

Radio Observations of the Giant Quasar 4C 34.47

W. J. Jägers¹, W. J. M. van Breugel², G. K. Miley¹, R. T. Schilizzi³, and R. G. Conway⁴

¹ Sterrewacht Leiden, P.O. Box 9513, 2300 RA Leiden, The Netherlands

² Sterrewacht Leiden, Present address: Kitt Peak National Observatory

³ Netherlands Foundation for Radio Astronomy, Dwingeloo

⁴ Nuffield Radio Astronomy Laboratories, University of Manchester, Jodrell Bank

Received August 10, accepted August 28, 1981

Summary. Multifrequency measurements of the giant radio source associated with the quasar 4C 34.47 are presented. The source, which is $\sim 7'$ in total extent with a prominent central core, has been mapped at 4995, 1415, and 610 MHz with the WSRT, and is shown to be edge-brightened. Significant linear polarization has been detected from the outer hot spots with directions which indicate that the magnetic field bends around the hot spots. The central core of the source is variable. *VLBI* observations on European baselines of the core show it to be extended along the large scale axis of the source.

Key words : quasar – radio structure – polarization – variability

I. Introduction

4C 34.47 is one of the largest radio sources known to be associated with a quasar. Conway et al. (1977) showed that the source was $440''$ in overall extent, and had a prominent unrevolved core. Using a Hubble constant of $75 \text{ km s}^{-1} \text{ Mpc}^{-1}$, a deceleration parameter of 1 and a redshift of 0.2055 (Wills and Wills, 1976) the luminosity distance of 4C 34.47 is 820 Mpc and its linear size is 1.2 Mpc. Because of its large angular size this quasar is an ideal candidate for multifrequency mapping. We have therefore observed it with the Westerbork Synthesis Radio Telescope (WSRT) at 5.0, 1.4, and 0.6 GHz. To derive information about the structure of the core we made further observations with 3 telescopes of the European *VLBI* network at 5 GHz.

II. Observations and Data Reduction

The observations with the WSRT were made at frequencies of 4995, 1415, and 609.5 MHz. The WSRT and its data reduction system have been described in detail by Baars and Hooghoudt (1974), Högbom and Brouw (1974), and van Someren-Gréve (1974). 3C 147 (Elsmore and Ryle, 1976) was used as a calibration source at the various frequencies and was assumed unpolarized with flux densities of 8.18 Jy at 5.0 GHz, 21.57 Jy at 1.4 GHz, and 37.78 Jy at 0.6 GHz. The data were Fourier transformed and

cleaned using the “clean” technique (Högbom, 1974) to remove the effects of grating rings and near-in sidelobes and to correct for the missing short spacings.

To make a satisfactory comparison between the intensity maps at two different frequencies, the resolution at the two frequencies must be the same. At both frequencies, the maps must have as closely as possible the same grating function and baseline coverage, measured in wavelengths. This was achieved by making specially tapered maps at the various frequencies and restoring with a similar Gaussian beam.

The core of 4C 34.47 was also observed for twelve hours at 5008 MHz with a *VLBI* network of three telescopes, one at Knockin, near Slough (UK), one at Effelsberg (Germany), and the WSRT in tied-array mode. In this case 2134+004 (Shimmins et al., 1968) was used as a calibration source with a measured flux density of 9.8 Jy and position (1950.0) of RA = $21^{\text{h}}34^{\text{m}}0.5^{\text{s}}21$ and DEC = $0^{\circ}28'25''.3$. After vector averaging the fringe amplitudes over five-minute periods some structure was seen on the longest baseline (Knockin-Effelsberg).

Relevant parameters pertaining to the various observations are listed in Table 1.

III. Results

a) Total Intensity Distribution

Contour maps of the total intensity distribution obtained with the WSRT are shown in Fig. 1. All the maps have been corrected for the primary beam attenuation. These corrections are important because the source size is comparable with the half power half-width of the primary beam at 5.0 and 1.4 GHz and at 0.6 GHz the telescope was inadvertently mispointed by 1° . Superimposed on the contour maps are the position angles of the linearly polarized intensity.

