O. F. Prilutskiĭ, I. L. Rozenthal', and V. V. Usov. On the Nature of Bursts of Cosmic γ Radiation. About six months ago, powerful bursts of γ radiation in the energy range 0.2–1.5 MeV were detected during processing of observations from Vela satellites. The bursts ranged from 0.1 to 30 sec in duration, the radiation flux densities reached $4 \cdot 10^{-4}$ erg/cm^2 · sec, and the total energy flux per pulse ranged from 10^{-5} to 2×10^{-4} erg/cm^2 (the lower limit of this range was determined by the sensitivity of the detector). As a rule, the time profile of a γ burst took the form of a sharp increase in radiation flux density followed by a slower decrease. In some cases, the decrease in the radiation flux density was nonmonotonic, and intensity maxima and minima lasting up to 0.1 sec were observed within a pulse. Detectors on the OSO-7 and IMP-6 satellites measured the spectra of the γ bursts. The observed spectra indicate both an exponential cutoff at an energy $\epsilon_\gamma \sim 150$ keV and a power-law decrease in the 11–100 keV range, with the hardness of the spectrum increasing with flux density.

Measurement of the difference between the times at which the γ-burst front was registered on several satellites made it possible to estimate the directions to their sources. It was found that objects within the solar system could not have generated the observed γ bursts. However, the presently available information is inadequate to decide whether the γ bursts are of galactic or metagalactic nature.

Several hypotheses have been advanced to account for the nature of the observed γ bursts. Thus, the original observers note the possibility that the γ bursts may be related to supernova flareups. But the original hypothesis of Colgate, who considered the generation of γ radiation in supernova outbursts, results in different characteristic times ($\tau \sim 10^{-5}$ sec) and energies ($\epsilon_\gamma \sim 1$ GeV) for the γ bursts. The increase of the presupernova's radius to $\sim 10^{12}$ cm that was proposed in Colgate's recent paper could bring the times and energies of the γ bursts close to the observed values, but then we have the problem of supporting the energy output. Namely, as was pointed out by D. K. Nadezhin and D. A. Frank-Kamenetskiĭ, a relativistic shock wave is weak in stars with small parabolic velocities (large radii) and, consequently, the energy that can be radiated in the γ band is small.

Stecker and Frost recently proposed that the sources of the γ bursts are flare stars, with the flare mechanism similar to that of solar flares. An argument in favor of this hypothesis is the similarity between the durations and spectra of the γ radiation in the bursts and the hard x-ray emission of solar flares. But in this model a γ burst should be accompanied by exceptionally powerful soft x-ray emission (with a flux $\gtrsim 1$ erg/cm^2 · sec). There is no doubt that this emission would be detected in the form of ionospheric disturbances.

Another possible mechanism for the formation of the γ bursts is nonstationary accretion on compact objects—white dwarfs, neutron stars, and "black holes." Two concrete models have been proposed in the paper by M. Harwit et al. for the generation of γ bursts during accretion.

In the first model, the γ bursts are related to accretion of comets on single neutron stars, and in the second to accretion of gas ejected from the normal component of a close binary system onto its compact companion. These models explain the energy and time characteristics of the γ bursts. The most complex question in these models is that concerning the possibility of explaining the observed frequency of the bursts. Thus, for example, the preservation of a dense cometary cloud in a supernova outburst is improbable.

It is also possible that the γ bursts are generated in the collapse of rotating magnetic stars with masses $10^5 M_\odot$ at cosmological distances. The activity of galactic nuclei is now being linked more and more frequently to the presence of precisely such supermassive stars. The energy fluxes, duration, spectra, and expected numbers of bursts calculated in the framework of this hypothesis are in agreement with the observed values.

The decisive test of the various hypotheses as to the nature of the γ bursts is a statistical test—determination of the number of bursts N(S) with flux larger than S. Correlated observations of this phenomenon in various ranges—radio, optical, x-ray, and gamma—must also play an important role in investigation of the γ bursts.

