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The soft X-Ray variability of PKS 2155-304

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Abstract. The BL Lac object PKS 2155−304 was studied in two very deep ROSAT HRI observations in May and in November, 1996 during a multi-wavelength monitoring campaign.

The observed intensity variations by more than a factor of two in May and by about 20% in November can be separated into slow flux changes with time scales comparable to the observation intervals and superposed, low-amplitude flares with durations of approximately one day.

A comparison with all previous ROSAT observations of PKS 2155−304 confirms the persistence of these phenomena. While over several years the historical amplitudes of variability have spanned a range of a factor of $\lesssim$ 4.5, PKS 2155−304 varies nearly as much over much shorter periods, thus showing that the dominant time scales in this blazar are truly quite short.

The close correspondence between the light curves of November 1996 and November 1991 strongly argues against a microlensing interpretation of these achromatic variations. BL Lac objects might be the first active galactic nuclei where systematic intrinsic temporal variations, like the precession of the jets, can be observed in X-rays given a sufficiently long observational coverage.

Key words: galaxies: active – galaxies: BL Lacertae objects: individual: PKS 2155-304 – galaxies: jets – X-rays: galaxies

1. Introduction

An understanding of the physical processes leading to the generation of the enormous luminosities observed from active galactic nuclei (AGN) and the explanation of the physical and morphological differences of the nuclear regions around the black hole giving rise to the various manifestations of the AGN phenomenon is one of the great challenges of modern astrophysics.

BL Lac objects represent a relatively small but highly exciting subgroup of the AGN population characterized by large luminosities, rapid variability, and high and variable polarization of the emitted radiation. As their spectra are smooth and nearly featureless at all wavelengths it is rather challenging to determine any physical parameters of these systems.

BL Lacs are thought to be dominated by relativistic jets seen at small angles to the line of sight (Urry & Padovani 1995, Königl 1989), and their radio-through-X-ray spectra are well fitted by inhomogeneous jet models (Bregman et al. 1987). However, the high energy emission of X-ray bright (or blue) BL Lacs (e.g. Maraschi 1998) may well be dominated by a single emission region, as suggested by the success of spectral models based on synchrotron and inverse Compton emission from a homogenous region (Tavecchio et al. 1998). On the basis of this model Chiappetti et al. (1999) determined recently the physical parameters of the emission region in PKS 2155-304 using simultaneous X-ray and gamma-ray observations obtained with BeppoSAX and EGRET. At the same time the source was detected for the first time at TeV energies and the measured flux turned out to be in agreement with that predicted by the model. Kataoka et al. (1999) arrived at similar values of the physical parameters from an ASCA observation of PKS 2155−304, using a time-dependent one-zone homogeneous Synchrotron-Self-Compton model.

Combining spectral and temporal information greatly constrains the jet physics, since different models predict different variability time scales. The measured lags between the light curves at different energies as well as spectral changes during intensity variations allow to probe the micro-physics of particle acceleration and radiation in the jet. Elucidating the structure of blazar jets, possible through multi-wavelength monitoring, is an essential precursor to understanding their formation and thus the extraction of energy from the central engine. The critical elements for effective multi-wavelength monitoring are a sufficiently rapid sampling to resolve variability, temporal coverage long enough to view several flares, and a wide wavelength coverage of the optically thin synchrotron component and, if possible, the Compton-scattered component.

The BL Lac object PKS 2155-304 is one of the best candidates for blazar monitoring because it is both rapidly variable and one of the brightest extragalactic objects in the ultraviolet and X-ray sky, i.e., bright enough that its variability can be re-

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solved at UV and X-ray wavelengths. Like most BL Lac objects, PKS 2155-304 has no strong emission features; the reported redshift of $z = 0.116$ (Falomo et al. 1993) was obtained from spectroscopy of the nebulosity surrounding the BL Lac object. PKS 2155-304 has previously been observed to be highly variable at both ultraviolet (Maraschi et al. 1986, Urry et al. 1988, Edelson et al. 1991) and X-ray wavelengths (Snyder et al. 1980, Treves et al. 1989, Sembay et al. 1993, Kataoka et al. 1999).

Multi-wavelength monitoring of PKS 2155-304 in November 1991 and in May 1994 has led to the best available data for any blazar at the time (Urry et al. 1993, Brinkmann et al. 1994, Courvoisier et al. 1995, Edelson et al. 1995, Urry et al. 1997, Pian et al. 1997, Pesce et al. 1997). This X-ray/EUV/UV/optical monitoring of PKS 2155-304 established for the first time that: (1) the X-ray through optical emission in blazars are closely related; (2) variability occurs on time scales less than 1 day; and (3) the X-ray flux leads the UV by a few hours to a few days. The tight X-ray/UV correlation and the overall UV to X-ray spectral shape confirmed the supposition that synchrotron emission is responsible for the optical-through-X-ray continuum in blazars and ruled out conclusively any significant optical/UV continuum in an accretion disk.

