

= Granat =

The International Astrophysical Observatory " GRANAT " (usually known as Granat ; Russian : ?????) , was a Soviet (later Russian) space observatory developed in collaboration with France , Denmark and Bulgaria . It was launched on 1 December 1989 aboard a Proton rocket and placed in a highly eccentric four @-@ day orbit , of which three were devoted to observations . It operated for almost nine years .

In September 1994 , after nearly five years of directed observations , the gas supply for its attitude control was exhausted and the observatory was placed in a non @-@ directed survey mode . Transmissions finally ceased on 27 November 1998 .

With seven different instruments on board , Granat was designed to observe the universe at energies ranging from X @-@ ray to gamma ray . Its main instrument , SIGMA , was capable of imaging both hard X @-@ ray and soft gamma @-@ ray sources . The PHEBUS instrument was meant to study gamma @-@ ray bursts and other transient X @-@ Ray sources . Other experiments such as ART @-@ P were intended to image X @-@ Ray sources in the 35 to 100 keV range . One instrument , WATCH , was designed to monitor the sky continuously and alert the other instruments to new or interesting X @-@ Ray sources . The ART @-@ S spectrometer covered the X @-@ ray energy range while the KONUS @-@ B and TOURNESOL experiments covered both the X @-@ ray and gamma ray spectrum .

= = Spacecraft = =

Granat was a three @-@ axis @-@ stabilized spacecraft and the last of the Venera @-@ class spacecraft produced by the Lavochkin Scientific Production Association . It was similar to the Astron observatory which was functional from 1983 to 1989 ; for this reason , the spacecraft was originally known as the Astron 2 . It weighed 4 @.@ 4 metric tons and carried almost 2 @.@ 3 metric tons of international scientific instrumentation . Granat stood 6 @.@ 5 m tall and had a total span of 8 @.@ 5 m across its solar arrays . The power made available to the scientific instruments was approximately 400 W.

= = Launch and orbit = =

The spacecraft was launched on 1 December 1989 aboard a Proton rocket from the Baikonur Cosmodrome in Kazakh SSR . It was placed in a highly eccentric 98 @-@ hour orbit with an initial apogee / perigee of 202 @,@ 480 km / 1 @,@ 760 km respectively and an inclination of 51 @.@ 9 degrees . This meant that solar and lunar perturbations would significantly increase the orbits inclination while reducing its eccentricity , such that the orbit had become near @-@ circular by the time Granat completed its directed observations in September 1994 . (By 1991 , the perigee had increased to 20 @,@ 000 km ; by September 1994 , the apogee / perigee was 59 @,@ 025 km / 144 @,@ 550 km at an inclination of 86 @.@ 7 degrees .)

Three days out of the four @-@ day orbit were devoted to observations . After over nine years in orbit , the observatory finally reentered the Earth 's atmosphere on May 25 , 1999 .

= = Instrumentation = =

= = = SIGMA = = =

The hard X @-@ ray and low @-@ energy gamma @-@ ray SIGMA telescope was a collaboration between CESR (Toulouse) and CEA (Saclay) . It covered the energy range 35 ? 1300 keV , with an effective area of 800 cm² and a maximum sensitivity field of view of ~ 5 ° × 5 ° . The maximum angular resolution was 15 arcmin . The energy resolution was 8 % at 511 keV . Its imaging capabilities were derived from the association of a coded mask and a position sensitive detector

based on the Anger camera principle .

=== ART @-@ P ===

The ART @-@ P X @-@ ray telescope was the responsibility of the IKI in Moscow . The instrument covered the energy range 4 to 60 keV for imaging and 4 to 100 keV for spectroscopy and timing . There were four identical modules of the ART @-@ P telescope , each consisting of a position sensitive multi @-@ wire proportional counter (MWPC) together with a URA coded mask . Each module had an effective area of approximately 600 cm ² , producing a field of view of 1 @.@ 8 ° by 1 @.@ 8 ° . The angular resolution was 5 arcmin ; temporal and energy resolutions were 3 @.@ 9 ms and 22 % at 6 keV , respectively . The instrument achieved a sensitivity of 0 @.@ 001 of the Crab nebula source (= 1 " mCrab ") in an eight @-@ hour exposure . The maximum time resolution was 4 ms .

=== ART @-@ S ===

The ART @-@ S X @-@ ray spectrometer , also built by the IKI , covered the energy range 3 to 100 keV . Its field of view was 2 ° by 2 ° . The instrument consisted of four detectors based on spectroscopic MWPCs , making an effective area of 2 @,@ 400 cm ² at 10 keV and 800 cm ² at 100 keV . The time resolution was 200 microseconds .

