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VARIATION OF THE SOLAR HE I 10830 Å LINE: 1977-1980

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ABSTRACT

Daily measurements of the equivalent width of the 10830 Å He I line integrated over the visible disk show:

1. An increase from about 32 to about 74 mÅ in the monthly mean values from the minimum to the maximum of the current solar cycle.

2. The monthly mean values are more smoothly varying than most other indices of solar activity.

3. Rotation modulates the daily values in a highly variable manner with amplitudes as large as ± 20%.

4. The apparent synodic rotation period is 29 days rather than the expected 27 days associated with active regions.

5. Despite great differences in the appearance of the sun in 3933 Å Ca I and 10830 Å He I, the central intensity of the former correlates with the equivalent width of the latter with a value r = 0.97.

INTRODUCTION

The 10830 Å line of He I is controlled in part by coronal radiation shining on the chromospheric layers where the line is formed (ref. 1). It is thus a convenient probe, readily observed from the ground with good spatial resolution (ref. 2), of coronal features such as coronal holes, bright points, filament channels, the bases of coronal streamers and other solar features which involve high temperatures (ref. 3). The line can be observed in a wide range of stars (ref. 4) and it is of considerable interest to ask how strong the line would appear in the sun, observed as a star, and how solar activity would be manifest in such observations. To address this problem, daily full disk spectroheliograms taken at Kitt Peak using the 10830 Å line have been

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spatially integrated to yield measurements of the equivalent width of the line in the sun seen as a star. The observations span a range from 1974 to the present but only 1977 through 1980 have been completely processed.

RESULTS

SOLAR CYCLE VARIATION

Figure 1 shows the variation of the 10830 Å line equivalent width averaged over one month intervals from 1976 to 1980. The low value of about 32 mÅ corresponds in time with the minimum of solar activity while the high value of 74 mÅ corresponds to the peak of solar activity in November 1979. This plot has been compared with monthly mean sunspot numbers, calcium plage index, 2800 MHz flux values, soft x-ray flux values, etc. The best correlation is with 2800 MHz flux but the 10830 Å values vary significantly more smoothly than this and other indices. Presumably this behavior is due to the relatively large contribution to the 10830 Å signal from old, long-lived active regions.

ROTATIONAL MODULATION

Plots of daily 10830 Å values covering a long time period show a clear signature of solar rotation. The typical behavior is a period of obvious modulation for 3-5 rotations followed by a similar period of little discernible rotational modulation. The amplitude of the modulation has been observed to be as large as ±20% of the mean values. Figure 2 shows an example of strong rotational modulation. The cause of this modulation can be found by examination of the spatially resolved daily images. The modulation is due to active regions clustered in a limited range in longitude for a period of a few months. Once in a while the clustering of active regions produces modulation at half the rotation period as, for example, in figure 3.

A surprise was the rotation period derived from the plots. It is found to be 29 days synodic rather than the 27-day synodic period expected for active regions. The cause of this discrepancy appears to be successive development of active regions at the eastern edge of an active longitude range together with rapid decay of active regions at the western edge of the range. The individual active regions within a limited range of active longitudes do rotate with the expected period of slightly more than 27 days. Whether or not this behavior in active region development indicates some large scale phenomenon requires further study.

COMPARISON WITH CALCIUM MEASUREMENTS

Images of the sun made with the 10830 Å He I line do not look like solar images made using other spectral lines. In particular, the helium images show filaments as the strongest features, a rather diffuse appearance to active regions, and a manifestation of coronal features such as coronal holes and bright points. Therefore if one compares daily integrated flux measurements of the sun made with 10830 Å and say 3933 Å Ca II, one would expect considerable differences. This comparison is shown in figure 4 based on daily measurements of the central intensity of the calcium K line by White and Livingston (ref. 5). Contrary to expectation, the agreement is very good with a linear correlation coefficient r = 0.97. Evidently active regions dominate the 10830 Å signal (as they do for the K line) so that other 10830 Å solar features which do not appear in the K line are feeble by comparison.

