Stellar Flaring Periodicities

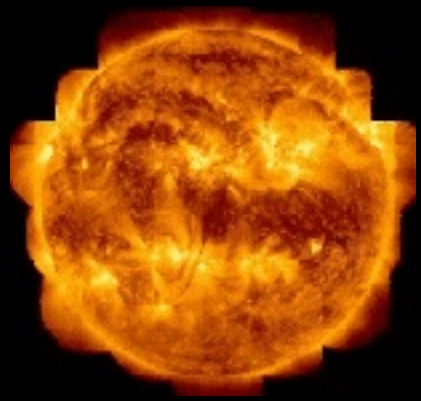
Maria Massi

(MPIfR)

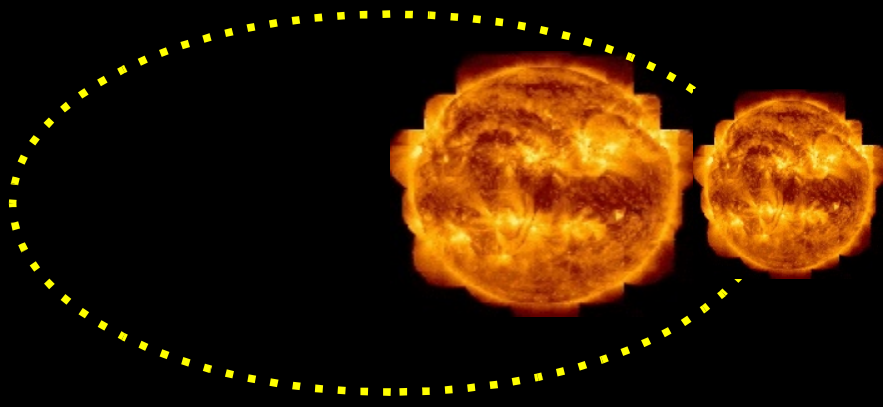
Outline of presentation: Flaring Periodicities

Intrinsic stellar flaring periodicities

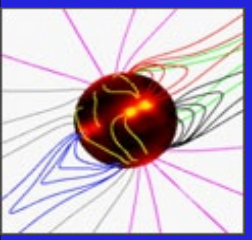
Single star



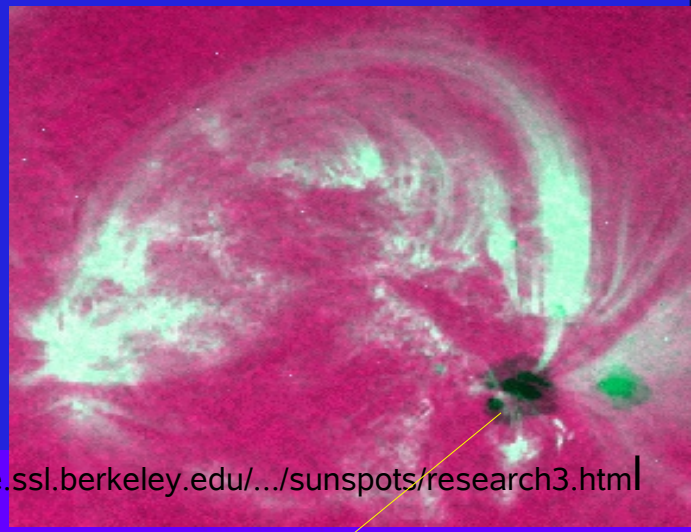
Inter-binary collisions (binary systems)



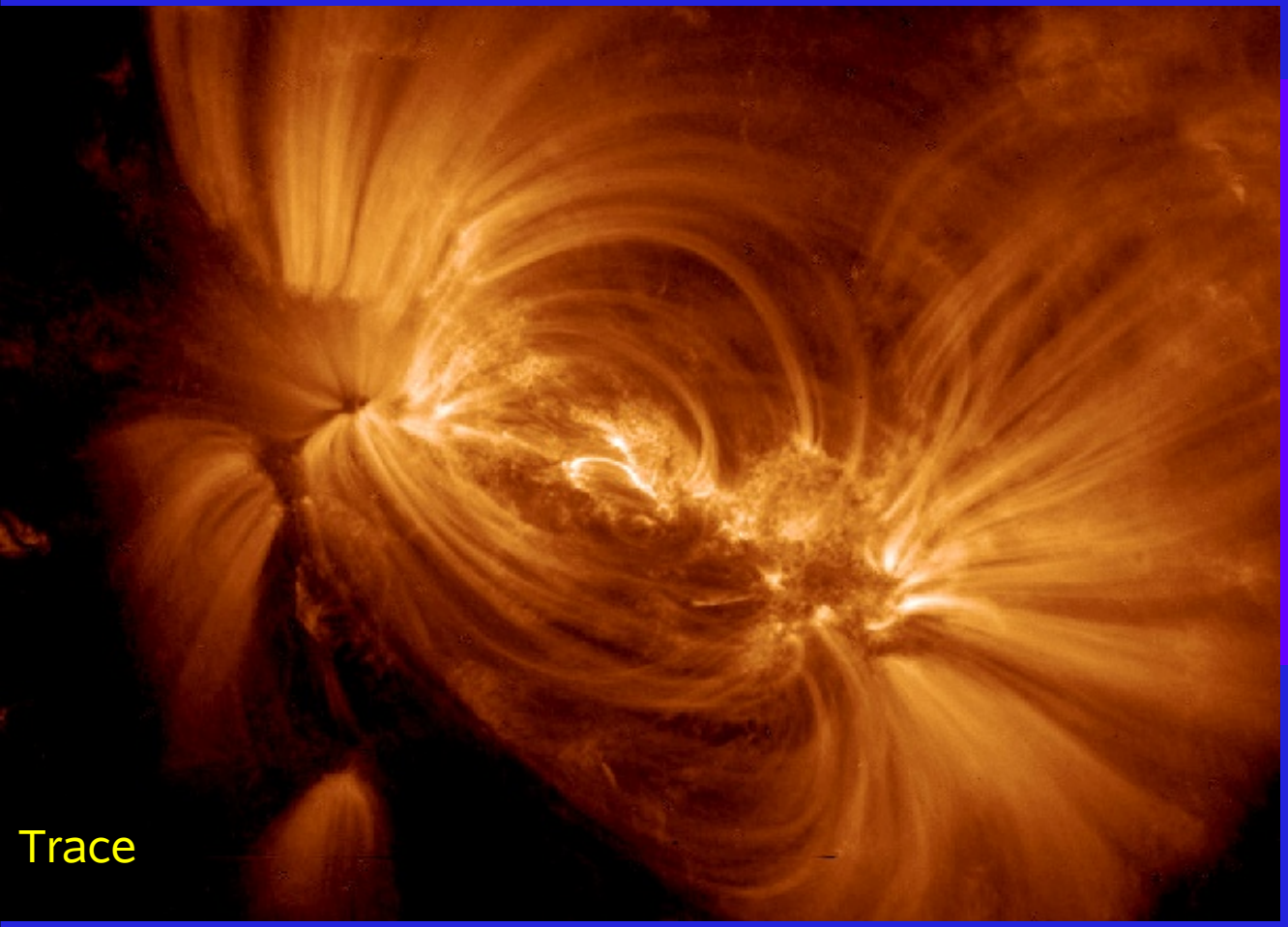
Building block of the Corona: coronal loops

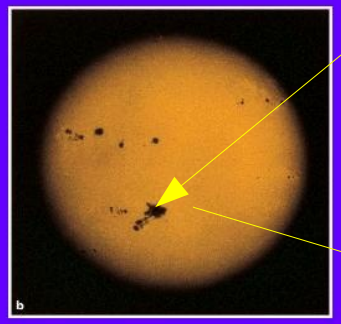


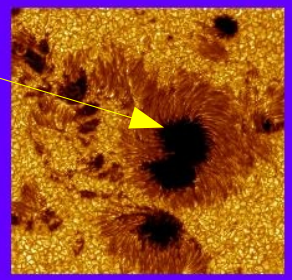
1. arc-like structures (X-ray images)
2. footpoints: Sunspots (Optical images)



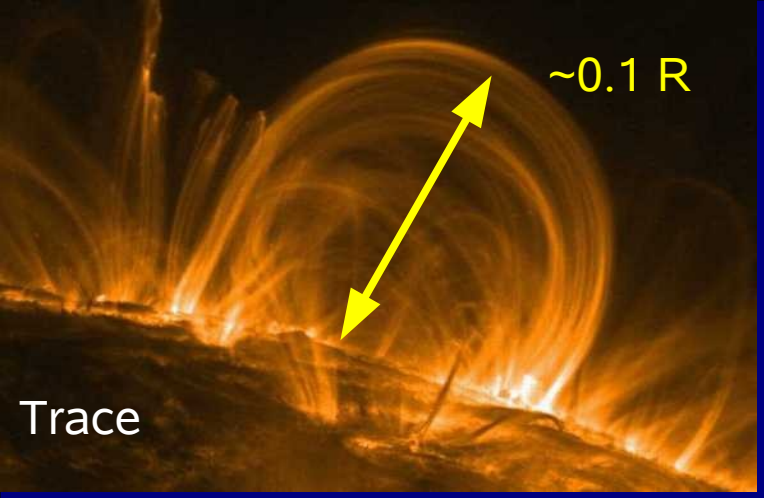
cse.ssl.berkeley.edu/.../sunspots/research3.html





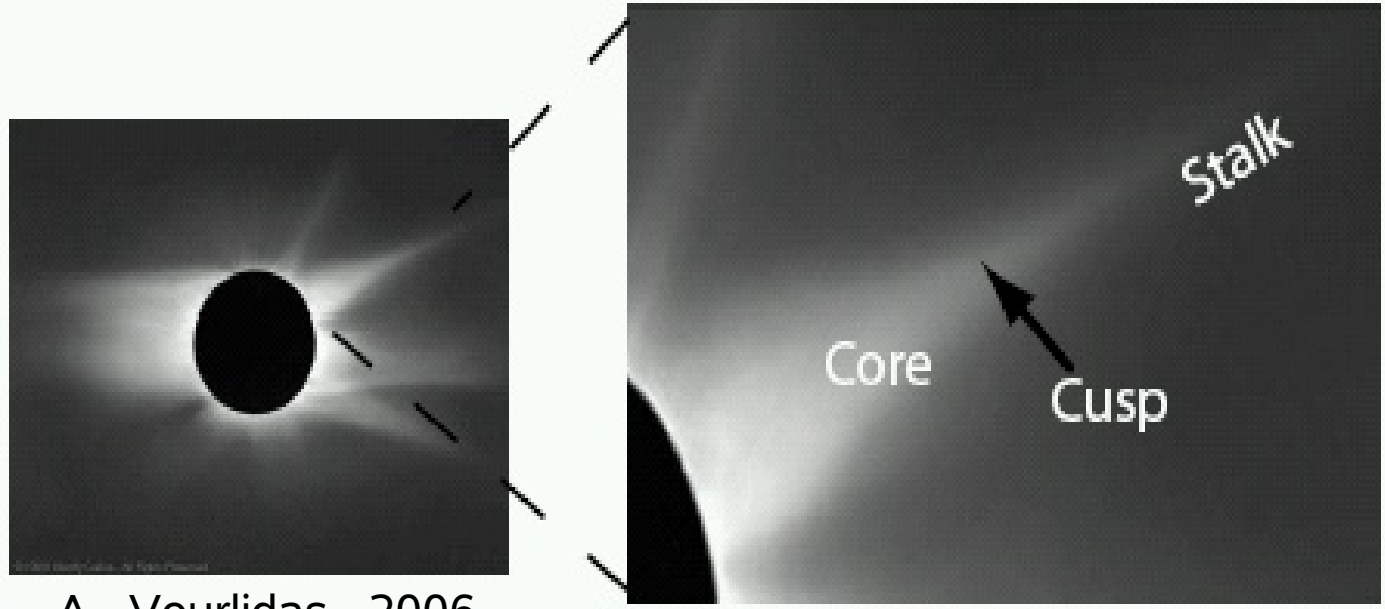


Coronal loops Sunspots



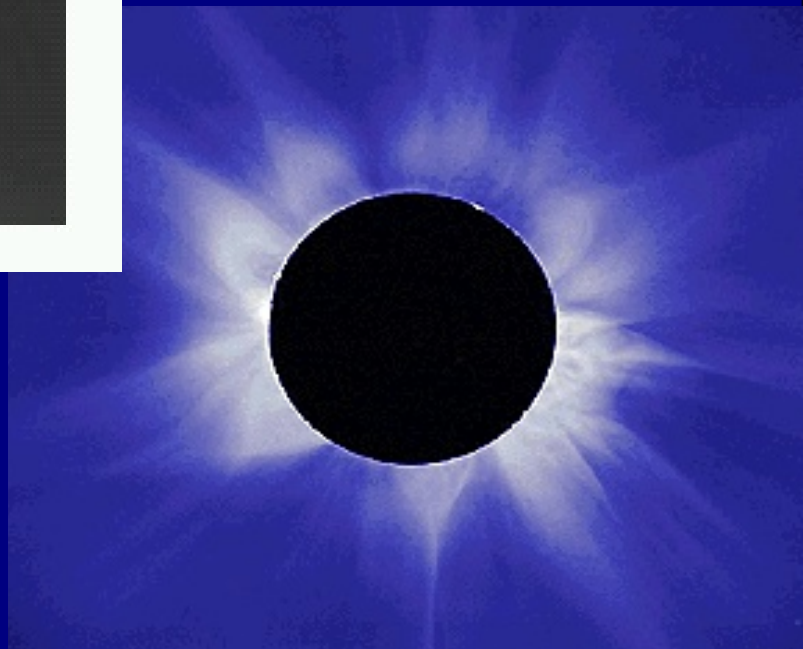
closed arc-like magnetic structures with size smaller than a solar radius

At large scale one observes much larger structures:
The helmet streamers: transition from closed to open field regions.



