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# Probing Surface Structure on Late-type Stars With FRESIP

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**Abstract.**

We discuss possible secondary scientific results obtainable with the FRESIP satellite in regards to surafce features on solar-like stars.

## 1. Introduction

Currently, for only one star, our Sun, is it possible to resolve surface features such as sunspots and plages. In the case of the Sun these features are well studied. For example, it is clear that the dark sunspots never cover more than 1% of the surface and tend to develop at mid latitudes with formation occurring closer to the equator as the 11-year solar cycle progresses. Through the remarkable work of the Mt. Wilson project we now know many stars possess surfaces covered unevenly with plage-like regions (Wilson 1978) and that stellar activity levels may undergo cyclic variations similar to the solar cycle (Baliunas & Vaughn 1985). Noyes et al. (1984) demonstrated the connection of the Ca II emission flux to the magnetic dynamo believed to be operating in rapidly rotating, convective stars. In general, the Ca II emission is strongest for stars with $P_{rot} \approx 1\text{-}3^d$ and gradually decreases as $P_{rot}$ increases. Similar relationships have been observed in other diagnostics (e.g., Simon & Fekel 1987; Strassmeier et al. 1990) and the rotation-activity relationship is now firmly established, at least for single stars.

Numerous late-type stars show photometric amplitude modulation which is believed to result from large, sunspot-like regions rotating in and out of view as the star rotates. The light curves of a few dozen stars have been modeled successfully using simple spot models (see Dempsey et al. 1992 for references). Results from modeling the photometric variations have been supported by high resolution spectroscopic studies, called Doppler imaging, for a very small subset of systems (< 12) and for a very few epochs. However, since good phase coverage is required and large amplitude photometric variations are easier to detect, these studies have been biased towards the short-period "hyper-active" systems. Furthermore, all stars studied in this manner have been relatively bright which usually means they are giant systems. Results from these studies are rather puzzeling since the detected spots are almost always at or near the pole, quite unlike the case of the Sun where spots tend to form closer to the equator. Does this result from studying only the "hyper-active" systems or is the Sun unusual among late-type stars? Or, perhaps, is the Sun going through some phase where its spot behavior deviates from the "norm", whatever that may be? More systems must be studied to answer these questions.

## 2. FRESIP

A major benefit of the FRESIP project will be the ability to detect and monitor surface features *on thousands of stars.* An immediate result of this is that a statistically significant number of stars of all spectral types can be sampled. Since the program stars will be dwarfs this will allow us to study the advent of spots in objects earlier than the Sun and to see how far down the main sequence such phenomena persist, i.e. do fully convective M stars posses spots. If possible, it would be desirable to include a sample of 200-300 class IV and III objects. This allows us to probe the characteristics of the future Sun.

In particular, surface features on the longer period ($P > 10 - 20^d$), less active systems will be studied in detail for the *first time.* This results from the fact that FRESIP will be able to detect photometric variations with periods greater than several weeks more easily than can be done from the earth. Earth based observations are limited by short observing seasons, weather and evolution of the surface features on timescales less than $P_{rot}$. A typically poor light curve is shown in Fig 1. Since it has also been established that the rotation period generally determines the activity level, the longer period systems will be less active and more solar-like than those studied to date. Therefore, the millimag precision of FRESIP will allow us to probe to lower thresholds, i.e, smaller spot or plage areas, available from the ground. The short period systems, and those with large photometric amplitudes, will be studied in greater detail than available using ground based photometers. This will allow the study of changes on very short timescales if present.

## 3. Simulations

To simulate some possible results we used the DOPPEL code discussed in Dempsey et al (1992) modified to yield the integrated magnitude over the 450 - 700 nm bandpass of the FRESIP satellite. The models simulated G and K dwarfs and a K giant. Only spots cooler than the photosphere were simulated since warmer areas will have similar results. Also, real life is far more complicated than the models presented here. In general it is likely that several cool spots will be present along with hot regions thus making the light curve rather complicated. However, we can use experience gained from modeling RS CVn systems (e.g., Strassmeier 1988; Strassmeier et al 1988; Jetsu et al. 1990; Dempsey et al. 1992, 1993) and concentrate on what new is detectable. The models assume a single, square spot with a temperature several hundred degrees lower than the surrounding photosphere. Note, we can only detect *assymmetries* in the spot/plage distribution since a unform spot, e.g., an equatorial belt, will affect the light curve equally at all phases. Furthermore, the detection threshold for our work can be increased easily by binning the data. For example, consider a star with a rotation period of 33 days. We could bin 8 hours of data into steps of 0.01 in phase with an accuracy of 0.001 mag/ sqrt(8) or 0.0004. Even with such large bins we will have better phase coverage than achieved from the ground.

