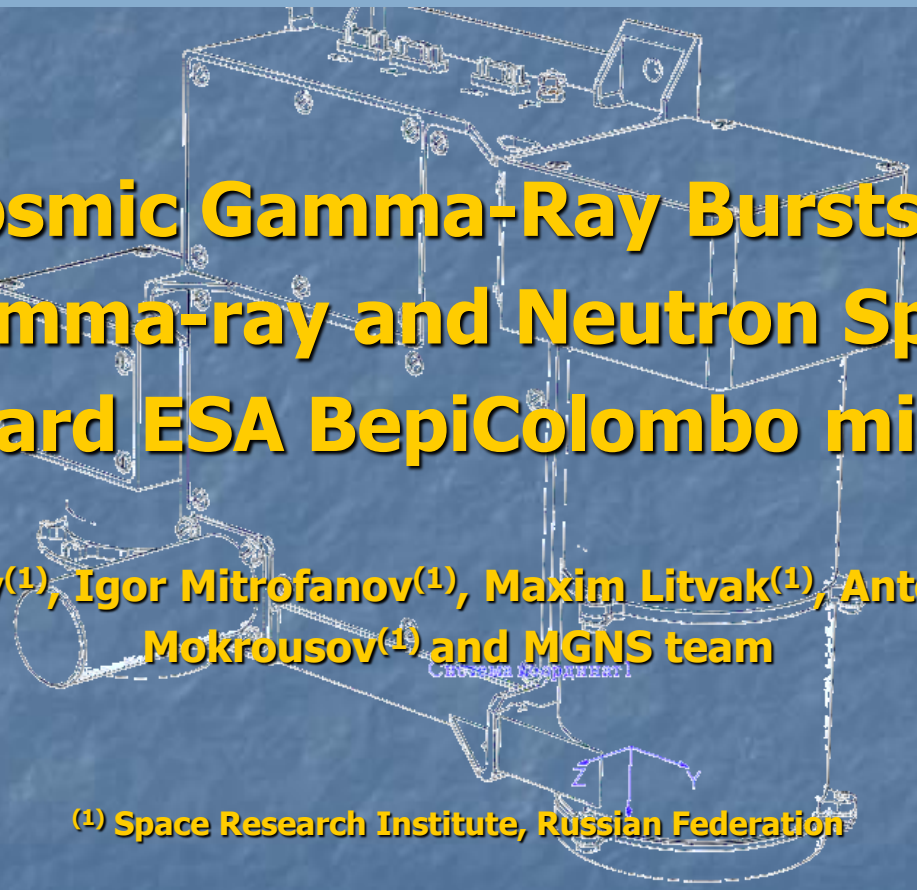
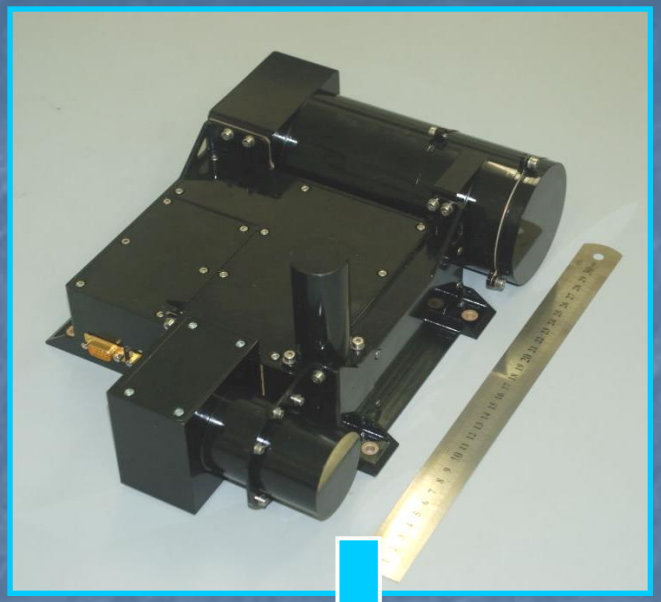
Ioffe Workshop on GRBs and other transient sources:
25 Years of Konus-Wind Experiment
September 9–13, 2019, St.Petersburg, Russia

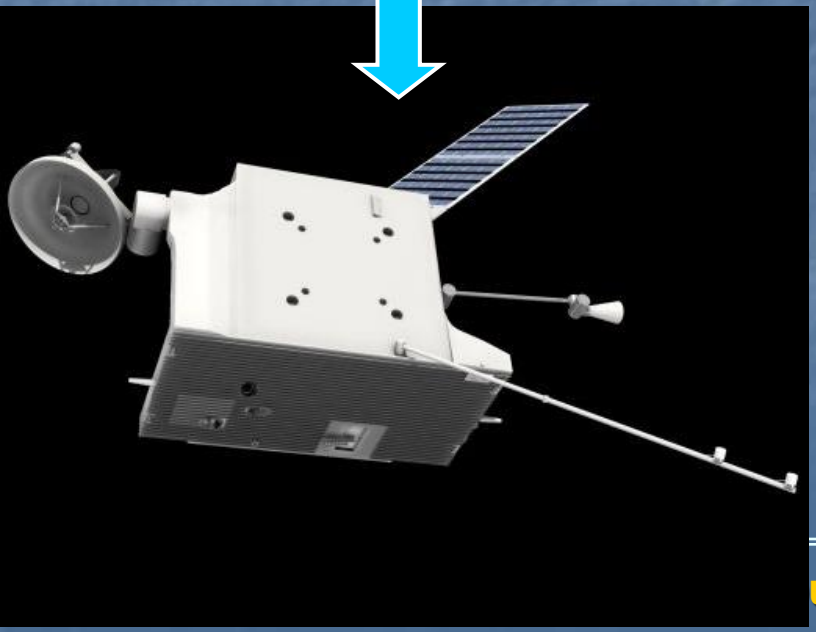
Studying cosmic Gamma-Ray Bursts by Russian Mercury Gamma-ray and Neutron Spectrometer onboard ESA BepiColombo mission



Alexander Kozyrev[1], Igor Mitrofanov[1], Maxim Litvak[1], Anton Sanin[1], Maxim Mokrousov[1] and MGNS team

[1] Space Research Institute, Russian Federation





MGNS: main characteristics

Goal: The gamma and neutron mapping of Mercury surface

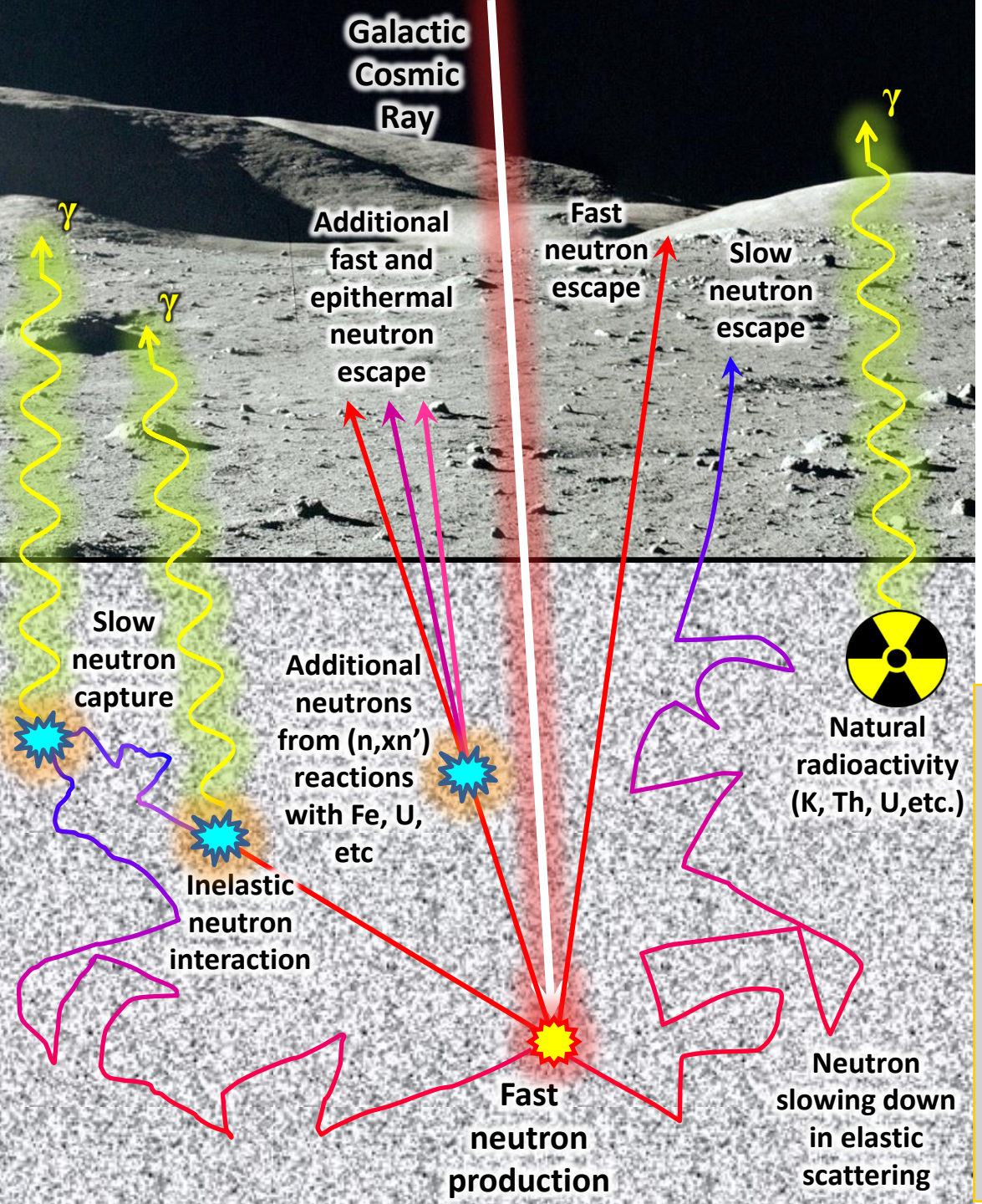
Science objectives:

