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Key Points:
- We present a previously undocumented observation of a large sunspot group for which the local meteorological conditions are known
- An unaided-eye sunspot observation was recorded in China on the following day
- Contemporary photographic and tabular data corroborate these observations

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Sunspot Observations on 10 and 11 February 1917: A Case Study in Collating Known and Previously Undocumented Records

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Abstract An extensive investigation of ships' logs, as part of the *Old Weather* citizen-science project, identified a sunspot observation made from HMS Hilary on 10 February 1917. This sunspot record was accompanied by detailed meteorological records that have enabled a reconstruction of the conditions under which the observation was made (overcast with detached clouds). Although there is no incontrovertible evidence that this was an unaided-eye observation, comparison with an unaided-eye observation recorded on the 11 February 1917 in a local treatise from Hénán province in China confirms that this sunspot group was visible to the unaided eye. White-light photographs from the Dehra Dun Observatory confirm the detailed description of the sunspot group provided by the naval observer. Moreover, comparisons with tabular data published by the Royal Observatory, Greenwich, confirm the statement that this was an unusually large sunspot group. Indeed, on 11 February 1917 the area of the sunspot group was greater than the area of any sunspot group recorded previously at the Royal Observatory, Greenwich. A comparison with a modern unaided-eye observation confirms that it is possible to observe sunspots under meteorological conditions similar to those experienced on-board HMS Hilary.

1. Introduction

All historical observations of sunspots contribute incrementally to our understanding of long-term variations in solar activity and the associated effects on the Earth (Clette et al., 2014). This paper presents a new British maritime observation of a large sunspot group, for which detailed information is also available on the prevailing meteorological conditions. It is shown that the recorded details of this sunspot group are completely consistent with both contemporary photographs of the Sun and published tabular data presenting the positions and areas of the large sunspot group as it crossed the solar disk (Vaquero & Vázquez, 2009). The collation of the available documents, including an unaided-eye sunspot record from China, provides a compelling case for assiduously archiving all important sunspot observations.

The log books of the armed merchant patrol ship, HMS Hilary, record an observation of a large sunspot group on the solar disk at noon on Saturday 10 February 1917 when the ship was sailing south-west of St Kilda in the Outer Hebrides. The SS Hilary (Figure 1) was one of many passenger and cargo ocean liners requisitioned by the Royal Navy in 1914 for wartime duties. As HMS Hilary she spent the rest of her days patrolling the seas around Scotland and Iceland, intercepting trade ships bound for Germany. On 25 May 1917, while refueling at the Scapa Flow naval base, HMS Hilary was torpedoed and sunk by a German submarine (U-88) with the loss of four crew members.

Most of the log books from HMS Hilary are contemporary copies. It was standard protocol for ships to keep the original log books on board and to send handwritten copies of the logs for each month to the Admiralty, ensuring that a record remained for all ships lost at sea. A small number of the Hilary's early original log-books from 1914 to 1915 were sent to the Admiralty but the majority of the surviving logs, including those for February 1917, are handwritten copies. The last copied log book to be received by the Admiralty from HMS Hilary was that of March 1917. The copied logs for April and May, together with the original logs, were lost

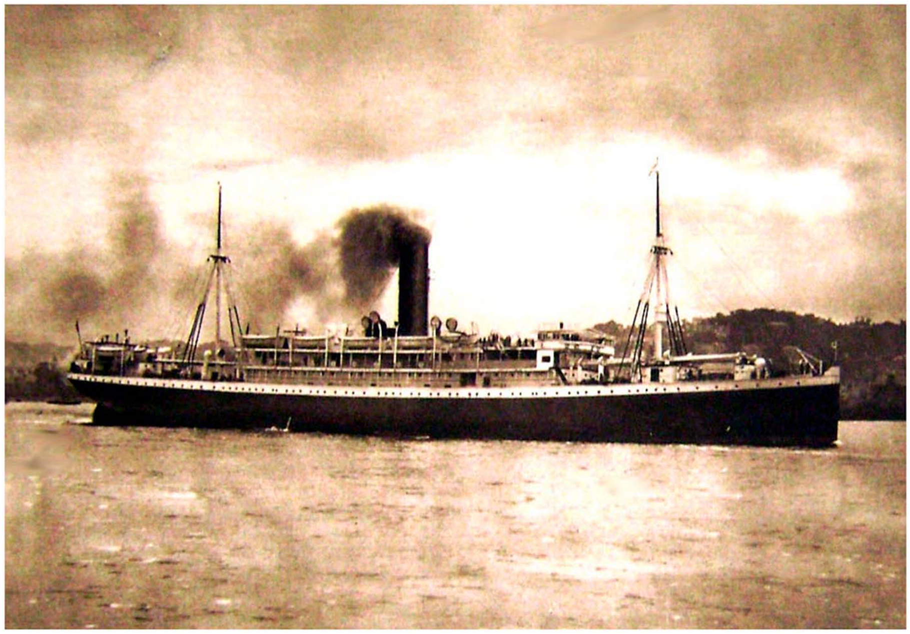

Figure 1. Photograph of SS Hilary as a passenger liner (Courtesy of Peter Swarbrick).

when the ship was destroyed. With this in mind, the handwritten copy of the original log entry for Saturday 10 February 1917 records an observation of a large sunspot group on the solar disk at *local* noon (*apparent ship time*). The ship records its location as 56°45′N, 11°44′W (Dead Reckoning 56°45′N, 11°55′W) placing it approximately 234 km south-west of St Kilda in the Outer Hebrides. The relevant page of HMS Hilary's logbook is reproduced in Figure 2 and the noon log entry in full together with an accompanying sketch is magnified in Figure 3. The text states explicitly *it appeared to be two [sunspots] with a narrow passage between them*. The sketch indicates two distinct sunspots in close proximity near the center of the Sun. The observer noted that, although he had seen sunspots before, he had never seen such large ones.

The meteorological conditions under which this observation was made can be assessed with reference to the observations contained within this same log entry. The air pressure of approximately 30.25 inches of mercury (about 1,025 mb) indicates that the overall weather system was probably anticyclonic. While humidity is a difficult quantity to measure, an estimate can be made by comparing the relative air (46° F) and wet-bulb (45° F) temperatures. These readings suggest a relative humidity of about 85% to 98% (allowing for rounded air temperatures). The sea and air temperatures are similar, which suggests that there was not much heating of the air during the day (a conclusion that is also reflected in the lack of variation in air temperature). The winds were westerly, relatively light and recorded as force 1–2, variable later, which is consistent with a high pressure system, since the pressure gradients are not large. The cloud cover is recorded as *OC* which represents overcast conditions with clouds detached. There is no mention of fog, mist, or haze on any day in this same period. The ship is running at 10–12 mph, close to its stated maximum speed of 12 knots (14 mph), which is again consistent with the ship moving through calm seas with good visibility. Inspection of the meteorological reanalysis data (Compo et al., 2011) for this location on 10 February 1917 reveals that these nautical measurements are consistent with the synoptic-scale meteorology.

