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Standing on the shoulders of giants: How star scientists influence their coauthors[☆]

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ABSTRACT

We examine whether and when star scientist collaborations produce indirect peer effects. We theorize that a star's social status causes a collaboration to act as a prism; it reduces quality uncertainty, leading to increased recognition of coauthors' ideas. We identify two moderators of prisms, other scientists' quality uncertainty and awareness of the collaboration, and link prisms to "sleeping beauties", articles that are initially overlooked and then rediscovered later. Empirically, we examine the effect on citations of collaborating with a star who either won, or – serving as the control group – who was nominated for but did not win, the Nobel Prize in Physics. We find that articles by the winners' coauthors (and which were published prior to the focal coauthor's first collaboration with the winner) receive a citation boost after the Nobel Prize is awarded, relative to articles by the coauthors of nominees, and that awareness and quality uncertainty moderate this effect. We further find that this difference in citations causes sleeping beauties written by the coauthors of Nobel Prize winners to be rediscovered faster. Our results clarify how star scientists' indirect peer effects impact their coauthors and, through sleeping beauties, how prisms matter for science more broadly.

1. Introduction

Scholars have long tried to understand and measure the effect that others have on our own behavior (Sacerdote, 2014). Recent research has started exploring peer effects in science and how collaborations between researchers affect their productivity (Agrawal et al., 2017). As scientific advances often emanate from stars, i.e., exceptionally productive researchers (Hohberger, 2016; Zucker and Darby, 1996), the literature has devoted significant attention to determining whether those who work with stars benefit from doing so.

A core finding of that work is that a collaboration can act as a pipe, a channel through which ideas can move from stars to their coauthors, resulting in changes to their output (Azoulay et al., 2010). This phenomenon is often classified as a direct peer effect because a star's action, her sharing of knowledge, influences her collaborators. Although that research has contributed to our knowledge of star scientist peer effects, it focuses on people who are directly connected to stars. Indeed, despite evidence that star influence extends beyond their direct contacts (Simcoe and Waguespack, 2011), little attention has been paid to stars' *indirect peer effects*, the influence they exert over third parties, scientists who do not collaborate with stars. Furthermore, while prior research has shown that star attributes (Oettl, 2012) and network characteristics (Grigoriou and Rothaermel, 2014) affect a star's ability to share knowledge with her coauthors, leading to variance in direct peer effects, these contingency factors cannot apply to indirect peer effects because stars do not collaborate with third parties, and consequently do not share their knowledge with them. As a result, the literature currently does not offer a compelling answer to the question of whether and when indirect peer effects may occur.

To resolve this puzzle, this paper explores how a collaboration with a star may act as a prism, a metaphorical label originating with (Podolny, 2001) that describes how social relations can affect others' perceptions. Research into prisms outside of science and scientific careers has shown that third parties may view a collaboration as an endorsement (Liu et al., 2015) that reduces third parties' quality uncertainty. Since status, defined as the respect and admiration one has in the eyes of others (Magee and Galinsky, 2008) is often seen by others as an indicator of quality (Lynn et al., 2009), we focus on status endorsements, whether a star scientist's social status affects the indirect peer effects that prisms transmit.

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Grounding indirect peer effects in a star's status helps us to identify a major driver of prisms as the intensity of a prism should vary with the status of the star. However, it is reasonable to assume that all stars are high-status individuals. At the same time, prior research on stars has argued that status differences, that is, differences in the level of respect and admiration that a star possesses, exist between stars (Sauer et al., 2010; Kehoe et al., 2018). Along these lines, there is some anecdotal support in the historical record for the idea of status differences in science. For instance, while Robert Oppenheimer and Edward Teller were both star scientists, Edward Teller possessed more respect and admiration in his contemporaries' eyes as demonstrated when other scientists referred to Teller, rather than Oppenheimer, as the 'father of the atomic bomb' (Teller and Shoolery, 2001). Given status differences among stars, we theorize that a star's social status causes other scientists to view a collaboration as an endorsement of her collaborator's quality leading to increased recognition of star collaborators' ideas and research.

To test this framework, we look to the Nobel Prize in Physics and compare the publications of the coauthors of the winners of the Nobel Prize to the coauthors of (non-winning) nominees. We focus on the Nobel Prize because research has shown that one reason that status differences emerge over time among star scientists is that some stars receive scientific awards like the Nobel Prize (Frey and Gallus, 2017; Jiang and Liu, 2018; Reschke et al., 2018). Since awards are given in recognition of stars' scientific achievements, they cause winners to be evaluated with even more respect and admiration and consequently seen as higher status than those merely nominated for the award. If prisms transmit indirect peer effects, then winner coauthor publications should receive more citations after the Nobel Prize is awarded relative to publications by (non-winning) nominee coauthors.

Crucially, our analysis focuses on articles published before the Nobel Prize and before the first recorded collaboration between a winner (or nominee) and their coauthor. By adopting this approach, we ensure that a star's resources or ideas cannot explain observed changes in citations around the time of the Nobel Prize event. Even if a collaboration made the coauthor a better scientist, such changes cannot affect the quality of published articles produced before their first collaboration. Also, it seems unlikely that, prior to their first collaboration, coauthors could predict which star would later win the Nobel Prize or would be nominated but never win the Nobel Prize. This mitigates selection issues and supports the use of the non-winning nominees' coauthors as a benchmark for winners' coauthors.

The first of our notable findings is that winner coauthor articles published prior to the Nobel Prize experience a 59 % increase in citations after the award relative to articles by (non-winning) nominee coauthors. Second, further restricting the sample to include articles published not only before the Nobel Prize event but also to being published before the first collaboration, we find a 29 % increase in the number of citations after the award relative to nominee coauthors' work. Third, falsification tests in which we vary the event window show that this increase in citations coincides precisely with winning the Nobel Prize; prisms occur when a star wins a prize. Fourth, we identify two important moderators of prisms. We find that third party awareness of the collaboration and other scientists' level of uncertainty about the coauthors' quality moderate and consequently shape prisms and the post-award citation bump.

These results clearly show that prisms impact the recognition of star coauthors' ideas and research. Yet the dynamics of recognition can vary; some papers instantaneously accrue many citations, others are forgotten, and still others are rediscovered after being unnoticed for many years. The bibliometric literature calls initially forgotten and then rediscovered papers "sleeping beauties" (Ke et al., 2015), defined as articles that lie dormant (or, "sleep") and only become highly cited (i.e., "awake") many years after publication. We propose that the prism effect originating from the Nobel Prize award reduces a beauty's time to awakening. In line with this argument, our results show that sleeping beauties produced by winners' coauthors are discovered and "wake-up", or become highly cited, earlier than sleeping beauties produced by nominees' coauthors. Our analysis identifies a driver of this dynamic that helps to explain variance in the time to rediscovery of once forgotten papers.

By analyzing prisms and indirect peer effects, this paper makes the following contributions. First, our results confirm that scientific collaborations may act as prisms that increase the recognition of star coauthor's ideas. This adds to our understanding of how people benefit from working with stars. Second, we provide evidence of two boundary conditions of star peer effects that differ from those discussed in research on pipes: awareness and quality uncertainty. This adds nuance to the literature on star scientists and their collaborations and furthers research into prisms which has not, to the best of our knowledge, yet identified contingencies. Third, the sleeping beauty analysis extends the main analysis to articles that follow a vastly different citation pattern from almost all other published research. Assuming citations are informative of the flow of scientific information, then prisms, via their impact on sleeping beauties, are shaping the movement of scientific knowledge across papers. By diverting other scientists' attention towards sleeping beauties produced by the coauthors of winners, prisms cause these articles to sleep for a shorter period of time. Since sleeping beauties contain valuable ideas, this effect of prisms may potentially shape the course of science itself.

2. Theoretical framework

2.1. Peer effects in science

Many scientific discoveries have been credited to a solitary author, such as Einstein's theory of relativity, Darwin's theory of evolution, or von Neumann's theory of games and economic behavior. However, over time, that individual-based model of science has given way to a more collaborative model, in which scientists work together to produce knowledge in the form of published articles (Wuchty et al., 2007). As a result, researchers interested in science increasingly focus on peer effects – how coauthors (i.e., scientists who work together to publish papers in scientific journals) impact each other (Agrawal et al., 2017; Azoulay et al., 2010; Borjas and Doran, 2012, 2015; Dahlander and McFarland, 2013; Oettl, 2012; Reschke et al., 2018; Simcoe and Waguespack, 2011; Waldinger, 2012).

Although any scientist can affect their colleagues, the literature has primarily focused on peer effects associated with star scientists because one of the most prominent and persistent features of the production of scientific research is its highly skewed distribution. Since the 1920s, a relatively small number of scientists have been responsible for a relatively large amount of published research (Lotka, 1926; Cole and Cole, 1972). Star scientists possess valuable and novel knowledge that enable them to be both productive and to engage in the creation of new scientific novels or scientific discoveries (Zucker and Darby, 1996). In essence, star scientists not only produce more research than non-star scientists but are also responsible for the generation of high-quality research (Rothaermel and Hess, 2007).

Research has shown that when stars share that knowledge, their collaborators' productivity improves (Oettl, 2012). Collaboration therefore acts as a pipe through which information flows from star to collaborator (Agrawal et al., 2017). When stars share their knowledge with their collaborators and their collaborators experience a gain in productivity, a direct peer effect is observed because the stars' actions influenced their co-workers. Azoulay et al. (2010) provide evidence of direct peer effects by showing that a star's unexpected death negatively affects coauthors' publication output.

