Athena Project Report

Randall Smith

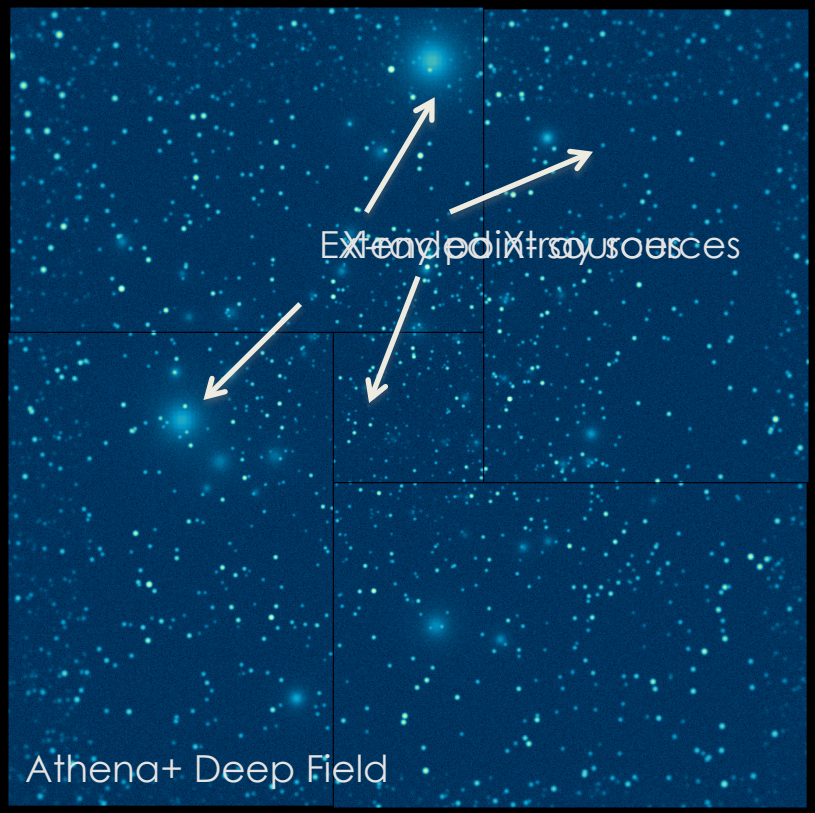
US Representative

Athena Science Study Team

Key questions for observational astrophysics in 2028

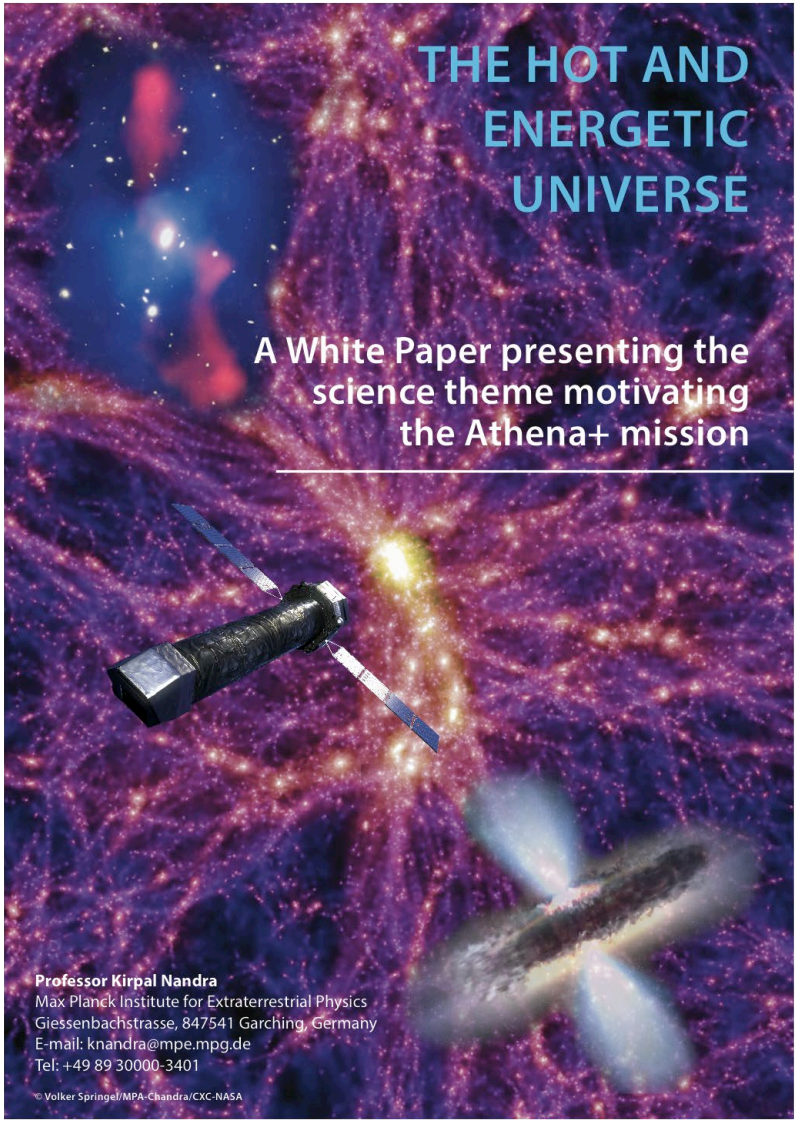
1. How does ordinary matter assemble into the large scale structures we see today?

