# Introduction to Radioastronomy:

## Data Reduction and Analysis (I)

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http://astro.u-strasbg.fr/~koppen/JKHome.html

# The ESA-Dresden Telescope

- Frequency 10..12 GHz (wavelength 3 cm)
- Radiometer (Flux calibrator = Holiday Inn)
- 1.2 m diameter satellite TV antenna

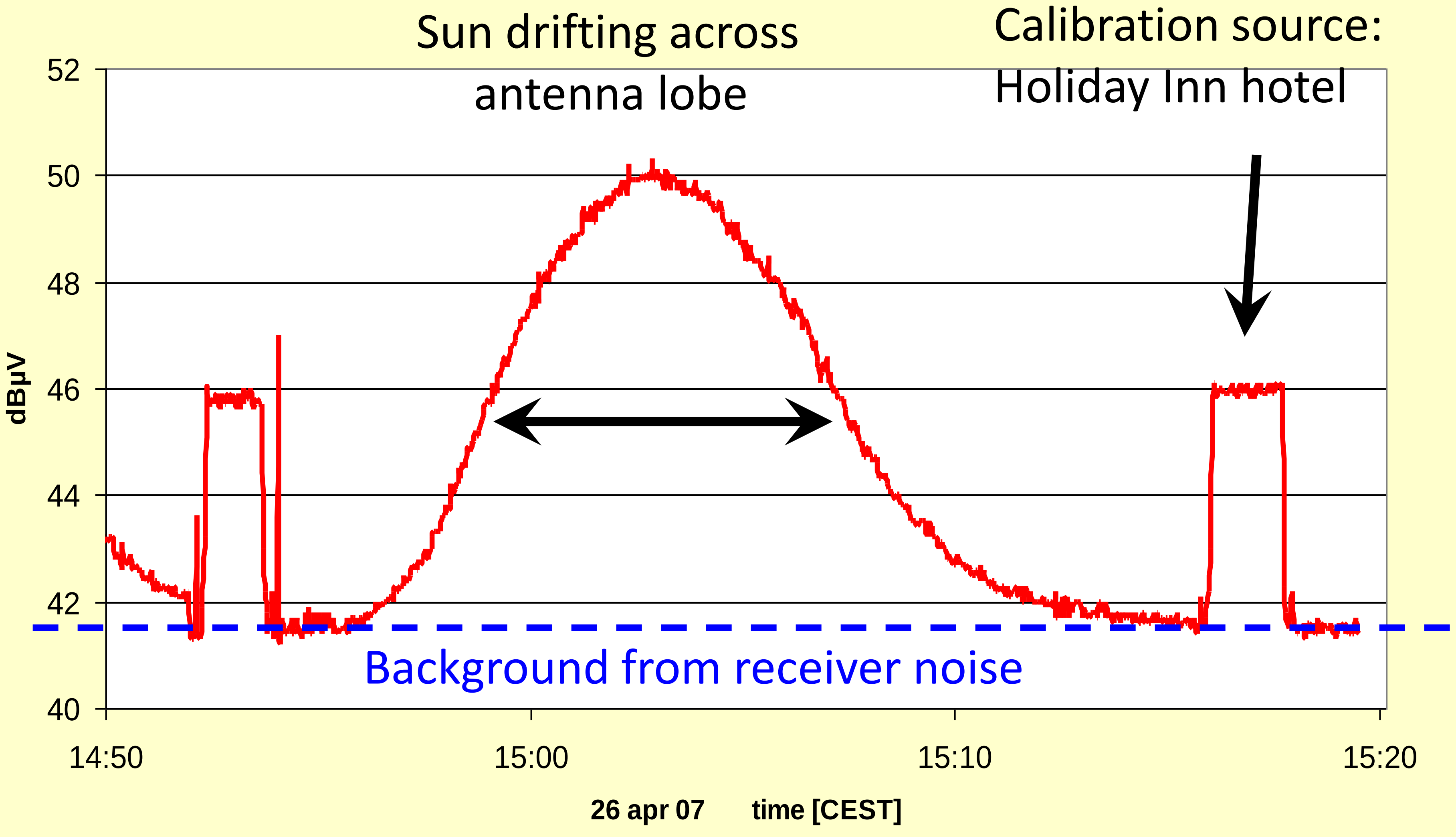
- Drift scan of the Sun or Moon

- http://astro.u-strasbg.fr/~koppen/10GHz/

# Determine surface temperatures of sun and moon

- Observe the passage of the sun through the antenna beam:
  - Maximum gives radio flux from the sun
  - The profile gives the width of antenna beam, needed to determine the beam filling factor
- Flux from calibrator source = source of known temperature = the ground (290 K)
- Observe empty sky = determine background noise (mainly from the front end (LNB) of the receiver system)

