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AO 0235+164: rapid flux variations caused by relativistic aberration effects

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Abstract. An unusual event of rapid flux density variations (with a timescale of ∼4 days) observed at 1.49, 4.86 and 8.44 GHz in the highly variable BL Lac object AO 0235+164 is analysed. The distinct properties of the burst are: (1) the flux density reached its maximum at 1.49 GHz earlier than at 4.86 and 8.44 GHz; (2) the duration of the burst decreased with decreasing frequency; (3) the variability amplitude increased with decreasing frequency. This behaviour is different from that of normal radio outbursts in blazars and cannot be explained easily with known models. We investigate the spectral evolution of the burst and suggest that the burst may be caused by relativistic aberration effects when a thin-shock moves with a large Lorentz factor ($\Gamma \gtrsim 25$) along slightly curved magnetic field lines in the jet.

Key words: radio continuum: galaxies – radiation mechanisms: non-thermal – galaxies: BL Lacertae objects: individual: AO 0235+164

1. Introduction

Intraday variability (IDV) is a common phenomenon in flat-spectrum compact extragalactic radio sources (Quirrenbach et al. 1992, Witzel 1992, Krichbaum et al. 1992, Witzel & Quirrenbach 1993, Kraus et al. 1999a), but its nature is not yet fully understood (Wagner & Witzel 1995). The central problem is related to the fact that if IDV is due to intrinsic causes, the short timescales would lead to extremely high brightness temperatures, from $\sim 10^{17}$ K up to $\sim 10^{21}$ K (e.g. in PKS 0405–385, Kedziora-Chudzcer et al. 1997). Such a wide range of high brightness temperatures may imply that under the term "intraday variability" (timescales from ∼1 day to ∼1 hour) very different kinds of events with distinct properties and origins occur.

In order to investigate the nature of IDV, multi-frequency observations of total flux intensity and polarization have been carried out in the radio and optical bands. It has been found that, in addition to short timescales, IDV-events have distinct properties: (1) a broad-band behaviour in the radio regime (∼2–20 cm) and a regular spectral pattern (Qian et al. 1996a); (2) a correlation between the radio and optical intraday variations (for example in 0716+714; Wagner et al. 1996, Qian et al. 1995a); (3) more dramatic variations in linear polarization (polarized flux density and polarization angle) than in total flux density (e.g. Kraus et al. 1999b); (4) a correlation or anti-correlation between total and polarized flux density and a rapid shift between the two kinds of relationship; (5) quasi-periodicity in some IDV sources, for example 0917+624 and 0716+714 (Quirrenbach et al. 1991, Qian et al. 1991a, Wegner & Witzel 1992). Many models, both intrinsic and extrinsic, have been proposed to explain these properties.

Most intrinsic models, except coherent emission models (Benford 1992), invoke relativistic motion of the variable components, with Lorentz factors $\Gamma \gtrsim 10$. These include: bulk motion with $\Gamma \gtrsim 100$ or electromagnetic winds (Blandford & Rees 1992); thin-shock propagation through inhomogeneous structures or turbulence in jets (Qian et al. 1991a, Marscher et al. 1992); (c) a swinging jet model (Gopal-Krishna & Wiita 1992); (d) helical motion of superluminal knots in fully collimated jets (lighthouse effect, Camenzind & Krokerberger 1992); (e) electron-sheets propagating through oblique standing shocks in jets (Spada et al. 1999).

Refractive interstellar scintillation (RISS) may be the most likely extrinsic mechanism for IDV (Rickett 1990, Rickett et al. 1995, Qian 1994a, 1994b, Qian et al. 1995b). In fact, if IDV is intrinsic, then the short timescales may imply that the IDV-component should have a very small angular size and should scintillate, too. So IDV may be understood as a mixture of intrinsic variations and scintillation.

Obviously, it is of great interest to distinguish between IDV as a phenomenon intrinsic to the compact radio sources and IDV that is primarily due to external effects. However, it is very difficult to disentangle the intrinsic variations from RISS. Therefore monitoring observations at several frequencies (total intensity and linear polarization) in radio bands and simultaneous optical-radio observations are important. VLBI polarization observations for directly measuring the source components responsible for the intraday variations are promising (Gabuzda et al. 1998). At least in PKS 2155−152, Kochanev & Gabuzda (1998) observed two VLBI-components: one was variable in polarization on intraday timescales and the other was non-variable. They interpreted the variation of polarization as being intrinsic, consistent with the suggestion by Qian et al. (1991a).

