ALFA/NGC2903 Memo 041129: On the rotation and sidelobes of ALFA (with Addendum dated 041206)

A1963 November Team (R. Giovanelli, M. Haynes, M. Putman, B. Catinella)

On Nov 28, observations started for the NGC2903 precursor proposal, A1963. At the end of the first night, a 20 minute segment of time was reserved for a simple experiment devised to test the accuracy of the ALFA feed rotation angle. We thus rotated the feed at the expected angle that would yield groups of beams drifting at the same declination. The three groups were beams 2, 0 and 5 at one dec, beams 3, 4 at a dec 5' to the N, beams 1, 6 at 5' to the S. The drifts lasted 120 sec, time sampling of 1 record per second, with the source 1021+219 (S=1.686 Jy) transiting at record 60 of the drift for beam 0. Five sets of drifts were obtained:

- drift 1 has beams 2, 0 and 5 going through the source; source seen in sidelobes of 3, 4 and sidelobes of 1, 6 as well
- drift 2 has beams 1, 6 going through the source; source seen in sidelobes of 2, 0 and 5 as well
- drift 3 has beams 3, 4 going through the source; source seen in sidelobes of 2, 0 and 5 as well
- drift 4 has source drifting between tracks of group (2, 0, 5) and group (1, 6)
- drift 5 has source drifting between tracks of group (2, 0, 5) and group (3, 4)

A 1 sec ON, 1 sec OFF cal scans were run after each drift. One can easily see that, if the rotation angle of the array were incorrect, the flux ratios measured for beams 2 and 5 (preceding and following beam 0) for the source would be different between drifts 1, 4 and 5, while with a well aligned array, those flux ratios would be the same for the 3 drifts. If, for example, beam 2 were drifting at a Dec slightly higher than beam 0 (and beam 5 therefore slightly lower), the ratio of measured fluxes between beam 2 and beam 5 would be higher in drift 5, intermediate in drift 1 and lower in drift 4. In spite of the coarse Dec sampling, the test is quite sensitive to even small rotation angle errors.

After logging in at AO, you can access the FITS files with the raw data at

/share/pserverf.sda3/wappdata,

files wapp.20041128.a1963.0011.fits to wapp.20041128.a1963.0015.fits. Other A1963 data files can be easily identified by searching for "A1963" embedded in the file names. IDL save files containing the same data in IDL drift structure format (after conversion with a current version of *filecreator*; the late September 04 version had a bug; for instructions on data conversion see the A1946 website) are in

/share/ngc2903/data/work

files 433323612.sav, 433323733CAL.sav, 433323736CAL.sav for drift 1, 433323854.sav, 433323976CAL.sav, 433323979CAL.sav for drift 2, 433324096.sav, 433324218CAL.sav, 433324221CAL.sav for drift 3, 433324340.sav, 433324462CAL.sav, 433324465CAL.sav for drift 4, 433324583.sav, 433324705CAL.sav, 433324708CAL.sav for drift 5.

Simple IDL procedures were written on the fly to process the data. You can find them in

/share/ngc2903/data/work/idlpro

They are *cal.pro, scalcont.pro* and *plot1021+219.pro.* The total power was estimated averaging the power over spectral channels 200 to 1500. The bandpass was 12.5 MHz wide for the 2048 channels (same as for the spectral line observations; we had no time to reset the IF/LO after ending the NGC2903 drifts). Cal values as listed in *cal.pro* were used to convert wapp counts to power units (K), as shown in the plots enclosed within this memo. Postscript files of the plots and this memo can be found in

/share/ngc2903/datawork/docs/drift1.ps to *drift5.ps*

The figures 1–5 show the total power for the continuum drifts 1 through 5. Polarization channels are averaged. Figure 1 shows drift 1, with the tracings of beam 0, 2 and 5 going through the center. Dividing the peak deflections by the source flux (1.686 Jy) yields the beam gain, in K/Jy. That of course assumes that (a) the source flux is accurate, (b) the source went exactly through the center of the three beams (2, 0 and 5), and (c) that the cal values in K are accurate: OK to first order, but for the moment DSSS (don't sweat the small stuff). The values obtained, 11.3 K/Jy for beam 0, 8.4 K/Jy for beam 2 and 8.7 K/Jy for beam 5, are not too far off the design mark. Below the tracings of beams 2, 0 and 5, the power detected by beams 1, 6, after multiplying the amplitude by a factor 5 and offsetting by 8 K, are shown. Above, are the tracings of beams 3 and 4, also blown up by a factor 5 and offset by +20 K. The sidelobes of beam 0 are mild (about 16 dB down) and symmetrical. You can see the awful sidelobes of the outer beams (preceding for beam 2, following for beam 5), which for beams 2 and 5 rise to about 8 dB, or about 1/6 of the main beam peak response. Since the half-circle sidelobe covers about 4 times as large a solid angle as the main beam, the potential severity of sidelobe contamination in mapping experiments such as this one is easily illustrated: if main beam and sidelobe were aiming at a region of uniform emission, nearly half of the detected photons would originate in the region covered by the sidelobe, more than 5' away from the position the main beam aims at.

