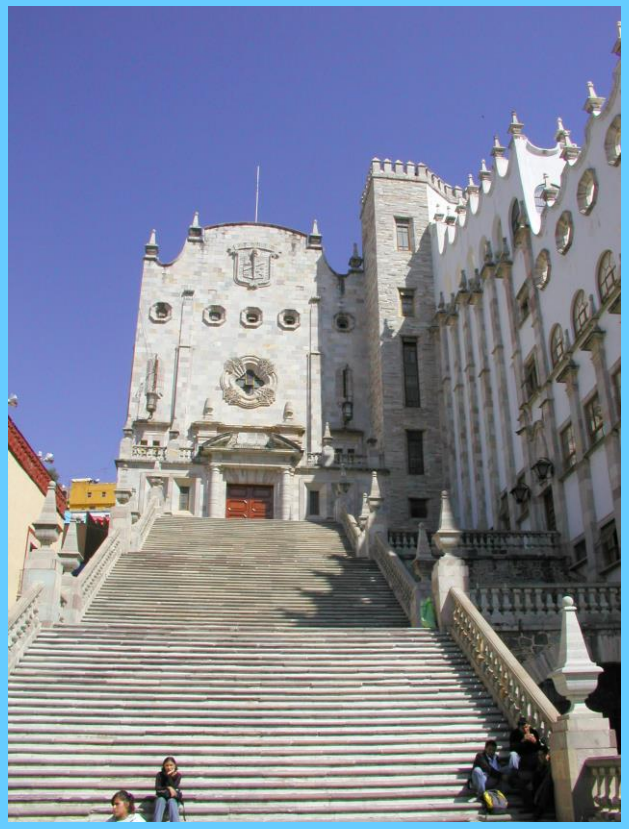
Magnetic activity and evolution of the four Hyades K giants

...and an old question of Olin Wilson answered

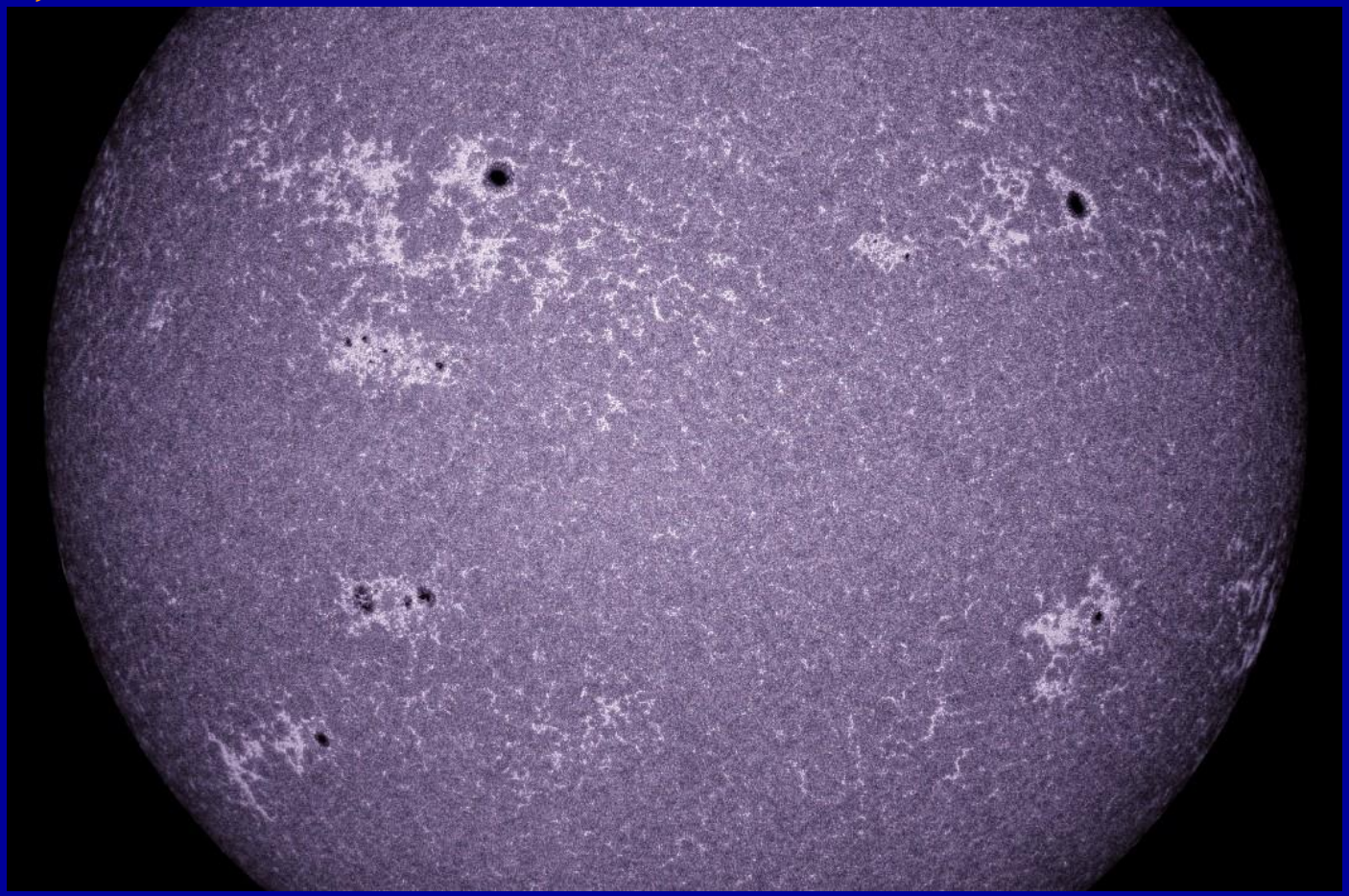
Klaus-Peter Schröder - Virtual Nordic Dynamo Seminar, Stockholm, 12.5. 2020
in collaboration with Jürgen Schmitt, Marco Mittag, Dennis Jack .....



