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Requirement Document / Specification (System, Subsystem, Unit, Equipment level)

Athena Science Requirements Document

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	Science Support Office
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APPROVAL

Title Athena Science Requirements Document	
Issue Number 1	**Revision Number** 5
Author David Lumb & J-W den Herder for Athena Science Team	**Date** 12/09/2016
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Note: Many contributions from the Athena Topical Panels, especially coordinated by Arne Rau. All of whom are thanked

CHANGE LOG

Reason for change	Issue Nr.	Revision Number	Date
More precisely defined surface brightness requirement and some typo's	1	5	3/8/2016
Minor update for optical load of the wide field instrument	1	4	28/7/2016
Major update following discussions in the ASST meeting #10 and some further clarifications	1	3	25/7/2016
Updates from Topical Panels Partly responding to request for clarifications from ESA	1	2	1/6/2016
Editorial	1	1	7/3/2016
Major update from ASST	1	0	18/1/2016

CHANGE RECORD

Issue Number 1	**Revision Number** 5		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
TOO Quick Look requirement changed to goal, and previous goal removed		52	
Modified text regarding moving bodies and preferred to remove duplication with 2a_103		51	
Clarify the use of background monitoring when not in focal point		47	
Removed incorrectly duplicated background requirements for focused point source light		46	
Quiescent background conditions changed to 80% of		44	

time for X-IFU			
Quiescent background conditions changed to 60% of time for WFI		43	
Change definition of requirement CTR-R-070 & 080		43	
Changed duplicate numbered requirement		39	
Remove duplicated requirement		35	
Modified requirement at 10keV		34	
Requirement dropped as WFI will not be operated without filter, due to contamination mitigation procedures		32	
Moved X-IFU area requirements to 2a		31	
Removed obsolete requirements on energy range		30	
2a-103: Not core science – leave as a 2b/2c and avoid duplication SCI-POI-G-040	1/6/2015	27	
Data latency requirement retired to 2b/2c level only	1/6/2015	26	
Added new requirement on 0.3keV effective area for X-IFU	1/6/2015	23	
Confirmed a 2sigma formulation for Absolute Pointing Knowledge Accuracy	1/6/2015	22	
Table 7.4 deleted	1/6/2015	19	7
Introductory bullets updated	1/6/2015	13	7
Revision from SWG 3. Merge Requirements 332/325. Update 336	1/6/2016	10-11 Table 6.1	6
Editorial	1/6/2016	6	Introductory text
Major update from ASST	18/1/2016	All	
Issue Number 1	**Revision Number 3**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Specified explicitly which requirements are still subject of further analysis (in addition to the calibration requirements listed in the previous version	25/7/2016	7	4
Specified that surface brightness sensitivity off-axis has been calculated for an area of 220 arcmin2	25/7/2016	21	2a-022
Specified 6 arcsec imaging quality for X-IFU (driven by relavant spatial scales of voids in clusters and/or shocks in e.g. SNR	25/7/2016	22	2a-031
Updated weak line sensitivity to 0.075 eV but this numbers needs to be checked	25/7/2016	23	2a-060
Specified instruments for which relative time accuracy and count rate capability apply	25/7/2016	25	2a-091 and 2a-100
Specified that Aeff calibration accuracy should be 8% (TBC)	25/7/2016	33	SCI-EA-R-140
Changed defocussing goal into a defocussing requirement	25/7/2016	35	SCI-ANR-R-012

Specified 1% deadtime knowledge accuracy for high spectral resolution instrument	25/7/2016	38	SCI-TMR-R-050
Introduced requirements for particle diverter (protons only)	25/7/2016	43	SCI-BCK-R-070, 080
Updated requirements for X-ray backgrounds and straylight baffle	25/7/2016	43	SCI-BCK-R-110, 120, 130
Issue Number 1	Revision Number 4		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Provided a consistent definition of the need for optical suppression in the wide field imager instrument (transferred from level 2a to a level 2c requirement	28/7/2016	26	Level 2a-102: optical brightness and SCI-BKG-R-170
Issue Number 1	Revision Number 5		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Clarified some inconsistencies between table 7.1 and the listed requirements: S/N for velocities is 5, relative flux calibration between 0.5-2 and 2-10, and defined optical load (instead of other)	8/9/2016	17	7.1
Corrected units and values for the GRASP requirement	8/9/2016	20	2a-011 and 2a-012
Updated surface brightness requirments (STILL OPEN)	8/9/2016	21	2a-020, 21, 22, 23
Corrected positional accuracy requirement (1 arcsec/3 sigma)	8/9/2016	22	2a-030

DISTRIBUTION

Name/Organisational Unit

Table of contents:

1 ACRONYMS

ADC	Analogue to Digital Conversion
AGN	Active Galactic Nucle(us)i
BH	Black Hole
DDF	Design Definition File
DJF	Design Justification File
EoS	Equation of State
FOV	Field of View
FRII	Faranoff-Riley - class II radio galaxy
FWHM	Full Width at Half Maximum
GRB	Gamma Ray Burst
HEW	Half Energy Width
ICM	Inter Cluster Medium
IMF	Initial Mass Function
ISM	Interstellar Medium
L_{bol}	Bolometric Luminosity
L_{edd}	Eddington Luminosity
MOP	Mock Observing Plan
NS	Neutron Star
PSF	Point Spread Function
QSO	Quasi-Stellar Object
R_{500}	Radius where density =500x critical
SMBH	Supermassive Black Hole
SN	Supernova
TBC	To Be Confirmed
TBD	To Be Determined
TDB	Barycentric Dynamical Time
TDE	Tidal Disruption Events
TOO	Target Of Opportunity
ULX	Ultra-Luminous X-ray Source
UTC	Coordinated Universal Time
WFI	Wide Field Imager
WHIM	Warm-Hot Intergalactic Medium
XDIN	X-ray Dim Isolated Neutron Star
XIFU	X-ray Integral Field Unit

2 REFERENCE DOCUMENTS

[RD1]	2013arXiv1306.2307N	June 2013	The Hot and Energetic Universe: A White Paper presenting the science theme motivating the Athena+ mission and all references to the supporting white papers
[RD2]	n/a	April 2014	Athena: the Advanced Telescope for High Energy Astrophysics (mission proposal to

			ESA)
[RD3]	http://sci.esa.int/ssc_report	October 2013	Report of the senior survey committee on the selection of the science themes for the L2 and L3 Launch opportunities in the cosmic vision programme
[RD4]	n/a	15 May 2015	Athena Science Impact Assessment
[RD5]	ECAP-ATHENA_WFI-RSP20150326	26 March 2015	Athena WFI response files
[RD6]	ECAP-ATHENA-XIFU-RSP20150327	27 March 2015	Athena X-IFU response files
[RD7]	SWG1.2-TN-0003	25 October 2015	the effect of the WFI background on Athena measurements in cluster outskirts
[RD8]	WFI-BSR-04-draft	21 May 2015	Bright source Performance of the Athena WFI

3 APPLICABLE DOCUMENT

[AD1]	Strawman_obsplan_athena	V2.0.x	Excel table with strawman observation plan

4 INTRODUCTION

In this Science Requirements Document the top level goals as described in the Hot and Energetic Universe White Paper [RD1] amended by the recommendations of the Senior Survey Committee [RD3] are translated into quantified science objectives (level 1). These science objectives are subsequently converted into mission requirements (level 2a) that are largely independent of the actual mission concept. These are than translated into level 2b requirements that are specific for the proposed mission concept. Additional mission requirements which are not related to the level 1 science objectives are defined as level 2c. It should be noted that different implementations for a level 2a requirement could be realized (e.g. the same point source sensitivity can be achieved by a different combination of effective area, angular resolution, particle induced background, and observing time).

In the current version of the SciRD we provide:

- *consolidated science goals* (L0)

- *science objectives* (L1) including required accuracies and sample sizes

- *science requirements* (level 2a) are performance specifications to achieve the science given in the L1 objectives without specifying the actual mission concept (e.g. sensitivities are given but not how they are achieved).

- *derived science requirements* (level 2b/2c). This list is largely dependent on the selected implementation of the mission in the mission proposal [RD2]. Level 2b follow directly from the level 2a. Level 2c is added to have top level reference requirements for non driving parameters which are not directly following from level 2a (e.g raster scan where an area is given for reference).

Some outstanding issues were identified which have not yet been resolved (but have no or limited effect on the system design of the mission). Apart of some parameters which need firm confirmation (given as (TBC) the key issues include:

- Calibration accuracy requirements are under study. Any values provided herein should be taken as initial estimates.
- The angular resolution of the X-IFU, which is the spectroscopic instrument and is not primarily used for the survey, does not need to be 5 arcsec (level 2a-030). Detailed studies about typical source scale variations need to be completed.
- The weak line sensitivity of the X-IFU is currently being studied (mostly relevant for the detection of the WHIM) and the effects of systematical errors on this parameter is being investigated (level 2a_060)
- The countrate capability of the X-IFU for 30% of the counts for a 1 Crab source with 30 eV resolution needs a full scientific justification considering the capability of the WFI as well (SCI-CTR-R-060)
- The countrate capability of the X-IFU for extended sources (SCI-CTR-080) needs confirmation
- The performance of the particle diverter (SCI-BCK-070/080) can only be confirmed once the characterization of the background in the Athena orbit is sufficiently characterized (ongoing study)

5 LEVEL 0 REQUIREMENTS

The level 0 requirements are based on the “Hot and Energetic Universe” White Paper [RD1], the report of the Senior Survey Committee[RD3] and the Athena Mission Proposal [RD2] and are summarized in Table 5-1.

Top level goal	Definition
The Hot Universe:	Determine how and when large-scale hot gas structures formed in the Universe and track their evolution from the formation epoch to the present day.
The Energetic Universe:	Perform a complete census of black hole growth in the Universe, determine the physical processes responsible for that growth and its influence on larger scales, and trace these and other energetic and transient phenomena to the earliest cosmic epochs.
Observatory and Discovery Science:	Provide a unique contribution to astrophysics in the 2030s by exploring high energy phenomena in all astrophysical contexts, including those yet to be discovered.

Table 5-1 Level 0 Requirements (top level scientific goals)

6 LEVEL 1 REQUIREMENTS

The science objectives (level 1 requirements) are given in the White Paper for the hot and energetic Universe [RD1] and in the mission proposal [RD2] and listed in the Table 6-1 below. Compared with the white paper and the mission proposal the listed science requirements are, where possible, quantified and use homogeneous sample sizes:

- *All results, detections etc. are to be established at the 5σ level, or equivalent*
- *A minimum of 10 objects per bin is required, when splitting samples as a function of parameters such as redshift or luminosity*
- *A minimum of 25 objects is required when attempting to establish a trend within a sample ag*ainst a given parameter (e.g. luminosity, redshift, mass)

It should be noted, however, that for good reasons not in all cases these guidelines are followed: (a) the number of solar system bodies is limited, (b) the number of desired WHIM filaments defines the number of systems to be measured in absorption and (c) only for a fraction of this follow up measurements in emission makes sense. This applies to more science objectives.

Table 6-1 Athena Science Objectives

reference and short description	Requirement (science objective)	Quantification
The Hot Universe		
R-SCIOBJ-111 First groups	Athena shall find the first building blocks of the dark matter structure filled with hot gas by detecting 25 evolved groups of galaxies at z>2 with M_{500}>5 x 10^{13} M_{sun} and determine the gas temperature of a representative sample. At least five groups are expected at z>2.5.	25 galaxy groups with gas temperature at z>2 to investigate L-T relation.
R-SCIOBJ-112 Cluster bulk motions and turbulence	Athena shall measure how gravitational energy is dissipated into bulk motions and gas turbulence in the galaxy cluster population, by achieving a 5 sigma detection of these quantities.	Kinetic energy dissipated from gravitational assembly in 10 regular & 10 irregular galaxy clusters in the nearby Universe.
R-SCIOBJ-121 Cluster entropy profile evolution	Athena shall determine which physical processes dominate the injection of non-gravitational energy into the intra-cluster medium as a function of cosmic epoch by measuring the structural properties (e.g., the entropy profiles) of galaxy groups and clusters. To differentiate between models of feedback and gas accretion, these measurements shall be achieved to the virial radius in local clusters and out to R500 up to z~2, with an uncertainty <25% (at R500 at z=2). Athena shall also measure the evolution of the scaling relations between bulk properties of the hot gas (e.g., the Lx-T relation) out to at least a redshift of 2, to a precision of <25%.	Cosmic history of the injection of entropy in cluster hot gas at 0<z<2. Investigate 10 clusters in each of 4 redshift bins and 3 mass bins (total 120 clusters).
R-SCIOBJ-122 Cluster chemical evolution	Athena shall constrain SN yields by measuring the abundances and distribution of rarer metals (e.g., Al, Cl, Mn, Co) in the cluster core, and more abundant metals (e.g., O, Si, Fe) to the virial radius, in local objects (5 σ detection). In distant clusters, Athena shall constrain the SNIa/SNcc ratio via relative abundances of more abundant metals (i.e., O, Si, Fe), and study their evolution in redshift and mass, as well as differences between distributions in core and up to ~R500 (5 σ detection).	Metal production and dispersal in cluster hot gas out to z=2. Observe 10 local clusters and 10 clusters per redshift bin per mass bin out to z~2. Total 100 clusters.

