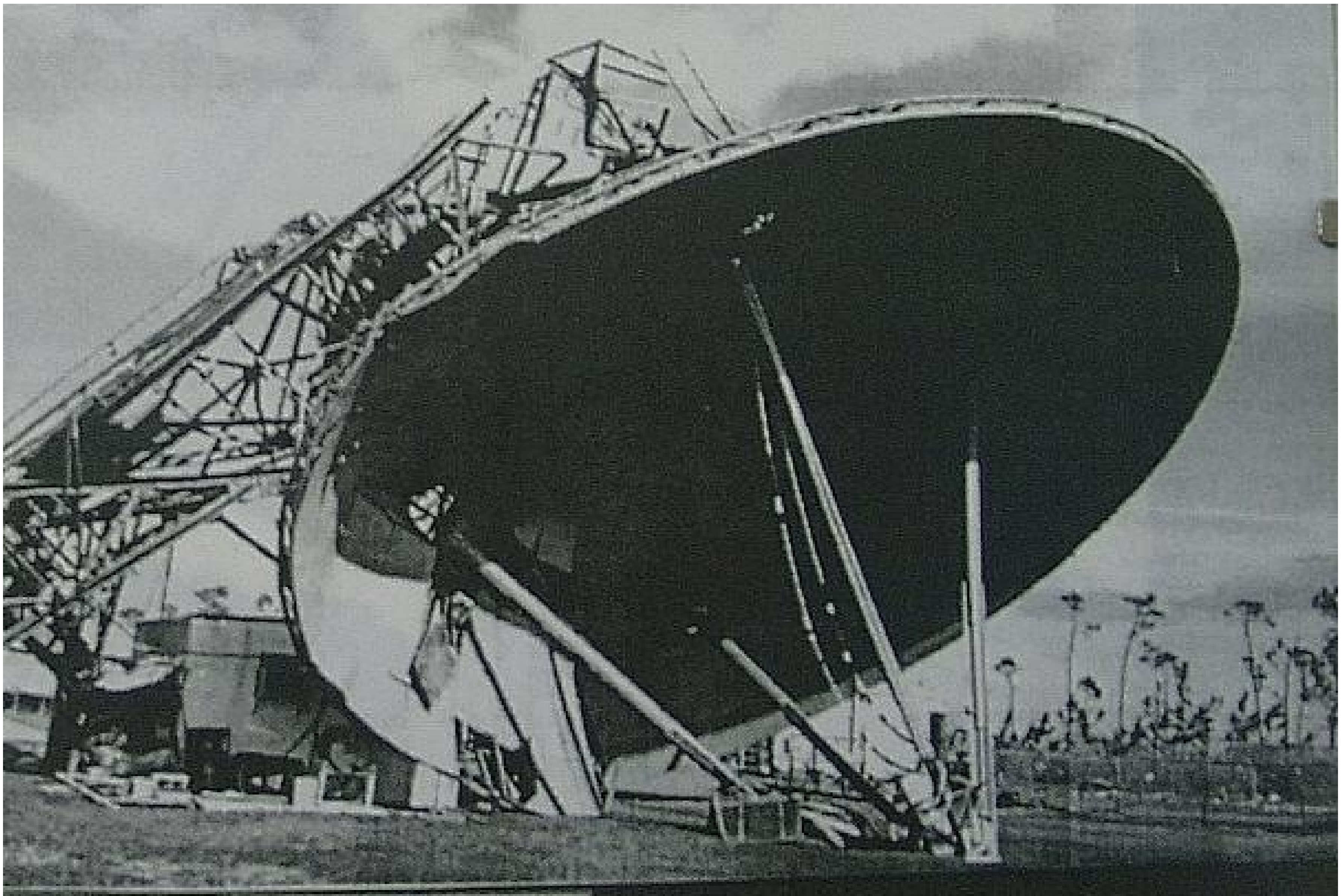
What can go wrong with Calibration

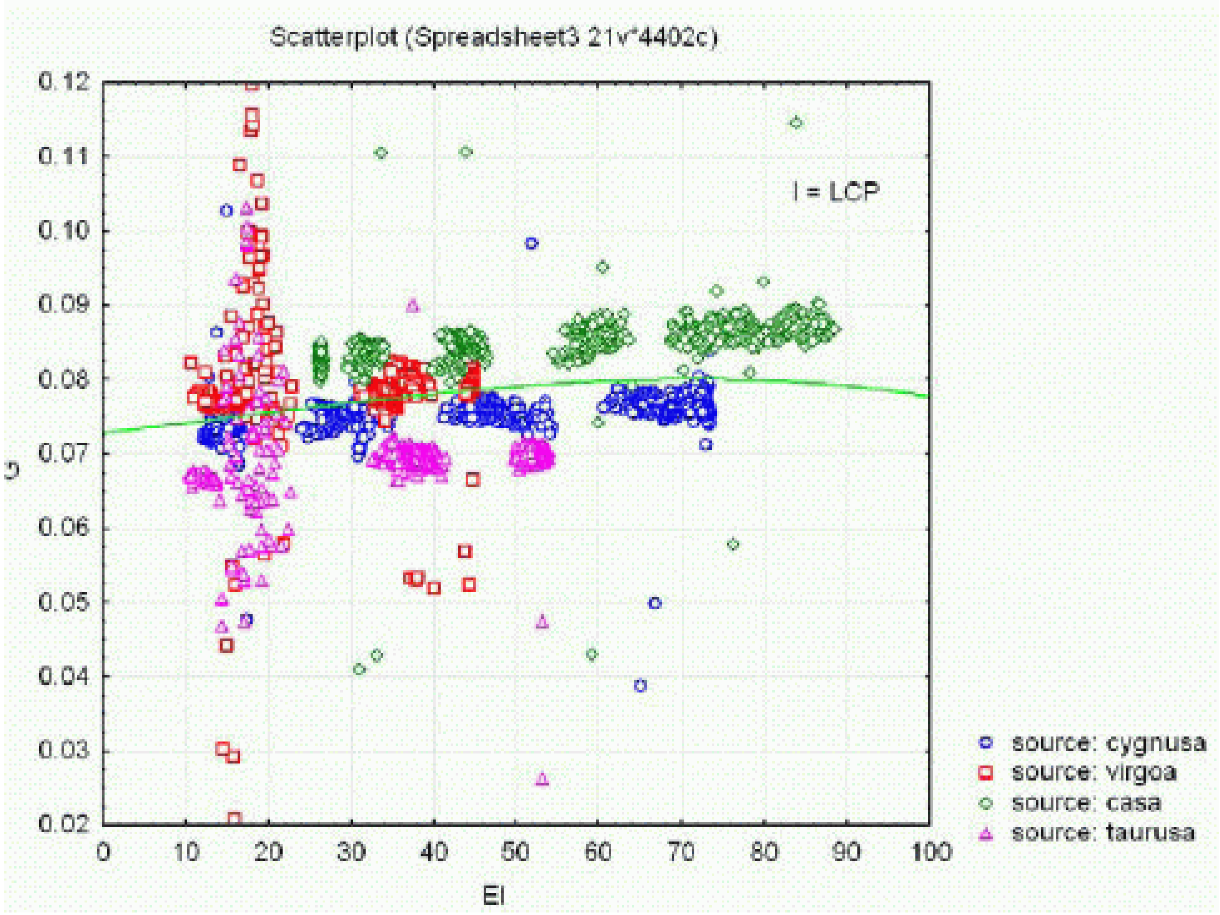


VLBI Calibration process

- Check pointing (fivpt)
- Run acquir/onoff to get gain/elevation curve and Tcal/frequency
- Use gnplt to make rxg files
- Use antabfs to make Tsys against time
- Carefully check if antabfs files are good
- Put on server within 2 weeks of observation

