PROBA2 Center

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Mid-term Periodicities of the LYRA data spectrum

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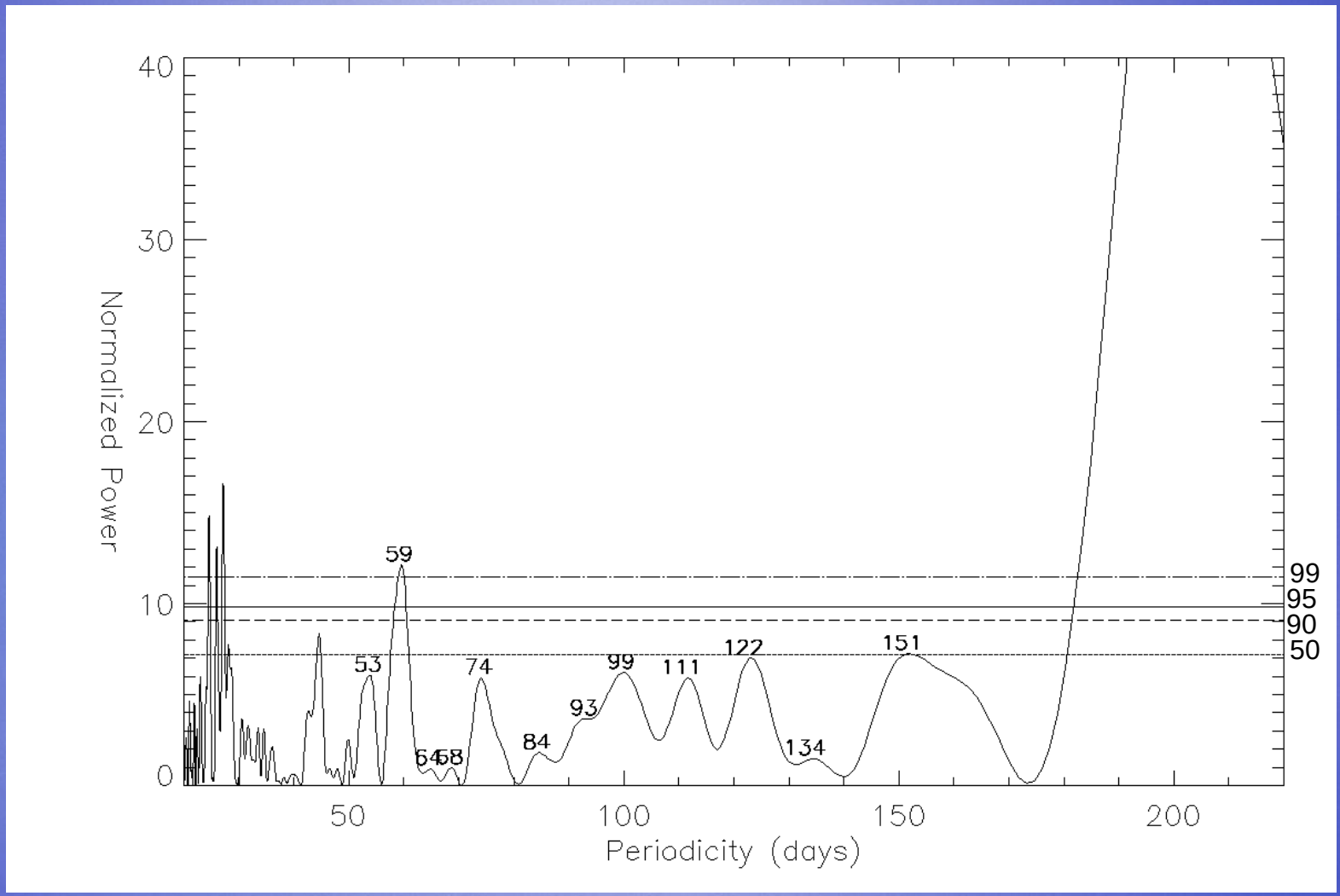
Outline

- **PROBA2/LYRA is a UV-EUV radiometer that has observed the Sun in a quasi-uninterrupted way over the past five years with two EUV channels: the aluminum channel(1-80nm) and the zirconium channel (1-20nm).**
- **We have analyzed the data produced by those two channels, searching for mid-term periodicities.**
- **We have compared those periodicities to the ones observed in the sunspot number, 10.7 cm flux, X-Rays flares indices and Daily Sunspots areas**
- **Analysis of data spectrum by Lomb-Scargle periodogram.**
- **We highlight different periodicities present in the spectra. We are mainly interested in the common periodicities of all signals: ~54, ~59, ~100, ~150**