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



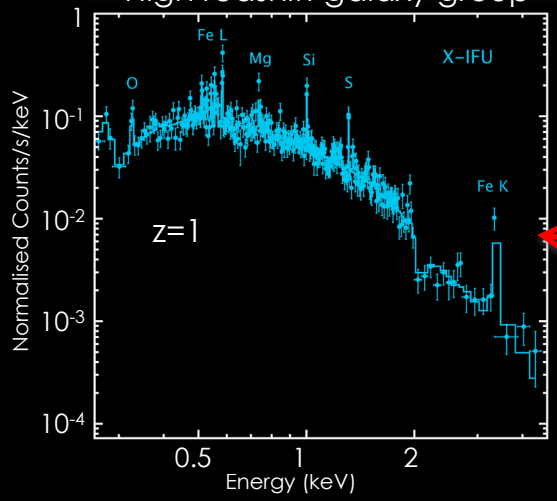
The Hot and Energetic Universe

- **The Hot Universe:** How does the ordinary matter assemble into the large-scale structures that we see today?
  - >50% of the baryons today are in a hot (>10^6 K) phase
  - there are as many hot (> 10^7 K) baryons in clusters as in stars over the entire Universe
- **The Energetic Universe:** How do black holes grow and influence the Universe?
  - Building a SMBH releases 30 × the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays

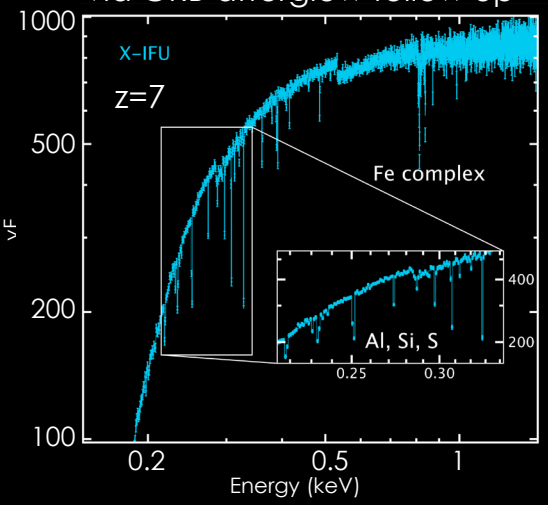


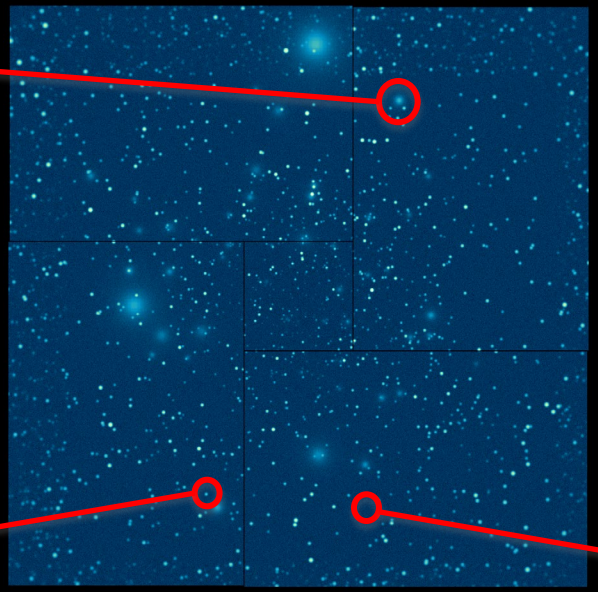
Athena
The first Deep Universe X-ray Observatory

