Your data
and “A priori” Calibration

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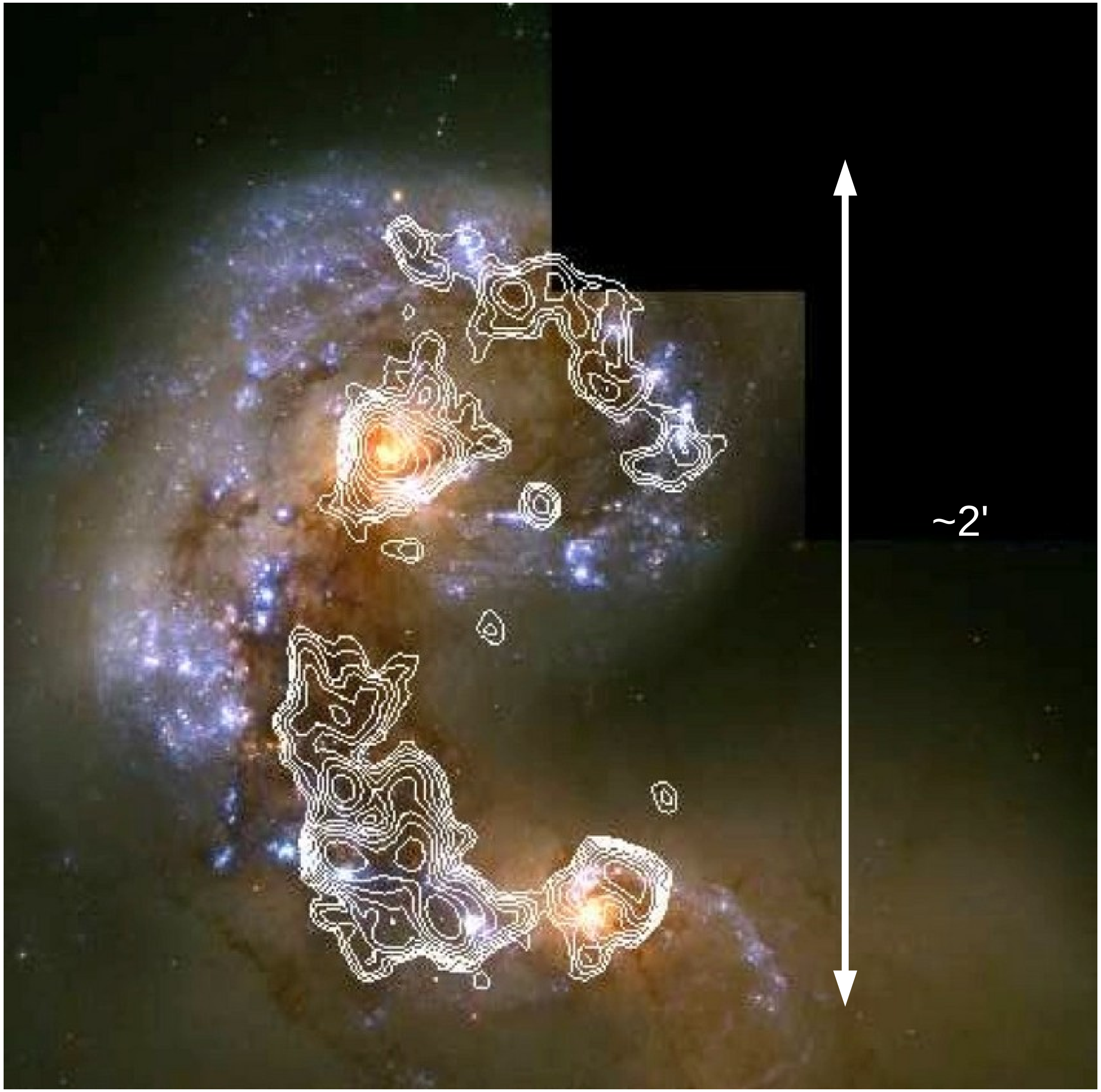
http://www.alma.inaf.it/index.php/Courses

NGC4038/4039

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

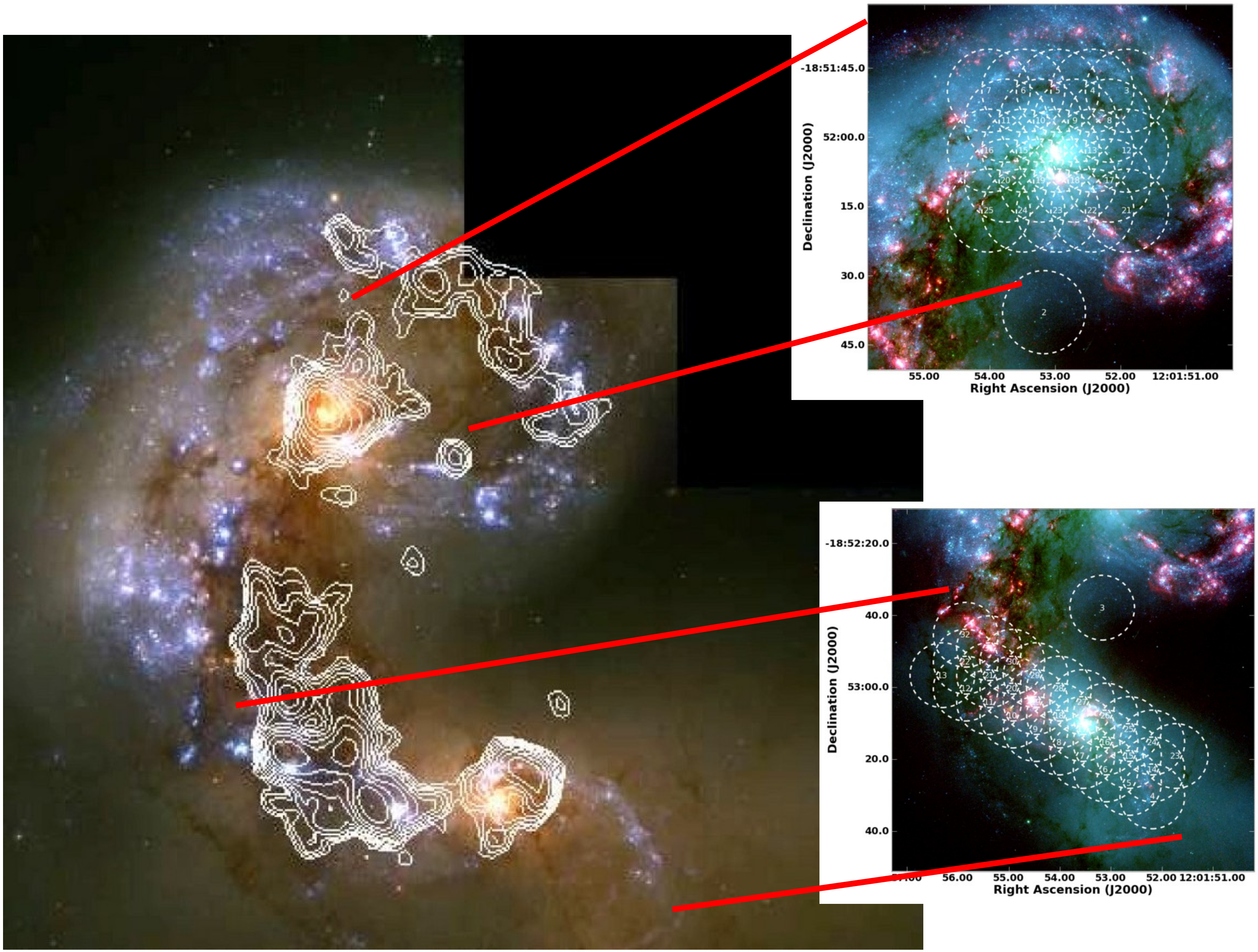
NGC4038/4039



Wilson et al. (2000)

Observations of CO(1-0)
resolution 3”x4”