Research on pipes has provided a powerful foundation for understanding peer effects in science. However, there is growing evidence that star scientist influence extends beyond their collaborators. For instance, Simcoe and Waguespack (2011) found that editors' behavior is influenced by the presence of a star's name on a paper. Yet little attention has been paid to stars' indirect peer effects, the influence they exert over third parties, other scientists who do not collaborate with stars. When a star is not in contact with a third party and a star causes third party behavior to change – e.g., an editor decides to accept a paper because a star is listed as an author – this changed behavior impacts collaborators (who then publish more papers because they work with a star than others who do not work with stars), and an indirect peer effect is observed. To further contrast indirect and direct peer effects, indirect peer effects do not impact the behavior of a star's collaborators: it is the perception and behavior of other scientists that changes rather than the individuals who work with stars.

Unlike direct peer effects, indirect peer effects occur when knowledge transfer is absent since the star is not in contact with the third party. They therefore require different drivers and boundary conditions from those studied in extant research (e.g., Khanna, 2021; Oettl, 2012). To enhance our understanding of indirect peer effects, this paper draws from the status and network literatures to identify both a driver (status) of prisms and delineate their boundary conditions (other scientists' awareness and other scientists' level of quality uncertainty).

2.2. *Collaborations as prisms*

This paper contends that star collaborations impact third parties because collaboration can act as a prism (Podolny, 2001). We associate prisms with indirect peer effects because prisms do not affect star collaborators' behavior. Rather, prisms change other scientists' behavior because the collaboration acts as a signal: it conveys information to third parties that helps them to make decisions (Connelly et al., 2011; Higgins et al., 2011; Spence, 1973). Such information is needed because, as Cole and Cole (1968, 397) noted: "Advances in science depend, at least in part, upon efficient communication of ideas. In an ideally efficient communication system, each scientist would know all the relevant work of the other investigators in his field. Of course, this idea is never approached in reality." Scientists often confront information overload and uncertainty. As the amount of research that can be consumed outstrips the time that can be devoted to it, many researchers are uncertain of whether the quality of a given article warrants its consumption. Given these conditions, many scientists rely on signals when deciding whether to read or cite a paper.

There are multiple signals that scientists use when engaging with scientific literature including but not limited to journal status, disciplinary excellence, and university affiliation. In addition, one important signal is who we associate or collaborate with, i.e. prisms. Unlike journal status or the other aforementioned signals, prisms are relational; they are not tied to the product (the scientific article) but rather are generated from the establishment of a coauthoring relationship between a star and another scientist. As a result, we make no assumptions about any deliberate communication of this signal. Furthermore, since third parties view or interpret collaborations as one person's endorsement of the other (Simcoe and Waguespack, 2011), prisms permit us to focus on status endorsements. Social status is often interpreted as a correlate of quality and, consequently, may explain why prisms effect other scientists' behavior (Podolny, 2001). If other scientists struggle to judge a paper's merit, the fact that a star scientist has chosen to work with the paper's author may be seen as an endorsement, an indicator of the author's positive qualities. In fact, the mere perception of a social relationship with a high-status individual can induce positive reputation evaluations even when such relations do not exist (Kilduff and Krackhardt, 1994). Along these lines, existing research has shown that status leads to discrepancies in attention (Reschke et al., 2018). For instance, Merton (1968) describes how eminent scientists may receive more attention than unknown scholars for comparable work. From that perspective, an association with a star increases the visibility of star collaborators and attracts the attention of other scientists who may then read star collaborators' papers and incorporate the ideas into their own work. For these reasons, a collaboration with a star scientist can act as a signal that provides information on quality, and the status of a star should influence the strength of any signal associated with a prism.

Thus, when we label collaborations as prisms, we mean there is a refraction of stars' status onto their collaborators. This encourages observers to make consequential inferences about collaborators, with the result that third parties pay more attention to star collaborators' research, leading to increased recognition of star collaborators' ideas.

2.3. *Variance in prisms*

While we have theorized that indirect peer effects flow from collaborations with stars because collaborations act as prisms, we do not expect all prisms to be equally effective. Drawing from signaling theory (Connelly et al., 2011), we contend that third party awareness of a collaboration and their level of quality uncertainty will moderate prismatic effects.

2.3.1. *Awareness*

One clear boundary condition to the operation of signals is their observability (Connelly et al., 2011), which refers to whether third parties notice or are aware of a scientist's collaboration with a star. When third parties are unaware of a collaboration, they cannot connect a star to her collaborators, which prevents prismatic effects from occurring. The following anecdote illustrates the importance of awareness. Lord Rayleigh, the winner of the 1904 Nobel Prize in physics, submitted a paper to the British Association for the Advancement of Science. His name did not appear on the paper, and the Committee "turned it down"; when the Committee discovered that Lord Rayleigh was an author, they found merit in the paper (Strutt, 1968, p. 228, as quoted in Merton, 1968 and cited in Simcoe and Waguespack, 2011).

When other scientists are unaware of a collaboration, it cannot convey quality information, and a star's scientist cannot refract onto her collaborators; this obviates the operation of prisms. Therefore, we posit that indirect peer effects should be concentrated among scientists who have multiple star collaborations, because it should be easier to connect a star to another person when they have frequently worked together. Conversely, indirect peer effects should be weak or nonexistent for those who have infrequently collaborated with a star.

2.3.2. *Quality uncertainty*

Even when other scientists observe a star collaboration, there may still be variance in the effect of that collaboration on other scientists' recognition of star collaborator research. We have argued that indirect peer effects occur because status reduces other scientists' quality uncertainty. This implies that when quality uncertainty is low, star collaborators may not benefit from indirect peer effects because the signal does not offer new information that facilitates the decision to engage with a scientific article. Similarly, when other scientists pay attention to star collaborators' research, the refraction of a star's status is unlikely to attract further attention. We follow prior research that has considered the signaler, the researcher who collaborates with a star, as a key source of heterogeneity in peer effects (Khanna, 2021; Oettl, 2012); we posit that signaler characteristics may influence the quality perception and attention of other scientists and consequently shape indirect peer effects.

While there are a variety of signaler characteristics that may impact the attention and quality perceptions of other scientists, we focus on whether a star collaborator is herself a star. As Khanna (2021, 11) writes, "star coauthors do not experience the same challenges as non-star coauthors." Other scientists likely perceive stars as individuals who produce high-quality research leading to low levels of quality uncertainty and, because of this perception, are also likely pay attention to their research. Thus, when a star collaborates with another star, it either does not act as an endorsement or has a relatively weak association with the perceptions of other scientists. Therefore, we expect indirect peer effects to be strongest for star collaborators who are not stars, and weakest for star collaborators who are star scientists.

2.4. *Sleeping beauties*

We have argued that prisms impact other scientists' recognition of star collaborators' research and ideas. However, there is considerable variance in how papers are recognized. While some articles quickly accrue many citations, it is also the case that most published research is forgotten (Hamilton, 1990). Recently, research in bibliometrics has uncovered a third option that lies between being cited and being forgotten, namely rediscovery. These papers are called sleeping beauties (Ke et al., 2015) – i.e., articles that go unnoticed ("sleep") for a lengthy period of time during which they receive no or very few citations, and then attract many citations ("awaken"; see Ke et al., 2015). This phenomenon is notable because articles normally have a finite citation period: Their rate of citation attraction peaks a few years after publication, and then steadily declines. Due to this deviation from the normal citation trajectory, and the fact that sleeping beauties eventually become highly-cited, the primary explanation for the sleeping beauties is that an article's content, specifically its novelty, delays its recognition (Ke et al., 2015). In essence, the idea contained within a sleeping beauty is ahead of its time (Van Raan, 2004; Wang et al., 2017). For instance, Albert Einstein, Boris Podolsky, and Nathan Rosen published a paper on an aspect of quantum mechanics in 1935 that did not receive widespread attention until 1994 because its core finding was simply not applicable until the 1990s. In this example, the field needed to catch up to the idea; in this way, the novelty of an article contributes to its delayed recognition.

An alternative to this novelty-based explanation is that with whom a scientist works influences when a sleeping beauty is recognized. Since the recognition of star collaborators' ideas increases post collaboration, it is possible that their sleeping beauties are dormant for a shorter period of time or that prisms cause collaborators' sleeping beauties to awaken sooner. Adding prisms to novelty increases our understanding of the dynamic of delayed recognition: novelty initially causes an article to be overlooked while prisms, and the status of stars helps to explain differences in when the period of delayed recognition comes to an end.

Furthermore, it is worth noting that research into status and recognition Reschke2018 has argued that one consequence of a refraction of status onto others is that it potentially funnels other scientists' attention towards the research of the star collaborator. Since citations are informative of the flow of scientific information (Sorenson and Fleming, 2004), the theorized relationship between prisms and sleeping beauties implies that prisms are shaping the movement of scientific information across papers. By diverting other scientists' attention towards star collaborators and increasing other scientists' recognition of star collaborators' ideas, prisms cause some valuable but neglected ideas to awake sooner and by doing so, potentially shape the course of science itself.

3. Data & methodology

3.1. *Empirical setting*

To test this theoretical framework, we compile a unique data set consisting of publications by coauthors of the nominees and winners of the Nobel Prize in Physics. We test whether articles by scientists who collaborate with a Nobel Prize winner attract more citations after the Nobel Prize is awarded relative to articles by coauthors of (non-winning) nominees.

The Nobel Prize in Physics has several features which make it an appealing empirical context for this paper. First, since this paper focuses on the impact that star scientists have on their coauthors, a setting which includes scientific collaboration is essential. Physics fulfills that requirement. Within this study's event window, solo authorship was relatively rare in physics (Cole and Cole, 1968; De Solla Price, 1963; Zuckerman, 1965).

Second, the Nobel Prize leads to status differences among star scientists. The Nobel Prize generally, and the Nobel Prize in Physics specifically, are universally regarded as the most prestigious award in science (Physics). As Zuckerman (1967, 391-392) observes, "[T]he Nobel prize is considered the most honorific of all awards in science. All but 1 % of the approximately 1300 physicists queried by the Coles [Cole and Cole, 1968] ranked it first among some hundred awards given for scientific achievement … physicist laureates had higher visibility scores – their work was more widely known – among physicists than the physicist members of the National Academy, itself an elite group." Research conducted on citation patterns in the 20th century has shown that a Nobel Prize increased the visibility of a scientist's work (Cole and Cole, 1967; Garfield, 2007), meaning that during our event window, other scientists were more likely to read and cite an article associated with a Nobel Prize winner.

