Atmospheric Opacity Measurements at Millimeter and Submillimeter Wavelengths at CASLEO (2552 m asl)

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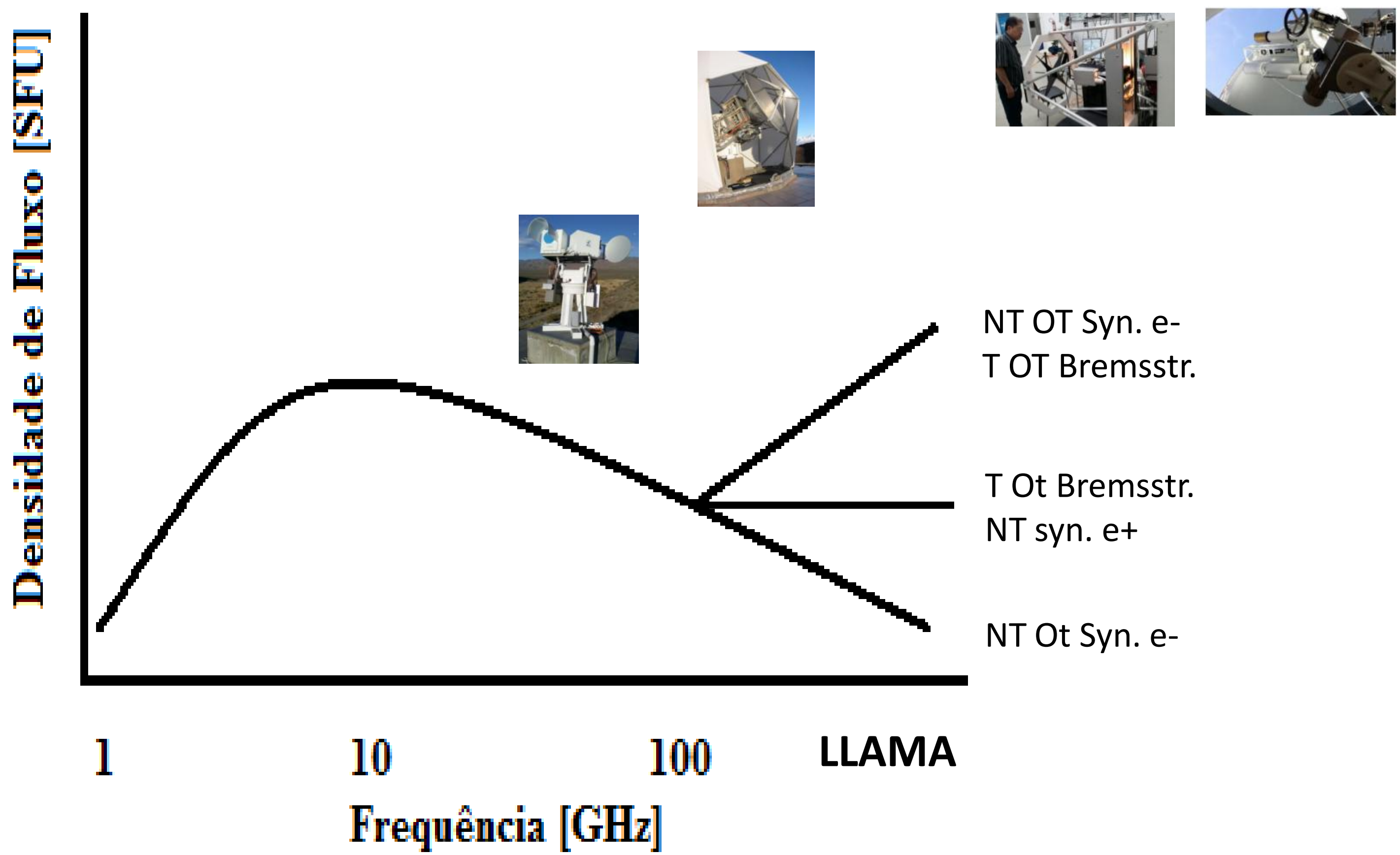
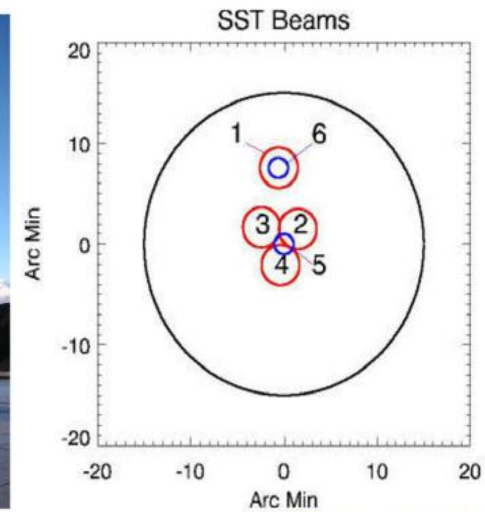
High-frequency solar flare spectra



