Stellar Activity with Kepler

stellar variability to precision radial velocities

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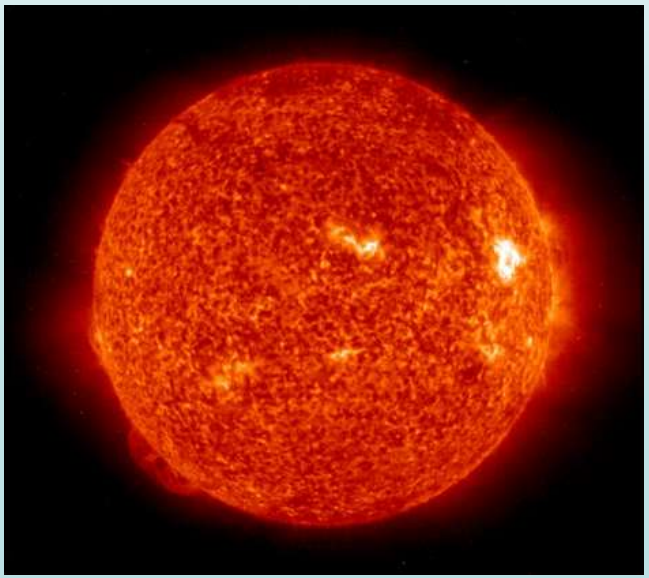
Kepler offers a new window on stellar variability

- Uninterrupted photometry of unprecedented precision
- Target stars of wide range in activity level and T_{eff}

Kepler can both find planets and help us better understand the challenges we face



Effect of Starspots on Doppler work:

RMS Doppler Velocity = 0.5 Δmag V_{eq} sin *i*

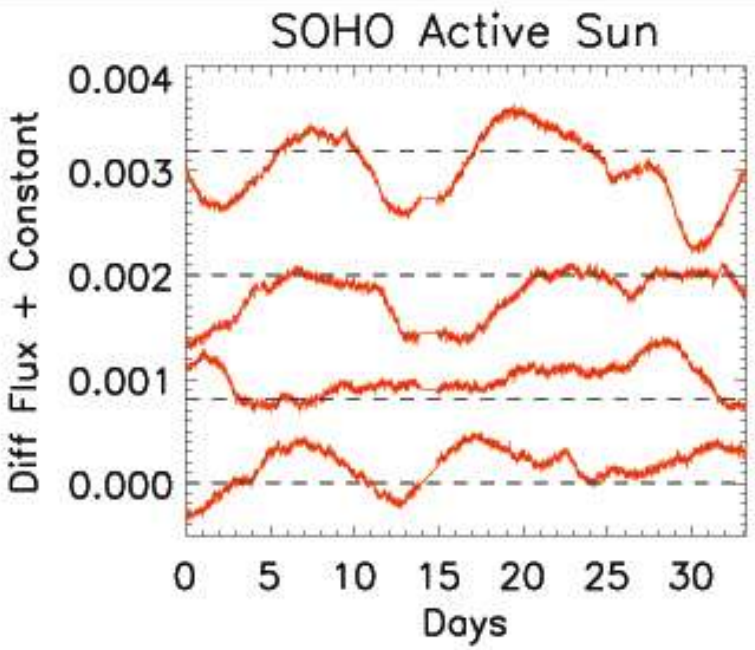
STARSPOT JITTER IN PHOTOMETRY, ASTROMETRY AND RADIAL VELOCITY MEASUREMENTS

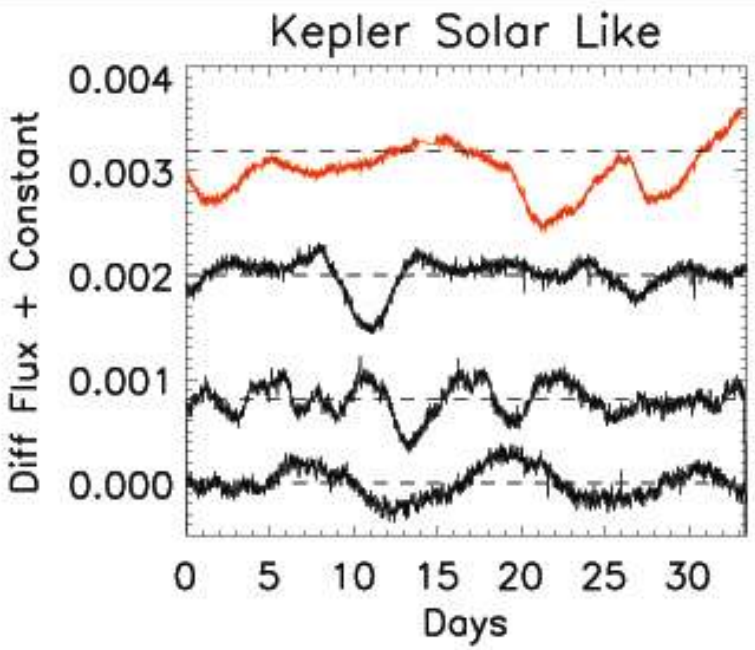
V.V. Makarov[1], C.A. Beichman[1], J.H. Catanzarite [2], D.A. Fischer[3], J. Lebreton[1], F. Malbet[1,4], M. Shao[2]

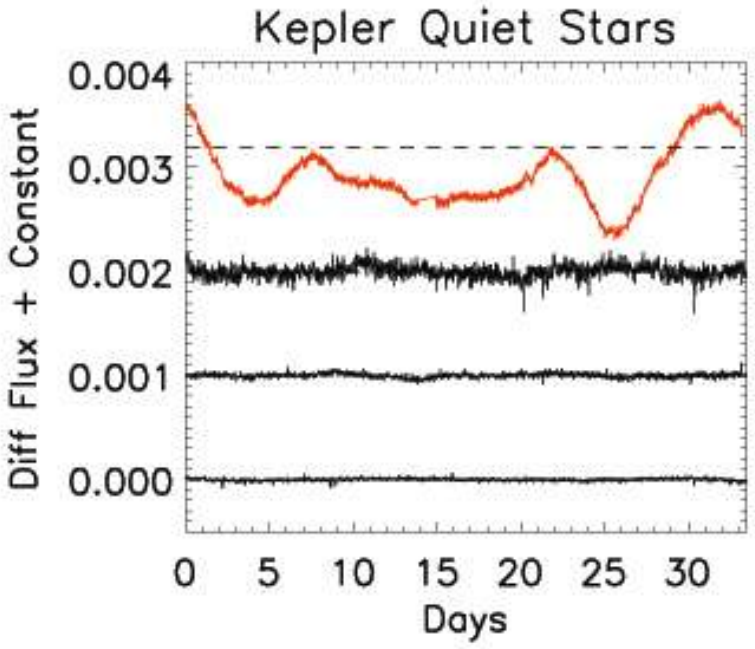
At a millimag of photometric variability,
reasonably low V_{rot}:
RMS ~ 0.001 mags * 2 km s^{-1} ~ *2 ms^{-1}*

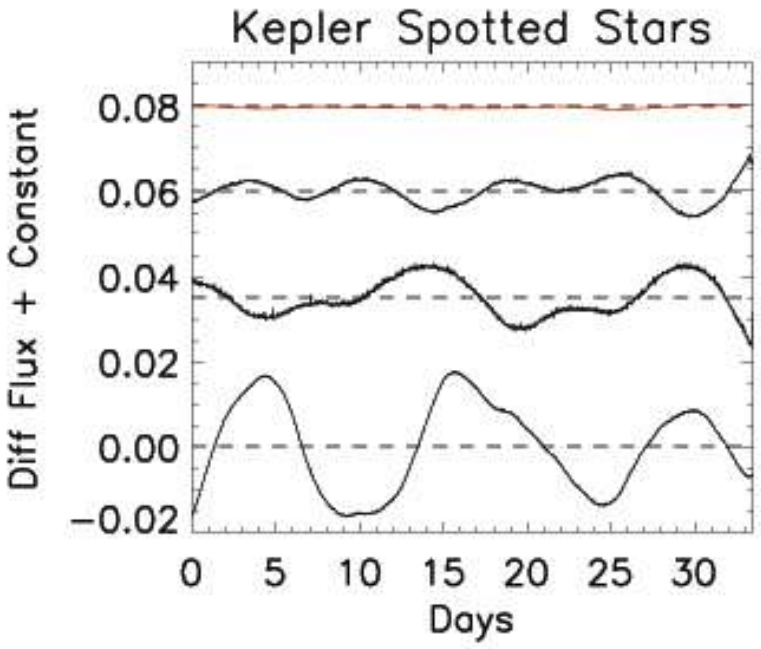
Kepler offers a new opportunity to translate between photometry and RV

- Simultaneous photometry can help reconstruct RV signal
- Spot modeling and RV variations can both estimate spot parameters
- Quantify: spot filling factor, differential rotation, etc.

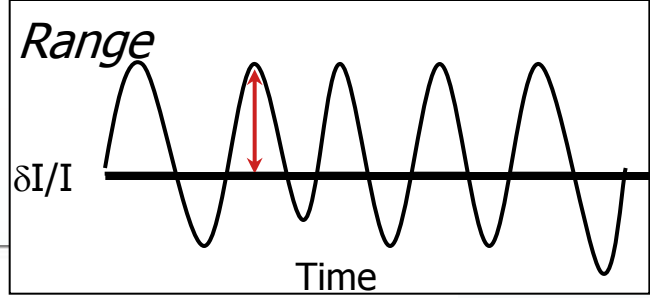

SOHO Active Sun
Diff Flux + Constant
0.004
0.003
0.002
0.001
0.000
0 5 10 15 20 25 30
Days

