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Introduction

where in the murky depths of mind
do idea-seeds sleep?
what seasons do they know
that make them wont to wake and grow
in spasms –
madly now, dormant then –
entangling all within their ken:
synaptic vines
to clamber
to the very stars.

My interest in the life and work of English astronomer William Huggins (1824–1910) began over twenty years ago in a graduate seminar on conceptual transfer within and among specialised scientific communities. The exchange of cultural baggage is a subtle dynamic that practitioners, particularly those working in long-established disciplines, usually take care to shield from public view. Our little group spent the semester analysing the far more transparent machinery of newer, still-developing hybrid disciplines like geophysics, biochemistry and astrobiology.

The topic meshed well with my own research interests at the time. I wanted to learn more about how the boundaries of scientific disciplines are established, policed and altered: What are the rules members must follow in investigating the natural world? What questions are deemed appropriate to ask? What do good answers to such questions look like and how can they be recognised? What constitutes an acceptable way of finding those answers? Who is allowed to participate in the search? Who says?

How better to find answers to these questions than to watch a scientific discipline during a period of change? I chose to explore the origins of astrophysics, a mature hybrid science that blends the methods, instruments and theories of chemistry and physics, as well as those of both mathematical and descriptive astronomy. The investigation offered me an opportunity to analyse the dynamics of cross-disciplinary borrowing, conceptual transfer and boundary realignment. It also shed light on the social, cultural and intellectual factors which catalyse and nurture the development of a new scientific discipline.

I was guided in my investigation by the fruitful model for scientific change proposed by Polish physician, Ludwik Fleck (1896–1961) in the 1930s.[1] Later models including those of

Thomas Kuhn[2] and Michel Foucault[3] also describe the complexities of scientific change, but they do so within the context of the systemic inertia that protects scientific endeavour from developing too eclectically. Kuhn's 'paradigm' and Foucault's 'episteme' represent the agreement that frames the linguistic and cognitive work space scientists share with their fellows. Change, in their models, occurs when agreement breaks down. 'Normal science' can only resume once the amplitude of disagreement within the community has been reduced to invisibility.

Rather than focus on scientific communities' drive to achieve conformity and consensus, Fleck drew attention to the creative force of the diversity within them. He recognised that every scientist is, more often than not, a member of more than one group of like-minded fellows who share a particular view, skill or interest. Fleck called these groups 'thought collectives' [*Denkkollectiven*]. Each thought collective is composed of both a small, specialised esoteric core surrounded by a larger, more peripheral, exoteric circle.[4] An individual may be situated within the esoteric core of one thought collective because of expertise or leadership qualities, and yet be accepted as (or simply consider himself or herself to be) a fringe, or exoteric, member of another thought collective of which other individuals form the core. For Fleck, one's place within this dynamic work space is a complex, and richly ambiguous, amalgam of self-perception and group selection that gives rise to what he called the 'intercollective communication of ideas'.[5]

Herein lay the utility of Fleck's model for my studies of change in the boundaries of scientific disciplines. Individuals with differing backgrounds and viewpoints, but who feel they speak a common language, co-exist within areas of overlapping thought collectives. They are exposed routinely to opportunities to apply their specialised theories and methods to the solution of a broad range of problems. Exoteric members of a thought collective thus play important roles in the process of concept change and transfer because they are in a position to act not so much as couriers between two different thought collectives, but as bilingual translators.

Astrophysics is built on a range of questions and methods that were unimaginable to individuals in the first half of the nineteenth century. At that time, positive knowledge of physical and chemical structure of celestial bodies was presumed to be unattainable by proper scientific methods, and hence relegated to the no-man's-land of mere speculation. One might entertain any number of untestable ideas about the origins of stars, or the reasons for their differences in colour, brightness and distribution, but such was not the stuff of science. What *was* considered positively knowable was the location of a celestial body on the sky. Gathering and interpreting this information defined the mission of the practising astronomer and determined the structure of his creative thought and work space. Astrophysics' emergence and efflorescence in the second half of the nineteenth century required the wholesale restructuring of the boundaries surrounding the theory and practice of astronomy. I wanted to know what made it possible to include such an unorthodox line of investigation within the traditional astronomical community. What prompted a segment of that community to move into this new thought space? If science is (to its credit) an inertial system, how do changes like this come about?