For a G dwarf it is possible to **easily** detect spots with a surface area covering $\approx 0.04\%$ of the total surface without binning the data (Fig 2). To date the smallest coverage measured on a star other than the Sun has been about 5%. Therefore it is clear that we will, for the first time, be able to detect solar-like spots which have never covered more than 1% of the Sun! Similar limits are found for the K dwarf and giant models differing due to contrast effects and spot brightness relative to total brightness. Binning the data as well as using readily available period finding algorithms well allow detection of features covering $< 0.1\%$.

## 4. Discussion

Question we hope to address with this project for the first time:

- Do the long period stars have spots like the Sun does, i.e. as we go to longer and longer period systems will we observe a continuous spectrum of smaller and smaller spot coverage?
- What is the statistical properties of surface features on G and K dwarfs. Since the convection zone depth is a critical parameter in dynamo theory we would expect to see differences, e.g., size, between spectral types.
- Do all stars have the same magnitude and direction of differential rotation as does the Sun? As indicated in Fig 3, we can also measure differential rotation on a number of stars by observing the change in period as the spots evolve to different latitudes. Preliminary results from Doppler imaging has shown conflicting results but there are only a couple of systems with adequate data.
- Is there any relation between the area spot coverage and the rotation period or cycle period? For example, do stars with small spot coverage tend to have longer cycle periods than those with large spots? It will not be possible to to measure cycles longer than 5-6 years but some of the "hyper-active" stars might have periods measurable in the lifetime in FRESIP.
- How do spots evolve on rotation and cycle times scales? Limited evidence exists that spot may stay stable for many rotation periods or change daily (Dempsey et al. 1993).

What is important to realize is **none of these questions can be answered with ground based instruments.**

## References

Baliunas, S. L. & Vaughn, A. H. 1985, Ann. Rev. Astron. Astrophys. 23, 379

Dempsey, R, Bopp, B, Strassmeier, K., Granados, A., Henry, G. & Hall, D. 1992, ApJ, 392, 187

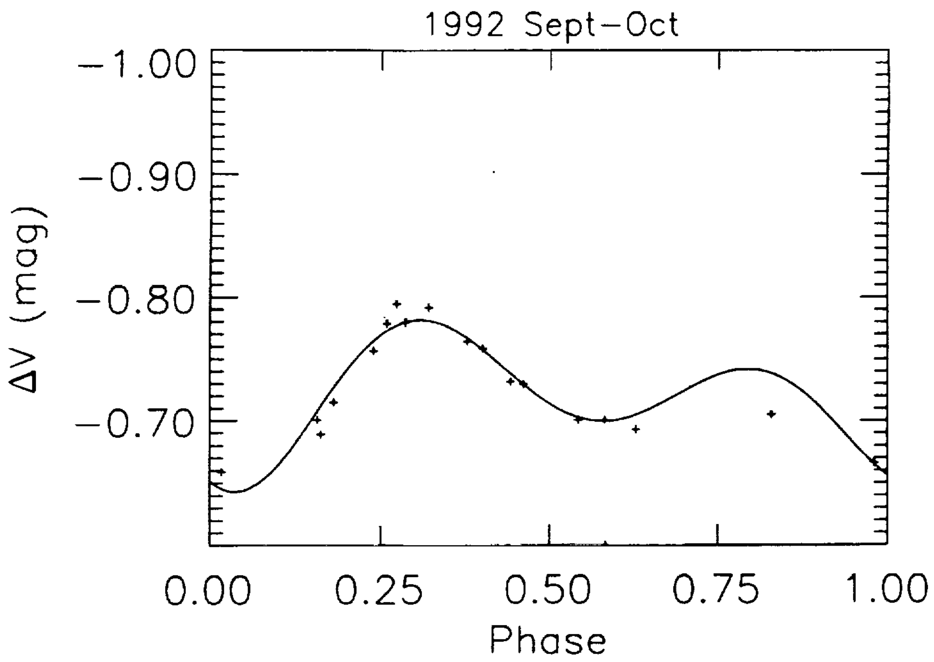

FIGURE I The measured light curve for IM Peg (Dempsey et al. 1993). Individual observations are indicated by plus signs. A model is shown by the solid line. Note the poor sampling, especially in the later portion of the light curve.