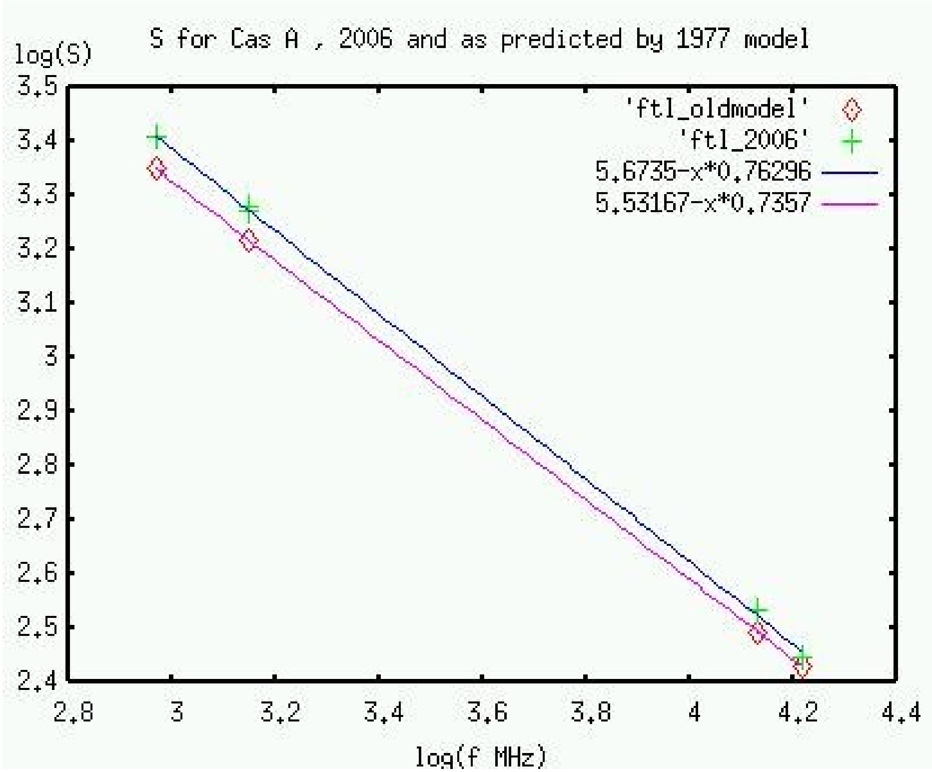
Flux density scale

- flux.ctl contains primary (Cas A, Tau A , Cyg A) and secondary, weaker calibrators. Cas and Tau are slowly getting weaker. Michael Lindqvist has compared primary sources



Spectrum of Cas A

- FS uses Baars (1977) model for decay of Cas A
- Recent literature shows slower decay
- The figure shows 2006 spectrum of Cas A and the spectrum predicted by 1977 model. The 1977 model is lower



Calibration sources at K-band

- Difficult to find strong sources: can use strong, flat-spectrum (3c273,3c84) or DR21
- Planets also possible, use script to get approximate position and flux density http://www.vlbi.de/vlbi/planets.html
- Stable weather needed for onoff , particularly K-band

