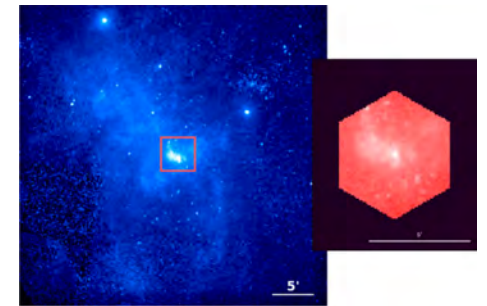
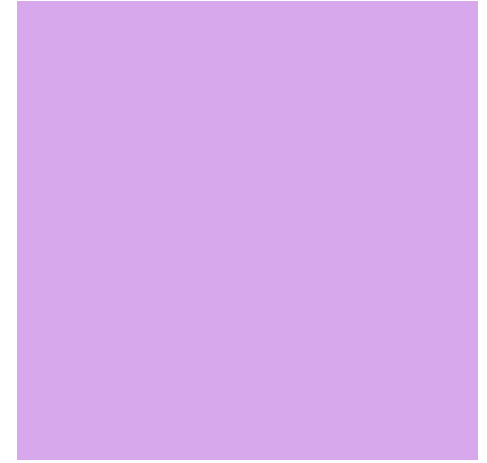
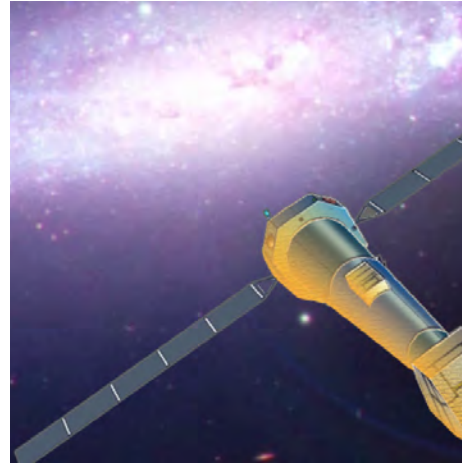


ATHENA

Exploring the Hot & Energetic
Universe

-
Status Update



Randall Smith

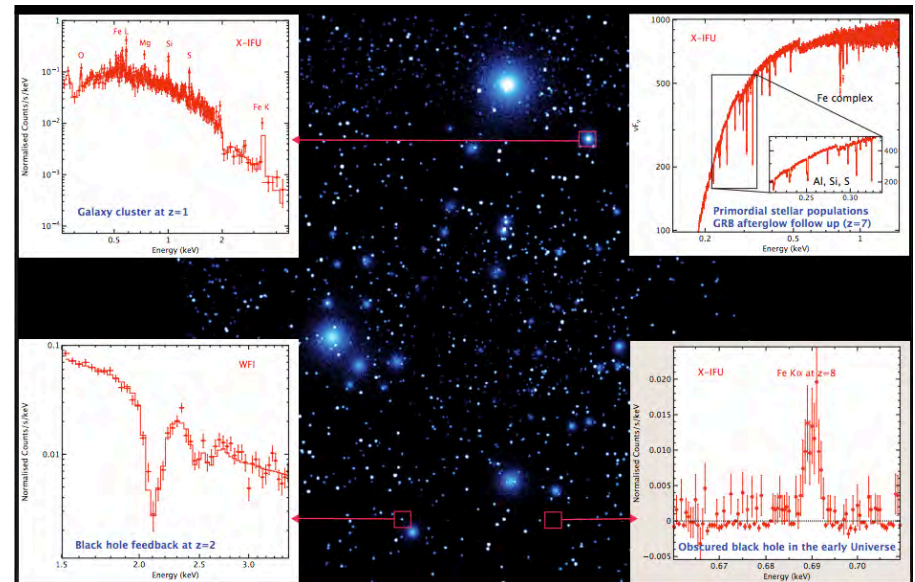
Smithsonian Astrophysical Observatory



X-ray SIG, January 8, 2018

Advanced Telescope for High-Energy Astrophysics

- Second Large (L2) mission of ESA Cosmic Vision 2015-2025
- Science theme: The Hot and Energetic Universe
 - How does ordinary matter assemble in the large-scale structures?
 - How do black holes grow and shape galaxies?
- In addition:
 - Fast ToO capability to study transient sources (GRB & others)
 - Observatory science across all corners of Astrophysics



