

Status of the GAMMA-400 Project

A. M. Galper

Trieste, Italy, May 2013

The main scientific objective of the GAMMA-400 Project, that was defined by Nobel laureate V. L. Ginzburg, is to search for peculiarity (of gamma-ray line) in the energy spectrum of high energy gamma radiation from discrete sources and diffuse radiation, that is the most effective method of solving the issue of the nature of dark matter.

Lidiya Kurnosova



УТВЕРЖДАЮ

Директор

Учреждения Российской академии наук

Физического института

им. П.Н. Лебедева РАН

академик



Месяц Г.А.

2009 г.

ПРОЕКТ ГАММА-400

ИССЛЕДОВАНИЕ КОСМИЧЕСКОГО ГАММА-ИЗЛУЧЕНИЯ
И ПОТОКОВ ЭЛЕКТРОНОВ И ПОЗИТРОНОВ В
ДИАПАЗОНЕ ЭНЕРГИЙ 1-3000 ГэВ

От ФИАН

Руководитель научного направления

академик

Гинзбург В.Л.

2009 г.

Научный руководитель проекта

ГАММА-400

профессор, г.н.с.

Гальпер А.М.

21 мая 2009 г.

Москва, 2009 г.

APPROVED

by the director of the

Institution of the Russian

Academy of Sciences

Lebedev Physical Institute

academician

Mesyats G. A.

THE GAMMA-400 PROJECT

THE RESEARCH OF A COSMIC GAMMA RAYS
AND ELECTRON+POSITRON FLUXES
IN THE ENERGY RANGE OF 1-3000 GeV

From LPI

Director of scientific branch

academician

Ginzburg V.L.

Scientific director of the

GAMMA-400 project

professor

Galper A.M.

Moscow, 2009

APPROVED

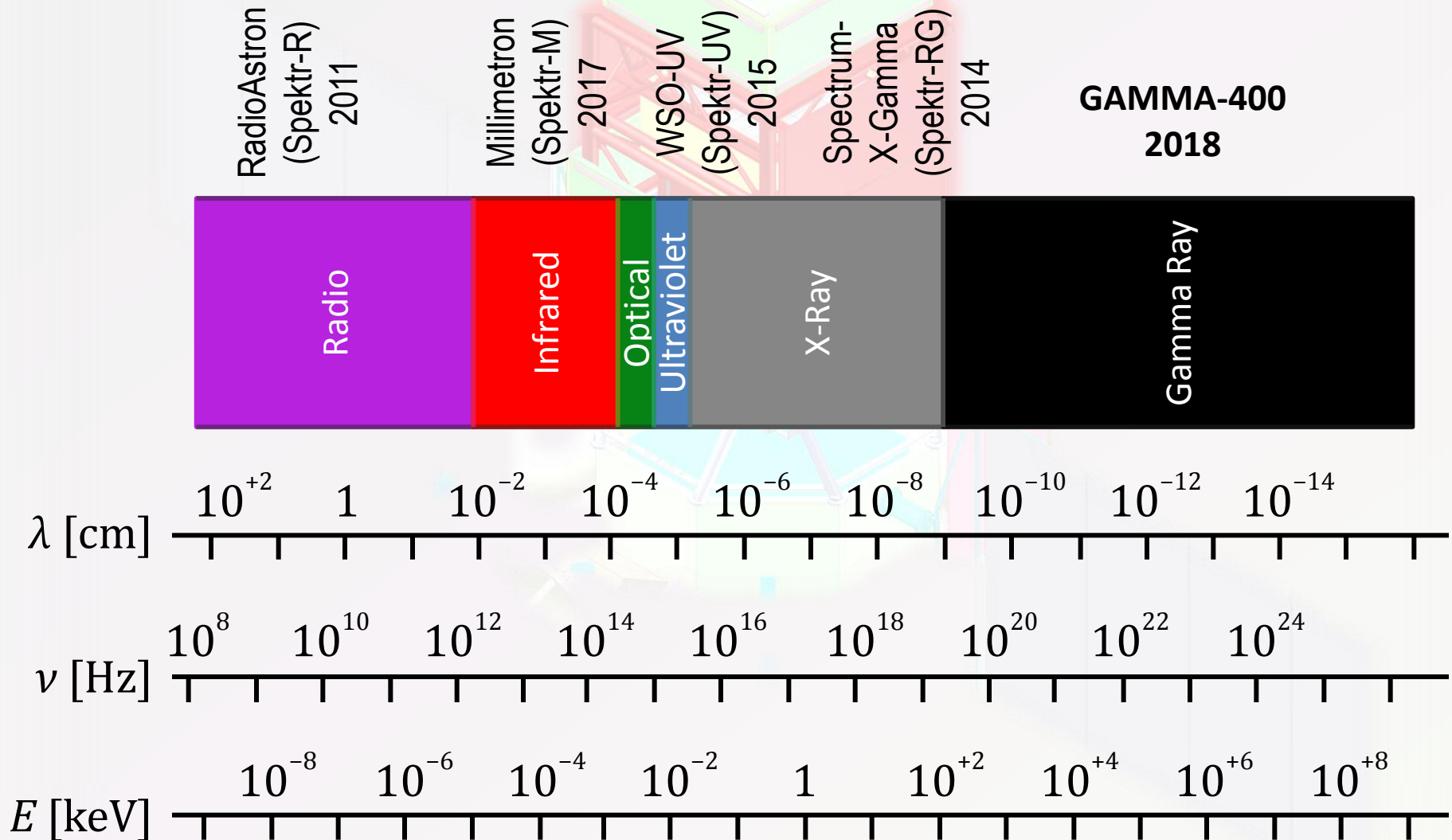
**by the decree of the Russian Government
of December 28, 2012 No. 2594-R**

**Russian Government program
“Russian Cosmic Activity in 2013–2020”**

In project:

**Making of three space observatories: “WSO-UV”,
“Spectrum-M” (“Millimetron”) and “GAMMA-400”
for the purpose of execution of research
of astrophysical objects in various electromagnetic ranges
and high energy gamma rays.**

Russian spacecrafts to research in various electromagnetic ranges



The international status of the project

The agreement with Ukraine on GAMMA-400

**ФЕДЕРАЛЬНОЕ КОСМИЧЕСКОЕ АГЕНТСТВО
(РОСКОСМОС)**

Щепкина ул., 42, Москва, РОССИЯ, ГСП-6, 107996. Факс (495) 688-90-63, (499) 975-44-67

**FEDERAL SPACE AGENCY
(ROSCOSMOS)**

42 Schepkinast., Moscow RUSSIA, GSP-6, 107996. Fax (495) 688-90-63, (499) 975-44-67

07.08.2012 № ВП-21-5803

Руководителям организаций

В целях организации выполнения «Программы российско-украинского сотрудничества в области исследования и использования космического пространства в мирных целях на 2012 – 2016 годы» (далее – Программа), подписанной 27 июня 2012 г., направляю Вам выписку из Программы с перечнем мероприятий, в которых Ваша организация выступает в качестве одного из основных исполнителей.

Выписка из Программы

российско-украинского сотрудничества в области исследования и использования космического пространства в мирных целях на 2012 - 2016 годы

Раздел 3. Фундаментальные и прикладные научные космические исследования

Шифр и наименование работ. Срок выполнения	В рамках каких программ (проектов) выполняется. Содержание совместных работ (услуг). Заказчик.	Исполнители (возможные исполнители)	Источник финансирования
«Гамма-400» Космическая обсерватория для исследований гамма-излучений в диапазоне высоких энергий 2012-2016 гг.	ФКП («Гамма-400»), ОКПУ («Наука»). Запуск обсерватории – 2016 год. Создание космической обсерватории для получения данных о природе «темной материи» во Вселенной, развития теории происхождения высокоэнергетических космических лучей и физики элементарных частиц. Заказчики: Роскосмос, РАН, ГКА Украины, НАНУ	Россия: ФИАН, НПО им. С.А. Лавочкина, НИЯУ МИФИ Украина: КЮ ГАО НАНУ, ХНУ им. В.Н. Каразина, ХНУ им. Т. Шевченко	Россия: Роскосмос, РАН Украина: ГКА Украины, НАНУ

The international status of the project

The agreement with Ukraine on GAMMA-400

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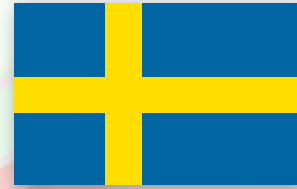
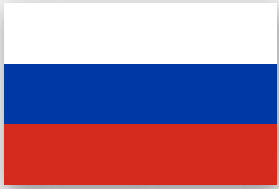
With a view to fulfil the “Russian-Ukrainian coöperation program of investigation and peaceful use of the outer space in 2012 to 2016” (further: the Program), signed in June 27, 2012, I send you an extract from the Program with a list of undertakings with your organization as one of the main executors.

