# Water vapour radiometry at the ATCA

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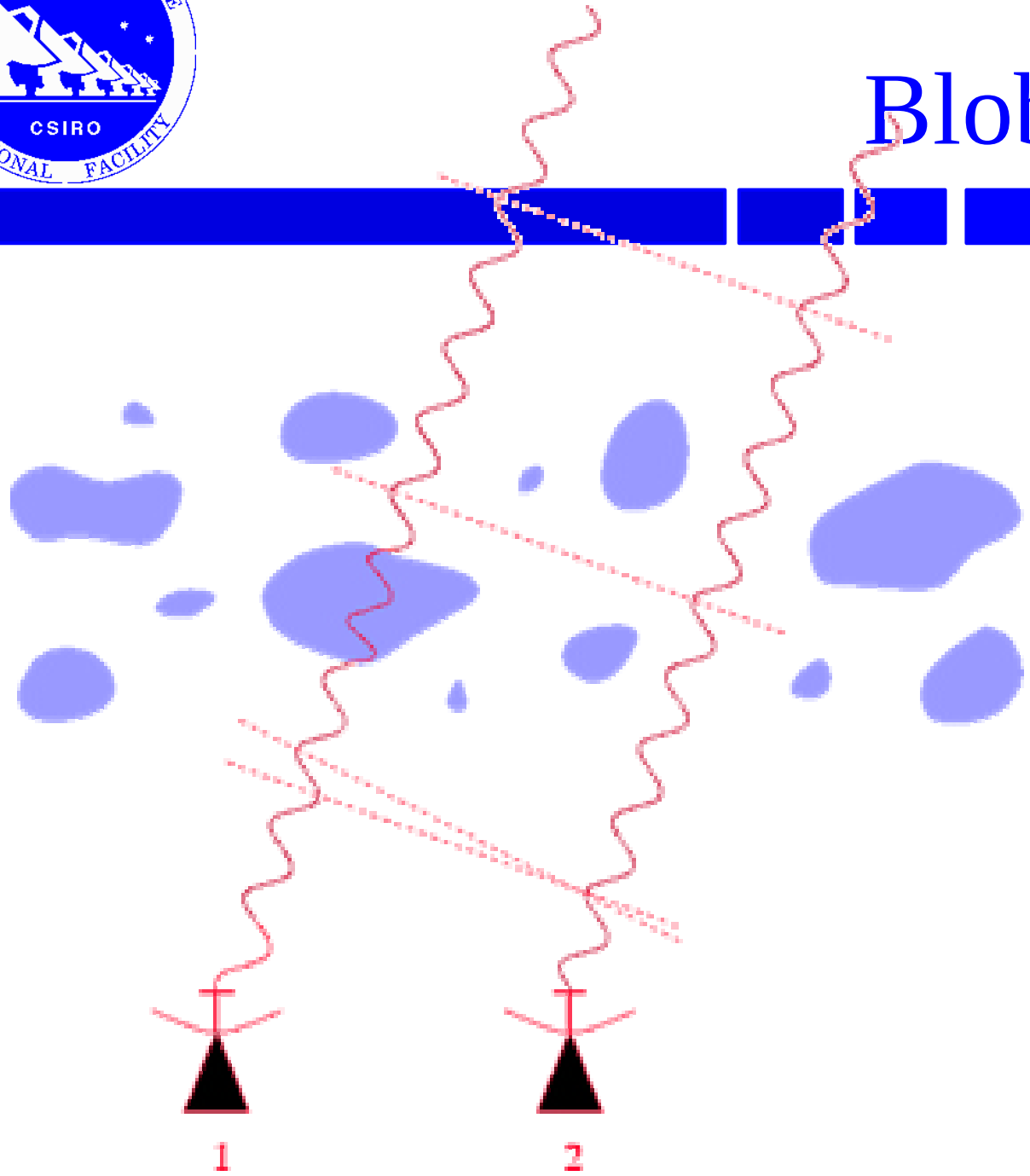
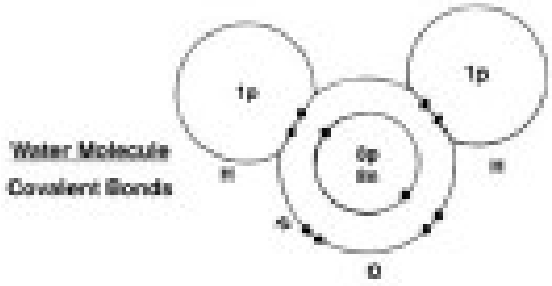
# Atmospheric composition and seeing

- The atmosphere is made up of $N_2$, $O_2$, $CO_2$ and about 5% water vapour.
- Water vapour has a condenses and freezes at a high temperature. It is unevenly mixed.
  - Water vapour content of the atmosphere is significantly affected by diurnal cycles.
  - Weather patterns significantly affect water vapour content.
  - Whereas $N_2$, $O_2$, $CO_2$ have a scale height of 8km, the scale height of water vapour is of order 2km.
- Water vapour fluctuations is the primary cause of radio seeing.

# Blobs of water




- Blobs exist on all size scales.
- Follow a so-called Kolmogorov spectrum of sizes.
- Typically the water vapour column for two sites 1 km apart are 99% the same – the so-called turbulent component consists of just 1% of the water.

