Ginzburg Conference on Physics

Lebedev Physical Institute

# Progress in Gamma-Ray Astronomy in Russia

A. M. Galper

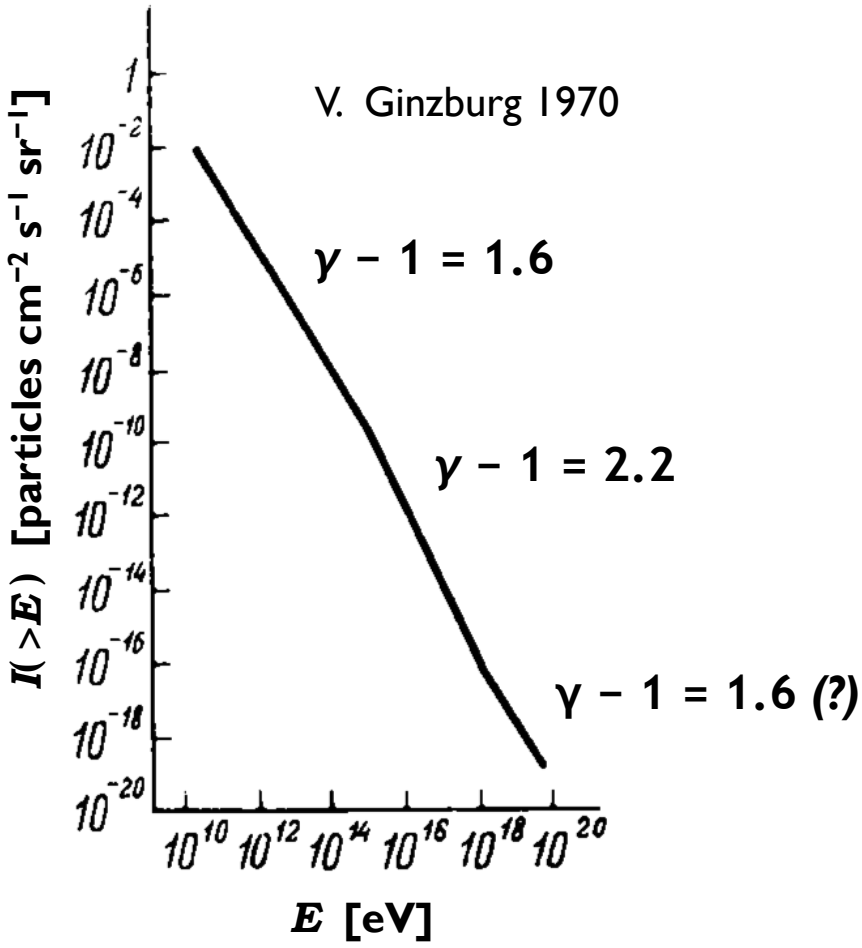
LPI, NRNU MEPhI

June 1, 2012

# GAMMA-RAY ASTRONOMY AND COSMIC RAYS

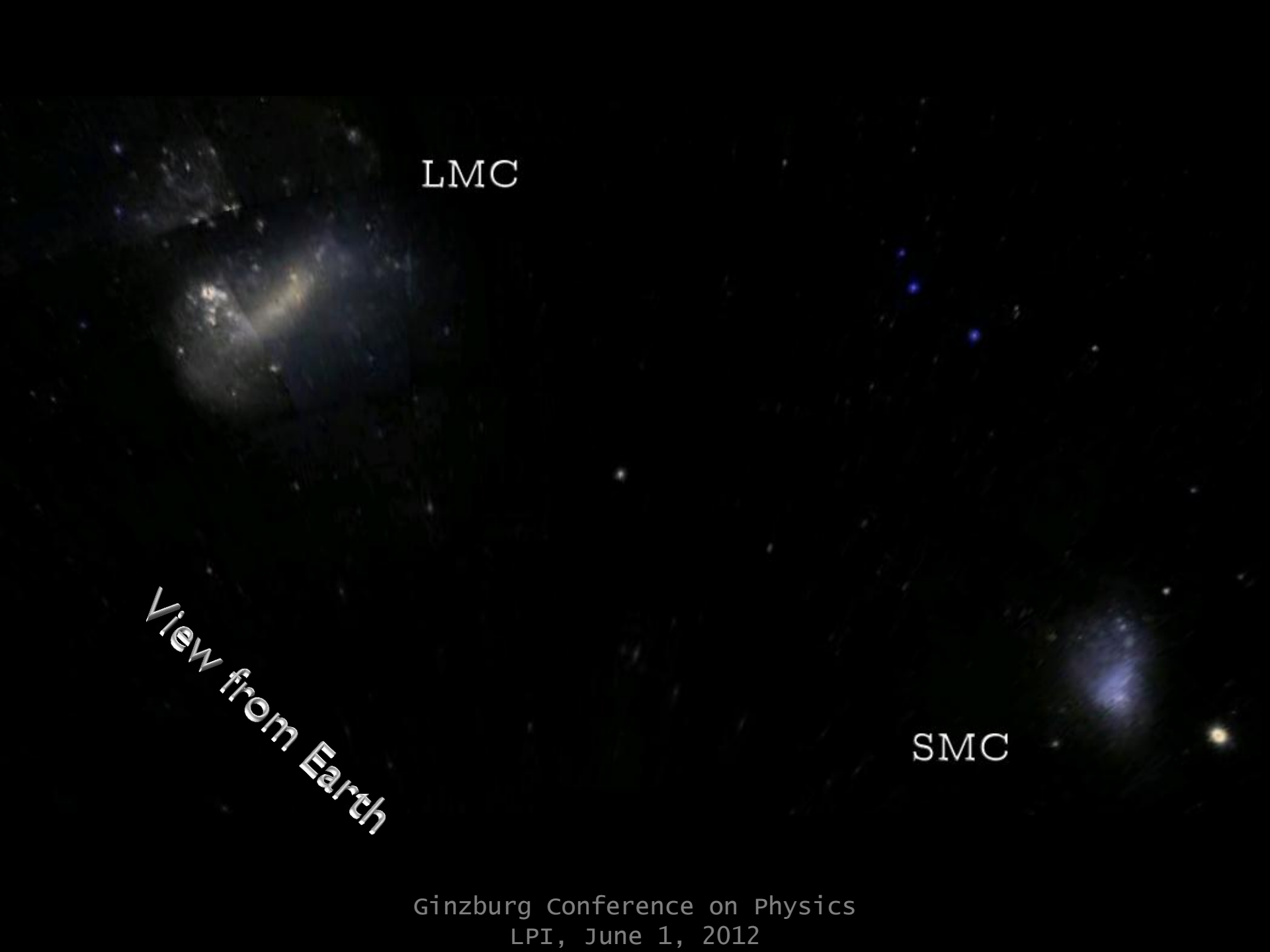
Ginzburg Conference on Physics
LPI, June 1, 2012

