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MSH 05-22: a giant radio source in the southern sky

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Summary. During a program of mapping a complete sample of extended radio sources with the Molonglo Observatory Synthesis Telescope (MOST), the source MSH 05-22 (0503-286) was discovered to be a giant radio source. Our map at 843 MHz clearly suggests the association of the observed radio emission, extending over 42 arcmin, with a 15.5 mag D-galaxy. The galaxy redshift of $z = 0.0384$ leads to a projected linear extent of 2.6 Mpc ($H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$), making this the largest known radio source in the southern sky.

Key words: radio galaxies – double radio sources

1. Introduction

The Molonglo Observatory Synthesis Telescope (MOST) is a multiple fan beam radio telescope capable of mapping up to $70 \times 70\,\mathrm{cosec}\,|\delta|$ arcmin field with a resolution of $43 \times 43\,\mathrm{cosec}\,|\delta|$ arcsec at 843 MHz. A description of the instrument and routine mapping procedures have been given by Mills (1981), Durdin, Large and Little (1984) and Crawford (1984). In view of the high sensitivity (rms noise $\sim$0.2 mJy for a 12 hour observation), it is also very useful for observing many fields quasi-simultaneously, moving from one field to another in a regular sequence under computer control. Using this facility, we observed about 700 sources selected from the Molonglo Reference Catalogue (MRC; Large et al., 1981) during the period 1984 September to 1985 February. This was followed by a program of mapping all the resolved sources in the sample with $S_{843} \geq 1$ Jy. Details of these observations will be given elsewhere (Subrahmanya 1986, in preparation). We present here our initial results for 0503-286, the largest source found in this survey. We follow the established convention for very extended sources in naming the source after the position of its optical counterpart.

The source 05-22 was originally catalogued by Mills, Slee and Hill (1960; MSH) with a peak flux density of 30 Jy and integrated flux density of 60 Jy at 85.5 MHz. This may imply either a single source resolved by the 48 arcmin beam or the presence of nearby confusing sources. When we surveyed the literature for subsequent observations of the source, we discovered striking inconsistencies among the reported flux densities. The source has been listed as two independent sources (0503-284 and 0503-290 in MRC) in all catalogues except MSH. The published flux densities for these two 'sources' are listed in Table 1. The more recent low-frequency catalogues generally account for only a fraction of the flux density given by MSH. This suggests that the 'sources' are heavily resolved by beams of a few arcmin, yet they were both unidentified on the Palomar Sky Survey. This is quite unusual for two such extended sources so close together in the sky. On the other hand, the MSH radio position agrees, within the quoted errors, with the optical position of a 15.5 mag galaxy MCG 05-13-003 (Vorontsov-Velyaminov and Arhipova 1968). Hence, if these discrepancies had been noticed earlier, the most natural interpretation would have been a single giant source associated with this galaxy.

Although our original 2 × 4 minute scans made in 1984 October revealed that both the 'sources' were well resolved, they were not adequate to suggest a physical association. In the first map obtained on 1985 October 7 using the MOST, the southern 'source' was outside the observed field of view. However, radio emission extending over 15 arcmin was detected from the northern part with a low-surface-brightness bridge of emission to a weak compact component which was found to coincide with the galaxy noted above. Inspection of the archived chart records at 408 MHz from the 1.6 km Molonglo Cross telescope strengthened our belief that a single large source was associated with MSH 05-22. Thereafter, we observed the whole source with the MOST

Table 1. Published flux densities of MSH 05-22

Freq. (MHz)	Beam (arcmin)	Flux density (Jy)		Ref.
		North	South	
85.5	48	60(total)		MSH
80	3.8	7	15	(a)
160	1.9	<2	<2	(a)
408	48	–	5.5	(b)
408	2.9	1.03	0.86	MRC
2700	7.9	0.72	0.60	(c)
5000	4.0	0.23	0.27	(c)

References: (a) Slee (1977); (b) Bolton et al. (1964); (c) Binette et al. (1981)

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and Fleurs Synthesis Telescope (FST) and also obtained the redshift of the galaxy through the service spectroscopy program of the Anglo Australian Telescope (AAT).

