ATCA flux density scale at 12mm

R.J. Sault

7 December 2003

The flux of PKSB1934-638 at centimetre wavelengths has been well-studied by Reynolds (1994), and is in routine use as the primary flux density reference for the ATCA. This flux density is based on measurements between 408 and 8640 MHz. Reynolds represented the flux density variation as a polynomial with log-log form:

$$\log_{10}(S_{\mathrm{Jy}}) = -30.7667 + 26.4908x - 7.0977x^2 + 0.605334x^3$$

where $x = \log_{10}(\nu_{\mathrm{MHz}})$. With the installation of receivers at the ATCA which operate in the 16-25 GHz window, there is a clear need for a flux density scale in this band.

Planets have traditionally been used as the flux density scale in this band, with Mars and Jupiter being the most appropriate for the ATCA. The *MIRIAD* task `plboot` implements a technique to use planets as primaries for a flux density scale. *MIRIAD* assumes a uniform black body of given brightness temperature. The radio size of the planet's disk is taken as optical size: ephemerides are computed to determine the apparent size and orientation of the planetary spheroid on the sky. Given these, the expected visibility function can be computed.

For the brightness temperature of Mars, Muhleman & Berge (1991) use a value of 197 ± 6K at $\lambda = 2.66$ mm, and argue that the spectrum is very flat longwards of a few millimetres. The value of Janssen & Welch (1973) at 1.35 cm is 181 ± 11 K. Bryan Butler (personal communication Nov 2001) says the brightness temperature is 192 and 190 K at 8.64 and 4.8 GHz, and that there is some variation with the side facing the Earth. In the 12-mm band, *MIRIAD* has adopted a brightness temperature varying linearly between 189 and 194.3 K over the frequency range 15 to 31.4 GHz respectively.

For Jupiter, *MIRIAD* adopts the fit to the observations given by de Pater & Massie (1985).

Mars and Jupiter are inadequate primary flux density references in many instances:

- they can be resolved out by extended arrays (baselines greater than a few hundred metres at 12-mm wavelength). Mars and Jupiter are typically 4-25 and 30-48 arcseconds in diameter.

- their location on the ecliptic means that they are in the northern sky, and so the amount of time that they are above the horizon is more limited than a southern source such as 1934-638.
- shadowing of northern sources can be problematic in some compact configurations.

Observations of 1934-638 over a 6-month period, using Mars as a primary flux calibrator, have shown that 1934-638 appears to be constant at 12mm wavelengths, and so still suitable as a reference for the flux density scale. Figure 1 gives a plot of the flux density of 1934-638 measure as a function of frequency over the 6-month period. The data were measured as part of project C1225 and as special observations to determine the flux density of 1934-638. The bulk of the observations were performed on 11 and 15 November, when 1934-638 and Mars tracked similar elevations and when the ATCA was configured so that two baselines did not resolve out Mars. The observations on 11 November aimed at measuring the flux density at a large number of frequencies, with each frequency being sampled at only one or two elevations. Observations on 15 November concentrated on getting a more limited frequency sample (4 well-spaced frequencies), but with each frequency being re-measured at several elevations. The data measurements were corrected by a model of the atmospheric opacity on the nights.

Observations showed good consistency, although there was a small number of clearly discrepant or low sensitivity points discarded.

Figure 1 also shows a fit (a log-log form) to the data. An attempt was made to make a single log-log fit to both the low frequency data of Reynolds as well as the 12-mm data. However a suitable fit could not be made if we insist that the low frequency values for the fit must differ only by a small amount from that of Reynolds. To produce a fit at 12mm wavelength, rather than to change Reynolds polynomial, we have chosen to find a least-squares polynomial which is constrained to be piecewise continuous (in flux density and first derivative) to Reynolds polynomial. We set the breakpoint between the two polynomial fits at 10 GHz. The polynomial we find is

$$\log_{10}(S_{\mathrm{Jy}}) = -202.6259 + 149.7321x - 36.4943x^2 + 2.9372x^3$$

where $x = \log_{10}(\nu_{\mathrm{MHz}})$.

