Rieger periodicity in solar activity

J. L. Ballester

Solar Physics Group

Universitat Illes Balears & IAC^3

Mallorca (Spain)

ISSI Team on Rossby waves in Astrophysics

Rieger periodicities in the Sun

- The so-called Rieger periodicity (RP) ranges, in general, between 150 - 160 days

- Other periodicities (128, 102, 78, 51 days) have also been claimed and have received the name of Rieger Type Periodicities (RTPs)

- Here, I'm only going to talk about the Rieger periodicity (RP) in solar activity indicators, its features and evidences supporting **one** of the proposed mechanisms to explain its origin

Rieger periodicity: first evidences

- The interest in short - term periodicities in solar activity was renewed by the discovery made by Rieger et al. (1984) of a periodicity around 154 days in 139 γ - ray and > 500 X- ray flares (1980 - 1983, Solar cycle 21)

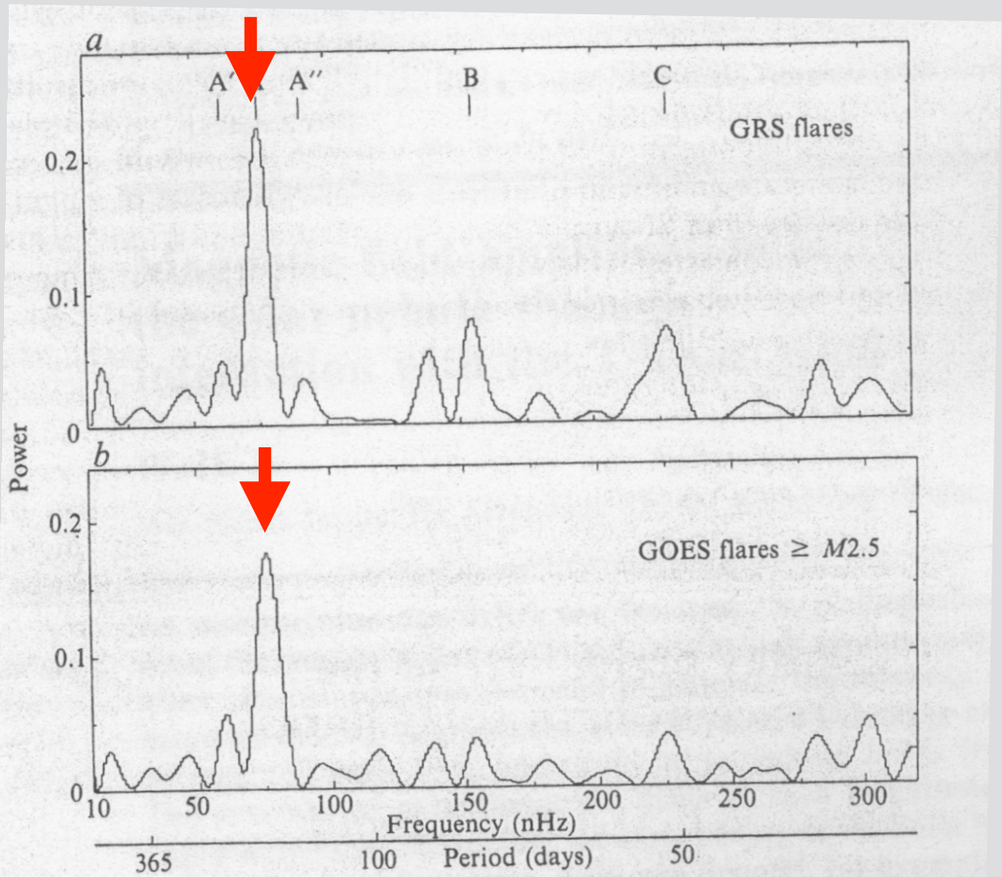
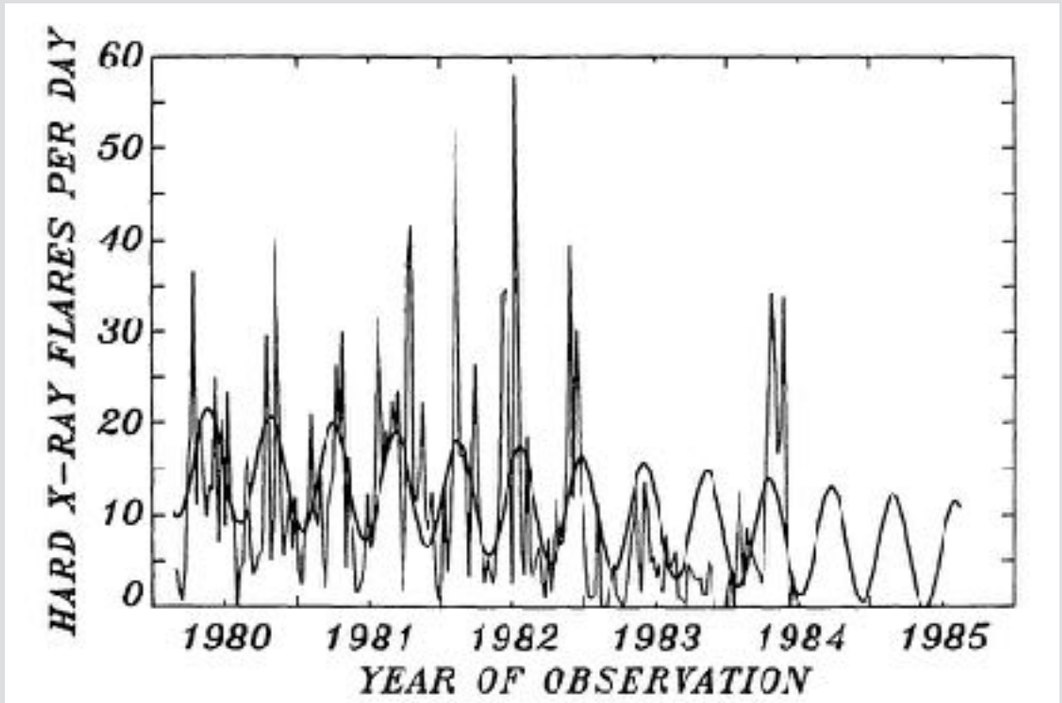
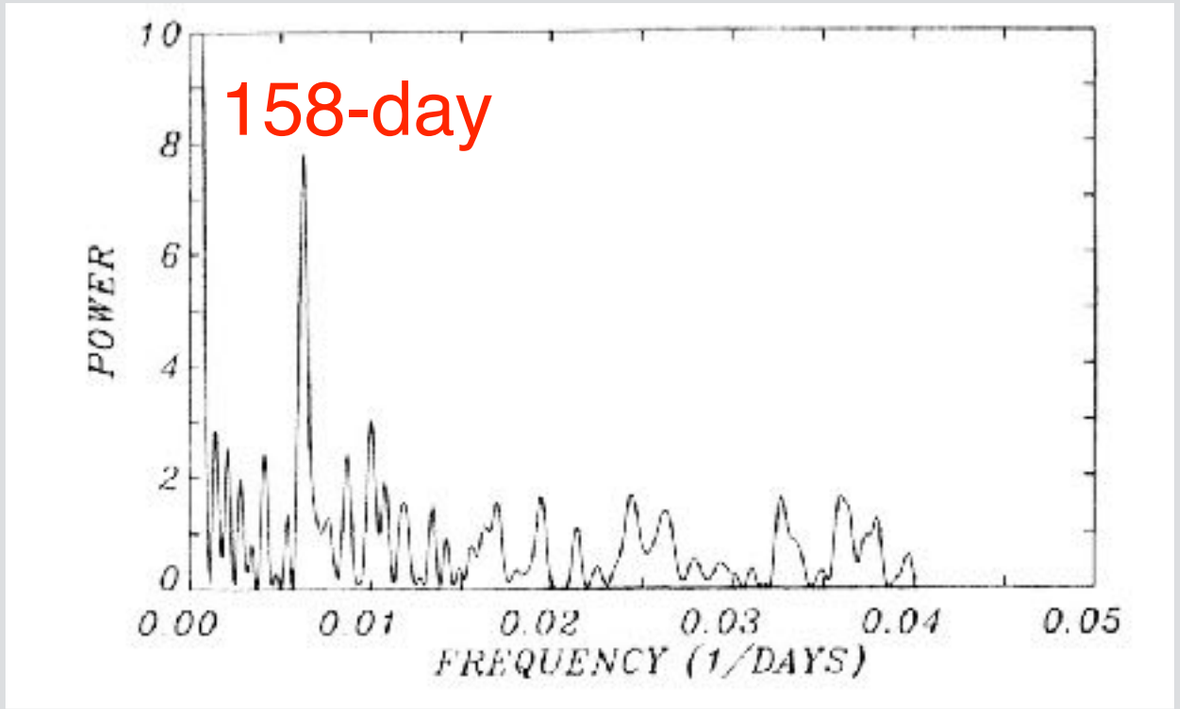


Fig. 2 *a*, Power spectrum of the time series shown in Fig. 1 (139 events). The individual peaks marked by letters are explained in the text. *b*, Power spectrum of GOES flares of ≥ *M* 2.5 (532 events) which occurred during the same time interval as the GRS flares.

Rieger periodicity: first evidences

- Kiplinger et al. 1985: 158-day periodicity found in 6755 hard X - ray flares (SMM, 1980 - 1984, Solar cycle 21)





- Left panel: Weekly averaged rate of flares plus sine wave with P = 158 days
- Right panel: Power spectrum of HXRBS low-energy events (< 140 kev)

Rieger periodicity: first evidences

- Bogart & Bai, 1985: microwave flares (1966 - 1983)
- Only around the maximum of both solar cycles!!
- Significance?

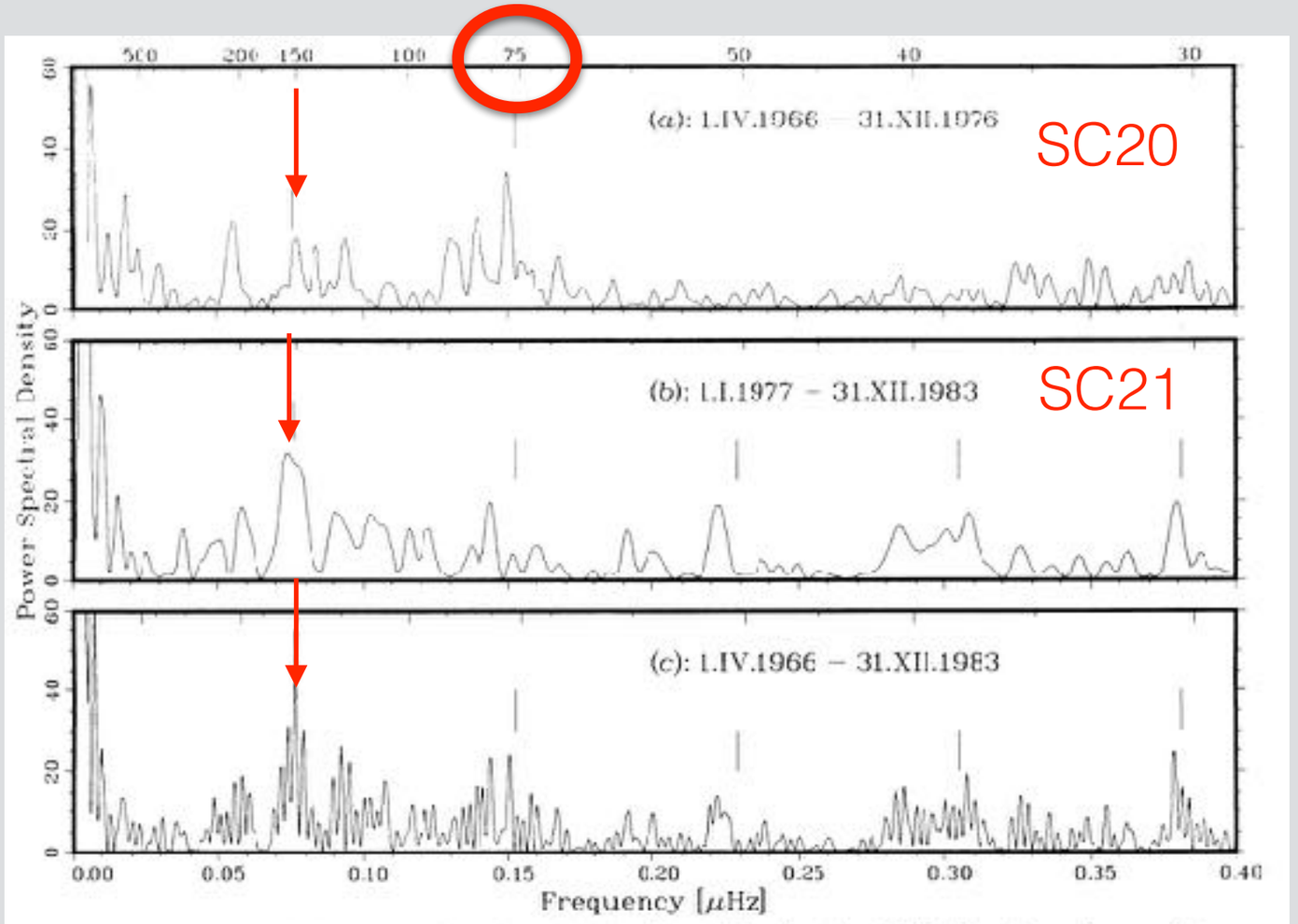


FIG. 2.—Power spectra of the daily counts of flares for cycles 20 and 21, individually and combined. Tick marks are shown at the frequency corresponding to a period of 151d8 and at its harmonics where nearby peaks are present.

Rieger periodicity: first evidences

- Phase coherence between cycles
- Periodicity: switch on/off??

