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3C279 Results Derived from Two-Frequency VSOP Observations

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Abstract

A series of VSOP observations of 3C 279 have been made at 1.6 and 5 GHz during the AO1 and AO2 periods. The milli-arcsecond scale structure of 3C 279 is dominated by the core and the jet component C4. The spectral index map obtained from the 1.6 GHz VSOP and 5 GHz ground-only maps shows an inverted spectrum at the core indicating synchrotron self-absorption. Due to the evolution of the VSOP beam, AO2 images show much finer details of parsec-scale components.

1 Introduction

The blazar 3C 279 (z=0.536) is a prominent EGRET gamma-ray source, displaying significant long-term variability and an episode of short-term flaring (Wehrle et al. 1998). 3C 279 was selected as a VLBI Space Observatory Programme (VSOP) Key Science Project source, and a series of VSOP observations have been made of 3C 279 to study the parsec-scale structure and its evolution, and to search to connections between the gamma-ray activity and the milli-arcsecond scale structure, such as the emergence of new jet components. This paper reviews the AO1 observations and presents first results from AO2 observations.

2 AO1 Observations

3C 279 was observed during the AO1 phase of the mission on 1998 January 9 at 1.6 GHz and 1998 January 10 at 5 GHz. The ground telescope arrays were made up of nine elements of the Very Long Baseline Array (VLBA) with the addition of the 70 m telescopes at Goldstone and Tidbinbilla at 1.6 GHz, and the Usuda 64 m at 5 GHz.

2.1 Jet Motions and Brightness Temperature

Preliminary images from these datasets are presented in Edwards et al. (1999) and Hirabayashi et al. (2000), with more detailed analysis given in Piner et al. (2000). The 5 GHz VSOP image shows that the parsec-scale radio emission is dominated by a double structure consisting of the compact core and the bright jet component 'C4' located 3 mas from the core at a position angle of $-115°$. In the 1.6 GHz image C4 is brighter than the core indicating synchrotron self-absorption in the core.

A total of six elliptical Gaussian components are required to fit the 5 GHz VSOP data (Piner et al. 2000). The first three of these components are interior to 1 mas, and represent the core and two components of the inner jet. The region interior to 1 mas is a complex region with multiple components and a stationary feature at $\sim$1 mas (Piner et al. these proceedings; Wehrle et al. 2000).

The component C4 has been moving along a position angle of $-115°$ for over 10 years (e.g. Unwin et al. 1989; Lister et al. 1998; Wardle et al. 1998) This position angle differs significantly from that of the kpc-scale emission and previous parsec-scale jet components, which had position angles of approximately $-140°$. The brightness distribution of C4 is asymmetric, with the leading edge being sharper than the trailing material, and the trailing material being located at position angles between $-115°$ and $-140°$ (Piner et al. 2000). The sharp leading edge of C4 is suggestive of a shock front, which is confirmed by polarization observations that show the leading edge of C4 has a magnetic field transverse to the jet (Lister et al. 1998; Wardle et al. 1998).

Our highest brightness temperature lower limit of $\sim 5 \times 10^{12}$ K for component C4 at 1.6 GHz (see Piner et al. 2000) implies a Doppler factor lower limit of 5 for the inverse Compton brightness temperature limit (Kellermann and Pauliny-Toth 1969). This Doppler factor is similar to that inferred from gamma-ray observations (Wehrle et al. 1998).

2.2 Spectral Index Map

The spectral index map made by comparing the matched resolution 1.6 GHz VSOP image and 5 GHz VLBA image (Piner et al. 2000) is shown in Color Figure 5 on page xvi of these proceedings. The color bar at the bottom of the image indicates the value of the spectral index ($S \propto \nu^{\alpha}$). Spectral index contours are also plotted at intervals of 0.5, from -2.5 to 2.5. The beam is the average of the 1.6 GHz VSOP beam and the 5 GHz VLBA beam: 3.1×1.1 mas at a position angle of $16°$.

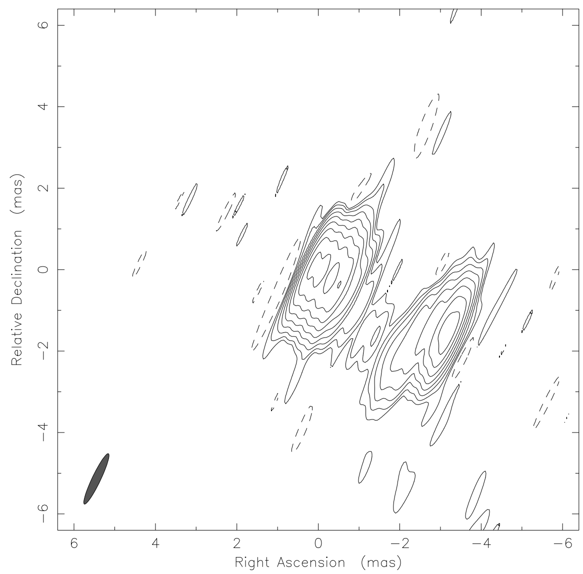

Figure 1: Preliminary image of the first 5 GHz AO2 observation on 15 March 1999. The map peak is 2.6 Jy, with contours of -1, 1, 2, 4 ... 256 $\times$ 7.6 mJy/beam. The beam FWHM is 1.4$\times$0.2 mas at a PA of $-26°$.

The core of 3C 279 has an inverted spectrum with steep spectral index gradients. The spectral index in the core region ranges from ~ 1.0 at the western edge to the theoretical limiting value for synchrotron self-absorption of 2.5 (assuming a constant magnetic field) over a small region at the eastern edge. The highly inverted spectrum at the eastern edge may imply the detection of a homogeneous compact component in this region, although a varying magnetic field in this region would complicate this interpretation.

The jet component C4 has a flat spectrum with α approximately 0.25. This is unusual, as jet components usually have steeper spectra ($\alpha < 0$), and may be indicative of a stronger shock, which in turn may explain why C4 has remained prominent for longer than previous jet components. The spectral index appears to vary smoothly between the front and trailing portions of C4, which suggests the trailing material may be physically associated with the leading edge and not an apparent connection due to our line of sight. Beyond C4 the spectral index steepens, a sign of a general tendency of energy loss of the emitting particles along the jet.

3 AO2 Observations

Due to the precession of HALCA's orbit, the first half of 1999 allowed VSOP observation to be made with a (u, v)-coverage offering maximum resolution along the jet. A preliminary image of the first AO2 epoch in March 1999 is shown in Figure 1. The jet components within 1 mas of the core, revealed by model-fitting in the AO1 data, are clearly seen in the AO2 image. Several more 5 GHz observations and another 1.6 GHz observation were made between March and July 1999, which will enable us to study the evolution of 3C 279 from AO1 to AO2 and shorter time-scale variations within AO2. Studying the evolution and motions of new components, changes in the brightness temperature of components and in the shocked edge of C4 are the main aims of these monitoring observations.

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