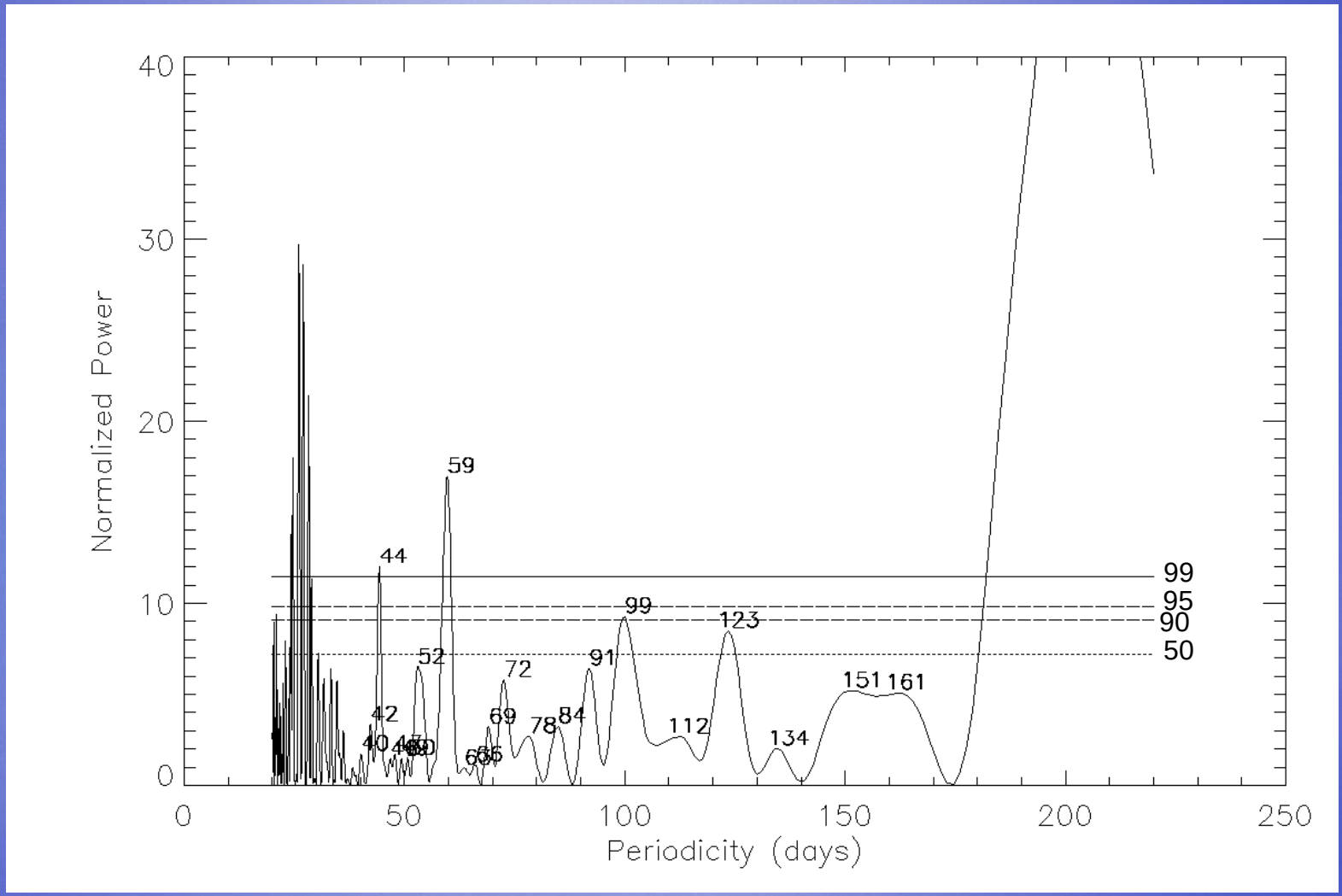
LYRA zirconium channel

Range of date 2010-04-01,2014-04-30



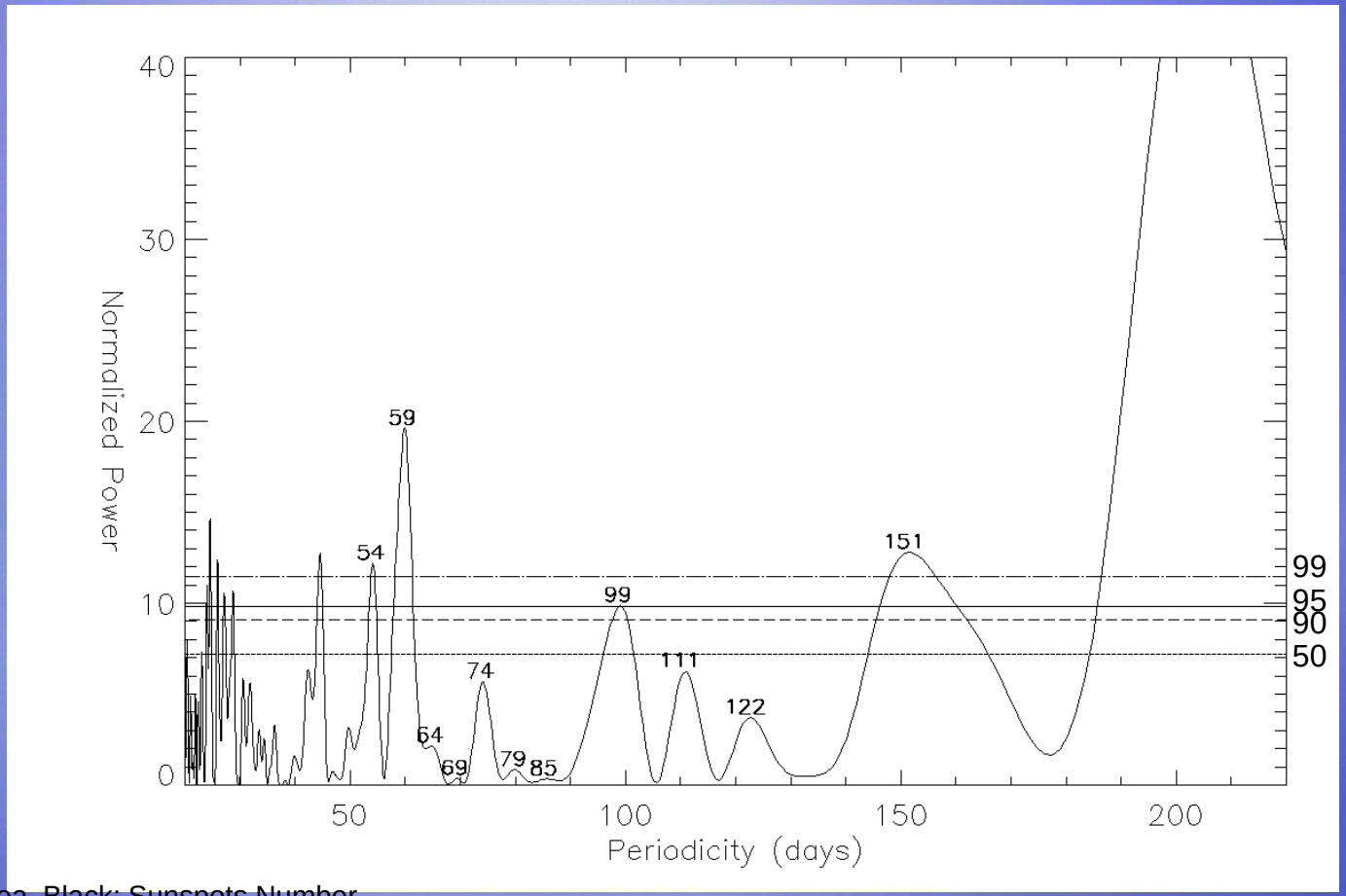
LYRA zirconium channel

Range of date 2010-04-01,2015-06-30