On 10 February 1917 at local noon, the Sun was at an elevation of 18.9° and at an azimuth of 180.0° (due south). Since the wind direction is quoted as westerly, it seems unlikely that the smoke from the ship's engines would have been of any aid in reducing the glare of the Sun, so the observation of sunspots is likely to have been made possible by the type of cloud cover alone.

2. Sunspot Observations Published by the Royal Greenwich Observatory

An important series of measurements that provide the positions and areas of sunspots and faculae on the solar disk was published in printed form by the Royal Observatory, Greenwich (up to the end of 1947), and subsequently by the Royal Greenwich Observatory (RGO; from the beginning of 1948 up to the end of 1976).

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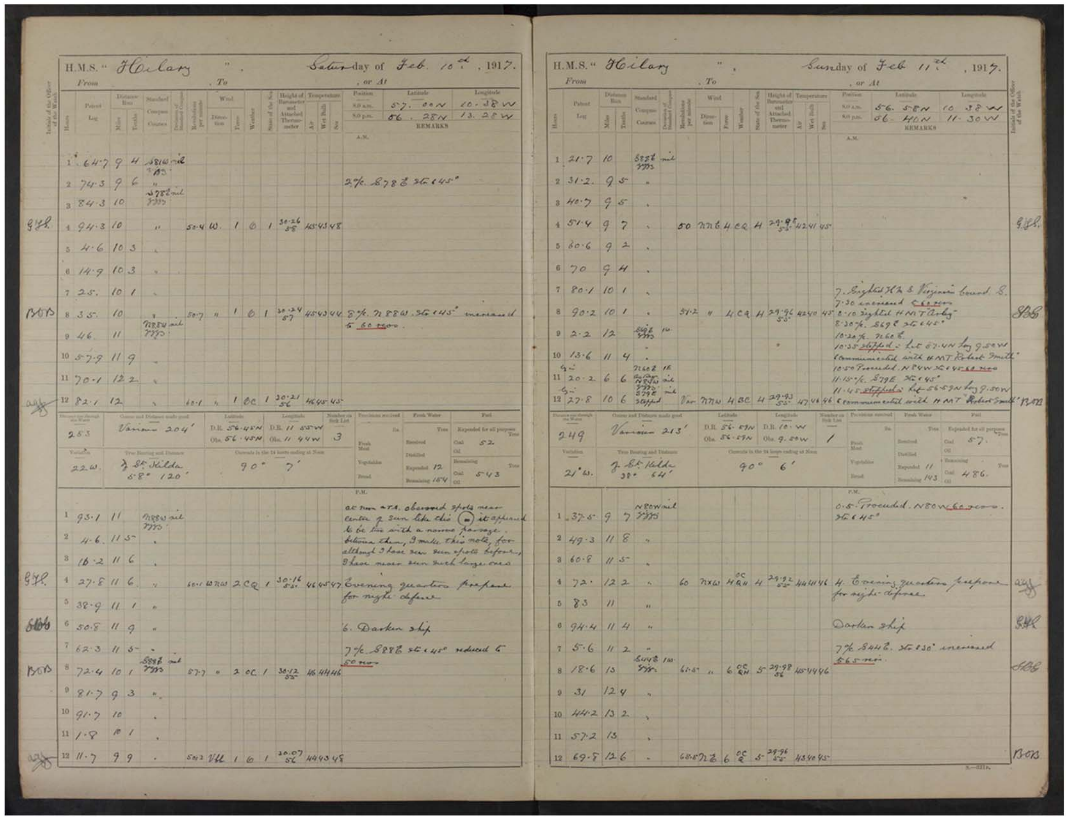

Figure 2. HMS Hilary log for 10 February 1917.

In accordance with current nomenclature and usage, all the sunspot and faculae data acquired during this long interval will be ascribed to the RGO. With the help of other solar observatories, the RGO acquired white-light photographs (photo-heliograms) of the Sun during an interval that is usually stated to extend from 17 April 1874 to 31 December 1976 (Willis et al., 1996, 2013). Thereafter, responsibility for the RGO program of solar observations was transferred formally to the Heliophysical Observatory, Debrecen, Hungary (Graham-Smith, 1978). The majority of white-light photographs obtained by the RGO were taken using photo-heliographs located at the following observatories: the Royal Observatory, Greenwich, until 02 May 1949, and the RGO, Herstmonceux, from 03 May 1949; the Royal Observatory, Cape of Good Hope, South Africa; the Dehra Dun Observatory, North-West Provinces (Uttar Pradesh), India; the Kodaikanal Observatory, Southern India (Tamil Nadu); and the Royal Alfred Observatory, Mauritius. The remaining gaps in the combined collection of photographs from these named observatories were largely filled by photographs generously supplied by a number of other solar observatories, including Harvard College Observatory, Melbourne

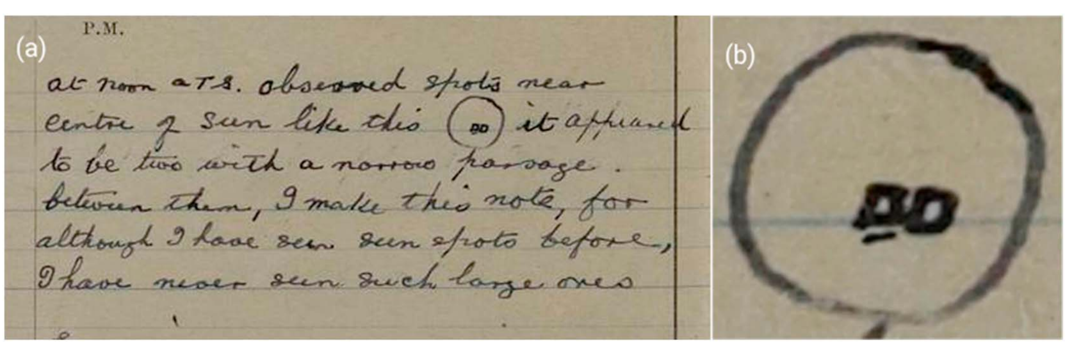

Figure 3. The relevant part of the log of HMS Hilary.