Nandra et al. 2013, arXiv: 1306.2307

Barcons et al. 2017, Astron Nachr

<http://www.the-athena-x-ray-observatory.eu>



Athena mission concept

- Single X-ray telescope, using Si pore optics, 5" resolution on-axis, 12m focal length
- Science Instrument Module including two instruments:
 - WFI sensitive imaging & timing
 - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch 2028, Ariane 6-4
- L2 halo orbit (TBC)
- Lifetime > 4 yr



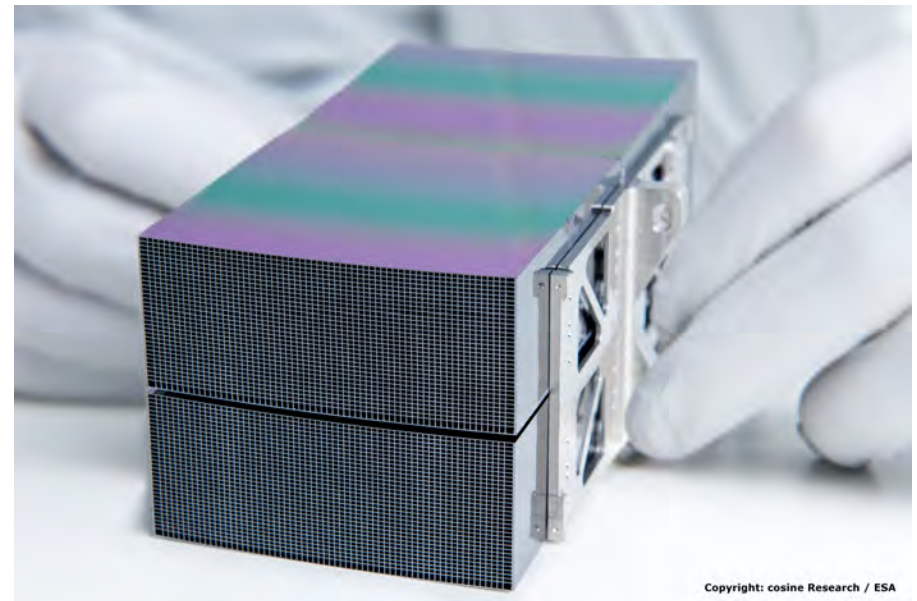
Athena concept, ESA CDF (Phase 0)

Ayre et al 2016, SPIE Proc 9905



The Athena X-ray optics

- Light-weight Si-pore optics:
 - 5" HEW on-axis
 - Degradation off-axis <10" @ 15'
 - 2 m² effective area @ 1 keV, with 3 m aperture diameter
 - Limited vignetting at 1 keV
 - 0.25 m² effective area @ 6 keV
- Athena optics development:
 - Grazing incidence optics, Wolter-I type (paraboloid-hyperboloid), largely with conical approximation
 - Vigorous development programme on-going.

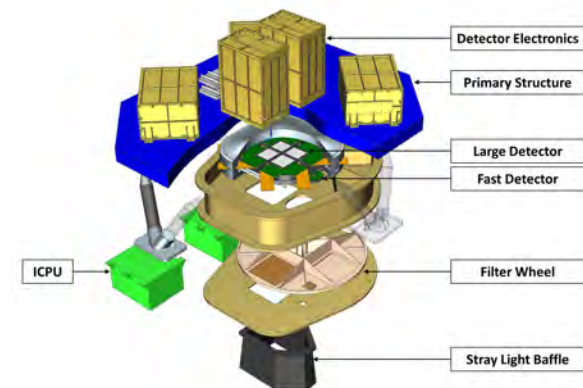


Credit: ESA and Cosine Research
Bavdaz et al 2016, SPIE Proc 9905



Wide Field Imager (WFI)

- Spectroscopic imaging device, based on Si detectors, using Active Pixel Sensors based on DEPFETs.
- Key performances;:
 - 120-150 eV spectral resolution,
 - 2.3'' pixel size (PSF oversampling)
 - Field of view: 40'x40'
 - Separate chip for fast readout of brightest sources
- Consortium led by MPE (Germany) with other European countries (AT, DK, FR, UK, IT, PL, PT, CH, GR) and NASA
- Optimized for sensitive and wide imaging and intermediate resolution spectroscopy, up to very bright sources



