Calibration of solar images at high radio frequencies through Cassiopeia A Supernova Remnant

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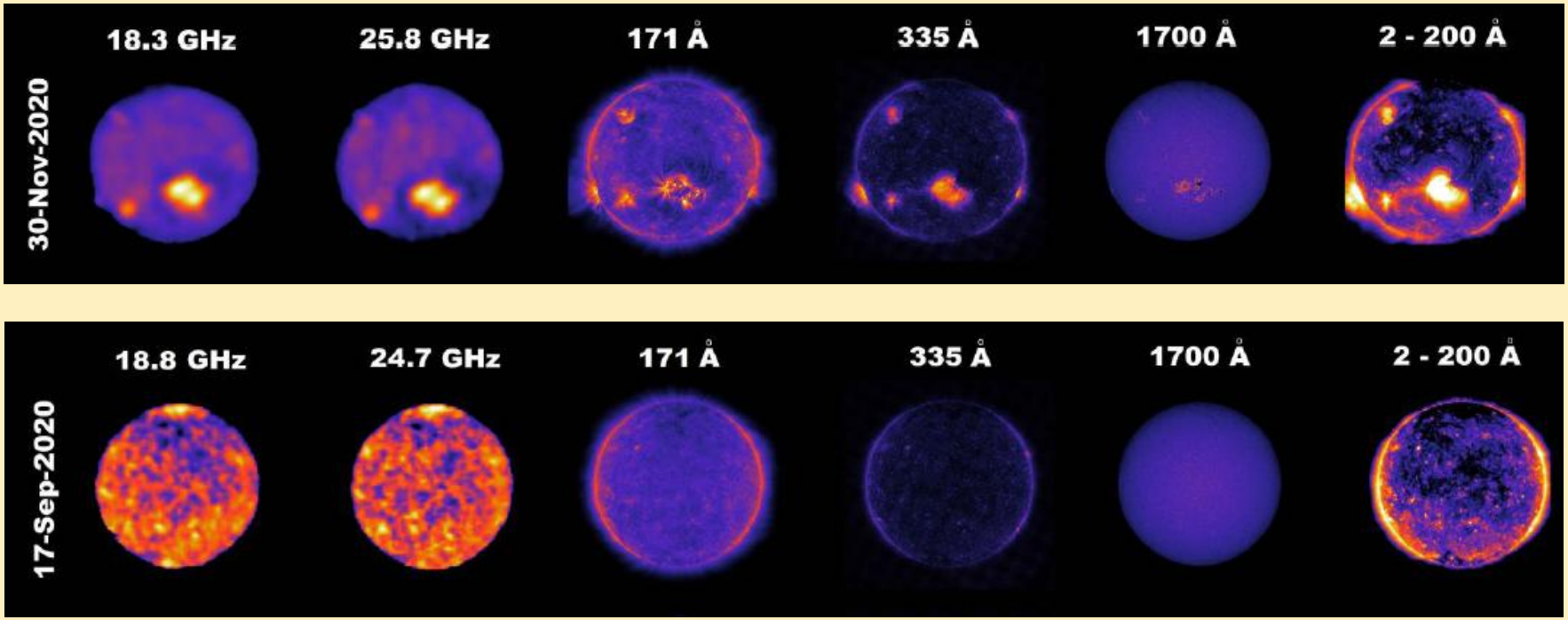
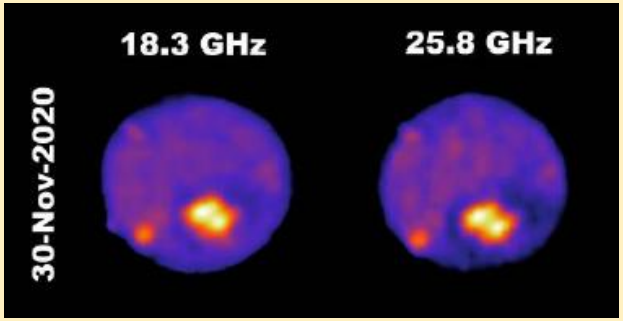
The SUNDISH Project

