Evidence of Rapid Optical Variability In
Selected Narrow-Line Seyfert 1 Galaxies

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Abstract

We present the first results of a search for the presence of rapid optical variability in a sample of five Narrow-Line Seyfert 1 galaxies. We find clear evidence of rapid variability for IRAS 13224-3809 with variations occurring on time scales of an hour. However, the results are less conclusive for the other four sources in our sample, Markarian 766, PG 1244+026, PG 1404+226 and Arakelian 564. While there are several instances among these latter objects where there is a hint that variability may be present, IRAS 13224-3809 provides the only conclusive evidence of rapid optical variability detected to date.

Key words: galaxies: active; quasars: general; seyfert: variability; optical: galaxies

1 Introduction

Narrow-line Seyfert 1 galaxies (NLS1) are an unusual and unique class of AGN which exhibit extreme X-ray properties. These galaxies are characterized by the following properties (Boller, Brandt and Fink 1996): (1) they have Balmer lines of hydrogen that are only slightly broader than the forbidden lines in their spectrum, (2) they tend to have strong Fe II and weak [O III] lines, and they thus tend to lie at one extreme of the Boroson & Green Eigenvector (Boroson and Green 1992), (3) X-ray observations have shown the existence of persistent giant-amplitude variability observed at soft X-ray energies, and (4) they exhibit a strong, soft X-ray excess emission and a steep 2-10 keV power-law continuum. The X-ray observations indicate that Narrow-Line Seyfert 1s are not rare and represent a substantial part of the Seyfert population. The
origin of the distinctive X-ray/optical properties is as yet unknown, but it has been suggested that it is linked to an extreme value of a primary physical parameter; e.g. the accretion rate, nuclear orientation and black hole spin have been suggested.

One of the intriguing characteristics of NLS1 galaxies is the existence of the persistent giant-amplitude variability observed at soft X-ray energies. Although variability is a well-known X-ray characteristic of Seyfert 1 galaxies, the extreme variability reported for IRAS 13224-3809 (Boller et al. 1997) is astonishing. As a result of these reports of extreme variability, we recognized that it would be important to determine if a similar phenomenon is present at optical wavelengths, and if so, what is the relationship between the variability observed in these different regimes.

2 Observations

The high-time-resolution observations of the NLS1s reported here were obtained with the 1.05-meter telescope at Lowell Observatory, the 0.6-meter telescope at Siding Spring Observatory, the 0.4-meter telescope at Braeside Observatory, and the 0.4-meter telescope at GSU's Hard Labor Creek Observatory. The observations were made with CCD cameras at each observatory equipped with a BVRI-filter set. Repeated exposures of 90-120 seconds were obtained for the star field containing the NLS1 galaxy and several comparison stars. These comparison stars were internally calibrated and are located on the same CCD frame as the object of interest. They were used as the reference standard stars in the data reduction process. The observations were reduced using the method of Howell and Jacoby (1986). Each exposure is processed through an aperture photometry routine which reduces the data as if it were produced by a multi-star photometer. Differential magnitudes can then be computed for any pair of stars on the frame. Thus, simultaneous observations of the NLS1, several comparison stars, and the sky background will allow one to remove variations which may be due to fluctuations in either atmospheric transparency or extinction. The aperture photometry routine used for these observations is either the CCDPHOT package or the apphot routine in IRAF.

The errors are determined from the scatter in the differential photometry of two comparison stars observed simultaneously with the object of interest. The length of the vertical bars attached to each data point corresponds to a 2σ error bar.
Fig. 1. The rapid optical variability of IRAS 13224-3809 is clearly present on the night of 1999 Feb 18. There is evidence for the presence of three flares with amplitudes ranging from 0.1 - 0.25 mag. occurring during the approximately 5 hours of monitoring on this night.

3 Results

During the past two years, we have embarked upon a program to monitor the rapid optical variability of a sample of five NLS1 galaxies. The primary goal of this program is the detection of rapid optical variations which may be the optical counterpart of the giant X-ray variability. We have recently determined that optical variations of smaller amplitude, but on similar timescales, to those seen at X-ray wavelengths are clearly present for IRAS 13224-3809. However, the results are less conclusive for the other four galaxies in our sample (AKN 564, MRK 766, PG 1404+226 and PG 1244+026).

IRAS 13224-3809 was monitored for rapid optical variability for five nights in 1999 February. The most extreme variability detected is displayed in Fig. 1. The object was monitored for approximately 5 hours on this night with the detection of three events: event 1 occurred at 1227.88 JD with an approximate amplitude of 0.12 mag; event 2 occurred at 1227.925 JD with an approximate amplitude of 0.2 mag; and event 3 occurred at 1227.97 JD with an approximate amplitude of 0.2 mag. The time scales of these flares are comparable to the time scales of the most rapid X-ray flares observed, but the amplitudes are
substantially smaller. These events may be the result of small discrete events, such as hot spots or flares in the accretion disk, or may be due to magnetic reconnections (Mineshige et al, 2000).

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