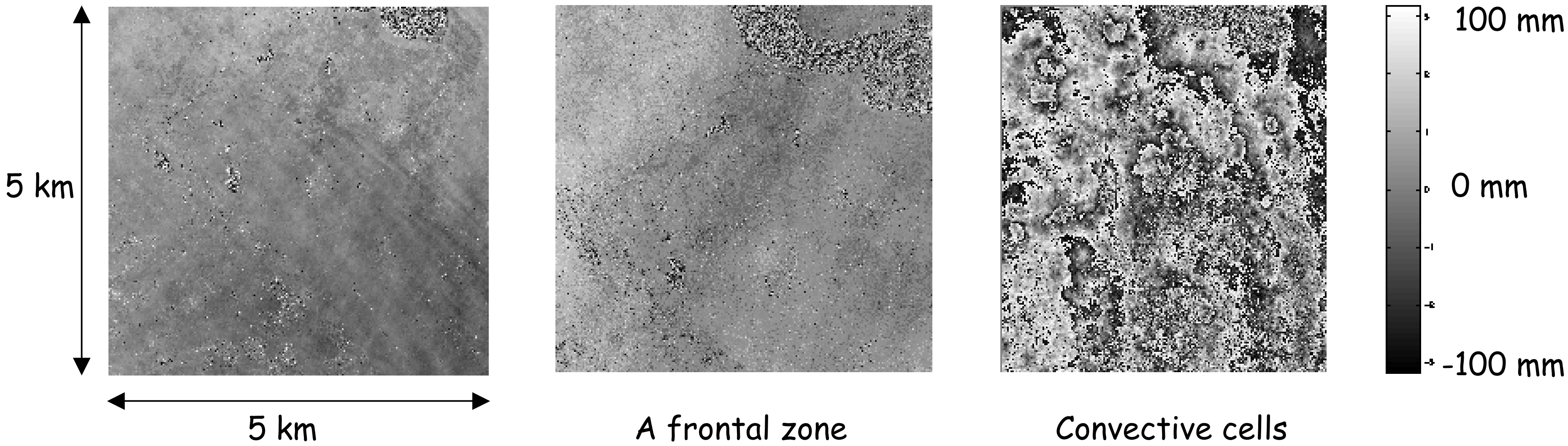
The Water Vapour Radiometer at Effelsberg

A. Roy
U. Teuber
R. Keller

The Troposphere as Seen from Orbit

Method: Synthetic Aperture Radar (Earth Resources Satellite)
Frequency: 9 GHz
Region: Groningen
Interferograms by differencing images from different days



Internal waves in a homogenously cloudy troposphere

A frontal zone

Convective cells

Hanssen (1997)

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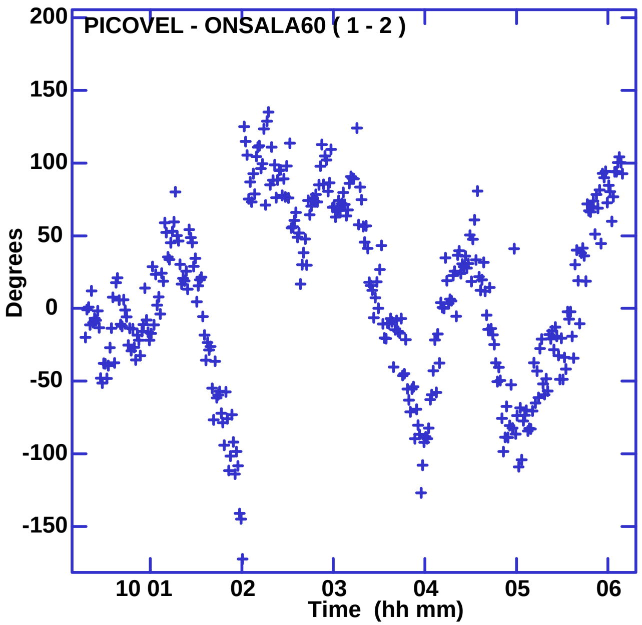
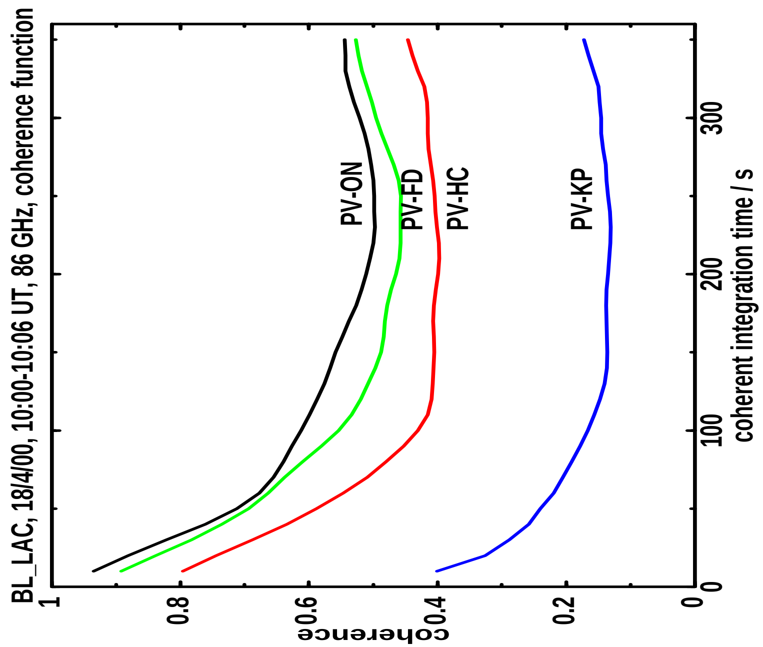
Troposphere Seen by VLBI at 86 GHz





ν = 18 to 26 GHz
$\Delta\nu$ = 900 MHz
Nchannel = 25
Treceiver = 200 K
σ = 61 mK per channel
sweep period = 5 s

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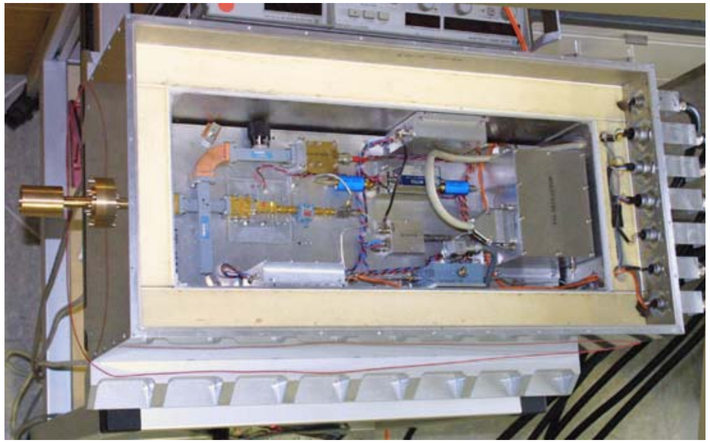
The Scanning 18-26 GHz WVR for Effelsberg



