Observational progress on accretion disks: a turning point

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Abstract:
A turning point has been reached in the observations of AGN for several reasons: (1) the development of a method to derive the mass of the central black hole (2) the identifications of several subsets of AGN which cover a wide range of accretion rates (3) the observations of the appearance of broad lines in galaxies which had previously displayed moderate signs or no signs at all of activity and (4) the growing evidence for a central massive black hole in normal galaxies.

This opens new avenues of investigations such as the exploration of the entire parameter space defined by the black hole mass and the accretion rate, and the observational exploration of the duty cycles of nuclear activity.

The most recent observations of the broad emission lines strengthen the disk plus wind model of the BLR, a model which appears at present, to be the most plausible.

1 Introduction

There are several independent lines of evidence for the presence of an accretion disk. In three energy ranges (mid X-rays, UV and optical) there is evidence for a dense cool medium which scatters, or absorbs and re-emits radiation emitted at higher energy by the central source (Pounds & al 1990; for a review, Ulrich, Maraschi & Urry 1997). Various considerations, in particular relative to the solid angle of this cool medium as viewed from the central source strongly suggest that this medium has a flat geometrical structure. An attractive possibility, entirely consistent with the observations, is to identify this flat structure with the accretion disk surrounding the black hole assumed to be present in AGN.

The disk is probably magnetized and magnetically accelerated outflows are the likely sources of the broad line region (BLR) gas clouds.

Recent and current work on this topic is reviewed. An agenda is drafted for AGN variability studies in the next decades and beyond.

2 Different types of continuum variations in the UV and X-ray ranges, and evidence for different emission mechanisms

2.1 The rapidly variable UV component and the irradiation model The UV continuum flux varies on all measurable time scales, minutes to decades. The
fastest variations are known to be incompatible with models of variable fueling in standard optically thick, geometrically thin, accretion disks (Clarke 1987). What could then cause the fast variations in low luminosity AGN? An answer is offered by the good correlation and the simultaneity observed between the variations of the UV continuum flux and the variations of the mid X-ray flux on time scales of weeks to months (Perola & al 1986, Warwick & al 1996, Clavel & al 1992).

This is the basis of the irradiation model in which the variable part of the UV continuum flux is thermal emission by a dense cool medium whose temperature is modulated by the incident variable X-ray flux. A consistency check for this model is that the energy in the variable X-ray component is larger than that in the UV variable component. This is indeed verified in low luminosity AGN, the only ones for which simultaneous UV/X-ray observations have been performed.

It is not known whether the irradiation model applies to high luminosity AGN for lack of enough simultaneous UV/X-ray observations (these AGN are in general are rather faint). These observations should be the priority of the next space missions capable of measuring the UV and mid X-ray flux of relatively faint objects.

Explosive reconnections probably dissipate significant power via magnetic flares within the disk corona (Galeev & al 1979, Blandford & Payne 1982) and X-ray emission is produced via inverse Compton emission in the hot corona surrounding the colder accretion disk (Haardt & Maraschi 1991). Turbulence and magnetic reconnections can produce a variable X-ray emission even if the accretion rate is constant.

2.2 The slow varying UV component On time scales of years the proportionality of the UV and medium X-ray fluxes, which is so remarkable on time scales of weeks to months, breaks down. Figure 1 shows the UV vs X-ray flux of NGC 4151 during campaigns of observations separated by several years. During each campaign, the UV continuum flux is correlated with the mid X-ray flux (though not in a detailed way) but between the two campaigns of 1983/1984 and 1993, the UV flux alone underwent a large increase. A similar situation is observed in NGC 5548 and F9 where on long time scales, the UV flux varies with a much larger amplitude than the X-ray flux (Clavel & al 1992; Morini & al 1986).

Figure 2 shows the variations of the flux of NGC 4151 at 1440 Å during the lifetime of IUE 1978-1996 (for clarity not all data points are plotted). There is a slow large amplitude variation on which is superposed episodes of fast variations which are those which can be explained by the irradiation process described in section 2.1. The mechanism for longer term (years) variations is unknown.

2.3 The Narrow Line Seyferts 1: Eddington accretion rate? The most extreme soft-X-ray variability occurs in Narrow-Line Seyfert 1 galaxies (NLS1), a subset of AGN with very steep X-ray spectra and narrow optical emission