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*Research Note*

# A typical SS 433 VLBI radio structure

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**Summary** VLBI observations of SS 433 with the European Network at 18 cm on 15 March 1986 show the source to contain a strong unresolved core, symmetrically placed structure on either side of the core, a sharp cut off at about 100 mas from the core and discontinous ejection, all features seen in earlier observations. We discuss evidence for a brightening zone around SS 433 (Vermeulen et al., 1987).

**Key words:** SS 433 – radio stars – VLBI

## 1. Introduction

We report the results of a single epoch observation of SS 433 with the European Very Long Baseline Interferometry Network at 18 cm wavelength. The original purpose of the measurement was to observe the extended structure of the SS 433 radio beams with high resolution. The observing epoch was chosen 2 months after the closest line of sight ejection of the beams in order to refine determination of the distance of SS 433 by fitting the expected locus of ballistic ejection on the kinematic model (Abell and Margon, 1979) to the radio structure observed. Unfortunately Effelsberg could not participate in the observations and therefore the shortest and the most sensitive baseline to extended structure (Effelsberg-Westerbork) was not available, and the refined distance determination could not be made.

However, the data obtained on the Westerbork-Jodrell Bank-Onsala baselines were of very good quality and the resulting map can be considered as a reliable addition to the series of SS 433 VLBI maps by the European VLBI Network (Romney et al., 1987; Schilizzi et al., 1984; Fejes, 1986 a; Vermeulen et al., 1987).

The importance of this single epoch observation now is that it gives further evidence of the characteristic features of the inner beams of SS 433 pointed out in a recent paper by Vermeulen et al. (1987). We will comment on this topic in Sect. 4 where we also summarize the evidence from earlier VLBI observation periods.

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## 2. Observations and data reduction

The observations of SS 433 were made with the European VLBI Network (EVN) on 15 March 1986 at 1667 MHz using MK III recording terminals with 28 MHz bandwidth. From the originally scheduled five stations, only three (Westerbork, Jodrell Bank – MK 2 and Onsala 25 m) functioned properly. The Westerbork array operated with all 14 antenna elements but recorded only 10 MHz bandwidth due to backend limitations at that time.

The data were correlated at the Max-Planck-Institut für Radioastronomie (Bonn, FRG). Following correlation, the data were coherently averaged for 180 s and calibrated using the MPIfR standard software for VLBI data reduction. Image analysis was subsequently performed in Dwingeloo, the Netherlands, using the Caltech (courtesy Dr. T.J. Pearson) and AIPS software packages. We used the same procedures as applied in earlier observations (Romney et al., 1987; Vermeulen et al., 1987).

## 3. Results

In Fig. 1 we present the visibility data on the three baselines available. Visibilities calculated from the CLEAN delta components are drawn as continous lines through the data. It is indicative of the high data and processing quality that no data points had to be edited out following the correlation.

The radio map is shown in Fig. 2. The structure consists of a strong unresolved component and 2 pairs of weaker components symmetrically located either side. The flux density of the strongest component exceeds that of the second most intense component by about a factor of 2; we identify the former with the core of the SS 433 system. The structure lies on the locus predicted by the 5-parameter kinematic model (Anderson et al., 1983) although there is a slight discrepancy in the location of the eastern most component. This discrepancy is, however, within the synthesized beamwidth of the EVN and is not considered significant.

The structure appears unresolved perpendicular to its elongation; in Fig. 3 we show a profile of the flux density variations along the predicted locus of ejection. The emission in both east and west directions is identical in terms of number of components and their locations with respect to the core, but not in terms of intensity. The first pair of blobs lie 40 mas from the core corresponding to an age of 4 days assuming a distance of 5.0 kpc (Romney et al., 1987). The second pair is located about 70 mas