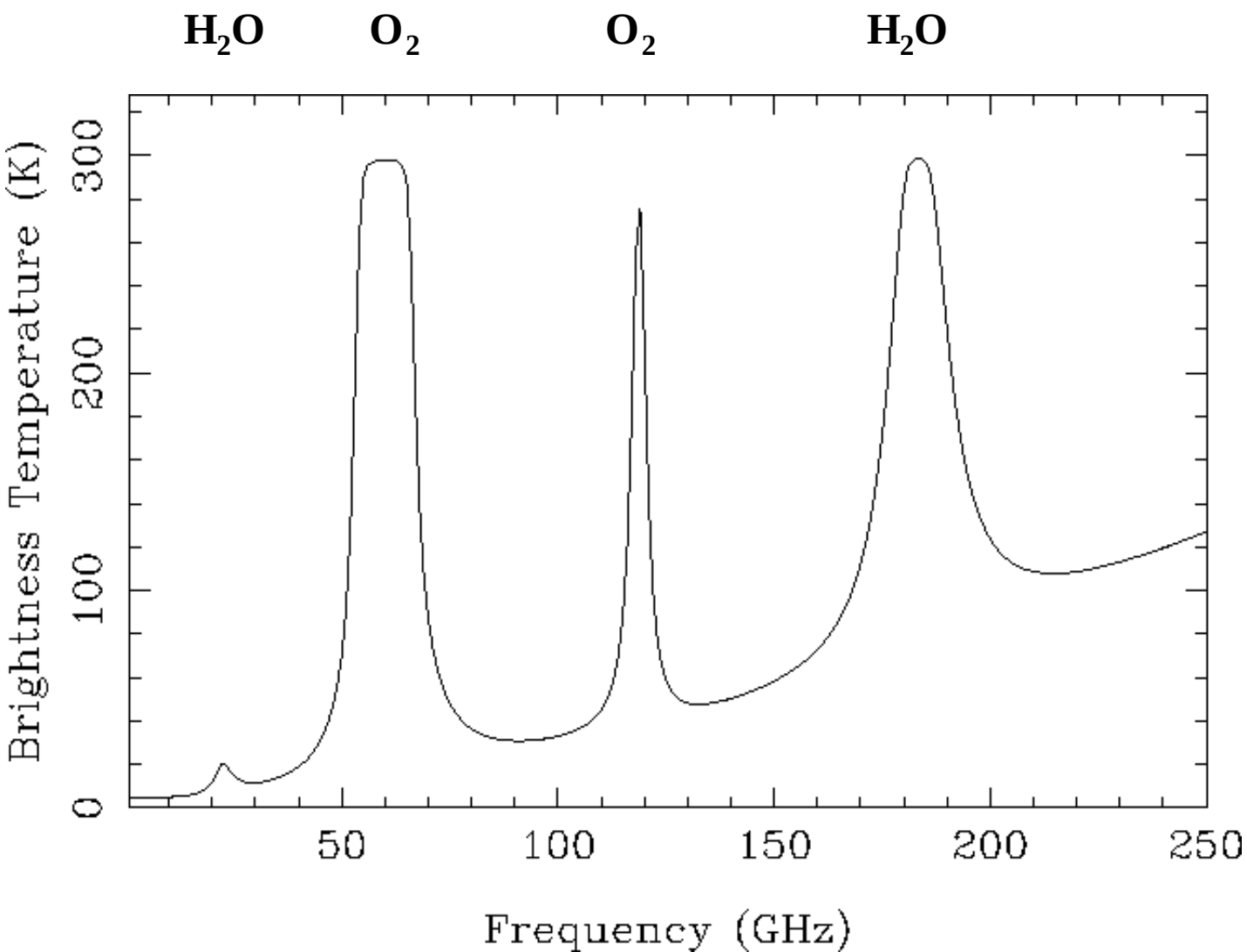
# How to measure water vapour content

- Traditional calibration, including fast switching.
- Artificial calibrators (e.g. satellites).

But water vapour column varies with time and position.

- Water vapour radiometry.
  - Water vapour causes excess path.
  - Water vapour is also a lossy medium, and so emits.
  - By measuring the emission, we can estimate the water vapour column.