High redshift galaxy group



Primordial stellar populations via GRB afterglow follow up

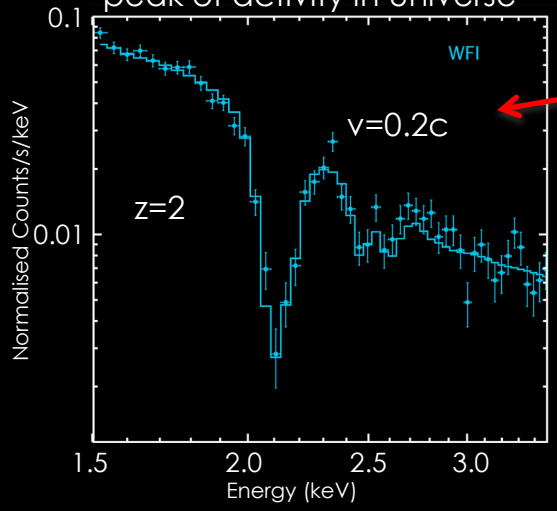




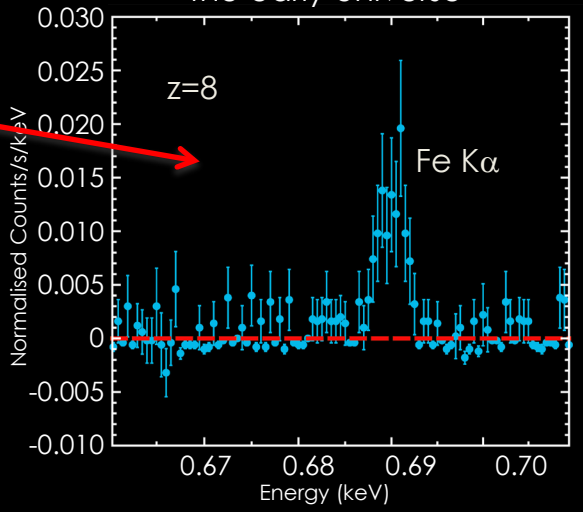
Athena Deep Field

Nandra, Barret, Barcons, Fabian, den Herder, Piro, Watson et al. 2013 arXiv 1306.2307

Black hole feedback at peak of activity in Universe



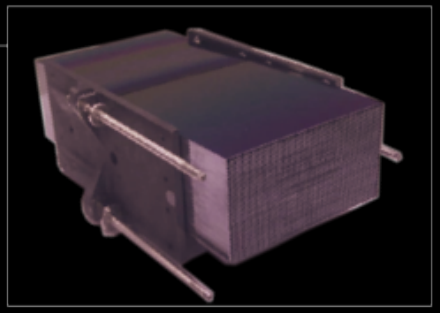
Obscured black hole in the early Universe



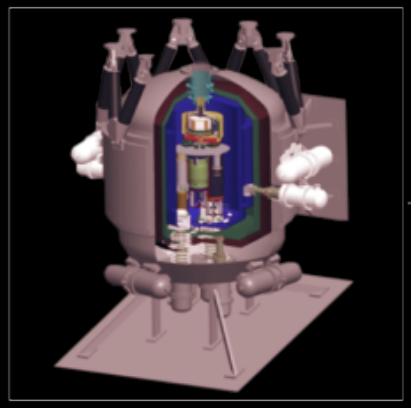
The Athena Observatory

Willingale et al, 2013
arXiv1308.6785

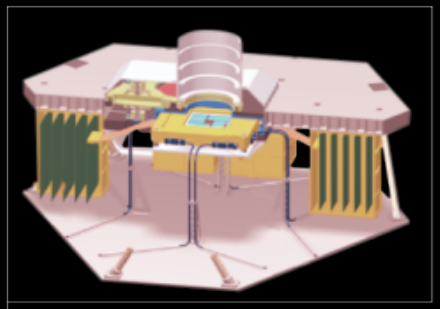
L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
5 year mission