2. Radio observations

The radio map of the source at 843 MHz is shown in Fig. 1, in which we have plotted the average of CLEANed maps obtained from MOST observations on 1985 October 31 and November 1. On each day, the source was observed between hour angles $\pm 5^{h}.5$, and an on-line map was generated using the standard procedure at Molonglo Observatory (Durdin et al., 1984). The raw maps were deconvolved using the standard CLEAN algorithm, and restored with a Gaussian beam of hpw 40 × 80 arcsec.

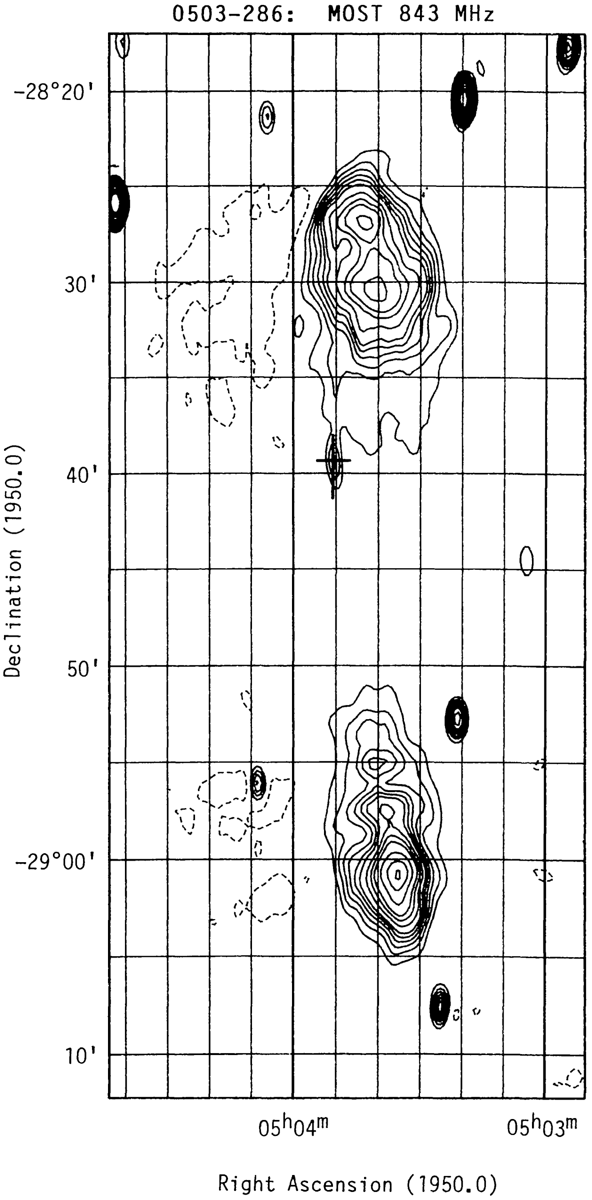

Fig. 1. MOST map of 0503-286 at 843 MHz. Optical position of the galaxy is indicated by a cross. Contour levels(mJy/beam): −5, 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100 and 120

The source has two prominent lobes typical of strong radio sources. The outer contours of the northern lobe are seen to extend to the compact component coinciding with the galaxy. The extended structure in the southern lobe is clearly seen to be aligned in the direction of the galaxy, although the dynamic range in the map shown in Fig. 1 is not sufficient to detect any bridge of emission. Our results at this stage are very preliminary since our analysis is based entirely on unedited data and there is also a likelihood of maps being affected by solar interference towards the end of the observations. In particular, this may have significantly affected the base level, which, in view of the large angular size of the source, introduces large uncertainties in the integrated flux density. We have tentatively estimated the total flux density as $S_{843} = 4 \pm 1$ Jy. The luminosity of the source at 843 MHz is thus $10^{24.3}$ W Hz^{-1} sr^{-1}, intermediate between the luminosities of sources of morphological class I and II as defined by Fanaroff and Riley (1974).