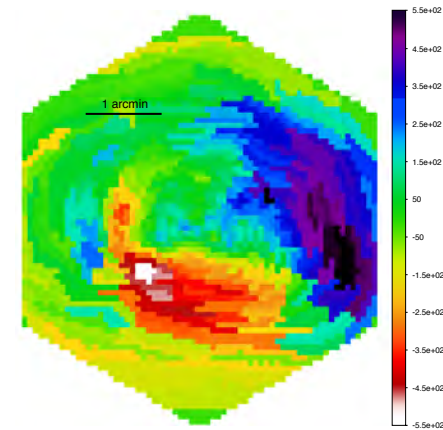
Meidiger et al 2016, SPIE Proc 9905
 Rau et al 2016, SPIE Proc 9905



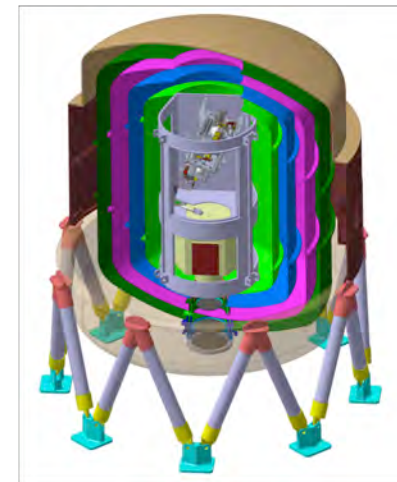
<http://www.mpe.mpg.de/ATHENA-WFI/>

X-ray Integral Field Unit (X-IFU)

- Cryogenic imaging spectrometer, based on Transition Edge Sensors, operated at 50 mK featuring an active cryogenic background rejection subsystem
- Key performance parameters:
 - 2.5 eV energy resolution @ <math><7\text{ keV}</math>
 - FoV 5' diameter
 - Pixel size <math><5''</math>
- Consortium led by CNES/IRAP-F, with SRON-NL, INAF-IT and other European partners (ES, CH, BE, FI, PL, DE), NASA and JAXA.
- Optimised for spatially resolved high-resolution X-ray spectroscopy



Courtesy: E. Pointecouteau, P. Peille, E. Pointecouteau, E. Rasia, V. Biffi, S. Borgani, K. Dolag, J. Wilms



Barret et al. 2016, SPIE Proc 9905

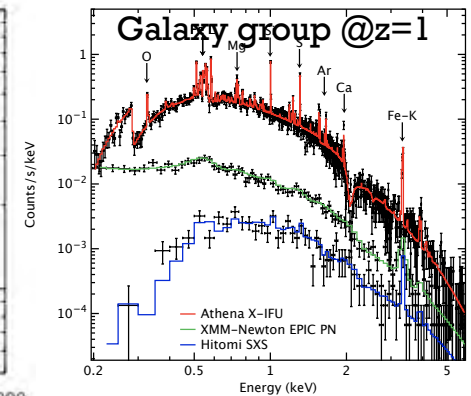
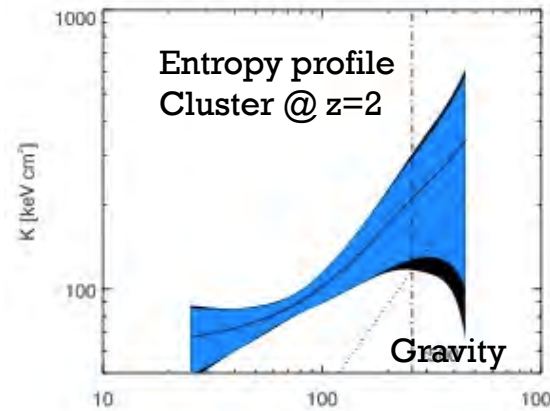
Lam Trong et al. 2016, SPIE Proc 9905