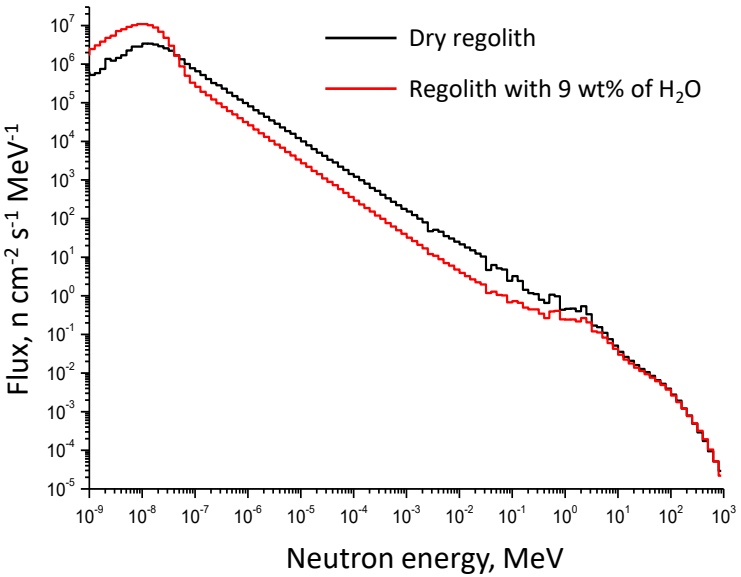
- The mapping of water content in Mercury subsurface
- The mapping of Mercury soil composition

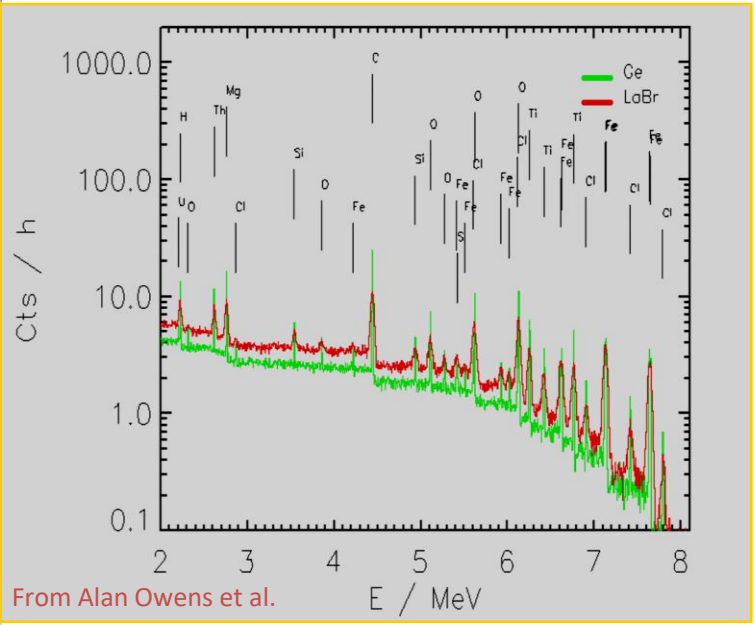
Parameters:

PARAMETER	VALUE
Mass	5.5 kg
Power	6.5 W
Surface Resolution	400 km
Minimal time resolution	2-4 sec
Energy range, neutrons	Multi energy bands covering 10^{-3} eV – 10 MeV
Energy range, gamma	300 keV – 10 MeV
Energy resolution, gamma	4,6% at 660 keV
Detectors	^{3}He proportional counters, stilben crystal, $CeBr_3$ crystal
Operational temperature range, deg / stabilization	(-20C, +45C) / 10 deg/h
Position	ESA: MPO BepiColombo
Altitude	400 km – 1500 km
Telemetry rate, Mbytes/day	HK: 0.57; SCI: 34.85; SCI SEL: up to 696.92

Nuclear planetology physics (briefly)







Neutron spectroscopy

- Neutron albedo of Mercury in broad energy range
  - Thermal neutrons
  - Epithermal neutrons below 1 MeV
  - Fast neutrons up to 10 MeV
  - Mapping
- Possible search for water in subsurface layer of planet
  - Detection of water
  - Mass fraction
  - How distributed trough depth
  - Mapping

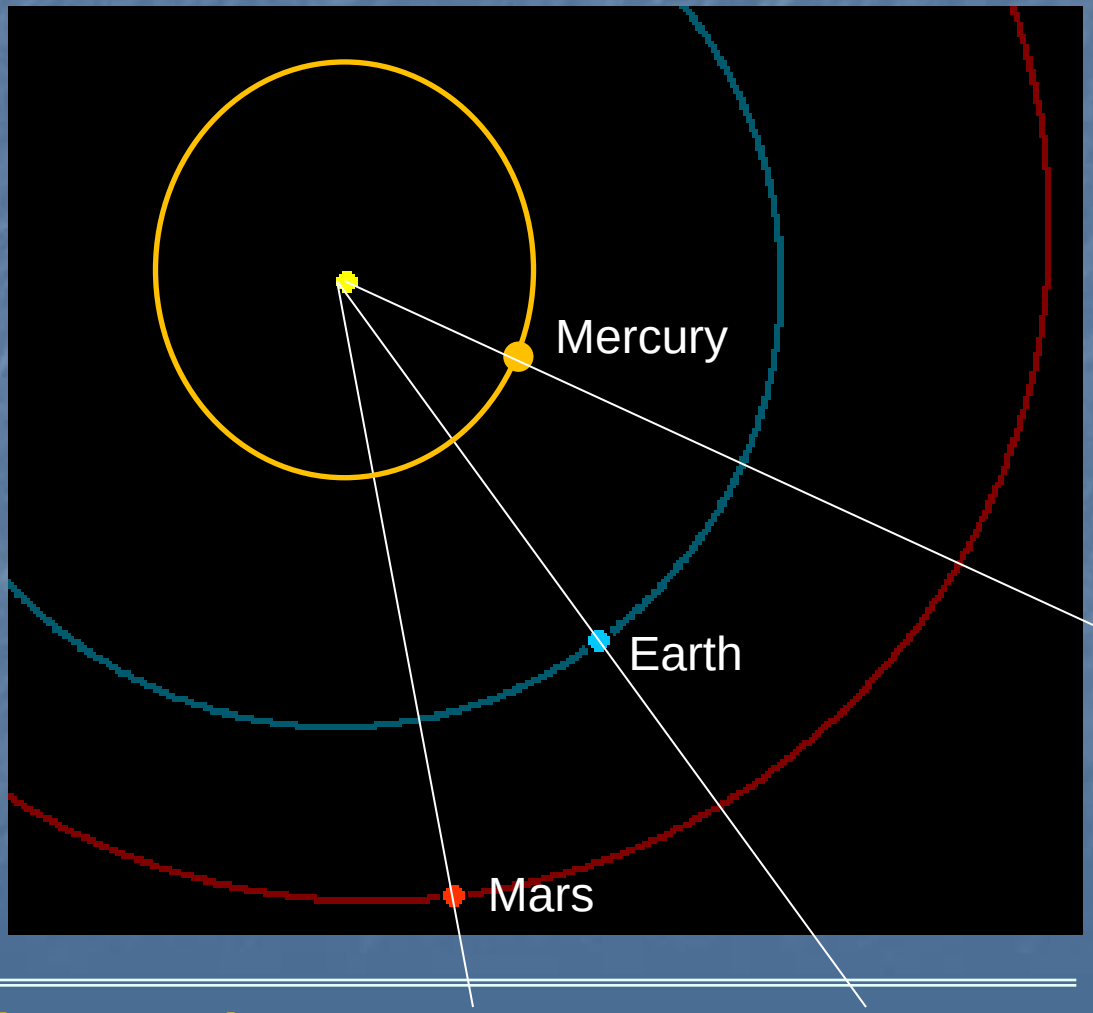
Gamma-ray spectroscopy

- **Gamma-ray spectroscopy of surface**
  - Sensitivity in energy range 300 keV-10MeV

