J. Space Weather Space Clim., **6**, A21 (2016)
DOI: 10.1051/swsc/2016016
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Research Article
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Aurorae observed by Giuseppe Toaldo in Padua (1766–1797)

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Received 21 July 2015 / Accepted 23 March 2016

ABSTRACT

A record is presented of the auroral observations made by Giuseppe Toaldo and his assistant Vincenzo Chiminello in Padua, Italy, in the second half of the 18th century. The historical sources consulted include the original manuscripts containing the meteorological records made by those two observers. A small catalogue is constructed with the 148 auroral observations. The characteristics of these observations are analysed. The main feature of this data set is that the annual number of auroral observations presents an intense peak at around 1779 and an abrupt decline at around 1790.

Key words. Aurora – Historical records – Solar Activity – Padua

1. Introduction

Aurorae are a manifestation of the interaction between solar winds and the Earth's magnetosphere. They have been recorded for millennia. Many auroral catalogues have been constructed over the years, e.g., Mairan (1733), Lovering (1866), Fritz (1873), Angot (1896), Tromholt (1902), Link (1962, 1964), Krivsky & Pejml (1988), Loysha et al. (1989), and Yau et al. (1995). These catalogues provide information for the study of the temporal variability of these phenomena. Also, the auroral dates and descriptions can be used as a proxy for solar and geomagnetic activity (Schove 1979; Krivsky 1984; Legrand et al. 1991; Schlamminger 1991; Schröder 1994a, 1994b; Willis & Stephenson 2001; Vázquez et al. 2014, 2016).

Most of these catalogues were made without any evaluation of the documentary sources to ensure their homogeneity and usefulness. Some common problems are: (i) the geographic coverage is usually excessive in the sense that the differing concentrations of documentary sources over the wide area are not taken into account; (ii) similarly, the temporal coverage is too long to take account of the different concentrations of documentary sources, and (iii) secondary documentary sources are used (not contemporary with the event recorded). For these reasons, such catalogues need to be analysed with some care because of the difficultly in evaluating the quality of the auroral series compiled in them (Vaquero & Vázquez 2009).

Nonetheless, there are some catalogues that have taken homogeneity into account since they comprise data from a single observer at a single location. Four auroral catalogues of this kind are:

(i) Silverman & Blanchard (1983), who analysed the auroral observations made by Wilson Bentley in Vermont, United States of America, covering the period 1883–1931.
(ii) Harrison (2005), who analysed the auroral records made by Thomas Hughes in Stroud, United Kingdom, covering the period 1771–1813.
(iii) Vaquero & Trigo (2005), who analysed the auroral observations made by the German engineers Praetorius and Schulze in Lisbon, Portugal, covering the period 1781–1793.
(iv) Vaquero et al. (2010), who analysed the aurorae recorded by Francisco Salvà (a doctor) in Barcelona covering the period 1780–1825.

Most of these catalogues were extracted from weather diaries. Indeed, weather diaries constitute a primary source providing first-hand information in a continuous way, with precise dating and frequently with sub-daily resolution. The temporal coverage varies from a few months to almost a lifetime. The use of this kind of documentary source enhances the quality of an auroral catalogue. Nonetheless, it remains difficult to quantify how other factors, such as observation conditions or cloudiness, might affect the homogeneity of these aurorae catalogues.

The present paper describes the reconstruction and analysis of a catalogue of aurorae observed at *La Specola* (The Observatory) in Padua (Italy) (45°24′07.5″ N, 11°52′06.8″ E). The catalogue has principally been extracted from the handwritten meteorological log maintained by Giuseppe Toaldo, director of La Specola and professor of astronomy and meteorology at the University of Padua. Toaldo was assisted by his nephew, Vincenzo Chiminello, who followed the same professional career as his uncle and operated following the same observation protocols. Each year, Toaldo published a summary of

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the log in the form of a journal entitled *Giornale Astro-Meteorologico* in which weather averages and events were commented on in terms of agriculture, health, and other aspects. This annual journal was considered for the catalogue as well as a study about aurorae that was published by Toaldo (1780). The period covered by the catalogue is 1766–1797 (31 years). This period is particularly interesting in terms of solar activity because there are few 18th century sunspot observations, especially for the years from 1777 to 1795 (Vaquero 2007). Moreover, the catalogue covers the first years of the Dalton Minimum in solar activity and almost all of the unusual Solar Cycle 4 (1784–1798) (Usoskin et al. 2009; Zolotova & Ponyavin 2011).

2. Methodology

It is important to establish who the observers were, what expertise they had, and which methodology they followed, but also to analyse the documentary sources from which the auroral catalogue has been obtained. After those considerations, we present the methodology to analyse the reliability of the auroral record collected. This analysis is focused on comparing the auroral register with physical phenomena and other concepts known in order to correlate them with auroral activity.