<http://x-ifu.irap.omp.eu/>

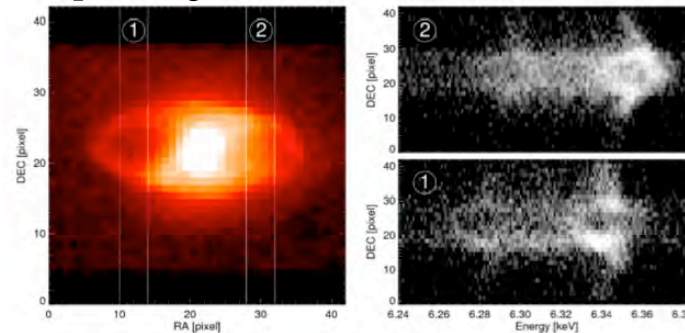


The Hot Universe

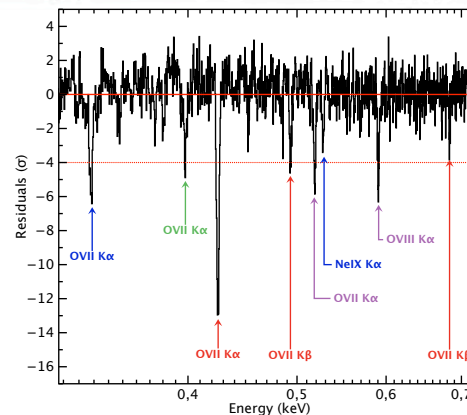
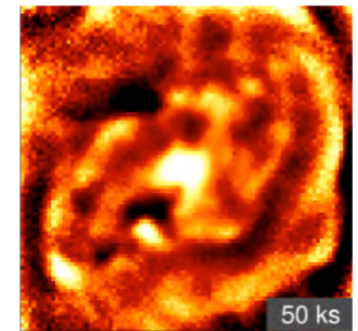
- Thermal history of hot baryons in clusters up to $z \sim 2$
- The quest for early galaxy groups @ $z > 2$
- Chemical evolution of cluster gas
- AGN feedback on cluster scales
- Missing baryons in the Warm & Hot Intergalactic Medium



Expanding bubbles in cool cluster cores



AGN-produced ripples

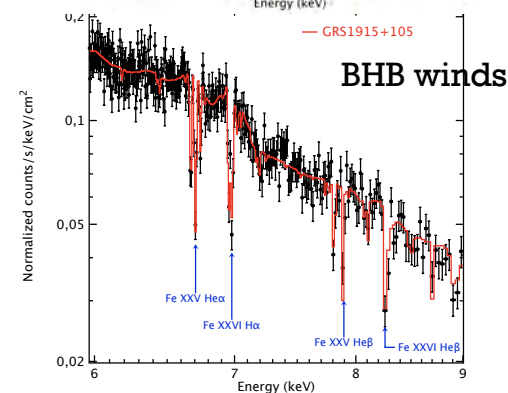
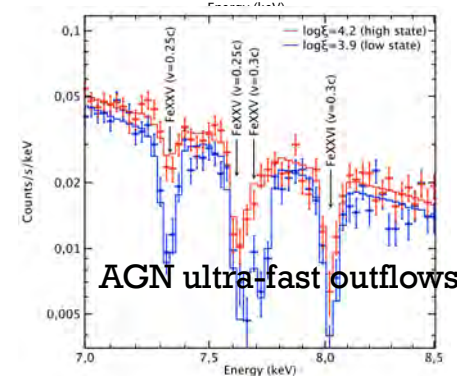
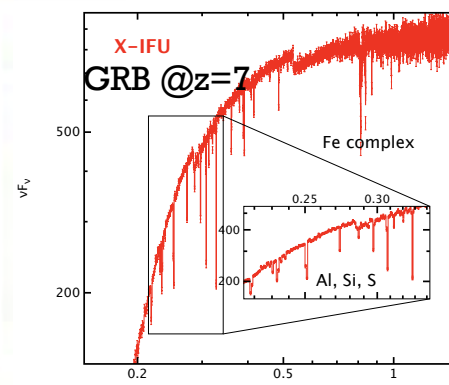
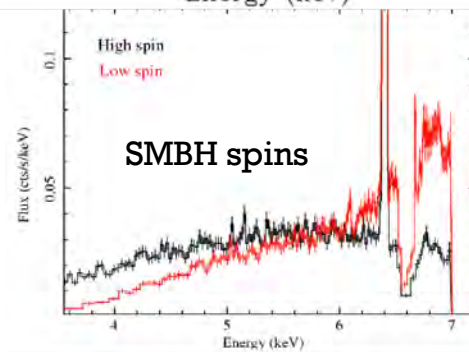
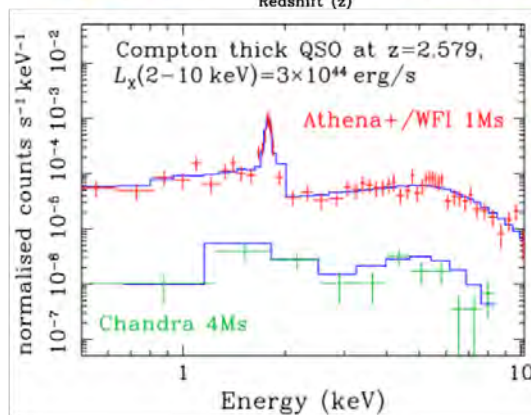
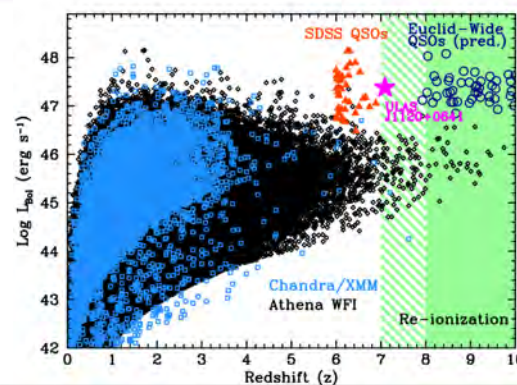


