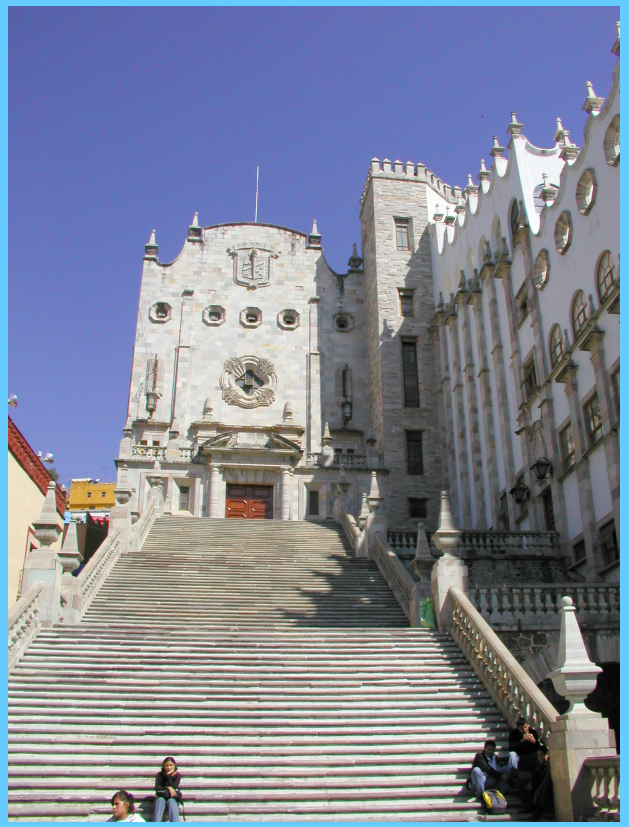
Magnetic activity of giant stars: no early retirement

Klaus-Peter Schröder **Guanajuato, 7th TIGRE WS Nov. 7, 2019**

with work from Marco Mittag, Jürgen Schmitt, Dennis Jack, Abigali Rodriguez



I) Stellar activity: why does it matter??

- it affects life in habitable zones!
(ex.: active cool dwarf stars, young Sun)

- to understand solar activity and the solar-terrestial connection in a wider context and over the solar evolution

II) X-ray view: Is cool giant activity fading away?

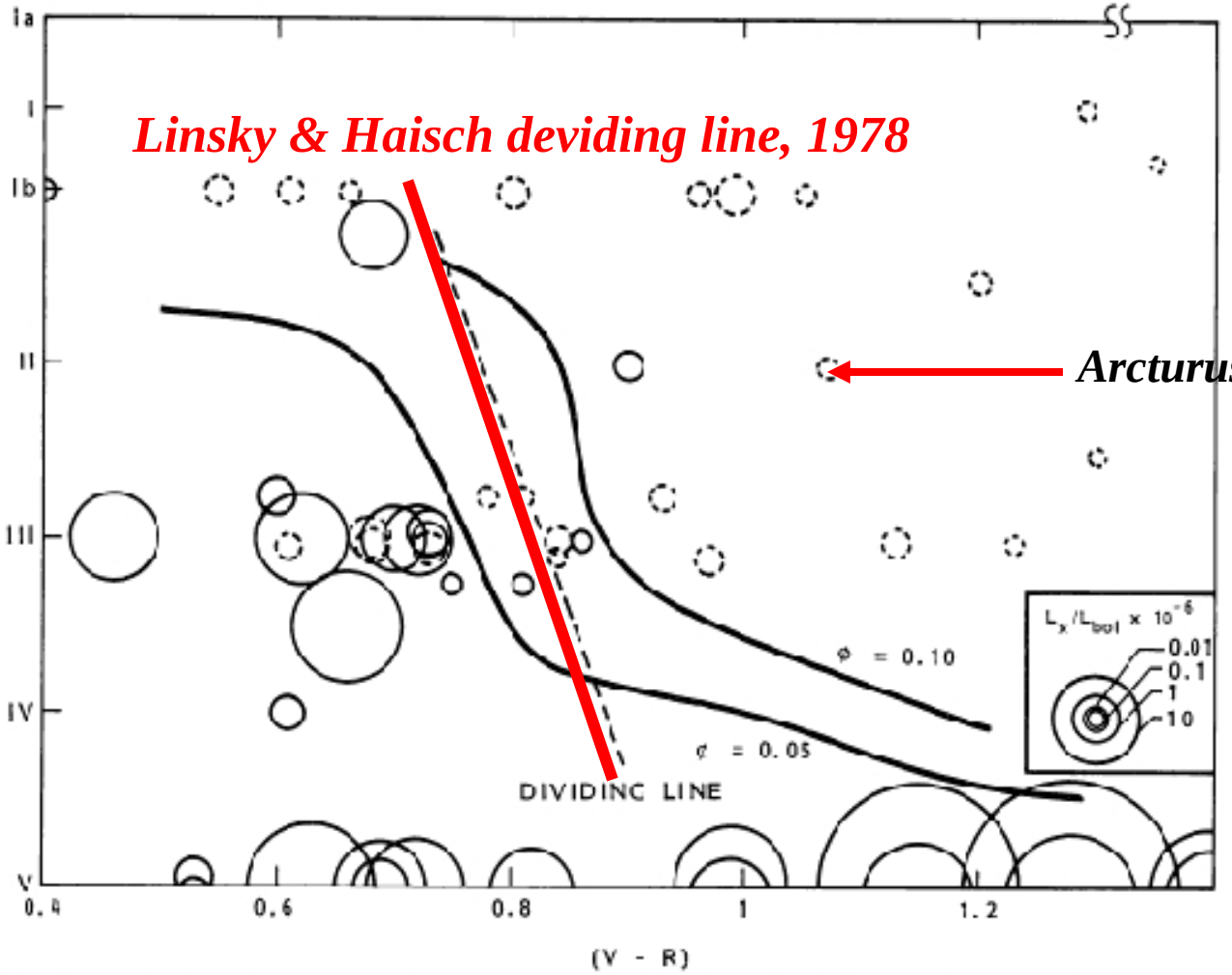


FIG. 2.—An H-R diagram showing the presence (*solid circles*) or absence (*broken circles*) of X-ray emission for all the late-type, single stars observed by Einstein. The sizes of the solid circles are proportional to the ratio of X-ray to bolometric luminosity. Note that the main sequence runs along the bottom of the diagram. The Linsky-Haisch dividing line is shown as a straight, dashed line. Contours of constant φ are indicated by the solid lines.

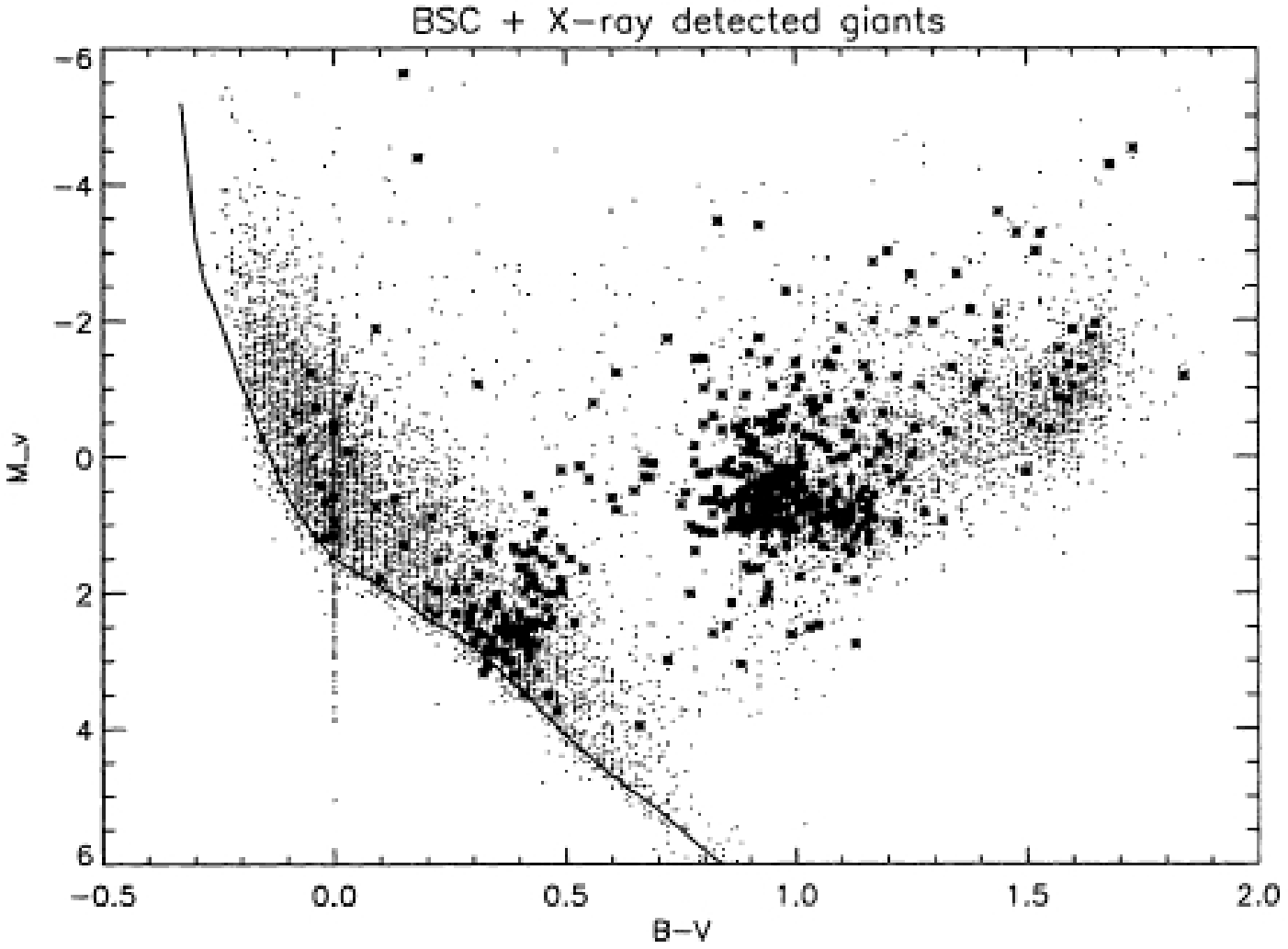
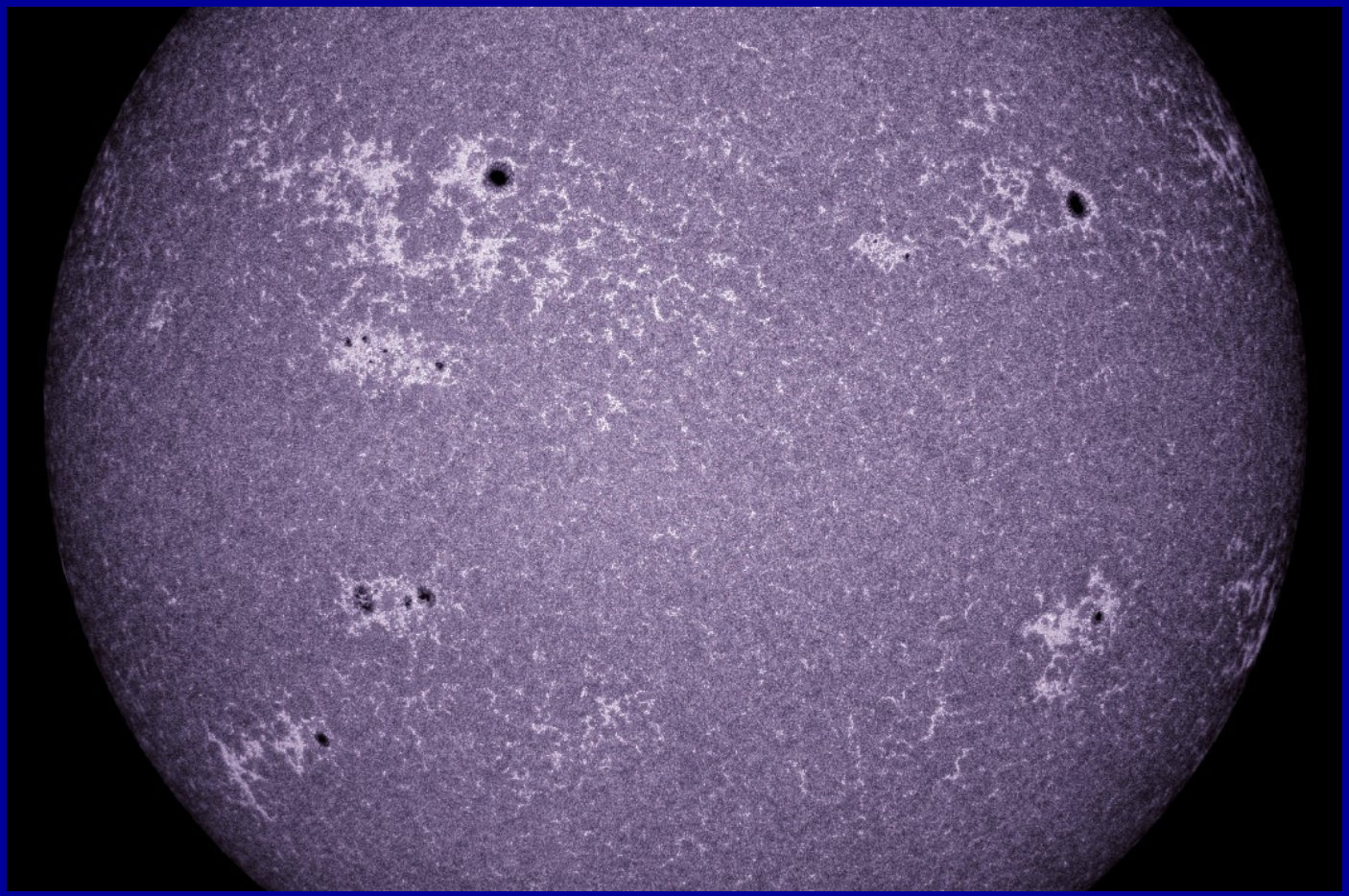