2.1. The observers

The unbroken series of meteorological observations in Padua was begun in 1725 by Marquis Giovanni Poleni (1683–1761), a leading scientist and professor of astronomy and meteorology at the University of Padua. He was a member and correspondent of the Royal Society, London. His log reported two observations a day from 1725 to 1764, with notes about the weather observations and main astronomical events, e.g., eclipses and aurorae (Camuffo 2002). Poleni was especially interested in meteorology, hydrology, and construction engineering. His notes about aurorae seem reliable, although he may have missed a number of events because he did not spend all his nights observing the sky.

Giuseppe Toaldo (1719–1797) started his studies at the Seminario Vescovile of Padua, gaining a degree in Theology in 1742. He edited the works of Galileo (Galilei 1744). In 1764, he was appointed to teach astronomy and meteorology at the University of Padua. He planned *La Specola* astronomical observatory and he also was its first director. One of his interests was astrometeorology, trying to find links between astronomical and meteorological events. Toaldo made invaluable daily observations in both fields (astronomy and meteorology), and was recognized internationally for his studies. For a review of Toaldo's life and studies, see Pigatto (2000), and for his observations, see Camuffo (2002).

Vincenzo Chiminello (1741–1813), Toaldo's nephew and co-worker, was also a meteorologist and astronomer. He collaborated in the observations from 1776 until Toaldo's death from an apoplectic stroke on 11 November 1797. Toaldo took measurements until 3 days before his death, thus making his dedication clear (Camuffo 2002). On Toaldo's death, Chiminello was appointed Director of *La Specola* and he held the chair of Astronomy and Meteorology at the University of Padua. Chiminello also suffered an apoplectic stroke in 1807 that limited his mobility and hence ability to climb the astronomy turret. Despite his engaging an assistant, Francesco Bertirossi-Busatta, the scientific activity of Chiminello clearly declined, decreasing the details in the records and the quantity and quality of the publications.

The scientific method requires making observations, recording data, and analysing data in a form that can be duplicated by other scientists. The apparatus and or method for conducting scientific observations have to be based on well-known scientific principles. Both Giuseppe Toaldo and Vincenzo Chiminello were leading astronomers, renowned in Europe, professors of the University of Padua. Their articles were published, translated or summarized in the journals of the main scientific societies, e.g. Royal Society, London, Societé Royale des Sciences, Paris, and similarly in Germany, Portugal and Russia. They had advanced notions of mathematics, geometry, arithmetic, algebra, trigonometry and theoretical knowledge in disciplines like astronomy and geography with the essential ideas of modern cosmology, general physics and mechanics clearly overcoming the old Aristotelian notions. First, Toaldo and then Chiminello held since 1765 the chair of Astronomy and Meteors at the Padua University. Toaldo however had created a background of technical expertise in meteorology and a tradition in astronomical observations, all these skills contributed to his experience in practical observations and to the idea of establishing an Astronomical Observatory in Padua: the *Specola*. First Toaldo and then Chiminello were Directors of the *Specola*. The same theoretical and practical background was taught and the same methodological approach in the observations was assigned with the time by Toaldo to his nephew Chiminello. Observation and insight were a key part of their scientific inquiry and they were internationally known for their work (e.g. Toaldo was cited several times in the Philosophical Transactions and Chiminello won the Prize of the Societas Meteorologica Palatina in Mannheim for his hygrometer). The other step in the scientific method, i.e., the inductive reasoning (hypothesize and to come up with an explanation) was also well established by the university studies of Logic and Mathematics performed by the two scientists. Moreover Toaldo and Chiminello, after their observations, always made a comparative analysis of characteristics of aurorae searching for other observers, in Italy and in Northern Europe that could have observed the same phenomenon. Finally if we look at the possible bias of the scientific method used by Toaldo and Chiminello in their observations of aurorae, we can estimate it as minimum as they used to perform daily observations when the weather allowed it (i.e., observations can be considered complete). These observations were performed to the naked eye and/or with the same (for both Toaldo and Chiminello) reliable and modern instruments for that time, and using the same methodology.

Another scholar, a contemporary of Toaldo, the abbot Giuseppe Gennari (1721–1800), in his diary entitled "*Notizie giornaliere di quanto avvenne specialmente in Padua dall*'anno 1739 all'anno 1800" [Daily news about events in Padua from 1739 to 1800] reported social and political happenings, extreme meteorological events, and some aurorae, often quoting Toaldo as an authoritative source.