A. Vourlidas 2006

LASCO coronagraphs show structures to 30 solar radii



Dynamical Corona

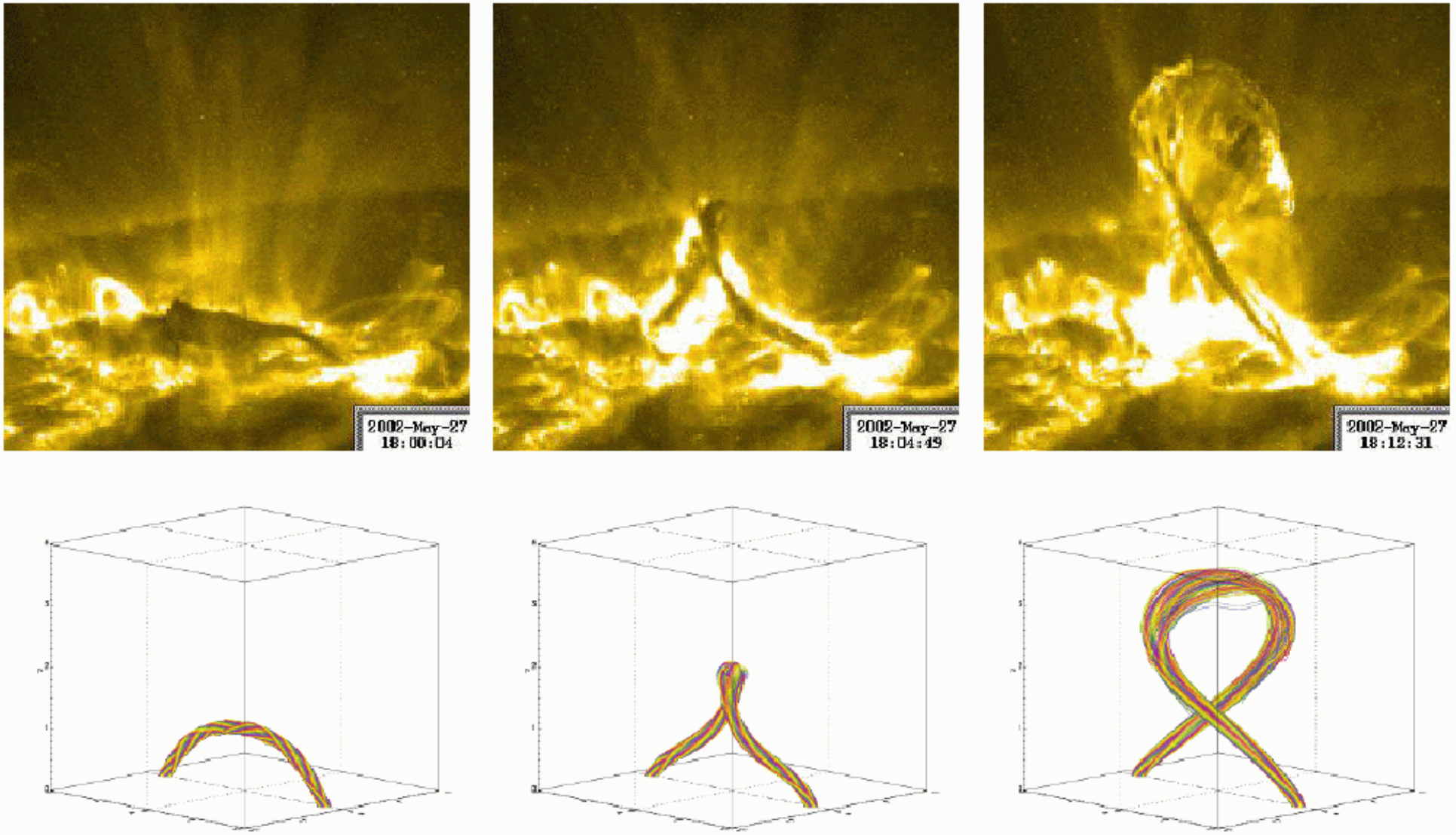


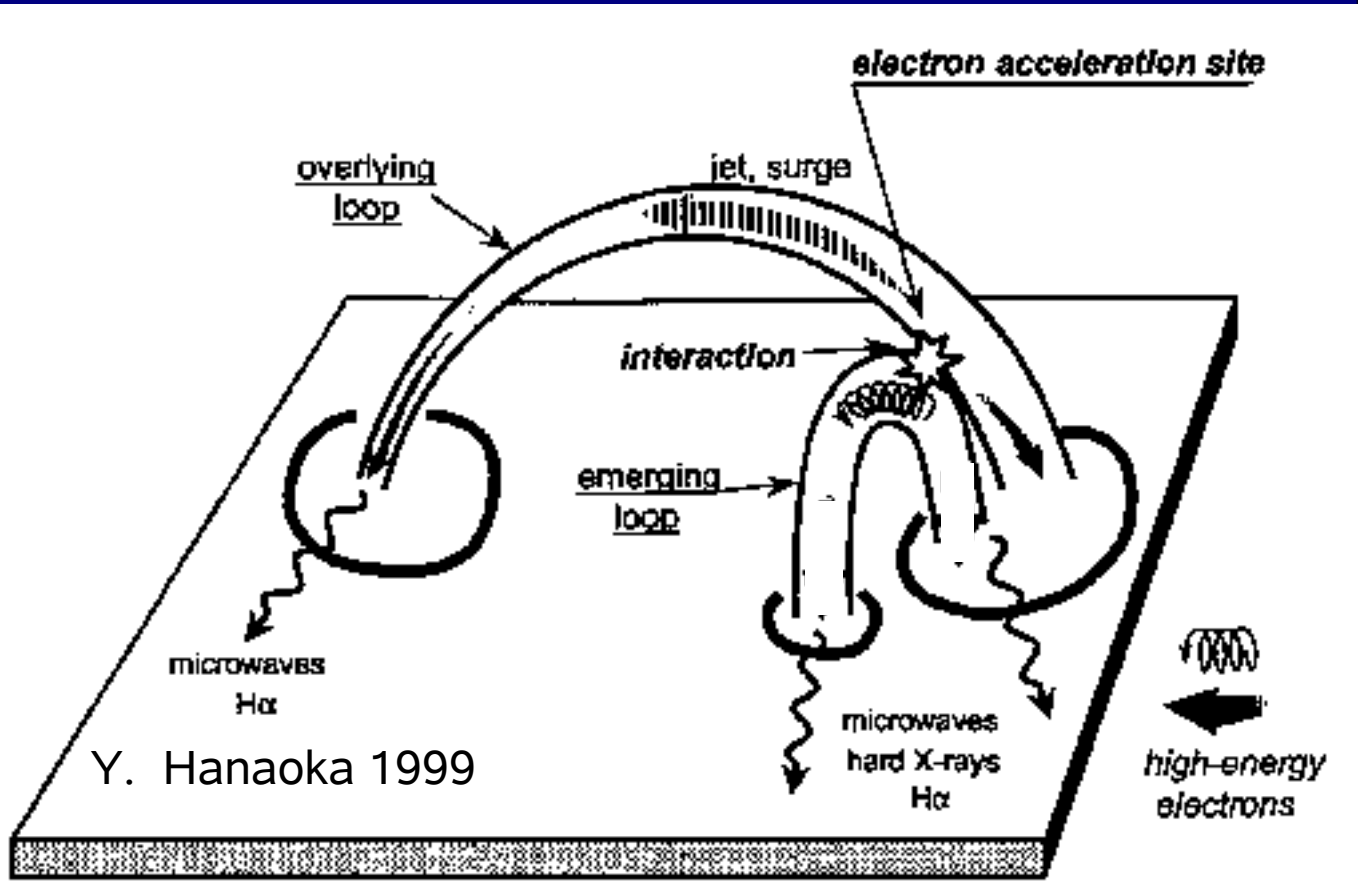
Figure 9. **Top:** TRACE 195 Å images of the confined filament eruption on 2002 May 27. The right image shows the filament after it has reached its maximum height. **Bottom:** magnetic field lines outlining the kink-unstable flux rope reproduced with 3D MHD simulations (Török & Kliem 2004).

ppt presentation : Markus Aschwanden (AIA/HMI workshop, Monterey 2006)

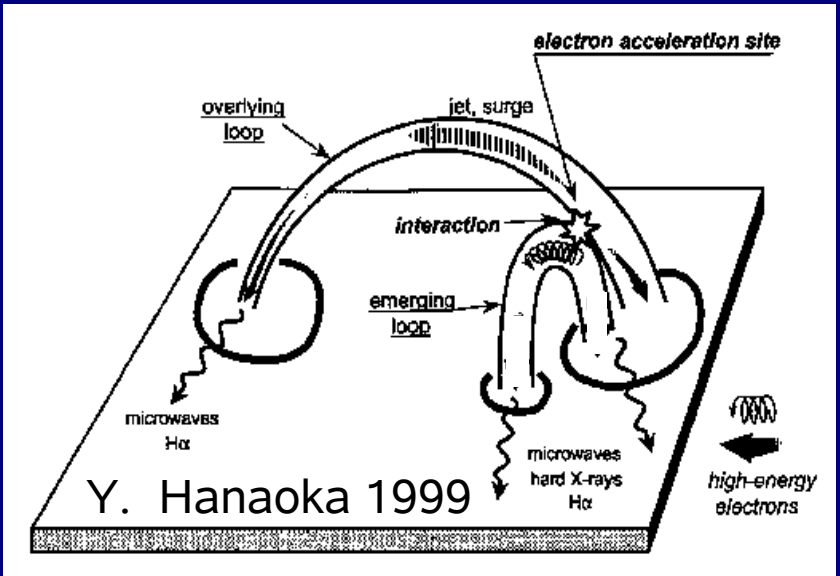
Loop-Loop interactions

www.astro.uni.wroc.pl/nauka/helpap/rf/1093.html

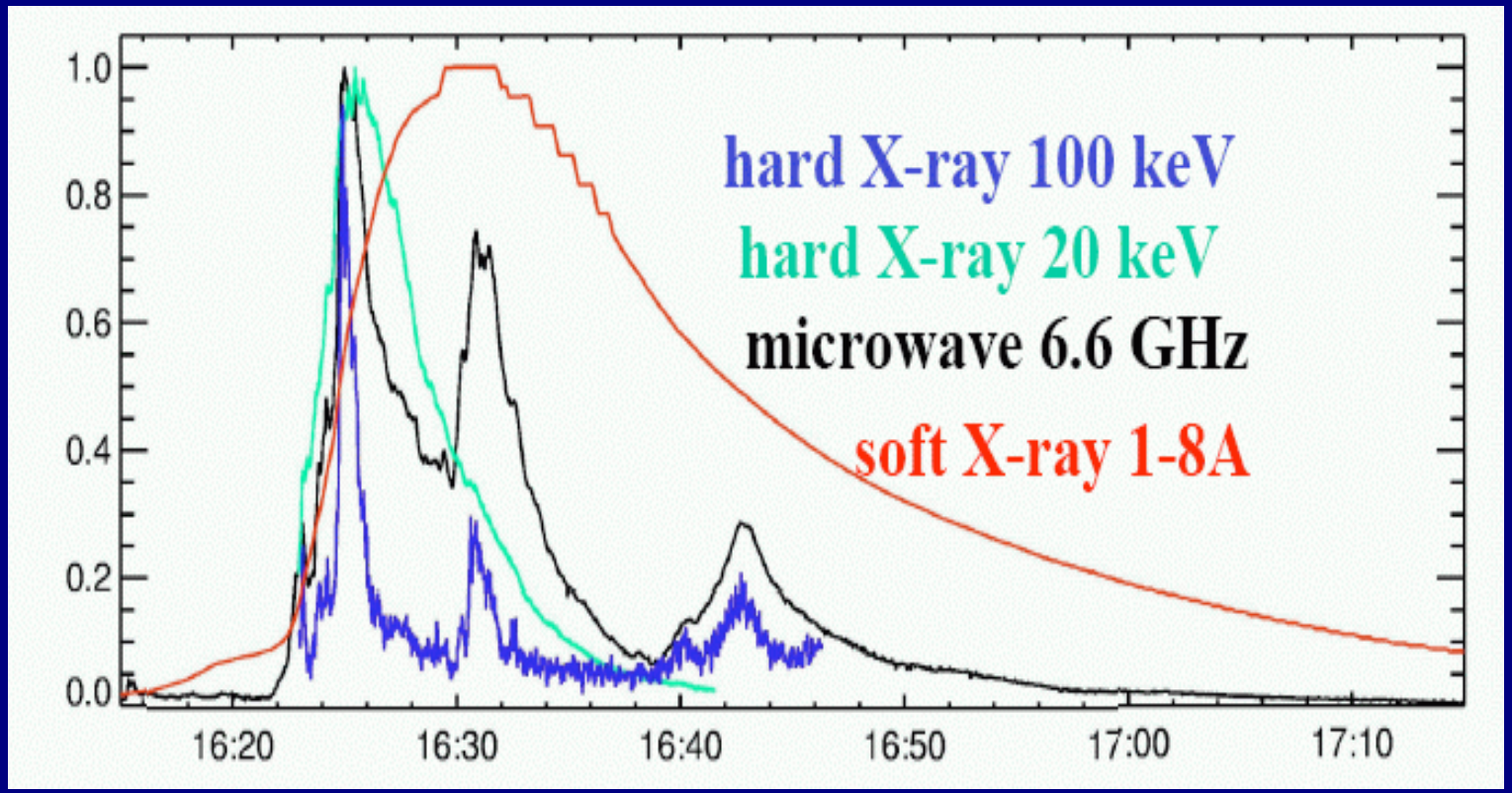
Magnetic-reconnection



Y. Hanaoka 1999


electron acceleration site
overlying loop
jet, surge
interaction
emerging loop
microwaves
Hα
microwaves
hard X-rays
Hα
high-energy electrons
Y. Hanaoka 1999

FLARE

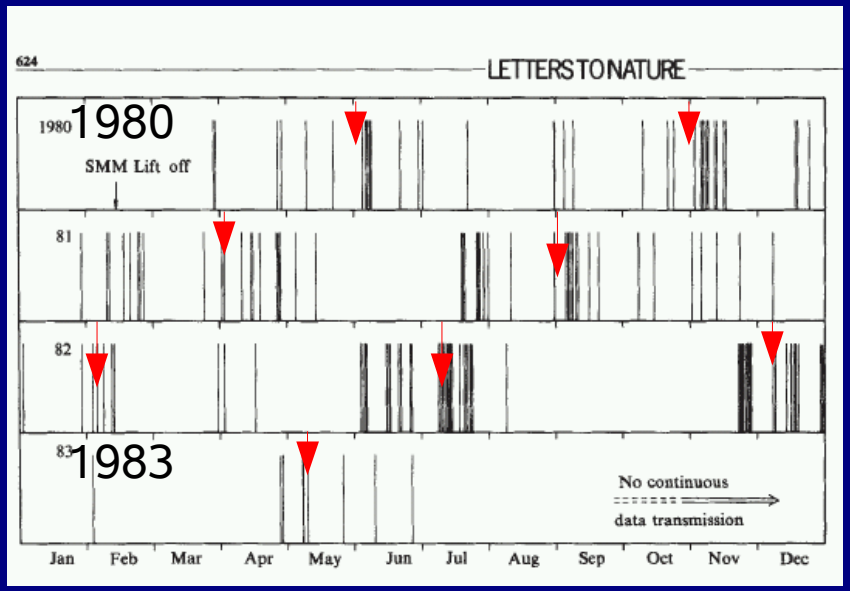

1.0
0.8
0.6
0.4
0.2
0.0
16:20
16:30
16:40
16:50
17:00
17:10
hard X-ray 100 keV
hard X-ray 20 keV
microwave 6.6 GHz
soft X-ray 1-8A

Stellar flaring periodicities

Are the loop-loop collisions casually occurring ?

„ A 154-day periodicity in the occurrence of hard flares ?“

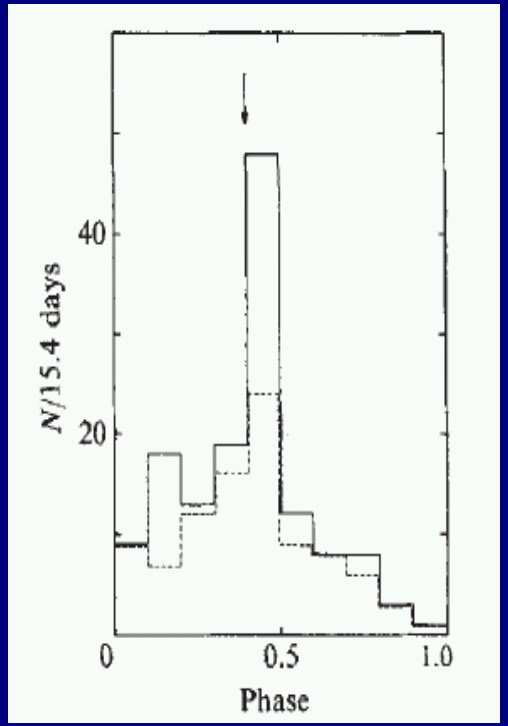
Rieger et al. Nature 1984



„ We also note that the flares tend to occur in groups which are spaced by about 5 months“

Folding of flare-event times with a period of 154 days and a bin size of ~ 15 days ----------> PHASE HISTOGRAM

The periodicity involves 35% of all flares observed



FLARING PERIODICITY
confirmed over all the electromagnetic spectrum:

gamma-ray	
X-ray	Rieger et al. 1984
H \alpha	Ichimoto et al. 1985
radio wavelengths	Bogart & Bai 1985

several „Rieger-type“ periodicities

Bai 1990, Lou 2000, Sturrock 2004

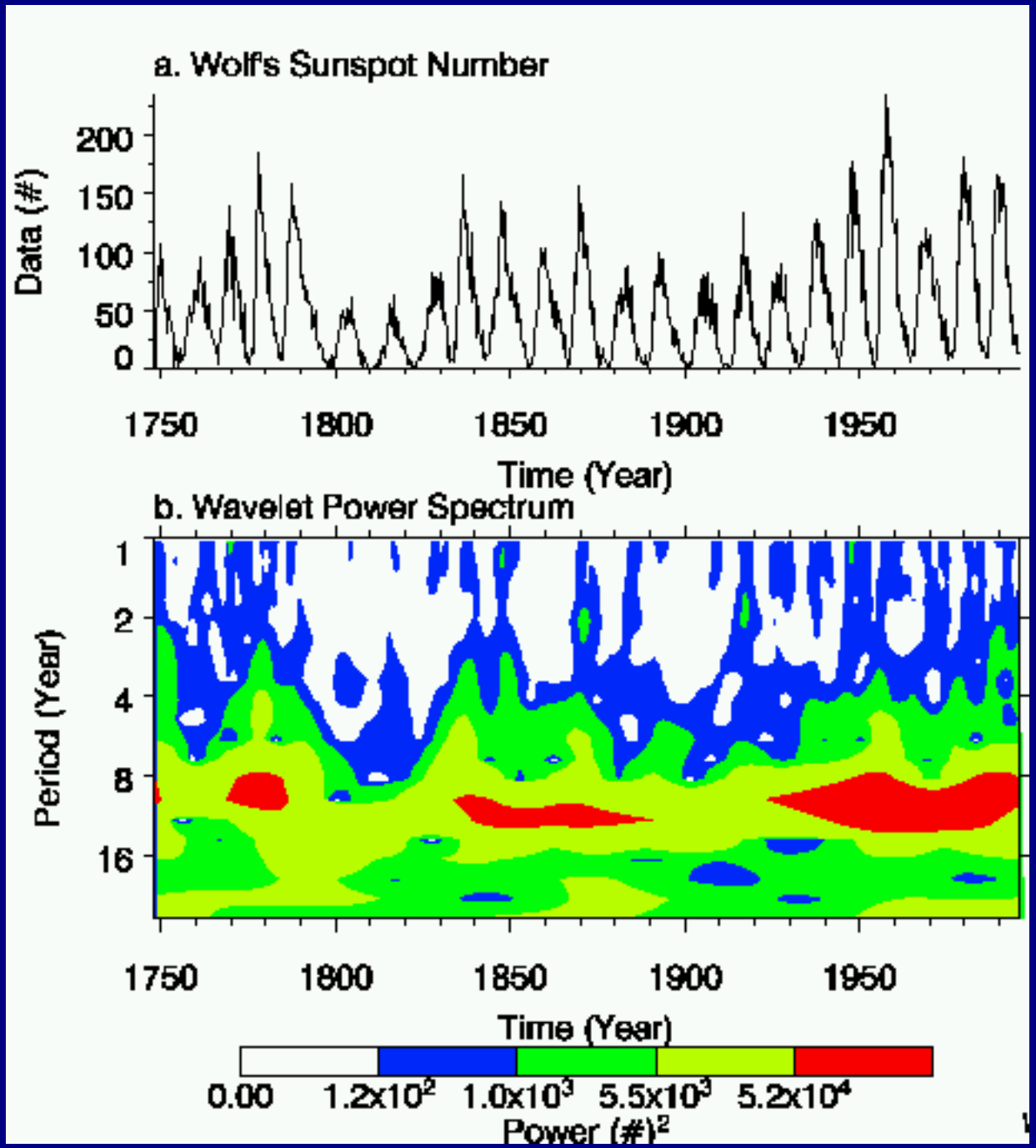
FLARING PERIODICITY
confirmed over all the electromagnetic spectrum:

gamma-ray	
X-ray	Rieger et al. 1984
H \alpha	Ichimoto et al. 1985
radio wavelengths	Bogart & Bai 1985

if it is originated from loop-loop collisions....

then the same periodicity should appear in sunspot occurrence.