ALMA field of view in Band 7 ~ 15 “



23 pointings

29 pointings

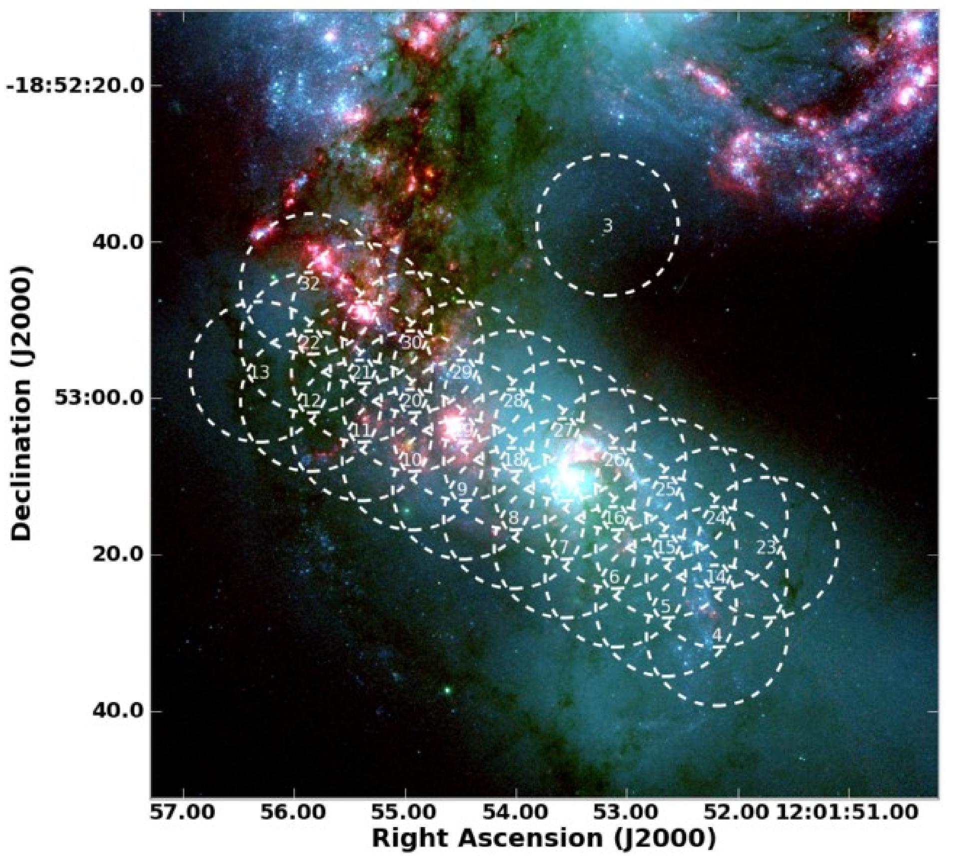
Antennae ALMA SV

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

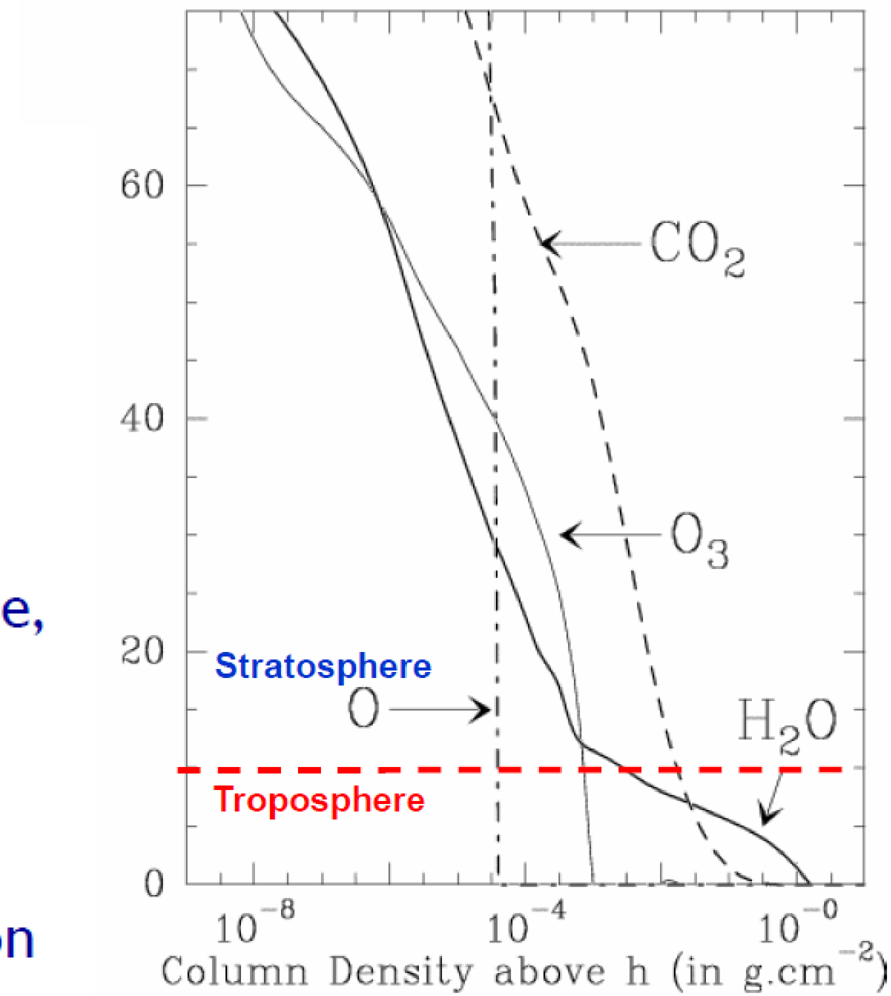
  → T_{sys} dominated by atmospheric noise

Peculiarities @ mm

The role of the troposphere

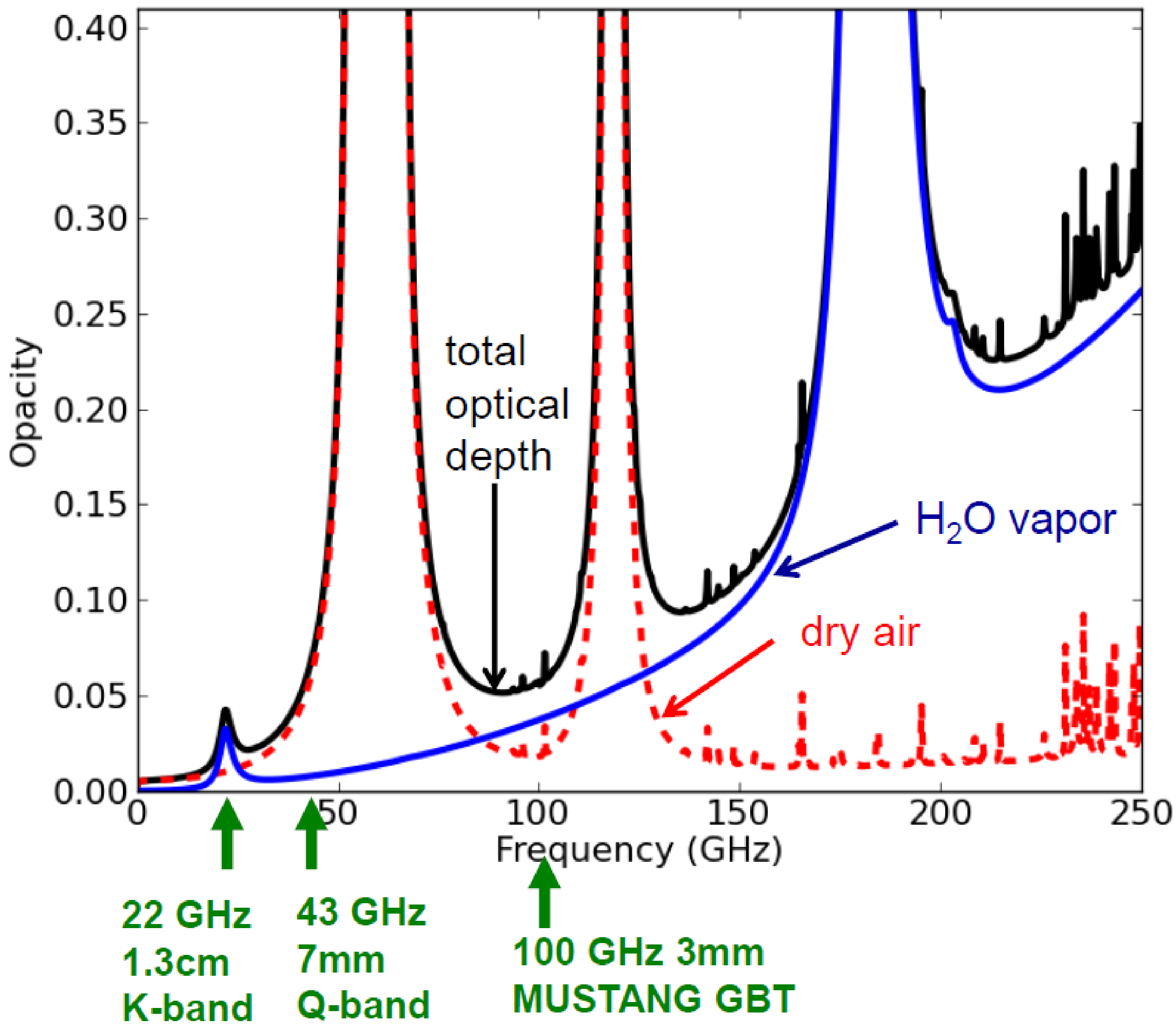
- H_2O (mostly vapor)
- "Hydrosols" (water droplets in clouds and fog)
- "Dry" constituents: O_2, O_3, CO_2, Ne, He, Ar, Kr, CH_4, N_2, H_2
- clouds & convection = time variation