Figure 2. X-ray detected giants of spectral type A to M in the H-R diagram (asterisks). Dots are all Bright-Star-Catalog stars with data from *Hipparcos*. A total of 450 objects was detected in the *ROSAT* all-sky survey. (Diagram supplied by Mathias Hünsch, MPE.)

III) Ca II H&K emission: total account of faculae

Eberhard & Schwarzschild 1913 discover stellar Ca II H&K emission in Arcturus and conclude that this giant star must have active regions like the Sun (but this is not so simple...).

In 1932, O.C. Wilson started work on Ca II H&K emission of stars

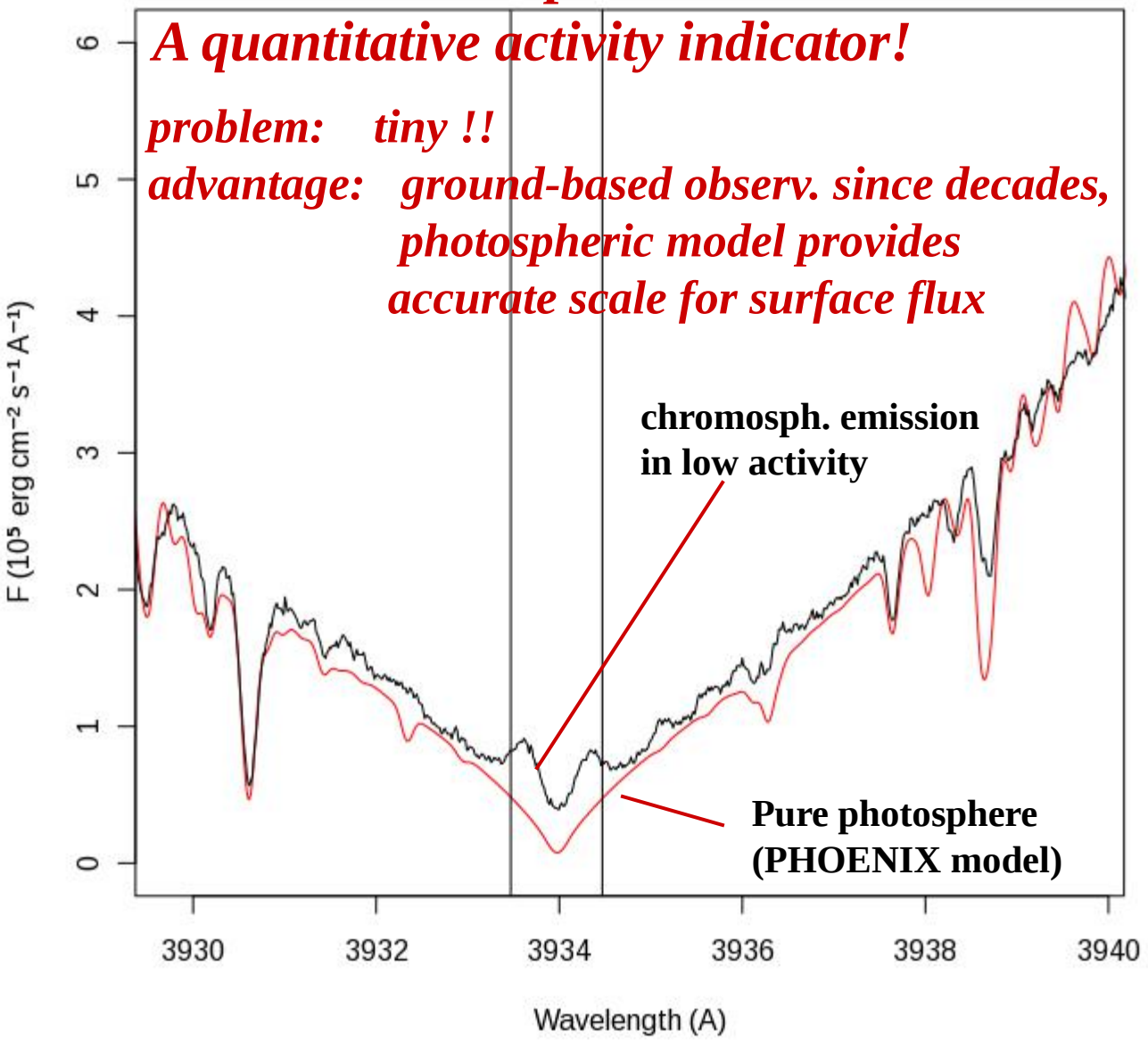


Ca II K chromospheric line emission

A quantitative activity indicator!

problem: *tiny !!*

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



Our pet project - to continue O.C. Wilson‘s work

[KPS & J. Schmitt, Violeta Gámez Rosas, Vivian Grisell Gómez Trejo, Dennis Jack, ...]

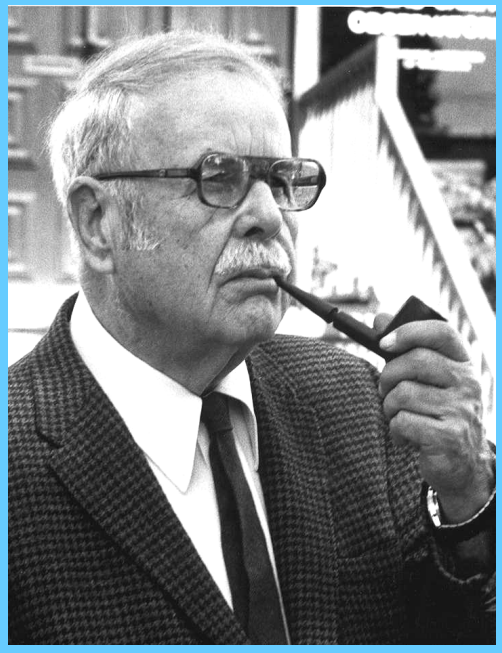
- ***monitoring the Ca II K chromospheric emission variability***

- ***sample: over 40 cool giants and >100 solar-type stars brighter than 7 mag, spectral type G-M, of different activity degrees***

- ***also: „the Sun“ (moonlight spectra), compared with MS F-K stars***

- ***duration: Wilson team covered 1962 to 1992, only some follow-up by Lick and Lowell Obs. (Wright, Hall, ...), using OC‘s „S-index“***

- ***we now wish to add 2 more decades (at least! :-) to probe for types of dynamo: mono-periodic, multiperiodic, chaotic?!***



=> What is the evolution of stellar activity??

The Mt. Wilson S-index to measure the CaII line emission (relative to the adjacent pseudocontinua):

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

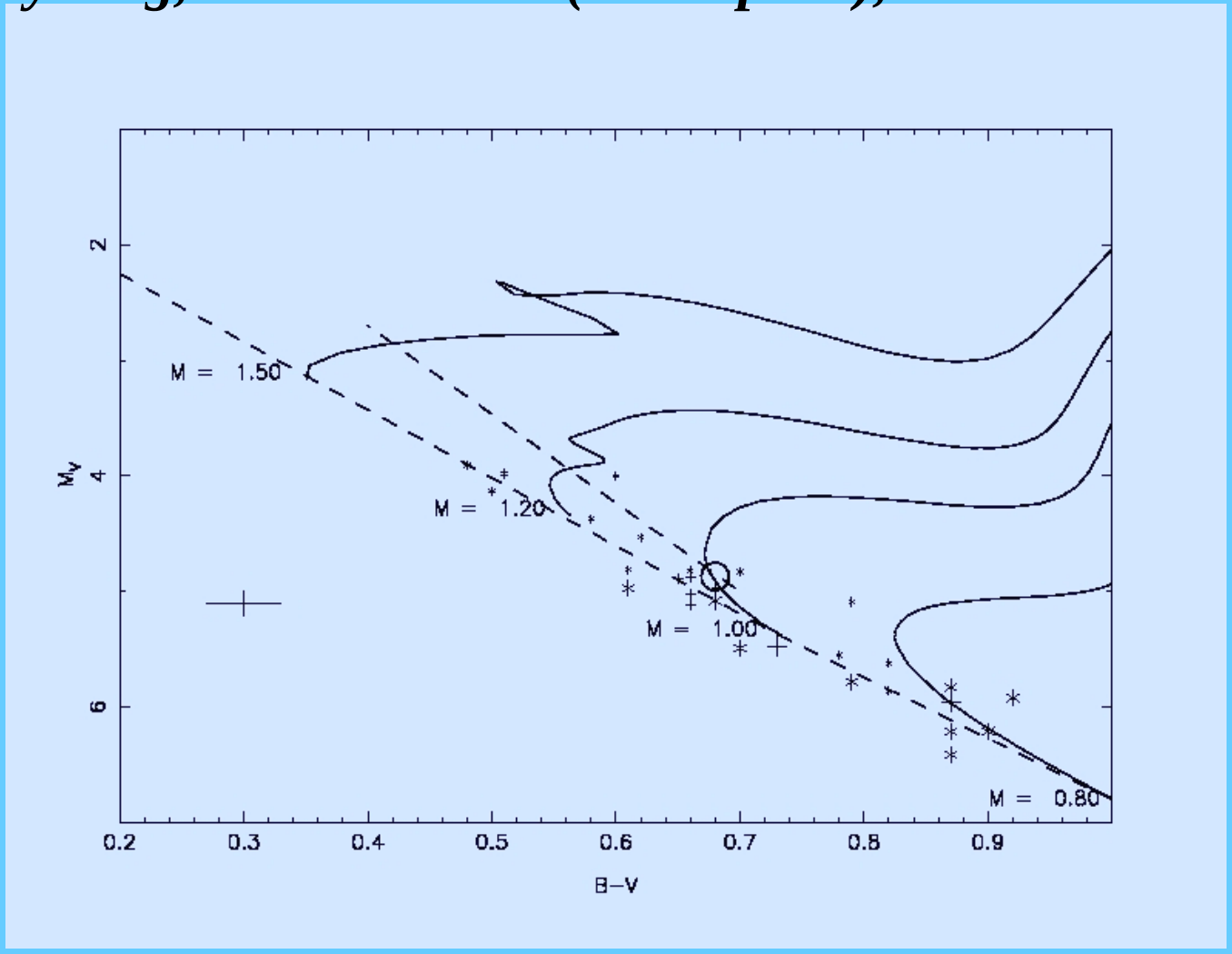
1 Angstr. wide line cores H&K / 20 Angstr. wide preudocontinua, as such S is independent of transparency. Calibration by standard stars.
=> Hence, S is of the order of the line core intensity over cont. intensity
Modern spectra: const. ~ 19, calibration by same set of stars as OCs

Advantages: S is independent of sky quality and calibration lamps, best detection of even the smallest emission in the CaII core, long time-line available (since 1960ies!!).