Nevertheless, the light curves of PKS 2155-304 from the two campaigns showed significant differences (Urry et al. 1997). In 1991 the X-ray/UV/optical variations were of similar low amplitude, the measured lag was quite small and the variations were nearly achromatic. In 1994, the X-ray flare was much larger than the nearest UV flare and the lag was at least two days. The larger-amplitude wavelength-dependent variability and larger lag in 1994 likely result from physical processes in the relativistic jet itself.

Neither campaign on PKS 2155-304 (much less for any other blazar) was ideal for good cross-correlations. The first campaign had only 3.5 days of overlap between X-ray and UV/optical, enough to show a clear correlation and to measure a tentative lag, but the X-rays and UV flux appear to diverge at the end. The second campaign was excellent in UV coverage but had less than two days of ASCA data. The X-ray flare appears to precede the EUV and UV flares by 1 and 2 days, respectively, but because only 2 of 12 days were covered in X-rays, this depends on the uncertain association of the X-ray flare with the UV (e.g., it could be related to another flare at the beginning of the UV light curve).

Therefore we designed a monitoring program that would produce high-quality light curves in several bands, including unprecedented spectral coverage in the ultraviolet, extreme ultraviolet, and soft-X-ray from the combination of IUE, EUVE, the ROSAT Wide Field Camera (WFC), and the ROSAT High Resolution Imager (HRI). At infrared wavelengths a 12-day light curve from ISO was obtained, at the highest X-ray energies a detailed monitoring and spectroscopy of PKS 2155−304 was performed with the Rossi XTE. The observations took place in 1996 May and November.

In this paper we will first present the results of the ROSAT HRI observations and then compare the results to previous measurements of PKS 2155−304 taken over the life time of ROSAT. A first comparison of the soft X-ray data with the Rossi XTE data at higher X-ray energies have been presented by Urry et al. (1998); Sambruna et al. (2000) present the results of an analysis of the temporal variations of the source in the RXTE X-ray band, and ISO results can be found in Bertone et al. (2000).

2. The X-ray observations

PKS 2155−304 was observed with the ROSAT HRI in 1996 from May 12, UT 21:11 to May 22, UT 21:52. A total of 80 pointings yielded an overall accepted time of $\gtrsim$ 33.4 ksec. The aim of the observations was to have as dense temporal spacing of observation intervals as possible, i.e., one pointing in every orbit. However, due to scheduling constraints larger gaps could not be avoided. The second observation run took place from November 23, UT 01:55 to November 25, UT 08:44 for a total of $\gtrsim$ 53 ksec in nine orbits. Correspondingly, the spacing of these data is much closer.

No other known object was seen in the field of view of the HRI. The quasar 2155-302 is not detected and the second brightest source, at a position of RA=$21^h58^m17^s$; Dec = -30^o $00'16''$, about 15 arcmin away from PKS 2155−304, has a count rate of $\sim 4.5 \times 10^{-3}$ cts s^{-1} and is optically unidentified.

The Rossi XTE observations overlap with the HRI pointings reasonably well, both in May and in November. In May, a simultaneous stretch of EUVE observations was obtained, as well as 14 pointings with ISO, covering the time May 13 to June 8 (Bertone et al. 2000). Unfortunately, the IUE satellite failed about two weeks prior to the observations.

2.1. Light-curves

Light curves were produced by using standard procedures from the EXSAS environment (Zimmermann et al. 1996). Source photons were extracted from a circle with $250''$ radius around the source center; the background was taken from the outer source-free region of the detector and amounted to typically less than 5% of the source counts.

In Fig. 1 we show a histogram of the background subtracted source counts radially integrated outwards from the center of the source. As there is clearly a residual rest - wobble visible in the slightly non-circular HRI image we used the above large extraction radius which then contains more than 99% of the photons from the source. The photons were corrected for vignetting and dead time and binned in 1 sec intervals. This turned out to be necessary as the accepted time intervals are frequently disrupted by short gaps. Finally, the binned data were summed up and used only if continuous stretches of more than 30 secs of data were obtained.

The WFC observations yielded 32.9 and 41.0 ksec of good observation time for the May and November 1996 pointings, respectively, with an average count rate of $\sim 3 \times 10^{-2}\,s^{-1}$, similar to that of the November 1991 observation. The WFC light curves were extracted as follows: to improve the statistics, the individual short observation slots were first re-binned into

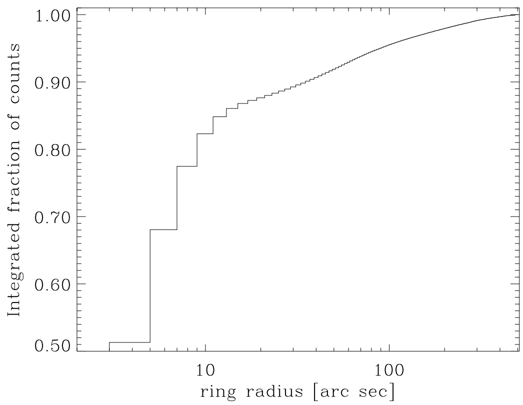

Fig. 1. Background subtracted, normalized fraction of HRI counts as function of the radius from the source center. The total data of the May 1996 observation were used.

sufficiently long (2-3 ksec), contiguous observation intervals. Then the number of photons within a circle with radius 10′ centered on PKS 2155-304 were counted for each of the individual observation intervals. The number of background photons was determined from an annulus with inner radius 15′ and outer radius 30′. The source count rate in each time interval was then calculated by subtracting the vignetting corrected number of background photons (normalized to the source extraction area) from the source photons and finally dividing it by the length of the individual observation interval.

