Photometric Variations in the Sun and Solar-type Stars

Mark Giampapa
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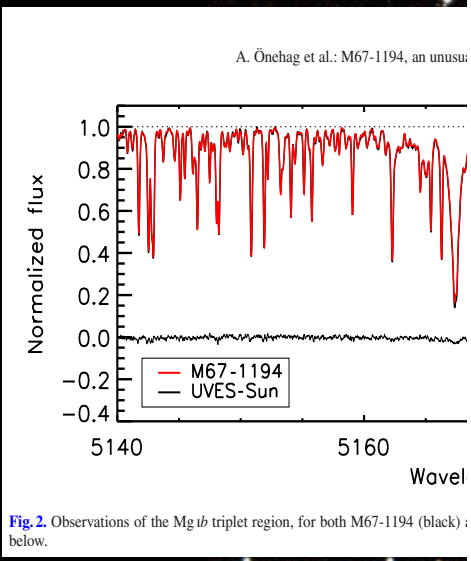
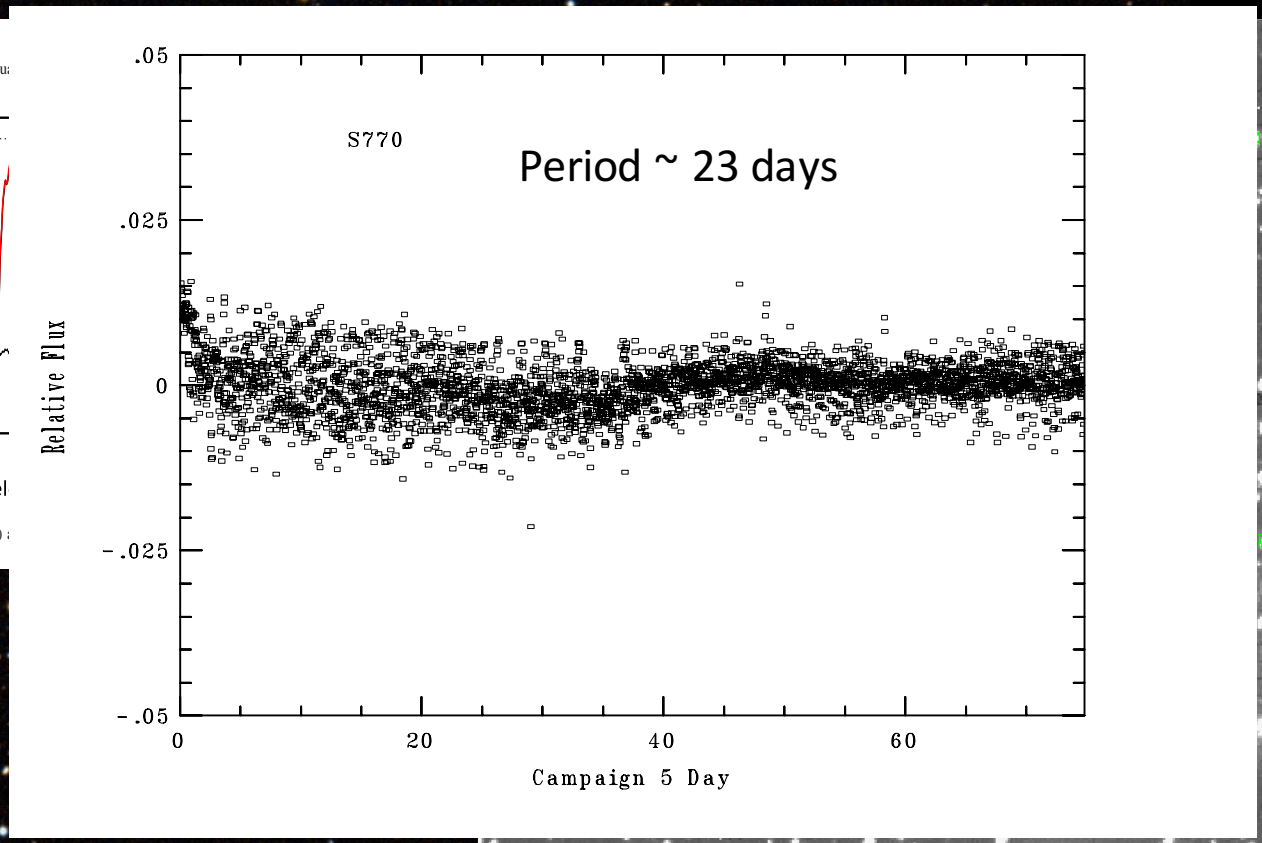
Collaborators: A. M. Cody (NASA/Ames)

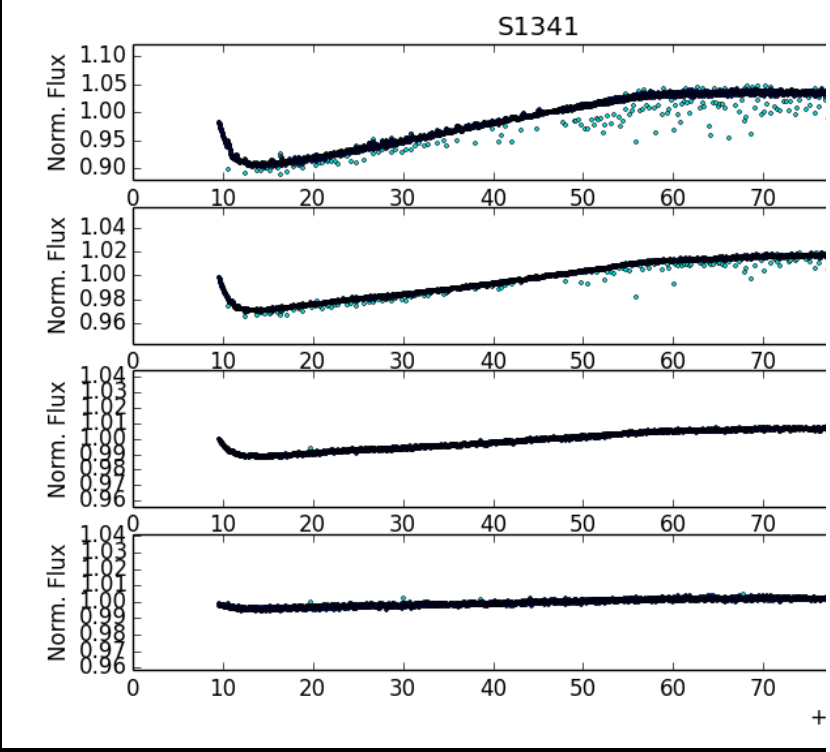
M67: a laboratory for the study of solar-type stars

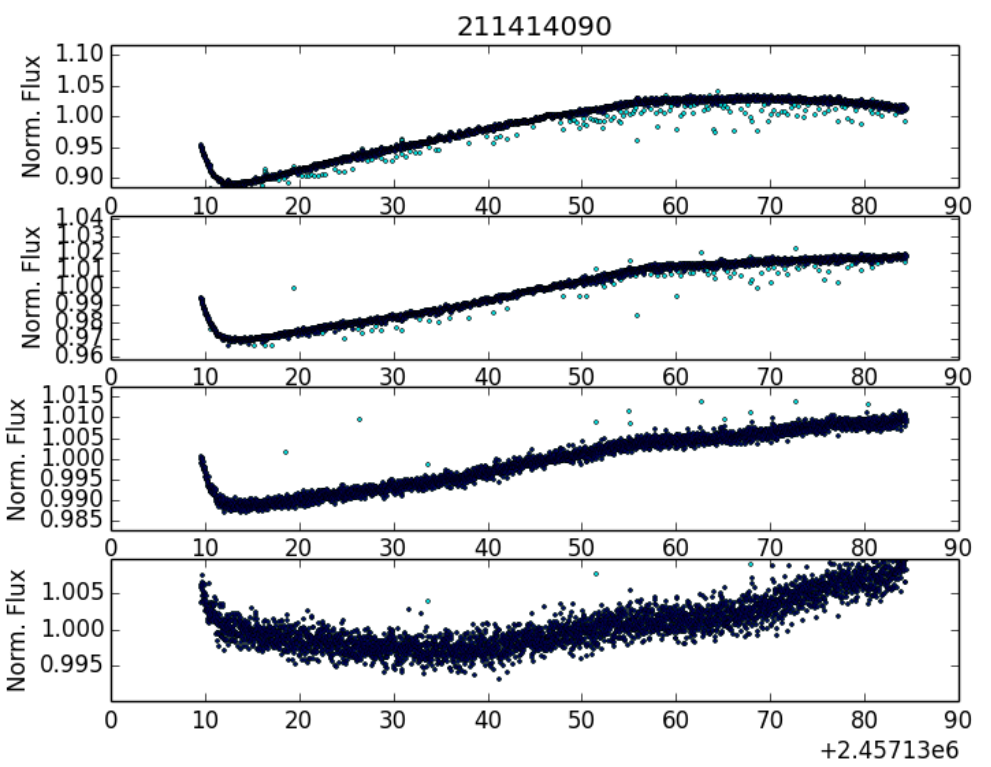




S770 (B – V) = 0.63
RV planet (> 0.34 M_J, P = 6.9 days)
(*Brucalassi+2013*)