The SUN



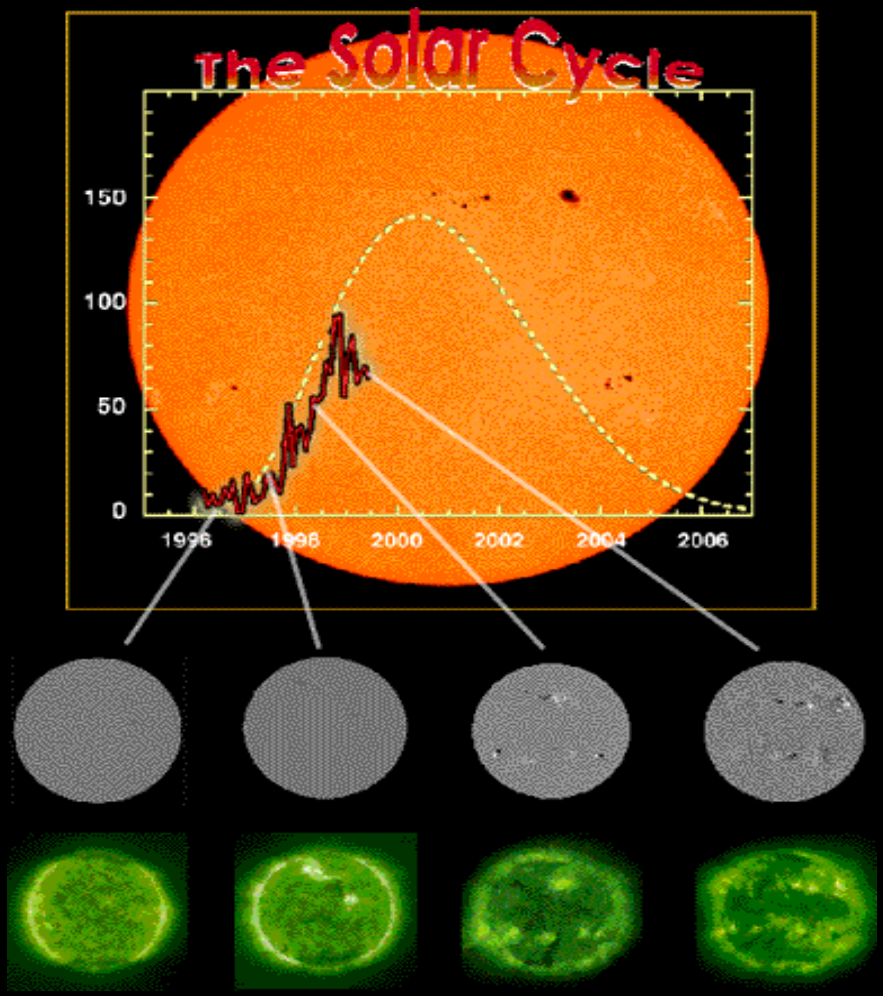
POWER SPECTRUM

Wavelet analysis

how the Fourier periods (*y*) vary in time (*x*).

http://ion.researchsystems.com/IONScript/wavelet/

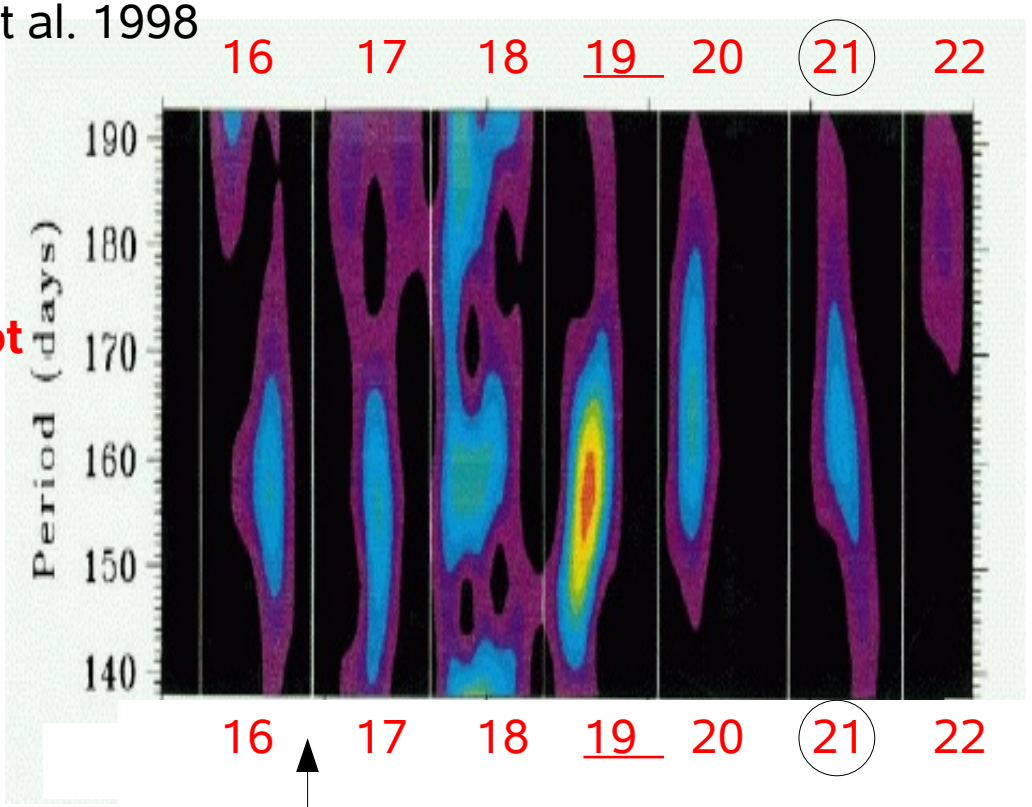
www.chabotspace.org/vsc/solar/thesun/images/solcycle-images-soho.gif



Research for short periodicities :

Timing analysis of **daily** sunspot areas/ group sunspot numbers

Oliver et al. 1998



Daily sunspot areas

1874 - 1993

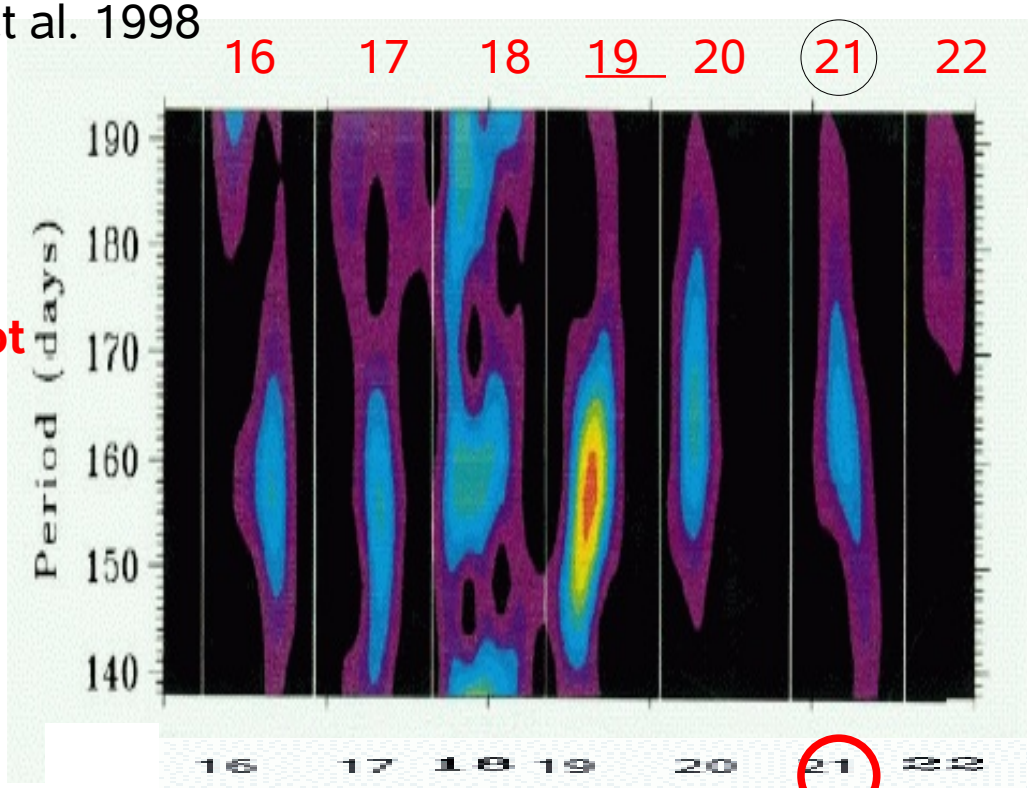
seven 11-yr cycles: from 16th to 22th

Solar activity minimum

Daily sunspot areas

Sunspot area:
The area of a sunspot is measured in a fraction (millionth) of the Sun's visible hemisphere.

Oliver et al. 1998



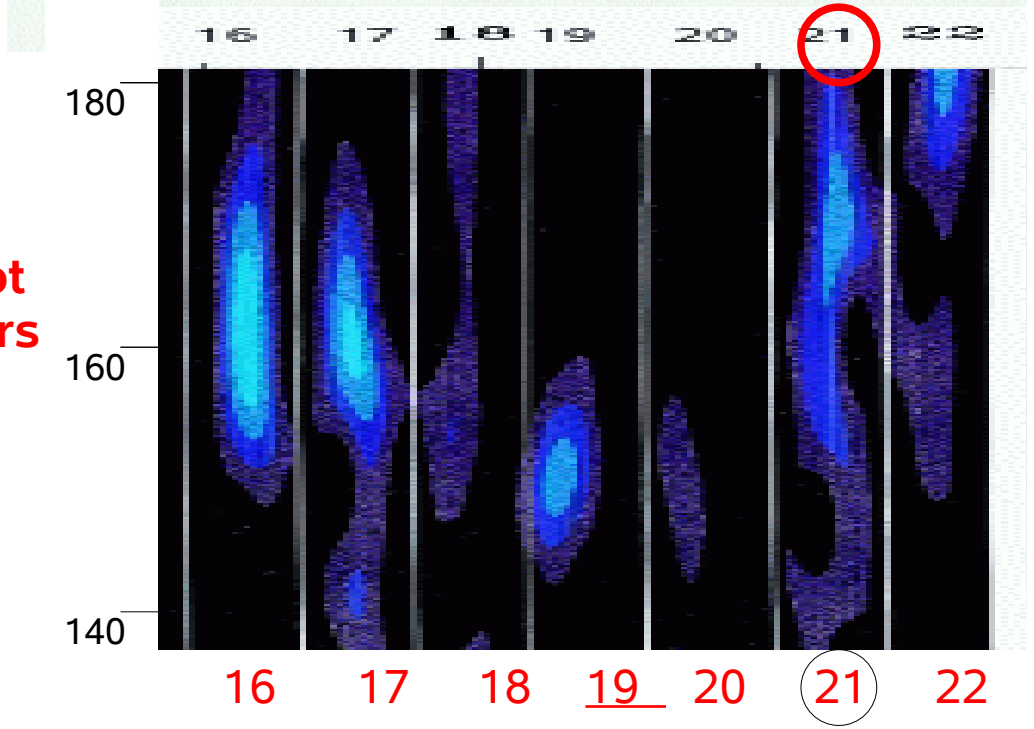
Daily sunspot areas

1874 - 1993

seven 11-yr cycles: from 16th to 22th

Daily sunspot areas

Sunspot area:
The area of a sunspot is measured in a fraction (millionth) of the Sun's visible hemisphere.



Daily group sunspot numbers

Daily group sunspot numbers

Sunspots usually appear in groups.

Normally it is easy to count the number of groups as they are spread out across the disk.

Difficulties can occur when sunspots appear close together.

