The origin of a major flare/ejection in a Broad-Line Radio Galaxy.

M. Perucho[1], I. Agudo[2], J.L. Gómez[2], M. Kadler[3], E. Ros[1] and Y.Y. Kovalev[1,4]
[1]Max-Planck-Institut für Radioastronomie, Bonn, Germany
[2]Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain
[3]NASA/Goddard Space Flight Center, Greenbelt, USA
[4]Astro Space Center of Lebedev Physical Institute, Moscow, Russia

Abstract

The evolution of the leading components of a major ejection in the BLRG 3C111 (Kadler et al. 2008) can be explained as the injection of a perturbation of denser material followed by diluted jet material. We have performed one-dimensional numerical Relativistic Hydrodynamics + emission tests in which a square perturbation in density is injected in a steady jet, without modifying the initial Lorentz factor. The setup is based on the results of multi-wavelength observational campaigns that showed a possible relation between dips in the X-ray emission from the accretion disk and the ejection of radio components in 3C120. Here we interpret that the dips in the X-ray emission imply a decrease in the jet injection rate following the ejection of the component. We show that faster perturbations than the jet produce different brightness distribution and evolution and fail to explain the observations. Our results allow to estimate the lifetime of the ejection event.

.

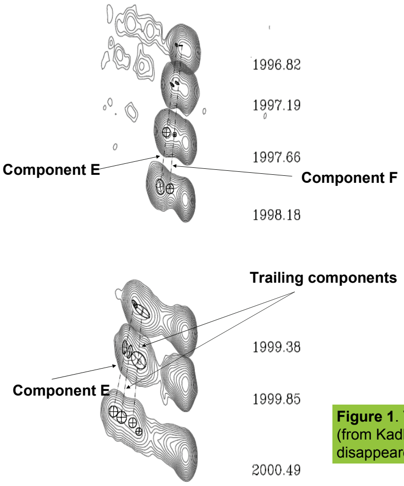

Figure 1. VLBA image of the jet in 3C 111 at different epochs (from Kadler et al. 2008). After epoch 1998.18 component F has disappeared and component E generates trailing shocks.

Background

Flaring events in radio frequencies are known to take place in Active Galactic Nuclei (AGN), usually followed by the observation of moving features in the parsec scale jets (Savolainen et al. 2002). It has been shown that the ejection of those components is related to dips in the X-ray emission from the active nucleus in the case of 3C120 (Marscher et al. 2002). A similar relation has been proposed for the jet in 3C111 in Marscher (2006). The dips in X-rays precede the observations of new radio-components. This allows to interpret them as shocks produced by the ejection of a blob of gas due to a larger fraction of the material in the inner accretion disc being accreted and (a part of it) injected into the jet. The loss of the inner regions of the disc in this process causes a decrease in the accretion rate, and thus, a decrease in the X-ray emission. The new component is observed in radio after some time, as it evolves downstream. The conditions for the ejection of blobs to occur are still unknown to us and their understanding requires a better knowledge of the exact processes and accretion-disk instabilities governing the generation of jets and jet perturbations in the most central regions of active galaxies. 3C111 is a BLRG located at z=0.049: 1 mas = 1 pc using standard Cosmological parameters.

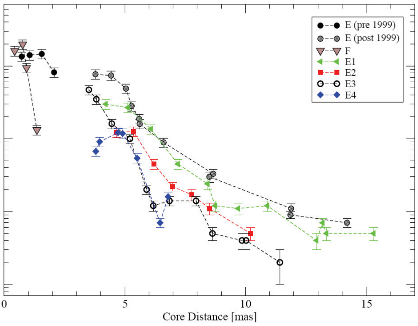

Figure 2 (from Kadler et al. 2008). Flux density evolution of components E and F, on the left hand side of the plot. A very strong flaring event in early 1996 gave rise to the ejection of two jet features observed at 15 GHz with the Very Long Baseline Array. Both components are interpreted to be ejected within < 3 months (epoch 1996.10). They show different speeds and evolution patterns: whereas component F is initially brighter (1996.82 and 1997.19) and fades out very rapidly (1997.66 and 1998.18), component E shows a slower decrease in density flux, and, after 1999, F has disappeared and E evolves accelerating and generating trailing components in its wake (Agudo et al. 2001). This evolution in brightness cannot be explained as due to a difference in the Doppler factor of the two components. We postulate that components E and F are the front and rear (fading) region of a single perturbation.

