Stellar surface structure and (low-mass) stellar evolution

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1. **Rotation-activity-age relations**
2. **STELLA Open Cluster Survey and diff. rot as f(age)**
3. **ZDI: spatially resolving stellar surface magnetic field**
4. **Outlook**

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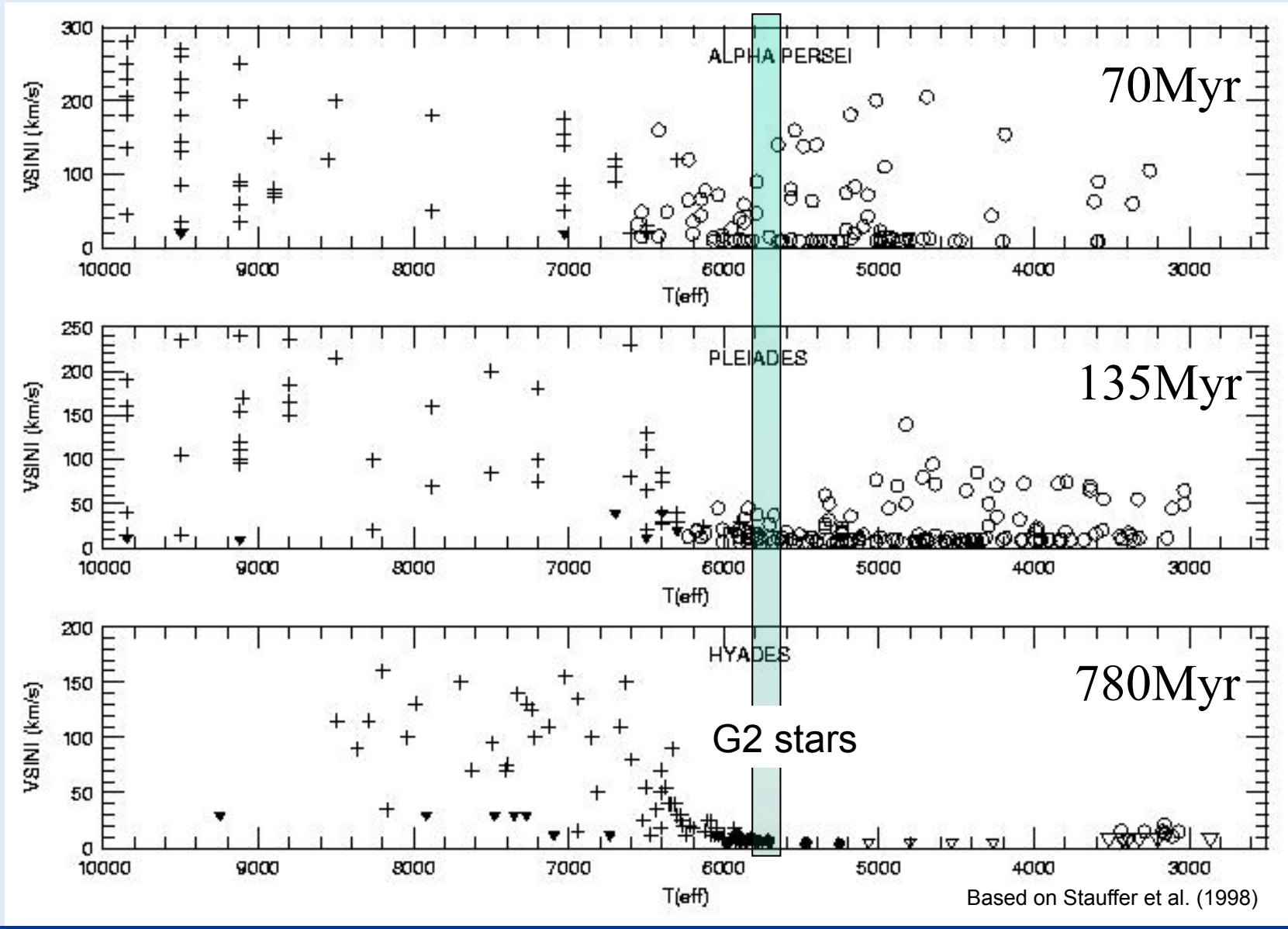
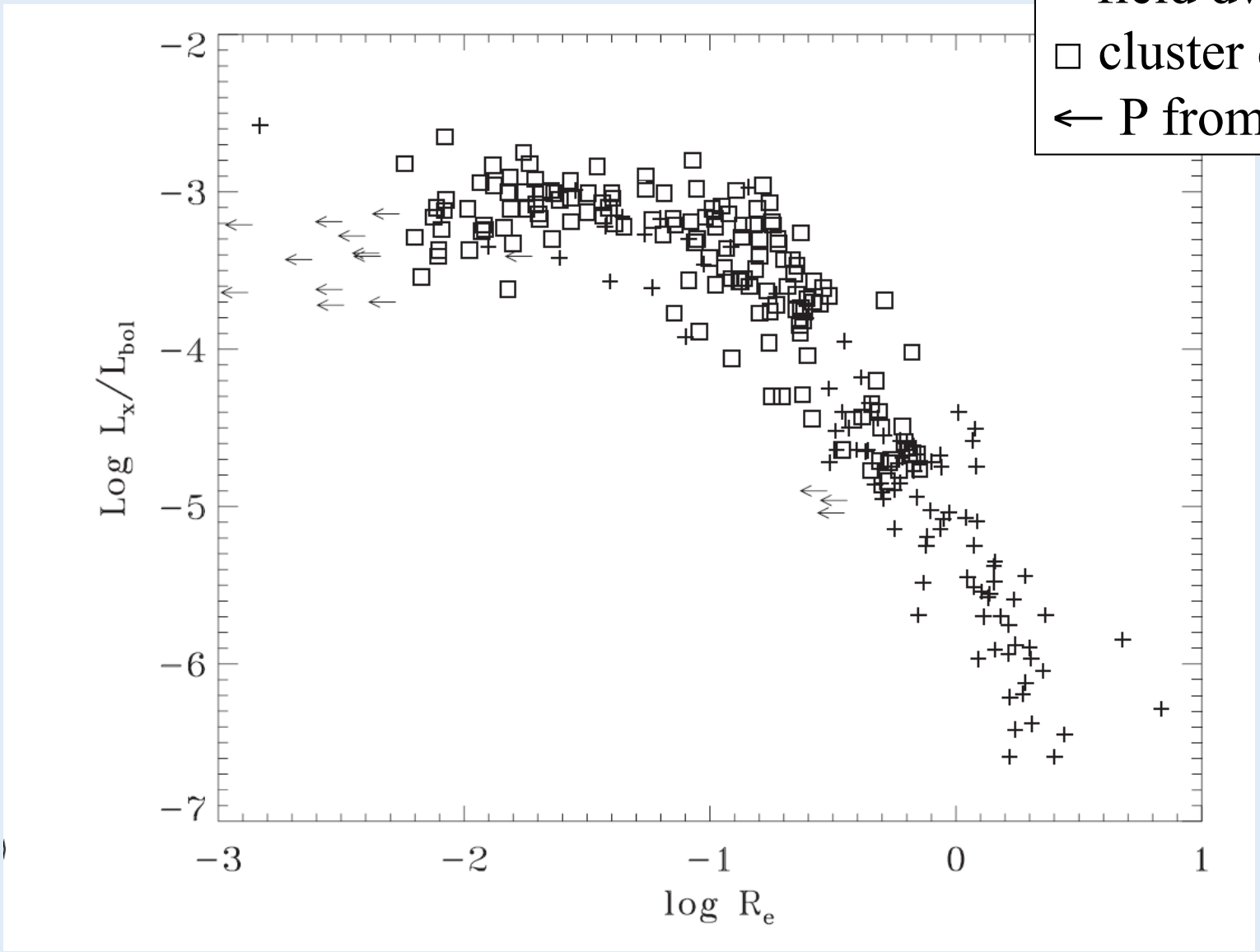
Interplay rotation and convection: magnetic braking