CONCLUSIONS

The 10830 Å He I line provides a satisfactory means for monitoring solar cycle variations of the chromosphere. In spite of its sensitivity to coronal radiation, the variation of the 10830 Å line strength with time closely follows other indices of solar activity, especially the 2800 MHz and K line integrated fluxes. The unique value of the 10830 Å line appears to be in measuring stellar cycles in other stars in which the K line is difficult to observe.

Experience with the sun suggests that use of chromospheric line fluctuations as indicators of stellar rotational periods is not straightforward. The rotation period we derive differs from the true rotation rate by 7%. This curious discrepancy may be due to a large-scale ordering of the occurrence of solar activity, and may therefore prove to be a powerful diagnostic of such a large scale phenomenon, but more work is needed.

It is surprising and somewhat disappointing that the 10830 Å line measurements agree so well with K line measurements. This means that high temperature phenomena in the solar atmosphere cannot be monitored easily with the 10830 Å line. Presumably the same difficulty would arise in monitoring other stars. The result is that it may prove to be very difficult to discern important features such as coronal holes in other stars by ground-based measurements.

REFERENCES

1. Goldberg, L.: The Temperature of the Solar Chromosphere. Ap. J., 89, 1939, pp. 673-678.

2. Livingston, W. C.; Harvey, J.; Pierce, A. K.; Schrage, D.; Gillespie, B.; Simmons, J.; and Slaughter, C.: Kitt Peak 60-cm Vacuum Telescope. Appl. Opt., 15, 1976, pp. 33-39.

3. Harvey, J. W.; and Sheeley, N. R., Jr.: A Comparison of He II 304 Å and He I 10830 Å Spectroheliograms. Sol. Phys., 54, 1977, pp. 343-351.

4. Zirin, H.: Further Observations of the λ10830 Helium Line in Stars and their Significance as a Measure of Stellar Activity. Ap. J., 208, 1976, pp. 414-425.

5. White, O. R.; and Livingston, W.: Solar Luminosity Variation. II. Behavior of Calcium H and K at Solar Minimum and the Onset of Cycle 21. Ap. J., 226, 1978, pp. 679-686.