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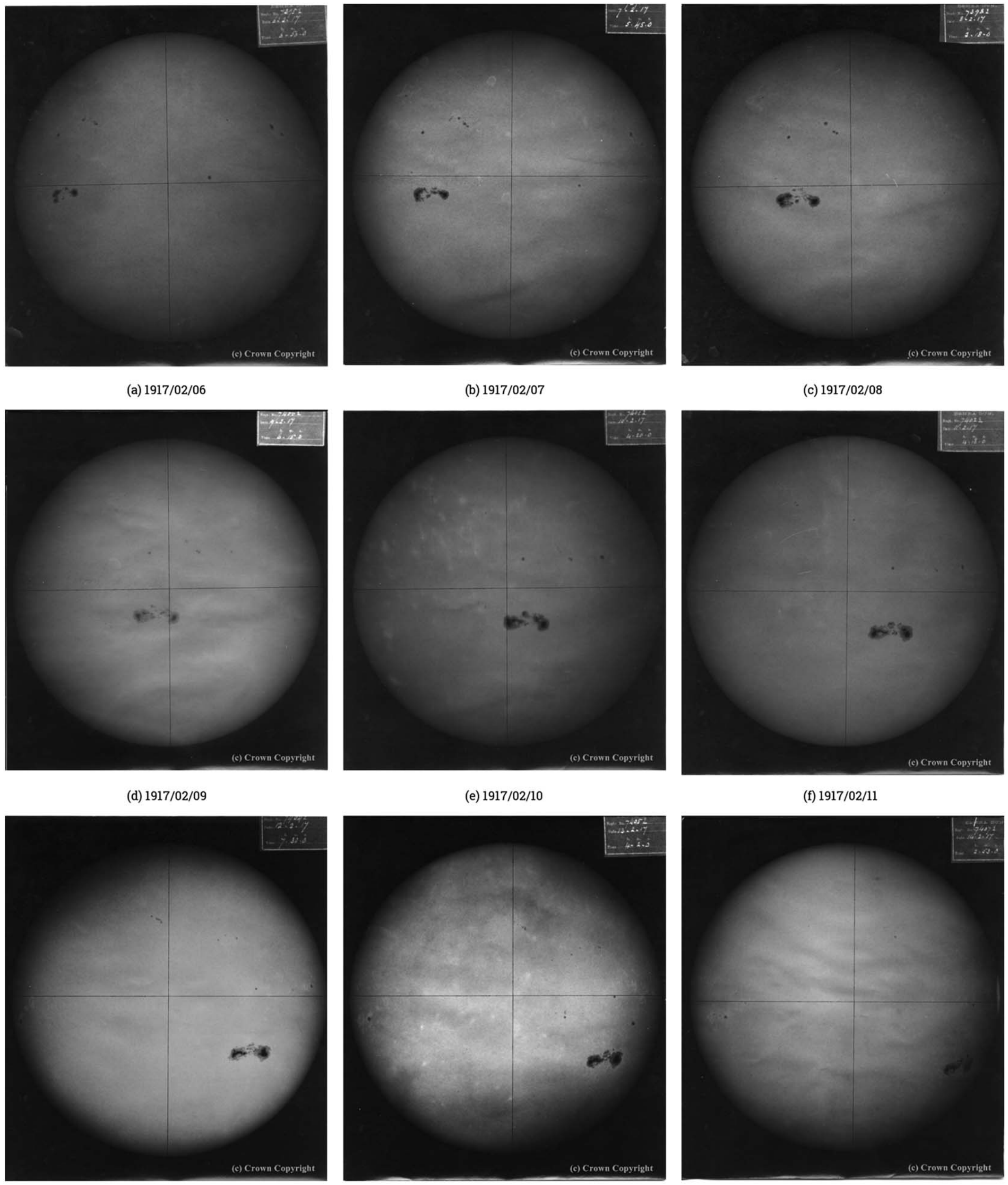

(a) 1917/02/06 (b) 1917/02/07 (c) 1917/02/08

(d) 1917/02/09 (e) 1917/02/10 (f) 1917/02/11

(g) 1917/02/12 (h) 1917/02/13 (i) 1917/02/14

Figure 4. The UK Solar System Data Centre has white-light images from the Dehra Dun Observatory for all days in February 1917 apart from 4 and 5 February. The quality of these prints is not that good. However, the only contact prints stored in the Cambridge University Library for the year 1917 lie within the interval 01 May to 30 December.

Observatory, Mount Wilson Observatory, and the US Naval Observatory (for further details, and a complete list of contributing observatories, see Willis et al., 2013).

The RGO published the measured positions and areas of individual sunspots or distinct groups of sunspots in a series of publications that constitute the *Greenwich Photo-heliographic Results (GPR) 1874–1976* (Greenwich Observations [1874–1955]; Royal Greenwich Observatory Bulletins [1956–1961]; Royal Observatory Annals [1962–1976]). These RGO publications provide tabulations of the measured positions and areas, both umbral and whole-spot (= umbral plus penumbral), of every sunspot group for most days of the year. The positions are referred first to a system of apparent polar coordinates (radial distance and position angle) on the Sun's disk and second to a system of heliographic coordinates (latitude and Carrington longitude) on the Sun's surface. The measured areas (in polar coordinates), that is the *projected areas* on the solar photographs, are corrected for foreshortening and the resulting corrected areas (in heliographic coordinates) are expressed in millionths of the Sun's visible hemisphere (msh). The printed versions of the *GPR 1874–1976* are now available online as PDF files at both the UK Solar System Data Centre (UKSSDC) at the Rutherford Appleton Laboratory (https://www.ukssdc.ac.uk/wdcc1/data_menu.html; use the *Photo-heliographic Results 1874–1976* link) and at the NOAA National Geophysical Data Center, Boulder, Colorado, United States (http://www.ngdc.noaa.gov/stp/solar/greenwich.html; use the *GPR Publications* link).

The only solar images in the RGO archives at the Cambridge University Library for the year 1917 are 87 contact prints in the interval 01 May to 30 December (http://janus.lib.cam.ac.uk/db/node.xsp?id=EAD%2FGBR%2F0180%2FRGO%2051), namely those with classmark MS.RGO.51/7151–7237. Indeed, there are no archived RGO contact prints for the entire 8-month interval 01 September 1916 to 30 April 1917.

3. The Large Sunspot Group Observed on 10 February 1917

3.1. Sunspot Group Number 7977

Figure 4 shows the white-light photographs acquired at the Dehra Dun Observatory, North-West Provinces (Uttar Pradesh), India, for the 9-day interval 06–14 February 1917, centered on the date of the sunspot observation recorded in the log of HMS Hilary. Contact prints of the original glass plates are archived in the UKSSDC: they are available for every day in February 1917 apart from 4 and 5 February. Although the Dehra Dun Observatory was one of the main observatories contributing to the program of sunspot observations organized under the aegis of the Royal Observatory, Greenwich, all the solar images used to produce the printed *GPR 1917* (Royal Observatory Greenwich, 1922) in the interval 06–14 February 1917 were acquired either at Greenwich (GREN) or at the Cape of Good Hope (CAPE). The attribution of solar photographs to observatories in the *GPR* is indicated in Column 3 of Table 1. Therefore, although the solar images from Greenwich and the Cape, during the interval 06–14 February 1917, might well have been of higher quality than those from Dehra Dun (Figure 4), it appears that they are no longer extant.

