

# Effects of rotation and magnetic fields on the structure and surface abundances of solar-type stars

Patrick Eggenberger

*Observatoire de l'Université de Genève*



# Physics of the models

- General input physics
- Atomic diffusion
- Rotation
  - Shellular rotation (Zahn 1992)
    - \* breaking of the spherical symmetry
    - \* meridional circulation
    - \* differential rotation and shear instabilities ( $D_{\text{shear}}$ )
    - \* horizontal turbulence ( $D_{\text{h}}$ )
  - $\Omega$  is approximately constant on isobar
- Magnetic fields
  - Disk locking
  - Convective dynamos and magnetic winds
  - Internal magnetic fields

# Effects of rotation

- $1 M_{\odot}$  models

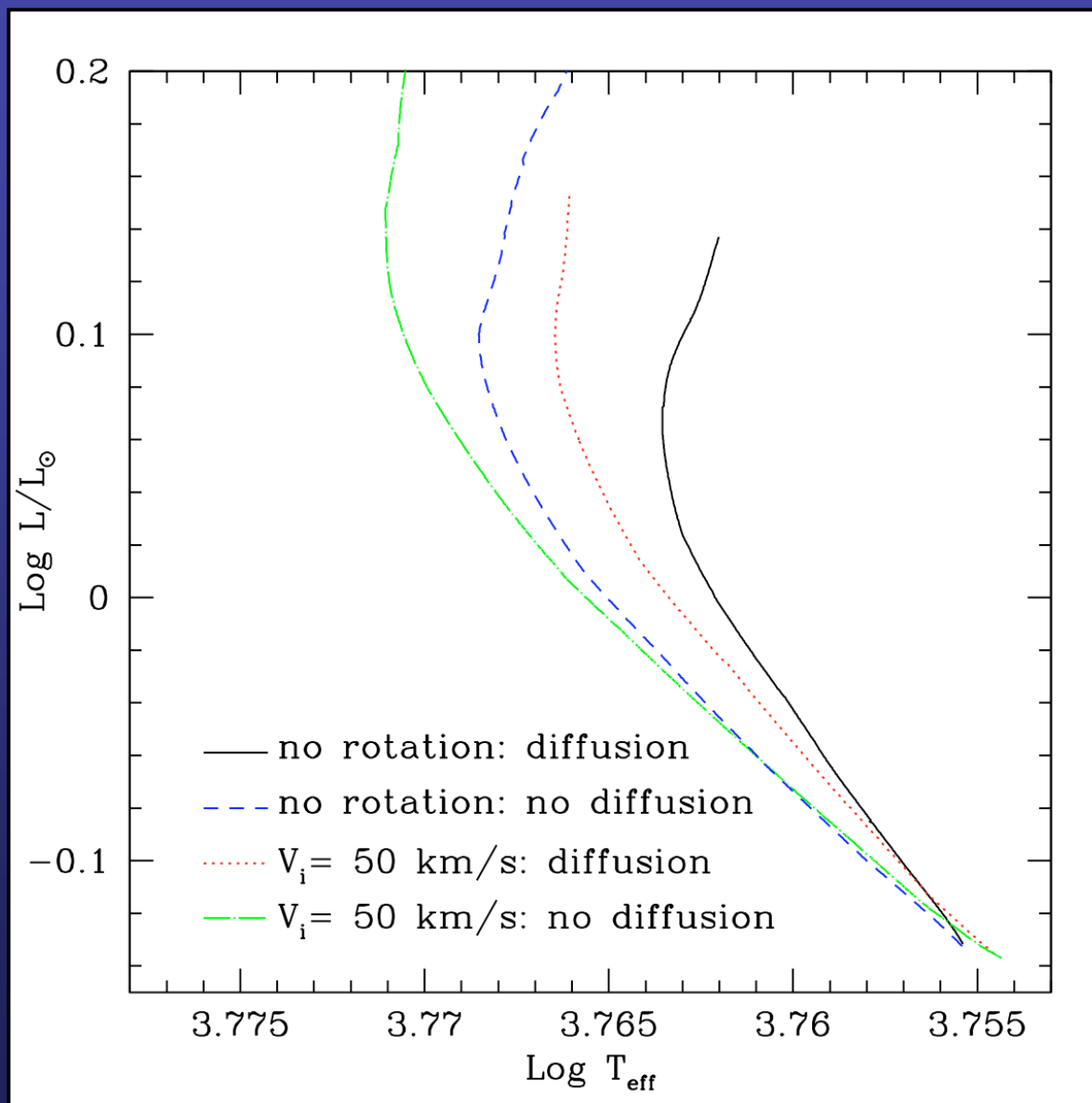
- Rotation:

shift to the blue due to rotational mixing

- Atomic diffusion:

decrease of L

and  $T_{\text{eff}}$



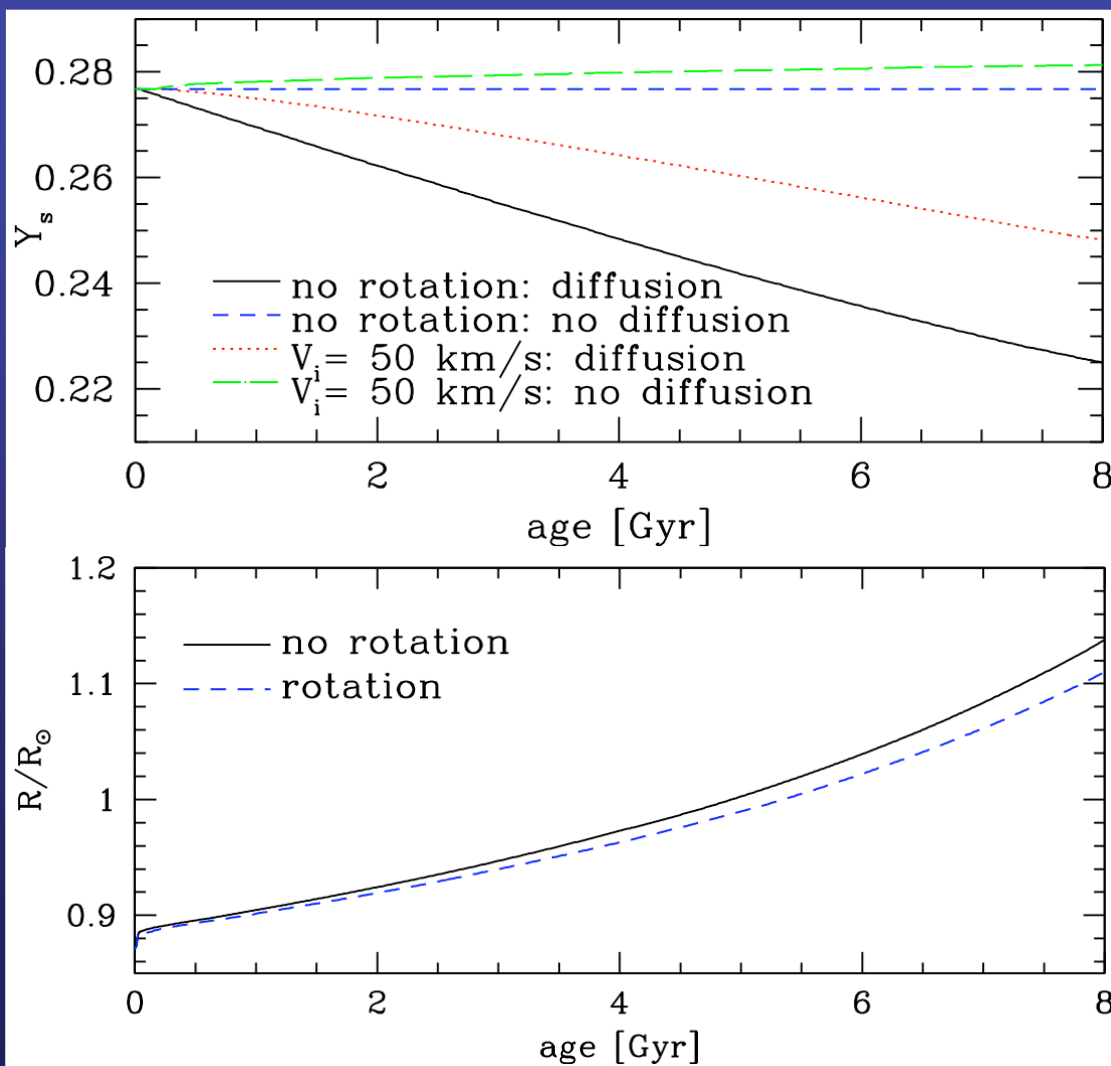
# Effects of rotation

- Surface abundances and global stellar properties

- Rotation:

counteracts the effects of atomic diffusion in the external layers

decrease of  $R$



# Effects of rotation

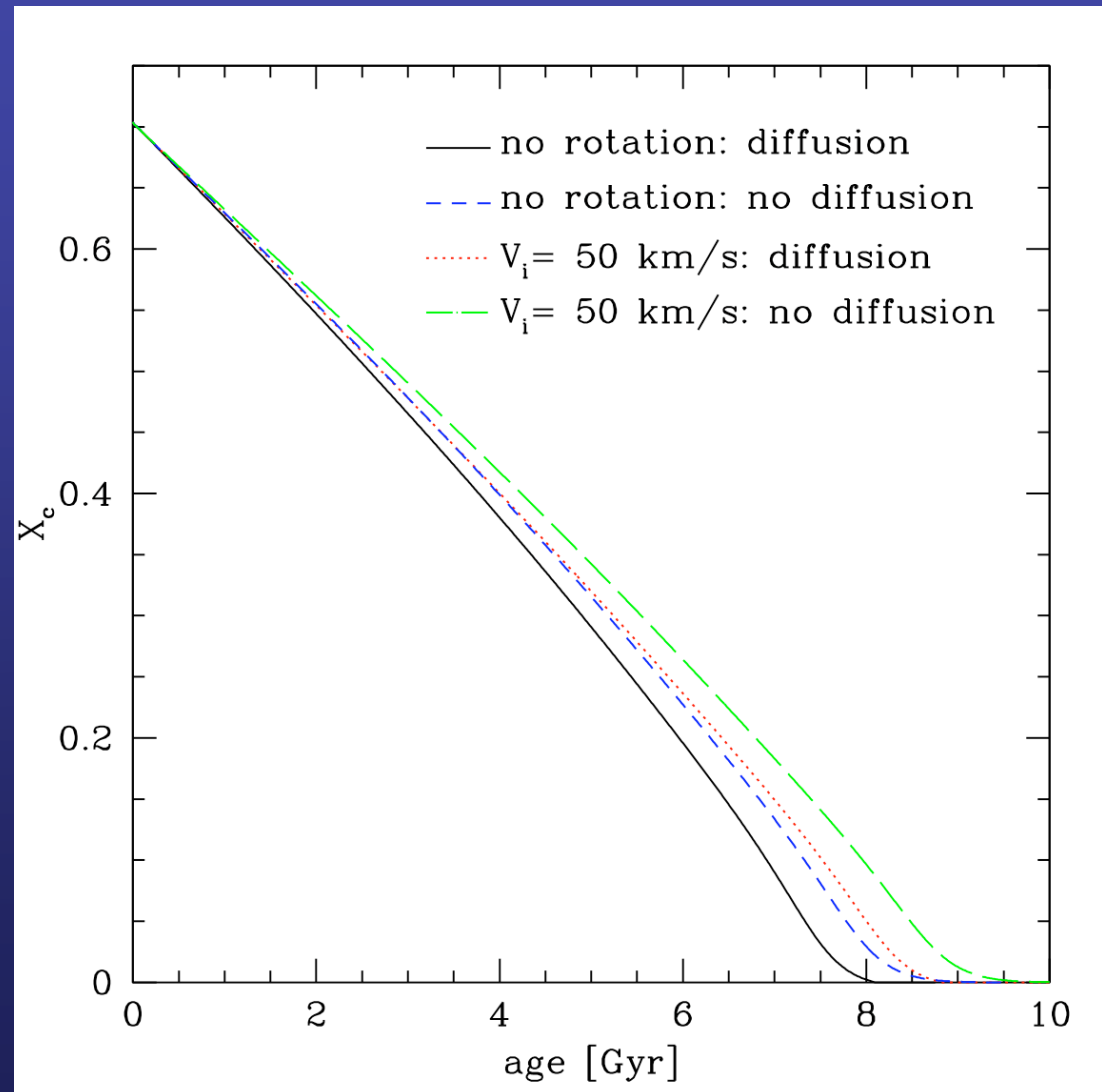
- Central layers

- Rotation:

- $X_c$  increases

- the MS lifetime is enhanced

- Larger efficiency of rotational mixing in the central layers



# Effects of rotation

- Asteroseismic diagnostics: global stellar properties

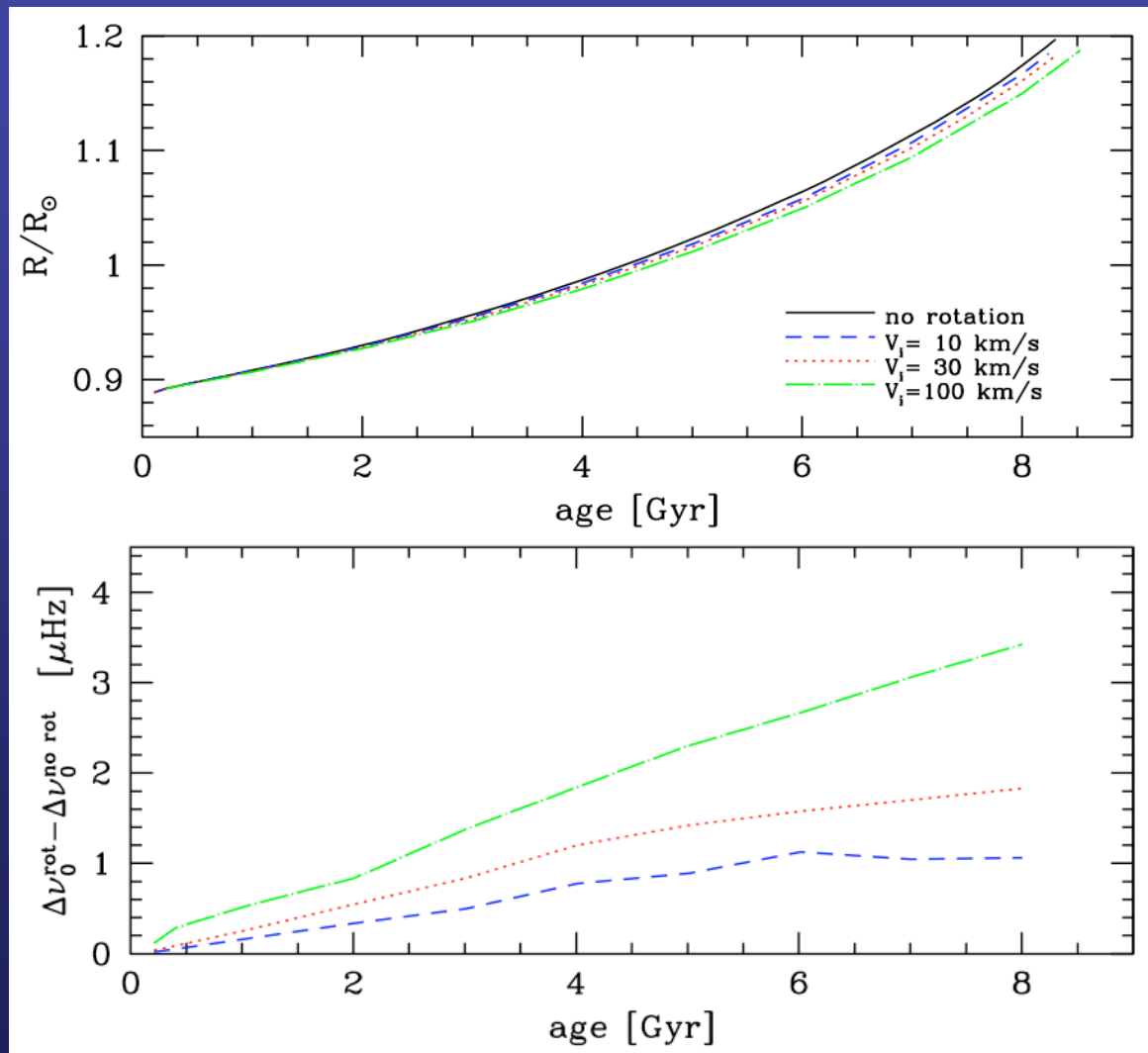
- Large separation:

$$\Delta \nu_0 \equiv \langle \nu_{n,l} - \nu_{n-1,l} \rangle$$

$$\Delta \nu_0 \sim t_{\text{dyn}}^{-1} \sim \langle \rho \rangle^{1/2}$$

- Rotation:

$\Delta \nu_0$  increases



# Effects of rotation

- Asteroseismic diagnostics: central layers

- Small separation:

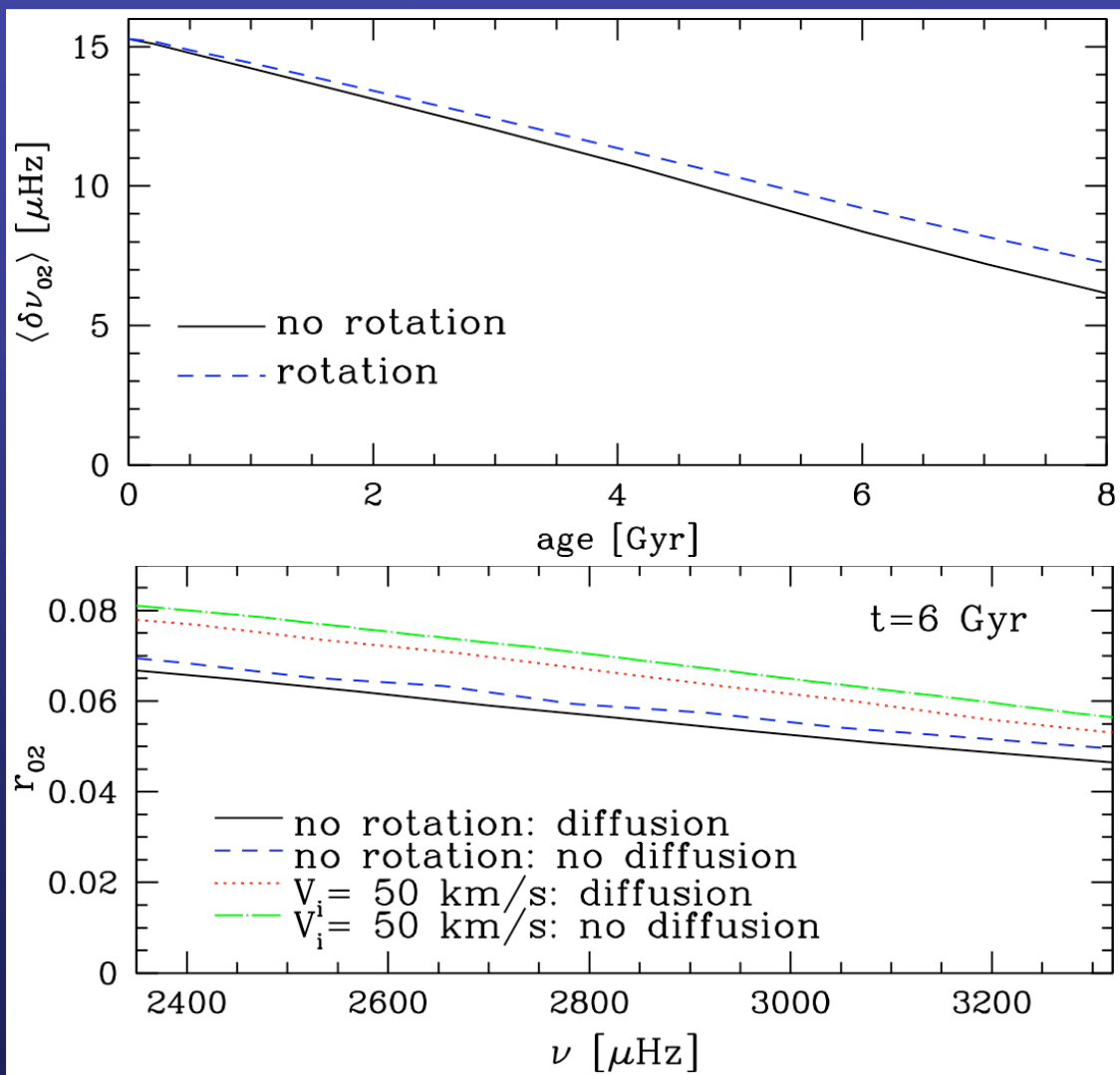
$$\langle \delta \nu_{02} \rangle \equiv \langle \nu_{n,l} - \nu_{n-1,l+2} \rangle$$

mainly sensitive to the conditions in the central regions ( $X_c$ )

$$r_{02} \equiv \delta \nu_{02} / \Delta \nu_{l=1}$$

- Rotation:

$\delta \nu_{02}$  and  $r_{02}$  increase



# Effects of magnetic fields

- The solar rotation profile

- Problem with shellular rotation

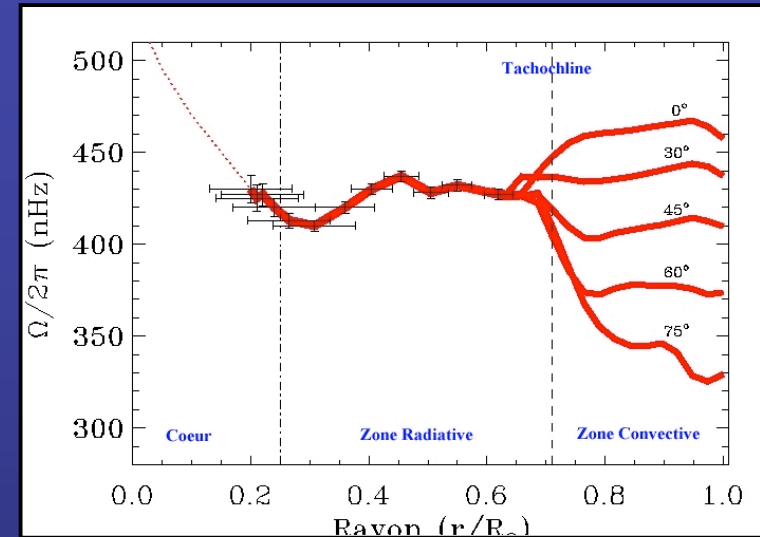
Pinsonneault et al. 1989

Chaboyer, Demarque & Pinsonneault 1995

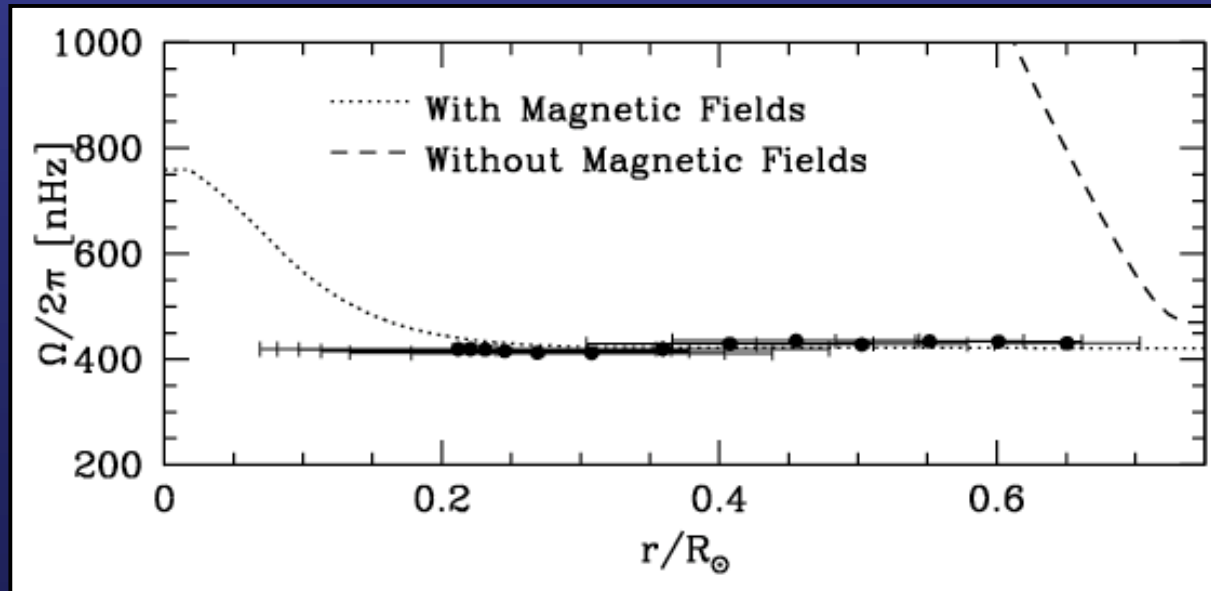
- Magnetic fields: Tayler-Spruit dynamo?

