Clusters of Solar Eclipses in the Maori Era

Emil Khalisi
D–69126 Heidelberg, Germany
e-mail: ekhalisi[dot]at[khalisi[dot]com

Abstract. A dozen of high-magnitude solar eclipses accumulated near New Zealand in the 15th century AD when the Maori inhabited the two main islands. Taking today’s capital Wellington as the point of reference, we counted ten events with magnitude larger than 0.9 between 1409 and 1516 AD and two more just below this value. The eclipses need not have been all observed on account of weather conditions. An allusion to a particular event that could be conveyed in a myth is discussed, but the dating turns out far from certain. We take the opportunity here to meet the astronomy of the Maori and their understanding of this natural phenomenon. Moreover, an announcement is made to a cluster of five central eclipses of the sun that will encounter New Zealand from 2035 to 2045.

Keywords: Eclipses, New Zealand, Maori, mythology, astronomical dating.

1 Introduction

Every planet in our Solar System except Mercury and Venus features eclipses. Some of the extraterrestrial obscurations will appear unusual and strange to us as regards totality and duration and, in some few cases, their progress. But they are nowhere as exciting as on Earth.

The variety of our terrestrial eclipses is owed to the fine-tuning of several astronomical factors: the apparent sizes of the sun and moon, the inclination of two rotational axes against the orbital plane, and the non-negligible tidal effect responsible for the slowing down of the daily rotation. Also, the shapes of tracks exhibit a diversity being unique in the Solar System. Different to other planets, an observer on Earth may experience a total or annular eclipse, compute certain cycles, and discover special features for his geographical spot. Both astronomy and mathematics push the door open to a bouquet of ideas for investigation. Involving historical aspects, the researcher is confronted with another realm full of anecdotes and stories of life facing ethnology, cultural history, and, most of all, scientific dating. Several issues have been encountered in our previous papers published on arXiv within the course of the current year.

This paper focuses on the 14th and 15th century AD when an extraordinary series of eclipses occurred in or near New Zealand. Our list of events reveals four decades, at least, with three or four closely spaced high-magnitude events. The islands were inhabited by the Maori people at that time. There is no straight account on eclipses known, but information on the Maori past is often interwoven with mythology in chants, tales, and folklore instead of writings. Such practice differs significantly from civilisations bequeathing persistent documents. In this paper we seize the opportunity to introduce a little bit of history of this people from the Pacific.

2 Colonisation of New Zealand

New Zealand remained untouched by man as one of the last spots on the map. The first pre-historic settlements emanated presumably from the Polynesian Islands (Fiji, Tonga, and Samoa) at about 800–1000 AD or, according to other estimations, at 200 BCE. The devastating decline of the biota began shortly thereafter. The ecological consequences upon the arrival of humans show similarities to many other sites in terms of deforestation and extinction of species.

There are two archaeological models that set the initial colonisation to either ≈800 AD with a small founding population of 10 to 20 individuals, or a later colonisation at 1280–1300 AD with a larger group of 100 to 200 individuals. Both assumptions can be however reconciled by a pause of about 500 years between the immigrations. Radiocarbon analysis supports the transformation of the wildlife by the intrusion of the omnivorous Pacific rat from 1280 AD on. This moment marks the earliest “visibility” of human presence. Tradition constructs legends how the first settlers arrived to New Zealand at a time as early as the 11th and 12th century. Today, an iconic date of 1350 AD is adopted and entrenched in the nationwide education system. It was established by Percy Smith (1840–1922), a New Zealand ethnographer, upon a mere exercise in averaging out genealogical lines in old narratives.

The first Polynesian settlers developed a distinct culture on the islands, now known as Maori, and called their homeland “Aotearoa”, often translated as “land of the white cloud”. Contact to European explorers opened up in 1642 when the seafarer Abel Tasman (1603–1659) discovered the land, and James Cook (1728–1779) came across a hundred years later mapping the coastline. Just as everywhere in the world, the colonial era faced deconstruction of the cultural heritage of the Maori, displacement of people, and disreg-
ard of their belief. Our modern knowledge about the indigenous people is quite sketchy, because useful relics are rare. It turns out difficult to grasp the pristine concepts of their views on nature and creation. A few petroglyphs are known but they depict predominantly humans and animals, barely natural phenomena. It will be daring to draw parallels between geometric figures and celestial objects to interpret a possible cosmology. Some ideas are fathomed out indirectly from the language itself. We know, e.g., that the Maori gave proper names to celestial objects. Besides planets and bright stars, also transient appearances like comets and meteors got their own name.