My preliminary seminar investigations formed the basis of my dissertation research.[6] I started by poking around in the theoretical and methodological stew of Britain's astronomical community during the last half of the nineteenth century using William Huggins as an historical probe. Huggins struck me as a logical choice to begin what I imagined would be a straightforward investigation into a well-documented episode in the history of science. After all, he was celebrated in his own lifetime as a self-taught pioneer who played a key role in introducing spectrum analysis into astronomical work. He began his career on the periphery of scientific London where he had ample opportunity to interact with astronomers, chemists, physicists, mathematicians and instrument makers of all stripes. He authored numerous articles documenting his ground-breaking use of the spectroscope to analyse the light of celestial bodies. Most notable among them was a retrospective essay, 'The new astronomy', in which he laid out in painstaking detail each step of his discovery-laden career.

To date, historians and scientists who have discussed William Huggins's contributions to astronomical spectroscopy have drawn on this considerable body of evidence.[7] I turned to the unpublished record. Indeed it is from unpublished documents that I have drawn the stuff and substance of the present work. Personal correspondence and observatory notebooks yielded what seemed at first to be an odd assortment of details and anecdotes. You may well wonder, *Gentle Reader*, why historians bother with all these cumbersome and potentially distracting episodes? I hope to convince you that lives are mosaics fashioned out of happenstance and numerous incremental day-to-day decisions rife with clutter and confusion, dead ends and mistakes. Private accounts expose the rough edges of decision making. More important, by putting human flesh on the skeletal prose of the public accounts, they show that even scientists are complex people with annoying personalities, with uncertainties and fears, with charm and pluck and wit.

What follows is less a definitive biography than an expeditionary report based on two decades of digging up and collecting the buried shards of Huggins's long and productive life.[8] I have carefully and, I hope, faithfully reassembled them to enable you to see, as I have, the hand, the instrument, the laboratory; to hear the voice, the scraping of the observatory dome, the zapping of the Geissler tube; to feel the frustration, the joy, the fear; to smell the battery's noxious fumes, the burning magnesium, the sweet night air; to taste the sweat, the ink, the long-forgotten cup of tea.

I also hope you may be motivated to join me in looking for the missing pieces.

1.1 The retrospective narrative

Permit me to illustrate the importance of the unpublished record in documenting the origins of astrophysics with the following story. In February 1893, Huggins received a query from Herbert Hall Turner (1861–1930), Chief Assistant to the Astronomer Royal at Greenwich. Turner was composing an obituary for the Royal Astronomical Society's (RAS) *Monthly Notices*. The subject was Lewis Morris Rutherfurd (1816–92), an American amateur astronomer, photographer and instrument designer, who had attracted the attention of colleagues on both sides of the Atlantic back in 1863 with news of his pioneering programme of stellar spectrum analysis. But ill-health and an aversion to publication had kept Rutherfurd's name out of sight and out of the collective mind of Britain's scientific community for many years.

Turner, a mere infant when Rutherfurd had made his mark, hoped that Huggins, who had twice met the man, would be able to provide some 'local colour' drawn from stellar spectroscopy's early days.[9] Unfortunately, the aging astronomer had no anecdotes to share. But he was happy to oblige Turner's request for clarification on the important, yet somewhat confused, matter of priority in the early efforts to map stellar spectra: who, exactly, among the first mappers of star spectra had done what, and when?