In Fig. 2 we show the HRI light curves of the May 96 (top panel) and November (bottom panel) observation as full dots. As the individual data intervals are of different length, between 30 sec and about 2000 sec, the statistical errors of the count rates vary, and in some cases they are smaller than the symbol sizes. The open squares in both panels represent the WFC count rates, multiplied by a factor of 200. Although the WFC light curves generally follow the intensity variations of the HRI their statistical significance is too low to allow any more quantitative conclusion about the behavior of the very soft X-rays.

The light curve of May 1996 shows variations as large as a factor of two in two days and a longer stretch of less variability ($\sim$ 20% amplitude). In November, the flux level was comparable but the variations are modest, about $\sim$ 20%, as in the PSPC observation of November '91 (see Sect. 2.2). However, note that these data are taken over only about 2.5 days and that there is a general decline in the average intensity.

Apart from some short time scale intensity fluctuations, which partly show large statistical uncertainties of the count rate determination, the long term light curves are rather smooth and do not show sharp, isolated flares, such as seen in May 1994 with ASCA. Despite several gaps due to the satellite scheduling constraints the two observations represent the most extended and complete light curves ever taken of the object.

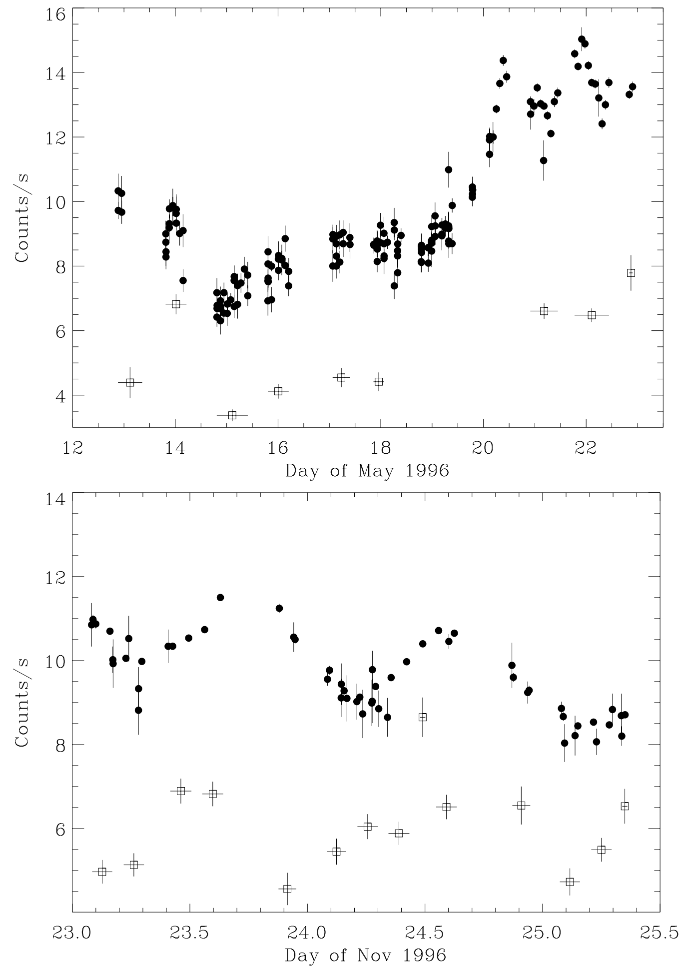

Fig. 2. HRI light curves of PKS 2155−304 in May 1996 (top) and November, 1996 (bottom). The full dots are the HRI data, open squares the WFC data, multiplied by a factor of 200.

Table 1. ROSAT observations of PKS 2155−304

number	Observation date	Instrument	duration
1	11/03/1990 – 11/05/1990	PSPC$^{a)}$	306 s
2	05/06/1991 – 05/06/1991	PSPC	2192 s
3	11/12/1991 – 11/15/1991	PSPC	52013 s
4	11/17/1992 – 11/17/1992	PSPC	1075 s
5	11/17/1992 – 11/19/1992	PSPC	1537 s
6	05/04/1993 – 05/05/1993	PSPC	6771 s
7	04/30/1994 – 05/01/1994	PSPC	5827 s
8	05/06/1994 – 05/16/1994	HRI	4827 s
9	10/30/1994 – 11/20/1994	HRI	13562 s
10	05/12/1996 – 05/22/1996	HRI	33410 s
11	11/23/1996 – 11/25/1996	HRI	53460 s

2.2. Comparison with previous ROSAT observations

In the ROSAT soft X-ray band PKS 2155−304 is the by far best studied BL Lac object. Several observation campaigns have been conducted between 1991 to 1996. Table 1 gives a summary of these observations. In total nearly 175 ksec have been spent on the source, first with the PSPC detector and since 1994 with the HRI.

