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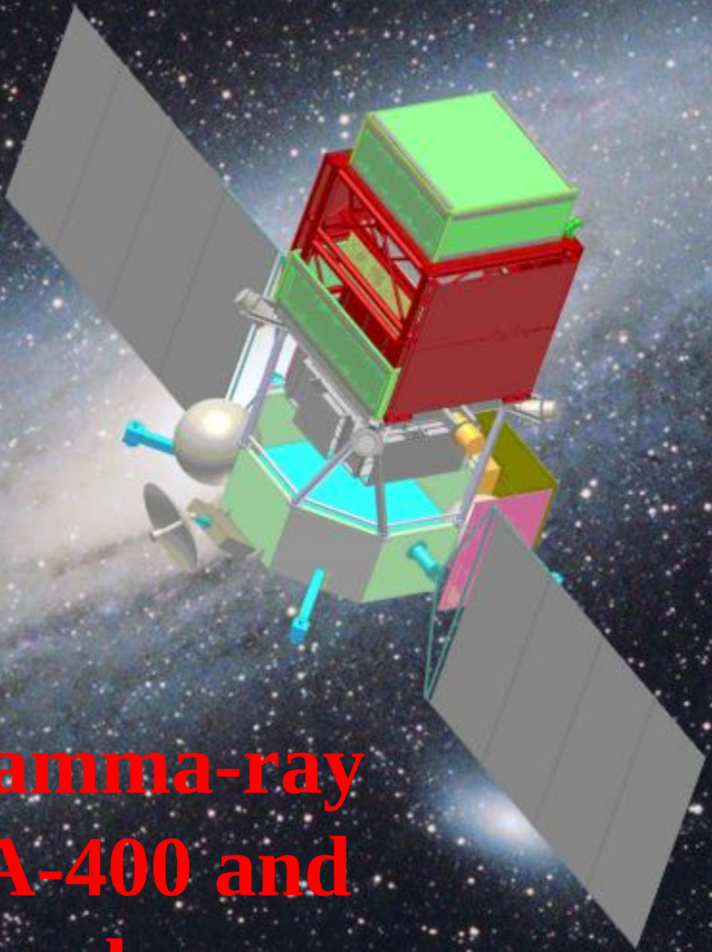

The space-based gamma-ray telescope GAMMA-400 and its scientific goals

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GAMMA-400 TEAM

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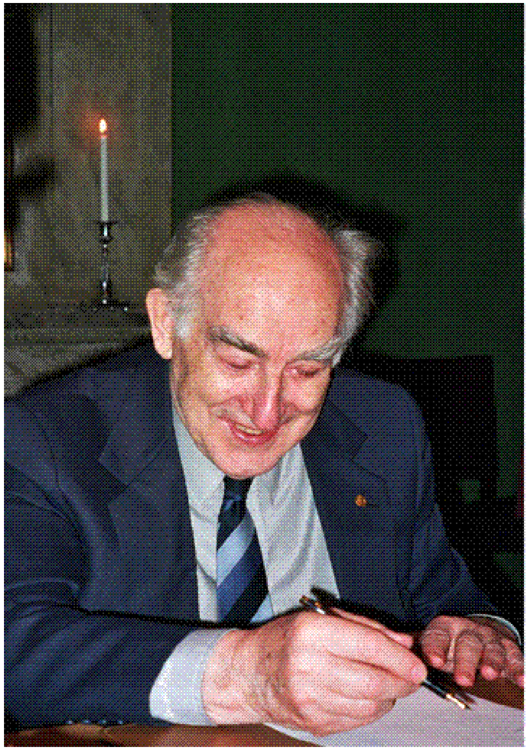
The present time of the development of high-energy gamma-ray astronomy outside the Earth’s atmosphere is possible to characterize as the Fermi-LAT era. Indeed, the basic information and basic scientific and methodological results are associated with the Fermi-LAT flight. The total number of gamma-ray sources has reached two thousand. A specific feature in the energy spectrum of the high-energy gamma-ray emission from the Galactic center has revealed. Obviously, the next important step in the development of gamma-ray astronomy outside the Earth’s atmosphere and understanding the nature of the processes occurring in the active variable astrophysical objects, such as the Galactic center, the Cygnus constellation, extended sources, unidentified sources from the Fermi-LAT catalog, will be obtaining the results by high-energy gamma-ray telescopes with higher angular and energy resolutions than the Fermi-LAT telescope.

Simultaneously with improving the physical characteristics, the signal/background ratio considerably increases that is fundamental to resolve high-energy gamma-ray lines, which can arise when annihilating or decaying the hypothetical dark matter particles.