R-SCIOBJ-131 Physics of cluster feedback	Athena shall measure the energy stored dynamically and thermally in the hot gas around the bubbles in a well defined sample of clusters, by measuring bulk motions and turbulence to 5-sigma, determining their relation to cluster and AGN properties (e.g. morphology, mass, X-ray luminosity and jet power), and for a sample of strong feedback systems shall determine the expansion speed of the shocked gas via spatially resolved line profiles and/or determine the locations of energy dissipation by measuring thermodynamical properties to 5-sigma on 10-kpc scales.	Bulk motions in 25 cluster cores with AGN, 10 of them mapped in detail to explore microphysics.
R-SCIOBJ-132 Feedback-induced cluster ripples	Athena shall determine the occurrence and impact of AGN feedback phenomena, and their relation to cluster and AGN properties, by detecting at 5σ at least 2 ripples in surface brightness produced by such mechanisms, and where possible measuring associated temperature changes, for a volume-limited sample spanning a range of spatial scales, AGN and cluster properties.	Detection of ripples in cluster gas created by AGN jet activity, in a sample of 25 clusters.
R-SCIOBJ-133 Heating/cooling balance in cluster feedback	Athena shall determine whether the rate of plasma cooling through X-ray temperatures is sufficient to fuel the AGN that are apparently stabilizing hot atmospheres by using temperature-sensitive line ratios to measure these rates over a broad temperature range in the cores of a sample of extreme cluster cores with the strongest feedback requirements, and in a sample of representative clusters to determine how these rates vary as a function of mass, temperature, dynamical state and AGN power.	Heating-cooling balance in hot gas of 10 cluster cooling cores.
R-SCIOBJ-134 Shock speeds of radio lobes in clusters	Athena shall determine the shock speeds of expanding radio lobes in a well-defined sample of FRII radio galaxies spanning 3 orders of magnitude in radio luminosity and an order of magnitude in source size, by distinguishing the gas temperature in shocked and undisturbed regions to >3σ level, to determine the population-wide impact and evolution of jet feedback in poor environments.	Shock speeds of expanding radio lobes in 10 clusters around radio galaxies for 2 source size and 2 radio power bins[1].
R-SCIOBJ-141 Missing Baryons	Athena shall measure the local cosmological baryon density in the WHIM to better than 10% and constrain structure formation models in the low-density regime by measuring the redshift distribution and physical parameters of 200 filaments against bright background sources, selected to probe various cosmic densities; and by performing a statistical analysis of the emission lines of heavy elements in a representative sky region and high-probability targets.	Detect 200 WHIM filaments in absorption, 150 towards BLLacs and 50 towards bright GRB afterglows to sample the WHIM up to z=1. Determine metal abundances from emission lines in targeted regions.
R-SCIOBJ-142 WHIM in emission	Athena shall detect WHIM filaments in emission associated to absorption detected against 15 GRBs, after they faded away.	Detect emission of WHIM filaments associated with systems detected in absorption detected against 15 GRB afterglows.
Energetic Universe		
R-SCIOBJ-211 High redshift SMBH	Athena shall determine the nature of the seeds of the earliest growing SMBH (z>6), characterize the processes that dominated their early growth and investigate the influence of accreting SMBH on the formation of galaxies. Populate the L_X-z plane at high redshift, specifically: identify > 400 AGN at z>6.	Detect 10 AGN with $10^{43.0} < L_x < 10^{43.5}$ erg/s at z=6-8 and 10 AGN with $10^{44.0} < L_x < 10^{44.5}$ erg/s at z=8-10. Constrain SMBH seeds.

[1] The 178 MHz radio luminosity is 5 10^{24} – 10^{27} $WHz^{-1}sr^{-1}$ with a boundary of 3 10^{25} $WHz^{-1}sr^{-1}$ and the range in the source size is 50 – 1000 kpc with a boundary at 350 kpc giving equal numbers (but this will be updated based on future surveys)

R-SCIOBJ-221 Complete AGN census	Athena shall determine the accretion energy density in the Universe, by measuring the X-ray luminosity function and obscuration properties of the AGN population with at least 10 Compton thick AGN per luminosity bin (0.5dex) and redshift bins (Δz=1) up to redshift z~3.5.	Spectral characterization of at least 10 Compton-Thick AGN with $10^{44.4}<L_x<10^{44.9}$ erg/s per unit z at z~3. Map obscured AGN/galaxy co-evolution.
R-SCIOBJ-222 Census of AGN outflows at z=1-4	Athena shall determine the incidence of strong and ionized absorbers, implying the presence of outflows, among the population of luminous AGN from z=1 to z=4.	Detect at least 10 warm absorbers in AGN with $10^{44}<L_x<10^{44.5}$ at z=1-4.
R-SCIOBJ-223 Mechanical energy of AGN outflows at z=1-3	Athena shall measure the mechanical energy of moderately ionized outflows in $L_X>L^*$ AGN at z=1-3.0, spanning a broad range of column densities and ionization parameters.	Measure the mechanical energy of outflows in luminous AGN at z=1-3, 10 per 3 luminosity bins and per 2 redshift bin of Δz=1 .
R-SCIOBJ-224 Ultra-fast outflows at z=1-4	Athena shall determine the incidence, duty cycle and energetics of transient Ultra-Fast Outflows (UFOs) in QSOs from z=1 to z=4.	Frequency and mechanical energy of UFOs at z=1-4.
R-SCIOBJ-231 AGN outflows in local Universe	Athena shall measure the kinetic energy in nearby AGN outflows and understand how accretion disks around SMBH launch winds and outflows.	Wind energetics in 25 nearby AGN out of 70. Wind launch physics from time resolved spectroscopy of 10 AGN.
R-SCIOBJ-232 Feedback in local AGN and star forming galaxies	Athena shall probe directly the interaction of winds from AGN and star-formation with their surroundings in local galaxies, to understand how the gas, metals and energy accelerated by winds are transferred into the circum-galactic medium, and to form a template for understanding AGN/starburst feedback at higher z.	Gas, metal and energy output from AGN and Starbursts in 25 (U)LIRGs with a variety of AGN/Starburst ratios.
R-SCIOBJ-241 AGN reverberation mapping	Athena shall determine the geometry of the hot corona-accretion disk system and constrain the origin of the hot corona in AGN.	Reverberation mapping of 8 bright local AGN with established lags.
R-SCIOBJ-242 AGN spin census	Athena shall determine the SMBH spin distribution in the local Universe as a probe of the growth process (mergers versus accretion, chaotic versus standard accretion).	Spin distribution (histogram) of 30 nearby SMBH.
R-SCIOBJ-251 GBH and NS spins and winds	Athena shall measure black hole spins of Galactic Black Holes (GBH) and Neutron Stars to provide insight into black hole birth events (GRBs and/or SN) that set stellar-mass black hole spins, and to study the relationship between accretion and outflows (winds and jets).	(a) Measure spins of 10 Galactic BHs and 10 NS through various methods and probe their accretion geometry and jet properties through reverberation mapping. (b) Measure winds in the same 10 Galactic BHs and 10 NS.
R-SCIOBJ-252 ULXs and SgrA*	Athena shall probe the characteristics of accretion at the extremes of L_{bol}/L_{Edd} through observations of ULXs (high accretion rate) and Sgr A* (low accretion rate) in order to determine the relationship between accretion and outflows in black hole systems across a broad scale of mass and luminosity, and to quantify the impact of accretion-driven outflows on the energy input into the surrounding ISM/IGM.	Accretion properties of 3 luminosity bins of 10 ULXs and monitor of the SgrA* environment.
R-SCIOBJ-261 High z GRBs	Athena shall probe the first generation of stars, the formation of the first black holes, the dissemination of the first metals and the primordial IMF. Determine the elemental abundances of the medium around high-z GRBs by deriving relative elemental abundances distinctive of primeval (Pop III) explosions versus evolved stellar populations in the spectrum of GRB afterglows.	Probe ISM of z>7 galaxies by ToO observations of 25 GRB afterglows.

R-SCIOBJ-262 TDEs	Athena shall study the nature of stellar disruption and the subsequent surge in accretion onto SMBHs during TDEs in order to probe the dynamics of tidal shearing in the proximity of the event horizon, characterize the orbital and physical evolution of the debris, probe the likelihood of disruption for a given stellar population, and gain insight into the effects of rapid accretion rate changes in AGN systems.	Probe 10 TDEs by ToO observations.

In the section of the table for the Observatory science the expected sample size for the MOP is usually excluded as this will be decided closer to the mission launch. In the description of the MOP some sample sizes, based on our current understanding will be used.

Observatory science		
R-SCIOBJ-311 Planetary X-ray spectroscopy	Athena shall establish how planetary magnetospheres and exospheres, and comets, respond to solar activity and to the interaction with the solar wind by spectral mapping of Jupiter atmosphere, of the Io Plasma Torus, of Mars' exosphere and from comets and by obtaining fluorescence spectra of Galilean Satellites for surface composition analyses. Athena shall search for evidence of X-ray aurorae on Saturn and for X-ray emission from Uranus and Neptune.	Auroral and exosphere X-ray emissions of solar system bodies (planets and moons) and cometary tails & their interaction with Solar Wind.
R-SCIOBJ-312 Stellar activity in exoplanet systems	Athena shall measure the magnetic interplay between stars and exo-planets in X-rays by measuring X-ray spectral variability over the activity cycle of the host star and over the planet's orbital period.	Effects of stellar magnetic activity of exo-planets through repeated observations through their orbits.
R-SCIOBJ-322 Colliding winds in binaries	Athena shall map the hot gas distribution in the wind interaction zone of binary systems where the winds from both components collide by phase-resolved spectroscopy.	Wind interactions in binaries through phase-resolved spectroscopy in 10 massive binaries.
R-SCIOBJ-323 Magnetospheric accretion in low mass stars	Athena shall measure magnetospheric accretion onto the photosphere and corona of young low-mass stars and brown dwarfs both in the field and selected star-forming regions by measuring time-series of high-resolution spectra to probe line-intensity variability from the accretion shock and post-shock plasmas, and the stellar corona.	Magnetospheric phenomena and/or accretion in nearby field M Stars, late-type PMS stars and BDs, and magnetospheric accretion phenomena and circumstellar disk interactions in YSOs in selected nearby SFRs.
R-SCIOBJ-324 Magnetic activity in ultra-cool dwarfs	Athena shall measure magnetic activity in late M stars and ultra-cool dwarf stars by monitoring their X-ray luminosity and temperature and during flares.	Magnetic activity in ultra-cool dwarf stars.
R-SCIOBJ-325 Mass loss in massive stars	Athena shall determine the geometry, porosity and mass-loss rate of stellar winds of isolated massive stars, especially in the presence of magnetic fields, for a sample of Galactic massive stars. Time resolved spectral analysis of X-ray emission from a sample of high mass X-ray binaries hosting supergiant and hyper-giant companions will yield independent estimates of massive star wind properties	Characterize the mass-loss and winds in a sample of early type stars and in HMXBs.
	Athena shall also study the metallicity dependence of stellar wind mass-loss via the observation of X-ray emission from populations of massive stars in galaxies of the Local Group.	Measure the X-ray spectra of selected OB associations (each containing at least 10 massive stars) in 3 different Local Group galaxies with different metallicities.
R-SCIOBJ-331 EoS of ultradense matter	Athena shall constrain the equation of state of neutron stars by obtaining X-ray spectra of quiescent low mass X-ray binaries with a good distance estimate.	Equation of state of dense matter from observations of LMXBs.

R-SCIOBJ-333 Masses of accreting white dwarfs	Athena shall determine the mass of accreting white dwarfs in cataclysmic binaries of different kinds within 15% accuracy, resolve their accretion regions to probe the magneto-ionospheric or inner disk interaction regions, and constrain processes of energy release (e.g. hydrodynamic accretion models).	Determine mass of accreting white dwarfs.
R-SCIOBJ-334 magnetars	Athena shall constrain the geometry of the magnetar and XDINs surface magnetic field by detecting energy and phase-dependent proton cyclotron lines, together with their harmonics, resulting from resonant scattering of the neutron star emission in the presence of magnetic structures close to its surface.	Characterize geometry of magnetars and XDINs.
S-SCIOBJ-335 PWN	Athena shall constrain transport and particle acceleration mechanisms and the magnetization of ultra-relativistic plasmas, together with the progenitors and energetics of supernova explosions making pulsar-wind nebulae, through observations of extended and relatively bright PWNe.	Constrain particle acceleration by the study of PWN.
S-SCIOBJ-336 Novae	Athena shall measure the chemical composition of Novae ejecta, testing SN type Ia progenitor scenarios via the single-degenerate channel and determining the corresponding chemical enrichment of the Galaxy. Athena shall further determine high-resolution spectra of the faint, soft, diffuse X-ray emission from planetary nebulae (PNe) to accurately determine their interior plasma abundances and temperatures, and to constrain the wind interaction processes that generate PNe hot bubbles.	Observe 3 novae going off during Athena mission.
S-SCIOBJ-337 double degenerate binaries	Athena shall test different evolutionary scenarios for double degenerate binaries and identify the most promising gravitational wave sources and Type Ia Supernova progenitors among these systems.	Observe double degenerate systems and one type 1A supernova at distance < 25 Mpc.
R-SCIOBJ-338 SN	Athena shall gain insight in BH birth through observations of Supernovae.	BH birth through 10 SN.
R-SCIOBJ-341 Chemistry of the cold ISM	Athena shall determine the chemistry of the cold interstellar medium through X-IFU observation of X-ray-absorption fine-structure features due to absorption by interstellar matter.	Chemical composition of cold ISM through absorption spectroscopy.
R-SCIOBJ-342 Dust scattering haloes	Athena shall constrain dust models from the dust size distribution and dust composition through imaging and spectroscopy of dust scattering halos.	Dust models and particle distribution through scattering halos.
R-SCIOBJ-343 Physics of the warm and hot ISM	Athena shall determine the chemical composition, the heating and the dynamics of the warm and hot gas of the interstellar medium in the Milky Way and nearby galaxies.	Characterize warm and hot ISM in the Galaxy and nearby galaxies.
R-SCIOBJ-344 Mapping of SNR	Athena shall constrain SN1a and core-collapse explosion models and the shock dynamics by 3d determination of kinematics, ionisation state and abundances of young galactic supernova remnants. .	3D mapping of SNR from SN1a and core-collapse SN.
R-SCIOBJ-351 SgrA*	Athena shall determine the origin of the emission from SgrA*, and understand its interactions with its surrounding Galactic Center regions	Characterization of the quiescent diffuse emission from SgrA*, the non-thermal flares and the X-ray reflection nebulae surrounding the Galactic Center

R-SCIOBJ-399 Discovery Science	The Athena mission shall make available an additional observing time beyond that needed for the above goals to enable proposer-driven observations of high energy phenomena which can not currently be formulated, because e.g. they are based on new discoveries by future multi-wavelength or multi-messenger facilities, or Athena itself.	Athena should be able to respond to scientific challenges triggered by new developments, including new multi-wavelength or other messenger observations.

