GAMMA-RAY ASTRONOMY IN RUSSIA: FROM ANNA-3 TO GAMMA-400

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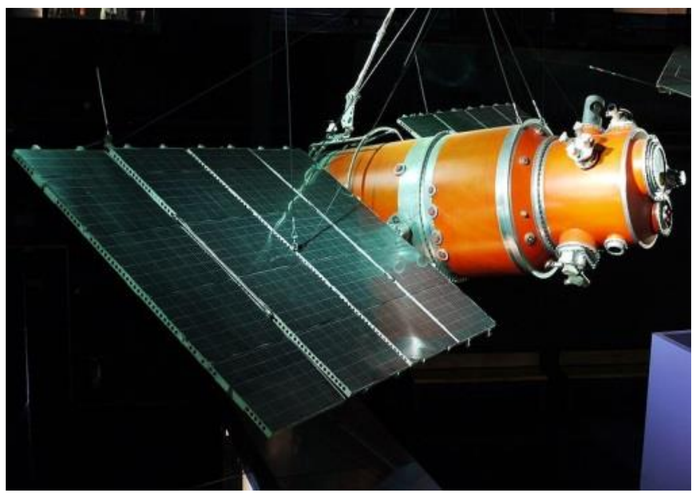
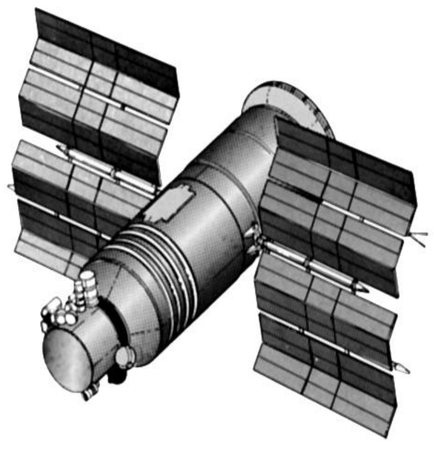
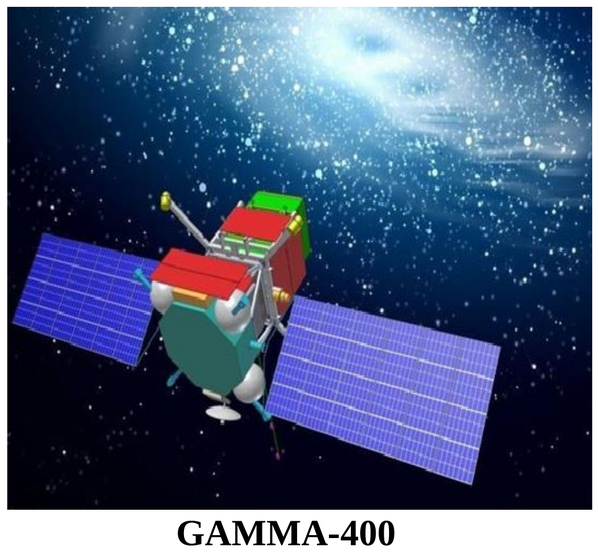


Anna-3 (Cosmos - 251, 264)
USSR
1968, 1969
200 MeV – 1 GeV



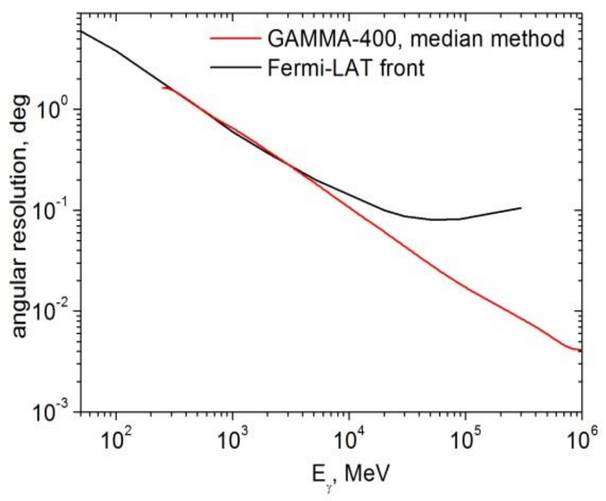
GAMMA-1
USSR
1990 – 1992
30 MeV – 5 GeV

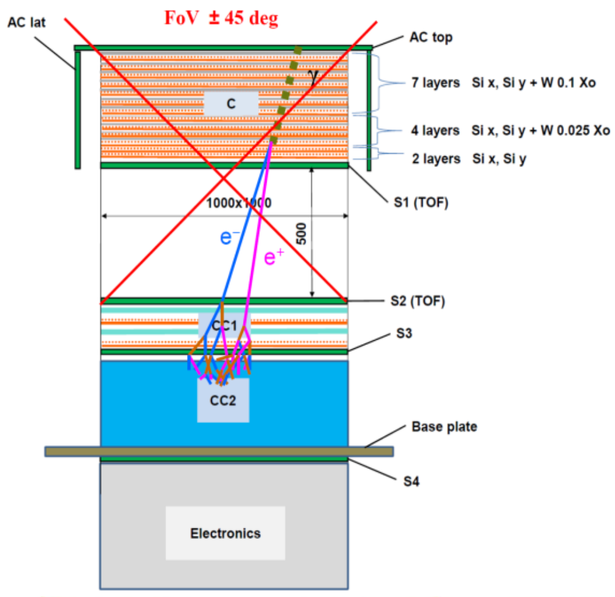
Coronas-Photon
Russia
2009-2010
0.3 MeV – 2 GeV