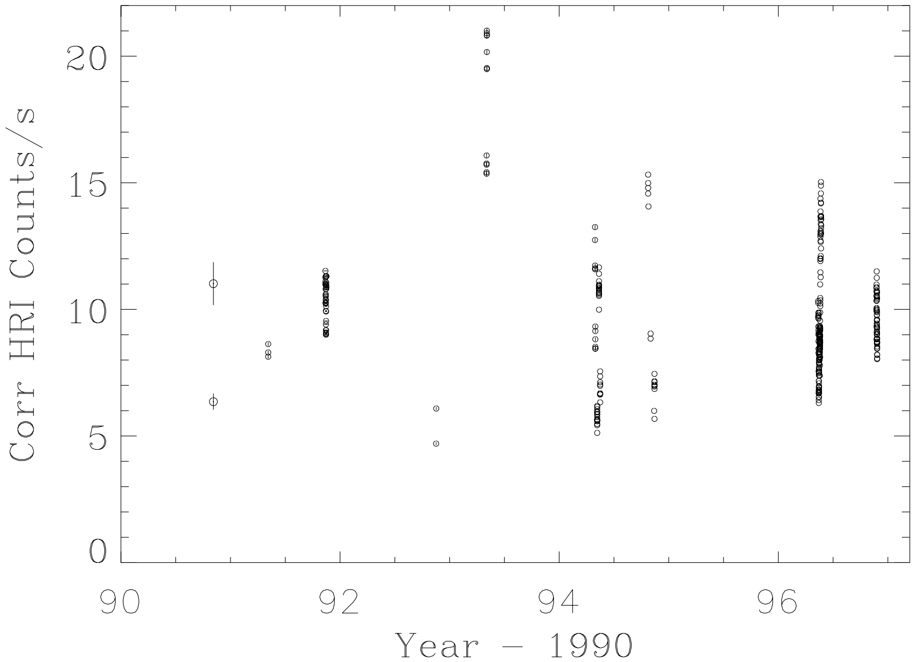

Fig. 3. Light curve of PKS 2155−304 between 1990 and 1996 as observed by ROSAT. Plotted are the HRI count rates as a function of time; every data point corresponds to a 400 s observation interval.

We re-analyzed all data and present in Fig. 3 the long term light curve of PKS 2155−304 as seen by ROSAT. Every data point represents a 400 s (one wobble period) average. For a comparison of the source intensities we converted the measured PSPC count rates into 'equivalent' HRI count rates. The conversion factor was determined by comparing the count rates obtained by folding the typical, soft X-ray spectrum with the PSPC and the HRI detectors. As reference spectrum we used an average power law obtained in the November, 1991 observation (Brinkmann et al. 1994, Table 2, OBI 3: photon index $\Gamma = 2.61$, $N_H = 1.38 \times 10^{20}$ cm^{-2}). With these values the count rates can be related via $CR_{HRI} = 0.21185 \times CR_{PSPC}$.

Long-term spectral variations should not change the conversion factor significantly as they seem to occur predominantly at higher X-ray energies (Sembay et al. 1993). Further, in both detectors the soft source has its maximal count rate at similar energies, below $\sim$ 1 keV. We tested the range of variations of the conversion factor by changing the spectral power law index by $\Delta\Gamma = \pm$ 0.3 from the above value which results in changes of the conversion factor by $\pm$ 0.022 (the numerical factor gets smaller for a steeper power law). This uncertainty in the count rate conversion of less than $\sim$ 10% is thus only a minor effect which can be neglected in the following discussion.

During the All-Sky Survey the source was found at an average intensity of about 39 cts s^{-1} in the PSPC. The power law slope was $\Gamma = 2.66 \pm 0.07$ and the object varied by about $\pm$ 20% during the $\sim$ 1.5 day Survey coverage; in Fig. 3 we plot the maximum and minimum rates with the errors during the corresponding individual orbits.

