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The weak solar cycle 24: monitoring chromospheric emission with TIGRE

Hamburg, 19.12. 2016

now monitoring solar and stellar chromospheric acvtivity at the DA: the 1.2m robotic telescope TIGRE

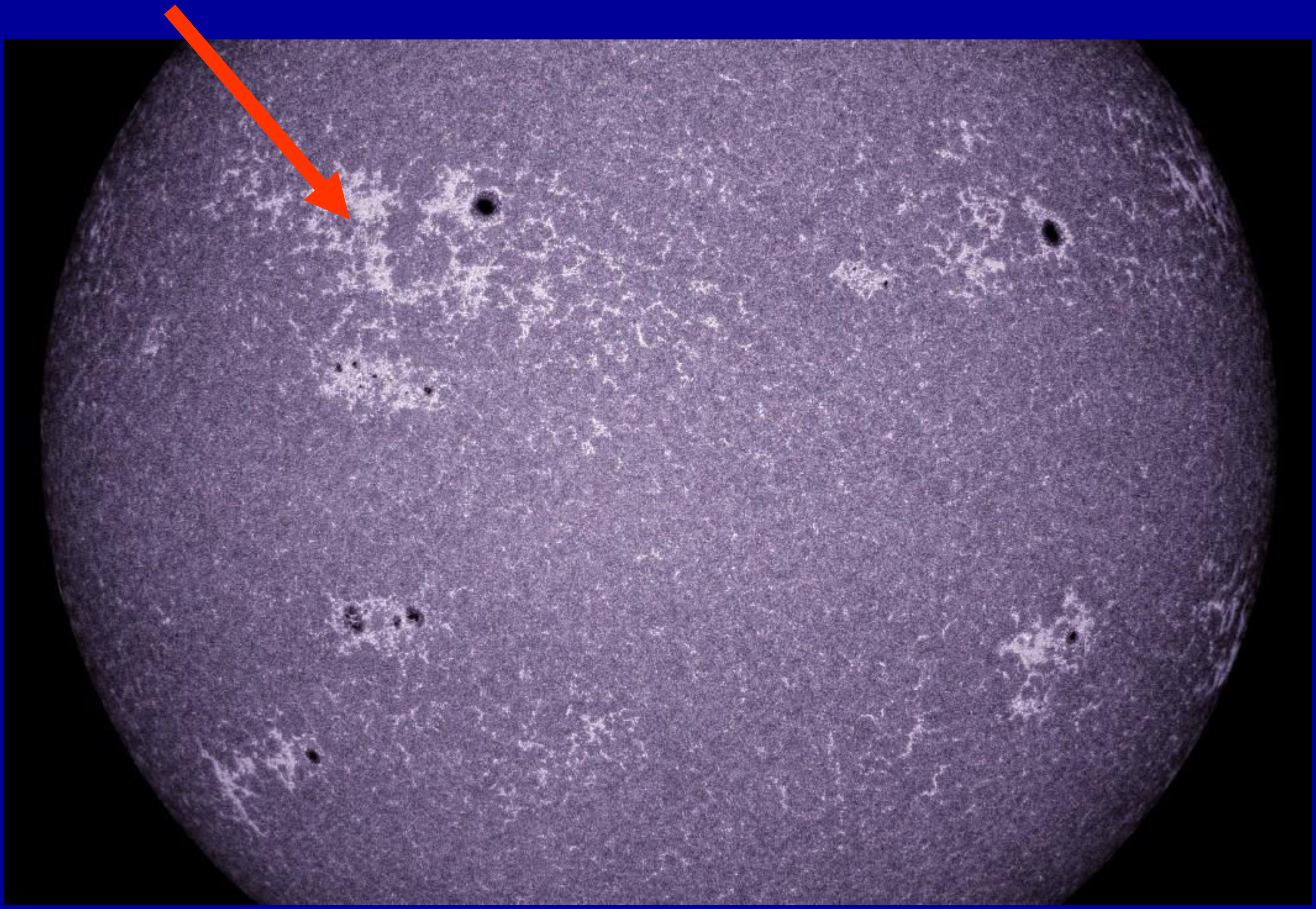
a first in 2008/9: an entirely inactive Sun

co-authors:
Marco Mittag
Jürgen Schmitt
...

UV from solar faculae coincides with Ca II K emission

- *integral solar irradiation and visual flux change only by 0.1%*
- *but the output of ultraviolet light (λ=320-200nm) is dominated by active regions and changes by several % (and more)*

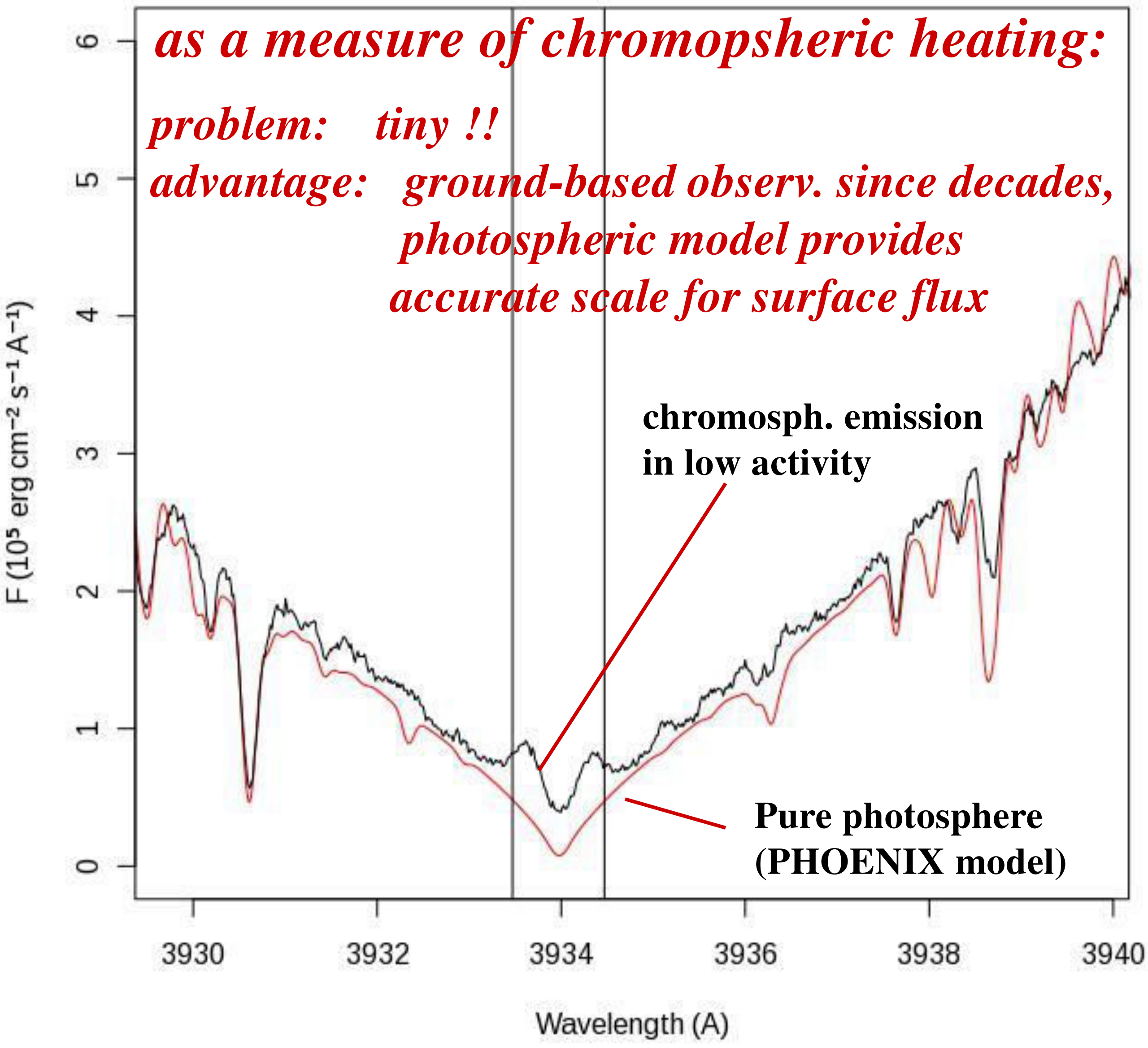
A good proxy is CaII K emission, forms at about same T_e!



Ca II K chromospheric line emission as a measure of chromopsheric heating:

problem: tiny !!

advantage: ground-based observ. since decades, photospheric model provides accurate scale for surface flux



The Mt. Wilson S-index to measure the CaII line emission:

$$S = const.\,(F_H + F_K) / (F_R + F_V)$$

1 Angstr. wide line cores H&K / 20 Angstr. wide quasi-continua, as such S is independent of transparency. Calibration by standard stars.

Hence, S is of the order of the line core intensity over cont. intensity
Modern spectra: const. ca. 19, star-calibrations needed.

Advantage: S is independent of sky quality and calibration lamps,
best detection of even the smallest emission in the CaII core.
Disadvantage: S does not directly compare with modern line fluxes!

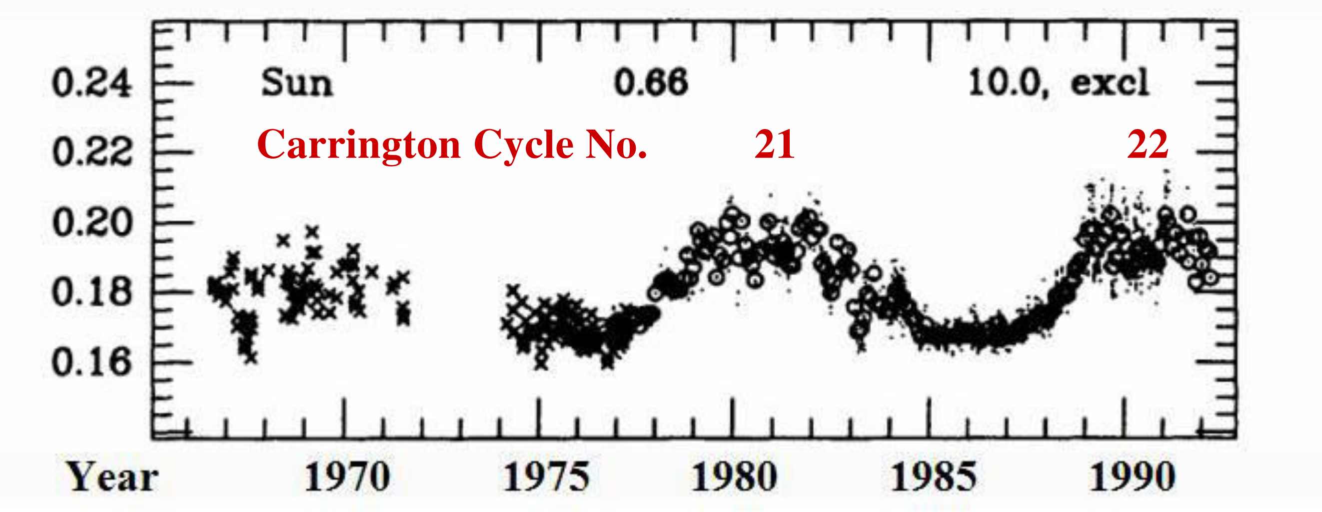
Wider context: we continue O.C. Wilson's work

