Fabian Menezes

Adriana Valio

The subterahertz Sun
Equatorial and polar radii from SST and ALMA

FABIAN MENEZES

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ADRIANA VALIO
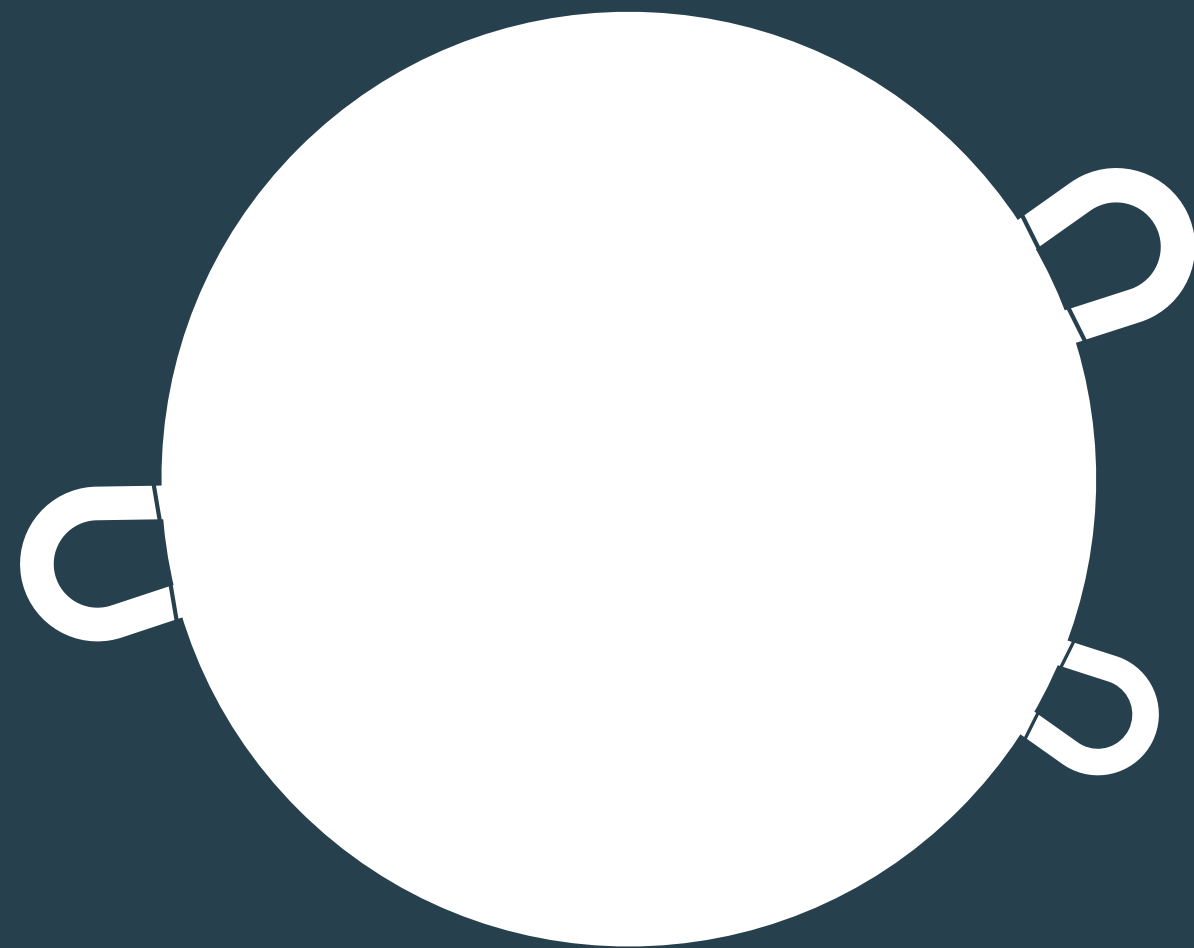
U. P. MACKENZIE - CRAAM

THE SUBTERAHERTZ SUN

EQUATORIAL AND POLAR RADII FROM SST AND ALMA

Why?

▸ 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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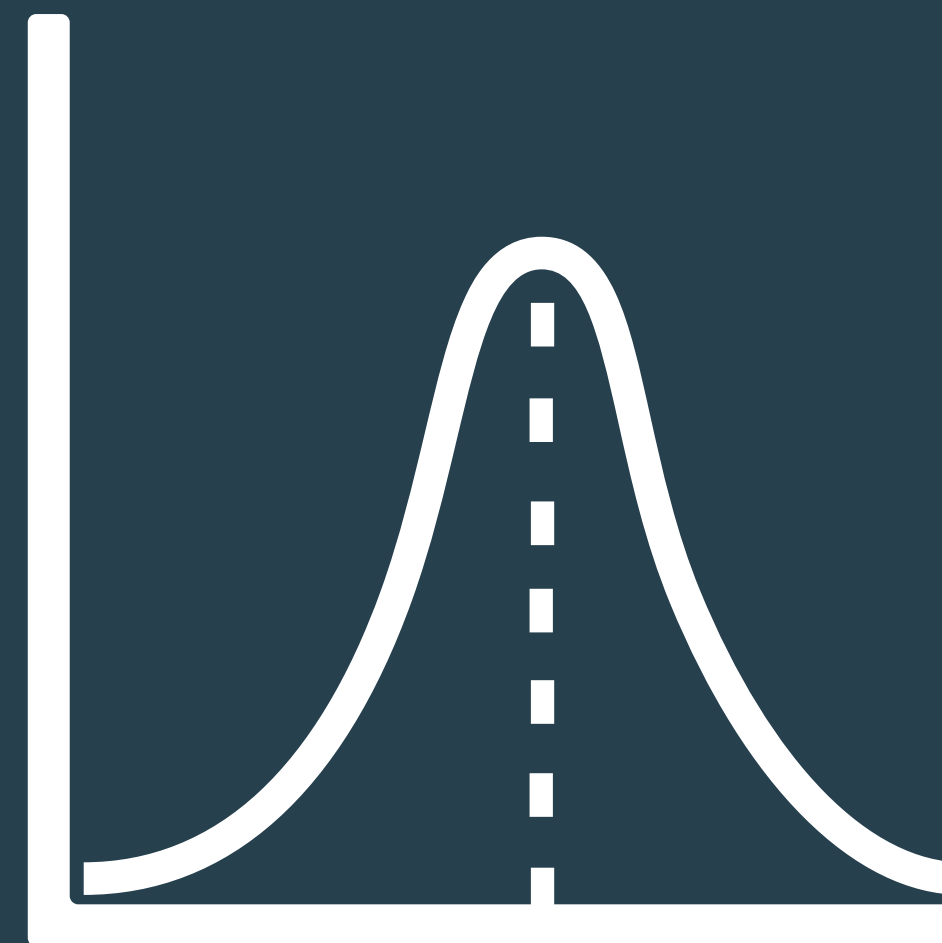‣ Gap of subterahertz frequencies in the measurements of the solar radius and other parameters of the atmosphere

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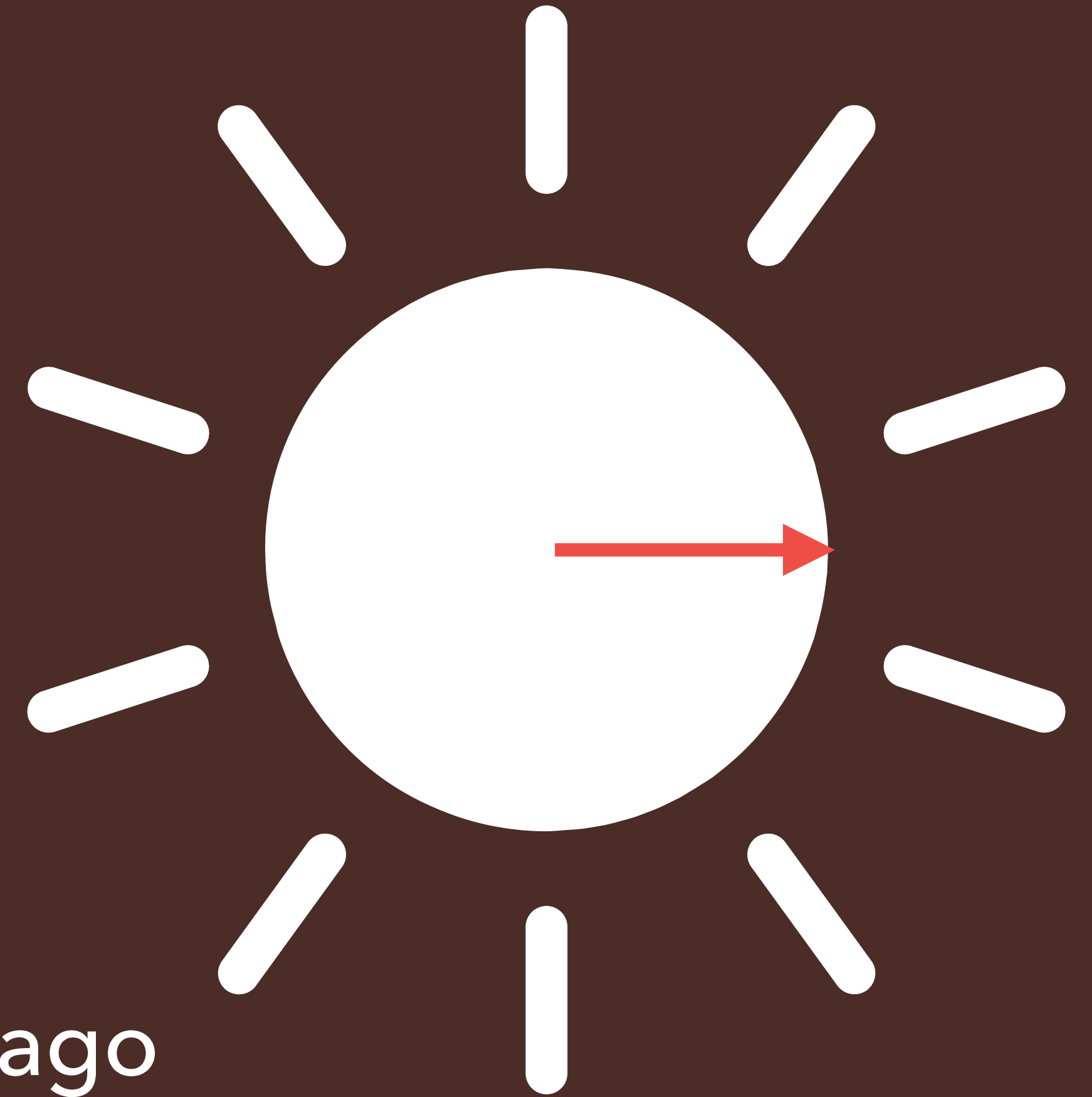▸ Gap of subterahertz frequencies in the measurements of the solar radius and other parameters of the atmosphere

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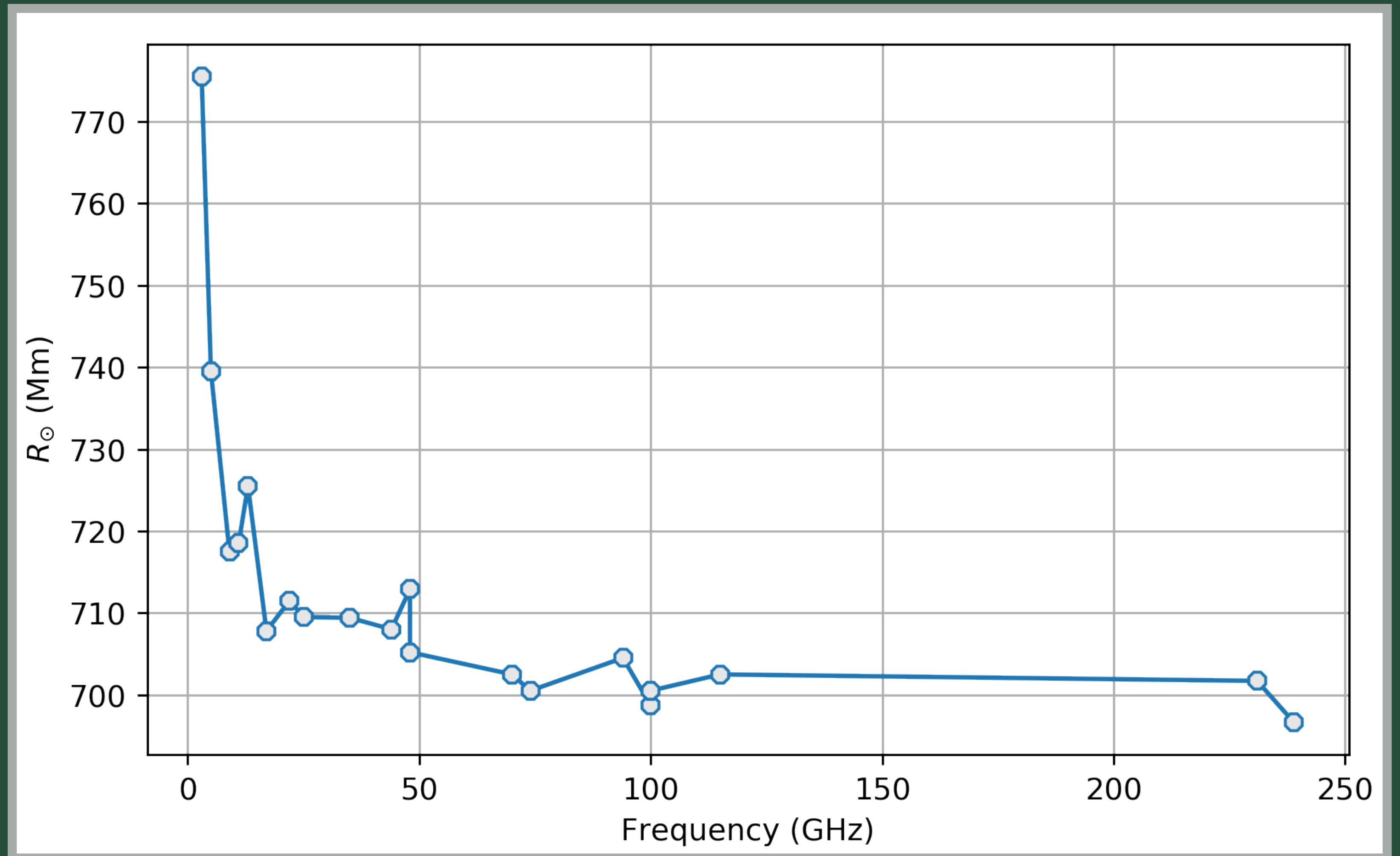▸ Gap of subterahertz frequencies in the measurements of the solar radius and other parameters of the atmosphere

Solar Radius

- $R_\odot^N = 6.957 \times 10^8$ m

- Centuries of measures

  - Vaquero et al. (2016) – 233 years

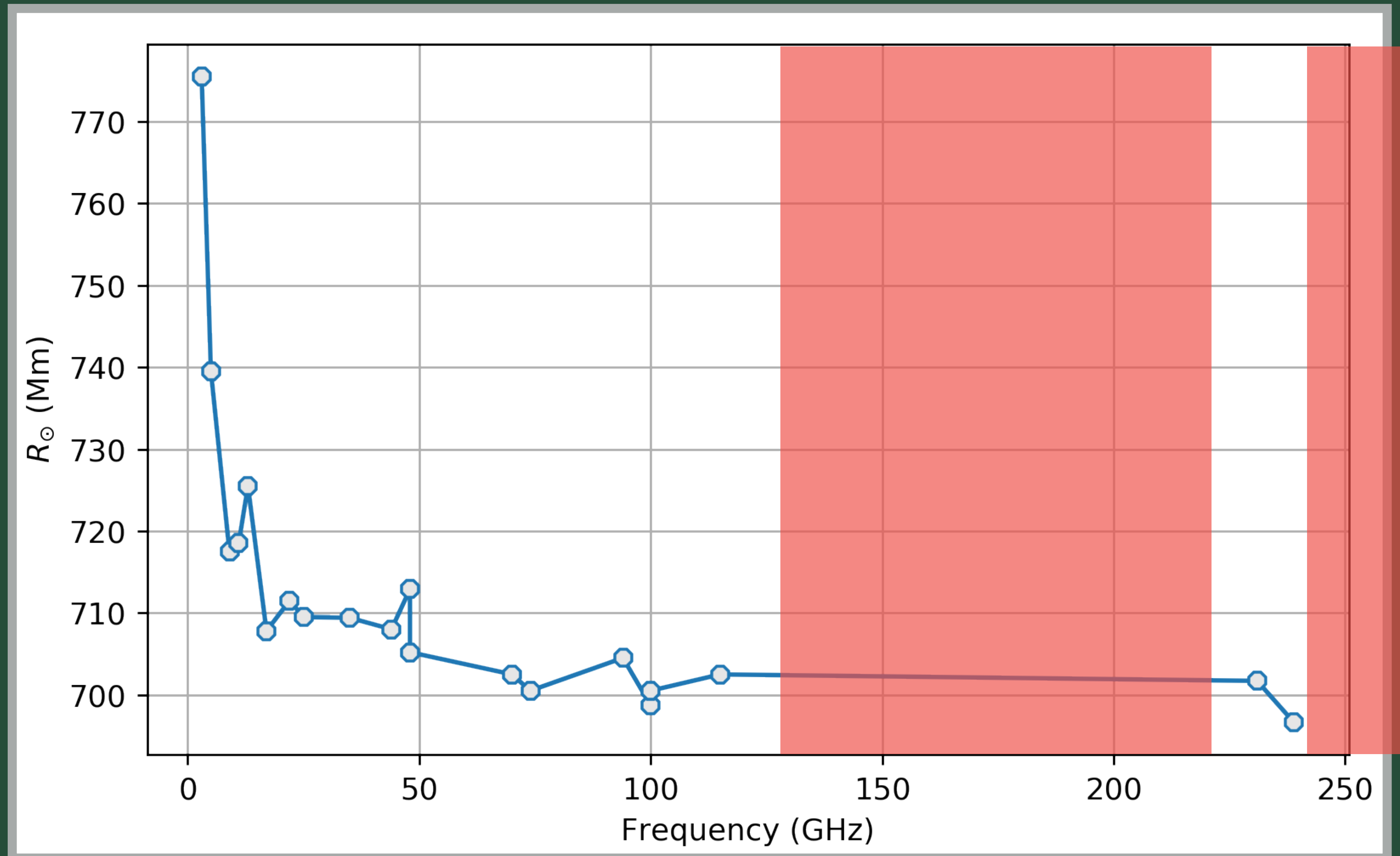 - Gilliland (1981) – 265 years

- Radio wavelengths started some decades ago

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Solar Radius

v (GHz)	R (Mm)	v (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
30	710.0	100 [d]	701
35	709.9	231	702.2
44	708.5	239	697.1
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Correlation to solar activity

- **Costa et al. (1999)**

  - Rádio Observatório de Itapetinga (**ROI**)

  - 48 GHz single-dish
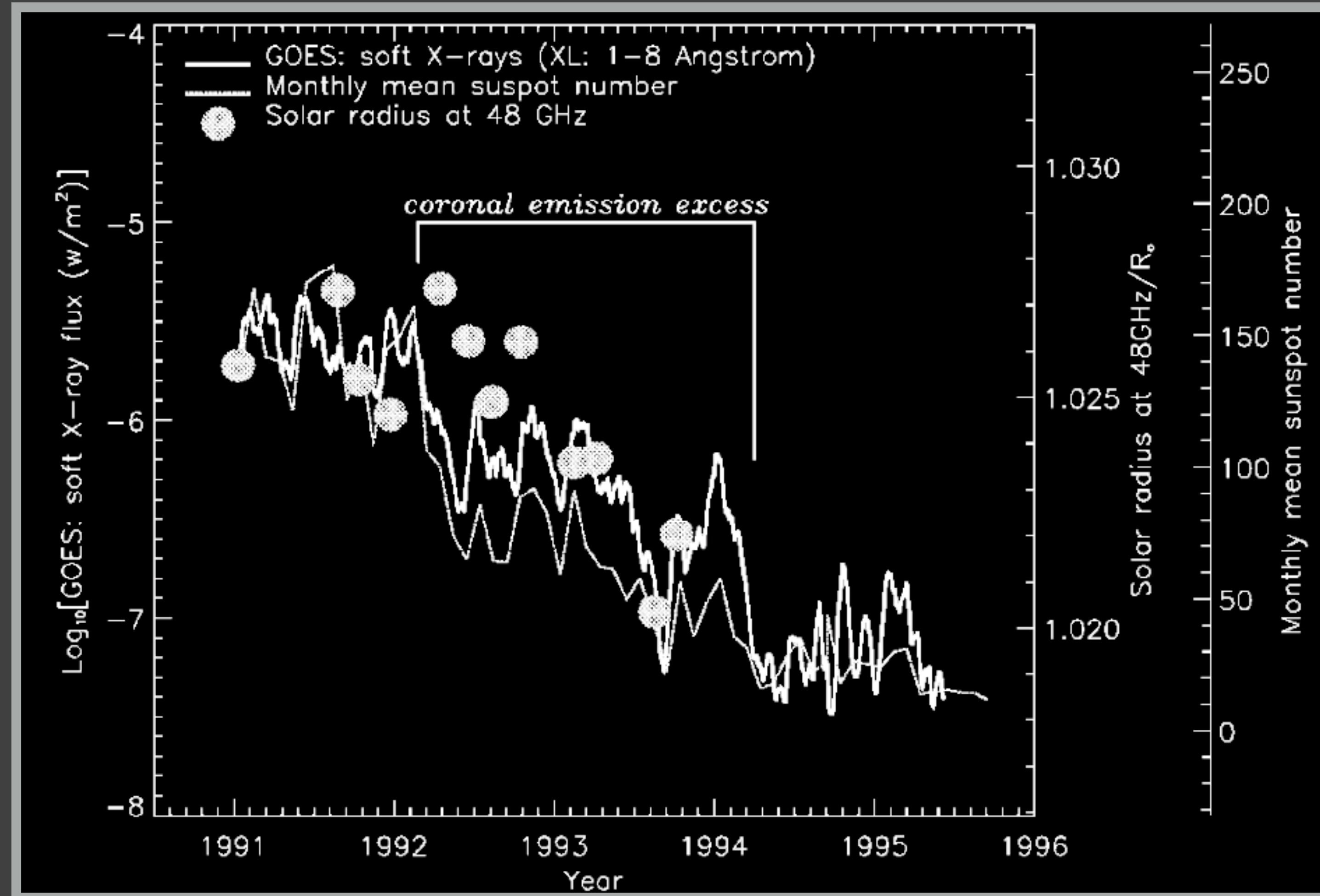
  - 1991 – 1993 (3 yrs)

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

Correlation to solar activity

▸ **Selhorst et al. (2004)**

    ▸ 17 GHz from NoRH

    ▸ 1992 – 2003 (1 cycle)

    ▸ Correlation coeficient: 0.88

    ▸ Polar radius: corr. coef.: –0.64

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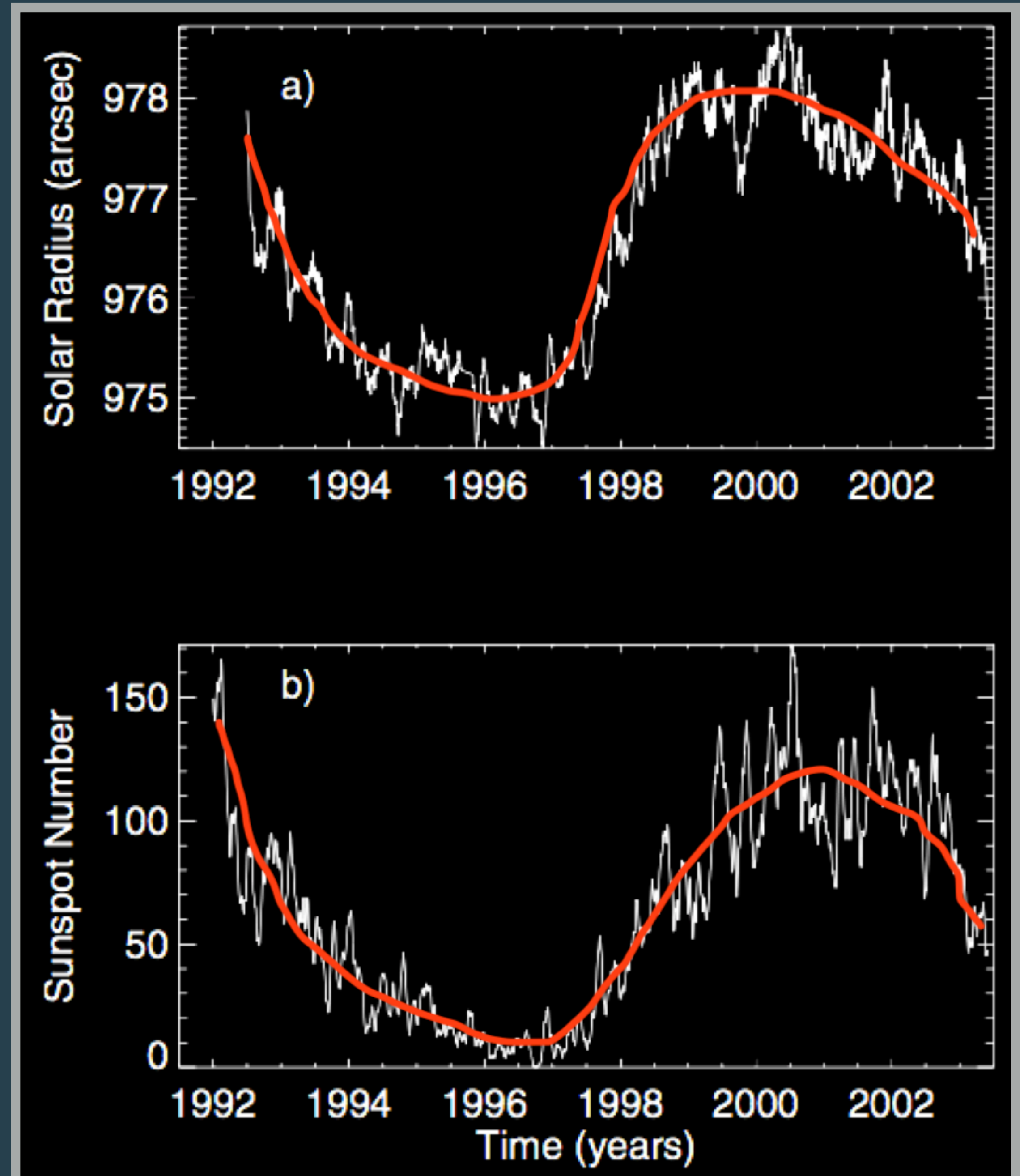
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▸ Avarage solar radius at 0.212 and 0.405 THz

