Recalibrating the 3mm flux density scale using planets and asteroids

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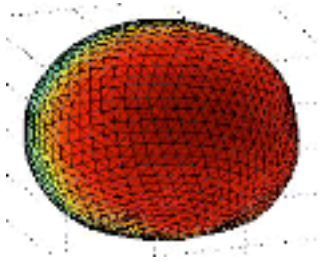
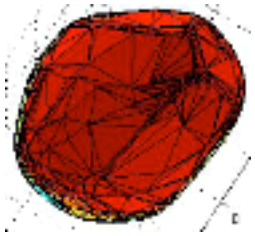




Thanks and disclaimer

Thank you ESA for inviting me!

My area is cm-submm observing and analysis — I don't make models! I defer to my colleagues on those questions.

Original Motivation

• Little known of asteroid emission properties at longer (λ > 1mm) wavelengths, including rotationally-resolved lightcurves

• Larger MBAs may have potential as extra calibrators at 3mm (eg for ATCA, other 3mm arrays), based on shorter-λ rotational uniformity

• Suggestion of Vesta's low emissivity from earlier 1mm work (Redman et al 1992), but Chamberlain et al (2007) obtained a 0.9mm lightcurve; and suggested Vesta's ThermoPhysical Model parameters could vary across the surface

• ThermoPhysical Model (TPM) is successful at submm/FIR (Lagerros 1998), however untested at longer $\lambda\lambda$

• Multiple sources observed in one transit would cut down on temporal or calibration variability: a good cross-calibration test!

Australia Telescope Compact Array

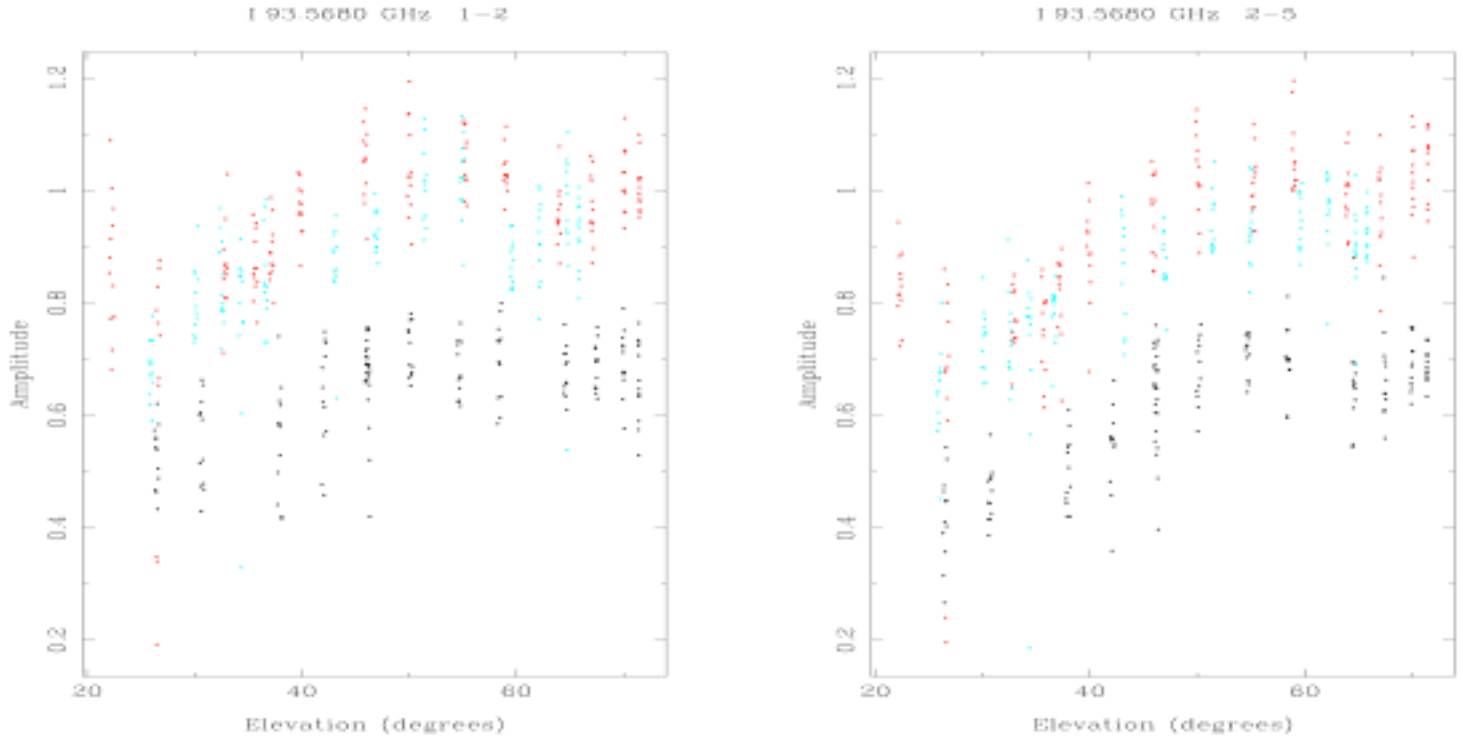
- 5 × 22m antennas
- 85–105 GHz dual-freq Rx *
- 2 × 128 MHz bw *
- baselines up to 300m, but phase stability a problem >200m

