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THE 1910 SOLAR CONFERENCE AND COOPERATION IN STELLAR SPECTROSCOPY

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Abstract: In the early twentieth century, cooperative astronomical programmes were not new: the Carte du Ciel project involved nearly twenty observatories. G.E. Hale's International Union for Cooperation in Solar Research, forerunner of the IAU, was organized in 1904. At the 1910 meeting of the American Astronomical Society, W.W. Campbell proposed to create a committee to foster cooperation in radial-velocity measurements. At the Pasadena meeting of the IUCSR, a scheme to pursue measurements of fainter stars emerged. Few observatories had telescopes sufficiently powerful for the work, the new 60-inch reflector at Mount Wilson being one of the exceptions. J.S. Plaskett, of the Dominion Observatory in Ottawa, brought into this group, determined that Canada would contribute. He was central to the eventual cooperative work in the 1920s and it was his 72-inch reflector at Victoria that became the template for a number of similar telescopes which would make significant contributions to stellar spectroscopy over the next forty years.

Keywords: spectroscopy, radial velocities, J.S. Plaskett, Lick Observatory, Mount Wilson Observatory, Dominion Astrophysical Observatory.

1 INTRODUCTION

While inter-institutional and international cooperation are commonplace in astronomy today, they were less important in the first third of the twentieth century. One of the most significant examples of cooperation was the joint programme of stellar radial-velocity measurements made by the Mount Wilson, Lick and Dominion Astrophysical Observatories in the 1920s. The origins of this venture lay in two meetings in the summer of 1910, the Harvard meeting of the Astronomical and Astrophysical Society of America and the conference of the Solar Union in Pasadena and Mount Wilson, California. While there were no immediate results from the discussions, cooperation to secure radial velocities of fainter stars was well underway by 1920. In the longer-term, this cooperative venture helped to set in motion the building of a generation of large, two-metre class reflectors designed for spectrographic research. Thanks to these instruments, radial velocity work continued into the 1960s. The figure linking the radial-velocity scheme and the eventual expansion of the instrumentation for stellar astronomy was the very junior participant of the former, John Stanley Plaskett (1865–1941). After brief discussions of the state of international cooperation in astronomy and radial-velocity research before 1910, I will turn to the meetings, their participants and the factors that worked against their vision. Next, Plaskett's role in these events and his participation in radial-velocity work on the 1920s and 1930s will be described, followed by remarks on where this programme led.

2 INTERNATIONAL COOPERATION IN ASTRONOMY

Although astronomers have been in contact with one another for more than two thousand years, one could argue that the first serious collaboration was implemented by Tycho Brahe (1546–1601), who maintained an impressive correspondence network and astronomical research institute. National networks, most notably centred on the Paris Observatory in the eighteenth and nineteenth centuries, linked observers for specific projects. Truly international gatherings date from a 1798 meeting organized by Baron F.X. von Zach (1754–1832) in Seeburg. Soon afterward, he and associates created the Vereinigte Astronomische Gesellschaft, partly to coordinate a search for the planet assumed to exist between the orbits of Mars and Jupiter. The modern Astronomische Gesellschaft was formed in Heidelberg in 1863 and by the end of that century was the most internationally-oriented astronomical society.

Organized cooperation in astronomical research emerged with the Carte du Ciel and Astrographic Catalogue project. Realizing the potential of photography for mapping stars, Admiral E.A.B. Mouchez (1821–1892), Director of the Paris Observatory, hosted an international meeting—the first Astrographic Conference—in Paris in April 1887. In this project, he had the firm support of David Gill (1843–1914), Director of the Cape Observatory. A key element of the Carte du Ciel was the idea of standardized photographic objectives. Of the twenty observatories—later twenty-two—willing to cooperate, European observatories mostly obtained their lenses from the Henry brothers in Paris, while the Empire observatories employed lenses designed by Gill and manufactured by Howard Grubb (1844–1931). An important contributor was the Royal Greenwich Observatory, where H.H. Turner (1861–1930) provided technical innovations for the project. Turner, who moved to Oxford in 1893, managed to complete about one-quarter of the Astrographic Catalogue. While still moving forward before World War I (Turner, 1912), the project was never completed: the Carte du Ciel never appeared but the catalogue of more than 4.6 million star positions later provided a base of comparison for the Hipparcos Catalogue of the 1990s.

In the early twentieth century, George Ellery Hale (Figure 1) took the next step in internationalization of astronomy with the formation of the International Union for Cooperation in Solar Research. As recently-named chairman of the Committee on Solar Research of the National Academy of Sciences, he had circularized colleagues around the world in 1904 to invite them to St. Louis to discuss cooperation. Delegates who attended agreed to form an international union for solar research with Hale at its head (Origins of the

Figure 1: George Ellery Hale (1868–1938) in 1916 (University of Chicago Yerkes Observatory, courtesy: AIP Emilio Segrè Visual Archives).

Union, 1906). The second meeting was held at Oxford in September 1905, with a third meeting at Meudon in May 1907.

By the time of the Pasadena meeting in 1910 (Figure 2), the Solar Union had existed for only six years and there was no international organization that could encompass the rising interest in stellar astrophysics. It is not surprising that the idea to extend the Union's work to a broader field would be raised. There must have been backroom discussion of the idea; in the event, it was Karl Schwarzschild (Figure 3) who rose at the conference to make the motion: "Ich möchte dann beantragen 'Die Union erweitert ihr Arbeitsgebiet über die Sonnenphysik hinaus auf Astrophysik im allgemeinen'" ["I would like to then move that 'The Union broaden its sphere of work beyond solar physics to astrophysics in general'"] (*Proceedings of the Conference*, 1911: 111). Alfred Fowler (1868–1940), Heinrich Kayser (1853–1940) and Turner all spoke in favour of the idea and it passed without demur. This helped to legitimize the discussions of the Radial Velocity Committee within a framework of wider international cooperation. Schwarzschild's motion was also, in effect, a major step towards the transformation of the Solar Union into the International Astronomical Union.

A third international cooperative scheme was launched in 1906 to obtain stellar statistics: this was Jacobus Kapteyn's Plan of Selected Areas (Lynds, 1963). Recognizing that obtaining observational data for all stars in the Galaxy was impossible, Kapteyn (Figure 4) designated 206 (with later additions) representative and distributed areas for observation. Eventually more than forty observatories participated, with Harvard, Yerkes and Mount Wilson as major American contributors (van Rhijn, 1930). Of the three cooperative projects underway by 1910, only the work of the Solar Union was truly devoted to astrophysics.