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



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

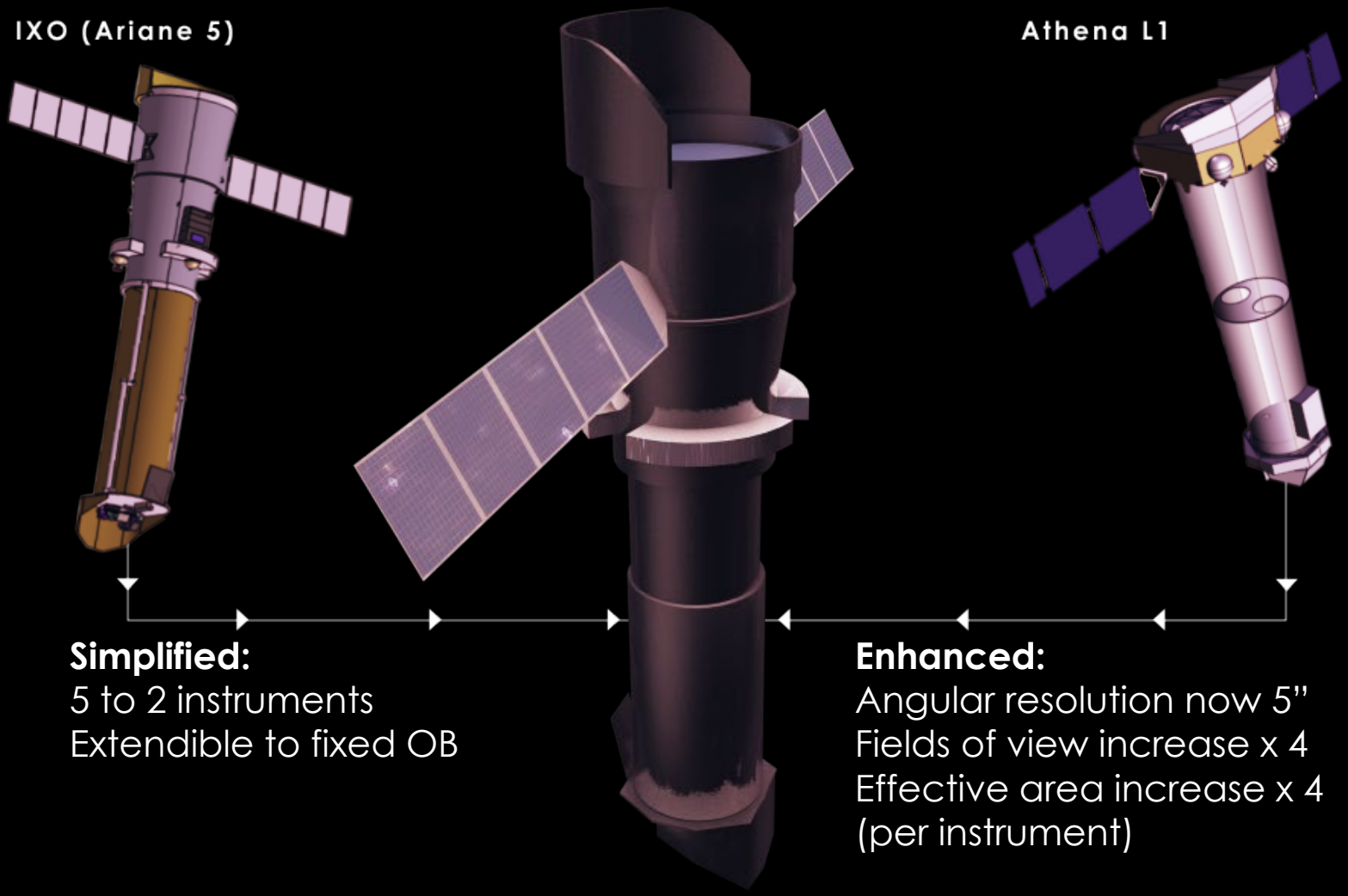


Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Barret et al., 2013 arXiv:1308.6784

Rau et al. 2013 arXiv1307.1709

Technical Maturity



Simplified:
5 to 2 instruments
Extendible to fixed OB

Enhanced:
Angular resolution now 5”
Fields of view increase x 4
Effective area increase x 4
(per instrument)

Athena Timeline to Date

Presentation on Science Themes for L2 mission:	September 2013
ESA Decision for “The Hot and Energetic Universe”:	November 2013
ESA Call for Hot and Energetic Universe Missions:	April 15, 2014 (due date)
ESA Decision for Athena for L2 mission:	June 2014
Formation of Athena Science Study Team:	July 2014
Initial Athena Concurrent Design Facility Run (CDF):	Sept/Oct 2014

Athena future tentative timeline

Phase A:	2015-2017
Phase B1:	2018-2019
Technology developments (TRL > 5-6):	2014-2019
System Requirements Review: (tbc)	End 2019
SPC adoption:	Feb 2020
Phase B2/C/D kick-off:	Nov 2020
Launch:	2028

Proposed approach for the Phase A

The Phase A will be split in two parts, A.1 and A.2

- **Phase A.1 is devoted to Mission Architecture Trade-offs and ends with a baseline selection**
  - The instrument definition is handled by the instrument teams
  - Potential contributions of JAXA and NASA may be refined at the end of the Phase A.1
  - The Mission Requirements are updated at the end of Phase A.1, in accordance with the selected baseline.
- **Phase A.2 is devoted to the Consolidation of the Mission Baseline and ends with the PRR**
  - Technical consolidation
  - Programmatic consolidation
  - Partnership consolidation