Disadvantages: - S does not directly compare with physical line fluxes!
- for supergiants, 1 Angstr. window is too narrow!!

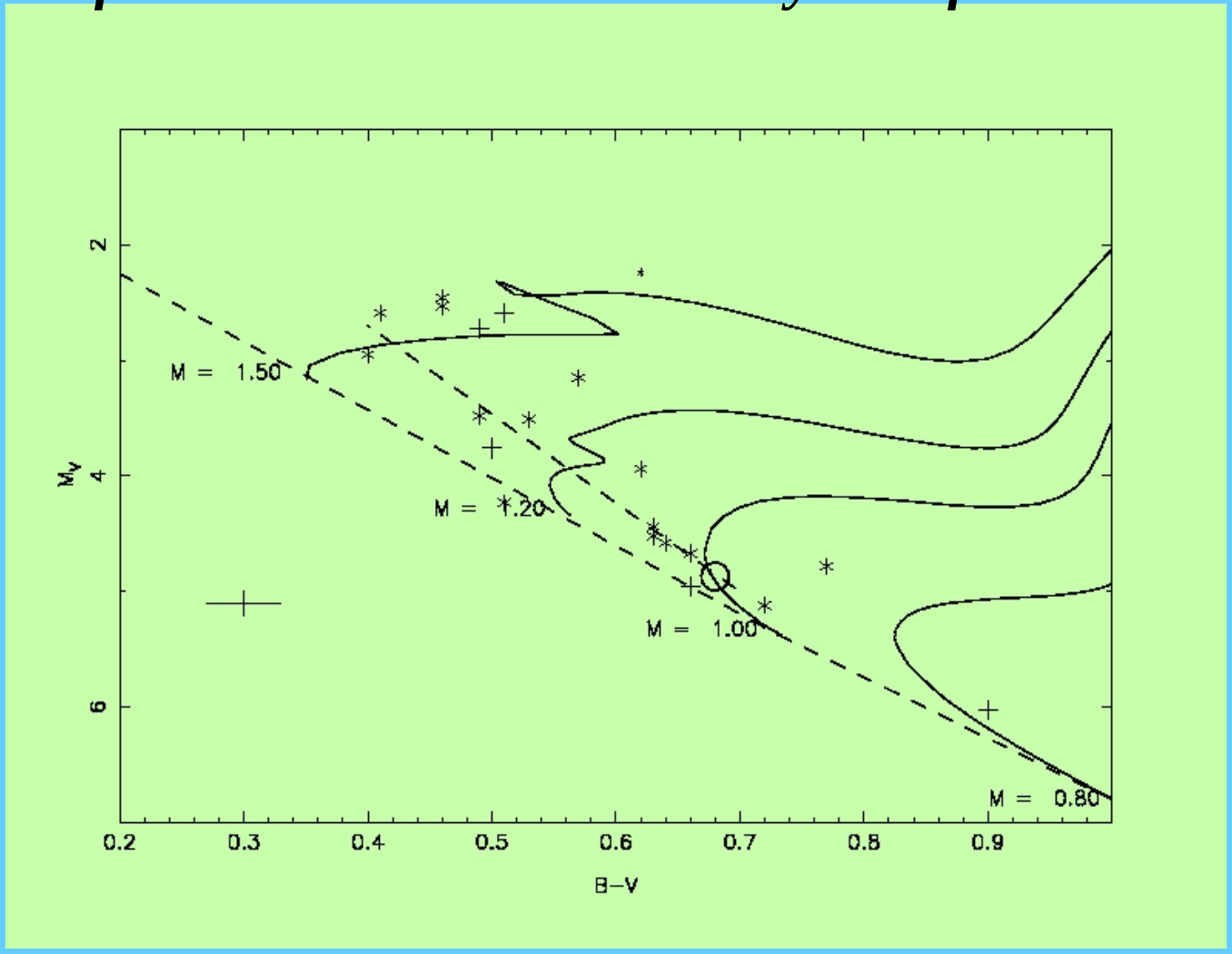
IV) Activity loss on main sequence – and then?!

Higly active Mt.Wilson MS-stars (S > 0.25 ... 0.5),
Z-adjusted to Z=0.02 evolution tracks on MS:
Very young, around ZAMS (no surprise), P-rot=5-10 days



Moderate Mt.Wilson MS-stars w/o long cycles (0.17<S < 0.25), Z-adjusted to Z=0.02 evolution tracks on MS, half to full MS-age mostly more massive than Sun, P-rot= 15-40 days

Note: we found some F-stars to have cycles of 3-8 months!



Summary from O.C. Wilsons main sequence stars:
stellar activity decreases with relative MS age
=> magnetic braking (Skumanich 1972) is evident on MS, but related to relative MS age

X-ray detections (ROSAT 1990ies) then show that activity is strongly revived in Hertzsprung gap, why?

Asteroseismology with Kepler on HG stars recently has proven that there is a fast core spin-up

V) Magnetic activity of K giants (reaching central Helium burning)

general considerations

Should we expect a dynamo very different from the one of the Sun? - because:

- *convective envelopes go huge, so that magnetic field created near its bottom cannot rise to photosphere intact (shown by Schüssler 1998)*
- *differential rotation occurs on radial scale, in Sun it is latitudinal*

A bit of history:

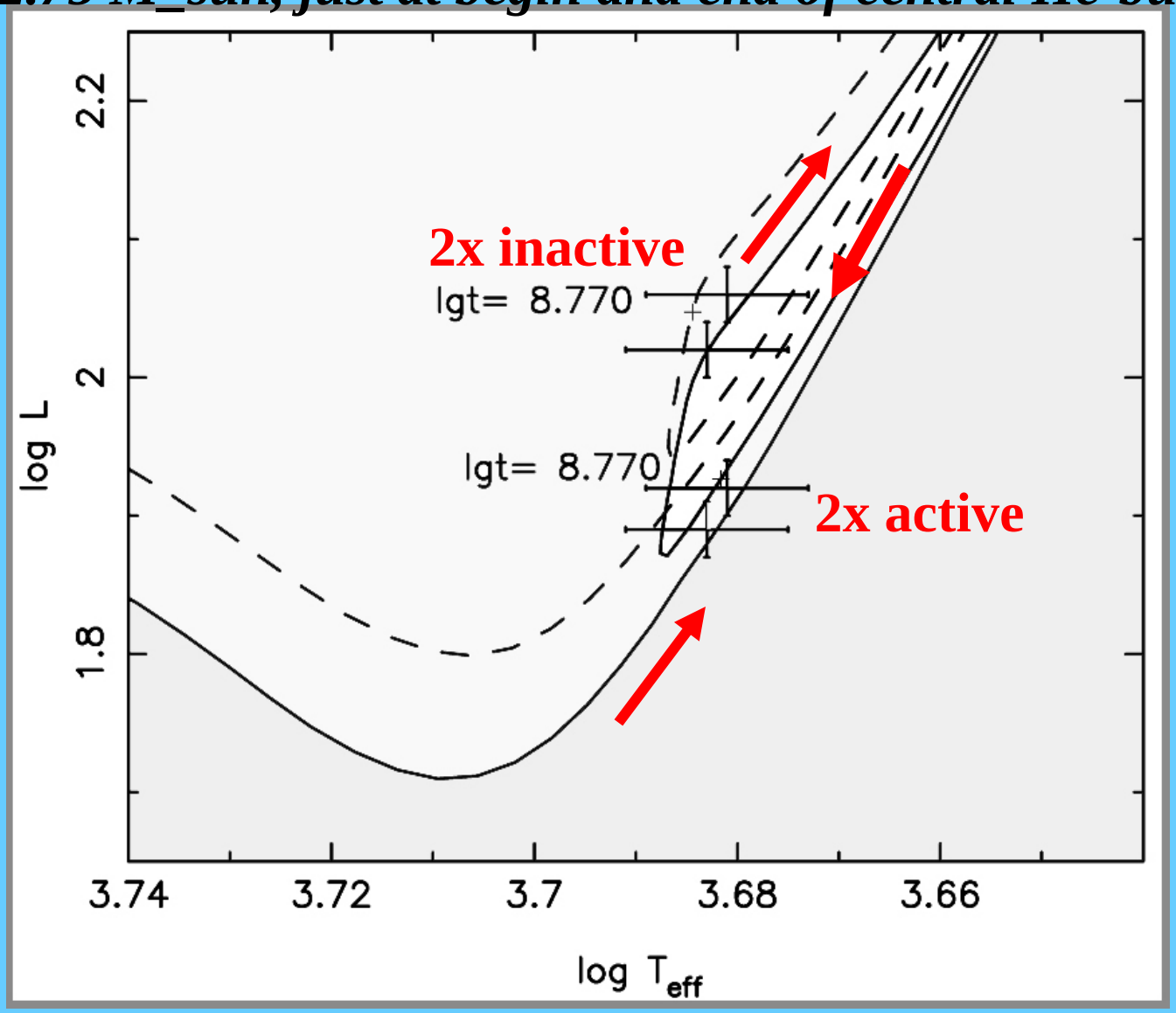
Skumanich 1972: activity is age-related

O.C. Wilson already knew then, that 2 of the 4 Hyades K giants are active, two are inactive. ...so, he rightfully asked (priv. comm. via Dieter Reimers):

„How come, when they are exactly the same age??“

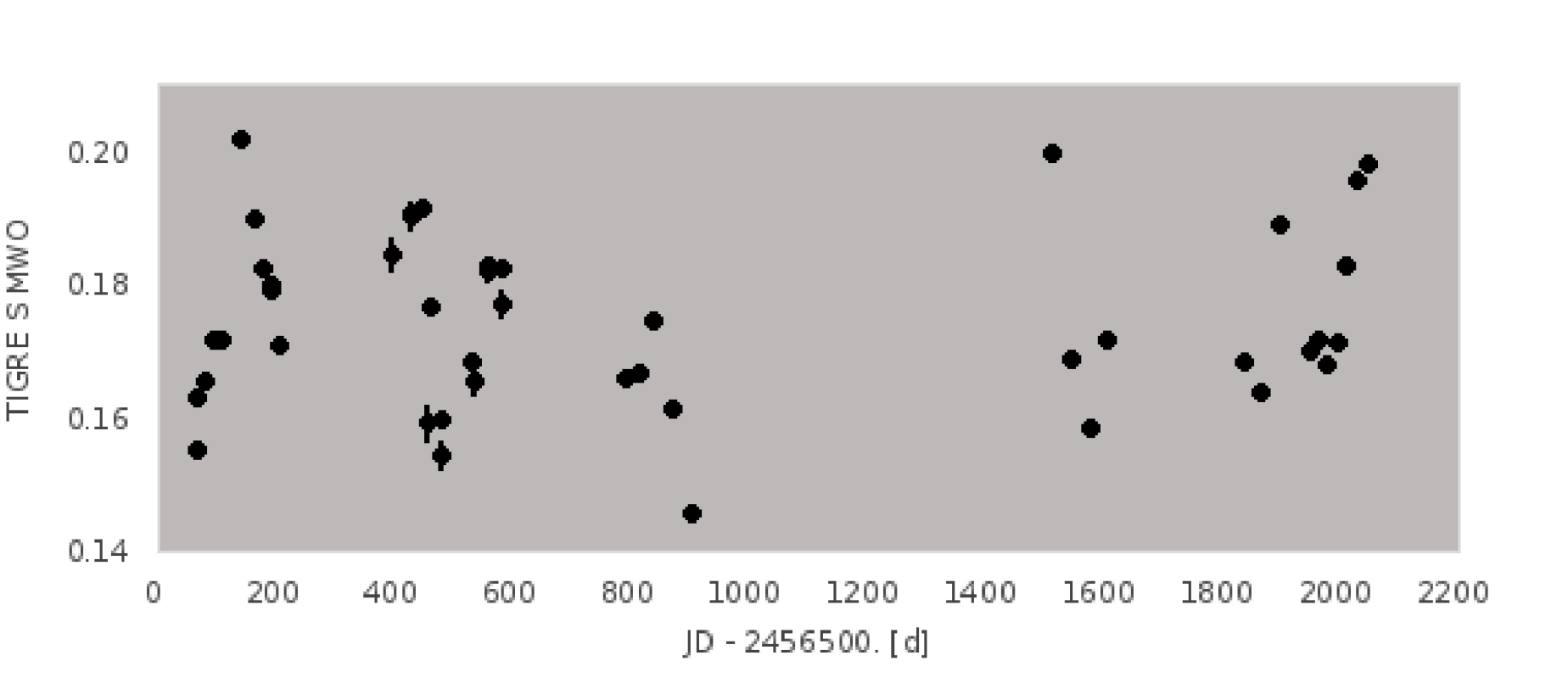
Evolution tracks of Hyades K giants:

central Helium burning (blue loop) phase at age 588 Myrs, but with 2.62 /2.75 M_sun, just at begin and end of central He-burning