# An example: the raw data



# Sample data (text file)

UT1102081334mf_moon.txt - Bloc-notes

Fichier Edition Format Affichage ?

```
#Freq.= 12500 MHz, SAT-IF= 1900 MHz, High Band, Horizontal Polar.
#Start at: 08.02.2011 13:34:49 UT
#   average over 1 samples per position
#       time[UT]   AZ   EL   <signal power[dBuV]>
13:34:54 108.2 0 44.6
13:34:57 108.2 0 44.8
13:34:59 108.2 0 44.8
13:35:01 108.2 0 44.8
13:35:03 108.2 0 44.8
13:35:06 108.2 0 44.7
13:35:08 108.2 0 44.6
13:35:10 108.2 0 44.8
13:35:13 108.2 0 44.7
13:35:15 108.2 0 44.8
13:35:17 108.2 0 44.8
13:35:20 108.2 0 44.7
13:35:22 108.2 0 44.7
13:35:24 108.2 0 44.6
13:35:27 108.2 0 44.6
13:35:29 108.2 0 44.7
13:35:31 108.2 0 44.7
```

# How to turn dB into power

- dB = 10 * log10(Signal power/Reference power)
- N.B. always give reference level:
  - dBm for 1mW, dBW for 1W,
  - dBμV for 1μV (means: 1μV at our receiver's 75 Ω input)
  - Antenna gain: dBd for dipole, dBi for isotropic

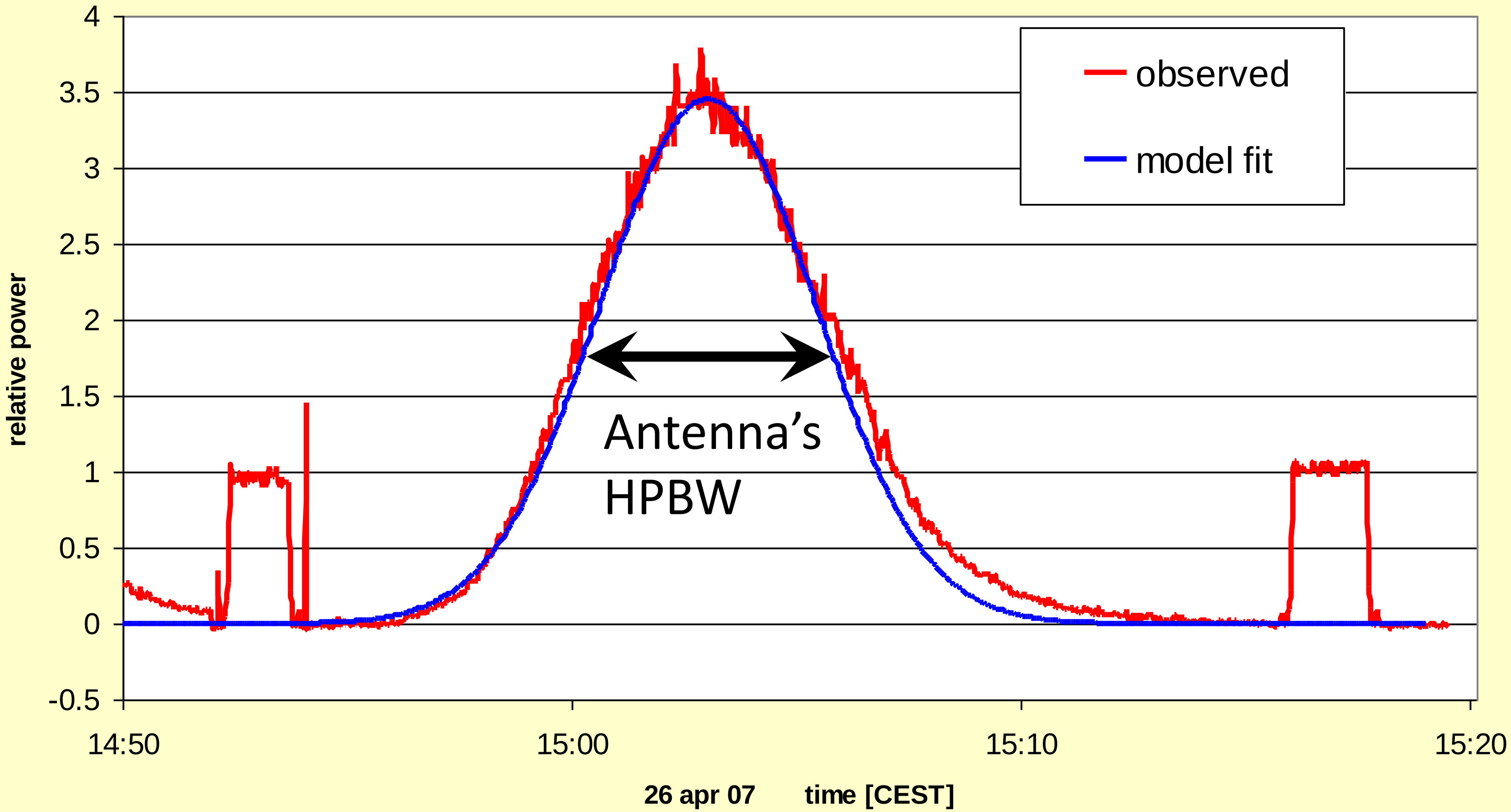
| 0 dB | +3 dB | +10 dB | -20 dB | +40 dB |
|---|---|---|---|---|
| 1 | 2 | 10 | 0.01 | 10000 |