Preliminary *K2* Results for Sun-like Stars in M67



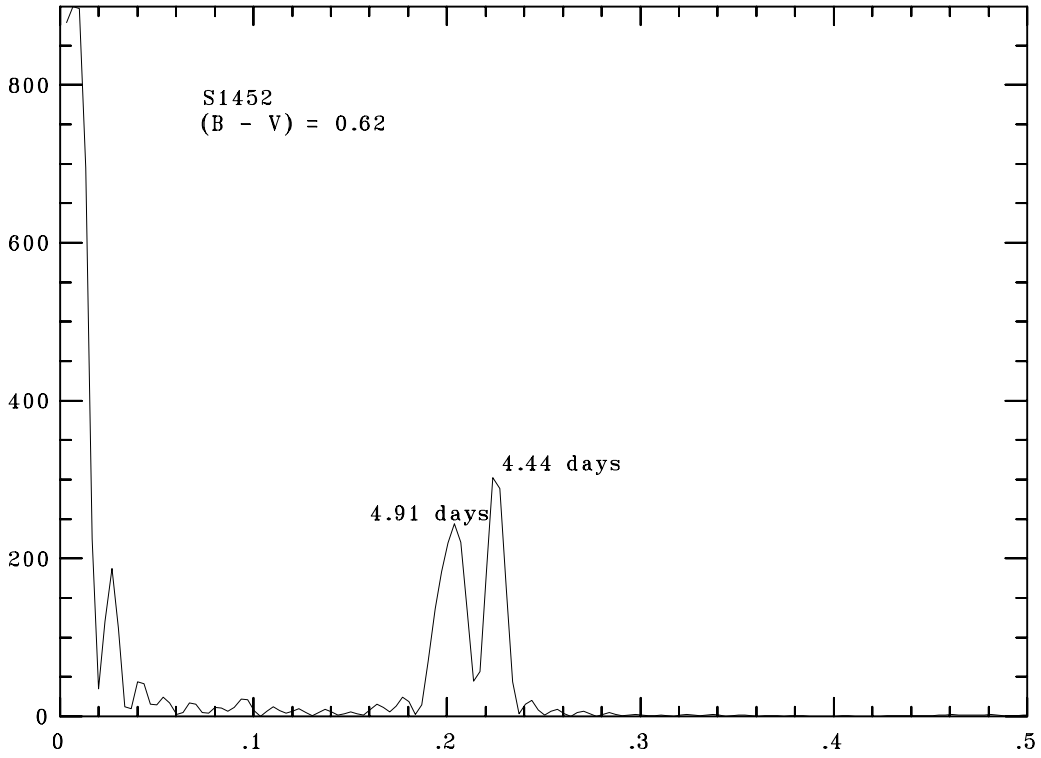


(B – V) = 0.62

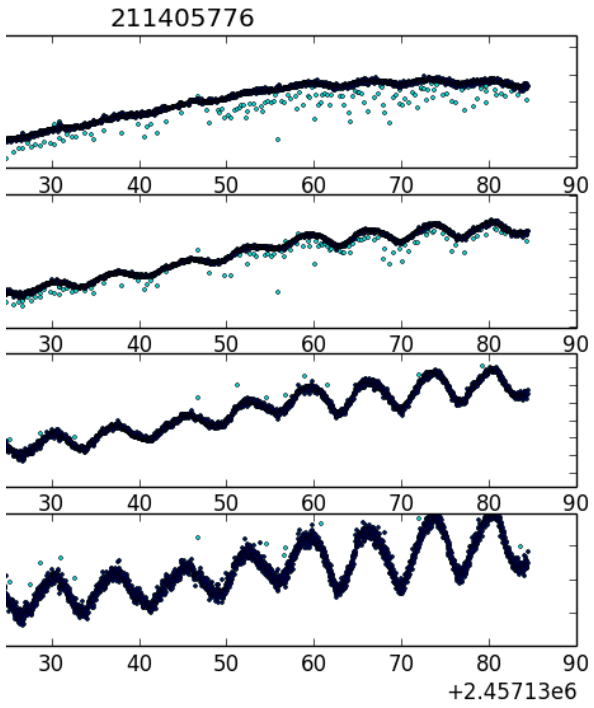
S785 (B – V) = 0.65
RV planet (>0.40 M_J, P = 5.1 d)
(Brucalassi+2013)

***K2* customized reductions by A. M. Cody (NASA/ARC)**

Preliminary *K2* Results for Solar-type Stars in M67



S1452, (B – V) = 0.62
v sin *i* = 4 km/s (Reiners & Giampapa 2009)
SB1 (Geller+2015)



S747, (B – V) = 0.65
SB2 (Reiners & Giampapa 2009; Geller+2015)

Preliminary *K2* Results for Sun-like Stars Members of M67

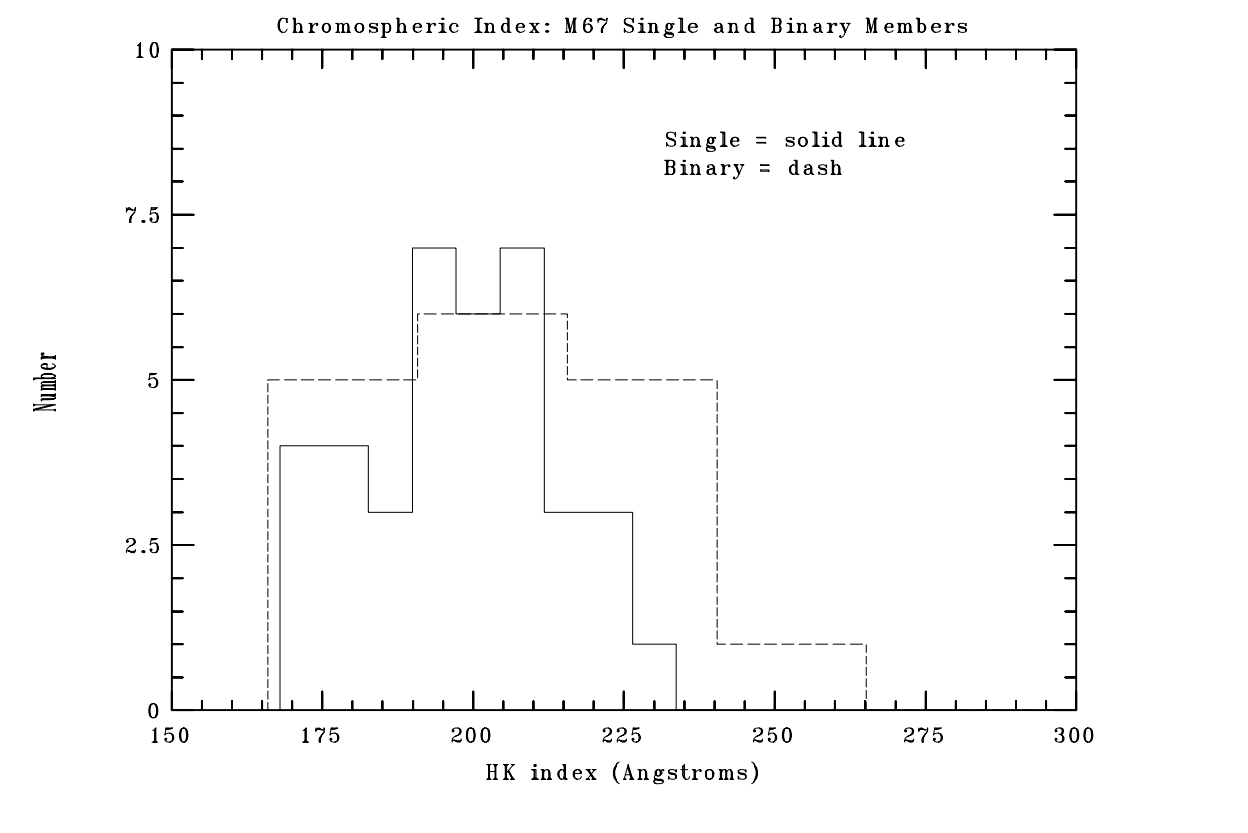
Single Members

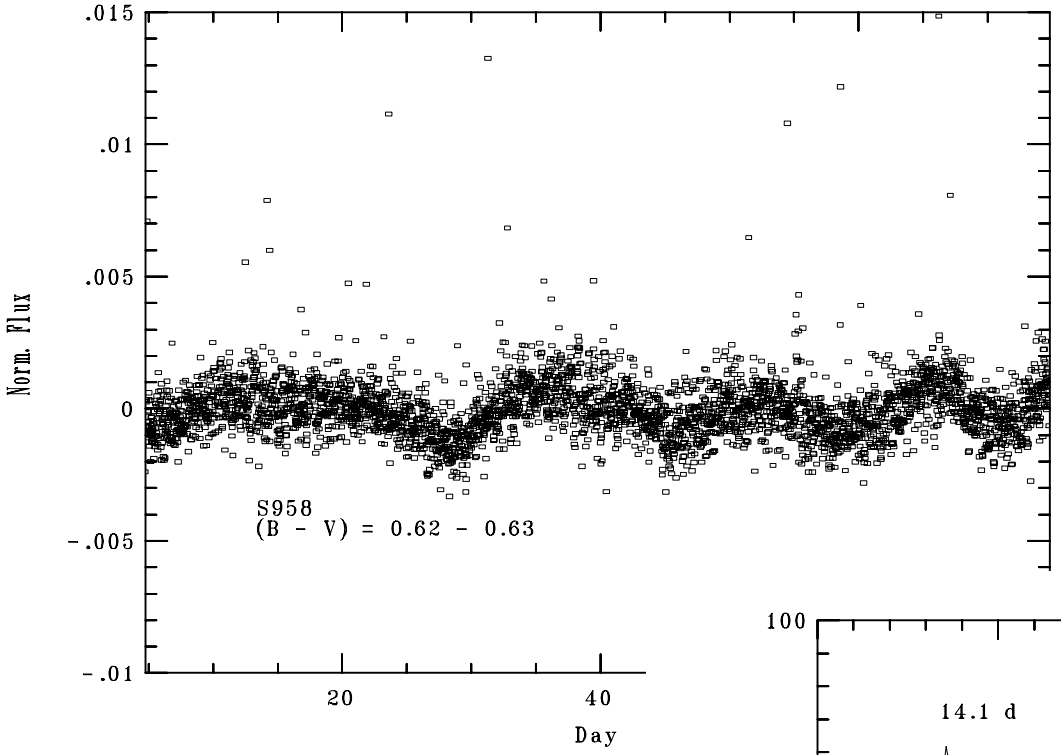
- Total = 53
- Not (obviously) periodic = 77%
- Candidates for further analysis = 19%
- Periodic = 4% (two stars)

Binary Members

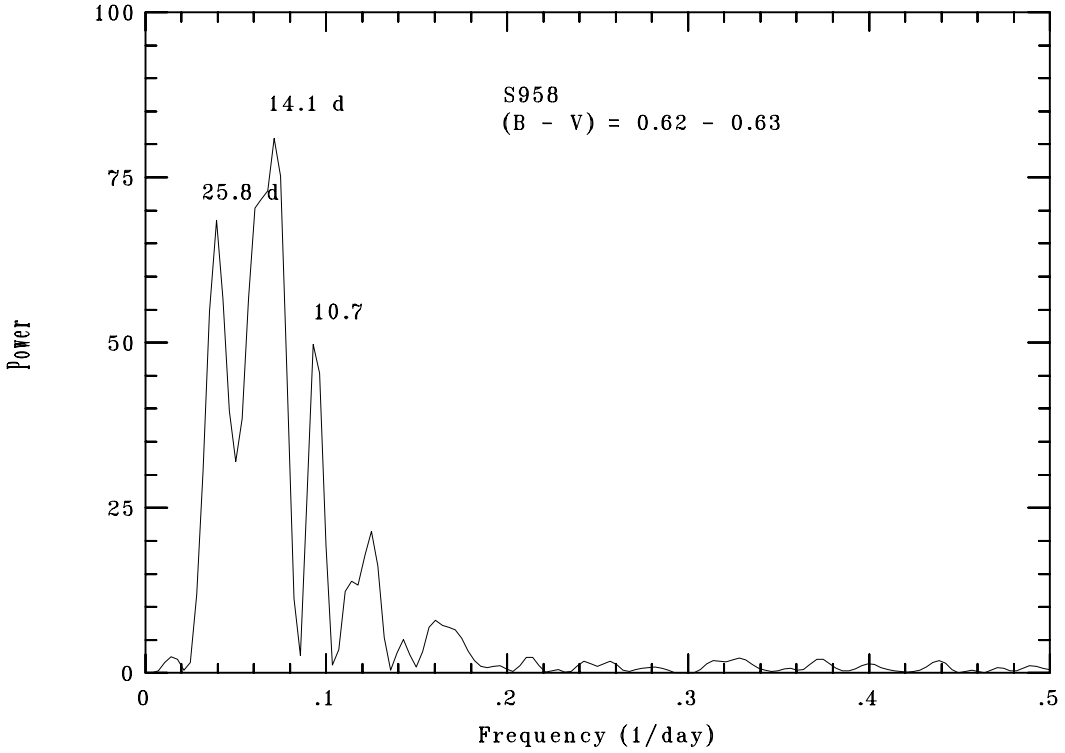
- Total = 26
- Not (obviously) periodic = 58%
- Candidates pending further analysis = 19%
- Obviously periodic = 23%