Overall, PKS 2155−304 showed a total variability by factors of $\sim$ 3 - 4 with an average HRI count rate of $\sim$ 10 cts s^{-1}, corresponding to a soft X-ray luminosity of $L_{0.1-2.4\,\mathrm{keV}} \sim 3.8 \times 10^{46}$ erg s^{-1}, assuming the above spectral parameters. The largest flux was observed in the May 1993 observation with a maximal PSPC count rate of more than 99 cts s^{-1}, the lowest in November 1992 with $\sim$ 22 cts s^{-1}. In both cases the spectrum could not be fit with a single power law but with broken power laws with break energy around 0.7 keV. The high intensity spectrum is flatter at low energies and steeper at high energies. The photon indices are ($\Gamma_l = 1.78 \pm 0.05, \Gamma_h = 2.78 \pm 0.06$; $\chi^2_{red} = 1.59$) and ($\Gamma_l = 2.0 \pm 0.2, \Gamma_h = 2.67 \pm 0.2$; $\chi^2_{red} = 1.14$), respectively. The largest variability seen in a single observation campaign occured in November 1994 when the count rate varied by a factor of 2.7 between two HRI pointings $\sim$ 21 days apart.

While over several years the historical amplitudes of variability have spanned a range of a factor of $\lesssim$ 4.5, PKS 2155−304 varies nearly as much over much shorter periods (factors of 2 in hours - days), thus showing that the dominant time scales in this blazar are truly quite short. Apart from the large variability visible in individual observations the average source flux seems to have remained constant over the years. The large variability of the source on short time scales, the relatively low duty cycle of the observations and the short durations of the individual observations of typically one day prevent further investigation of possible systematic long-term variations.

2.3. Short-term variability: time scale of days

Three ROSAT observations were long enough to study in detail variability on time scales of days, i.e., the observation no.3 in Table 1 which has been discussed already in Brinkmann et al. (1994) and the current HRI observations (nos. 10 and 11 in Table 1).

The most striking impression of the light curves is that on top of a long-term general flux variation there is a short-term variability occuring in form of relatively smooth single shots which appear to be approximately of triangular shape. We therefore

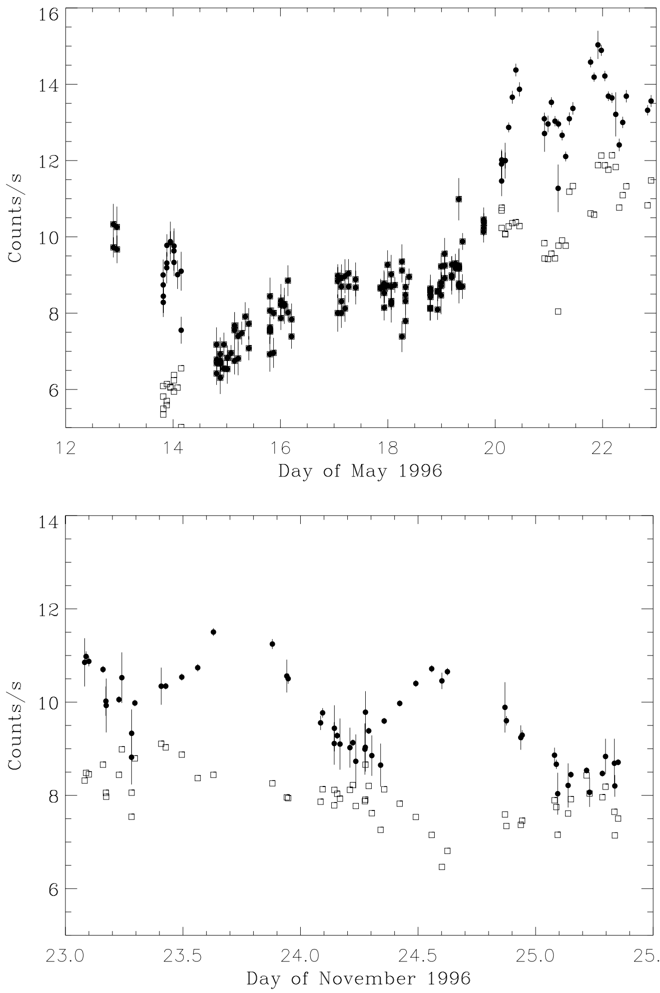

Fig. 4. Residual HRI light curves (as open squares) of PKS 2155−304 in May 1996 (top) and November, 1996 (bottom) obtained by subtracting individual 'shots' from the light curves of Fig. 2, plotted as filled dots.

subtracted such triangular shots from the prominent peaks in the light curves of May 1996 and November 1996, all with the same amplitude of 4 cts s^{-1}, and with a growth time scale of 10 cts s^{-1} per day and a slower decay time scale of $\sim$ 6.1 cts s^{-1} per day. These values were obtained by eye-fitting the residuals and not by a rigorous mathematical minimization of the variance of the data, thus the time scales as well as the exact shape of the shots must be regarded as first approximations. The residual light curves obtained with this procedure are shown in Fig. 4. Although some residuals, especially in the November 1996 observation indicate that not all the shots are identical (in particular, the amplitudes might vary) the resulting light curves are much smoother over most of the observation periods. The excess variance, a quantity to characterize the variability of a light curve (Nandra et al. 1997) is $(5.05 \pm 0.18) \cdot 10^{-2}$ for the May '96 observation, and $(7.43 \pm 1.2) \cdot 10^{-3}$ for the November '96 observation. After subtraction of the short duration triangular shots the variances have decreased to $(3.11 \pm 0.16) \cdot 10^{-2}$ and $(2.86 \pm 0.90) \cdot 10^{-3}$, respectively. This indicates that the variability of PKS 2155−304 consists of mainly two components: a long term smooth intensity variation with time scales of more than a week (see Fig. 4) and, superimposed, a component consisting of individual, relatively well defined smooth shots of flux occurring on a typical time scale of slightly less than a day. Their occurrence does not seem to be periodic. The shots taken above would correspond to an absolute growth time scale of $\delta L/\delta t \sim 4.4 \times 10^{41}$erg s^{-2}, and a slightly smaller decay time scale of $\sim 2.7 \times 10^{41}$ erg s^{-2}. It is worth noting that similar flares were also observed from PKS 2155−304 by SAX on November 20, 1996 (Giommi et al. 1998). In fact after converting the MECS count rate into the HRI count rate with PIMMS the amplitude turned out to correspond to 3–4.5 cts s^{-1} and the shape was similarly triangular.