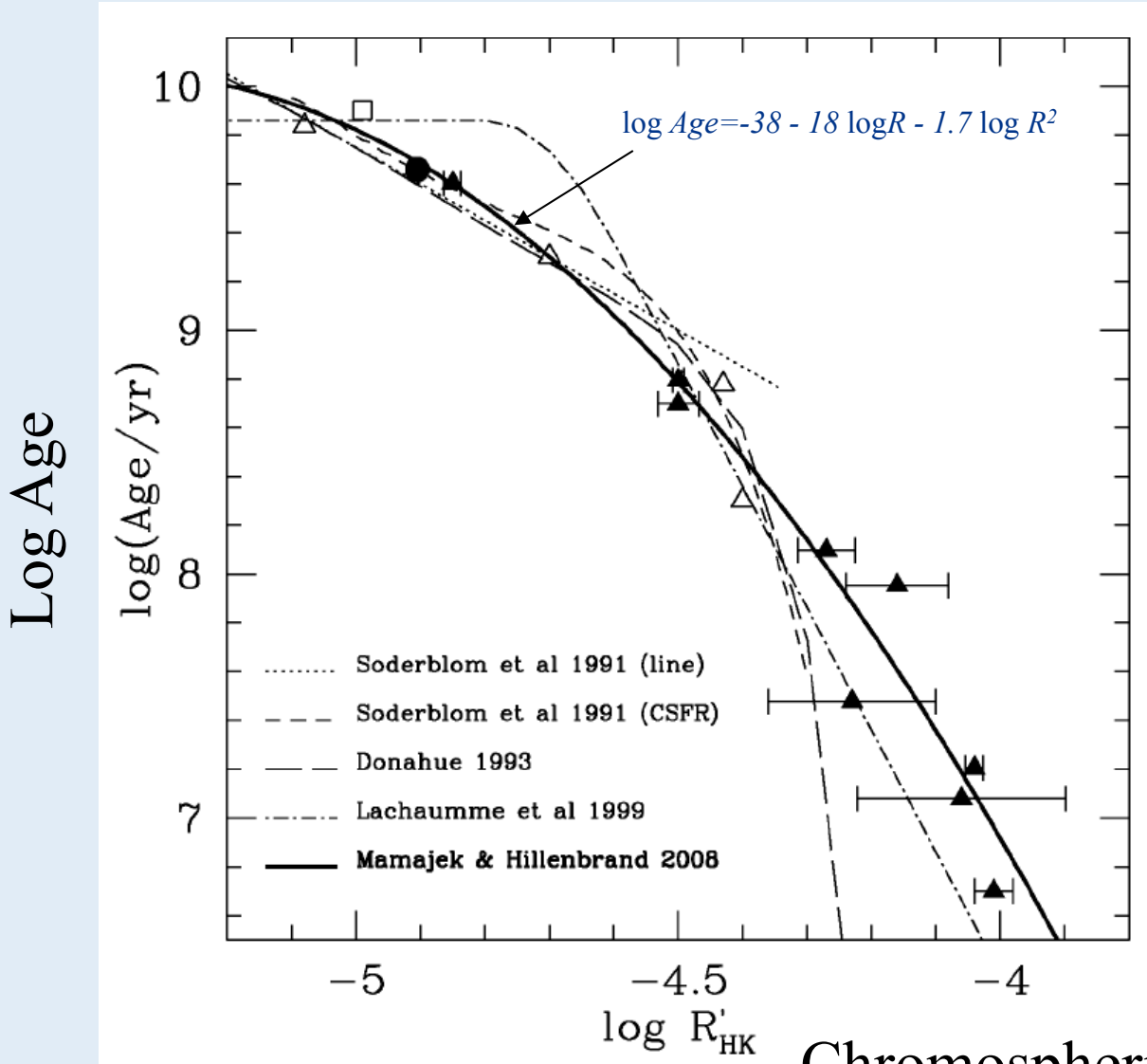
The rotation-activity relation: the „dynamo“

+ field dwarfs
□ cluster dwarfs
← P from vsini



Pizzolato et al. 2003, A&A

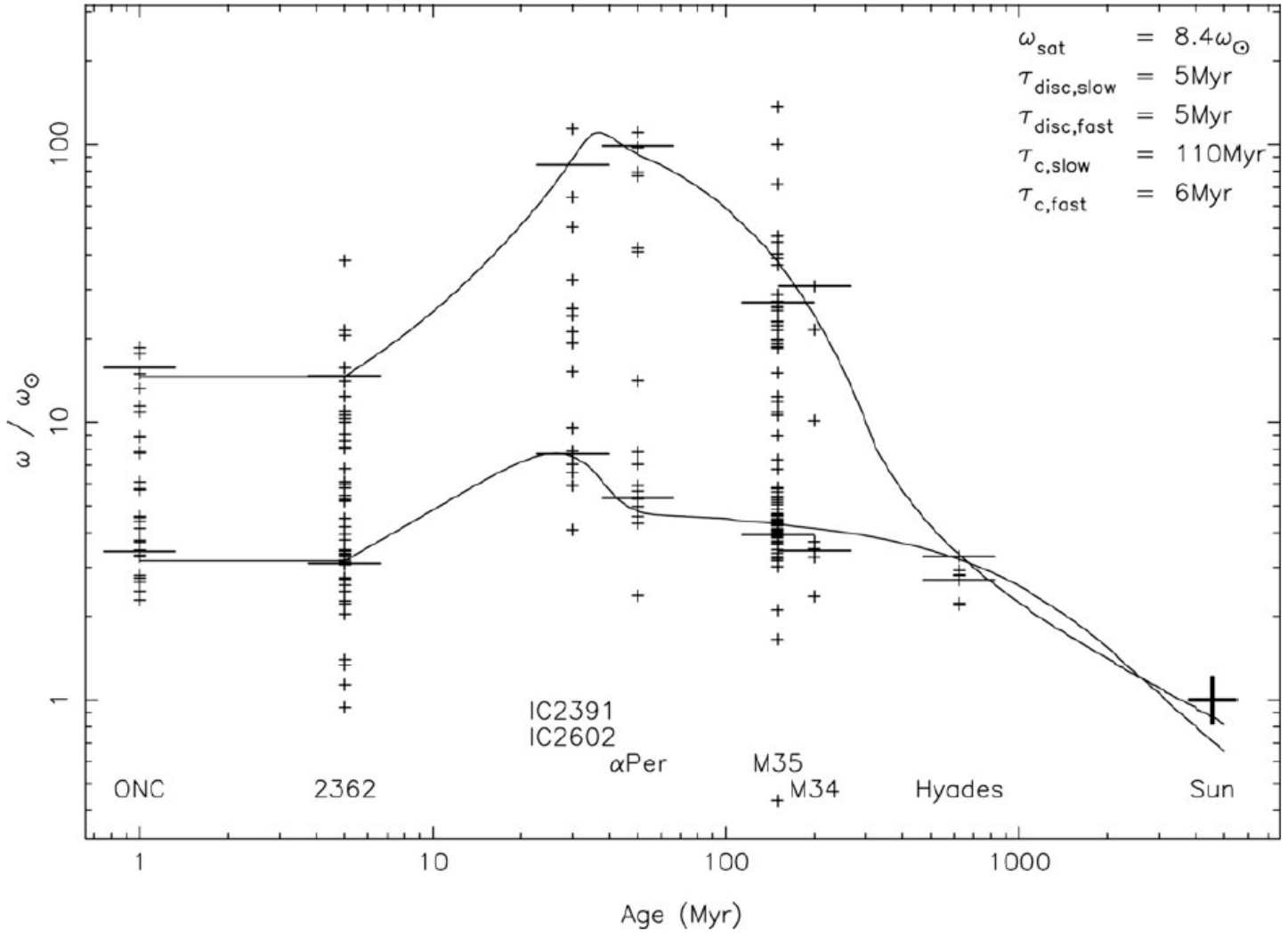
The age-activity relation for solar-type dwarfs



Mamajek, 2009
IAU S258
(see ApJ 687)

