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A METHODOLOGY FOR TESTING HORIZON ASTRONOMY IN AUSTRALIAN ABORIGINAL CULTURAL SITES: A CASE STUDY

Trevor M. Leaman[1*] and Duane W. Hamacher[2,3]

[1]School of Humanities and Languages, University of New South Wales, NSW, 2052, Australia
[2]Monash Indigenous Studies Centre, Monash University, Clayton, VIC, 3800, Australia
[3]Astrophysics Group, University of Southern Queensland, Toowoomba, QLD, 4350, Australia

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**Corresponding author: (t.leaman@unsw.edu.au)*

ABSTRACT

Aboriginal people connect landscape to the positions of the Sun and Moon throughout the year for time reckoning, seasonal calendars, and mythology as a memory aide. This can include the rising or setting of the Sun, Moon, and stars over significant landscape features. A significant corpus of Wiradjuri (Wiradyuri) astronomical knowledge has been fragmented, lost, or damaged due to colonisation. To aid in reconstructing this knowledge, we develop a novel methodology to examine potential links between the landscape and celestial movements. Our methodology, which we call *Significant Horizons*, ranks Aboriginal cultural sites according to their *potential* for astronomical utilisation. This is done by taking into consideration the cultural site's location and position within the environment and examines the surrounding horizon profile from that place. We rank each site on the number of solar and lunar alignments that occur on "notches" and "points" in these horizon profiles. To accomplish this, we utilize and combine the *Horizon* software package to generate these profiles and include the rising and setting positions of celestial bodies along it. We examine Aboriginal cultural sites within Wiradjuri country of central New South Wales as a case study. Our ranking system enables us to predict whether Wiradjuri cultural sites, such as ceremonial grounds, are likely to be astronomically-significant. We predict that ceremonial sites will have a higher ranking than subsistence sites, which hold a more utilitarian function. Our results are consistent with this prediction. We suggest further refinements to the methodology by including stars of cultural significance into the horizon analysis.

Notice to Aboriginal and Torres Strait Islander people: This paper contains brief references to Aboriginal cultural sites, including sites that may have been used for initiations. Apart from inferred possible astronomical connections to these sites, other cultural use and practices are not discussed, as it is restricted.

KEYWORDS: Aboriginal Australians, Aboriginal Astronomy, Horizon Astronomy, Aboriginal Cultural Sites, Wiradjuri

1. INTRODUCTION

The Wiradjuri (var: Wiradyuri) people of central New South Wales, Australia represent the largest Aboriginal language group in the state, and second largest in Australia (Figure 1). Having close similarities to their neighbours, such as the Kamilaroi/Gamilaroi and Ngemba/Ngiyampaa, Wiradjuri culture is rich in astronomical knowledge and traditions (Hamacher, 2014; Leaman & Hamacher, 2018). However, little of this astronomical knowledge has been adequately recorded or studied. The *Wiradjuri Astronomy Project* draws upon the available literature, museum and library archives, artworks, and ethnographic and archaeological studies to capture and record Wiradjuri astronomical knowledge and, with community involvement and participation, help pass it on to future generations.

Figure 1 Language map of SE Australia showing the Wiradjuri (Wiradyuri) in relation to neighbouring Aboriginal language groups[i].

One focus of this project is to determine whether Wiradjuri cultural sites, specifically those which feature stone arrangements, were places from which astronomical observations were, or could have been, made. Clues that such sites were used in this manner can be found in the following quotes:

> *"Little wonder that the Aborigine acquired a sound knowledge of the relative positions of the stars…and in his primitive observatory the Karaji kept a three days and three nights solitary vigil within a stone circle on a mountaintop, communing with Wanda, the Unknown Spirit"*
>
> – W.A. Squire (1897:60).

> *"… I well remember my father's astonishment and sense of discovery at finding that the natives knew the solstices just as truly as we did…it was done by means of certain fixed mountain-rocks known to the tribes…"*
>
> – M. Gilmore (1932:370).

> *"…. the Moon climbed up into the sky from a little hill, which stands straight up and is…the earthly home of Baiame."*
>
> - R.M. Berndt (1947:82)

Although many Wiradjuri cultural sites have been listed in the Aboriginal Heritage Information Management System (AHIMS) database[ii], others are still being re-discovered and yet to be included (Figure 2). The ethno-historical record indicates some of these sites contained an astronomical component. However, cultural disconnections to these sites from the effects of invasion, colonialism, and community displacement (MacDonald, 1998; Read, 1983; 1984) often makes establishing astronomical links difficult.