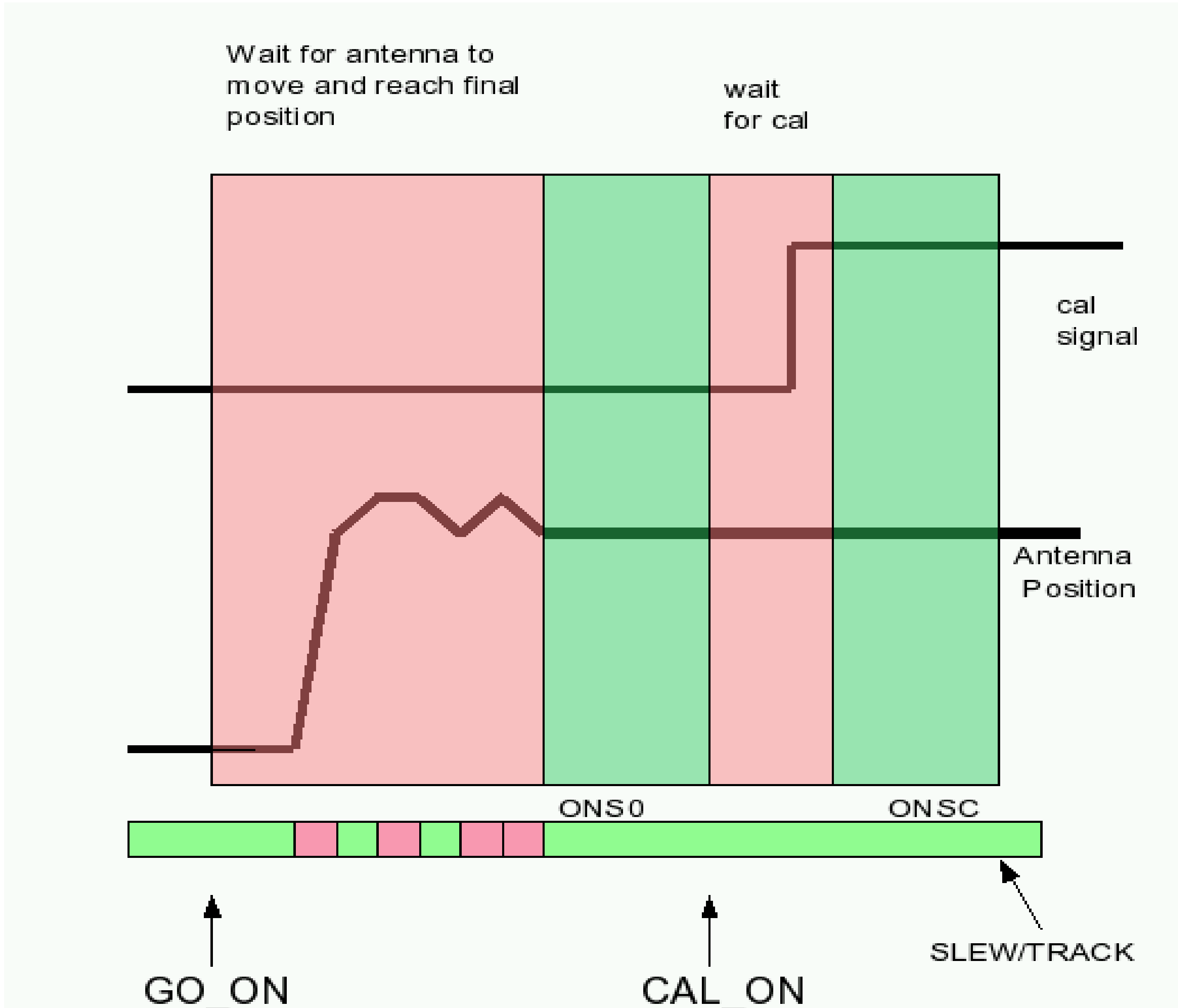
```
PLANETS for EFLSBERG, diam=100.0, location 50.535 -7.0
TIME 2006 066 10:19:31
source=mercury,233718.2,+012558.0,2000.0  APPSIZE  10.1 ELV  35.67
GHZ   22.2 FLUX   10.3 BEAMFILL  0.36
GHZ   32.0 FLUX   21.4 BEAMFILL  0.51
GHZ   43.2 FLUX   39.0 BEAMFILL  0.69
source=mars,042804.0,+233329.0,2000.0  APPSIZE   6.6 ELV  11.89
GHZ   22.2 FLUX    2.4 BEAMFILL  0.23
GHZ   32.0 FLUX    5.1 BEAMFILL  0.34
GHZ   43.2 FLUX    9.2 BEAMFILL  0.45
GHZ   86.4 FLUX   36.8 BEAMFILL  0.91
source=venus,201207.9,-160218.0,2000.0  APPSIZE  31.3 ELV  20.21
GHZ   22.2 FLUX  138.8 BEAMFILL  1.10
GHZ   32.0 FLUX  277.0 BEAMFILL  1.59
source=jupiter,150645.8,-161142.0,2000.0  APPSIZE  39.0 ELV -18.86
source=saturn,083047.9,+194150.0,2000.0  APPSIZE  18.9 ELV -17.76
source=uranus,225120.7,-080510.0,2000.0  APPSIZE   7.5 ELV  29.76
GHZ   22.2 FLUX    2.5 BEAMFILL  0.26
GHZ   32.0 FLUX    5.1 BEAMFILL  0.38
GHZ   43.2 FLUX    9.3 BEAMFILL  0.51
ENTRIES FOR /usr2/control/flux.ctl
mercury c 10000  90000  -7.67979  2.0000 -0.0000 10  disk  0.0028d
mars    c 10000  90000  -8.30698  2.0000 -0.0000  6  disk  0.0018d
venus   c 10000  18000   3.61657 -2.7230  0.5486 31  disk  0.0087d
venus   c 18000  30000  -8.18281  2.8343 -0.1056 31  disk  0.0087d
venus   c 30000  90000 -12.80772  4.8627 -0.3280 31  disk  0.0087d
jupiter c 10000  90000  -6.87050  2.0000 -0.0000 39  disk  0.0108d
saturn  c 10000  90000  -7.55122  2.0000 -0.0000 18  disk  0.0053d
uranus  c 10000  90000  -8.30259  2.0000 -0.0000  7  disk  0.0021d
~
```

Problems with onoff

- Data-taking must wait until antenna has finisehed moving.
- If not, get high RMS on 'ONSO'. Sometimes antenna reports 'on-source' before move has started.
- Must also allow time for cal to switch (Effelsberg 4 seconds)
- Careful 'tuning' necessary to make onoff work well, for example adjusting delays in caloffnf and improving antenna position reporting.

```
OFFS 125.5 -0.0000 -0.7801 1u  6089.0     8.5
OFFS 125.5 -0.0000 -0.7801 3u  6386.5     9.2
OFFS 125.5 -0.0000 -0.7801 5u  7351.5     9.2
OFFS 125.5 -0.0000 -0.7801 7u  6069.5    10.6
#antcn#Commanding new offsets       0       0
ONSO 143.1  0.0000  0.0000 1u  9142.0  1955.9
ONSO 143.1  0.0000  0.0000 3u 10151.0  2436.7
ONSO 143.1  0.0000  0.0000 5u 11687.5  2840.4
ONSO 143.1  0.0000  0.0000 7u  9627.5  2320.0
                                          ^
                                  RMS-----|
```

Phases of onoff

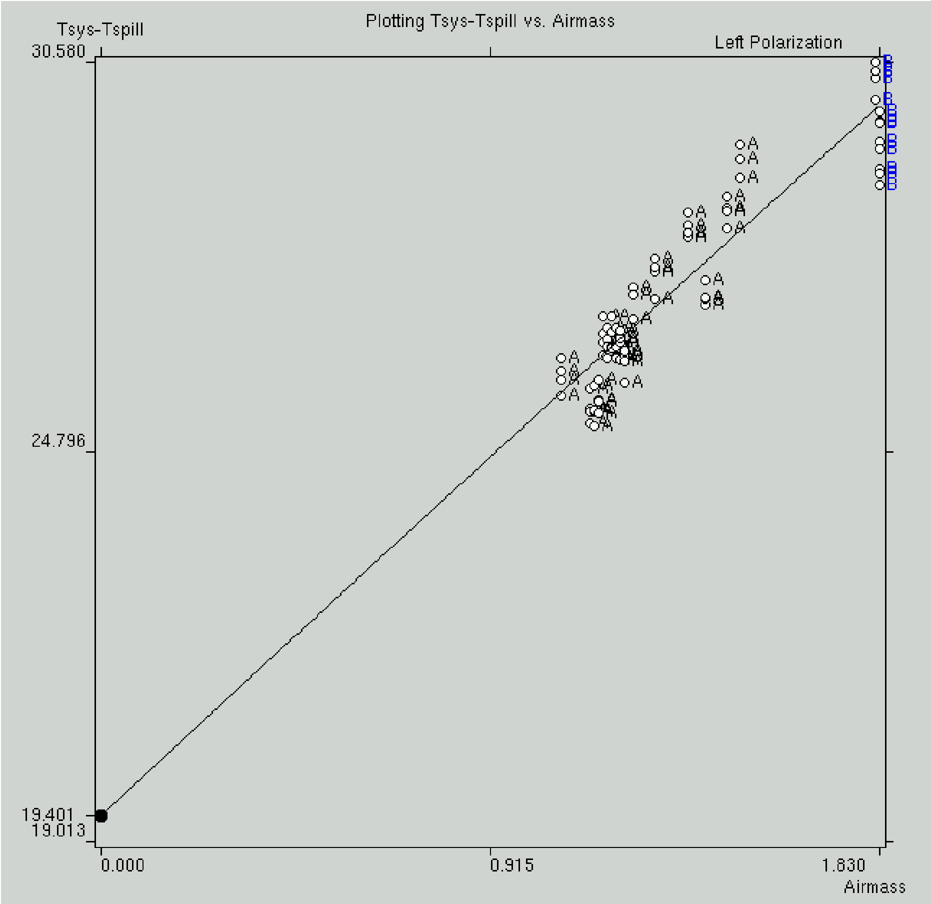


Phases of onoff, example

- FS sends signal go_on
- For several seconds, antenna still 'TRACKING'
- After several seconds, antenna begins to move, signal SLEWING
- Antenna passes correct position, signals TRACKING for 1 second, overshoots, finall settles on position
- Now ONS0 data collection can start
- Signal to switch on cal. Should wait for this: procedure 'caltsys' waits 2 seconds for cal, but no wait in point.prc
- ONSC data collection starts after short wait

