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RONALD A. McINTOSH: PIONEER SOUTHERN HEMISPHERE METEOR OBSERVER

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Abstract: The Auckland amateur astronomer Ronald A. McIntosh was New Zealand's premier meteor researcher from the mid-1920s through the mid-1940s and was a leading authority on Southern Hemisphere meteor showers. Using his own visual observations and those contributed by other members of the Meteor Section of the New Zealand Astronomical Society (later the Royal Astronomical Society of New Zealand) McIntosh was able to write a succession of research papers and reports on various aspects of meteor astronomy. Collectively, these made an important contribution to meteor science in the days before the advent of radar investigations of meteors.

In this paper we review McIntosh's meteor astronomy publications and then summarise the launch of New Zealand radar meteor astronomy immediately after World War II.

Keywords: Ronald A. McIntosh, New Zealand, meteors, meteor showers, radiants, heights, velocities, paths

1 INTRODUCTION

The science of meteor astronomy was still in its infancy early in the twentieth century. Little was known about cometary nuclei and their formation of meteoroids, although it had been found that some annual meteor showers had orbits similar to some comets. Research on the existence of non-shower (sporadic) meteors was in its infancy. Until after World War II, systematic meteor observers were rare in the Southern Hemisphere. The vast majority of meteor observations were made by observers based in Europe and North America, so from the late 1920's through into the mid-1950's, R.A. McIntosh and other members of the Meteor Section of the New Zealand Astronomical Society (NZAS) and its successor the Royal Astronomical Society of New Zealand (RASNZ) were able to make an important contribution to Southern Hemisphere meteor astronomy (Luciuk and Orchiston, 2010; Orchiston, 2016).

McIntosh was a journalist and had no formal astronomical training, but he was a dedicated observer of meteors (and of other astronomical phenomena). Although self-taught, he succeeded in calculating the shower radiants and orbits from the Meteor Section's observations. His work was acknowledged by professional meteor astronomers at the time, and current meteor publications still reference this talented New Zealander's meteor shower radiant observations.

Although photography was available when McIntosh was active, the New Zealand Meteor Section concentrated on naked-eye observations. Photography had advantages in meteor path accuracy, but was quite expensive for amateur observers and had relatively poor sensitivity to fainter meteors compared to naked-eye observations. After World War II (henceforth WWII), radar detection became the most efficient means of capturing meteor data, thereby bringing McIntosh's meteor observing to an end.

2 RONALD ALEXANDER McINTOSH: A BIOGRAPHICAL SKETCH

McIntosh (Figure 1) was born on 1904 January 21 to William John Alexander and Lucy Jane McIntosh in Auckland, New Zealand. His early schooling was at St. Mary's Convent and the Marist Brothers School in Auckland. Shortly

Figure 1: R.A. McIntosh ca. 1934 (Orchiston Collection).

before his fifteenth birthday he completed his Proficiency Examination and left school. He next attended Seddon Memorial Technical College's night classes, five nights a week. By the end of 1920, "… he passed eighth in the Public Service Entrance Examination and also obtained a partial pass in the Matriculation Examination." (Bateson, 1977: 82). In 1922, McIntosh studied for the Professional Accountants' Examination and achieved his pass in Economics and Mercantile Law. In 1923 he completed Company Law and Bankruptcy Law. This ended his formal education. His astronomical and computational knowledge were self-taught.

McIntosh had a variety of occupations during his lifetime (Orchiston, 2016: 524–526). His first position, after leaving Marist Brothers, was as an office boy. After College he became a junior clerk, then nine months later an accountant for a dairy company. In 1926, he joined the *New Zealand Herald* newspaper as a proofreader, and he eventually rose to the position of Cable Sub-Editor. McIntosh joined the New Zealand Army in 1941 June in the 1st Battalion, Auckland Regiment, and was posted to the Intelligence Section. One year later he went to the Intelligence Section of the Auckland Fortress Headquarters. He reached the rank of sergeant, was discharged in 1944, and returned to the *New Zealand Herald*.

In 1946, McIntosh resigned from the *Herald* to become Editor of *Young New Zealander.* After it ceased publication in 1948, he joined *White's Flying Magazine* for two years. He then joined the Auckland Public Relations Office as Manager of Printing, Publicity and Information, a position he held until 1957. He then rejoined the *New Zealand Herald* for two years as Senior Sub-Editor. He continued part-time for eight more years in this position and for four additional years as their Astronomical Correspondent.

McIntosh's interest in astronomy began in 1910, at age six, when his parents showed him Comet 1P/Halley. This was a particularly dramatic apparition (e.g. see Mackrell, 1985), and made a lasting impression on the young boy. By age 13, McIntosh was observing the Moon and comparing his observations with existing maps. In addition, "… he observed sunspots, Nova Aquilae 1918, the planets … a lunar eclipse and peculiar cloud formations." (Orchiston, 2016: 526). He started observing meteors in 1919, at the age of 15, when he joined the American Meteor Society, which was headed by Professor Charles P. Olivier (1884–1975; Taibi, 2017). Several years later, after an exchange of photographs, Olivier was surprised to find that he had been in contact with quite a young man. Olivier had the impression from the standard of McIntosh's papers that he was corresponding with a much older and more highly trained person (Bateson, 1977: 83).

Olivier urged McIntosh to come to the USA but he was not able to do so. Nonetheless, McIntosh still was able to build an international reputation as an astronomer, and this was recognized in 1936 when he was elected a member of the International Astronomical Union (a rare honour for a young New Zealand amateur astronomer), and in 1959 when he joined the Auckland War Memorial Museum Planetarium as their Lecturer-Demonstrator. He retired in 1972 (Bateson, 1977: 82–83).

In 1930 Ronald McIntosh married Harriet Catherine Munro in Whitianga (see Figure 2 for New Zealand localities mentioned in the text). They had two children, Heather Clare, born in 1933, and Ronald Bruce, born in 1937 (Orchiston, 2000). Ronald (senior) also was the proud grandfather of four grandchildren. He died on 17 May 1977 after a lengthy illness (Bateson, 1977: 86).

3 THE NEW ZEALAND METEOR SECTION

3.1 Introduction

In February 1928 the Meteor Section of the New Zealand Astronomical Society was formed (McIntosh, 1946b). The foundation members were Ronald Alexander McIntosh of Auckland, Frank Maine Bateson (1909–2007; Bateson, 1989) of Wellington and Ivan Leslie Thomsen (1910–1969; Eiby, 1970) of Dannevirke (see Figure 2), with McIntosh serving as Director. It is telling that all three ultimately would become professional astronomers.

Over its sixteen-year period of activity, nine different observers at various times contributed to the Section.[1] Apart from McIntosh, Bateson and Thomsen, others who were prominent were Maxwell (Max) Butterton of Wellington, Murray Geddes (1909–1944; Dickie, 2010) of Otekura (in Southland) and Albert Jones (1920–2013) of Timaru. Geddes also went on to become a professional astronomer, while Jones was recognized as one of the World's leading visual observers of variable stars (see Toone, 2016). Bateson, Geddes, Jones, Thomsen and Butterton and all feature in Figure 3.

The first objective of the Section was:

> … the fixing of the many unknown centres of radiation in the southern hemisphere, the linking up of observed radiants to reveal the presence of unsuspected meteor streams of long duration and a careful study of the behavior of the principal showers. (McIntosh, 1946b: 10–11).

Figure.2: New Zealand localities mentioned in this paper are shown in blue (map: Wayne Orchiston).

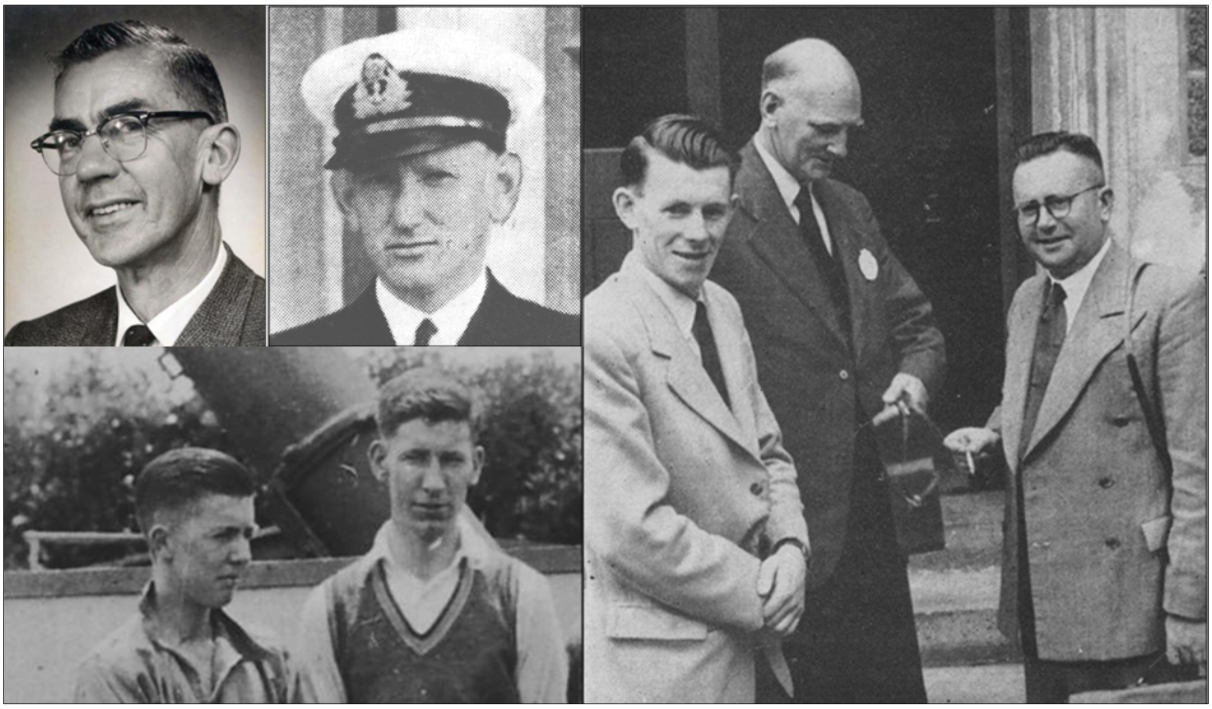


Figure 3: Astronomers who joined R.A. McIntosh as leading members of the New Zealand Astronomical Society's Meteor Section. Top left: Dr Frank Bateson (http://taurangahistorical.blogspot.com/2013_10_01_archive.html); top centre: Murray Geddes (Orchiston Collection); right (from left to right): Albert Jones, E.L. Morley and Ivan Thomsen (after Eiby, 1971: 19); bottom left: Max Butterton (left) and Bruce Stonehouse (right) (Orchiston Collection).

Between 1925 and 1945 members of the Meteor Section recorded 15,627 meteors, and McIntosh observed about half of these. By pooling all observations and analyzing them, McIntosh was able to produce regular Section Reports, as well as a succession of research papers that mainly were published in overseas astronomical journals, especially the *Journal of the Royal Astronomical Society of Canada*[2] and *Monthly Notices of the Royal Astronomical Society.* Publication was an important part of McIntosh's philosophy:

> … the amateur's task consists of observing, recording *and publishing*. *If the last of those is not done, the time spent on the former two is wasted.* It is all very well for a New Zealand observer to watch for meteors, to discover that they come from new radiants, and to store the information in his mind. If he does not publish it the knowledge will die with him and no one will know about the new radiants. (McIntosh, 1941a: 46; our italics).

McIntosh's reports on Southern Hemisphere meteor showers concentrated on their activity, colors, magnitudes, heights and radiant locations. His findings did not include data on meteor shower zenith hourly rates and population indices, which were not in use until well after he became inactive in meteor astronomy. The Meteor Section's work was carried out entirely visually with the naked eye, which allowed the detection of meteors as faint as magnitude 6, but had some uncertainties with regard to radiant positions and velocity determinations. Although telescopic observations were attempted, they did not produce significant results (e.g. McIntosh, 1929c; 1935k).

It is clear from descriptions of the procedures the Section used in recording their observations that accuracy was highly emphasized. Meteor Section observers followed the criteria developed in 1917 by the Meteor Committee of the American Astronomical Society to accurately determine the positions of the radiants of different meteor showers:

> 1a. A radiant shall be determined by not less than four meteors whose projected paths all intersect within a circle of 2° diameter, and are all observed within a period of at most four hours on one night, by one observer.
> 1b. Or by three meteors on one night and at least two on the next night, seen during the same approximate hours of G.M.T., and all five intersecting as above.
> 1c. Or by one stationary meteor …
> 3b. Under no circumstances shall a meteor be used to determine a radiant-point whose projected path passes more than 3.5° from the adopted point, and it is recommended that 2.5° be generally adopted as the usual limit.
> 4. Three meteors which fulfill (1a) shall be considered enough to give a confirmatory radiant for one determined on the same date of a previous year - i.e., where L, the

> meteoric apex, differs by less than 2° (Olivier, 1925: 90–91).

At this time, the effect of sporadic meteor pollution on determining low activity meteor shower radiants was not well understood, as Beech has pointed out:

> The modern day meteor astronomer now knows that probably only 10 to 30 per cent of the observed meteors actually belong to well-defined meteoroid streams. What this means is that the vast majority of observed meteors cannot in fact be traced to common radiant points. This principal while clear to modern astronomers was not, however, known to Denning or his contemporaries. They believed, in contrast, that all meteors could be traced to a radiant point, and that each radiant point could probably be associated with the orbit of a comet (Gyssens, 1998: 86).