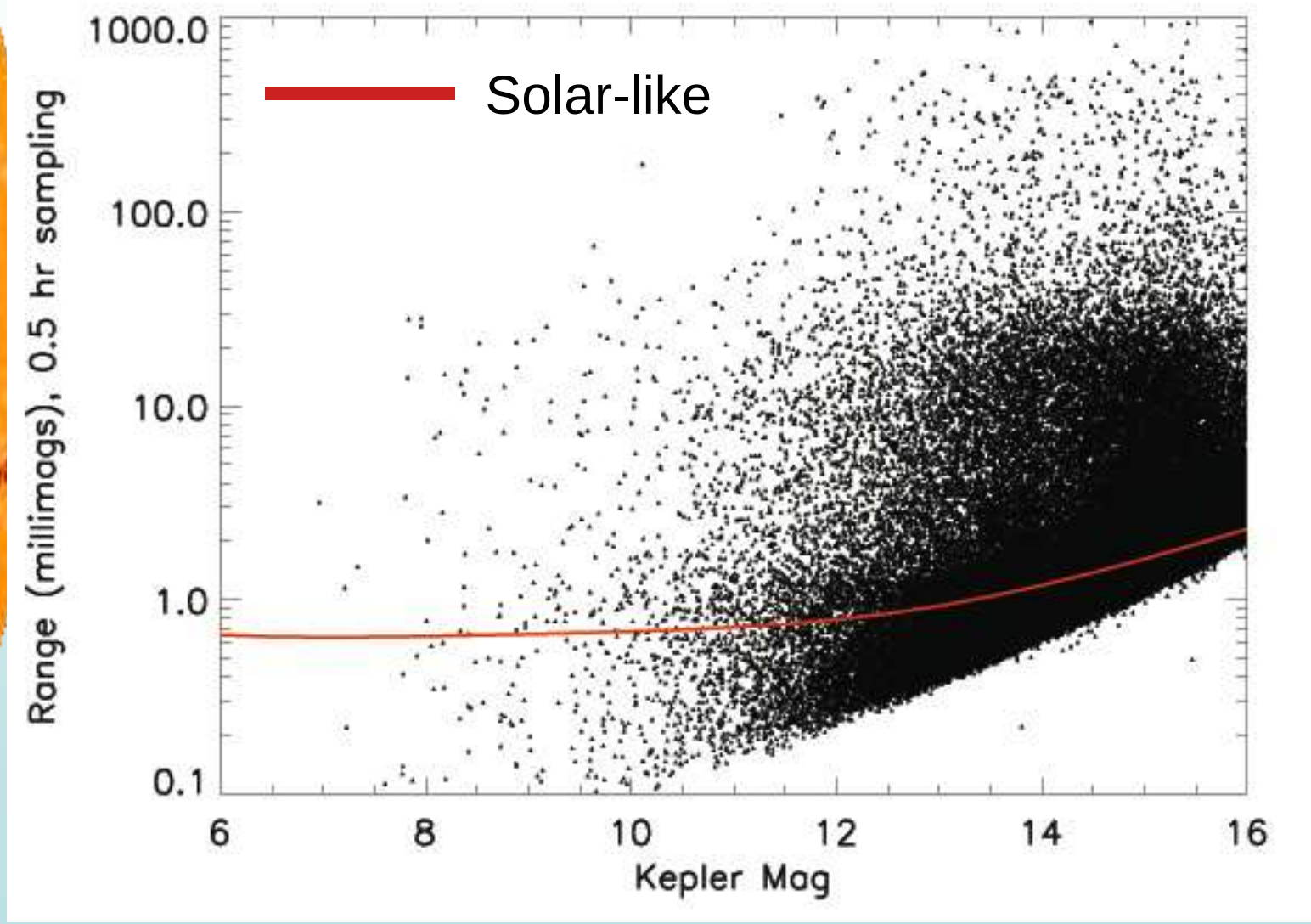

Kepler Solar Like
Diff Flux + Constant
0.004
0.003
0.002
0.001
0.000
0 5 10 15 20 25 30
Days


Kepler Quiet Stars
Diff Flux + Constant
0.004
0.003
0.002
0.001
0.000
0 5 10 15 20 25 30
Days

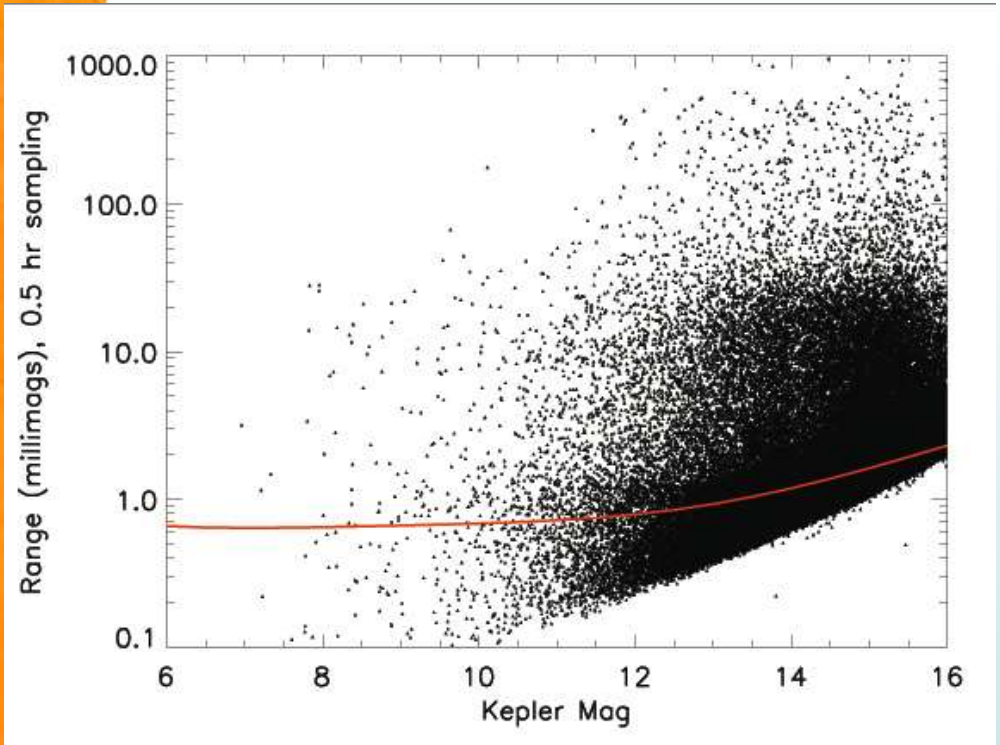

Kepler Spotted Stars
Diff Flux + Constant
0.08
0.06
0.04
0.02
0.00
−0.02
0 5 10 15 20 25 30
Days

What is Δmag?


Range
δI/I
Time


Solar-like
Range (millimags), 0.5 hr sampling
1000.0
100.0
10.0
1.0
0.1
6
8
10
12
14
16
Kepler Mag

Range of variability in Kepler stars

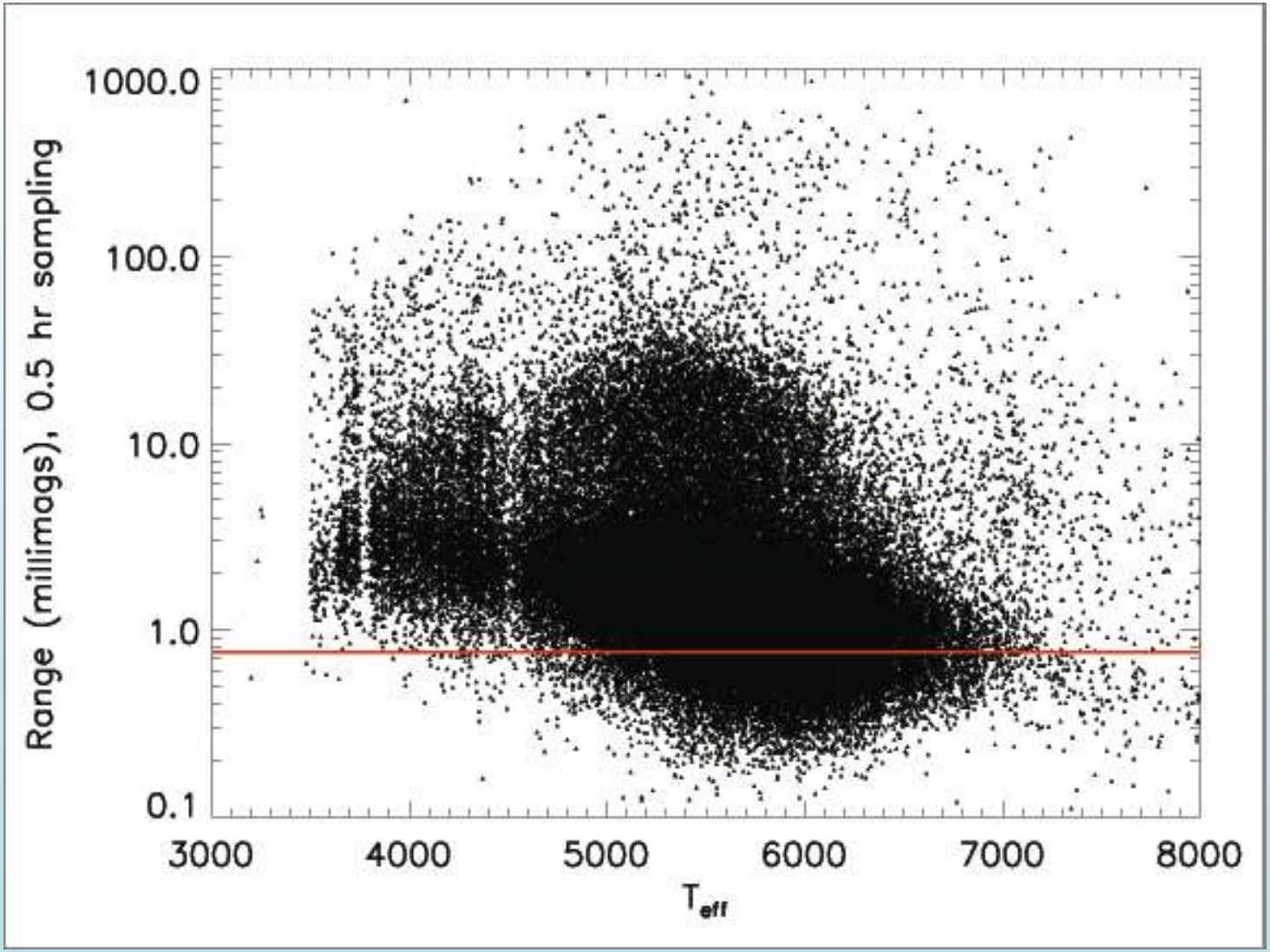


Minimum range in lightcurves increases for fainter stars-- rising “noise floor”

Smaller stellar signal for fainter stars combined with rising shot noise and fixed instrumental noise--

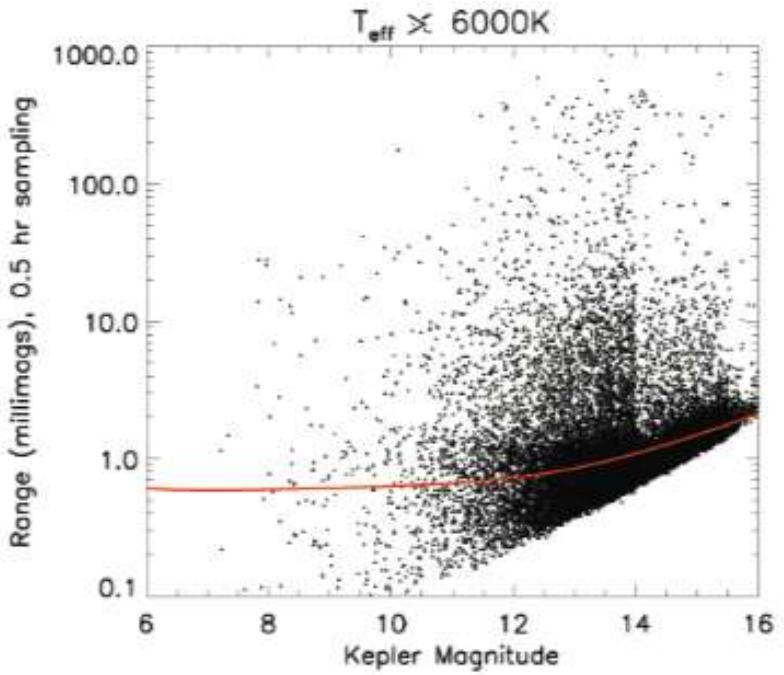
Minimum variability that can be detected is larger