7 LEVEL 2A REQUIREMENTS

Based on these science cases level 2a requirements have been defined. Clearly some of the science objectives have driven these requirements and these can be summarized as follows:

- *Point source sensitivity (on and off-axis)*: the required point sensitivity requirement is largely driven by the desire to measure the injection of entropy in cluster hot gas up to R_{500} and the detection of high redshift AGNs in the survey using the wide field imaging capability of Athena.

- *Effective area*: this impacts on sensitivity but is driven directly by the need to collect sufficient photons in a given integration time. For GRBs - also used as backlight for the WHIM studies - the integration time is directly related to the expected elapsed time between the trigger and the moment of data acquisition (with the X-IFU), so the signal-to-noise ratio for a given GRB flux then depends only on the effective area. In other cases the requirement is to measure time variations on a fixed timescale related to the properties of the source (reverberation mapping, accretion phenomena, nearby M stars).

- *Spatial Resolution:* this also impacts strongly on point source sensitivity but is also required to separate source features e.g. cavities, shocks and ripples in clusters of galaxies.

- *Spectral resolution and energy scale accuracy*: this is largely driven by the ability to measure velocities and velocity broadening with the high spectral resolution instrument. These include bulk motions in clusters of galaxies, wind energetics in nearby AGN.

- *The Target of Opportunity time*: this is mostly driven by the need to collect sufficient photons for fading events such as GRBs as backlight for the WHIM and high red-shift GRBs. Clearly some other science (TDE, SN) will also benefit from a fast response time.

- *Count rate capability and time resolution:* required to make observations of the brightest sources, for example for reverberation mapping and spin determination of bright X-ray binaries.

- *Weak line sensitivity*: depends on energy resolution, effective area and the requirements are driven by WHIM, metallicity studies (rare elements)

In the subsequent sections we provide the level 2a definitions, a reference to the appropriate table and the dependencies between the level 2a and level 2b requirements (where relevant for optimizations of the mission design). Note that calibration requirements are tentative

7.1 Level 2a definitions:

In this section we give the definition of the level 2a requirements including the relevant units

Table 7-1 Definitions for science requirements parameters

Requirement number	Parameter	Definition	Units
2a-001	point source sensitivity on axis (0.5-2 keV)	0.5-2 keV flux of point source detectable at 5 sigma in 100 ks (or 450 ks if specified)	erg/cm²/s
2a-003	point source sensitivity at 15 arcmin radius (0.5-2 keV)	0.5-2 keV flux of point source detectable at 5 sigma in 100 ks at a radius of 15 arcmin	erg/cm²/s
2a-010	survey speed	solid angle in 100 ks down to 2 x point source sensitivity	arcmin²
2a-011	GRASP at 1 keV	effective area times solid angle at 1 keV over full detector	m²deg²
2a-012	GRASP at 7 keV	effective area times solid angle at 7 keV over full detector	m²deg²
2a-020	surface brightness sensitivity on axis (0.5-2 keV)	0.5-2 keV flux per arcmin² detectable in 100 ks (5 sigma)	erg/cm²/s/arcmin²
2a-021	surface brightness sensitivity on axis (5-7 keV)	5-7 keV flux per arcmin² detectable in 100 ks (5 sigma)	erg/cm²/s/arcmin²
2a-022	surface brightness sensitivity at a given off-axis angle position (0.5-2 keV)	0.5-2 keV flux per arcmin2 detectable in 100 ks (5 sigma) at a radius of ~ 20 arcmin	erg/cm²/s/arcmin²
2a-023	surface brightness sensitivity at a given off-axis angle position (5-7 keV)	5-7 keV flux per arcmin2 detectable in 100 ks (5 sigma) at a radius of ~ 20 arcmin	erg/cm²/s/arcmin²
2a-030	positional accuracy	absolute positional error after reconstruction (3 sigma)	arcsec
2a-031	angular resolution	HEW for 0.5 - 2 keV	arcsec
2a-040	effective area at 1 keV	On axis effective area (telescope + instruments)	m²
2a-041	effective area at 7 keV	On axis effective area (telescope + instruments)	m²
2a-043	effective area at 0,3 keV	On axis effective area (telescope + instruments)	m²
2a-042	effective area at 10 keV	On axis effective area (telescope + instruments)	m²
2a-050	velocity resolution at 1 keV	error on turbulent velocity for a bright line (S/N >5)	km/s
2a-051	velocity resolution at 7 keV	error on turbulent velocity for a bright line (S/N >5)	km/s
2a-052	energy scale accuracy	Accuracy with which an energy can be reconstructed	eV
2a-060	weak line sensitivity at 1 keV	5 σ detectable equivalent width of unresolved emission/ absorption line at 1 keV against bright continuum	EW in eV
2a-061	weak line sensitivity at high energy (>7 keV)	5 σ detectable equivalent width of an unresolved emission or absorption line at indicated high energy against a bright continuum	EW in eV
2a-070	ToO trigger efficiency	Fraction of the time that a ToO trigger in a random position of the sky results in a successful X-IFU	Fraction

		observation.	
2a-071	ToO fluence capability at high spectral resolution	Minimum fluence to be measured by X-IFU in a GRB ToO observation.	erg/cm²
2a-080	absolute temperature calibration	Accuracy of temperature measurements from X-ray spectra	Percentage
2a-081	absolute flux calibration uncertainty	Maximum on-axis calibration error (rms) in 0.5-2 keV and 2-10 keV	Percentage
2a-082	relative flux uncertainty as function of energy	Maximum on-axis relative calibration error (rms) in 0.5 – 2 keV and 2-10 keV energy bands	Percentage
2a-090	absolute time accuracy	Maximum difference of internal clock with respect to universal system	Microsec
2a-091	relative time accuracy	Maximum rms internal clock error to detected events	Microsec
2a-100	countrate capability	Maximum countrate in an instrument where science goals can be achieved	erg/cm²/s
2a-102	optical load	Maximum visible magnitude that can be observed with no more than 10% energy resolution degradation at 7keV	m_v

7.2 Level 2a performance parameters dependencies

In this section we summarize the relations between level 2a requirements and level 2b requirements where relevant

Table 7-2 Definition of science parameters

Parameter	Definition
SNR	Signal-to-noise ratio
A_{eff}	Effective area (cm²)
t	Exposure time (s)
B_c	Background counts spectrum (counts keV^{-1})
b	Background counts per solid angle (counts arcmin^{-2})
p	PSF area or beam (arcmin²)
FOV	Field of view (arcmin^{-2})
Ω	Solid angle (arcmin^{-2})
F_b	Background surface brightness (erg cm^{-2} s^{-1} arcmin^{-2})
F_c	Continuum surface brightness (erg cm^{-2} s^{-1} arcmin^{-2})
E_{ph}	Line photon energy (keV)
c	Speed of Light (cm s^{-1})
σ	Turbulent velocity R.M.S. (km s^{-1})
$\Delta\sigma_{sys}$	Systematic limit of turbulent velocity (km s^{-1})
F_p	Point source sensitivity
ΔE	Energy resolution
δE	energy scale accuracy

Table 7-3 dependencies of level 2a requirements

Parameter	Units	Relation
Point source sensitivity (F_p)	erg/cm²/s in 100 ks	$F_p = 1.602 \cdot 10^{-9} \bar{E} \frac{SNR^2}{2A_{eff}t}\left(1+\sqrt{1+\frac{4bp}{SNR^2}}\right)$, where $b = \int_{0.5keV}^{2.0keV} B_c(E)dE$ is the number of background counts. $\bar{E}$ is the average energy in the spectrum. For the 0.5-2.0 keV band ~1keV is a reasonable number.
Survey speed (S_s)	arcmin² in 100 ks	$S_s = FOV\left(\frac{100ks \times A_{eff}F_p}{SNR^2}\right)\left(\frac{1}{1+\sqrt{1+\frac{4bp}{SNR^2}}}\right)\left(\frac{1}{1.602 \cdot 10^{-9}\bar{E}}\right)$ $b = \int_{0.5keV}^{2.0keV} B_c(E)dE$ is the number of background counts
GRASP	m²deg²	$G = A_{eff@1keV} \times FOV$ (Note: units are m² and deg²)
Surface brightness	erg/cm²/s/ arcmin²	$F_s = 1.602 \cdot 10^{-9} \bar{E} \frac{SNR^2}{2A_{eff}t\Omega}\left(1+\sqrt{1+\frac{4b_s}{SNR^2}}\right)$, where $b_s = \frac{\int_{0.5keV}^{2.0keV} B_c(E)dE}{\Omega}$
Spectral line sensitivity (1 and 6 keV)	erg cm⁻² s⁻¹ arcmin⁻²	$F_l = 1.602 \cdot 10^{-9} E_{ph} \frac{SNR^2}{2At\Omega}\left(1+\sqrt{1+\frac{4At\Omega}{SNR^2}\Delta E\left(F_c+F_b\right)}\right)$
Velocity resolution (1 or 7 keV)	km/s	$\Delta v \cong c\frac{\Delta E}{E}$
Energy scale accuracy	eV	$\delta v = c\frac{\delta E}{E}$

The level 2a requirements below describe the science performance of the mission without assuming a particular realisation of the mission. They are directly related to the level 1 requirements. (see separate excel file). For each requirement below, if a parent requirement is identified as particularly driving, the number is highlighted in red.

2a-001 Point source sensitivity (On-axis)

	Value	Units	Condition or Instrument	Parent Requirements
Definition	0.5-2 keV flux of point source detectable at 5 sigma			
Requirement	**$2.4\ 10^{-17}$ in 450 ks** **10^{-15} in 100 ks**	**erg cm^{-2} s^{-1}**	In WFI In X-IFU	111, 112, 121, 122, 134, 211, 323, 324, 325

Comments: 5 σ is set for homogeneity across all Athena objectives. The exposure time of 100 ks is a reasonable reference value but can vary from observation to observation

2a-003 Point source sensitivity (Off-axis)

	Value	Units	Condition or Instrument	Parent Requirements
Definition	0.5-2 keV flux of point source detectable at 5 sigma at a field radius of 15 arcmin			
Requirement	**$2.4\ 10^{-17}$ in 450 ks** **$7.2\ 10^{-17}$ in 80 ks**	**erg cm^{-2} s^{-1}**	In WFI	111, 122, 211, 221, 222, 224

Comments: Reference angle ensures the definition covers at least half the available solid angle, and a large proportion of PSF variation with field angle. The reference observing times chosen as representative for wide field survey strategies.

2a-010 Survey Speed

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Solid angle covered down to 2 x point source sensitivity in 100 ks			
Requirement	**1000**	**$arcmin^2$**	In WFI	111, 112, 121, 122, 211, 323

Comments: the numbers are representative for a reasonably efficient observing program

2a-011 Grasp at 1 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	integrated area times solid angle at 1 keV over full detector			
Requirement	**0.32** **0.0025**	**m^2 deg^2**	In WFI at 1 keV In X-IFU at 1 keV	111, 142, 221, 222, 224

2a-012 Grasp at 7 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	integrated area times solid angle at 1 keV over full detector			
Requirement	**0.014** **0.0025**	**m^2 deg^2**	In WFI at 7 keV In X-IFU at 7 keV	111, 142, 221, 222, 224

2a-020 Surface brightness sensitivity on axis

	Value	Units	Condition or Instrument	Parent Requirements
Definition	0.5-2 keV flux per $arcmin^2$ detectable in 100 ks (5 sigma)			
Requirement	**X.X 10^{-16} (integrated over circle with 5amin radius)** **XX (TBD) Integrated over an circular area with $1amin^2$)** **10^{-15} (TBC)**	**erg cm^{-2} s^{-1} $arcmin^{-2}$**	In WFI 0.5-2 keV In WFI 0.5-2 keV In X-IFU 0.5-2 keV	121, 122, 132, 134, 232, 342, 343

There are two different requirements for the WFI as the surface brightness sensitivity is related to the knowledge of the background which is different when integrated over a different regions.

2a-021 Surface brightness sensitivity on axis

	Value	Units	Condition or Instrument	Parent Requirements
Definition	5- 7 keV flux per $arcmin^2$ detectable in 100 ks (5 sigma)			
Requirement	**X.X 10^{-16} (integrated over circle with 5arcmin radius)** **XX (TBD) Integrated over an circular area with $1arcmin^2$)**	**erg cm^{-2} s^{-1} $arcmin^{-2}$**	In WFI 5 - 7 keV In WFI 5 - 7 keV	121, 122, 132, 134, 232, 342, 343

2a-022 Surface brightness sensitivity off axis

	Value	Units	Condition or Instrument	Parent Requirements
Definition	0.5-2 keV flux per $arcmin^2$ detectable in 100 ks (5 sigma)			
Requirement	**2.4 10^{-16}**	**erg cm^{-2} s^{-1}**	In WFI 0.5-2 keV	121, 122,

	(integrated over an annulus with inner radius of 17.77 arcmin and outer radius of 19.6arcmin (corresponding to R200=18.7arcmin and dr=0.1*R200) with a total area of ~220arcmin^2) **XX 10^{-16} (integrated over a circle with area 1 arcmin^2 an off-axis angle of 19 arcmin)**	**arcmin^{-2}**		

2a-023 Surface brightness sensitivity off axis

	Value	Units	Condition or Instrument	Parent Requirements
Definition	5-7 keV flux per arcmin^2 detectable in 100 ks (5 sigma)			
Requirement	**6.2 10^{-17} (integrated over an annulus with inner radius of 17.77 arcmin and outer radius of 19.6 arcmin (corresponding to R200=18.7amin and dr=0.1*R200) with a total area of ~220 arcmin^2)** **XX 10^{-16} (integrated over a circle with area 1 arcmin^2 an off-axis angle of 19arcmin)**	**erg cm^{-2} s^{-1} arcmin^{-2}**	In WFI 5 – 7 keV	121

2a-030 Positional accuracy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Absolute source location positional error after reconstruction (3 sigma)			
Requirement	**1.0** **2.5**	**arcseconds**	WFI X-IFU	111, 122, 211, 221, 261, 262, 323

Comments: a maximum off-axis distance of 20 armin can be assumed and needs to be achieved in a majority of the cases applying post-fact reconstruction.