McIntosh's assessment of his meteor observations was expressed as follows:

> … the little we know about the meteor radiants and rates in the southern hemisphere comes from the labours of our own Meteor Section, which, handicapped by small personnel, has not been able in the few years of its existence to gain a complete picture of meteor distribution in this unexplored hemisphere. Even in the behavior of the principal annual showers there are gaps in our knowledge waiting to be filled. (McIntosh, 1941c: 10).

The New Zealand climate was less than perfect for the observers. There were many rainy periods in Auckland, averaging 185 rain days annually with 100 days of at least 2.5 mm of rain. There was sunshine only 50% of the time annually and only 42% of the time in June and July. Average conditions in Wellington were quite similar (McLintock, 1966).

Following are three examples of the impact of the New Zealand weather on the Meteor Section projects (after McIntosh, n.d.):

- In preparing for the expected rich Leonid shower of November 1932, Meteor Section members were positioned in Auckland, Hamilton and New Plymouth. On the expected peak date of 17 November, all three cities were clouded out.
- McIntosh had arranged for a New Zealand group to observe meteors concurrently with the Second Byrd Antarctic Expedition in 1933. Observers were located at Auckland, Hamilton, New Plymouth, Eltham, Wellington and Dunedin. He reported that, "Almost universal bad weather was the factor which most spoiled our chances of success." (McIntosh, 1935h).
- Finally, in reporting results for 1934, McIntosh (1935m) said: "This was a very bad year for observing, being characterized by exceptionally cloudy weather."

This kind of weather must have been frustrating for Meteor Section observers, and certainly would have made it difficult to verify minor shower radiants on subsequent nights let alone on a yearly basis. In addition, observers also had to take the Moon's phase into consideration, which further limited observing opportunities.

3.2 Observing and Reduction Procedures

In "The Observation of Meteors", McIntosh (1941c) described the procedures that were used by Meteor Section members when observing and recording meteors. He detailed the best observing time, the period after midnight when over a dozen sporadic meteors per hour were normally visible on dark nights. He concluded that one could see about 24 meteors in two hours, allowing for the probable deduction of two radiants. This assumption, that all meteors can be tied to group radiant points, pervaded the thinking of many astronomers at the time. He also listed the major annual showers that could be viewed from New Zealand: the Lyrids, Eta Aquarids, Delta Aquarids, Orionids and the Geminids. He recommended that observation times of at least two hours were necessary for optimal opportunities to detect radiants.

In order to record meteor paths, McIntosh recommended using a cord to overlay the apparent path of a meteor on the background stars. The meteor's path could then be plotted on a gnomonic map, with an arrow denoting its direction, along with details such as the time of the observation, the maximum magnitude of the meteor, its duration and color, and the accuracy of the observation. If a train was observed, its duration also would be noted.[3] It would seem that the purpose of this research paper was to disseminate general information to beginners and to encourage interest in the observation of meteors from New Zealand.

4 McINTOSH'S METEOR RESEARCH

4.1 Introduction

In his Section, which expands on Luciuk (2007), we summarise the contents of McIntosh's key meteor publications. They illustrate the broad range of his interests, from radiant determination; the characteristics of known and new showers; to meteor heights, velocities, path lengths and colours; and fireballs and bolides.[4]

4.2 Meteor Showers

4.2.1 The Eta Aquarids

In "The Meteor Swarm of Halley's Comet", McIntosh (1929b) reported on the Section's effort to provide detailed information about the Eta Aquarid meteor shower. This shower peaks in May, a very rainy month in New Zealand, but Meteor Section members were able to observe 103 Aquarid meteors over 19.6 hours on 10 evenings. The Eta Aquarids were swift, with a predominance of green and white colors, and only eight were brighter than first magnitude. Many left trains.

The meteor paths were plotted on gnomonic maps, and radiants were determined on a nightly basis. McIntosh found that the radiant, which was quite diffuse and moved east about 1.1° and north about 0.5° daily against the background stars. This movement of the Eta Aquarid radiant confirmed the observations by Olivier and Dole (1921: 243) who, on the basis of observations made in 1910, 1911, 1913 and 1921 found

> … a slow motion of the radiant during the interval May 2 to May 11 inclusive, in the direction of increasing right ascension.

In this report, McIntosh demonstrated his ability to calculate the orbital elements of these meteors. Since the Eta Aquarid shower was associated with Comet 1P/Halley, he assumed a meteoroid semi-major axis equal to Halley's for the calculations. He also made a zenith attraction correction. His calculated elements compared very favourably with those published for the comet and Hoffmeister's (1913) determinations for the Eta Aquarids.

In his paper "The Aquarid Meteors", McIntosh (1931) responded to W.F. Denning's claim that the radiant of the Eta Aquarid shower was stationary.[5] William Frederick Denning (1848–1931), was one of Britain's leading meteor observers who died in the very same year that McIntosh published his 1931 paper. A dedicated amateur astronomer, Denning

> … spent most of his life in Bristol and seems to have earned an income from scientific journalism (see Beech, 1998). Although interested also in solar and planetary astronomy and furnished with a 25.4-cm (10-in) With-Browning reflector, from about 1870 Denning concentrated on naked eye observations of meteors, publishing his first meteor paper in *Monthly Notices of the Royal Astronomical Society* in 1872. (Orchiston, 2016: 530).

For many years Denning had proposed the existence of stationary radiants (e.g. see Denning, 1900), contrary to theory and to the views of most astronomers of the time (e.g. see Olivier, 1925: Chapters 10 and 11). McIntosh (1929b: 157–160) had earlier published his Meteor Section's observations that documented the motion of the Eta Aquarid radiant, while Denning (1930) insisted that it was stationary. McIntosh (1931) noted that no Eta Aquarid meteors have been observed by his group between 1 August and 15 December, so no stationary radiant existed. He pointed out that Denning had only observed 140 Eta Aquarids in 52 years, only about 3 Eta Aquarids per 48-day period yearly. He correctly criticized Denning's observational methodology. McIntosh was not intimidated by criticism from a famous observer like Denning (see Beech, 1990; 1998a; 1998b), as long as he had the observational evidence to refute the criticism.

Because the Eta Aquarid meteor shower was the most active one visible from the Southern Hemisphere it received a great deal of attention from the New Zealand Meteor Section. In 1935 McIntosh (1935a) published an important paper on the radiant of this shower, utilising observations made between 1929 and 1933. He derived 31 radiants from the five years of observations, and the radiants were weighted based on the number of meteors per radiant. This produced an accuracy in the radiant positions of about ±0.5°. The mean ecliptic longitude of the Aquarid radiant minus the longitude of the meteoric apex was 25.3° and its ecliptic latitude was +8.3°. The 4 May 1935 radiant position was determined to be 335.7° right ascension and –1.3° declination.

Figure 4 shows meteor activity plots of the New Zealand Section's observations during April–May. The lower curve reveals that there was a peak in Eta Aquarid activity around 4–5 May, when there were about 10 Eta Aquarids per hour. Jenniskens (2006: 705) puts the Eta Aquarid 6 May maximum at 28 meteors/hour. The German meteor and variable star expert, Dr Cuno Hoffmeister (1892–1968; Zejda, 2014) from the Sonneberg Observatory, observed the Eta Aquarids from South Africa and determined a maximum activity of 36 meteors per hour (Lovell, 1954: 264–265). McIntosh's lower maximum rate may have been due to a combination of non-zenith Eta Aquarid radiants and non-ideal sky conditions at the various New Zealand Section observing sites.

4.2.2 The Orionids

In "Observations of the Orionid Meteors", McIntosh (1929c) published a report on another meteor shower associated with Comet 1P/Halley. The Orionids was actually a Northern Hemisphere shower, so its radiant was low in the sky for New Zealand observers, with a zenith distance of >52°. On the basis of Denning's (1890) description, McIntosh anticipated that New Zealand observers would see

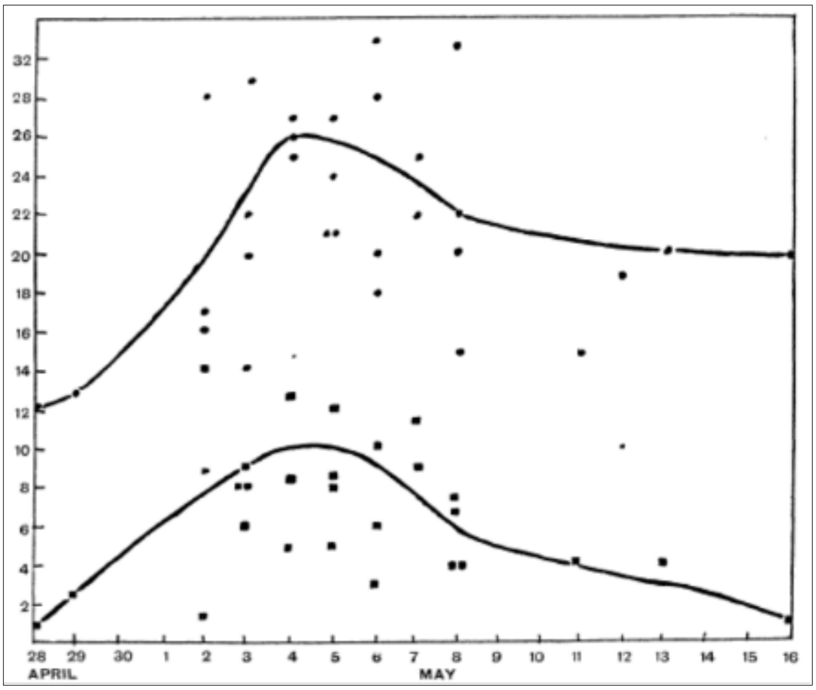


Figure 4: Total meteor (upper curve) and Eta Aquarid meteor (lower curve) hourly rates (after McIntosh, 1935a: 601).

> … long-pathed meteors with slow apparent velocity, owing to the considerable zenith distance of the radiant … The existence of this type of meteor from the shower has been shown in my observations of 1927 ([Olivier, 1928a] *Popular Astronomy*, **36**, 64) and 1928. (McIntosh, 1929c: 162).

McIntosh (*ibid.*) notes that "The Orionids in 1928 proved the most easily recorded meteors I have yet observed." Over a 7-day period during 14–24 October 1928 he and Section members recorded 54 Orionid meteors. Many were of a blue or red color, and almost half left trains. About 13% were brighter than first magnitude.

A major reason for the Section's Orionid observations was to define the centre of the radiant. A great deal of concentration was placed on radiant determination accuracy, to the detriment of paying attention to minor shower activity. Over a period of seven days, the radiant moved steadily eastwards (see Table 1), and McIntosh (1929c: 163) stated:

> … it is my strong personal opinion that there were two centres of activity in the same R.A. and 1° apart in dec (especially on October 15 and 24) which moved together in R.A. from day to day … My observations disclose that the radiant were without doubt clearly diffuse in declination, as was shown by a number of excellently determined meteors moving in R.A. on the earlier dates, and on October 24 by a stationary meteor and one other giving a radiant at 100°·1, +14°·2. The other seven Orionids seen on that date radiated from 99°·1, +13°·5.

To confirm all the meteors listed in Table 1 were indeed Orionids, McIntosh (1929c: 163) calculated the orbital elements of all of the meteors, except those on 23.64 October, and found "… excellent agreement between the various orbits, making it almost certain that they refer to the one stream of meteors."

McIntosh's results agreed with the Orionid radiants determined by Dole (1923) and Olivier (1923), all of which clearly ran counter to Denning's (1913) vehement claim that the radiant was stationary. Earlier, Olivier had been able to marshal

> … observations of over 6000 meteors collected over a period of nearly 10 yrs. In this way Olivier could boast a sound observational pedigree, and also expect his observations to carry some weight. (Beech, 1991b: 251).

It was only fitting that Olivier's young Antipodean prodigy should provide further evidence in support of the moving radiant thesis.

Table 1: The changing radiant position of the Orionids in October 1928 based on New Zealand observations (after McIntosh, 1929c: 163).

Date (Oct)	Radiant Position		No. of Meteors	Remarks
	R.A. (°)	Dec. (°)		
15.65	89.2	+14.2	15	Good
16.64	90.0	+15.0	9	Good
18.65	91.6	+14.6	4	Poor
20.62	92.5	+14.2	12	Good
23.64	93.5	+14.9	3	Poor*
24.64	99.4	+13.7	9	Good**

* Worthless as the R.A. depends on just one meteor.
** Mean of two radiants.

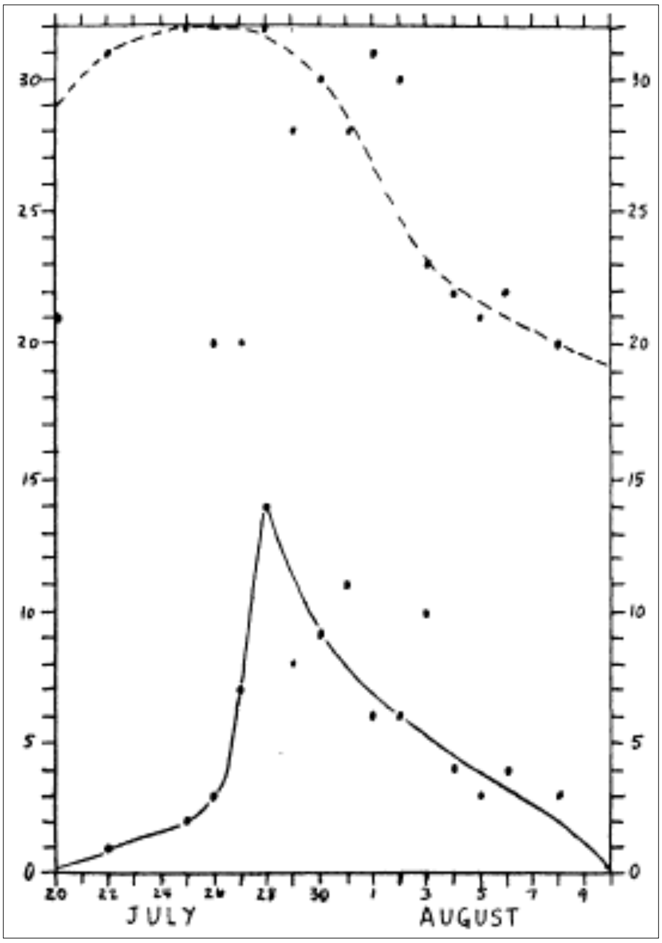


Figure 5: Total meteor (upper curve) and Delta Aquarid meteor (lower curve) hourly rates (after McIntosh, 1934a: 584).

