BIGHORNS status and results

Marcin Sokolowski and R. Wayth, S. Tremblay, S. Tingay (Curtin University / CAASTRO)

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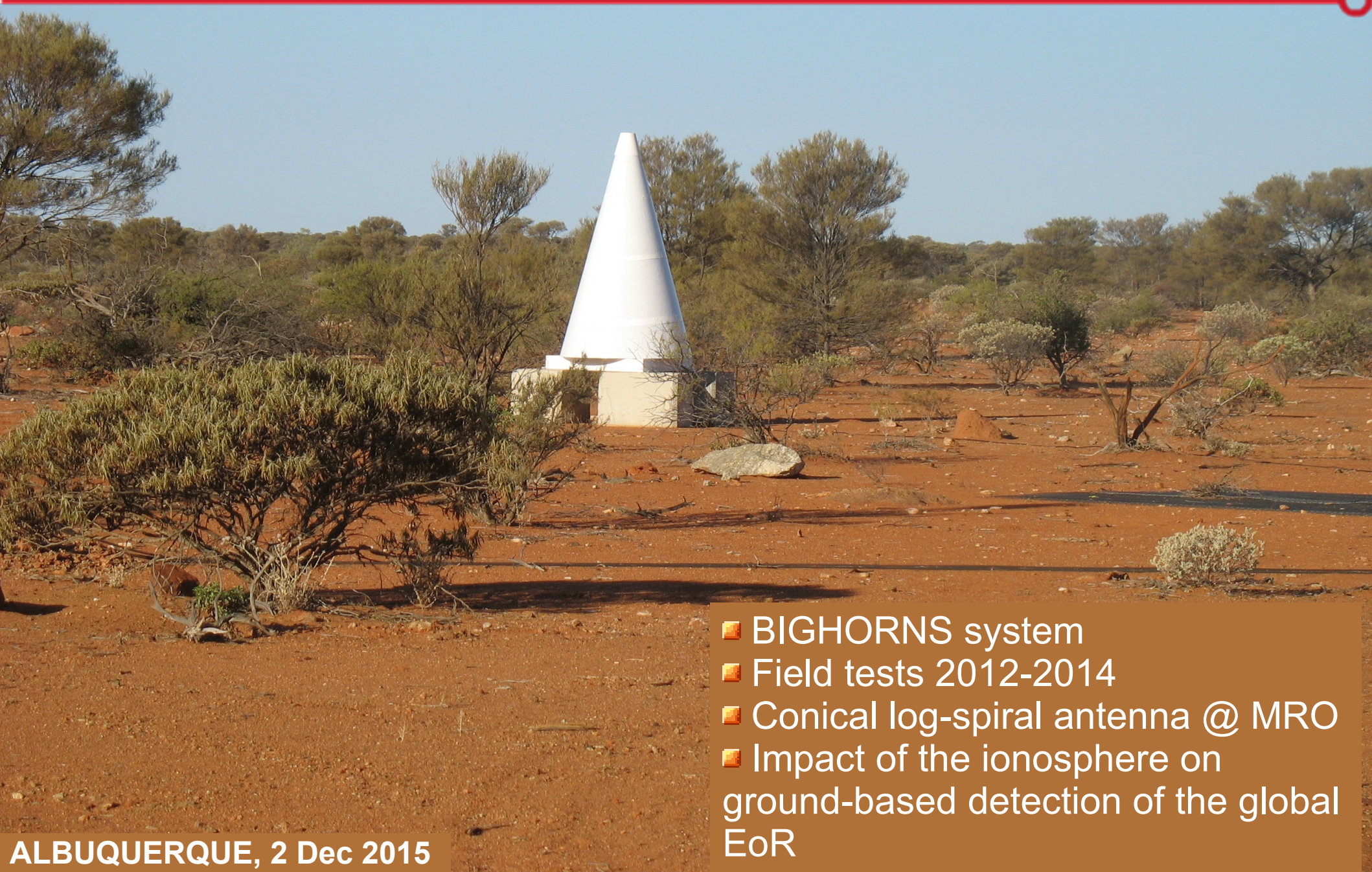

- BIGHORNS system
- Field tests 2012-2014
- Conical log-spiral antenna @ MRO
- Impact of the ionosphere on ground-based detection of the global EoR

ALBUQUERQUE, 2 Dec 2015

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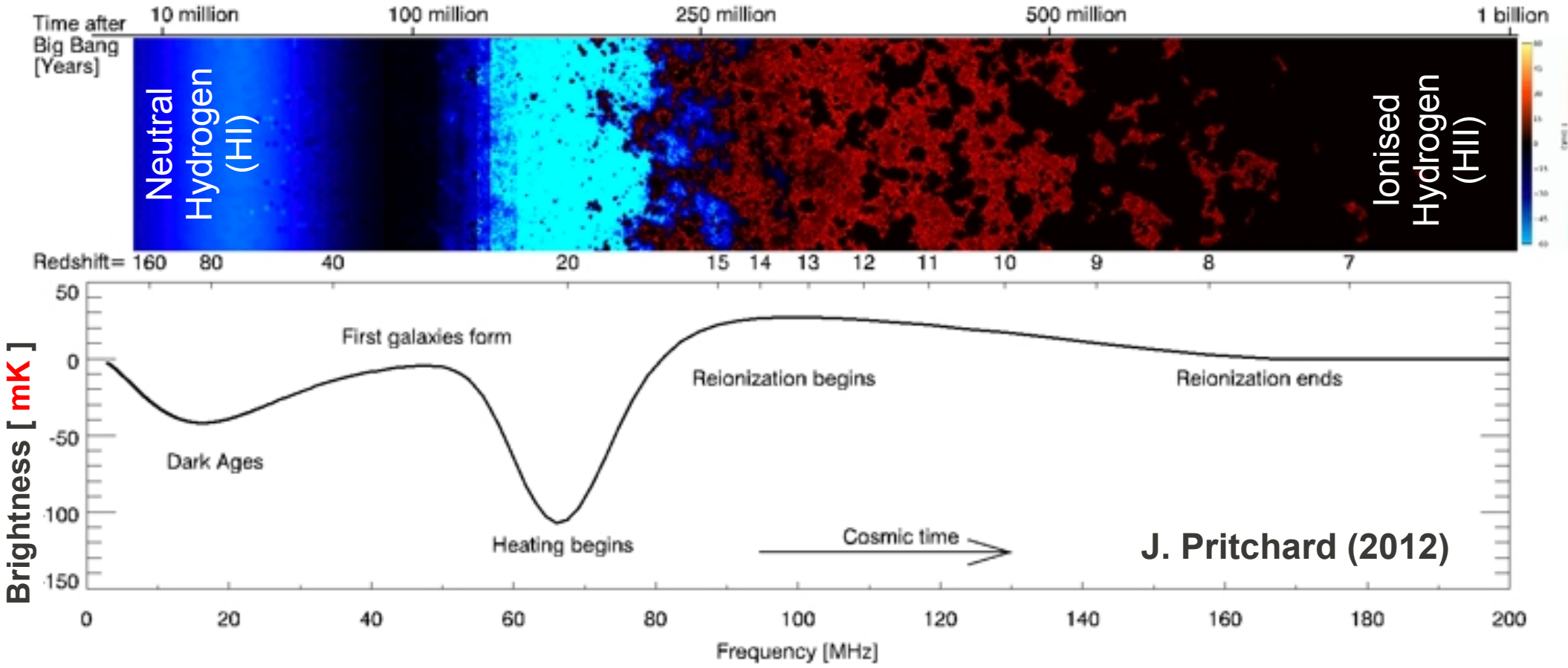
Global Epoch of Reionisation (EoR)



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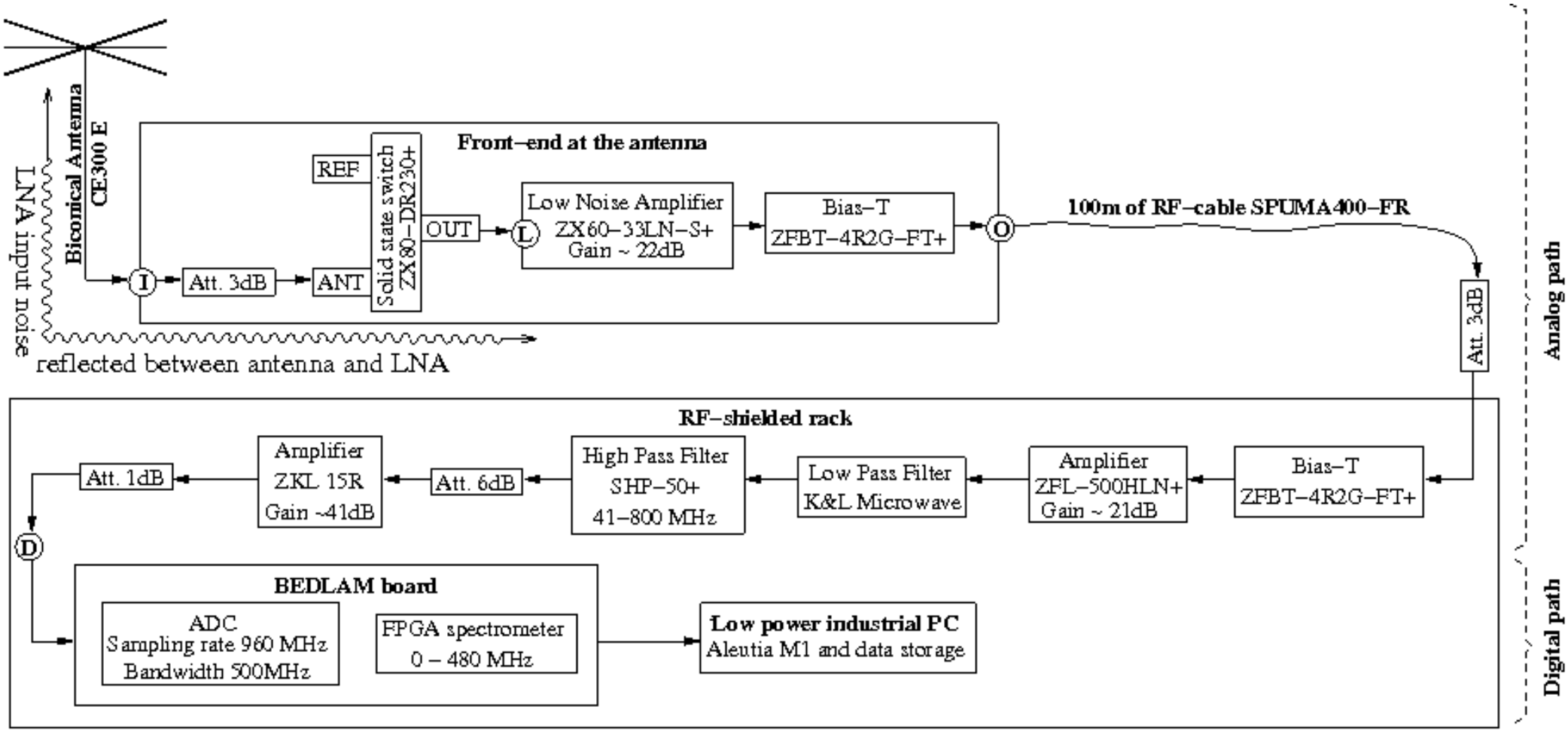
BIGHORNS system with a portable biconical antenna as it was used during short deployments in 2012 - 2014



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Deployment in Eyre Bird Observatory (December 2013)

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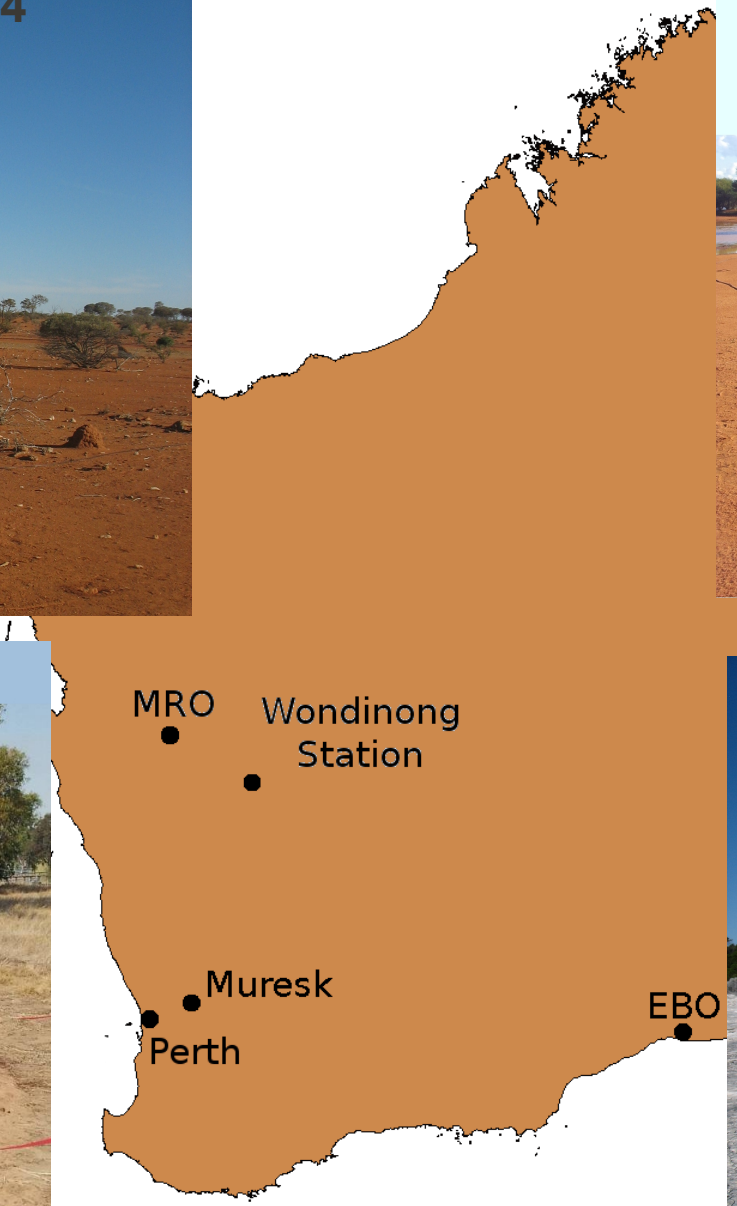
BIGHORNS 2012-2014 field tests in Western Australia