More recent analyses confirm the Nobel's pre-eminence (Gingras and Wallace, 2010; Harzing, 2013). Prior research has shown that scientific awards like the Nobel Prize cause scientists to be perceived with even more respect and admiration, or as higher status, than those who do not receive them (Borjas and Doran, 2015; Frey and Gallus, 2017; Lincoln et al., 2012). Crucially, research into whether the Nobel Prize changes the status of the winner has shown that Nobel Prize winners possess more social status than nominees (Baffes and Vamvakidis, 2011), supporting our contention that status differences among star scientists exist.

Third, Nobel Prize in Physics nominees are also scientific stars, thus ensuring that the reference group is a set of similarly high-quality coauthors. Harriet Zuckerman (1967) conducted qualitative research (interviews) with Nobel laureates in science during our event window; collaboration was a particular focus of her research, and her participants viewed the quality of the collaborators of Nobel Prize winners and nominees as comparable. Hence, the main difference between scientists who collaborated with winners and scientists who collaborated with nominees is the status of the star with whom they worked. Similarity in quality addresses a relatively simple alternative explanation to our results – that the quality of individual collaborators drives changes in citations – and helps us to determine whether, as we theorize, an indirect peer effect driven by social status exists. p Fourth, we argue that prisms influence third party recognition of a star collaborator's ideas. Prior research suggests that citations are an acceptable proxy for recognition (Deichmann et al., 2020; Ke et al., 2015; Reschke et al., 2018). Specific to our domain, the overall level of citations in Physics is relatively low. Both during and following our event window, physicists tend to cite narrowly and to more recent work, leading to no or relatively few ceremonial or crony citations (Cole, 1970; Meho, 2007). We therefore believe that a citation in physics within our historical event window represents an acknowledgement of another's discovery (Weick, 1995), which the citing paper leveraged.

Lastly, these features of our empirical context, including the frequency of collaborations, the prestige associated with the Nobel Prize, citation norms, and an abundance of new research that outstrips the time that scientists can devote to its consumption, persist today, ensuring that any conclusions drawn from this data are applicable to modern science.

3.2. Addressing selection issues

The features of our empirical context help us identify whether a prism effect exists. However, since the Nobel Prize is not awarded randomly, selection effects may affect comparisons of pre- and post-award citations. For instance, since both Nobel Prize winners and nominees carefully select with whom they work (Zuckerman, 1967), the science that they produce with their coauthors could, at least in part, be responsible for the consideration of the star for the Nobel Prize. Alternatively, the Nobel Prize could be endogenous to an article's citation trajectory; a very highly cited article, representing a groundbreaking scientific advancement, could cause the Nobel Prize to be awarded.

To address those issues, we focus the analysis on articles that do not include the Nobel Prize winner or nominee as an author. In particular, we construct two samples: (i) articles that predate the award; (ii) articles that predate the award and predate the first collaboration between the focal coauthor and the Nobel Prize winner or nominee. Using previously published articles that exclude the star has several advantages: First, it ensures that the resources associated with winning the Nobel Prize could not have directly influenced the quality of the articles. Second, it reduces the confounding effect of the Nobel Prize winner or nominee's human capital: Because the winner or nominee did not work on the focal article, any observed change in citations cannot reflect their direct contribution to the article. Third, since the content of an article is fixed once it is published, any change to the number of citations cannot come from changes to the article's content. Fourth, it limits endogeneity inherent in the Nobel Prize award to coauthors' quality as articles that are published by another scientist prior to their first-recorded collaboration with a winner are an unlikely cause of that winner's Nobel Prize. Furthermore, as the articles we focus on are either published prior to the award or published prior to the award and their first collaboration, it is unlikely that star collaborators were able to predict whether a star would later win the Nobel Prize or "only" be nominated but never win.

In conclusion, by addressing these sources of endogeneity, we are confident that our data provide a valid context in which to test for peer effects.

3.3. Dataset construction

The dataset construction process starts with the identification of scientists who have either won or been nominated for the Nobel Prize in Physics. The Alfred Nobel Memorial Foundation awards the Nobel Prize in Physics in recognition of those "who, during the preceding year ... have conferred the greatest benefit to mankind [through] the most important discovery or invention" (Norrby, 2010). Each year, prominent Swedish and international scientists individually and independently propose candidates for the award. Self-nominations are prohibited. The nomination window is open for five months, and all nominations are confidential. Upon reaching the nomination window deadline, a Royal Swedish Academy of Sciences' committee evaluates the nominees and submits its recommendation. The Academy then makes the final selection which is announced in October, followed by acceptance and award conferral in December. To protect the independence of that process, data concerning nominations is embargoed for 50 years after each award. For the Nobel Prize's 100th anniversary, Crawford (2002) produced a census of the Nobel Prizes in Physics and Chemistry, which includes the names of every person nominated for the Nobel Prize in Physics between 1901 and 1950 (inclusive). As the Crawford Census is this paper's primary source of information on nominees for the Nobel Prize in Physics, we only have nominee data for 1901 to 1950 (the period covered by the Crawford Census). Since the coauthors of winners and nominees published and accrued citations prior to 1901 and after 1950, we extend the sample of articles and citations to start in 1850, 50 years before the first Nobel Prize was awarded, and to end in 1975, 25 years after the last year for which we have information on Nobel nominees.

According to the Crawford Census, 282 scientists either won (64) or were nominated (218) for the Nobel Prize in Physics between 1901 and 1950. We use Microsoft Academic Search (MAS) to identify winner and nominee articles. Microsoft pairs every author name in its database with a unique author identifier, called a MAS-ID. To avoid the common-surname problem and to ensure that each identifier refers to the correct individual, two researchers manually and independently verified each name, ensuring that MAS-IDs (some individuals had more than one) correspond to the correct individual. We then merge those author identifiers with their publication output to create a dataset of all winner and nominee articles. We then eliminated letters, comments, reviews, patents, and periodicals - retaining only articles published in scientific journals, such as the Annals of Physics. Lastly, to ensure consistency between the data and the award rationale (i.e., discoveries in Physics), we removed all non-Physics journal articles from the dataset. Our remaining sample of 265 stars (64 winners and 201 nominees) published at least once in a physics journal between 1850 and 1975 (inclusive).[1]

Some of the scientists in the sample received multiple nominations, either before winning or without winning. Scientists awarded the Nobel Prize are categorized as winners and not included in the nominee group – that is, the winner and nominee groups are mutually exclusive. The event year used in the econometric estimation (see Section 3.2 for more information) is the winning year for Nobel Prize winners. For nominees, we only use the first year of nomination as the event year; subsequent years in which repeat nominations may have occurred are not coded as event years for nominees.[2] To ensure that the quality of nominee and winner scientists is comparable, we examine their performance before the event (win or nomination) via the number of papers published and the total number of citations accrued. We find no significant difference across those metrics; Table 1 (Panel A) reports this information.[3]

We then use winner and nominee article data to identify their coauthors. Any scientist who is listed at least once as an author on a published article that also has either a Nobel Prize winner or a nominee listed as an author is identified as a "collaborator." We exclude all winner-winner and winner-nominee relationships to be sure of the direction of influence in the relationship; thus, all retained collaborators

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[1] Out of the 17 nominees who did not publish and, as a result, are excluded from our dataset, seven patented rather than published. Four others, such as the Wright Brothers, were nominated in recognition of their aviation accomplishments and thus neither published nor patented. Neville Chamberlain was nominated yet did not contribute to Physics. Three nominations went to groups of scientists generically referred to as "researchers in nuclear energy", "nuclear scientists", and "researchers in particle acceleration". For the final two nominees, one (Jules Richard) wrote a prominent textbook while the other (Santiago Antunez Mayolo) was nominated for the first identification of the possible existence of the neutron element, which he announced via a conference presentation without publishing his results.

[2] Robustness tests that use later years of nomination yield substantially the same results (see Online Appendix A.4).

[3] Supporting the star status of both nominees and winners, the mean (95th percentile) of published articles in Physics journals per scientists during our sample period is 1.6 (7.3), which compares to a mean of 17.3 (17.0) for winners (nominees) in the year prior to the event. Similarly, the mean (95th percentile) number of citations in our sample period is 1.2 (3.1), which compares to a mean of 24.4 (24.2) citations for Nobel Prize winners (nominees) in the year prior to the event. For further robustness tests of winner-nominee comparability, see section A.4 and A.5 in the Online Appendix.

Table 1
Comparison Nobel Prize winners and nominees.