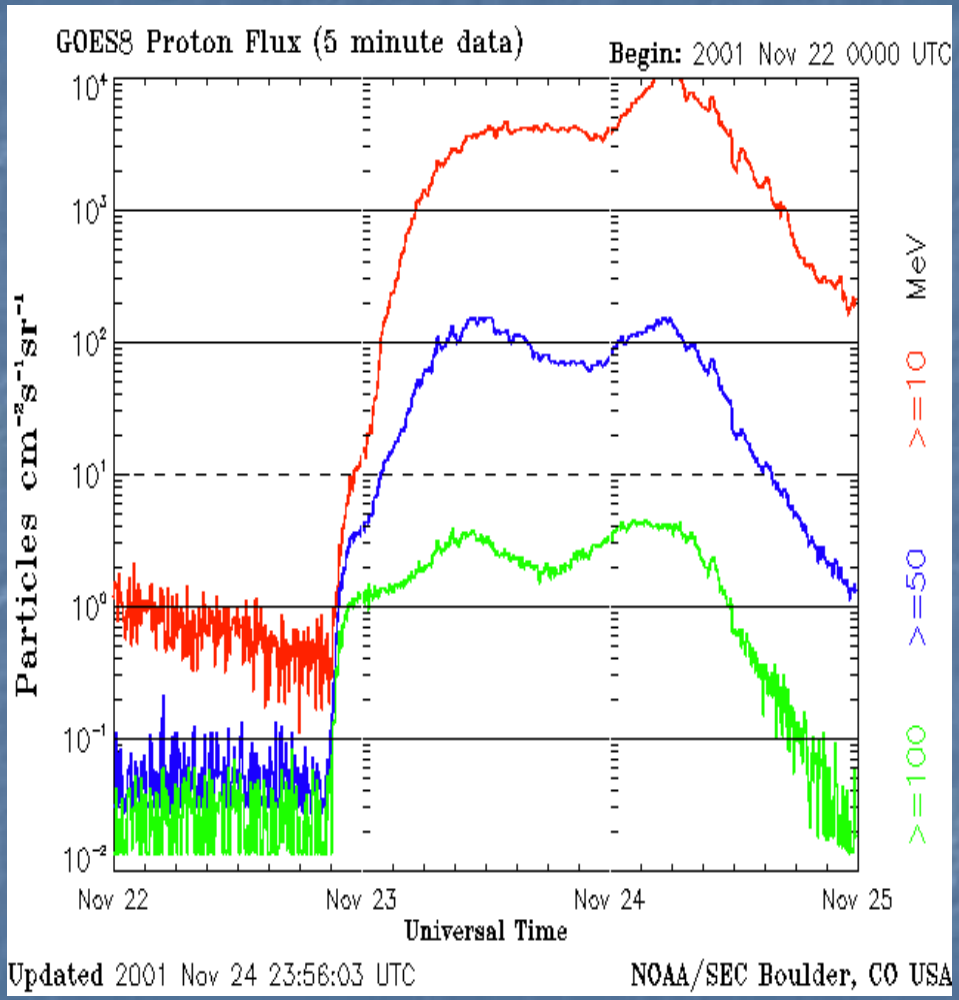
- **Definition of chemical composition of subsurface layer of Mercury**
  - Detection of set of basic gamma lines (C, Na, Fe, Al, K, Si, Th, U)
    - ✓ GLOBAL DETECTION: The line counts exceeds the level of 3 sigma above the continuum during the full orbital stage (exposure time=10000 hours).
    - ✓ GLOBAL MAPPING: The line counts exceeds the level of 3 sigma above the continuum for pixels of selected angular sizes of 10°-30° during the full orbital stage (exposure time = 100-1000 hours).

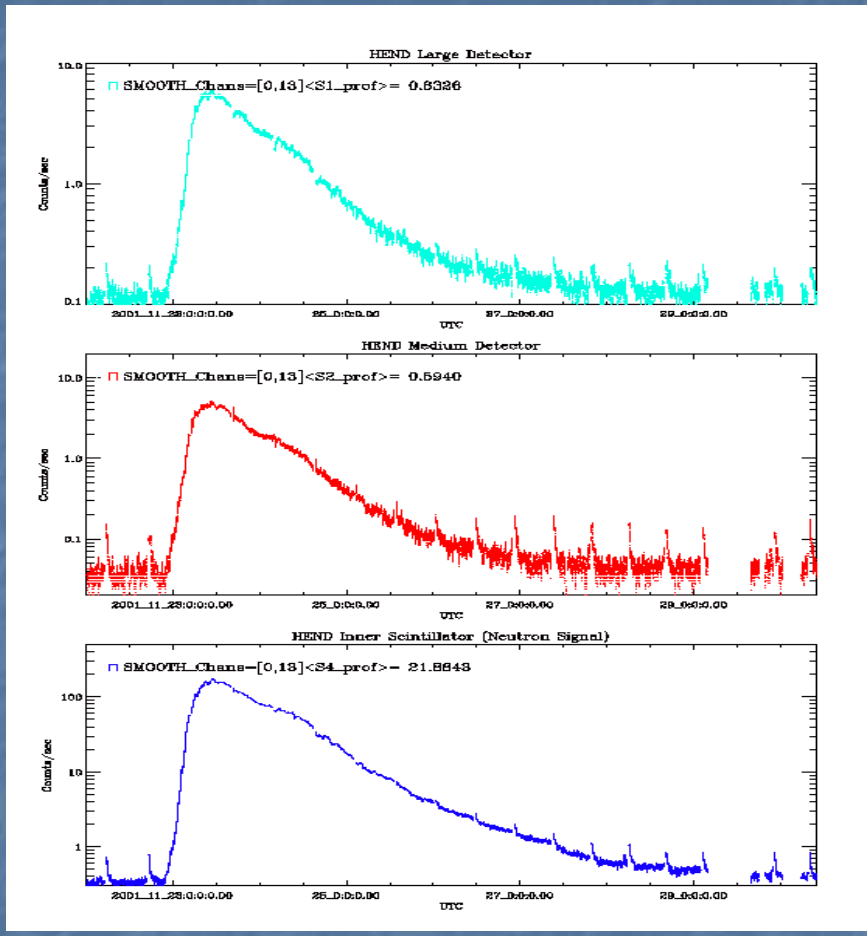
Additional task: Solar Flare registretion by MGNS instrument

- Neutron registration from the Solar Flare
- Stereoscopic observation Solar Flares by different instruments near Mercury, Earth and Mars.
- Estimation of neutron and gamma-ray components of radiation environment during the Solar Flares.



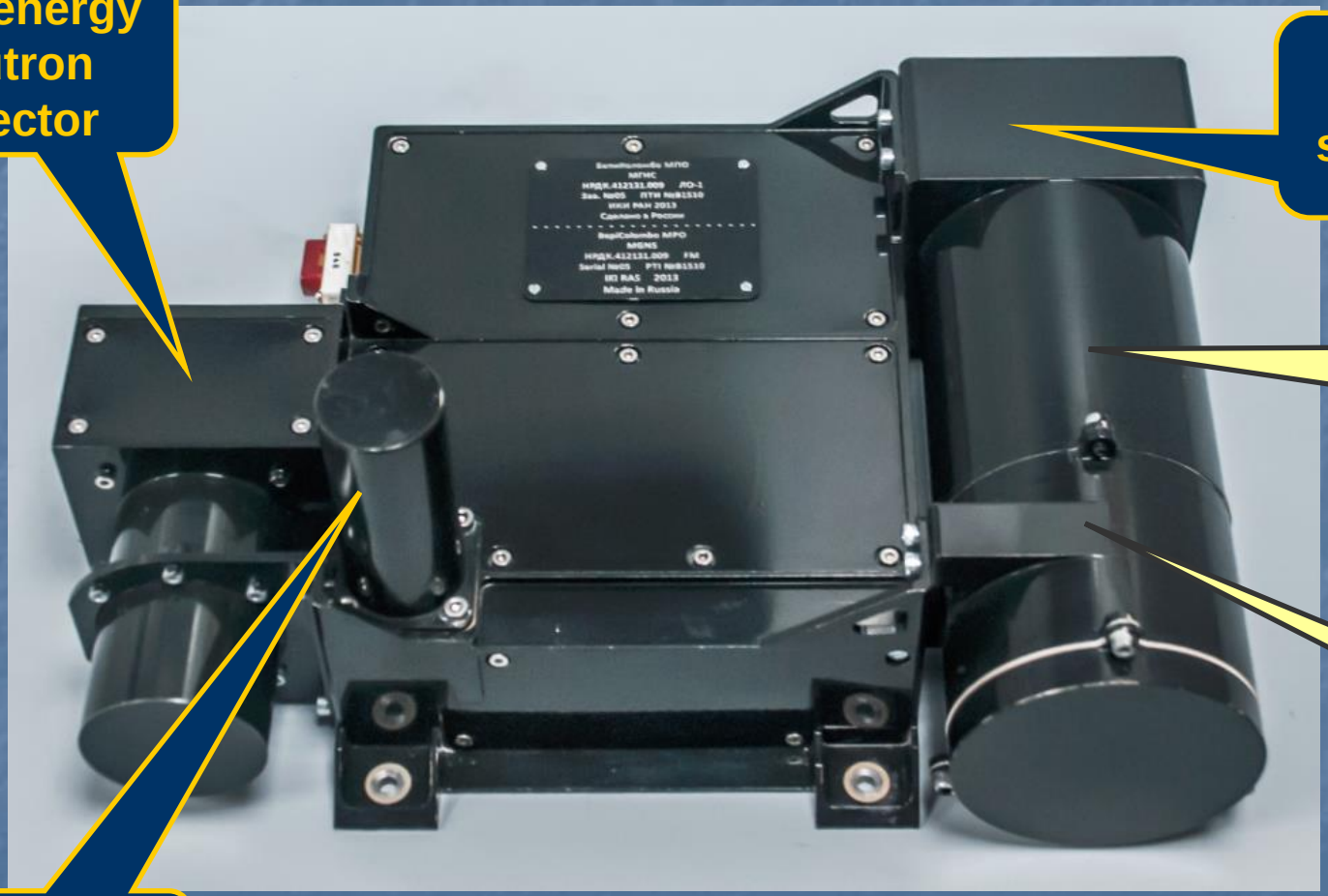
Example of additional task: Data of Solar Flare measured by GOES (Earth) and HEND (Mars)