Figure 2 shows the transits of the source through beams 1 and 6. Gains of 9.0 and 9.6 K/Jy are obtained for those. The source is barely detected by beams 2, 0 and 5. Figure 3 shows the transits of the source through beams 3 and 4. Gains of 8.2 and 7.4 K/Jy are obtained. The difference in the inferred gains for the N group of beams and the S group is interesting; is the separation in Dec. of the beams not exactly that expected from the model that provides beam positions, in which case a slight Dec. pointing error results in the apparent gain difference? Or are the cal values systematically off, in the N-S comparison? Is the effect caused or compounded by coma distortion of the main beam of the outer lobes? More clearly arguable, notice that beams 2, 0 and 5 detect the source much more strongly than in figure 2. The easiest explanation for this effect is that of a pointing error. An accurate estimate of the pointing error, using these data, would require a good knowledge of the outer lobe structure of the beams, which we still lack, but are geared to obtain in later parts of A1963.

Figure 4 shows the transit of the source between the group of beams (2, 0, 5) and that of (1, 6). The scale for beams 2, 0 and 5 is now the same as for beams 1 and 6. Note that beam 5 detects the source much more strongly than beam 2. Note also that the response of the main beam — which only grazed the source — is comparable with that of the sidelobe.

Figure 5 shows the transit of the source between the group of beams (2, 0, 5) and that of (3, 4). The display scale for beams 2, 0 and 5 is now the same as for beams 3 and 4. Note that beam 5 detects the source much more weakly than beam 2, the opposite of what's found in Figure 4. The simplest explanation for such an effect is that the rotation angle of the array has not placed beams (2, 0, 5) along a line of constant Dec., as intended. An error of about 2.5° in the array position angle is needed to explain the effect. The effect is compounded by a possible pointing error (the pointing error in R.A., as gauged from the transit time of beam 0 in drift 1, is quite small). A rotation angle offset also explains the change in the flux ratios between beams 3 and 4, respectively from drifts 3 to 5, and between beams 1 and 6, respectively from drifts 2 to 4.

The flux ratios of pairs of beams in different drifts are consistent with a combined Dec pointing error (pointing S) and an error in the rotation angle of 2.5°. Other explanations can be concocted, and the "problem" may be significantly less severe at other configurations (pointing errors were estimated during A1946 at several AZ, ZA combinations; they were usually smaller than 8"). This exercise illustrates the variance from the ideal behavior that could be expected in normal ALFA operating conditions, and thus is a useful aid in estimating how mapping observations could be impacted. This memo presents very preliminary results; its purpose is to make team members aware of A1963 data sets, activities and to facilitate their access and participation.

