X-ray Spectral Fitting

Prague | February 2022

7th February
14:00–15:00

- ***The past, present & future of X-ray spectral analysis (plenary)***
- Presenter: **Keith Arnaud**
  University of Maryland, USA
- Personal website
- ***Abstract:***
  I will give an introduction to spectral fitting in X-ray astronomy covering what we do, why we do it that way, and what the challenges are. I will finish with a look at the data that we are expecting in the future and how that will pose new challenges.

7th February
16:00–17:00

- ***High Energy Astrophysics Spectroscopy (plenary)***
- Presenter: **Richard Mushotzky**
  University of Maryland, USA
- Personal website
- ***Abstract:***
  High energy astrophysical spectroscopic observations have a unique role to play in astrophysics being able to derive (potentially) the basic physical parameters (e.g. temperature, density, magnetic field, gravity, chemical composition, ionization state, velocity information, emission process, equilbrium state etc) of a huge class of objects where gravity is very strong or are moving very fast or are 'very hot' or energetic such as the coronae of stars, neutron stars) stellar mass black holes, novae, young supernovae, supernova remnants, Active Galactic Nuclei (AGN), clusters of galaxies, star forming and elliptical galaxies (for a limited set). Detailed understanding of the spectra is key to a huge range of exciting and important issues ranging from the very small (the event horizons of black holes) to the very large (the structure and evolution of clusters of galaxies). However x-ray spectra cover a huge range of wavelengths, atomic species and ionization states as well as a large range of continuum physical processes. Thus interpreting the spectra to derive physical parameters is fundamentally challenging. I will present a (biased) overview of the field and present day challenges.

8th February
11:00–12:00

- ***Bayesian X-ray Analysis (plenary)***
- Presenter: **Johannes Buchner**
  Max Planck Institute for Extraterrestrial Physics, Germany
- Personal website
- ***Abstract:***
  I introduce inference with likelihoods in frequentist and Bayesian ways, different styles of model comparison, and Monte Carlo algorithms (Importance Sampling, MCMC and nested sampling) to address interesting science questions in practice. Briefly, BXA's features, diagnostics and outputs are discussed, before concluding with practical advice.

– ***X-ray spectral analysis in eROSITA Final Equatorial Depth Survey (eFEDS): an example of using BXA***
– Presenter: **Teng Liu**
Max Planck Institute for Extraterrestrial Physics, Germany
– Personal website
– ***Abstract:***
The eROSITA Final Equatorial Depth Survey (eFEDS) is the largest contiguous-eld X-ray survey at present, which yielded a large sample of X-ray sources with very rich multi-band photometric and spectroscopic coverage. Using the Bayesian method BXA, we perform a systematic X-ray spectral analysis for all the eFEDS sources adopting multiple spectral models. We investigate the capacity of eROSITA X-ray spectra for constraining AGN intrinsic absorption and spectral slope. Hierarchical Bayesian modeling (HBM) is used to estimate the spectral parameter distribution of the sample. The source fluxes and luminosities are measured from the posterior of the spectral fitting. Despite a large number of faint sources, our spectral fitting provides reasonable measurements of spectral shapes and intrinsic luminosities for a majority of the sources. Because of sample selection bias, the eFEDS AGN catalog is dominated by X-ray unobscured sources; the power-law emission of the hot corona is also relatively soft.

8th February
14:00–14:30

8th February
14:30–15:00

- ***XMMFITCAT-Z: Using photo-z information within BXA***
- Presenter: **Angel Ruiz**
  National Observatory of Athens, Greece
- Personal website
- ***Abstract:***
  The XMM-Newton spectral-fit Z catalogue (XMMFITCAT-Z) contains spectral-fitting results for 30,816 XMM-Newton detections, corresponding to 22,677 unique X-ray sources. This catalogue is produced by applying automated spectral fits using BXA to archival spectral data contained within the 3XMM serendipitous source catalogue, and using the distance information contained in XMMPZCAT (spectroscopic and/or photometric redshifts). In this talk I will present the advantages of using BXA for this project, in particular for including the full information contained in our photo-z estimation into the X-ray spectral fit.

– ***A BXA-driven study of reliability of X-ray Spectral fits in determining AGN torus morphology***

9th February
14:00–14:30

– Presenter: **Tathagata Saha**
Nicolaus Copernicus Astronomical Center, Poland

– ***Abstract:***
TBD.