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In order to investigate the relationship between IDV and superluminal motion, a search for IDV events in the most compact sources with highly superluminal motion (β_{app} $\gtrsim$30) would also be helpful. In this respect AO 0235+164[1] is an interesting source, because it has been suggested to have highly superluminal motion with $\Gamma \gtrsim$ 25–40 (Jones et al. 1984, Mutel 1990, Dondi & Ghiesllini 1995, Chu et al. 1996, Marscher & Marchenko 1999).

As a highly variable BL Lac object with a redshift z=0.94, 0235+164 has a history of undergoing rapid high amplitude variations in optical-IR and mm-radio bands (Webb et al. 1988, Kraus et al. 1999c). It was found to be a GeV γ-ray source with a hard spectrum (Hunter et al. 1993, von Montigny et al. 1995).

0235+164 has a very flat radio spectrum in the frequency range 0.3$-$100 GHz during quiet periods between outbursts. Cm- and mm-VLBI observations show that it has a very compact core (Jones et al. 1984, Gabuzda & Cawthorne 1996). The most distinctive feature of the radio-mm outbursts in 0235+164 is that the variations at low frequencies (0.3$-$1 GHz) are correlated with the variations at high frequencies ($>$1 GHz) (Padrielli et al. 1987, O'Dell et al. 1988, Altschuler et al. 1995).

O'Dell et al. (1988) interpreted the flux variations at eight frequencies (0.318$-$14.5 GHz) during the period 1979–1984 in terms of a relativistic jet injection model and found that the jet in 0235+164 should be oriented towards us at a viewing angle $\lesssim 2°$ with a jet-flow Lorentz factor $\Gamma \gtrsim$25. They concluded that even at the lowest frequency (0.318 GHz) RISS-induced variations on timescales of a few months should be less than 7%.

Additionally, since 0235+164 has two intervening foreground galaxy-systems with redshifts z=0.524 and z=0.85, gravitational microlensing may play a role in the optical and radio variations.

In this paper we will discuss a new model for the interpretation of an unusual event of rapid flux density variations observed in this object.

2. An unusual IDV event

2.1. Light curves of the event

Scheuer (1976) and Macleod et al. (1976) attempted to search for rapid variations in 0235+164 during radio outbursts at cm wavelengths, but did not find any variations on timescales of days or hours. Observations made by Quirrenbach et al. (1992) at 5 GHz in April 1990 revealed intraday variations for the first time, with a modulation index[2] m$\approx$ 6.3% ($\bar{S}$ $\approx$1.9 Jy). In September 1996, Romero et al. (1997) observed an IDV event at 5 GHz, when the source was weak ($\bar{S}$ $\approx$ 0.47 Jy) with a modulation index m $\approx$ 7 % and timescale $\sim$1.3 days. For further investigation of the intraday variations, Kraus et al. (1999c) made observations with high time-resolution at three frequencies (1.49, 4.86 and 8.44 GHz) in October 1992 during the period MJD[3]8895$-$8920. The observed light curves are shown in Fig. 1. As Kraus et al. (1999c) pointed out that the rapid variations are superimposed on a mm-radio outburst, which lasted from $\sim$1992.0 till $\sim$1994.0 with an amplitude of $\sim$3 Jy at 4.8 GHz. It can be seen clearly from Fig. 1 that there is an isolated burst with a timescale of $\sim$3.4 days and an amplitude of $\sim$0.3 Jy (at 1.49 GHz) during the period MJD8900$-$8910. Its prominent features are:

- There are distinct background levels to separate the burst at the three frequencies, especially at 1.49 GHz. The regular pattern of the ligthcurves implies that this may be regarded as an individual event.
- A cross-correlation analysis (Kraus et al. 1999c) shows that the maxima of flux density at the high frequencies (4.86 and 8.44 GHz) occur $\sim$0.7 days later than that at the lower frequency (1.49 GHz).
- The timescale at 4.86 and 8.44 GHz ($\sim$4.0 days) is longer than at 1.49 GHz ($\sim$3.3 days).
- The amplitudes of the burst at 1.49, 4.86 and 8.44 GHz are $\sim$ 0.3 Jy, $\sim$ 0.3 Jy and $\sim$ 0.25 Jy respectively. The corresponding modulation indices are $\sim$ 20 %, $\sim$ 12 % and $\sim$ 6 %. Hence the modulation index decreases with increasing frequency.
- If the variations are intrinsic, the apparent brightness temperature at 1.49 GHz would reach $\sim$ 10^{18} K, far in excess of the inverse Compton limit (Kellermann & Pauliny-Toth 1969). Therefore we have to deal with the high brightness temperature problem as typical for IDV sources.