Another issue is that the first ethnological studies were performed in the late 19th century, more than 100 years after the contact with the European explorers. It is unclear how many and which details of the original thoughts amalgamated with modern knowledge. Especially the voyage by James Cook was undertaken under the auspices of the Venus transit in 1769 involving astronomers [2]. None of the scientists thought of retaining the native culture for the record but rather proudly explained their own astronomical activities presenting the latest optical devices. A recent revitalisation of the pre-colonial understanding of the sky was launched by Pauline Harris and Rangi Matamua among others [3].

3 Education in Astronomy

The Maori people practised astronomy empirically. It was entangled into a kind of astrology in their everyday life. The astronomers were looked upon as “weather prophets” and had the status of reliable advisers for travellers and fishermen [4]. They knew the movement of stars, watched for special manifestations in the sky and made use of instantaneous appearances to forecast atmospheric conditions. From this they were able to gauge sea voyages, food-quest activities, and other seasonal effects.

Astral knowledge was firmly protected inside a small circle of adepts like priests, medicine men, chieftains, and persons of rank. The Maori operated astronomical schools visited by this circle [11]. Each year they assembled to compare their observations of the heavenly bodies and discussed the relevance of omens. Useful knowledge was exchanged about crops, fishing, or food gathering. Almost every village had such a school, according to the number of its inhabitants. The course lasted for about 3–5 months, and for non-members it was strictly prohibited to even sojourn the proximity of the educational lodge. When at a short distance the passers-by had to call to those within the hut. However, a Maori individual of those days knew about the sky more than an average person in our modern time.

Storytelling held a central place in Maori life. Considered as an important skill, this was the way how history was passed on, person to person down the generations. Historical events were embedded cryptically in descriptions that have become legends over time. Many stories and myths of the Polynesians contain “semi-historical” realism, since they preserved remnant information on important incidents as well as the natural environment. This regards the genealogical lineage of royal chiefs, volcanoes, cyclonic storms, or local customs. They are all embedded into the deeds of culture heroes who are themselves based on real persons whose history has been transmuted in great mythological cycles [10]. Certain details can be found across the breadth of the Pacific islands suggesting a common origin from about 2000 BCE.

Though recitation played a central role in Maori tradition, education to an astronomer still must have been a long-winded task without written records. In general, word-of-mouth transfer did hardly suffice to acquire the necessary practical knowledge about special phenomena. An „astronomer” was usually a senior member receiving the venerablness of the local group. The mean age of a Maori amounted to 31 to 32 years in the pre-European era (till ≈1770). Only few attained an age of 50 [7]. Although the Maori developed their own calendar taking notice of the seasons and motion of the moon, they did not count particular years. It seems that they found no use in tracing an exact chronology. The incident was remembered as it was but not the time of its occurrence. Durations of rulerships are not known, either.

Due to the rareness of a solar eclipse this extraordinary experience was granted to just a few. As an adjunct, oral tradition precludes the ability of finding a regularity within the appearances. Computations were not performed, nor predictions of future events made. Each eclipse came up entirely unexpected. Thus, we should be very careful deploying possible accounts as a marker for dating, since only the last real event would be remembered by the narrator, if he was lucky to witness it by himself. The reliability of any historical information passed through the filter of oral transmission cannot be trusted for more than one or two generations despite being viewed as “true” by the culture in which they are told. On the other side, it would be unwise to entirely dismiss such a traditional story, because Polynesians (as well as Aborigines in Australia) are very gifted observers who have proven their ability in memorisation, and also in documenting and understanding nature. The historical core of the story can be objectively retrieved and studied, as done by William Masse and his collaborators [9]. He demonstrated that the myths of Polynesians do preserve impressively accurate details.

