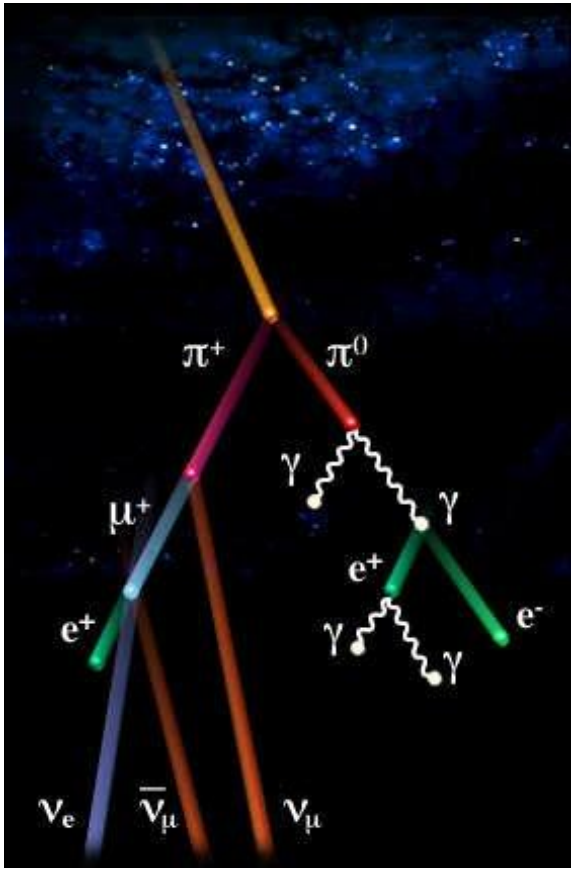
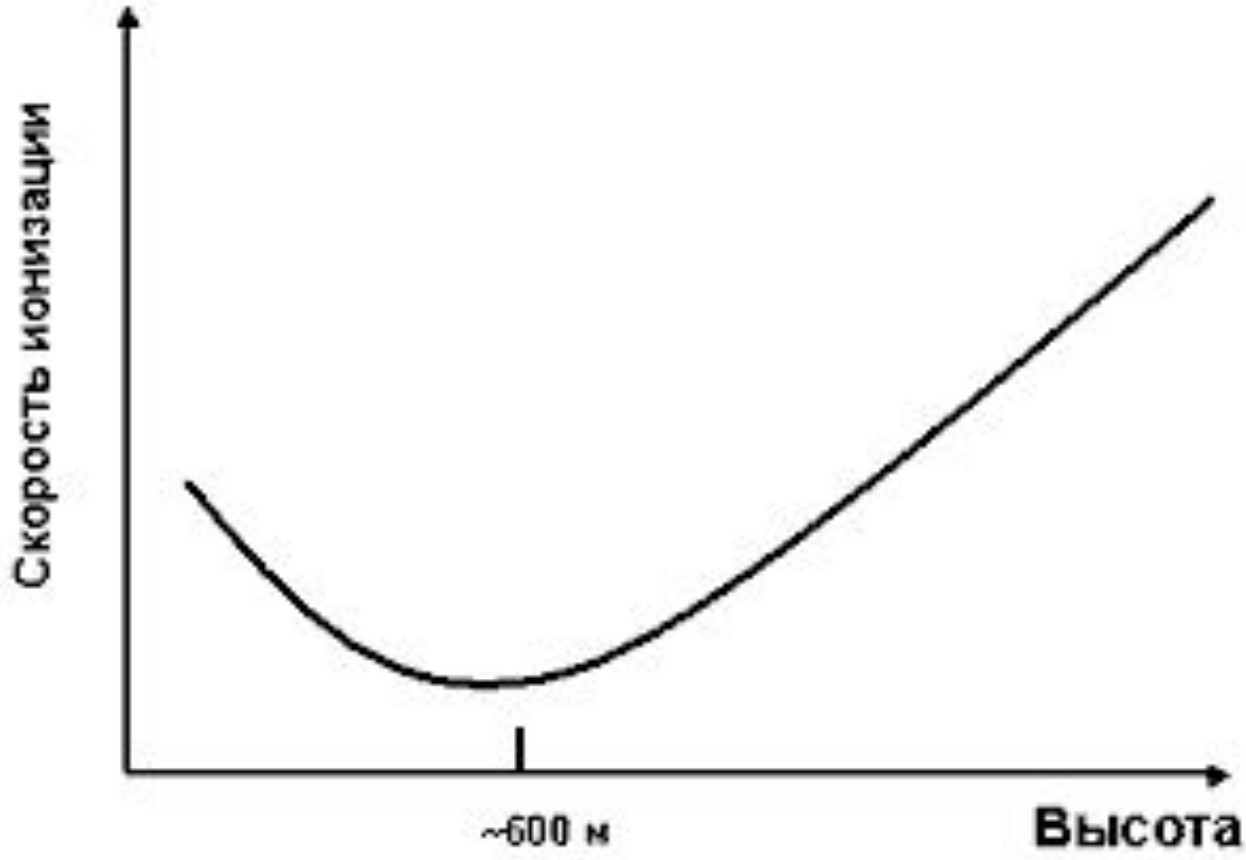
Космические лучи

Открытие космического излучения (В. Гесс, 1912 г.)



Нобелевская премия, 1936 г.

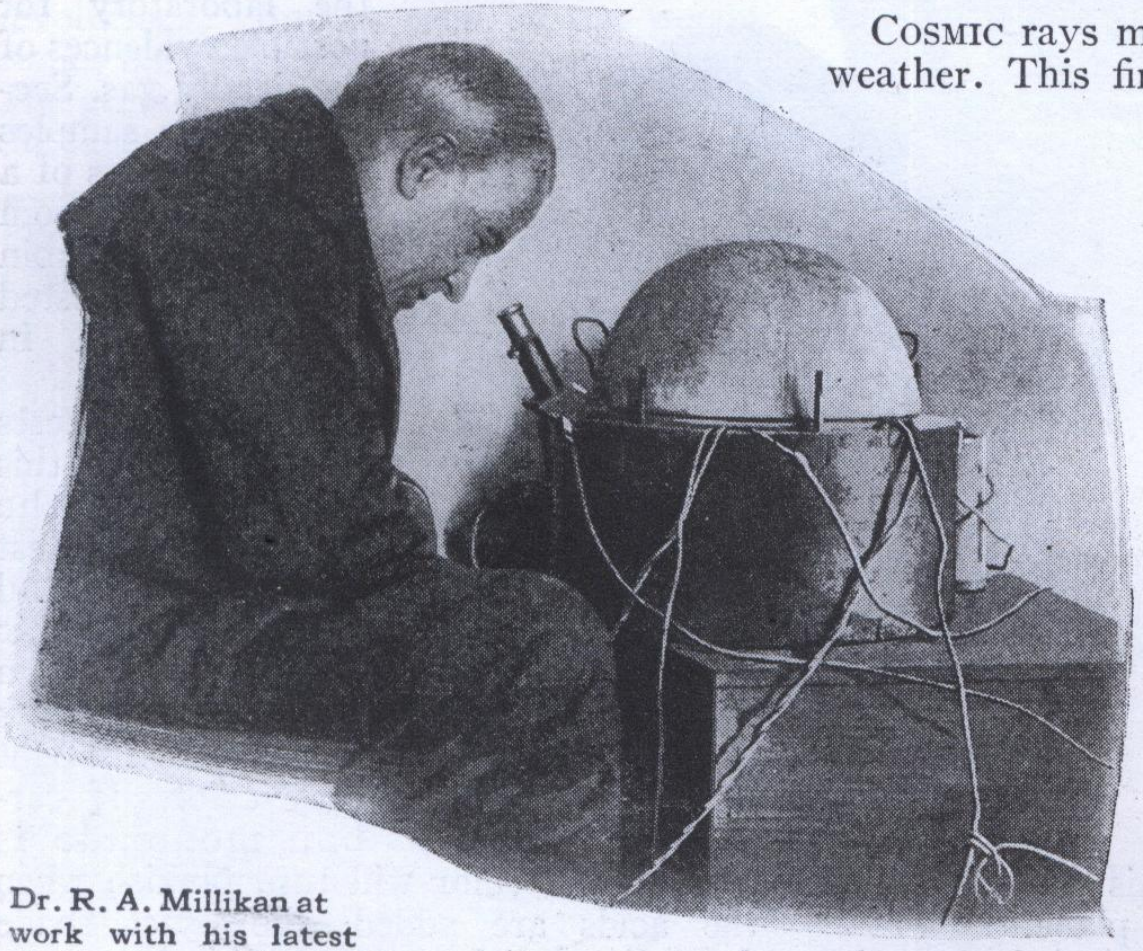
Опыты В.Гесса



Опыты Р.Милликена (1922-26 гг.)

КОСМИЧЕСКИЕ ЛУЧИ

COSMIC RAYS MAY FORECAST WEATHER



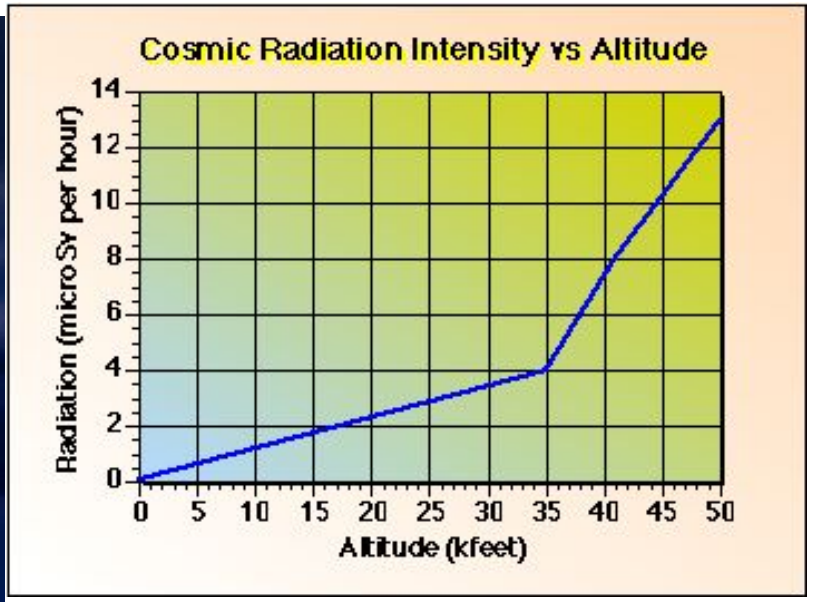
Dr. R. A. Millikan at work with his latest electroscope, with which he is studying the cosmic rays. He believes these mysterious rays may be used in making reliable forecasts of the weather.

COSMIC rays may help to prophesy the weather. This first practical use for the mysterious radiations from outer space was recently announced by Dr. R. A. Millikan, Calif. Institute of Technology physicist.

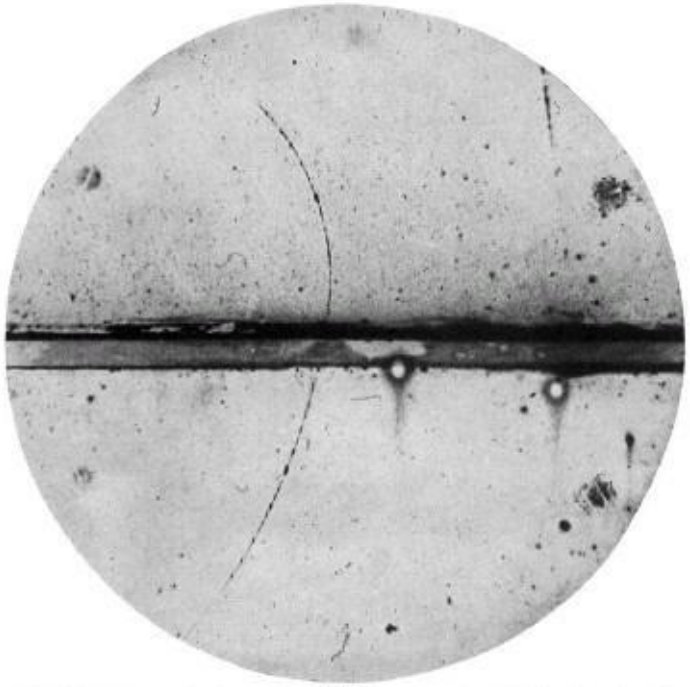
The "cosmic rays" are more penetrating than radium or X-rays, but it is not known whether they affect human beings.

Dr. Millikan, who discovered the source of the rays (P. S. M., July, '28, p. 13), has measured their strength with his new electroscope, and is able to determine high-altitude atmospheric conditions.

Радиационный фон на больших высотах

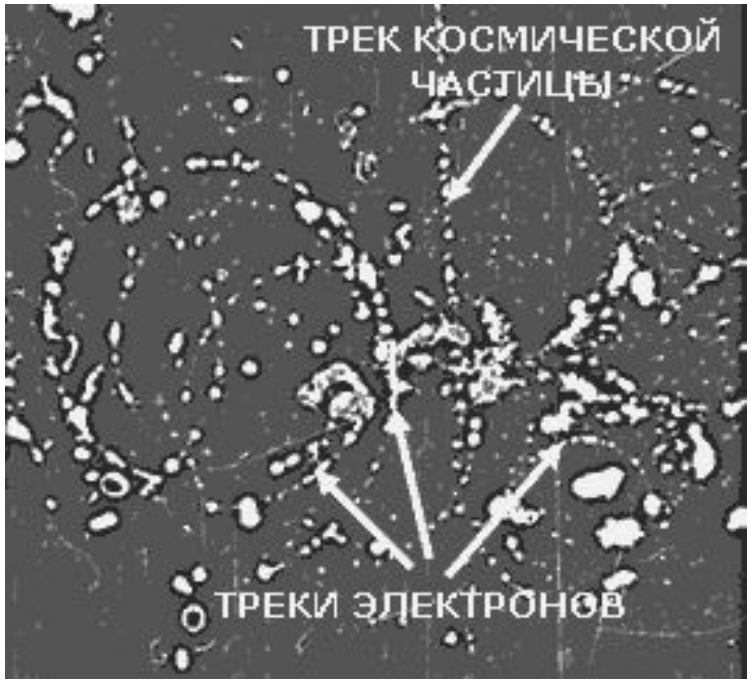


Открытие позитрона (К. Андерсон, 1932)

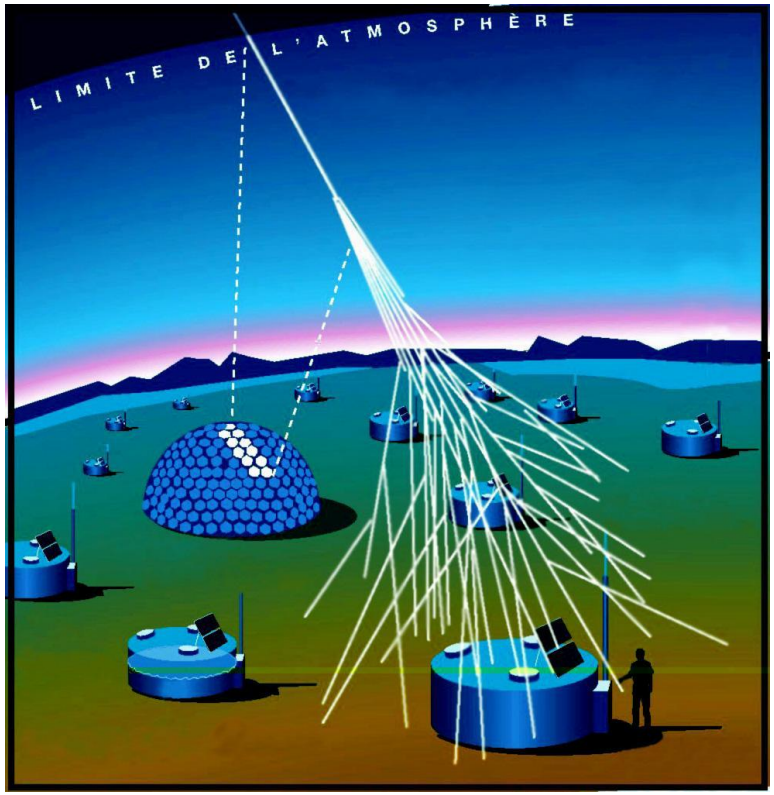


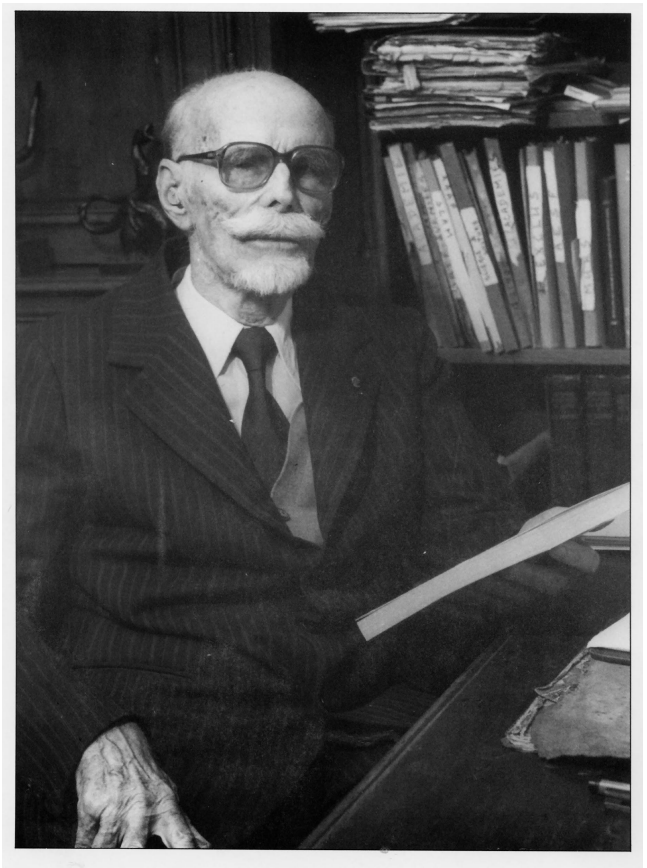
Нобелевская премия 1936 г.