2a – 031 Angular Resolution

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Half Energy Width (i.e. radius containing half detected photons)			
Requirement	**5** **6 (TBC)**	**arcseconds**	0.5 – 2 keV WFI 0.5 – 2 keV X-IFU	122, 131, 132, 134, 141, 142, 252

Comment: XIFU resolution accepted to be worse than WFI according to pixel sizes and most XIFU science is "aperture spectrophotometry" not imaging The HEW is driven by spatial scales of sources, confusion limit and discrimination of point sources

2a – 040 On-axis Effective Area at 1keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Total collecting area of combination of mirror and instrument following all loss factors at EoL			
Requirement	**1.5**	**m^2**		141, 241, 242, 251, 252, 261, 323

2a – 041 On-axis Effective Area at 7keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Total collecting area of combination of mirror and instrument following all loss factors at EoL			
Requirement	**0.17**	**m^2**		242, 251, 252, 261, 323

2a – 042 On-axis Effective Area at 10keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Total collecting area of combination of mirror and instrument following all loss factors at EoL			
Requirement	**0.04**	**m^2**	WFI	242

2a – 043 On-axis Effective Area at 0.3 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Total collecting area of combination of mirror and instrument following all loss factors at EoL			
Requirement	**0.1**	**m^2**	X-IFU	141, 142, 261

2a-050 Velocity resolution at 1 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Minimum detectable velocity shift between two unresolved lines with signal to noise ratio of 5 at 1 keV in a given observation, enabling the measurement of their respective fluxes			
Requirement	**100**	**km s^{-1}**	X-IFU	112, 131, 141, 142, 223, 231, 232, 261, 262, 332

Comments: Ability to resolve lines at soft energy, particularly OVII triplet but note the energy of this triplet is not exactly 1keV

2a-051 Velocity resolution at 7 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Minimum detectable velocity shift between two unresolved lines with signal to noise ratio of 5 at 7 keV in a given observation, enabling the measurement of their respective fluxes			
Requirement	**20**	**km s^{-1}**	X-IFU	112, 131, 232, 242, 251, 261, 262, 322, 323

Comments: Ability to resolve lines around Iron lines but note their energy is not exactly 6 keV

2a-052 Absolute energy scale accuracy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum r.m.s. variation in km/s of the absolute energy scale calibration with respect to an external velocity frame $\Delta E = vE/c$			
Requirement	**0.4**	**eV**	X-IFU	112, 122, 131, 141, 142, 231, 232, 261, 262, 322

Comments: Necessary to put together velocity mosaics

2a-060 Weak line sensitivity at 1 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	5σ detectable equivalent width of an unresolved emission or absorption line at 1 keV against a bright continuum			
Requirement	**0,075 (TBC)**	**eV equivalent width**	X-IFU	133, 141, 223, 231, 261

Comments: Driven by calibration uncertainties and systematics.

2a-061 Weak line sensitivity at 7 keV

	Value	Units	Condition or Instrument	Parent Requirements
Definition	5σ detectable equivalent width of an unresolved emission or absorption line at 7 keV against a bright continuum			
Requirement	**10**	**eV equivalent width**	X-IFU: in 50 ks against a point source with 3.5×10^{-5} photons keV^{-1} cm^{-2} s^{-1} at 8 keV (corresponding to a continuum flux of $F_{2\text{-}10}$ keV = 5×10^{-12} cgs for **Γ** = 1.8)	122, 231

*Comments: Driven by calibration uncertainties and systematics. *

2a-070 ToO trigger efficiency

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Fraction of the times that a ToO trigger in a random position of the high latitude sky (> 20 deg) results in a successful X-IFU observation			
Requirement	**0.5**	**Fraction**		141, 252, 261, 262

Comments: This does not specify how long does it take to get there, which is secured by the ToO fluence capability.

2a-071 ToO fluence capability

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Minimum fluence to be measured by the X-IFU in a successfully observed GRB ToO,			
Requirement	**10^{-6}**	**erg cm^{-2}**	characterized by a typical GRB decay profile to 10 mCrab flux after 4 hours	141, 261

2a-080 Absolute temperature/metallicity calibration uncertainty

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Fractional temperature uncertainty at a reference temperature			
Requirement	**4 (TBC)**	**%**	reference temperature of 5 keV (TBC) at redshift z=0.5, abundance Z=0.3 solar (assuming also a reference spectral model, e.g. APEC with Anders & Grevesse (1989) abundances	111, 112, 121, 122, 134, 232

2a-081 Absolute flux calibration uncertainty

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum on-axis calibration error (rms) in 0.5-2 keV and 2-10 keV			
Requirement	**8 (TBC)** **2 (TBC)**	**%**	At beginning of life Relative change in orbit	111, 121, 221, 251, 252, 261, 262

Comments: ensures we know the luminosity of objects, and, e.g., gas density profile of clusters.

2a-082 Relative flux calibration uncertainty as function of energy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum relative calibration error (rms) across a range of energies (0.5 to 2 and 2 to 10 keV TBC)			
Requirement	**5 (TBC)**	**%**	At beginning of life and also any relative change in orbit	132, 221, 251, 252, 261, 262

Comments: This definition covers the broad band calibration, but needs to be specified for small scale spectral ranges for X-IFU science (e.g. EXAFS signatures).

2a-090 Absolute Time Accuracy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum difference (3σ) between internal clock stamp to event datum with respect to universal system			
Requirement	**50**	**µsec**	After including all space segment and ground segment corrections,	251

Comments: includes orbit determination to derive solar system barycenter correction

2a-091 Relative Time Accuracy

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum rms internal clock error to arrival time of detected events			
Requirement	**10**	**µsec**	X-IFU	251

2a-100 Count Rate Capability

	Value	Units	Condition or Instrument	Parent Requirements
Definition	Maximum count rate in an instrument where the science goals can still be achieved			
Requirement	**1** **10^{-3} (10^{-2}: goal)**	**Crab**	WFI FAST detector with 80% throughput X-IFU: for this level a point source should give 80% high	141, 251, 252, 262, 341, 343

			resolution events (2.5 eV)	

2a-102 Optical Brightness

	Value	**Units**	**Condition or Instrument**	**Parent Requirements**
Definition	Maximum visible magnitude that can be observed with no more than 10% energy resolution degradation at 7keV			
Requirement	**2**	$\mathbf{m_v}$	X-IFU with selectable filter	311, 322, 325

8 LEVEL 2B/C REQUIREMENTS

The given level 2b and 2c requirements are related to the implementation of the Athena mission as proposed in the mission proposal. Some other optimizations could realize the same (or similar) science objectives (e.g. there is a trade between effective area, angular resolution, spectral resolution and ToO response time for various of the science objectives). Clearly some requirements are less far advanced. This is in particular true for:

- the accuracies with which the various parameters need to be calibrated
- the requirements and estimates for the background

Both are subject of dedicated discussions with experts

Below we first give the meaning of the various columns:

- *reference number* (maintained as other documents may refer to them in which case it is confusing if they disappear). If given with a yellow background it implies that there is still some open work.

- *requirement*: description of the requirement

- *value*: actual value

- *conditions* for which the requirement applies (high spectral resolution, wide field, fast chip, other conditions)

- *confidence level:* specifying the estimated level of confidence in the specified requirement:
  - 5 = very confident (accurate to better than 10%);
  - 4 = confident (accurate to better than 25%);
  - 3 = average (better than factor 2),
  - 2 = limited confidence (factor 10) and
  - 1 = poor (factor >> 10).

  Note that this is somewhat arbitrary and for some requirements limited confidence might still be acceptable (e.g. straylight at the entrance of the detectors could be sufficient to have specified with an accuracy of a factor 10)

- *justification:* justification of the requirement, where relevant a reference is made to an external document for additional details.

- *SciOBJ parent:* identification which science objectives are most directly affected by the given parameter where it should be noted that some capability (area) is important for all science we list only the more driving science objectives

- *Level 2a parent*: same as for the SciOBJ

- *Owner:* subsystem which should ensure the requirement (X-IFU, WFI, ESA for the other parts but this may be more explicitly defined by ESA [e.g. ground segment, satellite, launcher etc.])

- *Author:* originator of the requirement

- *Level:* specification level 2b if it is traced down from level 1 or level 2a. Level 2c requirements are added to complete the mission concept but are not driving and some may be transferred to the instrument requirement documents.

- *Change status:*
    - green: no problems foreseen with the current mission concept
    - blue: this is the smaller mirror area and has a penalty in science and in observation times (see ASIE report, xxx)
    - blank: this is a goal which means that it is not required

- *Comment:* additional information provided for the requirement

For the purpose of these requirements the Crab is defined as the XSPEC model powerlaw*tbabs (Γ=2.1, Norm=9.5 pho/cm^2/s/keV, N_H=0.4 10^{22} cm^{-2}).

These requirements are consistent with a set of response matrices which have been used in verification of the science objectives and the definition of the Mock Observing Plan. In this sense the mission implementation as dictated by the Level 2b/2c requirements is consistent with the mission proposal and the choice of the Hot and Energetic Universe as theme for the L2 launch. These response matrices, also used for the Athena Science Impact Exercise [RD4], are based on an inner radius of 25 cm, a specified outer radius, a rib spacing of 2.3 mm and a factor of 0.9 to correct for alignment errors and contamination. Details are given in [RD5] and [RD6] and the files names are:

athena_wfi_1469_onaxis_w_filter_v20150326.arf *radius = 1.47 m, with external filter*
athena_wfi_1190_onaxis_w_filter_v20150326.arf *radius = 1.19 m, with external filter*

and

athena_xifu_1469_onaxis_pitch265um_v20150327.arf *radius = 1.47 m*
athena_xifu_1190_onaxis_pitch265um_v20150327.arf *radius = 1.19 m*

The WFI response matrices without external filter have not been used as it is assumed that except for special cases, his external filter will be the nominal operational mode as it reduces the contamination

Table 8-1 Level 2b/2c requirements

	Requirement	Value	Condition	Confidence level	justification	SciOBJ Parent	Level 2a parent	Owner	Author	Level	Status	Comment
Effective area												
SCI-EA-R-010	Athena shall perform High Spectral Resolution observations by detecting X-rays in the range 0.2 - 12 keV	0.2 - 12 keV	High Spectral Resolution	4	Lowest energy defined by the need to detect red-shifted Carbon resonant lines in WHIM and high red-shift GRBs. Highest energy range defined by the need to constrain continuum above Fe-K line.	141, 142, 261, 242, 251		X-IFU	ASST	2b		The lower bound of the energy range is determined by the redshift of the Oxygen lines (0,57 keV and redshift 1.8), the upper bound by the energy range to constrain the continuum above the Fe-K line energy (should be larger than 10 keV). It should be noted that this is the range of the detector (ADC conversion) and that the area is defined in SCI-EA-R-30 at 0.3 keV
SCI-EA-R-020	Athena shall perform Wide Field observations by detecting X-rays in the range of 0.2 - 15 keV	0.2 - 15 keV	Wide Field (large FoV and fast chip)	5	Lowest measureable energy range defined by the need to detect warm absorbers at z~3.5 (R-SCIOBJ-222). Highest energy range defined by the ability to characterize reflection spectral features in order properly to utilize iron line diagnostics (R-SCIOBJ-221, 251,252).	221, 251, 252, 331		WFI	ASST	2b		The lower bound of the energy range is required to measure the warm absorbers at z~3.5, the upper bound by the energy range to constrain the continuum above the Fe-K line. It should be noted that this is the range of the detector threshold settings (ADC conversion) and that the area is defined in SCI-EA-R-40 at 0.2 keV
SCI-EA-R050a	Athena shall perform High Spectral Resolution observations with an Effective Area at the target of at least 0,15 m² at 0.3 keV.	≥ 0.15 m²	High Spectral Resolution at 0.3 keV	5	numbers are consistent with the response matrices used in the ASIE exercise and as such the baseline design of Athena will meet the science objectives	141, 142, 261		ESA / X-IFU	ASST	2a		Includes the internal optical filters and the filter wheel in open position, values are consistent with the mirror (ARF file given at the start of this section) which includes a factor 0.9 for alignment/ contamination
SCI-EA-R050b	Athena shall perform High Spectral Resolution observations with an Effective Area at the target of at least 0,10 m² at 0.3 keV.	≥ 0.10 m²	High Spectral Resolution at 0.3 keV	5	Number is inconsistent with the baseline mission design and as such there is some loss in science and a need for a longer mission duration to reduce the science impact of the reduced area	141, 142, 261		ESA / X-IFU	ASST	2a		All …b specifications correspond to the smaller effective area that will be at the cost of the science capability of the mission. However, it was decided to keep these values for reference and for the industrial studies but they should NOT be used as baseline according to the Athena Science Study Team