WHIM filaments against
10% brightest GRB afterglows



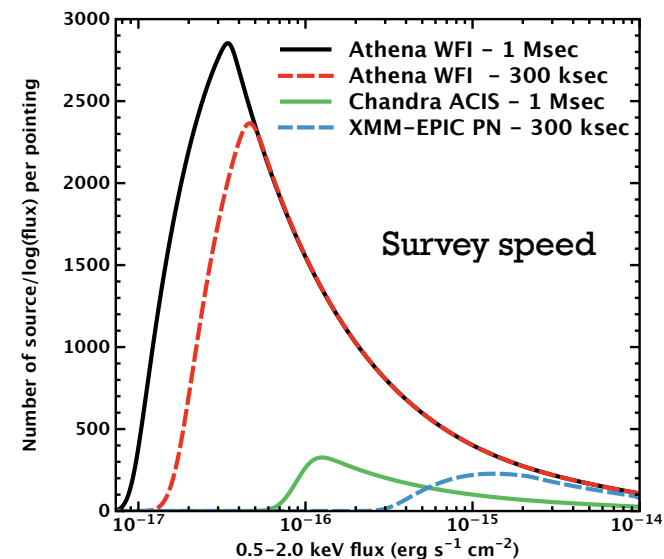
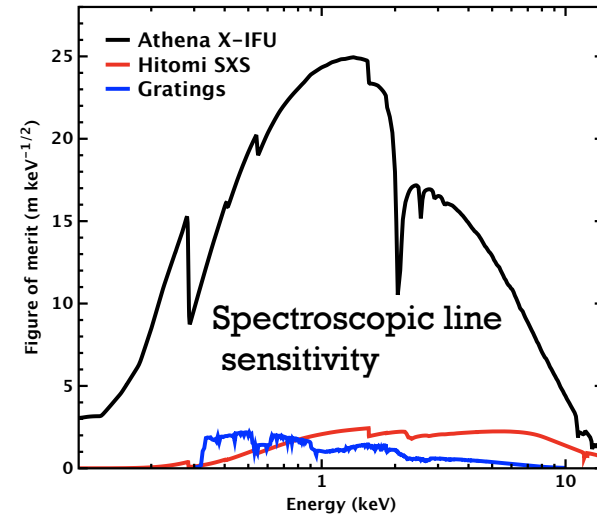
The Energetic Universe

- Find 100s of AGN at $z > 6$ and 10s at $z > 8$ representing the population of growing SMBH.
- Perform a complete census of obscured AGN out to $z = 3$. Measure incidence and energetics of AGN winds and outflows out to $z \sim 3$
- Probe the ISM of early galaxies through GRB afterglows
- Gas, energy and metal outflows from AGN and Starburst galaxies
- Perform a SMBH spin survey
- Measure stellar BH and NS spins and determine accretion geometry.



A transformational observatory, impacting all astrophysics

- Planets and solar system bodies
- Exoplanets: magnetic interplay
- Star formation, cool stars, brown dwarfs
- Massive stars: mass loss
- Supernovae: explosion mechanisms and shock physics
- Stellar endpoints (Neutron Stars)
- Interstellar medium
- ...