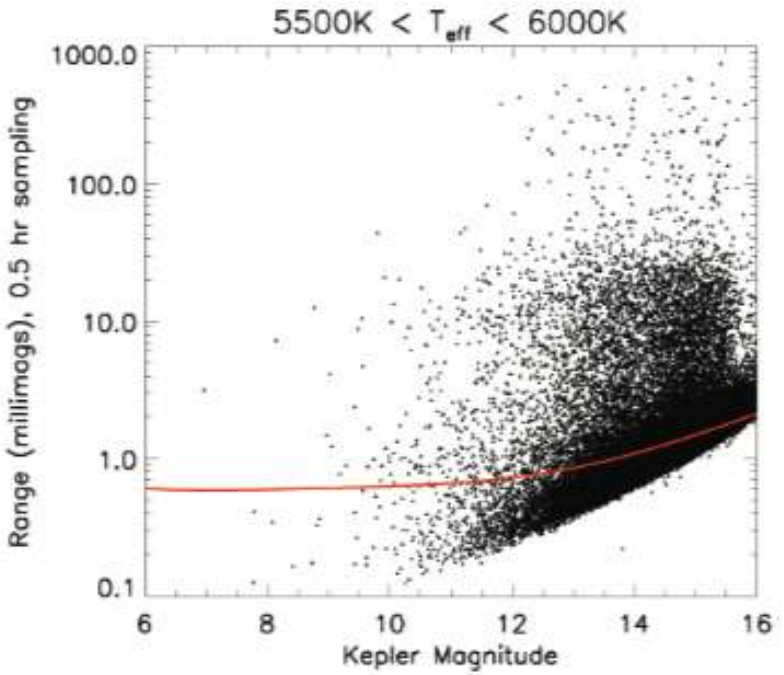
What is ∆mag?

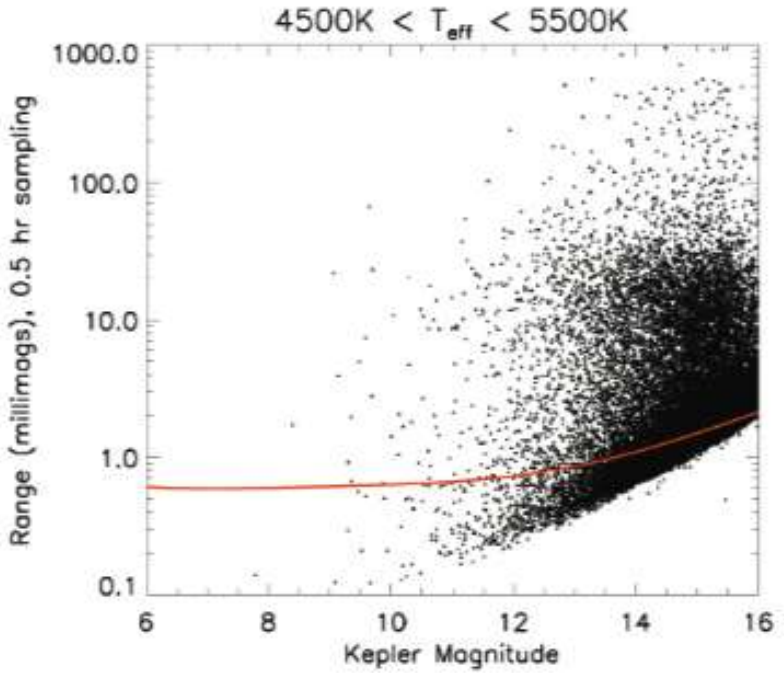

1000.0
100.0
10.0
1.0
0.1
Range (millimags), 0.5 hr sampling
3000
4000
5000
6000
7000
8000
T_eff

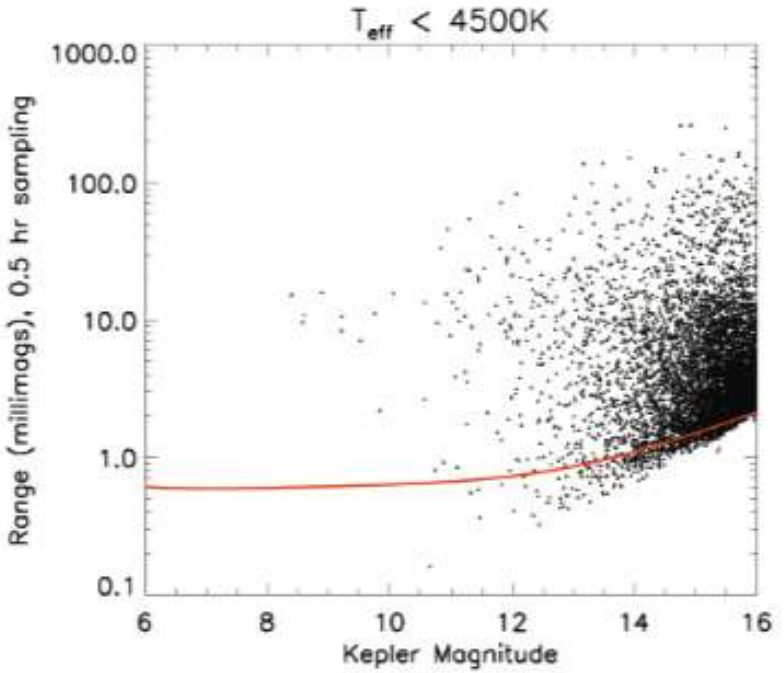
21,000 stars

35,000 stars









43,000 stars

6,500 stars

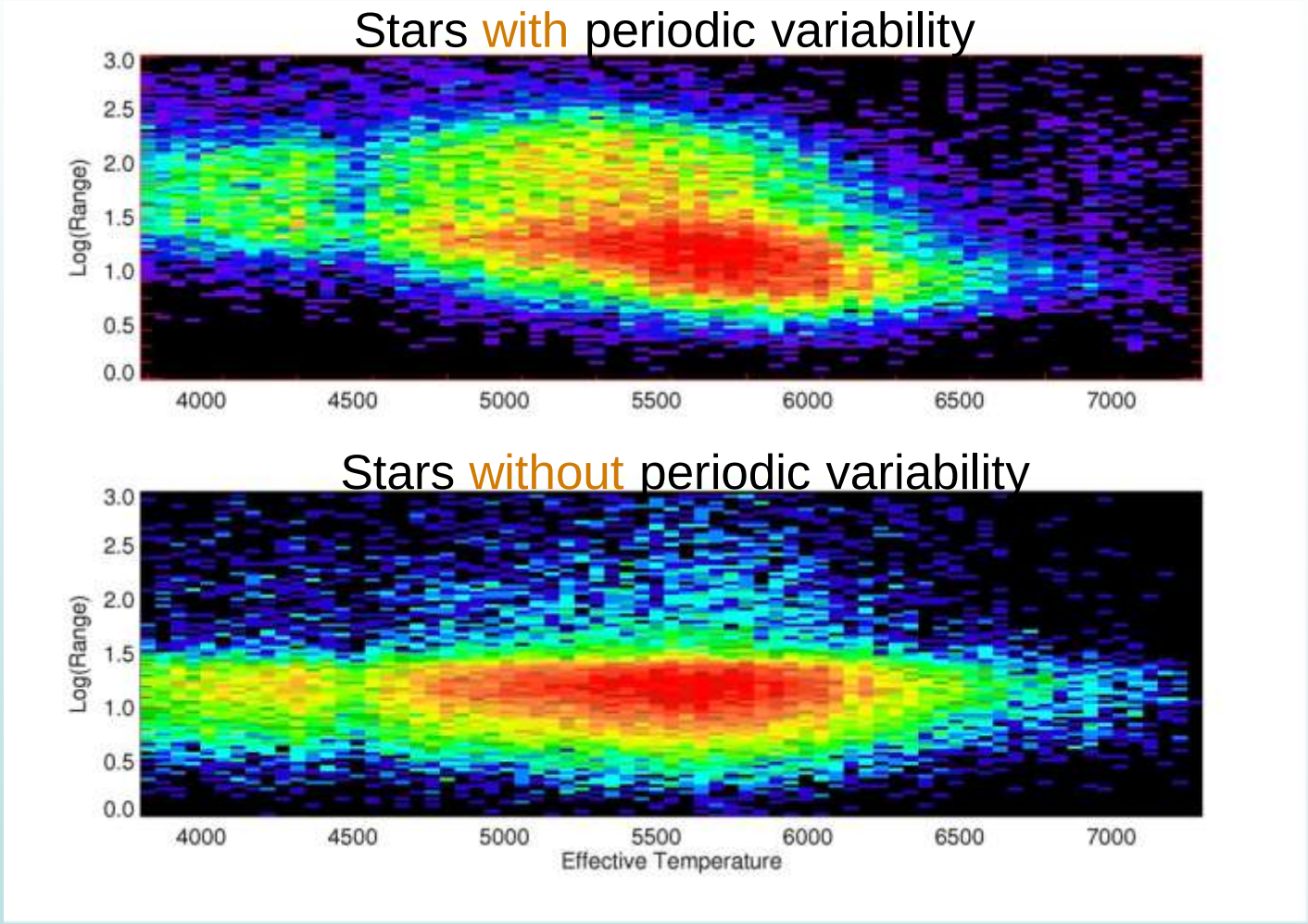
Entire sample: 46% of stars are more active than the active Sun, but only 18% are more than 2^{ce} as active.

Fraction of stars more active than the Sun

	T_{eff} > 6000 K	6000K > T_{eff} > 5500 K	5500 K> T_{eff} > 4500 K	T_{eff} < 4500 K
All stars	0.33 21023	0.37 42832	0.57 33288	0.87 6522
Bright stars	0.41 8747	0.31 6164	0.46 2613	0.84 369
Faint stars	0.33 12276	0.38 36668	0.57 30675	0.88 6153

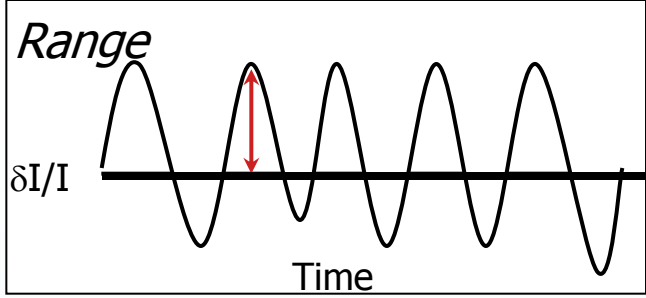
Boundary between "bright" and "faint" taken to be Kep Mag of 13.5

