Gauging the Sun: Comparative photometric and magnetic activity measurements of sunlike stars, 1984- 2001

G. W. Lockwood, J. C. Hall, & B. A. Skiff *(Lowell Obs.)*

G. W. Henry *(Tennessee State University)*

R. R. Radick *(AFRL/VS)*

S. L. Baliunas, W. Soon, & R. A. Donahue *(CfA)*

Abstract

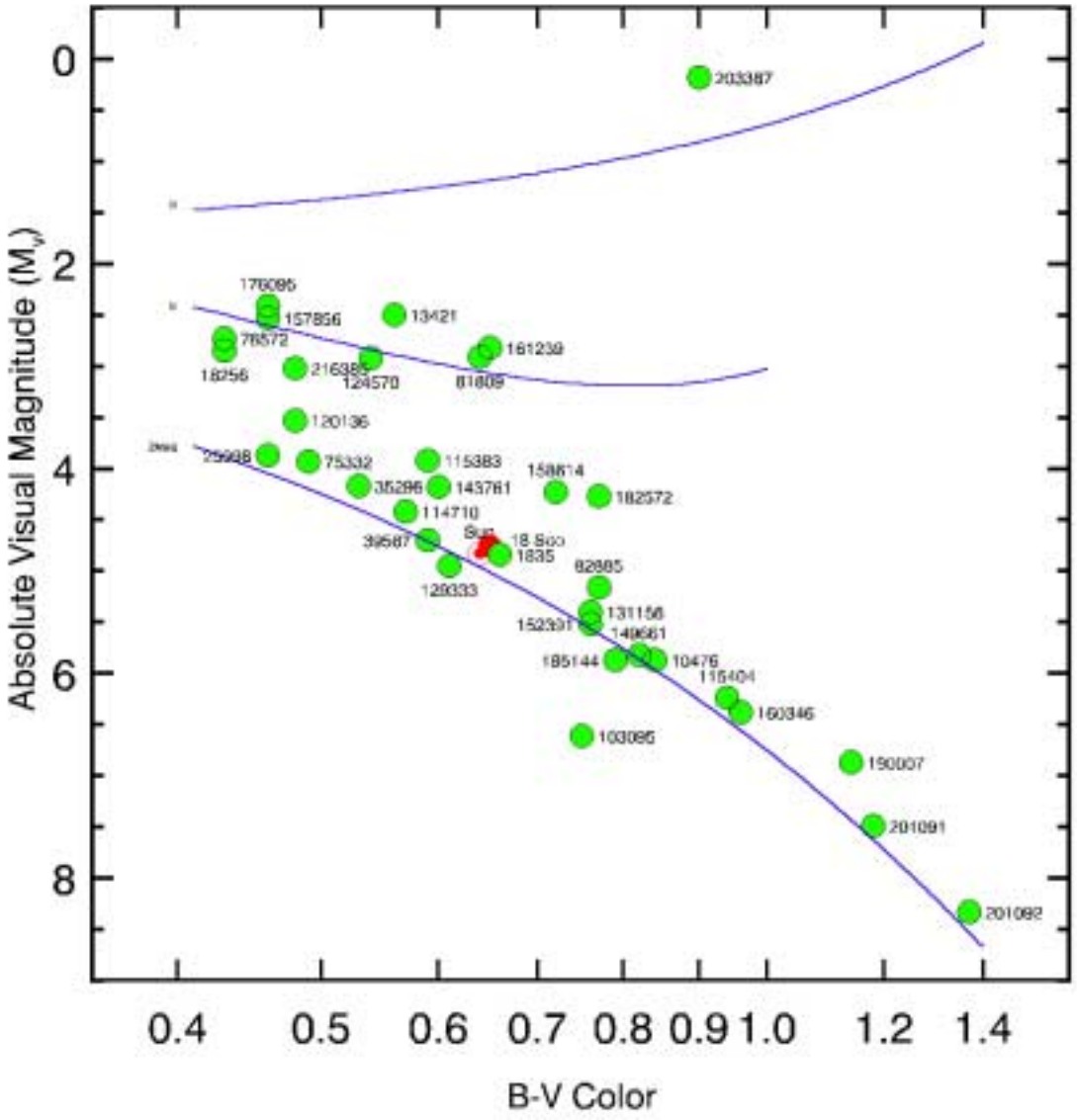
Visible light photometric observations of a small sample of sunlike stars with mean chromospheric activity levels similar to or slightly lower than the Sun's suggest that total solar irradiance variations on activity cycle timescales may be comparatively small (Lockwood et al. 1992, Nature 360, 653; Radick et al. 1998, ApJS 118, 239). The Sun's irradiance variation over the past two cycles is 0.04% rms compared with 0.1% rms for the stellar sample measured at Lowell from 1984 to 1995. This assertion can now be tested using new photometric measurements from Fairborn Observatory automated telescopes (1993-2001) that extend the duration of stellar observations to 17 years. Chromospheric activity measurements for these stars come from the Mount Wilson HK program (1966-2001) and the Lowell Observatory Solar Stellar Spectrograph program (1993-2001). In this presentation we will describe efforts to merge the overlapping Lowell and Fairborn photometry and the Mt. Wilson and Lowell HK measurements with the goal of reducing the uncertainties in previous efforts to characterize stellar photometric variations near the limit of detection.