Первое наблюдение следов космического излучения (Д.В.Скобельцын, 1936 г.)

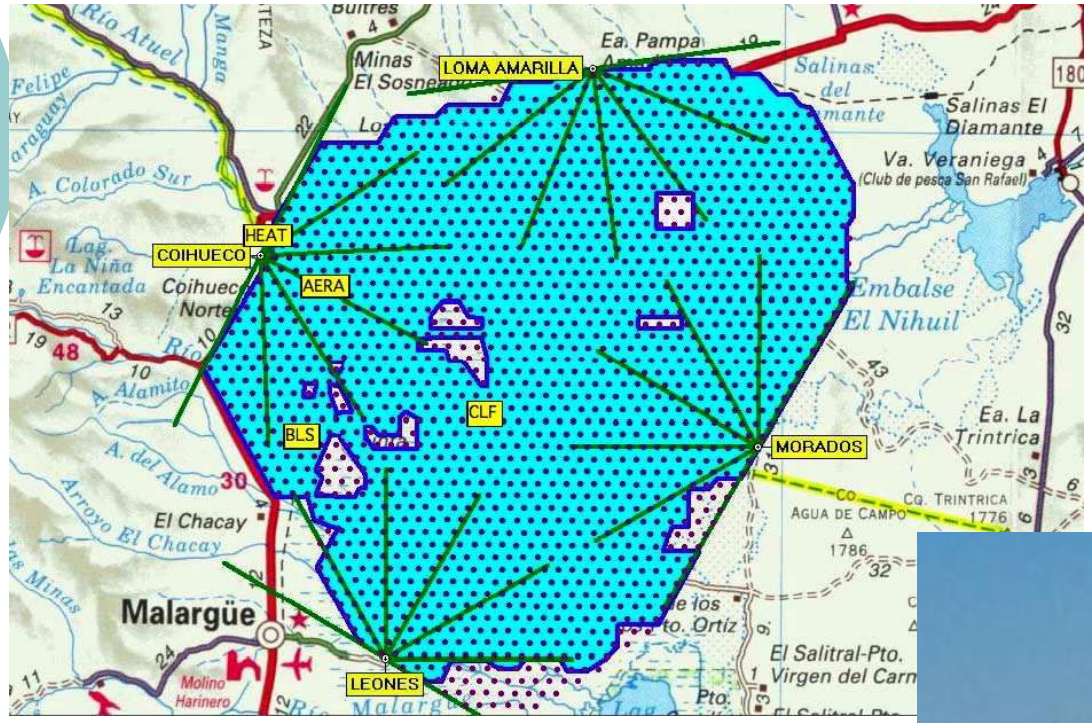


Описание широких атмосферных ливней (ШАЛ) (П.Оже, 1938 г.)





Pierre Auger Observatory

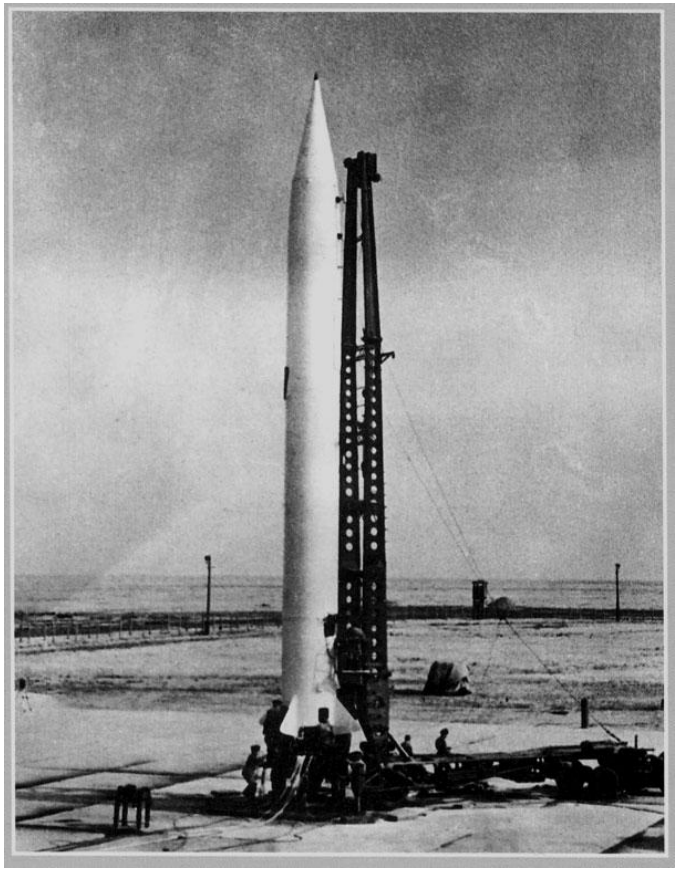


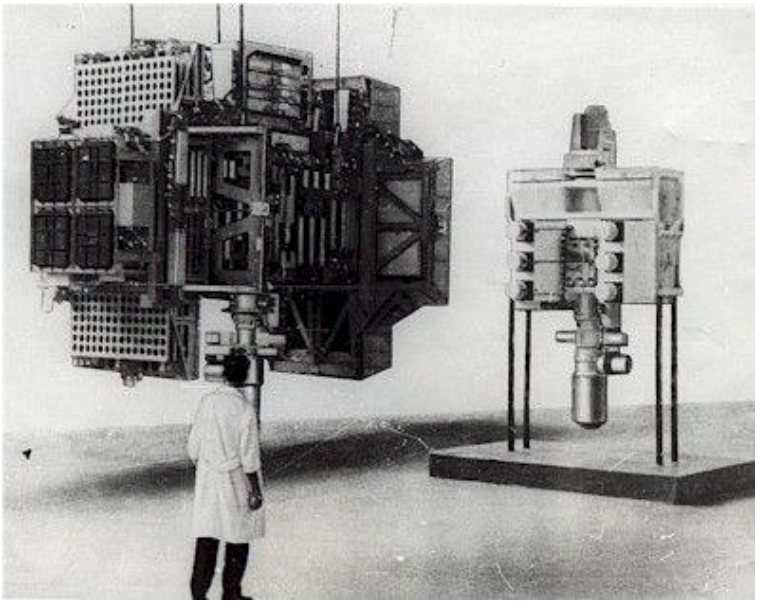
Эксперимент «Тунка»

Особенности изучения ШАЛ

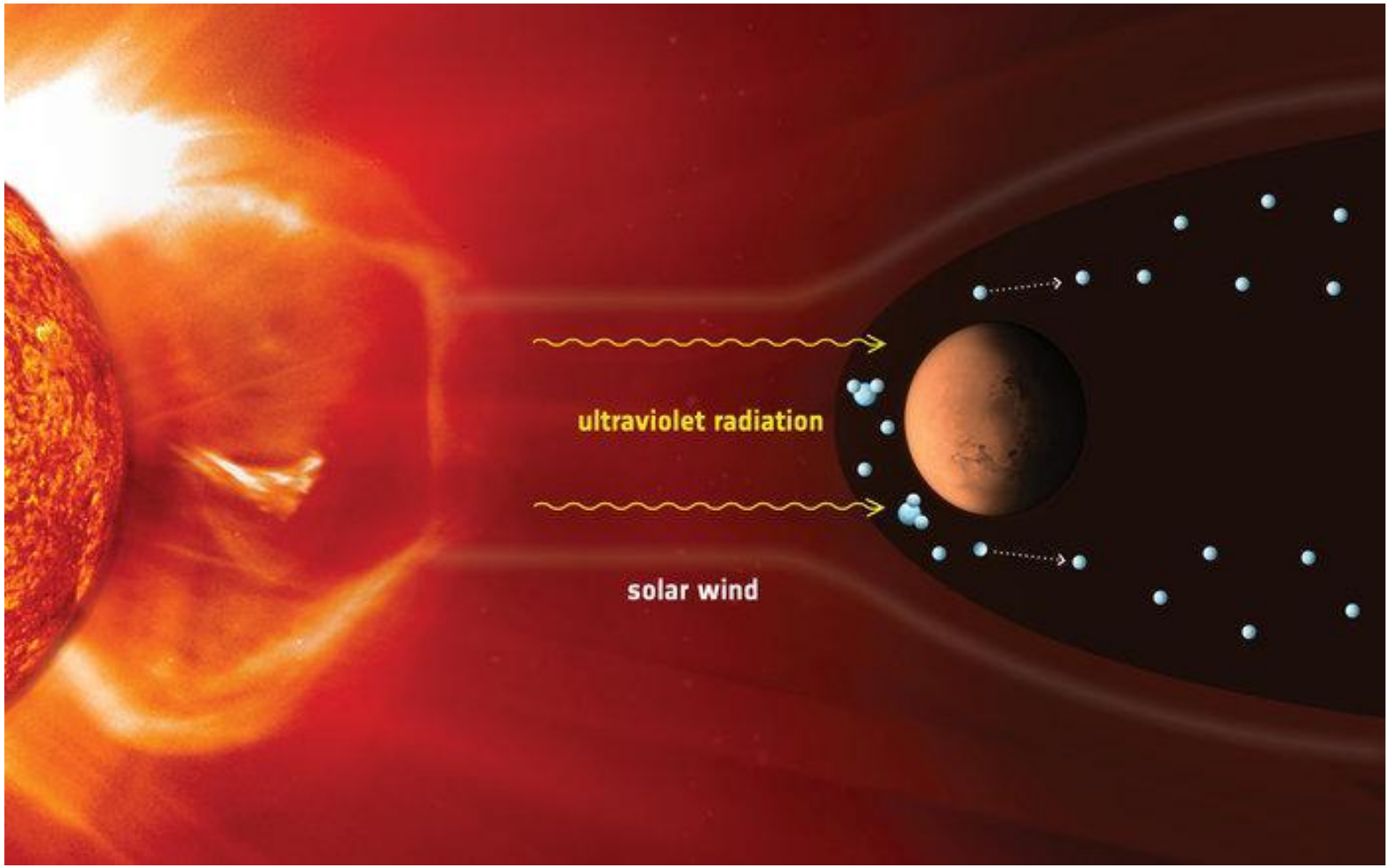
- Необходимы большие (по площади) массивы детекторов
- Метод эффективен для энергий свыше 100 ТэВ

Исследования космических лучей с помощью баллистических ракет

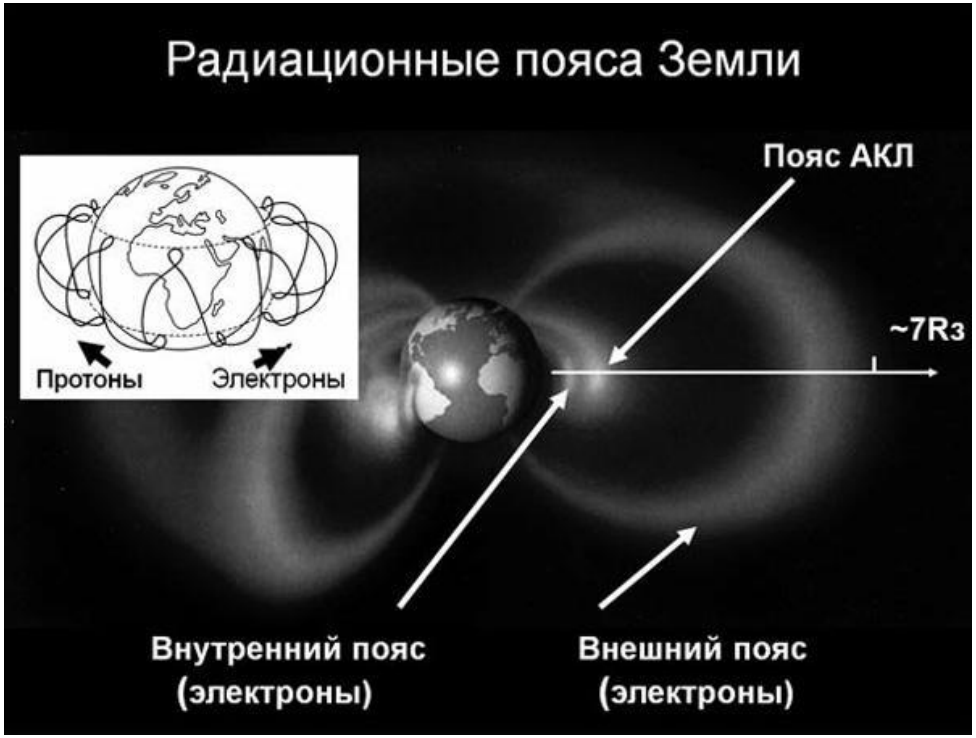


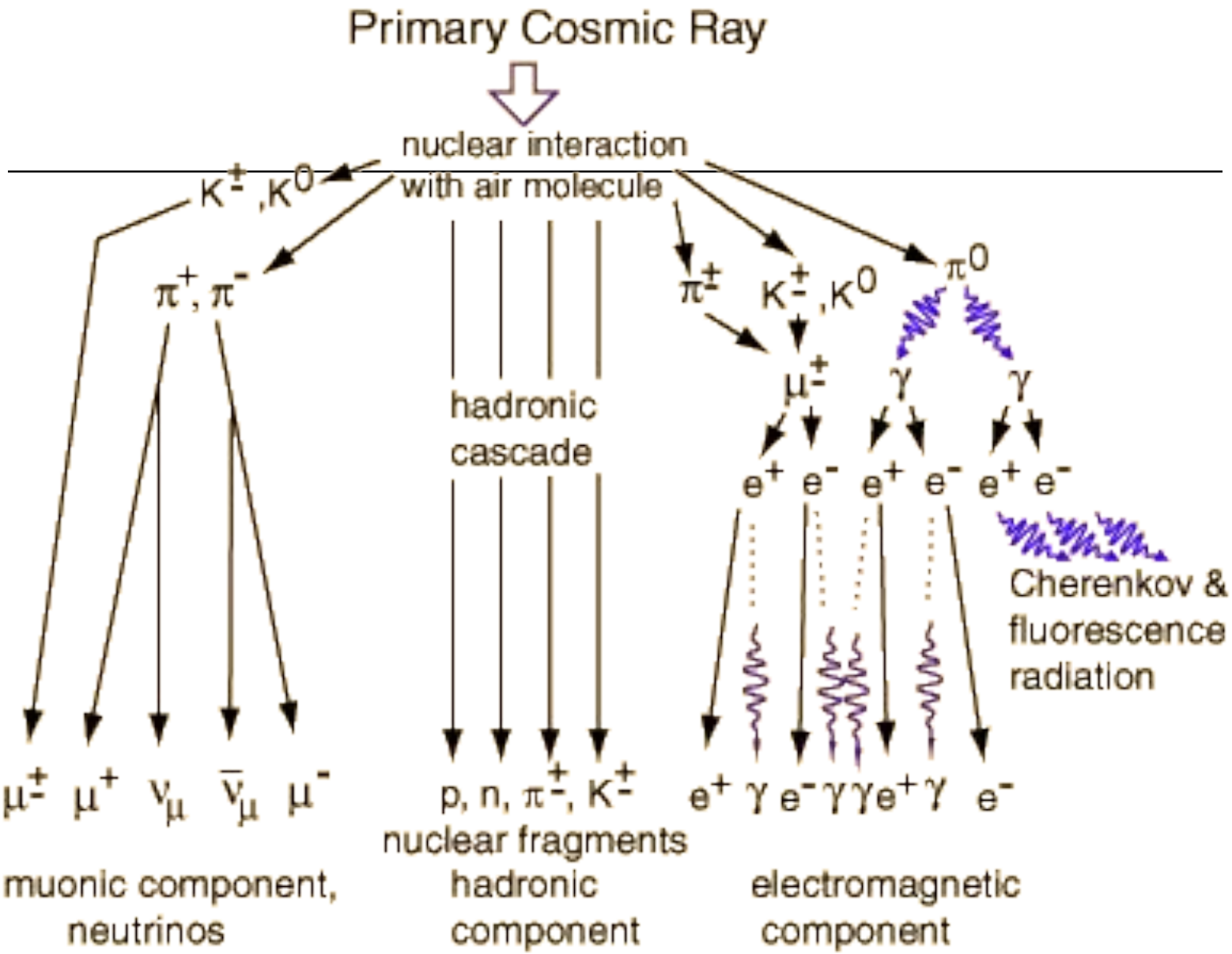


Радиационные пояса Земли (1958 г.)



