ATHENA

Exploring the Hot & Energetic Universe

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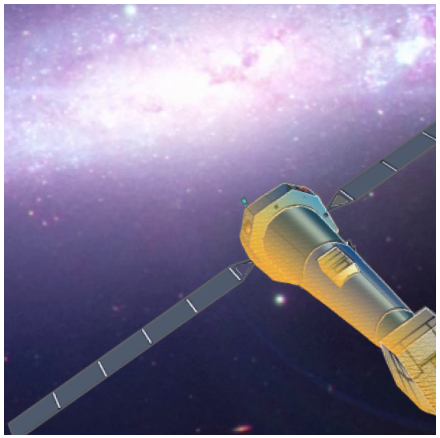
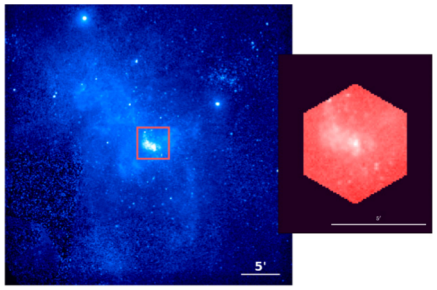
Status Update

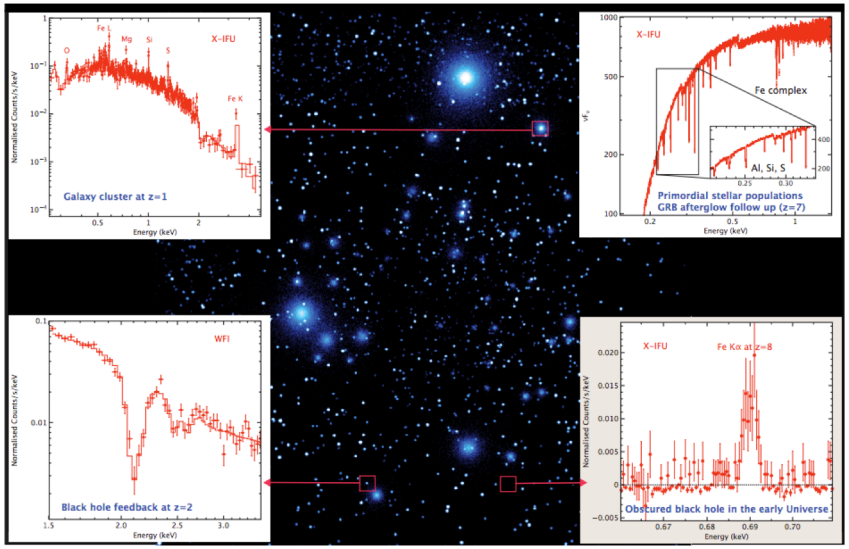




Andy Ptak (NASA/GSFC)
Randall Smith (SAO)

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 (GW counterparts, GRB & others)
  - Observatory science across all corners of Astrophysics