Dempsey, R. C., Bopp, B. W., Henry, G. & Hall, D. 1993, in proc of the 8th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, in press

Herbst, A. 1987, AJ 94, 150

Jetsu, L. et al. 1990, A&A 236, 423

Noyes, R. W., Hartmann, L. W., Baliunas, S. L., Duncan, D. K., & Vaughn, A. N. 1984, ApJ, 279, 763

Simon, T. & Fekel, F. C. 1987, ApJ, 316, 434

Strassmeier, K. G. 1988, Ap&SS, 140, 223

Strassmeier et al. 1988, A&A 192, 135

Strassmeier, K. G., Fekel, F. C., Bopp, B. W., Dempsey, R. C., & Henry, G. W. 1990, ApJS, 72, 191

Wilson, O. C. 1978, ApJ, 226, 379

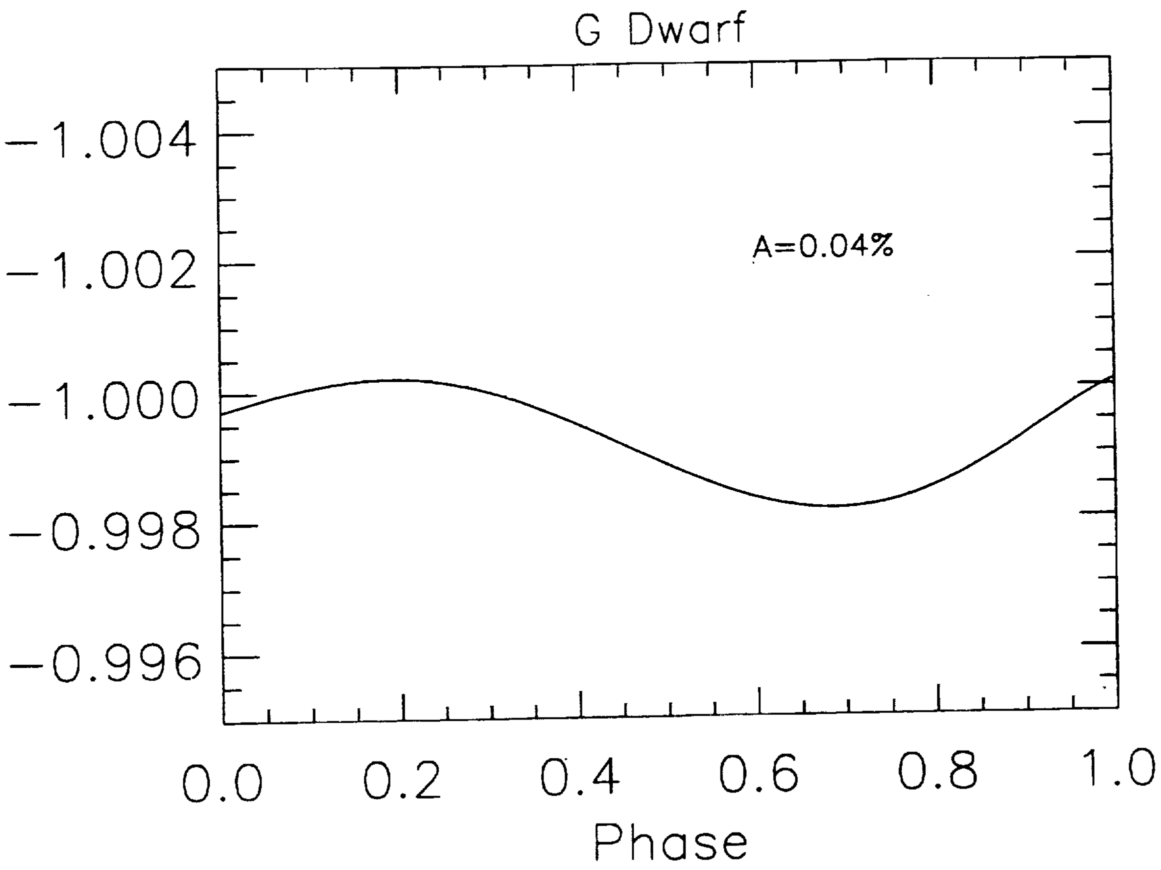

