Fabian Menezes
Adriana Valio

The subterahertz Sun

Equatorial and polar radii from SST and ALMA

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Equatorial and polar radii from SST and ALMA

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- Related to solar activity
- Its variations over time indicate changes in the solar atmosphere
- Important parameter to improve solar atmosphere models
- Gap of subterahertz frequencies in the measurements of the solar radius and other parameters of the atmosphere

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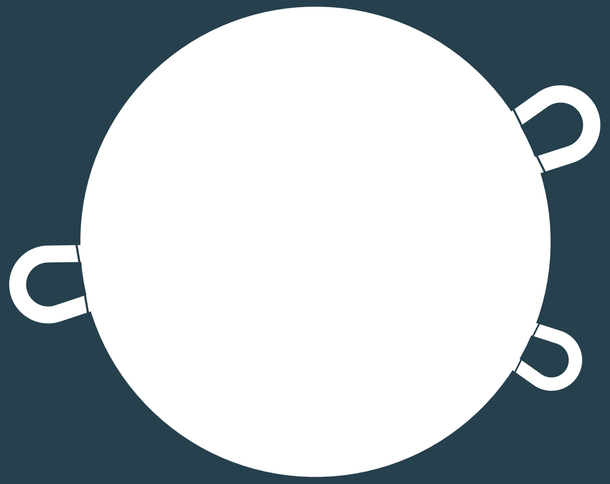

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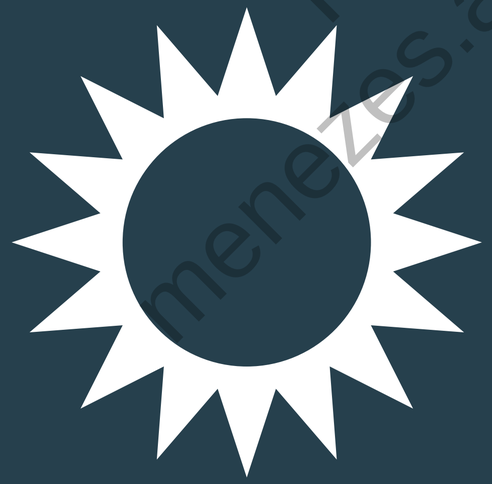

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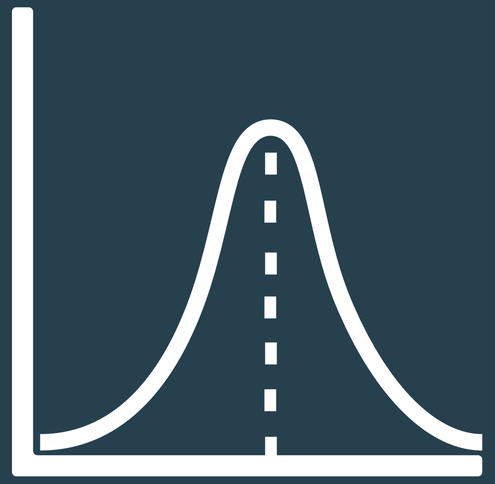

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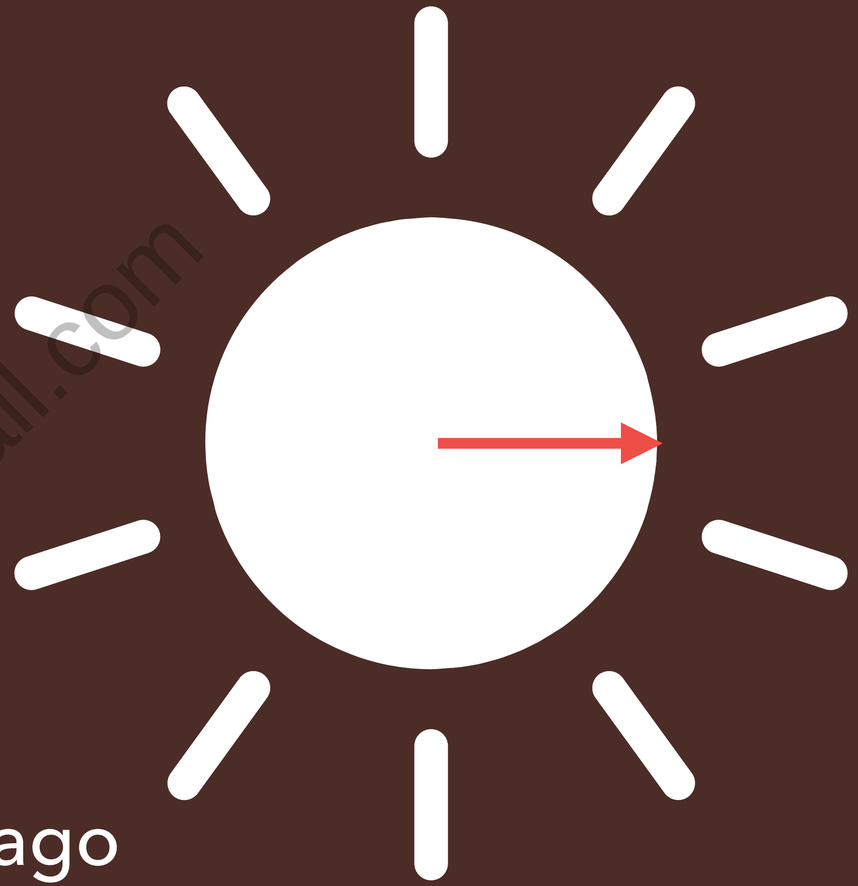
Solar Radius

- $R_{\odot}^{N} = 6.957 \times 10^{8}$ m
- Centuries of measures
  - Vaquero et al. (2016) – 233 years
  - Gilliland (1981) – 265 years
- Radio wavelengths started some decades ago



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ν (GHz)	R (Mm)	ν (GHz)	R (Mm)
11	719	48 [b]	713.4
16	718	70	703
17	708.3	74	701
22	712	94	705
25	710	100 [c]	699.2
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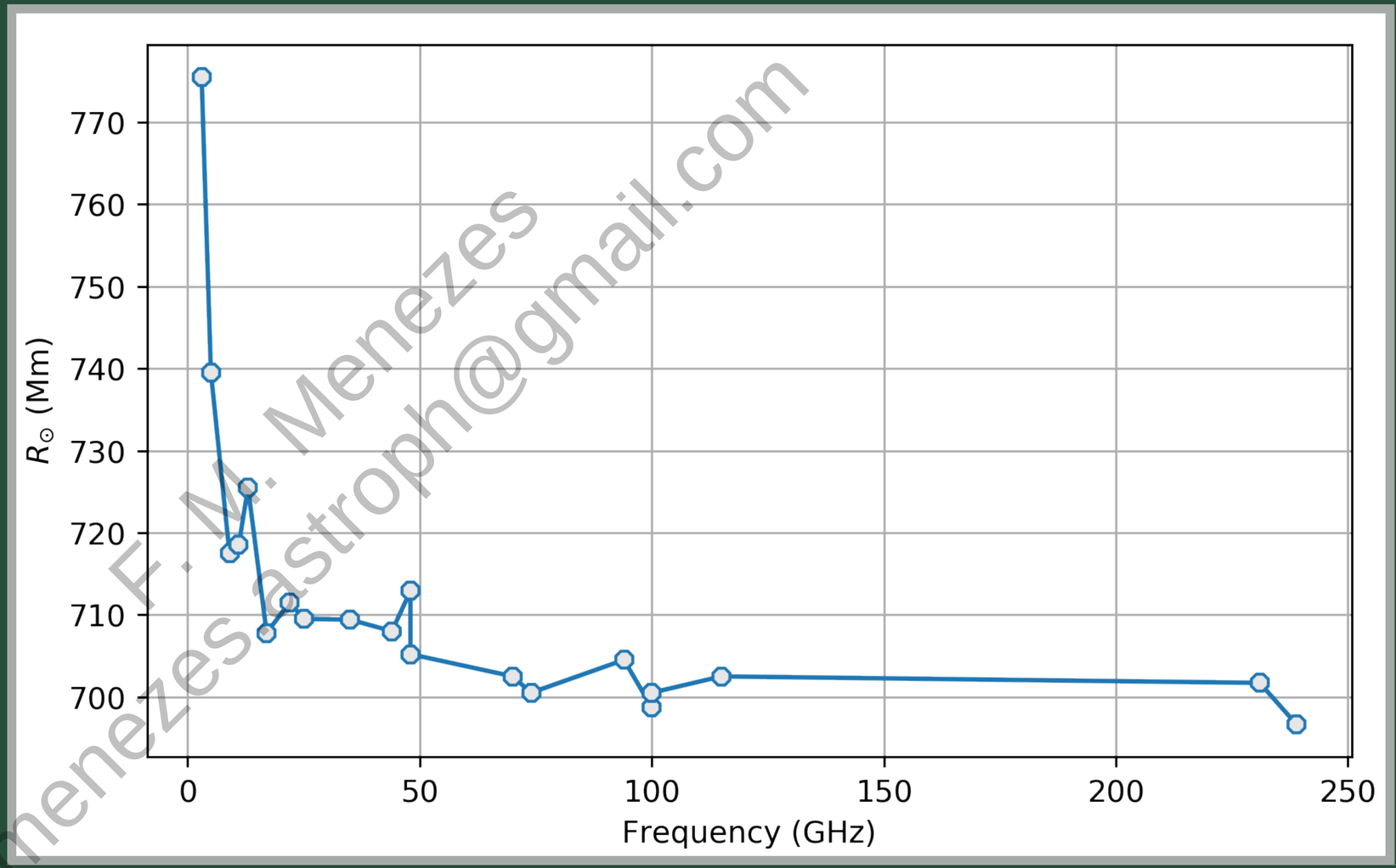

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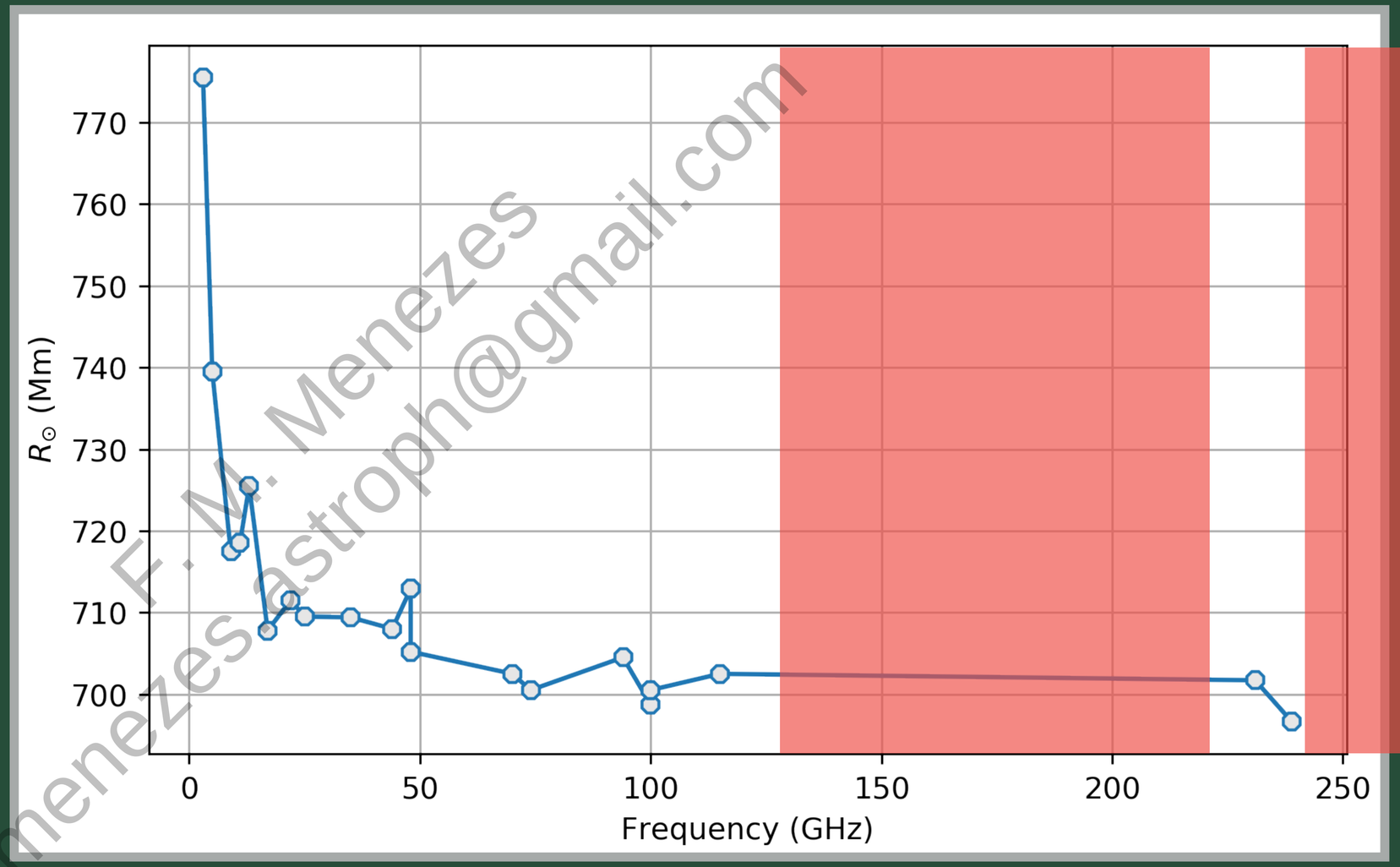

Correlation to solar activity

- **Costa et al. (1999)**
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  - 48 GHz single-dish
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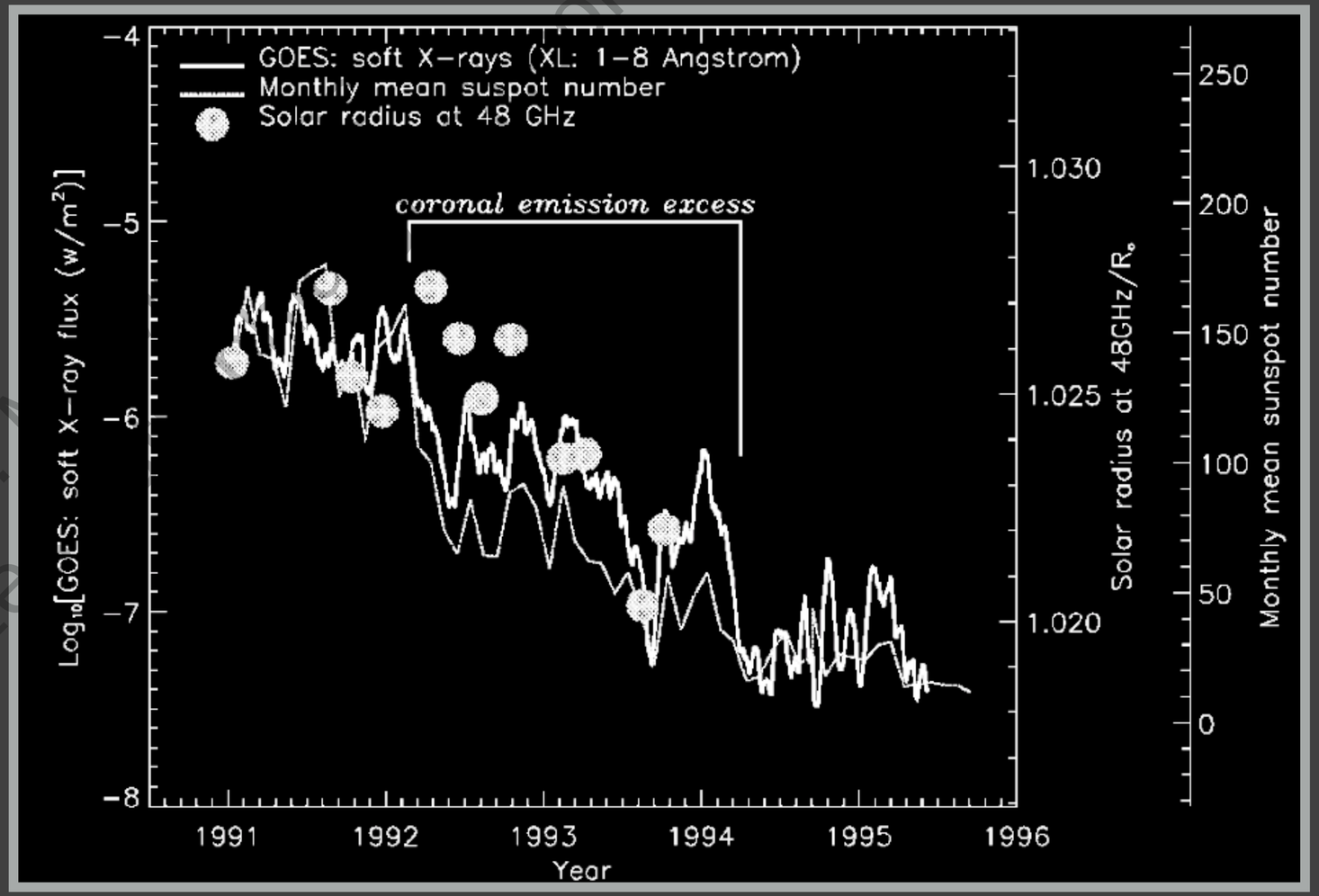

