Highlights of Astronomy, Vol. 12
International Astronomical Union, 2002
H. Rickman, ed.

Scientific Interpretation of Historical Auroral Records

David M. Willis

Department of Physics, University of Warwick, Coventry CV4 7AL, UK

F. Richard Stephenson

Department of Physics, University of Durham, Durham DH1 3LE, UK

Abstract. Recent research on the scientific interpretation of historical auroral records is summarised, with special emphasis on topics that provide physical insight into possible variations in geomagnetic disturbance and solar activity during the past two millennia.

1. Introduction

Historical auroral records provide one of the few direct means of examining possible long-term variations in geomagnetic disturbance and solar activity. This paper provides a succinct summary of recent investigations that illustrate the utility of the ancient auroral records. A brief review is first given of the diverse sources of ancient auroral records. Then the various temporal and spatial variations of the oriental auroral observations are described. Subsequently, a few selected case studies are discussed.

2. Auroral catalogues

Most of the results discussed in this paper are based on the catalogue of auroral observations from China, Korea and Japan (193 BC–AD 1770) compiled by Yau, Stephenson & Willis (1995). This new compilation of oriental auroral observations has as its nucleus the work of Keimatsu (1976) and Dai & Chen (1980). The material from the catalogue of Yau et al. (1995) has been supplemented with data from three further sources: (1) the catalogue of Chinese auroral observations published by the Beijing Observatory (1988); (2) a paper on ancient Japanese aurorae by Matsushita (1956); and (3) a comprehensive catalogue of Japanese astronomical records since AD 1600 by Osaki (1994).

The main catalogues of occidental auroral observations that have been utilised are those published by Fritz (1873), Seydl (1954) and Link (1962, 1964). Many other valuable catalogues exist, including those that present historical observations from individual countries; these are too numerous to list in this brief paper.

3. Space and time variations of oriental aurorae

The ancient oriental auroral observations exhibit both temporal and spatial variations. For example, there is a clear seasonal variation in the number of auroral sightings, with a marked maximum in the spring. However, this spring maximum is produced largely by an excess of Korean observations during the sixteenth and seventeenth centuries; this excess is discussed in Section 6. The seasonal variation in the number of oriental auroral observations is due partly to the seasonal variation of cloud cover over East Asia. The number of oriental auroral sightings also varies with the phase of the Moon, since it is easier to see faint aurorae near new Moon. Likewise, there is sometimes clear evidence for recurrent, though possibly intermittent, auroral activity on a time scale almost exactly equal to the synodic-solar-rotation period (27 days). Recorded azimuthal directions of oriental aurorae were usually very crude, no more than N, NE, E, SE, S, SW, W and NW. In both China and Japan, aurorae were seen predominantly in a northerly direction. This result can be understood in terms of a northern auroral oval that moves equatorwards during geomagnetic storms. In Korea, however, aurorae were seen predominantly in a southerly direction. No physical explanation can yet be offered for this last result, although it is apparently associated with the excess of Korean auroral observations during the sixteenth and seventeenth centuries.

4. Simultaneous auroral observations in East Asia and Europe

The early auroral observations have been examined in order to search for examples of strictly simultaneous and indisputably independent observations of the aurora borealis from spatially separated sites in East Asia (Willis & Stephenson 2000). In the period up to AD 1700, only five examples have been found of two or more oriental observations from separate sites *on the same night*. These occurred during the nights of AD 1101 January 31 (China, North China & Korea), AD 1138 October 6 (China & Korea), AD 1363 July 30 (China & Japan), AD 1582 March 8 (China & Japan) and AD 1653 March 2 (China & Japan). In addition, auroral displays occurred in Europe within two days of the auroral displays in East Asia on two (possibly three) of these five special occasions. These results suggest that a substantial number of the mid-latitude auroral displays recorded in the oriental histories are associated with intense geomagnetic storms (Willis & Stephenson 2000).

A further four examples of strictly simultaneous and indisputably independent observations of the aurora borealis *on the same night* from separate sites in East Asia have been found in the period AD 1700–1900. These occurred during the nights of AD 1730 February 15 (China, Japan & Europe), AD 1770 September 17 (China, Japan & Europe), AD 1859 September 2 (China, Japan, Europe & North America) and AD 1872 February 4 (China, Japan, Europe & Many Other Countries). The last two examples of simultaneous auroral observations in East Asia and Europe correspond to well-documented intense geomagnetic storms (Chapman 1957).