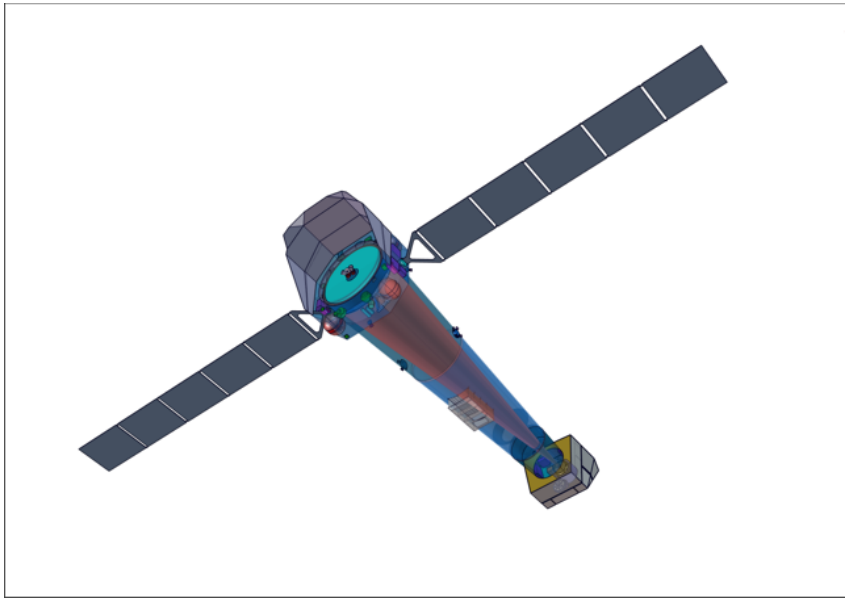


Nandra et al. 2013, arXiv: 1306.2307
Barcons et al. 2017, Astron Nachr

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

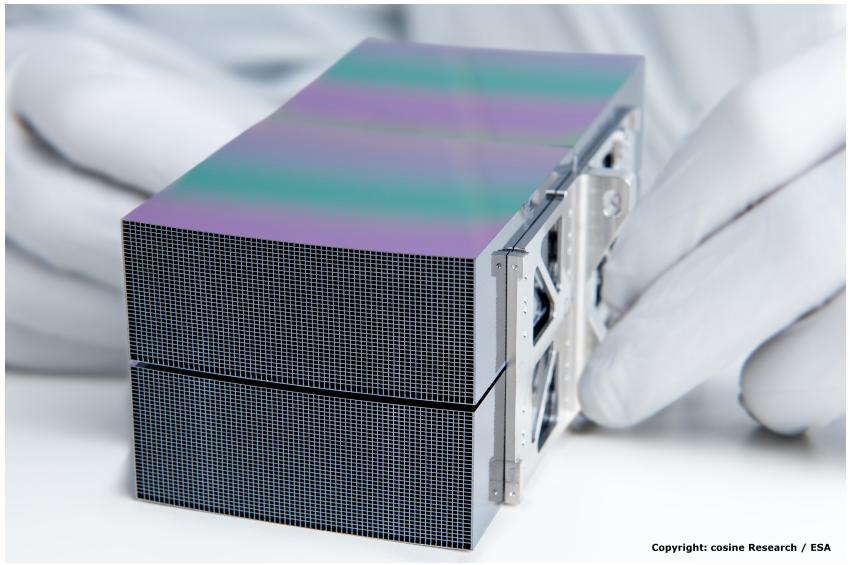


Athena concept, ESA CDF (Phase 0)

Ayre et al 2016, SPIE Proc 9905

The Athena X-ray optics

- Light-weight Si-pore optics:
  - 5” HEW on-axis requirement
  - Degradation off-axis <10” @ 15’
  - >1.4 m^2 effective area @ 1 keV, with 3 m aperture diameter
    - Limited vignetting at 1 keV
  - 0.25 m^2 effective area @ 6 keV
- Athena optics development:
  - Grazing incidence optics, Wolter-I type (paraboloid-hyperboloid), largely with conical approximation
  - Vigorous development programme on-going.

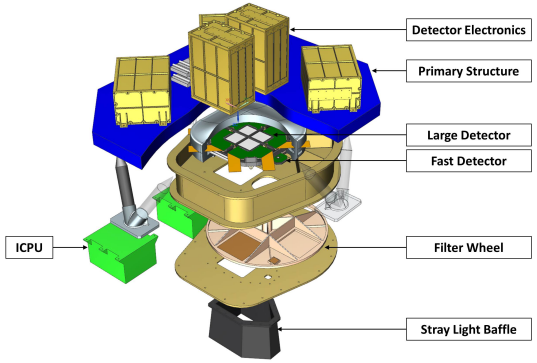


Credit: ESA and Cosine Research

Bavdaz et al 2016, SPIE Proc 9905

Wide Field Imager (WFI)

- Spectroscopic imaging device, 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 “fast readout” chip for 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

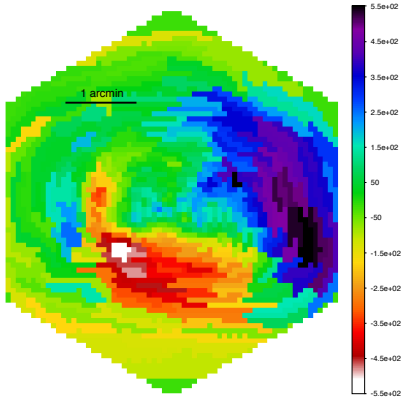


Meidiger et al 2016, SPIE Proc 9905
Rau et al 2016, SPIE Proc 9905

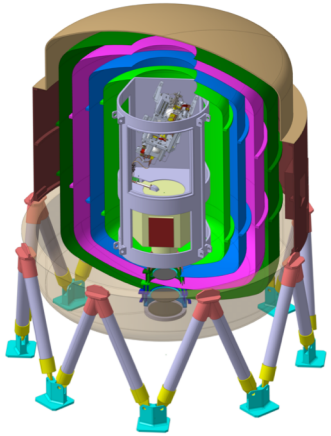
http://www.mpe.mpg.de/ATHENA-WFI/

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 @<7 keV
  - FoV 5’ diameter
  - Pixel size <5”
- 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