Surveys of the orientations of linear stone arrangements (Hamacher et al, 2012) indicate a preference for the cardinal directions (E-W, N-S), and Bora ceremonial sites appear to be oriented to the direction of the setting 'Sky Bora' in the Milky Way on the south-southeast horizon (Fuller et al, 2013). Another

stone arrangement, at Wurdi Youang (Wathaurong lands, Victoria), appears to mark the position of the setting Sun at the Solstices and Equinoxes (Norris et al, 2013).

Figure 2 The 'Kentucky Stone Arrangement', a newly discovered site in a north-facing saddle of a ridge in the Kentucky State Forest south of Neville, NSW, with views to the eastern and western horizon. The arrangement is yet to be properly surveyed and added to the AHIMS database

But what of the many other cultural sites scattered across the region? How many of these incorporated astronomical alignments or links? Answering this would normally require extensive fieldwork surveys, stretching the funds and resources of most research institutions. One way to circumvent this is to identify highly significant sites through an easy, inexpensive site selection process prior to any follow-up investigation. The methodology we apply here, called *Significant Horizons*, takes into consideration the positioning of cultural sites within the landscape. As the opening quotes (above) allude to, being in or near mountains or hilly terrain may offer the best horizon backdrop from which to observe astronomical phenomena, such as the rising and setting of the Sun, Moon and culturally important stars. The concept of *Horizon Astronomy* is not new and many examples can be found worldwide (e.g. see: Belmonte, 2015; Belmonte & Edwards, 2010; Ghezzi & Ruggles, 2007; McCluskey, 1990; Moyano, 2015). However, it has not previously been considered for, nor applied to, investigations into Australian Aboriginal astronomical traditions.

Significant Horizons utilises the cultural astronomy program *Horizon*[iii]. Originally designed for archaeo-astronomical investigations of European cultural sites (Higginbottom & Clay, 2014; 2016), it uses the Shuttle Radar Terrain Mapping (SRTM) 90 m digital elevation database[iv] to generate accurate and realistic horizon profiles for any selected location. This methodology ranks cultural sites of interest on a 10-point scale based on the number of solar and lunar (this survey), and/or stellar (future surveys) alignments to "notches" and "points" in these horizon profiles (Figure 3). The higher the ranking, the greater the potential for a site to be used to observe a rising or setting luni-solar alignment, and resources may then be directed towards further inquiry.

Here, we apply *Significant Horizons* to rank the solar and lunar alignments of 14 sites (Table 1) representing a cross-section of cultural activity types with the information required to conduct the study. These sites include ceremonial sites, stone arrangements, stone quarries, rock art sites, and sites where cultural significance is not yet fully established. The aim is to determine whether cultural sites of potential astronomical significance can be identified, and thus singled out for further investigation. Although exact site location coordinates were used in the analysis, the table only gives general location coordinates (within the nearest tenth of a degree Lat/Long) in order to protect their identity.