The shape of solar flare spectra is essential to know the nature of the radiation and the emission mechanisms at work. Atmospheric opacity is the main uncertainty of a reliable flux determination. E.g reduction fator 4 – 1000 at 405 GHz.

Opacity Measurements at CASLEO

405 GHz



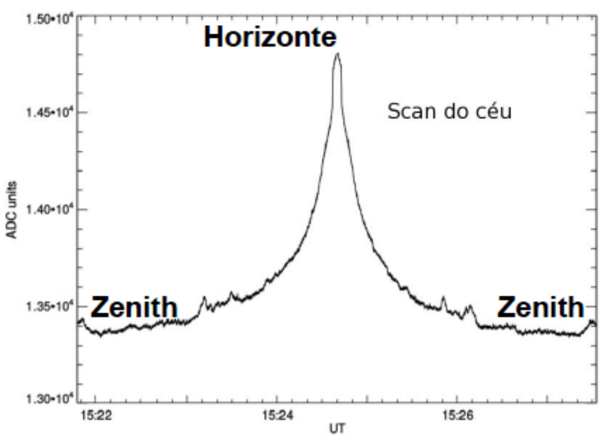
Kaufmann et al. (2008)

- 1.5 m Ø antenna
- 6 independent radiometers (4 @ 212 GHz and 2 @ 405 GHz)
- Cluster of 6 beams: HPBW ~ 4’ @ 212 GHz and HPBW ~ 2’ @ 405 GHz
- Cluster → multiple-beam technique
- First observations in 1999 (campaigns)
- Routine mode since 2002

Opacity Measurements at CASLEO

3 methods are used

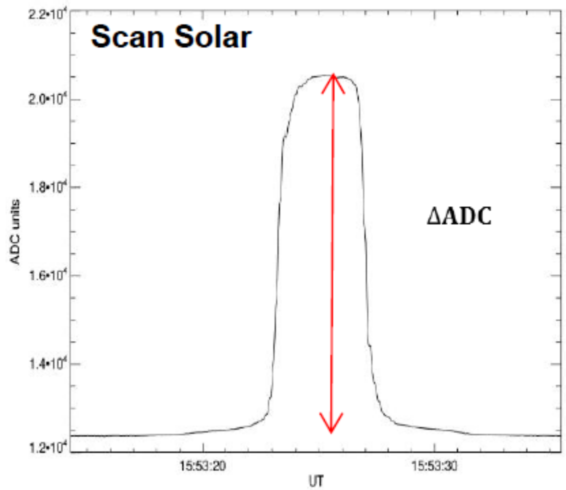
Tipping (sky scan/scan dip)



$$T_{obs} = T_{sky}(1 - e^{-\tau_\nu/\sin(El)}) + T_{off}$$

Not reliable for opaque conditions (Dicke et al, 1946; Melo et al. (2003, 2005), Cornejo, 2017)