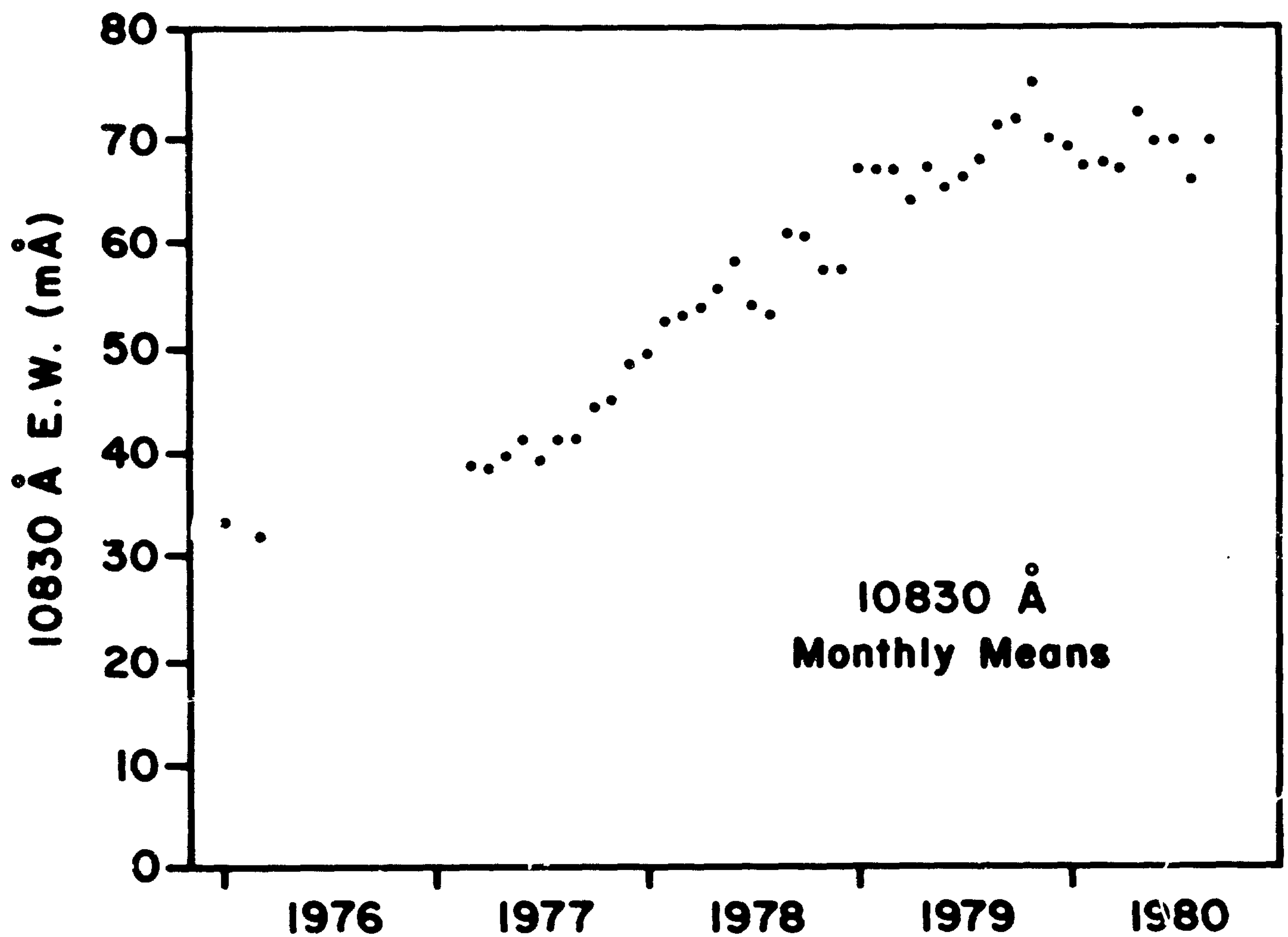

Figure 1. Monthly mean values of the equivalent width in mÅ of the 10830 Å line integrated over the solar disk. The values rise from solar activity minimum in 1976 to the maximum in late 1979.