During these sessions, McIntosh also determined the existence of eight minor shower radiants based on a total of 44 meteors. However, with today's knowledge of sporadic meteors, these minor shower radiants could not be accepted without additional supporting observations on succeeding years.

4.2.3 The Delta Aquarids

The Delta Aquarids were covered extensively between 1926 to 1933 by the Meteor Section, with 44 radiants from 515 meteors observed (McIntosh, 1934a). Of these, 88 alone were recorded in 1929, during 17h 18m of observing on eight nights between 26 July and 8 August (McIntosh, 1930b). McIntosh tabulated these 1929 results, and concluded:

> From the above positions it is clear that the radiant point is in daily motion eastwards. This is confirmed by a meteor from the shower observed telescopically by Mr. I.L. Thomsen … on August 1 … (McIntosh, 1930b: 235).

The duration of the shower was found to be 19 days:

> There was continuous activity of this shower from July 22, when the radiant is situated near R.A. 335°, Dec. –19°, until August 9, when it is at R.A. 352½°, Dec –12°. The maximum activity of the shower occurs on July 28 (Greenwich date), when the radiant-point lies close to the star Delta Aquarii … (McIntosh, 1934a: 583).

The lower curve in Figure 5 shows the changing zenith hourly rate of shower meteors with time during July–August. There is a sharp maximum of about 14 meteors per hour on 28 July. Denning (1900) had also gathered data on the Delta Aquarid maximum, and he observed a peak activity of ~5 meteors per hour (Lovell, 1954: 270–271).

McIntosh (1934a: 584) then used an improved method to create an ephemeris of the motion of the Delta Aquarid radiant point. Each radiant's celestial coordinate latitude and the longitudinal difference between the radiant and the apex of the Earth's motions was averaged to produce the right ascension and declination of the radiant. McIntosh (*ibid.*) pointed out that

> The principal advantage of this method is that the whole of the available data is used to determine the mean radiant, whereas under the earlier method the radiants ob-

> served on each day were treated separately, the mean daily positions being used to show the motion of the radiant-point.

McIntosh only used radiants recorded by the New Zealand Meteor Section in his paper, and he noted

> The fact for a period of nineteen days the radiants observed clustered about a fixed point in space, while at the same time that point through an arc of 17° in the sky, clearly establishes that the radiant-point of the Delta Aquarid stream moves in the manner required by theory. (McIntosh, 1934a: 585; cf. Olivier, 1929).

This was yet another oblique reference to Denning's stationary radiant hypothesis.

Finally, McIntosh (*ibid.*) concluded by calculating the following orbital elements for the shower on the date of its maximum activity:

$i = 55.8^\circ$
$\pi = 104.3^\circ$
$\Omega = 304.7^\circ$
$q = 0.0393$
1934 July 28.0

4.2.4 The Alpha Capricornids

While busy observing the Delta Aquarid shower in 1929, McIntosh (1930b: 236) noted that "Another shower sometimes prominent at this time emanates from Alpha Capricornus." The shower was poorly positioned for observation from New Zealand in 1929 and it was only possible to accurately determine the position of the radiant on just one night, 3.66 August.

This shower is now known to be derived from minor planet 2002 EX$_{12}$, which has been reclassified at periodic comet 169P/NEAT (Jenniskens and Vaubaillon, 2010).

4.2.5 The Beta Delphinids

McIntosh reported that

> In the course of routine observations of the Eta Aquarid meteoric shower over a period of eleven years, a minor radiant near Beta Delphini has frequently forced itself upon the attention of New Zealand meteor observers. (McIntosh, 1943a: 76).

This was a weak shower with rarely >2 meteors per hour, extending over several days, but McIntosh believed that its recurrence over a number of years left little doubt about its authenticity—even though it had not been noted previously by Northern Hemisphere meteor observers. McIntosh suggested that perhaps this was because of the contemporaneous Eta Aquarid shower, and "… the multiplicity of meteors visible early in May." (*ibid.*).

Notwithstanding McIntosh's conviction, the relative abundance of sporadic meteors and the paucity of 'shower meteors' listed in Table 2 does raise doubts about the existence of this meteor shower.

Table 2: The Beta Delphinid radiants (based on McIntosh, 1943a: 77).

Date (G.M.T.)		Radiant		No. Meteors	Observer
Year	May	R.A.	Dec.		
1929	7.69	307	+14	3	McIntosh
1929	8.69	307.5	+14.5	4	McIntosh
1929	11.69	307.7	+14	7	McIntosh
1930	6.69	305	+17	3	McIntosh
1930	7.68	308	+15	5	McIntosh
1930	8.67	307.5	+14.5	3	Geddes
1932	5.67	308	+15	4	Geddes
1932	8.68	309.2	+14.2	4	Geddes
1932	12.68	309.0	+14.0	4	McIntosh
1935	6.69	307	+11.5	4	McIntosh

4.2.6 The Index of Southern Meteor Showers

The most important and by far the most referenced paper by Ronald McIntosh was "An Index of Southern Meteor Showers" (McIntosh, 1935b), which listed 320 radiant positions determined from eight years of observations by members of the Meteor Section. In preparing his "Index", McIntosh (1935b: 710) also used other sources that contained southern declination radiants: Denning's (1899) "General catalogue of the radiants points …", publications of the American Meteor Society, papers in the *Journal* and *Memoirs* of the British Astronomical Association, plus Russian observations.

McIntosh's Meteor Section had strict procedures for the determination of shower radiants. The radiants were

> … determined mainly from meteors observed within four hours on one night, at least four produced paths intersecting within a circle 2° in diameter, or three meteors on one night and two on an adjacent night, intersecting as described above, or one stationary meteor, being required to form a radiant. (McIntosh, 1934b: 453).

This policy follows the guidelines that the American Astronomical Society published in 1917.

McIntosh (1935b: 711) noted that four radiants appeared to be stationary, but he postulated that with additional observations they "… will be resolved into a number of minor streams all showing the motion required by theory."

McIntosh's paper provided the most comprehensive list of southern radiants until the advent of radar after WWII. However, the paper also listed many chance radiants of sporadic meteors rather than shower meteors. Kronk (1988: xxi) felt that the list was not sufficiently selective and

> … many [over 52%] of the radiants were based on only one or two nights of observations – making the probability of the inclusion of sporadic radiants quite high.

During that era, many astronomers believed that all meteors were shower related.

Nonetheless, in his book *Meteor Showers* Kronk (1988) credits McIntosh with the discovery of the following nine minor showers:

(1) Gamma Normids. "Ronald A. McIntosh (Auckland, New Zealand) discovered this meteor shower on March 10.1, 1929." (Kronk, 1988: 38).
(2) Librids. "The primary sources for data supporting this steam's existence came from Ronald A. McIntosh's 1935 paper ..." (Kronk, 1988: 65).
(3) Northern May Ophiuchids. "During 1935 this shower experienced the beginning of recognition as an annual shower when Ronald A. McIntosh listed it in his paper 'An Index of Southern Meteor Showers'." (Kronk, 1988: 79).
(4) Southern May Ophiuchids. "The first apparent recognition of this stream as a potential annual producer of meteors was in 1935 [with] … McIntosh's paper …" (Kronk, 1988: 81).
(5) Ophiuchids. "The first formal recognition that this shower as a producer of annual activity was R. A. McIntosh …" (Kronk, 1988: 103).
(6) Omega Scorpiids. "McIntosh's radiant list … It was the first time activity had been officially recognized from this stream …" (Kronk, 1988: 111).
(7) June Scutids. "The discovery of this meteor shower should be credited to R. A. McIntosh, since it was listed in his classic work …" (Kronk, 1988: 114).
(8) Tau Capricornids. "The meteor shower was discovered by Ronald A. McIntosh and was listed in his classic paper …" (Kronk, 1988: 140).
(9) Alpha Puppids. "The discovery of this stream should be attributed to Ronald A. McIntosh … who listed this stream in his 1935 paper …" (Kronk, 1988: 270).

Another example of how McIntosh's observations are referenced in a modern publication can be found in Table 7 in Jenniskens' *Meteor Showers and their Parent Comets* (2006: 691–746), in which McIntosh's paper is referenced 19 times within the list of 240 meteor showers. Kronk references McIntosh 32 times in *Meteor Showers* (1988). Although McIntosh's "An Index to Southern Meteor Showers" is dated, it provides useful historical information.[6]

4.2.7 Radiants and the Fourth Report of the Meteor Section

McIntosh's last paper (1940c) concerning the Meteor Section's list of radiants claimed a total of 1021 radiants from 13,126 meteors by 1938. Radiant determination was carried out under the American Astronomical Society procedure, as noted previously.

McIntosh (1940c: 397) mentioned that their results had been criticized because of the paucity of meteors observed during radiant determinations, but he pointed out that he was "… reluctant to abandon these, in a practically virgin field such as we are working in …" while at the same time admitting that "… a portion of any radiant list must be erroneous." As is now apparent, a high percentage of the 1021 radiants were spurious due to sporadic interference and too few observed meteors per radiant.

4.2.8 The Velocities of Meteors in Meteor Showers

McIntosh (1936f) attempted to create a procedure using apparent radiant locations as a means of determining the heliocentric velocities of shower meteoroids. He proposed that accurate apparent telescopic radiant locations observations in opposite hemispheres could be utilized for this purpose by virtue of differing zenith attraction displacements:

> The displacement of a radiant toward the zenith depends on the zenith distance of the radiant and the velocity of the constituent meteors. It is simple to reverse the usual procedure, determining the meteor velocities from the observed displacement between two radiants determined at stations widely separated in latitude. (McIntosh, 1936f: 705).

For this, McIntosh (1936f: 706) derived the following equation:

$$\tan 0.5\pi = (V_p - V)/(V_p + V) \qquad (1)$$

where V is the unperturbed geocentric velocity of the meteors, V_p the same velocity perturbed by the Earth's attraction, and the angle π is the value of the displacement towards the zenith of a radiant on the horizon.

McIntosh (1936f: 706–707) developed two tables for this velocity determination procedure, where his Table I related the combined zenith distance from the two observations and the apparent declination displacement of the radiant to the zenith attraction on the horizon.

While McIntosh was particularly keen to use this technique for annual showers like the Orionids (which at the time had no known cometary parent), he did not reveal details of how values in Table I were calculated—and this would be his downfall as Davidson (1936: 75) pointed out that the idea was faulty:

> There is a fundamental error in the method

> which renders it useless, and this arises from the manner in which Table I is compiled.

This paper was McIntosh's only publication that was based on an erroneous concept.

4.2.9 The Accuracy of Meteor Shower Radiants

In "An Investigation of the Accuracy of Meteor Radiants" McIntosh (1940b) critically evaluated the accuracy of meteor radiants.

In "Concerning the fictitious radiants of Meteoric Streams" by the Russian astronomer V.A. Maltzev (1928), a simulation of random meteors concluded that more meteors than were typically observed were needed to confirm a radiant point. Öpik (1934) described the complex statistical process his Arizona Expedition used to determine 223 radiants from 22,000 meteor observations, or about 100 meteor observations per radiant. Öpik (1934: 2) claimed that "The majority of radiants published by various observers are probably only accidental configurations". The Maltzev and Öpik papers addressed meteor observer inaccuracies that resulted in erroneous radiant determinations.

McIntosh (1940b: 375) felt that Öpik's Arizona Expedition stated error rate of ± 8.4° for "… differences in angle of two simultaneous trails of the same meteor …" was much greater than that experienced by his Meteor Section, and so he carried out a statistical study based on his own results. His analysis of a random group of six radiants indicated a probable error of only ± 1.7° (McIntosh, 1940b: 376), substantially better than Öpik's Arizona Expedition experience. As a result, McIntosh concluded that his radiant procedures were adequate and that complex statistical tests were unnecessary for organizations whose error rates were as small as those of the New Zealand Meteor Section:

> The present investigation has demonstrated to me that a statistical analysis can never be the sole criterion of reality of radiant deductions, for there are factors in the deduction of radiants which mathematical formulae can not cope with. Briefly put, they are experience on the part of the investigator and the recurrence of meteor showers (McIntosh, 1940b: 379).

McIntosh (*ibid.*) felt that experienced meteor observers understood

> … that a certain meteor could not have emanated from a specific radiant, although apparently directed from it, while the laws of perspective act as a rough indication of radiation, the length of visible path being in direct proportion to the meteor's elongation from the radiant. Neither of these factors are taken into account in Öpik's statistical analysis, which is based solely on direction of flight.

However, it is now clear that additional meteor observations were in fact necessary for better discrimination between random sporadic and low activity shower radiants. McIntosh sometimes used fewer than half a dozen observed meteors for radiant determinations. McIntosh did not address Öpik's contention in this paper that only 15–26% of meteors belong to real or group radiants.