3 RADIAL VELOCITIES IN STELLAR SPECTROSCOPY

It was Edmund Halley (1656–1742) who recognized in 1718 that stellar proper motions exist, but not until accurate stellar parallaxes were available in the nineteenth century could tangential velocities be measured. For a true three-dimensional sense of stellar motion, line-of-sight velocities were necessary. A detailed account of the development of radial-velocity work can be found in Hearnshaw (1986). Following Angelo Secchi's (1818–1878) suggestion, William Huggins (1824–1910) made the first attempts to measure stellar radial velocities in the late 1860s (Huggins, 1868). With a 15-inch refractor at Tulse Hill, he was able to measure radial velocities of thirty stars, which he published in 1872 (Huggins, 1872). These were visual observations. In the same year, Henry Draper (1837–1882) obtained the first spectrogram in the USA but his contemporaries, notably E.W. Maunder (1851–1928) at Greenwich and James E. Keeler (1857–1900), working with the Lick Observatory 36-inch refractor in 1890-1891, observed radial velocities visually.

Much enhanced accuracy came with the application of photography to recording the spectra by Hermann C. Vogel (1841–1907) and Julius Scheiner (1858–1913) at Potsdam. Vogel, following Huggins' lead, had made visual observations of radial velocities. Photographic work in collaboration with Scheiner commenced at the new Potsdam Astrophysical Observatory with the 30-cm refractor in 1887. By 1892, Vogel was able to publish the radial velocities of fifty-one stars (Vogel, 1892). During the 1890s, a number

Figure 2: The Solar Union meeting in Pasadena, 1910. Among those mentioned in the text, the photo includes Adams, Campbell, Deslandres, Hale, Kapteyn, Plaskett, Pickering, Schlesinger, Schwarzschild, and Turner. (Mount Wilson and Palomar Observatories, courtesy AIP Emilio Segrè Visual Archives).

of other workers became active, including A.A. Belopolsky (1854–1934) at Pulkovo, Keeler at the Allegheny Observatory, H.-A. Deslandres (1853–1948) at Paris and Hugh F. Newall (1857–1944) at Cambridge. Even with large refractors, spectrograms were not easily obtained: Belopolsky, working with the 76-cm refractor with a spectrograph based upon Vogel's design, could obtain a spectrogram of a fourth magnitude star in an hour's exposure. Few telescopes in the world were larger than Pulkovo's; thus, unless much larger telescopes were constructed or much more efficient spectrographs and photographic emulsions became available, radial velocities for fainter stars would be a long time in coming.

By the late 1890s, the undisputed master of stellar spectroscopy was W.W. Campbell (Figure 5) at Lick Observatory. After Keeler's departure for Allegheny, Campbell experimented with Keeler's visual spectroscope and then had a new spectrograph built. Thanks to a donation from banker D.O. Mills (1825–1910), Campbell was able to design and have constructed a new spectrograph with Brashear optics. Ready in 1896, the Mills Spectrograph (Figure 6) utilized three prisms and included the iron arc comparison method pioneered by Vogel and Belopolsky. Campbell (1898) reported that he could obtain a satisfactory spectrum for a magnitude 5.0 star in about an hour. Attached to the world's second largest telescope, the Mills Spectrograph was a formidable instrument. Working with William H. Wright (1871–1959) from 1897, Campbell commenced an observing programme to obtain radial velocities of stars brighter than magnitude 5.51 within reach of Lick. Flexure and loss of light were serious problems with the Mills Spectrograph, leading Campbell to design a much improved model in 1902. After Campbell succeeded Keeler as Lick Director in 1901, he tapped Mills again for funds to create a southern station in Chile. With a 93-cm Cassegrain reflector, Wright (1911), who had been despatched to direct the D.O. Mills Expedition, was able to obtain the radial velocities of 150 southern stars by 1906.

But why amass radial-velocity data in the first place? The initial urge seems to have been to obtain a more complete idea about stellar motions. The first discoveries of spectroscopic binary stars by Vogel and by Edward C. Pickering (1846–1919) in 1889 launched an important facet of radial-velocity research as it was soon realized that spectroscopic binary stars could yield stellar masses (Batten, 1988). The Lick Observatory would become a major player in this arena. A more focused interest in stellar dynamics emerged with the announcement, at the International Congress of Arts and Science at the St. Louis Exposition in 1904 by Kapteyn, of the discovery of two star streams. While Kapteyn's data came from proper motions, it was immediately clear that radial velocities would provide valuable information on the structure of the Milky Way.

4 PLASKETT BUILDS HIS LINKS

J.S. Plaskett (Figure 7) backed into astronomy. A skilled mechanic, he had worked in industrial shops before being hired as mechanical assistant in the Physics Department at the University of Toronto in the 1890s. Already married with a family, he entered the University as a student and took his BA in physics, at the age

Figure 3: Karl Schwarzschild, 1873–1916 (courtesy: Springer-Verlag).

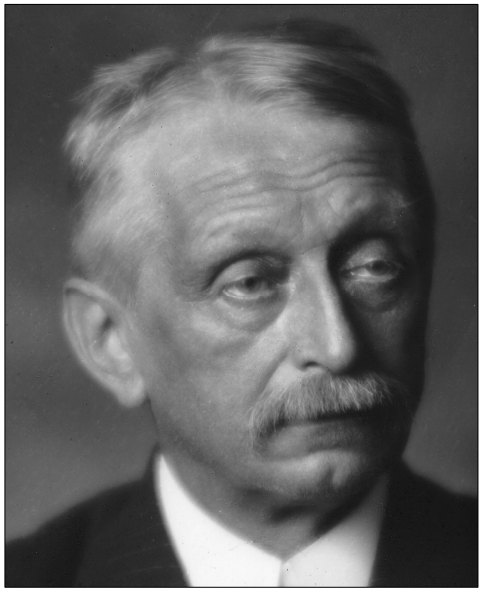

Figure 4: Jacobus Cornelius Kapteyn, 1851–1922 (courtesy: Adriaan Blaauw, University of Groningen).

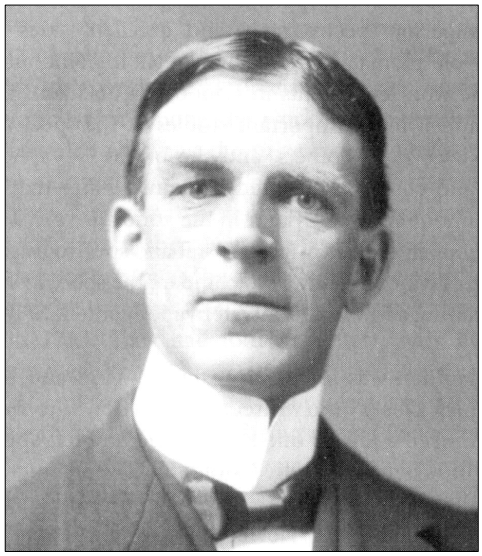

Figure 5: William Wallace Campbell, 1862–1938 (after Macpherson, 1905, facing p. 240).