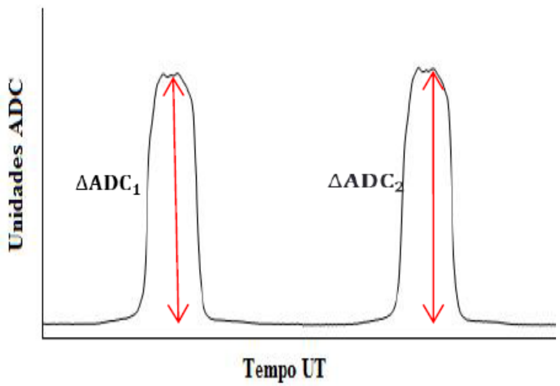
Solar Brightness



$$\Delta T_{ant} = \frac{\Delta ADC}{K} = P\, e^{-\tau/\sin(El)}$$

Depends on P and absolute temperature calibration. Allows determination of higher opacity values

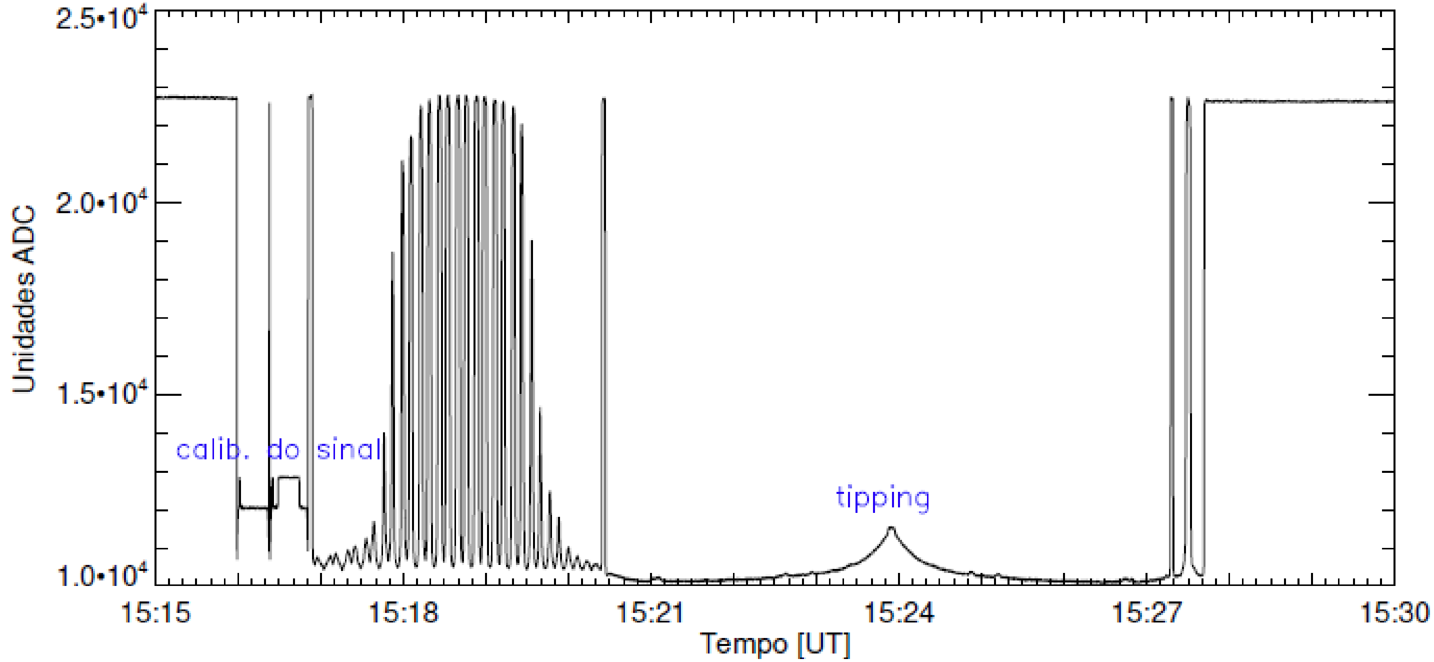
Extinction



$$\tau = \frac{ln(\Delta ADC_1/\Delta ADC_2)}{(1/\sin(El_2)) - (1/\sin(El_1))}$$

Independent on absolute temperature calibration (Melo et al. 2003, Cornejo, 2017)