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

Beginnings in Potsdam/GER: *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.*

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

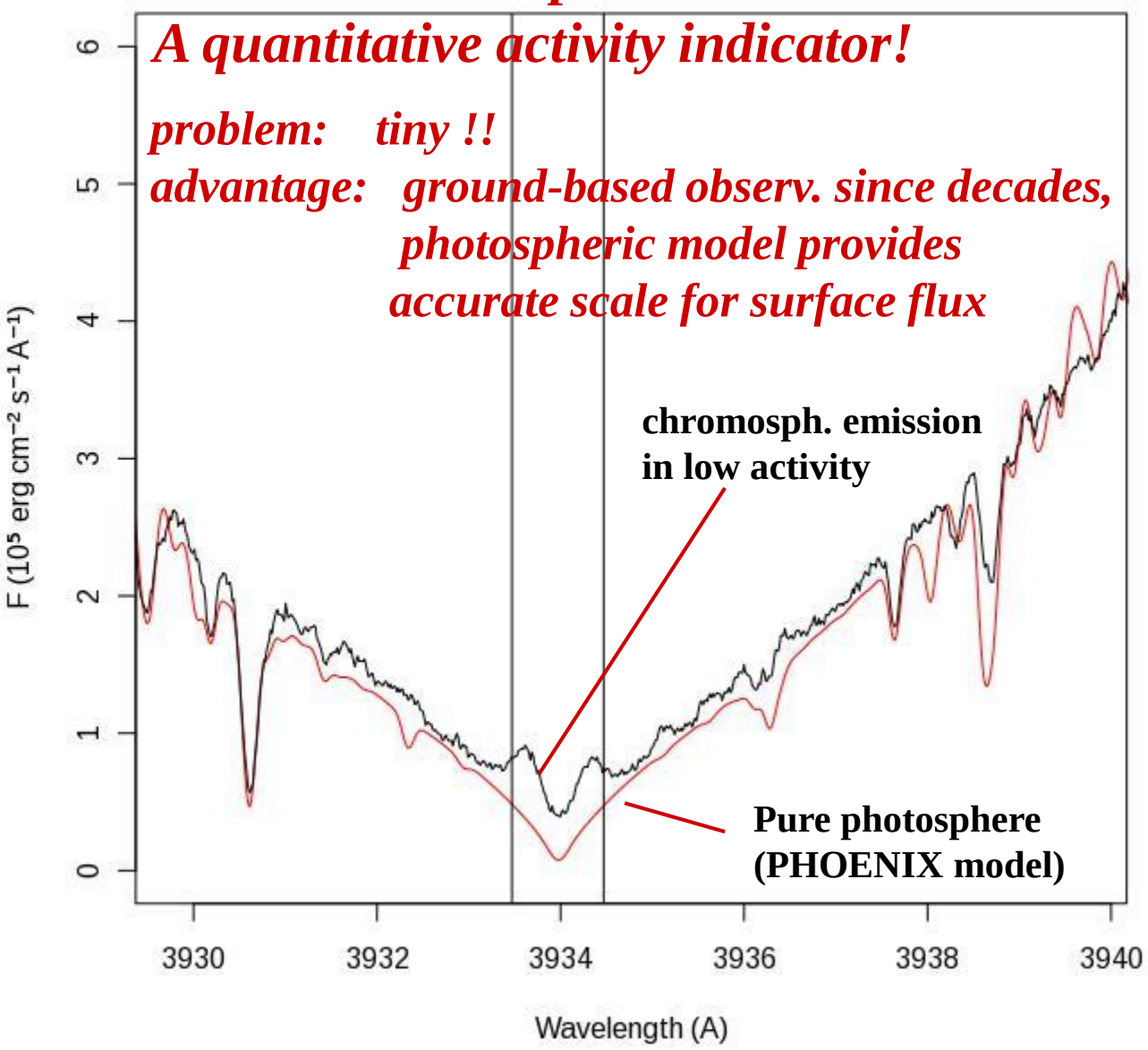


Ca II K chromospheric line emission

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, Marco Mittag, Dennis Jack, Faiber Rosas, ...]

- monitoring the Ca II K chromospheric emission variability

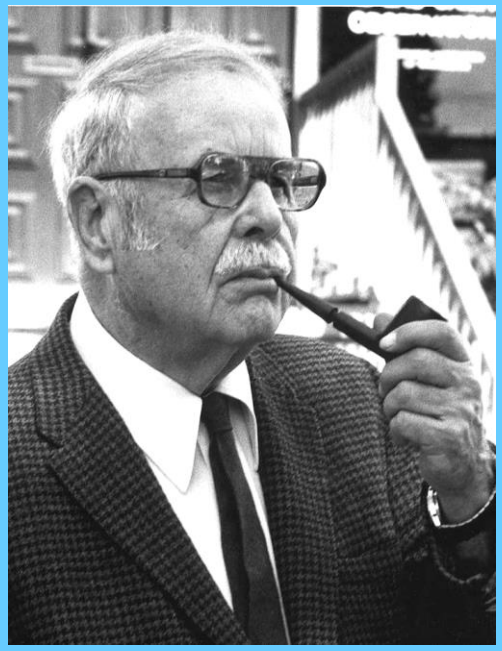
- sample: over 40 cool giants and >100 solar-type stars brighter than 7 mag, spectral type G-M, of different activity degrees

- 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):