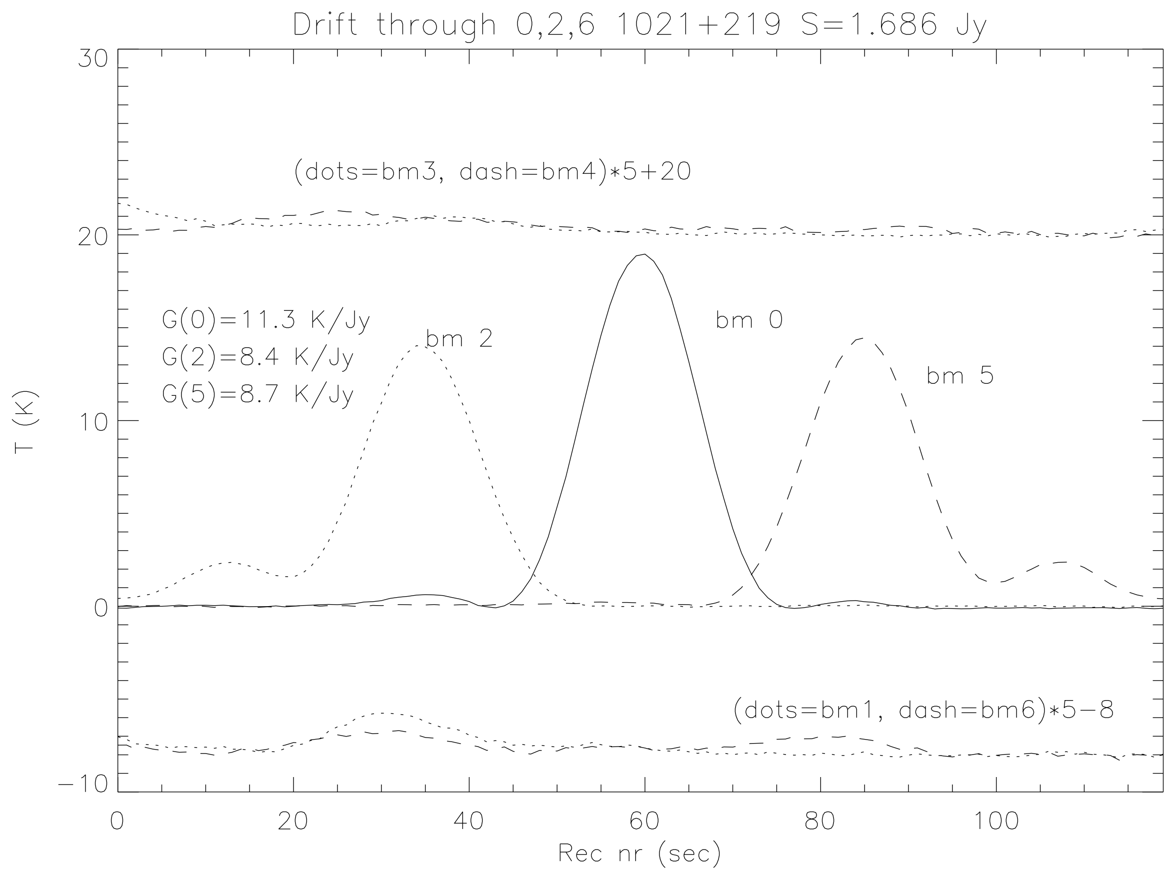

Fig. 1.— Drift 1: continuum power with source 1021+219 going through beams 2, 0 and 5. Tracings for the N group (beams 3 and 4) and fro the S group (beams 1 and 6) were blown up by a factor 5 and offset for overplotting.

Addendum on December 6, 2004: Confirmation Observations.

In order to confirm the effect reported last week, on the morning of Dec 7, a brief set of observations were made, in an analogous mode to those described earlier, i.e, in fixed azimuth drift mode. To further simplify the exercise and to avoid any ambiguities related to parallactic angle, all observations were made at the meridian, i.e AZ=180° and the ALFA rotation angle was set at the nominal location of 0°.

Drifts of 240 seconds duration were taken. The first was scheduled so that the radio source 1051+213 (S=1.253 Jy) would cross through the center of the beams 2, 0 and 5. Continuum data of that transit are shown in Figure 6. The second was scheduled with beam 0 pointing 1' to the South of the Dec. of the source 1103+220 (S=0.519 Jy), so that the source would cross between the set of beams (2, 0, 5) and the set of beams (3, 4). That transit is shown in Figure 7. The third