Opacity Measurements at CASLEO



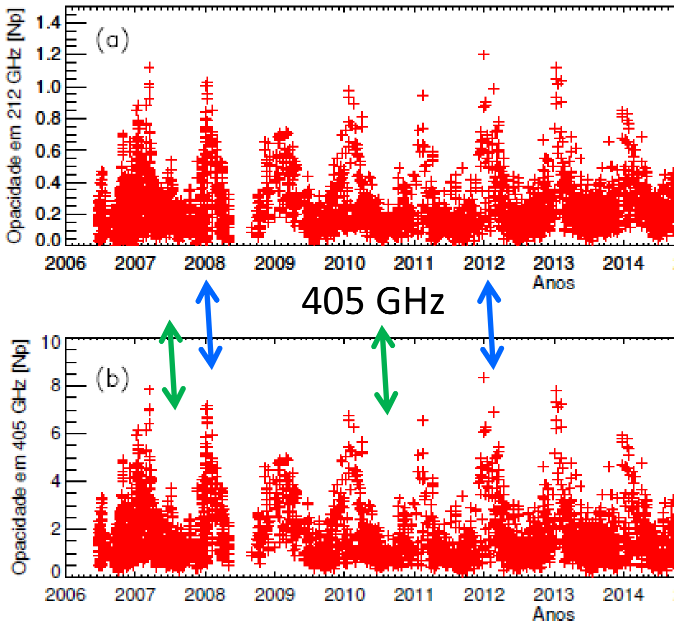
<u>Getting P (K)</u>

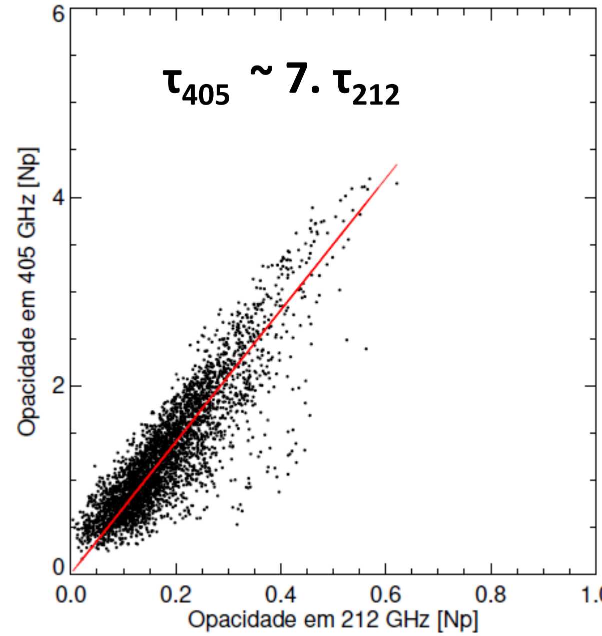
- **τ (tipping) from clear sky and dry days**
- **use this τ to compute P (solar scans)**
- **2008 – 2019 → get <P> for each SST beam**
- **use this <P> to estimate zenith opacity from solar brightness method**

$$\boxed{\tau = \sin(El)\left[\ln(\overline{\boldsymbol{P}}) - \ln\left(\frac{\Delta\, ADC}{K}\right)\right]}$$