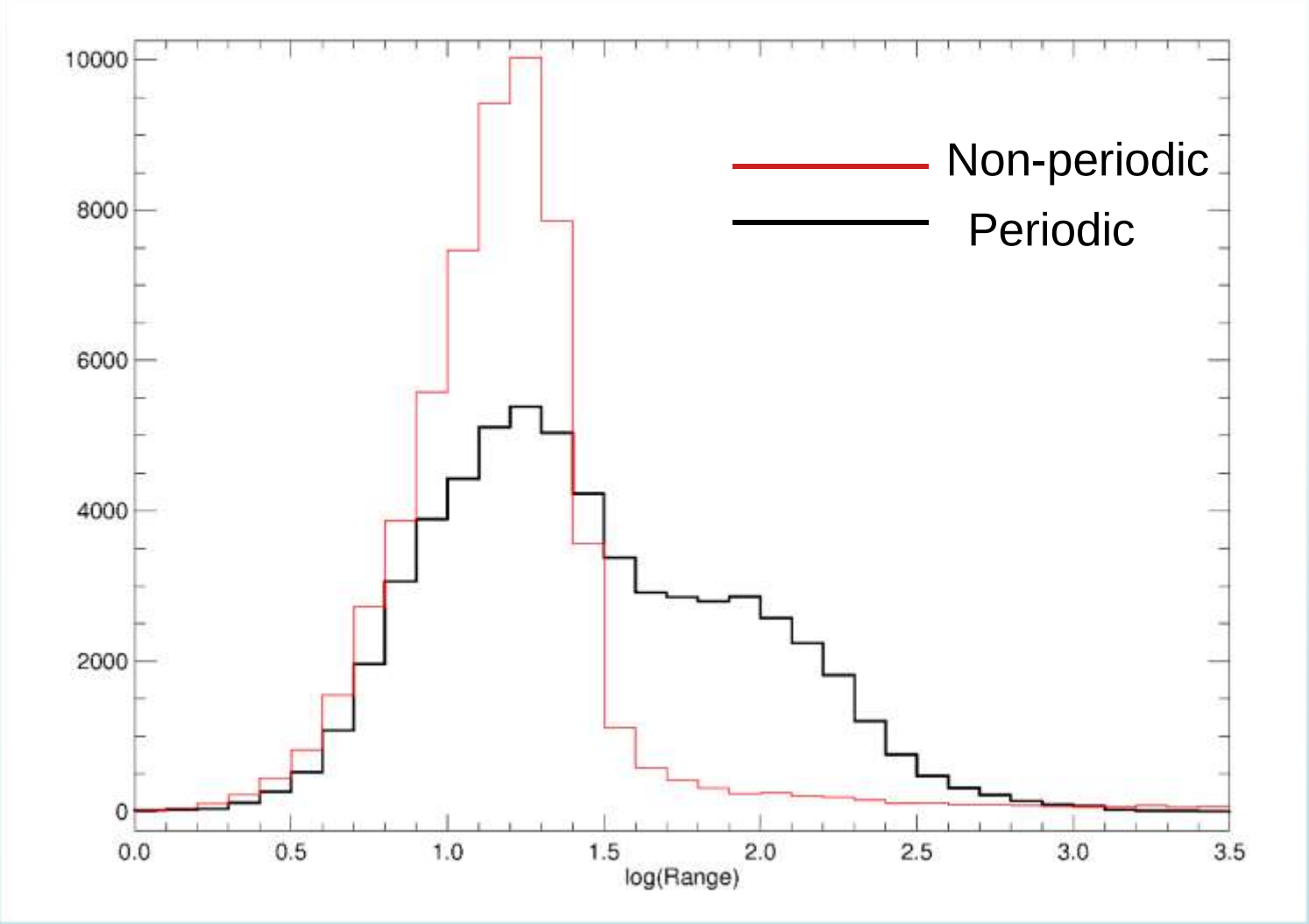
Q1 shows periodicity for short rotation periods*



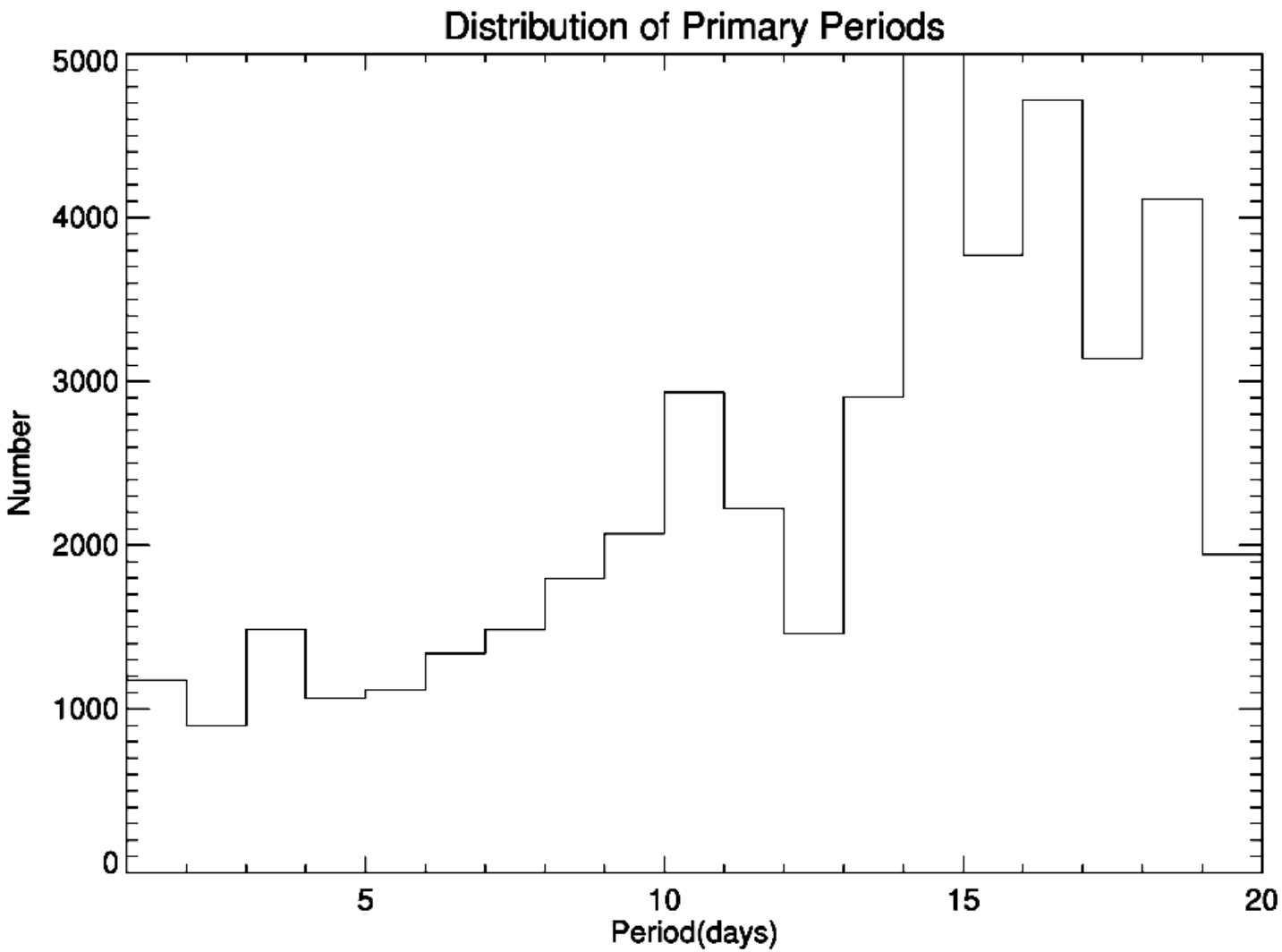
** Longer periods with additional data*

Basri, Walkowicz et al., submitted: arXiv:1008.1092





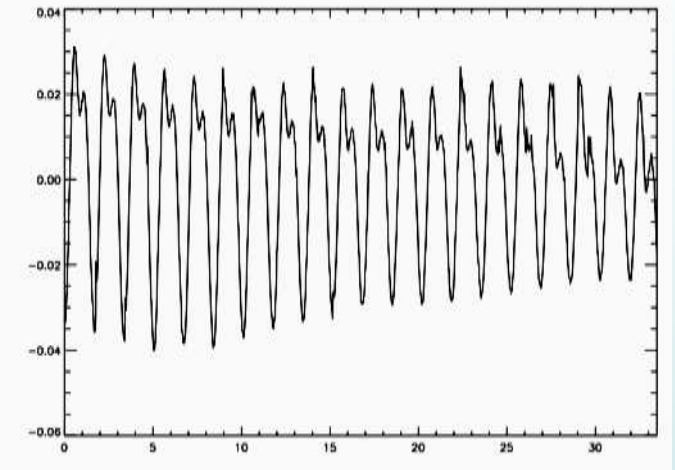
Basri, Walkowicz et al., submitted: arXiv:1008.1092

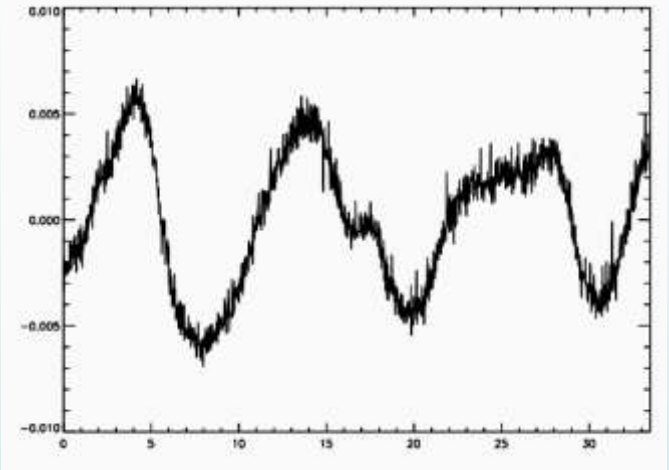


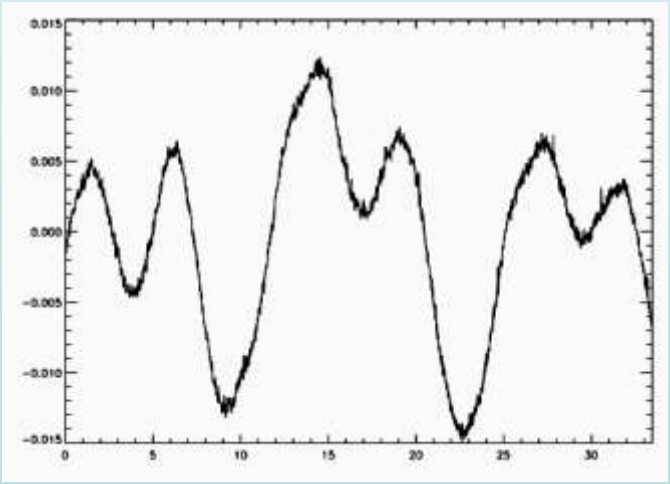
Basri, Walkowicz et al., submitted: arXiv:1008.1092

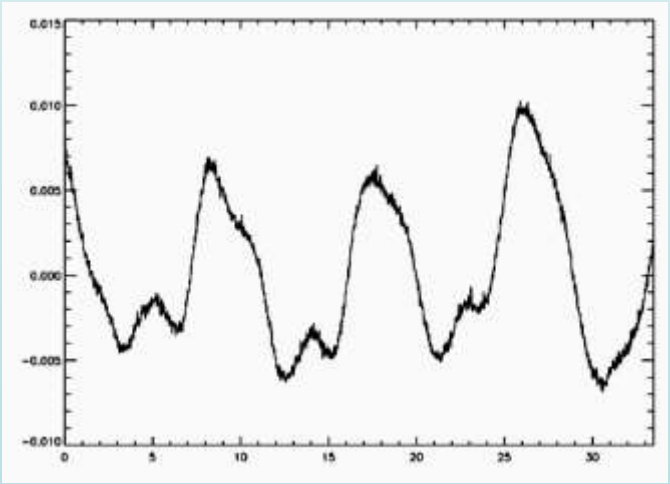
Differential rotation, spot evolution…

(lions and tigers and bears-- oh my!)