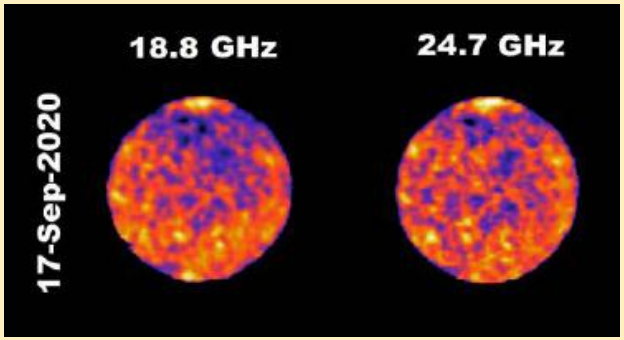


Monitor and produce single dish radio imaging of the solar atmosphere at high radio frequencies, for now K band (18-26 GHz)

The SUNDISH Project



Medicina Radio Telescope

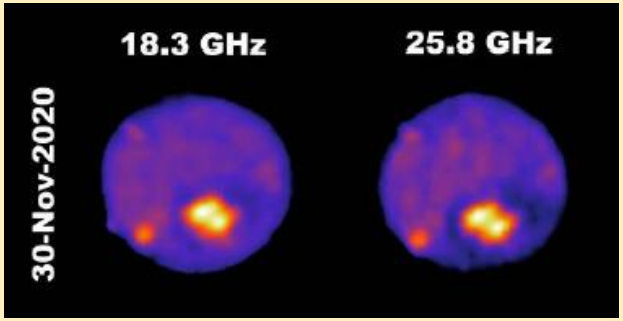


Sardinia Radio Telescope (SRT)

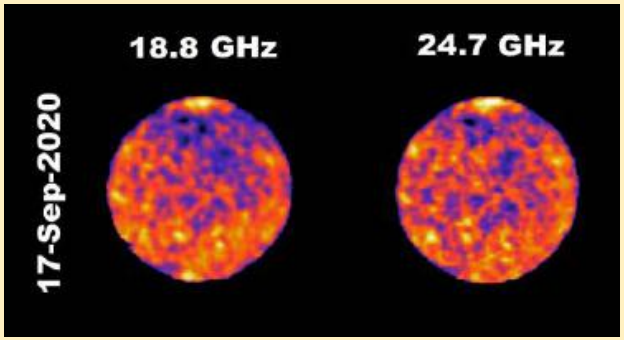
INAF Radiotelescopes

Dr Marco Marongiu's presentation for more details on the SUNDISH project (session 5.6, poster 794) or visit our website *https://sites.google.com/inaf.it/sundish*

The SUNDISH Project



Medicina Radio Telescope



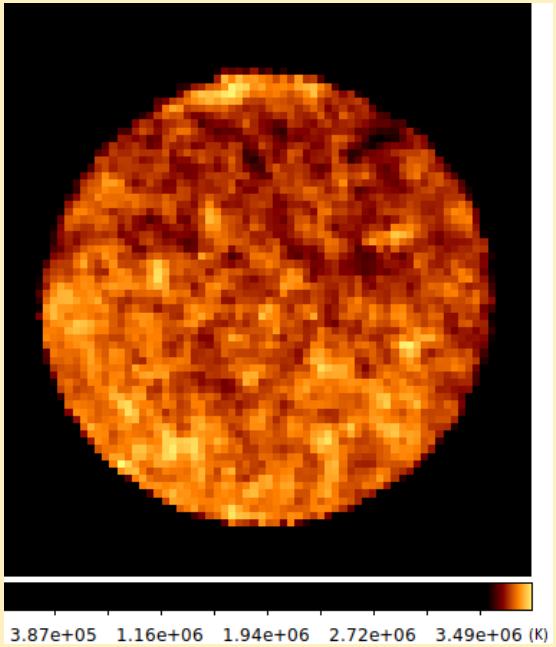
Sardinia Radio Telescope (SRT)

INAF Radiotelescopes

Is the Supernova Remant (SNR) Cassiopeia A a reliable calibrator for the radio Sun?