From the 5.0 GHz map it is clear that 4C 34.47 has a strong central core and two hot spots, a structure typical for high-luminosity sources associated with quasars. The hot spots are situated symmetrically with respect to the central core. The southern hot spot is stronger than the northern hot spot. At 1.4 GHz a bridge can be seen to extend from the core to the hot spots. Table 2 gives the positions of the radio maxima and the integrated values of total and polarized intensity, pertaining to the three components at the various wavelengths. In Table 3 some parameters describing the morphology of 4C 34.47 are listed.

Send offprint requests to: W. J. Jägers

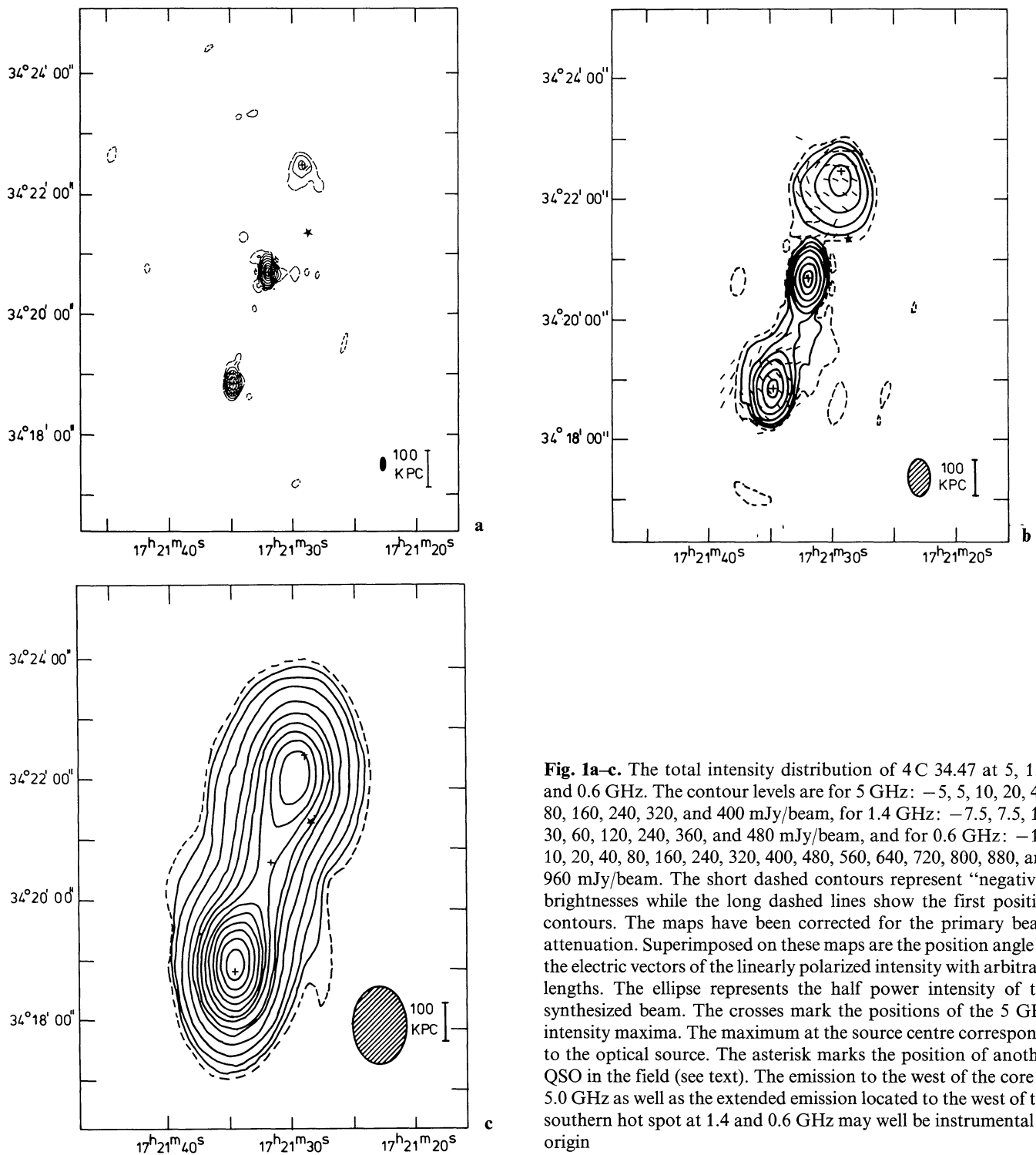


Fig. 1a-c. The total intensity distribution of 4C 34.47 at 5, 1.4, and 0.6 GHz. The contour levels are for 5 GHz: $-5, 5, 10, 20, 40, 80, 160, 240, 320$, and 400 mJy/beam, for 1.4 GHz: $-7.5, 7.5, 15, 30, 60, 120, 240, 360$, and 480 mJy/beam, and for 0.6 GHz: $-10, 10, 20, 40, 80, 160, 240, 320, 400, 480, 560, 640, 720, 800, 880$, and 960 mJy/beam. The short dashed contours represent “negative” brightnesses while the long dashed lines show the first positive beam attenuation. The maps have been corrected for the primary beam attenuation. Superimposed on these maps are the position angle of the electric vectors of the linearly polarized intensity with arbitrary lengths. The ellipse represents the half power intensity of the synthesized beam. The crosses mark the positions of the 5 GHz intensity maxima. The maximum at the source centre corresponds to the optical source. The asterisk marks the position of another QSO in the field (see text). The emission to the west of the core at 5.0 GHz as well as the extended emission located to the west of the southern hot spot at 1.4 and 0.6 GHz may well be instrumental in origin