Extract from the Russian-Ukrainian coöperation program of investigation and peaceful use of the outer space in 2012 to 2016

Section 3. Fundametal and applied scientific space research

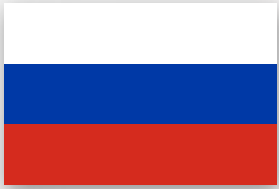
Name of a work, time constraints	Programs (projects) within the framework of which the work is being done. A matter of the work. A customer.	Executors (possible executors)	Funding source
«Гамма-400» “GAMMA-400” Space observatory for high energy gamma-ray research 2012–2016	FSP (“GAMMA-400”), National Space Program of Ukraine (“Science”). Launch of the observatory: 2016. Production of the space observatory to get data of the dark matter origin, to develop the HE CR origin theory and particle physics. Customers: ROSCOSMOS, RAS, SSA of Ukraine, NAS of Ukraine	Russia: LPI, Lavochkin Association, NRNU MEPhI Ukraine: CLO of MAO of NAS of Ukraine, Karazin Kharkov NU, Shevchenko Kiev NU	Russia: ROSCOSMOS, RAS Ukraine: SSA of Ukraine, NAS of Ukraine

GAMMA-400 Collaboration



**A. M. Galper, O. Adriani, R. L. Aptekar, I. V. Arkhangelskaja,
A. I. Arkhangelskiy, M. Boezio, V. Bonvicini, K. A. Boyarchuk,
M. I. Fradkin, Yu. V. Gusakov, V. A. Kaplin, V. A. Kachanov,
M. D. Kheyimits, A. A. Leonov, F. Longo, E. P. Mazets, P. Maestro,
P. Marrocchesi, I. A. Mereminskiy, V. V. Mikhailov, A. A. Moiseev,
E. Mocchiutti, N. Mori, I. V. Moskalenko, P. Yu. Naumov,
P. Papini, M. Pearce, P. Picozza, V. G. Rodin, M. F. Runtso,
R. Sparvoli, P. Spillantini, S. I. Suchkov, M. Tavani,
N. P. Topchiev, A. Vacchi, E. Vannuccini, Yu. T. Yurkin, N. Zampa,
V. G. Zverev, V. N. Zirakashvily.**

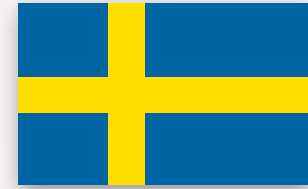
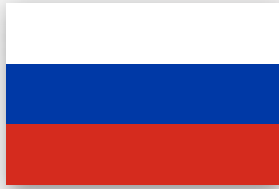
GAMMA-400 Collaboration



All collaborators take part in:

- Development of scientific program,
- Tests and calibrations of the GAMMA-400 instrument,
- Treatment of scientific information,
- Analysis of scientific data and publication of scientific results.

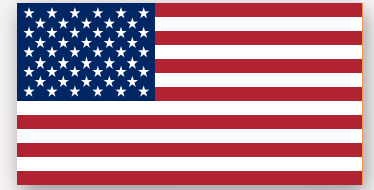
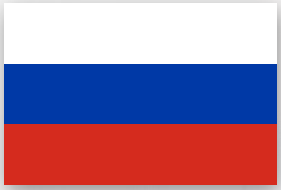
GAMMA-400 Collaboration



Coöperation in the design and production of scientific equipment

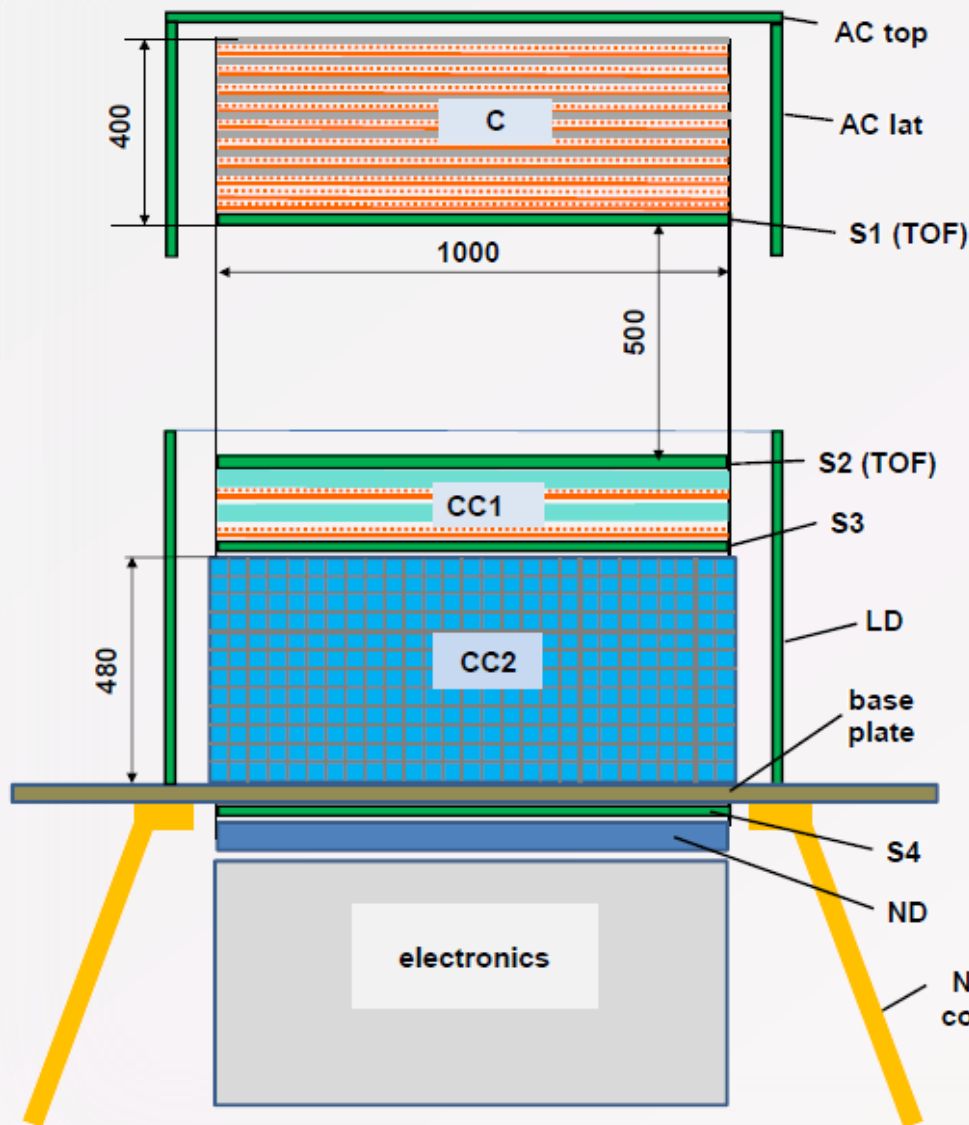
Russian scientific organizations	Foreign scientific organizations
LPI RAS — main collaborator	INFN (Italy) — stripped detector and calorimeter
NRNU MEPhI — detectors	INAF (Italy) — stripped detector
NIIEM — design, temperature control system	Taras Schevchenko National University (Ukraine) — Ukrainian main collaborator
NIISI RAS — electronics	CrAO (Ukraine) — ground-based observations
Ioffe Institute — Konus-FG burst monitor	IKI (Ukraine) — magnetometer
IKI — star sensor	ISM (Ukraine) — scintillators
IHEP — calorimeters, scintillators	KTH (Sweden) — anticoincidence
TsNIIMASH — space qualification	

GAMMA-400 Collaboration



Collaboration is
open to entrance

Physical diagram of the GAMMA-400 scientific equipment



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: Csl(Tl) 1Xo + Si(x,y) (pitch 0.5 mm)

CC2 - electromagnetic calorimeter
Csl(Tl) 23 Xo 3.6x3.6x3.6 cm³ - 28x28x12=9408 crystals

