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# Multi-wavelength Behaviour of III Zw2

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**Abstract:** III Zw2 was observed with XMM-Newton in July 2000. Its X-ray spectrum can be described by a power law of photon index  $\Gamma \approx 1.7$  with a Gaussian line at 6.7 keV. There is no significant evidence of intrinsic absorption within the source or of a soft X-ray excess. Multi-wavelength light curves over a period of 25 years show related variations from the radio to X-rays. We interpret the radio to optical emission as synchrotron radiation, self-absorbed in the radio/millimetre region, and the X-rays as mainly due to Compton up-scattering of low energy photons by the population of high energy electrons that give rise to the synchrotron radiation.

**Keywords:** accretion, accretion disks — galaxies: individual (III Zw2) — galaxies: active — galaxies: Seyfert — radio continuum: galaxies — X-rays: galaxies

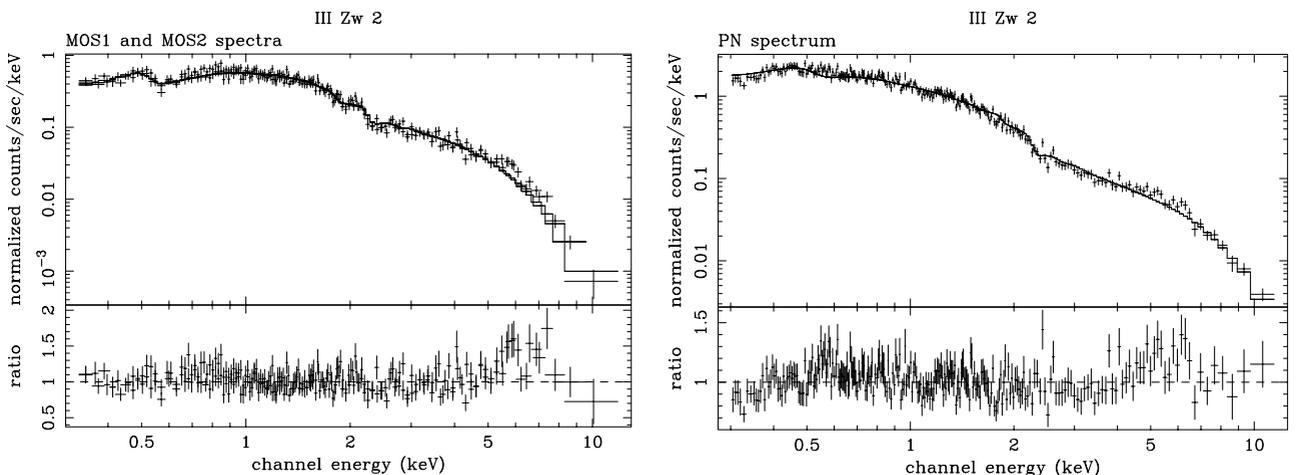
## 1 Introduction

III Zw2 (PG 0007+106, Mrk 1501) is a Seyfert 1 galaxy (Arp 1968; Khachikian & Weedman 1974; Osterbrock 1977) with  $z = 0.089$  (de Robertis 1985). Superluminal motion of radio emitting plasma has been observed recently in the source, and this is the first detection of its kind in a spiral galaxy (Brunthaler et al. 2000). The source has long been known to show large amplitude flux variations in the radio (Wright et al. 1977; Schnopper et al. 1978; Landau, Epstein, & Rather 1980; Aller et al. 1985; Falcke et al. 1999) and the optical (Lloyd 1984; Clements et al. 1995). Variations of smaller amplitude (of less than 50%) have also been detected in the IR (Lebofsky & Rieke 1980; Sembay, Hanson, & Coe 1987) and the UV (Chapman, Geller, & Huchra 1985). The X-ray temporal behaviour is less well studied, but comparison of

observations at different epochs hints that the X-ray flux might vary substantially. The X-ray spectra of III Zw2, obtained by SAS-3 (Schnopper et al. 1978), Ariel VI (Hall et al. 1981), and Einstein SSS (Petre et al. 1984), can be described by a power law of photon indices  $\Gamma \sim 1.3-1.7$ , with neutral absorption consistent with that of the Galactic column.

