Your data
and “A priori” Calibration

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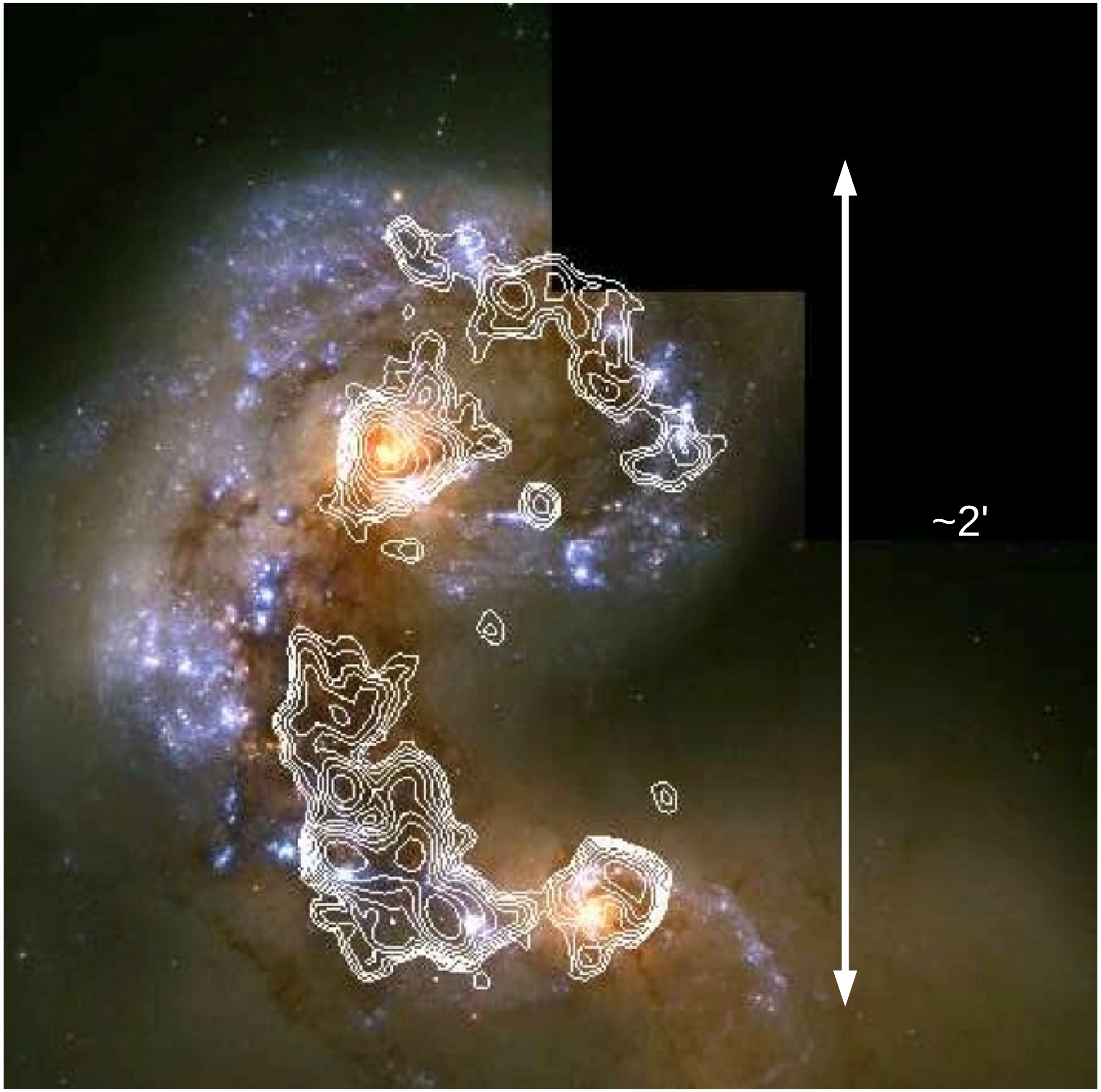
Antennae : NGC4038/4039

Nearby
(z=0.005688)
interacting galaxies:
NGC4038 & NGC4039

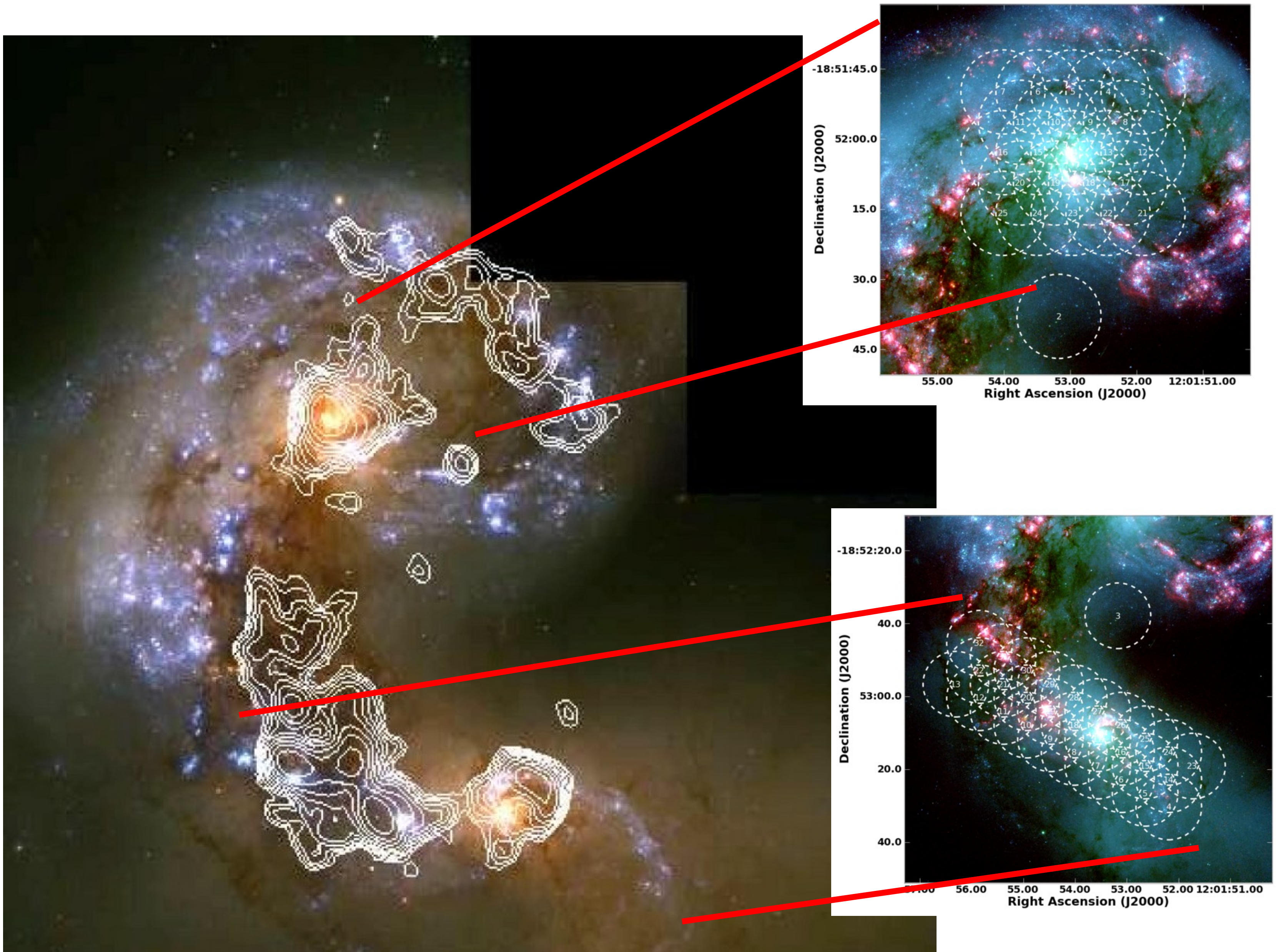
NGC4038/4039



Wilson et al. (2000)

Observations of CO(1-0)
resolution 3”x 4”

ALMA field of view in Band 7 ~ 15 “



23 pointings

29 pointings

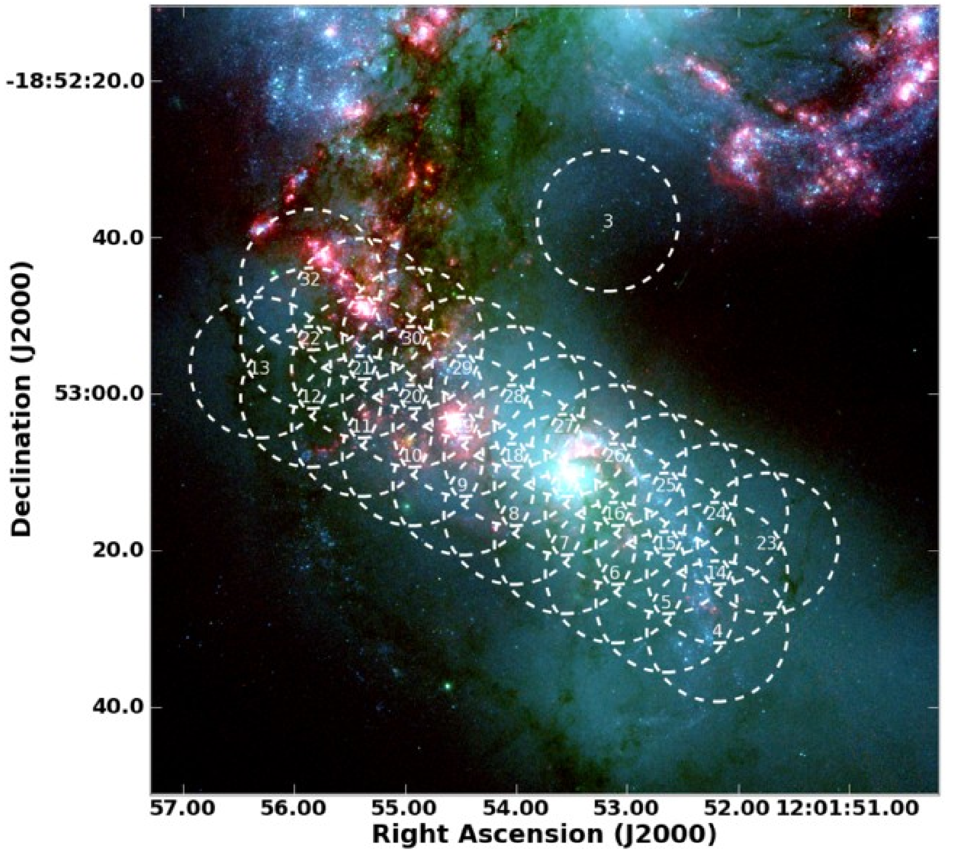
Antennae ALMA SV

ALMA Science Verification data targeting the CO (3-2) line

(rest frequency = 345.7960 GHz)

