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Planetary harmonics in the historical Hungarian aurora record (1523–1960)

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ABSTRACT

The historical Hungarian auroral record extends from 1523 to 1960 and is longer than the sunspot record. Harmonic analysis reveals four major multidecadal secular cycles forming an approximate harmonic set at periods of 42.85, 57.13, 85.7 and 171.4 years. These four frequencies are very close to the four major heliospheric oscillations relative to the center of mass of the solar system caused by Jupiter, Saturn, Uranus and Neptune. Similar frequencies are found in solar radiation models based on long cosmogenic isotope records (Steinhilber et al., 2012) and in long records of naked-eye sunspot observations (Vaquero et al., 2002). Harmonic regression models are used to reconstruct and forecast aurora and solar activity for the period 1956–2050. The model predicts: (1) the multidecadal solar minimum in the 1970s that is also observed in the sunspot record; (2) a solar maximum in 2000–2002 that is observed in the ACRIM total solar irradiance satellite composite; (3) a prolonged solar minimum centered in the 2030s. These findings support a hypothesis that the Sun, the heliosphere and the terrestrial magnetosphere are partially modulated by planetary gravitational and magnetic forces synchronized to planetary oscillations, as also found in other recent publications (Scafetta, 2010, 2012a, 2012c, 2012d; Abreu et al., 2012; Tan and Cheng, 2012).

1. Introduction

Auroras are among the most spectacular events observed in the sky (Akasofu, 2009; Brekke, 2012). The aurora oval covers most of the Arctic and Antarctic regions of the Earth, typically within 10°–20° from the magnetic poles. Auroras are space weather events regulated by the Sun, the heliosphere and the terrestrial magnetosphere (Moldwin, 2008). Auroras caused by the most energetic solar eruptions are occasionally observed at mid-to-low latitudes, facilitating the numerous historical records, in particular from central and southern European countries.

Historical auroral sighting records are valuable because they are the longest direct observational records available for studying solar and space weather dynamics. Catalogs of historical auroral records, in particular from the mid-latitudes, have been compiled since the 19th century (Fritz, 1873, 1881; Lovering et al., 1868; Angot, 1897) and updated later by other authors: see Křivský and Pejml, (1988), Silverman (1992) and numerous references therein.

The auroral global catalogs vary greatly in reliability. Before 1700 the data are sparse for various reasons; journal press was uncommon and many older documents may have been lost or destroyed. From 1700 to 1900 numerous records exists, but highly fragmented. Since 1900 the historical naked-eye auroral records have also become sparse for various reasons, including the addition of street lighting that has made it more difficult to observe auroras from central Europe. Since 1950 naked-eye collections of direct auroral sightings have been discontinued in favor of photographic and electronic records.

Reliability suffers as well because the global catalogs mix fragmented records from different regions that cover different time intervals. In some records sightings from North America, the United Kingdom, central and southern Europe and Asia are commingled (Angot, 1897; Křivský and Pejml, 1988). However, the frequency of sightings varies greatly among these regions, as demonstrated by Loomis in 1860 (Akasofu, 2009). The auroral oval moves as well; so in time the frequency of auroral sightings may increase in one region and decrease in another. When inhomogeneous records are combined into a single comprehensive catalog spurious trends and artificial patterns may emerge, as evident in Křivský and Pejml (1988): see also Fig. 1B.

Misinterpretations due to inhomogeneity artifacts in the global records can be minimized by studying carefully collected records as lengthy as possible from a well-defined region. Records from regions where auroral sightings are relatively rare may yield to records statistically more reliable on decadal scales since rare events are more likely to elicit the interest of observers and result in their documentation.

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We have chosen to study the historical Hungarian auroral record (Nordlichtbeobachtungen in Ungarn) that extends from 1523 to 1960 (Rethly and Berkes, 1963) to determine whether this direct observational solar related record presents the signature of planetary harmonics recently found in other related solar activity records (Scafetta, 2010, 2012a, 2012c, 2012d; Abreu et al., 2012; Tan and Cheng, 2012). The Hungarian auroral record is chosen because it is one of the longest available. The Hungarian record covers 438 years, longer than the 402-year sunspot number record that began in ~1610 with Galileo's telescope observations. The Hungarian auroral record appears to be sufficiently accurate and stable for our purpose, as explained in Section 2. We compare the auroral analysis results with those referring to a comprehensive planetary orbital function and to a lengthy solar radiation model based on cosmogenic isotope records (Steinhilber et al., 2012).