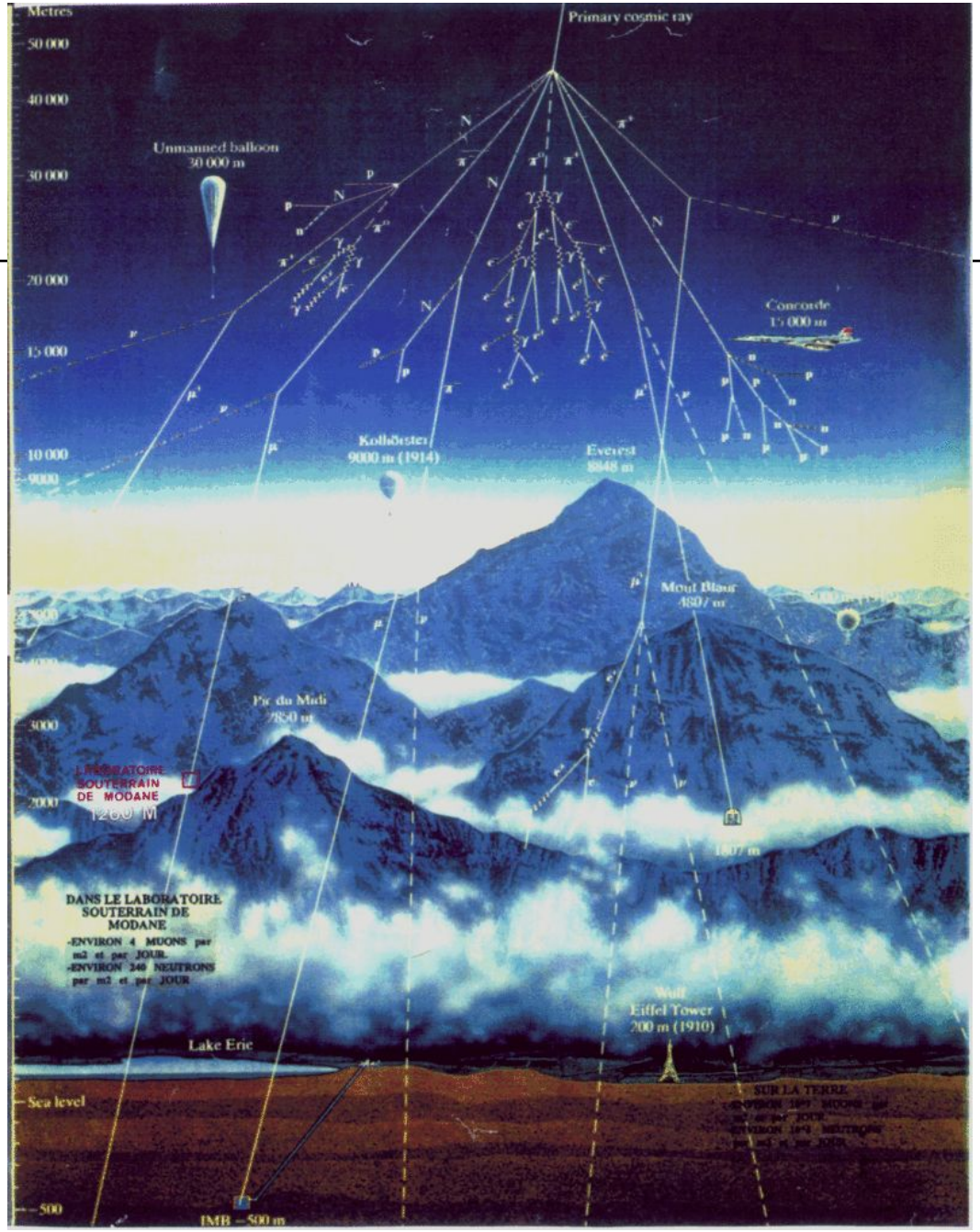
Вернов Сергей Николаевич




Primary Cosmic Ray
nuclear interaction
with air molecule
$K^{\pm}, K^0$
π^+, π^-
hadronic
cascade
$\pi^{\pm}$
$K^{\pm}, K^0$
π^0
$\mu^{\pm}$
γ
γ
e^+ e^- e^+ e^- e^+ e^-
Cherenkov &
fluorescence
radiation
$\mu^{\pm}$ μ^+ ν_μ $\bar{\nu}_\mu$ μ^-
p, n, $\pi^{\pm}$, $K^{\pm}$
e^+ γ e^- γ γ e^+ γ e^-
nuclear fragments
muonic component,
neutrinos
hadronic
component
electromagnetic
component

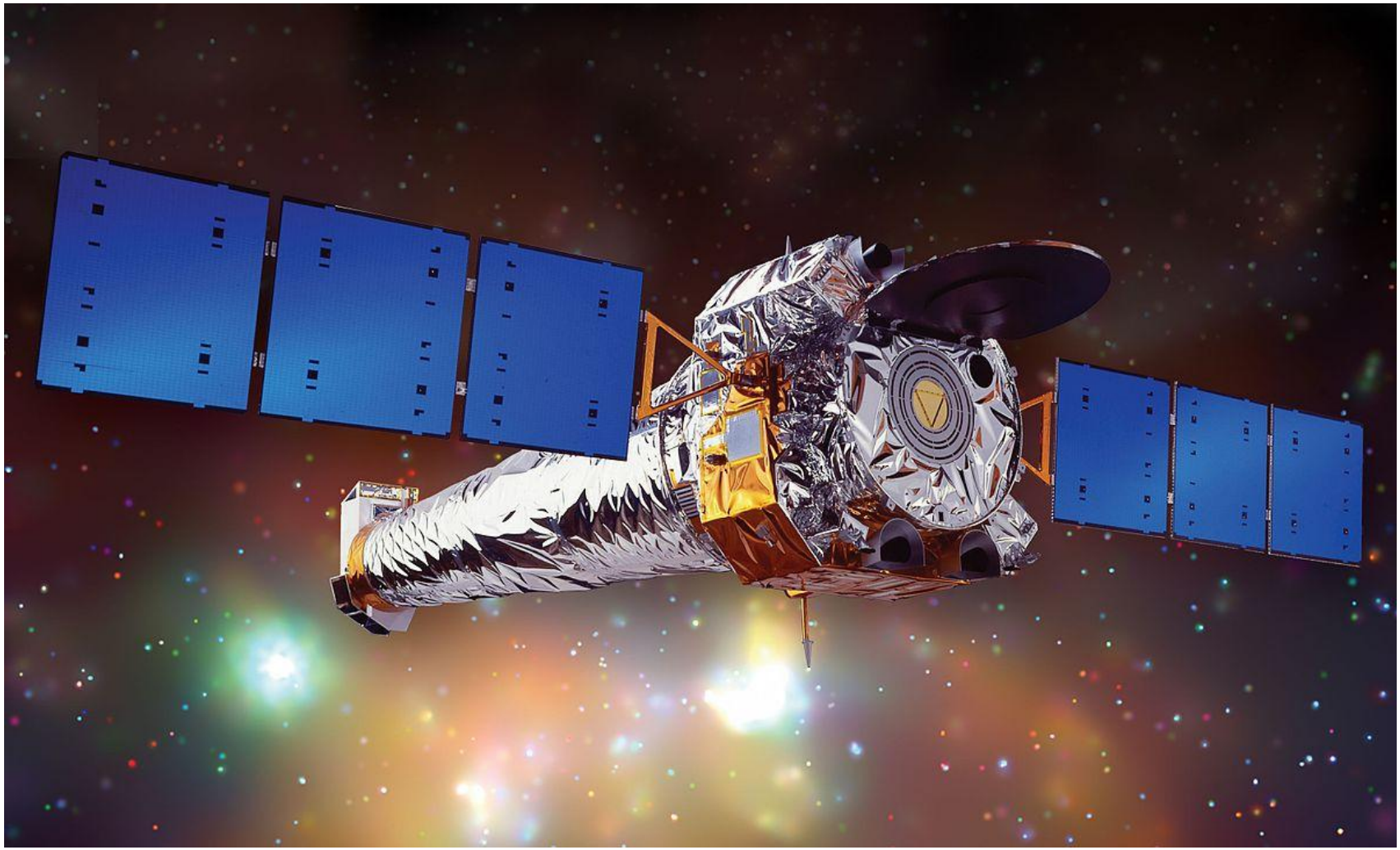
Состав первичного космического излучения

- Протоны сверхвысоких энергий (более 90%)
- Альфа-частицы (8-9%)
- Электроны (около 1%)
- Остальные частицы-менее 1%

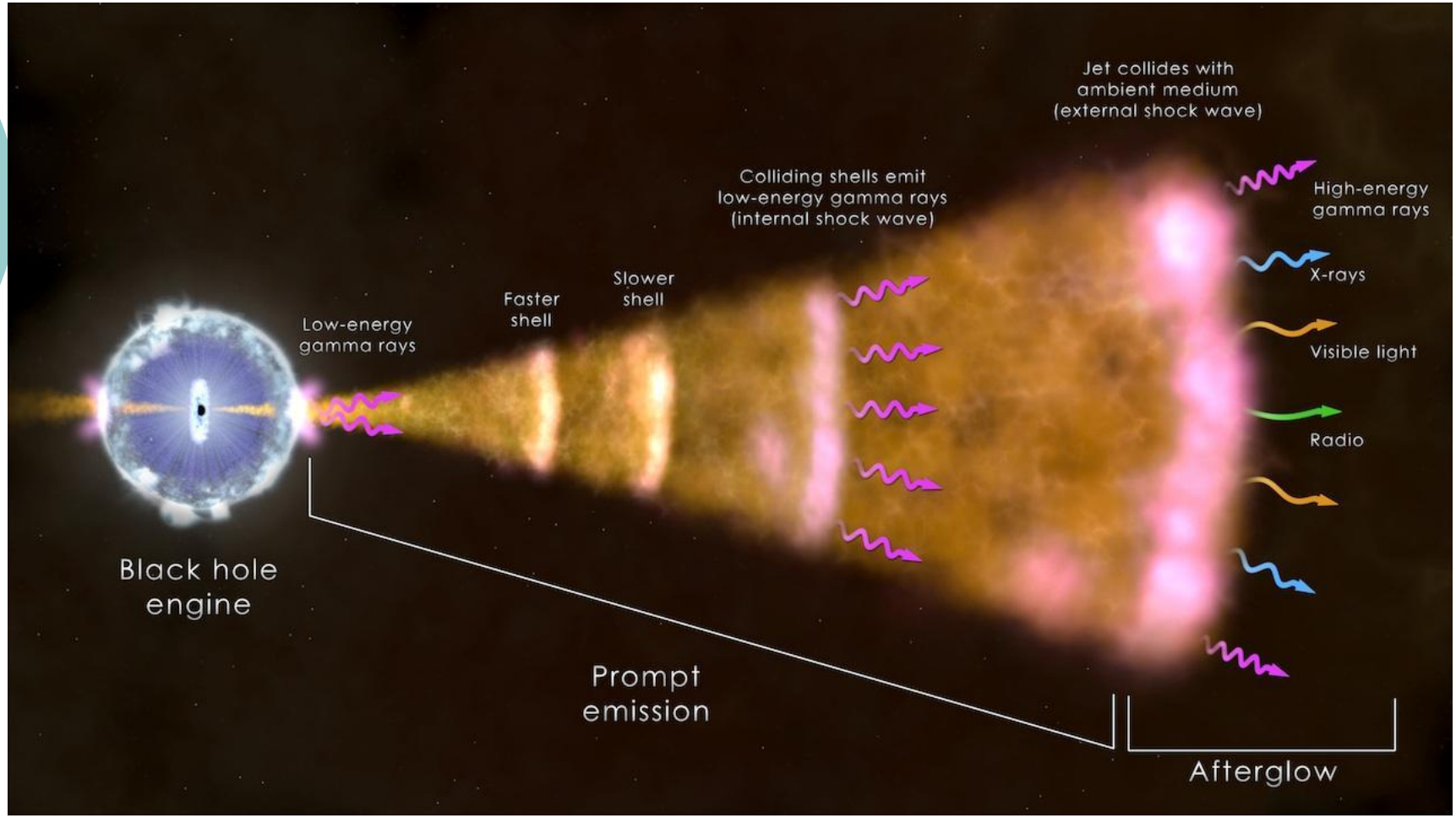

Metres
50 000
40 000
30 000
20 000
15 000
10 000
9000
3000
2000
Primary cosmic ray
Unmanned balloon
30 000 m
Concorde
15 000 m
Kolhörster
9000 m (1914)
Everest
8848 m
Mont Blanc
4807 m
Pic du Midi
2850 m
LABORATOIRE
SOUTERRAIN
DE MODANE
1260 M
1807 m
DANS LE LABORATOIRE
SOUTERRAIN DE
MODANE
-ENVIRON 4 MUONS par
m2 et par JOUR
-ENVIRON 240 NEUTRONS
par m2 et par JOUR
Lake Eric
Eiffel Tower
200 m (1910)
Sea level
500
IMB – 500 m
SUR LA TERRE

Подземные детекторы космического излучения (Баксанская Нейтринная Обсерватория)

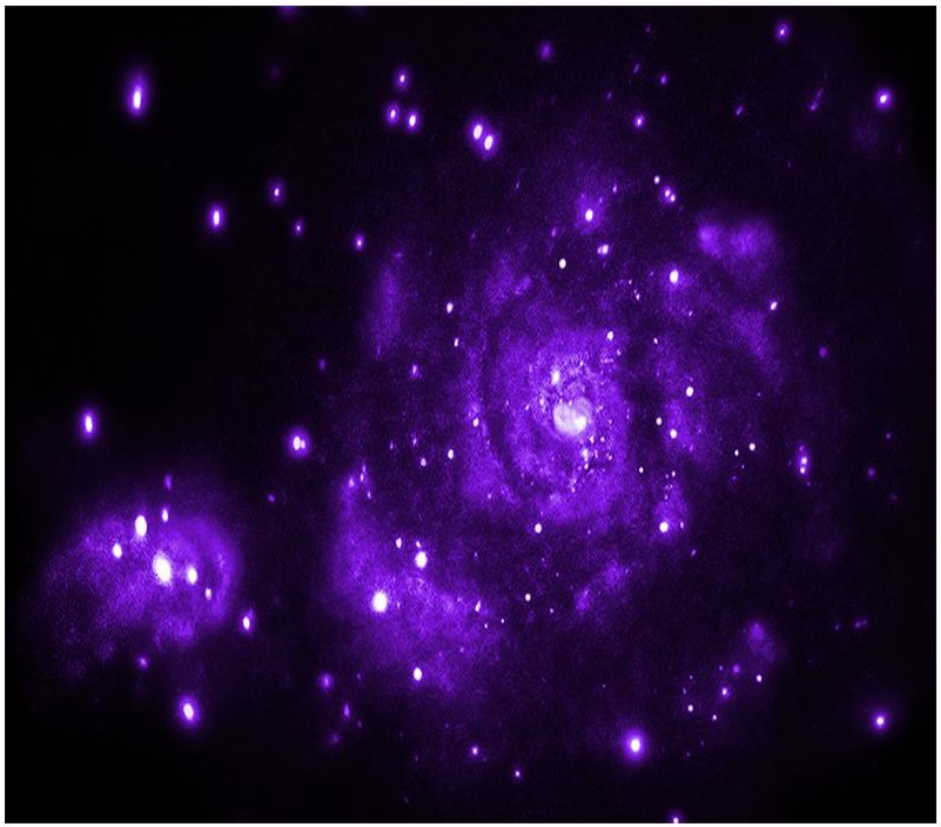
Орбитальные телескопы



Цветной космос?

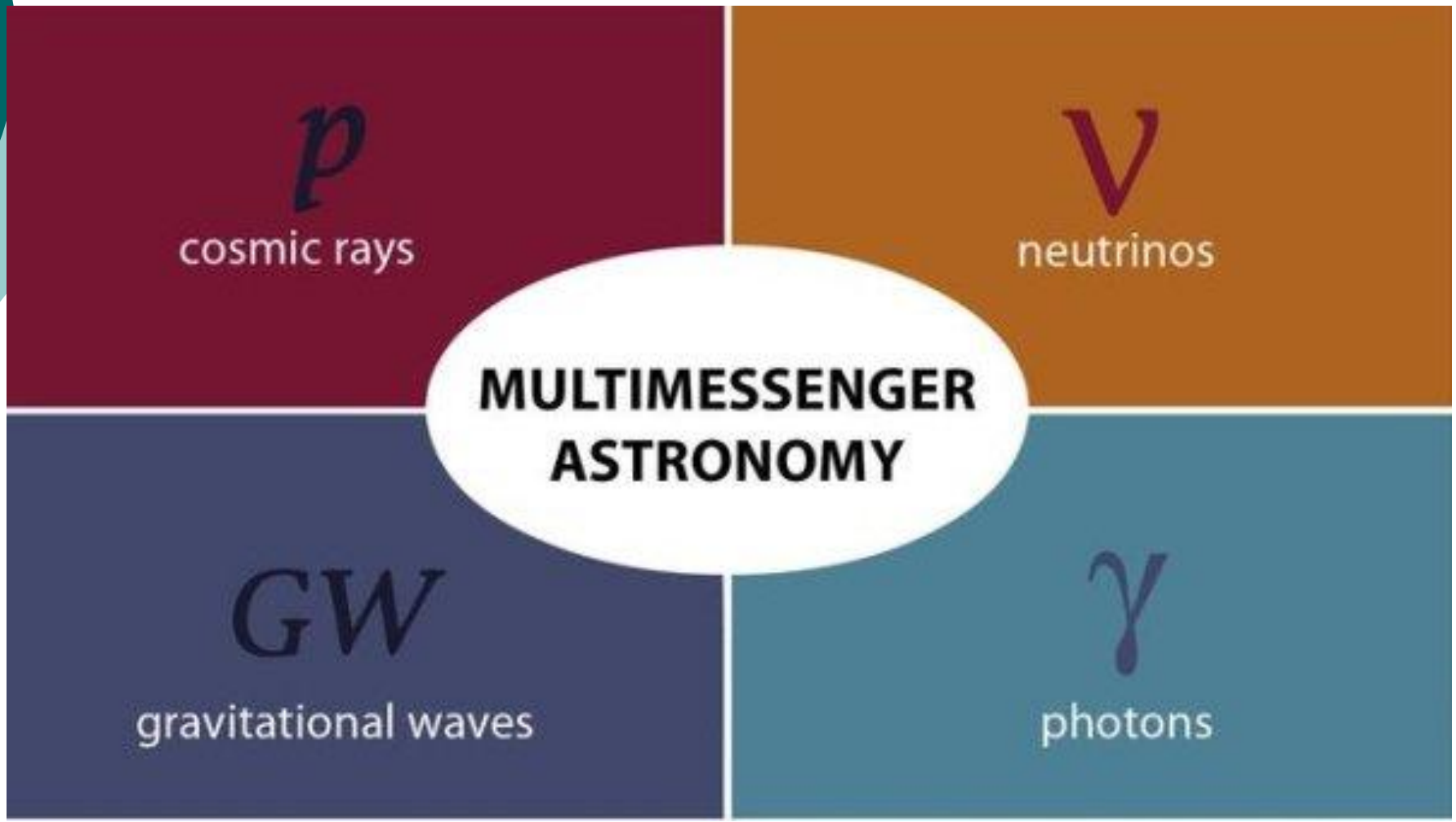

Jet collides with
ambient medium
(external shock wave)
Colliding shells emit
low-energy gamma rays
(internal shock wave)
High-energy
gamma rays
X-rays
Visible light
Radio
Slower
shell
Faster
shell
Low-energy
gamma rays
Black hole
engine
Prompt
emission
Afterglow

Источники рентгеновского излучения.