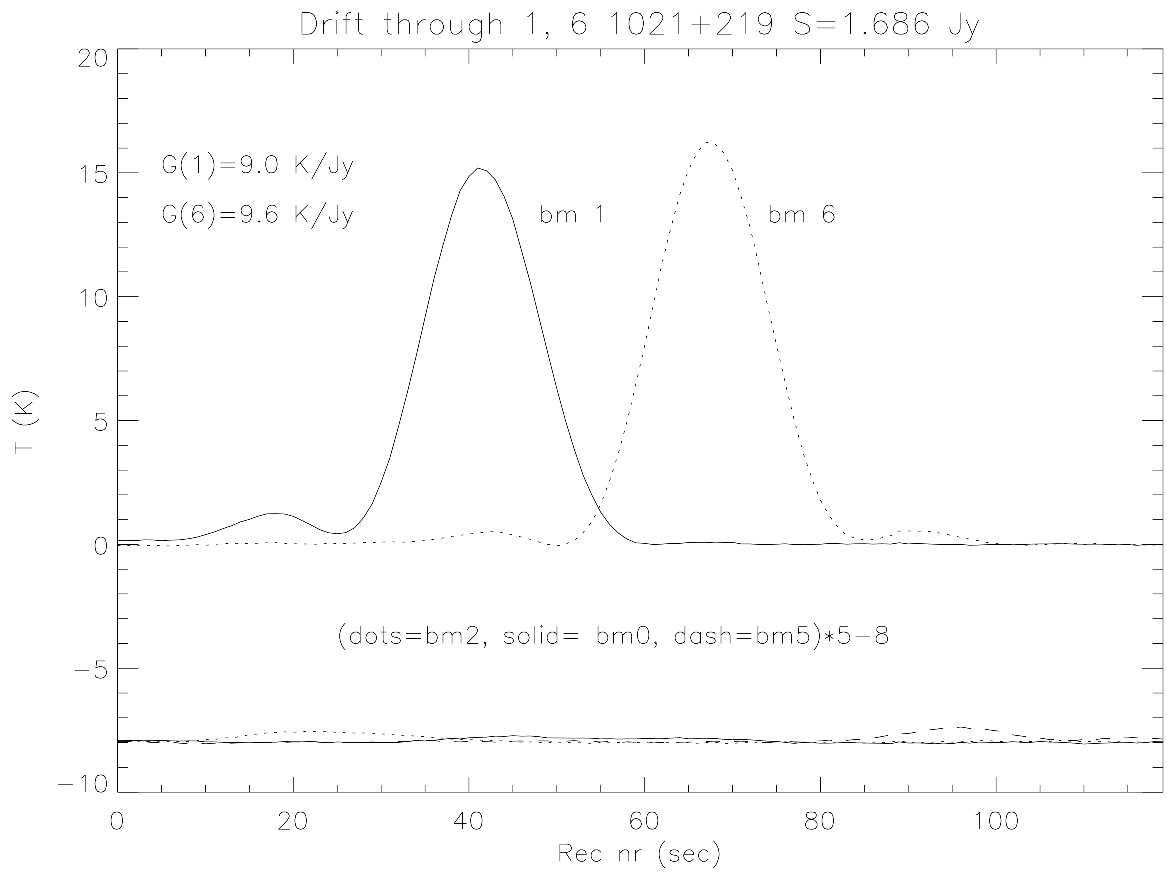

Fig. 2.— Drift 2: continuum power with source 1021+219 going through beams 1 and 6. Tracings for the center group (beams 2, 0 and 5) were blown up by a factor 5 and offset for overplotting.

drift was scheduled with beam 0 pointing 1' to the North of the Dec. of the radio source 1120+234 (S=1.362 Jy), so that the source would cross between the set of beams (2, 0, 5) and the set of beams (1, 6). The transit is shown in Figure 8.

All transits through beam 0 took place between 1 and 1.5 sec early, indicating an AZ pointing error which at the Decs. of the sources translates into about 15" to 20" in R.A. The ratio of detected powers between beams 2 and 5 reverses between Figures 7 and 8. The amplitude of the change is consistent with a Declination offset between the two beams of a bit over 15". Interpreted as an ALFA rotation angle offset, this translates into about 1.5°, in the sense that the current nominal setting of rotation angle = 0° places feed 2 to the North of feed 5, at AZ = 180°. The "real" rotation angle of zero (that which aligns beams 2, 0 and 5 in Dec.) would then occur at the current, nominal angle setting of +1.5°.

This result is more reliable than that obtained earlier in the week, as the peripheral drifts (figures 4 and 5) were farther from the center of beams 0, 2 and 5, where the beam structure would