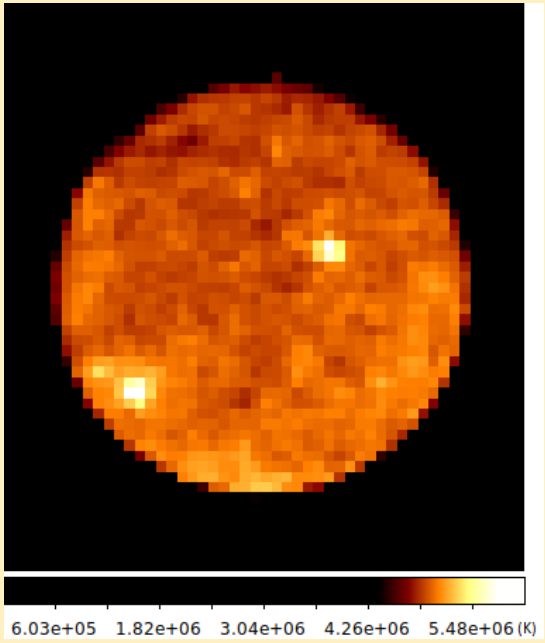
Radio solar emission components

Background stable emission: the **Quiet Sun**



Sardinia Radio Telescope (SRT); 09/10/2019; v:24.7GHz; ris:0.5 arcmin

Slowly varying component mostly associated with the **Active Regions**



Sardinia Radio Telescope (SRT); 28/01/2020; v:18.8 GHz; ris:0.8 arcmin

Occasional extreme and sudden energetic phenomena like **Flares**

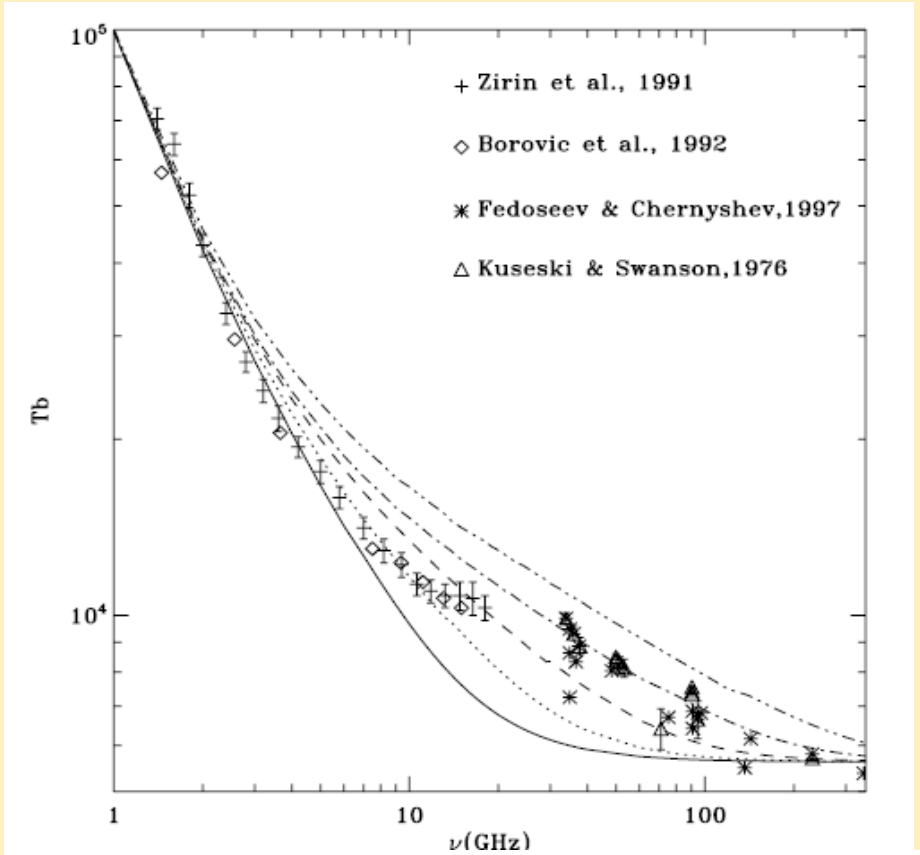
Solar Dynamics Observatory (**SDO**); 07/06/2011; extreme ultraviolet light

Radio Quiet Sun (QS)

