Transiting Planets
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The impact of stellar jitter on the confirmation of transiting exoplanet candidates around Solar-like stars

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Abstract. The radial velocity technique is commonly used to classify transiting exoplanet candidates. However, stars are intrinsically noisy in radial velocity. No good description of this noise has yet been proffered, although activity in general has been suggested as the source, making it impossible to evaluate its effect on signal detection. In this poster, we propose an activity-based model that incorporates both light and dark stellar spots, capable of producing both photometric and radial velocity time series. We demonstrate its consistency with both SOHO/VIRGO photometry and SOHO/GOLF radial velocities. We then use this model to establish lower and upper limits on the effects of intrinsic stellar noise on the metal lines used to follow up transit candidates, making use of Monte Carlo simulations. Based on these results, we can suggest an optimal observational sampling rate.

In the last decade, the radial velocity measurement precision has increased to the point that the intrinsic stellar noise has been detected in stars other than the Sun (Butler *et al.* 2004). While the radial velocity noise apparent in solar data has been studied extensively, little work has been done on analyzing its impact on the search for exoplanets. Bouchy, Pepe & Queloz 2001, while describing the fundamental photon noise limits for radial velocity measurements, mentioned that stars exhibited radial velocity variability due to pulsations and stellar activity and that these factors were poorly understood and needed to be investigated. This is an important issue to resolve for both planet searches using the radial velocity technique and those using transit surveys, as the classification of transiting exoplanet candidates relies on the radial velocity technique for confirmation.

Previous attempts have been made to explain radial velocity jitter using star spots (e.g.. Desort *et al.* 2007), but these attempts were limited by their use of only dark star spots. Our model differs from these in that we use bright spots in addition to the dark spots. In order to model the photometry of a Solar-like star, we simulate the evolution of individual spots, assuming a random occurrence of spots that will then decay with a certain lifetime. The simulated spots are then placed on the surface of a simulated star and rotated in agreement with the stellar rotation. Based on spot position, we then calculate the effect of the rotation on the radial velocity. The spot size can then be adjusted to fit the observed photometry and the resultant "photospheric" radial velocity variation calculated from that. This photospheric radial velocity variation represents the lower limit of what one can expect from radial velocity measured from metal lines. These models can then be calibrated with and compared to the SOHO photometry and radial velocities, which in turn represent the upper limit.

The following figures show the results of an analysis to evaluate the impact of stellar jitter on the detection of faint radial velocity signatures. We can conclude that a 5σ detection would require 8 years of monitoring for an Earth twin system. This is however, the same as it would be for Gaussian noise using the optimal sampling rate of once per week, with higher sampling rates yielding little to no improvement.

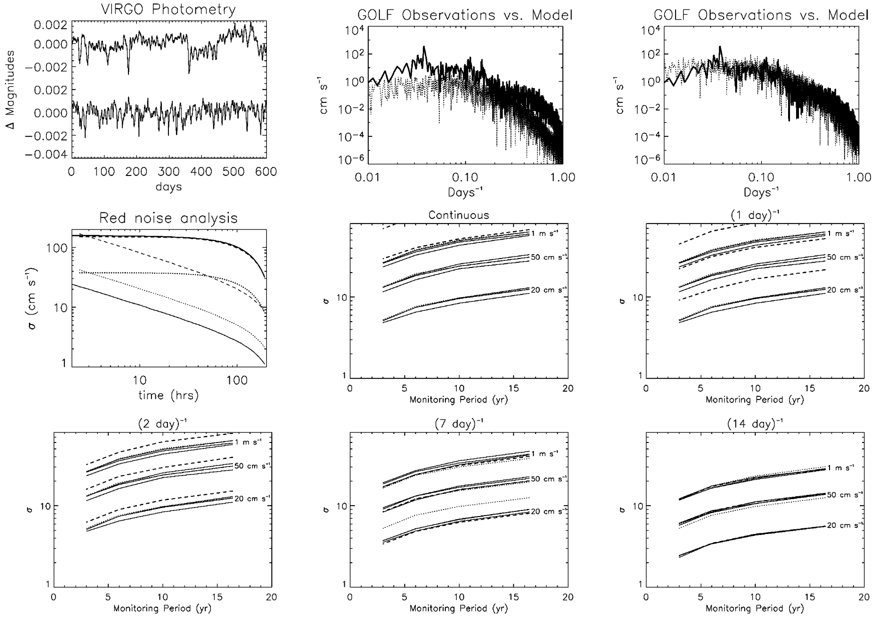

Figure 1. (top) SOHO vs. Model: (left) VIRGO photometric time series (top) vs. modeled time series (bottom). Outside some low-frequency noise, possibly due to the solar cycle, the two time series are visually consistent. (center-right) GOLF radial velocity power series (solid) vs. modeled "photospheric" radial velocity power series. These two power series are remarkably similar, outside of a scaling factor, included in the figure on the right. (middle-left) Red noise analysis. The solid lines are for the GOLF data, the dotted lines the photospheric model, and the dashed line the model scaled to match the noise levels in the GOLF data. The heavy lines are the GOLF/modeled data, while the light lines are Gaussian comparisons with the same σ_{rms} as the appropriate model/data. Notice that the GOLF data and the scaled model exhibit almost exactly the same red noise characteristics and that the noise is very much non-Gaussian. (Rest) Monte Carlo results showing detection significances for different signal amplitudes, signal periods, times monitored and sampling rates, ranging from continuous (top-left) to 1/30d (bottom-right). The faint solid lines are different periods with the same amplitude while the dotted line in each cluster represents modeled 10d periods and the lowest heavy dashed line represents the detection significance for the case of a signal amplitude of 0.2 m/s and 0.5 m/s of Gaussian noise – a level equal to the average of the "photospheric" modeled noise. Notice that for high sampling rates, the detection significance in Gaussian noise is much higher than that of the "observed" significance.

References

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