Ca II K-line Monitoring Program

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- **The National Solar Observatory/Sacramento Peak disk-integrated Calcium II K-line data set spans the period from November 1976 through the present.**
- **The data has been compared with several other data sets which also indicate the level of solar activity.**
- **The data has been used to estimate chromospheric heating as a function of the solar cycle.**
- **The data is available via ftp or through the web at NSO/SP.**

Observations

The observational set-up is similar to that used by Beckers, Bridges, and Gilliam (1976) to make the Sacramento Peak High Resolution Spectral Atlas of the Solar Irradiance.

The set-up uses the coleostat and the horizontal Littrow spectrograph of the Evans Coronal Facility (ECF) at Sacramento Peak.

A 5 mm focal length cylindrical lens focuses the solar image on the entrance slit of the spectrograph. This lens forms a one dimensional image of the sun which is slightly smaller in height than the spectrograph slit.

A decker slit behind the cylindrical lens blocks out excess light.

The Littrow is used in double pass to further reduce scattered light.

All of the light from the grating is imaged onto a photomultiplier tube.

The spectrum is scanned from 389.8 to 395.4 nm in 0.55 nm steps. Approximately 150 spectral scans are used to form a daily average.

The entrance slit is closed to measure noise and the intermediate slit is closed to measure scattered light.

Reduction

- **The daily averaged spectra are high frequency filter to remove residual noise.**
- **A gain and offset for each profile is determined by correlating 400 points in a continuum window in the red-wing of the line with a reference profile. This compensates for changes in the response of the photomultiplier.**
- **Each profile is then normalized by assuming that the mean value in a 0.0528 nm wide window at 0.1187 nm from the core has an intensity equal to 0.162 of the local continuum.**
- **7 parameters are deduced from the calibrated line profiles and used to measure changes in the K line over the solar cycle and to perform correlations with other data sets.**

Measured Parameters

EM	**Emission Index, The equivalent width in a 0.1 nm band centered on the K line core**
K_3	**Intensity in the Core**
K_{2V}/K_3	**Relative strength of the blue K_2 emission peak wrt the K_3 intensity**
K_{2V}-K_{2R}	**Separation of two emission maxima**
K_{1V}-K_{1R}	**Separation of blue and red K_1 minima**
K_{2V}/K_{2R}	**The line asymmetry, which is the ratio of the blue and red emission maxima**
WB	**The Wilson-Bappu parameter, width measured between the outer edges of the emission peaks**

Chromospheric Heating

Quantitiy (max-min)	Cycle	Total	Chromospheric
ΔEM	21	20.6%	45%
ΔEM	22	27.6%	55%
ΔK3	21	43%	49%
ΔK3	22	49%	57%

K3 and EM show similar increase over the solar cycle.

Heating and radiative loss rate over the cycle are not isolated to the high chromosphere.

Chromospheric Heating

$\Delta(K_{2V}/K_3)$ - 6% Average Decrease

- 19% Maximum Decrease

Chromospheric Opacity Decreases with increasing activity.

$$\frac{\Delta(I_{K2V})}{\langle I_{K2V}\rangle} \cong \frac{\Delta I_{K3}}{\langle I_{K3}\rangle} \Rightarrow \text{Uniform Heating}$$

K_{2V} - K_{2R} narrows and K_{1V} - K_{1R} widen at solar maximum as predicted by Ayres for non-radiative heating.

Ca II K-Line Regression Coefficients

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y = A + B*EM

	A	B	σ_a	σ_b	cc
K_3	-0.06	1.38	0.0007	0.007	0.99
K_3 Max	-0.06	*1.39*	0.004	0.04	0.94
K_3 Min	-0.03	*1.09*	0.003	0.04	0.93
K_{2V}	-0.03	1.45	0.006	0.007	0.99
K_{2V} Max	-0.04	*1.58*	0.003	0.03	0.98
K_{2V} Min	0.006	*1.04*	0.006	0.07	0.85
K_{2V}/K_3	2.40	-9.32	0.017	0.187	-0.83
K_{2V}/K_{2R}	1.84	-6.17	0.023	0.250	-0.59
ΔK_2	0.56	-2.09	0.009	0.093	0.56
ΔK_1	-0.26	9.59	0.015	0.164	0.87
WB	1.28	3.24	0.008	0.092	0.72

Max = Solar Maximum (89-92)
Min = Solar Minimum (85-86)

Ca II Parameters
Correlation Coefficients

	K3	WB	K2V/K2R	K2V/K3	DK1	Dk2
EM	0.99	0.79	-0.64	-0.88	0.90	-0.63
K3	-	0.78	-0.62	-0.92	0.90	-0.61
WB	-	-	-0.63	-0.69	0.95	-0.17
K2V/K2R	-	-	-	0.59	-0.67	0.35
K2V/K3	-	-	-	-	-0.78	0.51
DK1	-	-	-	-	-	-0.45

Ca Emission Index vs Other Parameters
Correlation Coefficients

	Raw	All	Min	Max	Rise	Fall
He EQW	0.92	0.71	0.65	0.75	0.53	0.57
B Corr	0.89	0.62	0.49	0.70	0.37	0.56
Lyman a	0.86	0.60	0.43	0.64	-	-
Radio	0.93	0.68	0.52	0.75	0.53	0.59
Sunspot #	0.87	0.58	0.52	0.62	0.55	0.54
Mg II	0.93	0.78	-	0.87	-	0.61

Raw - All data, with Solar Cycle Present
All - All data, with Solar Cycle Removed
Min - Solar Minimum (85-86)
Max - Solar Maximum (89-92)
Rise - Rising Phase of Cycle (87-88)
Fall - Declining Phase of Cycle (93-96)