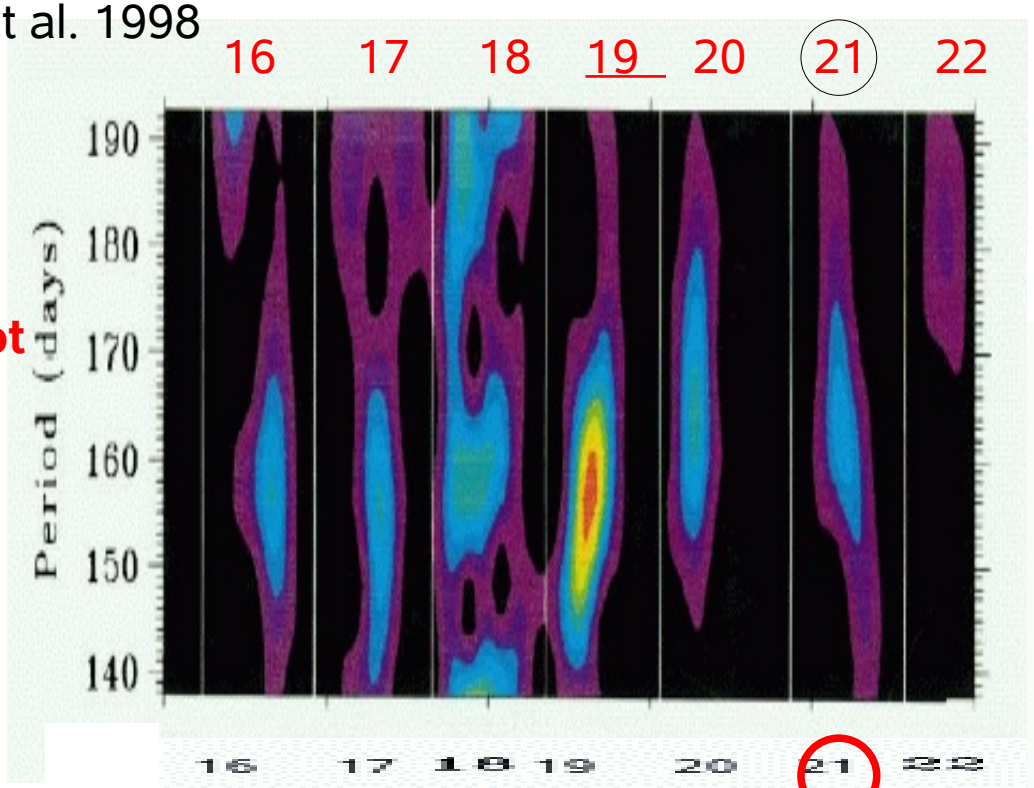
Ballester et al. 1999

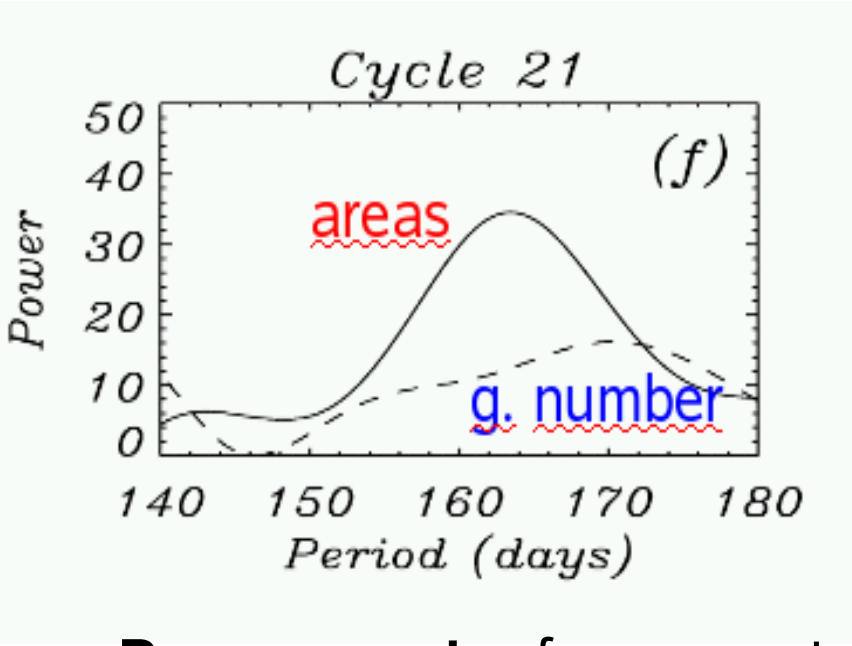
Oliver et al. 1998

1874 - 1993

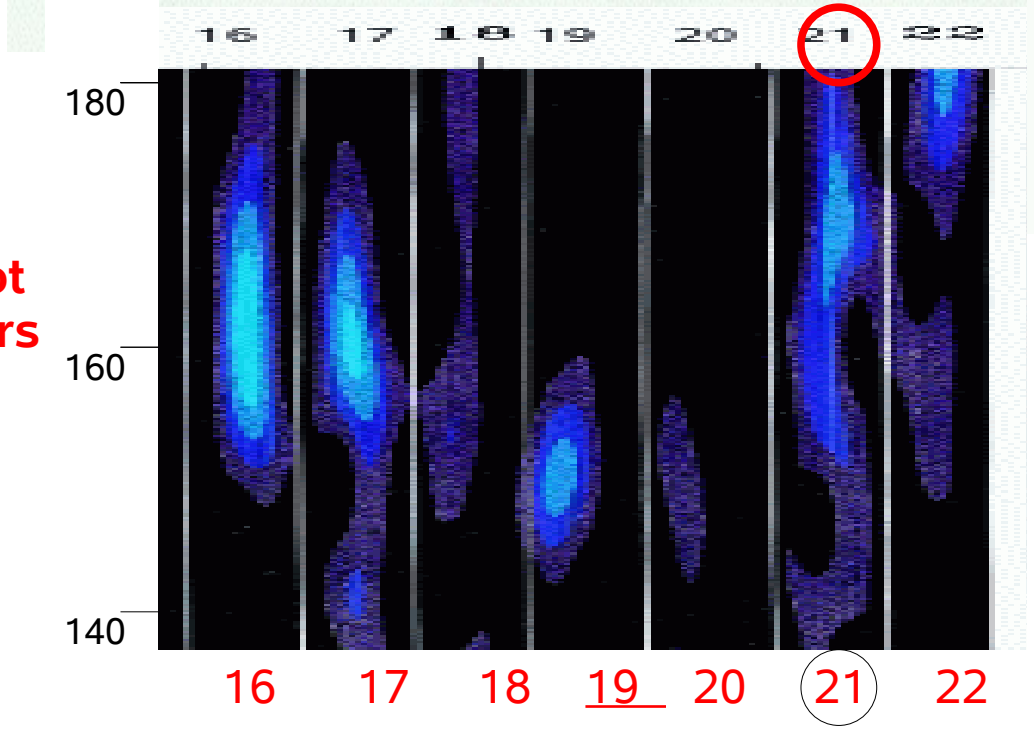
seven 11-yr cycles: from 16th to 22th

Daily sunspot areas





Daily group sunspot numbers



Power spectra for sunspot areas and group sunspot numbers for solar cycle 21

Ballester et al. 1999

Ballester et al 1999

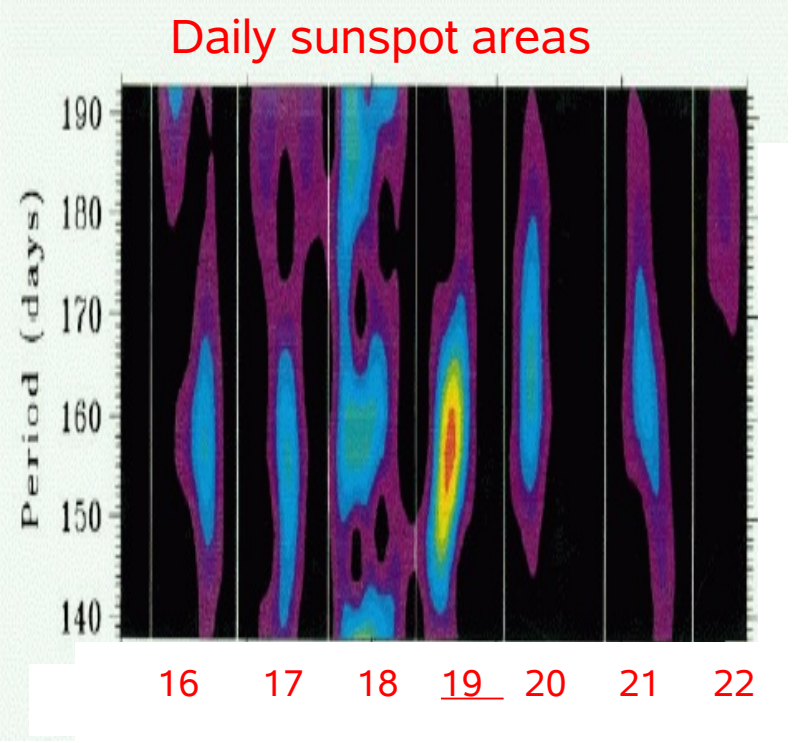
Two forms of periodic emergence of magnetic flux

1. Sunspot groups are periodically formed
every time in different regions

simultaneous increase
total sunspot area _and_ group sunspot numbers

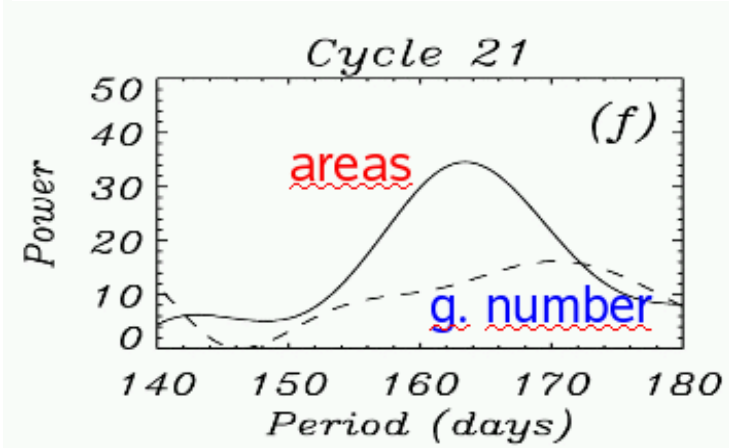
2. Sunspot groups are periodically formed
within already existing sunspot groups

increase
total sunspot area only



Sunspot groups periodically emerge
within already formed sunspot groups

(increase of sunspot areas only)



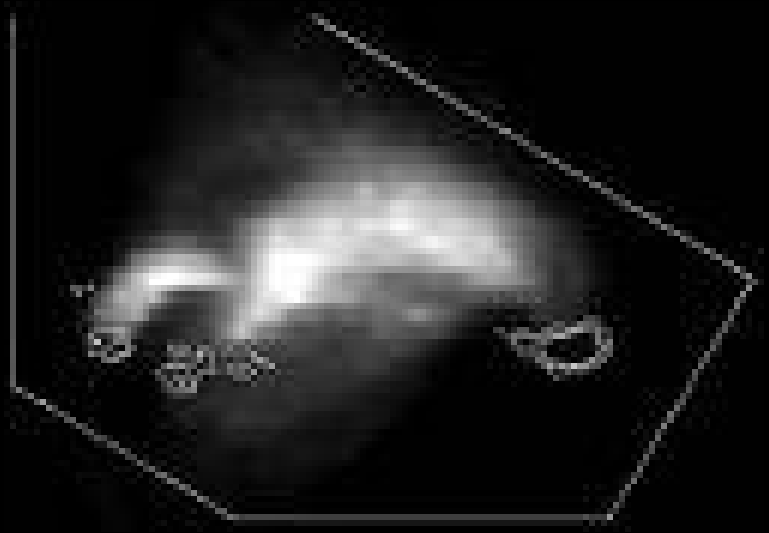
„We point out that this second type of emergence, which enhances the magnetic complexity of sunspot groups, is responsible for the appearance of the periodicity in high-energy solar flares .. during solar cycle 21.“

(Ballester et al. 1999)

For Rieger **Flaring** periodicities to occur:

1. There must be the same periodicity in the emergence of magnetic flux

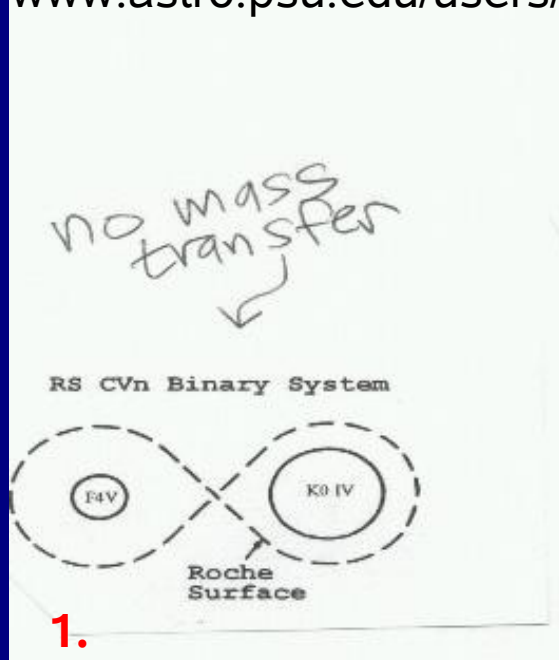
2. Successive emergences must occur in the same area

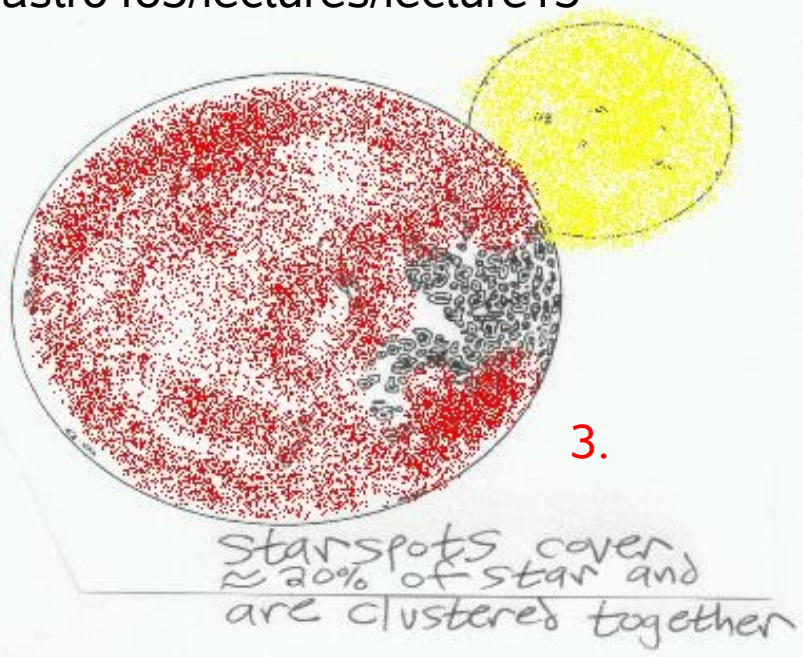


Discovered in 1984 the Rieger flaring periodicity is still considered a not fully understood solar phenomenum

solar ?

www.astro.psu.edu/users/niel/astro485/lectures/lecture13



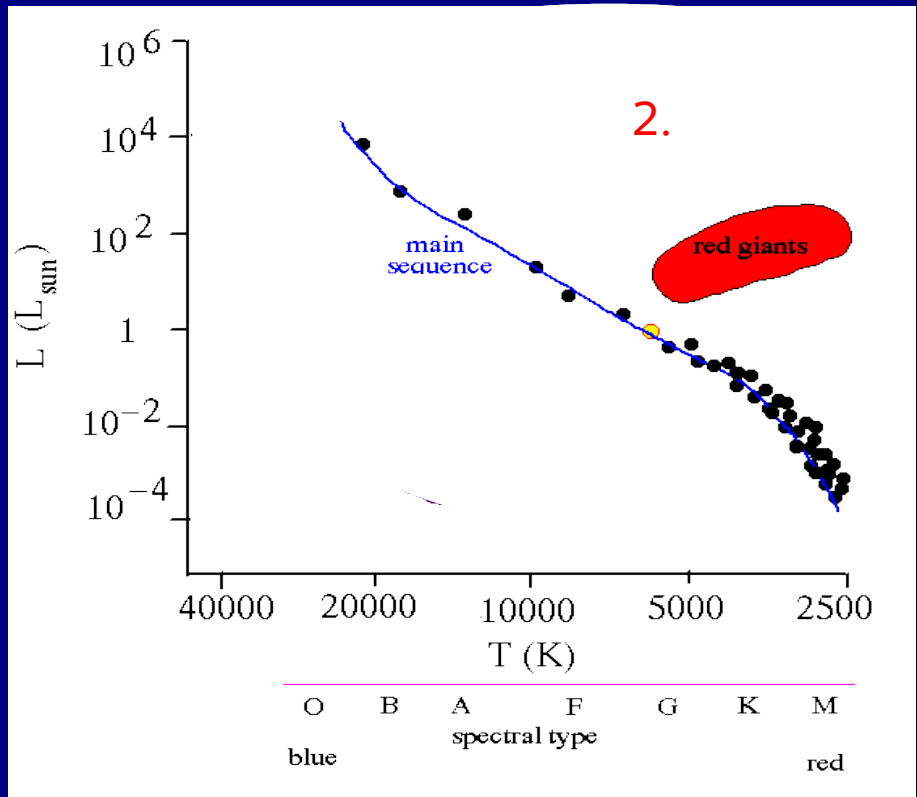


RS Cvn systems

1. close binary (tidally locked)
   $P_{rot} = P_{orb}$

2. active star: evolved (giant)