Simulations

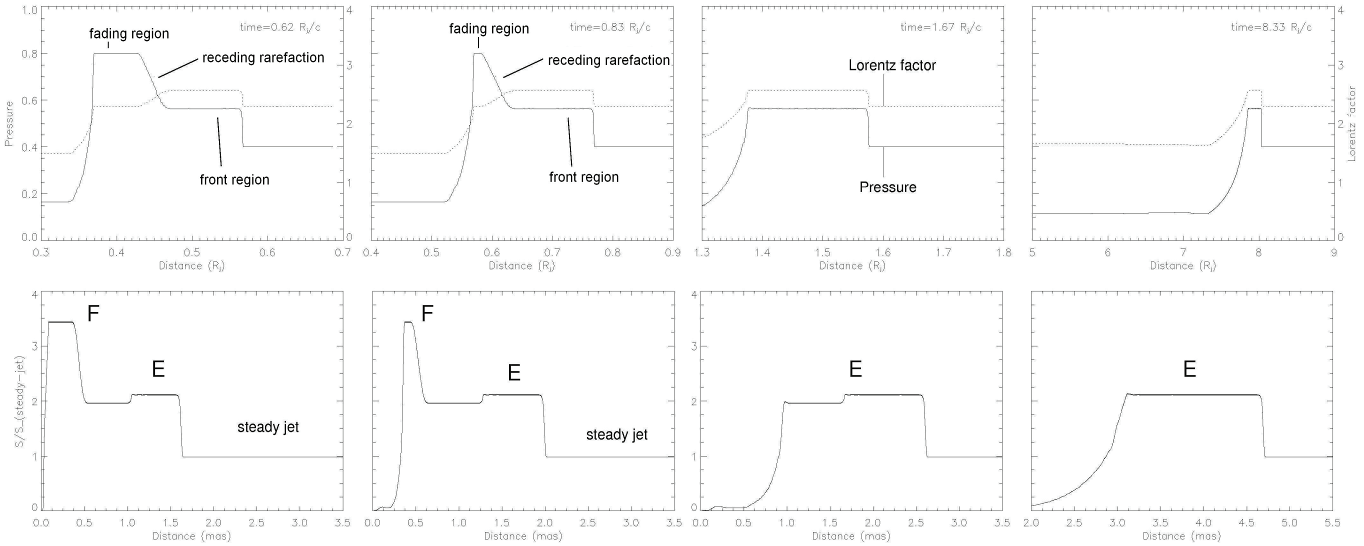

Figure 3. Four snapshots of the evolution (left to right) of hydrodynamical variables (top) and radio synchrotron emission at 20º to the line of sight (bottom) of a square perturbation injected in a steady jet, followed by a strong rarefaction. In the top panels, the dotted lines show the flow Lorentz factor and the solid lines show the pressure. The simulations were performed in 1D, so the plots represent axial cuts. A RHD numerical code was used (Martí et al. 1997, Perucho et al. 2005). The velocity of the initial flow is v_j=0.9 c; the perturbation is injected with a density twice that of the jet and velocity v_p=0.9c; the rarefied medium is injected after the perturbation with the same velocity as the initial flow, and pressure ten times smaller than that of the initial flow. Note the change of scale in the abcissae.

We have assumed that the ejection of the perturbation is followed by a decrease of the injection rate in the jet, as the inner part of the disk is depleted. We model this as a dilute, underpressured medium. The original jet injection rates should be recovered after some time. However, in this work we only focus on the evolution of the strong ejection and its surroundings.
The material in the fading region crosses the receding rarefaction separating it from the front region. Due to this fact, the front structure, which shows changed properties due to interaction with the steady jet, evolves increasing its size. The bottom panels in Fig.3 show the brightness evolution of the simulation (Gómez et al. 1997), at 20º to the line of sight and observer times equivalent to those in the top panels. These kind of simulations take into account all the relativistic effects. In this case, the simulation confirms the fact that component F disappears.
A simulation in which the perturbation is not only overpressured but also has higher Lorentz factor is not able to reproduce the observed evolution (see Perucho et al., submitted). This result is in agreement with that in Lobanov & Zensus (1999), who explain the spectral evolution of the central regions in the quasar as the consequence of the quasi-periodic ejection of denser, not faster, components.

The lifetime of the ejection

We can give an estimate of the lifetime of the ejection event in the black-hole/inner-accretion-disk system.
We consider that:
a) The perturbation started to be ejected in the observed jet in 1996.10,
b) the receding rarefaction eroding component F moves with the observed velocity v_F=0.91 c, and
c) the last epoch at which component F is observed (1998.18) is taken as the time in which the receding rarefaction has completely eroded component F -- the latter is justified since the flux of component F is one order of magnitude smaller than that of component E in this epoch.

We calculate the time that some material needs to catch up the rarefaction, and provide an estimate of the time lapse from the onset of ejection until the last gas of the perturbation is ejected. We use the velocity of component E as an upper limit for the velocity of the fluid. The ejection of gas had to end (1.98±0.02) years before epoch 1998.18, this is, (0.10±0.02) years after 1996.10. That is **Δt ≤ (36±7) days** between the ejection of the first material and that of the last portion of gas in the perturbation. This lapse of time should be smaller if the gas catching up the rarefaction is slower than the velocity of the head, as it should be expected.

Summary and Conclusions

- The evolution of the leading components of a major ejection in the BLRG 3C111 can be explained as the injection of a perturbation of denser material followed by dilute medium.
- Faster perturbations than the jet produce different brightness distribution and evolution and thus fail to explain the observations.
- Following the results in our simulations, we compute a duration of **Δt ≤ (36±7)days** for the enhanced matter injection.
- It is important to check the duration of different ejection events and the periodicity of these ejections in several sources and to put them in relation with calculated black-hole masses and physical properties in the nucleus.

Bibliography

Agudo, I., Gómez, J.L., Martí, J.M., et al. 2001, ApJ, 549, L183
Gómez, J.L., Martí, J.M., Marscher, A.P., Ibañez, J.M., Alberdi, A. 1997, ApJ, 482, L133
Kadler, M., Ros, E., Perucho, M. et al. 2008, ApJ, 680, 867
Lobanov, A.P., Zensus, J.A. 1999, ApJ, 521, 509
Marscher, A.P., Jorstad, S.G., Gómez, J.L. et al. 2002, Nature, 417, 625
Marscher, A.P. 2006, Astron. Nachrichten, 327, 217
Martí, J.M., Müller, E., Font, J.A., Ibáñez,J.M., Marquina, A. 1997, ApJ, 479, 151
Perucho, M., Martí, J.M., Hanasz, M. 2005, A&A, 443, 863
Savolainen, T., Wilk, K., Valtaoja, E., Jorstad, S.G., Marscher, A.P. 2002, A&A, 394, 851