ALMA field of view ~ 15 “ ----> mosaics

Your dataset is an observation of the Southern region



Peculiarities @ mm

With increasing frequency:

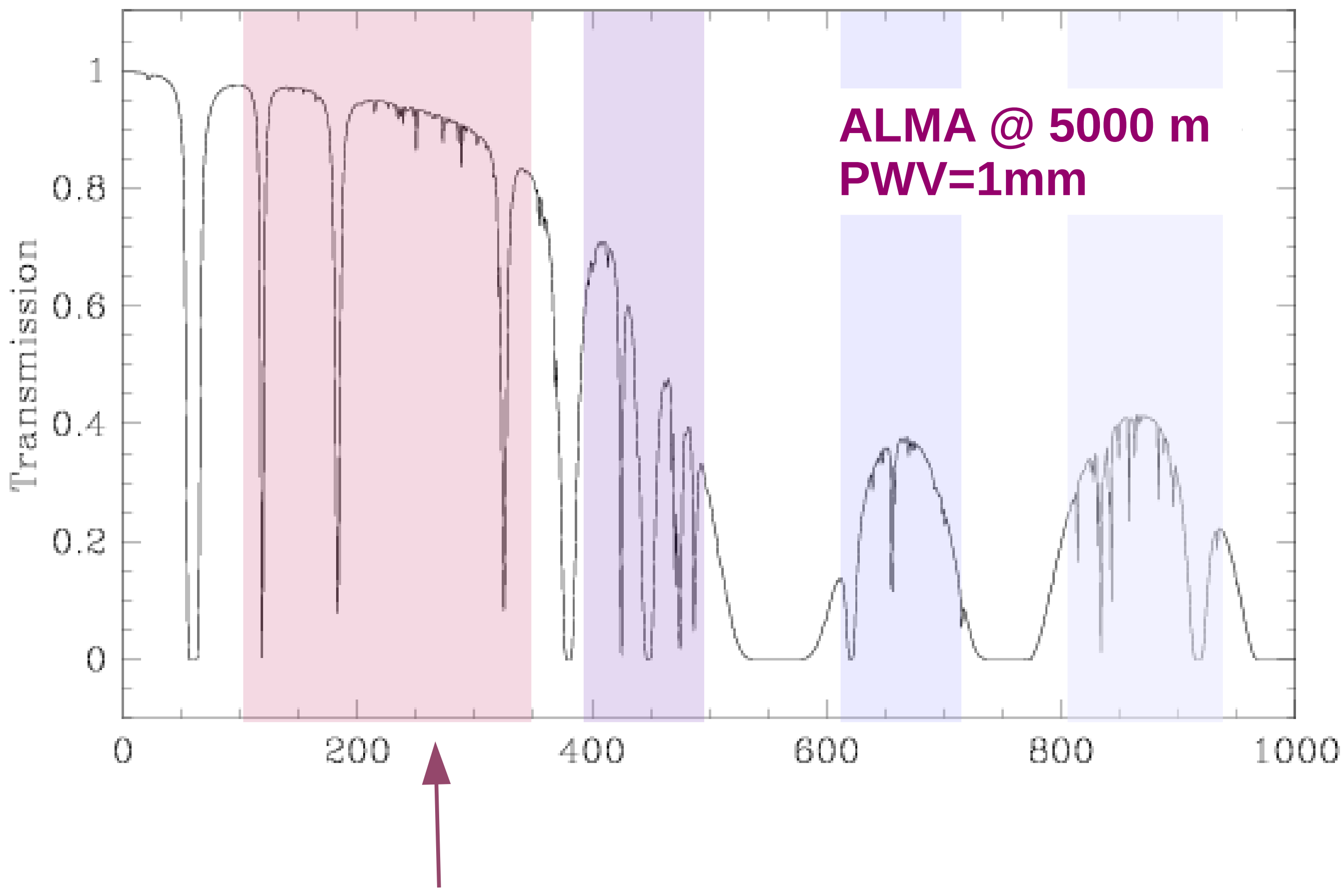
- **No external human interferences in the data**

- **No ionospheric effect**

- Tropospheric effects: absorption and delay of signal
  - → stronger weather dependency
  - → T_{sys} dominated by atmospheric noise

