4^{th} Dynamo Thinkshop

Dipartimento di Fisica

Università degli Studi di Roma Tor Vergata

Aula Grassano – November 25-26, 2019

Preliminary Program

Monday 25^{th} of November

10:00 Registration and Welcome (*A. Bigazzi*)

Session Dynamo

10:30 Stochastic Resonance in complex systems, *Roberto Benzi*

11:00 Schwabe, Gleissberg, Suess-de Vries: A simple model for synchronizing solar cycles by planetary forces *F. Stefani, A. Giesecke, M. Seilmayer, T. Weier*

11:40 Can stochastic resonance explain the amplification of planetary tidal forcing? *Carlo Albert and Simone Ulzega*

12:10 Baysian inference methods for the calibration of stochastic dynamo models *Simone Ulzega and Carlo Albert*

12:40 Lunch

14:30 Synchronization in mean field dynamo models and precessing flows, *Andre Giesecke, Martin Seilmayer, Frank Stefani, Tom Weier*

15:00 Solar magnetic variability: main period and other periods; where do they come from?" Antonio Ferriz Mas

15:30 TBD

16:00 TBD

16:30 Discussion

20:00 Social Dinner in Trastevere

Tuesday 25th of November

Session Long-Term Solar Variability

9:45 Annual information on solar cycles from tree rings and ice cores, *Jürg Beer*

10:15 Challenges and limitations of the long-term sunspot-number record, José M. Vaquero

10:45 Long-term (1749-2015) variations of solar UV spectral indices, *Berrilli F., Criscuol S.i, Lovric M., Penza V.*

11:15 Historical TSI reconstruction from Solar Modulation Data, Penza V., Berrilli F., Criscuoli S.

11:45 -----

12:00 Discussion

13:00 End of Thinkshop

Stochastic Resonance in complex systems

Roberto Benzi

Stochastic Resonance in complex systems with a particular emphasis on the MHD field.

Schwabe, Gleissberg, Suess-de Vries: A simple model for synchronizing solar cycles by planetary forces

F. Stefani, A. Giesecke, M. Seilmayer, T. Weier
Helmholtz-Zentrum Dresden-Rossendorf

Aiming at a simple and consistent planetary synchronization model of both short-term and long-term solar cycles we analyze Schove's data of the cycle minima and maxima. Their residuals from the average cycle duration of 11.07 years show a high degree of regularity, comprising a dominant period of 200 years (Suess-de Vries cycle), and a few periods around 90 years (Gleissberg cycle). Based on Dicke's ratio between the mean square of the residuals to the mean square of the difference of two consecutive residuals, we conjecture that the Schwabe cycle is synchronized, very likely via a helicity-mediated parametric resonance, by the 11.07 years alignment cycle of the tidally dominant planets Venus, Earth and Jupiter. In an attempt to explain the rather regular long-term behaviour, we enhance our Parker-type solar dynamo model by a modulation of the field-storage capacity of the tachocline with the 19.86 years periodicity of the movement of the sun around the barycenter of the solar system, which results basically from the Jupiter-Saturn synodes. Not surprisingly, this modulation leads to a 193-year beat period of dynamo activity which is indeed close to the observed 200 years Suess-de Vries cycle. In cases, the model produces also additional peaks at typical Gleissberg frequencies, which might be interpreted as beat periods of the Schwabe cycle with the Jupiter-Uranus (13.81-year) or the Jupiter-Neptune (12.78-year) synodes.

Can stochastic resonance explain the amplification of planetary tidal forcing?

Carlo Albert and Simone Ulzega

Repeated Grand Minima revealed by proxies of solar activity suggest that the Sun alternates between two stable states, a quiescent and an active one. If the intrinsic noise of the solar dynamo allows for a frequent switching between these stable states, a tiny periodic modulation of the corresponding transition probabilities can be greatly amplified – a phenomenon known as stochastic resonance. It is well-known that Babcock-Leighton-type dynamo models can be reduced to a stochastic iterative map model capable of capturing the essential low-frequency features of the solar dynamo mechanism. In such a simplified framework, we give numerical evidence that a tiny tidal modulation of the minimal magnetic field required for flux-tube buoyancy is greatly amplified by the dynamo, provided that it operates close enough to a critical bifurcation point. Inference with more refined dynamo models is required to test this “criticality hypothesis”.

Baysian inference methods for the calibration of stochastic dynamo models

Simone Ulzega (1) and Carlo Albert (2)
(1) ZHAW, Zurich University of Applied Sciences, Institute for Applied Simulation, Switzerland
(2) Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland

In essentially all applied sciences, data-driven modeling heavily relies on a sound calibration of model parameters to measured data for understanding the underlying mechanisms that lead to observed features. Solar dynamo models are no exception. Bayesian statistics is a consistent framework for parameter inference where knowledge about model parameters is expressed through probability distributions and updated using measured data. However, Bayesian inference with non-linear stochastic models can become computationally extremely expensive and it is therefore hardly ever applied. In recent years, sophisticated and scalable algorithms have emerged, which have the potential of making Bayesian inference for stochastic models feasible. We investigate the power of Approximate Baysian Computation (ABC), enhanced by Machine Learning methods, and Hamiltonian Monte Carlo algorithms applied to solar dynamo models.