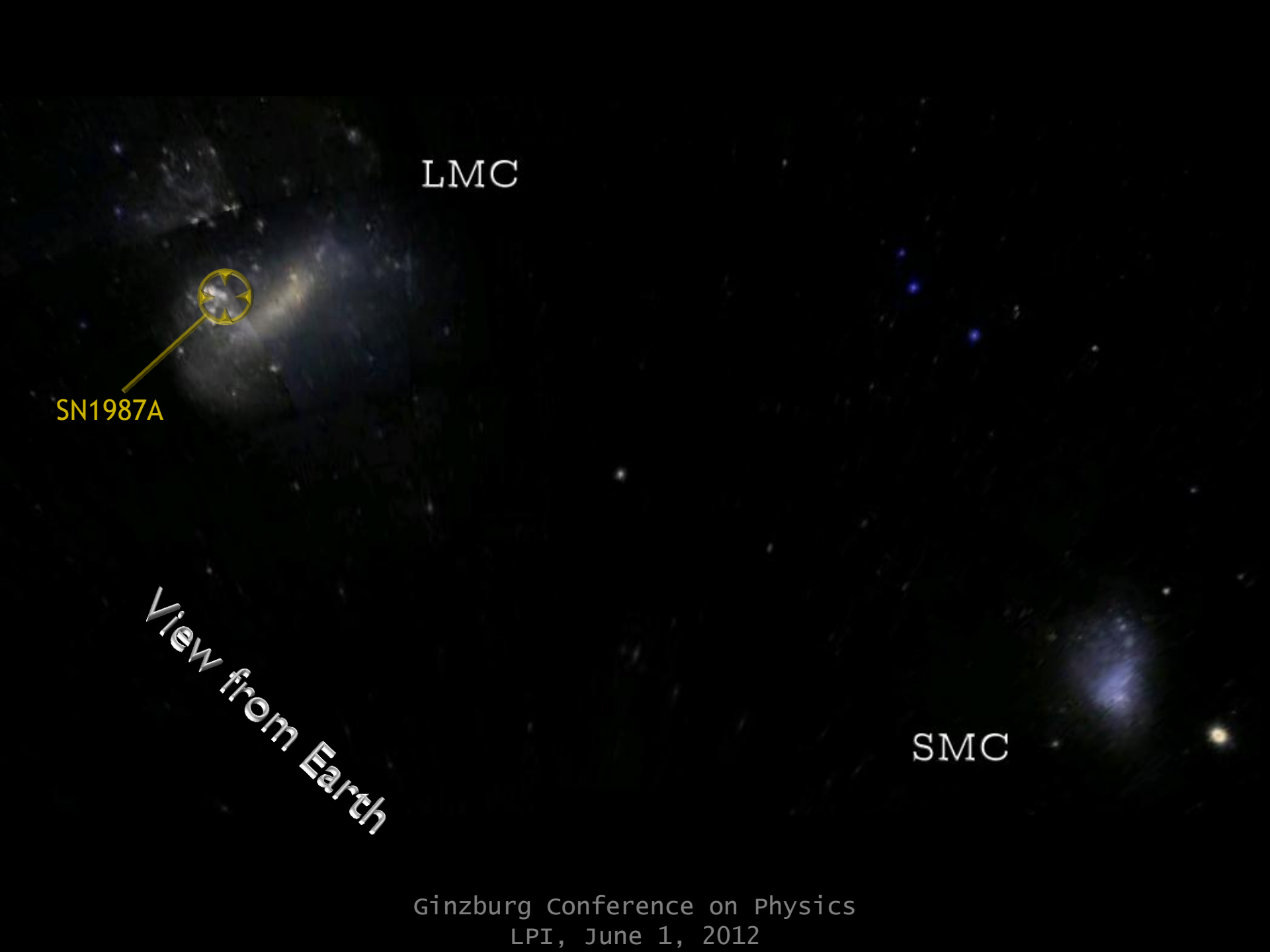
# Spectrum known in 70s




Integral CR spectrum


Milky Way
LMC
SMC
View from
Andromeda Galaxy


LMC
View from Earth
SMC


LMC
SN1987A
View from Earth
SMC

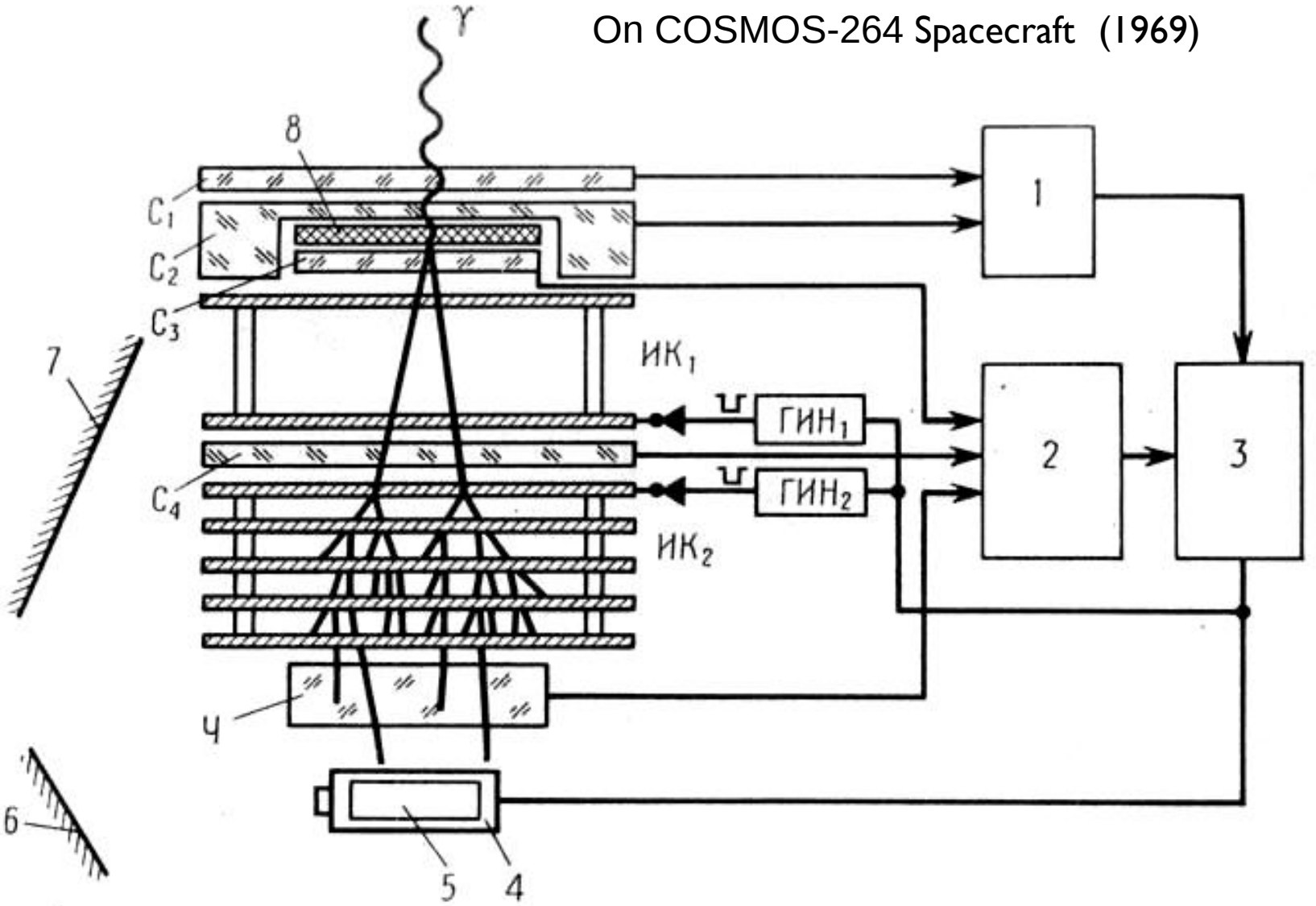
# Fluxes from Magellanic Clouds

The galactic and extragalactic CR density are assumed to be both equal to $10^{-12}$ erg cm$^{-3}$ in the prediction