# Data reduction (MS-Excel, small program, …)

- Convert dB values into linear power values
- … Subtract the average background power from ALL signals (the background noise is from the receiving system and always present)…
- … divide by the calibration power:
- We get the relative signal power

$$RP = \frac{\mathbf{10^{\wedge}(dB\_signal/10) – 10^{\wedge}(dB\_backgrd/10)}}{\mathbf{10^{\wedge}(dB\_calibrator/10) – 10^{\wedge}(dB\_backgrd/10)}}$$

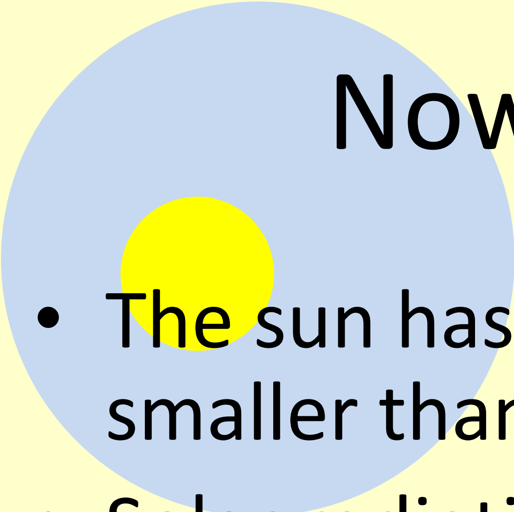
# From the reduced data …



# … we get this information

- The peak power from the sun is 3.5 times that of the calibrator
- ➔ the solar « antenna temperature » thus is 3.5 * 290 K

- The sun took about 7 minutes to cross the antenna beam (measured at half power)
- The rotation of the Earth takes the Sun across the sky in 360°/24 hrs = 1°/4 min
- ➔ the antenna's HPBW: about 7/4 = 1.7°



# Now the interpretation

- The sun has a diameter of 0.5°, thus much smaller than the antenna beam
- Solar radiation fills the antenna beam with only a fraction of $(0.5°/1.7°)^2 = 1/12$
- The calibrator of T=290 K fills the entire beam, so if one wants to get a solar signal of 3.5 times the calibrator, the solar surface temperature must be 12 times higher than the antenna temperature:

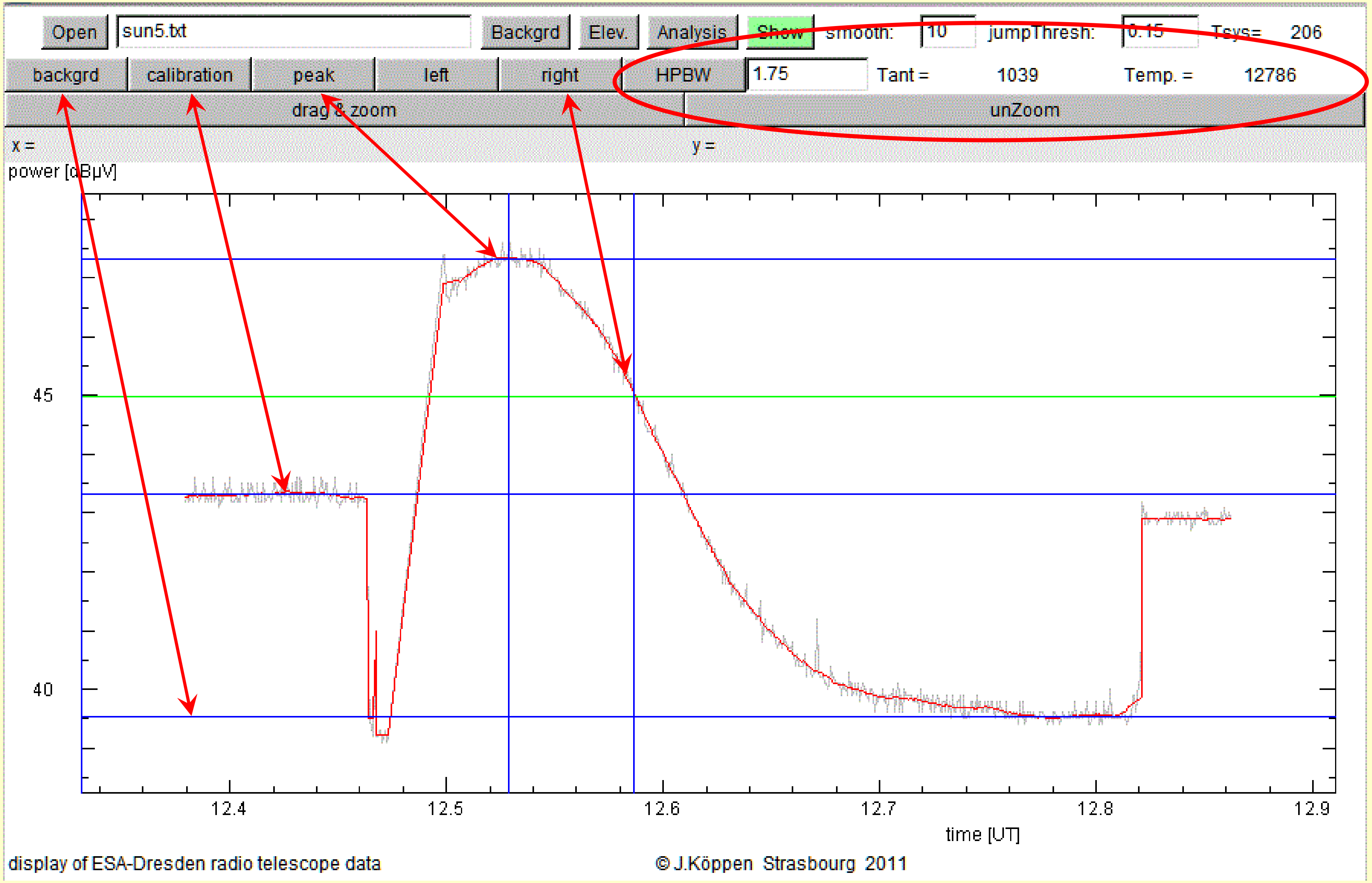
# The temperature of the solar surface is:

$$290\ \mathrm{K} * 3.5 * 12 = 12000\ \mathrm{K}$$

Ground calibration

Measured: peak and width

# With DresdenViewer.java



# That's fine, but …

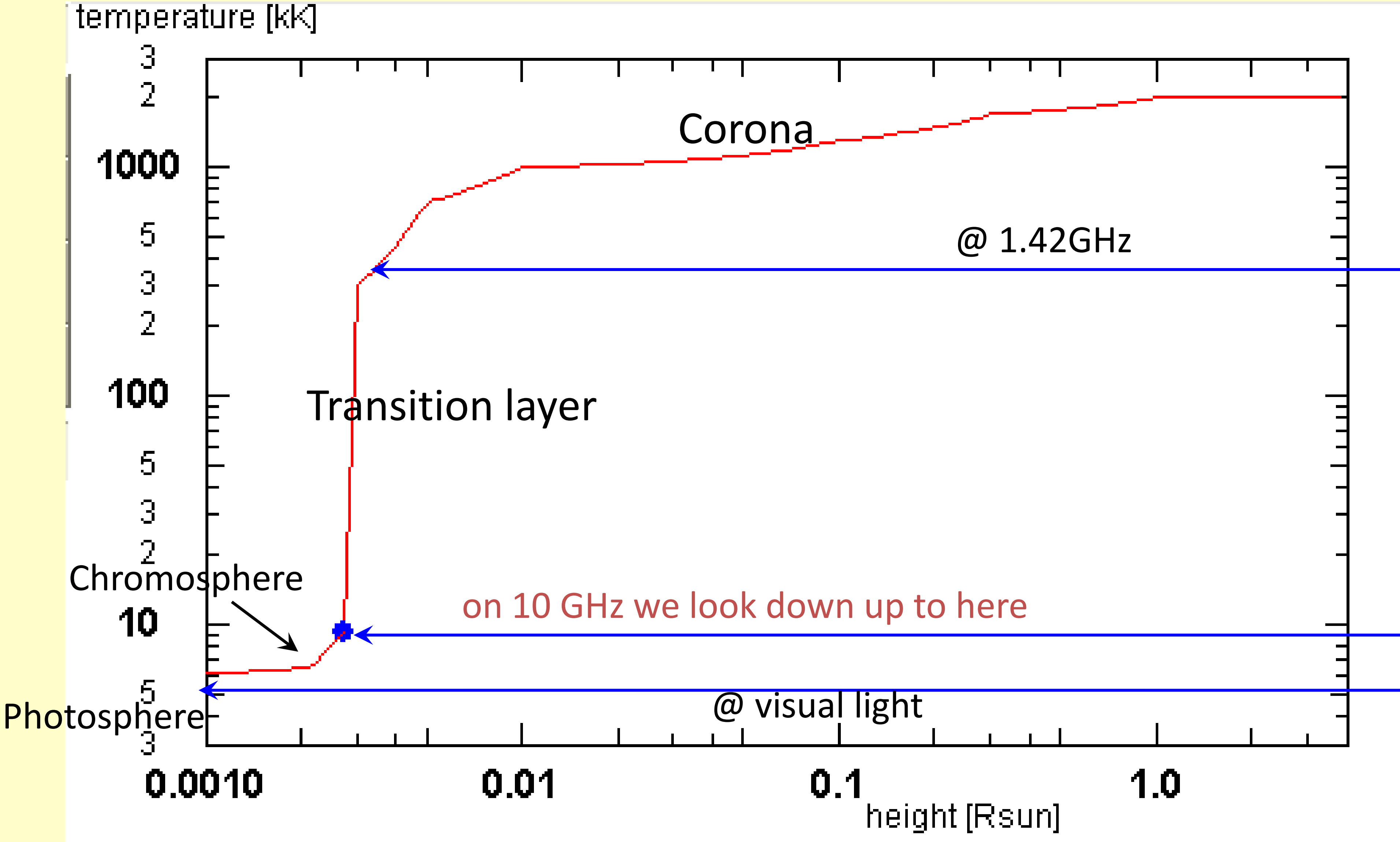
- The calibration before and after the observation is different! What would be if it had changed linearly between these times?
- also: the sky background may change …

- … hence, a quick, standard-type data reduction may not be sufficient!

# But that’s NOT the photosphere

- The outer layers of the sun (corona and chromosphere) are not fully transparent to radio waves at 10 GHz
- At that frequency we can look only down into the Transition Layer, which is between corona and chromosphere. Here, the temperature rises steeply from the 5000 K above the photosphere to the millions K in the corona.