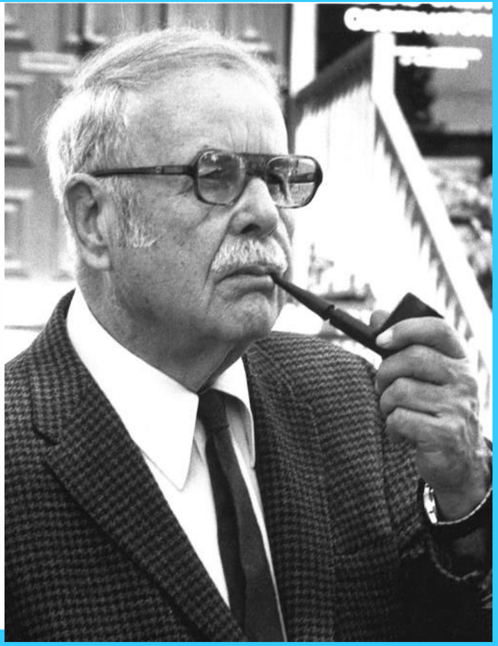
- ***monitoring the Ca II K chromospheric emission variability, by „S-index" = a measure relative to pseudo-continuum***

- ***sample: over 100 stars brighter than 7 mag, spectral type F-K, plus about 40 cool giants of different activity degrees***

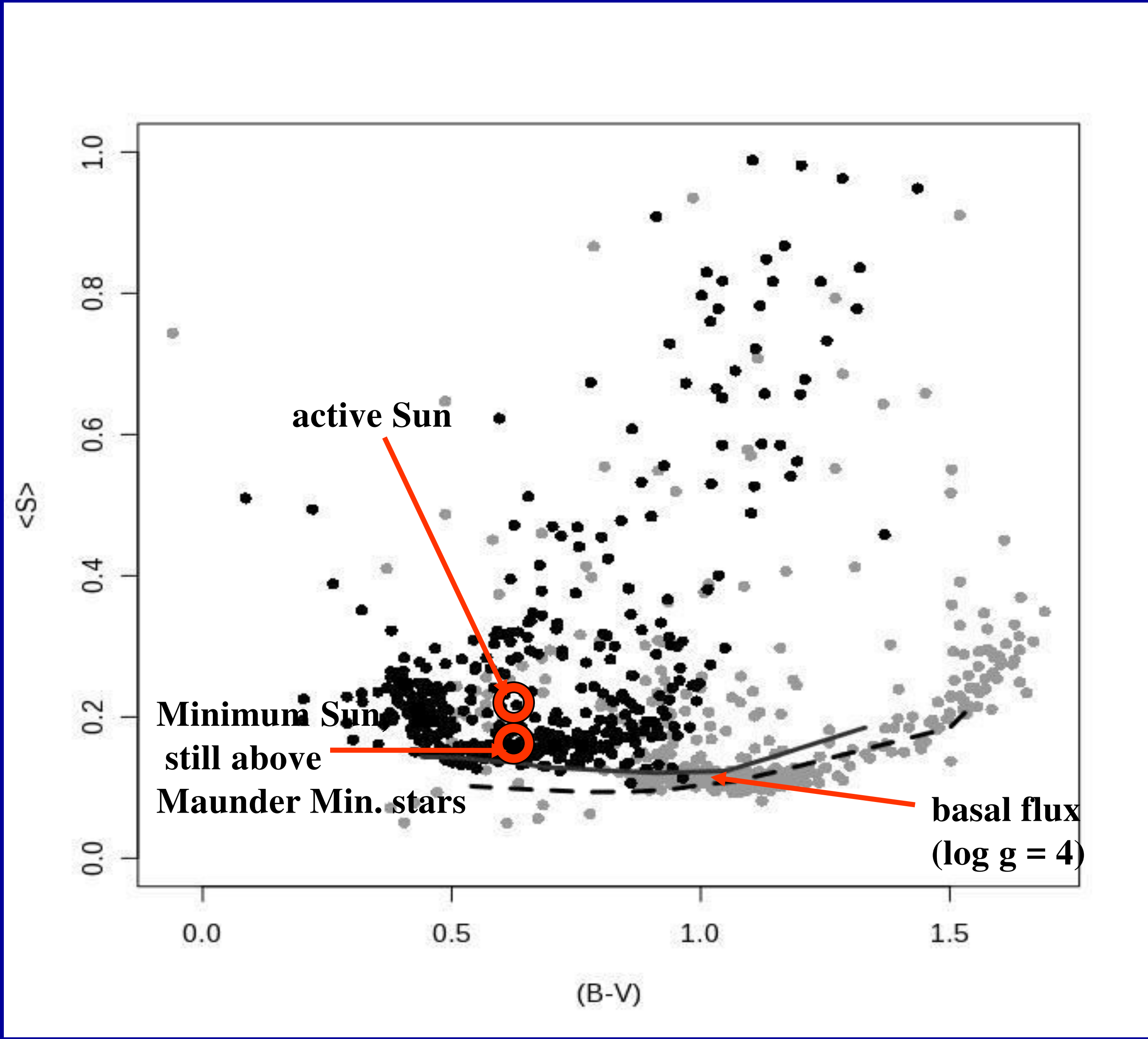
- ***includes „the Sun as a star" via moonlight spectra !***