SCI-EA-R-060a	Athena shall perform High spectral resolution observations with an Effective Area at the target of at least 1.50 m² at 1 keV.	≥ 1.50 m²	High Spectral Resolution at 1 keV	5	Enable spectral determinations (eg. Temperatures of faint groups, WHIM filaments), characterize AGN outflows and perform AGN reverberation mapping by accumulating sufficient photons in characteristic timescales. See also SCI-EA-R050a	141, 141, 142, 223, 241, 261	2a-40	ESA / X-IFU	ASST	2a		At the core the need to accumulate enough photons per unit time. Not all can be compensated by longer observing times, due to background limitations for example. 1keV represents the peak of assumed detection efficiency and of spectrum. The Effective Area here is the ARF as in the response files, i.e. taking into account detector QE. The given values correspond to 95% of the ARFs used in the ASIE exercise as this is considered a lower limit. In the earlier version 1.47 m² was the reference number
SCI-EA-R-060b	Athena shall perform High Spectral Resolution observations with an Effective Area at the target of at least 1.05 m² at 1 keV.	≥ 1.05 m²	High Spectral Resolution at 1 keV	5	Enable spectral determinations (eg. Temperatures of faint groups, WHIM filaments), characterize AGN outflows and perform AGN reverberation mapping by accumulating sufficient photons in characteristic timescales See also SCI-EA-R050b	141, 142, 223, 241, 251 261	2a-040	ESA / X-IFU	ASST	2a		At the core the need to accumulate enough photons per unit time. Not all can be compensated by longer observing times, due to background limitations for example. 1keV represents the peak of assumed detection efficiency and of spectrum. Note that the effective area here is the ARF as in the response files, i.e. taking into account detector QE etc. see also SCI-EA-R-050b
SCI-EA-G-060	Athena should perform all observations with a mirror Effective Area at the target of at least 2.5 m² at 1 keV	≥ 2.5 m²	at 1 keV	5	All science will improve and time needed for core science will be less. This is a top level enhancement for the mission	141, 142, 223, 224, 231, 241, 251 261	2a-040	ESA	ASST	2a		Higher effective area enables better science and/or achieves core science goals in shorter time. This is a demanding goal but together with the angular resolution are the two top priorities to enhance the science and are therefore maintained
SCI-EA-R-070a	Athena shall perform High Spectral Resolution observations with an Effective Area at the target of at least 0.16 m² at 7 keV (corresponds to 0,24 at 6 keV).	≥ 0.16 m²	High Spectral Resolution at 7 keV	5	Perform reverberation mapping and characterize spins in Black Holes. Characterize the metals' distribution in clusters. See also SCI-EA-R050a	112, 221, 231, 242, 251, 252	2a-41	ESA / X-IFU	ASST	2a		Need to accumulate enough photons per unit time at the iron line. Not all can be compensated by longer observing times, due to typical source variability timescales for example.

SCI-EA-R-070b	Athena shall perform High Spectral Resolution observations with an Effective Area at the target of at least 0.16 m² at 7 keV (corresponds to 0,24 at 6 keV).	≥ 0.16 m²	High Spectral Resolution at 7 keV	5	Perform reverberation mapping and characterize spins in Black Holes. Characterize the metals' distribution in clusters. See also SCI-EA-R050b	112, 221, 231, 242, 251, 252 1	2a-41	ESA / X-IFU	ASST	2a		Need to accumulate enough photons per unit time at the iron line. Not all can be compensated by longer observing times, due to typical source variability timescales for example. The value for the larger and smaller mirrors are identical as the area at high energies is determined by the inner radii.
SCI-EA-G-070	Athena should perform all observations with a mirror Effective Area at the target of at least 0.20 m² at 7 keV (corresponds to 0.29 @ 6 keV	≥ 0.20 m²	High spectral resolution and wide field at 7 keV	5	All science will improve and time needed for core science will be less. This is a top level enhancement for the mission	141, 142, 223, 241, 261	2a-041	ESA	ASST	2a	2a	Higher effective area enables better science and/or achieves core science goals in shorter time. At 6 keV the important diagnostics Fe-K line is located
SCI-EA-R-081a	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 0.11 m² at 0.2 keV.	≥ 0.11 m²	Wide Field (large FoV, fast chip) at 0.2 keV with external filter	5	Perform multi-tiered survey for necessary sample of high-z AGN, obscuration, outflows, and find high-z galaxy groups. As there will be bright sources in the field of view an external filter will be applied See also SCI-EA-R050a	111, 211, 221, 222, 224		ESA / WFI	ASST	2c		Corresponds to the ARF as this already includes a factor 0.9 The WFI numbers are given with the filter from the filter wheel to take into account the presence of bright optical sources
SCI-EA-R-081b	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 0.08 m² at 0.2 keV.	≥ 0.08 m²	Wide Field (large FoV, fast chip) at 0.2 keV with external filter	5	Perform multi-tiered survey for necessary sample of high-z AGN, obscuration, outflows, and find high-z galaxy groups. See also SCI-EA-R050b	111, 211, 221, 222, 224		ESA / WFI	ASST	2c		Corresponds to the ARF as this already includes a factor 0.9 The WFI numbers are given with the filter from the filter wheel to take into account the presence of bright optical sources see also SCI-EA-R-050b
SCI-EA-R-091a	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 1.80 m² at 1 keV.	≥ 1.80 m²	Wide Field (large FoV, fast chip) at 1 keV with external filter	5	Perform multi-tiered survey for necessary sample of high-z AGN, obscuration, outflows, and find high-z galaxy groups. See also SCI-EA-R050a	111, 211, 221, 222, 224	2a-040	ESA / WFI	ASST	2a		Needed to accumulate enough photons per unit time. Less area can in a part be compensated by observing times (but this needs to include effects such as the background, see [RD4] for such analysis. 1keV represents the peak of assumed detection efficiency and of spectrum. The WFI numbers are given with the filter from the filter wheel to take into account the presence of bright optical

												sources
SCI-EA-R-091b	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 1.29 m² at 1 keV.	≥ 1.29 m²	Wide Field (large FoV, fast chip) at 1 keV with external filter	5	Perform multi-tiered survey for necessary sample of high-z AGN, obscuration, outflows, and find high-z galaxy groups. See also SCI-EA-R050b	111, 211, 221, 222, 224	2a-040	ESA / WFI	ASST	2a		Needed to accumulate enough photons per unit time. Less area can in a part be compensated by observing times (but this needs to include effects such as the background, see [RD4] for such analysis. 1keV represents the peak of assumed detection efficiency and of spectrum. The WFI numbers are given with the filter from the filter wheel to take into account the presence of bright optical sources see also SCI-EA-R-050b
SCI-EA-R-100a/b	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 0.18 m² at 7 keV (0.26 at 6 keV).	≥ 0.18 m²	Wide Field (large FoV, fast chip) at 7 keV	5	Effective area needed for Fe-K complex. Perform reverberation mapping and characterize spins in Black Holes. Find Compton Thick AGN. Characterize the metals' distribution in clusters. See also SCI-EA-R050a	251, 252, 331, 332	2a-041	ESA / WFI	ASST	2a		External filter does not affect the area at 7 keV
SCI-EA-R-110a/b	Athena shall perform Wide-Field observations with an Effective Area at the target of at least 0.04 m² at 10 keV.	≥ 0.04 m²	Wide Field (large FoV, fast chip) at 10 keV	4	Perform reverberation mapping and characterize spins in Black Holes. Find Compton Thick AGN. Characterize the metals' distribution in clusters. See also SCI-EA-R050a	112, 211, 221, 231, 242, 251	2a-042	ESA / WFI	ASST	2a		Need to accumulate enough photons per unit time at the iron line. Not all can be compensated by longer observing times, due to typical source variability timescales or due to background limitations. No need for a separate requirement (a/b) for different mirror radii as it is determined by the inner shells and the focal length It is noted that the current level 2a requirement is 0.04 m² and the 0.06 m2 is the expected value

SCI-EA-R-120a	Athena shall perform Wide Field observations with a grasp of 0.40 m^2deg^2 at 1 keV.	≥ 0.40 m^2deg^2	Wide Field (large FoV) at 1 keV with external filter	5	survey speed, See also SCI-EA-R050a	111, 211, 221, 222, 224	2a-011	ESA / WFI	ASST	2a		Corresponds to 95% of Dick's calculated grasp after including 93% throughput from the external filter and on-chip protection layer.
SCI-EA-R-120b	Athena shall perform Wide Field observations with a grasp of 0.26 m^2deg^2 at 1keV.	≥ 0.26 m^2deg^2	Wide Field (large FoV) at 1 keV with external filter	5	survey speed See also SCI-EA-R050b	111, 211, 221, 222, 224	2a-011	ESA / WFI	ASST	2a		Corresponds to 95% of Dick's calculated grasp after including 93% throughput from the external filter and on-chip protection layer.
SCI-EA-R-130a	Athena shall perform Wide Field observations with a grasp of 0.018 m^2deg^2 at 7 keV (corresponds to 0.03 at 6 keV)	≥ 0.018 m^2deg^2	Wide Field (large FoV) at 7 keV with external filter	5	survey speed See also SCI-EA-R050a	111, 211, 221, 222, 224	2a-012	ESA / WFI	ASST	2a		Corresponds to 95% of Dick's calculated grasp after including 93% throughput from the external filter and on-chip protection layer. Instead of effective area 6 keV is used as reference because it determines the survey speed for the lower energies
SCI-EA-R-140	The calibration of the absolute effective area shall be accurate to better than 8 % at 1keV for the wide field observations over a radius of 10 arcmin	≤ 8 % (TBC)	Wide field (large FoV and fast chip) < 10 arcmin off-axis at 1 keV	4	Needed for science goals involving L_x-T and L_x-z relations Note that the confidence level 4 means that the accuracy can be in a range of 7.5% to 12,5 %	111, 121, 211, 221	2a-081	ESA/ WFI	ASST	2a		Note that the required accuracy in level 2a is currently 8%, 10% is realistically feasible and any further reduction needs a detailed justification
SCI-EA-R-141	The calibration of the absolute effective area shall be accurate to better than 10% at 1 keV for the High Spectral Resolution observations (on-axis)	≤ 10%	High Spectral Resolution at 1 keV	4	Needed for science goals involving L_x-T and L_x-z relations	111, 121, 211, 221	2a-081	ESA/ X-IFU	ASST	2a		Note that the required accuracy in level 2a is currently 8%, 10% is realistically feasible and any further reduction needs a detailed justification
SCI-EA-R-150	The calibration of the relative effective area for the wide field observations shall be accurate at +/- 3% (TBC) between 0.5 and 10 keV on target	≤ 3% (TBC)	Wide Field (large FoV and fast chip) on target 0.5-10 keV	3	Accurate parameter estimation for broad-band spectral models, like power laws, black bodies, and thermal models.	All		ESA / WFI	ASST	2a		

SCI-EA-R-160	The calibration of the relative effective area for the high spectral resolution observations shall be accurate at +/- 5% (TBC) between 0.5 and 10 keV on target	≤ 5% (TBC)	High Spectral Resolution and Wide Field 0.5-10 keV	3	Accurate continuum level estimation for broad-band (thermal) models with lines. See also SCI-EA-R-150.	All		ESA / X-IFU	ASST	2a		The detection of WHIM abs lines requires systematic effect in the continuum (area) at the level of 1% but this is over very small energy bands. Difference wity WFI also needs to be addressed but, for the time being, it is assumed that with a larger energy band, the constraints on the WFI can be different and more constrained
SCI-EA-R-170	The change of effective area between ground and begin-of-life shall be less than 10% at 0.3 keV (TBC) on target	≤ 10% (TBC)	High spectral resolution and wide field 0.3 keV	5	Contamination introduces uncertainties in N_H and therefore also broad-band model parameters.	All		ESA/ X-IFU/ WFI	ASST	2b		
SCI-EA-R-171	The change of effective area between begin-of-life and end-of-life shall be less than 10% at 0.3 keV (TBC) on target	≤ 10% (TBC)	High spectral resolution and wide field 0.3 keV	5	Contamination introduces uncertainties in N_H and therefore also broad-band model parameters.	All		ESA/ X-IFU/ WFI	ASST	2b		
Angular resolution												
SCI-ANR-R-010	Athena shall perform wide field observations, on-axis, with an angular resolution of 5'' Half Energy Width (HEW) on-axis over an energy range of 0.2 – 7 keV.	≤ 5'' HEW	Wide Field (large FoV) on-axis 0.2 - 7 keV	5	This performance allows deepest surveys not to be compromised by confusion, and ensures 50kpc sized structures can be discriminated in clusters at z~2.	111, 112, 122, 132, 221, 222, 224		ESA/WFI	ASST	2b		On axis is the optical axis of the telescope and it is assumed that this is the target position
SCI-ANR-G-010	Athena should be able to perform wide field observations, on-axis, with an angular resolution of 3” HEW on-axis over an energy range of 0.2 - 7 keV.	≤ 3'' HEW	Wide Field (large FoV) on-axis 0.2 - 7 keV	5	This performance allows goal sensitivity in deepest surveys, and reduces spectral background contamination in faint sources by a factor ~2, while allowing galaxy scales to be discriminated in clusters at Z~2.	111, 112, 122, 221, 222, 224		ESA /WFI	ASST	2b		On axis is the optical axis of the telescope and it is assumed that this is the target position. The current WFI design is able to exploit this better resolution.