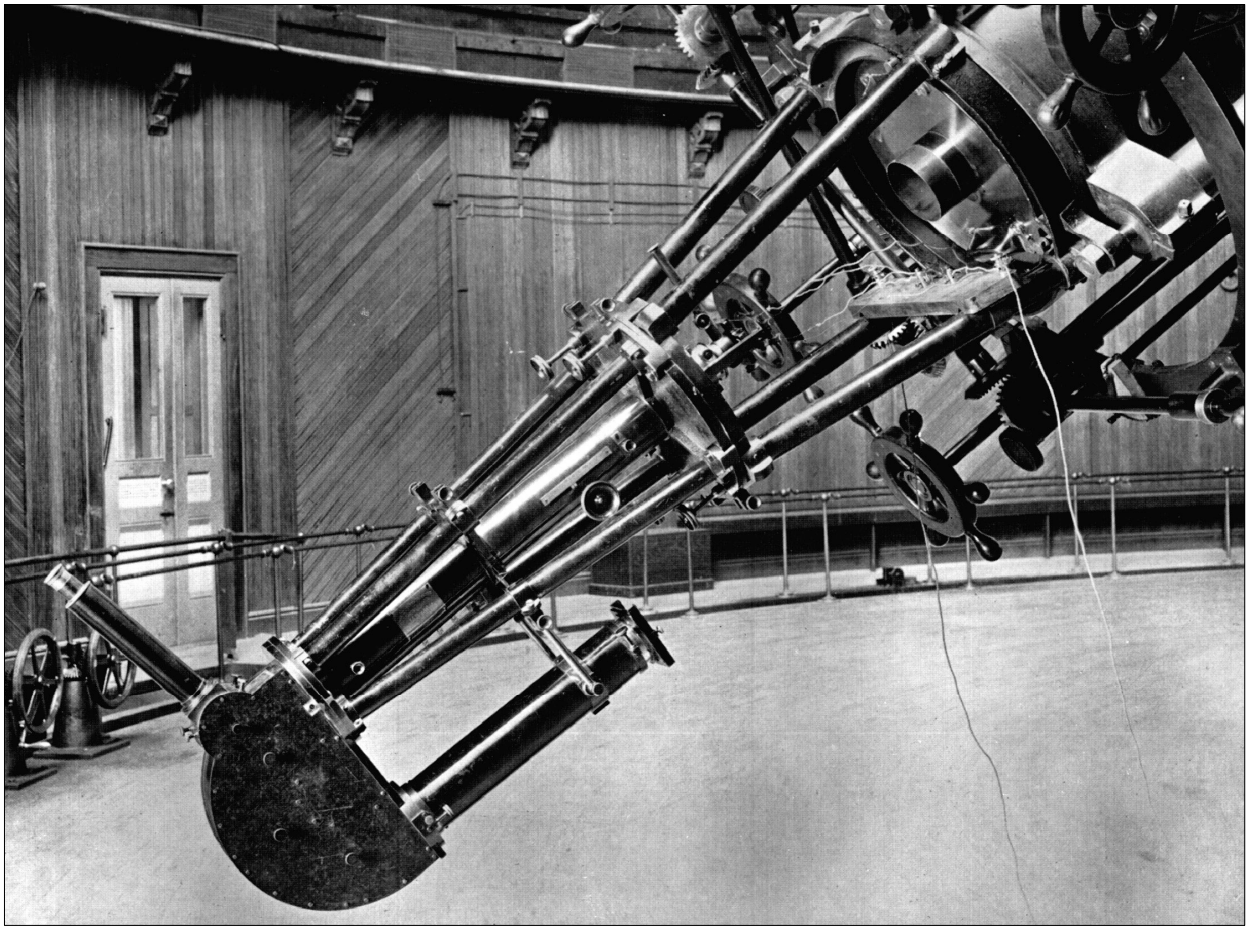

Figure 6: The Mills Spectrograph mounted on the Lick 36-inch refractor (after Campbell, 1928).

of thirty-three, in 1899. There was as yet no astronomy programme at the University and there is no indication of Plaskett's interest in the subject. Continuing

Figure 7: John S. Plaskett (courtesy: National Research Council of Canada, Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory).

in the employ of the University, he turned his attention to experiments in colour photography. In 1902, upon hearing that the Dominion Observatory, then being erected in Ottawa, was seeking employees, Plaskett applied and was hired the following year as Mechanical Superintendent.

When the initial staff was assembled in 1903, there were only two permanent employees—Dr William F. King (1854–1916) and Otto J. Klotz (1852–1923)—both of whom were veterans of the survey of western Canada and neither of whom had a direct interest in astrophysics. Nonetheless, they ensured the Observatory was equipped with a Warner and Swasey 15-inch equatorial refractor with Brashear optics. With the telescope came an off-the-shelf spectrograph (Figure 8). None of the staff had any experience with such equipment, so Plaskett was placed in charge of the instrument. An ambitious man, he immediately began thinking about research projects for the Observatory and wrote to key figures in American astronomy. Early in 1906, with King's blessing, he undertook a 'grand tour' of American observatories, including Lick, Yerkes, Lowell, Mount Wilson, Allegheny, Flower, Harvard and the US Naval Observatory. This brought him into direct contact with later correspondents such as Campbell, Schlesinger and Hale. From a mechanic's point of view, the highlight was having Campbell show him the details of the rebuilt Mills Spectrograph at Lick.

From what he saw and heard, radial-velocity work appealed the most to him and he wrote to Edwin B.

Frost (1866–1935) at Yerkes for advice. Frost replied on 19 June 1906 that he believed the Dominion Observatory's telescope would be capable of dealing with brighter stars and spectroscopic binaries. As he noted, K.F. Küstner (1856–1936) in Bonn had been successful with a somewhat smaller instrument (Frost, 1906). At that point, Frost who, like Belopolsky, had trained under Vogel, was a key American radial-velocity researcher. Plaskett also approached Hale with the idea of entering solar research; during the decade, with much encouragement from Hale, Plaskett built a horizontal solar telescope and began working on solar rotation. It was this work that brought him into contact with Walter S. Adams (1876–1956) (Figure 9) at Mount Wilson and linked the Dominion Observatory to the Solar Union.