– ***Deriving redshifts from X-ray spectra of obscured AGN using BXA***
– Presenter: **Charlotte Simmonds**
University of Geneva, Switzerland
– Personal website
– ***Abstract:***

9th February
14:30–15:00

Redshifts are fundamental for our understanding of extragalactic X-ray sources. Ambiguous counterpart associations, expensive optical spectroscopy and/or multimission multiwavelength coverage to resolve degeneracies make estimation often difficult in practice. In this talk I will present a work in which we attempt to constrain redshifts of obscured Active Galactic Nuclei (AGN) using only low-resolution X-ray spectra by fitting AGN X-ray spectra with a moderately complex spectral model incorporating a corona, torus obscurer and warm mirror. Using the Bayesian X-ray Astronomy (BXA) package, we constrain redshift, column density, photon index and luminosity simultaneously. Comparing with spectroscopic redshifts, we find an outlier fraction of 8%, indicating that our model assumptions are valid. The independent XZ estimate is easy to apply and effective for a large fraction of obscured AGN in todays deep surveys without the need for any additional data. Comparing to different redshift estimation methods, XZ can resolve degeneracies in photometric redshifts, help to detect potential association problems and confirm uncertain single-line spectroscopic redshifts.

7th February
14:00–14:30

- ***Complex modelling with many datasets within BXA***
- Presenter: **Devang Liya**
  Indian Institute of Science Education and Research Mohali, India
- Personal website
- ***Abstract:***
  X-ray observations of heavily obscured Active Galactic Nuclei (AGN) provide a rare unique opportunity to study the circum-nuclear environment and its evolution in great detail. This can be crucial in our understanding of the unified model of AGNs in X-ray. In this talk, I will present preliminary results from an ongoing broadband spectral study of one such heavily obscured AGN. We find that the unified model is much more complicated than we thought, with complex geometrical parameters playing an important role. The talk will also show how BXA is an ideal tool for our study where we fit complex models to multiple datasets. Finally, I will show a few tricks to speed up the BXA fitting tasks.

7th February
14:30–15:00

- ***Exploring the obscuration properties of AGN in the Chandra Deep Wide Field Survey with BXA***
- Presenter: **Alberto Masini**
  Scuola Internazionale Superiore di Studi Avanzati, Italy
- Personal website
- ***Abstract:***
  Most active galactic nuclei (AGN) are obscured by some amount of gas along the line of sight. The shape of the photoelectric cutoff produced in the soft X-rays is very sensitive to the exact amount of column density, making X-ray spectroscopy a powerful tool to measure it.
  With the aim of tracking how obscuration evolves with AGN luminosity and redshift, I will illustrate an ongoing project to systematically measure with BXA the column density of a large sample of ∼6.5k X-ray selected AGN from the most recent Chandra deep survey in Boötes.
  All spectra are fitted, independently from their number of photons, to mitigate selection effects: for this reason, BXA is the ideal tool to perform this kind of analysis. Preliminary results suggest that the fraction of obscured AGN strongly evolves with both redshift and luminosity, shedding new light on the complex interplay between the AGN and its surrounding environment.

11th February
14:00–14:30

– ***Bayesian spectral analysis for large XMM surveys***
– Presenter: **Lingsong Ge**
University of Geneva, Switzerland
– ***Abstract:***
TBD.

– ***The synergy between Monte Carlo Radiative Transfer and Artificial Neural Networks***
– Presenter: **Gabriele Matzeu**
University of Bologna, Italy
– Personal website
– ***Abstract:***

11th February
14:30–15:00

We present a new state-of-the-art X-Ray Accretion Disk-wind Emulator (XRADE) based on the Monte Carlo multi-dimensional (3D) radiative transfer DISK-WIND code initially developed by Sim et al. 2008,2010. The DISK-WIND model can provide a physically motivated self-consistent treatment of both the absorption and emission that is produced in the accretion disk-wind as well as computing the ionization state and velocity field within the flow.

Whereas XRADE is produced through a process that combines X-ray tracing with supervised machine learning. As a result we develop a novel emulation method consisting in training, validating and testing the simulated synthetic disk-wind spectra into a purposely built artificial neural network. We find that the trained emulator can emulate a synthetic spectrum for a particular parameter set in a fraction of a second in comparison to a 10-50 minutes (CCD resolution) or ∼3 hours (for 2 eV micro-calorimeter resolution) when using the standard MCRT pipeline.

The emulator does not suffer issues with multi-dimensional spaces that are typically faced by traditional interpolation methods. By expanding the DISK-WIND table of synthetic spectra across a larger parameter space, the XRADE tables presented here will be suitable to be applied to a wide number of AGN sources with across black hole mass, ionizing luminosities and accretion rates scales.

The implementation of XRADE will be very useful particularly in anticipation of future X-ray detectors such as the micro-calorimeters on board future missions: JAXA/NASA XRISM/Resolve (FWHM resolution of ∼6 eV at Fe K) and ESA Athena/X-IFU (FWHM resolution of 2.5 eV at 6 keV).