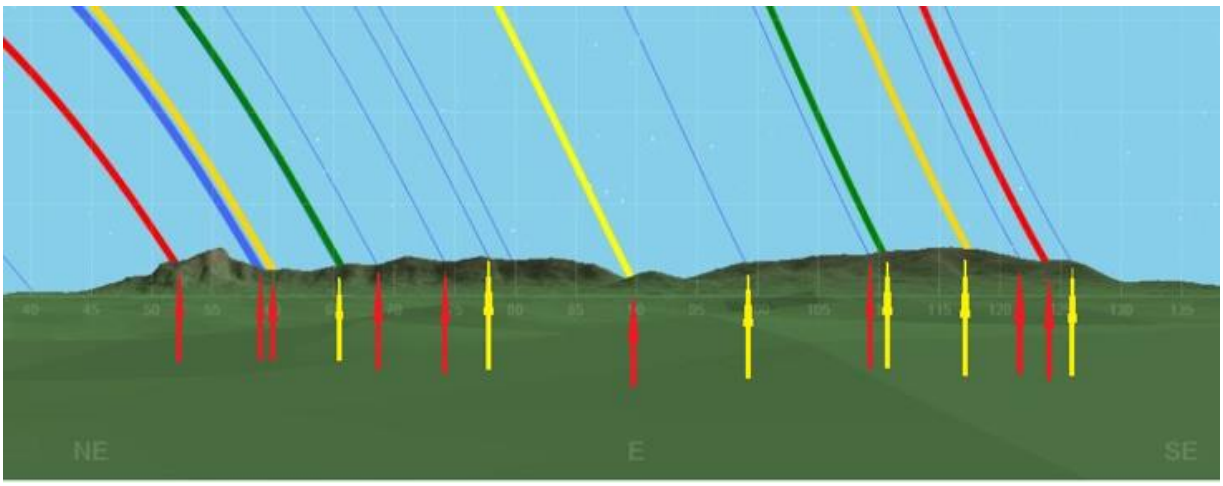

Figure 3 Eastern horizon profile of Kengal (The Rock) from the Kengal Lake Gilman site showing astronomical alignments with "Notches" (red arrows) and "Points" (yellow arrows). Yellow lines indicate paths of the Sun at the June (left), December (right) Solstice and Equinox (centre). The paths of the major and minor Lunar standstills are indicated by the red and green lines, respectively. The Pleiades (thick blue line) and important cultural stars (thin blue lines) are also indicated, and are part of a follow-up study.

2. METHODOLOGY

2.1. SELECTION OF ASTRONOMICAL OBJECT AND PHENOMENON FOR ALIGNMENT ANALYSIS

Table 2 lists the astronomical object and associated phenomena that were tested in this analysis. For solar observations, the horizon positions for the solstices and equinoxes were used. Similarly, the major and minor lunar standstills were used for lunar observations.

2.2. GENERATING HORIZON PROFILES

In order for the *Horizon* program to generate horizon profiles, it is necessary to first convert the appropriate SRTM terrain data to a format the program can use. Instructions on how this is done can be found in the user manual provided with the *Horizon* program upon downloading.

Horizon profiles for each of the 14 sites (Table 1) were created individually using the *Horizon* program. All profile images were processed with a 1.5x vertical stretch factor to overcome minor profile smoothing due to the way the radar terrain data is processed. The resulting profile images are thus a closer match to what the eye sees (Higginbottom & Clay, 2014; 2016).

Table 1 AHIMS site card number (where applicable), location (to nearest tenth of a degree Lat/Long) and site description of the 16 sites studied in this paper. Site codes: stone arrangement (S); quarry (Q); bora (B); art site (A); scar trees (T); suspected but yet to be confirmed as a cultural site (U).

Site	AHIMS Site Card Number	Latitude	Longitude	Code
Merri Abba	n/a	33°.3S	146°.0E	U(B?)
Mt Horrible	44-3-0025	33°.3S	149°.8E	S
Mt Pleasant	44-2-0015	33°.3S	149°.5E	S
Alectown	35-6-0008	33°.0S	148°.2E	S
Kentucky	n/a	33°.7S	149°.1E	S
Goobundry	n/a	32°.8S	147°.5E	Q(B?)
Snake Rock	n/a	32°.7S	147°.8E	A
Bogolong Hill	43-6-0007	33°.9S	148°.2E	SB
Kengal Lake Gilman	n/a	35°.3S	147°.0E	U
Kengal Little Rock	n/a	35°.3S	147°.0E	U
Wagga Wagga CSU	n/a	35°.0S	147°.4E	B
Rocky Outcrop SSR	n/a	33°.0S	147°.5E	U
Manildra	44-1-0004	33°.2S	148°.7E	S
Meranburn	44-1-0024	33°.1S	148°.5E	ST

Table 2 Number and type (Solar and Lunar) of observations used to create the matrices used in site ranking calculations.

Observation Type	Phenomenon/Object	Eastern Horizon	Western Horizon	Observations	Observations per Type
Solar	June Solstice	1	1	2	6
	December Solstice	1	1	2	
	Mar/Sept Equinox	1	1	2	
Lunar	Major Standstill N	1	1	2	8
	Major Standstill S	1	1	2	
	Minor Standstill N	1	1	2	
	Minor Standstill S	1	1	2	
	Total Observations	**7**	**7**	**14**	

2.3. GENERATING THE ALIGNMENT MATRICES

Each site profile image was visually inspected for solar and lunar 'notch' and 'point' alignments along the eastern and western horizons. Alignments were totalled for each astronomical phenomenon, and converted to a 10-point 'Ranking' for graphical analysis.