=== PHEBUS ===

The PHEBUS experiment was designed by CESR (Toulouse) to record high energy transient events in the range 100 keV to 100 MeV . It consisted of two independent detectors and their associated electronics . Each detector consisted of a bismuth germanate (BGO) crystal 78 mm in diameter by 120 mm thick , surrounded by a plastic anti @-@ coincidence jacket . The two detectors were arranged on the spacecraft so as to observe 4? steradians . The burst mode was triggered when the count rate in the 0 @.@ 1 to 1 @.@ 5 MeV energy range exceeded the background level by 8 sigma in either 0 @.@ 25 or 1 @.@ 0 seconds . There were 116 energy channels .

=== WATCH ===

Starting in January 1990 , four WATCH instruments , designed by the Danish Space Research Institute , were in operation on the Granat observatory . The instruments could localize bright sources in the 6 to 180 keV range to within 0 @.@ 5 ° using a Rotation Modulation Collimator . Taken together , the instruments ' three fields of view covered approximately 75 % of the sky . The energy resolution was 30 % FWHM at 60 keV . During quiet periods , count rates in two energy bands (6 to 15 and 15 to 180 keV) were accumulated for 4 , 8 , or 16 seconds , depending on onboard computer memory availability . During a burst or transient event , count rates were accumulated with a time resolution of 1 second per 36 energy channels .

=== KONUS @-@ B ===

The KONUS @-@ B instrument , designed by the Ioffe Physico @-@ Technical Institute in St. Petersburg , consisted of seven detectors distributed around the spacecraft that responded to photons of 10 keV to 8 MeV energy . They consisted of NaI (TI) scintillator crystals 200 mm in diameter by 50 mm thick behind a Be entrance window . The side surfaces were protected by a 5 mm thick lead layer . The burst detection threshold was 500 to 50 microjoules per square meter (5 × 10 @-@ 7 to 5 × 10 @-@ 8 erg / cm ²) , depending on the burst spectrum and rise time . Spectra were taken in two 31 @-@ channel pulse height analyzers (PHAs) , of which the first eight were measured with 1 / 16 s time resolution and the remaining with variable time resolutions depending on the count rate . The range of resolutions covered 0 @.@ 25 to 8 s .

The KONUS @-@ B instrument operated from 11 December 1989 until 20 February 1990 . Over that period , the " on " time for the experiment was 27 days . Some 60 solar flares and 19 cosmic gamma @-@ ray bursts were detected .

= = = TOURNESOL = = =

The French TOURNESOL instrument consisted of four proportional counters and two optical detectors . The proportional counters detected photons between 2 keV and 20 MeV in a 6 ° by 6 ° field of view . The visible detectors had a field of view of 5 ° by 5 ° . The instrument was designed to look for optical counterparts of high @-@ energy burst sources , as well as performing spectral analysis of the high @-@ energy events .

= = Science results = =

Over the initial four years of directed observations , Granat observed many galactic and extra @-@ galactic X @-@ ray sources with emphasis on the deep imaging and spectroscopy of the galactic center , broad @-@ band observations of black hole candidates , and X @-@ ray novae . After 1994 , the observatory was switched to survey mode and carried out a sensitive all @-@ sky survey in the 40 to 200 keV energy band .

Some of the highlights included :

A very deep imaging (more than 5 million seconds duration) of the galactic center region .

Discovery of electron @-@ positron annihilation lines from the galactic microquasar 1E1740 @-@ 294 and the X @-@ ray Nova Muscae .

Study of spectra and time variability of black hole candidates .

Across eight years of observations , Granat discovered some twenty new X @-@ ray sources , i.e. candidate black holes and neutron stars . Consequently , their designations begin with " GRS " meaning " GRANAT source " . Examples are GRS 1915 + 105 (the first microquasar discovered in our galaxy) and GRS 1124 @-@ 683 .

= = Impact of the dissolution of the Soviet Union = =

After the end of the Soviet Union , two problems arose for the project . The first was geopolitical in nature : the main spacecraft control center was located at the Yevpatoria facility in the Crimea region . This control center was significant in the Soviet space program , being one of only two in the country equipped with a 70 m dish antenna . With the breakup of the Union , the Crimea region , although mostly populated by ethnic Russians , found itself part of the newly independent Ukraine and the center was put under Ukrainian national control , prompting new political hurdles .

The main and most urgent problem , however , was in finding funds to support the continued operation of the spacecraft amid the spending crunch in post @-@ Soviet Russia . The French space agency , having already contributed significantly to the project (both scientifically and financially) , took upon itself to fund the continuing operations directly .