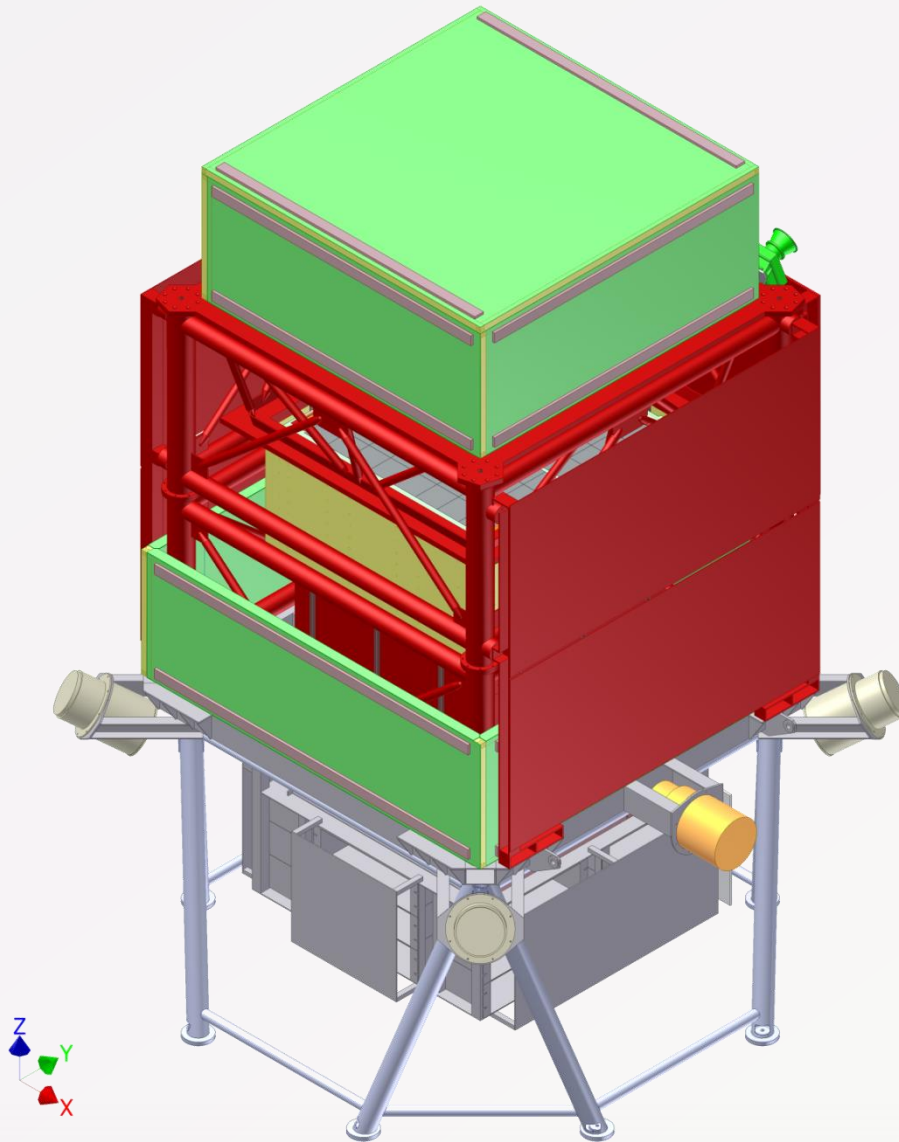
LD - 4 lateral calorimeter detectors

ND - neutron detector

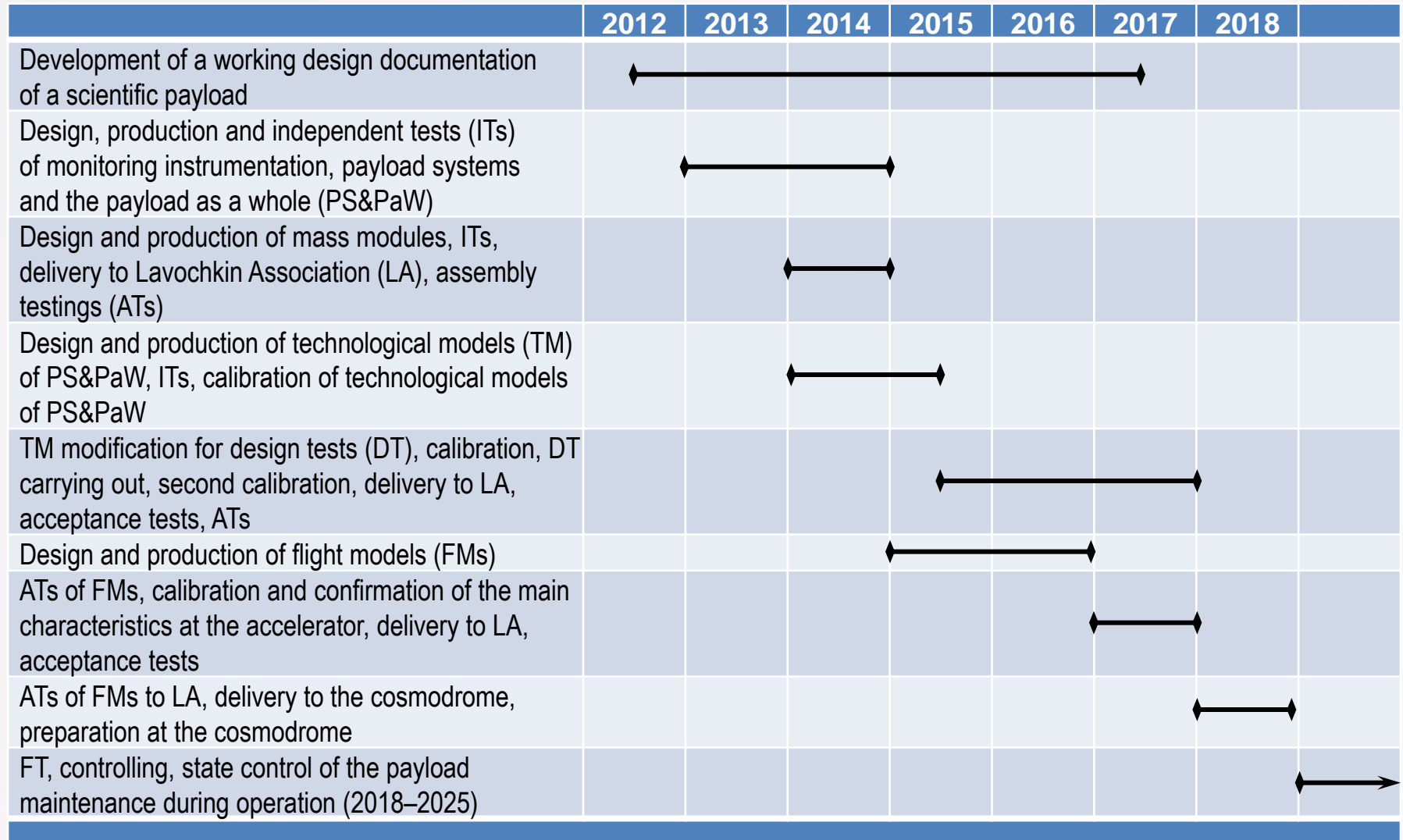
Comparison between characteristics of existing and planned gamma-ray telescopes

	space gamma-ray telescopes			ground gamma-ray telescopes		
	Fermi	AMS-2	GAMMA-400	H.E.S.S.-II	MAGIC	CTA
energy range [GeV]	0.02–300	10–1000	0.1–3000	> 30	> 50	> 20
acceptance [m ² sr]	2.4	0.4	1.2	0.01	0.01	0.1
effective area [m ²]	0.8	0.2	0.6	10 ⁵	10 ⁵	10 ⁶
angular resolution ($E_\gamma > 100$ GeV)	0.2°	1.0°	< 0.02°	0.07°	0.05°	0.06°
energy resolution ($E_\gamma > 100$ GeV)	10%	3%	1–2%	15%	15%	10%