## 2 X-ray Spectrum

We observed III Zw2 with XMM-Newton (Jansen et al. 2001) on 7 July 2000. (Details of the observations and data analysis will be presented elsewhere.) Figure 1 shows the spectra (in the observer frame) from the two EPIC CCD instruments aboard the satellite (MOS spectra in the left panel and PN spectrum in the right panel). We fit the spectra initially with a power law and a fixed Galactic



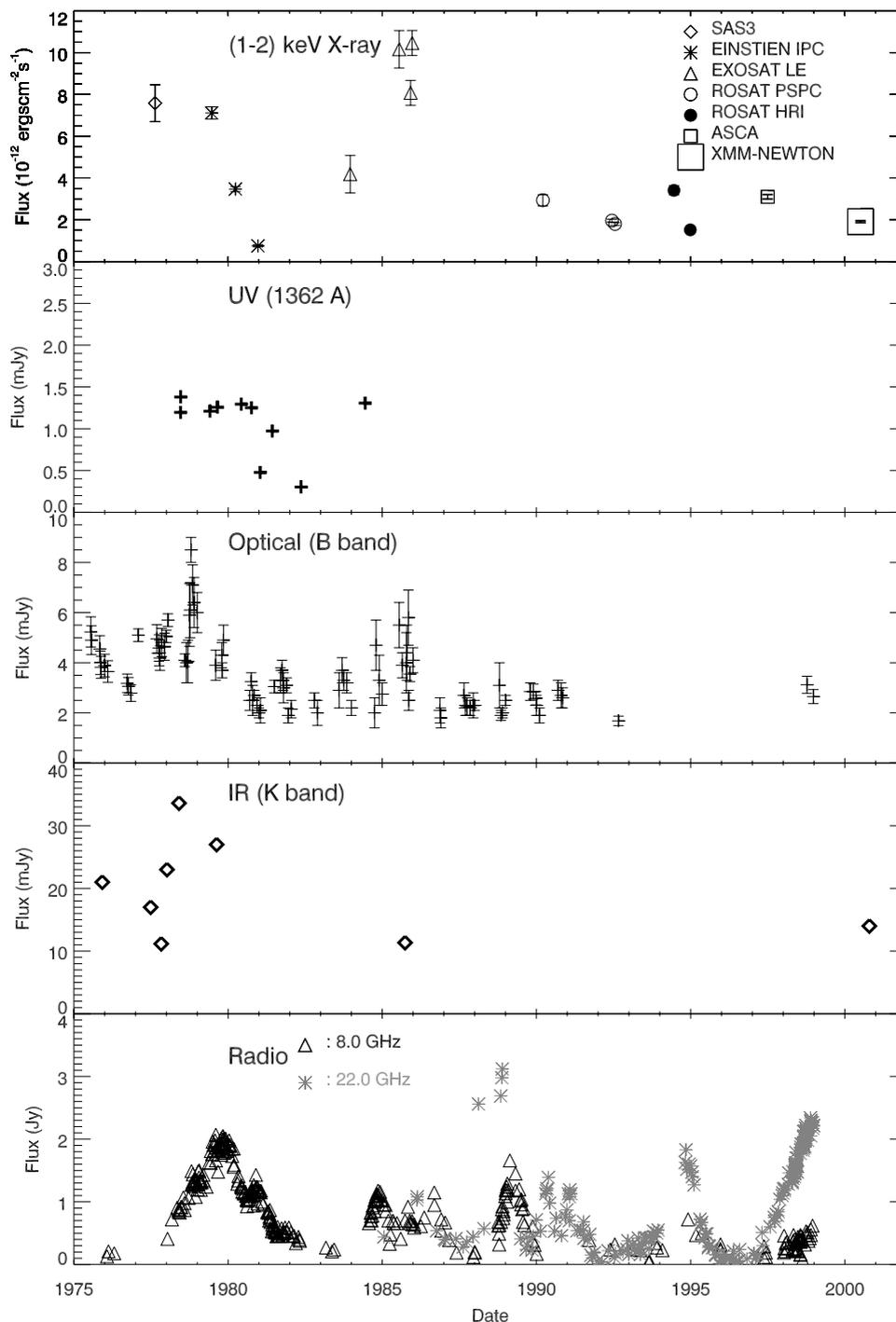
**Figure 1** Left panel shows a simultaneous power law fit to the MOS1 and MOS2 spectrum ( $\Gamma = 1.73 \pm 0.01$ ,  $\chi^2/\text{dof} = 295/253$ ). Right panel shows a power law fit to the PN spectrum ( $\Gamma = 1.75 \pm 0.01$ ,  $\chi^2/\text{dof} = 317/226$ ). The Galactic column was fixed at  $N_{\text{H}} = 5.72 \times 10^{20} \text{ cm}^{-2}$  in both cases. We caution that the PN has a calibration uncertainty of about 150 eV.

column of  $N_{\text{H}} = 5.72 \times 10^{20} \text{ cm}^{-2}$ . The MOS spectra give a photon index of  $\Gamma = 1.73 \pm 0.01$ , and a similar value is obtained for the PN spectrum, which is consistent with previous observations. Excess emission, however, remains at energies  $\sim 5\text{--}7 \text{ keV}$ . Adding a Gaussian (at  $E = 6.76 \pm 0.22 \text{ keV}$  in the rest frame of the source) to the power law improves the fit to the MOS data significantly (with  $\Delta\chi^2 = 45.8$  for 3 parameters), suggesting the presence of a broad iron line (or perhaps blended iron lines), with an EW  $\sim 1.5 \text{ keV}$ . There is no evidence for a soft X-ray

excess. The absorption can be explained by the line-of-sight Galactic absorption, consistent with the finding of previous observations (Hall et al. 1981; Petre et al. 1984; Kaastra & de Korte 1988).