With the help of newly-hired junior assistants, Plaskett inaugurated work on radial velocities and spectroscopic binaries. He was open to cooperation, and Frost was known publicly as a proponent of cooperative work: in 1902, Frost published an article, "Cooperation in observing radial velocities of selected stars", in the *Astrophysical Journal*. In that year, he had distributed two circular letters to the key radial velocities workers—Belopolsky, Campbell, Deslandres, Gill, Newall, Vogel and Henry C. Lord (1866–1926) of the McMillin Observatory of the Ohio State University—to ask for their cooperation to observe twenty 'fundamental velocity stars' and to compare their measurements. Frost's proposal was received with approval. Once his own work was up and running, Plaskett turned to Frost for advice on what to do with his data. Frost (1907a) replied that

> In the present state of research on the radial velocities of stars, so much remains to be done that it seems important to avoid duplication of work in certain directions, and to secure instead cooperation where feasible.

He suggested that the *Astrophysical Journal* might be the vehicle to let people know what the Dominion Observatory planned. If others already have plates, they might share them. He invited Plaskett to announce his intentions in the pages of the Journal, of which he had been Editor since 1902. Plaskett did send a list of stars he intended to target; in reply, Frost (1907b) suggested that it might be time for the establishment of a Standing Committee on Stellar Spectroscopy in the Astronomical and Astrophysical Society of America.

5 THE COMMITTEE ON RADIAL VELOCITIES

From 17 to 19 August 1910 members of the Astronomical and Astrophysical Society of America gathered in Cambridge, Massachusetts (Figure 10). Their host was Edward C. Pickering, Director of the Harvard College Observatory and an internationally-recognized authority on stellar classification; he was also, like Hale, an apostle of international cooperation. Despite its name, the Society had a modest international flavour, with a handful of Canadian members and the occasional visitor from overseas. The 1910 meeting was noteworthy thanks to a contingent of European and British astronomers *en route* to Hale's Solar Union conference to be held in Pasadena a week later. Two proposals which would invoke international cooperation were mooted in Cambridge during the meeting. First was a proposal by Pickering that a committee be struck to find consensus on a stellar spectral-classification scheme. North American astronomers were familiar with Pickering's Henry Draper Catalog classification scheme but it was not uncontested: both Norman Lockyer (1836–1920) and Vogel had competing systems (see Hearnshaw, 2010).

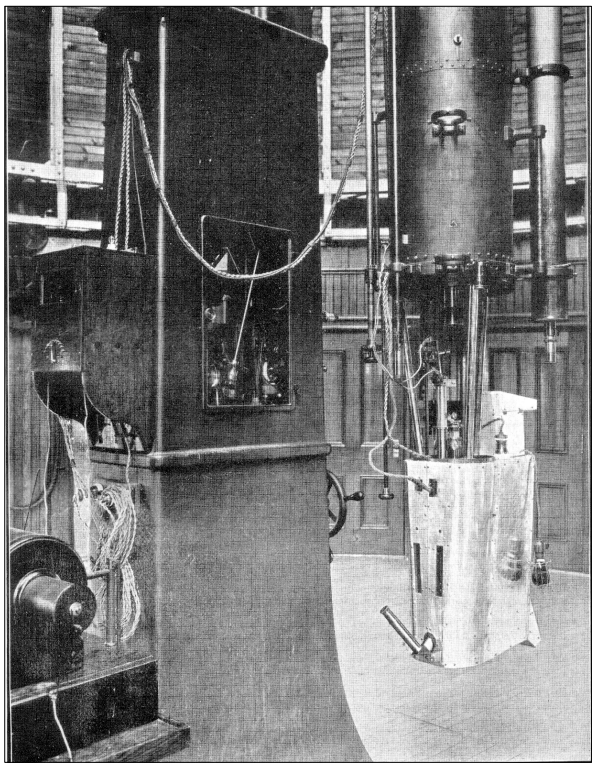

Figure 8: The spectrograph of the Dominion Observatory 15-inch refractor (*Report of the Chief Astronomer*, 1907).

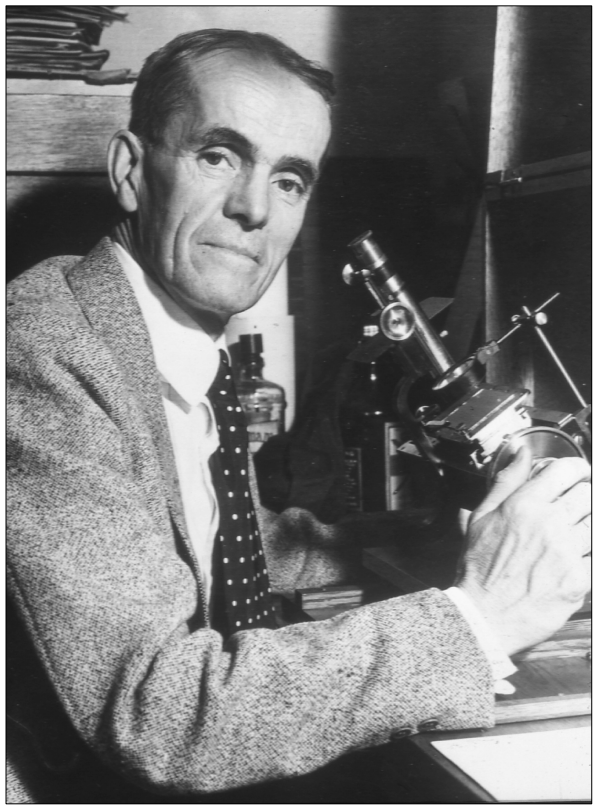

Figure 9: Walter S. Adams (courtesy: Yerkes Observatory, University of Chicago).

Figure 10: August 1910 meeting of the Astronomical and Astrophysical Society of America (after Plaskett, 1910).

The Committee on Classification was cooperative in the sense that Pickering was hoping to obtain wide consensus on a system which could be adopted as an international standard (DeVorkin, 1981). This form of cooperation—which combined intense Committee discussion, circulation of a questionnaire and commentaries from experts from a number of nations—was really a high-level form of housekeeping.

Pickering's team at Harvard had worked assiduously for years obtaining and classifying spectra. He was not asking for astronomers at other observatories to undertake a commitment for further, extensive observational and classificatory work. Detailed Committee discussion mostly occurred on the train west from Boston to California (Plotkin, 1978).

Somewhat overshadowed by the Classification Committee was a second Committee devoted to international cooperation in radial-velocity determinations. This was Campbell's dream, which he proposed in a letter of 9 August 1910 to William J. Hussey (1863–1926), Secretary of the Society. In it he suggested a Committee be struck "… to study and report upon the subject of cooperation on the part of observatories engaged in the measurement of stellar radial velocities." (Campbell, 1912b). Campbell's idea was a programme to observe stars fainter than fifth magnitude. There was no need for a cooperative effort for brighter stars, as Lick and its Chilean station had systematically worked through these—the programme largely finished in 1909—except for a few spectroscopic binaries. At the Cambridge meeting it was Campbell who proposed striking the Committee. It is not clear whether Campbell proposed names for the Committee, whether they volunteered or were proposed by third parties. All the members selected were to travel by train to California and to re-convene for further discussions during the Solar Union meeting. Those selected were a veritable 'Who's Who' of stellar spectroscopy (Figure 11): besides Campbell there was Newall from the Cambridge Solar Observatory; Frost of Yerkes; Johannes Hartmann (1865–1936) of Göttingen University; Karl Schwarzschild of the Potsdam Astrophysical Observatory; Frank Schlesinger (1871–1943) of the Allegheny Observatory and Plaskett of the Dominion Observatory. Hartmann and Percival Lowell (1855–1916) were added when the Committee came together at Mount Wilson (Plaskett, 1910), but the latter seems not to have participated in any meaningful way.

