Modeling the radio flaring behaviour of 3C273

L.C.L.Botti* and F.E. de Melo†

*Centro de Rádio-Astronomia e Astrofísica Mackenzie (CRAAM), São Paulo, Brazil and Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, Brazil
†Centro de Rádio-Astronomia e Astrofísica Mackenzie (CRAAM), São Paulo, Brazil and Escola Politécnica (EPUSP), Universidade de Sáo Paulo (USP), Sáo Paulo, Brazil

Abstract. We present a procedure to obtain the observed characteristics of synchrotron outbursts in relativistic jets. We have used a representative radio long-term light curves of 3C273 at 4.8, 8.0, 14.5, 22.0 and 43.0 GHz to derive the spectral and temporal evolution of a typical outburst. The technique consists in an analysis and decomposition of these light curves into a series of twenty identical flares. We fit the same outbursts simultaneously to 3 light curves covering 3 frequencies at radio domain. The development of a flare is a function of time and frequency. We find that the obtained outburst's evolution is in satisfactory qualitative agreement with the expectations of shock models in relativistic jets. The main goal is to obtain the spectral and temporal characteristics of a typical flare. Individual flares differ only by a few parameters when compared with a typical flare. The relevant parameters of three-stage shock models were found in a second approach. Marscher and Gear (1985) identified three stages of the evolution of the shock according to the dominant cooling process of the electrons: the Compton scattering loss phase, the synchrotron radiation loss phase and the adiabatic expansion loss phase.

Keywords: 3C273, variability, quasar
PACS: 95.75.Wx,9585.Bh,98.54.Aj

INTRODUCTION

Models for the emitting region should yield predictions for the evolution of the spectrum of newly created components. Light curves of quasars show evidence of outbursts propagating from high to low frequencies. Observing powerful extragalactic radio sources is of utmost importance to try to find out the source of these objects' energies which are emitted in all the radio band of the spectrum as well as in other electromagnetic spectrum ranges (optical, infrared, x-rays). Another question is how to explain the presence of radio lobes several hundreds of kpc far from the nuclear source and the presence of collimation in the low scale jets (pc) and high scale lobes (kpc). The knowledge of radio lobe morphology and the interaction between them and the intergalactic medium that surrounds them are greatly important to try to understand the physics involved in this process. We may estimate some parameters such as jet speed and density from the knowledge of the interaction between the jet and the medium around it. Quasars, BL Lacertae objects and active galactic nuclei show prominent variability at many wavelengths, which has been used to provide clues to the size and structure of the region producing the radiation. Several models for the variability of compact radio sources have been proposed since 1963 (see, e.g., Slish 1963, Shklovsky 1965, van der Laan 1966, Pauliny-Toth and Kellermann 1966, Rees 1967, Kellermann and Pauliny-Toth 1967, Pauliny-Toth and Kellermann 1968, Condon and Dressel 1973, Jones et al.

CP784, *Magnetic Fields in the Universe: From Laboratory and Stars to Primordial Structures*
edited by E. M. de Gouveia Dal Pino, G. Lugones, and A. Lazarian

1974, Pacini and Salvati 1974, Pacholczyk and Scott 1976, Peterson and King III 1975, de Bruyn 1976, Marscher 1977, Jones and Tobin 1977, Terrell 1977, Marscher 1978, Pacholczyk 1979, Blandford and Konigl 1979, Spangler 1980, Konigl 1981) An important step in the understanding of the flares was taken by Marsher and Gear in 1985 , when they studied the strong 1983 outburst of the quasar 3C273. They perceived that the major problem of radio variability studies is that the mean time between events is often less than the decay time of each event (Marscher and Gear 1985). Then the separation between the bursting component and quiescent emission is very difficult. Three stages of the evolution of the shock wave propagating down a relativistic jet were identified, according to the dominant cooling process of the electrons: the Compton scattering loss phase; the synchrotron radiation loss phase and the adiabatic expansion loss phase. Another shock model was developed by Valtaoja et al. in 1992. They also identified three stages of the evolution of the shock. Their model, based on observations, describes qualitatively theses three stages. The properties of the outbursts were extracted from the observations. This is very difficult because of the brevity of the outbursts at high frequencies (a few days to months at submillimetre spectral range) and at radio frequencies, because they often overlap due to their longer duration. These studies were based on separate outbursts. Simultaneous multi-frequencies spectra were constructed for as many epochs as possible after the subtraction of a more slowly varying emission (constant with the time). A different approach was developed by Turler et al. (1999). Turler's idea was to decompose several light curves covering a large time span into a series of identical flares. The fit was made simultaneously to the same outbursts to several light curves, at several frequencies (from the radio to submillimetre frequencies). The aim was to obtain both the spectral and temporal properties of a typical flare (Turler et al. 1999). We have used in this work light curves of 3C273 at 4.8 GHz, 8.0 GHz, 14.5 GHz, 22 GHz and 43 GHz (Itapetinga and Michigan radiotelescopes data). We fit three of these light curves (at 4.8 GHz, 8.0 GHz and 14.5 GHz) simultaneously to the same outbursts. The Itapetinga light curves at 22 and 43 GHz were used to determine the 3C273 behaviour before 1980 and for the estimation of the quiescent emission. The light curve of each outburst at a given frequency is described by a simple analytical function in the Turler's model. The technique consists in an analysis and decomposition of these light curves into a series of twenty similar flares, covering a period of 24 years- from 1980 to 2004. The method has therefore many free parameters to a wide range of different situations. Several parameters were also derived from the three-stage shock models (the second procedure).