Column density as function of altitude



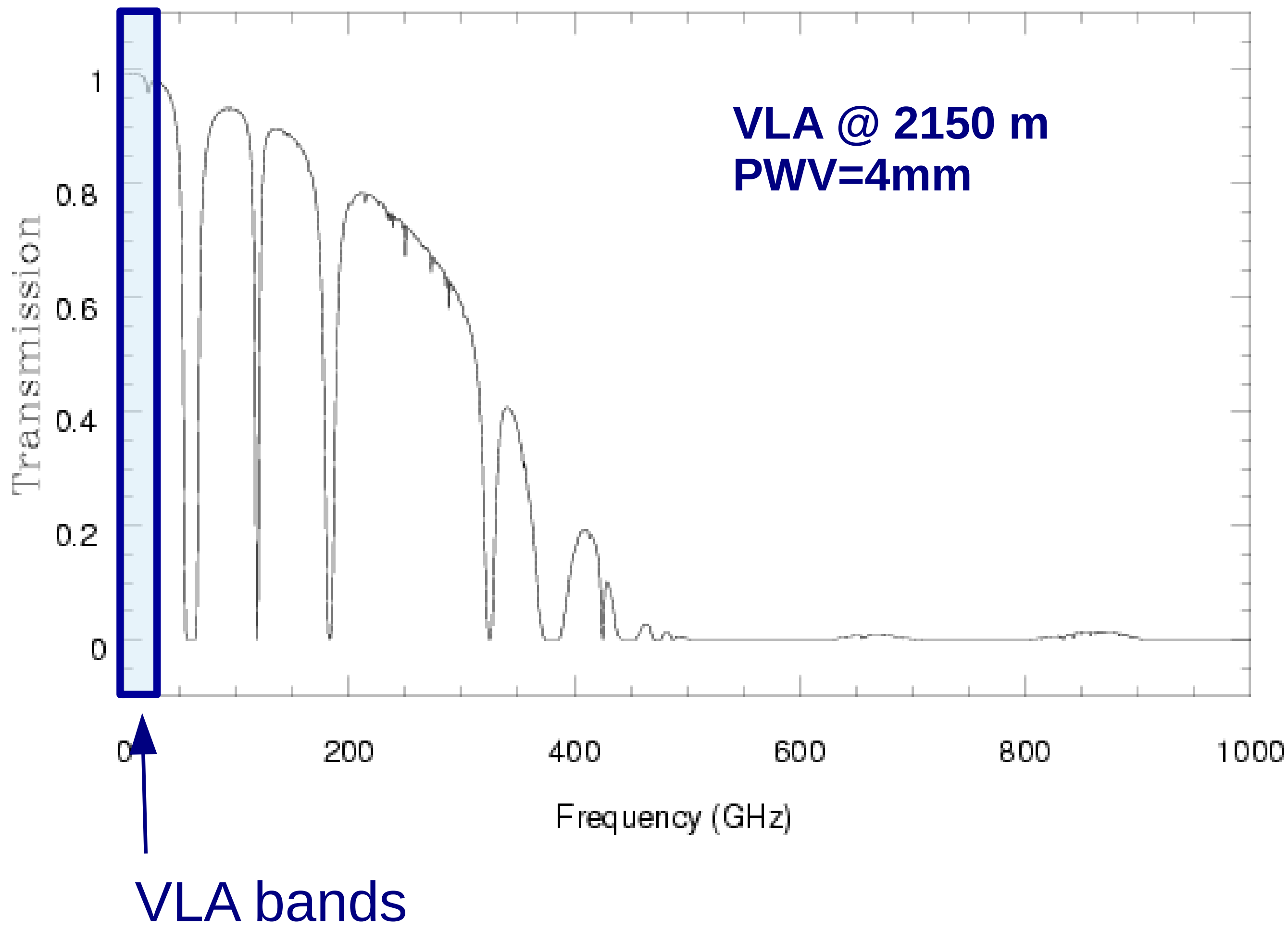
Peculiarities @ mm

Optical depth as function of frequency



Peculiarities @ mm

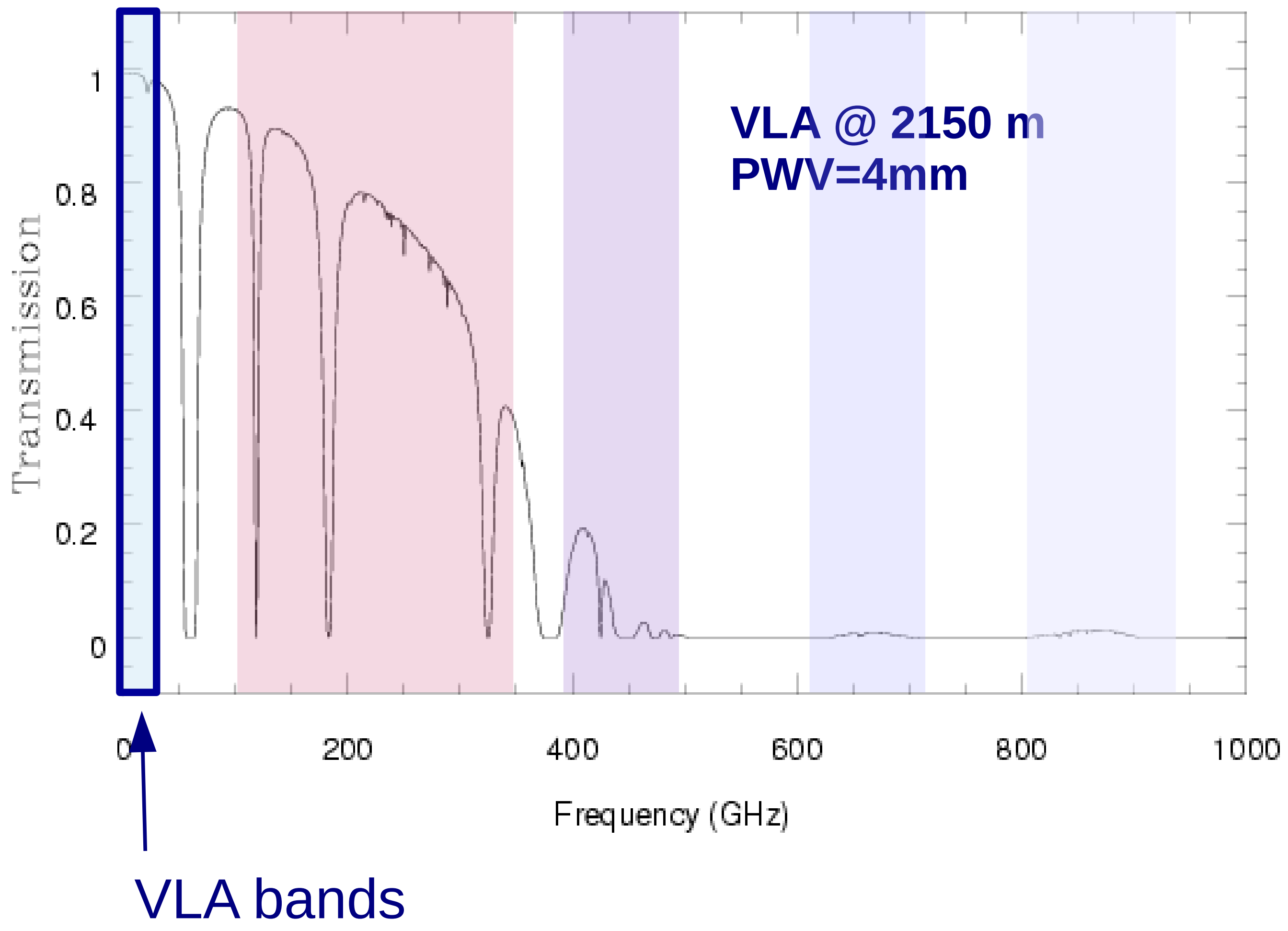
Tropospheric opacity depends on altitude



Atmospheric transmission not a problem @ $\lambda >$ cm

Peculiarities @ mm

Tropospheric opacity depends on altitude



Atmospheric transmission not a problem @ λ > cm

Peculiarities @ mm

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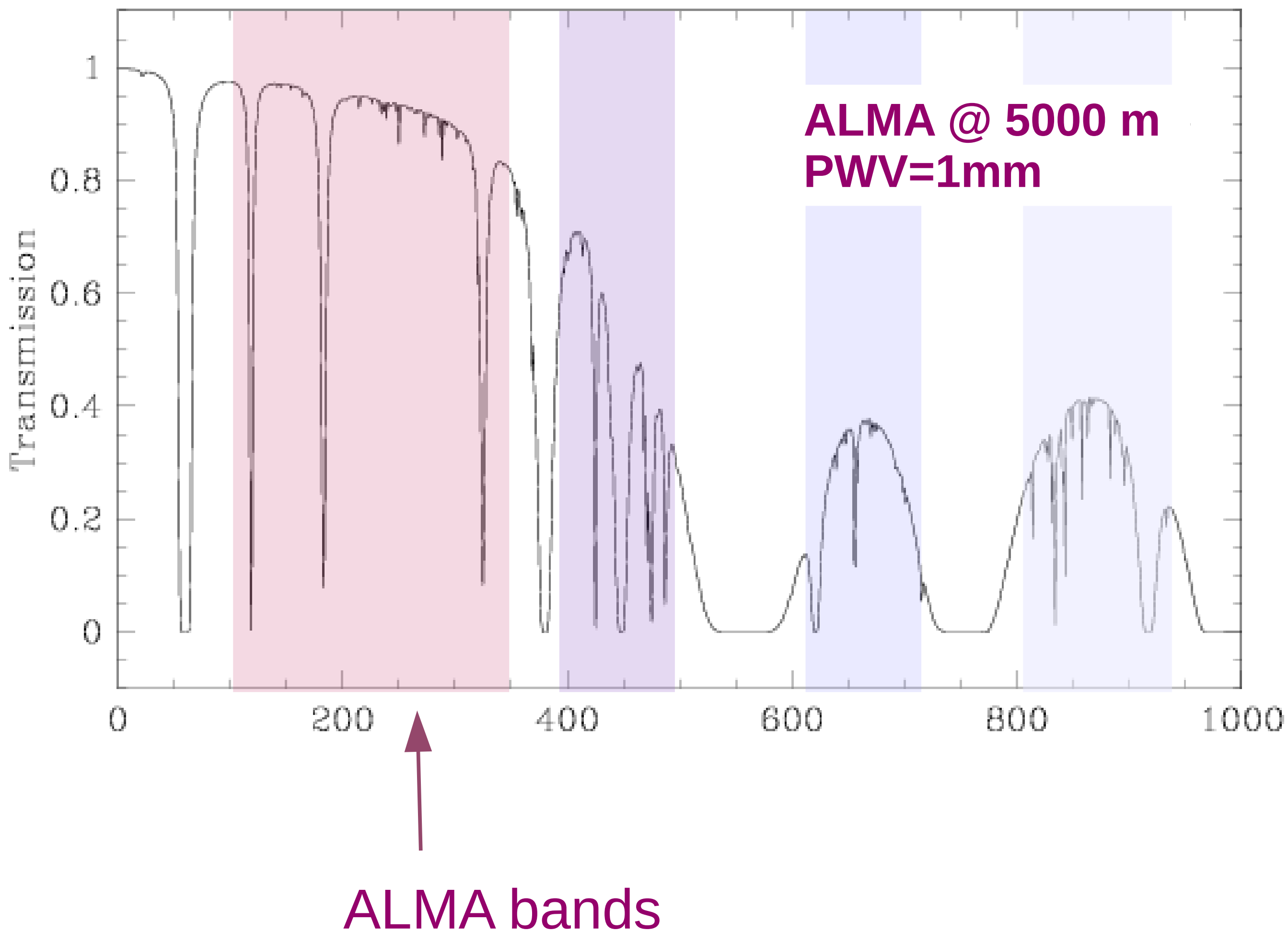
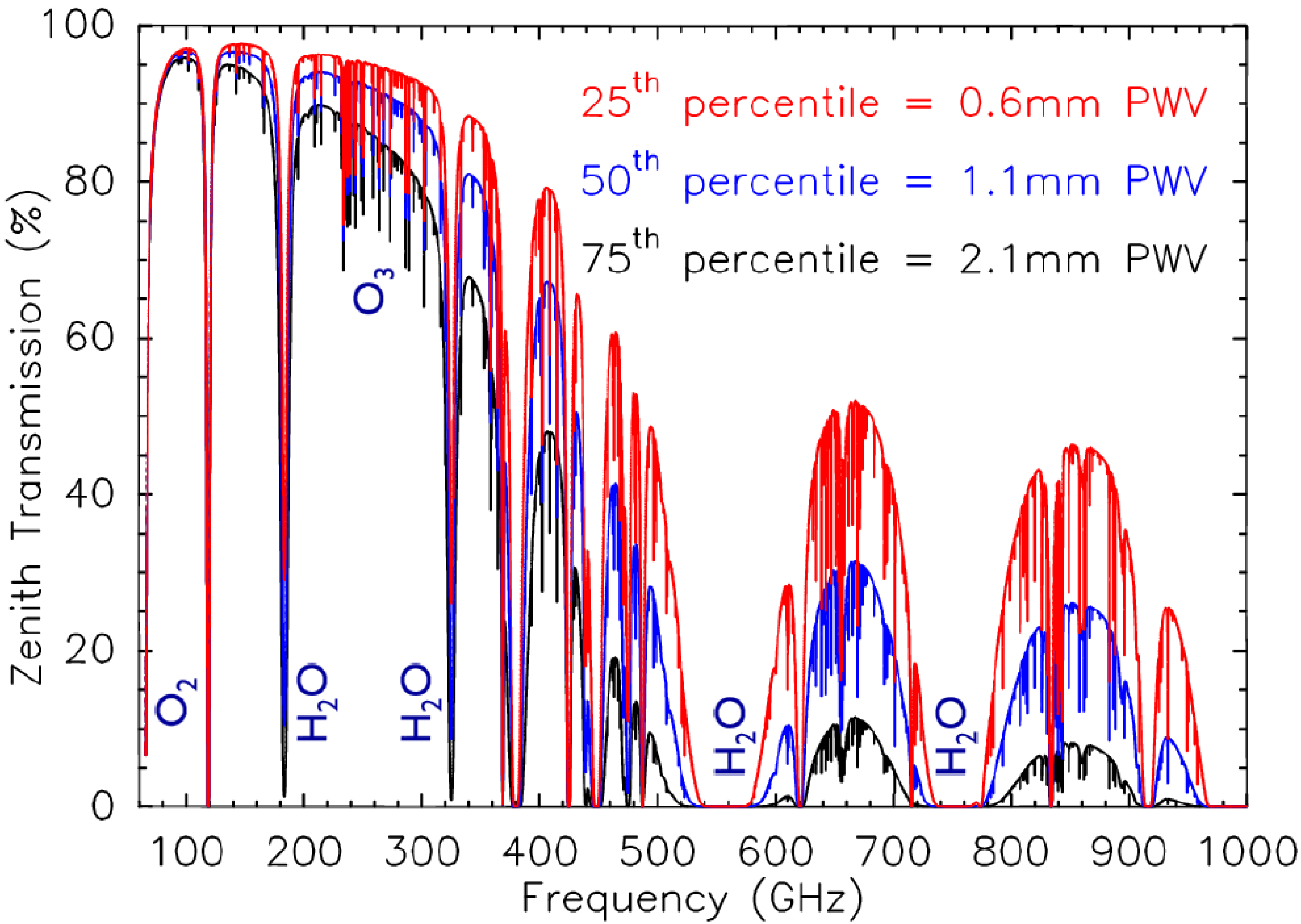