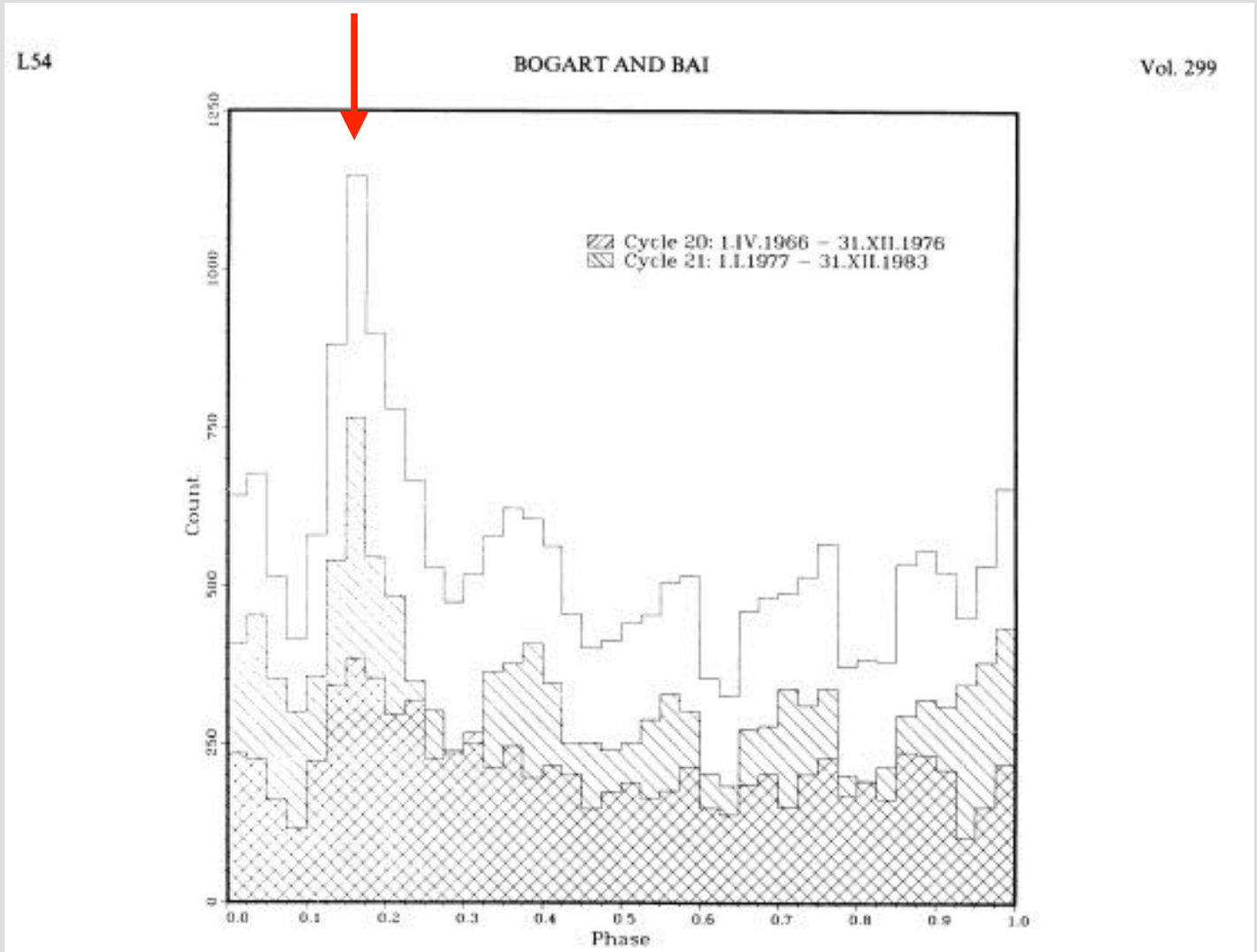
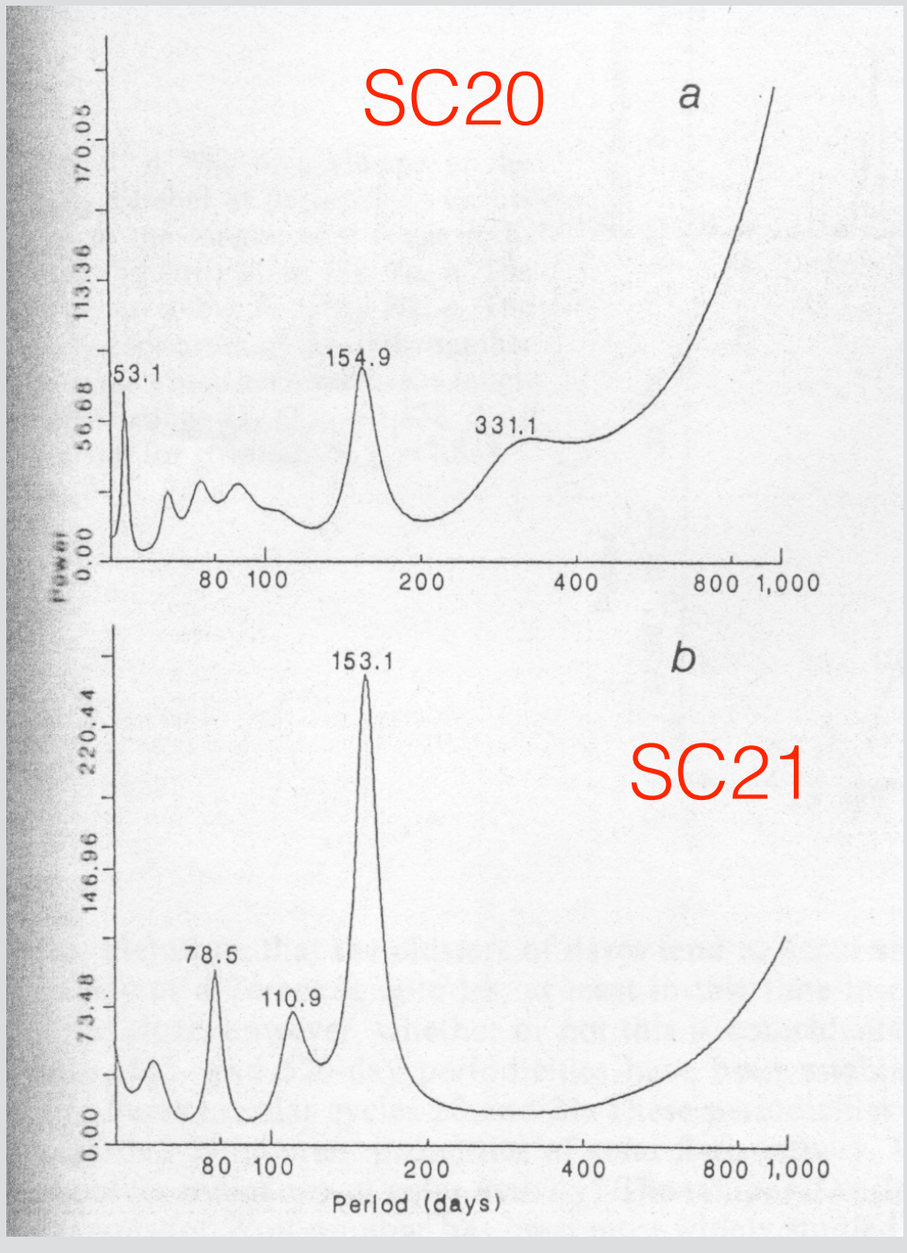


FIG. 3.—Phase distribution of the starting time of flares with respect to an assumed period of $151^d.8$. The zero of phase is taken arbitrarily at 00:00 UT on 1966 April 1.

Rieger periodicity: first evidences

- Ichimoto et al. 1985:155-day periodicity detected in 8821 Hα flares (1965 - 1984)



Rieger periodicity: first evidences

- Bai & Sturrock, 1987: 442 HXRBS "Major" flares (1980 - 1983)
- Major: peak intensities > 1000 counts/s
- Same periodicity appears in the north and south hemispheres (Significance??)

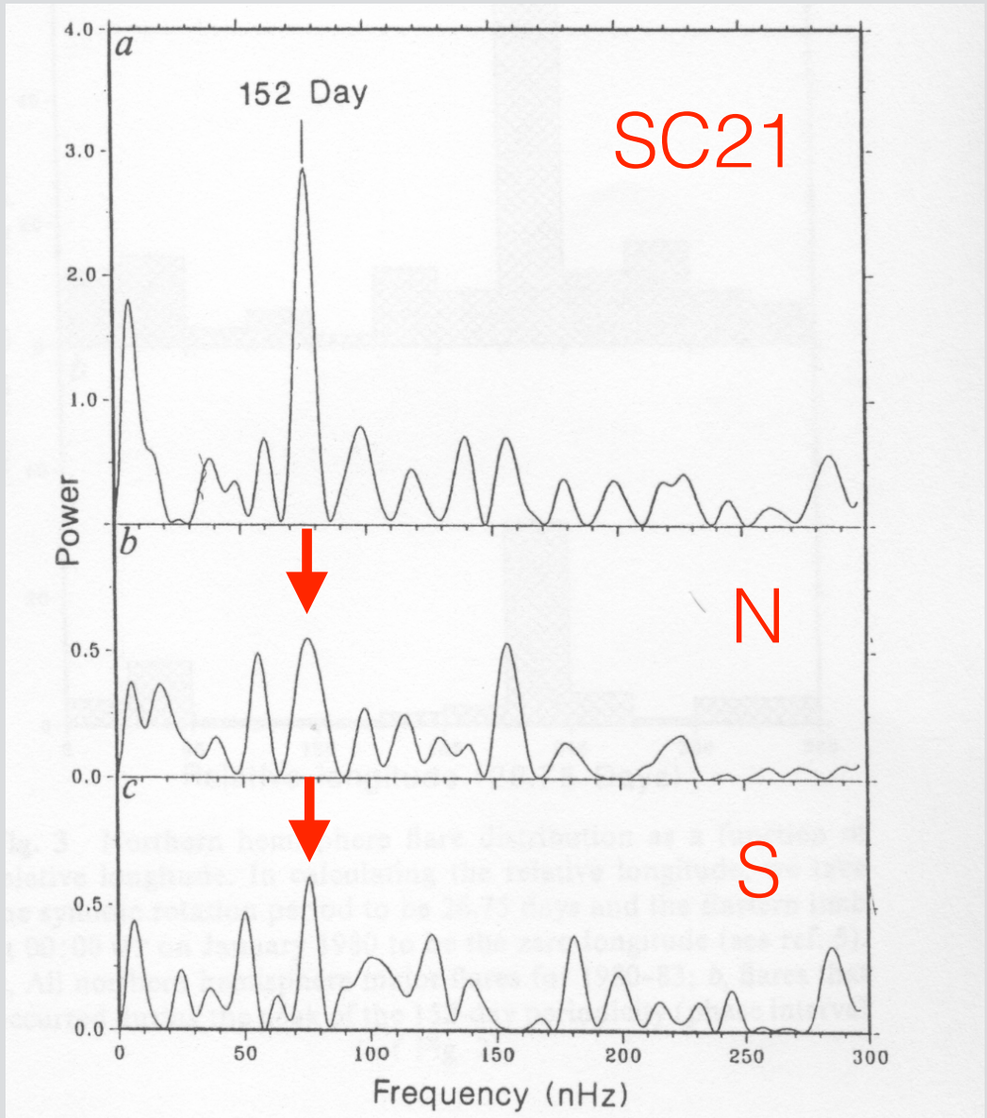
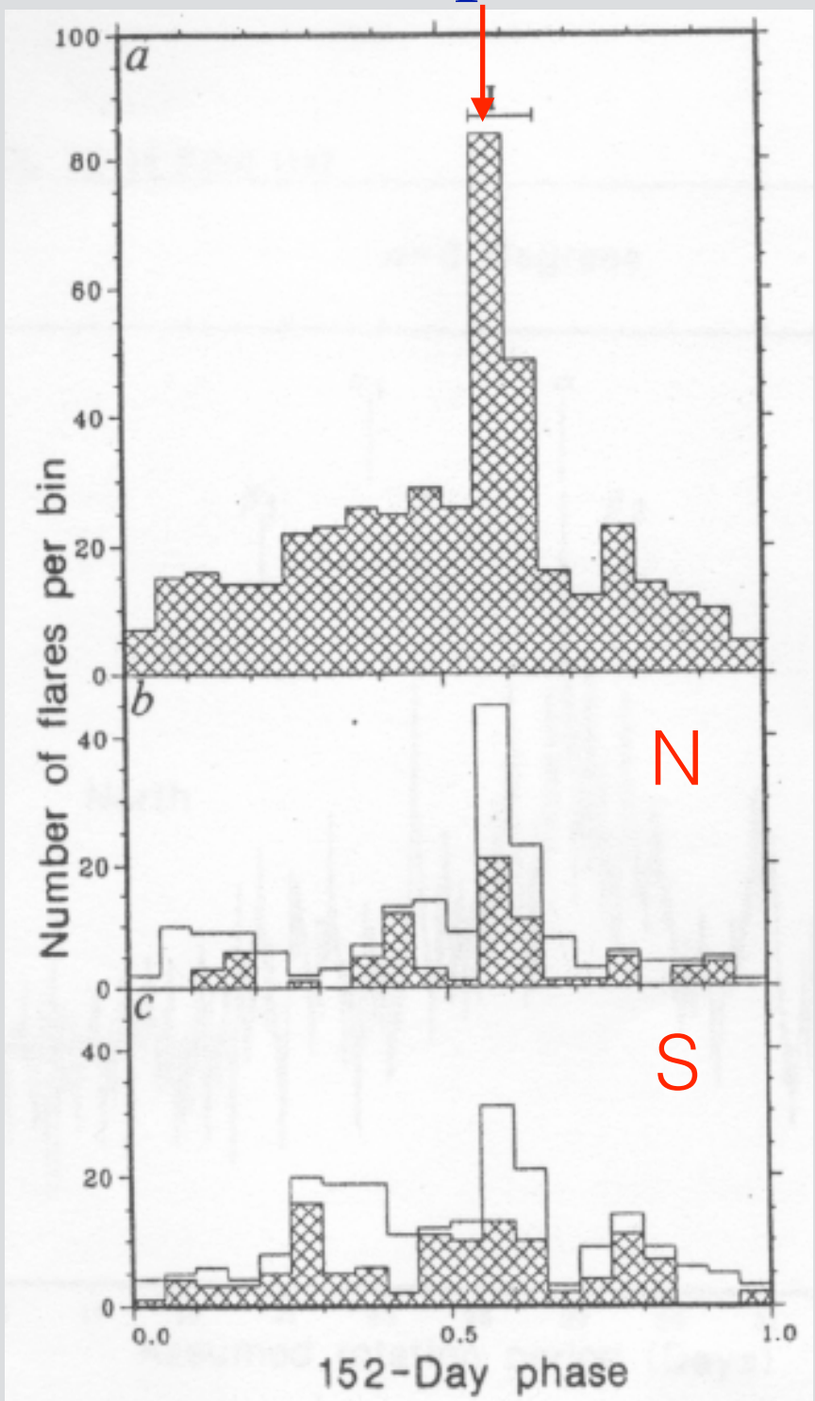


Fig. 1 Fourier power spectra for major flares observed with HXRBS from February 1980 to December 1983: *a*, all flares, *b*, northern hemisphere flares, and *c*, southern hemisphere flares. In *b* and *c* there exist some other peaks comparable to the 152-day peaks, but only the 152-day peaks are common to both hemispheres.