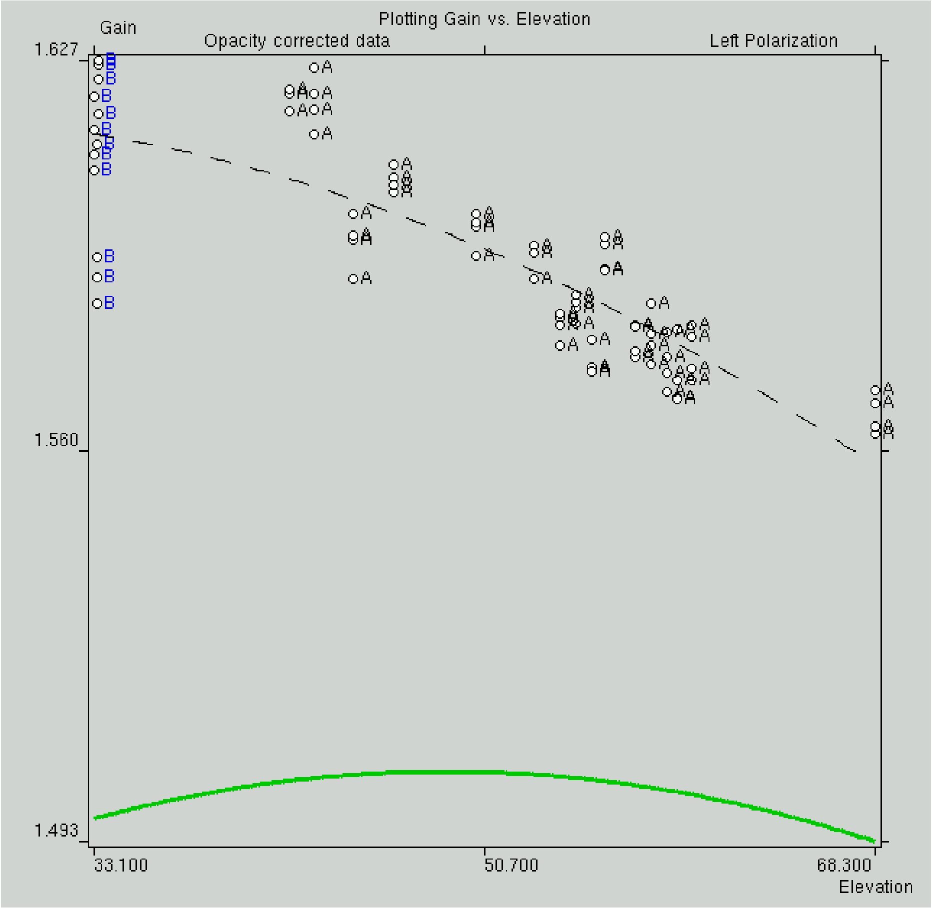
Using gnplt

- If onoff data is good, gnplt works very well
- To get opacity correction, first find Trec by using Tsys-Tspill shortcut



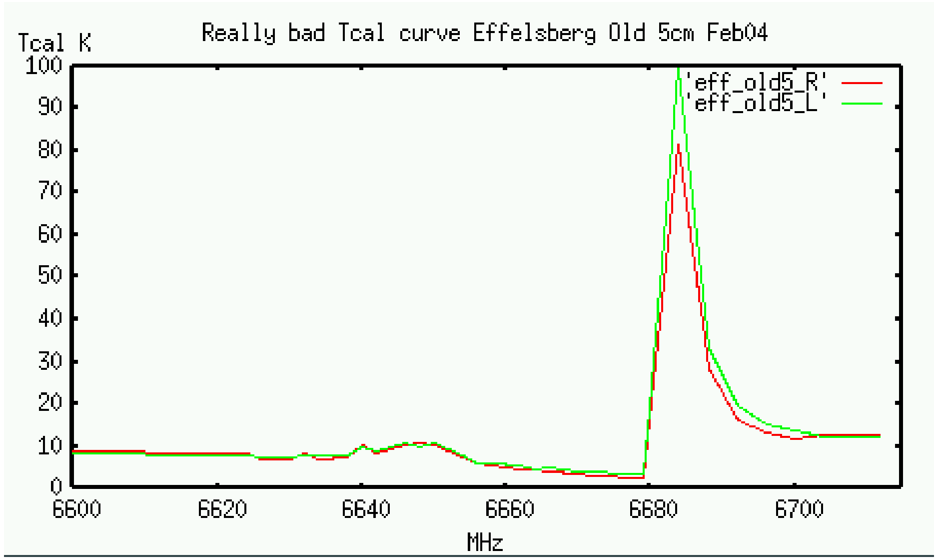
gnplt: opacity

- Can correct data points by measured opacity
- In plot, standard gaincurve is green, fitted curve with opacity shown dotted
- But note: what we need for antab is **green curve**, since we want real antenna gain including atmosphere
- So measure gain curve without opacity correction



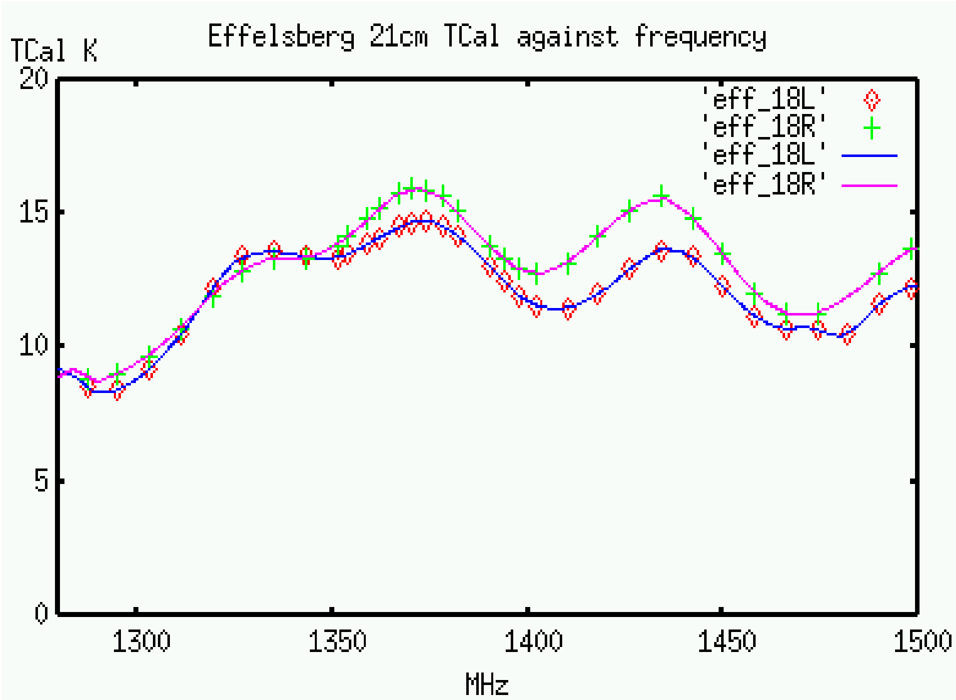
Data in rxg files

- Some receivers have really bad variation of Tcal against frequency, the example shows Effelsberg 5cm Feb 2004.
- The resonance is at methanol frequency and makes calibration difficult