Difference due to the scale height of water vapor

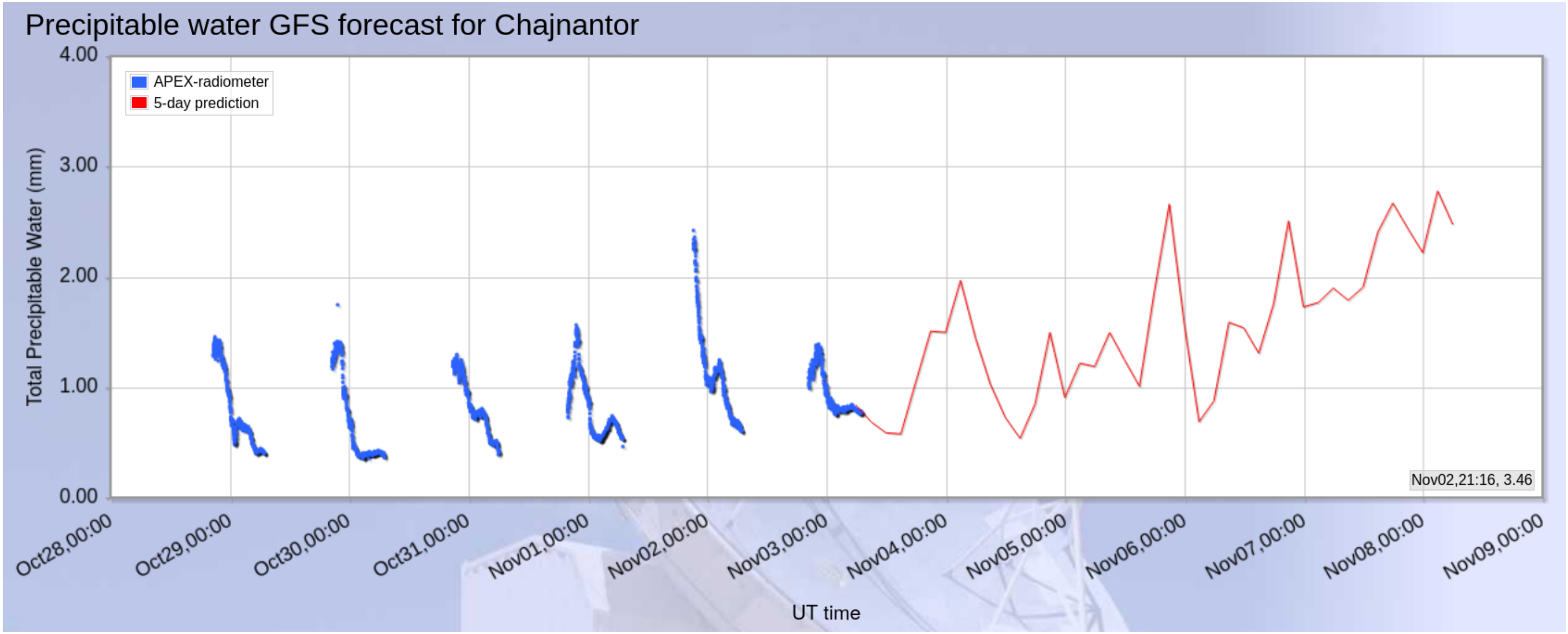
Peculiarities @ mm

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

Peculiarities @ mm

Mean effect of atmosphere on Phase

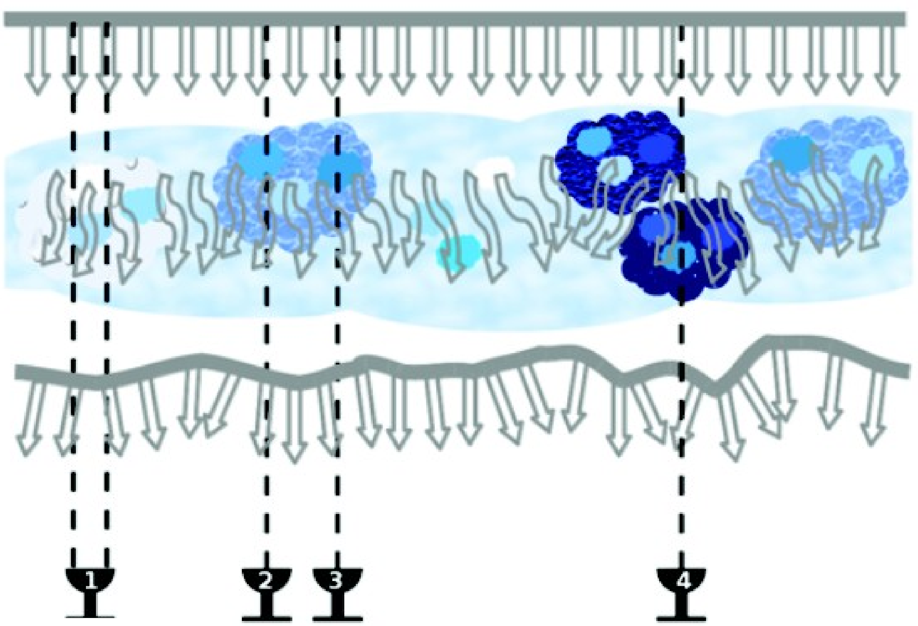
Variations in precipitable water vapor (PWV) cause phase fluctuations, worse at higher frequencies, resulting in:

- 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



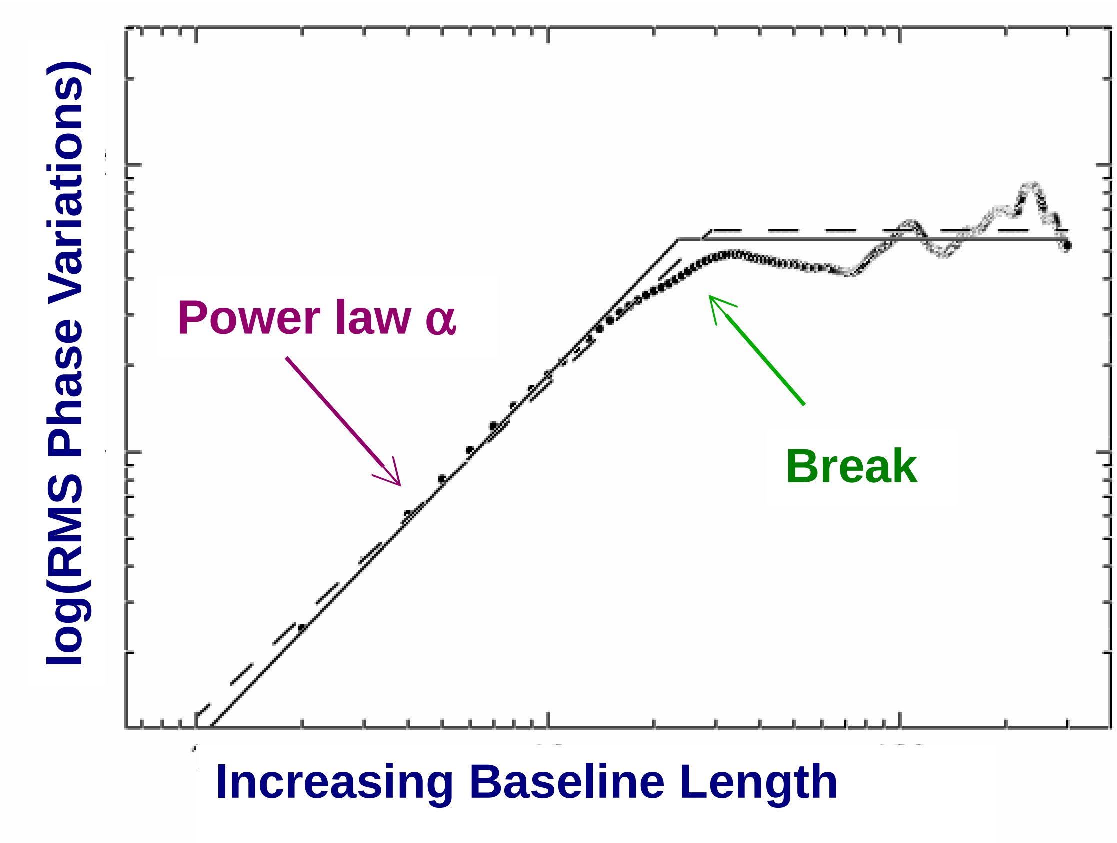
The phase change experienced by an e.m. wave can be related to pwv

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

Hogg, Guiraud, & Decker, 1981

Peculiarities @ mm

Atmospheric phase fluctuations



Phase noise

Kolmogorov turbulence theory

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

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

Peculiarities @ mm

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....