It seems that the above properties are difficult to explain in terms of extrinsic mechanisms. Interstellar scintillation (RISS) predicts that the variability timescale at lower frequency should be longer than that at high frequency and this is contrary to the observations. Since there are several foreground galaxies along the line-of-sight towards 0235+164, a gravitational microlensing interpretation has been attempted. It was shown (Kraus et al. 1999c) that, although the microlensing mechanism could explain the observed variations, a very small component size in the range of $\sim\mu$as at 20 cm is needed. This would result in an intrinsic brightness temperature of the order of 10^{15} K, three orders of magnitude above the inverse Compton limit. A specific model of free-free absorption by a foreground medium was also proposed to explain the shorter duration of the burst at 20 cm. However, it was found that very high Doppler factors were needed for the variable component passing behind the absorbing screen.

2.2. Spectral variations

For the interpretation of the observed properties of this burst, the best way may be to study its spectral variations. For doing so, we need to separate the burst from the background. Fortunately, the baseline levels at the three observing frequencies can be quite well defined, especially at 1.49 GHz. This makes the separation more convincing.

[1] For the rest of the paper we skip the designation AO for brevity.

[2] The modulation index m is defined by m = $\Delta S/\bar{S}$, where $\bar{S}$ is the average flux density and ΔS the root-mean-square of the flux density fluctuations.

[3] Modified Julian Date (MJD) is defined by MJD = JD – 2440000

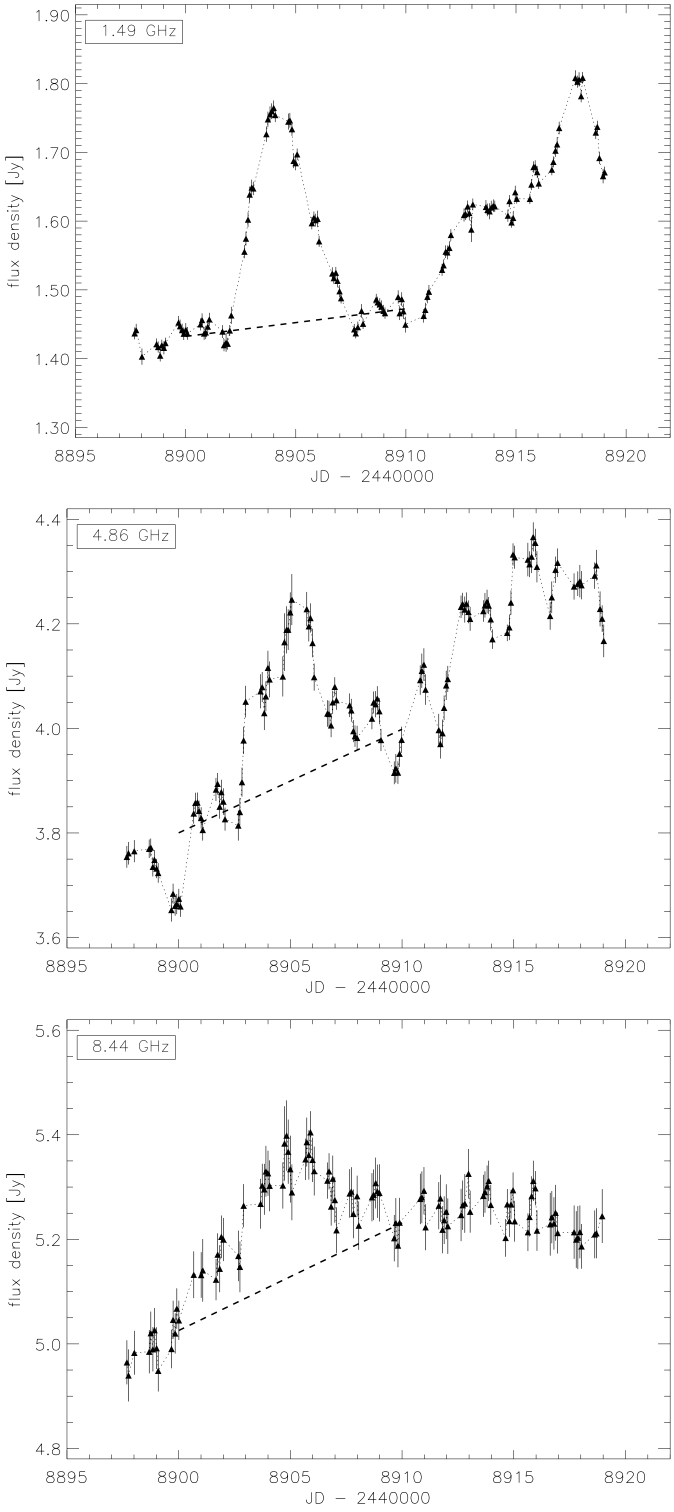

Fig. 1. The light curves observed at 1.49, 4.86 and 8.44 GHz. The dashed lines show the baseline levels chosen in the model simulations. See text.

