**V. G. Kirillov-Ugryumov, R. Z. Sagdeev, and Yu. P. Semenov.** *The outlook for observational gamma astronomy.* The prospects for any branch of observational astronomy are determined by the development of its experimental methods and the engineering and financial backing available for implementation of its scientific programs.

Soft gamma radiation with energies from 0.1 to 10 MeV is of interest to astrophysics because this range includes the nuclear energy spectra and the positron-annihilation line. Significant progress in study of the soft cosmic gamma radiation is expected with the launching of the heavy American HEAO satellites. HEAO-3, which was launched in September of 1979, is equipped with a gamma spectrometer with a 400-$cm^3$ germanium crystal. The spectrometer has a resolution of 2.2 keV at an energy per quantum of about 1 MeV. A plan is being prepared for use of the space shuttle to launch the GRO gamma-ray observatory, which will carry five large instruments for study of the soft gamma radiation and medium-energy gamma rays.

The prototype of the modern spacecraft-borne medium-energy gamma-ray telescope was the Soviet instrument carried aboard the Kosmos 251 and Kosmos 264 satellites.[1] All telescopes of this type have as components multiplate spark chambers for registration of the electron-positron pairs from gamma-quantum conversion and a system of scintillation and directional Cherenkov counters to trigger the spark chambers and suppress the charged-particle background.

Much of our recent statistical information on the medium-energy range, where the spectrum may present a broad $\pi^0$-meson maximum, has been obtained from the special-purpose European COS-B satellite.[2] At the same time, since the energy threshold of the telescope on COS-B was above 50 MeV, the range of the spectrum from 10 to 50 MeV has not yet been thoroughly investigated. Measurements of the gamma-ray fluxes in this range would make it possible to determine the ratio of the electronic and nuclear components in the cosmic rays. This is important for analysis of possible sources of high-energy particles and for understanding of the mechanism of flares, including those on the sun.

The MIFI has developed a telescope for the gamma-quantum range from 10 to 100 MeV. It was possible to lower the telescope's registration threshold by reducing the chamber-electrode thickness to 0.01 of the radiation length and using a time-of-flight system instead of the Cherenkov counter. The first model of the telescope has been tested successfully on high altitude balloons in the USSR and in India.[3]

In spite of the impressive results obtained in studies of cosmic sources of gamma rays with energies above 50 MeV with the aid of the SAS-2 and COS-B satellites,[4,5] several problems of fundamental interest to astrophysics still remain open. Among them is the question as to the composition of the gamma radiation: does the main contribution to this flux come from the diffuse component that arises on interaction of the cosmic rays with the interstellar gas or from unresolved discrete sources?

Nor is the nature of the discrete sources themselves clear, except for the two gamma pulsars. Solution of such problems will require the development of a new generation of gamma telescopes with much higher sensitivity and improved energy and angular resolutions. Gamma-band investigation of nonstationary objects of the type, for example, of the Seyfert galaxy NGC 4151, where the x-ray emission is subject to sharp fluctuations on the scale of minutes, requires simultaneous coordinated measurements in various regions of the electromagnetic spectrum.

Plans for an orbiting cosmic observatory (OCO) from which objects can be studied simultaneously in the x-ray band and two gamma subbands, are being prepared in the USSR by a group of laboratories (the coordinating agency is the USSR Academy of Sciences Institute of Space Research) with the participation of two laboratories at Saclay and Toulouse in France.

According to the plans, the observatory's scientific equipment—up to two tons of it—will be injected into an orbit around 300 km high at some time during the next few years. The vehicle will train the telescope's axes onto the object of study and stabilize them during exposures with an error of 30′ or less.

The main instrument aboard the OCO will be a "Gamma" telescope for study of gamma quanta with energies above 50 MeV.[6] The telescope's wide-gap 50 ×50-cm spark chamber will reduce the error of measurement of the angles of arrival of 100-MeV gamma quanta to 2°. A vidicon tube will be used to register the sparks. The option of photographic recording will also be provided for precision measurements and inflight calibration of the system.

Figure 1 shows results of chamber test measurements made in beams of tagged gamma quanta on the DESI (German) and Academy of Sciences Physics Institute (FIAN) "Pakhra" accelerators.[7] Work is now being done on a system that will make some of the measurements with a grid-type coding collimator over the spark chamber and improve angular resolution to 20 minutes of arc.[8]

In the design of the telescope, special attention was given to study of background conditions. A special experiment is being performed for this purpose with a scaled-down gamma telescope on the Salyut 6-Soyuz-

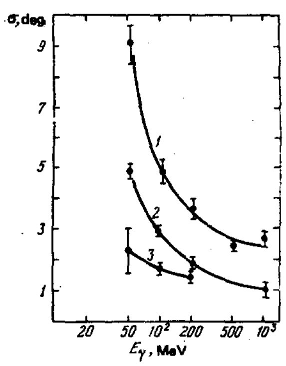


FIG. 1. Calibration results for spark chambers of "Gamma-1" telecope. 1—angular resolution of COS-B telescope; 2—angular resolution of "Gamma" telescope spark chambers; 3—angular resolution of improved spark chambers of "Gamma" telescope, calibration on "Pakhra" accelerator.

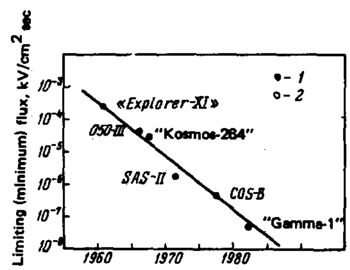


FIG. 2. Gamma-flux limits reached in various telescopes (1) and hypothetical limit of "Gamma" telescope (2).

Progress orbiting complex. To suppress the charged-particle and secondary gamma-quantum background, the control system of the "Gamma" telescope incorporates anticoincidence counters, a gas Cherenkov counter with thresholds of 9 MeV for electrons and 18 GeV for protons, and a time-of-flight system with a resolution of 1 nsec on a 70-cm base. An ionization calorimeter coupled to the telescope will make it possible to measure gamma-quantum energies accurate to about 35%.

For coordinated study of x-ray and gamma radiation, the observatory is also to have a "Disk-M" scintillation telescope to register gamma radiation at 0.1–10 MeV and a "Pul'sar X-2" instrument for x-rays with energies from 2 to 25 keV. The scintillation telescope uses the principle of the modulation anticollimator, which makes it possible to improve angular resolution to 30′. This procedure was tested with success on the "Meteor" satellite in 1977.[9] The "Pul'sar X-2" x-ray telescope incorporates the "Spectre 2" mini-computer developed by French specialists for simultaneous correlation measurement of the periods and intensities of several x-ray pulsars. The collimator axes of the "Pul'sar's" four proportional counters diverge from one another to permit determination of the position of the radiation source from the ratios of the counting rates in different detectors. The source periods that can be measured range from 8 msec to several days. The system will be able to detect a periodic x-ray source with an intensity 1/500 of that of the Crab Nebula.

The spatial positions of the telescope's axes are determined accurate to 5–10′ with the aid of star sensors. The standard exposure time for a source is 2 months. Figure 2 compares the sensitivities of the "Gamma" telescope and other systems.

The construction of space observations is just as necessary to the development of astrophysics as the construction of accelerators is for elementary-particle physics, and it is important even now to proceed with the development of large gamma telescopes with angular resolutions in the minutes of arc and energy resolutions of a few percent.


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