From the spectral comparisons it was found (Table 2) that the spectral index ($S \propto \nu^\alpha$) of both of the hot spots is ~ -0.75 between 0.6 and 5.0 GHz. The core has a spectral index of -0.25 between 5.0 and 1.4 GHz. Between 1.4 and 0.6 GHz its spectrum is even flatter.

In Table 2 we list the minimum energy densities for the three components calculated on the basis of the usual assumptions (e. g. Miley, 1980): cylindrical symmetry, equal energy in heavy par-

ticles and electrons, a filling factor of unity and a power law radio spectrum extending from 10^7 to 10^{11} Hz.

The core has been identified with the optical QSO 1721+343 which has a redshift of 0.2055. There is another QSO (Hewitt and Burbidge, 1980) visible in the field of 4C 34.47, whose position is marked by the asterisk in Fig. 1. This has a redshift of 1.80 and no detectable radio emission. There is no evidence that the two QSO's are connected.

Table 1. Observational parameters

	Observing Frequency and Bandwidth		Observation Dates		Half Power Width Primary Beam	Half Power Width Synthesized Beam	RMS Noise
	MHz	MHz	Year	Date	(arcmin)	RA x DEC (arcsec)	mJy/beam
WSRT	4995	10	1979	105	5.3	6 x 10	0.3
	1415	4	1976	334	18.7	24 x 36	0.2
	609.5	4	1976	287	44.1	56 x 79	0.5
VLBI					Baselines Telescopes	Min.Lobe Spacing (arcsec)	RMS Noise mJy
	5008	2	1980	154/155	Effelsberg-Westerbork (267 km)	0.046	10
					Effelsberg-Knockin (728 km)	0.017	17

Table 2. Integrated parameters pertaining to the three components at the three wavelengths