| | Ginzburg's Prediction (June 1, 1972) | Experiment Fermi LAT (2010) |
|---|---|---|
| **Gamma-ray flux from LMC** | $2\times10^{-7}$ cm$^{-2}$ s$^{-1}$ Nature (Sept. 4, 1972) | $(2.6 \pm 0.2)\times10^{-7}$ cm$^{-2}$ s$^{-1}$ arXiv: 1001.3298 |
| **Gamma-ray flux from SMC** | $1\times10^{-7}$ cm$^{-2}$ s$^{-1}$ Nature (Sept. 4, 1972) | $(0.37 \pm 0.07)\times10^{-7}$ cm$^{-2}$ s$^{-1}$ arXiv: 1008.2127 |
| **Their ratio** | **2** | **7.0 ± 1.4** |

# ANNA-III Gamma-Ray Telescope

On COSMOS-264 Spacecraft (1969)

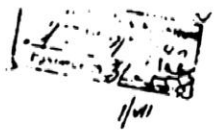


# Session of the Presidium of the Academy of sciences of USSR on June 1, 1972:

- 1. Academician V.L. Ginzburg. Gamma-ray astronomy and cosmic rays.
- 2. Doctor A.M. Galper. The possibilities of creation of gamma-ray telescopes

# The Minutes

Протокольно:



2. Поручить Отделению общей физики и астрономии и Отделению ядерной физики до 1 июля с.г. обсудить состояние и перспективы гамма-астрономии в СССР и представить в Президиум АН СССР предложения по ее дальнейшему развитию.

Президент
А.Александров

(С академиком В.Л. Гинзбургом текст согласован. 1/VI-72. С.Кудрявцев)

Minutes

2. Presidium of Academy of Sciences charges the Section of General Physics and Astronomy and the Section of Nuclear Physics to discuss the status and vistas of gamma astronomy in USSR before July 1 and to submit proposals for its development to the Presidium of USSR Academy of Sciences.

President

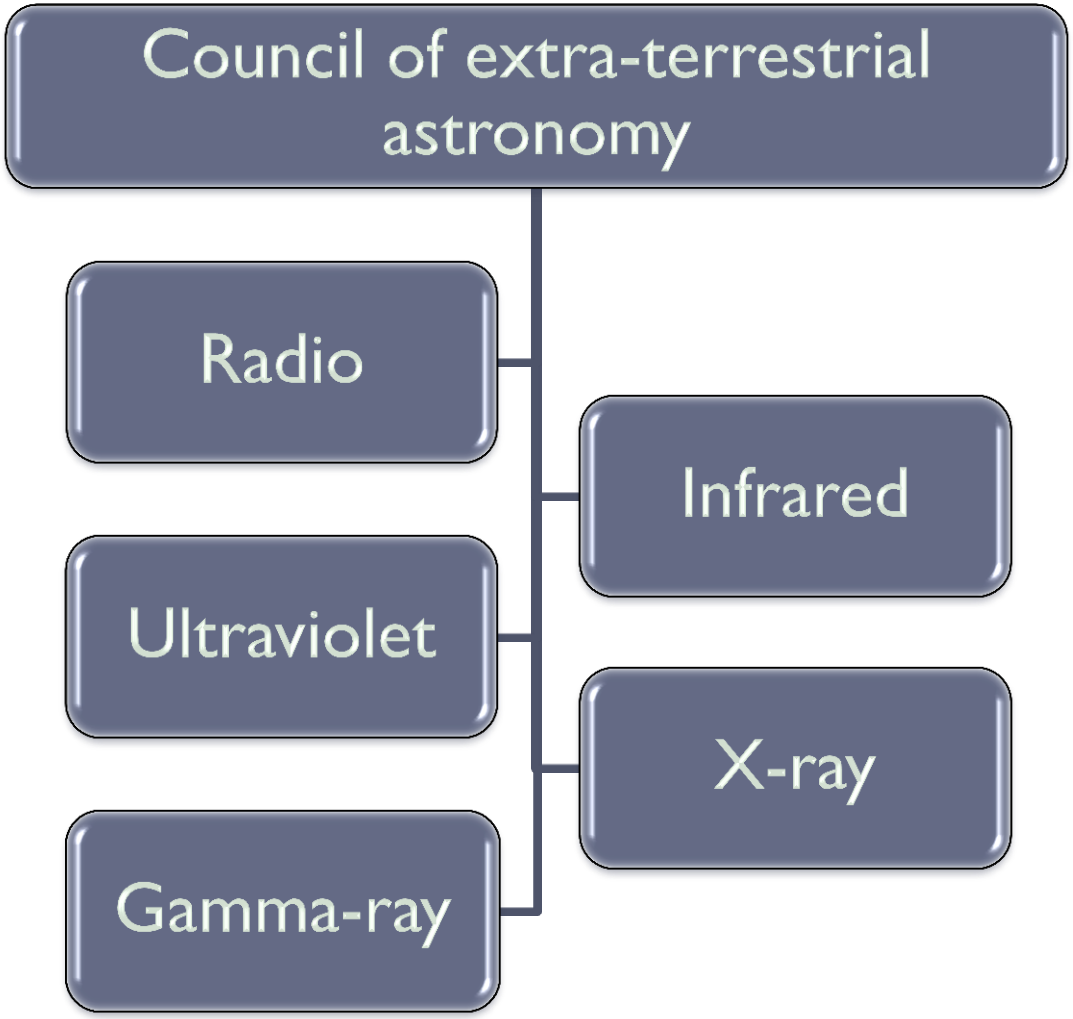
(Text is agreed with academician V. L. Ginzburg)