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

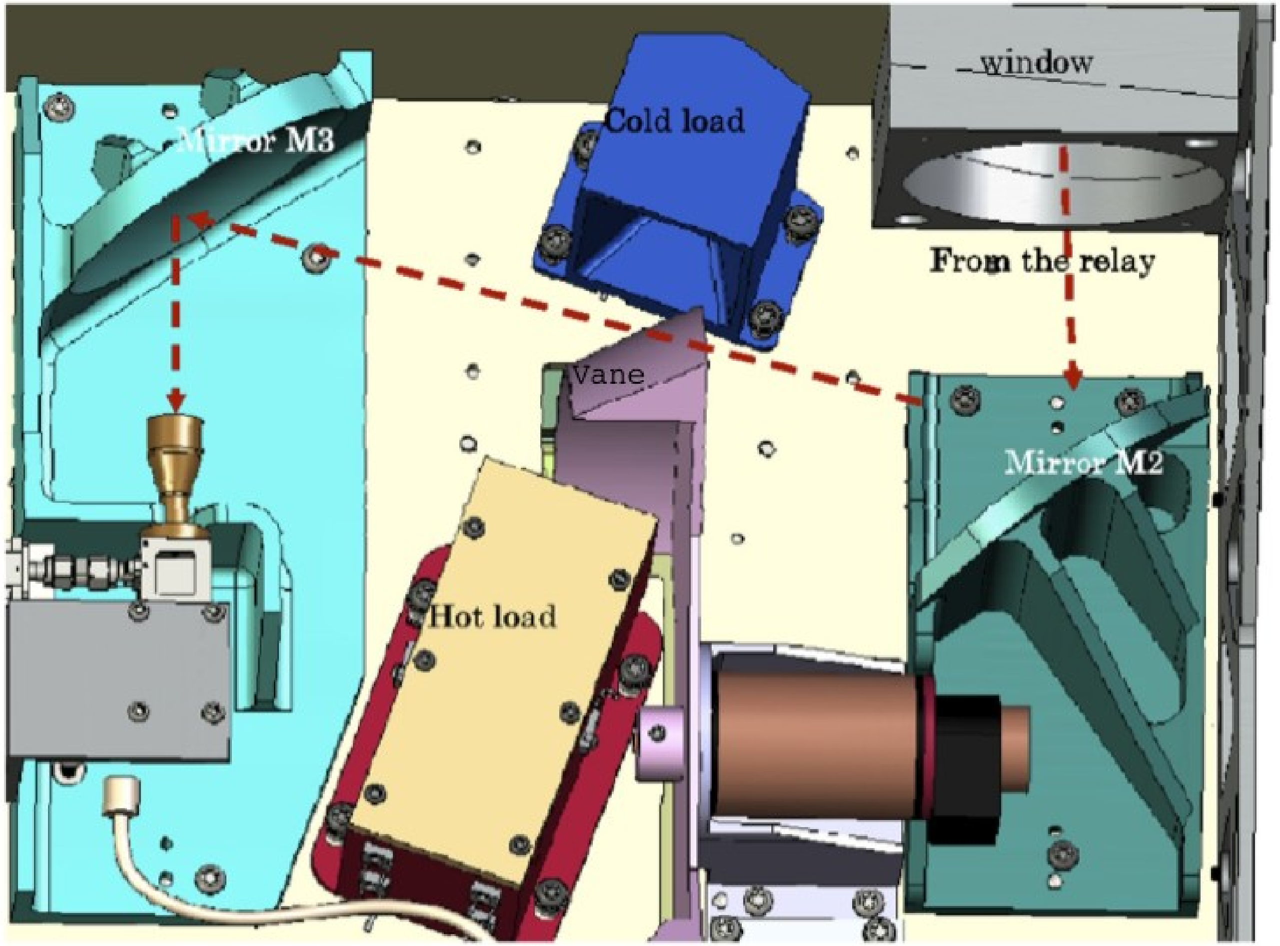
and the phase noise is worse at longer baselines...

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

Peculiarities @ mm

WVR correction

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



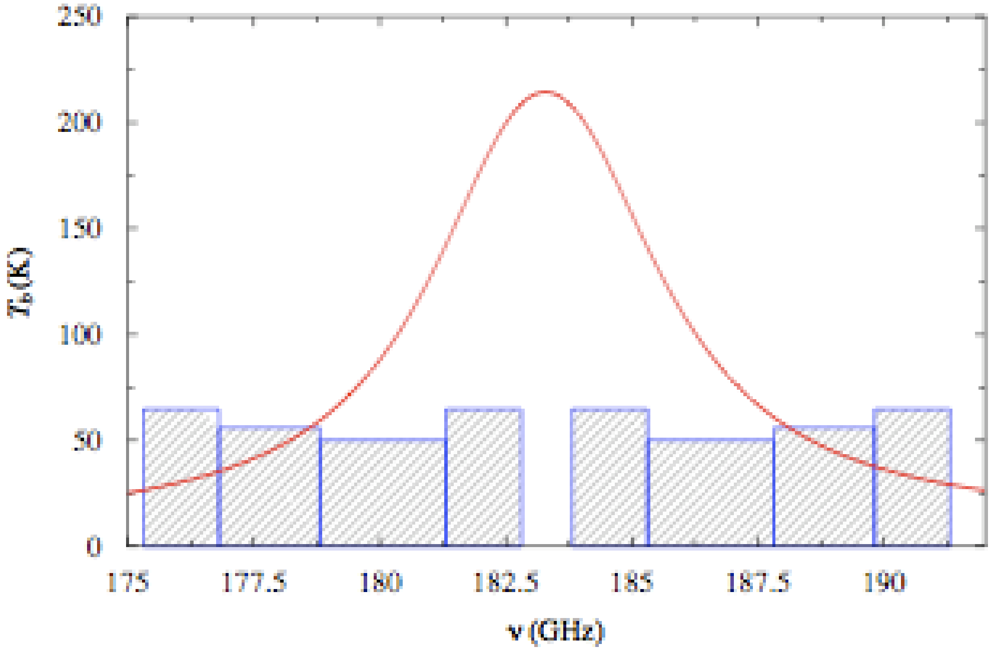
Peculiarities @ mm

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



Peculiarities @ mm

WVR correction

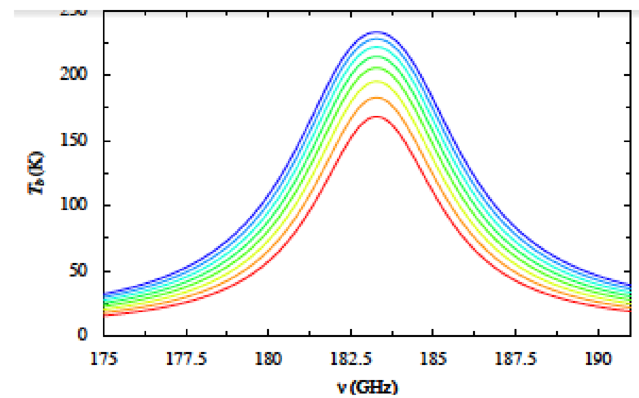
Each ALMA 12 m antenna has a water **vapour radiometer**

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

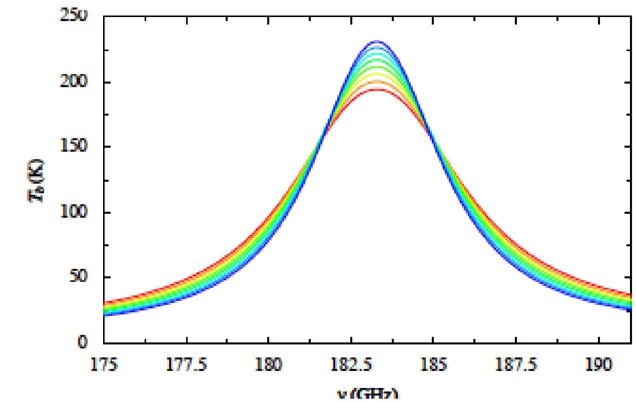
Data taken every second

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

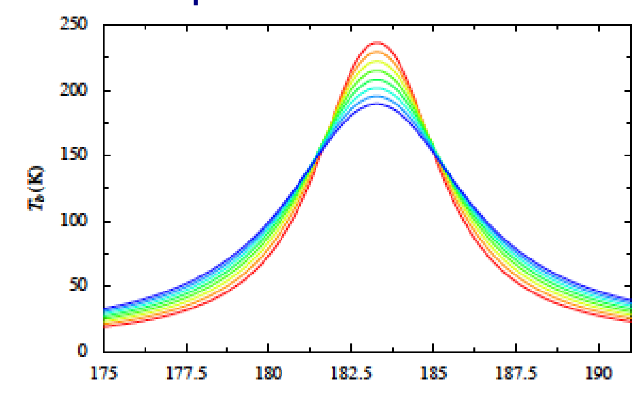
$$\varphi_e \approx \frac{12.6\pi}{\lambda} \cdot pwv$$



PWV from 0.6 to 1.3 mm



Temperature 230-300 K

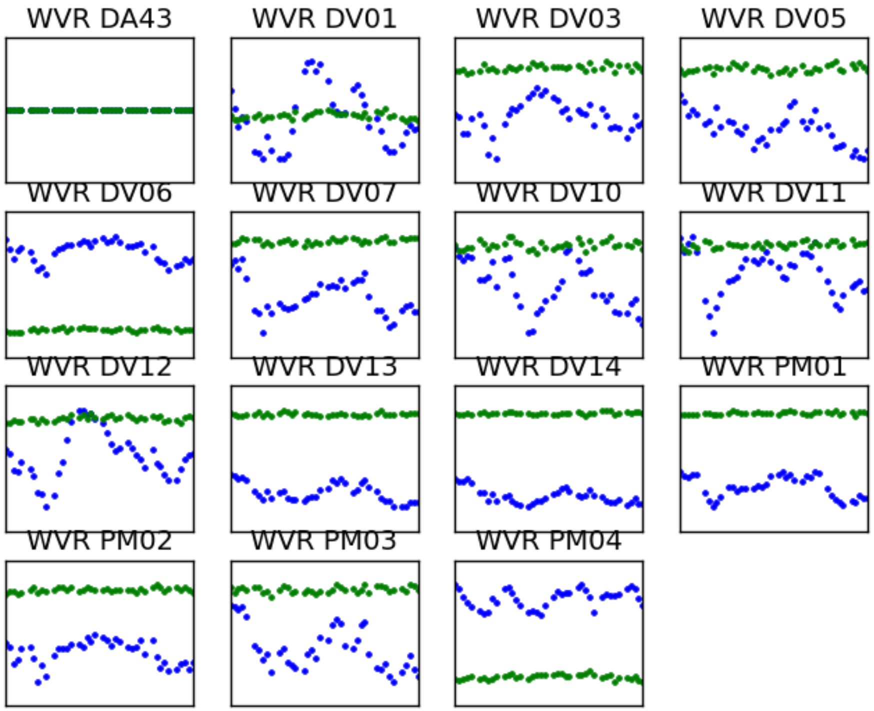


Pressure 400-750 mBar

Peculiarities @ mm

WVR correction

Band 6 (230 GHz)