Panel A: Comparison of Nobel Prize winners and nominees prior to award or nomination

	Nominees			*Winners*			*Difference in means*	*Difference in medians*
	Mean	Median	S.D.	Mean	Median	S.D.	*t*-statistic	*z*-statistic
Number of articles	17.02	7.5	25.75	17.34	6.0	29.7	0.09	−0.530
Number of citations	24.27	8.0	48.80	24.42	10.0	38.8	0.02	0.125

Panel B: Comparison coauthors of Nobel Prize winners and nominees

	Scientists who collaborated with Nobel Prize nominees			*Scientists who collaborated with Nobel Prize winners*		
	Number of coauthors	Number of articles	Average number of citations	Number of coauthors	Number of articles	Average number of citations
1850–1874	42	369	0.005	5	41	0.000
1875–1899	311	4293	0.160	37	417	0.008
1900–1924	688	7714	0.462	158	2262	0.397
1925–1949	999	11,804	1.274	304	5172	2.031
1950–1975	618	6789	4.949	193	2520	8.510
1850–1975	1752	31,205	3.010	425	10,477	5.378

Panel C: Descriptive statistics

	Scientists who collaborated with Nobel Prize nominees				*Scientists who collaborated with Nobel Prize winners*			
Variables	Mean	SD	Min	Max	Mean	SD	Min	Max
Log cumulative citations	0.071	0.293	0.000	4.963	0.109	0.358	0.000	5.075
Post award	0.819	0.386	0.000	1.000	0.858	0.359	0.000	1.000
Career age	43.60	24.22	0.000	125.0	38.66	20.24	0.000	125.0
Article age	29.95	21.87	0.000	125.0	24.66	18.33	0.000	125.0
Number of observations	1,649,678				441,007			

are non-winners and non-nominees.[4] Between 1850 and 1975 (inclusive), 2177 scientists worked with nominees and winners with 1752 scientists collaborating with nominees, and 425 with winners. Table 1 (Panel B) provides information on the number of collaborations across the event window. Next, we use the authors' MAS-IDs to identify all the articles by the coauthors of winners and nominees. A very small number of articles (247) had both types of coauthors (i.e., the author team included coauthors of winners and nominees). These articles were removed from the sample. Between 1850 and 1975, scientists who collaborated with winners and nominees jointly published 41,682 unique articles. The coauthors of nominees and winners published a total of 31,205 and 10,477 unique articles, respectively. MAS also includes citation information for each article, with a total of 570 million cited-to-citing article pairs. We first remove all self-citations, then merge the citation information with the publication information, resulting in a dataset with observations at the article-year level. Since articles are typically cited after they have been published, an article first appears in the dataset in its publication year with observations for each year thereafter until 1975 (included). The articles written by the coauthors of nominees received an average of 3.010 citations per year between 1850 and 1975. Articles written by the coauthors of winners received an average of 5.378 citations per year over this period. Table 1 (Panel B) also provides information on the distribution of citations over the event window.

Finally, we enrich the dataset with additional data from MAS. We first add an article's research area covering 65 topics (denoted in MAS as "fields of study"), such as nuclear physics or applied mathematics. That allows us to use fixed effects to account for variation in citation practices across scientific sub-fields, and to address changes in citations that might arise from an increase in the popularity of a given scientific topic.

For the *first sample*, articles that predate the award, the final dataset consists of 2,090,685 article-author-year observations. For the *second sample*, articles that predate both the award and the first collaboration between the focal coauthor and the Nobel Prize winner or nominee, the final dataset consists of 1,051,877 article-author-year observations.[5]

3.4. Econometric estimation

Following the approach of Waldinger (2012) and Borjas and Doran (2012, 2015), we embed the analysis into a difference-in-differences linear regression framework. The first difference consists of whether the focal scientist works with either a Nobel Prize winner or a nominee. The second difference is the time period, i.e., before versus after winning or being nominated for the Nobel Prize. We estimate the following empirical model:

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[4] Some coauthors (about 4 % of the sample) worked with multiple non-winning nominees. We coded the earliest nomination of a star as the event year. Coauthors who worked with multiple nominees were then linked with the first nominee with whom they worked. In addition, some coauthors (about 3 %) worked with both nominees and winners; they were coded as only working with winners, and we used the winning year for their event year. Robustness tests in which these individuals and their articles are removed yield very similar results (see Online Appendix A.3).

[5] There are benefits from examining the two samples of articles separately: The sample of articles published prior to the Nobel Prize event includes all the articles published by a star collaborator at the time of the Nobel Prize event. Hence, it is the most accurate measure of the prism effect that the collaborator experiences. In contrast, the second sample consists of older articles – those that were produced not only prior to the Nobel Prize event but also before the first-ever collaboration with the star. While we would expect a weaker prism effect for these older articles (due to the general decline in citations for published work; see Brzezinski, 2015), this sample is cleaner in terms of econometric identification – that is, in ensuring that these articles were not directly affected by the stars.

$$\mathit{Log\ of\ cumulative\ citations}_{ijt} = \begin{array}{l} \alpha + \beta_1 \mathit{Post\ award}_{it} \\ + \beta_2 (\mathit{Scientist\ collaborated} \\ \mathit{with\ winner} \times \mathit{Post\ award})_{it} + \gamma X_{ijt} + \delta_i + \lambda_j + \phi_{jt} + \varepsilon_{ijt} \end{array} \tag{1}$$

---

where the dependent variable c_{ijt} is the cumulative number of citations that article j by scientist i has received by year t. We take the log of that outcome to address its skewed nature.[6]

The indicator variable *Post award* equals one in the years after the winner or nominee with whom the focal scientist worked either won or was first nominated for the Nobel Prize and equals zero otherwise. As the specification includes scientist fixed effects, we do not include the time-invariant indicator variable *Scientist collaborated with winner*. The coefficient of interest is β_2, which captures the change in an article's accumulated citations for the coauthors of Nobel Prize winners after the prize has been awarded, relative to the change in citations of the articles of the coauthors of non-winning nominees after their first non-winning nomination. X_{ijt} is a vector of control variables that includes a scientist's *Career age*, defined as the years since a scientist's first article was published, and *Article age*, defined as the years since an article's publication, at year t. Table 1 Panel C provides the descriptive statistics.

We further include scientist fixed effects δ_i, article fixed effects λ_j, and an article's fields of study × year fixed effects ϕ_{jt} which respectively absorb time-invariant attributes of scientists, articles, and any time trends in annual citations in a given physics subfield (this accounts for changes in the popularity of a given scientific topic).[7] Since there is serial correlation in an article's cumulative citations across years, we cluster standard errors at the article level, which allows for arbitrary patterns of autocorrelation within articles' cumulative citations count.[8] The following section reports the results of estimating this model.

4. Results

4.1. Parallel trends

The key assumption of a difference-in-differences analysis is the parallel trends assumption (see Angrist and Pischke, 2008, 221–248). In our context, this requires that differences in citations across groups (winner coauthors and nominee coauthors) are relatively constant prior to the Nobel Prize event. A visual inspection offers a useful check and is the norm to judge parallel trends prior to the event or treatment. Fig. 1 restricts the sample to ten years around the event year and plots the number of citations that the average article of the coauthors of winners receives, relative to the average article for the coauthors of nominees. According to Fig. 1, coauthors of winners receive on average more citations, yet the difference prior to the event is by-and-large constant, such that the two groups' citations indeed exhibit parallel trends. In the years following the Nobel Prize award, the coauthors of winners experience a strong citation increase while the citations of nominee coauthors stay relatively unchanged. The delay in the increase by roughly two years is consistent with the time that other scientists would likely have required to publish new work that includes those citations.

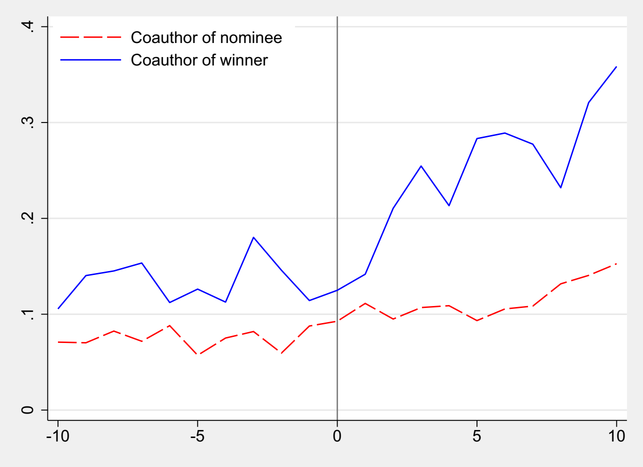

Fig. 1. Citation changes around event year.
Notes: This figure shows the number of citations in a given year for the average article by coauthors of nominees or coauthors of Nobel Prize winners. Citations are adjusted for the upwards citation trend.

Fig. 2 presents the results from a univariate version of Eq. (1) in graphical form that illustrates the duration of winner coauthors' post-event change in citations. We split the Post award indicator variable

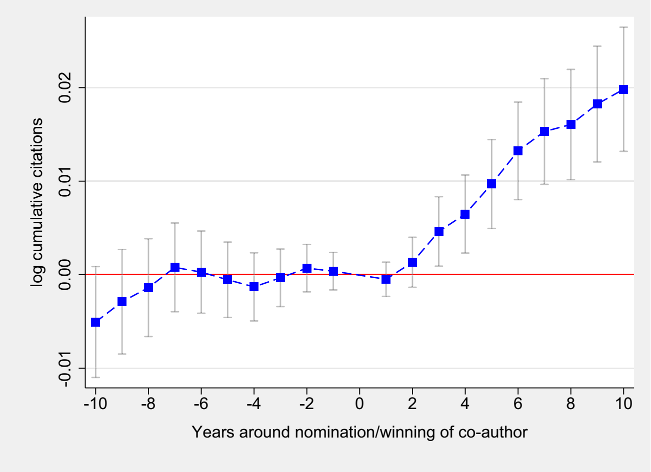

Fig. 2. Citations for winner coauthors.
Notes: This figure plots the point estimates γ_τ from the equation below, which splits the *Post award* indicator variable of Eq. (1) into separate annual indicator variables t, one for each year in [−10,10] around the Nobel Prize event year. That is, we run the following linear specification: $c_{ijt} = \alpha + \sum_{\tau=-10}^{10} (\beta_\tau t_\tau + \gamma_\tau (\mathit{Scientists\ collaborated\ with\ winner} \ \times t)_{i,\ \tau}) + \delta_i + \varepsilon_{ijt}$. The vertical bars correspond to the estimates' 95 % confidence intervals with standard errors clustered at the article level.

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[6] Since the log of zero is undefined, c_{ijt} is defined as the logarithm of 1 plus the cumulative citations of article j in year t. We prefer a linear regression framework over the choice of a Poisson count model because of overdispersion in the dataset, a large number of zeros in the dependent variable, and the large number of fixed effects in our preferred specification. However, when using a Poisson count model, our main results are substantially similar (see Online Appendix A2).