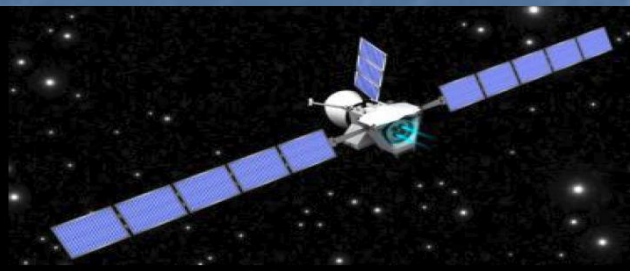


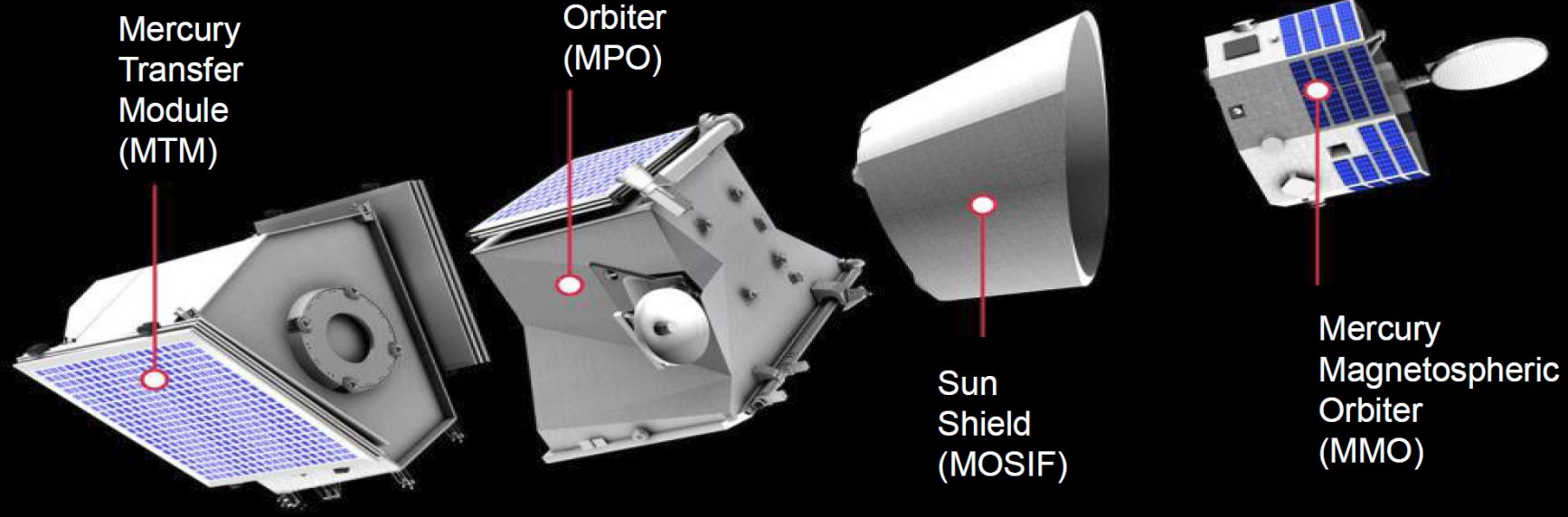
Time profile of secondary neutrons from spacecraft and Mars surface

