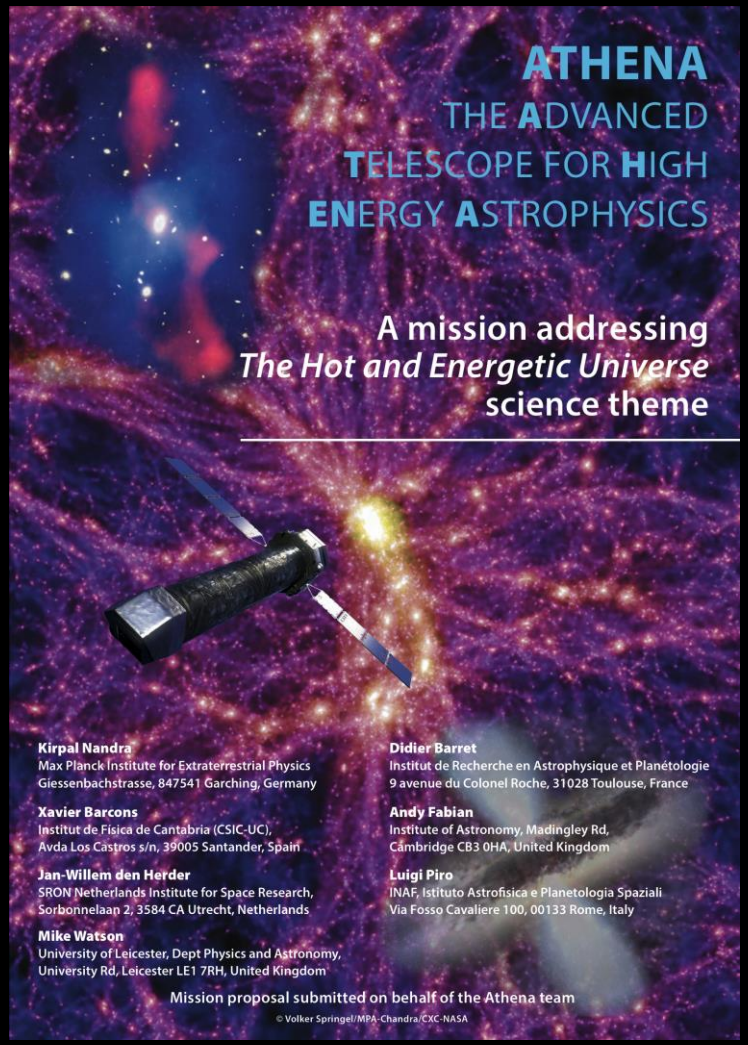
Synergies between ATHENA and e-ASTROGAM

Massimo Cappi (INAF/IASF-Bo)
on behalf of the Athena Consortium

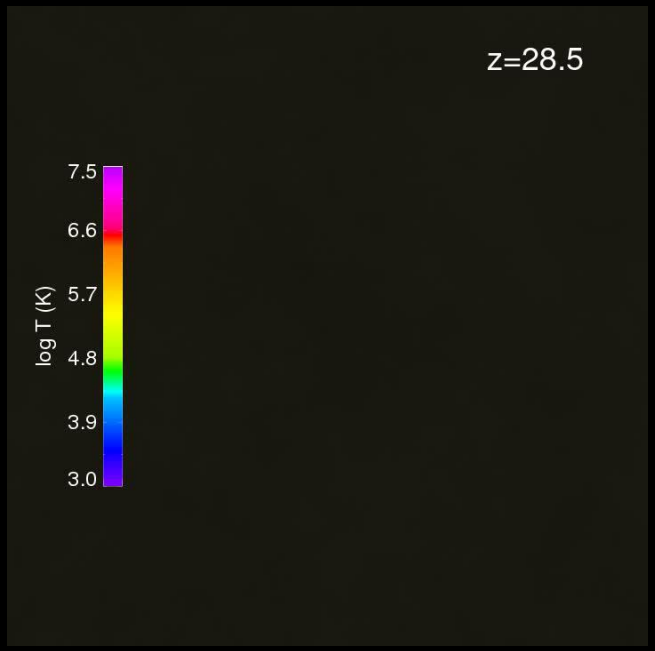


Outline

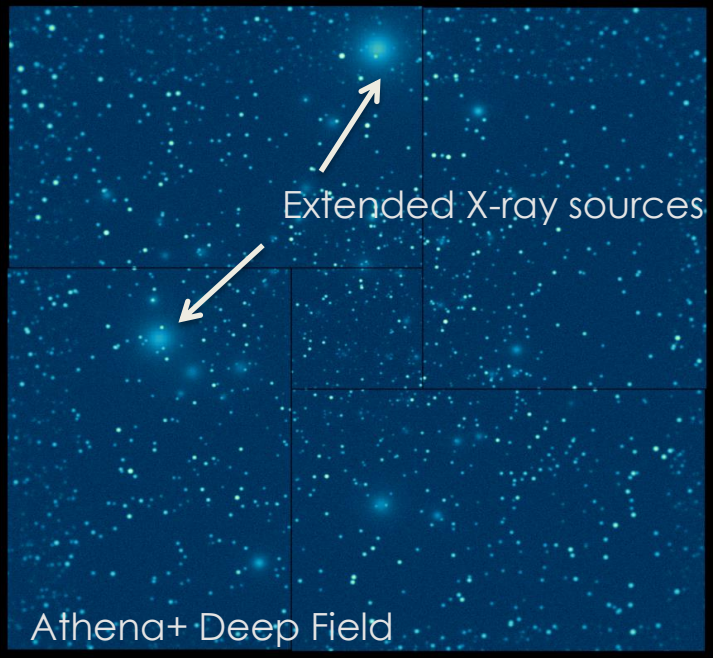
- ***ATHENA's core Science (The Hot and Energetic Universe)***
- ***Mission&Instruments***
- ***International Context***
- ***Schedule and programmatics***
- ***Synergies with e-ASTROGAM***