In hindsight, we can now see that although McIntosh was technically correct about the accuracy of Meteor Section reports, he did not realize that credible radiant determinations did require more meteor sightings than his Section could provide, given the limited number of observers and inclement weather conditions.

4.3 The Heights of Meteors

While McIntosh (1940d) was carrying out his study of the "Seasonal Variation on the Height of Meteors" he discovered that Öpik had published a similar study based on his Arizona Expedition observations (Öpik and Shapely, 1937). Öpik's study was based on two station visual observations of 3540 meteors, and his statistical analysis utilized harmonic means for heights which produce lower heights than arithmetic means, to mitigate observational errors. Care was taken to discriminate between sporadic and shower meteors, and to carry out separate analyses for each.

McIntosh's paper utilized published outside sources of meteor heights, which had a total of 2874 meteors. Denning's 950 meteors were a prime source of meteor heights. McIntosh made use of three additional British sources with 794 meteors, and he also employed 1130 meteors from other countries. In selecting these meteors he rejected any meteors with an appearance height >125 miles or 200 km, and

> Naturally, as the investigation concerned seasonal variations, any meteors observed in the southern hemisphere were also excluded. (McIntosh, 1940d: 511).

This automatically eliminated the use of any New Zealand Meteor Section observations.

McIntosh did not use Öpik's corrections. He used arithmetic means, except for his comparison of British data with Öpik, which he did via harmonic means. His analysis was divided into three groups: I. Denning; II. Denning plus additional British; III. All data. McIntosh described meteor height as follows: "… the height of appearance (*Ha*), the height at mid-point (*Hm*), and the height at disappearance (*Hd*)." (*ibid.*). McIntosh (1940d: 513) then proceeded

Table 3: Mean height (*H*) of all meteors in miles (after McIntosh, 1940d: 513).

Showers and Non-showers Meteors		*Ha*		*Hm*		*Hd*	
		Meteors	*H*	Meteors	*H*	Meteors	*H*
Showers		624	76.0	620	64.0	638	53.9
Non-Showers	Group I	820	67.7	821	56.0	830	44.9
	Group II	1427	68.3	1432	56.3	1458	45.6
	Group III	1996	68.0	1980	56.2	2113	44.1
All Meteors		2620	70.0	2600	58.0	2851	44.7

Table 4: Meteor showers excluded from McIntosh's study of seasonal variations in the heights of meteors (after McIntosh, 1940d: 515).

Date or Date Range	Name of Shower	Radiant Position	
		R.A. (°)	Dec. (°)
2–3 January	Quadrantids	232	+52
20–21 April	Lyrids	270	+34
1–7 May	Eta Aquarids	336	0
July–August	Delta Aquarids	345	–17
July–August	Perseids	44	+57
15–25 October	Orionids	90	+15
15 November	Leonids	151	+22
10–12 December	Geminids	106	+32

to list "… the average heights of the meteors used in this work, which will be useful later for comparison with the seasonal heights." These are shown here in Table 3.

Before he could proceed further, McIntosh had to decide how to treat meteors associated with showers, and whether to include all in his study, or reject some. He found this difficult to resolve, but ended up deciding "… to exclude from the computations all constituents of the following annual meteor showers …" (McIntosh, 1940d: 515), which we list here in Table 4.

That said, McIntosh then proceeded to analyse data for the rejected shower meteors separately, and compare them with Öpik's conclusions. McIntosh (1940d: 517) found that

> … shower meteors, far from having in excess of the sporadic range, as indicated in Öpik's research, have a range amounting to only 0.82 of the sporadic range.

He documented this in Tabe III in his paper, and came up with what, at first glance, seemed to be an imaginative way of possibly explaining this. He noted that in his US study of meteor spectra (see Tors and Orchiston, 2009), Millman (1932; 1937) had found that shower meteors were mainly or exclusively stony, while 64% of sporadic meteors were iron. McIntosh (1940d: 517) therefore suggested that if these statistics applied to all meteors then

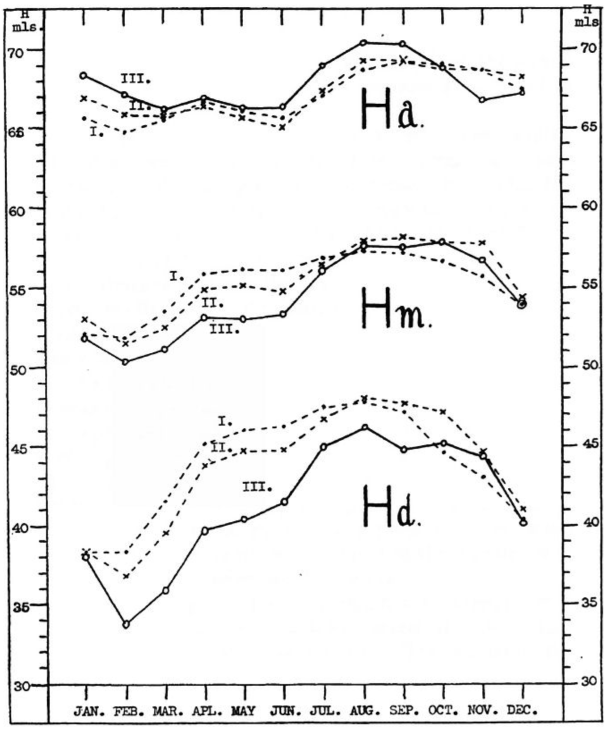
> … composition may be the factor causing the observed greater heights of shower meteors, for the stones could conceivably be volatilized at greater heights than the irons.
>
> On the other hand, the slower-moving shower meteors should not become luminous as high as the faster sporadic meteors. The velocity factor, therefore, working in the opposite direction, may off-set the composition factor and create a stalemate.

This example more than anything else illustrates McIntosh's endeavours to utilise all available data when trying to analyse and explain meteor observations.

McIntosh then investigated the variation in sporadic meteor heights (in miles) calculated with arithmetic means, and his resulting plots are shown here in Figure 6. There was general agreement in all three groups and for the appearance (*Ha*), mid-path (*Hm*) and disappearance (*Hd*) heights that heights were at their lowest early in the year (February) and highest six months later (August). However, meteor path lengths were longer in the winter. Note also that height variability was minimal in the *Ha* group and increased as heights decreased in the *Hd* group. The main reason for these meteor height variations likely was due to seasonal changes in the atmospheric density of upper meteoroid paths. Greater atmospheric densities would create meteor appearances at higher elevations.

McIntosh (1949d: 523) noted that when the monthly ranges of *Ha–Hd* were determined, there was "A marked seasonal variation in the width of the zone in which meteors occur …" as documented here in Table 5.

McIntosh then computed harmonic mean averages for the group I and group II meteors so they could be compared with Öpik's Arizona Expedition results in Figure 7. Note that the equivalent of McIntosh's *Hm* is Öpik's *Hc* designation (black filled triangles). The seasonal trends are similar for both studies. However, there is a significant difference in heights of the *Hd* cluster. The Öpik disappearance meteor height line occurs at considerably higher elevations than in McIntosh's plot. The meteor path



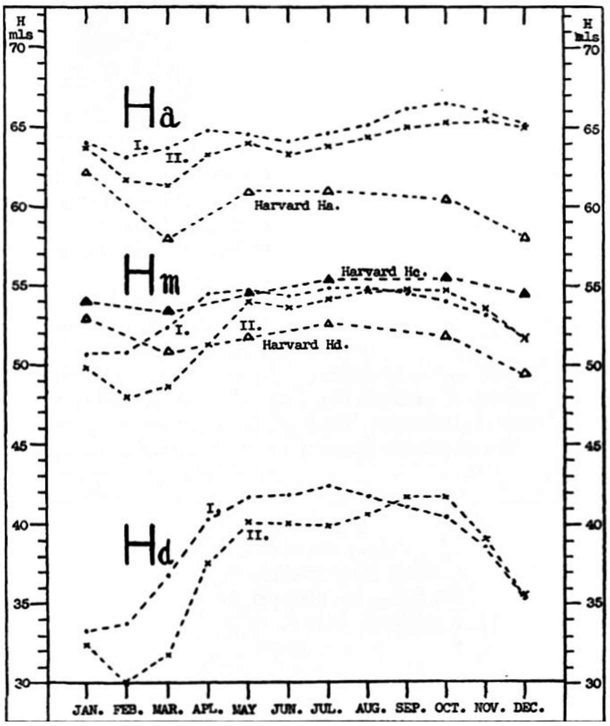


Figure 6 (left): Seasonal variation in heights of sporadic meteors, in miles (after McIntosh, 1940d: 520).
Figure 7 (right): A comparison with Öpik for heights for groups I and II, with heights in miles (after McIntosh, 1940d: 525).

lengths (*Ha–Hd*) determined by McIntosh in Figure 7 were approximately 24 miles (35.6 km) while Öpik's were about 9 miles (14.5 km). Table 6, developed by Hawkins, was constructed on the basis of +3 visual magnitude meteors and had path lengths of 10–11 km. On the other hand, Lovell's Table 60 of Porter's data (Lovell, 1954: 194), had sporadic meteor path lengths of about 34 km. It is not clear why McIntosh's and Porter's meteor path lengths differed so much from those of Öpik and Hawkins.

Table 5: Variations in the width of the meteor zone throughout the year, in miles (after McIntosh, 1940d: 523).

Month	Group I	Group II	Group III
January	27.3	28.6	30.4
February	26.4	29.0	33.4
March	24.0	26.2	30.3
April	21.4	22.6	27.2
May	20.1	20.9	23.9
June	19.4	20.3	24.9
July	19.5	20.3	24.0
August	20.9	21.3	24.2
September	23.2	21.6	25.5
October	24.6	21.7	23.7
November	25.7	24.3	22.3
December	27.1	27.2	27.0

4.4 The Velocities and Heights of Meteors and Fireballs

In "The Velocities of Meteors" McIntosh (1943c) researched findings by other meteor observers on the accuracy of velocity determinations and the relationship of meteor appearance heights and their velocities. Some of the studies McIntosh (1943c: 305) covered were by

> … Maltzev, using the data contained in the Von Niessl-Hoffmeister catalogue, Wegener, for meteors brighter than Jupiter, and Öpik, from material gathered by the Arizona Meteor Expedition.

Using Denning's data, Plummer (1941) determined the correlation coefficient between the height of appearance of a meteor and its velocity was ~0.5.

McIntosh (1943c) compared Denning's velocity estimates versus theoretical determinations for the Quadrantids, Lyrids, Perseids, Orionids, Leonids and Geminids as a test of the data's validity. He used harmonic means for his analysis rather than arithmetic means. See Table 7 for Denning's observed versus theoretical velocity comparison. Although the unweighted mean of Denning's O–C velocities was quite small, it was clear that there were

Table 6: Meteor velocity heights (after Hawkins, 1964: 76).

Velocity (km/s)	Start Height (km)	Height at Maximum Light (km)	End Height (km)
10	80	75	70
20	91	86	80
30	96	91	86
40	101	95	90
50	104	99	94
60	108	102	97
70	110	105	100

Table 7: Denning's observed velocity vs. theoretical velocity, in miles/second (McIntosh, 1943c: 307).

Shower	n	Velocity		
		Observ.	Theor.	O–C
Quadrantids	18	24.8	27.3	–2.5
Lyrids	10	34.0	30.1	+3.9
Perseids	92	38.1	38.7	–0.6
Orionids	7	41.2	41.1	+0.1
Leonids	29	47.1	44.9	+2.2
Geminids	9	23.5	28.0	–4.5
Total	165	Unweighted Mean		–0.3

significant variations on a shower-by-shower basis. The velocity deviations in Denning's calculations ranged from near zero for the Orionids to 16% for the Geminids. To elaborate, Table 7 revealed

> … that although individual meteors from a periodic shower may diverge considerably from the theoretical velocity, when averages are taken, even of small groups, the agreement is surprisingly close … (McIntosh, 1943c: 307).

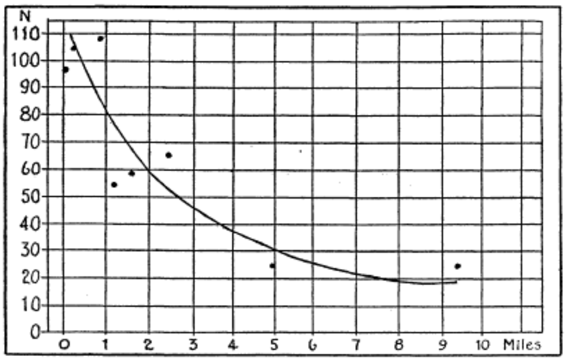


Figure 8: The relationship between velocity and height for meteors and fireballs (after McIntosh, 1943c: 309).

To investigate further the relationship between meteor height and velocity, McIntosh divided Denning's data into four classes:

(1) sporadic meteors;
(2) shower meteors;
(3) sporadic fireballs; and
(4) shower fireballs,

where 'fireballs' were defined as having apparent visual magnitudes equalling or brighter than Jupiter, i.e. –2.5 (Olivier, 1925: 7). McIntosh listed the mean heights of the four groups in a table, and then plotted them—see Figure 8. This analysis confirmed the earlier belief that fireballs began higher and ended lower in the atmosphere than ordinary meteors, because of their larger masses. McIntosh (1943c: 310) also concluded that

> … shower objects, both in the meteor and fireball classes, appear to have their luminous paths higher in the atmosphere than sporadic objects, shower meteors beginning 4.1 mi. higher than sporadic meteors and ending 2.0 mi. higher, while the shower fireballs have heights 3.0 and 7.9 mi. in excess of sporadic fireballs.