2.4. CONVERTING ALIGNMENT MATRICES TO RANKINGS

Conversion of matrices to 10-point rankings was done by the application of a simple formula, followed by rounding to the nearest whole number:

$$R_{S,L} = (A_n / A_T) \times 10$$

where $R_{S,L}$ is the site rank (solar or lunar), A_n is the number of observed alignments, and A_T is the total number of alignments possible.

For example, for a site with alignments on the December and June solstice only in the eastern horizon, and December solstice and equinox only in the western horizon, the solar rank for this site would be:

$$R_s = (4/6) \times 10 = 6.67 = 7$$ (rounded to nearest whole number).

The lunar ($A_T = 8$) and combined ($A_T = 14$) rankings were calculated similarly.

2.5. STATISTICAL ANALYSIS

For each of the 14 cultural sites, four alternate sites were chosen using a random number generator randomised on seconds of arc, such that their latitudes and longitudes fall within a range of ± 0.1 degrees of that cultural site[v]. Horizon profiles and alignment matrices were analysed in the same manner as for the cultural sites. These data were used to provide a statistical comparison (mean ± σ) between the cultural site and nearby alternative sites, to highlight the probability that a cultural site was deliberately chosen due to its suitability for observing the astronomical phenomena discussed.

3. RESULTS AND DISCUSSION

The solar and lunar site rankings for the 14 sites studied here were plotted graphically (Figures 4 & 5). Of note are two sites which scored particularly highly, namely Mount Pleasant (rankings: solar 8, lunar 5, combined 6) and Kengal Lake Gilman (solar 8, lunar 8, combined 8). Mount Pleasant is a flat-topped hill just to the west of Bathurst with views to both east and west horizons. The site originally had a series of stone cairns along the top of the plateau (Gresser, 1961) which are now difficult to see or no longer visible. The Bathurst Wiradyuri considered Mount Pleasant second only to Wahluu (Mount Panorama - which also featured several stone arrangements near the summit) in terms of cultural significance (Anonymous Wiradjuri informant, pers. comm. 2015). For this, and its statistically significant high site ranking, further investigation is recommended.