2.4. Short-term variability: time scale of minutes

The very dense light curve of November 1996 and the virtual independence of the HRI count rate from the wobbling motion of the satellite allows an analysis of the temporal variations on time scales of minutes. Accumulating the data in 100 sec time bins we have typically 1000 counts per bin, i.e., the statistical error is of the order of $\sim$ 3%.

In Fig. 5 we plot the light curve from the November 1996 observation. The light curve clearly shows the well defined long term intensity variations and the large scatter of the data taken over the individual satellite orbits. This scatter is so strong that, in general, the long term trend of the intensity variation cannot be seen in a particular orbit when a linear least square fit for the long term variations is applied to the data. Further, about a third of the individual orbits yield unacceptable fits ($\chi^2_{red} > 1.5$), often with indications for substructures in the data with time scales of 600–700 secs. The time scales involved are similar to those found in the optical ($\sim$ 15 min, Paltani et al. 1997).

A periodogram analysis of the data yielded a strong signal at the satellite's orbital period of $\sim$ 5730 sec. From the window function we found that the remaining peaks are related to the irregular scheduling of the actual observation interval (typically ~ 1500 s long) during the different satellite orbits. Therefore, the rapid variability of the HRI flux must be attributed to variations of the instrumental conditions over the satellite's orbit. On shorter time scales (100 s to 1000 s) there are no statistically significant indications for persistent periodic source flux variations.

2.5. Structure function analysis

A structure function analysis is a method to quantifying time variability without the problems encountered in the traditional Fourier analysis technique in case of unevenly sampled data. The general definition of structure functions and their basic properties are given by Simonetti et al. (1985). The first-order structure function measures the mean deviation for data points separated by a time lag τ, $SF(\tau) = \langle [F(t) - F(t+\tau)]^2 \rangle$. It is commonly characterized in terms of its slope: $b = d\log(SF)/d\log\tau$. One of the most useful features of the struc-

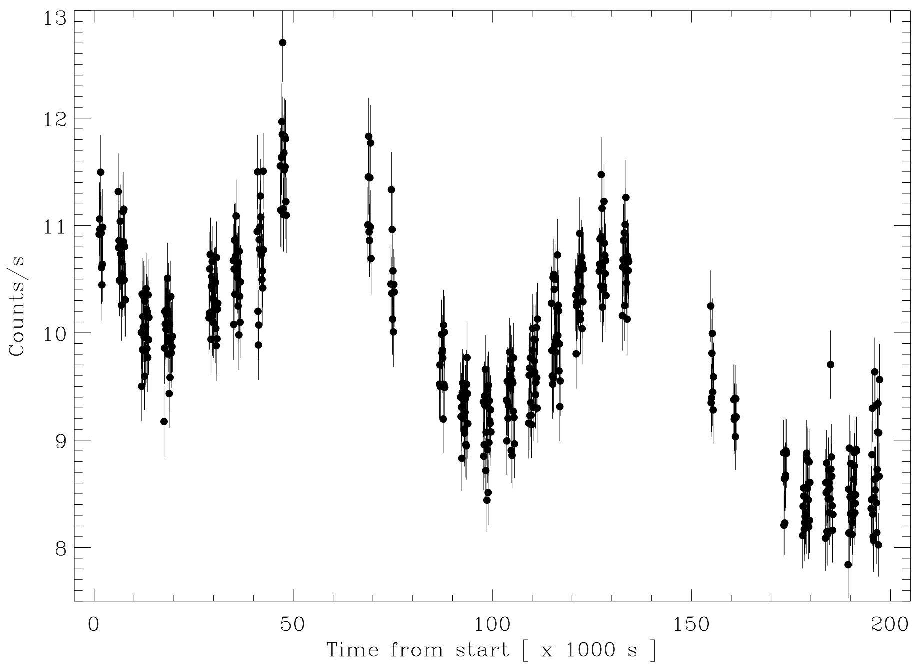

Fig. 5. HRI light curve of PKS 2155−304 in November 1996. Data are binned in 100 sec intervals. Time runs from start of the observation.