LYRA aluminium channel

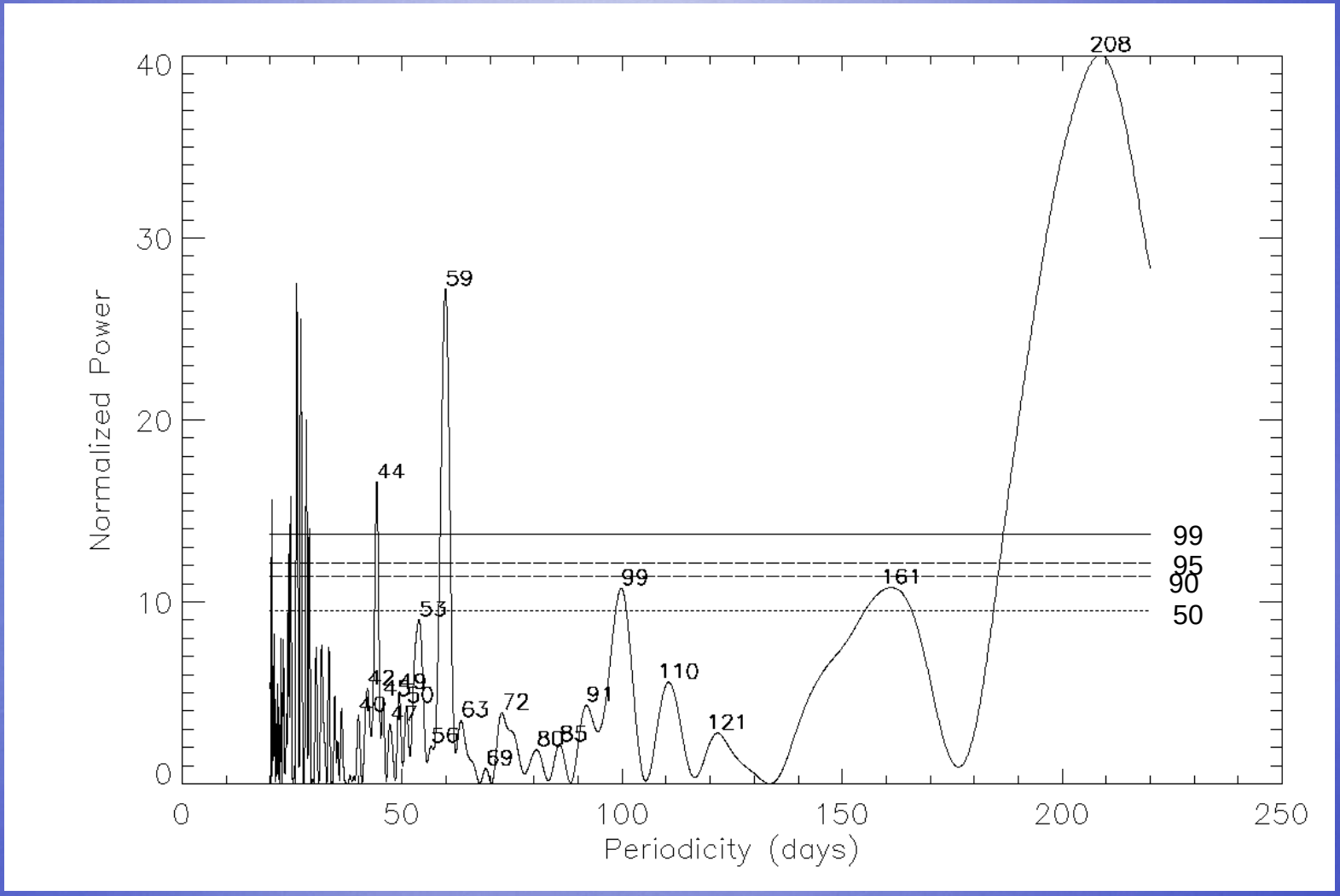
Range of date 2010-04-01,2014-04-30



Red: Sunspots area, Black: Sunspots Number

LYRA Aluminium channel

Range of date 2010-04-01,2015-06-30

