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A Revised Flux Scale for the AT Compact Array

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Abstract

A revised set of flux density estimates is presented for the radio source 1934–638, over the frequency range 1.4GHz to 8.6GHz. The main purpose of this revision is to bring the ATCA flux density scale into better agreement with the scales used at Northern hemisphere observatories, the VLA in particular. The revised scale defined here is believed to be consistent with current Northern scales at the 1~2% level over the range 1–10GHz. It is recommended that the revised scale be implemented as the default option in all ATCA observing and reduction software, as it represents a significant correction to the scale currently in use.

Introduction

Flux density calibration of ATCA observations has to date relied almost exclusively on the source 1934–638, using absolute flux densities determined more than 20 years ago. Most ATCA observations use, either directly or indirectly, a polynomial fit of log Flux versus log Frequency originally derived by G. White (16/10/89), who used the flux densities from the Parkes Catalogue and the MRC flux at 408MHz. This polynomial is currently implemented in the on-line calibration software at the ATCA, and in the AIPS and Miriad reduction packages.

It is now clear (Reynolds, E-mail Bulletin, Oct 93) that either 1934–638 has varied substantially since the epoch of the Parkes Catalogue, or that the Parkes Catalogue flux scale differs significantly from more recent determinations, principally that of Baars *et al.* (1977). This document compiles the best recent flux measurements of 1934–638, placed on a scale consistent with those in use at Northern observatories, from which an improved polynomial fit is derived.

The Flux Density Measurements

The flux density estimates used in this redetermination of the 1934–638 spectrum are listed in the second column of Table 1. The fitted value from the revised polynomial is shown in column 3 while the difference between this and the previous fit is shown in column 4 (in the sense *new-old*). The origin of each measurement is given in column 5 with additional notes below the Table. The formal errors in all measurements above 1GHz are ~1% or less and are not shown. The flux values listed are of three types;

Molonglo The Molonglo Reference Catalogue (MRC) at 408MHz is on the scale of Wyllie (1969) which Baars *et al.* conclude is very close to their own. The MOST flux scale at 843MHz is essentially an interpolation between the Wyllie 408MHz scale and the scale of the Parkes Catalogue.

ATCA The values designated as 'ATCA' in column 5 of the Table were all made with the AT Compact Array using the calibrator 3C286 as the reference. As this source has structure at the ~ 2arcsec level, the total flux was estimated by using only the shortest interferometer spacings or by extrapolating the flux density to zero spacing (e.g. McConnell & McKay 1994). Where possible (Nov 93, Jun 94) elevation-dependent effects were minimised by observing both sources at similar elevations.

There is good evidence from Bonn (Ott *et al.* 1993) and the VLA (Perley 1993, priv. comm.) that, in the frequency range 1~10GHz, 3C286 has not changed by more than ~1% from the spectrum published by Baars *et al.*. The ATCA flux densities in the Table have all been calculated using the Ott *et al.* spectrum for 3C286, which differs by no more than 1~2% from either the Baars *et al.* spectrum or from the spectrum currently used at the VLA.

Single-Dish The values whose origin are indicated in the Table as 'Tidbinbilla' and/or 'Parkes' are single dish measurements against the calibration source Hydra A, but with Virgo A also occasionally used. As both these sources have considerable angular extent it was necessary to estimate correction factors based on models of the source structure. These factors amount to as much as 5% for Hydra A and 10% for Virgo A, but are probably accurate to 2~3%. (It is intended to measure these factors more accurately at Parkes in the near future).

Ott *et al.* found that both Hydra A and Virgo A have changed significantly from their Baars *et al.* values so in each case the revised spectrum of Ott *et al.* has been used. It is clear from the Table that the single dish fluxes agree rather well with the ATCA interferometer fluxes, confirming the flux ratio of 3C286 to Hydra A implied in the results of Ott *et al.*.