Vitaly Ginzburg (1916-2009)

Lidiya Kurnosova (1918-2006)

At the end of the last century the Nobel laureate academician Vitaly Ginzburg (LPI) and professor Lidiya Kurnosova (LPI) were initiated the GAMMA-400 project in Russia to search for dark matter particles using the gamma-ray astronomy methods. Within the framework of this project, which has become international, the precision gamma-ray telescope GAMMA-400 with high physical and technical characteristics is designed.

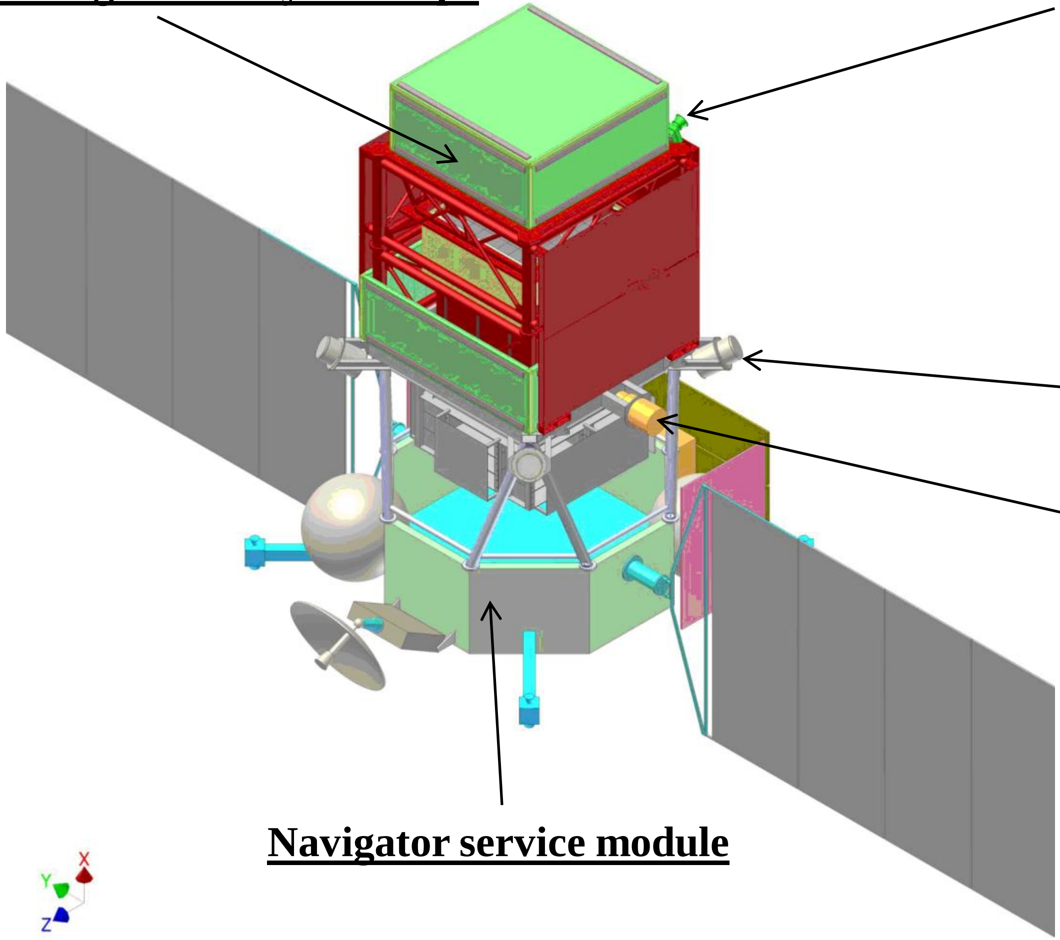
GAMMA-400 SCIENTIFIC GOALS

The GAMMA-400 main scientific goals are: study of the origin of the dark matter by means of gamma-ray astronomy; precise measurements of Galactic and extragalactic discrete astrophysical sources; research of high-energy gamma-ray bursts; research of high energy electron + positron fluxes; research of high-energy nuclei fluxes.

GAMMA-400 GAMMA-RAY TELESCOPE

GAMMA-400 is optimized for the energy 100 GeV with the best parameters: the angular resolution ~0.01º, the energy resolution ~1%, and the proton rejection factor ~10^6, but is able to measure gamma-ray and electron + positron fluxes in the energy range from 100 MeV to 10 TeV. The GAMMA-400 effective area is ~5000 cm^2 at $E_\gamma > 1$ GeV, the total mass is 4100 kg, the power consumption is ~2000 W, and a telemetry downlink capability is 100 GB/day. Together with the gamma-ray telescope GAMMA-400, the space observatory will include two star sensors for determining the GAMMA-400 axes with accuracy of approximately 5'', two magnetometers, and the KONUS-FG gamma-ray burst monitor.