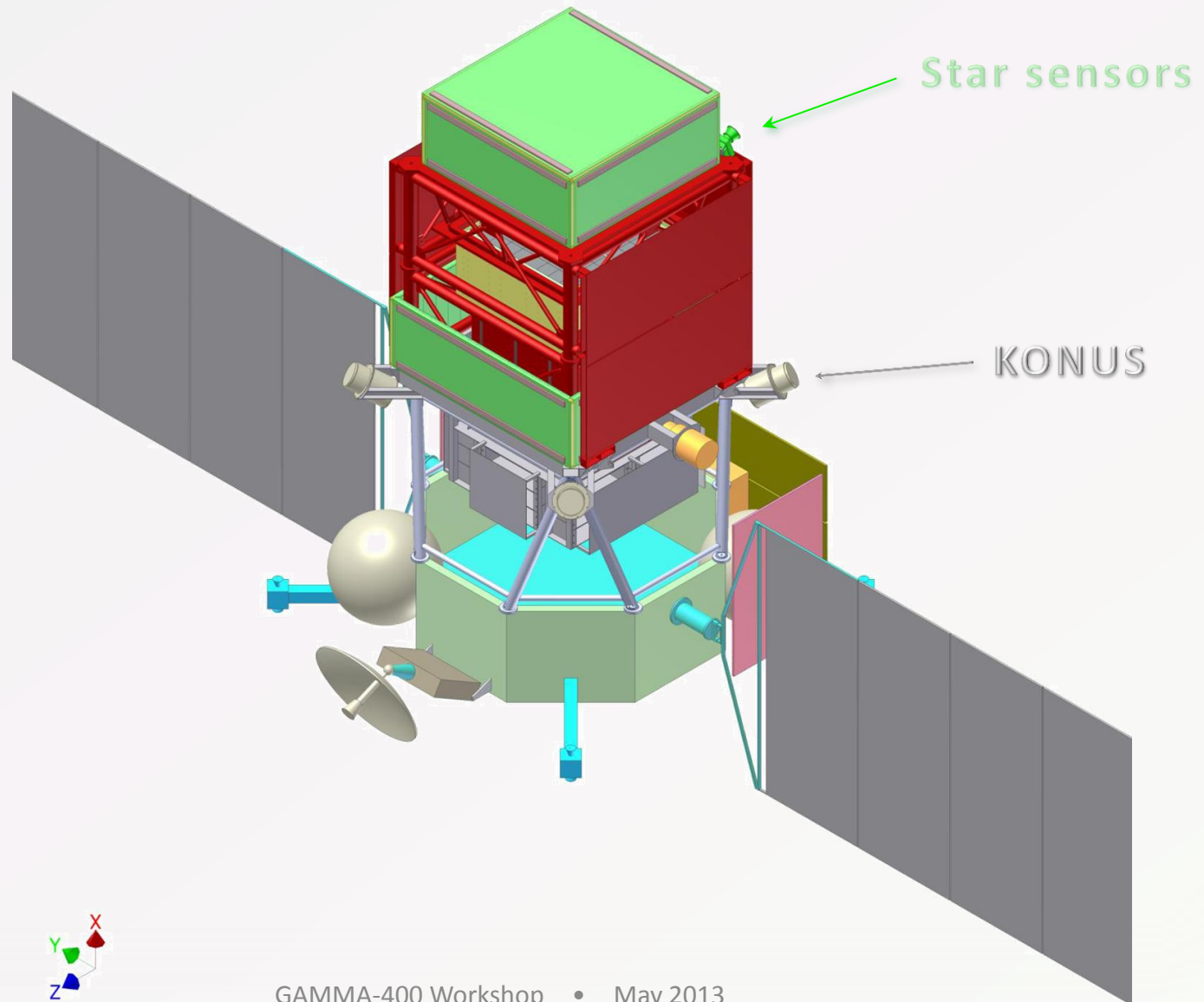
3D model of the scientific equipment



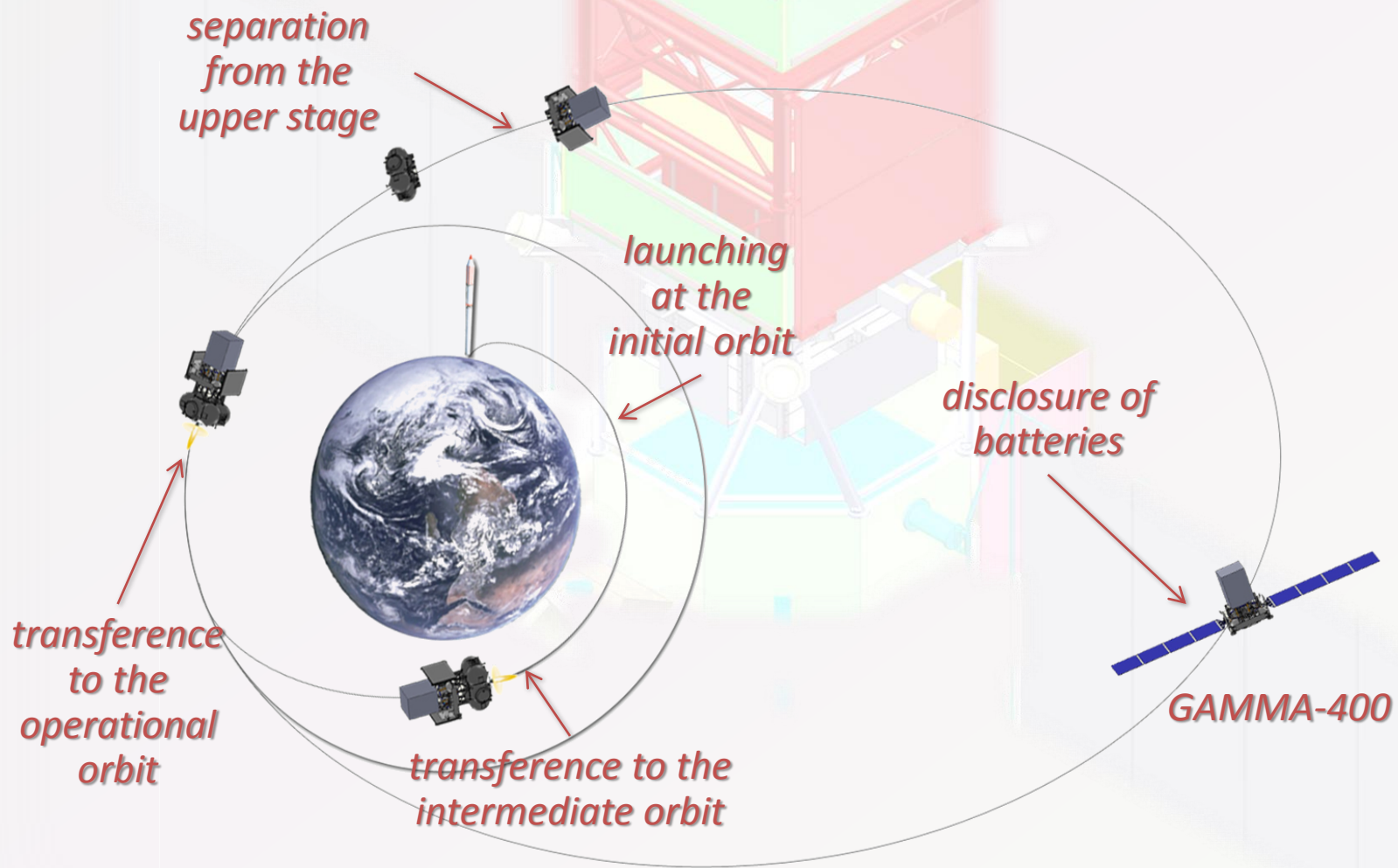
Plan for further works for the development of scientific equipment “GAMMA-400” according to the General schedule



GAMMA-400 scientific equipment on “Navigator” service core module



Launching scheme



Orbit evolution



Research of discrete sources of high energy gamma radiation

- The effectiveness of observation (the **signal-to-background ratio**) of discrete sources by gamma-ray telescope GAMMA-400 is up to **100 times better** than that by Fermi/LAT.
- The **energy resolution** for 100 GeV photon is **5 times higher** than that of Fermi/LAT.
- GAMMA-400 **collects data 3 times faster** than Fermi/LAT does.
- Continuous **long-term measurements** and detailed **analysis of the luminosity variability** of a source can be done.

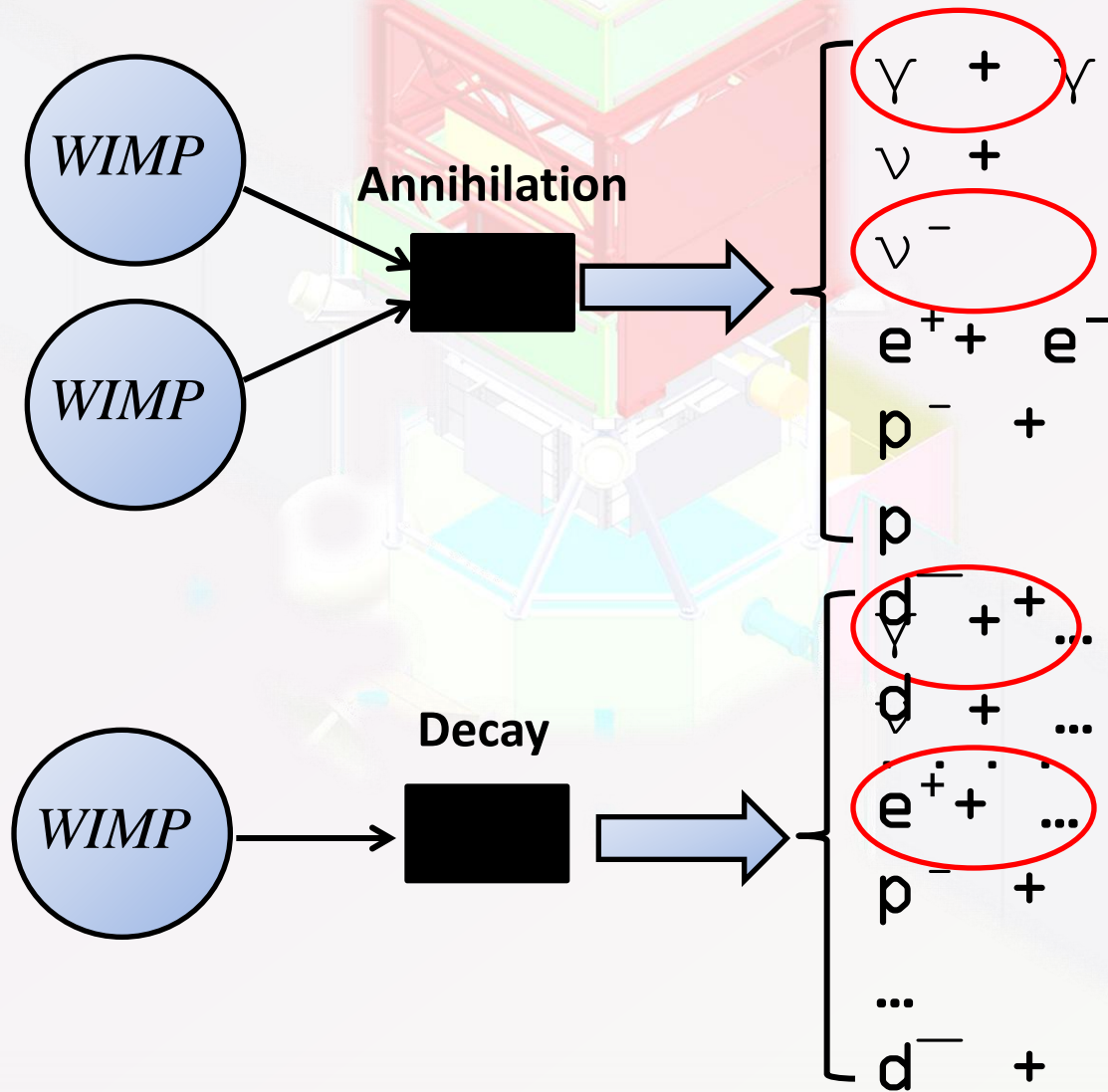
Primary tasks of the project

- a) Study of the origin of the dark matter by means of gamma-ray astronomy;
- b) Precise measurements of discrete astrophysical sources in the Milky Way;
- c) Research of high energy gamma-ray bursts;
- d) Research of high energy e^-e^+ -fluxes;
- e) Research of high energy light nuclei fluxes.



