Project Details

ROSES ID: NNH15ZDA001N
Selection Year: 2015
Program Element: Focused Science Topic

Topic: The Solar-Stellar Connection

Project Title:
Identifying Causal Relationships in Stellar Activity Cycle Dynamics

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Summary:
Science Goals and Objectives: Magnetic activity similar to the sun is observed on a variety of cool stars with convection envelopes. Stellar rotation coupled with convective motions give rise to the development of strong magnetic fields. High precision spectroscopy and photometry measurements have detected cycles in the magnetic activity of stars similar to the 11 year solar cycle. The goal of this project is to discover causal relationships that govern stellar cycle dynamics utilizing spectroscopy and photometry measurements from sun-like stars. In particular, our investigation will relate basic observables, such as mass, metallicity, radius, rotation rate, depth of convection zone, and differential rotation rates with total solar irradiance and starspot properties including: total spottedness and switching of dominant activity between longitudes (flip-flop cycles). We will focus on determining which factors control the periodicity of starspots, how stellar cycles evolve with the age of stars, and which factors determine deep global minima in stellar cycle dynamics.

Methodology: We will utilize a set of information-theoretical tools that have been recently developed to examine cause and effect relationships in observational datasets. Transfer entropy and mutual redundancy are entropy-based measures of dependency (e.g. mutual information) that are based on conditional probabilities and can be used to measure the directed information transfer between two variables. The conditional redundancy will be used to systematically isolate controlling variables from a set of input measurements. Once causal variables are identified, we will construct coupling functions to describe the dependence of stellar cycle dynamics on the causal variables using the principle of maximization of information.

Proposed Contribution to the Focus Team Effort and Relevance to NASA: This investigation will contribute to the focus team effort 3.1.2 ``The Solar-Stellar Connection.'' The proposed techniques will be used to identify processes (variables) that control total solar irradiance and starspot cycles, including periodicity and deep global minima, and to construct nonlinear maps that capture the activity cycle dynamics and have predictive value. The proposed project relies heavily on collaborations with observers and modelers on the LWS team. Our plan is to work with observers on the team to compile a database of variables that characterize the magnetic activity cycle dynamics and to identify causal variables that control the dynamics. We will work with team modelers to evaluate the output from predictive models to ensure that they adequately capture the system dynamics, and we will use the principle of maximization of information to construct predictive models for starspot dynamics. Identification of observables and model parameters that control solar cycle dynamics will also advance Goal 1 from the Heliophysics Decadal survey ``Determine the origins of the Sun's activity and predict the variations in the space environment.''

Publication References:

no references