://github.com/jdwor/gendercitation.

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The authors declare no competing interests.

Additional information

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