Rieger periodicity: first evidences

- Phase coherence between hemispheres



Rieger periodicity: a first summary

- Found in many solar activity indicators by different authors

1992A&A...2

Table 2. Prior detections of the near 155-d periodicity in solar observational data

Solar cycle	Time interval	Sunspot areas		Sunspot blocking function	Apparent solar diameter	Solar irrad.	10.7 cm radio flux	Zurich sunspot number	Flares							Plage index	Aurorae
		Period	FAP						γ-ray	X-ray	Hα	Microw.	Proton	Energ. e⁻	Solar flare index		
	1683-1718				155												
9	1842-1845																150
12	1878-1889																141 150
14	1901-1913																146
19	1954-1964			159													
20	1964-1976			159			159	159									
21	1976-1984			159	155		159	159								159	
1-21	1749-1979							155.4									
12-21	1878-1982			156													
19-21	1954-1982			155			155	155									
19-20	1/58-12/71												154				
20-21	1/65-2/84										155						
20-21	4/66-12/83											152					
20-21	1/66-12/86														152		
21	2/80-9/83								154								
21	2/80-4/84					155				158							
21	2/80-8/85									152							
21	9/78-12/82													153			
21	2/78-8/83												154				
21	2/78-8/83											154					
12-14	1878-1913	148	> 0.1%														
13-15	1889-1923	148	"														
14-16	1901-1933	154	"														
15-17	1913-1944	155.5	"														
16-18	1923-1954	157.1	"														
17-19	1933-1964	157.1	"														
18-20	1944-1976	157.1	"														
19-21	1954-1984	155.1	"														
13-21	1889-1984	155	"														

Carbonell & Ballester, 1992

Rieger periodicity: N-S Asymmetry?

- N - S asymmetry of periodicity in 685 (300N, 385S) M and X class events (Kiplinger et al. 1985)
- Also in sunspot areas (Carbonell & Ballester, 1992)

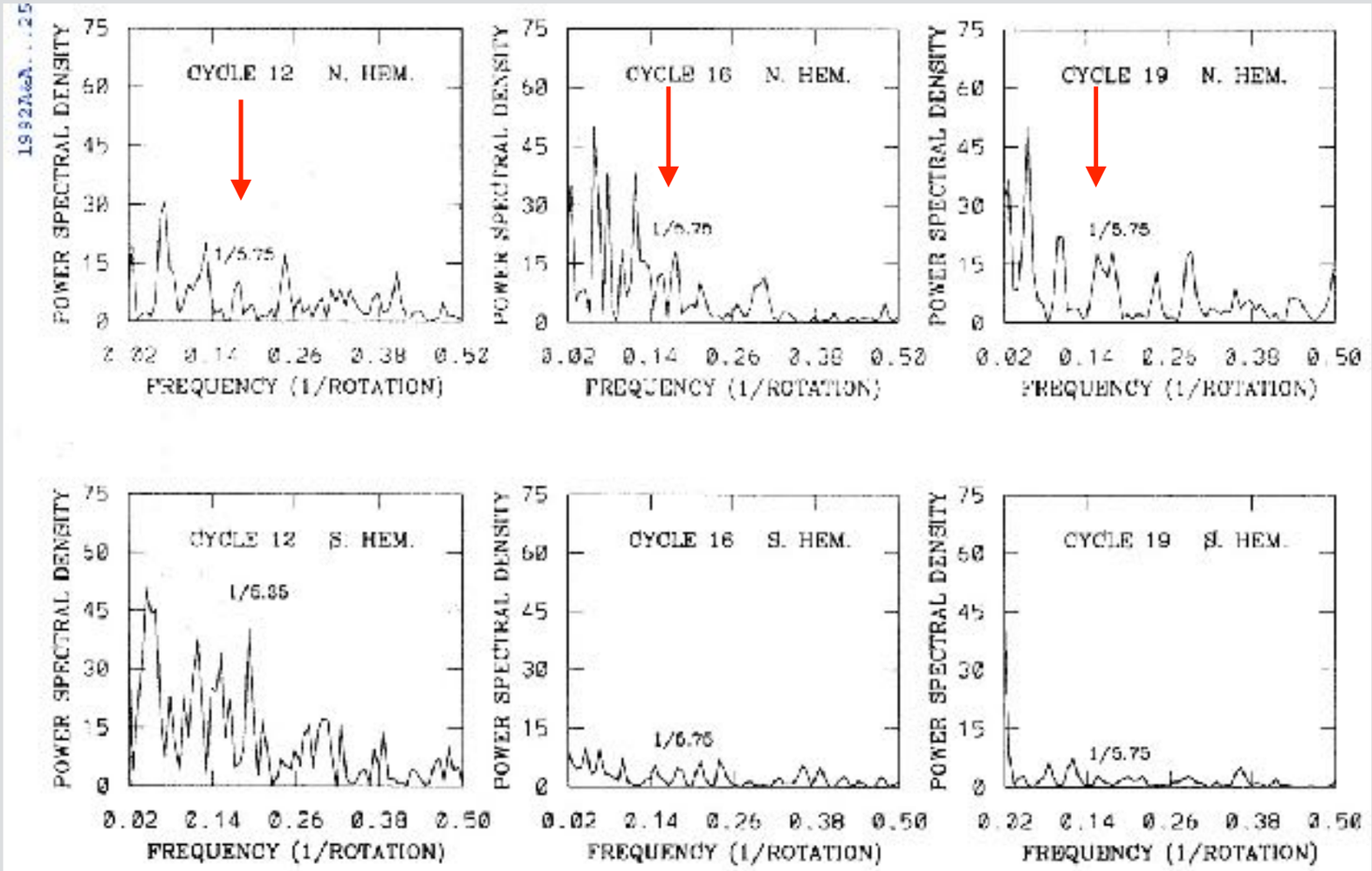


Fig. 16. Power spectra of hemispheric sunspot areas per Carrington rotation, for solar cycles 12, 16 and 19

Rieger periodicity: reported features

- Intermittency: periodicity appears around the maximum
- Strong in some cycles, weak or lacking in other
- Phase coherence between different cycles
- Phase coherence between hemispheres
- N - S asymmetry

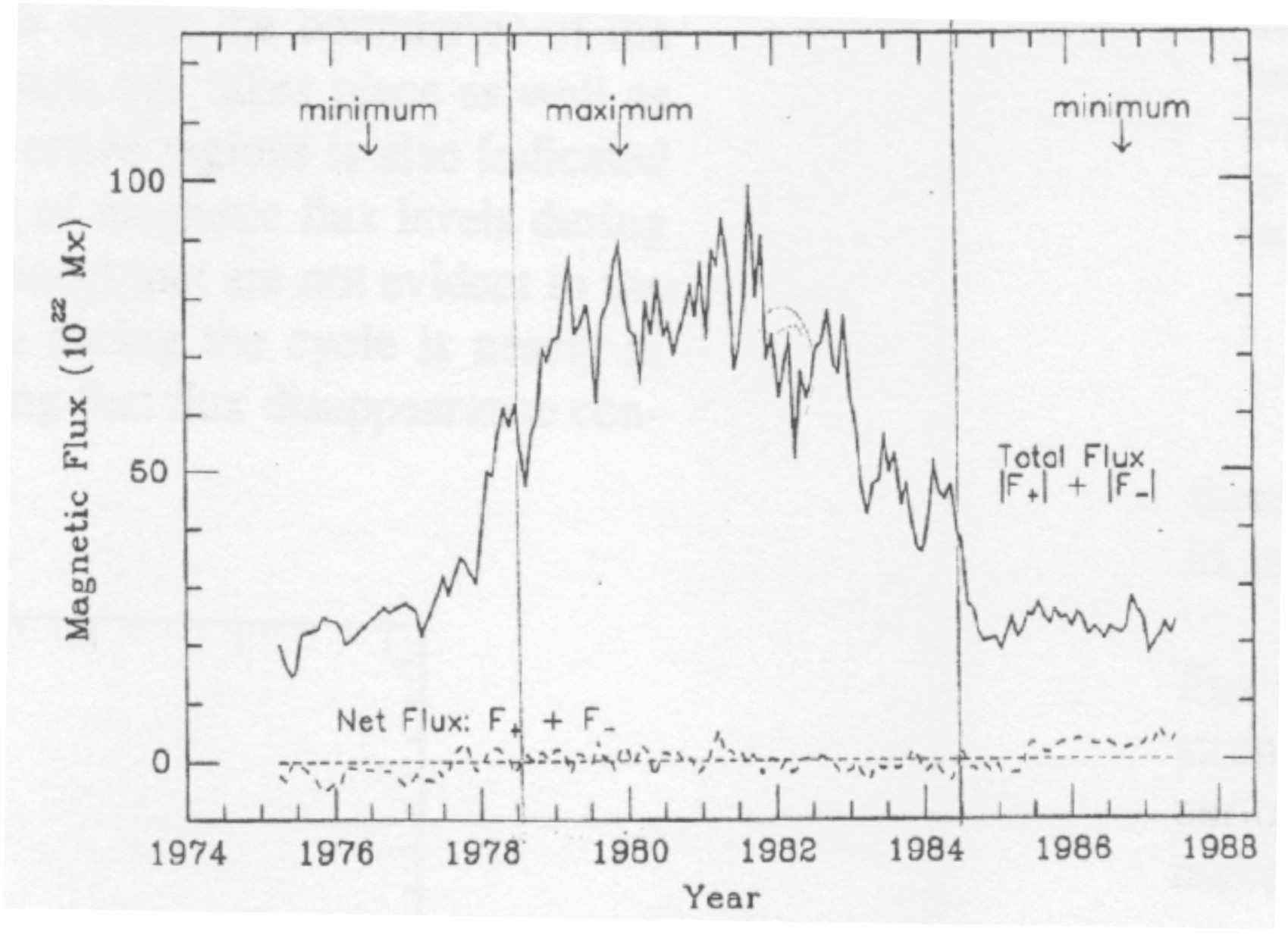
Rieger periodicity: Magnetic flux

- Ichimoto et al. 1985: Periodicity originates in strongly magnetized regions and is related to the timescale for the storage and/or escape of the magnetic field in the solar convection zone

- Along solar cycle 21, Rabin et al. (1991) found quasi - periodic pulses of enhanced magnetic activity with a duration of 5 rotations during the years of the maximum

- Periodicity as a consequence of such activity pulses!!

Rieger periodicity: Magnetic flux



Total and net magnetic fluxes during SC21
(Rabin et al. 1991)

Rieger periodicity: Magnetic flux

Splitting in weak and strong-field components

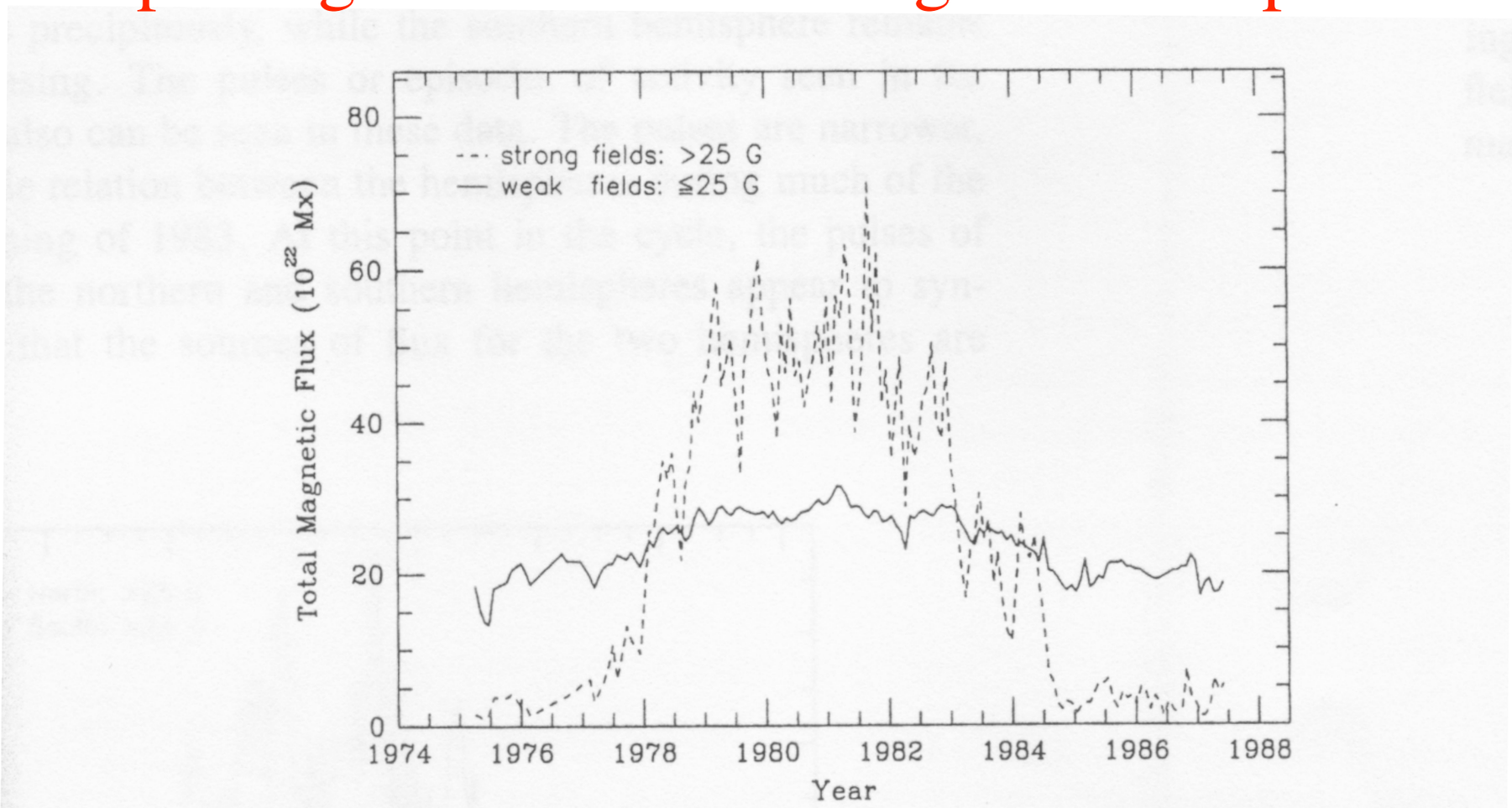


Fig. 7. Total magnetic flux divided into strong- and weak-field components. During the early and late parts of the cycle, the weak component dominates; from 1978 to 1983 the strong component substantially exceeds the level of flux observed in the weak fields. The pulses of activity evident in the strong component are not seen in weak component. The strong component varies by at least a factor of 15 from minimum to maximum while the weak component varies by a factor of 2 or less.

