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ScienceDirect
Advances in Space Research 38 (2006) 1382–1386
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

X-ray and Gamma-ray properties of AGN: Results from XMM-Newton, Chandra and INTEGRAL

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Received 6 December 2004; received in revised form 29 April 2005; accepted 5 May 2005

Abstract

The X-ray observatories XMM-Newton and Chandra provided a wealth of exciting new results on active galaxies, and many more are expected to emerge soon from the Gamma-ray mission INTEGRAL. Chandra delivered X-ray images of outstanding detail, reaching subarcsecond spatial resolution for the first time in X-ray astronomy. XMM-Newton with its high sensitivity provided X-ray spectra of unprecedented signal/noise. Spectra are resolved in great detail with the spectrometers aboard XMM-Newton and Chandra for the first time. INTEGRAL is dedicated to imaging and spectroscopy in the X-ray and Gamma-ray regime up to 3 MeV with significantly improved sensitivity and resolution as compared to previous Gamma-ray missions. The X-ray and Gamma-ray imaging and spectral observations are greatly improving our understanding of the physical processes in the central region of active galaxies. Here, I give a review of recent X-ray and Gamma-ray results on Active Galactic Nuclei.

Keywords: Active galactic nuclei; Black holes; X-rays; Gamma-rays; XMM-Newton; Integral; Chandra

1. Introduction

High-energy emission provides us with important information on the physical conditions in the active cores of galaxies. The X-ray missions Chandra (Weisskopf et al., 2002) and XMM-Newton (Jansen et al., 2001) have delivered data of unprecedented quality and have greatly increased our knowledge on the central regions of Active Galactic Nuclei (AGN). This is due to the superb spatial resolution of Chandra, providing images rich in details on the 1 arcsec-level for the first time, and due to the increase in spectral resolution of XMM and Chandra, providing X-ray spectra with a wealth of features including many narrow absorption and emission lines, detected in X-rays for the first time. The new Gamma-ray observatory INTEGRAL (Winkler et al., 2003) has provided first new results on AGN and many more results are expected in the near future. Below, a short review of results on AGN from these observatories is given.

2. Absorption-line spectroscopy

2.1. Ionized absorbers in Seyfert 1 galaxies

Cold and 'warm' (ionized) absorbers have been detected in all types of AGN from low to high redshift. The absorbing material, located in the central region of AGN, is thought to play an important role in AGN unification scenarios, in explaining the X-ray background, in black hole growth and AGN evolution. Recognized earlier, ionized absorbers have now become the most important X-ray diagnostic of the central region of AGN, imprinting many absorption (and emission) lines

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0273-1177/$30
doi:10.1016/j.asr.2005.05.016

on soft X-ray spectra of Seyfert 1 galaxies which have been detected with the grating spectrometers aboard XMM-Newton and Chandra.

Generally, the following results emerged (e.g. Kaastra et al., 2000, 2002, 2004; Kaspi et al., 2002; Sako et al., 2001; Collinge et al., 2001; Komossa et al., 2001; Branduardi-Raymont et al., 2001; Lee et al., 2001; Yaqoob et al., 2003; Steenbrugge et al., 2003; McKernan et al., 2003; Netzer et al., 2002, 2003; Piconcelli et al., 2004; Krongold et al., 2003, 2005):

- Warm absorbers are indeed photoionized.
- Their structures are complex and multi-component.
- The spread in ionization parameters is a least a factor 100.
- The column densities range between $N_H \simeq 10^{21}$ and few $\times 10^{23}$ cm^{-2}.
- Most ionized absorbers are in outflow with typical velocities of $v \simeq 500$–1000 km/s.
- There is continuing evidence that some warm absorbers contain dust.

Origin and location of the ionized material are still subject to some uncertainties. Estimates place a number of warm absorbers beyond the Broad Line Region (BLR) at $d \approx 0.1$–1 pc, while in other cases a spatial coincidence with the BLR is possible or favored.

Another important issue is the relation between X-ray and UV ionized absorbers. There are several lines of evidence that both components are closely related (e.g., Elvis, these proceedings). In some cases there is a one-to-one match between X-ray and UV-absorbers while others show non-identical properties.

The detailed atomic physics involved in producing the X-ray spectra of Seyfert galaxies, and the consequences for our understanding of the central region of AGN, are still under scrutiny. The X-ray spectra of the brightest AGN are so rich, that it will take a while until all available information is extracted from them.

2.2. The case of NGC 3783

While all AGN in deep fields are exposed for megaseconds, the record for the deepest grating observation of a nearby galaxy is held by NGC 3783. The warm absorber of this source was discovered in pioneering work by Turner et al. (1993). The 900 ks Chandra spectrum (e.g. Fig. 1 of Kaspi et al., 2002; Krongold et al., 2003, 2005; Netzer et al., 2003; see Behar et al., 2003 for a discussion of the XMM-RGS spectrum) exhibits a wealth of absorption and emission features from many different elements.

The warm absorber in NGC 3783 is multi-component with a wide range of ionization and each of the $\sim$3 components is further split in two different kinematic components (Netzer et al., 2003). According to the analysis of Netzer et al., all three components are thermally stable and of the same gas pressure.

The X-ray emission of NGC 3783 varies on short and longer terms. The long-term (20–120 days) variability is mostly dominated by the appearance and disappearance of a soft excess, while the short-term variability (<4 days) is not accompanied by any spectral variability. Krongold et al. (2005), Elvis et al. (2004) identify opacity changes in the Fe UTA on the timescale of 31 days, responding to a change in the ionizing continuum. This constrains the density of the ionized material and locates it within 6 pc of the center. According to Krongold et al., this component of the warm absorber is likely heavily clumped.

3. Emission-line spectroscopy

Basically, the trend emerged that Seyfert 1 X-ray spectra are dominated by absorption features, while Seyfert 2 X-ray spectra are dominated by emission-lines. There are some exceptions, like NGC 4151, a classical Seyfert 1 galaxy of type 1.5 which in X-rays looks more like a Seyfert 2. Only very few AGN X-ray spectra turned out to be completely featureless (e.g. Marshall et al., 2003).

3.1. X-ray emission in Seyfert 2 galaxies

The X-ray emission lines detected in the spectra of several Seyfert 2 galaxies (e.g. Kahn et al., 2001; Sambruna et al., 2001; Brinkman et al., 2002; Sako et al., 2000, 2002; Ogle et al., 2003) and in NGC 4151 (Ogle et al., 2000) contain important information on the conditions in the line-emitting medium, like temperature, density, and the main gas excitation/ionization mechanism; photoionization or collisional ionization. Of particular importance in determining the main power mechanism of the lines are the Helium-like triplets, the widths of the radiative recombination continua, and the strengths of the Fe–L complexes.

The general trend emerged, that the extended gas in Seyfert 2 galaxies appears to be photoionized out to relatively large distances from the nucleus.

The emission lines in the X-ray spectrum of NGC 4151 are narrow and exhibit properties characteristic for the narrow-line region.

In several nearby Seyferts the X-ray emission is spatially resolved and widely extended and coincides with the optical ‘radiation cones’.

Column densities are sometimes similar to that of warm absorbers which has motivated the suggestion that, possibly, the extended gas in Seyfert 2 galaxies represents warm absorbers seen outside the line-of-sight.