The source was observed at 1415 MHz using the FST on 1985 October 19 and 20. The FST has a resolution about twice as good as that of the MOST, but has much lower sensitivity (Bunton et al. 1984). In the present case, the correlator noise from the longer baselines, which are insensitive to extended structure, would further degrade the signal/noise ratio. In our preliminary results presented here, we have therefore ignored the longer baselines in the visibility and restored the CLEANed maps with a Gaussian of hpw 40 × 80 arcsec, the same as that of the MOST map in Fig. 1. The resulting combined low-resolution map is shown in Fig. 2. Again, the integrated flux-density was estimated roughly from the map as 2.1 ± 0.5 Jy. Our estimates at 843 MHz and 1415 MHz, the flux densities given in the MSH catalogue at 85.5 MHz, and those at 2.7 and 5 GHz from the Parkes catalogue (Table 1), are all consistent with an overall spectral index $\alpha = 1.1 \pm 0.1$ ($S \propto \nu^{-\alpha}$) for the source.

Due to the very low surface brightness of the source, we expect to be able to improve our results with more elaborate processing of the data. We also plan further observations with both the MOST and FST. It is also planned to map the source at 408 MHz using the data archives from the Molonglo Cross telescope. A detailed interpretation of our results and a quantitative comparison between the maps at different frequencies will be attempted at that stage and the results will be published in due course.

3. Optical observations

The galaxy coincident with the compact radio component is a 15.5 mag D galaxy. It is clearly the brightest member of a sparse group of galaxies which includes at least one spiral. Its optical position was measured from the blue plate of the Palomar Sky Survey as

$$\alpha(\mathrm{B1950}) = 05^{h}03^{m}50^{s}.95 \pm 0^{s}.03$$

$$\delta(\mathrm{B1950}) = -28°39'18''.3 \pm 0''.5$$

A low resolution (7 Å FWHM) spectrum of the galaxy was obtained at the AAT on 1985 November 3 through the service spectroscopy program. The detector was the Image Photon Counting System and the integration time was 2000 s through cloud with a 1 arcsec slit; relative spectrophotometric calibration was obtained from narrow-slit observations of the white dwarf L870-2 with the slit at the parallactic angle.

