Multiwavelength Astrophysics Laboratory:
High-energy (X-ray) module

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A few notes before starting

- Differently from the other two labs (optical and radio/mm), students will be in contact with several staff researchers and a PhD student (tutor). You will *receive a significant amount of inputs and suggestions by different people* − then you will do your own, motivated choices − and *you will be treated as you were part of a research group*. This is a fundamental experience if your goal is to do research in your career.

- The high-energy/X-ray module is thought and 'built' differently from the other labs. Tutorials are still present, but organized in such a way that students should primarily listen and understand how to reduce and analyze X-ray data without necessarily typing commands on their own simultaneously with the teacher.

- Commands can be found in slides/on-line threads/tutorials/notebooks; it is not mandatory to remember specific commands but to understand the principles of the analysis and the fundamental steps.

- During their own data analysis, to ease and speed-up the process, students are suggested to write in a file all of the commands, including a description of what they are doing. This is helpful to (i) remember the fundamental steps of the analysis for the final powerpoint presentation and to (ii) repeat procedures, if needed, using a simple 'cut & paste'.

X-ray laboratory module: Lessons + Tutorials. I

Useful: review some AGN lessons (on Virtuale)

- AGN classification/demography/Unified scheme – lesson 3
- AGN X-ray spectral components – lesson 4
- Radio-jetted AGN (RL-AGN) – lesson 5
- AGN evolution and AGN-galaxy coevolution – lesson 10
- Feedback in AGN – lesson 13

You are supposed to already know about these topics from last/current academic year

Available on the Lab website https://indico.ict.inaf.it/event/3432/

- X-ray surveys and AGN evolution (S. Marchesi)
- AGN spectral energy distribution and AGN-galaxy coevolution (L. Barchiesi)
- AGN feedback: multi-wavelength indications and X-ray winds/outflows (E. Bertola)
- Radio-loud AGN (P Grandi)

First week of high-energy lab

- Fundamental parameters of X-ray telescopes and detectors
- Pills of statistics and applications to X-rays
- Chandra/XMM/XSPEC/Fermi tutorials
- Presentation of data handling projects

NEWS: not all students will attend all the lessons of the first week

X-ray laboratory module: Lessons + Tutorials. II

I week

- **Monday, 17.11** (9−11, room M, all students):
  - 9:15−9:30: C. Vignali: *Introduction to the high-energy module*
  - 9:30−10:40: M. Dadina: *Fundamental parameters of X-ray telescopes and detectors*
  - 10:40−11: Random assignment of the exercises to the groups

- **Tuesday, 18.11** (12-14, room M, all students):
  - 12-13:15: C. Vignali: *Pills of Statistics*

- **Wednesday, 19.11** (9−11):
  - 9:15-11: C. Vignali: *Chandra tutorial* (room M, Chandra groups)
  - 9:15-11: E. Bronzini: *installation of Fermi software* (seminar room INAF/OAS@CNR, Fermi groups)
  - 9:15-11: E. Torresi: *XMM-Newton tutorial* (Aula Sollima, INAF-OAS, Via Gobetti 93/3, XMM groups)

- **Thursday, 20.11** (14−18):
  - 14:15−16: Installation of Virtual Machines (room M: Chandra groups + XMM groups)
  - 16−18: C. Vignali: *XSPEC (spectral analysis) tutorial* (room M: Chandra groups + XMM groups)
  - 14:15−16: P. Grandi: *Introduction to Fermi* (seminar room INAF/OAS@ CNR, Fermi groups)
  - 16−18: E. Bronzini: *Jupiter notebook for Fermi data analysis* (seminar room INAF/OAS@CNR, Fermi groups)

- **Friday, 21.11** (9−13):
  - 9−11:30: C. Vignali, S. Marchesi: *Presentation of data-analysis exercises* (room M, Chandra groups)
  - 9−11:30: E. Torresi, M. Dadina: *Presentation of data-analysis exercises* (room 214, XMM groups)
  - 9−11:30: P. Grandi, E. Bronzini: *Presentation of data-analysis exercises* (seminar room INAF/OAS@CNR, Fermi groups)
  - 11:45−13: Start of the high-energy laboratory (All)

X-ray laboratory module: Lessons + Tutorials. III

Software

- We will give you indications on the installation of Virtual Machines on your laptops with all the relevant high-energy software already installed.

- For those of you who will experience problems with this installation, we will provide excess to remote servers with all the relevant high-energy software already installed.