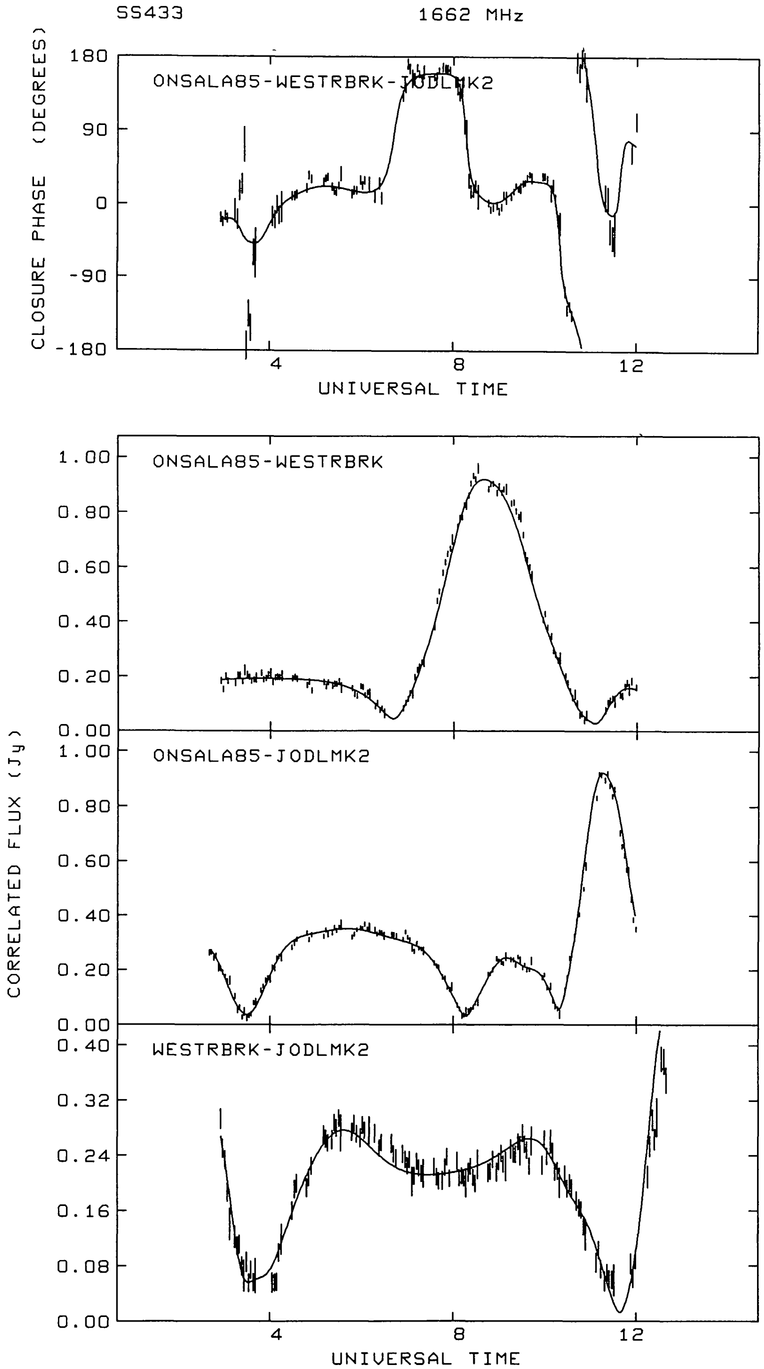


**Fig. 1.** The closure phase and the fringe amplitude for the three interferometer baselines. The observed data are shown as vertical bars. The calculated (model) closure phase and fringe amplitudes for the map are shown as solid curves

from the core which implies an age of 8 days. The eastern blobs are brighter than the corresponding ones on the western side. Moreover the most distant eastern blob is the most intense one. The structure abruptly drops to the <2% level at about 100 mas on both side of the core. About 30% of the total flux is contained in the unresolved core.

The integrated flux density ratio of the eastern beam to the western beam is 1.53. According to the kinematic model the western jet is approaching the observer at this epoch, but the ejection angle to the line of sight is large (84°–88°) and no Doppler boosting effects are expected in the observed brightness distribution (Fejes, 1986 b). Therefore the observed east-west asymmetry in the brightness distribution must be attributed to intrinsic asymmetric ejection or to differential environmental or evolutionary effects.

## 4. Discussion

Vermeulen et al. (1987) pointed out some characteristic features of the inner radio structure of SS 433 which had not been firmly established previously. For example:

(1) the unique identification of the core (SS 433 stellar system) with the brightest component in the structure;