▸ Height above photosphere where these emissions are being mainly created

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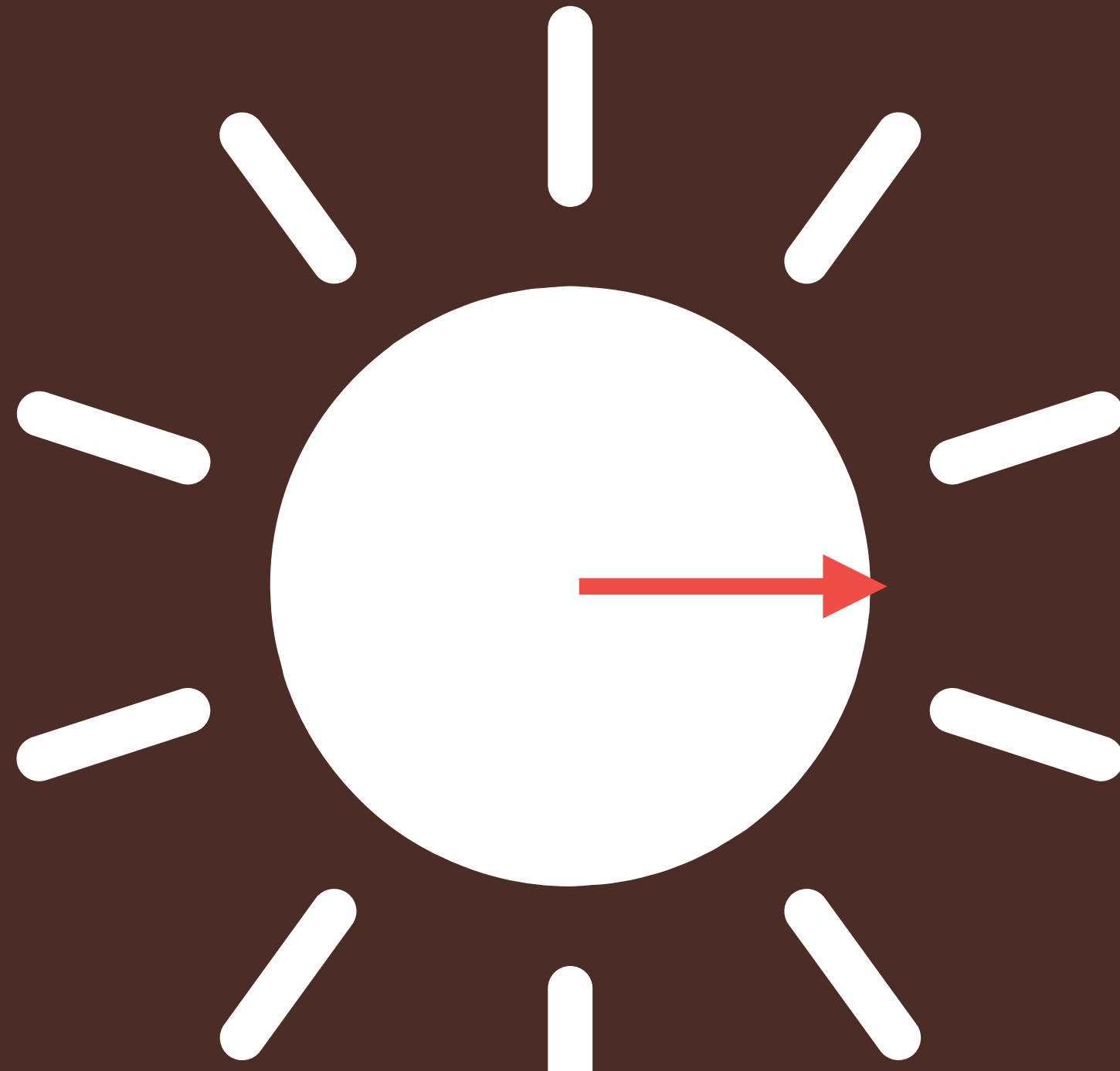
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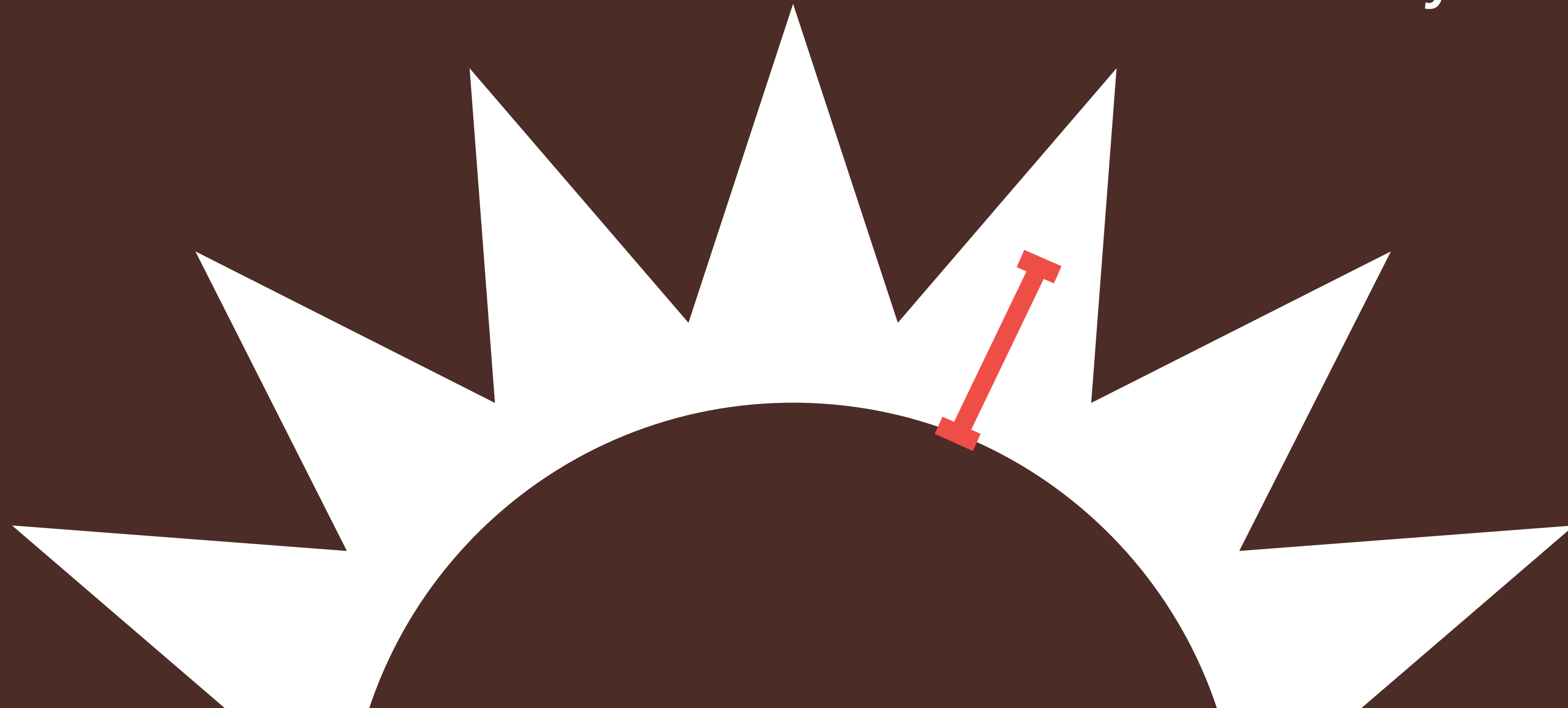
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Solar Submillimeter Telescope

‣ CASLEO - San Juan, Argentina (Andes, 2550 m)

‣ from 2007 to 2017

‣ 0.212 THz: 4 beams, HPBW = 4'

‣ 0.405 THz: 2 beams, HPBW = 2'

‣ Time resolution: 5 millisec.
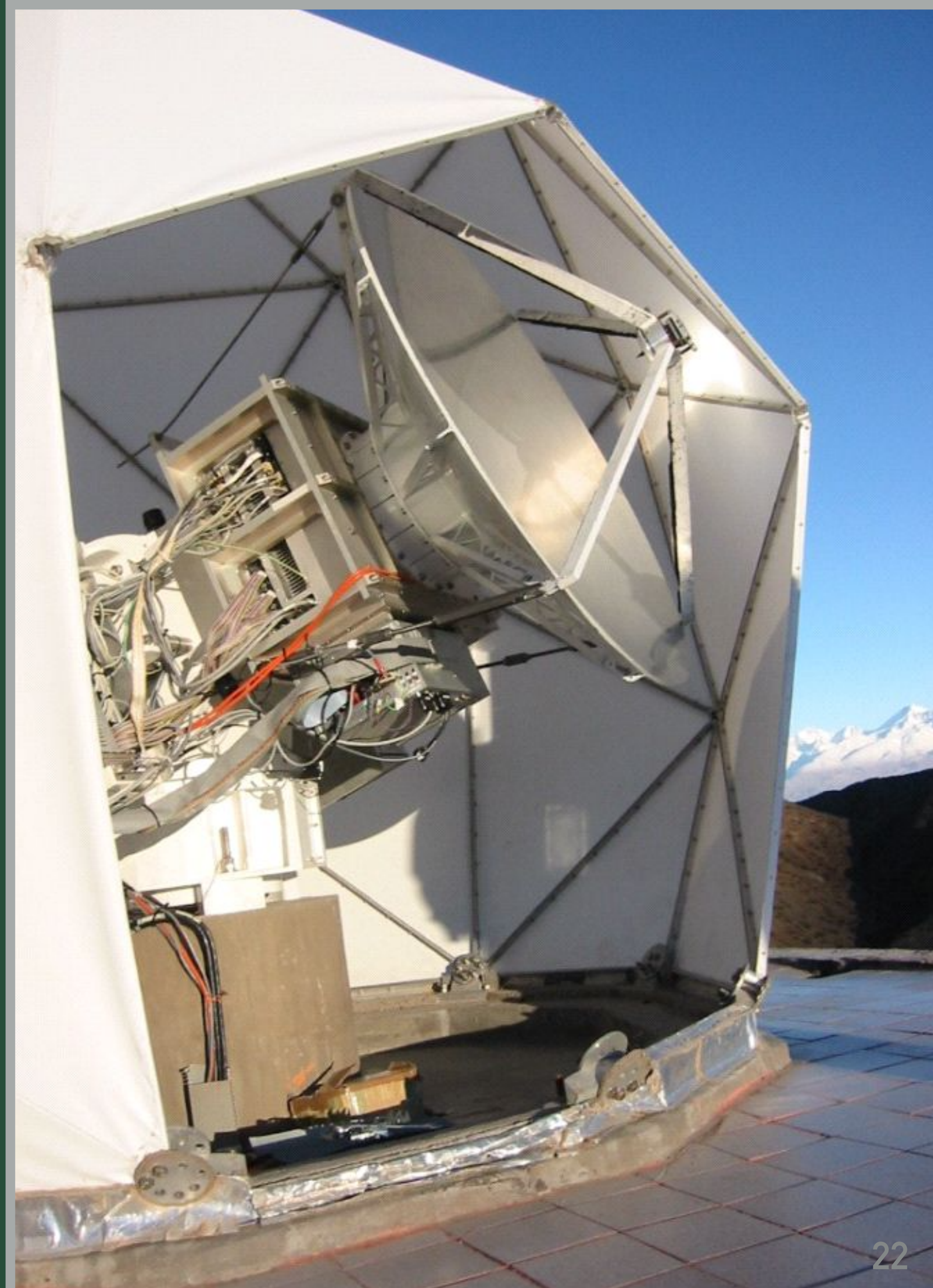
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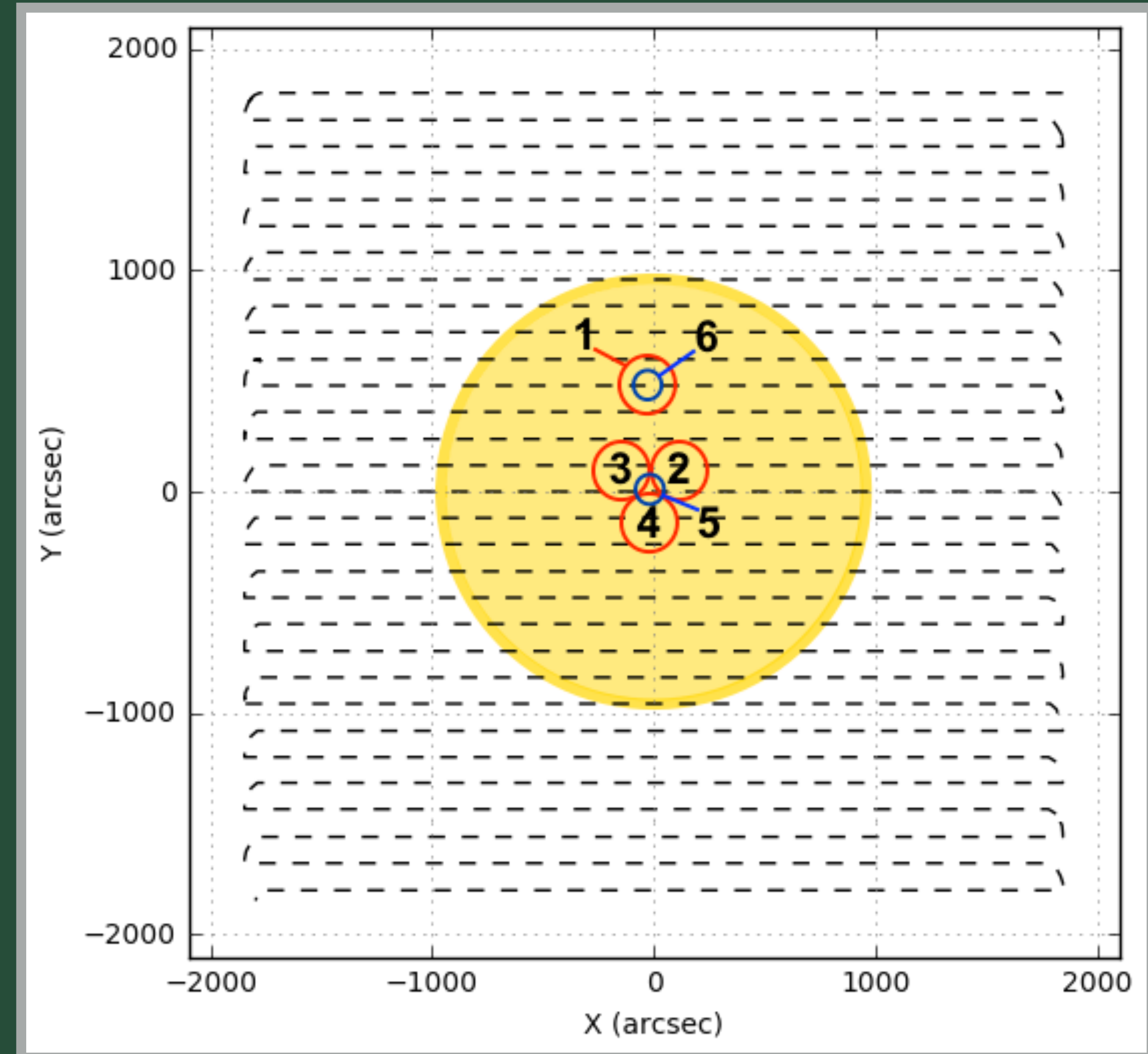
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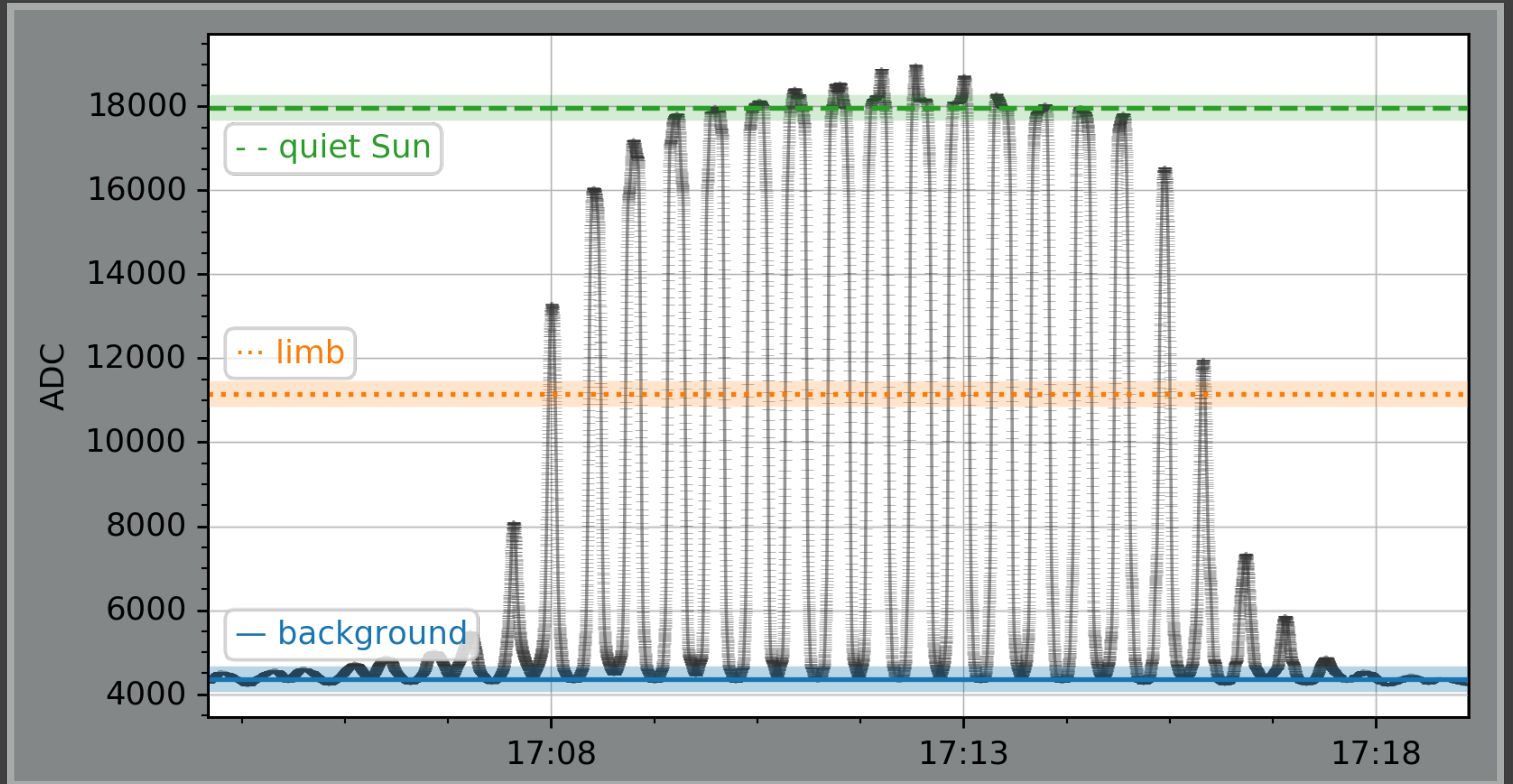
Background, quiet sun & limb levels

▸ Get the coordinates corresponding to the limb level

▸ Made for every scan of the map
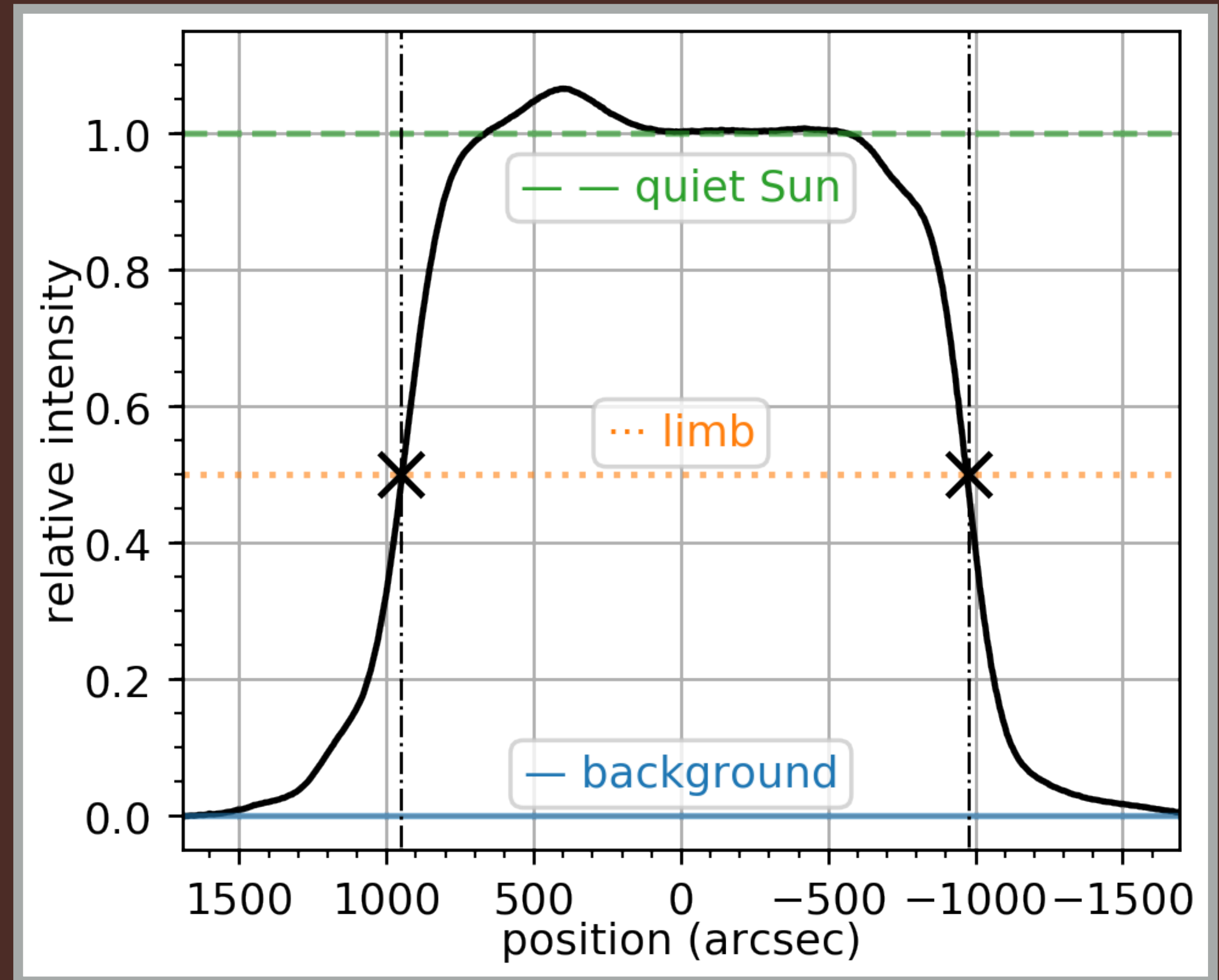
Background, quiet sun & limb levels

▸ A circle (red line) is fitted using the limb points
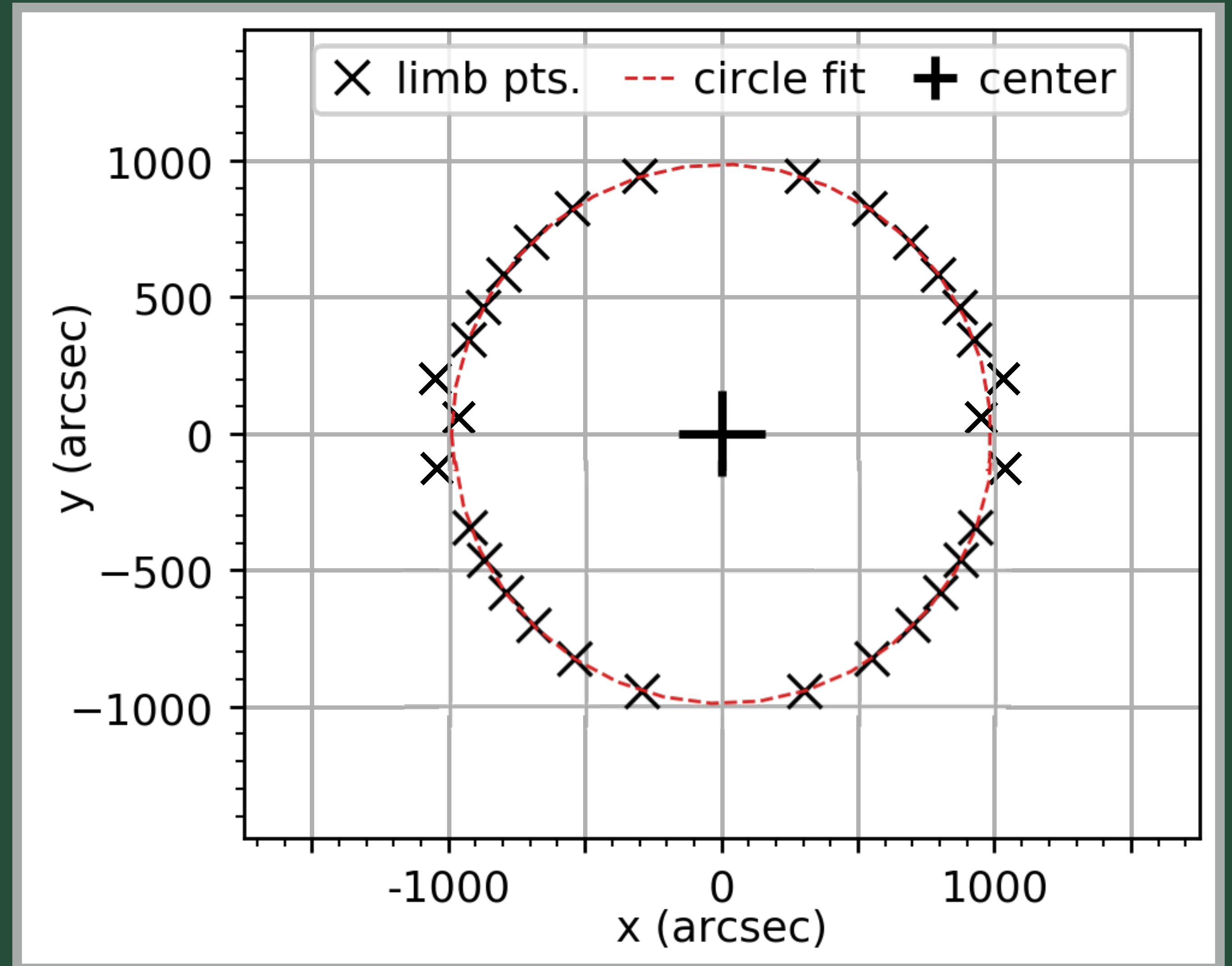
Results
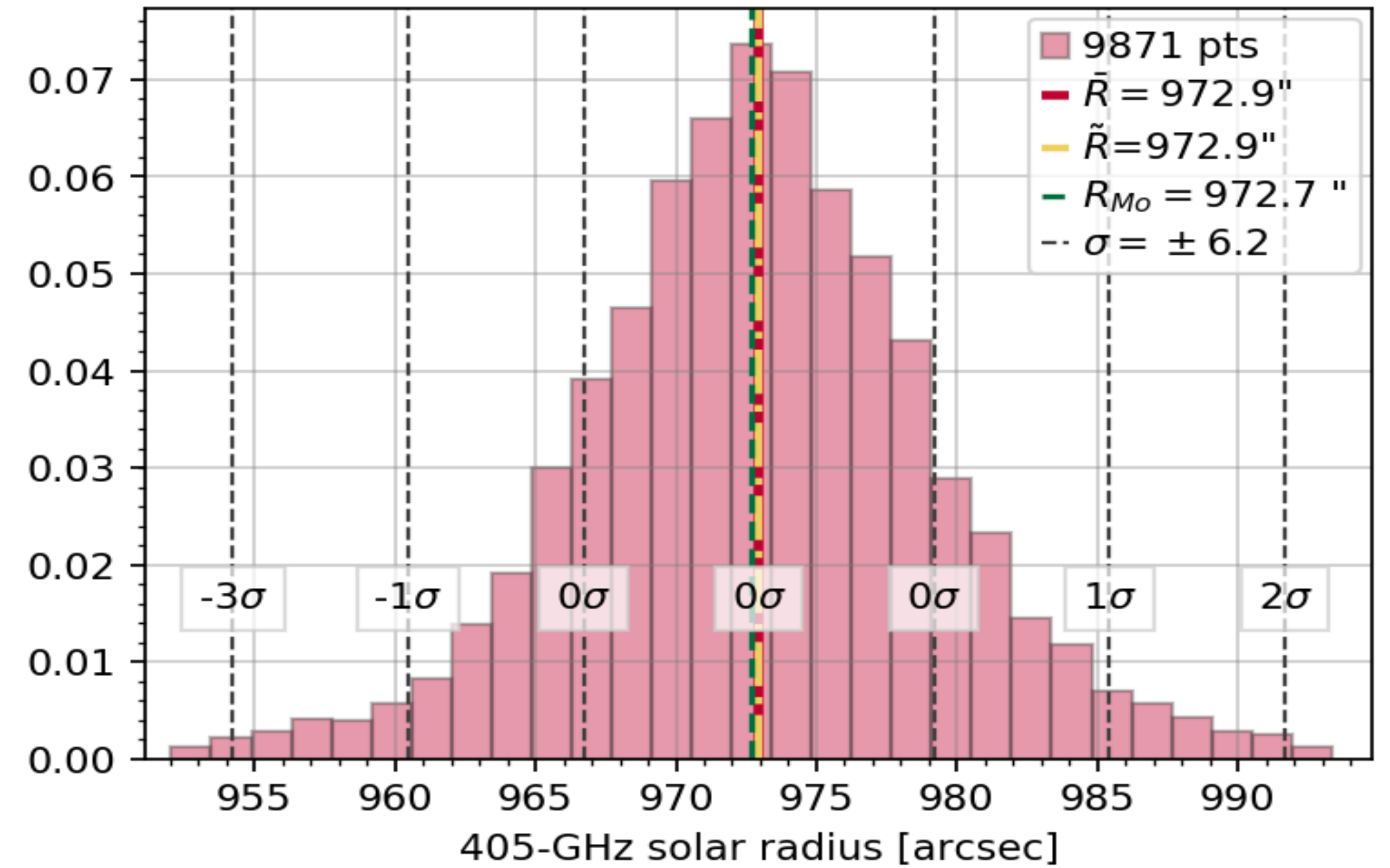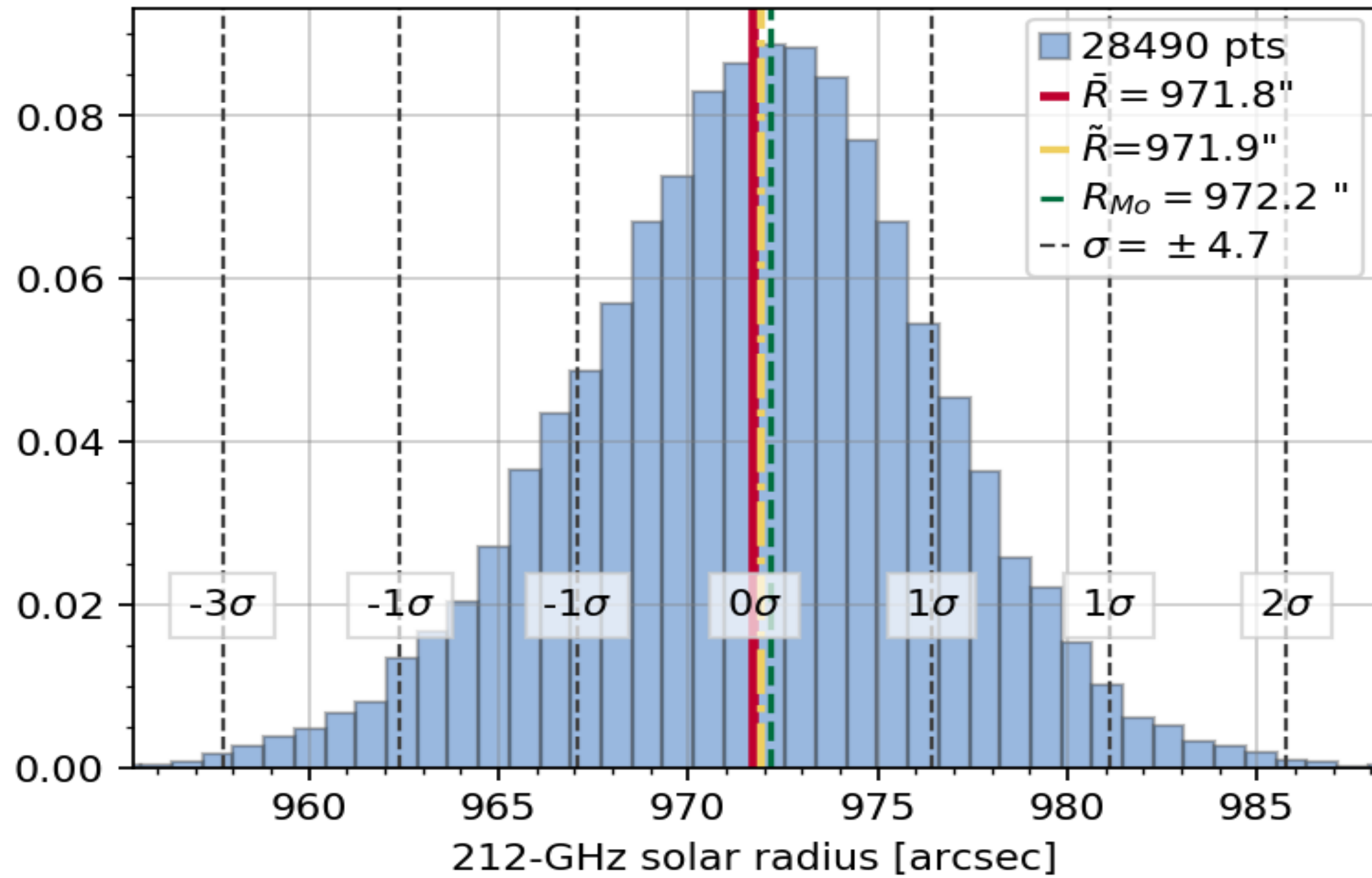
0,212 THz — 0,405 THz