(Rabin et al. 1991)

Rieger periodicity: Magnetic flux

Hemispheric distribution of strong-field component

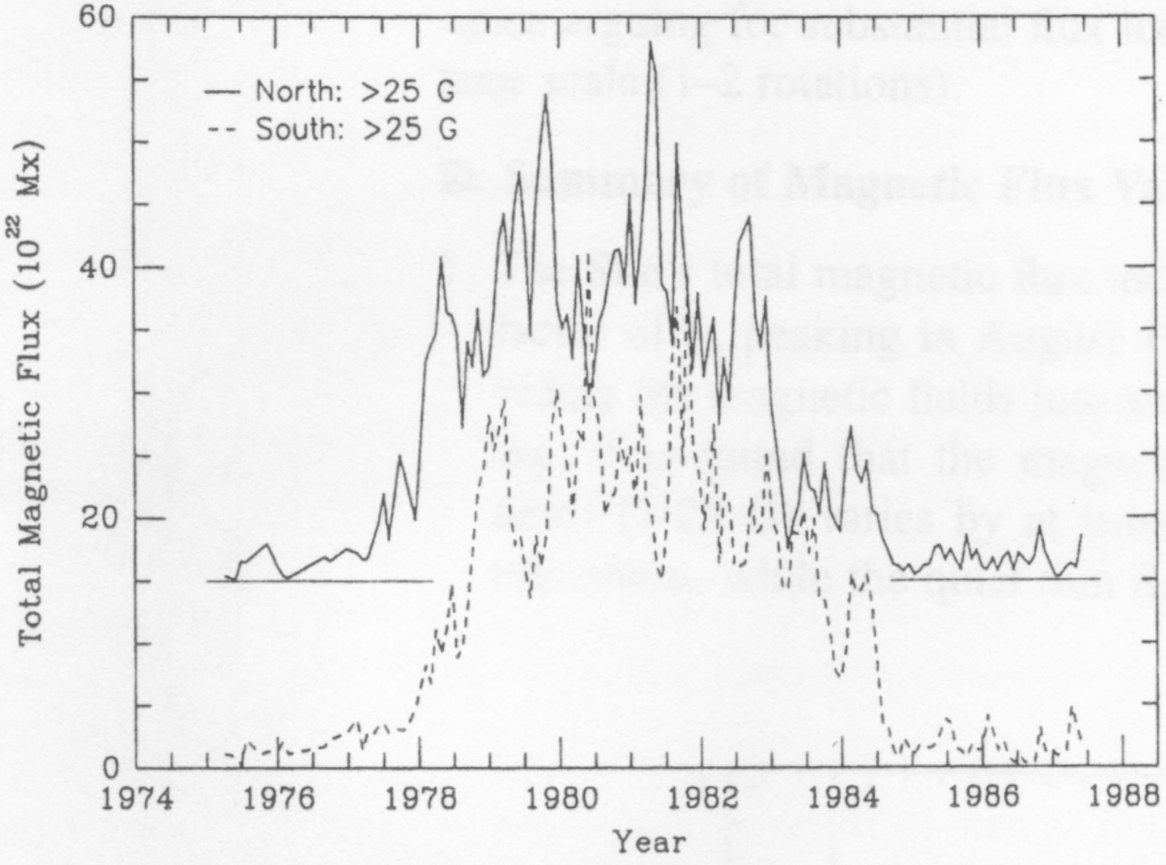
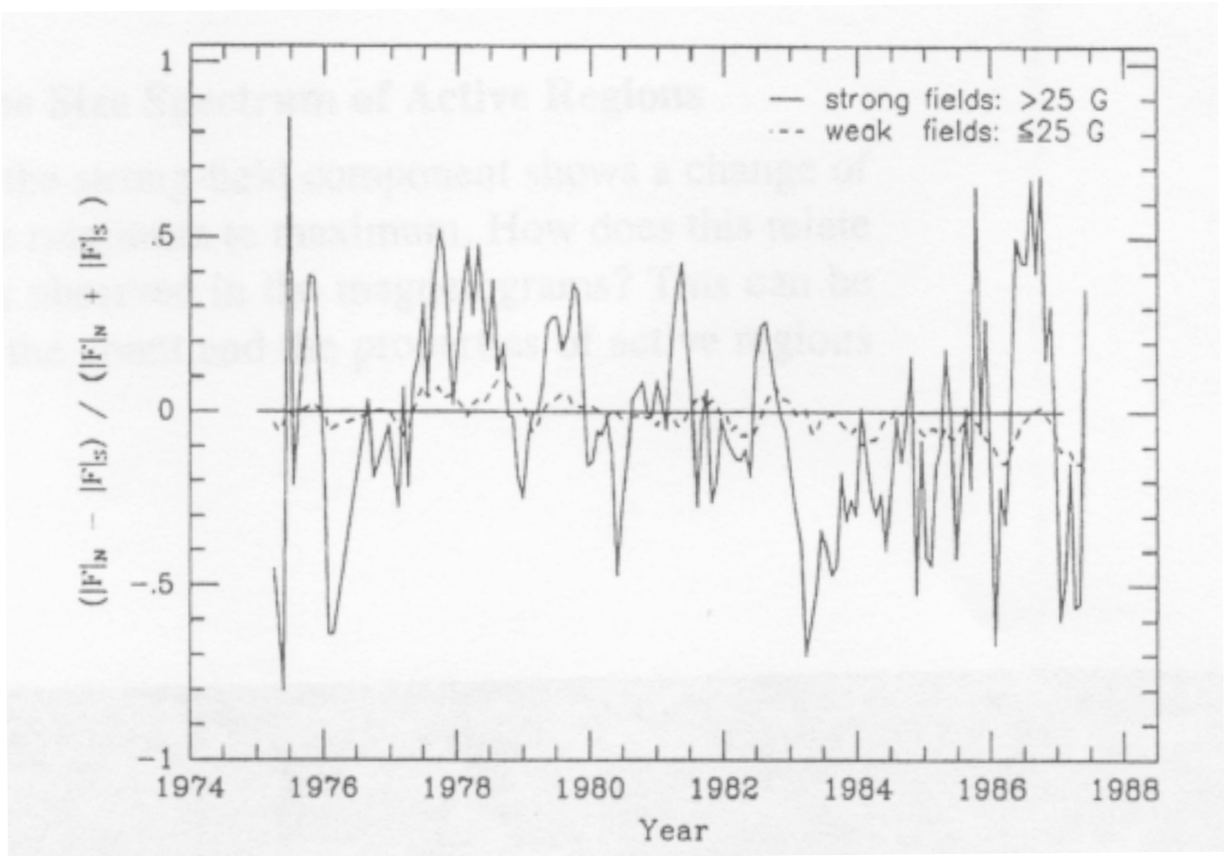


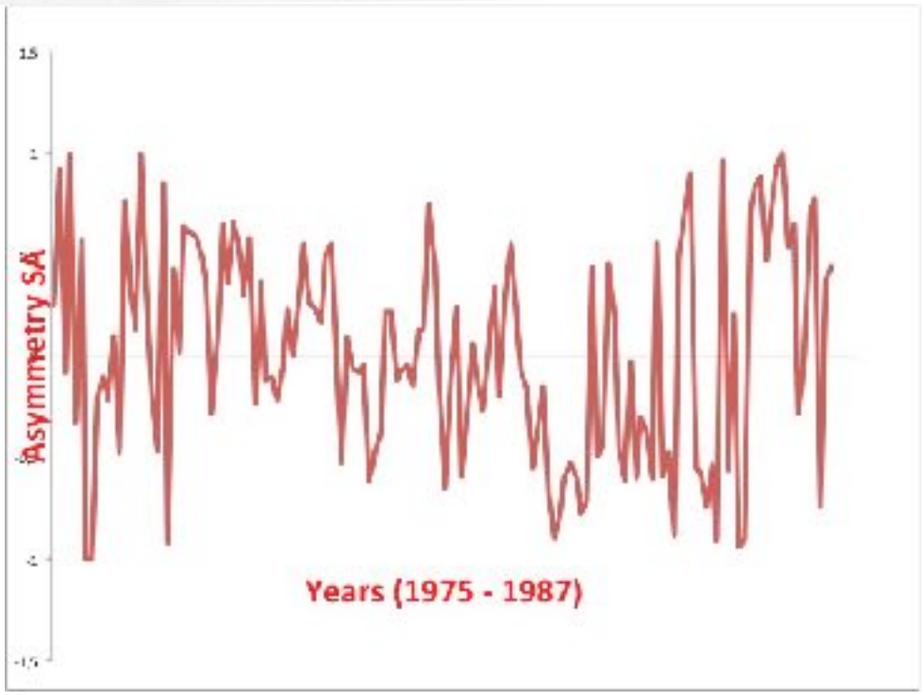
Fig. 8. Total magnetic flux in the strong component for northern and southern hemispheres separately. There the general level of activity in the southern hemisphere lags the northern hemisphere by ~ 9 rotations. Pulses of activity appear to be uncorrelated between the hemispheres until 1983, when they appear to synchronize.

(Rabin et al. 1991)

N-S asymmetry of the magnetic flux



Asymmetry index (N-S/N+S) for weak and strong fields during solar cycle 21. (Rabin et al. 1991)



Asymmetry index (N-S/N+S) for sunspot areas during solar cycle 21

N-S asymmetry of solar activity

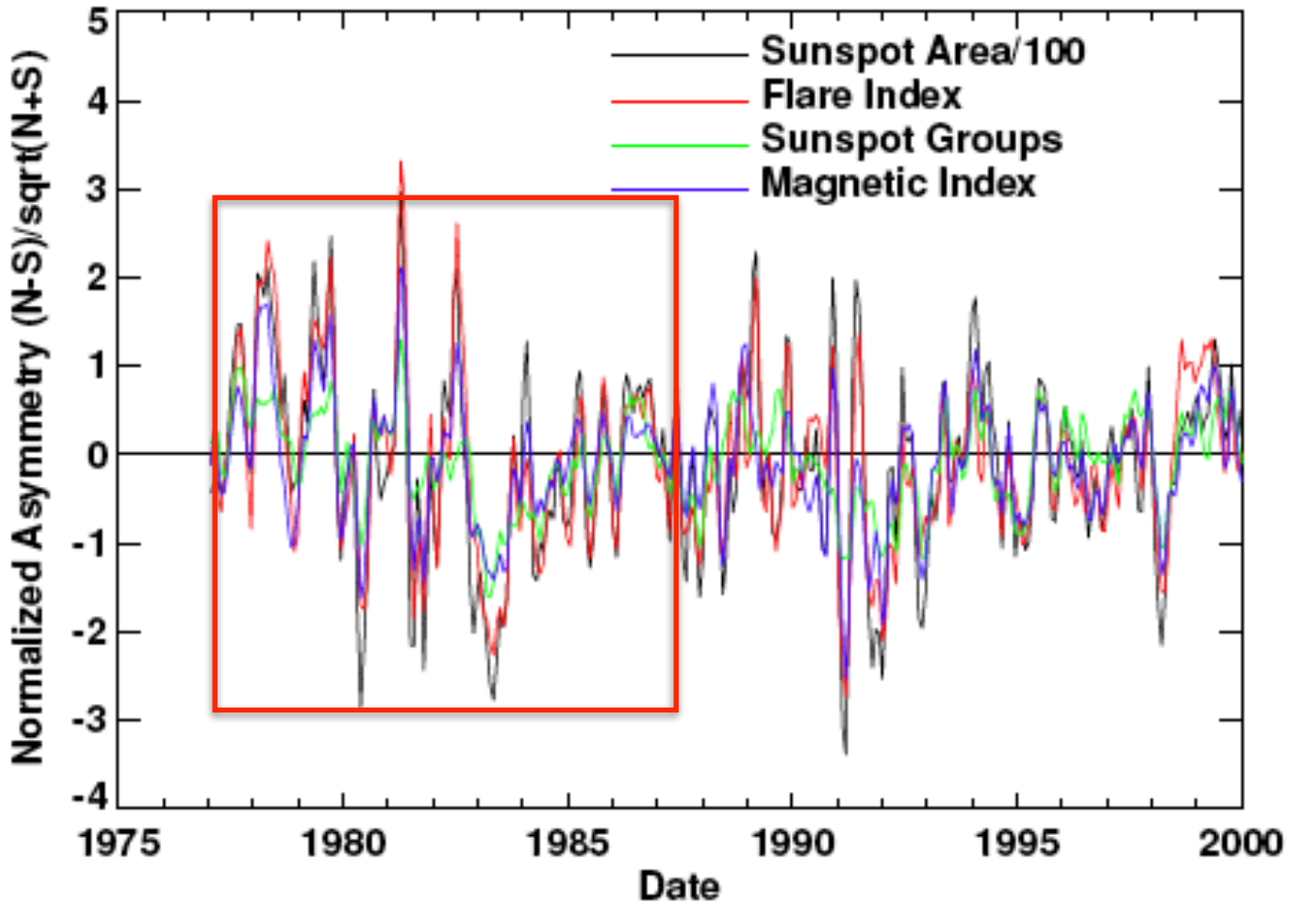


Figure 33: Normalized north-south asymmetry $(N-S)/\sqrt{(N+S)}$ in four different activity indicators for individual Carrington rotations. Sunspot area is plotted in black. The Flare Index is shown in red. The number of sunspot groups is shown in green. The Magnetic Index is plotted in blue.