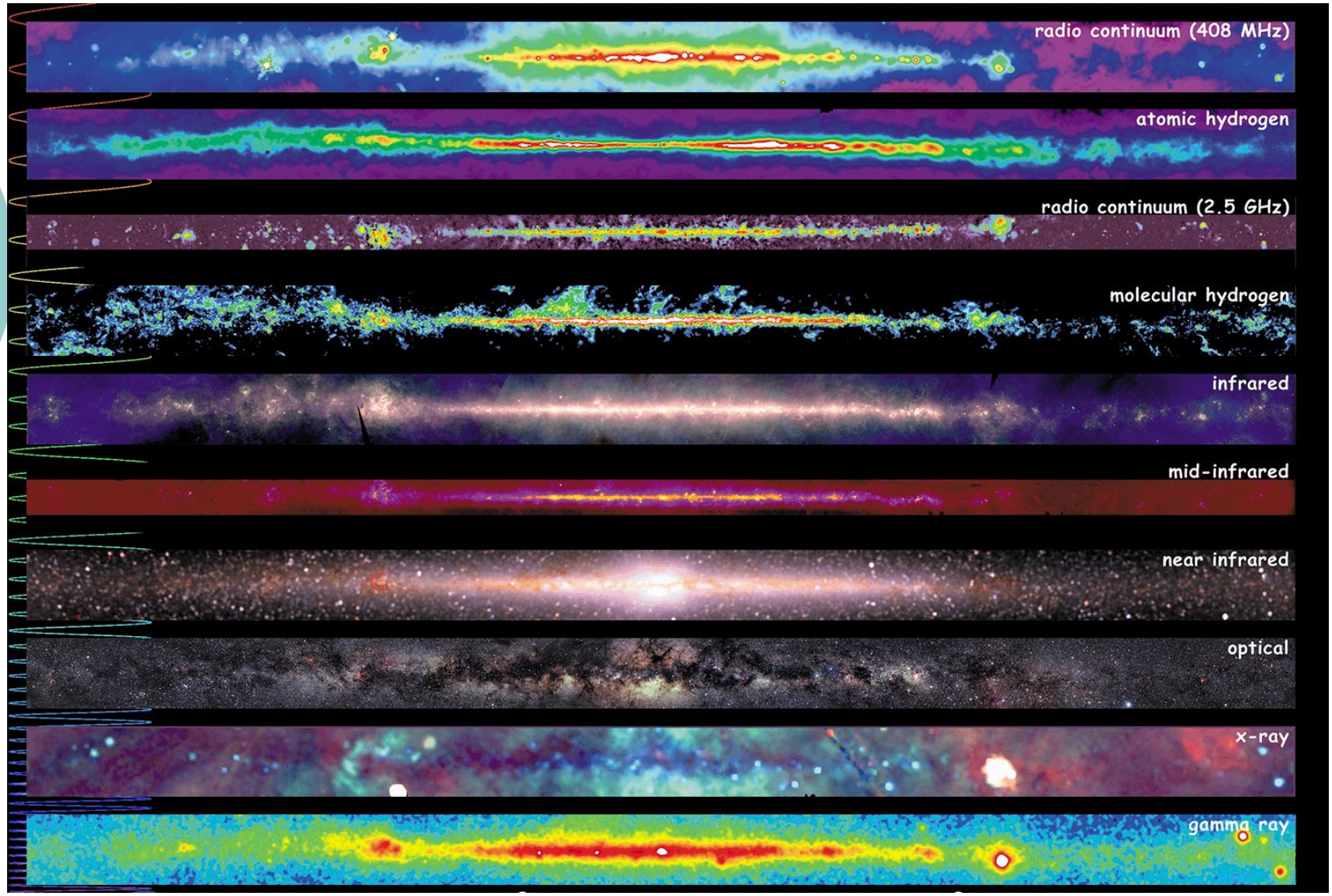


Слева - избражение в рентгене по данным CHANDRA, справа - оптика по данным Hubble.

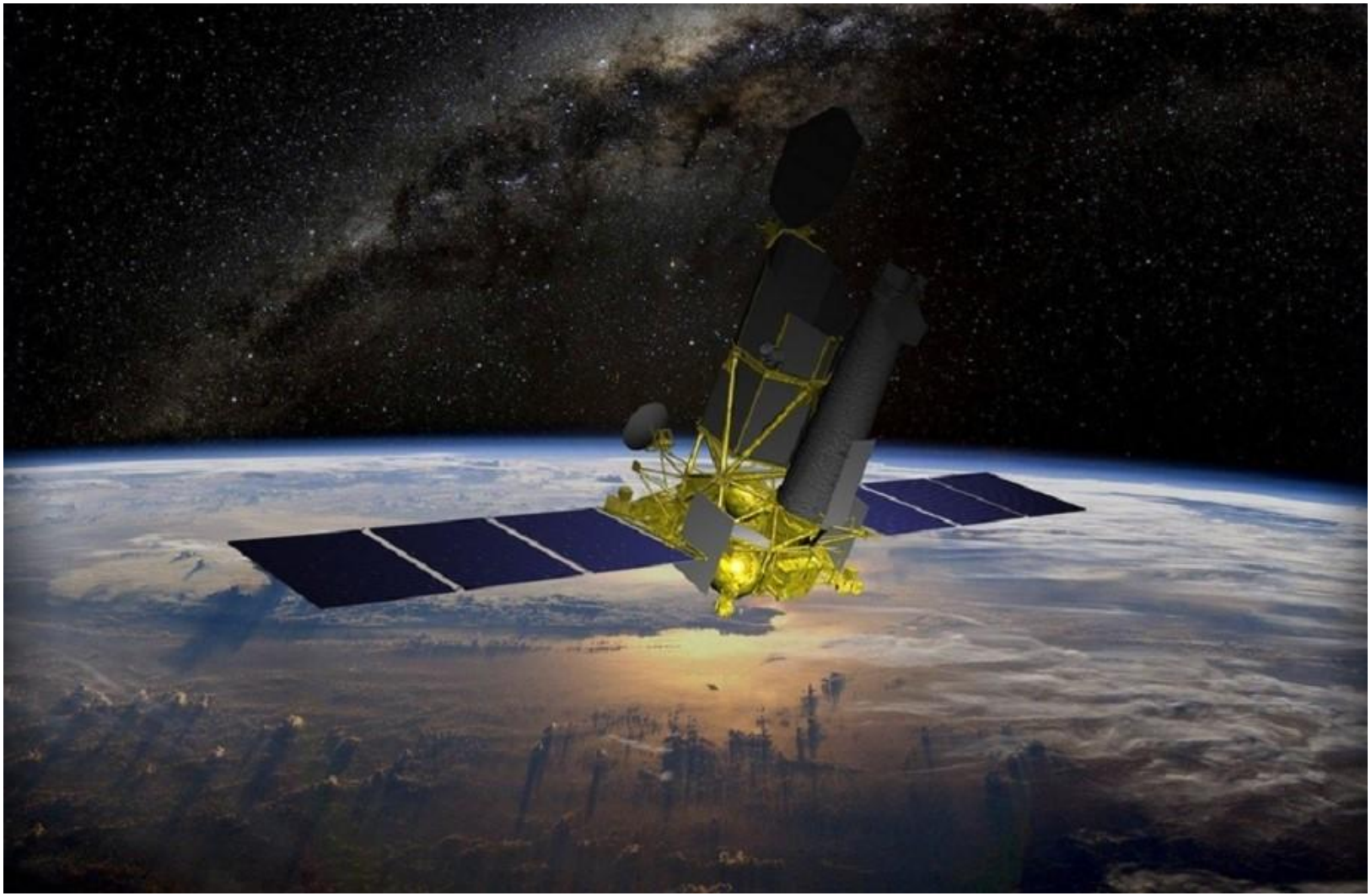
Мультимессенджер



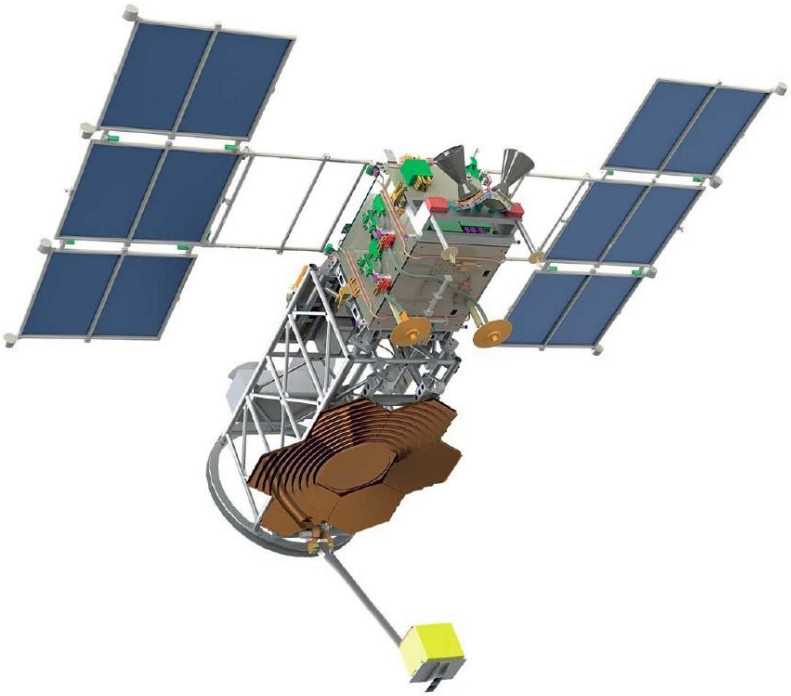
«Мультимессенджер» на примере события 17 августа 2017 г.


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray

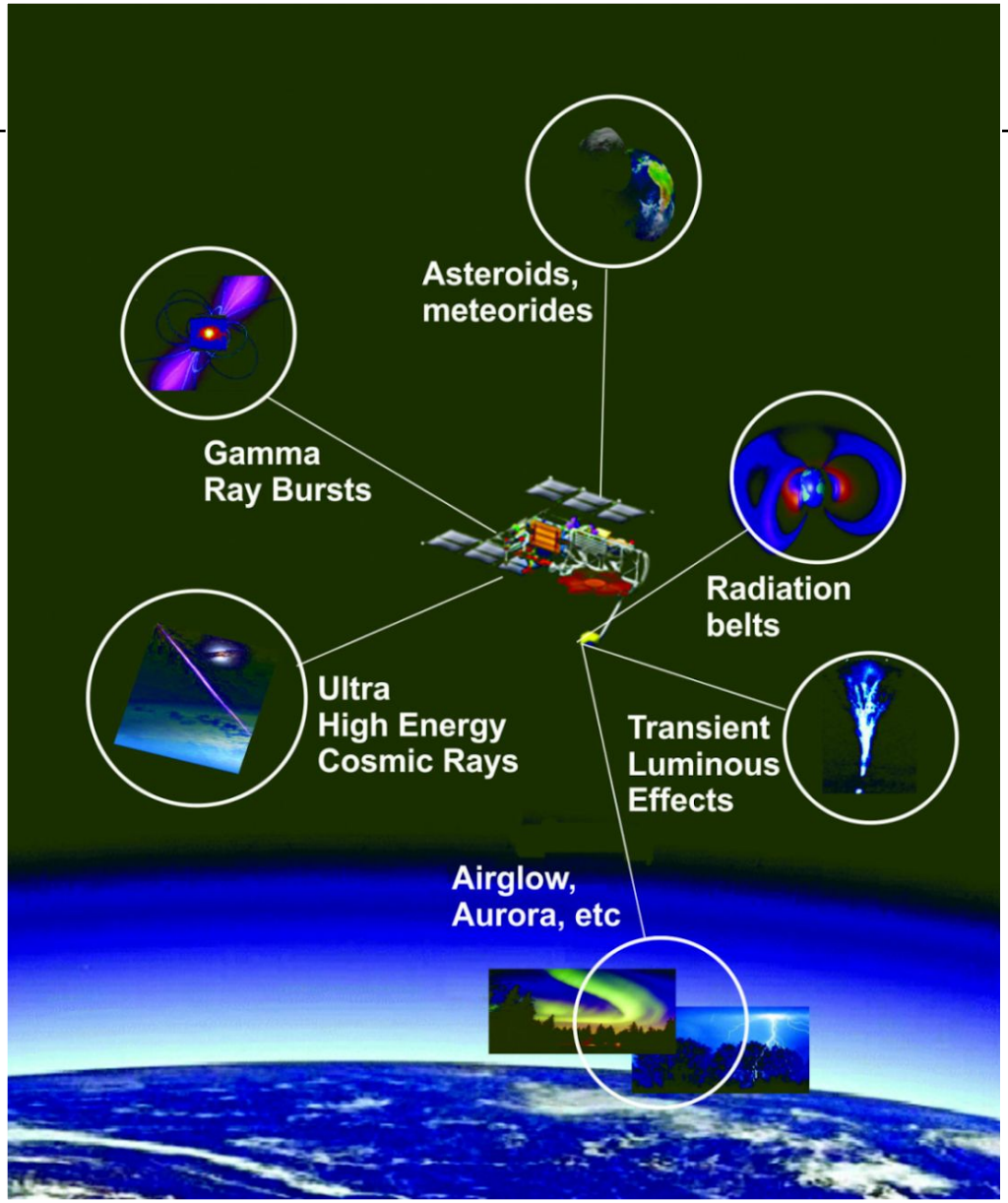
Рентгеновский телескоп «Спектр-РГ»



Университетский спутник «Ломоносов»



SCIENCE ON BOARD: EXTREME EVENTS IN SPACE

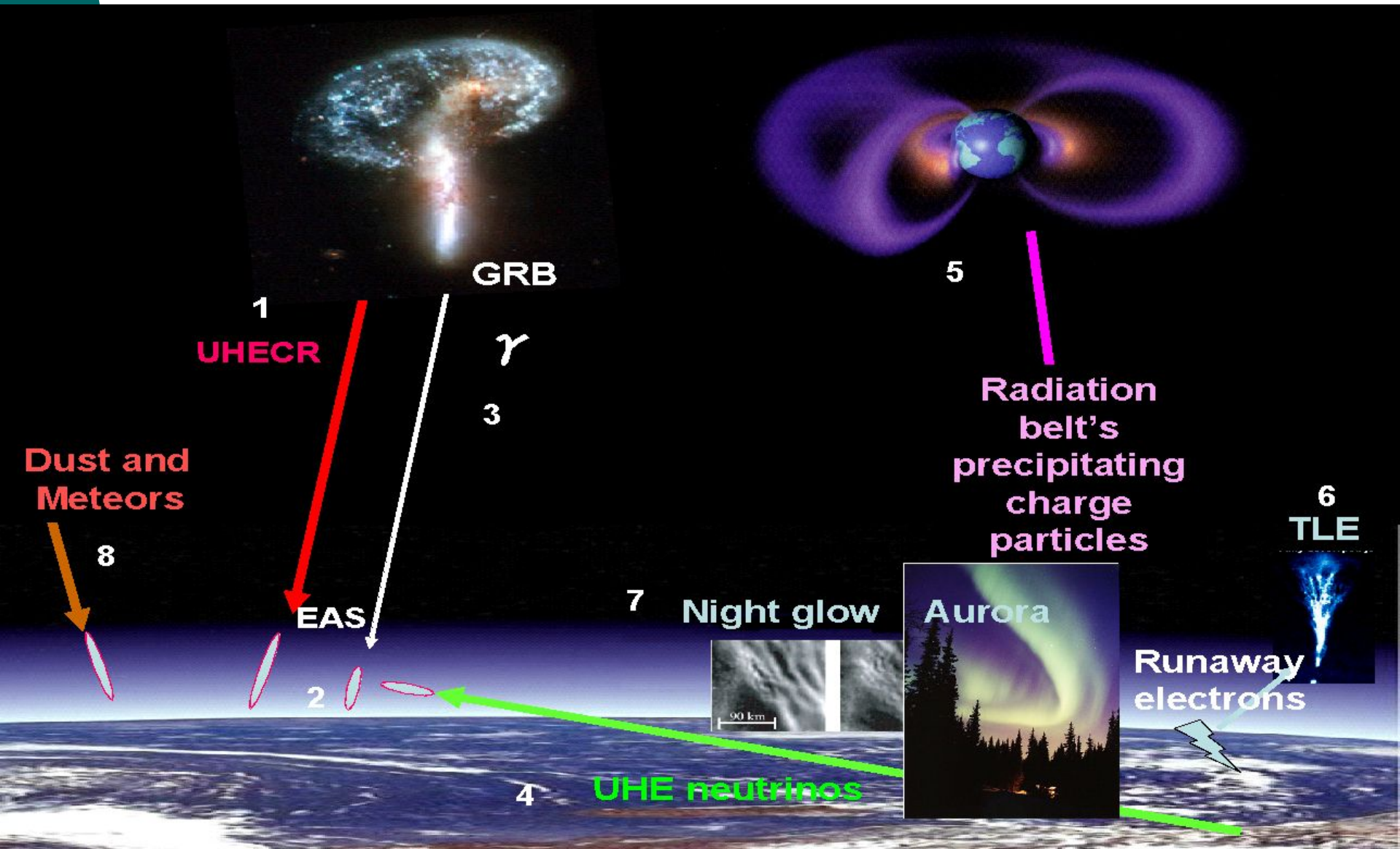


TUS parameters

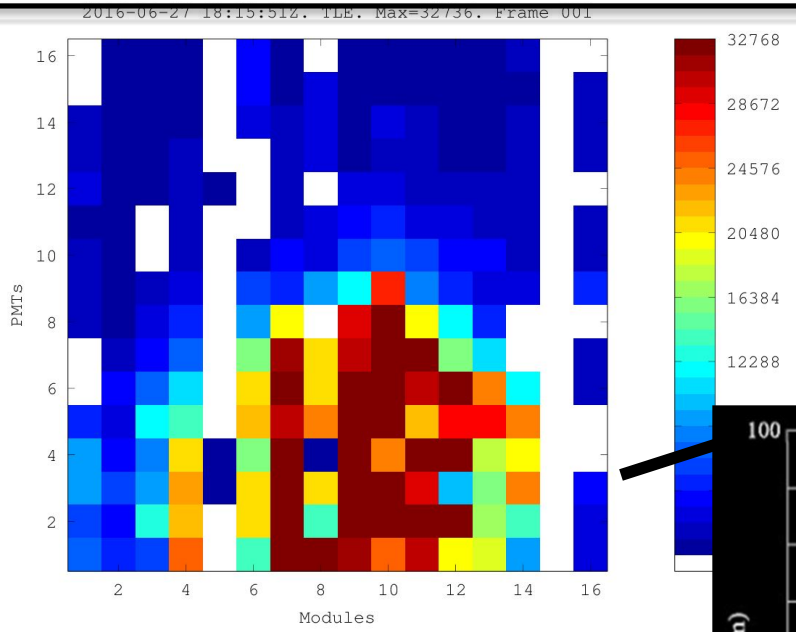
MASS	< 60 kg
POWER	65 W
DATA TEANSMISSION	200 MB /day
FOV	±4,5 degree
## PIXELS	256
FOV of pixels	10 mrad (5×5 km)
MIRROW	~2 m^2
FOCUS LENTH	1,5 m