### 3 Multi-wavelength Variability

Figure 2 shows the multi-wavelength light curves of III Zw2 from 1975 to 2000. The X-ray data, with the exception of the XMM observation, are from the HEASARC



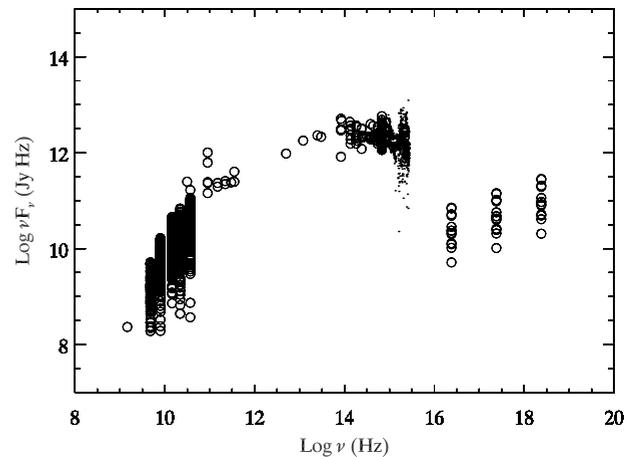
**Figure 2** Multi-wavelength light curves of III Zw2 showing flux variations, with increasing wavelengths from top to bottom. (See Section 3 for the sources of data.)

archives. Non-imaging X-ray observations, with the exception of the SAS-3 flux of August 1977 (Schnopper et al. 1978), have been excluded from our analysis due to the presence of a bright X-ray source approximately 12 arcmin from III Zw2. This source may have been responsible for the contamination of the EXOSAT ME flux measurements of III Zw2 in 1985 (see Tagliaferri et al. 1988). As the spectral photon indices are similar in the XMM observation and in previous X-ray observations (e.g. Hall et al. 1981; Petre et al. 1984), we have used the power law index  $\Gamma = 1.7$  (deduced from the XMM EPIC data, Section 2) to determine the 1–2 keV flux for all observations. The optical light curve is a combination of CCD data of the La Palma archives and various photographic monitoring observations (Lloyd 1984; Clements et al. 1995). The UV data are from the IUE archives (see also Chapman et al. 1985), the IR data are compiled from various publications (Neugebauer et al. 1979; Lebofsky & Rieke 1980; Condon et al. 1981; Hyland & Allen 1982; McAlary et al. 1983; Edelson & Malkan 1987; Sembay et al. 1987), and the radio data at 22 GHz are from Metsähovi (H. Terasranta 2001, private communication) and at 8 GHz are from Michigan 26 m (M. F. Aller 2001, private communication).

The radio and optical wavelengths are better monitored (with optical up to 1990) than the other wavelengths. The source shows 10- and 20-fold variations in X-rays and in radio respectively over timescales of years. The amplitude of variations is relatively smaller in optical and IR. The optical and X-ray observations seem to be correlated, but the correlation is less certain between other wavelengths. Comparison of flares at the optical and radio wavelengths indicate the possibility that the 8 GHz radio flux peaks later than the optical flux (Clements et al. 1995). However, the sampling of the data is not good enough to quantify the exact time lead/lag between flares at other wavelengths.

#### 4 Spectral Energy Distribution

Figure 3 shows the spectral energy distribution of III Zw2, incorporating data from 1975 to 2001. The lack of spread in data in the frequency range  $10^{11}$ – $10^{14}$  Hz is probably due to insufficient sampling in that region. The spectrum peaks at the optical/IR wavelengths, with no evidence for an excess in UV and soft X-rays. The absence of a thermal blackbody component in the broad-band spectrum casts doubts on a model in which a substantial proportion of UV/X-rays are emitted from an optically thick accretion disk (cf. Kaastra & de Korte 1988). The large amplitude flare observed in all wavelengths around 1980 suggests the possibility that the emission from X-rays to radio has a common origin. One possibility is that the broad-band emission from  $10^9$ – $10^{14}$  Hz is due to synchrotron radiation from a cloud of relativistic electrons. The synchrotron emission would be self-absorbed in the radio/millimetre region and would have a high energy cutoff at wavelengths shortward of the optical.



**Figure 3** Spectral energy distribution for III Zw2. It includes radio to X-ray data taken over the last 25 years. (See Section 3 for the sources of data.)

The X-rays are, however, unlikely to be direct synchrotron emission. From the coincidence of X-ray flares with those in the other wavelengths (observed in the 1980s, especially in optical), we interpret the X-rays as Compton up-scattered emission by high energy relativistic electrons that give rise to radio and optical/IR synchrotron radiation. High time resolution, multi-wavelength polarisation observations are required to verify whether or not the broad-band radio and optical radiation is of synchrotron origin.

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