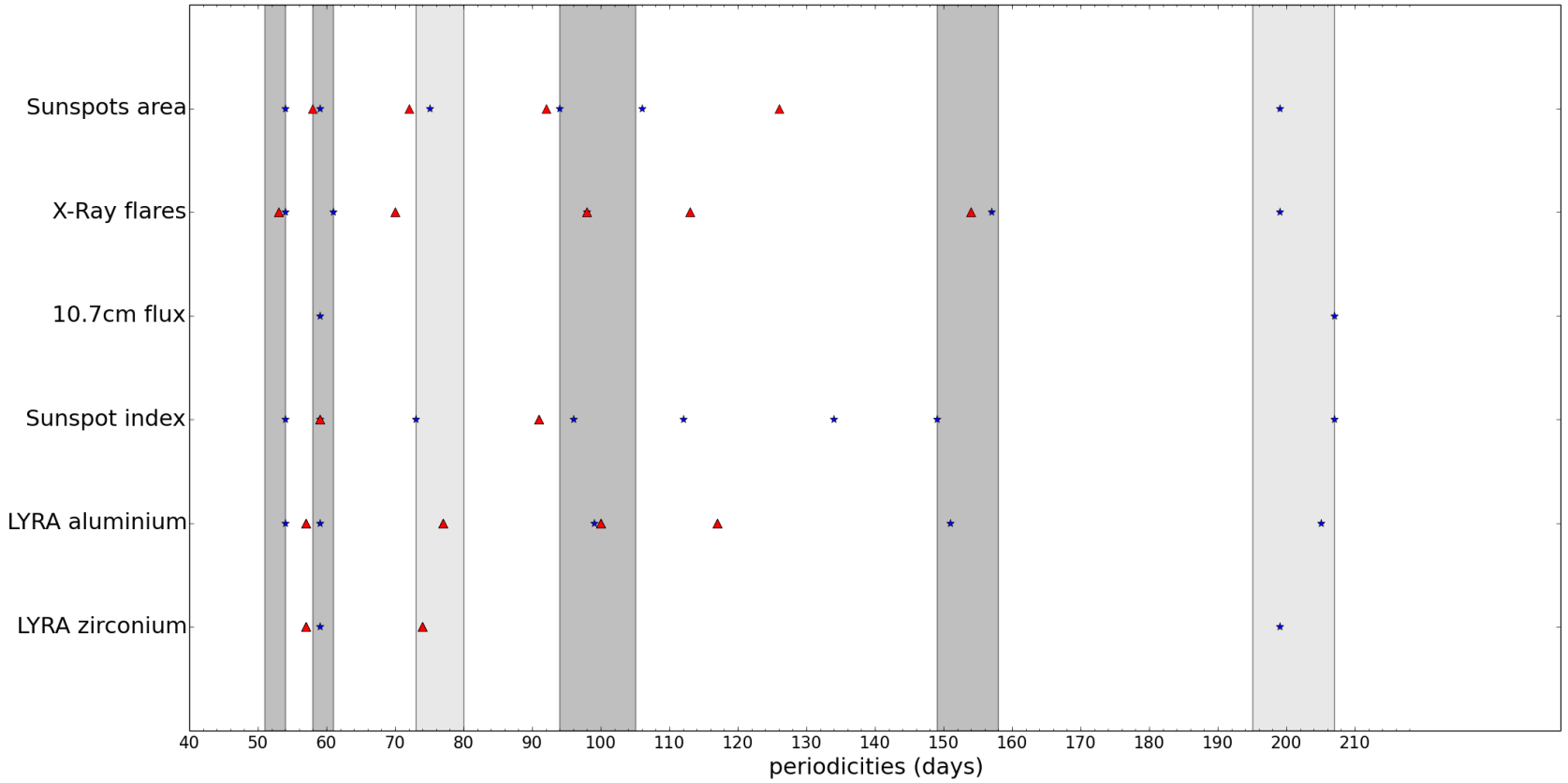


Periodicities
Set of data: April 2010 and April 2014

Table 3. Periodicities found in the Lomb Scargle periodograms with a significance larger than 90% and between 50 and 90 % in parenthesis