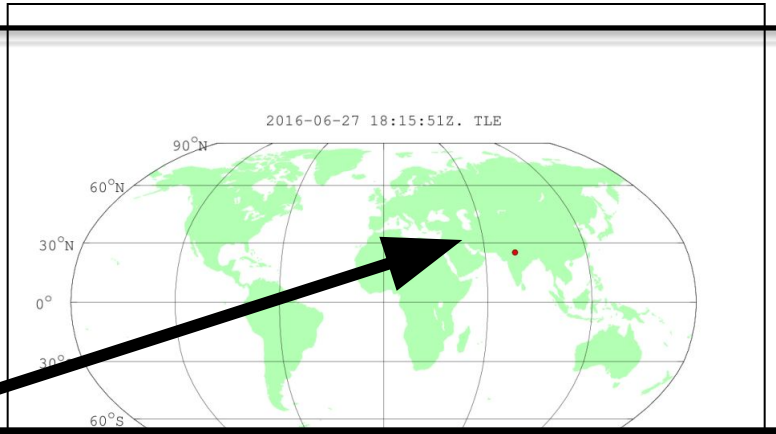
E –threshold > $5*10^{19}$eV

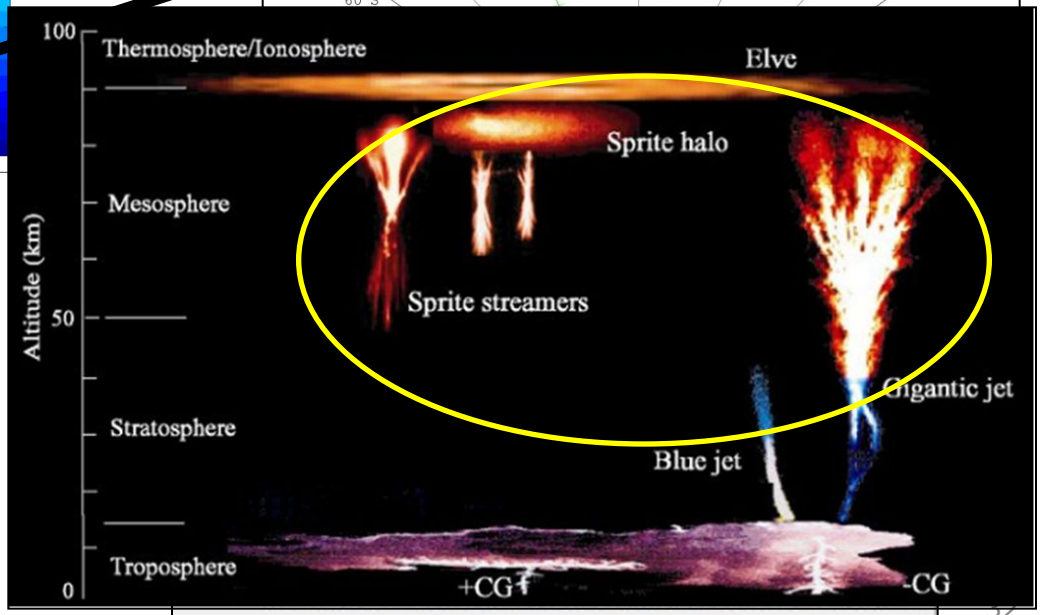
Earth's atmosphere as a target for the space emissions



Powerful TLE (0,4 msec – TLE regime)





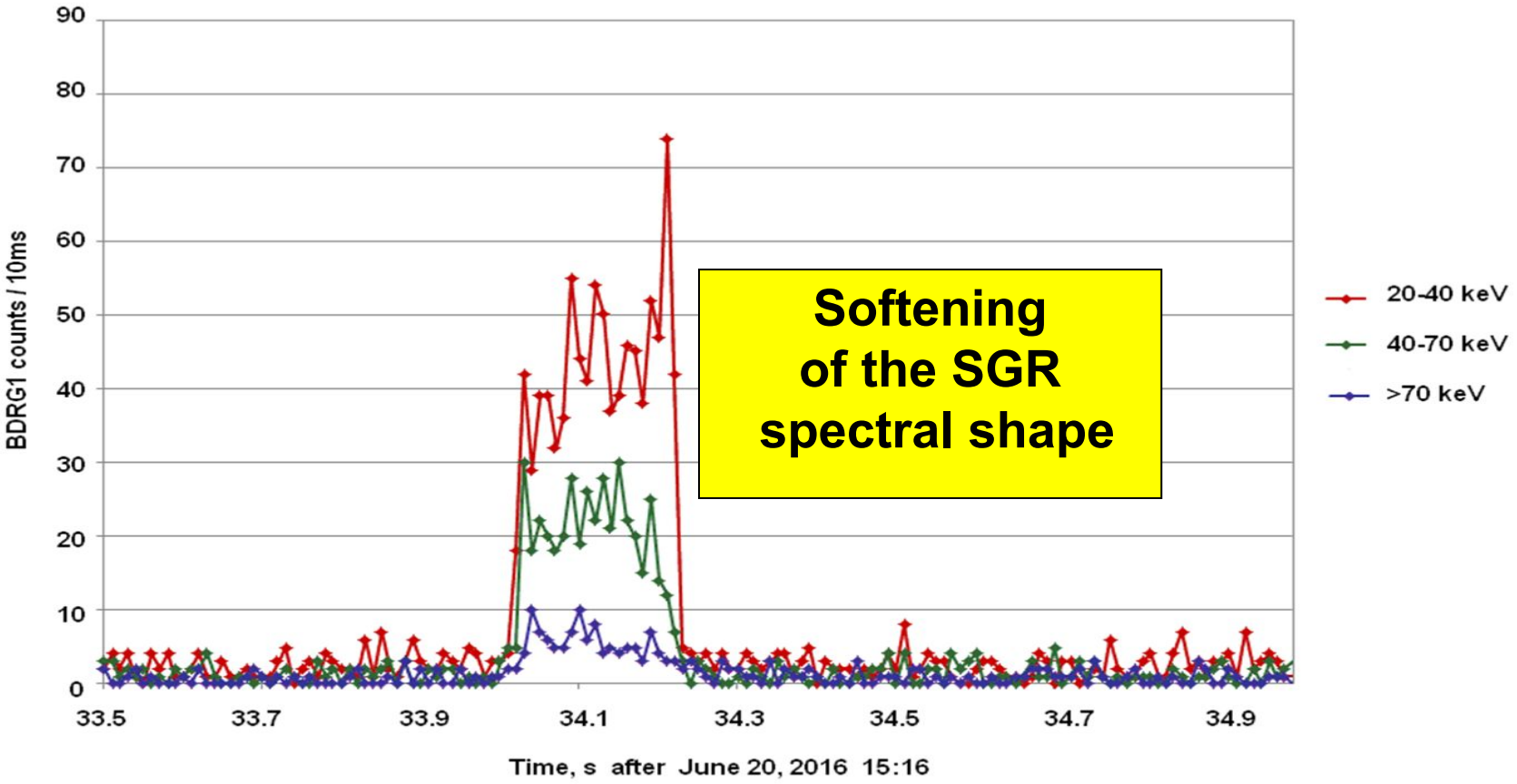


Spatial – temporal dynamics of TLE

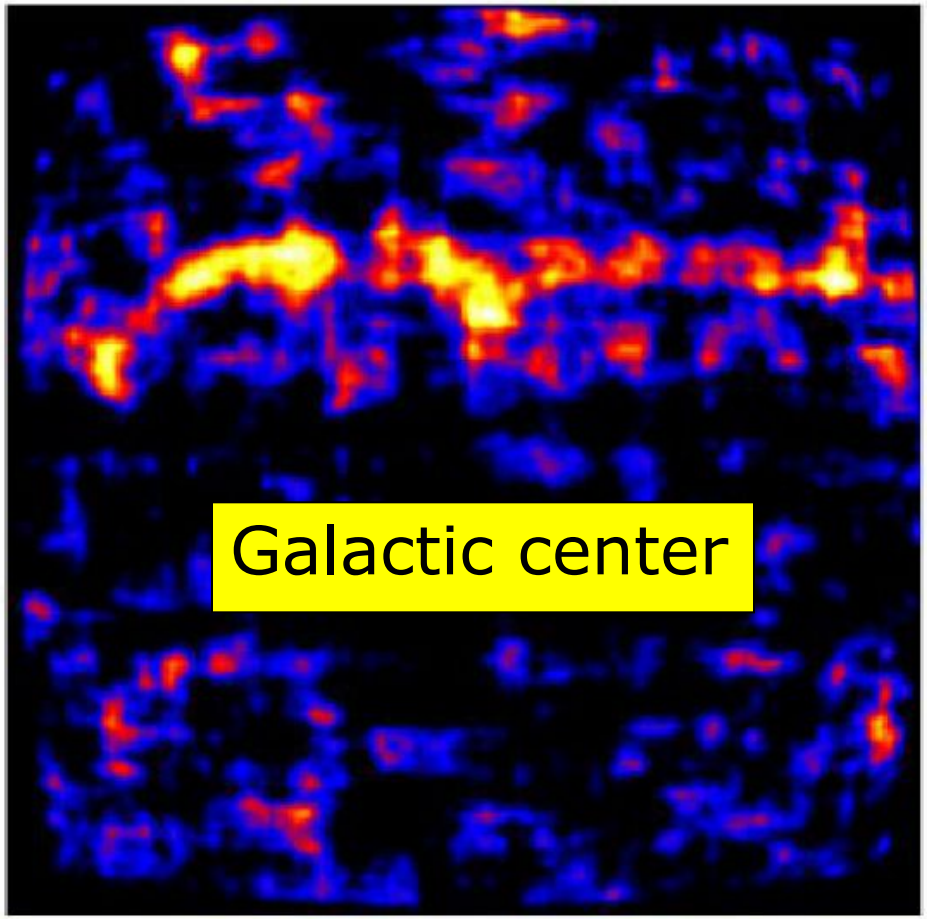
Dynamical recording

SGR JUNE 20, 2016 LIGHTCURVE THIN STRUCTURE

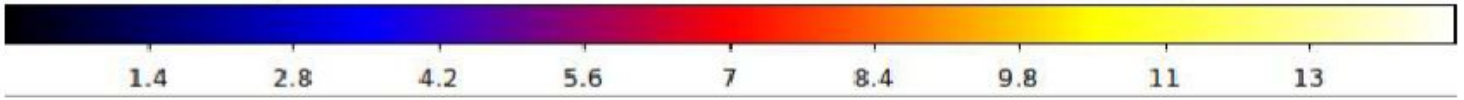
(Time resolution 0.001s)



3. UFFO UBAT data: Correlation map from offline analysis



Color indicates SNR

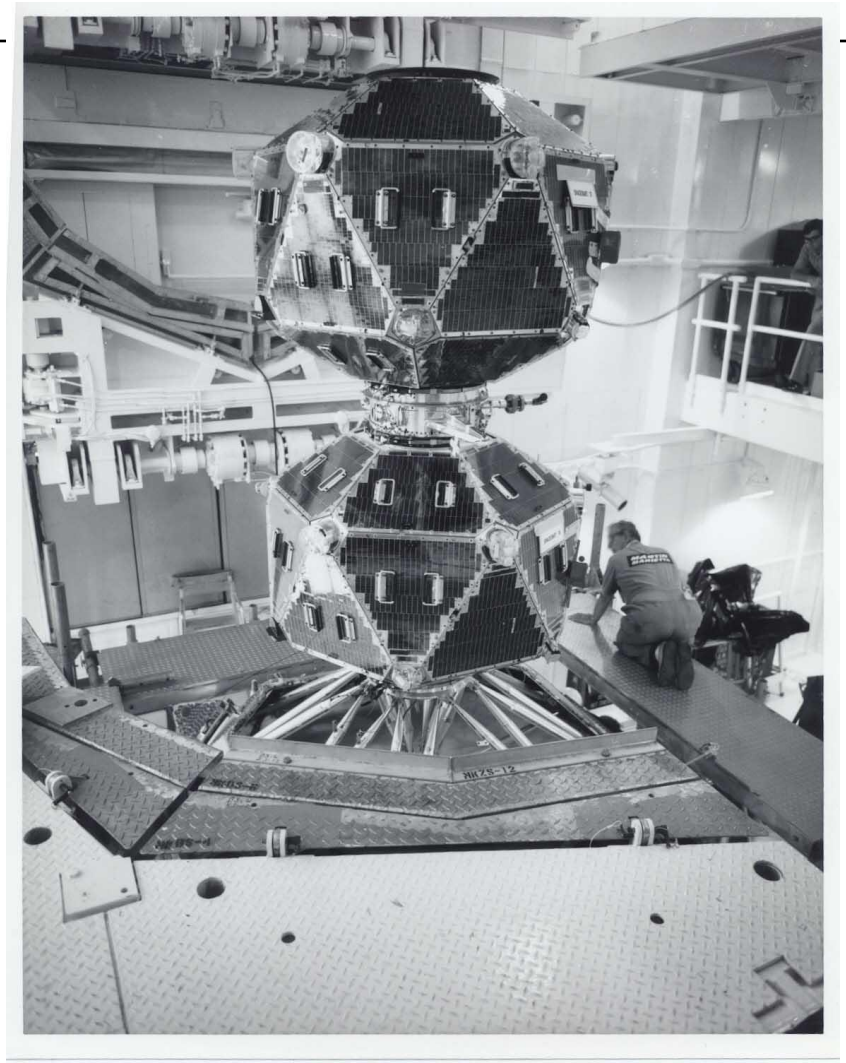


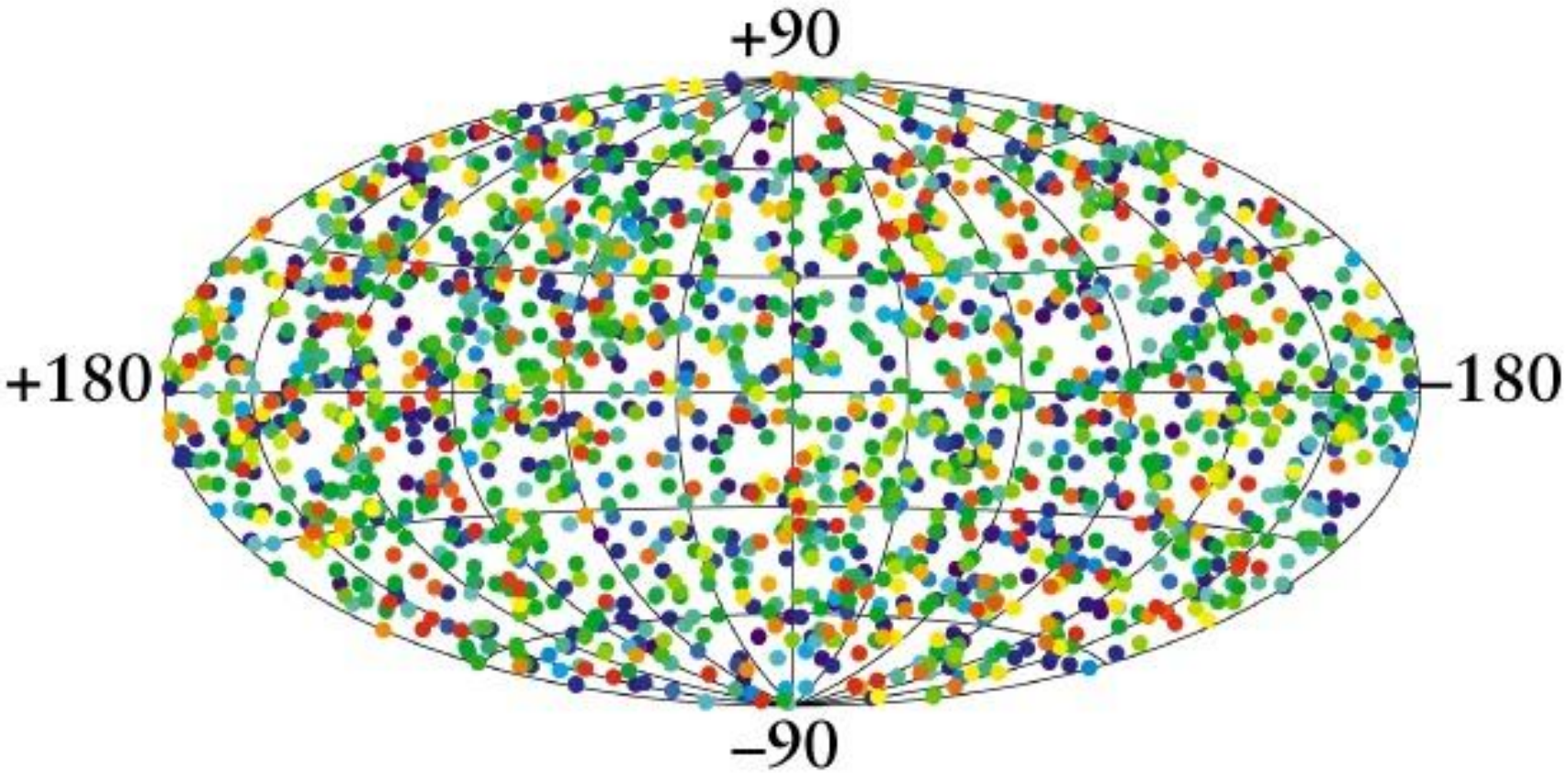
1. Image trigger threshold was set to be 14.
2. Triggered point has no meaning because no drift correction was made for this run. However it can be done in offline with the input of satellite movement, for example given by BI or extracted from SMT data.
3. Data taken for 150 seconds corresponding to the movement of ~7 degrees. This map has 70 x 70 deg FOV.
4. Total counts are 6.293 cnts/sec/cm2 (Background 5.9, Source 0.393), which looks three times larger than expected. Need to be studied; instrument problem, too many cosmic rays hits, or seeing a part of galactic

