

REVEALING THE ROOTS OF STELLAR CYCLES

Christoffer Karoff
Aarhus University
GO40016

We propose to observe 20 of the brightest, most Sun-like, stars in the Kepler field in short cadence simultaneous with the Kepler mission and from the Nordic Optical Telescope. Astronomers have been making telescopic observations of sunspots since the time of Galileo, gradually building a historical record showing a periodic rise and fall in the number of sunspots every 11 years. We now know that sunspots are regions with an enhanced local magnetic field, so this 11-year cycle actually traces a variation in surface magnetism. Attempts to understand this behavior theoretically often invoke a combination of differential rotation, convection, and meridional flow to modulate the field through a magnetic dynamo (for a recent review see e.g. Charbonneau 2010, *Living Rev. Solar Phys.*, 3). The Kepler mission can provide the observations of stars other than the Sun that are needed in order to take dynamo modelling to the next level, with the ultimate goal of being able to produce dynamo models that can provide us with reliable forecasts of activity in future solar cycles. Although we cannot observe spots on other Sun-like stars directly, these areas of concentrated magnetic field produce strong emission in the calcium spectral lines. The intensity of the emission scales with the amount of non-thermal heating in the chromosphere, making these lines a useful proxy for the strength of, and fractional area covered by, magnetic fields. In this way stellar activity has been monitored in over 111 stars over the last 40 years with the Mount Wilson survey. This survey has revealed that around half of the Sun-like stars show clear periodic cycles, with periods between 2.5 and 25 years (Baliunas et al. 1995, *ApJ*, 438, 269). Later studies of this and other samples suggest that there are two different kinds of stellar cycles for Sun-like stars - one active and one inactive (Saar & Brandenburg 1999, *ApJ*, 524, 295), a separation also known as the Vaughan-Preston gap (Vaughan & Preston 1980, *PASP*, 92, 385). The reason for this bifurcation could be that the dynamo is operating at the top of the near surface convection zone in the active stars whereas it is operating at the base in the inactive stars (Bohm-Vitense, 2007, *ApJ*, 657, 486). Stellar cycles can also be observed using asteroseismology, as has been shown by helioseismic observations of small frequency shifts of the p-modes (Chaplin et al. 2007, *ApJ*, 659, 1749) and in amplitude changes of the p-modes (Chaplin et al. 2000, *MNRAS*, 313, 32). By combining the asteroseismic manifestations of stellar cycles that we can obtain from Kepler with ground-based activity measurements from the Nordic Optical Telescope we will be able to impose hard constraints on the dynamo models, as these models will need to account simultaneously for the variations seen in the calcium emission lines and in the p modes. These constraints can be tightened further by including information from asteroseismology on the interior structure and dynamics of these stars - most importantly the depth and rotation profile of the convection zone (Karoff et al. 2009, *MNRAS*, 1226). Also, observations of the activity in the Kepler targets will allow us to relate the results from the asteroseismic analysis to various results from stellar activity surveys such as the age-rotation-activity relations (Skumanich 1972, *ApJ*, 171, 565). The 20 stars we propose to observe as part of the GO proposal have all been observed continuously since quarter 5 and none of them are on module 3. During that last two years we have obtained 6 epochs of ground-based activity measurements from the Nordic Optical Telescope and we intend to continue to observe these stars with the Nordic Optical Telescope in the years to come.