Key questions for observational astrophysics in 2028

1. How does ordinary matter assemble into the large scale structures we see today?



Oppenheimer et al. 2009



Pointecouteau, Reiprich et al., 2013
arXiv1306.2319

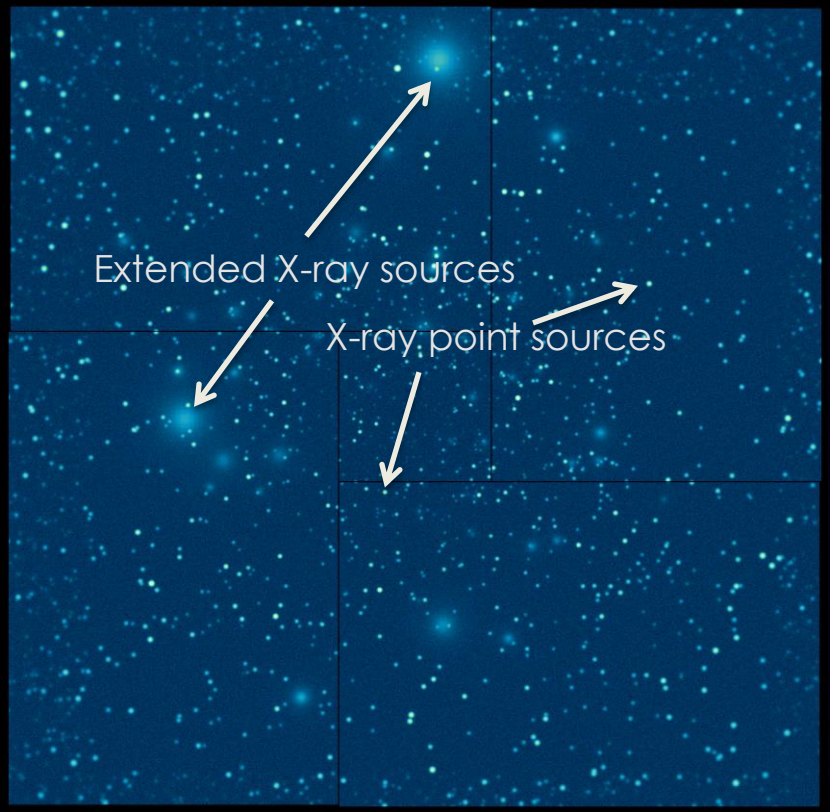
>50% of the baryons today are in a hot (>10^6 K) phase:

- **first groups and clusters characterization and evolution**
- **cluster astrophysics (bulk motion, turbulence, outskirsts, Ab.)**
- **AGN-clusters feedback**
- **WHIM**

Key questions for observational astrophysics in 2028

1. How does ordinary matter assemble into the large scale structures we see today?

2. How do black holes grow and shape the Universe?



Athena Deep Field

Building a SMBH releases 30 × the binding energy of a galaxy; and 15% of the energy output in the Universe is in X-rays (mostly released via accretion):

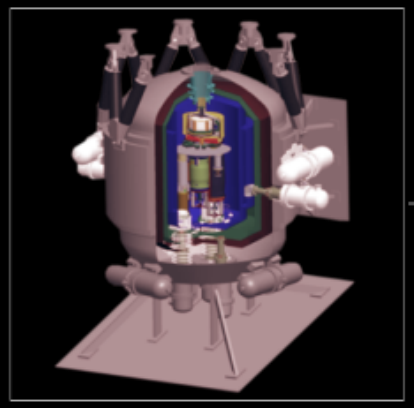
High-z (>6) QSOs, CT AGN, QSO feedback,

AGN astrophysics, BH spins, High-z GRBs and transient

The Athena Observatory

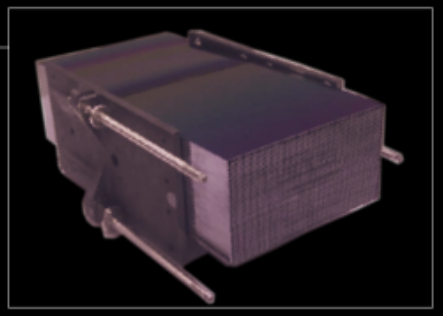
Willingale et al, 2013
arXiv1308.6785

L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
>5 year mission

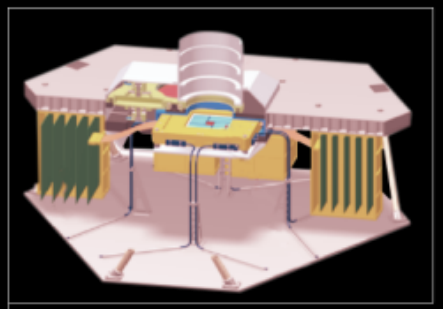


X-ray Integral Field Unit:
ΔE: 2.5 eV over 0.5-10 keV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2013 arXiv:1308.6784



Silicon Pore Optics:
2 m^2 at 1 keV, 0.25 @ 7 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: 3 10^{-17} erg cm^{-2} s^{-1}



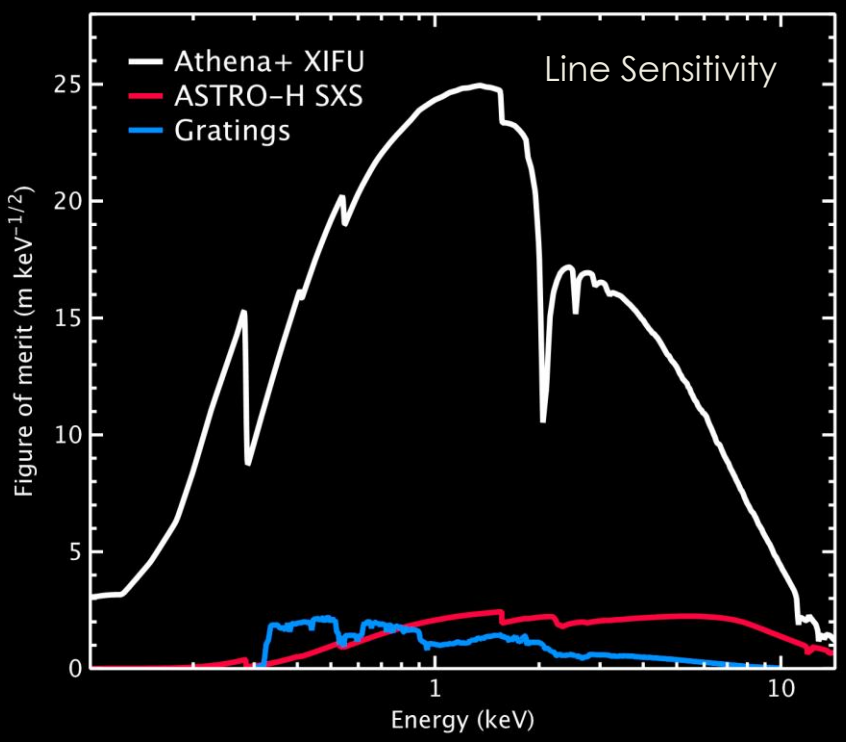
Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Rau et al. 2013 arXiv1307.1709