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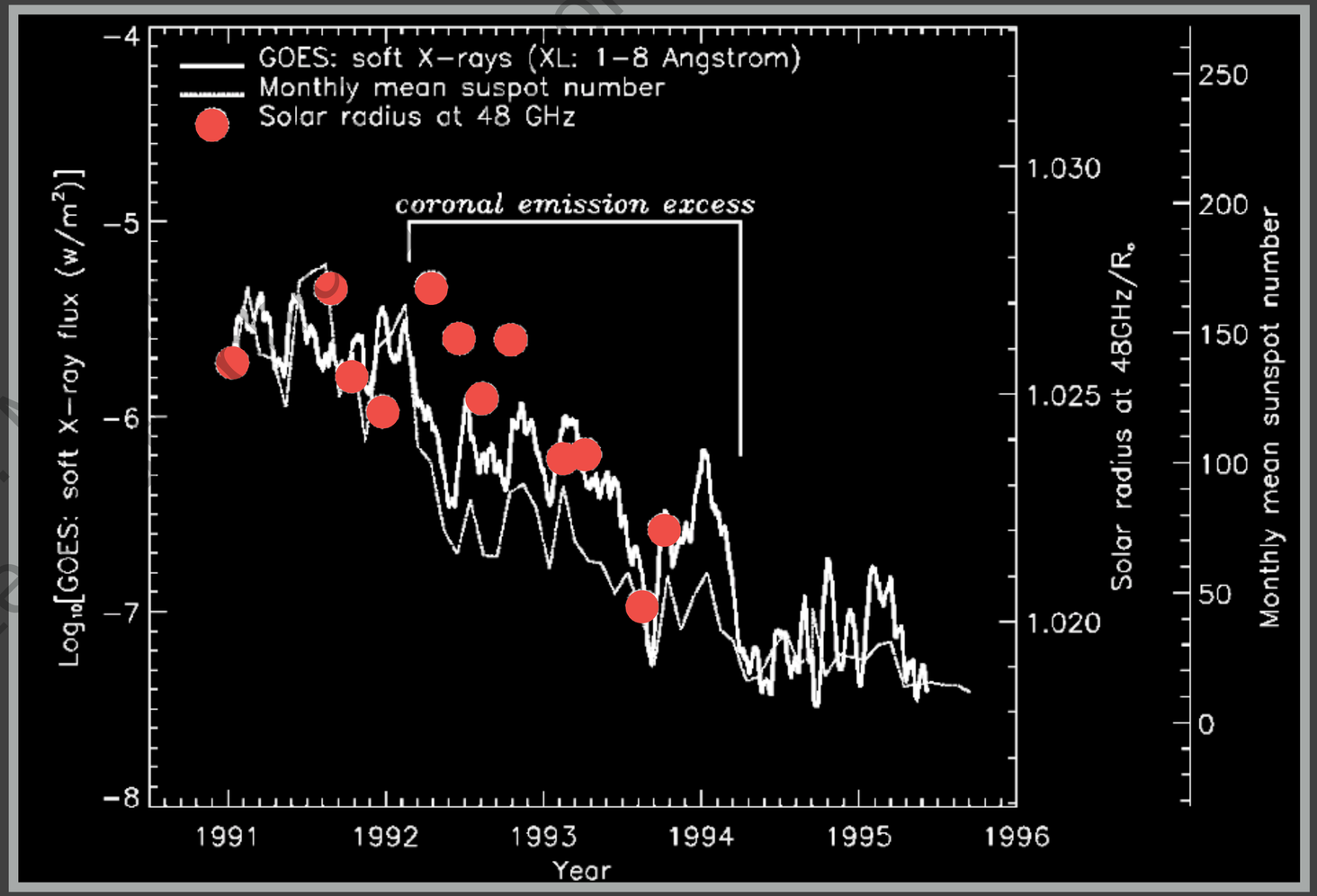
$$\frac{R_{48}}{R_\odot} = 1.029 - 0.0015(\text{year} - 1990)$$



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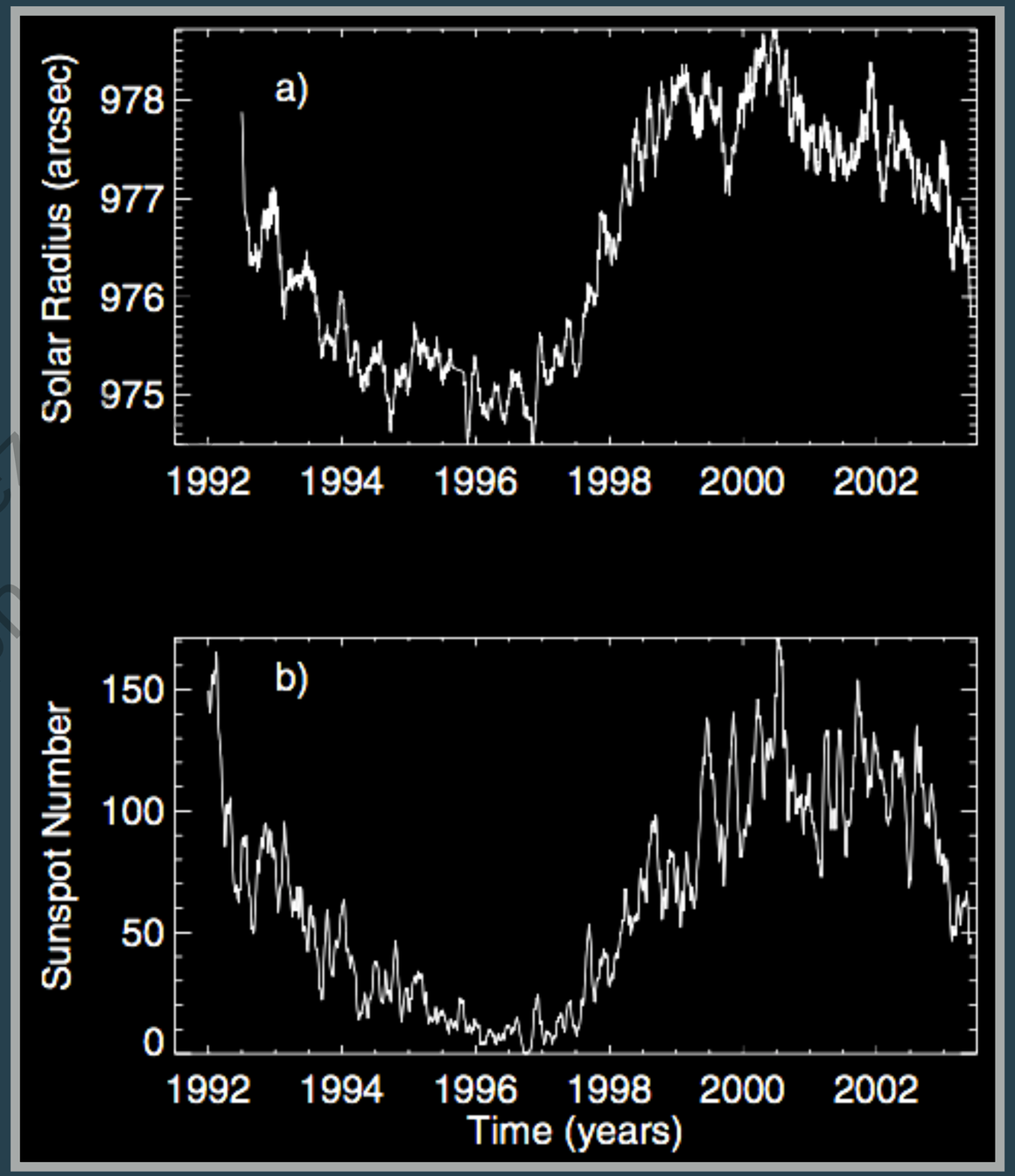

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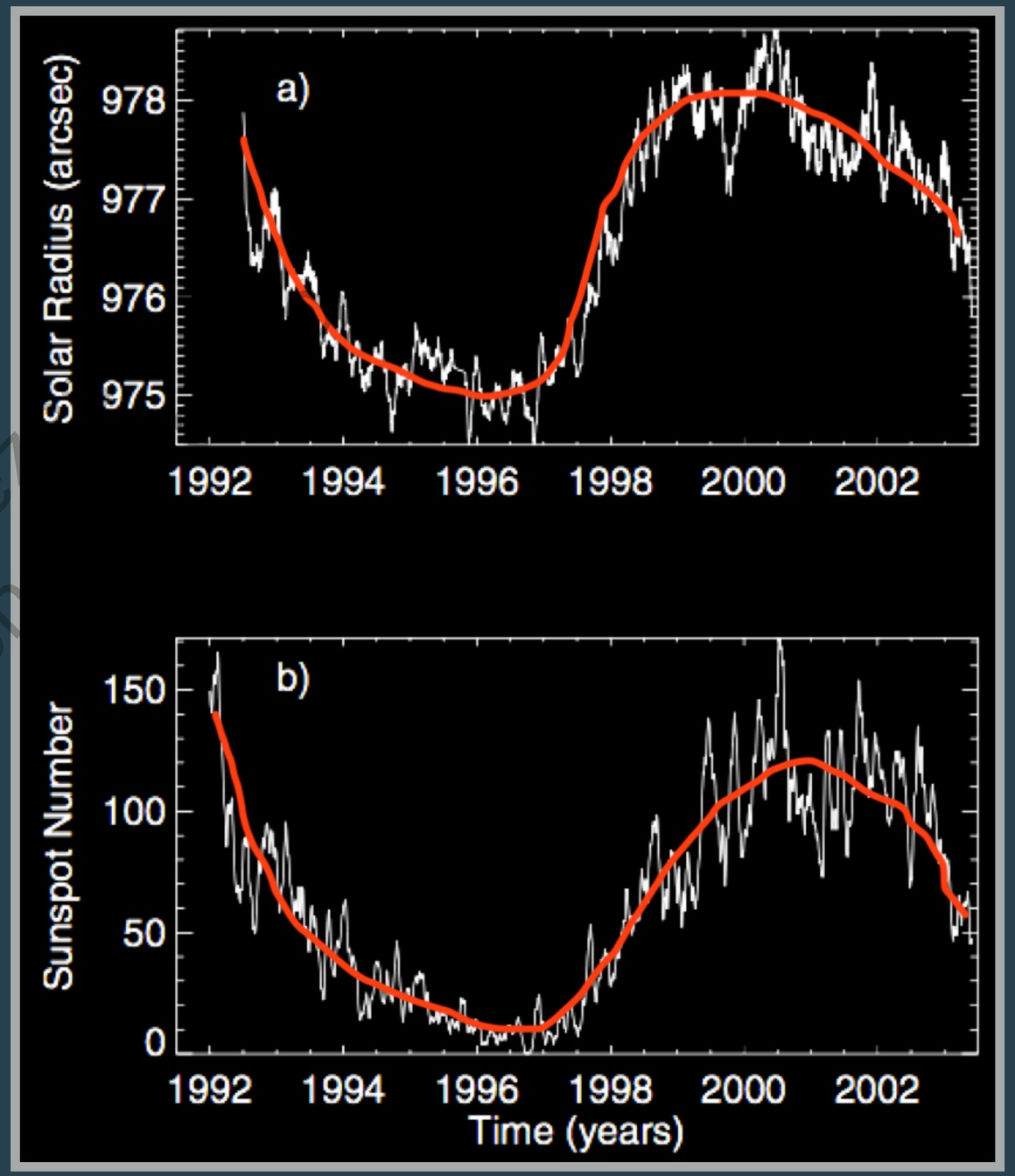

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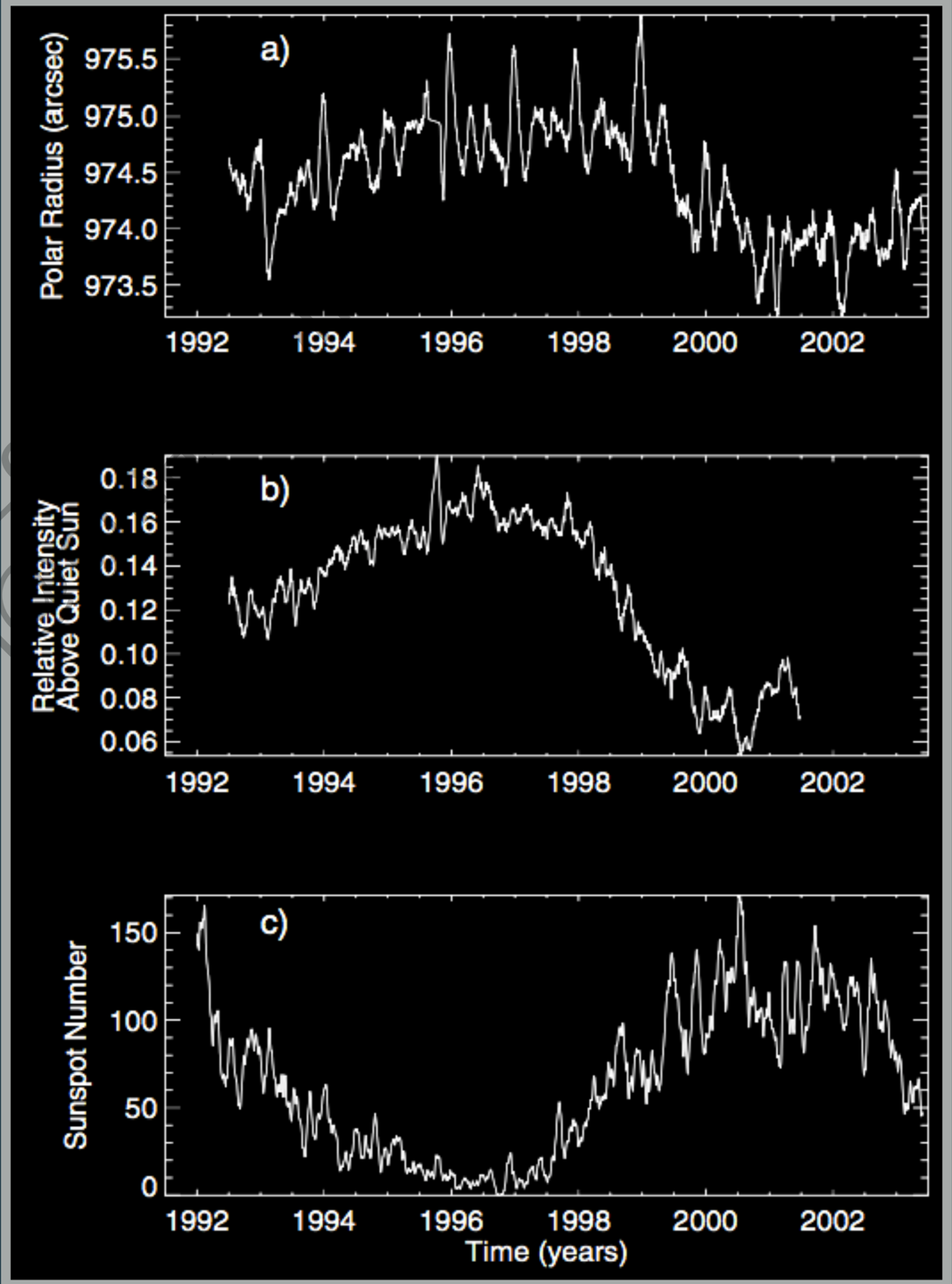