Peculiarities @ mm

Tropospheric opacity depends on altitude

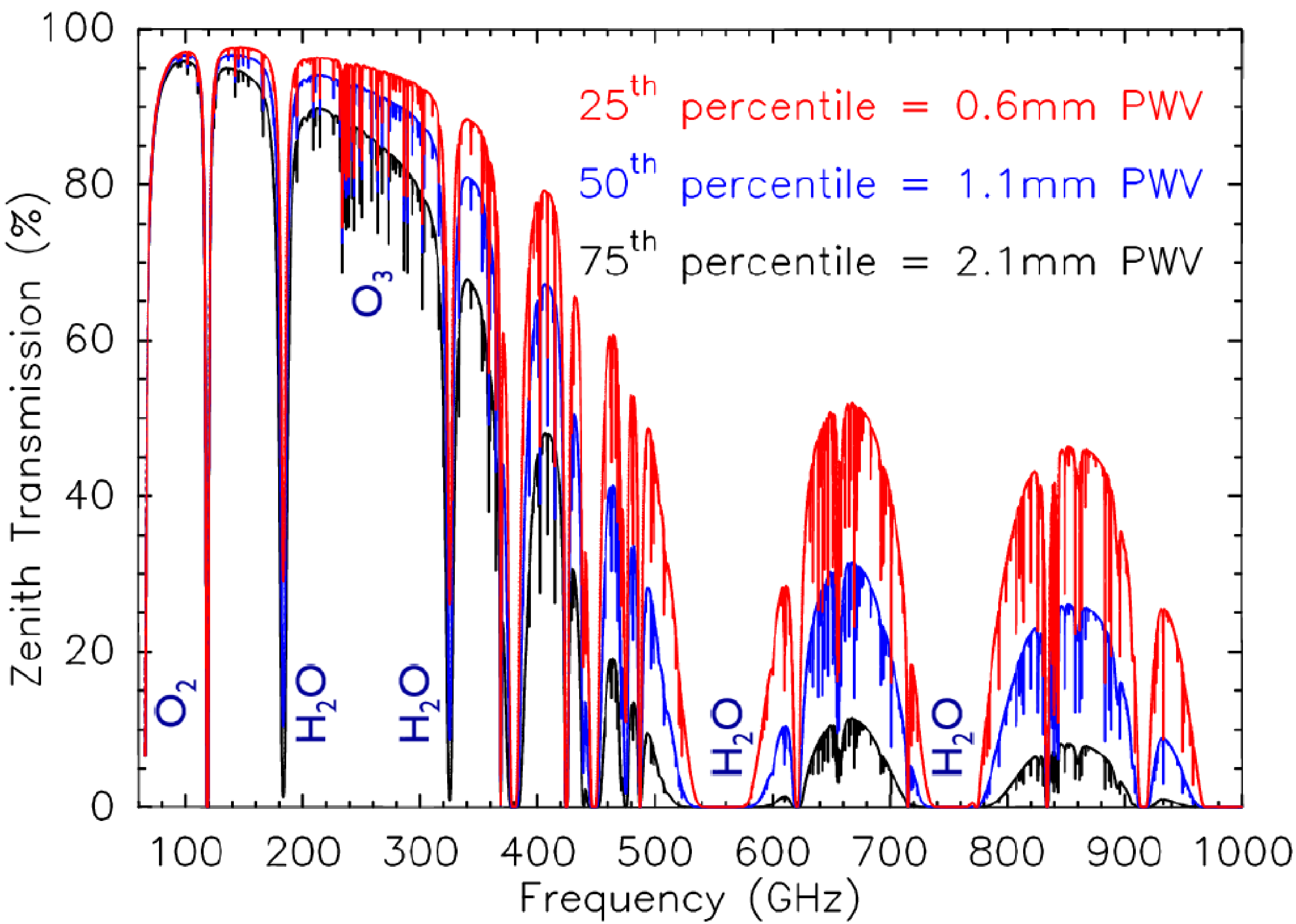


Difference due to the scale height of water vapor

ALMA bands

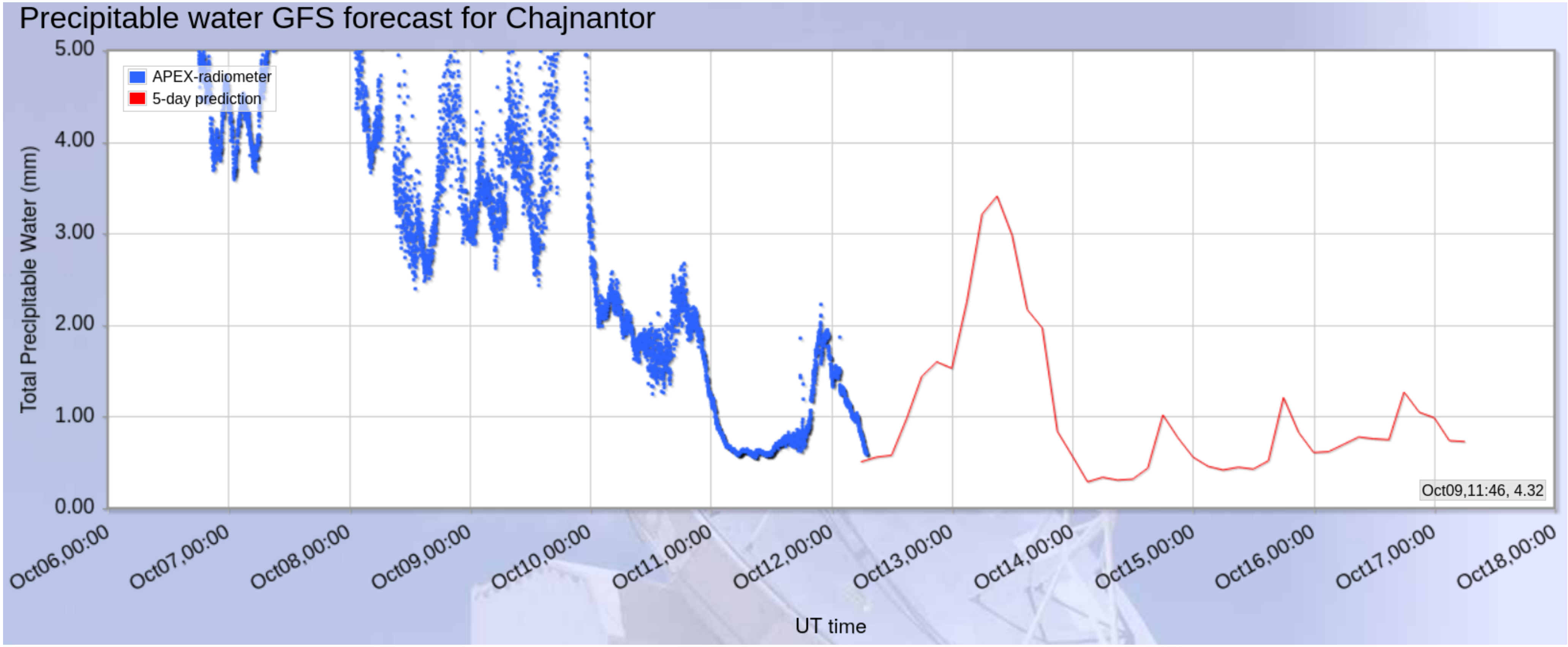
Peculiarities @ mm

PWV= Precipitable Water Vapour



Dynamic scheduling

To efficiently use ALMA's capabilities under varying environmental conditions:



http://www.apex-telescope.org/weather/RadioMeter/index.php

Dynamic scheduling

To efficiently use ALMA's capabilities under varying environmental conditions,
an observation is divided in blocks of self-consistent observations **EBs "Execution blocks"**

The project we are working on has 6 EBs:

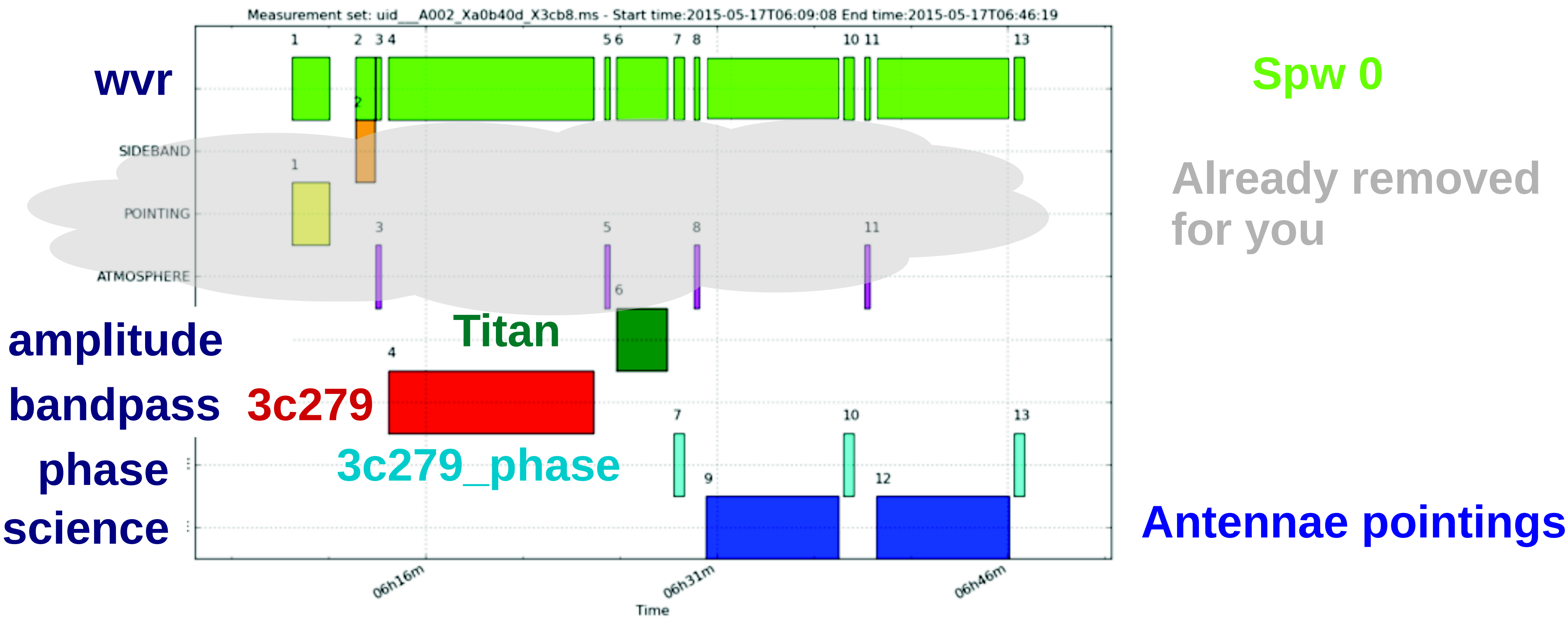
uid___A002_X1ff7b0_X1c8
uid___A002_X207fe4_X1f7
uid___A002_X207fe4_X4d7
uid___A002_X215db8_X18
uid___A002_X215db8_X1d5
uid___A002_X215db8_X392

Each of them contains all the observations of the calibrators needed to properly calibrate the scientific data

Each EB contains:

The scientific target and all the calibrators needed

In your dataset



A priori calibration

wvr and Tsys calibration are done “a priori” without observations of dedicated calibrators

These calibrations have been applied to your dataset already.

Mean effect of atmosphere on Phase

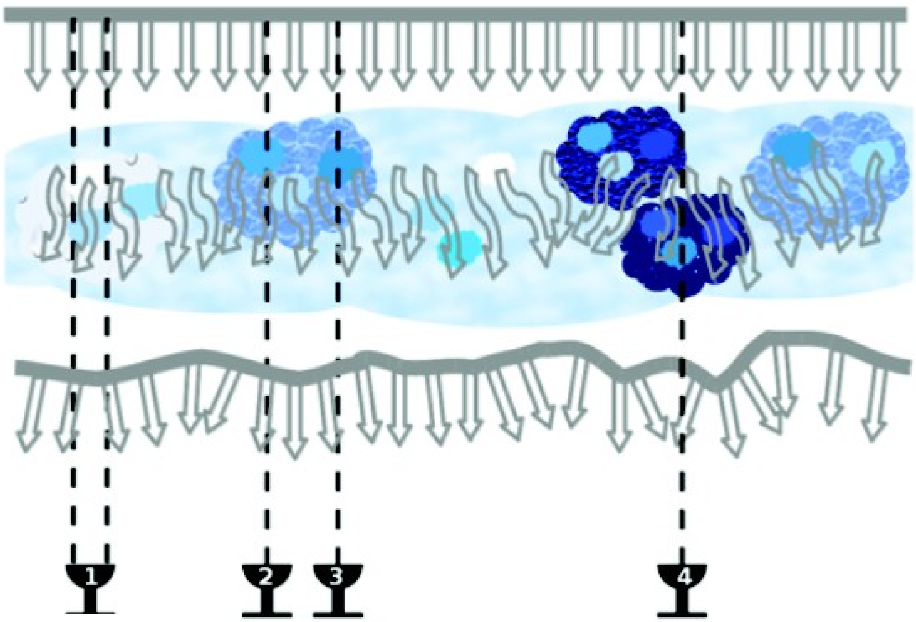
Variations in precipitable water vapor (PWV) cause phase fluctuations, worse at higher frequencies, resulting in:

- Phase shift due to refractive index $n \neq 1$
- Low coherence (loss of sensitivity)

Patches of air with different pwv
(and hence index of refraction)
affect the incoming wave front differently.