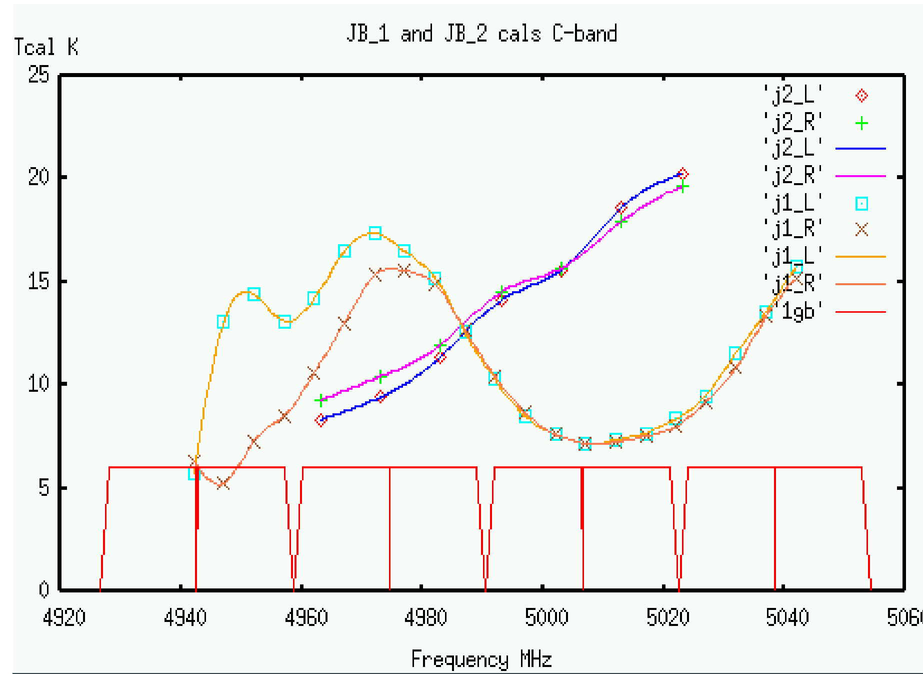
More typical rxg data

- More typical example: ripple caused by reflections in calibration system. Here points are plotted every 8MHz.
- To get a Tcal value for each channel, interpolation is needed. This can be inaccurate.



1GHbit/sec: 32MHz channels

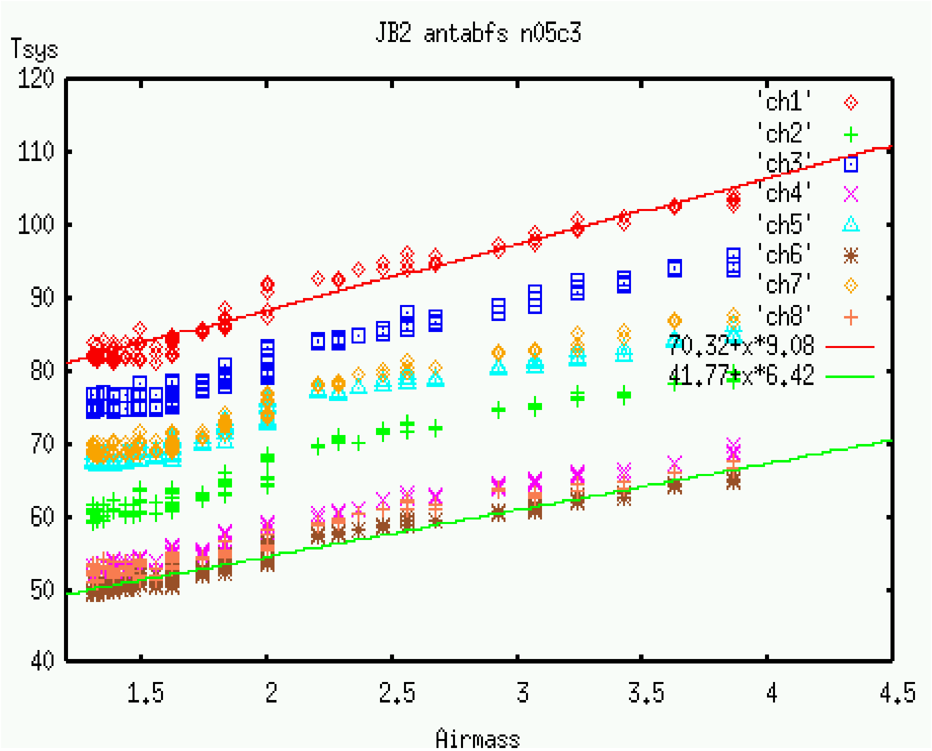
- This shows 6cm Tcal for Jodrell antennas
- The LSB and USB channels for 1Gbps are shown below
- For Mk4, both sidebands are detected together, so one calibration value for 32MHz
- Because of large variations, large difference of Tcal used for different channels – this leads to inaccurate calibration




```
L1: bbc01, 4942.49 MHz, BW=16.00 LSB, Tcal= 6.5 K
L2: bbc01, 4942.49 MHz, BW=16.00 USB, Tcal= 6.5 K
L3: bbc03, 4974.49 MHz, BW=16.00 LSB, Tcal=16.9 K
L4: bbc03, 4974.49 MHz, BW=16.00 USB, Tcal=16.9 K
L5: bbc05, 5006.49 MHz, BW=16.00 LSB, Tcal= 7.2 K
L6: bbc05, 5006.49 MHz, BW=16.00 USB, Tcal= 7.2 K
L7: bbc07, 5038.49 MHz, BW=16.00 LSB, Tcal=14.2 K
L8: bbc07, 5038.49 MHz, BW=16.00 USB, Tcal=14.2 K
```