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V. S. Troitskiĭ, L. N. Bondar', and A. M. Starodubtsev. The Search for Sporadic Radio Emission from Space. The search for irregular pulsed radio emission from space that might be associated with various explosive processes in the cosmos, or accompany the gravity waves emanating from the center of the Galaxy that were observed by Weber or, finally, that might be due to activity of an extraterrestrial civilization possibly present in the neighborhood of the solar system has recently been intensified. Weber's waves have high energy at the earth, and their explanation requires a source at the Galactic center with a power output on the order of 10^{51} erg/sec · Hz. In the powerful processes associated with the collapse of massive objects, it seems inevitable that at least a minute part of the energy should exist in the form of electromagnetic waves.

Several groups of investigators have recently been formed to engage in the search for irregular pulsed radio emission from space: in England (the Cambridge group), in the USA (Princeton and Bell Telephone groups), in Canada, and in the USSR (Scientific Research Radiophysics Institute, Academy of Sciences Institute of Cosmic Radiation). The Table gives a brief sketch of their observing conditions. The purpose of the study[1] was to look for pulsed irregular radio emission from the region of the Galactic center that might perhaps accompany Weber gravity waves. Local noise was excluded by conducting observations simultaneously at five stations: Cambridge, Dublin, Harwell, Glasgow, and Malta. Provision was also made for elimination of local interference by measuring the velocity dispersion of the wave as the difference between the arrival times of pulses at a slightly different frequency. The group reported 242 double coincidences in 1114 hours of observations made at night from May through August of 1970 at a frequency of 151 MHz. Six triple coincidences were observed in 586 hours. No cases of coincidence at four

Place	Time of observation	λ, cm	Number of stations operating simultaneously	Object	Sensitivity, flux units	Antenna: Δφ, deg	Authors
England (Cambridge)	May-August, 1970	200	5	Galactic center	$5 \cdot 10^3$	15	W. Charman et al.
USA (Princeton)	May-August 1970	1.5	1	Same	10^6	12	R. Partridge
USA (Bell Telephone)	January-March, 1971	2	2	» »	10^2	0.2	Same
		1.5	2	Crab Nebula	10^6	1.2	G. Wrixon
Canada	June-December, 1971	35	1		10^2	1.4	V. Huges and D. Retallack
USSR (Scientific Research Radiophysics Institute)	1970—1973	50	4	Entire sky	10^4	Dipole	V. S. Troitskiĭ et al.
		35	2	» »	10^4	»	Same
		21	2	» »	10^4	»	» »
		15	2	» »	10^4	»	» »
		8	2	» »	10^4	»	» »
		3	2	» »	10^4	»	» »
USSR (Academy of Sciences Inst. Cosmic Radiation)	1972	70—50	2	» »	10^4	»	N. S. Kardashev et al.

or five stations were observed during the observations. The expected numbers of purely random coincidences are given by the same figures. The authors conclude that they had not observed a single case of pulsed radio emission of cosmic origin in 368 hours of observations.

Radio emission pulses at $\gamma = 2$ cm were investigated in[2] at the times at which, according to Weber, gravity waves are received from the center of the Galaxy. It was found as a result of observations from January through March of 1971 that six radio pulses fell into intervals of ±2 minutes from the arrival times of Weber pulses. A calculation showed that this number was close to the number of random coincidences. The authors conclude that no radio accompaniment of Weber waves was observed accurate to $5 \cdot 10^6$ flux units. They advance several causes to account for this fact. The dispersion delay of the radio waves may be 10^4—10^4 times longer than expected, with the result that correlation is lost; the radio pulse is of longer duration than the gravity pulse, and the apparatus did not reliably register intensity changes taking place during a time on the order of 50 sec or longer. Further, the sources of Weber waves put out an extremely small fraction of their energy in the radio band. Hypotheses touching upon fundamental conclusions of the general theory of relativity have also been advanced; for example, if the velocity of the gravity waves differs from the velocity of light by only one part in 10^{-10}, the correspondence with the radio accompaniment will be lost.