Huggins began with Joseph von Fraunhofer's (1787–1826) first observations of the spectra of a few bright stars in 1823[10] and concluded with the resurrection of research interest in this subject four decades later by a handful of astronomers including himself, Rutherfurd, and Italian astronomer Giovanni Battista Donati (1826–73).[11] He attributed the near-simultaneous burst of activity to Gustav Kirchhoff's (1824–87) 'discovery of the true meaning of the Fraunhofer lines' announced in 1859.[12] But, as for assigning priority for stellar spectroscopy, he argued that the concept had little meaning because he and these few others took their initial steps '*independently and unknown to each other* [original emphasis]' – all were 'first' in a sense. In fact – he took pains to note – Rutherfurd's 1863 paper on the subject had completely surprised (and probably annoyed) him, arriving as it did on the very evening he was preparing to publicise the results of his own research undertaken with chemist William Allen Miller (1817–70).

Huggins had been the last of these three men to subject starlight to spectroscopic study. In 1893, he could afford to regard priority with an air of gracious disinterest. As the trio's sole surviving member, he now found the question of who had taken this or that first little step so long ago to be less critical in terms of the long view of history than who had done the most over the intervening years to carry the field forward. He dismissed Donati's early measures as unreliable, and, in a postscript, reminded Turner that Rutherfurd had abandoned this line of investigation soon after conceiving it, thus forfeiting any claim to be considered a 'founder' of stellar spectroscopy. That title, in Huggins's view, clearly belonged to himself. It had been bestowed upon him by Agnes Mary Clerke (1842–1907) in her *Popular History of Astronomy*, and he was not going to cede it willingly.[13]

His comments betray the intensity of his anxiety about the public perception of his contributions to astronomical physics – an anxiety that became more central to his thinking as he grew older. Throughout his lengthy career, his discoveries drew colleagues' acclaim and imitation as well as their criticism and reinterpretation, a consequence of working on the cutting edge of a new scientific specialty. Early on, he learned the hard and, for him, discomfiting lesson that making a discovery guarantees the discoverer neither lifelong credit for it, nor control over its perceived place in the evolving history of the field. To retain control requires vigilance and continual reinsertion of one's own version of events into the public record.

In his published essay on Rutherfurd's life, Turner included a near-verbatim, yet unattributed, recitation of Huggins's personal recollection of events related to spectroscopy's introduction into astronomical investigation.[14] It formed the seed of what eventually became the traditional story of the origins of astrophysics. Huggins diligently nurtured this precious seed over the next few years. It germinated in the text of a stirring essay he wrote titled 'The new astronomy: A personal retrospect' (see Appendix). When the popular magazine *Nineteenth Century* published the piece in 1897, the now-hardy sprout took root in fertile soil.

'The new astronomy' exemplifies what Warren Hagstrom has called the 'scientist's account': an uncomplicated story of a scientific community's origins that both legitimates the work of its past and present researchers and socialises its new recruits.[15] Constructed with tautological clarity, these synthetic narratives reduce the muddle of theoretical and experimental options that really confronted the community's early researchers to a set of clear-cut alternatives.

To take narratives like the 'The new astronomy' at face value is to fall into an alluring trap. Like deftly embroidered curtains, they delight their intended audience while keeping the embarrassing clutter of regrettable missteps and frustrating reversals out of sight, out of mind and ultimately out of the collective's memory. By masking, even deleting from the record, the complexities and uncertainties that mark the first forays into a new realm of scientific investigation, they diminish the role played by calculated risk, negotiation and persuasion in establishing it as a valid branch of scientific inquiry.

1.2 Chapter summaries

In the chapters that follow I will lift the obscuring curtain of 'The new astronomy' to reveal Huggins as less of a single-minded, focused and exhaustive researcher, than a scientific entrepreneur who possessed considerable skill at selecting research projects, designing and manipulating instruments for specific mensurational tasks, and rallying influential colleagues' support for his investigative ventures. The task is threefold: first, to present a new interpretation of the events that marked the development of William Huggins's career based on an in-depth examination of his unpublished notebooks and correspondence; second, to bring to light the research options he perceived were available to him and analyse the actions he ultimately took in the context of mid-nineteenth-century British amateur astronomy; and finally, to present a new account of the synergy of his career and the rise of astronomical physics in light of his private and public accounts.