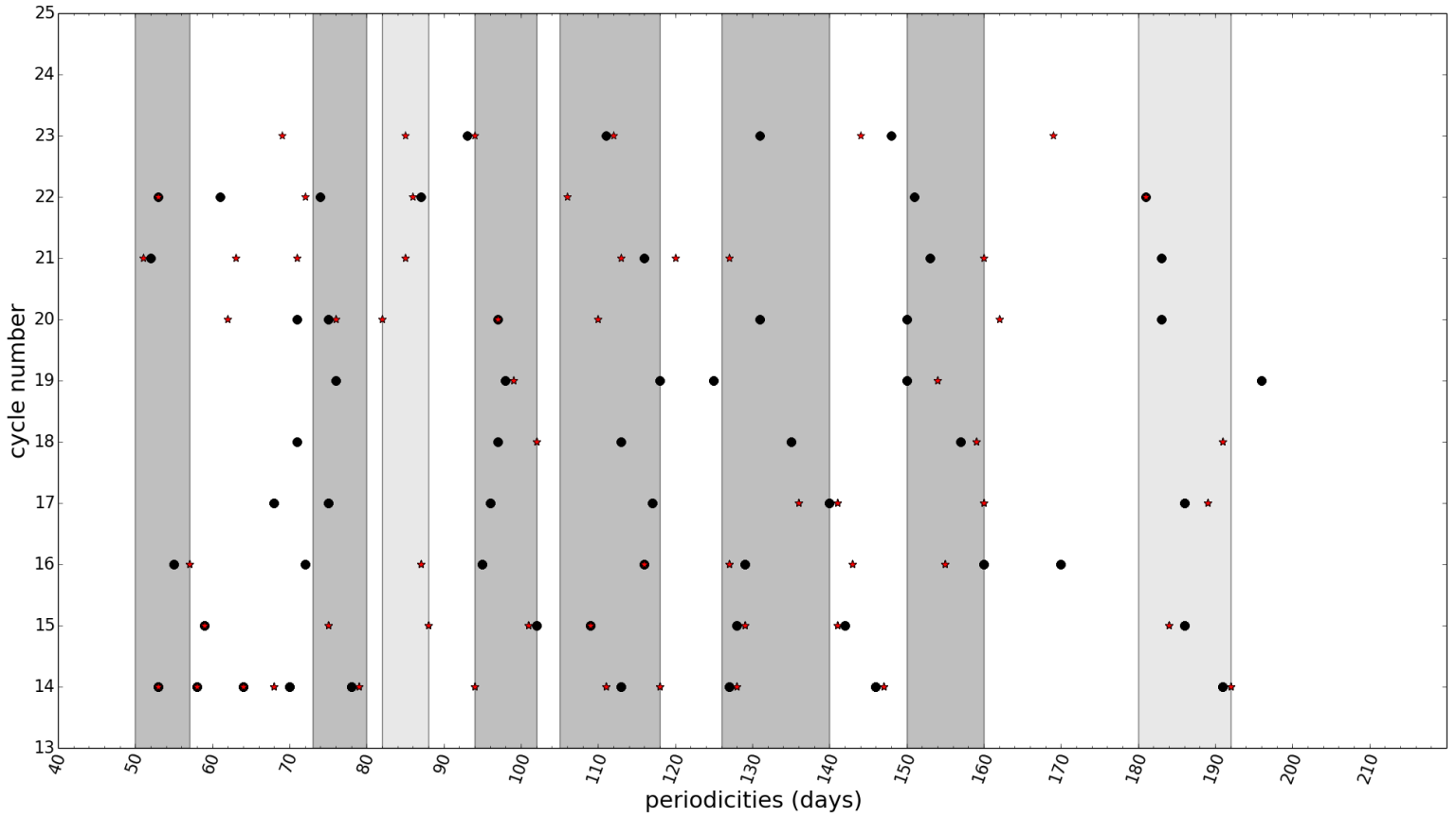
	zr	al	ri	f10	flares	area
	28	28	29	28	28	29
*	-	54	54	-	54	54
	-	-	-	-	57	-
*	59	59	59	59	61	59
	-	-	73	-	-	75
	-			(88)	-	(81)
*	-	99	96	(95)	98	94
	-	-	112	-	-	106
	(122)	-	123	-	-	-
	-	-	134	-	-	-
*	(151)	151	149	-	157	-
	-	-	167	-	-	-
	199	-	207	207	199	199

Summary of periodicities with 90% of significance.



