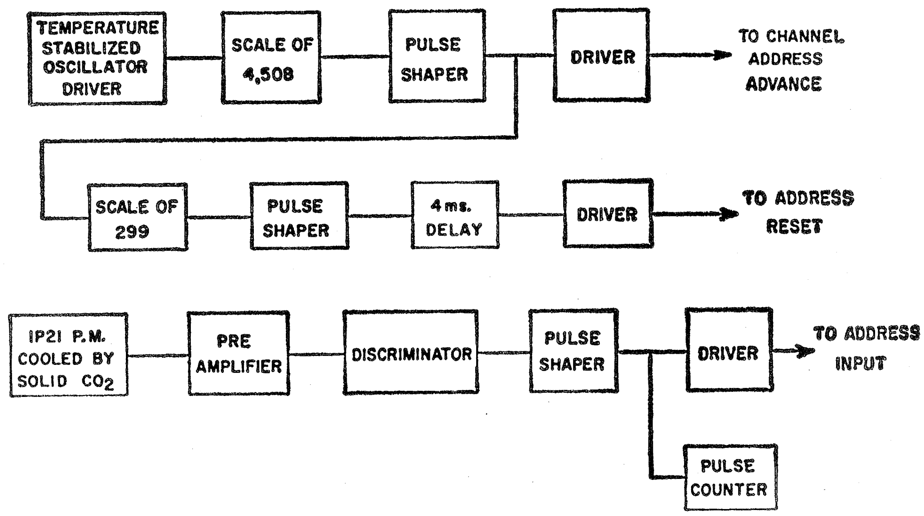

Fig. 1. Block diagram of the data-handling system. The master oscillator frequency was 1.008007 Mhz at the time of the experiment.

odicity to 1 part in 10^6. The clock can be adjusted daily to compensate for the orbital motion of the earth. The time interval of our clock is subdivided into 299 equal subintervals, generating pulses which advance the channel address of a 400-channel pulse-height analyzer (Radiation Instruments Development Laboratories) used as a time-of-arrival sorter. The master clock resets the zero of the channel address. Photons from the direction of Ryle's star are detected by a 1P21 photomultiplier, cooled by solid CO_2 to reduce dark current. Photoelectron pulses are amplified, discriminated against noise, shaped, and fed into the analyzer. We were thus able to measure the phase of arrival of each photon relative to our local clock.

The 1P21 is mounted on the 24-inch (61-cm) Cassegrain telescope at the Mees Observatory near Bristol, New York. Also mounted on the telescope is an off-set guider, a B filter, and a variety of apertures. The off-set guiding technique is necessary because an 18th magnitude star is not visible to the eye on our telescope. The object star has coordinates of right ascension (1950) $19^h19^m36\overset{s}{.}88$, declination (1950) $21°46'57\overset{''}{.}4$, and we guided from AGK2 + 21° · 1963 with coordinates α (1950), $19^h19^m23\overset{s}{.}4$ and δ (1950), $21°41'42''$ so as to unambiguously place the object star well within a 25-second diameter aperture. The data were taken on 6 April 1968 between 4:20 and 4:30 a.m. Eastern Standard Time.

Several stars of known blue magnitude were imaged in the 25-second aperture preceding the 1P21 tube. From these direct measurements, we expect 110 count/min from an 18th magnitude star. During the 10 minutes available for observing Ryle's star, we accumulated an average of 128 count/channel in our time-of-arrival analyzer. This is almost all sky background. If the entire optical output of the star were to arrive in a time interval equal to Hewish's estimate of pulse width, we would expect an excess of 275 counts in each of four adjacent channels. This total count would represent about 40 standard deviations above sky background. No four-channel sequence was found to give a count more than 2.4 standard deviations above the mean.

Our estimates of the upper limits to the pulsation intensities are computed as follows. All the counts in 299 sets of a number (k) of adjacent channels are summed. The largest sum of any k adjacent channels is noted for each k. No statistically significant deviations from the mean were found. If we assume that the largest fluctuation we see represents an observation of a repetitive optical pulse of $k \times 4.4$ msec duration, then we ask what the pulsation would be if our observations correspond to a downward statistical fluctuation with a 5 percent probability of occurrence. Table 1 shows the result of such an analysis. It contains the grouping of channels investigated (k) and our 95 percent confidence estimate of an upper limit to pulsation pulse count. For example, Hewish (*1*) claims that the intrinsic radio pulse was 16 msec long. If one wants to ask for the optical pulsation in this mode, one takes the entry for k equal to 4. It shows an upper limit to this mode of pulsation of 98 counts, to be compared with the total optical output from an 18th magnitude blue star of 1100 counts during the same 10-minute period.