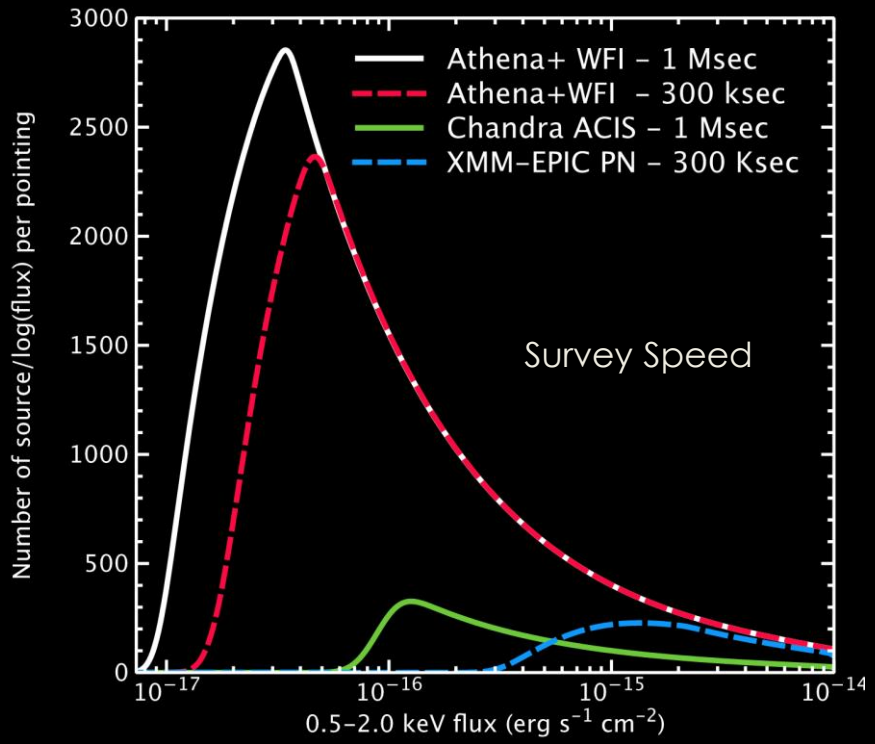
Launch 2028, Hexapod switch and defocusing mechanism, Ariane 6, L2 (TBC)

The first Deep Universe X-ray Observatory

Athena has vastly improved capabilities compared to current or planned facilities, and will provide **transformational** science on virtually all areas of astrophysics



X-ray spectroscopy at the peak of the activity of the Universe



Deep survey capability into the dark ages and epoch of reionization

A great ("two-legs") machine to address the Hot and Energetic Universe theme at both low-z (astrophysics) and high-z (cosmology/evolution)

Schedule

✓ Hot&Energetic Univ. Theme selected for ESA L2	Nov. 2013
✓ Athena Mission selected	Jun. 2014
✓ Phase A and B1	on going
➢ Implementation Phase	2019
➢ Launch	2028
➢ Operations:	5 +5 years

Programmatics

- ESA led missions, with international collaboration (<20%) from NASA and JAXA
- ESA responsible of mission systems, spacecraft, launcher, mirror, operations and SOC
- Instruments and Science Ground Segment elements to be provided by the Member States < ~ 400 M€
- ESA Cost at Completion ~ 1 B€

People Involved (as of today)

The Athena+ Co-ordination Group: Xavier Barcons (ES), Didier Barret (FR), Andy Fabian (UK), Jan-Willem den Herder (NL), Kirpal Nandra (DE), Luigi Piro (IT), Mike Watson (UK)