MGNS mechanical design: high energy neutron detector and gamma-ray spectrometer

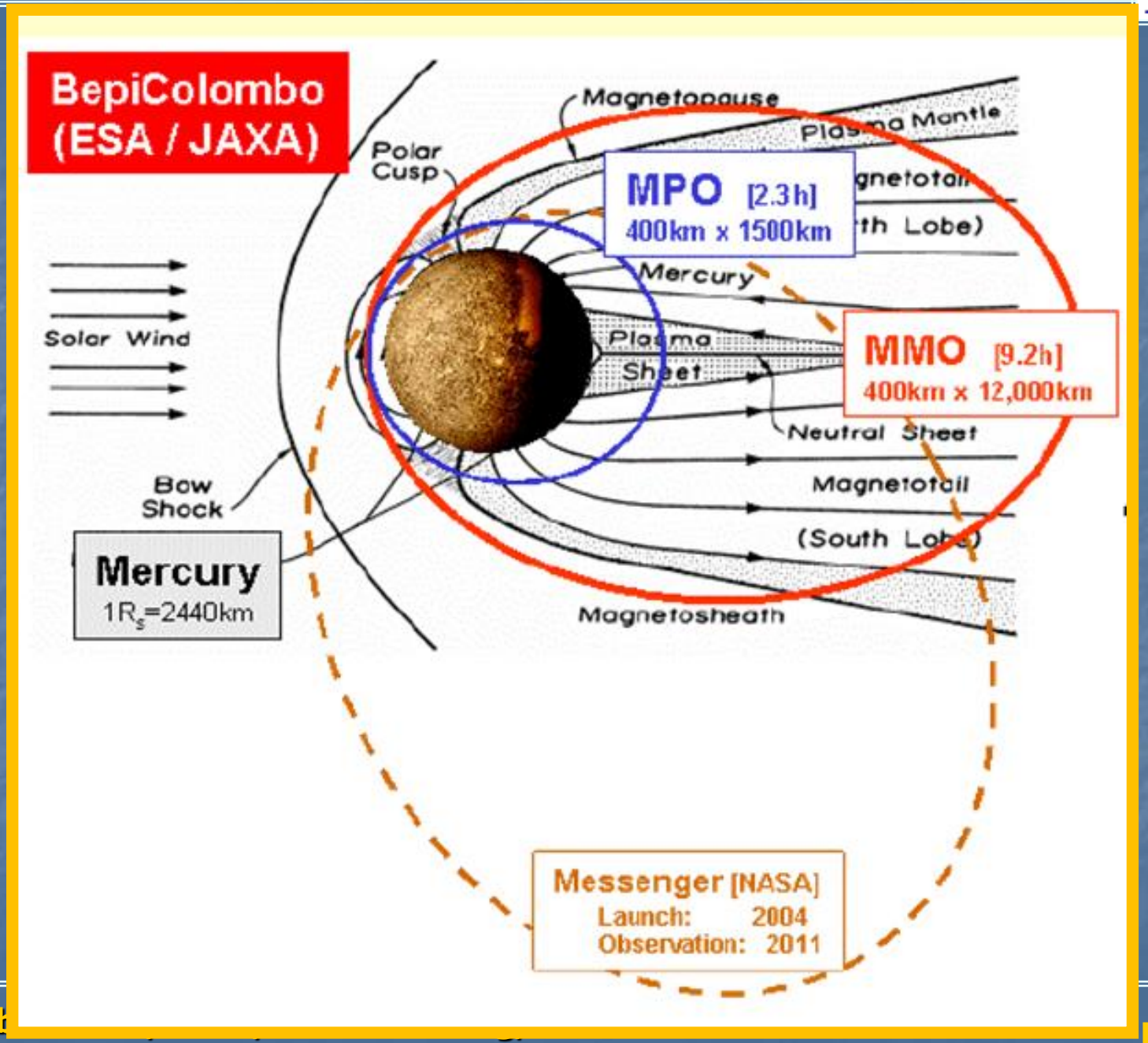


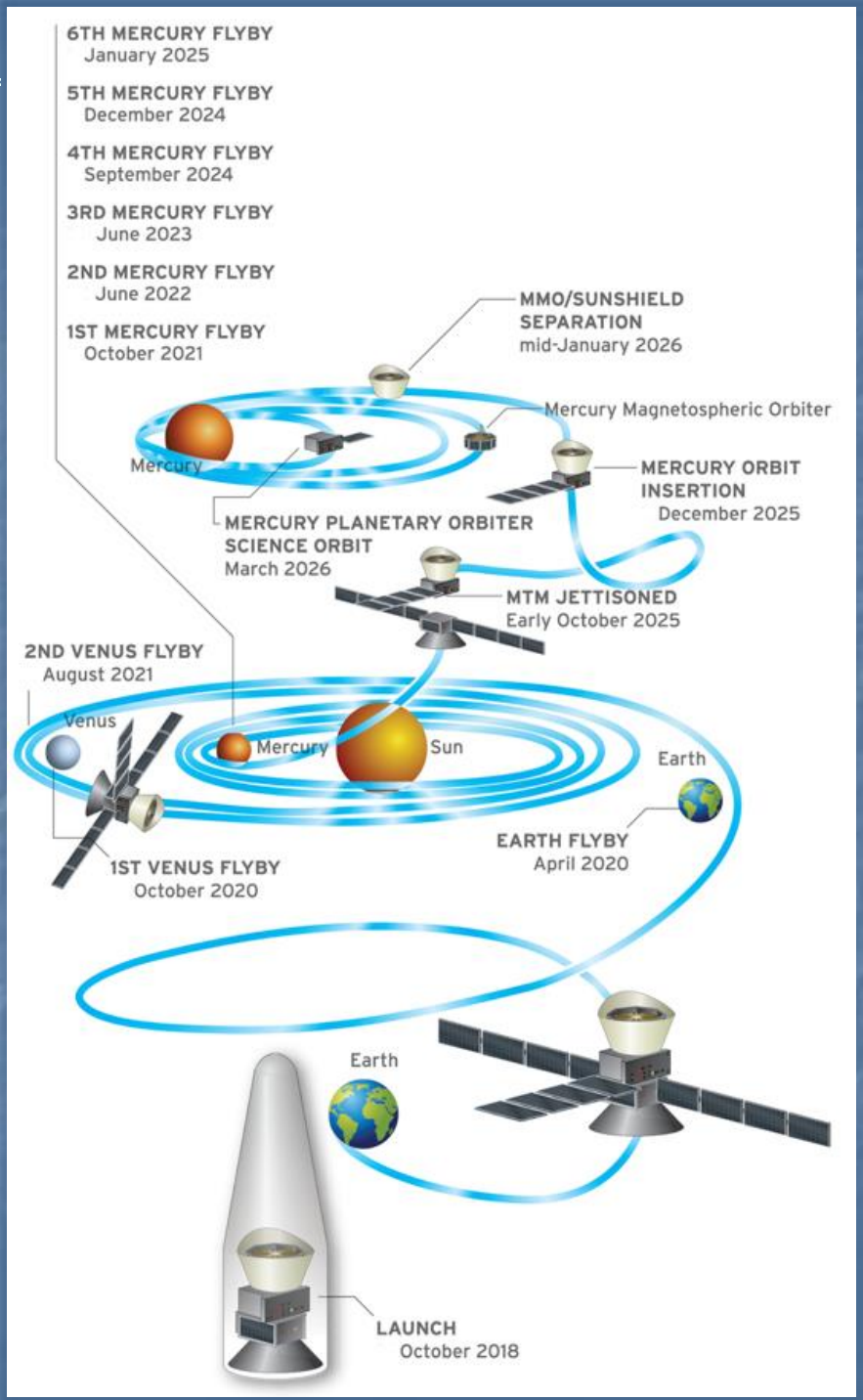
BepiColombo Spacecraft Configuration





Mercury Composite Spacecraft (MCS)

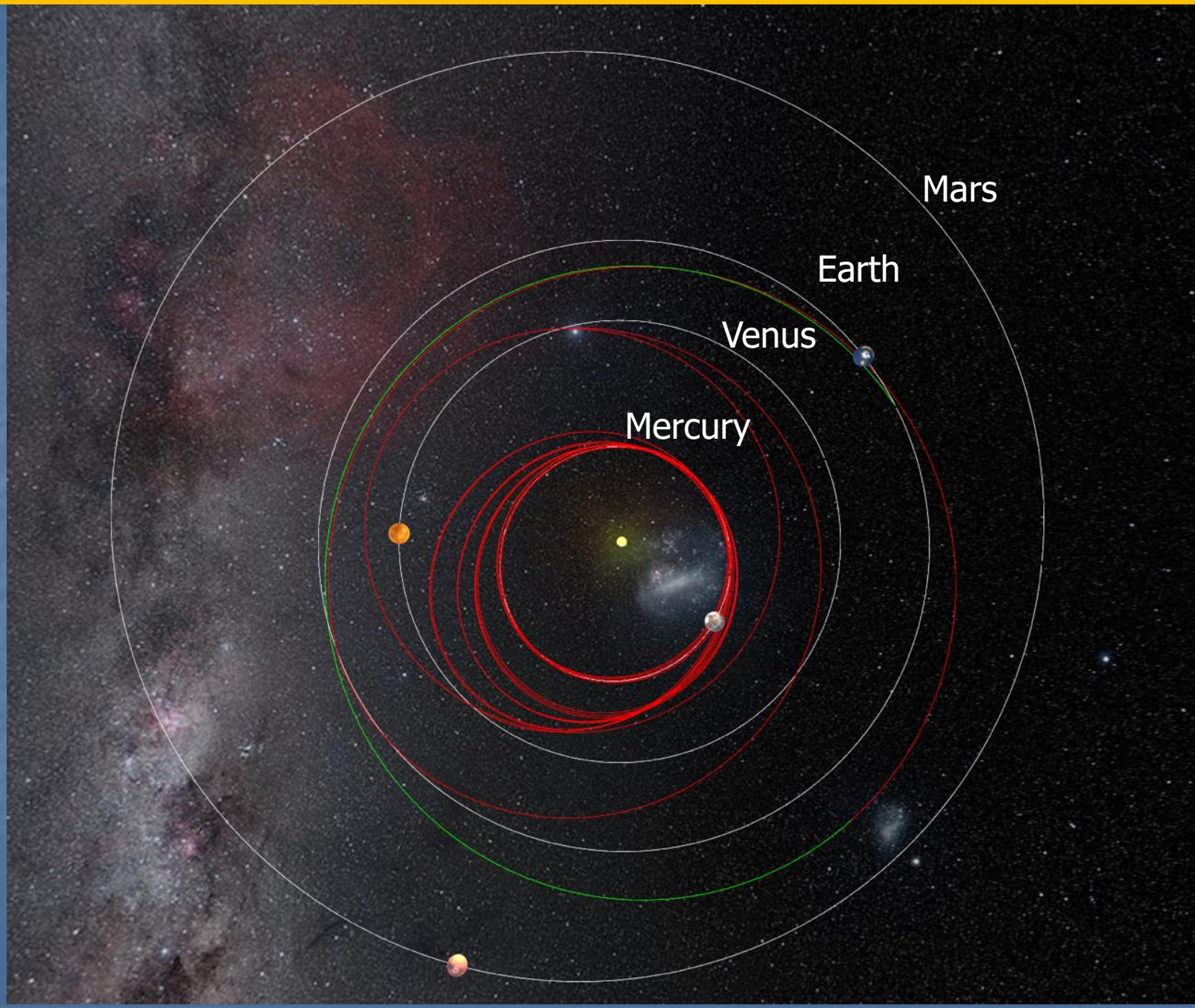

BepiColombo
(ESA / JAXA)
Magnetopause
Plasma Mantle
Polar
Cusp
MPO [2.3h]
400km x 1500km
Mercury
Solar Wind
Plasma
Sheet
MMO [9.2h]
400km x 12,000km
Neutral Sheet
Bow
Shock
Magnetotail
(South Lobe)
Mercury
1R$_s$=2440km
Magnetosheath
Messenger [NASA]
Launch: 2004
Observation: 2011



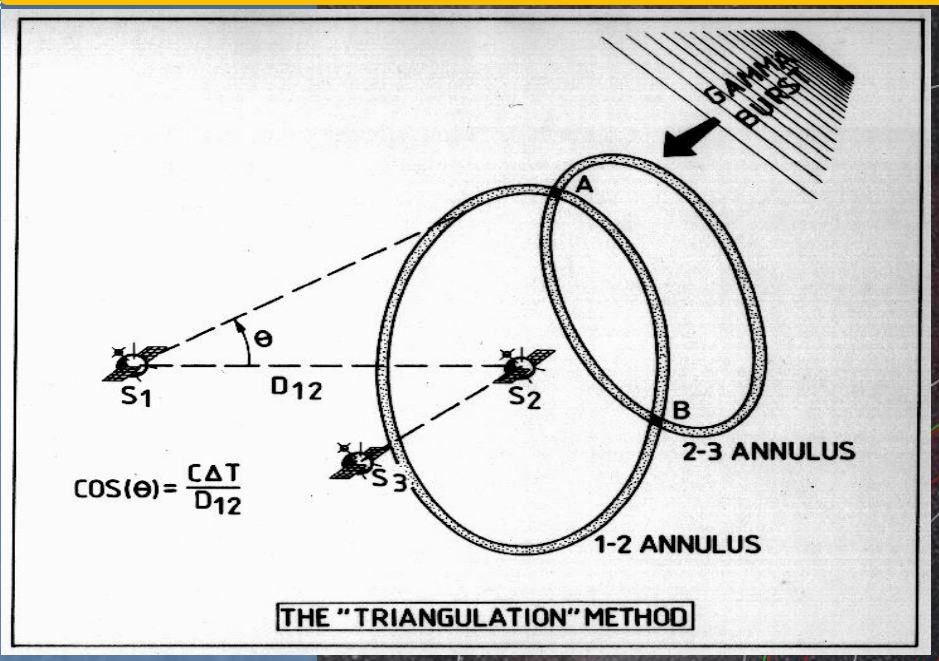
During the cruise of 7.2 years toward the inner part of the Solar System, BepiColombo will make 1 flyby to the Earth, 2 to Venus, and 6 to Mercury. Only part of its payload will be obstructed by the sunshield (MOSIF) and the MTM spacecraft, allowing the operations of many instruments.