From: Baliunas et al. 1995

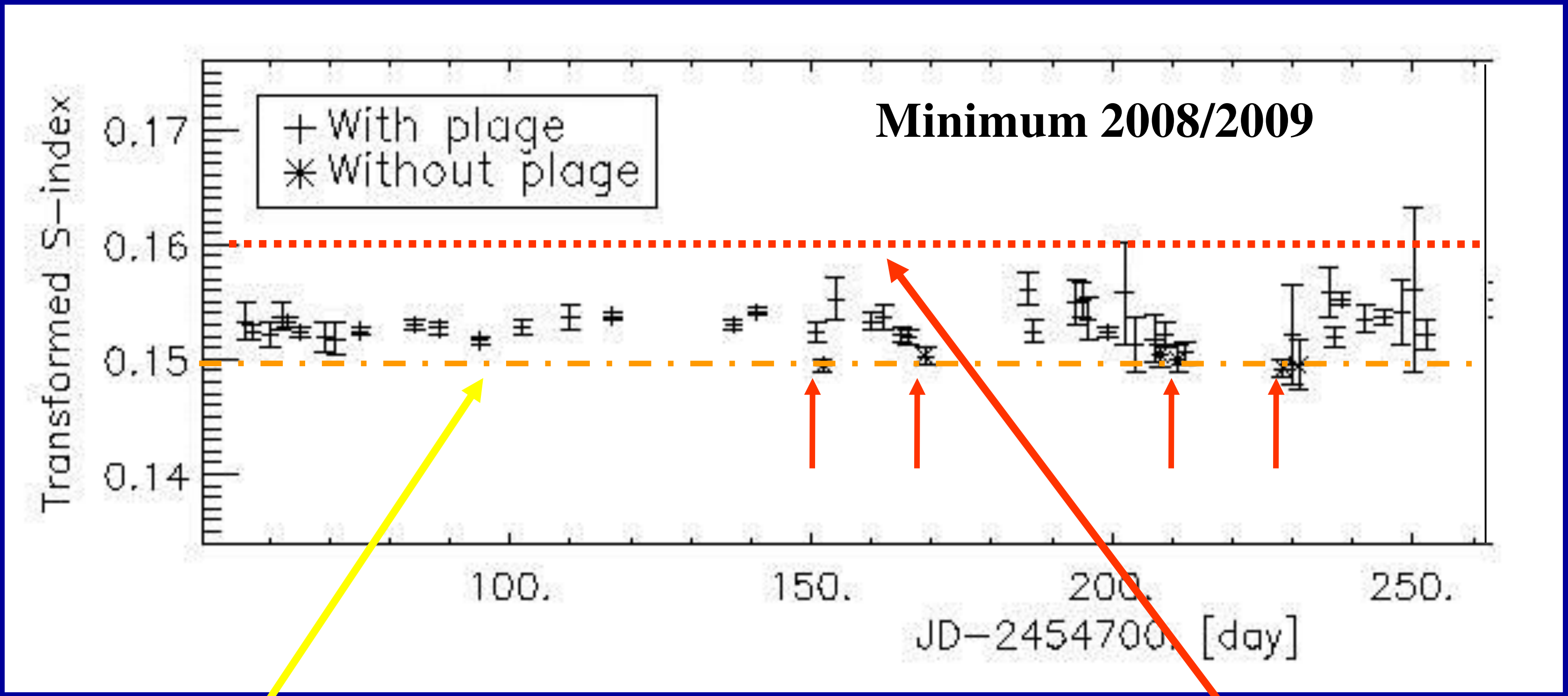




S-index of Mt. Wilson project stars & the Sun



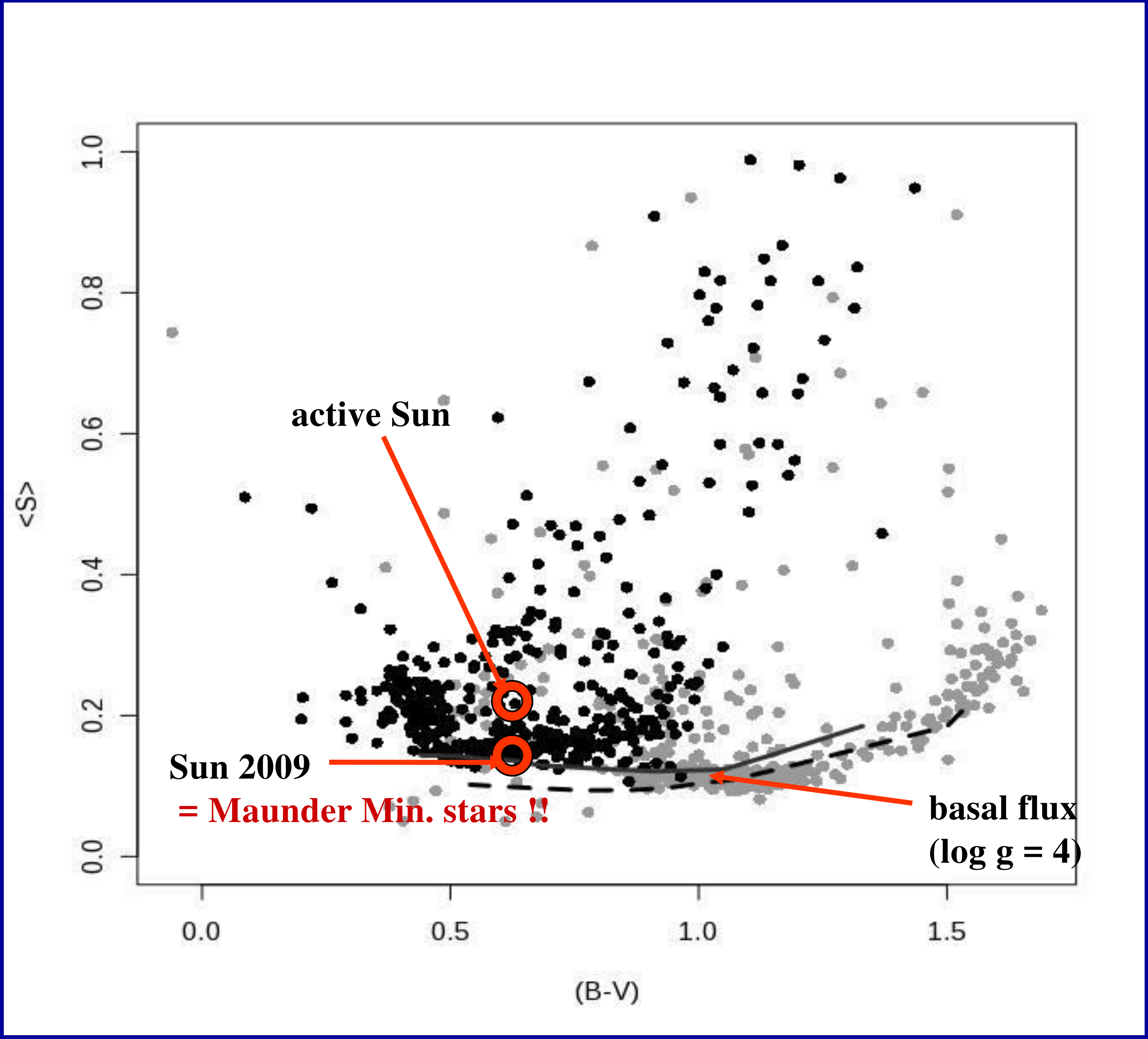
But: then came the unusual minimum of 2008/09, TIGRE, and the PhD of Marco....!



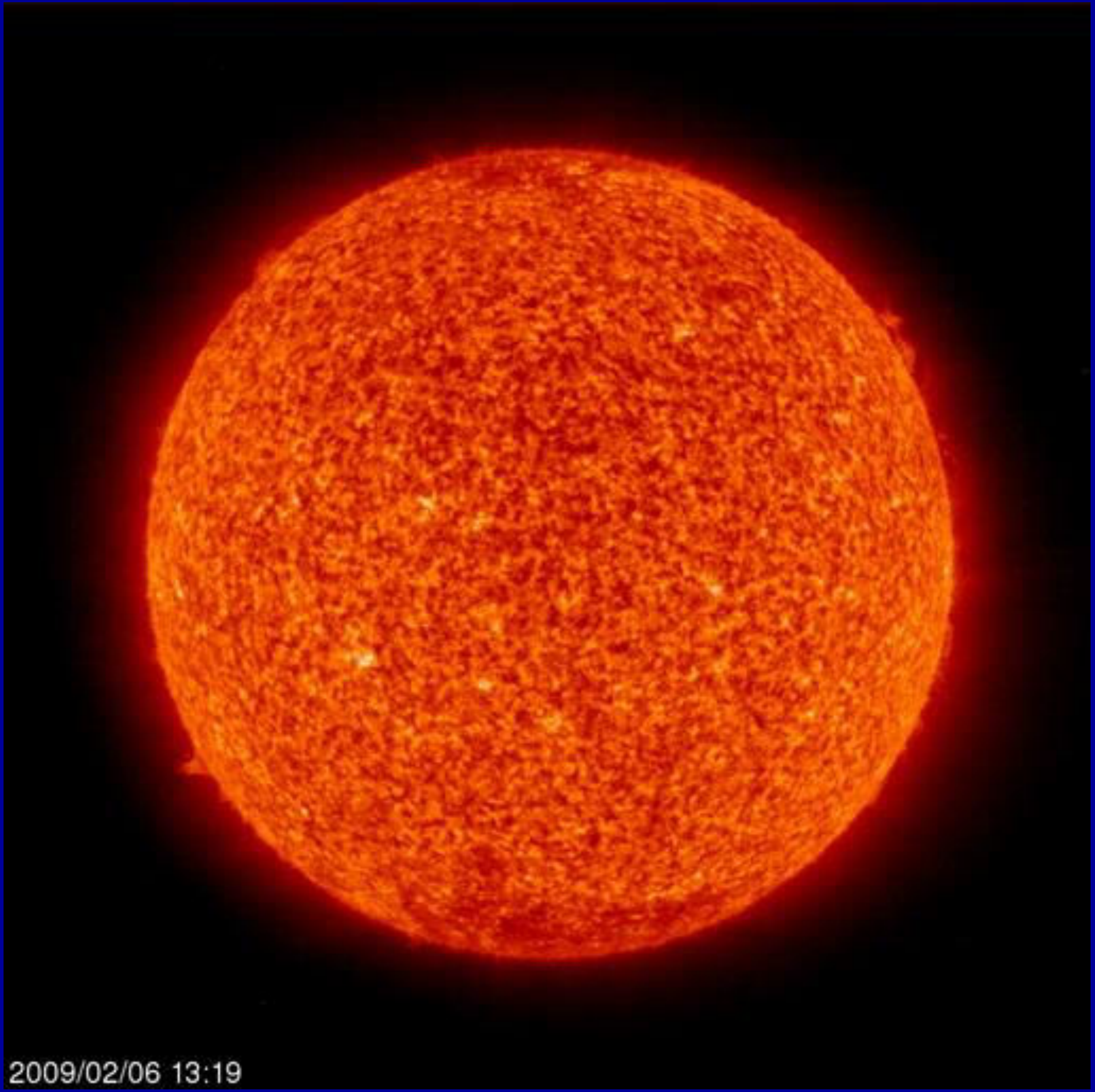
solar S-index in normal minimum

S-index of solar-type Maunder-Minimum stars

In 2008/9, the Sun reached the basal flux of „dead“ stars !



...THIS is, how the Sun looked like in Maunder Minimum!!



the basal-flux Sun:

NO active regions at all!
=> any basal heating is not from activity!
=> mechanical / dissip. of accoustic waves ?

And where does all the magnetic fine-structure come from ?!!

~2% of convect. energy is converted into random fluxtubes (by a „local dynamo“, see Vögler & Schüssler 2007) and into the minimal X-ray flux (Schmitt ´97)

Other activity indicators and what they mean:

Re (sunspot number, since nearly 200 yrs):
strong magnetic field through the photosphere

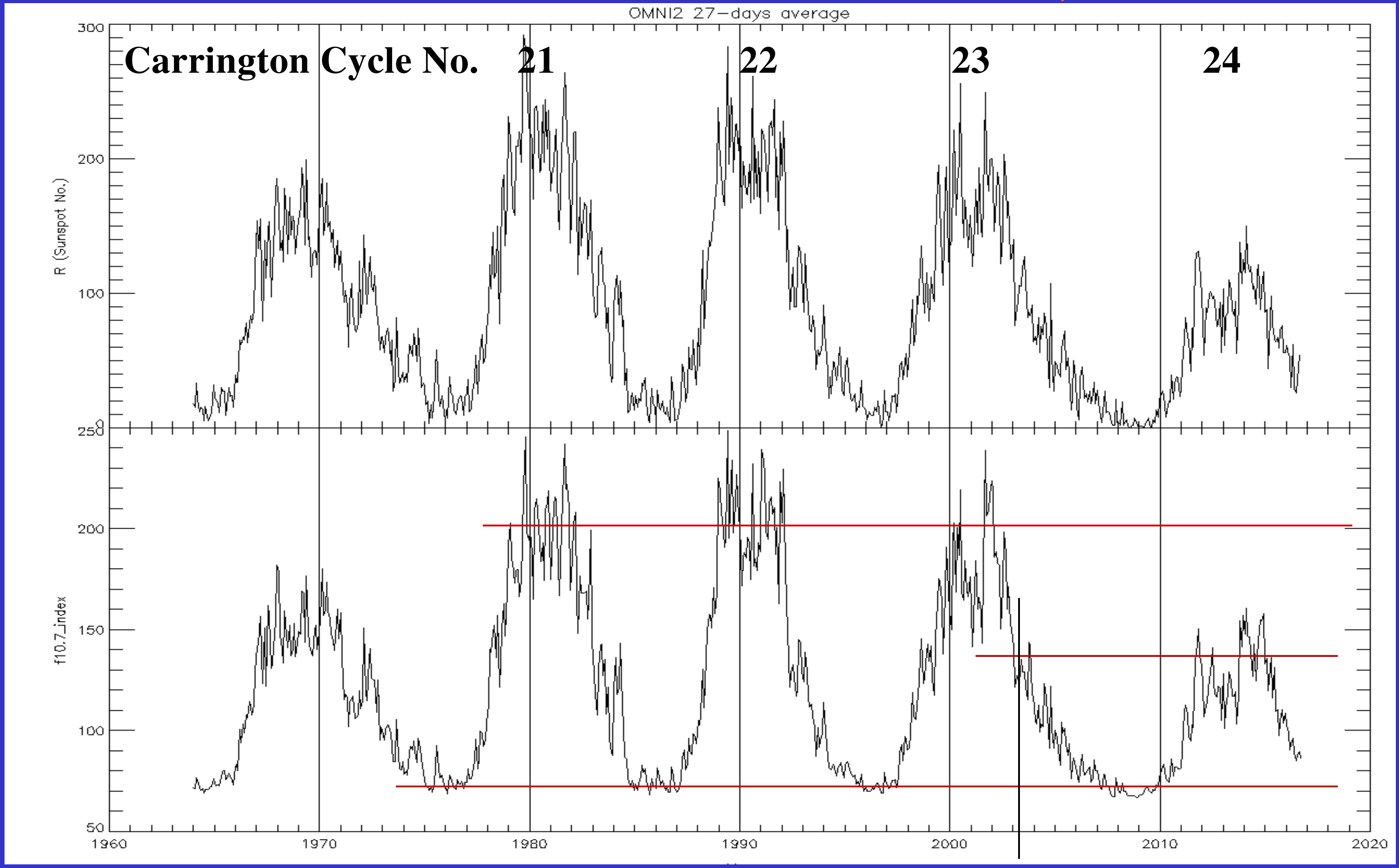
F10.7 (radioflux at λ=10.7cm, since ~50 years):
magnetic field volume in the lower corona

S-value (MWO-calibration, since nearly 50 years):
heating (magn. & mech.) of the chromosphere

related: variation of the far-UV flux (SOLSTICE, since 13 years), responsible for stratospheric heating by photodissipation of molecules