# Neutral atmosphere

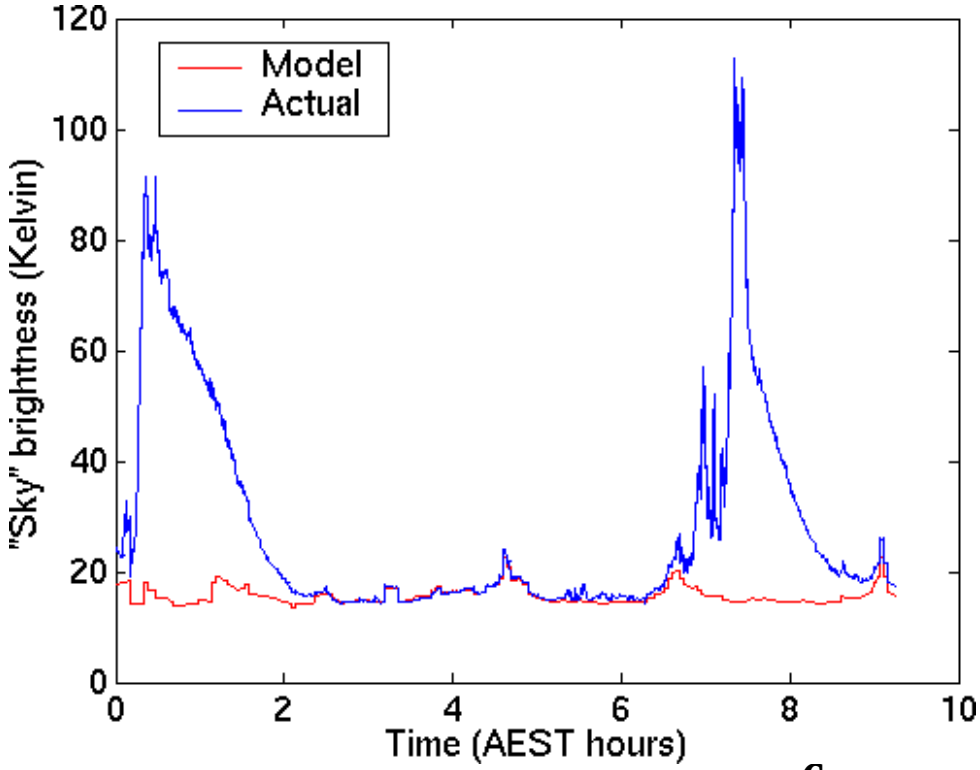


# Two basic approachs

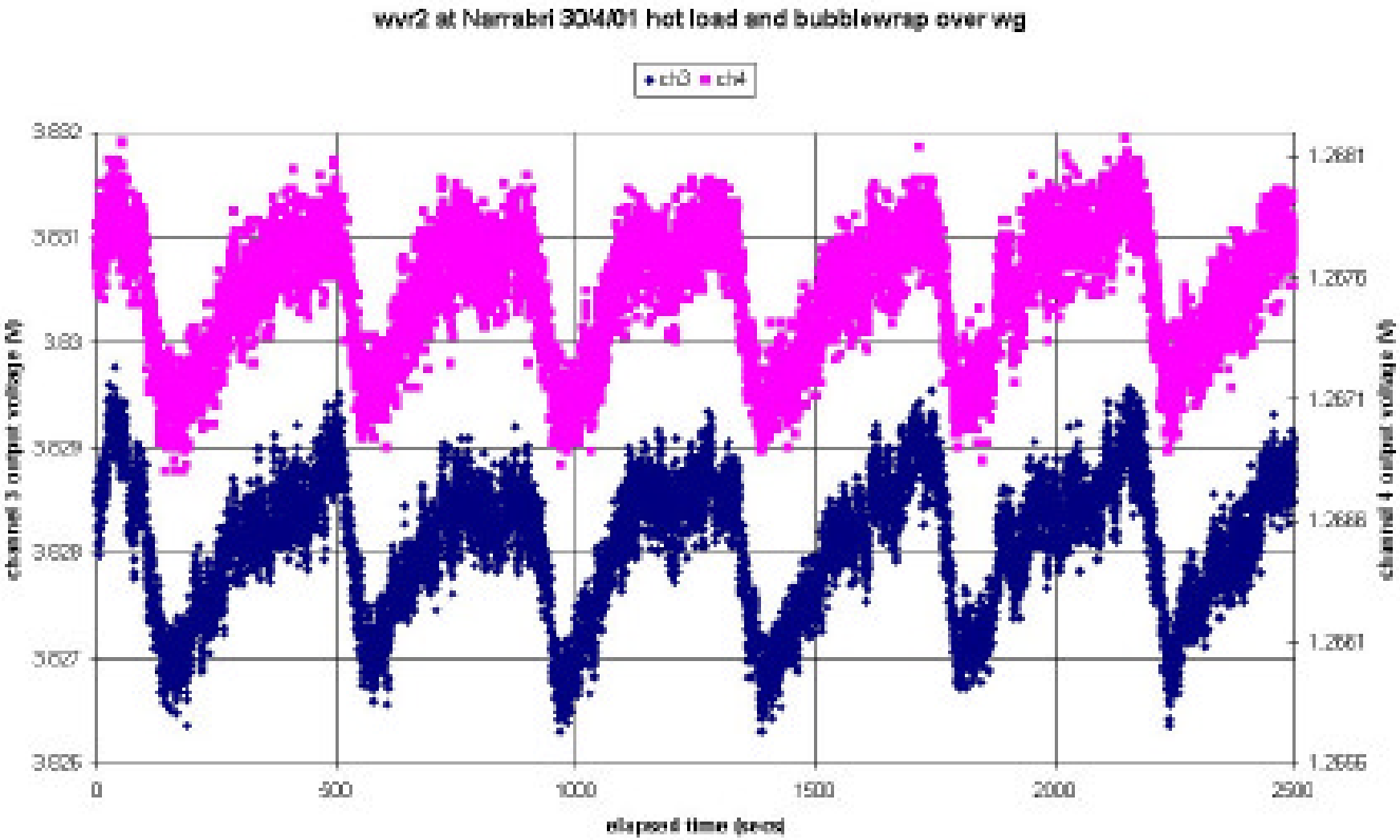
- Measure continuum fluctuations.
- Measure multiple channels near a line.