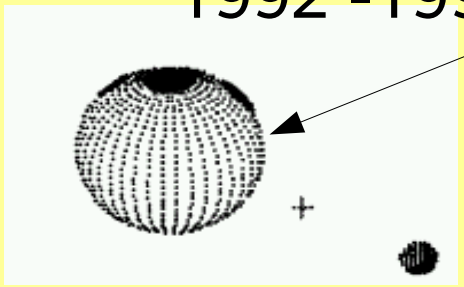
3. large dark spots

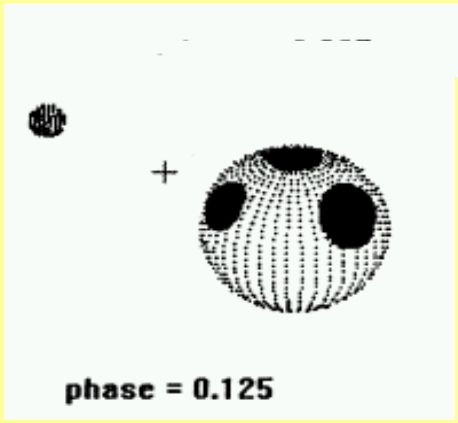


UX Arietis

„spotfree“ hemisphere

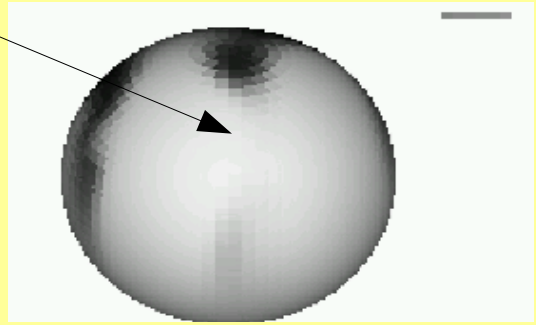
1992 -1993

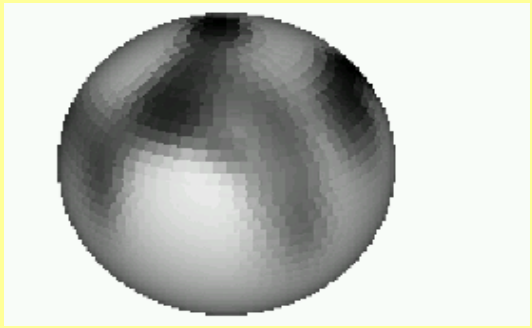




Elias et al. 1995

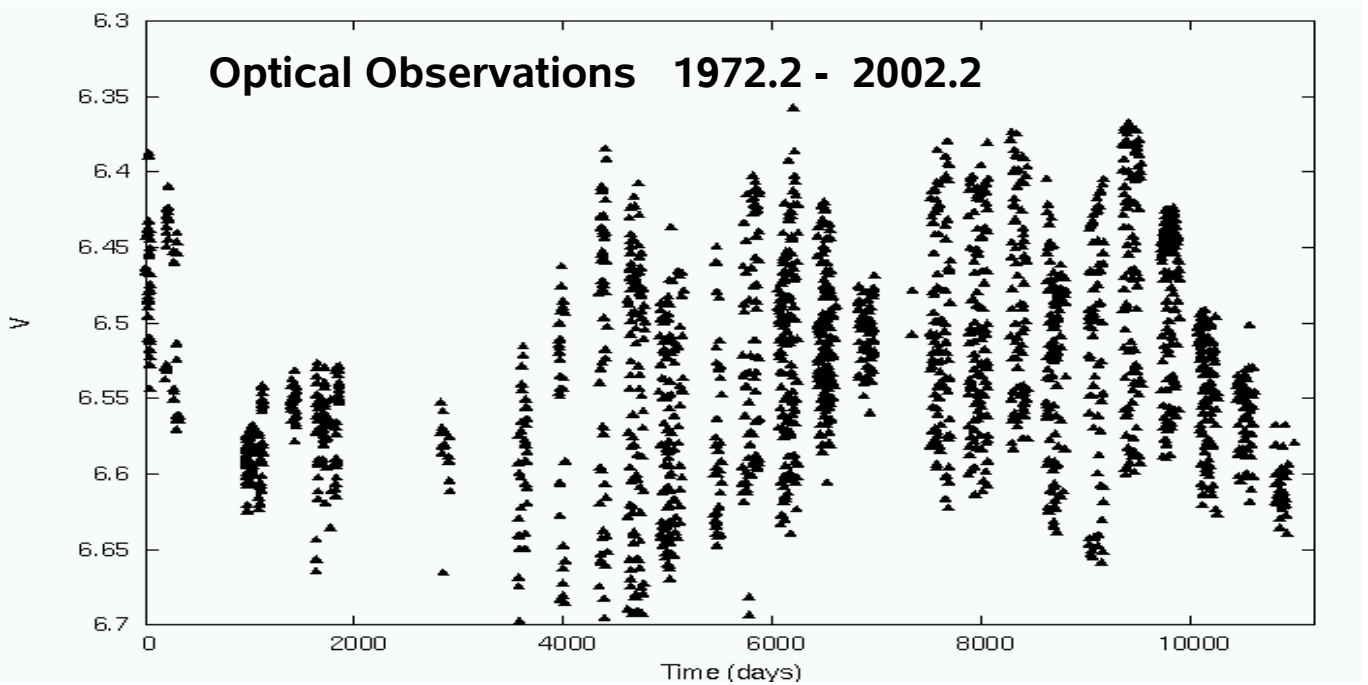
2001-2002



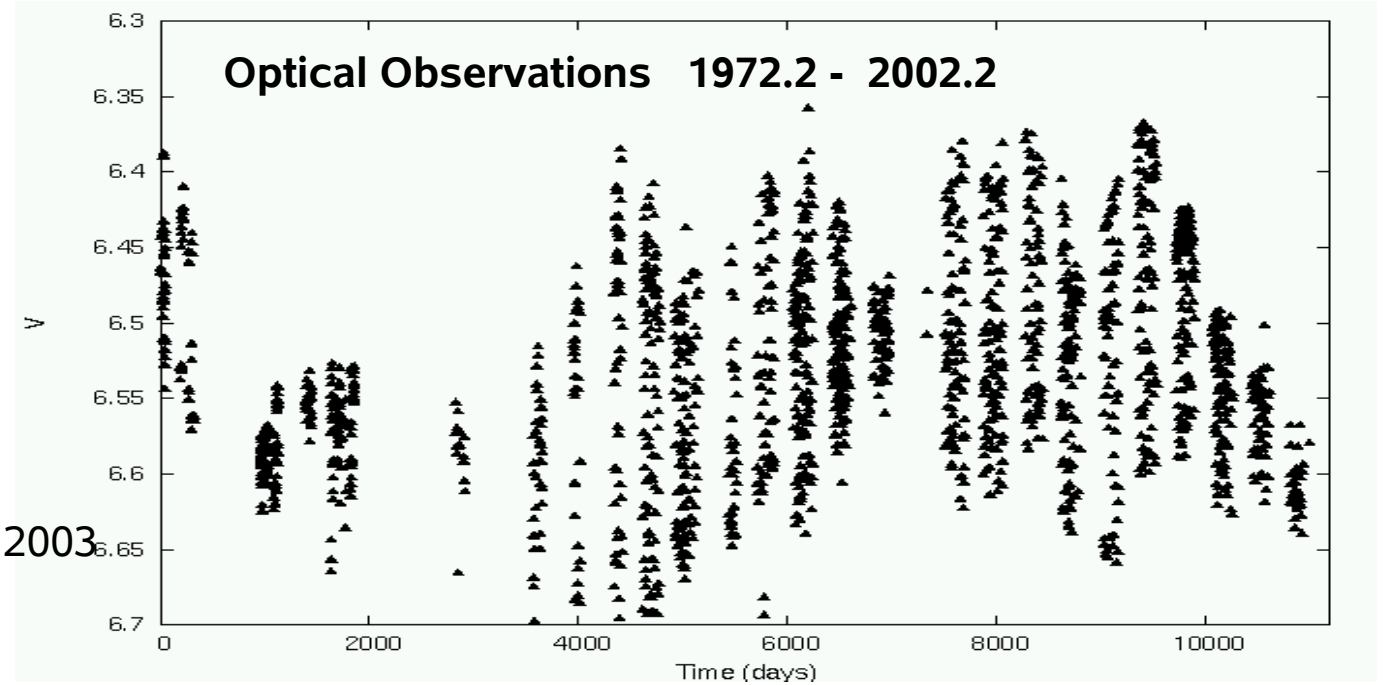


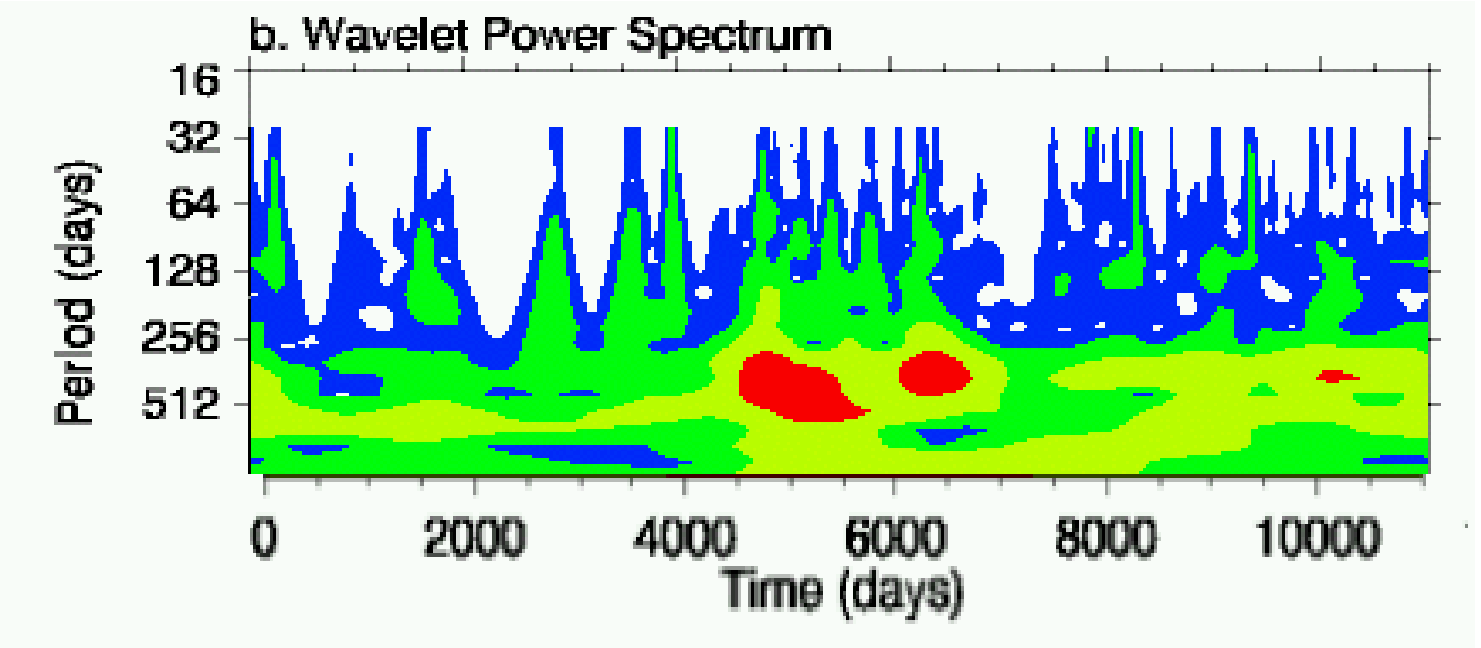
Gu 2006

Photometric V observations of UX Ari (from Aarum Ulvas & Henry 2003)