(See Eka's talk, next thursday)

$N-S/(N+S)^{0.5}$

(Hathaway, 2010)

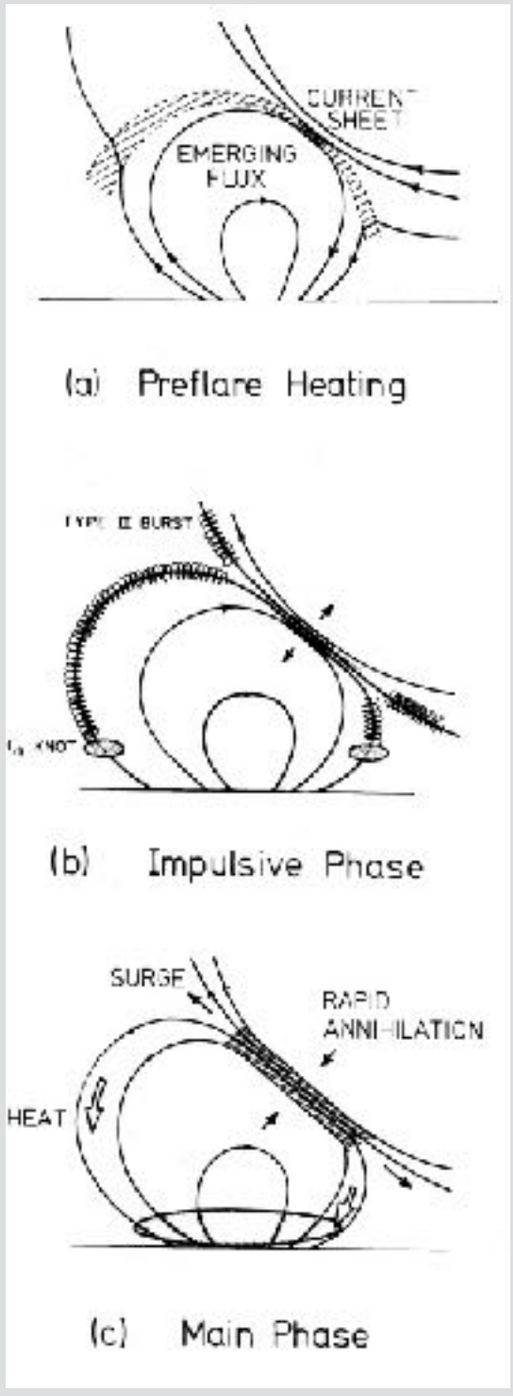
Rieger periodicity: Magnetic flux

- Why the high – energy flares display this intermittent periodicity?

- Lean (1990), Brueckner & Cook (1990), Carbonell & Ballester (1990; 1992) suggested a link between the increase in the flare rate occurrence and the emergence of magnetic flux through the photosphere

- Energetic solar flares are based on reconnection between emergent magnetic flux and old flux (Heyvaerts et al. 1977; Priest, 1990; Forbes, 1991)

Rieger periodicity: Magnetic flux



(Heyvaerts, Priest & Rust, 1977)

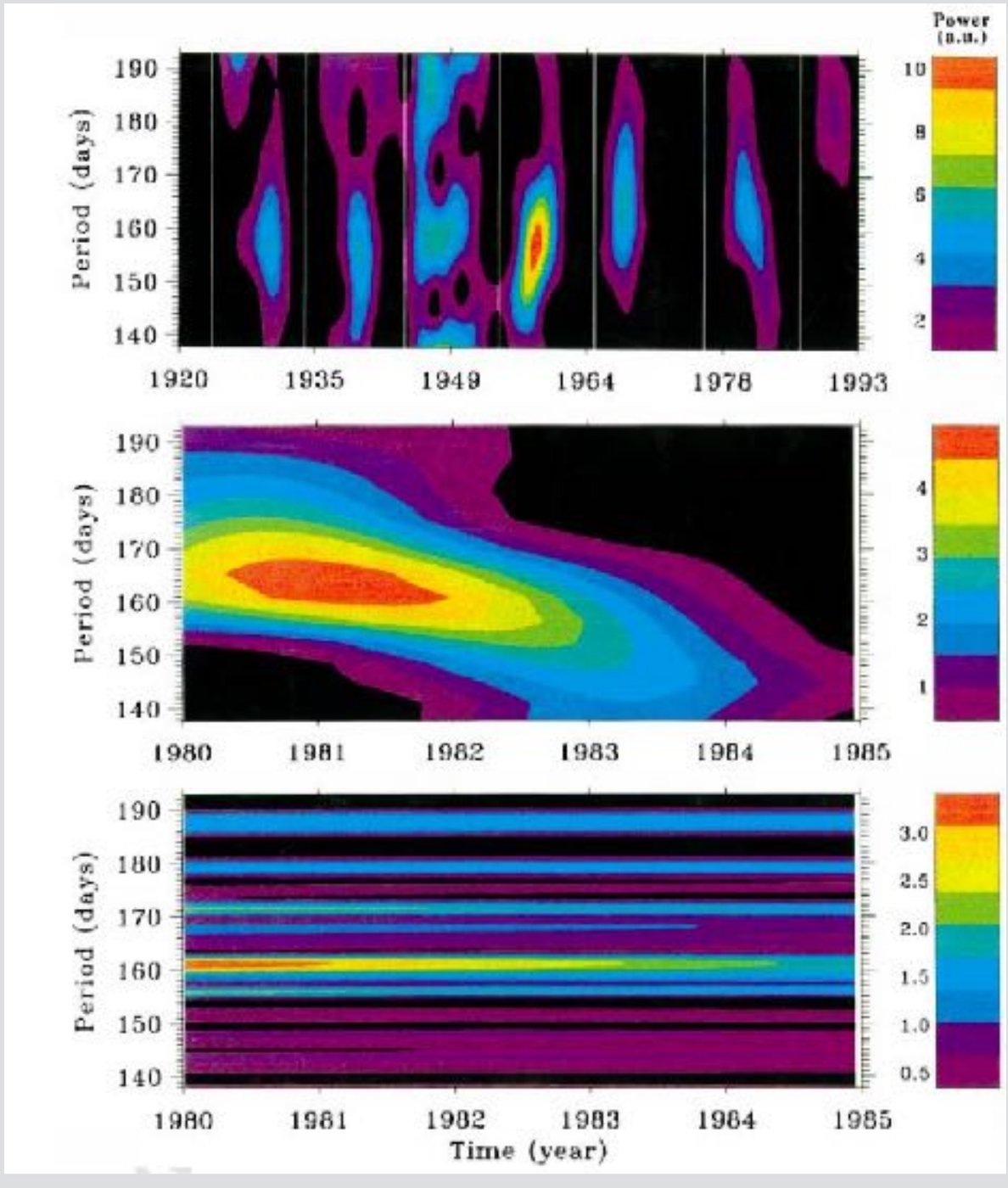
Rieger periodicity: Magnetic flux

- Then, could a periodic increase in the occurrence rate of energetic flares be related to a periodic emergence of magnetic flux producing a periodic variation of the total sunspot area?

- Needed to prove that there has been a temporal and frequency coincidence between the occurrence of the periodicity in high-energy flares and in sunspot areas

- Wavelet analysis applied to a time series made of daily sunspot areas between 1874 and 1993 in order to study the temporal variation with time scales around 160 days

Rieger periodicity: Magnetic flux



(Oliver et al. 1998)

Rieger periodicity: Magnetic flux

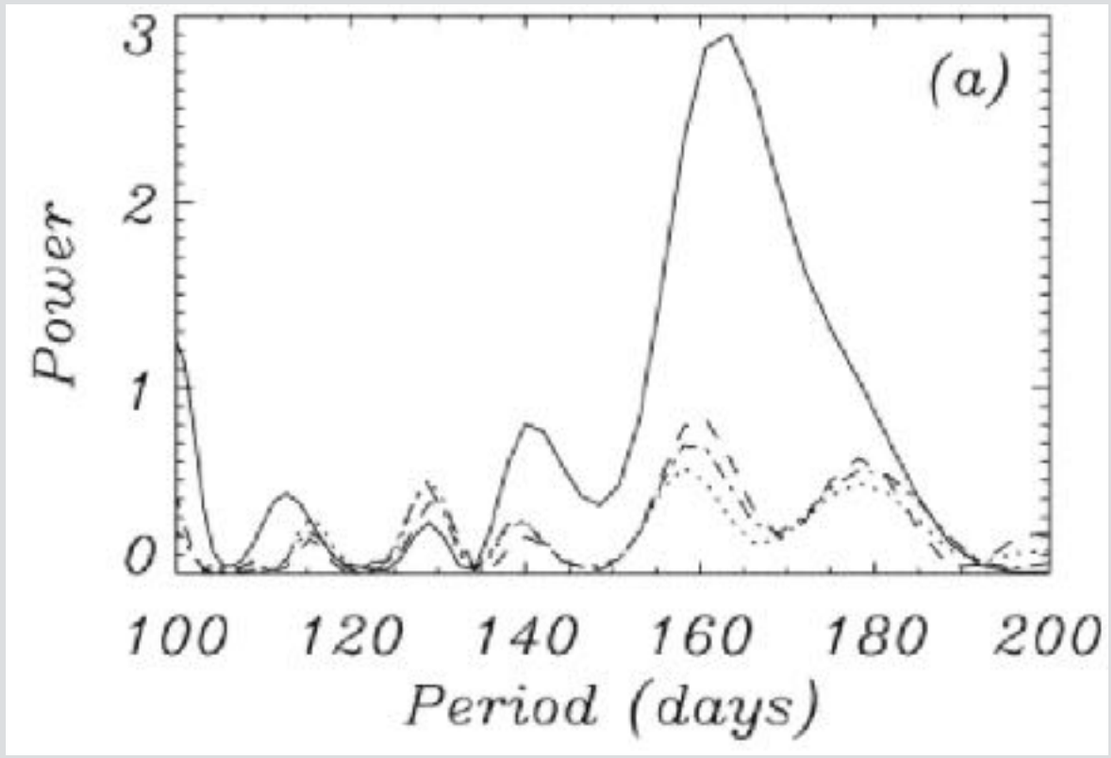
- The periodicity in the photospheric magnetic flux

- MWTF (1966-2000); KPMF (1975 - 2000; B > 25 G); MPSI (1970 - 2000; 10 > B > 100 G); MWSI (1970 - 2000, B > 100 G)

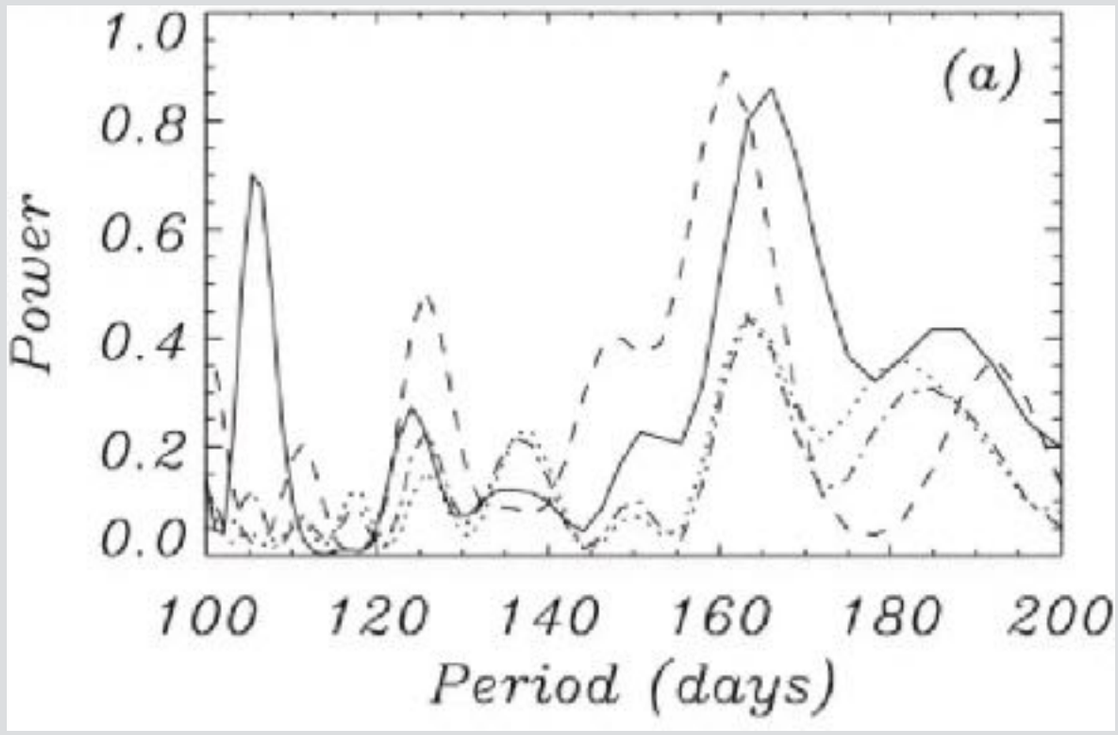
- Data restricted to time intervals around the maximum of solar cycles 21 and 22