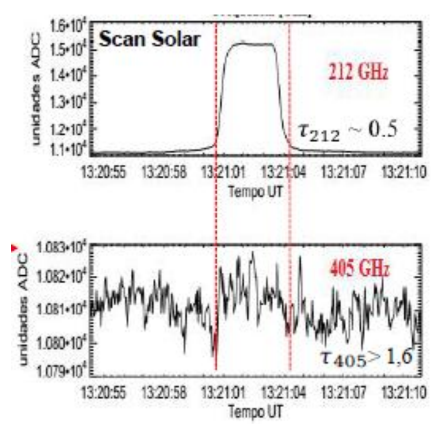
Opacity Measurements at CASLEO

212 GHz

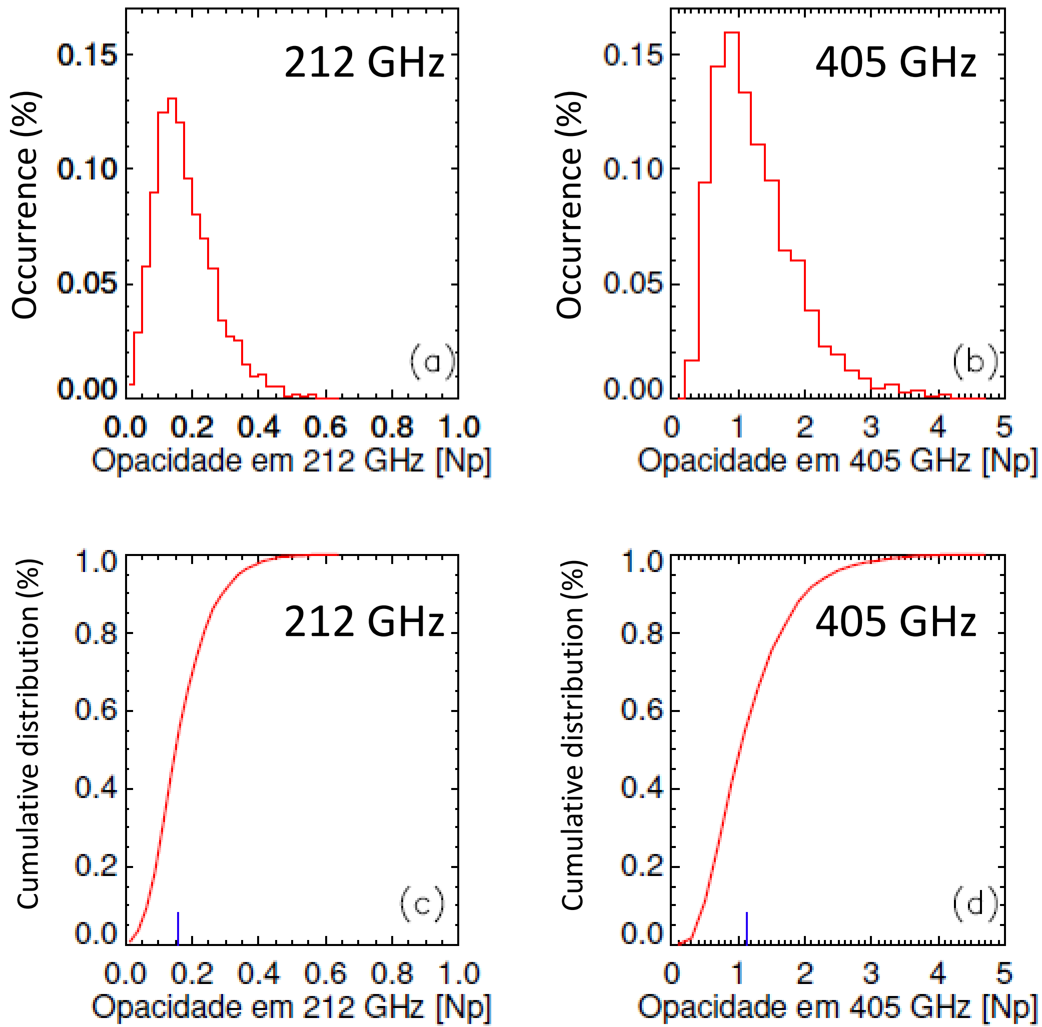


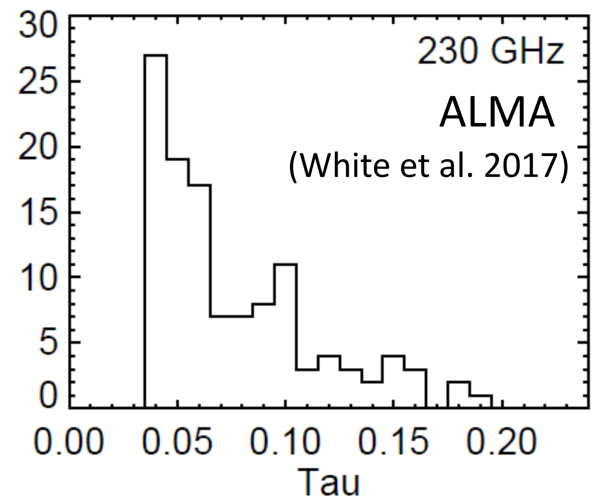


- alternance of lower opacity values in Winter
- and higher opacity values in Summer