X-ray laboratory: groups and projects. I

Group	Last Name	First Name
1	Cussini	Sofia
1	Calaon	Erika
1	Venturi	Daphne
2	Bono	Chiara
2	Falzoni	Federico
2	Rosetti	Noemi
3	Rosania	Maria Chiara
3	Ferruzzi	Fosca
3	Lunardi	Caetano
4	Coppola	Alessandro
4	Di Prima	Adelina
4	Pavone	Giuseppe Loris
5	Gozzi	Samuele
5	Centanni	Matteo
5	Palmieri	Luca
6	Pepe	Giulia
6	Salvemini	Nicola
6	Bellomare	Giulia
7	Caccese	Pietro
7	Bonetti	Sofia
7	Ruozzi	Luca
8	Benedetti	Camilla
8	Sanseverinati	Sara
8	Pucci	Simone
9	Beyaz	Canday
9	Azar	Amin
9	Masoudnezhad	Amirhossein
10	Delpoggetto	Ettore
10	Pucci	Daniele
10	Redana	Davide
11	Santucci	Lucia
11	Triozzi	Agnese
11	Patil	Shritej
12	Caiozzo	Nilo
12	Sangermano	Alessio
12	Parente	Lorenzo
13	Veggetti	Valentina
13	Singh	Gagandeep
13	Bahr	Yousra
14	Kizhakkot	Arjun
14	Das	Khushbu
14	Patterson	Claire Claude
15	Veeramuthu	Vineeth
15	George	Abel John
15	Jaison	Aswin
16	Kerdikoshvili	Nino
16	Markoudakis	Ioannis
16	Karakotia	Christina
17	Kazemlee	Tina
17	Gialanella	Francesca
17	Calazans	Victor
18	Poojari	Yash Ravindra
18	Sera	Giovanni
18	Daniela	Alvisi
19	Ahmed	Aftab
19	Movaffaghi	Yasaman
19	Sida	Abenezer Tesfaye
20	Colombari	Alice
20	Scattolin	Daniele
20	Touhami	Samy
21	Castro	Juan
21	Khalil	Jasmine
21	Yipeng	Yao
22	Jiiya	Yao
22	Chinchwadkar	Rohit
22	Gebreel	Yosussef
23	Langeroudi	Soroush Ataee
23	Noroozi	Samane
23	Khodaei	Elaheh
24	Bhagat	Ankit Kumar
24	Kalisetty	Mohit Narayan
24	Chowdhury	Nibedita
25	Chavan	Om Mohan
25	Sinha	Mayank
25	Mahalim	Yash

75 students → 25 groups of 3 students each

X-ray laboratory: groups and projects. II

Situation as a.a. 2024-25

Test	Target	Goal	Data
1	Pictor A	**Nucleus** [Eastern Lobe; magnetic field]	XMM
2	Pictor A	**Jet & Hotspot & Knot** [SED hotspot; NuSTAR spectra]	Chandra [NuSTAR]
3	NGC 3783	**Nucleus** [additional observation, different state]	XMM
4	NGC 5135	**Nucleus + companion SFG** [NuSTAR spectra]	Chandra [NuSTAR]
5	CDF-S	**Plots on mosaic catalogs + comparison vs. 7Ms CDF-S + obscured AGN spectral analysis** [CR → Flux conversion; other X-ray spectra]	Chandra
6	TXS 0506+056	**High-energy data centered on neutrino detection → LC, spectrum, source variability** [source spectrum and significance in simulated CTAO data]	Fermi [CTAO]

We reconsidered some of the exercises, building new ones and simplifying the 'old' ones

X-ray laboratory: groups and projects. III

# Exercise	Source	X-ray data
1	NGC5135	Chandra
2	CDF-S	Chandra
3	NGC1068	XMM-Newton
4	3C382/3C33	XMM-Newton
5	TXS0506+056	Fermi

- **More details on the exercises: Friday**
- **Data ← → group association: today (random)**

X-ray laboratory webpage. I

Lessons, Tutorials, Bibliography, threads, links to X-ray software + useful stuff…

X-ray Laboratory 2025

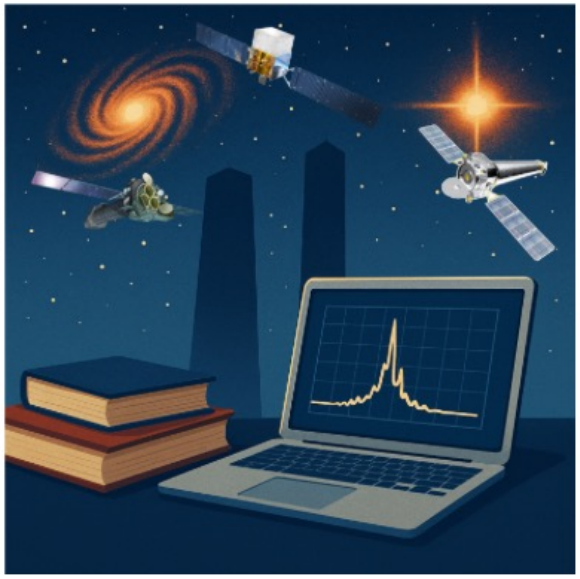
17 November 2025 to 12 December 2025
Europe/Rome timezone