Thermal bremsstrahlung in local thermodynamic equilibrium

Easier to study compared to other frequencies

Through the QS calibration we can calibrate the entire Sun



Quiet Sun Values extrapolated from different works

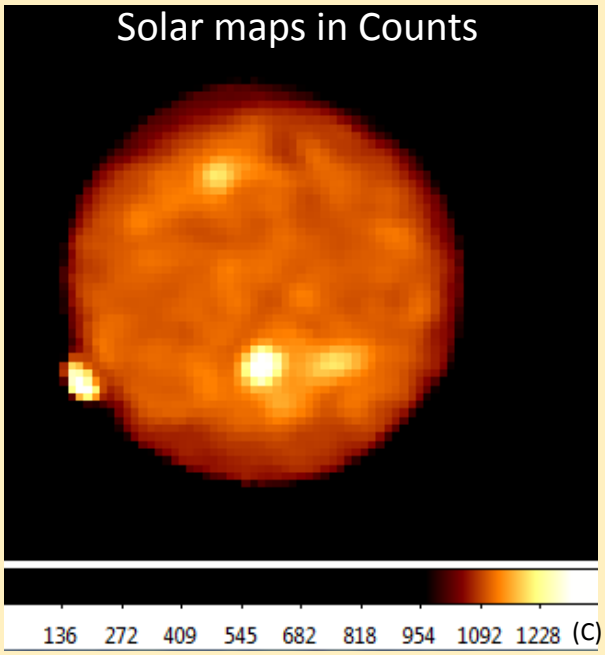
E. Landi, F. Chiuderi Drago 2008

Calibration procedure: C-T conversion factor

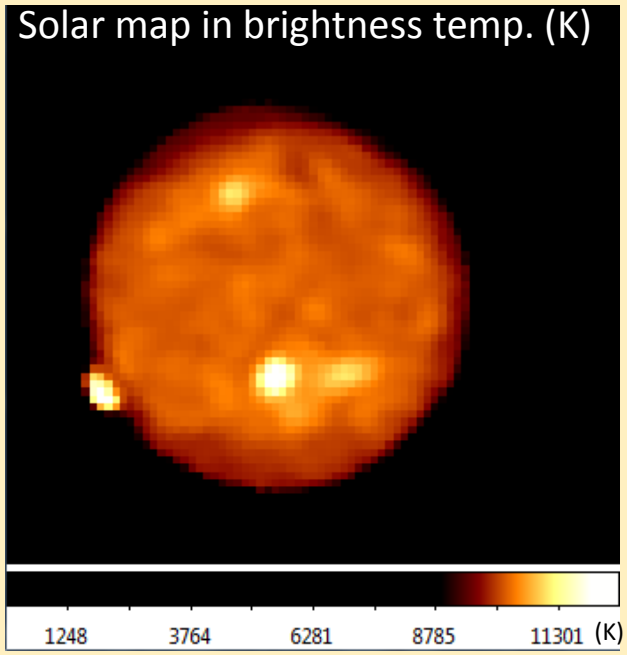
Maps expressed in counts do not have a physical meaning (counts ∝ source flux within the instrument beam and Brightness Temperature)

Counts value change each observing session

Find a count-to-kelvin conversion factor for each observing session

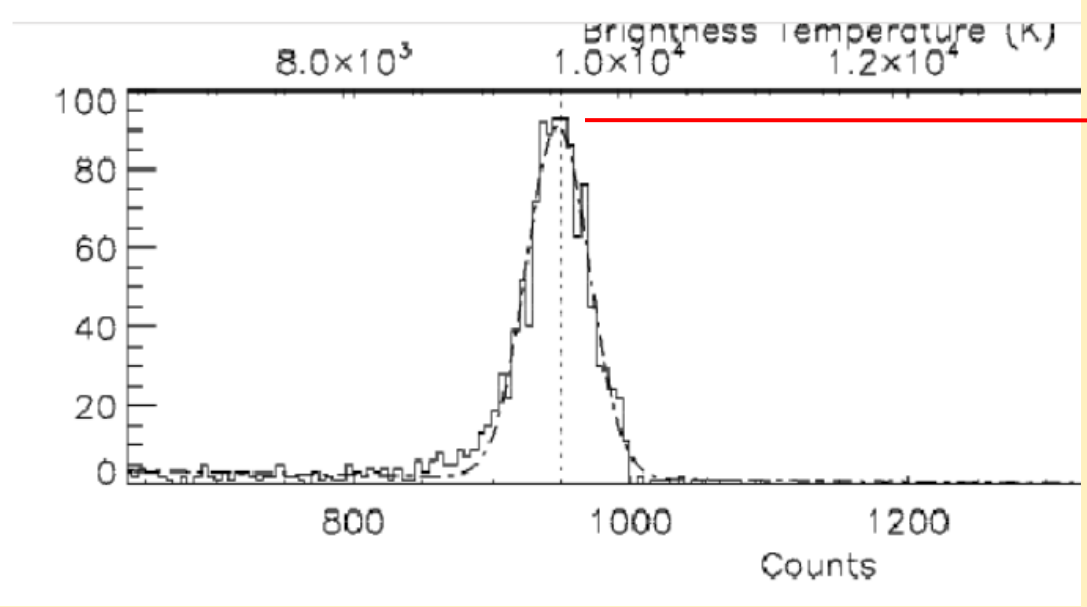


Count-to-kelvin conversion factor



Calibration procedure: Gaussian fit

Gaussian fit of the image histogram (counts distribution among pixels)