- $\tau_{405} \sim 7. \tau_{212}$



Opacity Measurements at CASLEO



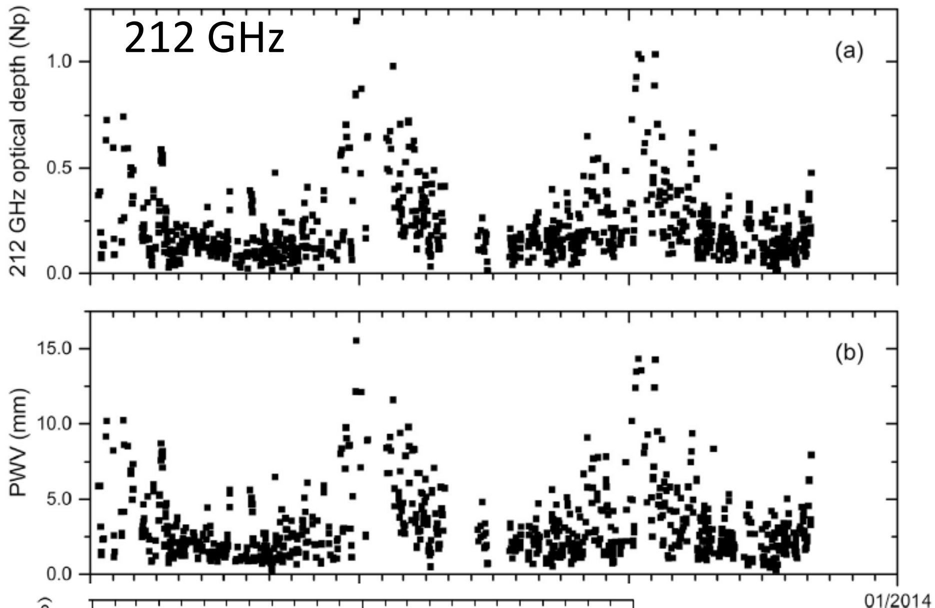


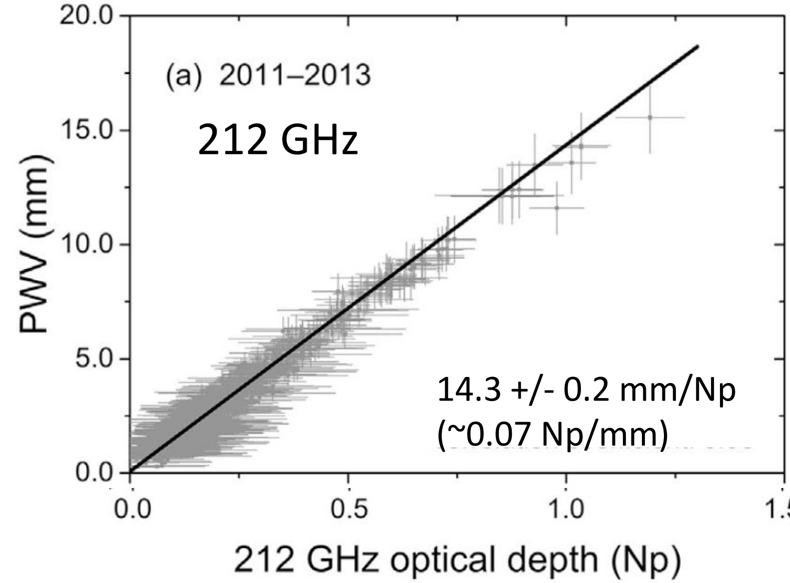
- Higher occurence 0.15 (0.9) Np @ 212 (405) GHz
- 50 % of time with transmission > 85% @ 212 GHz and > 35% @ 405 GHz