4 Woman in the Moon

The Maori language knows a number of terms for the sun in a specific context. It makes a difference when it is dealt with a reddish sun close to the horizon, or when denoting the time of day, or when it is used in a ceremonial act, or when personified with a deity — in each case a different expression was used. Elsdon Best (1856–1931), a writer and ethnographer who interviewed many Maori about their mythology and culture, enumerates many personified forms of that luminary [11]. Considerable respect was paid to the sun in rituals. Best rejects some contrary opinions by early anthropologists that no exuberant devotion would have exis-
Eclipses of the sun and moon are such striking phenomena disturbing normality that every culture wished for an explanation. Any myth about eclipses proves that people spent thoughts about their cause. In New Zealand, the demigod Maui who takes on a variety of roles in the folklore of many peoples throughout the entire Pacific region is said to have fastened the sun to the moon such that, as the former went down, the other being pulled after it \[13\]. At stated seasons Maui places his hand between the sun and the earth that there will be no light.

Like in the case of the sun, various names are applied to the moon, mostly female names. Colloquially she is called “Marama”, but the personified form is “Hina”. Both names are widespread in Polynesia, with some dialectic changes, adopting diverse roles in respect of the demigod Maui. For example, Hina is sometimes made his sister, or his mother (Hawaii), or wife (Tuamotu Islands), or daughter of other mythical beings with varying relationship to the protagonist. The moon itself is not considered as a deity but rather a kind of a natural phenomenon will already be a recognition of an adoration.

In analogy to our “Man in the Moon” the Maori mythology renders a “Woman in the Moon”, her name being Rona. She acts as a malignant being trying to attack and destroy the orb \[1\]. A popular fireside story is that Rona once lived on earth and went out to a spring for water one night carrying her gourd water-vessels. On her way back the moon disappeared behind a cloud, and Rona could not see the path. She stumbled in the dark across a root protruding out of the ground and cursed the moon for her fall. Marama, the moon, heard this and snatched her up into the sky. Rona tried to impede the assault by clinging to a tree, but the tree was teared out of the ground, together with its roots, and transferred to the moon, too. Yet, Rona is seen there in the shape of the dark patches as well as the tree and the gourd-vessels (Fig. \[1\]). During a lunar eclipse Rona battles with the moon, thus, the latter cannot be seen. After the combat the moon bathes in the “waters of life” and returns reinvigorated, young and beautiful.

Similar stories about a girl who is taken to the moon is known from a number of Siberian peoples \[4\]. In some cases they deal with an orphan, in another version she is freezing, another again speaks of a girl with an evil stepmother. A striking parallel to the Maori story is that the girl was likewise on her way fetching water.

5 Blocks of Eclipses

Taking up a more scientific view, we were not able to detect a firm record on a distinct eclipse for dating purposes. In search for outstanding events in the time before the Europeans we deployed the *Five Millennium Canon of Eclipses* by Fred Espenak \[2\]. Table 1 presents all occurrences of magnitude larger than 0.5 in the 14th and 15th century.

The magnitude (mag) of an eclipse denotes the ratio of the diameter of the moon, $\theta_M$, to the diameter of the sun, $\theta_\odot$, as seen from earth:

$$
\text{mag} = \frac{\left(\theta_\odot + \theta_M - \Delta\right)}{2 \theta_\odot},
$$

with $\Delta$ being the distance of the centres of the two disks. Both $\theta_\odot$ and $\theta_M$ have an angular diameter of $\approx 0.5^\circ$, while their minute variations are due to the alternating distance of each body at its perihelion/aphelion and perigee/apogee, respectively. If mag is $> 1$, the eclipse will be total. The magnitude is not the same as “obscurity” which is the fraction of the area of the sun’s disk covered by the moon. A solar eclipse is not necessarily noticed, since the lighting conditions will change above a magnitude $\approx 0.75$ depending on random factors like weather, attention of the observer, and perhaps the time of day.

When peering through the list, one can detect two or three decades harbouring “eclipse quadruples”, meaning that four high-magnitude events are tightly spaced. Intriguing is the period from 1424 to 1435 when the tracks passed over or close to the main islands of New Zealand (Fig. 2). This interval is expandable by 3 more years respectively. If mag is $> 1$, the eclipse will be total. The magnitude is not the same as “obscurity” which is the fraction of the area of the sun’s disk covered by the moon. A solar eclipse is not necessarily noticed, since the lighting conditions will change above a magnitude $\approx 0.75$ depending on random factors like weather, attention of the observer, and perhaps the time of day.