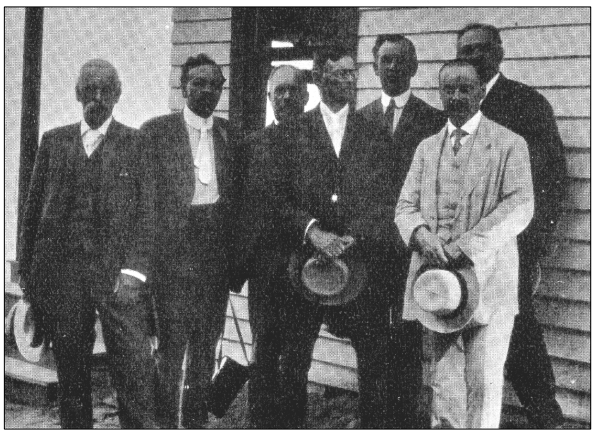

Figure 11: The Radial Velocity Committee at Mount Wilson. Left to right: Newall, Plaskett, Hartmann, Frost, Campbell, Schwarzschild, Schlesinger (Plaskett, 1910).

Curiously, two key workers in the field, Belopolsky and Deslandres, were not named for the Committee, although both were at Pasadena. They may have been sounded out but declined to join. Neither were they nor Lockyer named for the Classification Committee. There was considerable overlap of Pickering's Classification Committee and Campbell's Radial Velocity Committee, with Campbell, Frost, Newall, Plaskett, Schlesinger and Schwarzschild serving on both. Plaskett reported that the Committee had one meeting at Mount Wilson on 1 September "… where the question was discussed in a general way, with especial reference to means of overcoming the enormous loss of light in all modern spectrographs." (Plaskett, 1910:

376). By way of a preliminary report (Plaskett, 1911), Campbell wrote to Hussey after the meeting noting that the Committee felt that there was not the requisite instrumentation to tackle fainter stars and suggested that observatories focus on spectroscopic binaries. Committee members did not know in August 1910 whether the Solar Observatory at Mount Wilson would participate in their work; its two-year-old 60-inch telescope (Figure 12) was the most powerful instrument in the world. A few months after the meeting, Adams consulted with Campbell on future work and agreed to undertake radial-velocity observations of stars fainter than magnitude 5.5. Campbell was disappointed that so few could carry on the work. He noted that the spectrograph on the 36-inch refractor, when in the Littrow form, could obtain spectrograms of stars down to magnitude 7.0 with reasonable accuracy and exposure times. Plaskett's response to Campbell's preliminary report was to reaffirm his desire to improve spectrograph efficiency, given that he had no immediate prospect of a larger telescope.

6 THE AFTERMATH OF THE 1910 MEETINGS

Campbell had intended to provide a report of the Committee's deliberations at the 1911 Ottawa meeting of the Astronomical and Astrophysical Society of America. At the time of the meeting, he found himself in a Munich hospital recovering from typhoid fever; he sent his regrets to King, which were read out at the meeting (Chant, 1911). No publication or official report ever appeared. The energetic Campbell and his colleagues continued their work unabated at Lick. Systematic stellar radial-velocity work terminated with the publication in 1913 of a catalogue of 915 stars (Campbell, 1913a). During the decade from 1910 to 1919, Campbell, Wright and Joseph Moore (1878–1949) concentrated on nebular spectroscopy.

Most of the other Committee members abandoned radial-velocity work in the following decade. Newall had published a number of radial-velocity measurements in 1903 and 1905 and designed and built spectrographs. His site and instrument—he was effectively restricted to fourth-magnitude stars—were factors limiting further work although, in the event, a serious bout of illness led Newall to abandon stellar work and shift to solar research after 1904 (Hutchins, 2008: 301). He published nothing on radial velocities after the Solar Union meeting. Hartmann, although an accomplished spectroscopist, also published nothing further on the subject. Having lost the Directorship of the Potsdam Observatory to Schwarzschild, he had moved to Göttingen in 1909 where he had no access to modern equipment. Schwarzschild himself had never published on radial velocities. He joined the German army in 1914 and was dead from illness two years later. Schlesinger, at Allegheny Observatory, had the 30-inch Thaw refractor available from 1914 but his interest lay in stellar parallaxes, although his assistants, Zaccheus Daniel (1874–1964) and Frank Jordan (1865–1941), published a few papers on stellar radial velocities and binary star orbits. Parallaxes continued to be central for Schlesinger after his move to Yale in 1920. Frost had made a promising start at Yerkes but with the move of his collaborator, Adams, to California and a heavy administrative load, he essentially dropped out of active research. The increasing loss of his eyesight from 1915 spelled the end of observational work. That left only Plaskett, but he, having realized the value of the large reflector when he saw G.W. Ritchey's 60-inch telescope at Mount Wilson, put his energies into obtaining a large reflector for the Dominion Observatory. While some radial-velocity work continued at Ottawa, it was performed by his assistants. Thus, apart from Campbell and Plaskett, the personal commitment to radial-velocity work was lacking in the Committee members.

Campbell and Plaskett remained in touch. In 1911, the former described Lick's efforts in Chile and noted that the only observatories prosecuting radial-velocity work were Lick, Allegheny, Lowell, Ottawa and Yerkes in North America; Bonn, Potsdam and Pulkovo in Europe; and, in the southern hemisphere, only the Cape and the Lick station. Mount Wilson had just commenced work, and Michigan would soon join in with Ralph Curtiss' (1880–1929) new 37.5-inch reflector at the Detroit Observatory (Campbell, 1911b).