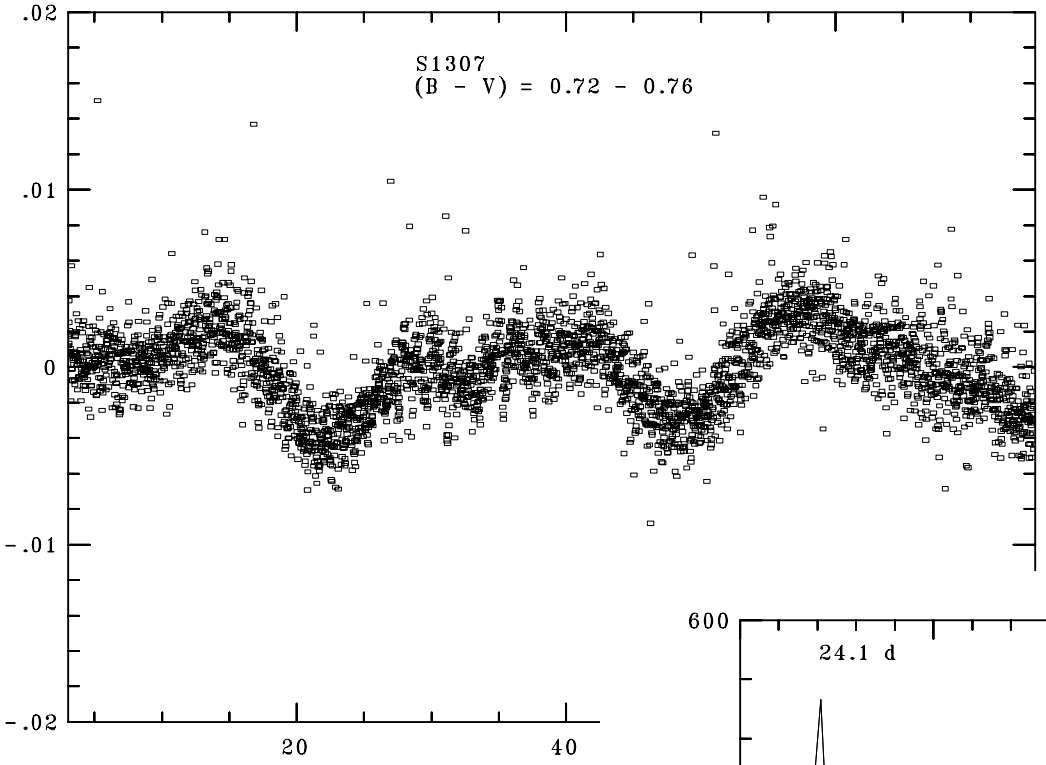
Activity distribution: single & binary members



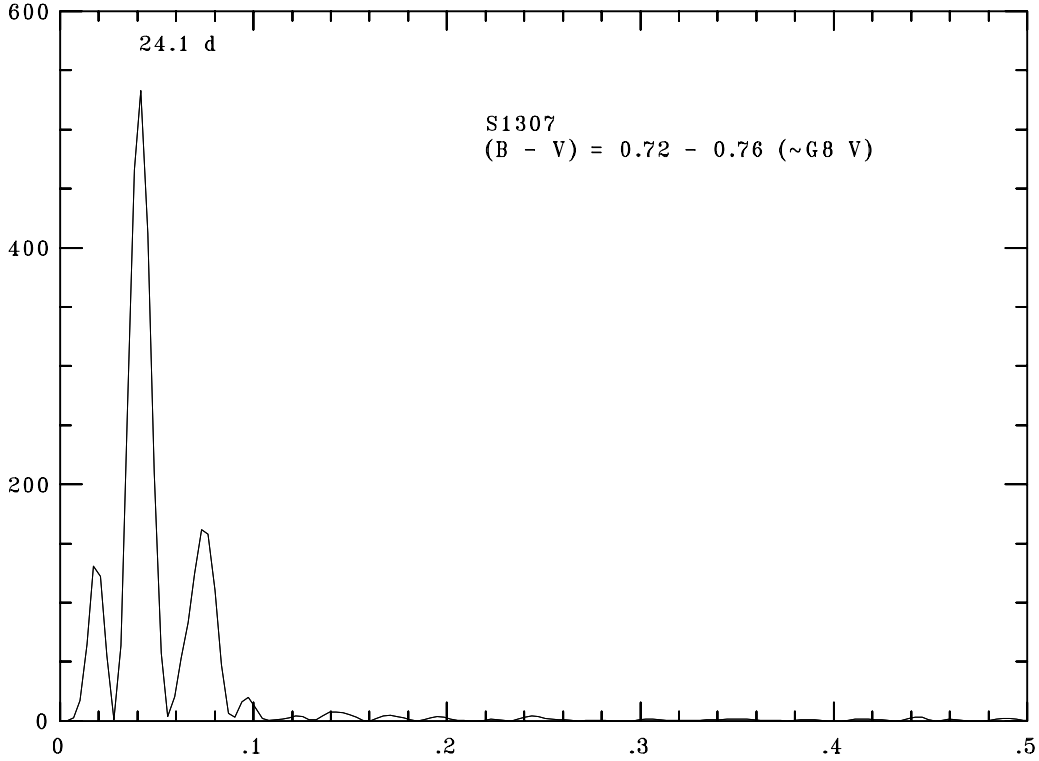

.015
.01
.005
0
-.005
-.01
Norm. Flux
S958
(B - V) = 0.62 - 0.63
20
40
Day

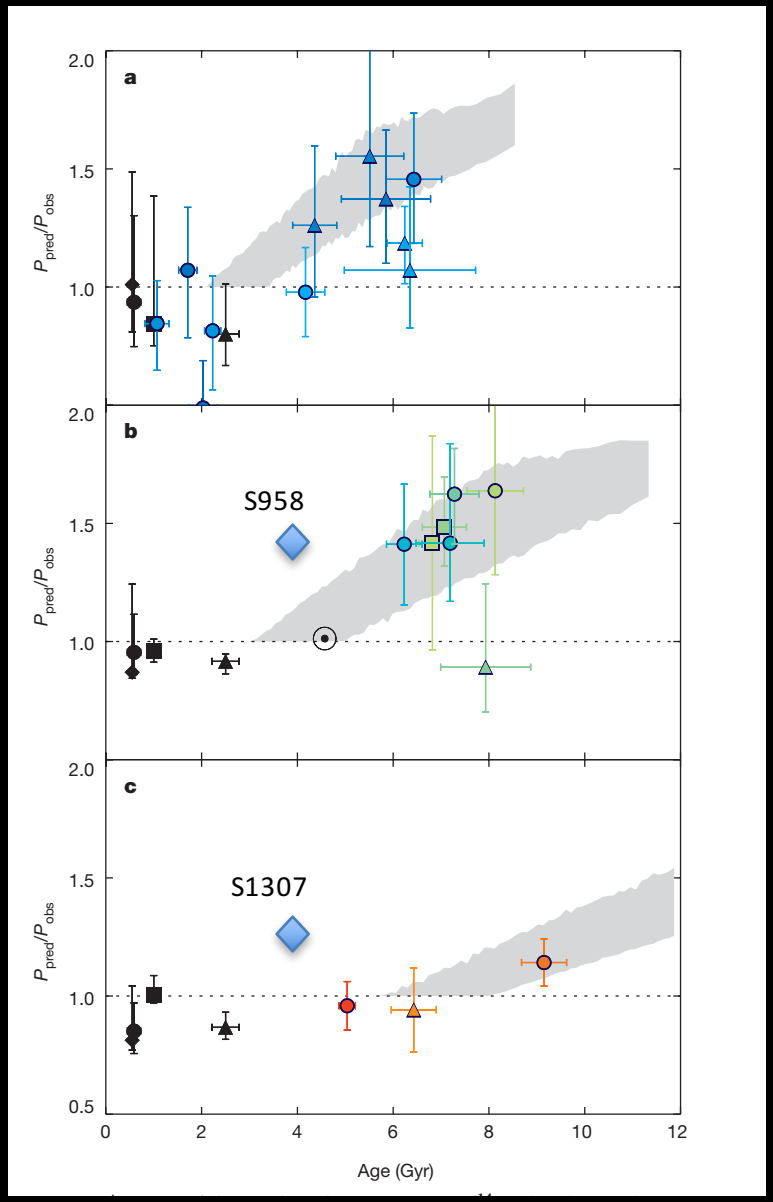
P ~ 18 days


100
75
50
25
0
Power
14.1 d
25.8 d
10.7
S958
(B - V) = 0.62 - 0.63
0
.1
.2
.3
.4
.5
Frequency (1/day)


S1307
(B - V) = 0.72 - 0.76
.02
.01
0
-.01
-.02
20
40

P ~ 24 days


24.1 d
S1307
(B - V) = 0.72 - 0.76 (~G8 V)
600
400
200
0
0
.1
.2
.3
.4
.5



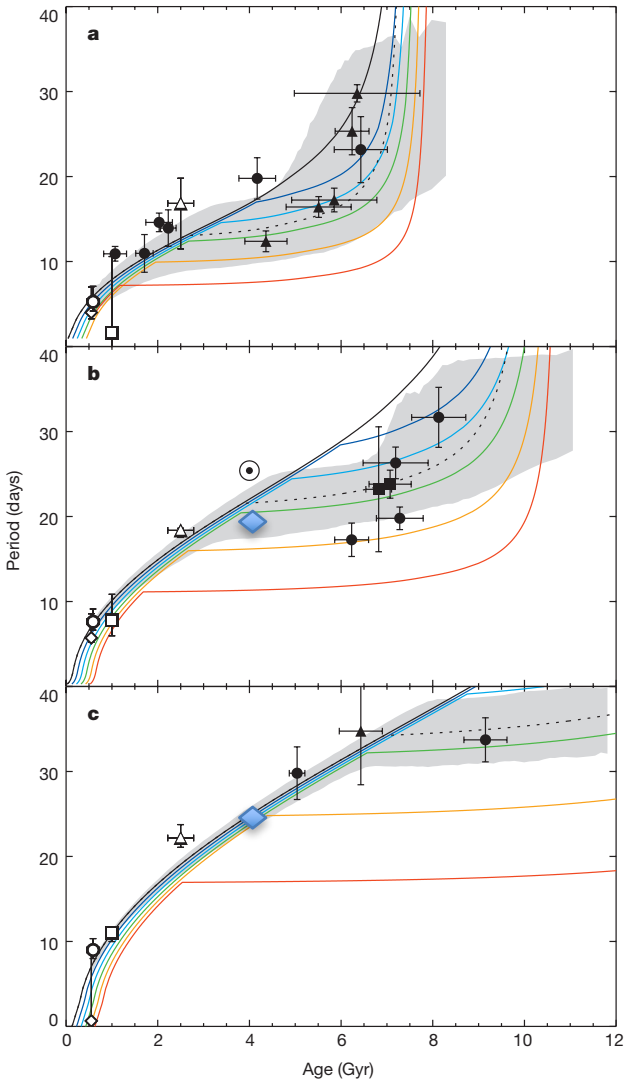
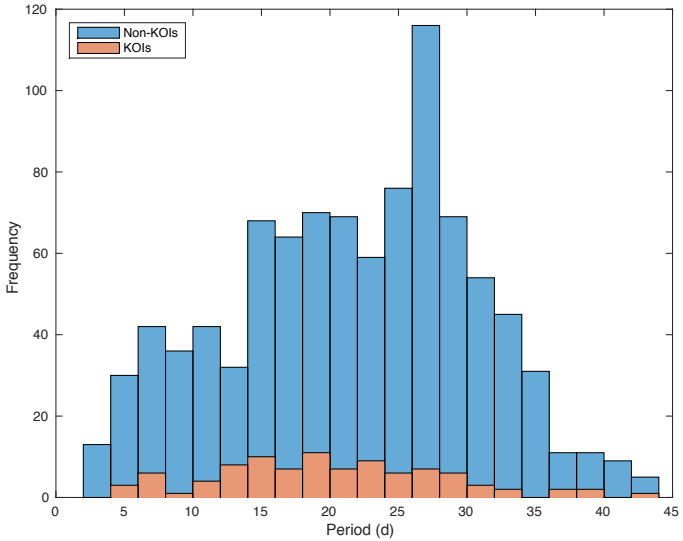