Chromospheric activity

The age-rotation relation for solar-type dwarfs



Irwin & Bouvier, 2009, IAU S258

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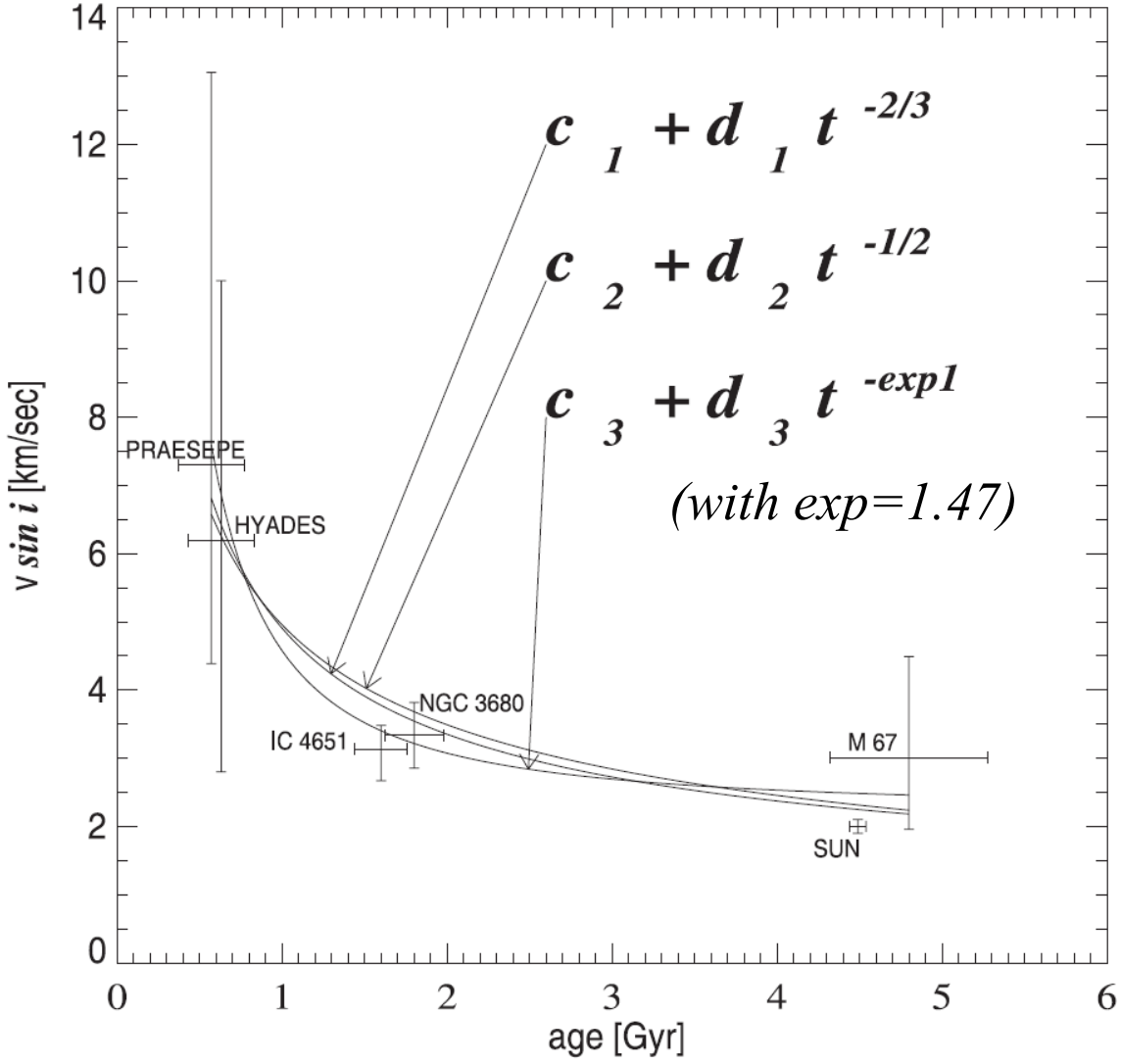
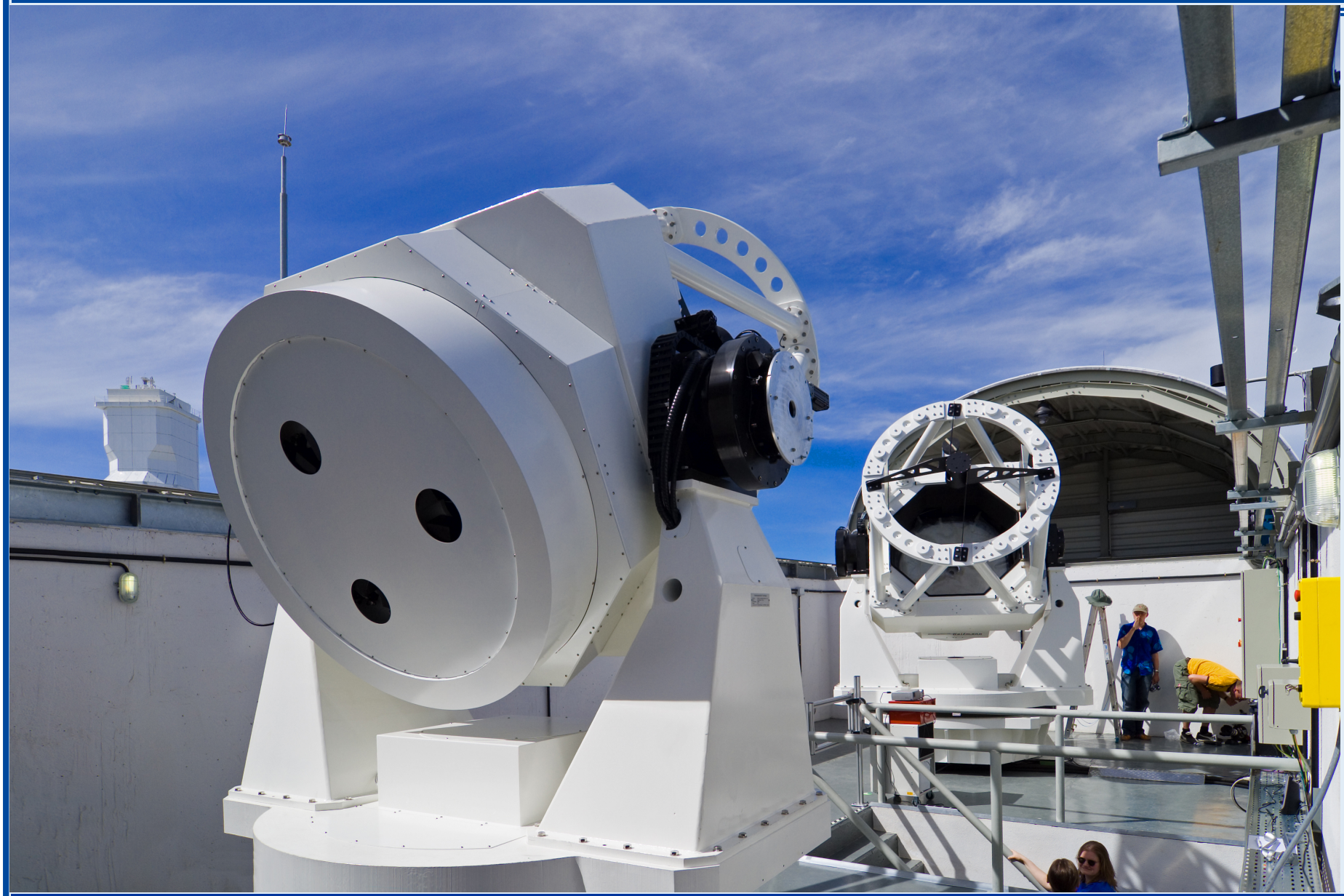
The age-rotation relation for solar-type dwarfs

