modern forgery (*10*); and the results confirm this fact also.

The authorship of the two remaining paintings, ascribed to Vermeer, has been questioned (*11*). Since these paintings first appeared in the art market in the early 1920's, the method was applied to them. The results indicate that it is unlikely that these paintings are 20th-century forgeries. The method, of course, cannot prove that any one painter was the author of a particular work. It does indicate that in these two cases the lead in the paintings was refined at least 100 years ago.

The analyses of the last two paintings were completed, using our older procedure (*12*), before we fully realized the possible compromising effect of the large amounts of natural earth pigments in the samples. In this case, I believe we circumvented this potential difficulty by analyzing the material for uranium. The reasoning is that any significant quantity of radium and radiolead from the natural iron ocher present, made by grinding rock, must be accompanied by an equivalent quantity of uranium, their ultimate precursor. Fluorometric analyses, of the solutions remaining after our radium analysis, and neutron activation analyses of small samples (less than 1 mg) of the original materials, failed to detect uranium. For these two independent methods, I estimate (*13*) the uranium content to be less than 1 (fluorometry) and 0.9 (activation analysis) disintegration per minute per gram of Pb for "Laughing Girl," and less than 0.1 (fluorometry) and 0.1 (activation analysis) disintegration per minute per gram of Pb for "Lace-maker." These limits are well below the concentrations of Ra^{226} and Pb^{210} activity found in the respective samples (Table 1); and, therefore, the results appear to be valid. It would, of course, be ideal if additional samples could be examined by the new method; but, unfortunately, obtaining further samples of sufficient size from these two paintings would be extremely difficult.

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2. For example, one series of experiments in which 11 disintegrations per minute (dpm) of Ra^{226} were added to a sample of white lead, previously found to contain approximately 0.5 dpm, resulted in radium recoveries of 11, 11, and 10 dpm with corrections for chemical yields based on Ba^{133} measurements of 74, 46, and 85 percent, respectively.
3. The procedure incorporates parts of the procedure given by D. N. Sunderman and C. W. Townley, *Nat. Acad. of Sci.–Nat. Res. Council Rep.* **3010**, 47 (1960).
4. The filter support used and the results obtained with a similar quantity of barium sulfate as a carrying precipitate are described by B. Keisch and A. S. Levine, *Anal. Chem.* **38**, 1969 (1966).
5. For the Ra^{226} (which is most affected by the presence of impurities), the measured concentration in the white lead used was 0.4 ± 0.2 dpm per gram of lead. Analysis of the mixture by the new method gave 0.6 ± 0.2 dpm per gram of lead, while the old method resulted in 1.4 ± 0.4 dpm per gram of lead. The latter result compares with the value of 2.6 ± 0.8 dpm per gram of lead calculated as the total contribution from the ocher and the white lead.
6. The logarithms of the calculated separation factors exhibit a normal distribution (*1*).
7. For uncertainties in the measurements of Ra^{226} and Po^{210} of 10 percent (one standard deviation), which is typical for these low-level determinations, the uncertainties in $[1 - (Ra)/(Po)]$ at values of 0.9, 0.5, and 0.1 are approximately 1.6, 14, and 130 percent, respectively.
8. P. Coremans, *Van Meegeren's Faked Vermeers and De Hooghs* (Meulenhoff, Amsterdam, 1949).
9. Such an ore would also require the large uranium content to be homogeneously mixed with the lead because heterogeneities containing the entire uranium series would have been removed during ore beneficiation. Needless to say, such an ore is unknown, particularly in the lead mines of 17th-century Europe.
10. W. Froentjes and A. M. de Wild, *Burlington Mag.* **92**, 297 (1950).
11. A. B. de Vries, *Jan Vermeer van Delft* (Batsford, London, 1948), pp. 64–65, and supplement.
12. These results, as well as all of the results reported previously (*1*) and used here in Fig. 1, were obtained at Nuclear Science & Engineering Corporation.
13. For the fluorometric analyses, we would have been able to measure these quantities with an estimated uncertainty of approximately 50 percent. For the activation analyses, the quantities represent an uncertainty of 1 standard deviation in the comparison of the actual samples with blank samples.
14. I thank E. R. Feidler, J. Walker, and the National Gallery of Art, Washington, D.C., for supporting this work; J. H. Leopold, P. J. J. van Thiel, H. Kühn, and E. Hulmer, in addition to those shown in Table 1, for aid in obtaining samples; R. L. Feller for his valuable advice and criticism; and C. Sizemore for her assistance with the analyses.