The large sunspot group in the series of photographs presented in Figure 4 is Group Number 7977 in the Greenwich system of numbering sunspots (Willis et al., 2013). For completeness, Table 1 presents all the relevant information on Group Number 7977 during its entire transit across the solar disk (03–16 February 1917), as extracted from the *GPR 1917* (Royal Observatory Greenwich, 1922). The central meridian passage of this sunspot group occurred at about 12:00 UT on 09 February (Royal Greenwich Observatory, 1955, page 49).

3.2. Relative Size of Sunspot Group Number 7977

Group Number 7977 was the eighth largest in the interval 1874–1954 in terms of its maximum whole-spot area (3590 msh), corrected for foreshortening and expressed in millionths of the Sun's visible hemisphere (Royal Greenwich Observatory, 1955, page 61), but only nineteenth largest in terms of its mean area (2176 msh). The maximum umbral area (552 msh) occurred on 11 February and the maximum whole-spot area (3590 msh) occurred on 14 February, as indicated in Table 1.

At the time of its occurrence (03–16 February 1917), however, Group Number 7977 had the largest *maximum* whole-spot area (3590 msh)—on 14 February 1917 (Table 1)—ever measured by the RGO staff (Royal Observatory Greenwich, 1922). More precisely, on 10 February 1917 the daily whole-spot area (3020 msh) of Group Number 7977 was the sixth largest daily whole-spot area measured by the RGO staff since 17 April 1874, the date of commencement of the RGO data sets defined at the end of section 2.

The canonical threshold for the detection of a sunspot with the unaided eye has often been cited as 500 msh (e.g., Newton, 1958, page 86; Royal Greenwich Observatory, 1955, page 41). As discussed in the paper by Willis et al. (1996), it is possible to detect sunspots with somewhat smaller (whole-spot) areas under optimum viewing conditions. Comparing Figures 2 and 10 in the paper by Willis et al. (1996) provides an *approximate* visual representation of the size of Group Number 7977 compared with the minimum size of a sunspot that can be detected by the average human eye (Keller & Friedli, 1992).

It should be noted that the digital data set used in this investigation (https://www.ukssdc.ac.uk/wdcc1/data_menu.html; use the *Photo-heliographic Results 1874–1976* link) is not in absolute agreement with the printed versions of the *GPR, 1874–1976*. Resolving all such discrepancies is well beyond the intended scope of the present paper.

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Table 1

Positions and Areas of Sunspot Group Number 7977 During its Transit Across the Solar Disk (03–16 February 1917), Extracted From the Greenwich Photo-heliographic Results, 1917 (Royal Observatory Greenwich, 1922)

			Measures		Position		Area		Extant photograph (Dehra Dun: DHRA)	
Date	G.M.T. (Civil)	Observatory code	Dist.	Pos. angle	Long.	Lat.	Umbrae	Whole spots	(hr-min-s)	(UT)
1917 February 03	33.365	CAPE	.988	106.1	7.7	−16.8	0	13	06-52-00	33.286
1917 February 04	34.345	CAPE	.927	104.7	8.6	−16.0	34	176	No photograph	
1917 February 05	35.323	CAPE	.830	105.2	7.9	−16.2	66	465	No photograph	
1917 February 06	36.534	CAPE	.632	106.5	9.5	−15.4	134	1,134	06-56-00	36.289
1917 February 07	37.537	GREN	.447	113.5	10.0	−16.1	369	1,998	05-45-00	37.240
1917 February 08	38.470	GREN	.276	127.2	9.7	−15.9	393	2,510	03-18-00	38.138
1917 February 09	39.374	CAPE	.163	170.2	9.3	−15.8	423	2,497	06-15-00	39.260
1917 February 10	40.584	CAPE	.295	236.4	9.7	−15.8	332	3,020	04-20-00	40.181
1917 February 11	41.360	CAPE	.435	248.4	9.5	−15.2	552	3,399	04-18-00	41.179
1917 February 12	42.325	CAPE	.608	252.5	8.9	−15.9	444	3,187	07-30-00	42.313
1917 February 13	43.510	GREN	.793	256.0	9.0	−15.2	535	3,467	04-02-00	43.168
1917 February 14	44.397	GREN	.897	255.6	9.1	−15.9	457	3,590	02-53-00	44.120
1917 February 15	45.592	GREN	.979	253.9	8.4	−17.1	381	2,830	04-02-00	45.168
1917 February 16	46.363	CAPE	.991	252.0	2.9	−18.7	72	621	07-04-00	46.294

Note. Column 1 gives the civil date in the form: year, month, day. Column 2 gives the day number and decimals of a day reckoning from midnight at the commencement of the year (N.B. 1 January is Day 0). Column 3 gives the four-letter code (Willis et al., 2013) for the observatory—Cape of Good Hope (CAPE), or Greenwich (GREN)—that acquired the photograph used to obtain the measures, positions, and areas. Column 4 gives the distance of Group 7977 from the Sun's center in terms of the Sun's radius, and Column 5 gives the position angle of Group 7977 measured from the north pole of the Sun's axis in the direction N, E, S, W, N. Columns 6 and 7 give the heliographic longitude and latitude, respectively, of Group 7977, as derived from the measures. Columns 8 and 9 give the umbral area and whole-spot area (= umbral + penumbral area) of Group 7977, after being corrected for foreshortening, in millionths of the Sun's visible hemisphere (msh). Column 10 indicates the availability and time (U.T. in hours, minutes, and seconds) of an extant photograph acquired at the Dehra Dun Observatory (DHRA) during the interval 03–16 February 1917. Column 11 gives the day number and decimals of a day for the DHRA photographs (cf. Column 2).

