# Stellar cycles and flip-flop phenomenon

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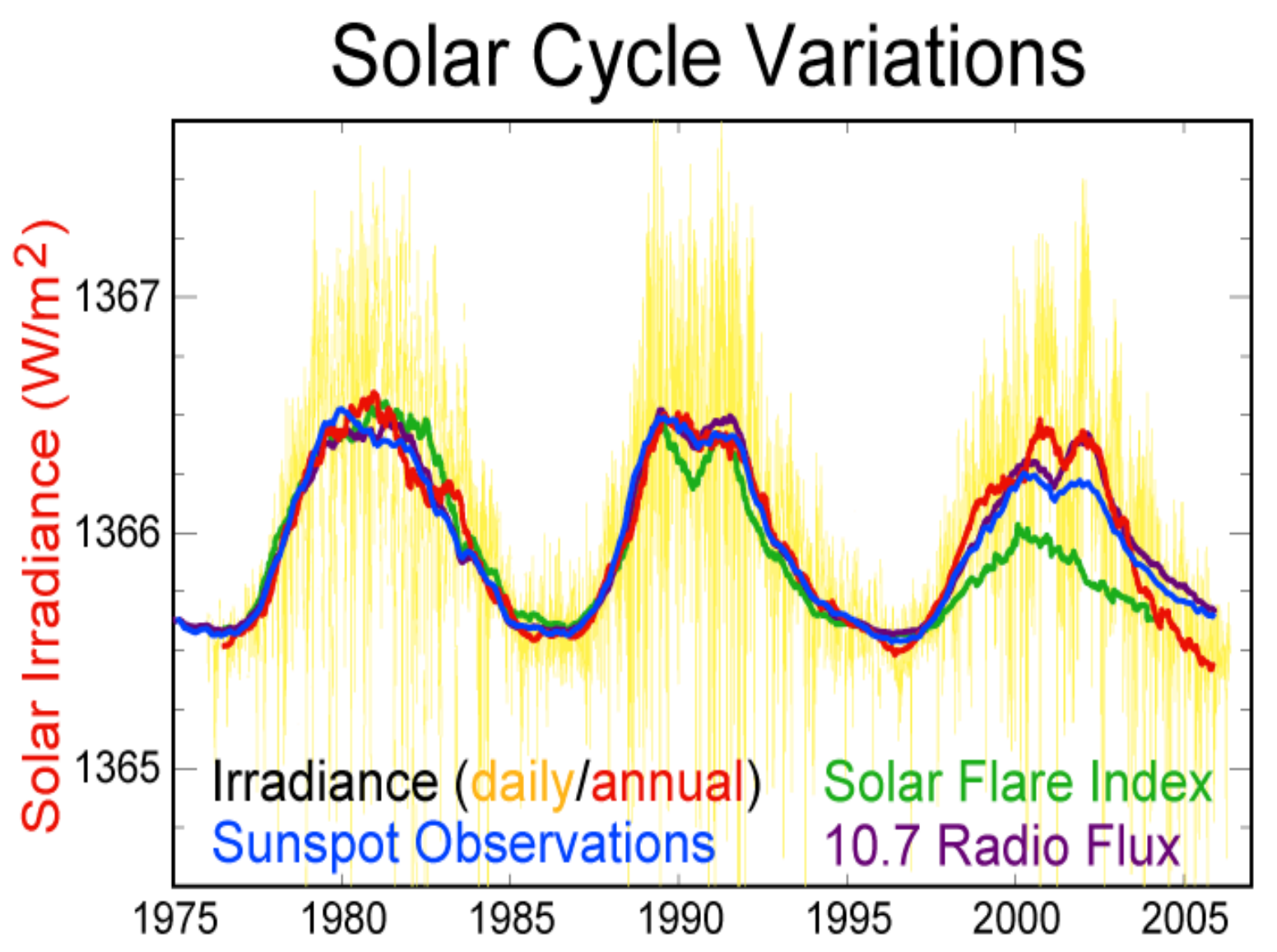
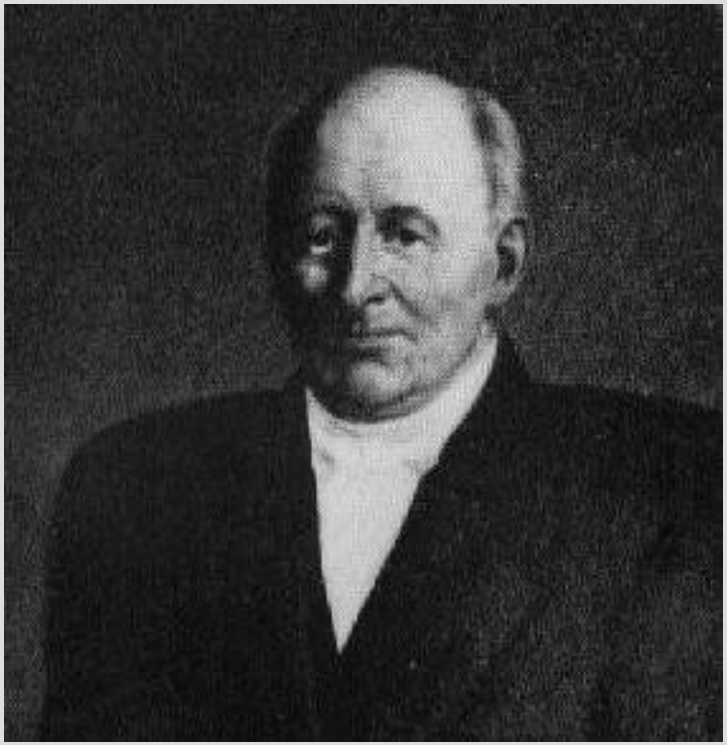
# Outline

- Solar cycle
- Stellar cycles  (Many thanks to Katalin Oláh!)
- Flip-flop phenomenon