The Athena+ Working Groups: Christophe Adami (FR), **James Aird (UK),** Jose Manuel Afonso (PT), Dave Alexander (UK), Costanza Argiroffi (IT), Monique Arnaud (FR), Jean-Luc Atteia (F), Marc Audard (CH), Carles Badenes (US), Jean Ballet (FR), Lucia Ballo (IT), Aya Bamba (JP), Anil Bhardwaj (IN), Elia Stefano Battistelli (IT), Werner Becker (DE), Michaël De Becker (BE), Ehud Behar (IL), Stefano Bianchi (IT), Veronica Biffi (IT), Laura Birzan (NL), Fabrizio Bocchino (IT), Slavko Bogdanov (US), Laurence Boirin (FR), Thomas Boller (DE), Stefano Borgani (IT), Katharina Borm (DE), Hervé Bourdin (IT), Richard Bower (UK), Valentina Braito (IT), Enzo Branchini (IT), **Graziella Branduardi-Raymont (UK),** Joel Bregman (USA), Laura Brenneman (USA), Murray Brightman (DE), Marcus Brüggen (DE), Johannes Buchner (DE), Esra Bulbul (USA), Marcella Brusa (IT), Michal Bursa (CZ), Alessandro Caccianiga (IT), Ed Cackett (USA), Sergio Campana (IT), Nico Cappelluti (IT), **Massimo Cappi (IT), Francisco Carrera (ES),** Maite Ceballos (ES), Finn Christensen (DK), You-Hua Chu (US), Eugene Churazov (DE), Nicolas Clerc (DE), Stephane Corbel (F), Amalia Corral (GR), **Andrea Comastri (IT), Elisa Costantini (NL), Judith Croston (UK),** Mauro Dadina (IT), Antonino D'Ai (IT), **Anne Decourchelle (FR),** Roberto Della Ceca (IT), Konrad Dennerl (DE), Klaus Dolag (DE), **Chris Done (UK), Michal Dovciak (CZ),** Jeremy Drake (US), Dominique Eckert (S), Alastair Edge (UK), **Stefano Ettori (IT)**, Yuichiro Ezoe (JP), Eric Feigelson (US), Rob Fender (UK), Chiara Feruglio (FR), **Alexis Finoguenov (FI)**, Fabrizio Fiore (IT), Massimiliano Galeazzi (IT), Sarah Gallagher (CA), Poshak Gandi (UK), Massimo Gaspari (IT), Fabio Gastaldello (IT), **Antonis Georgakakis (DE),** Ioannis Georgantopoulos (GR), Marat Gilfanov (DE), Myriam Gitti (IT), Randy Gladstone (USA), Rene Goosmann (FR), Eric Gosset (BE), Nicolas Grosso (FR), Manul Guedel (AT), Martin Guerrero (ES), Frank Haberl (DE), Martin Hardcastle (UK), Sebastian Heinz (US), Almudena Alonso Herrero (ES), Anthony Hervé (FR), Mats Holmstrom (SE), Kazushi Iwasawa (ES), **Peter Jonker (NL), Jelle Kaastra (NL),** Erin Kara (UK), Vladimir Karas (CZ), Joel Kastner (US), Andrew King (UK), Daria Kosenko (FR), Dimita Koutroumpa (FR), Ralph Kraft (US), Ingo Kreykenbohm (D), Rosine Lallement (FR), J. Lee (US), Marianne Lemoine-Goumard (FR), Andrew Lobban (UK), Giuseppe Lodato (IT), Lorenzo Lovisari (DE), Ian McCarthy (UK), Brian McNamara (CA), Antonio Maggio (IT), Roberto Maiolino (UK), Barbara De Marco (DE), Silvia Mateos (ES), **Giorgio Matt (IT),** Ben Maughan (UK), Pasquale Mazzotta (IT), Mariano Mendez (NL), Andrea Merloni (DE), Giuseppina Micela (IT), Marco Miceli (IT), Robert Mignani (IT), Jon Miller (US), Giovanni Miniutti (ES), Silvano Molendi (IT), Rodolfo Montez (ES), Alberto Moretti (IT), **Christian Motch (F)R**, Yaël Nazé (BE), Jukka Nevalainen (FI), Fabrizio Nicastro (IT), Paul Nulsen (US), Takaya Ohashi (JP), **Paul O'Brien (UK)**, Julian Osborne (UK), Lida Oskinova (DE), Florian Pacaud (DE), Frederik Paerels (US), Mat Page (UK), Iossif Papadakis (GR), Giovanni Pareschi (IT), Robert Petre (US), Pierre-Olivier Petrucci (FR), Enrico Piconcelli (IT), Ignazio Pillitteri (IT), C. Pinto (UK), Jelle de Plaa (NL), **Etienne Pointecouteau (FR),** Trevor Ponman (UK), Gabriele Ponti (DE), Delphine Porquet (FR), Ken Pounds (UK), **Gabriel Pratt (FR),** Peter Predehl (DE), Daniel Proga (US), Dimitrios Psaltis (US), David Rafferty (NL), Miriam Ramos-Ceja (DE), Piero Ranalli (IT), Elena Rasia (US), Arne Rau (DE), **Gregor Rauw (BE),** Nanda Rea (IT), Andy Read (UK), James Reeves (UK), **Thomas Reiprich (DE)**, Matthieu Renaud (FR), Chris Reynolds (US), Guido Risaliti (IT), Jerome Rodriguez (FR), Paola Rodriguez Hidalgo (CA), Mauro Roncarelli (IT), David Rosario (DE), Mariachiara Rossetti (IT), Agata Roszanska (PL), Emmanouil Rovilos (UK), Ruben Salvaterra (IT), Mara Salvato (DE), Tiziana Di Salvo (IT), **Jeremy Sanders (DE),** Jorge Sanz-Forcada (ES), Kevin Schawinski (CH), Joop Schaye (NL), **Salvatore Sciortino (IT),** Paola Severgnini (I), Francesco Shankar (FR), Stuart Sim (IE), Christian Schmid (DE), Randall Smith (US), Andrew Steiner (US), Beate Stelzer (IT), Gordon Stewart (UK), Tod Strohmayer (US), Lothar Strüder (DE), Ming Sun (US), Yoh Takei (JP), Andreas Tiengo (IT), Francesco Tombesi (US), Ginevra Trinchieri (IT), Asif ud-Doula (US), Eugenio Ursino (NL), Lynne Valencic (US), Eros Vanzella (IT), Simon Vaughan (UK), Cristian Vignali (IT), Jacco Vink (NL), Fabio Vito (IT), Marta Volonteri (FR), Daniel Wang (US), Natalie Webb (FR), Richard Willingale (UK), **Joern Wilms (DE),** Michael Wise (NL), Diana Worrall (UK), Andrew Young (UK), Luca Zampieri (IT), Jean In't Zand (NL), Andreas Zezas (GR), Yuying Zhang (DE), Irina Zhuravleva (US)

Bold Face Denotes Working Group Chairs

Athena Study Science Team (ASST):
D. Lumb, K. Nandra, D. Barret, A. Decourchelle, X. Barcons, J.-W. den Herder, A. Fabian, K. Matsumoto, L. Piro, R. Smith, D. Willingale

Athena Working Group Members
(>800 community researchers)

Athena supporters
(>2000+ astronomers)

More information, white paper, mission proposal, supporting papers, technical supplements, etc. at: *http://the-athena-x-ray-observatory.eu/*

International context

To date, the only "approved" X-ray observatory for the >2030s

Athena is a crucial part of the suite of large great observatories needed to reach the science objectives of astronomy in the coming decades

Synergies with e-ASTROGAM (I/IV)

(Recall that Athena will be YOUR mission/observatory!)

I- Point sources (from very faint to very bright)

Accretion+ejection mechanisms

-Blazars astrophysics (X-IFU defocused!)

-X-ray Binaries + Pulsars (X-IFU defocused!)

-GRBs (X-IFU) up to z~10? (ToO in 4 hrs)

-SNe, tidal disruption events (X-IFU)

-Gravitational Waves counteparts (?)

II- Diffuse sources (typically faint)

Acceleration mechanisms

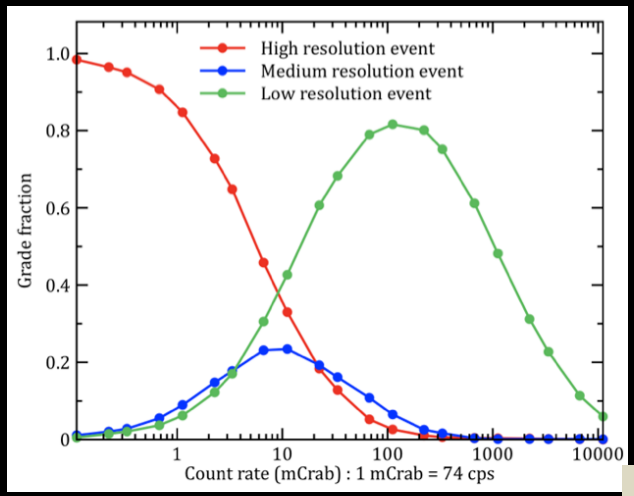
-Clusters (X-IFU imaging, WFI)