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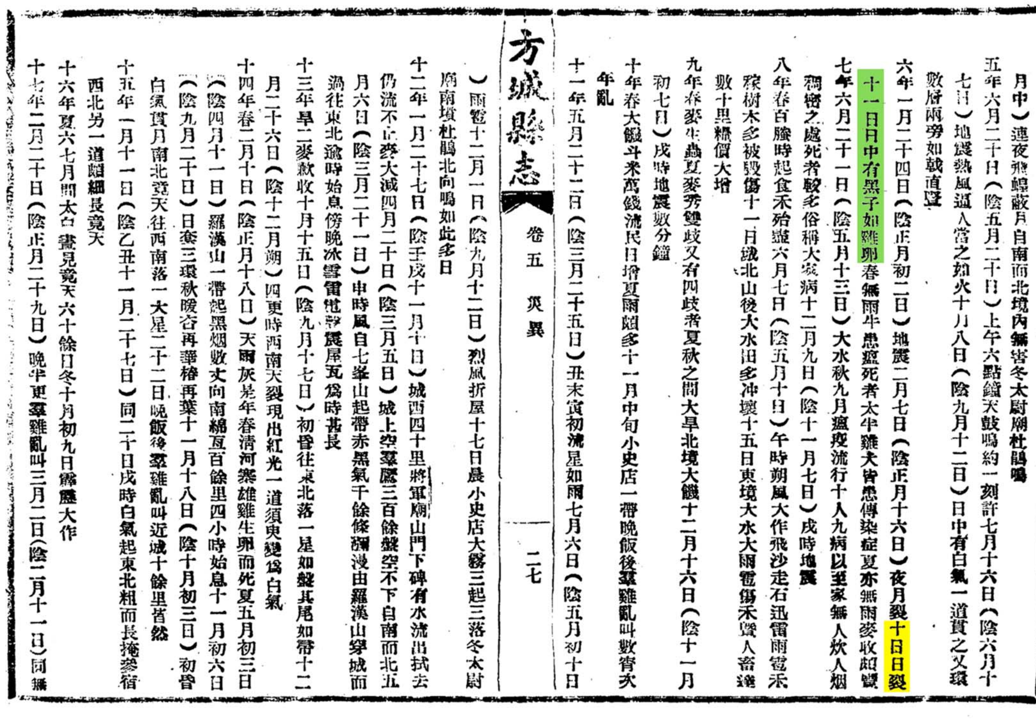
月中）連夜飛蝗蔽月自南而北境內無害冬太尉廟杜鵑鳴
五年六月二十日（陰五月二十日）上午六點鐘天鼓鳴約一刻許七月十六日（陰六月十
七日）地震熱風逼人當之如火十月八日（陰九月十二日）日中有白氣一道貫之又環
數層兩旁如戟直豎
六年一月二十四日（陰正月初二日）地震二月七日（陰正月十六日）夜月裂十日日裂
十一日日中有黑子如雞卵春無雨牛患瘟死者太半雞犬皆患傳染症夏亦無雨麥收甚豐
七年六月二十一日（陰五月十三日）大水秋九月瘟疫流行十人九病以至家無人炊人烟
稠密之處死者較多俗稱大疫病十二月九日（陰十一月七日）戌時地震
八年春白臉時起食禾殆盡六月七日（陰五月十日）午時朔風大作飛沙走石迅雷雨雹禾
稼樹木多被毀傷十一日鐵北山後大水田多沖壞十五日東境大水大雨雹傷禾毀人畜幾
數十里糧價大增
九年春麥生蟲夏麥秀雙歧又有四歧者夏秋之間大旱北境大饑十二月十六日（陰十一月
初七日）戌時地震數分鐘
十年春大饑斗米萬錢流民日增夏雨頗多十一月中旬小史店一帶晚飯後羣雞亂叫數宵夾
年亂
十一年五月二十二日（陰三月二十五日）丑末寅初流星如雨七月六日（陰五月初十日

方城縣志 卷五 災異 二七

）雨雹十二月一日（陰九月十二日）烈風折屋十七日晨小史店大霧三起三落冬太尉
廟南墳杜鵑北向鳴如此多日
十二年一月二十七日（陰壬戌十一月十一日）城西四十里將軍廟山門下碑有水流出拭去
仍流不止麥大減四月二十日（陰三月五日）城上空羣鷹三百餘盤空不下自南而北五
月六日（陰三月二十一日）申時風自七峯山起帶赤黑氣千餘條瀰漫由羅漢山穿城而
過往東北逾時始息傍晚冰雹雷電壞屋瓦爲時甚長
十三年旱二麥歉收十月十五日（陰九月十七日）初昏往東北落一星如盤其尾如帚十二
月二十六日（陰十二月朔）四更時西南天裂現出紅光一道須臾變爲白氣
十四年春二月十日（陰正月十八日）天雨灰是年春清河寨雄雞生卵而死夏五月初三日
（陰四月十一日）羅漢山一帶起黑烟數丈向南綿亘百餘里四小時始息十一月初六日
（陰九月二十日）日套三環秋暖谷再華椿再葉十一月十八日（陰十月初三日）初昏
白氣貫月南北竟天往西南落一大星二十二日晚飯後羣雞亂叫近城十餘里皆然
十五年一月十一日（陰乙丑十一月二十七日）同二十日戌時白氣起東北粗而長掩參宿
西北另一道細長竟天
十六年夏六七月間太白晝見竟天六十餘日冬十月初九日霹靂大作
十七年二月二十日（陰正月二十九日）晚半更羣雞亂叫三月二日（陰二月十一日）同

Figure 5. The Chinese sunspot records on 10–11 February 1917 from the *Fāngchéng Xiànzhì*. The record stating *The Sun was split* on 10 February is highlighted in yellow and the record stating *Within the Sun there was a black spot like a hen's egg* on 11 February is highlighted in green.

3.3. Accuracy of the Entry in the Log of HMS Hilary

It is first necessary to consider the bibliographical status of the log of HMS Hilary and hence the accuracy of the thumbnail sketch in the entry for 10 February 1917 (Figure 3). As noted in section 1, it was standard protocol for British naval ships to keep the original log books on board and to send handwritten copies of the logs for each complete month to the Admiralty, thereby ensuring that a record existed for all ships lost at sea. Instructions for making copies of ship's logs are contained in *The King's Regulations and Admiralty Instructions for the Government of His Majesty's Naval Service*, 1913 (https://archive.org/details/kingsregulations01greaiala); the relevant parts of this document are presented in Appendix B).

While there is no means of assessing either the accuracy of the copied sketch in Figure 3 or the thoroughness of the checks carried out by the Navigating Officer, at the very least the sunspot sketch in Figure 3b with two distinct sunspots in close proximity near the center of the Sun and the associated text describing two [sunspots] with a narrow passage between them are consistent with each other.

In addition, the contemporary sunspot measurements published by the RGO (Table 1) substantiate the accuracy of the sunspot sketch and the veracity of the associated text (Figure 3). On 10 February 1917 the sunspot group near the center of the Sun (Group No. 7977) was clearly large enough to be seen with the unaided eye. As the whole-spot area (3020 msh) on 10 February 1917 was the sixth largest measured by staff at the Royal Observatory, Greenwich, since the first entry (21 July 1873) in the complete series of RGO publications tabulating sunspot (and facular) data, the entry in the log of HMS Hilary by the observer, *noting that although he had seen sun spots before, he had never seen such large ones*, appears to be completely credible. Moreover, the whole-spot area on 11 February 1917 was greater than the whole-spot area on any day (for which a solar photograph was acquired) in the preceding 43.5 years.

Moreover, the twin structure of the sunspot group depicted in the log book (Figure 3) is also confirmed in the Footnotes to the GPR 1917 (Royal Observatory Greenwich, 1922). These Footnotes provide the following description of Group Number 7977 (3–16 February): "A magnificent group of the stream type of which both the early formation and maximum development appear within the visible hemisphere. The group is naturally divided into three portions—the leader and rear spots and a much smaller intermediate portion. The leader, which develops from a small spot on Feb. 3, soon appears as a gigantic one of regular type. The rear spot is elongated and more complex, and before Feb. 11 is the largest member. Its major axis, which in the early stage is at right angles to the solar equator, becomes parallel to it by Feb. 8 by the formation spreading toward the center of the stream. The intermediate portion consists of an irregular cluster of spots which condenses after Feb. 9 and practically connects the leader and rear spot together. Only the last portion of the group remains in view on the west limb on Feb. 16. Groups 7981, 7982 and 7984 are small subordinate groups."