The interplanetary trajectory provides the different spacecraft configurations during the cruise phase.

BepiColombo Interplanetary Cruise Trajectory



BepiColombo Interplanetary Cruise Trajectory



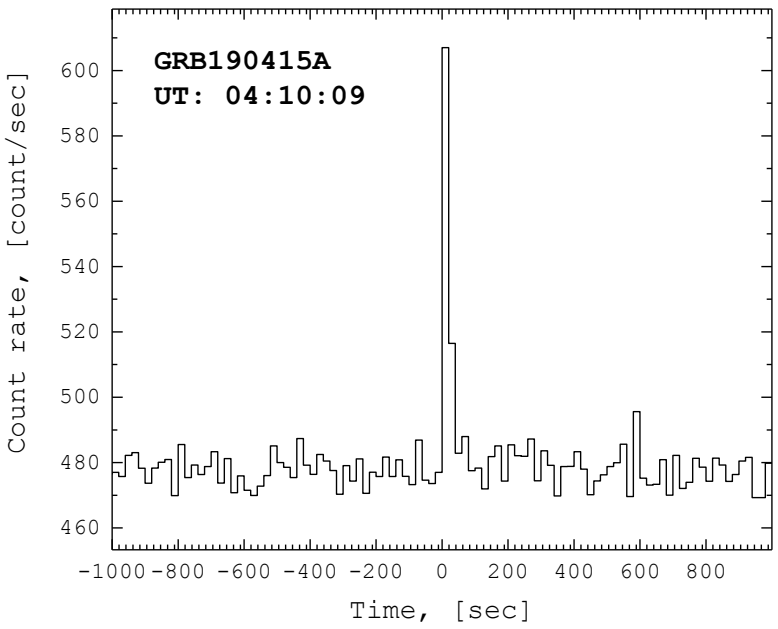
Mars

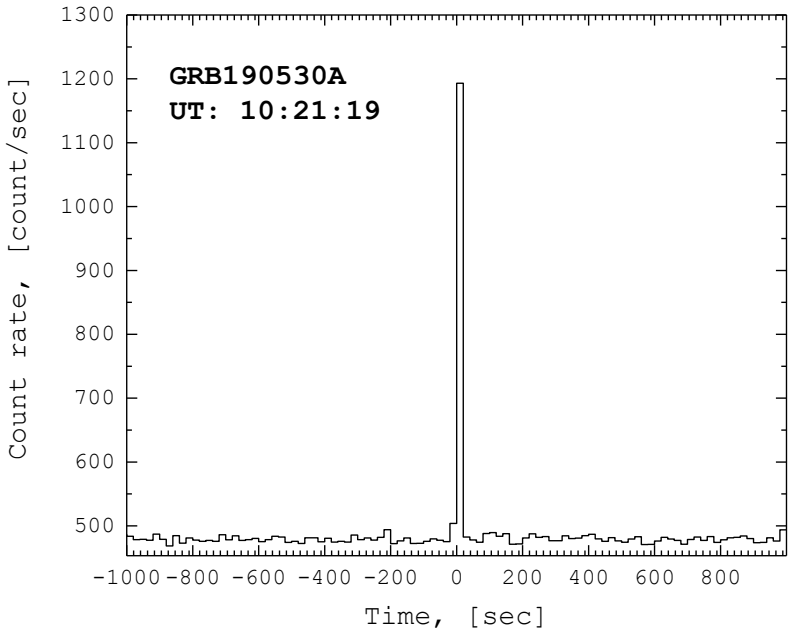
Earth

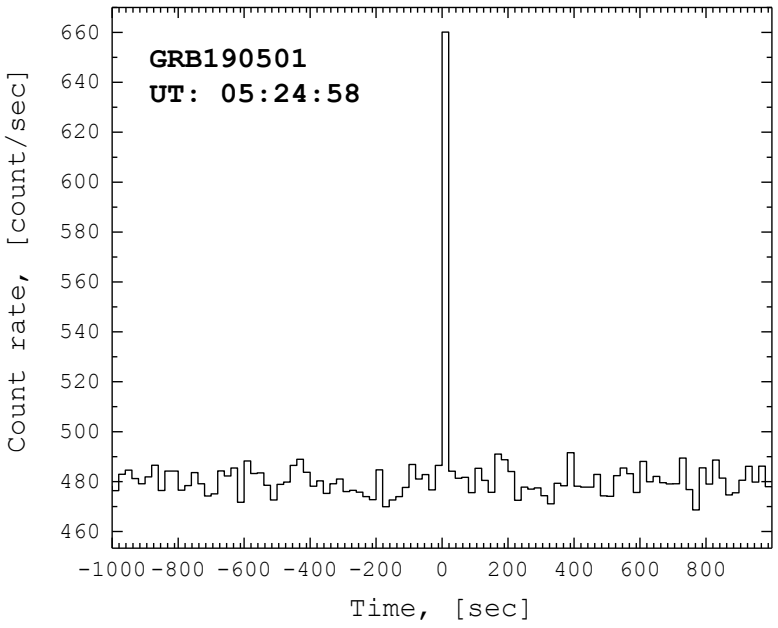
Venus

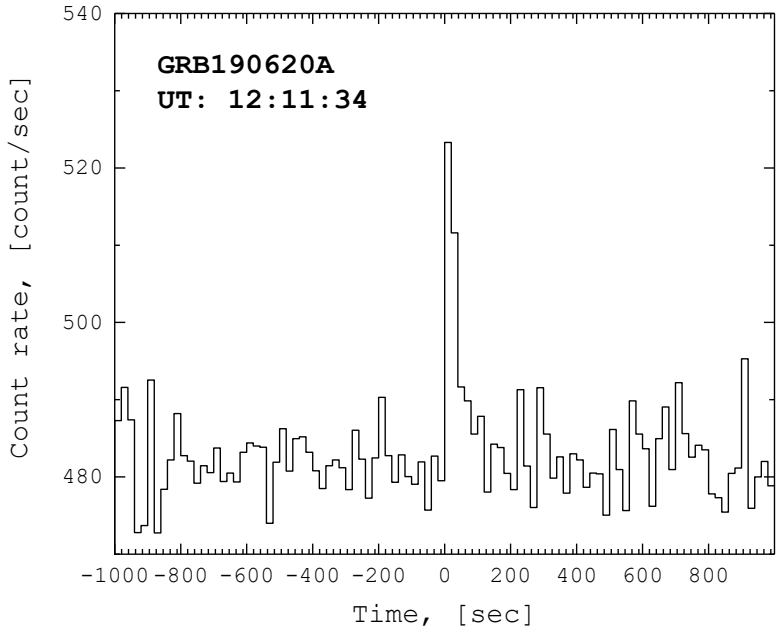
Mercury

Examples of MGNS GRBs time profiles

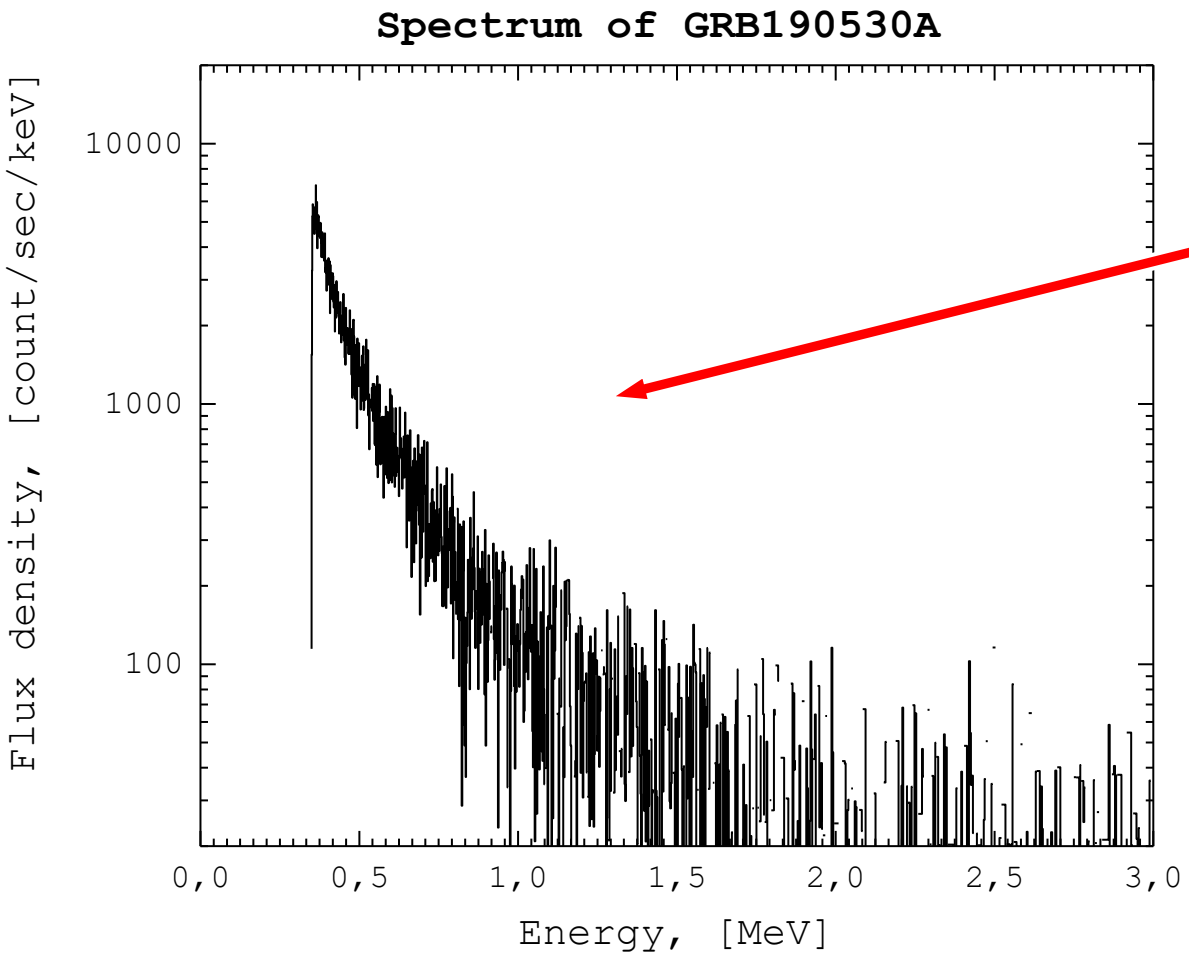


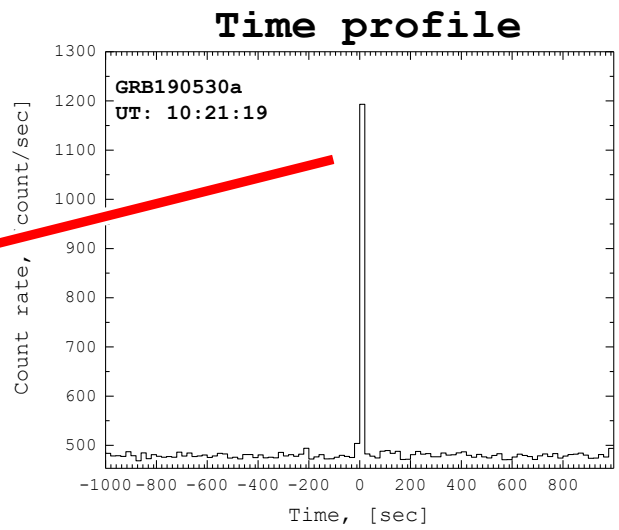




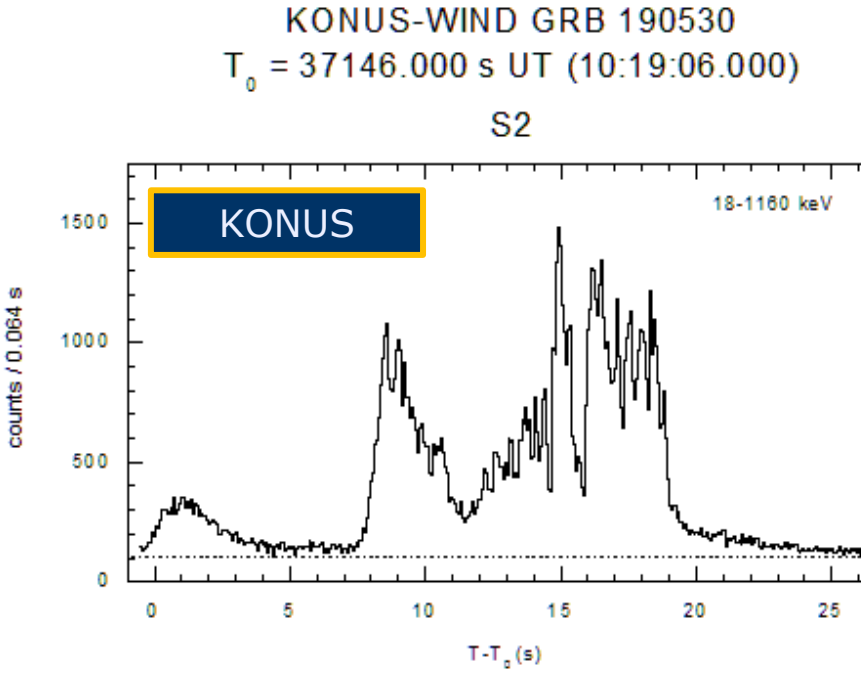


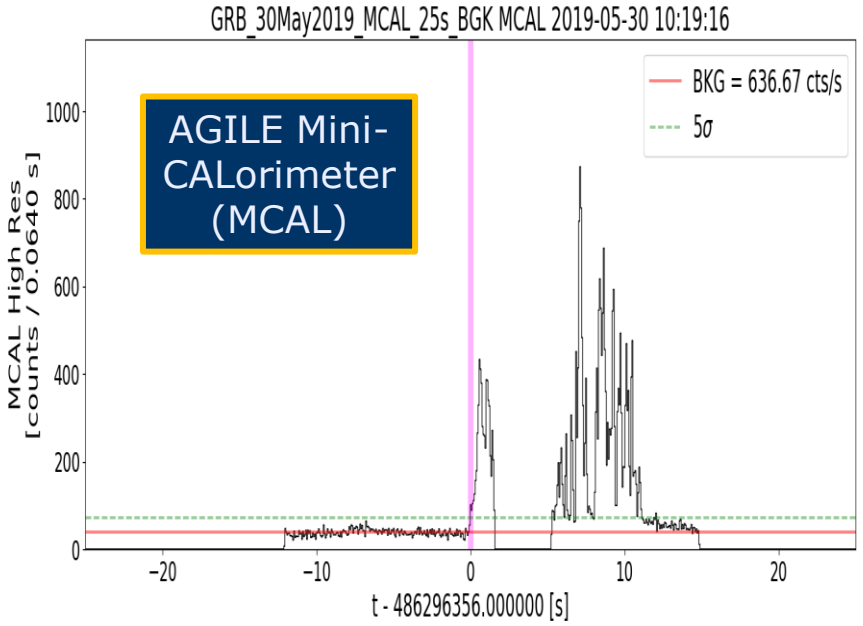
MGNS spectrum for GRB 190530A

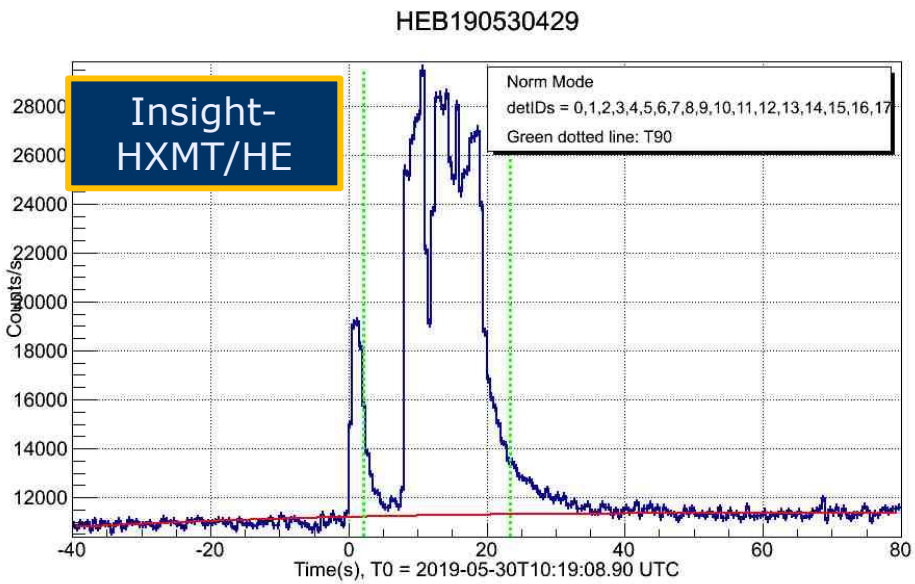