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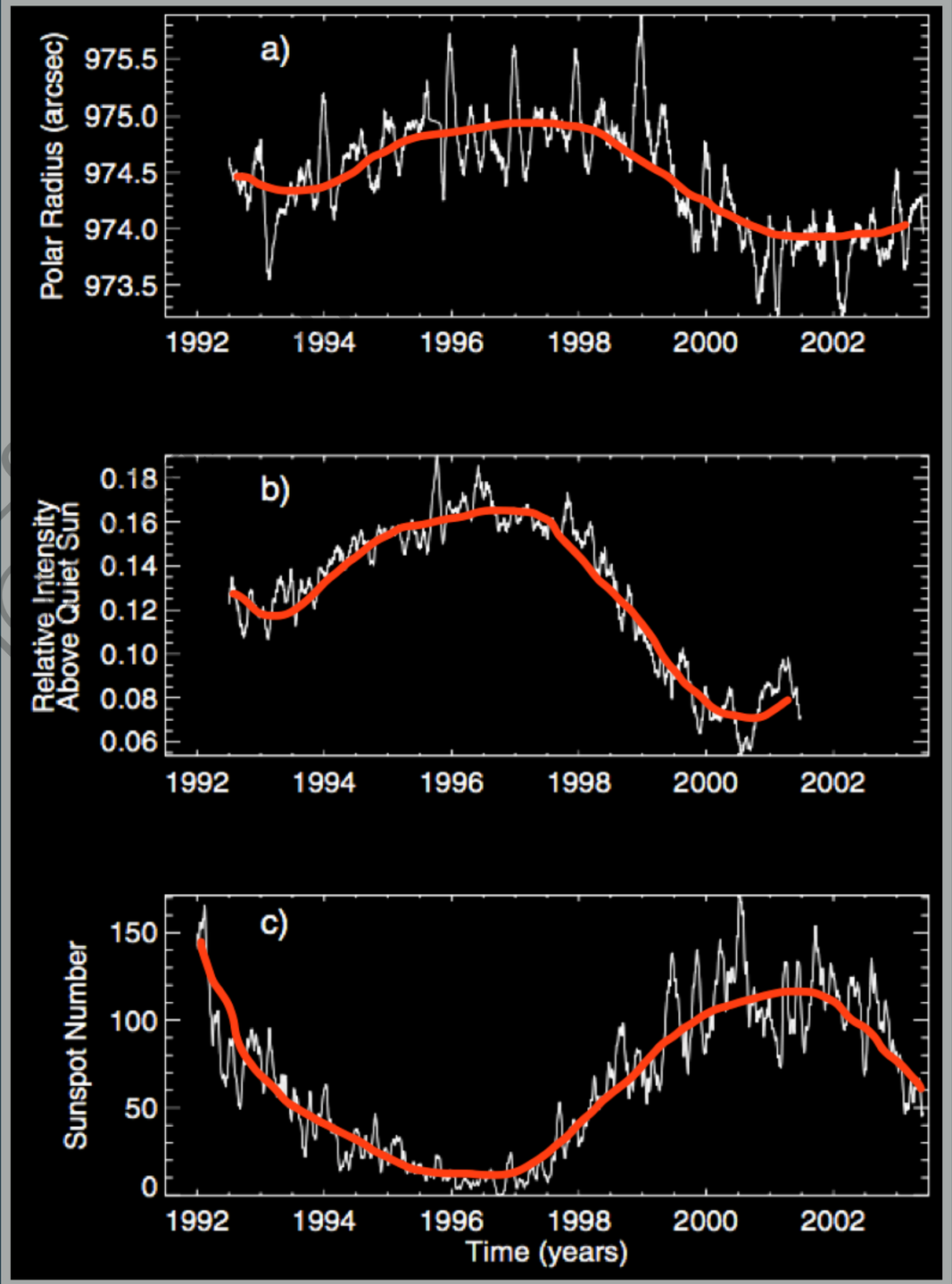

Goals

- Avarage solar radius at 0,212 e 0,405 THz
- Height above photosphere where these emissions are being mainly created
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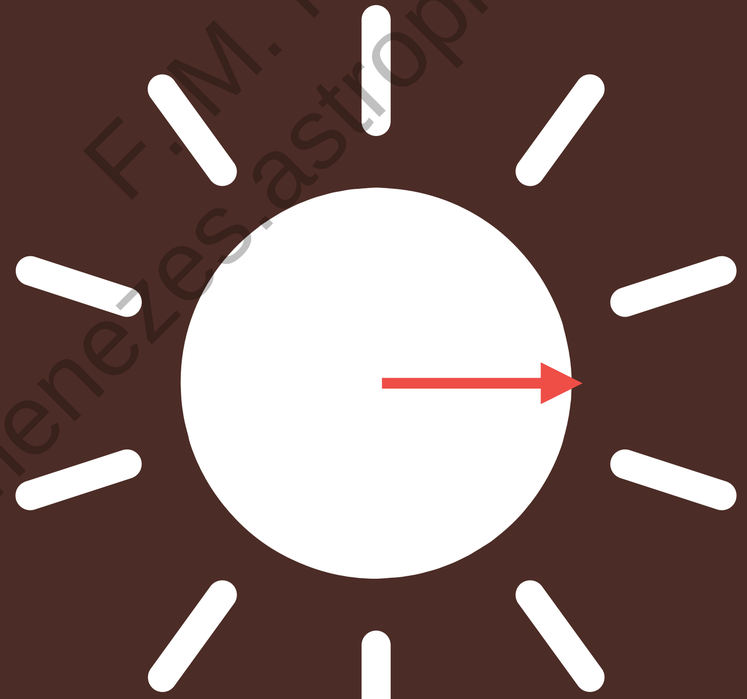

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Solar Submillimeter Telescope

- CASLEO - San Juan, Argentina (Andes, 2550 m)
- from 1999 to 2017
- 0.212 THz: 4 beams, HPBW = 4'
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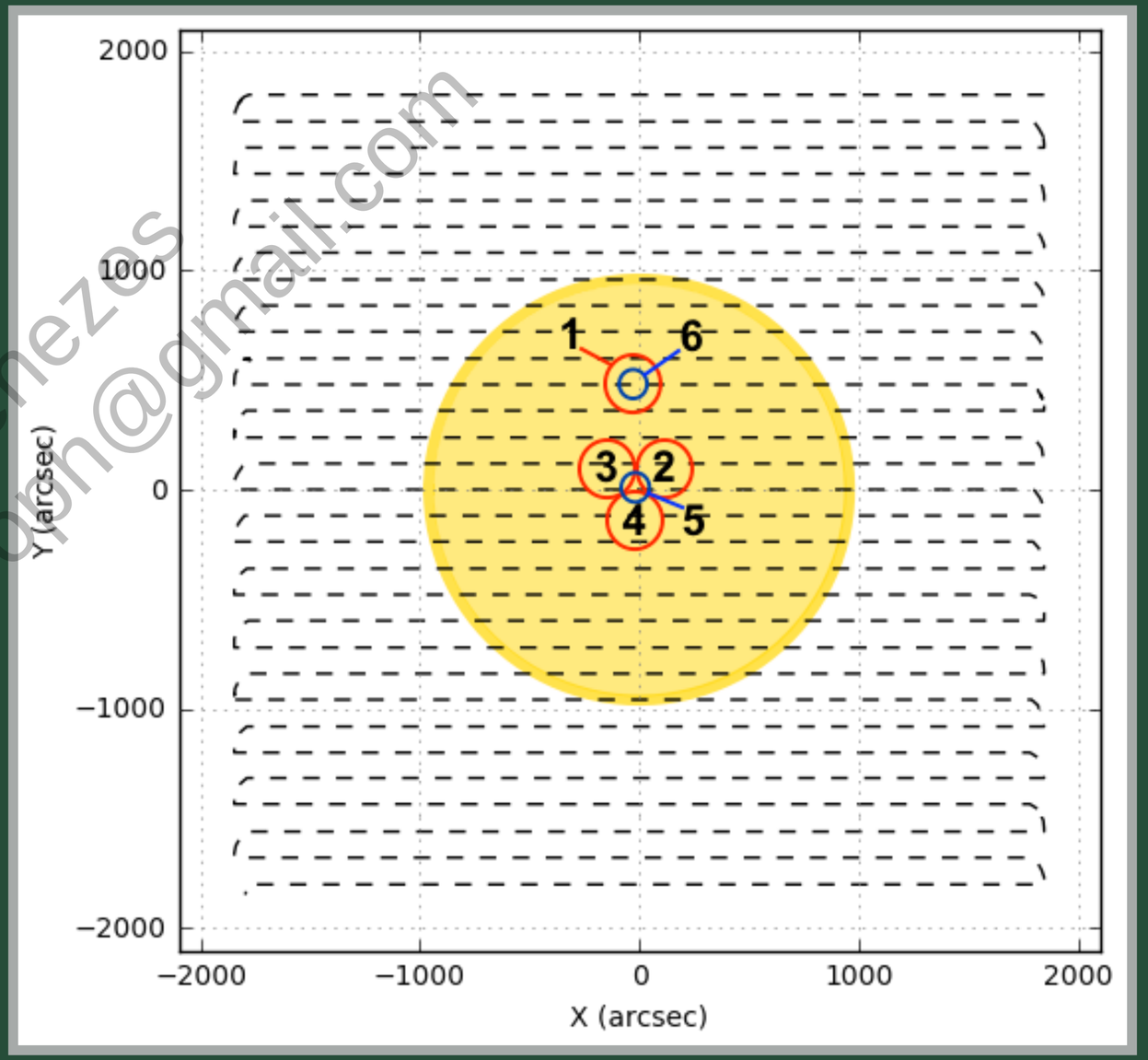

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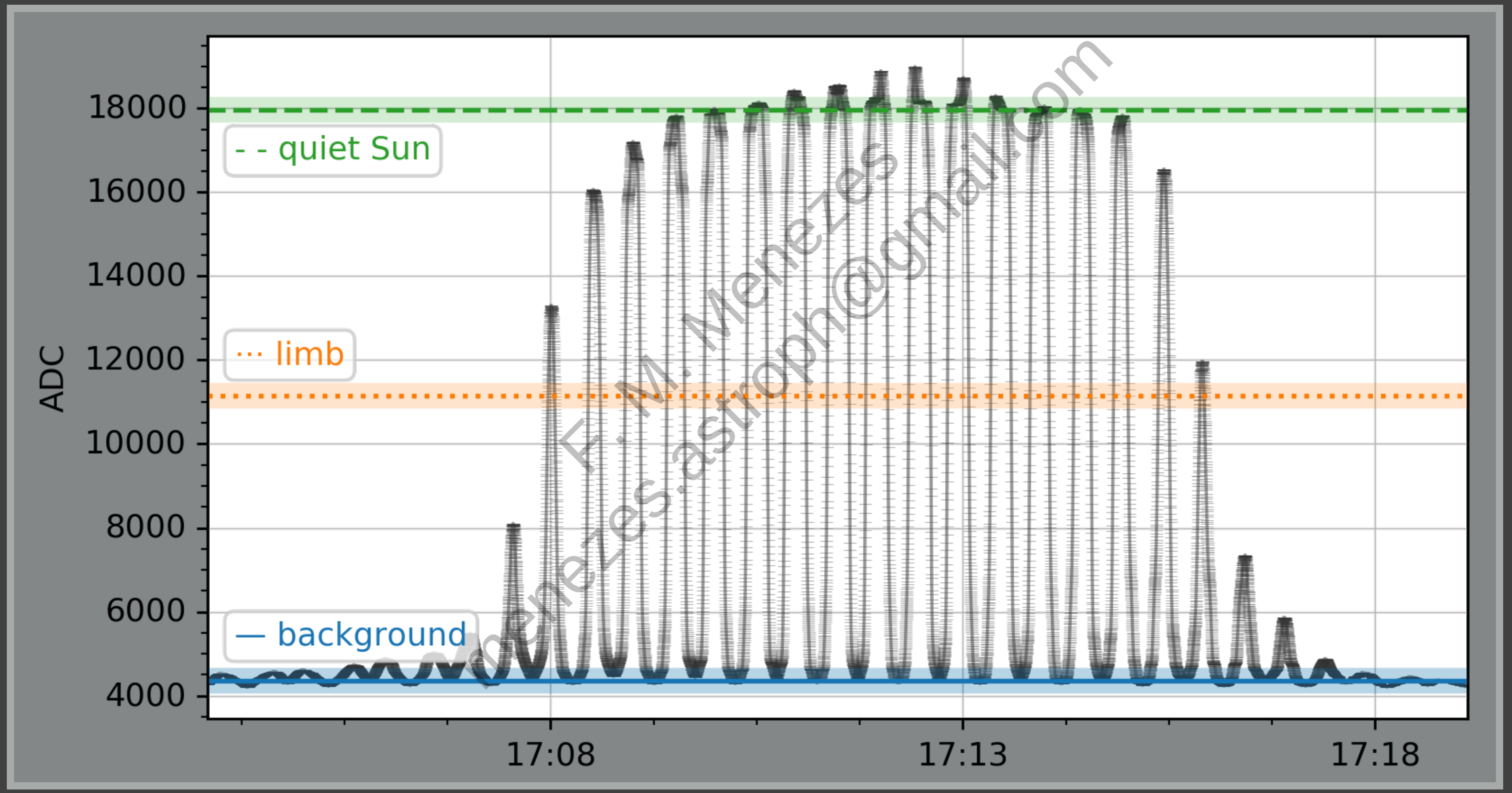
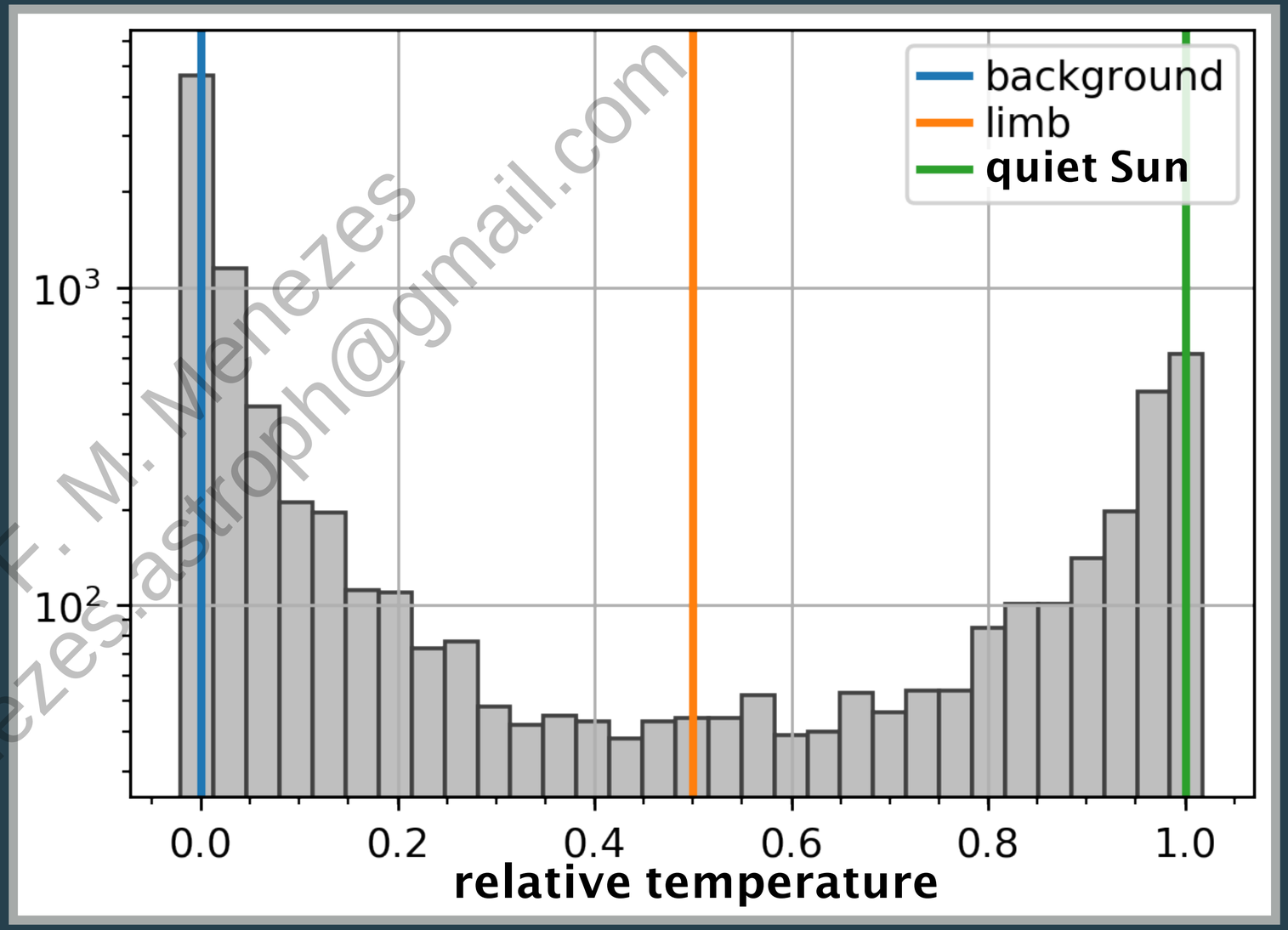