		Total	North Component	Core	South Component
Position: Right Ascension	h m s	17 21 29.26±0.05	17 21 31.97±0.05	17 21 31.97±0.05	17 21 34.87±0.05
Declination	° ' "	34 22 28.2±0.5	34 20 41.2±0.5	34 20 41.2±0.5	34 18 51.0±0.5
5.0 GHz: Total intensity	mJy	800±40	150±20	440±30	200±30
Linearly polarized intensity	%	4±1	7±1	1±1	15±2
Angle of electric vector	°	-50±5	-42±2	-51±3	-54±3
1.4 GHz: Total intensity	mJy	1620±80	418±20	610±30	562±30
Linearly polarized intensity	%	3±1	7±1	0.5±0.5	12±2
Angle of electric vector	°	50±5	69±3	-78±3	41±2
0.6 GHz: Total intensity	mJy	2521±120	788±50	< 500	1202±70
Spectral Index between 5.0 and 1.4 GHz			-0.75±0.1	-0.25±0.1	-0.75±0.1
Spectral Index between 1.4 and 0.6 GHz			-0.75±0.3	> -0.1	-0.75±0.1
Minimum Energy Density	erg.cm ⁻³		6.2 x 10 ⁻¹²	3.9 x 10 ⁻⁹	1.2 x 10 ⁻¹¹

* Values determined from the 5.0 GHz convolved map.

Table 3. Some parameters of 4C 34.47

$H_0 = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$; $q_0 = 1$; $z = 0.2055$	
luminosity distance	820 Mpc
diameter distance	565 Mpc
distance between the hot spots and the core (5 GHz)	0.33±0.03 Mpc
position angle of the extended source	162°±5°
position angle of the core	157°±5°
length of the major axis (0.6 GHz)	1.2±0.1 Mpc
length of the minor axis (0.6 GHz)	0.7±0.1 Mpc
1 arcsec is equivalent to a linear extent of	2.7 kpc

b) Linear Polarization Distribution

Maps of the polarization distributions at 5.0 and 1.4 GHz are shown in Figs. 2 and 3. At 5.0 GHz the maximum linear polarization percentage detected in the southern component is 52%, while the maximum in the northern component is 38%. The

core is slightly ($\sim 1\%$) polarized. It is clear that in the northern hot spot the percentage polarization on the western and south-western side is higher than in the rest of the hot spot, while in the southern hot spot the percentage polarization is highest on the eastern and north-eastern sides. The linearly polarized intensity distribution is thus rotationally symmetric with respect to the QSO.

In contrast, on the lower resolution 1.4 GHz maps, the percentage polarization appears to increase from the centre of the hot spot edges. No polarization was detected from the core at 1.4 GHz. Enhanced polarization near the edges of extended radio components seem to be a general property of radio sources (van Breugel and Jägers, 1982).

At 1.4 GHz, the electric vectors bend around the edges of the hot spot suggesting the presence of a circumferential field. Comparison between the polarization map at 5.0 and 1.4 GHz indicates that although the rotation of the electric vector is $\sim 110^\circ$ there is no significant depolarization in the hot spots. As the electric vector position angle at 5.0 GHz is distributed uniformly and there is no depolarization in the hot spots, the internal rotation measure may be small.

c) Variability of the Core

Conway et al. (1977) observed 4C 34.47 with the WSRT in 1973/74, and found the following values of the intensity of the