1 / VI–72

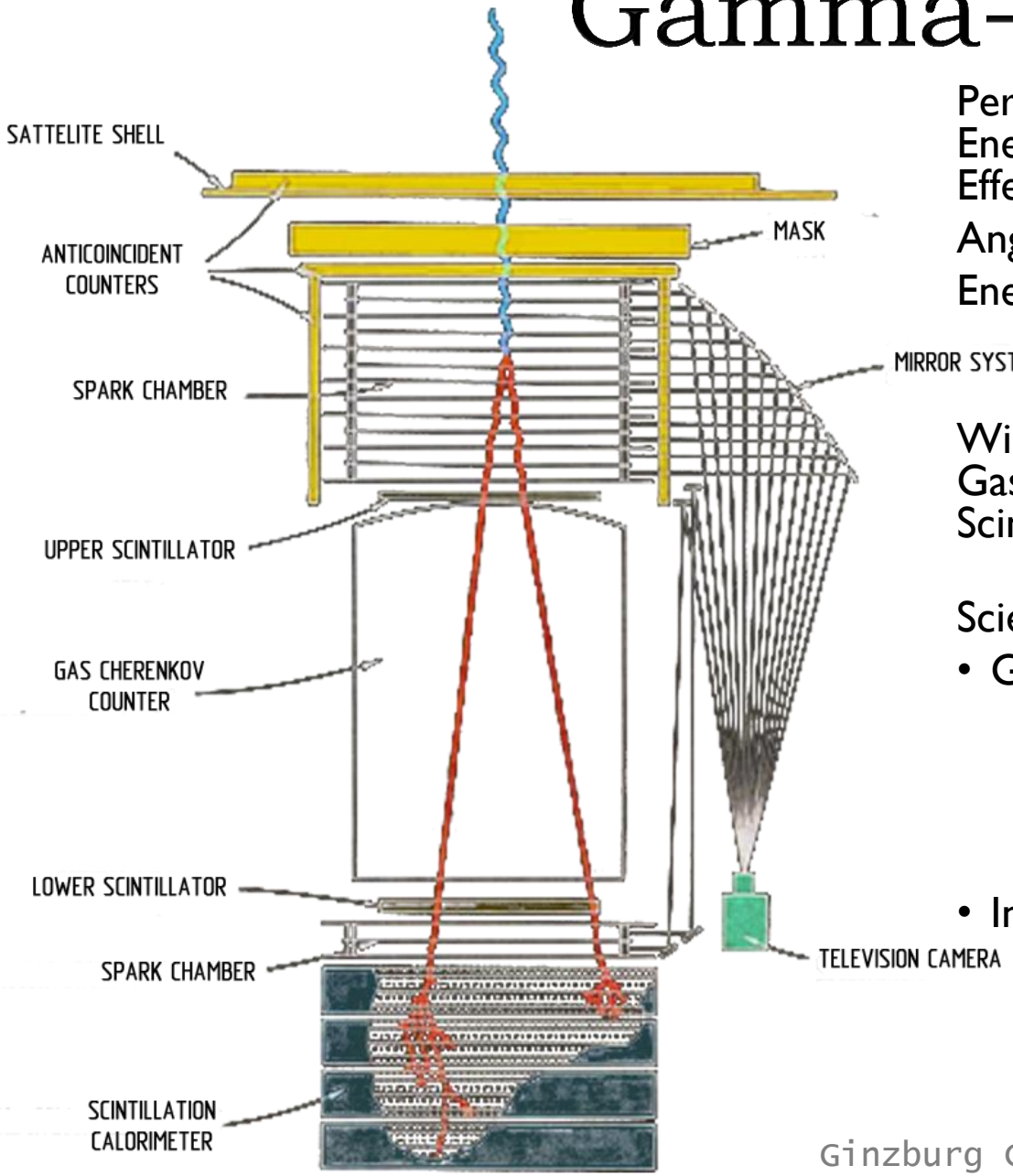
# Decision

- In July 1972, V. Keldysh, the president of USSR Academy of Sciences, signed an order:
  - To create a Council of extra-terrestrial astronomy.
  - To assign every year a sum of 3.5 million rubles to the development of extra-terrestrial astronomy and 0.7 million rubles to the creation of the gamma-ray telescope.

# Sections


Council of extra-terrestrial astronomy
Radio
Infrared
Ultraviolet
X-ray
Gamma-ray

# Gamma-1




| | |
|---|---|
| Period: | 1990-1992 |
| Energy range: | 50 MeV–5 GeV |
| Effective area: | 1400 $cm^2$, |
| Angular resolution (300 MeV): | 1.2° |
| Energy resolution (550 MeV): | 34% |

Wide-gap spark chamber,
Gas Cherenkov counter,
Scintillation lead calorimeter of 7.4 r.l.

Scientific results:

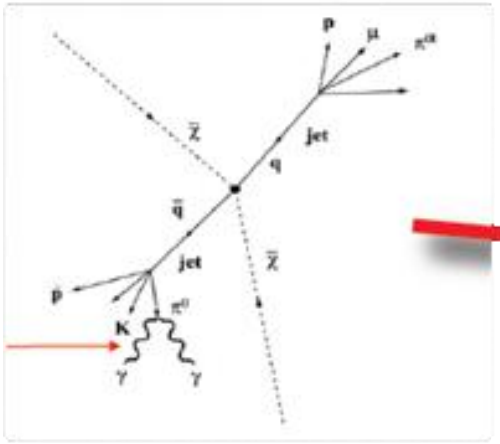
- Gamma rays registered from:
  - The Galactic Center,
  - Many galactic objects (Geminga, Crab, Hercules-X1, Cygnus-X3, Vela).
- In 1991, during the solar maximum, solar flares with high energy (several GeV) gamma rays were first registered.

# GAMMA-RAY ASTRONOMY AND DARK MATTER

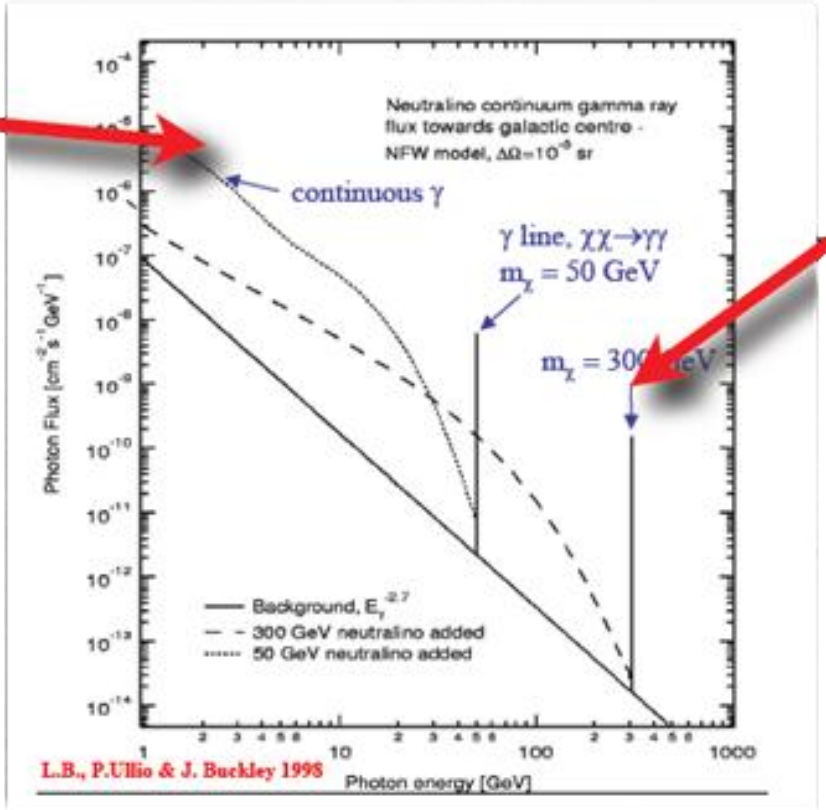
Ginzburg Conference on Physics
LPI, June 1, 2012

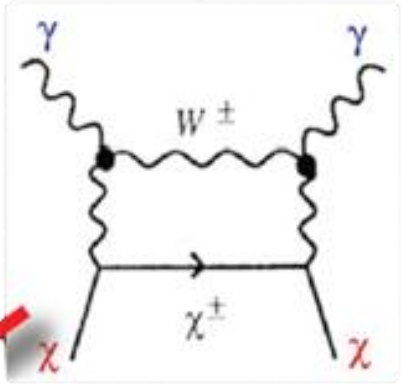
# γ-Rays Produced by Dark Matter

In regions of the highest dark matter density, dark matter particles and their antiparticles are expected to **annihilate into gamma-rays**, either directly into a **gamma-ray line** (with energy equal to the mass of the dark matter particle times the speed of light squared $E_\gamma = m_\chi c^2$) or a **broad spectrum of gamma-rays**.