The stellar sample

Color-luminosity diagram for stars observed photometrically at Lowell and and Fairborn.

Parallel Ca II H and K measurements for these stars are made at Mount Wilson and Lowell.

Note the position of the Sun and the solar analog 18 Sco just below the center of the figure.

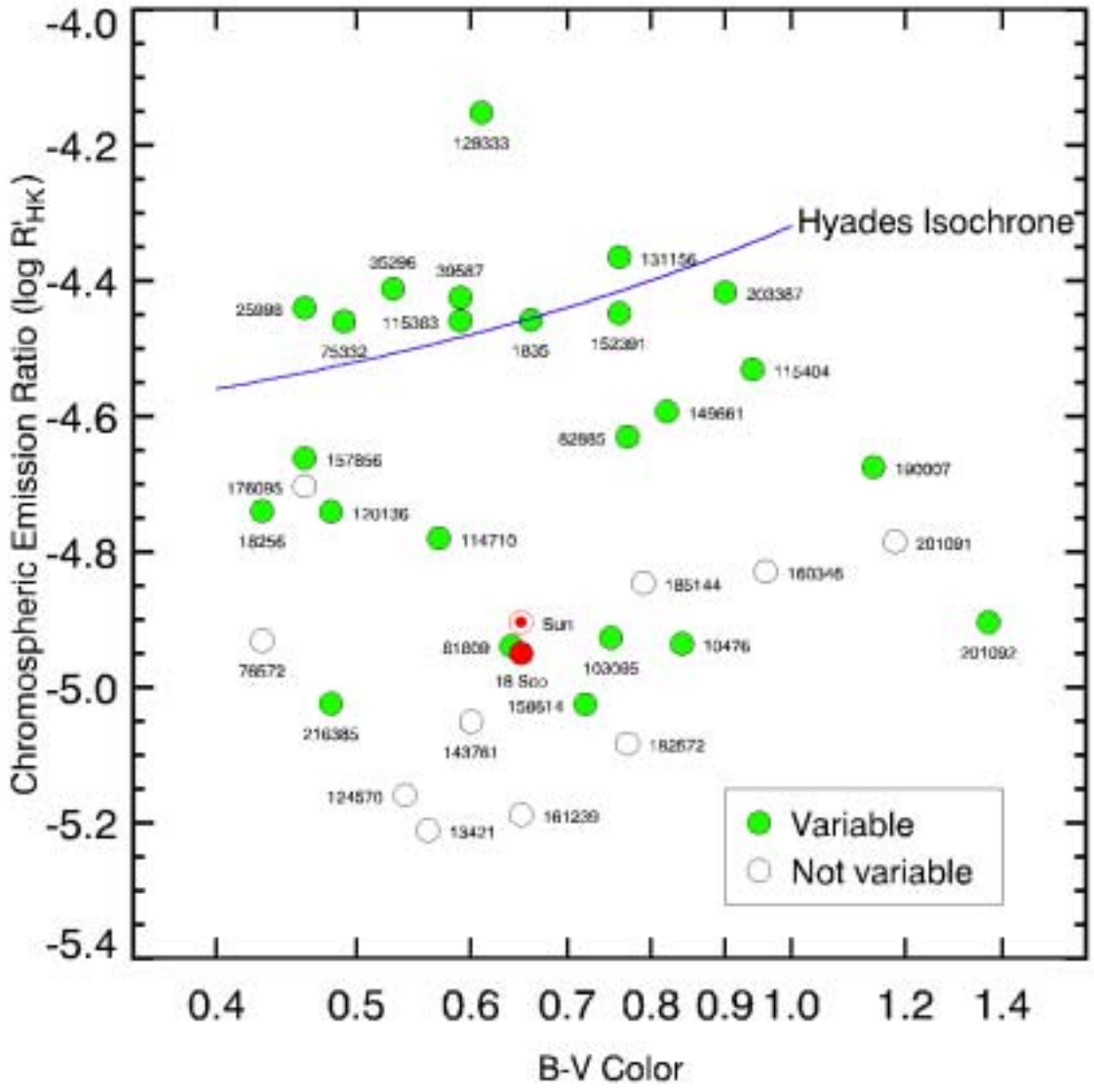


Which stars vary?