Red: Wavelet transform, Blue: Lomb-Scargle periodogram

Periodicities per cycles for the sunspots index and sunspots areas



Red: Sunspots area, Black: Sunspots Number

Cycles

Cycle	started	Finished	Duration	Max (smooth SSN)	Min (smooth SSN)	Spotless days
Solar cycle 14	1902 September	1913 December	11.5	64.2 (Feb 1906)	1.5	~1019
Solar cycle 15	1913 December	1923 May	10.0	105.4 (Aug 1917)	5.6	534
Solar cycle 16	1923 May	1933 September	10.1	78.1 (Apr 1928)	3.5	568
Solar cycle 17	1933 September	1944 January	10.4	119.2 (Apr 1937)	7.7	269
Solar cycle 18	1944 January	1954 February	10.2	151.8 (May 1947)	3.4	446
Solar cycle 19	1954 February	1964 October	10.5	201.3 (Mar 1958)	9.6	227
Solar cycle 20	1964 October	1976 May	11.7	110.6 (Nov 1968)	12.2	272
Solar cycle 21	1976 May	1986 March	10.3	164.5 (Dec 1979)	12.3	273
Solar cycle 22	1986 March	1996 June	9.7	158.5 (Jul 1989)	8.0	309
Solar cycle 23	1996 June	2008 January	11.7	120.8 (Mar 2000)	1.7	821
Solar cycle 24	2008 January			81.9 (Apr 2014)		

Conclusions

- We analyzed the spectral content of two LYRA channels (aluminum and zirconium channels).
- We compared the LYRA spectra obtained to other solar indices representing the solar activity: the sunspots index, the 10.7 radio flux, but also the number of X-Ray flare events, the sunspots area.

- LYRA spectra exhibit a similar behavior as the other ones. Such a good correlation reinforces the validity of our LYRA data.

- Some periodicities are well described in the literature, like the 28 and 160-day (Rieger et al 1984) periods. Others have only been mentionned a couple of time. The fact that they can be clearly identified in our data is an argument in favor of their existence.

- Four periodicities are visible in the various datasets for the cycle 24: ~54, ~59, ~100,~150.

- The analyze of the Sunspot area and Sunspot number spectrum when covering the solar cycles 14-23 give the four main periodicities but also additional periodicities: 75,110,130 and 185

To DO:

- The analysis of periodicity amplitudes of the Sunspot area and Sunspot number when covering the solar cycles 14-23 could be interesting.
- Quantization of the peaks width
- Analysis of periodicities with time windows of different sizes. Check the evolution of periodicities with time and with window size.
- Analysis of the periodicity ~130, which is also found by M.Mefta and al. at Latmos.

Lomb-Scargle periodogram

For a times series $X(t_i)$, where $i = 1, 2, \ldots, N_0$, the periodogram as a function of the frequency ω is defined (Scargle 1982) as

$$P_X(\omega) = \frac{1}{2}\left\{\frac{[\sum_{j=1}^{N_0} X(t_j)\cos\omega(t_j-\tau)]^2}{\sum_{j=1}^{N_0}\cos^2\omega(t_j-\tau)} + \frac{[\sum_{j=1}^{N_0} X(t_j)\sin\omega(t_j-\tau)]^2}{\sum_{j=1}^{N_0}\sin^2\omega(t_j-\tau)}\right\},$$