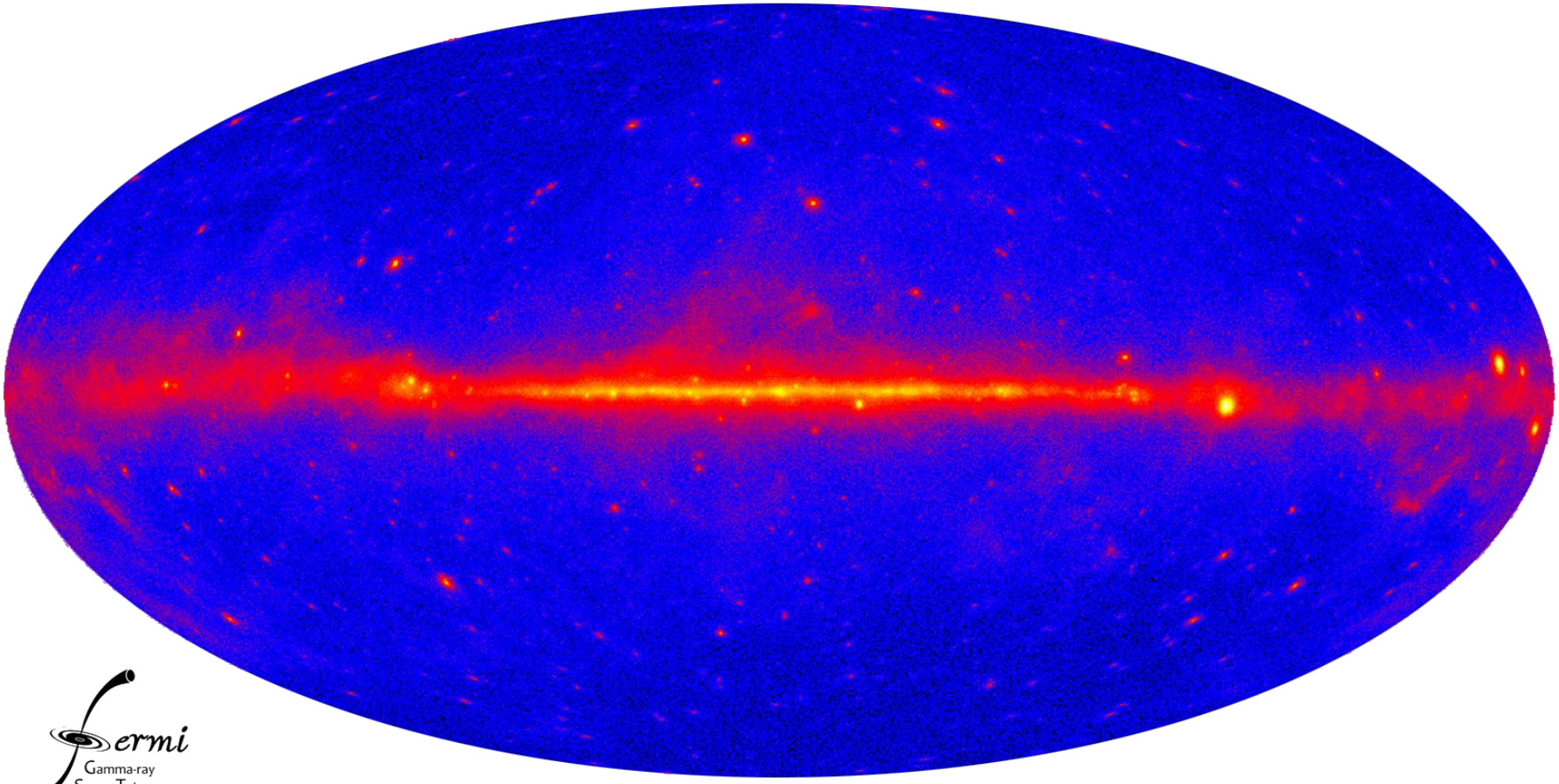

L. Bergström 2006



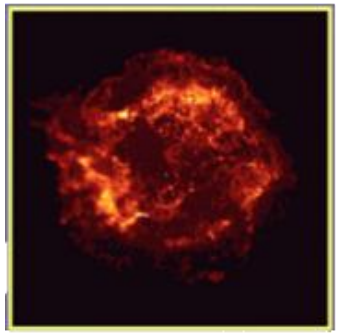

Jungman and Kamionkowsky 1994

# Fermi Gamma-Ray Sky Map



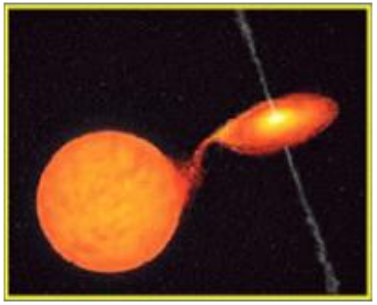
Fermi
Gamma-ray
Space Telescope

# Gamma-Ray Sources

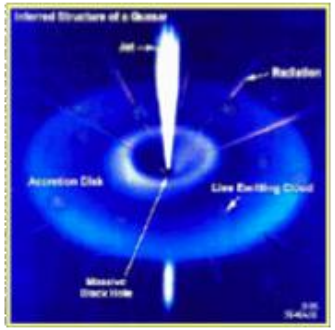


SNRs

Pulsars and PWNe



Micro quasars X-ray binaries




AGNs

GRBs

# Some of the recent experimental claims for possible dark matter detection, and a comment on the present status.

(L. Bergström, arXiv: 1205.4882)

| **Experiment** | **Status of claim** |
|---|---|
| DAMA/LIBRA annual modulation[66] | Unexplained at the moment; not confirmed by other experiments [68, 69, 72, 73] |
| CoGeNT excess events and annual modulation [71] | Tension with other data [68, 69, 72, 73] |
| CRESST excess events [75] | Tension with other data [68, 69, 72, 73] |
| EGRET excess of GeV photons [76, 77] | Due to instrument error (?) – not confirmed by Fermi-LAT [78] |
| INTEGRAL 511 keV $\gamma$-line from galactic centre region [79] | Does not seem to have spherical symmetry – shows an asymmetry which follows the disk (?) [80] |

. . .