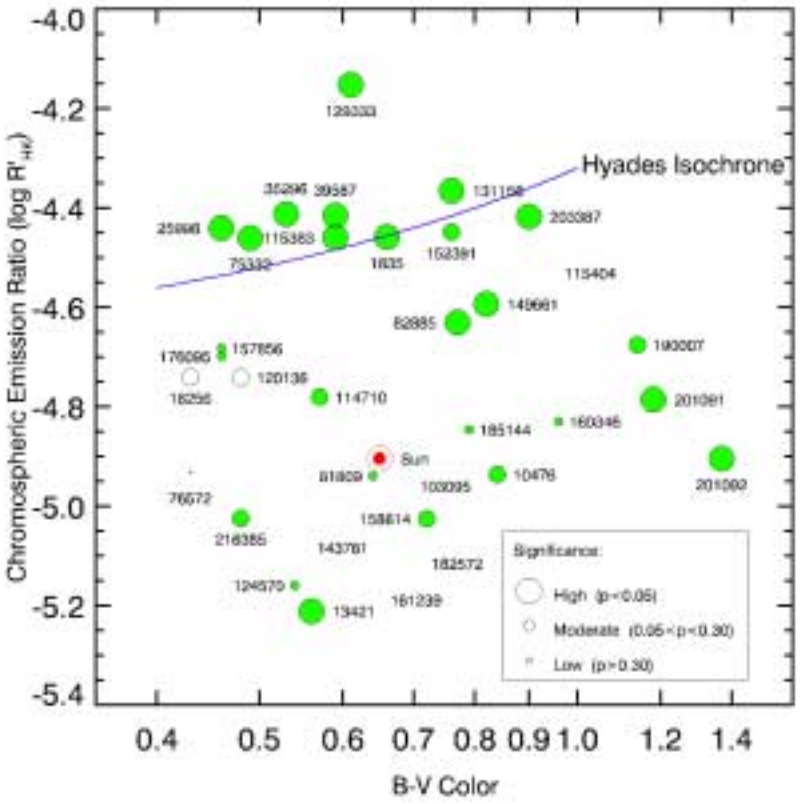
Filled circles indicate stars found to be photometrically variable from Lowell Observatory observations, 1984-2000.

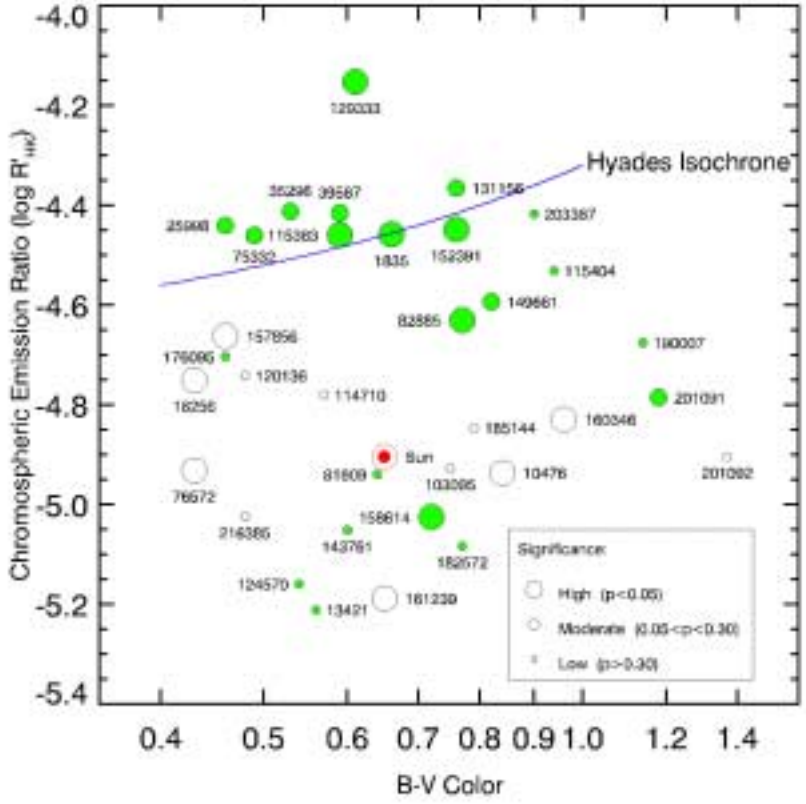
APT observations of the solar analog 18 Sco show no significant variations over 5 years.

The ordinate scale, log R'$_{HK}$ estimates the fraction of stellar flux emitted from the chromosphere. It is derived from the observed HK emission flux index, "S".