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

1 Angstr. wide line cores H&K / 20 Angstr. wide pseudocontinua, 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!!

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

to retake Wilson-Work

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

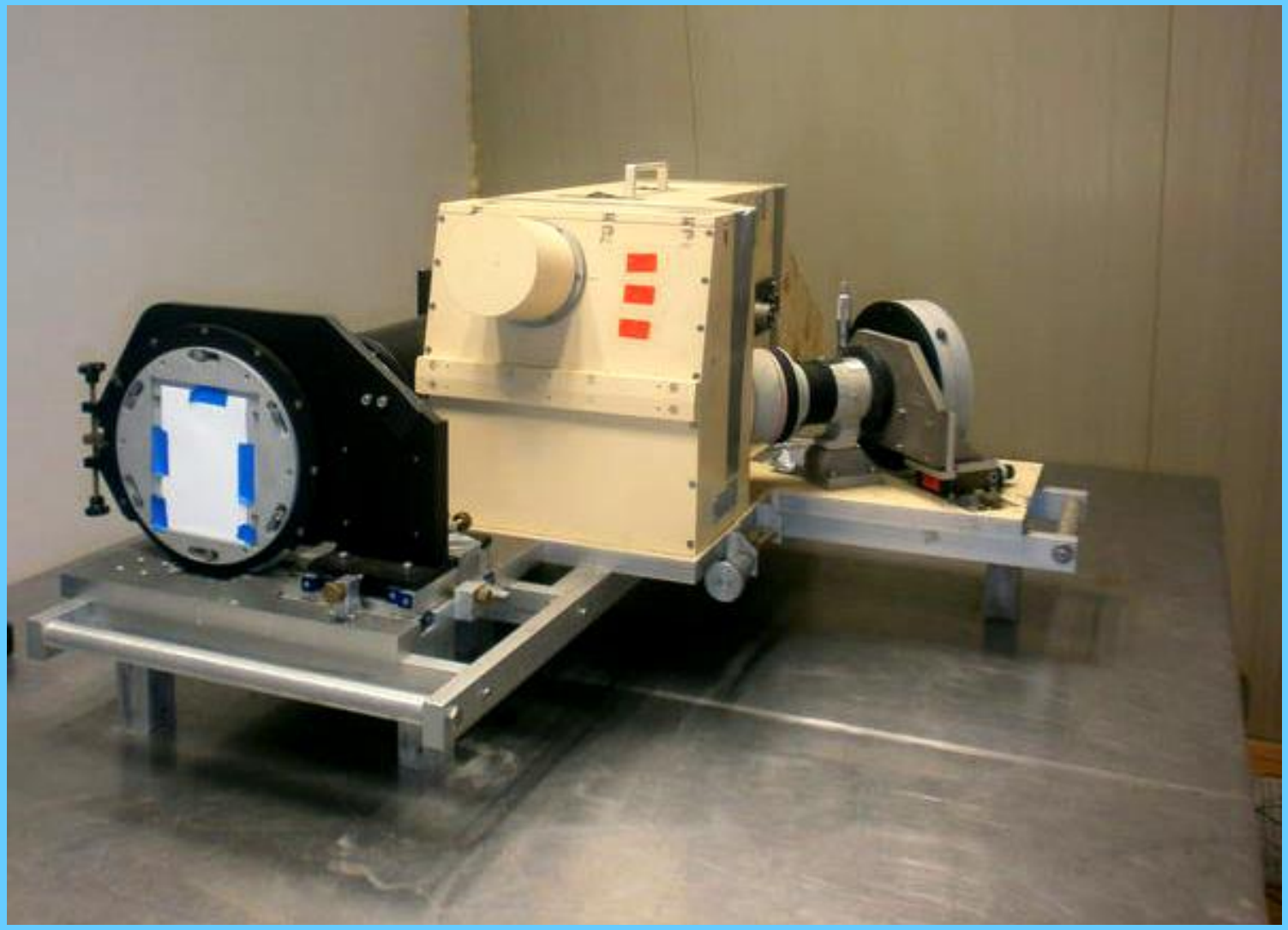
TIGRE in central MEX, Guanajuato

Spring 2013: Arrival & montage of the HRT - now renamed into: „TIGRE“

HEROS:

The fiber-fed double-channel spectrograph,

here:
adaptor for optical fibre and guider camera



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

III) Magnetic activity during central He-burning (K giant clump stars)

General considerations:

Giants are active, but how? Should we expect a dynamo very different from the one of the Sun (and so probably to look very different?), because:

- convective envelopes get huge, so that magnetic field created near its bottom cannot rise to photosphere intact (shown by Schüssler 1998)

- differential rotation in giants occurs on the radial scale deep inside, in Sun it is latiitudional

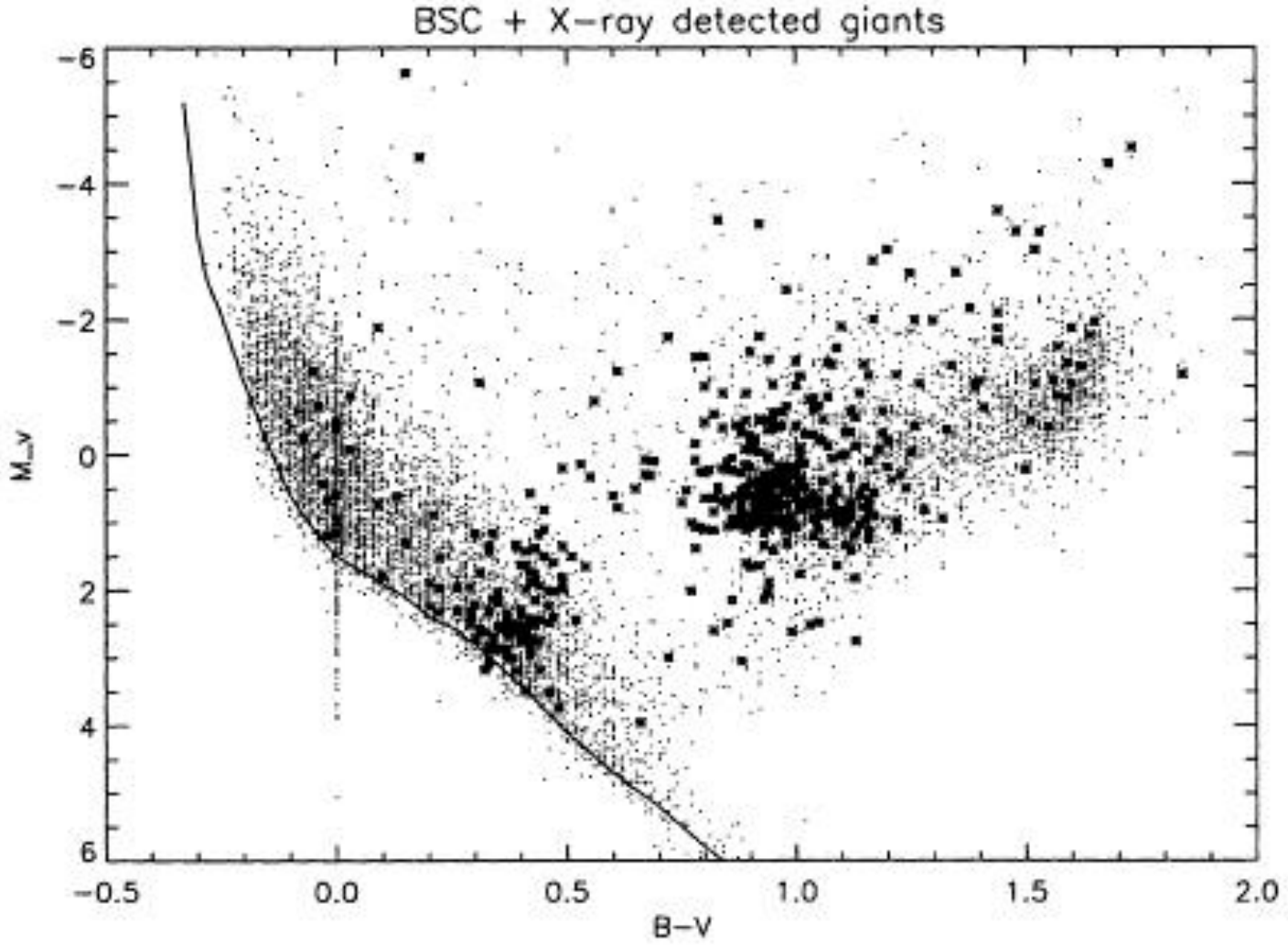


Figure 2. X-ray detected giants of spectral type A to M in the H-R diagram (asterisks). Dots are all Bright-Star-Catalog stars with data from *Hipparcos*. A total of 450 objects was detected in the *ROSAT* all-sky survey. (Diagram supplied by Mathias Hünsch, MPE.)