Synchronization in mean field dynamo models and precessing flows

Andre Giesecke, Martin Seilmayer, Frank Stefani, Tom Weier

Synchronization is a fundamental phenomenon in nonlinear dynamical systems. In my presentation I will refer to essential features of synchronized systems with focus on a kinematic dynamo model driven by two counter-rotating disks including weak periodic perturbations. Similar concepts can be used to explain the behavior of triadic resonances in a precession driven flow, which may be seen as a precursor for the transition into a turbulent regime found at a critical precession ratio in the DRESDYN water experiment. Finally, I show the connection to the synchronized solar dynamo model presented by Frank Stefani, where the magnetic field frequencies are determined by the tidal forces caused by planets surrounding the sun.

Solar magnetic variability: main period and other periods; where do they come from?"

Antonio Ferriz Mas

The cycle of solar magnetic activity has an average period of 10.8 years (the well-known 11-year period of the Schwabe cycle based on the sunspot number, which was interrupted by the Maunder minimum in the 17^{th} century). The analysis of cosmogenic radionuclides from natural archives (such as ^{10}Be in ice cores and ^{14}C in tree rings) allows the reconstruction of solar magnetic activity and shows that [1] the Sun's magnetic activity did not cease during that miminum, its period being about 11 years throughout, and [2] that the 11-year period has been very stable as far back into the past as we can trace the solar cycle with the help of those proxies. Apart from the 11-year period of solar magnetic activity, other periods appear on longer timescales: namely around 2200 years (Hallstatt), 980 years, 207 years (de Vries), 90 years (Gleissberg) and others.

While the existence of the above mentioned periods ramains undisputed, the question naturally arises as where they all come from. Abreu et al. 2012 suggested that some of the longer periods (from the Gleissberg cycle upwards) may be caused by the tidal coupling between the planets and the tachocline in the solar interior. Although this tidal coupling is actually very weak, the excellent agreement among several of the cycles found in proxy records of solar activity of the past 10,000 years and the cycles present in the torque exerted by the planets on a non-spherically symmetric tachocline hints at a possible mechanism (that would require some sort of resonant amplification).

As to the main period of solar magnetic activity: we do not know yet what sets the number ”11 years”. That the orbital period of Jupiter is 11.86 years is probably only a mere coincidence (the tidal force of Jupiter on the Sun is similar to that of Venus, with an orbital period of 225 days). Within the classical mean-field picture (a kinematik approach) it is often claimed that the dynamo period follows from the dynamo number, which in turns follows from the Reynolds numbers of the α–effect and the (largely heuristic) α–effect.

The magnetic solar activity cycle is probably a by-product of the complicated internal dynamics of the solar convection zone, in which turbulent convection, differential rotation and meridional circulation are intermingled in a complicated way. Deriving the period of the solar activity cycle from the underlying physics is for sure much more complicated that playing around with free parameters in the framework of the mean-field approach.

Annual information on solar cycles from tree rings and ice cores

Jürg Beer

Recent new quasi-annual records of 14C in tree rings and 10Be in an Antarctic ice core covering approximately 1000 years have the potential to study in more detail the properties of Schwabe cycles and their persistency in time. Improved Bayesian spectral analysis provides in addition to the period also the phase.

The analysis of these new records is presented and compared to the analysis of the monthly sunspot record.

Long-term (1749-2015) variations of solar UV spectral indices

Francesco Berrilli, Serena Criscuoli, Mija Lovric, Valentina Penza

Solar radiation variability spans a wide range in time, ranging from seconds to decadal and longer. The nearly 40 years of measurements of solar irradiance from space established that the total solar irradiance varies by ∼0.1% in phase with the Sun's magnetic cycle. Specific intervals of the solar spectrum, e.g., ultraviolet, vary by orders of magnitude more. These variations can affect the Earth's climate in a complex nonlinear way. Specifically, some of the processes of interaction between solar UV radiation and the earth's atmosphere involve threshold processes. For this reason a new spectral UV index based on the (FUV-MUV) color, calculated using SORCE SOLSTICE integrated fluxes in the FUV and MUV bands, has been recently introduced. Here we report the reconstructions of the (FUV-MUV) color index, and Ca II K and Mg II core-to-wing indices from 1749-2015, performed with a semi-empirical approach based on the reconstruction of the area coverage of solar magnetic features, i.e., sunspot, faculae and network. The agreement between the indices calculated with our approach and the composites obtained with state-of-the-art and complex techniques applied to full disk observations make us optimistic about the possibility of using this kind of simplified approaches in the study of the behavior of the sun in the past, when it is no longer possible to use techniques based on full disk images.

Challenges and limitations of the long-term sunspot-number record.

José M. Vaquero
Universidad de Extremadura, Spain

The solar activity of the past is a subject of great interest for geoscientists and astrophysicists. On the one hand, solar activity is the main driver of the heliosphere and the magnetosphere. On the other hand, it is a natural forcing of the atmosphere and its dynamics, although the mechanisms of this forcing are complicated and non-linear. We can study the historical observations of sunspots preserved in the archives and libraries to reconstruct the solar activity of the past, obtaining an index commonly called "relative sunspot number". In any case, telescopic observations only exist in the last four centuries [although they cover the interesting Maunder minimum (1645-1715), a period when solar activity was very low]. In this contribution, a clear visual guide is provided than can be used to easily assess observational coverage for different periods, as well as the level of disagreement between currently proposed sunspot group number series.

Historical TSI reconstruction from Solar Modulation Data

Penza V., Berrilli F., Criscuoli S.

In the this work we correlate Solar Modulation Data, open-access available, with SSN data record. This correlation generates a connection cycle-by-cycle between the datasets in the overlap time period (from 1750 to present) and allows to estimate the SSN signal back in time. We apply the calculated SSN values to estimate the corresponding TSI variations.