Figure 3 | The effects of a Ro_{crit} threshold on rotational evolution. Panels are divided according to decreasing ZAMS T_{eff}: **a**, 5,900–6,200 K; **b**, 5,600–5,900 K; **c**, 5,100–5,400 K (as in Fig. 2). Black symbols represent open stellar clusters, as follows: diamonds, M37; circles, Praesepe; squares, NGC

van Saders+2016; Nature, 529, 181



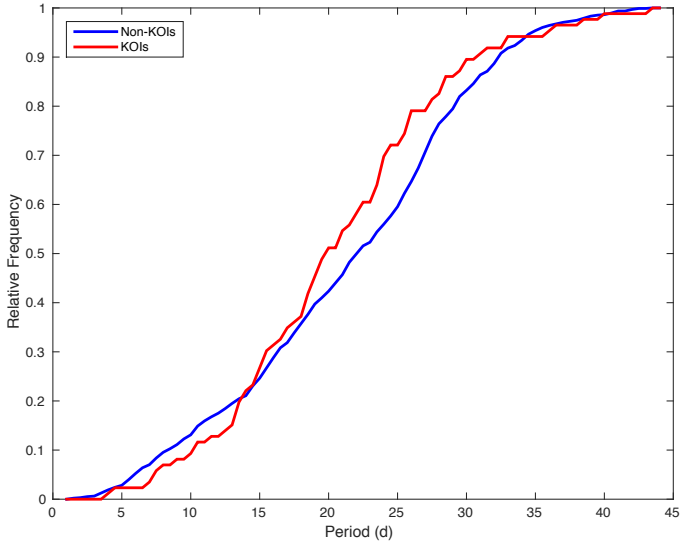
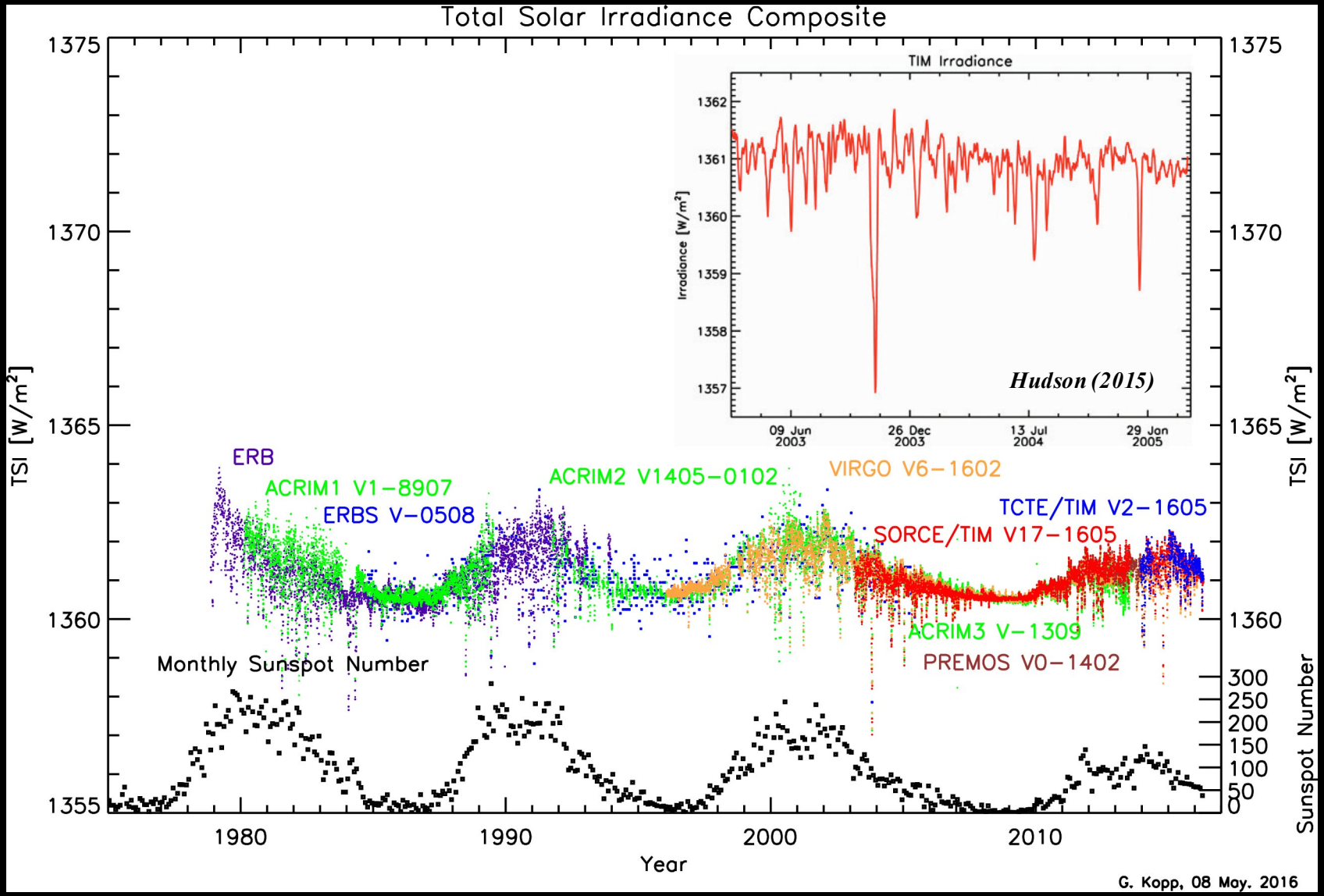


Fig. 8: The left panel compares histograms for the period distributions for the KOI and non-KOI samples, while the right shows CFDs for these cases and further compares Jupiter-hosting systems to the rest of the KOI distribution. A K-S test shows that the period distributions for the two cases (KOI and non-KOI) differ ($p = 0.01$), with the planet-hosting sample showing a tendency to shorter periods, but is unable (with $p = 0.06$) to discern any statistically significant difference between the Jupiter host population and the remainder of the KOI population.

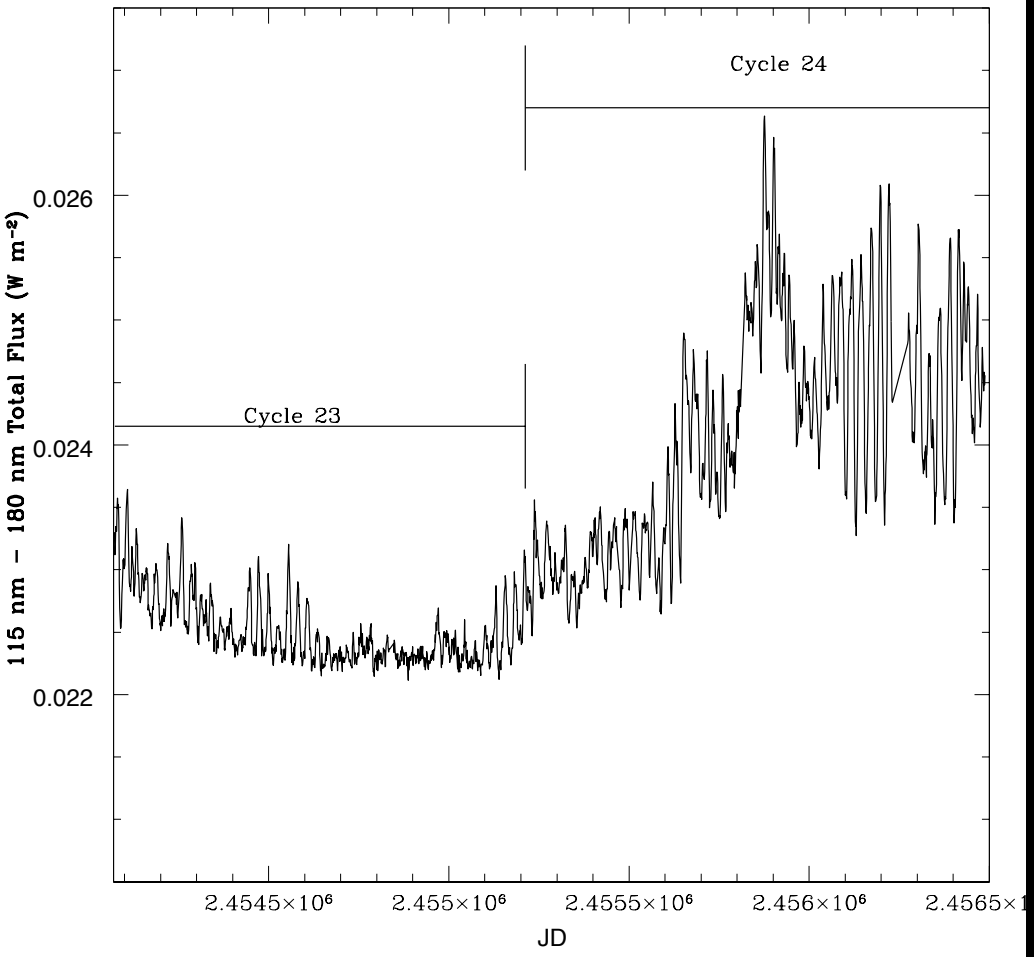
submitted to **Journal of Space Weather and Space Climate**

Rotation, Activity, and Stellar Obliquities in a Large Uniform Sample of *Kepler* Solar Analogs