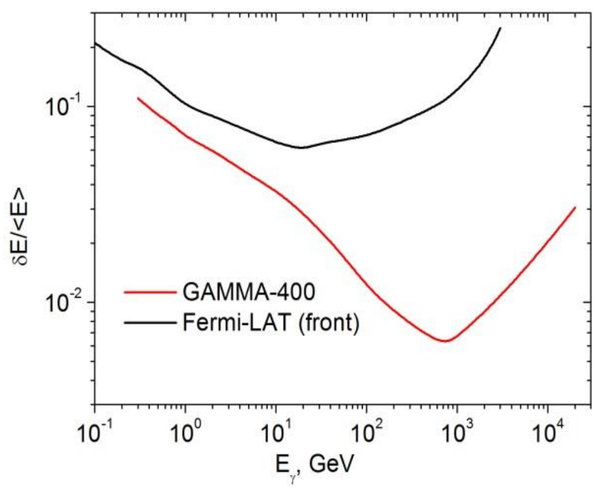


GAMMA-400
Russia
~2025
20 MeV - 10 TeV

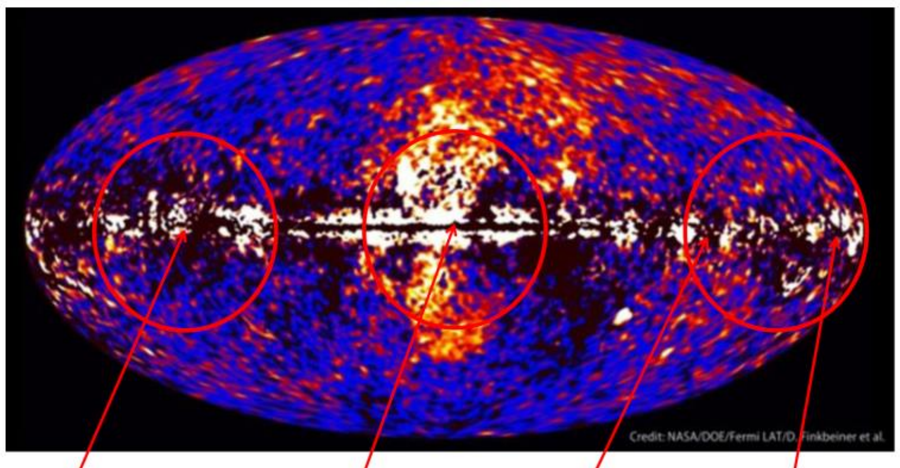
In 1967-1968, simultaneously with OSO-3, A. Galper et al. began to study gamma-ray emission in the energy range of 30-100 MeV on the Cosmos 208, 251, 264 satellites. Gamma-ray emission was detected from the Galactic disk and also from the radio source 3C 120. In 1972, when studying on balloons (E_γ > 40 MeV), as well as at the Crimean ground-based astrophysical observatory ($E_\gamma > 10^{12}$ eV), gamma-ray emission from the variable source Cyg X-3 with 4.8 h period was detected for the first time in the gamma-ray range. In 1990-1992, GAMMA-1 gamma-ray telescope detected gamma-ray emission from Vela, Geminga, Cyg X-3, Hercules X-1, as well as, for the first time, the high-energy (E_γ > 1 GeV) gamma-ray emission from Sun during solar flares on March 26 and June 15, 1991. In 2009-2010, Coronas-Photon detected gamma-ray emission in the energy range of 0.3-2000 MeV. GAMMA-400, currently developing gamma-ray telescope, together with X-ray telescope will precisely and detailed observe in the energy range of ~20 MeV to ~10000 GeV and 3-30 keV the Galactic plane, especially, Galactic Center, Fermi Bubbles, Crab, Cygnus, etc. GAMMA-400 will operate in the highly elliptic orbit continuously for a long time with the unprecedented angular (~0.01° at E_γ = 100 GeV) and energy (~1% at E_γ = 100 GeV) resolutions better than the Fermi-LAT, as well as ground gamma-ray telescopes, by a factor of 5-10. GAMMA-400 will permit to resolve gamma-ray lines from annihilation or decay of dark matter particles, identify many discrete sources (many of which are variable), to clarify the structure of extended sources, to specify the data on the diffuse emission.