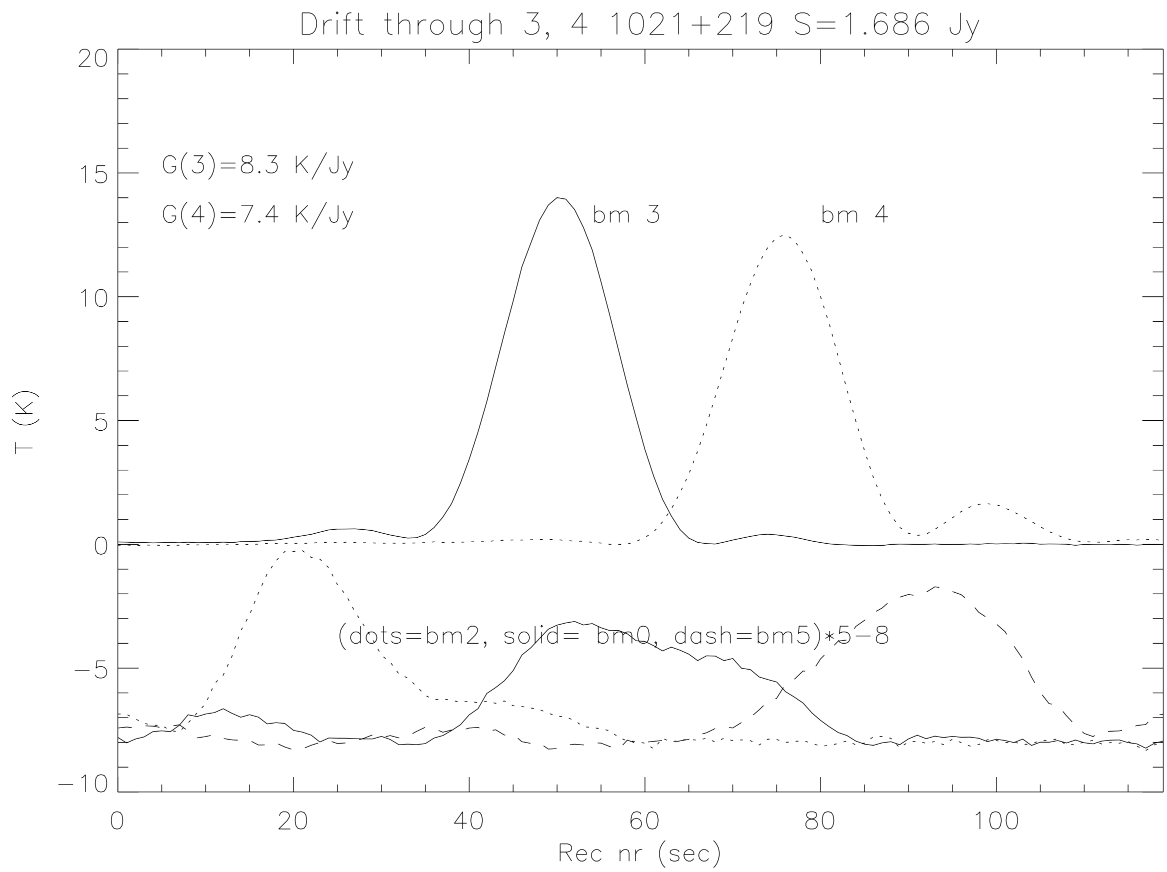

Fig. 3.— Drift 3: continuum power with source 1021+219 going through beams 3 and 4. Tracings for the center group (beams 2, 0 and 5) were blown up by a factor 5 and offset for overplotting.

be more affected by distortions.

This result is being discussed with experienced AO staff, for corroboration.

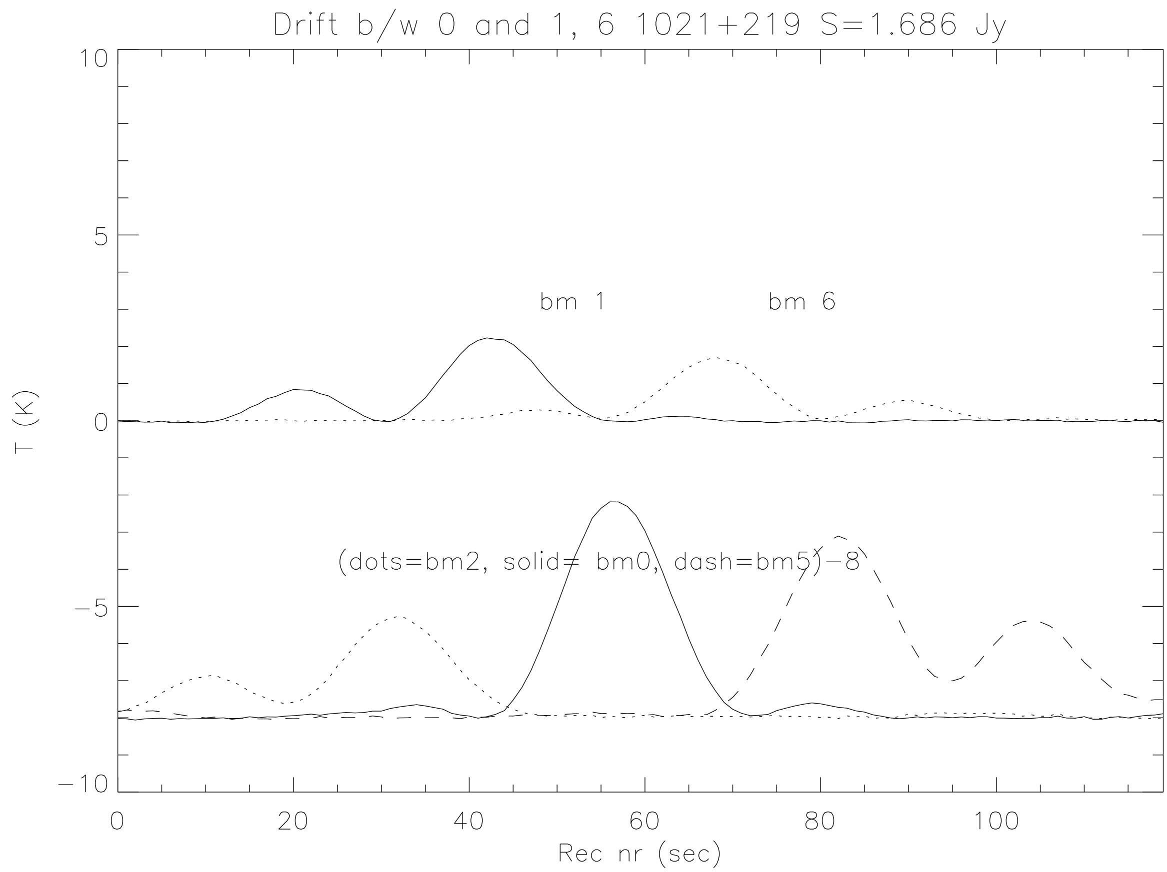

Fig. 4.— Drift 4: continuum power with source 1021+219 going between beam group (2, 0, 5) and group (1, 6). Tracings for the center group (beams 2, 0 and 5) were offset for overplotting. In this drift the source runs only 2' 10" from the nominal center group of beams, and 2' 50" from the outer one.