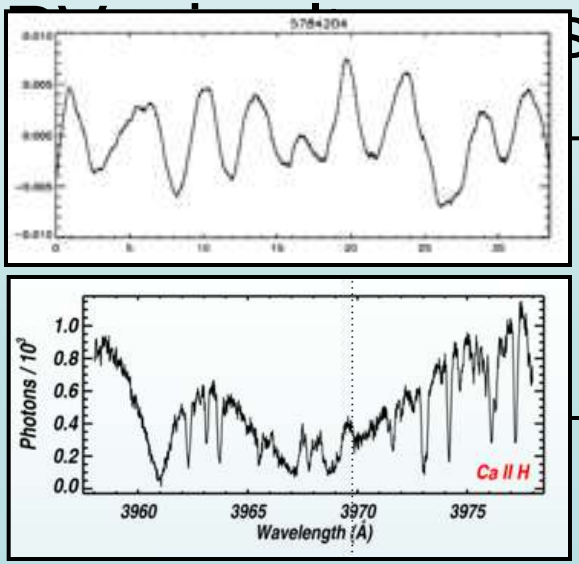




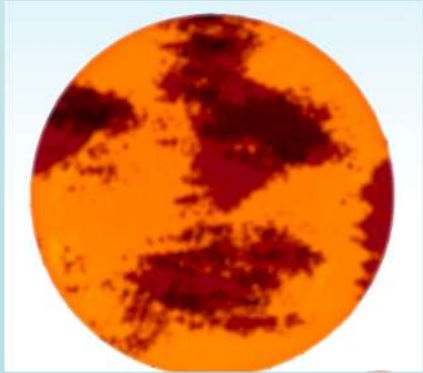


The Kepler Activity Project

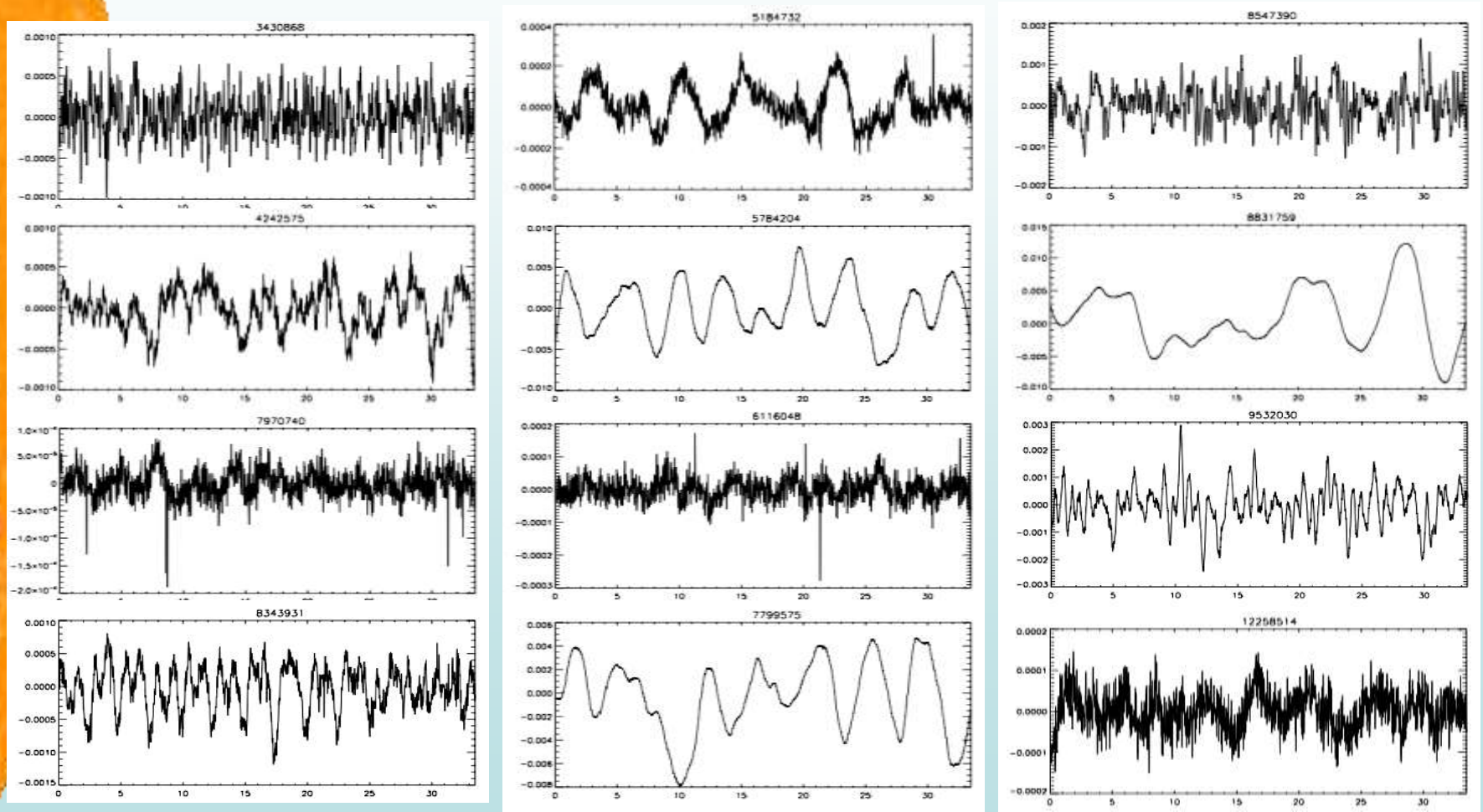
- Select bright dwarfs with Kepler photometry
  - 12 FGKM dwarfs brighter than Kp of 8.5
- Observe regularly to obtain RVs with HIRES
- Compare spectroscopic activity tracers to
  s photometry



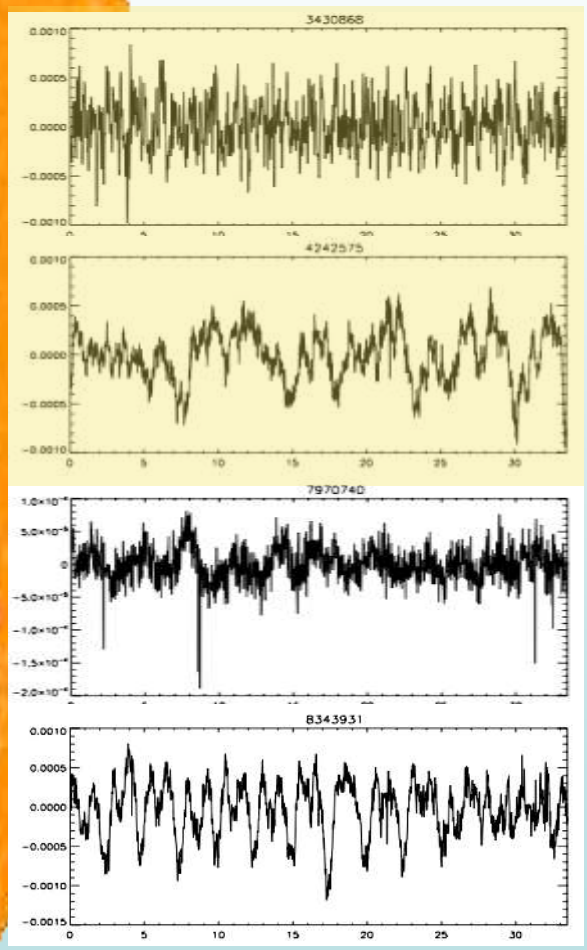
?

