and 2) are those reported by von Brentano. The values of J and π used for the five levels in each nucleus are, respectively, $\frac{7}{2}^-$, $\frac{3}{2}^-$, $\frac{3}{2}^-$, $\frac{5}{2}^-$, and $\frac{5}{2}^-$. The dashed curve was obtained by changing the J value assumed for the third resonance shown in each figure from $\frac{3}{2}$ to $\frac{1}{2}$, while doubling the partial elastic widths in order to give approximately the same elastic-scattering cross sections.

The third resonance in each case clearly corresponds to a $\frac{1}{2}^-$ level. This assignment is in disagreement with the interpretation of this state by Holm and Martin[7] and by Fulmer, McCarthy, and Cohen[8] as a $\frac{3}{2}^-$ level arising from the coupling of the $f_{7/2}$ single-particle state with a 2^+ collective excitation of the core.

Comparison can also be made with the results of Wurm et al.[9] for protons scattered from ^{142}Nd and of Marouchian et al.[10] for scattering from ^{144}Sm. In both of these cases the third analog resonance was assigned $J^\pi = \frac{3}{2}^-$ on the basis of elastic cross-section data at many angles. However, since these two targets have the same closed neutron shell as ^{138}Ba and ^{140}Ce, our measurements suggest that these angular-momentum assignments may also be in error. The erroneous assignments in this case probably arose because the assumption was made[9] that the off-resonance spin-flip scattering amplitudes can be neglected. The presence of nonzero polarization between the resonances indicates that this is not the case.

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[2]In contrast, the earlier work of C. F. Moore and G. E. Terrell [Phys. Rev. Letters 16, 804 (1966)] did not require off-resonance polarization measurements.

[3]D. Robson and A. M. Lane, to be published; and D. Robson, in Recent Progress in Nuclear Physics with Tandems (Max-Planck-Institut für Kernphysik, Heidelberg, Germany, 1966).

[4]The cross section and polarization can be obtained from S by using the expressions of S. J. Moss and W. Haeberli [Nucl. Phys. 72, 429 (1965)] after setting $f_l^{\pm} = [\exp(-2i\omega_l)S_l^{\pm} - 1]/2i$ and changing the sign of B, which is in error in Eq. (5) of that paper.

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PECULIAR VELOCITY OF THE SUN AND THE COSMIC MICROWAVE BACKGROUND

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The sun's peculiar velocity with respect to distant galaxies is roughly estimated from the red-shift data for nearby galaxies to be ~400 km/sec toward $l_{\rm II} \sim 335°$, $b_{\rm II} \sim 7°$. Future observations on the angular distribution of the cosmic microwave background should be able to test this estimate, if the background has a cosmological origin. If the test is successful it would imply that a "local" inertial frame is nonrotating with respect to distant matter to an accuracy of 10^{-3} sec of arc per century, which would represent a 5000-fold increase of accuracy.

The remarkable measurements of Partridge and Wilkinson[1] indicate that the excess microwave background is highly isotropic along the celestial equator. They found no 24-h asymmetry with an amplitude greater than ±0.1% (of 3°K), and thereby derived an upper limit of about 300 km/sec for the equatorial component of the sun's velocity relative to the effective source of the radiation. If the radiation has a cosmological origin,[2] then this effective source would actually be the distant matter (red shift $z \gg 1$) which last scattered the radiation. In that case it should become possible to measure the "absolute" motion of the solar system, that is, its motion relative to the universe as a whole.

This intriguing situation makes it desirable to estimate the sun's peculiar velocity with respect to distant galaxies from a study of the red-shift data. We might expect this peculiar velocity to agree with that derivable from the microwave background although in principle all the galaxies concerned (which have $z < 0.5$) could be moving as a whole relative to matter with larger red shifts.[3] In any case such a comparison might give us information about the large-scale components of the velocity spectrum of the matter in the universe. Moreover, an agreement between the two peculiar velocities would strengthen the hypothesis that the microwave radiation is not confined to our galaxy.

This problem is particularly pressing because the sun's rotational velocity in our galaxy (~250 km/sec)[4] is not much less than the upper limit already obtained by Partridge and Wilkinson. According to Mach's principle[5] we would expect this rotational velocity to represent motion relative to distant matter, and so relative to the sources of the microwave background. A relatively small improvement in the measurement of the directional properties of the background would then be capable of revealing this rotational motion.[6] However, we wish to point out that the rotation of our galaxy may not be the main contributor to the sun's peculiar velocity relative to distant matter.

Following Rubin,[7] Ogorodnikoff,[8] and de Vaucouleurs,[9] we shall assume that our galaxy belongs to a flattened supercluster dominated by the Virgo cluster of galaxies. According to these authors, this system is undergoing differential rotation and expansion. The analysis of de Vaucouleurs is the most detailed, and despite the criticisms of van Albada,[10] (which have been partially answered by de Vaucouleurs[9]), we shall adopt his point of view. We differ only in that we reject certain galaxies as possible members of the supercluster, which has the consequence that we derive a smaller value than does de Vaucouleurs for the differential expansion. A detailed discussion of the problem will be given elsewhere; here we merely wish to make a rough estimate of the possible contributions of the differential motions to the sun's peculiar velocity.