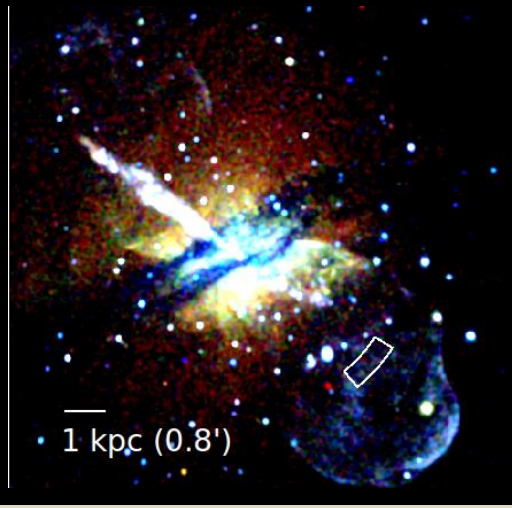
-Radio galaxies (X-IFU imaging)

-PWNe (X-IFU imaging, WFI)

-SNRs (X-IFU imaging, WFI), heavy elements production

- Galactic Center + SgrA*





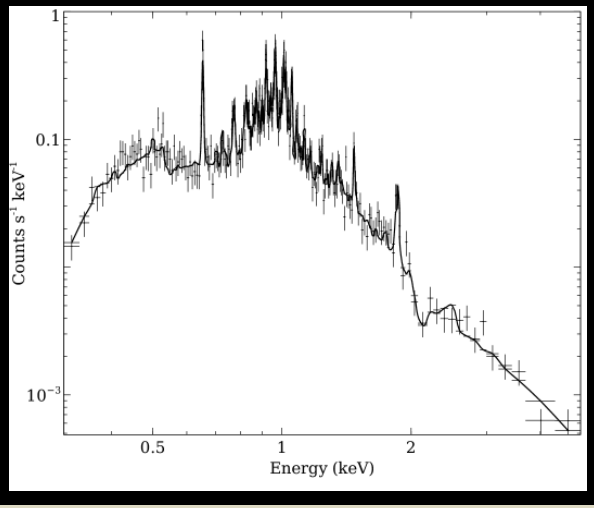


Fig. 5. Simulated WFI pseudo-colour image (l) and X-IFU spectrum (r) from the region indicated, for a 50-ks observation of Centaurus A, demonstrating *Athena+*'s ability to obtain the first direct measurements of advance speed for a strong radio-lobe shock. The shock speed can be determined to within 10% via measurements of line broadening from small regions of the X-ray shell emission dominated by thermal emission (Croston et al. 2009).

Synergies with e-ASTROGAM (II/IV)

I- Point sources (from very faint to very bright) → Accretion+ejection mechanisms

"Persistent/known sources":

-Blazars astrophysics (X-IFU defocused!)

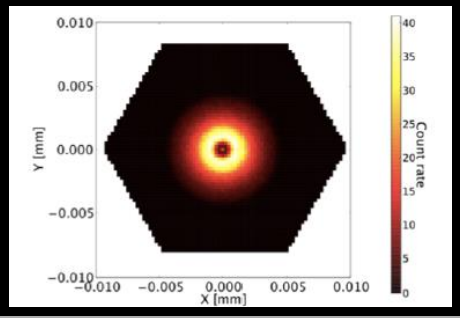
-X-ray Binaries + Pulsars (X-IFU defocused!)

N.B: 1 Crab ~ 100000 cps

Made possible now also with X-IFU (defocused mode)

Hexapod to switch and defocus

→



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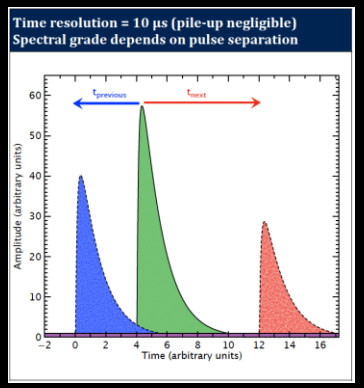

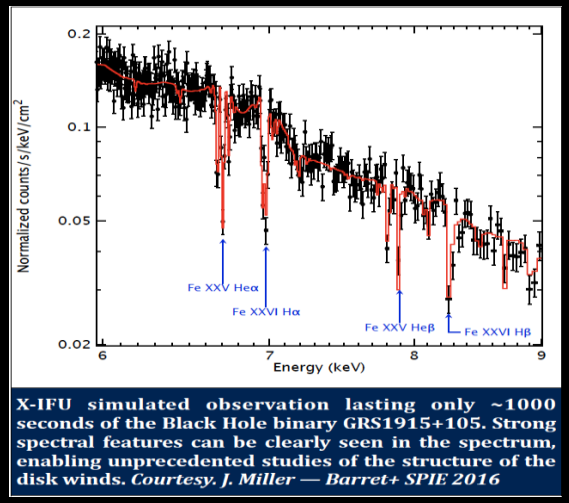

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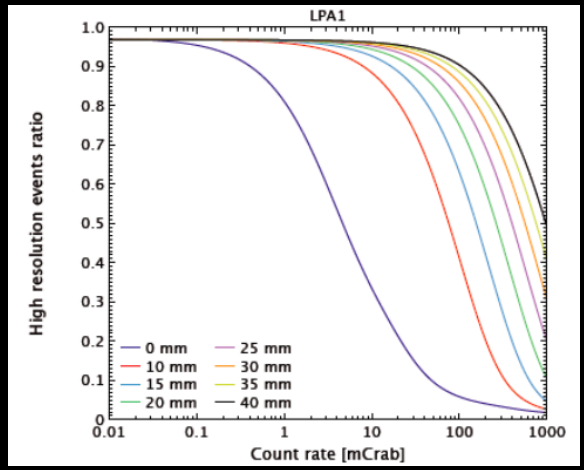


Example: Winds in XRBs, even when in outburst (up to ~Crab)

Synergies with e-ASTROGAM (III/IV)

I- Point sources (from very faint to very bright) → Accretion+ejection mechanisms

