The reconstruction of solar activity in the context of solar dynamo modeling

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Abstract We discuss problems of interpretation of sunspot data for use in solar dynamo modelling. The variety of the current sunspot reconstructions of archival data creates substantial difficulties for such an endeavour. We suggest a possible strategy to avoid these problems. The point is that we have to accept the possibility of several solar activity reconstructions that are contradictory in detail, and have to compare several possible reconstructions with dynamo models. The point is that a given reconstruction may not cover all the time interval of interest because this reconstruction requires information unavailable at earlier or later times.

Key words: Sunspots; solar activity; solar cycle

Introduction

Archival telescopic data provide an important possibility to compare results of dynamo modelling with observational data. The difficulty here is that the message from archival data is that solar activity is not just a cyclical process and that from time to time substantial deviations such as the Maunder minimum occur. The substantial decrease in solar activity at the middle and the end of the XVIIth century until the beginning of the XVIIIth, as well as several similar Grand minima in the more remote past, are visible in isotopic data obtained from analysis of carbon isotopic systems in tree rings and from beryllium isotopic systems in natural ice. However the temporal resolution of isotopic methods is limited (e.g. Usoskin et al., 2015). This is why historical records of telescopic observations of sunspots provide a brilliant opportunity to clarify the nature of the last Grand minimum, i.e. the Maunder minimum, and to use this information for validation of solar dynamo models that describe the physical process believed to be responsible for solar cycle activity. Such analysis became possible in the 1990s after publication of the solar activity reconstruction (Hoyt and Schatten, 1998, and reconstruction for the Maunder minimum is based mainly on Ribes and Nesme-Ribes, 1993). Comparison of the reconstructions with dynamo models (Sokoloff and Nesme-Ribes, 1994) demonstrated that mixed parity solutions of the mean-field equations for the solar dynamo have to be considered, as this occurs with solar dynamo engine near the end of the Maunder minimum. The corresponding studies based on the reconstruction Hoyt and Schatten (1998) are summarized in, e.g., Sokoloff (2004).

Recent progress in reconstruction of archival data (e.g. Arlt and Weiss, 2014; Vázquez et al., 2016) has provided new and important material for comparison with solar dynamo models. The message is that Grand minima are far from being unique deviations from purely cyclical behaviour, and that the history of solar activity in the XVIIIth – early XIXth centuries provides interesting examples of various deviations such as a lost cycle (Usoskin et al., 2009), episodes of unusual symmetry (Sokoloff et al., 2010), etc. It looks natural to develop other solar dynamo models in order to include such deviations.

The point here however is that at the same time astronomers have become much more critical concerning historical sunspot data and other archival solar activity records (e.g. Svalgaard and Schatten, 2016). If these criticisms are fully accepted, the data from a few contemporary cycles only can be used for comparison with solar dynamo models.

These contradictory tendencies, i.e. the substantial enlargement of interesting messages from the archives and insufficiently critical acceptance of archival data, need to be discussed in the context of dynamo modeling. This is the aim of this paper.

Dynamo modeling based on inhomogeneous data

It looks reasonable to believe that the key feature in the above problem is that we are presented here with a situation that is quite unusual in physics and astronomy. The time scale of the processes under discussion is long in comparison with human time scales and those of modern society. Indeed, the solar cycle time scale is about 22 years and a single observer can observe not more than 2 (maybe 3 in exceptional cases) cycles. Contemporary scientific progress is rapid enough to make the scientific background for observational work now and half a century ago substantially different. The compilation of archival records from several observers is also a highly nontrivial undertaking. On the other hand, the time interval over which instrumental archival data are available (about 400 years) contains quite a lot of interesting information and is short enough to believe that we more or less understand the motivations of our predecessors. It seems unreasonable just to discard archival data and to base dynamo investigations on contemporary information and stellar analogies only.

More generally, the point is that we cannot currently observe phenomenon of interest with the methods recognized by contemporary science, and reproduce the phenomenon as many times as we would like to do. This situation is unusual for physical studies, however it is a typical situation for various historical studies. It seems that we have to accept some concepts of historical studies in this topic. Such a necessity appears rather unencouraging set against the background of opinion that sciences are divided between physics and stamp collecting (E.Rutherford in Birks, 1962); however this still looks preferable to deadlock.

Accepting this point, we can suggest several ways how the interface between the historical record and dynamo modelling can be elaborated. Of course, the suggestions listed below are quite natural and are used from time to time in practical work. However they have not been collected together and presented and discussed in an explicit form.

We have to accept the possibility of several solar activity reconstructions that are contradictory in detail, and have to compare several possible reconstructions with dynamo models. The point is that a given reconstruction may not cover all the time interval of interest because this reconstruction requires information unavailable at earlier or later times. For contemporary examples of such reconstructions see e.g. Lefevre and F.Clette (2014); Usoskin et al. (2016). This will make the results of comparisons less definite, but it seems preferable to basing comparisons on only a single reconstruction.

In historical studies it was recognized that a particular reconstruction of historical events does not tell the whole truth, but rather just indicates a path to criticism of the accepted sources of information. This observation applies also to reconstruction of historical solar activity data, and we now illustrate this point using arguments of Usoskin et al. (2015) concerning a reconstruction of solar activity during the Maunder minimum era, suggested in Zolotova and Ponyavin (2015).

The fundamental point is that archival information concerning the Maunder minimum comes from various sources of differing quality and one source can contradict another. Any reconstruction of solar activity for the Maunder minimum era has to choose some sources and discard others. Zolotova and Ponyavin (2015) base their choice on an assumption which appears attractive, i.e. to keep the results based on drawings and discard data based on narrative accounts. As a result, the reconstruction suggested by Zolotova and Ponyavin (2015) presents the Maunder minimum as an ordinary secular minimum similar to the current weak solar minimum. Usoskin et al. (2015) criticizes this reconstruction and stresses in particular the following points. The basic idea that information provided by drawings is more complete than that from the corresponding narratives does not fit the cases for which both kinds of information are available. Another point is that the reconstruction suggested in Zolotova and Ponyavin (2015) contradicts isotopic data, which give substantially lower levels of solar activity than suggested by this reconstruction.

One consequence of the approach under discussion is the necessity to make all relevant archival data public available in a digital form. It is insufficient to make publically available just the reconstruction and basic published materials, rather it is important to learn more about details of observations and motivations of the observers. Usually details of the personal life and work of scientists of the present have only a potential historical interest. However this is not the case for the historical solar activity studies. The key issue here is, to what extent were observers of Paris observatory at the time of the Maunder minimum times persistent in their observational efforts? The contemporary state of the publication effort in the problem means that we have to look at the problem using the interpretation of Ribes and E.Nesme-Ribes (1993) only, and this looks inadequate for the current state of affairs. Extensive publication of archival data is a goal which is far from being recognized as worthwhile by the funding bodies, and a change of opinion here is very important.

Conclusions

We believe that contemporary difficulties in the application of archival data for validation of solar dynamo models can be overcome by a fuller acceptance of archival data as a source of astronomical information.

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