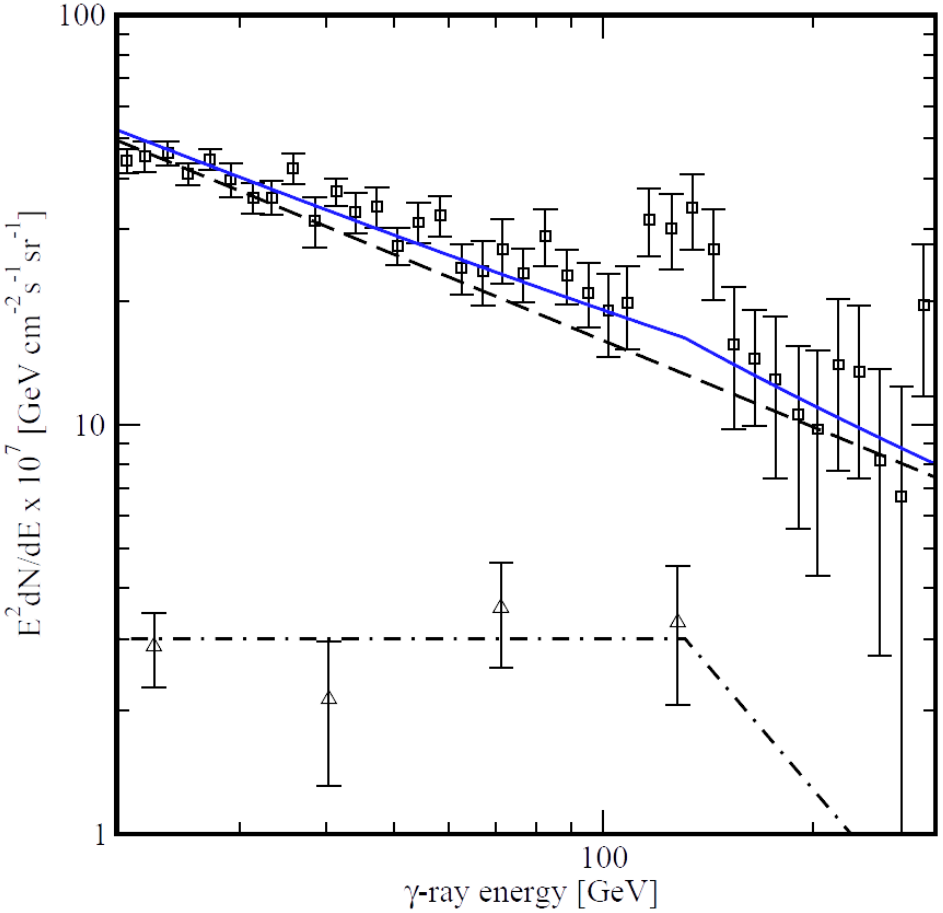
# Some of the recent experimental claims for possible dark matter detection, and a comment on the present status.

(L. Bergström, arXiv: 1205.4882)

• • •

| | |
|---|---|
| PAMELA: Anomalous ratio of cosmic ray positrons/electrons [81] | May be due to DM [82], or pulsars [83] – energy signature not unique for DM |
| Fermi-LAT positrons + electrons [31] | May be due to DM [82], or pulsars [83] – energy signature not unique for DM |
| Fermi-LAT GeV $\gamma$-ray excess towards galactic centre [84] | Unexplained at the moment – astrophysical explanations possible [85, 86], no statement from the Fermi-LAT collaboration |
| WMAP radio "haze" [87] | Has a correspondence in "Fermi bubbles" [88] – probably caused by outflow from the galactic centre |
| $\gamma$-ray structure [89] in public Fermi-LAT data [90] from galaxy clusters. | Very weak indication, could be cosmic-ray induced emission? |

# Gamma Ray Spectrum




C. Weniger, arXiv: 1204.2797,

L. Bergström, arXiv: 1205.4882

The public Fermi-LAT [90] data extracted from [92] (squares; "Reg.4, SOURCE class", in [92]) as well as the spectrum of the Fermi bubbles [88] (triangles). The dashed line is a featureless $E_\gamma^{-2.7}$ spectrum, and the dash-dotted line is a simple fit to the Fermi bubble data, where the actual location of the break and the slope above the break are unknown. The solid line is the summed spectrum (power-law plus bubbles), assuming that the break is coincidentally at the same energy as the line excess.

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(L. Bergström, arXiv: 1205.4882)

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| $\gamma$ line at 130 GeV [91, 92, 93] in Fermi-LAT public data [90] | $3.3\sigma - 4.6\sigma$ effect, unexplained at the moment. Not confirmed by the Fermi-LAT collaboration [94]. |

# THE GAMMA-400 PROJECT

Ginzburg Conference on Physics
LPI, June 1, 2012

# The Title Page

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 Lebedev Physical Institute
of the Russian Academy
of Sciences
academician
Mesyats G.A.

THE GAMMA-400 PROJECT
RESEARCH OF THE COSMIC GAMMA RADIATION
AND OF ELECTRON AND POSITRON FLUXES IN
ENERGY RANGE OF 1–3000 GeV

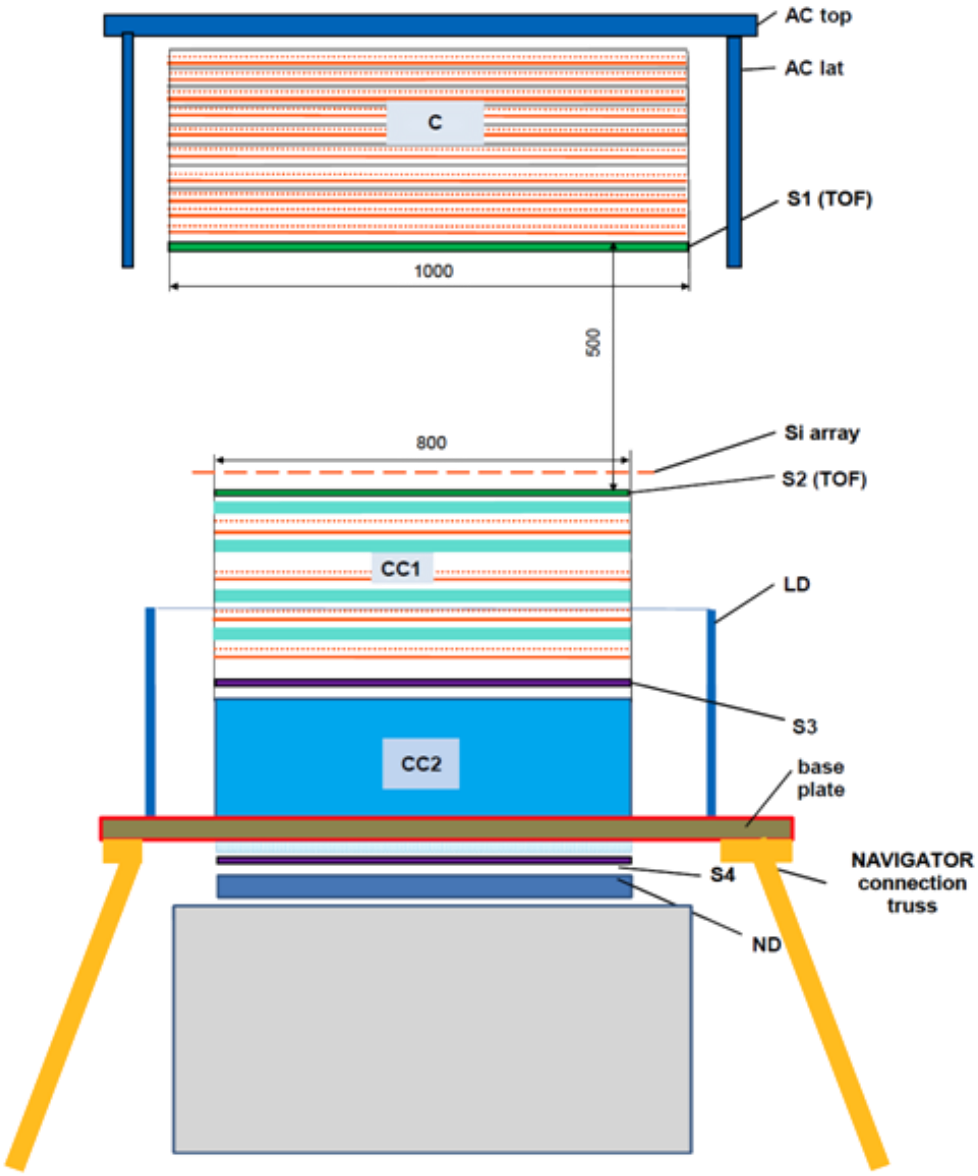
LPI

Scientific chief of problem
academician Ginzburg V. L.

