VARIATIONS IN THE MEAN LINE OF SIGHT VELOCITY OF THE SUN: 1976 - 1985

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ABSTRACT. Measurements of the line of sight velocity of the sun with respect to earth have been obtained at Izaña (Tenerife) during the years 1976 to 1985. The mean values found for each year show a trend of ~30 m/s from minimum to maximum. Their mean value is of 583.1 ± .2 m/s which is 92% of the gravitational red shift predicted by theory and their variation seems to be related to the solar cycle with the clear exception of 1985. The most likely interpretation is that the velocity limb shift effect, averaged over the whole sun, is the cause of the slight disagreement with theory and this effect changes with time.

1. OBSERVATIONS AND METHOD OF ANALYSIS

Using data obtained at Izaña (Tenerife) on integral sunlight during several periods of time in the years 1976 to 1985, with a resonant scattering spectrometer (Brookes et al., 1978), the radial velocity of the sun has been measured for each day of observation and the gravitational redshift (from now on GRS) has been determined.

The sun has been observed at the line KI7699Å. The spectrometer measures photons, that come from the left (L) and right (R) wings of the line alternately. The ratio r = (L-R) / (L + R) can be obtained and it is proportional to the relative line of sight velocity between the sun and the observer.

The observed velocity can be displayed as the sum of the following terms:

$$V_{obs} = V_{orb} + V_{spin} + V_{grs} + V_{osc}$$

where V_{orb} is the radial orbital velocity due to the small excentricity of the earth's orbit; V_{spin} is the line of sight velocity of the laboratory relative to the earth's centre; V_{grs} is the gravitational red shift, and, finally, V_{osc} is the time dependent velocity due to solar oscillations (~1m/s) (see Figure 1).

There are several ways of determining the GRS. The easiest one is a null test : if $V_{obs} = 0$, then $V_{grs} = -V_{orb}(t_c) - V_{spin}(t_c)$

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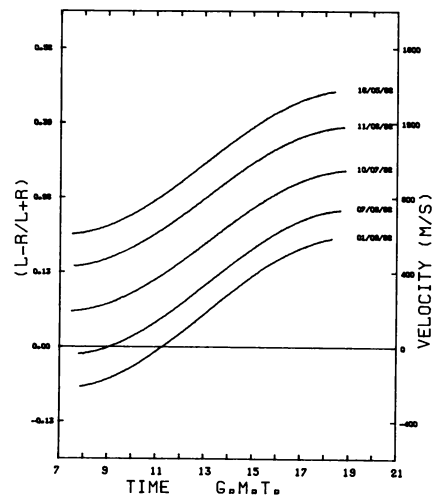

FIGURE 1. Plots of raw data obtained during some days of 1982 observing season. The terms V_{spin}, diurnal variation with an amplitude of some 400 m/s, and V_{orb}, seasonal variation (vary from +500 to - 500 m/s during the year), can be clearly seen. Notice that only from 1st of August to the end of November the observed velocity changes sign.

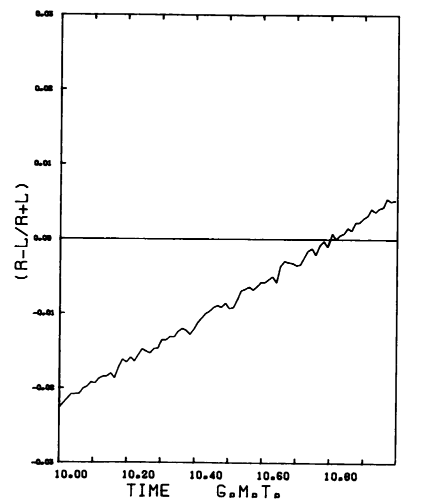

FIGURE 2. Small portion of a daily run where the crossing point is easily seen; the crossing time t_c can be calculated by fitting a straight line. We use 20 points (separated 42 seconds) before and after the points where V_{obs} changes sign. After this first determination a new straight line is fitted on the same number of points centered around the new value found and a final value for t_c is obtained.

So, knowing the crossing time t_c (see Figure 2), V_{grs} can be calculated. This way of obtaining the GRS is very convenient because it is independent from the line shape, ground and instrumental noise.
When this analysis is applied to the data collected for the years from 1976 to 1985, the results obtained for V_{grs} are shown in Figure 3.