2.2. The documentary sources consulted

Three primary documentary sources were consulted to compile the Toaldo catalogue: (i) the original manuscript of Toaldo's meteorological log, (ii) the annual publications of the Giornale Astro-Meteorologico (published by Toaldo in the period 1778–1797, and later by his nephew, Chiminello) and (iii) an article written by Toaldo about the aurora of 29 February 1780

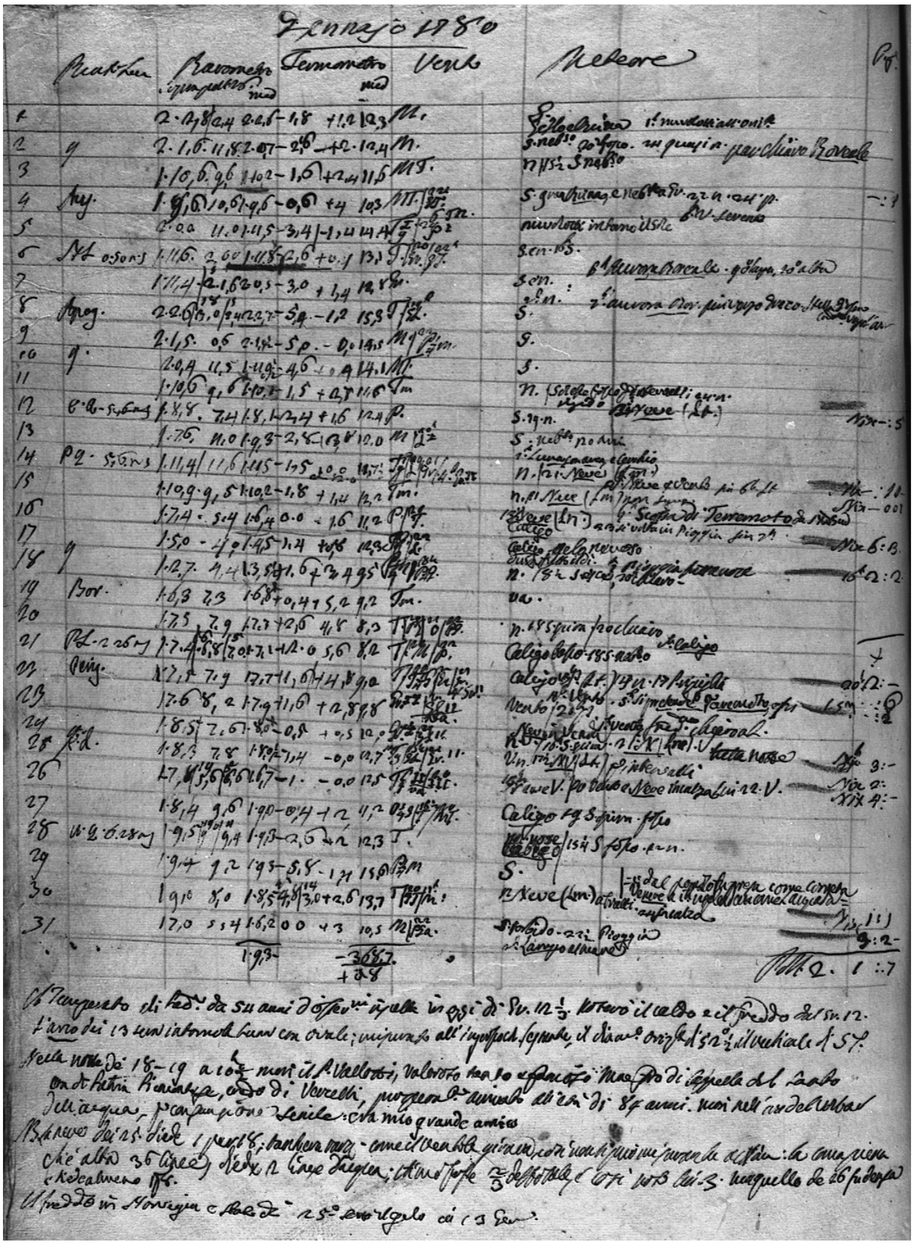

Fig. 1. A manuscript sheet of Toaldo's astrometeorological observations carried out in January 1780, today preserved in the historical archive of *La Specola* in Padua (courtesy of the Historical Archive of the Astronomical Observatory in Padua).

(Toaldo 1780). There follows a brief description of these primary sources:

(i) The meteorological log contains weather observations from 1 May 1766 to 7 November 1797 (the last observation made by Toaldo). The manuscript reports the meteorological observations made by Toaldo and Chiminello in the Astronomical Observatory of Padua. The log was maintained by Toaldo, except when he was away and Chiminello made the observation instead. Each page shows the daily observations of one month (Fig. 1). The columns are, from left to right: the day, lunar point (here Toaldo registers the *Novilunio* (NL; new moon), *Plenilunio* (PL; full moon), *Primo Quarto* (PQ; first quarter), *Ultimo Quarto* (UQ; last quarter), *Perigeo* (P; perigee), *Apogeo* (Ap; apogee), *Lunistizio Australe* (A; minor standstill) *Lunistizio Boreale* (B; major standstill), *Equinozio ascendente* (EA; ascending equinox), *Equinozio descendente* (ED; descending equinox), *quartale* (q; quarter)), barometer, thermometer, wind, meteorological description, and rainfall. Toaldo had a theory about the influence of the moon in the weather (for details see Toaldo 1781). The meteorological information in this manuscript has been studied by Camuffo and collaborators in various papers (Camuffo 1984, 2002; Cocheo & Camuffo 2002; Camuffo et al. 2014). The information about the auroral observations appear in the column devoted to the meteorological description, annotated as "aurora boreale", "chiaror boreale", or similar. A more detailed description of the auroral event frequently appears at the bottom of the page, with information about the time, position, colour, or duration of the event. A total of 136 references to aurorae appear during the 31 years studied for the present catalogue. From an in-depth analysis, all these observations (except one) appear reliable according with the date, time and description of the event. The exception was the description of the event of 14 November 1790, in which the auroral features are unclear. Toaldo's annotation is that in the sky there appeared "*un auro d'aurora boreale… un chiaro no commune*" (an aurora borealis light… an uncommon brightness). This is not a clear description. Moreover, the time of this observation (20 h Italian Time) is a very improbable time to see an aurora. Toaldo used the so-called "Italian Time" that had been in use in Europe since the Middle Ages. This style was typical of the Army of Rome, and followed the Church's liturgical services. The new day began at twilight, about 30 min after sunset when darkness was dominant. Church bells would then announce the end of the day and the call to Compline or Night Prayer (Camuffo 2002; Camuffo & Bertolin 2012). The day was divided into 24 h, with all nights starting at hour 0, but noon falling at different times over the calendar year. This style was useful in astronomy because all the observations made during the same night had the same date. The use of the present-day style with the day starting at midnight began in 1789, imposed by the French Revolution. Therefore, the aurora of 14 November 1790, visible 4 h before the dark nocturnal sky, has been flagged as dubious.

(ii) *Giornale Astro-Meteorologico*: This publication was an annual astronomical and meteorological journal that Toaldo founded and edited in 1778. It was a publication with astronomical ephemerides, scientific articles, meteorological observations, and weather events from the previous year (Camuffo 2002). The references to aurorae appear in the section of meteorological observations, and in some scientific articles. This historical source has more errors in the dates than the other two sources. The journal registered 33 aurorae from 1778 to 1790. The aurora recorded on 11 March 1788 is probably a misprint for that of 11 February 1788 (registered with the correct date in the meteorological log and confirmed in other places of Europe: Spain, Eoehelle, Montmorency, Brussels, Middelburg, Mannheim, Geneva, Buda, Munich, Peissenberg, Tegernsee, Eatisbon, Erfurt, Lena, Sagan, Berlin,…). Therefore, the event on 11 March is flagged as being dubious. Another 2 events, on 22 March 1787 and 3 November 1788, appear in the *Giornale* of 1805 and 1806 respectively but not in the *Giornale* of 1788 and 1789, and are not mentioned in the meteorological log. However, reference to these two observations reported by Toaldo appears in the Angot catalogue (Angot 1896) for places below latitude 55°, so that we have considered them to be real aurorae.

(iii) *Descrizione dell'*aurora boreale del di'XXIX Febrajo MDCCLXXX: dal signor abbate Guiuseppe Toaldo (Description of the aurora borealis on 29 February 1780 by the abbot Guiuseppe Toaldo): Article published by Toaldo in the *Saggi Scientifici e Letterari dell'*Accademia di Padova (Tome I, pages 178–194). In this text, Toaldo explains the phenomena of the aurorae borealis, and presents a list of the aurorae observed in Padua or nearby areas during the period 1768–1780 (54 aurorae in total). He states that no reference to this phenomenon being observed in Padua can be found for the period 1629–1707. In fact, aurorae at low latitudes were very infrequent during these years of reduced solar activity, years which mostly correspond to the Maunder minimum (Maunder 1894; Eddy 1976). Toaldo continues with the famous aurorae of 1716, 1726, and 1737, noting that, at the time when he was publishing the article (the paper is dated 2 March 1780), aurorae become "frequent and familiar". Indeed, the year 1780 was one of maximum solar activity in Solar Cycle 3. Toaldo described in detail the aurora on 29 February 1780: "*vidi a tramontana un segmento de luce candidissima, similissima all'Alba chiara. Il candor di questa luce era rilevato da un arco, o ponte di fosca nuvola… Erano le ore 7:30 della sera (ore astronomiche) l'ampiezza dell'arco che trovai di 120 gradi, e la sua freccia o altezza non era piú che di 10…*" ("I saw in the north a segment of very white light, similar to a clear sunrise. This light was revealed to be an arch or a bridge of hazy cloud… It was 7:30 in the evening (astronomical time), the amplitude of the arch was 120°, and its arrow or height was not more than 10…"). He also gave information about the observation of this aurora in France (Languedoc, Béziers, and Montpellier) and Rome. References to this aurora are found also for Madrid "*… a las 8h de la noche, estendiendose por toda la region septentrional, pasando algunas nubecitas luminosas sobre el cenit hacia la region austral, esta se repitió el 1 de marzo pero con menos intensidad*" (… at 8 p.m. extending over the whole northern region, some luminous clouds crossed over the zenith towards the austral region. This was repeated on the 1st of March but with less intensity) (Rico Sinobas 1855; Vaquero et al. 2003).