Polynomial Fit to the Data

A 3rd order polynomial (cubic) expressing log Flux versus log Frequency was fitted to the data in the first two columns of the Table to produce the values in the third column. All values were given equal weight. The fitting procedure does not cope particularly well with the complex spectral shape of 1934–638, and deviates by as much as ~1% from a smooth curve drawn by hand (e.g. all the 4.8GHz data points fall slightly below the fit). Proceeding to a 4th order polynomial did not greatly improve the fit however and given the convenience of the polynomial form, no attempt has been made to investigate other methods of interpolation or fitting. It should be noted that at frequencies other than those tabulated here (e.g. 6.7GHz) the polynomial fit may not interpolate accurately the true spectral shape of 1934–638 and errors somewhat larger than 1~2% are possible. The derived 3rd order polynomial is given by;

$$\log S = -30.7667 + 26.4908 \log F - 7.0977(\log F)^2 + 0.605334(\log F)^3,$$

where S is the flux density of 1934–638 in Jy, and F is the frequency in MHz. The fit is drawn in Figure 1, with the measurements tabulated in column 2 of the Table shown as crosses.

Frequency (MHz)	Flux Density (Jy)	Fitted (Jy)	Change	Origin
408	6.24	6.14	−1.9%	MRC (Large *et al.*, 1981
843	13.65	13.89	−3.5%	MOST (Campbell-Wilson & Hunstead 1994)
1380	14.96	14.95	−7.9%	ATCA (Nov 93)
1413	14.87	14.88	−8.1%	Parkes (LSS)
1612	14.47	14.33	−9.3%	Parkes (JC)
1660	14.06	14.18	−9.5%	Parkes (LSS)
1665	14.21	14.16	−9.5%	Tidbinbilla (JER)
2295	11.95	11.85	−11.4%	Tidbinbilla, Parkes (JER)
2378	11.75	11.55	−11.5%	ATCA (Nov 93)
4800	5.81	5.83	−7.9%	ATCA (Nov 93)
4800	5.76	5.83		ATCA (Jun 94)
4835	5.72	5.78	−7.8%	ATCA (Jul 94)
4850	5.74	5.76	−7.8%	Parkes (JER)
8415	2.99	2.94	+8.5%	ATCA (Jul 94)
8420	2.97	2.93	+8.5%	Tidbinbilla, Parkes (JER)
8640	2.81	2.84	+9.8%	ATCA (Nov 93)
8640	2.81	2.84		ATCA (Jun 94)

Single-dish measurements at Parkes and Tidbinbilla made by J. Reynolds (JER), L. Staveley-Smith (LSS) and J. Chapman (JC).
ATCA measurements in Nov 93 made by A. Tzioumis.
ATCA measurements in Jun 94 made by D. McConnell & D.McKay (1994).
ATCA measurements in Jul 94 made by S. White.

