Radio to gamma-ray connection in blazars

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Introduction

Already during the Compton mission, our team studied the connection between gamma-ray emission and radio emission in blazars. Our work (e.g., Valtaoja et al. 1995; Lähteenmäki et al. 2000, 2001, 2003; Tornikoski et al. 1999, 2000, 2002) has shown that there seems to be a connection between the high radio frequency and gamma-ray activity.

In Lähteenmäki & Valtaoja (2003) we showed that both the EGRET detection probability and the strength of the gamma-ray emission depend on the concurrent high-frequency radio state of each source. The sources detected during individual EGRET pointings had ongoing radio flares, and especially the strongest gamma-ray detections occured during the rise or the peak of the radio flare (Fig. 1).

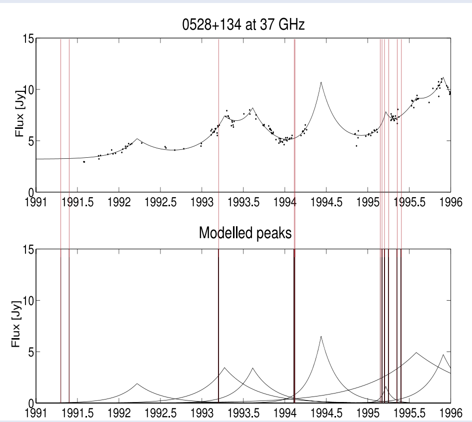

Fig.1. Metsähovi 37 GHz radio monitoring data (upper panel) and exponential model fits of the radio flare components (lower panel) for sources with strong gamma-ray flares detected by EGRET (vertical red lines).

Strong gamma-ray emission is thus detected preferably or only during the rising phases of strong high-frequency radio flares. They do not precede radio variations. Gamma-rays therefore originate in the shocks, not very close to the BH/accretion disk as commonly assumed. A strong gamma-ray flare is typically detected one or two months after the beginning of a radio flare. The corresponding average linear distance of the gamma-ray emission region from the AGN core is estimated to be a few parsecs, significantly further downstream the jet than the accretion disk or the BLR.

Comparison with VLBI data (Jorstad et al. 2001; Valtaoja et al. 2002; Savolainen et al. 2002) agrees with these conclusions: the radio flux rises when a new shock has been created in the jet, and strong gamma-ray flares are associated with the formation of the new shock. Jorstad et al. (2001) also found that the average delay from the zero epoch / ejection of a new VLBI component to the gamma-ray flare was, on the average, two months.

For the strong gamma-ray flares, originating parsecs downstream the jet, the synchrotron self-Compton mechanism seems to be the only viable alternative. The External Compton mechanism may be important in some sources, possibly for generating small amounts of "baseline gamma-ray flux". In any case, realistic two-component (i.e., shock and jet) models with realistic parameters will be further tested in order to understand the gamma-ray production in shocked jets, and the physics of relativistic flows in general.

Activities during the GLAST Mission

During the GLAST mission we will investigate the relationship between radio and gamma-ray emission in blazars in more detail. With a sensitivity exceeding EGRET by two orders of magnitude, GLAST is likely to revolutionize our understanding of high energy processes in AGNs.

Currently our team is developing methods for identifying the true synchrotron SED components from real observations instead of pure theoretical models (see the poster by Lindfors et al. for more details). We will use actual, observed synchrotron SEDs compiled from multifrequency monitoring data, for tracing the evolution of the synchrotron components. We can also use VLBI observations to improve SED modelling by providing the spectra of individual jet components (Fig. 2).

By combining multifrequency radio monitoring data with VLBI, we can study the details of the shock formation. Dense total flux density and VLBI monitoring can reveal the temporal relationship between the new shocks and the gamma ray flares.

In order to fully understand the various emission mechanisms at work, we also need information about the physical parameters of the emitting region. By providing unsurpassed spatial resolution, high frequency VLBI can reveal directly the sites of electron acceleration and enhanced synchrotron emission. From the data we can extract such parameters as bulk Lorentz factor, Doppler factor, and the angle between the jet and our line of sight (Jorstad et al. 2005; Savolainen et al. 2006). Our group is planning to perform a detailed case study of 3C273 with the VLBA during the first years of GLAST operations.

It is possible, from simultaneous multifrequency VLBI observations, to deduce the magnetic field density in the core and along the jet, as well as the energy density of the emitting particles and the anticipated amount of synchrotron self-Compton emission (see e.g. Marscher 1987). Extracting spectral information from multifrequency VLBI data is a notoriously difficult task, but our recent work indicates that by using the VLBA and a model-fit based analysis method, high quality spectra of different emission features in the parsec scale jets can be extracted (Savolainen, 2006; Savolainen et al. 2007). In order to study the relation between the gamma-ray activity and various intrinsic physical parameters of the jet, multifrequency VLBI observations of a complete sample of AGNs is desirable. Feasibility of such campaign during the GLAST era is being studied (a pilot VLBA programme by Y. Y. Kovalev et al. (BK134)).

Our long term monitoring studies have provided us with detailed information about the variability timescales of a large number of AGNs (Hovatta et al 2007). We will use our radio flare database and the associated statistical studies to predict (or at least, to make educated guesses) when a source is going to be in an active state. As stated above, the high-frequency radio and the gamma-ray activity should be closely related, and thus we can define triggering criteria for detecting certain blazars in an active gamma state with GLAST.

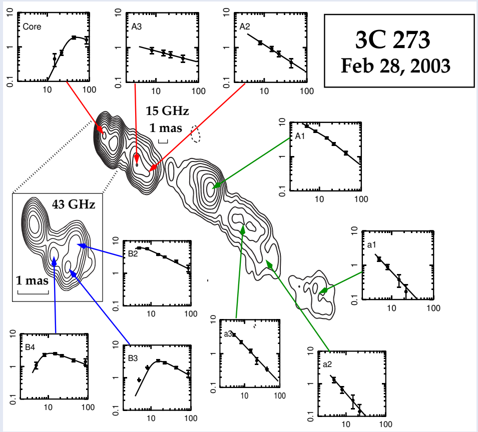

Fig. 2. Radio-mm spectra of the different jet features in the pc-scale outflow of 3C273, extracted from multifrequency VLBI observations (5-86 GHz). Note how we are able to directly observe the synchrotron self-absorption peak within 2 mas from the mm-core. Also, the spectra of components B2 and B3 indicate that there is a significant gradient in the magnetic field density across the jet. For more information, see Savolainen (2006) and Savolainen et al. (2007).

Conclusions

• The strongest gamma-ray emission in AGNs originates downstream the relativistic jet, within the same shocks that produce the synchrotron radio flares.

• The present models for gamma-ray production are inadequate, since they typically model the gamma-ray inverse Compton flux as coming from the jet, with significant disk or BLR external Compton components.

• During the GLAST mission we will concentrate on improving our model by using the true, observed total flux density monitoring and multifrequency VLBI data, and the physical parameters that can be extracted from them.

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