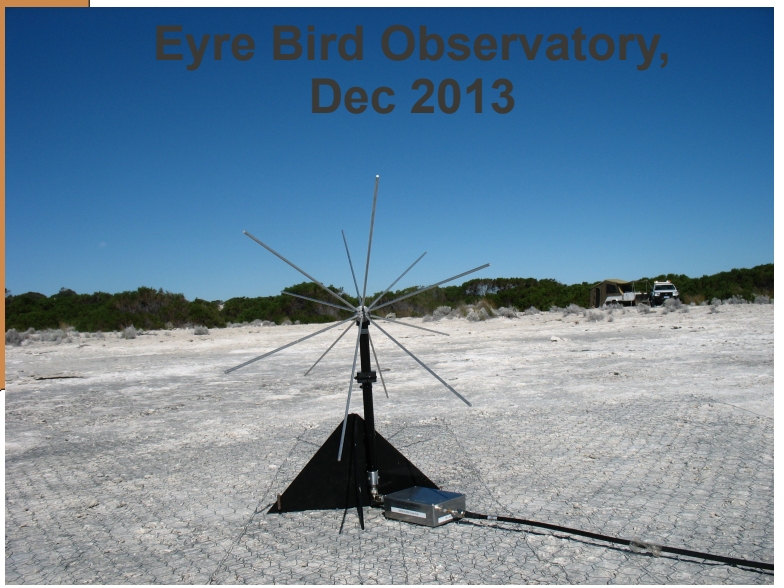
MRO, October 2014

Wondinong Station, April 2014



Muresk, 2012

Eyre Bird Observatory, Dec 2013



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BIGHORNS conical log-spiral antenna (left-hand circularly polarised)

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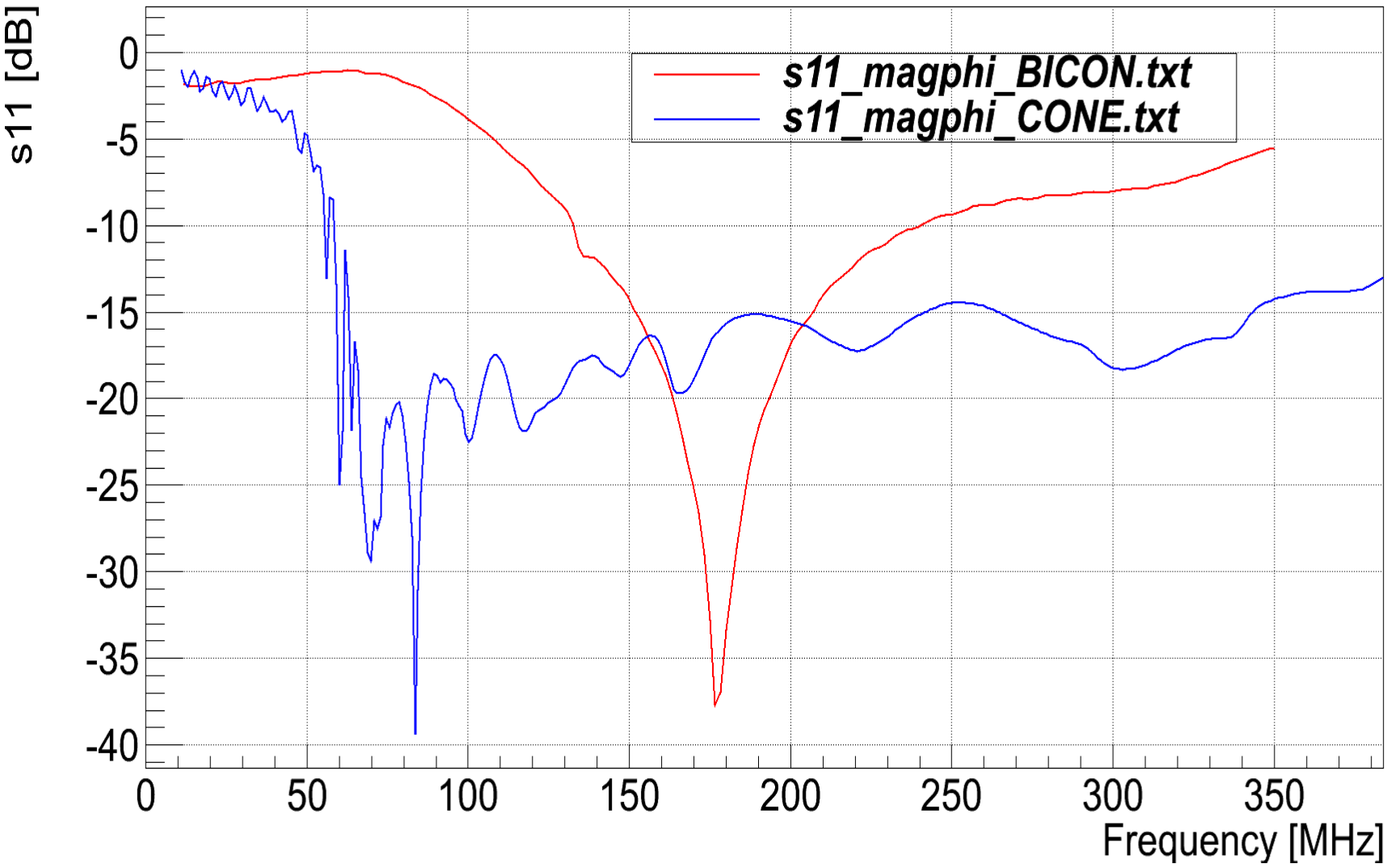
Reflection coefficients of conical log spiral vs biconical antenna



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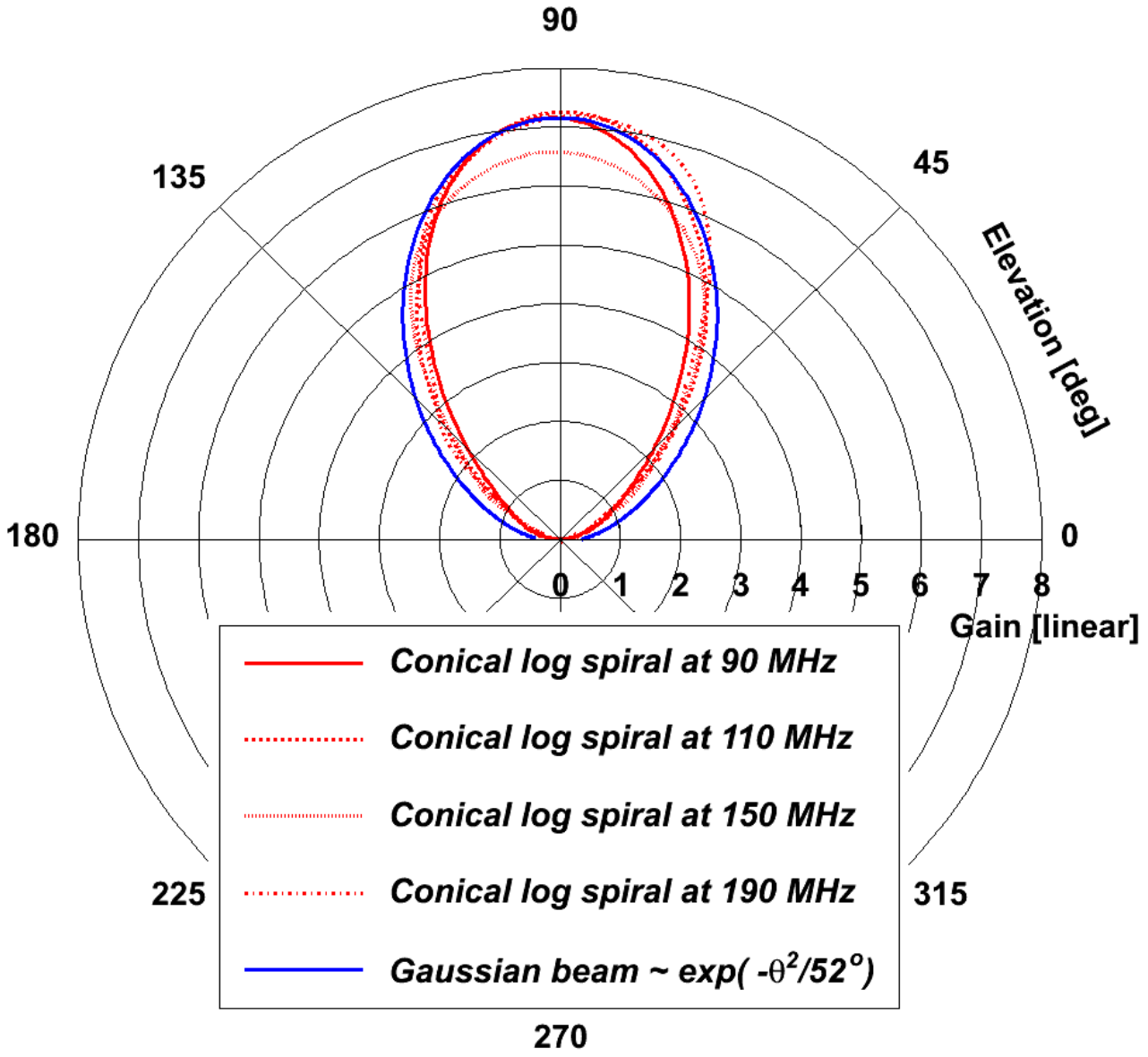
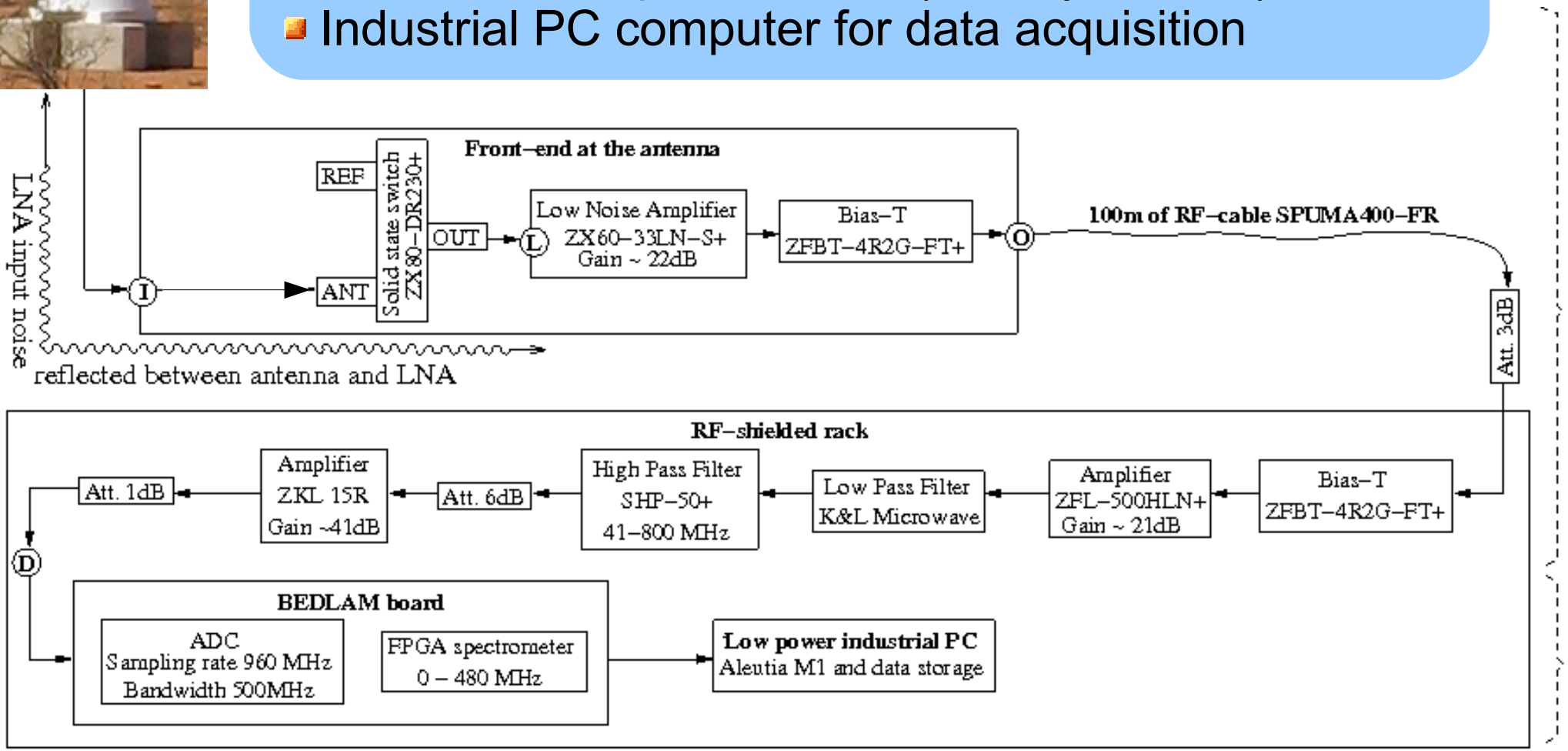
Antenna beam simulated in FEKO