Antenna 1, 2, 3 see slightly different disturbances

Sky above antenna 4 varies independently

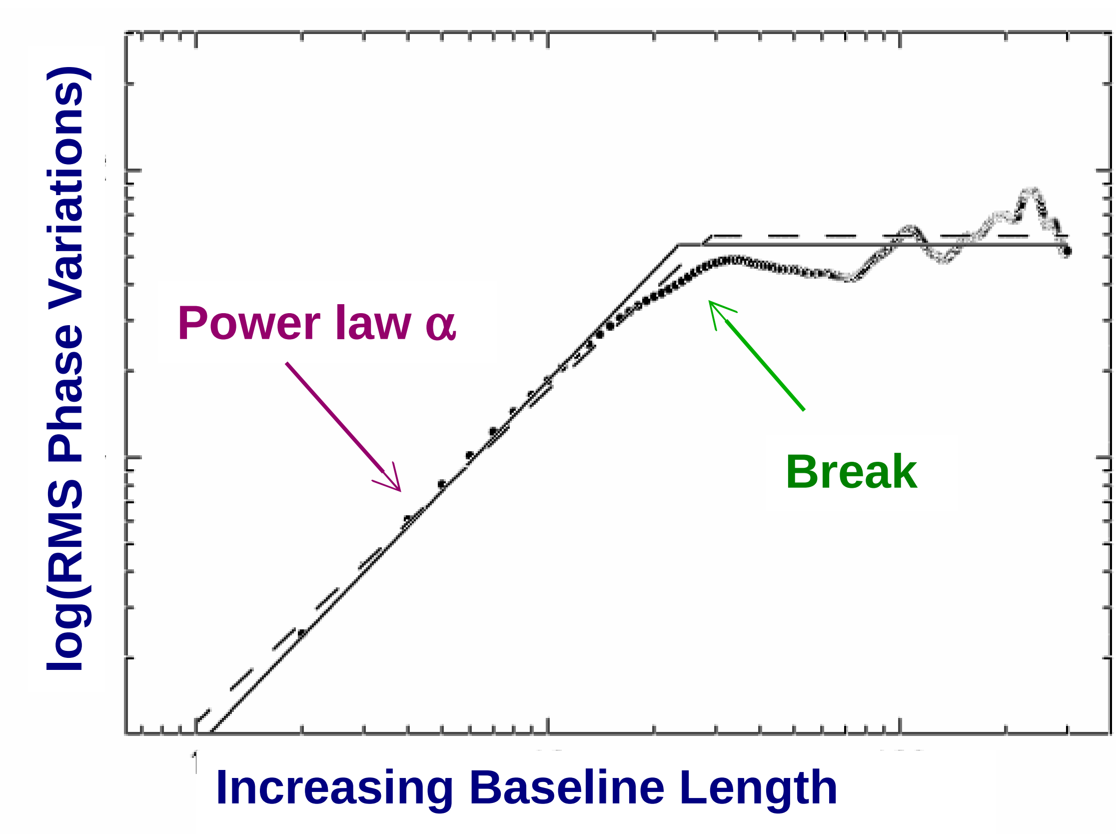


The phase change experienced by an e.m. wave can be related to pwv

$$\varphi_e \approx \frac{12.6\pi}{\lambda} \cdot pwv$$

Hogg, Guiraud, & Decker, 1981

Atmospheric phase fluctuations



Kolmogorov
turbulence
theory

Phase noise

$$\varphi_{rms} = \frac{K\, b^{\alpha}}{\lambda}$$

b=baseline length (km)
α = 1/3 to 5/6 (thin or thick atmosphere)
λ = wavelength (mm)
K constant (~100 for ALMA)

The break is typically @ baseline lengths
few hundred meters to few km
(scale of the turbulent layers)

Break and maximum are weather
and wavelength dependent

Atmospheric phase fluctuations → decorrelation

We lose integrated flux because visibility vectors partly cancel out

$$\langle V \rangle = V_o \langle e^{i\varphi} \rangle = V_o e^{-(\varphi_{rms}^2)/2}$$

$$\varphi_{rms} = 1 \text{ radian} \rightarrow \langle V \rangle = 0.60\, V_0$$

In summary

Fluctuations in the line-of-sight pwv of an antenna cause phase variations of the order of ~30 deg / sec at 90 GHz, and scales linearly with frequency....

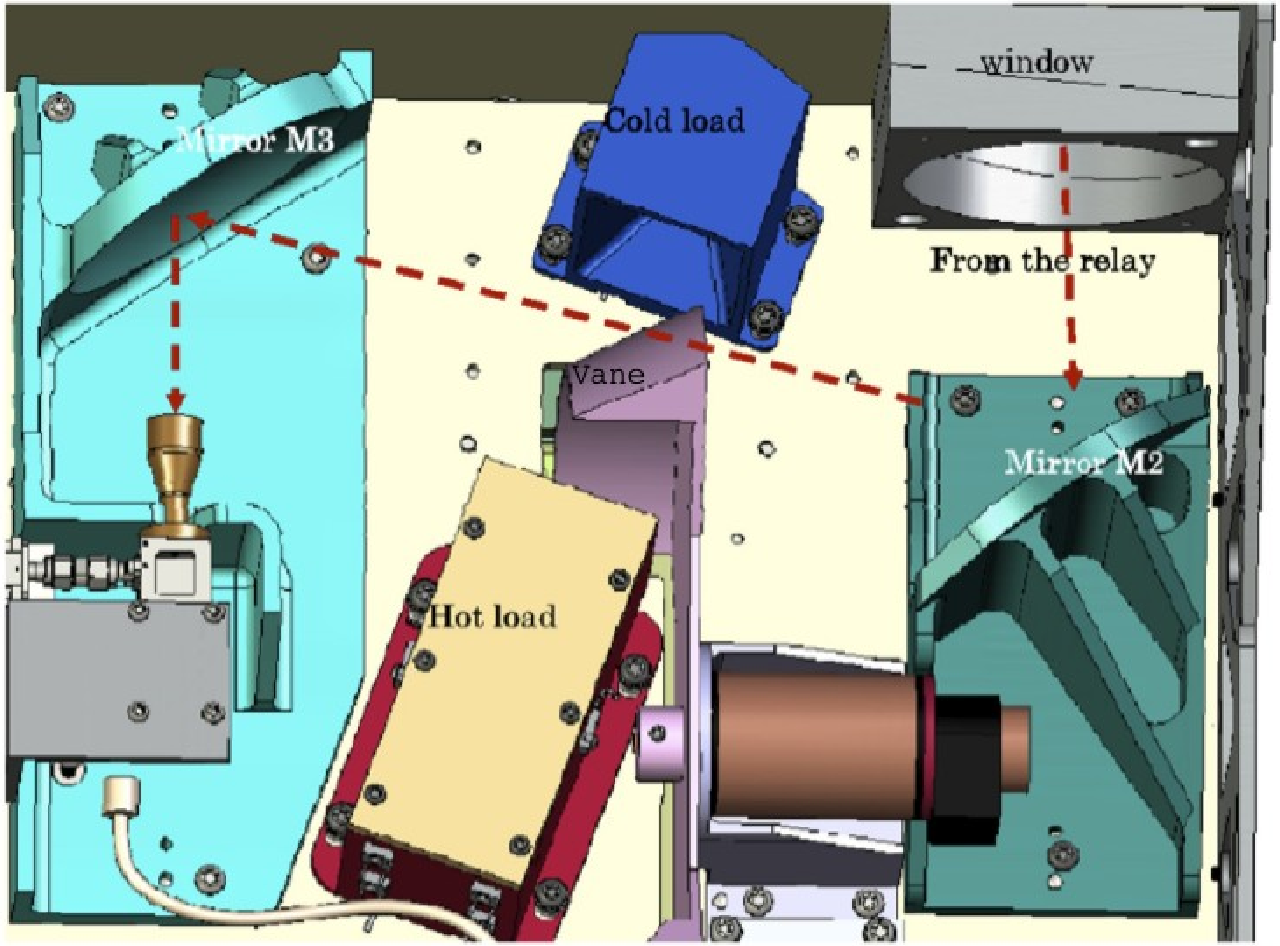
$$\varphi_e \approx \frac{12.6\pi}{\lambda} \cdot pwv$$

and the phase noise is worse at longer baselines...

$$\varphi_{rms} = \frac{K\, b^{\alpha}}{\lambda}$$

WVR correction

Each ALMA 12 m antenna has a **water vapour radiometer**

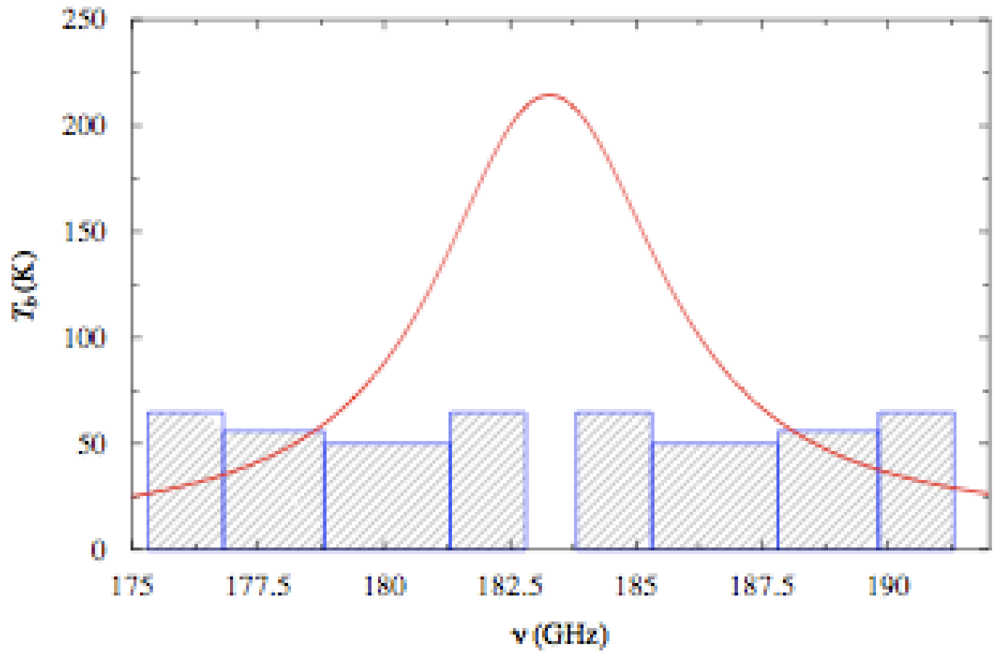


WVR correction

Each ALMA 12 m antenna has a water **vapour radiometer**

Four “channels” flanking the peak of the 183 GHz water line

Data taken every second



WVR correction

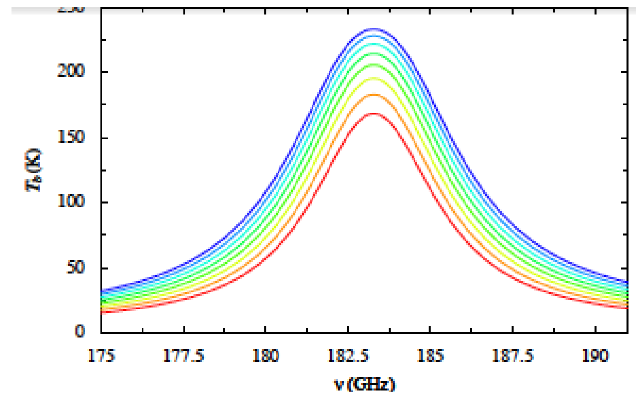
Each ALMA 12 m antenna has a water **vapour radiometer**