Proposed approach for the Phase A

The Phase A will be split in two parts, A.1 and A.2

- **Phase A.1 is devoted to Mission Architecture Trade-offs and ends with a baseline selection**
  - The instrument definition is handled by the instrument teams
  - ***Potential contributions of JAXA and NASA may be refined at the end of the Phase A.1***
  - The Mission Requirements are updated at the end of Phase A.1, in accordance with the selected baseline.
- **Phase A.2 is devoted to the Consolidation of the Mission Baseline and ends with the PRR**
  - Technical consolidation
  - Programmatic consolidation
  - Partnership consolidation

Instrumentation activities during Phase A

Phase A.1 instrumentation activities:

- Preliminary definition of the instruments for the two configurations (parallel studies to the industrial studies)
- Perform preliminary programmatic assessment for both configurations
- Inputs to MCR data package

Phase A.2 instrumentation activities

- AO would be issued early in Phase A.2, after the baseline selection
- Selection of instrument consortia (SPC approval)
- Preliminary design and interface consolidation
- Inputs to PRR data package

Tentative ESA Athena Timeline

Mission requirement documents (preliminary):	mid-Feb 2015
Phase A ITT:	Feb-May 2015
Phase A.1 kick-offs (parallel contracts):	May 2015
MCR data package:	End March 2016
MCR completed:	May 2016
Baseline selection:	June 2016
Phase A.2 kick-off:	June 2016
AO for science instruments:	Early July 2016
Selection of Instrument consortia:	November 2016
PRR data package:	November 2017
PRR completed (end of Phase A):	Dec 2017

NASA Athena Activities

- Call for US ASST representatives: June 2014
- Selection of US ASST rep: July 2014
- Call for US Athena SWG members: November 2014
- Decision on SWG membership: January 2015
- NASA RFI for Athena Focal Plane Instruments: December 2015

July 2014 SST DCL

- Several dozen applications
- Applications of very high quality, senior/leaders of community well represented
- Committee formed to review applications
- Randall Smith recommended
- NASA nomination with ESA appointment

Physics of the Cosmos Program Analysis Group (PhysPAG)

Call for U.S. Scientists to serve on the ATHENA Science Study Team

Dear Colleague,

NASA is now soliciting applications and nominations for individuals affiliated with U.S. institutions to participate in the ESA Science Study Team for The "Advanced Telescope for High-ENergy Astrophysics" (ATHENA).

Background: In November 2013, ESA selected the "Hot and Energetic Universe" as the theme of the second large mission (L2) in its Cosmic Vision program. The theme is to be addressed by an X-ray Observatory led by ESA, to be launched in 2028. On June 27, **ESA announced that the Advanced Telescope for High Energy Astrophysics, ATHENA, is the mission concept to fulfill this theme**. ESA will assemble a Science Study Team (SST) to initiate the required study activities during the Assessment Phase of the ATHENA concept.

NASA will be working with ESA to define the possible NASA contribution to this ESA-led X-ray mission. ESA anticipates appointing a NASA-nominated and ESA-selected scientist affiliated with a U.S. institution to be a member of the ATHENA SST.

Nomination Letters: Applications and nominations to serve as NASA-nominated member of the SST should consist of a cover letter including a statement of expertise pertinent to serving on the SST, a one-page Curriculum Vitae including publications, and a statement of availability and commitment to serve on the ATHENA SST during its ~2 year lifetime. Applications and nominations will be accepted for candidates affiliated with U.S. institutions.

Applications are due Monday, July 7, 2014 at 5 pm local time. Only email applications of a single PDF file will be accepted. Please submit your application via email to Dr. M. Garcia, **michael.r.garcia@nasa.gov**.

NASA will provide funding for travel to the ATHENA SST meetings.

The applications will be reviewed at NASA Headquarters. The Astrophysics Division Director will select the scientist for nomination to ESA.

NASA Point of Contact:
Dr. Michael Garcia
NASA ATHENA Program Scientist
Telephone: 202-358-1053
E-mail: **michael.r.garcia@nasa.gov**

PCOS Athena Web Page

Physics of the Cosmos

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- Documents
- Presentations
- Newsletters
- PhysPAG and SIGs
- NASA Astrophysics Program Offices
- **2015: The Centennial of General Relativity**
- Sign up for PCOS News and Announcements

2014-2015 ESA-NASA Athena Study

In November 2013, ESA selected the "Hot and Energetic Universe" as the theme of the second large mission (L2) in its Cosmic Vision program. The theme is to be addressed by an X-ray Observatory led by ESA, to be launched in 2028. On June 27, 2014, ESA announced that the Athena is the mission to concept to fulfill this theme (see **http://sci.esa.int/cosmic-vision/54241-athena-to-study-the-hot-and-energetic-universe/**). NASA is be working with ESA to define the possible NASA contribution to this ESA-led X-ray mission.