Background, quiet sun & limb levels

- Background is the most common value (mode)
- Quiet Sun level is the most common value within the solar disk (second peak in the histogram)
- Limb level is the half of the quiet Sun level



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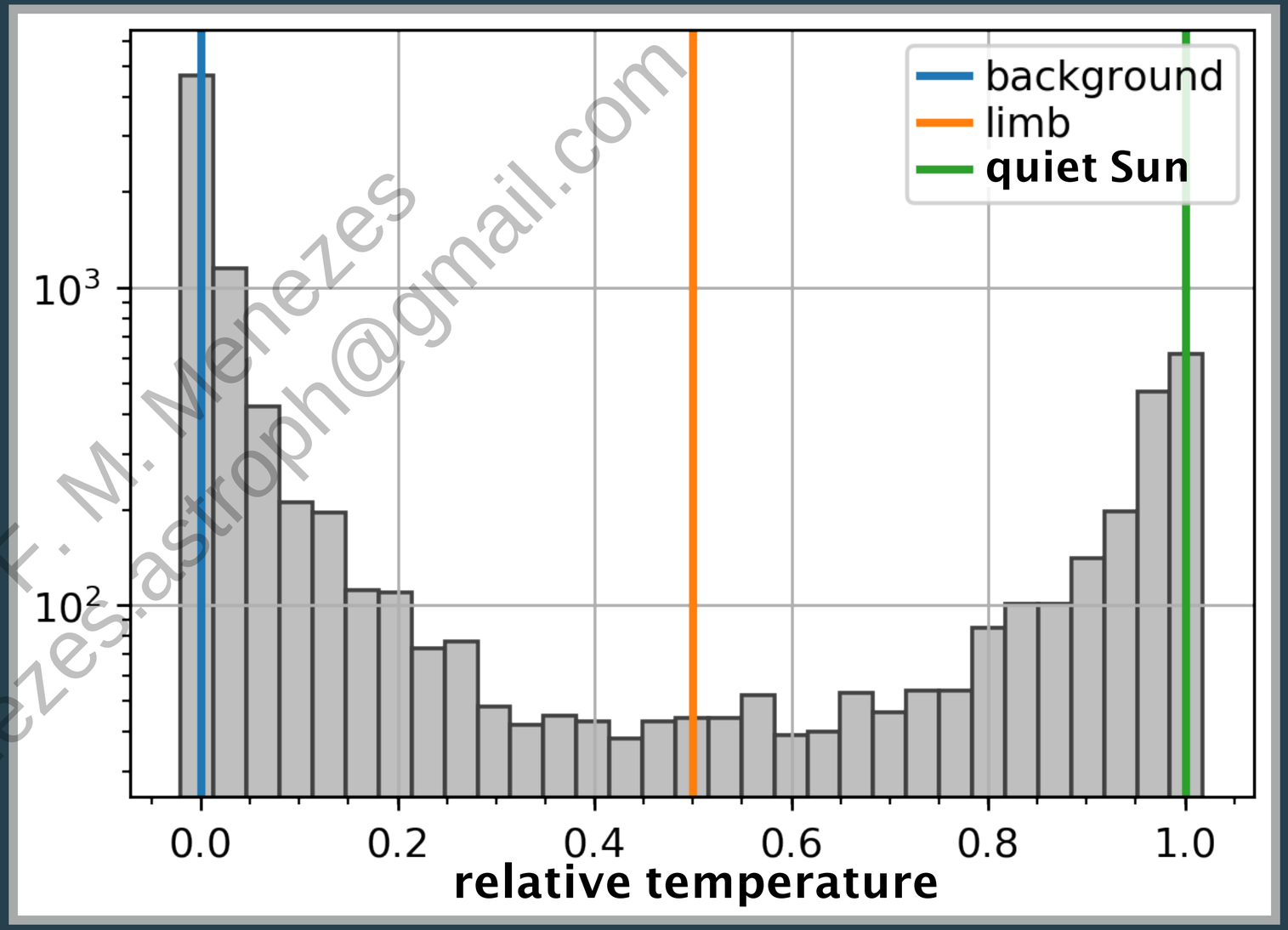

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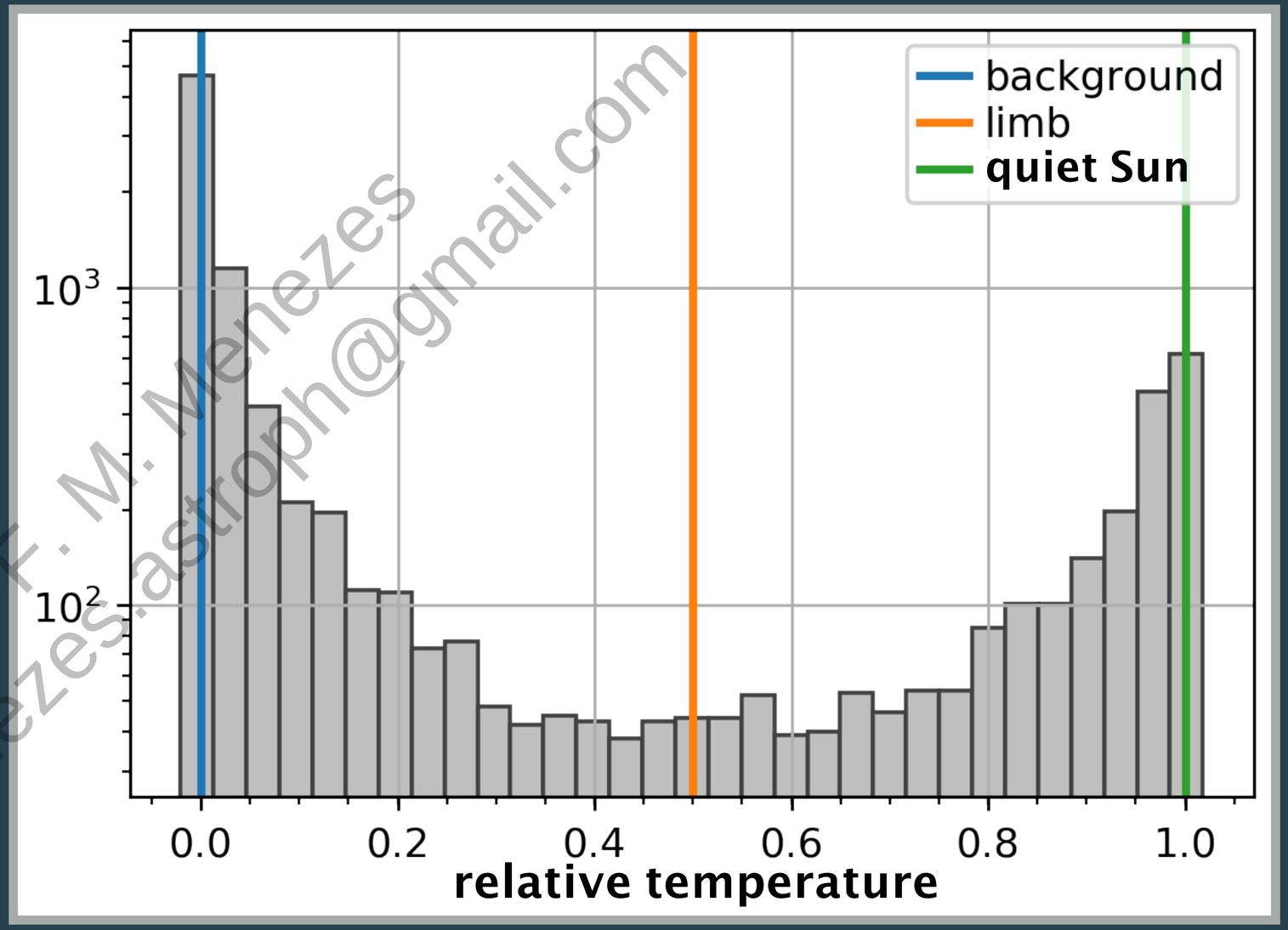

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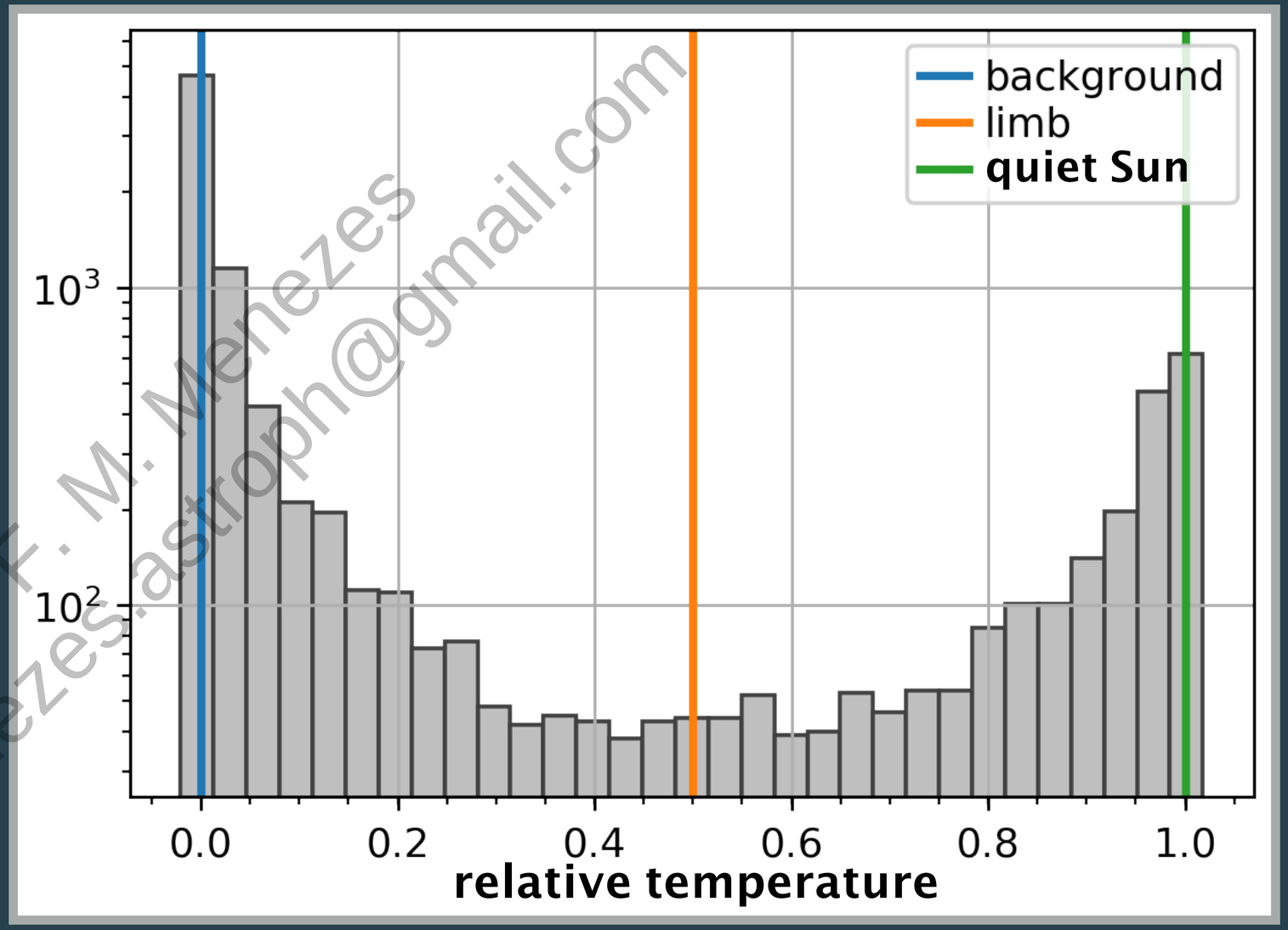

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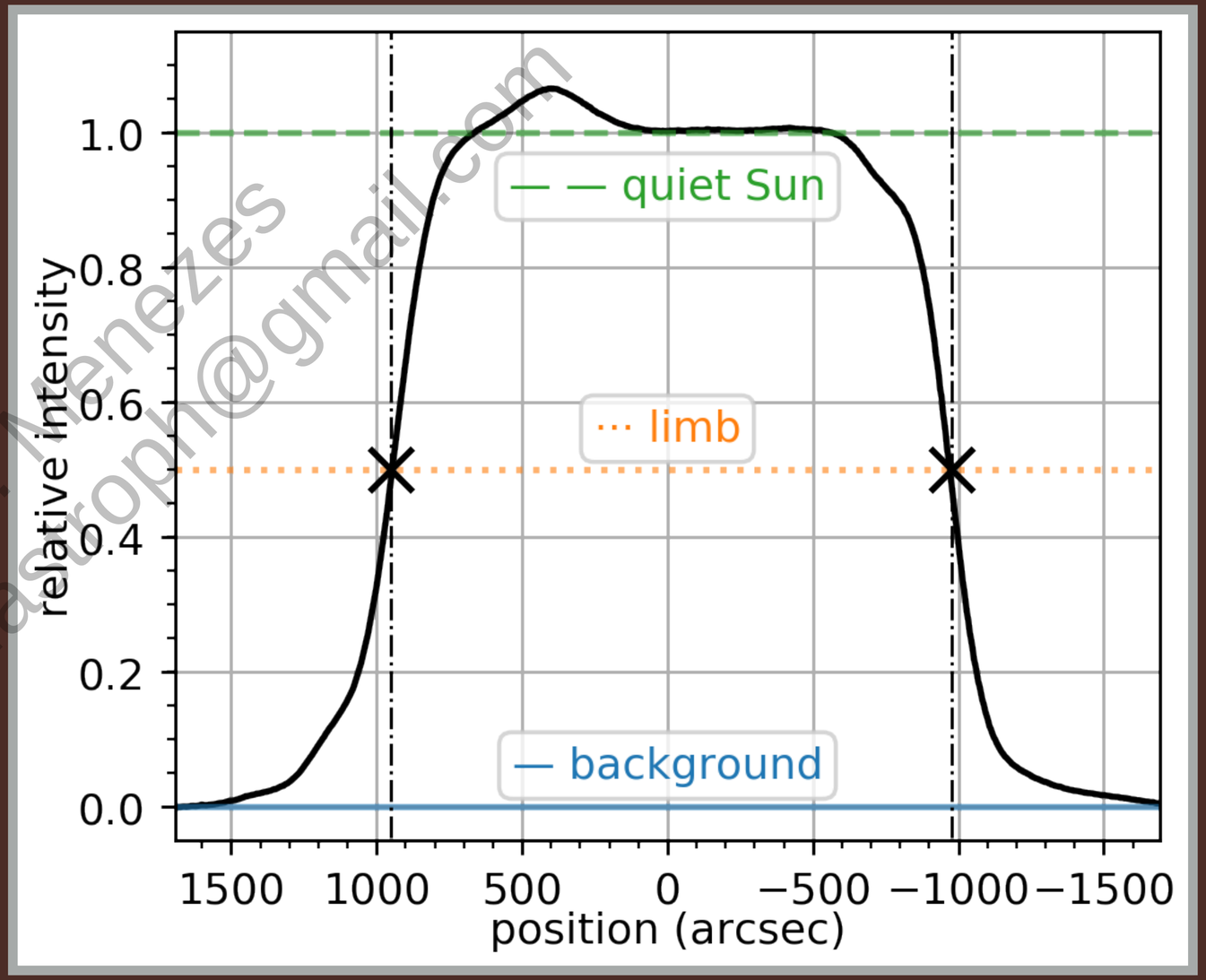