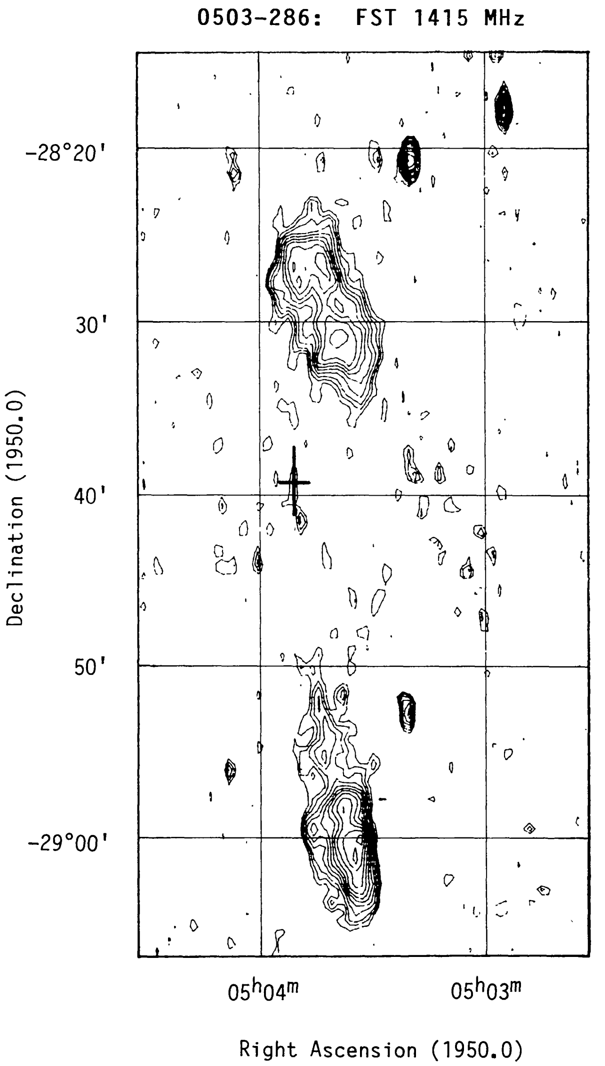

Fig. 2. FST map of 0503-286 at 1415 MHz at the same resolution as the 843 MHz map in Fig. 1. The galaxy position is marked with a cross. Contour levels (mJy/beam): −6, 6, 8, 10, 12.5, 15, 17.5, 20, 22.5, 25, 30, 40, 50

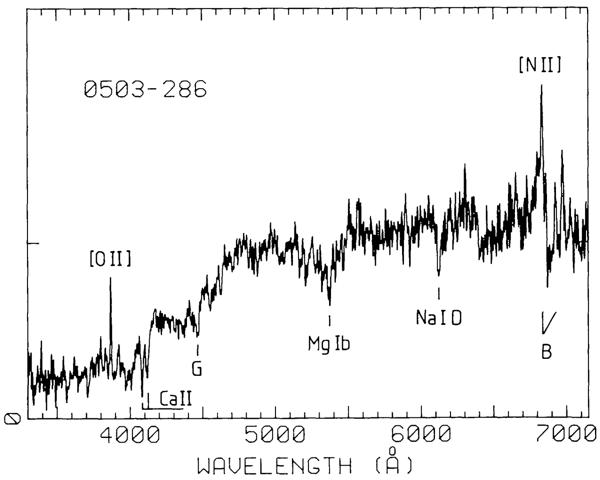

Fig. 3. AAT spectrum of 0503-286 at a resolution of 7 Å FWHM. The ordinate is proportional to flux density per unit wavelength. The most prominent emission and absorption features are indicated

The spectrum is shown in Fig. 3. It is a typical elliptical galaxy spectrum dominated by integrated starlight. There is no evidence of a non-thermal continuum. The weak emission due to [O II] λ 3727, [N II] $\lambda\lambda$ 6548,6583 and probable [S II] $\lambda\lambda$ 6716,6730 indicates a gas content intermediate between field galaxies and cluster ellipticals. There is no detectable Balmer or [O III] emission, both of which are commonly seen in more powerful radio galaxies. The mean heliocentric redshift determined from both emission and absorption features is $z = 0.0384 \pm 0.0002$.

4. Discussion

The source 0503-286 has a morphology typical of the majority of strong radio sources – two prominent lobes and a compact component between the lobes coinciding with the associated galaxy. The observed radio emission extends over 42 arcmin between the outermost contours in Fig. 1. The corresponding linear size of 2.6 Mpc ($H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$) in the plane of the sky makes this the largest known source in the southern sky. The unusual radio morphology seen in Fig. 1 may simply be the result of projection effects on a 'bent-double' source (Reynolds, 1980). The bent structure would arise from motion of the galaxy relative to an intergalactic medium, which is plausible due to the presence of an associated group of galaxies. Since the extent of the radio source is comparable with the size of a cluster, it is likely that anisotropy in the intergalactic medium has also influenced source symmetry. As in the case of other giant radio sources like 3C 236 or DA 240 (Willis et al., 1974), detailed mapping at several frequencies is the first step in trying to understand the energy generation and transport mechanisms as well as the properties of the intergalactic medium through which the lobes have expanded.

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