GAMMA-400 SCIENTIFIC COMPLEX ON THE NAVIGATOR SERVICE MODULE



GAMMA-400 gamma-ray telescope

Star sensors (2)
(Space Research Institute)

Gamma-ray burst monitor “Konus-FG” (6)
(Ioffe Physical Technical Institute, St. Petersburg)

4 direction detectors on telescopic booms

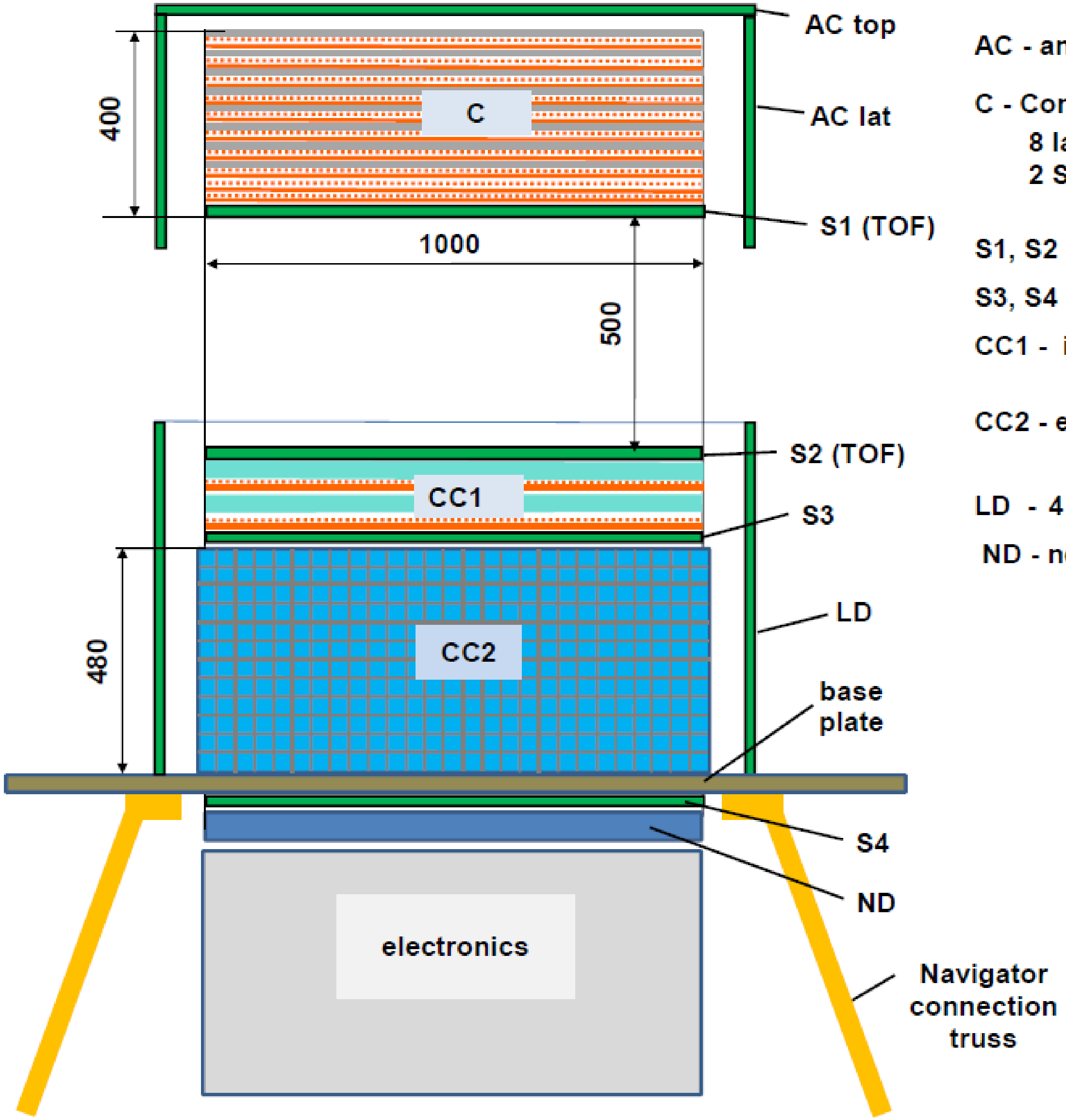
2 spectrometric detectors

Magnetometer (2)
(Ukraine, Lviv)
on telescopic boom

Navigator service module

The GAMMA-400 spacecraft and Navigator service module are designed by Lavochkin Association

GAMMA-400 PHYSICAL SCHEME



AC - anticoincidence detectors (AC top , AC lat)

C - Converter-Tracker - total 1 Xo
8 layers W 0.1 Xo +Si (x,y) (pitch 0.1mm)
2 Si(x,y) no W