Front-end opened

Control unit

First light, April 2002, Bonn

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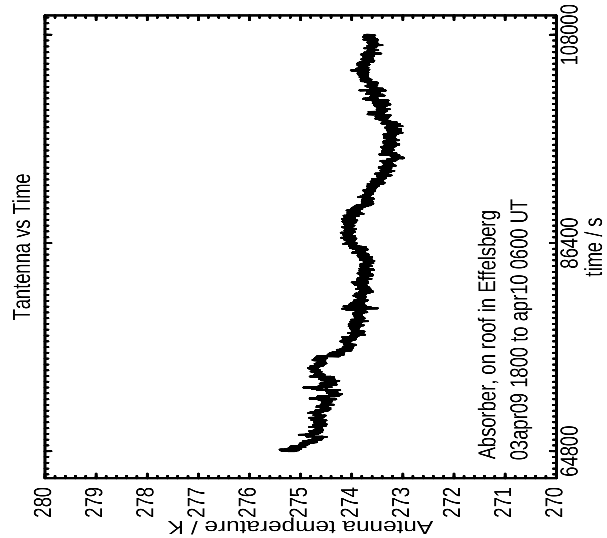
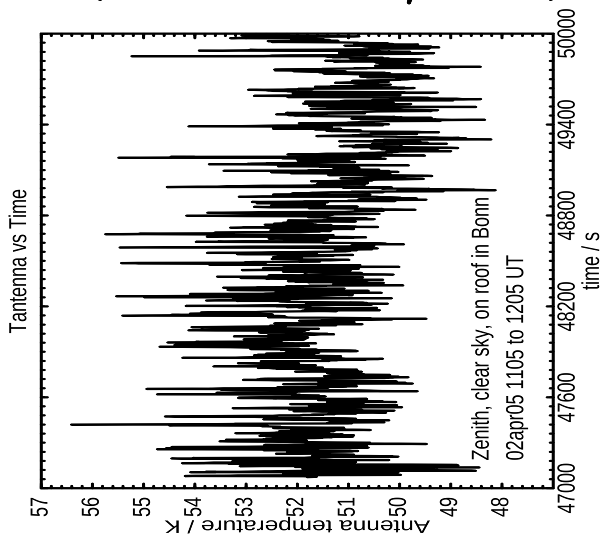
WVR View of Atmospheric Turbulence

Absorber

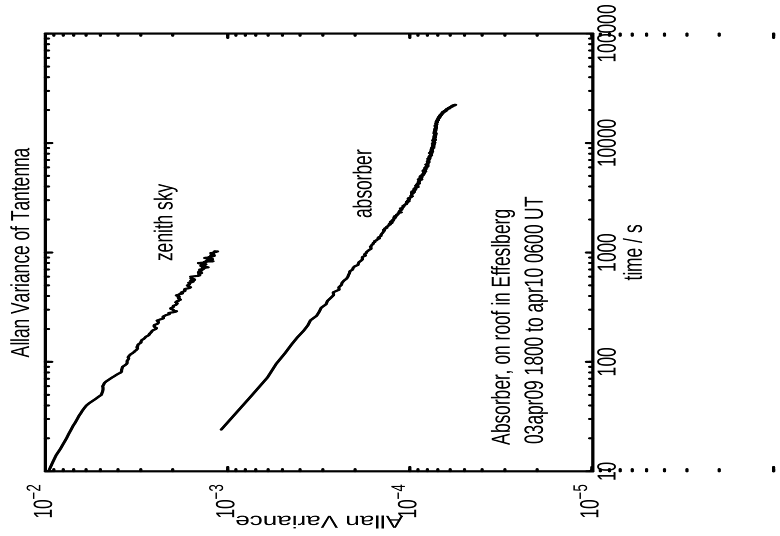


12 h

Zenith sky
(clear blue, dry, cold)



1 h



- gain stability: 2.7×10^{-4} over 400 s
- sensitivity: 61 mK for τ_{int} = 0.025 s
  (0.038 mm rms path length noise for τ_{int} = 3 s)

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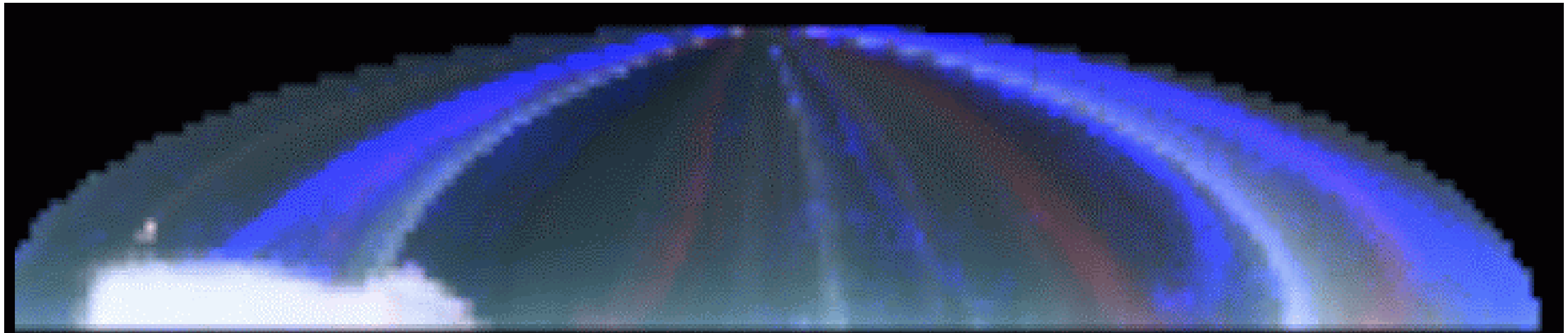
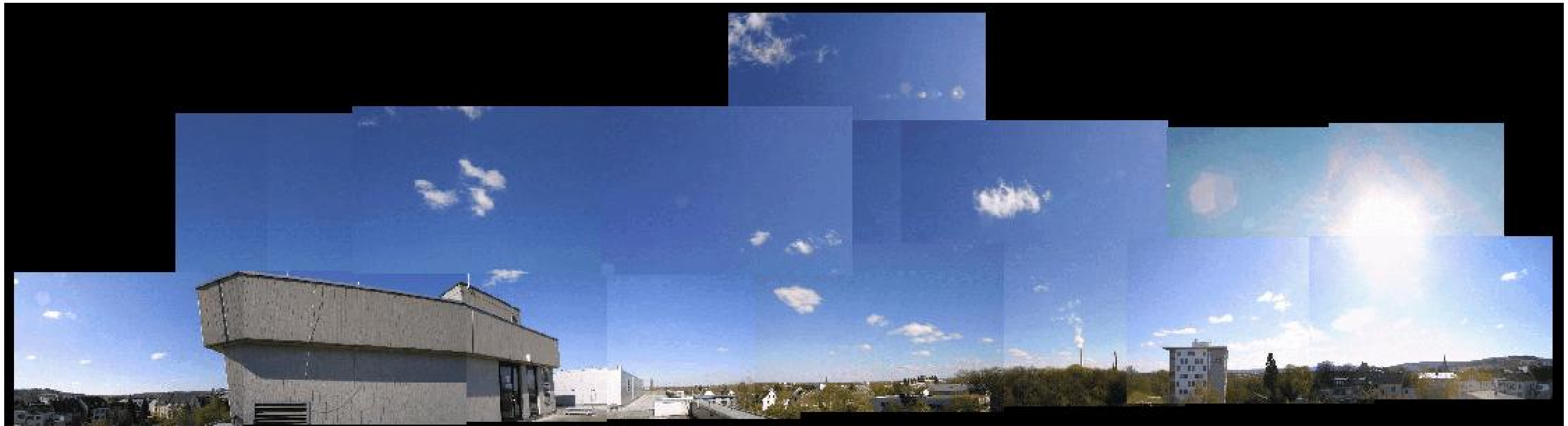
WVR Panorama of Bonn