In sum, all the documents consulted allowed 148 auroral events to be identified, 2 of which we perceived to be dubious. For this reason, those two events were removed from further consideration, and the following analysis will be based on the 146 reliable auroral events. Nonetheless, all the information recovered has been incorporated into the Supplementary Material of this article, including the two dubious events.

In order to evaluate the reliability of the Toaldo catalogue, we studied the visibility conditions of the aurorae in terms of the time of observation and the illuminated fraction of the moon. We evaluated the Toaldo catalogue in accordance with the knowledge of the geomagnetic activity, studying the month of observation, and the auroral direction. We made a comparison between two regional auroral catalogues (Angot 1896 and Krivsky & Pejml 1988) and the Toaldo catalogue (observations from a single place taken by observers who applied the same methodology and compiled from primary documentary sources). Finally, we evaluated the relationship between the Sunspot Number and the Toaldo auroral catalogue.

3. Results

3.1. Reliability of the observations

Figure 2 shows the times of the observations (in the original Italian Time) of the aurorae. Note that only 75 records have this information. The observations are more frequent during the 5 h after sunset. It should be noted that each aurora was labelled with the time of its first observation. The duration of the event is not always provided, although many events lasted for various hours. For example, Toaldo's annotation

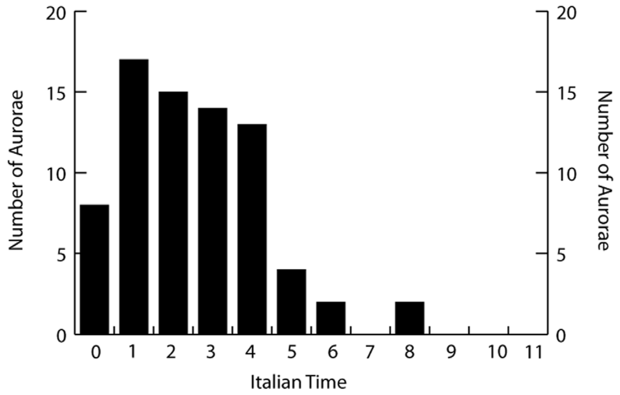

Fig. 2. Hourly distribution of aurorae on the original time scale (i.e., Ora Italica).

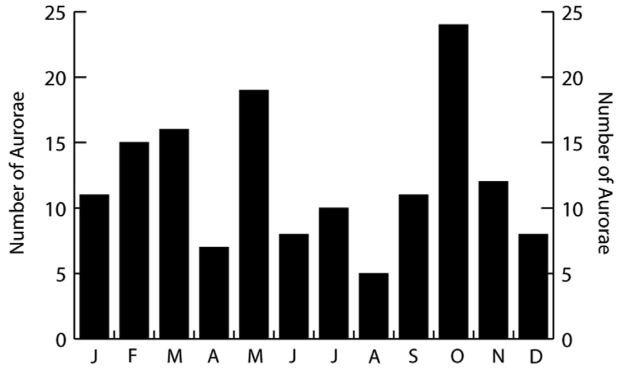

Fig. 4. Monthly distribution of aurorae.

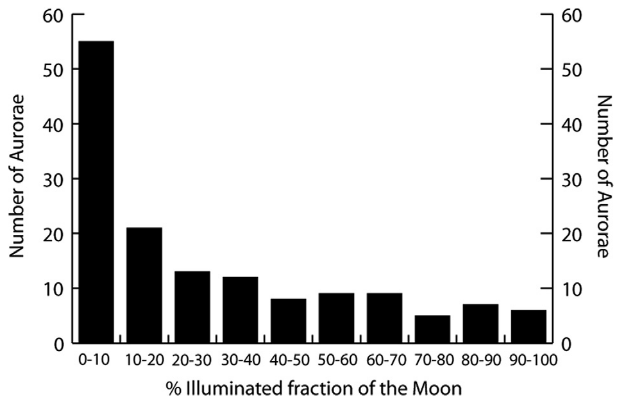

Fig. 3. Number of aurorae as a function of the illuminated fraction of the Moon.