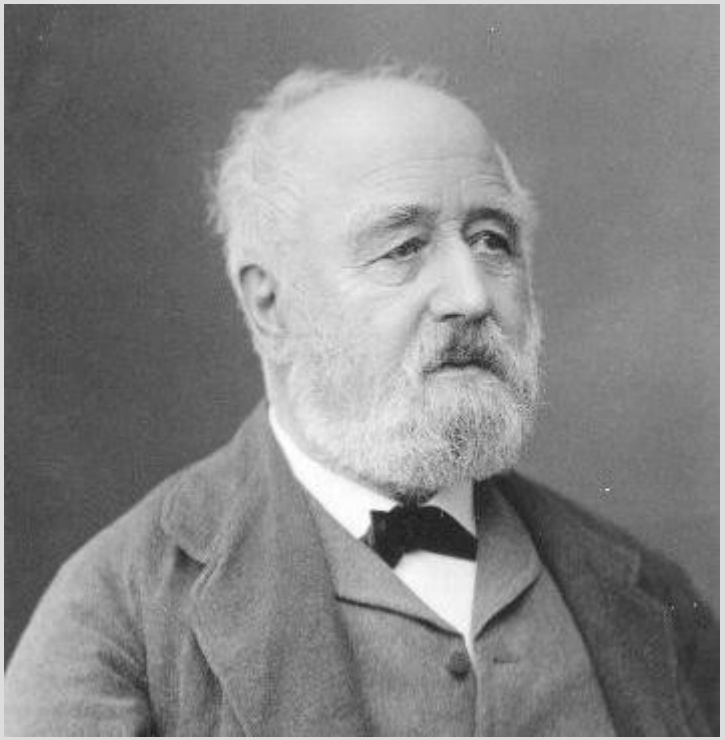
# Solar 11 year cycle II



# Two Gentlemen

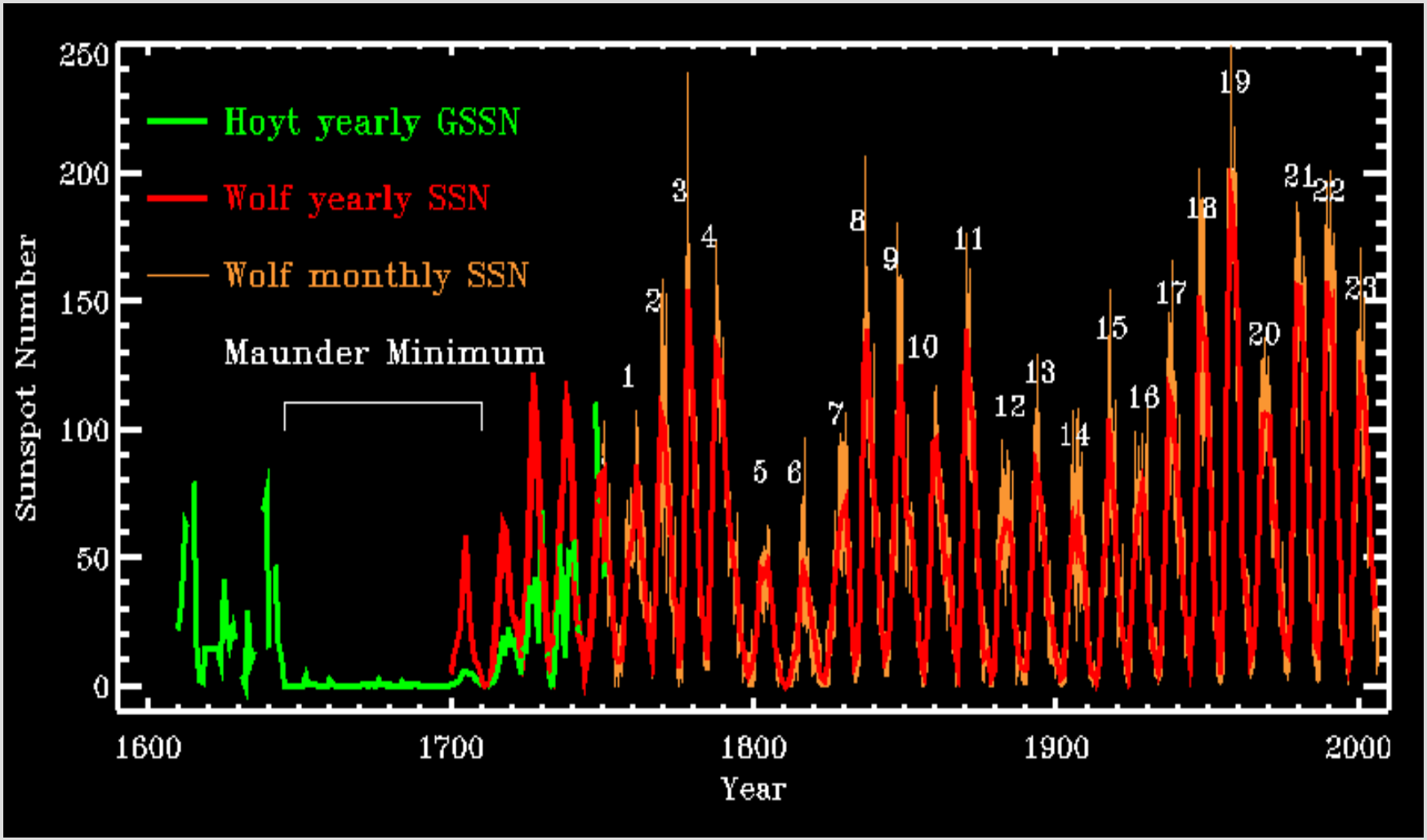


Schwabe

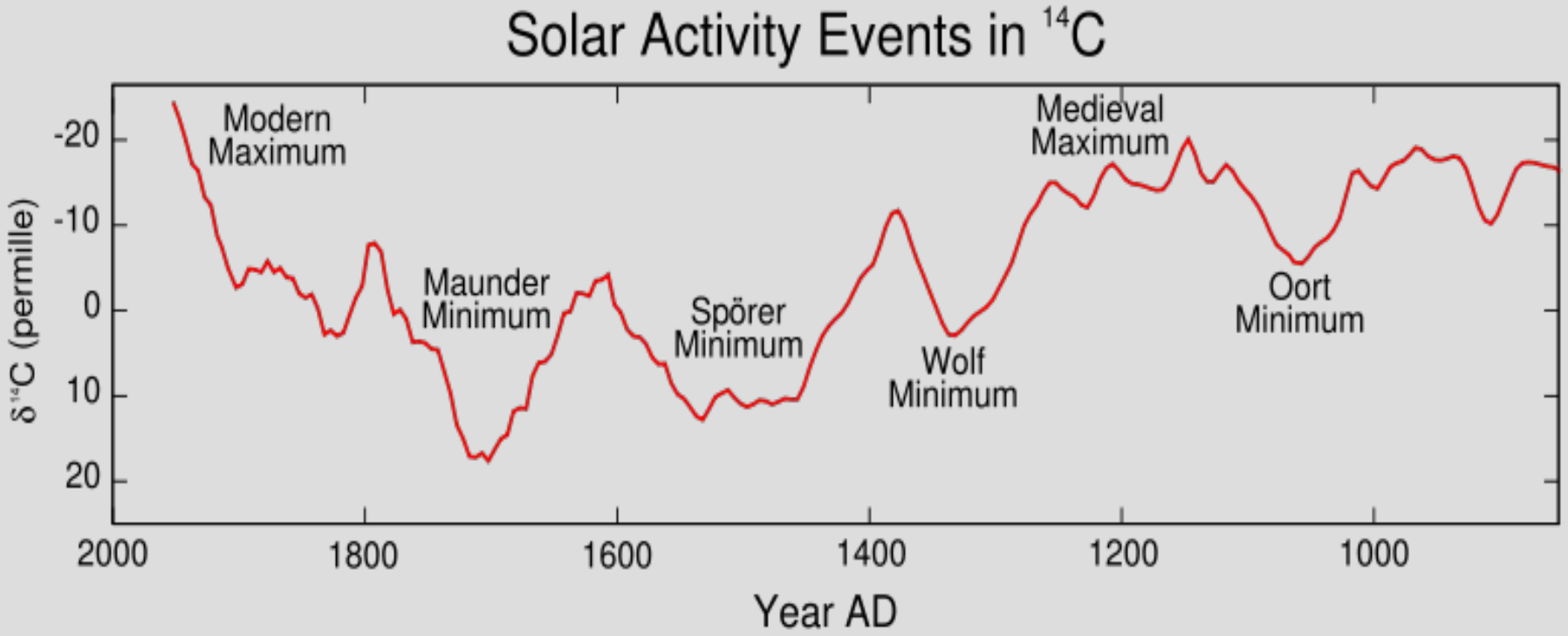


Wolf

# Long-term observations of the solar cycle



# Long-term observations of the solar cycle II

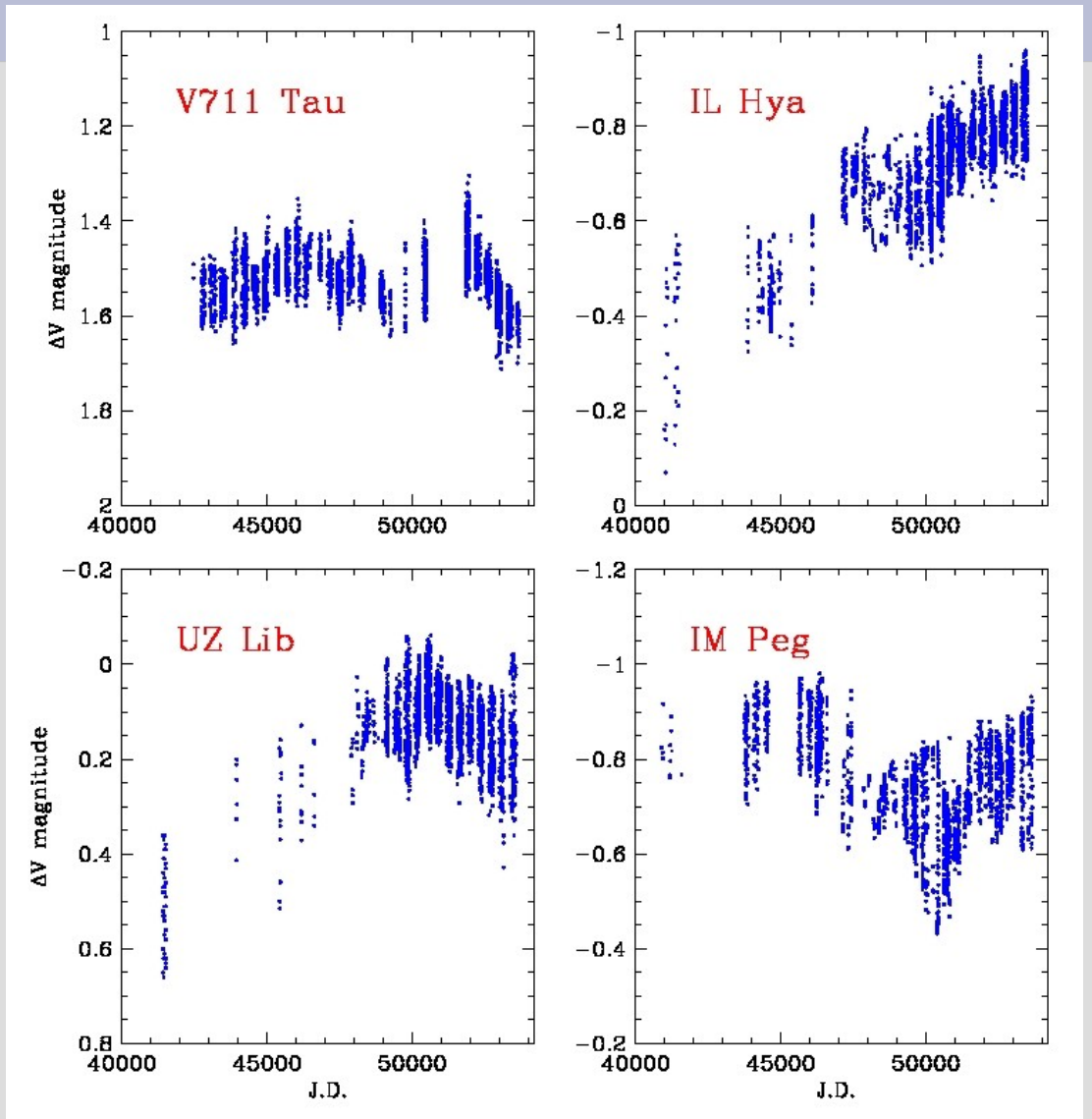


# Stellar cycles

$P_{rot}$ :

2.84 d

4.76 d




1 mag.

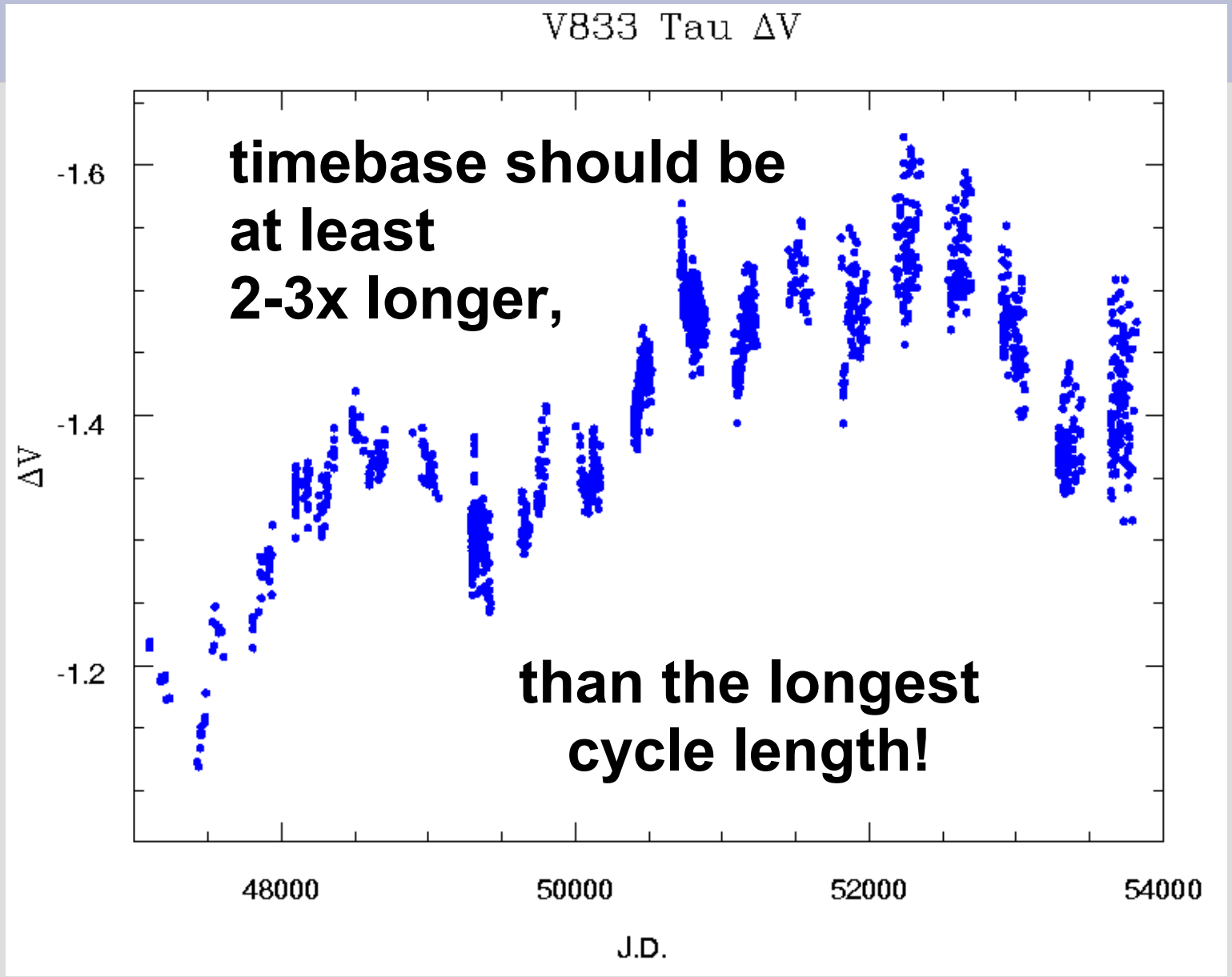
~1000 K!