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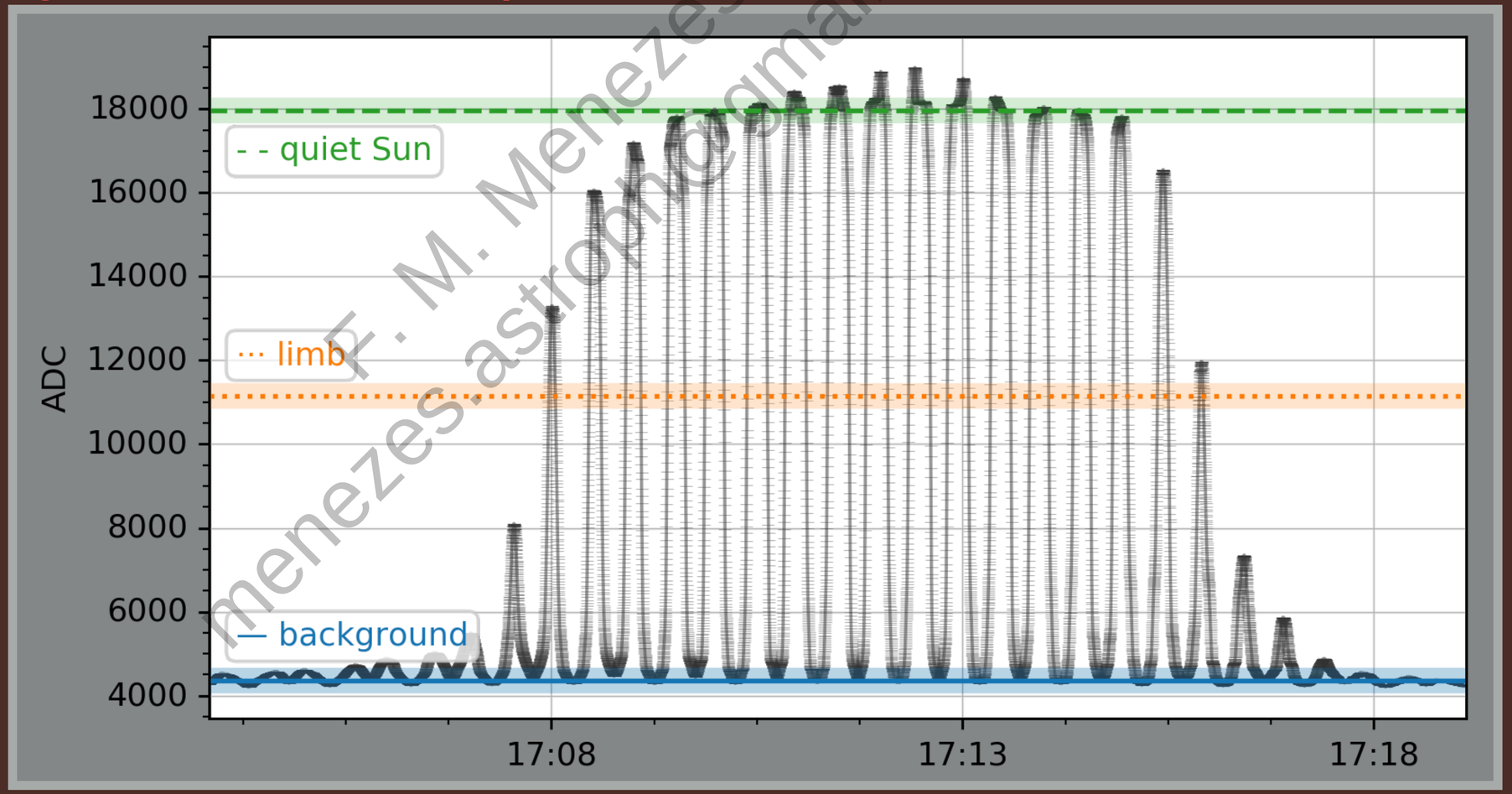

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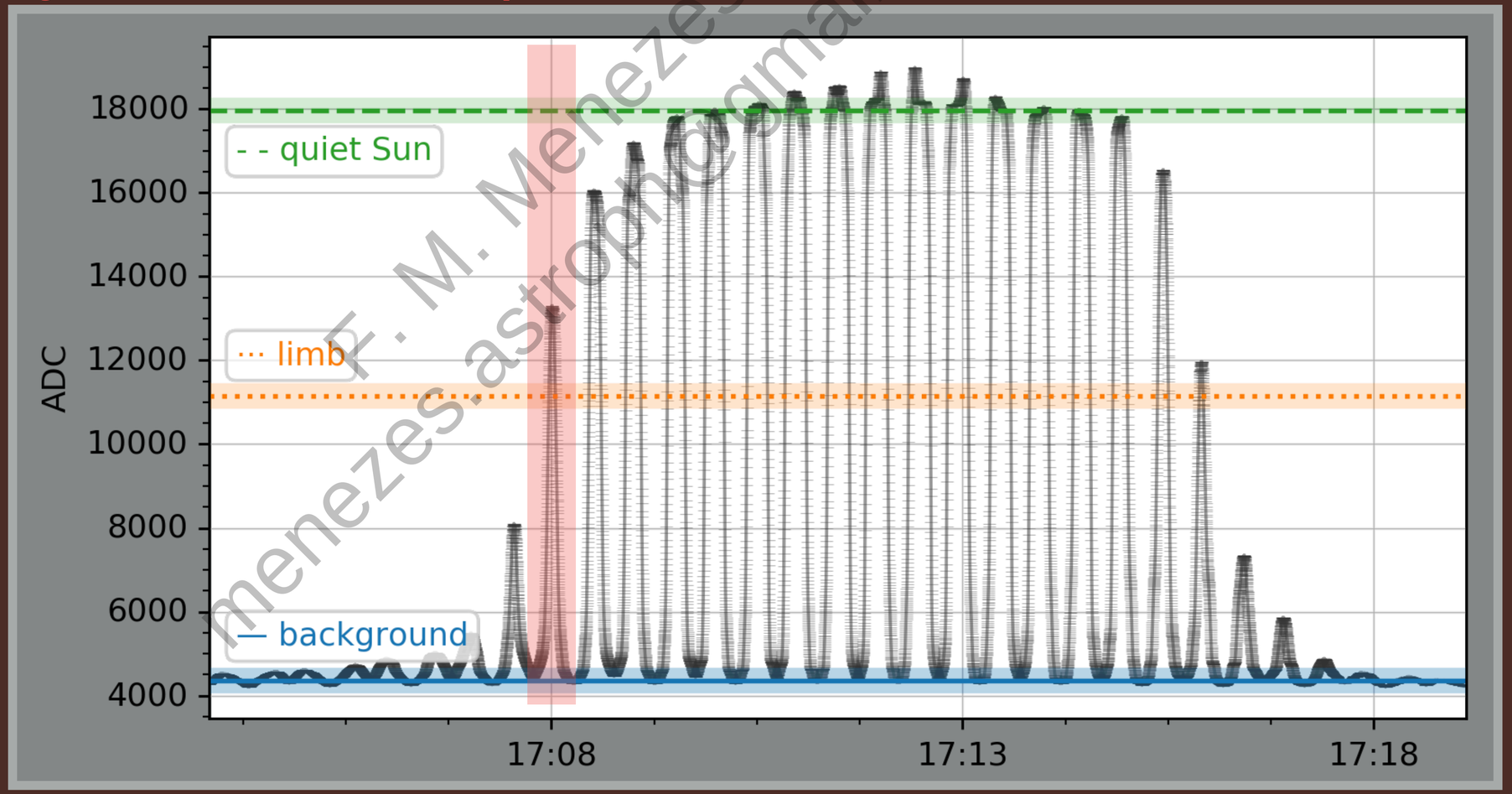

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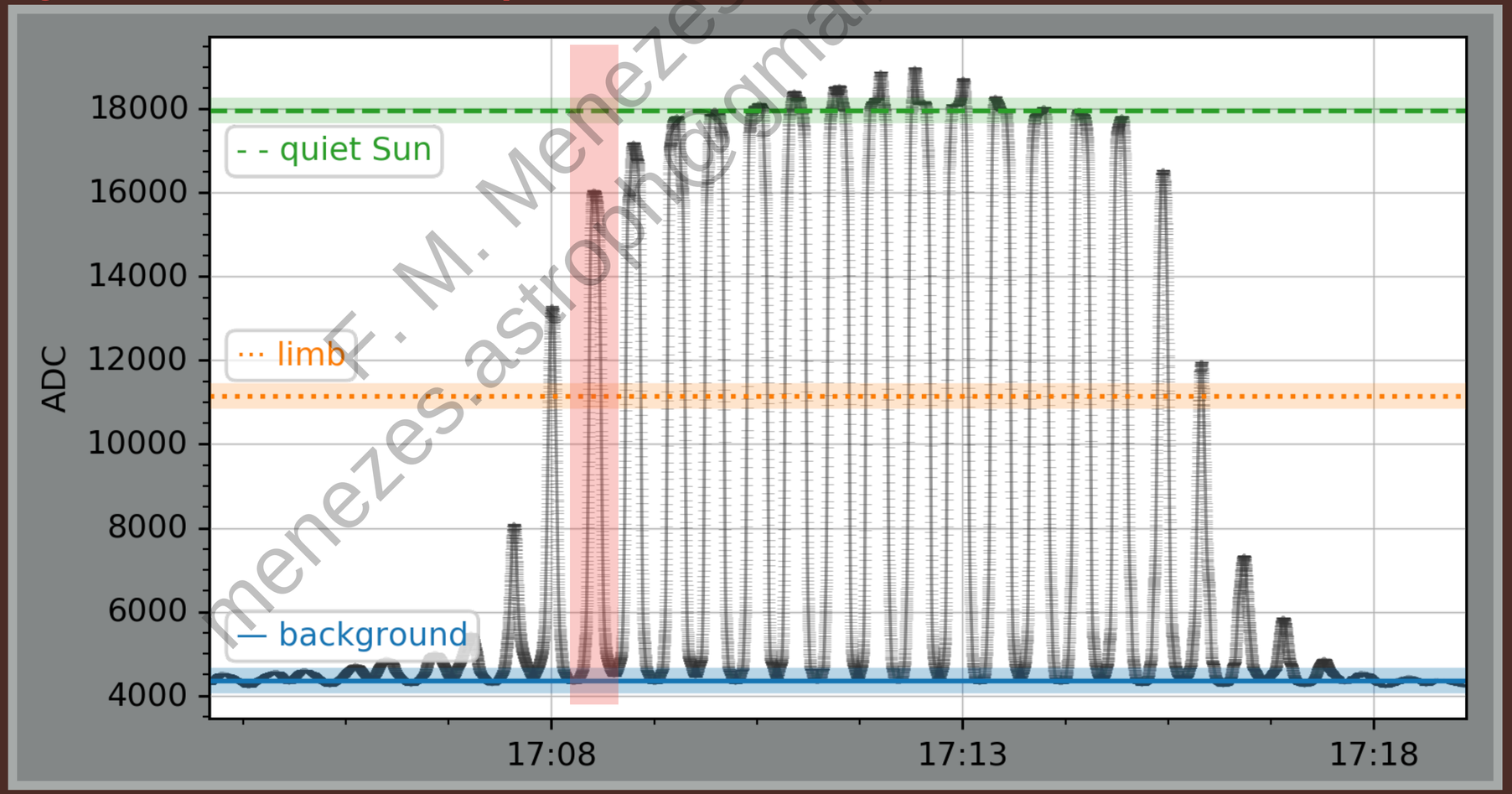

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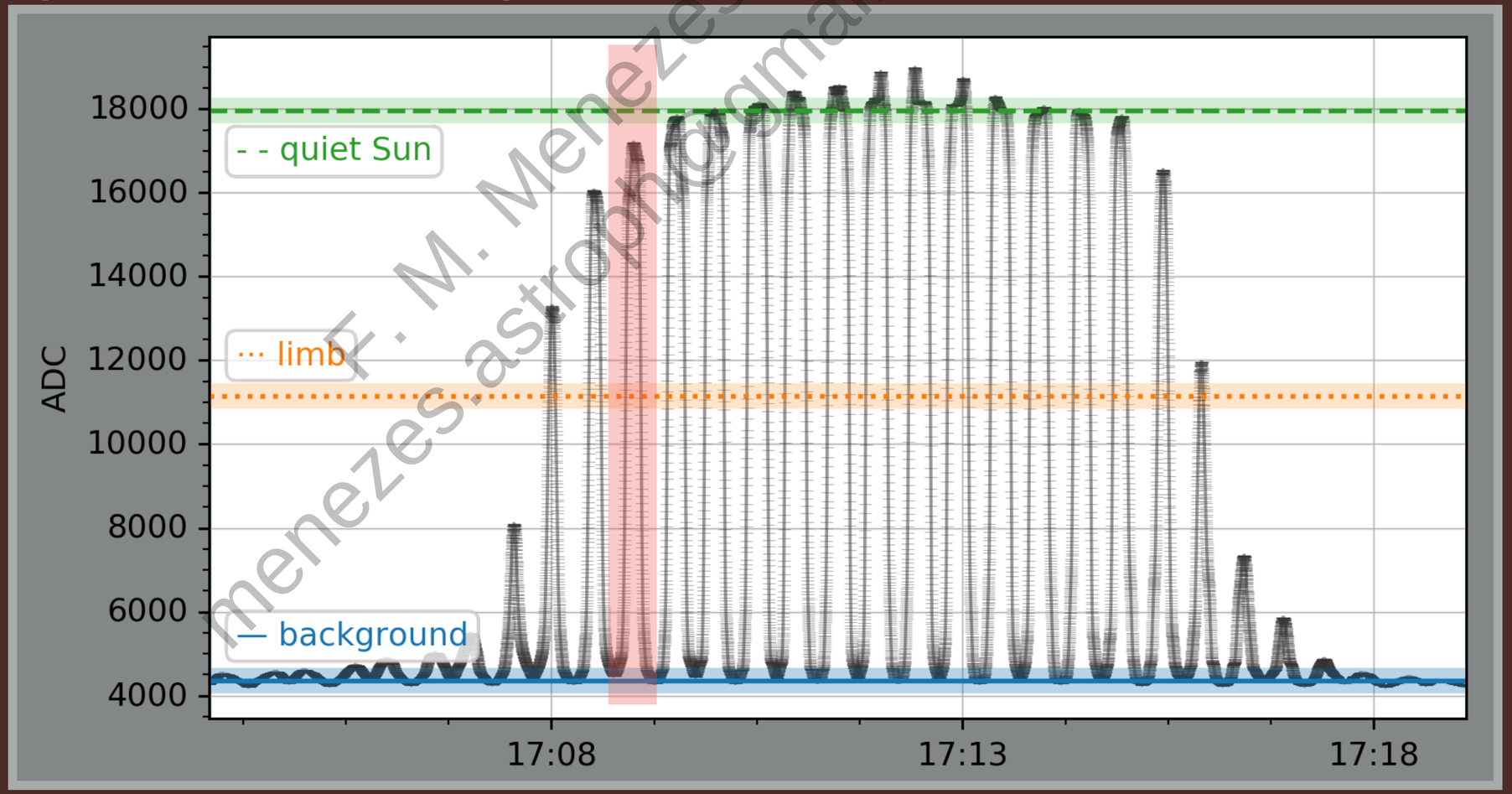