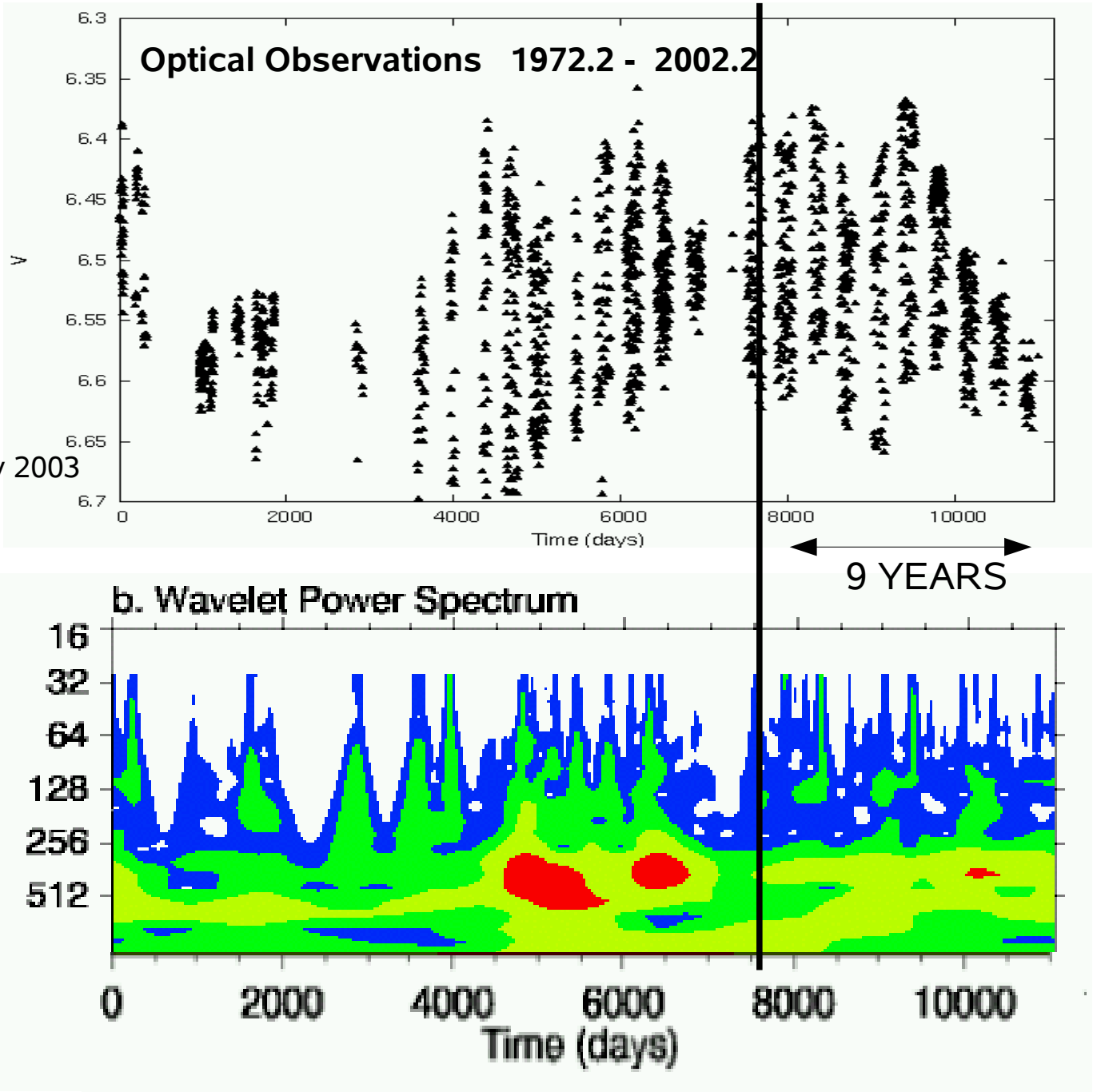


Aarum Ulvas & Henry 2003

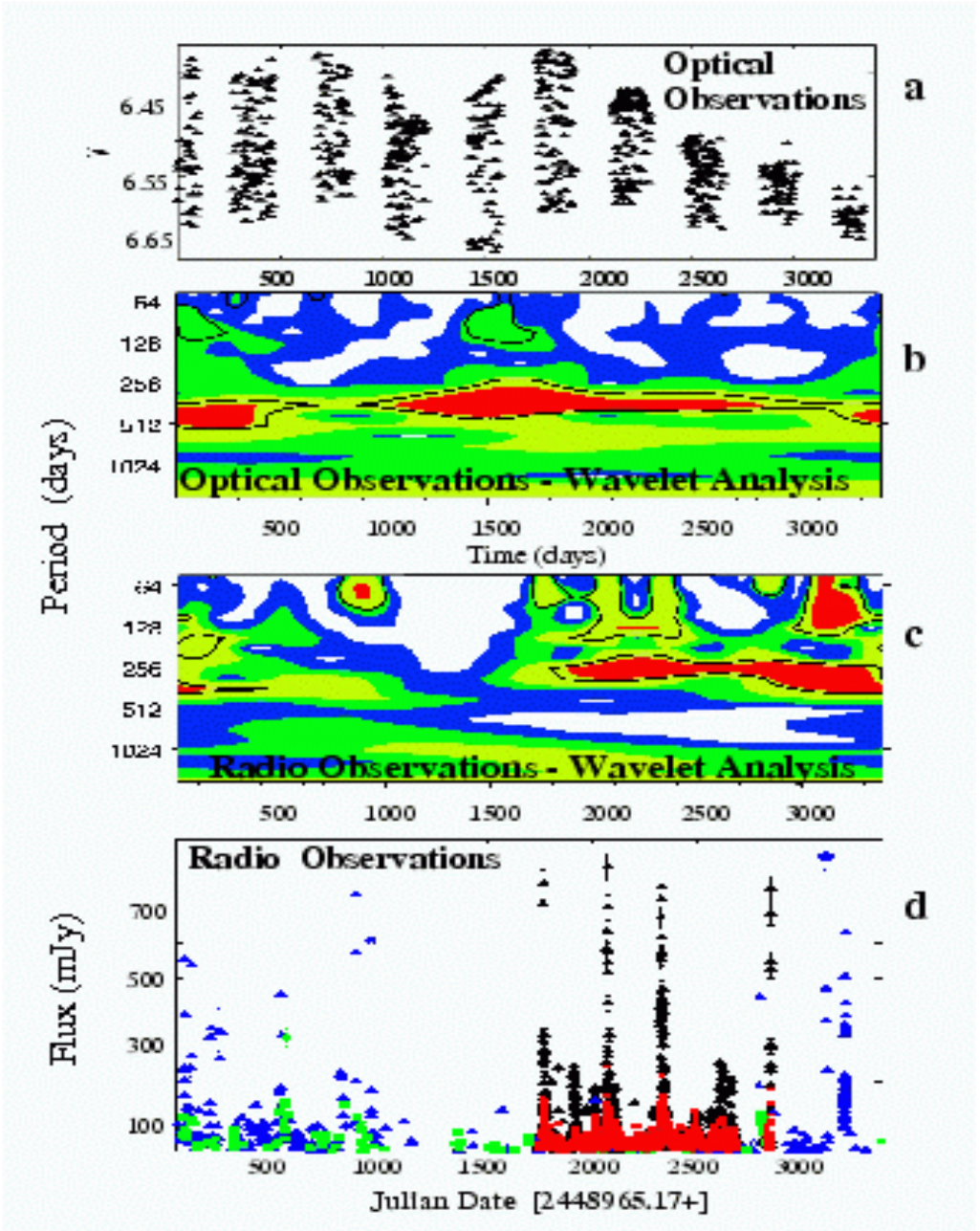




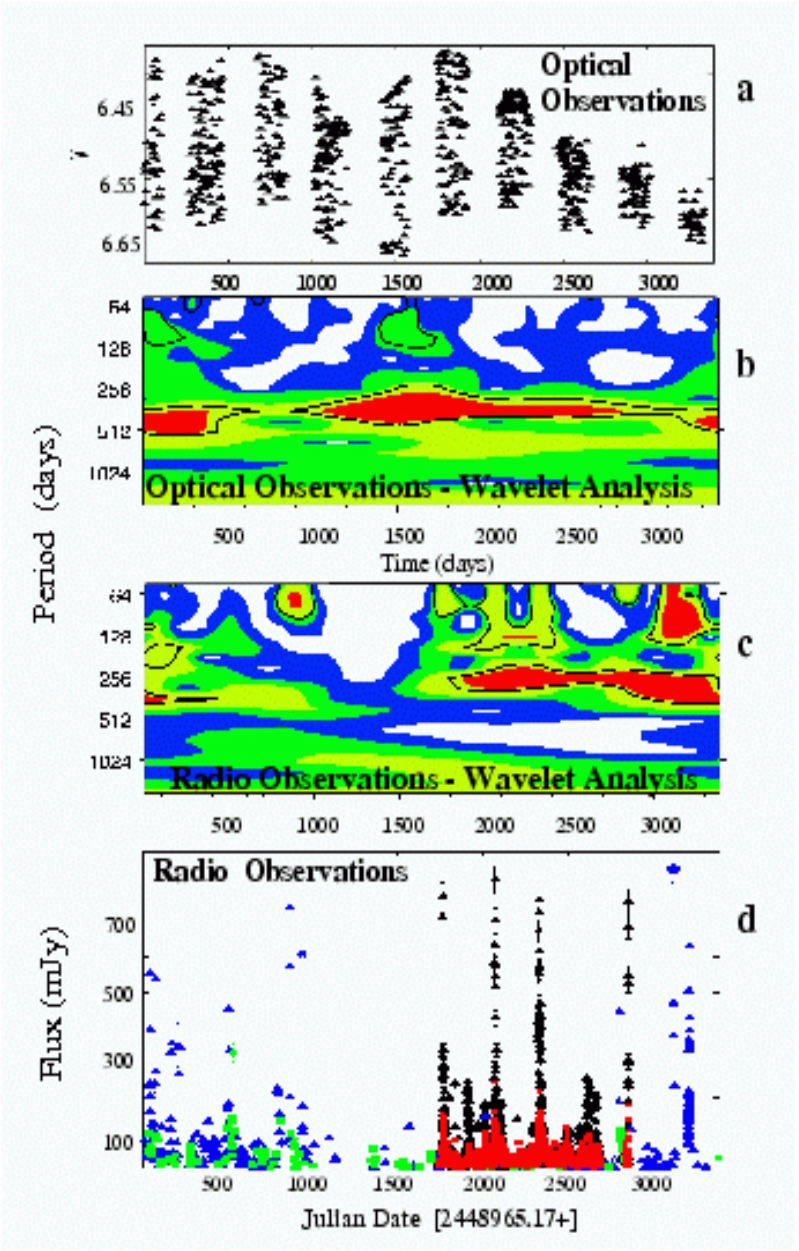
Aarum Ulvas & Henry 2003

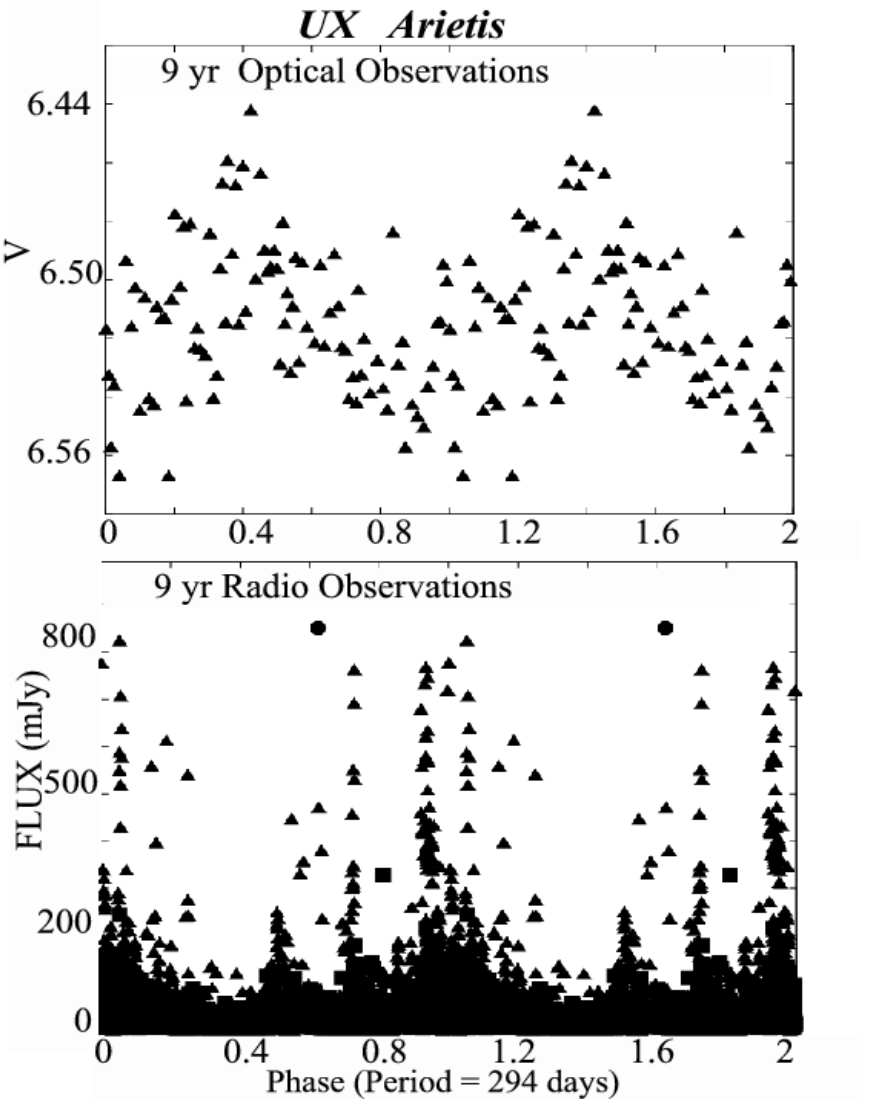


during the 9-year interval there are also radio observations

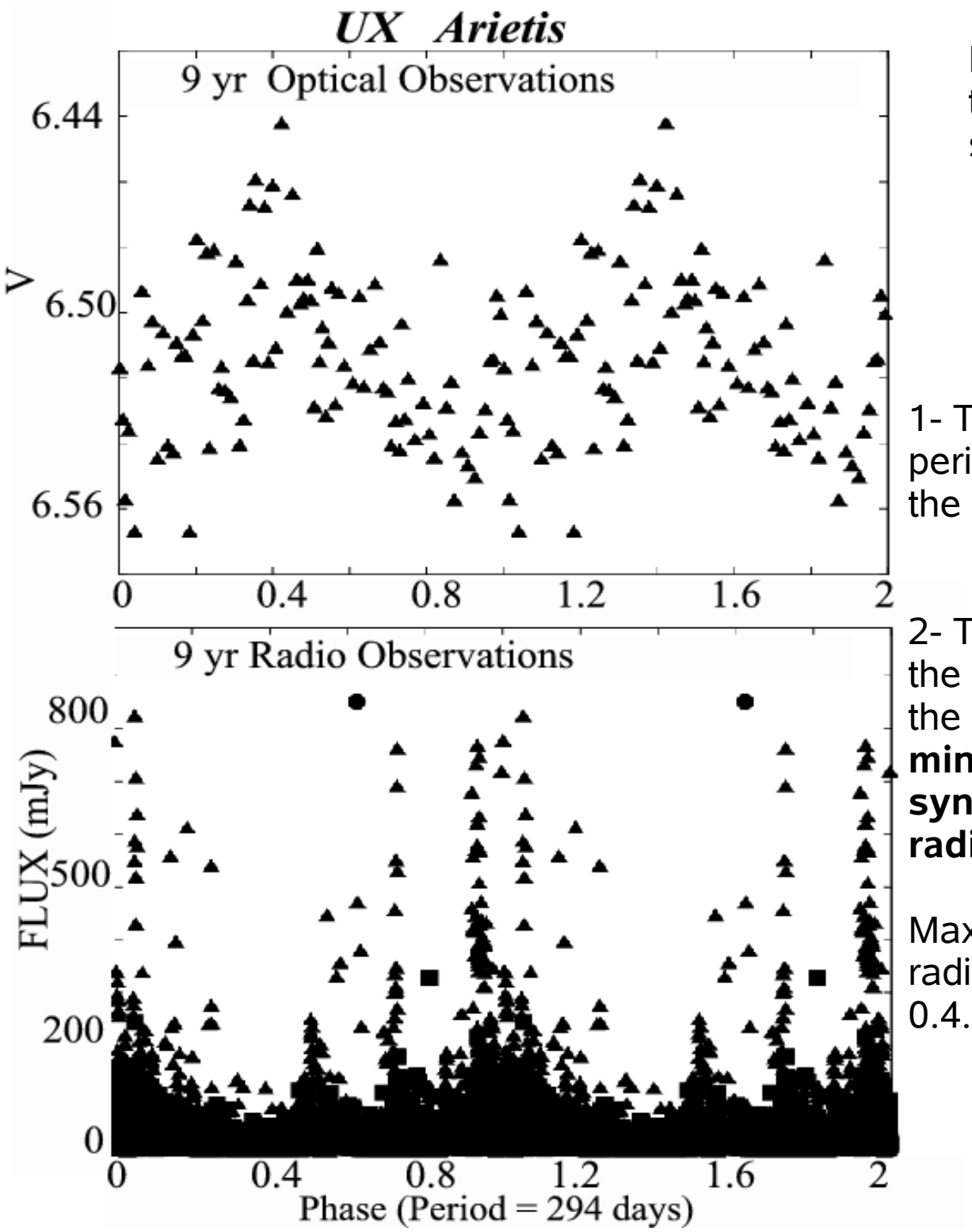


Massi, Neidhöfer, Carpentier, Ros 2005





Massi, Neidhöfer, Carpentier, Ros 2005

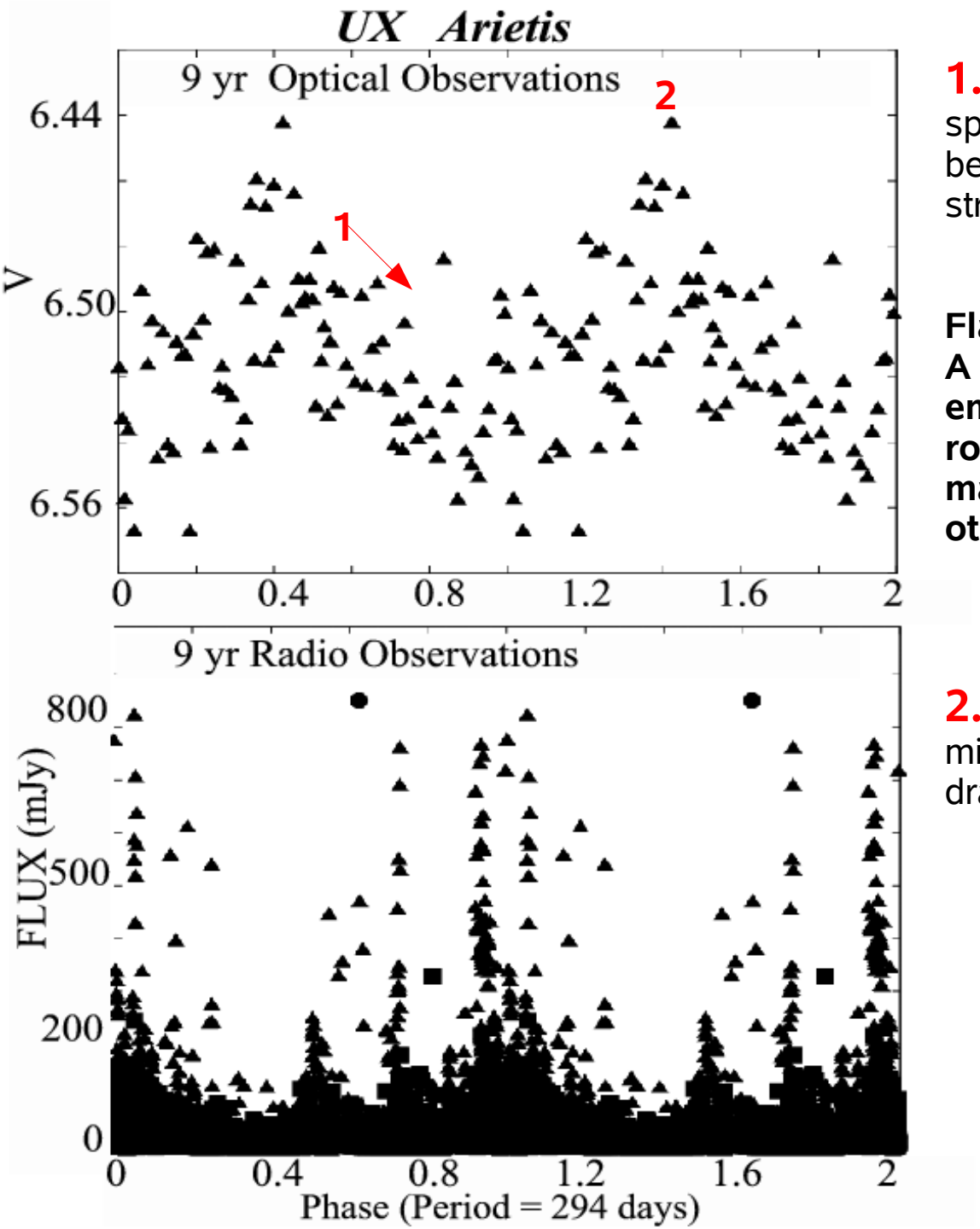


Results of the timing analysis of two completely independent data sets (optical and radio ones)

1- The data folded with the 294 -day period cluster, confirming the result of the timing analysis

2- There exists a relationship between the radio curve and the optical curve: the maximum V magnitude (**i.e. the minimum spot coverage) is synchronized with the minimum in radio flaring activity.**

Maximum V magnitude and minimum radio flux density occur both at phase 0.4.



1. During the initial phase of the cycle, the spotted surface progressively increases because of the emergence of new magnetic structures.

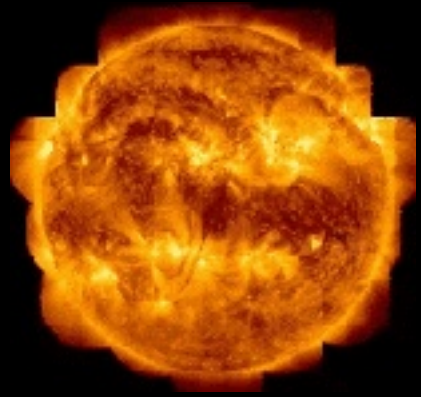
Flares can be observed (phase 0.6-1.2). A possible explanation is that the emergence area remains roughly localized so that new and older magnetic structures interact with each other.

2. At the peak of the optical curve (i.e. minimum spot activity) the flaring activity dramatically stops.

Flaring Periodicities

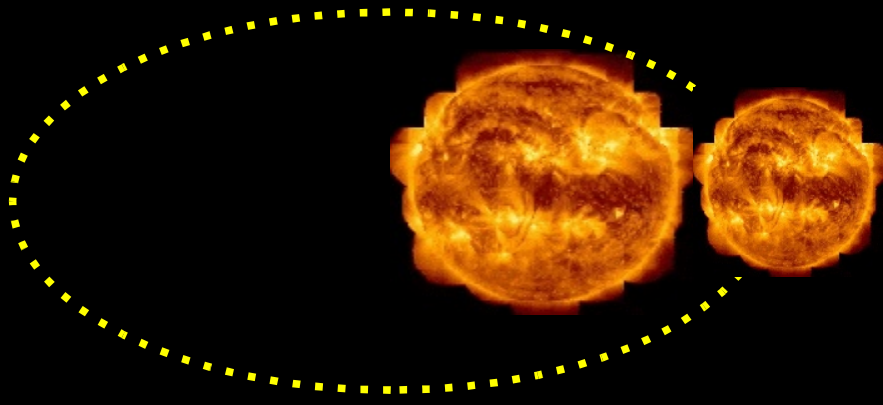
Rieger-type periodicities: not only a solar phenomenon

Overlap of consecutive periodically emerging magnetic flux tubes.



PART II:

Inter-binary collisions (binary systems)