We conclude that no pulsations to the order of 10 percent of the total light output of the 18th magnitude star in a mode similar to the radio observations was seen on the morning of 6 April. The strength of radio signals at that time is not known to us. Considerable improvement in the experiment will be made with more prolonged observations. We have also sought evidence for a sinusoidal variation of the intensity of this object. Again nothing was found above statistical fluctuations in the background rate.

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6. We thank Prof. S. Sharpless for his encouragement and assistance, and R. A. Majka for help in designing and building the timing devices. We thank H. Brian Richer for his assistance in aligning and guiding the telescope during the preliminary test runs of the experiment.

15 April 1968

Pulse Structure of the Pulsating Radio Source in Vulpecula

Abstract. *The pulses from the pulsating radio source at right ascension 19 hours 19 minutes, declination +22 degrees have the following characteristics: (i) they begin with a sharp leading edge; (ii) they terminate after 37 milliseconds; and (iii) they consist of three subpulses, the first of which is both the strongest and the best defined.*

The remarkable pulsating radio source described by Hewish *et al.* (*1*) has been under observation with the 1000-foot (304.8-m) radio telescope of the Arecibo Ionospheric Observatory (AIO) since 29 February 1968 (*2*). Of great interest has been the observation of the detailed morphology of the individual pulses emitted by the object, since such information should go far in revealing the size of the emitting object and the physical mechanism responsible for the radio emission. Some pulse shapes have been published (*3*). The results of the early Arecibo observations are presented here.

Early observations of pulse shape were conducted primarily at radio frequencies of 73.8 and 111.5 Mhz because the source is extremely active and intense at these frequencies. As many as ten pulses with a flux density of 200×10^{-26} watt m^{-2} hz^{-1} may be expected in a 10-minute interval. Observations were made with feeds consisting of two three-element yagi antennas and conventional superheterodyne radiometers. Artificial pulses were radiated at the radiotelescope to insure that the components of the radiometer system were not distorting the observed pulse shapes. The radiometer output was presented on a storage oscilloscope whose sweep was synchronized with the known times of pulse arrival, and with which pulse presentations would be stored and photographed.

Visual observations showed that there was significant fine structure in the pulse shape which required time constants of the order of 1 to 3 msec if no detail more intense than noise fluctuations was to be lost. These short time constants place a restriction on the maximum radiometer bandwidth which may be used without loss of pulse detail. This is a result of the drift of the pulse arrival time with radio frequency (*1–3*), which causes the pulse to arrive at the higher frequency boundary of the accepted frequency band earlier than at the lower frequency boundary. If there is to be no smearing of pulse detail by this phenomenon, the bandwidth B must be such that this time differential is of the order of the time constant τ or less, or

$$B < \left(\frac{d\nu}{dt}\right)_{\text{pulse}} \cdot \tau < \frac{\nu^3 c \tau}{\int \nu_p^2 \, dl}$$

where c is the velocity of light, l is the distance to the object, and the plasma frequency, $\nu_p = 8.98 \times 10^{-3}\, n_e^{1/2}$ Mhz, when n_e is in electrons per cubic centimeter. Numerically, when the data for this radio source is taken (*3*)

$$B < 9.5\,(10^{-6})\,\nu^3 \tau \text{ Mhz} \qquad (1)$$

when ν is expressed in Mhz. With a time constant of 3 msec, this demands a bandwidth less than 40 khz at 111.5 Mhz, and less than 12 khz at 73.8 Mhz. This requirement is met in some of the observations presented here, and it is noted where this is not so.

Visual inspection of a large number of pulses has revealed the following major characteristics of the pulse shape:

1) All pulses commence abruptly with a very sharp leading edge. When the ratio of signal to noise is high, the pulse may be seen to rise to maximum intensity in less than 3 msec. No significant precursor to pulse onset has been observed.

2) The pulse terminates abruptly after 37 msec. No significant evidence of radiation at a later time has been observed. This overall pulse length is the same, to within 1 msec, at both 73.8 and 111.5 Mhz.

