CTA and Athena synergies

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©WFI Team. Athena mission: ESA/IRAP/CNRS/UT3/CNES/Fab&Fab.



CTA key targets

- Galactic center
- LMC
- Galactic plane
- Galaxy Clusters
- Star forming systems
- Transient phenomena

—> all involves hot gas —> also main targets for Athena

Active Galactic Nuclei



Pulsar wind nebulae



supernova remnants



Gamma Ray Bursts







Athena timeline Advanced Telescope for High-ENergy Astrophysics

- ESA L-class mission selected on June 2014 and now in the study phase
- It will be proposed for "adoption" in June 2023
- Planned launch: 2035
- By the time of the Athena launch, CTA will routinely observe at full nominal sensitivity

https://www.esa.int/Science_Exploration/Space_Science/Athena_factsheet









Athena - Advanced Telescope for High ENergy Astrophysics

• X-ray telescope, 12 mt focal length, 2 instruments at focus:

- Wide Field Imager (WFI, FoV=40'x40' (~0.4 deg2), ΔE=0.2-15 keV) for high count rate, moderate resolution spectroscopy and angular resolution of 5" on-axis

- X-ray Integral Field Unit (X-IFU) for high-spectral resolution imaging (2.5 eV up to 7 keV) in the 0.2-12 keV band, with 5" pixel and 5' FoV (diameter).



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Athena - Advanced Telescope for High ENergy Astrophysics



Athena sensitivity allows to characterize a lar cm²s, 2-10 keV, with 100 ks)

Piro et al. arXiv: 2110.15677

Athena sensitivity allows to characterize a large number of X-ray sources (e.g. ~3 x 10⁻¹⁶ erg/

Athena - Advanced Telescope for High ENergy Astrophysics

X-ray spectral properties will be determined with Ahena with great precision

Ex: for a source with $\Gamma = 2.5$, NH = 10²⁰ cm⁻², flux 10⁻¹³ erg cm⁻² s⁻¹

 $-> d\Gamma/\Gamma \sim 1(\sim 4)\%$ with 100(10) ks

 10^{-1} 10^{-2}

dΓ/Γ

 10^{-3} 10^{0}

dNH/NH 10^{-1}

 10^{-2}



Piro et al. arXiv: 2110.15677

CTA+Athena synergies: SNR or AGN broad band SED

Athena will characterize the X-ray spectral properties, the physical and chemical properties of the local environment \rightarrow crucial for γ -ray flux predictions in order to constrain leptonic vs hadronic models



SNR RX J0852.0-4622



































- Athena will perform ~5 ToO/ months from "External triggers" that however will be likely poorly localized in the sky
- CTA fast reaction (<30s) and large FoV —> sky localization down to ~few armin —> Athena will identify the source
- CTA Science Alert Generation System (SAG) in development as an in-kind contribution at OAS —> crucial role in this synergy (Bulgarelli's talk)

arcse



Credit: I. Bartos (adapted from)

- GRB 190829A observed with **H.E.S.S.** at 358 Mpc, $\Delta E = 0.18-3.3$ TeV, $\Delta T = 4 56$ hrs
- X-ray behaviour closely traces the VHE one up to >1 day
- Athena+CTA —> high temporal resolution monitoring of X-ray to γ -ray SED

Photon index



372 Science, Abdalla+2021

- Hard VHE spectral index —> incompatible with standard SSC model (blue) —> sync. spectrum up to VHE with hard electron tail(orange) or 2-zone em. model (?)
- Athena WFI/X-IFU:
 - $d\Gamma/\Gamma = 0.5-1\%$ (expo:104s @ 5x10-12 erg/cm2s) —> x10 better than Swift/XRT
 - Circumburst density measure





- short GRB160821B
 with kilonova (Troja et al. 2019) —> NS-NS
 mergers emit at VHE!
- 3G GW detectors + CTA+Athena will fully characterize NS-NS/ NS-BH mergers
- "Early warning" alerts can be exploited to monitor early phases (e.g. Chan+18,Li+21)



Acciari et al. 2021

NS-NS merger "Early Warning alerts" from 2G



- Nearby CBC signals can provide SNR above 2G network threshold already before merger
- "Early Warning alerts" for EM follow-up are planned for the next observation runs with ΔT~O(10) min



GW170817-like system with a total network SNR of 32 will already accumulate an SNR of 11 about a minute before merger

https://emfollow.docs.ligo.org/userguide/early_warning.html

TABLE II: Statistical Summary of Results For Early Warning

Network	d	n	100	0.5	2	5	10
	(Mpc)		sec	hrs	hrs	hrs	hrs
\mathbf{ET}	40	500	100%	100%	99%	66%	18%
	200		58%	39%	13%	2%	0%
	400		28%	16%	4%	0%	0%
	800		9%	4%	0%	0%	0%
	1600		3%	1%	0%	0%	0%
	Uniform 1	3000	2%	1%	0%	0%	0%
ET & CE	40	500	100%	100%	99%	66%	18%
	200		100%	74%	13.4%	2%	0%
	400		98%	27%	4%	0%	0%
	800		51%	4%	0%	0%	0%
	1600		5%	1%	0%	0%	0%
	Uniform $^{\rm 1}$	5000	4%	1%	0%	0%	0%

¹Uniformly distributed in the comoving volume.

A brief statistical summary of the results for early warning. In the first row, we again use d to denote distance and n the number of injections. The third to the seventh columns indicate the fraction of detectable events that meet the early warning criteria within the corresponding times.

Summary

- operate at full sensitivty
- CTA
- allowing Athena to observe (5 ToO/month, \sim 4hr) —> Science Alert Generation system in development at OAS is crucial for CTA+Athena synery!

• Athena ESA mission is planned to launched on 2035 when CTA will routinely

• Athena can provide accurate angular resolution (few arcseconds) and high quality 0.2-15 keV spectra for a large number of γ -ray sources detected with

• CTA will refine sky localization from GW/neutrino/GRB transient sources



Thank you!

WFI Team. Athena mission: ESA/IRAP/CNRS/UT3/CNES/Fab&Fab.



Back-up slides

- Kilonova afterglows in Xray can be monitored with Athena
- -> insight on the mass and velocity of NS-NS merger ejecta
- The long-timescales of such component allows Athena for long exposures, e.g. 3×10^{-17} erg s⁻¹ cm⁻² in 0.5-2 keV band



Kilonova afterglow

Piro et al. arXiv: 2110.15677



- Long time monitoring with ATHENA of GRB afterglows provide insight on the jet morphology
- Athena will reach 3x10⁻¹⁷ erg/ cm2s (0.5-2 keV) with 400ks of exposure allowing for long and deep monitoring of offaxis afterglows



Piro et al. arXiv: 2110.15677



CTA detection of GW events will refine their sky localization down to few arcmin allowing Athena to monitor the X-ray counterpart

The BNS merger GW170817 is still followed up

X-ray light curve morphology depends on jet energy and velocity angular distribution

Athena will reach 3x10⁻¹⁷ erg/cm2s (0.5-2 keV) with 400ks of exposure allowing for long and deep monitoring of off-axis afterglows



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