Four "channels" flanking the peak of the 183 GHz water line

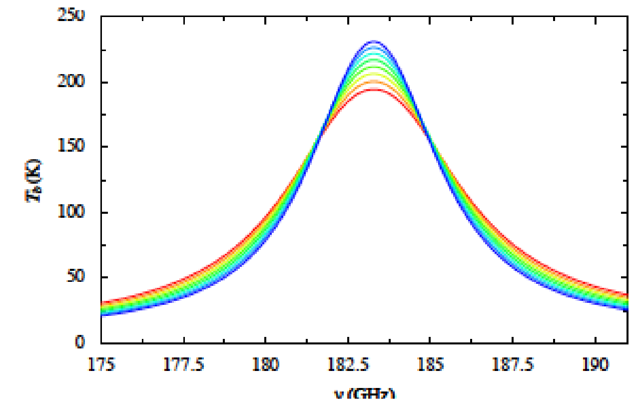
Data taken every second

Convert 183 GHZ brightness to PWV (wvrgcal):
model PWV, temperature and pressure
compare to the observed "spectrum"
compute the correction:

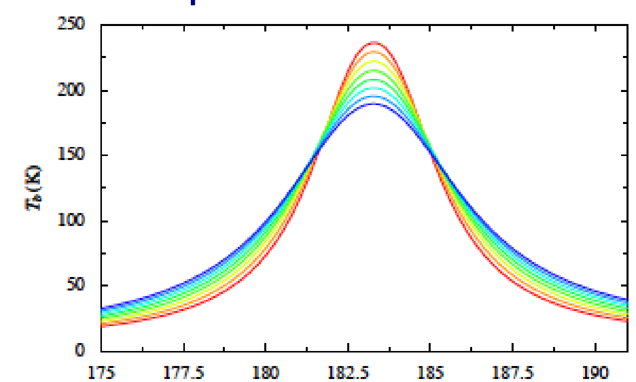
$$\varphi_e \approx \frac{12.6\pi}{\lambda} \cdot pwv$$



PWV from 0.6 to 1.3 mm



Temperature 230-300 K

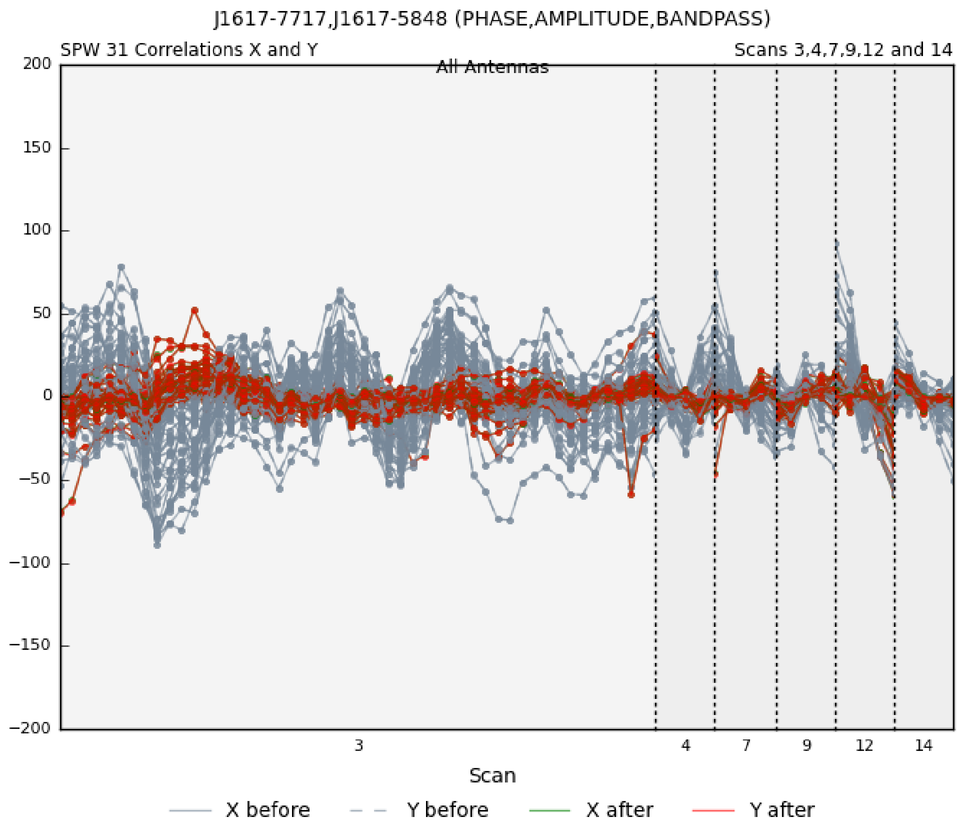


Pressure 400-750 mBar

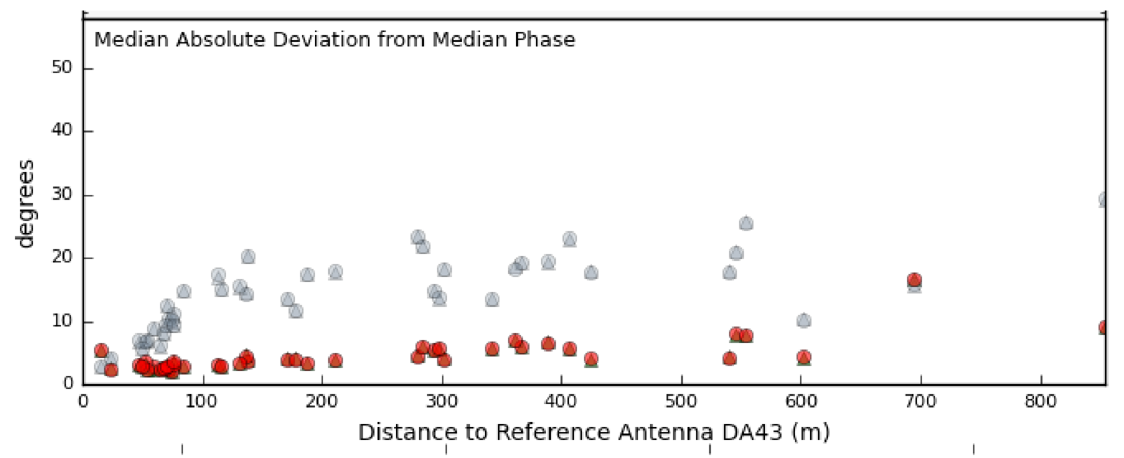
WVR correction

Deviation from median phase

vs time



vs distance to Reference Antenna



the phase noise is worse at longer baselines

$$\varphi_{rms} = \frac{K\, b^{\alpha}}{\lambda}$$

Before & after wvr correction

Tsys dominated by atmospheric term

e.g. to observe a 1 Jy source with a 10 m radiotelescope we have to measure $T_A \sim 0.04$ K against $T_{sys} \sim 100$ K

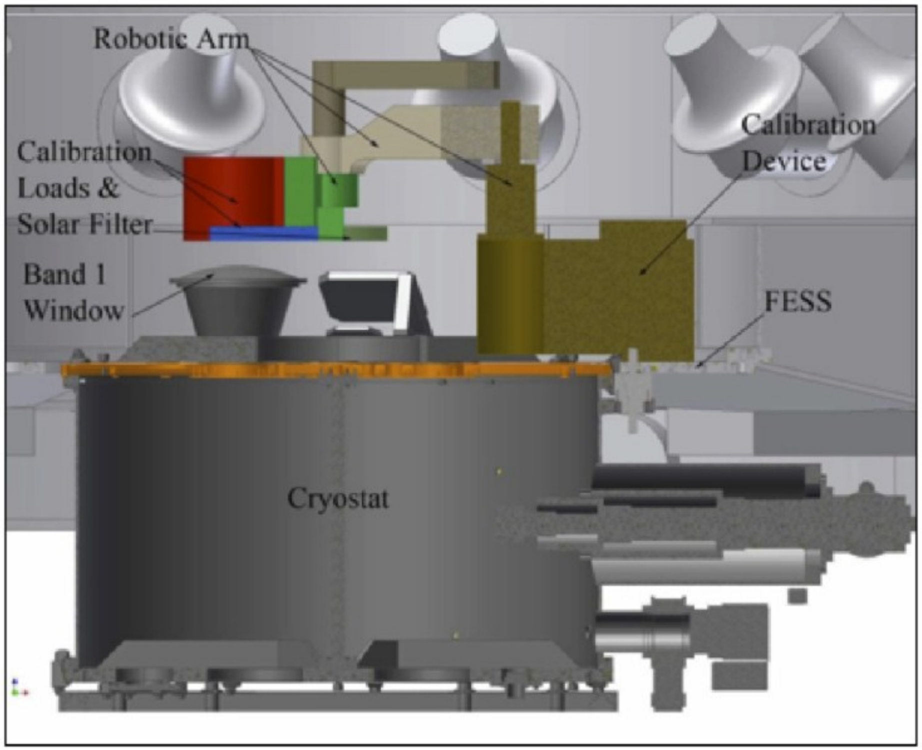
$$T_{sys} \sim T_{atm}\,(1- e^{-\tau}) + T_{rx}$$