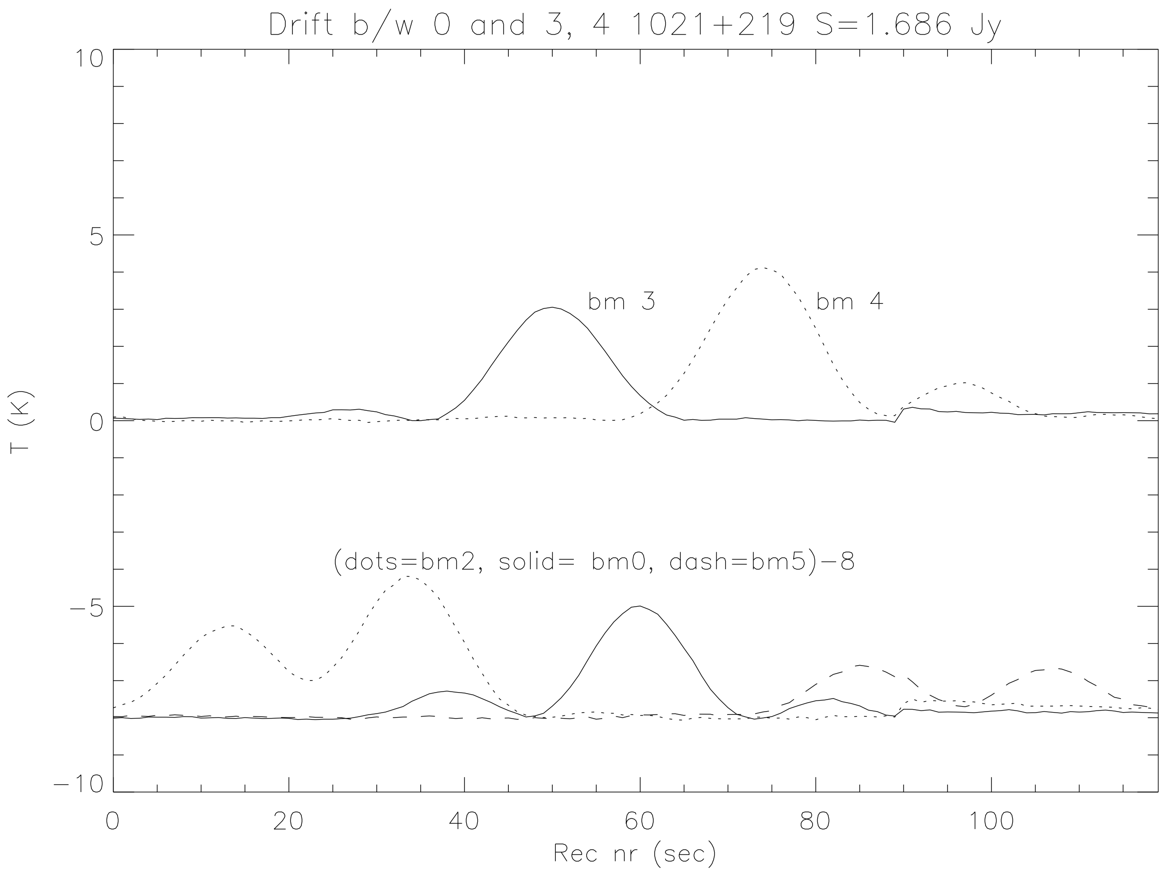

Fig. 5.— Drift 5: continuum power with source 1021+219 going between beam group (2, 0, 5) and group (3, 4). Tracings for the center group (beams 2, 0 and 5) were offset for overplotting. In this drift the source runs 2' 30" from the nominal center group of beams, and 2' 30" from the outer one.