3) There is a complicated variation of intensity during the 37-msec interval of radiation. In a majority of cases, the "pulse" consists, in fact, of an ensemble of three pulses, hereafter called "subpulses," the first reaching maximum intensity 6 msec after pulse onset, the second reaching maximum intensity 18 msec after pulse onset, and the third 30 msec after pulse onset. In almost every case, the first subpulse is both strongest and best defined. The later subpulses are uncorrelated in intensity with one another, and pulses have been observed in which the second subpulse is essentially absent while the third subpulse is as strong as the first. Occasionally one of the later subpulses will exceed the first subpulse in intensity. The statistics of relative subpulse intensities can be obtained from digital recording and analysis of the pulse shapes.

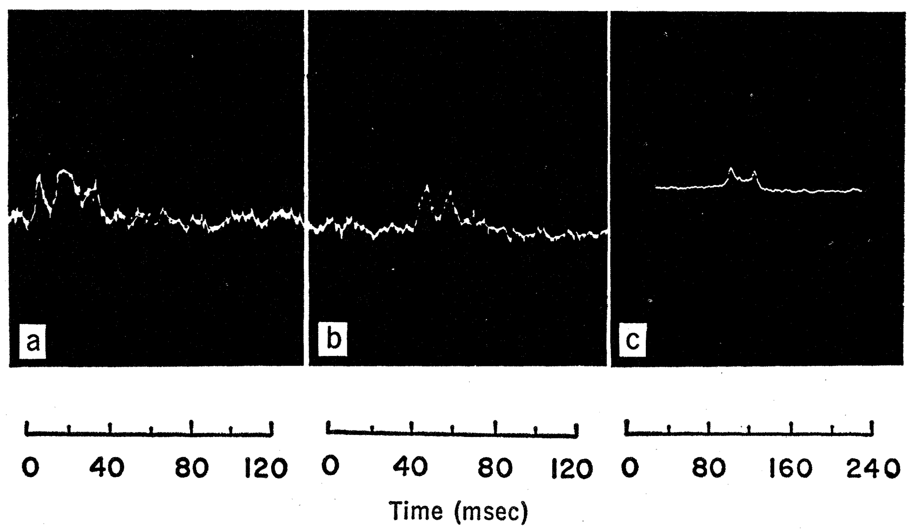

Fig. 1. Photographs of oscilloscope presentations of pulses observed at a radio frequency of 111.5 Mhz. In (a) and (b), the radiometer time constant is 1 msec, and the bandwidth is 25 khz, leading to an effective averaging interval of about 2 msec. In (c), the time constant is 3 msec and the bandwidth is 50 khz, leading to an effective averaging interval of about 3 msec. In all figures, the time base is drawn with an arbitrary origin; the position of the pulse on the trace does not imply that the pulse lagged or led its expected arrival time; (a) and (b) were obtained 6 March; (c) was obtained 5 March.

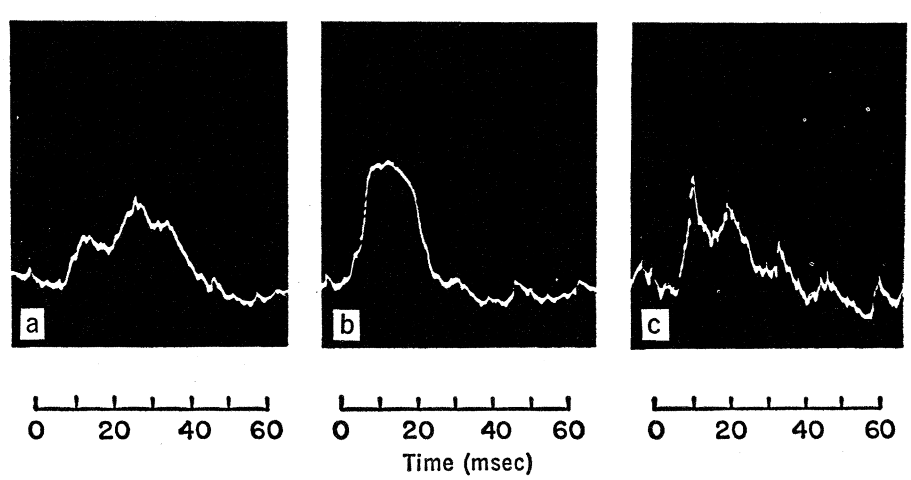

Fig. 2. Photographs of oscilloscope presentations of pulses at 73.8 Mhz. The time constant is 3 msec. In (a) and (b), the bandwidth is 25 khz, giving an effective averaging interval of about 6 msec. In (c), the bandwidth is 10 khz, giving an effective averaging interval of about 3 msec. Recordings made 9 March 1968.

