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A Correlated Optical-Infrared Outburst of Mrk 744: Strong Evidence For Thermal Dust Reverberation

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Abstract. Simultaneous optical and infrared monitoring of a sample of 50 Seyfert 1 galaxies and quasars has revealed an outburst of the active galaxy Markarian 744. Cross-correlation analysis indicates that the IR lags the optical light curve by roughly one month. A simple model developed by the author can fully explain the IR variability of this object in terms of thermal dust reverberation.

1. Introduction

Throughout 1995, I carried out a monitoring program on over 50 Seyfert 1 galaxies and quasars in optical (V) and infrared (K') wavebands. They were observed approximately once a month from about 1994 November to 1995 December. The bulk of the data were obtained with a 0.61-m telescope teamed with the UCLA IR Camera KCam (McLean 1994) and a Photometrics Star 1 CCD camera. A dichroic beam splitter installed in the telescope provided the means for obtaining data simultaneously at V and K'. Photometry in a constant $10''$ aperture was obtained and calibrated both with standard stars and with field objects for differential photometry.

The telescope is a newly refurbished instrument on the UCLA campus in the middle of some of the worst light-polluted skies Earth has to offer, but I have found the location suitable for obtaining light curves of relatively bright objects (Nelson & McLean 1996). Since this instrument was quite under-subscribed (I was normally the only user), I was able to use it as a dedicated telescope to observe many objects repeatedly with little concern about cloudy nights on a very flexible schedule.

2. Observations

The most exciting and readily obvious feature in the data set is shown in Fig. 1: a relatively sharp and well-defined outburst of the Seyfert galaxy Mrk 744 observed at both V and K'. Mrk 744 has been classified variously in the literature as Seyfert 1.5, 1.8, or 1.9. It is a close companion to NGC 3788, with which it appears to be interacting, and it has no previously reported variability at optical or IR wavelengths. In fact, there are only four published IR data points for this galaxy (Gezari et al. 1993).

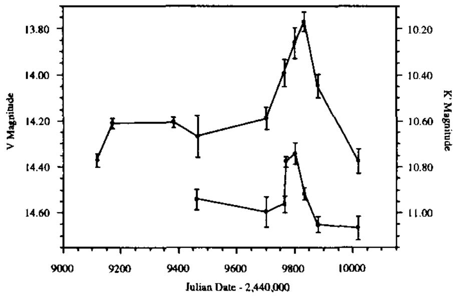

Figure 1. V (lower, filled circles) and K' (upper, open circles) light curves for the galaxy Mrk 744.

One may notice in Fig. 1 that the IR outburst appears to be delayed relative to the optical outburst. This suspicion is borne out by the cross-correlation function, which peaks at a lag time of 32 ± 7 days. Therefore a natural explanation for the IR variability is provided by thermal dust reverberation, a reprocessing of the unobserved UV light curve into IR radiation by warm dust.

Such a process has been suggested elsewhere, most notably for Fairall 9 by Clavel, Wamsteker, & Glass (1989), and their analysis applied to this galaxy yields support for a thermal dust model, since for a 10^{42} ergs s^{-1} UV flux, the dust temperature at a distance of 32 light-days is 1100 K, well below the theoretical evaporation temperature for carbon grains.

To test this model in more detail, a full reverberation code was developed by the author to calculate an output IR light curve given a series of optical observations. To infer the unobserved UV light curve, parameters for scaling the luminosity and variability amplitude of the optical light curve were included. These can be employed as free parameters, along with a number of others, such as maximum and minimum grain temperatures, density terms, and optical properties of the grains. A simplex fitting routine intelligently wanders through the parameter space to find a local minimum. An extremely good fit to the data was derived using three free parameters, and the details and assumptions concerning this model have been described elsewhere (Nelson 1996).

The Mrk 744 outburst is the most obvious 'interesting' case culled from a large database of nearly 600 separate observations of 50 AGNs. This data set forms the core of my Ph.D. thesis, which will be completed in Fall 1996.

References

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