•Continuum systems are prone to many systematic effects.

•Line systems can discriminate between systematics and “true signal” by using physical knowledge about the line shape.

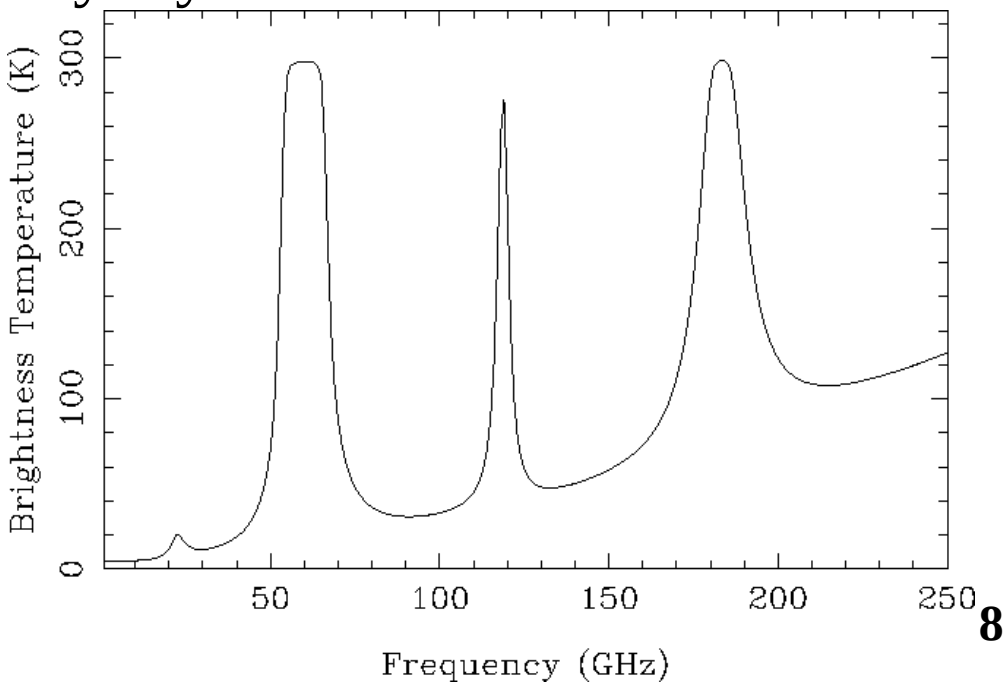


# Air conditioner cycling

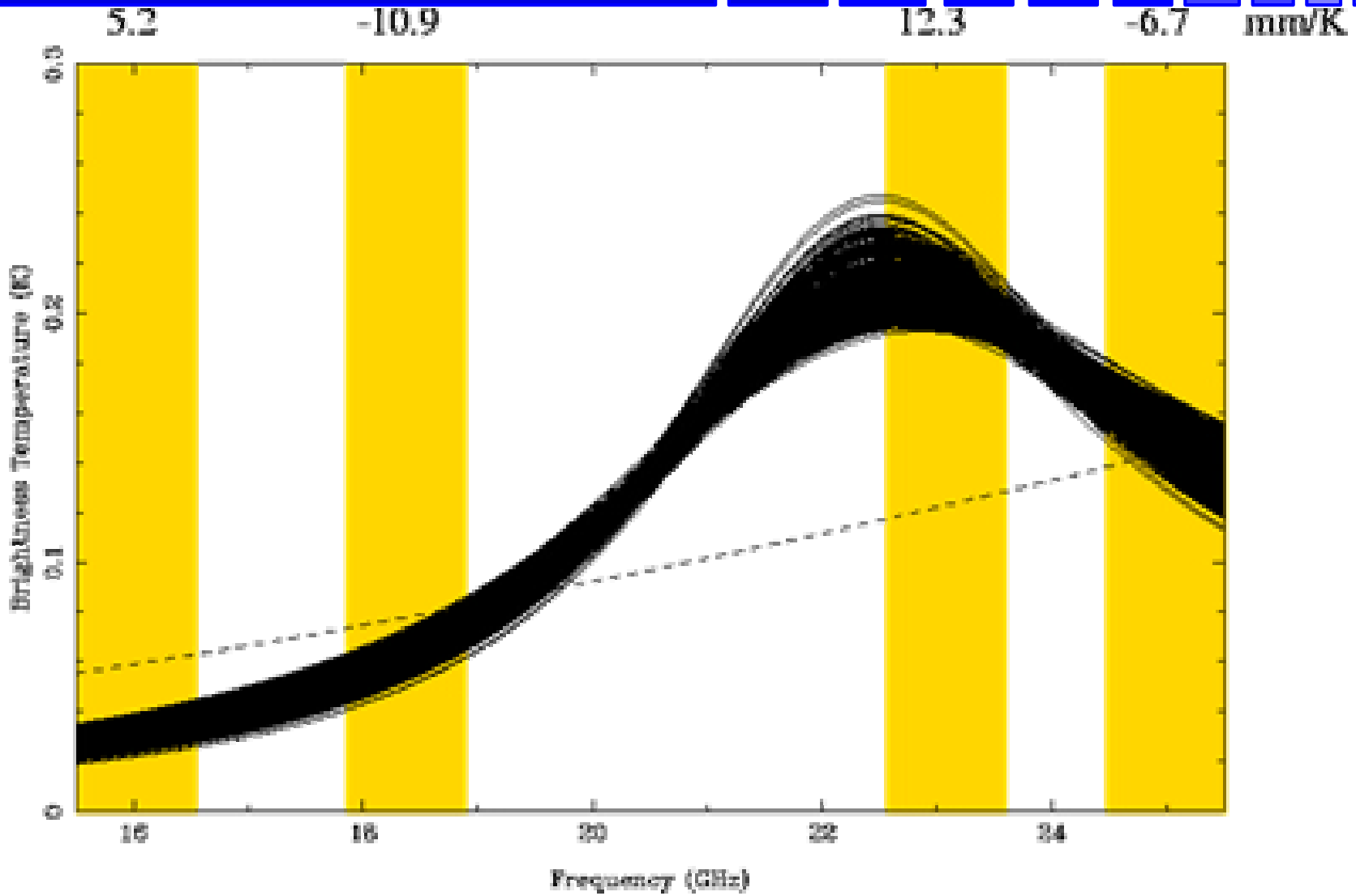