Источники первичного космического излучения

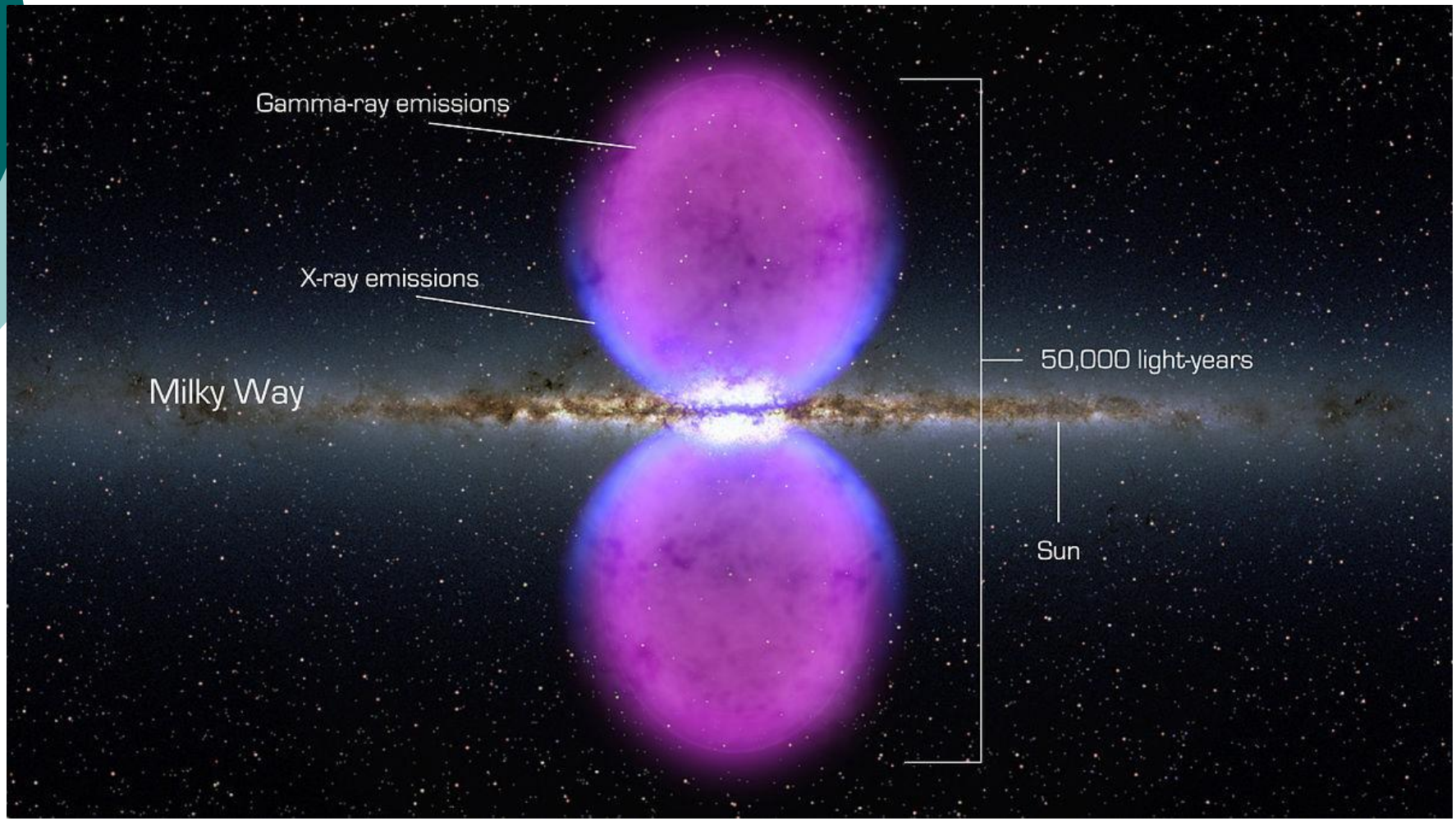
- Сверхновые
- Активные ядра галактик
- Гамма-всплески
- Квазары
- Чёрные дыры
- Магнетары
- и др…

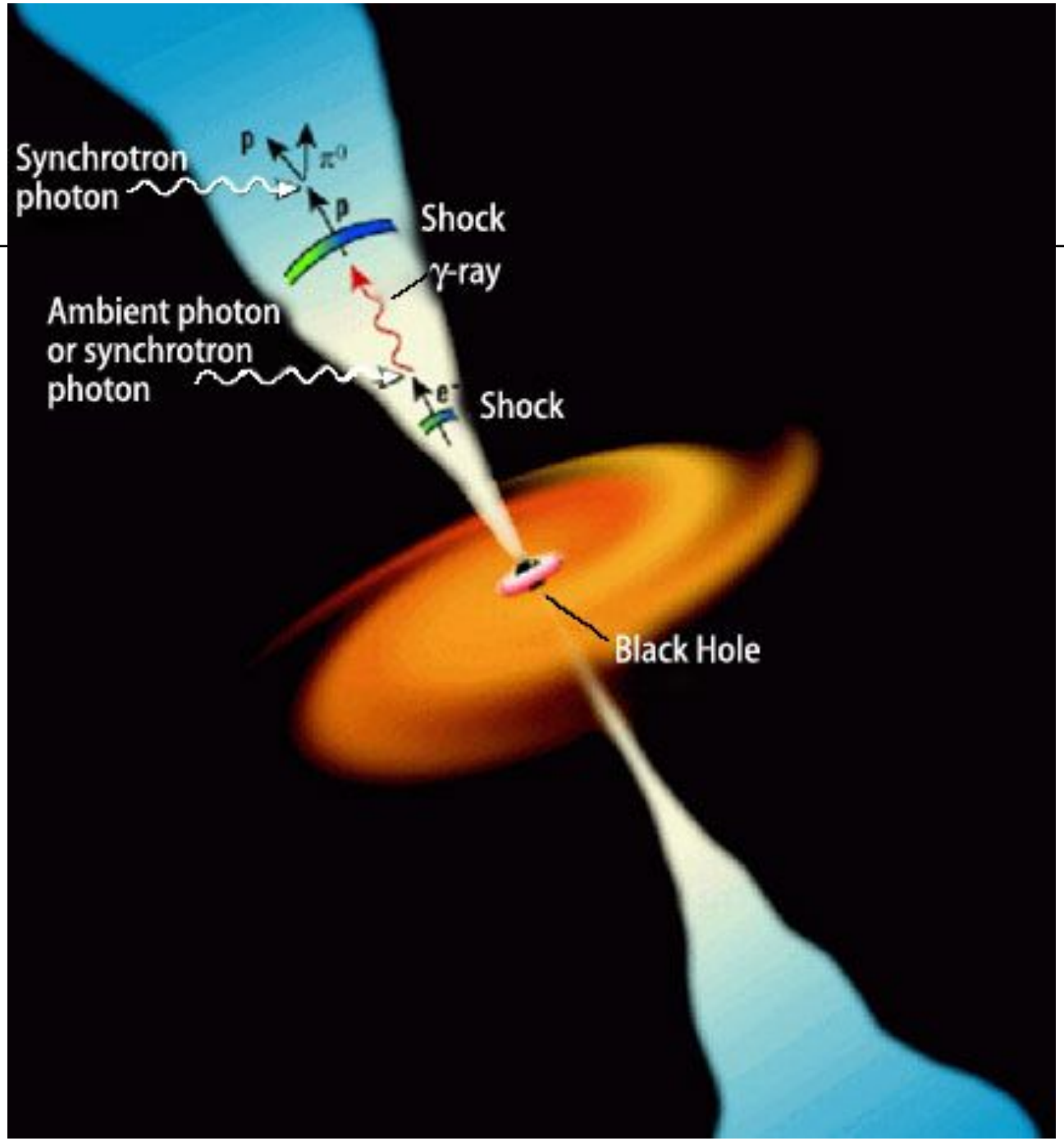
Гамма-всплески (1967 г.)



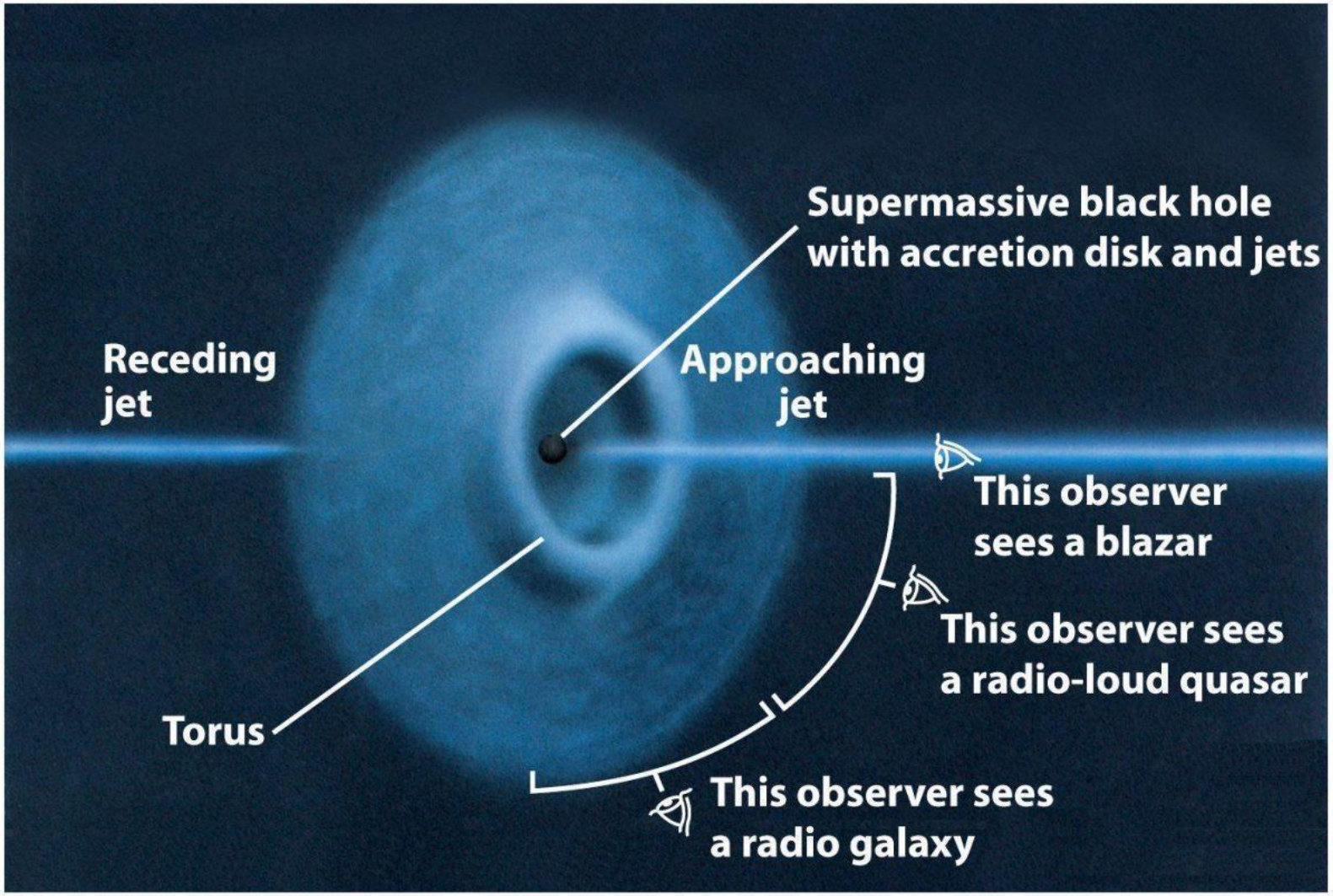

+90
+180
–180
–90

Пузыри Ферми (2009 г.)

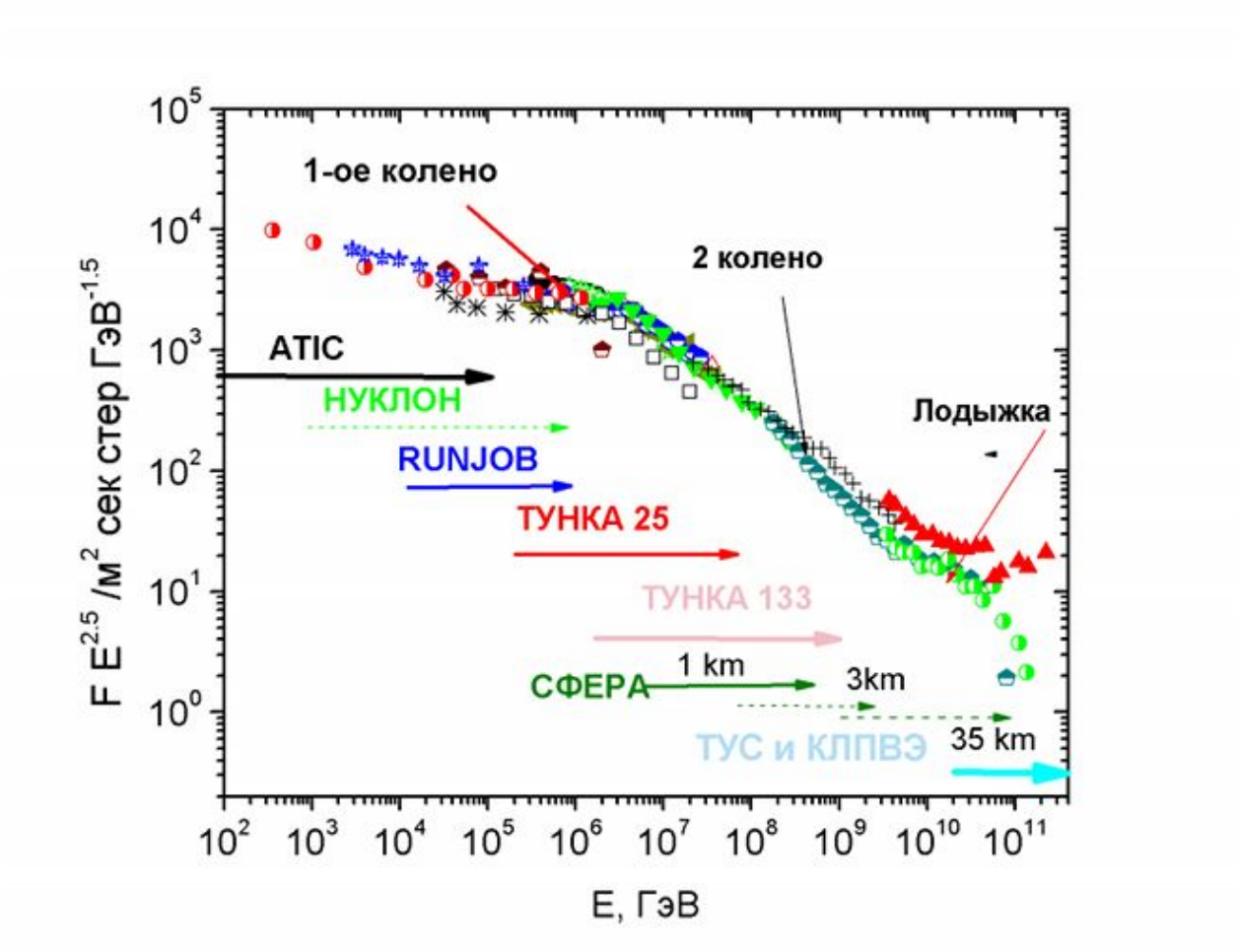



Synchrotron photon
p
π^0
p
Shock
γ-ray
Ambient photon or synchrotron photon
e^-
Shock
Black Hole