[7] Article fixed effects do not subsume scientist fixed effects because coauthors of a winner or nominee can co-produce an article.

[8] Bertrand et al. (2004) show in the context of a difference-in-differences setup that clustering at the group level (here, article level) leads to consistent standard errors as long as the number of groups is sufficiently large. The authors show that as few as 50 groups are sufficient to avoid over-rejecting a null hypothesis (pp. 271–274); we note that our analysis contains many thousands of articles/groups.

in Eq. (1) into separate annual indicator variables t, one for each year in the 20 years (± 10) around the Nobel Prize event. Since Fig. 1 shows that winner coauthors receive on average more citations prior to the event, we add scientist fixed effects to control for any time-invariant differences between the two groups. As a result, the coefficients on the annual interaction terms capture – for any given year – the citation difference between winner and nominee coauthors that is in excess of any time-invariant difference. Fig. 2 shows a reasonably constant citation difference between nominee coauthors and winner coauthors in the years leading up to the Nobel Prize event, again followed by an increase in the difference some two to three years thereafter. Although Fig. 2 shows that growth in the citation difference may persist for up to 10 years, the confidence intervals become wider over time, which suggests that a flattening of the effect may occur after the initial five years. Fig. 1 and Fig. 2 provide a visual inspection of the pre-event difference in citations between coauthor groups. Based on these figures, we are confident that this difference is relatively constant, and therefore nominee coauthors are a useful counterfactual or baseline for winner coauthors.

4.2. *Collaborations as prisms*

We report the results of estimating the difference-in-differences framework in Eq. (1) in Table 2. Model 1 examines the effect of collaborating with a Nobel Prize winner on all scientific articles that were published before the award year, whereas Model 2 investigates the impact of working with a Nobel Prize winner on articles published before the award year and before the focal scientist collaborated with the award winner for the first time.

We find a positive and highly significant effect of the interaction term *Scientist collaborated with winner* × *Post award* on citations across both models. In economic terms, in Model 1, articles by scientists who collaborate with winners receive in the post-award period a citation increase of 58.9 % relative to the post-event citation count for the coauthors of nominees (see details in footnote).[9] In Model 2, articles published before the first collaboration receive a citation increase of 29.0 %.[10] The lower citation increase in Model 2 is consistent with older articles typically attracting fewer citations. We note that the vector of fixed effects controls for time-invariant characteristics inherent to scientists, articles, and, on a yearly basis, scientific topics; we also control for article age and scientists' career age.

4.2.1. *Timing of prisms*

To further tie the increase in citations to the timing of the Nobel Prize event, we conduct a falsification test. We repeat the analysis of Model 2 in Table 3 in a narrow 5-year window [−2, +2] around the Nobel Prize event; that is, from two years before to two years after the event. In separate regressions, we then slide this 5-year window to center on placebo-event years prior to and after the actual Nobel Prize event. If, as argued, the award triggers a prism effect, then we expect a significant increase in citations around the Nobel Prize event. Otherwise, we may observe a different pattern of results. Moreover, as new citations may lead to further additional citations, the analysis allows us also to judge for the significance of any later citation increases. The results, shown in Table 3, are as follows. We find that the coefficients of the interaction term *Scientist collaborated with winner* × *Post award* are not statistically significant in the placebo event year windows prior to the actual event. In contrast, in a narrow [−2, +2] window that is centered on the actual event, the coefficient is significant at the 5 % level with a *t*-statistic of 2.52. Since the citation increase coincides precisely with the Nobel Prize, time-invariant unobservables (including coauthor quality selection effects) are hence unlikely to explain our results. Finally, we find several positive but insignificant coefficients when the placebo event year occurs in the post-award period.

Table 2
Effect of collaboration on citations.

Dependent variable	*Log cumulative citations*	
Sample	*Citations to articles published prior to Nobel Prize award*	*Citations to articles published prior to Nobel Prize award and first collaboration*
Model	(1)	(2)
Post award	0.011*** (0.002)	0.011*** (0.002)
Scientist collaborated with winner × Post award	0.016*** (0.004)	0.013** (0.004)
Observations	2,073,031	1,051,877
R-squared	0.804	0.782
Control variables	Yes	Yes
Scientist FE	Yes	Yes
Article FE	Yes	Yes
Field of study × Year FE	Yes	Yes

Notes: This table reports coefficients for two ordinary least square (OLS) regressions. Observations are at the article-author-year level. The dependent variable is the natural logarithm of one plus the number of citations that an article accumulated up to a given year (excluding any self-citations). Control variables include *Article age* and *Career age*. Robust standard errors are clustered at the article-level (40,746 clusters in Model 1; 17,507 clusters in Model 2) and reported in parentheses. ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

Taken together, the analysis reported in Tables 2 and 3 reveals that

Table 3
Falsification test.

	Event year	Window	Coefficient	Standard error	*t*-Statistic
Placebo	−10	[−12, −8]	0.001	0.003	0.31
	−9	[−11, −7]	0.001	0.003	0.24
	−8	[−10, −6]	0.002	0.003	0.68
	−7	[−9, −5]	0.001	0.003	0.46
	−6	[−8, −4]	0.001	0.002	0.35
	−5	[−7, −3]	0.001	0.002	0.54
	−4	[−6, −2]	−0.001	0.002	−0.50
	−3	[−5, −1]	−0.000	0.002	−0.05
Actual	**0**	**[−2, 2]**	**0.005**	**0.002**	**2.52******
Placebo	3	[1, 5]	−0.001	0.002	−0.50
	4	[2, 6]	−0.001	0.002	−0.35
	5	[3, 7]	−0.001	0.001	−0.41
	6	[4, 8]	0.001	0.001	0.92
	7	[5, 9]	0.002	0.001	1.41
	8	[6, 10]	0.002	0.001	1.35
	9	[7, 11]	0.001	0.001	0.62
	10	[8, 12]	0.002	0.001	1.34

Notes: The table reports the coefficient on *Scientist collaborated with winner* × *Post award* from repeated regressions using the specification from Table 4, Model 2. Each ordinary least squares regression uses a window of 5 years around the actual or placebo event year. We omit placebo event years −2, −1, 1 and 2 as the placebo event windows would include the actual event year 0. Robust standard errors are clustered at the article-level. ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

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[9] By the final year prior to the Nobel Prize award, the average coauthor of a Nobel Prize winner had been publishing for 15.3 years, had published 15.4 articles, and – with most articles not receiving a citation in a given year – received 0.421 citations per year prior to the award. In the post-award period, annual citations to those articles then increased by 0.248 (=(exp(0.016)-1)*15.4), relative to the post-nomination citation count for coauthors of non-winning Nobel Prize nominees. The change represents an increase of 58.9 % (=(0.421 + 0.248)/0.421–1).

[10] By the final year prior to the Nobel Prize award, the average coauthor of a Nobel Prize winner had published for 15.1 years, had published 12.1 articles in the year prior to the award, and – with most articles not receiving a citation in a given year – received 0.546 citations per year prior to the award. In the post-award period, the annual citations to those articles then increased by 0.158 (=(exp(0.013)-1)*12.1), relative to the post-nomination citation count of coauthors of non-winning Nobel Prize nominees. The change represents an increase of 29.0 % (=(0.546 + 0.158)/0.546–1).

Table 4

Boundary conditions of the effect of collaboration on citations.

Dependent variable	*Log cumulative citations*			
Sample	Citations to articles published prior to Nobel Prize			
Model	(1)	(2)	(3)	(4)
Post award	−0.002	0.015***	−0.001	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Scientist collaborated with winner × Post award	0.027***	0.011***	0.014***	0.013***
	(0.008)	(0.004)	(0.003)	(0.003)
Scientist collaborated with winner × Post award × Single star collaboration	−0.017**			
	(0.008)			
Scientist collaborated with winner × Post award × # of star collaboration		0.013*		
		(0.007)		
Scientist collaborated with winner × Post award × Star coauthor by citations			−0.053***	
			(0.010)	
Scientist collaborated with winner × Post award × Star coauthor by citations & publications				−0.051***
				(0.010)
Observations	2,073,031	2,073,031	2,073,031	2,073,031
R-squared	0.814	0.814	0.815	0.815
Control variables	Yes	Yes	Yes	Yes
Scientist FEs	Yes	Yes	Yes	Yes
Article FEs	Yes	Yes	Yes	Yes
Field of Study × Year FE	Yes	Yes	Yes	Yes

Notes: This table reports the coefficients for ordinary least square regressions. Observations are at the article-author-year level. The dependent variable is the natural logarithm of one plus the number of citations that an article accumulated up to a given year (excluding any self-citations). Control variables include *Article age* and *Career age*. All specifications also include the "margin variables" for the triple interaction terms (e.g., in Model 1, *Single star collaboration*, *Scientist collaborated with winner* × *Single star collaboration*, and *Single star collaboration* × *Post award*). *Star coauthor by citations* (*by citations and publications*) is an indicator variable that is 1 for coauthors that are in the top 10 % of citations (top 10 % of citations and articles published) prior to the event year. Robust standard errors are clustered at the article-level (41,435 clusters in all models) and reported in parentheses. ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

citations to articles by winners' coauthors increase after the Nobel Prize relative to citations to articles by nominees' coauthors. This supports our argument that collaborations function as prisms that channel indirect peer effects from a star. We also find, as theorized, that the timing of prisms is linked to scientific awards: the Nobel Prize in Physics causes a collaboration with a star scientist to function as a prism that increases the recognition of coauthors' ideas.

4.3. Boundary conditions of prisms

Having established this core result, we now delineate boundary conditions of prisms and consider whether other scientists' awareness and their level of quality uncertainty moderate and shape the indirect peer effects that prisms transmit. Table 4 (Models 1–4) has these results.