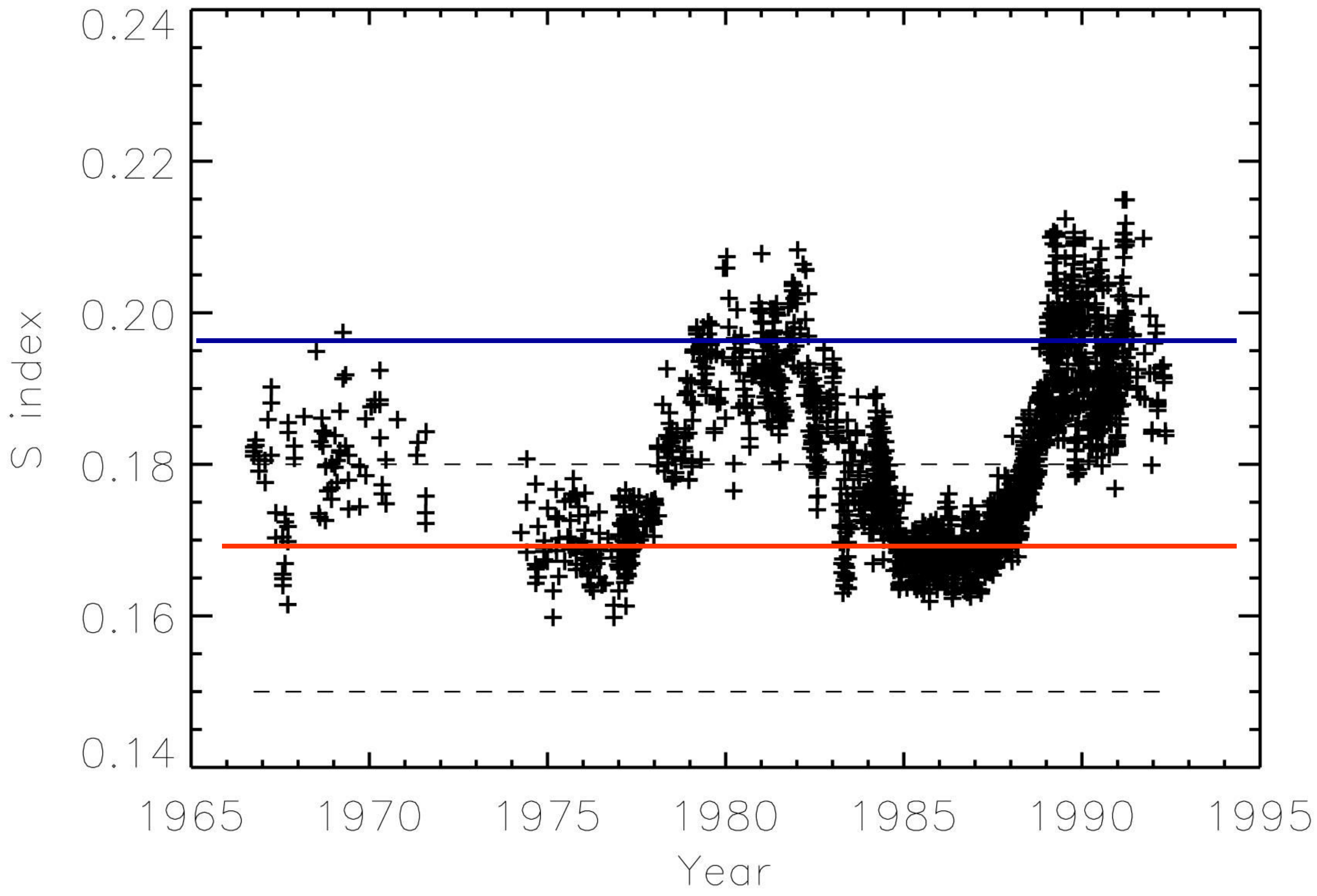
Now all eyes on cycle 24: what is going on?!

Sunspot numbers R and F10.7cm coronal radioflux, both show only about 50% strength of previous cycles

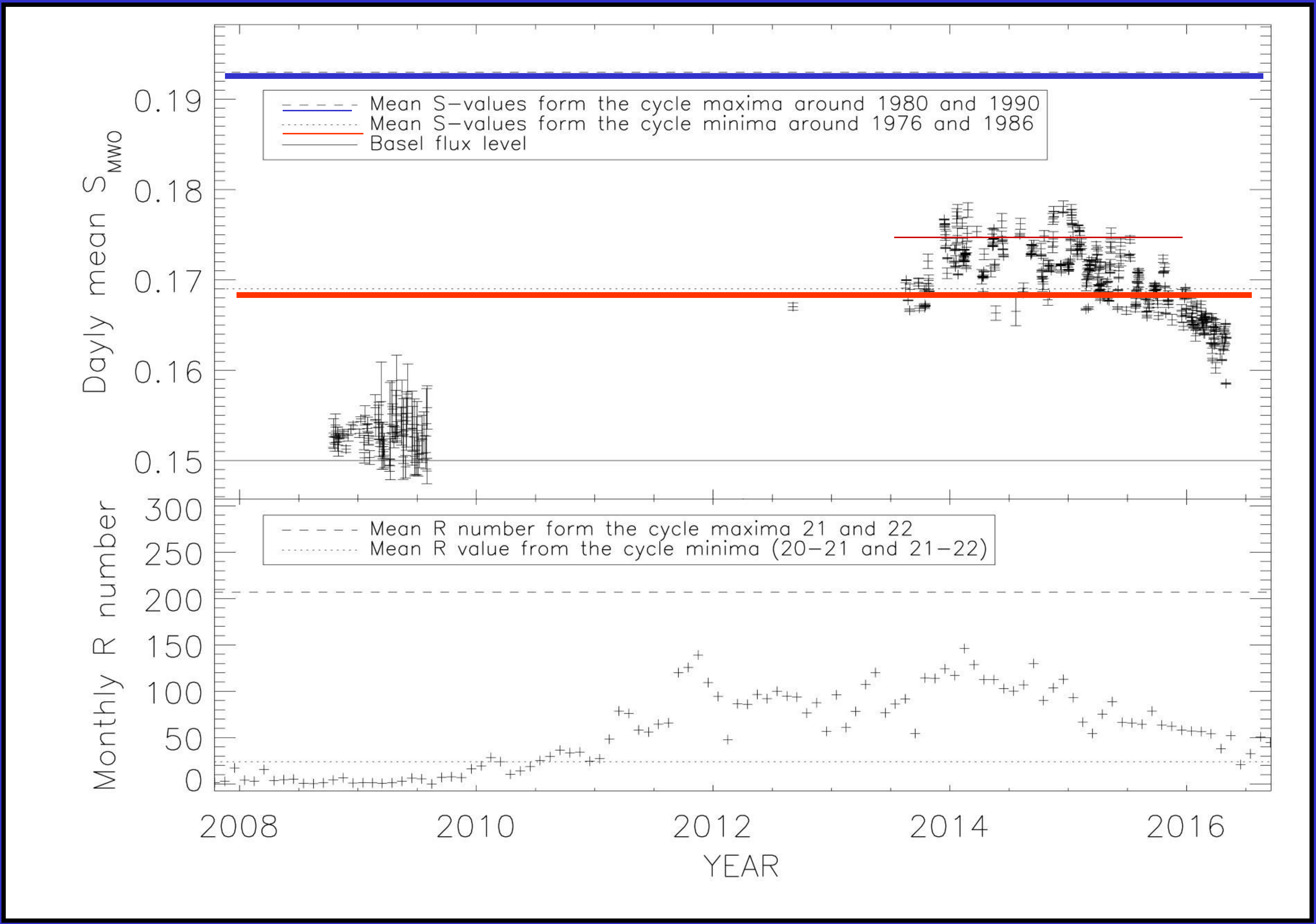


<F10.7> – 65 ~ 0.7 <Re> ; 65 = minimal F10.7 value on entirely inactive days.
Maximum cycle 24 compares with activity in 2003 (mid-decline of cycle 23)

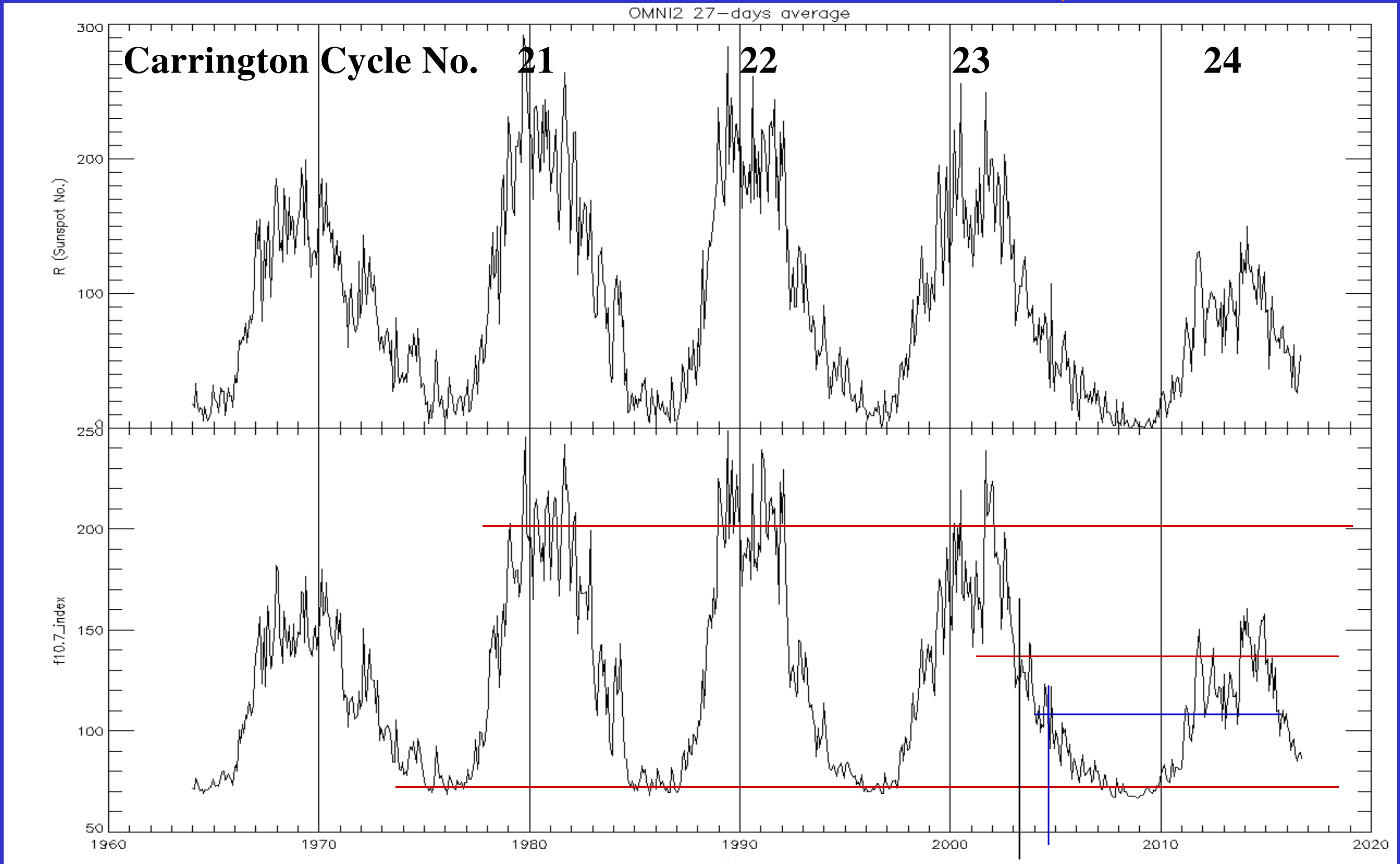
El trabajo de Olin Wilson et al., Mt.Wilson /CA