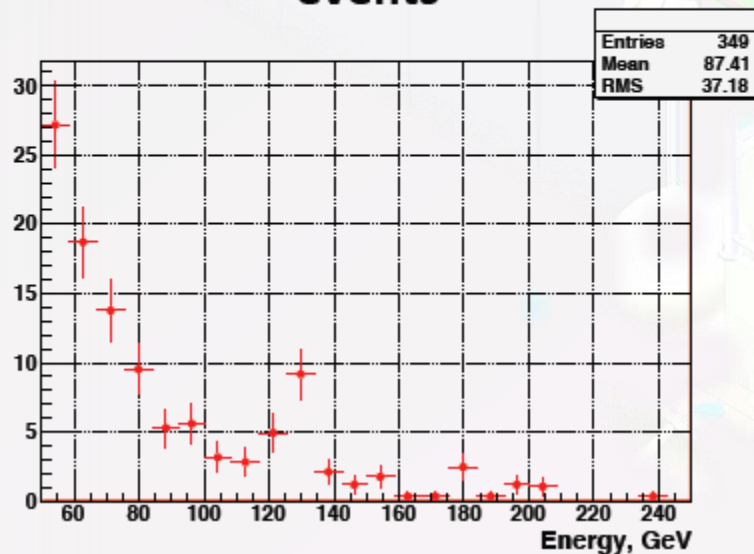
STUDY OF THE ORIGIN OF THE DARK MATTER BY MEANS OF GAMMA-RAY ASTRONOMY

Indirect methods of dark matter particle registration

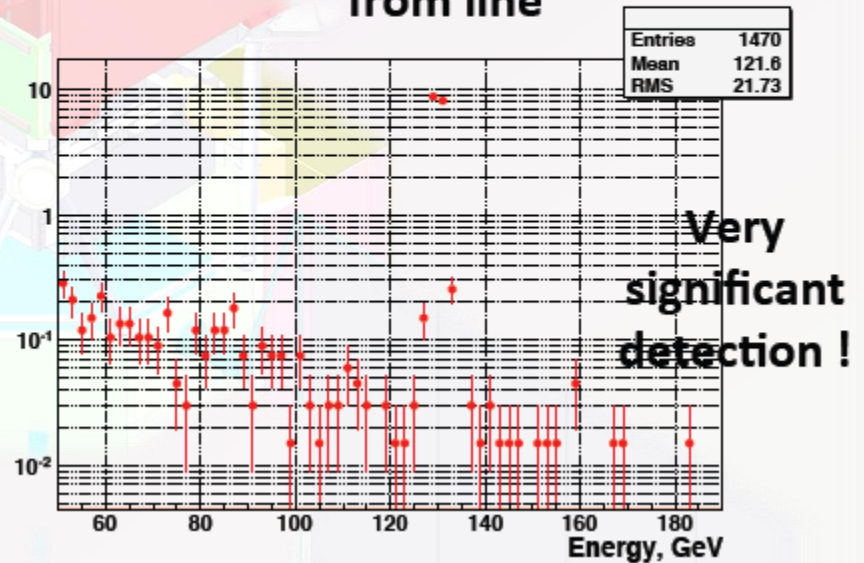


Improvement of energy resolution

LAT-like instrument, 300 events

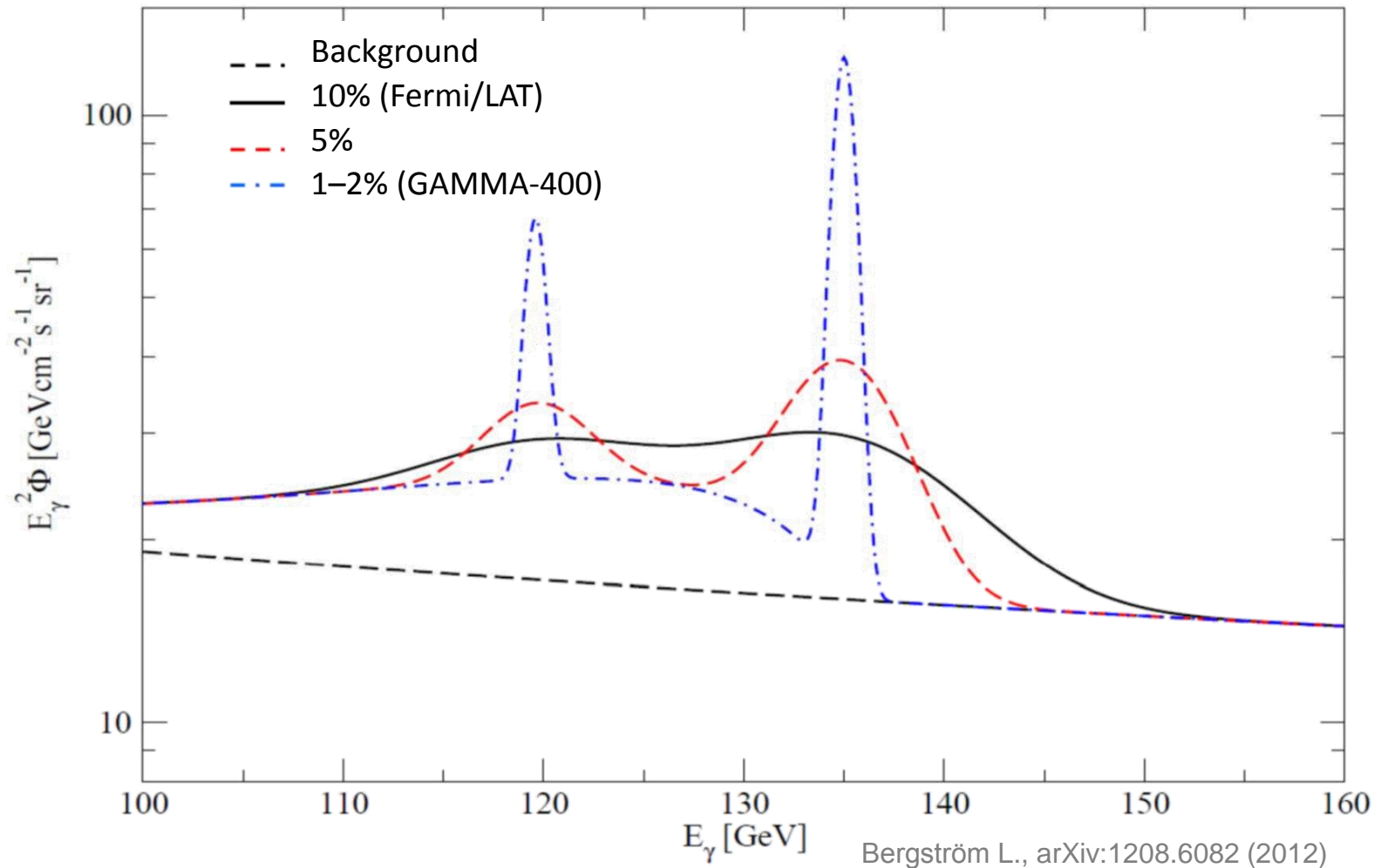


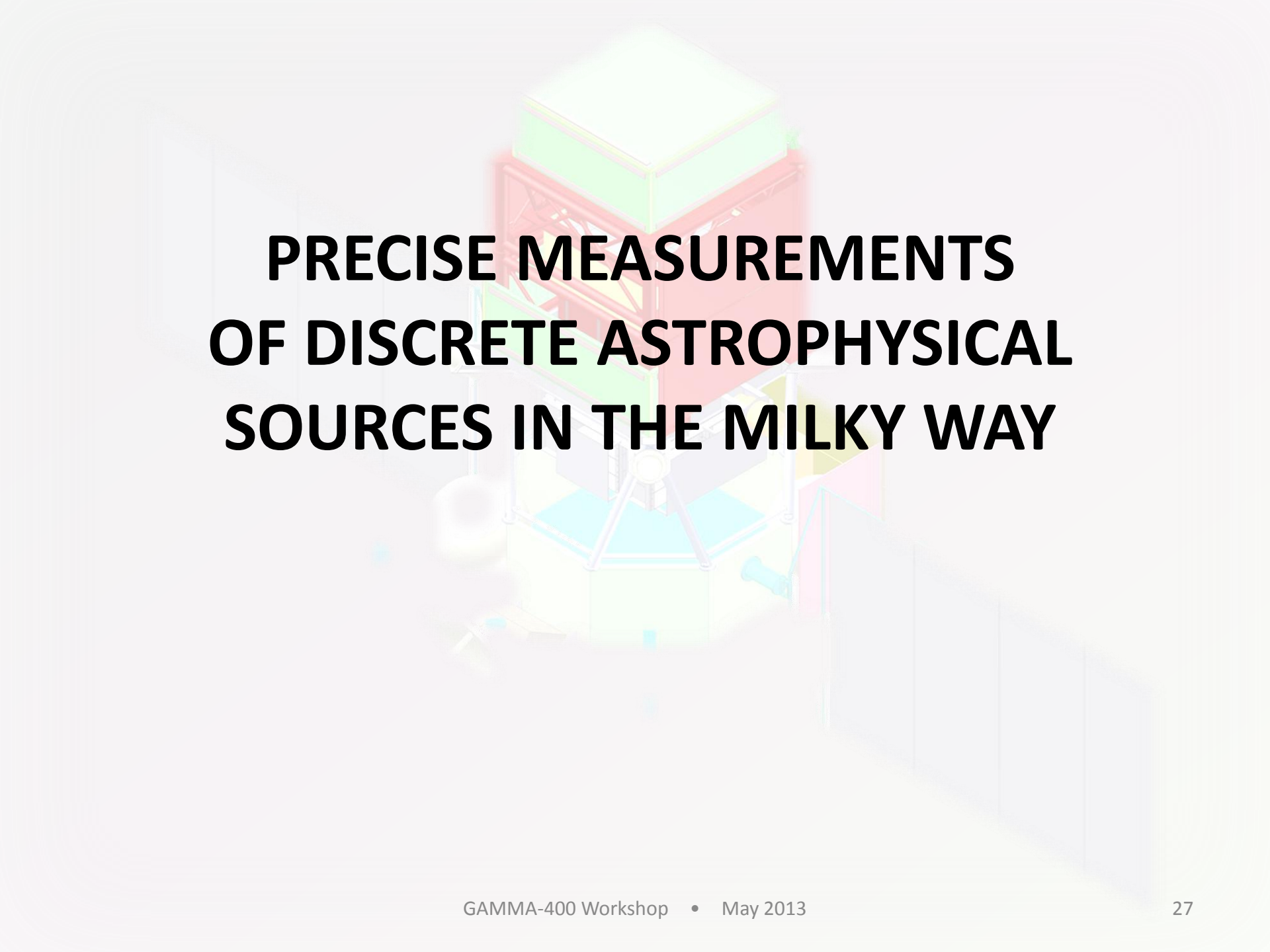
Gamma-400, 10X better dE/E , 10X better PSF
(100X less background), same # of events
from line