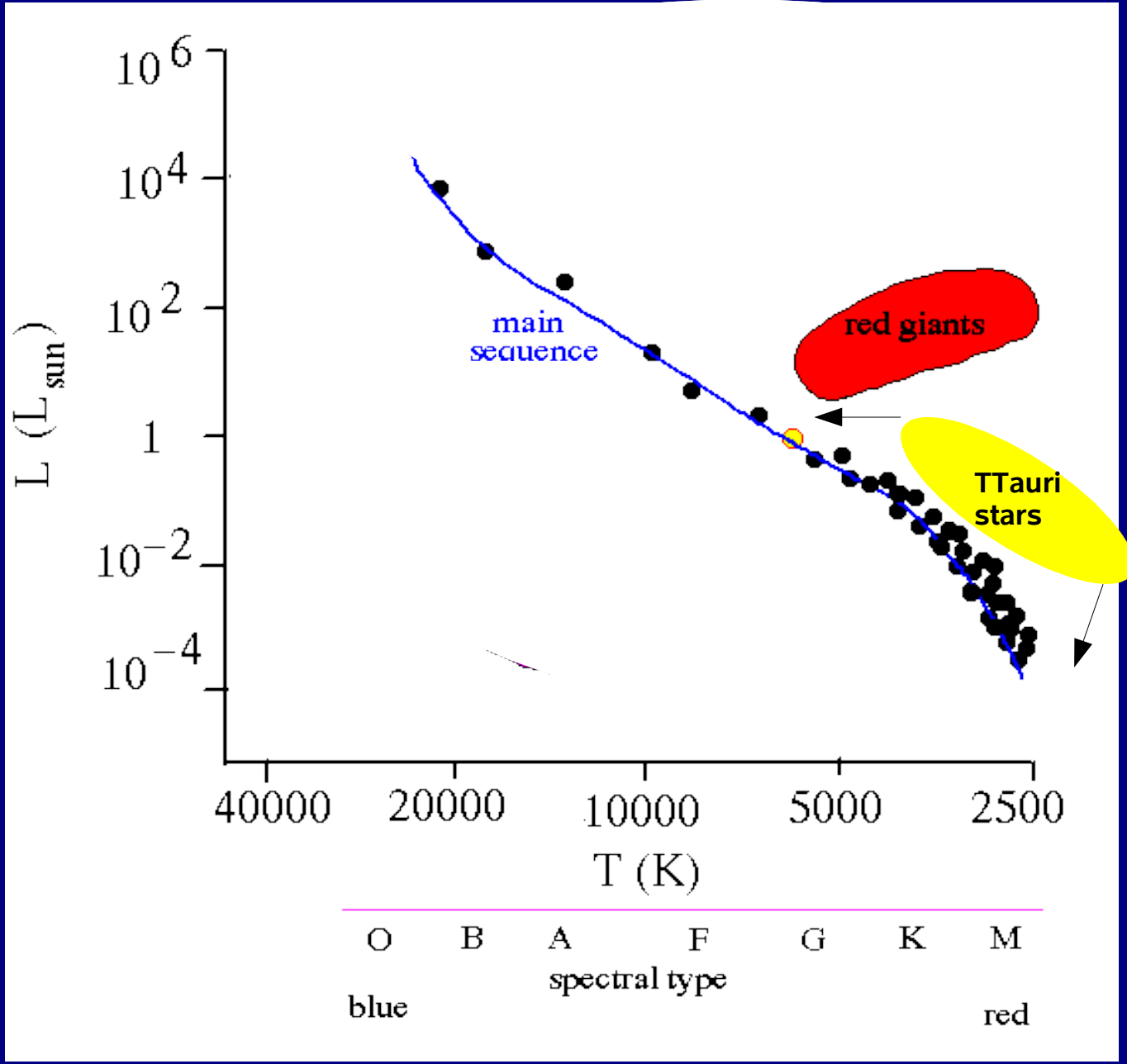


weak-line T Tauri Stars

Pre-main sequence star

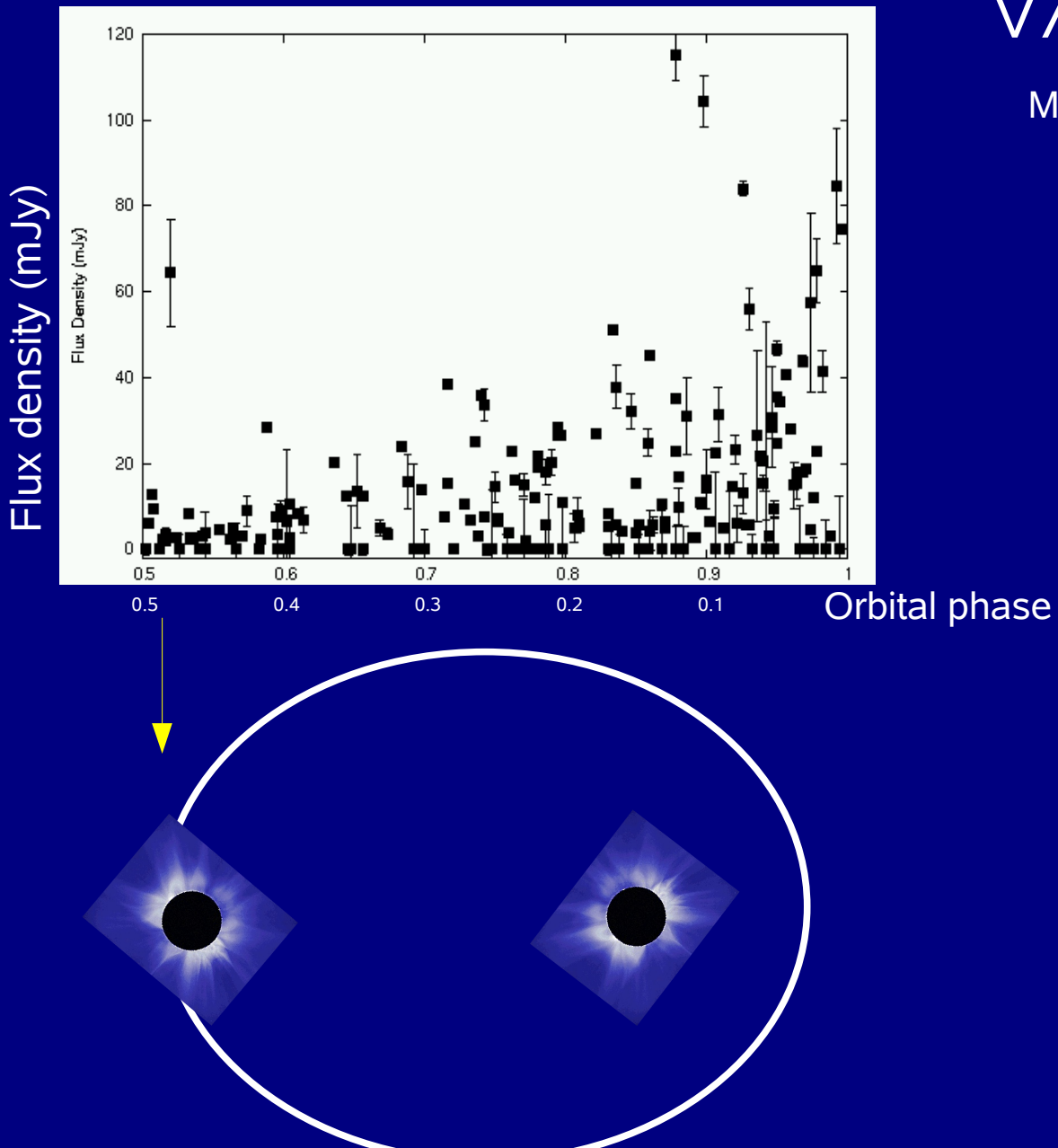
large dark spots similar to RS Cvn's

No-disk (weak-line TTauri)



V773Tau A

Massi, Menten,Neidhöfer 2002



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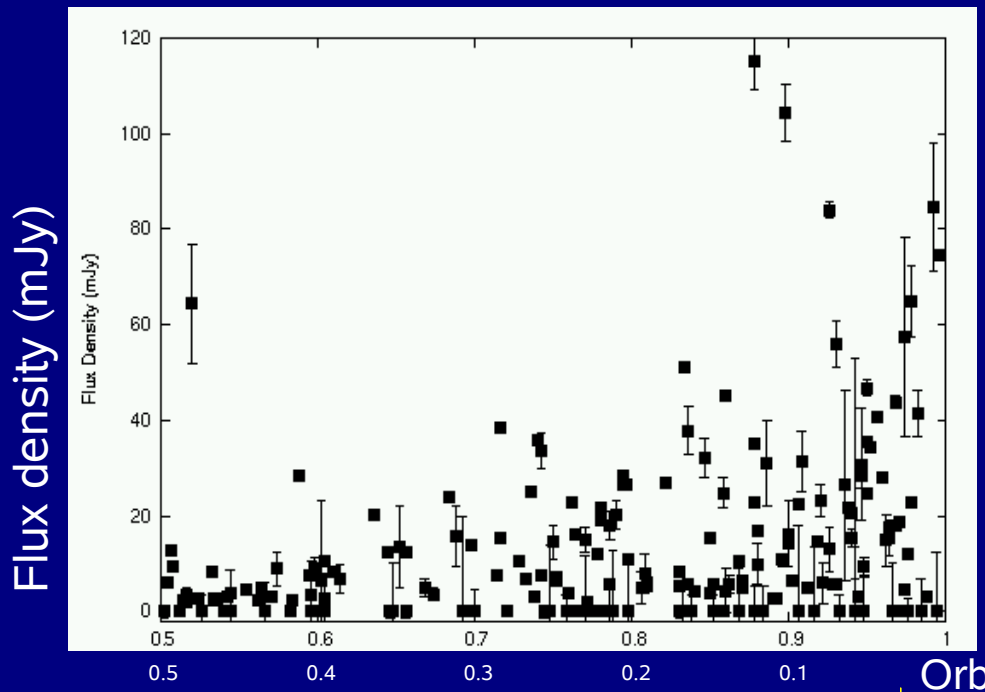
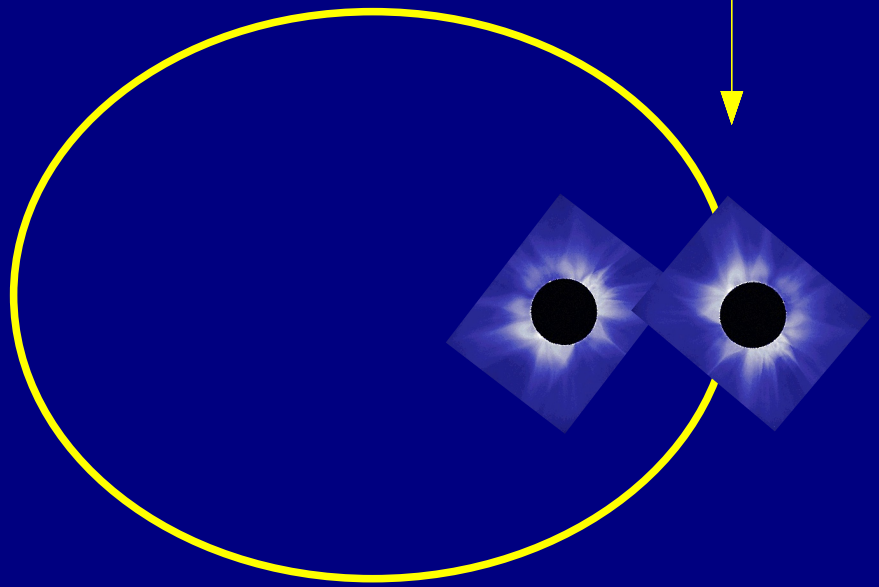
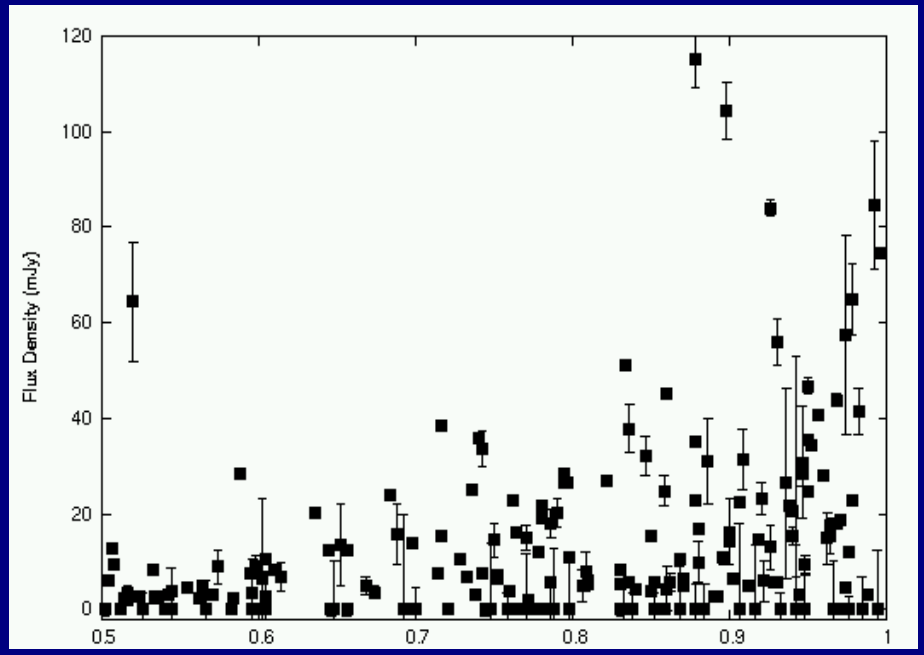
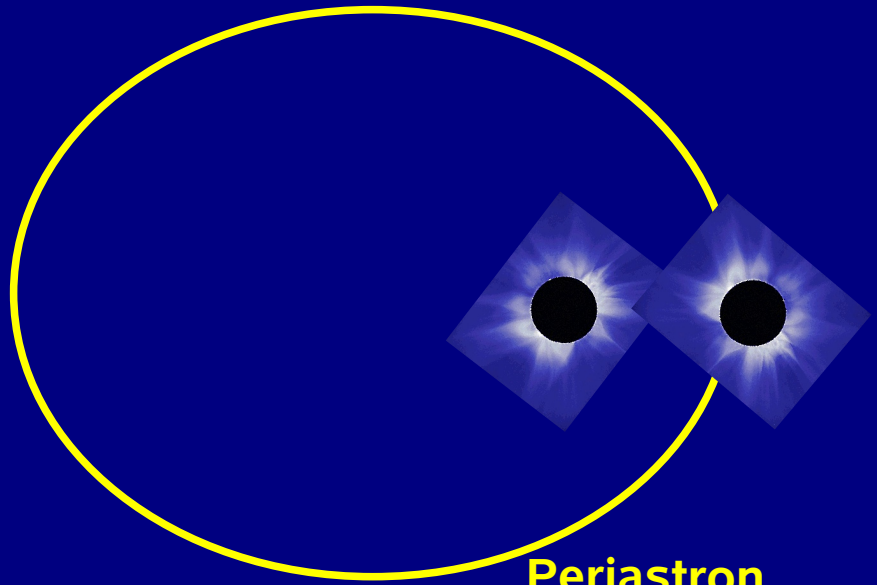
Massi, Menten, Neidhöfer 2002





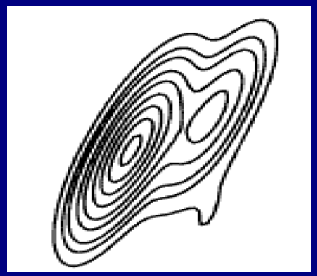


Inter-binary loop collisions around periastron passage.



Phillips et al 1996

size ~ stellar size

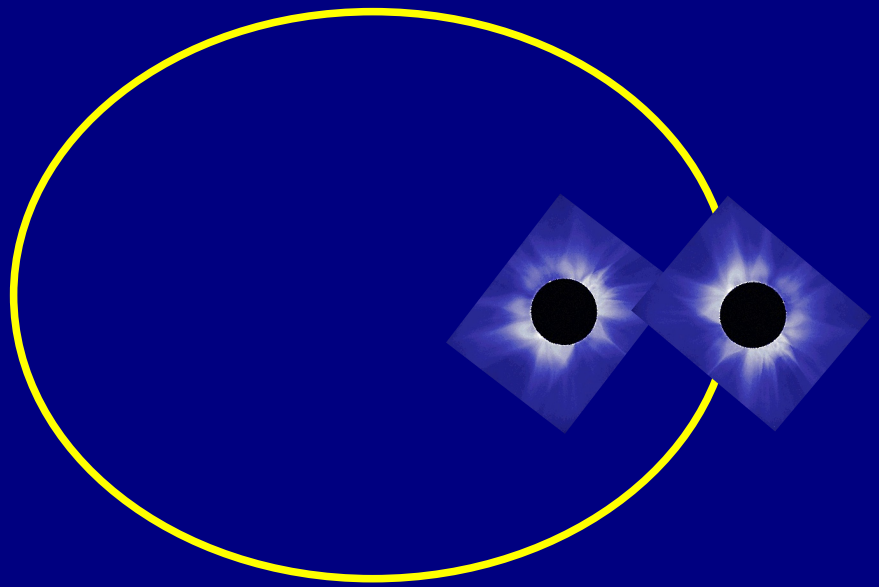


Phillips et al 1996

size ~ binary separation

Inter-binary loop collisions around periastron passage.

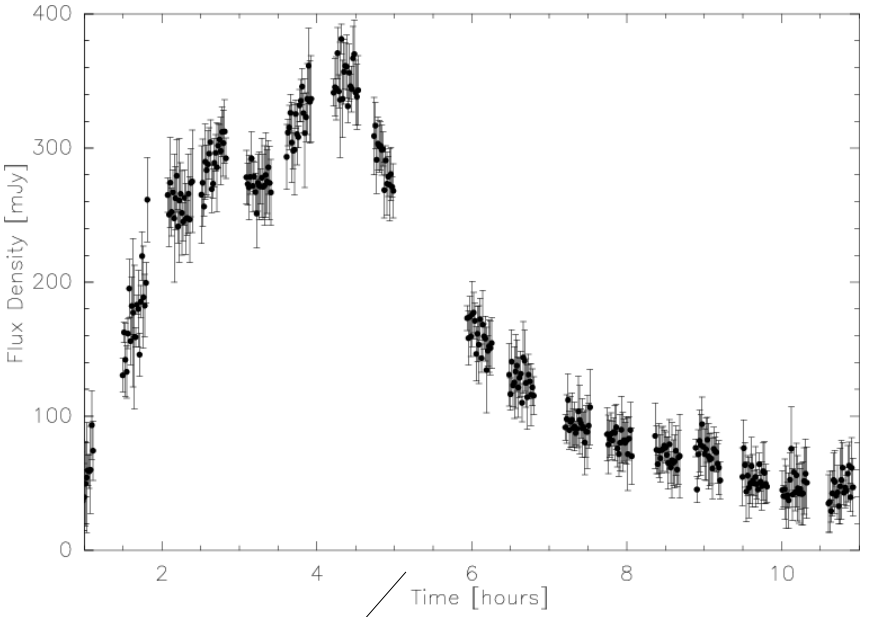
Skinner et al. (1997) determined a size of ~1 stellar radius
Tsuboi et al. (1998) a size of ~1 stellar radius



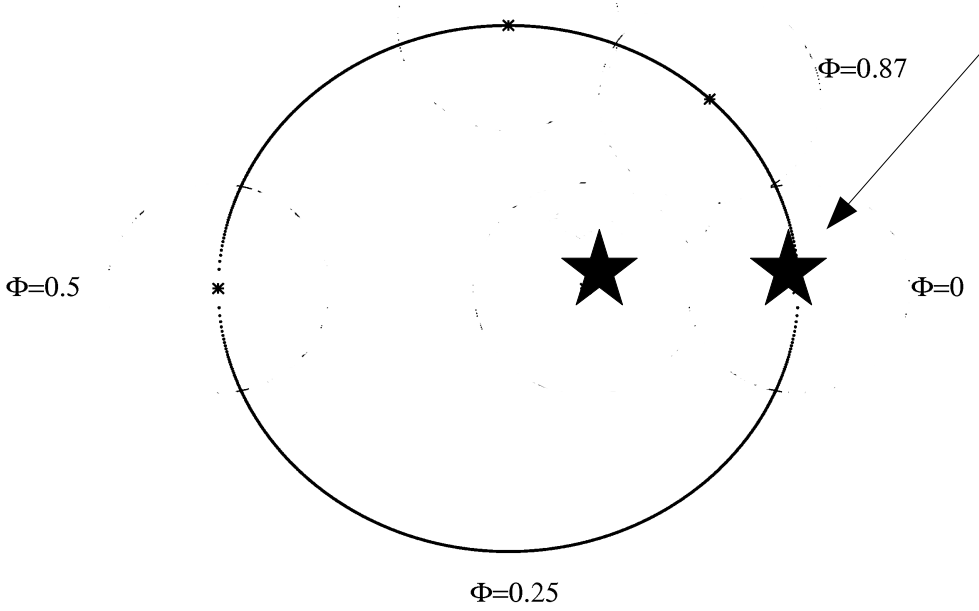
Periastron
23 R_*

3mm long-duration observation at periastron passage with the Plateau de Bure Interferometer