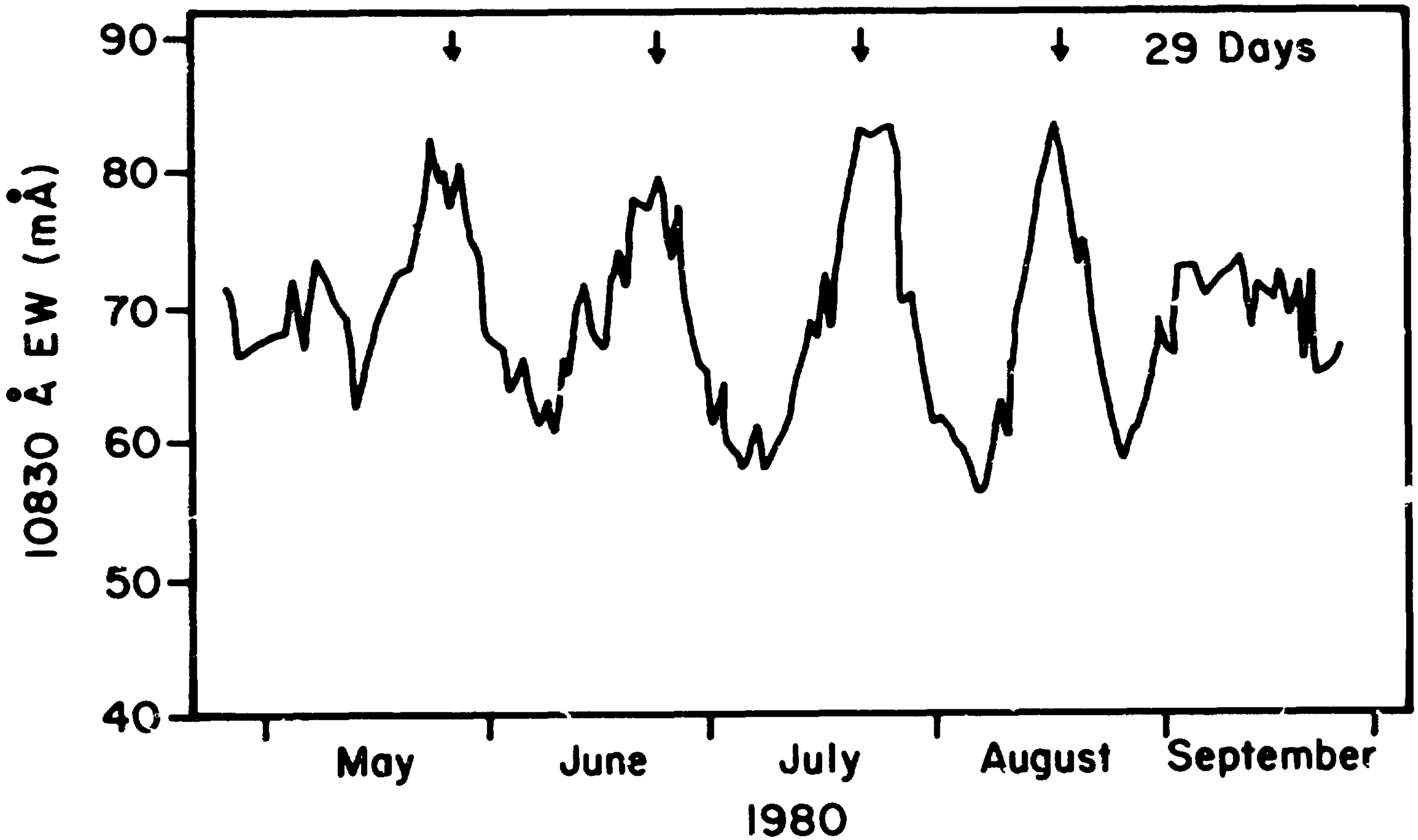

Figure 2. Daily values of the equivalent width in mÅ of the 10830 Å line integrated over the solar disk for a period of strong rotational modulation of the signal. Arrows indicate a synodic recurrence period of 29 days rather than the expected 27 days.

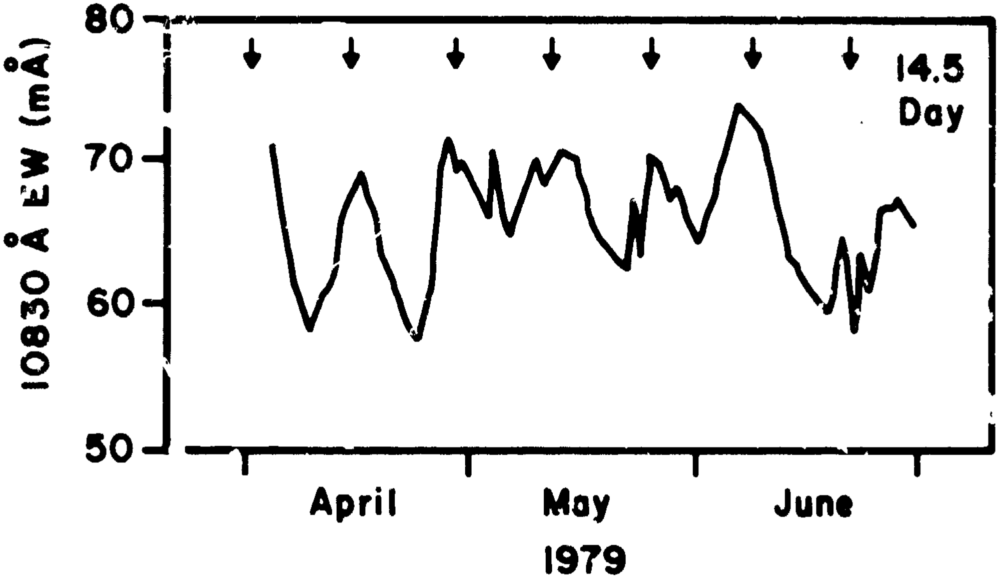

Figure 3. Daily values of the equivalent width in mÅ of the 10830 Å line integrated over the solar disk for a period when the rotational modulation was dominated by a 14.5 day period rather than the 27 day period normally present.