The objective of[3] was the same as in the preceding study. Two stations located 10 km apart were worked simultaneously to separate interference. Observations were made at a wavelength of 1.5 cm at both stations—Havehold College and Bell Laboratories—with the more sensitive apparatus at the latter location. Only one coincident event was observed from May through August 1970, and it was theoretically accidental. Observations of the Crab Nebula were made in the same study; not a single coincident burst was observed. The paper[4] reported observations of the Galactic center from June through December of 1971 at the wavelength 35 cm. Ninety-seven events were recorded in 270 hours of observations. The average density of the events was one in three hours. None of them fell into the ± 5-minute interval around the time of a Weber burst. It was found that the radio pulses were coming from the region of the Galactic center, mostly from an area around the point with the coordinates

$$\alpha = 17^{\mathrm{h}}48.2^{\mathrm{m}} \pm 1.3^{\mathrm{m}}, \quad \delta = 28^\circ\, 58' \pm 52' \quad (1950\ \text{г.}).$$

The registered pulses were shorter than 1 second in duration; the fluxes were of the order of $4 \times 10^{-24}\ {}^{2}/\mathrm{m}^{3}\mathrm{Hz}$ and the density 10 pulses per day. It is supposed that they are giant and hence rare pulses from the pulsar PSR 1749-28, whose position falls into the square of the region emitting the pulses. The authors also discuss the possibility of emission when matter falls into a "black hole."

The result of all these studies was an estimate of the upper intensity limit of radio waves that might possibly accompany the gravity waves. This intensity is less than one part in 10^{27} of the intensity of the gravity waves. If Weber gravity waves from space are a reality, the fact that they are not accompanied by noticeable electromagnetic radiation raises many serious questions, not only of model but also of general physical nature. V. B. Braginskiĭ recently showed experimentally that Weber was very likely in error in concluding that he had observed gravity waves from space (see[5]).

It is observed in the cited foreign papers that no relation was detected between the individual events and various individual solar-activity or ionospheric-process effects. It should be noted that searches for bursts of optical and x-ray emission were performed simultaneously in order to detect correlations with gravity-wave bursts. It appears that very short optical bursts ranging from 1 to 50 μsec are observed in the night sky, but they do not correlate with the Weber bursts. According to Baird and Pomerantz[6], who made balloon measurements of x-ray emission, x-ray bursts are observed to coincide nonaccidentally with Weber bursts. The upper limit of the x-ray pulse energy was estimated and found to be nine orders smaller than the energy in a pulse of Weber gravity waves.

Our studies were begun simultaneously with the foreign ones. Their basic purpose was to search for random sporadic cosmic emissions with a relation to the activity of an extraterrestrial civilization or other causes. Events of duration longer than one second were recorded in these measurements. Slow bursts with times of several seconds were suppressed in the ICR measurements, as they were in the foreign measurements. V. L. Ginzburg drew attention to the fact that searches for irregular pulsed radiation from space have now acquired a new aspect with the discovery of bursts of γ radiation of cosmic origin. Searches for their radio accompaniment are of great interest for establishing the nature of the γ bursts. In general, it appears that a kind of new independent direction is emerging in radio astronomy—the search for and investigation of irregular episodic emissions from space.

Observations of the sporadic background radio emission at the SRRPI (Gor'kiĭ) were conducted from September through November 1970 simultaneously at four stations in the USSR (Murmansk area, Gor'kiĭ area, Crimea, and Ussuriĭsk) at a wavelength $\lambda = 50$ cm, and in June and October 1971 at wavelengths from 3 to 50 cm at two of the stations (Gor'kiĭ region and Crimea). In July and August 1972, synchronous observations were made at three points: Gor'kiĭ area, Crimea, and the ship "Akademik Kurchatov," which was cruising near the Equator in the Atlantic Ocean. The studies showed[7] that bursts of sporadic radio emission and noise storms of varying duration and intensity occur in the centimeter and decimeter bands. Bursts and noise storms of global nature are encountered. During the time from September 1970 through November 1972 (150 observing days), 5800 bursts were registered at λ = 50 cm and 1900 at other wavelengths. There were 25 noise storms lasting more than an hour at 50 cm, and 650 lasting longer than 10 minutes. Among all of the bursts at the 50-cm wavelength, there were about 400 double and 130 triple coincidences. No similarities of form were observed between any of the observed bursts. This means that they are of near-earth origin and do not come from the remote cosmos. The generation phenomenon occurs either at great heights, on the order of several thousand kilometers (the height from which the Crimea and Ussuriĭsk are simultaneously visible), or at heights in the hundreds of kilometers, in which case the generation region would cover a wide area. Figure 1 shows the diurnal variation of the experimental and probable number densities of coinciding bursts, $\bar{n}_2$ (hr^{-1}). The figure shows morning and evening density maxima on the diurnal curve of burst coincidences at different stations, resembling the maxima in the diurnal curve of magnetic disturbances. Bursts coincide at three stations only during the day. The most probable cause of the sporadic radio emission may be generation in the earth's ionomagnetosphere due to the various corpuscular streams incoming from the sun and from the radiation belts.