Using the data points on either side of the burst, a least square fit was made to obtain the linear baseline levels (S(t)) at the three frequencies. The results are:

$$S(t)_{1.49} \ = \ 1.43 + 0.0040\,(t - t_0) \qquad (1)$$

$$S(t)_{4.86} \ = \ 3.80 + 0.0198\,(t - t_0) \qquad (2)$$

$$S(t)_{8.44} \ = \ 5.03 + 0.0206\,(t - t_0) \qquad (3)$$

Here epoch t_0 = MJD8900 and $S(t)_{1.49}$, $S(t)_{4.86}$ and $S(t)_{8.44}$ are in units of Jy. The linear baselines are shown in Fig. 1 by dashed lines. These baselines are basically the same as those derived by Kraus et al. (1999c), where the light curves were fitted by a linear baseline and one gaussian component, using all data points before MJD8910.

After subtracting the respective 'background levels', the individual light curves of the IDV event are obtained at the three frequencies (during the period MJD8900−8910) and shown in Fig. 2 (dotted lines). It is seen more clearly that the flux peaks first at 1.49 GHz and later at the higher frequencies. We found that these light curves can be well fitted by a homogeneous synchrotron source with an optically thin spectral index $\alpha \simeq -0.25$ ($S_\nu \propto \nu^\alpha$). The results of our model simulation are shown in Fig. 2 and Fig. 3. In Fig. 2 the dashed lines show the fit to the light curves observed at the three frequencies. In Fig. 3 the observed spectra for seven epochs (MJD8902, 8903, 8904, 8905, 8906, 8907, 8908) are fitted by a homogeneous synchrotron spectrum. It can be seen from Fig. 2 and Fig. 3 that the model-simulation for the spectral variations of the intraday burst is quite satisfactory, especially for the main part of the burst (during the interval MJD8903−8906).

The derived spectral index $\alpha \simeq -0.25$ is consistent with the values obtained from the cm-mm outbursts in this source (O'Dell et al. 1988, Valtaoja et al. 1988, Altschuler et al. 1995). This may imply that the relativistic electrons responsible for the IDV event and for the cm-mm outbursts are produced by a similar mechanism. This is also similar to the IDV events in other sources like QSO 0917+164 and BLO 0716+714 (Qian et al. 1996b).

2.3. Intrinsic models for the spectral evolution

We have derived the evolutionary track $S_m(\nu_m)$ of the spectral turnover of the burst, which is shown in Fig. 3 (filled-circles with dashed line). It exhibits an unusual, but regular pattern: the turnover frequency ν_m always increased with time, while the turnover flux density S_m first increased and then decreased. In other words, the burst became optically thick at 1.49 GHz, while it remained optically thin at 4.86 and 8.44 GHz. This behaviour is quite different from that of ordinary cm-mm outbursts (Marscher & Gear 1985, Valtaoja et al. 1992, Qian et al. 1996a).

As shown in Fig. 2 and Fig. 3, the simulated spectral evolution explains the observed behaviour of the burst quite well, especially its shorter duration at 20 cm and the time-lag of the peaks at the higher frequencies. To understand the physics of this burst we thus have to interpret the spectral track $S_m(\nu_m)$.

However, the existing models, both plasmon models or shock models (Pacholczyk & Scott 1976, Kellermann & Pauliny-Toth 1981, Marscher & Gear 1985, Marscher 1990, Valtaoja et al. 1992, Qian et al. 1996a) cannot provide an appropriate explanation for the spectral behaviour of the burst. Although we cannot rule out that a combination of the above