12.7 d

24.5 d

~38 years

# Measuring the cycles for decades...

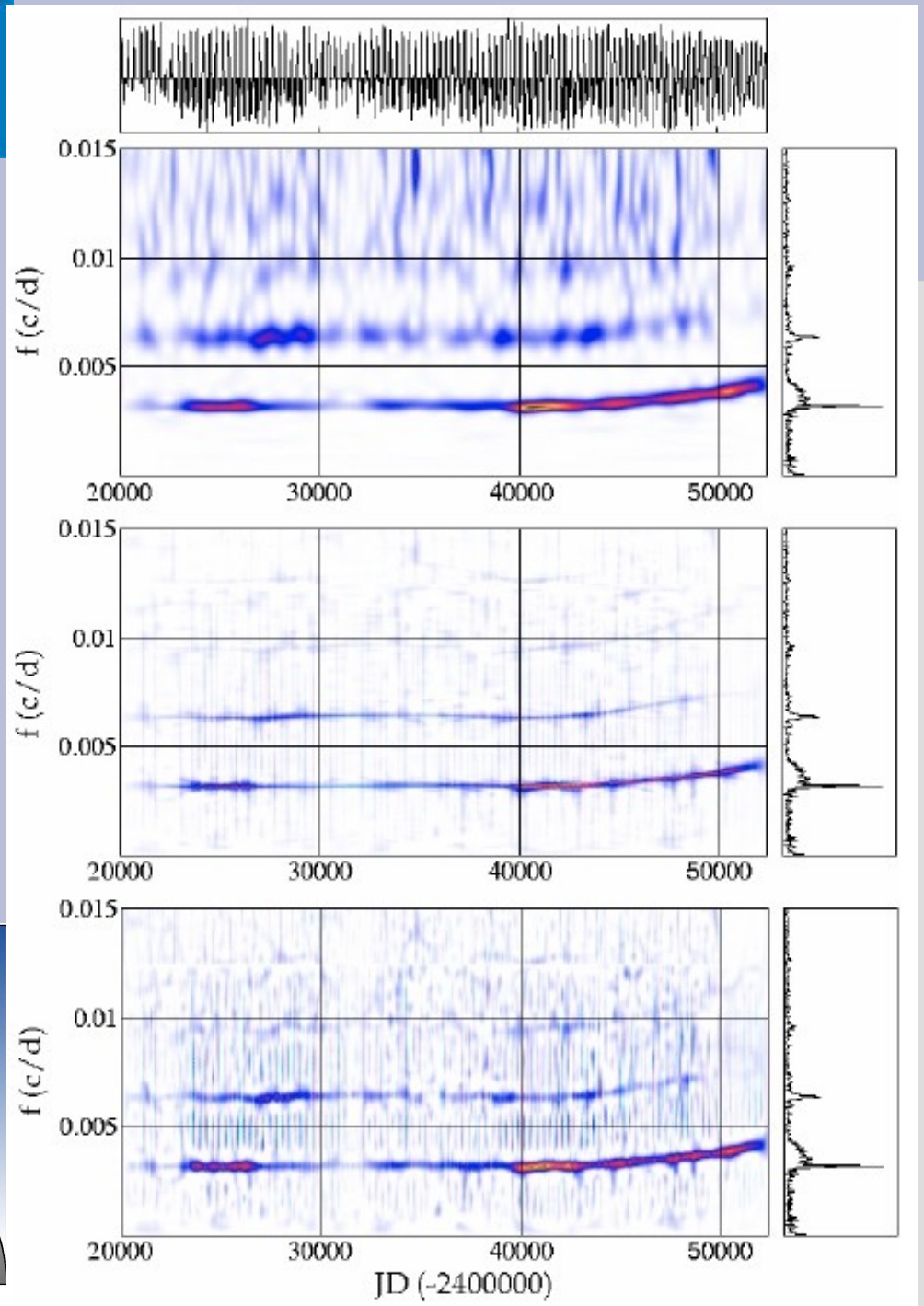


# Many periodic phenomena are not constant in time

- Frequencies appear and disappear
- The length of the periods change
  - Examples: binary orbits, pulsation periods
- Many active stars show multiple activity cycles
  - Parallel and/or alternating?
  - Constant and/or variable?

# Time-Frequency analysis

- Time-frequency analysis identifies the time at which various signal frequencies are present, usually by calculating a spectrum at regular intervals of time.
- Several different methods:
  - Short-term Fourier analysis
  - Wavelets
  - Choi-Williams distribution
  - Zhao-Atlas-Marks distribution
  - etc




# Example: T Umi

**Mira star with changing pulsational period**

*wavelet*

*Choi-Williams distribution*

*Zhao-Atlas-Marks distribution*

**Szathmáry et al. 2003**

AIP

# Test for activity cycles

**Periodic signal:**

$f(t)=A\ sin\ [2\pi(\omega t)]$ changing: $\omega = \omega_0 + \beta t$

$\beta$ = rate of change

**Suppose two cycles**

5.48 yrs (changing)

$A_1 = 0.2$

$\omega_{0,1} = 0.0005$

$\beta = 0.00000001$

2.47 yrs (constant)

$A_2 = 0.1$

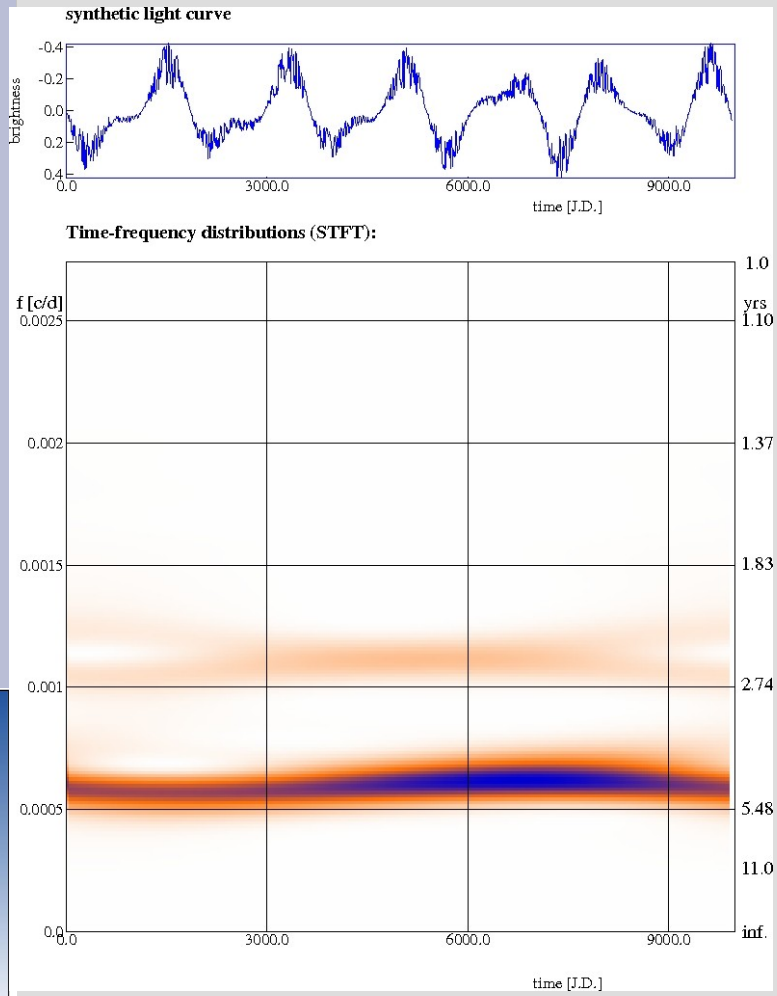
$\omega_{0,2} = 0.00111$

T = 10000 days (27.4 yrs, typical dataset)

AIP

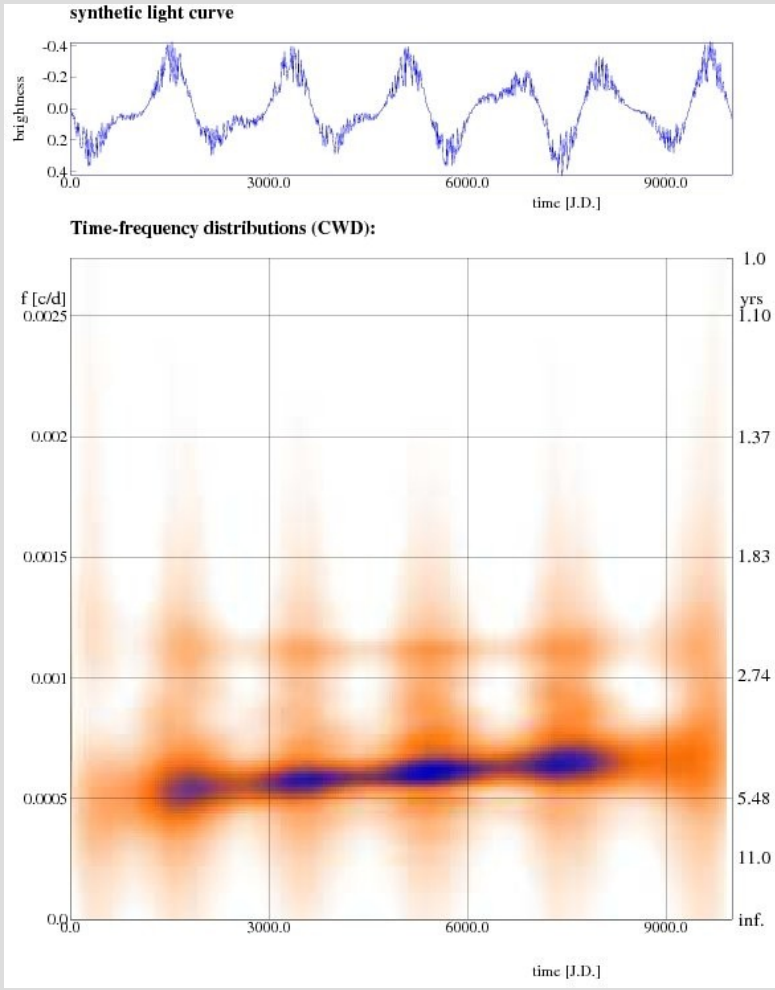
# Test cycle lengths: 5.48 yrs (changing)
# 2.47 yrs (constant)