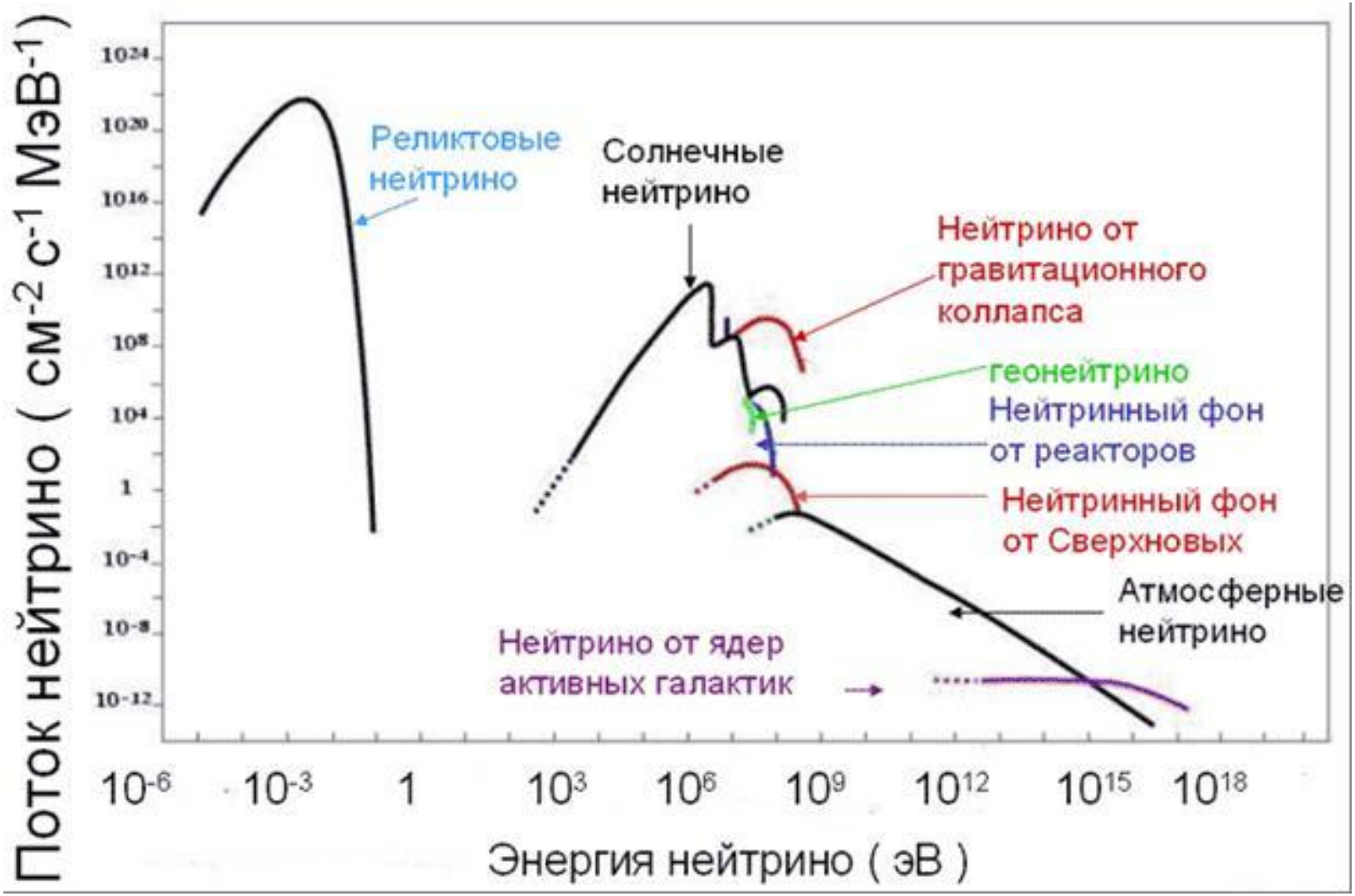
Унифицированная модель



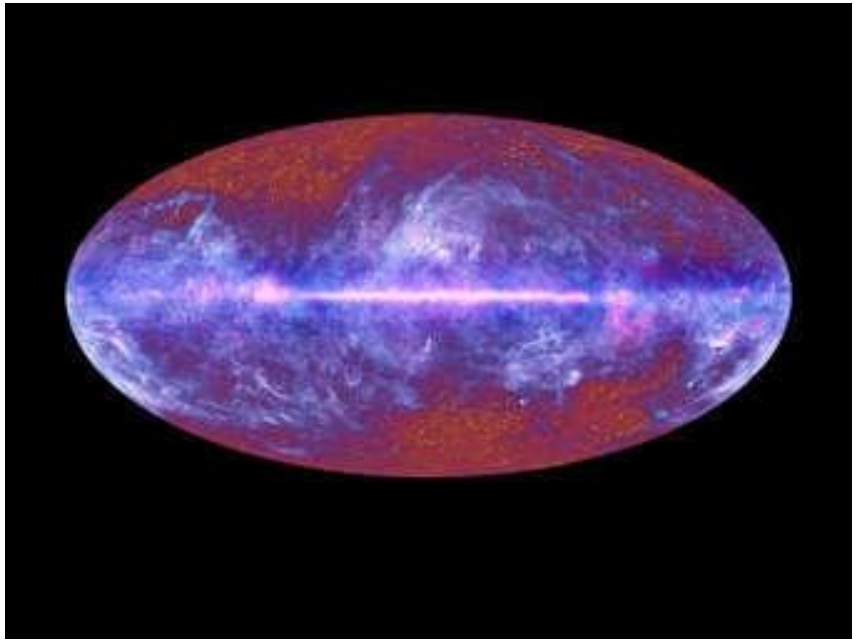
Спектр первичного космического излучения



Спектр нейтрино

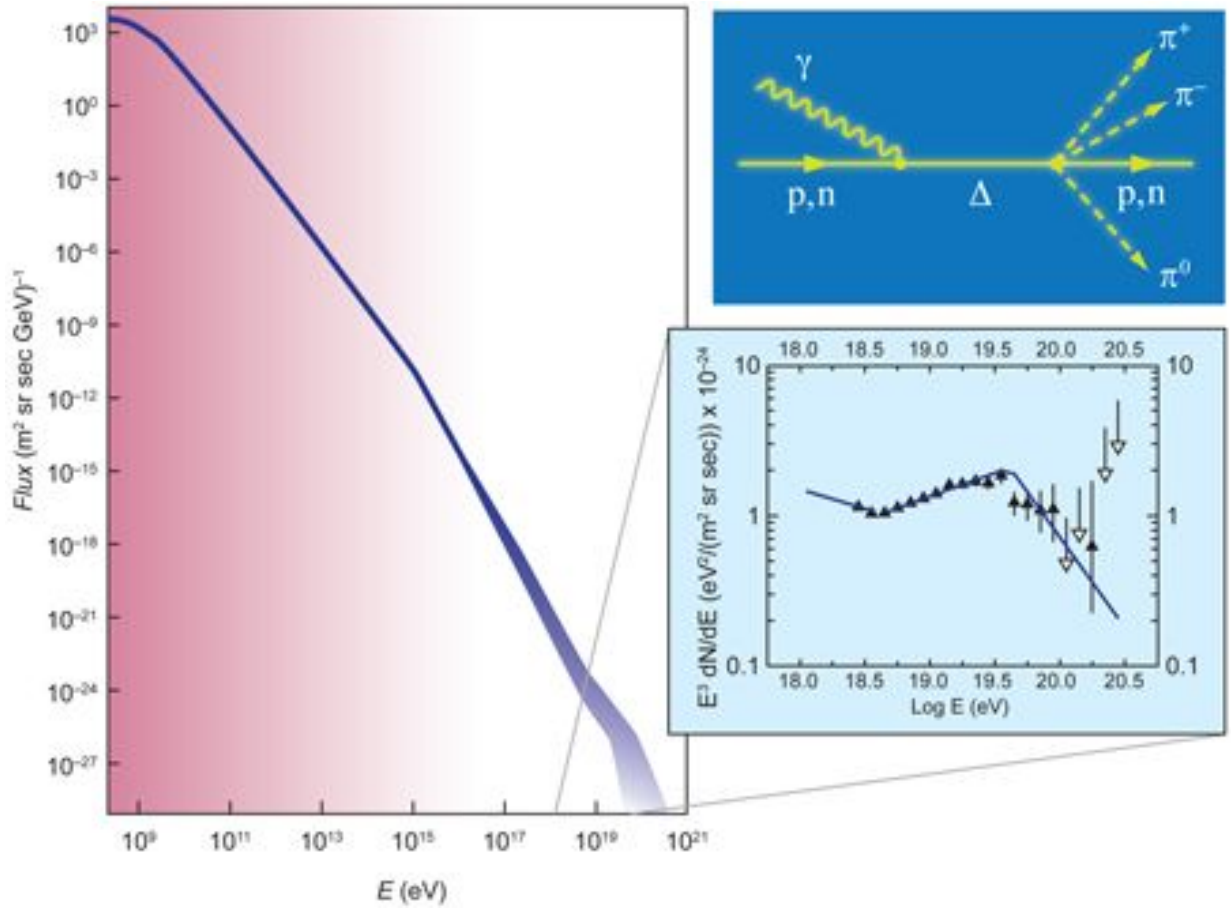


Реликтовое излучение (А.Пензиас, Р.Вильсон, 1961 г.)

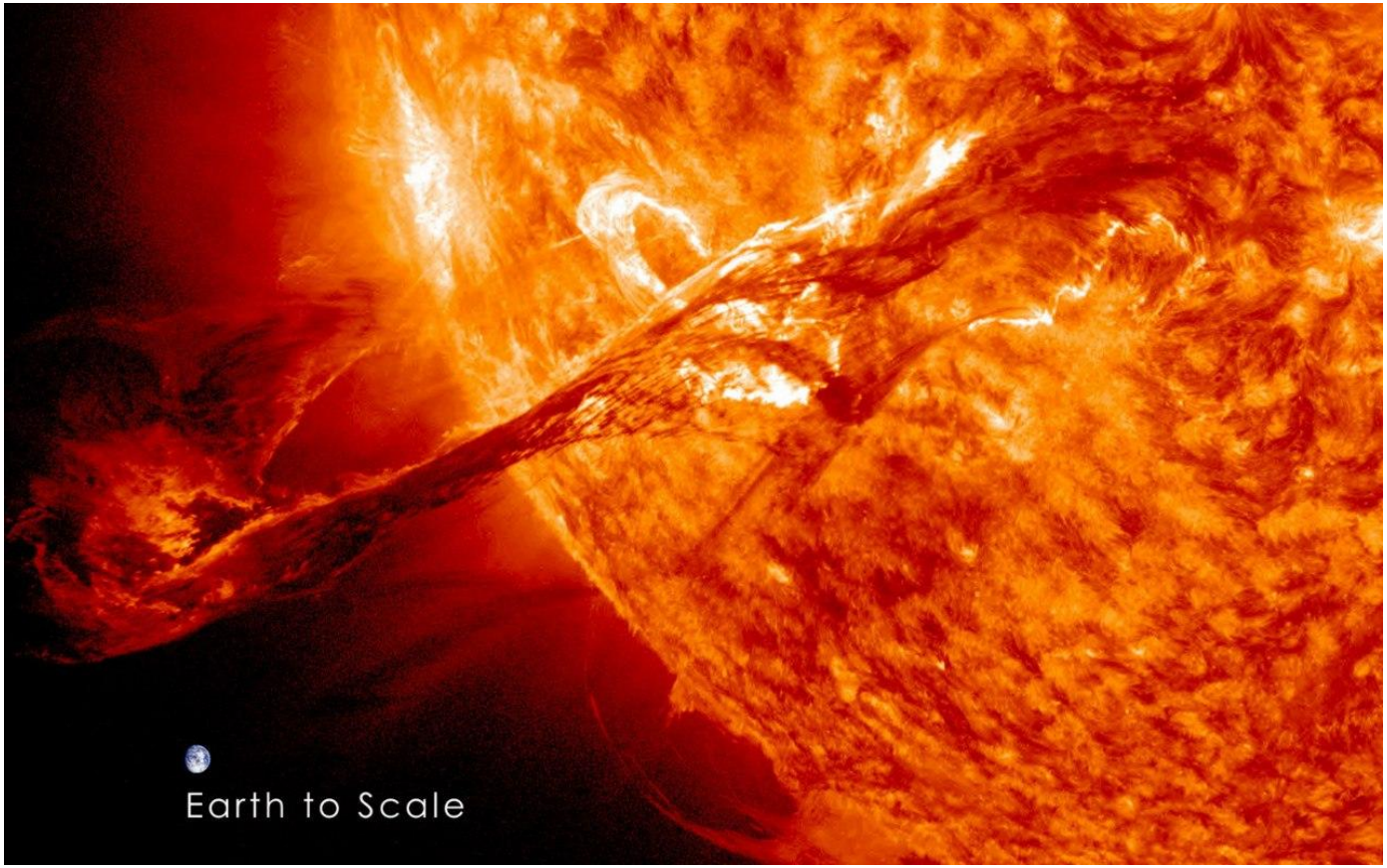


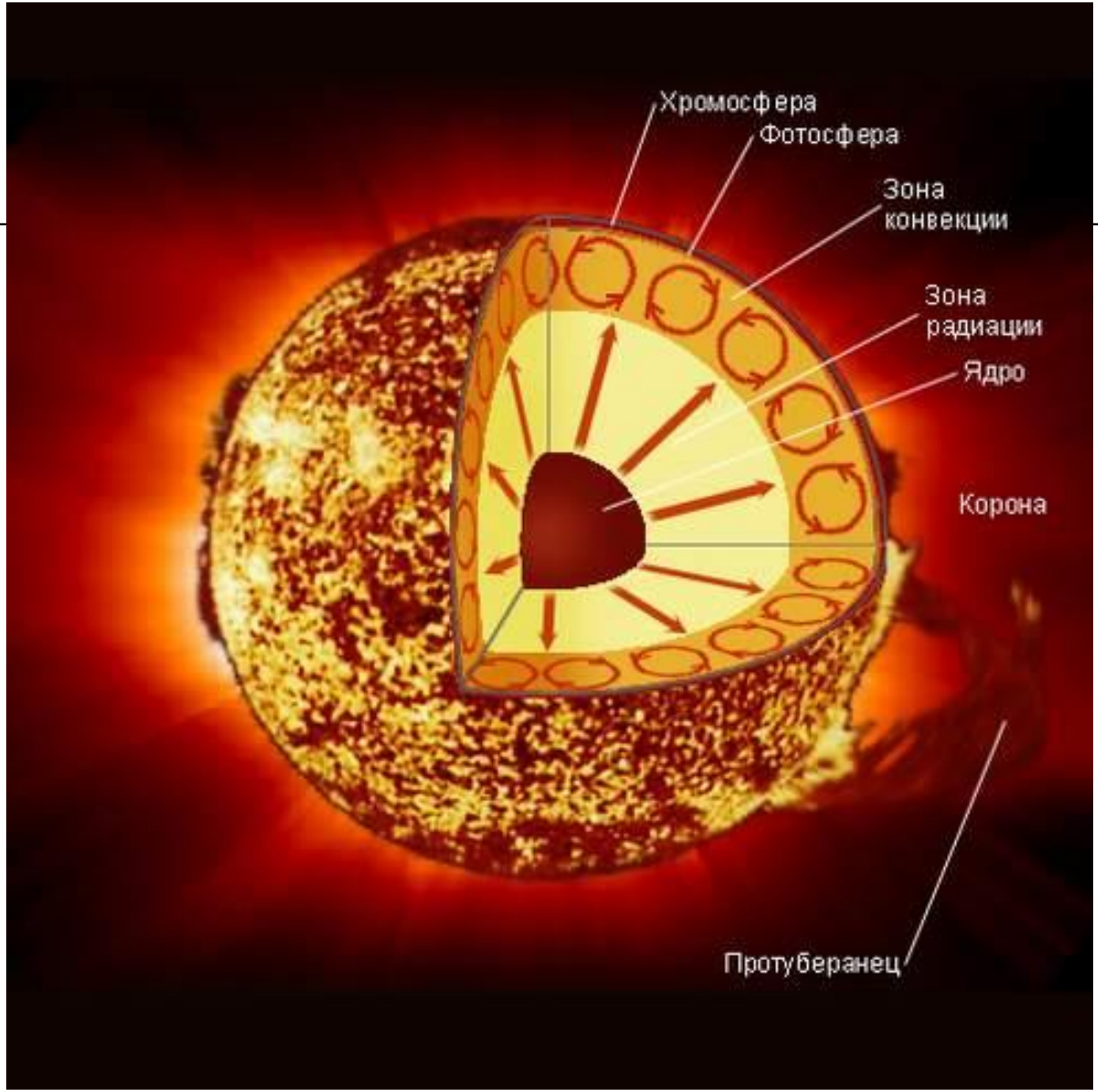
Нобелевская премия, 1978 г.

ГЗК-обрезание (К.Грейзен,Г.Т.Зацепин,В.А.Кузьмин, 1966 г.)