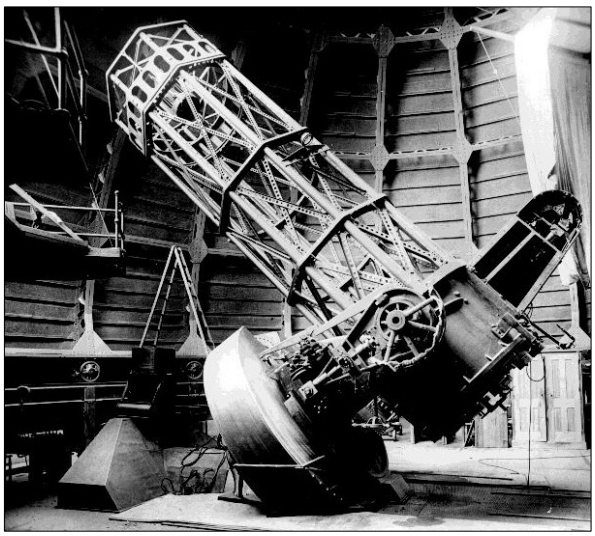

Figure 12: The 60-inch reflector at Mount Wilson with the three-prism spectrograph (after Adams, 1912: Plate 10).

Plaskett recognized he could not continue to participate in an international spectroscopic enterprise with the limited equipment in Ottawa. His quest to obtain a large reflector for the Observatory was focused upon keeping Canada (and himself) 'in the game', and he called upon his contacts for support at critical moments in his lobbying efforts. The Astronomical and Astrophysical Society of America met at the Dominion Observatory in 1911, the first meeting of the AASA outside the United States.[1] Plaskett had worked with King to lure the Society north, partly to obtain its sanction for the telescope project. When he heard that the Society had endorsed the scheme, Campbell (1911a) wrote to King to add his approbation:

> My investigations on the radial velocities of stars have led me to take a special interest in the Dominion Observatory's researches in the same field, by Dr. Plaskett. Considering the size of the telescope at Dr. Plaskett's command, his results have certainly been all that the most hopeful could have wished.

Campbell added that the work needed to be pressed to stars of fainter magnitude, so a large telescope was essential.

For further support, Plaskett called upon other members of the Committee on Radial Velocities—Schle-

singer, Newall and Schwarzschild—along with Frank Dyson (1868–1939) at Greenwich and Pickering at Harvard. Schwarzschild (1912), in writing to King, lauded Plaskett's publications which

> … belong to the class which are awaited by us with eagerness for the reason that they are of the best in the province of radial velocity determinations.

For Schwarzschild, it had been a friendly rivalry but now astronomers needed to reach sixth-magnitude stars. He reminded King that the Committee formed in 1910 had hoped to partition the work for northern hemisphere observatories but only Lick and Mount Wilson were capable of reaching stars between magnitude 5 and 6.5. At the same time, in writing to

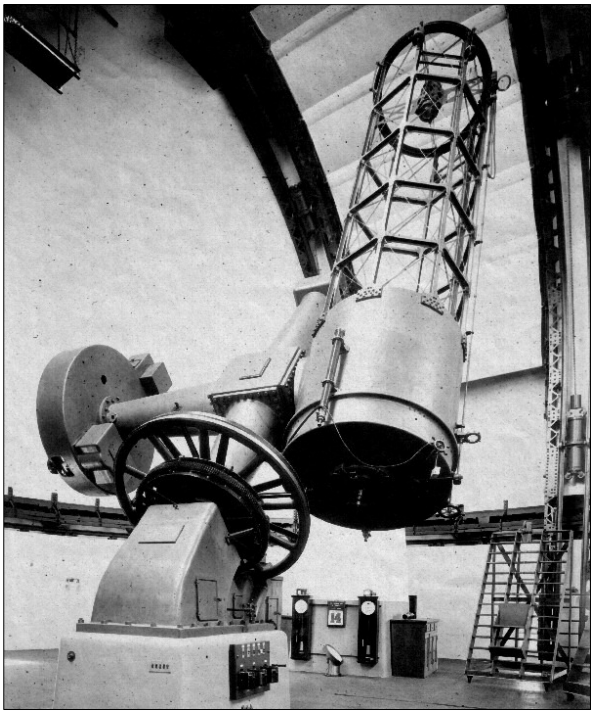

Figure 13: The 72-inch reflector of the Dominion Astrophysical Observatory, now rightly named the John S. Plaskett Telescope (courtesy: National Research Council of Canada, Herzberg Institute of Astrophysics, Dominion Astrophysical Observatory).

King, Campbell (1912a) reiterated the need for cooperation:

> There ought to be a coöperative organization of observatories possessing large telescopes to the end that the sky would be divided amongst these observatories for the spectrographic observations referred to. There is so much to be done that even half a dozen large institutions in each of the hemispheres cannot complete the work within a generation.

The project obtained the blessing of the Canadian Government but observations would not commence in Victoria until the spring of 1918.

It is clear that the Committee on Radial Velocities, despite its hope of international cooperation, could not follow through on its promise. First, there was the limitation of instruments capable of such work. Only two refractors, those at Lick and at Yerkes, were large enough to permit radial-velocity work on fainter stars. Campbell could obtain usable spectrograms of sixth-magnitude stars, but those required 2.5-hour exposures. While the Yerkes refractor was marginally larger, its site was inferior and its staff uninterested. Most of the other large refractors in America and Europe were in the 70-80 cm range; they were simply not capable of pushing the limits to fainter stars. Only one reflector of large size, the Mount Wilson 60-inch, was up to the challenge; larger reflectors at Mount Wilson and Victoria were almost a decade away. No large telescope projects were underway in Europe.

A second limitation came with the outbreak of war in 1914, which sundered international scientific cooperation. In October 1914 Adams, in remarking upon cooperation in solar research, admitted to Plaskett that

> … it seems questionable whether it would be desirable for us to inaugurate work which would require a considerable amount of cooperation during the present extraordinary state of international affair. (Adams, 1914).

This would have applied equally to stellar spectroscopy. German astronomers, so prominent in the rise of astronomical spectroscopy, were soon seen as pariahs by American, British and French astronomers. We need only recall that the British heard about Einstein's relativity through the conduit of de Sitter in the neutral Netherlands. Near war's end, Kapteyn and others argued to salvage international cooperation but to no avail (Kevles, 1971). When the International Astronomical Union came together in 1919, Hale, who had been a key scientific adviser to the American government, and his associates ensured that Germany was not part of the IAU.

7 A COOPERATIVE PROGRAMME FINALLY LAUNCHED

The hopes of the original Committee were quickly deflated. Then came the war. Only during the last year of the war did a gleam of hope for a revival of a cooperative venture appear. In this Plaskett was to become a pivotal actor. As early as 1913, when the Canadian Government agreed to order the 72-inch telescope, Plaskett had signaled that radial-velocity work would be its primary purpose, which Campbell (1913b) was pleased to hear. Hale had been kept in the loop and in November 1916 welcomed Plaskett's plan to come down to Pasadena to discuss the future observing programme for Victoria. By the next summer, work was sufficiently advanced for Plaskett to initiate planning. As he mentioned to Adams, with three large telescopes soon to be in operation on the west coast, cooperation would be needed; he had written Hale for advice but as he was away from Pasadena much of the time mostly in Washington for war work, Adams became the key contact and Plaskett (1917) planned to travel south for detailed discussions with him.