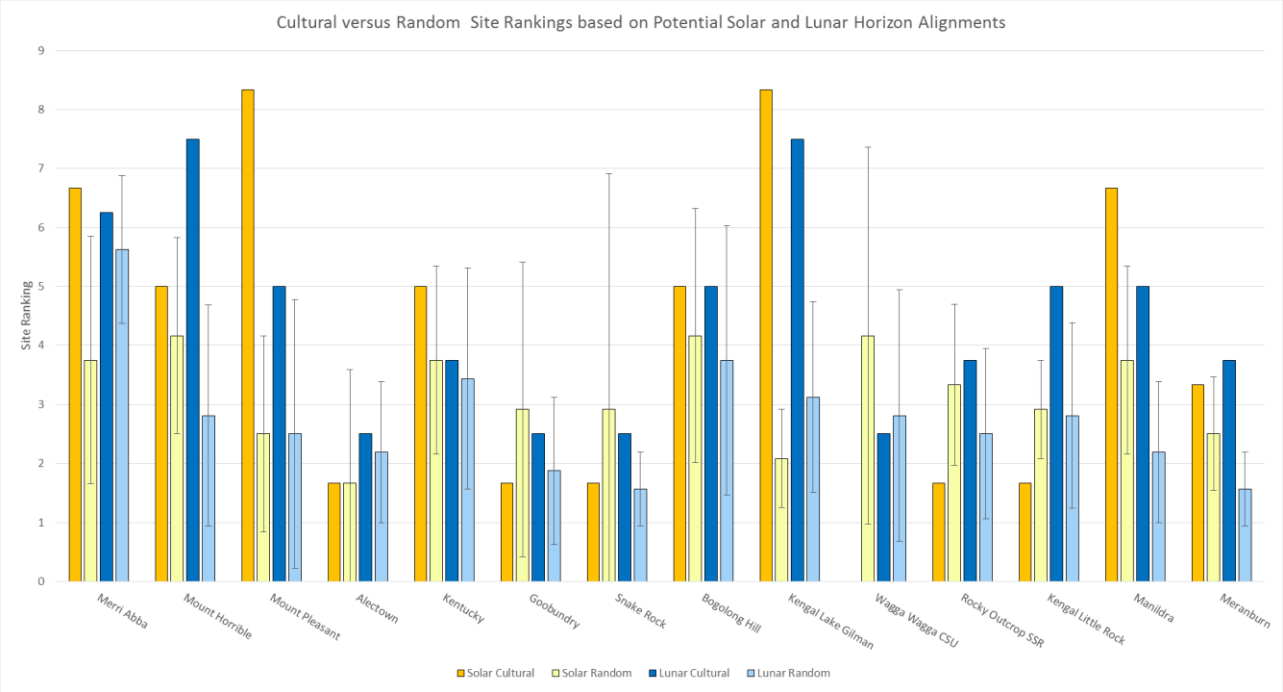

Figure 4 Individual solar and Lunar horizon site rankings for each of the 14 cultural sites studied in this survey. Error bars on Random Sites represent the standard deviation of site ranking over four randomly selected alternative sites within 0.1 degrees Lat/Long (~10 km N-S, E-W) of the cultural sites listed in Table 1.

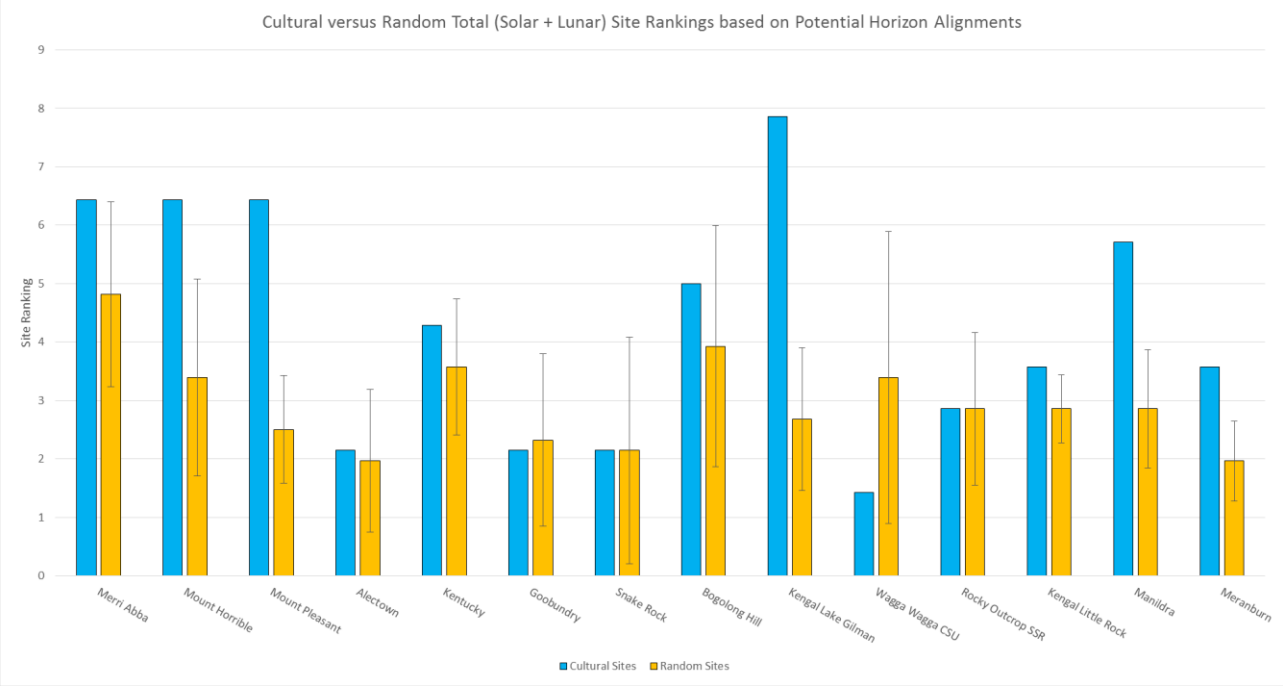

Figure 5 Combined solar and lunar horizon alignment site ranking for each of the 14 cultural sites studied in this survey. Error bars on Random Sites represent the standard deviation of site ranking over four randomly selected alternative sites within 0.1 degrees Lat/Long (~10 km N-S, E-W) of the cultural sites listed in Table 1.