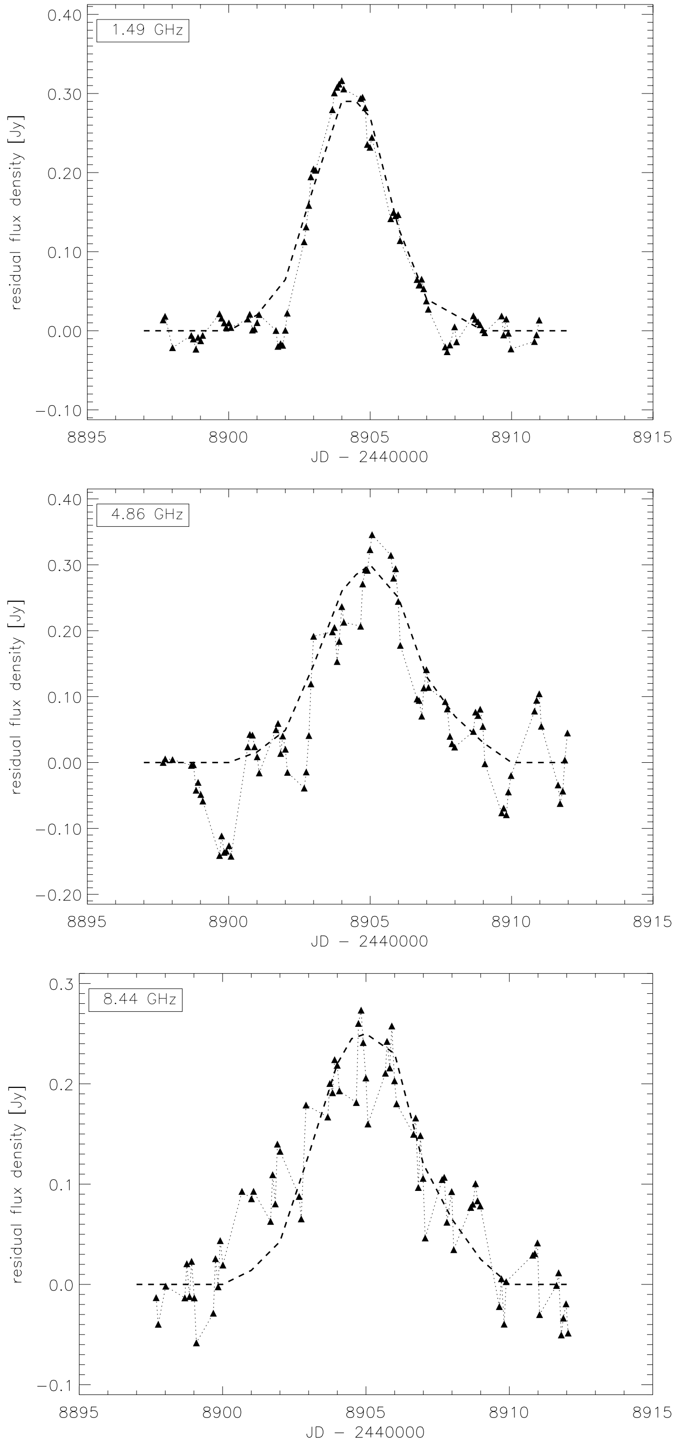

Fig. 2. The observed light curves of the burst (dotted-lines with filled triangles) and its model simulation (dashed-lines)

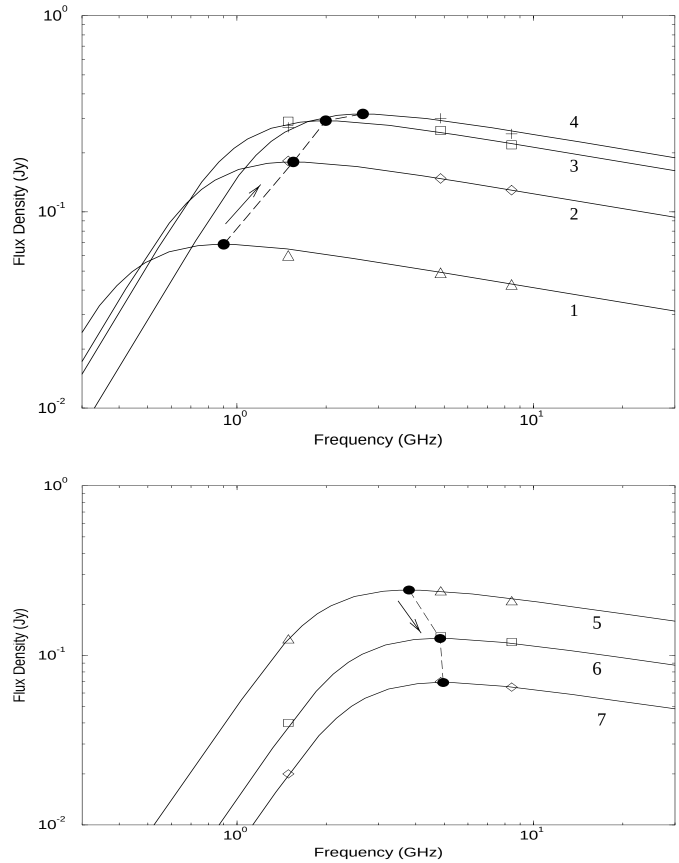

Fig. 3. The synchrotron spectra simulated for the burst (α= -0.25) and its spectral track (dashed-line). Filled circles show the spectral maxima and the arrows indicate the direction of the spectral evolution. The seven spectra are for epochs MJD8902, 8903, 8904, 8905 (upper panel, labeled by 1, 2, 3, 4), 8906, 8907, 8908 (lower panel, labeled by 5, 6, 7) respectively.

models might be capable to interpret the spectral evolution, we consider a new kind of model to explain the observed spectral behaviour.