The ESA Athena page is here, which should be consulted for information about the mission: **http://www.cosmos.esa.int/web/athena**

In July 2014, NASA issued a **Dear Colleague Letter** asking for community participation in the ESA Athena Science Study Team.

One U.S. scientist, Randall Smith of the Harvard-Smithsonian Center for Astrophysics, has been selected for the SST. Robert Petre of GSFC and Michael Garcia of NASA/HQ are ex-officio members. The full membership of ESA's Athena SST is given in the list below (see **http://www.cosmos.esa.int/web/athena/science-study-team**).

- **ESA's Athena Science Study Team:**
  - Xavier Barcons (IFCA, ES)
  - Didier Barret (IRAP, FR)
  - Anne Decourchelle (CEA Saclay, FR)
  - Jan-Willem den Herder (SRON, NL)
  - Andrew Fabian (Cambridge, UK)
  - Hironori Matsumoto (Nagoya U, JP)
  - Kirpal Nandra (MPE, DE)
  - Luigi Piro (INAF, IT)
  - Randall Smith (CfA, U.S.)
  - Richard Willingale (Leicester, UK)

Program News

1 Oct 2014
2014 Program Annual Technology Report (PATR) now available » **[PDF]**

9 Sep 2014
Astrophysics Division of NASA's Science Mission Directorate issues open call for nominations to serve on Executive Committee of NASA's Physics of the Cosmos Program Analysis Group » **[PDF]**

7 Aug 2014
IPSIG White Paper now available » **[PDF]**

Project News

Chandra News
27 Oct 2014
NASA's Chandra Observatory Identifies Impact of Cosmic Chaos on Star Birth » **Details**

Fermi News
21 Oct 2014
NASA's Fermi Satellite Finds Hints of Starquakes in Magnetar 'Storm' » **Details**

Planck News
23 Oct 2013
Last Command Sent to ESA's Planck Space Telescope
» **Details**

Athena Science Study Team

ESA appointed the ASST to provide guidance on all scientific aspects during the Assessment Phase for the Athena mission, under the leadership of an Athena Lead Scientist. The following tasks have been charged by ESA to the ASST:

1. Provide scientific oversight in the fields associated to the scientific theme "The hot and energetic Universe", as described in the "Report of the Senior Survey Committee on the selection on science themes for the L2 and L3 missions in the Cosmic Vision programme" (available at http://sci.esa.int/cosmic-vision/53261-report-on-sciencethemes-for-the-l2-and-l3-missions/#)
2. Review and propose updates to the mission scientific requirements
3. Assess the scientific aspects of the mission performance
4. Assist in making any top-level trade-offs
5. Support the preparation of the observing plan and calibration strategy
6. Assist in setting-up scientific requirements on the Science Ground Segment
7. Advise on the preparation of the Science Management Plan
8. Produce the Definition Study report
9. Act as a focus for the interests of the broad scientific community

ASST Working Groups

It is expected that an Athena Science Team will replace the ASST after payload selection, with an updated remit. It is envisaged that the Working Group structure proposed here will continue supporting the new team, with the needed updates.

Remit of the Working Groups

- At the request of the ASST, WGs will conduct studies on scientific or technical aspects that are required in support of Athena
- Advise the ASST in any necessary updates of the science requirements and all other relevant studies under the responsibility of the ASST
- Advise the ASST with respect to technical issues and trade-offs
- Promote Athena as a major astronomical observatory

ASST Working Groups

- Each WG shall have a number of scientific and/or technically experienced members; appropriate nationality, field of expertise and gender balance shall be sought.
- WG members shall be appointed by the ASST**. In the case of scientists from USA institutions, they shall be encouraged to apply for WG membership to the ASST through NASA**.
- Appointments shall be for a fixed period of time, depending on the phasing of the project, and may be renewed. It is foreseen that the WG membership will go through a staggered renewal process, where up to 1/3 of its membership will be renewed each time, making sure that knowledge and appropriate balances are kept at all times.
- A WG chair shall be appointed among the ASST members by the Athena Lead Scientist, following agreement by the ASST, and for the same period (also renewable). WG co-chairs from the ASST or the community might be appointed following the same rules.
  - The WG chair shall be the primary interface between the WG and the ASST. She/he shall report to the ASST on the WG activities and will be the regular transmission channel of the ASST requests to the WG.
  - The WG chair and co-chairs shall call for WG meetings, lead the discussions, organise the WG structure, trigger and follow up the activities and prepare reports to be delivered to the ASST.