To lay some essential groundwork, Chapter 2 begins with a look at the community of astronomers in the first half of the nineteenth century.[16] What puzzles piqued their interest and challenged their ingenuity? How did they define the boundaries of acceptable research? What theories, methods and instruments did they consider to be legitimate means for attacking these problems? How did the spectroscope, a laboratory instrument used by physicists and chemists to analyse light, work its way into the core of the astronomical enterprise?

Chapter 3 reviews significant events in the life of William Huggins up to the time he was elected to fellowship in the Royal Astronomical Society in 1854 and constructed his home observatory. What avocational choices did he perceive were available to him as a young and maturing adult? When and why did he become interested in astronomy? How did he acquire and develop sufficient technical and methodological expertise to make the transition from novice to serious amateur? Who influenced his choice of methods, instruments and observational agenda?

The fourth chapter focuses on the reception of Kirchhoff's radiation law in England. How might a novice amateur astronomer like Huggins have become aware of the German physicist's work? How do his later recollections compare with contemporary records of events? Can these accounts be reconciled to restore elided details of his plan to apply Kirchhoff's method to the stars?

In 1864, Huggins shifted his attention from scrutinising the spectra of stars to examining those of nebulae. Chapter 5 explores this bold move, which ultimately propelled him to a position of prestige and authority among fellow astronomers. At the time, there were still questions that remained unanswered concerning the physical nature of these celestial objects. For many astronomers, the 'riddle of the nebulae' was simply irresolvable. How did Huggins convince them to change their minds?

Chapter 6 examines Huggins's observational programme in the period immediately following the announcement of his spectroscopic observations of nebulae.[17] Although his reminiscences later in life give the impression that he spent all, or much, of his time on the spectroscopic study of stellar and nebular objects, ambition and curiosity led him to explore a number of different subjects – the light of a nova, the heat of celestial bodies, the glow of fireworks and meteors – in innovative and often technically challenging ways. How did he maximise his opportunities for new discoveries and avoid being identified as a speculative or impulsive dilettante?

Chapter 7 looks at Huggins's most influential contribution to astronomy: his application in 1868 of the spectroscope to detect – and Doppler's principle to measure – stellar motion in the line of sight. Undertaken entirely by visual means, it was an audacious effort fraught with overwhelming mensurational and interpretive difficulties. How did Huggins overcome these challenges and ultimately persuade his contemporaries that he had, in fact, accomplished what he claimed? What impact did being able to measure the radial velocity of a star have on the research interests of positional astronomers and their attitudes toward celestial spectroscopy?

Chapter 8 focuses on Huggins's career in the wake of his line-of-sight research. He developed a reputation for care in making observations and caution in suggesting explanations for the phenomena he observed. By cultivating important alliances to great personal advantage, he was awarded custodianship of a state-of-the-art telescope paid for with funds appropriated by the Royal Society. How did taking responsibility for the instrument affect Huggins's research agenda? How did he handle the logistics of carrying out a productive observing programme, and fend off criticism from disgruntled colleagues?

Chapter 9 joins William Huggins on an expedition he led to Oran, Algeria, in 1870 to analyse the light of the solar corona during a total eclipse. It is the only eclipse expedition in which he played a role, yet mention of it is conspicuously missing from his retrospective account. What motivated him and his colleagues to embark on such a difficult journey? In organising the expedition, what challenges did he face in terms of leadership and resourcefulness? How did the expedition affect his future research efforts?

Accounts of Huggins's work always mention that he was assisted in his research by his wife, Margaret Lindsay (née Murray) Huggins (1848–1915). Chapter 10 presents evidence from her lengthy and detailed notebook entries to demonstrate that she was more than an able assistant, amanuensis and illustrator whose work conformed to her husband's research interests. What do these unpublished sources reveal about the effect of Margaret's presence and expertise on the research agenda at the Tulse Hill observatory? Why do published accounts trivialise and even obscure the extent of her contributions to the astronomical investigations she performed with her husband despite the fact that she is often the principal source of information about that work?

