

Calibration of Galactic HI Spectra Using the GBT Spectrometer VEGAS

Felix J. Lockman (NRAO, Green Bank) and Kevin Harrington (UMASS, Amherst)

21 July 2015

SUMMARY: *Galactic HI spectra measured with the new GBT spectrometer VEGAS, in the mode most commonly used for this type of work, are in good agreement with spectra in the same directions measured with the old GBT spectrometer. The L band noise calibration appears to be unchanged over at least the last five years.*

The GBT is regularly used for measurements of the 21cm line from the Milky Way, and as there is HI emission in all directions of the sky, the accuracy of the data may be limited by stray radiation as well as the more usual issues in calibration. After an extensive investigation, Boothroyd et al (2011; hereafter B11) derived the all-sky response of the GBT's L-band receiving system at 1420 MHz, making it possible to use the GBT for absolutely-calibrated 21cm HI measurements corrected for stray radiation with unprecedented accuracy. The B11 calibration is in regular use for projects ranging from studies of the Galactic ISM (Wakker et al 2011, Fox et al 2015) to removal of foregrounds for Planck investigations of the cosmic infrared background (Planck Collaboration, 2011, 2014).

Now that the spectrometer has been replaced by VEGAS, it is of interest to determine if anything in the calibration procedure described in B11 has changed. As B11 also derived a correction to the nominal antenna temperature scale of the GBT at L band, and it is of interest as well to check whether the noise calibration has remained constant over the five years since the last of the B11 data were taken.

Under GBT proposal 15A_499, we observed eight widely-separated directions towards background AGN whose foreground HI was measured on the GBT by Wakker, Lockman & Brown (2011; hereafter WLB11) and reduced and calibrated following B11. The calibration direction S6 was also observed. The observations were made during the afternoon of 3 July 2015. All the directions were observed for two minutes with a fixed value of the frequency-switch offset, then the offset was changed and the set of directions was re-observed. The directions spanned elevations 24° - 74° and azimuth 81° - 330° . Most directions were observed three times with frequency switching intervals ± 2.0 , ± 1.75 and ± 1.5 MHz. The configuration file used for the ± 2.0 MHz setup is attached.

Each scan was reduced separately, calibrated and corrected for stray radiation as described in B11, and a cubic polynomial was removed from emission-free regions of the spectra. A slight difference was found in the antenna temperature scale between the polarizations 0 and 1: $T(0)/T(1) = 1.023 \pm 0.022$, but the B11 calibration assumes that both linear polarizations are averaged.

After averaging the two polarizations, the spectra were used to calculate a hydrogen column density following WLB11. The ratio of the resulting column densities is

$$\text{VEGAS/Spectrometer} = 1.012 \pm 0.032$$

where the error is one standard deviation. Results for the three different frequency-switched intervals were, on average, identical to better than 1%. Old and new HI spectra toward PG1001+291, a direction of low HI intensity where systematic effects would be expected to be most extreme, are shown in Figure 1. The small differences are consistent with baseline fitting errors and uncertainties in the stray radiation correction at low velocity.

We conclude that VEGAS produces 21cm HI spectra essentially identical to those from the old GBT spectrometer.

REFERENCES

- Boothroyd, A.I., Blagrove, K., Lockman, F.J., Martin, P.G., Pinheiro-Goncalves, D., Srikanth, S. 2011, A&A, 536, 81*
- Fox, A., Bordoloi, R., Savage, B.D., et al. 2015, ApJ, 799, 7*
- Planck Collaboration: Ade, P.A., Aghanim, N., Arnaud, M. et al, 2011, A&A, 536, 18*
- Planck Collaboration: Ade, P.A., Aghanim, N., Arnaud, M. et al, 2014 A&A, 571, 30*
- Wakker, B.P., Lockman, F.J., Brown, J.M 2011, ApJ, 728, 159*

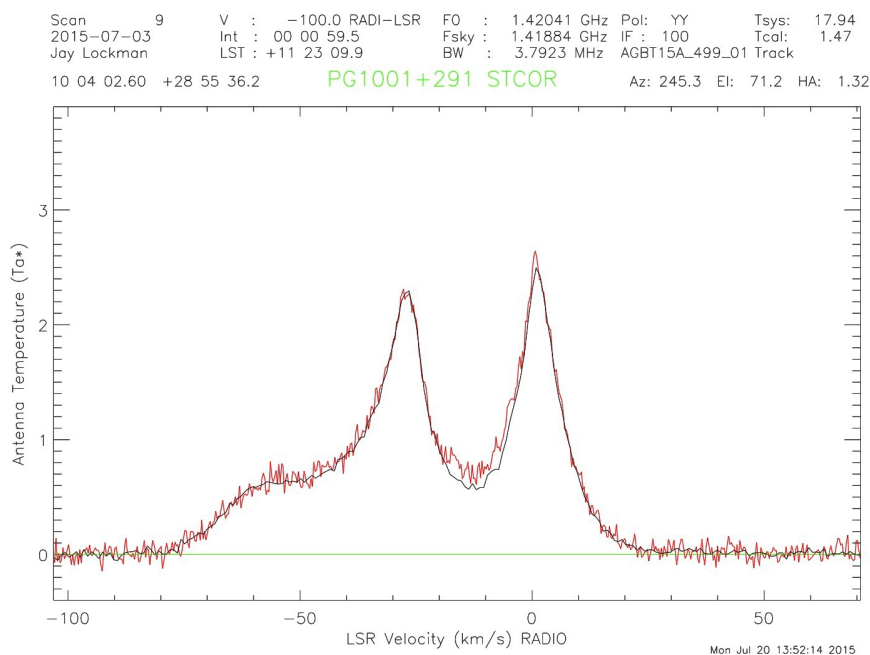


Figure 1: 21cm HI spectra toward PG1001+291 taken with the old GBT spectrometer (black) and VEGAS (red) reduced as described in B11. The spectra are identical to within the known uncertainties.

APPENDIX: the VEGAS configuration used for the tests

```
Configure("""  
receiver      = 'Rcvr1_2'  
obstype       = 'Spectroscopy'  
backend       = 'VEGAS'  
nwin          = 1  
restfreq     = 1420.4058  
deltafreq    = 0.0  
bandwidth    = 23.44  
vegas.subband = 8  
swmode       = "sp"  
swtype       = "fsw"  
swper        = 1.0  
swfreq       = -2.0,2.0  ## this was varied  
tint         = 20.0  
vlow         = 0  
vhigh        = 0  
vframe       = "lsrk"  
vdef         = "Radio"  
noisecal     = "lo"  
pol          = "Linear"  
nchan        = "medium-high"  
""")
```

Balance()