Alexander Moiseev Aspen 2013 Closing in
on Dark Matter

Improvement of energy resolution





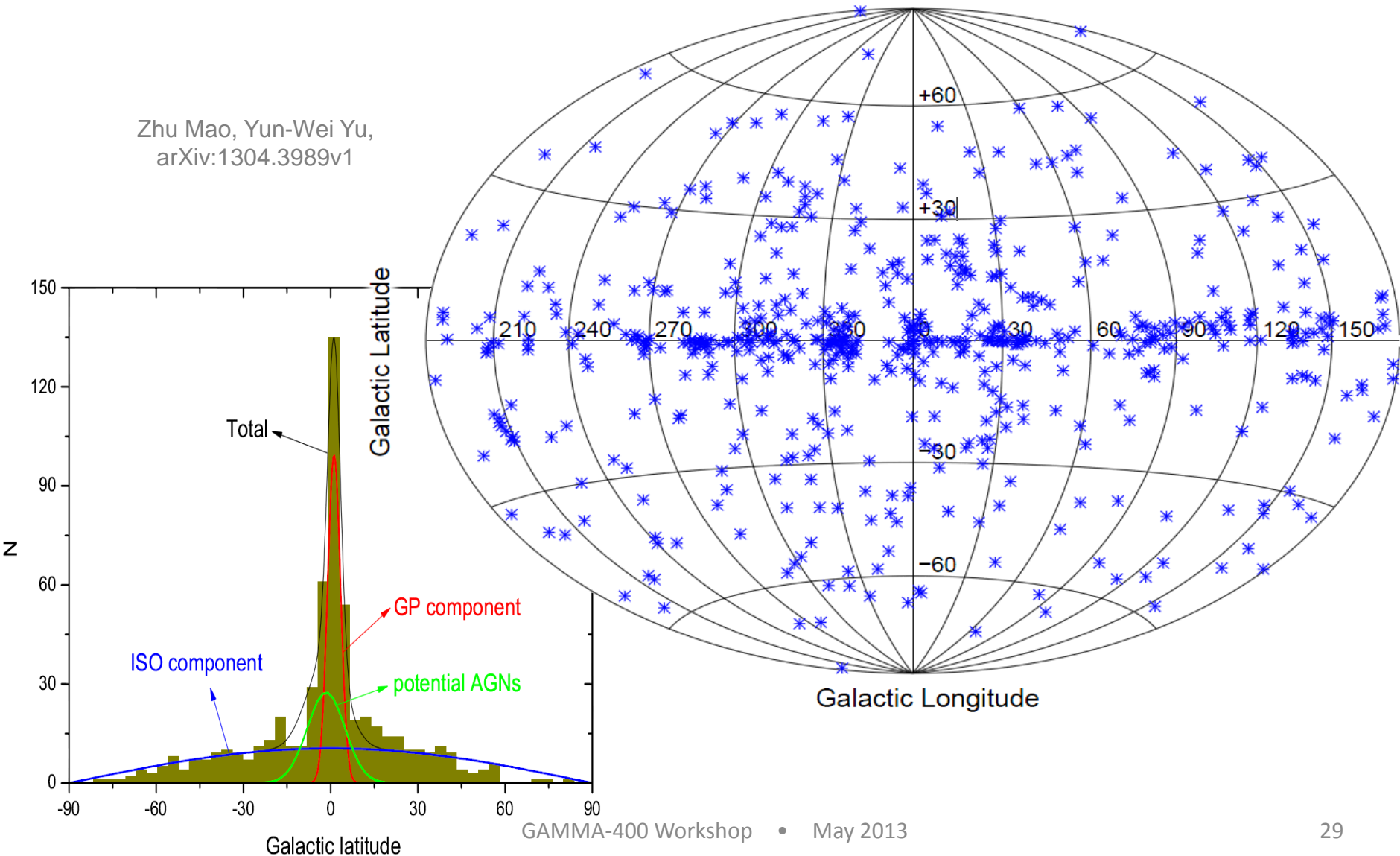
PRECISE MEASUREMENTS OF DISCRETE ASTROPHYSICAL SOURCES IN THE MILKY WAY

Table 5. LAT 2FGL Source Classes

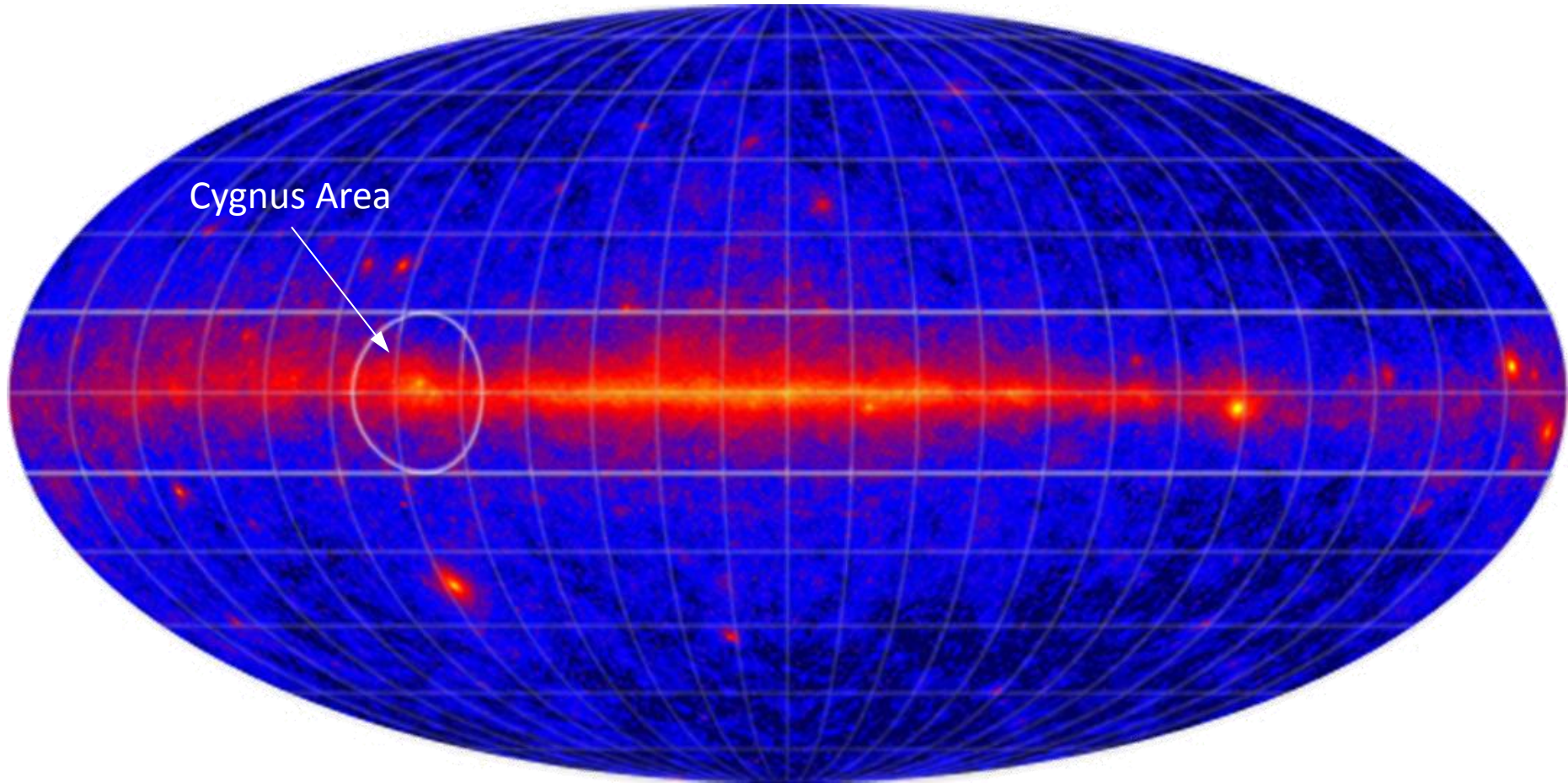
Description	Identified		Associated	
	Designator	Number	Designator	Number
Pulsar, identified by pulsations	PSR	83	...	...
Pulsar, no pulsations seen in LAT yet	...	...	psr	25
Pulsar wind nebula	PWN	3	pwn	0
Supernova remnant	SNR	6	snr	4
Supernova remnant / Pulsar wind nebula	...	...	†	58
Globular cluster	GLC	0	glc	11
High-mass binary	HMB	4	hmb	0
Nova	NOV	1	nov	0
BL Lac type of blazar	BZB	7	bzb	428
FSRQ type of blazar	BZQ	17	bzq	353
Non-blazar active galaxy	AGN	1	agn	10
Radio galaxy	RDG	2	rdg	10
Seyfert galaxy	SEY	1	sey	5
Active galaxy of uncertain type	AGU	0	agu	257
Normal galaxy (or part)	GAL	2	gal	4
Starburst galaxy	SBG	0	sbg	4
Class uncertain	...	...	...	1
Unassociated	...	...	...	576
Total	...	127	...	1746