Water-Vapour Radiometer, Bonn, 27 Feb to 01 Mar 2003. Red: 19.10 GHz Green: 21.86 GHz Blue: 24.62 GHz

WVR construction: *U. Teuber & A. Keller* Project scientist: *A. L. Roy* Image rendering in IDL: *A. Bertarini*

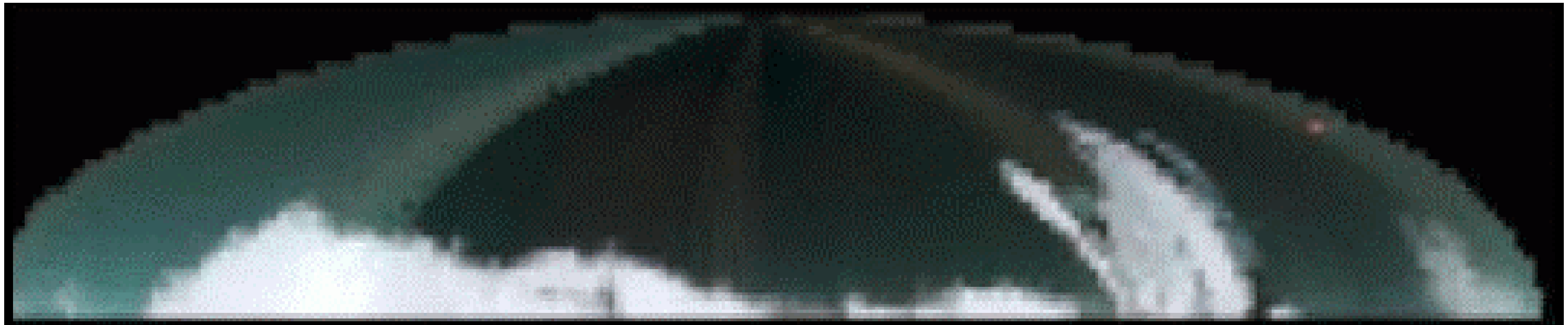


Bonn panorama, from location of water-vapour radiometer on MPIfR roof, 07 Apr 2003

Move to Effelsberg

March 20th, 2003

WVR Panorama of Effelsberg

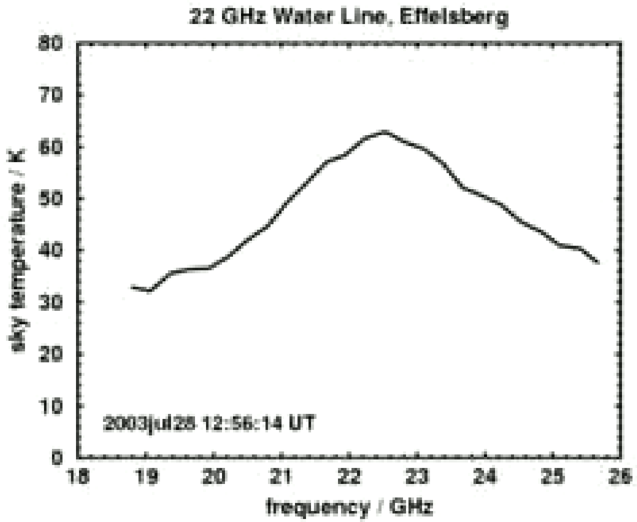


Water–Vapour Radiometer, Effelsberg, 21 to 25 Mar 2003 Red: 29.35 GHz Green: 22.23 GHz Blue: 24.35 GHz

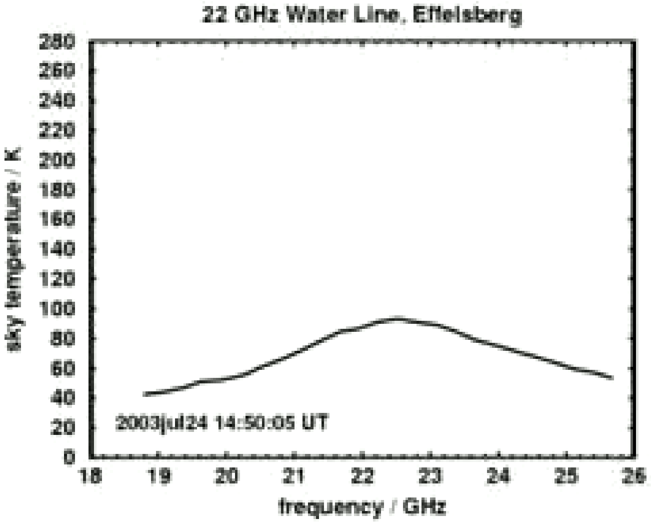
WVR construction: *U. Teuber & R. Keller* Project scientist: *A. L. Roy* Image rendering in IDL: *A. Bertarini*

Effelsberg panorama, from location of water-vapour radiometer on control building roof, 04 Apr 2003