OBSERVATIONS

This work is based on the light curves of the Itapetinga and Michigan database at 4.8 GHz, 8.0 GHz, 14.5 GHz, 22 GHz and 43 GHz. The observations were made at the frequencies of 22 and 43 GHz with the 13.7-m radome enclosed Itapetinga radiotelescope (Atibaia, Brazil), during the period from July 1980 to december 2004. The feed consisted of a retangular horn, sensitive to the vertical component of the E vector. The half-power beamwidths were 4.2' and 2.1' at 22 and 43 GHz, respectively. The receiver was a K-band mixer with 1 GHz d.s.b., giving a sytem temperature of about

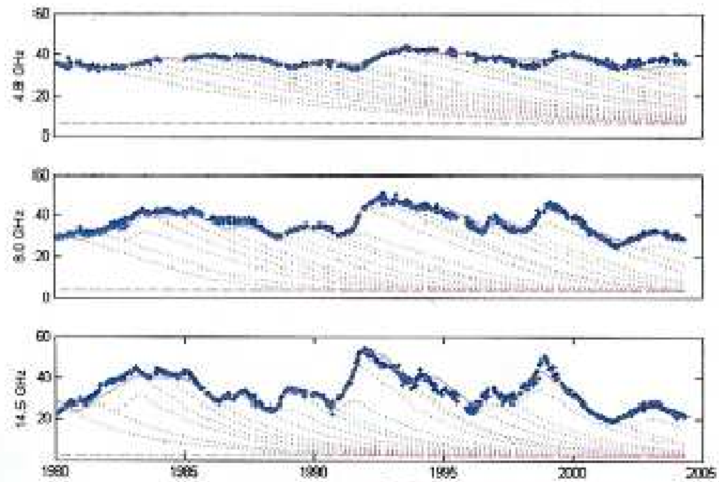

FIGURE 1. Ligth curves of 3C273 (Flux density (Jy) x Time (years)) at 4.8 GHz, 8.0 GHz and 14.5 GHz decomposed into series of 20 outbursts (dotted lines). The dashed line is the hot spot contribution (Two-stage evolution).

700K. The receiver was operated in the total-power mode. The observations consisted of scans through the source at constant elevation, with an amplitude in the sky of 60' at 22 GHz and 30'at 43 GHz. At low frequencies (4.8, 8.0 and 14.5 GHz) we have used the measurements of the University of Michigan Radio Astronomy Observatory (UMRAO).

THE TWO-STAGE EVOLUTION

We have used a simple analytical function to describe the 3C273 light curve of each outburst at a given frequency. This function is described in two different ways. We have two stages: rising phase and decaying phase. This function defines the temporal evolution of a flare (see, e.g. Turler et al 1999). Figure 1 shows three light curves with the outbursts parameterized as a simple analytical function. The principal characteristics of the light curves are reproduced by the model above. The overall fit has a reduced χ^2 value = 0.23.

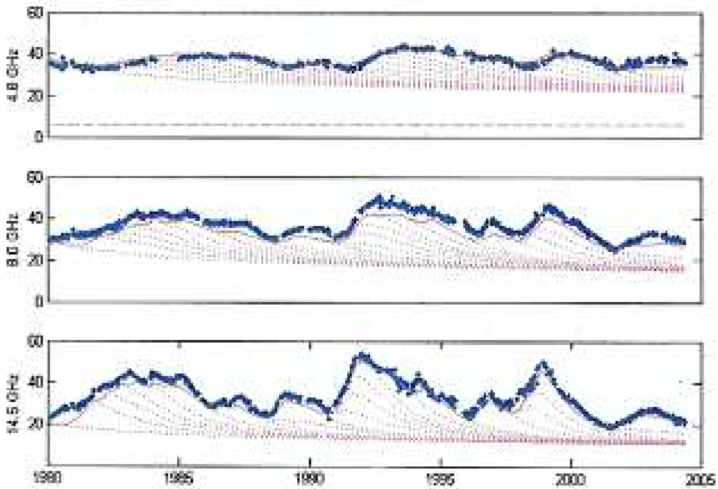

FIGURE 2. Ligth curves of 3C273 (Flux density (Jy) x Time (years)) at 4.8 GHz, 8.0 GHz and 14.5 GHz decomposed into a series of 20 outbursts (dotted lines). The dashed line is the hot spot contribution (Three-stage evolution).