## Short-term Fourier Transformation




lower resolution,
artificial bend

## Choi-Williams distribution

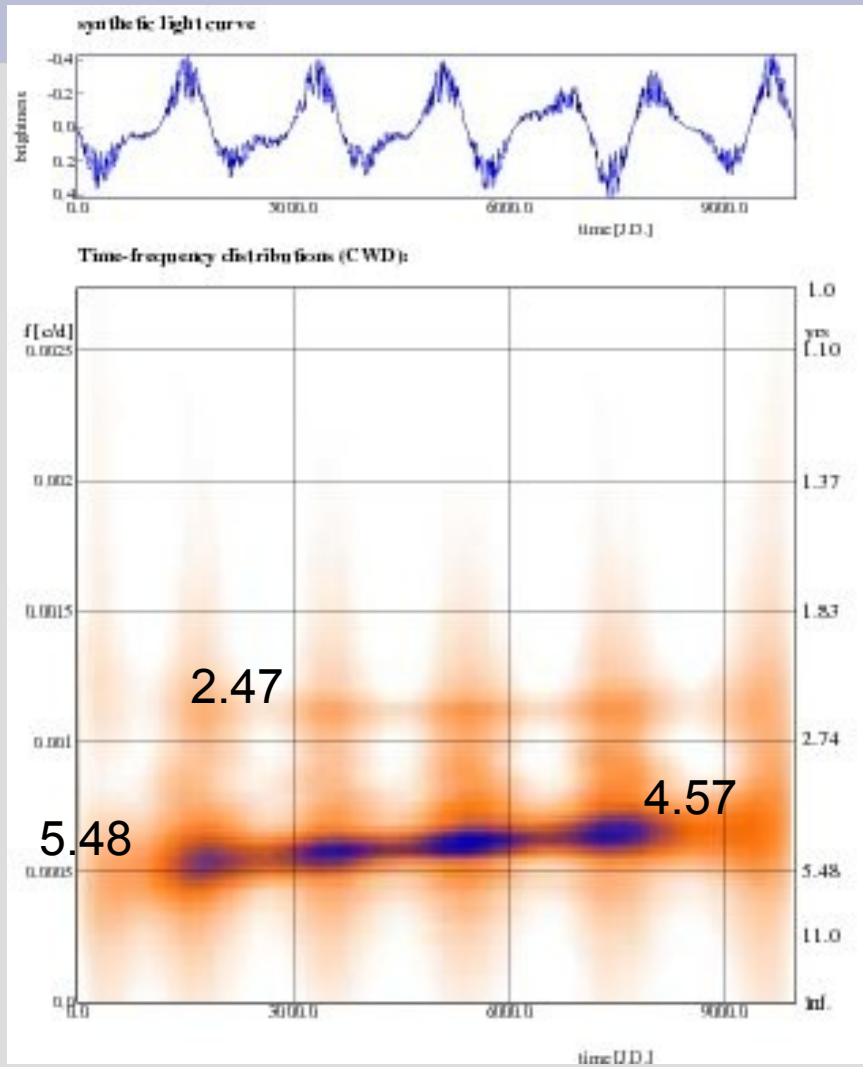


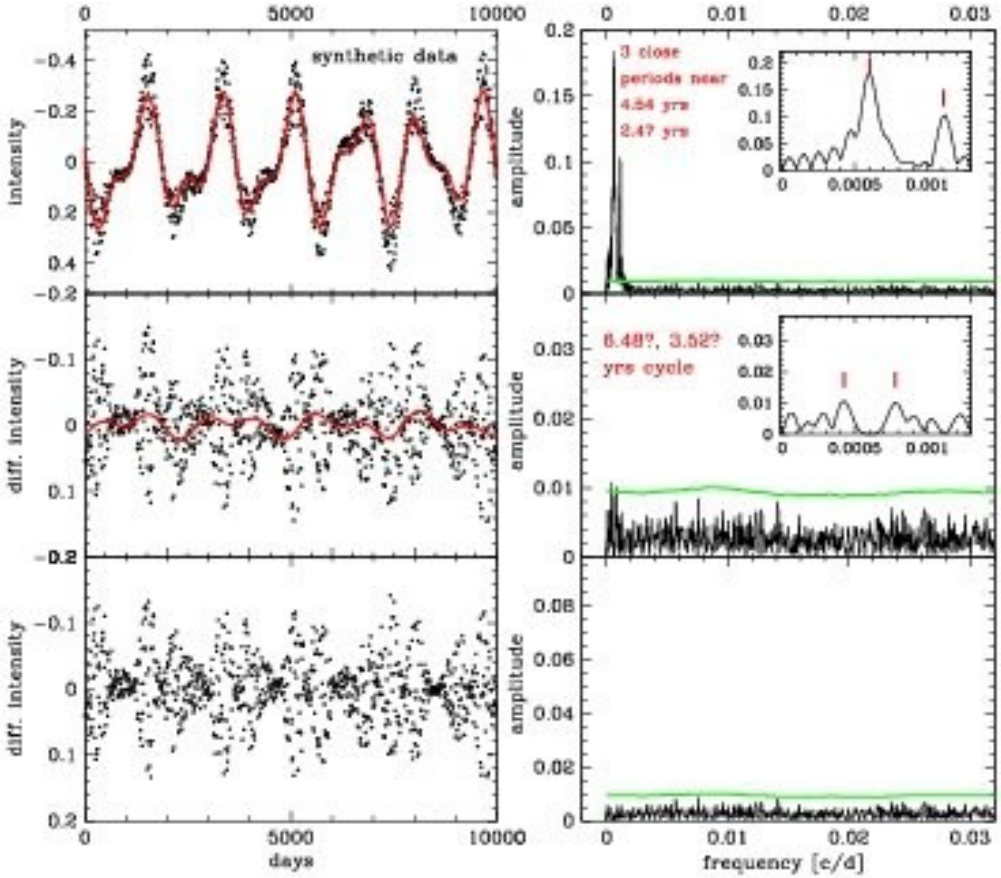

higher resolution

AIP

**5.48 yrs (changing) +**
**2.47 yrs (constant)**

**3 close periods near 4.54 yrs**
**+ 2.47 yrs**
**weak signal at 6.5 and 3.5 yrs**

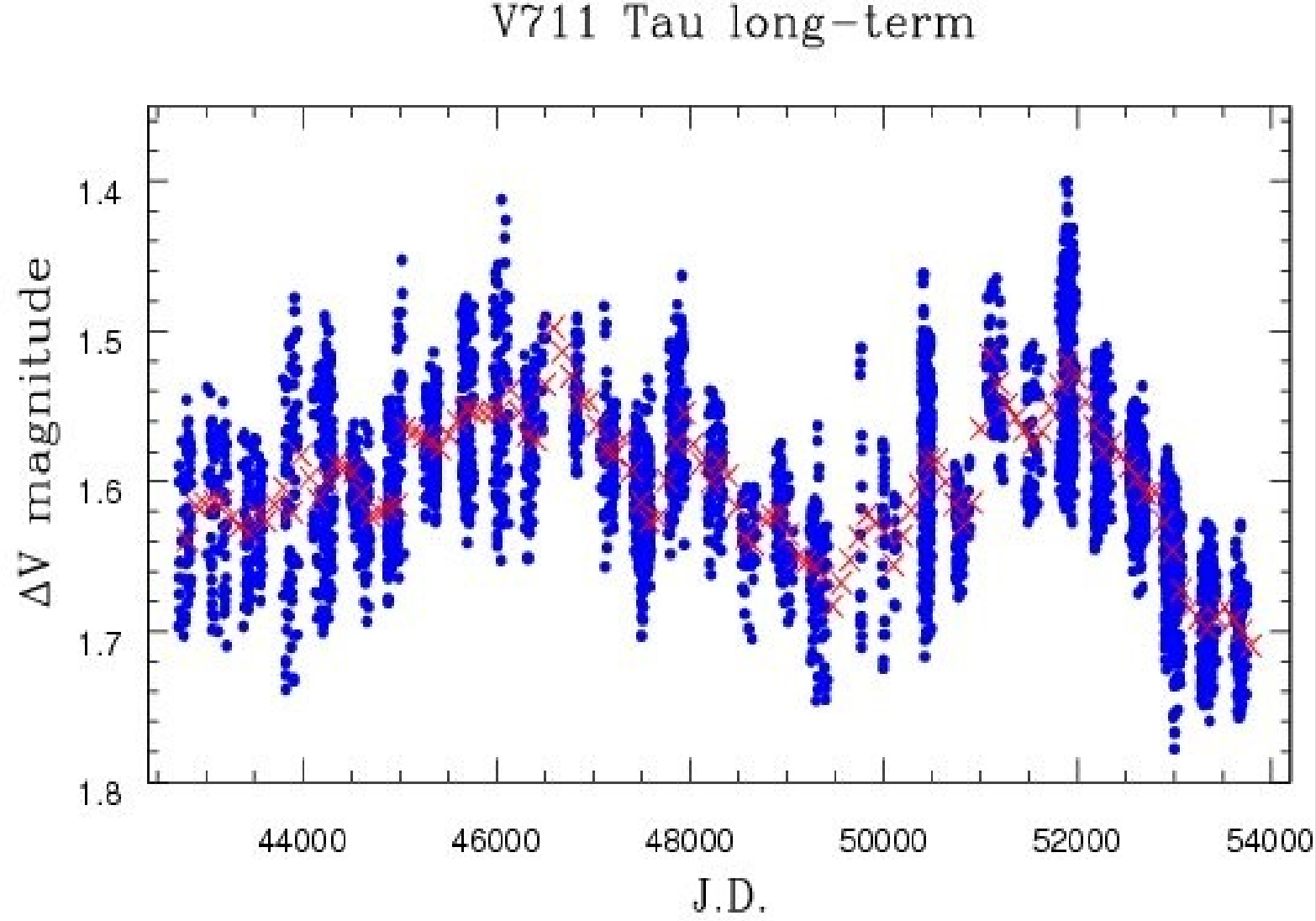



**Choi-Williams distribution**

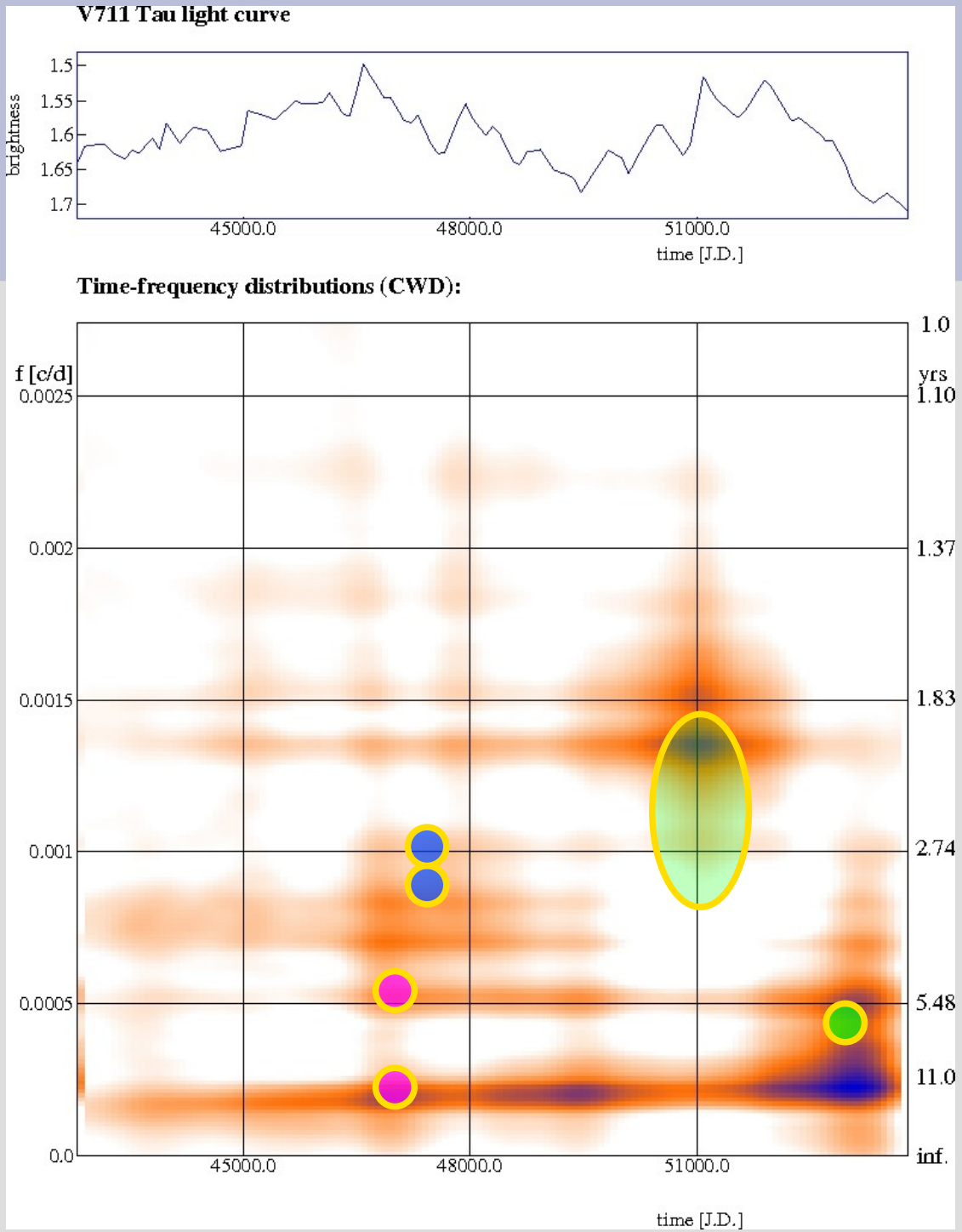
**Fourier analysis**

# One real example: V711 Tau




AIP

# V711 Tau




## Earlier cycle length determinations:

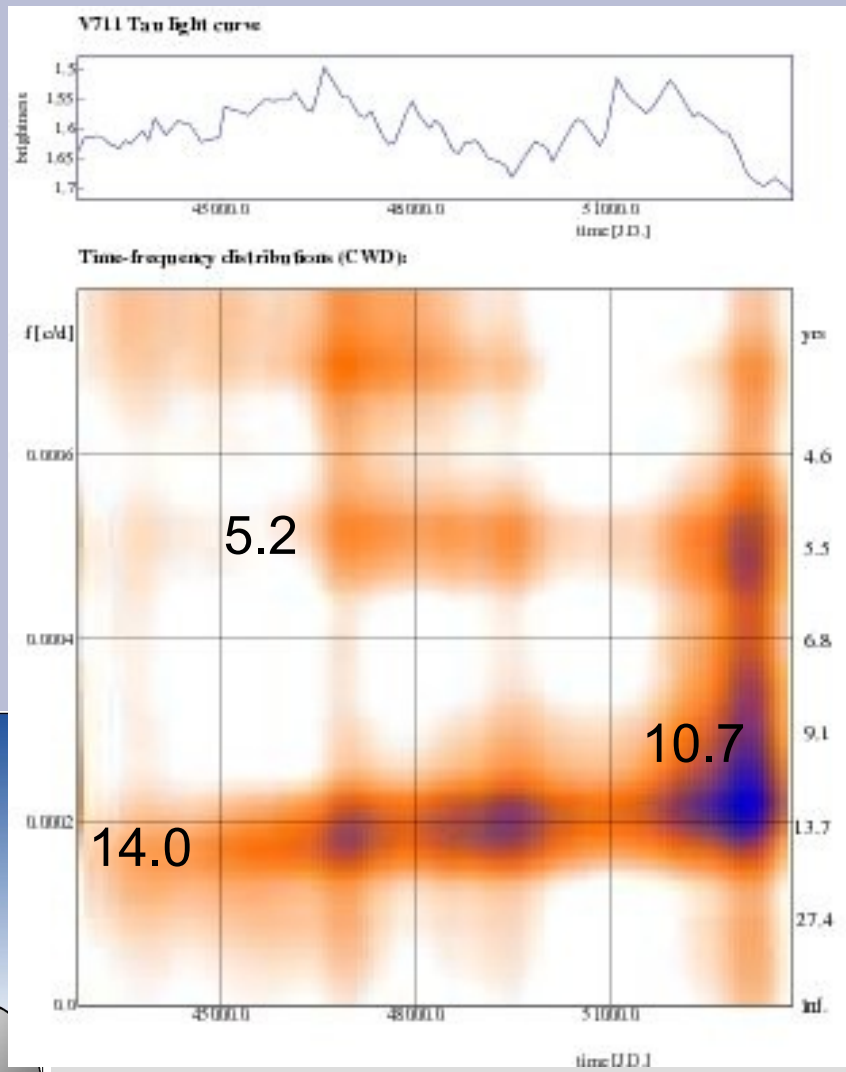
Lanza et al. 2006, A&A 455,595