FIGURE II The predicted light curve of a G dwarf. Parameters used are: $T_{photosphere} = 5800K$, $T_{spot} = 3800$, radius = 1 $R_o$, inclination = 45 degrees. A single spot with an area of 0.04% was placed arbitrarily on the surface. The y-axis is in magnitudes. The amplitude is approximately 0.002 mag and would be easily detectable with the FRESIP satellite.

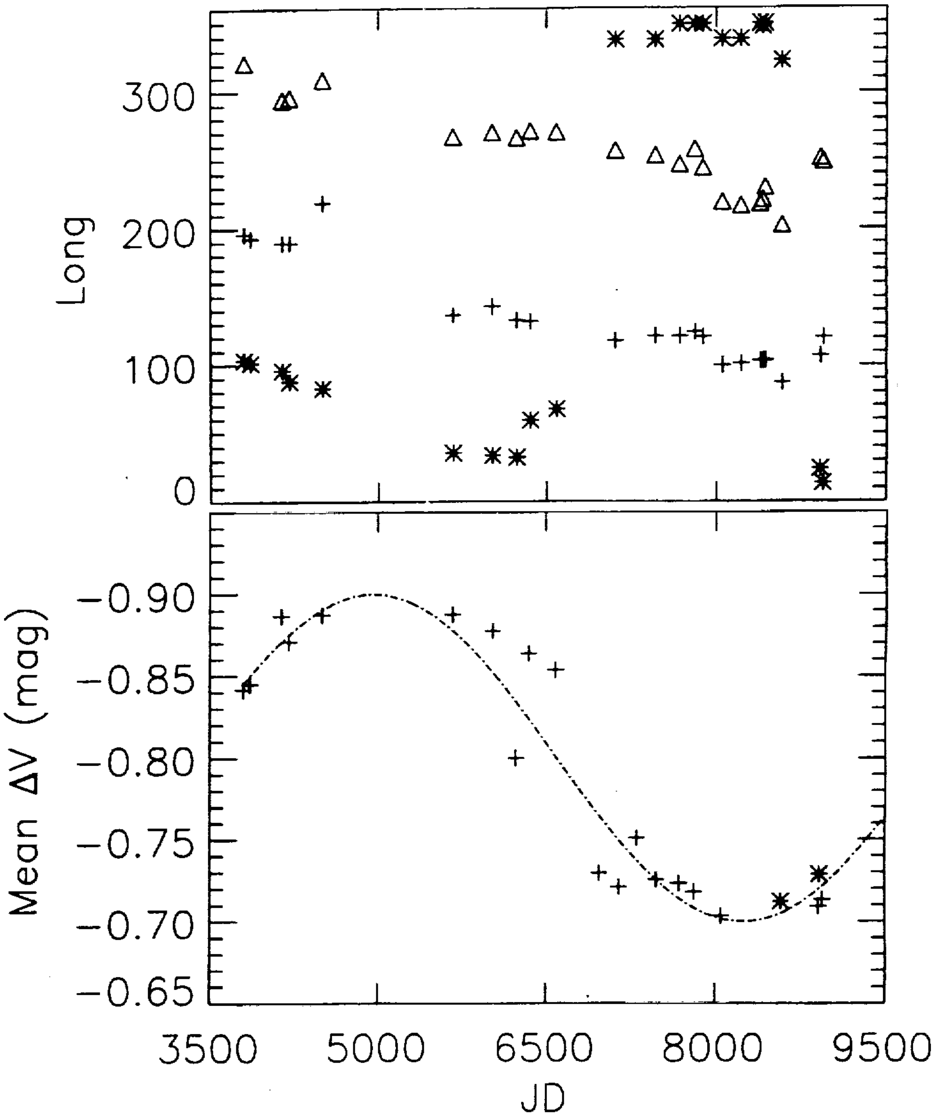

FIGURE III Longitude of spots (top) and mean brightness (bottom) on IM Peg over 15 years. This illustrates that while we know spots evolve on long timescales the information is rather poor.