Frequencies	R (arcsec)	R ($R_\odot$)	R (10^3 km)	Height (10^3 km)
0.2 THz	972 ± 5	1.013 ± 0.005	704 ± 3	9 ± 3
0.4 THz	973 ± 6	1.014 ± 0.007	705 ± 5	10 ± 5
Optical	959.63	1	6.957	0

ALMA

- 0.239 THz

- 6 maps 17-20 Dec 2015
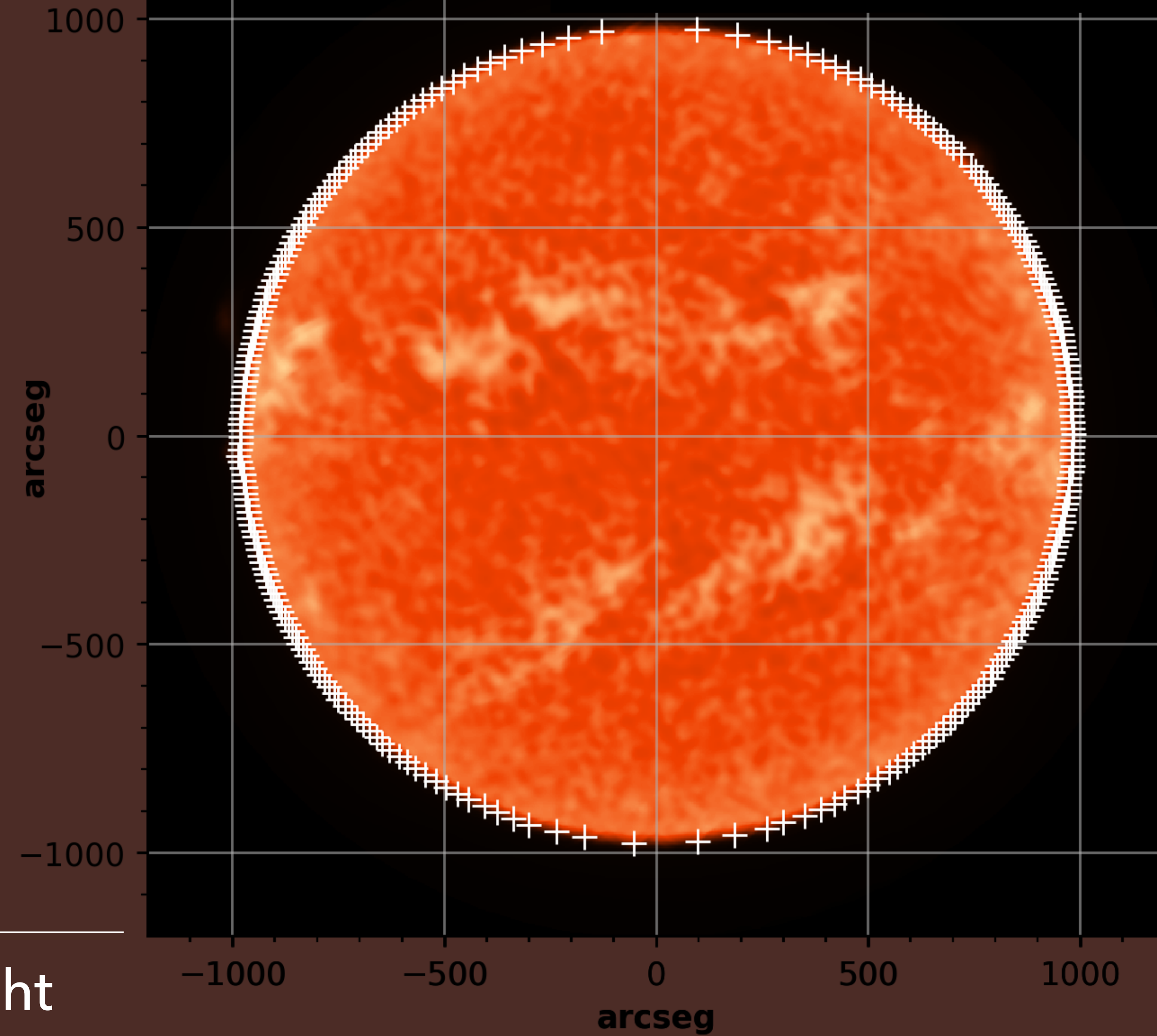
0.2 THz	R (arcsec)	R (10^8 m)	Height (10^6 m)
SST	972 ± 5	704 ± 3	9 ± 3
ALMA	961.6 ± 2.1	697.1 ± 1.5	1.6 ± 1.5

$R_{SSC} = 963.4"$ $\Delta R = 9.8"$ $R_{conv} = 973.2"$
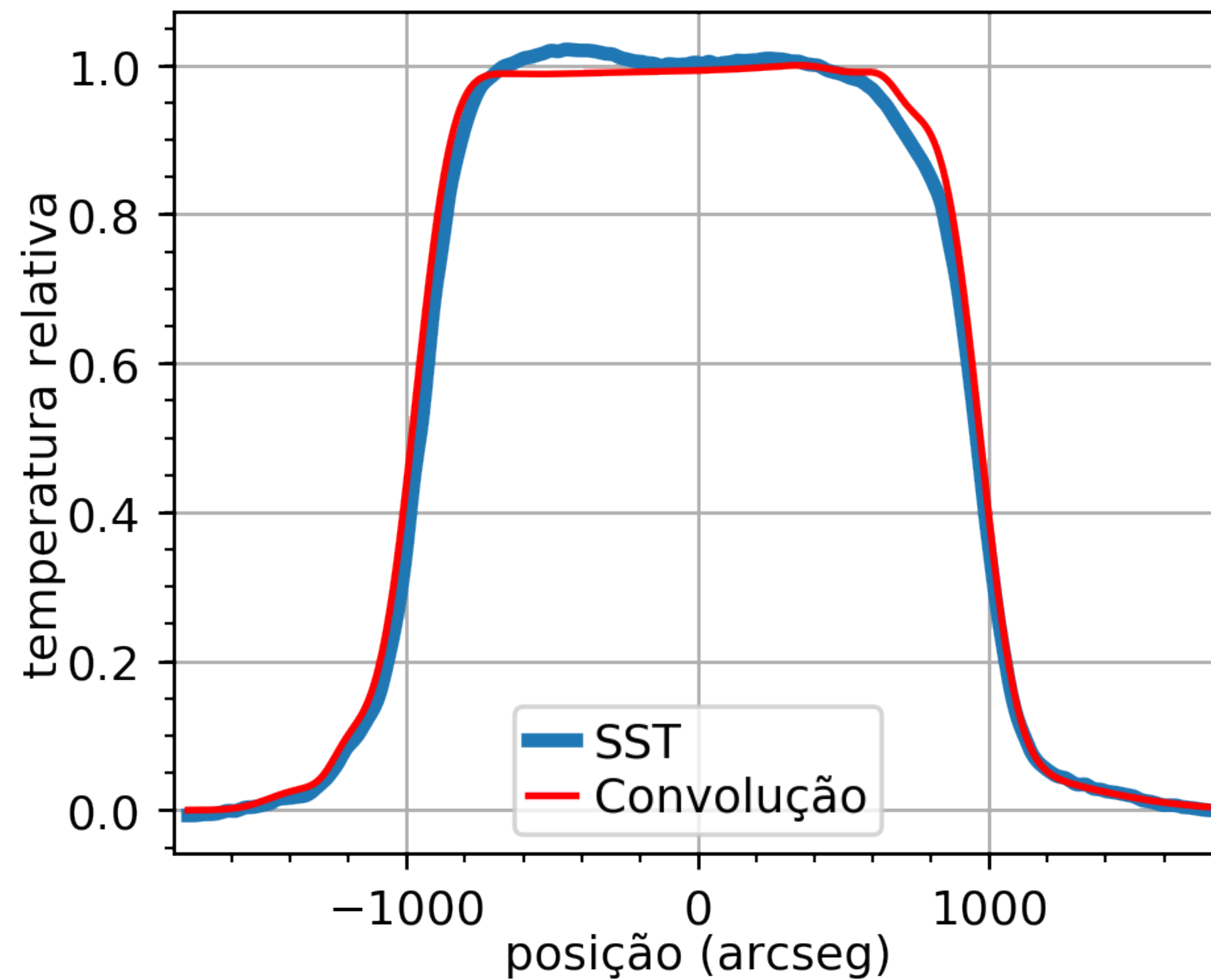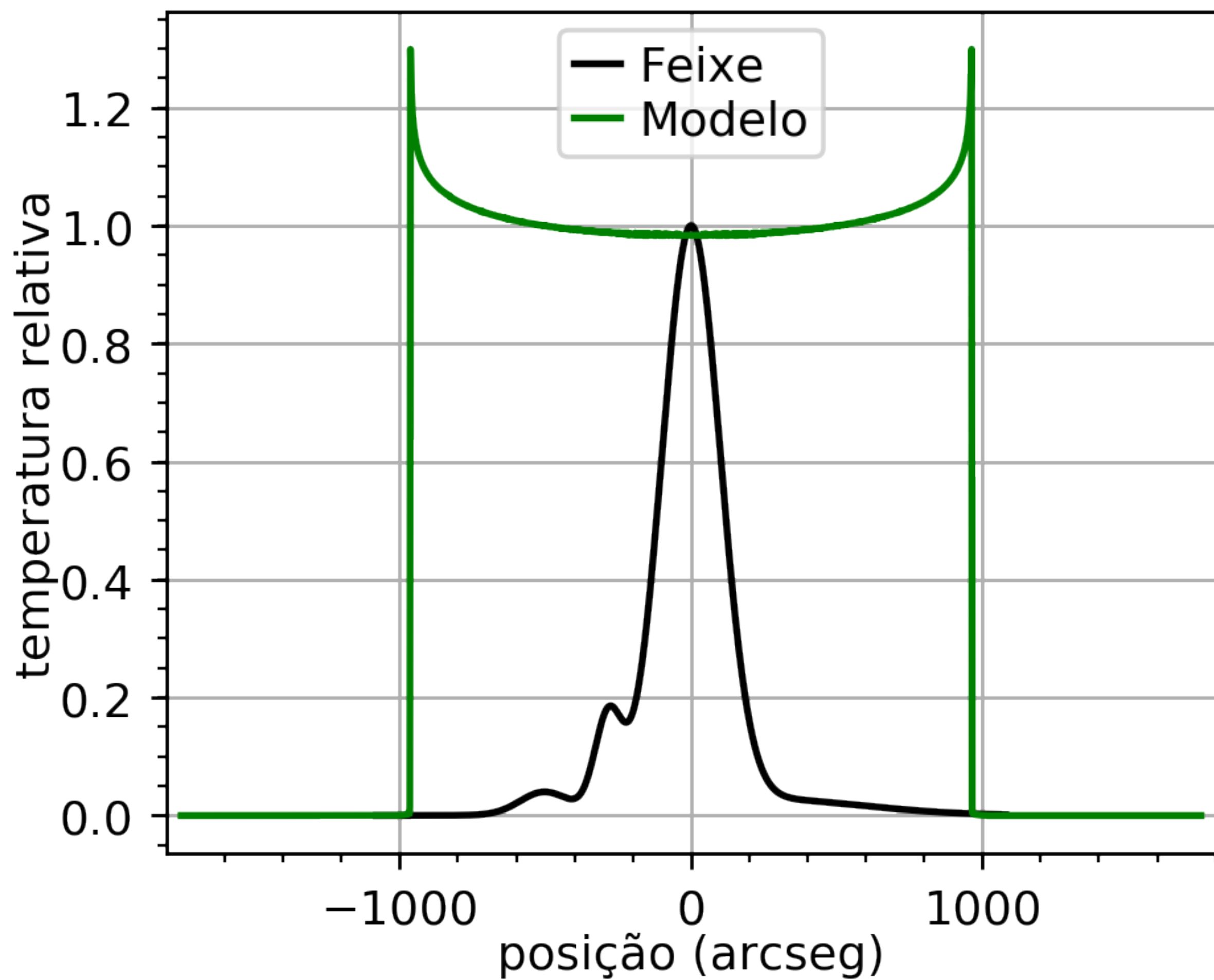
R_{SSC} = 962.7"   ΔR = 11.2"   R_{conv} = 973.9"
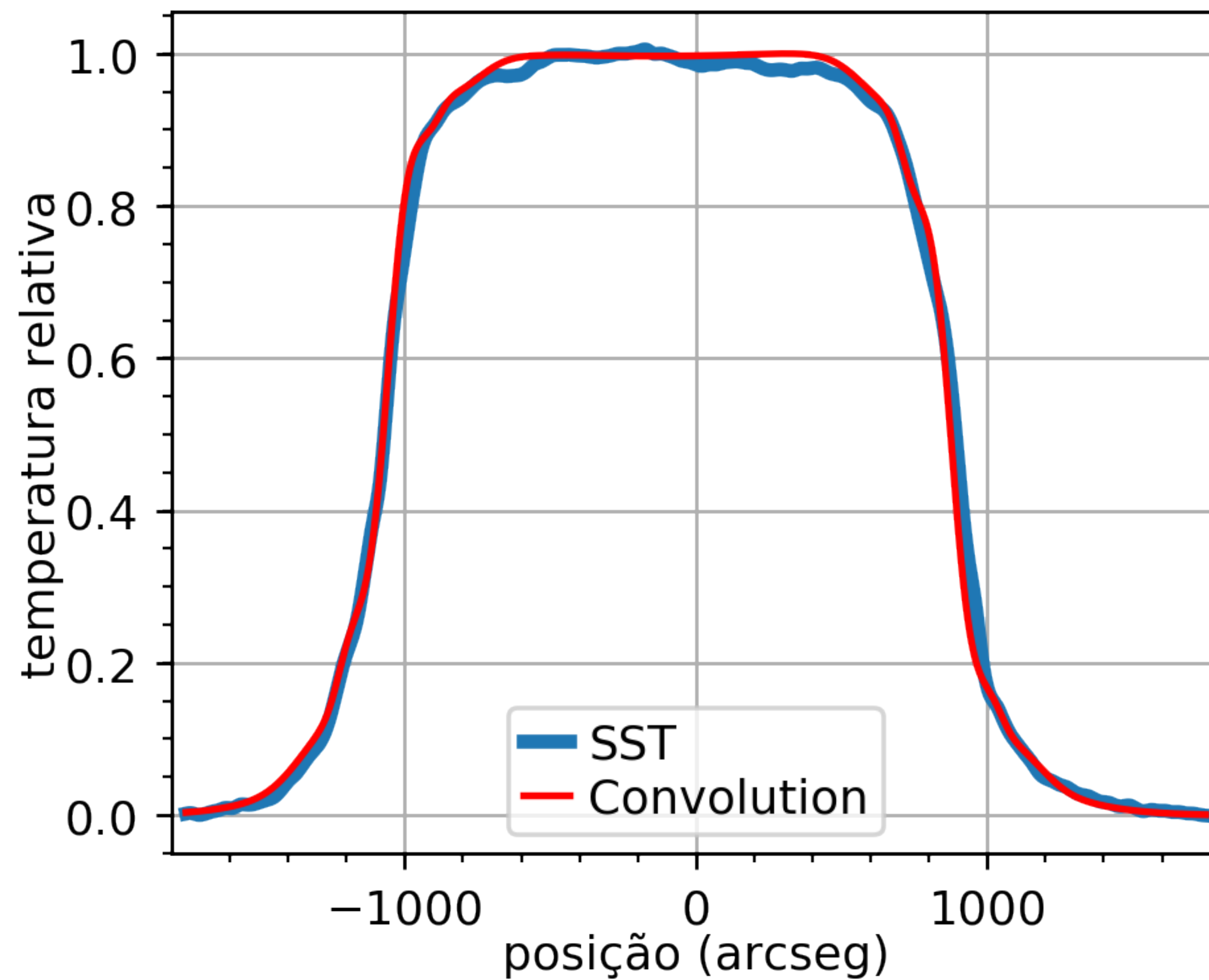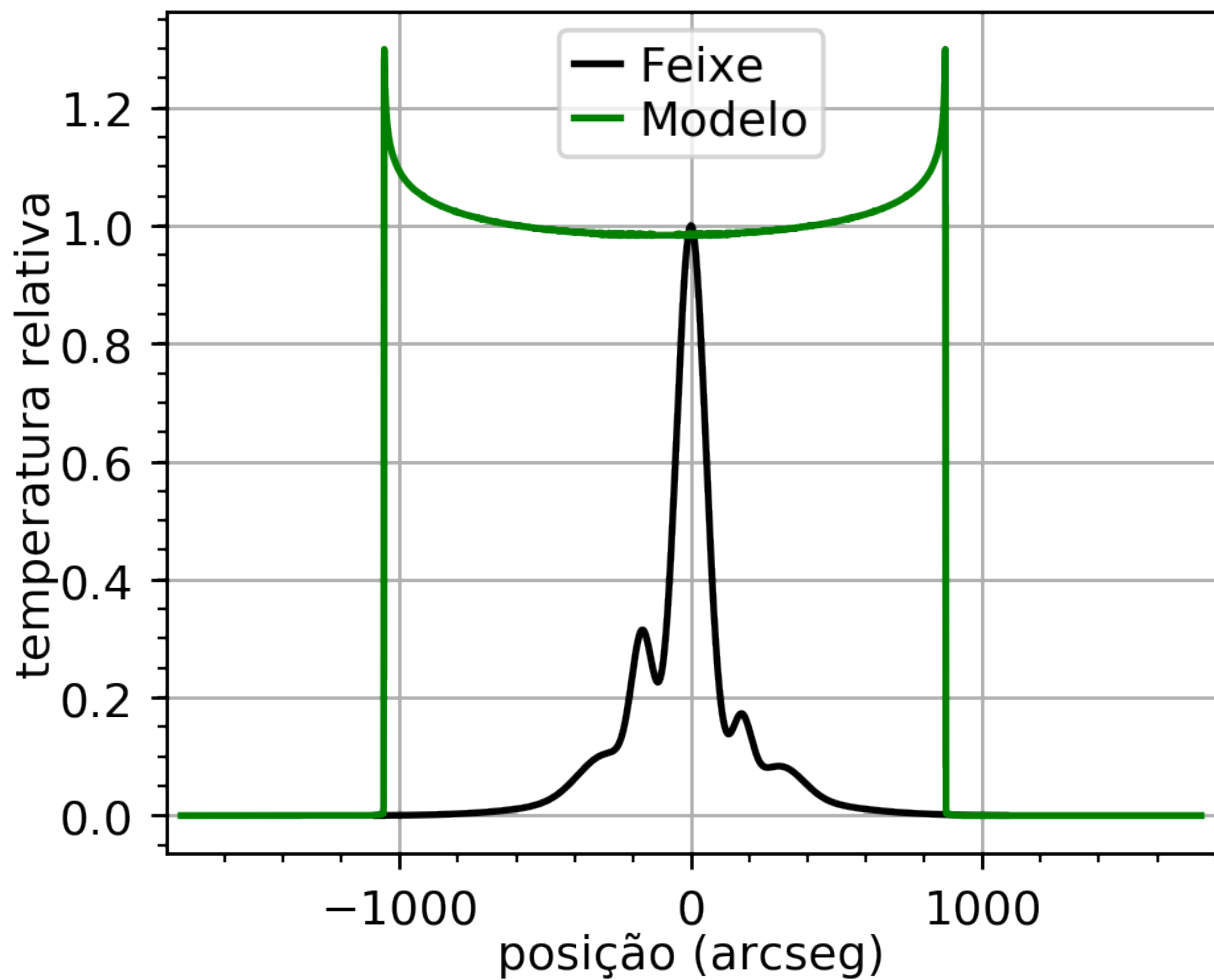
ALMA

- ▸ 0.239 THz

- ▸ 2015 Dec 17

0.2 THz	R (arcsec)	Height (10^6 m)
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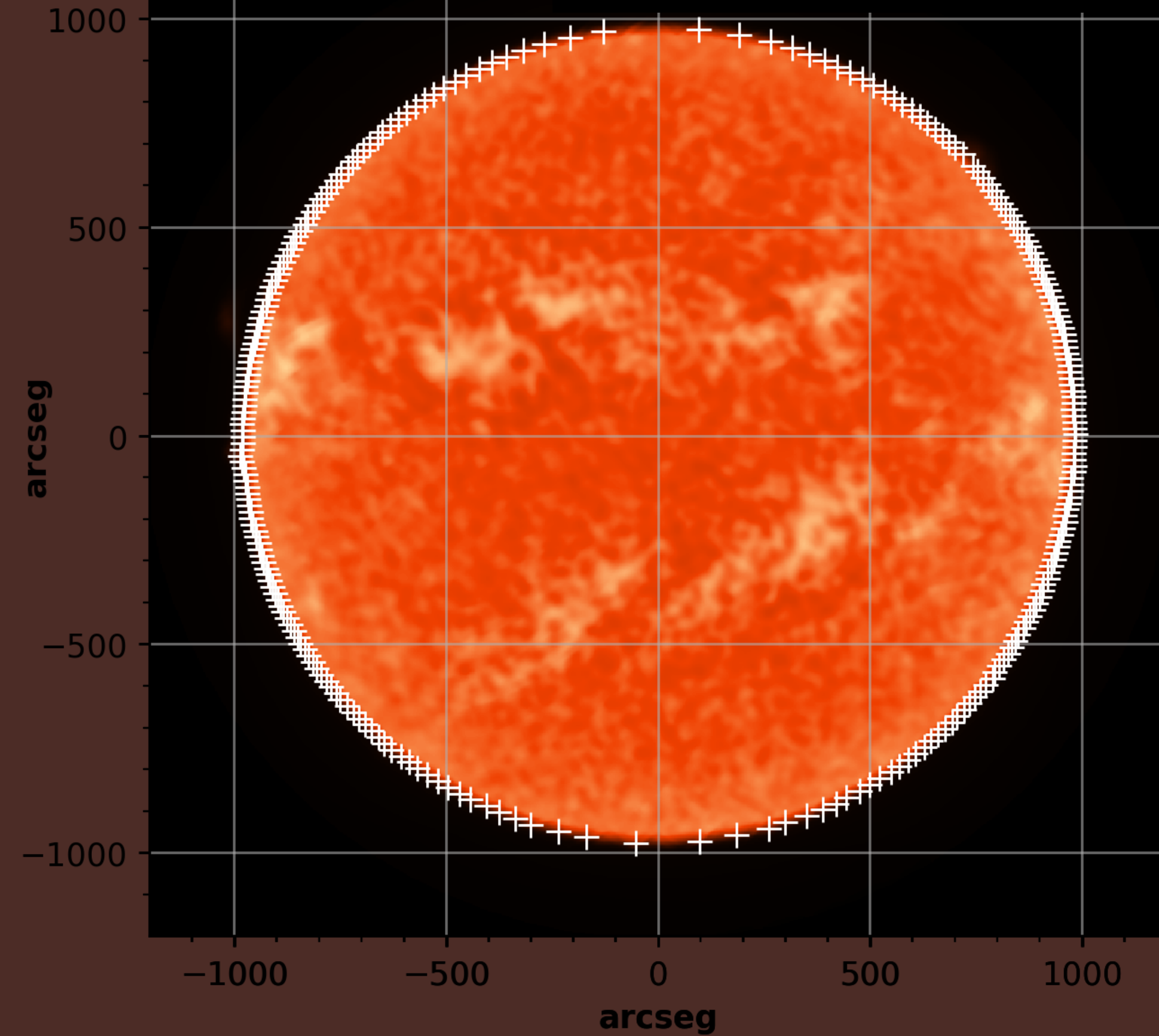
Correlation to the sunspot cycle
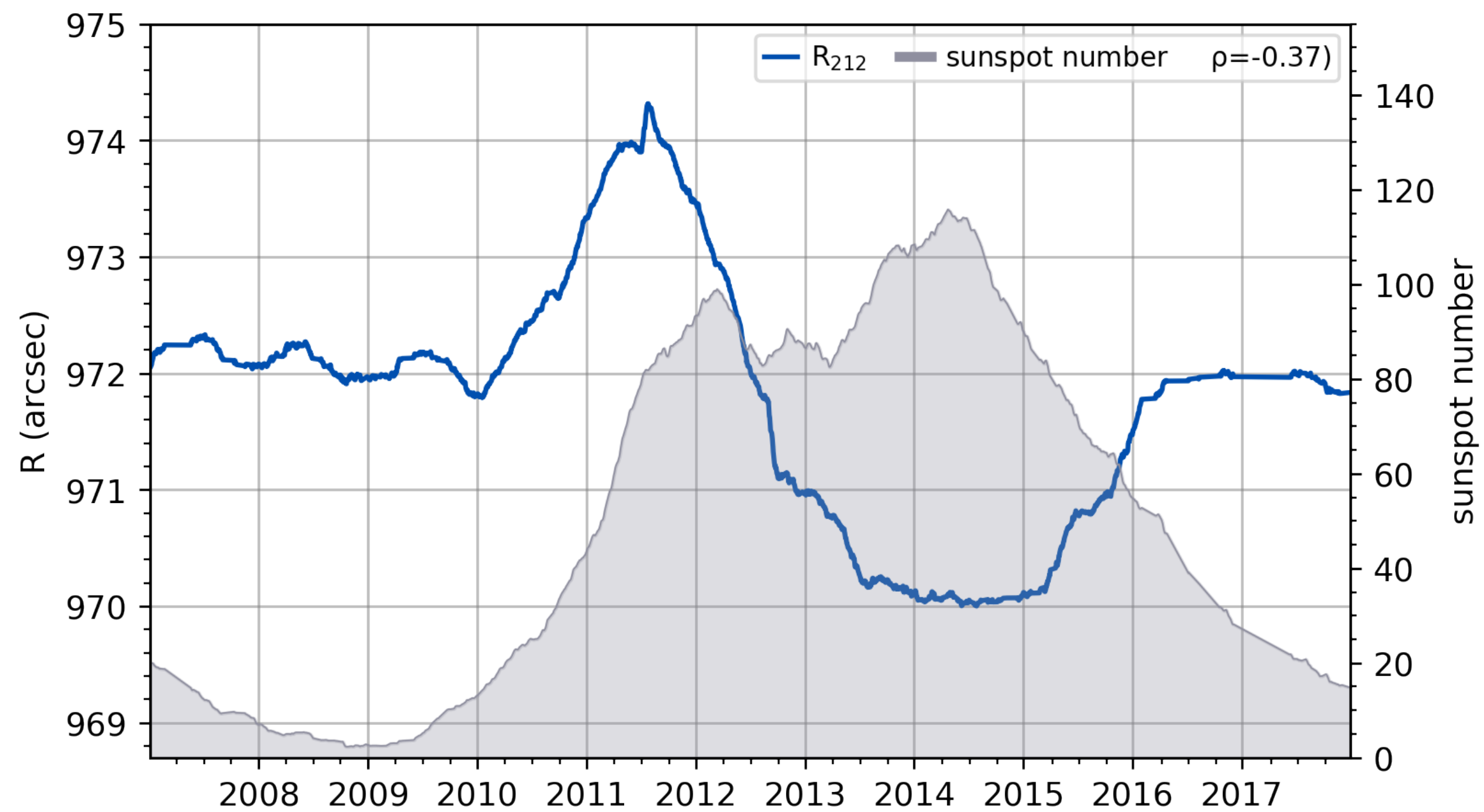
0,212 THz
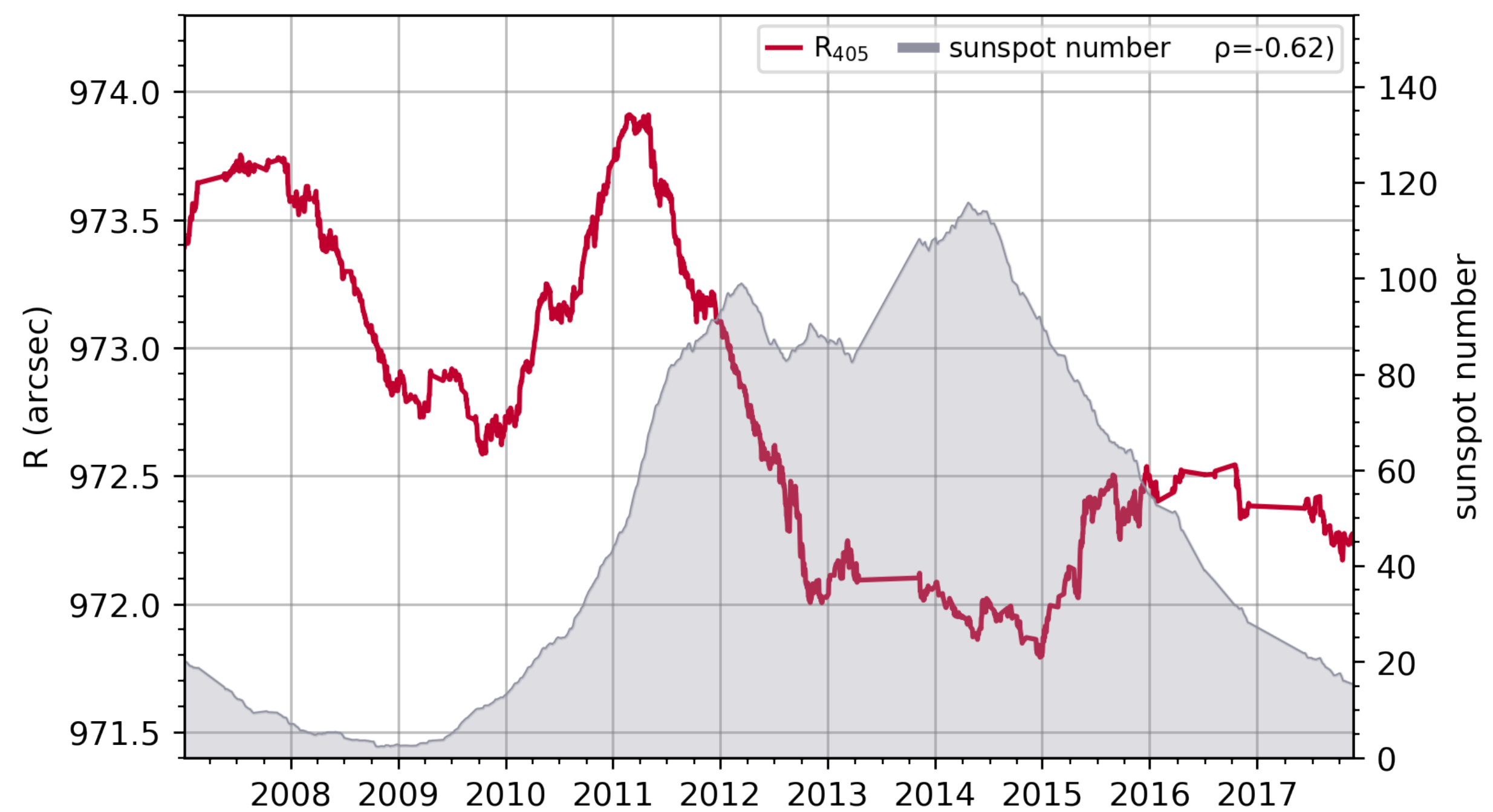
0,405 THz