This pattern confirmed the earlier study by McIntosh (1940d) reported here in Section 4.3. That said, McIntosh (1943c: 311) warned that "The fastest meteors may not be the highest."

Table 8: The harmonic mean velocities of meteors and fireballs in miles/sec (after McIntosh, 1943c: 311).

Sporadic or Shower	Meteors		Fireballs	
	n	Velocity	n	Velocity
Sporadic	437	22.2	298	18.9
Shower	102	36.0	69	37.2

Using the data under investigation McIntosh derived the harmonic mean velocities of meteors and fireballs listed in Table 8. He concluded that

> In the sporadic objects the slower observed velocities of the fireballs probably arose from the increased air resistance experienced by these objects … (*ibid*.).

He then proceeded to describe that characteristics of *the average meteor and fireball*, as listed in Table 9.

In the final section of his paper, McIntosh was interested in reviewing the accuracy of the data on meteorite and fireball heights and velocities. He noted that

> Meteor heights do not differ from the mean solely because of observational errors. It appears that the principal portion of their frequency spread arises from what Opik has termed the "cosmical spread." The varying compositions and masses of individual meteors make it highly improbable that, if errors of observation were eliminated, the meteors would all occur at the same heights. (McIntosh, 1943c: 312).

He then looked at the real heights of meteors reported by Denning and observed by the British Astronomical Association's Meteor Section. Figure 9 shows McIntosh's (1943c) analysis of the appearance and disappearance of fireballs and meteors versus their velocity. The plots confirmed that fireballs appeared higher and disappeared lower than ordinary meteors, probably due to their greater meteoroid masses, and fireball path lengths were ~50% longer than those of meteors. In Maltzev's (1930) analysis of fireballs from the von Niessel-Hoffmeister catalogue, path lengths were positively correlated with velocity, with lengths ranging from 20 km at 10 km/s to 100 km at 110 km/s (Lovell, 1954: 147). This differs markedly from the fireball plots in Figure 9.

4.5 Meteor Path Lengths

In his paper, "The Luminous Paths of Meteors" McIntosh (1944a) investigated the relationship between meteor path length and the path's angle of inclination as it entered the Earth's at-

Table 9: The average meteor and fireball (after McIntosh, 1943c: 311).

Parameter	Denning's Fireball	Denning's Meteor	Average Meteor*
Magnitude	–5	1.5	3.0
Duration	4.25 sec	1.7 sec.	0.5 sec.
Appearance Height	65.3 miles	62.5 miles	-----
Disappearance Height	33.5 miles	43,0 miles	-----
Path Length	81 miles	37 miles	11 miles
Angle of Incidence	55°	55°	55°
Geocentric Velocity	19 miles/sec	22 miles/sec	-----

* Values listed in this column are based on data assembled by the NZAS Meteor Section and published in McIntosh (1943b), except for the Path Length value which is based on unpublished data.

mosphere. To accomplish this, he utilized meteor heights compiled by W.F. Denning (e.g. see Denning, 1897; 1912; 1916; 1917; 1919). Since inclinations were not published, he calculated them via the following equation:

$$\sin i = (H_a - H_d)/P \qquad (2)$$

where i is the meteor path angle of inclination, H_a is the height of meteor appearance, H_d is the height of meteor disappearance, and P is the meteor path length.

Path lengths determined from Denning's meteor heights are shown in Figure 10. The sporadic meteor path lengths (dotted lines) are longer in winter than in summer for the 809 meteors. However, mean heights of appearance for sporadic meteors are higher in summer than in winter. The inclination to path length trends of the two showers is similar to that of sporadic meteors. There were 41 Leonid meteors in the study and 126 Perseids. McIntosh (1944a: 200) concluded that:

> The path lengths of meteors are shown to be dependent upon the inclination of their paths in the atmosphere, the length of path varying inversely with the altitude of the radiant above the horizon.
>
> The heights of meteors are not affected by slope of path, while distance and atmospheric absorption probably account for the longer-pathed meteors being brighter.

McIntosh defended his use of Denning's data for the study from criticisms by Porter (1943: 134), who claimed that Denning's lists were

> … not all computed by a rigid method, but each path was liable to adjustment by the computer exercising an independent and non-methodical judgment.

McIntosh used Denning's data-set because it

> … was the largest and most homogeneous contribution to the study of real heights at the time and … without it the various correlations and statistical inferences could not have been drawn. (McIntosh, 1944a: 199).

The viability of Denning's data was also rationalized because "… the mean difference between observed and theoretical velocities for 165 meteors amounted to only –0.3 miles per second [–0.48 km/s]." (*ibid.*).

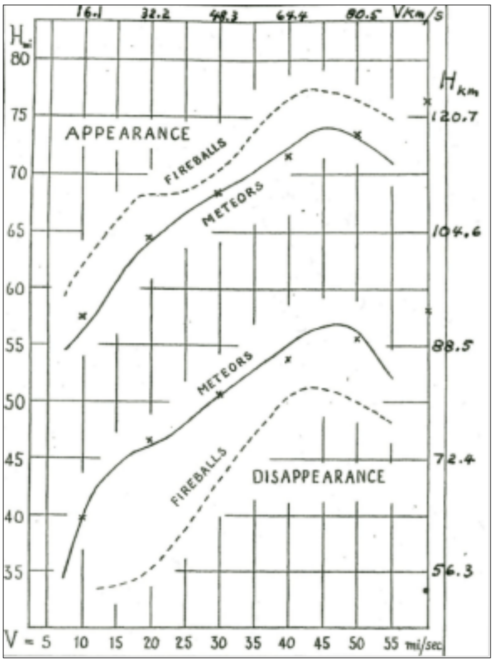


Figure 9: Analysis of the appearance and disappearance heights of meteors and fireball (based on McIntosh, 1943c: 314).

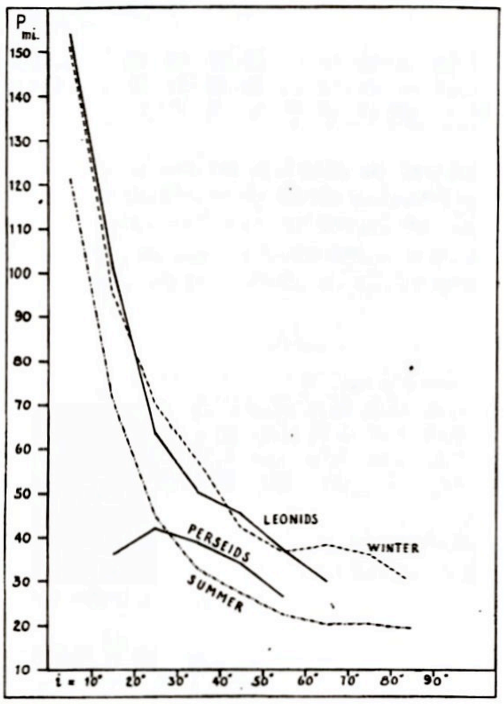


Figure 10: Path lengths of sporadic and shower meteor (after McIntosh, 1944a: 197).

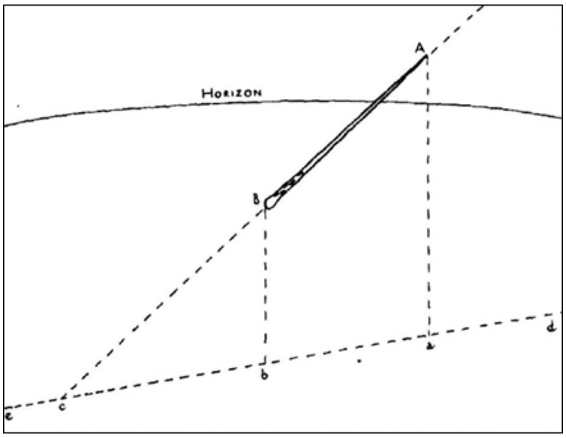


Figure 11: The observer's location in relation to path of the fireball (after McIntosh, 1938a: 8).

4.6 Reports of Individual Fireballs and Bolides

4.6.1 Collation and Reduction of the Observations

As a successful journalist, McIntosh (1932a: 205) made very effective use of the media—and especially newspapers—to obtain reports of fireballs and bolides observed from throughout New Zealand:

> When a bright fireball is witnessed an appeal to the press generally results in bringing to light a number of people who have seen the object. By collecting the scanty and somewhat hazy information that these people are able to supply from their widely scattered stations it is sometimes possible at a very good estimate of a fireball's real path.

In order to facilitate rapid reporting of fireball observations, and "… primarily to forward promptly press clippings regarding New Zealand Fireballs …" (McIntosh, n.d.: 1934), in 1934 agencies were established in Auckland, Hamilton, New Plymouth, Wanganui, Napier, Eketahuna, Wellington, Nelson, Christchurch, Dunedin and Otekura.

McIntosh received accounts of fireball observations from experienced and inexperienced observers, and often their reports contained contradictory information. Nonetheless, for each fireball he tried to derive reliable information about its location, height, path length, velocity, radiant and flight duration, and he described any detonations that were noticed. Observers occasionally also supplied data on the color, brightness and the train. Where possible, McIntosh attempted to create a map showing where the fireball crossed the country.

Table 10: The apparent path of the fireball.

Location	*Description*
At a	Begins at the zenith, falls vertically
At b	Rises vertically, ends at the zenith
At c	Appears stationary
On da	Falls vertically
On ab	Rises and falls vertically, crosses the zenith
On bc	Rises vertically
On ce	Falls vertically

In a paper titled "Determination of the Real Paths of Fireballs", McIntosh (1938a) details the procedures he used in gathering data and in carrying out calculations. This paper shows that McIntosh was very organized in soliciting fireball observations from untrained observers. He effectively utilized newspapers and radio stations, asking for:

> (1) exact location of observer; (2) date and time of appearance of meteor; (3) the position of its path in the sky with reference to the stars, by compass bearings, or in relation to terrestrial objects; (4) particulars of any noises which accompanied or followed the meteor; (5) description of the brightness of the object and its trail, and (6) the length of time the meteor (and trail) remained visible (McIntosh, 1938a: 3).

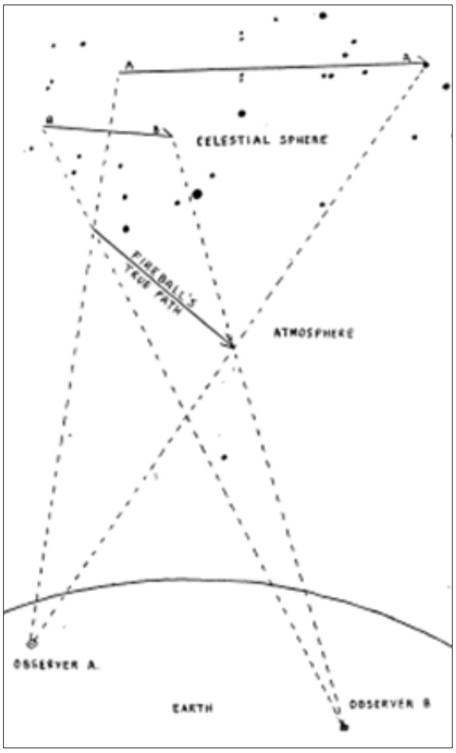


Figure 12: Duplicate fireball observations (after McIntosh, 1932a: 204).

McIntosh would then examine information sent to him and sort data that appeared most detailed and accurate. He illustrated the potential locations of observers relative to the fireball in Figure 11. In Table 10 McIntosh describes an observer's view of the fireball, depending on where one is located in Figure 11. These perceptions helped him place an observer relative to the fireball. Meanwhile, Figure 12 illustrates the apparent paths of the fireball relative to background stars if seen by two distantly separated observers. McIntosh concluded his paper with extensive explanations of the spherical geometry formulae he used to complete his analysis of a fireball's path.

McIntosh provided details of fireballs seen from New Zealand in a series of short papers that were published in *the Journal of the British Astronomical Association* (McIntosh, 1929a; 1930a; 1930c; 1930d; 1932b; 1934d) or in *Southern Stars*, the journal of the New Zealand Astronomical Society (McIntosh, 1940a; 1945). He also described some of these events in his newspaper columns (e.g. Aries, 1954; McIntosh, 1970b), pointing out that since the advent of the 'Space Age' not all fireballs had to be associated with meteroids as some could represent space debris—even a Russian weather satellite retuning to Earth (e.g. see McIntosh, 1970a).

There is no point in describing each of the fireballs that McIntosh published. Instead, we will take one example, the fireball of 17 May 1933, to illustrate his analytical procedure and the types of specific results he typically derived when researching fireballs.

4.6.2 The Fireball of 17 May 1933

McIntosh (1934d: 74) describes how

> On the night of 1933 May 17, at 10.5 p.m. a fireball which fell over Cook Strait [between the North and South Islands] and was widely observed in the Wellington Province of New Zealand provided the most remarkable meteoric record on display in this country.

Initially reports from the public were collected by the Dominion Astronomer, Dr C.E. Adams (1870–1945), but McIntosh followed up on this and ended up with 48 reports, most of which derived from observers in Wellington, the nation's capital. The reports revealed the basic characteristics of the fireball:

> Beginning with a brilliant flash which lit up the district like a vivid lightning flash, attracting the attention of many people outdoors at the time, it fell rapidly toward the sea, ending 3½ seconds later in a brilliant explosive flash. Midway in its path a thick trail almost as bright as the fireball itself shone prominently for a minute. This slowly faded for a further four minutes, until it finally disappeared. (McIntosh (1934d: 74–75).