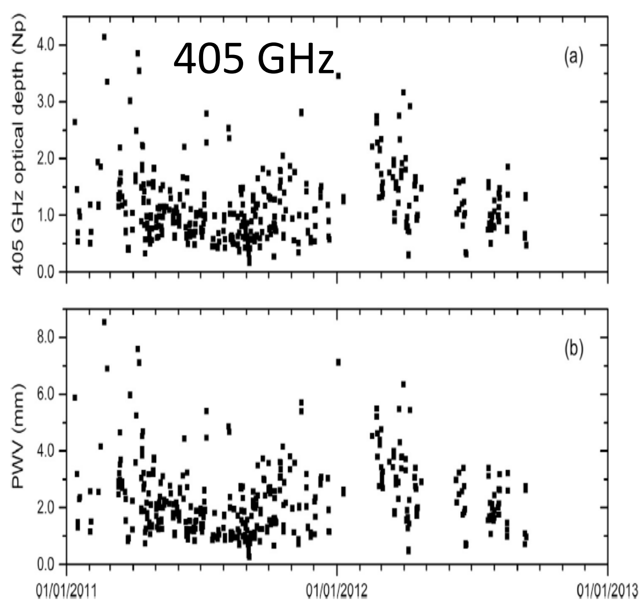
(Cornejo et al. 2021)

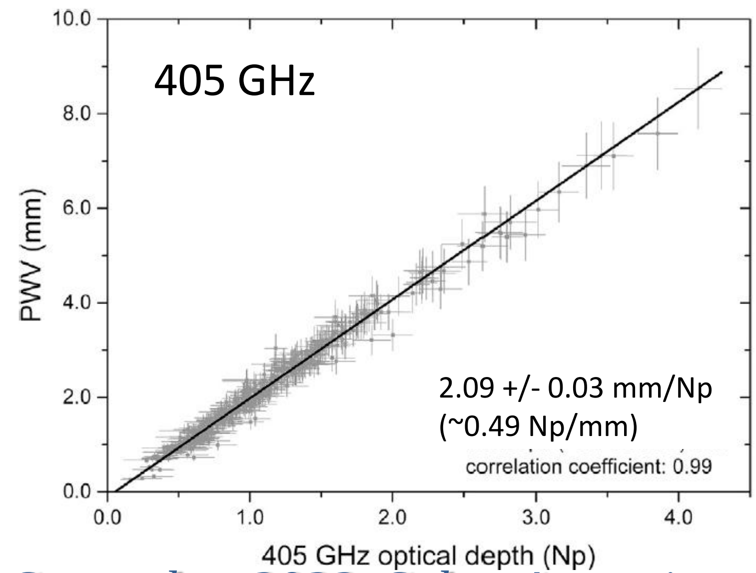
Opacity versus PWV (AERONET)