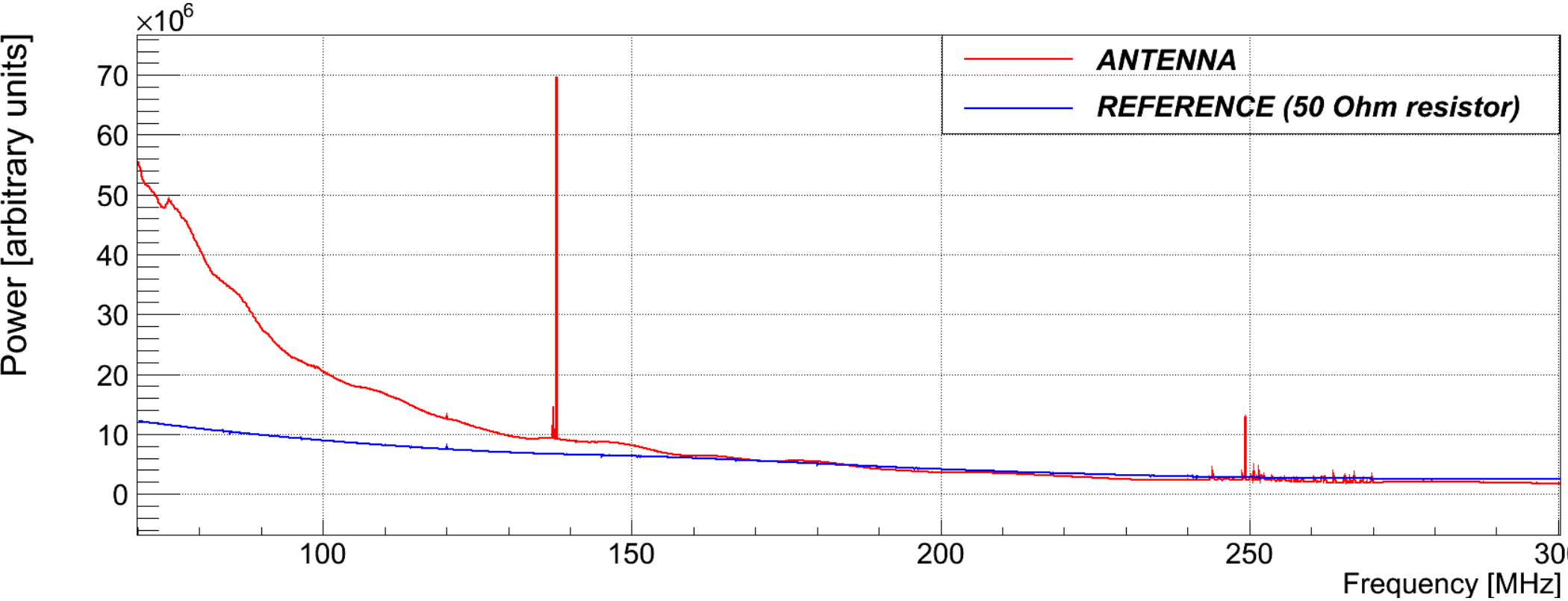


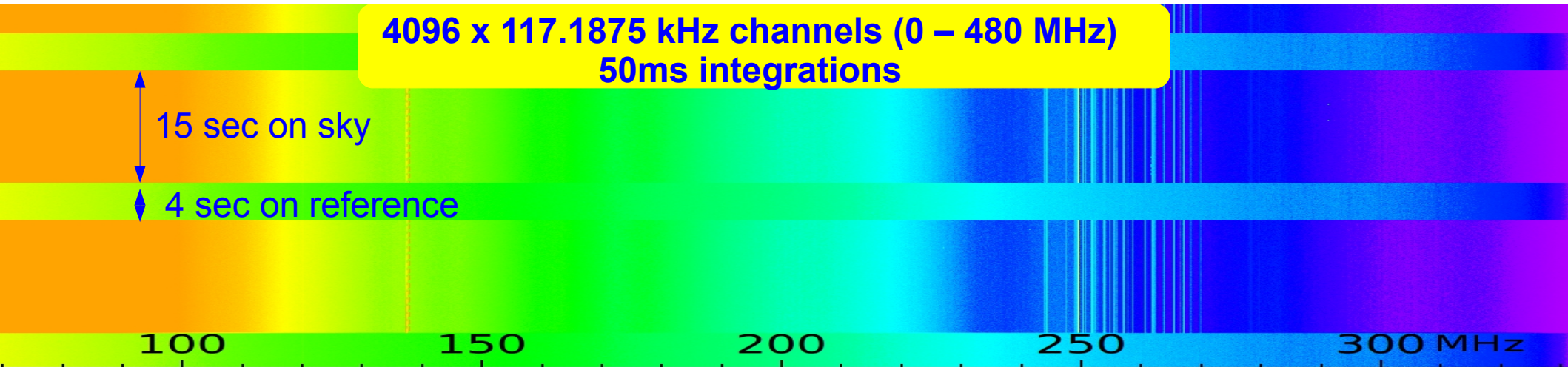
BIGHORNS conical log-spiral antenna at the MRO since October 2014

- Conical log-spiral antenna (built at Curtin University)
- Switching between antenna and calibrator
- ~70 dB of gain in analogue signal path
- FPGA based spectrometer (built by CSIRO)
- Industrial PC computer for data acquisition



Data reduction and radio frequency interference (RFI) excision





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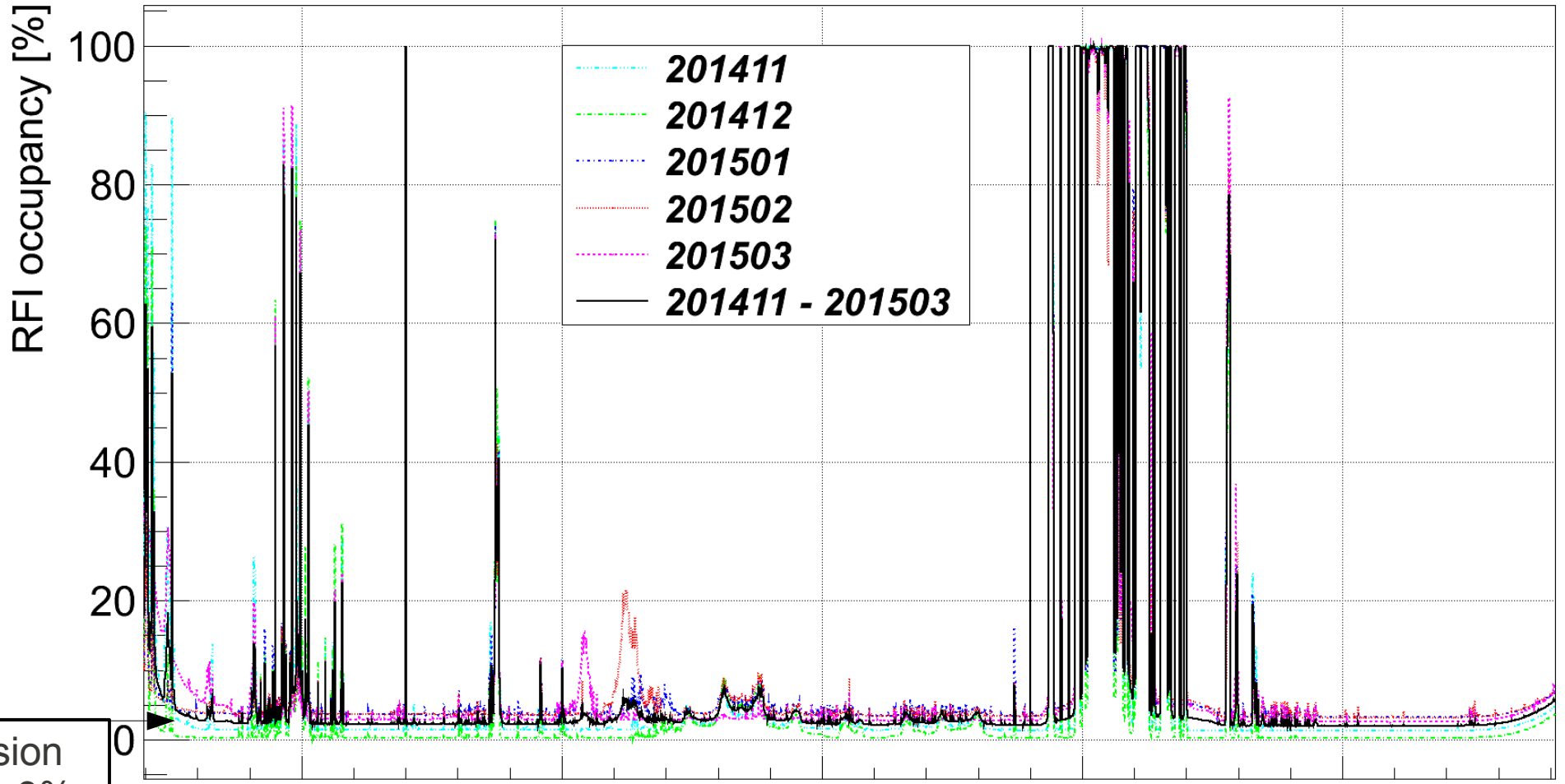
Data processing

- State (antenna / reference) identification
- Radio-frequency interference (RFI) exicision (total/channel power + Andre's Offringa aoflagger)
- Calibrate sky data in temperature units [Kelvin]
- Data reduction – averaging of N integrations (1 hour LST bins)
- Excision of variability such as solar activity (daytime) and lightning
- Selection of consistent data sample – collected in very similar conditions (ambient temperature ±3 K)

Nighttime occupancy based on data collected between 2014-10-24 and 2015-03-31



Excision floor ~3% due to broadband receiver saturation or lightning

FM band

ORBCOMM satellites (137 – 138 MHz)

Digital TV/radio

Military satellites

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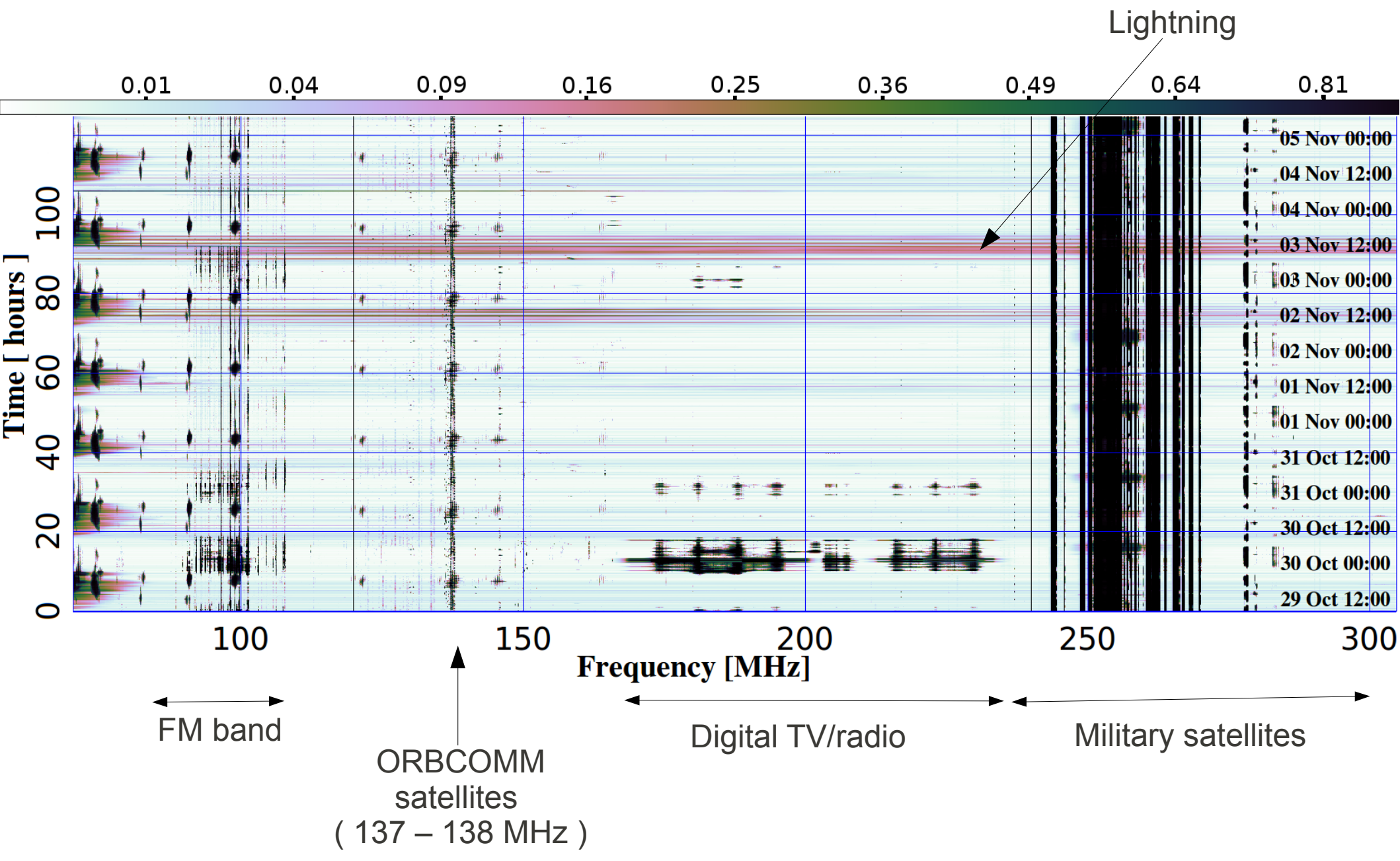
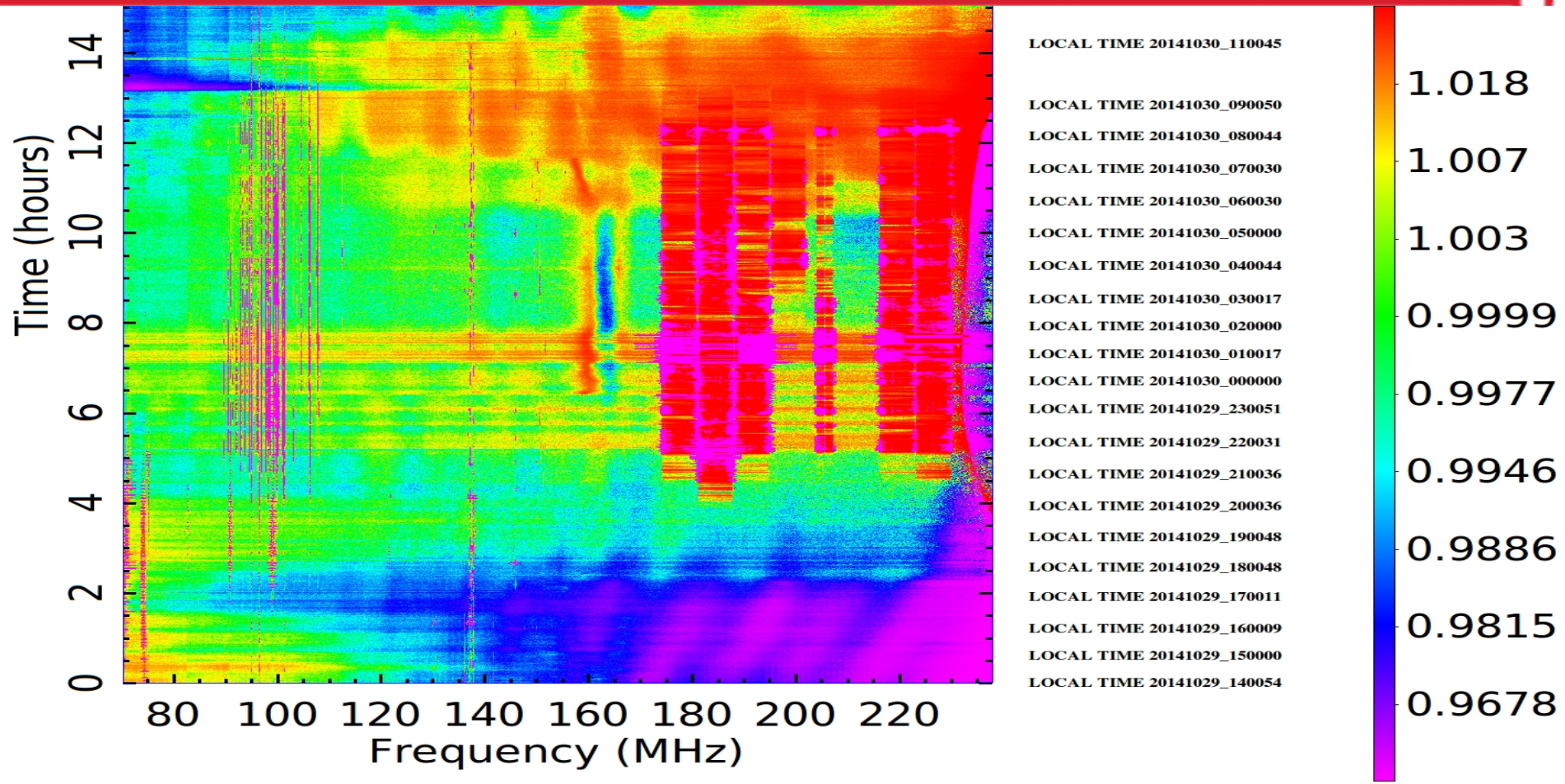
Nighttime occupancy in 10 minute bins between 2015-10-29 and 2015-11-05