The 72-inch (1.83-m) telescope (Figure 13) began operations in May 1918. Plaskett had written to Kapteyn in late 1917 asking for advice. Kapteyn had suggested tackling stars in Boss' Preliminary General Catalogue, which had been published in 1910. When Campbell visited Victoria at this time, he committed Lick to a cooperative venture, offering to take brighter stars from declination –5º to the pole if Mount Wilson and the DAO would take the rest. But, as Plaskett reminded Campbell, there were only himself and R.K. Young (1886–1977) to do all the work; they could tackle 1,000-1,200 stars but no more (Plaskett, 1918a;

1918b). Hale was willing to cooperate and was sure that Adams would share in the work. Observing Boss stars would not work, however; Adams was well advanced on working through the list and expected to complete the work within eighteen months. As Plaskett told Campbell, there was no point in tackling Boss stars, although Hale had suggested observing all stars brighter than a certain limit in selected areas. Plaskett felt that the chance of Mount Wilson co-operating was now small. In the meantime, the DAO could tackle stars north of the celestial equator brighter than magnitude 6.5 or about 1,500 stars (Hale, 1918; Plaskett, 1918c). What would Campbell counsel? Campbell's reply (1918) suggests that he was never sanguine about the prospects:

> I read your first suggestions as to the cooperative plans and likewise the comments in your last letter. I think I made it clear, on your first mentioning the subject, that my expectation of the outcome is in good agreement with what the sequel developed. There would seem to be nothing gained by pursuing the subject further.

By the end of July 1918, however, Adams agreed to cooperate and to divvy up the remaining Boss stars with Lick and the DAO, while hoping that spectroscopic parallax observations would overlap to some extent. Plaskett knew that Mount Wilson had concentrated on later spectral types (F to M) and offered to begin with the O-type stars, which turned out later to have been fortuitous (Adams, 1918; Plaskett, 1918e; 1918f). The work was a grind: at Victoria, Plaskett and Young did all the observing—an entire night each —plus the measuring of plates and the computations with no assistance from staff like at Mount Wilson. Nonetheless, as he reported to Hale, it was routine work that a national institution should undertake and a contribution to the good of science (Plaskett, 1918d). By 1922, Adams and Alfred Joy (1882–1973) assembled a catalogue of 1,013 stars whose radial velocities had been measured from plates from both the 60-inch and 100-inch reflectors (Adams and Joy, 1922). In Victoria, Plaskett and Young had been joined by W.E. Harper (1878–1940) from the Ottawa staff and by Plaskett's son, Harry (1893–1980), allowing for a quickening of pace; their first fruits appeared in 1921 (Plaskett et al., 1921). Over time, staff would push the instrument to stars as faint as magnitude 9, depending upon the spectral type of the star and dispersion of the spectrograph (Batten, pers. comm.., 2010).

Radial-velocity work did continue at other observatories, but few could reach any but the brighter stars. Despite the interest in this field of research, the number of workers remained small. Struve and Zebergs (1962) estimated the number of professional astronomers in the world in 1920 at about 1,000. Of these, a search of the Harvard ADS for the period 1920-1925 shows approximately fifty people publishing on radial velocities. This was a rather small subset of astronomy, and the number of workers involved in systematic observation was considerably smaller. Up to this point, cooperation had been worked out on a personal basis; from the mid-1920s, the organizational focus for radial-velocity work was in the International Astronomical Union (IAU).

8 RADIAL-VELOCITY WORK IN A LARGER CONTEXT

Plaskett had maintained his contact with Hale after the 1910 meeting, although most of his correspondence with the Mount Wilson staff was with Adams. Hale was pleased to hear of the progress of the Victoria telescope, but international cooperation was still on his mind. Adams had shown him Plaskett's letter on radial-velocity cooperation; Hale (1918), as President of the National Research Council, had a special duty to foster such ventures. A few months later, the International Council of Scientific Unions, another pet project of Hale's, met in Paris. The delegates at the November 1918 meeting, wanting to expand the cooperative efforts already in progress with the Carte du Ciel and the Solar Union, voted to create the IAU.

Hale, in another of his roles as a member of the National Academy of Sciences, established the American section of the proposed Union in Washington, DC, in March 1919. At that time, eighteen research areas were identified for committees, one of which was radial velocities. One of the delegates was Schlesinger, Plaskett's long-time friend. They had spent time together at the 1913 Bonn meeting of the Solar Union and, although their research interests diverged, had maintained contact. Schlesinger (1919) put down Plaskett's name for the Radial Velocity Committee, although Plaskett was not an American. Joel Stebbins (1878–1966) confirmed that he would join Adams and Campbell on the American Committee. The three were asked to prepare a report which would be delivered to the organizational meeting, probably in July (Stebbins, 1919).

This must have been awkward for Plaskett. He reported to Hale on 3 July 1919 that he had recently attended a meeting of the Royal Society of Canada but no mention was made about Canadian participation in the new Union (Plaskett, 1919). Plaskett certainly desired Canadian membership in the Union and asked Hale's advice on how to proceed, considering the former was a member of an American Committee. Hale was supportive: "Be assured that it will be a pleasure for us to cooperate with you in every possible way." (Hale, 1919). Canada became an adhering nation in 1920 but when the first regular meeting of the IAU opened in Rome in 1922, Plaskett found that Dominion Astronomer Otto Klotz would be the Canadian delegate, with R.K. Young as second choice. This decision, he reported to Hale petulantly, had probably been 'engineered' by Ottawa as his success had never been well received (Plaskett, 1922a). In fact, Klotz and Plaskett had had cool relations since the latter's move to British Columbia. However, a year later Klotz was dead and Plaskett had much more freedom of action in Victoria. He was also soon in the thick of IAU activities. With the establishment of commissions at the Rome meeting, Plaskett was elected to Commission 27 (Variable Stars), Commission 29 (Stellar Classification) and Commission 30 (Radial Velocities). The west-coast group dominated Commission 30 for decades: Campbell was President for 1922-1932; followed by Plaskett for 1932-1935; by Adams for 1935-1948; and by Joseph A. Pearce (1893–1988), later a Director of the DAO, for 1948-1952. Over the years, five of the nineteen Commission Presidents have been Canadians.