- Periodograms and wavelets

Rieger periodicity: Magnetic flux



Solar cycle 21



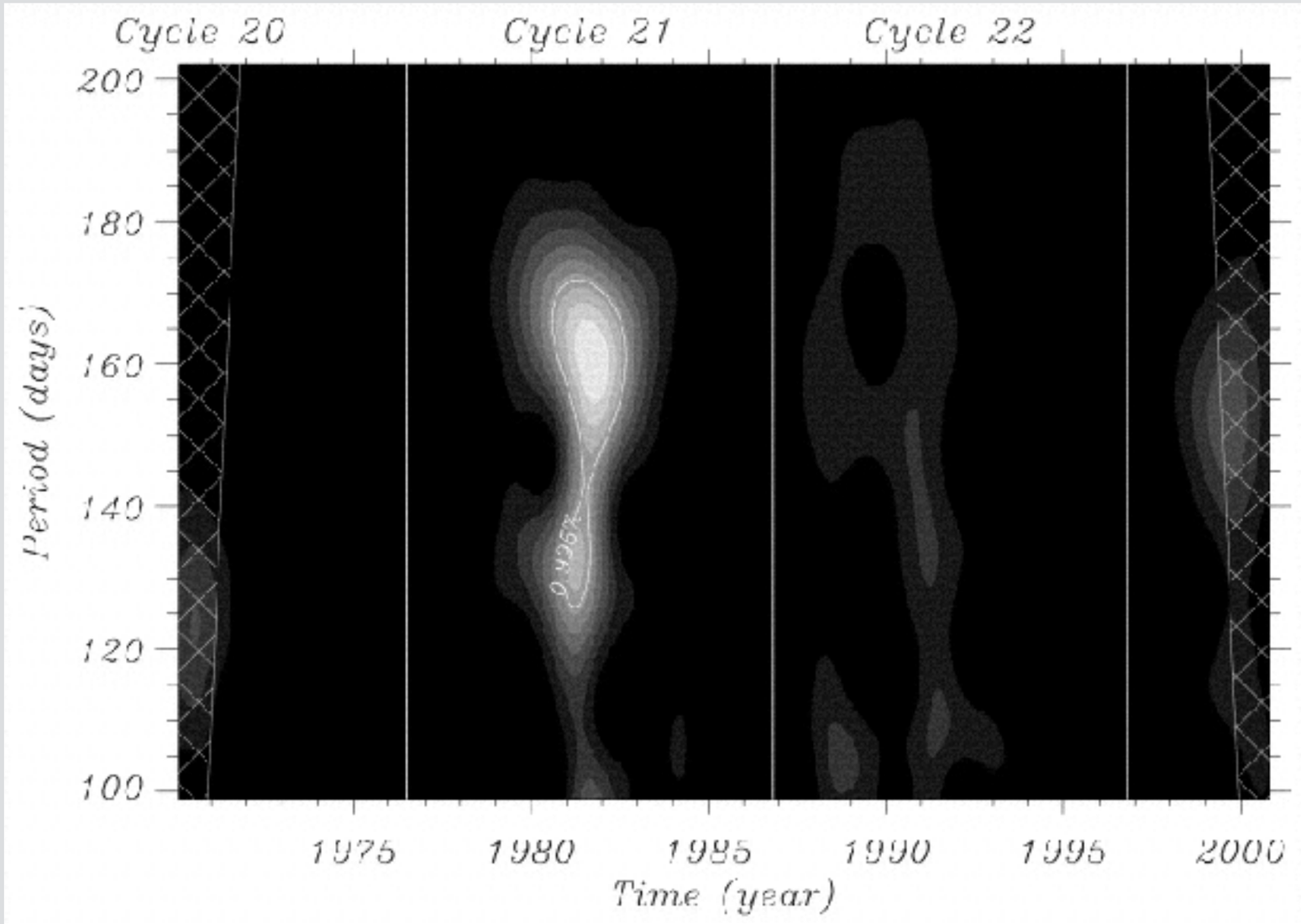
Solar cycle 22

MWSI solid, KPMF dashed,
MWTF dash-dotted, MPSI dotted

(Ballester et al. 2002)

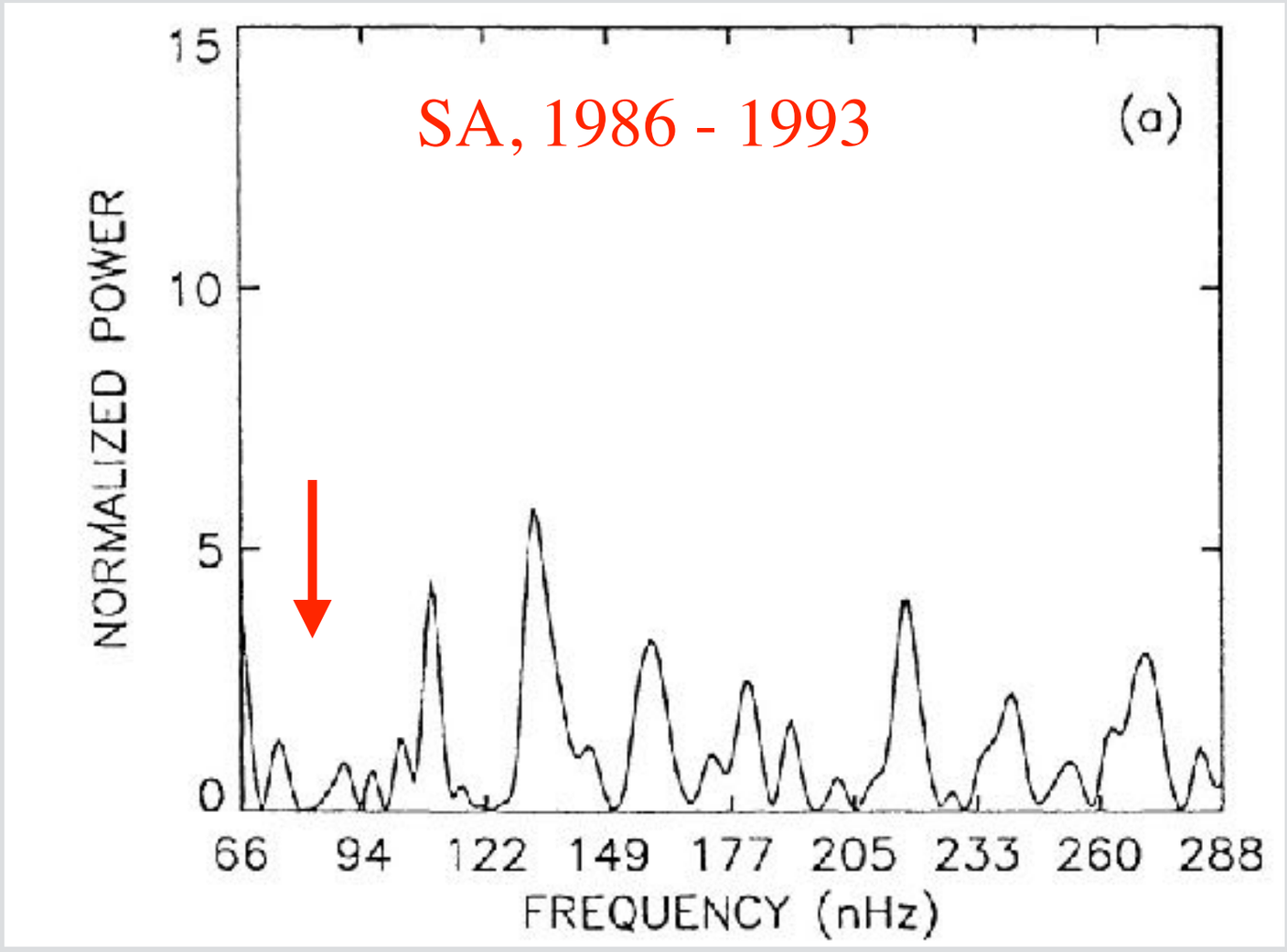
Rieger periodicity: Magnetic flux

Photospheric magnetic flux (MWSI)



(Ballester et al. 2002)

Rieger periodicity in solar cycle 22

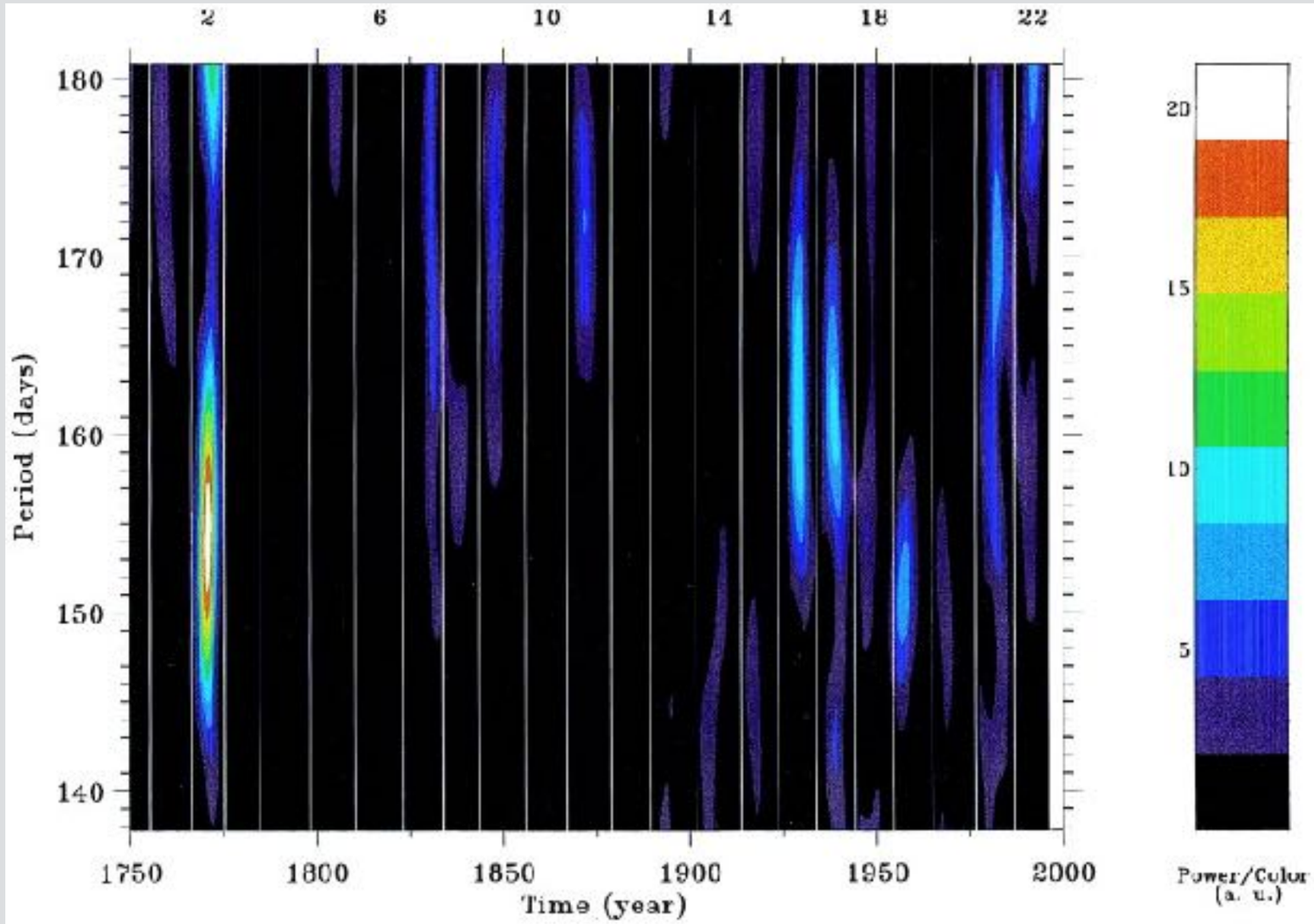


(Oliver & Ballester, 1995)

- Kile & Cliver (1991), Bai (1992a), Özgüç & Ataç (1994), using microwave flares, X - ray flares and flare index, did not find any evidence of its presence during solar cycle 22

Rieger periodicity in GSN

- Hoyt and Schatten (1998): Homogeneous database of group sunspot number(s) (GSN; 1610–1995, Solar Cycles 1 - 22)



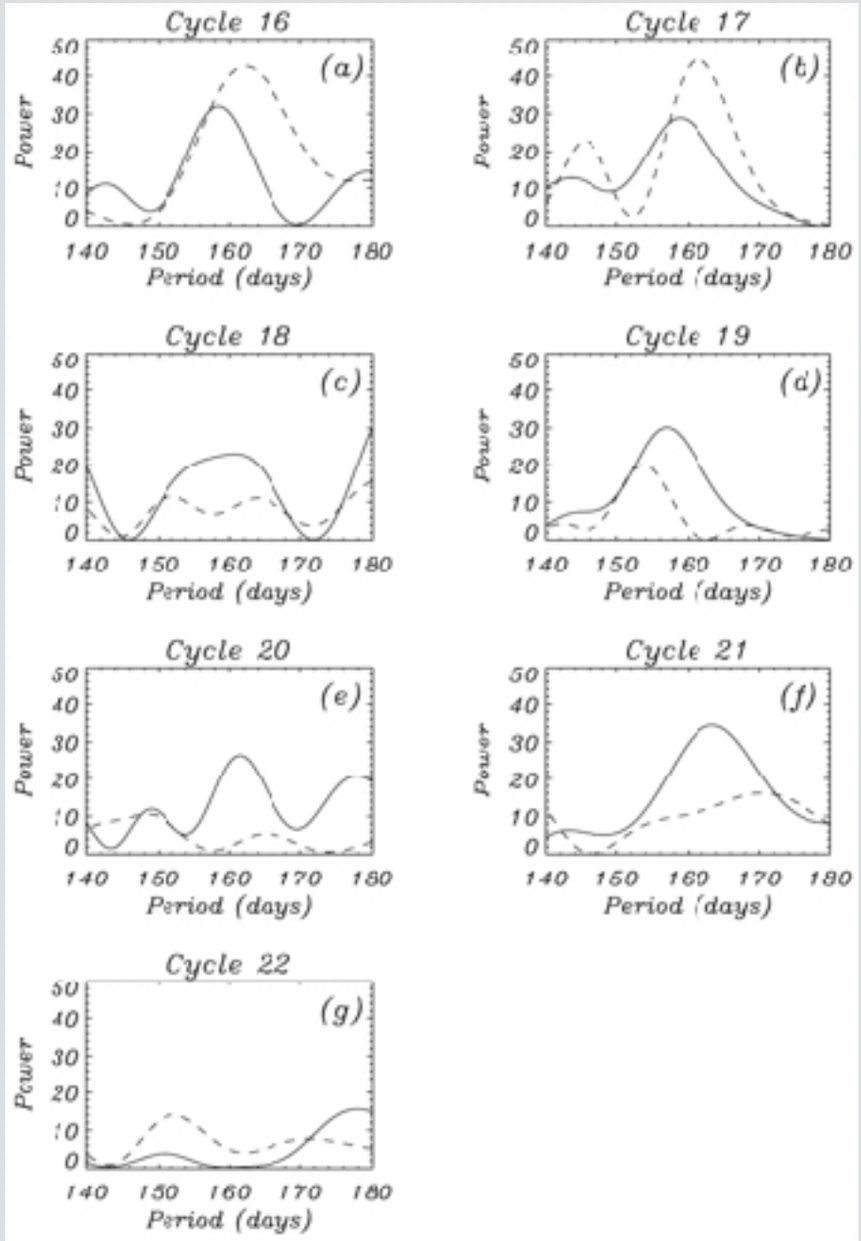
(Ballester et al. 1999)