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Optical Pulse of a Periodic Radio Star

Abstract. *The pulsating radio star reported by Hewish* et al. (1) *has been studied in the blue region of the optical spectrum and found to have a pulse amplitude less than 10 percent of the photon count expected for 18th magnitude. No upper limit to a sinusoidal oscillation less than or equal to a complete modulation can be set.*

A rapidly pulsating radio star, observed at 81 Mhz, has been reported by Hewish *et al.* (*1*). An optical identification of the source (*2*) suggests that it is associated with a blue star of magnitude 18. The principal radio feature is a recurrent sharp pulse with a duration of a few tens of milliseconds and a repetition period of $1.3372795 \pm .0000020$ seconds. The object has also been seen by Davies *et al.* (*3*) at 151, 240, and 408 Mhz.

Models for these objects have been put forward by Saslaw *et al.* (*4*) and by Ostriker (*5*). In one model, the pulsations arise from a gravitational lens effect around a neutron star binary. In the other, radio emission arises from active regions on a rapidly rotating white dwarf. Clearly more experimental observations are needed to constrain the classes of possible mechanism, and a search for periodic behavior at optical wavelengths is called for in particular. Observation of optical pulsation in the blue object tentatively associated with the radio signals would provide conclusive confirmation of that identification. To this end we have constructed a system which searches specifically for periodic fluctuations of the light intensity from the blue star at the frequency of the pulsating radio source. We have taken preliminary observations and can report seeing no pulsations. Upper limits to optical pulsations in several possible modes are presented.

Our experimental technique relies heavily on the precision with which Hewish *et al.* (*1*) have quoted the periodicity of the radio source. Figure 1 is a schematic diagram of the system we use. A 1-Mhz quartz crystal forms a clock which matches the radio peri-

Table 1. The duration of hypothetical optical burst within the 1.337-second cycle is represented by Δt. The mode limited is the 95 percent confidence level upper limit to the number of photons associated with such bursts accumulated over a 10-minute observation time.

k (channels)	Δt (msec)	Mode limits (counts)
1	4.4	53
2	8.8	84
3	13.2	88
4	17.6	98
5	22	116
6	26.4	126
7	30.8	144
8	35.2	151
9	39.6	168
10	44.0	158
15	66	173
20	88	206

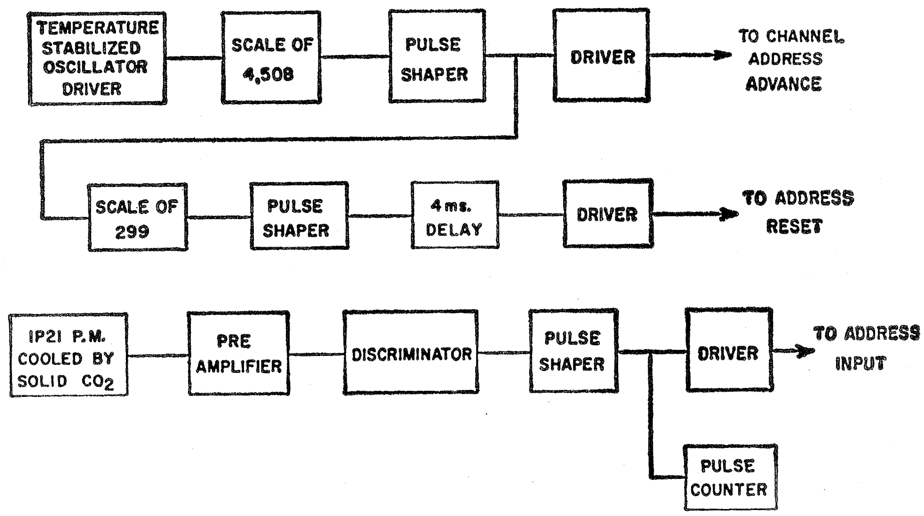

Fig. 1. Block diagram of the data-handling system. The master oscillator frequency was 1.008007 Mhz at the time of the experiment.

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) $19^h19^m36^s.88$, declination (1950) $21°46'57''.4$, and we guided from AGK2 + 21° · 1963 with coordinates α (1950), $19^h19^m23^s.4$ 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.

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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