Equatorial and polar radii

▸ Equatorial radius
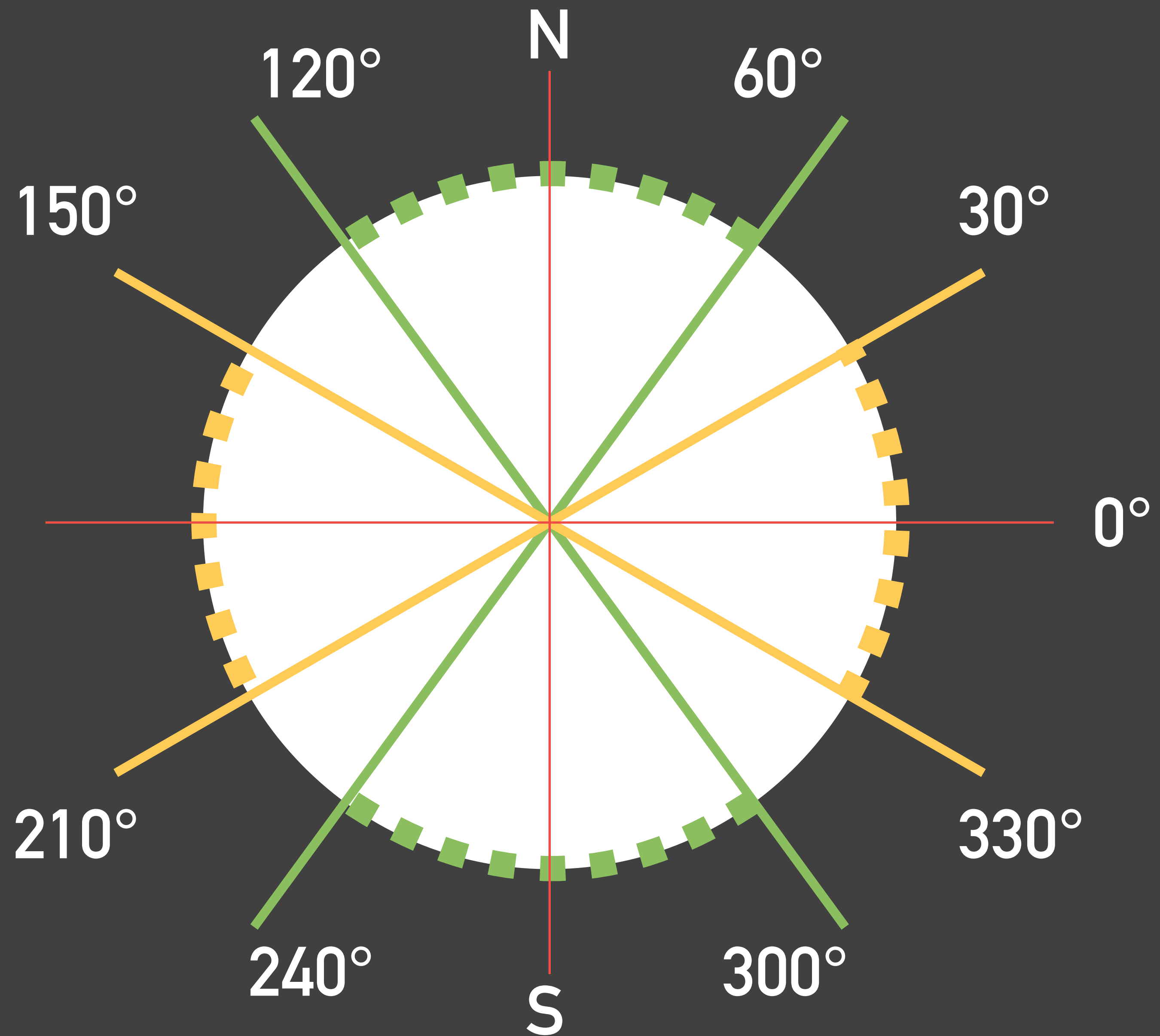
▸ Polar radius

Correlation to the sunspot cycle
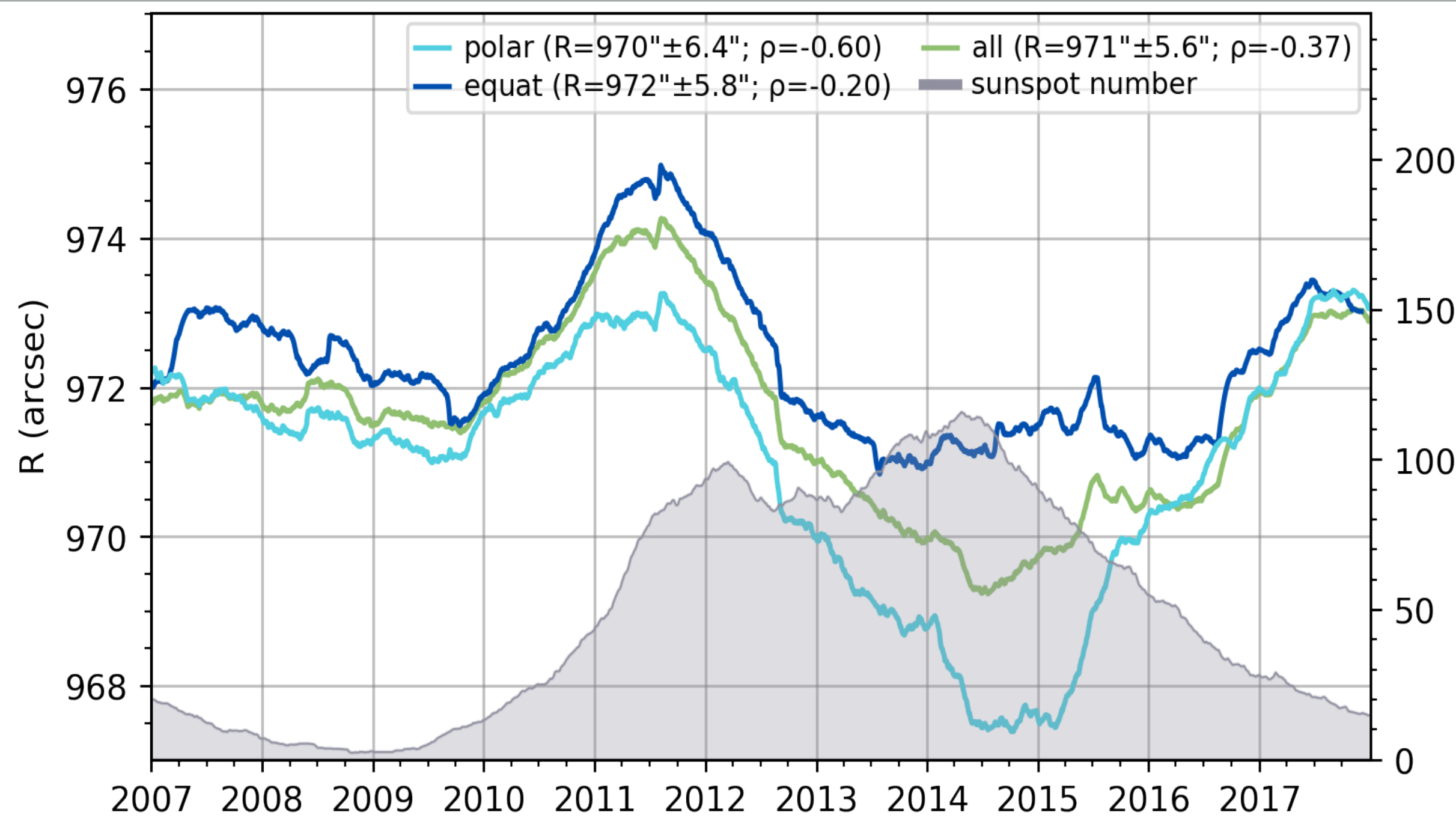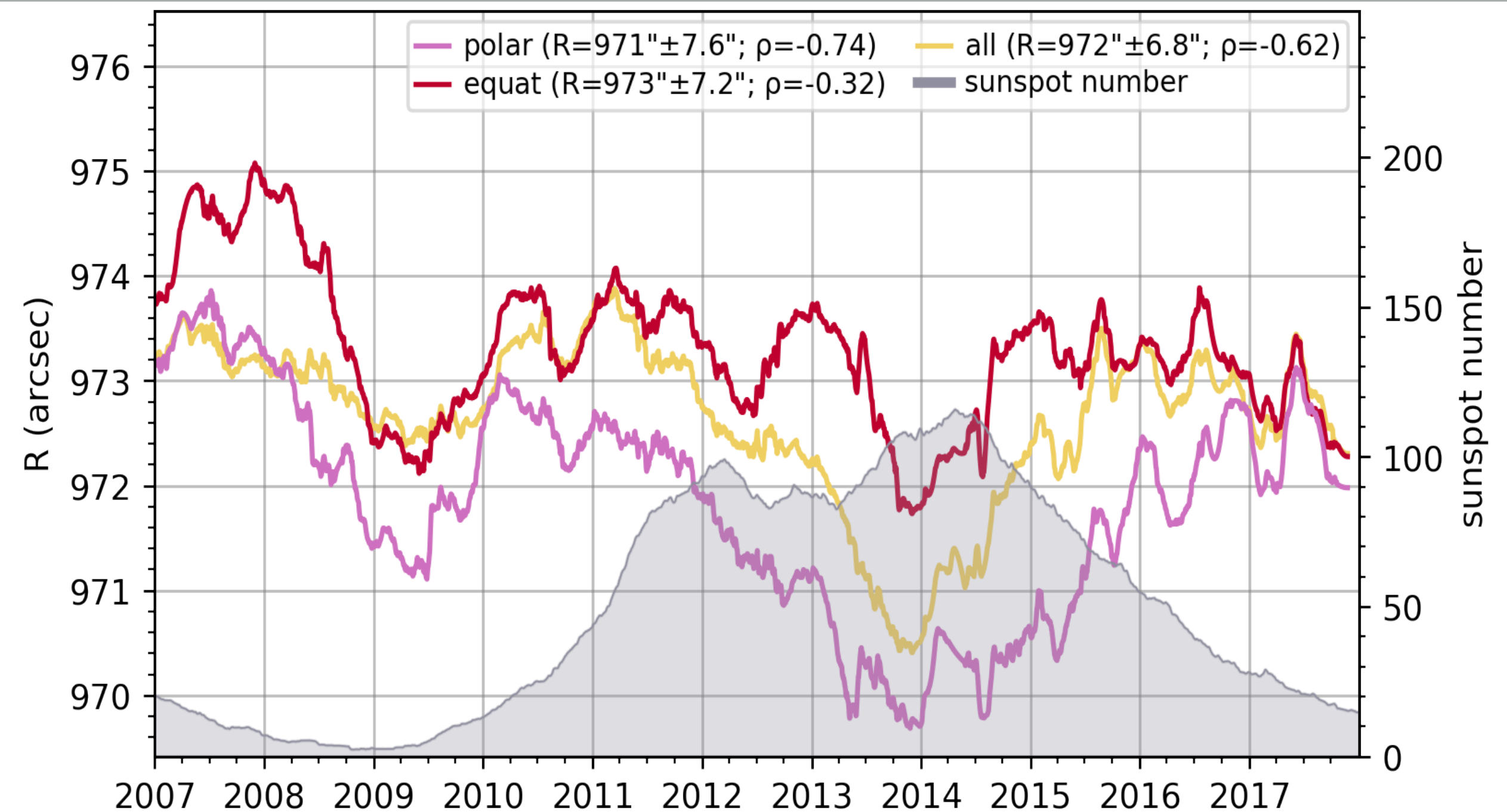
1-year smooth

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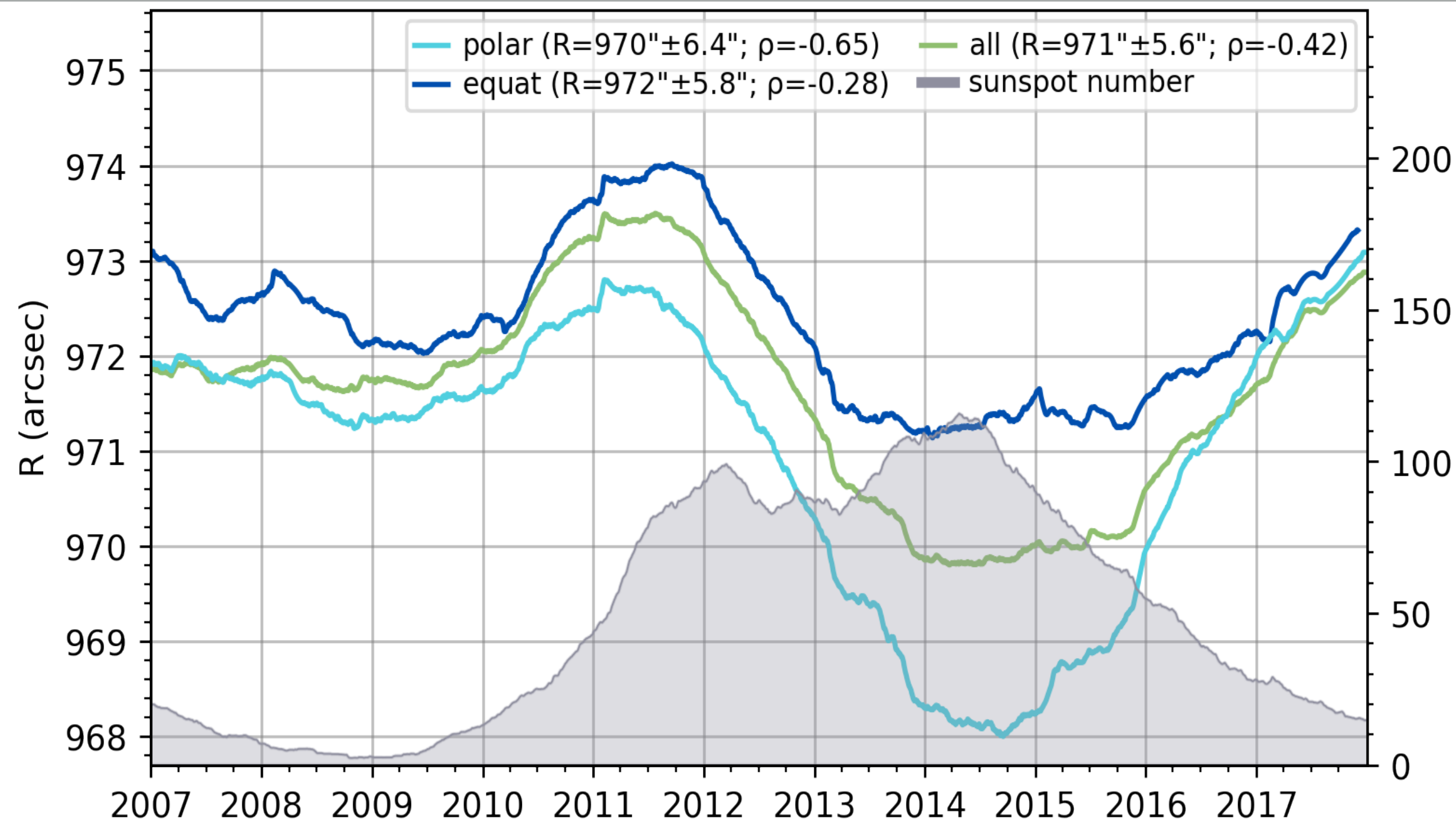
2-year smooth
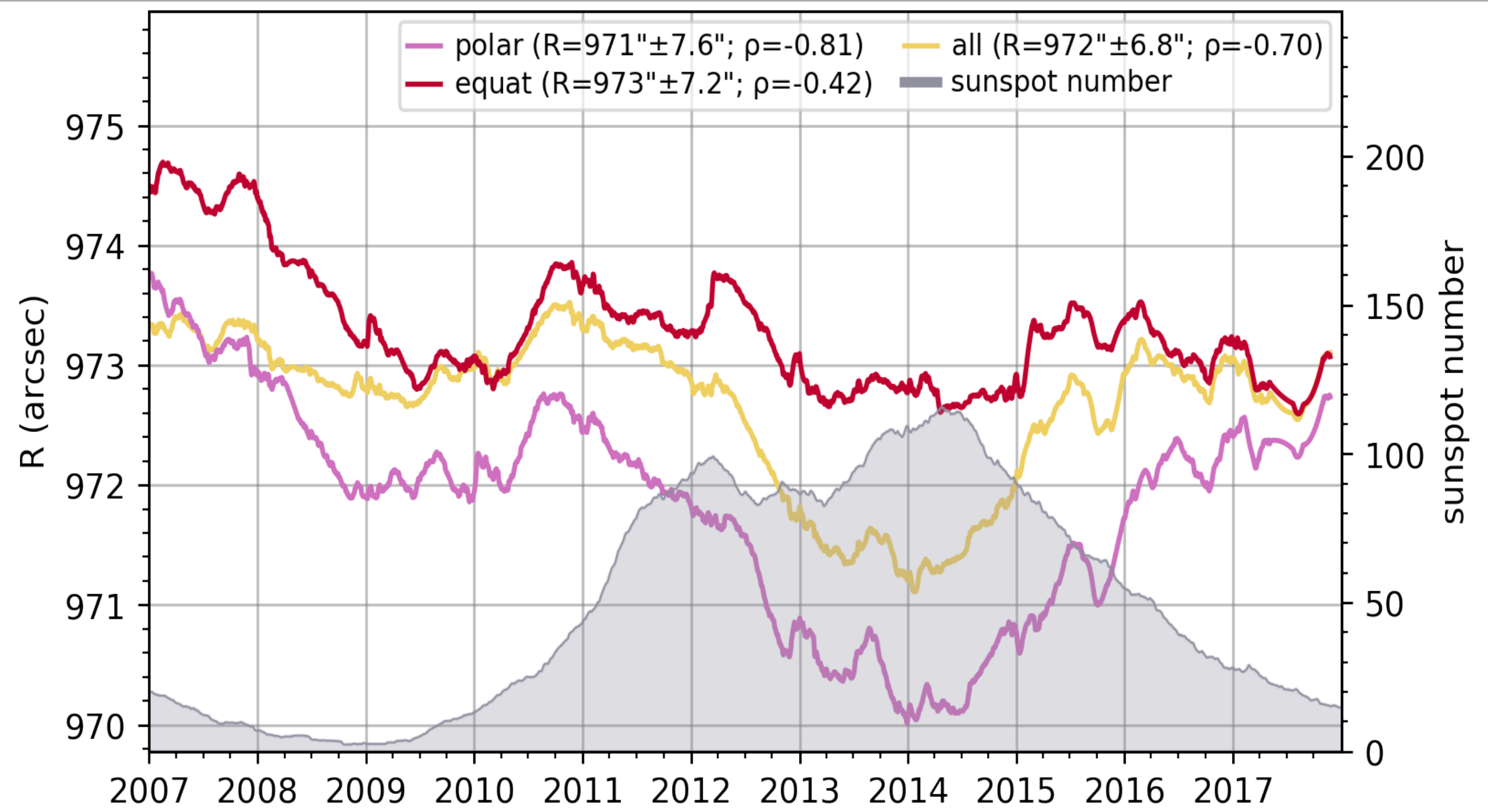
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Correlation to the sunspot cycle

4-year smooth
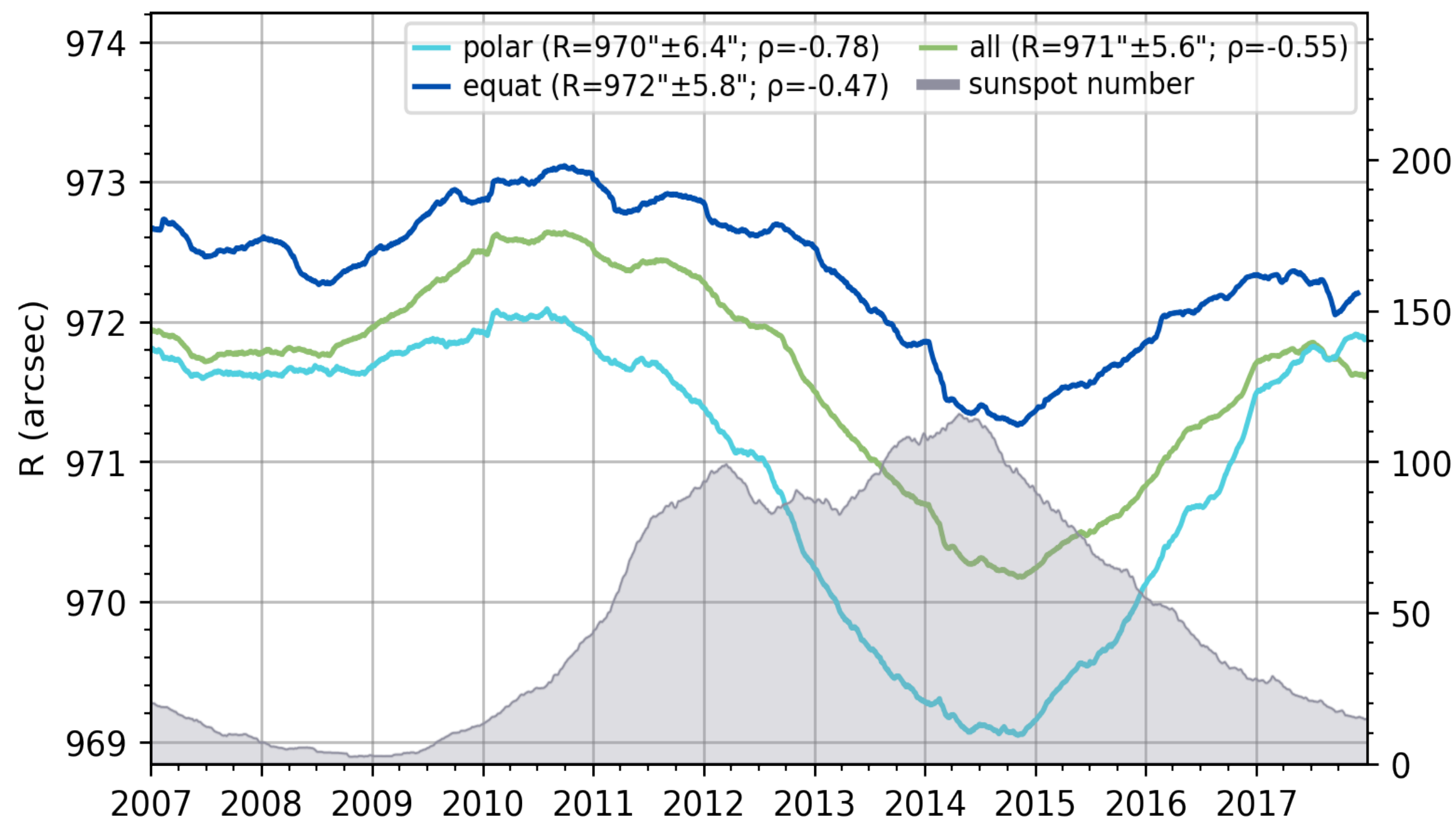
0,212 THz
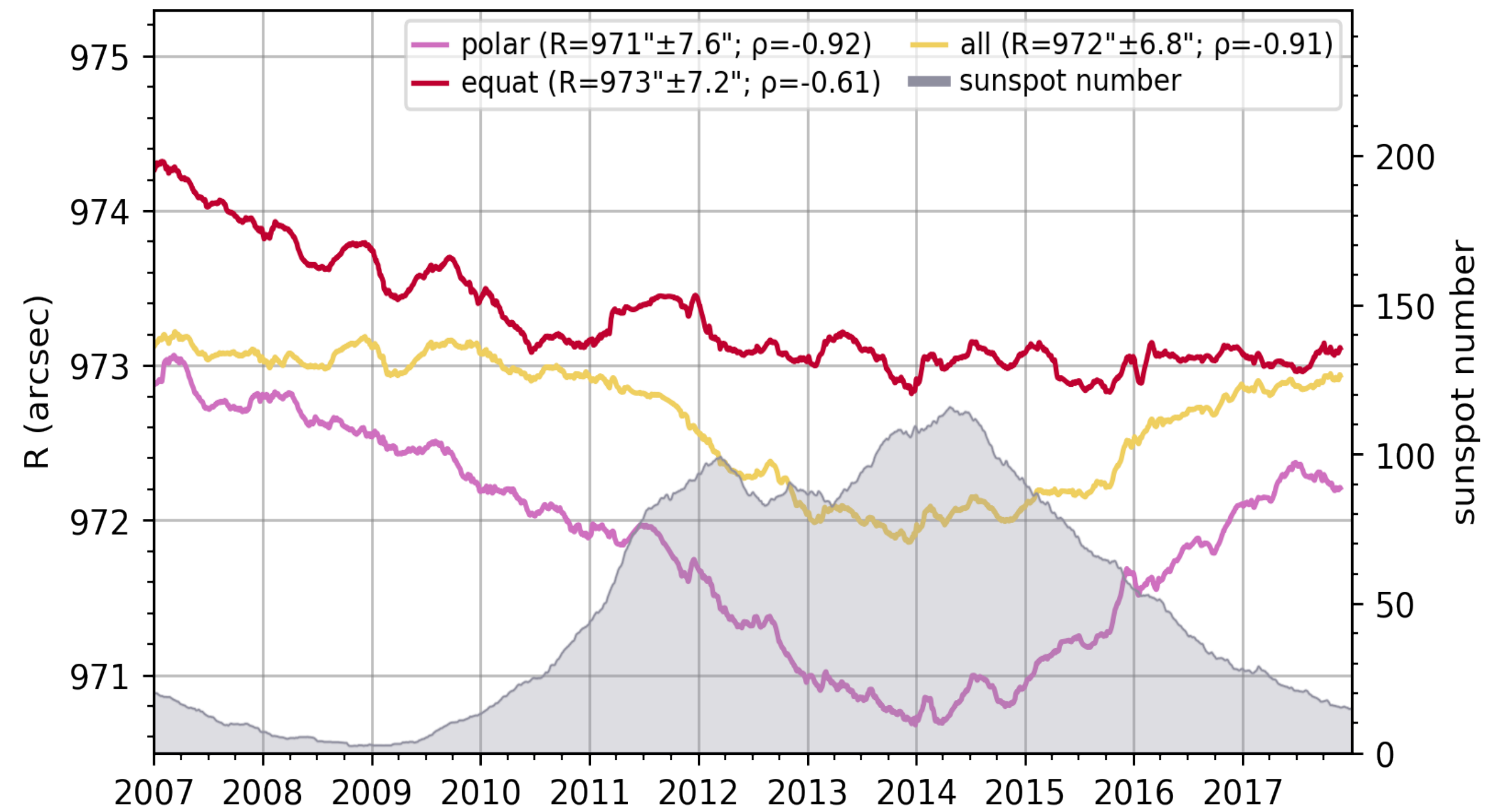
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Equatorial and polar radii