Rotational line broadening

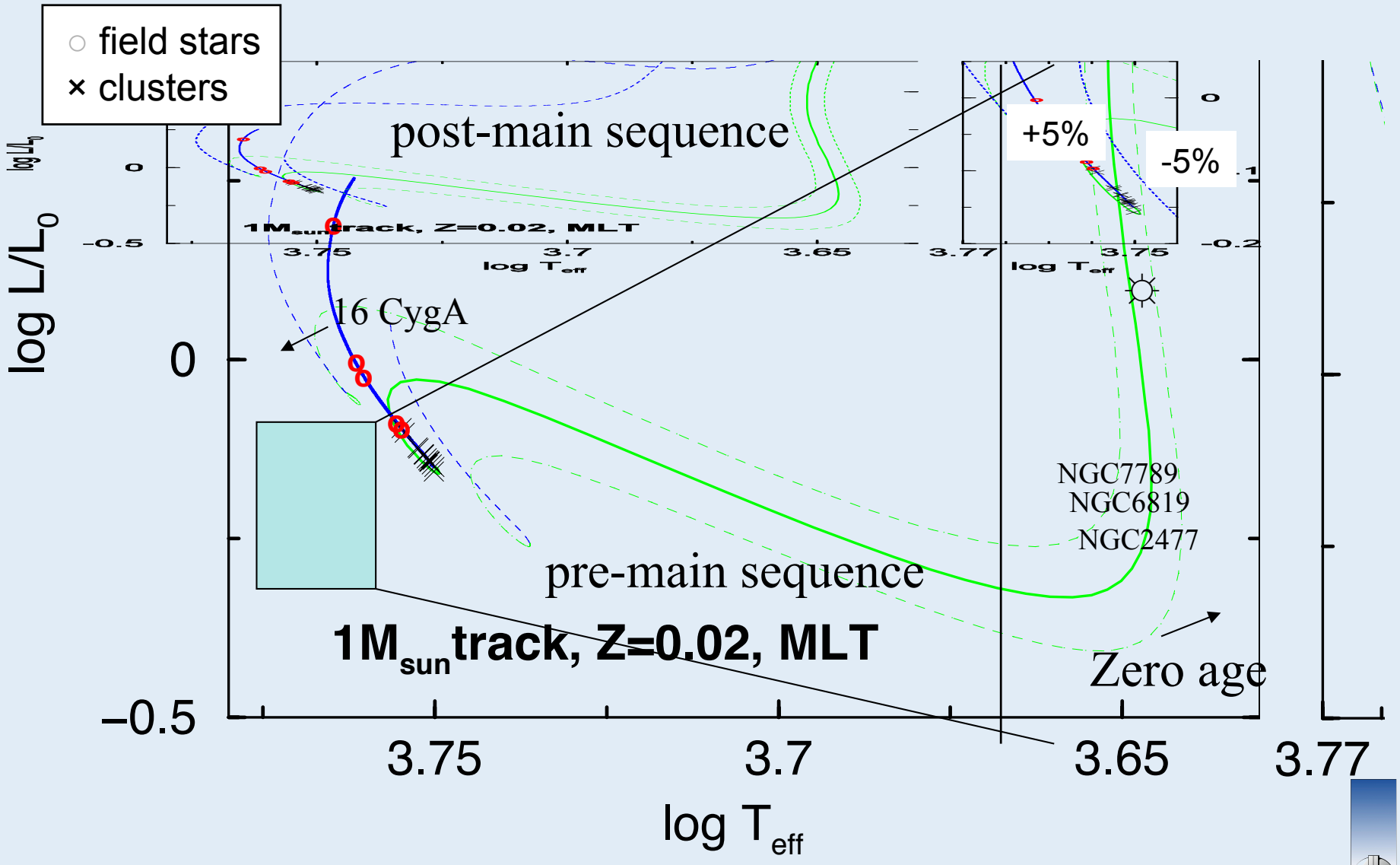


Pace & Pasquini, 2004, A&A

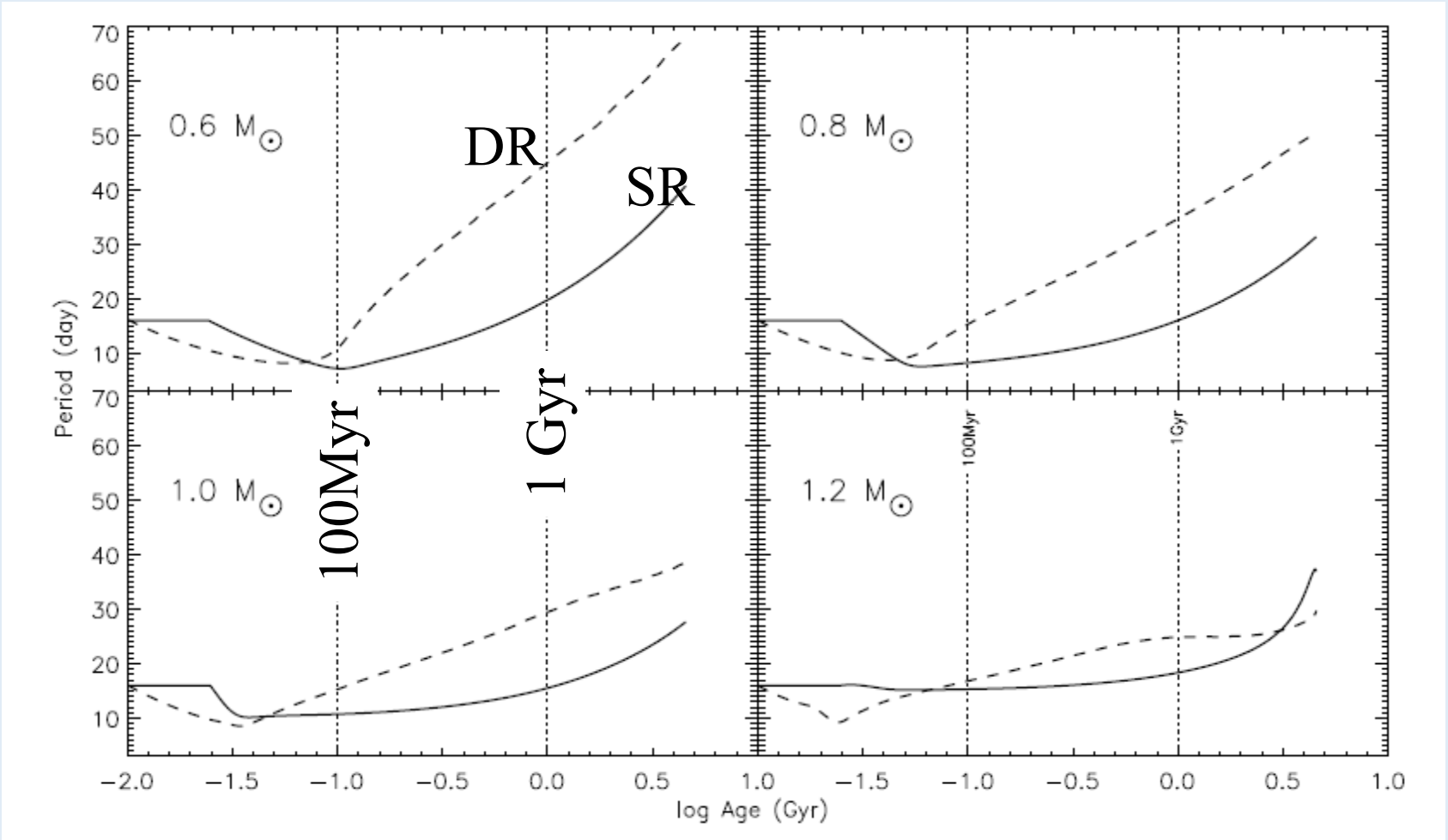
The STELLA Open Cluster Survey



The STELLA Open Cluster Survey



Goal: Evidence for internal differential rotation?



Rotation Period

Barnes et al. 2001

Log Age

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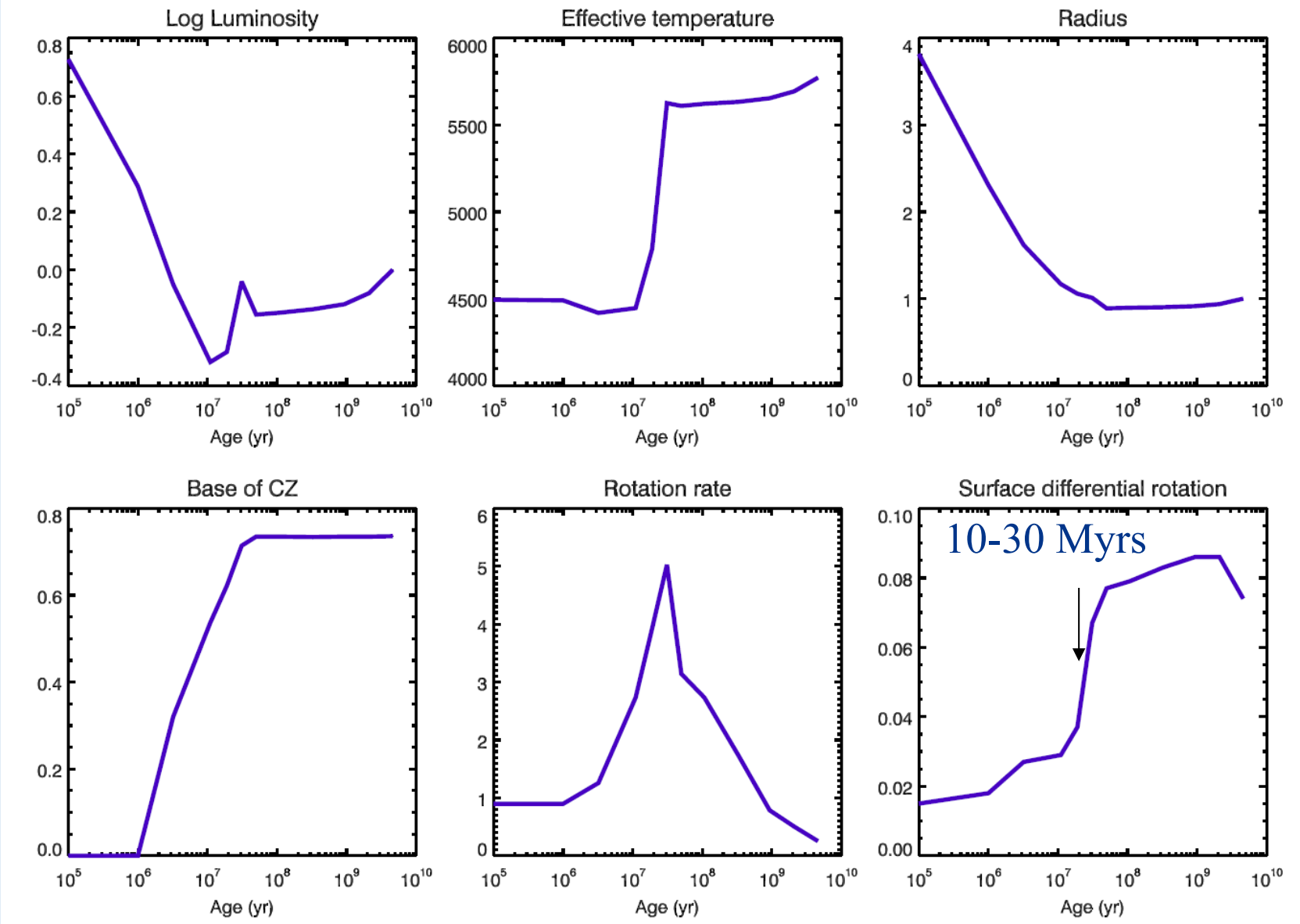
Comparison with theory („Küker & Stix“ models)