The main difficulty in understanding the spectral variations of the event is that during the entire intraday burst, the turnover frequency always increased. We suppose that this behaviour is related to the high superluminal motion and its associated effects.

3. Relativistic aberration effects and a new model

3.1. General considerations

In order to find an explanation for the spectral evolution of the intraday burst observed in 0235+164, we point out that, in general, variations in flux density and polarization of a relativistically moving source can be caused by: (1) a change of the intrinsic radiation; (2) a change of the Doppler boosting factor, which is related to the change of Lorentz factor and viewing angle; (3) a change of the aberration angle, if the emission of the source is highly anisotropic in the comoving frame. In the ultra-relativistic approximation (Blandford & Königl 1979), the variations of the flux density and polarization caused by the change of the viewing angle may dominate, since a slight change of the viewing angle would lead to a dramatic change of the Doppler boosting factor and the aberration angle.

VLBI observations have shown that in highly superluminal sources, VLBI knots often move along strongly curved trajectories (Qian et al. 1991b, 1996c, Gabuzda & Cawthorne 1996, Britzen et al. 1998, Krichbaum et al. 1998). These bent trajectories may be caused by helical magnetic fields. VLBI observations have also shown that in both quasars and BL Lac objects, not only transverse magnetic fields, but also strong longitudinal magnetic fields are observed (Marscher 1998, Ojha et al. 1998, Wardle 1998). In the case of longitudinal fields, the synchrotron emission of VLBI-knots in their comoving frame would be anisotropic. Thus a shock moving along curved longitudinal field lines would cause dramatic variations of the radiation owing to the change of Doppler factor and aberration angle, if its viewing angle $\theta \lesssim 1/\Gamma$ (Blandford & Königl 1979). Therefore, in the study of the origin of IDV both Doppler beaming and anisotropy of emission in the comoving frame should be taken into account.

Gopal-Krishna & Wiita (1992) have proposed a model for intraday variability, in which a thin shock moves along a swinging jet, assuming that the synchrotron emission of the shock is stable in the comoving frame. In this model, the flux density variation is solely due to the change of the Doppler beaming factor caused by the change of the viewing angle, because the shock radiation is isotropic in the comoving frame at frequencies where the plasma is optically thin. But the variation of the linear polarization (degree of polarization and polarized flux density) is due to the change of aberration angle, because the polarized emission of the shock is anisotropic in the comoving frame. The model predicts correlations between the variation of total flux density, polarized flux density and apparent superluminal motion.

In addition, relativistic aberration has been invoked to interpret rapid polarization angle swings. Blandford & Königl (1979) explained a PA swing observed in 0235+164 in terms of relativistic aberration, assuming that an electron cloud was accelerated along the magnetic field of the jet. Königl & Choudhouri (1985) discussed shocks propagating along jets and illuminating helical magnetic fields in order to produce PA swings larger than 180° on timescales of a few months through relativistic aberration. They described the relations between flux density, polarization degree and polarized flux density. Large PA-swing events observed in 0917+624 and 1150+81 on intraday timescales might be also related to such an effect (Quirrenbach et al. 1989, Qian et al. 1991a, Gabuzda et al. 1999).

As described in the introduction, 0235+164 exhibits one of the highest superluminal speeds. Therefore, when we interpret the spectral evolution of the intraday burst observed in 0235+164, both the change of Doppler boosting factor and aberration angle should be taken into account. In fact, in the case of $\Gamma \gtrsim 25$ a small change of the viewing angle (e.g. from $\sim 0^\circ$ to $\sim 2.^\circ 3$) would result in a large swing of the aberration angle (from $\sim 0^\circ$ to $\sim 90^\circ$). Hence, in the case of anisotropic emission, the large change of the aberration angle could produce dramatic variations of the observed flux density and linear polarization, in addition to the variations caused by the change of Doppler beaming factor. We have found that such a model can help to explain the peculiar spectral variations in 0235+164.