At lower frequencies T_{rx} is dominant

At higher frequencies (mm/submm) the noise associated with the atmosphere T_{atm} is dominant, and acts like a blackbody emitter, attenuating the astronomical signal

Tsys measured

ALMA front end are equipped with an Amplitude Calibration Device (ACD)



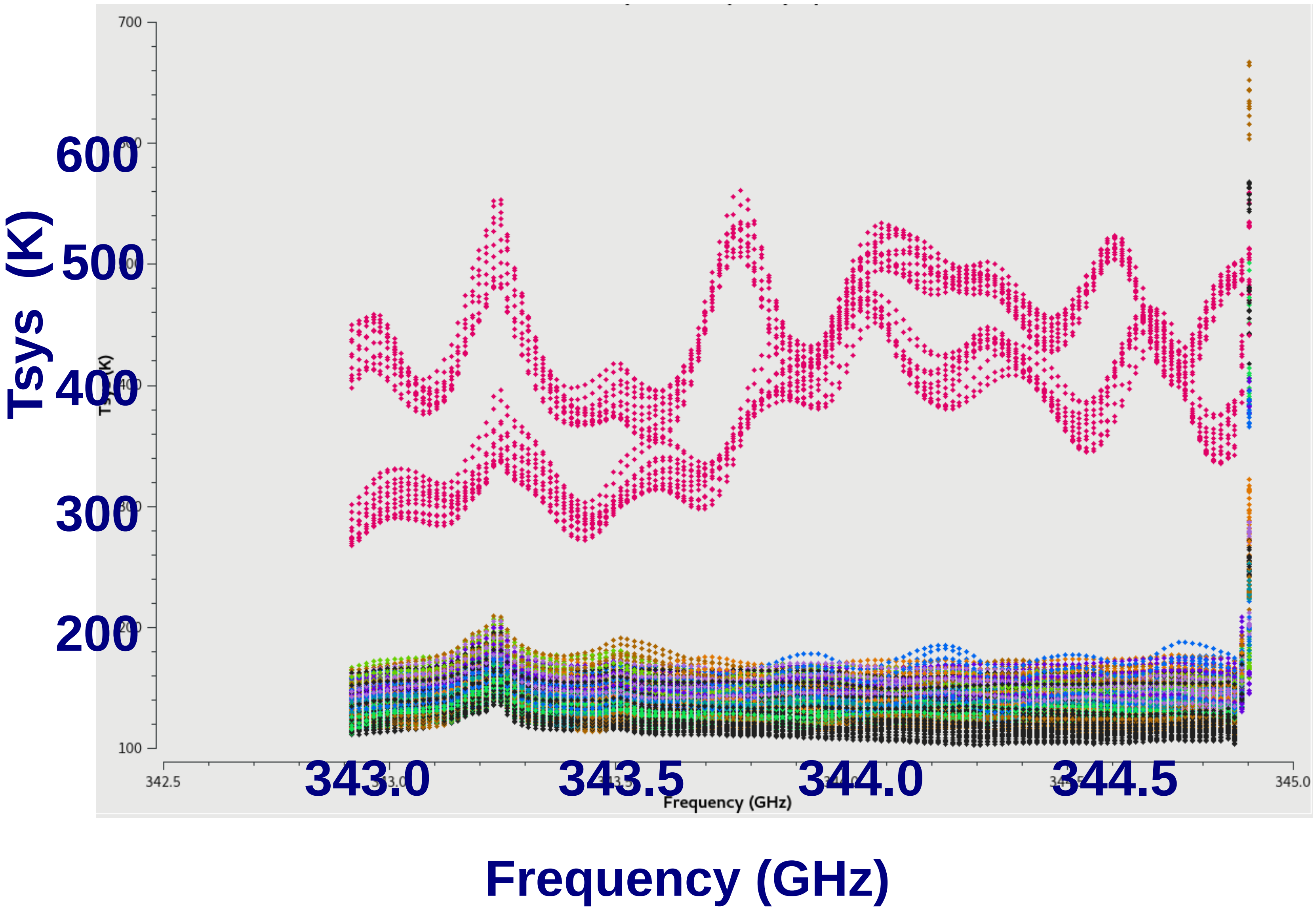
→ To measure T_{sys} and T_{rx} stored in tables

Every scan could have a Tsys measurement, but <400 GHz relatively constant ~10min.
Tsys spectra are applied off-line to the correlated data.

Assuming correlated data in units of % correlation multiplication by Tsys will change the unit to Kelvin