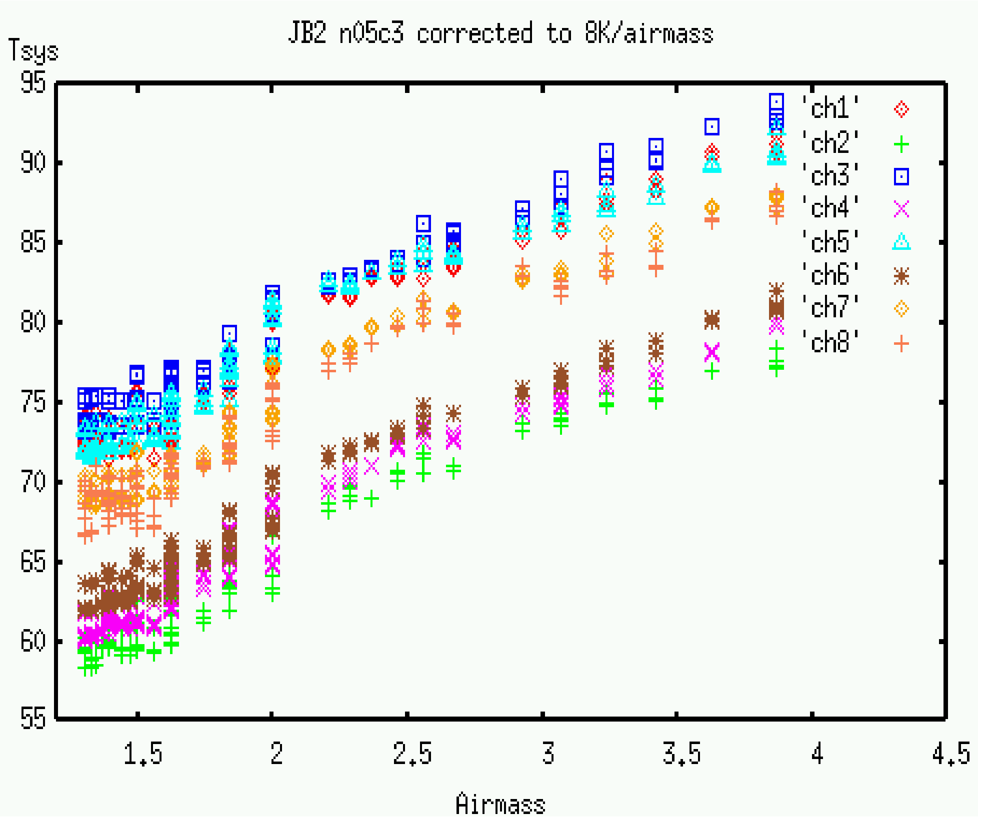
Effect of large Tcal variations

- Tsys against airmass for a station with large Tcal variations
- We expect same gradient for all channels
- Fitted gradient varies between 9.1K and 6.4K / airmass
- Obviously the Tcal values used for some of the channels need adjustment



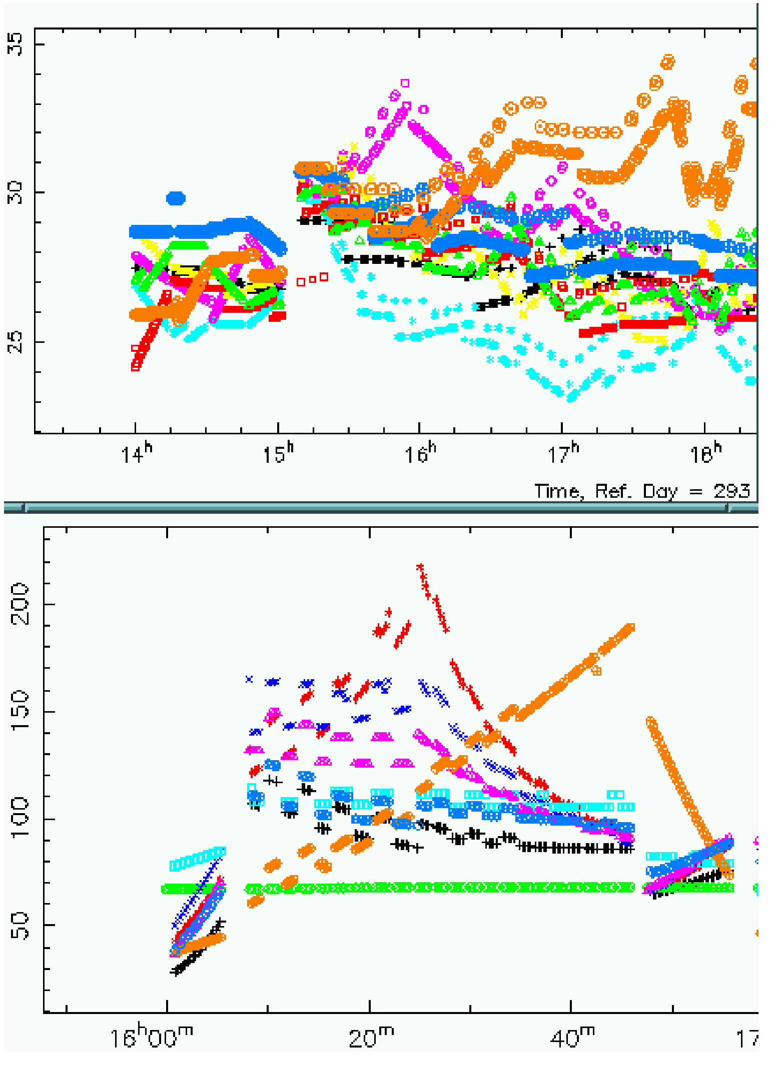
Experiment: Use Gradient to Correct

- Adjust Tcal for each channel so that all have a gradient of 8K / airmass
- Now we see 2 groups
- These are LCP and RCP channels, obviously with different Trec (channel 8 does not fit this picture)
- Conclusion: careful attention to rxg values used, visual inspection of antabfs files each station produces