Statistics of tropospheric ducting events



Month	Nights	Evening storms	Strong (> 10 dB)	Moderate (> 3 dB)	Weak (< 3 dB)
2014-(10, 11)	38	7	2	3	7
2014-12	31	2	3	1	7
2015-01	31	11	2	1	3
2015-02	28	13	0	3	3
2015-03	16	5	0	0	2

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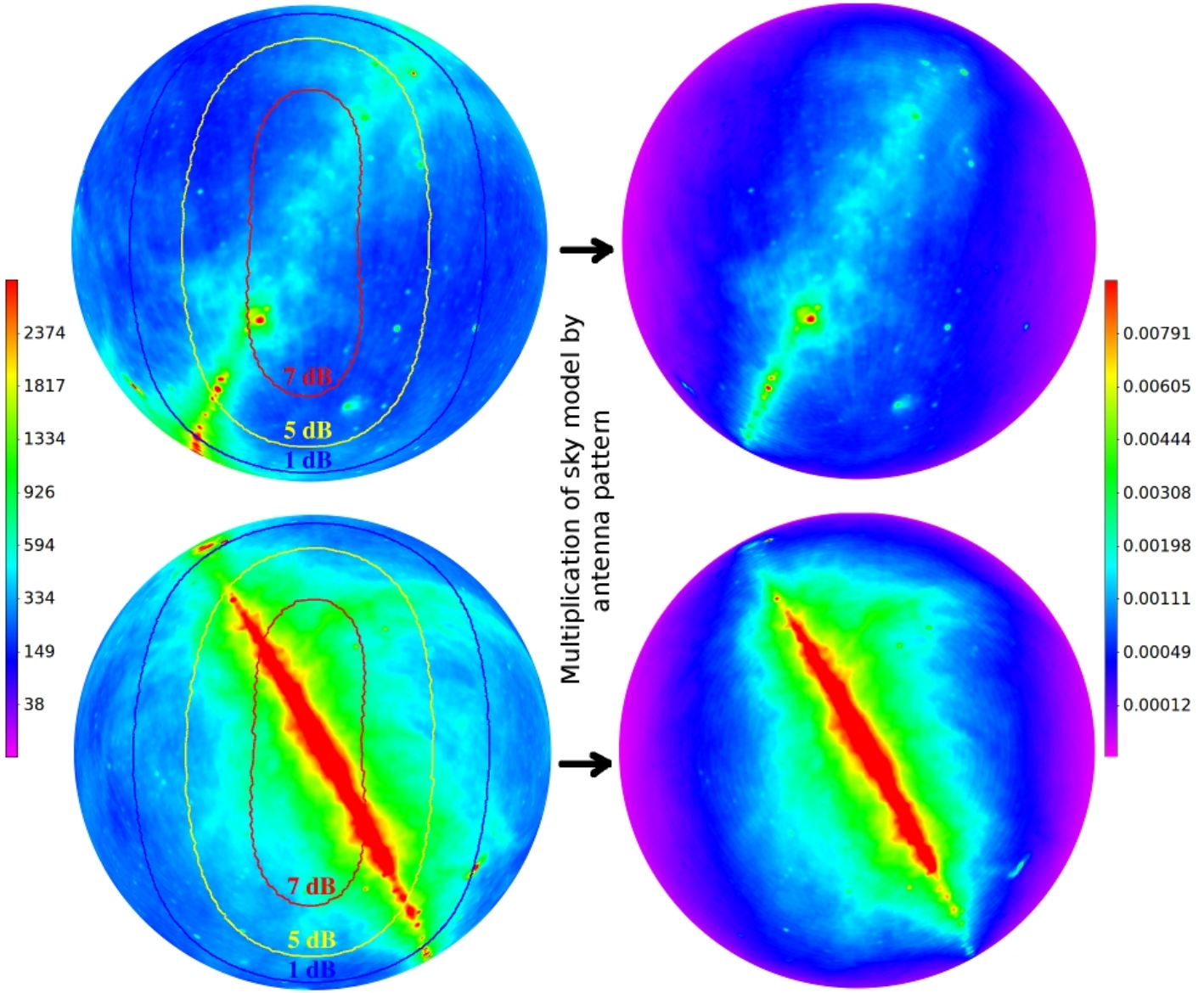
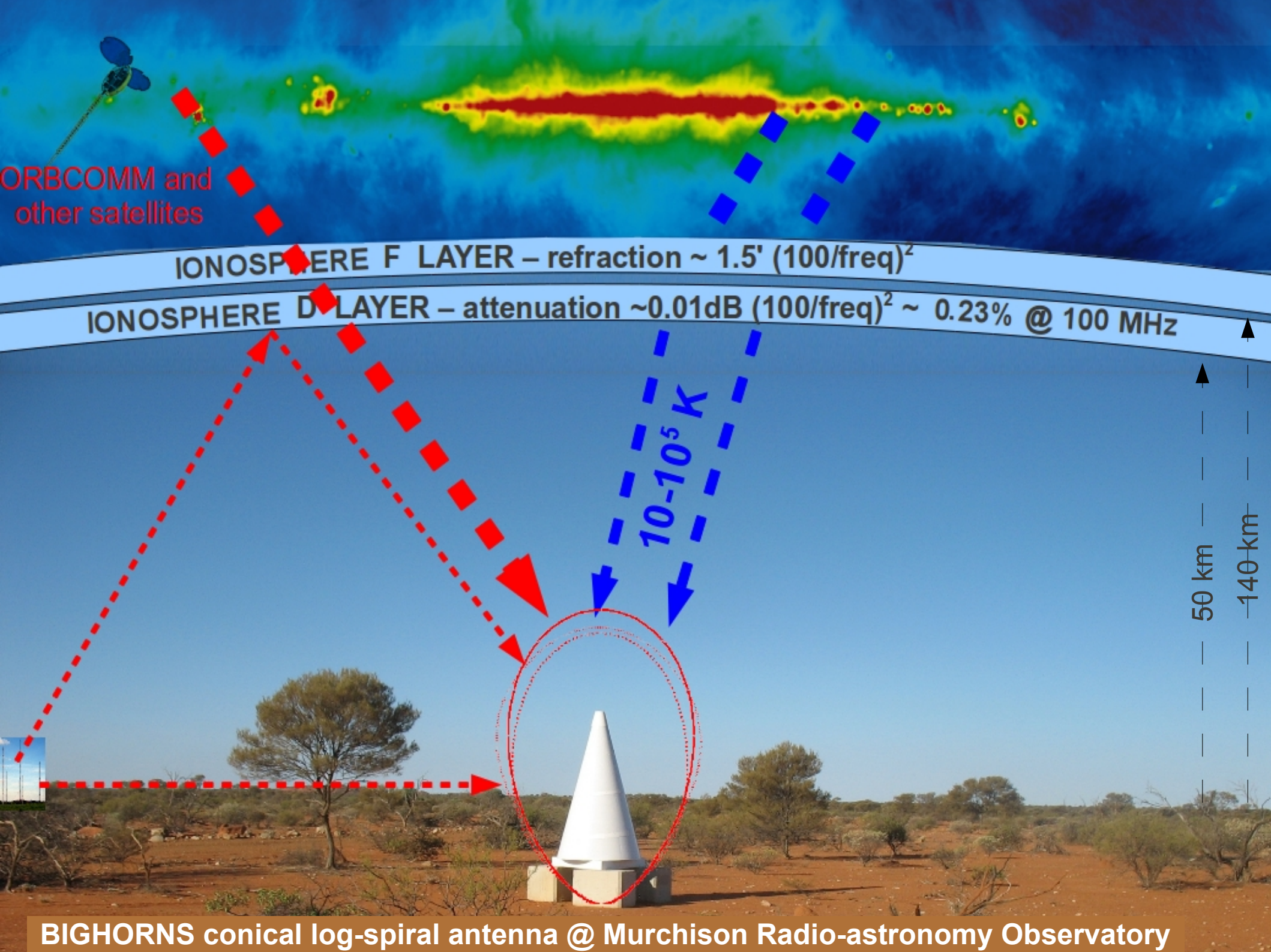
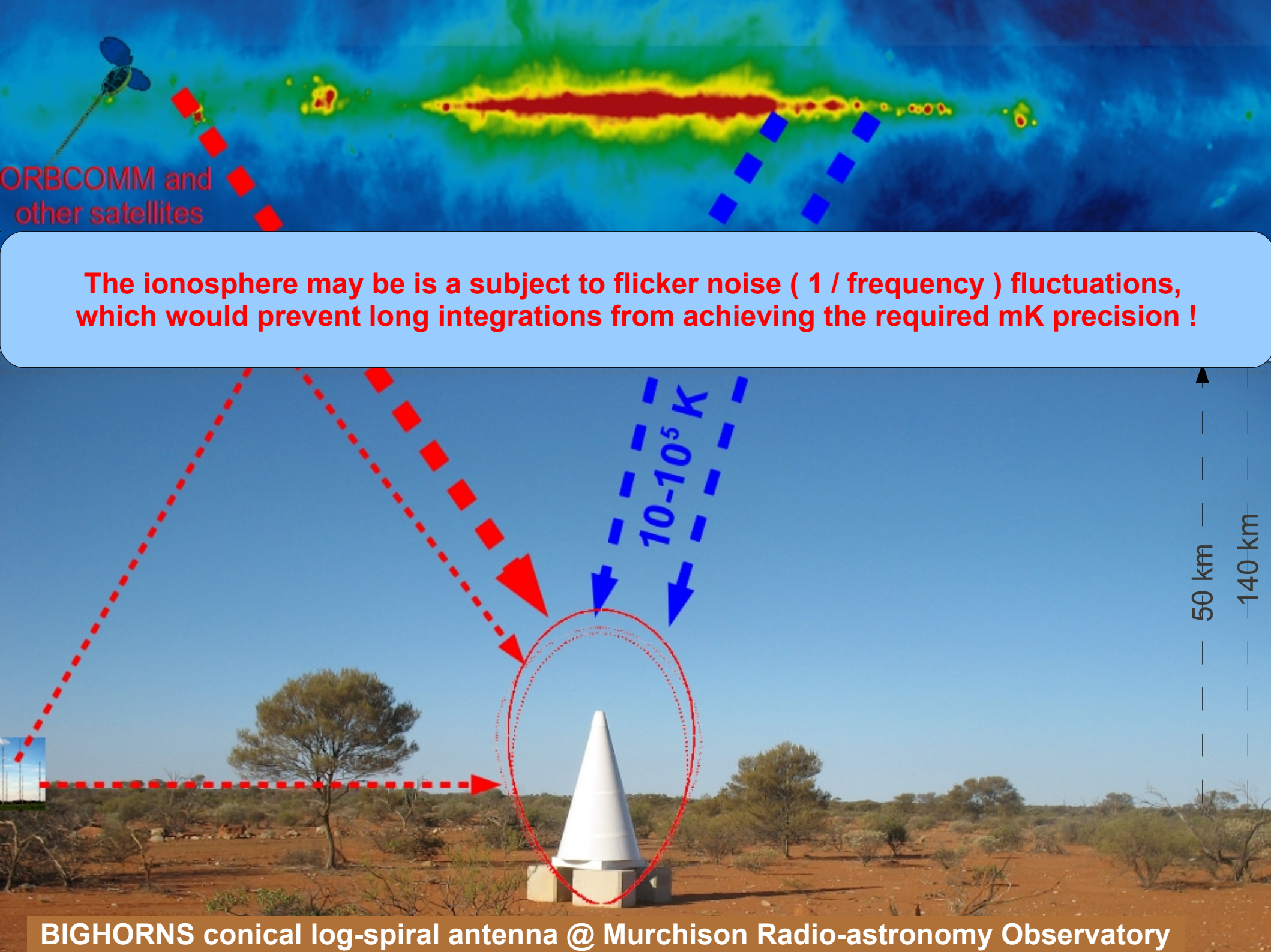
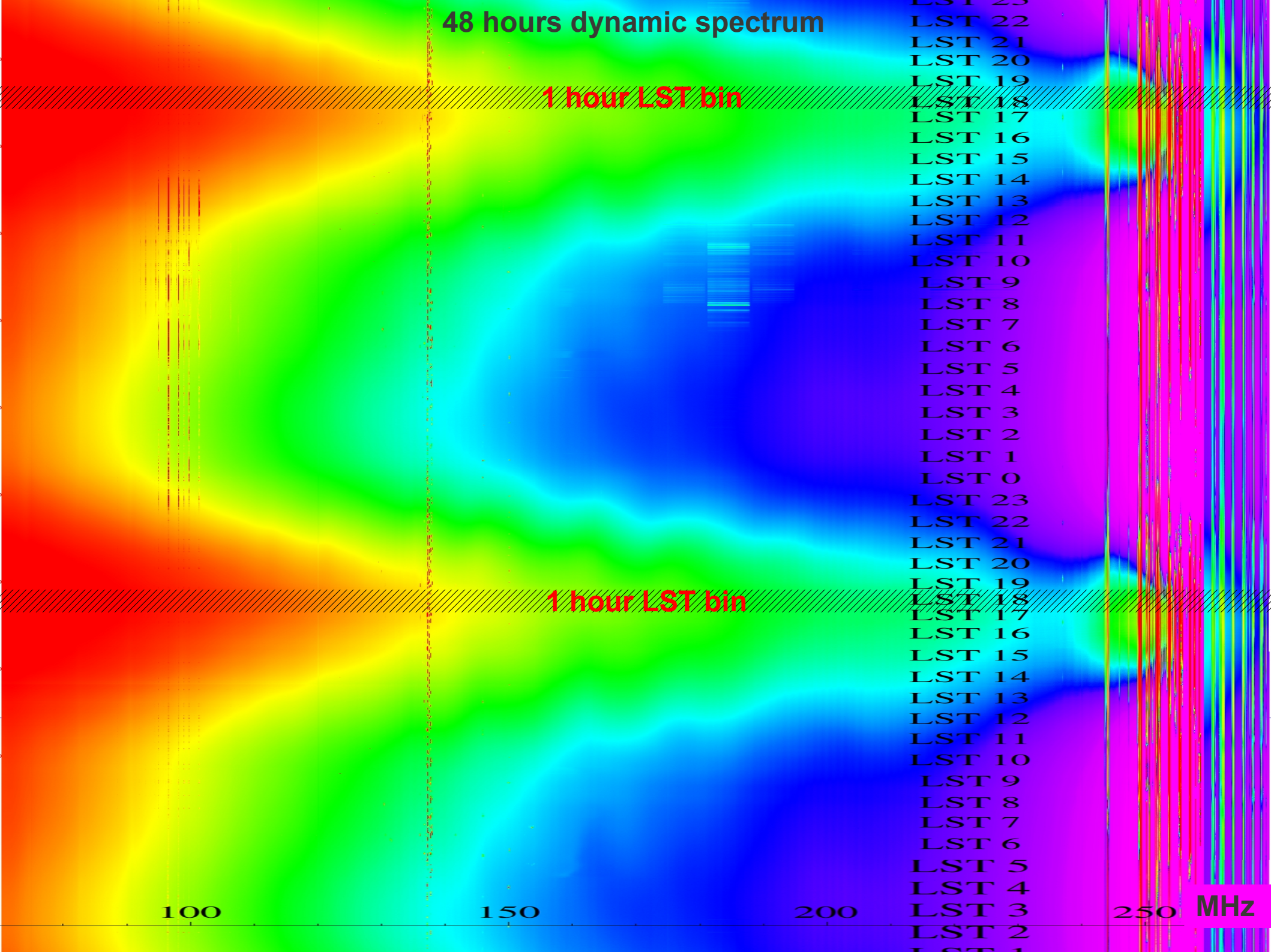
Calibration compared with sky model integrated with simulated antenna pattern