where τ is defined by the equation

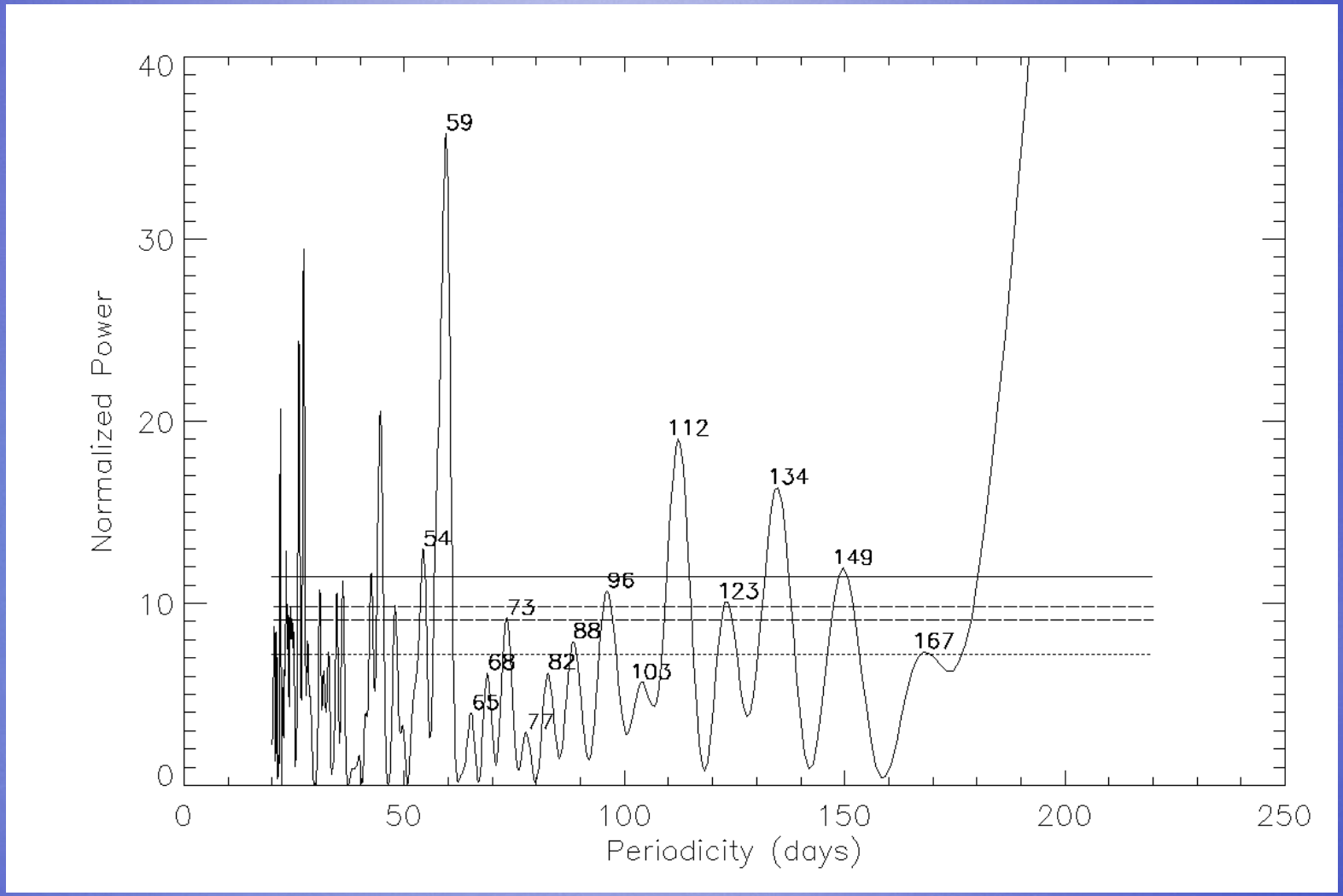
$$\tan(2\omega\tau) = \left(\sum_{j=1}^{N_0}\sin 2\omega t_j\right)\Big/\left(\sum_{j=1}^{N_0}\cos 2\omega t_j\right).$$

Significance:

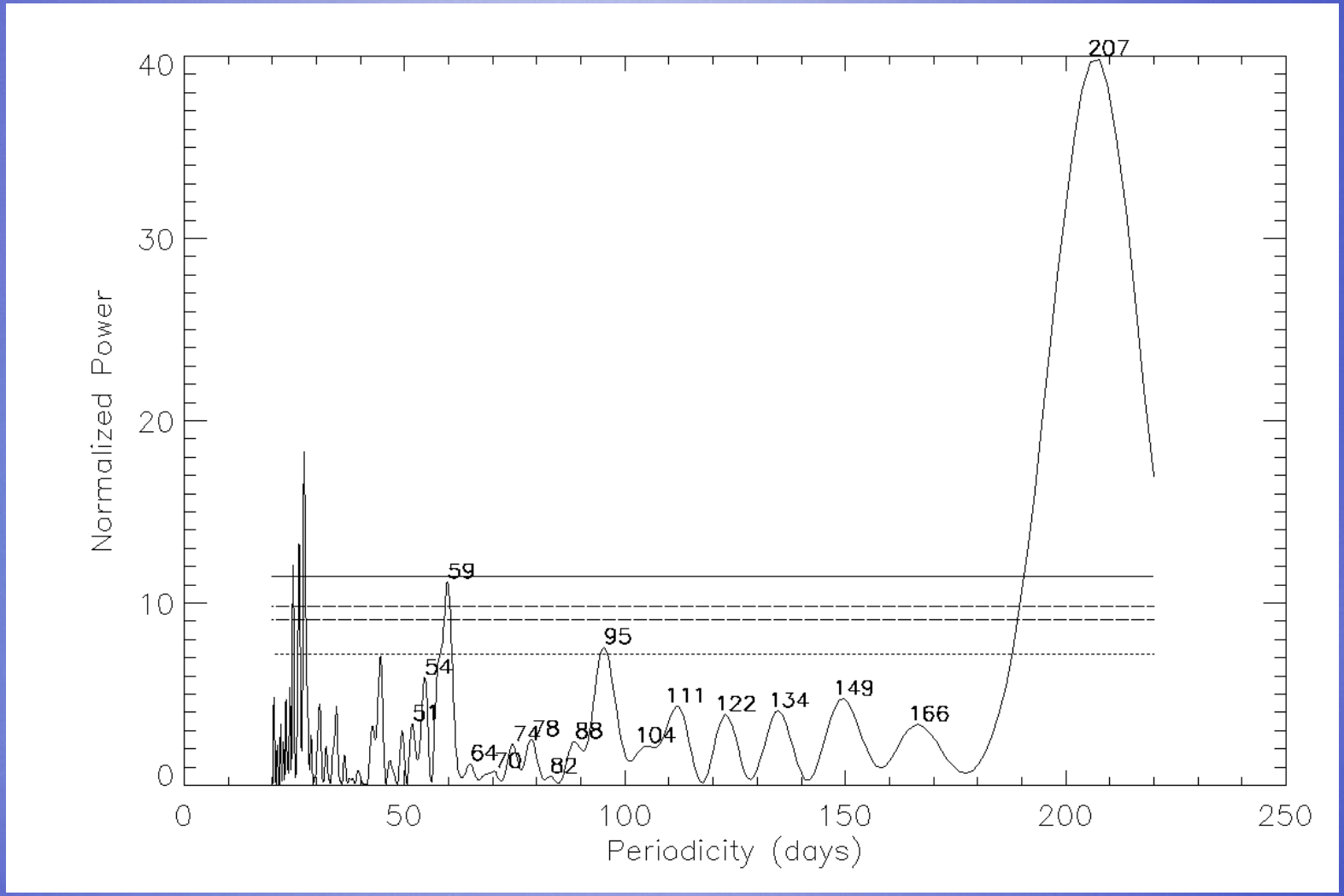
- signi = -ln(1 - ((1-fap)^(1./horne)))
- Number of independent frequencies(Horne and Baliunas)

```
n0    = n_elements(time)
horne = long(-6.362+1.193*n0+0.00098*n0^2.)
        if (horne LT 0) THEN horne=5
```