Remarkable is also a very tight block of three eclipses within 5 years in the 1460ies. The first eclipse however was at sunrise when the maximum obscuration had already passed. The 15th century stood out, in particular, because almost each decade offered a spectacular event, and each generation could have experienced one or several solar eclipses, in principle. If only half of the events in these blocks
Table 1: Solar eclipses over New Zealand with a magnitude >0.50. The magnitude, local time and altitude refer to today’s capital Wellington (41.4° S, 174.8° E). Eclipse types: (T)otal, (A)nnular, (H)ybrid, and (P)artial. Clusters of special interest are highlighted. The lower part of the table contains only central tracks over the mainland in the 21st century.

| Date | Type | LT  | Alt. [°] | Magn. | Remark |
|------|------|-----|----------|-------|--------|
| 1285 Nov 28 | H    | 12:39 | 68.9    | 0.770 | off the northern coast |
| 1293 Dec 29 | A    | 18:06 | 51.1    | 0.867 | central in the north, sunset |
| 1301 Aug 05 | T    | 13:12 | 31.6    | 0.907 | total on the northern coast |
| 1308 Mar 23 | T    | 14:05 | 37.0    | 0.519 | |
| 1310 Jul 27 | T    | 12:52 | 30.1    | 0.842 | |
| 1315 Oct 29 | A    | 13:04 | 59.4    | 0.602 | |
| 1317 Mar 14 | T    | 13:40 | 43.7    | 0.861 | |
| 1324 Oct 19 | A    | 7:56  | 32.9    | 0.520 | |
| 1330 Jan 20 | A    | 7:29  | 25.7    | 0.776 | central on the southern tip |
| 1348 Jan 31 | A    | 18:11 | 11.0    | 0.531 | at sunset |
| 1355 Sep 07 | T    | 12:11 | 44.6    | 0.785 | central on the southern tip, sunset |
| 1359 Jun 26 | A    | 15:08 | 12.8    | 0.778 | |
| 1364 Aug 27 | T    | 11:55 | 41.8    | 0.696 | |
| 1368 Jun 16 | A    | 8:35  | 9.5     | 0.854 | central on the northern tip, sunrise |
| 1369 Nov 30 | A    | 14:05 | 57.1    | 0.600 | |
| 1371 Apr 16 | T    | 13:27 | 32.3    | 0.807 | |
| 1376 Jan 21 | T    | 6:12  | 11.1    | 0.819 | off the northern coast, sunrise |
| 1379 Nov 10 | A    | 8:55  | 47.5    | 0.654 | |
| 1381 Apr 25 | P    | 12:22 | 32.7    | 0.573 | |
| 1384 Feb 21 | A    | 7:15  | 16.4    | 0.832 | central on the southern tip, sunrise |
| 1390 Apr 15 | H    | 9:54  | 28.7    | 0.543 | |
| 1398 Oct 24 | T    | 12:38 | 53.0    | 0.600 | |
| 1393 Nov 11 | A    | 15:28 | 22.9    | 0.855 | |
| 1407 Jul 22 | T    | 16:16 | 5.0     | 0.909 | annular on South Island, sunset |
| 1421 Feb 04 | A    | 15:25 | 40.7    | 0.647 | |
| 1427 Mar 27 | T    | 8:00  | 17.0    | 0.861 | off the southern coast, sunrise |
| 1431 Sep 09 | A    | 14:40 | 32.8    | 0.855 | annular on North Island |
| 1433 Dec 14 | A    | 8:05  | 33.5    | 0.745 | annular on the South Island |
| 1441 Nov 02 | T    | 13:56 | 53.1    | 0.890 | total on South Island |
| 1450 Jul 19 | T    | 16:16 | 5.0     | 0.909 | annular on South Island, sunset |
| 1452 Oct 20 | A    | 15:25 | 40.7    | 0.647 | |
| 1455 Dec 27 | T    | 8:00  | 17.0    | 0.861 | off the southern coast, sunrise |
| 1460 Jan 15 | A    | 8:20  | 32.8    | 0.855 | |
| 1462 Apr 28 | T    | 13:28 | 53.0    | 0.600 | |
| 1463 Nov 11 | A    | 15:28 | 22.9    | 0.855 | |
| 1467 Oct 31 | T    | 5:04  | 3.5     | 0.900 | sunrise |
| 1478 Feb 03 | A    | 15:25 | 40.7    | 0.647 | |
| 1482 Mar 27 | T    | 8:00  | 17.0    | 0.861 | off the southern coast, sunrise |
| 1485 Sep 09 | A    | 14:40 | 32.8    | 0.855 | annular on North Island |
| 1488 Jan 14 | A    | 8:05  | 33.5    | 0.745 | annular on the South Island |
| 1491 Nov 02 | T    | 13:56 | 53.1    | 0.890 | total on South Island |
| 1500 Jul 10 | H    | 16:16 | 5.0     | 0.909 | annular on South Island, sunset |
| 1517 Jun 30 | A    | 13:24 | 23.7    | 0.921 | annular on northern coast |
| 2028 Jul 22 | T    | 16:02 | 8.0     | 0.854 | total on mainland, sunset |
| 2035 Mar 09 | A    | 9:35  | 39.1    | 0.987 | central in outskirts of Wellington |
| 2037 Jul 13 | T    | 15:25 | 11.9    | 0.955 | total on North Island, sunset |
| 2038 Dec 26 | T    | 13:01 | 68.1    | 0.989 | total on mainland |
| 2042 Oct 14 | A    | 15:13 | 33.8    | 0.858 | central on South Island |
| 2045 Feb 16 | A    | 10:35 | 53.4    | 0.960 | central in Wellington |
| 2066 Dec 17 | T    | 12:02 | 72.0    | 0.832 | total on Stewart Island |
| 2068 May 31 | T    | 16:48 | −2.2    | 0.866 | total on South Island, sunset |
| 2079 Oct 24 | A    | 5:07  | 0.8     | 0.969 | central on mainland, sunrise |
| 2096 Nov 15 | A    | 12:58 | 62.6    | 0.815 | central on North Island |
| 2099 May 21 | A    | 8:59  | 20.2    | 0.804 | near miss: ≈100 km |
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Figure 2: Three annular eclipses (yellow) and three total eclipses (grey) within 14 years in New Zealand in the 15th century. The last three events of 1435, 1437, and 1438 would be seen partial onshore.