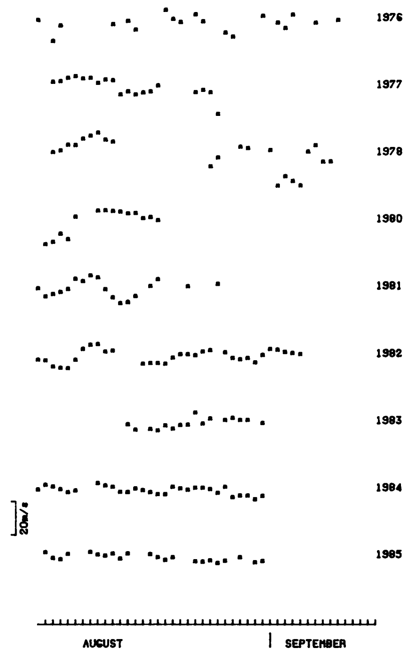

FIGURE 3. Plots of V_{grs} values in m/s found using the crossing time method for the observed days in the years 1976 to 1985. The dispersion of points is different from year to year and a variation of $\sim$13 days is visible which has already been discussed (Claverie et al 1982).

However, we are now interested in looking at the variation of the mean value along the years, as can be seen in Figure 4.
When fitting a sine wave to the data, with the clear exception of 1985, a mean value of V_{grs} = 583.1 m/s is found, which represents 92% of the predicted effect. A variation of 14.5 m/s of amplitude and 10.9 years of period is also obtained.

2. INTERPRETATION OF THE RESULTS

One possible explanation for the discrepancy between the theoretic and experimental value of GRS thanks to the limb effect. This effect, a change on the red shift of the sun as one moves from the centre to the limb, is known observationally and explained in terms of a velocity field associated with the granulation. When the sun is observed as a star some non zero average blue shift is observed which can explain the above discrepancy. If the variation of the mean GRS value along the years is due to a variation in the limb shift then the solar velocity fields associated with the granules are also changing. With the exception of 1985, there exists a good correlation between the variation of GRS and the solar activity cycle. If the numerical model made by Beckers and Nelson (1978) is used, this variation would mean a shallower convection zone at the maximum of solar activity. The GRS value in 1985 does not agree with the above discussion, probably because a longer cycle might be involved in the interpretation of the observations.

There are other possibilities such as the isotope shift and the presence of a planetary system. Due to the existence of two stable isotopes, with different abundances, the isotope shift arises. Saturation effects by changes in the optical thickness of the sun or in the laboratory can produce a line shift; to observe the variation found along the years, the optical thickness of the sun's layers should have changed by a fair amount. Finally, the observations can not be explained by the existence of our planetary system, because these effects have already been taken into account when calculating V_{orb} from the astronomical ephemerys.

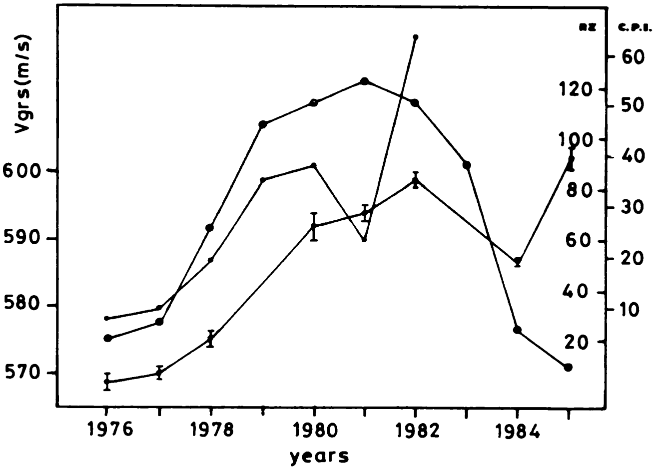

FIGURE 4. Mean value of V_{grs} for the first 15 days of August, (we have chosen these days to compare the same days for all the years) with the error bars being the error of the mean. Two solar activities indices are also plotted for comparison:CPI, the Calcium Plage Index and R_z the Zurich or International sunspot number.

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REFERENCES

-Beckers,J.M. , Nelson,G.D.:1978. Sol. Phys.,**58**,243
-Brookes,J.R. , Issak,G.R. , van der Raay,H.B. :1978. MNRAS,**185**,1
-Claverie,A. , Isaak,G.R. , Mc Leod,C.P. , van der Raay,H.B. , Pallé,P.L. , Roca Cortés,T. :1982. Nature,**299**,709