BIGHORNS conical log-spiral antenna @ Murchison Radio-astronomy Observatory


ORBCOMM and
other satellites
The ionosphere may be is a subject to flicker noise (1 / frequency) fluctuations,
which would prevent long integrations from achieving the required mK precision !
10-10^5 K
50 km
140 km
BIGHORNS conical log-spiral antenna @ Murchison Radio-astronomy Observatory


48 hours dynamic spectrum
1 hour LST bin
1 hour LST bin
LST 22
LST 21
LST 20
LST 19
LST 18
LST 17
LST 16
LST 15
LST 14
LST 13
LST 12
LST 11
LST 10
LST 9
LST 8
LST 7
LST 6
LST 5
LST 4
LST 3
LST 2
LST 1
LST 0
LST 23
LST 22
LST 21
LST 20
LST 19
LST 18
LST 17
LST 16
LST 15
LST 14
LST 13
LST 12
LST 11
LST 10
LST 9
LST 8
LST 7
LST 6
LST 5
LST 4
LST 3
LST 2
100
150
200
250
MHz

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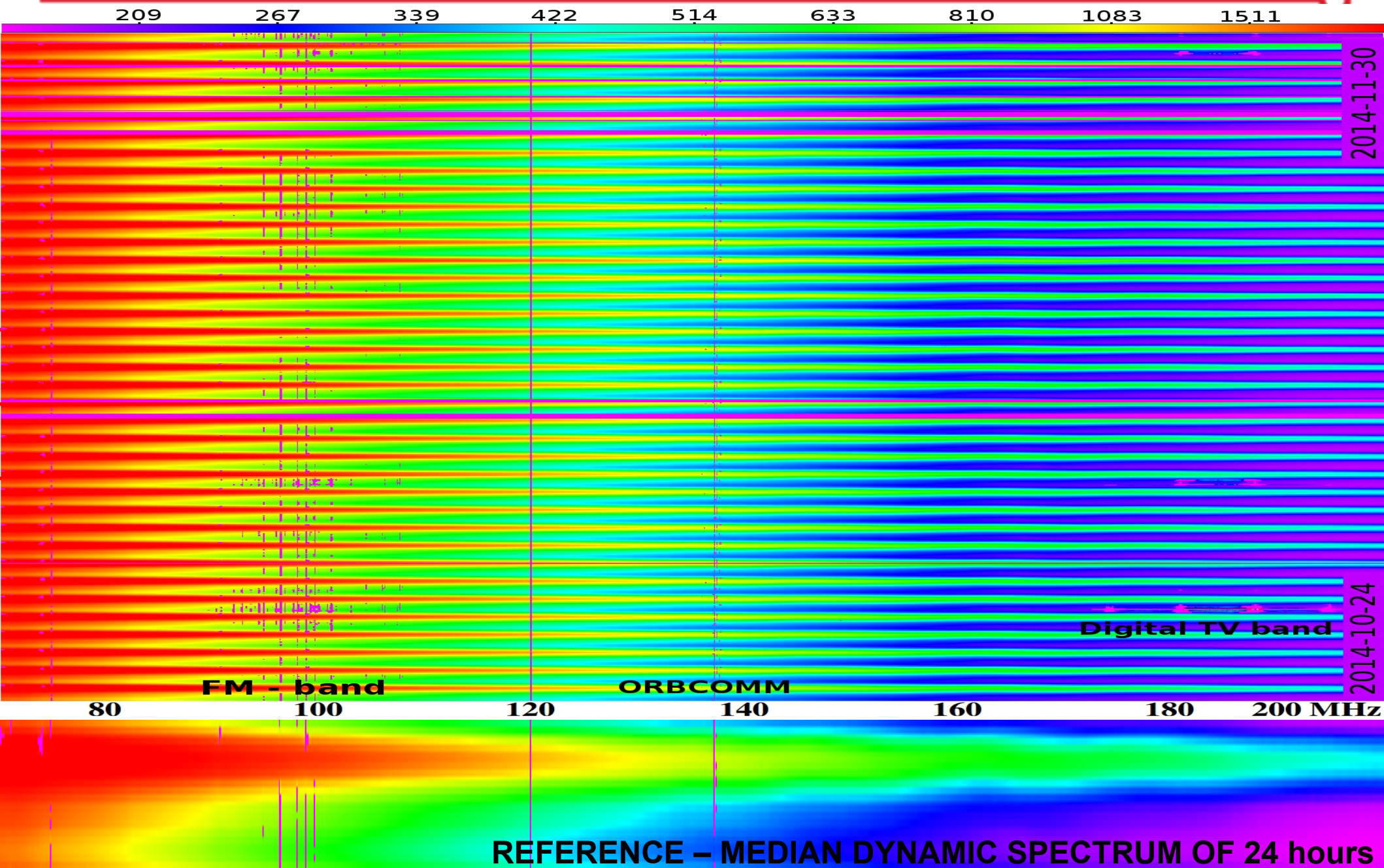
Calibrated Nov 2014 dynamic spectrum in 1 hour temporal resolution



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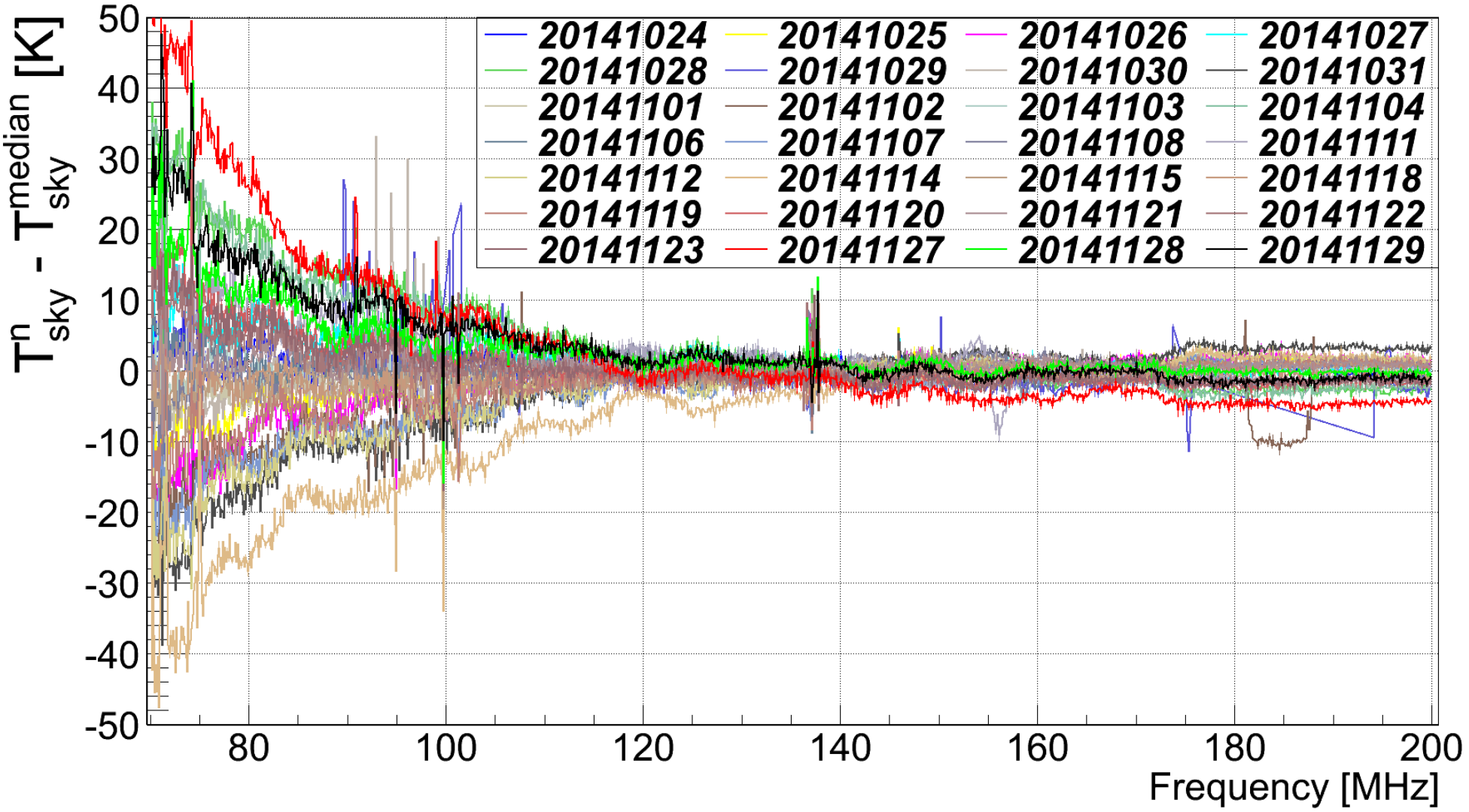
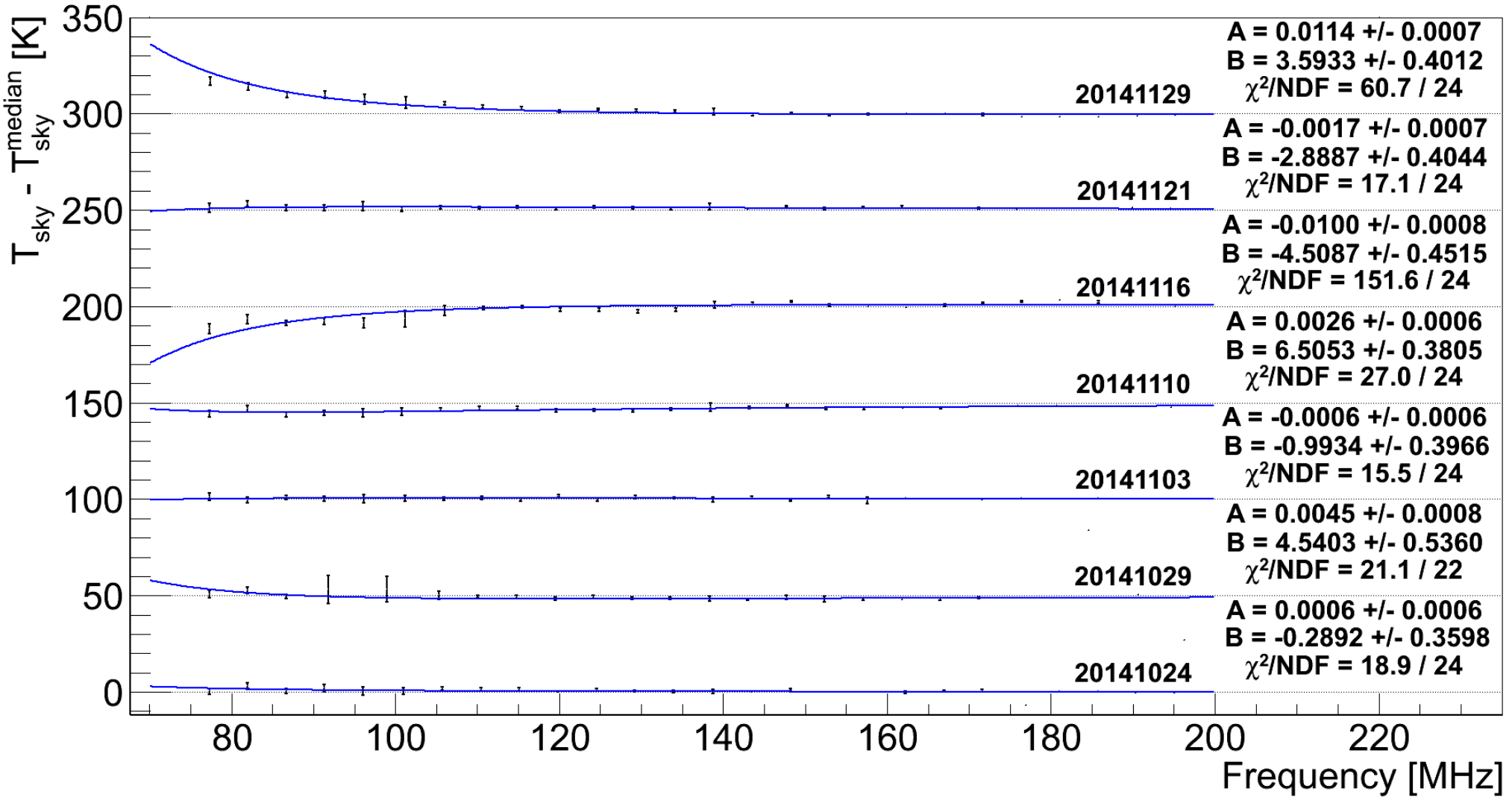
Differences between 1 hour LST spectra and median spectrum calculated for data collected in Oct/Nov 2014 at LST range 0 – 1 hour



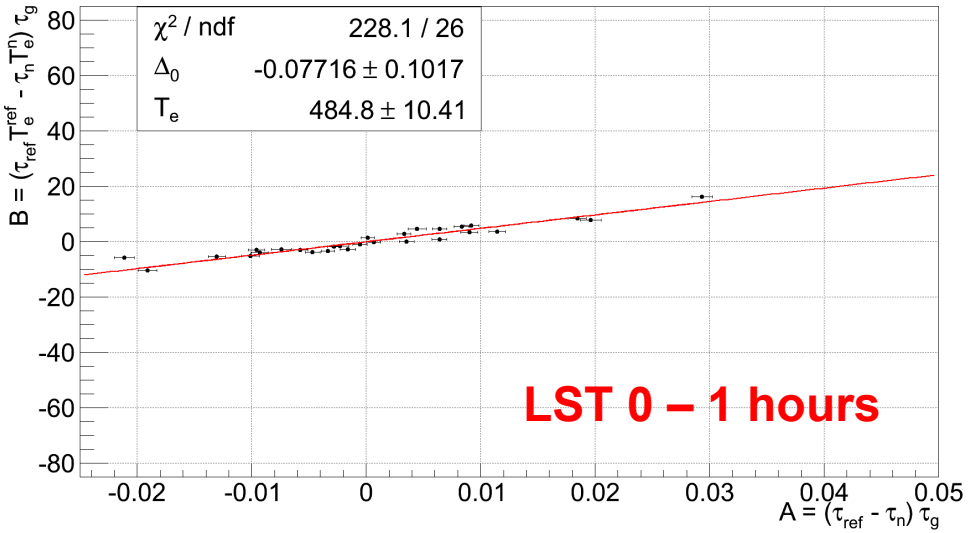
Fitting dependence expected for ionospheric absorption and thermal emission