Mt. Wilson and TIGRE S-data:

example HD27371: signatures of rotation and activity cycle



eye: fractions of P=150...200 d signatures

but: 2 regions 30-60° in L apart prolong wiggle

⇒ analysis: max. probability ~ 140 days rotation

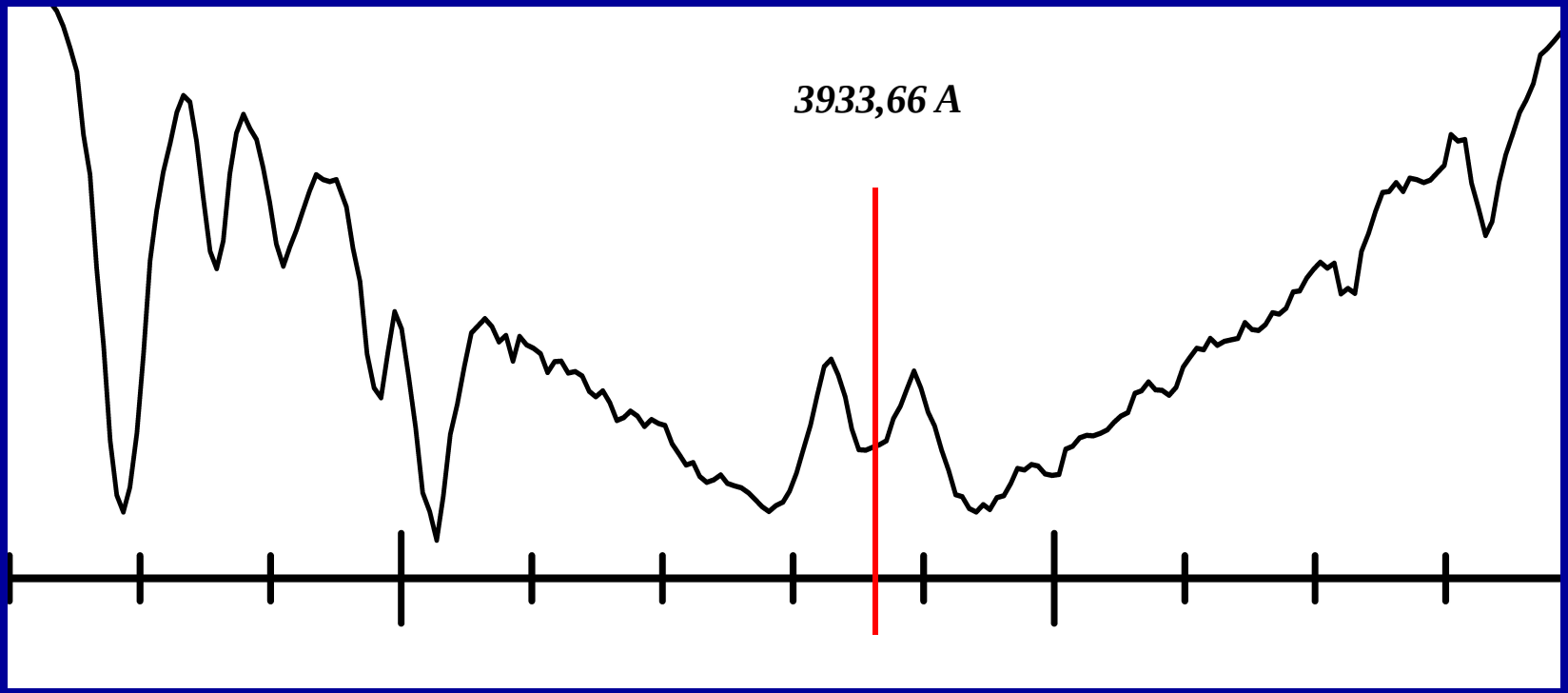
1) *The 4 Hyades K giants show that activity is higher than solar at the beginning of central He-burning, but goes inactive towards the end of that phase => magnetic braking again, here*

2) *Surprise: the activity of the 2 active Hyades giants looks like the solar with cycles of ~15 yrs. Despite 1/100 the gravity and huge convective envelopes....*

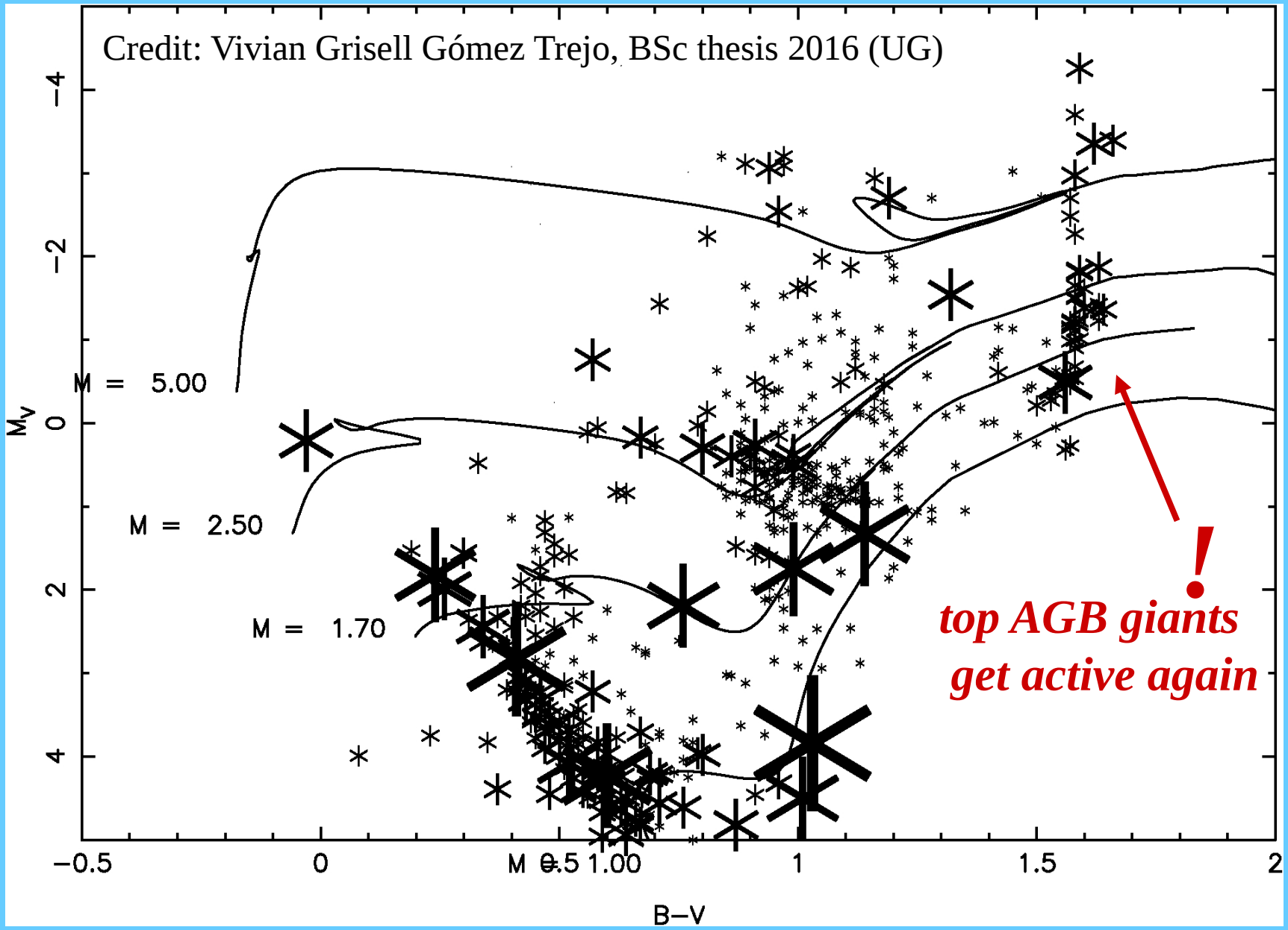
3) *at same activity level (Rossby number), active K giants rotate 10x slower => convective turnover*
time is 10x longer than in solar dynamo-active layers

VI) Outlook: and the more evolved giants?

Eberhard & Schwarzschild 1913, Potsdam: Arcturus has Ca II K emission, „is active“, but in fact it is here mainly due to better contrast



S-values Duncan et al. 1991 for stars with parallax > 10 σ



VII) Conclusions:

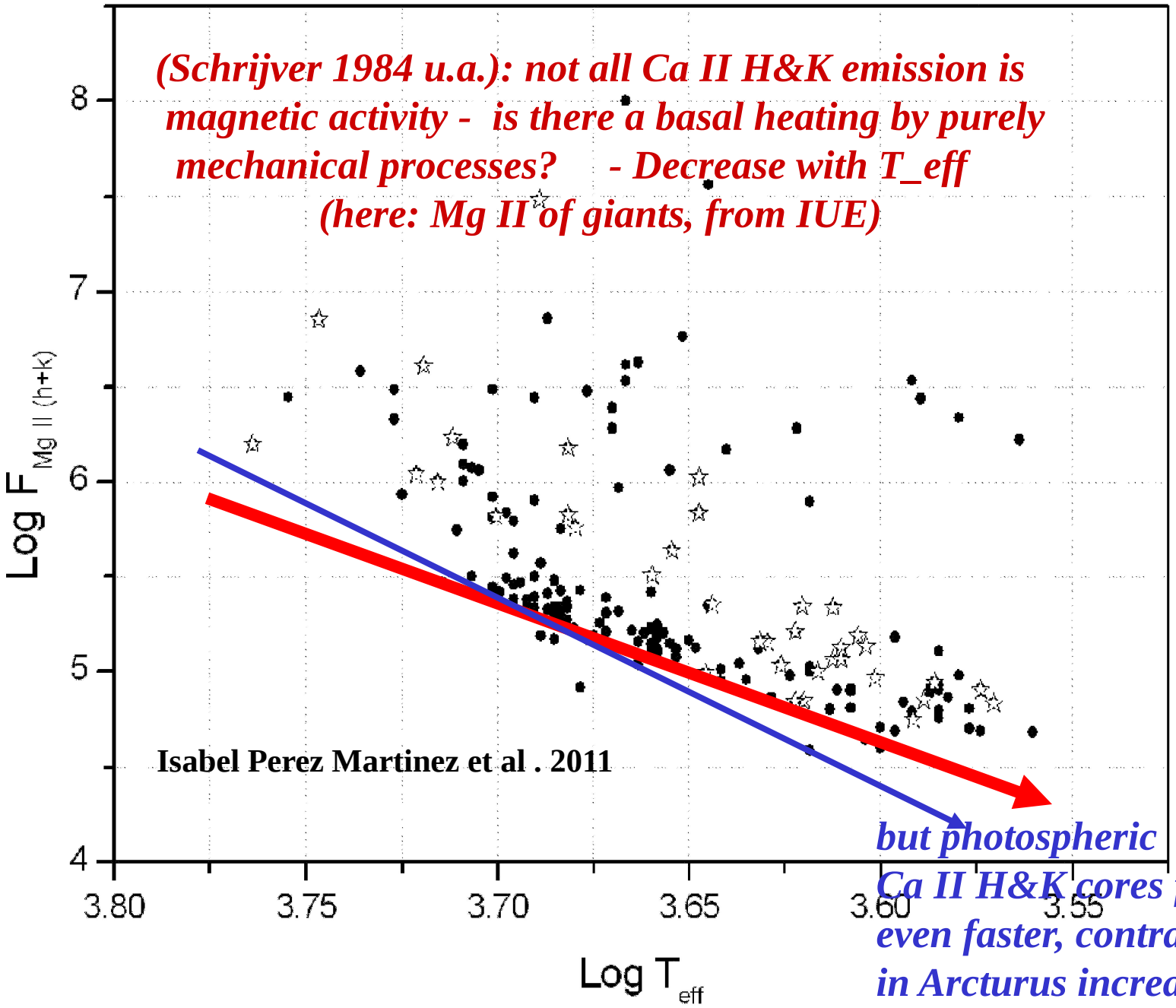
1) In phases of a stable core (MS, K-giants: central H-burning and He-burning), activity decreases by magnetic braking

2) But in phases of core contraction magnetic activity increases again - and fastest stellar evolution (HG, large mass) coincides with the strongest rejuvenation!