Scattered Cumulus, 2003 Jul 28, 1300 UT



Storm, 2003 Jul 24, 1500 UT



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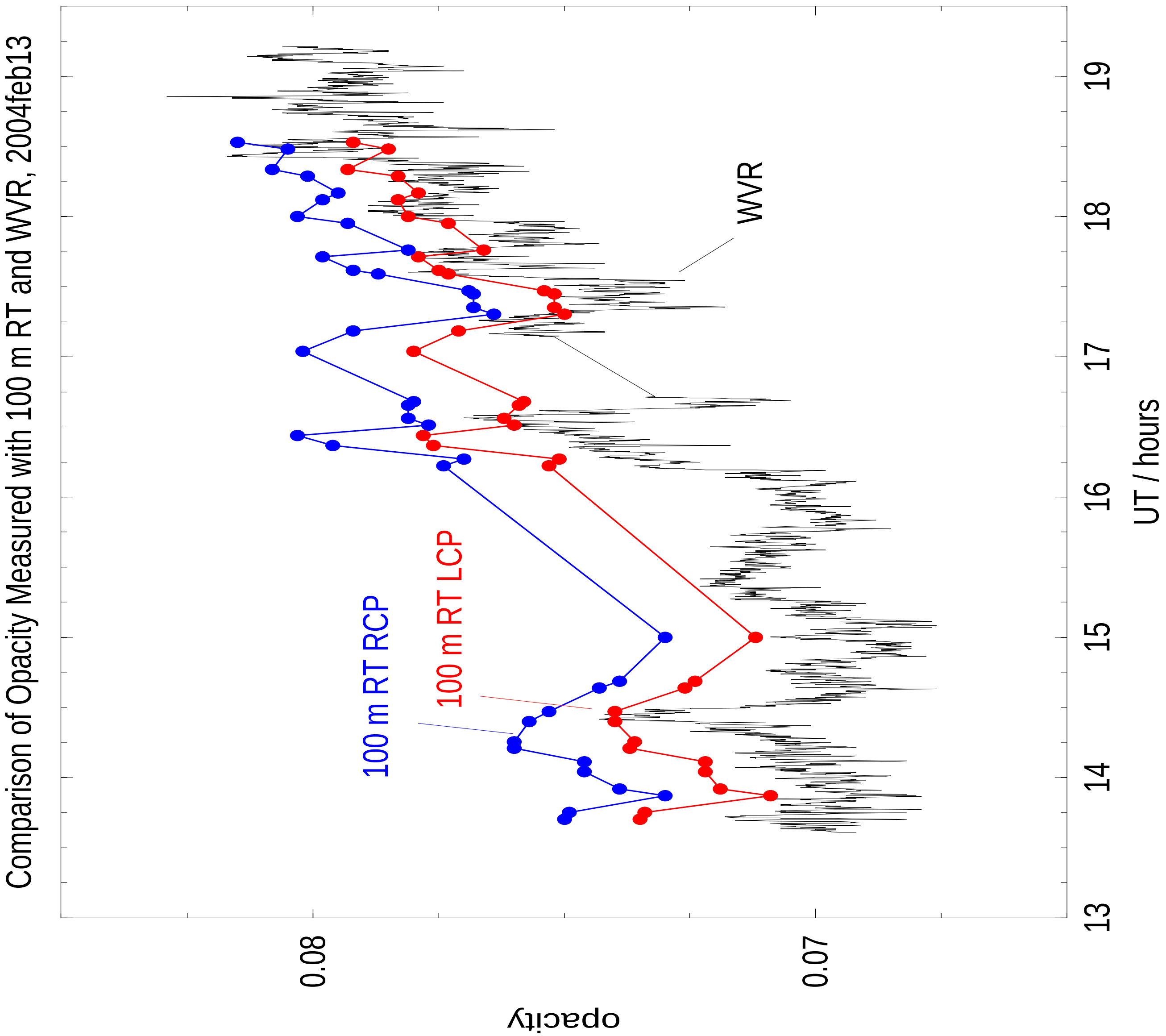
Validation of Opacity Measurement



Move to Focus Cabin

March 16th, 2004

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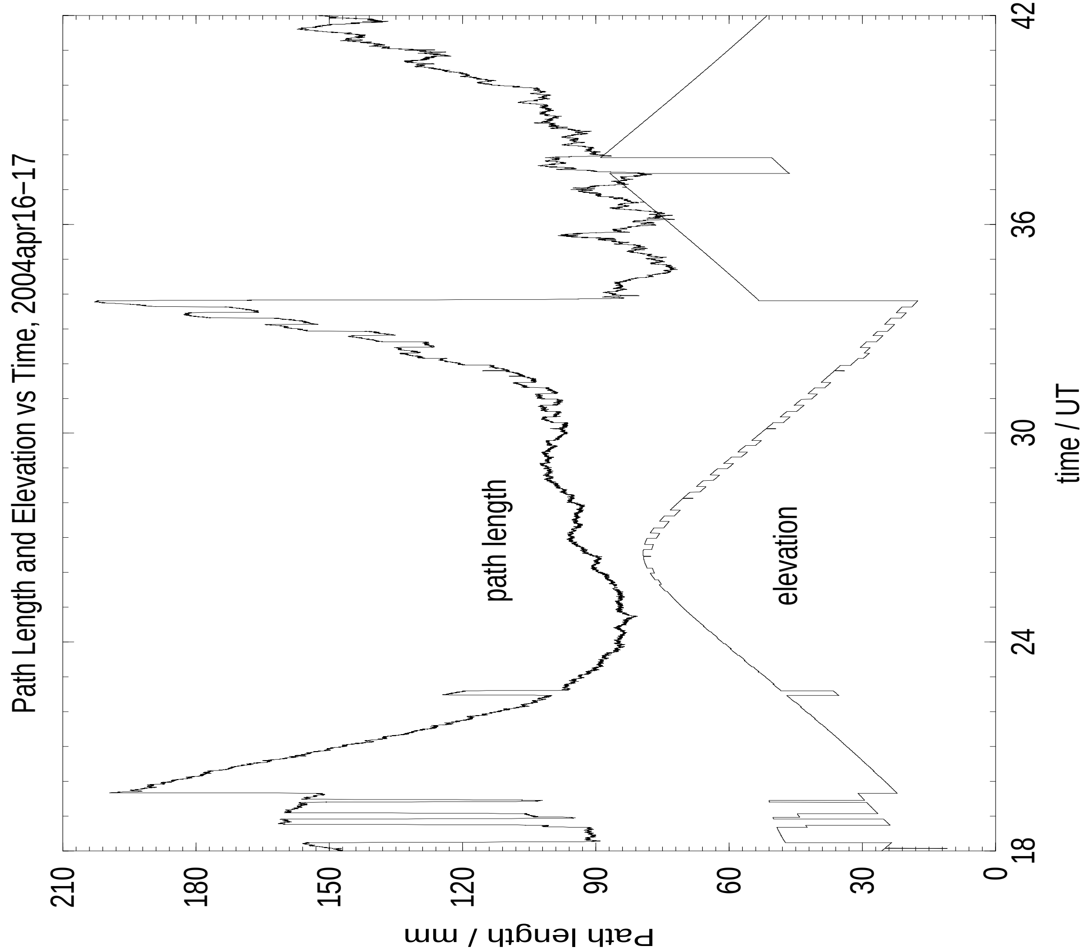
WVR Path Data from 3 mm VLBI, April 2004