S1, S2 - TOF detectors

S3, S4 calorimeter scintillator detectors

CC1 - imaging calorimeter (2Xo)
2 layers: CsI(Tl) 1Xo + Si(x,y) (pitch 0.1 mm)

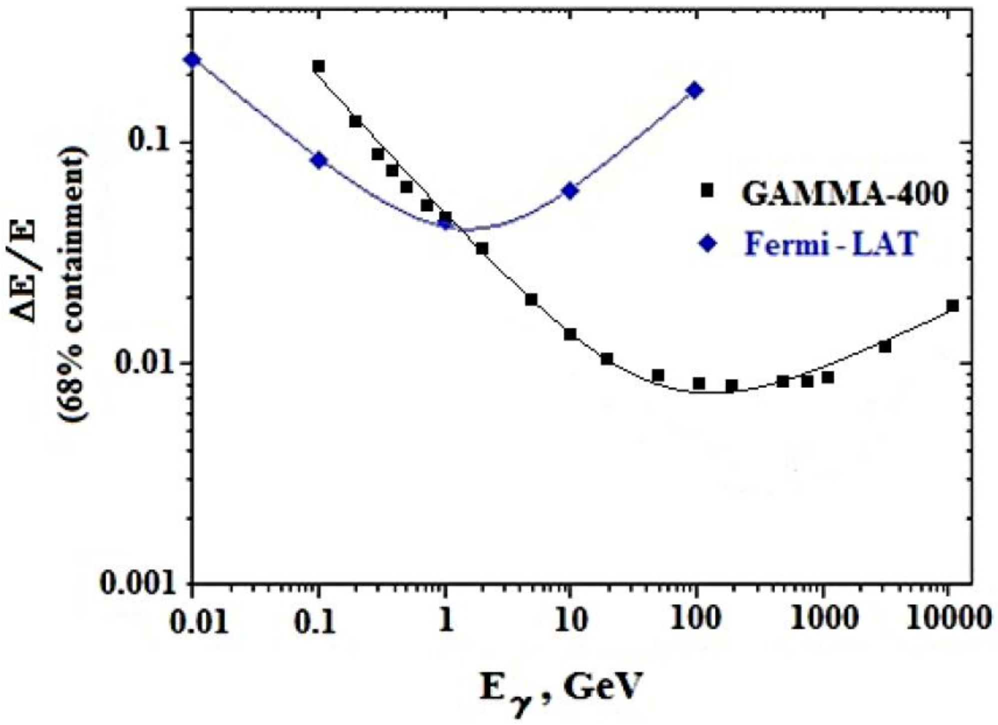
CC2 - electromagnetic calorimeter
CsI(Tl) 23 Xo 3.6x3.6x3.6 cm^3 - 28x28x12=9408 crystals

LD - 4 lateral calorimeter detectors

ND - neutron detector

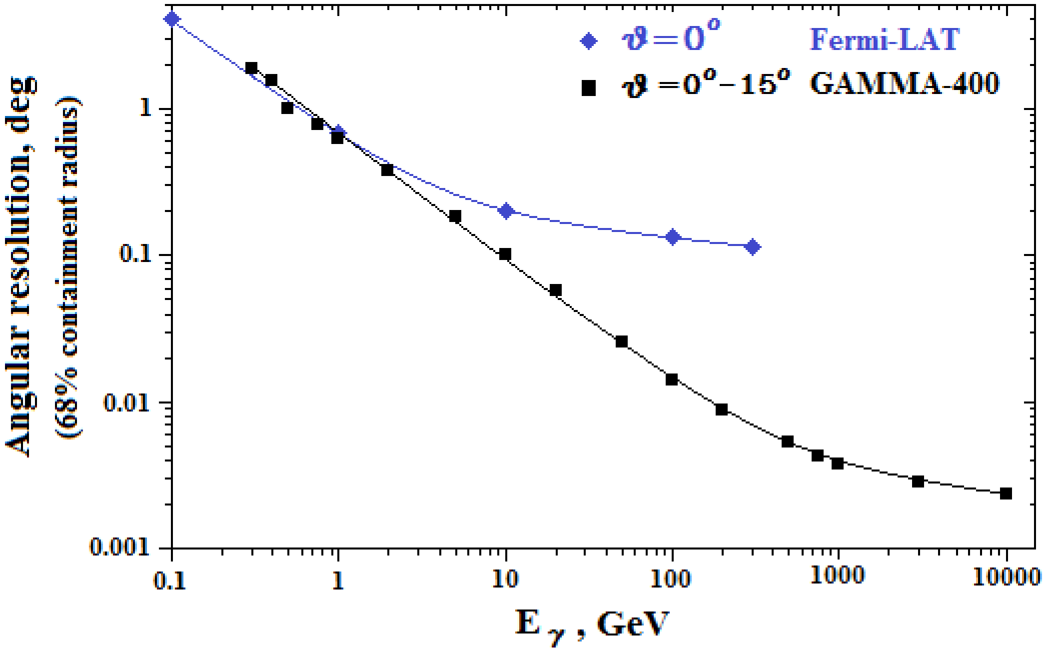
Comparison of the main parameters for GAMMA-400 and Fermi-LAT