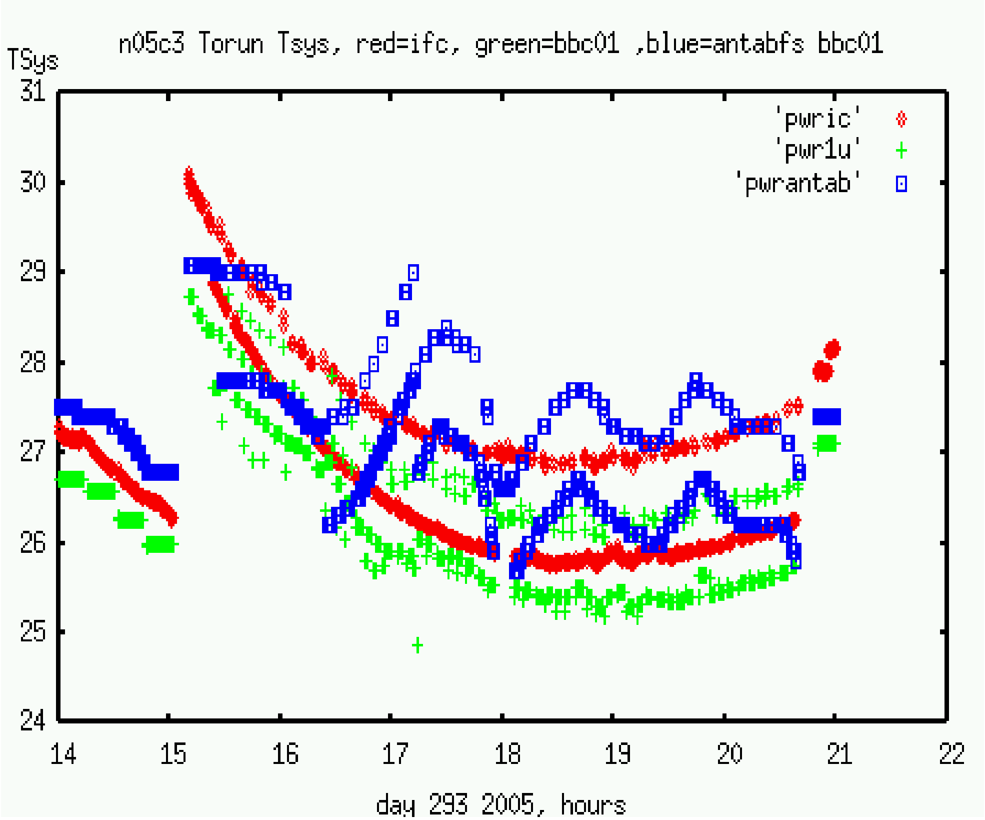
Problems with antabfs files: VLBA4

- Noto, Torun, Shanghai, Cambridge have VLBA4 terminals
- 'tpicd' is given by gain steps which keep BBC output levelled, 0.14dB at mid-range
- Cambridge does not do any calibration
- Others, particularly Torun, show chaotic behaviour in antabfs files
- Examples (N05C3, N05L2) show problems at dB steps

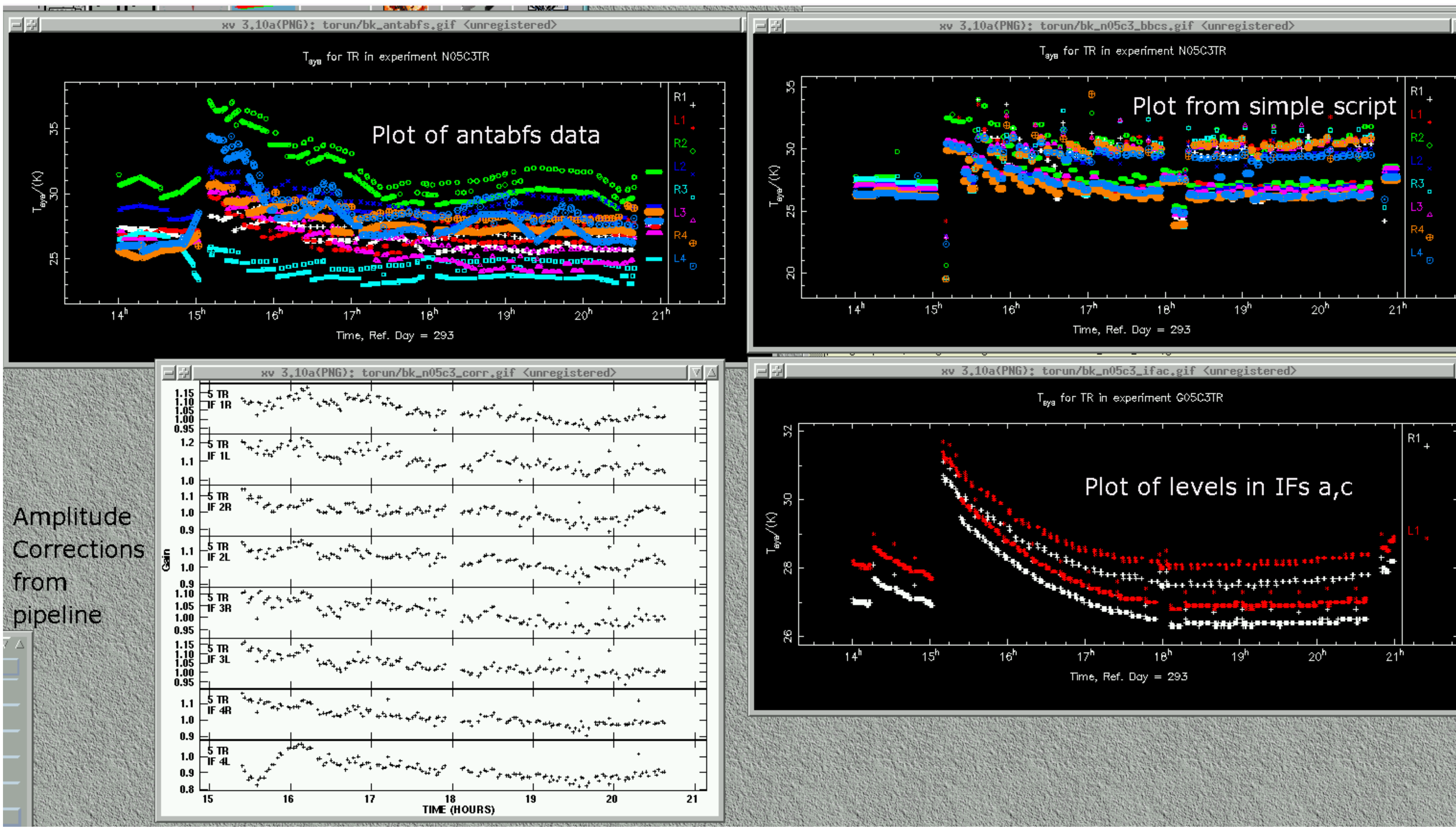


Torun N05C3 antabfs data

- After 15:30, antenna is going on and off 3C454.3, 1.5K Tant, so two traces seen
- Blue trace is taken from antabfs
- Red trace is IF level from Channel 'c'. Obviously system is low-noise, stable and antenna gain is high.
- The green trace uses tpi and tpgain from log, scaling according to dB. The trace also looks OK.
- Green trace shows limitations of tpgain method, but something is wrong with antabfs output