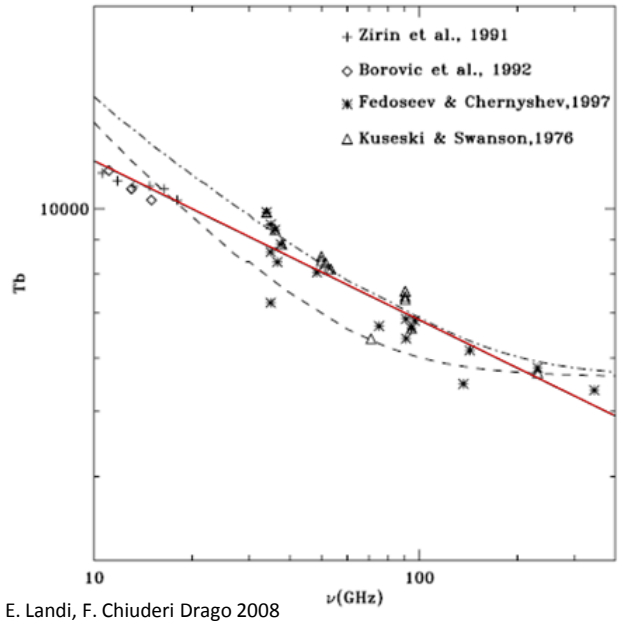


Peak counts

Accurate estimation of the average counts from the QS

Find brightness temperature associated to the peak count value

Calibration procedure: Self calibration



E. Landi, F. Chiuderi Drago 2008

Linear fit (on a logarithmic scale) of the radio brightness temperature at frequencies ν≥10 GHz (solid red line)

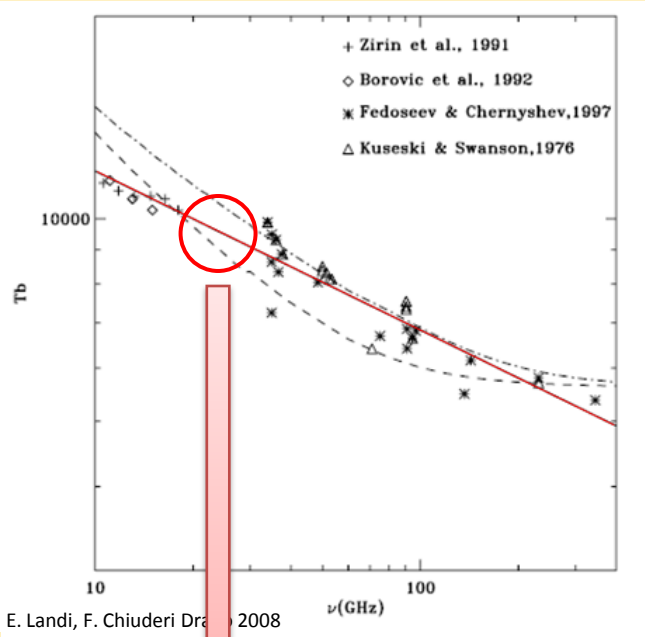
Self calibration

Extrapolate QS temperature from E. Landi, F. Chiuderi Drago (2008) fit

$$\log T_b = a + b \log \nu$$

T_b brightness temperature (K), a=6.43, b=-0.236,
ν frequency (Hz)

Calibration procedure: Self calibration



E. Landi, F. Chiuderi Dra[illegible] 2008

Linear fit (on [illegible] logarithmic scale) of the radio brightness tem[illegible]rature at frequencies ν≥10 GHz (solid red line)