had been perceived by the same observer, they would have left a lasting impression. Such a state of affairs we claim, e.g., for the Egyptian pharaoh Akhenaten who might have witnessed three high-magnitude eclipses, see [5]. One possible Maori account is discussed in the next section below. Further triples occurred in the time intervals from 1163 to 1167 as well as 1545 to 1554 (both not in the list) with their magnitudes ranging at somewhat lower values than above.

The second half of the 15th century was characterised by a phase of low solar activity, the so-called Spörer-Minimum. This is a period of suspended sunspot activity lasting from 1460 to 1550 AD. The total eclipses of 1463 and 1491 over the South Island could have presented a pale corona and probably no prominences. These concomitants of totality, which are not visible in partial or annular eclipses, were already mentioned in European literature before, but the scientific discussion picked up momentum in the late 17th century. An individual, who usually sees a total eclipse once in his lifetime, has the disadvantage of no direct comparison of events. The observer refers to the sudden darkness and its psychological impact. It is the multiple experience that would have raised awareness of the existence about such things like the corona and prominences. Ancient scholars were much too amazed about the abruptness that they did not pay attention to such intricacies for many centuries.

In our time, eclipses lost their dread. They have become a tourist attraction, and eclipse chasers will have their fortune in the years 2035 to 2045. New Zealand will be hit by a quintuple of central events (Fig. 3). There exits a small region about 75 km off the Eastern coast of North Island where four of the five eclipses can be seen centrally ( quadruple point). The eclipses in the 21st century surpass by number those of the Maori era. The histogram in Figure 4 gives an overview of central events per century that traversed the main islands during the past millennium up until 2500 AD. The area size of New Zealand is akin to United Kingdom, but it is blessed with eclipses in our time. The principal advantage of the country, however, is its elongated shape (1400 km in North-South direction vs. 900 km for the UK) boosting the probability to be crossed by an umbra or antumbra.

6 An Ancient Eclipse Record?

A recent study on the early Maori settlement made a dating attempt based on an alleged eclipse from ancient times. Ockie Simmonds and Kiyotaka Tanikawa believe that two Polynesian tribes from the eastern Pacific arrived later than commonly believed, in late 1408, and witnessed the solar eclipse of 9 October 1409 [8]. That statement made us re-check the circumstances.
The arguments rely on the genealogy of the tribes involving 24 generations of 25 years on average. Using these numbers, the authors estimated the two seafaring groups by tracking down the names of chieftains from their modern ancestors at 1900 AD. In their conclusion, that journey across the ocean would have taken place about 600 years ago providing an approximate time range for further analysis in more detail.