3.2. A specific model

We propose a specific model to explain the unusual spectral variations of the burst observed in 0235+164. We consider a thin shock propagating along the jet, which has a longitudinal magnetic field and we assume that the shock has a width R_* perpendicular to the jet-axis and a thickness $x_* \ll R_*$. Here and in the following, the symbol $*$ describes the parameters in the comoving frame. In order to investigate the aberration effects of a relativistically moving source in the case of anisotropic emission, one needs to solve the radiative-transfer equation (Lind & Blandford 1985). But for simplicity and as a crude approximation, we first calculate the turnover frequency and turnover flux density in the comoving frame and then transform them into the observer's frame. Thus we have:

$$\nu_m \approx A(s) N_{0*}^{\frac{2}{s+4}} l_*^{\frac{2}{s+4}} (H_* \sin\theta_*)^{\frac{s+2}{s+4}} \frac{\delta}{(1+z)} \qquad (4)$$

$$S_m \approx B(s) N_{0*}^{\frac{5}{s+4}} l_*^{\frac{5}{s+4}} (H_* \sin\theta_*)^{\frac{2s+3}{s+4}} \sigma_* (\frac{\delta}{1+z})^3 \quad ; \qquad (5)$$

where

$$\cos\theta_* = \frac{\cos\theta - \beta}{1 - \beta\cos\theta} \qquad (6)$$

$$\delta = \frac{1}{\Gamma(1-\beta\cos\theta)} \qquad (7)$$

$$l_* = x_*/\cos\theta_* \qquad (8)$$

$$\sigma_* = R_*^2 \cos\theta_* \qquad (9)$$

$$A(s) = \tau_m^{-\frac{2}{s+4}} c_6(s)^{\frac{2}{s+4}} (2c_1) \qquad (10)$$

$$B(s) = J(s) c_6(s)^{\frac{5}{s+4}} c_{14}(s)^{-1} (2c_1)^{\frac{5}{2}} D_l^{-2} (1+z)^4 \qquad (11)$$

Here N_{0*} is the normalization of the energy distribution of relativistic electrons ($N_*(E_*) = N_{0*} {E_*}^{-s}$, in cgs units, assuming the distribution to be isotropic, s=1–2α), H_* is the strength of the magnetic field (G), θ_* the aberration angle, δ the Doppler factor, and z the redshift. l_* denotes the length of the source along the line-of-sight in the comoving frame (l_* = R_* if $\theta_* = 90^\circ$), and σ_* is the projected area of the source. τ_m(s) is the optical depth at the turnover frequency, D_l the luminosity distance, c_1, c_6(s), c_{14}(s) are coefficients of the synchrotron radiation theory and $J(s) = J(\tau_m^{-\frac{2}{s+4}}$,s) is a function of s (Pacholczyk 1970).

From the formulae for the turnover frequency ν_m and turnover flux density S_m we find that:

$$S_m \propto \nu_m^{\frac{5}{2}} (H_* \sin\theta_*)^{-\frac{1}{2}} \left(\frac{\delta}{1+z}\right)^{\frac{1}{2}} \sigma_* \qquad (12)$$

The formulae (4), (5) and (12) give us some clues to find an appropriate model to explain the spectral evolution of the IDV event.

It can be shown from Eq. (4) that in the case of a thin shock propagating along slightly curved longitudinal field lines, when the viewing angle θ changes from about 0 to $\sim 1/\Gamma$, the turnover frequency ν_m always increases. This is because the effect of the increasing l_* and θ_* dominates over the decrease of δ. (For simplicity we assume that N_{0*} and H_* are constants). However,

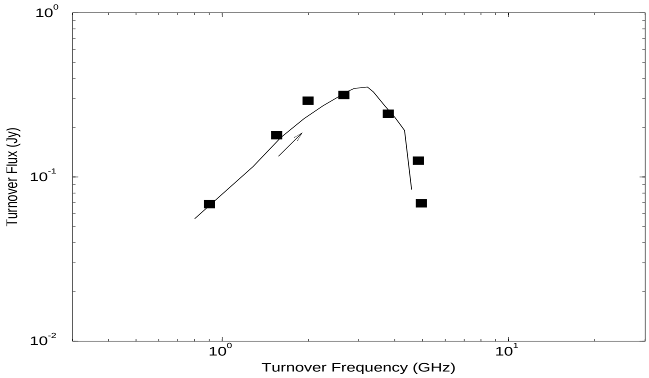

Fig. 4. Simulation of the observed spectral track $S_m(\nu_m)$: A thin shock propagates along longitudinal field lines with the viewing angle changing from $\sim 0.1°$ to $\sim 2.3°$, $\Gamma = 25$. The solid line denotes the model, the squares show the turnovers at the seven observing epochs (see Fig. 3).