D. Buzasi,[1] A. Lezcano[1] and H. L. Preston[2]


Total Solar Irradiance Composite
TSI [W/m²]
Year
Sunspot Number
1375
1370
1365
1360
1355
1980
1990
2000
2010
300
250
200
150
100
50
0
ERB
ACRIM1 V1−8907
ERBS V−0508
ACRIM2 V1405−0102
VIRGO V6−1602
TCTE/TIM V2−1605
SORCE/TIM V17−1605
ACRIM3 V−1309
PREMOS V0−1402
Monthly Sunspot Number
TIM Irradiance
Irradiance [W/m²]
1362
1361
1360
1359
1358
1357
09 Jun 2003
26 Dec 2003
13 Jul 2004
29 Jan 2005
Hudson (2015)
G. Kopp, 08 May. 2016

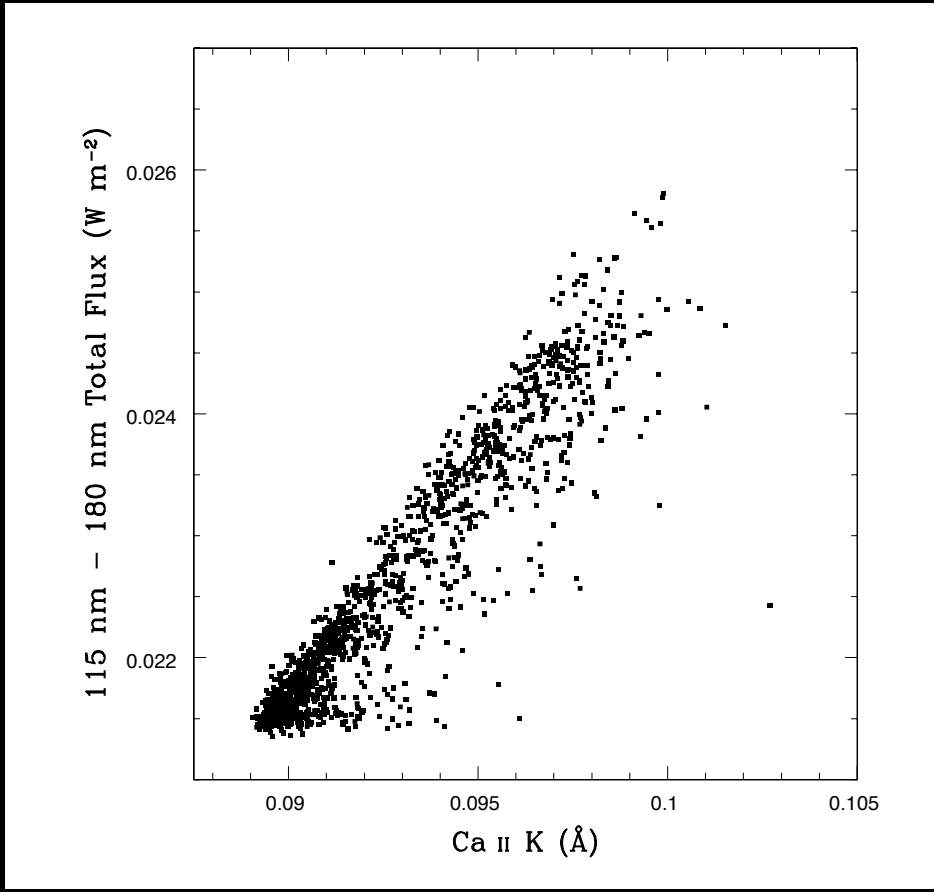
Relative Change in Solar Spectral Irradiance

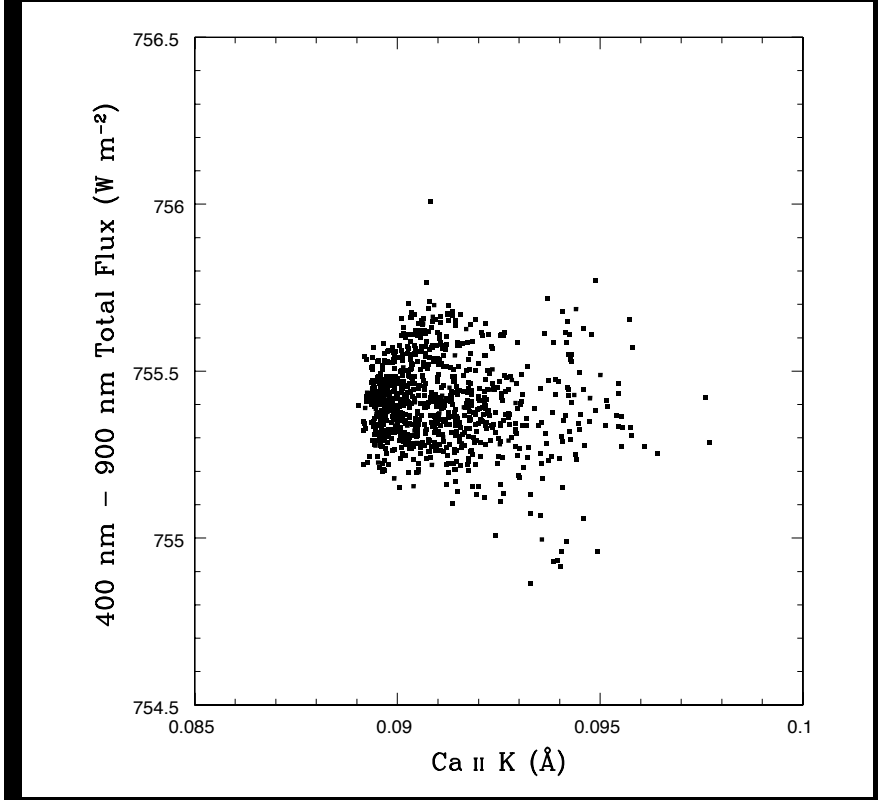


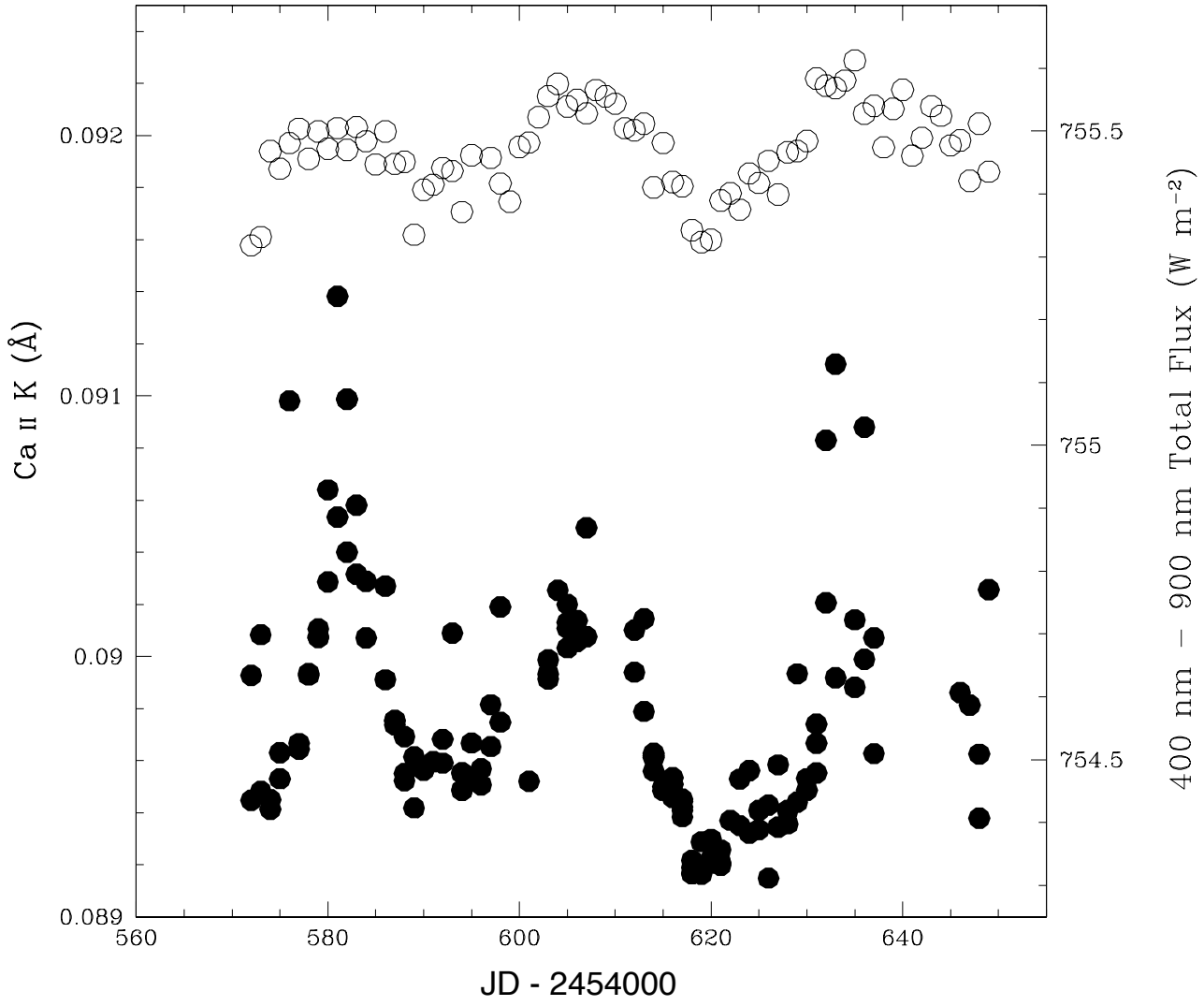
dF/F ~ 17%

- **UV wavelengths > 160 nm: 15%**
- **65 nm – 160 nm: 15% to 70%**
- **1 nm – 65 nm: factors of 1.5 to 7**
- **Ly α ~ total solar flux < 150 nm**