A bit of history:

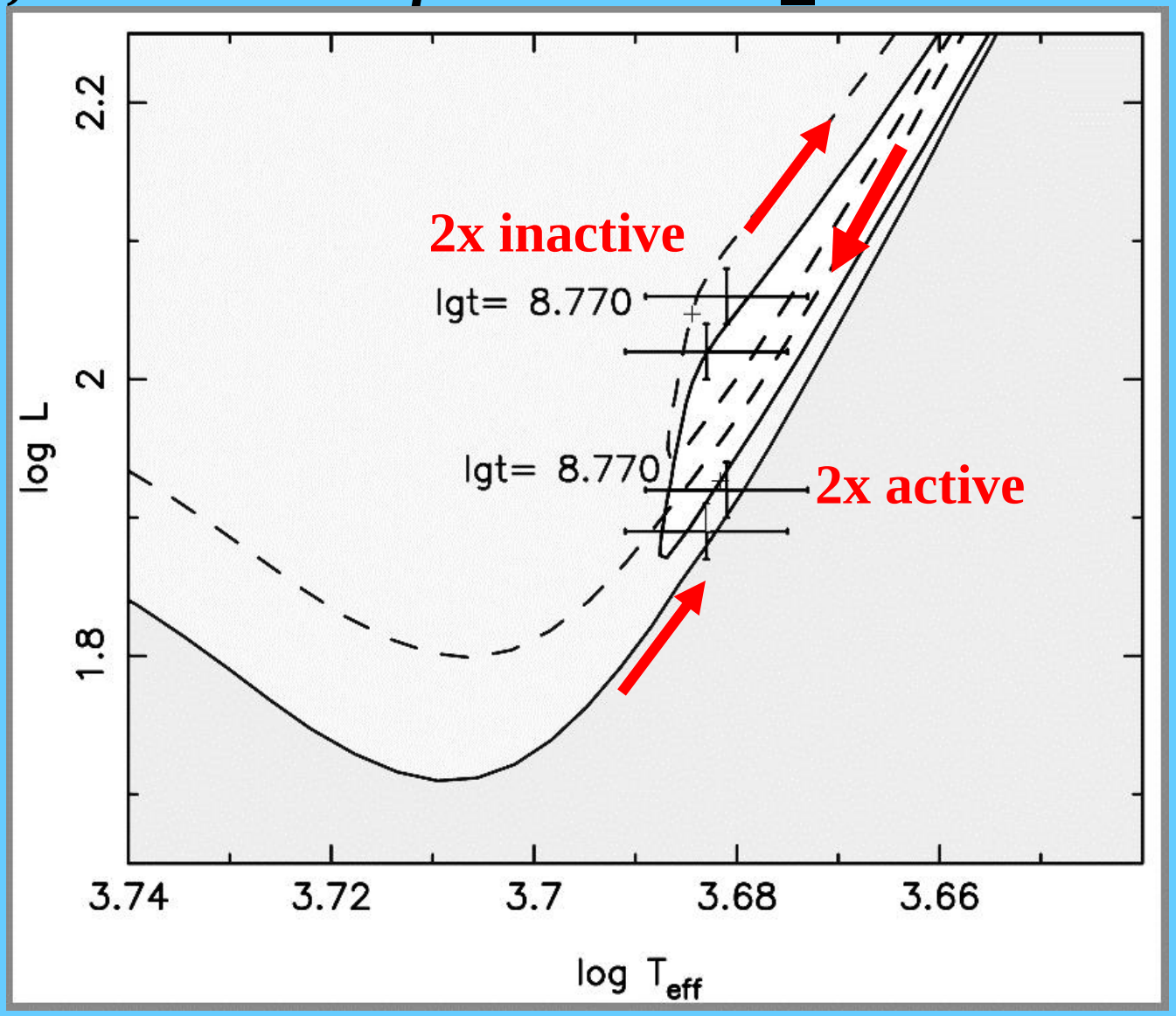
Skumanich 1972: magnetic braking => activity is age-related .... but:

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. to Dieter Reimers in 1972, and later by Baliunas, Hartmann, Dupree 1983):

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

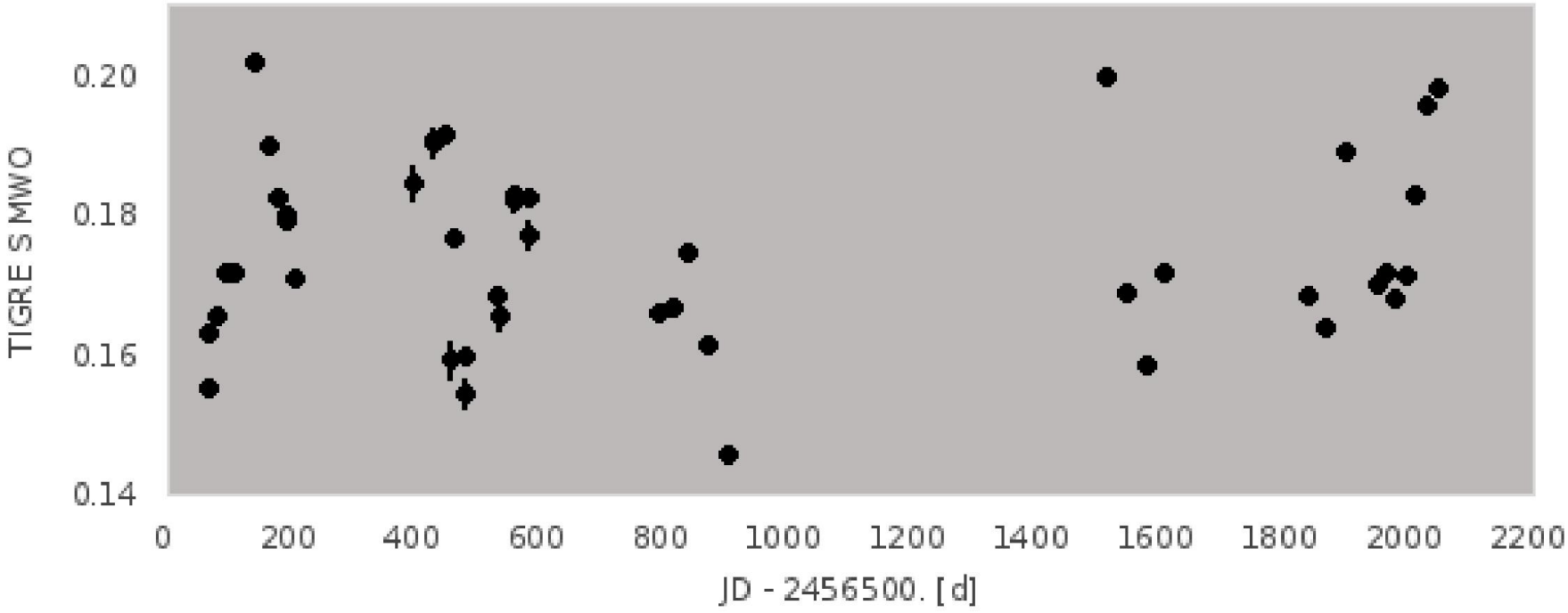
Evolution tracks of Hyades K giants **(see Schröder et al. 2020)**
120 Myrs long central Helium burning (blue loop) at age of 588 Myrs, with masses of 2.62 /2.75 M_sun