Rieger periodicity in SA vs GSN

- Correlation of the periodicity between SA and GSN? SA (solid); GSN (dashed)

- Periodic emergence inside already formed SG increases SA but not GSN (SC 20, 21), which increases magnetic complexity and the periodicity appears in solar flares

- Periodic emergence forming new SG in spotless regions increases SA and GSN (SC 16, 17). No periodicity should appear in energetic solar flares due to the small magnetic complexity of SG

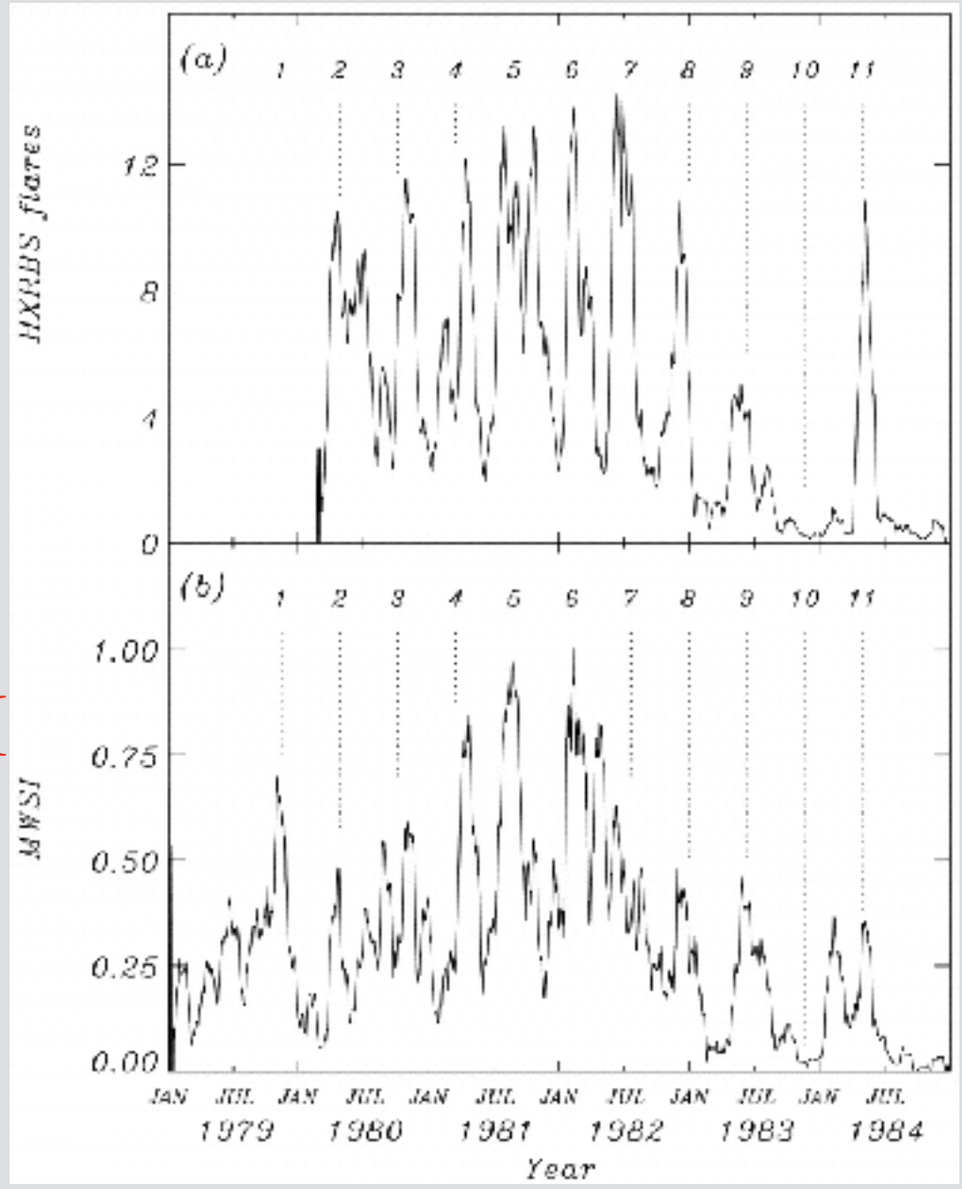


(Ballester et al. 1999)

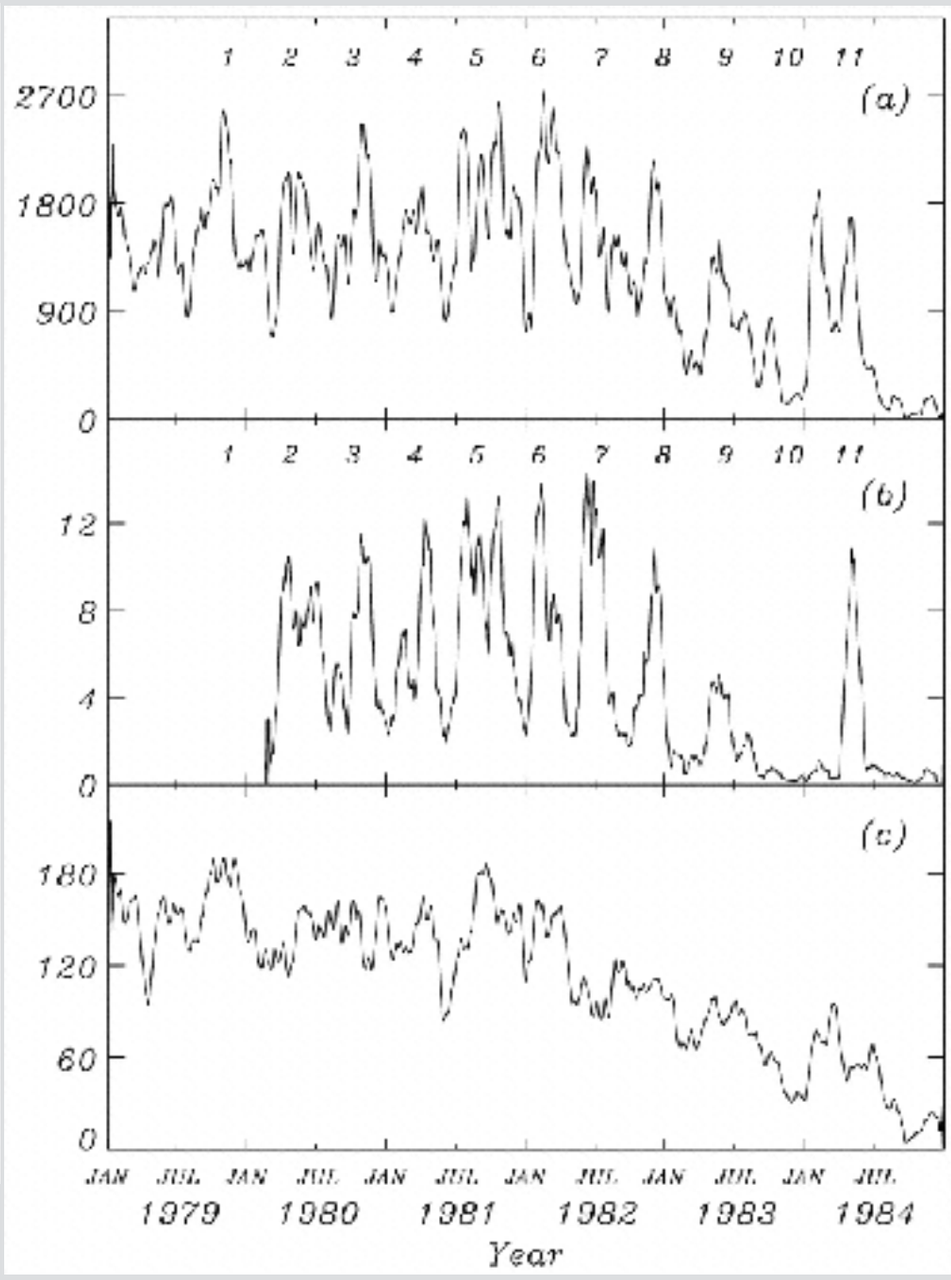
RP: Simultaneity in activity indicators (SC21)

XRF

MWSI



(Ballester et al. 2002, 2004)



SA

XRF

GSN

What causes the periodic emergence of flux?
(See Temury's talk)

Rieger periodicity in solar cycle 23

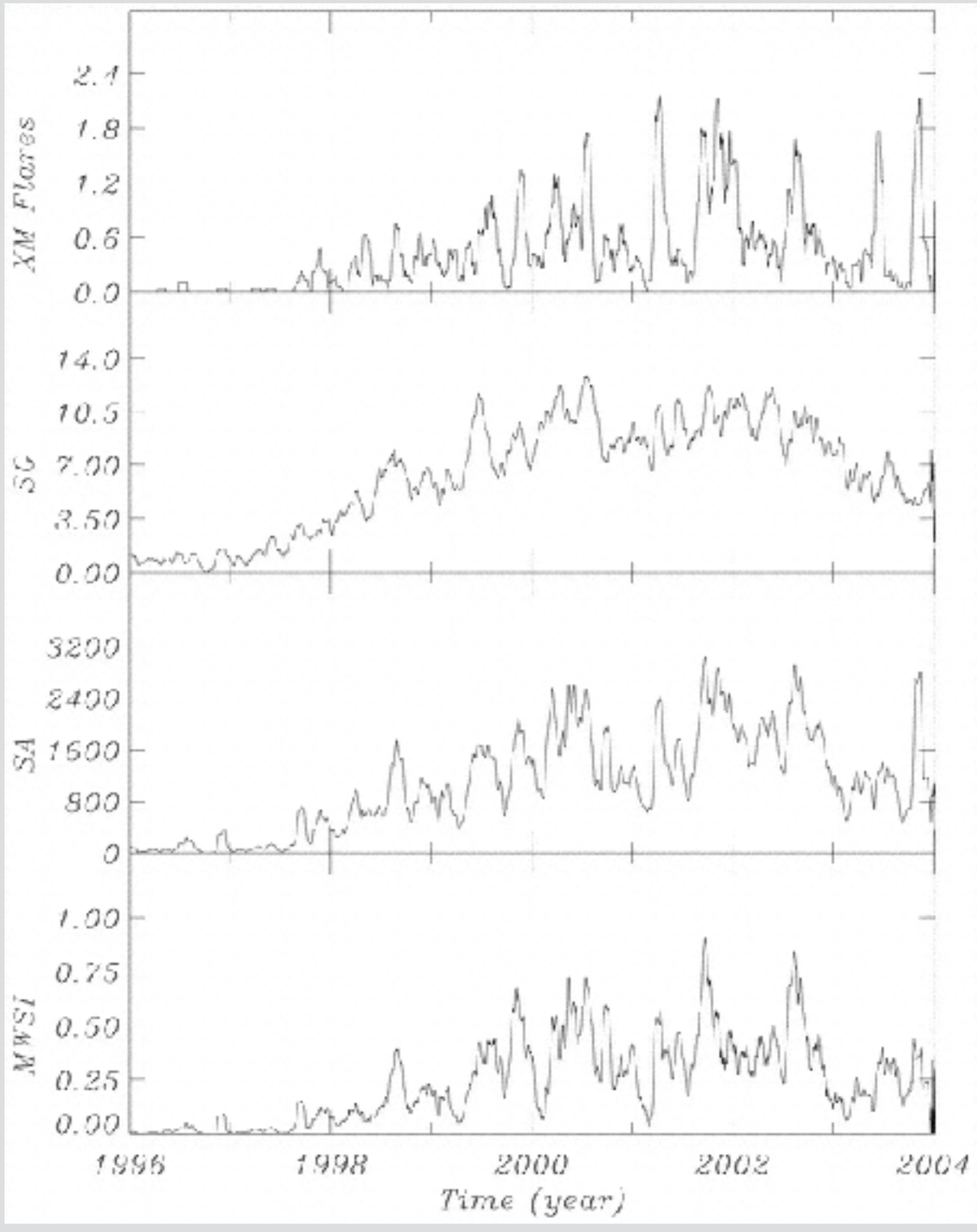
Solar Cycle 23

X-M Flares →

GSN →

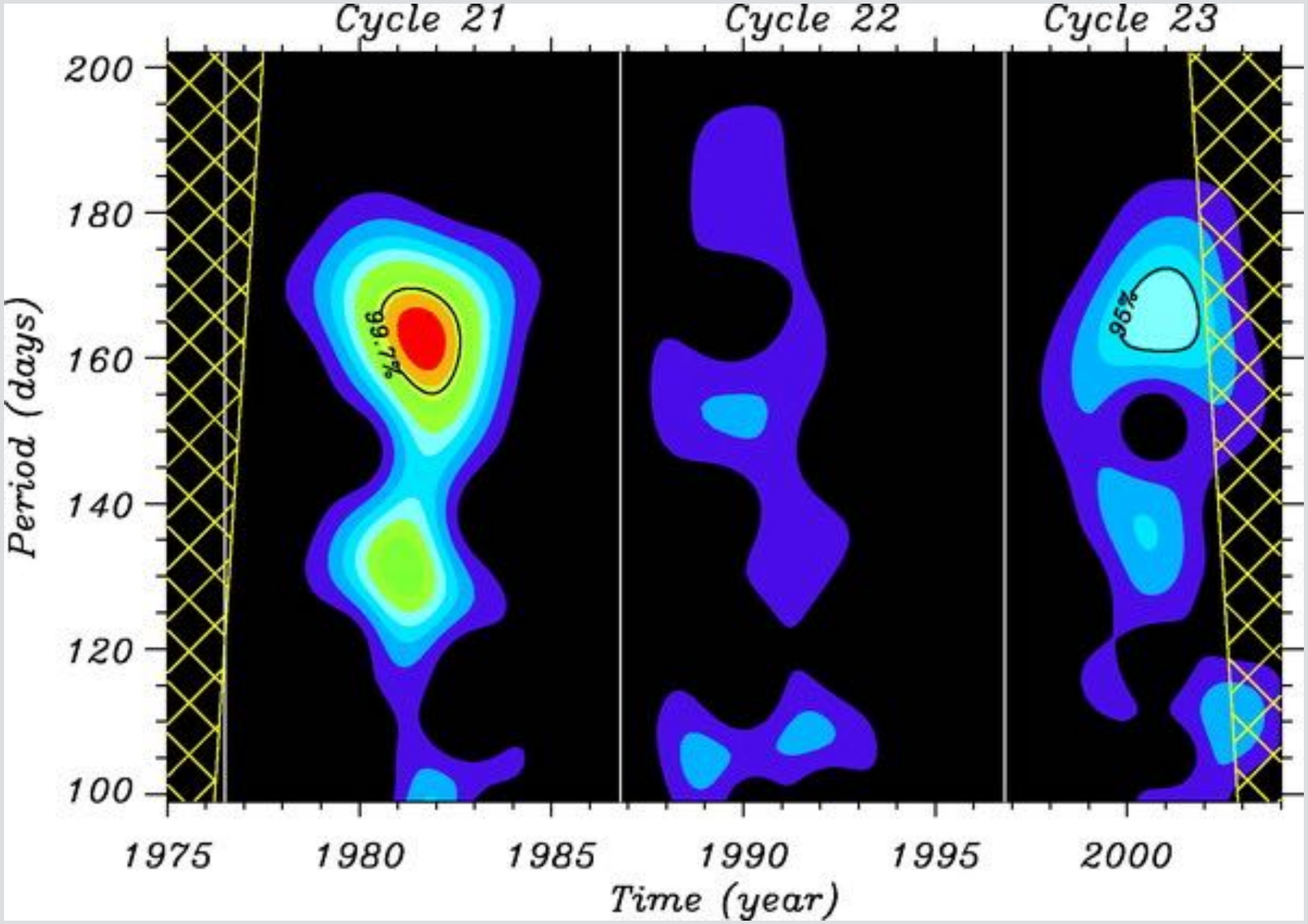
SA →

MWSI →



Rieger periodicity: Magnetic flux

Photospheric magnetic flux (Ballester et al. 2004)



