Reports

Optical Search for Pulsations from Pulsating Radio Source CP 1919

Abstract. *Optical observations of the 18th magnitude blue star and of the faint red object in the approximate location of the pulsating radio source CP 1919 disclose no pulsations of visible light, in a mode similar to that of the radio pulsations, of more than 0.4 percent or 0.8 percent, respectively, of the total visible output; or, for a sinusoidal modulation with the same period, no more than a 4-percent, or 8-percent, root-mean-square intensity fluctuation.*

The observation by Hewish *et al.* (*1*) of a rapidly pulsating radio source has led us to look for similar pulsations of the same object in the optical region of the spectrum. Using a 1-mile (1.6-km) radio telescope, Ryle and Bailey (*2*) determined the position of CP 1919 to be right ascension (1950.0), $19^h19^m37.0^s \pm 0.2^s$; declination (1950.0), $21°47' 02'' \pm 10''$; from the Palomar Sky Survey plates of this region, they suggested two possible optical sources that may be associated with the radio source, one an 18th magnitude blue star and the other a fainter red object. With Harvard plates and the Palomar Sky Survey, we have compared the stars in this region with stars in the nearby galactic cluster NGC 6802, for which photoelectrically calibrated magnitudes exist (*3*). We estimate the photographic magnitude of the blue star to be 19.0 ± 0.3.

Our observations were made with the Harvard 61-inch (1.54-m) telescope at Agassiz Station (Harvard, Mass.) on the mornings of 18, 19, 20, and 23 April and 7 and 8 May. We used apertures of about 7 and 40 arcsec in diameter and looked at the blue star indicated by Ryle and Bailey (April observations) and at the nearby faint red object (May observations). These stars were never visible by eye, but a clearly visible 16.2 magnitude star 105 arcsec to the south was used as a reference. With calibrated *x,y* screws we could offset from this reference star to the desired coordinates and subsequently use the reference star for offset guiding.

The light passing through the 7-arcsec aperture was focused on an ITT FW-130 photomultiplier having an S20 photocathode. The dark count, at −20°C, of only 3 count/sec is negligible compared to the typical 100 count/sec from the sky background. Just before offsetting, we measured the excess count rate over the sky background for the 16.2 magnitude reference star. The measured count rate of 100 count/sec from this star leads us to expect about 7.5 count/sec from the 19th magnitude blue star.

The individual photomultiplier pulses were recorded after amplification (Fig. 1) on one channel of a two-channel magnetic-tape recorder, while timing pulses were simultaneously recorded on the second channel. The timing pulses, derived from a stable crystal clock, consisted of 0.1-msec negative pulses at a 1-khz rate and a single positive pulse for every 5×2^{17} negative pulses (that is, one positive pulse approximately every 11 minutes). Since the clock was in continuous operation, the slow pulses, used as timing markers, permitted coherent superposition of several nights' data.

A 400-channel multiscaler was used to analyze the data by sorting the signal pulses according to their time of arrival. The 1-khz timing pulses, divided by 16, were used to advance the storing address, while each photomultiplier pulse raised by one the count in the operating address. We decided to sort with a periodicity of four radio pulsation periods [5.4388200 seconds, as determined from the new period reported by Radhakrishnan *et al.* (*4*), with Doppler correction] so that any optical pulsations at the radio period would show up as four equally spaced

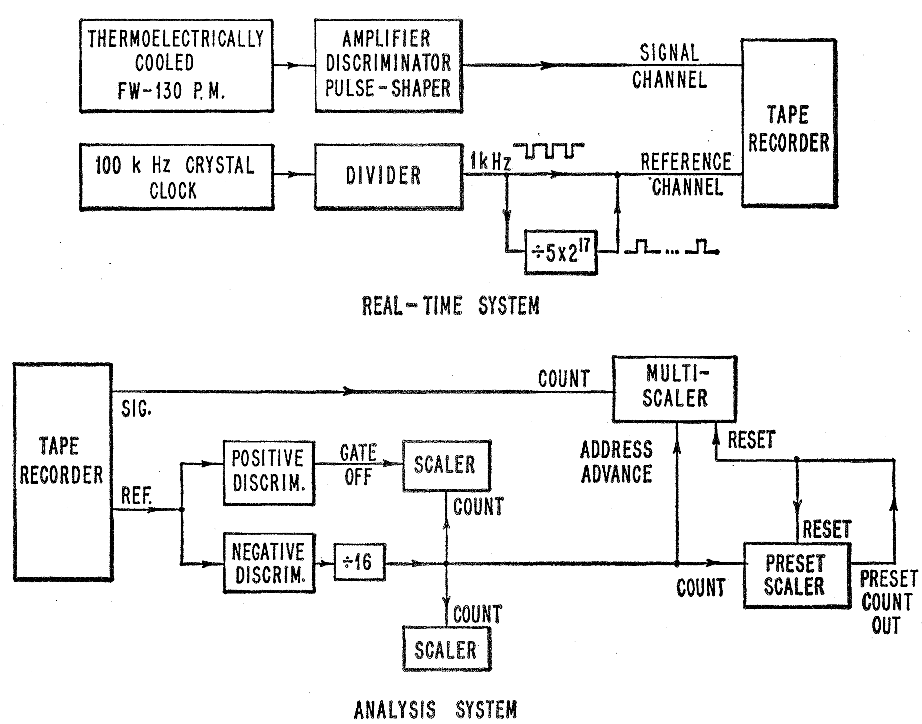

Fig. 1. Block diagram of recording system and analysis system.