Most observers noted the unusual brightness of the fireball and even people "… in the heart of the brightly lit city of Wellington had their attention attracted by the flash." (McIntosh (1934d: 76). Meanwhile, seven people in dark locations "… reported that the fireball illuminated their surroundings." (*ibid.*). Reports indicated that the fireball was blue in colour, and seven people reported that it "… ended in an explosion with a sudden increase in brightness at that moment." (*ibid.*).

From the mass of observations, McIntosh (1934d: 75–76) derived the following information about the path of the fireball:

Height at appearance		38.5 miles
Height at disappearance		6 miles
Length of path, projected		41 miles
Length of path, true		52 miles
Slope of path		38°
Azimuth of path		74.5° W. of S.
Began at	Longitude	175° 38′ E
	Latitude	–41° 25′
Ended at	Longitude	174° 53′ E
	Latitude	–41° 30′
Duration		3.5 seconds
Apparent velocity		15 miles/sec.
Radiant		R.A. 154° 21′
		Dec. –14° 27′

Figure 13 shows the real path of the fireball, and the position of the train that was observed.

McIntosh (1934d: 76) then proceeded to compute the orbital elements (epoch 1933.0):

$\omega = 168.3°$
$\Omega = 236.0°$
$i = 7.7°$
$q = 0.998$
$e = 1.0$
1933.44097

The only anomalous aspect of the 'Cook Strait bolide' that set it apart from other fireballs observed from New Zealand was the absence of any detonations. As McIntosh explained in a newspaper article written many years later

> All objects in the [Earth's] atmosphere which travel faster than the speed of sound create shock waves which come to our ears as one or more load detonations … [With fireballs] one or more detonations may be heard, or the noise may be almost continuous like the role of thunder of a fuscillade of gunfire. (Aries, 1954).

He elaborated with examples:

> One meteor which passed over the Waikato [near Hamilton] on June 15, 1930, was at first mistaken for an earthquake. Loud bangs were heard and windows rattled ... (*ibid.*).

To McIntosh's great surprise, the 17 May 1933 fireball was silent:

> It is a most remarkable fact that 44 observers, all situated at distances of from 12 to 30 miles from the fireball's path … *heard no detonations*. (McIntosh, 1934d: 79; our italics).

How to best explain this? McIntosh (*ibid.*) suggested that

> … the direct ballistic waves covered an un-

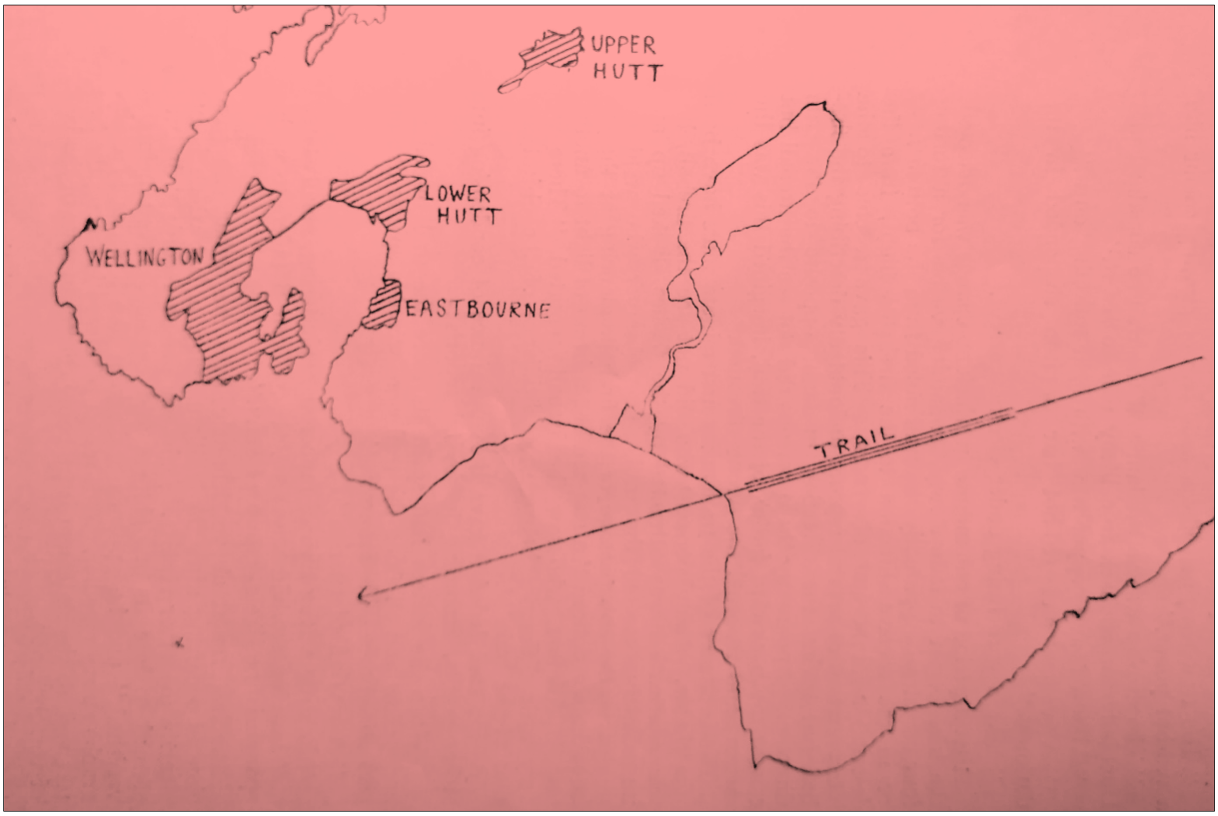


Figure 13: The path of the fireball of 17 May 1933 crossing southeastern Wairarapa and ending over Cook Strait, derived almost entirely from observers located in Wellington, Upper Hutt, Lower Hutt and Eastborne (after McIntosh, 1934d: 77).

Table 11 The percentages of meteors of different colours observed by Section members between 1925 and 1931 inclusive (after McIntosh, 1934b: 451).

Year	Observer	Red	Orange	Yellow	Green	Blue	White	Total
1925–1928	McIntosh	9.93	1.92	2.03	1.92	5.32	78.88	1823
1929	McIntosh	8.55	5.50	2.53	4.28	4.99	68.15	1146
1930	McIntosh	4.02	3.60	1.05	1.48	5.61	82.24	473
1931	McIntosh	1.70	3.40	2.28	2.84	5.11	84.67	176
1931	Geddes	10.69	5.65	6.25	2.17	6.69	68.55	1151
1929–1931	Bateson	2.63	0.66	----	6.58	4.60	85.53	152
Average		8.70	3.80	2.99	2.66	7.15	74.70	4921

> usually small area immediately under the path of the body [where there were no observers], with an unusually large zone of silence, or that not every meteor which penetrates deeply into the Earth's atmosphere is capable of creating detonations.

From what we now know about fireballs, in the case of the 1933 Cook Strait Fireball the former explanation is more likely.

4.7 Meteor Colours

On the basis of 4,921 meteors observed by Section members during 1925–1931 McIntosh (1934b) was able to compile a table revealing the relative abundances of meteors of different colours. Details are presented here in Table 11, with ~75% of all meteors coloured white; however, elsewhere McIntosh (1929d: 463) has suggested that many of his 'blue' meteors should in fact be reclassified as 'white'.

5 DISCUSSION

5.1 R.A. McIntosh and Southern Hemisphere Meteors

Ronald McIntosh was the right person in the right location at the right time. His meteor work filled an important gap in observational activity in the early to mid-twentieth century and his place in the history of meteor research and observations is assured by his meteor astronomy leadership in New Zealand and by his publications. The success of the New Zealand Meteor Section was a testament to his leadership skills. By personally doing the calculations for the Section he assured that results were consistent and accurate.[7] In spite of not having had a formal scientific education, McIntosh was able to deal with complex orbital and statistical calculations. In addition to earning a living in his various occupations, he found time to educate himself in astronomy, carry out meteor observations, coordinate Meteor Section activity, participate in multiple organizations, carry out research, and write dozens of papers that were published in New Zealand and international journals.

As amateur observers, the Meteor Section members made use of naked-eye observations rather than utilizing photographic techniques. This allowed the recording of faint meteors, and also permitted the discovery of lower activity meteor showers. The Meteor Section employed telescopic observations on a very limited basis since McIntosh (1929c) found that these did not produce significant results (but see McIntosh, 1951b). McIntosh's careful implementation of Olivier's suggestions for meteor shower radiant procedures produced relatively accurate results for naked-eye observations. It was difficult to repeat the confirmation of radiants on succeeding evenings or on an annual basis due to New Zealand's poor weather conditions. Even when weather conditions were favorable, a shortage of committed meteor observers was always a concern:

> The need for additional meteor observers in the Southern Hemisphere, and especially in this country, remains acute … In the past ten years, for example, there were 150 dates in the year on which no observations have been secured, while on a further 109 days observations have been secured only once in the period. On only 106 days of the year have observations been secured more than once. (McIntosh, 1936e: 70).

As a result of inclement weather and observer shortages, one-time low activity shower radiant determinations were compromised by pollution from sporadic meteors. Beech has pointed out that:

> The modern day meteor astronomer now knows that probably only 10 to 30 per cent of the observed meteors actually belong to well-defined meteoroid streams. What this means is that the vast majority of observed meteors cannot in fact be traced to common radiant points. This principal while clear to modern astronomers was not, however, known to Denning or his contemporaries. They believed, in contrast, that all meteors could be traced to a radiant point, and that each radiant point could probably be associated with the orbit of a comet (Gyssens, *Editor-in-Chief*, 1998b: 86).

The prevalence of sporadic meteors began to be recognized when Öpik (1934) published his Arizona Expedition radiants paper. McIntosh (1940b) was familiar with Öpik's paper, when he wrote in "An Investigation of the Accuracy of Meteor Radiants", claiming that his Section's observations were more accurate than those of the Arizona Expedition. Therefore, he was incorrectly convinced that only a small number of observed meteors were needed to determine a stream's radiant. This resulted in many spurious radiants. However, he made no mention of Öpik's finding that most meteors were sporadics and could not have common or group radiants. Olivier's published comments of sporadic meteors not being of cometary origin came fairly late. In "The Velocities of Sporadic Meteors," Olivier (1956: 389) opened with, "The determination of the velocities of meteors, not apparently connected with cometary streams, is of the highest importance."

McIntosh was justly proud of the work he and the New Zealand Meteor Section accomplished, and he published their results as a contribution to the contemporary knowledge base of meteor astronomy. Apparently, there was criticism from some in the Royal New Zealand Astronomical Society with the way that McIntosh publicized the activities of the Meteor Section:

> Criticism has been published in the Society's journal [*Southern Stars*] of the publications of papers. To the writer's view the amateur's task consists of observing, recording *and publishing*. If the last of those is not done, the time spent on the former two is wasted. (McIntosh, 1941a: 46; our italics; c.f. McIntosh, 1940e: 64).

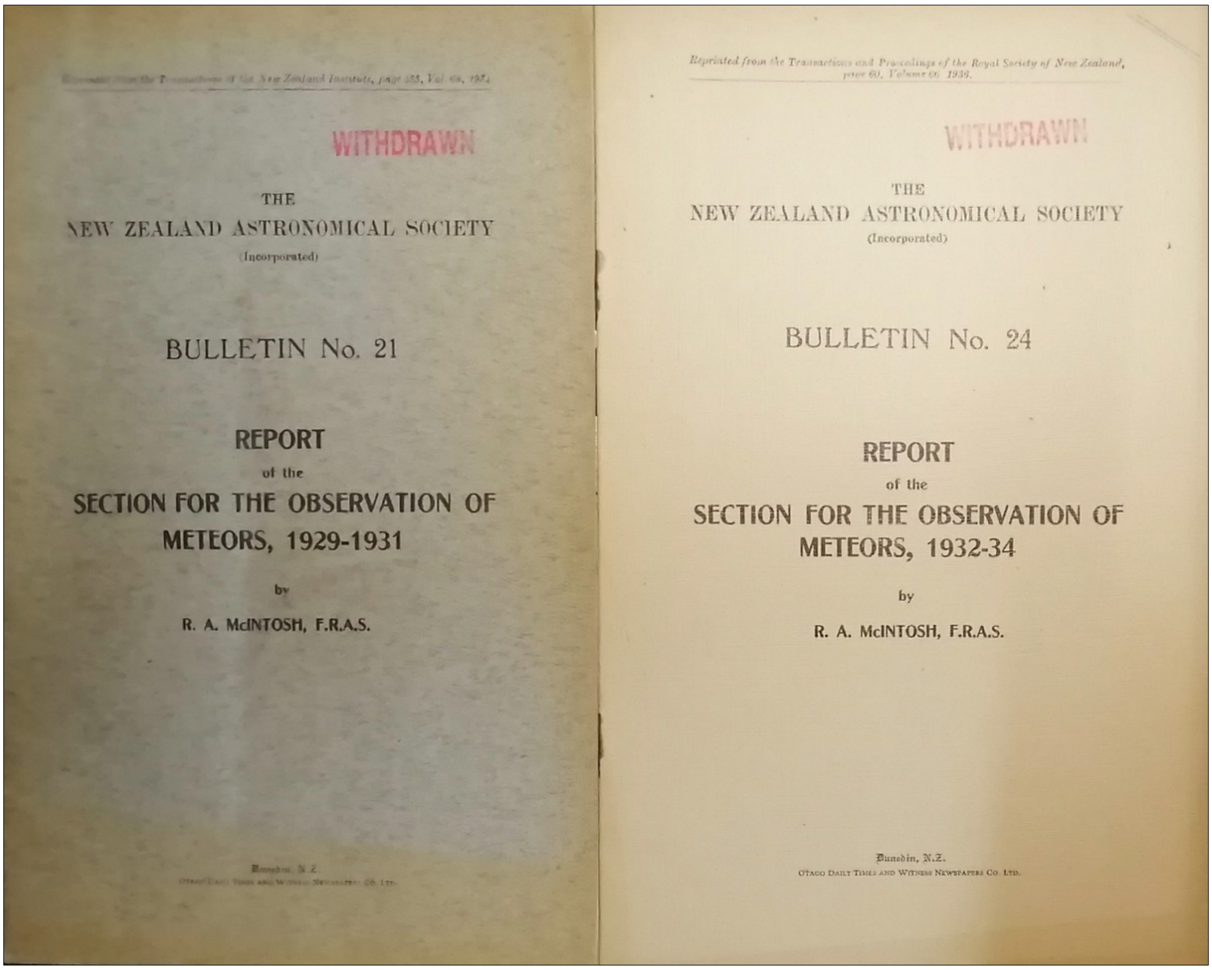
But McIntosh went far beyond merely publishing scientific papers about the work of the Meteor Section in the prestigious *Monthly Notices of the Royal Astronomical Society*, and in the *Journal of the British Astronomical Association* and the *Journal of the Royal Astronomical Society of Canada*. He felt it was essential to keep Section members, other members of the Society and overseas meteor astronomers up-to-date with the work of the Section, and he achieved this by publishing regular Reports of the Section (see Table 12). Up until the outbreak of WWII, the Section Reports were published in the *Transactions of the New Zealand Institute*, which, through journal exchanges, reached a wide international audience. All this changed with arrival of war and its disruption to observational astronomy. McIntosh (1939c) chose to publish an Annual Report for 1938 in *Southern Stars*, and after a 3-three year hiatus during the initial phase of the war, he resumed annual publications from 1942 (McIntosh, 1942; 1944b; 1944d).