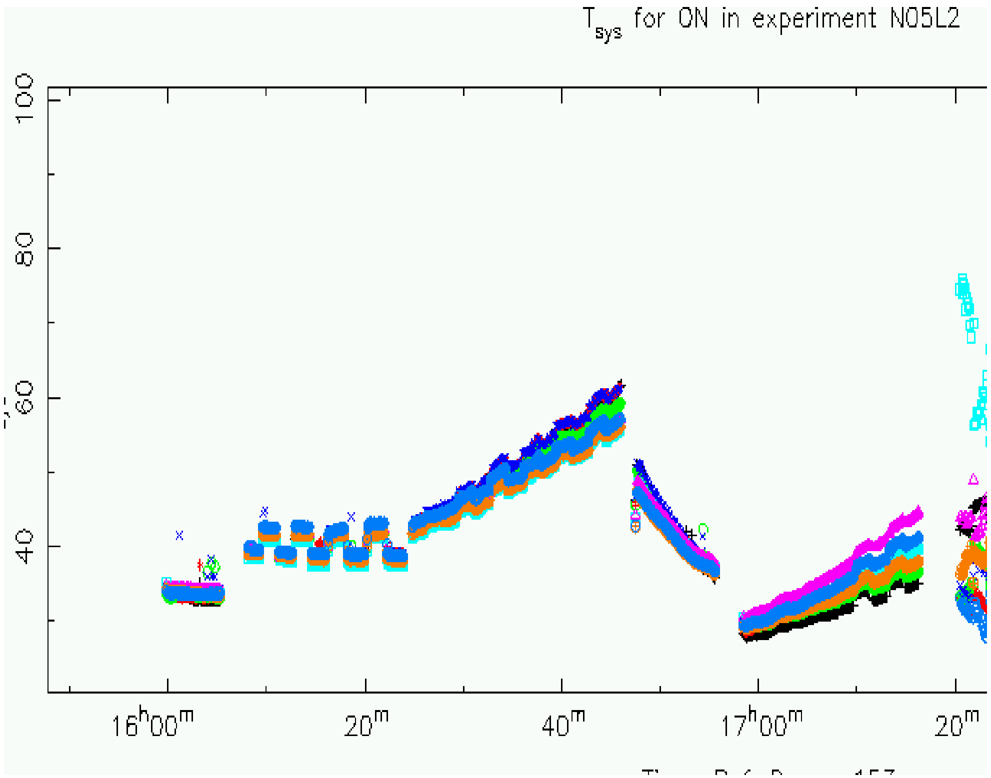


N05C3: Tr: more detail



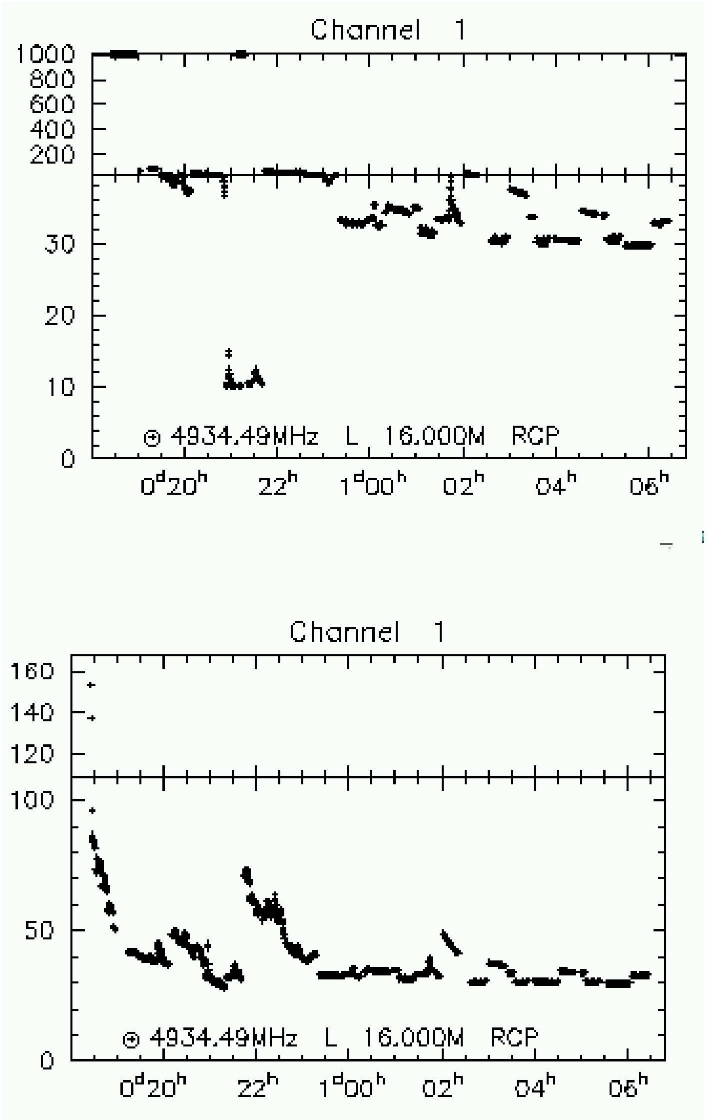
Log Problems

- Often Tsys taken while antenna is moving. If Tant big and Tcal small, problems
- If bad Tsys included by accident, problems in antab data (picture)
- Often first Tsys in an experiment is bad. If not fixed, up to 1 hour of uncalibrated data.
- Must inspect all antabfs files, edit bad Tsys points to make sure they are not included.



Need to edit logs

- Figures show Effelsberg Tsys for EL033B before and after editing log
- Editing needed was to flag some Tsys measurements as 'bad' although the 'onsource' check was OK, and to mark the first Tsys, which failed the test, as 'good'
- Plotting antabfs files with 'plot_tsys.pl' tool is very important



RFI Problems

- RFI messes up onoff and Tsys measurements.
- Particular problems at 18cm, Iridium 1610-1626MHz and at S-band (UMTS), soon Galileo will mess up redshifted HI.
- At 18cm, two lowest channels centred at 1602 and 1618 are most affected (see: http://www.astron.nl/craf/iridium.html)
- Best to do 18cm onoff measurements at local nighttime, when Iridium activity is low.

Amplitude Corrections from Pipeline

- The final check is amplitude corrections from the pipeline, example: http://archive.jive.nl/scripts/arch.php?exp=N05L2_050602
- Files like n05l2_3C273B_CALIB_AMP.PS.gz give the amplitude corrections. In this example the faulty antabfs data for VLBA4 stations lead to rapid variations in amplitude correction, different from channel to channel
- Note that amplitude corrections are relative, and may also be weighted by antenna gain: so if an array has one 300m antenna and several 25m antennas, bad calibration of the 300m antenna would lead to large corrections for the 25 antennas being found, even if these antennas were perfectly calibrated

Conclusions

- Do not use Cas A because of variability. Care with Tau A
- Use strong sources: at K-band DR21, flat-spectrum sources, planets
- In good weather conditions, several integrations per data point for onoff to get RMS estimate
- Tcal not too big (nonlinearity), not too small, value should be constant against frequency
- Visual examination of rxg values and antabfs at stations before posting
- If problems with antab files, edit logs, adjust rxg values
- Visual inspection of antabfs files at JIVE
- For VLBA4 stations, antabfs needs fixing

Alternative Calibration for VLBA4

- VLBA BBCs use an 80Hz switching signal for noise-adding radiometry, using a switched Tcal of 1-5K, decoded in each BBC
- This gives continuous, stable calibration at the expense of a slightly increased Tsys.
- This would be a solution for Cambridge, assuming the change of signal level at 80Hz passes through the link. Note that the 900musec down the Cambridge radio link is not negligible compared with 1 phase at 80Hz.
- An experimental FS based on FS-9.6.9 has been made which implements this.

References

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