The sense of variation





Short Time Scale **Cyclic Time Scale**

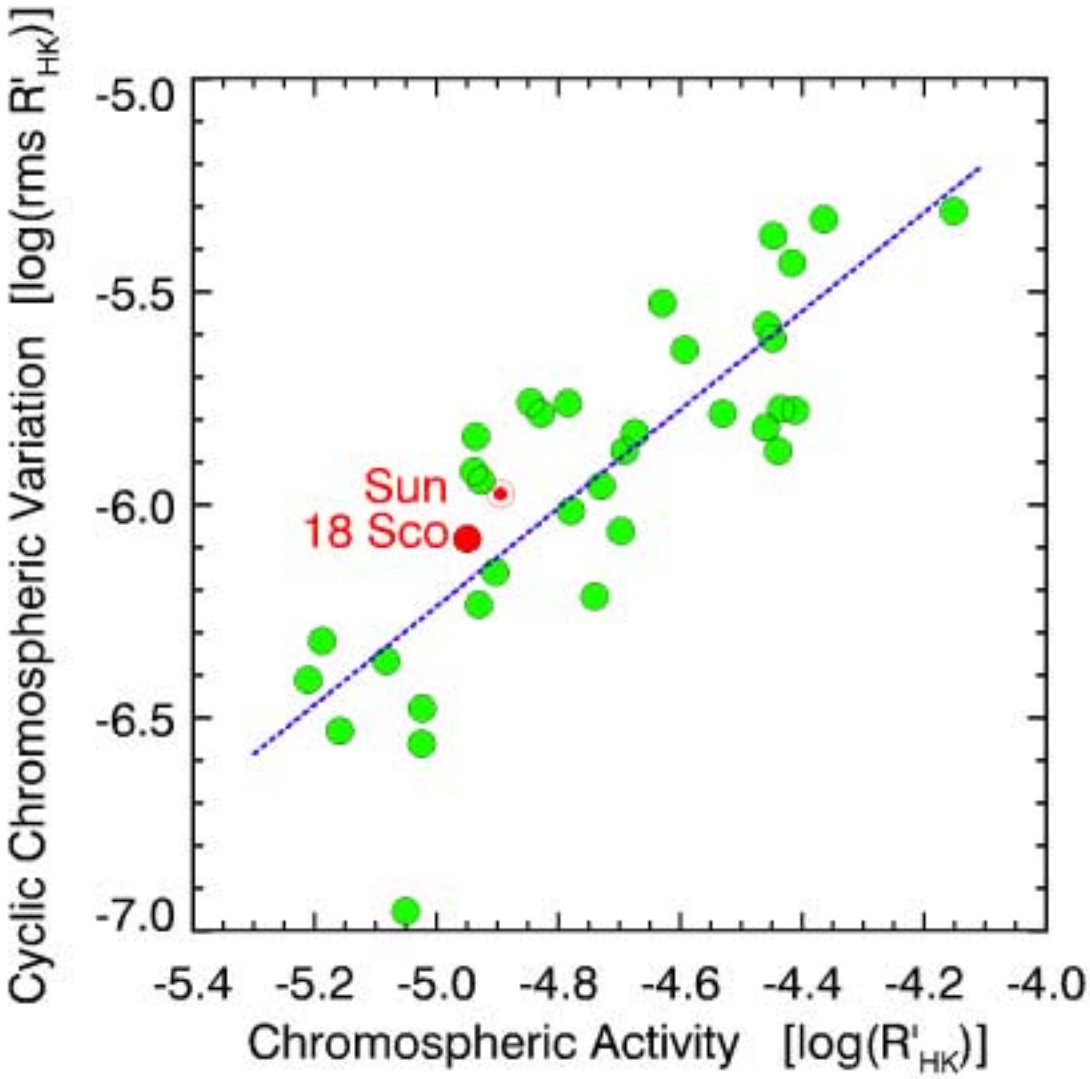
- **Activity correlated with brightness variation (young stars)**
- **Activity anti-correlated with brightness variation (Sun and solar age stars)**

The Sun among the stars

Magnetic activity on cycle timescales

Cyclic magnetic activity, measured in the H and K lines of Ca II, obeys a power relation with respect to mean chromospheric activity.

The Sun and the solar analog 18 Sco are slightly more active than average than stars of similar mean chromospheric activity.