In 1882, over a decade after his expedition to Oran, Huggins launched an effort to photograph the solar corona without an eclipse. The years-long project is the subject of Chapter 11.[18] His initial perception of success in this project led him to pursue it for many years with great zeal and conviction. Correspondence and notebook entries show that it tested the strength of his persuasive power and encouraged him to build an international network of confirmatory witnesses. The difficulties he faced in achieving his goal, rather than stifling his research efforts, motivated him to improve his research methods and instrumentation. By what means did he hope to convince others of the validity of his coronal photographs? How does a scientific community achieve consensus on what counts as conclusive evidence?

Chapter 12 investigates the circumstances leading up to Margaret Huggins's public debut as her husband's collaborative assistant. Beginning in 1887, the Hugginses photographed and analysed the spectrum of the Orion nebula hoping to identify the physical and chemical cause of the bright lines William had described in his first observations of nebular spectra more than two decades earlier. Their findings embroiled them in a controversy with Joseph Norman Lockyer (1836–1920), founder and editor of *Nature*. What was Margaret's role in this challenging research effort? Why, after fifteen years of collaborative work, did the Hugginses choose to publish their first joint paper on this controversial subject?

Chapter 13 discusses the steps taken by the Royal Society to control the intensifying dispute between Huggins and Lockyer and restore civility within its ranks. What strategies did Huggins employ to maintain his position on the cutting edge of astronomical research? How did his cultivation of alliances with prominent American astronomers influence his professional standing with astronomers both at home and abroad?

Even as he approached eighty years of age, Huggins continued to search for new and innovative ways to apply the spectroscope's analytical power. Chapter 14 brings to light one of his lesser-known research efforts: the spectroscopic study of radium's natural glow. Why have these investigations been forgotten? He also became increasingly nostalgic and wary of encroachment upon his past accomplishments. He penned his stirring retrospective essay, 'The new astronomy' (1897), and, with Margaret's invaluable assistance, he edited a collection of essays on stellar classification titled *The Atlas of Representative Star Spectra* (1899). What role have these works played in the construction of William Huggins's historical legacy?

Chapter 15 begins with a look at the final years of Huggins's life and the steps he took to pass on responsibility for the 'new' astronomy's future development to the next generation of researchers. After relinquishing the telescope that had been on loan to him from the RS for nearly four decades, William worked with Margaret to edit a collection of his scientific papers (1909), which they arranged topically and introduced with excerpts from

'The new astronomy'. How did Margaret establish herself as architect and vigilant guardian of her husband's public image after his death in 1910?

1.3 A note on the unpublished sources

Tracking down Huggins's correspondence has been, and continues to be, a worthy challenge. The archival record is extensive, but it is far from complete. Unpublished documents that would shed new light upon Huggins's innovative work in ultraviolet spectroscopy, for example, have yet to be uncovered. In addition, I have found no collection of his received correspondence, save copies made by his correspondents for their own records, and the handful of letters pasted into Huggins's observatory notebooks. They may have been lost or destroyed after his death. I am sure there are more materials yet to be discovered.

There is no one repository for his outgoing letters. Principal collections can be found in the Scientific Manuscripts Collection, Manuscripts and Archives of the Cambridge University Library (CUL), the Library of the Royal Society of London (RSL), the Library of the Royal Astronomical Society of London (RASL), the Huntington Library in San Marino, California (HL), and the Mary Lea Shane Archives (MLSA) of the Lick Observatory (LO) in Santa Cruz, California.

The papers of George Gabriel Stokes (1819–1903), long-time physical secretary of the Royal Society, are held in the CUL Manuscripts Room. Stokes's papers contain over three decades of letters from William Huggins as well as correspondence from Lockyer, Miller, Warren De la Rue (1815–89), Thomas Romney Robinson (1792–1882), Henry Enfield Roscoe (1833–1915), Alexander Strange (1818–76) and others.

The CUL is also home to the massive collection of documents from the Royal Greenwich Observatory (RGO), including, it would seem, every scrap of paper on which a spot of ink or stray pencil mark was deposited during the lengthy tenure (1835–81) of Astronomer Royal George Biddell Airy (1801–92). Airy's papers are a rich source of information about his personal and administrative concerns as he and his Greenwich staff confronted the need to include spectroscopic measures in their daily routine.