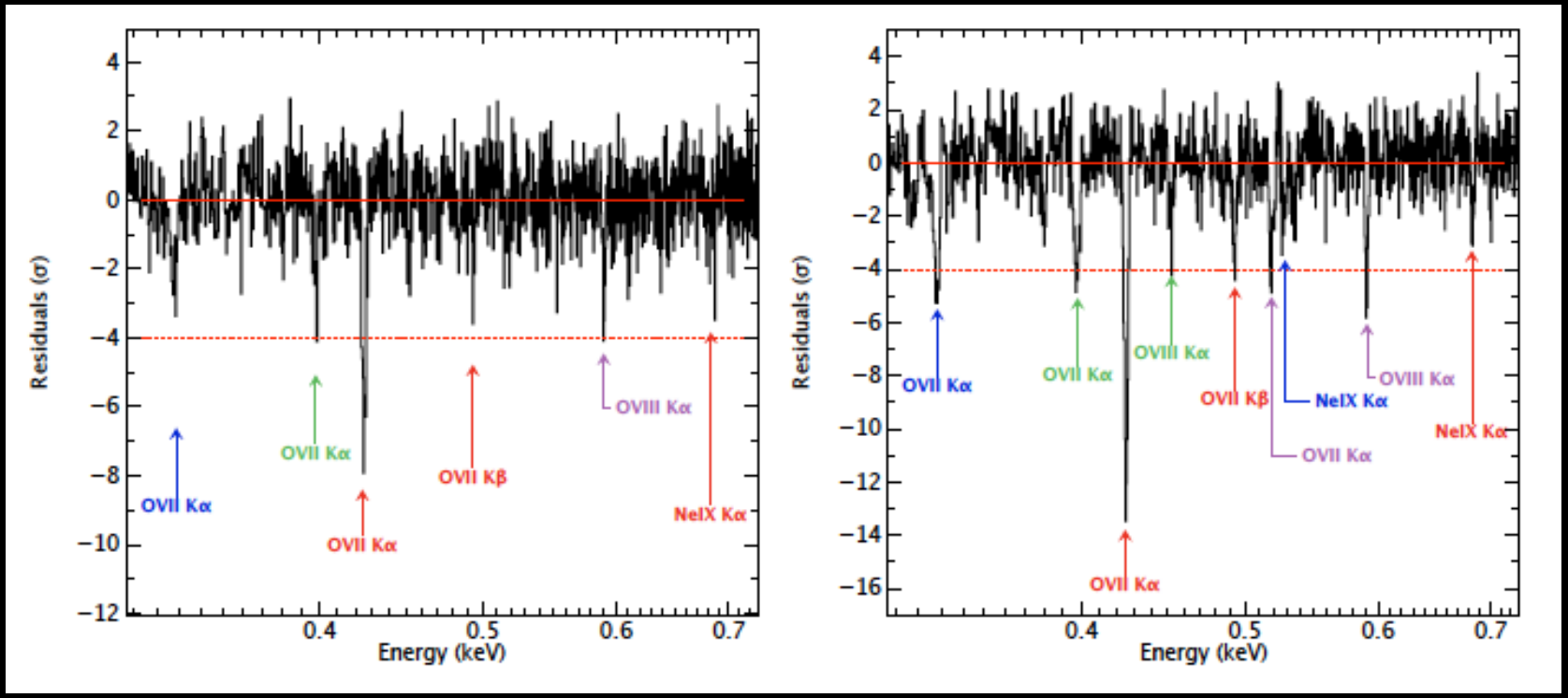
"Transient/Unknown sources":

-GRBs (X-IFU) up to z~10? (ToO in 4 hrs)

-SNe, tidal disruption events (X-IFU)

-Gravitational Waves counteparts (?)

Examples of X-IFU follow-up spectra along l.o.s of:
GRBs (Left), or Blazars (Right), or TDEs/GWs (?)



Synergies with e-ASTROGAM (IV/IV)

II- Diffuse sources – Thermal vs Non-thermal Acceleration mechanisms

Extragalactic Sources:

-Clusters (X-IFU imaging, WFI)

-Radio galaxies (X-IFU imaging)

Galactic Sources:

-PWNe (X-IFU imaging, WFI)

-SNRs (X-IFU imaging, WFI), heavy elements production

- Galactic Center + SgrA*

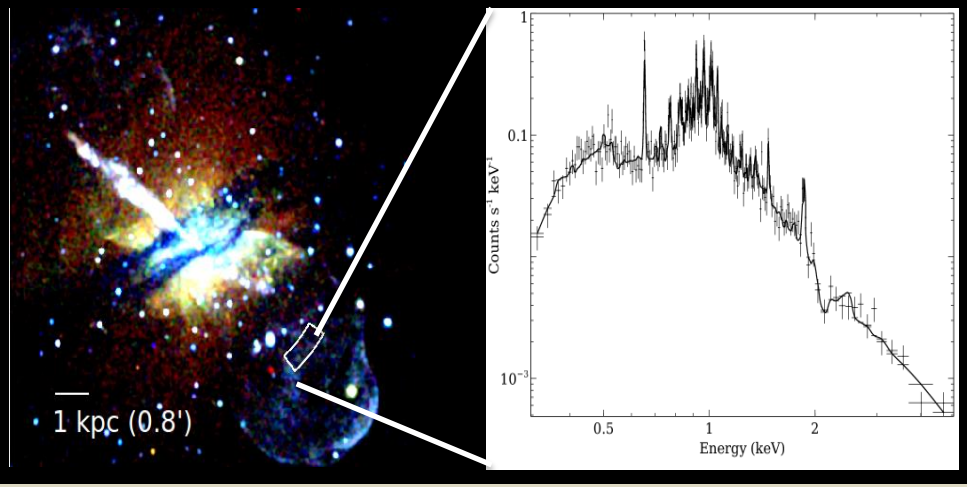
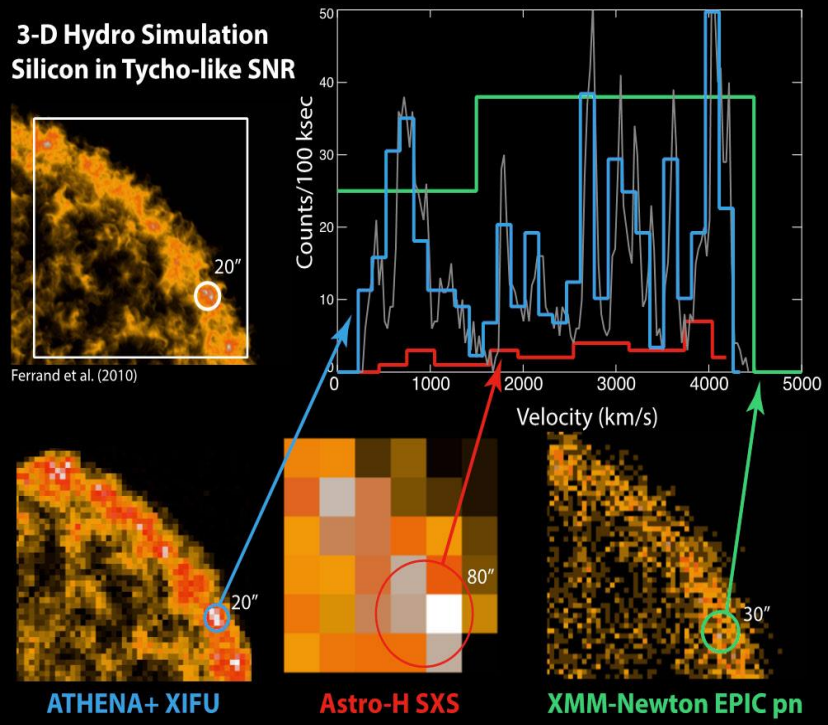


Fig. 5. Simulated WFI pseudo-colour image (l) and X-IFU spectrum (r) from the region indicated, for a 50-ks observation of Centaurus A, demonstrating *Athena*+'s ability to obtain the first direct measurements of advance speed for a strong radio-lobe shock. The shock speed can be determined to within 10% via measurements of line broadening from small regions of the X-ray shell emission dominated by thermal emission (Croston et al. 2009).