	Fermi-LAT	**GAMMA-400**
Orbit	circular, 565 km	high-elliptical, 500-300 000 km
Energy range	20 MeV - 300 GeV	100 MeV – 10 000 GeV
Effective area (E_γ > 1 GeV)	~8000 cm^2	~5000 cm^2
Coordinate detectors	Si strips (pitch 0.23 mm)	Si strips (pitch 0.1 mm)
Angular resolution (E_γ > 100 GeV)	~0.1°	~0.01°
Calorimeter - thickness	CsI ~$8.5X_0$	CsI(Tl)+Si strips ~$25X_0$
Energy resolution (E_γ > 100 GeV)	~10%	~1%
Proton rejection coefficient	~10^4	~10^6
Mass	2800 kg	4100 kg
Telemetry downlink capability	15 GB/day	100 GB/day



Energy resolution vs.
energy for normal incidence
for Fermi-LAT and
GAMMA-400

Angular resolution vs.
energy for Fermi-LAT
(for normal incidence) and
GAMMA-400 (for θ=0°-15°)

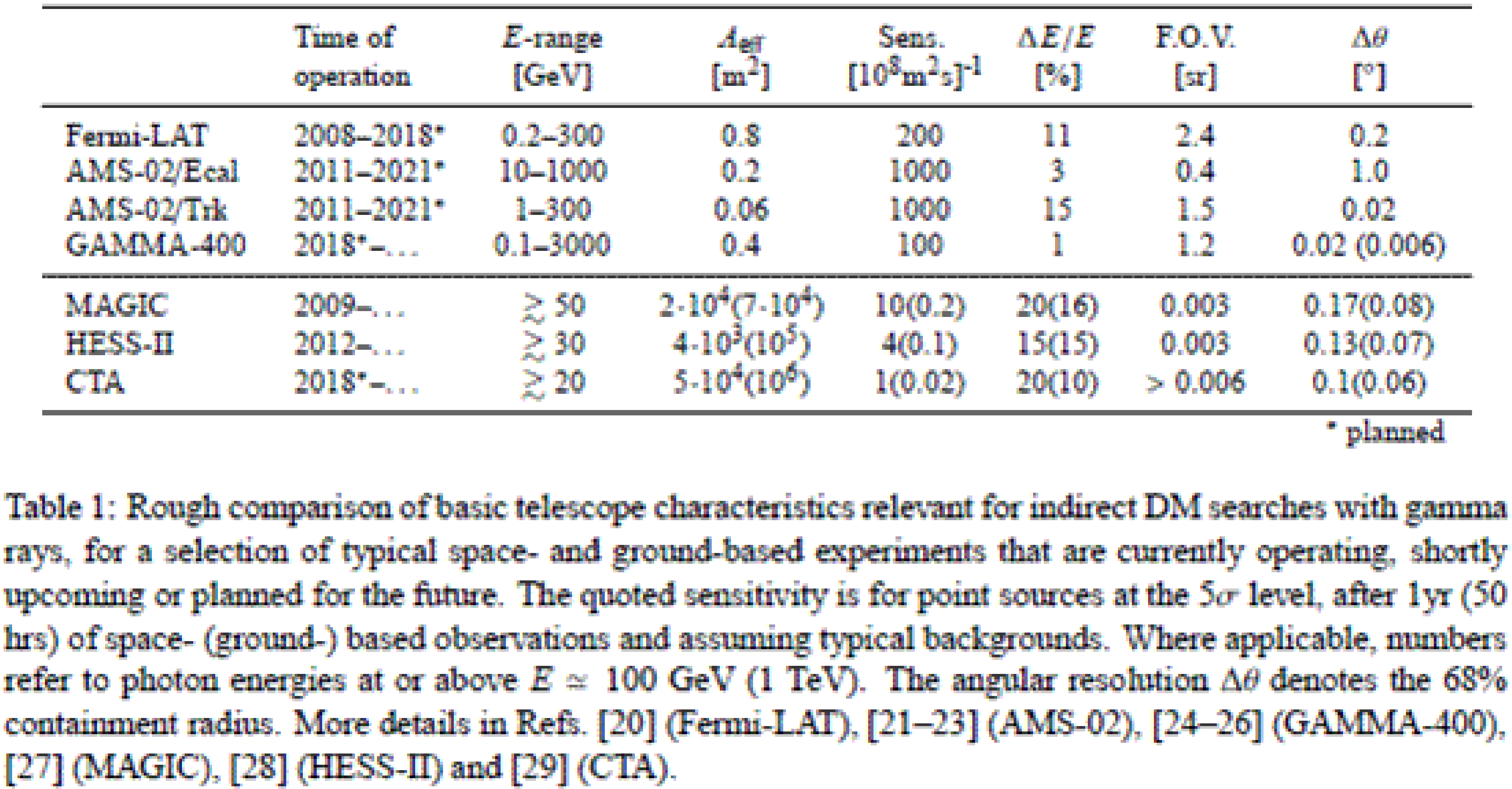


Using the data from the TeV Gamma-Ray Source Catalogue (from the ground-based facilities), we can calculate expected number of gammas, which GAMMA-400 will detect during 100 days of observation (the GAMMA-400 effective area is 5000 cm^2).

Name	**Facility**	**Spectr. index**	**Integr. flux F(> 100 GeV), 10^{-9} $cm^{-2}s^{-1}$**	**Expected gammas N(> 100 GeV) per 100 days**
1ES 1011+496	MAGIC	4.0	67.7	2921
1ES 1218+304	MAGIC	3.0	4.09	177
1ES 1959+650	MAGIC	2.78	5.805	251
1ES 2344+514	MAGIC	3.3	1.67	72
3C 279	MAGIC	4.11	219.0	9458
BL Lac	MAGIC	3.64	3.18	138
Crab	H.E.S.S., MAGIC	2.48	11.7	504
MAGIC J0616+225	MAGIC, VERITAS	3.1	0.605	26
Mkn 180	MAGIC	3.25	3.60	155
Mkn 421	H.E.S.S., MAGIC	3.2	6.05	261
Mkn 501	MAGIC	2.28	10.7	463
PG 1553+113	H.E.S.S., MAGIC	4.01	204.0	8833