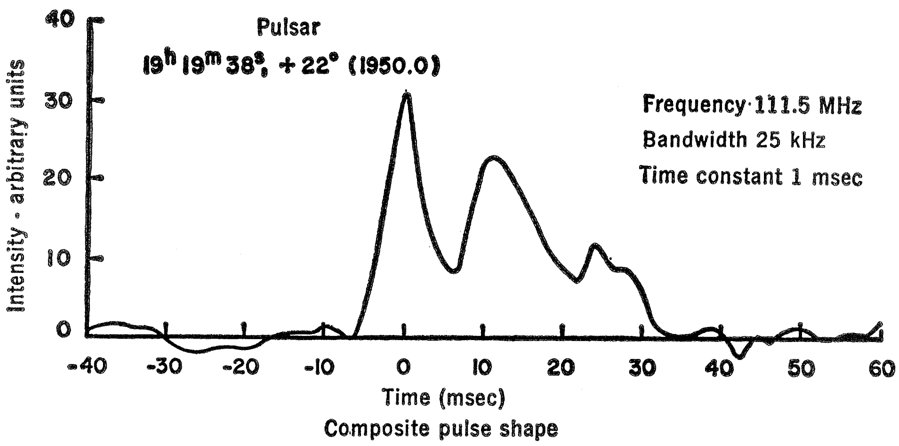

Fig. 3. Sum of pulse shapes of three strong pulses recorded at 111.5 Mhz on 6 March 1968. This is an approximation to the "typical" pulse shape; individual pulses vary greatly in shape from the result given here. The effective averaging interval due to bandwidth is 3 msec.

Figures 1 and 2 are photographs of pulses illustrating the above described behavior at 111.5 and 73.8 Mhz, respectively. In Fig. 1a is a pulse in which all three components have nearly equal amplitude. In Fig. 1b is a pulse in which the first two subpulses are nearly equally strong, whereas the third is barely detectable. Figure 1c shows a pulse in which the first and third components are strong.

Figure 2a shows a pulse at 73.8 Mhz in which the second subpulse is dominant. In Fig. 2b only the first two subpulses are present and unresolved; the lack of resolution may be a result of the bandwidth used, which smooths the recorded intensity with a time scale of the order of 6 msec. Figure 2c is an example of a pulse recorded with a 10-khz bandwidth which causes a 3-msec time resolution to be retained. The typical three subpulses are seen here, as well as the very sharp leading edge which goes from zero to full intensity in about 4 msec. In view of the 3-msec time constant used, the first subpulse must have been already decreasing in intensity when the recorded maximum was observed, an indication that the actual rise time was considerably less than 4 msec.

Figure 3 gives the mean of three very intense pulses at 111.5 Mhz, which is presented here to make generally available a good approximation to the "typical" pulse shape. The basic three-subpulse structure which appears in the AIO data is visible in the pulse shapes determined at Jodrell Bank (*3*). The pulse morphology presented here is for the strongest pulses, those of about 200 flux unit intensity. Visual inspection of weaker pulses gives the strong impression that the weaker pulses possess this same morphology, but definitive recorded data are not yet available.