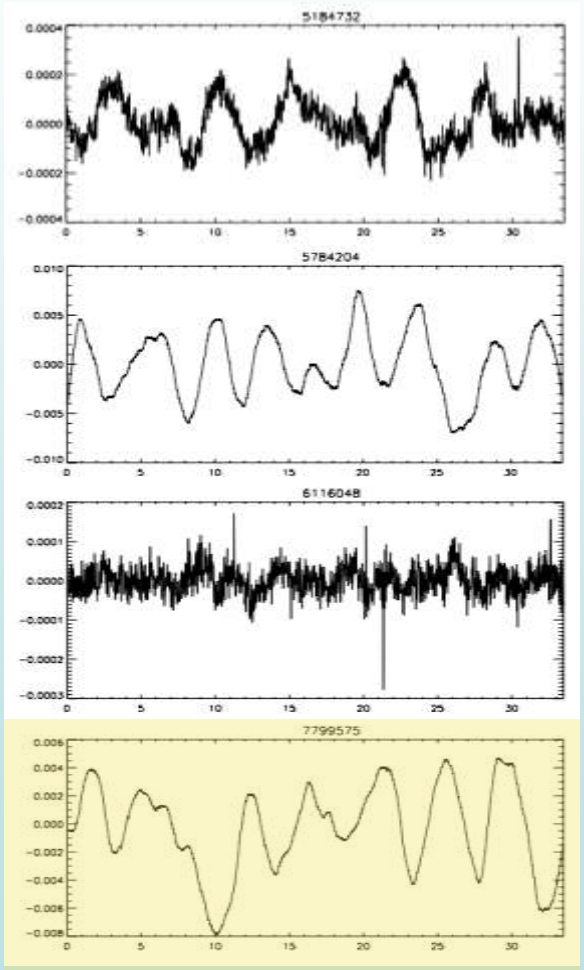


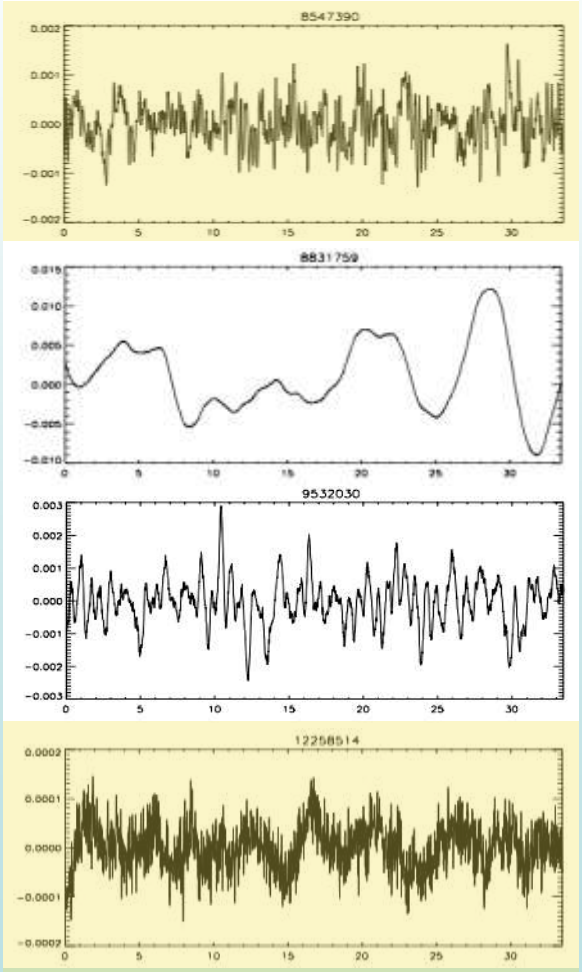
The Stellar Lineup

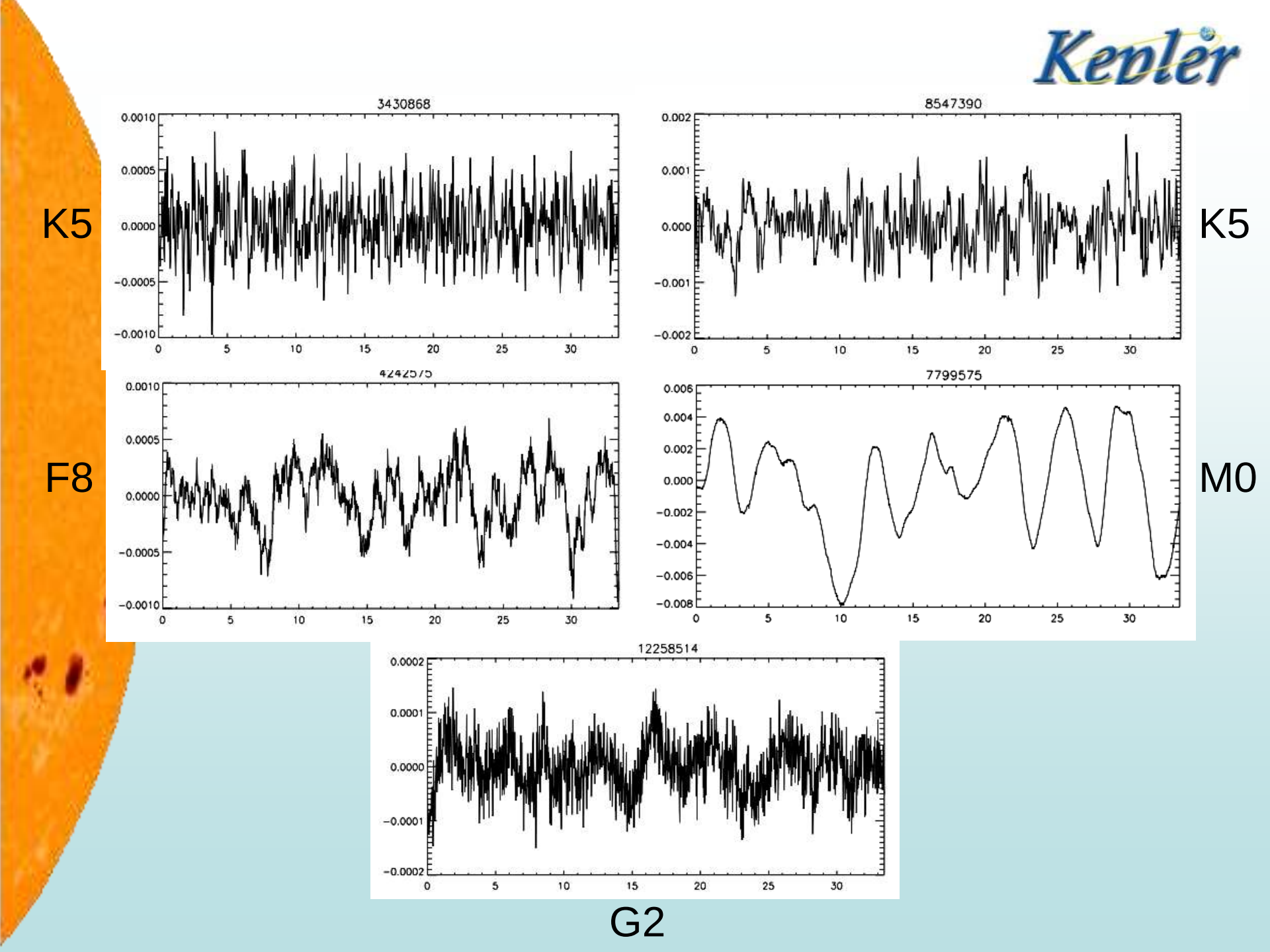


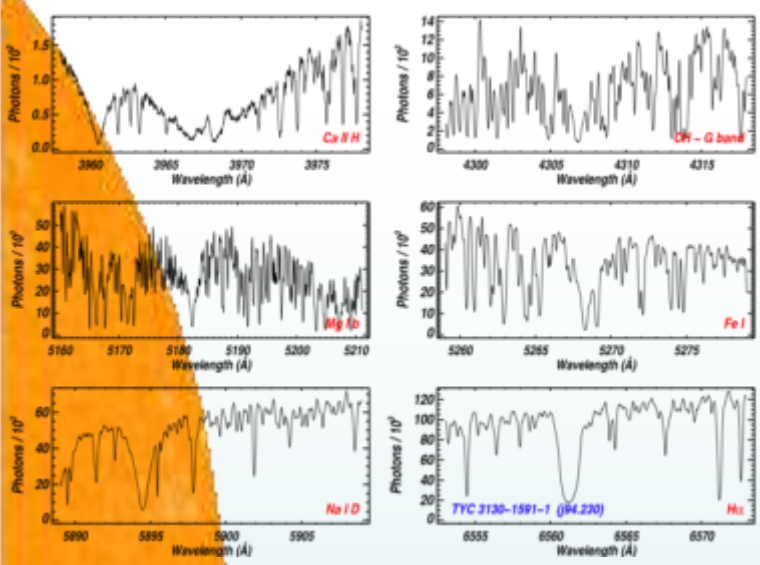
The Stellar Lineup



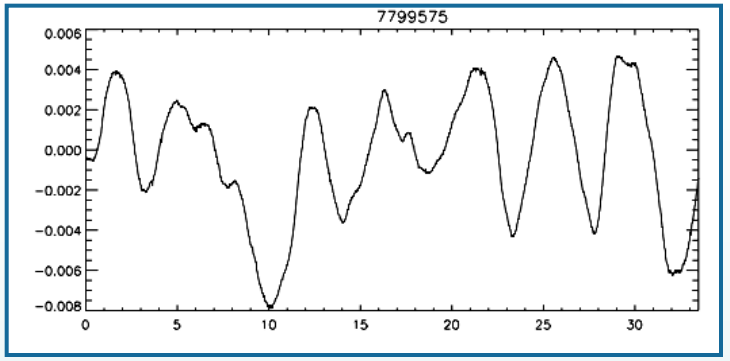





Kepler
3430868
8547390
K5
K5
F8
M0
7799575
12258514
G2



Kepler



KIC Parameters

T_{eff} = 3965

Log(g) = 4.416

[Fe/H] = 0.256

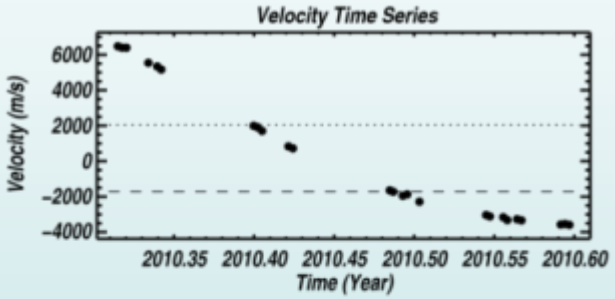
SME Parameters

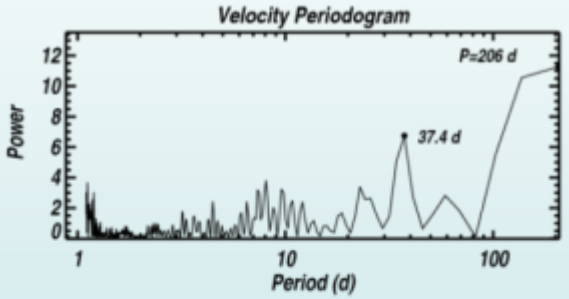
T_{eff} = 4271 (78)

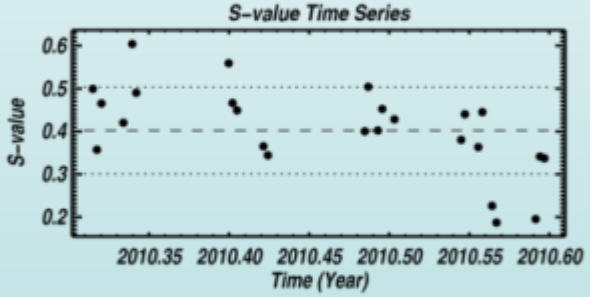
Log(g) = 3.28 (0.30)

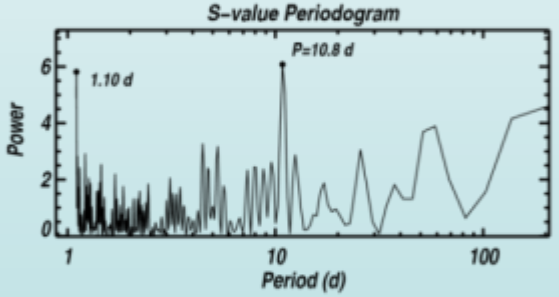
[Fe/H] = 0.56 (0.12)