3) Is this the action of core spin-up?!
=> get to know dynamo, get rotation rates..


but much work remains to be done..
Gracias!

The discovery of Basal chromospheric flux

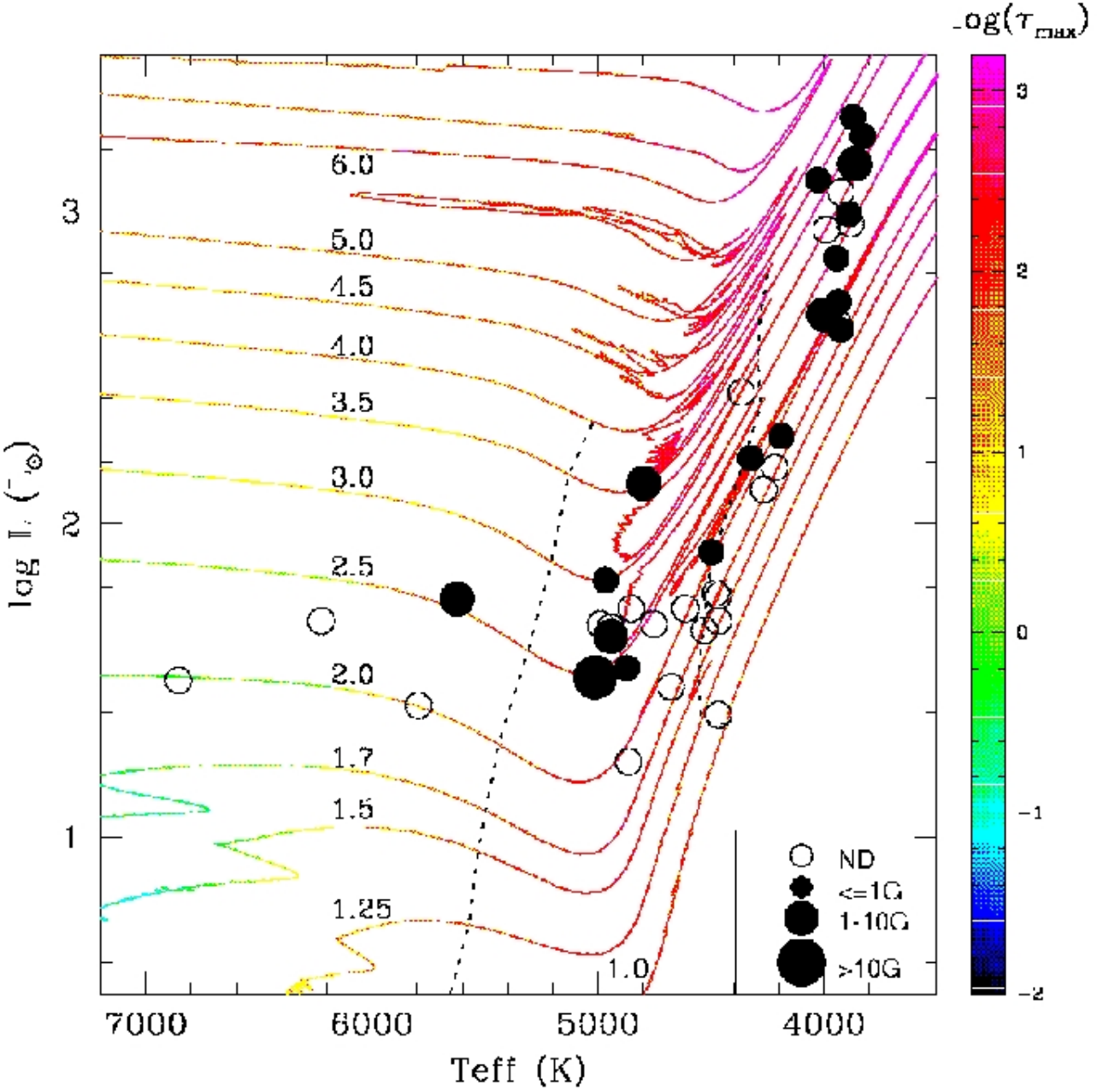


By 2015: magnetic field detections until up the AGB!

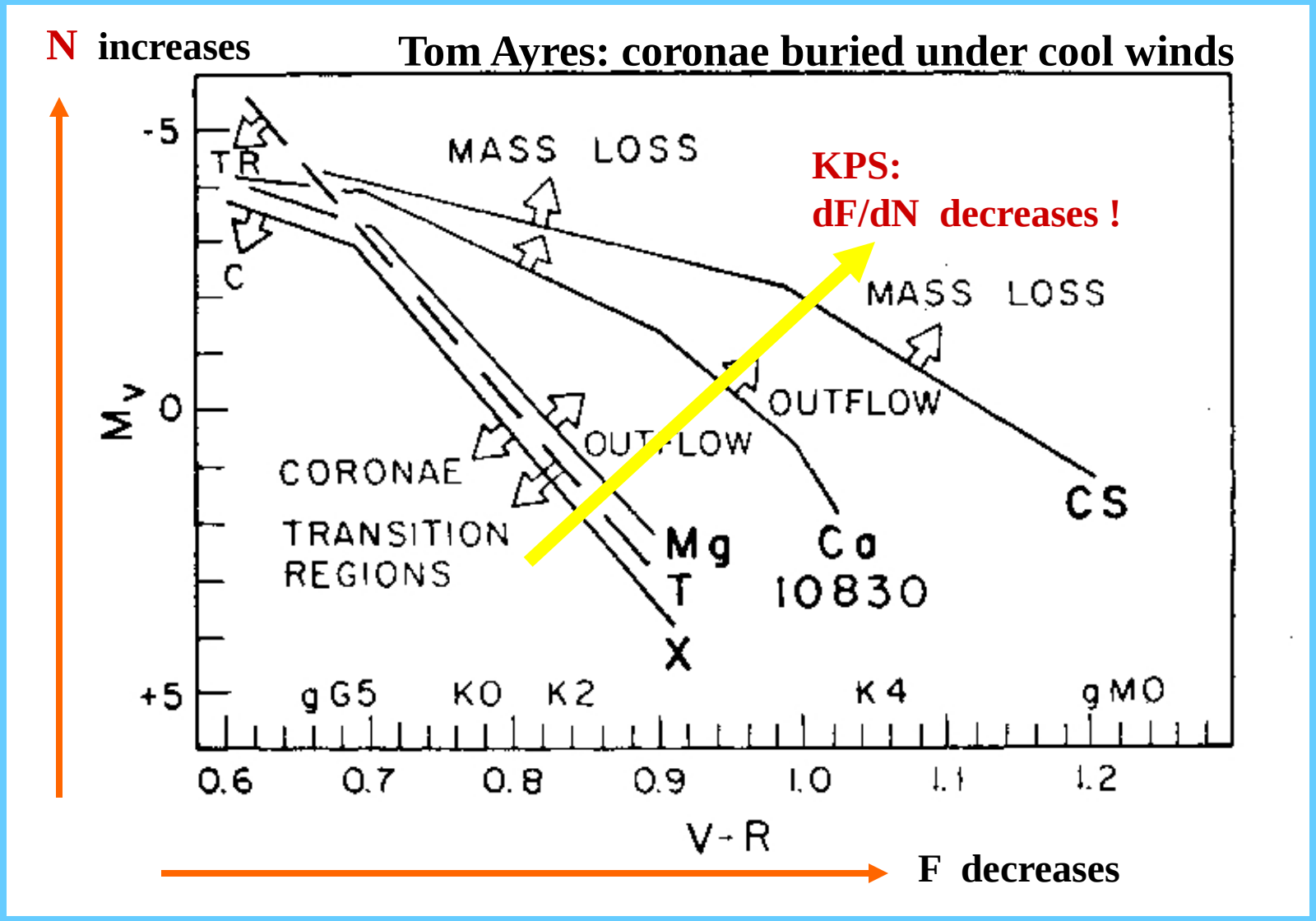
=> giant activity is NOT going into retirement !

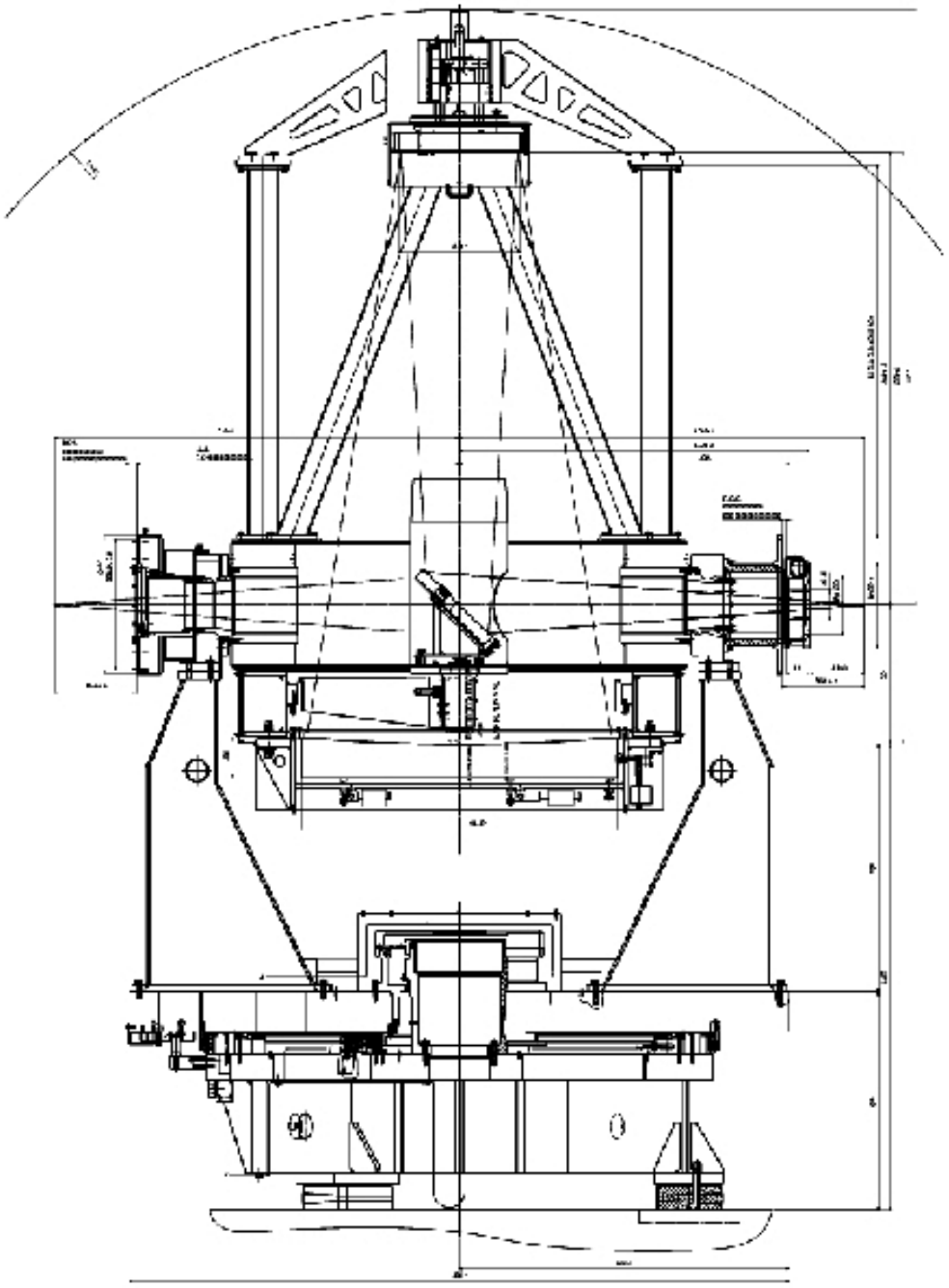
(consider Arcturus as a little active)