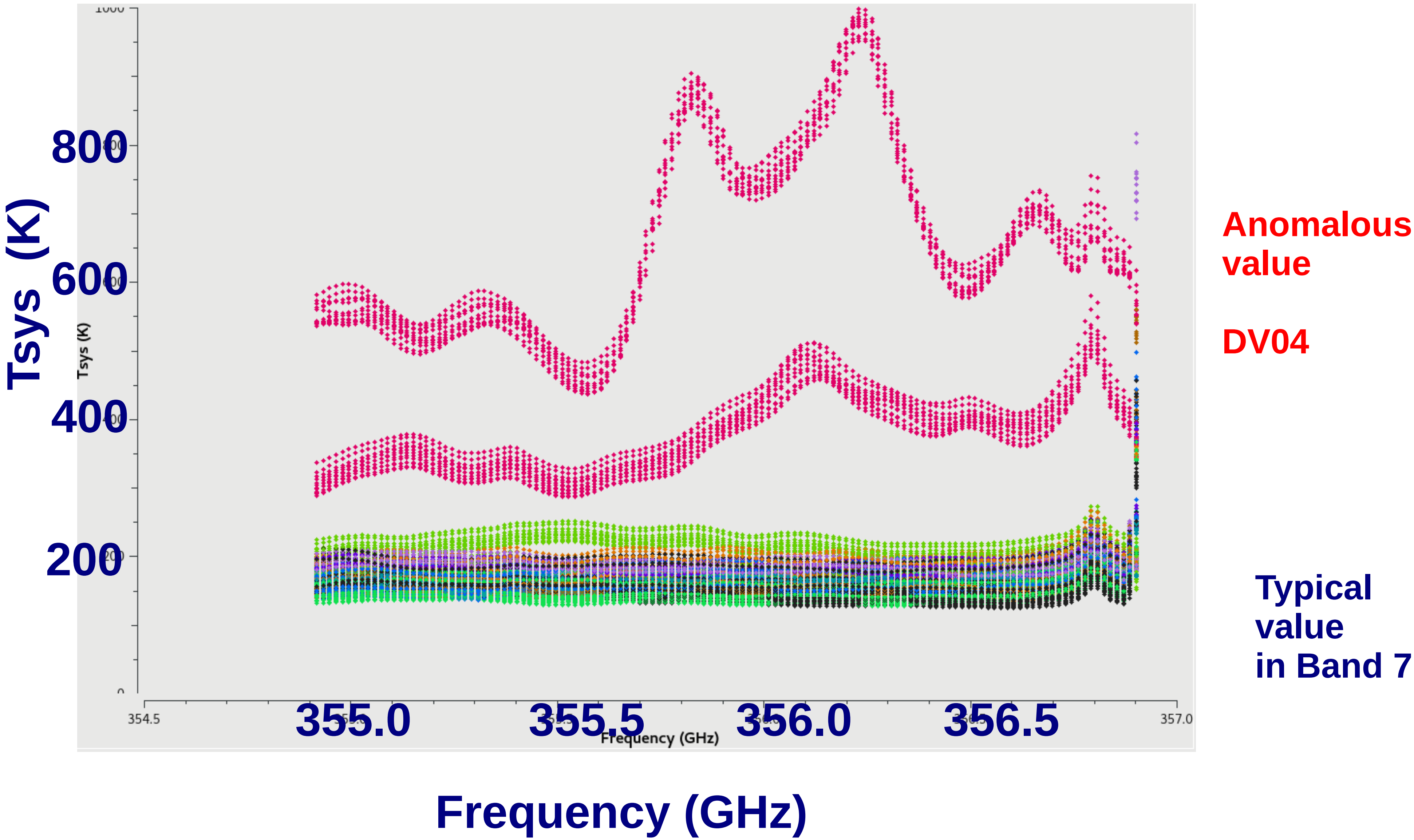
Tsys measured

Tsys in your dataset: in color different antennas

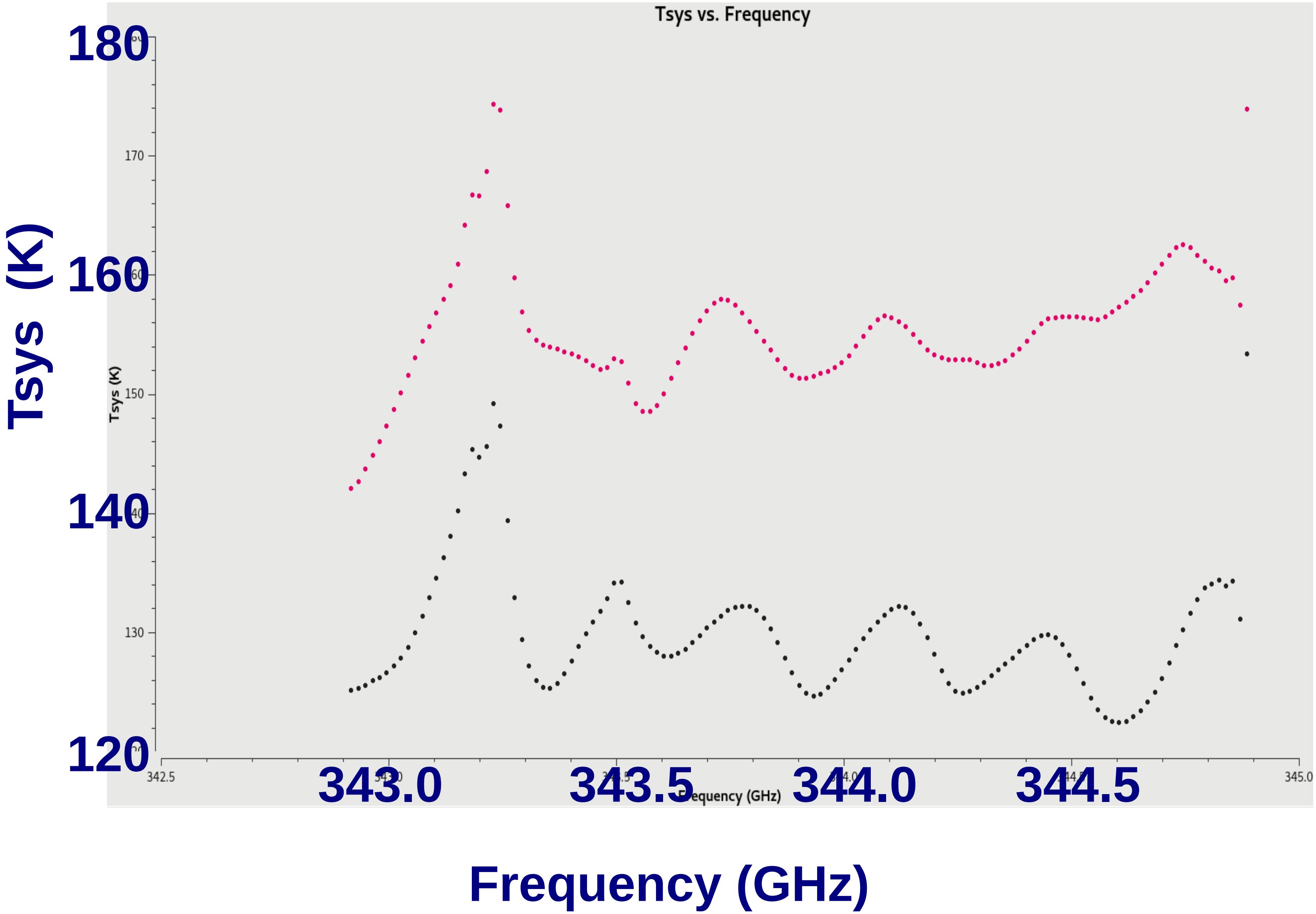


Tsys measured

Tsys in your dataset: in color different antennas

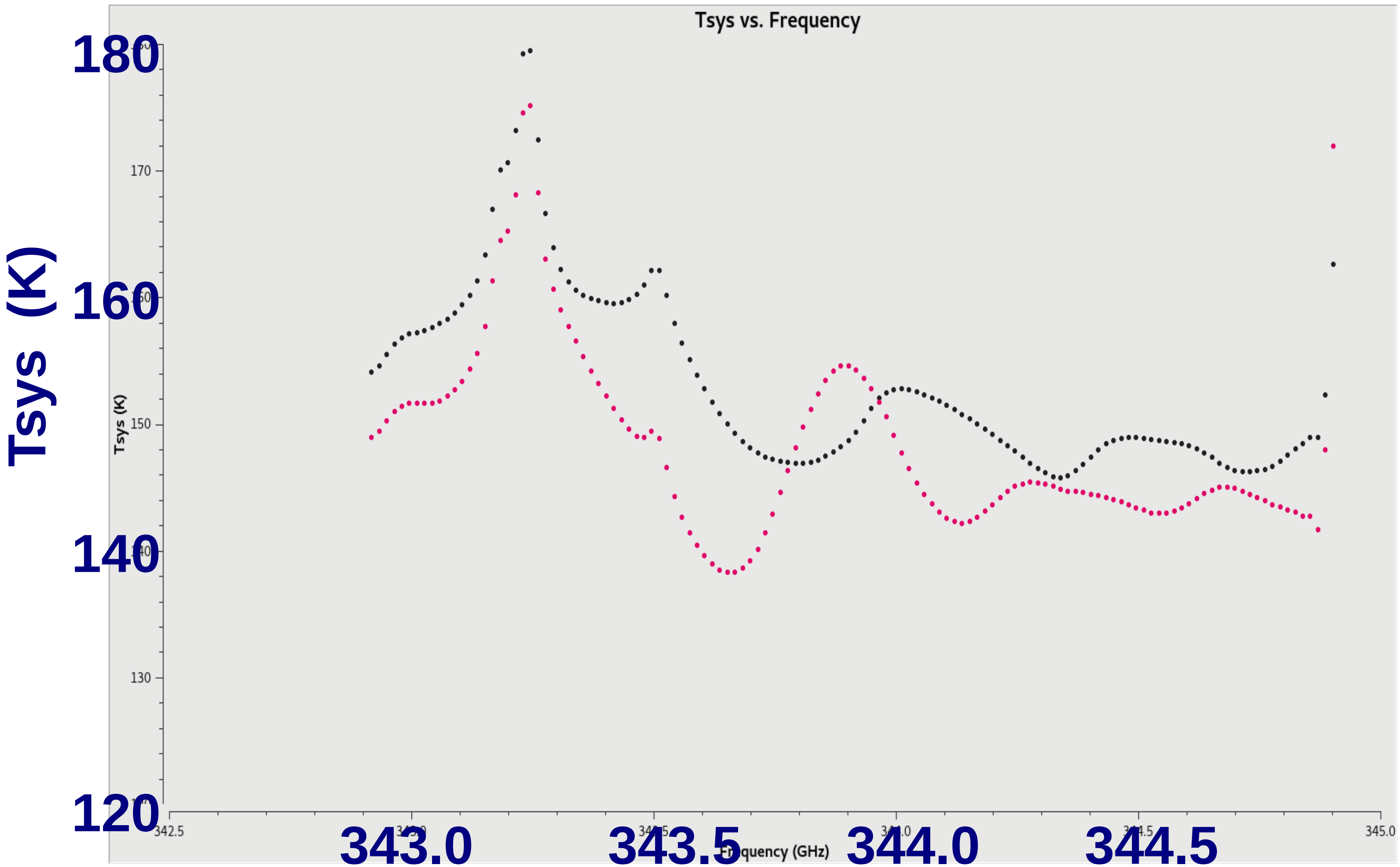


Antenna DV07: in color different corr



Tsys measured

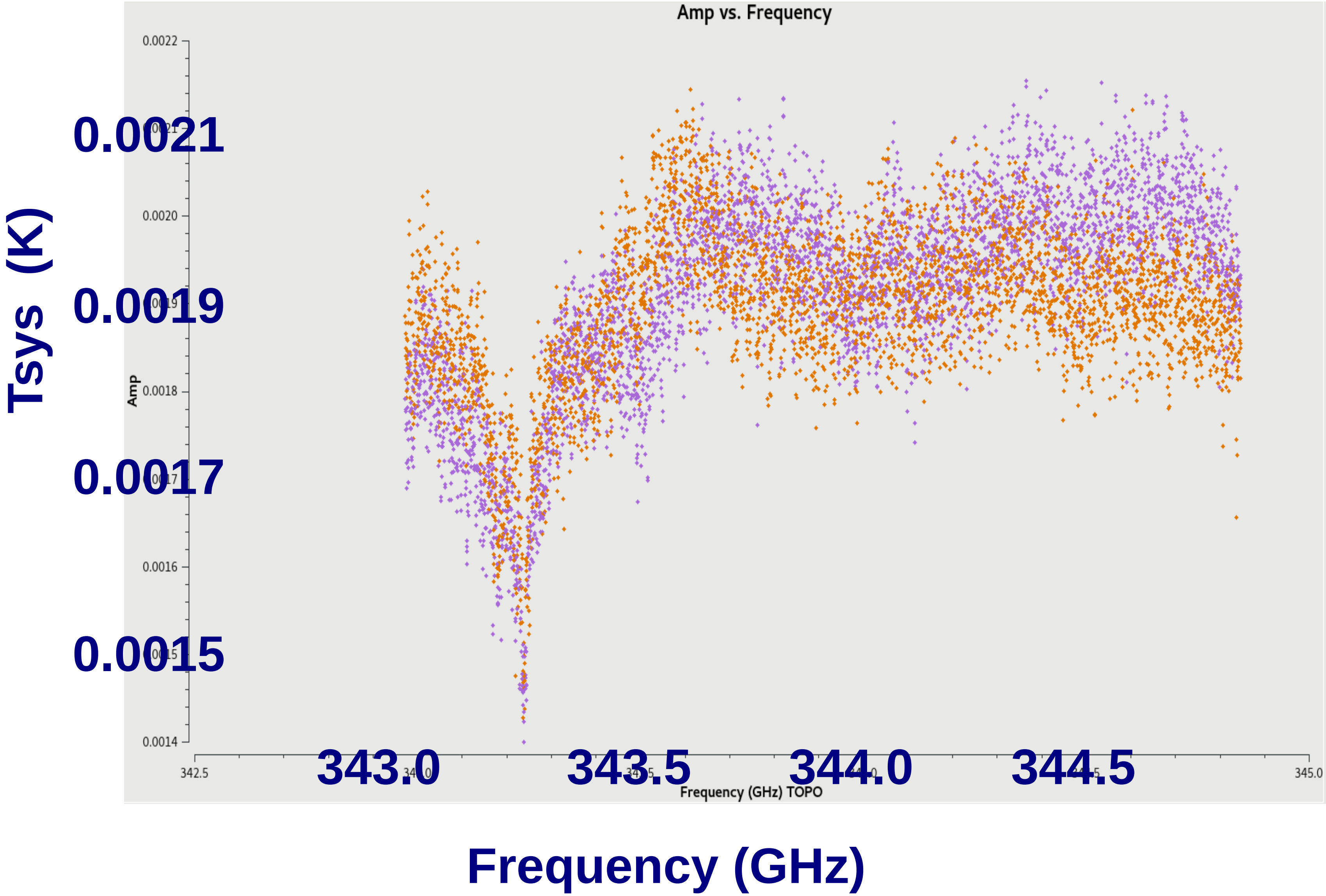
Antenna DV06: in color different corr



Typical value in Band 7