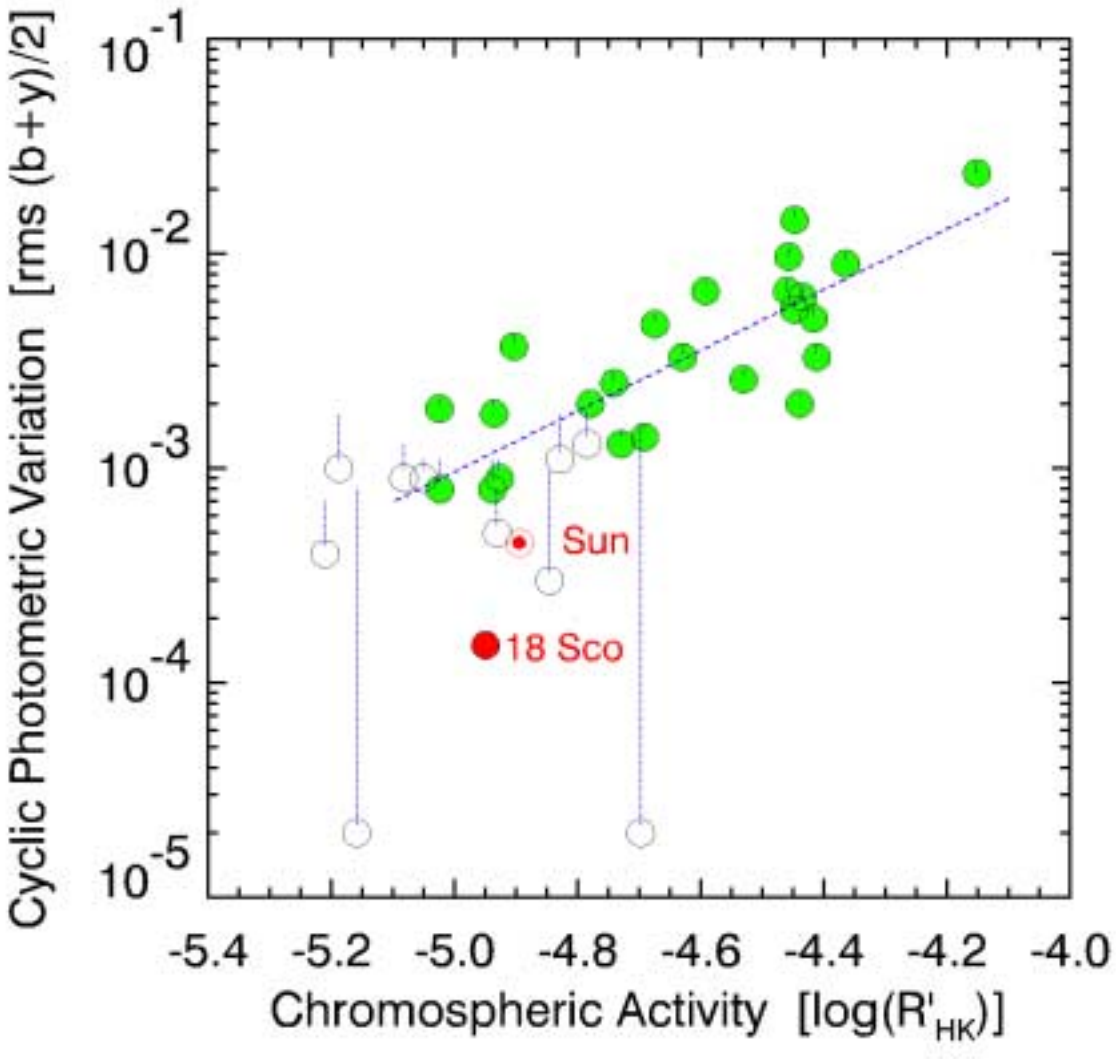
The Sun among the stars

Photometric activity on cycle timescales

Cycle timescale photometric variations also follow a power law. Filled symbols indicate variability.

The Sun's irradiance variations may be relatively small compared with stars of similar mean chromospheric activity.
The solar analog 18 Sco may be even less variable than the Sun, although another decade of observation is needed to be sure.

Drop lines indicate a correction for the variability of comparison stars.



The Sun: a cycling old star

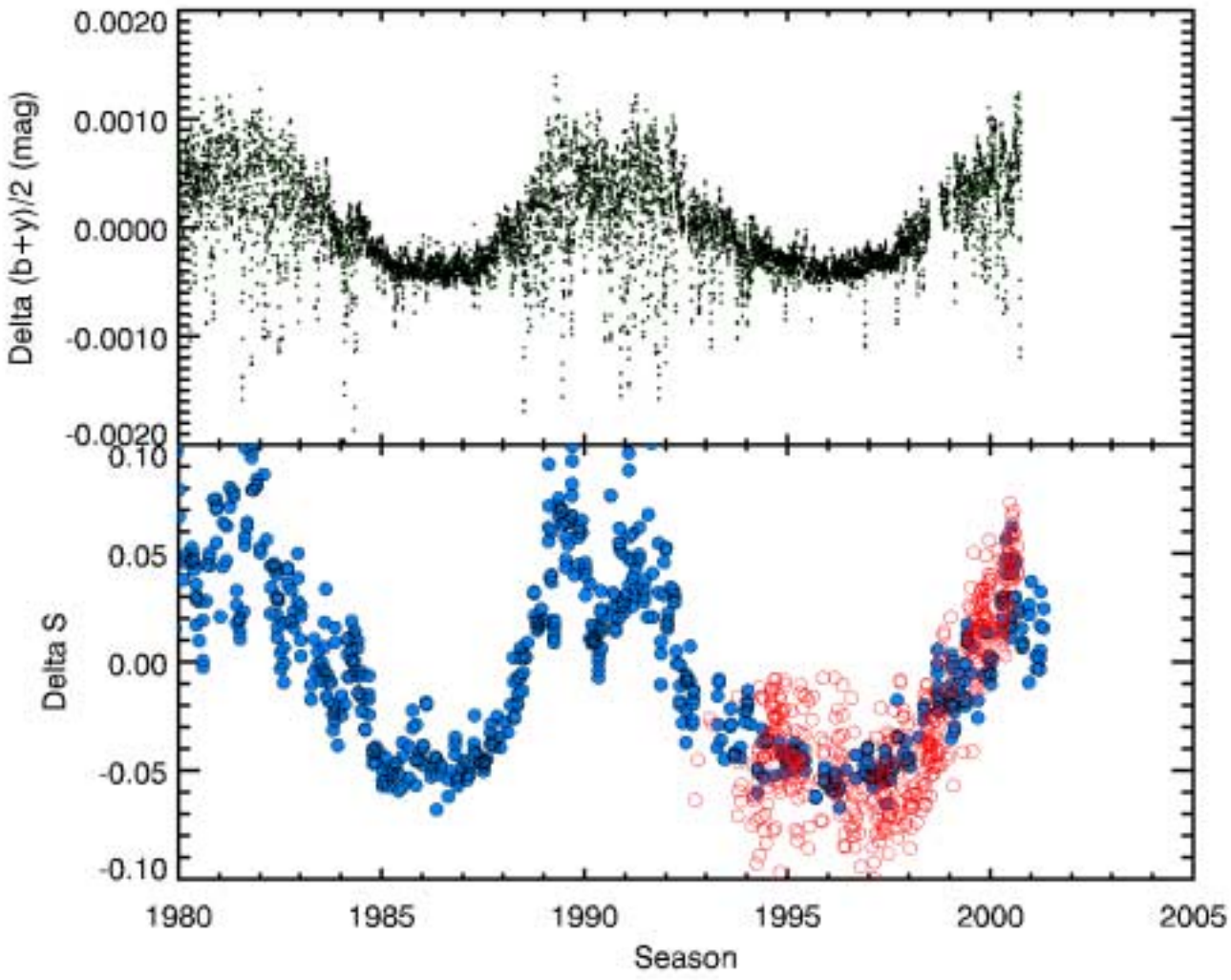
Total irradiance variation scaled to (b+y)/2 stellar mag scale