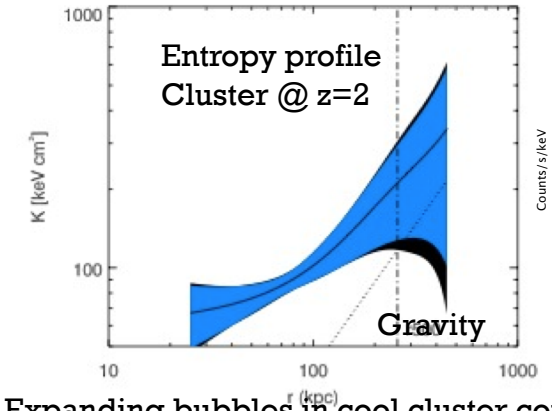


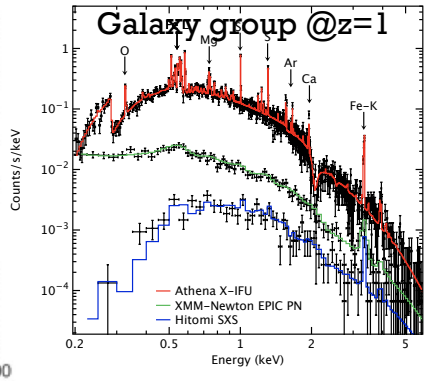
Barret et al. 2016, SPIE Proc 9905
Lam Trong et al. 2016, SPIE Proc 9905