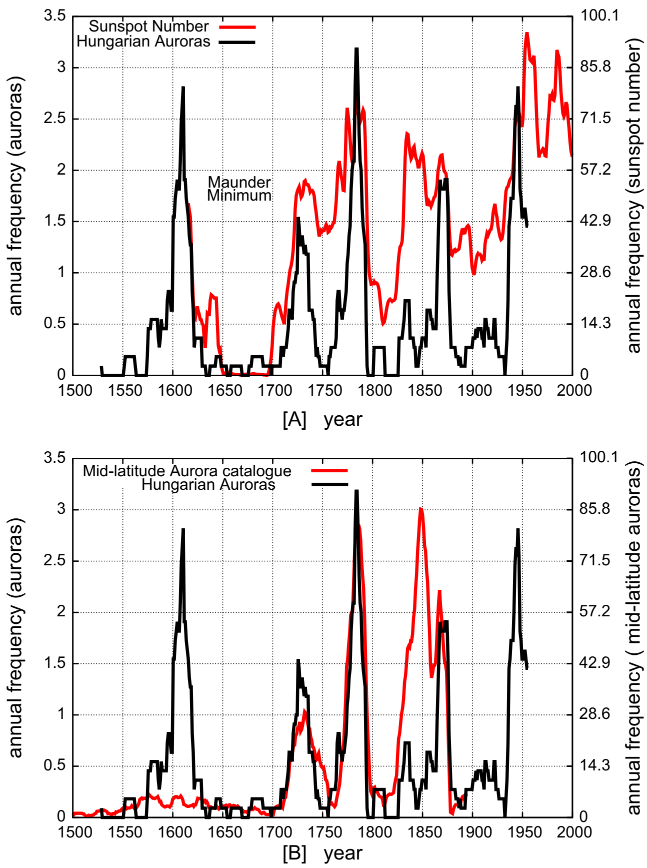

Fig. 1. (A) Hungarian auroral record (black) (Rethly and Berkes, 1963) (see Table 1) against the Sunspot number record (red): correlation coeff. $r=0.7$, $p<0.0001$. (B) Hungarian auroral record against the global mid-latitude aurora catalog (red) (Křivský and Pejml, 1988): correlation coeff. $r=0.5$, $p<0.0001$. The data are processed with a 11-year moving average algorithm. (Data from http://www.ngdc.noaa.gov/stp/aeronomy/aurorae.html and http://www.ngdc.noaa.gov/stp/solar/ssndata.html). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Data and analysis

The annual frequency of the historical Hungarian auroral record (Rethly and Berkes, 1963) is reported in Table 1. In this region auroral sightings are rare with, on average, about one event every two years. To highlight the multidecadal dynamical pattern in the record we used an 11-year moving average algorithm since the auroral frequency correlates with the ~11-year solar cycle (Akasofu, 2009) and only a few auroras per year are present. The results are shown in Fig. 1.

Fig. 1A compares the Hungarian auroral record with the sunspot number record. The maxima of the Hungarian auroral record (near 1610, 1725, 1784, 1834, 1870, 1913 and 1945) correspond closely with the maxima in the sunspot record. The Maunder (1645–1715) and Dalton (1790–1830) solar activity minima are clearly seen in both records. The sunspot number record presents a continuous upward long term trend since 1600 (average before 1780=27, average from 1780 to 1960=48; ratio 1.77). The Hungarian auroral record presents a statistically compatible trend (average before 1780=0.44, average from 1780 to 1960=0.71; ratio 1.61). During the sunspot minima it returns to zero because only the most massive solar eruptions can produce auroras visible at low latitudes and these eruptions are very rare during prolonged solar minima.

The statistical compatibility of the sunspot record and aurora record trends before and after 1780 suggests the Hungarian aurora record is sufficiently stable. Thus, the fact that polar aurora might have been more or less systematically observed in Hungary after the Universitäts-Sternwarte in Budapest was established in 1780 does not appear to have significantly changed the statistical properties of the aurora record. The slight increase of the number of Hungarian polar aurorae since 1800 is more likely due to the increased solar activity, as revealed by the sunspot record, than to an artifact due to more regular university-based observations.

Secondary discrepancies exist such as a sunspot peak in ~1955 that does not match the Hungarian auroral record, which shows a peak in ~1945. However, an auroral peak in the 1940s is found also in a compilation of German auroral observations from

Table 1
Number of auroral sightings per year: historical Hungarian aurora record, 1523-1960, (Rethly and Berkes, 1963). See also the Appendix.

Year	n	Year	n	Year	n	Year	n	Year	n	Year	n	Year	n	Year	n
1523	1	1607	2	1681	1	1730	7	1778	1	1835	1	1880	1	1940	4
1556	1	1608	1	1684	1	1734	1	1779	4	1836	1	1882	1	1941	8
1557	1	1609	1	1692	1	1736	2	1780	5	1837	2	1892	1	1942	1
1579	2	1610	2	1704	1	1737	2	1781	3	1847	1	1898	2	1943	2
1580	3	1611	1	1713	2	1739	1	1782	1	1851	1	1903	1	1946	3
1583	1	1612	3	1716	1	1741	1	1783	4	1852	1	1905	1	1947	5
1591	2	1613	5	1719	1	1749	1	1784	2	1854	1	1908	1	1948	2
1592	1	1614	2	1720	1	1761	2	1785	1	1859	4	1909	1	1949	1
1593	2	1615	4	1721	2	1763	1	1786	1	1862	1	1910	1	1950	5
1599	3	1623	3	1724	1	1768	1	1787	8	1869	5	1917	3	1951	1
1600	1	1627	1	1725	3	1769	4	1788	5	1870	8	1920	1	1957	4
1602	1	1642	1	1726	1	1770	1	1789	1	1871	4	1926	2	1958	4
1604	2	1648	1	1727	1	1775	1	1806	3	1872	3	1938	2	1959	1
1605	10	1663	1	1728	1	1777	1	1831	4	1877	1	1939	2	1960	1