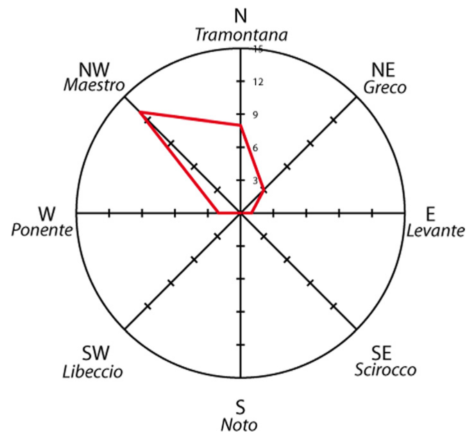

Fig. 5. Direction of the aurorae. In italics are reported the commonest wind-direction names Toaldo uses for all his astrometeorological observations.

for the aurora on 22 March 1786 is "started at four and lasted all night", but this aurora is represented in Figure 2 only at 4 h. The observations at the earliest 0 h in Italian Time were affected by the twilight, and hence are fewer in number than those of 1 h. Depending on the season, these earliest observations would have been at around 18:00–19:00 WET in autumn and winter and around 20:00–21:00 in spring. The aurora on 3 June 1790 is recorded "*a 20 h sera*" ("at 20 h evening" in Italian Time, equal to about 16:30 in WET), too early to see an aurora. Thus we think that this is an error in the register, and probably corresponds to 2 h (i.e., 22:30 WET). For this reason, this aurora has been excluded from Figure 2.

Figure 3 shows the number of aurorae as a function of the percentage illuminated fraction of the Moon. As expected, as the reflected fraction of the Moon increases, the number of aurorae observed decreases. Most aurorae were seen close to the New Moon, and almost 50% were observed with less than 20% of the Moon's disk illuminated.

Figure 4 shows the monthly distribution of the auroral events. October was the month with most aurorae observed (the autumn equinox). Seasonally, autumn (32.2%) and spring (28.8%) have more aurorae than summer (17.7%) and winter (23.3%), following the semi-annual variation of geomagnetic activity. There are three proposed mechanisms to explain this seasonality of geomagnetic activity. They are the equinoctial hypothesis (McIntosh 1959), the axial hypothesis (Cortie 1912), and the Russell-McPherron effect (Russell & McPherron 1973).

Since the Toaldo's observations cover a few decades, we calculated the variation of the geomagnetic latitude in Padua (45°24′ N) during the 18th century and the first half of the 19th century. To this aim we used the geomagnetic model *gufm1* (Jackson et al. 2000). Using the centered dipole approximation, we obtained the geomagnetic latitude of Padua from the distance of this city to the geomagnetic pole. The results reveal that the geomagnetic latitude of Padua varied almost linearly from 49.5° in 1700 to 46.8° in 1850. Information about the direction or azimuth of the aurorae is available only for 27 events (Fig. 5). The preferential directions are north-west (NW) and north (N) (70% of the aurorae). This is physically coherent with the position of magnetic north at these dates (Legrand et al. 1991).

All the factors considered here (time, lunar phase, monthly distribution, and directions) agree with what one expects for quality observations. We therefore conclude that Toaldo's observations are reliable.

3.2. Comparison with other catalogues

We compared the data in the present study with other two widely used catalogues (Angot 1896; Krivsky & Pejml 1988). Such a comparison is interesting because these catalogues are limited to aurorae observed below 55° N latitude.

During the period studied, and especially from 1776 to 1798, the Krivsky & Pejml (1988) and Angot (1896) catalogues are similar (Fig. 6a). Nevertheless, this strong coincidence is only found for those decades. For the previous years, Angot recorded more aurorae than did Krivsky & Pejml,

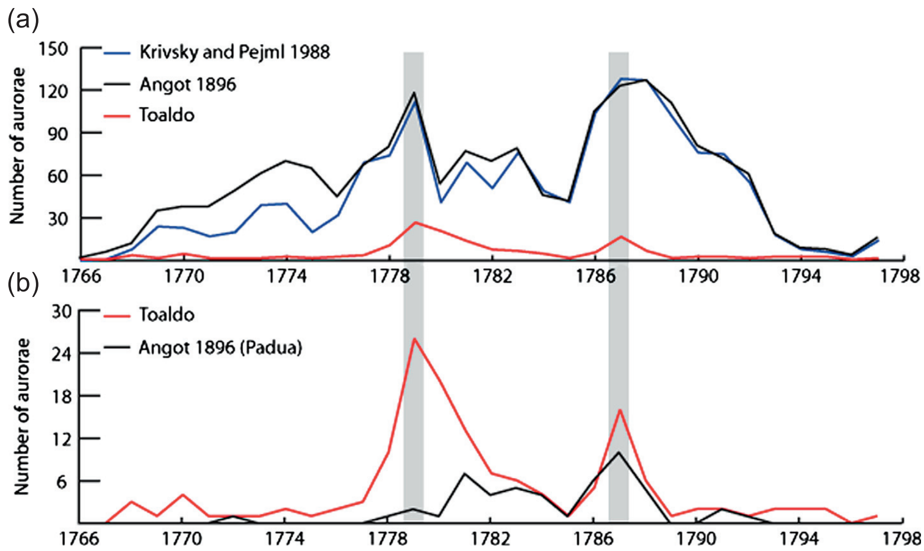

Fig. 6. (a) Comparison of the Toaldo, the Krivsky & Pejml (1988), and the Angot (1896) catalogues. (b) Comparison of the Toaldo and the Angot (1896) catalogues considering only the aurorae observed in Padua.