Science Working Groups

SWG1 HOT UNIVERSE (Chair: A.C. Fabian, co-Chair: T. Reiprich)

- SWG 1.1 The evolution of galaxy groups and clusters
- SWG 1.2 The astrophysics of galaxy groups and clusters
- SWG 1.3 AGN feedback in galaxy clusters and groups
- SWG 1.4 The missing baryons and the warm-hot intergalactic medium

SWG2 ENERGETIC UNIVERSE (Chair: X. Barcons, co-Chair: M. Cappi)

- SWG 2.1 Formation and growth of the earliest SMBH
- SWG 2.2 Understanding the build-up of SMBH and galaxies
- SWG 2.3 Astrophysics of feedback in local AGN
- SWG 2.4 The close environments of supermassive black holes
- SWG 2.5 Luminous Extragalactic Transients

SWG3: OBSERVATORY AND MULTI-WAVELENGTH SCIENCE (Chair: A. Decourchelle, co-Chairs: H. Matsumoto, R. Smith)

- SWG 3.1 Solar system and exoplanets
- SWG 3.2 Star formation and evolution
- SWG 3.3 End points of stellar evolution
- SWG 3.4 The astrophysics of supernova remnants and the interstellar medium
- SWG 3.5 Multi-wavelength working group
- SWG 3.6 Atomic Data

Mission Working Groups

TWG4: TELESCOPE WORKING GROUP (Chair: R. Willingale, co-Chair: G. Pareschi)

MWG5: MISSION WORKING GROUP (Chair: J-W Den Herder, co-Chair: L. Piro)

- MWG 5.1 Ground Segment
- MWG 5.2 Background
- MWG 5.3 Inter-Calibration
- MWG 5.4 End-to-end simulations
- MWG 5.5 Advanced Analysis tools
- MWG 5.6 GRB external triggers and TOOs

November 2014 Working Groups DCL

- NASA nomination, SST appointment
- Double Green light method
- Received 81 high-quality applications
- Anticipate funding ~20 (nominated) members for travel
- Anticipate additional non-funded (endorsed) members

NASA Members in Athena SST Working Groups

Dear Colleague,

NASA is now soliciting applications and nominations for individuals affiliated with U.S. institutions to participate in the Working Groups which report to the ESA Athena (L2) Science Study Team.

Background: In November 2013, ESA selected the "Hot and Energetic Universe" as the theme of the second large mission (L2) in its Cosmic Vision program. The theme is to be addressed by an X-ray Observatory led by ESA, to be launched in 2028. On June 27, 2014 ESA announced that Athena is the mission concept to fulfill this theme (see http://sci.esa.int/cosmic-vision/54241-athena-to-study-the-hot-and-energetic-universe/) NASA is working with ESA to define the possible NASA contribution to this ESA-led X-ray mission.

ESA has assembled a Science Study Team (SST) to initiate the required study activities during the Assessment Phase of the Athena concept. The charge for the Athena SST can be found at http://www.cosmos.esa.int/web/athena/science-study-team. NASA is represented on this SST by Randall Smith of the CfA; Robert Petre (GSFC) and Michael Garcia (HQ) are ex-officio members of the SST. The Athena SST will be advised by a set of Working Groups which are being assembled at this time. The structure of, and Terms of Reference for, these Working Groups can be found at: http://www.cosmos.esa.int/web/Athena/community-wg.

NASA anticipates nominating ~1 NASA-nominated and SST-appointed scientist to be a member of each of these ~20 Working Groups. It is possible that some Working Groups will not require NASA representation, and that others may have more than one NASA-funded representative. NASA will provide travel funding to Working Group meetings for NASA-nominated working group members.

The SST may appoint additional US scientists to the working groups who are not nominated by NASA. NASA anticipates endorsing these additional US scientists to be appointed by the SST. NASA will provide no funding for working group members who are not NASA-nominated.

Nomination Letters: Applications and nominations to serve as NASA-nominated and/or NASA-endorsed member of the Athena SST Working Groups should consist of a two-page cover letter including a statement of which specific sub-WG is being applied for and expertise pertinent to serving on that Working Group, a one-page Curriculum Vitae including publications, and a statement of availability and commitment to serve on the Working Groups during their ~4 year lifetime.

Applications and nominations will be considered only for candidates affiliated with U.S. institutions.

Applications are due Monday Dec 1 at 5 pm EST. Only email applications of a single PDF file will be accepted. Please submit your application via email to Dr. M. Garcia, michael.r.garcia@nasa.gov.