# Which line? 22.3 vs 183 GHz

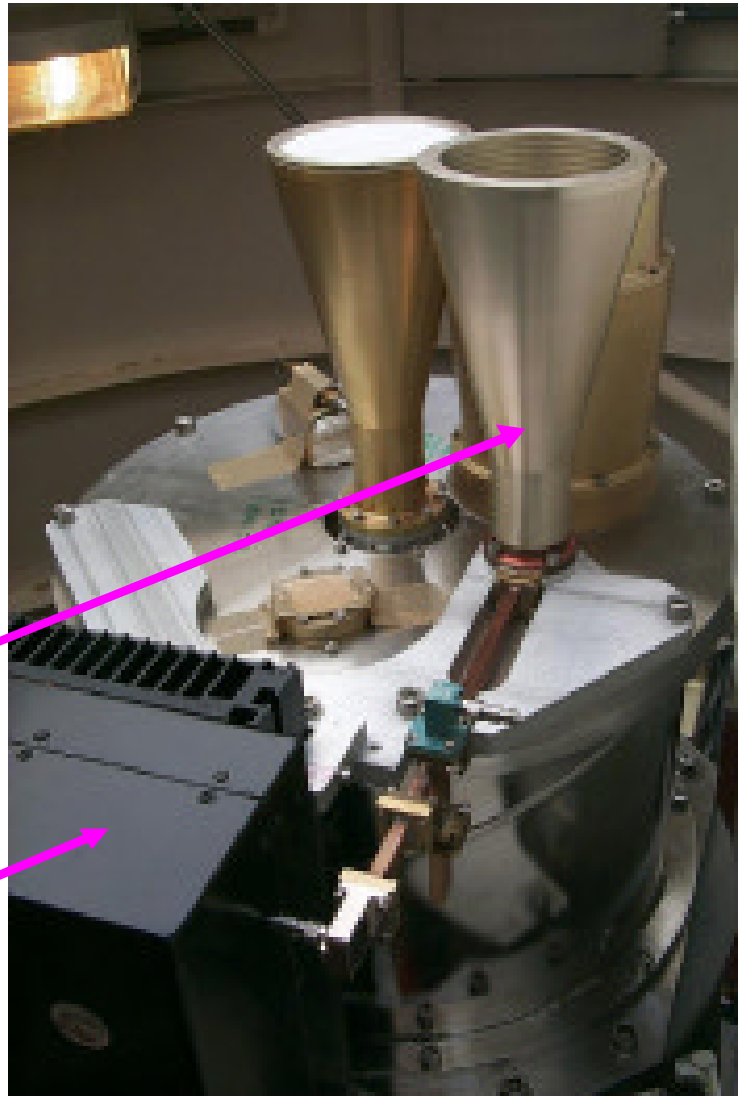
- 183 GHz line saturates at the ATCA site.
- The antennas do not work at 183 GHz.
- Raw sensitivity is not a major problem; the main problem is always systematics.