SCI-ANR-R-011	Athena shall perform High Spectral Resolution observations, on-axis, with an angular resolution of 6" Half Energy Width (HEW) on-axis over an energy range of 0.2 – 7 keV.	≤ 6 " HEW (TBC)	High Spectral Resolution on-axis 0.2 - 7 keV	4	The angular scale matches with the size of variations in the source and takes into account the FoV and number of pixels	111, 112, 122, 132, 221, 222, 224		ESA/ X-IFU	ASST	2b		On axis is the optical axis of the telescope and it is assumed that this is the target position
SCI-ANR-R-012	Athena shall perform high spectral resolution observations with an angular resolution of 10 ≤ HEW ≤ 60" HEW when out of focus over an energy range of 0.2 – 7 keV.	between 10 and 60"	High Spectral Resolution on-axis 0.2 - 7 keV	5	This defocussing allows the increase the maximum source intensity for strong point sources by a factor 4 to about 150	141, 251, 341		ESA	X-IFU	2b		On axis is the optical axis of the telescope and it is assumed that this is the target position. The range corresponds to an out of focus translation of 25 mm. Hence a range of +35 mm to - 5 mm out of focus allows for alignment tolerances and the out of focus need
SCI-ANR-R-020	Athena shall perform all observations, on-axis, with an angular resolution of less than 20" HEW on-axis over the energy range 7 - 12 keV.	≤ 20" HEW	All obs. on-axis 7 – 12 keV	4	Without a constraint on PSF at higher energies, the spectral extraction for point sources becomes extremely complex, rendering reverberation and iron line diagnostics impossible.	251, 252		ESA	ASST	2b		Essentially a constraint on the quality of innermost optical shells figure, as well as scattering properties of mirror surface finish, The estimated effective area is in the order of 20 cm2. This is, of course, not valid in case a defocus position is realized to address SCI-ANR-G-011.
SCI-ANR-R-030	Athena shall perform wide field observations, with an angular resolution of <10" HEW at 20' off-axis over an energy range of 0.2 - 7 keV	≤ 10" HEW	Wide Field (large FoV) 20' off-axis 0.2 - 7 keV	4	Ensures wide field tiered survey can detect the AGN populations such that luminosity functions can be accumulated in a reasonable time.	211, 221, 222		ESA	ASST	2b		To ensure that the PSF at field edges is not so large as to grossly degrade the sensitivity over large solid angles. Data analysis is greatly simplified if PSF changes slowly with radius and azimuth. The requirement is given for 20' off-axis. It should be noted that for a rectangular device the diagonal is 56 arcmin but the corners will be used for background estimates. In this case the PSF is undefined over 27% of the sensor area (minus the chip gaps).
Spectral resolution												

SCI-SPR-R-010	Athena shall perform High Spectral Resolution observations with a mean spectral resolution of 2.5 eV at 7 keV.	≤ 2.5 eV	High Spectral Resolution FWHM at 7 keV	5	Defined by weak absorption lines sensitivity, and bulk velocity determination of 20 km/s.	112, 131, 133, 141, 142, 261		X-IFU	ASST	2b		the mean is averaged over the full size of the sensor and allows for outliers
SCI-SPR-G-010	Athena should perform High Spectral Resolution observations with a mean spectral resolution of 1.5 eV FWHM at 1 keV.	≤ 1.5 eV	High Spectral Resolution FWHM at 1 keV	5	Improved spectral resolution directly scale to better WHIM sensitivity and velocity determination for point sources	141, 142, 131		X-IFU	ASST	2b		Could be realized for point sources over part of the Field of View
SCI-SPR-R-020	Athena should perform High Spectral Resolution observations with a mean energy calibration accuracy of 0.4 eV over the range of 0.3 - 7 keV	≤ 0.4 eV	High Spectral Resolution 0.3 - 7 keV	5	Absolute energy accuracy is required to be able to centroid across any spectral line feature with 2.5eV resolution	112, 122, 131, 141, 142, 231, 232, 261, 322	2a-052	X-IFU	ASST	2a		Accuracy for the centroid, but also the stability of calibration is required (or to be reconstructable)
SCI-SPR-R-030	Athena shall perform Wide Field observations with a mean spectral resolution of 170 eV at 7 keV over the field of view	≤ 170 eV	Wide Field (large FoV, fast chip) FWHM at 7 keV	5	Measuring spins and reverberation in Galactic BH.	242, 251, 252		WFI	ASST	2b		Also the response function must be very well characterized so that systematic residuals can be minimized and do not become misinterpreted as astrophysical signals.
SCI-SPR-G-030	Athena should perform Wide Field observations with a mean spectral resolution of 160 eV at 7 keV over the field of view	≤ 160 eV	Wide Field (large FoV, fast chip) FWHM at 7 keV	5	Improved performance compared to SCI-SPR-R-030.	242, 251, 252		WFI	ASST	2b		
SCI-SPR-R-040	Athena shall perform Wide Field observations with a mean spectral resolution of 80 eV at 1 keV over the field of view	≤ 80 eV	Wide Field (large FoV, fast chip) FWHM at 1 keV	5	Characterize broad temperatures for any source with >1000 photons. Spectral features in high-z AGN/Clusters	111, 121, 241, 252, 221		WFI	ASST	2b		
SCI-SPR-R-050	Athena shall perform Wide Field observations with a mean energy calibration accuracy of ≤ 10 eV, over the energy range 0.2-10 keV and the field of view	≤ 10 eV	Wide Field (large FoV, fast chip) 0.2 - 10 keV	5	Redshift accuracy <1% in surveys.	121, 211, 221		WFI	ASST	2b		

SCI-SPR-R-060	Athena shall perform High spectral resolution observations with a energy resolution homogeneity (FWHM) over the field of view and energy range 0.3 – 7 keV.	≤ 0.5 eV (TBC)	High spectral resolution 0.3 - 7 keV	4	Homogeneous mapping of turbulence in cluster cores.	112, 131		X-IFU	ASST	2c		It is not expected that each pixel will have the same resolution, With a homogeneity of 0.5 eV any pixel will have a resolution less than 3 eV which allows, together with the dithering, a homogeneous mapping of extended sources
SCI-SPR-R-070	Athena shall perform High spectral resolution observations with the spectral resolution calibrated to better than 6%	≤ 0.15 eV (TBC)	High spectral resolution 0.3 - 7 keV	3	Lower systematic limit for turbulence measurements to <20 km/s	112, 131		X-IFU	ASST	2c		The 0.15 eV might be not needed if the limit on turbulence measurements is 20 km/s
Field of view												
SCI-FOV-R-010	Athena shall perform High spectral resolution observations with a Field of View equivalent with a 5' diameter.	≥ 5' Ø	High spectral resolution Field	5	Cover cooling cores and jet energy dissipation volumes in clusters with a single IFU pointing. Cover error boxes of typical GRB alert from a coded mask quality instrument trigger	112, 122, 131, 133, 142		X-IFU	ASST	2b		Nearby clusters (z<0.03) and 100kpc cooling core radius just fit within 5 arcmin diameter limiting the need for mosaicking (increase in observing time) actual design might not be circular (e.g. Hexagon) but the integrated FoV should be consistent with 5 arcmin diameter
~~SCI-FOV-G-010~~	Dropped: goal field of view for high spectral imaging											
SCI-FOV-R-020	Athena shall perform Wide Field observations with a Field of View of 40'x40'	≥ 40' x 40'	Wide field (large FoV)	5	Measure entropy profiles across a cluster. Detect sufficient z~6-8 AGN in a wide field tiered survey.	111, 121, 132, 134, 211, 221, 222, 241		WFI	ASST	2b		Assumes a modest vignetting (2.3 mm rib spacing corresponding to 0.5 at 1 keV and 023 at 6 keV near edge of FoV). Any cluster for Z<0.05 will have virial radius extending beyond the WFI field. This does not define the shape but defines the area in arcmin2 allowing for a filling factor of 0.9 on the area (current design gives 1450 arcmin2
~~SCI-FOV-G-020~~	Droppe goal, Field of view of Wide field image not 50 x 50 arcmin											
Time												
SCI-TMR-	Athena shall perform all observations with an absolute	≤ 50 µs	All observation	5	Obtain energy dependent folded light curves for millisecond pulsars	331, 332		ESA	ASST	2a		The requirement for the high spectral resolution and wide field and fast

R-010	timing accuracy of 50µs.		s									chip observations are given in the following requirements. This is the accuracy between the on-board clock and absolute time
SCI-TMR-R-015	Athena shall detect individual photons with a time resolution of 10µs for High spectral resolution Observations.	≤ 10 µs	High spectral resolution	5	Allows coordinated observations of pulsars at other wavelength facilities.	331, 332		X-IFU	ASST	2c		
SCI-TMR-R-020	Athena shall detect individual photons with a time resolution of 5 ms (TBC) for Wide-Field observations.	≤ 5 ms (TBC)	Wide-Field (large FoV)	5	Needs science justification			WFI	ASST	2c		Minimum time is 1.3 ms but there is a strong science justification (it is mostly countrate capability, hence re-classified as 2c and 5 ms is used
SCI-TMR-R-030	Athena shall detect individual photons with a time resolution of 80 µs for the WFI fast chip.	≤ 80 µs	Wide-Field (fast chip)	3	Time resolved spectroscopy of (millisecond) pulsars.	331		WFI	ASST	2c		Science justification is not followed from the core science but it is also related to count rate capability
SCI-TMR-G-030	Athena should detect individual photons with a time resolution of 40 µs for the WFI fast chip.	≤ 40 µs	Wide-Field (fast chip)	3	Improved performance compared to SCI-TMR-R-030	331		WFI	ASST	2c		
SCI-TMR-R-050	Athena shall achieve knowledge of the instrumental dead time at the level of 1 % or High spectral resolution observations.	1 %	High spectral resolution	3	Important for absolute flux of bright sources and timing analysis			X-IFU	ASST	2c		The WFI does not have a deadtime (all pixels are active all the time) and therefore this is only specified for the X-IFU. The event dead-time of the TES array is known accurately (event length) and this value determined the knowledge about the deadtime in the cryoAC due to saturation of the detector
Count rate												
SCI-CTR-R-010	Athena shall perform WFI fast chip observations of point sources to a flux of $2x10^{-8}$ erg s^{1} cm^{-2} with < 1% pile up.	≤ 1% pile up for Crab	Wide-Field (fast chip) 2-10 keV point source 1 Crab ($2x10^{-8}$ erg s^{1} cm^{-2})	5	Achieve spectral diagnostic of bright X-ray binaries and compact objects. See WFI-BSR-04draft	251, 252, 331, 332		WFI	ASST	2b		Special mode of WFI to achieve high count rate measurement of binaries (only restricted field of view window), level corresponds to 1 Crab. Piile-up are multiple photons in a single pixel during one read-out or in adjacent pixels such that the treating them as two separate photons.

SCI-CTR-R-011	Athena shall perform WFI fast chip observations of point sources to a flux of $2x10^{-8}$ erg s^1 cm^{-2} with >80 % throughput.	80% throughput, for Crab	Wide-Field (fast chip) 2-10 keV point source 1 Crab ($2x10^{-8}$ erg s^1 cm^{-2})	5	Achieve spectral diagnostic of bright X-ray binaries and compact objects. See also WFI-BSR-04draft	251, 252, 331, 332		WFI	ASST	2b		Special mode of WFI to achieve high count rate measurement of binaries (only restricted field of view window), level corresponds to 1 Crab. Throughput is defined as the number of events recorded at the ground divided by the number of photons in the mirror PSF which trigger the detector (e.g. not the photons which are absorbed in the filter deposited on the detector as this is already accounted for in the QE). It defines, however, the PSF coverage of the fast chip in combination with the pointing error.
SCI-CTR-R-020	Athena shall perform WFI fast chip observations of point sources to a count rate of 300 kct/s for a Crab like source (2.5 Crab)	300 kct/s	Fast Chip 2-10 keV point source 2.5 Crab	5	R-SCIOBJ-251 Some sources (or flares) can be brighter than 1 Crab and this specifies the maximum rate which the fast chip mode should be able to handle			WFI	ASST	2b		This defines the maximum throughput of the instrument (not the telemetry rate as one could use more than a single day to transfer this information
SCI-CTR-R-021	Athena shall perform observations with the large WFI FoV with a total (FoV-integrated) count rate of 100 kct/s with a Crab like spectrum.	100 kct/s	Wide Field (large FoV) 2-10 keV	5				WFI	ASST	2b		This defines the maximum throughput of the instrument (not the telemetry rate as one could use more than a single day to transfer this information. This rate corresponds to > 9 times the countrate for CasA
SCI-CTR-R-030	Athena shall be able to collect observations with a continuous duration of 1 day of point sources to a flux of $2x10^{-8}$ erg s^1 cm^{-2} for a Crab like source.	10^{10} counts	Wide Field (fast chip) S/C	5	R-SDCIOBJ-251 This corresponds to the maximum data (fast chip) for a 1 day observation of the Crab			WFI	ASST	2b		This defines the maximum onboard storage capacity as more days can be used to transfer the observed events to the ground. E.g., 100ks XTE J1550-564 (2.5Crab) will produce 300 ct/s, corresponding to a data rate of ~700 Gbit per day, a factor of ~10 above the currently available telemetry rate. If the resources of the instrument/spacecraft allow this, this could size the onboard memory but the observations can also be split in a

												number of shorter observations on subsequent days.
SCI-CTR-R-040	Athena shall perform High spectral resolution observations of point sources to a count rate of 2x10^{-11} erg s^{1} cm^{-2} with >80% throughput with 2.5 eV energy resolution.	> 80% throughput resolution < 2.5 eV	High spectral resolution 2-10 keV 1mCrab (2x10^{-11} erg s^{1} cm^{-2})	5	For GRB afterglows it is important to retain the good spectral resolution (2.5 eV) over a large fraction of events (80% of events falling on the detector)	141, 261		X-IFU	ASST	2b		Anticipated nominal count rate capability to achieve good X-IFU spectral performance
SCI-CTR-G-050	Athena should perform High spectral resolution observations of point sources to a count rate of 2x10^{-10} erg s^{1} cm^{-2} with >80% throughput with 2.5 eV energy resolution.	> 80% through-put with resolution < 2.5 eV for 10 mCrab	High spectral resolution 2-10 keV 10 mCrab (2x10^{-11} erg s^{1} cm^{-2})	5	For GRB afterglows it is important to retain the good spectral resolution (2.5 eV). With the goal no bright GRB afterglows will be lost due to a degraded spectral resolution (all bursts are expected to be < 10 mCrab after 4 hours)	141, 261		X-IFU	ASST	2b		Anticipated potential count rate capability to achieve good X-IFU spectral performance which is important for GRB afterglows (the most interesting GRBs are in 1 - 10 mCrab range after 4 hours).
SCI-CTR-R-060	Athena shall perform High spectral resolution observations of point sources to a count rate of 2x10^{-8} erg s^{1} cm^{-2}with >30% (TBC) throughput but degraded resolution (30 eV, TBC)	30% (TBC) through-put ΔE < 30 eV (TBC)	High spectral resolution 2-10 keV 1 Crab (2x10^{-8} erg s^{1} cm^{-2})	3	Achieve spectral diagnostic of bright X-ray binaries and compact objects with better spectral resolution than in SCI-CTR-01 but at the cost of efficiency. The driving science case should be explored further considering the WFI capability	251, 252, 331, 332.		X-IFU	ASST	2c		
SCI-CTR-R-070	ATHENA shall perform Wide Field observations with a pile-up <1% in the energy range of 0.2-10keV for the brightest knots in SNRs (3e^{-5} ph/cm^{2}/s/arcsec^{2}) in a 5' circle for a spectrum defined as *phabs*nei* with N_H= 1.7e^{22} cm^{-2}, kT = 2.2 keV, and tau = 3.6e^{10} s cm^{-3}	1%	Wide Field 0.2-10 keV extended sources of 3 x 10^{-5} erg/cm^{2}/s/arcsec^{2} in 5' radius Cas A knot- like spectrum	3				WFI	ASST	2b		