(Cassiano et al. 2018) Simultaneous measurents



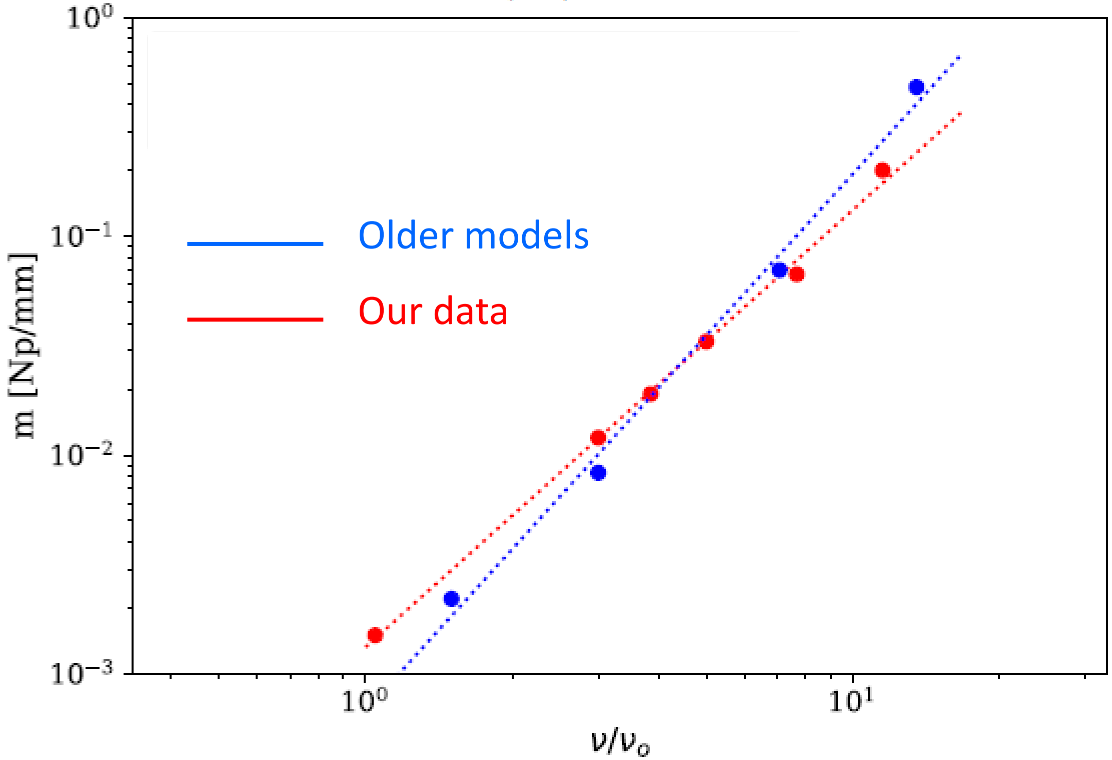


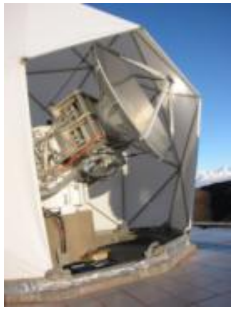




Combining POEMAS (45, 90 GHz) with SST (212 and 405 GHz)

$$m = m_\circ \left(\frac{\nu}{\nu_\circ} \right)^a , \quad \nu_\circ = 30 \text{ GHz}$$





Freq. (GHz)	m (Np/mm)	c (Np)
45	2.2×10^{-3}	6.2×10^{-2}
90	8.3×10^{-3}	3.3×10^{-2}
212	7.0×10^{-2}	5.0×10^{-3}
405	4.8×10^{-1}	5.3×10^{-2}

Conclusions

The knowledge of Earth's atmosphere emission and absorption spectrum is of crucial importance for the absolute calibration of ground-based millimeter and submillimeter observations. And thus to understand the nature of the radiation during, e.g. solar flares, as well as the emission mechanisms responsible for it.

Determination of atmospheric opacity at CASLEO show that it is an observatory for millimeter and submillimeter measurements of similar (even sometimes better) characteristics compared with other observatories at same altitude.

Opacity numbers were obtained using the solar brightness model.

At 212 GHz, for 50% of the time we get transmission above 85%
At 405 GHz, for 50% of the time we get transmission above 35%
We find that opacity at 405 GHz is about 7 times that at 212 GHz

We quantify the role of PWV in atmospheric transmission

We were able to find a relation for the atmospheric opacity in the 45 – 405 GHz range

These observational results will help us to refine existing atmospheric transmission models, a necessary condition to improve calibration of present and future radiotelescopes.