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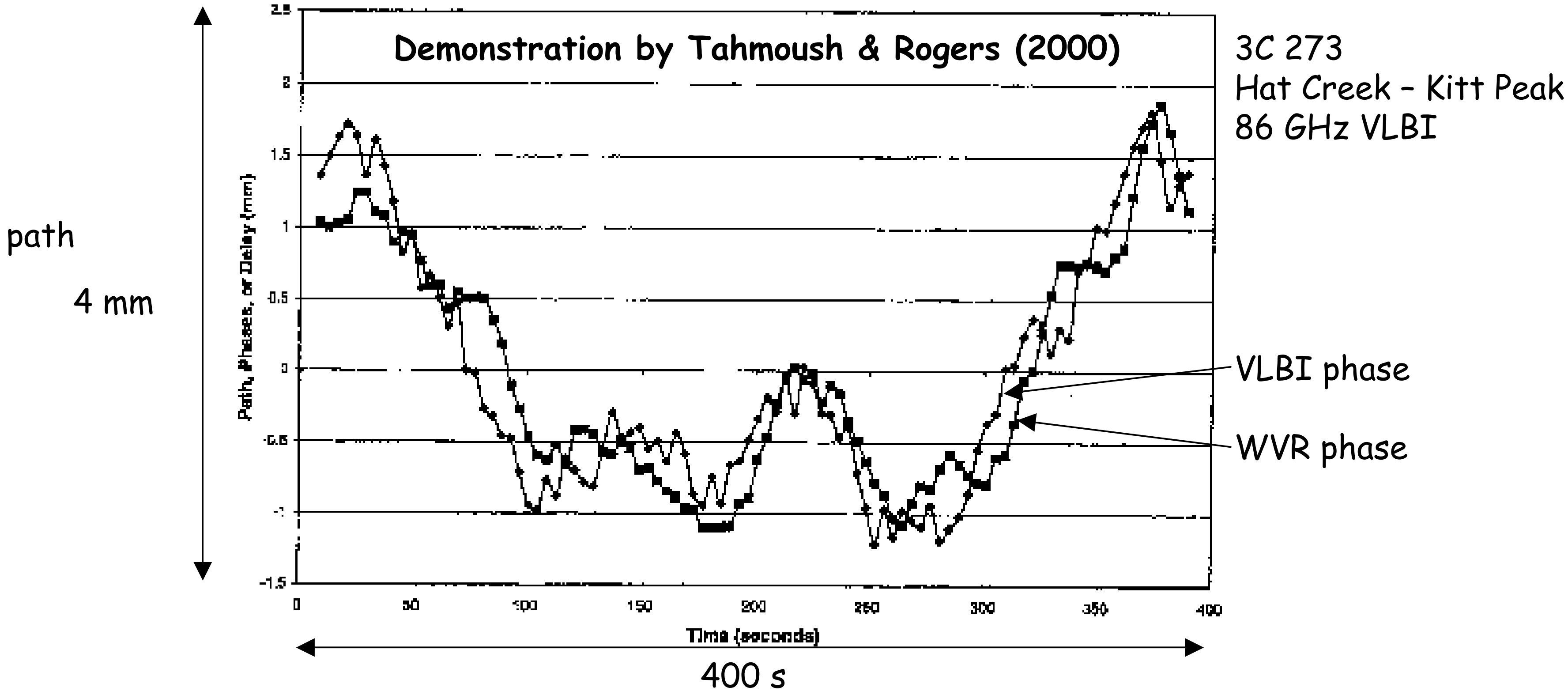
VLBI Phase Correction Demo



- RMS phase noise reduced from 0.88 mm to 0.34 mm after correction.
- Coherent SNR rose by 68 %.

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Conclusion

- **Effelsberg has a WVR**
- Opacities agree with those from 100 m RT
- Stability is 2.7×10^{-4} in 400 s
- Sensitivity is 61 mK in 0.025 s integration time

Data available at:
http://www.mpifr-bonn.mpg.de/staff/aroy/wvr.html

Future

- Validate phase correction (2004 Apr 3 mm VLBI campaign)
- Validate zenith total delay (2005 Mar geodetic campaign)
- Software for archive and export to AIPS (Rottmann, RadioNet)
- Hardware: (once usefulness established)
  - improve temperature stabilization
  - reduce spillover with new feed?
  - improve integration time efficiency
  - better beam overlap: move to prime focus receiver boxes

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WVR Performance Requirements

Opacity Measurement

Aim: correct visibility amplitude to 1 % (1 σ)

WVR spec: absolute calibration accuracy $\leq$ 14 % (1 σ)
thermal noise per measurement $\leq$ 2.7 K.

Tropospheric Phase Correction

Aim: coherence at 86 GHz = 0.9 over 300 s
requires $\leq \lambda$ / 20 path

WVR spec: thermal noise $\leq$ 14 mK in 3 s
gain stability: 3.9 x 10^{-4} in 300 s

Zenith Wet Delay Measurement

Aim: 1 mm absolute error on zenith wet delay

WVR spec: absolute calibration accuracy 1 % (1 σ)
bandpass calibration flatness 0.1 %