Vital statistics

B-V: 0.65 M_v: 4.83
T_{eff}: 5787 Sp: G2V
<S>: 0.18 log R'$_{HK}$: -4.94

rms_{phot}: 0.0005
rms_{CaII}: 0.007

Chromospheric variation
-blue: NSO Ca II measurements
-red: Lowell SSS K flux (scaled)



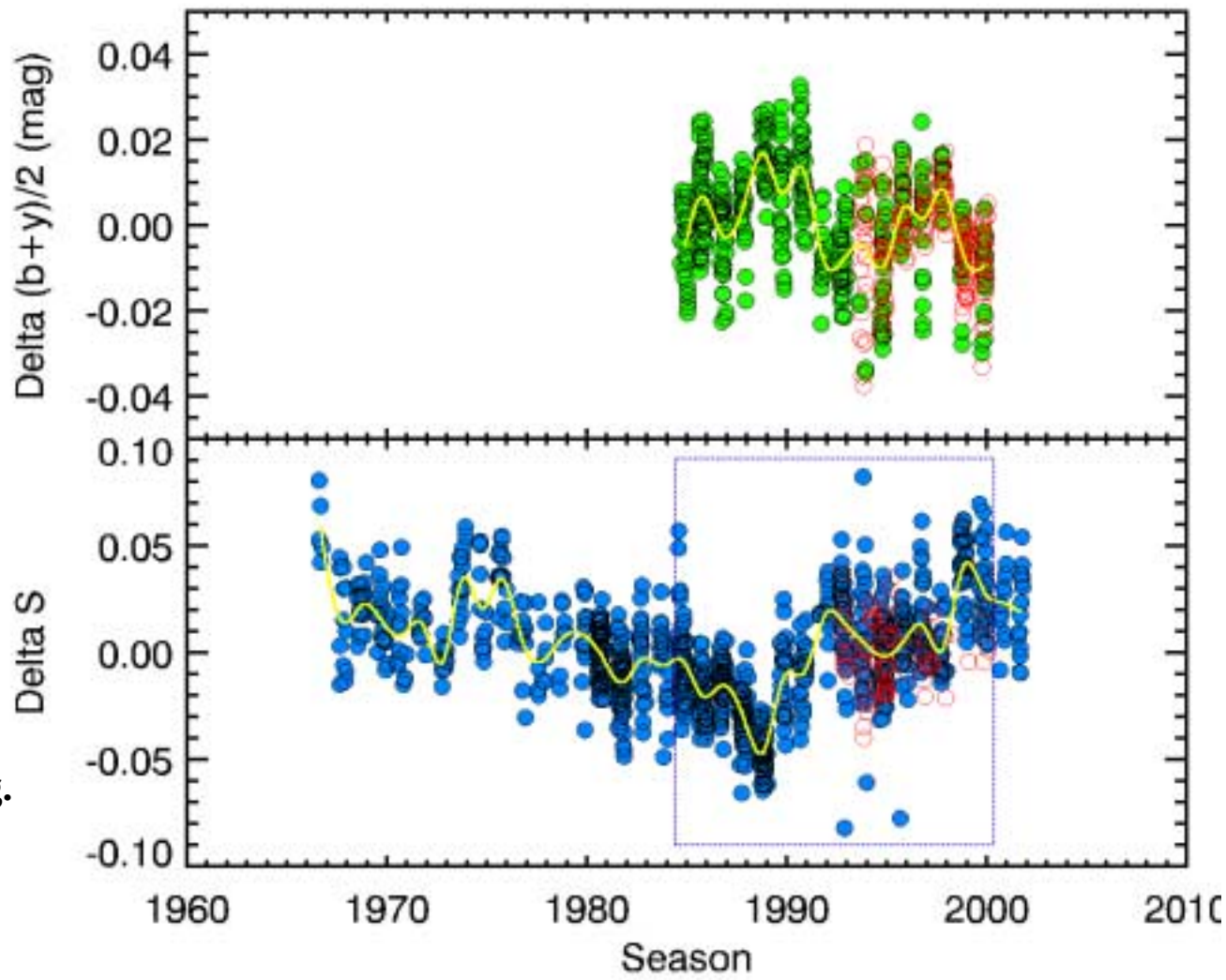
HD 1835: an active young star

b,y brightness var. (mag)
-green : Lowell
-red : Fairborn APT

Vital statistics
B-V: 0.66 M_v: 4.84
T_{eff}: 5754 Sp: G2.5V
<S>: 0.33 log R' $_{HK}$: -4.46

rms_{phot}: 0.0097
rms_{CaII}: 0.019

Chromospheric variation
-blue: Mt. Wilson HK prog.
-red: Lowell SSS prog.