5. A recurrent geomagnetic storm during December in AD 1128

The earliest known drawing of sunspots appears in *The Chronicle of John of Worcester* (Stephenson & Willis 1999). In this medieval chronicle, the Latin text describing the sunspots is accompanied by a colourful drawing, albeit idealised, which shows the apparent positions and sizes of two sunspots on the solar disk. The date of this observation of sunspots from Worcester in England can be firmly established as AD 1128 December 8. About five days after this observation of sunspots on the solar disk, on the night of AD 1128 December 13, a red auroral display was observed from Songdo (Kaesong) in Korea (Yau et al. 1995). This auroral observation was recorded in the *Koryo-sa*, the official Korean chronicle of the period. In addition, five Chinese and five Korean auroral observations were recorded in various East-Asian histories between the middle of AD 1127 and the middle of AD 1129. The ten auroral records in this interval correspond to six distinct auroral events, which provide evidence for recurrent, though possibly intermittent, auroral activity on a timescale almost exactly equal to the synodic-solar-rotation period (27 days). The six distinct auroral events were apparently associated with two series of recurrent geomagnetic storms, which were sufficiently intense to produce mid-latitude auroral displays in East Asia.

These ancient solar and auroral observations can be interpreted in terms of present-day understanding of solar-terrestrial physics. Contemporary ground-based and satellite measurements have indicated that recurrent geomagnetic storms are usually a feature of the declining phase of the solar cycle. Moreover, the strength of such recurrent geomagnetic storms has been classified as moderate rather than intense. The recurrent geomagnetic storms occurring during the interval AD 1127–1129 must have been intense, however, to produce mid-latitude auroral displays over China and Korea, some of which appeared or extended to the south of the observing site. Therefore, either the two series of recurrent geomagnetic storms occurred near a medieval sunspot maximum or, if they occurred near a medieval sunspot minimum, the level of solar activity must have been significantly higher during the twelfth century than it has been during the past four centuries.

6. Excess of Korean auroral observations during the sixteenth and seventeenth centuries

A particularly remarkable circumstance is the very large number of Korean auroral records between about AD 1510 and 1560 and again around AD 1625. These follow a very repetitive style in which the phenomenon observed is likened to either a *fire* or a *flame* (Yau et al. 1995). These Korean observations seemingly correspond to relatively faint, and sometimes featureless, red auroral emissions. As yet, no entirely convincing explanation has been given for the huge excess of Korean sightings around these two particular periods (Willis & Stephenson 2000). Further research needs to be undertaken on this topic.

7. Conjugate auroral observations on AD 1770 September 16

Observations of the aurora australis on the night of AD 1770 September 16 have been recorded in the journals of Joseph Banks and Sydney Parkinson, written on board *HMS Endeavour* during the first voyage of Captain Cook to Australia (Willis, Stephenson, & Singh 1996). Both descriptions of the aurora australis refer to a red light or glow in the southern sky, accompanied by rays of a brighter coloured light extending directly upwards. Observations of the aurora borealis on the same night have been recorded in Chinese provincial histories, which refer to auroral displays in the northern sky. These provincial histories also indicate that red auroral displays were observed each night during the interval 1770 September 16–18. Assuming that the red light seen in both hemispheres was predominantly 630-nm ('red line') emission from excited atomic oxygen, the magnetic field model of Bloxham & Jackson (1992) can be used to show that these early auroral descriptions are consistent with conjugate auroral observations during an intense geomagnetic storm. These observations provide the earliest example yet known of conjugate auroral sightings.

8. Conclusions

The results presented in this brief summary provide important, if incomplete, information on variations in auroral activity, and hence geomagnetic activity, during historical times. Investigations of the present type should eventually help to establish a partial solar-cycle chronology for the past two millennia.

References

Beijing Observatory (Ed.) 1988, Zhongguo Gudai Tianxiang Jilu Zongji, (Kiangxu: Kexue Jishi Chubanshe)

Bloxham, J., & Jackson, A. 1992, J. Geophys. Res., 97, 19, 537

Chapman, S. 1957, Nature, 179, 7

Dai N.-Z., & Chen M.-D. 1980, Kejishiwenji, 6, 87

Fritz, H. 1873, Verzeichniß Beobachteter Polarlichter (Wien: C. Gerold's Sohn)

Keimatsu, M. 1976, Ann. Sci. Kanazawa Univ., 13, 1

Link, F. 1962, Geofys. Sborník, 10, 297

Link, F. 1964, Geofys. Sborník, 12, 501

Matsushita, S. 1956, J. Geophys. Res., 61, 297

Osaki, S. 1994, Kinsei Nihon Temmon Shiryo (Tokyo: Hara Shobo)

Seydl, O. 1954, Geofys. Sborník, 2, 159

Stephenson, F.R., & Willis, D.M. 1999, A&G, 40, 6.21

Willis, D.M., & Stephenson, F.R. 2000, Ann. Geophysicae, 18, 1

Willis, D.M., Stephenson, F.R., & Singh, J.R. 1996, QJRAS, 37, 733

Yau, K.K.C., Stephenson, F.R., & Willis, D.M. 1995, A Catalogue of Auroral Observations from China, Korea and Japan (193 BC–AD 1770), Rutherford Appleton Laboratory Technical Report RAL–TR–95–073