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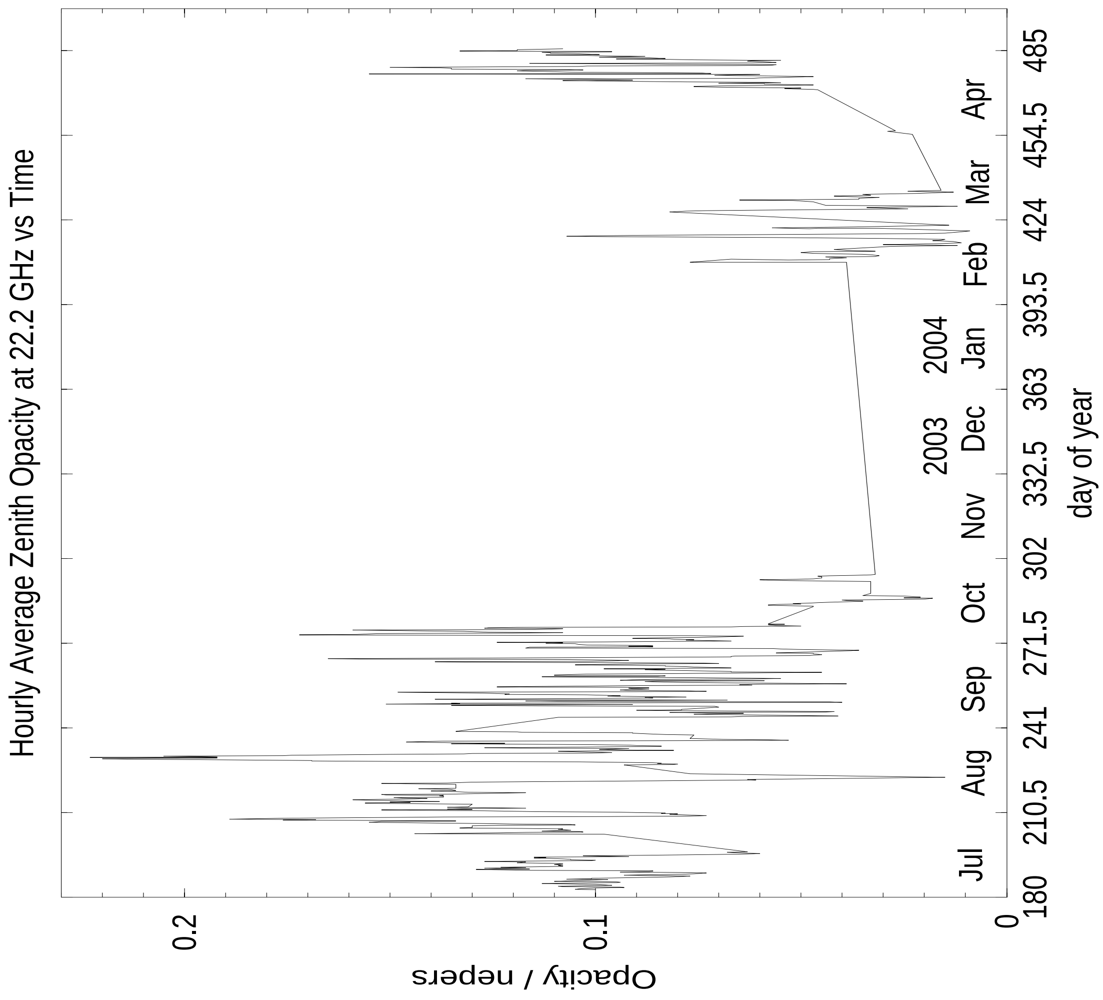
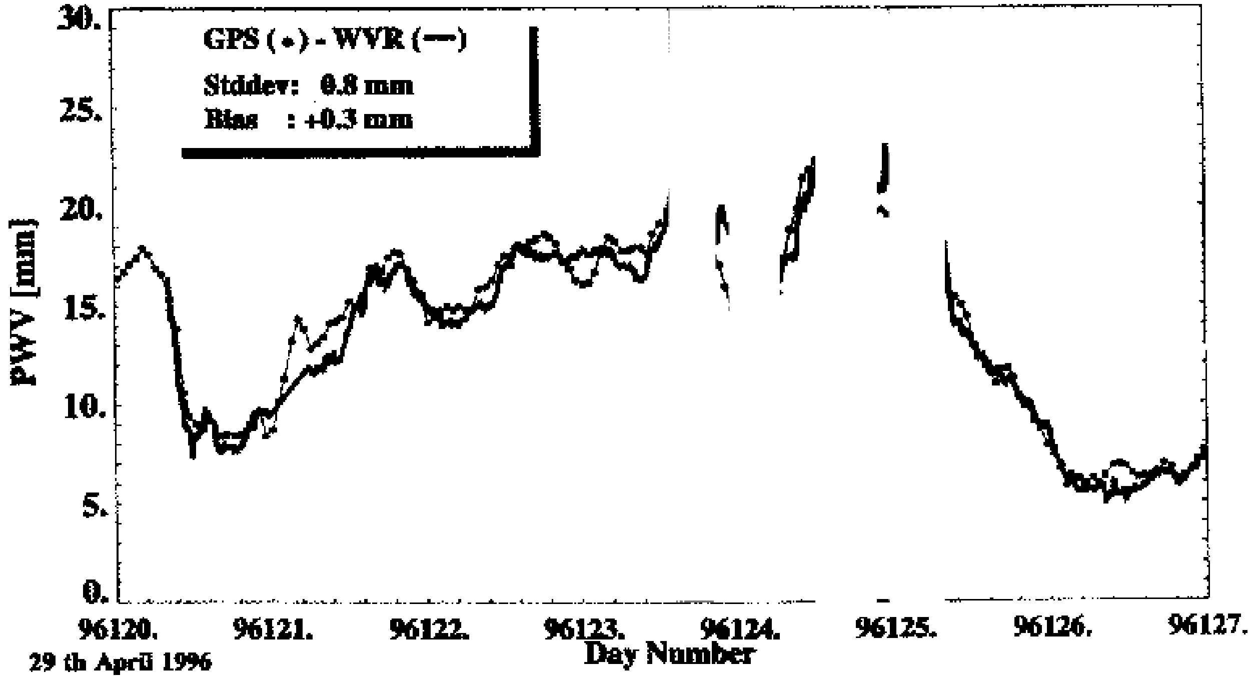
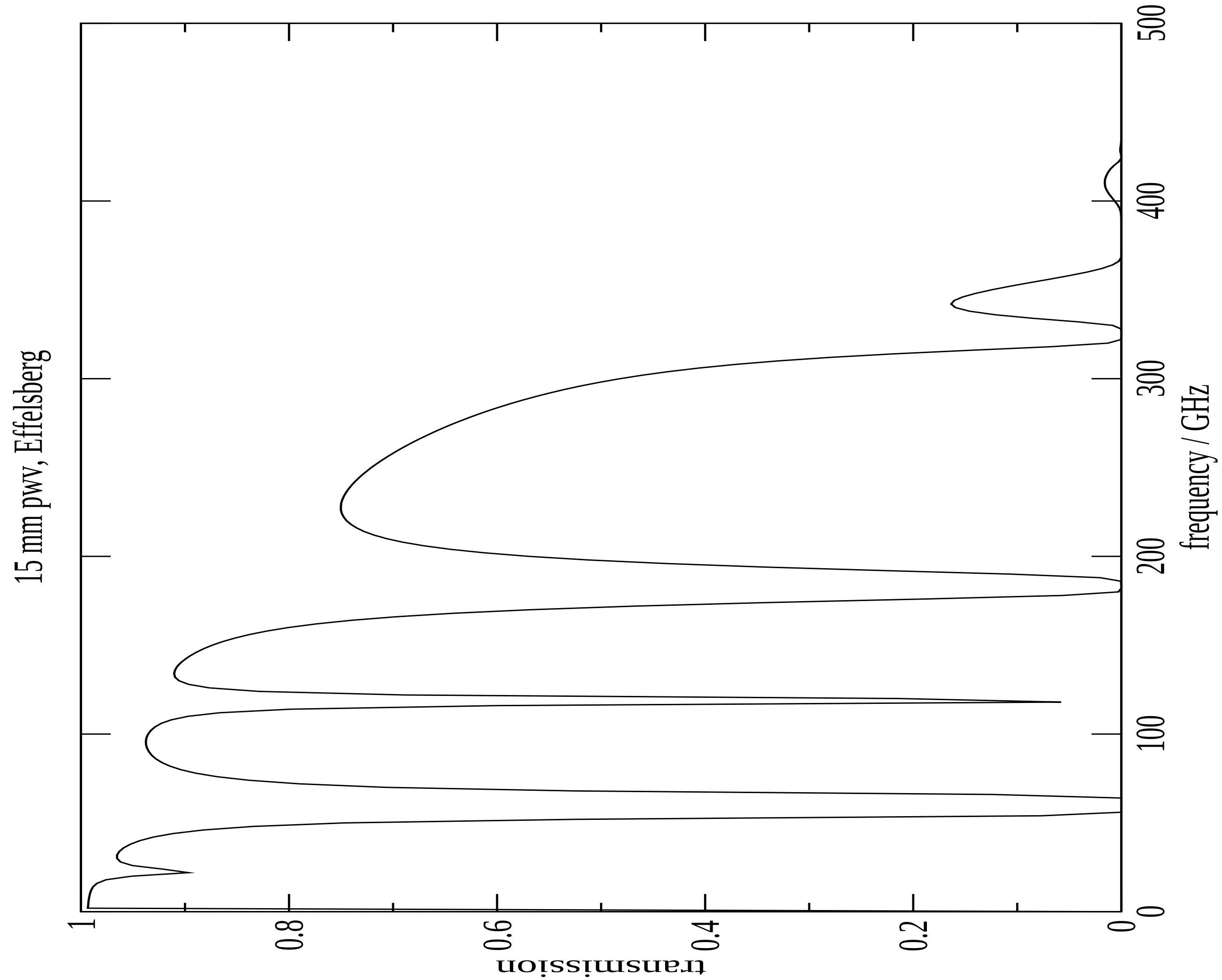
Opacity Statistics at Effelsberg