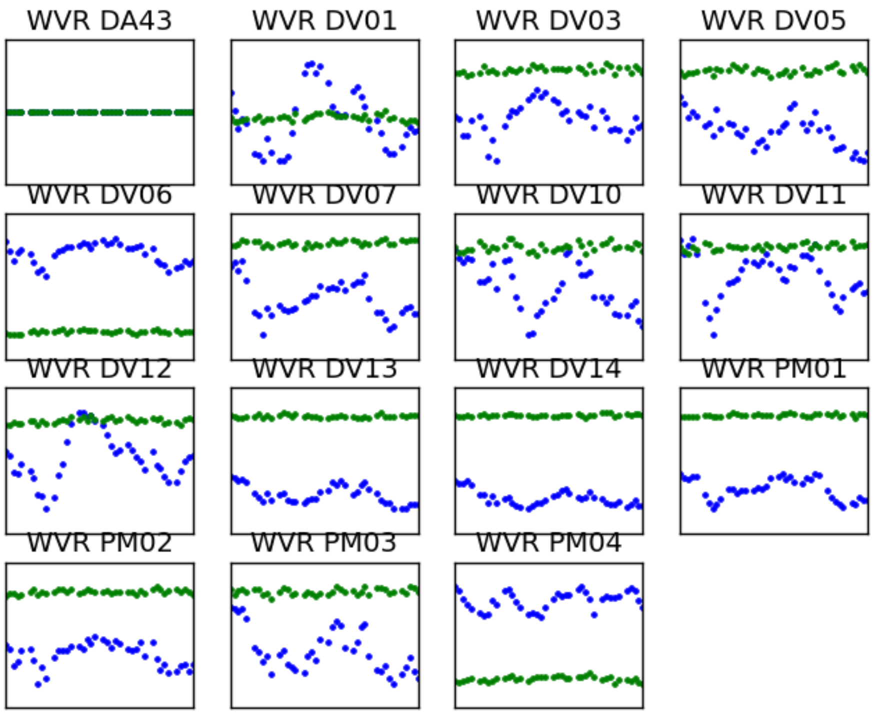


Raw phases & WVR corrected phases

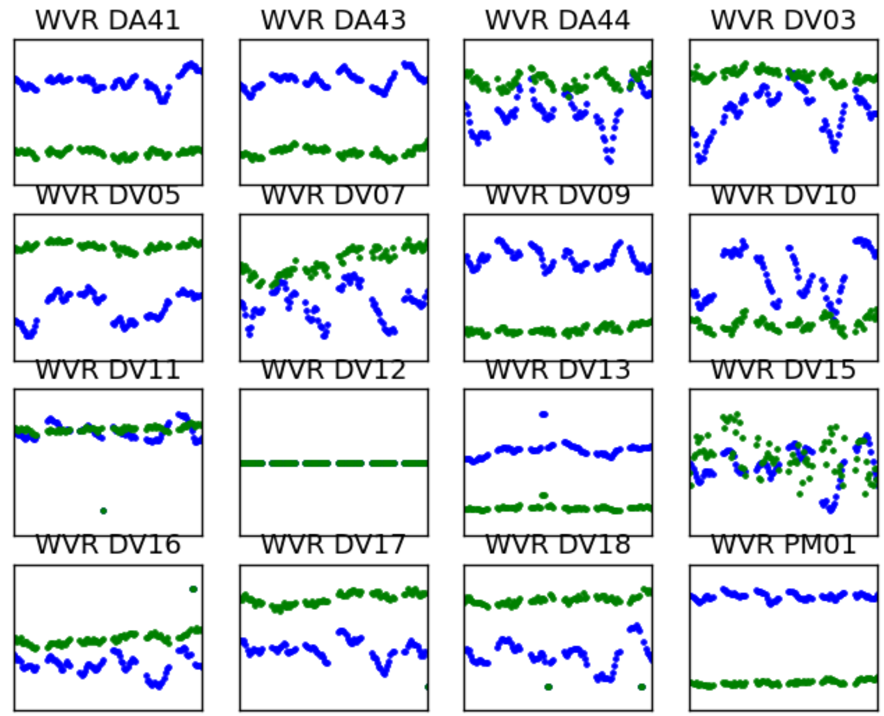
Peculiarities @ mm

WVR correction

Band 6 (230 GHz)



Band 7 (340 GHz)