bumps on the analyzed data and would thereby be easily distinguished from any other spurious bursts. A preset counter, set to the nearest integral count corresponding to the desired analysis period, was used to reset the 400-channel analyzer. The preset counter was periodically altered to achieve the exact desired period. The exact phase of each morning's data was determined with a scaler that counted the number of 1-khz timing pulses from the beginning of the run to the first slow (positive) timing pulse. The system was checked by generating and tape-recording a "signal" that was precisely coherent with the timing pulses—in fact, simply the timing pulses divided by 2^{16}. A slightly incommensurate period was chosen, and the corrections were made as just described. After 30 minutes of analysis, all the pulses were in a single channel, indicating proper operation with maximum resolution.

With our system we could analyze the data for any expected period, a flexibility that enabled us to reanalyze the data when the first reported period (*1*) was found to be in error (*4*). Each night's data were analyzed for the presence of optical pulsations having the same period as that reported for the radio source CP 1919 (with appropriate Doppler correction). No pulsations were evident. Therefore, in order to make the strongest possible statements based on our data, we combined coherently into a four-period display the data obtained during the April observations, representing a total observing time of about 4 hours and containing a total of more than 10^6 pulses. Still seeing no bumps, we further combined all the data into a one-period display (Fig. 2). The average of 14,000 counts in each 16-msec channel implies a standard deviation of 118 counts per channel (the measured standard deviation being indeed 124 counts per channel). From this it is evident that an excess of 370 counts (that is, more than 3 standard deviations) in any one of the channels would have been readily detected.

If the blue star with an expected count rate of 7.5 count/sec radiated its entire visible output within one 16-msec channel every 1.337 seconds, we would expect to find over the total analysis time 87,000 counts in that channel. This is 700 standard deviations above our noise level. Thus, we can say that

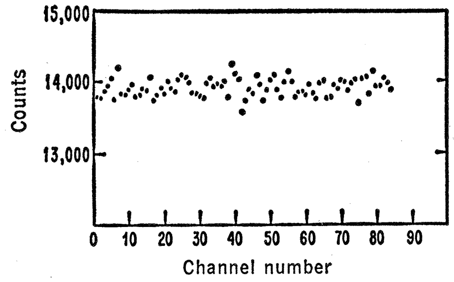

Fig. 2. Analyzed data of 18, 19, 20, and 23 April.

if the 19th magnitude star is modulated with a pattern similar to that of the radio source, then the fluctuation in any 16-msec interval contains less than 0.4 percent of the total visible output over the whole cycle. A similar analysis can be carried out for pulses of longer duration by simply adding together groups of adjacent channels. Such a technique, again with the criterion of 3 standard deviations being used, indicates that any sinusoidal modulation at the radio-star period corresponds to less than a 4-percent root-mean-square (r.m.s.) intensity variation. We have also analyzed the observation of 19 April (the longest single run) with 4-msec time resolution; here we get 334 channels of about 1200 counts each. Again, no extrastatistical fluctuations are observed, thus limiting any optical pulsation of 4 msec (or less) to less than 0.35 percent of the total visible output.

In addition we tested for a possible sinusoidal variation at twice the radio period, and none was found outside the statistical limit of 6 percent r.m.s. This is not inconsistent with the small effect reported by Lynds *et al.* (*5*) since the size of their effect is about half our minimum detectable signal; it should also be noted that their aperture accepted a larger area of sky.

Using a Wratten 25 filter, we obtained from the faint red object a one-period display of approximately 750 counts per 16-msec channel. Using the fact that this red star's image on the Palomar red plate is comparable to that of the nearby blue star, we estimate that about 120 counts per channel originate from the red star, and thus conclude that any optical pulsation of 16 msec or less contains less than 0.8 percent of the total visible output in a 1.337-second interval. Similarly, the sinusoidal variation at the radio-star period is less than 8 percent r.m.s.

We also looked at the sky with a larger (40 arcsec in diameter) circular aperture, both with and without the red filter, and detected no significant fluctuations. In terms of a 19th magnitude star within this acceptance angle, any short pulsations contain less than 5 percent of its visible output over a 1.337-second cycle, and any sinusoidal variation is less than 50 percent r.m.s.

We conclude that if the 19th magnitude blue star or the nearby red star has some connection with the radio source CP 1919, the physical mechanism that causes the radio pulses does not make itself very evident at optical frequencies (*6, 7*). Perhaps one should not have expected this connection, since the small proper motion of the blue star reported by Luyten (*8*), 0″.016 per year, suggests a distance of several hundred parsecs, several times larger than that deduced from the frequency-dependent arrival times of radio pulses (*1*). A distance of this order is also suggested by the apparent photographic magnitude since, if the distance to the blue star were 300 parsecs and its light not appreciably dimmed by interstellar matter, its absolute photographic magnitude would be +11.6, quite typical of white dwarfs.

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References and Notes

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