The statistical characteristics of the bursts were studied (length and intensity distributions, diurnal variation, etc.). It was shown that the average duration of the bursts varies from 0.5 to 4.5 min, depends on the epoch of the observations, and does not depend on the wavelength or the place of the observations. The monthly average single-burst densities $\bar{n}_1$ and the densities of double and triple burst coincidences $\bar{n}_2$ and $\bar{n}_3$ depend on the epoch of the observations, although this dependence was not observed for the average intensity of the bursts. The monthly average burst density increases in proportion to wavelength over the entire wavelength range from 3 to 50 cm. The radiation in the bursts is partially polarized, and they have spectral widths of 0.02 to 1 GHz. The average intensity of the bursts referred to the brightness temperature of the sky is 40—50°K, which gives a radiant flux of $(3-5) \times 10^{21}$ W/m^{2}Hz. The analysis given in[8] indicated that the coefficients of correlation of the monthly average density of single and coinciding bursts and noise storms with the monthly average areas of sunspots and chromospheric flares are the same, ranging from 0.75 to 0.85. Thus, the entire set of properties of the bursts and noise storms of background sporadic radio emission indicates a statistical relation to the solar activity indices. This is illustrated graphically in Fig. 2, which shows plots obtained from the time dependences $\bar{n}_1(t)$, $\bar{n}_2(t)$ and $\bar{S}_P(t)$, $\bar{S}_F(t)$ for the monthly average density $\bar{n}_1$ of single flares as a function of the monthly average areas of sunspots and chromospheric flares for the entire period of the observations, which spans an appreciable part of the 11-year solar activity cycle; various sporadic radio emission mechanisms were considered.

Bursts of the background radio emission were compared with the dates of 16 γ-radiation bursts during 1970—1972. It was found that simultaneous observations were made on only one day, 30 June 1971. On this day, synchronous observations of the radio emission was made at Gor'kiĭ and in the Crimea at wavelengths of 20, 35, and 50 cm. It does not seem accidental that a radio burst was observed in the Crimea at 20^{h}29^{m}30^s Moscow Time on precisely this day, anticipating a γ-radiation burst by 30 seconds. The burst had an effective temperature of 8°K, which corresponds to a flux of $5 \cdot 10^{-22}$ W/m^2; the burst lasted for 20 seconds and was bell-shaped. No bursts were observed at around that time either at Gor'kiĭ or in the Crimea, either at 50 cm or at any of the other wavelengths. The Galactic center was on the local horizon for the observations in the Crimea, but below the horizon at Gor'kiĭ.

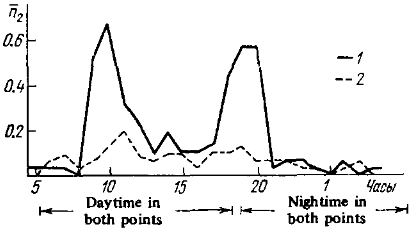

FIG. 1. Diurnal trends of actual and probable densities of double Gor'kiĭ-Crimea coincidences, averaged over the period from September 1 to November 2, 1970 (λ = 50 cm). 1—Actual number of coincidences; 2—random number of coincidences.

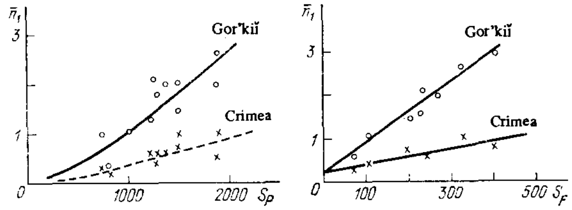

FIG. 2. Monthly average density of single bursts $\bar{n}_1$ as a function of sunspot area and chromospheric-flare area in 1970-1972 for the Crimea and Gor'kiĭ (λ = 50 cm).

The bursts of sporadic radio emission from near-earth space that we observed are capable of masking cosmic pulses strongly, making it difficult to observe them. From this standpoint, the centimeter band is the most suitable one for observations of radio-emission pulses.

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