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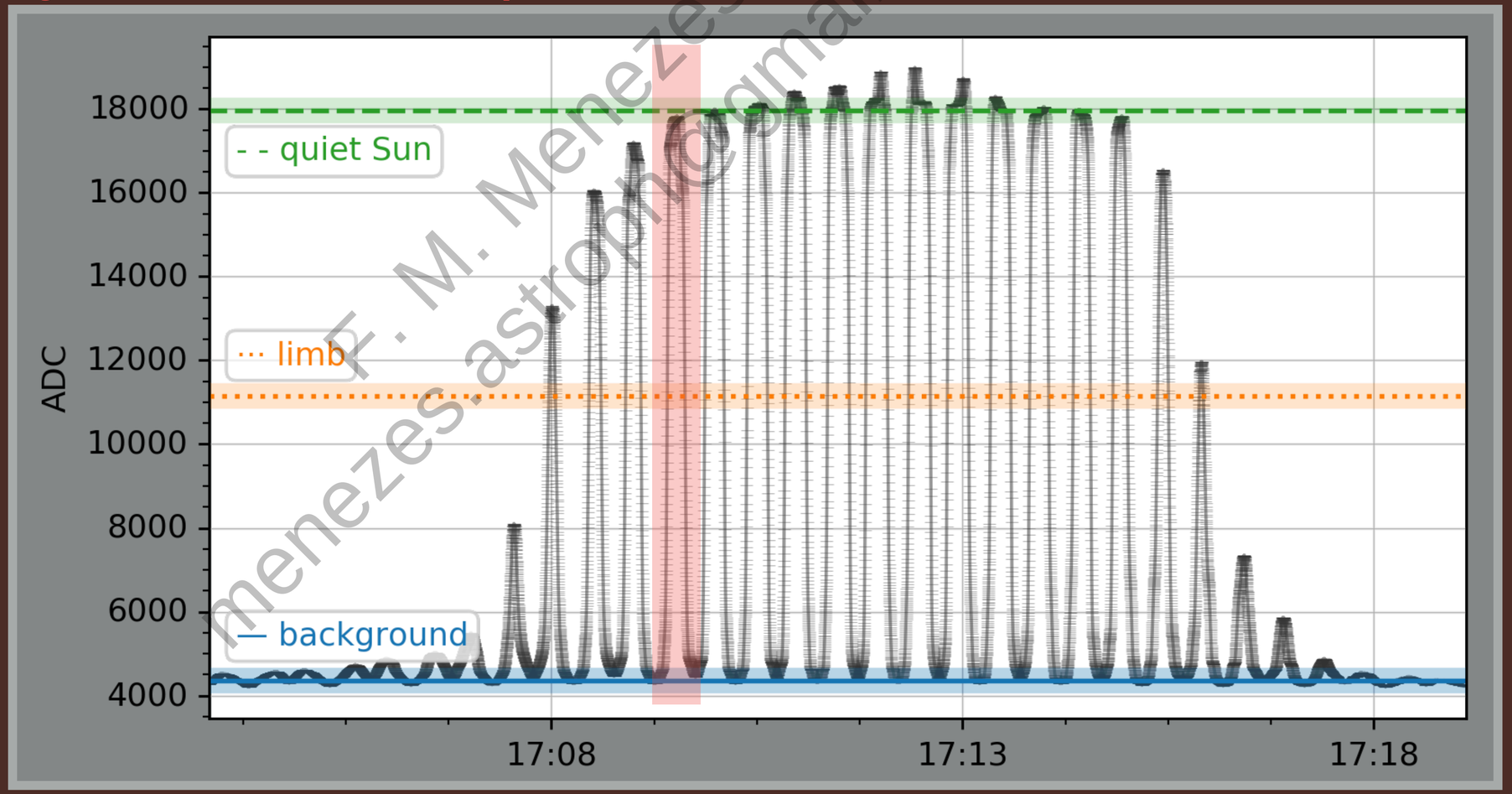

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- A circle (red line) is fitted using the limb points
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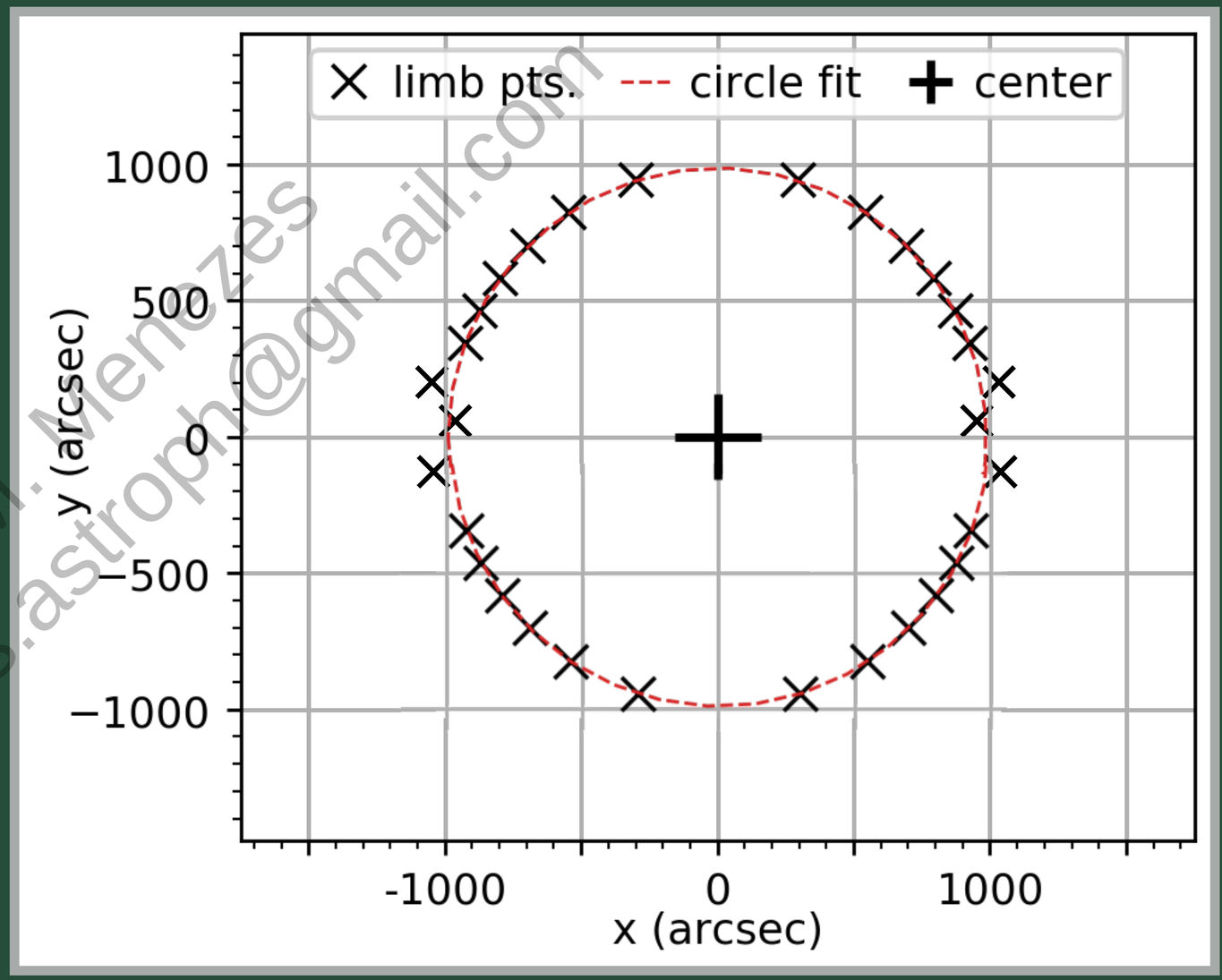

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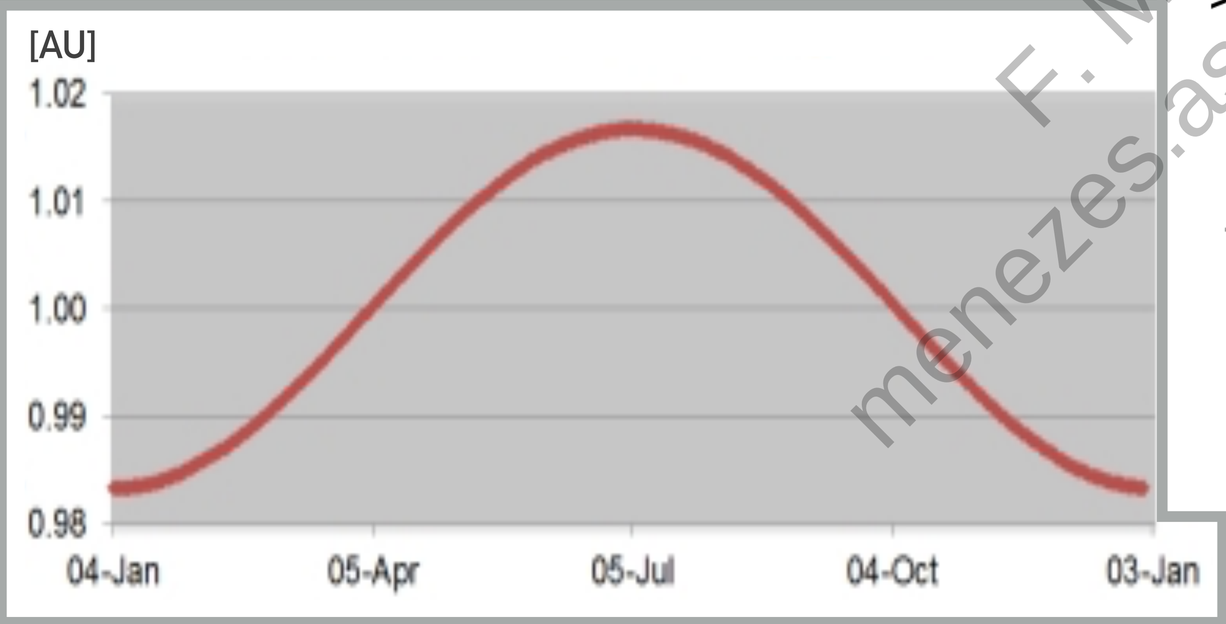
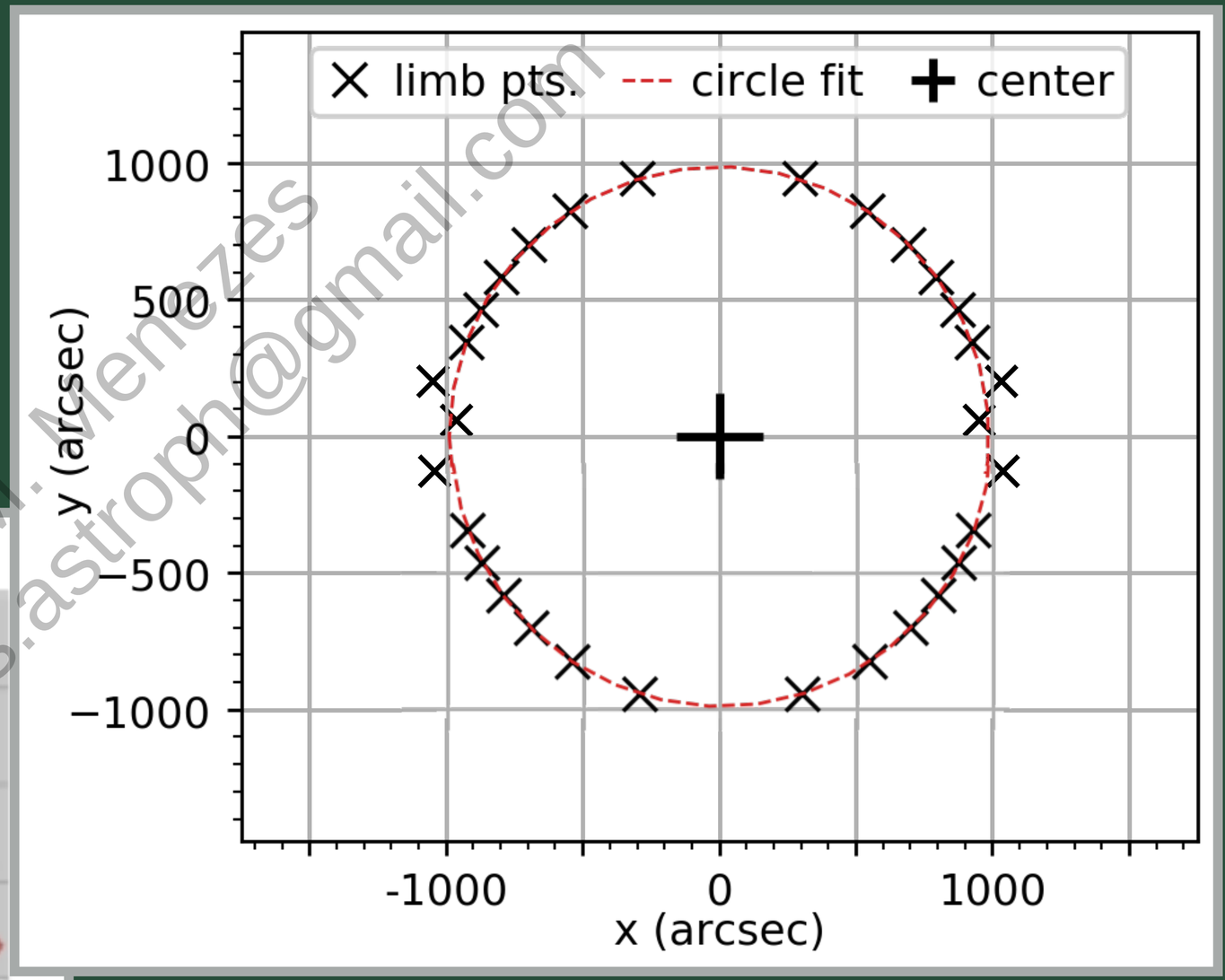
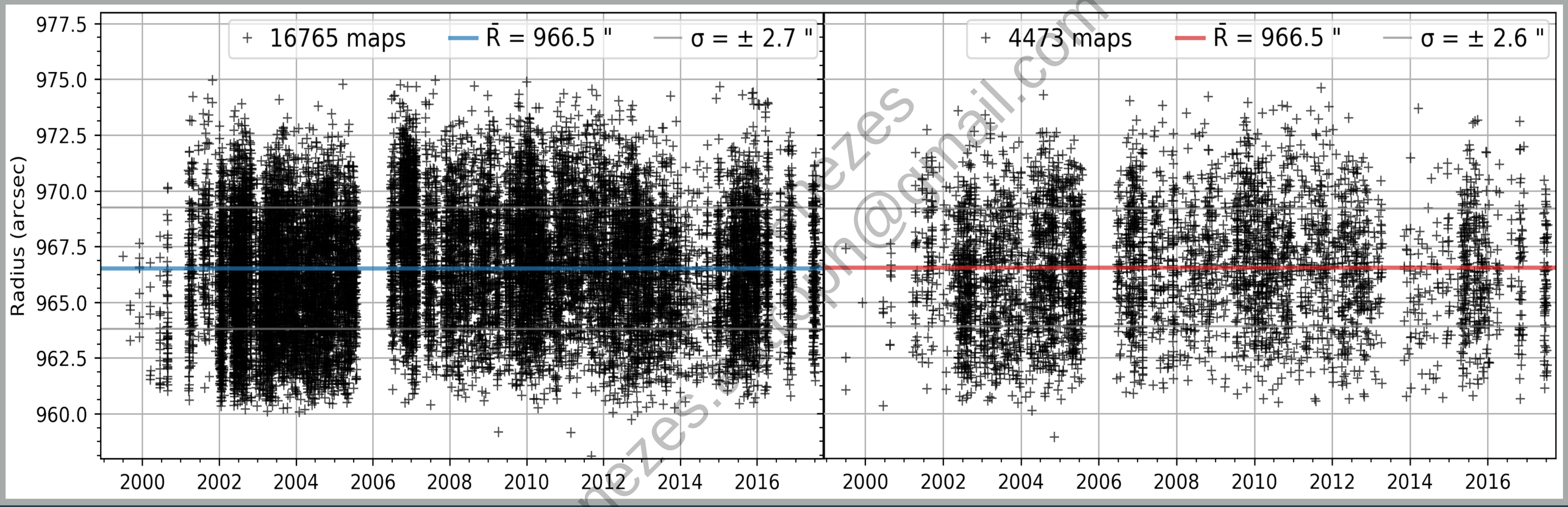




