3mm calibration at the VLBA

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3mm at the VLBA

- 2 VLBA antennas have no 3mm receiver:
  - HN, SC; unfortunately, the two eastern-most ones!
- 2 VLBA antennas have 3mm receivers covering 80-90 GHz:
  - BR, LA
- 6 VLBA antennas have 3mm receivers covering 80-96 GHz:
  - FD, KP, MK, NL, OV, PT
- Typical SEFD: 4200 Jy
  - Ranges from 3100 Jy at LA to 5800 Jy at OV
- Remember: VLBA antennas designed to frequency of 50 GHz

System temperature calculation

- All VLBA receiver bands make use of continuous switched power
- HW/SW at stations deliver switched and total power every second
- Post-observation software (rdbetsm) breaks each scan into equal duration intervals (typically about 30 sec long) and computes Tsys based on tabulated Tcal values
- Tsys values are available either as an ANTAB-formatted file or files that the DiFX software can import for direct "calibration transfer"

Gain and pointing

- Almost every week after maintenance period ends a series of pointing observations lasting 4 to 6 hours is performed
- Usually pointing runs are restricted to a handful of receivers, but sometimes all bands are included
- Approximately annually, or when deemed necessary (after major maintenance), all recent pointing data is analysed
  - Pointing model is developed
  - Gain vs. elevation is computed
- If changes are significant, updates are made to pointing model and gain tables
- vlba_gains.key contains current and historical values

Pointing, continued

- Blind VLBA pointing is better than 10 arcseconds.
- Referenced pointing improves things, maybe to 5 arcseconds.
- Note: 3mm beam is about 30 arcseconds, so referenced pointing really helps.
- Most VLBA antennas experience periodic pointing wobble of about 3 arcseconds, mostly in elevation.

Weather and Opacity

- All VLBA sites have weather stations which collect standard metrology measurements: temperature, humidity, wind speed and direction, integrated precipitation.
  - Goes to ANTAB file and/or DiFX
- Opacity can be estimated from weather data assuming no clouds.
- More typically, Tsys as a function of elevation observed over some timescale is used to estimate opacity.
  - Essentially unintentional sky dips
  - Can be explicitly scheduled if desired, but note: no Tsys generated when not on source.

Resources

- VLBA (and VLA, GBT to some level) calibration is documented in VLBA Sensitivity Upgrade Memo 44: http://library.nrao.edu/public/memos/vlba/up/VLBASU_44.pdf
- General VLBA performance can be found at the Observational Status Summary: https://science.nrao.edu/facilities/vlba/docs/manuals/oss
- Instructions for getting VLBA calibration data can be found at: https://science.nrao.edu/facilities/vlba/calibration-and-tools/caliblogs
- Referenced pointing examples can be found in the sched distribution. Sched documentation discusses its use in some detail.

4mm calibration at GBT

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4mm Receiver at GBT

- 4mm heterodyne receiver spans 67 to 92 GHz
  - Dual-beam receiver; VLBA uses just one of them
- Note: new ARGUS array
  - 16 heterodyne receivers spanning 75 to 115 GHz
  - No immediate intentions of using for VLBI
- Zenith SEFD: 150 Jy at 90 GHz
- 90 GHz pushes the performance limits of the GBT
  - Thermal stability of the dish structure
  - Site weather conditions
  - Pointing in wind