THE THREE-STAGE EVOLUTION

The shock model of Marscher and Gear 1985 describe the evolution of the shock by three distinct stages: a rising phase, a peaking phase and a declining phase. We model the light curve at different frequencies and the resulting conventional flare is qualitatively in accordance with the Marscher and Gear (1985) model. We show in the fig. 2 the same light curves as in fig. 1. The overall fit has the reduced χ^2 value = 0.15.

CONCLUSION

By using the radio observations of the quasar 3C273 we can explain the behaviour of this source and we can obtain the properties of the spectral and temporal evolution of a typical outburst. It is possible to reproduce the several shapes of the radio light curves with only about 20 outbursts, starting simultaneously at all frequencies. The results suggest that the outbursts can be related to the VLBI knots. The quasar 3C273 shows short-term variability, complex temporal behaviour and impulsive events that make this source unique and very difficult to study. We obtained similar values for most parameters when we made a direct comparison with the results obtained by Turler et al. 2000. We have estimated the value of 2.67 for the index s of the electron energy distribution N (E), and Turler et al. 2000 found a value of about 2.05 . The k index has a value of about 2.77 here and 3.00 there. The value 2.7 is expected if the jet flow was adiabatic.The r index found by Turler et al. 2000 was about 0.80 and we obtained a value of about 0.68. This good value of about 0.68 means that we have a non-conical jet. The b index of about 2.24 obtained in this work is bigger than the value 1.58 obtained by Turler et al. 2000.

ACKNOWLEDGMENTS

We thank M. Aller for providing us unpublished measurements of 3C273 at 4.8, 8.0 and 14.5 GHz, M. Turler for helpful discussions and E. M. de Gouveia Dal Pino for your kind help. This research has made use of data from the University of Michigan Radio Astronomy Observatory which has been supported by the University of Michigan and the National Science Foundation. This work was partially supported by the Brazilian agencies FAPESP and CNPq.

REFERENCES

1. A.P. Marscher W.K. Gear, The Astrophysical Journal, 298,114-127 (1985)
2. V.I. Slish, Nature, 199 (4894), 682-682 (1963)
3. J. Shklovsky, Nature, 206(4980): 176-177 (1965)
4. H. Van der Laan, Nature, 211 (5054): 1131-1133 (1966)
5. I.I.K.Pauliny-Toth and K.I. Kellermann, The Astrophysical Journal, 146(3), 634-645 (1966)
6. M.F. Rees, Monthly Notices of the Astronomical Society, 135 (4), 345-360 (1967)
7. K.I. Kellermann,I.I.K. Pauliny-Toth, Nature, 213(5080), 977-980 (1967)
8. I.I.K.Pauliny-Toth and K.I. Kellermann, The Astrophysical Journal, 152(3), L169-L175 (1968)
9. J.J. Condon and L.L. Dressel, The Astrophysical Letters, 15 (4), 203-207 (1973)
10. T.W. Jones, S.L O'Dell, W.A. Stein, The Astrophysical Journal, 188(2), 353-368 (1974)
11. F. Pacini and M. Salvati, The Astrophysical Journal, 188(2), L55-L58 (1974)
12. A.G. Pacholczyk and J.S. Scott, The Astrophysical Journal, 203(2), 313-322 (1976)
13. F.W. Peterson and C. King III, The Astrophysical Journal, 195 (3), 753-759 (1975)
14. A.G. de Bruyn, Astronomy and Astrophysics, 52 (2), 439-447 (1976)
15. A.P. Marscher, The Astrophysical Journal, 216(1), 244-256 (1977)
16. T.W. Jones and D. Tobin, The Astrophysical Journal, 215(2), 474-482 (1977)
17. J. Terrell, The Astrophysical Journal, 213(3), L93-L97 (1977)
18. A.P. Marscher, The Astrophysical Journal, 224(3), 816-825 (1978)
19. A.G. Pacholczyk., Procesos no térmicos em fuentes galácticas y extragalácticas. Barcelona. Reverte, 283 p. (1979)
20. R. D. Blandford, A. Konigl, The Astrophysical Journal, 232, 34-48 (1974)
21. S.R. Spangler, Astrophysical Letters, 20, 123-129 (1980)

22. A. Konigl, 1981. The Astrophysical Journal, 243, 700-709 (1981)
23. E. Valtaoja, H. Terasranta, S.Urpo, N.S. Nesterov, M.Lainela, M.Valtonen., Astronomy and Astrophysics, 254, 71-79 (1992)
24. M. Turler, T.J.-L. Courvoisier , S. Paltani, Astronomy and Astrophysics, 349, 45-54 (1999)
25. M. Turler, T.J.-L. Courvoisier, S. Paltani, Astronomy and Astrophysics, 361, 850-862 (2000)