Mt. Wilson and TIGRE S-data:

example HD27371: signatures of rotation and activity cycle

see Schröder et al. 2020



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

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

⇒ analysis: max. probability ~ 140 days rotation

-0.5

1) *The 4 Hyades K giants show that activity is higher than solar at the beginning of central He-burning, but becomes inactive towards the end of that phase => magnetic braking as on MS ?!*

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 & same Rossby No., active K giants rotate ~10x slower than active MS stars => empirical convective turnover time must also be 10x longer than in solar dynamo (how deep?)*

(note: Ro = P_rot / tau_to => as if tau_to ~ g $^{-1/2}$

A note on convective turnover-times tau_to:

- *theoretical tau_to dificult, scaled convection models allow only for a local tau_to = α Hp/v_conv, which is (see Kim&Demarque 1996) about 40% of the global tau_to in a solar model with rotation and meridional mixing (i.e., 17d : 44d, 1/2 Hp above bottom of convection zone). Note: global tau_to ~ longest P_rot (solar stars) !!*
- *values of Δ T, v_conv increase considerably with height, and tau_to decreases quickly, depends strongly on definition*
- *No models w/ rotation exist for giants. Our solar model w/o rotation gives about 16d for a local tau_to near bottom of convection zone, while it is 450d for a Hyades K giant model. That is a factor 30, much more than rotation periods suggest via Ro number (factor 10).*

=> Match higher up in convection zone?? (Brandenbg. 2005)

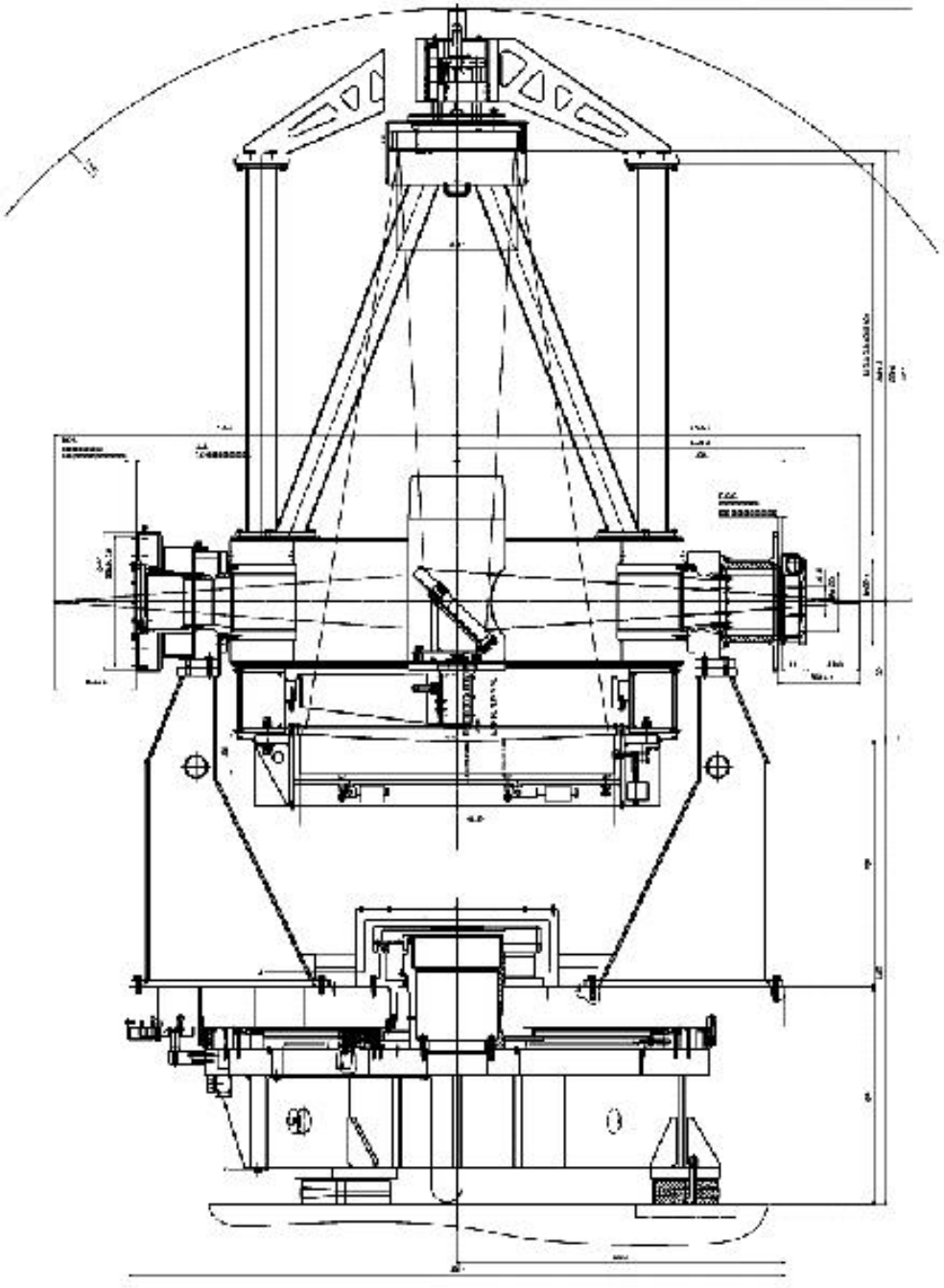
Outlook - a speculation:

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

2) But in phases of core contraction magnetic activity increases (notably HG, faster with larger mass): is core spin-up rejuvenating giant activity?

3) Is the giant dynamo the same as in the Sun, and in which heights does it operate? => study more rotation rates


...much more work remains to be done
Gracias!