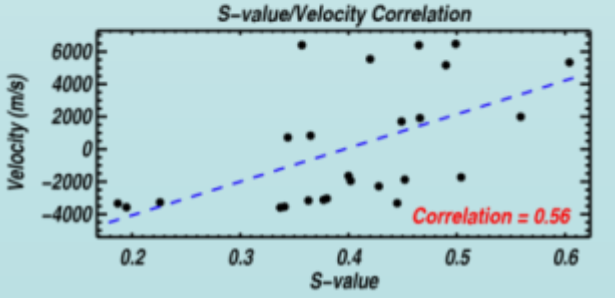
Poor SME fit











3130–1591–1

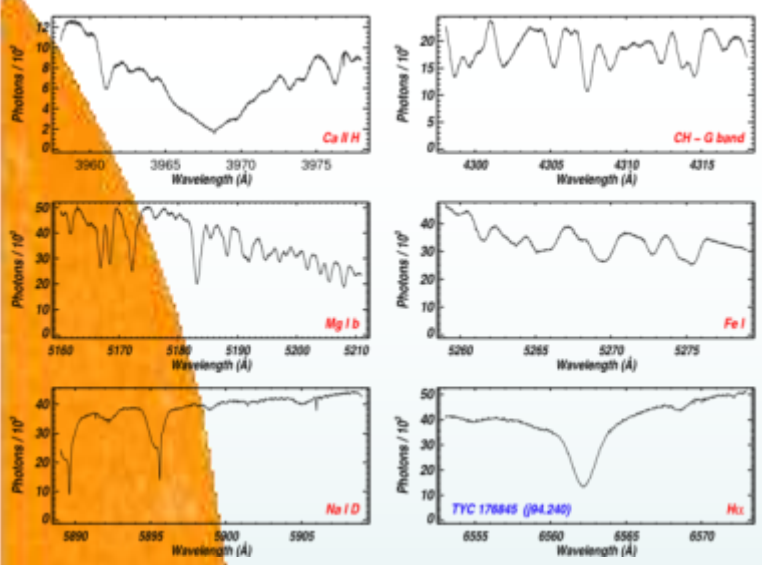
S–value = 0.402 ± 0.101

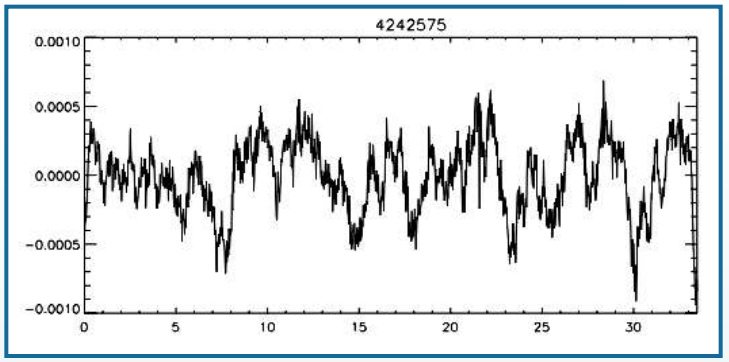
log(R'$_{HK}$) = 0.0 ± 0.0

P_{rot} ~ 0 days

Correlation = 0.56

Mon Aug 9 17:51:45 PDT 2010





KIC Parameters

T_{eff} = 6010

Log(g) = 4.243

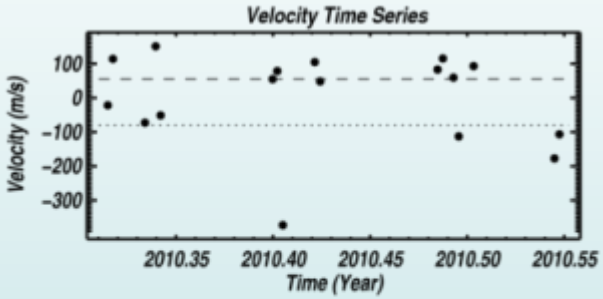
[Fe/H] = -0.147

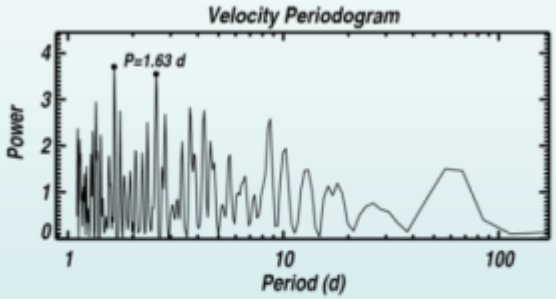
SME Parameters

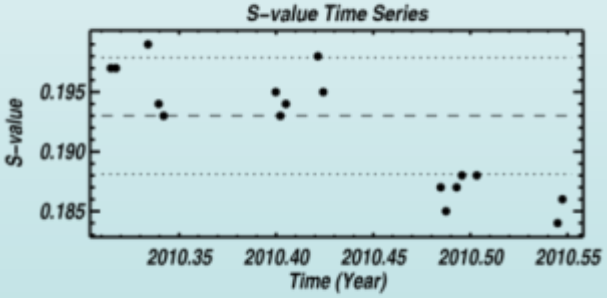
T_{eff} = 6369 (92)

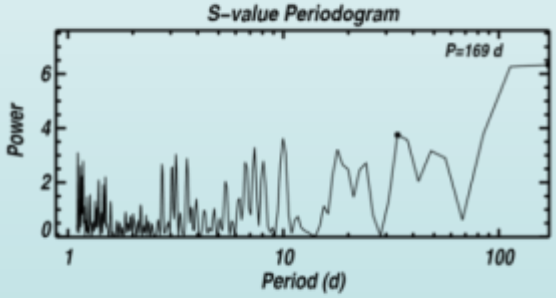
Log(g) = 4.29 (0.07)

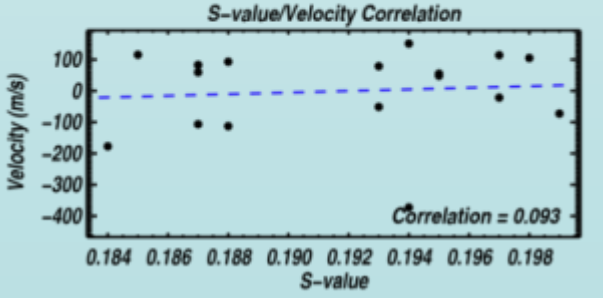
[Fe/H] = 0.47 (0.04)











176845

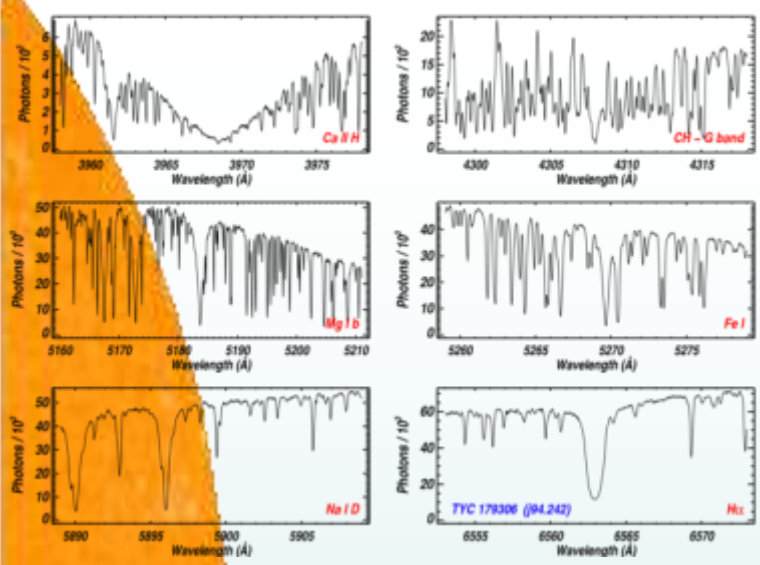
S–value = 0.193 ± 0.005

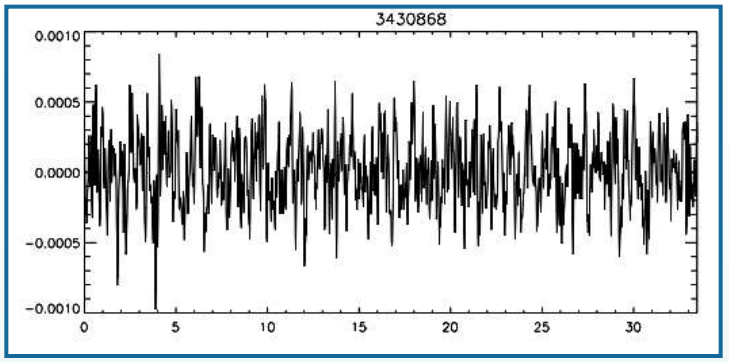
log(R'$_{HK}$) = 0.0 ± 0.0

P_{rot} ~ 0 days

Correlation = 0.093

Mon Aug 9 17:51:39 PDT 2010





KIC Parameters

T_{eff} = 4729

Log(g) = 4.584

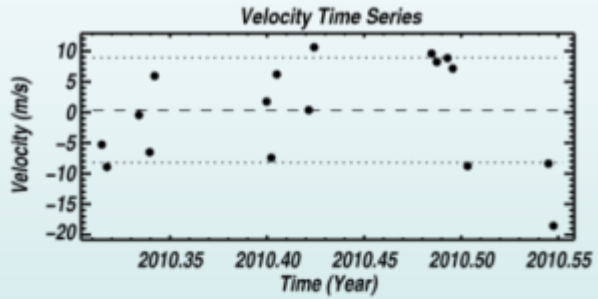
[Fe/H] = -2.500

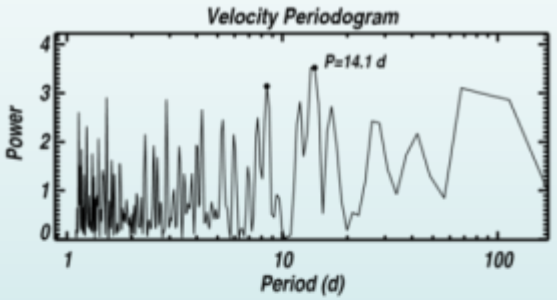
SME Parameters

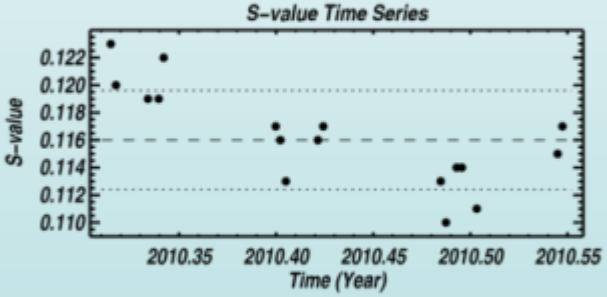
T_{eff} = 5297 (44)

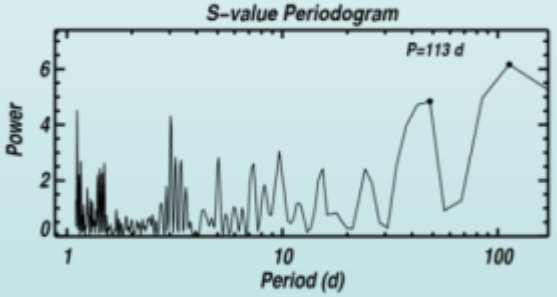
Log(g) = 3.37 (0.06)

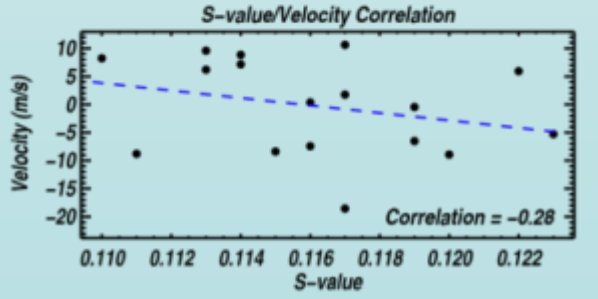
[Fe/H] = 0.29 (0.04)