4.3.1. Awareness

In order for a collaboration to act as a prism, other scientists must be aware of the collaboration. We use the number of collaborations as a proxy for awareness because it should be easier to connect a star to a coauthor when they have worked together frequently. Since the median number of collaborations prior to the event year is one, we create a dummy variable *Single collaboration* that identifies whether there was only a single collaboration prior to the event year. Specifically, this dummy variable is coded as 1 if a coauthor had only one joint paper with a star prior to the star's nomination for the Nobel Prize, else 0. We then supplement Eq. (1) with a triple-interaction term – *Scientist collaborated with winner* × *Post-award* × *Single collaboration*. As shown in Model 1 of Table 4, the two-way interaction, *Scientist collaborated with winner* × *Post-award*, remains positive, significant, and of similar magnitude to the coefficient of the interaction term in Model 1 of Table 2. More importantly, the coefficient on the *Single collaboration* dummy indicates a significantly negative effect on citations for when a coauthor has only a single collaboration with a star (relative to coauthors with multiple collaborations). This is consistent with the expectation for a stronger citation effect when other scientists are more likely to be aware of a coauthor's collaboration with a winning star when the coauthor had multiple collaborations.[11]

In a separate triple-differences specification, we use a continuous variable that records the number of prior collaborations with the star prior to the award (*Number of star collaborations*) to measure the intensive margin of the signal. Model 2 in Table 4 examines whether the post-award citation jump among winner coauthors is related to the number of collaborations prior to the event year. We find a positive and significant triple interaction term, which indicates that the signaling value of a collaboration increases linearly with the number of times that the star and her collaborator have published together. We interpret these results as evidence that other scientists' awareness of the collaboration is an important moderator for the magnitude of the prism effect.

4.3.2. Quality uncertainty

While awareness is a key boundary condition of prisms, there may be heterogeneity in the effect of prisms even when other scientists are aware of the collaboration. Specifically, signaler characteristics may influence other scientists' quality uncertainty and, consequently, impact indirect peer effects because these characteristics provide information on quality independently of coauthors' collaboration with the Nobel Prize winner or nominee. The signaler characteristic we focus on is whether a star's coauthor is herself a star as other scientists will likely have less quality uncertainty when considering whether to engage with coauthors' work when a coauthor is herself a star. Scholars who research star scientists typically identify stars either via their consideration for a scientific award like the Nobel Prize (Azoulay et al., 2010; Azoulay et al., 2014; Reschke et al., 2018) or their performance levels (Hess and Rothaermel, 2011) meaning that scientists are seen as stars when their performance exceeds a specified threshold. Since our main identification strategy draws on the Nobel Prize, we utilize performance levels to identify which winner or nominee coauthors are stars; coauthors that have a certain number of citations are considered stars.[12]

Specifically, we use two measures based on an annual count of citations and based on an annual count of publications and citations. First, the dummy variable *Star coauthor by citations* identifies coauthors that fall within the top 10 % of the citation distribution prior to the event year. Second, the dummy variable *Star coauthor by citations & publications* is coded as one for coauthors that are in the top 10 % of the citation distribution and the top 10 % of publication distribution prior to the event. According to these criteria, 49 (37) coauthors, of whom 15 (10)

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[11] Specifically, the negative coefficient indicates that coauthors with a single collaboration receive fewer citations than winners with multiple collaborations but still experience a post award citation increase relative to the coauthors of nominees. This conclusion is derived from the joint effect of the variables in the three-way interaction: for a coauthor with multiple collaborations the joint effect is the 0.025 (=−0.002 + 0.027) while the joint effect for a coauthor with a single collaboration is lower by −0.017 while still positive overall. This indicates that the effect of the post-award citation bump weakens but does not disappear if a star only collaborates once with a coauthor.

[12] These two approaches are consistent with each other as those who are either nominated for or receive a scientific prize are often highly cited scholars. More broadly, these approaches both emphasize the quality of a scientist's research as a determinant of stardom. While the Nobel Prize explicitly recognizes those responsible for impactful scientific discoveries, citations can be seen as other scientists' recognition of the importance of one's work. Given this consistency, it is possible to view performance thresholds as complementary to our main identification strategy.

are coauthors of winners and 34 (27) are coauthors of nominees, are stars themselves just prior to the event year. We then supplement Eq. (1) with a triple-interaction term – *Scientist collaborated with winner* × *Post-award* × *Star coauthor by citations* or *Scientist collaborated with winner* × *Post-award* × *Star coauthor by citations & publications*. We report the results of these triple-difference specifications in Table 4.[13]

Model 3 examines the effect of coauthors' star status (citations only) on prisms. We find a significant and negative effect of a collaboration with a Nobel Prize winner on citations for star coauthors. Model 4 examines the effect of coauthors' star status on prisms (citations and publications); we again find a significant and negative effect of a collaboration with a Nobel prize winner on citations for star coauthors. These coefficients suggest that the post-award citation increase is concentrated among non-stars and that other scientists' quality uncertainty, a key mechanism underlying prisms, moderates the prism effect.

4.4. Robustness analysis

We conduct additional analyses to test the validity of these findings; those results are provided in the Online Appendix. We examine whether changes in the model specification (Table A.1) and alternative models, such as the use of a count model (Table A.2), influence the results shown in Table 2. We also examine the impact of alternative control groups that further reduce any potentially unobserved differences between the articles of winner coauthors and those by nominee coauthors. We do so by excluding coauthors who worked with both winners and nominees, and by limiting nominee coauthor articles in the control group to those that i) are most similar in *Article age* and *Career age* at the time of the Nobel Prize event to winner coauthor articles; ii) are by the coauthors of the nominee who had been under consideration for the Nobel Prize for the most similar duration to the winner; and iii) are by the coauthors of the most competitive (or "best")[14] nominee in each event year (see Tables A.3 – A.5). Throughout these tests, we find results consistent with those presented in Table 3.

4.5. Sleeping beauties

Sleeping beauties are articles that, upon publication, do not receive citations ('sleep') yet, after a long period of time, become highly cited ('awaken'). Ke et al. (2015) propose a sleeping beauty coefficient that can be calculated for any publication. The coefficient is based on the comparison between an article's citation history and a citation reference line that connects the citations in the publication year with the number of citations it receives in the year when it receives the most citations. Formally, the sleeping beauty coefficient is defined as:

$$B = \sum_{t=0}^{t_{\max}} \frac{\frac{c_{t,max}-c_0}{t_{\max}}^{*} t + c_0 - c_t}{max\{1, c_t\}} \tag{2.1}$$

where c_t is the number of citations that an article receives in the tth year after its publication, and t is the age of the article. Following Ke et al. (2015), we assume that the article receives its maximum number of yearly citations, $c_{t,\ max}$, at time t_{max}, and that time t_{max} takes a value between 0 and the maximum time value observed. Then $[(c_{t,\ max} - c_0)\ t_{max}]$ is the slope of the line connecting two points in a time-citation plane, the maximum number of citations an article receives in a year and the number of citations it received in its year of publication.

Ke et al. (2015) complement this sleeping beauty coefficient with a measure for an article's awakening time. Formally, the awakening time is defined as:

$$t_\alpha = arg\left\{ \max_{t \le t_{\max}} \quad 0.2 d_t \right\}, \tag{2.2}$$

where d_t is given by

$$d_t = \frac{|c_{t_{max}} - c_0| t - t_{max} c_t + t_{max} c_0}{\sqrt{(c_{t_{max}} - c_0)^2 + t_{max}^2}}. \tag{2.3}$$

Following this equation, awakening time t_a is then the time t at which the distance d_t between the point (t, c_t) and the reference line l_t reaches its maximum.

We compute the sleeping beauty coefficient for each publication in the dataset. While the coefficient is a continuous value that describes the steepness in the citation surge in relation to the length of the dormant period, Ke, Ferrara, Radicchi, and Flammini (2015, 7428) argue that articles with a coefficient above 20 resemble a sleeping beauty; they experience a trough and then a peak in citations. Therefore, we create a sleeping beauty indicator variable that is set to one (zero) if an article's coefficient equals or exceeds (falls below) 20. Sleeping beauties comprise roughly 10 % of all physics articles authored by the coauthors of winners and nominees that were published in our event window. Finally, we calculate the awakening time – the year in which an article awakes from its "sleep" – for each sleeping beauty in our dataset.

We use *time to awakening* as the dependent variable in a difference-in-differences equation, similar to that outlined in Eq. (1). Since we are interested in identifying the effects of collaboration with a winner on the duration of a sleeping beauty's dormancy period, we use survival analysis to model the impact of working with a winner on the amount of time that an article "sleeps" before it awakens. Table 5 reports hazard ratios with coefficients, standard errors, and *p*-values. Hazard ratios above (below) one indicate a higher (lower) risk for non-survival; in our context, hazard ratios above (below) one imply a shorter (longer) time until discovery. We find hazard ratios that are significantly above one for the key interaction term *Scientist collaborated with winner* × *Post award* in both models. This means that the articles of scientists who work with Nobel Prize winners awaken faster relative to those of the coauthors of Nobel Prize nominees.

5. Discussion & conclusion

5.1. General discussion

Joining a rich tradition of scholarship that turns the lens of inquiry onto researchers themselves, we analyze how eminent, or star, scientists influence their coauthors. In contrast to prior literature, we explore how partnering with a star scientist signals collaborators' quality to the scientific community, and use the status and network literatures to theorize how indirect peer effects flow from these prisms. Empirically, we find that the articles of the coauthors of Nobel Prize winners – published without the winner as an author, before the award, and before the coauthor first collaborated with the winner – experience a citation increase that precisely coincides with the timing of the Nobel Prize. We identify two boundary conditions that shape prisms, namely other scientists' awareness and their level of quality uncertainty. Lastly, we show that prisms reduce the time to discovery of sleeping beauties produced by star coauthors.