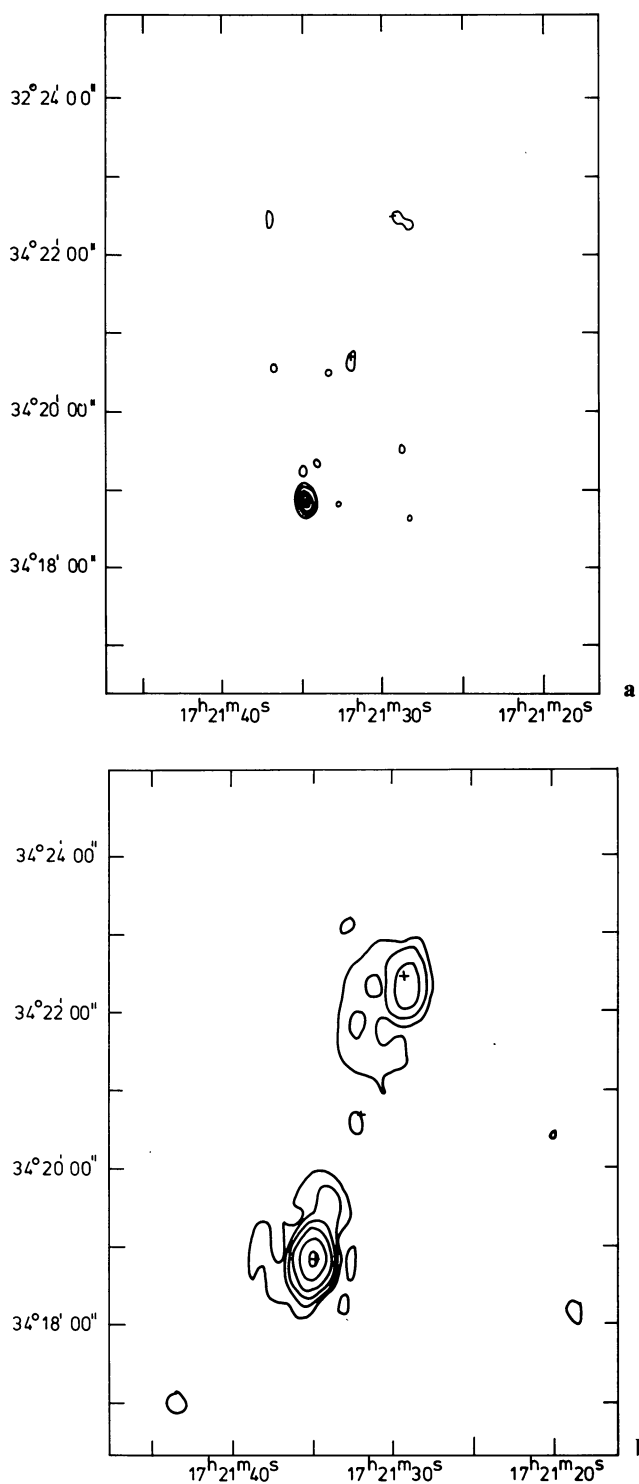


Fig. 2a and b. The linearly polarized intensity distribution of 4C 34.47 at 5.0 and 1.4 GHz, also corrected for the primary beam attenuation. The contour levels are for 5.0 GHz: 2, 4, 8, 12, 16, and 20 mJy/beam and for 1.4 GHz: 2, 4, 8, 16, 32, 48, and 64 mJy/beam. The crosses mark the positions of the 4.9 GHz total intensity maxima