The mythological story to which the heroic individuals of the tribes are connected is said to contain information on a sudden darkening. The persons must have witnessed the totality of an eclipse, the authors of the study assume. Additionally, the names of two or three geographical places on North Island would point to the newcomers’ walking tour when they explored the volcanic plateau around Lake Taupo following their arrival. These places are named after the members of that tribe. One of them, for example, is said to have been pursued by an “evil witch”. He sought shelter in a rock and escaped her. That place is now sacred in the memory of the Maori and, moreover, a government protected site. Using extra information on key persons, the authors infer the eclipse of 9 October 1409 as the most appropriate event that swept over the region (Fig. 5).

The work is characterised by an industrious collection of semantical details on Maori legends, an ability of proper recitation, and a decent sense of locality. However, the reasoning appears weak to us from the scientific point of view. The authors point out in their introduction how crude and unsatisfactory the 25-years-generation-count actually is for establishing a chronology. In spite of their own warnings they adhere to the relative sequence of traditional genealogies and eventually fail to provide absolute historical markers. The happenings are solely pinned to that alleged eclipse. It would be much appreciated, if a few intermediate pillars backed those 600 years between then and now (comets, encounters of planets, or natural disasters). Another advantage would arise from independent evidence, for instance, samples for radiocarbon analysis or other substantiated material. Even without this kind of hard evidence we cannot approve of the smooth linearity of rulerships of 25 years, as if there were never premature deaths nor conflicts among contender rulers nor any other troubles affecting the timeline somehow.

Among other inconsistencies we wonder about those three protagonists of the tribe, one of which is said to have perished in the cold. From our point of view, this is no proof for the onset of snow, nor does it tell anything about the season. The authors go on suggesting locations on the North Island where the persons might be overtaken by the shadow of the solar eclipse. Comparing their suggested locations with the track of 1409, all of them would have stayed outside the zone. If accepting that sudden darkness to be an eclipse, we discovered two other events for the North Island including Lake Taupo: 23 Apr 1735 and 8 Feb 1739 (Fig. 5). They exhibit an almost identical path. Both would agree with the locations proposed by the authors much better, although we express serious doubts whether their exact positions can be retrieved at all. There would even be a third totality in 1748, a bit outside the region in question though. It would be easier to suspect a slip in the story than a displacement of the eclipse track at will in order to please the plot. We abstain from discussing other flaws in the line of argumentation.

As pointed out by Rawiri Taonui [10], migratory stories contain the greatest mix of history and symbolism. They are the most difficult to interpret and have led to much distortion in publications as writers often overemphasised the content. For New Zealand more than 40 “first arrival traditions” are known, and each large tribe claims one or more ancestors to have settled there at some time between 950 and 1350. Even in case of the lineage being true, one sole hint centred on the eclipse will hardly suffice to withstand the test as regards the absolute timescale.

### 7 Summary

Our investigation of solar eclipses in the southern hemisphere of the earth revealed a good number of closely spaced tracks in the region of New Zealand: triples and quadruples within a decade. Three such blocks piled up in
the 15th century when the Maori inhabited the islands. A quintuple will commence in 2035. Such clusterings are statistical outliers making eclipses on Earth something special among the planets.

We gained beneficial insight into the native culture of New Zealand that used to preserve its history in semi-mythological tales. Being aware of the risks at judging a mental attitude completely different from the modern European comprehension, we cannot hearken back to substantiated accounts about an observation of an eclipse. Astronomical dating out of myths remains precarious. We want to encourage those being familiar with the mythology and folklore of the Maori to search for probable eclipses but likewise hand out advice to be cautious at interpretation. Not every mention of a sudden darkness means an eclipse. Sky dimming may have manifold reasons. A total event under an overcast sky could pass unnoticed, even if standing inside the totality zone. There will be a lot to discover in the old narratives when exercising due care.

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Figure 5: Four total eclipses on North Island. Red dots show the locations of the Maori explorers in the myth as suggested by [8]. The track of 1748 is unshaded for clarity.