Lack of measurements in K band

Self calibration

Extrapolate QS temperature from E. Landi, F. Chiuderi Drago (2008) fit

$$\log T_b = a + b \log \nu$$

T_b brightness temperature (K), a=6.43, b=-0.236,
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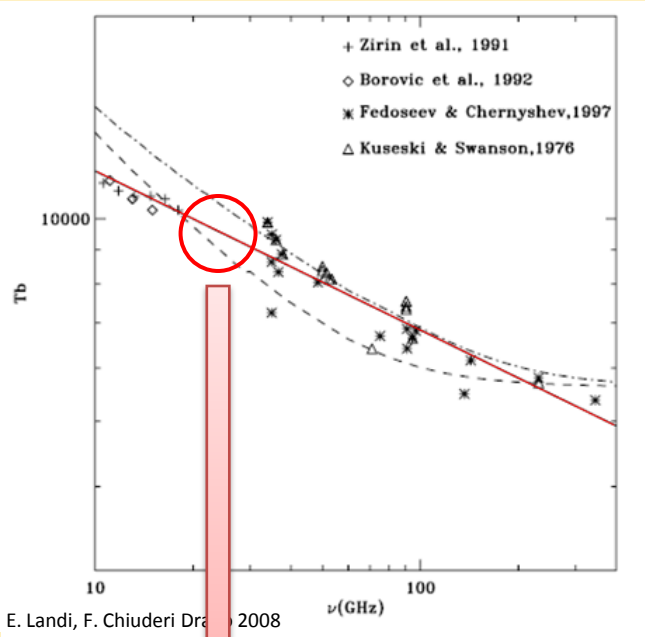
Calibration procedure: Absolute Calibration



E. Landi, F. Chiuderi Dra[illegible] 2008

Linear fit (on [illegible] logarithmic scale) of the radio brightness tem[illegible]rature at frequencies ν≥10 GHz (solid red line)

Lack of measurements in K band

External source → **Absolute calibration**

Self calibration

Extrapolate QS temperature from E. Landi, F. Chiuderi Drago (2008) fit

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T_b brightness temperature (K), a=6.43, b=-0.236,
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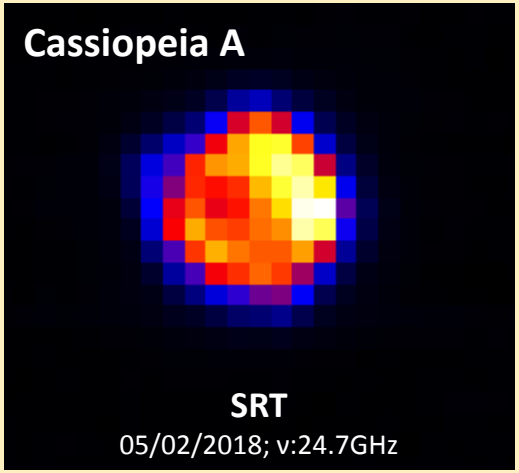


Cassiopeia A

Why using Cassiopeia A (CasA) and not a standard point like calibrator?

- **Very bright**, still small dimension and regular shape;
- well studied in literature;
- **circumpolar** at our latitudes;

Possible to observe both the Sun and the calibrator in the **same observing session** with the solar attenuations.

