Evidence for a high accretion rate as the defining parameter of Narrow-Line Seyfert 1 galaxies

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Abstract

X-ray spectral features which are unusually strong in many Narrow Line Seyfert galaxies are found to be consistent with reflection from strongly ionized matter, providing further evidence of a high accretion rate in these objects and offering a unique signature of that key parameter in future observations.

Key words: galaxies: active; X-rays: galaxies; galaxies: individual (Ark 564)

1 Introduction

The abstracts of papers for this meeting showed a strengthening consensus that the defining parameter of Narrow Line Seyfert 1 galaxies (NLS1s) is indeed a high accretion rate. That proposal was first made1 by direct analogy with the X-ray properties of GBHC in their high state, where it was also noted that the resulting increase in ionising flux would lead to the 'broad line' clouds forming at larger radii, providing a natural explanation for the narrow permitted optical lines characteristic of NLS1. A prediction that the hard X-ray spectrum of NLS1 would be unusually steep, due to increased cooling of the Comptonising electrons, was borne out by subsequent ASCA spectra2.

In the present paper we discuss the interpretation of additional spectral features, apparently characteristic of NLS1, which lends further support to the high accretion rate thesis and offers the exciting potential of a direct observational signature of one of the fundamental parameters of the AGN phenomenon.
2 Reflection from an ionized disc

The importance of ‘reflection’ in modifying the observed X-ray spectra of AGN, in turn providing a key diagnostic of the accretion process believed to be the source of power in AGN, was established almost 10 years ago. For many Seyfert galaxies and low luminosity QSOs, a good explanation of the observed hard X-ray spectral features (Fe K fluorescence line, 10–20 keV ‘hump’) is provided by re-processing of order a half of the ‘primary’ X-ray power law flux, in dense, cold matter (the putative accretion disc). A number of attempts have subsequently been made to model the effects of the external irradiation on the ionisation state of the reflecting material and hence predict the resulting modification of the reflected spectrum. An early study noted the potential significance of a high accretion rate, and strong X-radiation, in ionising the outer disc layers, finding the ionisation parameter to scale with $\dot{m}^3$ (where $\dot{m} = M / M_{\text{Edd}}$).

Until very recently, all ionized disc models had made the simplifying assumption of a constant density (Ross et al. and refs therein), notwithstanding that such a situation is physically unrealistic. One constant density model (PEXRIV) has been adapted to the XSPEC spectral fitting procedure, and has therefore been used to assess recent X-ray data from ASCA and BeppoSAX. However, PEXRIV also lacks any emission components.

A new approach has now been made to calculate the photoionisation, and subsequent X-ray reflection characteristics, of an accretion disc in which the density is determined from a hydrostatic balance and solved simultaneously with the ionisation balance and radiative transfer. The predictions of this, more physically realistic model, differ significantly from those of the constant density models. In particular, three discrete thermally stable layers are predicted,
whose optical depths and effective temperatures depend critically on the intensity and spectral index of the irradiating X-rays. In the case of a ‘normal’ Seyfert 1, the outermost layer, closest to the ionising source, is predicted to be almost fully ionized and at the local Compton temperature ($\sim 10^7 - 10^8$ K), while at larger depths the temperature decreases sharply to the thermal disc temperature. In terms of the reflected X-ray spectrum, the upper layer is effectively a good mirror, introducing few spectral features, while the lowest layer will act like a cold (neutral) reflector, yielding the Fe K 6.4 keV line and 10–20 keV reflection hump.

However, with a steeper (and implicitly more intense) incident spectrum – as is typical of the ultrasoft NLS1s – the Nayakshin et al. model predicts a region of substantial optical depth with intermediate temperature ($T \sim 10^6$ K) and ionisation. Reflection from such material would superimpose significant spectral features on the emerging X-ray spectrum, as is found with many NLS1.

A steep X-ray spectral slope is a primary feature of NLS1, of course. Also, the interpretation that NLS1s operate at a high accretion rate implies an unusually high intensity of soft XUV flux, precisely the irradiation conditions required in the ‘hydrostatic balance’ models\textsuperscript{6} to give an intermediate temperature, stable region with sufficient optical depth to imprint significant ionisation features on the reflected X-ray spectrum.

A recent study of the bright NLS1 Ark 564\textsuperscript{7}, in which ASCA and RXTE data have been combined to give simultaneous spectral coverage from 1–20 keV, has revealed several features identified as arising from reflection in an ionized disc. See also Vaughan et al. in these Proceedings.

3 A new BeppoSAX spectrum of Ark 564

While our ASCA/RXTE study of Ark 564 provides good evidence for ionized reflection features, in terms of the Fe K-absorption edge and ‘soft excess’ near 1 keV, the instrumental uncertainties of the ASCA data restricted the analysis below $\sim 1$ keV. We have therefore tested our spectral fitting against archived BeppoSAX data, where the combination of the LECS, MECS and PDS instruments provide good cover down to $\sim 0.2$ keV (and to above 15 keV). Figure 1 shows a simple power law is an unacceptable fit to the BeppoSAX data ($\chi^2 = 1.34$), with residual features similar to those from the ASCA/RXTE fit. Figure 2 reproduces the fit to a power law plus ionized disc reflector, the latter being modelled by PEXRIV plus emission features of O viii Lyman-\(\alpha\) at 0.65 keV and the O viii recombination continuum above 0.87 keV. The equivalent widths of both oxygen emission features are $\sim 90$ eV and the excel-
lent overall spectral fit has a $\chi^2_\nu$ of 1.02. We draw particular attention to the strength of the \Oviii recombination continuum, a feature largely ignored in previous attempts to fit the $\sim 1$ keV emission features in NLS1 (but included in the spectral fit of Mrk 38). The \Oviii recombination continuum also shows up strongly in the relevant models of Nayakshin et al., and we further note the self-consistency of the ionized disc explanation with a temperature of $\sim 10^6$ K derived from the measured width of the recombination continuum.

4 Discussion

There is now good evidence that another distinguishing property of NLS1 is the presence of strong spectral features superimposed on an intrinsically steep power law. At least for Ark 564, we find that ALL the observed spectral features, from the ionized Fe K-absorption edge to the ‘soft excess’ below $\sim 1$ keV, can be interpreted as arising from an ionized disc. We note encouraging agreement with the predictions of the model of Nayakshin et al., where the unusual intensity and steepness of the intrinsic X-ray emission of a NLS1 is critical for a significant optical depth of intermediate ionisation to occur. We note, in passing, that this interpretation offers the exciting future prospect of using X-ray spectra as a unique diagnostic of the accretion rate in AGN.

Finally, a comment on the question of NLS1 being ‘low mass’ or ‘high accretion rate’ objects, a debate continued in this meeting. That difference may be merely semantic, given that the NLS1 and ‘normal’ Seyfert 1 galaxies accessible to current observation lie in a limited range of luminosity. Correspondingly, NLS1 tend to be both high accretion rate and low mass (for their luminosity). More sensitive future X-ray observations should allow the expected differences in appearance of high mass AGN with different accretion rates to be studied.

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