# Water line system



# WVR system



**WVR feed**

**WVR unit**

# Doubly differential system

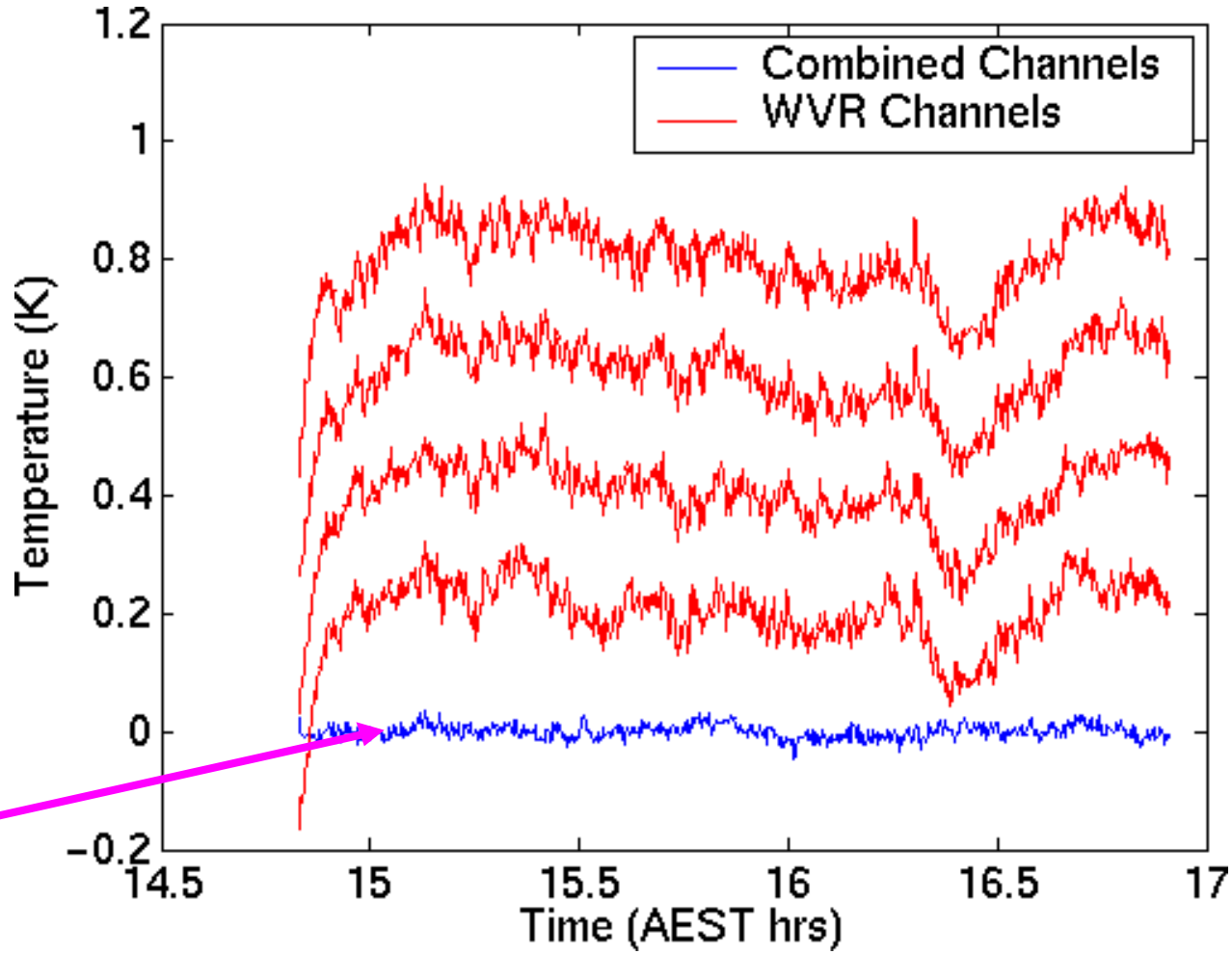
- Using ("differencing") multiple spectral channels differences out a large number of instrumental systematics.

- Because only differential phase is of interest, the importance of meteorological models is much reduced.