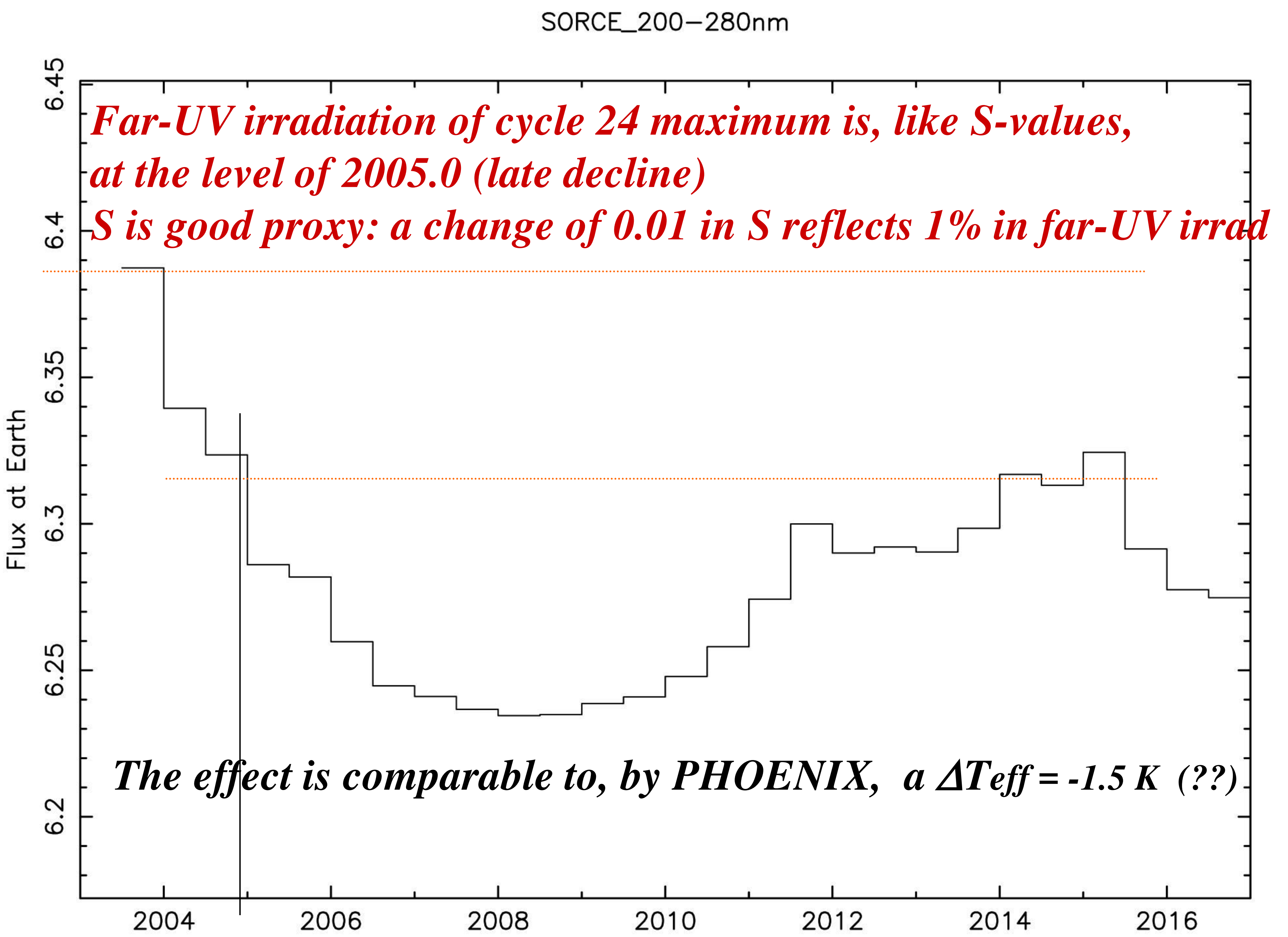
Chromospheric emission of cycle 24 is only <30% of previous maxima



A 30% of previous cycle maxima strength, as of chromospheric emission (S-values) compares to the activity of 2005, not o early 2003 !



S_basal = 0.150, S_max_av = 0.193: S does not scale ! Goes deeper now


SORCE_200–280nm
Far-UV irradiation of cycle 24 maximum is, like S-values,
at the level of 2005.0 (late decline)
S is good proxy: a change of 0.01 in S reflects 1% in far-UV irrad
The effect is comparable to, by PHOENIX, a ΔTeff = -1.5 K (??)
Flux at Earth
6.45
6.4
6.35
6.3
6.25
6.2
2004
2006
2008
2010
2012
2014
2016

Impact of the solar far-UV light (λ=320-200 nm)

=> *more activity = more far-UV = more stratospheric heating*

=> *less activity = cooler stratosphere = slower jetstream*

=> *Wider oszillation, less strength of jetstream and NAO,*
in winter cold high pressure areas build up, blocking situation

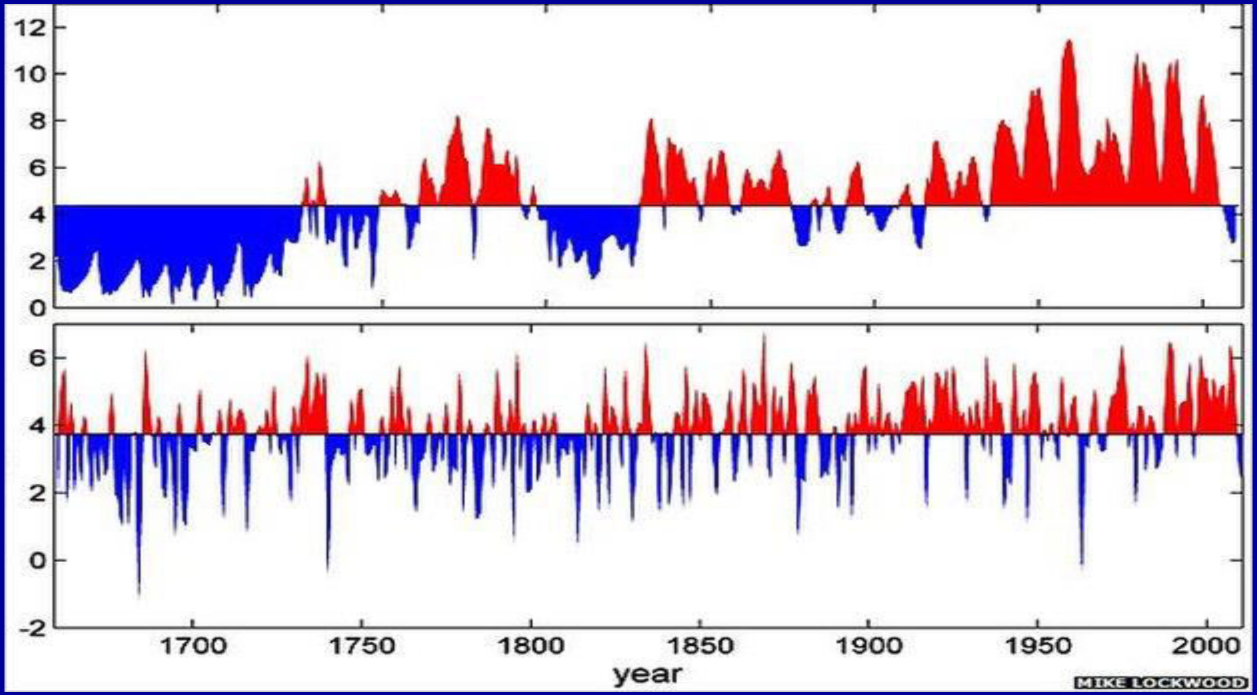
Sunspot number:

Abve/below average
=>

Winters:
moderate

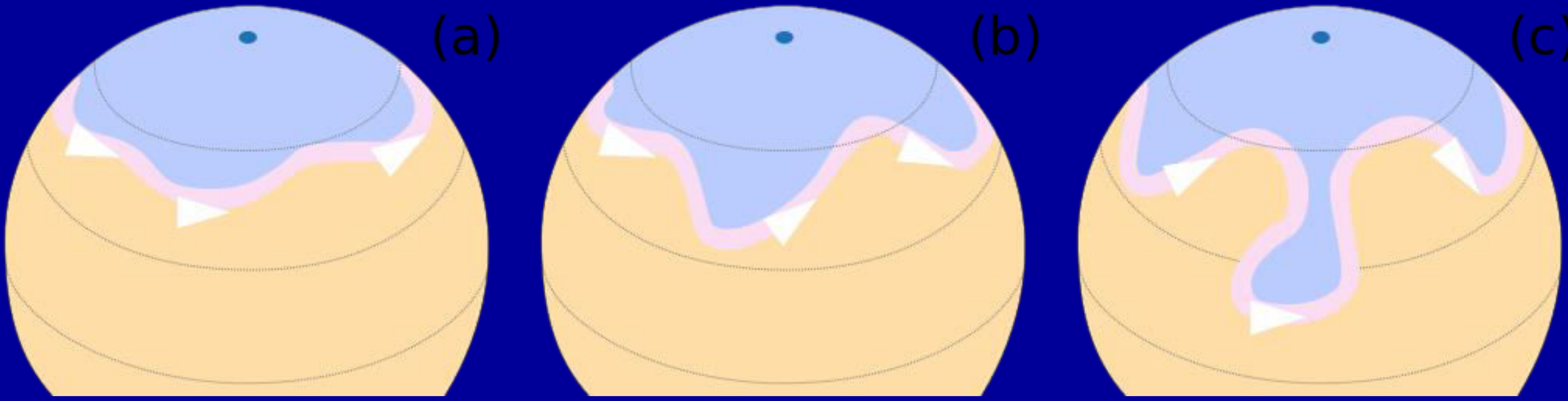
extreme

from:
London Met-Office
Scaiffe et al. 2011



How does a winter blocking situation work?

Despite stratosphere being cooler by only 1° at low solar activity, weaker and wider oszillating jetsream cannot move cold bubbles as easily as strong jetstream in high solar activity



Conclusions:

I) Solar activity cycle 24 is only half as strong as the past 3 cycles when seen by sunspot numbers and F10.7cm

II) Chromospheric emission is significantly lower than other activity indicators (cycle 24 at 30% max. strength)

III) The same effect is seen in the far-UV (200-280nm)!