NASA funding will be limited to travel to these Working Group meetings for NASA-nominated members.

The applications will be reviewed by the Physics of the Cosmos Program Office and by the Astrophysics Division at NASA Headquarters. The Astrophysics Division Director will select the scientists for nomination to the Athena SST, and those nominations will be forwarded to the Athena SST for possible appointment.

NASA Point of Contact:
Dr. Michael Garcia
202-358-1052
Michael.R.Garcia@nasa.gov

And Now, Some Words From HQ

Paul Hertz's slide on Athena, presented October 21st at the STSci Institute Committee meeting

ESA's L2 Advanced X-ray Observatory: Athena

- The Advanced Telescope for High Energy Astrophysics (Athena) has been selected for the ESA L2 slot. Launch date ~2028.
- NASA and ESA are discussing a potential NASA contribution.
  - The Decadal Survey recommended an international partnership for an advanced X-ray observatory.
  - NASA solicited applications for a U.S. representative on the ESA Athena Science Study Team. Randall Smith (CfA) is U.S. member. Robert Petre (GSFC) and Michael Garcia (HQ) are ex officio. First meeting July 2014.
  - An ESA instrument AO will be released in early 2015.
- NASA's FY15 budget request supports a potential Athena partnership.
  - NASA will continue investing in technologies likely to be appropriate for an Athena contribution; investments include both directed and competed SAT investigations.
  - NASA is budgeting for development of contributed flight hardware, U.S. participation in the Athena science team, and a U.S. data center and GO program.
- NASA has suggested the following types of contributions, limited to $100-150M for contributed flight hardware.
  - Portions of the calorimeter instrument
  - Inner mirror shells
  - Portions of the wide field imager
  - Contribution to science data center (U.S. node)

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Instrument RFI

- Request for Information (RFI) released Dec 23, 2014
- Due date Feb 2, 2015
- Will ask for possible hardware and non-hardware contributions
- Will document level of interest, possible types of contributions
- Endorsement of PI of instrument proto-consortia required
- Will inform NASA's program planning, including possible future solicitations.
- Program planning will be coordinated with ESA Instrument AO
  - Must allow NASA/Instrument PI sufficient time to incorporate contribution into proposal submitted ESA
  - Goal is to finish US process ~2 months before ESA AO due date
  - PIs can be involved in process before selections finalized
  - This is only process currently planned to allow NASA contributions to instruments


Formulation
Implementation
Primary Ops
Extended Ops
XMM-Newton (ESA)
Swift
Suzaku (JAXA)
Fermi
Euclid (ESA)
JWST
Hubble
Kepler
Spitzer
ASTRO-H (JAXA)
Chandra
NICER (on ISS)
TESS
NuSTAR
LISA Pathfinder (ESA)
SOFIA
BACK-UP
NASA Astrophysics
Recently Completed
Planck 2013
Herschel 2013
GALEX 2013

AAS High Energy Astronomy Division

- August 2014 HEAD meeting in Chicago
- Special Session on Future X-ray Missions
  - Kirpal Nandra talk on Athena
- Special Athena Session – Attended by ~50 US Scientists
  - They were enthusiastic about possible participation
  - Interest was expressed in both hardware and science team contributions
  - Hardware contribution of $100M-$150M allows interesting contributions

Athena

Advanced Telescope for High Energy Astrophysics

- **Second ESA Cosmic Vision Large mission**
  - L-class with NASA/JAXA participation
  - Decadal Survey recommendation
  - Large X-ray mirror, X-IFU and WFI instruments
- **Launch Date:** 2028
- **Breakthrough Technologies**:
  - High Throughput, Wide FOV, High spectral resolution X-ray Astronomy
  - 10x Chandra area, 100x improved non-dispersive spectral resolution, 5x FOV.
- **Science Objectives**: The Hot and Energetic Universe:
How does ordinary matter assemble into the large scale structures that we see today?
How do black holes grow and shape the Universe?

CURRENT STATUS:

- Selected as 2nd Large mission in ESA Cosmic Visions Program
- Currently in 2 year Assessment Phase
- NASA is involved in Study Phase via membership on ESA-chartered Athena Science Study Team and Science Working Groups
- NASA budgeting for a $100M-$150M hardware contribution, plus a US GO program and a U.S. data center
- NASA continues to invest in Athena technologies via SAT and directed investigations.
- NASA and ESA are discussing possible NASA contributions, such as:
  - Handshake on NASA provided sensor array for the X-ray calorimeter instrument (X-IFU)
  - Portions of the Wide Field Imager
  - Portions of the X-ray Mirror
  - Contribution to science data center (U.S. node)