Specifications

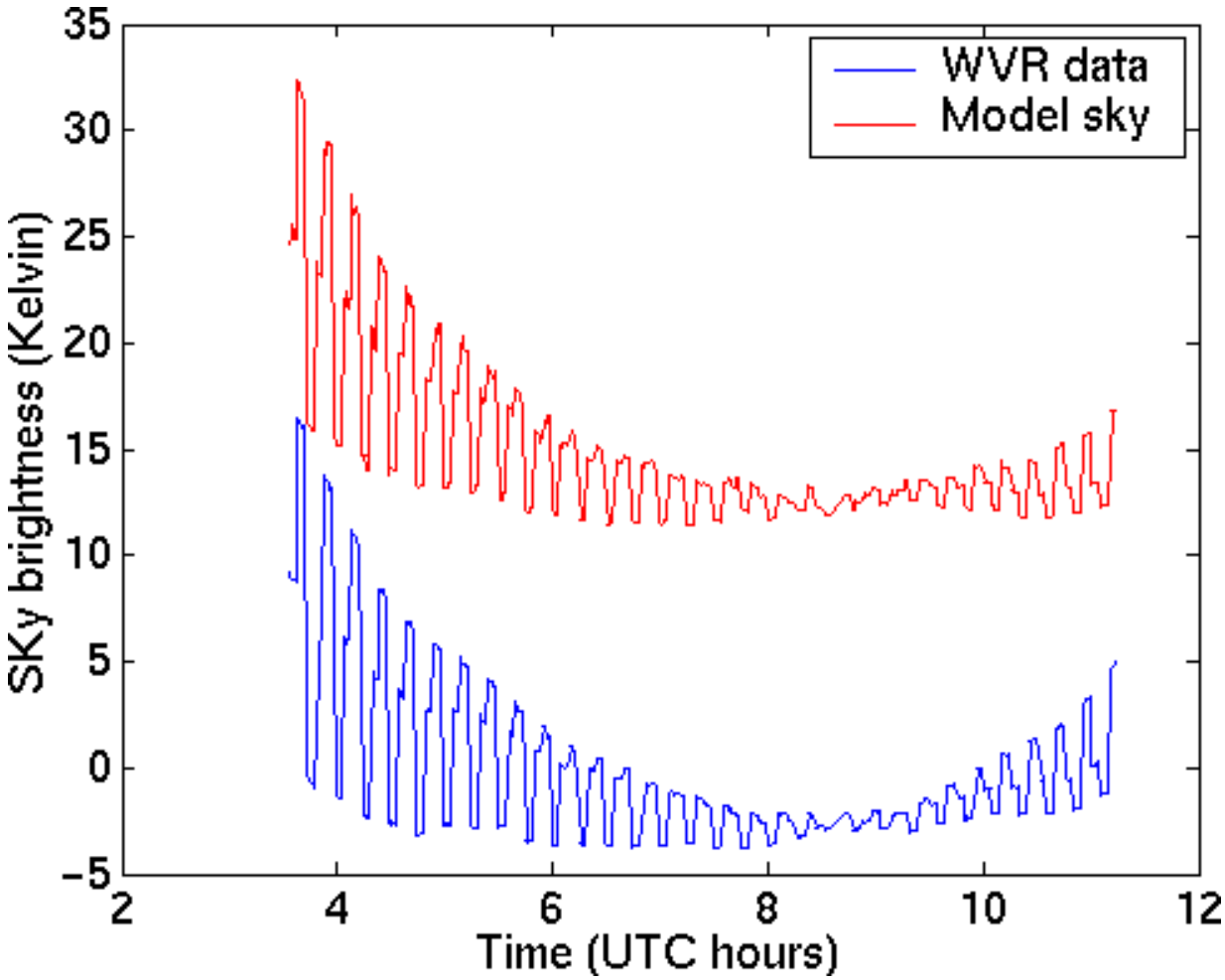
- Measure rms path fluctuations of 100 microns $\Rightarrow 10^{o}$ at 3.6mm $\Rightarrow$ about 10 mK of brightness fluctuation.