https://indico.ict.inaf.it/event/3432

- Overview
- PROGRAM
- LESSONS
- TUTORIALS
- PROJECTS
- USEFUL MATERIAL
- USEFUL LINKS
- TEACHERS
- BIBLIOGRAPHY

****WELCOME TO THE *X-RAY LABORATORY 2025* ****

In collaboration with the Department of Physics and Astronomy of the University of Bologna (DIFA), OAS-Bologna organizes combined seminars/laboratories investigating Active Galactic Nuclei (AGN) through the analysis of their high-energy emission (X-ray/gamma-ray).



The laboratory will be held from November 17th to December 12th (last week optional).

Students are introduced to the current problematics of supermassive black holes to contextualize their data analysis projects. At the end of the laboratory, students re required to present their results in a PowerPoint presentation, similar to that at an Astrophysical Conference.

Design: E. Torresi

X-ray laboratory webpage. II

Link to useful links with guides, threads, tutorials

USEFUL LINKS

XMM-Newton (SAS)

- XMM-Newton ABC Guide
- SAS Users Guide
- XMM-Newton threads
- XMM-Newton Users Handbook
- XMM-Newton pile up

Chandra (CIAO)

- Introduction to CIAO
- Science Threads
- The Chandra ABC Guide to Pileup

FERMI

- CICERONE (fermitools)
- Fermipy

ds9

- SAOImage DS9 Users Manual

XSPEC

- XSPEC on-line manual

LINUX

- Handbook of LINUX commands (in Italian)
- Summary of LINUX commands
- Advanced guide to LINUX

Other useful links

1. Energy conversion
2. F-test
3. DeltaChi square distribution for a given number of dof and a given value of P
4. Calculation of the logarithmic error bars

Presentation of students' work and Exams. I

- Evaluation for each lab, then 'averaged' over the three modules → vote

[30-	outstanding	0
[29-30[	excellent	E
[28-29[	very good	VG
[26-28[	good	G
[23-26[	satisfactory	Sa
[18-23[	sufficient	Su
<18	failed	F

Evaluation criteria
content/presentation/commitment/language

- Communication to the students at the end of all three labs
- Students can either accept the vote or have an oral examination (**previous votes are then not considered anymore**) → the 'classic' exam at the end of the lab is then optional (students' choice). **Students may not decline a grade more than twice**
  - **RADIO/mm LAB**: written report (one per group, max=15 pages)
  - **OPTICAL LAB/X-RAY LAB**: powerpoint presentation (one per group)
- Exams dates:
  - Radio/mm: reports due by 12.01.26, discussion+exams: week 26th–30th Jan.
  - High-Energy: powerpoint presentations, week 12th–26th Jan.
  - Optical: powerpoint presentations, week 19th–23rd Jan.

For mark<18 and those not accepting the final vote: date in Feb. (tbc)

Presentation of students' work and Exams. II

1. About **10 minutes/student**. Questions are typically at the end of each of the sub-parts of your presentation
2. The number of slides is indicatively 1 slide/minute. You must select what you want to show us and your main results (not everything!)
3. Prepare your presentation in such a way that it can be easily sub-divided into 3 sub-parts (if the group is made of 3 persons, …)
4. We will **randomly** decide who is presenting what in each presentation
5. You can prepare hidden slides to be used just in case you want to properly answer to one of our questions
6. Avoid too many animations
7. It is fundamental that you **introduce the source** in a broad scientific context (i.e., what is the principal science problem that you may want to address), **identify the main points of the process of data analysis and interpretation** (within the available time) and that you are fully prepared on these issues

Presentation of students' work and Exams. III

RECAP

- Scientific problem and goals of the project
- Presentation of the source and its main properties
- Data available (having in mind the main characteristics of the adopted instruments)
- Data analysis
- Presentation of the results and discussion

Remember: Each student should have the entire presentation clear in his/her mind (it is a work made by/within the group)

We will decide who (within each group) is presenting each sub-part of the presentation

Web page – Multiwavelength Astrophysics Lab course

https://www.unibo.it/sitoweb/cristian.vignali/en

Teaching → 96385 – Multiwavelength Astrophysics Laboratory

Please check the latest news/announcements for all updates

Lessons
Virtual Learning Environment
+
https://indico.ict.inaf.it/event/3432/

Please, COMMUNICATE WITH TEACHERS USING YOUR UNIBO EMAILS