Rieger periodicity in solar cycle 23

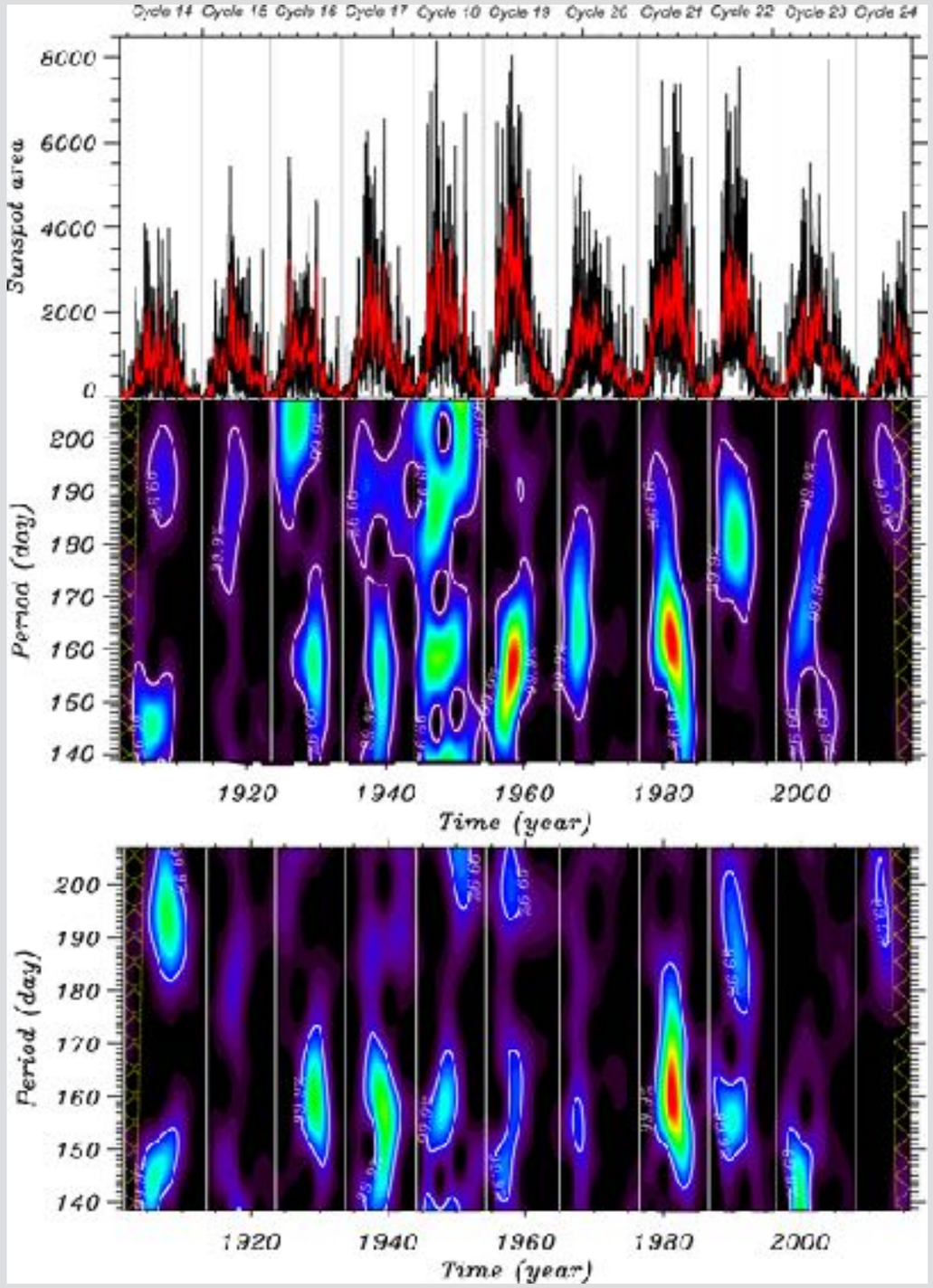
- The periodicity appears in MWSI but is weaker in SA wavelet and negligible in GSN and flares

- Chumak et al. (2003) studied the time behaviour of total SA and magnetic flux in 10 NOAA active regions corresponding to 1989
- There is no always a positive correlation between total SA and magnetic flux
- Sometimes total SA remains constant while magnetic flux increases/decreases
- Also, anticorrelation

Rieger periodicity in SA and SN (SC 14 - 24)

SA

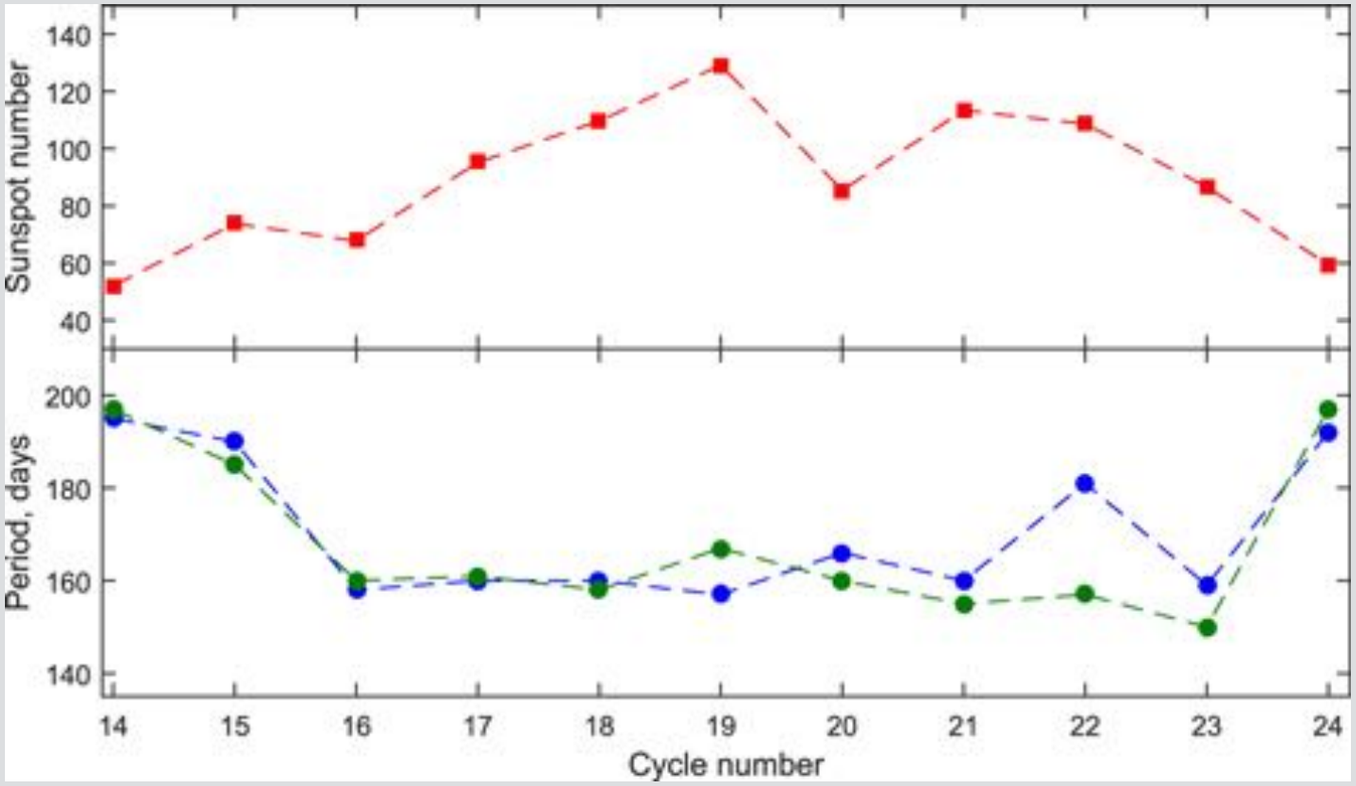
SN

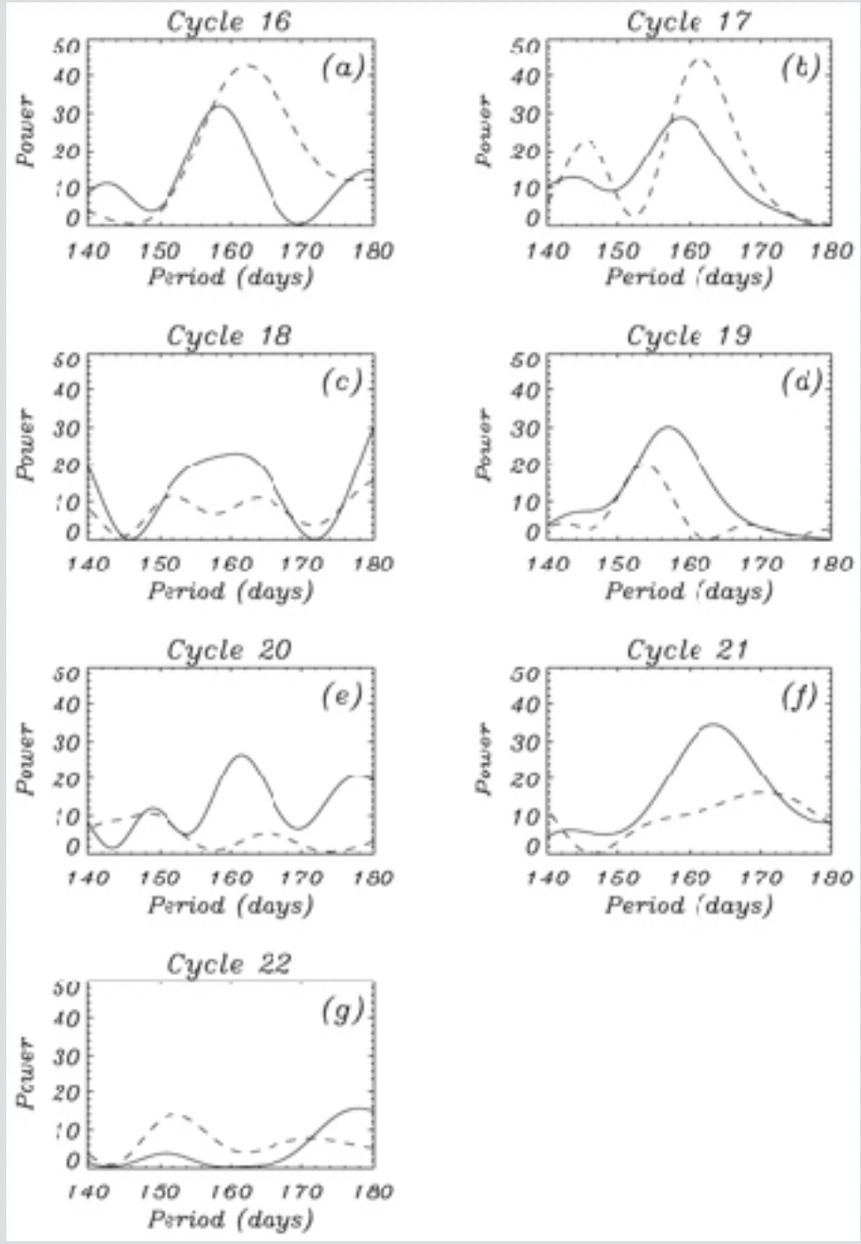


Gurgenashvili et al. 2016

(See Eka's talk, this afternoon)

Rieger periodicity: Temporal evolution





Blue: SA; Green: SN
(Gurgenashvili et al. 2016)

(Ballester et al. 1999)

RP: Features remaining to be fully explained

- Intermittency: periodicity appears around the maximum. Is it switched off during other periods or not?
- Strong in some cycles, weak or lacking in other
- Period shift between cycles
- Phase coherence between different cycles?
- Phase coherence between hemispheres? Is solar maximum happening in both hemispheres at the same time?
- N - S asymmetry? Periodicity seems to favour the dominant hemisphere
- Significance in periodicity analysis

Rieger periodicity in the Sun: Why?

Trixie, the Flagston's blonde baby girl who loves "talking" (through thought balloons) to Sunbeam, a ray of sunlight

Acknowledgements

- Part of the results shown here come from a joint collaboration with Prof. R. Oliver and Dr. M. Carbonell

- Some new plots have been done in collaboration with Dr. M. Carbonell