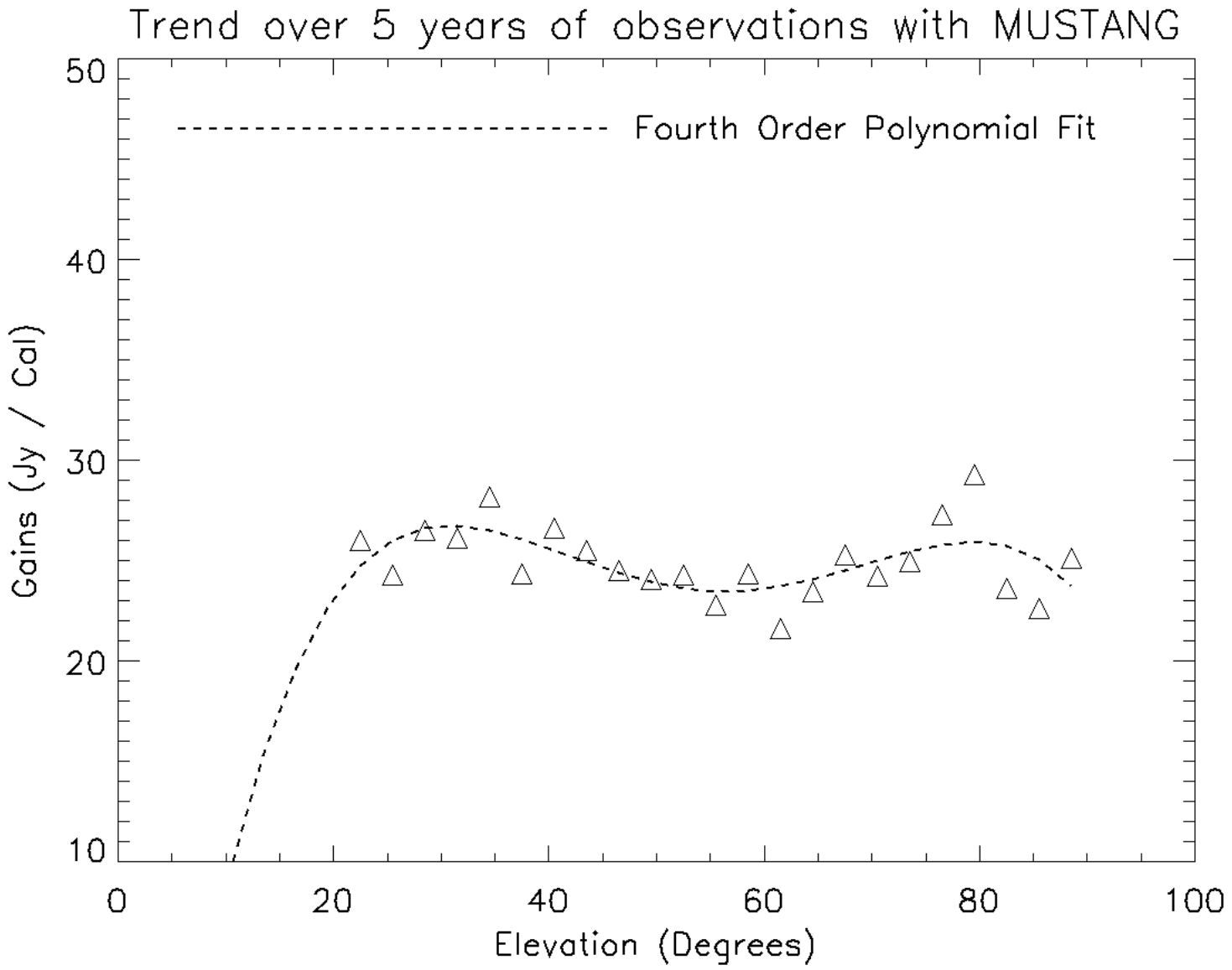
Dish surface and gain

- GBT has active surface with 2209 actuators for 2004 panels
- Open-loop mechanism corrects for gravitational sag
- Out-Of-Focus (OOF) holography can measure deformation relative to gravity model; mostly thermal
- Uncorrected gain between 30% and 50% lower than OOF-corrected
- OOF takes 45 minutes, including focus and pointing
- OOF should be done prior to night observations and maybe every 4 to 6 hours at night
- OOF should be performed every 2 hours during day, or not at all

Gain

- Gain vs. elevation is tabulated in a file parallel to vlba_gains.key
  - gain.gb; currently has no 3mm/4mm entries – to be corrected…
  - Gain is typically 35% at 90 GHz
    - Active surface means limited elevation dependence
- Elevation dependence is roughly orthogonal to thermal effects
- How to know actual gain?
  - Can make special observation before each OOF and interpolate
  - Better: look at total power on bright source every 30 minutes
    - Can use resolved sources – they are more plentiful and stable
    - Choose source at similar elevation

Inverse gain vs. elevation



Pointing

- Typical precision (RMS per axis)
  - Tracking: 1”
  - Offset (calibrated from 10 deg away): 2”
  - Blind: 7”
- Note: beam size is about 5”
- Pointing scan should be performed every hour; takes 10 minutes
- Note that temperature sensors on various GBT structures feed into the real-time pointing model.

Tsys

- 4mm receiver has "calibration wheel" with 6 slots:
  - Blank – linear polarization
  - ¼-wave plate – circular polarization
  - Hot load (ambient)
  - Cold load (Rx temperature)
  - 2 other slots not relevant for single-beam operation
- ¼-wave plate used during VLBI regular observing
  - But… could go linear if that route opens up in the future
- Hot/cold used before and after each scan to calculate Tsys
- GBT staff (Frank Ghigo) generates table of Tsys after each obs

Opacity

- No special tipping device at GBT
- Can use same technique used by VLBA (Tsys vs. elevation)
- More typically, the GB weather data is used, and has been shown to be very accurate

Resources

- GBT 4mm information: http://www.gb.nrao.edu/4mm/
- GBT proposers guide: http://www.gb.nrao.edu/gbtprops/man/GBTpg.pdf
- High frequency weather forecasts for GBT: http://www.gb.nrao.edu/~rmaddale/Weather/index.html

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