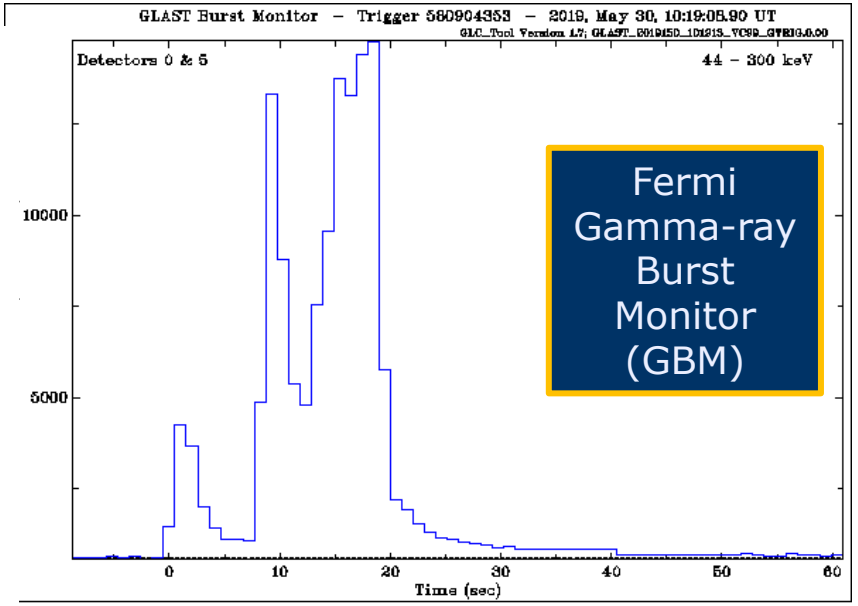


GRB 190530a by other experiments

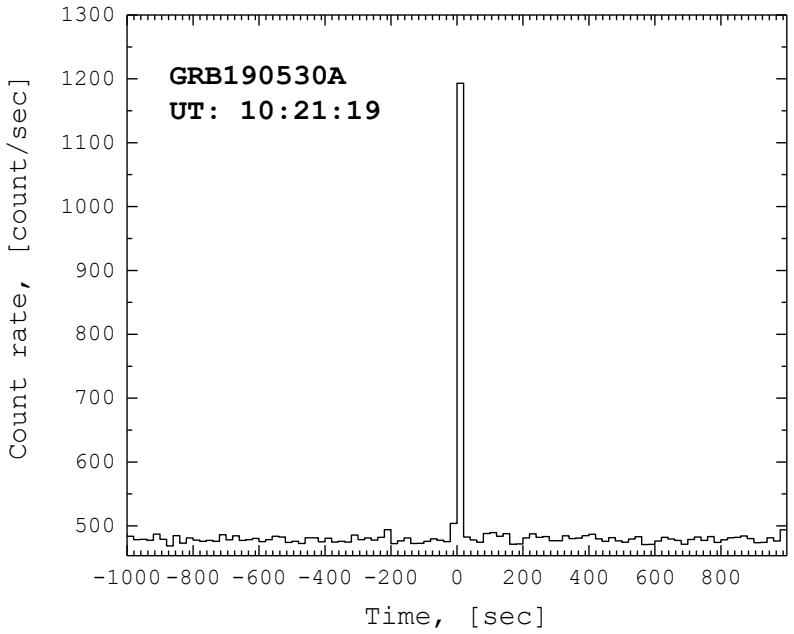


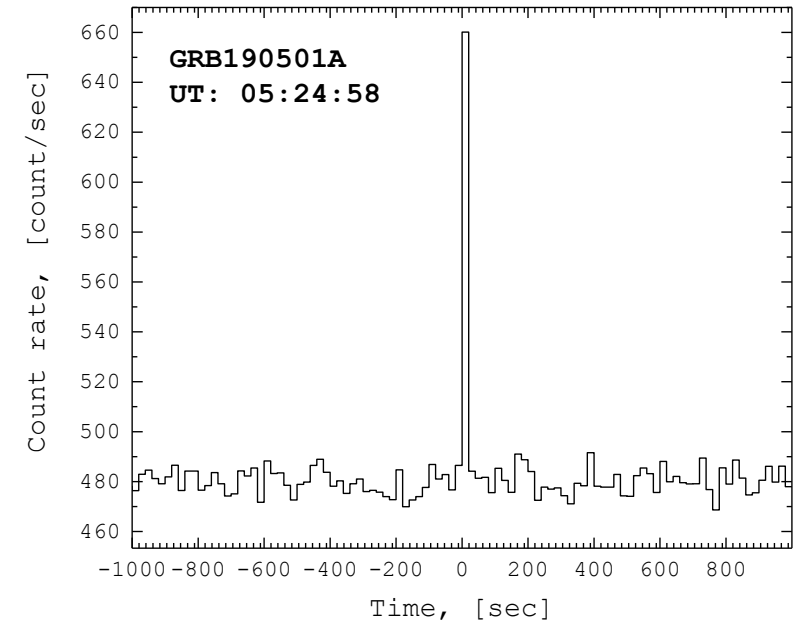




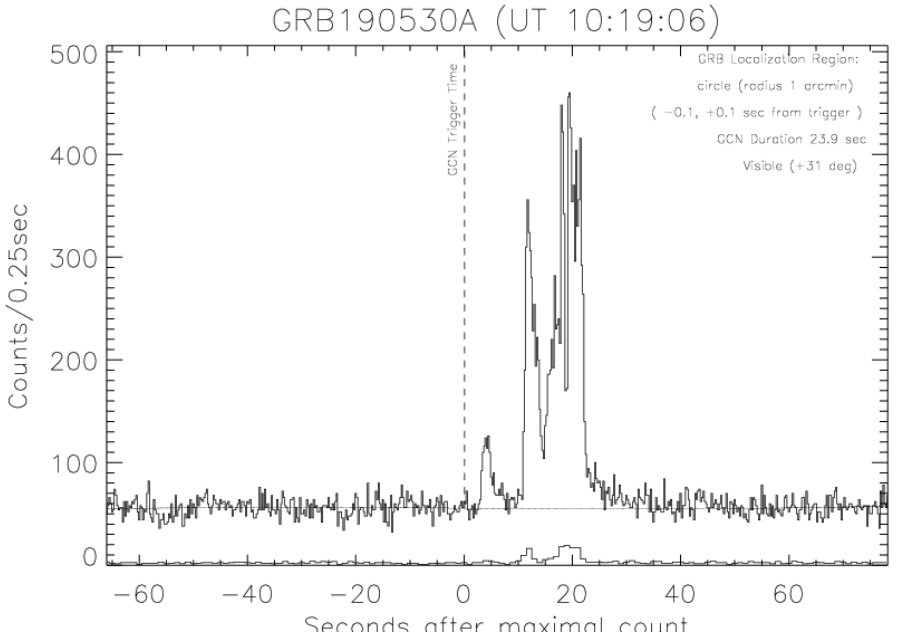


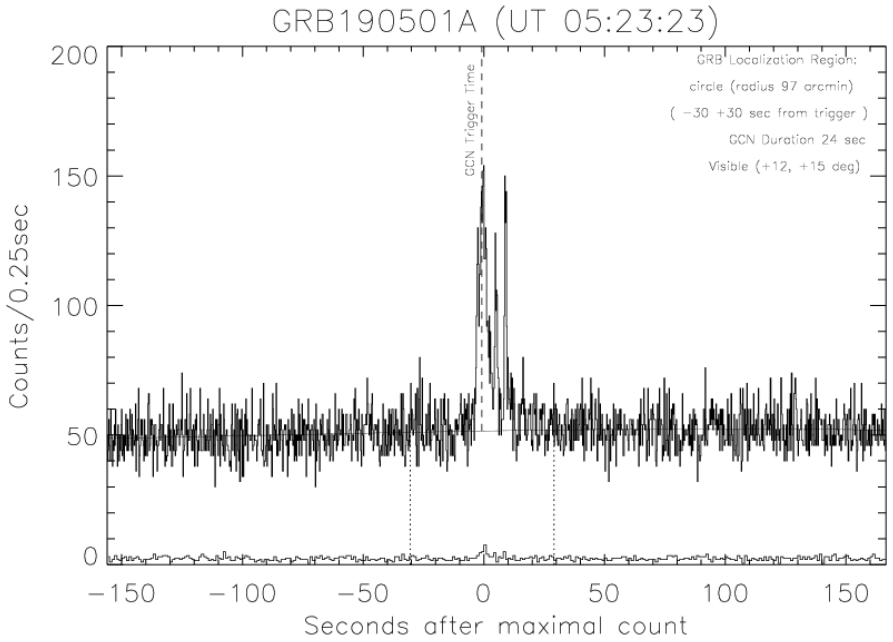
MGNS


GRB190530A
UT: 10:21:19
Count rate, [count/sec]
Time, [sec]


GRB190501A
UT: 05:24:58
Count rate, [count/sec]
Time, [sec]

HEND


GRB190530A (UT 10:19:06)
GRB Localization Region:
circle (radius 1 arcmin)
(−0.1, +0.1 sec from trigger)
GCN Duration 23.9 sec
Visible (+31 deg)
GCN Trigger Time
Counts/0.25sec
Seconds after maximal count


GRB190501A (UT 05:23:23)
GRB Localization Region:
circle (radius 97 arcmin)
(−30 +30 sec from trigger)
GCN Duration 24 sec
Visible (+12, +15 deg)
GCN Trigger Time
Counts/0.25sec
Seconds after maximal count

CONCLUSION:

- MGNS instrument has detected 6 GRBs since the beginning of work in space at Desember 3, 2018:

  1. GRB190415A (IPN)
  2. GRB190501A (HEND, IPN)
  3. GRB190530A (HEND, IPN)
  4. GRB190611B (HEND, IPN)
  5. GRB190620A (HEND)
  6. GRB190727B (IPN)

- The MGNS instrument will operate continuously during the cruise stage until December 5, 2025 and the subsequent mapping stage of Mercury until May 1, 2028 (except for short periods for trajectory correction). At the cruise and mapping stages, the instrument will generate gamma-ray time profiles with a time resolution of 20 sec and 2 sec, respectively.