Raw phases & WVR corrected phases

Peculiarities @ mm

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

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

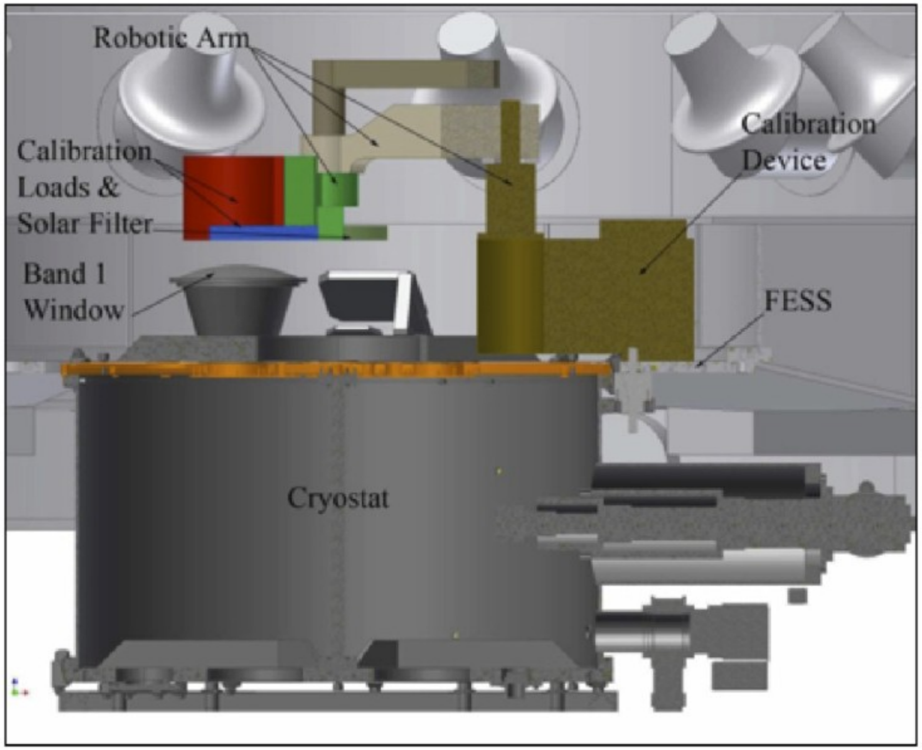
At lower frequencies T_{rx} is dominant

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

Peculiarities @ mm

System noise temperature

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

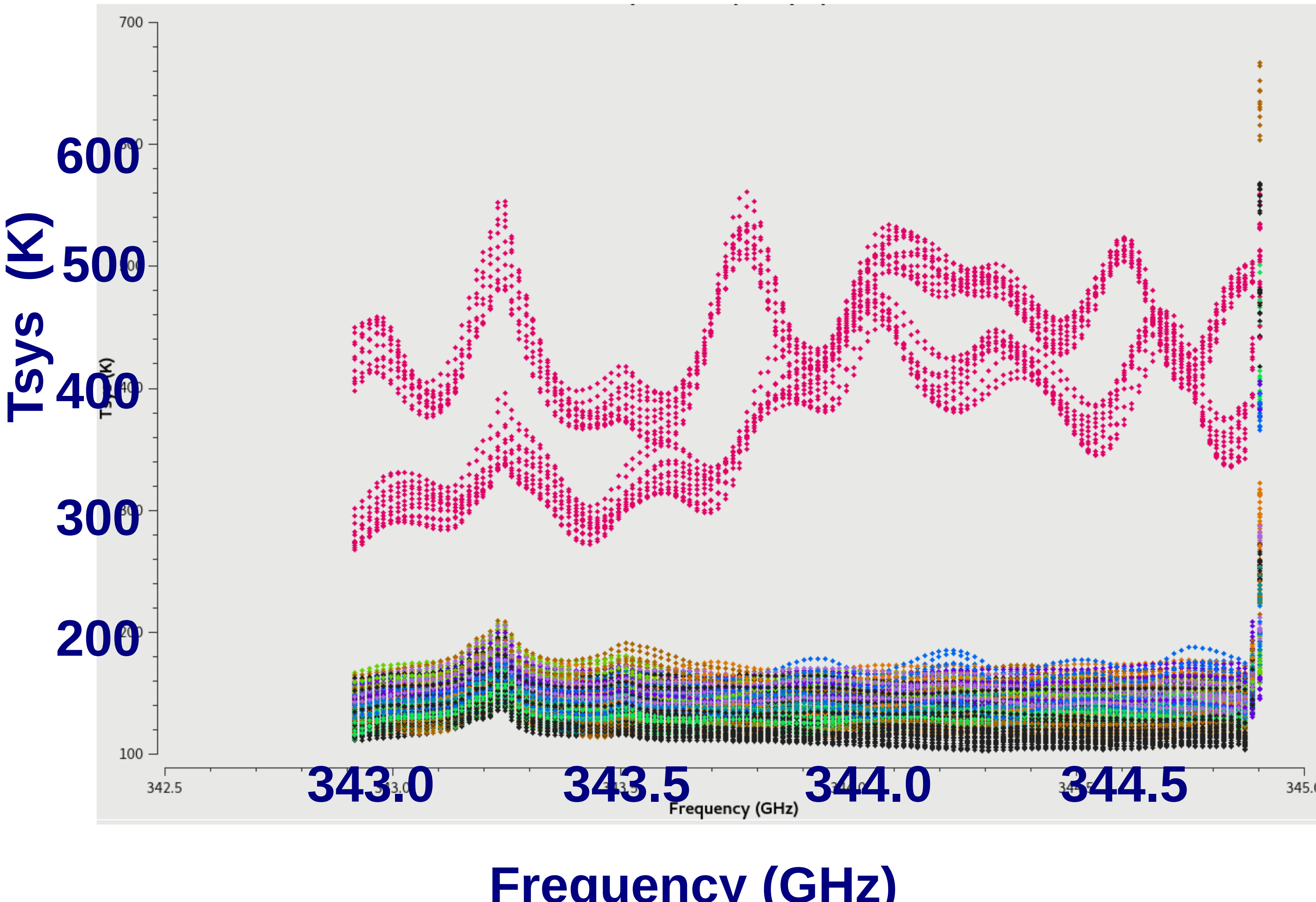


→ To measure T_{sys} and T_{rx} stored in tables

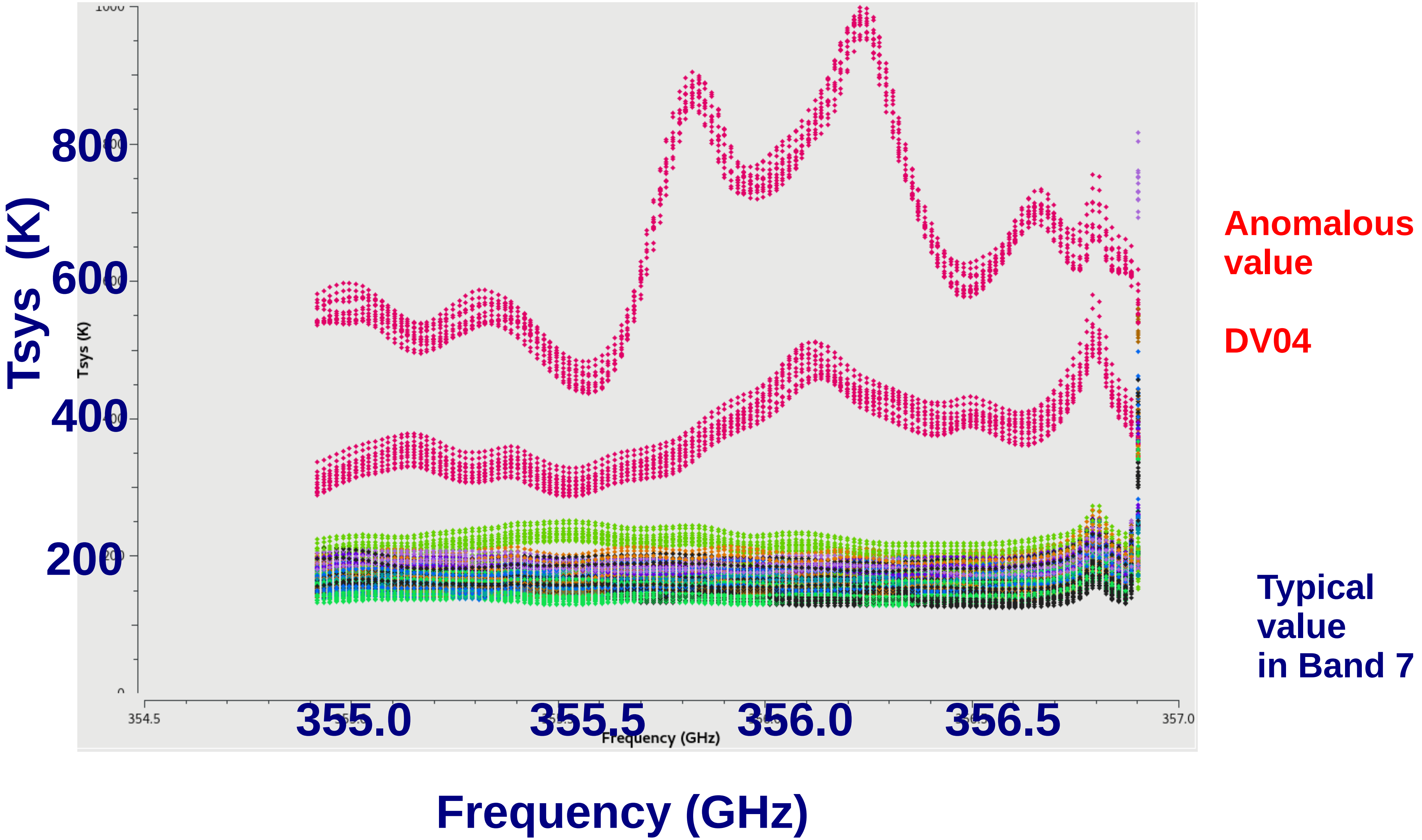
Every scan could have a Tsys measurement, but <400 GHz relatively constant ~10min.
Tsys spectra are applied off-line to the correlated data.

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

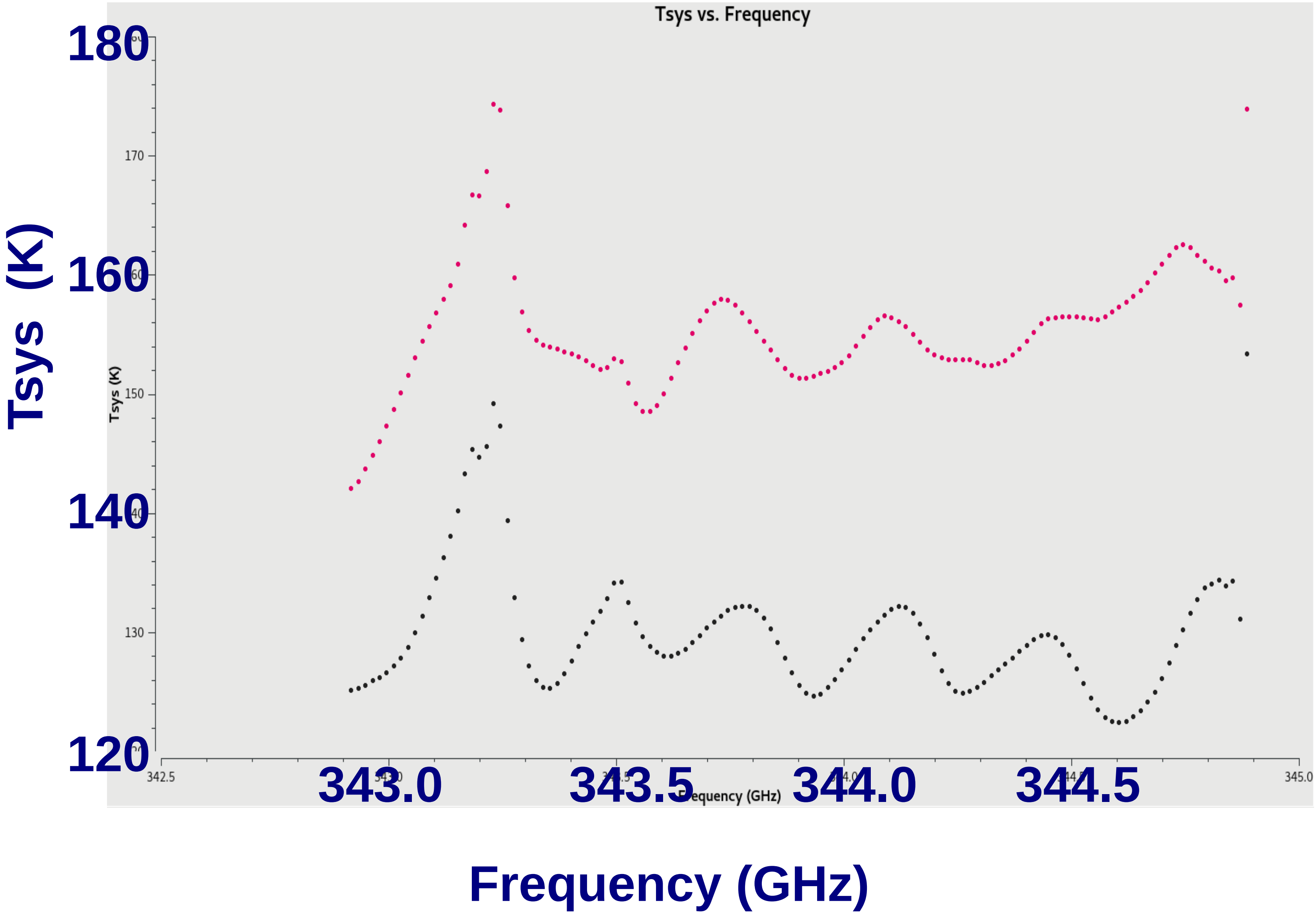
Tsys in your dataset: in color different antennas