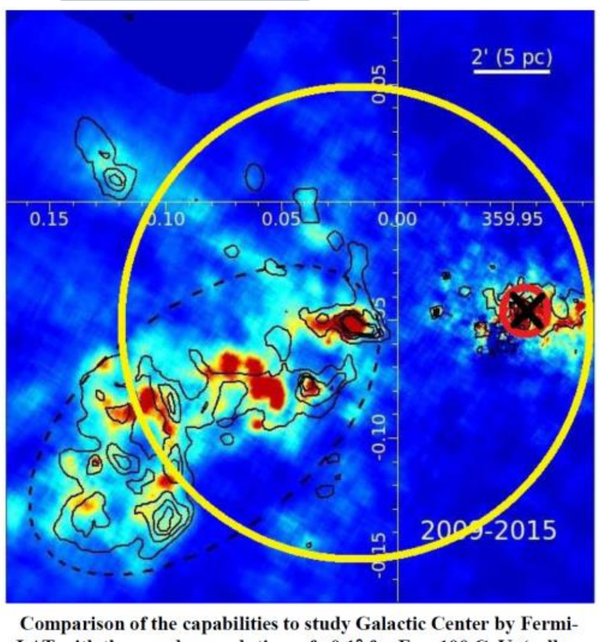






Galactic Center, Fermi Bubbles, Crab, Cygnus, Vela, Geminga, and other regions will be observed with the GAMMA-400 aperture of ±45°

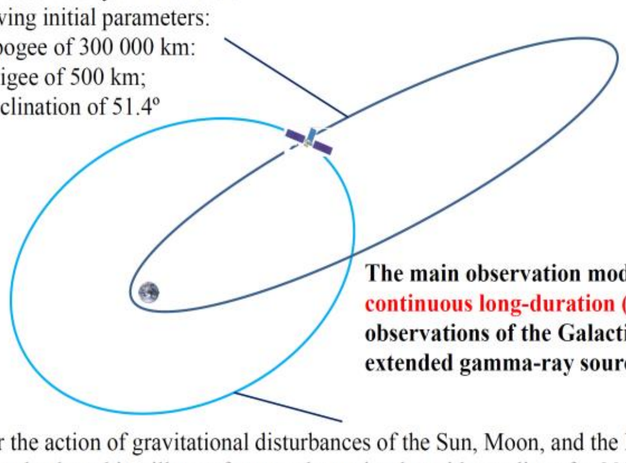




Comparison of the capabilities to study Galactic Center by Fermi-LAT with the angular resolution of ~0.1° for E_γ = 100 GeV (yellow circle) and GAMMA-400 with the angular resolution of ~0.01° for E_γ = 100 GeV (red circle), using Chandra X-ray observation. The Sgr A* position is marked by cross.

The GAMMA-400 orbit evolution and observation modes

The orbit of the GAMMA-400 space observatory will have the following initial parameters:
-an apogee of 300 000 km:
-a perigee of 500 km;
-an inclination of 51.4º



The main observation mode is continuous long-duration (~100 days) observations of the Galactic Center, extended gamma-ray sources, etc.

Under the action of gravitational disturbances of the Sun, Moon, and the Earth after ~6 months the orbit will transform to about circular with a radius of ~200 000 km and will be without the Earth's occultation and out of radiation belts.

	AGILE Italy	Fermi-LAT USA	CALET Japan	DAMPE China	GAMMA-400 Russia
	2007-	2008-	2015-	2015-	~2025
Orbit, km	540	560	500	500	500-300000
Energy range	30 MeV – 50 GeV	100 MeV - 300 GeV	10 GeV – 10 TeV	10 GeV – 10 TeV	20 MeV – 10 TeV
Sensitive area, m^2	0.2	1.8	0.2	0.6	1
Coordinate detectors	Si strips (121 μm pitch)	Si strips (230 μm pitch)	Scint. fibers (Ø 1 mm)	Si strips (120 μm pitch)	Si strips (80 μm pitch)
Angular resolution	1.2° (E_γ = 400 MeV)	~0.1° (E_γ = 100 GeV)	~0,24° (E_γ = 100 GeV)	~0,1° (E_γ = 100 GeV)	~0.01° (E_γ = 100 GeV)
Calorimeter	CsI(Tl)	CsI(Tl)	PWO	BGO	CsI(Tl) + Si strips
- thickness, X_0	1.5	8.5	27	32	23
Energy resolution	50% (E_γ = 1 GeV)	~10% (E_γ = 100 GeV)	~2% (E_γ = 100 GeV)	~1,5% (E_γ = 100 GeV)	~1% (E_γ = 100 GeV)
Mass, kg	120	2900	610	1340	4500
Telemetry volume, GByte/day		20	5		100

GAMMA-400 space mission represents a unique opportunity to study low-energy and high-energy gamma rays and search for dark matter particles with unprecedented angular and energy accuracy.

According to the Russian Federal Space Program 2016-2025 GAMMA-400 continues to be funded by Roscosmos and the GAMMA-400 space observatory is scheduled to launch in 2025-2026.