Auriere et al., 2015



..... BUT: missing a corona is not (only) activity-related





HRT: Technical Data

Company: Halfmann, GER

Mount: Alt-Az

Weight: 15 tons

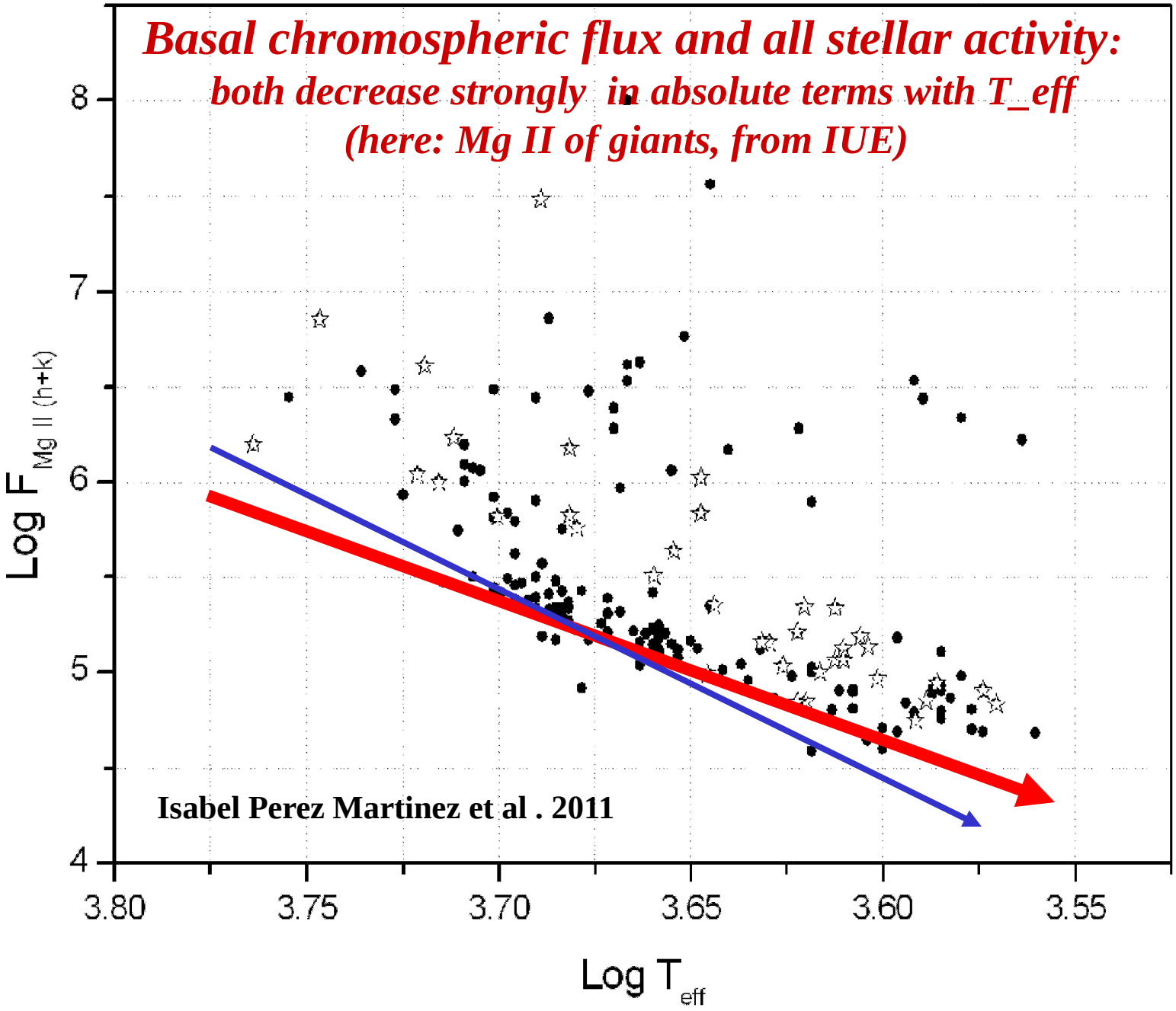
Optics: Cassegrain-Nasmyth, Zerodur (!), 1.2m f/8

Field of view: 7‘

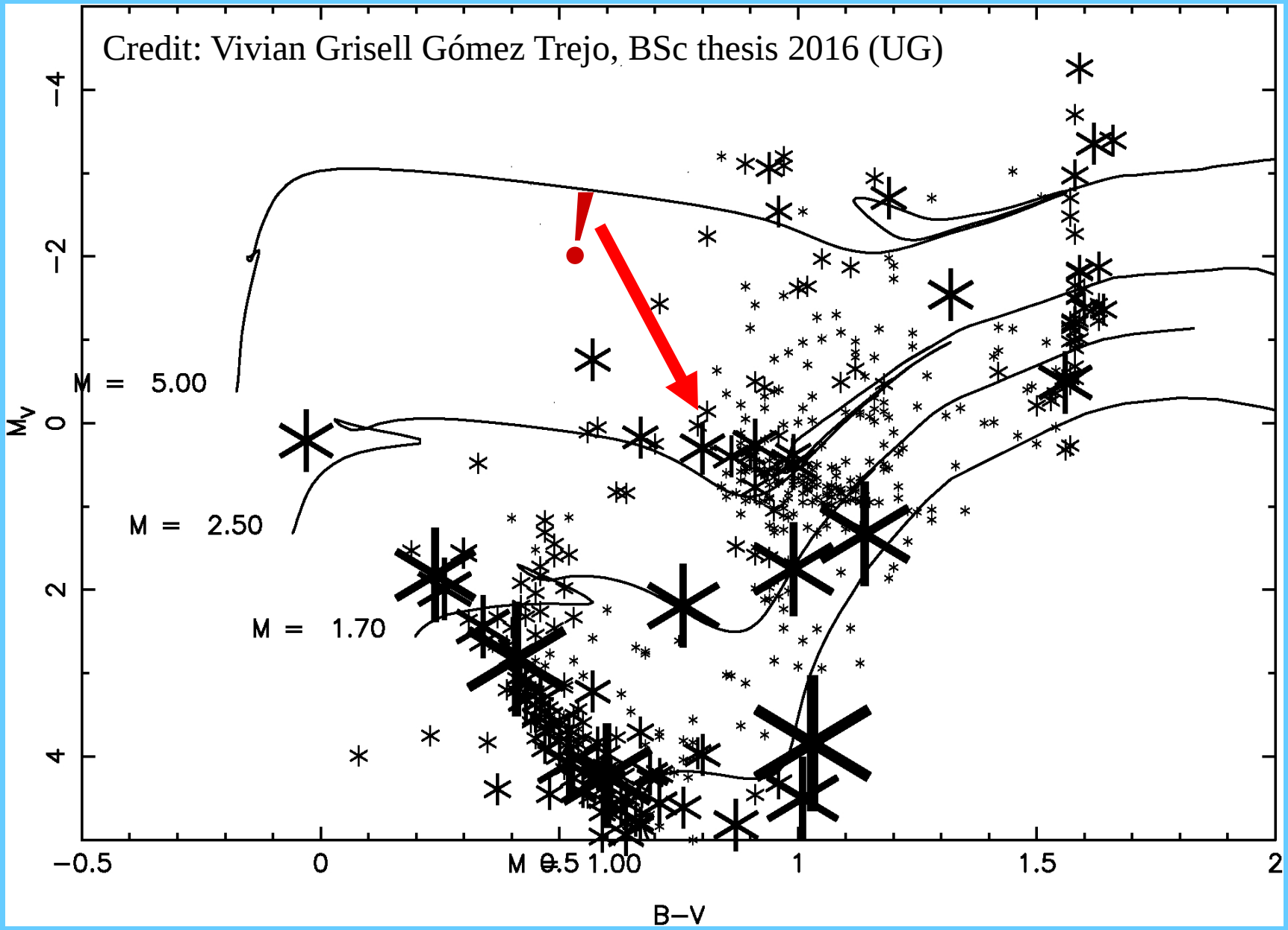
Tracking accuracy: ~0.5“ (unguided !)

Pointing accuracy: ~3“

See: Schmitt et al. 2014, AN


Basal chromospheric flux and all stellar activity:
both decrease strongly in absolute terms with T_eff
(here: Mg II of giants, from IUE)
Isabel Perez Martinez et al . 2011
Log F Mg II (h+k)
Log T eff
8
7
6
5
4
3.80
3.75
3.70
3.65
3.60
3.55

S-values Duncan et al. 1991 for stars with parallax > 10 σ

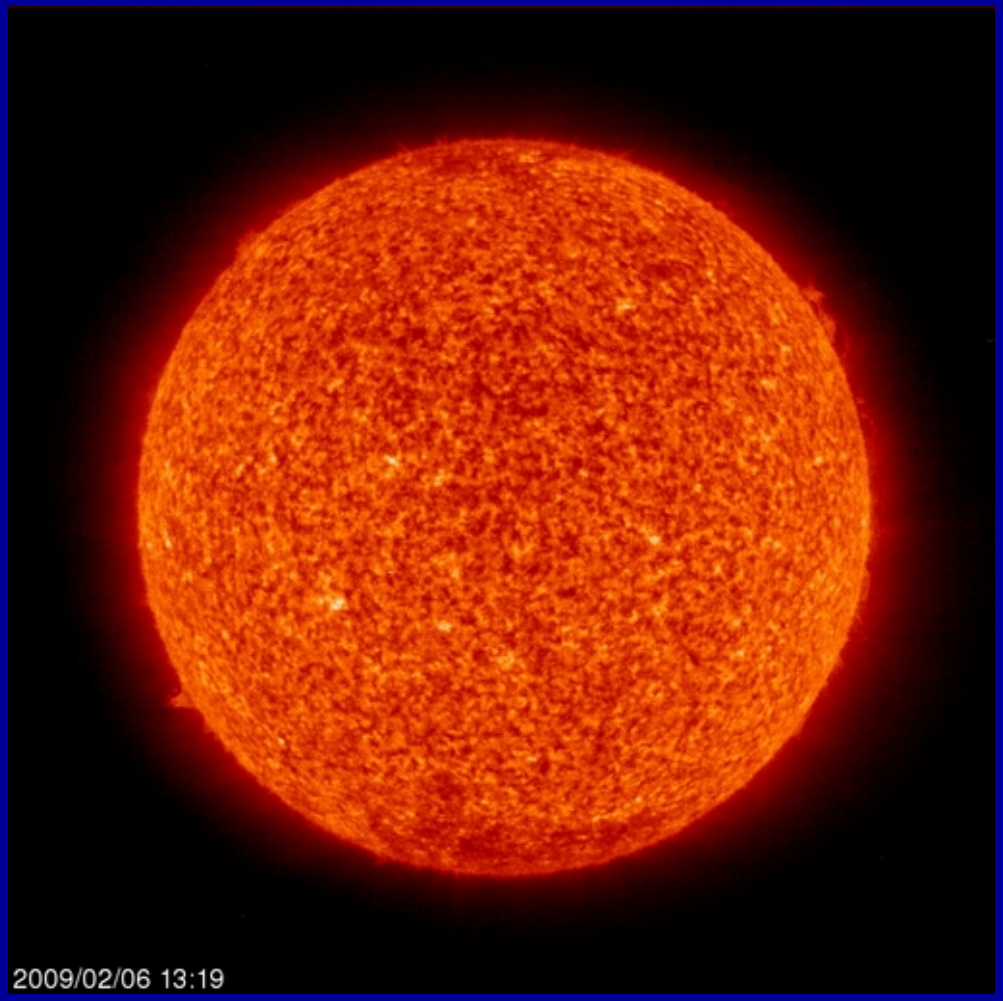


Science-Philosophy of TIGRE:

- *dedicated: spectroscopic monitoring fills a strategic gap*
- *autonomous, robotic operation: low operation costs, also:*
- *accessible site with many nights sufficient for spectroscopy*
- *almost immediate (24hr) response to targets of opportunity*
- *efficient: automatic data-reduction pipeline and on-line archive for its users => fast observational data for students!*
- *international colaborations (with Univ. Hamburg and Liège) and foreign work-stays available to our UG students*
- *open to colaborations outside the 3 funding universities*