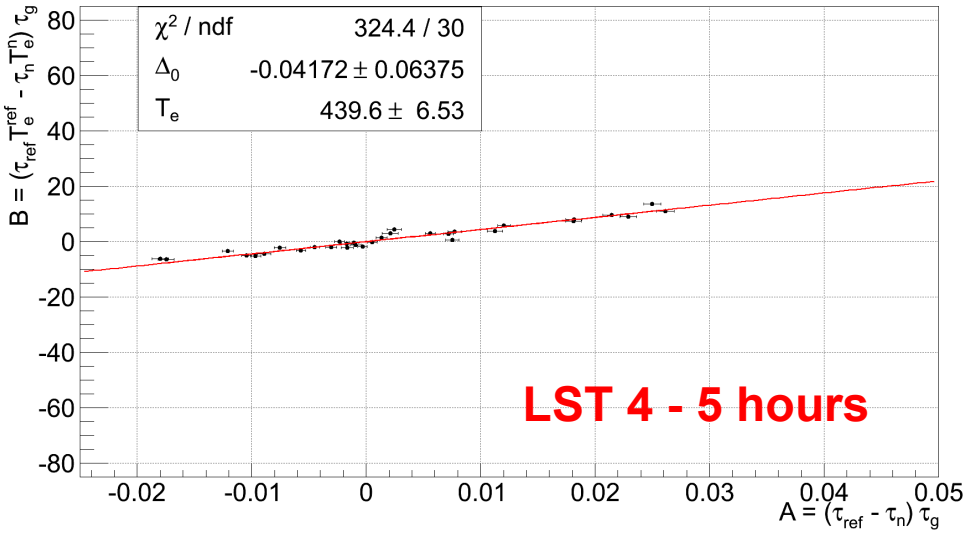
$$\sim A(100/\nu_{MHz})^2 + B\,(100/\nu_{MHz})^{2+2.6}$$

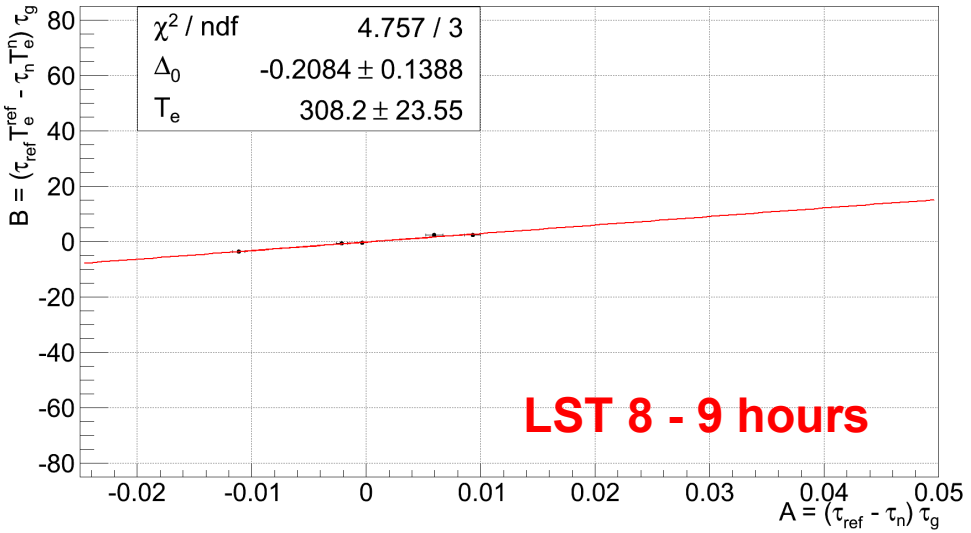
Emission term **Absorption/~~refraction~~ term**

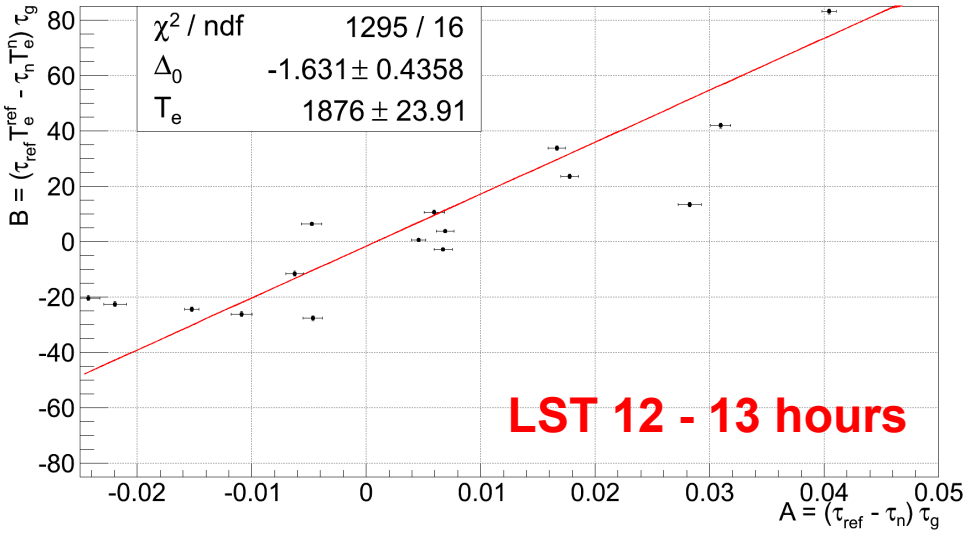


Correlation between fitted parameters A and B yields electron temperature at a given LST









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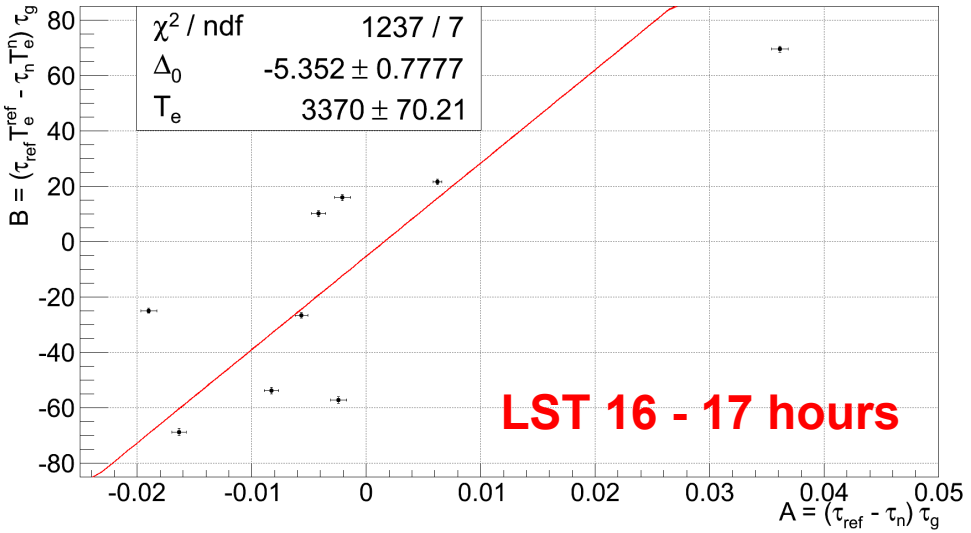
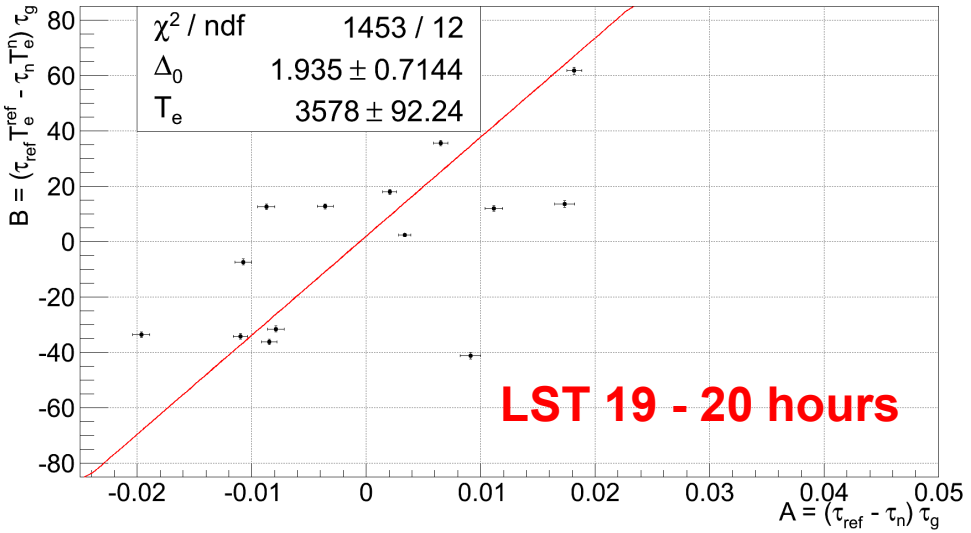
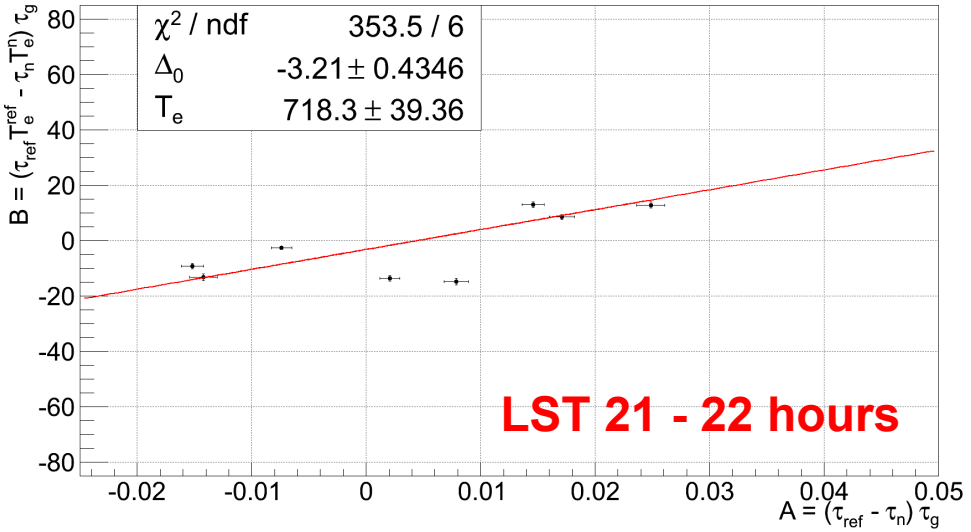
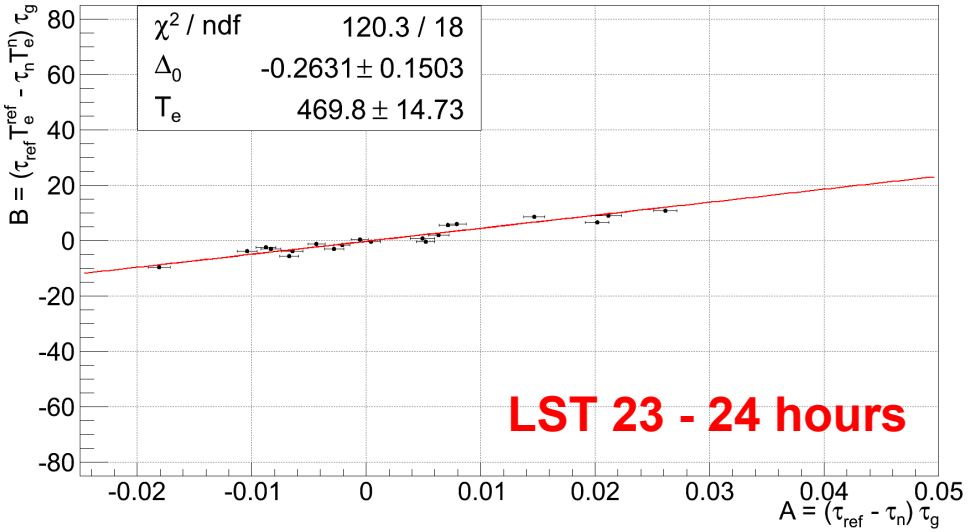
Correlation between fitted parameters A and B yields electron temperature at a given LST