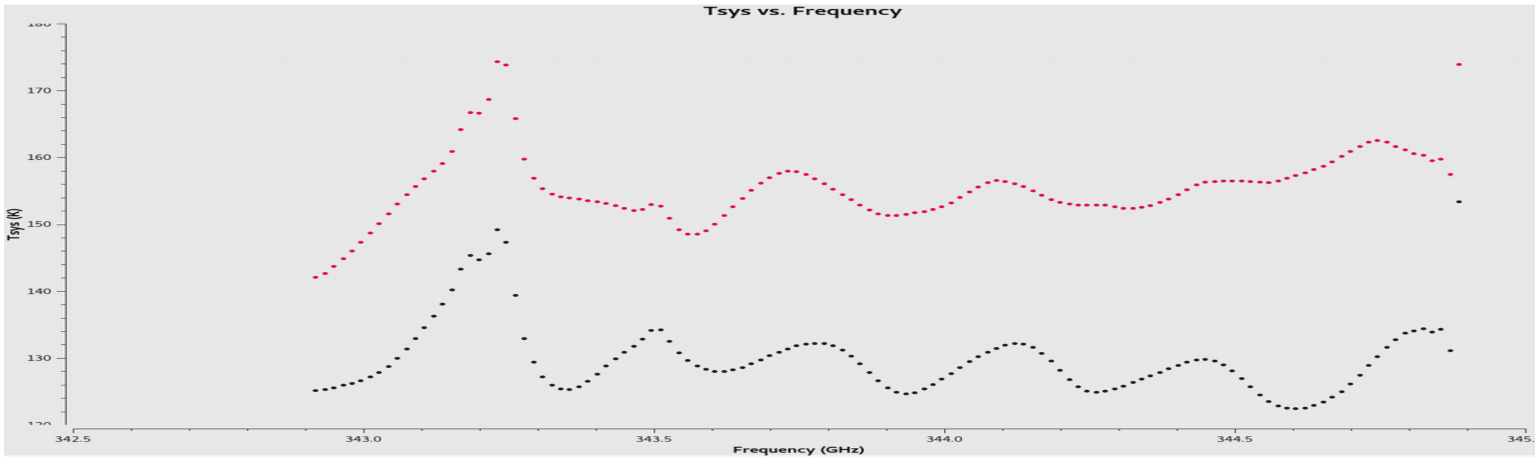
Frequency (GHz)

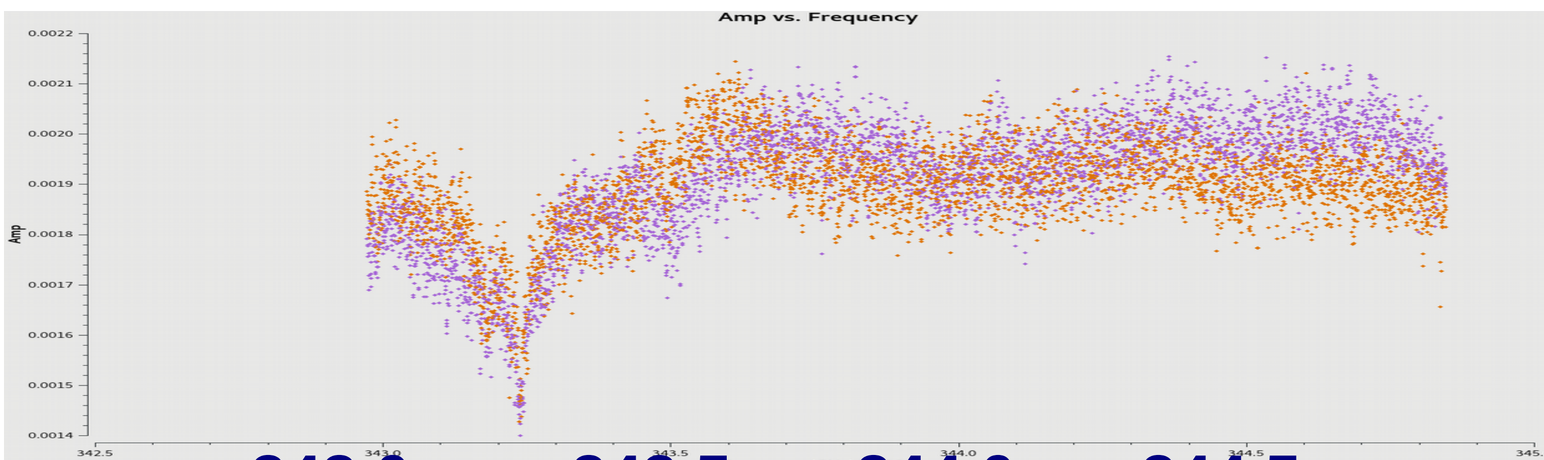
Baseline DV06&DV07: in color different corr



Baseline DV06&DV07: in color different corr

Tsys (K)





343.0 343.5 344.0 344.5

Frequency (GHz)

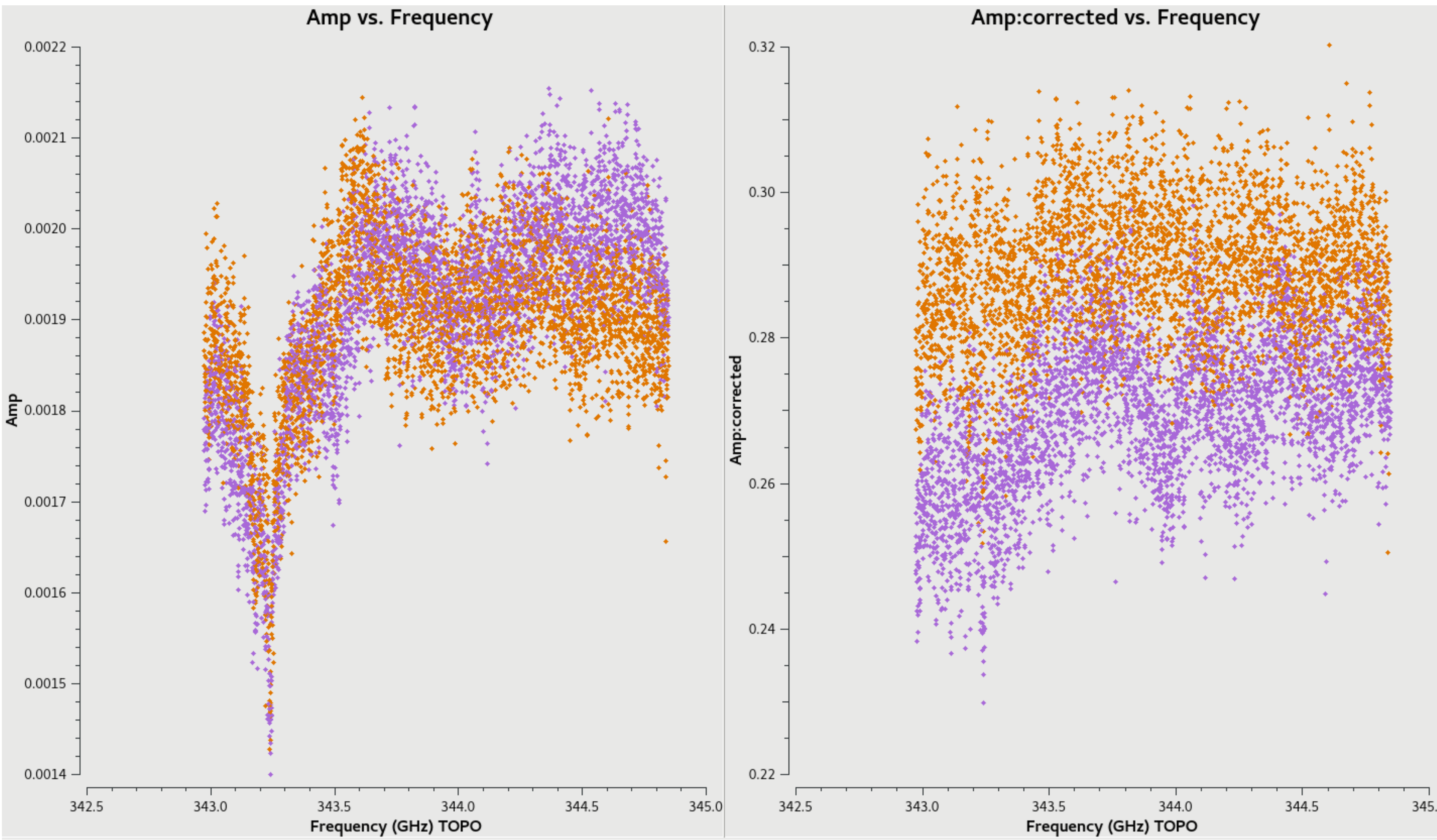
Tsys calibration

DV06 & DV07

The attenuation
Is corrected

Before

After



Tsys calibration

DV06 & DV07

K

The data are now Temperature in K

Before **After**