179306

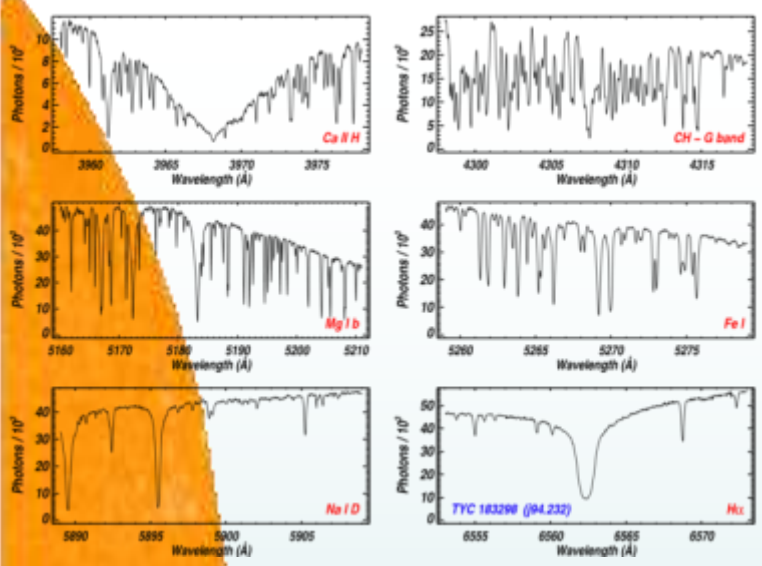
S–value = 0.116 ± 0.004

log(R'$_{HK}$) = 0.0 ± 0.0

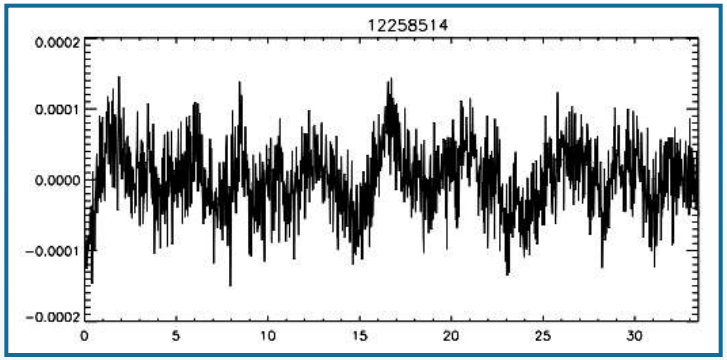
P$_{rot}$ ~ 0 days

Correlation = –0.28

Mon Aug 9 17:51:52 PDT 2010



Kepler



KIC Parameters

T_{eff} = 5808

Log(g) = 4.301

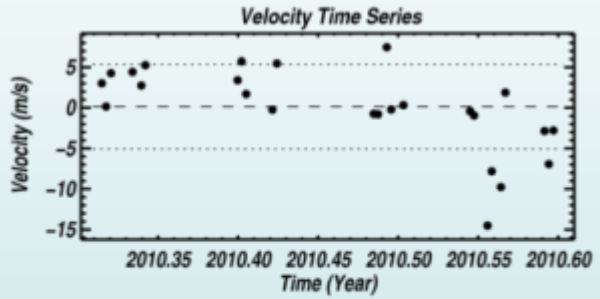
[Fe/H] = 0.086

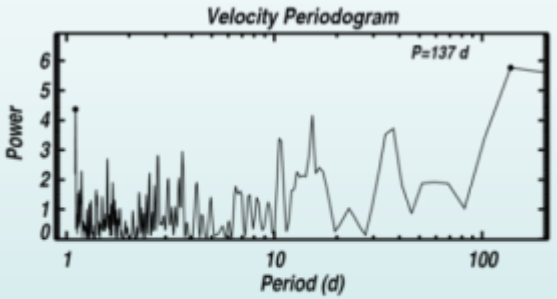
SME Parameters

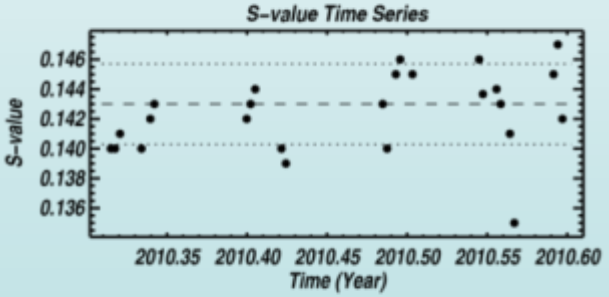
T_{eff} = 5946 (44)

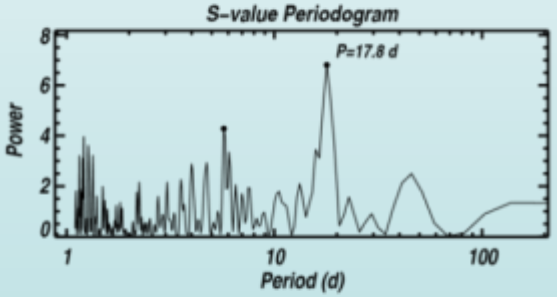
Log(g) = 4.06 (0.06)

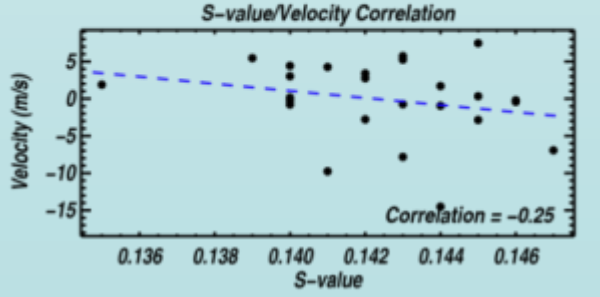
[Fe/H] = 0.07 (0.04)











183298

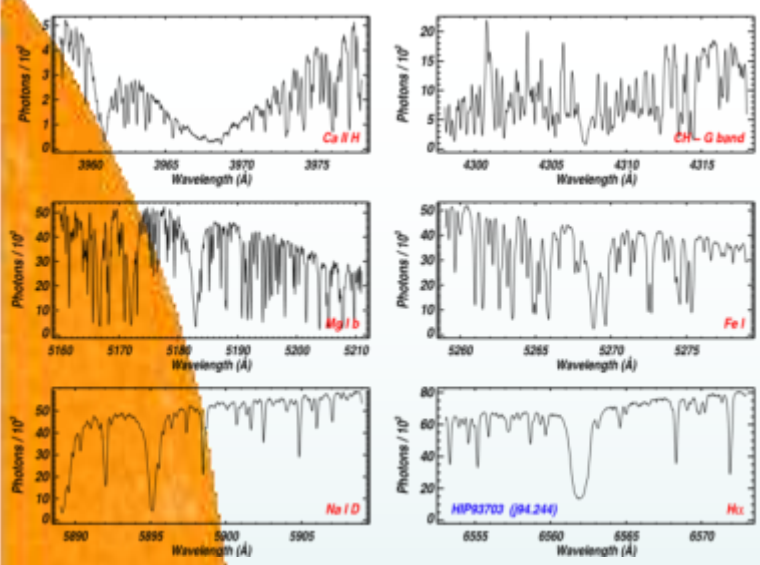
S–value = 0.143 ± 0.003

log(R'$_{HK}$) = 0.0 ± 0.0

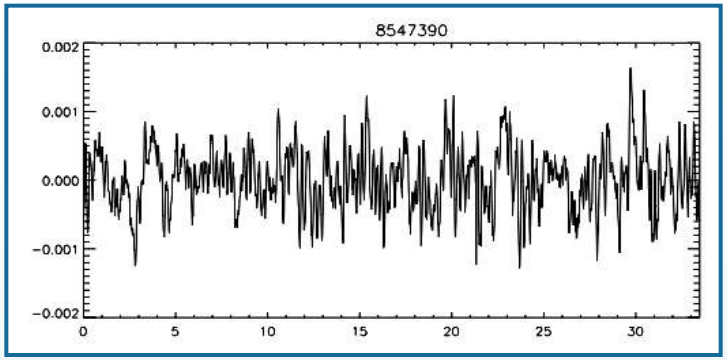
P$_{rot}$ ~ 0 days

Correlation = –0.25

Mon Aug 9 17:52:05 PDT 2010



Kepler



KIC Parameters

T_{eff} = 4643

Log(g) = 4.609

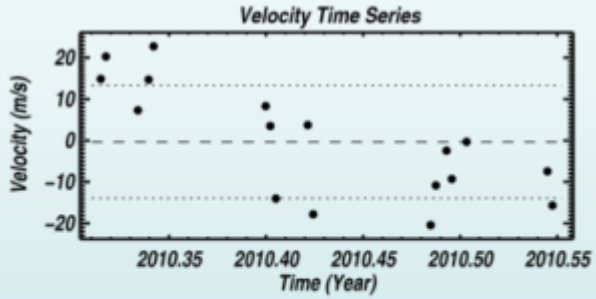
[Fe/H] = 0.118

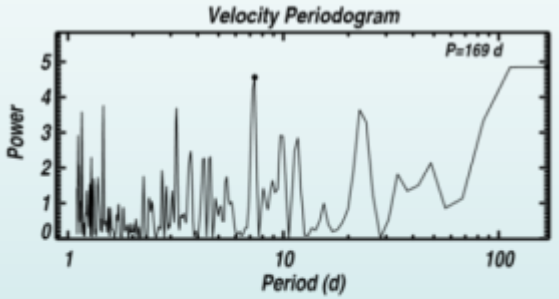
SME Parameters

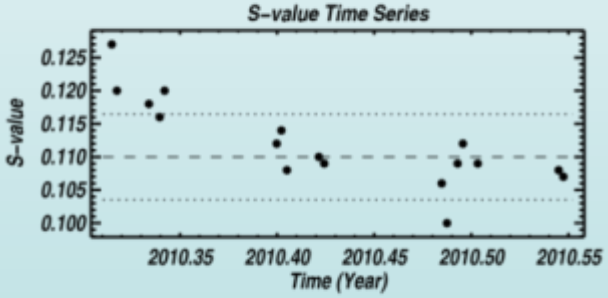
T_{eff} = 4924 (58)

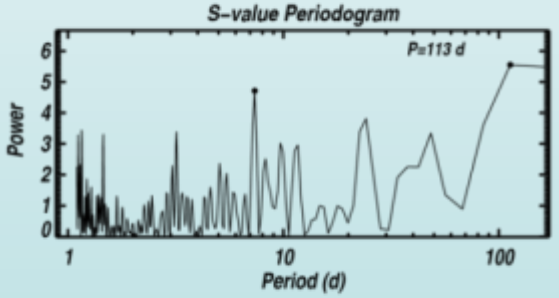
Log(g) = 3.07 (0.10)

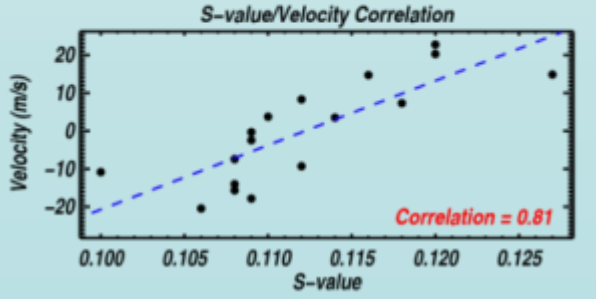
[Fe/H] = 0.33 (0.05)











hip93703

S–value = 0.110 ± 0.006

log(R'$_{HK}$) = 0.0 ± 0.0

P_{rot} ~ 0 days

Correlation = 0.81

Mon Aug 9 17:51:58 PDT 2010

Summary

- Variability above solar is common, not exceptional
- Stellar activity introduces quasi-periodic signals at a variety of timescales
- Simultaneous RVs and photometry may help us better understand how activity affects planet detection
- Spot modeling also in progress–

  stay tuned!

Fin