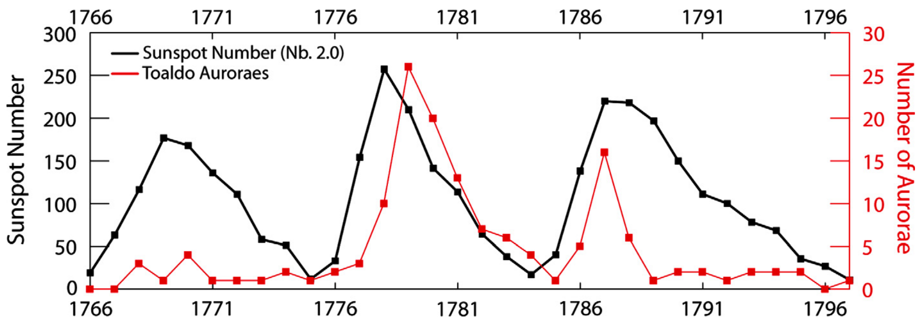

Fig. 7. Comparison of the aurorae recorded by Toaldo with the Sunspot Number Version Nb. 2.0 (source: WDC-SILSO, Royal Observatory of Belgium, Brussels).

with the reverse being the case for the subsequent years (until 1850) (data not shown). Two maxima in the numbers of recorded aurorae, in 1779 and 1787, are identified in all three catalogues. Nevertheless, in the Toaldo's catalogue the 1779 maxima is greater than that of 1787 (1779: 26 aurorae; 1787: 16 aurorae), while both Krivsky & Pejml (112, 128) and Angot (117, 126) show similar numbers in both years. Furthermore, the 1787 maxima in the Toaldo's catalogue has a clearly identifiable peak, whereas the maxima in the other two catalogues are in the form of a plateau that covers a four-year period (1786–1789). In addition, the number of aurorae after this maximum declines sharply in the Toaldo's catalogue, but not in the Krivsky & Pejml or and Angot catalogues. Some of these differences are surely due to the fact that the two catalogues being compared cover aurorae observed anywhere below 55° N latitude, whereas Padua is at a latitude 10° further south than this upper limit. Therefore, once solar activity decreased, and the aurorae disappeared in Padua, they might still be observed at higher latitudes, i.e., from 46° N to 55° N.

During Toaldo's observation period, Angot (1896) recorded 50 aurorae in Padua (Fig. 6b). Although 38 of these events were also recorded by Toaldo, 9 are not in the Toaldo catalogue and 3 differ by one day.

These last 3 cases could be attributable to the dating style or time of observation. Indeed, Toaldo used Italian Time, and hence just one date for the whole night starting from twilight. Angot, however, used French time with two dates for each night either side of midnight. We excluded the possibility that there existed other independent observers in Padua because all scientific observations were presented and commented on in Padua's Accademia Galileiana di Scienze Lettere ed Arti at periodic meetings, and the scientific and cultural living environment in Padua has been carefully investigated. Another scholar, contemporary with Toaldo, the abbot Giuseppe Gennari in his weather diary (Gennari 1984) reported 12 aurorae, all of which are also recorded by Toaldo, and indeed, for most of them, Gennari specifies that the aurorae had been observed and described by Toaldo.

Moreover, none of the 9 aurorae recorded by Angot but not by Toaldo are recorded in the independent catalogue of Aragonès & Ordaz (2010) for the Iberian Peninsula. Our opinion is that these 9 aurorae are compilation errors in the Angot catalogue, probably due to Angot being a secondary source not contemporary with the events, and to his having copied information from many documents uncritically. The same can be said for analogous comparisons of other exceptional events, e.g., extremely severe weather events with the Venice lagoon and rivers in northern Italy being frozen over that are reported by the French scientist Arago but are not supported by local documents. For the city of Padua during the Toaldo period, Angot has an error rate of 18% in the aurorae recorded.

This relevant percentage suggests that it is best to be cautious when analysing catalogues based on secondary sources. Comparing only the Padua aurorae recorded by both Toaldo and Angot (Fig. 6b), one observes that, while the 1787 maximum appears similar in the two catalogues, the 1779 maximum in the Toaldo catalogue is clearly underestimated and delayed in the Angot catalogue.