from the formula (5) it can be seen that the turnover flux density S_m can vary in two phases: (1) when θ changes from $\sim$0 to $\sim 1/(2\Gamma)$, S_m would increase with increasing l_* and θ_*, because the effect of the two parameters exceeds the decreasing σ_* and δ; (2) when θ changes from $\sim 1/(2\Gamma)$ to $\sim 1/\Gamma$, S_m decreases. This is because the effect of the decreasing σ_* and δ predominates. This can also be seen from formula (12), which shows that S_m can decrease, even when ν_m increases, if σ_*, δ and $(\sin\theta_*)^{-\frac{1}{2}}$ decrease.

A simple specific model simulation for the observed spectral track is shown in Fig. 4. The model parameters are: $R_* = 0.375$ mas, $x_* = 0.1R_*$, $\Gamma = 25$, $N_{0*} = 10^{-5}$ (cgs – units), $H_* = 1.8 \times 10^{-2}$ G. When $\theta = 1.5°$, $\theta_* = 66.4°$, the apparent angular size is calculated to be 0.375 mas×0.150 mas, $S_m \approx 0.272$ Jy and $\nu_m \approx 3.69$ GHz. When the viewing angle θ changes from about $0.1°$ to $2.3°$ (correspondingly the aberration angle θ_* changes from $\sim 5°$ to about $90°$) the modeled spectral track (solid line) fits the observed track quite well, for both the rising and declining phases.

4. Discussion

We have proposed a very simple model to explain the unusual spectral variations of the burst observed in 0235+164. It is shown that this event may be related to the anisotropic radiation of a thin shock moving along the longitudinal magnetic field of the slightly curved jet with a very large Lorentz factor and at a very small angle towards the observer. The model fits the observed spectral track quite well, although the model is obviously oversimplified. In order to check the main idea, i.e. the assumption of a thin shock moving in the longitudinal magnetic field of the jet, we have used the contemporaneous polarization observations at 14.5 GHz made by the University of Michigan group to find the polarization angle during the outburst[4]. We found that during the period from 30 September to 19 October, 1992 (or MJD 8896–8915), the average of the polarization angles observed on eight days is 82° (±7°), implying that the magnetic field in the outbursting region is directed approximately to the north at a position angle –8°. This coincides unexpectedly well with the direction of the jet observed by VLBI (Marscher & Marchenko 1999) and provides a favourable support for the model.

However, the thin shock model has some weakness, mainly in the formation of thin shocks at cm wavelengths, because at these wavelengths radiative losses are considered to be ineffective (Marscher & Gear 1985). Marscher (1996), however, has pointed out that the onset of turbulence behind a shock front might cause the magnetic field geometry to change within a short distance of the shock front. The fact that variations in polarization observed in IDV events appear always much more rapid than those in total flux density is consistent with such an idea. Hydrodynamic simulations (e.g. Gómez et al. 1997) have shown that propagating and standing shocks can be significantly thinner than the width of the jet. An alternative mechanism for the formation of a thin shock might be that in shock fronts current sheets could be formed (Meisenheimer et al. 1997, Jones et al. 1997). They could play a role for electron acceleration and the production of IDV. As well known, current sheets can be extremely thin. In our model, the observed timescale is related to the motion of the shock along a curving trajectory. The adopted thickness of the shock (x_*) is approximately equal to c$\cdot\Delta t_{obs}\cdot\frac{\delta}{(1+z)}$ (c – speed of light, Δt_{obs}– timescale of the event). The width of the shock (R_*) is adopted to be $10x_*$. In this case, if the viewing angle is less than about $\delta^{-1}\arcsin(x_*/R_*)$, the transformation between the apparent brightness temperature and the comoving brightness temperature is: $\frac{T_{com}}{T_{app}} \approx (\frac{\delta}{1+z})^{-3}\cdot(\frac{R_*}{x_*})^{-2}$. Therefore, a Lorentz factor of $\sim$25 is sufficient to bring the comoving brightness temperature down to the Compton limit. However, such a large value of the dimension ratio ($\frac{R_*}{x_*}$) needs to be further investigated. If we reduce this ratio, a larger Lorentz factor would be required.

For further studies of the origin of rapid variations and IDV in 0235+164, multi-frequency observations are important, because distinctive spectral variations may be a significant clue to distinguish between different mechnisms. VLBI (space-VLBI) observations (especially polarization observations) are also important in order to directly measure the components which produce the rapid variations. The available results have shown great promise (Gabuzda et al. 1999, Krichbaum et al. 2000).

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