IV) This may be typical of a grand minimum, in which the Sun seems to enter again, and the reduced far-UV irradiation can explain northern hemisphere climate effects such as more cold winters

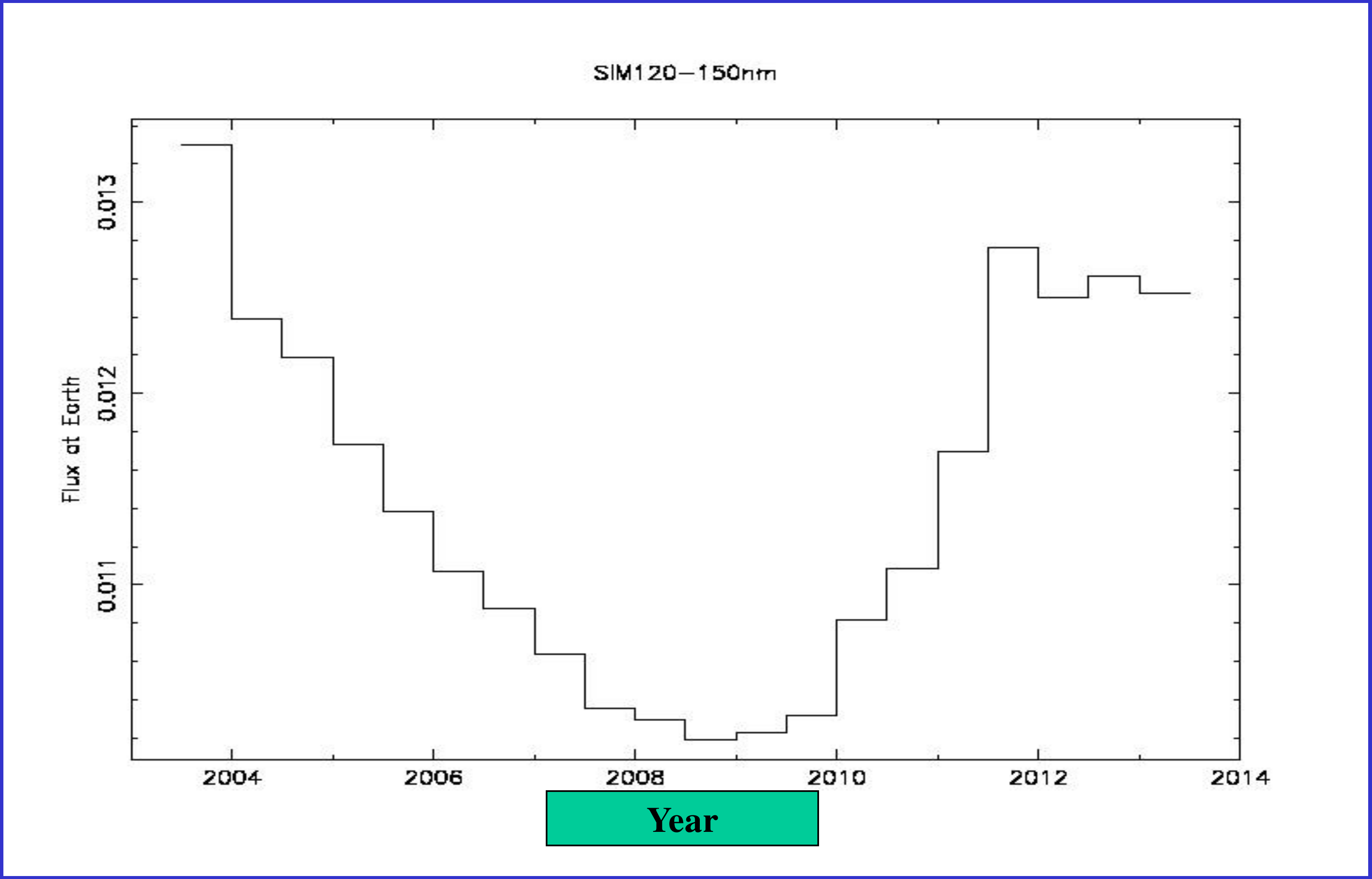
Related Question to work on with „el TIGRE“:

Monitor more true solar analogues (in activity) to find out: How frequent are Maunder Minimum episodes?


Much work remains to be done.....
Gracias!

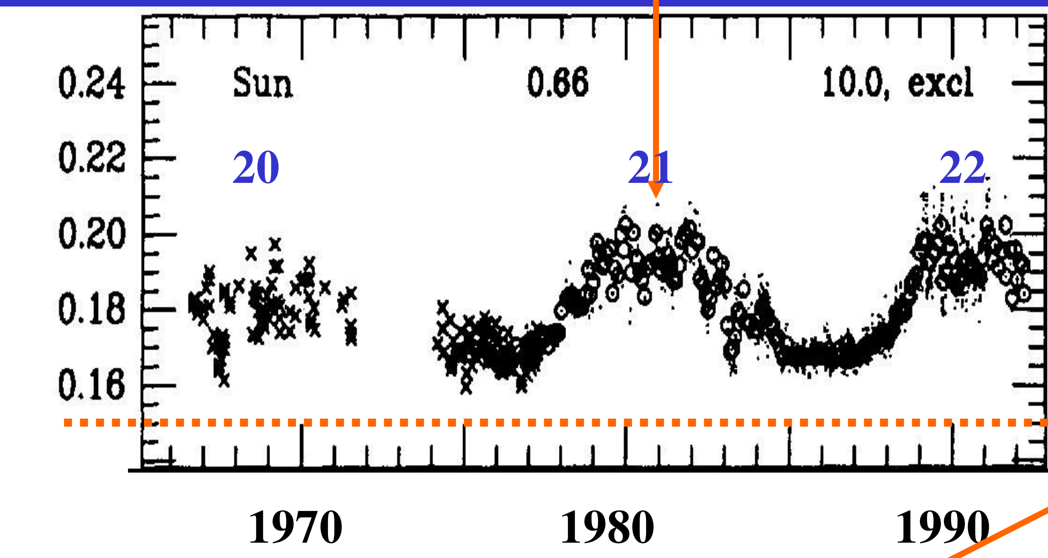
SOLSTICE far-UV flux, chromospheric emission dominates:

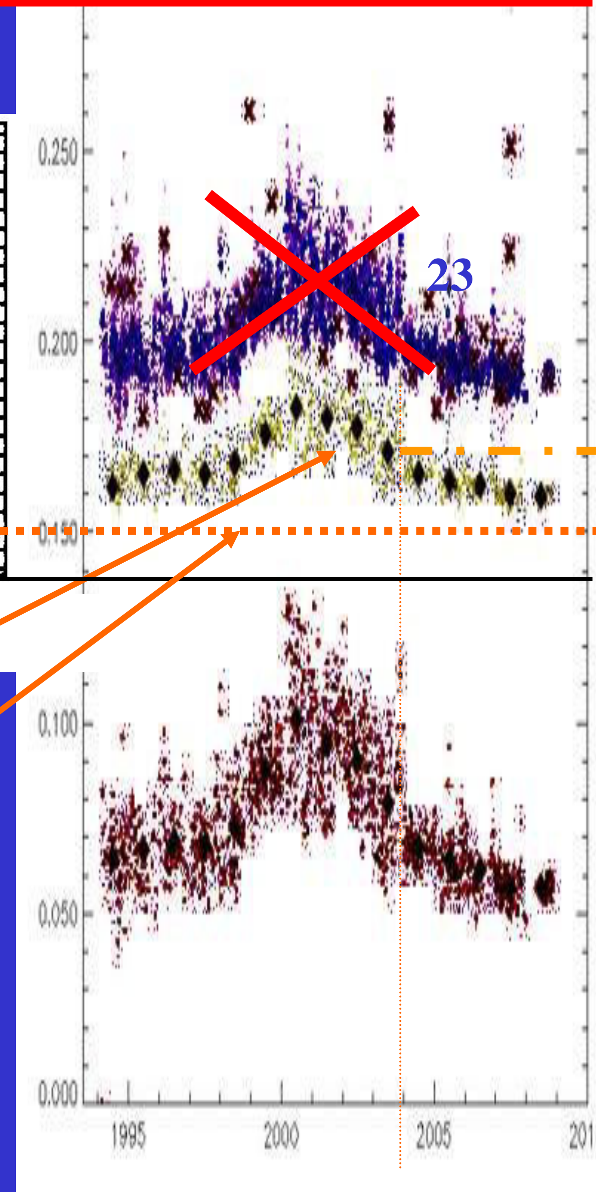
today, same level as of 2004 is regained (as before)



The present cycle 24 seen in historic context:

S-Sun from Mt.Wilson and Lick





24

today: 0.17

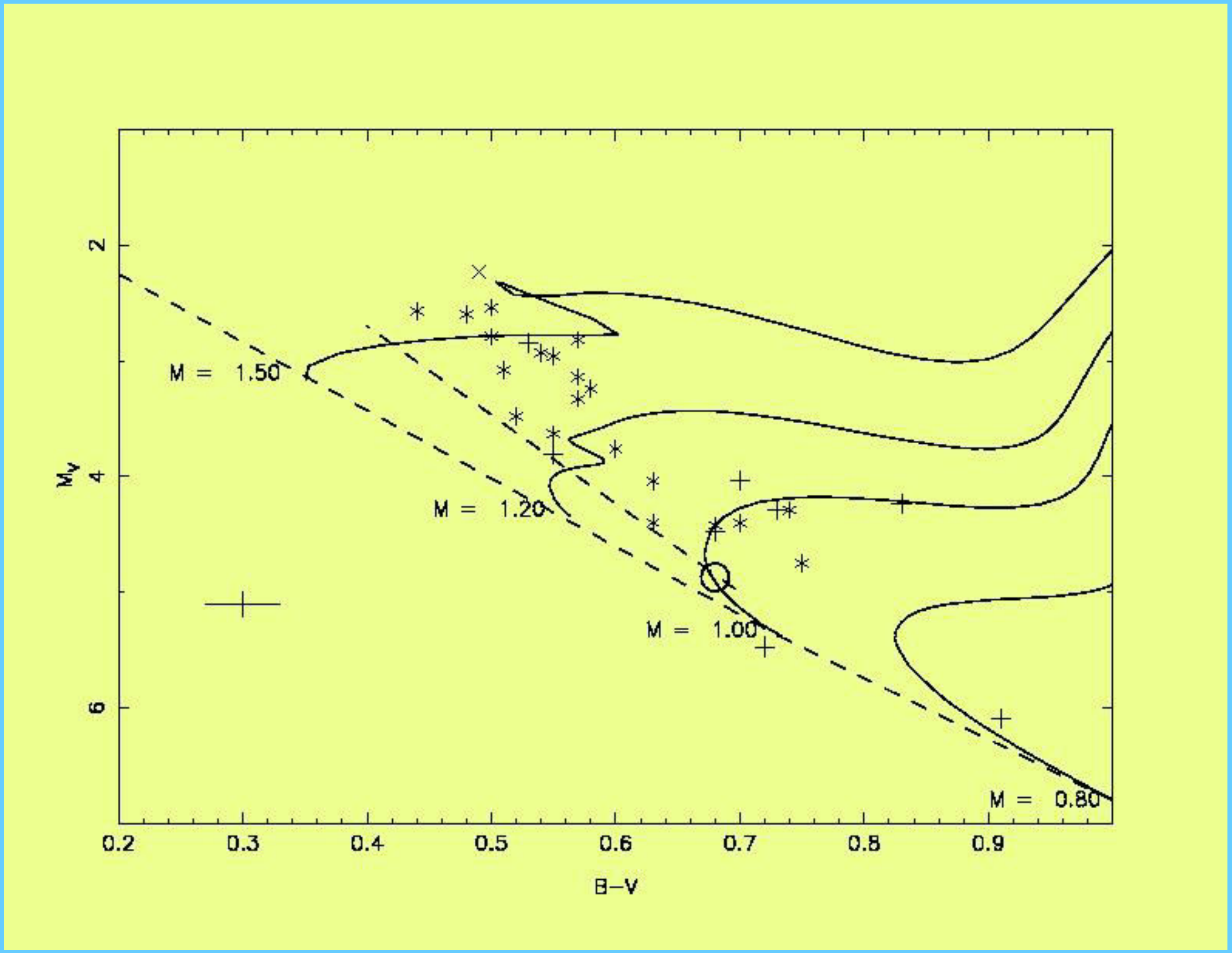
(TIGRE)

present level as of 2004 or 1987 minimum!