Vogt et al. 1999 ApJS 121, 547

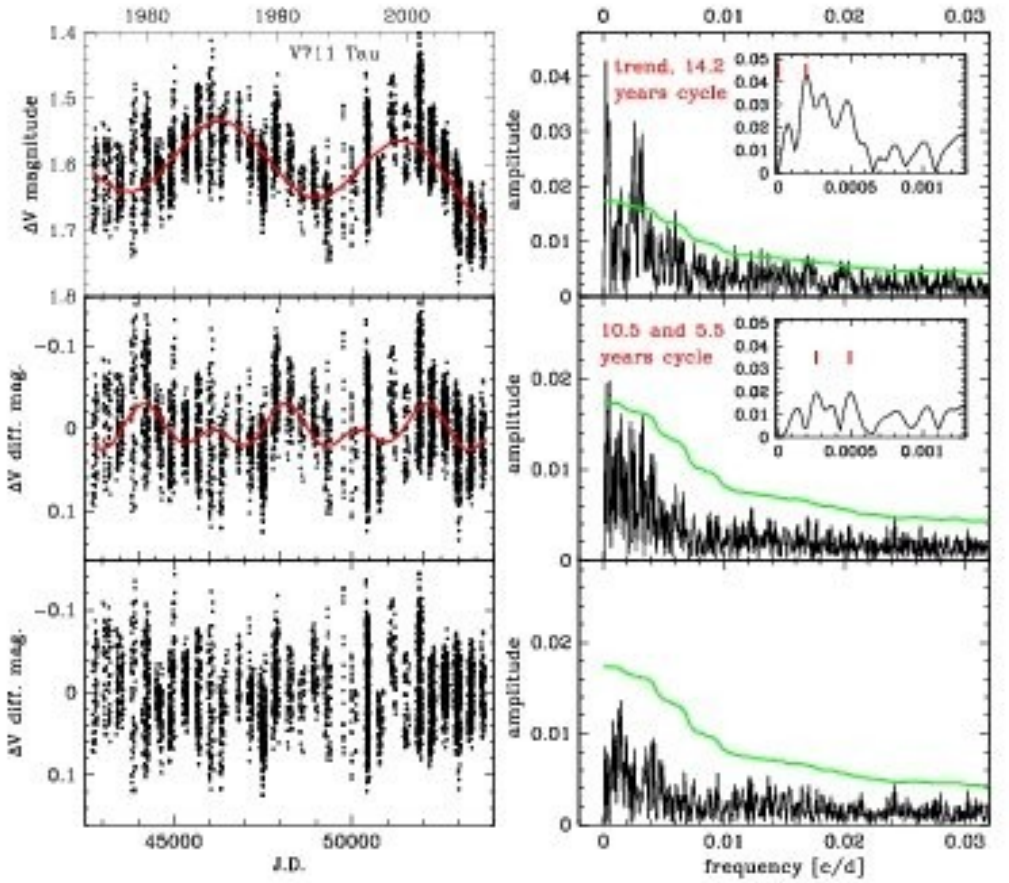
Henry et al. 1995 ApJ 97, 513

# V711 Tau time-frequency and Fourier results (detail)

## one changing cycle between 10.7 – 14 years with a rate of 0.11 year/year = 40 days/year



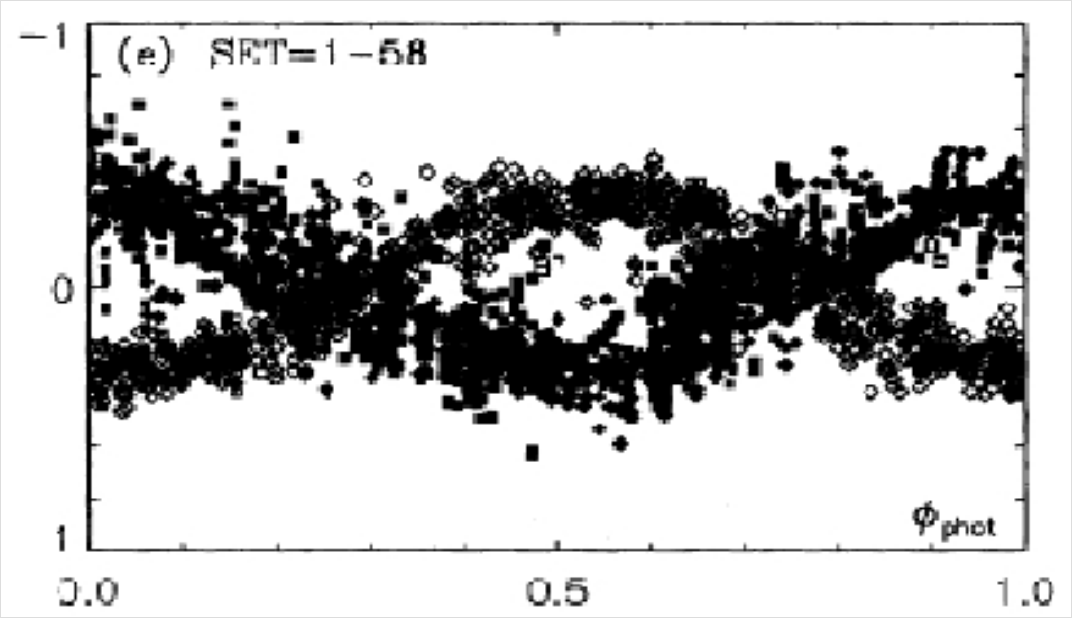

5.5, 10.5, 14.2 years' cycles



What else do we see when we look at the stellar photometry in more detail?

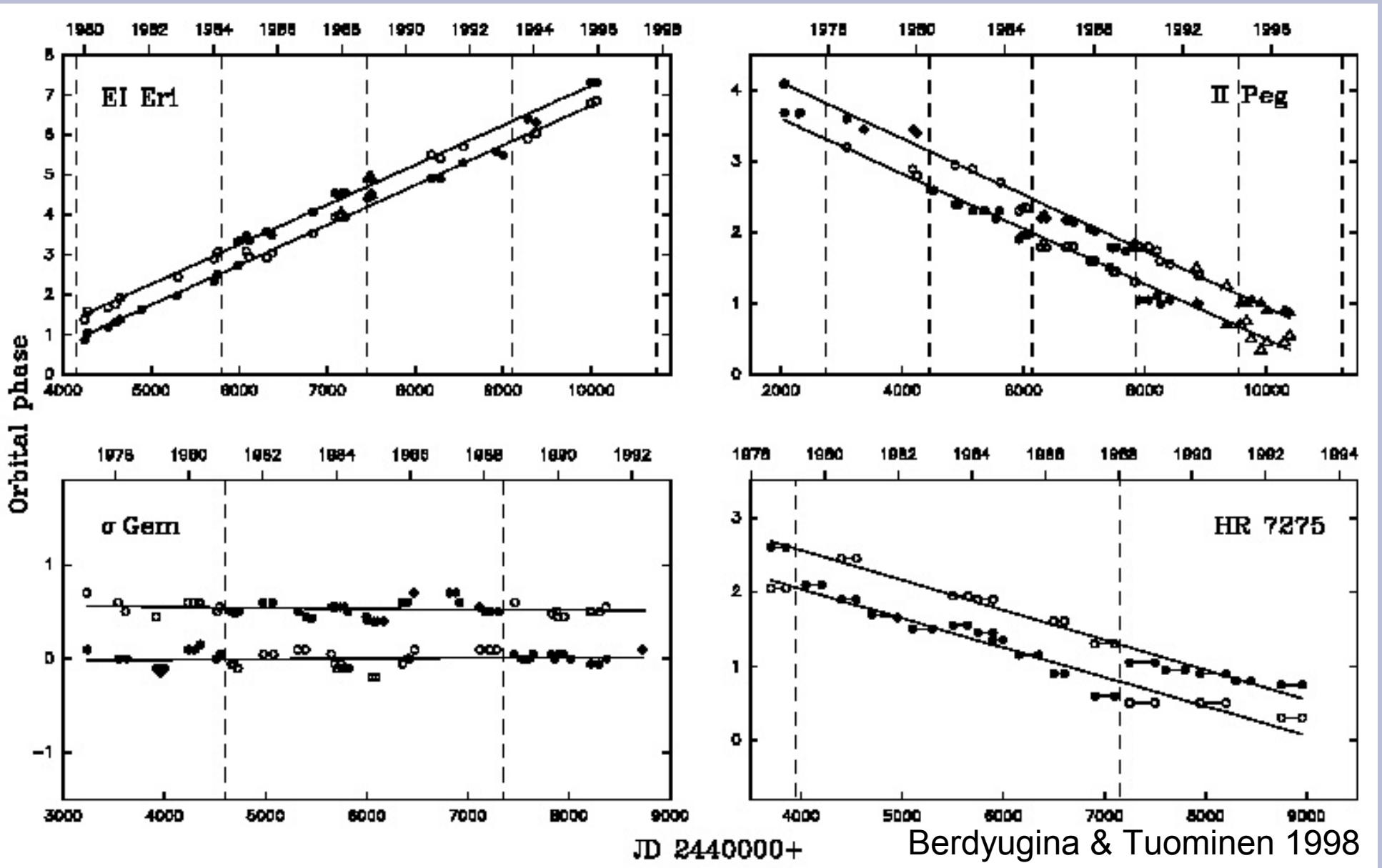
# Flip-flop phenomenon

- Discovered on the single giant FK Com in the early 1990's (Jetsu et al. 1993)
- Activity concentrates on two permanent active longitudes and flips between them every few years



