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Millimeter VLBI Observations of the Gamma-Ray Blazar NRAO 530

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Abstract. We present here 3 epochs of 3 and 7 millimeter wavelength VLBI observations and 2 epochs of lower frequency VLBA imaging of the gamma-ray blazar NRAO 530. These observations document the evolution of the parsec scale jet in this source during the brightest flare in 3 decades. New jet components were created during the flare and are probably related to an increase in gamma-ray activity. The components travel at superluminal velocities, further confirming the connection between superluminal sources and gamma-ray blazars. The rapid evolution of the source makes tracking of components difficult. It appears that either components significantly decelerate or that there is rapid cooling and acceleration of elections. We may be identifying structure due to standing shocks. The jet is bent on all scales between 100 μarcsec to 10 arcsec. The results indicate the ability of 3 mm wavelength imaging to probe the nuclei of blazars rapidly and reliably.

The blazar NRAO 530 has been firmly identified as a high energy gamma-ray source through observations with EGRET (Mattox et al. 1997). Recently, NRAO 530 underwent its brightest flare in 3 decades. That flare peaked at 3 millimeter wavelength in April 1995. In Bower et al. (1997) we presented a study of the evolution of the flare at radio and gamma-ray wavelengths as well as 3 millimeter VLBI observations obtained near the peak of the flare. We concluded that the gamma-ray and 3 millimeter fluxes were correlated over 4 years and that new VLBI components traveling superluminally were produced during the flare. Here, we consider the evolution of the parsec-scale structure following the peak of the flare.

An 8 GHz image of NRAO 530 obtained with the VLBA in October 1995 shows a jet with a position angle of 13°. This axis is 60 degrees to the east of the base of the kiloparsec-scale jet observed with the VLA (Zhang 1996, private communication). A second VLBA observation at 8 GHz in October 1996 showed a similar structure. In both images, the new flux due to the flare is unresolved in the core. The structure in the jet is consistent with $\beta_{app} \approx 2 \pm 1$.

We show in Figure 1 VLBI images of the core of NRAO 530 at 86, 43 and 22 GHz between 1994 and 1996. The 86 GHz images were obtained through observations with the Coordinated Millimeter VLBI Array. The 43 and 22 GHz images were obtained with the VLBA. The 22 GHz images do not include structure seen on larger scales, which includes a jet parallel to the 8 GHz jet. The images show that new structure appeared between the first and second epochs at 86 and 43 GHz. The position angle of the jet axis is between 28 and 73°, indicating that the jet bends on scales as small as 100 μarcsec. A new component is not resolved from the core in the first 22 GHz image. We estimate an apparent velocity of $7.5 \pm 2c$ for the newly appearing components in the 86 and 43 GHz images.

Registration of components between the second and third epochs is difficult. In the simplest registration, we associate the brightest components with each other. We find an apparent velocity of $2.1c$, implying a significant deceleration.

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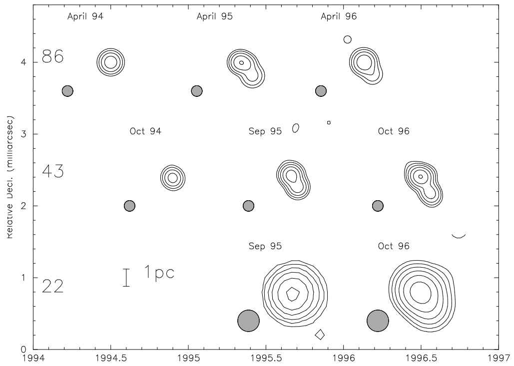

Figure 1. VLBI images of NRAO 530 at 86, 43 and 22 GHz between 1994 and 1996. The images are centered on the ordinate by the date of observation. The convolving beam is shown to the lower left for each image. The contour levels are 0.10, 0.25, 0.60, 1.49, 3.66 and 9.00 Jy/beam. A bar in the image shows the scale of 1 pc = 0.24 mas. The 86 GHz images are from models. The dynamic range of the 43 and 22 GHz images are on the order of 100 and 1000, respectively.

Alternatively, we can assume that the brightest component of the second epoch evolves into the faint component in the north east and that the brightest component of the third epoch is newly emitted from the southwest component. The northeast component is weakly detected in the 86, 43 and 22 GHz observations and has a spectrum peaked below 43 GHz. The apparent velocities for the outer and inner component are $7.2c$ and $5.1c$, consistent with the earlier apparent velocity. This registration requires significant cooling of the electrons in the outer component. This component at 43 GHz declines from 7.4 to 0.2 Jy, implying a magnetic field on the order of 0.5 G if the losses are due to synchrotron cooling. A significant acceleration of electrons must occur in the inner component, producing the new 11.5 Jy component at 43 GHz. The rising and declining fluxes must occur on the same timescales to insure the stable observed 90 GHz flux.

A more consistent explanation may involve standing shocks at the location of the two brightest components. Because the initial rise in the total flux does not indicate the creation of a new component in this model, the apparent velocities calculated for the first epoch do not apply. The faint components seen in the third epochs represent weaker traveling shocks. This model is similar to the phenomena seen in 3C 454.3 at 43 GHz (Marscher, these proceedings, p. 25).

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References

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