Young SNR in constant evolution

Secular variation of the radio flux density of CasA

$$d(\ln \nu) = a + b \ln \nu + c\, \nu^{-2.1},$$

where

$$a = -0.633 \pm 0.024\%\ \text{year}^{-1},$$

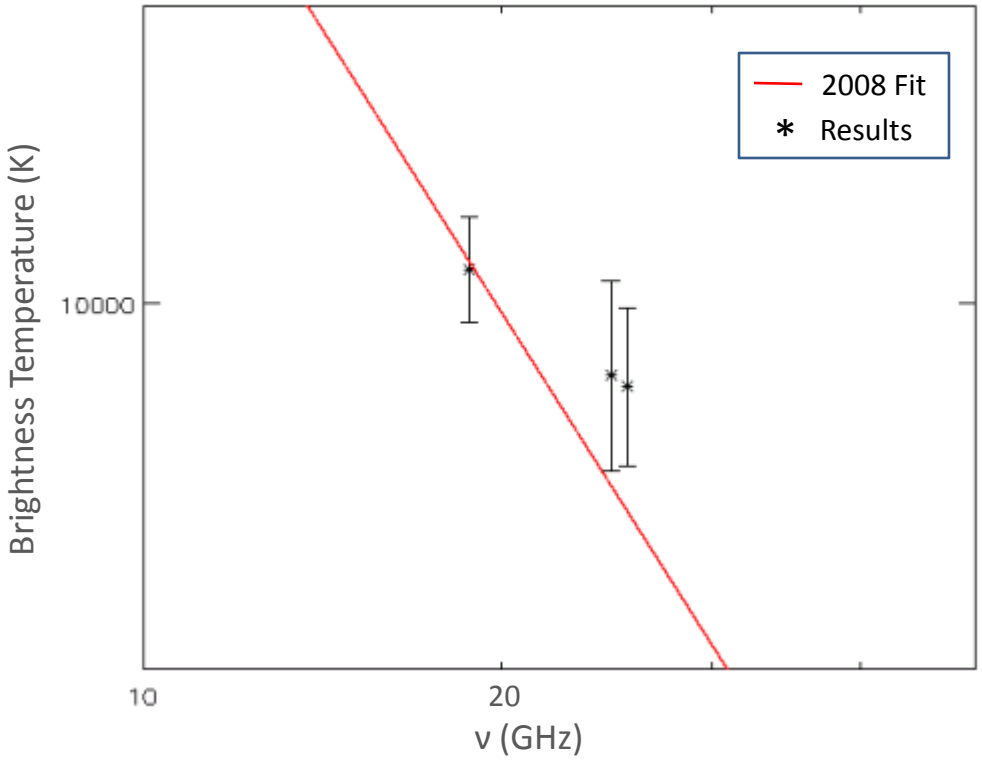
$$b = 0.039 \pm 0.008\%\ \text{year}^{-1},$$

$$c = (1.509 \pm 0.162) \times 10^{-5}\%\ \text{year}^{-1}.$$

E. N. Vinyaikin 2014

Preliminary results and future work

QS value from absolute calibration



ν_{obs} [GHz]	$Cas\ A_f$ [Jy]	T_{QS} [K]	Fit_{dev} [%]
18.8	247.9 ± 5.7 (Oct–2020)	10099 ± 154	0.24
24.7	205.3 ± 4.8 (Oct–2019)	9799 ± 268	3.24
25.5	201.1 ± 4.7 (May–2019)	9764 ± 223	3.65

Accordance with the fit at 1-2 σ

Main error sources:

- CasA flux estimation
- Opacity

Mean relative error value: 3%

Maximum fit deviation: 3.7%

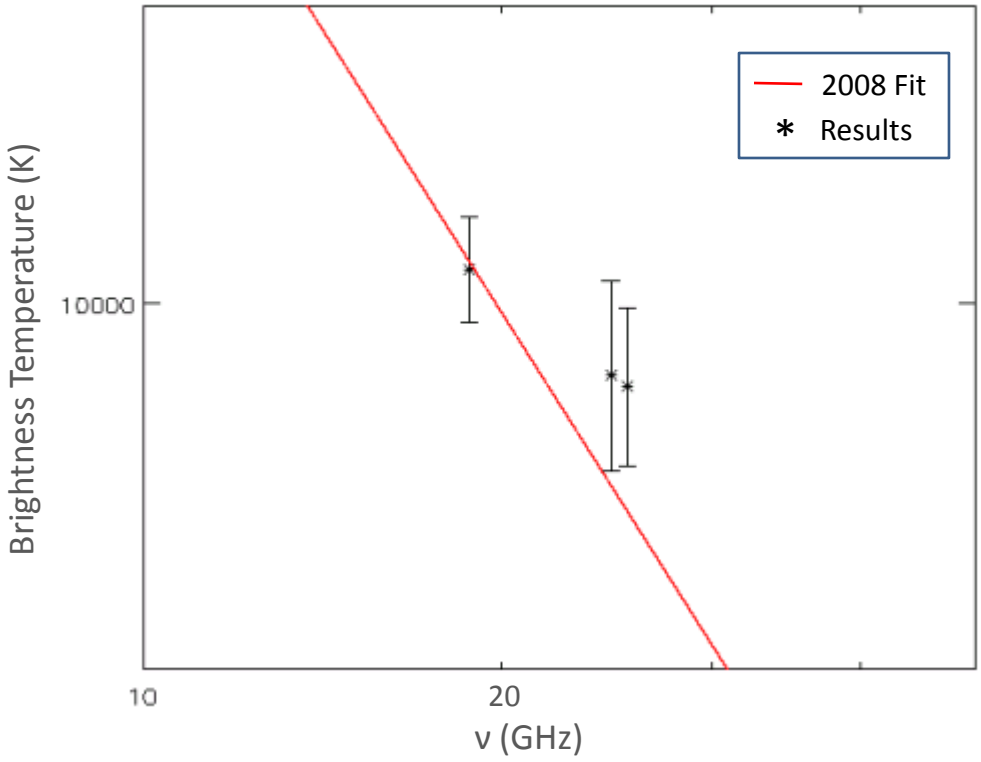
Strong indicator trustworthiness of CasA as a calibrator source for the Radio QS