c/o. M. Küker

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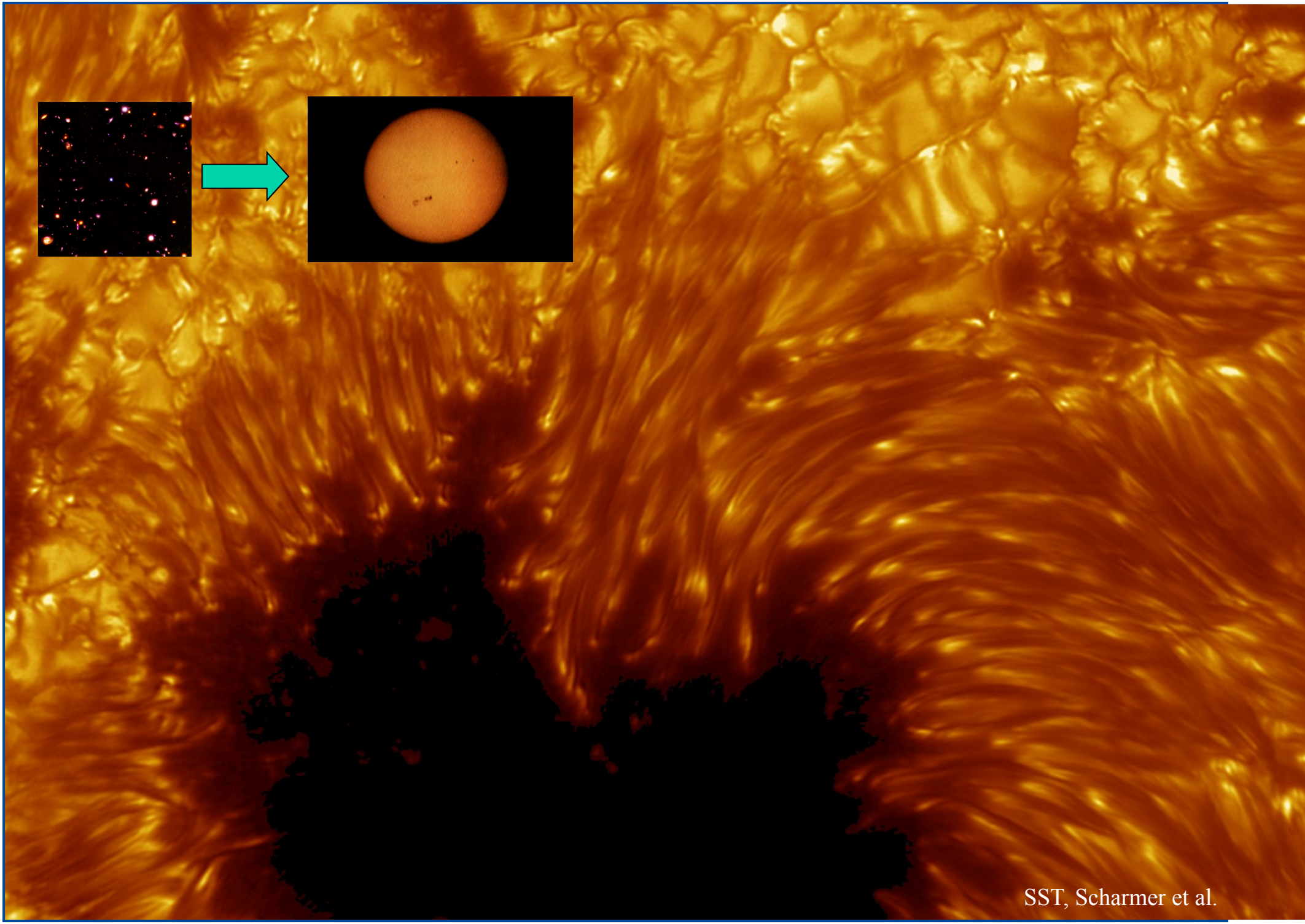
SST, Scharmer et al.

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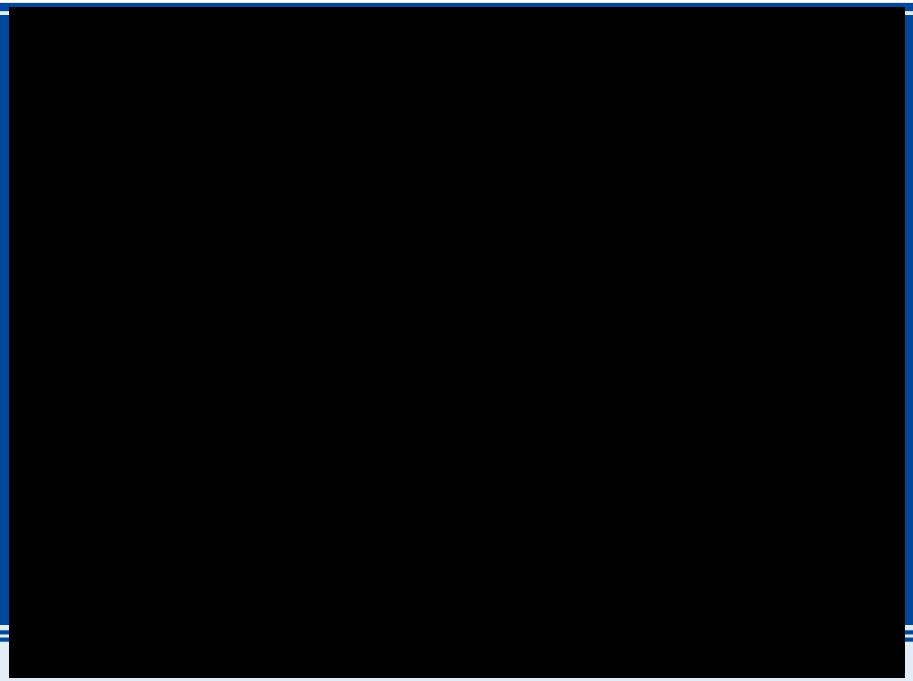
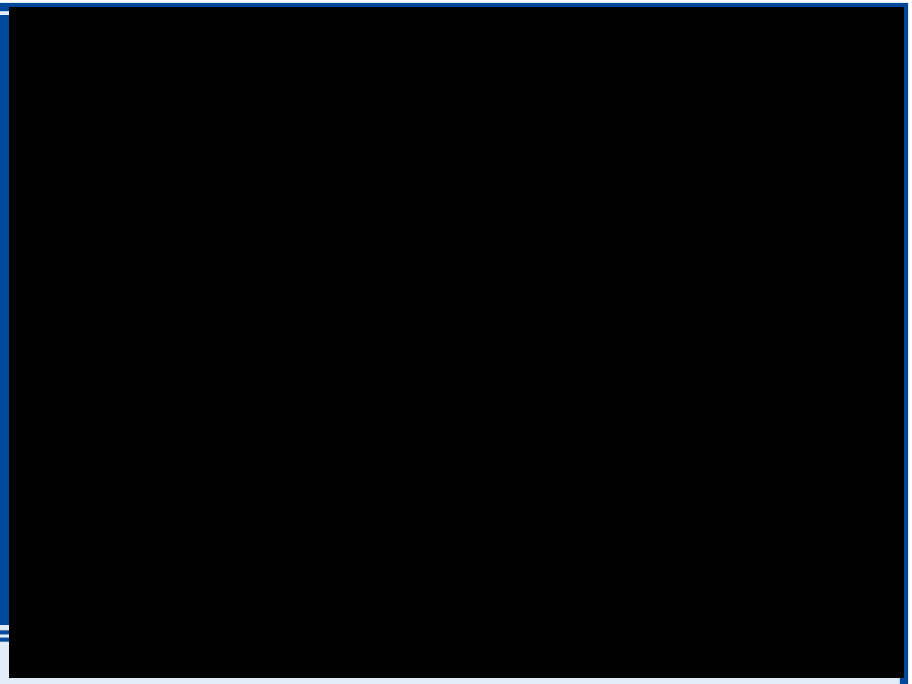