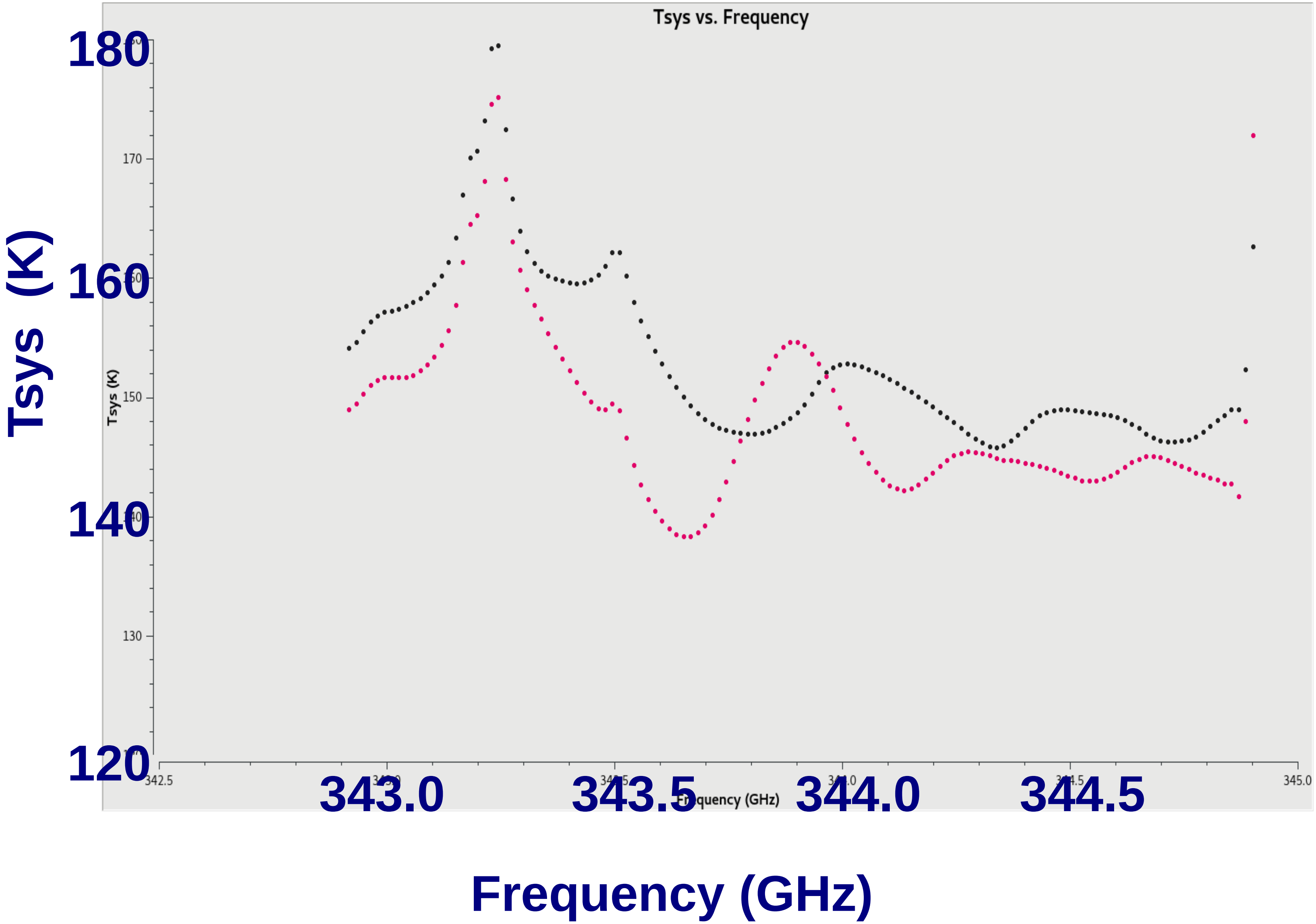
Tsys in your dataset: in color different antennas



Antenna DV07: in color different corr

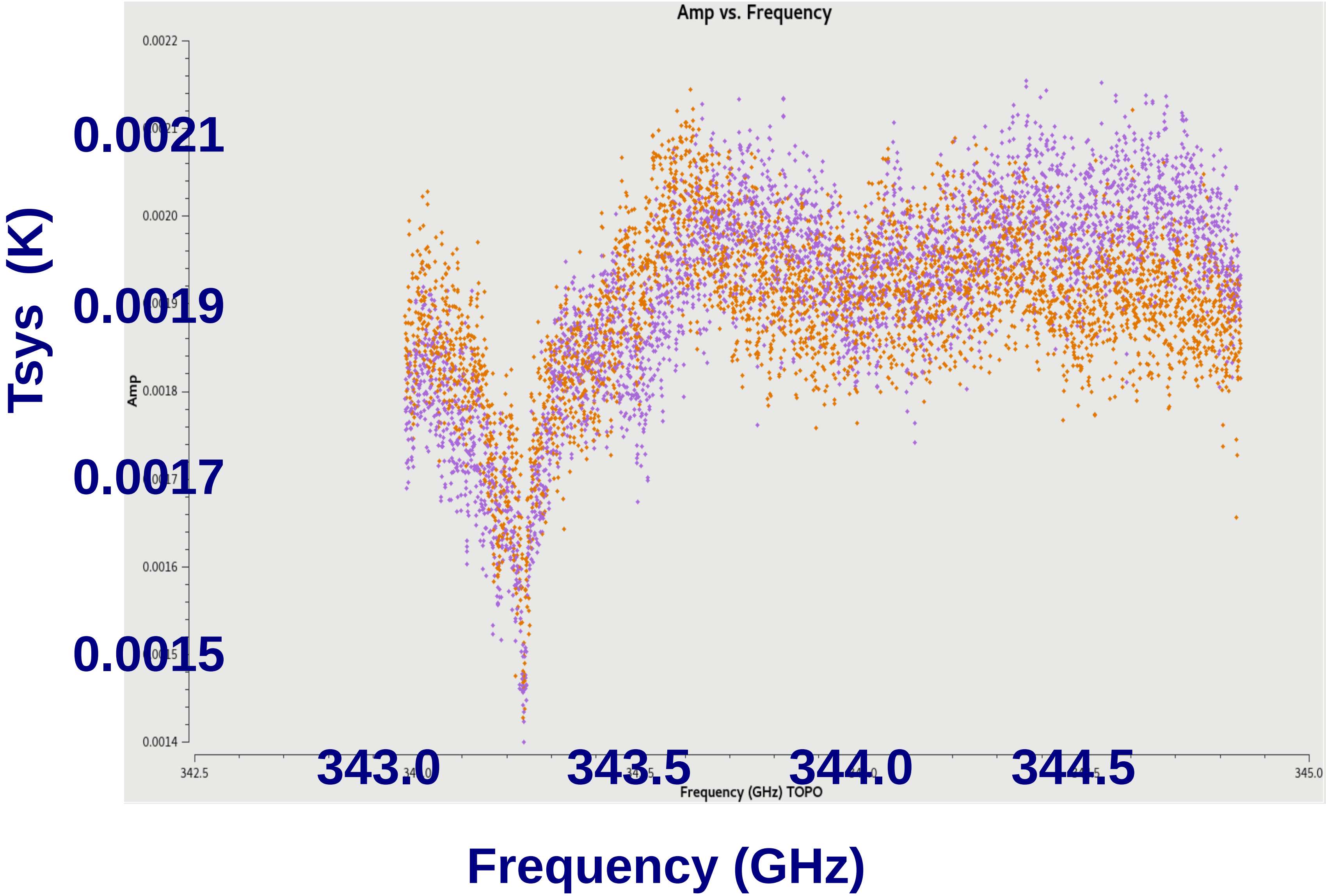


Antenna DV06: in color different corr



Typical value in Band 7

Baseline DV06&DV07: in color different corr



Baseline DV06&DV07: in color different corr

Tsys (K)

343.0 343.5 344.0 344.5

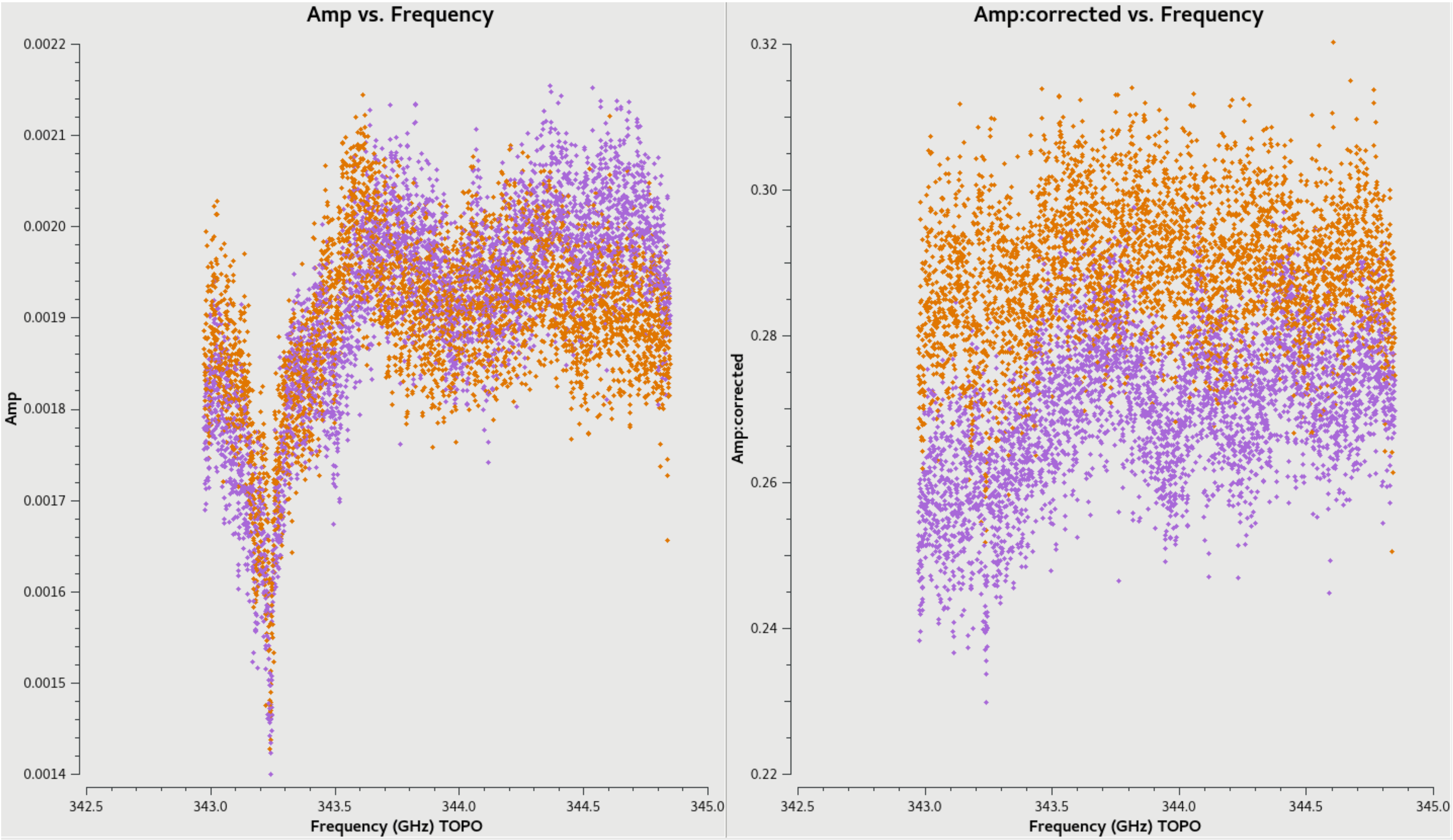
Frequency (GHz)

Tsys calibration

DV06 & DV07

The attenuation
Is corrected

Before **After**



Tsys calibration

DV06 & DV07

K

The data are now Temperature in K

Before

After