* Upgrades underway or planned, to 75–116 GHz MMICs and 2 GHz bw

Along the way, we discovered ATCA has a number of calibration issues, which we could nevertheless address:
— gain-elevation correction
— absolute flux scale

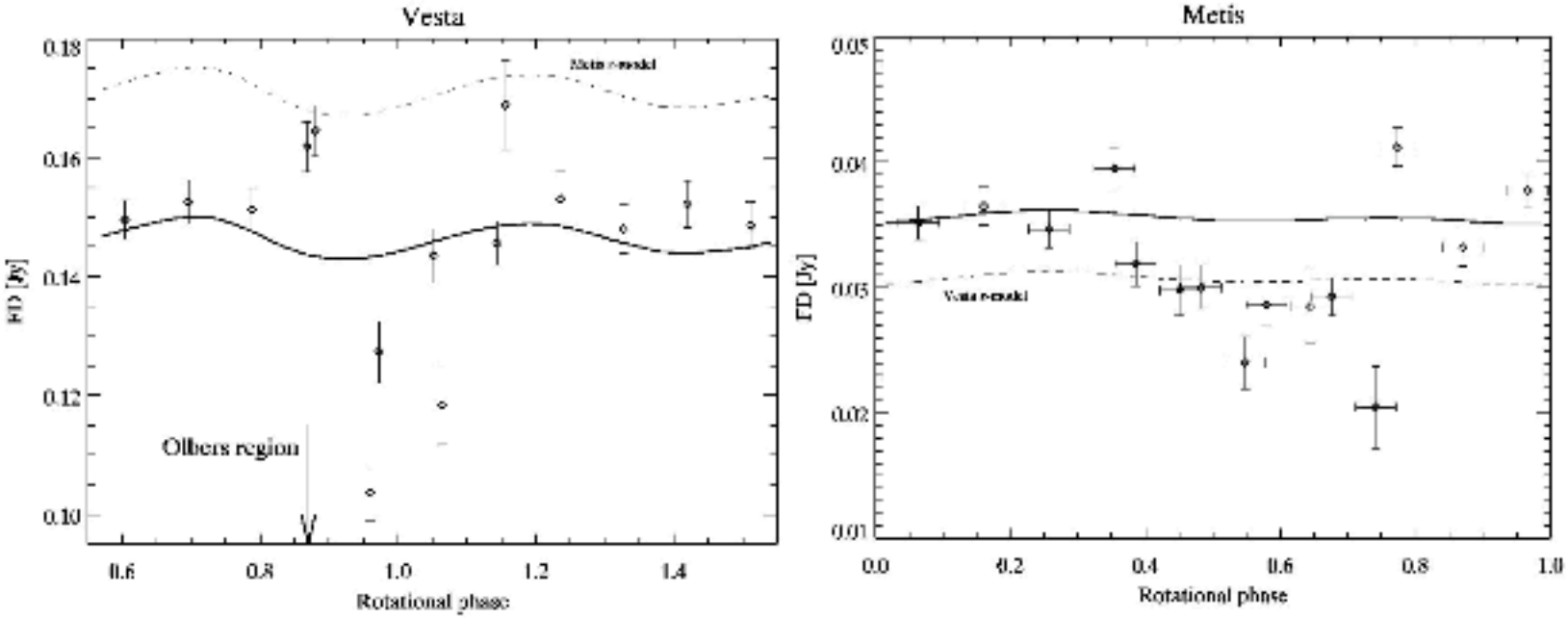
Calibration

ATCA antennas' gain-elevation dependence at 3mm not well-determined.