PKS 2155-304	H.E.S.S., MAGIC	3.53	69.0	2983
RX J0852.0-4622	H.E.S.S.	2.2	0.331	14
RX J1713.7-3946	H.E.S.S.	2.84	0.618	27
W Com	VERITAS	3.8	4.570	198

COMPARISON OF BASIC PARAMETERS OF OPERATED, EXISTING, AND PLANNED SPACE-BASED AND GROUND-BASED INSTRUMENTS

	SPACE-BASED INSTRUMENTS					**GROUND-BASED GAMMA-RAY FACILITIES**			
	EGRET	**AGILE**	**Fermi-LAT**	**CALET**	**GAMMA-400**	**H.E.S.S.-II**	**MAGIC**	**VERITAS**	**CTA**
Operation period	1991-2000	2007-	2008-	2014	2019	2012-	2009-	2007-	2018
Energy range, GeV	0.03-30	0.03-50	0.02-300	10-10000	**0.1-10000**	> 30	> 50	> 100	> 20
Angular resolution ($E_\gamma > 100$ GeV)	0.2° (E_γ~0.5 GeV)	0.1° (E_γ~1 GeV)	0.1°	0.1°	**~0.01°**	0.07°	0.07° (E_γ = 300 GeV)	0.1°	0.1° (E_γ = 100 GeV) 0.03° (E_γ = 10 TeV)
Energy resolution ($E_\gamma > 100$ GeV)	15% (E_γ~0.5 GeV)	50% (E_γ~1 GeV)	10%	2%	**~1%**	15%	20% (E_γ = 100 GeV) 15% (E_γ = 1 TeV)	15%	20% (E_γ = 100 GeV) 5% (E_γ = 10 TeV)



	Time of operation	E-range [GeV]	A_{eff} [m^2]	Sens. [10^8m^{2}s]$^{-1}$	$\Delta E/E$ [%]	F.O.V. [sr]	$\Delta\theta$ [°]
Fermi-LAT	2008–2018*	0.2–300	0.8	200	11	2.4	0.2
AMS-02/Ecal	2011–2021*	10–1000	0.2	1000	3	0.4	1.0
AMS-02/Trk	2011–2021*	1–300	0.06	1000	15	1.5	0.02
GAMMA-400	2018*–…	0.1–3000	0.4	100	1	1.2	0.02 (0.006)
MAGIC	2009–…	$\gtrsim 50$	$2\cdot10^4(7\cdot10^4)$	10(0.2)	20(16)	0.003	0.17(0.08)
HESS-II	2012–…	$\gtrsim 30$	$4\cdot10^3(10^5)$	4(0.1)	15(15)	0.003	0.13(0.07)
CTA	2018*–…	$\gtrsim 20$	$5\cdot10^4(10^6)$	1(0.02)	20(10)	> 0.006	0.1(0.06)

