Blazars Overview

(...not a review!)

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1978: BLAZARS (Ed Spiegel)

BISMARCK’S “AFTER-DINNER” SPEECH
“Gentlemen, there is really no more Turkey.”
RELATIVISTIC JETS AS COMPACT RADIO SOURCES

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ABSTRACT

Variable extragalactic radio sources, associated with the nuclei of galaxies and quasars, are interpreted in terms of a supersonic relativistic jet. It is proposed that radio emission originates both from the quasi-steady jet itself and from behind strong shock waves which either propagate in the jet, or which are formed behind dense condensations (clouds) that are accelerated to relativistic speeds by the flow. In this way the source could display apparent superluminal expansion in which the moving component (associated with a shock) and the stationary component (associated with the optically-thick core of the jet) would have comparable, Doppler-boosted fluxes. Specific models for the dynamical and radiative properties of the jet and of individual shocks are presented. Kinematical consequences of the relativistic motion are described for flux and polarization measurements, as well as for VLBI observations of superluminal sources. It is argued that the majority of bright compact sources are observed along lines of sight making small ($\lesssim 10^\circ$) angles to the jet velocity. This hypothesis has important consequences for the interpretation of low-frequency variable sources, optically-violent variable quasars, Lacertids, and extended double sources. These are briefly outlined, and some specific observational tests are proposed.

Subject headings: BL Lacertae objects — galaxies: nuclei — quasars — radio sources: galaxies — radio sources: variable
1982: ESKO MEETS DEBORAH!
Nature 314, 146 - 148 (14 March 1985); doi:10.1038/314146a0

Periodicity in the BL Lac object OJ287
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A 15.7-min periodicity in OJ287
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1984: QUESTIONS!

Fig. 1.—Total intensity map of 3C 111 at 1.4 GHz, with 1′34 × 1′20 resolution. The bright central component is coincident with the nucleus of the optical galaxy. The contour levels are −3.7, −1.2, 1.2, 2.5, 3.7, 4.9, 6.1, 8.8, 22, 37, 86, 220, and 470 mJy per beam.
MODELS FOR HIGH-FREQUENCY RADIO OUTBURSTS IN EXTRAGALACTIC SOURCES, WITH APPLICATION TO THE EARLY 1983 MILLIMETER-TO-INFRARED FLARE OF 3C 273

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ABSTRACT

We present models for the variability of compact radio sources with specific application to the early 1983 millimeter-to-infrared flare of the quasar 3C 273. We show that the early evolution of the outburst spectrum is most readily explained if the flaring component is expanding. In our models the effects of individual events are first detected in the millimeter-to-infrared region of the spectrum, as observed in 3C 273. The models include the effects of synchrotron, Compton, and expansion losses as well as variable injection of relativistic electrons and magnetic field. We find that a model based on a uniform expanding source requires rather artificial variations of particle injection with source radius if it is to explain the 3C 273 flare data presented by Robson et al. The observed behavior is obtained in a more natural way by a second model in which the outburst is due to a shock wave passing through an adiabatic, conical, relativistic jet. We extend the application of this model by showing that it can reproduce many of the characteristics of general radio source variability. The model can also naturally explain the production and evolution of superluminal knots on VLBI maps and their tendency to collectively form relatively flat radio spectra, as well as the variable X-ray emission observed from 3C 273 and other similar sources. The minimum time scale of variability can be as short as \( \sim 1 \) day, despite the rather large distance (> 1 pc) of the shock from the central energy source of the quasar.
Ten years of 3C 279 cm-to-optical variations modelled as ”M & G” shocks in a jet (Lindfors et al., 2006)
1989: ORIENTATION

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Is Every Quasar Beamed?
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Abstract
A companion paper (Barthel et al.) reports the discovery of superluminal motion in the core of 4C 34.47, the largest known quasi-stellar radio source.

Subject headings: quasars — radio sources — superluminal motion

Blazars: < 10°...15°
Data from Lähteenmäki & Valtaoja 1999

\[ \Gamma, \theta \text{ from flux variations and VLBI} \]
1991: EGRET AND GAMMA-RAYS

synchrotron

inverse Compton

$\log \nu_{\ell}$ (erg s$^{-1}$ cm$^{-2}$)

$\log \nu$ (Hz)
Six times 3C 279, June 1991
State-of-art in IC modelling
(Hartmann et al. 2001)

BUT...
**EGRET vs continuum sample: radio flare starts \(~2\) months before the gamma flare**
[Valtaoja & Teräsranta 1995; Lähteenmäki & Valtaoja 2003]

\[ P = 99.9 \% \]

**3C 279: the more distant the shock, the weaker the gamma flare** [Lindfors et al. 2006]

\[ P = 99.98\% \]

**EGRET vs VLBI sample: new component emerges \(~2\) months before the gamma flare**
[Jorstad et al. 2001]

\[ P = 99.999\% \]
2 months equals parsecs, so External Compton fails...

...but the only alternative, synchrotron-self-Compton also fails (Lindfors et al. 2005, 2006)

Heh.
From basic parameters to observed phenomena?

jet speed
collimation
turbulence
luminosity
maximum e energy
magnetic field strength
p/e⁺/e⁻ density
...

BH mass
BH spin
accretion rate
parent galaxy
DATA:
Exponential, sharp flares (Valtaoja et al. 1999)

Theory and simulations: quite different flare shapes (Gomez et al. 1997)
VLBA with all frequencies and polarization... (Savolainen et al., 2006, 2007)

3C 273
Feb 28, 2003
...gives us basic information of jets!

magnetic field vs. distance

electron energy density vs. distance

+ jet/mf structures, instabilities, nonrelativistic plasma, speeds, IC fluxes,
...
Spectral energy distributions (Nieppola et al. 2006)
Blazar sequence?
(Ghisellini et al. 1998)

Most powerful sources have lowest synchrotron peak frequencies

One-parameter (total power) family:
...but no predicted luminosity – peak frequency dependence? 
(Nieppola et al. 2006)

...or even the opposite when corrected for Doppler boosting? 
(Saloranta, Nieppola, unpublished)
BH MASS as the fundamental parameter?
(work in progress, Tuorla & Metsähovi:

2 main observables:
- $L(\text{peak})$
- $\nu(\text{peak})$

DOPPLER

2 main jet parameters:
- $\Gamma$ (jet speed)
- $\theta$ (viewing angle)

CORRECTIONS!
Big BH mass $\rightarrow$ fast jet
Check: viewing angle does not depend on mass
Big BH mass $\rightarrow$ high absolute luminosity
Peak frequency depends (also?) on other parameters than just black hole mass

(Fan and Cao 2004)
Fast jets have low peak frequencies
Jet speed does not depend on jet luminosity

Lorentz factor
(Lähteenmäki and Vahtoja 1999)

Absolute luminosity
(Doppler-corrected)
(Saloranta, unpublished)
BH MASS correlates with:

- jet speed
- jet luminosity
- peak freq (inversely)

cross-correlations (or not):

Need more parameters!
LUMINOSITY and PEAK FREQUENCY depend on accretion rate (Wang et al. 2002)

PEAK FREQUENCY depends on viewing angle (Saloranta, Nieppola, unpubl.)