sunspot numbers shows components at 89.6, 57.1, 11.2, 9.9 and 8.1 yr. We estimate, therefore, that to a first approximation, the repetitition period for a waveform produced by the superposition of sinusoids having these periods is about 179 yr ($2\times89.6 = 179.2$; $3\times57.1 = 171.3$; $16\times11.2 = 179.2$; $18\times9.9 = 178.2$; $22\times8.1 = 178.2$).

That an 89.6-yr component is found in the spectrum suggests that the Sun may be behaving as a nonlinear (square law) device, passing not only the two major driving frequencies (11.2 and 9.9-yr periods), but also generating components corresponding to twice the driving frequencies, and to the sum and difference frequencies. Thus, we might expect to find spectral components at the following frequencies:

$f_2 - f_1$: 89.6 yr
$f_1 + f_2$: 5.3 yr
$2f_1$: 5.6 yr
$2f_2$: 5.0 yr

Weak, but significant, components are found in the 214-yr MESA spectrum at periods of 4.8, 5.5 and 5.8 yr (correlation analysis yields period estimates of 4.8, 5.3 and 5.8 yr) and these may represent the expected heterodyne components.

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1 Cohen, T. J., and Lintz, P. R., *Nature*, **250**, 398–400 (1974).

Population stratification as an explanation of IQ and ABO association

A RECENT study[1] of English villages claims to have shown significant differences in mean IQ between some of the ABO blood group phenotypes. The population can be divided into two groups, namely those who were born locally and those who were born elsewhere, henceforth referred to as locals and non-locals respectively. There is a significant difference in ABO frequencies between the two groups. The frequency of ABO phenotypes varies significantly[2] throughout England, so that differences in frequencies between the local and non-local populations are not surprising. Also, the non-locals have significantly higher mean IQs than the locals, regardless of the blood group phenotype. The authors[1] claim that "There is thus genetic evidence for at least two population groups in the area, but this alone cannot be responsible for the association between ABO blood group and IQ which the analysis reveals."

We should like to suggest that the observed association could in fact be the result of this stratification of the population. The combination of the difference in ABO frequencies and the difference in mean IQ between the local and non-local groups causes an association. This is explained below in a very simple model.

The population is divided into two groups, local and non-local. Each group is subdivided into, for example, blood groups, which will be labelled 1, 2, and 3. The population frequencies of blood group i are p_i and q_i for locals and non-locals respectively

$$(i = 1,2,3, \sum_{i=1}^{3} p_i = 1 = \sum_{i=1}^{3} q_i)$$

The total sample size of locals is N_1 and non-locals N_2. (Table 1). Define $M = N_1/(N_1+N_2)$.

Denote the mean IQ of locals by x_1 and that of the non-locals by x_2 (independent of blood group). Then the mean IQ of blood group 1, denoted a_1 is given by

$$a_1 = \frac{N_1p_1x_1+N_2q_1x_2}{N_1p_1+N_2q_1}$$

$$= \frac{Mp_1x_1+(1-M)q_1x_2}{Mp_1+(1-M)q_1}$$

Similarly the mean IQ of blood group 2 is

$$a_2 = \frac{Mp_2x_1+(1-M)q_2x_2}{Mp_2+(1-M)q_2}$$

So

$$a_1-a_2 = \frac{M(1-M)(x_1-x_2)(p_1q_2-q_1p_2)}{(Mp_1+(1-M)q_1)(Mp_2+(1-M)q_2)}$$

Thus $a_1 \neq a_2$ if $x_1 \neq x_2$ and $p_1q_2 \neq q_1p_2$. So if the mean IQ of the locals and non-locals is different and their blood group frequencies are also different, then in the total population the mean IQ of each blood group will be different.

Is this sufficient to explain the difference observed in the Otmoor study? The appropriate parameter values are obtained from Tables 4 and 5 of that paper[1]. They are $p_1 = 0.5238$, $q_1 = 0.3869$, $p_2 = 0.3691$, $q_2 = 0.4696$, $p_3 = 0.1071$, $q_3 = 0.1435$, $x_1 = 100.671$, $x_2 = 110.965$. (Blood group 1 refers to the A_1 phenotype and 2 to O.) The values of N_1 and N_2 in those Tables 4 and 5 are different. But the same general result holds for both sets of numbers. The values in Table 4 will be used as they are closest to the total used in Table 1. Thus $N_1 = 168$, $N_2 = 460$ so $M = 0.2675$.

Table 1 Numbers observed in each subgroup

Blood group	Local	Non-local
1	N_1p_1	N_2q_1
2	N_1p_2	N_2q_2
3	N_1p_3	N_2q_3

Using this model we estimate that the mean IQ of A_1 phenotypes in the total population sampled would be 107.56 and the mean IQ of O phenotypes 108.67. Thus the expected difference in mean IQ between these two blood groups, for this particular population, is 1.11. (The standard error of this estimate is 0.15 so that the difference predicted is significantly different from zero.) The observed values of 106.95 and 109.75 for A_1 and O respectively are not significantly different from these expected values. Although the observed difference of 2.8 IQ points is significantly different from zero it is not significantly different from the estimated expected value of 1.11. Thus the stratification of the population would be an adequate explanation of the observed differences in IQ between the blood groups.

The model described above does not take account of the observed sex differences in IQ and ABO frequencies, but can be simply extended to do so. In this case the expected difference in IQ between the A_1 and O phenotypes is 1.2 and the same general result applies.

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1 Gibson, J. B., Harrison, G. A., Clarke, V. A., and Hiorns, R. W., *Nature*, **246**, 498 (1973).
2 Kopec, A. C., *The Distribution of the Blood Groups in the United Kingdom* (Oxford University Press, London, 1970).

GIBSON, HARRISON and HIORNS REPLY—We appreciate the model proposed by Thomson and Bodmer and accept that its application to the Otmoor data makes the hypothesis that the association we reported between ABO blood group status and IQ is caused by the presence of two population groups in the area (locally born and non-locally born), more likely than we originally thought. We still however consider that this explanation as we originally stated, is unlikely to be the sole cause for the association on the following grounds.

On the basis of the model, the ability of a test to detect IQ differences between people of blood groups A_1 and O ought to be greatest in those villages where the proportions of locals and non-locals are most equal. There is no relationship between this proportion and the level of association in the various villages. Indeed, in Beckley and Horton, where the sample contained the second highest proportion of locally-born subjects, the