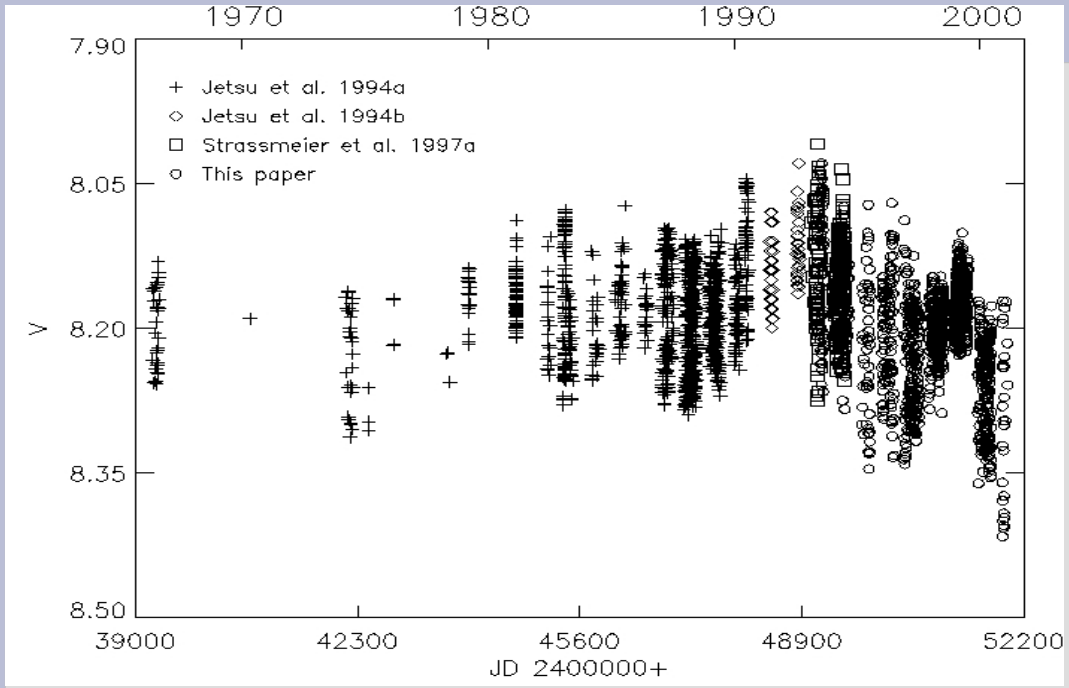

Jetsu et al. 1993

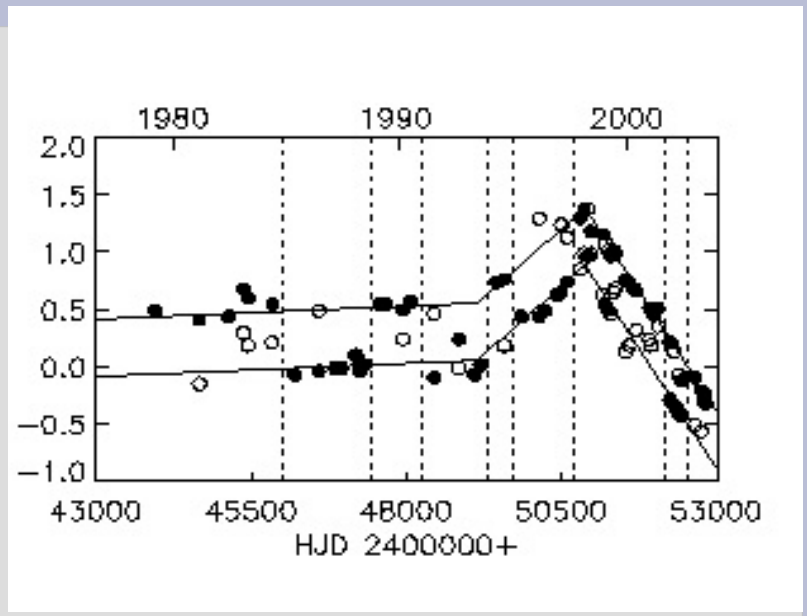
# Flip-flops in RS CVn binaries

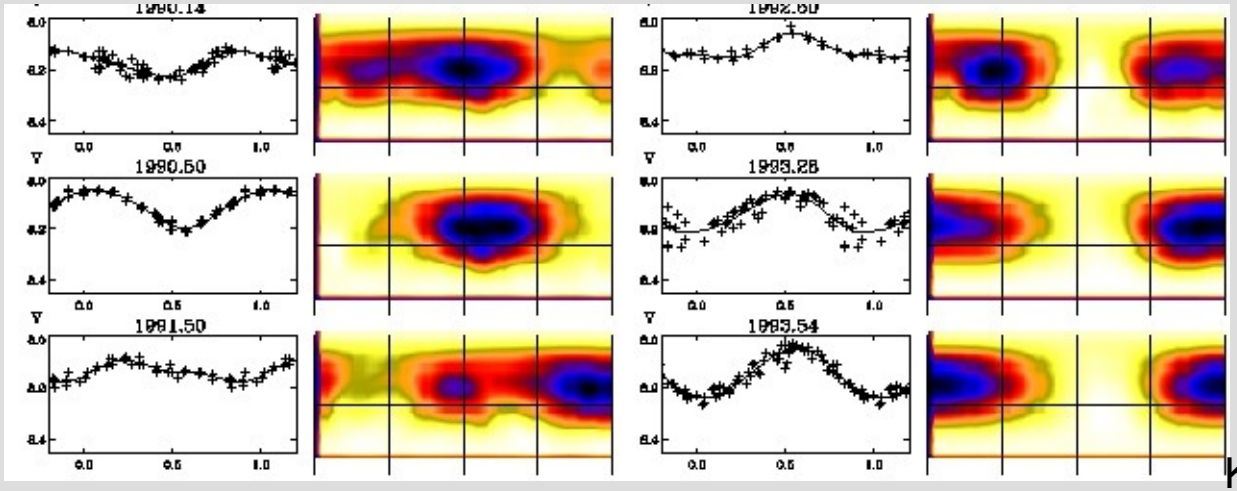



Berdyugina & Tuominen 1998

# How to study flip-flops?

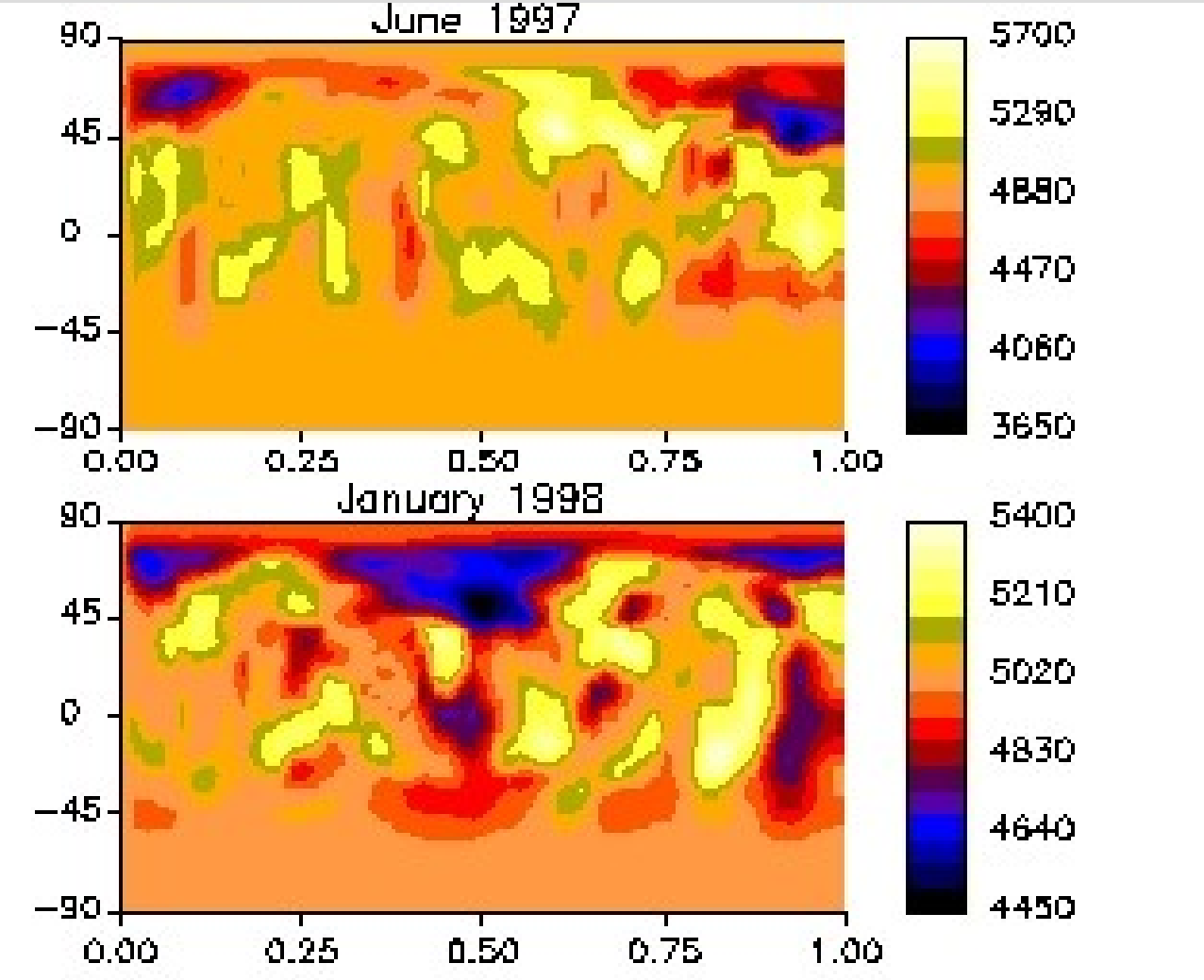



Korhonen et al. 2002

# Flip-flops in detail




Korhonen et al. 2001

# Stars with flip-flops

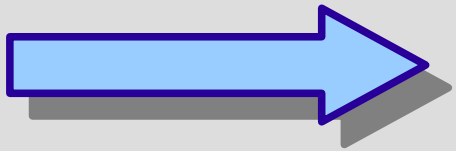
- Since then flip-flops have been discovered in several stars:

| | |
|---|---|
| 3 young solar analogues | 4.0-5.5 years |
| 2 FK Com type single giants | 4.0-6.4 years |
| 7 RS CVn binaries | 4.0-17.5 years |

Flip-flop cycle length of 3.7 years has been suggested for the Sun, but this results is debated

# Modelling flip-flops I

- Non-axisymmetric dynamos show active longitude structure, but no oscillations
- Axisymmetric dyamos do not show active longitudes, but oscillate

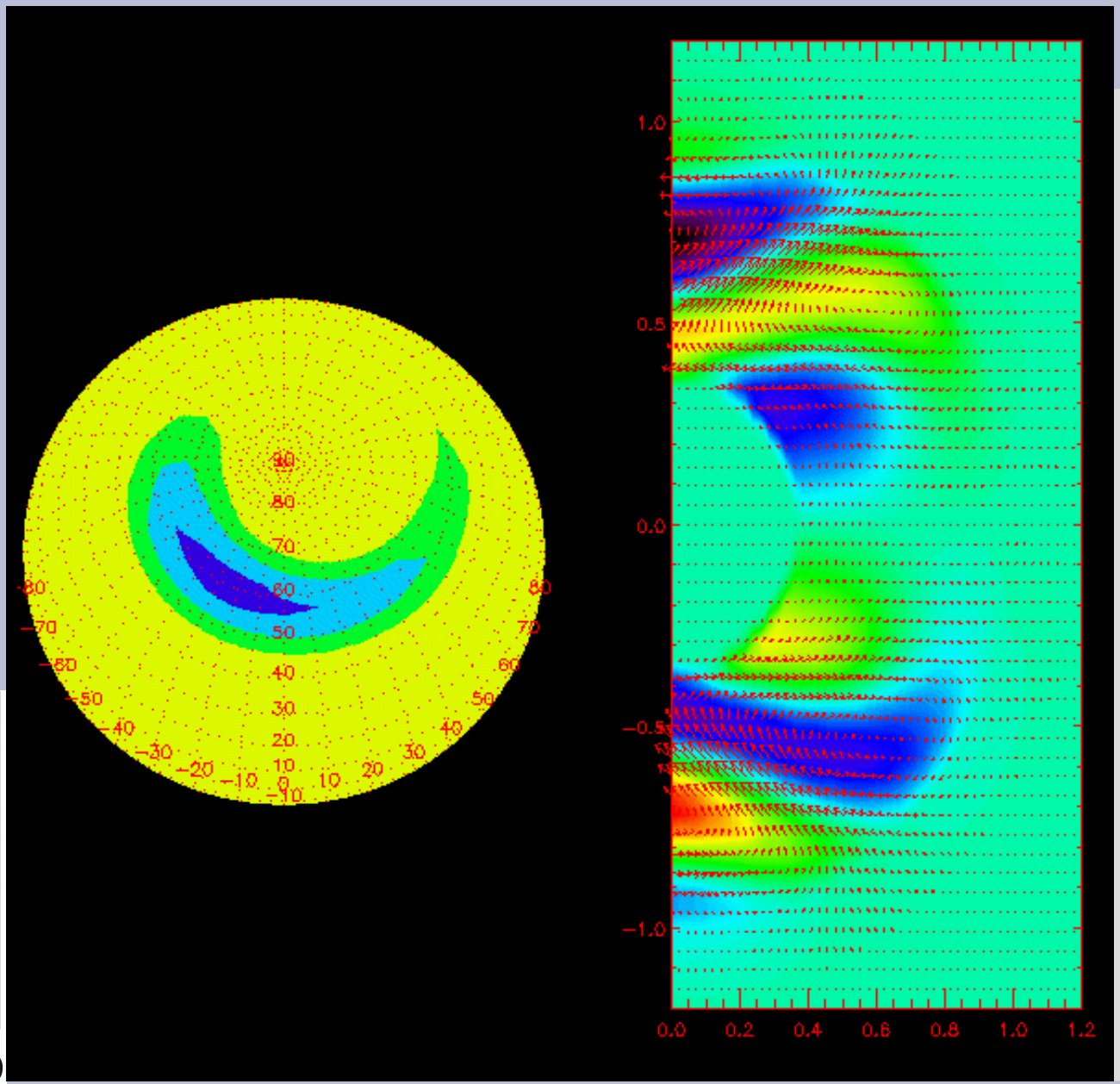


**For explaining the flip-flop phenomenon both properties are needed**

# Modelling flip-flops II

- There are models that can produce non-axisymmetric dynmos:
  - With anisotropic $\alpha$-effect
  - With weak differential rotation
- First models showing the flip-flop properties were by Moss (2004, 2005). He used axis distance dependant internal rotation law.
- Other models: Fluri & Berdyugina 2004; Elstner & Korhonen 2005