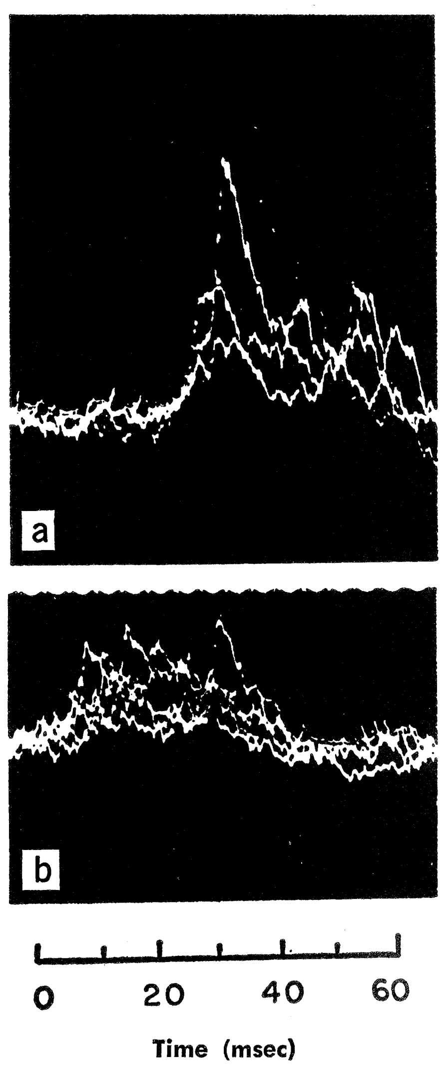

Fig. 4. Photographs of oscilloscope presentations of a number of consecutive pulses observed at 111.5 Mhz, 6 March 1968. Time constant was 3 msec, and bandwidth was 25 khz, giving an effective averaging interval of 3 msec. Note in (a) the lack of any significant precursor radiation prior to onset of steep leading edges. Note in (b) the lack of faint pulses following the termination of the main pulse radiation.

Figures 4a and 4b are photographs of the stored oscilloscope traces of a number of consecutive pulses. Figure 4a illustrates the lack of significant precursor radiation and the sharp leading edge of the pulses, and Fig. 4b illustrates the absence of radiation after the apparent termination of the pulse.

Other than the basic pulse structure given above, a few results are obtainable from our limited data:

1) Since the duration of a well-defined first subpulse is about 10 msec, the maximum size of the region or object emitting this pulse is 3000 km. It is possible that the separate subpulses are all emitted in sequence from the same region or object and that the emitting entity is less than about 3000 km. In any case, it will be smaller than the value associated with the overall pulse duration, 37 msec, which gives a maximum size of 11,000 km. These size estimates refer strictly only to the size of the object launching the disturbance which results in the observed radio emission. Should this disturbance in fact be converted in a surrounding medium to radio emission which is markedly nonisotropic, with a preferred direction which maintains a fixed relationship to the direction of the disturbance velocity vector (for example, stimulated emission, which seems unlikely in this case), then the actual emitting region can be much larger than the values given above.

2) The equality in pulse duration and similarity in pulse morphology at two widely differing frequencies suggests that the entire radio spectrum is generated in the same volume. This is supported by the exact fit between the delay in the time of pulse arrival at different frequencies and an explanation in terms of the effects of electrons between the earth and the source. Furthermore, the frequency independence of pulse width shows that the pulse structure is not a result of propagation through a magnetoplasma.

3) With an emitting region of less than 3000 km, the observation of flux densities of the order of 100 flux units over a bandwidth of 40 Mhz (*2, 3*), and a distance of 65 parsecs (*1*), the radio energy emitted per unit area by the object in each subpulse is greater than 10^{10} erg/cm^2. This is equivalent to a mean radiation emittance in the radio spectrum alone which exceeds one-tenth that of the solar surface at all wavelengths.

4) The arrival time of the first subpulse can be timed, in a single pulse, to an accuracy of about 2 msec. This means that the pulse period can be measured with two pulses to an accuracy of one part in 10^6 in an hour, one part in 10^7 in a day, and one part in 10^9 in a year. By the observation of many pulses in the observing period, these accuracies can be improved by perhaps two orders of magnitude.

5) The construction of models of the radio emitting object and associated physical processes must lead to a situation in which three primary subpulses, nearly equally spaced in time, must occur, but with large variations in relative subpulse intensity from pulse to pulse. Although several concepts of the object leading to two subpulses can be imagined, no schemes producing three subpulses readily present themselves.

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26 March 1968

Beta Mercaptolactate-Cysteine Disulfide: Analog of Cystine in the Urine of a Mentally Retarded Patient

Abstract. *β-Mercaptolactate-cysteine disulfide, a hitherto undescribed analog of cystine, was isolated from the urine of a mentally retarded patient. The properties of this substance are described, and its structure is confirmed by mass spectrometry and by partial synthesis.*

Metabolic abnormalities were discovered in a number of patients in mental institutions in Massachusetts who were screened for such by the urine nitroprusside test. As judged by the results of paper chromatography of the urine, most of these patients were either homozygous or heterozygous for cystinuria. However, in the urine of one patient a heretofore undescribed amino acid was found. This patient (45 years old) was the product of a sibling mating, had no physical abnormalities, but was mentally retarded (I.Q. = 50). No excess of cystine was found in fresh urine, and the new amino acid gave a pink color with the cyanide-nitroprusside reagent.