Thanks to the on-going work on radial velocities of individual stars and published orbits of spectroscopic binary stars, accumulating data called for the pro-

duction of regular catalogues. From the early 1920s, except for its southern station, Lick was largely out of the picture for radial-velocity work, although Moore contributed a few papers and Peter van de Kamp (1901–1995) undertook a more detailed study of solar motion. Campbell's election to the Presidencies of the IAU and the American Astronomical Society in 1922 and his appointment as President of the University of California in 1922 largely removed him from active research. Lick's contribution in the 1920s and 1930s was to compile updates to Campbell's catalogue. The staff at Mount Wilson, on the other hand, with two large reflectors, continued to be active. Adams and Joy employed the 100-inch (2.54-m) reflector from 1918, continuing to concentrate upon the late-type stars. Two catalogues, one in 1923 and a second in 1929, provided the radial velocities of an additional 1,754 stars (Adams and Joy, 1923; Adams et al., 1929).

Both Adams and Plaskett had other interests in stellar spectroscopy. The former and his colleagues developed the method of spectroscopic parallax and pursued absolute magnitude observations, while the latter and his colleagues carried on their work on spectroscopic binaries. With Plaskett's appointment to the American Radial Velocity Committee, this opened another possibility for cooperation on spectroscopic binaries. In 1920, he suggested to Adams that the new Committee deal with the issue of spectroscopic binary observations piling up faster than anyone could deal with them; a meeting of the west-coast members of the Committee might be useful (Plaskett, 1920). With no immediate action, Plaskett (1922b) wrote to Campbell in April 1922 to suggest a meeting of the Mount Wilson, Lick and DAO staff to talk about further cooperation. What Campbell had in mind was a revision of his 1910 catalogue of spectroscopic binaries (Campbell, 1910). Young and Harper had hoped to undertake a new catalogue at Victoria, but evidently Campbell's wish prevailed. R.G. Aitken (1864–1951), another of Plaskett's long-time friends, was relieved to hear that the DAO would not pursue their project, which would please Campbell. Plaskett thought that Lick had abandoned the idea years earlier but agreed to provide his unpublished data; in fact, he had already written to Mount Wilson, Yerkes, Allegheny, Ann Arbor, the Cape, Vienna, Potsdam, Pulkovo and Yale to solicit material (Aitken, 1924; Plaskett, 1924). Adams (1924) was not pleased with the outcome:

> I am sorry that you are not going to compile the catalogue of spectroscopic binaries at Victoria. I feel that you would do it very much more satisfactorily than Dr. Campbell could in view of the great amount of work which he has on his hands. I suppose, however, that you are rather helpless in the matter so long as he presses his intentions to carry out this work.

Adams turned out to be partly right: it was not Campbell who undertook the third catalogue but Joseph Moore (1924). Moore also produced the fourth and fifth catalogues in 1936 and 1948, respectively. After Moore's death, the torch was passed to the DAO with the intention that Pearce and Petrie produce a new edition, but for various reasons neither could do so (Batten, pers. comm., 2010) and eventually Alan Batten (1967) produced the sixth catalogue in 1967.

By the late 1920s, the increasing mountain of spectroscopic binary star data called for a catalogue with weighted values. After discussion in IAU Commission 30, Plaskett (who was then the President) and its members delegated the task to Moore, who produced a catalogue of the radial velocities of more than 6,700 stars (Moore, 1932). The Lick Observatory monopoly on cataloguing was eventually broken: Ralph Wilson (1886–1960) of Mount Wilson, produced a much larger catalogue, of some 15,107 stars, in the early 1950s (Wilson, 1953). Three quarters of the radial-velocity determinations had come from Mount Wilson, Lick and the DAO.

The original impulse to undertake large-scale measurements of stellar radial velocities had come in the wake of Kapteyn's work on stellar motions. Harlow Shapley's (1885–1972) publication in 1922 suggesting that the centre of the Milky Way was as much as 20 kpc from the Solar System was a clue for Bertil Lindblad (1895–1965) to suggest our Galaxy is a disk with differential rotation (Shapley, 1922; Lindblad, 1925). Given the mass of radial-velocity data available by the late 1920s, Jan Oort (1927) was able to argue persuasively for the idea. Not surprisingly, some of his data came from publications from Lick, Mount Wilson and Victoria. As Plaskett and Pearce had accumulated data on O-type stars which, thanks to their intrinsic brightnesses, allowed for a probe to greater depths, plus a number of B-stype stars, they were able to confirm Oort's model almost immediately (see Plaskett, 1928; Plaskett and Pearce, 1934). In fact, Plaskett had visited Oort in Leiden in 1927 and was likely already attuned to Lindblad's and Oort's ideas. This was a satisfactory result of a decade's work.

9 CONCLUSION

Plaskett retired in 1935 but left a long-reaching legacy. Radial-velocity work continued at Victoria in the hands of Pearce and later Robert M. Petrie (1906–1966) and their colleagues, who turned to a more ambitious survey of O- and B-type stars with magnitudes down to 9.0. Others on the Victoria staff undertook more limited surveys of the radial velocities of A- and K-type stars. Young, one of Plaskett's early assistants at both Ottawa and Victoria, had moved to the Astronomy Department at the University of Toronto in 1924. Toronto had no large telescope but thanks to the unflagging efforts of the Department's head, Clarence Augustus Chant (1865–1956), the University opened the David Dunlap Observatory in 1935, which was equipped with a 74-inch (1.88-m) reflector patterned on the Victoria instrument. Young had supplied the technical expertise for the telescope's design. As this was an instrument that was built primarily for spectroscopy, radial-velocity work also continued at Toronto under Young and his successors as Director, Frank Hogg (1904–1951) and Jack Heard (1907–1976). Even as late as the mid-1950s, Henry King (1955: 312) could write in reference to Campbell's discovery that corrected radial velocities of stars change steadily with Harvard spectral class:

> This significant relationship together with work in radial velocities in general, has received and continues to receive the close attention of the astronomers at Mt. Wilson, at Victoria, B.C., and at Toronto.

The other long-term effect was, as I have argued elsewhere (Jarrell, 1999), the construction of a genera-

tion of two-metre reflectors based upon Plaskett's design. The work of most of these telescopes was spectroscopic as none was as powerful as the 100-inch and later 200-inch telescopes for extragalactic research. Hearnshaw (1986) notes a number of important stellar radial-velocity workers. Otto Struve (1897 –1963) and his co-workers used the 82-inch reflector at the McDonald Observatory from 1939, reviving the Yerkes tradition. In the late 1940s, the 74-inch Radcliffe reflector in Pretoria was brought into play to reinaugurate southern hemisphere radial-velocity work, particularly by A.D. Thackeray (1910–1978). A similar instrument at Mount Stromlo in the mid-1950s allowed for the expansion of Australian efforts in this work. While this important line of research lost its lustre by the 1960s, an enormous mass of data was available, much of it procured by the astronomers and instruments of the cooperative ventures that had their origins in 1910.

10 NOTES

1. The Society would take its current name, the American Astronomical Society, three years later.

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RG48 (followed by the volume number) = Dominion Astrophysical Observatory records

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