Conclusions

- Athena is a unique Observatory for X-ray Astronomy for the 2030s.
- Complement the suite of major class facilities at other ν's
- Athena is synergic to e-ASTROGAM in (at least) the field(s) of "Particle acceleration(s)" in Compact and Diffuse, Galactic and Extragalactic, Energetic Sources (XRBs, Blazars, SNRs, Radio-Gal/clusters, etc.)
- Next steps for Athena are: Phase A + B1, towards adoption end of 2019

Thank you very much for your attention

Optics

ESA responsibility

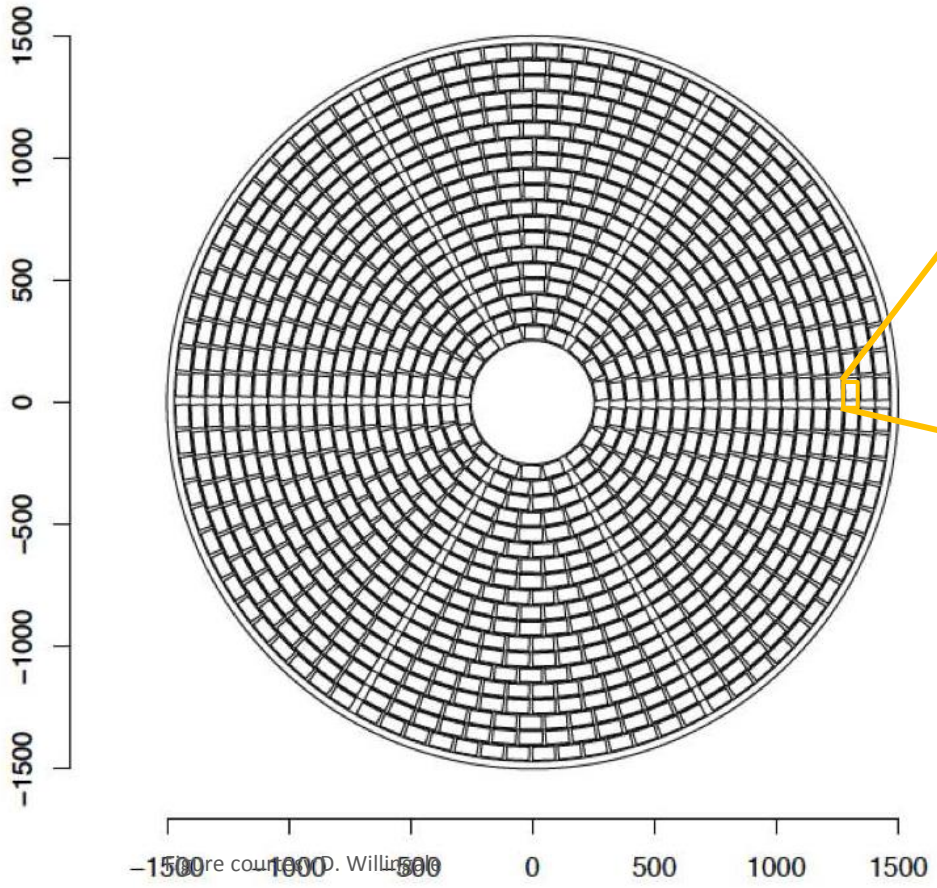
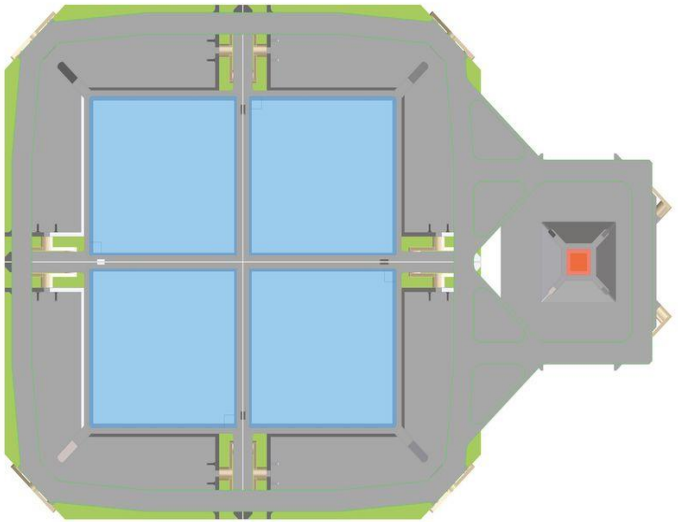