Results



0,212 THZ

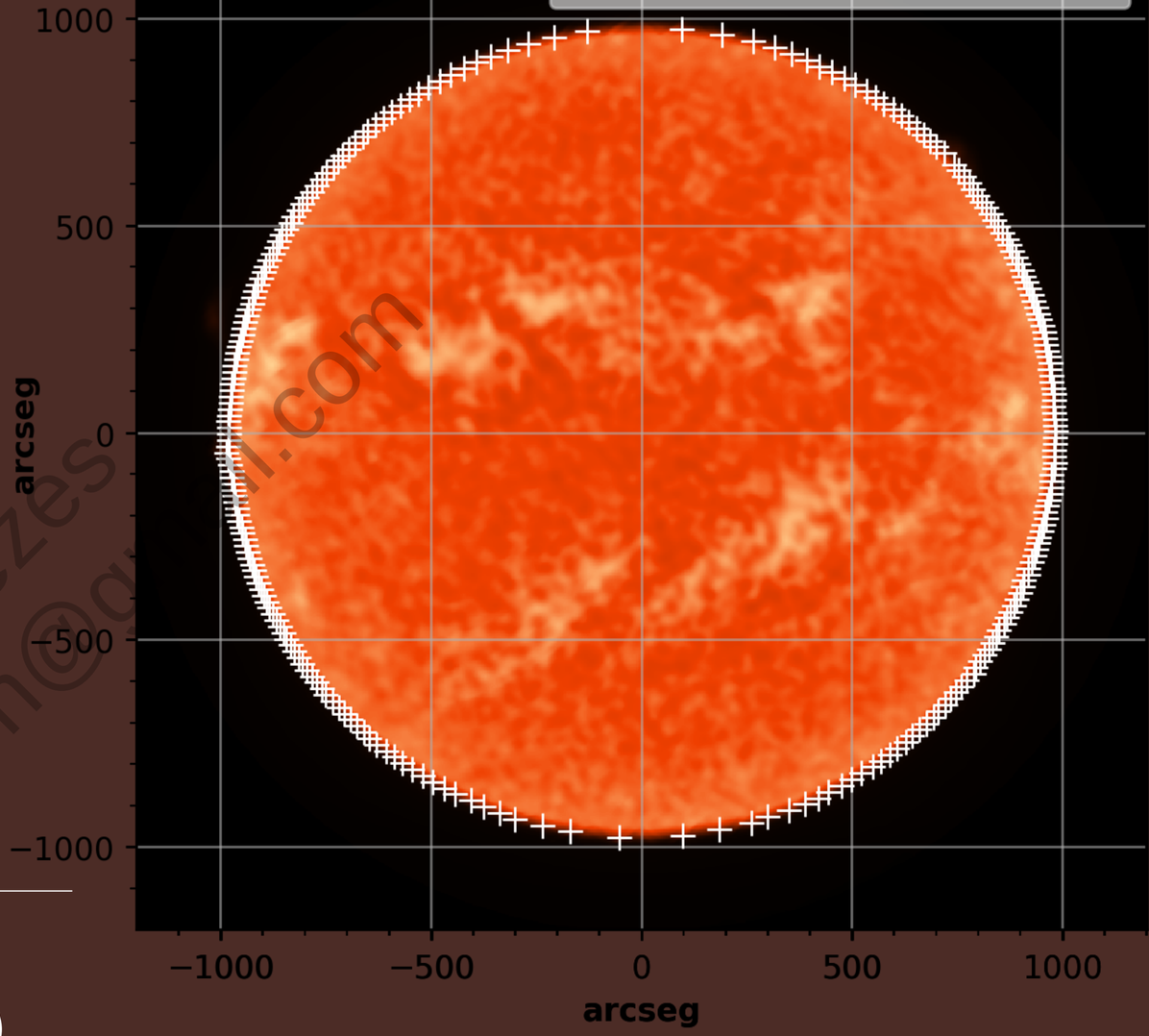
0,405 THz

Results

Frequency	Radius (arcsec)	Radius ($R_\odot$)	Radius (10^8 m)	Altitude (10^6 m)
212 GHz	966 ± 2.7	1.007 ± 0.003	7.01 ± 0.02	5.0 ± 2.0
405 GHz	966 ± 2.6	1.007 ± 0.003	7.01 ± 0.02	5.0 ± 2.0
Optical	959.63	1	6.957	0

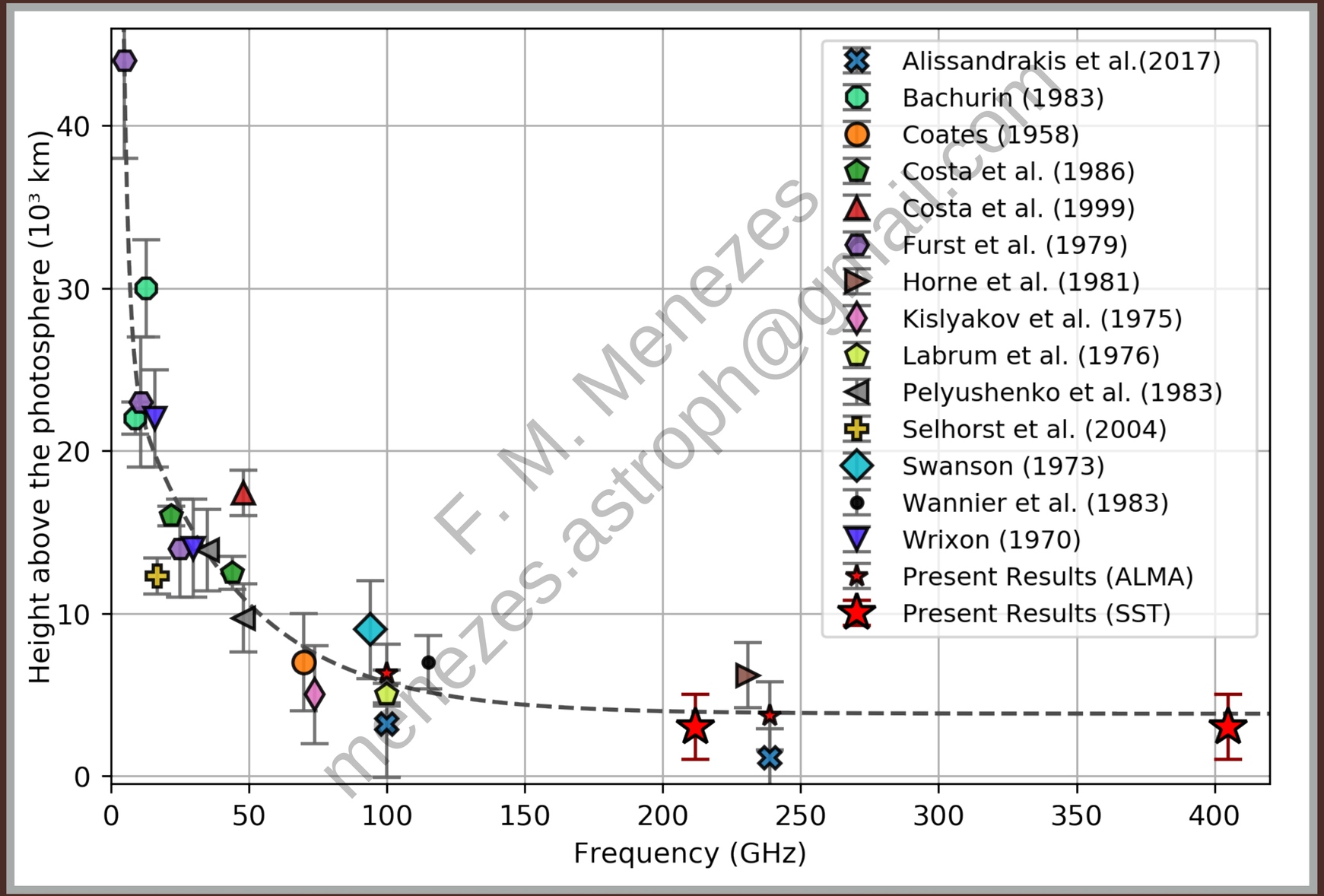
ALMA

- 0.239 THz
- 2015 Dec 17



0.2 THz	*R* (arcsec)	*R* (10^8 m)	Height (10^6 m)
SST	966 ± 2.7	7.01 ± 0.02	5.0 ± 2.0
ALMA	962.9 ± 1.9	6.980 ± 1.3	2.3 ± 1.3

Results


Height above the photosphere (10³ km)
Frequency (GHz)
0
10
20
30
40
0
50
100
150
200
250
300
350
400
Alissandrakis et al.(2017)
Bachurin (1983)
Coates (1958)
Costa et al. (1986)
Costa et al. (1999)
Furst et al. (1979)
Horne et al. (1981)
Kislyakov et al. (1975)
Labrum et al. (1976)
Pelyushenko et al. (1983)
Selhorst et al. (2004)
Swanson (1973)
Wannier et al. (1983)
Wrixon (1970)
Present Results (ALMA)
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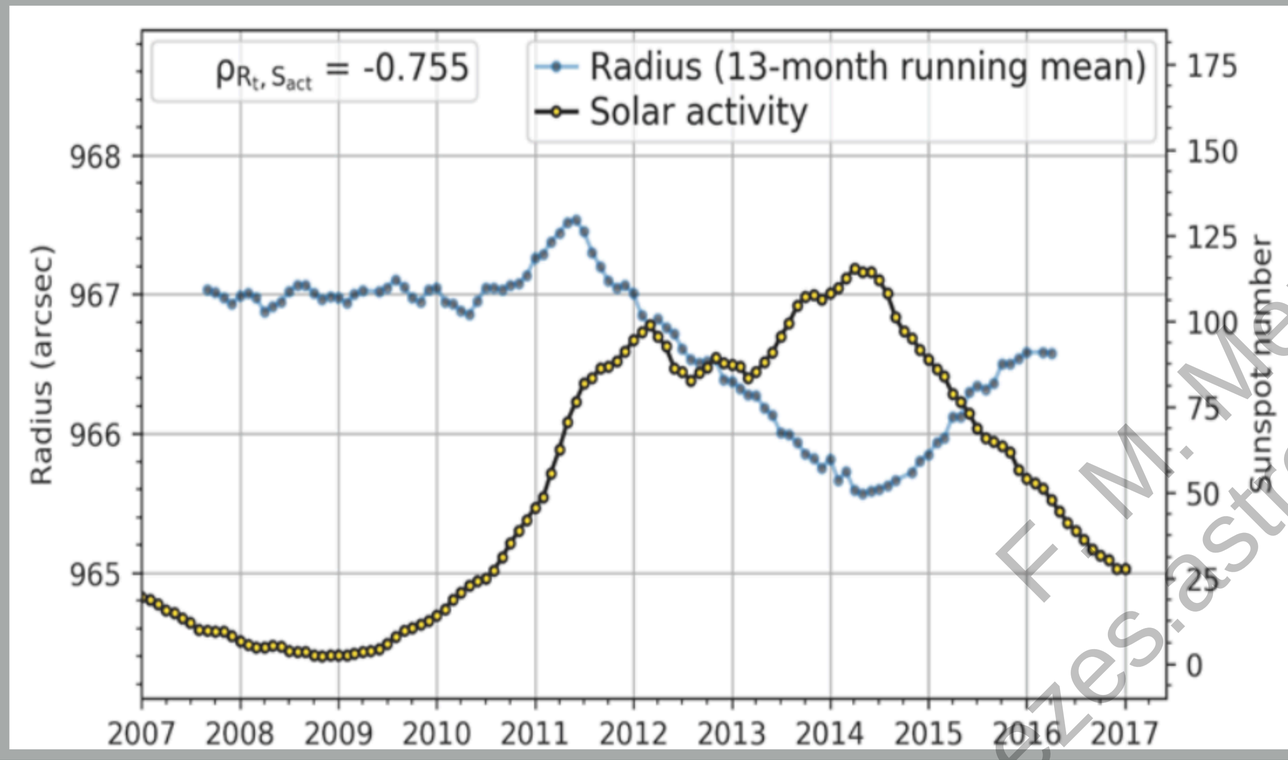
Correlation to the sunspot cycle



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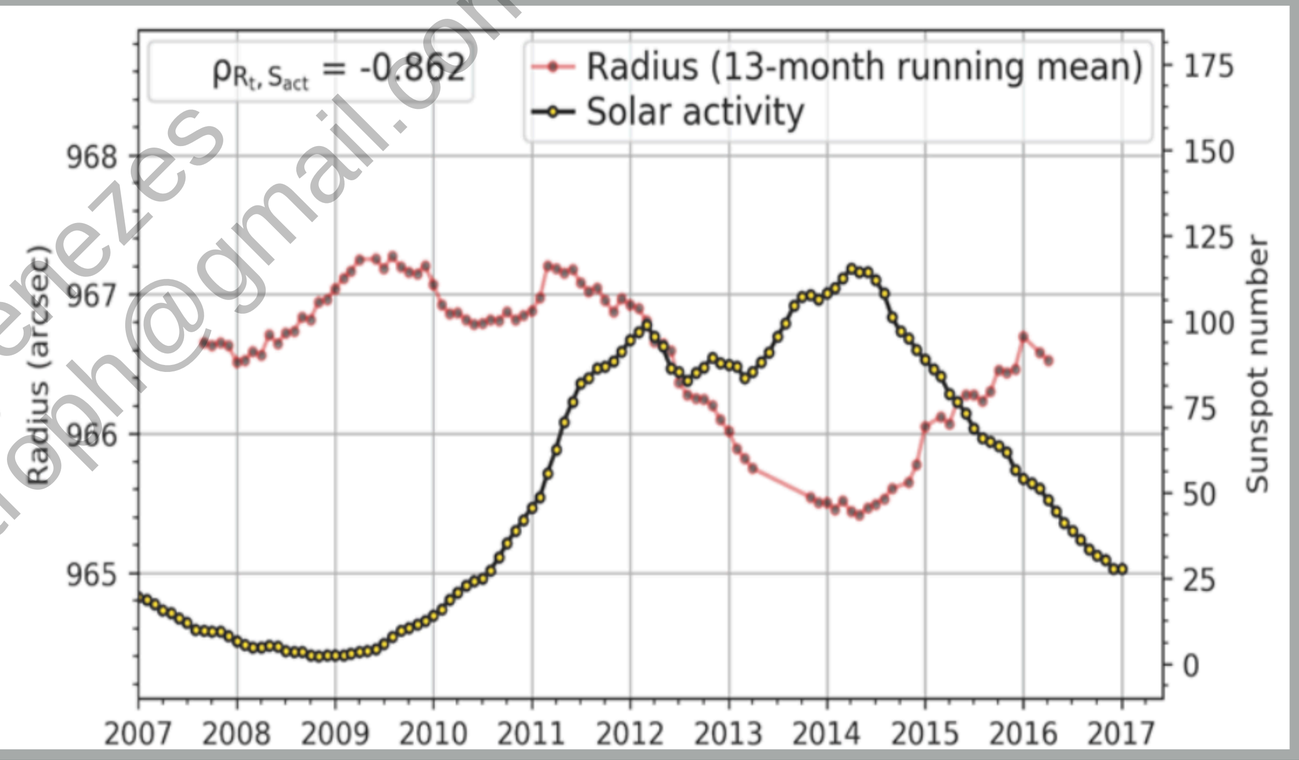
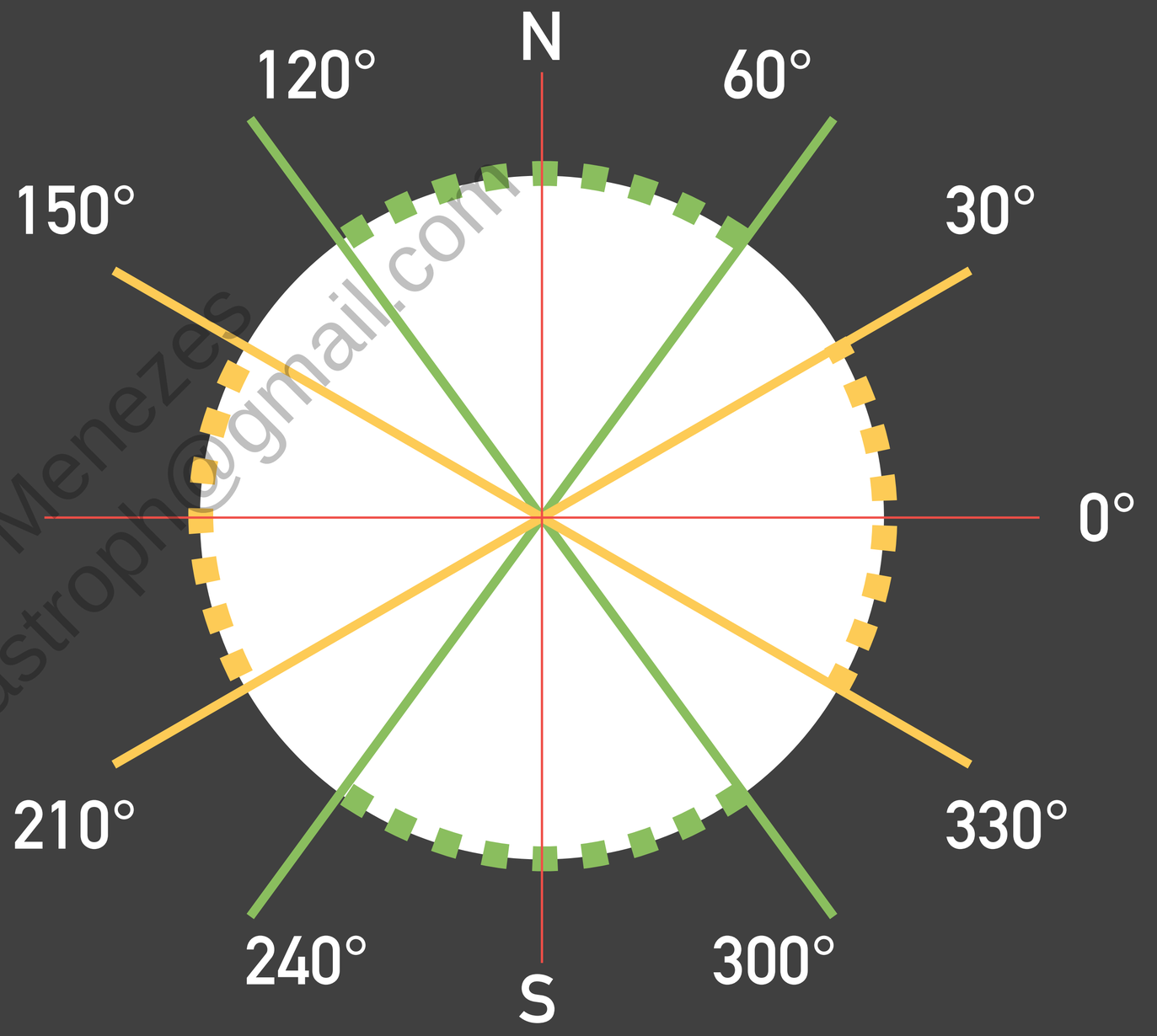