Among the archived RGO records are those from the Royal Observatory at the Cape of Good Hope. Of particular relevance to the story of William Huggins are the numerous letters he exchanged with Her Majesty's Astronomer at the Cape, David Gill (1843–1914), as he guided Gill in implementing his method of photographing the solar corona without an eclipse.[19]

In addition to the correspondence of William Huggins, the RSL holds significant collections of correspondence of such scientific notables as Lockyer, Miller, William Crookes (1832–1919), John Frederick William Herschel (1792–1871), Joseph Larmor (1857–1942) and Arthur Schuster (1851–1934), to name a few. Of special interest are the numerous letters from Margaret Huggins to Larmor, particularly those written after her husband's death. The RSL has also preserved valuable referee reports written in review of colleagues' papers. These documents offer a glimpse of the critical reception of the scientific elite to new ideas being presented in papers before the Royal Society.

The RASL contains many letters written by Huggins, chiefly on matters of Society business. Of particular interest are his written communiqués to the gifted illustrator

William Henry Wesley (1841–1922), who served as the Society's assistant secretary from 1874 until his death. Huggins presented the RAS with some of his own drawings made during observations throughout his career. These items deserve more intensive examination. The library also holds letters from his RAS colleagues including De la Rue, Lockyer and American astronomer George Ellery Hale (1868–1938).

What has survived of Huggins's direct correspondence with Lockyer is held at the University of Exeter (UEL). These letters provide insight into the evolution of the working relationship between these two men. The Library of King's College, London, holds a number of interesting documents and letters related to Miller's tenure there as Professor of Chemistry. Letters Huggins wrote to mathematician Alfred Bray Kempe (1849–1922), dealing principally with administration of the Royal Society and Kempe's tenure as the Society's treasurer, can be found in the collection of the West Sussex Record Office, Chichester. Several letters from Huggins to physician Henry Wentworth Acland (1815–1900) are held in Oxford's Bodleian Library. Letters from Huggins to Lawrence Parsons, 4th Earl of Rosse (1840–1908), can be found in the Rosse papers at Birr Castle in Ireland.

In the United States, the MLSA of the Lick Observatory hold a number of letters of interest to the history of early astrophysics. A well-indexed collection, it contains letters Huggins wrote to Edward Singleton Holden (1846–1914) and William Wallace Campbell (1862–1938), as well as many exchanged among prominent astronomers of the day including Holden, Campbell, Hale, Hugh Frank Newall (1857–1944), Lockyer, James Edward Keeler (1857–1900) and Henry Draper (1837–81). The David Peck Todd (1855–1939) papers at Yale University Library (YUL) and the Charles Augustus Young (1834–1908) papers at Dartmouth College (DCL) contain important letters from both William and Margaret Huggins. Most of George Ellery Hale's papers are held at the California Institute of Technology (CIT) in Pasadena, California. Others remain in the collection of the Huntington Library (HL) in San Marino, California. Most of the papers at the CIT have been placed on microfilm and can be examined at other libraries (the Museum of American History of the Smithsonian Institution in Washington, DC, for example, and the University of Massachusetts, Amherst). The Hale papers include Hale's correspondence with Huggins and Lockyer, as well as other international figures who played a role in the early development of astrophysics.

The Library of Congress Manuscript Collection holds Simon Newcomb's (1835–1909) papers and the correspondence of Thomas Jefferson Jackson See (1866–1962). Worthy of special note in the Newcomb papers is the diary of Mrs Newcomb describing her experiences on the solar eclipse expedition to Gibraltar in December 1870. The Harvard University Library (HUL) holds important correspondence between Huggins and Harvard Observatory Director, Edward Charles Pickering (1846–1919). In addition, the New York City Public Library (NYPL) is the repository for the Henry Draper papers which contain important letters from Huggins, John William Draper (1811–82), Holden, William Lassell (1799–1880) and Richard Anthony Proctor (1837–88), among others.