Rotation 1

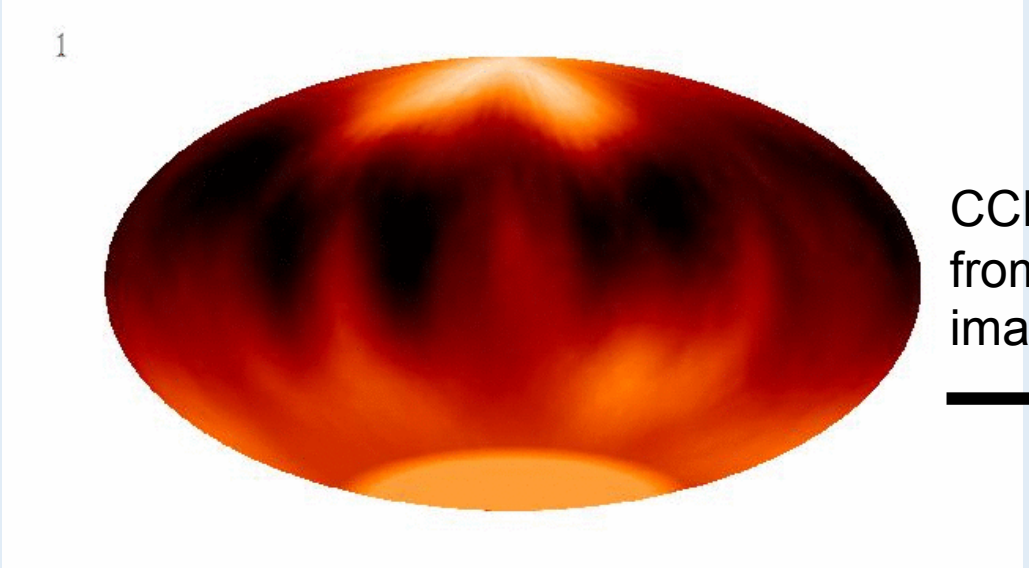


Rotation 2

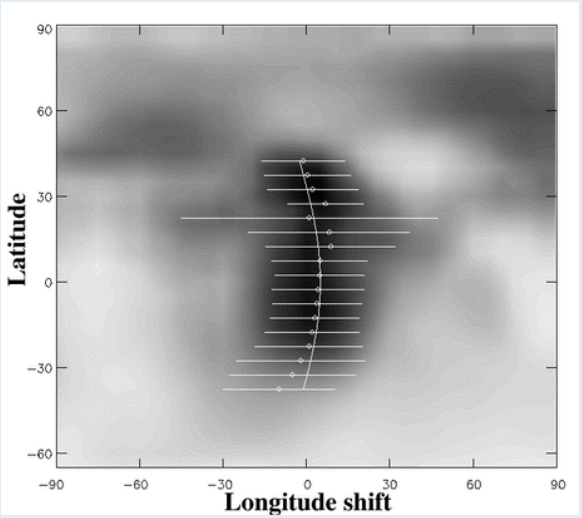
Rotation 3

Rotation 4

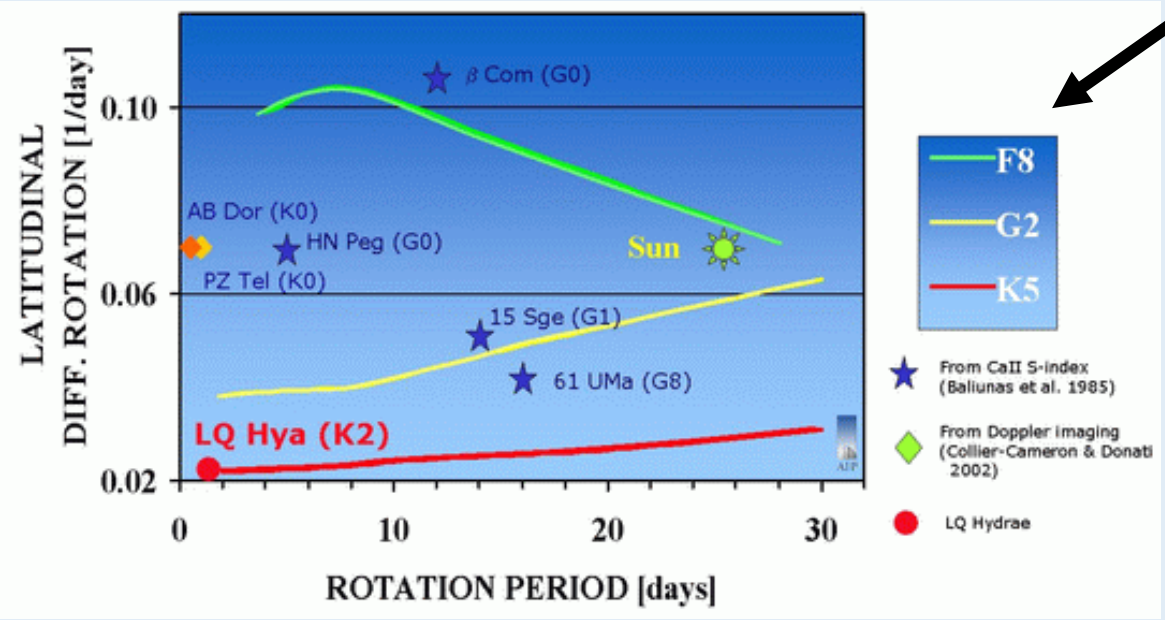
LQ Hya (K2V, 120Myr, $15\Omega_{sun}$): latitudinal shear roughly a factor of 3 weaker than on the Sun



CCF from 28 images



Comparison with models



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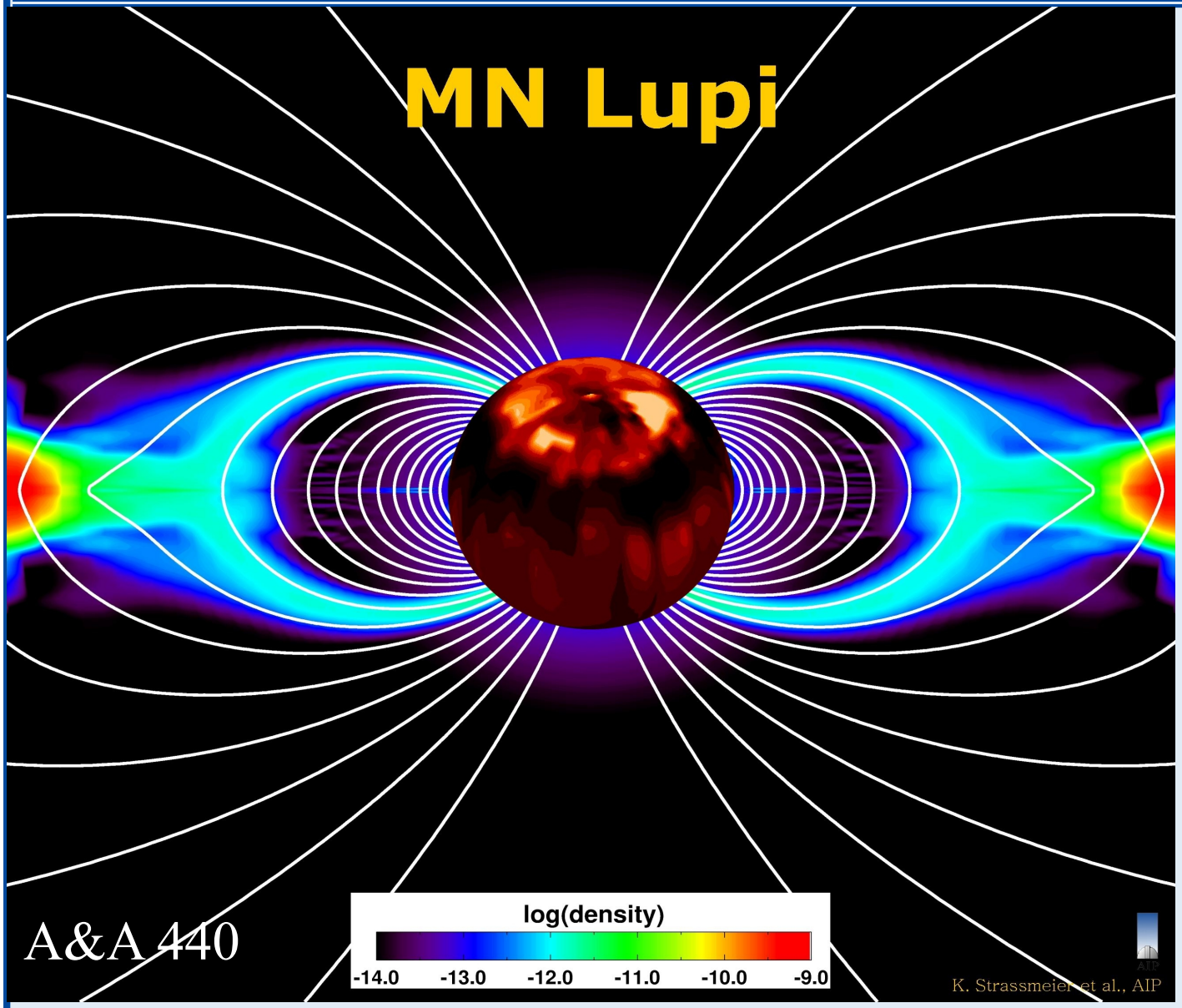
e.g. PMS stellar surfaces (0.6Ms,20Myr,60Ωs)



- Magnetospheric accretion model fits Doppler images and predicts a polar field of 3 kG.