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

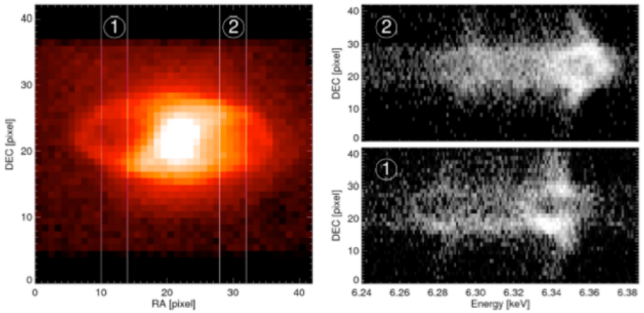
The Hot Universe

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

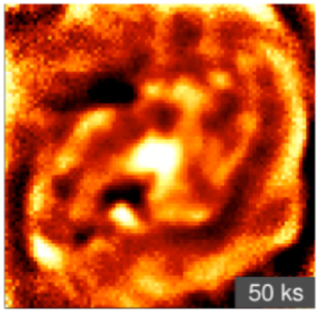


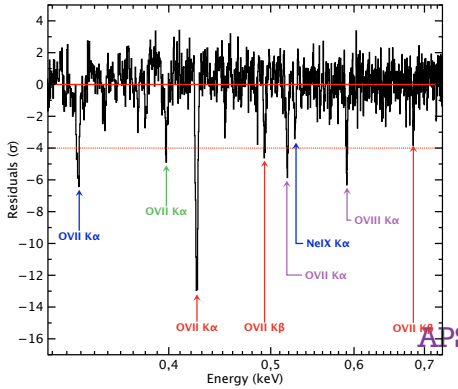


Expanding bubbles in cool cluster cores



AGN-produced ripples

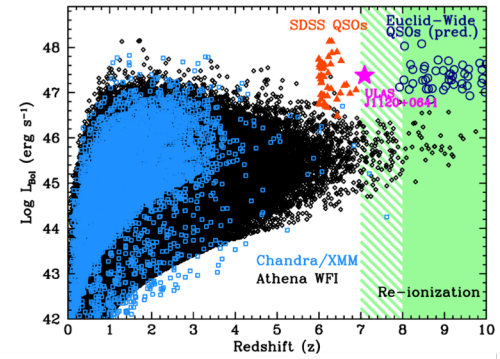


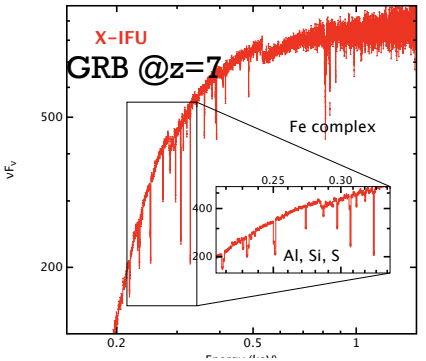


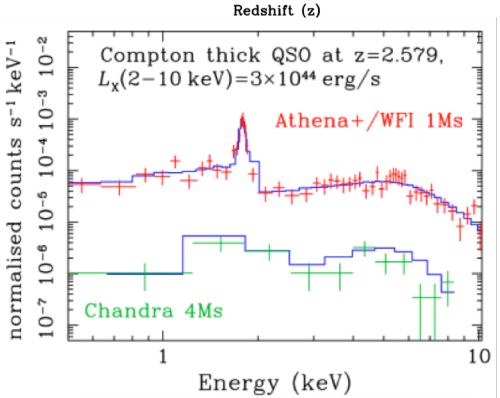
WHIM filaments against 10% brightest GRB afterglows

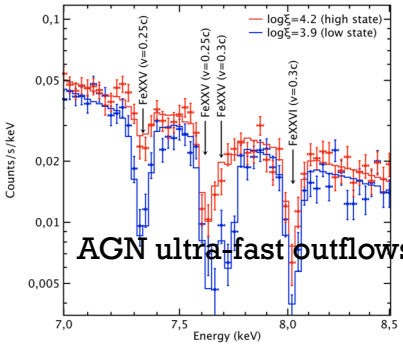
The Energetic Universe

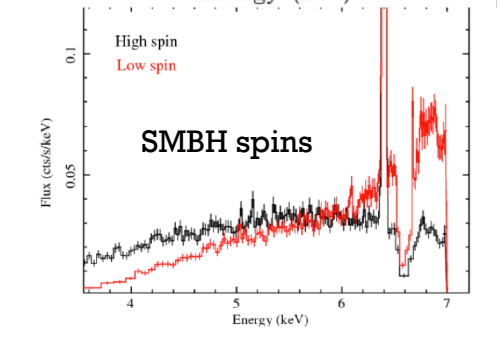
- Find 100s of AGN at z>6 and 10s at z>8 representing the population of growing SMBH.
- Perform a complete census of obscured AGN out to z=3. Measure incidence and energetics of AGN winds and outflows out to z~3
- Probe the ISM of early galaxies through GRB afterglows
- Gas, energy and metal outflows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