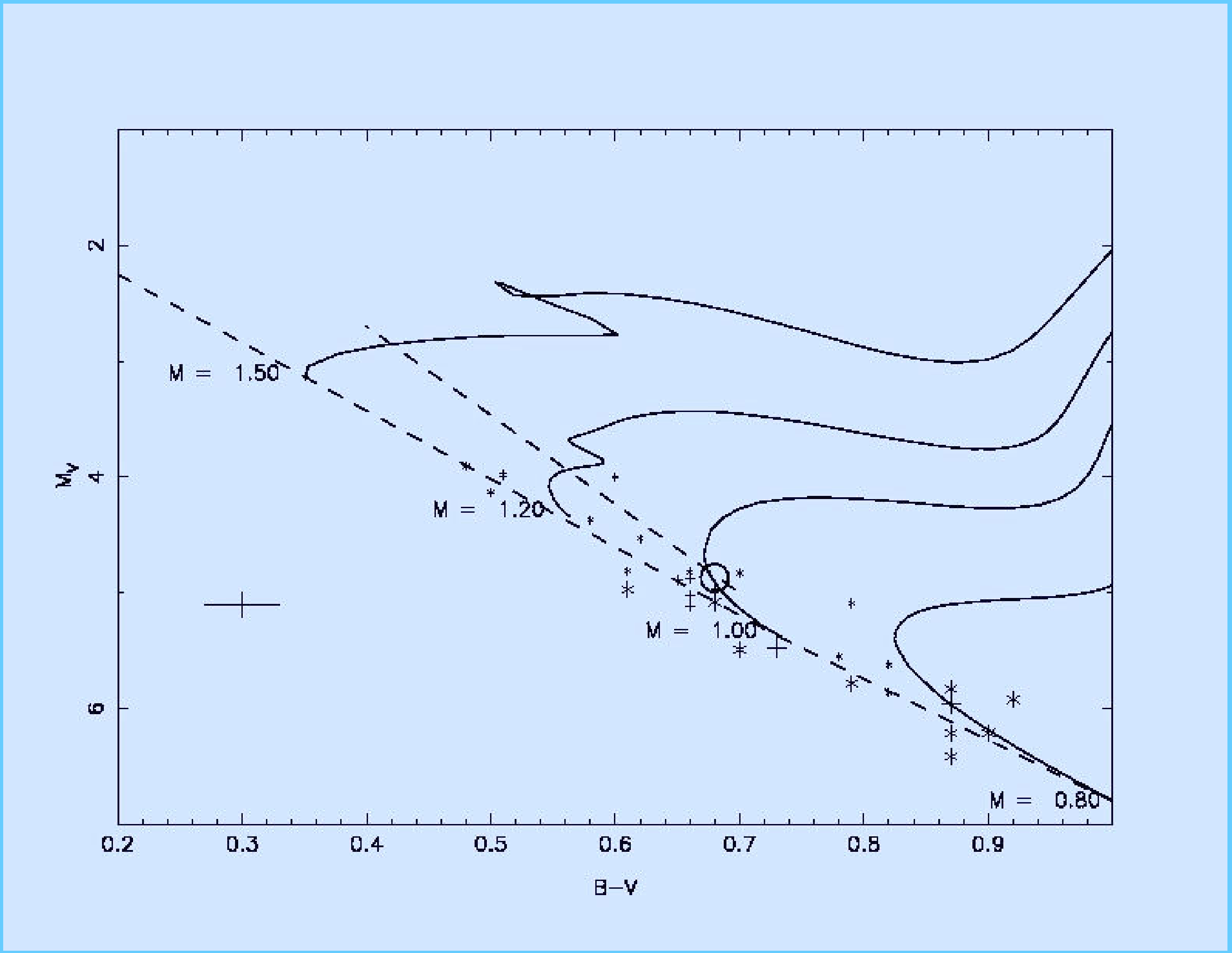
S-Lick-Obs.

basal Ca II K flux level in S
(reached on some days in 2008/9)

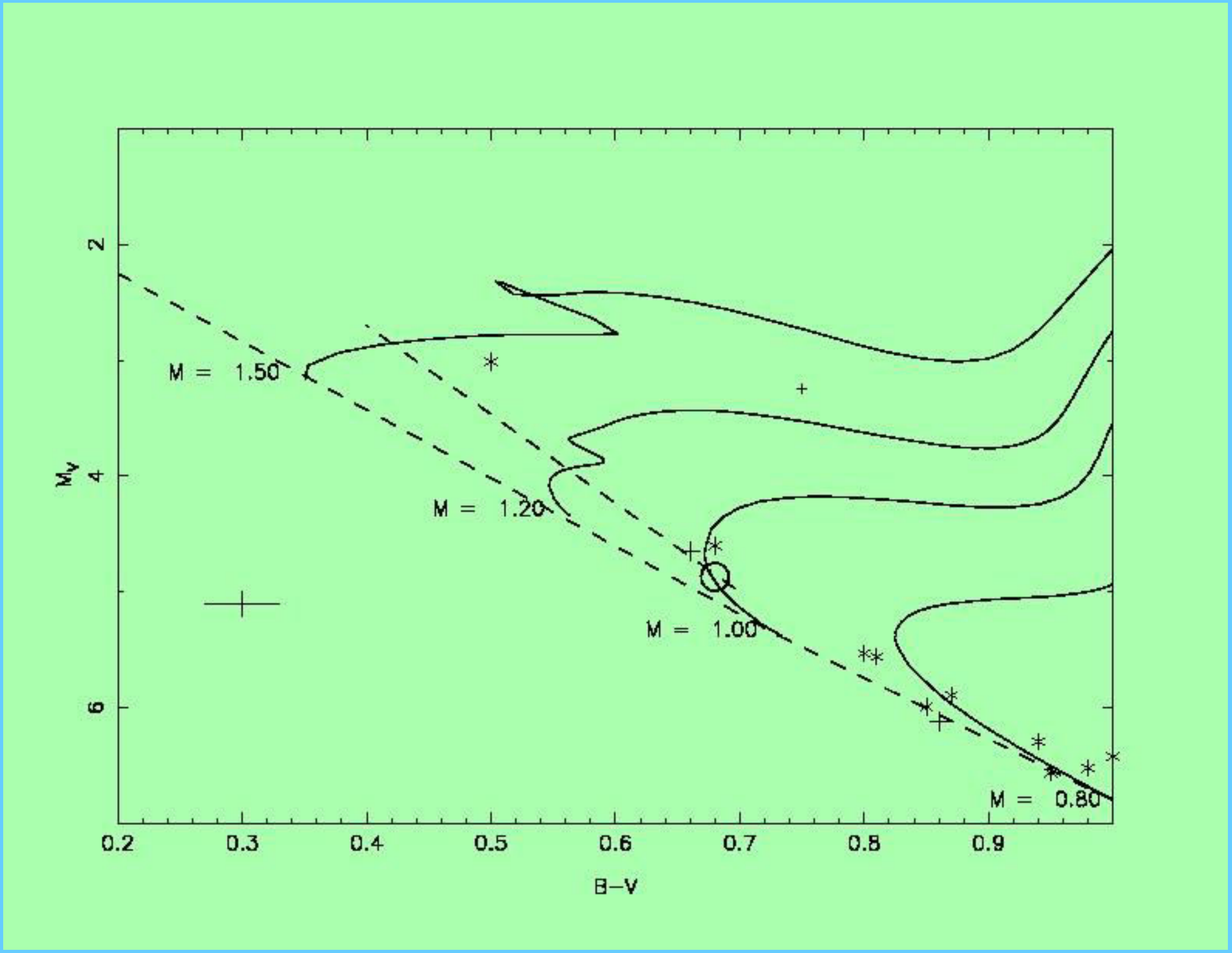
Inactive Mt.Wilson MS-stars (S < 0.17, near basal) over Z=0.02 evolution tracks, now adjusted for metallicity-differences:
All these stars are over 50% MS-lifetime (- -), most over 75%!
Note: NO evolved/inactive stars < 1 M_sun, age-limited.....