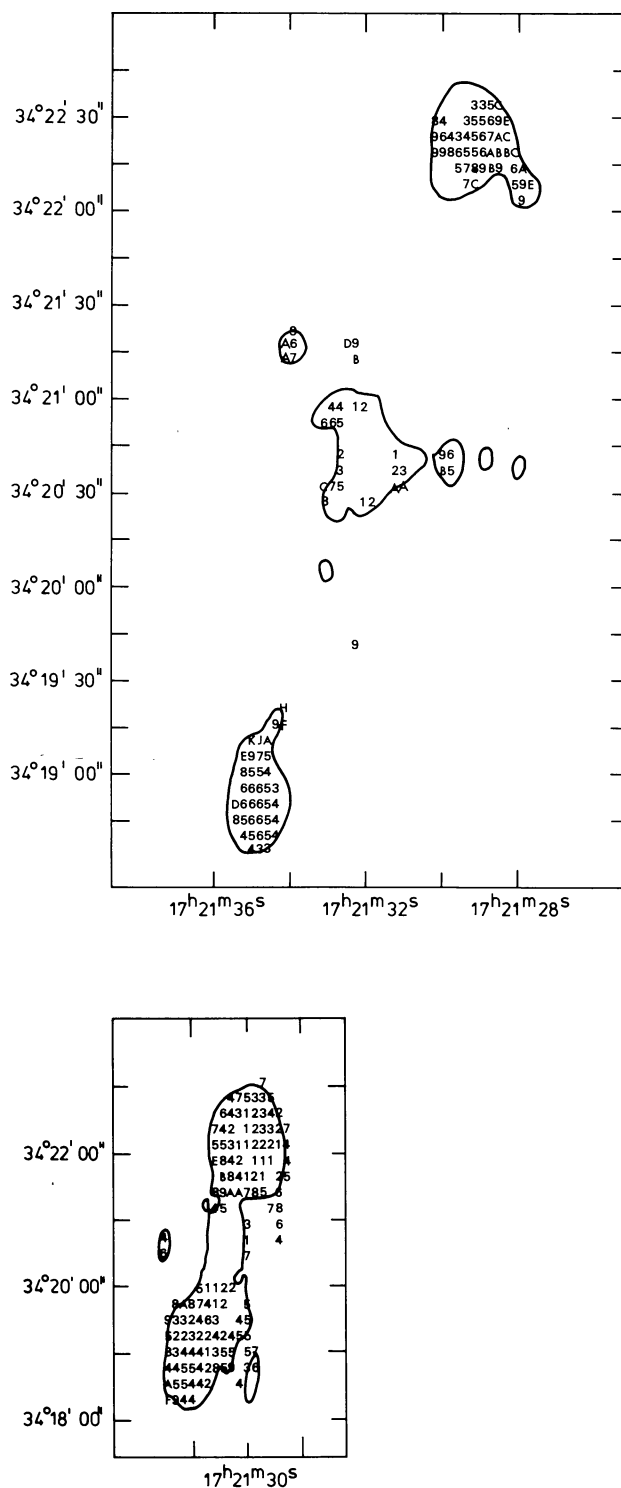


Fig. 3a and b. These figures show the percentage polarization at 5.0 and 1.4 GHz. For both figures the contour interval is 2.5%. "1" means that the percentage is between 2.5 and 5.0%, "2" that it is between 5.0 and 7.5% etc., "A" means that it is between 25.0 and 27.5%, "B" that it is between 27.5 and 30.0% etc. For display reasons the scale in these figures is different from the scale in the total intensity plots. The continuous line corresponds to the first contour of the total intensity plot

Table 4. Models of the core

Model	Flux (Jy)	Diameter (mas) ^{* +}	Position Angle (degrees) ⁺⁺	Goodness of fit
Line Gaussian	0.33	5.5	155	1.40
Elliptical Gaussian	0.33	5.6 x 2.2	161	1.41
Double points	0.22/0.11	4.8 (separation)	155	1.40

^{*}mas - milliarcsec

⁺the estimated error is 1 mas

⁺⁺the estimated error is 5°

core: 5.0 GHz, 508 ± 20 mJy at epoch 1974.3; 1.4 GHz, 580 ± 20 mJy at epoch 1973.9. Comparison with Table 2 shows that little if any change occurred between 1973.9 and 1976.9, but that the 5.0 GHz flux density dropped by 25% between 1974.3 and 1979.3.

The quasar is also highly variable at optical frequencies (McGimsey and Miller, 1978). The most rapid variation found was a 0^m6 rise in *B* over 28 d, setting an upper limit to the size of the optical emission in the line of sight of $2.4 \cdot 10^{-2}$ pc.

d) Structure of the Core

The core was unresolved, both for the observations made with the WSRT and those made at the shorter *VLBI* baseline. However, significant variation of the fringe visibility with hour angle was observed on the longest (Knockin-Effelsberg) baseline. The results of attempts to fit various models to the data are shown in Table 4. Since the source was only slightly resolved there was little difference between the "goodness of fit" given by the various models. The data clearly indicate that the source is extended by 5 ± 1 milli arc s in a position angle of $157^\circ \pm 5^\circ$. The size of the radio core ($\sim 1.4 \cdot 10^{-2}$ pc) is therefore within the upper limit to the size of the optical QSO obtained by McGimsey and Miller and the position angle is not significantly different from the position angle of the overall axis of the source.

IV. Discussion

4C 34.47 has a narrow edge-brightened double structure (Miley, 1980) which is typical of high luminosity radio sources. The core is resolved along the same position angle as the extended radio emission. The morphology of 4C 34.47 is very similar to that of the radio galaxy 3C 390.3, which has been mapped at 5 GHz by Harris (1972) showing a central core and two bright small hot spots. The core of 3C 390.3 is also resolved along the same axis as the extended radio emission (Walker et al., 1976; Preuss et al., 1980). The morphological resemblance between the radio source in the quasar 4C 34.47 and the radio galaxy 3C 390.3 is consistent with the picture that quasars with extended radio sources are active phases of high luminosity radio galaxies.