This paper makes the following contributions. First, we advance research on star scientists by investigating prisms and indirect peer effects – a phenomenon that has received less scholarly attention than direct peer effects and the "pipes" that convey them. We offer a clean empirical test of the value of star collaborations that addresses an

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[13] We use the sample of articles that are published prior to the Nobel Prize event since, in general, more recent articles are more likely to be cited, leading to a more accurate estimate of the prism effect.

[14] As developed further in the Online Appendix (section OA.5), we use four definitions for "best": 1) The greatest number of unsuccessful prior nominations; 2) The greatest number of distinct nominators; 3) The greatest sum of Authority scores of the distinct nominators; and 4) The greatest number of nominators who themselves were Nobel Laureates.

Table 5
Effect of collaboration on delayed recognition.

Dependent variable sample	*Time to awakening*							
	Sleeping beauties published prior to award				Sleeping beauties published prior to award and first collaboration			
	Hazard ratio	Coeff.	Std. error	*p*-Value	Hazard ratio	Coeff.	Std. error	*p*-Value
Scientist collaborated with winner	0.978	−0.023	0.071	0.748	0.898	−0.108	0.090	0.232
Post award	0.656***	−0.422***	0.054	0.001	0.622***	−0.475***	0.077	0.001
Scientist collaborated with winner × *Post award*	1.186**	0.170**	0.078	0.029	1.293**	0.257**	0.138	0.016
Observations	118,223				53,874			
Log-likelihood	−5084.6				−2284.4			
Control variables	Yes				Yes			
Year FE	Yes				Yes			

Notes: This table shows the change in the duration until discovery for articles ("sleeping beauties") published by coauthors of winners or nominees. The sample in Model 1 includes 1504 (winner) / 4083 (nominee) sleeping beauties; the sample in Model 2 further restricts the sample and includes 617 (winner) / 1569 (nominee) sleeping beauties. Sleeping beauties are defined as articles with a sleeping beauty coefficient larger than 20 (Ke et al., 2015). The dependent variable is each article's "awakening time" (Ke et al., 2015), which is an indicator variable that is set to one in the year when it awakens and is zero in years prior to that. The table contains the hazard ratios from survival models with coefficient, standard errors, and *p*-values. Control variables include *Article age* and *Career age*. $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.10$.

important potential confound, namely the transfer of resources and information from the star to her collaborator. By confirming that collaborations can act as prisms that increase the recognition of star coauthors' ideas, we identify an alternative explanation for the benefits of star collaboration. One important difference between this paper and prior research on pipes is that we show that collaborators can benefit from their association with a star even when knowledge sharing, a key mechanism that enables pipes, does not occur. While we have focused on the absence of knowledge sharing between a star and third parties, it is also the case that a star may choose not to share knowledge with her collaborators. Nothing in our results suggest that, under these conditions, indirect peer effects would not apply; thus, star collaborators may benefit from working with a star without necessarily learning from the star with whom they work.

Second, we provide evidence of two vital yet underdeveloped boundary conditions of the positive effects of working with stars. We add nuance to the peer effect literature by demonstrating that the positive effects of associations with (Nobel) prize winners are moderated by other scientists' awareness of the collaboration and their level of quality uncertainty. These boundary conditions differ from the boundary conditions investigated in the literature on pipes, which mostly have focused on signaler characteristics that affect knowledge sharing. If direct peer effects involve capabilities, insofar as a star must possess knowledge to share and the collaborator must understand it, indirect peer effects involve perception. Moreover, the identification of these contingencies contributes to the literature on prisms which, to the best of our knowledge, has not yet identified limits to their effects.

Third, the sleeping beauty analysis provides evidence of the generality of prisms while also demonstrating the relevance of prisms to science more broadly. For generality, sleeping beauties are articles that follow a vastly different citation pattern from almost all other published research. The fact that prisms contribute to an earlier (re)discovery of sleeping beauties shows that prisms influence the recognition of all types of scientific articles, including those that experience non-linear citation patterns. In terms of relevance, as Reschke et al. (2018) have argued, status not only impacts quality uncertainty but also other scientists' attention. By diverting other scientists' attention towards the sleeping beauties that belong to the coauthors of winners, prisms cause some valuable but neglected ideas to awaken sooner than others. Following research that treats citations as informative of the diffusion of scientific knowledge across articles (Sorenson and Fleming, 2004), through sleeping beauties, we show that prisms not only matter for star collaborators but also for science more broadly.

5.2. *Scope conditions*

Our analysis also has limitations. First, we assume that all citing behavior is positive. As such, we ignore post-publication review, corrections, and retractions because such practices were far less prevalent in physics across our event window. Yet there is also negative citing behavior, such as rebuttal citations (notably, in the social sciences). While physics may be less prone to this conduct and research into negative citations suggest that it is a relatively infrequent activity (Catalini et al., 2015), we cannot rule it out. As a result, future research might explore whether indirect peer effects vary with citation motivation.

A second limitation relates to constraints inherent in the dataset. Although we draw from a comprehensive source of bibliometric data, our dataset lacks rich biographical data – such as the degree-granting university or the Ph.D. supervisor – that might otherwise enhance the analysis. Unfortunately, one limitation of historical data is that this information (particularly from the 19th century) often is simply not available. More granular information would help researchers to identify additional boundary conditions of prisms.

A third limitation is that a collaboration results from two scientists choosing to work together. The effects documented in this article are conditional on an observed (selection into) collaboration, meaning that they may be related to unobserved characteristics of coauthors that caused a star to choose to work with them. While our research design tries to minimize any selection effects (e.g., by focusing on papers published pre-collaboration, the use of multiple control groups, or the inclusion of various fixed effects; please see the Online Appendix for more details), we cannot fully rule out such a selection effect. Consequently, the decision to coauthor with a star is a key condition for our results. Future research might want to incorporate further determinants of collaborations so that it is possible to identify the extent to which unobserved characteristics may impact peer effects, like prisms, that stem from collaboration.

Fourth, the effect of coauthoring with a winner is estimated relative to the coauthors of nominees. We use the coauthors of nominees as our quality benchmark for the coauthors of winners. However, this also limits the external validity of our results. We cannot be certain that the coauthors of nominees did not also experience a change in citations relative to other scientists after the unsuccessful (although ostensibly secret) Nobel Prize nomination.

Finally, another limitation is our use of historical data, which raises the question of whether our results are applicable to today's research environment. On the one hand, there are several features of our empirical context that persist today – such as the rarity of solo authorship, the high frequency of collaborations, and the prestige associated with the Nobel Prize. Perhaps more importantly, our theory assumes that there is an imbalance between the amount of time that scientists can devote to reading the literature and the amount of scientific literature that exists. Extant research on change in the number of scientific articles produced over time suggests that there are substantially more articles published today than in our event window (Herrmannova and Knoth, 2016). This implies that the theorized imbalance has either remained unchanged or has increased, as there is more literature to read and only a set amount of time to do so. Since these underlying conditions – the need for signals to determine which literature to engage with, the frequency of collaboration between scientists, and the prestige of the Nobel Prize – have not changed, it seems likely that prisms still exist and that indirect peer effects in contemporary science could be stronger than in the historical sample that we analyze.

On the other hand, there are some clear differences between our empirical context and contemporary science, among them the dramatic drop in transportation, communication, and search costs over the last few decades. These differences may impact how the effects that this paper uncovers might function today. One possibility is that the aforementioned advances in communication technology may have increased the number of available quality signals. For instance, when using a search engine that indexes scientific articles, such as Google Scholar, the number of citations that a paper has received is displayed along with article title, author name, and journal. In our event window, scientists had at best very limited access to computers and very likely did not use them to search the literature – they may have only had journal, affiliation, and author names as potential signals of quality. This change in communication technology means that scientists today are likely exposed to more signals than in the past. Future research could focus on which signal other scientists pay attention to first. Perhaps prisms play more of a complementary role in contemporary science as scientists use the ‘who we collaborate with’ signal to supplement the signals sent by citations. In other words, a paper with few citations may at first appear to be ‘low quality’ and scientists then use author affiliations and journal status to determine whether there is an alternative indicator of quality that supports the decision to engage with the paper. In sum, our use of historical data and the age of the sample limits definitive conclusions to the historical period captured in our event window. Since the underlying conditions that led to reliance on prisms remain, we believe that the scope of this paper is not limited to historical events and that prisms still matter today.

5.3. Future research

This reflection on the various assumptions underlying our analyses also suggests some areas for expansion. First, future research might explore whether the number of collaborative relationships, and thus of *several* prisms, has a bearing on the effects we report. Future research could use the posthumous bestowal or rescission of awards as an alternative strategy for estimating cumulative prisms. Furthermore, by excluding winner-winner and winner-nominee coauthor relationships, we potentially missed “inherited” influence through “families” of scientists and alternative forms of collaboration (such as Ph.D. mentorship) that also could serve as prisms. Lastly, future research could query whether papers concentrated in a single field or spread across several fields are more affected by prisms and identify whether what drives success for individual scientists is aligned with or divergent from the field.

Second, future research could investigate the relative strength of different signals of quality in a contemporary research context and whether the presence of additional signals weakens or strengthens the signal that collaborations provide.

Third, future research might explore whether indirect peer effects are only positive. For instance, scientific scandals that culminate in retractions may lead to negative indirect peer effect as these prisms signal collaborators are perhaps lower quality than initially expected (Jin et al., 2019). Alternatively, the sleeping beauties analysis reveals that with whom a scientist works contributes to differences in when sleeping beauties awaken in order to impact a scientific field. If science benefits from the emergence of novel findings (Uzzi et al., 2013), then the rate of scientific progress might experience a delay that does not stem from an article’s content but instead, from qualities of its producer.

5.4. Conclusion

We examined the consequences of star scientist collaboration and found that the status of a star caused a collaboration to act as a prism that transmits indirect peer effects. Star collaborations changed other scientists’ perceptions of coauthor research and led to increased recognition of coauthors’ ideas. Our results clarify whether and when star scientists impact their coauthors, illustrate how working with stars impacts the movement of scientific information across papers, and demonstrate how the mere presence of a star scientist can shape science itself.