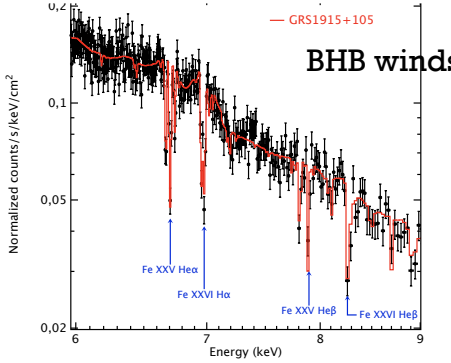






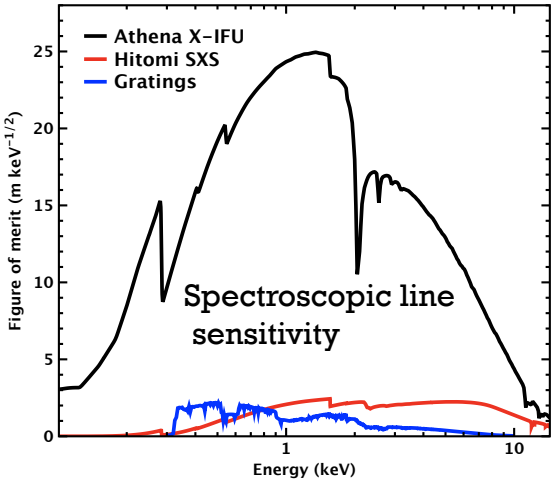


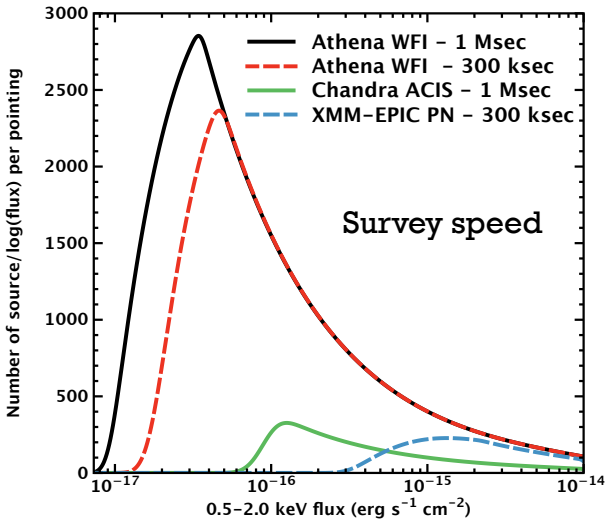




A transformational observatory, impacting all astrophysics

- 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

- 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

ASST Studies in 2017: CORE

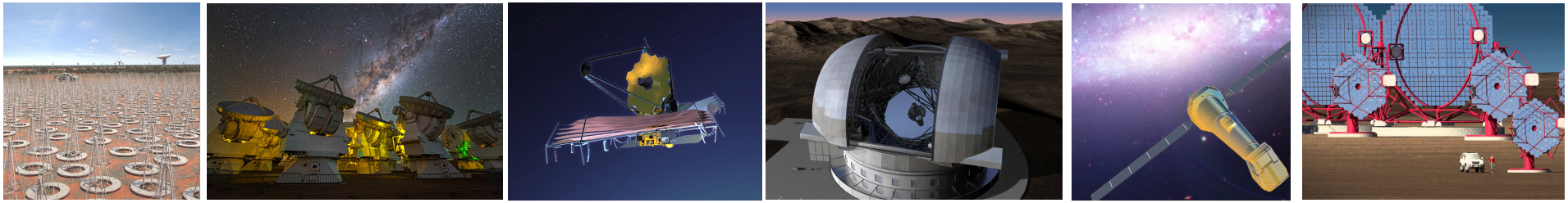
- CORE: Cost-driven Observation Reprogramming Exercise
  - Involved WG chairs to evaluate options
  - Options included
    - Removal of 5 mirror rows (with a corresponding reduction in the effective area)
    - Reduction in the field-of-regard requirement (saving hardware costs e.g. for the deployable 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.
    - Much less desirable options: reducing focal length or removing inner mirror rows, both reducing the E>2 keV X-ray effective area

Next Steps

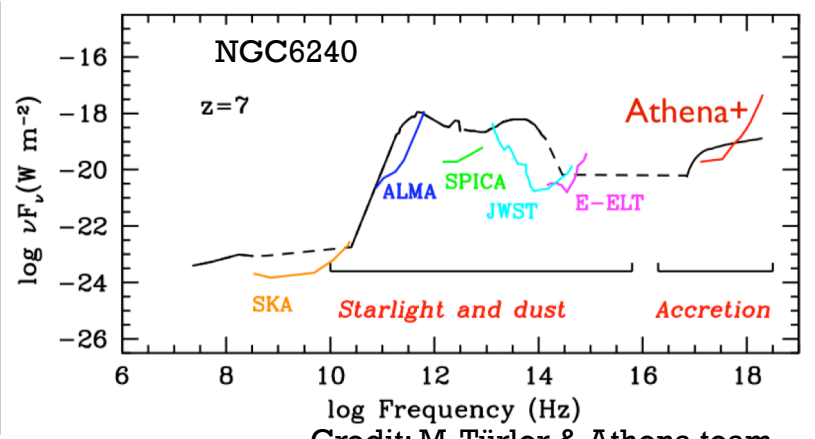
- **Next Athena Conference: September 24-28, 2018 in Palermo**
- Results of industrial studies under evaluation at ESA now
  - Next step will be to run delta cost estimates using reductions recommended from CORE exercise to confirm cost-cap is met (Q2/2018)
  - Mission Selection Review planned for 2019
  - Mission Adoption Review planned for 2020
- NASA contributions being confirmed.
  - X-IFU contribution of focal plane array; work ongoing (technology development)
  - WFI contribution of ASIC design assistance & possible science module for background reduction; other contributions under discussion
  - Possible contribution of vibration control system to reduce launch shock
  - Possible contribution 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
  - US contribution to the Science Ground System (science pipeline and calibration)

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



Credit: M. Türler & Athena team