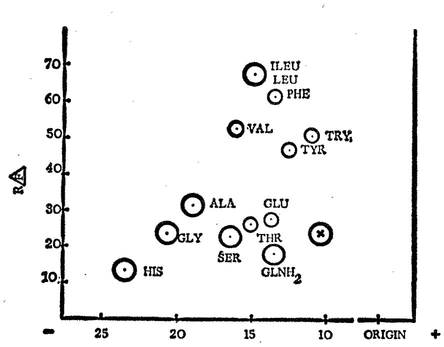

Fig. 1. Representation of the migration of β-mercaptolactate-cysteine disulfide (circled *X*). Electrophoresis in the horizontal direction was performed in 8 percent formic acid, *p*H 1.6; 3.5 kv; 170 ma; 45 minutes. Chromatography in the vertical direction in butanol: acetic acid: water (12:3:5).

The new amino acid was separated from other naturally occurring amino acids by a combination of high-voltage electrophoresis and partition chromatography (*1*) (Fig. 1). The isoelectric point of this amino acid was *p*H 2.2. Upon thin-layer chromatography (*2*) the new substance ran close to cystine. In cation-exchange chromatography (Technicon automatic amino acid analyzer) the new substance eluted between threonine and glutamic acid; the ratio of light absorption at 440 nm to that at 570 nm was a little higher than is usual for nonsulfur-containing amino acids and was comparable to that found for cystine. For isolation of the amino acid the urine was adjusted to *p*H 8 and poured onto a Dowex 2 ion-exchange column (acetate form). The column was eluted with 1*N* acetic acid and then with 4*N* acetic acid. The 4*N* acetic acid eluate was applied directly to an ion-exchange column of Dowex 50 (H+). This column was washed first with water and then with 1*N* ammonia. The ammonia eluate was evaporated at reduced pressure. The pigmented residue was placed on a column of Bio-Gel P-2. The fractions obtained by elution with water were evaporated at reduced pressure. The active fraction was purified by high-voltage electrophoresis (Whatman 3MM paper washed in buffer: pyridine–acetic acid, 0.07*M*, *p*H 5.2). The area containing the active fraction was cut out, and the new amino acid was eluted with water. The material could be reduced with either dithiothreitol or sodium borohydride. The reduced product was treated with iodoacetic acid, and the only ninhydrin-positive substance identifiable was carboxymethylcysteine. Oxidation of the amino acid with either bromine water or performic acid yielded cysteic acid. The substance was therefore thought to be an unsymmetrical disulfide, one half being cysteine and the other half, a ninhydrin-negative substance. The new amino acid was unstable in water at neutral *p*H, and after a few days three substances could be detected on high-voltage electrophoresis with the H_2PtCl_6–KI reagent. One was the original material, one was cystine, and the other a new disulfide which we believe to be derived from the ninhydrin-negative portion of the molecule. This new disulfide did not migrate on high-voltage electrophoresis in aqueous formic acid (*p*H, 1.6) but migrated much more rapidly than the original substance toward the anode at *p*H 5.2 and was isolated after purification in this system.

Further definitive information was obtained from the mass spectra of a series of more volatile derivatives. These comprised the methyl-, propyl-, and butyltrifluoroacetyl esters of the new amino acid and the methyl-, propyl-, and butyltrifluoroacetyl esters of the ninhydrin-negative disulfide derived from it. All derivatives were prepared by the method of Gehrke and Stalling (*3*). Mass spectral measurements (Varian MAT SM1) indicated molecular ion formulas compatible with a parent structure $C_6H_{11}NO_5S_2$. The presence of two carboxyl groups was confirmed by the shift of 28 mass units between molecule ions of the propyl and butyl esters. The presence of two sulfur atoms was inferred from isotope-ratio determinations ($S^{34}:S^{32}$) on the molecule ion peaks in each spectrum. From the foregoing mass-spectrometry data the structure of the parent substance which is most consistent with the data is