SCI-CTR-R-080	Athena shall perform High spectral resolution observations of extended sources to a count rate of 0.02 $erg.s^{-1}.cm^{-2}.sr^{-1}$ with 90 % throughput	90%	High spectral resolution 0.2-10k eV extended source, SNR spectrum	1		344		X-IFU	ASST	2b		
SCI-CTR-R-100	Athena shall perform Wide Field observations of extended sources to a count rate of 3 x 10^{-5} $ph/cm^2/s/arcsec^2$ with a >90% throughput for a spectrum defined as phabs*nei with N_H= 1.7e22 cm^{-2}, kT = 2.2 keV, and tau = 3.6e10 s cm^{-3}.	> 90%	Wide Field (large FoV) 0.2-10 keV extended sources of 3x 10^{-5} $ph/cm^2/s/arcsec^2$ in 5' radius Cas A knot-like spectrum	5				WFI	ASST	2b		
Background: particles (quiescent and flaring)												
SCI-BKG-R-010	Athena shall achieve a not focused non-X-ray background for Wide-Field observations of < 5 10^{-3} counts s^{-1} cm^{-2} keV^{-1} in 60% of the observing time between 2 keV – 7 keV	≤5 10^{-3} counts s^{-1} cm^{-2} keV^{-1} 60% (TBC) 2- 10 keV	Wide Field (large FoV) 60% of the observing time	4	Ensures low surface brightness (faint cluster or outskirts) spectral features at 6keV or the bremmstrahlung exponential cut-off can be determined. This excludes the particles (soft protons) entering the telescope. Although there is some variation in this level, the focused part through the mirror is the highly variable part See SWG1.2-TN-003	121, 221		ESA / WFI	ASST	2b		The non X-ray background refers to events not registered as cosmic X-ray events (direct particles and secondaries) which fall in the X-ray band between 0.1 and 15 keV. No similar requirement is needed for the fast chip as the background will be similar and the source intensity will be much stronger.
SCI-BKG-G-010	Athena should achieve a not focused non-X-ray background for Wide-Field observations of < 2 10^{-3} counts s^{-1} cm^{-2} keV^{-1} in 60% of the observing time between 2keV – 7 keV	≤2 10^{-3} counts s^{-1} cm^{-2} keV^{-1} 60% (TBC) 2- 10 keV	Wide Field (large FoV) 60% of the observing time	4	Ensures low surface brightness (faint cluster or outskirts) spectral features at 6keV or the bremmstrahlung exponential cut-off can be determined.	121, 221		ESA / WFI	ASST	2b		The non X-ray background refers to events not registered as cosmic X-ray events (direct particles and secondaries) which fall in the X-ray band between 0.1 and 15 keV. The goal is very demanding

SCI-BKG-R-020	Athena shall achieve a not focused non-X-ray background for High spectral resolution observations of < 5 10^{-3} counts s^{-1} cm^{-2} keV^{-1} in 80% (TBC) of the observing time between 2keV – 10 keV	< 5 10^{-3}counts s^{-1} cm^{-2} keV^{-1} 80% (TBC) 2- 10 keV	High spectral resolution 60% of the observing time	3	See also SWG1.2-TN-003	122		ESA / X-IFU	ASST	2b		
SCI-BKG-G-020	Athena should achieve a not focused non-X-ray background for High spectral resolution observations of < < 2 10^{-3} counts s^{-1} cm^{-2} keV^{-1} in 80% of the observing time between 2keV – 10 keV	< 2 10^{-3}counts s^{-1} cm^{-2} keV^{-1} 80% (TBC) 2- 10 keV	High spectral resolution 80% of the observing time	4		122		ESA / X-IFU	ASST	2b		The goal is ambitious and clearly a lower background is better.
SCI-BKG-R-030	Athena shall achieve a knowledge of the non focused charged particle background to within 2% for Wide-Field observations of 100 ks or longer over scales of 9 $arcmin^2$ or larger above 1 keV	< 2 % (TBC)	Wide field of View 100 ks 9 $arcmin^2$ E>1 keV	3	Especially important for low surface-brightness objects.	111, 121, 122		WFI, X-IFU	ASST	2b		Stated few % but not quantified, so we propose 2% TBC.
SCI-BKG-G-030	Athena should achieve a knowledge of the non focused charged particle background to within 1% for Wide field observations of 100 ks or longer over scales of 9 $arcmin^2$ or larger above 1 keV	< 1 % (TBC)	Wide field of view 100 ks 9 $arcmin^2$ E>1 keV	4	A very good knowledge about the background (and it predictability) can partially compensate for a higher than desired background, See SWG1.2-TN-0003.	111, 121, 122		WFI, X-IFU	ASST	2b		
SCI-BKG-R-031	Athena shall achieve a knowledge of the non focused charged particle background to within 2% TBC for High spectral resolution observations of 100 ks or longer over scales of 9 $arcmin^2$ or larger above 1 keV	< 2 % (TBC)	High spectral resolution 100 ks 9 $arcmin^2$ E>1 keV	3	Especially important for low surface-brightness objects.	111, 121, 122		WFI, X-IFU	ASST	2b		Stated few % but not quantified, so we propose 2% TBC.
SCI-BKG-R-040	Athena shall achieve a particle background transmitted through the mirrors (primarily electrons and protons) which is <10% TBC of the non-X-ray background as specified in SCI-BKG-R-010 for > 90% of the observing time	< 10% of SCI-BKG-R-010 rate, >90% of time (TBC)	Wide Field (large FoV)	3	MOP Data with a too high particle background need to be rejected and hence affect the net observing time.			ESA, WFI	ASST	2b		This defines the properties of the magnetic deflector. It is currently not clear that this is feasible. Possible mitigation is that a larger fraction of the observations has a higher background and/or the orbit selection (e.g. L1)

	anywhere in the field of view											
SCI-BKG-R-050	Athena shall achieve a particle background transmitted through the mirrors (primarily electrons and protons) which is <10% TBC of the total background as specified in SCI-BKG-R-020 for > 90% of the observing time anywhere in the field of view	< 10% of SCI-BKG-R-020 rate, >90% of time (TBC)	High spectral resolution	3	MOP Data with a too high particle background need to be rejected and hence affect the net observing time			ESA, X-IFU	ASST	2b		This is less demanding that SCI-BCK-R-040 as bith the filter is thinner and the FoV is a factor 8 larger
SCI-BKG-R-060	Athena should achieve a knowledge of the focused charged particle background to within 10% TBC for observations of 100 ks or longer over scales of $9 arcmin^2$ or larger above 1 keV	< 10% of tot bkg rate, >90% of time (TBC)	All observation s 100 ks $9 arcmin^2$ E>1 keV	3				ESA	ASST	2b		
SCI-BCK-R-070	Athena shall achieve the rejection of 10^{-4} of protons up to 30 keV from entering the field of view of the wide field instrument	10^{-4} at 30 keV protons (TBC)	Wide-Field (large FoV)	3	Achieving a sufficiently low background during a major part of the observations requires the rejection of protons transmitted through the mirror			ESA	ASST	2c		Related to SCI-BCK-R-010 but confirmation of the energy and rejection requires the completion of the background study. As secondary results electrons to nn keV will be rejected as well
SCI-BCK-R-080	Athena shall achieve the rejection of 10^{-4} of protons up to 30 keV from entering the field of view of the high spectral resolution instrument	10^{-4} at 30 keV protons (TBC)	high spectral resolution	3	Achieving a sufficiently low background during a major part of the observations requires the rejection of protons transmitted through the mirror			ESA	ASST	2c		Related to SCI-BCK-R-010 but confirmation of the energy and rejection requires the completion of the background study. As secondary results electrons to nn keV will be rejected as well
Background: X-rays												
SCI-BKG-R-110	Athena shall achieve a stray X-ray count rate from the diffuse X-ray sky (transmitted through but not focused by the mirrors) which is <10% of the total background in the 0.7 – 2 keV band averaged over the full field of view	< 10% of tot bkg rate in 0.7 – 2 keV band	Wide-Field (large FoV)	3	Driven by the large survey. This value is directly linked to the strategy and required observing time.	211		ESA	ASST	2b		This defines the relative need for X-ray straylight baffles. In the current design the SPO provides sufficiently internal baffling that this condition is met. If a further reduction of the straylight background is feasible, it would allow a more efficient survey strategy.
SCI-BKG-R-120	Athena shall suppress X-Ray Stray Light from any point X-ray source outside the field of view at 45' off-axis to a factor of 2 10^{-3} less than flux observed from the same source seen on-axis over an energy range	< 2 10^{-3}	At 45 arc min off axis 0.5-10 keV	4	Straylight (X-rays from outside the FoV which reach the focal plane of the WFI) will affect some of the science goals (especially cluster entropy profiles and the survey of the SMBH). A lower straylight level than	121, 211, (323, 325)		ESA	ASST	2c		This is a good reference value to meet SCI-BKC-R-110 This requirement based on the analysis by Willingale in the Optics supporting paper (fig. 18) and is

	of 0.5-10 keV for all observations.				specified will make the observations more time efficient .							consistent with the internal baffling of the SPO without additional straylight baffle.
SCI-BKG-R-130	Athena shall achieve a knowledge of the stray X-ray count rate for wide field observations with > 100 ks exposures on scales of 9 arcmin² anywhere in the field of view out to an off-axis angle of 20' and for energies < 3 keV of < 5%	5 % at < 3 keV	Wide-Field (Large FoV) 100 ks 9 arcmin²	4	For cluster entropy profiles a highr level of stray X-ray countrate is acceptable provided it is sufficiently accurately known.	121		ESA	ASST	2b		
Background: optical load												
SCI-BKG-R-150	Athena shall have the option to suppress UV/optical/IR light from bright stars (O star, 4500 K, Mv=2) with not more than 0.2 eV resolution degradation	0.2 eV for Mv=2	high spectral resolution baseline filters	4	For optical bright stars the resolution degradation has to be limited.	322, 332		X-IFU	ASST	2c		The current estimate is that a reduction of 10^7 is needed but this depends on the optical properties of the der filter and the properties of the optics (e.g. area)
SCI-BKG-G-150	Athena shall have the option to suppress UV/optical/IR light from bright stars (O star, 4500 K, Mv=7) with not more than 0.2 eV resolution degradation	0.2 eV for Mv=7	high spectral resolution baseline filters	4	The probability to have an optical star with Mv>7 in the FoV of the X-ifu is less than 1% and this filter allows the degradation of the energy resolution for such bright stars to less than 0.2 eV irrespective of its position	322, 331		X-IFU	ASST	2c		May need additional science justification
SCI-BKG-R-160	The optical load at the entrance of the instruments not coming through the mirror should be less than 10^9 photons/cm²/s assuming an solar (Teff=5800K) spectrum	10^9 ph/cm²/s (TBC)	Both instruments, from xx to yy nm	2	This is driven by the X-IFU with the FW in the open position and the baseline filters in the dewar and a contribution to the resolution budget of < 0.02 eV.	TBD		ESA	ASST	2c		

SCI-BKG-R-170	Athena shall have the option to suppress UV/optical/IR light from bright stars (O star, 45000K, mv=7) for wide-field observations with not more than 10% energy resolution degradation at 7keV.	17eV at 7keV for mv=7mag	Wide Field (large & smnall	3	Optically bright objects will cause an additional loading that translates into an offset of the energy scale and a degradation of the resolution. This can be suppressed with an adequate choice of on-chip surface layer and external optical light blocking filter.	311, 322, 325		WFI	ASST	2c		The WFI filter is primarily a contamination filter and should be as thin as feasible (to increase the low X-ray transmission).
Background: other components												
SCI-BKG-R-210	Athena shall perform particle background measurements for the wide field observations, while not in the focal plane, for at least 2/3 of the time it does not performs scientific observations.	66% (TBC)	Wide Field (large & small FoV)	3	Needed to construct a detailed spectro-spatial-temporal model of the background and needed to constrain the background knowledge with an accuracy better than 2%.			ESA / WFI	ASST	2c		
SCI-BKG-G-210	Athena WFI should perform particle background measurements for the wide field observations, whenever not in the focal plane or performing other calibrations.	Up to 100 %	Wide Field (large & small fov)	3	Needed to construct a detailed spectro-spatial-temporal model of the background			ESA / WFI	ASST	2c		
SCI-BKG-R-220	Athena high spectral instrument shall perform particle background measurements, while not in the focal plane, for at least 20% (TBC) of the time it does not performs scientific observations.	20% TBC	High spectral resolution	3	Needed to construct a detailed spectro-spatial-temporal model of the bkg.			ESA / X-IFU	ASST	2c		
SCI-BKG-R-230	Athena shall have the option of measure the particle only background for Wide Field Observations during normal observations.	20% of the sensitive area	Wide Field (large fov)	3	This is needed to monitor the instrumental background during (selected) science observations.			ESA / WFI	ASST	2c		Different approaches can be considered: have some of he corners of the detector blocked for photons from the mirror (the four edges) in a continuous way or by applying a dedicated filter. Alternatively the closed position of the filter wheel can be part of the time inserted (time modulation of the background). Different options are under study
SCI-BKG-R-240	Athena shall have the option of measure the particle only background for Wide Field Observations during normal observations.	15% of the sensitive area	High spectral resolution	3	This is needed to monitor the instrumental background during science observations.			ESA / X-IFU	ASST	2c		See also SCI-BKG-R-230 but for the X-IFU there is hardly any vignetting thus reducing the area in a fixed way implies a loss of GRASP by the same number.