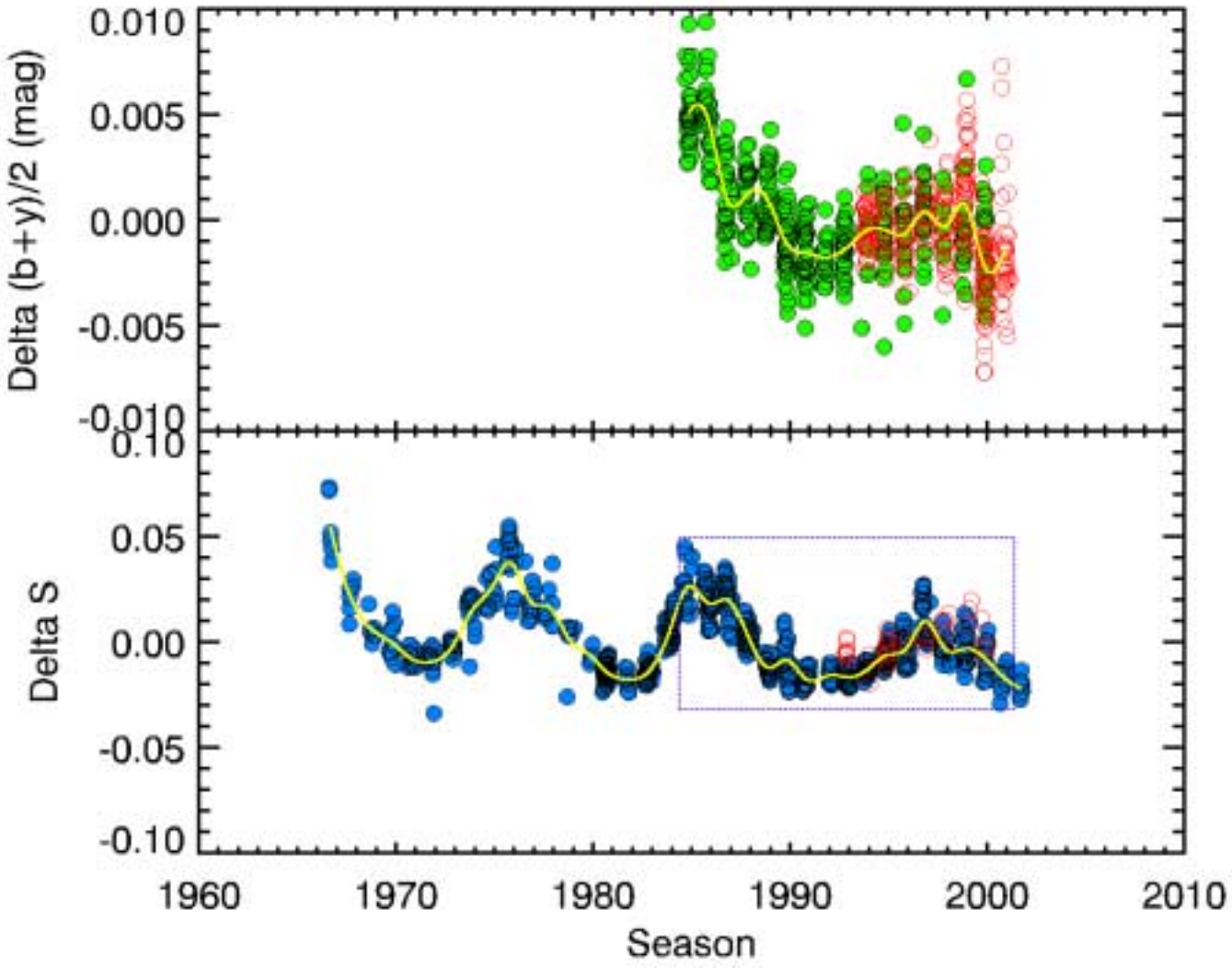
HD 10476: a cycling old star

b,y brightness var. (mag)
-green : Lowell
-red : Fairborn APT

Vital statistics
B-V: 0.84 M_v: 5.87
T_{eff}: 5194 Sp: K1V
<S>: 0.19 log R' $_{HK}$: -4.94

rms_{phot}: 0.0018
rms_{CaII}: 0.016

Chromospheric variation
-blue: Mt. Wilson HK prog.
-red: Lowell SSS prog,



HD 146233: the perfect solar twin?