Zenith Delay using GPS



Water-Vapour Radiometry Basics



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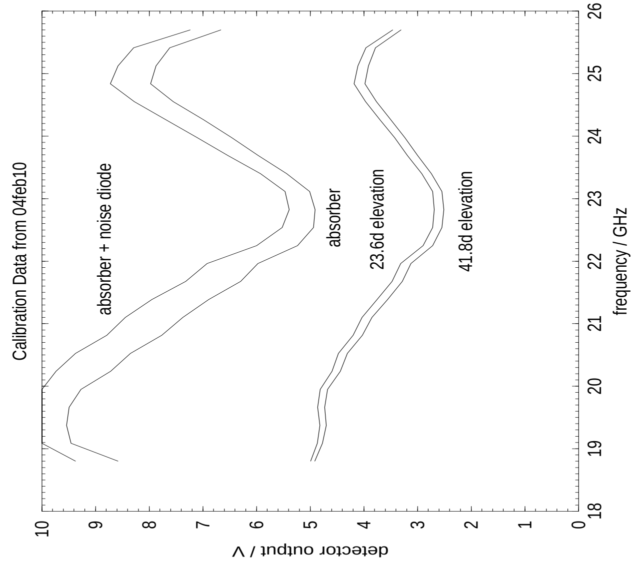
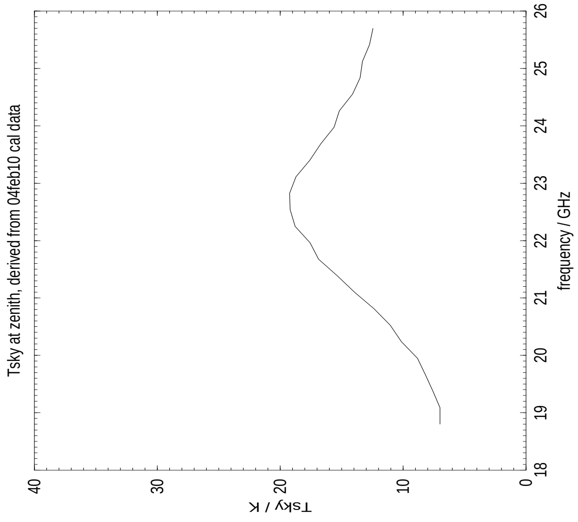
Gain Calibration

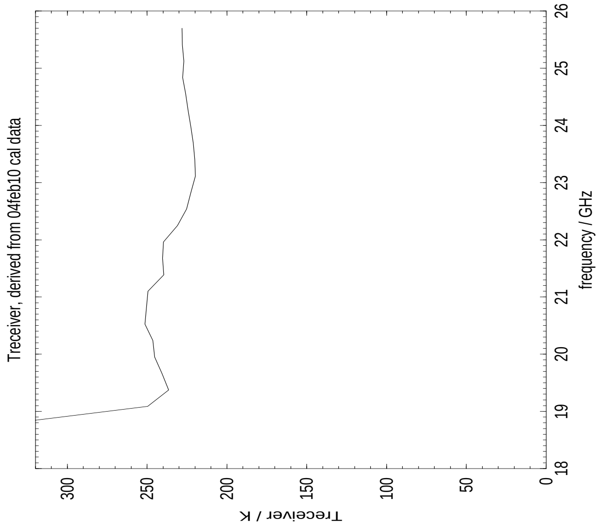
Measure: hot load
sky dip at two elevations
noise diode on/off