SOLIS ISS and SORCE SOLSTICE



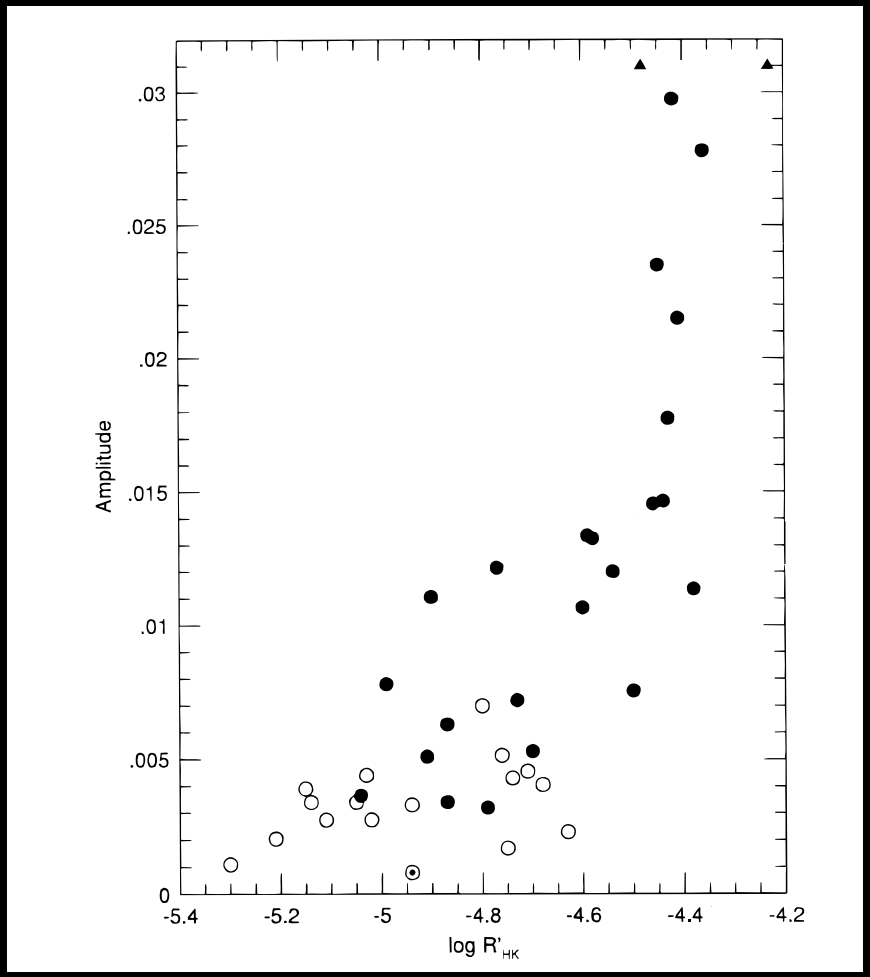


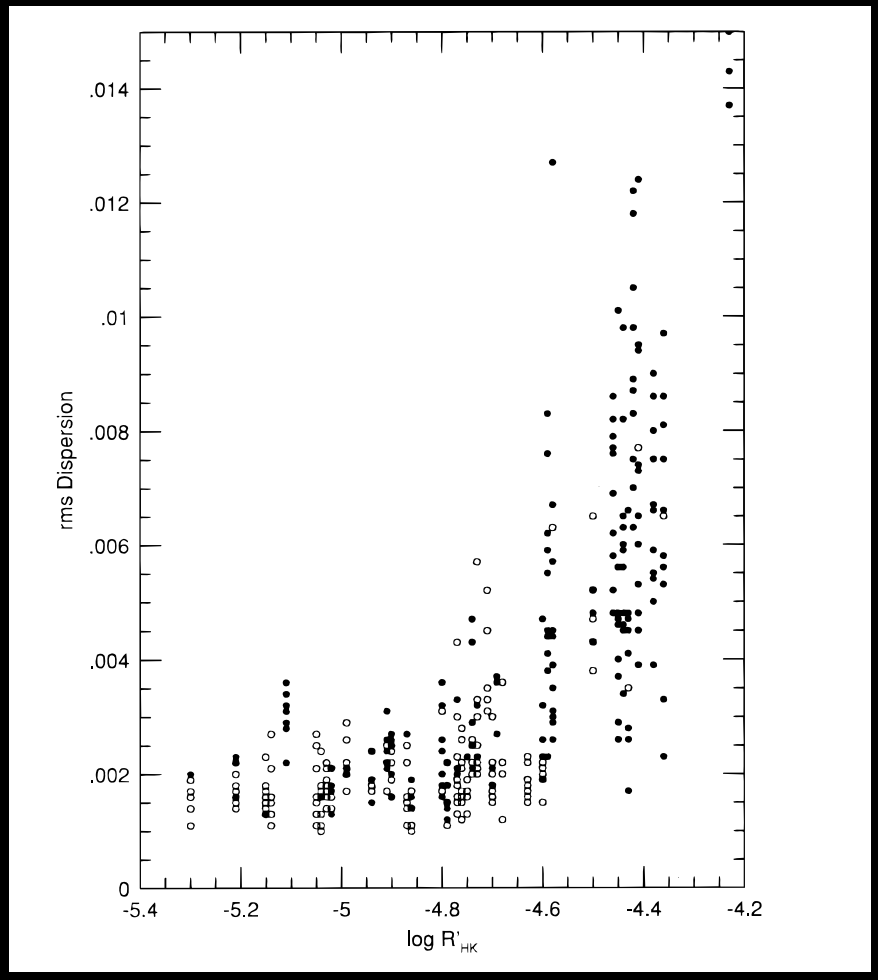


Open circles = SIM data

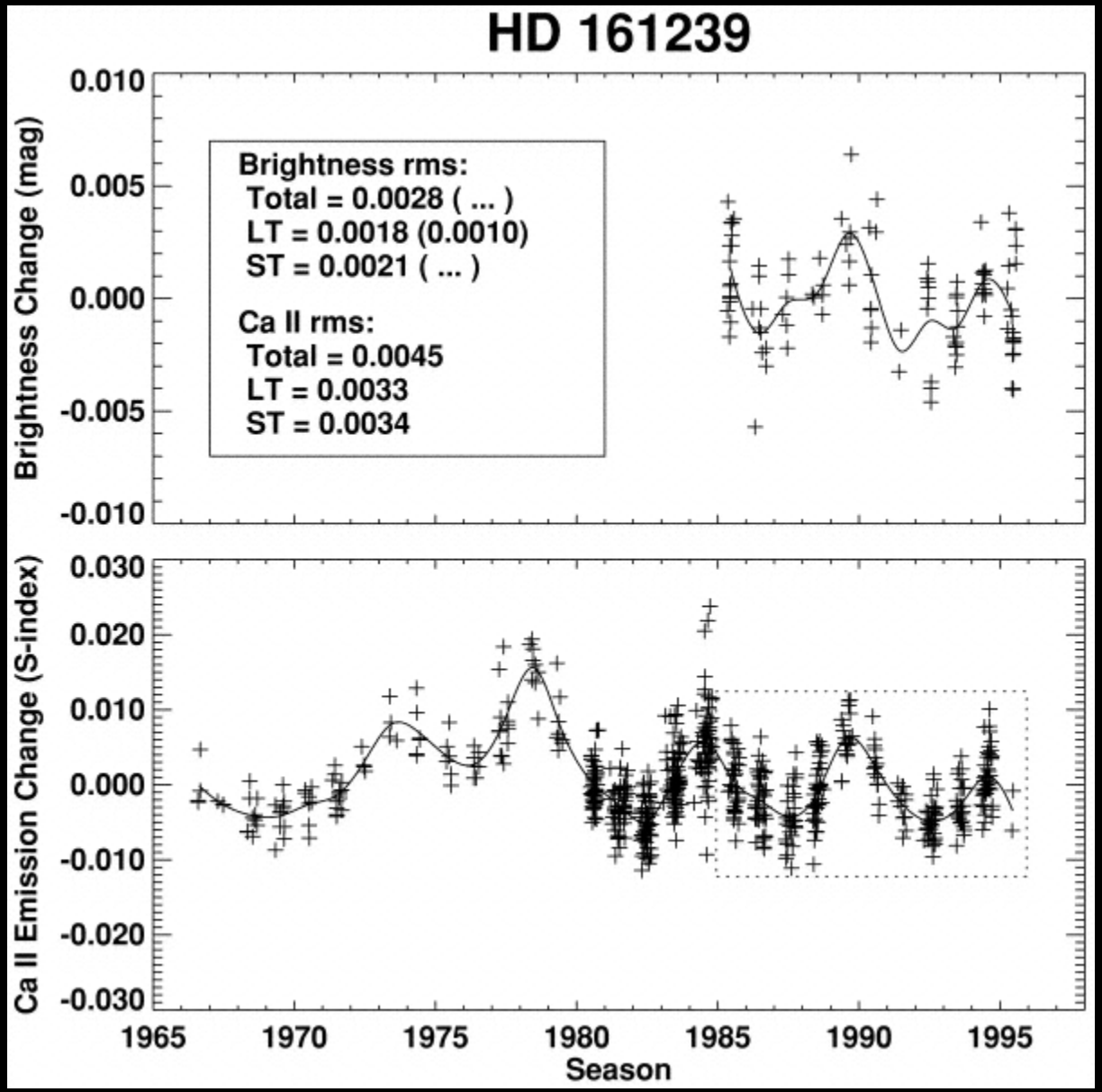
Filled circles = Ca II K data

Stellar Brightness Variations

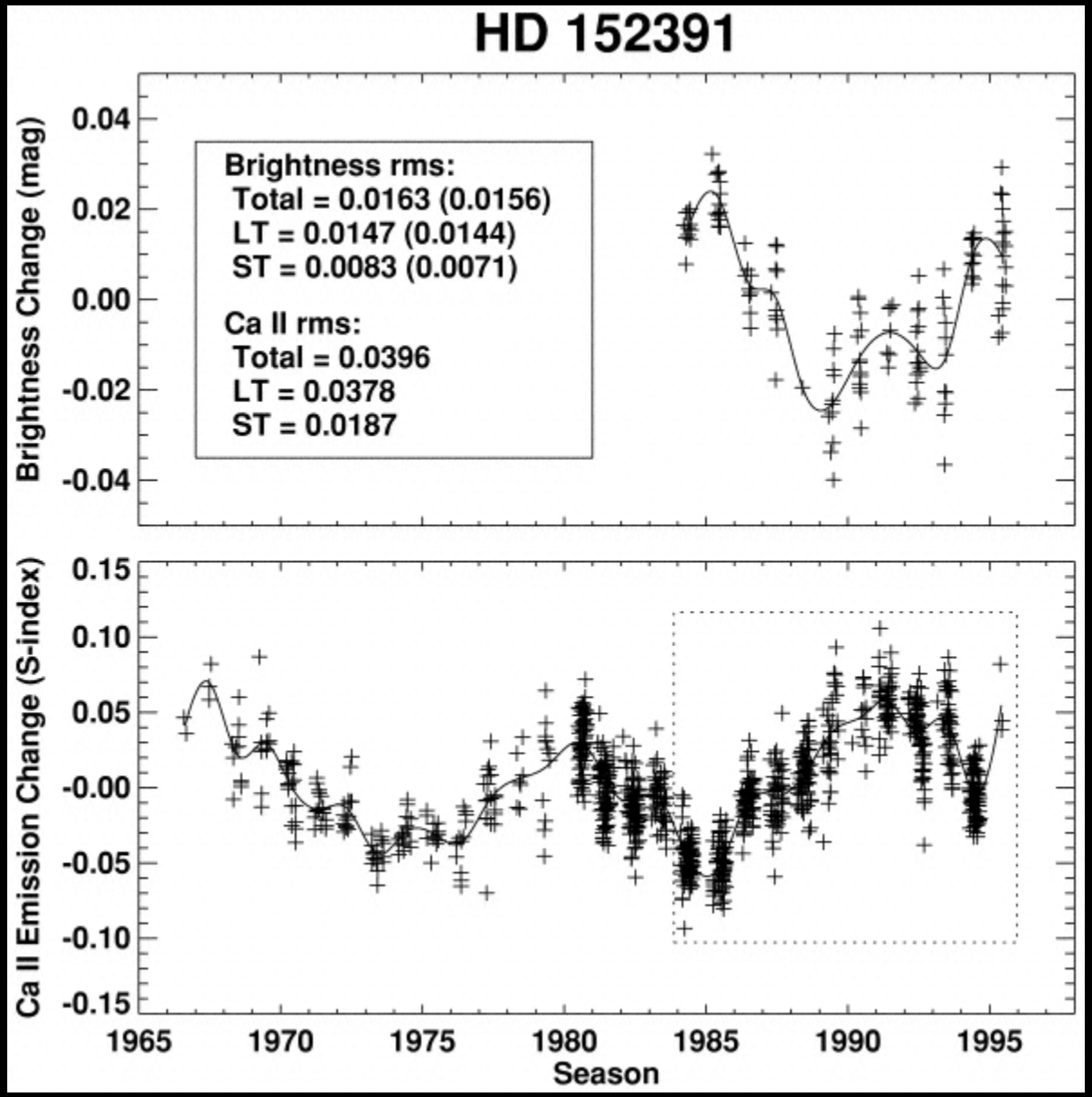


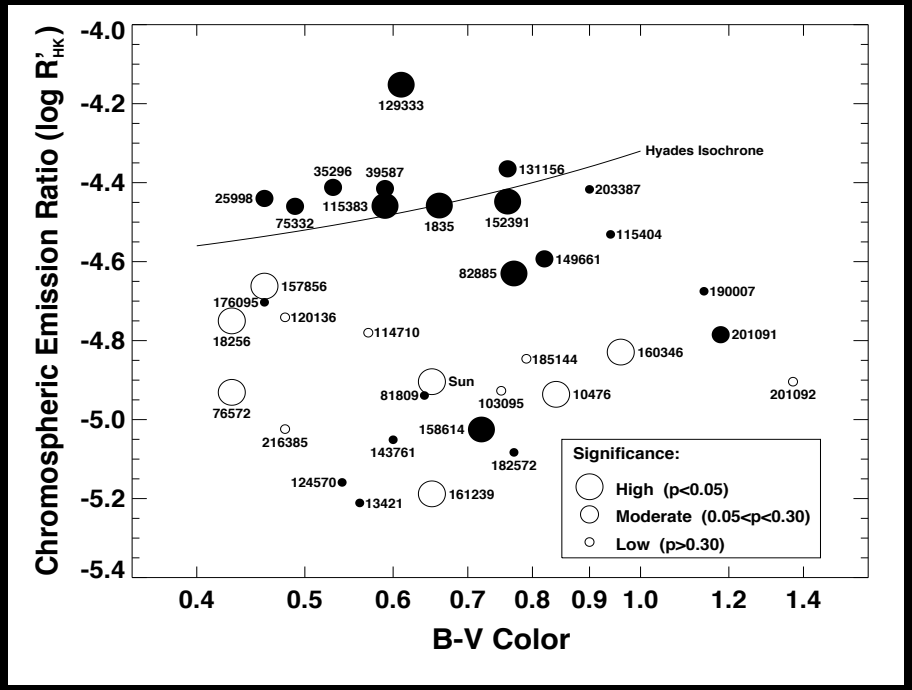


Lockwood et al. (1997; ApJ, 485, 789)

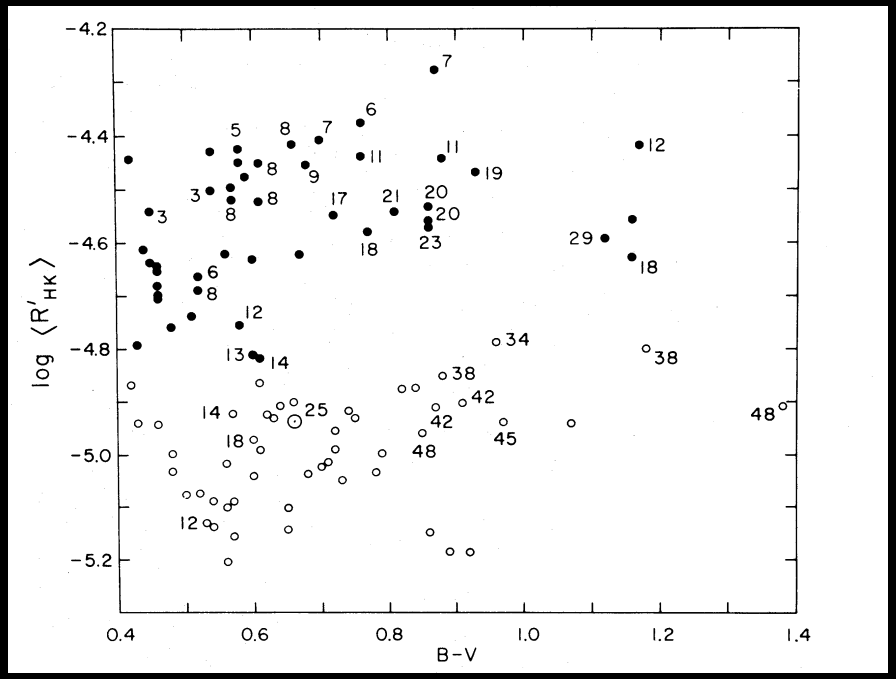


Mark Giampapa , National Solar Observatory


HD 152391
Brightness rms:
Total = 0.0163 (0.0156)
LT = 0.0147 (0.0144)
ST = 0.0083 (0.0071)
Ca II rms:
Total = 0.0396
LT = 0.0378
