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Mission Requirements
and
Call for Instrument Concepts

Feasibility studies of space-based instrumentation for future gamma-ray missions are to be carried out by a group of laboratories working in the framework of AHEAD (http://ahead.iaps.inaf.it/), under the auspices of the European Horizon 2020 program.
In order to draw on the widest possible expertise and to make sure that all possible developments and innovations are considered in the follow-up studies of instrumentation, the present call for instrument concepts is issued.

Objective

The European Gamma-Ray community has a long and successful record in designing, realizing and observing with space observatories. At present, a large number of laboratories prepare the future through ambitious R&D programs on the key technologies required for the next step in space. Given the limited number of flight opportunities, and the fierce competition to get selected by a space agency, it is important to present mature proposals in response to the rare calls of opportunity.
In order to improve the chances of a future gamma-ray astrophysics mission, AHEAD/WP9 is developing tools that enable performance evaluation, for the selection and further development of an instrument concept, based on state of the art technologies, to be proposed for the next generation of gamma-ray observatory.
During the initial phases of AHEAD/WP9, a Science Advisory Group considered the prime scientific questions that might be addressed by a future space mission operating in the energy domain 100 keV – 100 MeV. The group has attempted to identify the most relevant, fundamental astrophysical problems only gamma-ray astronomy would be able solve. Appendix I contains a synopsis of the white paper resulting from these studies; the two top-priorities being *Gamma-Ray Bursts* and *Nuclear Science* (including Stellar Explosions, Low Energy Cosmic-Rays, Positrons). Appendix II is the associated table of requirements, elaborated by the Instrument Working Group.

Proposals

Proposals are limited in length to 2 A4 pages (minimum font size 11 pt), and must contain the following information:

- Proposal title;
- Name and contact information of Lead Proposer;
- Team members (institutions, scientists) insofar as known/available;

- Brief description of the measurement concept; and how the IWG requirements are to be addressed
- Any other relevant information (e.g., mission concept, payload/instruments, orbit).

While the proposals will emphasis instrument concepts, note that the mission category targeted for the study corresponds to a medium-size class mission of the European Space Agency. As an example for the key characteristics of an M mission, you may consult ESA's M5 Call (http://www.cosmos.esa.int/web/call-for-m5-missions).

The call is open to the high-energy astrophysics community at large. Suggestions should be sent to pvb@irap.omp.eu by July 14, 2016.

Proposals will be evaluated by the Instrument Working Group. Two or three mission concepts will be selected for detailed assessment before August 15.

Starting in fall 2016, the selected instrument concepts will be modeled and evaluated within the Simulation Working Group (SWG) of AHEAD/WP9 (laboratories of the SWG are listed in Appendix III). A final report on all studied concept will be made available by the end of 2018.

Those submitting ideas adopted for inclusion in the comparative studies may be invited to join the study team of the WP9 laboratories[1]

[1] Proposers that are not part of AHEAD may apply for support from the AHEAD "Visitor Programme"

Appendix I   Summary of the prioritary science objectives

Gamma-Ray Bursts

Since their serendipitous discovery more than four decades ago, most gamma-ray bursts (GRBs) have been shown to originate at cosmological distances, in the catastrophic death of massive stars. The collapse of a massive star into a black hole releases a huge amount of gravitational energy and surrounding material is accelerated to near the speed of light in a narrow jet, producing the luminous flash of gamma-rays that allows us to see these cosmic lighthouses across much of the observable universe. The nearest GRBs from such 'collapsars' are excellent electromagnetic counterpart candidates to gravitational wave (GW) events. In addition, coalescing binaries, thought to be the progenitors of the 'short' subset of GRBs, are widely viewed as the most promising sources of gravitational waves. The detection and localization of these events is therefore a priority in the new era of gravitational wave astronomy and in the future era of space-based GW measurements.

More in general, because of their huge luminosities (up to > 10^{53} erg radiated in few tens of seconds) emitted by the most relativistic jets known (Lorentz factor $\Gamma > 100$) and their redshift distribution extending up to at least z ~9, GRBs offer enormous potential as powerful probes of the early Universe (evolution of stars, galaxies and the inter-galactic medium up to the epoch of re-ionization, population III stars), as test-beds for fundamental physics (e.g., constraining limits on violations of Lorentz invariance), and as laboratories for matter and radiation under extreme conditions.

Sensitive measurements by next generation gamma-ray experiments, especially if complemented by lower-energy instrumentation, will allow a substantial step forward in these GRB-related research areas, which are of extreme interest for several fields of astrophysics, cosmology and fundamental physics, and will provide an ideal synergy with the large multi-wavelength and multi-messenger facilities that will be operative in the next decade (e.g., eLISA, E-ELT, SKA, CTA, ATHENA, neutrino observatories).

Nuclear Sciences (Stellar Explosions, Low Energy Cosmic-Rays, Positrons)

Gamma-ray line emission in the MeV domain is obtained through the decay/de-excitation of radioactive/stable nuclei, which have been produced/excited by high-energy astrophysical phenomena, like supernova explosions or cosmic rays. They provide unique information on the isotopic identity of the emitters, on the underlying physical processes (e.g. nucleosynthesis, spallation etc.) and on the physical conditions of the - otherwise inaccessible – emitting region. Progress in the field has been slow, being hampered by poor angular resolution (by astronomy standards) and sensitivity limitations, due to large instrumental backgrounds. Despite these drawbacks, the field offers great potential for the study of various high-energy astrophysical processes, concerning a large fraction of the astrophysical community. Three topics of high priority have been identified: the physics of thermonuclear supernovae, the puzzling origin of Galactic positrons and the yet unexplored field of low energy cosmic rays.