* planned

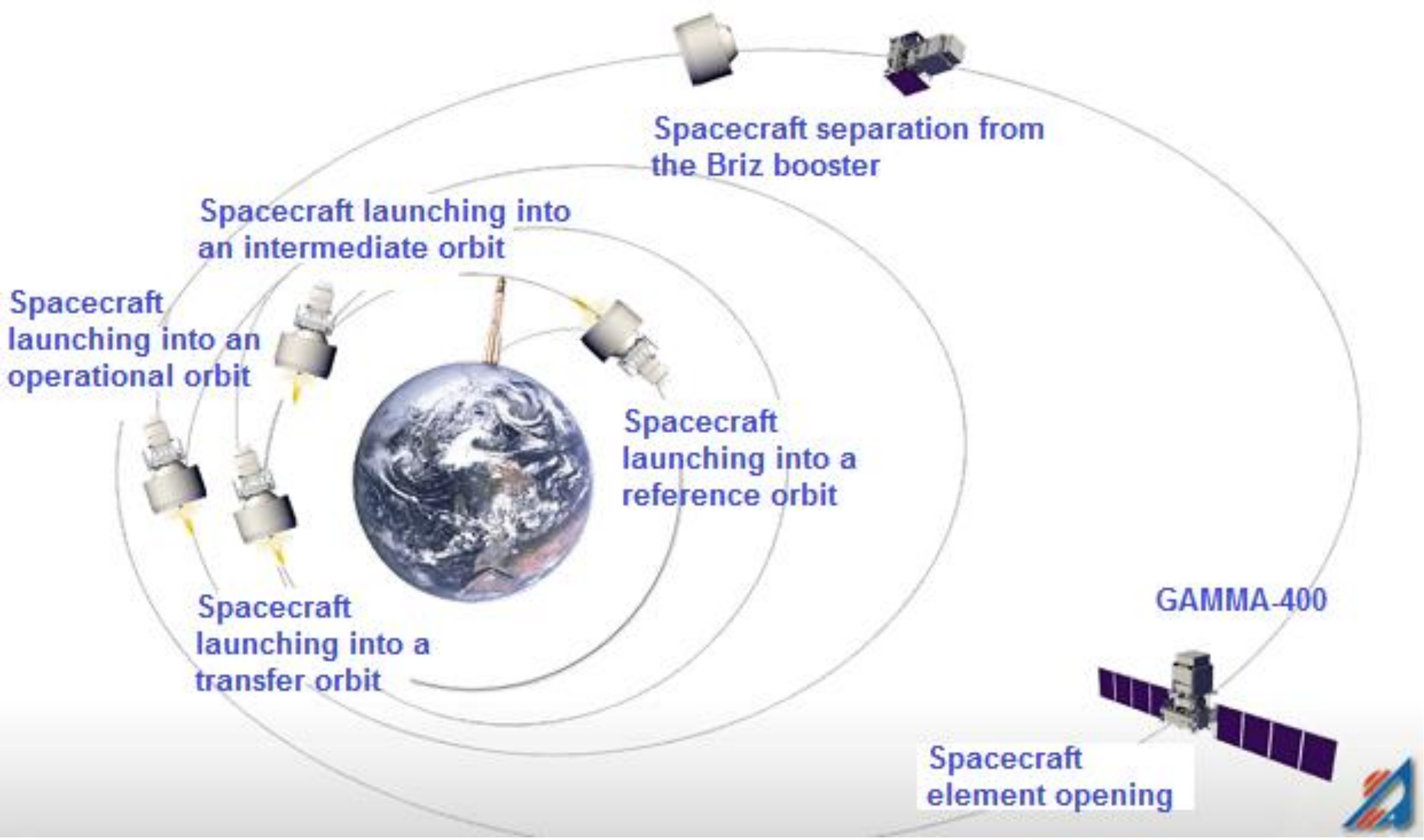
Table 1: Rough comparison of basic telescope characteristics relevant for indirect DM searches with gamma rays, for a selection of typical space- and ground-based experiments that are currently operating, shortly upcoming or planned for the future. The quoted sensitivity is for point sources at the 5σ level, after 1yr (50 hrs) of space- (ground-) based observations and assuming typical backgrounds. Where applicable, numbers refer to photon energies at or above $E \simeq 100$ GeV (1 TeV). The angular resolution $\Delta\theta$ denotes the 68% containment radius. More details in Refs. [20] (Fermi-LAT), [21–23] (AMS-02), [24–26] (GAMMA-400), [27] (MAGIC), [28] (HESS-II) and [29] (CTA).