ST = 0.0187
Brightness Change (mag)
0.04
0.02
0.00
-0.02
-0.04
Ca II Emission Change (S-index)
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
1965
1970
1975
1980
1985
1990
1995
Season



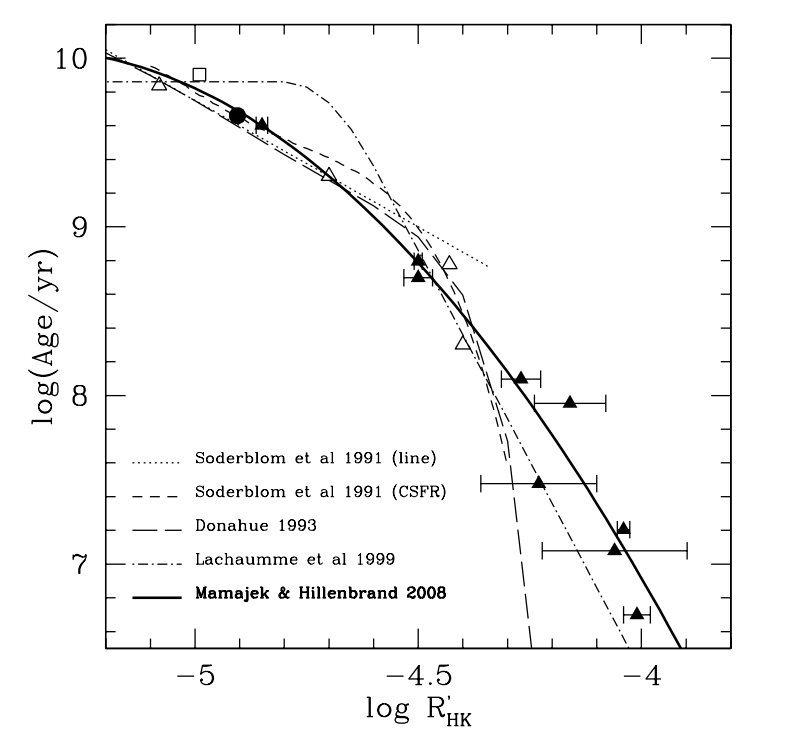
Radick et al. (1998; ApJS, 118, 239)



Noyes et al. (1984; ApJ, 279, 763)

V-P Gap location & Brightness Correlation change:

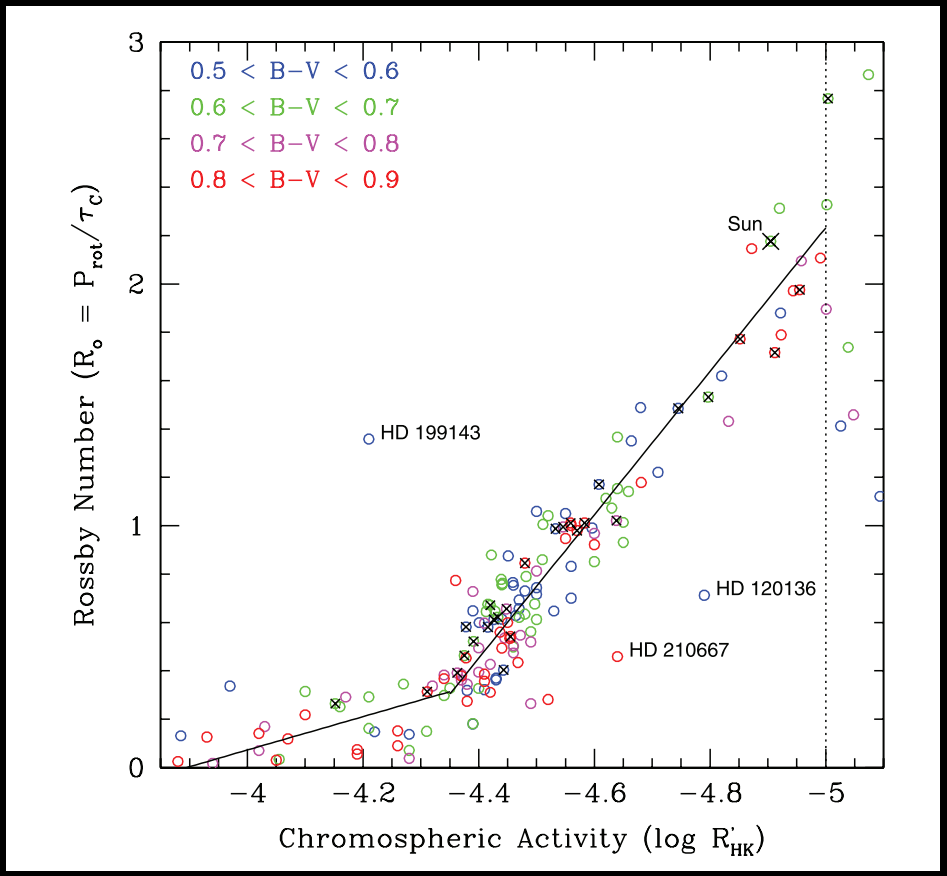
$$\log R'_{HK} \sim -4.7$$



$$\log \tau = -38.053 - 17.912 \log R'_{\mathrm{HK}} - 1.6675 \log\left(R'_{\mathrm{HK}}\right)^2 \quad (3)$$

τ ~ 2 Gyr (~ NGC 752)

Mamajek & Hillenbrand (2008)