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“

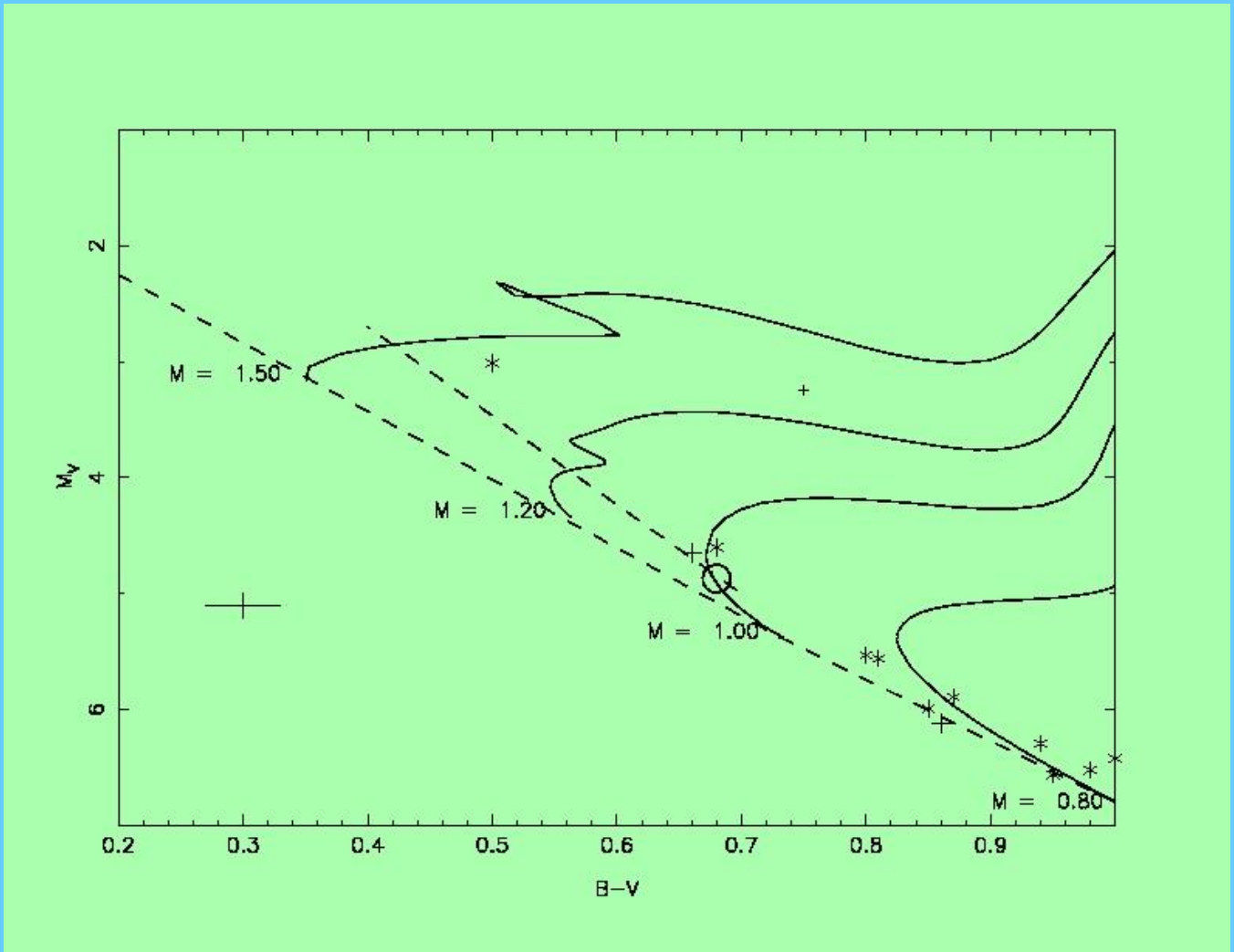
See: Schmitt et al. 2014, AN

Science-Philosophy of TIGRE:

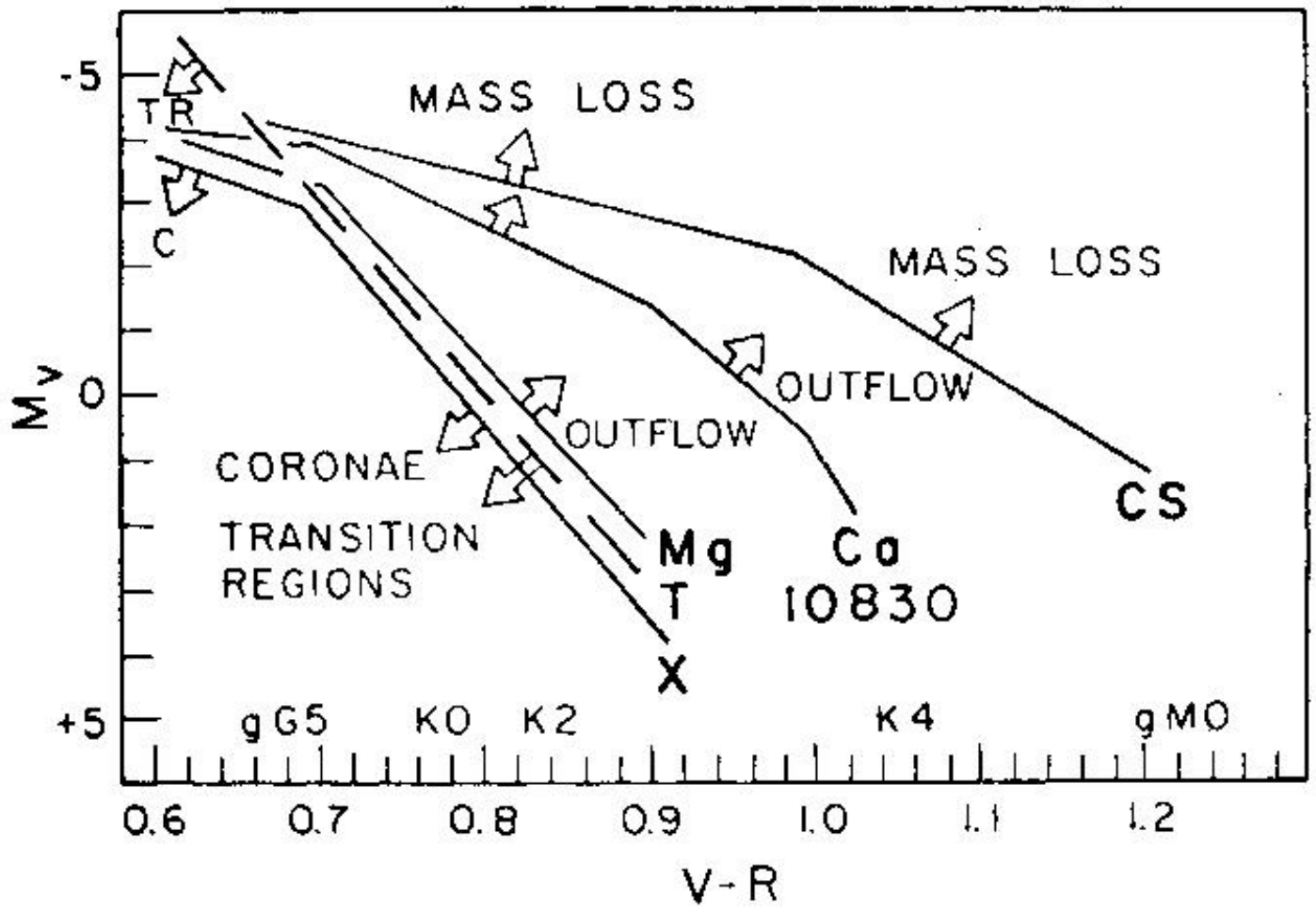
- dedicated: spectroscopic monitoring fills a strategic gap
- autonomous, robotic operation: low operation costs, also:
- accessible site with many nights sufficient for spectroscopy
- almost immediate (24hr) response to targets of opportunity
- efficient: automatic data-reduction pipeline and on-line 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