R (arcsec)	All pts.	Equat.	Polar
ALMA (0.2 THz)	961.6 ± 2.1	962.2 ± 1.9	961.1 ± 1.1
SST (0.2 THz)	972 ± 5	972 ± 5	970 ± 5
SST (0.4 THz)	973 ± 6	973 ± 7	972 ± 7

Corr. coef.	All pts.	Equat.	Polar
0.2 THz	-0.37 – -0.55	-0.20 – -0.47	-0.60 – -0.78
0.4 THz	-0.62 – -0.91	-0.32 – -0.61	-0.74 – -0.92
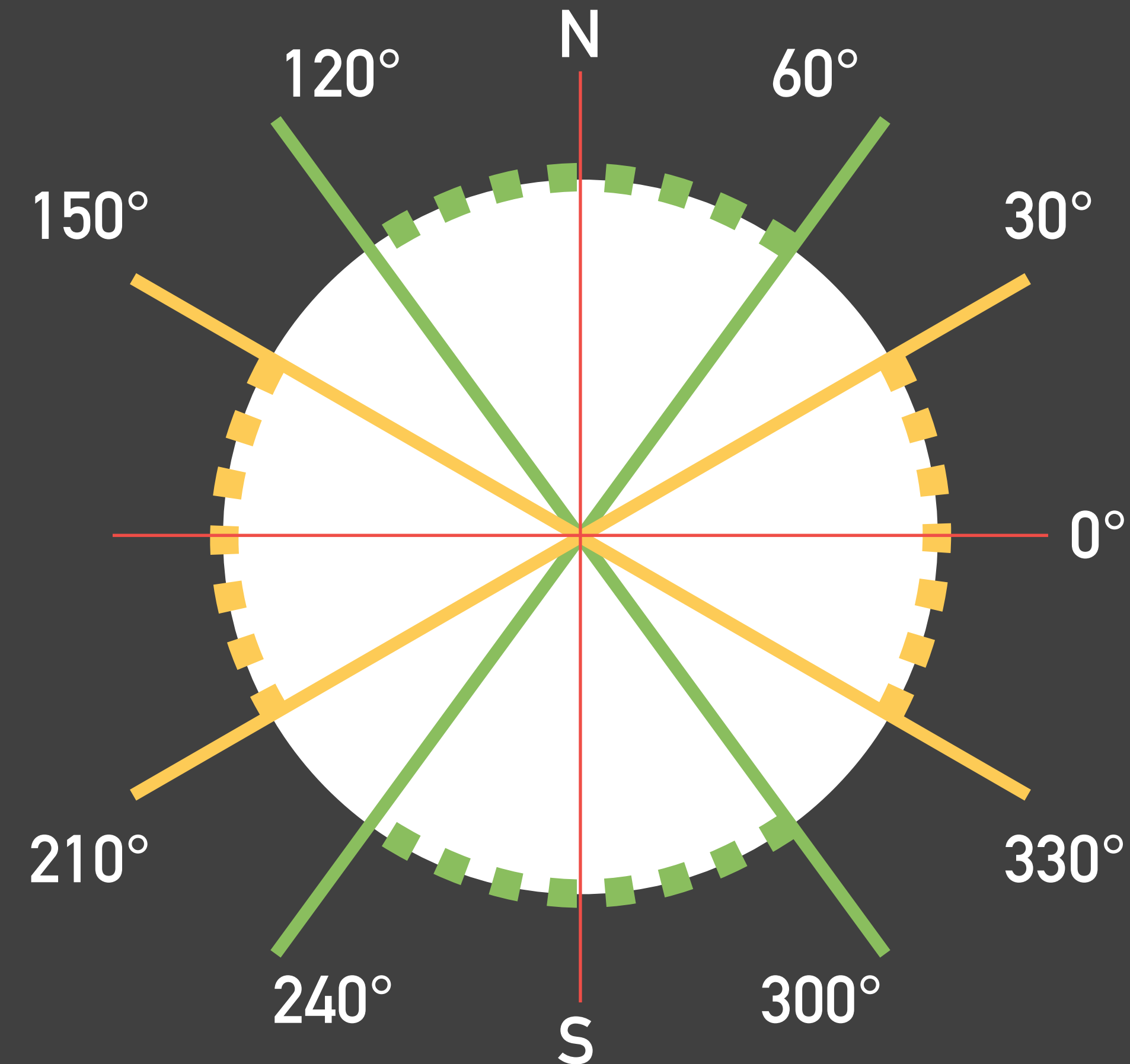
▶ Equatorial radius