In addition to the formal, early, multi-page Reports (see Figure 14), McIntosh wrote numerous short reports under the title "Meteor Section" or "Meteor News" specifically for Section members and others in the New Zealand

Table 12: Formal Reports published by the Meteor Section of the NZAS, 1927–1938.

Reporting Period	No. of Report Pages	Obs'ing Time (hr min)	Total Met-eors	Naked Eye Observers	References
1927–1928	17	194 37	2157	Bateson, McIntosh, Thomsen	McIntosh, 1929d
1929–1931	24	295 44	4013	Bateson, Butterton, Geddes, McIntosh, Morshead, Thomsen	McIntosh, 1934b
1932–1934	12	252 09	3962	Alchin, Bateson, Bryce, Butterton, Geddes, McIntosh, Morshead,	McIntosh, 1936e
1935–1938	10	190 38	2994	Bateson, Geddes, Fairbrother, McIntosh	McIntosh, 1940c

* The total number of observations for the year is not mentioned. Albert Jones alone contributing 1184.



WITHDRAWN

THE
NEW ZEALAND ASTRONOMICAL SOCIETY
(Incorporated)

BULLETIN No. 21

REPORT
of the
SECTION FOR THE OBSERVATION OF
METEORS, 1929-1931

by

R. A. McINTOSH, F.R.A.S.

Reprinted from the Transactions and Proceedings of the Royal Society of New Zealand,
page 60, Volume 66 1936.

WITHDRAWN

THE
NEW ZEALAND ASTRONOMICAL SOCIETY
(Incorporated)

BULLETIN No. 24

REPORT
of the
SECTION FOR THE OBSERVATION OF
METEORS, 1932-34

by

R. A. McINTOSH, F.R.A.S.

Dunedin, N.Z.
Otago Daily Times and Witness Newspapers Co. Ltd.

Figure 14: Front covers of two of the New Zealand Astronomical Society Meteor Section Reports, which were published as booklets by the New Zealand Institute (photograph: Darunee Lingling Orchiston).

Astronomical Society and its successor, the Royal Astronomical Society of New Zealand.

These that were published in *Southern Stars* (McIntosh, 1934c; 1935c; 1935d; 1935e; 1935f; 1935g; 1935i; 1935j; 1936a; 1936b; 1936c; 1936d; 1937a; 1937b; 1937c; 1939a; 1941a; 1941b; 1944c; 1946c; 1948; 1949; 1950; 1951a; 1952; 1953; 1955), and mainly provided news about international meteor astronomy.

Occasionally, McIntosh (1935n; 1939b; 1946a) also wrote separate reports of these international developments.

5.2 New Zealand Meteor Section Observers and the Physical Characteristics of Meteors

With a decade and a half of data to draw on, in 1943 McIntosh (1943b) carried out a detailed study of the physical characteristics of meteors which members of the Meteor Section had observed since the Section's inception. This paper illustrates McIntosh's interest in understanding observer accuracy in relation to meteor observing experience. McIntosh tried to determine how accuracy was related to the individual experience of his team members. The key members of the Section were F.M. Bateson (B), S. Fairbrother (F), M. Geddes (G) and himself

(M). Of these four, Bateson and Fairbrother were considered inexperienced.

With respect to meteor magnitudes, McIntosh concluded that he over-estimated meteor brightness in the middle magnitudes, while Fairbrother underestimated brighter meteors. The average meteor magnitude for 12,809 meteors was +3. "The deviations of the observers from the mean values were: F 4% error, G 2%, M 3%, others 2.5%." (McIntosh, 1943b: 302). The experienced G and M were consistent on brightness estimation, while the inexperienced F was erratic. More than half of the Section's observed meteors had durations of 0.4 to 0.6 seconds, and only 3% lasted more than one second. Deviations from the means indicated errors of F 3.4%, G 1.5% and M 0.9%.

McIntosh made an interesting observation on how the Meteor Section's meteor paths were plotted. They used gnomonic maps, but path lengths were measured "… by reference to a standard scale, instead of by the more accurate graticule superimposed on the maps." (McIntosh, 1943b: 304). This meant that path lengths were inaccurate near edges of the maps, by several degrees. The mean path lengths for the observers were B 6.1°, F 9.4°, G 5.9°, and M 10.3°. An independent value in the literature gave a mean meteor length of 8.3°, which implied that "Bateson and Geddes consistently plot their paths too short, and Fairbrother and McIntosh record theirs too long." (McIntosh, 1943b: 305). McIntosh's analysis of the Meteor Section's mean meteor characteristics is shown in Table 13.

Notwithstanding these results, McIntosh had a strong belief that experienced amateur meteor observers were the equal in skill to professional astronomers. When Dr C.C. Wylie (1935) of Iowa University wrote that he ranked professional meteor astronomers higher than amateurs, McIntosh (1935c: 136) was quick to provide a rebuttal: "… perhaps the "amateurs" Dr. Wylie has in mind are what we would describe as "beginners" in this country."

5.3 The Advent Radar Meteor Astronomy at the University of Canterbury

Professor Sir Alfred Charles Bernard Lovell (1913–2012; Davies et al., 2016) from Manchester University is widely recognized as the 'founding father of radar meteor astronomy', a field that he and a team of collaborators avidly pursued immediately after WWII at Jodrell Bank field station (see Lovell, 1954).

By good fortune, two New Zealanders who were enrolled in PhDs in Lovell's group formed part of this research collaboration. One was Congreve John Banwell (1908–1982; Fraser, 2016) and the other was Clifton Darfield Ellyett (1915–2006; Keay, 2006), both Physics graduates from the University of Canterbury in Christchurch. Banwell eventually abandoned his PhD studies and returned to New Zealand, but only after co-authoring papers with Lovell on solar radio emission and radar meteors (Lovell and Banwell, 1946; Lovell et al., 1947; Prentice et al,, 1947). Once in New Zealand Banwell turned his back on radio and radar astronomy, and went on to build an international reputation through his studies of geothermal activity, especially at Wairakei (see Dawson, 1989).

Ellyett also co-authored papers on radar observations of meteors at Jodrell Bank (see Davies and Ellyett,1949; Ellyett, 1949; Ellyett and Davies, 1948), and when he returned to New Zealand he initiated radar meteor studies in the Physics Department at his *alma mater*, the University of Canterbury. In doing this, he founded a field station on farm land at a radio quiet site near Rolleston, on the Canterbury Plains to the southwest of Christchurch (see Figure 1).

Table 13: Average values for different Meteor Section observers based on the observation of 12,809 meteors (after McIntosh, 1943c: 310).

Parameter	Untrained Observers	Trained Observers
Magnitude	3.4	0.9
Duration (seconds)	0.43	0.72
Path Length (°)	7.7	14.5
Coloured (%)	21.6	25.0

Using his regular nom-de-plume 'Aries', on various occasions McIntosh reported on the work of Ellyett's team in his newspaper column "The Newest in Science". Starting on 28 August 1951, he announced that the Nuffield Foundation in England had provided a grant so that Ellyett could carry out radar meteor research in New Zealand (Aries, 1951). He explained to readers:

> It is only since the war that radar has been used to supplement visual work in the study of meteors and through them to glean additional knowledge of the high atmosphere in which they occur. It has proved a powerful weapon.

From time to time, McIntosh provided progress reports on Ellyett's research through his newspaper columns. For example, when discussing the international URSI conference held in Sydney in August 1952, he wrote:

> The importance of his [Ellyett's] work lies in the fact that nothing is known of daytime meteor showers in this [i.e. the southern] hemisphere, and the results gained by Dr Ellyett will be a valuable supplement to the work being performed in the Northern Hem-

isphere. Aries (1952).

Ellyett soon built up a small radar astronomy research group, which became known for its pioneering investigation of southern meteors and meteor showers (see Keay, 1965). While the important contributions that were made to New Zealand and international meteor astronomy by Ellyett, and his successor, Professor Jack Baggaley, deserve to be fully researched and published, they lie beyond the scope of the present paper.[8]

5.4 The Close Down of New Zealand's First Meteor Section

Without having access to Council Minutes of the Royal Astronomical Society of New Zealand it is impossible to determine precisely when the Meteor Section closed.

As early as 1941, in the height of war, McIntosh was foreshadowing the close-down of the Section:

> The fourth report of the Meteor Section, covering the years 1935-1938, appeared during the year. Unless there is an influx of active observers it will probably be the last of its line. (McIntosh, 1941a: 45).

Clearly these much-needed new observers appeared, especially after the end of WWII. Thus, the May 1948 Meteor Section report in *Southern Stars* mentions two new observers, J.L. Stichbury of Patumahoe and B.J. Marples of Dunedin, but once again McIntosh (1948) advises that his own "… occupation has interfered considerably with his spare time, and no observations have been possible during the year." McIntosh (*ibid.*) also warned, "It appears that observations in pre-war quantity will not be possible in the future …"

The next Meteor Section report (McIntosh, 1949) indicates that Albert Jones and the aforementioned Mr Stichbury, have been joined by two new beginner observers, R.W. Humphrey and I.T. Pickens. Then in the following year's report we see that Stichbury and Pickens have teamed up to carry out co-ordinated dual observations in order to determine meteor heights (McIntosh, 1950: 155), but there is no further mention of Mr Humphrey.

The Section then appeared to have stagg-ered along until 1954 without any observational input from its Director, and the final report published in *Southern Stars* (McIntosh, 1955) effectively marks the demise of the Section. The celebrated Meteor Section of the New Zealand Astronomical Society, and from 1948 the Royal Astronomical Society of New Zealand, had existed for almost 30 years, and during the 1930s and early 1940s it made a major contribution to various aspects of international meteor astronomy (e.g. see McIntosh, 1938b).

6 CONCLUDING REMARKS

In 1901 the world's pre-eminent meteor observer, Britain's William Frederick Denning, published a paper in *Observatory* singing the praises of Southern Hemisphere meteor astronomy:

> The very great majority of the showers having radiants of more than 30 S Declination still await suitable observations. It is true that Neumayer at Melbourne recorded about 2000 meteors during the years 1858-63, and that Heis determined 39 radiants from then, but these results were very meagre and unsatisfactory. (Denning, 1901: 196).

Denning (*ibid.*) then went on to point out:

> What is required is a searching watch of the southern sky, prolonged over several years, by an observer of experience in, and special aptitude for, this branch of work. The field being practically unexplored, there is a mass of valuable and interesting materials to be gleaned by any one who will essay to gather them.

Just three years later Ronald McIntosh was born in Auckland, and he would prove to be that 'special person' Denning was looking for, although with the passage of time Denning would hardly have relished the fact that McIntosh chose to side with the American Professor of Astronomy, Charles Pollard Olivier, and challenge his 'stationary radiant' hypothesis.

As we have seen in this paper,

> The New Zealand Meteor Section … burst like a comet into a virgin sky. Practically nothing was known of the radiants to be found in southern skies or of their varying rates of activity. (McIntosh, 1946b: 11).