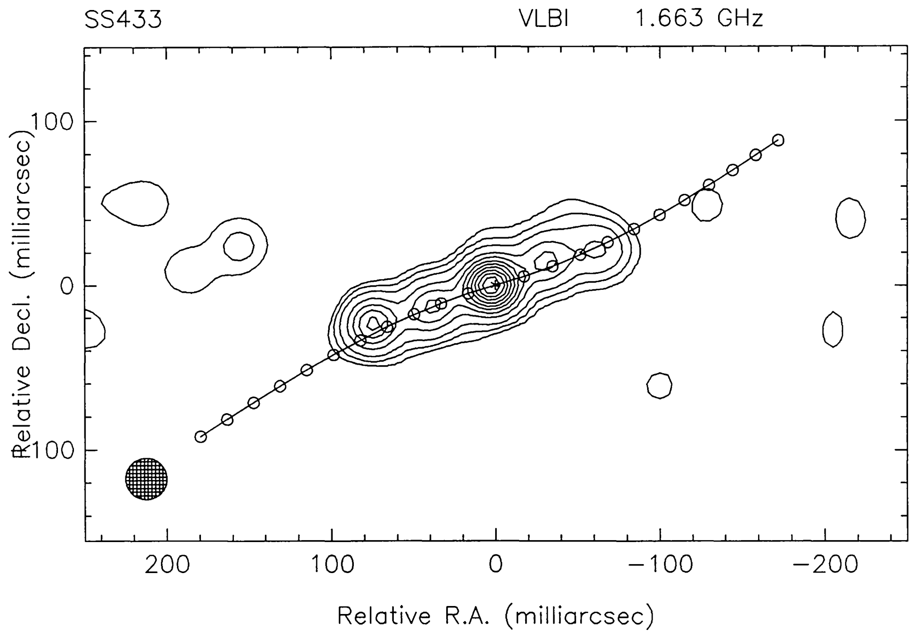


**Fig. 2.** Hybrid map of SS 433 observed at 18 cm wavelength on 15 March 1986. The convolving beam used in this representation was 25 mas in extent and circular. The contour levels are 2, 5, 10, 20, ... 90% of the peak intensity (225 mJy/beam). The curve drawn through the structure is the locus of ejection based on the 5-parameter kinematic model (Anderson et al., 1983). Circles are drawn at two-day intervals along the locus

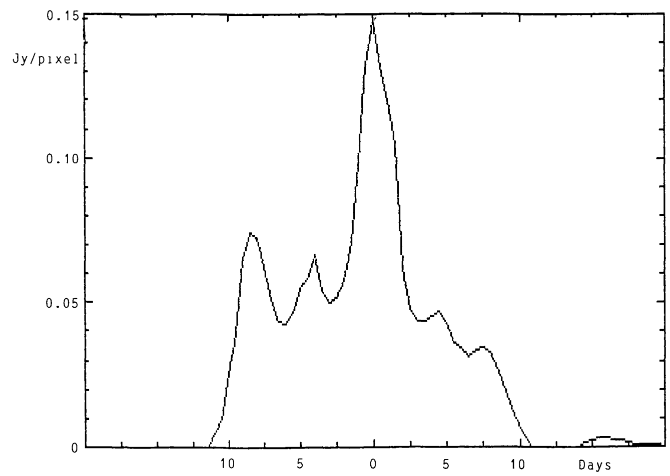


**Fig. 3.** Crosscut through the map in Fig. 2 along the predicted locus of ejection of material. The pixel size is 0.5 day in proper motion and flux densities were integrated for an angular distance of ±20 mas perpendicular to the crosscut

(2) the discontinous nature of the emission on the 10 mas scale;
(3) the production of blobs, on average, every 2–5 days; and
(4) the sudden drop in intensity at about 100 mas from the core.

The new VLBI results described in Sect. 3 of this Research Note support the general character of these conclusions. Our map shows an unresolved dominant core component and two discrete blob pairs either side of the core, presumably produced 4 and 8 days before the observation. There is also a very sudden drop in intensity at about 100 mas from the core.

Vermeulen et al. present evidence for a radio brightening zone located at about 4 $10^{15}$ cm from the SS 433 binary. Some aspects of the structure in Fig. 2 are in good agreement with the postulated existence of the brightening zone. The brightness of the blob at the eastern edge is somewhat greater than the inner eastern blob, which is half its age. This may be an effect of the brightening zone.

In retrospect the 5 GHz maps presented by Romney et al. (1987) also provide strong support for the existence of a "brightening zone". In their April, May and June 1981 maps, emission patches can be seen at a distance of 50 to 100 mas on either side of the core; they are separated from the central structure by regions without emission. Adjacent to the unresolved core in each of these maps, features akin to those seen in later maps by Vermeulen et al. (1987) are present. Taking into account the reduced resolution, the 18 cm map observed in February 1981, and the December 1980 map at 21 cm, again presented by Romney et al. (1987), may also show the brightening zone: there are knots between 50 and 100 mas from the core, and the flux density rapidly declines thereafter.

Schilizzi et al. (1984) had only very limited baseline coverage for their series of 6 maps. Yet they found evidence for a "blowpipe", as they called it, from which separate blobs emerged at a distance of 50 mas. This is in good agreement with the location of the "brightening zone" though the 1984 map structures found are strongly asymmetric.

The June 1984 VLBI map presented by Fejes (1986 a) also shows a rather distinct inner structure located up to 150 mas from the core and clearly separated from weaker much more extended structure. The eastern beam in this map may be affected by brightening while the western beam fades smoothly.

## 5. Conclusion

The VLBI radio structure of SS 433 observed on 15 March 1986 with the EVN at 18 cm has most of the characteristic features seen in earlier VLBI maps made at a number of wavelengths. It is consistent with evidence for the radio brightening zone around SS 433 found by Vermeulen et al. (1987).

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