Can compensate for this by treating as a normal gain variation, but should really re-derive each antenna's GE curve.

Vesta & Metis in 2004



From Müller & Barnes (2004). Discovered that these can't make good calibrators at 3mm, since there is clear evidence of hemispherical variations in surface properties, probably grain size distribution.

Rotationally averaged at 94 GHz, V = 147.3±3.8 mJy, M = 33.5±1.0 mJy
Hints of spectral index variations too (93.0 & 95.5 GHz).

VM2004

Relative flux scale between V&M was determined to ~5%. Because of GE curve uncertainties, absolute flux was only obtained to ~11%, but this should be reducible to 5% too.

Variability seen in V&M was over >1 rotation, but not correlated with each other, so light curves seem good. TPM models strongly constrained by shape and other parameters; emissivity variations seem the only way to get this. This implies surface grainsize distributions change with position. Chamberlain et al (2007) approach seems unlikely. ***"Texture really does matter."***

Needs good 3mm weather though (low and slowly varying water vapour content above instrument). Then cross-calibration approach can give excellent (5%) results, taking out multi-epoch calibration or instrumental effects.

Planets & asteroids in 2007

Revisit ATCA for favourable conjunction of Mars, Uranus, Neptune, Ceres, & Pallas in mid-2007. This time we wanted to get a cross-calibration as accurately as possible, and solve for ATCA's gain-elevation correction.

Observed all 5 sources at 6 frequencies (and 2 polarisations): 85.056, 87.104, 93.504 95.552, 102.464, and 104.512 GHz (so 60 independent measurements), but only 10 unknowns, ie flux density S_0 at 100 GHz and spectral index α, for each body in

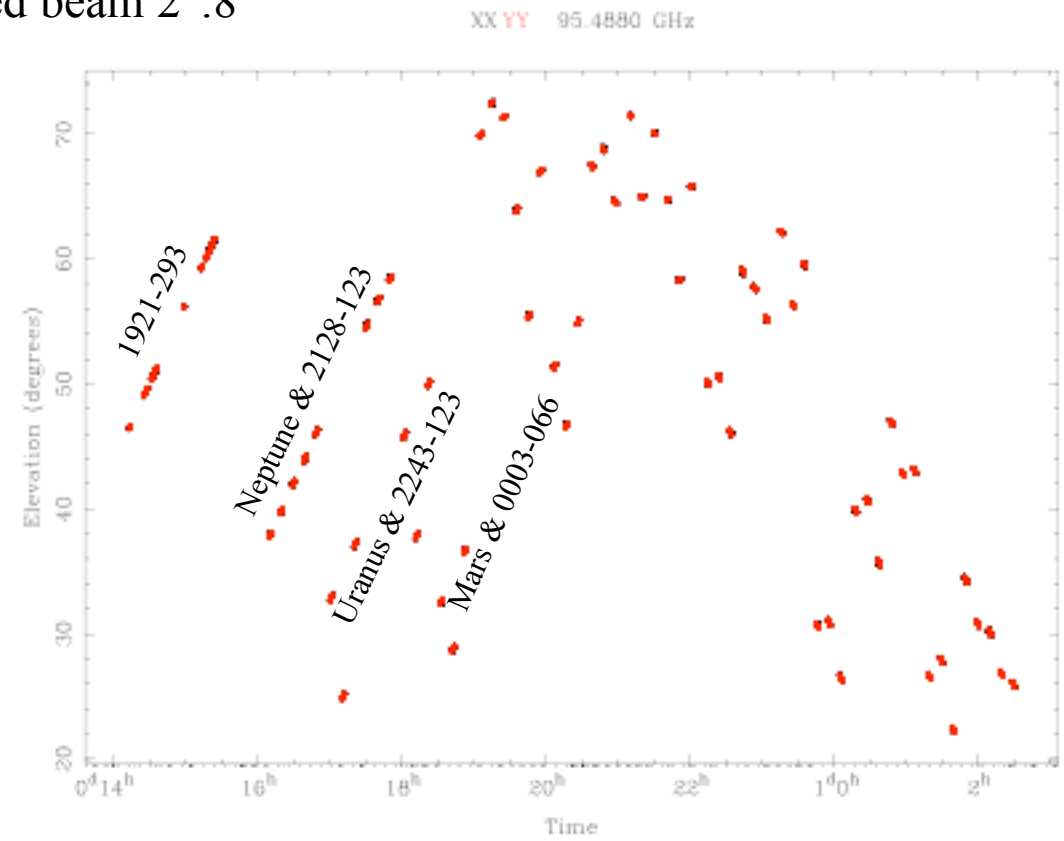
$$S_\nu = S_0 \, (\nu \, / 100 \text{ GHz})^\alpha$$