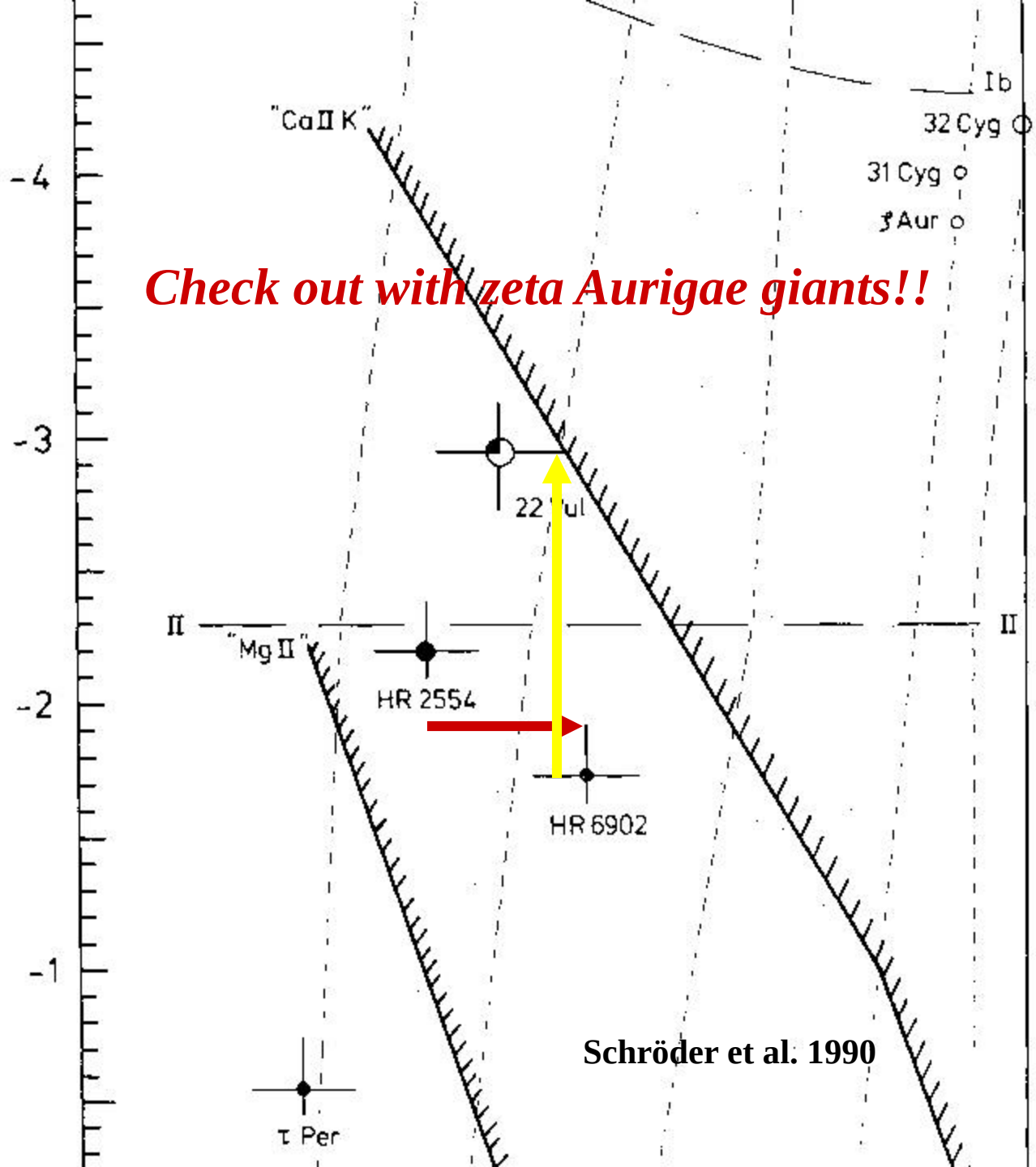
- key programmes:
  - stellar and solar activity monitoring (short- and long-term)
  - novae and supernovae monitoring (short- to medium-term)
  - very hot stars and binaries (short- to medium term variability)
  - exoplanet-hoststars and planet-star relationships