Figure courtesy D. Willingale

Wide Field Imager

WFI consortium lead: Germany

FoV = 40 arcmin ↔ Size = 140 mm



4 large DEPFET sensor chips

512 x 512 pixels with 130 µm x 130 µm

sensitive area → 67 x 67 mm^2

Time resolution: **1.28 ms**

1 fast timing DEPFET sensor

64 x 64 pixels with 130 µm x 130 µm

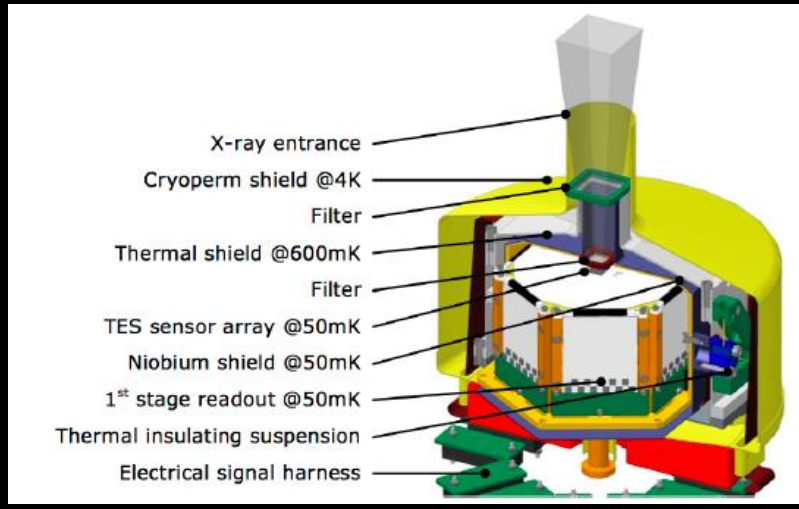
sensitive area → 8.3 x 8.3 mm^2

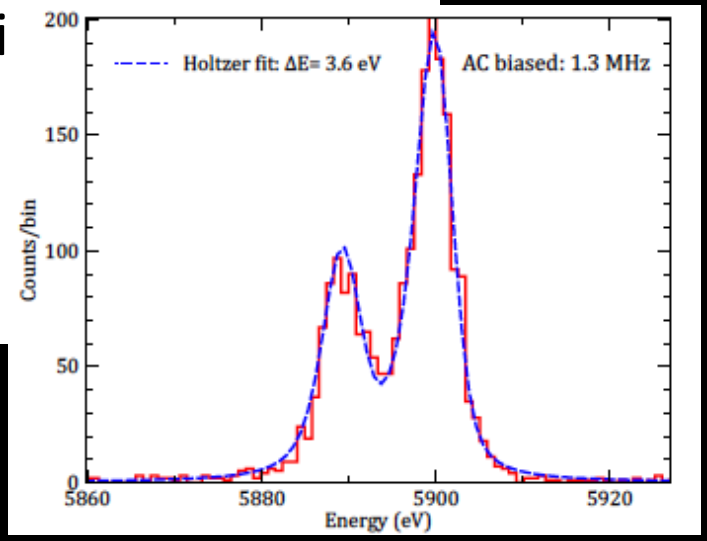
Time resolution: **160 µs** (or **80 µs** with 2-line readout option)

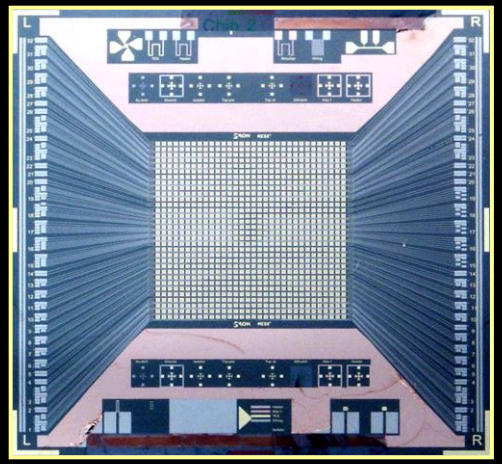
Window mode: 8+8 lines (36 arcsec ≈ 7 x PSF): **20 µs** (or **10 µs** with 2-line readout option)

X-Ray Integral Field Unit

- XIFU consortium lead: France (PI), Italy & Holland (CoPI)
- Transition Edge Sensor microcalorimeter in cryo (50 mK)
- 4-kpixel array
- Large TES-based CryoAC for Low instrumental background
- Read-out: FDM multi







Italy in ATHENA

- Science, Mission and Instruments with a leading role of Italian scientists and industry.
- **XIFU CoPI** + synergical participation to WFI
- Roles & Community: 1 in the ESA Study Team, 9 Italian co-chairs of Mission &Science WGs + 160 Italian members
- Italian Key institutions are:
  - INAF: IAPS(RM), IASF-MI, IASF-Bo, IASF-Pa, OABrera, OABo, OATo, OAPa, OaTs, OAArcetri, OARM, OANa
  - Univ. &INFN Genova, Univ Rm1,Rm2Rm3, Univ. Bo, Univ. Pa, Un.Mi
  - CNR, IFN-RM
- Industrial role from mission prime-ship, subsystems, instrument cutting-edge technologies, mirror assembly (TAS,CGS,FBK, Mediolario,..)
- Italian contributions formalized at the ESA-Leading Funding Agencies meeting in Otc. 2014

Athena: the new generation powerful X-ray observatory

Planets

(interaction of solar wind with planet environment and comets)

Exoplanets

Stellar physics

Supernovae

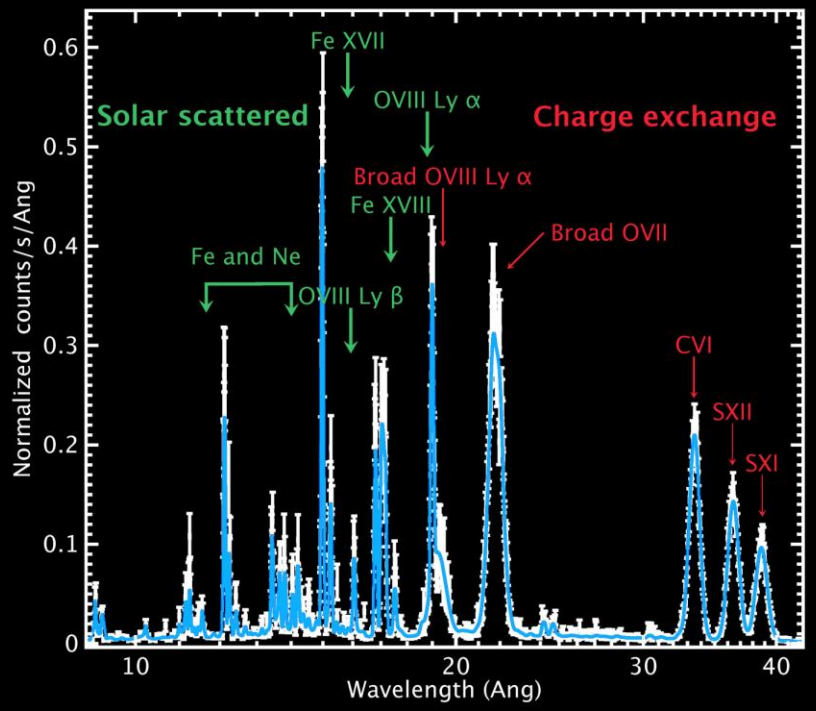
(explosion mechanism, heavy element production)

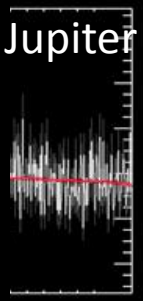
Stellar endpoints

(physics of outflows and winds in X-ray binaries)

Sgr A*

Interstellar dust and medium





Branduardi-Raymont, Sciortino, et al., 2013 arXiv 1306.2332; Sciortino, Rauw et al., 2013 arXiv1306.2333; Motch, Wilms, et al., 2013 arXiv1306.2334; Decourchelle, Costantini et al., 2013 arXiv1306.2335