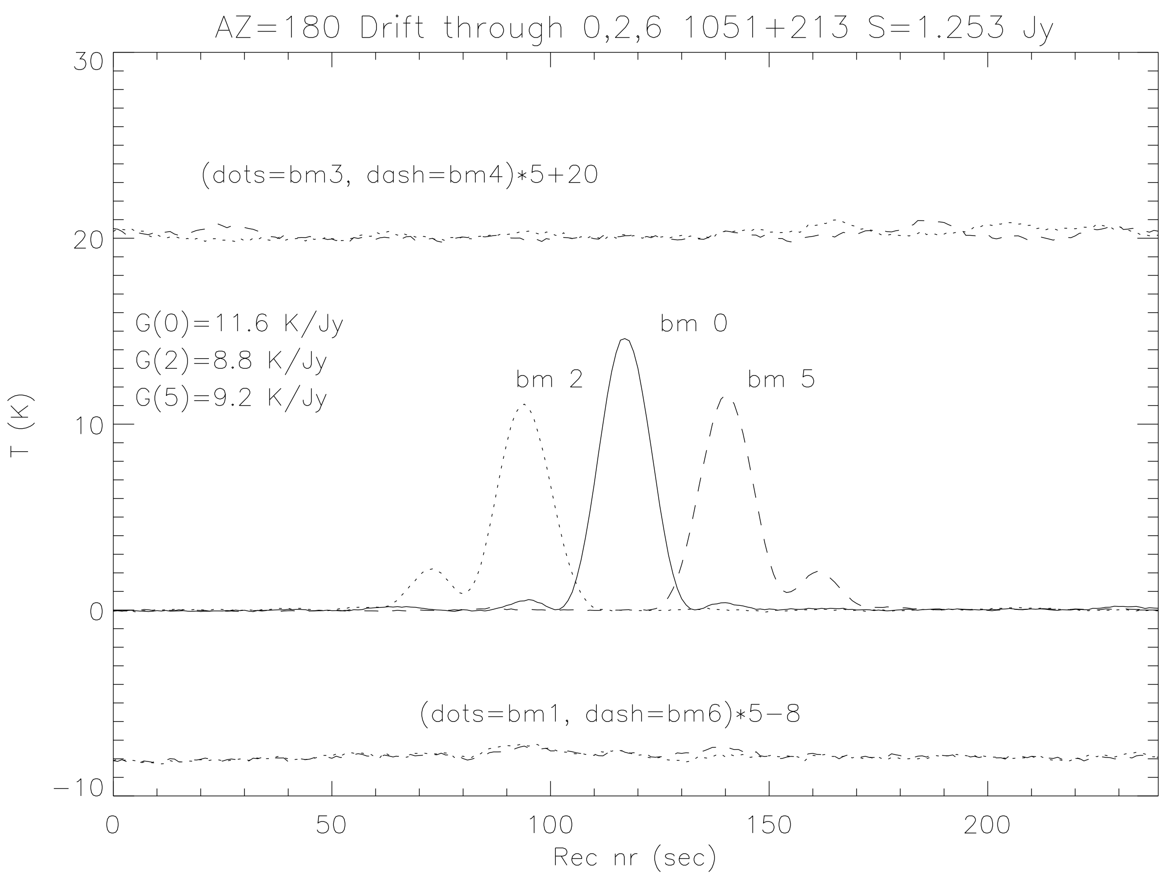

Fig. 6.— Drift 6: continuum power with source 1051+213 nominally going through the centers of beam group (2, 0, 5) and group, at AZ=180°. Tracings for the outer groups of beams were offset for overplotting.