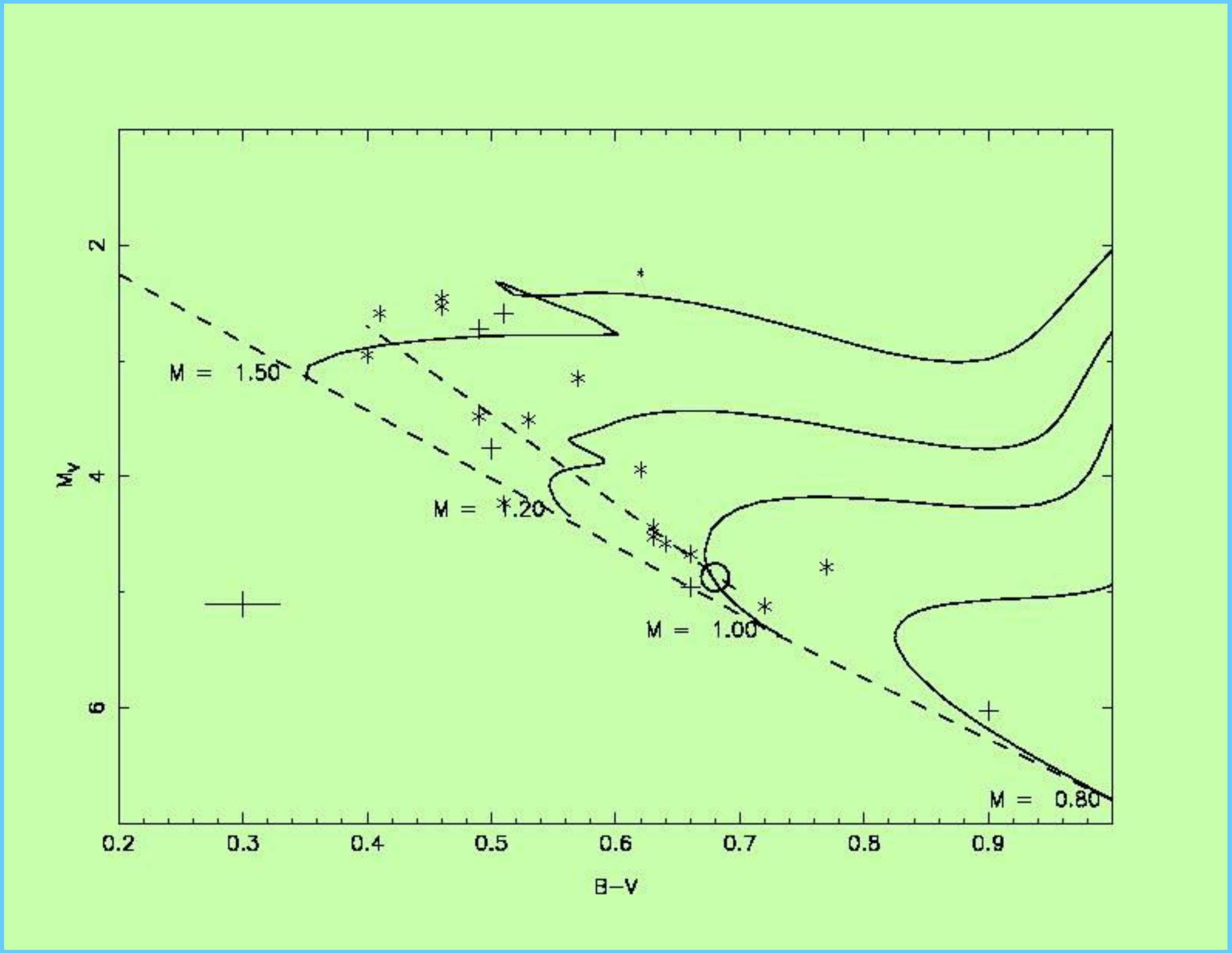
Higly active Mt.Wilson MS-stars (S > 0.25 ... 0.5), Z-adjusted, over Z=0.02 evolution tracks on MS: Very young, scattered around the ZAMS (no surprise)



Moderate, cyclic Mt.Wilson MS-stars (0.17<S < 0.25), Z-adjusted, over Z=0.02 evolution tracks on MS: Surprise: mostly less massive than the Sun!! (~50% MS-lifetime)



Moderate, irregular Mt.Wilson MS-stars (0.17<S < 0.25), Z-adjusted, over Z=0.02 evolution tracks on MS: Evolved between 50% and 75% of their MS-lifetime



Comparison with theory of magnetic breaking:

Reiners & Mohanty (2012, ApJ 746) find a relative intrinsic braking efficiency for the angular momentum of MS-stars of

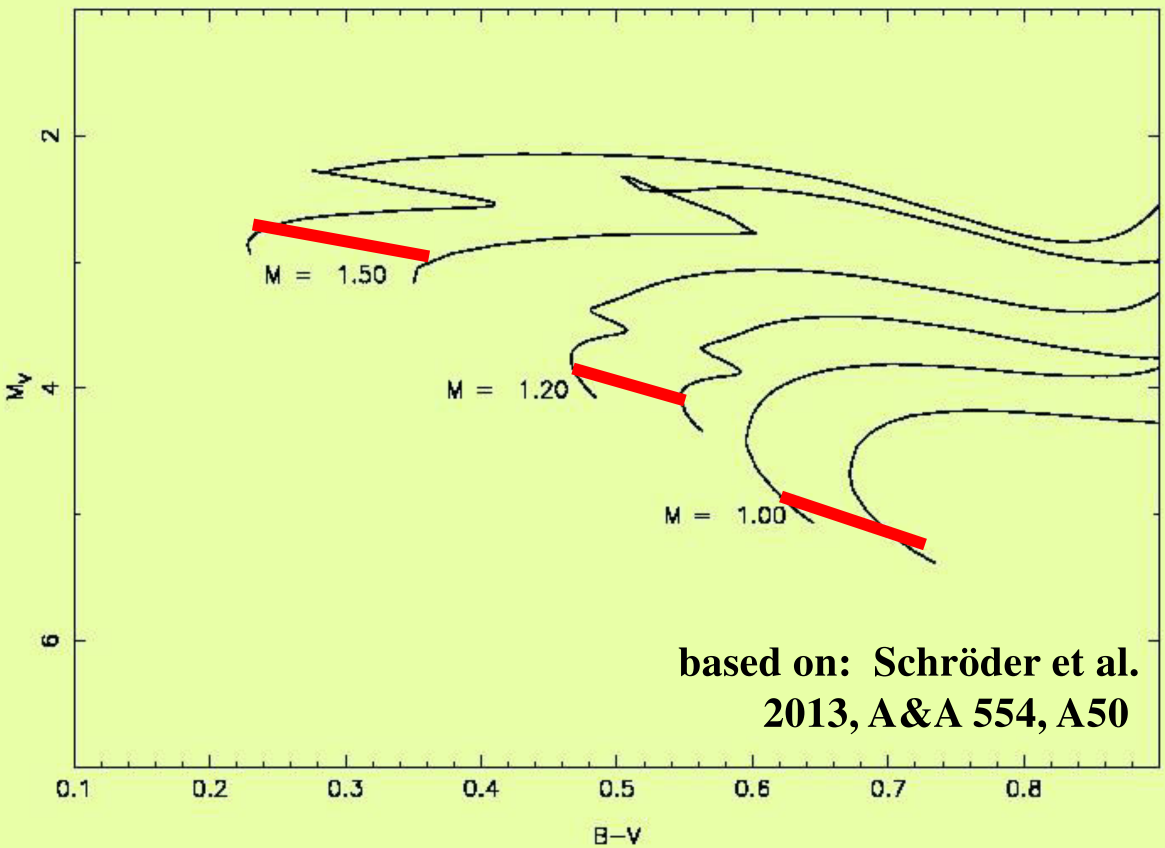
$$dJ/J \sim R^{16/3} M^{-2/3}$$

Since on the MS (solar-type stars) we find $R \sim M^{0.7}$, and the decay-time tau ~ $(dJ/J)^{-1}$, this yields

$$tau \sim M^{-3} \qquad \sim tau\_MS\ !$$

Conclusion: ***The solar activity cycle is at its stability limit by BOTH, advanced evolution and by the mass of the Sun (empir. upper limit)***

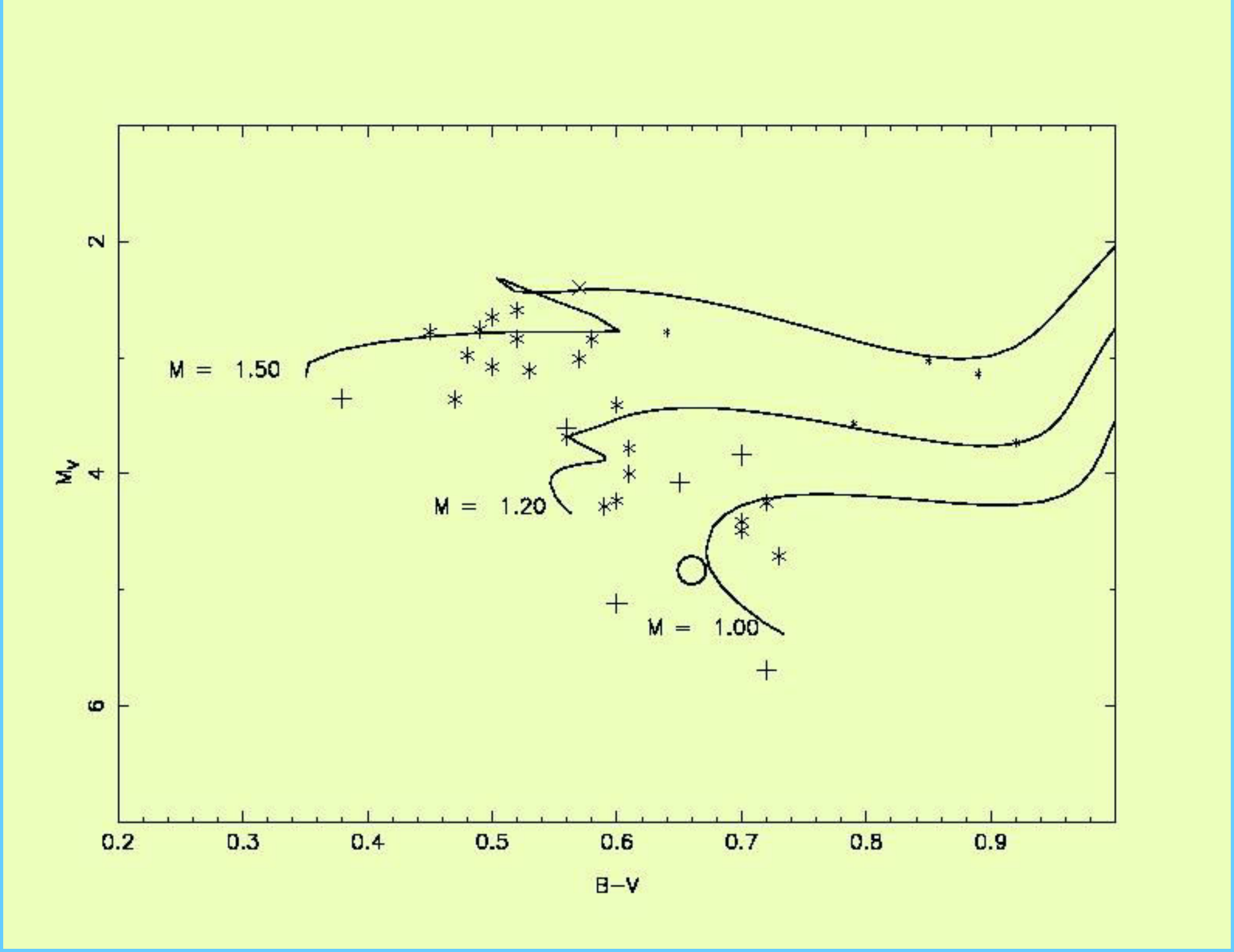
Evolution tracks for Z=0.02 (left set) and Z=0.01 (right):
Metallicity does matter for HRD position on the MS !
Holmberg et al. 2009 & Geneva-Copenhagen ubvy photom.:
Mt. Wilson stars occupy a range of Z ~ 0.005 ... 0.04 !



based on: Schröder et al. 2013, A&A 554, A50

The stellar perspective of solar activity:

Inactive Mt.Wilson MS-stars (S < 0.17) over Z=0.02 evolution tracks: more evolved than the Sun (circle)!



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