The large linear size of 4C 34.47 coupled with the relatively large strength of its core are of interest on two counts. First it argues against the Scheuer-Readhead model (1979) as being applicable to the cores of extended radio sources. In the Scheuer-Readhead picture the strength of radio cores is thought to be governed mainly by relativistic enhancement associated with their orientation rather than by the intrinsic nuclear activity. The

relative weakness of the cores in extended radio sources is attributed to the line of sight component of their ejection velocities being small to their orientation. But because 4C 34.47 has one of the largest linear sizes of any known quasar it is presumably approximately oriented in the plane of the sky. Its relative strong core is therefore almost certainly produced by intrinsic effects.

Second, the large size and strong core of 4C 34.47 is relevant to the correlation between $H\beta$ line-width and extended radio structure noticed by Miley and Miller (1979). Quasars associated with extended radio sources were found to have wider $H\beta$ lines than the compact (core dominated) sources. It is not clear whether this correlation is primarily related to the presence of extended radio emission or to the relative strength of the core. Since 4C 34.47 has the narrowest line of all the extended sources measured, its strong core is evidence that the broad $H\beta$ line is associated with the presence of weak cores rather than with the existence of extended emission.

Acknowledgements. We thank the staff of the Westerbork Radio Telescope and the Reduction Group for their work on these observations, and W. Brokaar for preparation of the figures.

The Westerbork Radio Observatory is operated by the Netherlands Foundation for Radio Astronomy with the financial support of the Netherlands Organization for the Advancement of pure Research (ZWO).

References

- Baars, J.W.M., Hooghoudt, B.G.: 1974, *Astron. Astrophys.* **31**, 323
- van Breugel, W.J.M., Jägers, W.J.: (in preparation)
- Conway, R.G., Burn, B.J., Vallee, J.P.: 1977, *Astron. Astrophys. Suppl.* **27**, 155
- Elsmore, B., Ryle, M.: 1976, *Monthly Notices Roy. Astron. Soc.* **174**, 411
- Harris, A.: 1972, *Monthly Notices Roy. Astron. Soc.* **158**, 1
- Hewitt, A., Burbidge, G.: 1980, *Astrophys. J. Suppl.* **43**, 57
- Högbom, J.A.: 1974, *Astron. Astrophys. Suppl.* **15**, 147
- Högbom, J.A., Brouw, W.N.: 1974, *Astron. Astrophys.* **33**, 289
- Longair, M.S., Riley, J.M.: 1979, *Monthly Notices Roy. Astron. Soc.* **188**, 625
- McGimsey, B.Q., Miller, H.R.: 1978, *Astron. Astrophys. Suppl.* **31**, 147
- Miley, G.K., Miller, J.S.: 1979, *Astrophys. J. Letters* **228**, L55
- Miley, G.K.: 1980, *Ann. Rev. Astron. Astrophys.* **18**, 165

- Preuss, E., Kellermann, K.I., Pauliny-Toth, I.I.K., Shaffer, D.B.: 1980, *Astrophys. J. Letters* **240**, L7
- Scheuer, P.A.G., Readhead, A.C.S.: 1979, *Nature* **277**, 182
- Shimmins, A.J., Searle, L., Andrew, B.H., Brandie, G.W.: 1968, *Astrophys. Letters* **1**, 167
- Simard-Normandin, M., Kronberg, P.P.: 1979, *Nature* **279**, 15
- van Someren-Gréve, H.W.: 1974, *Astron. Astrophys. Suppl.* **15**, 343
- Walker, R.C., Lo, K.Y., Burke, B.F.: 1976, *Astrophys. J.* **208**, 296
- Wills, D., Wills, B.J.: 1976, *Astrophys. J. Suppl.* **31**, 143