GAMMA-400 project
principal investigator
professor l.r.f. Galper A. M.

Moscow, 2009

# Gamma-400 physical Scheme



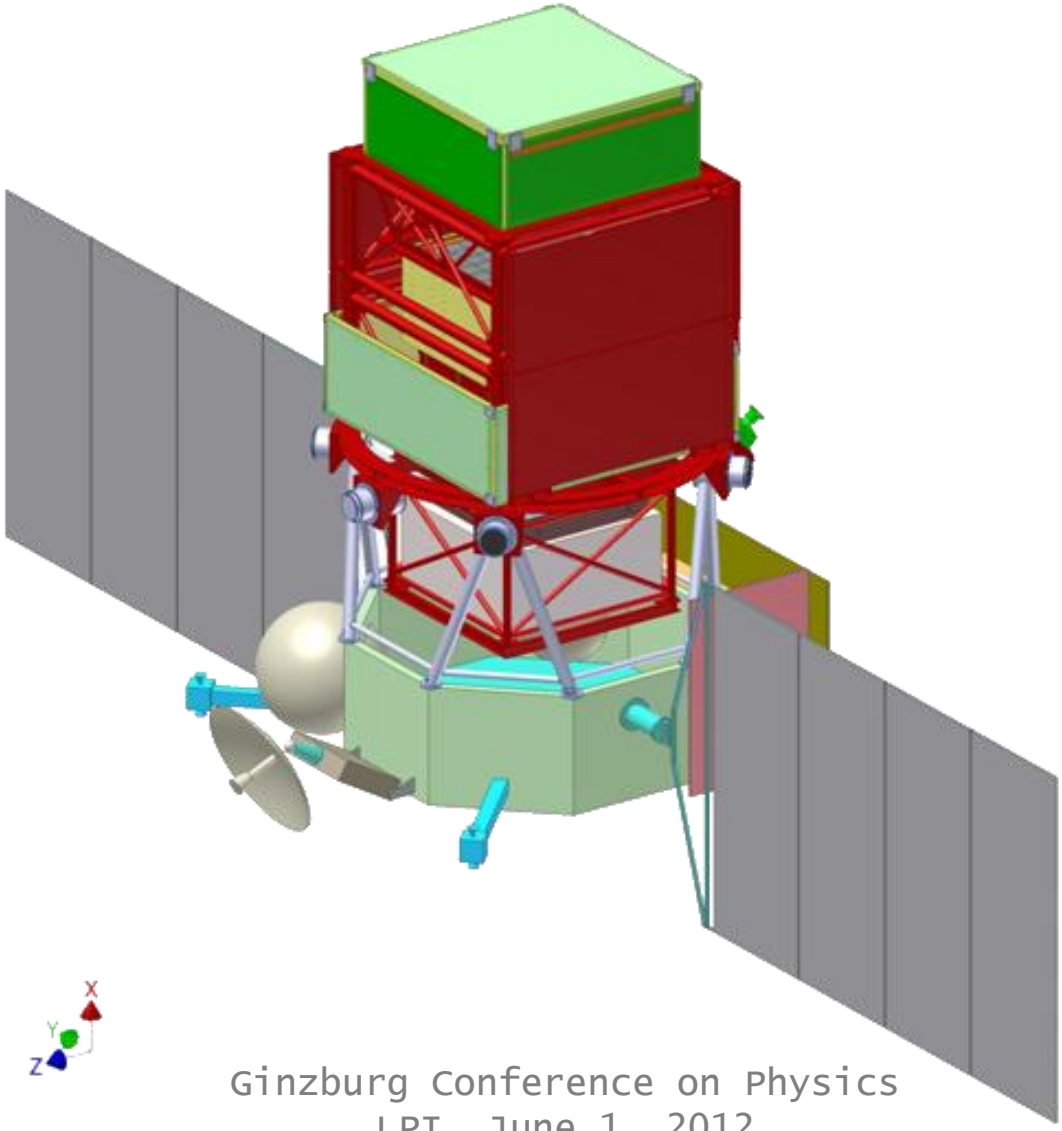

**Main characteristics**

| | |
|---|---|
| Energy range | 100 MeV – 3 TeV |
| Energy resolution | |
| (at $E\gamma$ > 100 GeV): | ~1% |
| Angular resolution | |
| (at $E\gamma$ > 100 GeV): | ~ 0.01° |
| Rejection factor: | ~ $5 \times 10^5$ |
| Power consumption: | 2000 W |
| Total mass: | 2600 kg |