Therefore, the entry in the log of HMS Hilary, which provides a thumbnail sketch of the sunspot group and notes that there appeared to be two [sunspots] with a narrow passage between them (Figure 3), is remarkably accurate, as is also confirmed conclusively by the white-light photograph acquired at the Dehra Dun Observatory on 10 February 1917 (Figure 4e). Consequently, although the existing log of HMS Hilary for February 1917 is a copy and not the original (or *autograph*) manuscript, there seems to be no valid reason to doubt its accuracy.

4. The Same Sunspot Group Recorded in a Chinese Local Treatise

4.1. The Chinese Unaided-Eye Sunspot Observation on 11 February 1917

An unaided-eye sunspot observation on 11 February 1917, the day after the entry in the log of HMS Hilary, was recorded in the Local Treatise of Hénán Province, China, entitled *Fāngchéng Xiànzhì* (*Treatise of Fāngchéng County*). The relevant record appears in a special section on *Portents* (災異, *Zāiyì*) in the old edition of the *Fāngchéng Xiànzhì* (Figure 5) and appears in a special section on *Unusual Phenomena in History* in the new edition. The older edition of the *Fāngchéng Xiànzhì* was published in 1942 and the section on Portents spans the years 723 to 1942. The newer edition was published in 1992 and the section on Unusual Phenomena in History spans the years 1511 to 1984.

The brief description of the sunspot observation on 11 February 1917 may be translated as follows: "Within the Sun (日中, *rìzhōng*) there was (有, *yǒu*) a black spot (黑子, *hēizi*), like (如, *rú*) a hen's egg (雞卵, *jīluǎn*)" (*Fāngchéng Xiànzhì*, v.5, f.27a). The Chinese text that has been translated into English in the previous sentence is highlighted in green in Figure 5, which reproduces records appearing in the section on Portents in the old edition of the *Fāngchéng Xiànzhì*. These portents were witnessed in or near Fāngchéng-xiàn (33°15′N, 113°00′E), just northwest of Nányáng City in Hénán Province. In the preceding translation, the Chinese characters for each word, followed by the romanizations in pinyin, are presented in parentheses. The two relevant sections of the *Fāngchéng Xiànzhì* record not only sunspots but also other astronomical and meteorological phenomena such as comets, aurorae, halos, mists, rainfall, and even the unusual activities of animals/insects, such as a swarm of butterflies (*Fāngchéng Xiànzhì*, v.5, ff.22a–22b).

Inspection of the meteorological reanalysis data (Compo et al., 2011) indicates that on 11 February 1917 there were light winds below 4 m/s across North East China, which was under a ridge of high pressure extending from the north. Relative humidity in the region was low (30–40%), so there was almost certainly little or no cloud with the air temperature close to freezing (0° C). At 33°15′N, 113°00′E the air was clearly dry and cloudless at all heights.

The unaided-eye Chinese sunspot observation on 11 February 1917 is listed in *A Revised Catalogue of Far Eastern Observations of Sunspots (165 BC to AD 1918)*, compiled by Yau and Stephenson (1988): this catalog was compiled from the old edition of the *Fāngchéng Xiànzhì*. Yau and Stephenson (1988), following Chen (1984), give the date of the sunspot sighting as *6th year of the republic, 1st month, 20th day*. This date is equivalent to 11 February 1917 in the Gregorian calendar, as indicated in the old edition of the *Fāngchéng Xiànzhì* (see Figure 5). The calendar conversion tables of Xue and Ouyang (1956) have been used to confirm the date 11 February 1917, which is in accord with the date in the new edition of the *Fāngchéng Xiànzhì*.

In a comparison between Oriental and Occidental sunspot observations, which used this revised catalog, Willis et al. (1996) showed that the large sunspot group observed in Hénán Province, China, on 11 February 1917 was certainly large enough to be seen with unaided eye. However, at the time of that investigation (1996), no photographs from either the Dehra Dun Observatory or any other solar observatory were listed in the RGO catalogs for the year 1917. Hence, an approximate reconstructed solar image, based on the published positions and areas of sunspots in the *GPR 1917* (Royal Observatory Greenwich, 1922), was used to estimate the projected umbral and penumbral areas of the sunspot group observed on 11 February 1917 (Willis et al., 1996, Figure 10).

4.2. Descriptions of Sunspots in East Asian Histories

Apart from the large number of unqualified references to black *dots* (*diǎn*), *spots* (*zǐ*), and *vapors* (*qì*), the East Asian historical records *frequently* describe unaided-eye sunspot sightings in terms of approximately circular or elliptical shapes such as *a chestnut*, *a clenched fist*, *a coin*, *a cup*, *a date*, *a duck's egg*, *a goose's egg*, *a hen's egg*, *a melon*, *a peach*, *a pear*, *a pellet*, and *a plum* (e.g., Hayakawa et al., 2015; Hayakawa, Iwahashi, et al., 2017; Hayakawa, Tamazawa, et al., 2017; Keimatsu, 1970; Lee et al., 2004; Willis et al., 1996; Yang et al., 1998). Alternatively, the East Asian historical records *occasionally* describe sunspot sightings in terms of irregular shapes such as *a flying bird*, *a crow*, *a flying crow*, *a three-legged crow*, *a cutlass*, *a ladle*, *a flying magpie*, *a man*, *three men*, *three human shadows*, and *a flying swallow* (e.g., Hayakawa et al., 2018; Willis et al., 1996).

However, the precise interpretation of the varying descriptions of sunspots in East Asian astronomical records is still being investigated (e.g., Hayakawa et al., 2015; Lee et al., 2004; Yang et al., 1998), although it has been recognized for some time that such picturesque descriptions may not provide reliable quantitative information on sunspot size (Clark & Stephenson, 1978; Stephenson & Clark, 1978). In addition, it must be conceded there is no evidence indicating that the astronomical records in Local Treatises result from observations made by contemporary professional astronomers. Conversely, it is generally agreed that the astronomical records in Official Histories usually result from observations made by contemporary professional astronomers in East Asia (e.g., Hayakawa et al., 2015; Hayakawa, Iwahashi, Tamazawa, et al., 2017; Hayakawa, Tamazawa, et al., 2017; Keimatsu, 1970; Tamazawa et al., 2017; Tanikawa & Sôma, 2004; Yang et al., 1998). Further research is required to determine if such graphic descriptions of sunspots have exactly the same meaning in both the Official Histories and the Local Treatises.