The distribution of 573 2FGL unassociated sources

Zhu Mao, Yun-Wei Yu,
arXiv:1304.3989v1

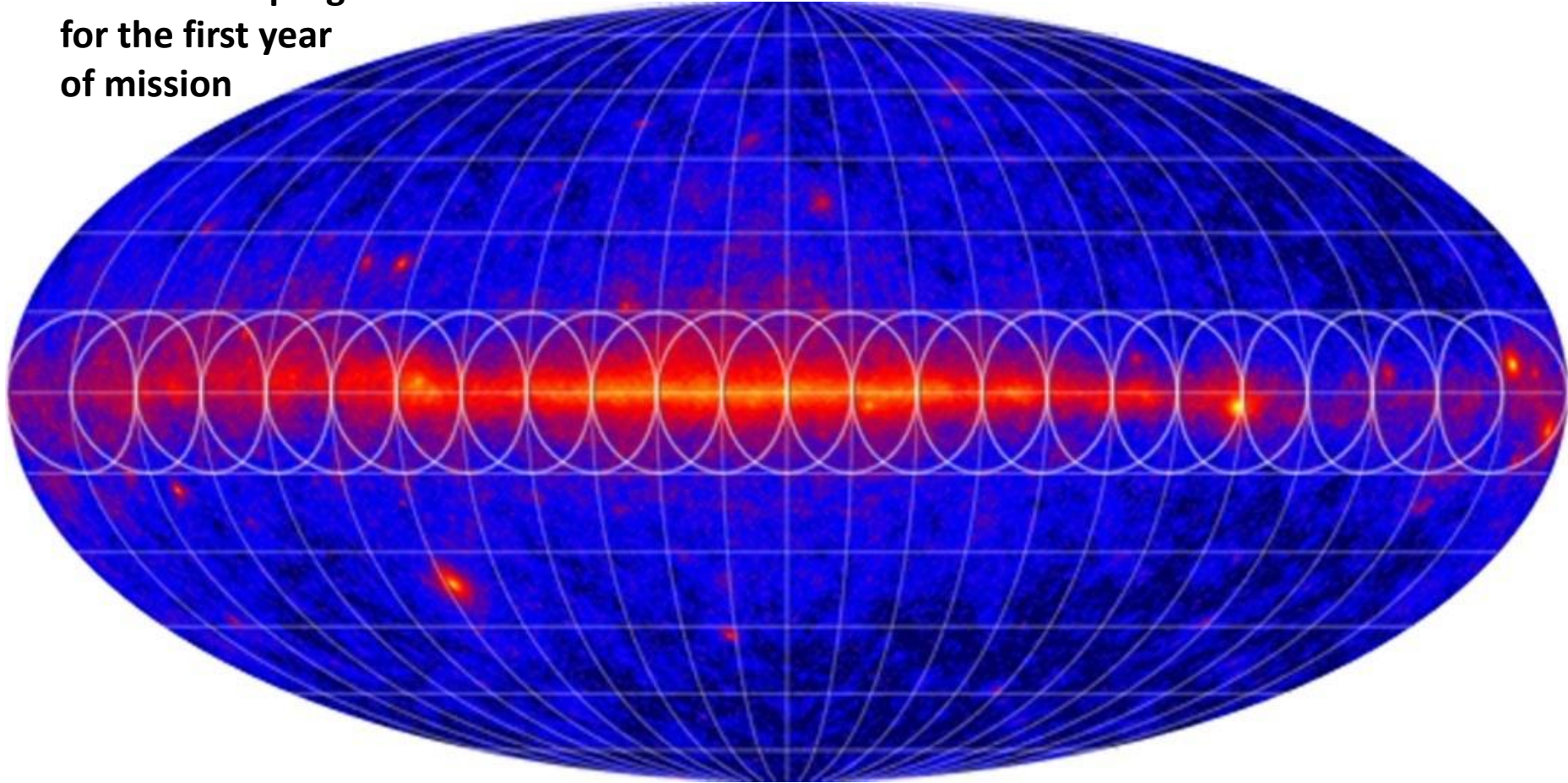


Fermi Gamma-Ray Sky



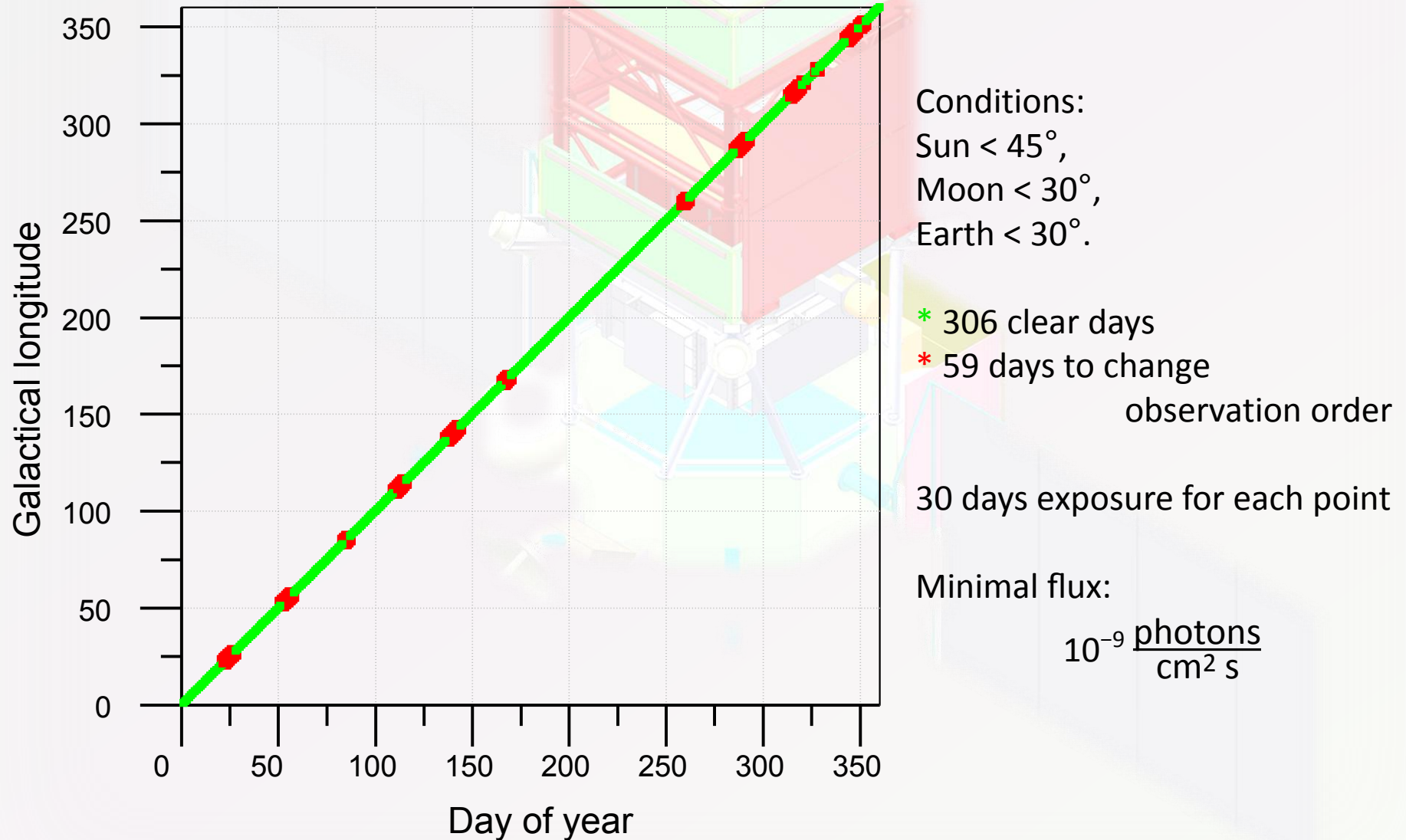
Fermi Gamma-Ray Sky

**GAMMA-400
observation program
for the first year
of mission**



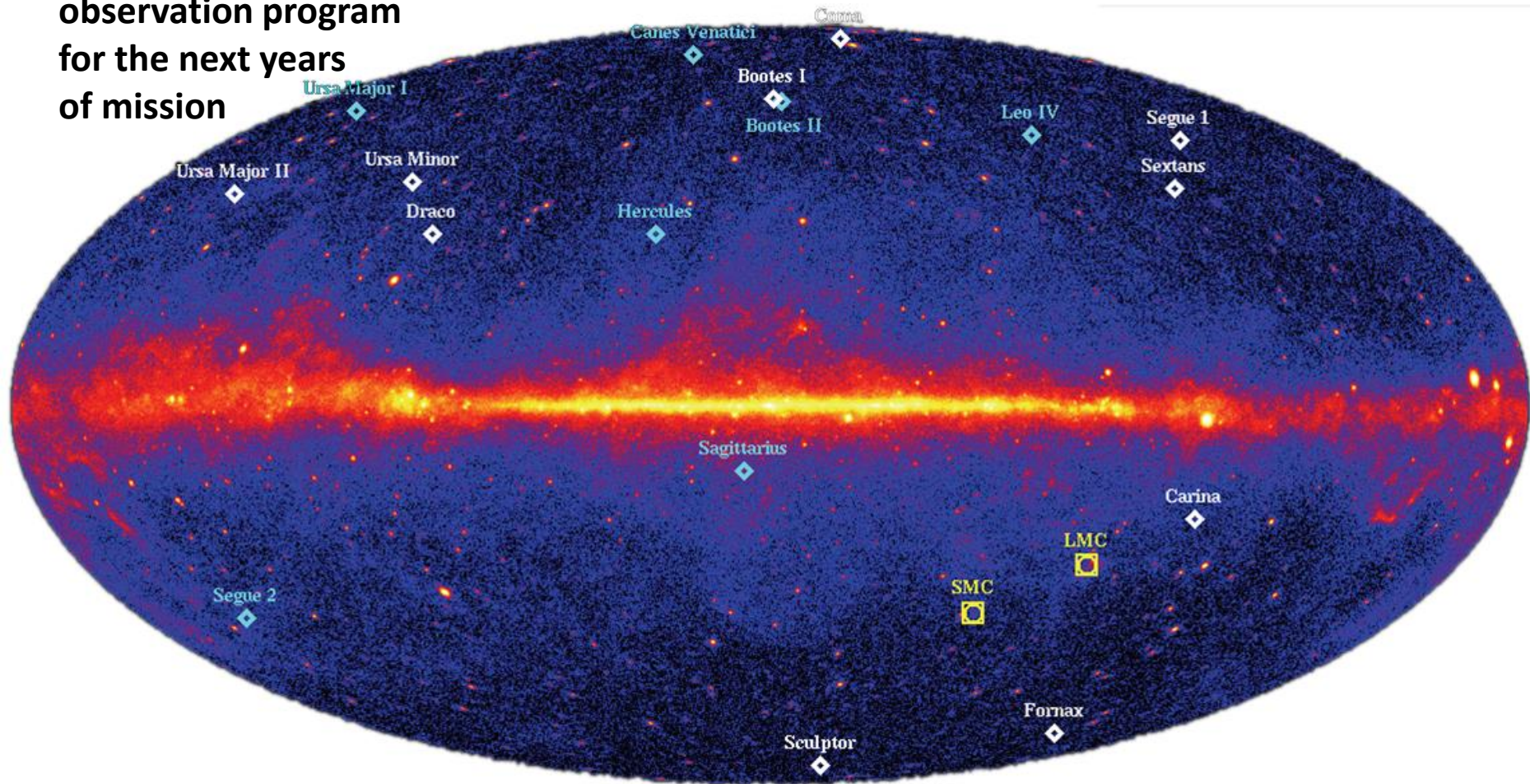
Scanning of the Galaxy

Preliminary program of observations (first year of flight)



Fermi Gamma-Ray Sky

GAMMA-400
observation program
for the next years
of mission



Observation of dwarf spherical galaxies

Extended sources used in the 2FGL analysis

2FGL Name	Extended Source	Spatial Form	Spectral Form	Reference
2FGL J0059.0–7242e	SMC	2D Gaussian	Exp Cutoff PL	Abdo et al. (2010e)
2FGL J0526.6–6825e	LMC	2D Gaussian ^a	Exp Cutoff PL	Abdo et al. (2010q)
2FGL J0617.2+2234e	IC 443	2D Gaussian	Log Parabola	Abdo et al. (2010p)
2FGL J0833.1–4511e	Vela X	Disk	Power Law	Abdo et al. (2010l)
2FGL J1324.0–4330e	Centaurus A (lobes)	Contour Map	Power Law	Abdo et al. (2010f)
2FGL J1514.0–5915e	MSH 15–52	Disk	Power Law	Abdo et al. (2010d)
2FGL J1801.3–2326e	W28	Disk	Log Parabola	Abdo et al. (2010k)
2FGL J1805.6–2136e	W30	Disk	Log Parabola	...
2FGL J1824.5–1351e	HESS J1825–137	2D Gaussian	Power Law	Grondin et al. (2011a)
2FGL J1855.9+0121e	W44	Ring	Log Parabola	Abdo et al. (2010o)
2FGL J1923.2+1408e	W51C	Disk	Log Parabola	Abdo et al. (2009b)
2FGL J2051.0+3040e	Cygnus Loop	Ring	Exp Cutoff PL	...