# Response to “constant” temperature

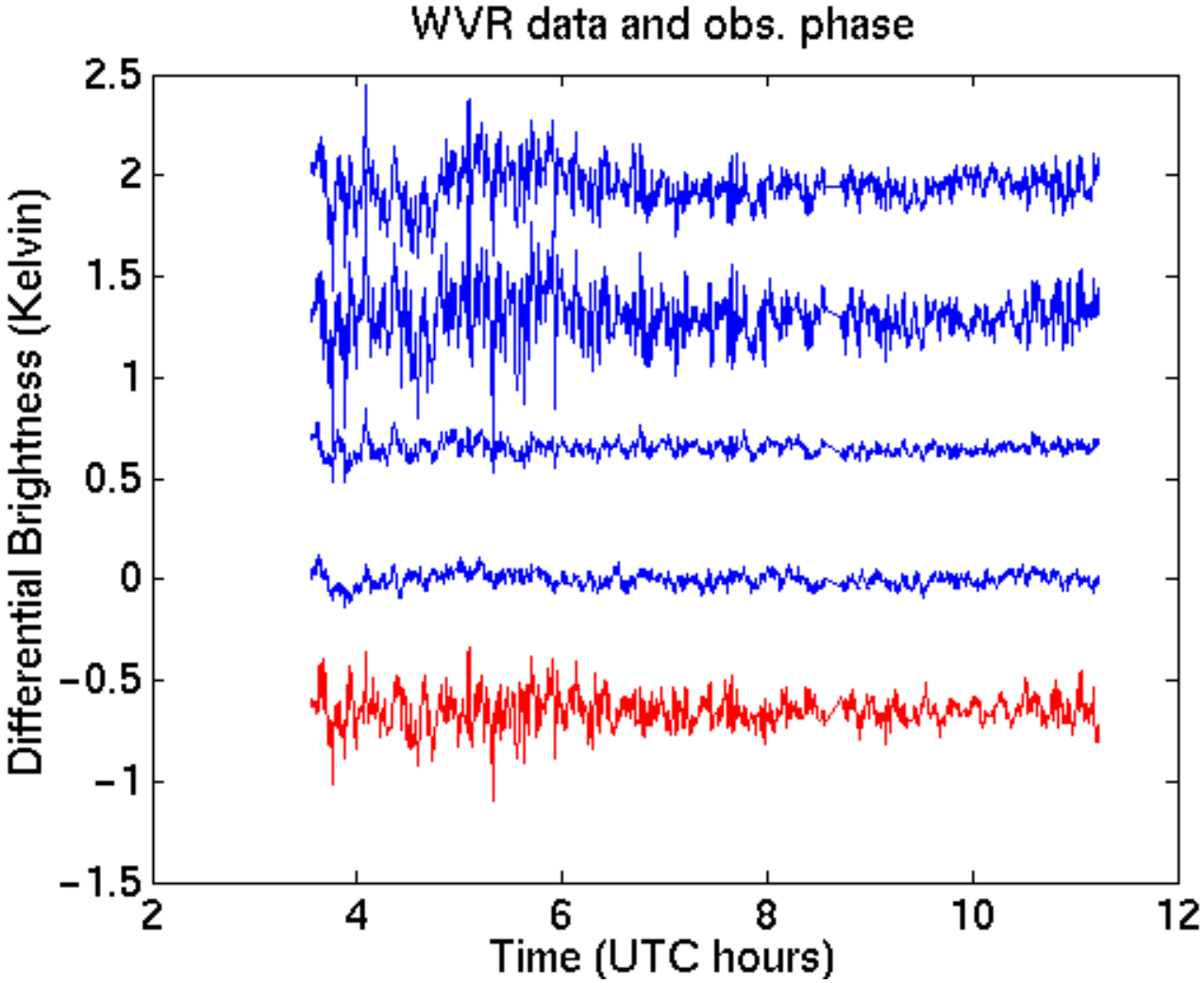



RMS = 12 mK

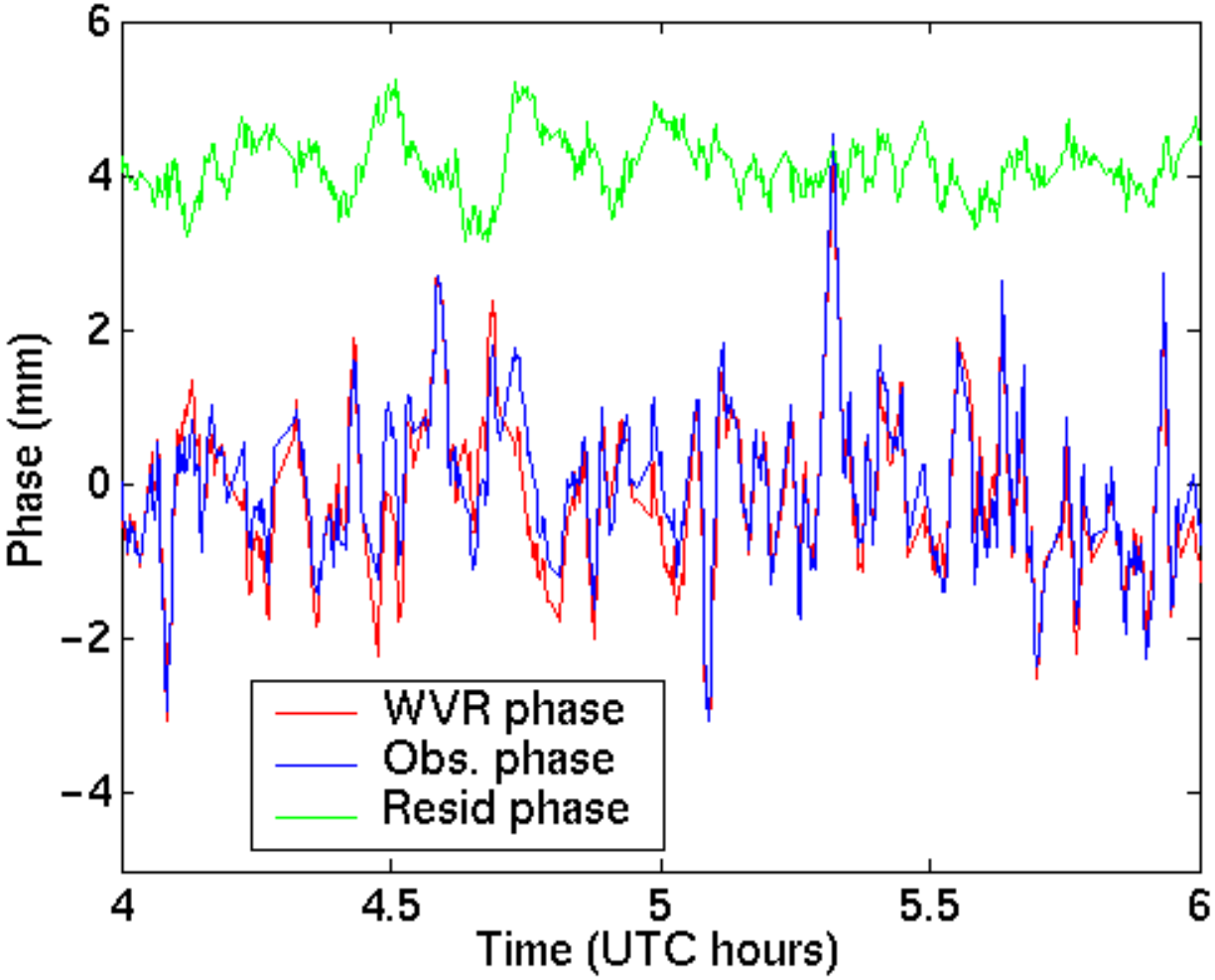
# Sky brightness fluctuations



# Response to atmospheric water vapour



# Phase correction



# Current state

- Two prototype radiometers undergoing evaluation and testing.
- Astronomically measured phase shows a ~ 400 micron component that is clearly instrumental rather than atmospheric. *Needs to be understood*!
- Residual error (in tests intended to mimic “real” use) is about 300-350 microns rms (c.f. target of 100 microns).
- Limiting factors are believed to be understood – corrective measures being taken.
- Go ahead for construction of 3 additional units likely soon.

# Extreme temperature cycling