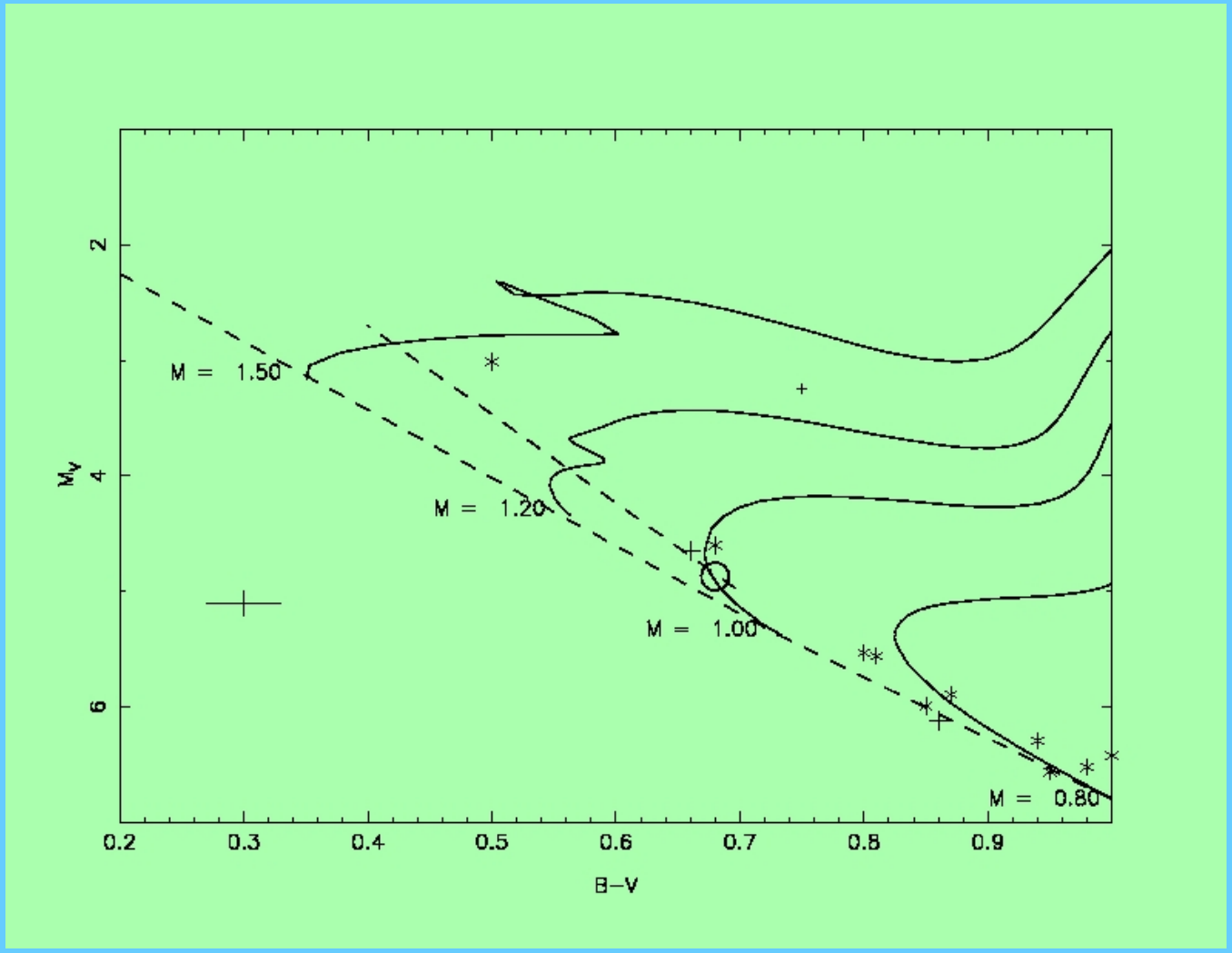
- *key programmes:*
  - *stellar and solar activity monitoring (short- and long-term)*
  - *novae and supernovae monitoring (short- to medium-term)*
  - *very hot stars and binaries (short- to medium term variability)*
  - *exoplanet-hoststars and planet-star relationships*

III) The Sun as a (cool main sequence) STAR

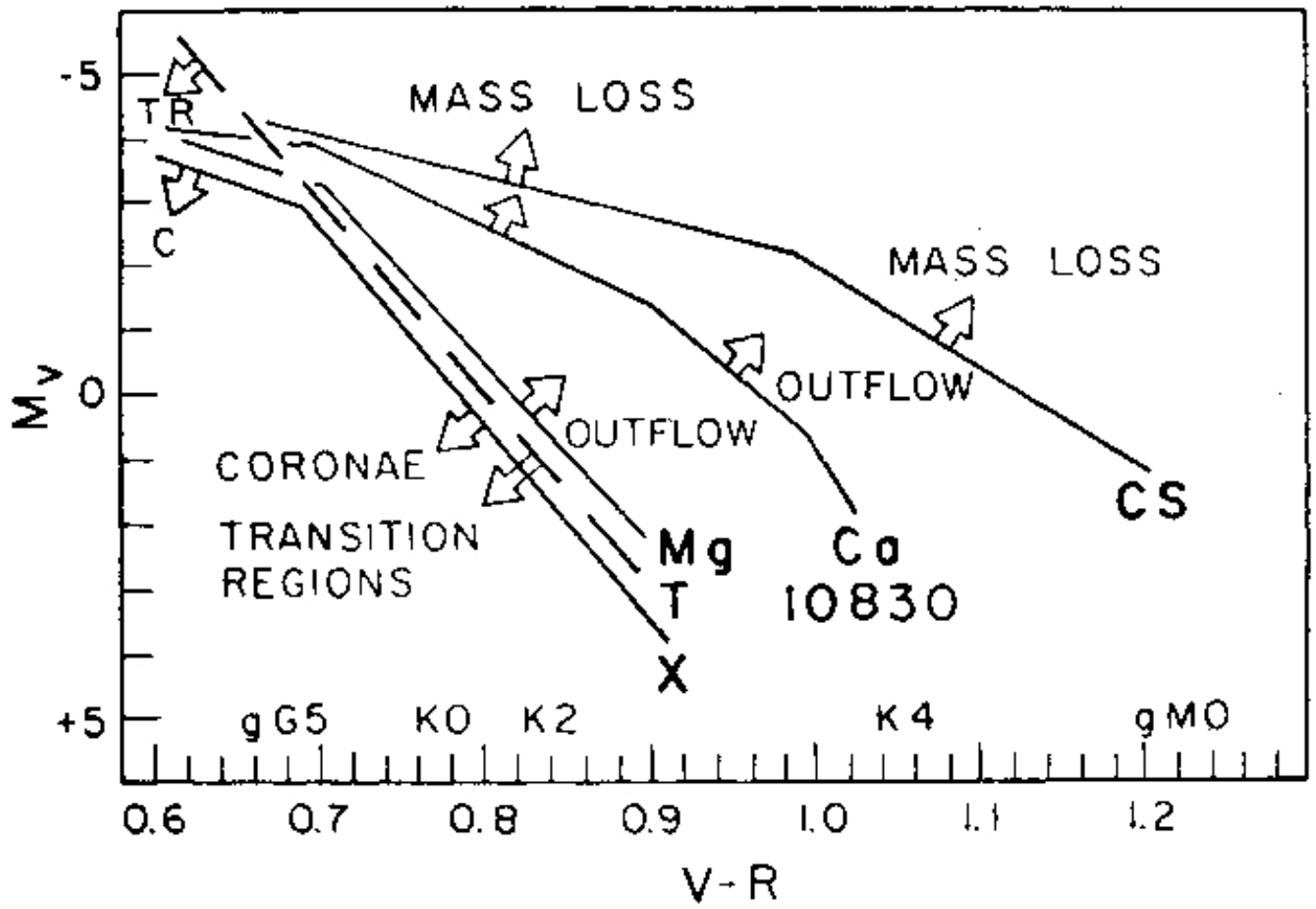


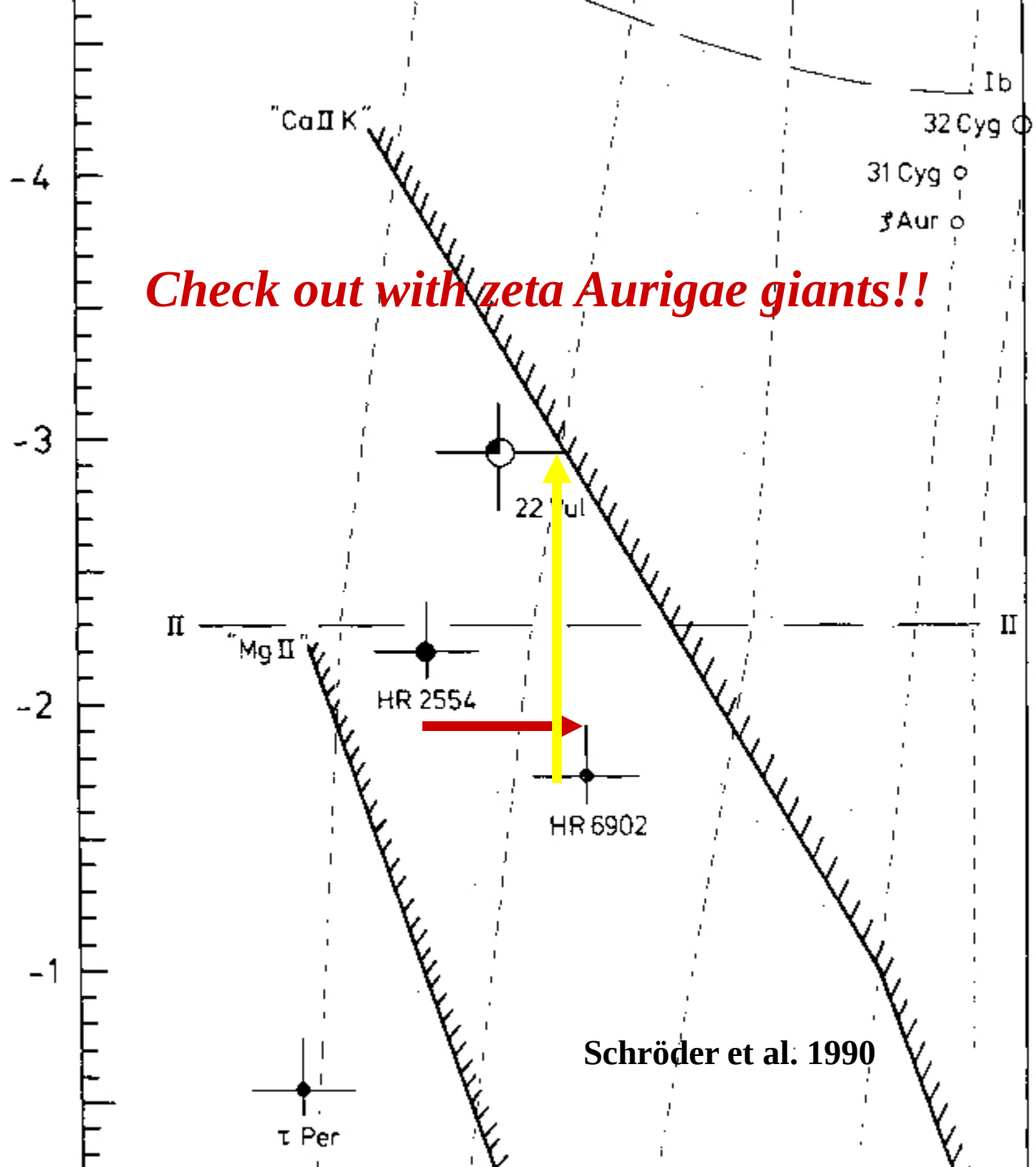
...here on a totally inactive day

Moderate, cyclic Mt.Wilson MS-stars (0.17<S < 0.25),
Z-adjusted to Z=0.02 evolution tracks on MS, about half MS-age
Surprise: mostly less massive than the Sun! P-rot = 15-25 days