In 1914, Huggins's widow, Margaret, gave six observatory notebooks to Wellesley College near Boston, Massachusetts, along with a wide range of small astronomical instruments and other items from the Tulse Hill observatory, as well as many personal items and objets d'arts that she and her husband had accumulated during their travels. Currently held in Wellesley College's Special Collections (WCL/SC), the notebooks span forty-five years of his observing career from 1856 to 1901.[20] Because Margaret assumed the task of recording the couple's observations in the notebooks following their marriage in 1875, examination of the notebook accounts from that time forward brings into vivid relief, for the first time, the full extent of her collaborative role in the work done at Tulse Hill.

Notes

1. Fleck, *Genesis and Development of a Scientific Fact* (1979).
2. Kuhn, *The Structure of Scientific Revolutions* (1970).
3. Foucault, *The Order of Things* (1970).
4. Fleck, *Genesis and Development of a Scientific Fact* (1979), p. 104.
5. *Ibid*., pp. 109–110.
6. B. J. Becker, 'Ecclecticism, opportunism, and the evolution of a new research agenda' (1993).
7. See, for example, Maunder, *Sir William Huggins and Spectroscopic Astronomy* (1913); Dyson, 'Sir William Huggins' (1910); Newall, 'Sir William Huggins' (1910–11) and 'William Huggins' (1911); W. W. Campbell, 'Sir William Huggins' (1910); H. S. Williams, *The Great Astronomers* (1932); Meadows, 'The origins of astrophysics' (1984); Glass, *Revolutionaries of the Cosmos* (2006), ch. 5.
8. For earlier reports, see B. J. Becker, 'Margaret and William Huggins at work in the Tulse Hill Observatory' (1996); 'Priority, persuasion, and the virtue of perseverance' (2000); 'Visionary memories' (2001); 'Celestial spectroscopy' (2003); and 'From dilettante to serious amateur' (2010).
9. The substance of Turner's request, whether oral or written, must be inferred from Huggins's reply. See W. Huggins to Turner, 15 February 1893, Correspondence of the Society, RASL.
10. Fraunhofer had actually observed stellar spectra before 1815: 'With the same set up, I made observations of a few first magnitude fixed stars.' Fraunhofer, 'Bestimmung des Brechungs- und Farbenzerstreuungs-Vermögens …' (1817), p. 220. Huggins's mention of 1823 must refer to the paper's appearance in English translation in the *Edinburgh Philosophical Journal*.
11. For whatever reason, he made no mention of James Carpenter, whose comparisons of stellar spectra were performed at Greenwich under the direction of the Astronomer Royal, George Airy.
12. Kirchhoff, 'Über die Fraunhofer'schen Linien' (1860).
13. Clerke named Vatican astronomer Father Angelo Secchi as another founder of this new science. Secchi began his spectroscopic investigations shortly after Huggins, so was not among the very first stellar spectroscopists, thus technically justifying Huggins's failure to name him. Clerke, *A Popular History of Astronomy* (1885), p. 421. Unless otherwise noted, all citations from *A Popular History of Astronomy* are from this first edition.
14. Turner, 'Lewis Morris Rutherfurd' (1893).
15. Hagstrom, *The Scientific Community* (1965), pp. 211–15.
16. Earlier versions of portions of Chapters 1–3 appeared in B. J. Becker, 'Visionary memories', *JHA* **32** (2001); 'Celestial spectroscopy' (2003); and 'La spettroscopia e la nascita dell'astrofisica' (2003).
17. An earlier version of portions of this chapter appeared in B. J. Becker, 'From dilettante to serious amateur' (2010).
18. An earlier version of portions of this chapter appeared in B. J. Becker, 'Priority, persuasion, and the virtue of perseverance' (2000).
19. The South African Astronomical Observatory also holds a number of letters Huggins sent to David Gill during his tenure as Astronomer Royal at the Cape.
20. S. F. Whiting, in 'Diaries' (1917). For a summary of the contents of the notebooks, see Morgan, 'Huggins archives' (1980).