http://arxiv.org/abs/1208.5481

Torsten Bringmann, Christoph Weniger

Gamma Ray Signals from Dark Matter:
Concepts, Status and Prospects

THE GAMMA-400 SPACECRAFT LAUNCHING SCHEME

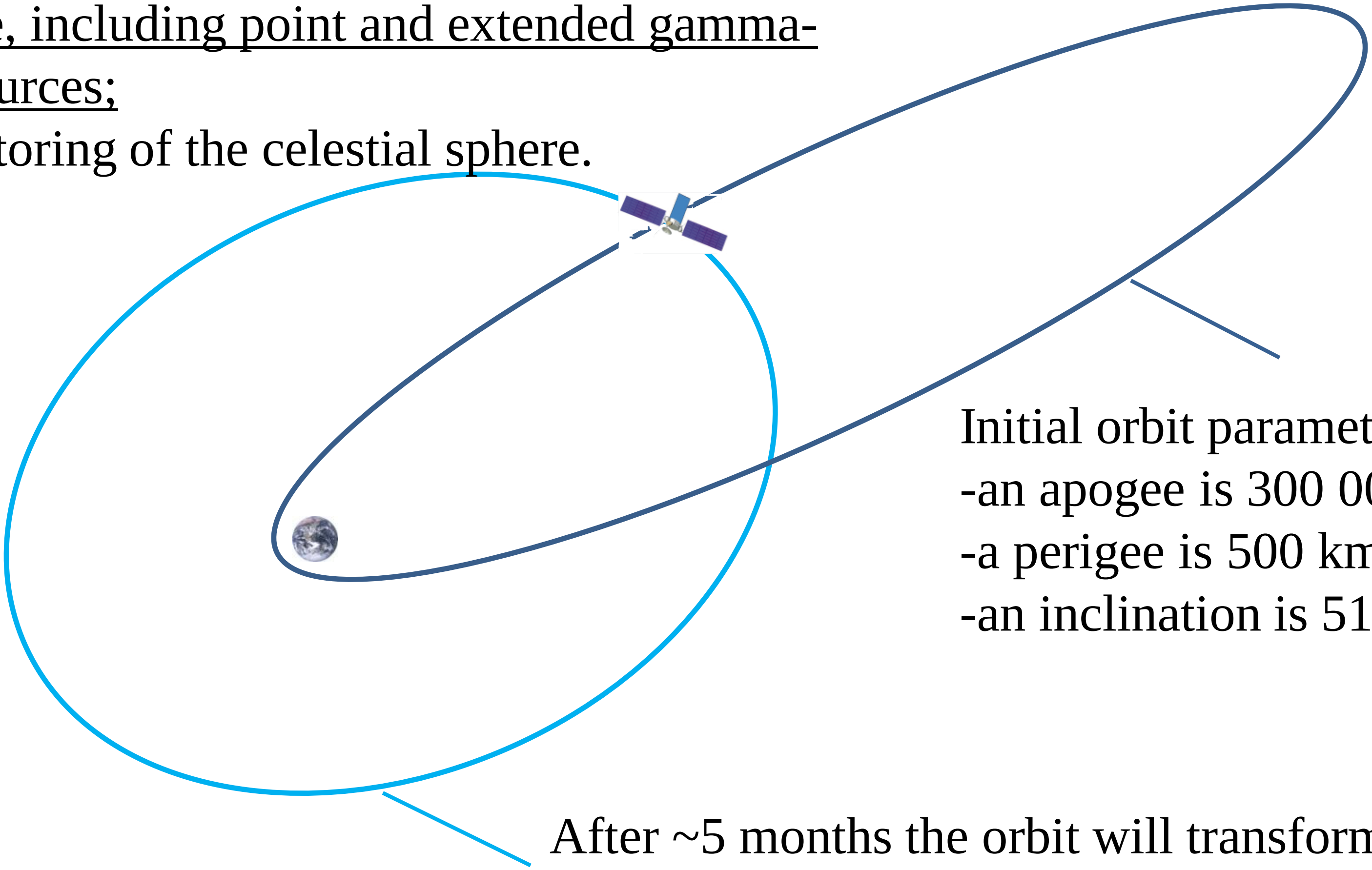


The GAMMA-400 project is included in the Russian Federal Space Program and funded by the Russian Space Agency. The launch of the GAMMA-400 space observatory is planned in 2019 using the more powerful Proton launch vehicle + Briz booster instead of Zenit launch vehicle + Fregat booster.

The expected mission duration is more than 7 years.

OBSERVATION MODES AND THE GAMMA-400 ORBIT EVOLUTION

Observation modes:
- continuous long-duration (~100 days) observation of some regions of celestial sphere, including point and extended gamma-ray sources;
-monitoring of the celestial sphere.



Initial orbit parameters:
-an apogee is 300 000 km:
-a perigee is 500 km;
-an inclination is 51.4°

After ~5 months the orbit will transform to circular with a radius of ~150 000 km.

The GAMMA-400 collaboration is open for specialists ready to take part in designing and manufacturing the GAMMA-400 gamma-ray telescope.

http://gamma400.lebedev.ru/indexeng.html