The average radial velocities of nearby galaxies in the plane of the supercluster would be expected to satisfy the kinematical relation

$$\vec{V} = K\vec{r} + \sigma\cdot\vec{r},$$

where K, σ are the local expansion and shear of the velocity field, and $\vec{r}$ is the mean distance of the galaxies concerned. In noninvariant form we have[11]

$$\vec{V} = \vec{r}\{K + (A^2 + C^2)^{1/2}\sin 2(l - l_0 + \epsilon)\}, \tag{1}$$

where

$$K = \frac{1}{2}\left(\frac{\partial \Pi_0}{\partial \varpi} + \frac{\Pi_0}{\varpi} + \frac{1}{\varpi}\frac{\partial \Theta_0}{\partial \theta}\right),$$

$$A = \frac{1}{2}\left(\frac{\partial \Theta_0}{\partial \varpi} - \frac{\Theta_0}{\varpi} + \frac{1}{\varpi}\frac{\partial \Pi_0}{\partial \theta}\right),$$

$$C = \frac{1}{2}\left(\frac{\partial \Pi_0}{\partial \varpi} - \frac{\Pi_0}{\varpi} - \frac{1}{\varpi}\frac{\partial \Theta_0}{\partial \theta}\right),$$

in cylindrical coordinates (ϖ, θ) whose (distant) origin has longitude l_0, Π_0 and Θ_0 are the local velocity components in these coordinates, and

$$\tan 2\epsilon = C/A.$$

If ϵ is small, one of the principal axes of shear points nearly towards l_0, and if on configurational grounds l_0 is the direction of the center of the system, it is natural to assume that the system is differentially rotating around this center, and also undergoing a small differential expansion. (This is the procedure used in studying the rotation of the galaxy.)

By fitting (1) to de Vaucouleur's computations of the mean radial velocity of galaxies in the magnitude range 8.0-9.9 derived from the red-shift data of Humason, Mayall, and Sandage,[12] we find

$$Kr \sim 600 \text{ km/sec},$$

$$(A^2 + C^2)^{1/2} r \sim 300 \text{ km/sec},$$

$$\epsilon \sim 15°,$$

if we choose for l_0 the longitude of the Virgo cluster. Since ϵ is a fairly small angle, we may speak of differential rotation and expansion about this cluster. We estimate that $r \sim 6$ Mpc, and so

$$A \sim 45 \text{ km/sec Mpc},$$

$$C \sim 25 \text{ km/sec Mpc}.$$

This velocity field may be determined by the eddy which presumably gave rise to the supercluster but it may also have dynamical significance in relation to the gravitational action of the Virgo cluster. Following de Vaucouleurs we assume that this cluster has a mass $\sim 10^{48}$ g, the value derived from applying the virial theorem to the velocities of galaxies in the cluster. For circular velocities we would have $A = \frac{3}{4}(GM)^{1/2}/\varpi^{3/2} \sim 50$ km/sec Mpc, and we may estimate C very roughly as $GM/\Pi_0\varpi^2 \sim 25$ km/sec Mpc, values which are comparable with our previous estimates (the close agreement being fortuitous). We may then derive rough values for the peculiar velocities by assuming that the transverse velocities Θ are indeed circular and taking for the peculiar radial velocities $\delta\Pi$ the quantity $GM/\Pi\varpi$. We then find

$$\Theta_0 \sim 600 \text{ km/sec},$$

$$\delta\Pi_0 \sim 250 \text{ km/sec}.$$

By contrast de Vaucouleurs obtained $\Theta_0 \sim 500$ km/sec, $\delta\Pi_0 \sim 650$ km/sec. This latter velocity seems rather large since, as Sandage[13] has emphasized, the Virgo cluster lies close to the red-shift apparent magnitude relation for radio galaxies and brightest galaxies of rich clusters.

To obtain the sun's net peculiar velocity we have to compound three peculiar motions: (i) The solar motion with respect to the local standard of rest as determined by the local group of galaxies. This motion includes both the rotation of our galaxy and its local peculiar motion. We adopt the value[14] of 300 km/sec in the direction $l_{\rm II} \sim 107°$, $b_{\rm II} \sim -7°$. (ii) The rotational velocity of our galaxy in the Virgo supercluster, 600 km/sec towards $l_{\rm II} \sim 319°$, $b_{\rm II} \sim -14°$. (iii) Our peculiar velocity towards Virgo, 250 km/sec towards $l_{\rm II} \sim 287°$, $b_{\rm II} \sim 72.3°$.

On these assumptions our net peculiar velocity is

$$415 \text{ km/sec towards } l_{\rm II} \sim 335°,\ b_{\rm II} \sim 7°.$$

On de Vaucouleurs' assumptions we find 630 km/sec towards $l_{\rm II} \sim 330°$, $b_{\rm II} \sim 45°$. If we provisionally neglect a possible peculiar velocity of the Virgo supercluster with respect to its neighbors, we may compare the results with the observations of Partridge and Wilkinson. They found for the mean amplitude of a 24-h asymmetry on the celestial equator the value $0.03 \pm 0.07\,\%$ with the maximum temperature at a right ascension of $15^{\rm h}30^{\rm m}$, although, as they point out, very little weight should be attached to this hour angle. In terms of new galactic coordinates this direction is $l_{\rm II} \sim 357°$, $b_{\rm II} \sim 37°$, and the observations permit a velocity of up to about 300 km/sec in this direction. In fact, our estimate gives a peculiar velocity in this direction of about 350 km/sec, while de Vaucouleurs's gives about 550 km/sec. Clearly a relatively small improvement in the precision of the observations, and their extension away from the celestial equator, should clarify this situation considerably. In particular, we may note that if our estimate turns out to be in reasonable agreement with observation it would tend to confirm the hypothesis that the sun is rotating around the Virgo cluster with a velocity ~600 km/sec. It would also imply that "local" inertial frames are nonrotating with respect to distant matter to an accuracy of 10^{-3} sec of arc per century, a 5000-fold increase on the present accuracy of this comparison.

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