▶ Polar radius

Cross-Correlation
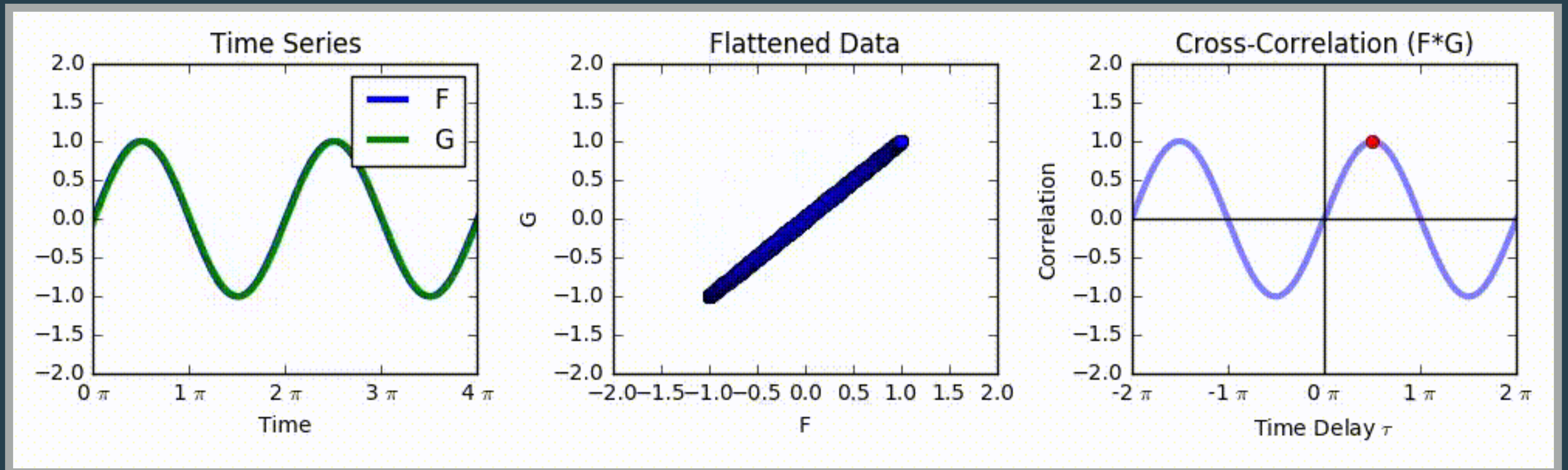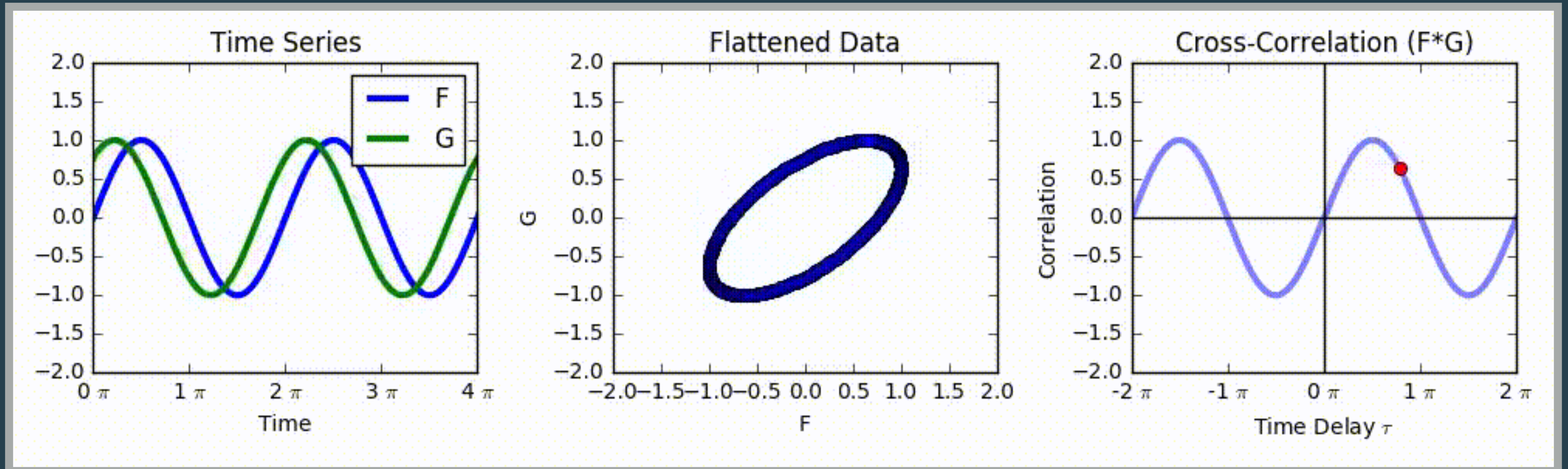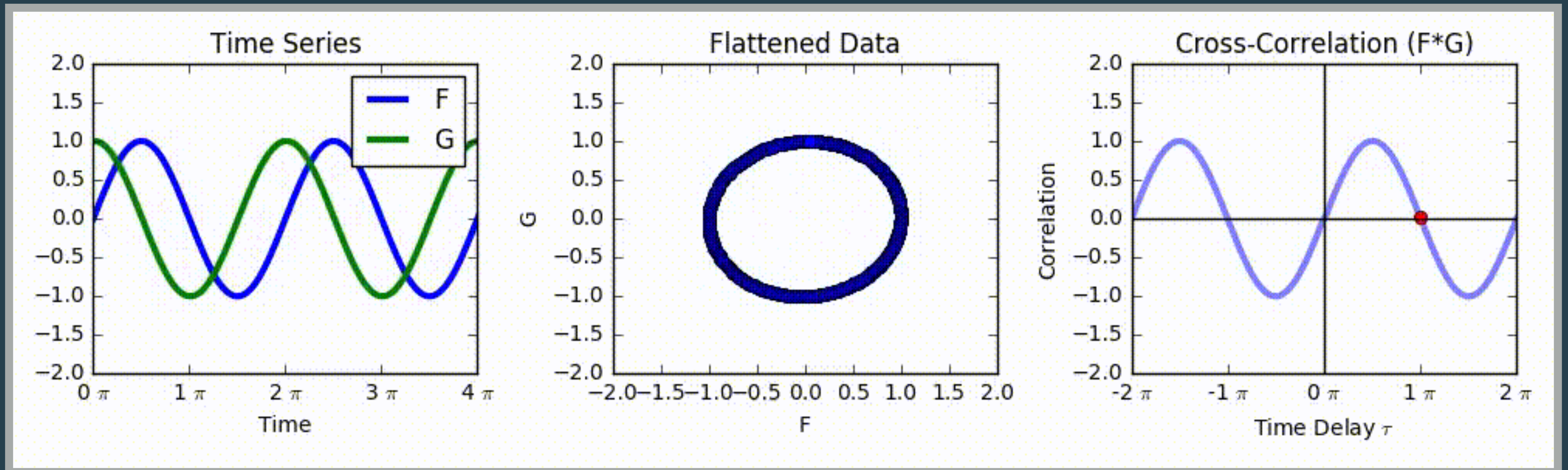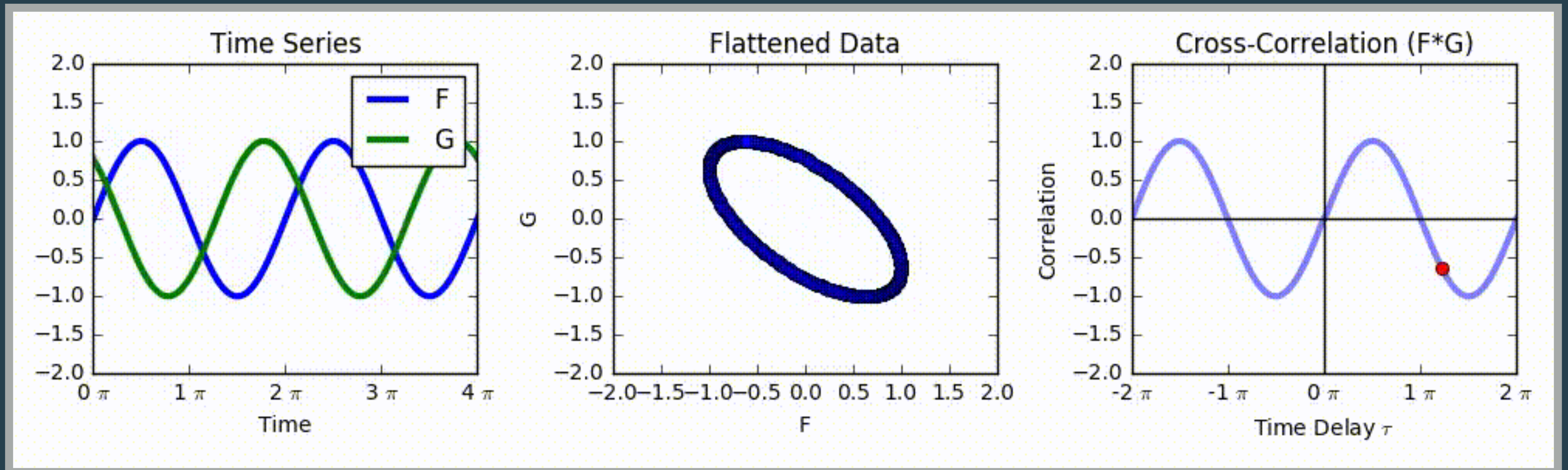
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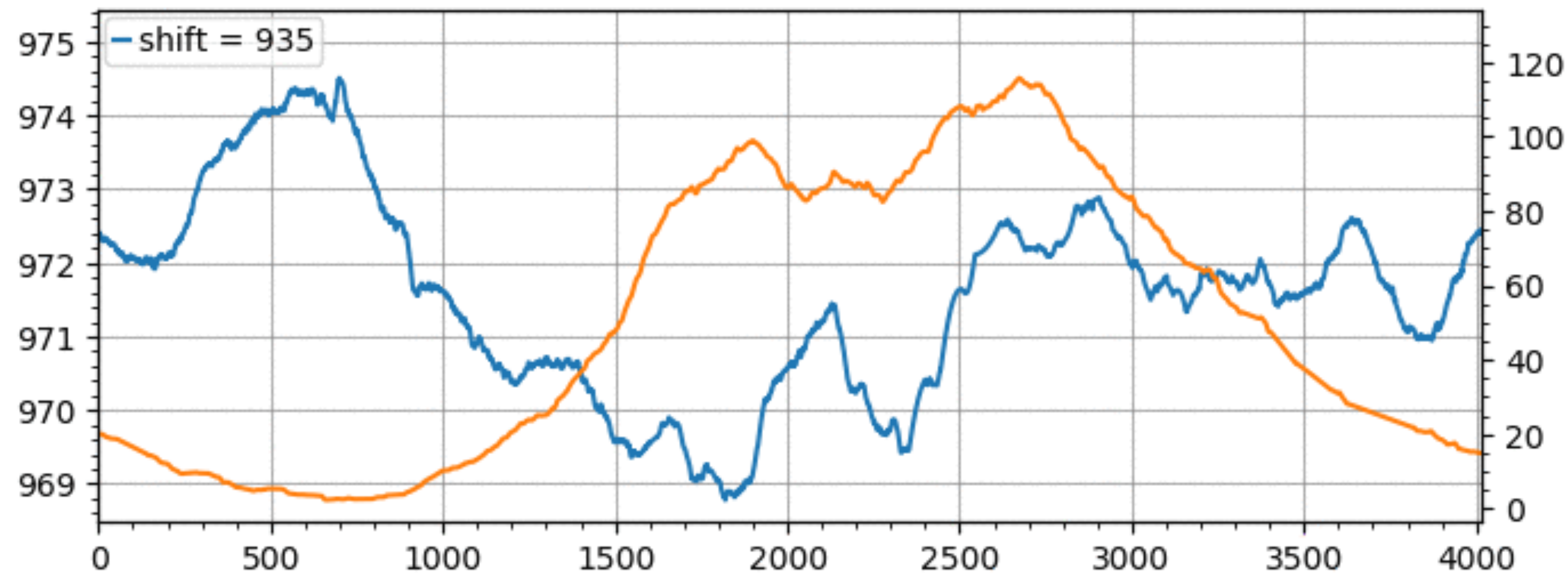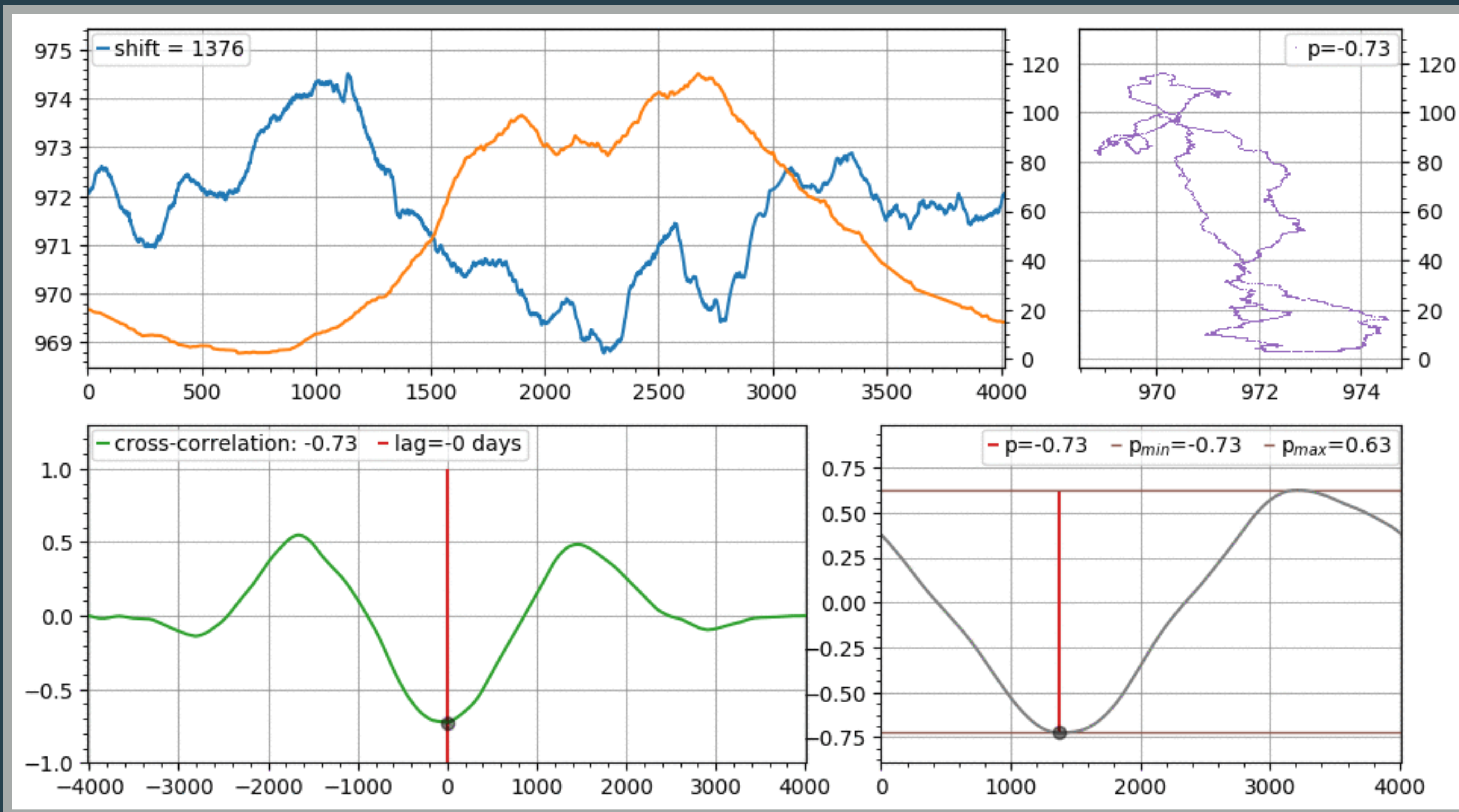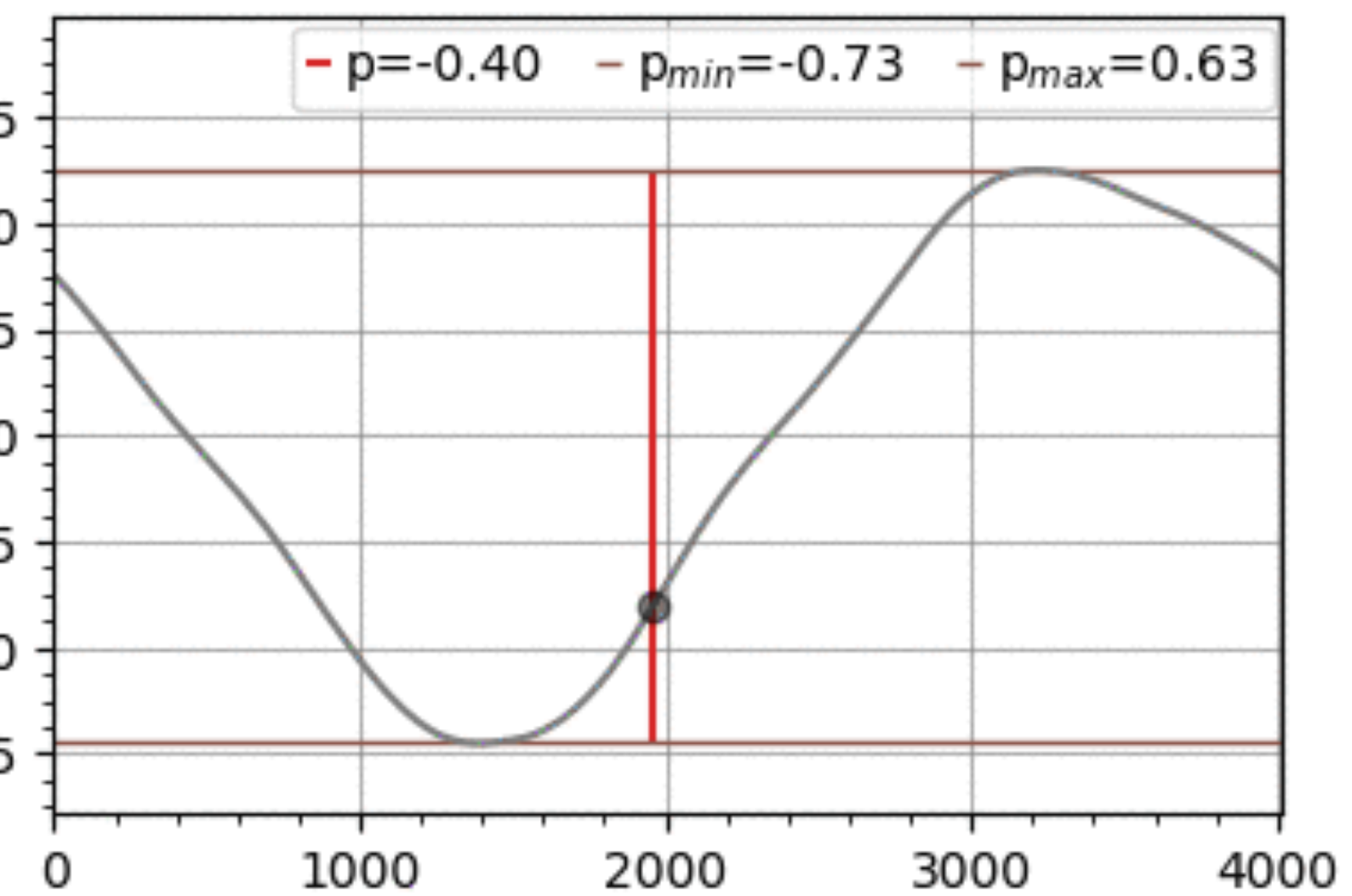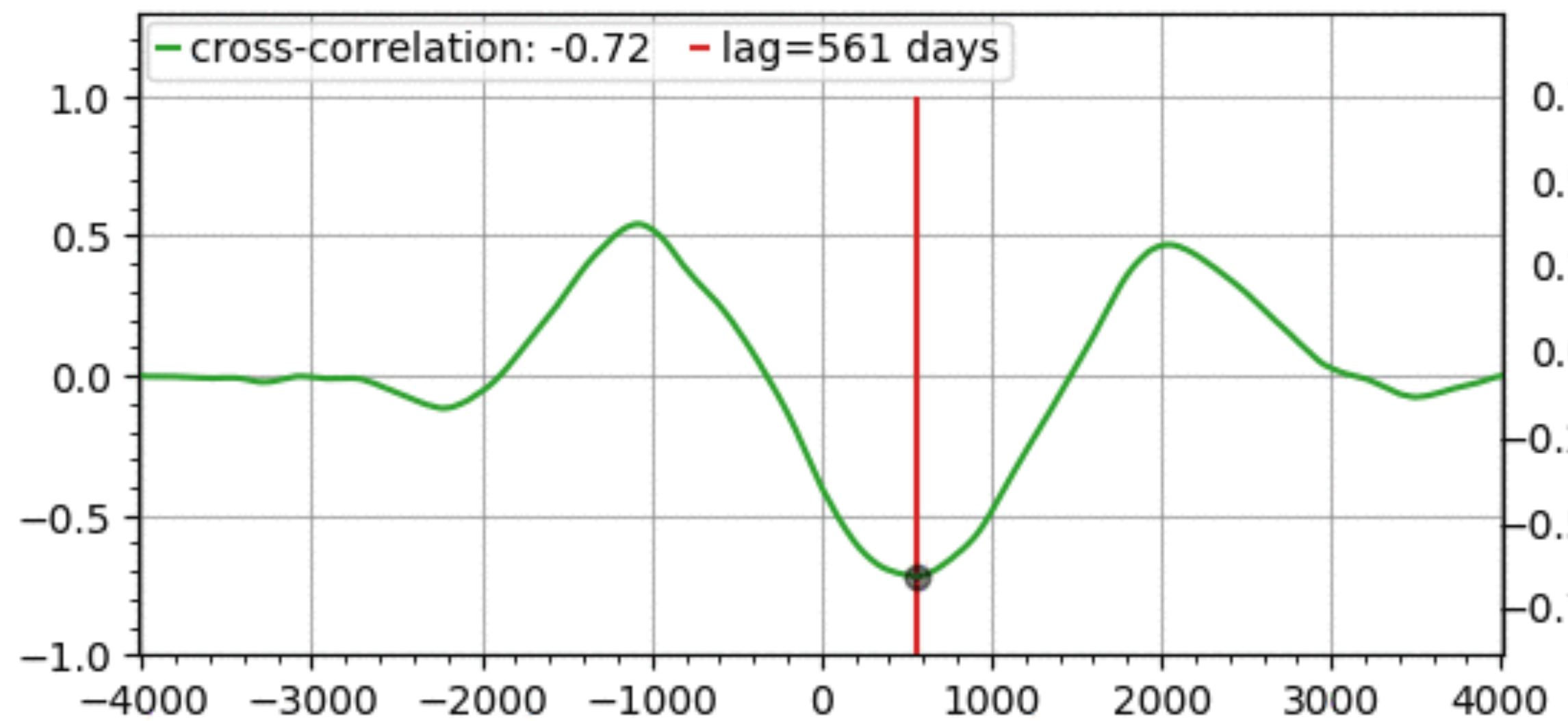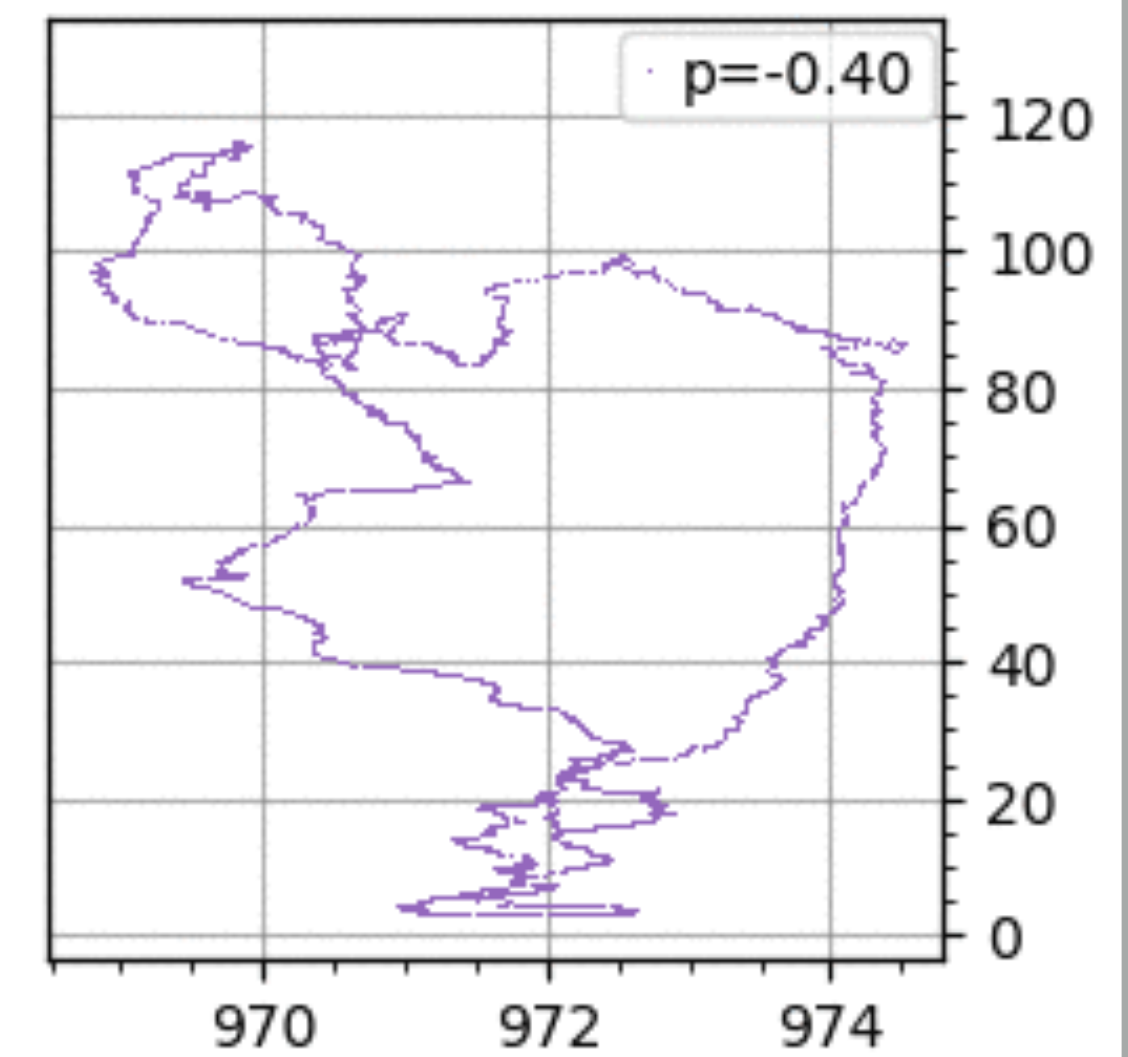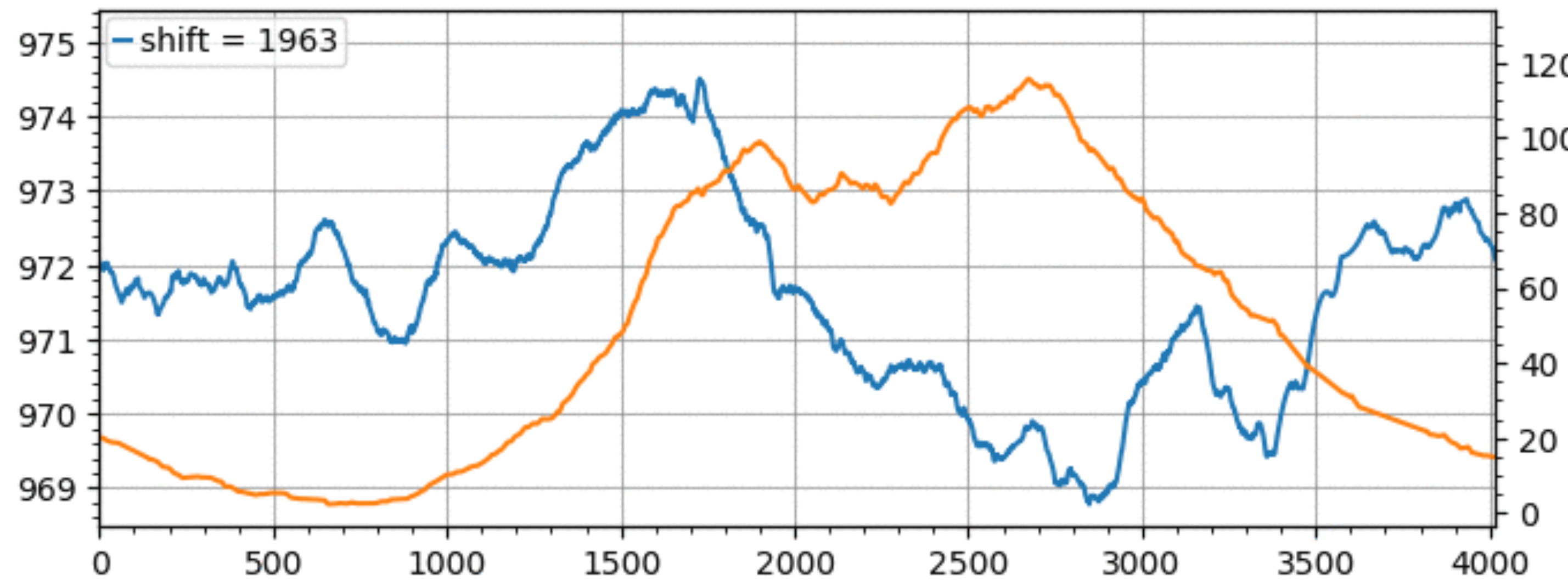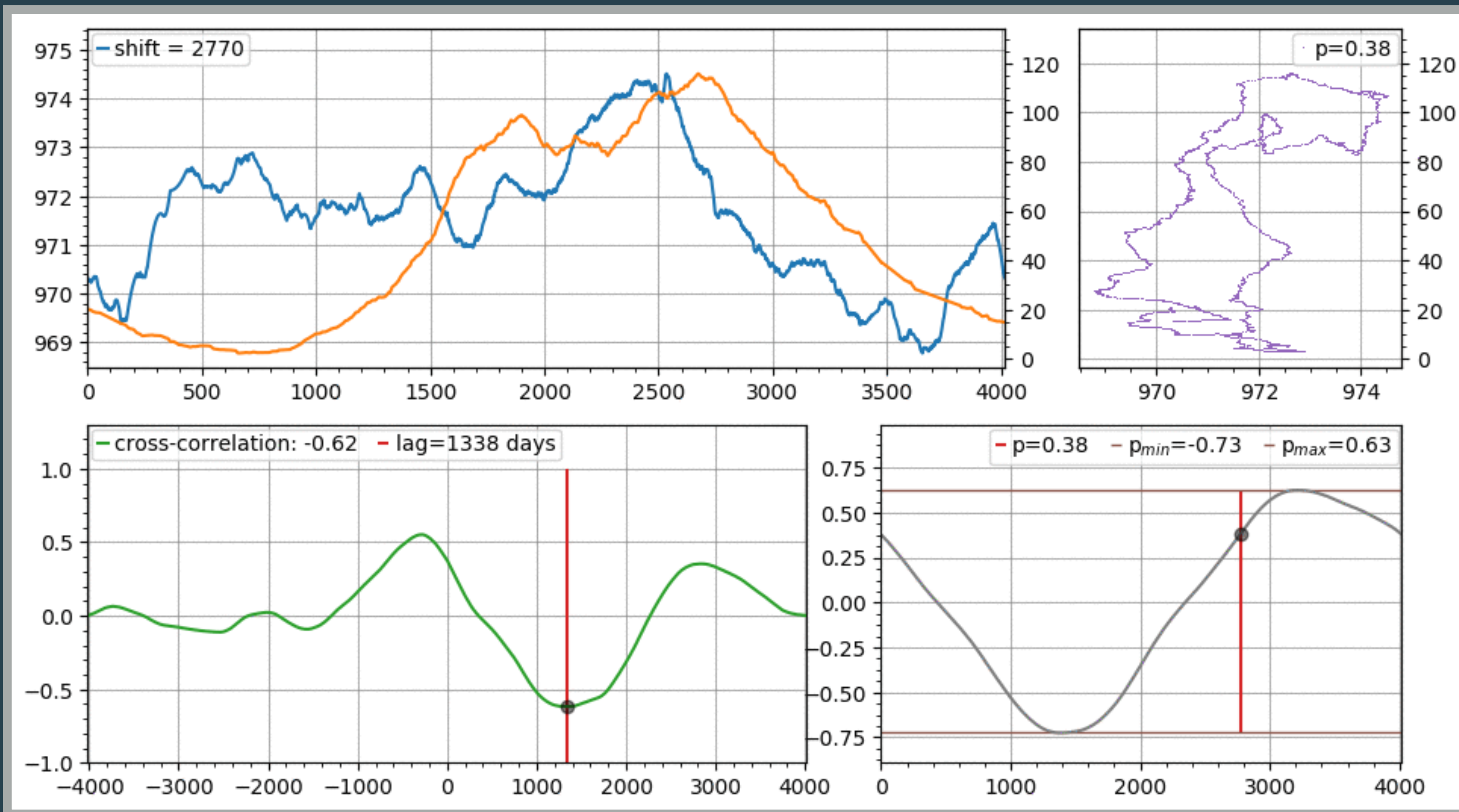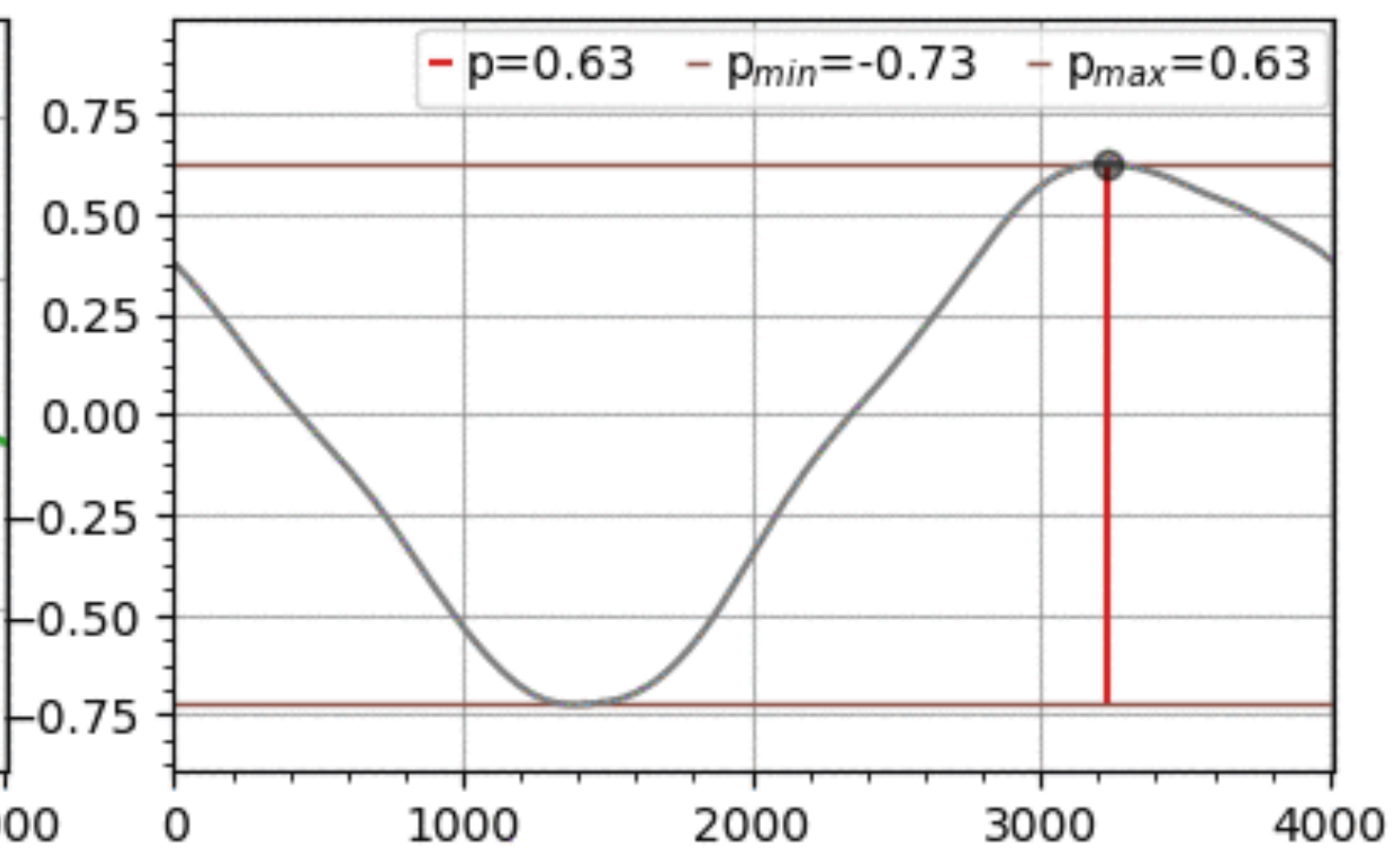# Cross-Correlation
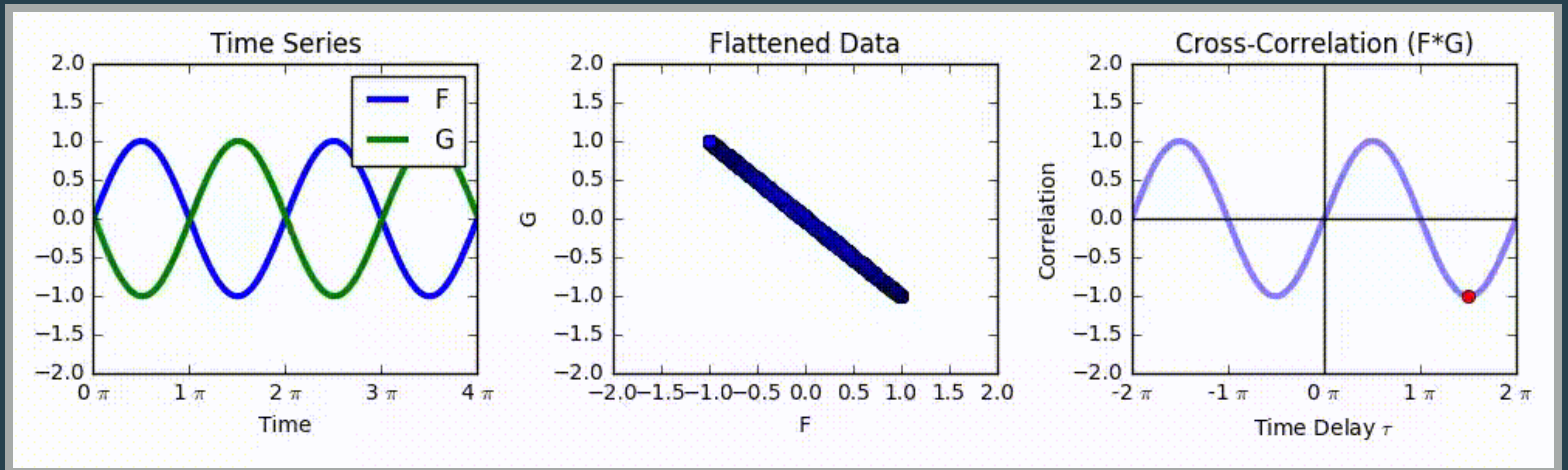
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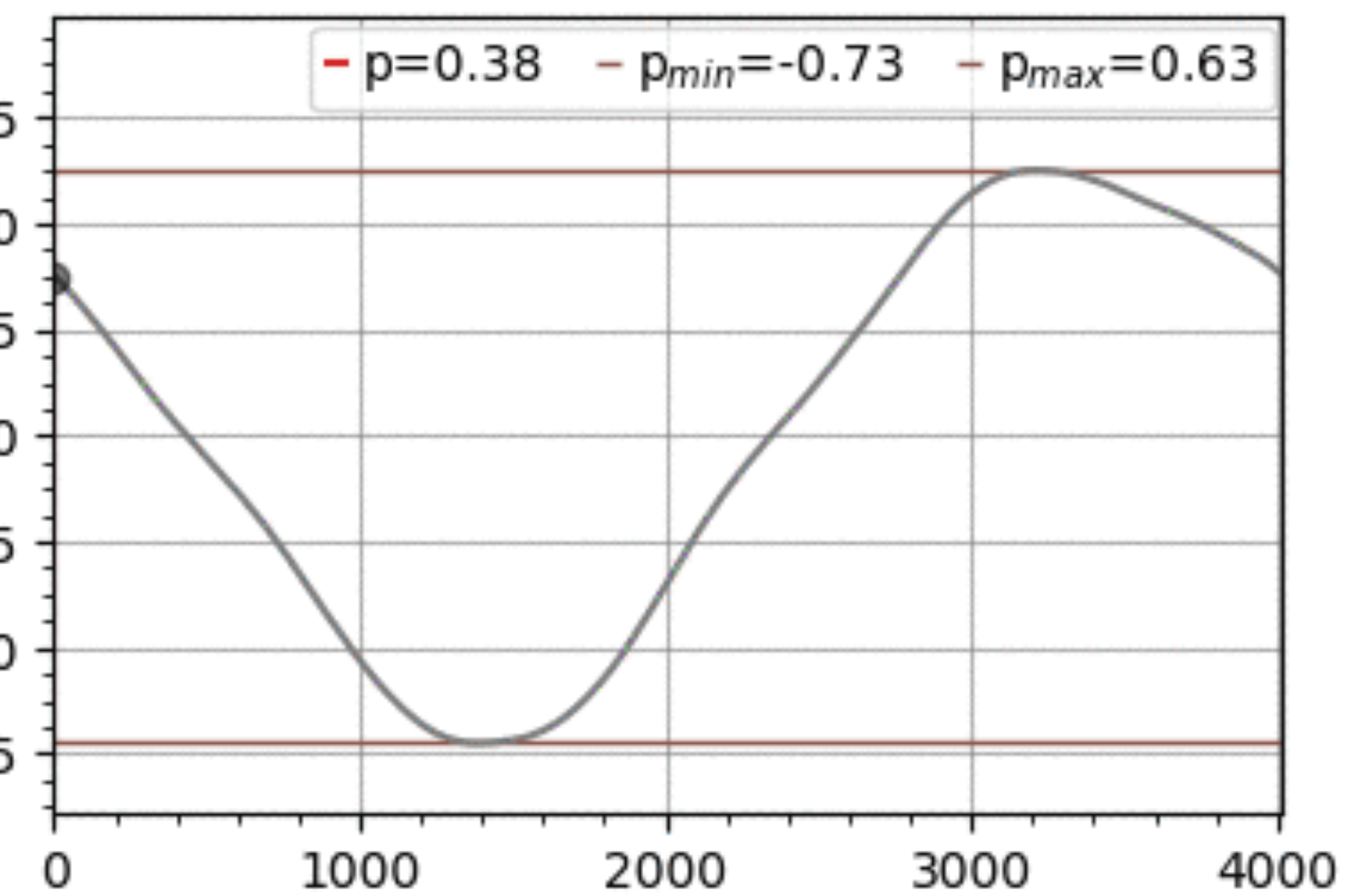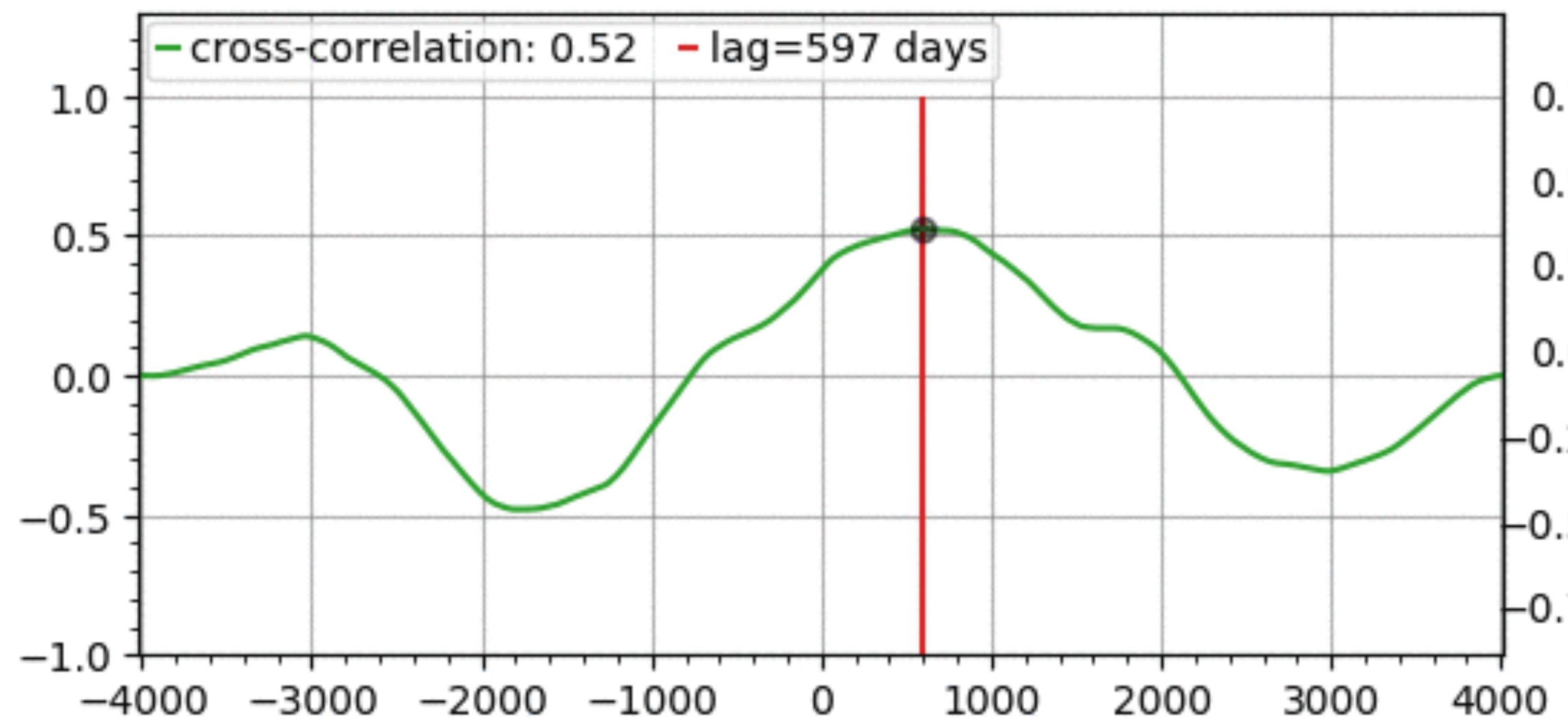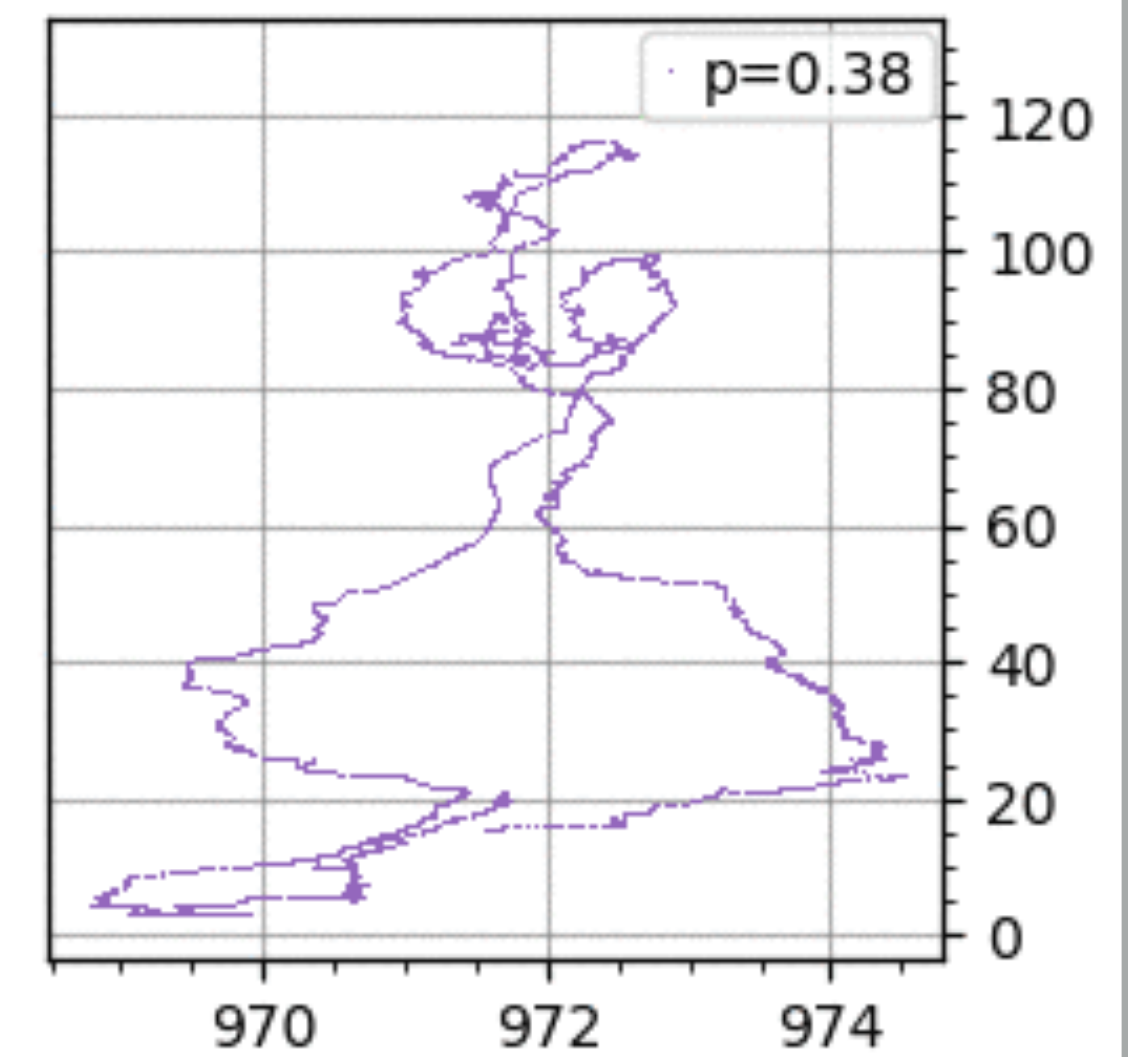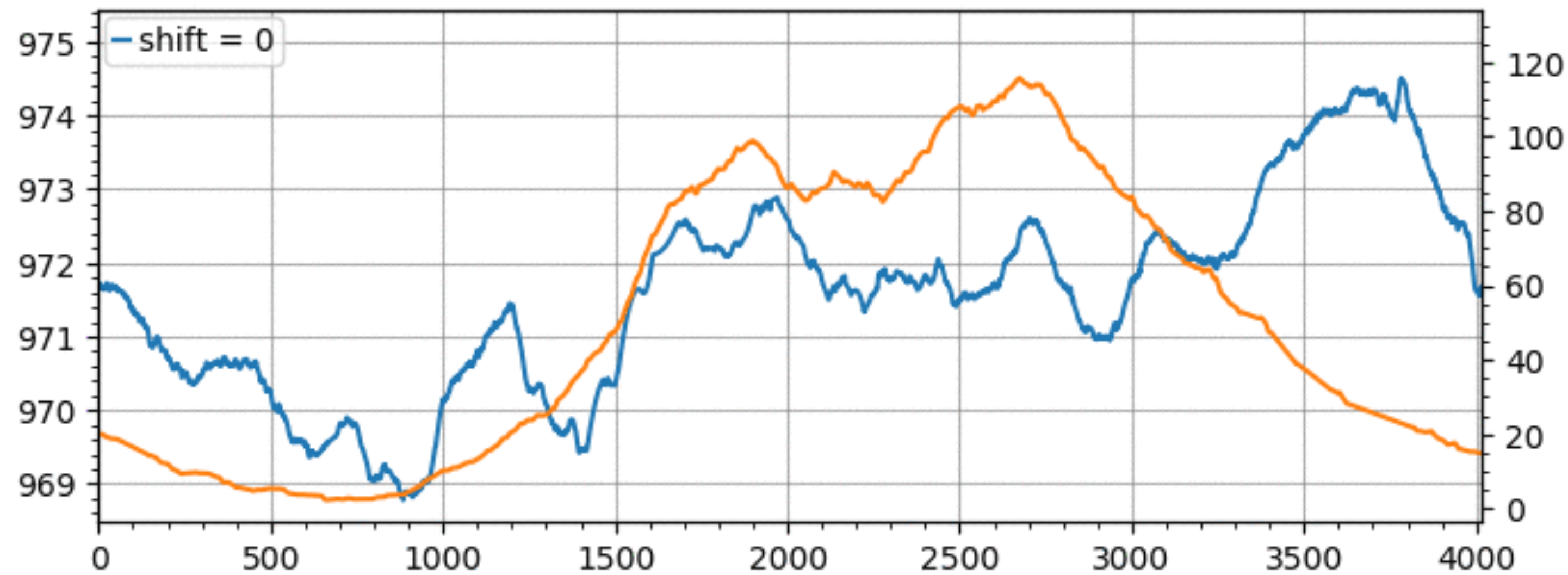
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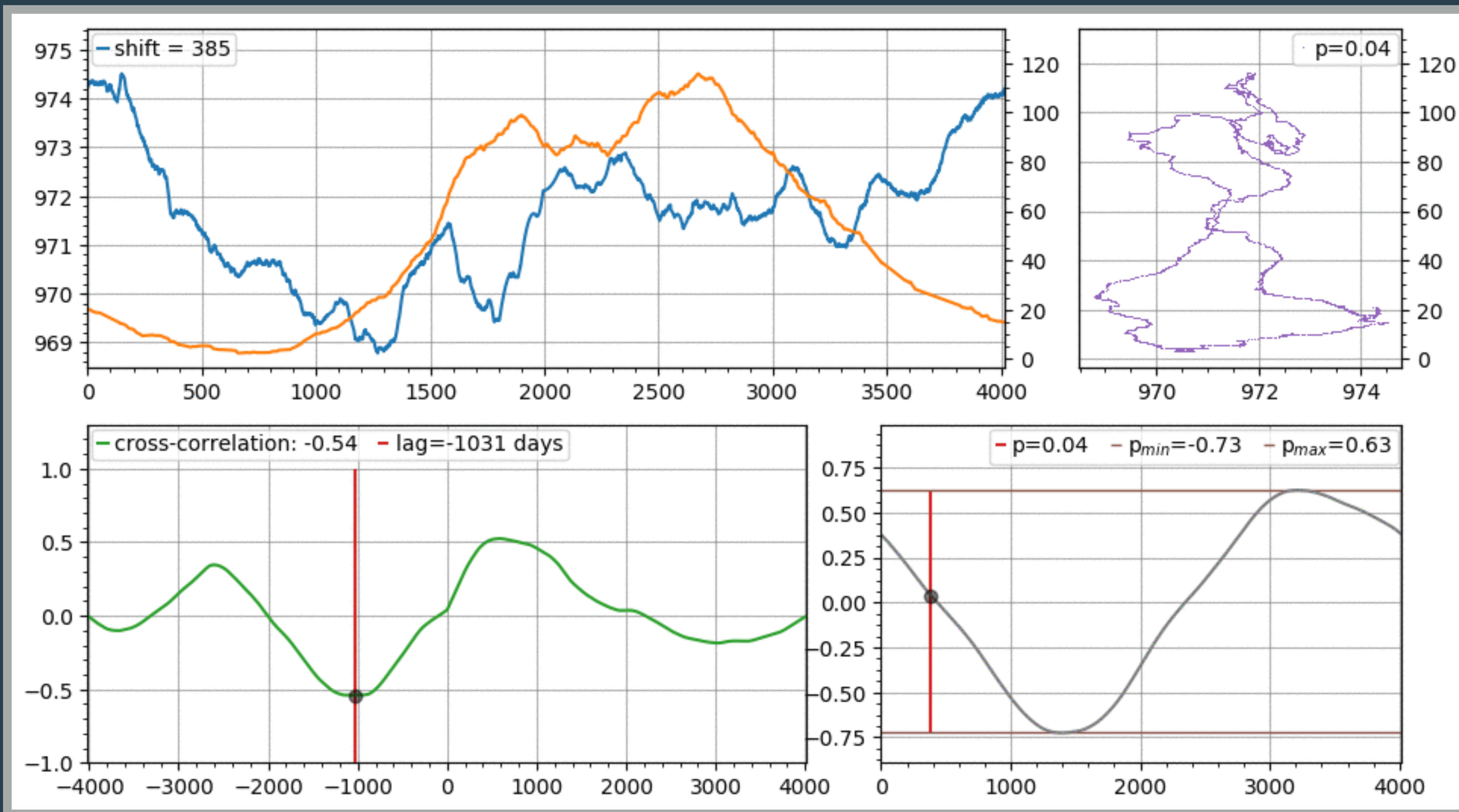
1-year smooth