Athena Project status

- Phase A on-going, Jun 2015 until late 2018
 - Two parallel industrial studies
 - System-level tradeoffs, spacecraft conceptual design.
 - Development of the 2 instrument concepts by the consortia
 - Studies under review at ESA now for technical feasibility and cost
 - On-going Technology Development Activities (Optics, X-IFU Detector Cooling System, Background characterisation etc)
 - Contribution from external partners being secured (NASA & JAXA)



ASST Studies in 2017: SIMO & CORE

- The ESA technical studies showed that Athena faced both a Mass and a Cost issue.
 - The mass problem was complicated based on the as-yet-unknown lifting capability of an Ariane 6 rocket
 - The cost problem is set by the €1.05B cost cap for the ESA part of the mission
- SIMO : Science Impact of Mass-saving Options
 - Study of science impact by all working groups
 - Meeting at SRON of WG chairs in February 2017
 - Result was discussed at March 2017 ASST meeting with result that
“The ASST recommends that ESA proceeds with the study using the full 20-row mirror, but agrees that if the system mass non-compliance persists at a decision point to be determined by the ESA project team, then the outer mirror row may be removed without further discussion or trade-off.”



ASST Studies in 2017: SIMO & CORE

- CORE: Cost-driven Observation Reprogramming Exercise
 - Again involved WG chairs to evaluate options
 - Relied upon results from SIMO to understand scale of impact of various changes
 - Options included
 - Removal of 5 mirror rows (with a corresponding reduction in the effective area)
 - Reduction in the field-of-regard requirement (saving hardware costs e.g. for the deployable sunshield and solar array drive mechanism)
 - Reductions in operation costs (e.g. via a shorter mission lifetime and reduced ground system support for ToOs).
 - The ASST concluded that **if necessary** it is preferable to remove the 5 outer rows of the mirror, preserving the high-energy response of the mirror as well as the etandu (area x fov) while reducing the on-axis 1 keV effective area from 2m^2 as proposed to 1.4m^2 , with a reduction in nominal mission lifetime from 5 to 4 years.



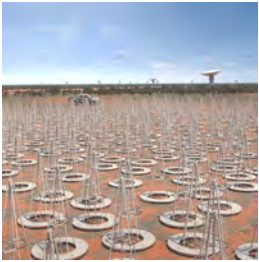
Next Steps

- **Next Athena Conference: September 24-28, 2018 in Palermo**
- Results of industrial studies under evaluation at ESA now
 - Next step will be to run delta cost estimates using reductions recommended from CORE exercise to confirm cost-cap is met (Q2/2018)
 - Mission Selection Review planned for 2019
 - Mission Adoption Review planned for 2020
- NASA contributions being confirmed.
 - X-IFU contribution of focal plane array; work ongoing
 - WFI contribution of ASIC design assistance & possible science module for background reduction; other contributions under discussion
 - Possible contribution to ESA of vibration control system to reduce launch shock
 - Possible contribution to ESA of XRCF facilities
 - Alignment verification and calibration could take place at NASA Marshall's X-ray Calibration and Cryogenic facilities
 - Discussions are, as usual, ongoing



Athena in the late 2020s astronomical landscape

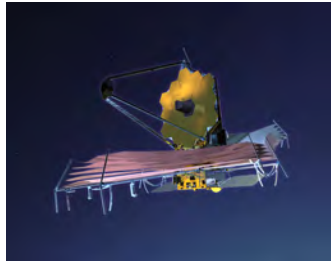
SKA



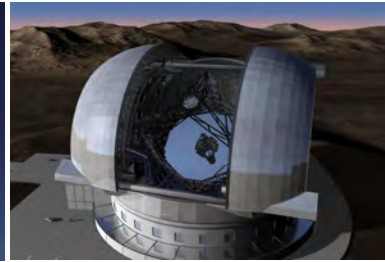
ALMA



JWST



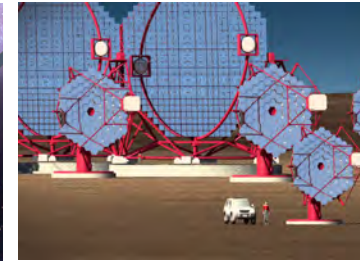
E-ELT



Athena



CTA



- Athena will be a transformational X-ray observatory addressing the Hot and Energetic Universe theme, with the potential to impact all corners of astrophysics
 - Will be part of the suite of large facilities in the late 2020s enabling unprecedented studies & discoveries
- Project development (currently Phase A) is making good progress