In any case, the reference to a hen's egg in the Chinese record for 11 February 1917 suggests the oriental observer was unable to detect the detailed sunspot group structure shown in Figure 4 with the unaided eye, possibly because of limited resolution, although the RGO Footnotes to the GPR 1917 state (for Group Number 7977) "The intermediate portion consists of an irregular cluster of spots which condenses after Feb. 9 and practically connects the leader and rear spot together." Therefore, it is not entirely surprising that the detailed structure of the sunspot group could not be detected with unaided eye on 11 February. Nevertheless, the log of HMS Hilary (Figure 3) refers to two [sunspots] with a narrow passage between them on 10 February 1917. However, it should be noted that the meteorological reanalysis data (Compo et al., 2011) indicates that the atmospheric viewing conditions in Hénán Province (little or no clouds) were quite different to those experienced on-board HMS Hilary (overcast with detached clouds). Moreover, Group Number 7977 achieved its maximum daily umbral area (552 msh) on 11 January 1917 (Table 1), which is completely consistent with an unaided eye sunspot observation on that day.

4.3. A Chinese Solar or Meteorological Record on 10 February 1917

Unfortunately, the *Fāngchéng Xiànzhì* does not provide information on the daily weather conditions in Hénán Province. However, on the day before the sunspot record on 11 February 1917, there is another interesting record stating *The Sun was split* (日裂, *rìliè*; *Fāngchéng Xiànzhì*, v.5, f.27a). Once again, the calendar conversion tables of Xue and Ouyang (1956) have been used to confirm the date 10 February 1917, which is also in accord with the date in the new edition of the *Fāngchéng Xiànzhì*. The relevant record, which is highlighted in yellow in Figure 5, indicates that the sky was not totally overcast throughout the day at Fāngchénng-xiàn on 10 February, since the Sun was clearly seen sometime during daylight hours. Inspection of the meteorological reanalysis data (Compo et al., 2011) indicates that the air was dry (though not as dry as on the following day) and that there was little cloud (if any) below 500 hPa. Certainly, any cumulus formation from low-level ascent is unlikely. Any cloud is likely to have been high and consequently semi-transparent. Although the interpretation of the historical record on 10 February is not completely clear, it is just possible that it relates to the sunspot observation on 11 February. Many earlier references to black vapors in East Asian records use similar terms in describing a *black vapor* that *divided* the Sun (分, *fēn*) or *penetrated* the Sun (貫, *guàn*) (Yau & Stephenson, 1988). As a specific example, sunspot records on an unknown day between 14 December 304 and 11 January 305 (only the Chinese lunar month is given) state "Within the Sun there was a black vapour; it divided the Sun" (*Sòngshū*, v.34, p.1017) and "In the Sun there was black vapour dividing the Sun" (*Jìnshū*, v.12, p.342). As a further example, on 4 January 505 another sunspot record states "A black vapour penetrated he Sun" (*Wèishū*, v.105, p.2339). Therefore, it is possible that the observer in Hénán Province saw the large sunspot group on 10 February as well as on 11 February. This interpretation is far from being firmly established, however, and the terminology used might possibly suggest some local atmospheric phenomenon crossing the Sun's surface.

5. Discussion and Conclusions

This paper presents a detailed case study of sunspot observations on two adjacent dates, namely 10 and 11 February 1917. The sunspot observation on 10 February has been found in the log book of the British armed merchant patrol ship HMS Hilary, formerly the passenger liner SS Hilary (Figure 1), as a by-product of a citizen-science project (*Old Weather*) that searches for *Old Weather Records* in ships' log books (Figures 2 and 3). The sunspot observation on 11 February 1917 is recorded in a Local Treatise from Hénán Province, China, in a special section on Portents (Figure 5). Quite apart from emphasizing the merit of citizen-science projects, this particular case study also indicates the value of the long-term, systematic observations of the Sun, such as the program of sunspot observations performed under the aegis of the Royal Observatory, Greenwich, and the slightly more fortuitous, but equally valuable, observations of the Sun recorded in East Asian histories.

Similarly, the derivation of the International Sunspot Number (previously called the Wolf Sunspot Number and the Zürich Sunspot Number) has relied heavily on the indispensable contributions made by *amateur* sunspot observers (Clette et al., 2014). In the UK, the bimonthly issues of the *Journal of the British Astronomical Association* provide summaries of the sunspot observations made by members of the Solar Section of the British Astronomical Association.

In addition, the present investigation also indicates the crucial importance of assiduously archiving irreplaceable sunspot data. Moreover, arguments can be adduced for the compilation of *Living Sunspot Databases*, analogous to *Living Reviews in Solar Physics*, that can be revised and updated regularly. In addition, such sunspot databases should be augmented with meteorological data whenever possible. It would be particularly valuable if databases of sunspot observations recorded in East Asian and European histories, which contain informative descriptive text, could be searched interactively for the use of particular words and phrases. It is possible that such studies would reveal evidence of linguistic persistence, that is the tendency for the wording used to describe a sunspot observation to be influenced by the wording used in the immediately preceding sunspot records.

5.1. Serendipitous Sunspot Science

If it had not been for the standard practice of making handwritten copies of the log books of HMS Hilary for each month and sending these copies to the Admiralty, all the log books would have been lost when the ship was sunk on 25 May 1917. In this scenario, the information presented in Figures 2 and 3 would not exist.

Similarly, white-light solar photographs from the Dehra Dun Observatory exist for every day in February 1917 apart from 4 and 5 February (Figure 4 and Table 1). Conversely, the only contact prints stored in the Cambridge University Library for the year 1917 lie within the interval 01 May to 30 December (MS.RGO.51/7151 – 7237). Therefore, it appears that the *superior* solar photographs taken at the Cape and Greenwich, which were used to measure the positions and areas for Group Number 7977 (Table 1), are no longer extant. Consequently, it is extremely fortunate that the *inferior* photographs from Dehra Dun still exist, and are now archived in the UKSSDC, thereby enabling the detailed shape of Sunspot Group Number 7977 to be illustrated in Figure 4.

The efforts of policy makers in the UK have understandably been focused first on curation of the original RGO photographs of the Sun. This careful curation applies both to the original glass plates acquired in the interval 1918 – 1976, which are now archived in the Bodleian Libraries, University of Oxford, and the contact prints made from some, but not all, of the original glass plates acquired in the earlier interval 1873 – 1917, which are archived in the Cambridge University Library. Although the RGO white-light photographs of the Sun (both the glass plates and the contact prints) have now been securely archived, no dedicated resources have yet been allocated to research projects that utilize this unique set of photographs. The first task should be to make these photographs available to the scientific community in a user-friendly form.

