ABSTRACT
We present here two epochs of Space VLBI Observations at 18 cm of the BL-Lac type object Mkn 501. Thanks to the high resolution of these new data we have found that the inner jet is centrally brightened at its beginning but becomes extended and limb brightened at \( \sim 8 \) mas from the core. Moreover a comparison between the two epochs shows the presence of a proper motion with apparent velocity = 6.7c. Observational data have been used to constrain the jet velocity and orientation.

INTRODUCTION AND OBSERVATIONS
Markarian 501 (Mkn 501) is a BL-Lac type object at \( z = 0.034 \). It is a well studied source in radio, optical and X-ray bands being one of the brightest Bl-Lac object at all wavelengths. It was the second source (after Mkn 421) to be detected at TeV energies. In the radio band it has a total radio power at 408 MHz of \( 8.9 \times 10^{24} \) W/Hz consistent with the expectation of unified scheme models that BL-Lac type sources are FR I galaxies seen on the line of sight (we use \( H_0 = 50 \) km sec\(^{-1}\) Mpc\(^{-1}\)).

We observed this source in August 4, 1997 during an orbit checkout of the HALCA satellite, with the following observing array: VLBA (observing time 7h); Goldstone (4h); HALCA with the Green Bank tracking station (3h only). The data were correlated in Socorro, calibrated and reduced with the AIPS package (15 Apr. 1997 version). Only the 1st IF gave useful data. On April 8, 1998 the source was observed again for 10h with the following array: VLBA, Goldstone, Robledo, HALCA with the Green Bank and Madrid tracking stations. The data were correlated in Socorro and reduced with the AIPS package (15 Apr 1998 version). We found good data from all the telescopes and for both IFs. Amplitude calibration was done initially for VLBA telescopes only and after applied to the whole array. All data were globally fringe fitted and then self-calibrated.

SOURCE MORPHOLOGY AND JET DYNAMICS
At parsec resolution Mkn 501 shows a one-sided jet structure which changes its orientation from \( \sim 140^\circ \) to \( \sim 30^\circ \). In Fig. 1 we show a full resolution map obtained from uniform weighted data, while in Fig. 2 a map obtained with a larger beam is shown. From an analysis of the two maps we note a clear change in the jet structure at about 8 mas from the core. At the beginning the jet is transversally resolved but it is centrally brightened. After an elongated feature the jet brightness becomes limb brightened: the maximum of the surface brightness is clearly on both sides of the parsec scale jet. We interpret this observational result as an indication of a change in the jet physical
Figure 1: Full resolution Mkn 501 map obtained with space VLBI. The HPBW is $2 \times 1$ mas at PA $= -15^\circ$. The noise level is 0.7 mJy/beam. Levels are: -2 1.5 2 3 4 6 8 10 20 30 50 70 100 150 200 250 300 350 mJy/beam.

Figure 2: Space VLBI map of Mkn 501 at the resolution of $2.9 \times 1.5$ mas (PA = $-10^\circ$). The noise level is 0.3 mJy/beam. Levels are: -2 1.5 2 3 4 6 8 10 20 30 50 70 100 150 200 250 300 350 mJy/beam.
properties at $\sim 8$ mas (7.4 pc) from the core. The limb brightened jet is visible for 20-25 mas ($\sim 20$ pc) after where it shows a large change in its Position Angle (PA) and a dramatic expansion (Fig. 3). This extended jet is visible for more than 100 mas and appears edge brightened. No evidence of a helical structure is visible in our maps.

**JET ORIENTATION AND VELOCITY**

We produced identical maps from the first and second epoch data with a HPBW = $2.9 \times 1.5$ mas in PA $-9.7^\circ$. The two maps are in good agreement, but suggest the existence of proper motion between the two epochs. We are aware that to measure a proper motion with only two epochs data may give unreliable results, however the good quality of present data and the agreement between the whole structure strongly suggests the presence of a proper motion with apparent velocity $\sim 6.7c$. More Space VLBI Observations have been requested to confirm this result. We note that in the second epoch, the core is resolved and with a lower peak flux density if compared with the first epoch, suggesting that a new component is emerging out. Such an apparent velocity implies that the real jet velocity has to be $\geq 0.989c$ and the jet has to be oriented at an angle smaller than $17^\circ$.

We used the available VLBI data to derive constraints on the jet velocity and orientation (see Giovannini et al. 1994, ApJ 435, 116) for a more detailed discussion). Assuming that parsec scale jets are intrinsically two-sided and symmetric, we can constrain the jet velocity and orientation from the observed jet asymmetry. In our maps the Jet/CounterJet ratio is $\geq 200$ and therefore we can give the following constraint on the jet velocity ($\beta = v/c$) and orientation ($\theta$): $\beta \cos \theta \geq 0.79$. Moreover from the known correlation between the core power and the unbeamed total radio power (Giovannini...
et al., 1988, A.A. 199, 73) we can derive the expected intrinsic core radio power from the observed total radio power. Comparing the expected and the observed core radio power we obtain that Mkn 501 has to be oriented at $\theta \lesssim 26^\circ$ with $\beta$ in the range 1 - 0.88.

If we assume that the bulk and pattern jet velocity are comparable in the inner parsec scale jet, we can compare the constraints derived from the J/CJ ratio and the core dominance with those obtained from the measured proper motion. From these data we derive that Mkn 501 is oriented at $\sim 10^\circ$ - $15^\circ$ with respect to the line of sight, with a velocity in the range 0.990 - 0.999 c. We note that a higher velocity or a smaller angle implies a too high doppler factor which would give a too strong parsec radio core with respect to the total flux density.

DISCUSSION AND CONCLUSIONS

Thanks to the high resolution provided by Space VLBI Data we have observed that the parsec scale jet of Mkn 501 shows a change in its physical properties at 8 mas from the core: the inner jet is centrally brightened, but after a vertical shock-like structure it becomes limb brightened. The change in the morphological shape reflects a change in the jet physical properties probably due to its interaction with the surrounding medium. Moreover comparing the two epoch maps available we have measured a possible proper motion with an apparent velocity $\sim 6.7$ c. From VLBI data we have derived that Mkn 501 is oriented at an angle of $10^\circ$ - $15^\circ$ and has an intrinsic velocity in the range 0.990 - 0.999 c. We note that current models of gamma ray emission and intra-day variability suggest that in the inner region ($0.003$ - $0.03$ pc) the jet should be oriented at $\theta \lesssim 5.7^\circ$ and should have a Lorentz factor $\gamma \gtrsim 10$ (see e.g. Salvati et al., 1998, ApJ in press). These figures seem to be in contrast with the derived constraints from VLBI radio data, however we note that the regions where the radio emission (the core region) and the gamma and X-Ray emission are produced, are not coincident, being the former at a larger distance from the core than the latter. We estimate that the radio core has a size $\gtrsim 0.05$ pc. Therefore radio and gamma ray data are in agreement if when moving from 0.003 pc to 0.05 pc the jet orientation changes from $\sim 5^\circ$ to $\sim 10^\circ$. Such a change in the jet orientation is consistent with the distorted morphology found in the parsec scale of Mkn 501. A jet velocity decrease is not necessary if the measured apparent velocity is confirmed by new data. However morphological changes in the jet suggests that jet deceleration possibly exists in the transition region discussed above.

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