0,405 THz

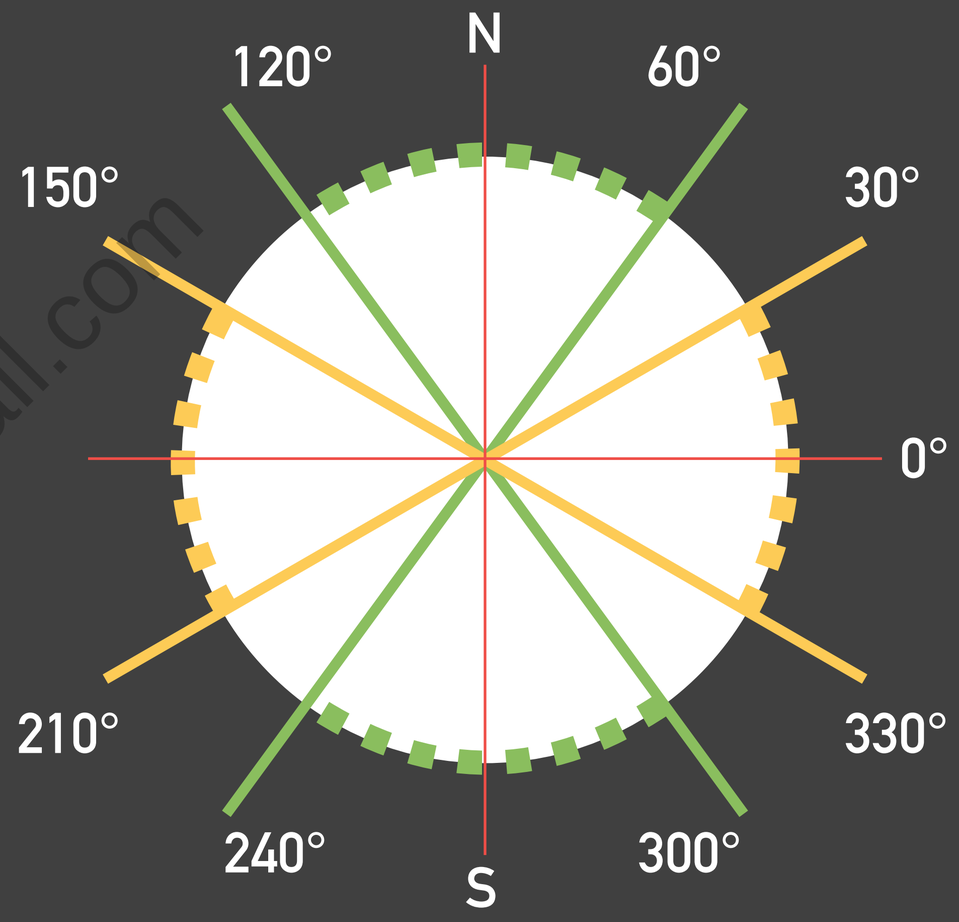
Equatorial and polar radii

- Equatorial radius
- Polar radius



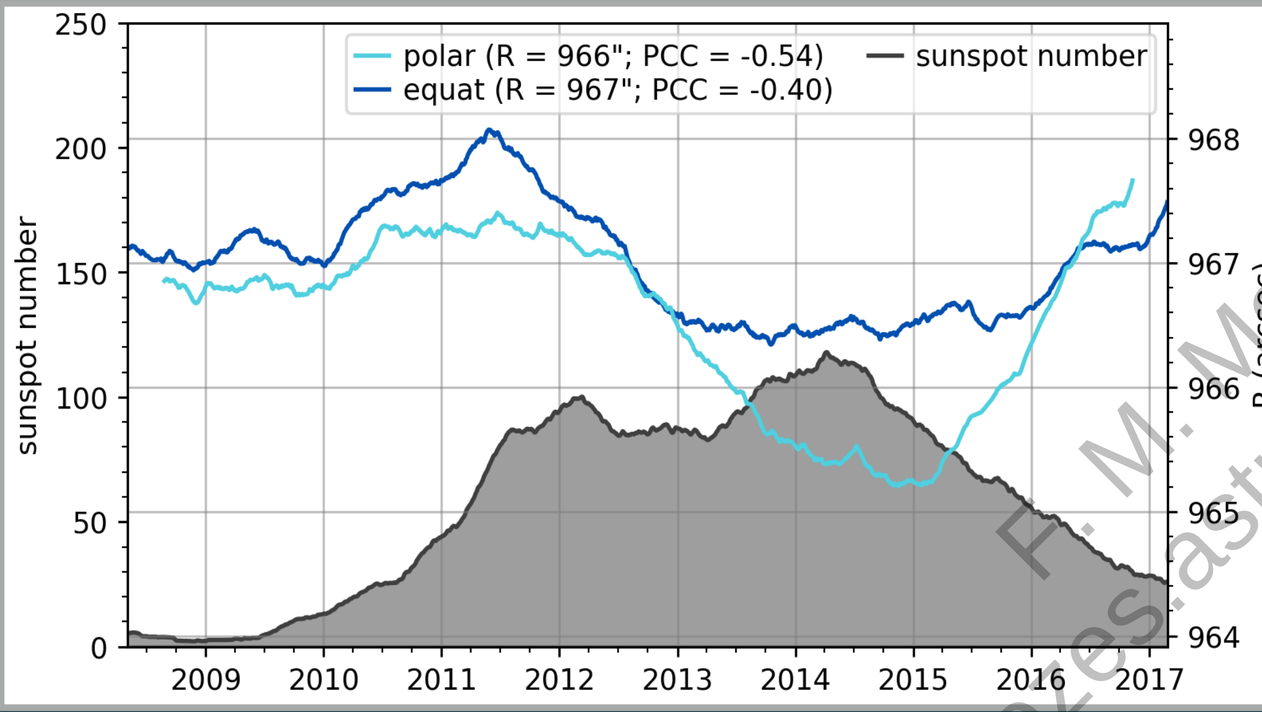
Equatorial and polar radii

R (arcsec)	All pts.	Equat.	Polar
ALMA (0.2 THz)	962.9 ± 1.9	964.2 ± 1.9	962.1 ± 1.1
SST (0.2 THz)	966 ± 2.7	966 ± 3.3	966 ± 3.5
SST (0.4 THz)	966 ± 2.6	967 ± 3.2	966 ± 3.4



- Equatorial radius
- Polar radius

Correlation to the sunspot cycle



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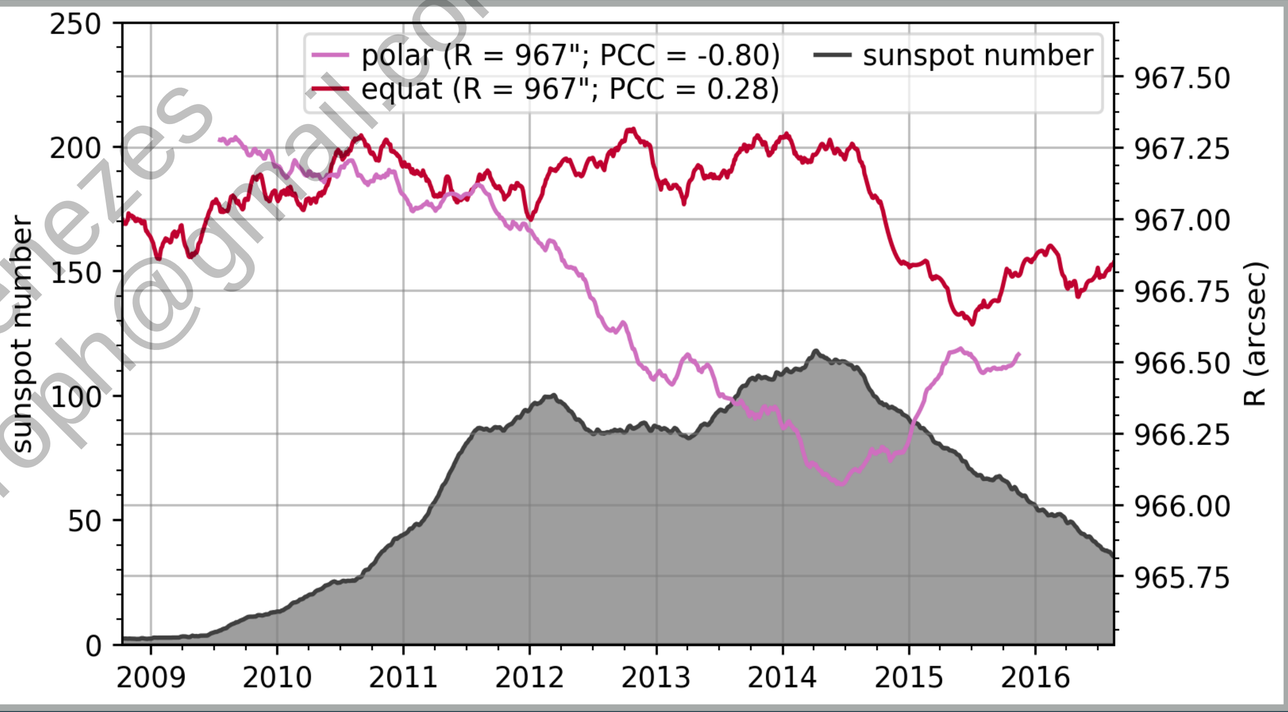
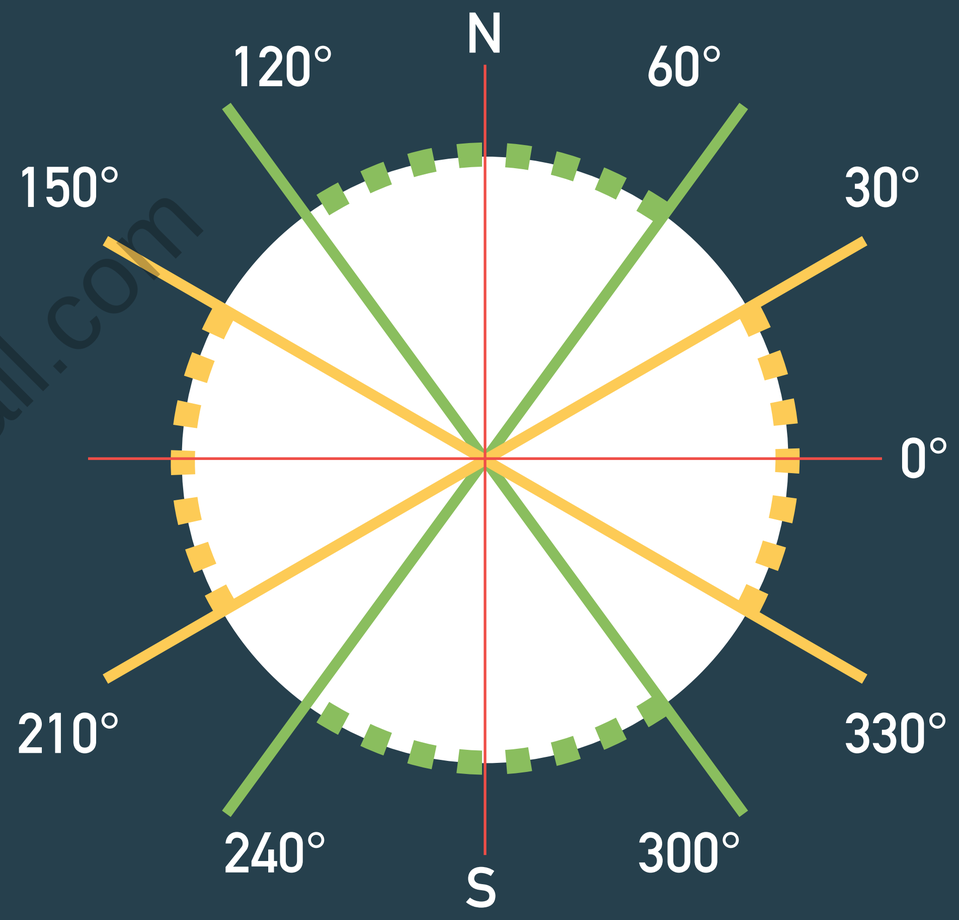


0,405 THz

Correlation to the sunspot cycle

SST	All pts.	Equat.	Polar
0.2 THz	-0.75	-0.40	-0.54
0.4 THz	-0.86	0.28	-0.80



- Equatorial radius
- Polar radius

Final remarks

- Mean solar radii at both frequencies, R = 966" ± 3"
  - Between 2500 - 7500 km above photosphere (chromosphere - corona)
  - Solar atm. models predict these freq. to be at the chromosphere
- Polar radii at both freq. are anticorr. to sunspot cycle
  - At 17 GHz there are a significant increase of polar limb brightening during solar minimum (Selhorst, 2004)
  - High solar activity is associated with increased magnetic fields, which would lead to a reduced energy flux transported by convection (Gilliland, 1981).
- 0.405 THz equat. radius weakly correlated to sunspot cycle
- 0.212 THz equat. radius anticorrelated to sunspot cycle

Aknowledgements

Mack
Pesquisa

Centro de Rádio Astronomia e Astrofísica Mackenzie

CAPES

ALMA

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youtube.com/DragõesdeGaragem

youtube.com/AstroTubers

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