- Hot spots are the heating points of accretion shocks Warm cap is the trailed and redistributed impact energy

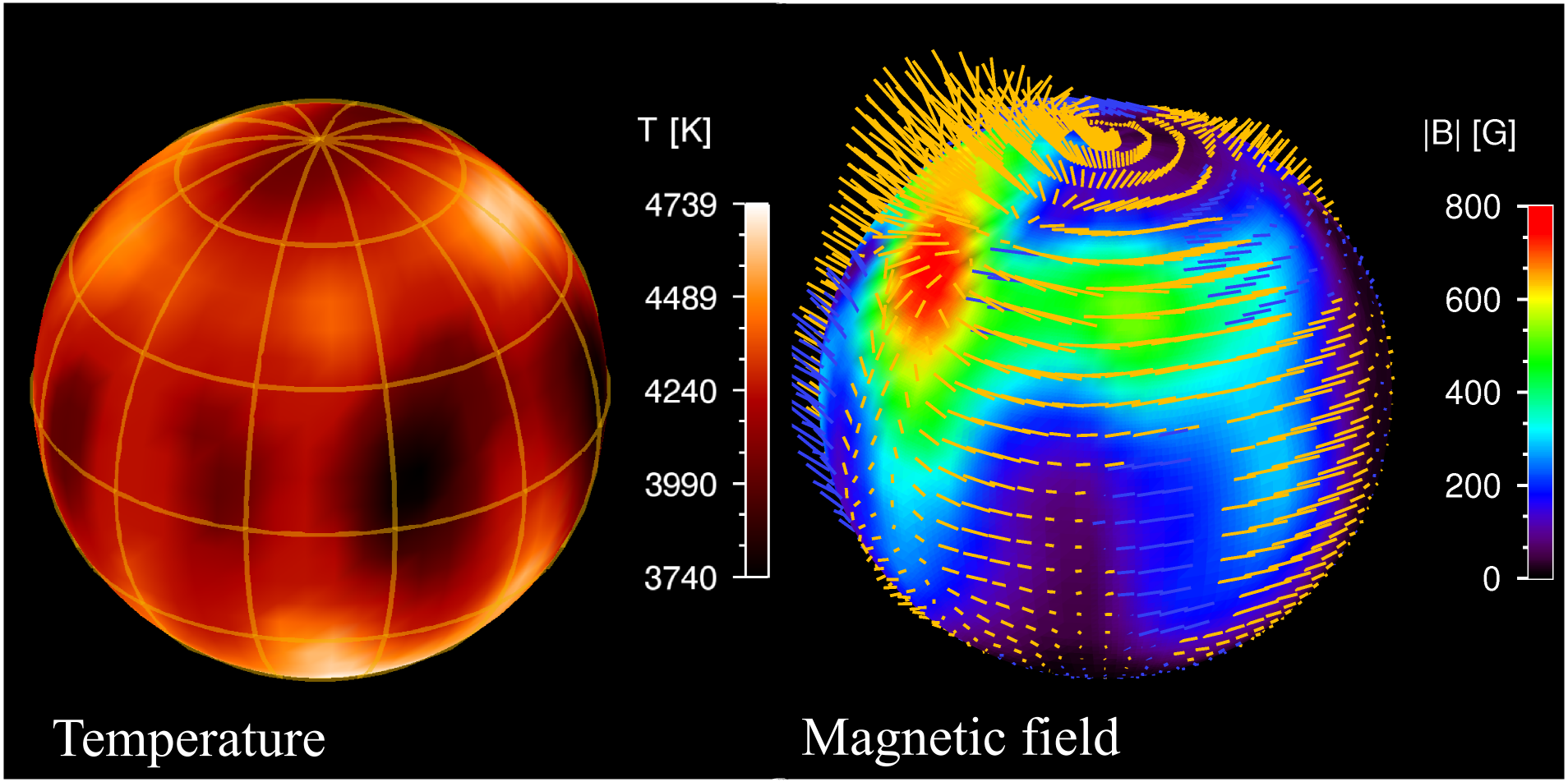
- Cool spots are likely of local magnetic origin

- „Cool“ hemisphere is obscuration due to the inner rim of the disk

Zeeman Doppler Imaging

- Extention of the DI technique to polarized line profiles (Semel 1989, Donati et al. 1990, Piskunov et al. 1991, Rice 2002, Carroll et al. 2007).
- For cool stars currently only Stokes V accessible.
- Even then, all ZDI maps so far are either from LSD or from PCA denoised line profiles.
- Solar-type stars are the most difficult (long period, short spot/plage lifetime, small-scale fields, complex global field geometry).
- Long-haul goal: recover magnetic field and area and obtain surface **magnetic flux** as f(age)

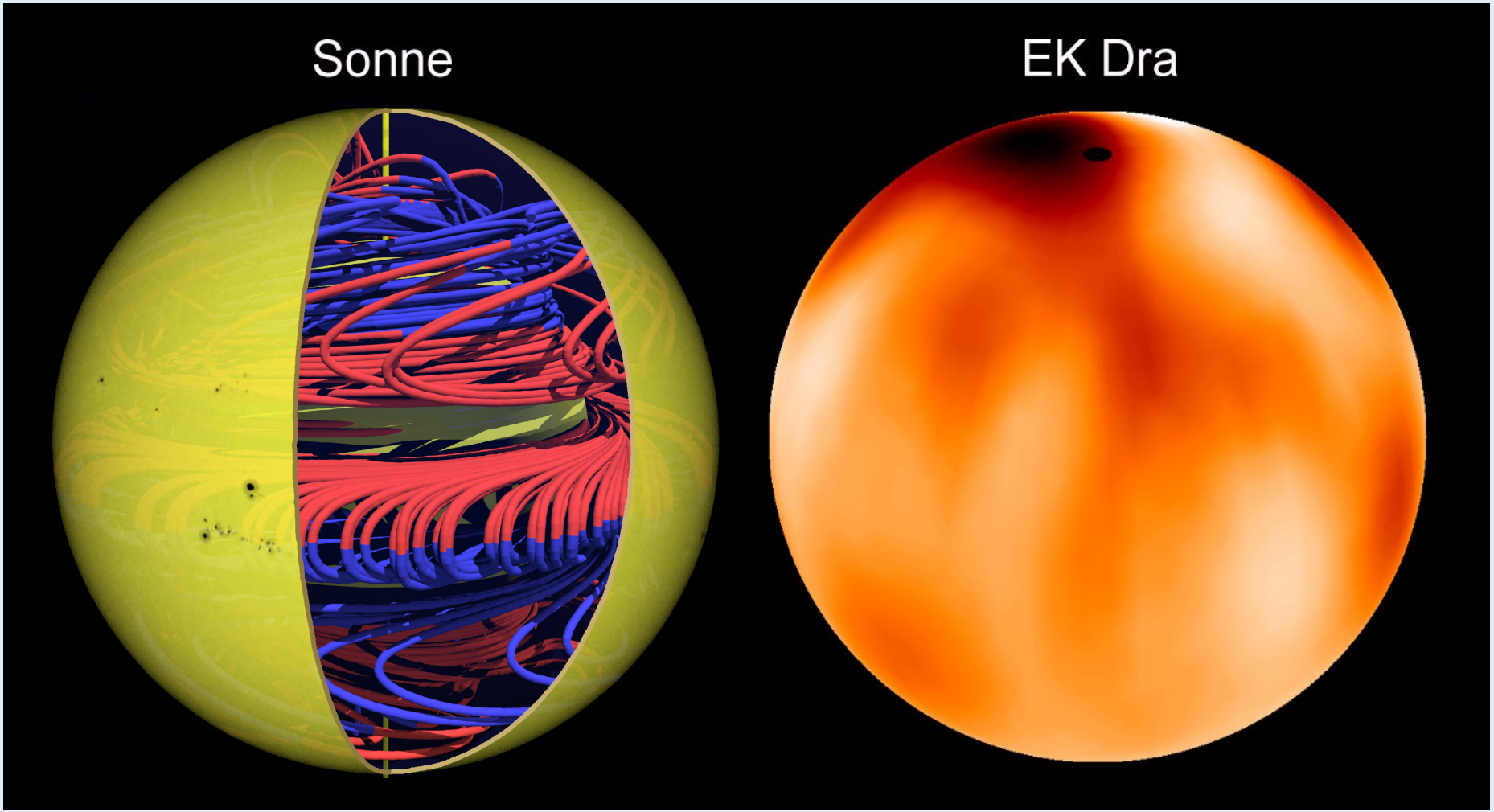
Application to II Peg: still just Stokes V



Carroll, Kopf, Strassmeier, Ilyin & Tuominen 2008

II Peg is an active RS CVn binary though.