List of discrete sources from ground observations which may be observed by GAMMA-400 in 100 days.

Name	Instrument	Spectral index	Integral flux $F(> 100 \text{ GeV})$, $10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$	Expected number of gamma $N(> 100 \text{ GeV})$ For 100 days
1ES 1011+496	MAGIC	4.0	67.7	2336.7
1ES 1218+304	MAGIC	3.0	4.09	141.3
1ES 1959+650	MAGIC	2.78	5.805	200.7
1ES 2344+514	MAGIC	3.3	1.67	57.7
3C 279	MAGIC	4.11	219.0	7566.7
BL Lac	MAGIC	3.64	3.18	110.0
Crab	H.E.S.S., MAGIC	2.48	11.7	403.3
MAGIC J0616+225	MAGIC, VERITAS	3.1	0.605	20.9
Mkn 180	MAGIC	3.25	3.60	124.3
Mkn 421	H.E.S.S., MAGIC	3.2	6.05	209.0
Mkn 501	MAGIC	2.28	10.7	370.0
PG 1553+113	H.E.S.S., MAGIC	4.01	204.0	7066.7
PKS 2155-304	H.E.S.S., MAGIC	3.53	69.0	2386.7
RX J0852.0-4622	H.E.S.S.	2.2	0.331	11.4
RX J1713.7-3946	H.E.S.S.	2.84	0.618	21.4
W Com	VERITAS	3.8	4.570	158.0

Current 2-year phase “Technical project”

1. detailed analysis of physical and technical characteristics of the instrument;
2. design and fabrication of prototypes of gamma-ray telescope systems and their GSE for testing technical solutions in laboratory;
3. design and fabrication of laboratory prototype of “GAMMA-400” including prototypes (point 2) and GSE for testing technical solutions;
4. detailing of the scientific program of
 - research,
 - development of list of astrophysical objects to observe and
 - estimation of expected results of observation.



Thanks for your
attention!