Astrometry												
SCI-AST-R-010	Athena shall achieve an astrometric error of <3" to 99.7% confidence level for 90% all observations.	3 arcsec 3 sigma	90% of all observation s	5	Centroid sources with sufficient accuracy to allow cross-wavelength and inter-facility identification. In diffuse extended objects need good localization in difficult centroiding conditions. This condition may not always be achieved (due to guide stars in special pointings)	131, 134		ESA / WFI	ASST	2b		Assumes that in diffuse extended object, the ability to use cross-ID to improve the pointing knowledge is not possible. Then some features need to be localized to better than angular resolution using the intrinsic observatory pointing performance.
SCI-AST-R-020	Athena shall achieve a reconstructed Astrometric error of <1" to 99.7% confidence level for Wide Field observations	1 arcsec 3 sigma	Wide field After correlation with known source positions	5	Identify high red shift and obscured AGN positions with multi-waveband counterparts once an initial astrometric field solution is found.	211, 221		ESA/ WFI	ASST	2b		XMM-Newton achieves 1.2 arcsec depending on signal-noise levels. This is a goal as it is determined by the number of known positions of X-ray sources in the Field of View
SCI-AST-R-030	Athena shall have the capability to set up to 3 different positions of the large FoV of the wide field instrument in the focus of the optics (on-axis)	3 focus positions on the detector	Wide field (large FoV)	5	For many observations it is undesirable to have the on-axis focus point at the center of the detector (where there is a gap). Additional positions include in two different quadrants (center and another position). This may need to be duplicated because of redundancy			ESA/ WFI	ASST	2c		
Target of opportunity												
SCI-TOO-R-010	Athena shall be able to perform High spectral resolution observations of a GRB-afterglow ToO in four hours for at least 50 ks for 40% of the GRB afterglows anywhere on the sky	4 hours, 50 ks	High spectral resolution	5	Allows a sufficient number of GRB alerts to be observed with sufficient fluence to utilize the full X-IFU resolution properties to detect WHIM filaments	141, 261		ESA / X-IFU	ASST	2a		Corresponds to 67% of GRBs with a Field of regard of 60% or 80% of GRBs with a 50% Field of Regard. This requirement includes also the setup time and availability of the X-IFU (which is less than 100% (80%, TBC) 100% availability). In a 50 ks observation we will get a significant part of the fluence (It should be noted that this requirement can be relaxed if either the area or the spectral resolution improves.

SCI-TOO-G-020	Athena should perform all observations of all ToOs within 4 hours of the receipt of an external ToO alert.	4 hours	All observations	5	Observatory Science, e.g. R-SCIOBJ-322, 332	322, 331, 311		ESA	ASST	2b		Not all ToOS require to be as time critical as GRBs and therefore this is specified as goal. The difference with SCI-TOO-R-01 is that this goal should apply to all sources within the Field of Regard
SCI-TOO-R-030	Athena shall be able to complete its full mission lifetime with a rate of 2 ToOs per month	2 ToOs/ month	for a 10 year mission duration	5	Based on science goals and MOP two ToOs per month are a realistic assumption	141, 261, 262, 338		ESA	ASST	2b		more can be selected on scientific grounds but may reduce the consumables faster than designed. For the purpose of this requirement we assume the extended mission duration of 10 years.
SCI-TOO-G-030	Athena should be able to complete its full mission lifetime with a rate of 5 ToOs per month	5 ToOs/ month	for a 10 year mission duration	4	Based on science goals and MOP giving more flexibility in number of ToOs	141, 261, 262, 338		ESA	ASST	2b		Allows for more follow up measurements without endangering life time of the mission
Observations												
SCI-OBS-R-010	Athena shall be able to perform any type of observation within a Field of Regard of 50% of the sky at the end of nominal life.	50%		5	Number of potential GRBs is limited over nominal mission lifetime and with the specified Field of Regard, it is expected to achieve the required number of GRBs.	141, 261		ESA	ASST	2b		
SCI-OBS-G-010	Athena should be able to perform any type of observation within a Field of Regard of 60% of the sky at the end of nominal life.	60%		5	Improved performance compared to the requirement	141, 261		ESA	ASST	2b		Requirement for Field of Regard for ToO targets will improve the statistics or could be used to relax other requirements (reaction time, area, spectral resolution)
SCI-OBS-R-020	Athena shall support continuous observations of 50 ks	50 ks	All observations	5	Allows to construct un-aliased temporal power spectrum density of binary objects. Efficient coverage of survey fields without interruptions.	141, 261, MOP		ESA	ASST	2b		This is a minimum, longer observing times can improve the observing efficiency as a large fraction (76%) of the proposed observing time is larger than 50 ks and 34 % of the overall time is larger than 100 ks. However, this could be traded with dimensioning of other satellite properties (such as the need to unload reaction wheels)
SCI-OBS-G-020	Athena should support continuous observations of 100 ks	100 ks	All observations	5	Improved capability compared to the requirement.	MOP		ESA	ASST	2b		Longer observations allow for a significant fraction (66%) of the observations in the MOP to be completed without interruption and hence may improve the observing efficiency.

SCI-OBS-R-021	Athena shall be able to perform a 50 ks observation of ToOs after the completion of the pointing maneuver for the ToO	50 ks after repointing	High spectral resolution instrument	5	Allows to collect about 70% of all events which can be accumulated for a 100 ks GRB observation after the start after 4 hours (assumes average behaviour from sample of light curves from SWIFT))	141, 261		ESA, X-IFU	ASST	2b		Will define the capability of the X-IFU cooling system and can be achieved by long observing times or by sufficiently fast regeneration of the cooling system. In practice the ground operations will need at least 3 hours to respond, in which case the 50 ks observing time can be reached by a regeneration time of less than 3 hours.
SCI-OBS_G-021	Athena should be able to perform an observation with a total of 100ksec in semi-continuous mode (SCI-OBS-R-022), of ToOs after the completion of the pointing maneuver for the ToO	100 ks after repointing	High spectral resolution Instrument	5	Improved capability (about 30%) compared to the requirement	141, 261		ESA, X-IFU	ASST	2b		Applies as a minimum in cases when the regeneration before the too has been fully completed and can support a longer observation
SCI-OBS-R-022	Athena shall be able to perform semi-continuous observations with a total of at least 100ks of a source where the intervals between subsequent observations is less than 2 ks	2 ks intervals	All observations	5	There are many > 50 ks observations but these can be split into separate observations, in practice this could imply an observation of 2 x 50 ks interleaved with 2 ks for satellite keeping, the onboard memory needs to be scoped to at least 100 ks	MOP		ESA	ASST	2c		This allows to reduce the size of the onboard system to store momentum. It may affect the observing efficiency negatively. It is assumed that the (WFI) observation can continue with the proper post facto attitude reconstruction but the onboard control will be reduced
SCI-OBS-R-030	Athena shall offer a minimum observing duration of 1ks.	1ks		5	MOP: correlation function mapping for the WHIM. The 1ks is a factor 10 shorter than currently foreseen in the MOP but provides additional flexibility.	141, 261		ESA	ASST	2b		Note that in the current version of the MOP 10 ks is a typical short observation when performing a correlation mapping.
SCI-OBS-R-040	Athena shall provide a continuous target accessibility of 2 weeks in any 6-months period.	2 weeks in any 6 months period		5	Ensures scheduling of a critical long observation can be achieved without complex constraint checking.	MOP		ESA	ASST	2b		Science requirement is to ensure good visibility of a large pool of targets in the observing plan to ensure it can be executed in a reasonable lifetime. Relevant areas are the patches of the sky survey
SCI-OBS-R-050	Athena shall be able to execute the Mock Observation Plan in the nominal mission duration	5 years	85% observing efficiency	5	Mock observing plan	All science		ESA	ASST	2b		Issue 2.0 of the MOP is too ambitious and requires 85% observing efficiency. An open action to see if a reduced observing efficiency is feasible exist (MoP 2.1). Periods of high background are allowed when the sources are bright (see background requirements)

Pointing												
SCI-POI-R-010	The Athena Mission shall provide capability for Dithering to disentangle detector and target features over a user selectable area and pattern between 25" (for pixel to pixel variations in High spectral resolution) and 300 " (for Wide Field observations) with a speed varying between 0.01 and 0.2 arcsec/s	2" – 300" speed of 0.01 – 0.2 arcsec/s		4	Ensure that instrumental artifacts such as efficiency variations can be flattened out and averaged. In addition this is required to average the background over scales sufficiently large to be characterized with the required statistical accuracy (SCI-BKG-R-050 and SCI-BCK-R-110) Proposed pattern is a Lissajous pattern but this is not yet optimized	111, 112, 121, 122, 132		ESA	ASST	2b		Applies particularly to all extended objects - clusters of galaxies and Supernova remnant. The ranges are from a a part of the PSF up to 5 arcmin (more than the gap between the WFI chip. This should be a user selectable mode, as time variability science or high countrate science (in the WFI) could be compromised by this.
SCI-POI-R-020	The Athena Mission shall provide the capability for Raster scan to cover a up to 3 x 3 degree² area with a user specified step size and pattern	Steps to cover up to 3x3 degrees		5	R- SCIOBJ-211, 222, 224. Allows efficient construction of wide field surveys. ConOps [DJF_10]			ESA	ASST	2c		An implementation whereby automated progression from one "observation" to the next can occur without additional observatory set-up processes (implemented on XMM after some years in orbit). The 3 x 3 degree² allows efficient surveys whereas the sun aspect angle constraints will not affect the survey strategy. A user specified step size should be implemented.
SCI-POI-R-030	Athena shall provide Target Acquisition (APE) of 7 arcsec in 95% of the cases	7 arcsec	High spectral resolution	4	This APE defines the size of the high count rate section of the X-IFU and the size of the fast chip part of the WFI. In both cases these parts will cover >80% of the events on an on-axis point source.	331, 342		ESA	ASST	2b		FoV for X-IFU is 5' and an APE of 10" is not needed. For the WFI Fast Chip the FoV is 147 arcsec. Therefore a APE of 20 arcsec (about one tenth of the FoV) seems to be realistic but the number may need to be updated once the defocussing mechanism is decided. However, a high countrate/high spectral resolution sub-array for the X-IFU is under consideration and with a smaller APE, the size of this section can be reduced/optimized
SCI-POI-G-040	ATHENA should be able to track solar system bodies while observing, so as to avoid degraded instrument performance. This implies the capability to track a maximum angular rate of target	up to 100 arcsec/hr and 20 arcmin/hr	High spectral resolution or Wide field of View	5	The purpose of this requirement is to have an efficient observation of moving objects (planets and comets)	311		ESA	ASST	2b		

	movement across the celestial sphere of 20 arcmin/hr, taken to be the value for a comet with high proper motion. Planets are known to move slower than this (~110 arcsec/hr max)											
Latency												
SCI-LAT-R-010	Athena shall make available level 1 data to the user for their observation within 15 working days of the end of the observation for 95% of the observations	15 working days in 95% of the observations		4	This allows users to inspect the data and trigger any potential follow up measurement while it is not driving the design of the SGS			ESA	ASST	2c		Allows a small fraction of data to be re-processed before released
SCI-LAT-G-020	Athena shall make available Quick Look data to the user for observations which were a ToO within 1 working day of the end of the observation for 90% of the time	1 working day in 90% of the time		4	In case of a ToO follow up observations are likely and in general these data will be made available to the user in a 1 day time (may not include all aspec corrections)			ESA	ASST	2c		The quicklook data should allow for a verification of the spectrum and source intensity and can be used to provide feedback to the project scientist on appropriateness of continuation of the ToO. The quicklook data need not to be complete (e.g. processed orbit/aspect data). Allows for a small fraction of the data where due to e.g. non availability of a ground station, this is not achieved
SCI-LAT-R-030	Athena shall make available relevant instrument data to the instrument teams for health checking within 1 working day during the normal operational phase	1 working day in 90% of the observations		5				ESA	X-IFU / WFI	2c		real health checking needs to be done onboard by the onboard software and ground contacts cannot always be guaranteed
SCI-LAT-R-040	During the commissioning phase, Athena shall make available relevant instrument data to the instrument teams for health checking in near-real time.	Near real time		5	This is strictly spoken no science requirement but a health/operational requirement from the instrument teams			ESA	X-IFU / WFI	2c		Secure maximum coverage during commissioning phase.

9 DEFINITIONS

9.1 Collected Definitions

Half Energy Width – the diameter (or equivalent in two dimensions of asymmetric PSF) containing half the X-ray photons from a point source

Effective Area – the collecting area at an instantaneous X-ray energy, E, [$Aeff$ (E)] of the Athena system is a product of the Effective Area provided to the focal plane by the SC [$Aeff\_SC$(E)] and the QE of the instrument [Q_{inst}(E)]. The former includes all losses such as vignetting due to pointing and mis-alignment, the latter including all effects at instrument-level including filters, dead spaces and event processing selections.

Relative Effective Area – the change in effective area between two energy ranges

Absolute Time – a time datum referred to the detection of an event in a detector in UTC (or synchronously running system such as TAI). It shall be assumed that the space and ground segments secure necessary conversions to alternate standard systems such as TDB Barycentric Dynamical Time

mCrab Flux – a convenient conversion between the flux in an energy band for a Crab-like reference spectrum, and the X-ray count rate is frequently used. Assuming a power law from 0.1-10keV and a low absorbing column 1m Crab is ~2 10^{-11} erg/cm^2/s.