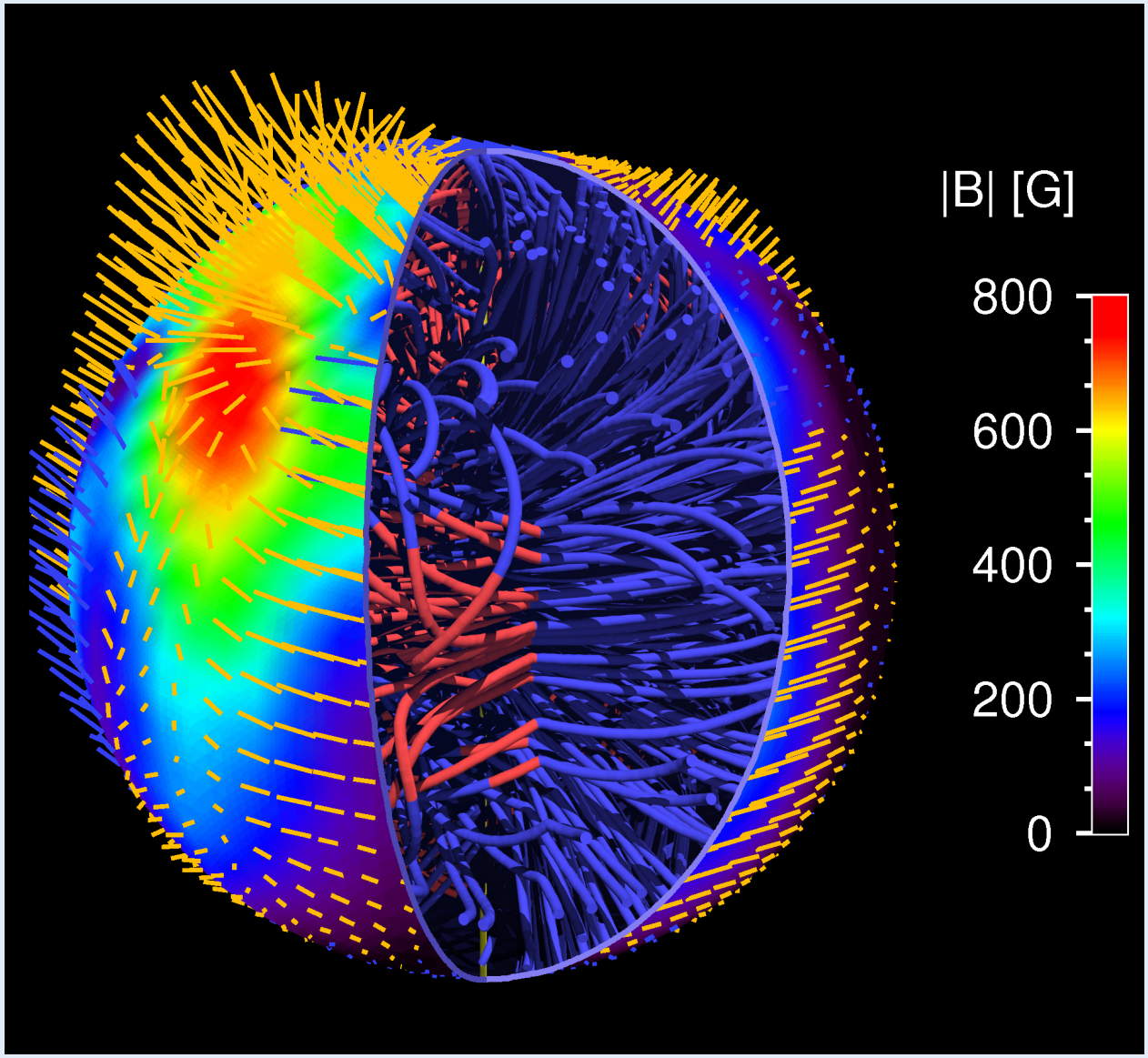
Summary: sunspots represent link to the internal dynamo



Strassmeier & Rice 1999

Single G2V, $10\Omega_{Sun}$

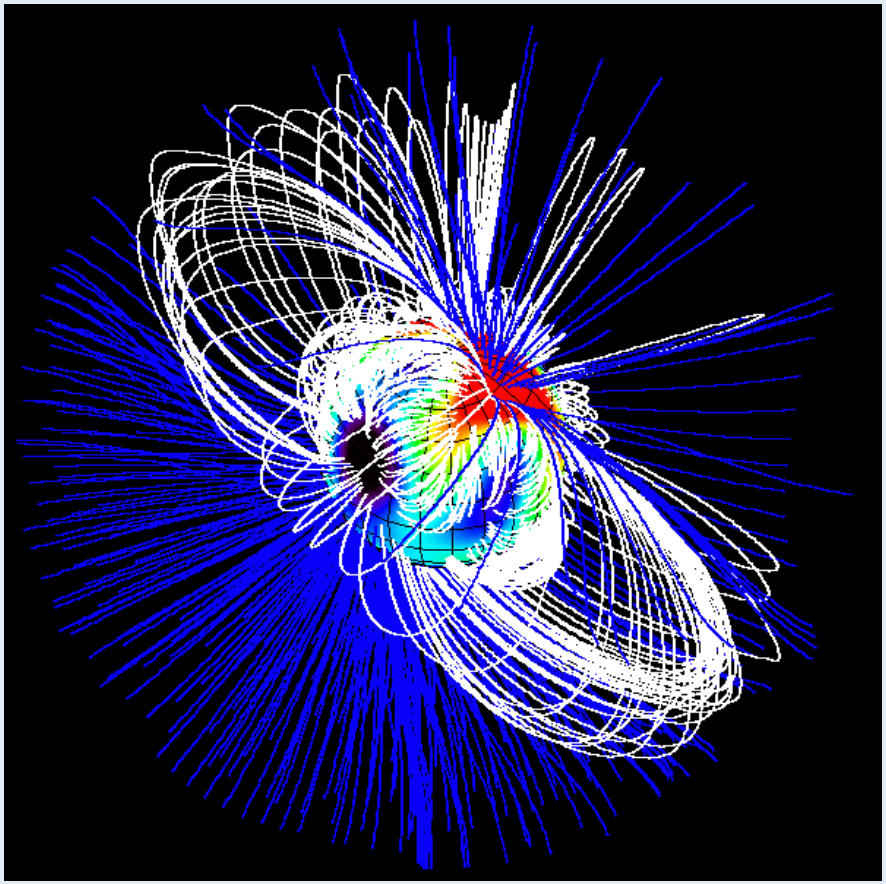
Outlook: link surface to interior …



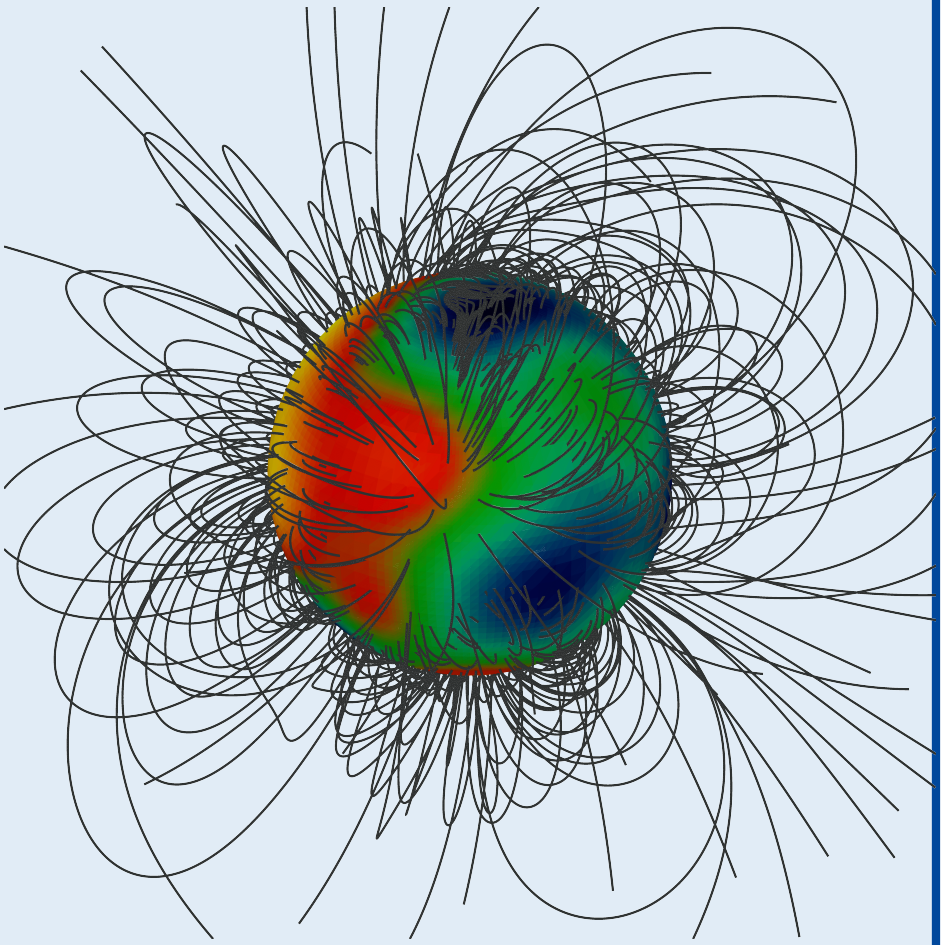
Solar surface appears to be a **fingerprint** of the internal dynamo, why not also for stars?

Simulation by R. Arlt

… and the exterior



Cool dwarf star
c/o Jardine & Donati



White dwarf
c/o Beuermann, Euchner & Jordan

Polarimetric precision and limiting magnitude

Covering 0.4-1μm at R=100,000 [illegible] integration :

42m E-ELT

$\delta P/P=10$ [illegible]

$\delta P/P=$ [illegible] $V\approx 8^{m}$;

$\delta P/P=10^{-1}$: $V\approx 11^{m}$;

$\delta P/P=10^{-2}$: $V\approx 16^{m}$; ($K\approx 12^{m}$ G2 star)

$\delta P/P=10^{-1}$: $V\approx 21^{m}$.

… allows access to bright Quasars, globular cluster K dwarfs, brown dwarfs in nearby Open Clusters, solar-system bodies as faint as Triton and all the way to the Galactic-Centre O & AGB stars.