# The atmosphere of the Sun:



# Some finer points

- Depending on their declination $\delta$ (the distance from the celestial equator) the sun and the moon move across the sky with a speed of $0.25°/\min * \cos\delta$
- Their angular diameters are not constant (can be obtained from software)
- These numbers you get from

  http://astro.u-strasbg.fr/~koppen/orrery/

- The antenna pattern may not be circular, that is the HPBW may vary with the direction how the sun moves across the beam. Only at lunchtime it travels horizontally

# http://astro.u-strasbg.fr/~koppen/orrery/

--- Sun ---

| | |
|---|---|
| Rising time | 3h 36m 9s UTC |
| Setting time | 19h 19m 49s UTC |
| Right Ascension | 4h 50m 13s |
| Declination | 22° 28' 9" = 22.4691° |
| Magnitude | -26.7 |
| angular diameter | 31.4 ' = 0.524° |
| Azimut | 59° 14' 24" = 59.2399° |
| Elevation | 3° 23' 51" = 3.3976° |
| Direction of movement in the sky | 38.004 ° |
| Horizontal movement | 0.183 °/min |
| Movement in Elevation | 0.143 °/min |

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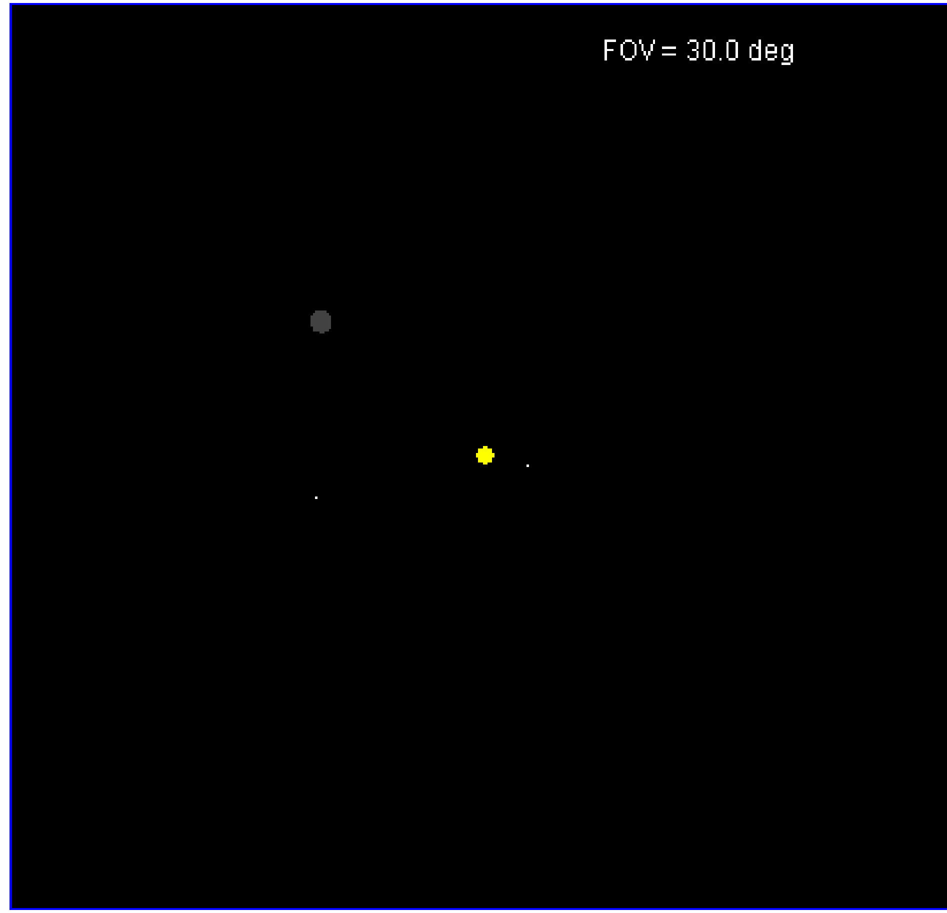
Configuration | Celestial bodies | Utilities




now: Wednesday 04/06/2008 04h00 UTC JD: 2454621.6667

Backward | Forward | 1 | Day(s)

^ | Zoom +

Initial | <- | Centre | -> | Zoom -

V

Track the body | Show data of the body

# Measured antenna pattern (contour spacing: 1dB)