Cross-Correlation
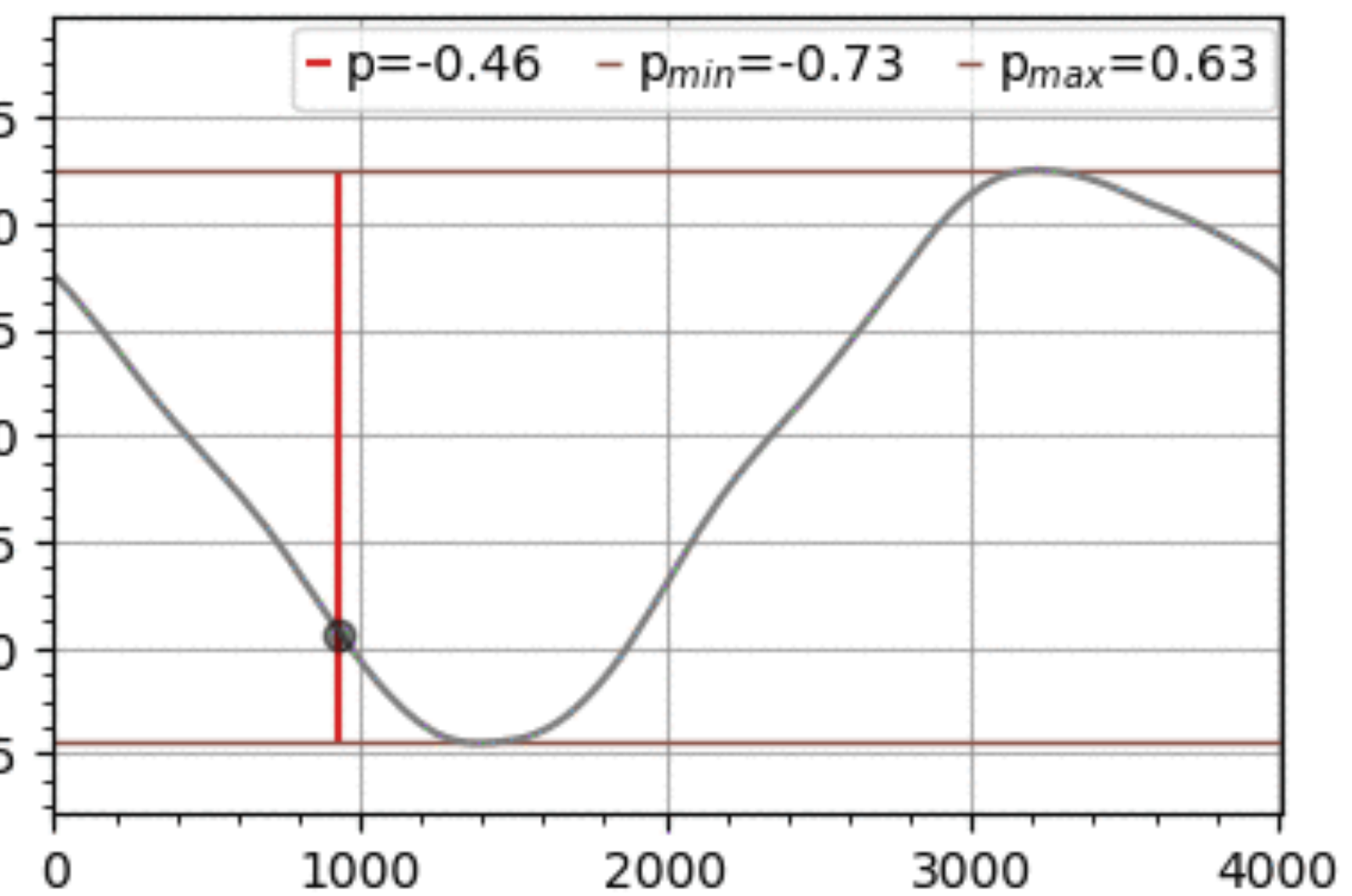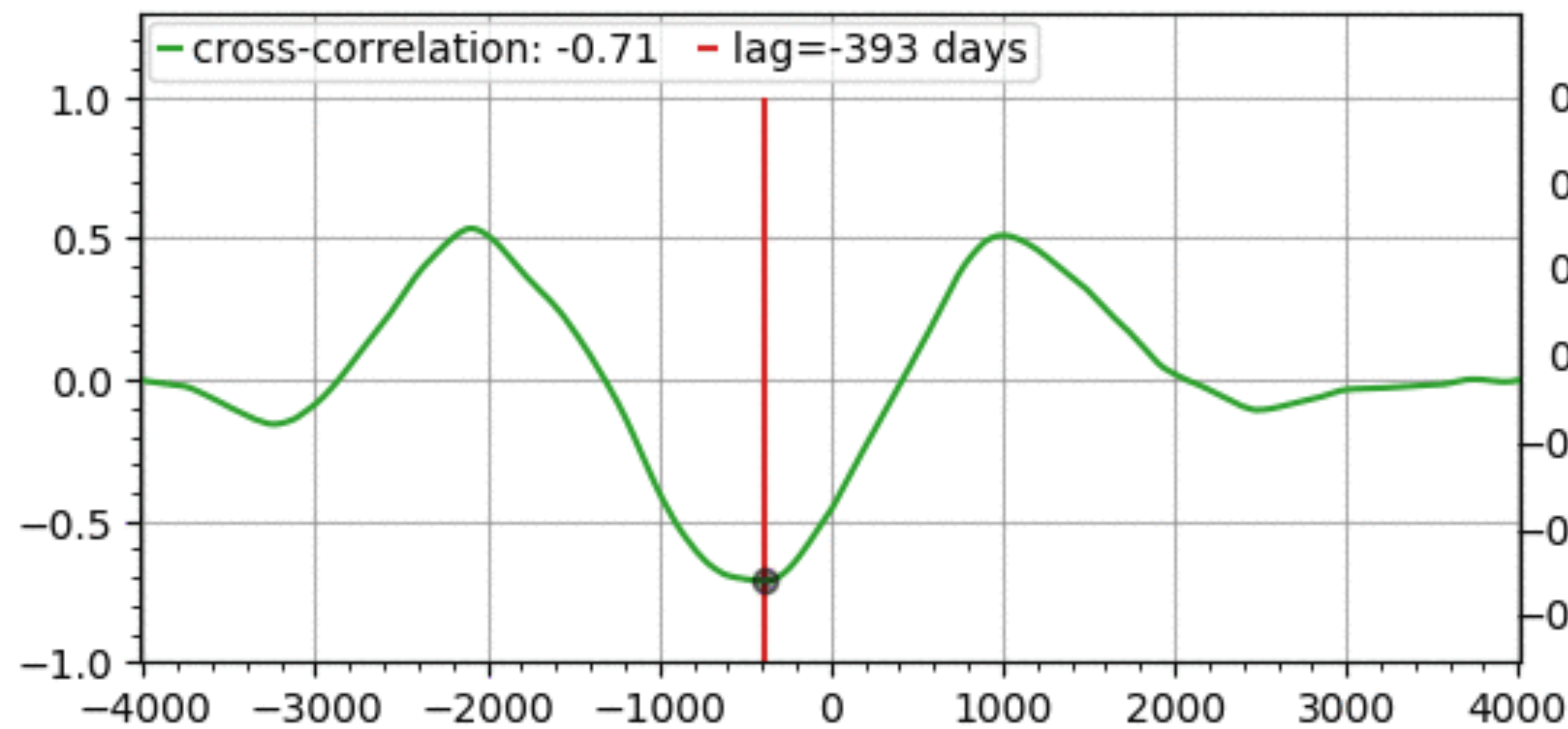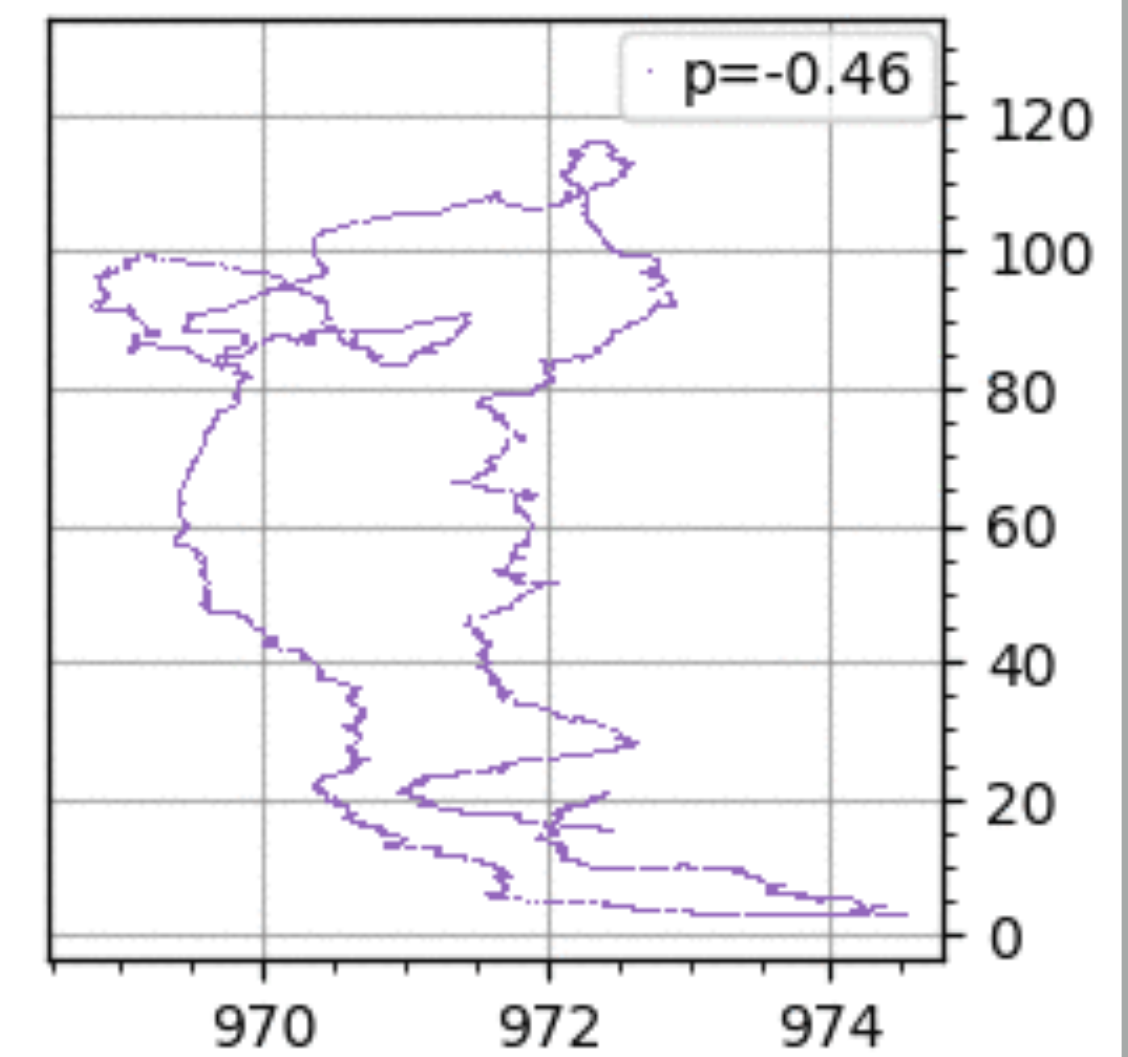
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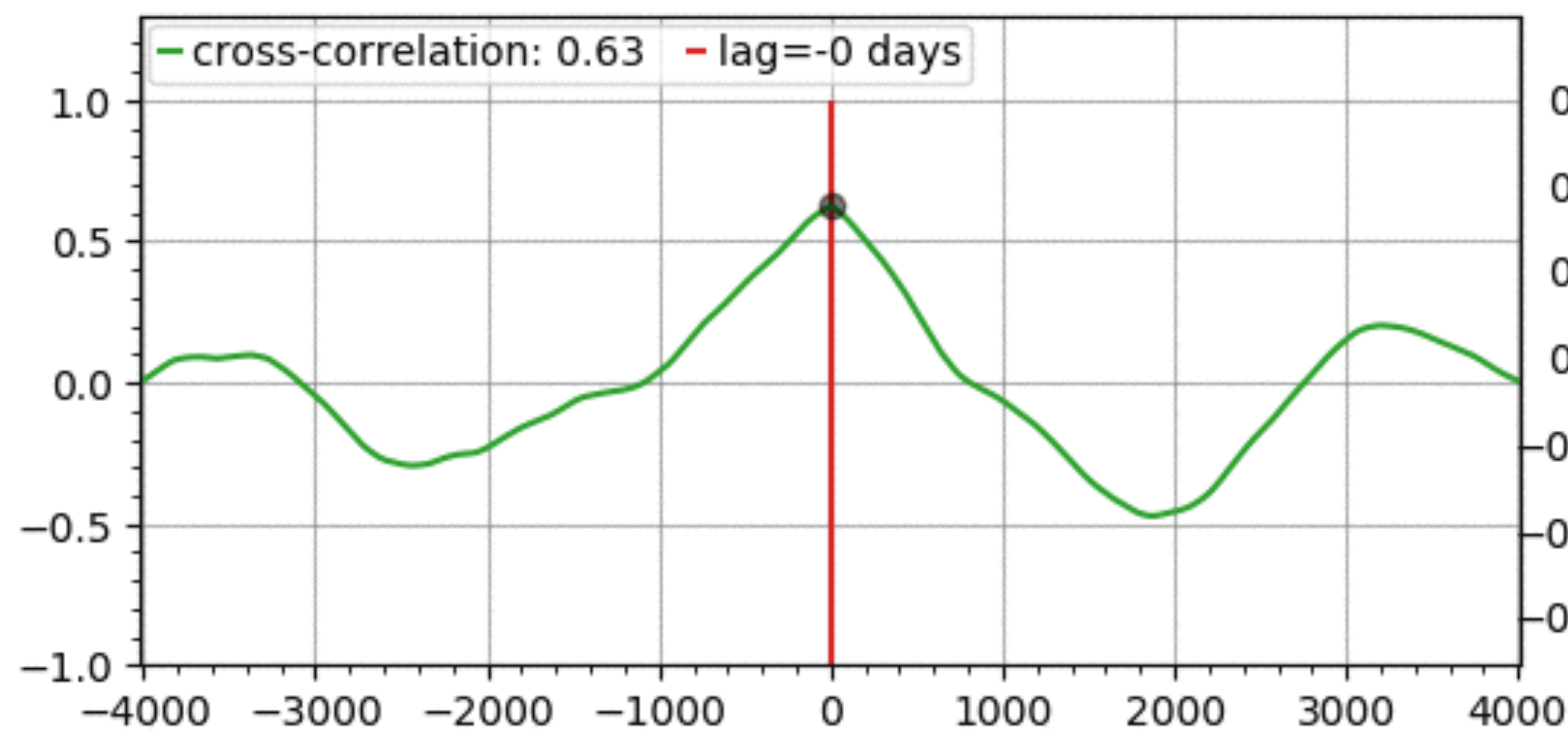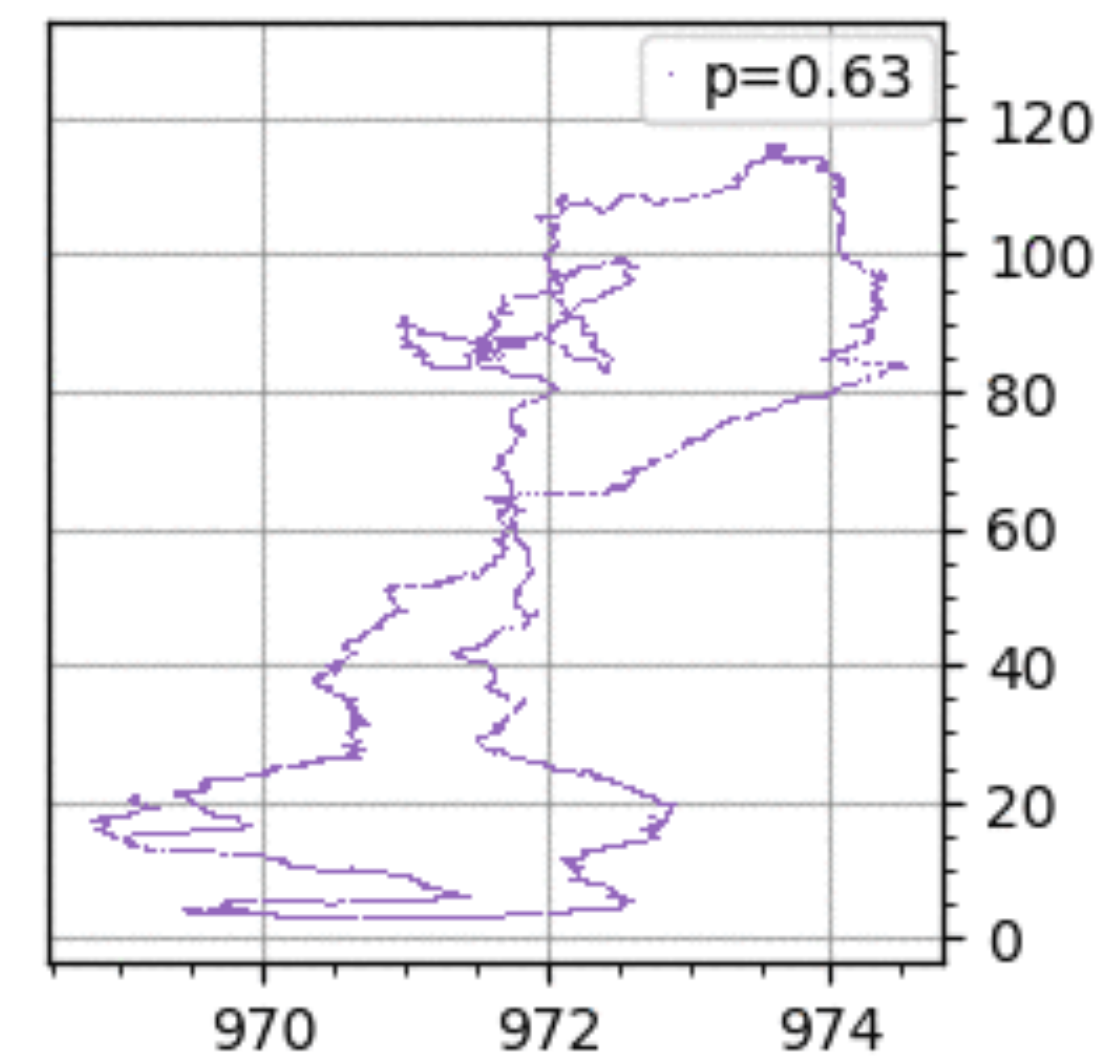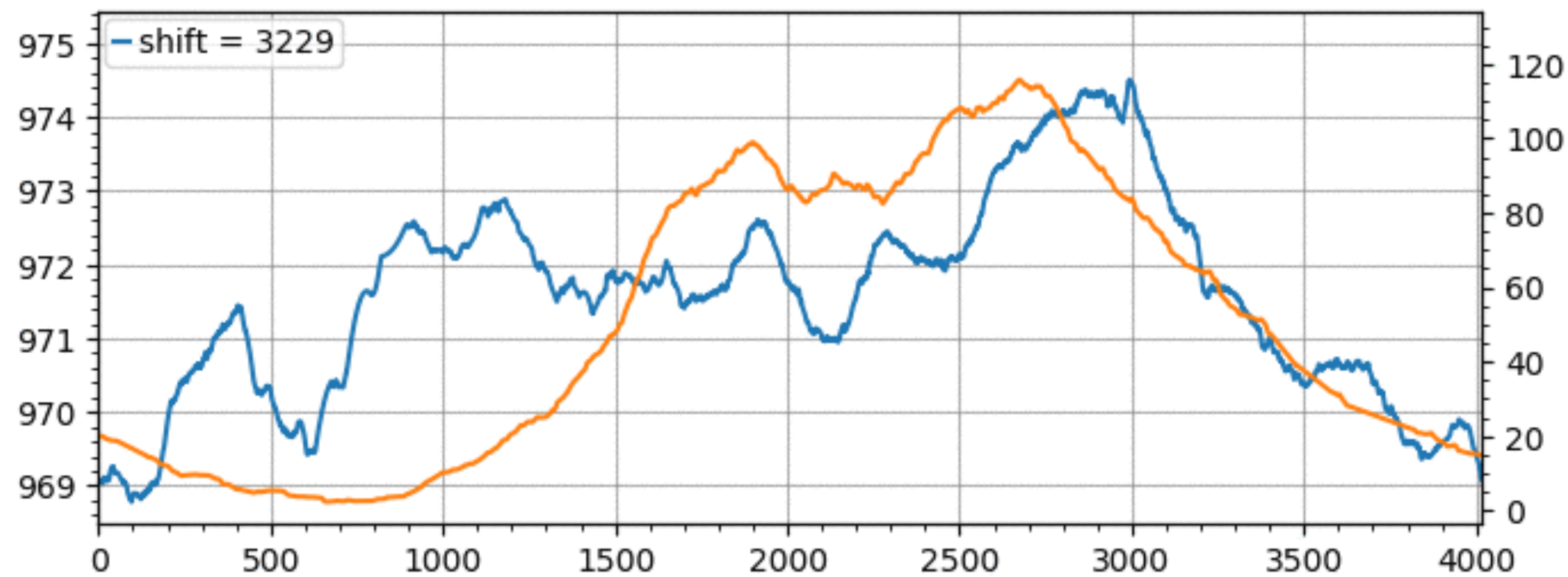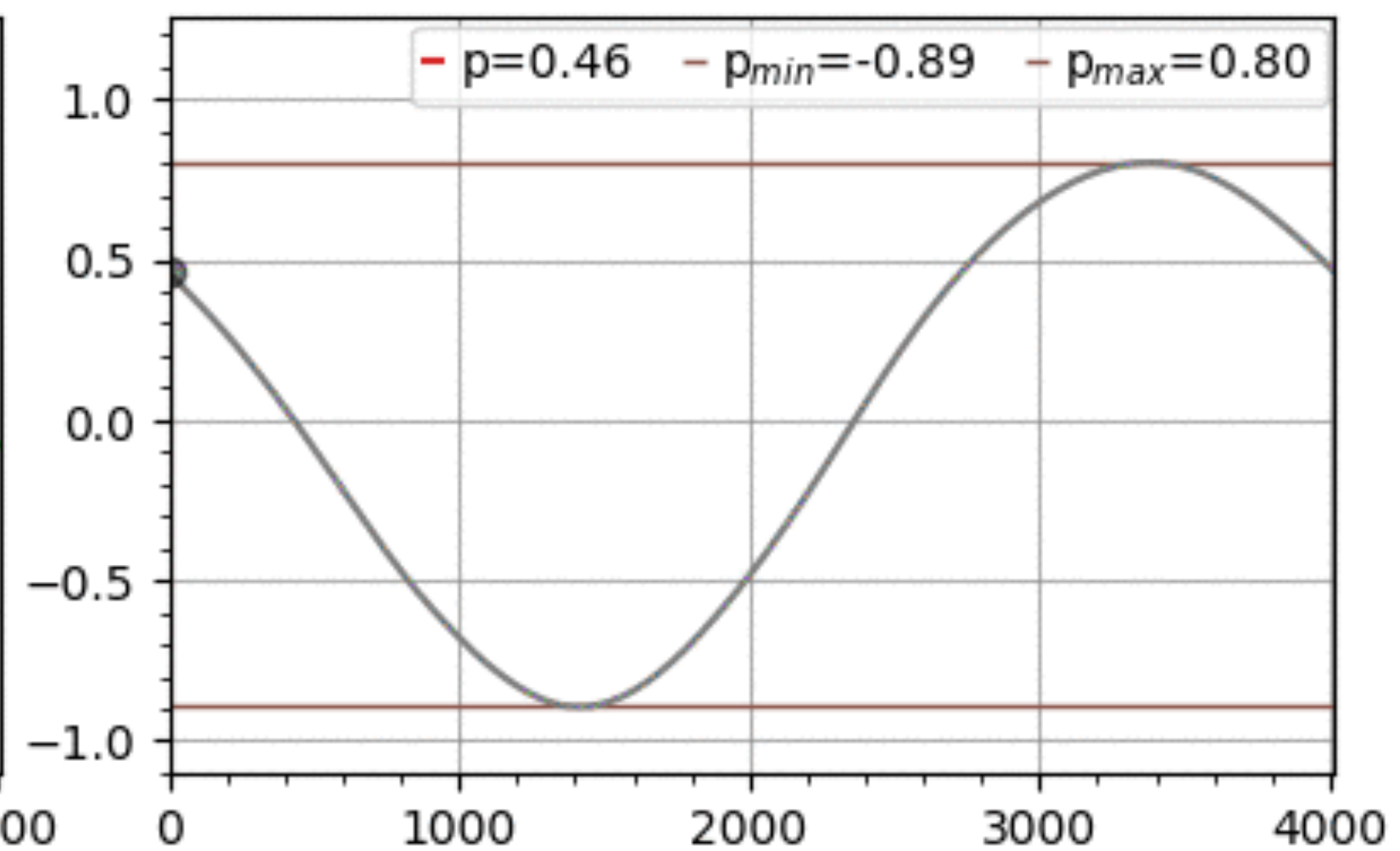# Cross-Correlation
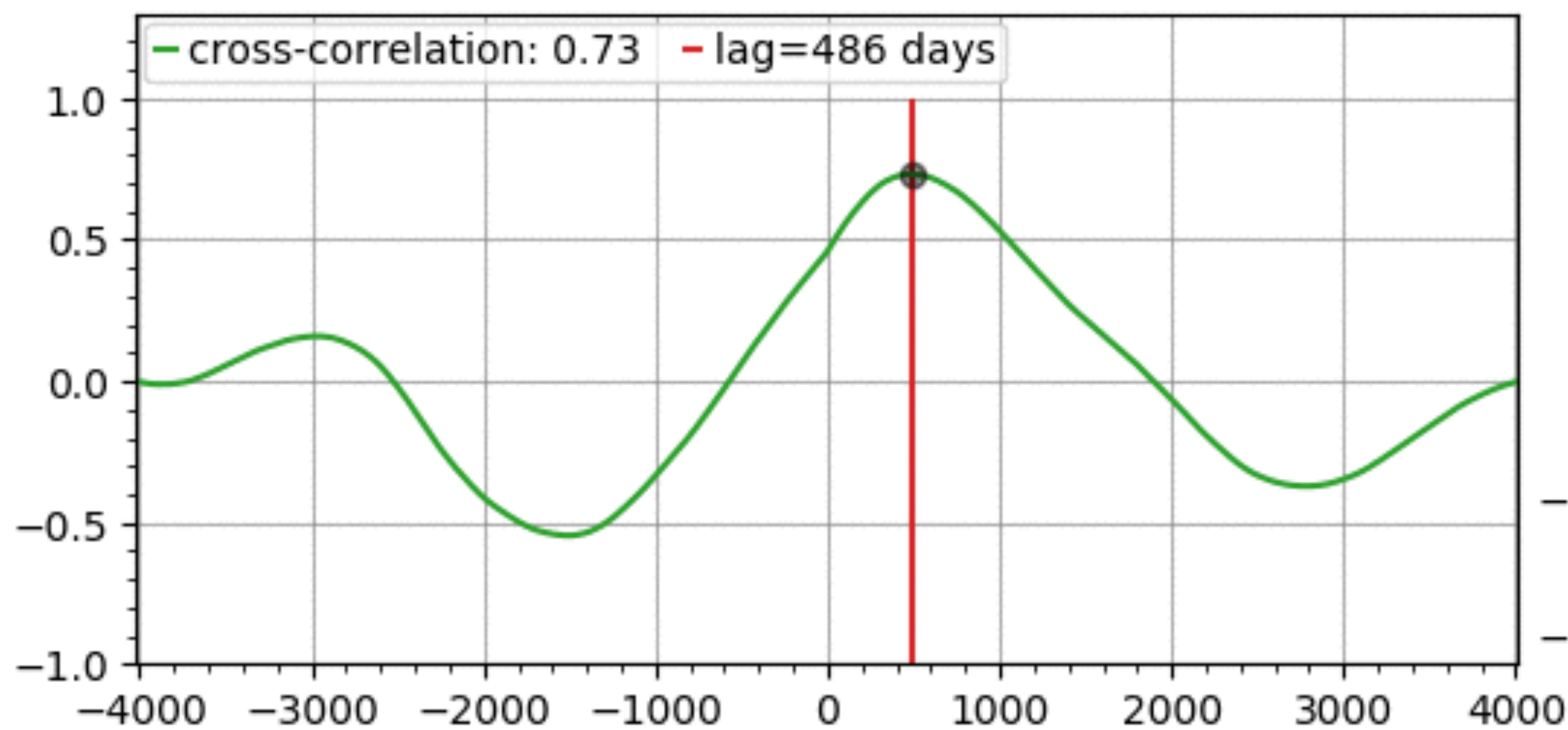
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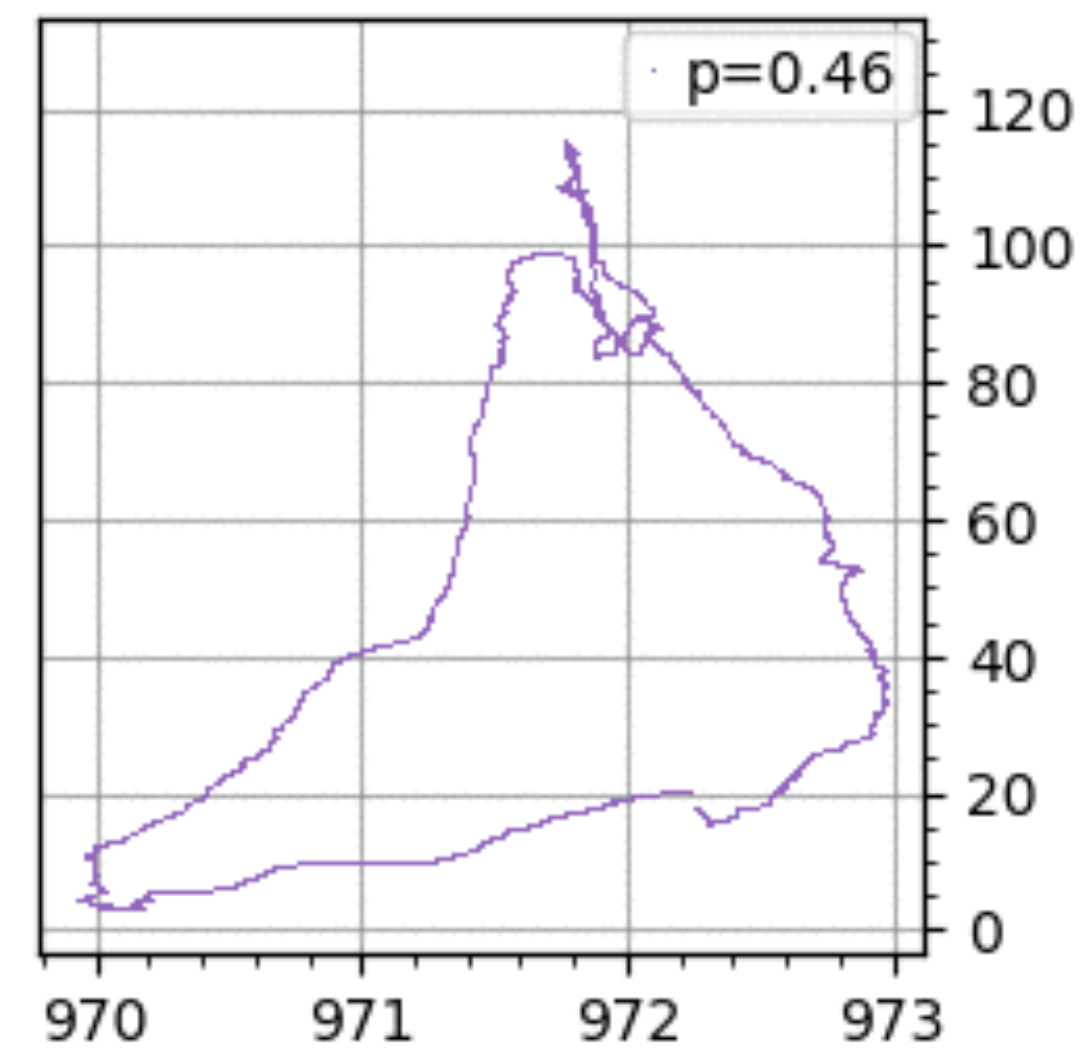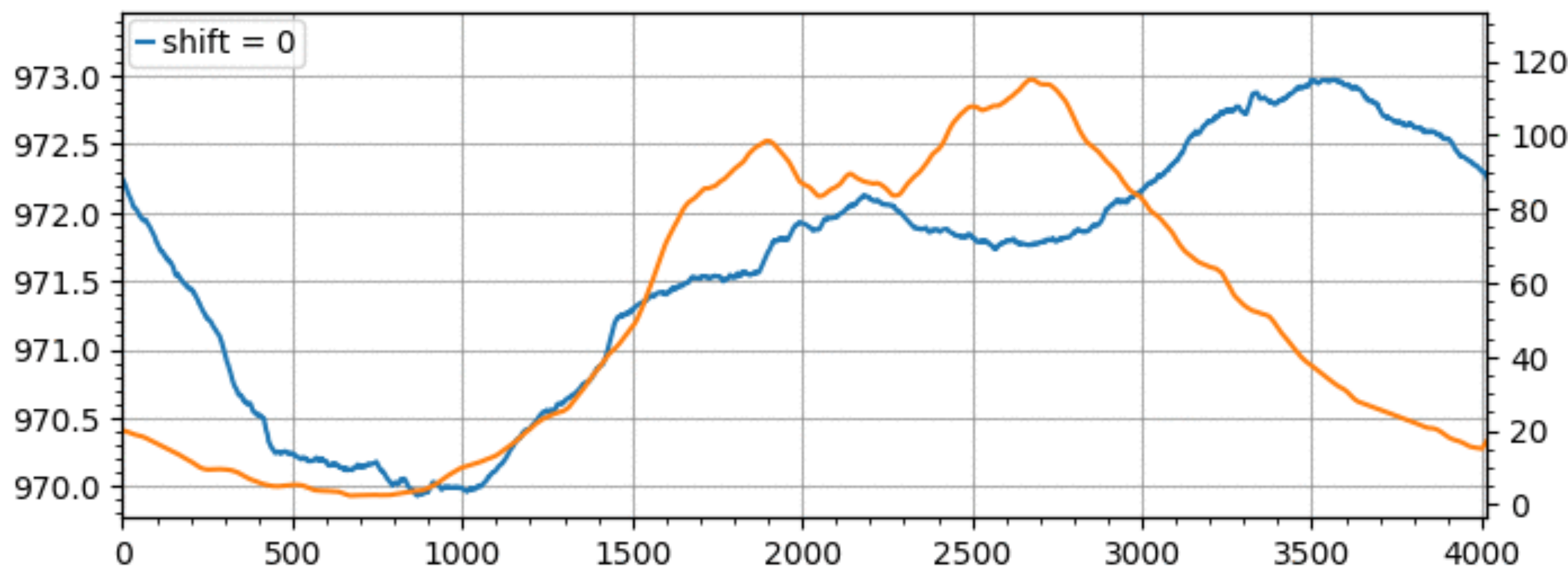
Cross-Correlation