CRediT authorship contribution statement

Nathan Betancourt: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Torsten Jochem:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Sarah M. G. Otner:** Conceptualization, Funding acquisition, Investigation, Resources, Writing – original draft, Writing – review & editing, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Agrawal, A., McHale, J., Oettl, A., 2017. How stars matter: recruiting and peer effects in evolutionary biology. Res. Policy 46, 853–867.

Angrist, J.D., Pischke, J.S., 2008. Mostly Harmless Econometrics: An empiricist’s Companion. Princeton University Press, Princeton, N.J.

Azoulay, P., Graff Zivin, J.S., Wang, J., 2010. Superstar extinction. Q. J. Econ. 125, 549–589.

Azoulay, P., Stuart, T., Wang, Y., 2014. Matthew: effect or fable? Manag. Sci. 60, 92–109.

Baffes, J., Vamvakidis, A., 2011. Are you too young for the Nobel Prize? Res. Policy 40, 1345–1353.

Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust differences-in-differences estimates? Q. J. Econ. 119, 249–275.

Borjas, G.J., Doran, K.B., 2012. The collapse of the Soviet Union and the productivity of American mathematicians. Q. J. Econ. 127, 1143–1203.

Borjas, G.J., Doran, K.B., 2015. Prizes and productivity: how winning the fields medal affects scientific output. J. Hum. Resour. 50, 728–758.

Brzezinski, M., 2015. Power laws in citation distributions: evidence from Scopus. Scientometrics 103, 213–228.

Catalini, C., Lacetera, N., Oettl, A., 2015. The inicidence and role of negative citations in science. Proc. Natl. Acad. Sci. U.S.A. 112.

Cole, S., 1970. Professional standing and the reception of scientific discoveries. Am. J. Sociol. 76, 286–306.

Cole, S., Cole, J.R., 1967. Scientific output and recognition: a study in the operation of the reward system in science. Am. Sociol. Rev. 32, 377–390.

Cole, S., Cole, J.R., 1968. Visbility and tthe structural bases of awareness of scientific research. Am. Sociol. Rev. 33, 397–413.

Cole, J.R., Cole, S., 1972. The Ortega hypothesis. Science 178, 368–375.

Connelly, B.L., Certo, S., Ireland, R.D., Reutzel, C., 2011. Signaling theory: a review and assessment. J. Manag. 37, 39–67.

Crawford, E.T., 2002. The Nobel Population 1901-1950: A Census of the Nominators and Nominees for the Prizes in Physics and Chemistry. Universal Academy Press, Tokyo, Japan.

Dahlander, L., McFarland, D.A., 2013. Ties that last: tie formation and persistence in research collaborations over time. Adm. Sci. Q. 58, 69–110.

De Solla Price, D.J., 1963. Little Science, Big Science. Columbia University Press.

Deichmann, D., Moser, C., Birkholz, J.M., Nerghes, A., Groenewegen, P., Wang, S., 2020. Ideas with impact: how connectivity shapes idea diffusion. Res. Policy 49, 103881.

Frey, B.S., Gallus, J., 2017. Towards an economics of awards. J. Econ. Surv. 31, 190–200.

Garfield, E., 2007. The evolution of the Science Citation Index. Int. Microbiol. 10, 65–69.

Gingras, Y., Wallace, M.L., 2010. Why it has become more difficult to predict Nobel Prize winners: a bibliometric analysis of nominees and winners of the chemistry and physics prizes (1901–2007). Scientometrics 82, 401–412.

Grigoriou, K., Rothaermel, F.T., 2014. Structural microfoundations of innovation: the role of relational stars. J. Manag. 40, 586–615.

Hamilton, D.P., 1990. Publishing by – and for? – the numbers: new evidence raises the possibility that a majority of scientific papers make negligible contributions to knowledge. Science 250, 1331–1332.

Harzing, A.W., 2013. A preliminary test of Google Scholar as a source for citation data: a longitudinal study of Nobel prize winners. Scientometrics 94, 1057–1075.

Herrmannova, D., Knoth, P., 2016. An analysis of the Microsoft Academic Graph. D-lib Magazine 22, 37.

Hess, A.M., Rothaermel, F.T., 2011. When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry. Strateg. Manag. J. 32, 895–909.

Higgins, M.J., Stephan, P.E., Thursby, J.G., 2011. Conveying quality and value in emerging industries: star scientists and the role of signals in biotechnology. Res. Policy 40, 605–617.

Hohberger, J., 2016. Does it pay to stand on the shoulders of giants? An analysis of the inventions of star inventors in the biotechnology sector. Res. Policy 45, 682–698.

Jiang, F., Liu, N., 2018. The hierarchical status of international academic awards in social sciences. Scientometrics 117, 2091–2115.

Jin, G.Z., Jones, B., Lu, S.F., Uzzi, B., 2019. The reverse Matthew effect: catastrophe and consequence in scientific teams. Rev. Econ. Stat. 101, 492–506.

Ke, Q., Ferrara, E., Radicchi, F., Flammini, A., 2015. Defining and identifying sleeping beauties in science. Proc. Natl. Acad. Sci. 112, 7426–7431.

Kehoe, R.R., Lepak, D.P., Bentley, F.S., 2018. Let's call a star a star: task performance, external status, and exceptional contributors in organizations. J. Manag. 44, 1848–1872.

Khanna, R., 2021. Aftermath of a tragedy: a star's death and coauthors' subsequent productivity. Res. Policy 50, 1041–1059.

Kilduff, M., Krackhardt, D., 1994. Bringing the individual Back in: a structural analysis of the internal market for reputation in organizations. Acad. Manag. J. 37, 87–108.

Lincoln, A.E., Pincus, S., Koster, J.B., Leboy, P.S., 2012. The Matilda effect in science: awards and prizes in the US, 1990s and 2000s. Soc. Stud. Sci. 42, 307–320.

Liu, D., Brass, D.J., Lu, Y., Chen, D., 2015. Friendships in online peer-to-peer lending: pipes, prisms, and relational herding. MIS Q. 39, 729–742.

Lotka, A.J., 1926. The frequency distribution of scientific productivity. J. Wash. Acad. Sci. 16, 317–323.

Lynn, F.B., Podolny, J.M., Tao, L., 2009. A sociological (de) construction of the relationship between status and quality. Am. J. Sociol. 115, 755–804.

Magee, J.C., Galinsky, A.D., 2008. Social hierarchy: the self-reinforcing nature of power and status. Acad. Manag. Ann. 2, 351–398.

Meho, L.I., 2007. The rise and rise of citation analysis. Physics World 20, 32.

Merton, R.K., 1968. The Matthew effect in science. Science 158, 56–63.

Norrby, E., 2010. Nobel Prizes and Life Sciences. World Scientific Publishing.

Oettl, A., 2012. Reconceptualizing stars: scientist helpfulness and peer performance. Manag. Sci. 58, 1122–1140.

Podolny, J.M., 2001. Networks as the pipes and prisms of the market. Am. J. Sociol. 107, 33–60.

Reschke, B.P., Azoulay, P., Stuart, T.E., 2018. Status spillovers: the effect of status-conferring prizes on the allocation of attention. Adm. Sci. Q. 63, 819–847.

Rothaermel, F.T., Hess, A.M., 2007. Building dynamic capabilities: innovation driven by individual-, firm-, and network-level effects. Organ. Sci. 18, 898–921.

Sacerdote, B., 2014. Experimental and quasi-experimental analysis of peer effects: two steps forward? Annu. Rev. Econ. 6, 253–272.

Sauer, S.J., Thomas-Hunt, M.C., Morris, P.A., 2010. Too good to be true? The unintended signaling effects of educational prestige on external expectations of team performance. Organ. Sci. 21, 1108–1120.

Simcoe, T.S., Waguespack, D.M., 2011. Status, quality, and attention: what's in a (missing) name? Manag. Sci. 57, 274–290.

Sorenson, O., Fleming, L., 2004. Science and the diffusion of knowledge. Res. Policy 33, 1615–1634.

Spence, M., 1973. Job market signaling. Q. J. Econ. 87, 355–374.

Strutt, R.J., 1968. The Life of John William Strutt: Third Baron Rayleigh. University of Milwaukee Press, Milwaukee, WI.

Teller, E., Shoolery, J., 2001. Memoirs: A Twentieth-century Journey in Science and Politics. Perseus Books, Cambridge, MA.

Uzzi, B., Mukherjee, S., Stringer, M., Jones, B., 2013. Atypical combinations and scientific impact. Science 342, 468–472.

Van Raan, A.F., 2004. Sleeping beauties in science. Scientometrics 59, 467–472.

Waldinger, F., 2012. Peer effects in science: evidence from the dismissal of scientists in Nazi Germany. Rev. Econ. Stud. 79, 838–861.

Wang, J., Veugelers, R., Stephan, P., 2017. Bias against novelty in science: a cautionary tale for users of bibliometric indicators. Res. Policy 46, 1416–1436.

Weick, K.E., 1995. Sensemaking in Organizations. SAGE Publications.

Wuchty, S., Jones, B.F., Uzzi, B., 2007. The increasing dominance of teams in production of knowledge. Science 316, 1036–1039.

Zucker, L.G., Darby, M.R., 1996. Star scientists and institutional transformation: patterns of invention and innovation in the formation of the biotechnology industry. Proc. Natl. Acad. Sci. 93, 12709–12716.

Zuckerman, H., 1965. Nobel Laureates in the United States: A Sociological Study of Scientific Collaboration. Columbia University Press, New York.

Zuckerman, H., 1967. Nobel laureates in science: patterns of productivity, collaboration, and authorship. Am. Sociol. Rev. 32, 391–403.