b,y brightness var. (mag)
-green : Lowell
-red : Fairborn APT

Vital statistics

B-V: 0.65 M_v: 4.76

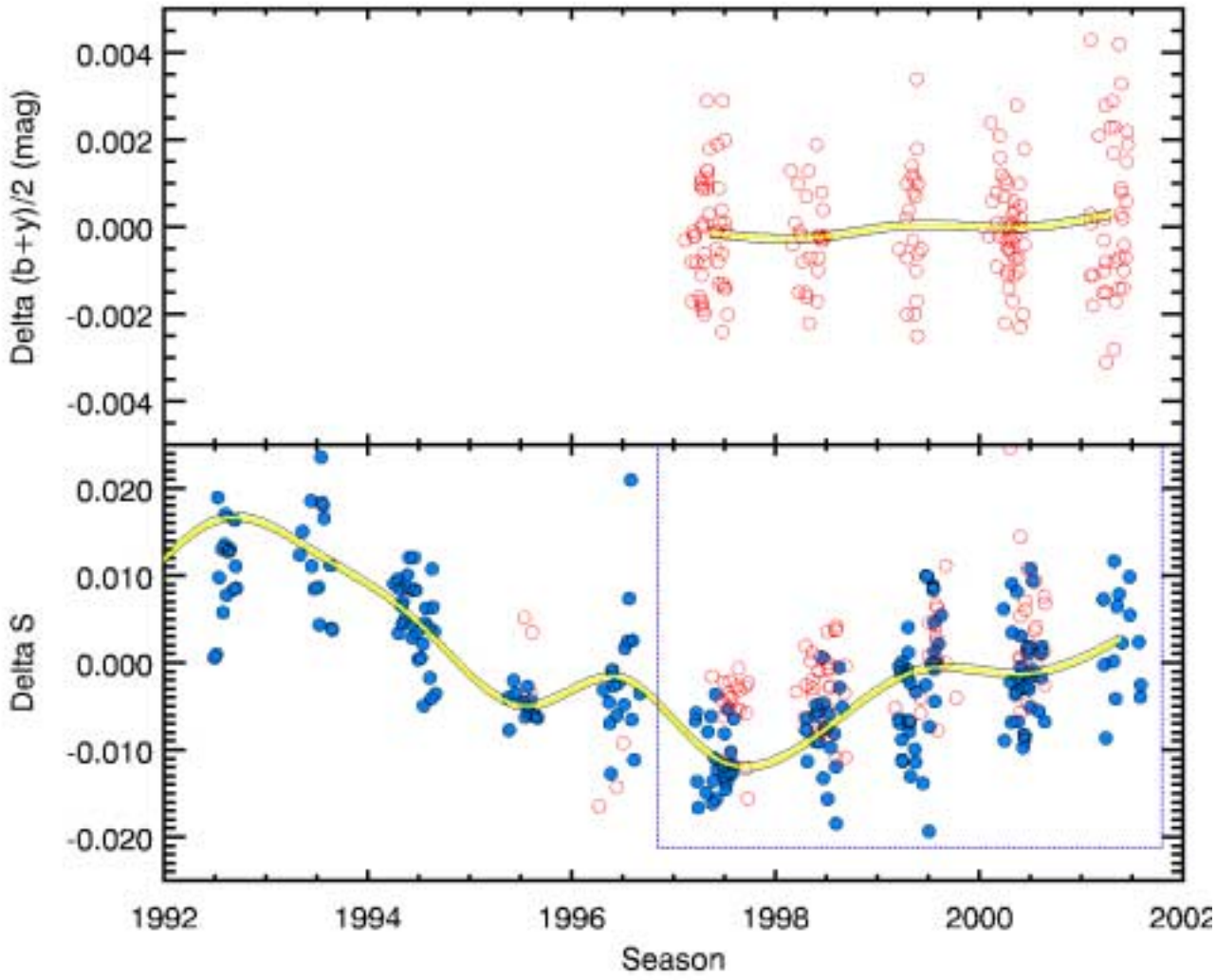
T_{eff}: 5817 Sp: G2V

<S>: 0.17 log R' $_{HK}$: -4.94

rms_{phot}: 0.0002

rms_{CaII}: 0.006

Chromospheric variation
-blue: Mt. Wilson HK prog.
-yellow: Lowell SSS prog.



Conclusions

1. **Many Sunlike stars display activity cycles**
2. **The Sun's photometric activity appears to be relatively small relative to some similar stars**
3. **The Sun is not unusual in terms of its magnetic activity behavior**
4. **Perfect solar twins appear to be relatively scarce in the solar neighborhood. 18 Sco is the currently favored best candidate**
5. **Data from two photometric programs can be successfully merged**
6. **Data from two spectroscopic programs can be successfully merged**

Further reading

A sample from the past 11 years

Evidence of a pronounced activity cycle in the solar twin 18 Scorpii. Hall and Lockwood 2000. ApJ **545**, L43-L45.

Photometric and Ca II H and K spectroscopic variations in nearby Sun-like stars with planets. III. Henry, Baliunas,Donahue, Fekel, and Soon 2000. ApJ **415**, 413-437.

Patterns of variation among Sunlike Stars. Radick, Lockwood, Skiff, Skiff, and Baliunas 1998. ApJS **118**, 239-258.

The solar activity cycle. I. Observations of the end of cycle 22, 1993 September-1997 February. Hall and Lockwood 1998. ApJ **493**, 494-504.

The photometric variability of Sun-like stars: Observations and results, 1984-1996. Lockwood, Skiff, and Radick 1997**.** ApJ **485,** 780-811.

Chromospheric variations in main-sequence stars. II. Baliunas, Donahue, Soon et al. 1995. ApJ **438**, 269-287.

Long-term solar brightness changes estimated from a survey of Sun-like stars. Lockwood, Skiff, Baliunas, and Radick 1991. Nature **360**, 653-655.

Data sources

***b*, *y* photometry from the Lowell Observatory, 1984-2000**

***b*, *y* photometry from the Fairborn Observatory, 1993-2002**

Stellar Ca II "S" index from the Mount Wilson HK program, 1966-2002

Stellar and solar HK fluxes from the Lowell Observatory Solar Stellar Spectrograph ("S^3") program, 1992-2002, converted to "S"

Solar K emission equivalent width data from the National Solar Observatory, converted to "S"

Funding credits

Lockwood, Hall, and Skiff are supported by a grant from NSF.

Baliunas, Donahue, and Soon are supported by the Air Force Office of Scientific Research

Henry is supported by grants from NSF and NASA.

Radick is supported by the Air Force Office of Scientific Research