# Modelling flip-flops III




Solar type rotation law, but with differential rotation 10% of the solar value

Anisotropic $\alpha$-effect

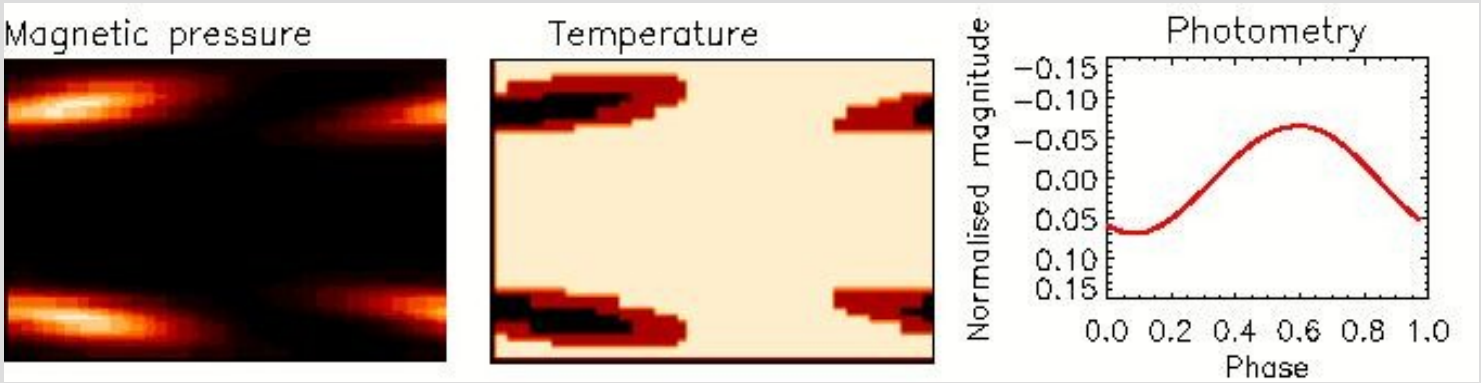
Positive alpha on the northern hemisphere

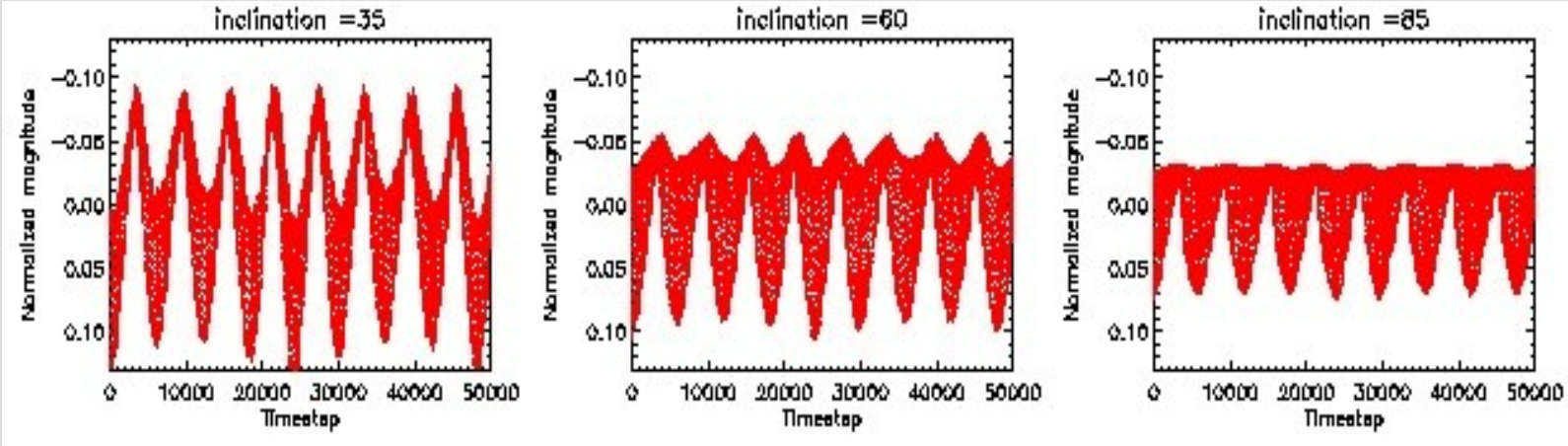
Figure:
Stellar view: magnetic pressure on the surface
Cut view:
mg field vectors (arrows)
vertical fields (colours)

Elstner & Korhonen 2005

# Light-curves from the dynamo models

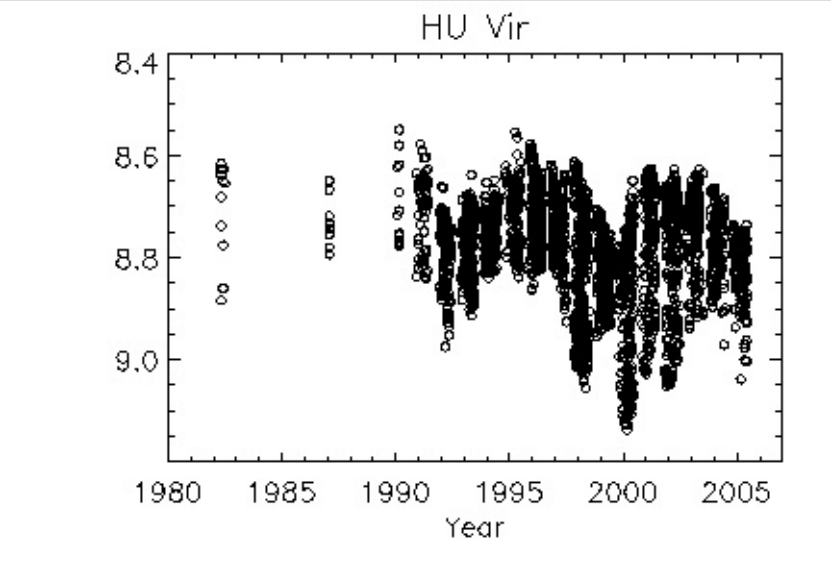
- The dynamo calculations were converted into synthetic photometric observations to study the paterns caused by the flip-flop phenomenon

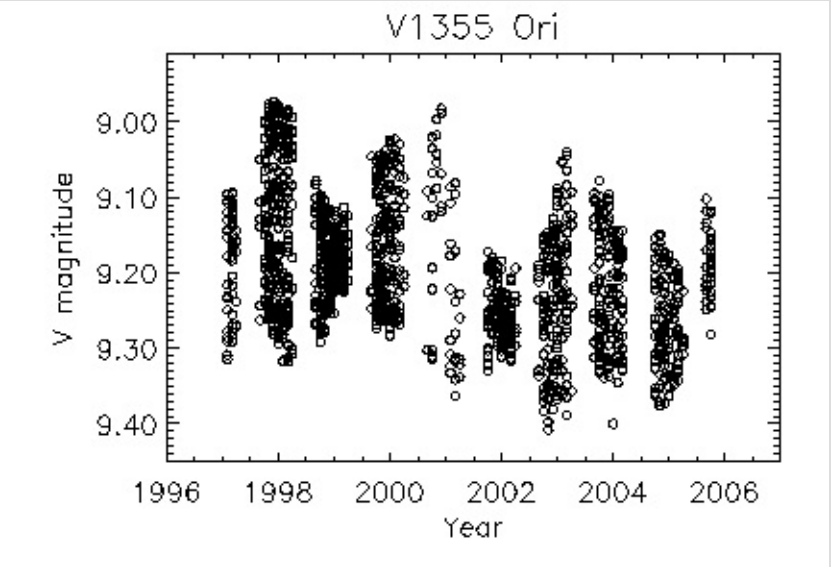


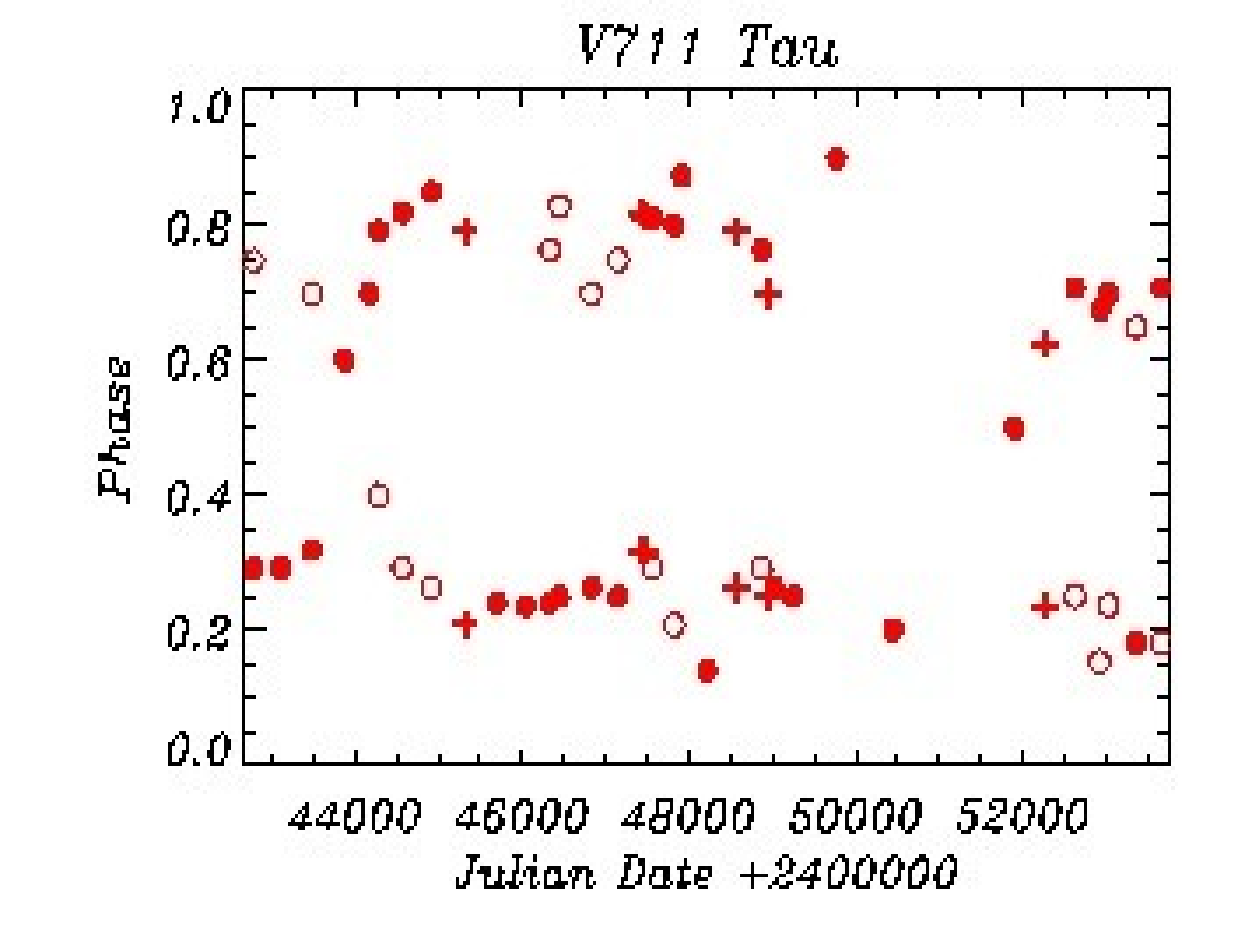
# Finding new flip-flop stars

- Interesting targets for further study from old photometry
- Stars with long-term photometry similar to the modelling results
- Stars with already know active longitudes
- Investigated 15 stars using light-curve inversion techniques