3.3. Solar and auroral activity

In this section, we shall describe comparison we made between the sunspot number and the number of aurorae recorded by Toaldo. The period observed from 1766 to 1797 covered three solar cycles (Fig. 7). In this figure, we have used the "new" sunspot number published recently by WDC-SILSO, Royal Observatory of Belgium (see Clette et al. 2014). This is an improved version of the sunspot number replacing the International Sunspot Number (Clette et al. 2007) and the Group Sunspot Number (Hoyt & Schatten 1998).

The annual number of aurorae observed by Toaldo was related to the solar activity. Three cycles can be detected in the number of aurorae that match three solar cycles which occurred during the same period. However, the amplitude of these cycles in the auroral series is variable. The highest peak, observed in 1779, is delayed by one year with respect to the solar cycle maximum. This outstanding peak of auroral activity in Padua also appears in other series of observations at a global scale (Silverman 1992). The solar and heliospheric sources of auroral phenomena are related to the topology of the magnetic field of the solar atmosphere. Two different sources can be noted: the Coronal Mass Ejections (CMEs) and the high-speed solar wind. The CME rate approximately follows the solar cycle (Robbrecht et al. 2009) and the long-lived coronal holes (that are the sources of high-speed solar wind) occur more frequently in the declining phase of the sunspot cycle (Verbanac et al. 2011). Therefore, the peak of auroral activity is usually delayed respect to the peak of the sunspot number. Another notable feature is the sharp decrease in auroral activity at around 1790 in Padua. This sharp decrease was also observed in the numbers of aurorae recorded by Francisco Salvà in Barcelona (Vaquero et al. 2010). The sunspot number declined more slowly, however, just at the onset of the Dalton Minimum of solar activity. Anyway, we should take into account that many years are below five aurorae, so the loss of some aurorae by cloud cover can modify significantly the shape of the auroral curve.

Some authors have suggested that a "lost" solar cycle is present in the 1790s (Usoskin et al. 2009). Unfortunately, the small number of aurorae observed by Toaldo in the 1790s cannot provide any relevant information about the existence of any such lost solar cycle in this decade.

4. Conclusions

A homogeneous long-term auroral series observed in Padua has been recovered from primary source documents written by extremely competent and dedicated observers. The series might only have missed some events due to cloud cover. In order to get an idea of how relevant this cloud-cover problem might be, during the period 1725–1800, the minimum and maximum frequency of rainy days was 79 and 147 per year, with a mean of 107 days per year (Camuffo 1984). To evaluate the reliability of the selected catalogue the auroral visibility is analysed as a function of time and month of observation, direction and illuminated fraction of the moon. Most of the aurora events were seen within the first 5 h after the sunset and around 50% of them were registered when the moon's disk was illuminated to less than 20%. That shows the number of aurorae events seen increases with the lowering of the reflected fraction of the moon, as expected. In addition, the main concentration of aurorae events showed a seasonality of geomagnetic activity focused on autumn but also a polarization on the direction of them (NW, N) which is physically coherent with the position of the magnetic north at these dates. The comparison of the aurorae recorded in Padova by the Toaldo catalogue and regional catalogues (i.e., Angot 1896) points out that Angot recorded less auroral events than Toaldo's (50 and 148, respectively). Moreover, the 18% of the events recorded by Angot are dubious. So we have to be careful working with regional catalogues based on secondary sources. The Toaldo's catalogue shows a secular maximum of the auroral activity at around 1780 which was also observed at a global scale (Silverman 1992). The auroral activity showed a sharp decline beginning in 1789, marking the onset of the Dalton Minimum, although the solar activity declined less rapidly. The sparse auroral data in the 1790s are insufficient to support any hypotheses about whether or not there exists a lost solar cycle in this decade.

Acknowledgements. This research was supported by the Spanish Ministerio de Ciencia e Innovación (Projects AYA2008-04864/AYA and AYA2014-57556-P), the Junta de Extremadura (Research Group Grant No. GR15137), and the Universidad de las Fuerzas Armadas of Ecuador (ESPE) (Project 2015-PIC-014). Fernando Domínguez-Castro was partially supported by the Ecuadorian Government (Secretaría de Educación Superior, Ciencia, Tecnologia e Innovación) through a PROMETEO project. The authors are indebted to Prof. Luisa Pigatto and Dr Valeria Zanini, responsible for the Historical Archives of the Astronomical Observatory of Padua, for their assistance during the archival research. The editor thanks Magnar Gullikstad Johnsen and an anonymous referee for their assistance in evaluating this paper.

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Cite this article as: Domínguez-Castro F, Vaquero JM, Bertolin C, Gallego MC, De la Guía C, et al. Aurorae observed by Giuseppe Toaldo in Padua (1766–1797). *J. Space Weather Space Clim.*, **6**, A21, 2016, DOI: 10.1051/swsc/2016016.