where S_ν is flux density at frequency ν. This gives the relative flux scale for all bodies, and then we fit an absolute flux scale by comparing to models (esp. for Uranus & Neptune).

For Ceres & Pallas, can do this ***at each point in time*** for constructing light-curves.

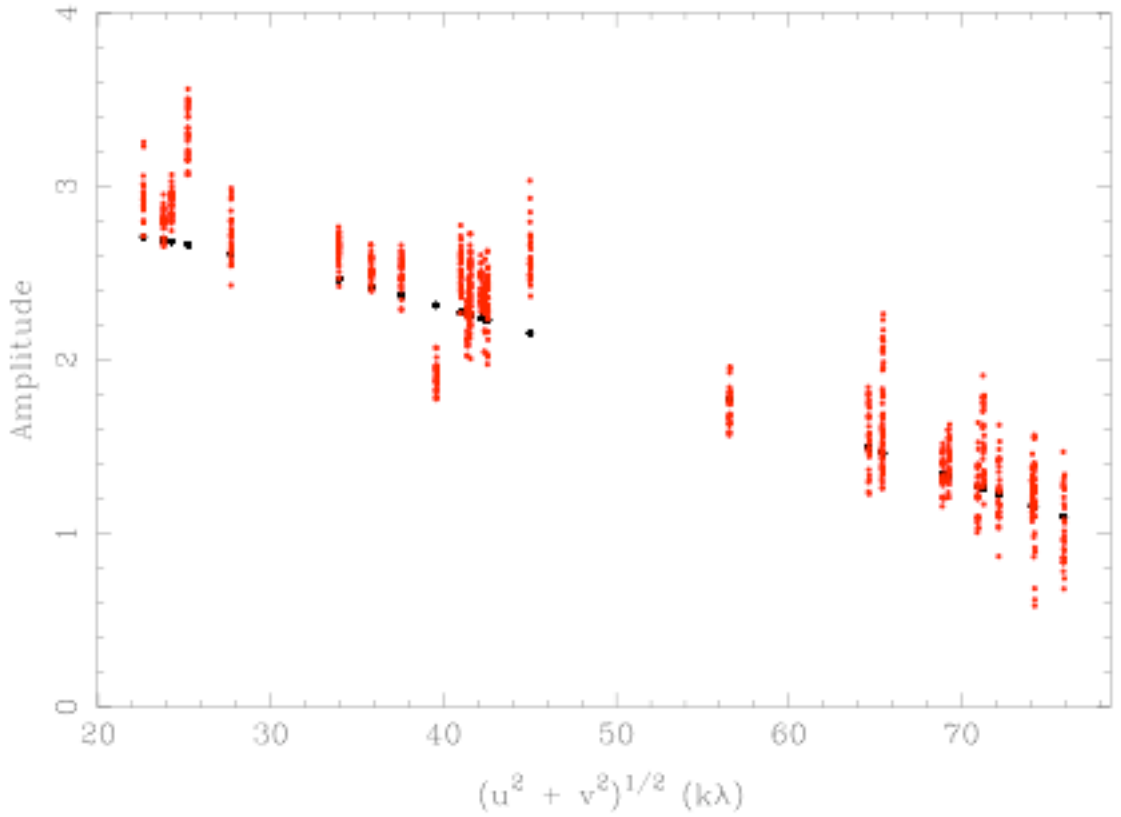
Calibration, part 2

Can still treat GE correction as a normal variation, but get indeterminate jumps in amplitude gain without a proper GE curve. Weather not as good as in 2004. Synthesised beam 2″.8