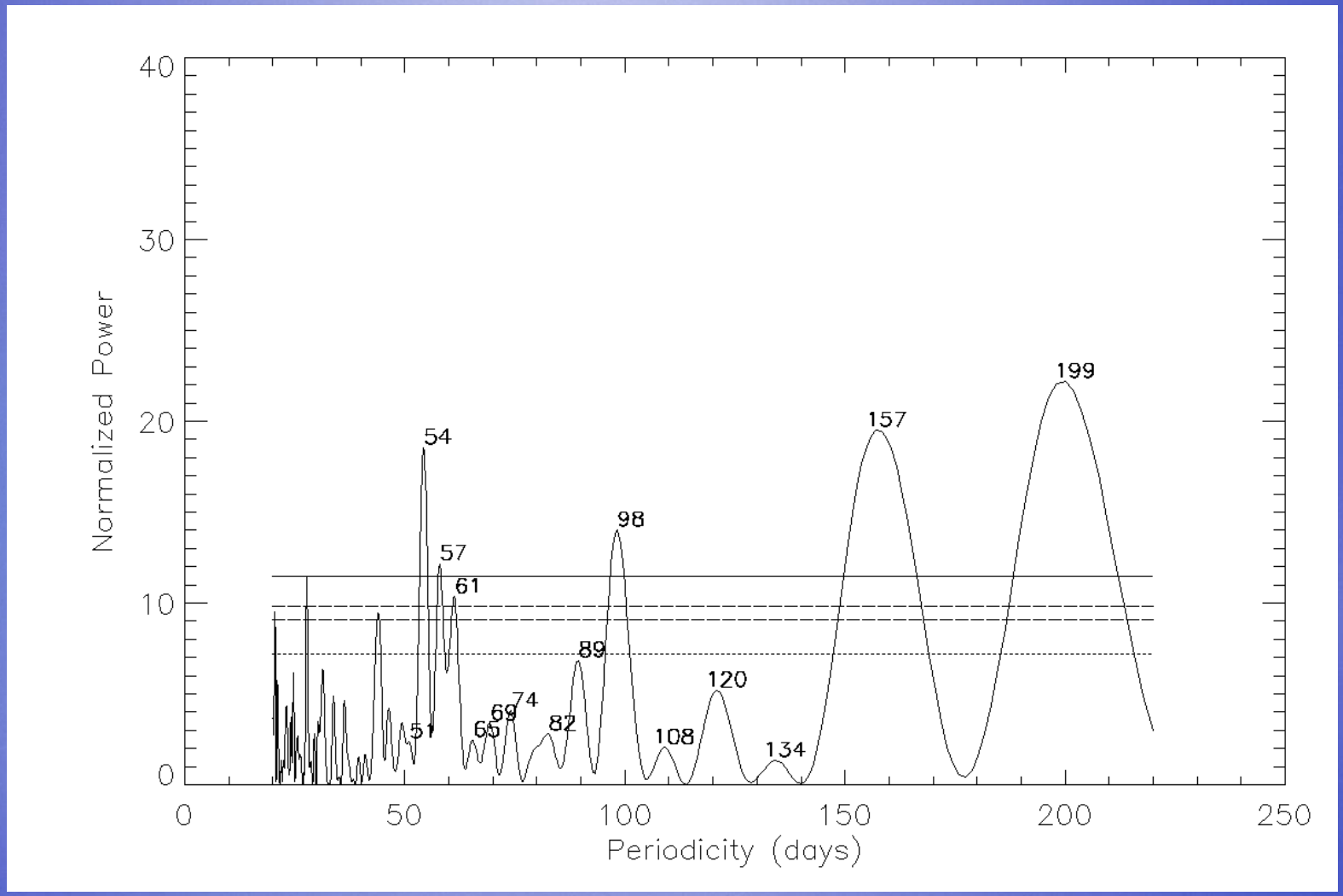
Sunspot index spectrum



F10.7 cm Flux spectrum



Flares index spectrum



Sunspot area spectrum