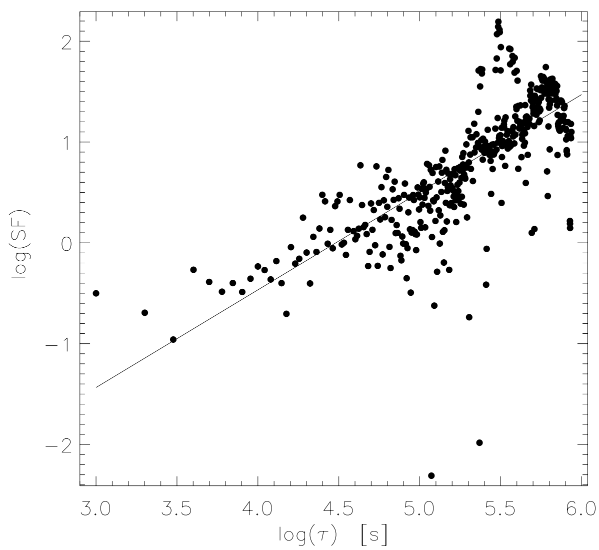

Fig. 6. Structure function of PKS 2155−304. Time lags are in secs.

ture function is its ability to discern the range of time scales that contribute to the variations in the data set. For lags shorter than the smallest correlation time scale and for lags longer than the longest correlation time scale, the structure function displays two plateau states ($b = 0$) at different levels. These regions are linked by a curve whose slope depends on the nature of the intrinsic variation of the source (e.g. flicker noise, shot noise, etc.).

The large scatter of the structure function shown in Fig. 6 must be attributed to the sparse, highly irregularly spaced data, taken over long time scales of years. PKS 2155–304 shows little variation at time scales lower than 10^4s. For longer time scales the slope of the structure function is $b = 0.97 \pm 0.04$. This indicates typical correlation time scales for PKS 2155–304 of the order of days and the nature of the variation of the source can be ascribed to shot noise. This result is fully consistent with the findings of Hughes et al. (1992), who found for a sample of 20 BL Lac objects an average slope of 0.94 ± 0.37.

3. Persistence of the variations

In Fig. 7 we overlaid the light curves measured in November 1991 (open circles) and in November 1996 (open squares). The only adjustments made are a shift of the time axis by -11 days for the November 1996 data and the conversion of the PSPC count rates to equivalent HRI count rates according to the conversion factor as described in Sect. 2.2. The errors of the PSPC data are generally smaller than the symbol sizes.

There is a striking correspondence between these two data sets, taken five years apart. Both times the source was obviously in a very similar intensity state, the shots occured with nearly exactly the same temporal separations, even the shapes of the shots (or the modulation) seem to have changed only slightly.

Although a chance coincidence of the occurrence of the shots cannot be ruled out, given the short data stretches, the persistence of the phenomenon over several years indicates that the intensity variations in PKS 2155−304 do not appear randomly but in a rather well defined pattern. Whether this is related to some underlying periodicity in the system cannot be judged from the short data stretches available.

4. Discussion

Multi-wavelength variability studies have been used frequently to determine the physical conditions of the central engines of BL Lac objects. However, in most cases the irregularities in the variability patterns and the puzzling spectral behavior of these sources have frustrated simple interpretations.