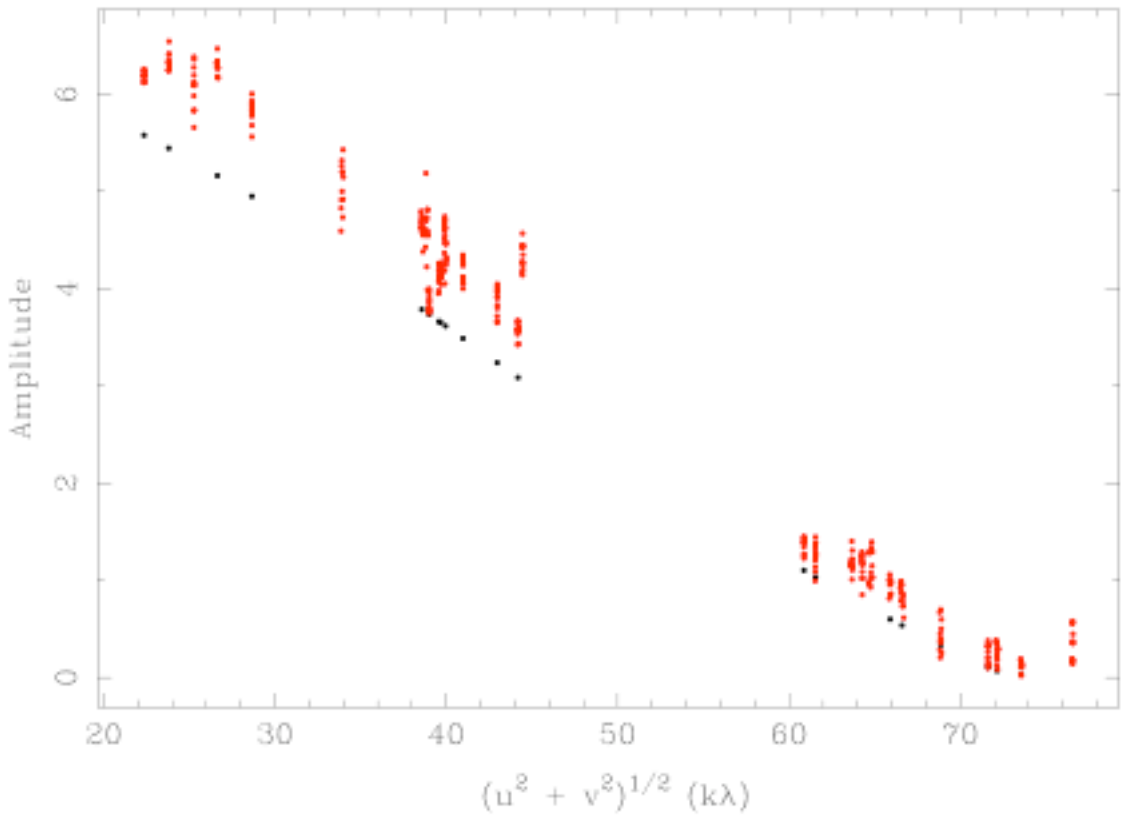
Neptune 2007

3/7 of calibrated data (when phases most stable), plus fit = 2.92 ± 0.04 Jy
Fitted disk = 2″.22 *cf* ephemeris 2″.28