# Comparison of main characteristics

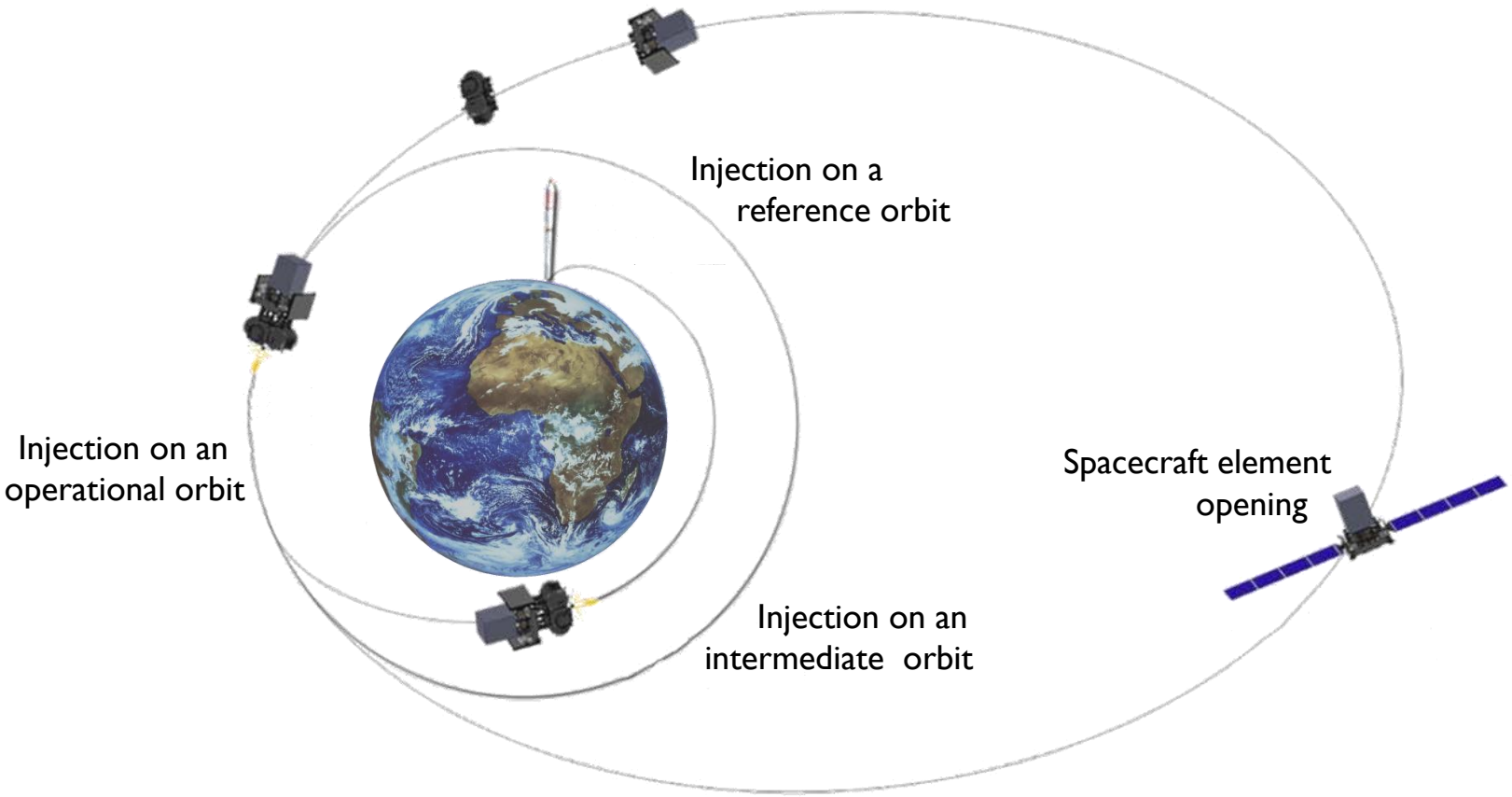
| | SPACE GAMMA-RAY TELESCOPES | | | | GROUND BASED GAMMA-RAY TELESCOPES | | |
|---|---|---|---|---|---|---|---|
| | EGRET | AGILE | Fermi | GAMMA 400 | H.E.S.S.-II | MAGIC-II | VERITAS |
| | USA | ITALY | USA | RUSSIA | NAMIBIA | SPAIN, CANARY ISLANDS | USA, ARIZONA |
| Energy Range [GeV] | 0.03–30 | 0.03–50 | 0.1––300 | 0.1––3000 | 100 | 50 | 100 |
| Angular resolution ($E_\gamma$ > 100 GeV) [degrees] | 0.5 ($E_\gamma$~10 GeV) | 0.1 ($E_\gamma$~30 GeV) | 0,1 | 0.01 | 0.1 | 0.1 | 0.1 |
| Energy resolution ($E_\gamma$ > 100 GeV) [percent] | 20 ($E_\gamma$~10 GeV) | 50 ($E_\gamma$~30 GeV) | 10 | 1 | 15 | 20 | 15 |

# GAMMA-400
# on the *Navigator* platform

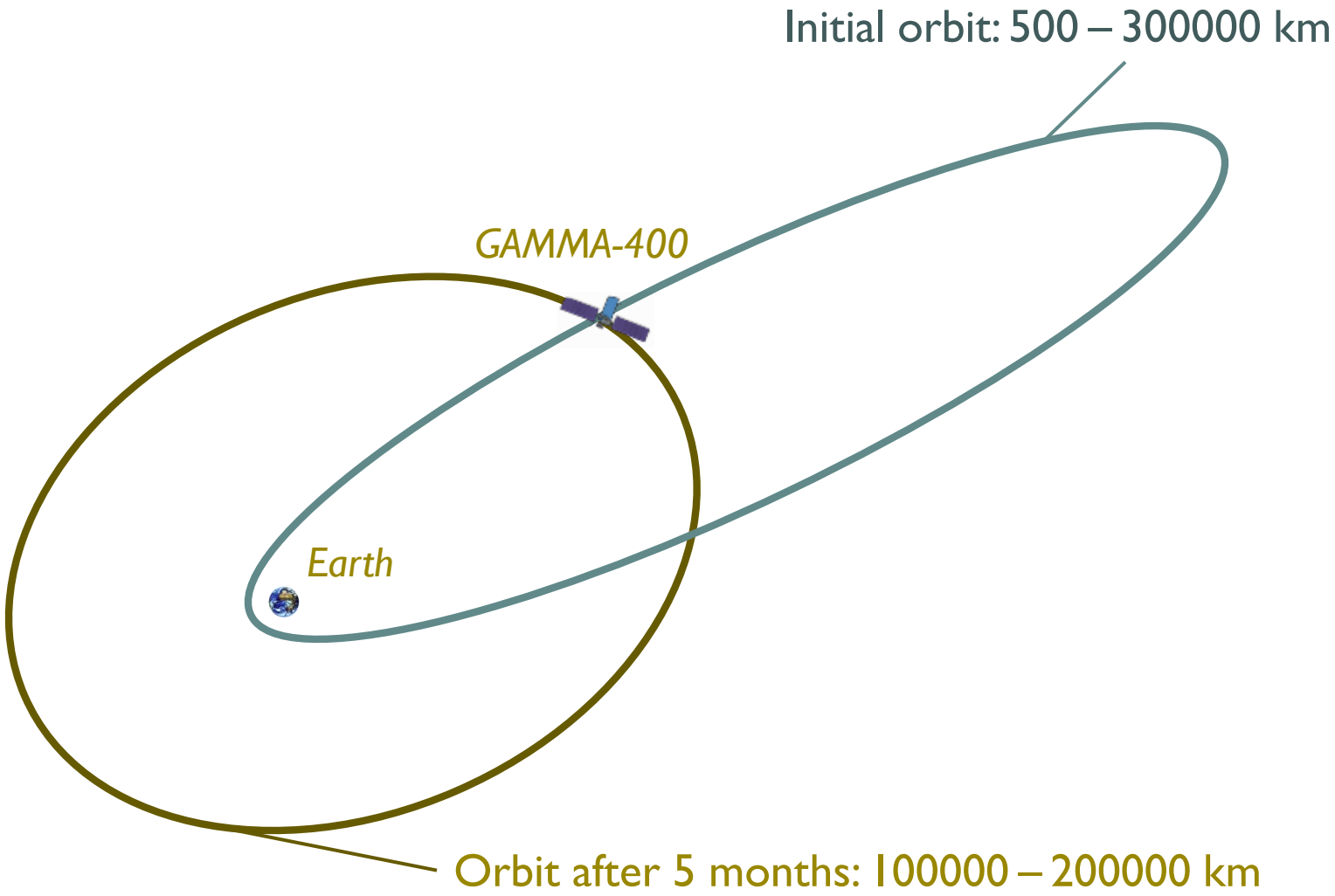


# GAMMA-400 Launching Scheme

*Prospective launching date: 2018–2019*



# GAMMA-400 Orbit



# Conclusion

• Cosmic rays were discovered one hundred years ago. 60 years later galactic or extragalactic origin of cosmic rays is still not known. Vitaly Ginsburg proposed solution to this problem. Today this problem has been solved—the bulk of CRs has a galactic origin.

• This year marks 80 years since the discovery of dark matter in the Universe. Today its nature is still not known. Vitaly Ginsburg proposed the way to solve this problem: the search for traces of self-annihilation of hypothetical dark matter. Today we are moving in this direction.