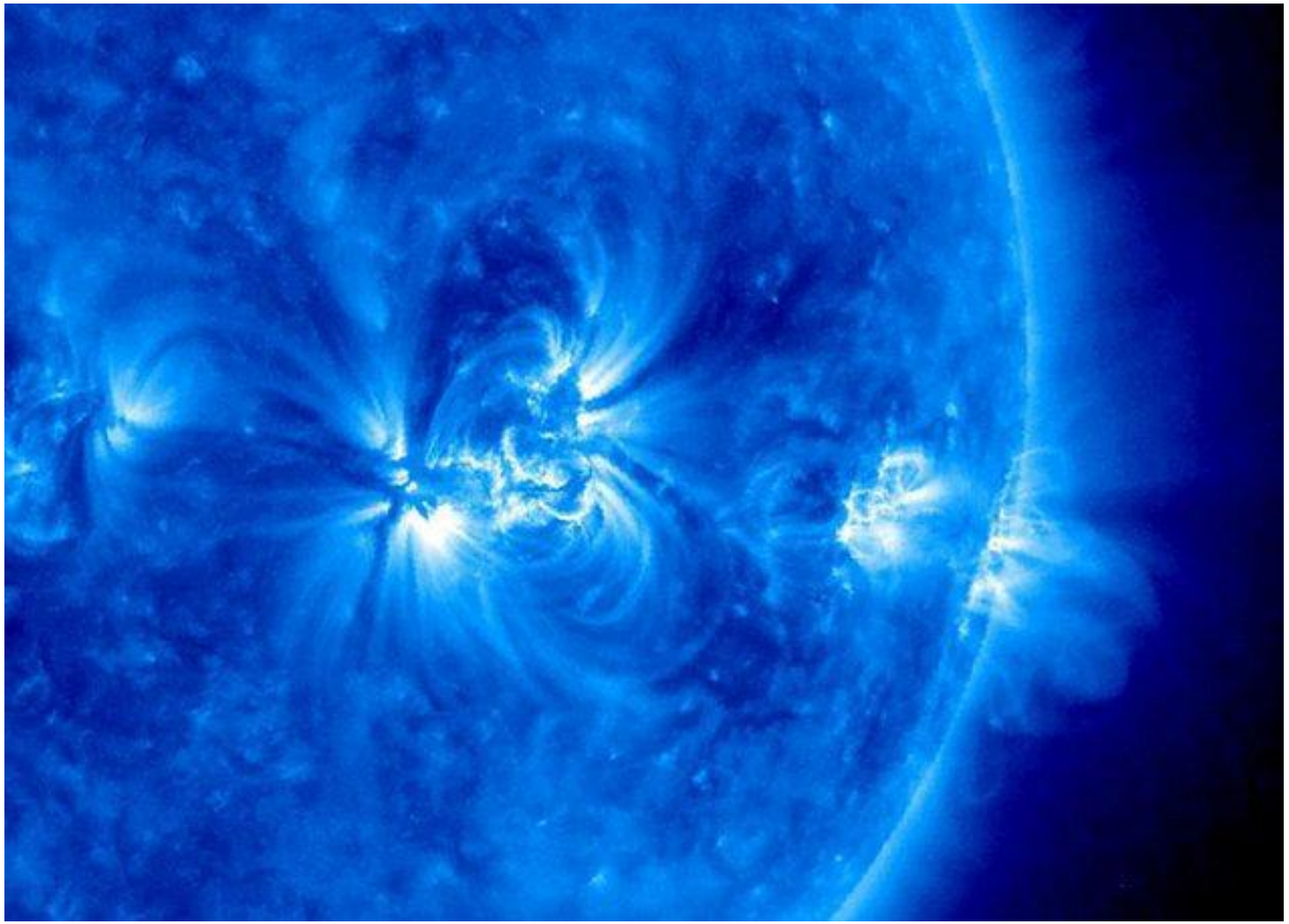


Физика Солнца




Хромосфера
Фотосфера
Зона конвекции
Зона радиации
Ядро
Корона
Протуберанец

Солнце в ультрафиолетовой части спектра



Протонный спектр Солнца

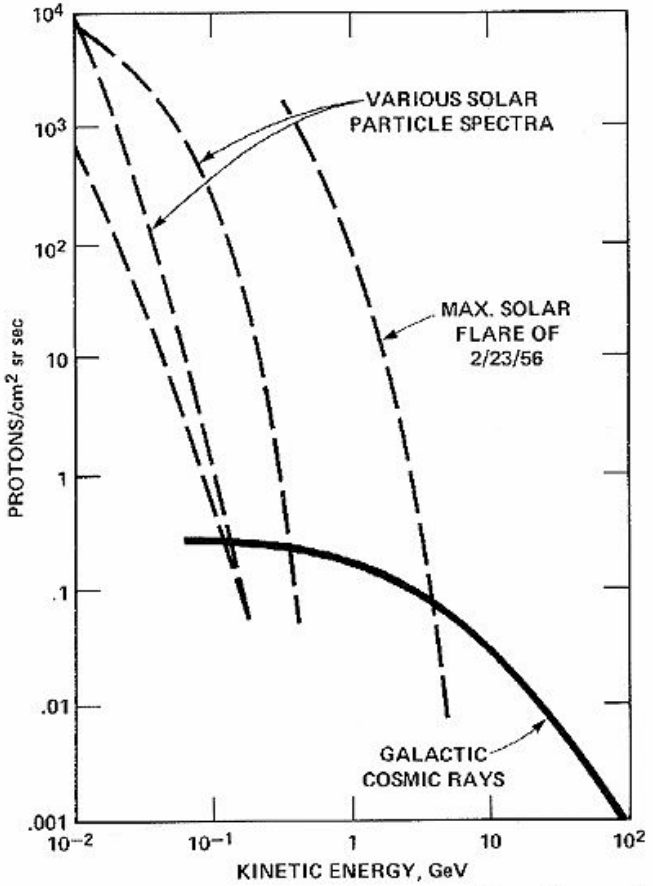
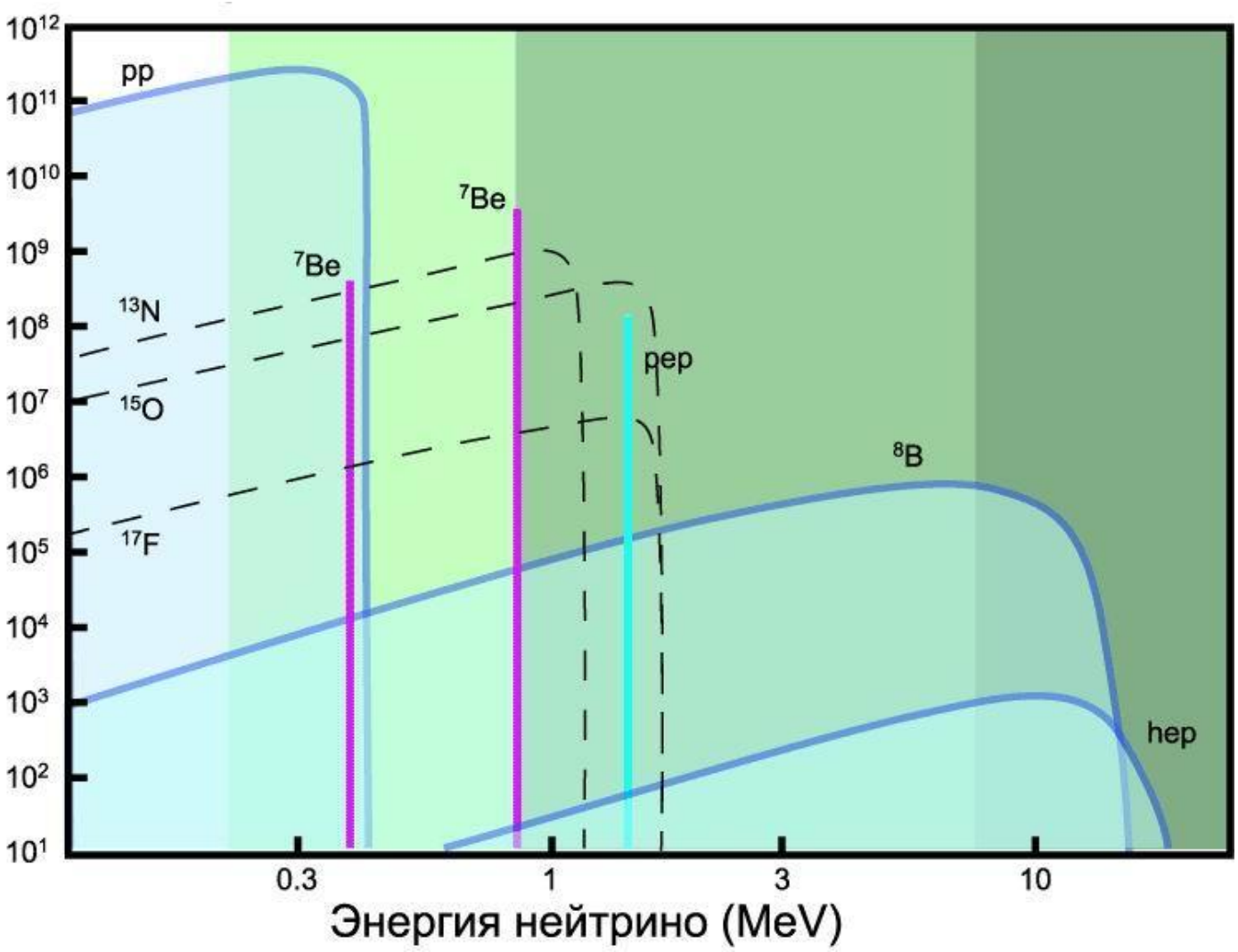
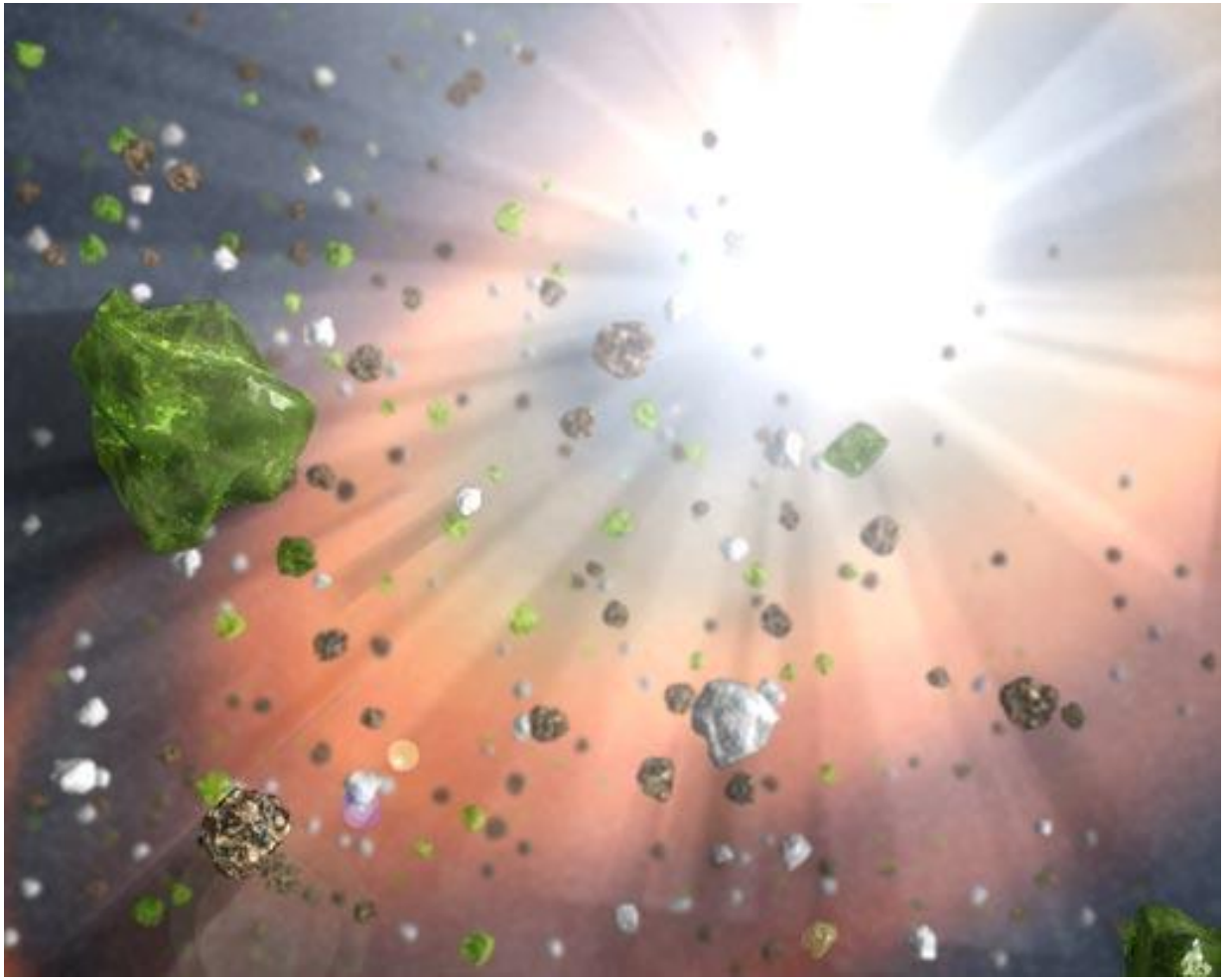


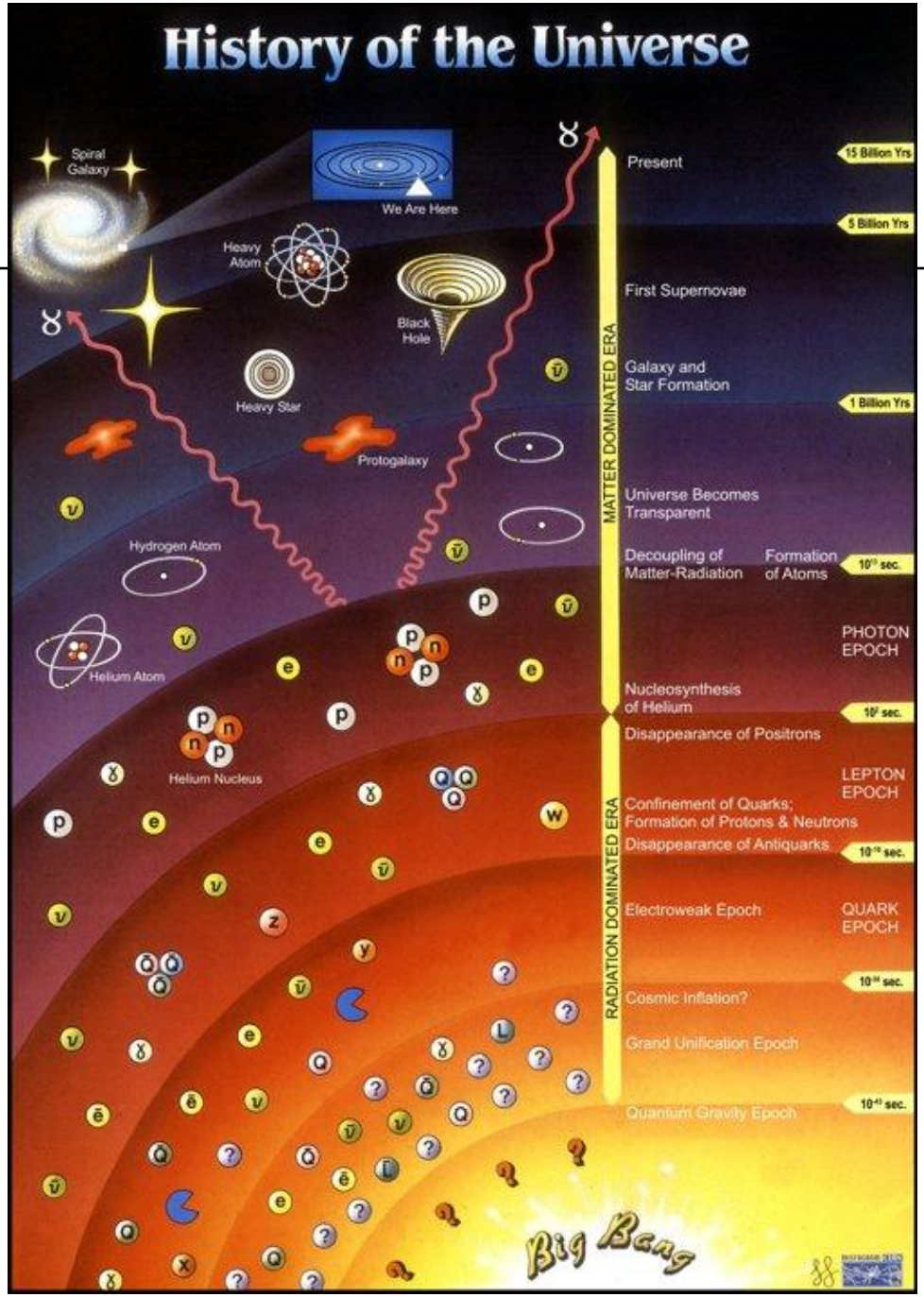
Figure 2-6.– *Energy spectra from several moderate size solar flares (dotted curves) compared with galactic cosmic ray spectrum.*

Нейтринный спектр Солнца



Элементы современной космологии




History of the Universe
Spiral Galaxy
We Are Here
Heavy Atom
Black Hole
Heavy Star
Protogalaxy
Hydrogen Atom
Helium Atom
Helium Nucleus
Present
15 Billion Yrs
5 Billion Yrs
First Supernovae
Galaxy and Star Formation
1 Billion Yrs
MATTER DOMINATED ERA
Universe Becomes Transparent
Decoupling of Matter-Radiation
Formation of Atoms
PHOTON EPOCH
Nucleosynthesis of Helium
Disappearance of Positrons
LEPTON EPOCH
Confinement of Quarks; Formation of Protons & Neutrons
Disappearance of Antiquarks
RADIATION DOMINATED ERA
Electroweak Epoch
QUARK EPOCH
Cosmic Inflation?
Grand Unification Epoch
Quantum Gravity Epoch
Big Bang

Некоторые вопросы

- Первичные бозоны(?)
- «Горячая Вселенная»
- Ассиметрия частицы-античастицы
- Механизм возникновения кварков и лептонов
- …..