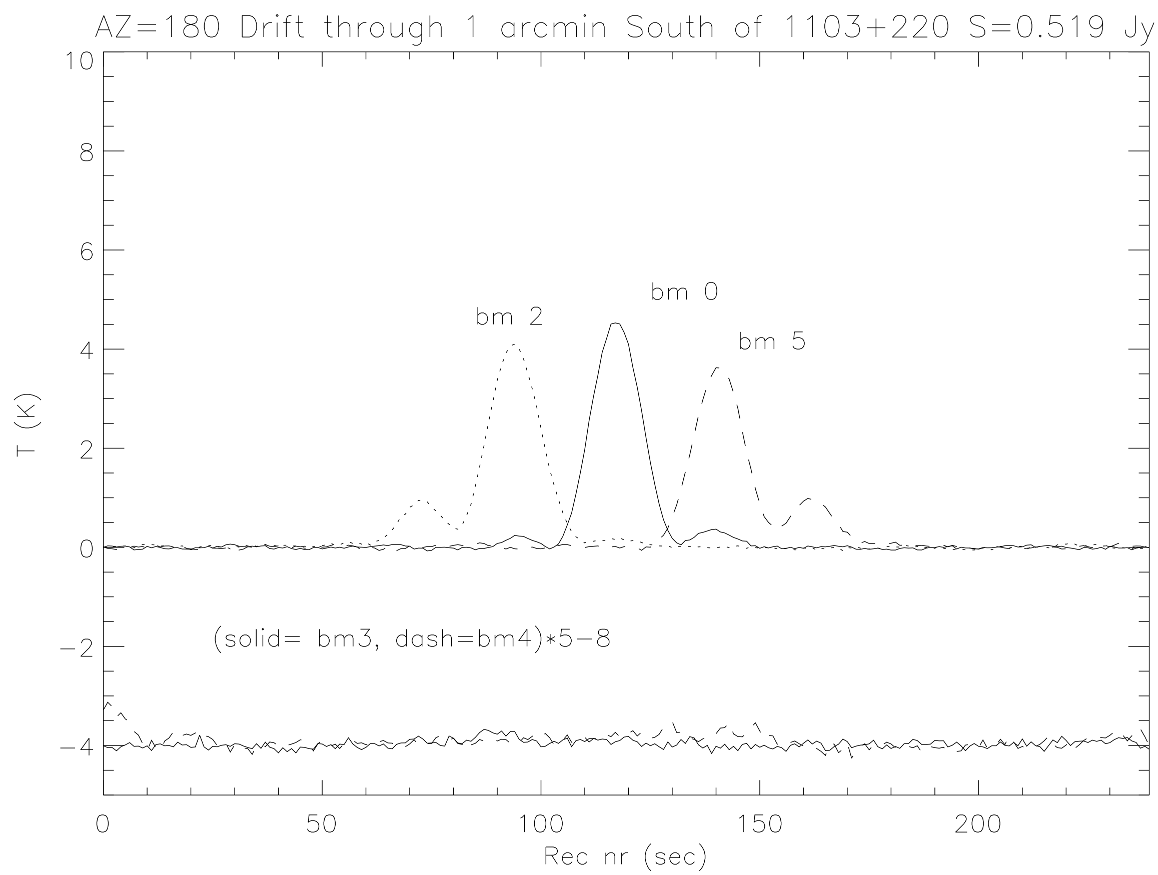

Fig. 7.— Drift 7: continuum power with source 1103+220 going between beam group (2, 0, 5) and group (3, 4) at AZ=180°. In this drift the source runs 1' from the nominal center group of beams.

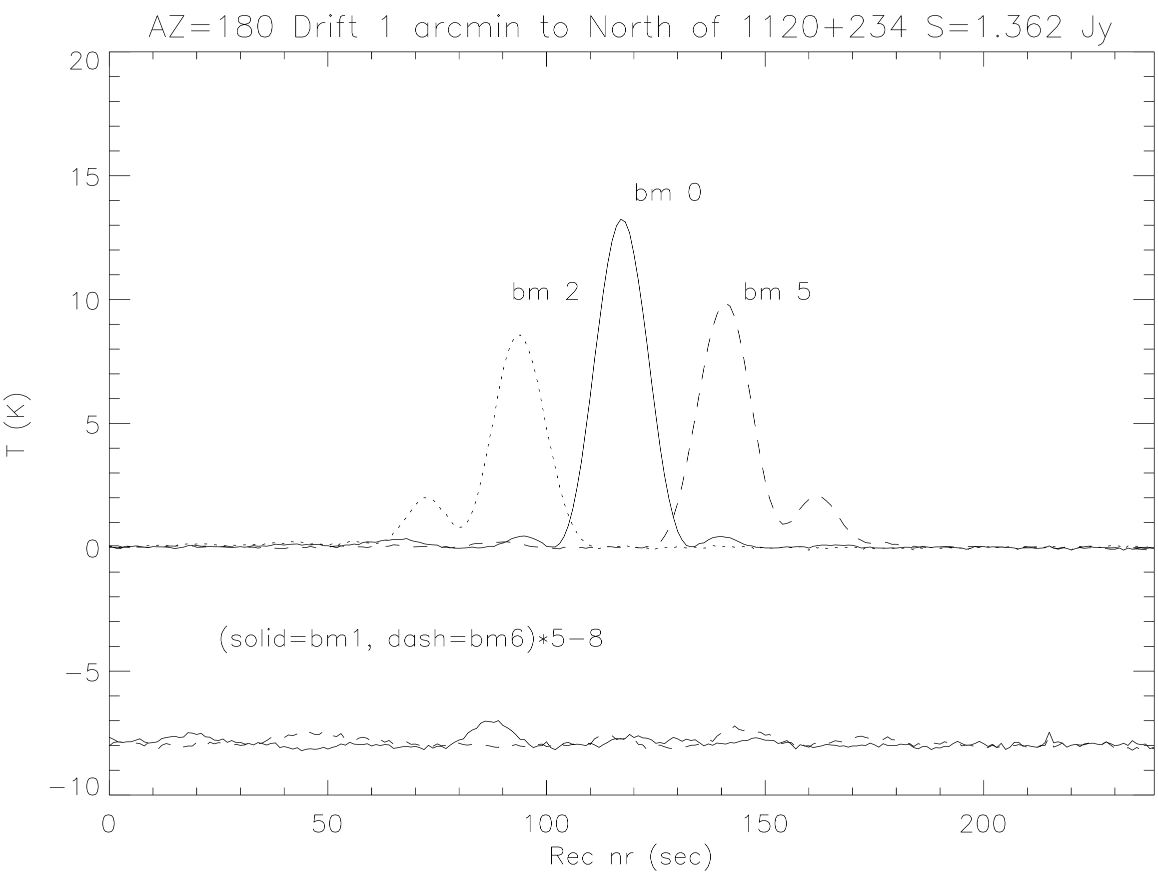

Fig. 8.— Drift 8: continuum power with source 1120+234 going between beam group (2, 0, 5) and group (1, 6) at AZ=180°. In this drift the source runs 1' from the nominal center group of beams.