McIntosh therefore was an important pioneering Southern Hemisphere meteor observer, whose activities through his Meteor Section brought data to the world that were unavailable prior to his efforts. He very carefully followed the radiant determination practices of Olivier's Meteor Committee, which were the best in existence at the time (although, as Hoffleit (1988) documents, Yale University's William Lewis Elkin, 1855–1933, had earlier shown the potential of using photography *in lieu* of human naked eye observations—see Olivier, 1937). McIntosh carried out the computations for the Meteor Section, assuring accuracy and consistency for the apparent radiant determinations. However, New Zealand weather conditions and shortages of meteor observers often hampered multiple-day observations needed to confirm radiants. Nonetheless, this gifted amateur astronomer broke new meteor astronomy ground

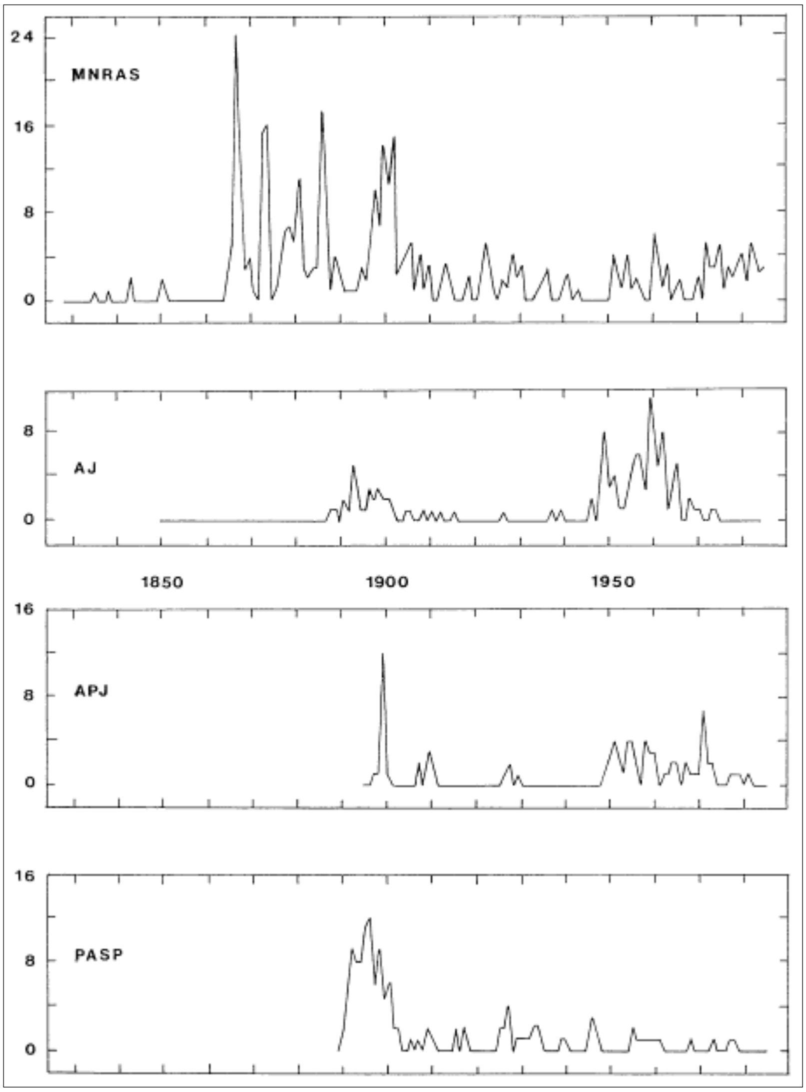


Figure 15: The variation in the number of meteor papers appearing per year in *Monthly Notices of the Royal Astronomical Society*, *The Astronomical Journal*, *The Astrophysical Journal*, and *Publications of the Astronomical Society of the Pacific* (after Beech, 1988: 189).

in the Southern Hemisphere because of his leadership, his research publications, and his Section's observations.

In this regard, McIntosh's appearance was timely from an international perspective, as he and the New Zealand Meteor Section were active during the 1920s through 1940s, a time when there was a relative hiatus in meteor studies. This is illustrated graphically in Figure 15, where there are two intensive periods of publication: around 1890–1900 and 1945–1970. Only *Monthly Notices of the Royal Astronomical Society* (McIntosh's preferred journal) published meteor papers in any numbers throughout the period 1890–1970 (although the two aforementioned peaks are also apparent). Beech (1988) now sees meteor astronomy as a 'mature science', preceded by a period of development from 1900. Critical here was

> A seemingly harmonious marriage between observations and theory [that] thus arose for some twenty years lasting from the early 1930s to the early 1950s. (Beech, 1988: 193).

McIntosh and his Meteor Section, as suppliers of observations, were very much a part of this 'marriage'.

It has been said that

> Meteoric astronomy forms a singularly complicated branch [of astronomy], and it requires a man to probe deeply into the subject and to study patiently its observational aspects for many years. The accurate reduction of materials also involves a very careful discrimination and knowledge gained from lengthy experience.

While this quotation perfectly fits McIntosh's profile, it was actually an autobiographical explanation written by his nemesis, W.F. Denning

(1915: 334).

McIntosh's name is best known at an international level for his meteor work, but we should remember that from 1927 he owned a 14-inch (35.6-cm) equatorially-mounted Newtonian reflector and was a skilled telescopic observer, especially of the Moon and Jupiter (Orchiston, 2016: 540–550). He also was an independent discoverer of Comet C/1941 B1 (de Kock-Paraskevopoulos)—see Orchiston et al. (2020). Meanwhile, McIntosh published a succession of research papers on the history of New Zealand astronomy, including Māori astronomy (for a summary see Orchiston, 2016: 551–552); helped found the Auckland Observatory, with its 20-inch (0.5-cm) Zeiss reflector; and made an outstanding contribution to astronomical education and outreach, mainly through his astronomical column in the *New Zealand Herald* newspaper, his activities at the Auckland Observatory, and as the 'Lecturer-Demonstrator' at the planetarium in the Auckland War Memorial Museum (Orchiston, 2016: 552–556). He played key long-term roles in the Auckland Astronomical Society and the New Zealand (later Royal) Astronomical Society; was a member of the IAU; and belonged to and published in the journals of leading overseas astronomical societies, such as the British Astronomical Association and the Royal Astronomical Society of Canada (e.g. see Orchiston, 2016: Table 19.3).

7 NOTES

1. At various times McIntosh decried the lack of active meteor observers (e.g. see McIntosh, 1929d; 1936e; 1940c; 1940e), but New Zealand was a spacious country with a tiny population and soon World War II would intervene and disrupt all of the New Zealand Astronomical Society's observing sections. During the war McIntosh (1941a) was so busy that he had to abandon meteor observing himself, and he devoted whatever time and energy he could assign to astronomy to the analysis of prior observations and to writing research papers on this work.
2. This particular journal was chosen because at this time the Canadian astronomer Peter McKenzie Millman (1906–1990; Russell, 1991) from the David Dunlop Observatory and later the Dominion Observatory was very active and had a large number of amateur astronomers observing meteors under his direction (Millman, 1937; Tors, 2006). Immediately after WWII, Donald William Robert McKinley (b. 1912) from the National Research Council began carrying out radar observations of meteors, in a radar-visual-photographic collaboration with Millman. Consequently, meteor astronomy had a high research profile in Canada, and the *Journal of the Royal Astronomical Society of Canada* regularly included papers on meteors (see Jarrell, 2009).
3. A train is

   > … the luminescent cloud, left behind along part of the trail. The train is visible after the meteor had disappeared; it is fading out gradually, lasting a few seconds, sometimes minutes, and even hours. (Öpik, 1951).

   The aforementioned 'trial' is

   > … the visible portion of the path of the meteor in the atmosphere. The trail is observable only during the short duration of the flight of the meteor. (*ibid.*).

   Beech (1987: 445) points out that

   > While enduring trains are not common, there is as long history of their observation, and an equally long-lasting confusion as to their origin. Present-day mechanisms for the production of coloured and long-enduring meteor trains are complex and based on a detailed knowledge of the chemical structure of the Earth's atmosphere and the process of meteor ablation.
4. Hughes (1990) reminds us that some meteor observers used their observations of meteor heights, path lengths, velocities and trains to investigate the temperature, winds and electron density of the Earth's ionosphere. McIntosh and his team were solely interested in meteors as astronomical objects, and McIntosh never published any papers where he used the Section's meteor observations to probe the atmosphere.
5. Upon critically reviewing the stationary radiant debate, Beech (1991b: 250–251) writes:

   > As the nineteenth century drew to a close, the existence of stationary radiants was generally accepted as a proven fact. Denning had been awarded the Gold Medal of the RAS for his work … and his observations had attracted general support from several high ranking British astronomers (e.g. A.S. Herschel, H.H. Turner, and R. Ball). The complete lack of any explanatory theory for stationary radiants was not, at that time, seen as a fatal problem.

   Beech (1991a: 444) saw Herschel's death in 1907 as critical, for with it Denning

   > … lost a very important ally. Herschel's support and promotion of the stationary radiant concept in 'professional circles', had been important in the early debate … [but] The truly fatal attack on the stationary radiant concept began shortly after Herschel's death, in 1912, when Olivier published the first of his articles on the topic.
6. McIntosh's (1935b) major paper on south-

ern meteor radiants also provided the inspiration for later New Zealand meteor observers, such as Ken Morse (1976) of Gisborne (and later Wellington) and J.E. Morgan (1979) of Renwick. McIntosh's paper also provided the lead author of this paper (WO) with the basic list of radiants needed when he began serious meteor observing in 1959. First he looked at the Phoenicid meteor shower (see Orchiston, 1963), but one of his objectives was to investigate some of McIntosh's minor radiants, and in the process he even discovered a new one to add to the list (see Orchiston, 1964).

7. As early as 1928, Professor Olivier (1928b) wrote this about McIntosh:

> R.A. McIntosh has been observing for about 10 years and besides has given much study to the technical side of meteoric astronomy. A close examination of his records and results has convinced the writer that the work of Mr. McIntosh now may be considered as of the highest class and can be accepted by astronomers with confidence in its accuracy.

   As Richard Taibi (pers. comm., August 2021) reminds us, this is high praise indeed, coming as it does from a professional astronomer who was "Chairman of the American Astronomical Society's Meteor Committee and President of the IAU's Commission 22 on Meteors …"

8. Such a study would make an excellent history of astronomy PhD project.

8 ACKNOWLEDGEMENTS

We would like to thank the late Mrs Jackie St George for giving the first author extensive archival records that she obtained from the descendants of Ronald McIntosh. We also wish to thank Richard Taibi (USA) for providing useful information, and Mrs Darunee Lingling Orchiston for kindly supplying Figure 14. Research for this paper involved substantial use of ADS.

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Wayne's recent books include *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Skies Changed* (2015, Springer, co-authored by Stella Cottam), *Exploring the History of New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits* (2016, Springer); *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy* (2017, Springer), *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe* (2017, Springer, co-edited by Tsuko Nakamura), *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities* (2021, Springer, co-edited by Mayank Vahia) and *Golden Years of Australian Radio Astronomy: An Illustrated History* (2021, Springer, co-authored by Peter Robertson and Woody Sullivan). Wayne has also edited or co-edited a succession of conference proceedings.

Since 1985 Wayne has been a member of the IAU, and he is the current Immediate Past President of Commission C3 (History of Astronomy). He is also a member of the International Society for Archaeoastronomy and Astronomy in Culture (ISAAC); the IUHPST's Commission for the History of Ancient and Medieval Astronomy; and the IAU Working Groups on Archaeoastronomy and Astronomy in Culture, and Ethnoastronomy and Intangible Heritage. He is the Founding Chair of the History & Heritage Working Group of the SE Asian Astronomy Network (which is very involved in archaeoastronomy and ethnoastronomy). In 1998 he co-founded the *Journal of Astronomical History and Heritage* and is the current Managing Editor. He and Dr Stella Cottam were co-recipients of the American Astronomical Society's 2019 Donald Osterbrock Book Prize, and minor planet '48471 Orchiston' is named after him.

John Drummond became fixated with astronomy at the age of ten when his mother pointed out 'The Pot' in Orion to him. From that moment on he was hooked on the Universe. Joining the Junior Section of the local Gisborne Astronomical Society not long after, John would regularly do group meteor watches, telescope viewing and listen to astronomy talks. He also developed an interest in photography, and it was not long before he combined these two interests and began astrophotography. John's photographs have been used in many overseas books and magazines—and were used on two New Zealand stamps. He was the Director of the Royal Astronomical Society of New Zealand's Astrophotography Section for thirteen years, until 2018. He is currently the Director of the Society's Comet and Meteor Section.

John lives about 10km west of Gisborne, on the east coast of the North Island of New Zealand, and has a range of reflecting telescopes up to 0.5-metres in diameter. He regularly images with these telescopes and CCDs, and also carries out astrometry of comets, asteroids and NEOs, and sends his observations to the IAU Minor Planet Center. John has also confirmed several comets. His Possum Observatory has the IAU code E94. John has also co-discovered about 20 exoplanets in collaboration with the Ohio State University—including the unusual 2-Earth-mass planet orbiting a binary star, which forced astronomers to rethink planetary formation models. John is a co-author of more than 60 research papers, and he is also a contributing editor for the *Australian Sky and Telescope* magazine. He enjoys giving talks around New Zealand on historically-famous astronomers.

John was the President of the Royal Astronomical Society of New Zealand from 2016 to 2018 and is currently the Society's Executive Secretary; in 2019 he was made a Fellow of the Royal Astronomical Society of New Zealand. In 2016 John was awarded an MSc (Astronomy) by Swinburne University in Melbourne (Australia), and currently he is researching the history of cometary astronomy in New Zealand as a part-time off-campus internet-based PhD student in the Centre for Astrophysics at the University of Southern Queensland (Australia), co-supervised by Dr Carolyn Brown and the first author of this paper.

When not doing astronomy, John is a secondary school science teacher. He also enjoys surfing the great waves of Gisborne and pottering around on his small farm tending to his sheep.

Michael Luciuk is a US amateur astronomer with an interest in astrophysics, astronomical instrumentation, and meteors. In 1953 he graduated with a BSc in Engineering Physics, and in 2007 pursued his interest in astronomy by completing a part-time off-campus Master of Astronomy through James Cook University, Townsville (Australia). As part of that degree, Michael carried out research on the meteor observations of the New Zealand amateur astronomer, Ronald McIntosh, for his mini-thesis project (supervised by the first author of this paper).