5.2. Unaided-Eye Sunspot Observations

There is an extensive literature on unaided-eye sunspot observations, part of which includes some limited discussion of the prevailing meteorological conditions under which such unaided-eye observations were made. Although it is not the purpose of the present paper to review this extensive literature, the inclusion of a few brief comments is justified. In the case of the historical East Asian sunspot observations, for example, it is clear from the various records that sunspots were often sighted when the brightness of the Sun was much reduced, for example, when the Sun was low in the sky (near sunrise or sunset), or when fog, haze, or mist prevailed, as noted by Yau and Stephenson (1988). Moreover, individual records occasionally indicate explicitly that the Sun appeared to be red, orange, or yellow. Similarly, according to the *Niconovsky* and other Russian chronicles,

Figure 6. Photograph taken with a DSLR camera of sunspots also observed with the unaided eye through cloud on 20 October 2014.

dark spots were seen on the Sun in Russia during the summer of both 1365 and 1371 (Hayakawa, Tamazawa, et al. 2017; Vyssotsky, 1949). These groups of Russian observations were made at the time of forest fires, associated with severe droughts. In these cases, the smoke from the forest fires would have substantially dimmed the Sun.

Although it is not certain that the sunspot observation recorded in the log book of HMS Hilary was made without any optical aid, and hence could accurately be described as an *unaided-eye* observation, it seems reasonable to assume that nothing more than a pair of binoculars or a naval telescope would have been available to the crew. The prevailing meteorological conditions on 10 February, which are also included in the ship's log (Figure 2, left-hand side), indicate that the sunspot observation was made under overcast conditions with clouds detached. The position of the Sun, the course of the ship, and the prevailing wind direction suggests that the observation is unlikely to have been affected by smoke from the ship's engine and so in this particular case the observation of two sunspots in close proximity was likely to have been made possible by the type of cloud cover alone. Moreover, inspection of the meteorological reanalysis data (Compo et al., 2011) reveals that the meteorological measurements made on-board HMS Hilary are consistent with the synoptic-scale meteorology.

The sunspot observation on 11 February 1917, recorded in the Local Treatise of Hénán Province in China entitled *Fāngchéng Xiànzhì* (Treatise of Fāngchéng Province), was almost certainly made with the unaided eye. Although there is currently no known information on the local time at which this unaided-eye sunspot observation was made, the prevailing meteorological conditions at or near Fāngchéng-xiàn (33°15′N, 113°00′E) indicate that the air was clearly dry and cloudless at all heights.

The photograph shown in Figure 6 was taken by one of the authors (JW) on 20 October 2014 at 14:15 UT (sunset time on that day was 17:01, GMT). The singular importance of this photograph is that it was taken deliberately, using an ordinary DSLR camera and the filtering provided by an overcast sky, immediately after seeing sunspots with the unaided eye. The photograph was taken using a zoom lens operating at a focal length of 400 mm. The image shown in Figure 6, therefore, reveals more fine detail than could be seen with the unaided eye. Nevertheless, Figure 6 clearly indicates that sunspots could be seen with the unaided eye through cloud at 14:15 UT on 20 October 2014. The sky that day was completely overcast with additional fast moving low detached clouds providing the additional filtration required to observe the sunspots with the unaided eye. Using the same cloud classification system as that used on-board HMS Hilary (Figure 2), the cloud cover at the time the photograph in Figure 6 was taken would be classified as *OC*—the same as that recorded during the noon sunspot observation in the log book of HMS Hilary.

Further research is now required to understand the full range of atmospheric and meteorological conditions under which sunspots can be seen with the unaided eye.

The authors hope that the research reported in this paper, which resulted from the fortuitous sunspot observation recorded in the log of HMS Hilary, will be a fitting tribute to the sterling endeavors of all the citizen-science volunteers who have worked so diligently on the Old Weather project.

Appendix A: References to Historical Documents

A1. The Log Books of HMS Hilary

The Log Books of HMS Hilary form part of The National Archives of the UK (TNA): ADM 53/44341-HILARY. These log books are Crown Copyright and are held at the National Archives. They are made available under the terms and conditions of the Open Government Licence, a copy of which can be found at http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/. Transcriptions and images of the pages from the log books of HMS Hilary are available at http://www.naval-history.net/OWShips-WW1-08-HMS_Hilary.htm.

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A2. The Local Treatise of Hênán Province

The references for the old and new editions of the *Fāngchéng Xiànzhì* are as follows:

Old Edition: 杜緒贊, 張嘉謀『方城縣志』, Dù Xùzàn, Zhāng Jiāmóu, *Treatise of Fāngchéng County*, 1942

New Edition: 方城縣地方志編纂委員『方城縣志』, 中州古籍出版社(Zhōngzhōu gǔjí chūbǎnshè), Committee of Compilation of Local Treatise of Fāngchéng County, *Treatise of Fāngchéng County*, 1992.

Appendix B: The King's Regulations and Admiralty Instructions

Instructions for making copies of ship's logs are contained in *The King's Regulations and Admiralty Instructions for the Government of His Majesty's Naval Service*, His Majesty's Stationary Office, London, 1913. A digital copy is available at https://archive.org/details/kingsregulations01greaiala.

For the purposes of the present paper, the relevant entries in the King's Regulation are as follows:

Article **1026.** [Page 345] **Disposal of the Log and Monthly Copy.**—At the end of each calendar month, the Navigating Officer is to transmit, through the Captain to the Commander-in-Chief, a complete copy of the log book for the period signed by himself. He is to deliver the original log book, signed by himself, to the Captain, when it is filled up, to be kept by him until the ship is paid off, and then to be sent to the Deputy Cashier in Charge, Royal Victoria Yard, Deptford, for custody as a permanent record. If the Navigating Officer is superseded, he is to sign the original log book then in his possession, and deliver it to his successor, who is to give him a receipt for it; and the Captain is to give him a receipt whenever he delivers the book to him. These receipts are to be retained by the Navigating Officer for six months.

Article **1849.** [Page 637] **Disposal of Logs.**—[1.] Original logs received by the Captain from the Navigating Officer in accordance with Article **1026** are to be kept in the ship until she is paid off, when they are to be forwarded by the Captain to the Deputy Cashier in Charge, Royal Victoria Yard, Deptford, for custody as a permanent record.

2. The logs of sea-going tenders, on form S. 321, are to be forwarded half-yearly in original to the Deputy Cashier in Charge, Royal Victoria Yard, Deptford.

3. The log books of ships temporarily commissioned, and of torpedo boat destroyers engaged in instructional duties, are to be rendered on form S. 321a, and are also to be sent to Deptford.

4. The Captain will obtain a receipt from the Deputy Cashier in Charge, Royal Victoria Yard, Deptford, for all log books forwarded to him, which receipt is to be transmitted to the Secretary of the Admiralty.

On being superseded, he is similarly to obtain and forward to the Secretary of the Admiralty a receipt for all log books handed over to his successor.

5. **Monthly copy of Log.**—A complete copy of the log, on form S. 321b, is to be forwarded monthly from every ship except ships temporarily commissioned (see clause 3) and stationary ships at home and abroad.

The copy is to be made under the immediate direction and responsibility of the Navigating Officer (Article **1026**) who will certify that it is a complete copy of the original log. It is to be signed by the Captain and forwarded by him to the Commander-in-Chief, by whom it is to be transmitted to the Secretary of the Admiralty as soon as it shall be no longer necessary to keep it on the station for purposes of reference.

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