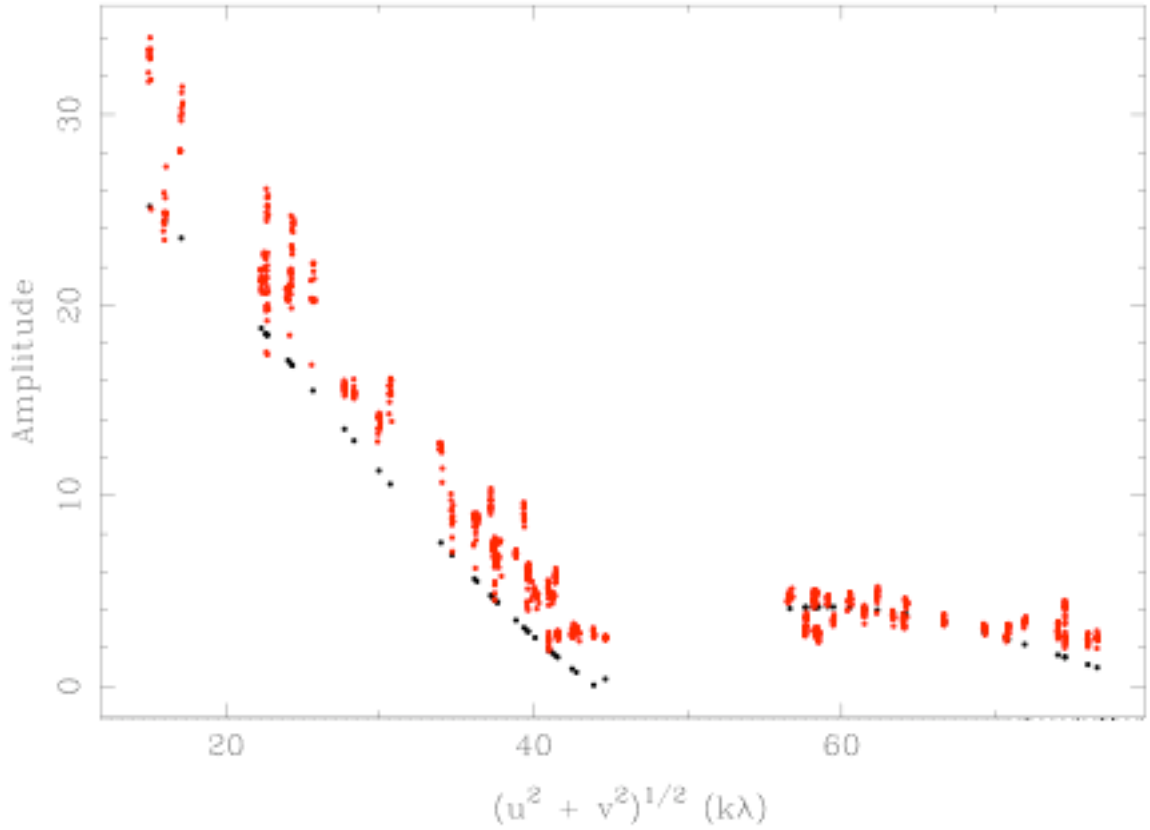
Uranus 2007

2/7 of calibrated data (when phases most stable), plus fit = 6.66 ± 0.15 Jy
Fitted disk = 3″.45 *cf* ephemeris 3″.46



Mars 2007

9/10 of calibrated data (except one baseline), plus fit = 31.48 ± 0.37 Jy.
Fitted disk = 5″.72 *cf* ephemeris 5″.60



Preliminary results

Miriad fitting routines obviously underfit amplitudes by ~10%: need to revise up. However the standard ATCA secondary calibrator is ~20% too bright: revise down? Analysis ongoing on exactly how to account for knowable telescope factors. So far:

	Model predictions	Ratio (D/M)
Mars at 93.5 GHz = 31.48 ± 0.37 Jy		
Uranus at 93.5 GHz = 6.66 ± 0.15 Jy	7.94 ± 0.67	0.84 ± 0.07
Neptune at 93.5 GHz = 2.92 ± 0.04 Jy	3.47 ± 0.29	0.84 ± 0.07

Flux ratios:

M/N = 10.78 ± 0.20		
U/N = 2.28 ± 0.06	2.29 ± 0.27	1.00 ± 0.12

So planet models seem to be pretty good at 3mm.

Future work

Complete analysis for other 5 frequencies.

ATCA backend upgrade to 2 GHz: 8 times better! Can do more asteroids, faster, more reliably.

I am now accepting job offers to pursue these matters. All reasonable offers will be considered!

Pallas too

Phases poor on second day.