Table 1: Revised Flux Density Estimates for 1934–638

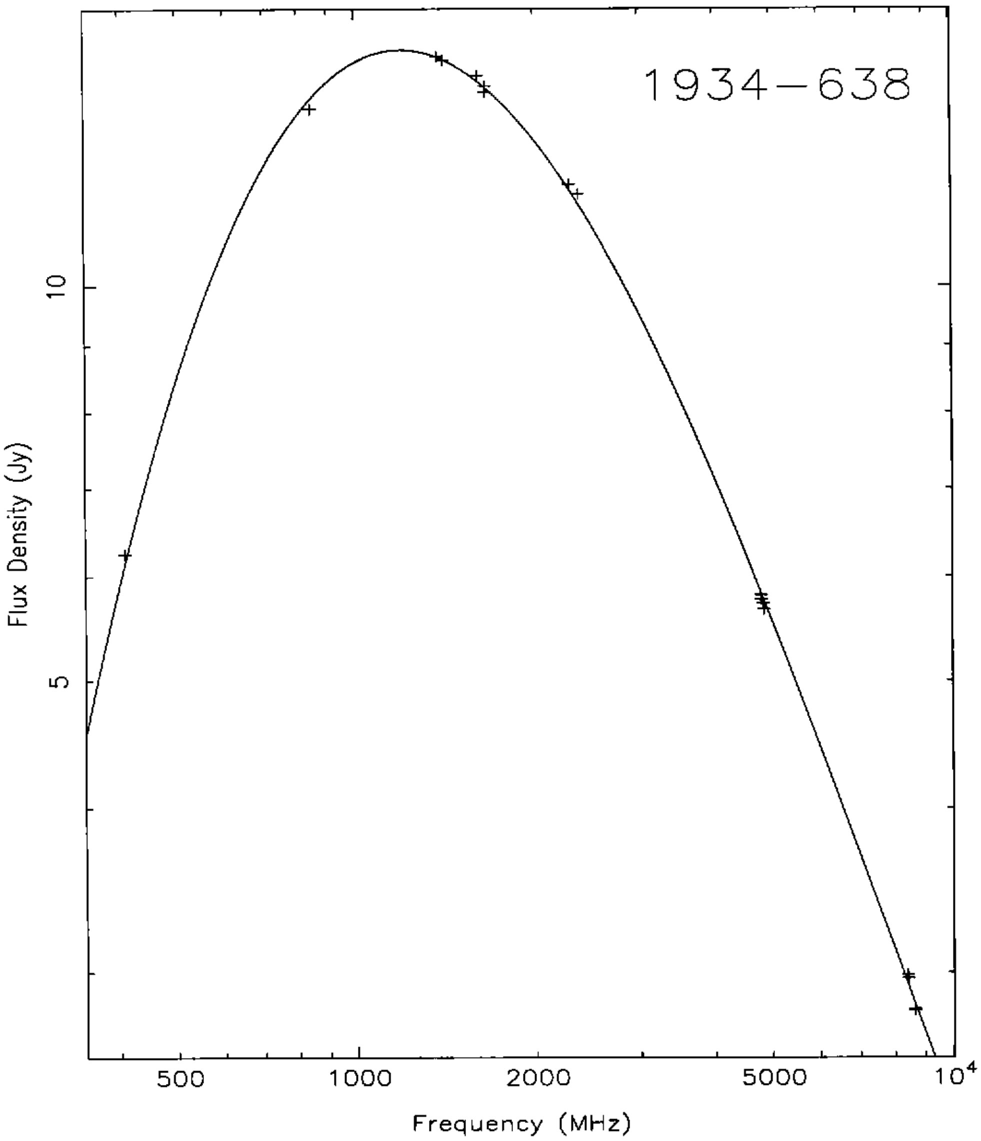

Figure 1: Flux density measurements of 1934–638, with 3rd order polynomial fit.

Conclusions

As the revised spectrum above differs substantially from that currently in use it follows that spectral indices calculated from existing ATCA observations may include significant errors. In the worst case, spectral indices computed between 4.8GHz and 8.6GHz are too steep by ~0.3 . It is therefore recommended that the above expression for the flux density for 1934–638 be implemented as soon as possible as the default in both the ATCA online calibration software (CACAL) and the standard reduction packages (AIPS and Miriad).

Although there is no evidence among the flux density measurements described here that 1934–638 is time-variable, it is intended to continue monitoring the source both with the ATCA and Parkes not only to check for variability but to improve the spectral sampling across the ATCA observing bands (e.g. 6.7GHz). An ATCA observing program (C280) is also underway to isolate additional compact Southern sources suitable for flux calibration, allowing the flux scale to be defined by a grid of calibration sources rather than relying solely on 1934–638.

Finally, it is worth pointing out that the emphasis of this analysis has been to reconcile the ATCA flux scale with those in use in the North, rather than define the spectrum of 1934–638 in an absolute sense. While the spectrum presented here is tied to the widely-used absolute spectrum of 3C286 and 3C295 defined by Baars *et al.*, more recently Gough (1994) has found evidence above 8GHz for a significantly greater absolute flux density for 1934–638 than the figures given here. This question may possibly be resolved by more accurate single-dish measurements of 1934–638 and Virgo A, for which latter source the absolute spectrum has been measured directly.

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