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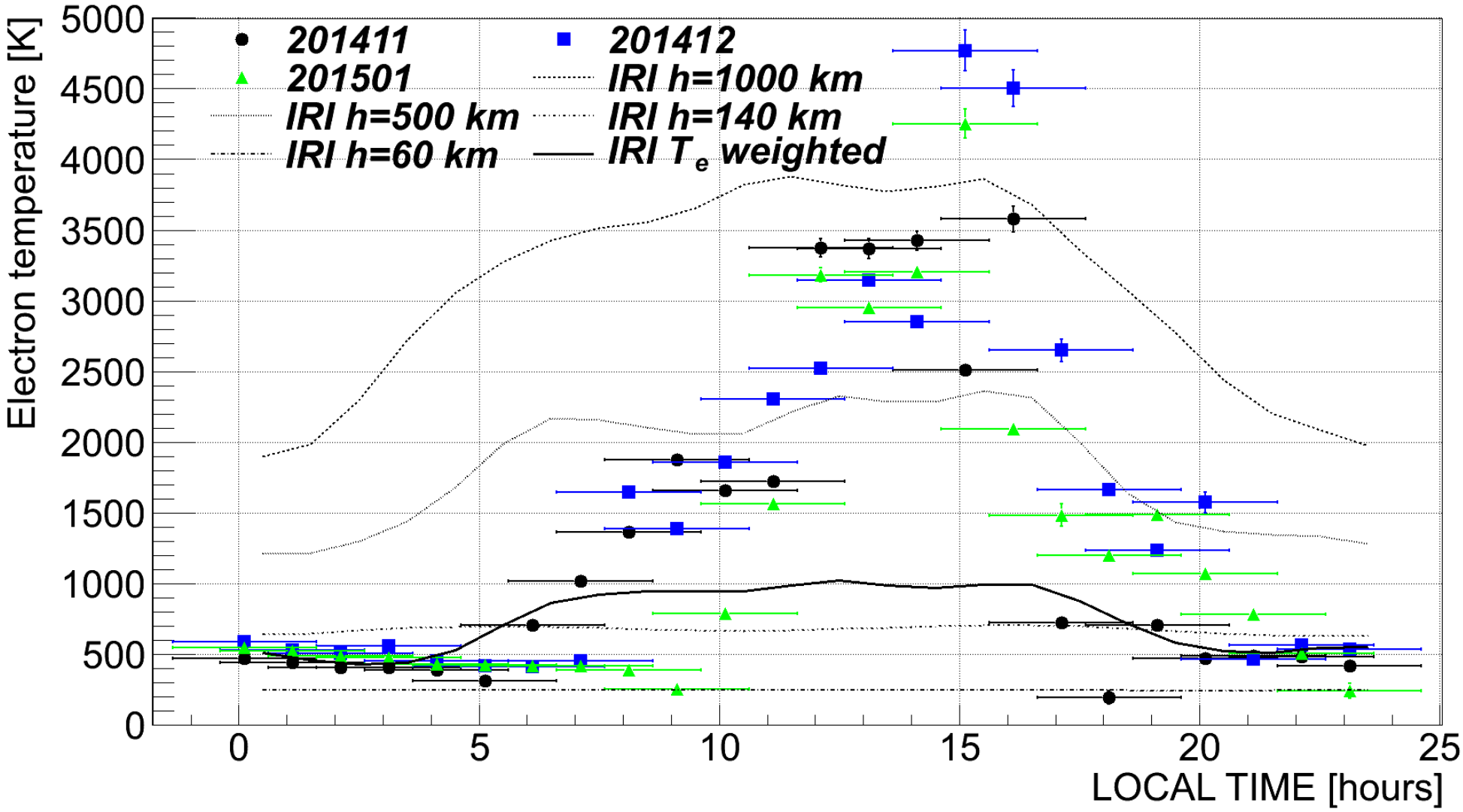
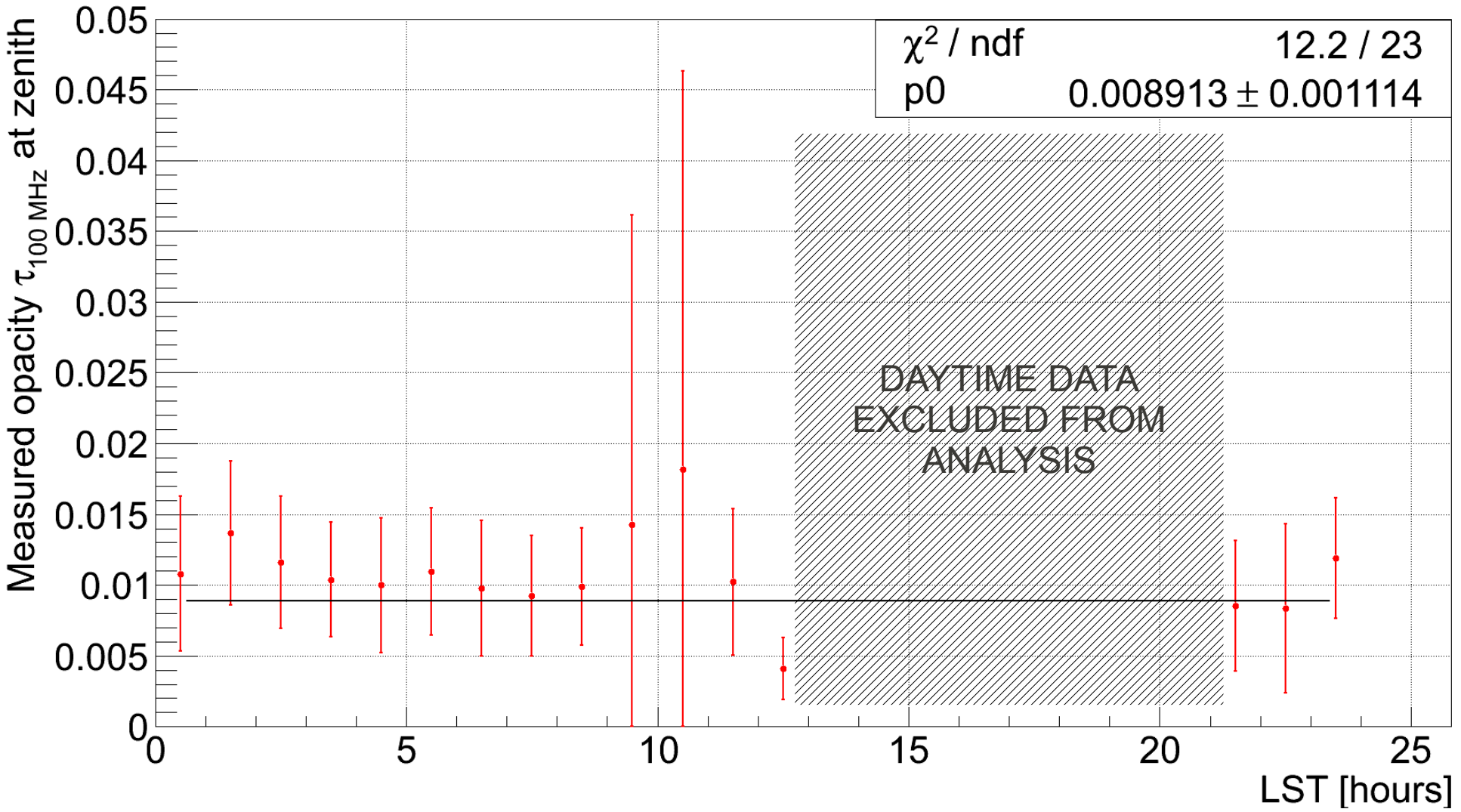
Electron temperature vs. local time



Absorption at 100 MHz measured with respect to quiet day curve (maximum curve) for every LST



Values larger than typically cited in literature, possibly because of:

- Quiet day curve (QDC) based on only 3 months of data
- Depends on time of the year, solar cycle etc.

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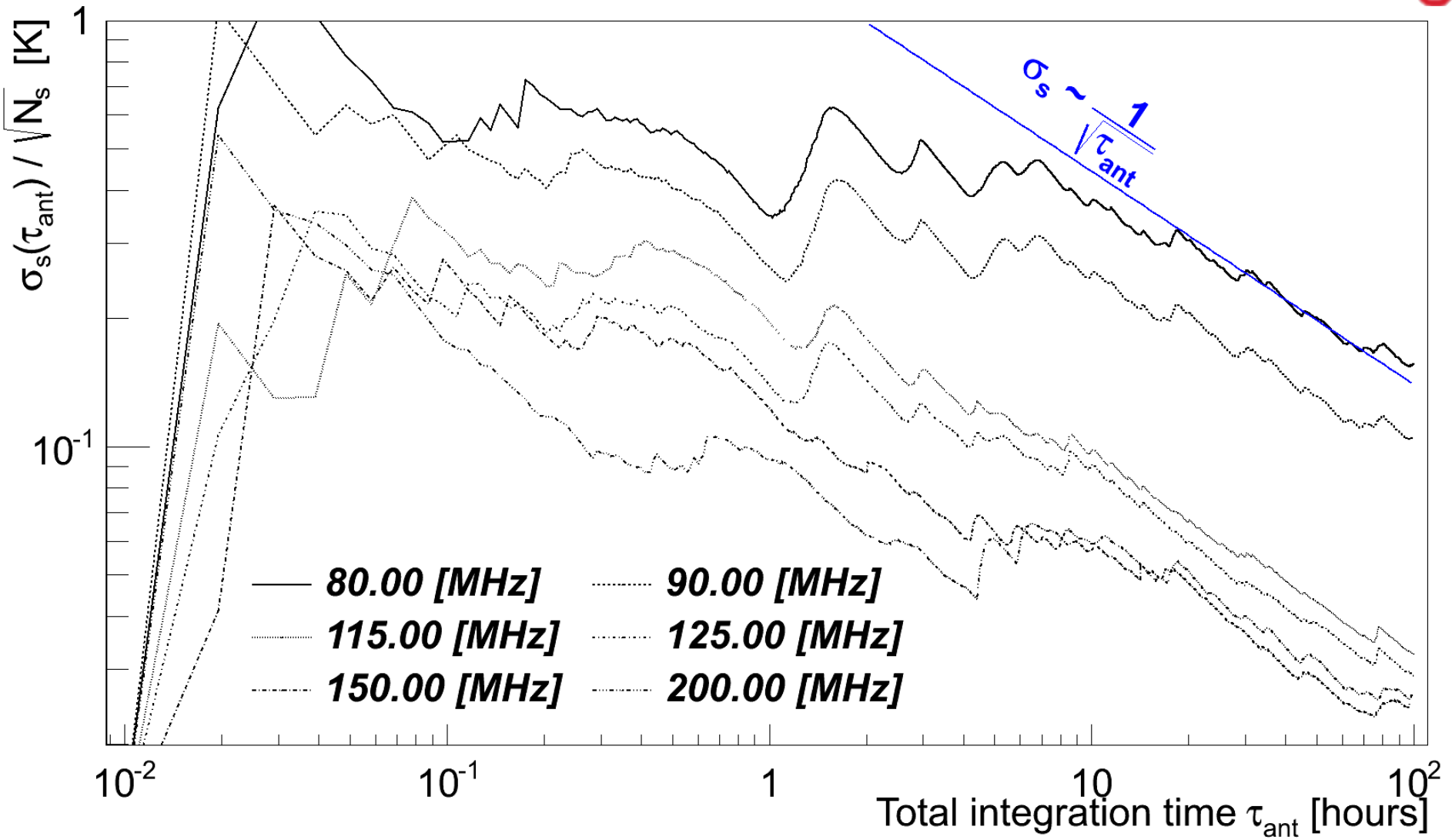
Can mK precision be obtained by ground-based instruments ?



Based on statistical test on 3 months of data, the standard deviation remains approximately constant with increasing number of sample integrations.

Therefore, the standard error of the mean should decrease as 1/sqrt(N)

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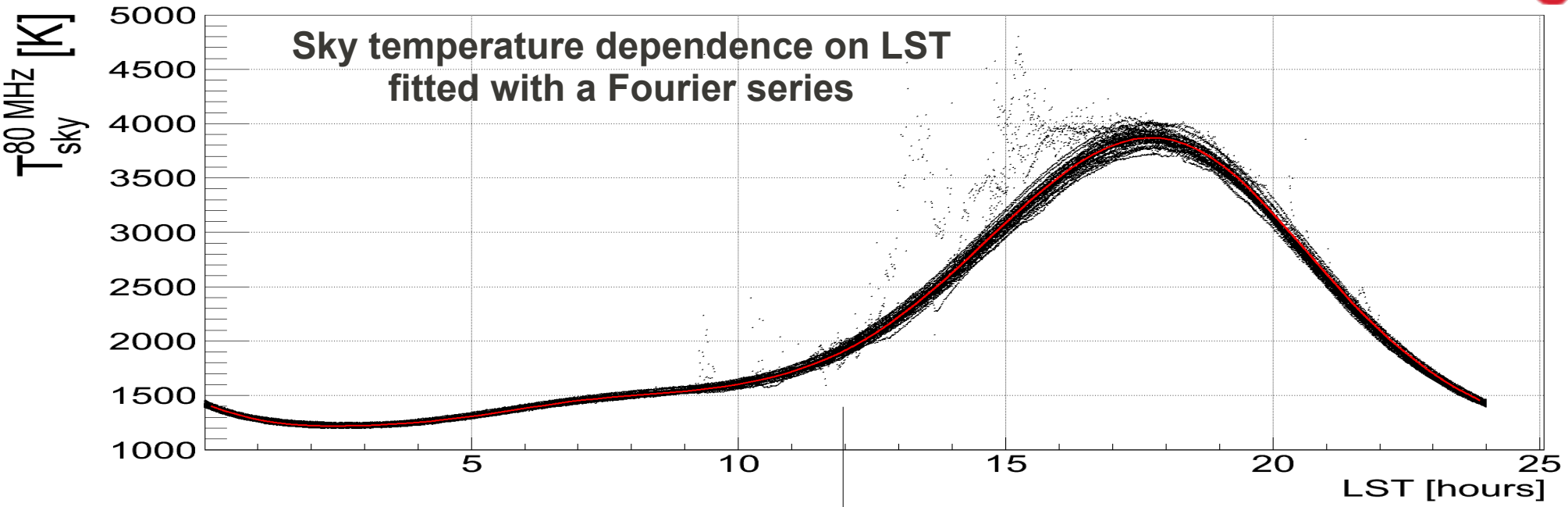
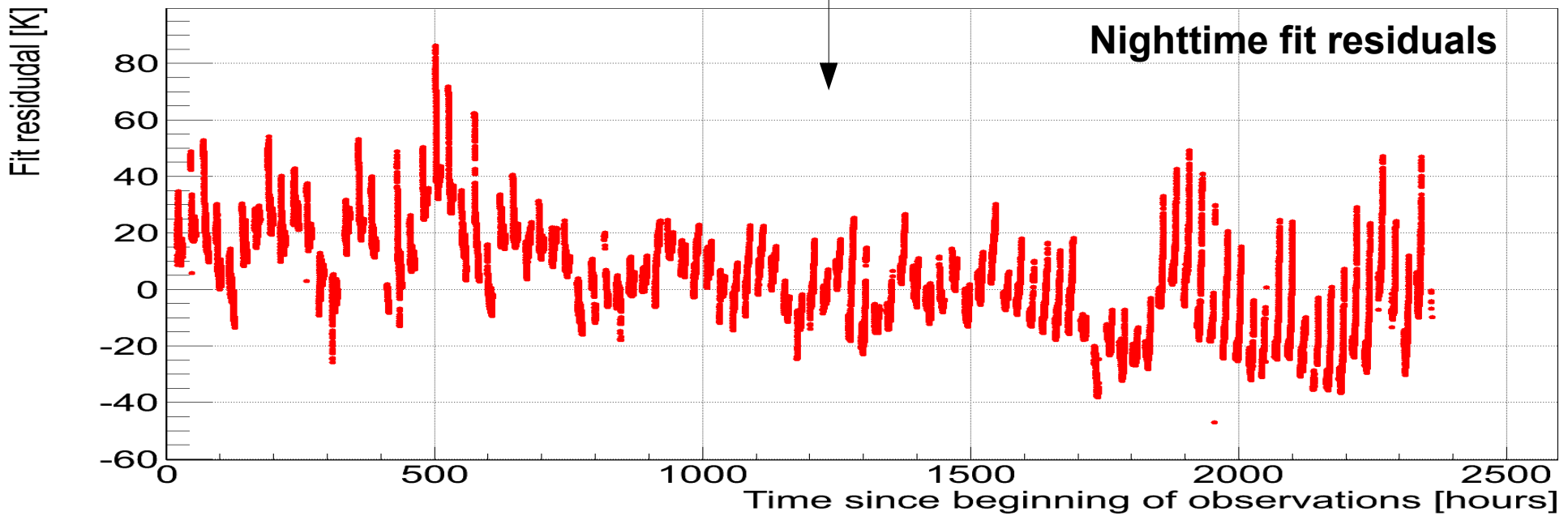
Fluctuations of sky temperature averaged in 80 – 85 MHz bin