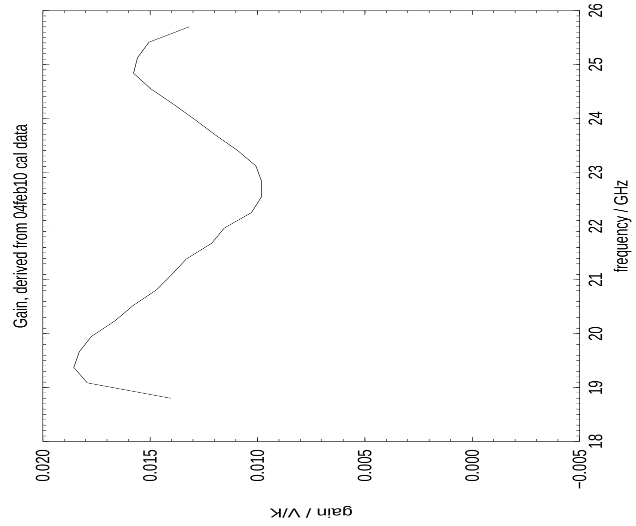
Derive: Tsky



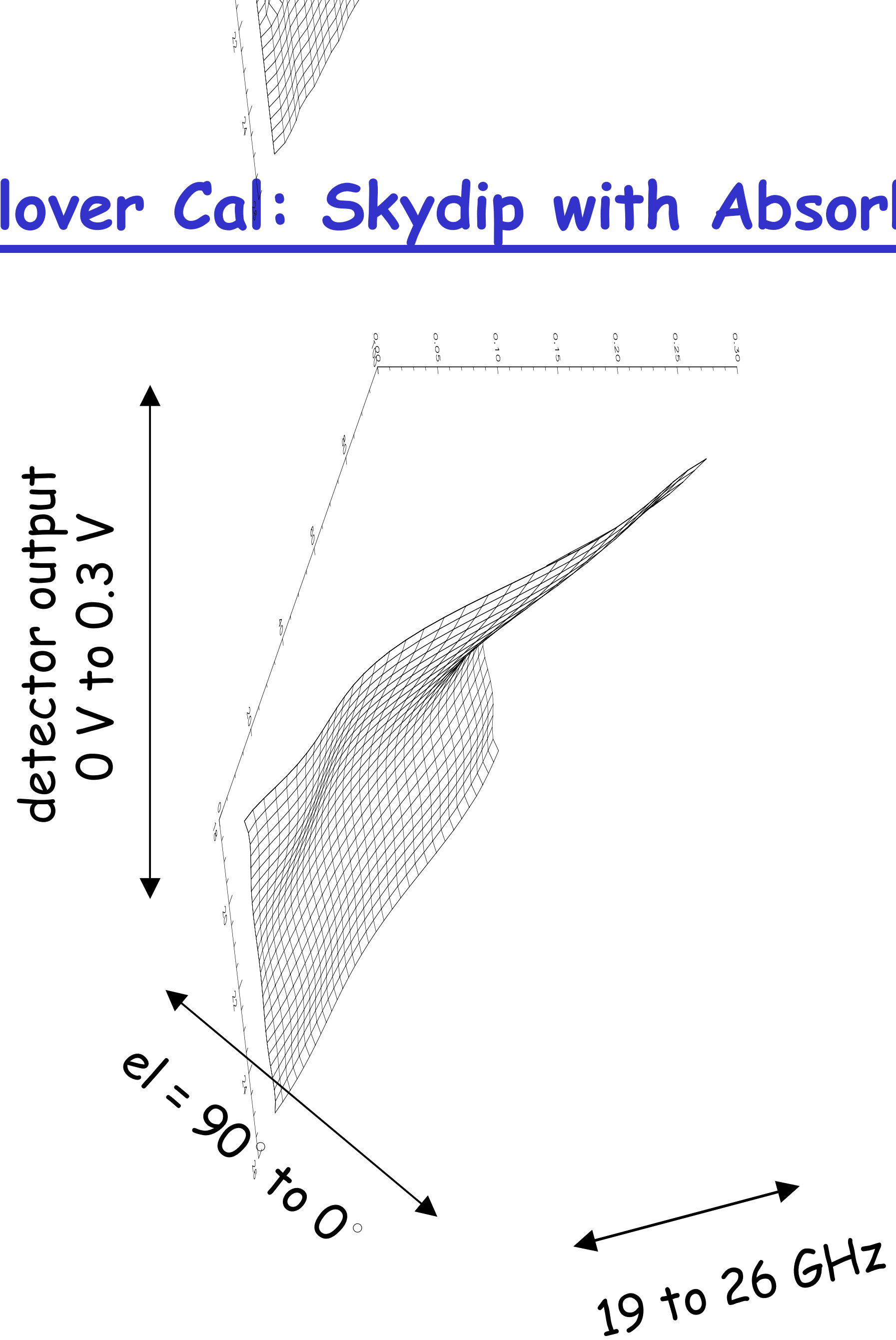
Treceiver



gain



Spillover Cal: Skydip with Absorber on Dish



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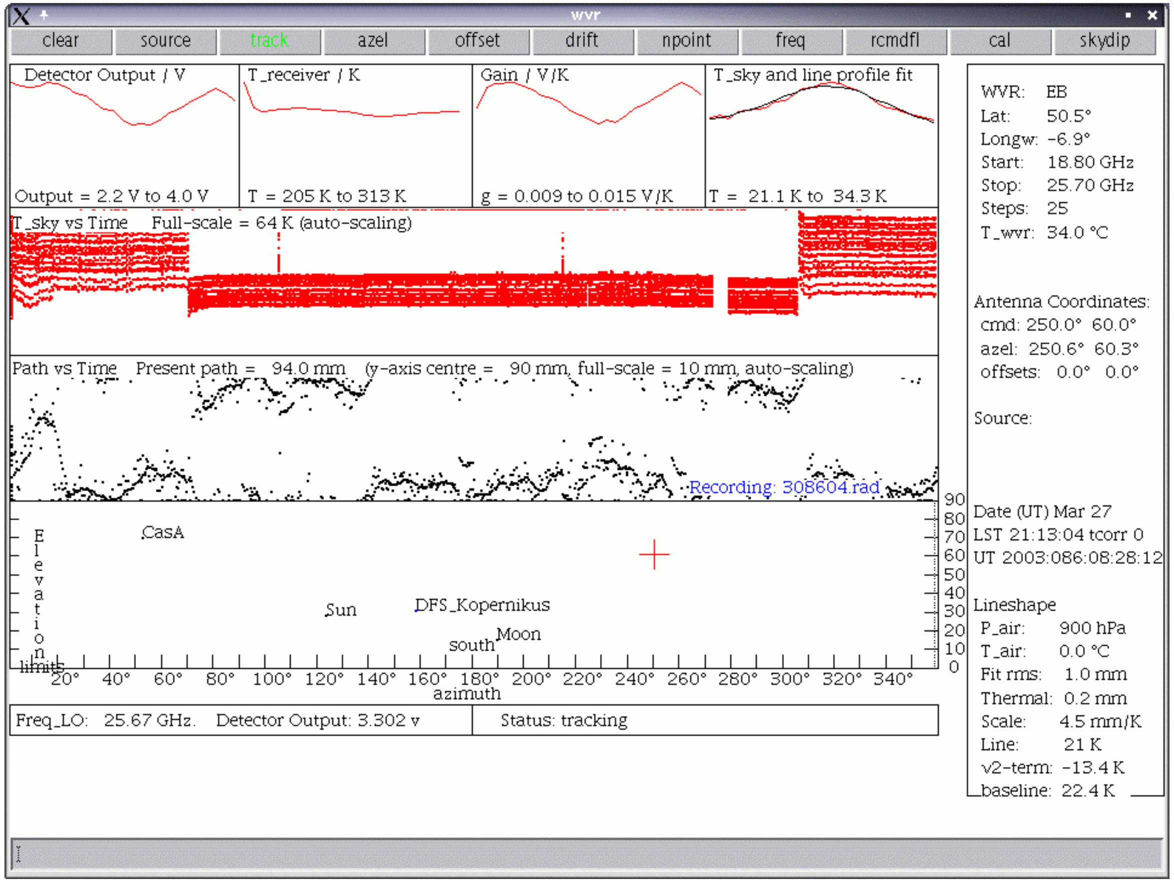
WVR Control Panel



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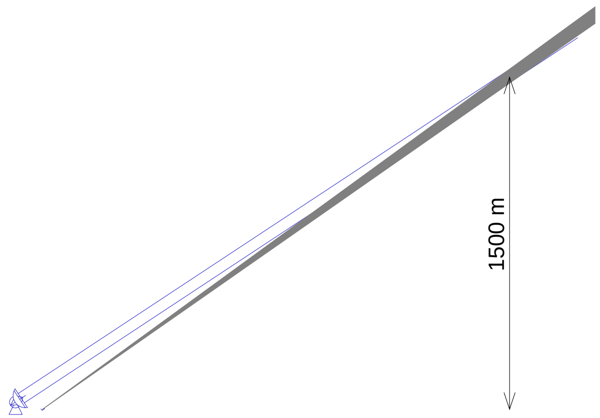
WVR Beam Geometry



Beam overlap, April 2003

Beam overlap, April 2004

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Future Developments

- Validate phase correction (3 mm VLBI from 2004 April 16-20)
- Validate zenith total delay using geodetic VLBI (2005 Mar campaign)
- Software development: (Rottmann, FP6 RadioNet, started May 3)
  data paths into AIPS and CLASS
  data archive
  online (web-based) real-time display
- Investigate limitations on calibration accuracy
- Hardware development: (once usefulness established)

temperature stabilization:	further improvements
spillover:	reduce with new feed?
integration time efficiency:	Data acquisition system upgrade
beam overlap:	move to prime focus receiver boxes

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Conclusions

- **WVR installation complete; WVR now running**
- Opacities agree with those from 100 m RT
- Validation of phase-correction data in progress
- Web-based display & archive access coming soon
- Radiometer stability is 2.7 x 10^{-4} in 400 s
- Radiometer sensitivity is 61 mK in 0.025 s integration time

Get data at:
http://www.mpifr-bonn.mpg.de/staff/aroy/wvr.html