↓ So

Strong indicator trustworthiness of CasA as a calibrator source for the Radio SUN

Preliminary results and future work

QS value from absolute calibration



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More data are needed for a definitive result

Solar studies up to 100 GHz strong opacity attenuation

Solar studies lower than 10 GHz E. Landi, F. Chiuderi Drago (2008) fit no more valid

Thanks for your attention

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Results and future work: table

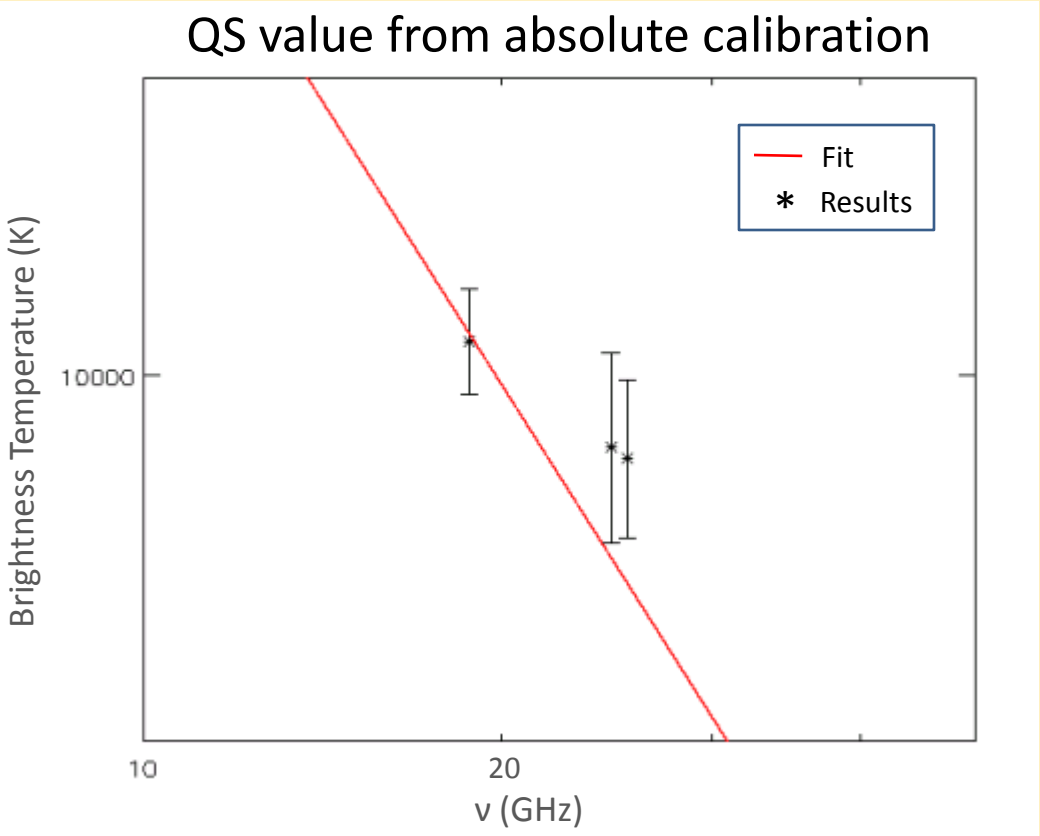

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Table of results: QS brightness levels obtained from the image absolute calibration process.

ν_{obs} is the central observing frequency;

Cas A_f lists the SNR Cassiopeia A integrated fluxes (and related observation epochs);

TQS is the measured QS brightness temperature;

Fit_{dev} expresses the percentage deviation from the expected value extrapolated from Landi and Chiuderi Drago (2008).