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



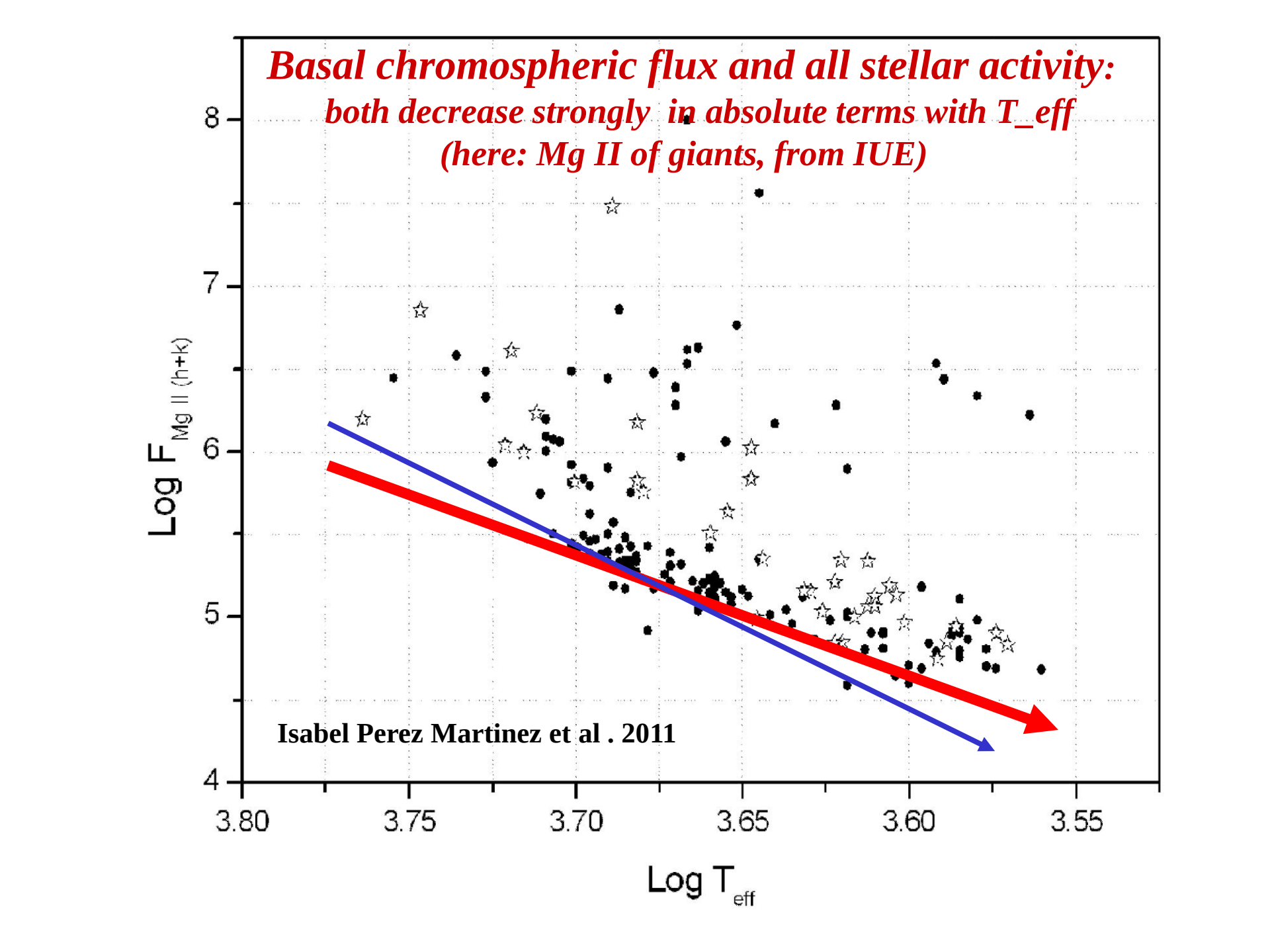
Despite many exceptions (Ayres, Reimers 1990ies) – true is:
Division corona / cool wind is sharp among inactive stars!



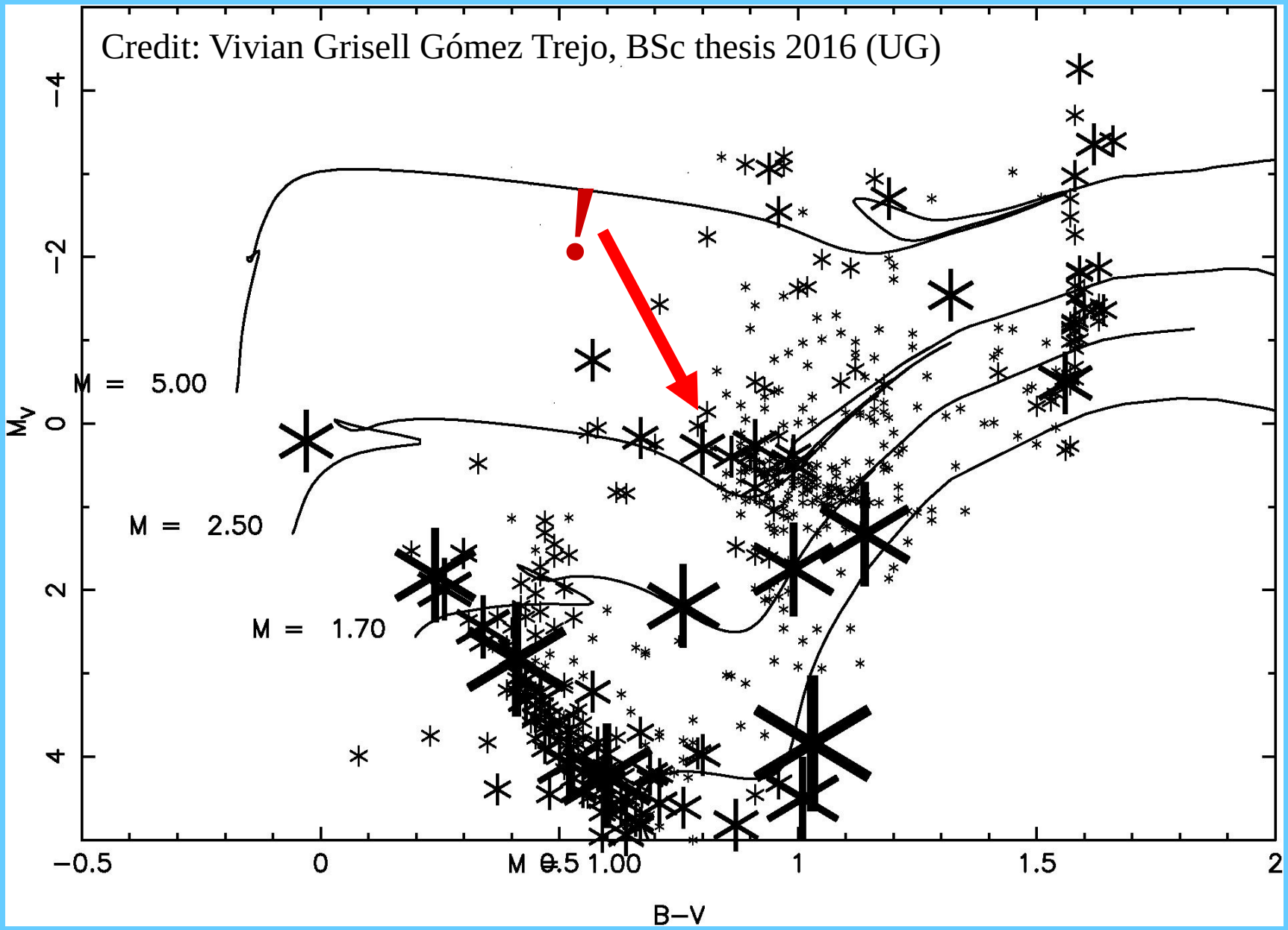


Check out with zeta Aurigae giants!!

Schröder et al. 1990


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



AGB giants: magnetic field detections ! => CaII is by activity

and: giant activity is much more normal, than we thought !

(so, consider Arcturus as a little active)

Auriere et al., 2015