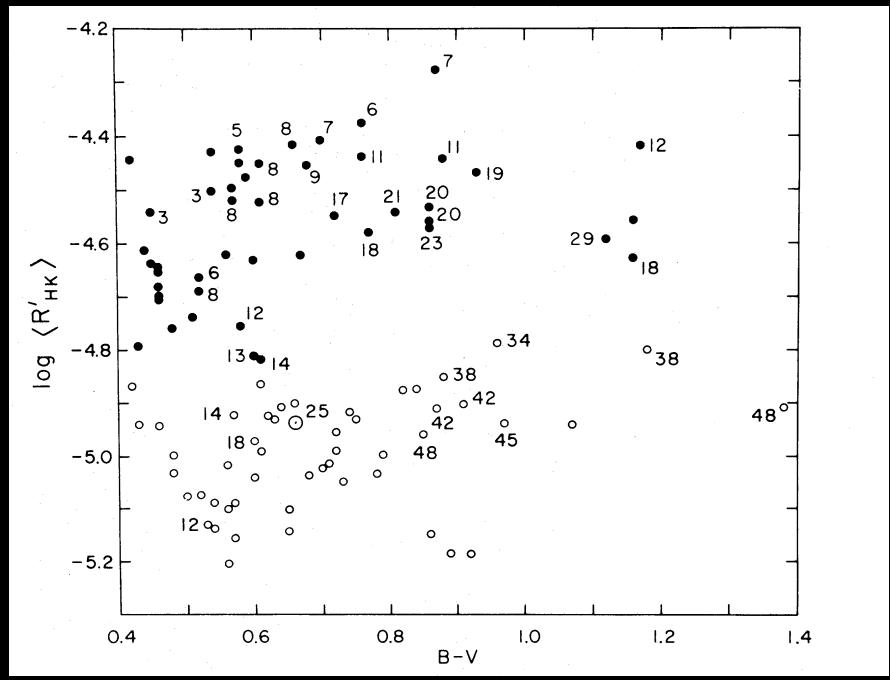


Mamajek & Hillenbrand (2008)

$$\mathrm{Ro} = (0.808 \pm 0.014) - (2.966 \pm 0.098)\left(\log R'_{\mathrm{HK}} + 4.52\right) \quad (5)$$

$\log R'_{HK} \sim -4.7$ ⟶ **R_o = 1.49**

P ~ 18 days for sun-like star.



SUMMARY

- **The transition between facular dominance and spot dominance in stellar brightness variations roughly coincides in log R'_{HK} with the occurrence of the Vaughan-Preston gap.**
- **The nature of the correlation between chromospheric spectral features and irradiance is very much dependent on wavelength and time scale in the Sun.**
- **The potential interplay between facular and spot contrasts and fractional area coverages should be considered in the interpretation of stellar photometric light curves.**

Asymmetric Case

$$\Delta F/F_{star} = (f_{smin} - f_{smax})(1 - F_{spot}/F_{star}) + \begin{bmatrix} f_{fmax} \\ -f_{fmin} \end{bmatrix} \epsilon$$

The photometric range is amplified if $f_{fmax} \gg f_{fmin}$

$f_{fmin} \gg f_{fmax}$

amplitude of photometric variability is actually reduced.

$\epsilon \sim (f_{smin} - f_{smax})$

Giampapa (2016)

SUMMARY

- ***K2*** **preliminary results for solar-type members in M67 indicate:**
- **Nearly 80% of the single members do not show any obvious periodicity**
- **Clear periodicity occurs in some binaries (SB1, SB2). Most binary members do not show obvious periodicity**
- **Two single members show obvious periodicity with periods that appear to be in a critical Rossby number regime for reduced magnetic braking and spin down.**
- **In rapid rotators possible binarity should be ruled out with high precision RV measurements ($\leq$ 0.4 km s^{-1})**
- **The potential impact of close-in Jupiters on rotational evolution should be considered**

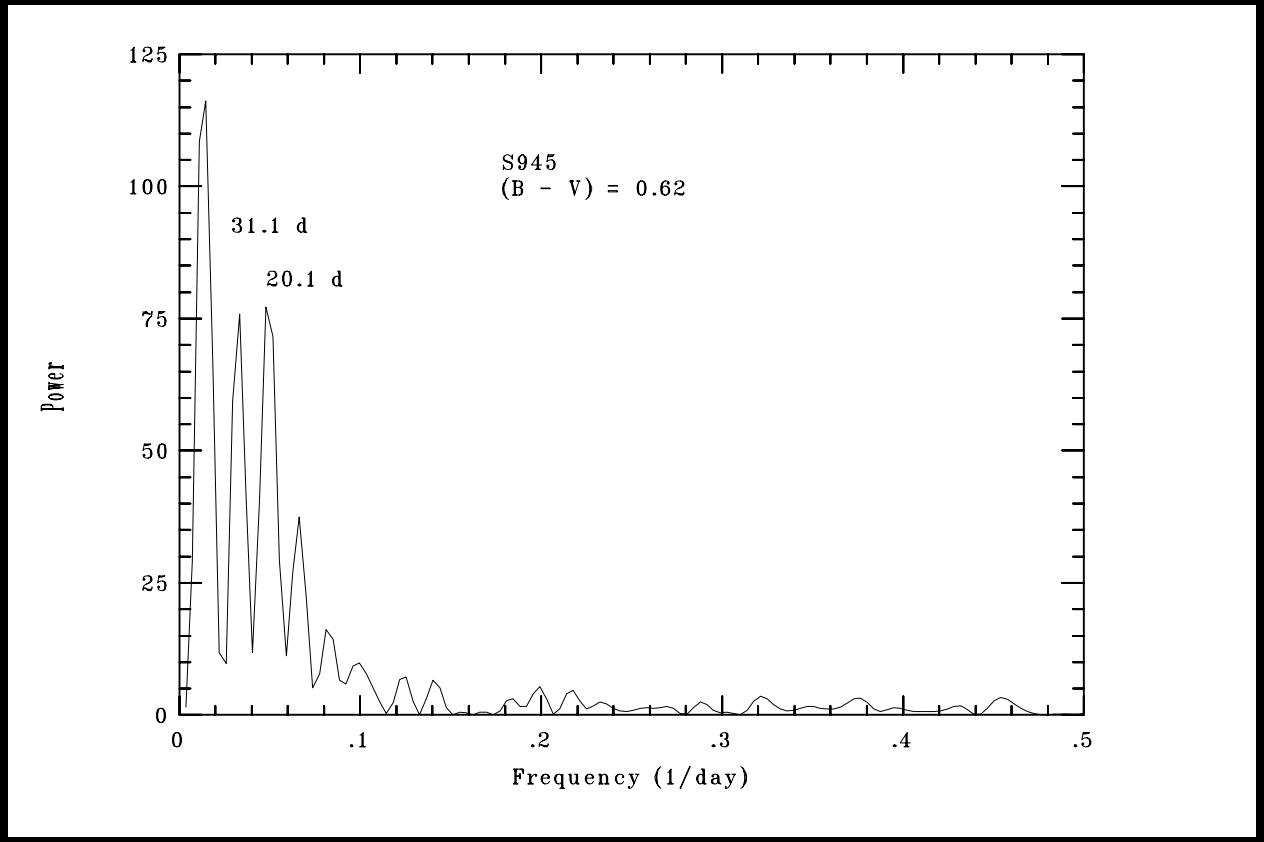

END

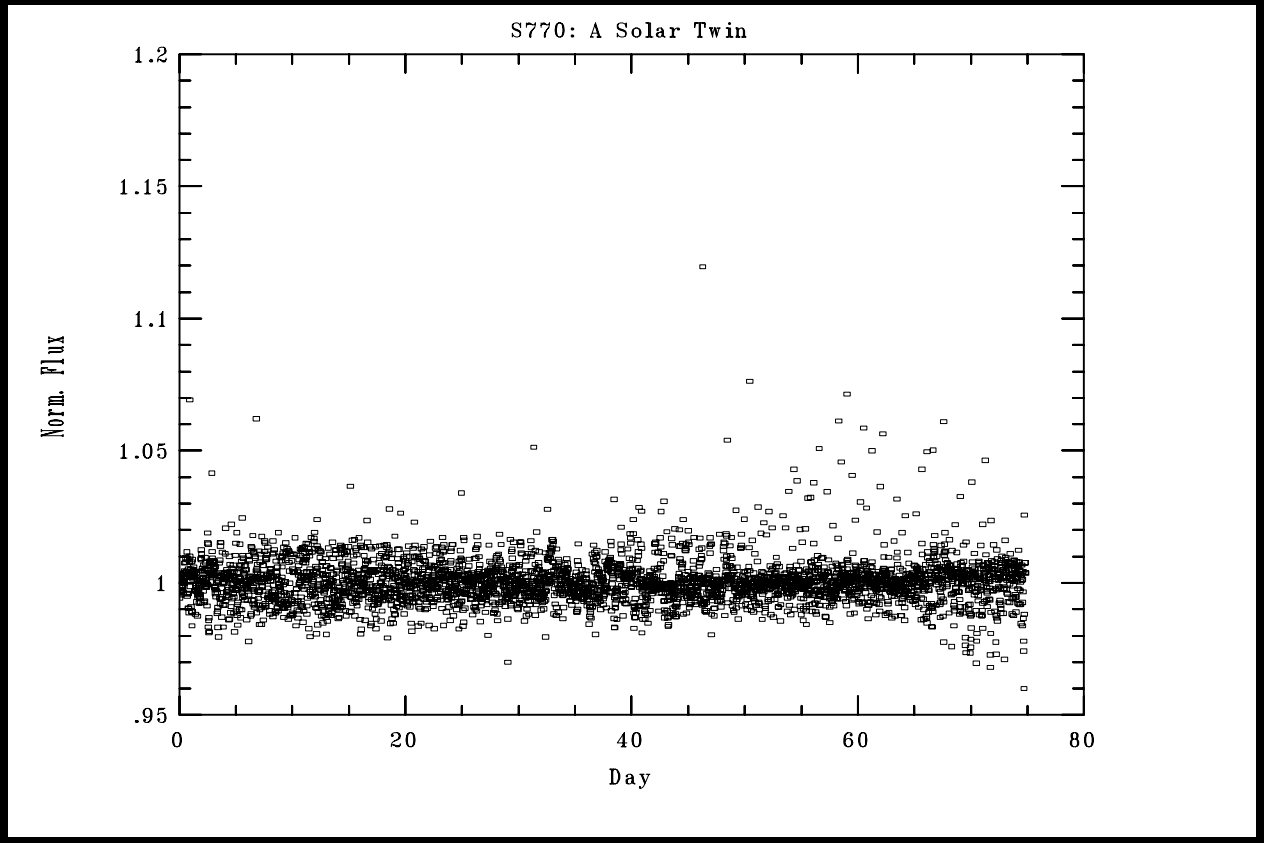
Summary

- Re-examined correlation of "*Kep V*" vs. K-line parameter in blocks of consecutive data entries of 10, 20, 30…300 ~ 10 days – 300 days.
- Only 9 such blocks with $|r| \geq 0.70$, corresponding to ~ one-half to one solar rotation period
- Highest single occurrences were r = 0.90 over a sequence of 13 days and r = -0.86 over 11 consecutive days

Overall

- 237 sequences with $|r| < 0.3$
- 81 blocks with $0.3 \leq |r| < 0.5$
- 39 sequences $|r| \geq 0.5$
- For all blocks $|r| = 0.055$


125
100
75
50
25
0
Power
S945
(B - V) = 0.62
31.1 d
20.1 d
0
.1
.2
.3
.4
.5
Frequency (1/day)



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