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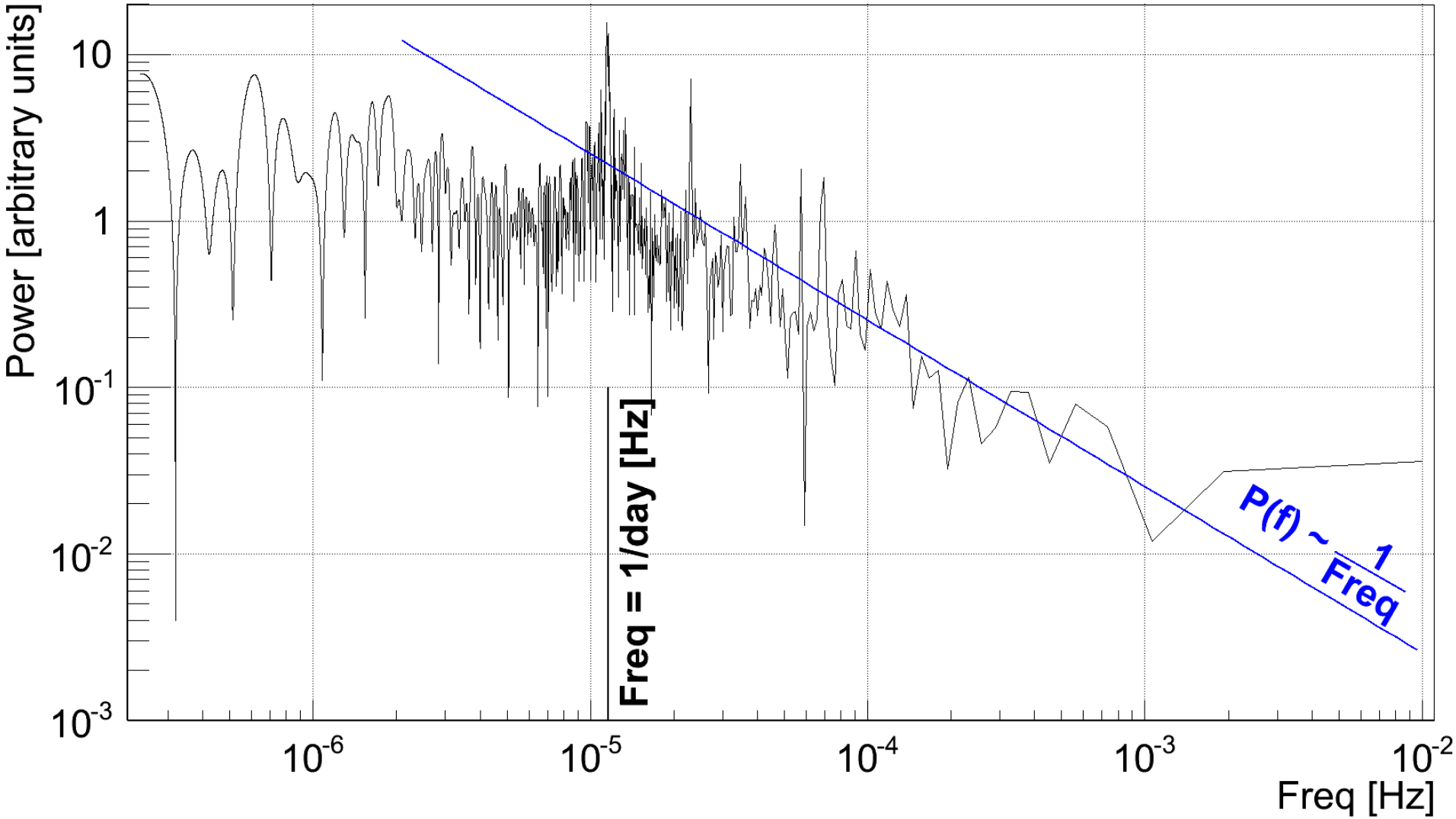
Power spectrum of the observed fluctuations



Flicker noise seems to flatten at frequencies below ~ 1 / day.
Therefore, miliKelvin precision should be possible for ground-based instruments !

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Summary

- BIGHORNS system with a conical log-spiral antenna was deployed at the MRO in October 2014 and collected about 12 months of data in 50ms resolution
- We used Oct 2014 – March 2015 data to study the impact of the ionosphere on the ground-based detection of the global Epoch of Reionisation
- Using BIGHORNS calibrated data we were able to measure some parameters of the ionosphere such as electron temperature and optical depth
- Ionospheric effects are ~2-3 orders of magnitude larger than the global EoR signal and particularly at nighttime are **dominated by absorption and emission**, whilst refraction seems to be a few times less significant
- Our analysis indicates that flicker noise characteristics of the stochastic fluctuations due to ionosphere **the mK precision can be obtained by ground-based instruments after very long integrations**
- The BIGHORNS system has collected a large amount of data which we used to study statistical properties of the RFI at the MRO (probability distributions of occupancy and power)

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Variations and tests of different system configurations

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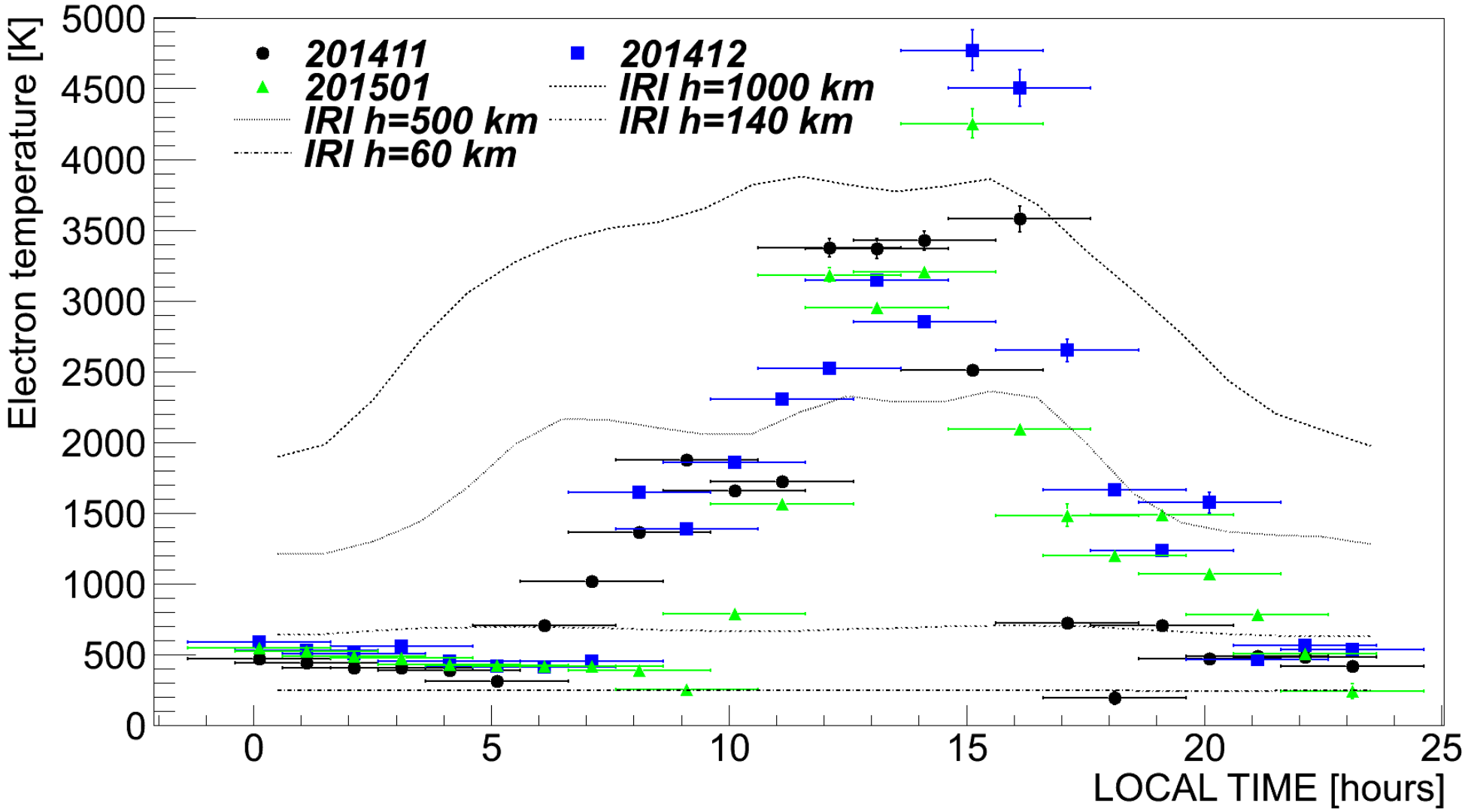
Electron temperature



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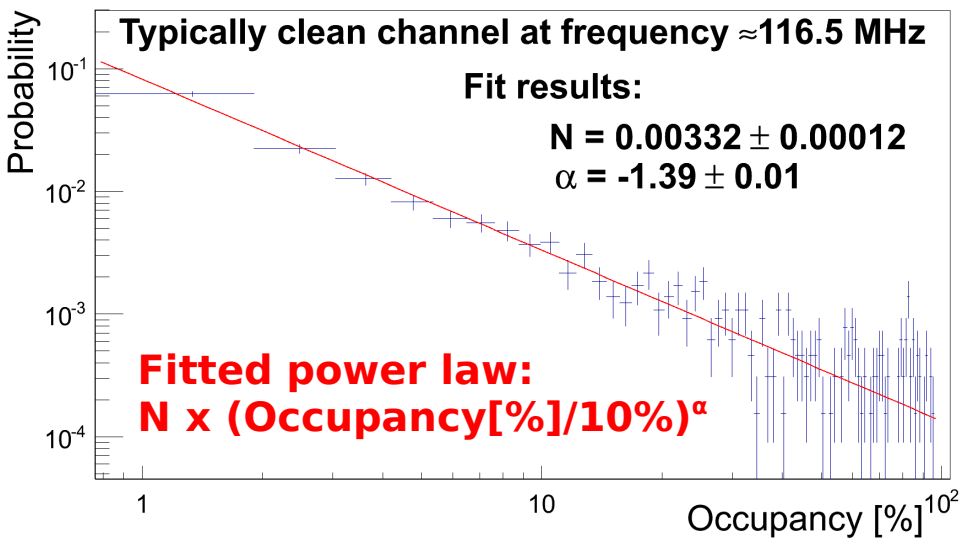
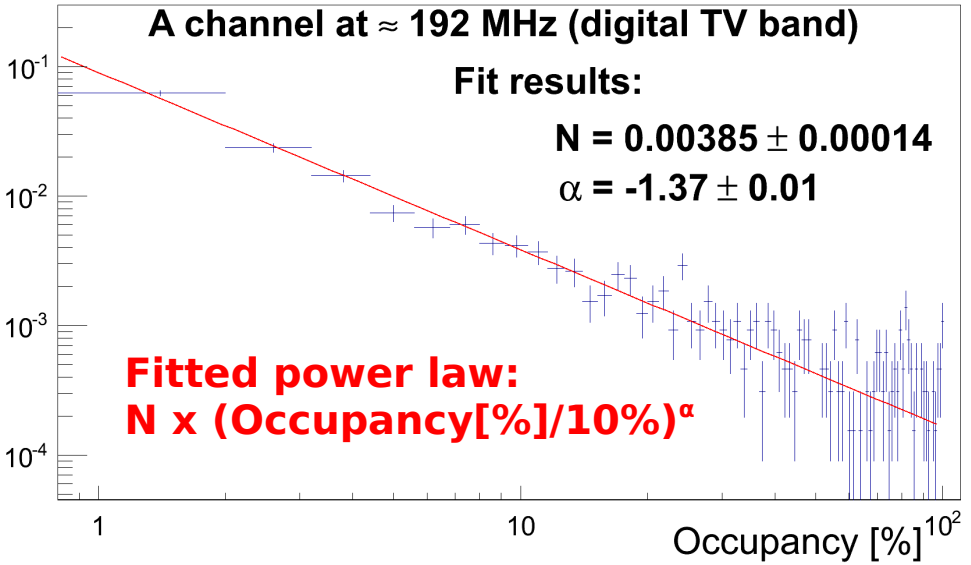
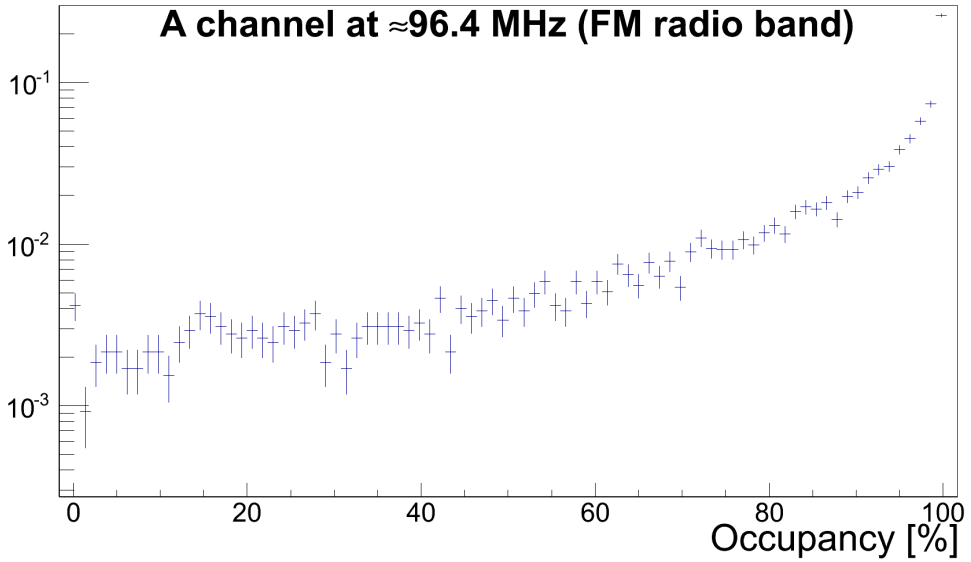
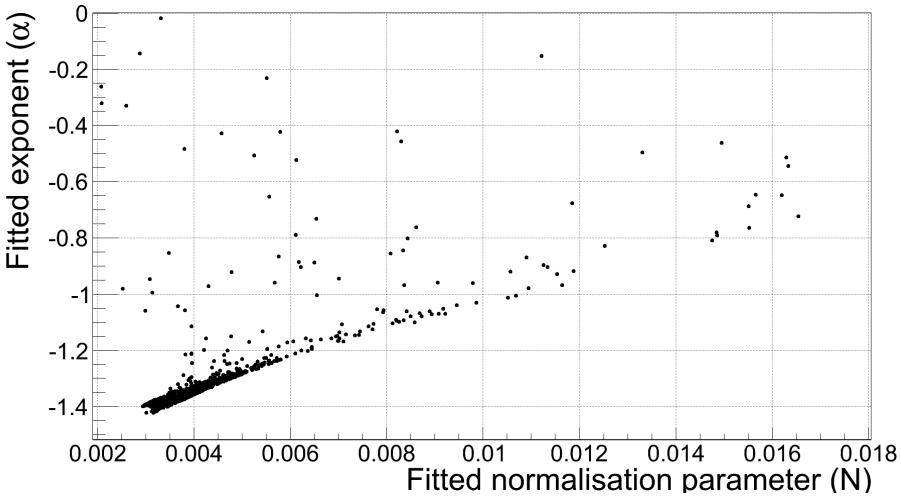
Occupancy distributions in representative channels









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Distributions of RFI power in individual frequency channels