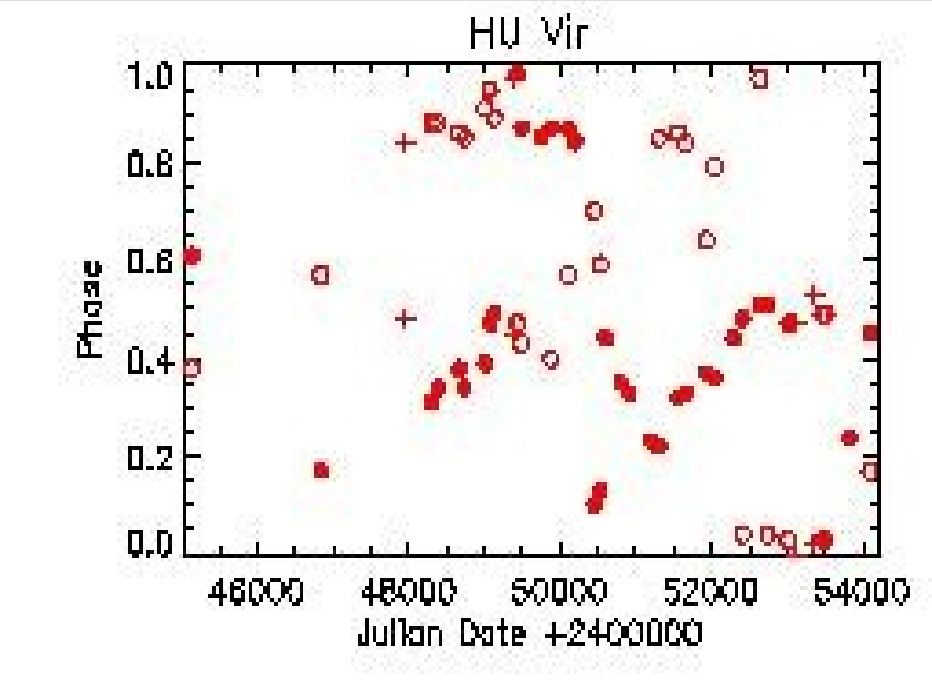


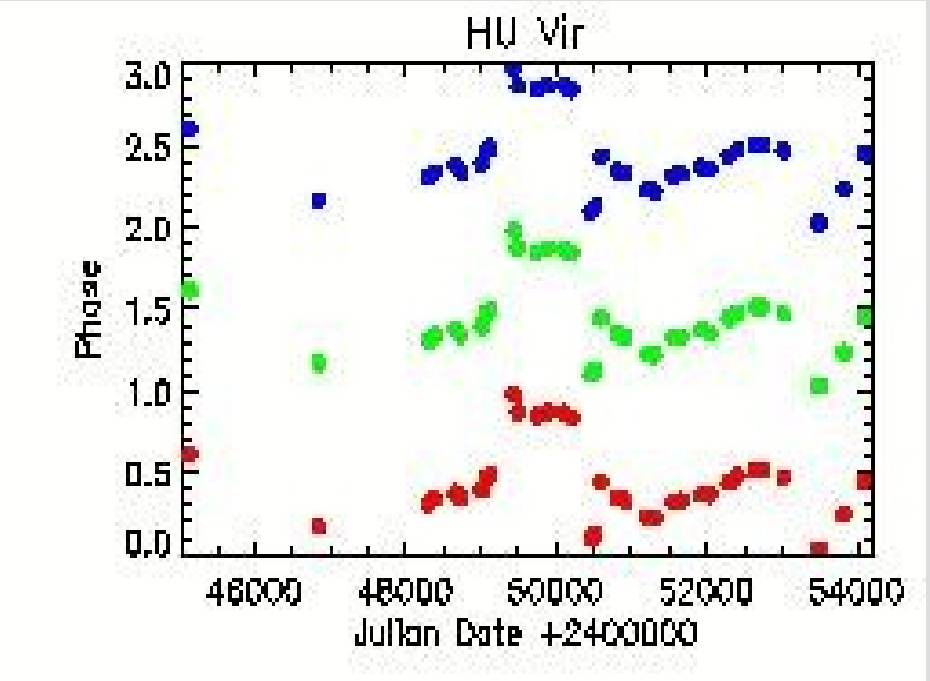



# Sometimes phases nicely between 0 and 1

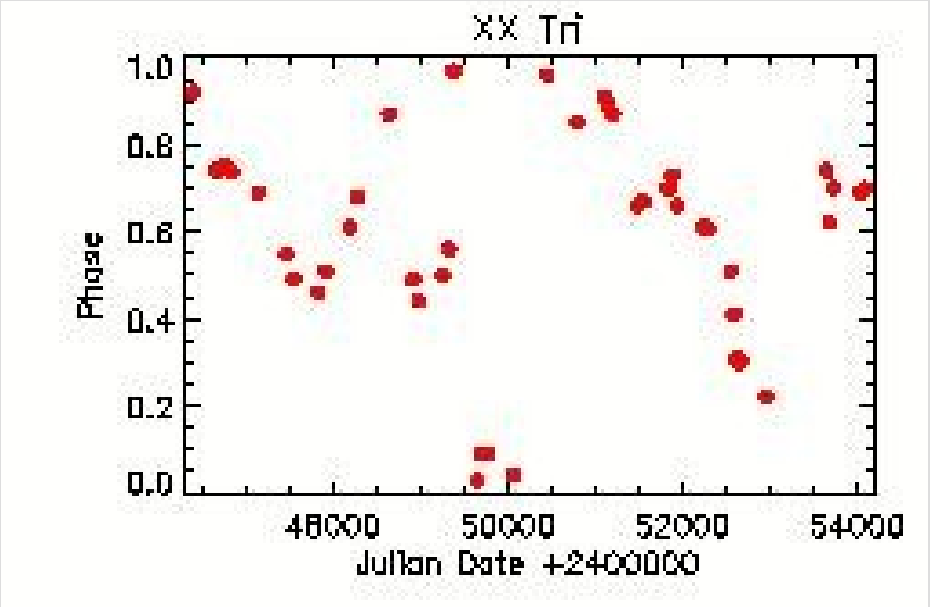


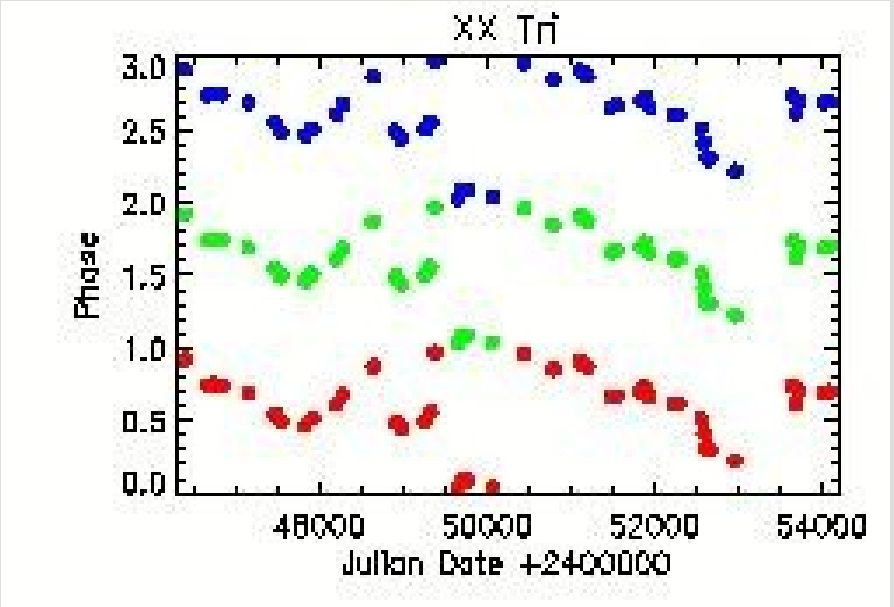
# Sometimes a bit messier



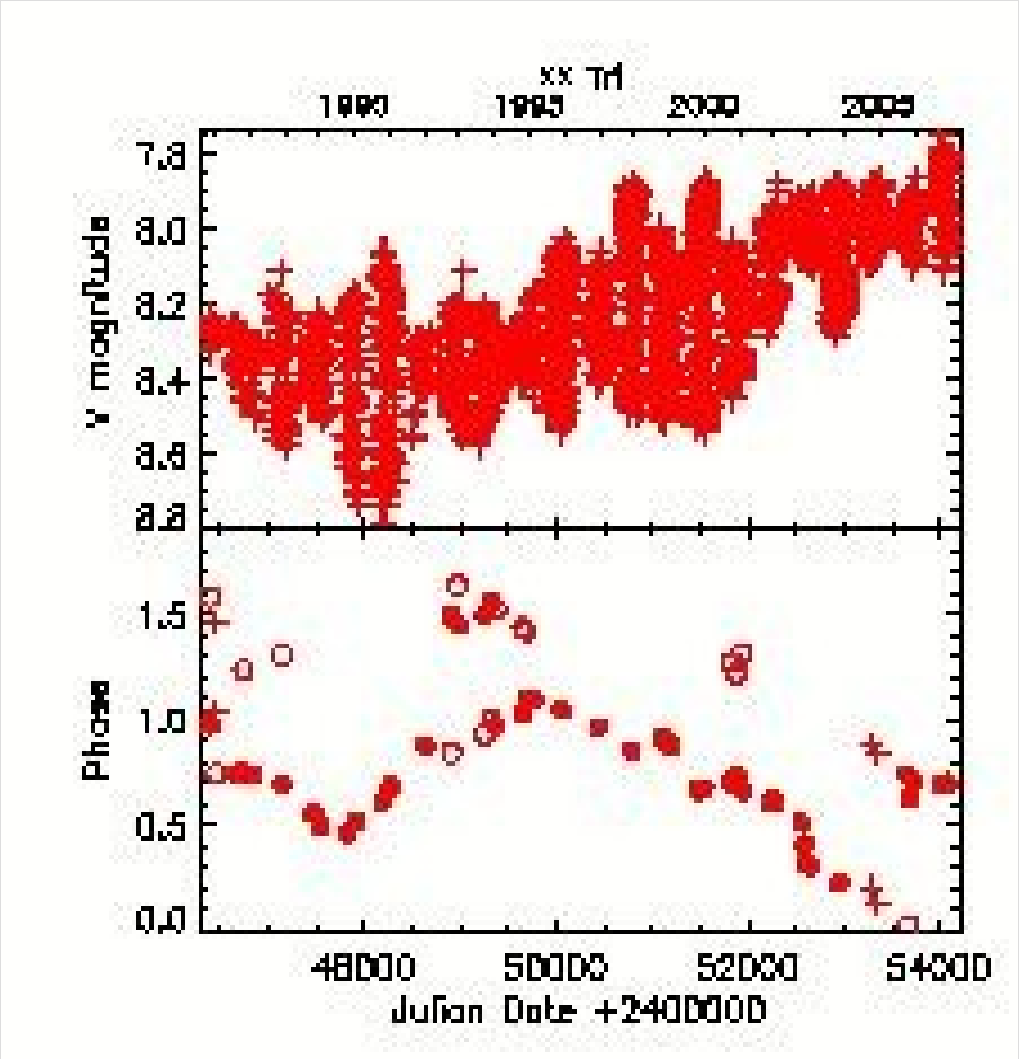



# One more example



# And the same again



# Something to try

- Use the programme Torben introduced yesterday for studying active stars
- You can find one data set from:

www.aip.de/~hkorhone/school/HUVir_test.dat

- The task is to try what kinds of periods you will find. And remember that we are not talking about pulsations here, but rotation periods of days and even much longer activity cycles