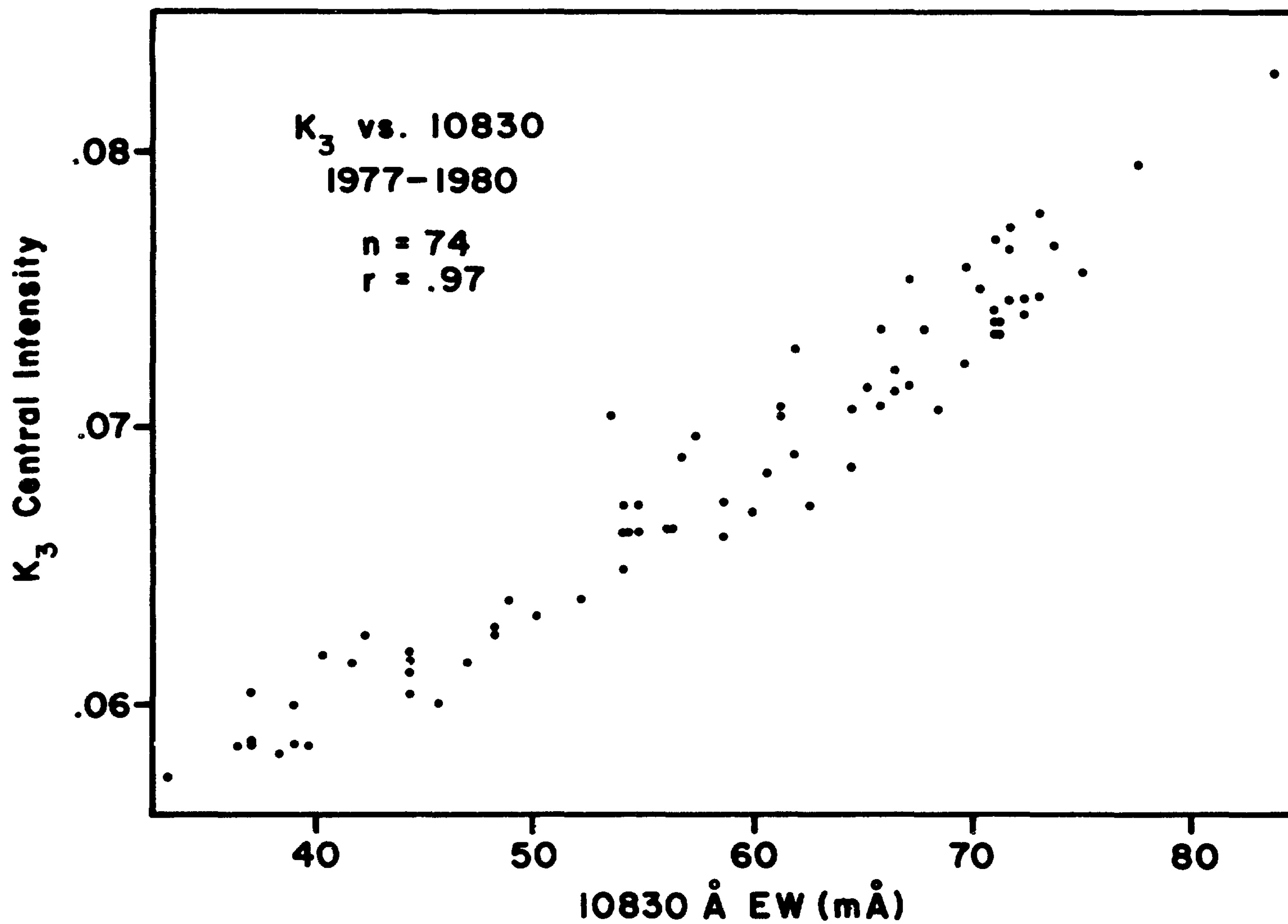

Figure 4. Scatter plot of the central intensity of the calcium K line and the equivalent width of the 10830 Å line. Each point represents observations made within a few hours of each other on 74 different days from 1977 through 1980.