References

de Pater, I., Massie, S.T., 1985, "Models of the millimeter-centimeter spectra of the giant planets", Icarus, 62, 143

Janssen, M.A., Welch, W.J., 1973, "Mars and Jupiter: Radio Emission at 1.35 cm", Icarus, 18, 502

Muhleman, D.O., Berge, G.L., 1991, "Observations of Mars, Uranus, Neptune, Io, Europa, Ganymede, and Callisto at a wavelength of 2.66 mm", Icarus, 92, 263

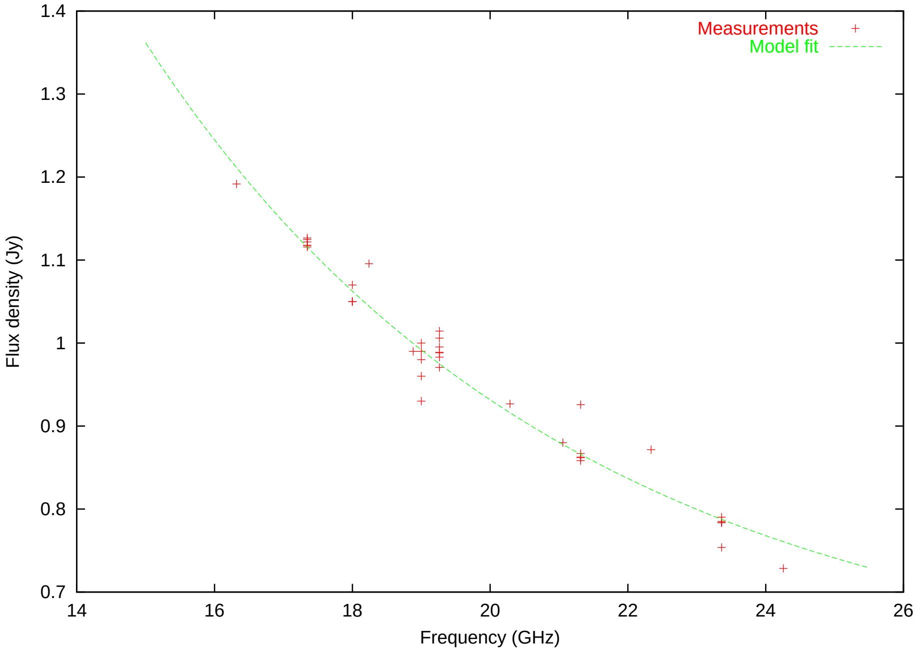

Figure 1: Measurements of the flux density of 1934-638 in the 12-mm band, together with a fit to the data.

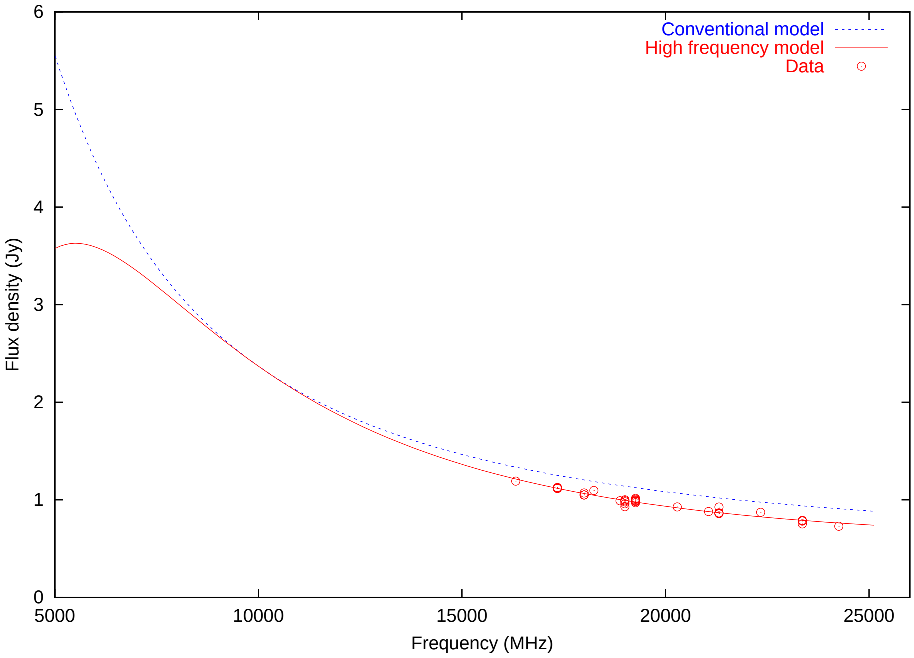

Figure 2: Comparison between low-frequency (Reynolds) and 12-mm fit to 1934-638 measurements. Note the osculatory contact at 10 GHz.

Reynolds, J.E., 1994, "A revised flux scale for the AT Compact Array", ATNF Memo AT/39.3/040 (http://www.atnf.csiro.au/observers/memos/d96783~1.pdf)

Rudy, D.J., Muhleman, D.O., Berge, G.L., Jakosky, B.M., Christensen, P.R., 1987, "Mars - VLA observations of the northern hemisphere and the north polar region at wavelengths of 2 and 6 cm"Icarus, 71, 159