The Kengal Lake Gilman site is one of three sites of interest in the vicinity of Kengal (The Rock), a prominent and highly culturally significant feature of the landscape about 30 km SW of Wagga Wagga. Kengal is linked to Dreamings associated with the great creator, Baiame (Berndt, 1974; Hartland, 1898). In one such Dreaming, Baiame used Kengal to step off into the sky to settle a dispute between the Sun and Moon. In the process, he left his three dingo companions behind, becoming the three surrounding hills (C. Heckenberg, pers. comm. 2015). The Lake Gilman site, just to the west of Kengal, is a women's site known to the local community.

Other sites worth investigating further are Merri Abba (solar 7, lunar 6, combined 6) and Mount Horrible (solar 5, lunar 8, combined 6). The newly identified stone arrangement site at Kentucky (Figure 2) appears not to occupy a site of any solar or lunar astronomical significance, as does the Alectown stone arrangement site.

Lastly, of the three lowest ranked sites, Snake Rock is a rock art site and Goobundry is a recorded stone tool quarry (although a 'Bora' site was recorded in the area). Their low rankings may be indicative of their terrestrial (i.e. non-astronomical) cultural function or purpose. The third site, Rocky Outcrop SSR (solar 2, lunar 4, combined 3), is a suspected cultural site of undefined purpose and consists of a small stone ridge breaking through relatively flat ground. Its cultural significance may be through a connection to a possible Dreaming track running from a rock art site at West Cookeys (Black Ridge) 12 km to the north, through the outcrop, to Seven Sisters Ridge (also a rock art site) 6.5 km to the SW (R. Shepherd, pers. comm. 2017). However, there may also be an astronomical link: the outcrop is situated such that the Celestial Emu[vi] can be seen setting over Seven Sisters Ridge. Upon checking other horizon profiles, there were three other sites (Mt Horrible, Bogolong Hill, Meranburn) for which possible alignments on the setting Celestial Emu occurred. This highlights a need for a further development of the methodology to also take this and other astronomical (i.e. stellar) alignment into consideration for future site ranking studies.

4. CONCLUSION

Here, we describe a simple methodology which:

(1) Aids in determining possible astronomical associations of cultural sites;
(2) Assists with site selection for more thorough investigation; and
(3) Compliments (but not replaces) other methodologies such as archival studies, ethnography, and on-site surveys.

A major advantage of this technique is that calculations can be done off-site anywhere at any time, and is not subject to adverse weather conditions affecting observations with a narrow window of opportunity, such as at the solstices, equinoxes, and lunar standstills.

This paper describes the application of this methodology to 14 Wiradjuri cultural sites to test its ability to discriminate between different cultural site use types based on possible solar and lunar alignments. Of these, four sites (Mt Pleasant, Kengal Lake Gilman, Merri Abba, Mt Horrible) were deemed highly significant and worthy of further analysis.

It is hoped that the analysis of more cultural sites will further refine our methodology and ultimately demonstrate its usefulness in archaeoastronomy. A more in-depth follow-up of this methodology is currently being undertaken by the authors.

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[i] https://upload.wikimedia.org/wikipedia/commons/f/f4/Wiradjuri_Map.png

[ii] www.environment.nsw.gov.au/licences/AboriginalHeritageInformationManagementSystem.htm

[iii] www.agksmith.net/horizon

[iv] http://srtm.csi.cgiar.org/srtmdata/

[v] 0.1 degrees of arc at the latitude and longitude of the cultural sites studied equates to ~10km linear distance.

[vi] The Celestial Emu is found in Aboriginal traditions across Australia, including the Wiradjuri (Hamacher 2014). It comprises the dark spaces in the Milky Way stretching from the Coalsack nebula in Crux to the galactic bulge in Scorpius and Sagittarius. The rising and setting of the emu at dusk is a significant cultural event in Aboriginal traditions (Fuller et al, 2013; 2014).