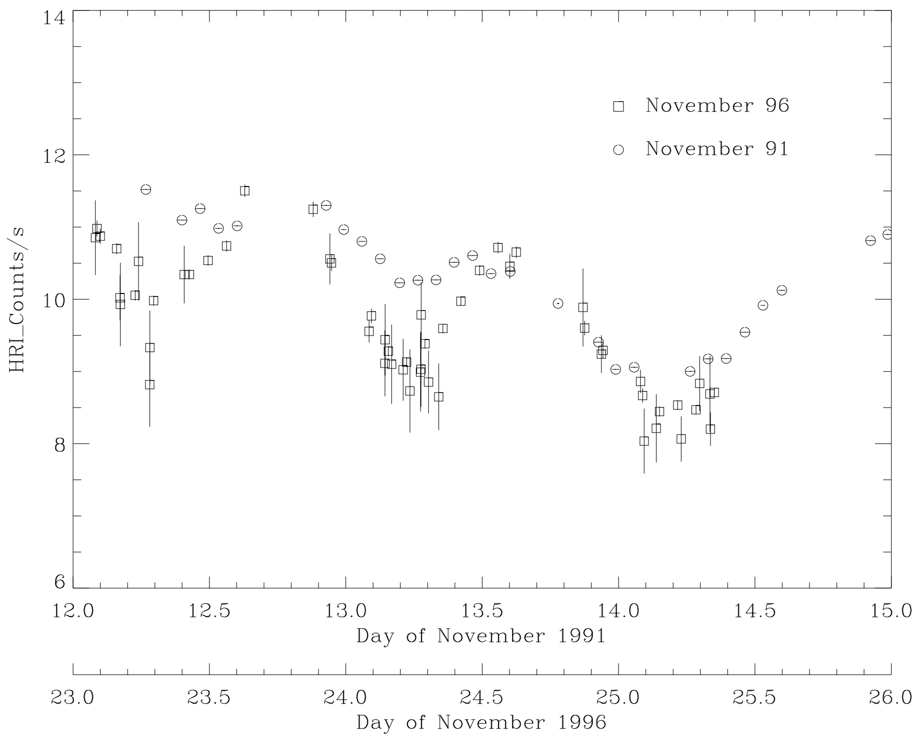

Fig. 7. Overlay of the light-curves of the November 1991 observation (open circles) and the November 1996 observation (open squares). The time axis of the Nov. 96 data has been shifted by -11 days, the Nov 91 PSPC data have been converted to equivalent HRI count rates.

The extended ROSAT observations of PKS 2155−304 in May 1996 and November 1996 suggest that the X-ray variability is due to several "modes": one, varying smoothly with time scales of more than a week, a second, consisting of individual shots with duration of one day and repetition rates of about one per day and, possibly, low-amplitude 'flickering' with scales of 10 minutes. The sharp, isolated flares, such as seen in May 1994 with ASCA and in November 1996 /1997 with BeppoSAX have timescales similar to those of the "shots" and could represent high amplitude "events" within the same phenomenology. Unfortunately the structure function is not sufficiently well determined to reveal critical timescales. However it is important to recall that the latter flares show significant spectral variability while the low amplitude "shots" first revealed with ROSAT were essentially achromatic. While the absence of spectral variations could be due to the limited spectral band of ROSAT and to the limited amplitude of the events we cannot exclude that they represent an intrinsically different "mode" of variability.

The long term variations might be directly related to geometrical changes of the system, either to helical trajectories of moving knots in a relativistic jet (Camenzind & Krockenberger 1992) or to a precession of the jet. For example, the residual light curve of May 1996 is well fit by a straight line with a slope of 0.58 HRI counts/sec/day. If we interpret this smooth increase of flux in terms of a varying Doppler boosting caused by changes of the viewing conditions of a precessing relativistic jet we obtain a bulk velocity of the flow of $\beta = 0.997$–0.998 (i.e. $\Gamma_{jet} \sim 16$) and a viewing angle in the range $\theta = 0.1^{\rm o} - 1.5^{\rm o}$.

The short-term variability, the shots, occuring on time-scales of about a day can be successfully explained either in the accelerating inner jet model by a sudden increase of the density of energetic electrons (Georganopoulos & Marscher 1997) or by particle acceleration at shocks traveling down the relativistic jet (Kirk et al. 1998). As the HRI detector does not provide energy information we cannot use any spectral information for a more detailed comparison of the different radiation models (see Urry et al. 1997).

In the framework of a time dependent model of synchrotron self-Compton emission from a homogeneous region the quasi-symmetric shape of the short flares can be reproduced quite well, provided that light-travel effects are properly taken into account (Chiaberge & Ghisellini 1999, Kataoka et al. 1999). In this framework, the symmetric flares observed at optical and X-ray wavelengths at several occasions, strongly constrain the injection and the cooling time scales: the injection time must be of the same order as the source light-crossing time scale R/c, while the cooling time must be shorter than R/c. With such a model Kataoka et al. (1999) were able to reproduce the temporal evolution of the spectrum as well as the light curve during the flare of PKS 2155−304 in May 1994, after determining all input parameters (required to specify the model) in a self-consistent way from observables obtained during the quiescence state of the source.

Alternatively, one might attribute the low amplitude shots (which seem to repeat, but not periodically) to geometry and the long term increase and large flares to particle acceleration. The rotation period expected for a magnetic helix would be 2πR/c, i.e., about 2 hours for $M = 10^8$ and $R = R_S$. It could obviously be stretched to 12 hours to explain the recurrent (supposedly achromatic) fluctuations. Future observations with good spectral resolution and sufficient temporal coverage might allow to discriminate these scenarios.

The systematic pattern in this variability, most clearly noticed in the striking similarity between light curves taken five years apart, indicates the presence of some kind of temporal memory in the source which is not accounted for in the above models but could be accounted for by variations associated to a varying aspect like a helix associated with the rotational dragging of a magnetic field. If the shots or outbursts, characteristic for the short-term variability, occur in blobs of enhanced activity traveling down the jet then they cannot be generated randomly; a rather well defined physical mechanism must at least initiate the generation of these regions. Finally, geometrical viewing constraints might play a role as well for the observed variability pattern. These temporal structures further seem to firmly rule out a microlensing interpretation put forward to explain the nearly achromatic light curve of November 1991 (Treves et al. 1997).

Finally, the accumulation of all the individual ROSAT observations clearly shows that in general, long and continuous observations are required to unravel the physical conditions of AGN and PKS 2155−304 might be one of the prime objects where this can be achieved with current X-ray missions.

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