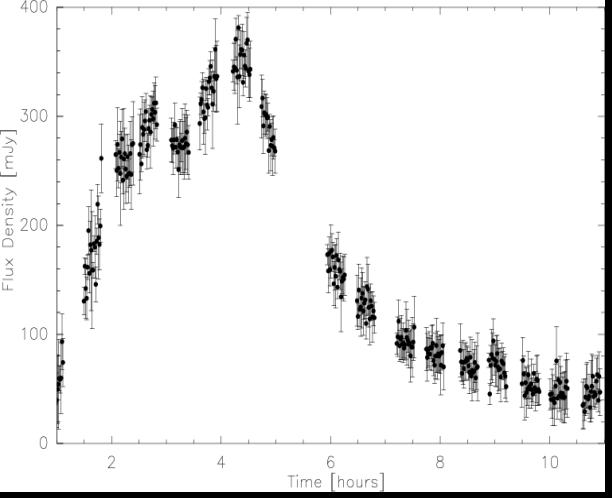
FLARE EVOLUTION



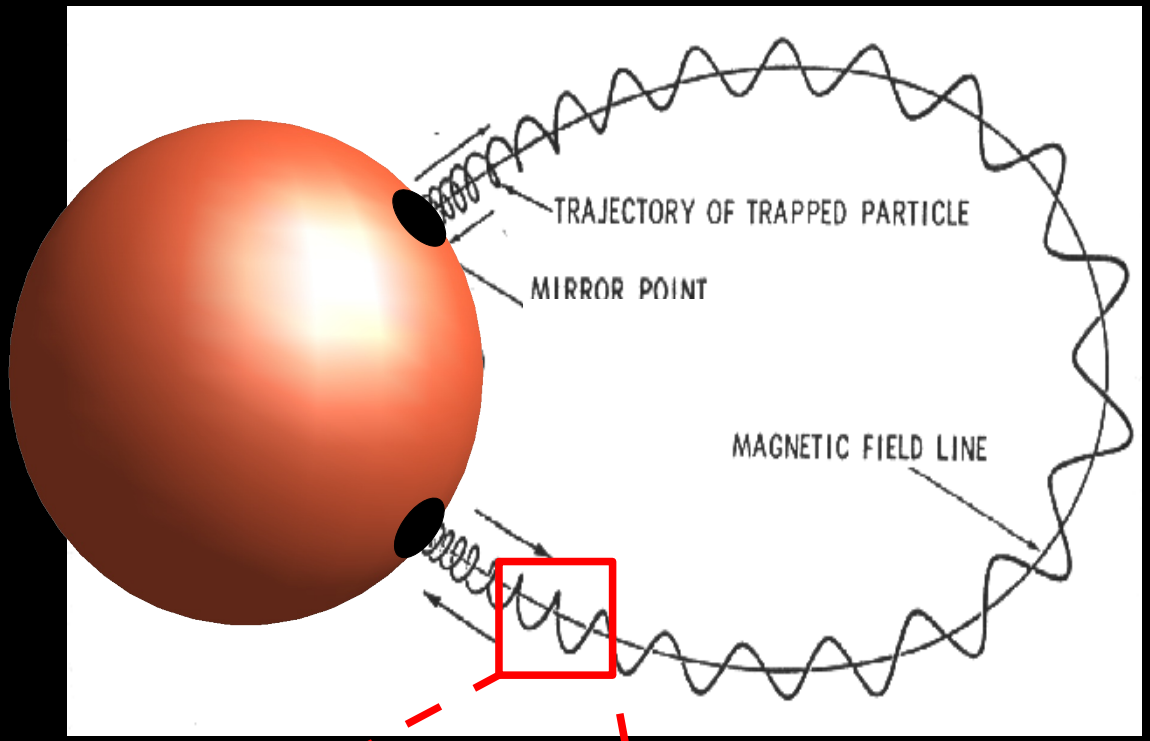
e-folding time: 2.3 h



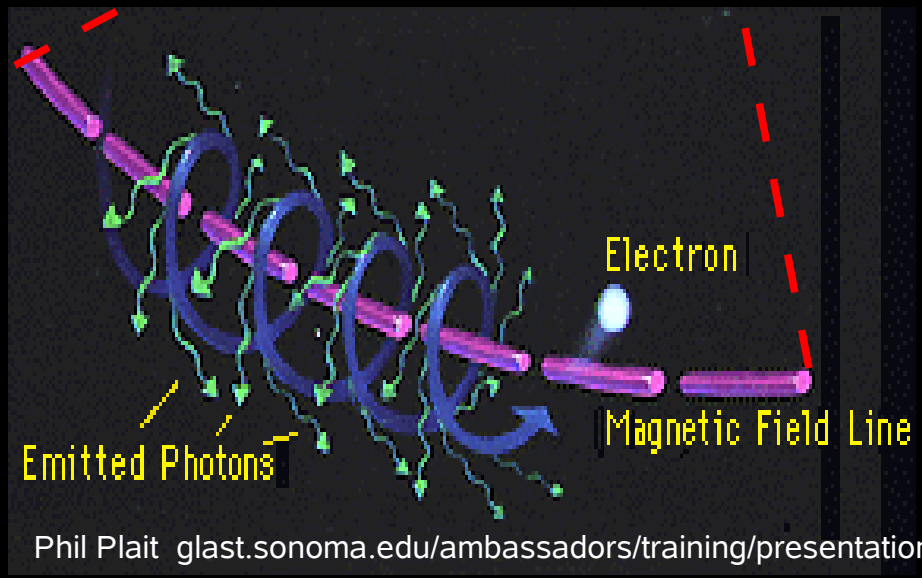
Massi, Forbrich, Torricelli, Menten, Neidhöfer, Misuri,Bertoldi 2006



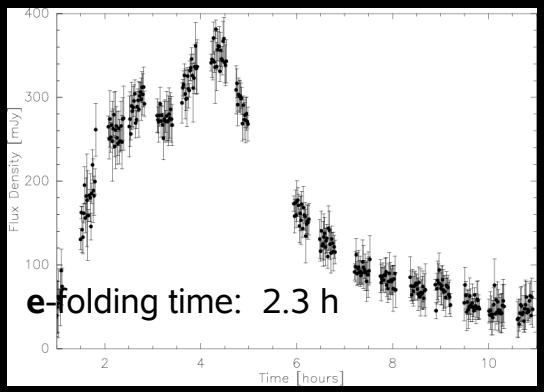
Sergio Bottai: hep.fi.infn.it/AIRWATCH/uhecr-4.ppt

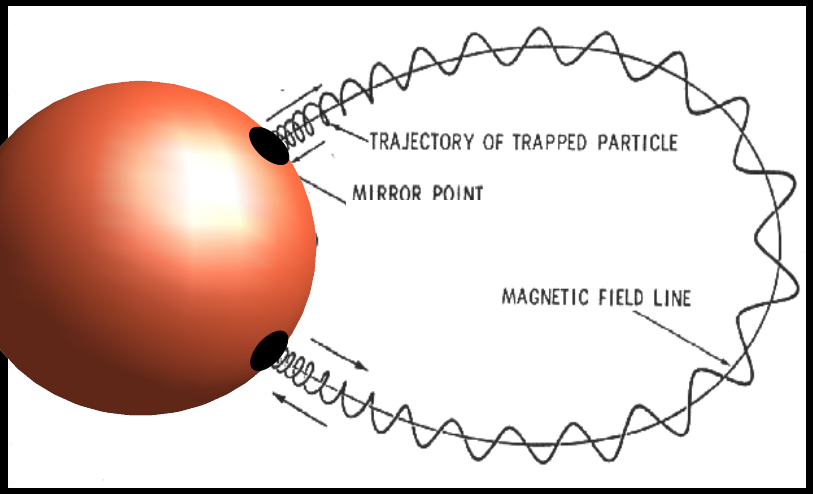


Synchrotron Radiation



Phil Plait glast.sonoma.edu/ambassadors/training/presentations/

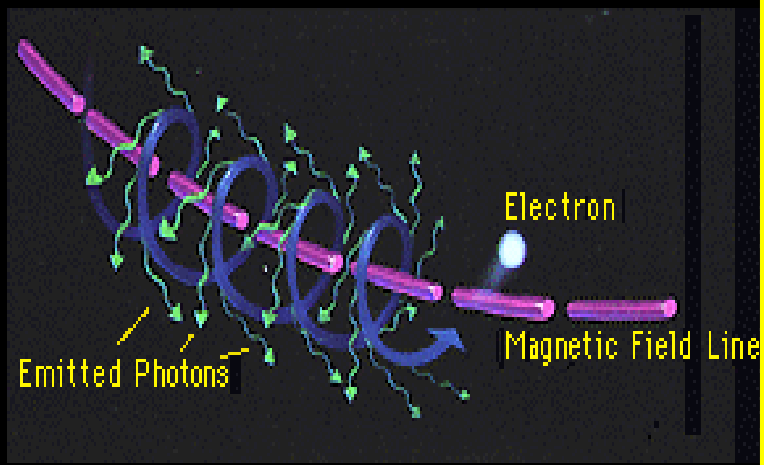




Energetic losses of the relativistic electrons ?

Magnetic field

by synchrotron radiation

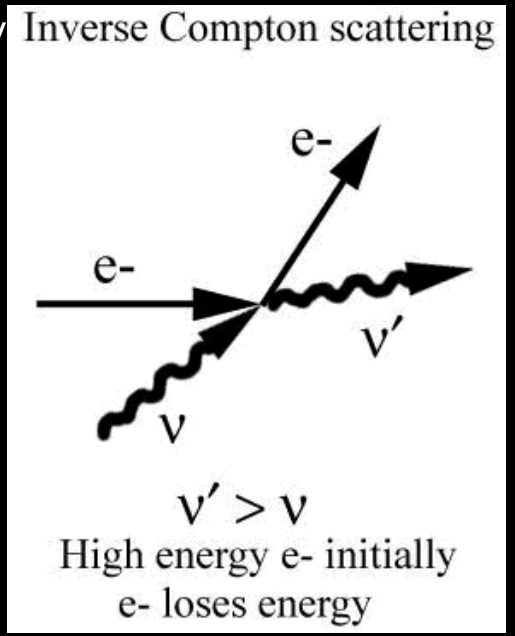


Matter

by collisions

Radiation field

(by Inverse Compton scattering)



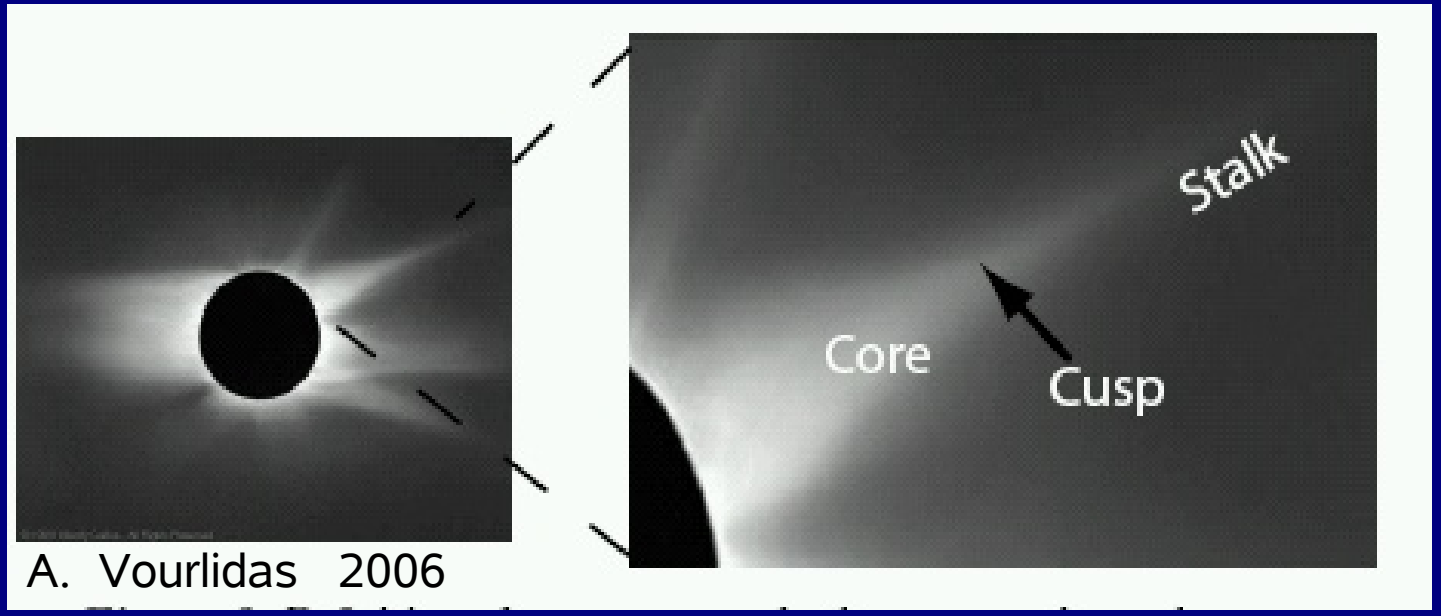
Since the fast decay of the emission cannot be attributed to energetic losses of the electrons,

Since the fast decay of the emission cannot be attributed to energetic losses of the electrons,

it may be caused by
leakage of the particles themselves

LEAKAGE

Helmet Streamers



A. Vourlidas 2006

.transition between closed and open structures

.extended several stellar radii (they naturally fulfill the requirement of large size)

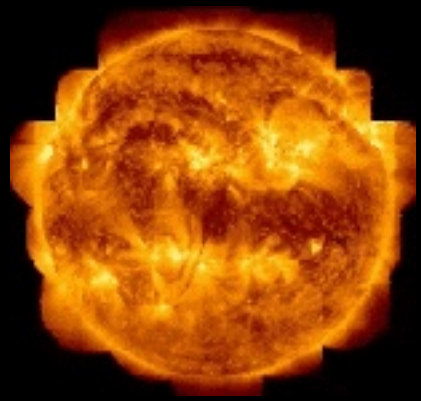
Skinner et al. (1997) determined a size of ~1 stellar radius
Tsuboi et al. (1998) a size of ~1 stellar radius

Feigelson et al. (1994) observed a steady X-ray flux combined with radio variability

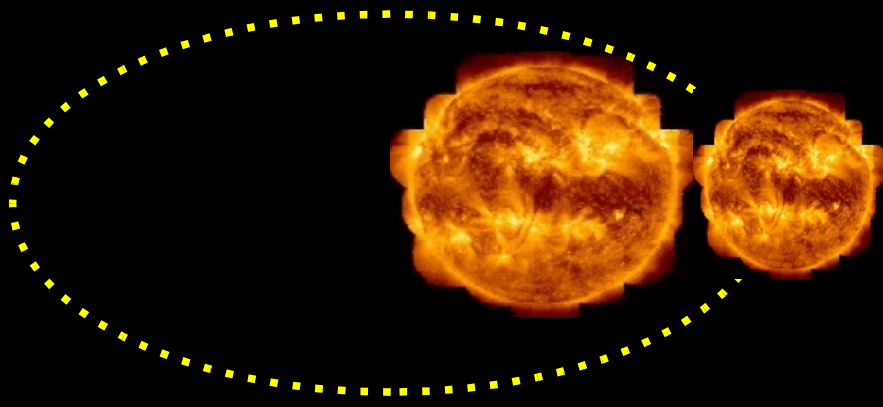
CONCLUSIONS: Flaring Periodicities

Intrinsic stellar flaring periodicities

Single star



Inter-binary collisions (binary systems)



Conclusions

I. Intrinsic stellar periodicities: Sun, UX Arietis

1. There exists a middle-term periodicity in flux emergence.

2. The emergence occurs in „preferred“ areas

→ the factor triggering periodic flares
is magnetic reconnection between old and new
periodically emerging magnetic flux
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Conclusions

I. Intrinsic stellar periodicities: Sun, UX Arietis

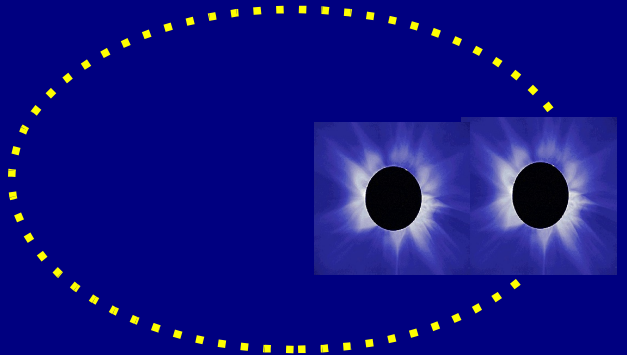
1. There exists a middle-term periodicity in flux emergence.
2. The emergence occurs in „preferred“ areas

→ the factor triggering periodic flares is magnetic reconnection between old and new periodically emerging magnetic flux in „preferred“ areas

II. Inter-Binary collisions

1. Helmet streamers, structures up to 30 stellar radii and only partially confining the plasma, are probably present also on other stars than the Sun.

→ the factor triggering periodic flares in V773Tau is magnetic reconnection between magnetic structures belonging to the two different stars



Thank you