1-year smooth

Cross-Correlation

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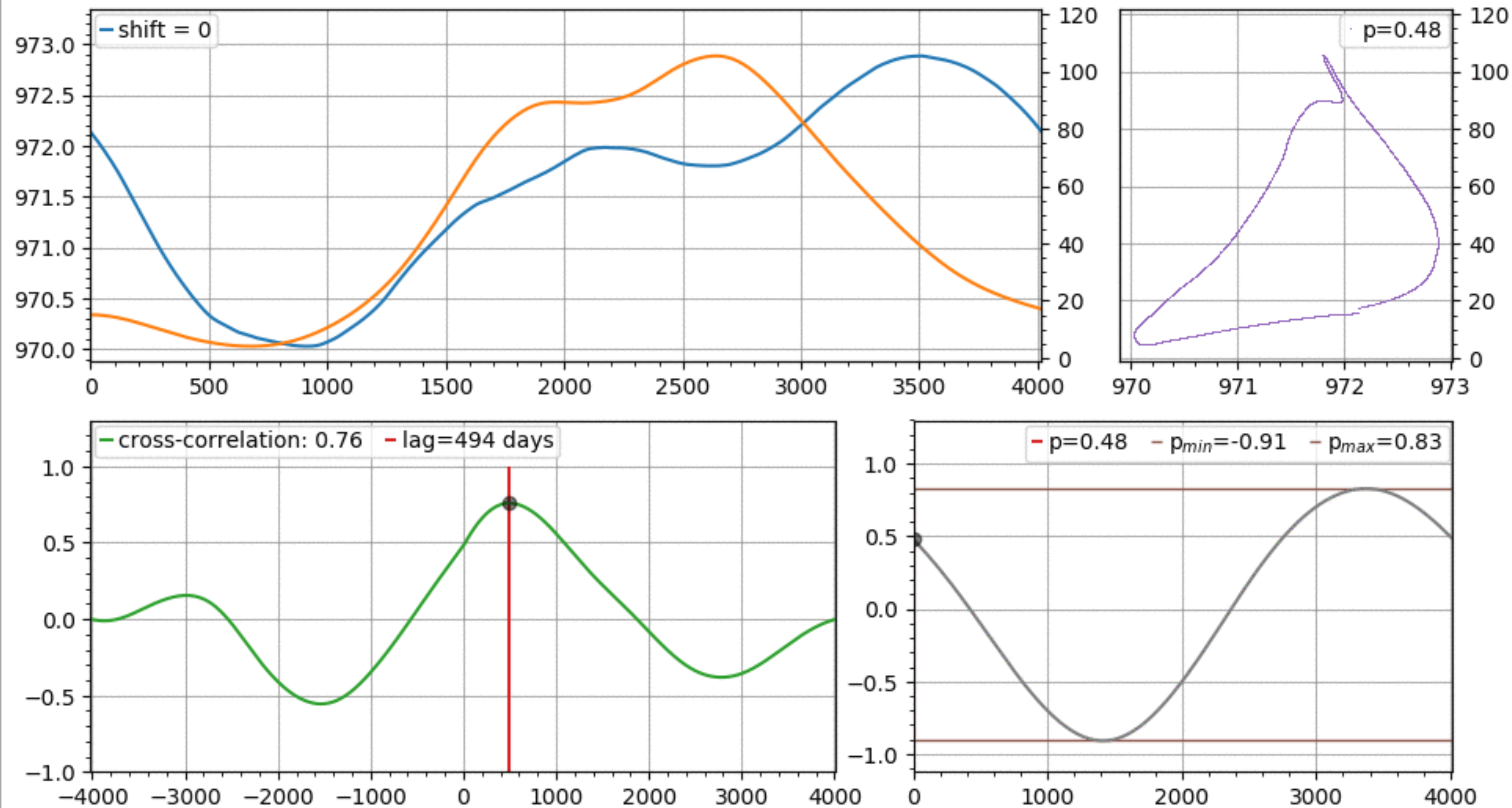# Cross-Correlation

2-year smooth

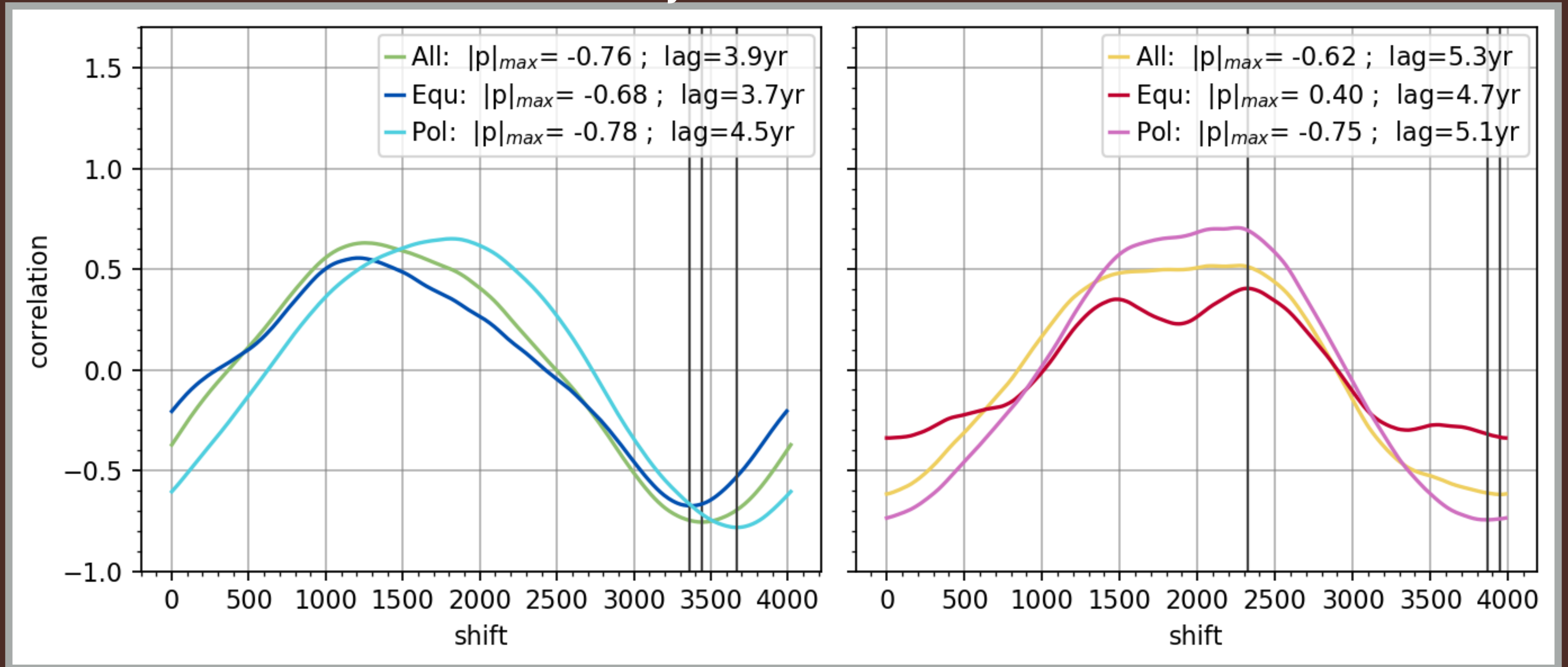# Cross-Correlation

2-year double smooth

Correlation to the sunspot cycle

1-year smooth

0,212 THz   0,405 THz
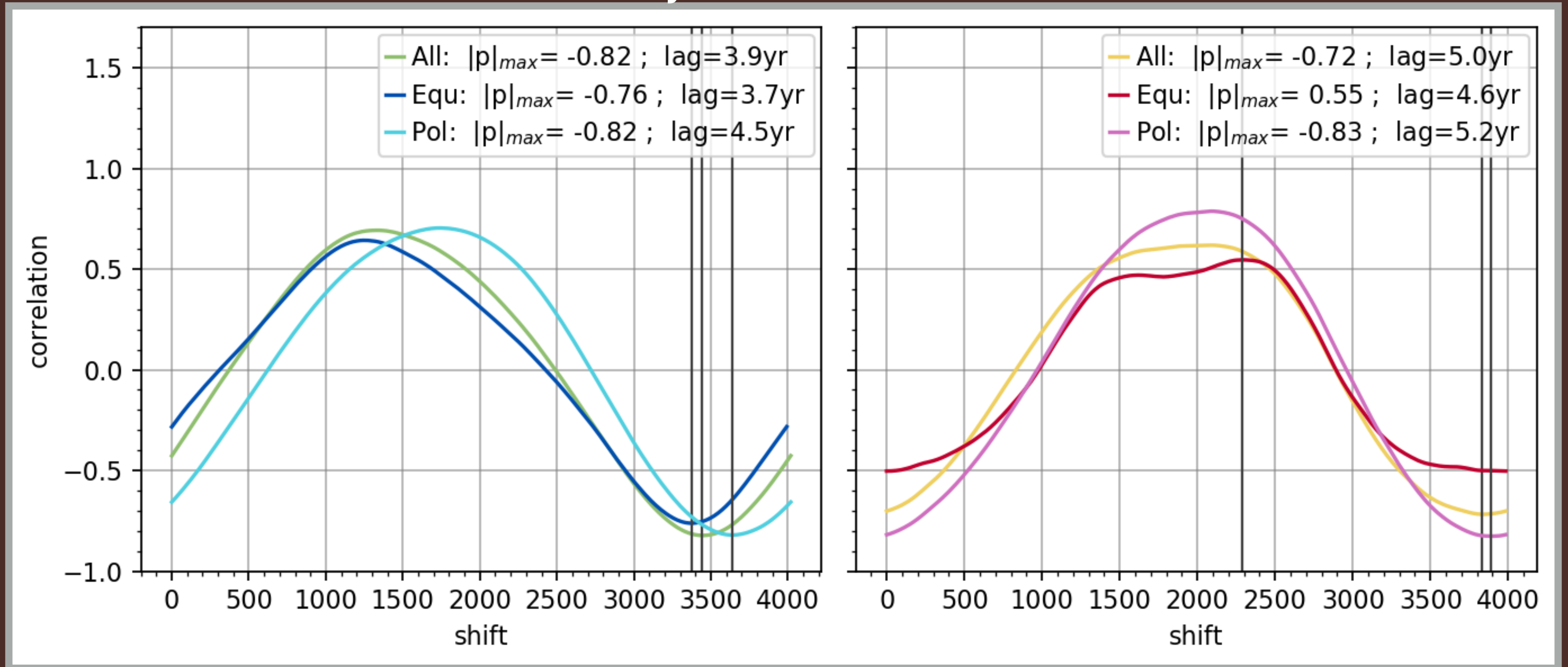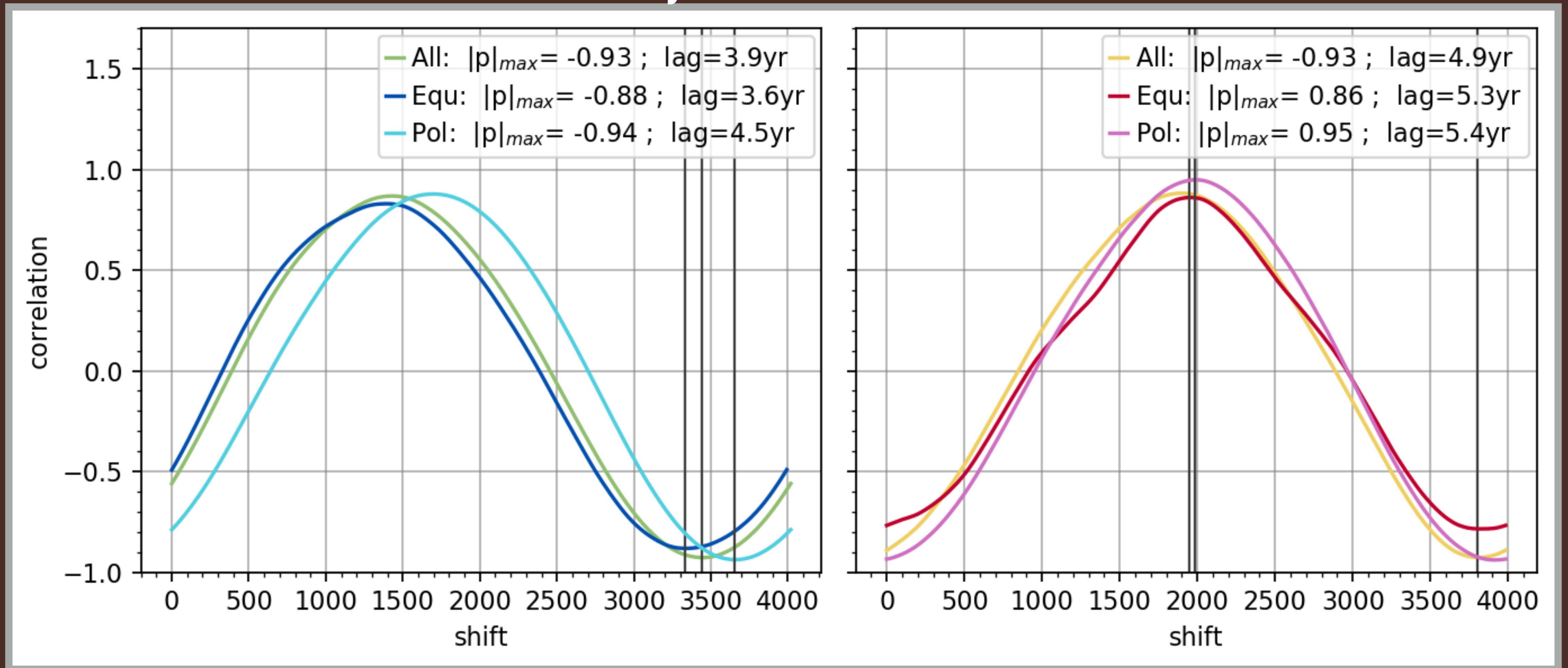
Correlation to the sunspot cycle

2-year smooth

0,212 THz   0,405 THz

Correlation to the sunspot cycle

4-year smooth

0,212 THz   0,405 THz

Final remarks

▸ Mean solar radii: R_{212} = 972" ± 5" | R_{405} = 973" ± 6"

  ▸ Subtracting ΔR: R_{212} = 962" ± 5" | R_{405} = 962" ± 6"

  ▸ Approx. 1900 km above photosphere (chromosphere)

▸ Correlation between solar radius and sunspot cycle

  ▸ Strongly anticorrelated

    ▸ Lag (phase difference): ~4 yr (212), ~5 yr (405)

  ▸ At 17 GHz there are a significant increase of polar limb brightening during solar minimum (Selhorst, 2004)

  ▸ Increase of B field complexity: ↓convect. ↑radiat.

Aknowledgements

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