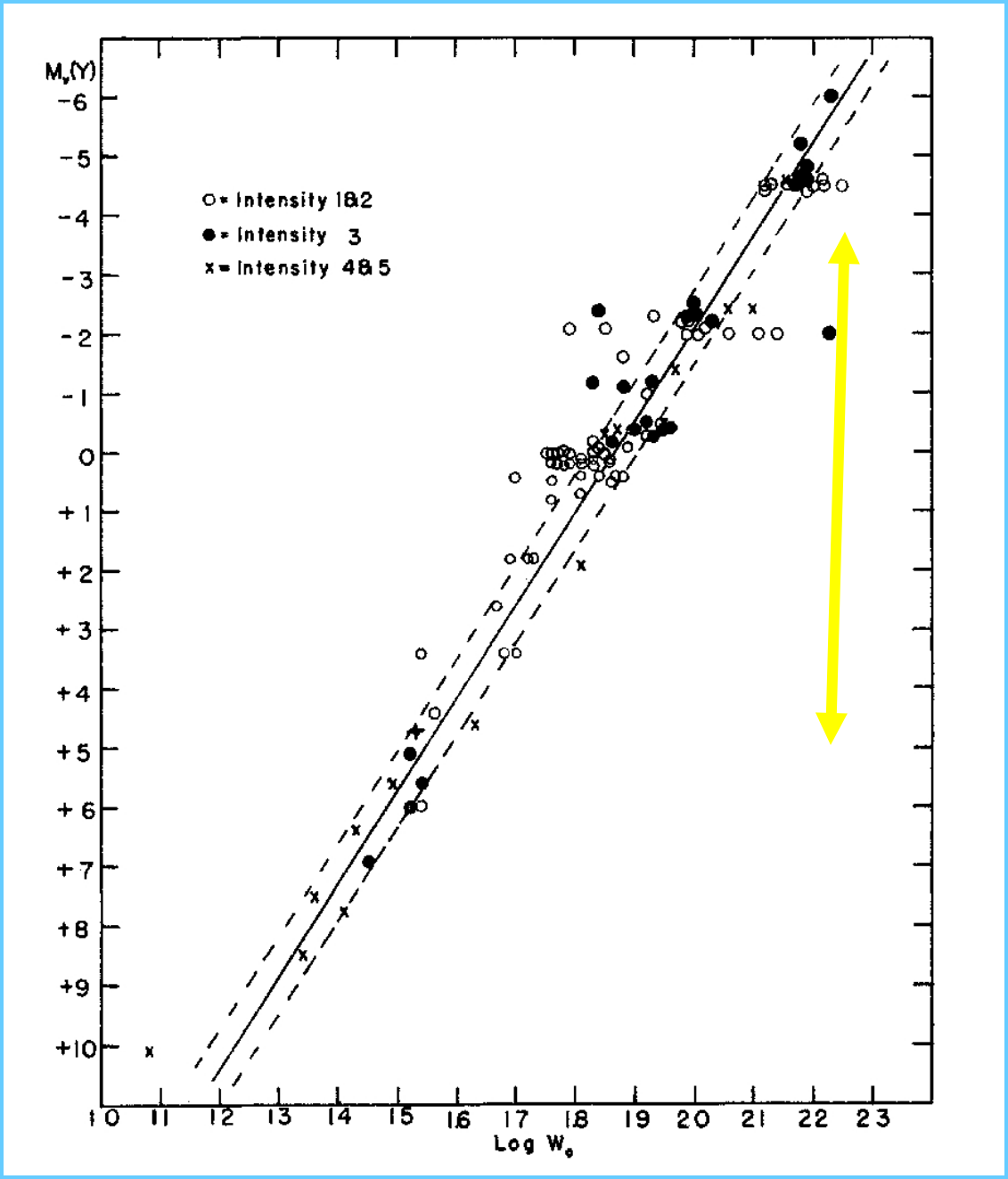


Despite many exceptions (Ayres, Reimers 1990ies) – true is:
Division corona / cool wind is sharp among inactive stars!





Check out with zeta Aurigae giants!!



Giants are very different in L, R and g:

Wilson-Bappu-Effect:

$$W \sim g^{-0.18...-0.25}$$

line-saturation by increasing column density w/

$$N \sim g^{-0.5}$$

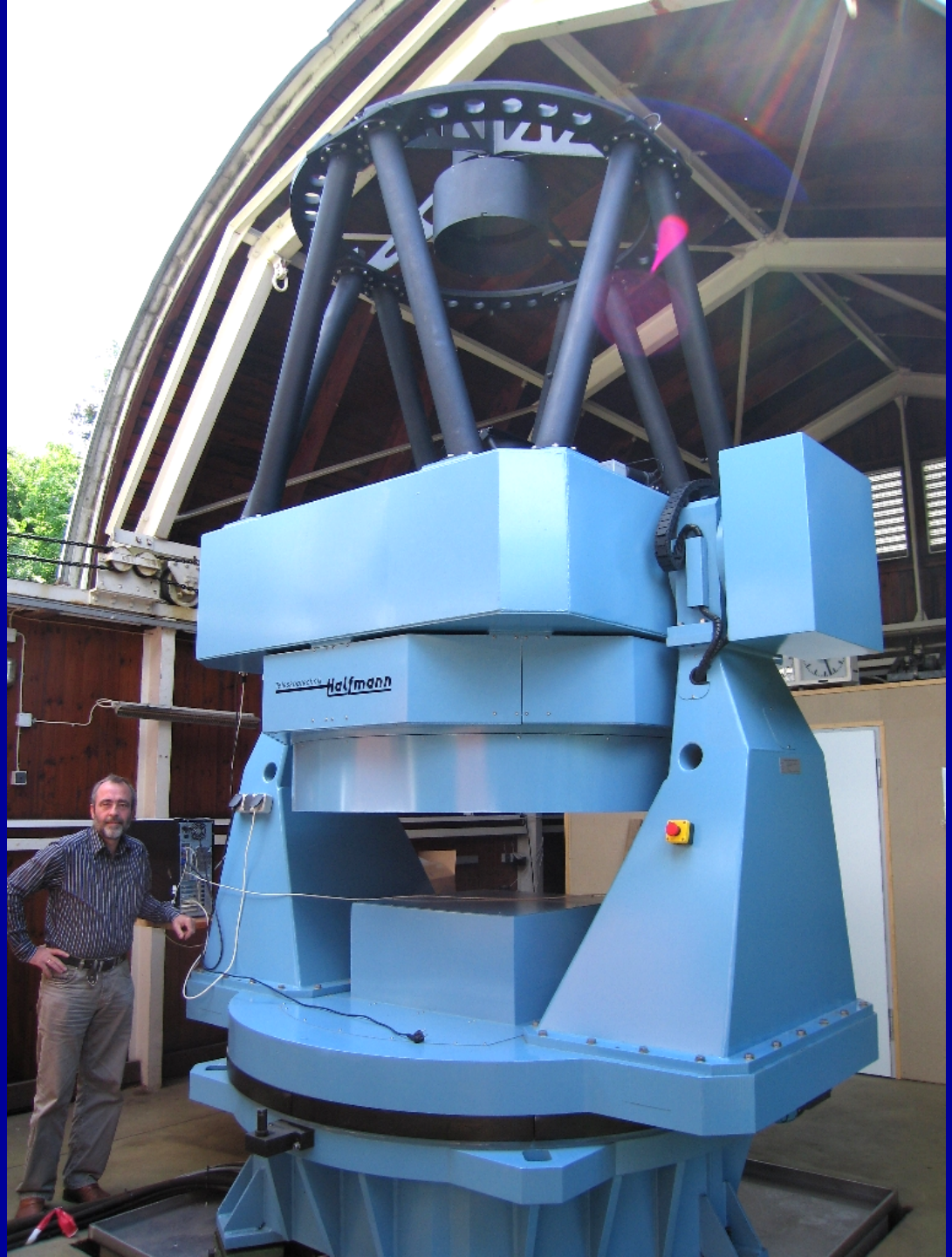
(Ayres & Linsky, 1975/78)

=> purely hydrostatic effect via increasing (with N) line saturation

I) Hamburg Robotic Teleskope
(HRT, <2013, Group Prof. J. Schmitt)

to retake Wilson-Work

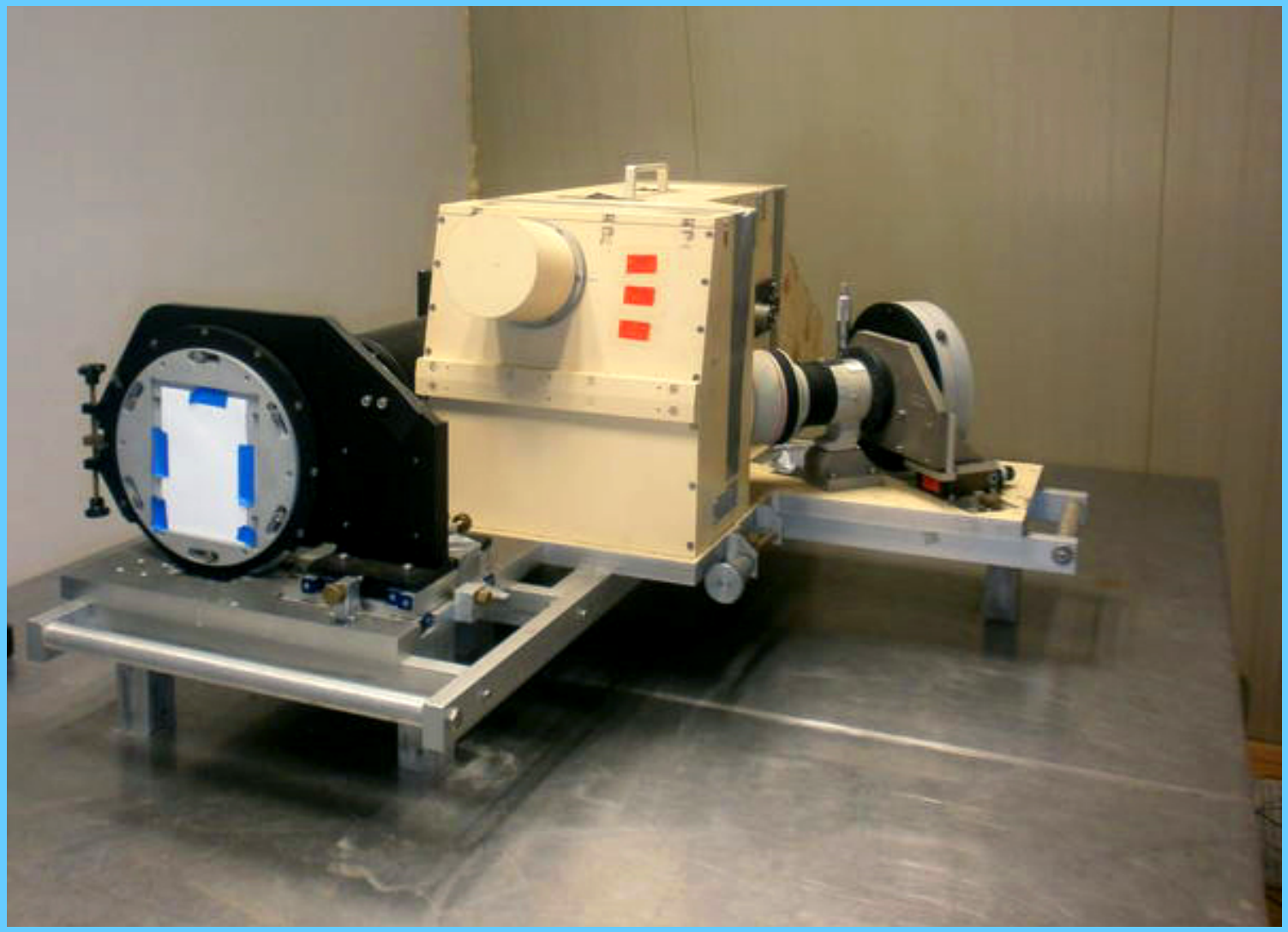
=> now as TIGRE: Telescopio Internacional de Guanajuato Espectroscopico Robotico



HEROS:

The fiber-fed double-channel spectrograph,

here:
the adaptor for the optical fibre and guiding camera



HEROS: fiber-fed Spektrograph (L.Stw. Heidelberg), air-conditioned and stable table, R=21.000 in red and blue chanel, to ~10 mag