Legacy Science topics include

- Pulsars physics (high B fields, testing Lorentz invariance …)
- Extragalactic compact objects: jets, the disk/jet transition, testing Lorentz invariance
- Galactic compact obj / binaries : jets, the disk/jet transition, testing Lorentz invariance
- Nuclear lines from compact objects (neutron capture)
- Dark Matter signatures
- Galactic Centre Physics (central black hole, interaction with surrounding medium)
- High-z AGNs
- Origin of the "Fermi Bubbles"
- MeV extragalactic background / Baryon asymmetry at cosmological distances
- Solar flare physics
- Terrestrial Gamma-Ray Flashes

Appendix II - table of instrument requirements (elaborated by the IWG) a)

	E [MeV]	dE @ [MeV]	FOV [sr]	Angular Resolution	Timing [microsec]	Sensitivity	Realtime alert	polarimetry
GRB need	0.05-3000	<10% at 0.3 MeV	> 2-3 sr (~250 GRBs/yr)	Localization accuracy < 40' (120 GRBs/yr) to < 5' (~20 brightest GRBs/yr)*	< 10	0.05 ph cm^{-2} s^{-1} (peak, 0.2 – 2 MeV, 1s)	yes	MDP ~ 5-10 % (in ~100 GRBs)
GRB extended	0.05 – 2	<10% at 0.3 MeV	> 2-3 sr	Localization accuracy < 40' to < 5'	< 10	$5x10^{-4}$ ph cm^{-2} s^{-1} (1000s from onset, 1000 s duration, 0.2-2MeV)	Yes	MDP ~ 5-10 % (in ~100 GRBs)
GRB afterglow Good to have	0.05 - 1	<10% at 0.3 MeV	<5 arcmin	Angular resolution <1'	-	(Assumptions: brightest 15% GRBs, 12 hrs after events, 10 ks duration, ph cm^{-2} $s^{-1}keV^{-1}$) $1.8x10^{-7}$ (0.1-0.3 MeV)	Yes	MDP ~ 5-10 % (in ~100 GRBs)

Appendix II - table of instrument requirements (elaborated by the IWG) b)

	E [MeV]	dE @ [MeV]	FOV [sr]	Angular Resolution	Timing [μsec]	Sensitivity	Realtime alert
NS SN1a need	0.1 - 2	3%-5%	N/A	N/A	-	3.10^{-7} ph cm^{-2} s^{-1} keV^{-1} (1Ms/ 847 keV, 3 σ cont. sensitivity, line width 35 keV)	N/A
NS SN1a good to have	0.05 - 2	0.3%			-	10^{-7} ph cm^{-2} s^{-1} keV^{-1} (1 Ms / 847 keV) 3 σ cont sensitivity, line width 35 keV) 10^{-7} ph cm^{-2} s^{-1} keV^{-1} (1 Ms / 158 keV, 3 σ cont sensitivity, line width 20 keV)	158 keV line from ^{56}Ni should be observed around the maximum
NS e^+ need	0.3 – 0.8	5%		< 1°		$5 \cdot 10^{-6}$ ph cm^{-2} s^{-1} point source everywhere (all-sky mapping)	
NS e+ good to have	0.1 - 2	0.2%		< 5 '(in GC) diffuse emission at Gal. anti-center		10^{-6} ph cm^{-2} s^{-1} point source 1.6×10^{-4} ph cm^{-2} s^{-1} sr^{-1}	
NS LECR need	0.1 - 10	2% at 5 MeV	>1 sr	1°	-	10^{-4} ph cm^{-2} s^{-1} sr^{-1} @ 3-8 MeV (inner Galaxy)	-
NS LECR good to have	0.1 - 10	1% at 5 MeV		< 1°	-	5 10^{-7} ph cm^{-2} s^{-1} in ~10^{-2} sr @ 3–8 MeV band (Orion A)	-

Appendix III - Working groups of WP9/AHEAD

Science Advisory Group (SAG)

Lorenzo Amati, INAF Bologna; Lorraine Hanlon, UC Dublin; Jordi Isern, CSIC-IEEC Barcelona
Aldo Morselli, INFN Rome; Uwe Oberlack, Uni Mainz; Nicolas Prantzos, IAP Paris
Constancia Providencia, ILL Coimbra; Piero Rosati, INFN Ferrara; Regis Terrier, APC Paris; Peter von Ballmoos, IRAP Toulouse

Instrument Working Group (IWG) of WP9

Ezio Caroli, INAF/IASF-Bologna; Filippo Frontera, INFN Ferrara; Gerry Skinner; Margarida Hernanz, CSIC-IEEC Barcelona; Gottfried Kanbach, MPE Garching; Vincent Tatischeff, CSNSM Orsay; Peter von Ballmoos, IRAP Toulouse

Simulation Working Group (SWG)

Laboratories that will be involved in the modeling the selected instrument concepts include:

IRAP Toulouse, CSNSM Orsay, APC Paris, CEA Saclay, UCD Dublin, CSIC-IEEC Barcelona, INFN Roma Tor Vergata, LIP Coimbra, University of Ferrara