Spruit 1999, 2002; Maeder & Meynet 2004, 2005

see also Denissenkov & Pinsonneault 2007; Zahn et al. 2007



Garcia et al. 2007



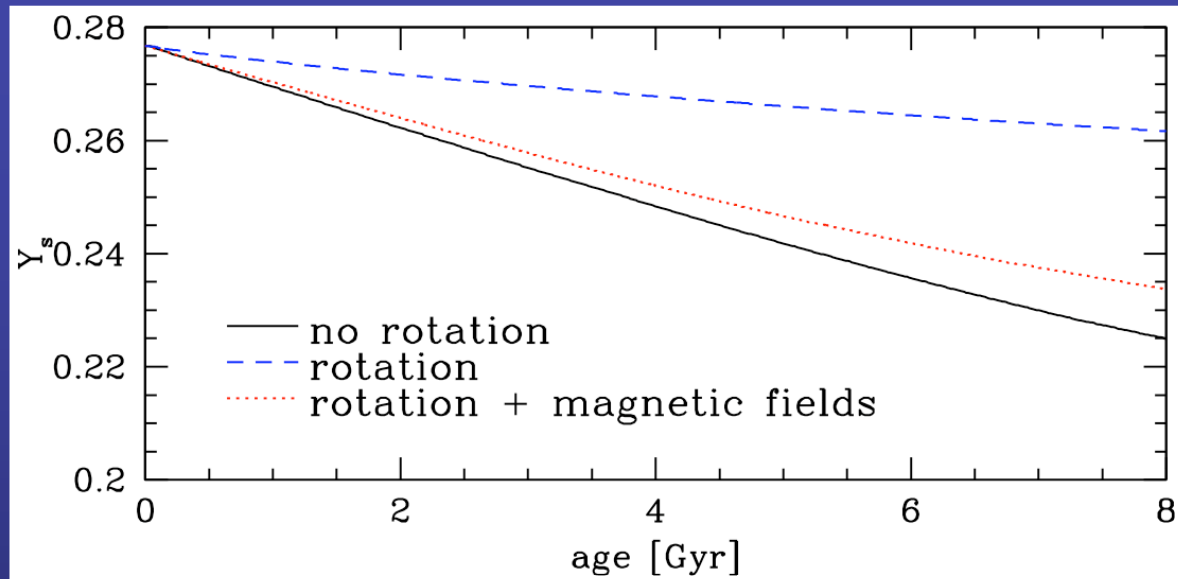
Genève Eggenberger, Maeder & Meynet 2005



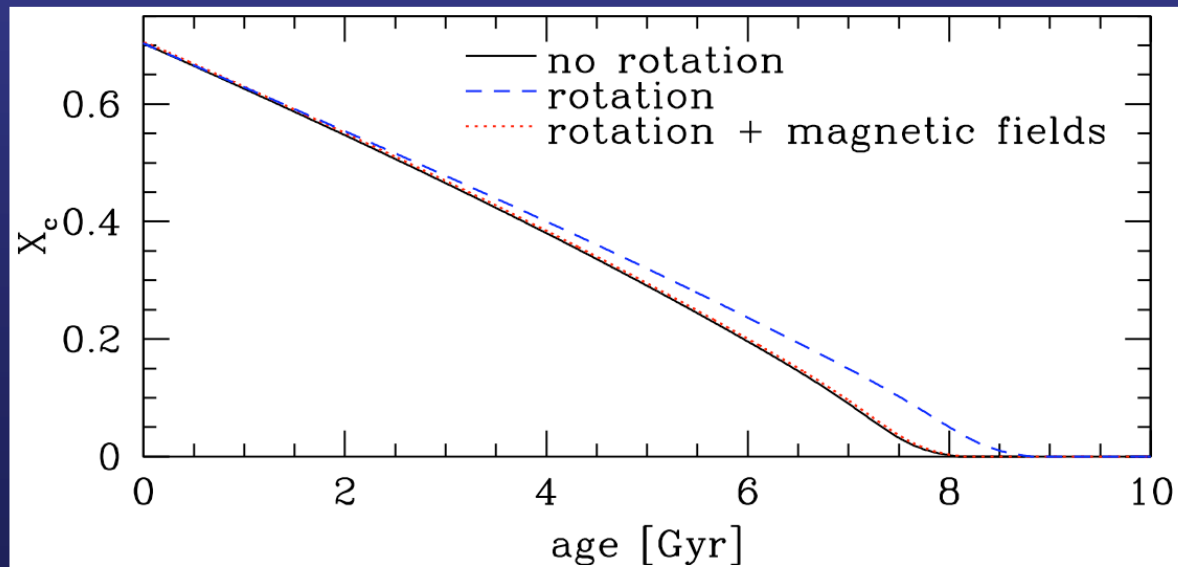
# Effects of magnetic fields

- Surface abundances

- magnetic fields:  
mixing is strongly  
reduced

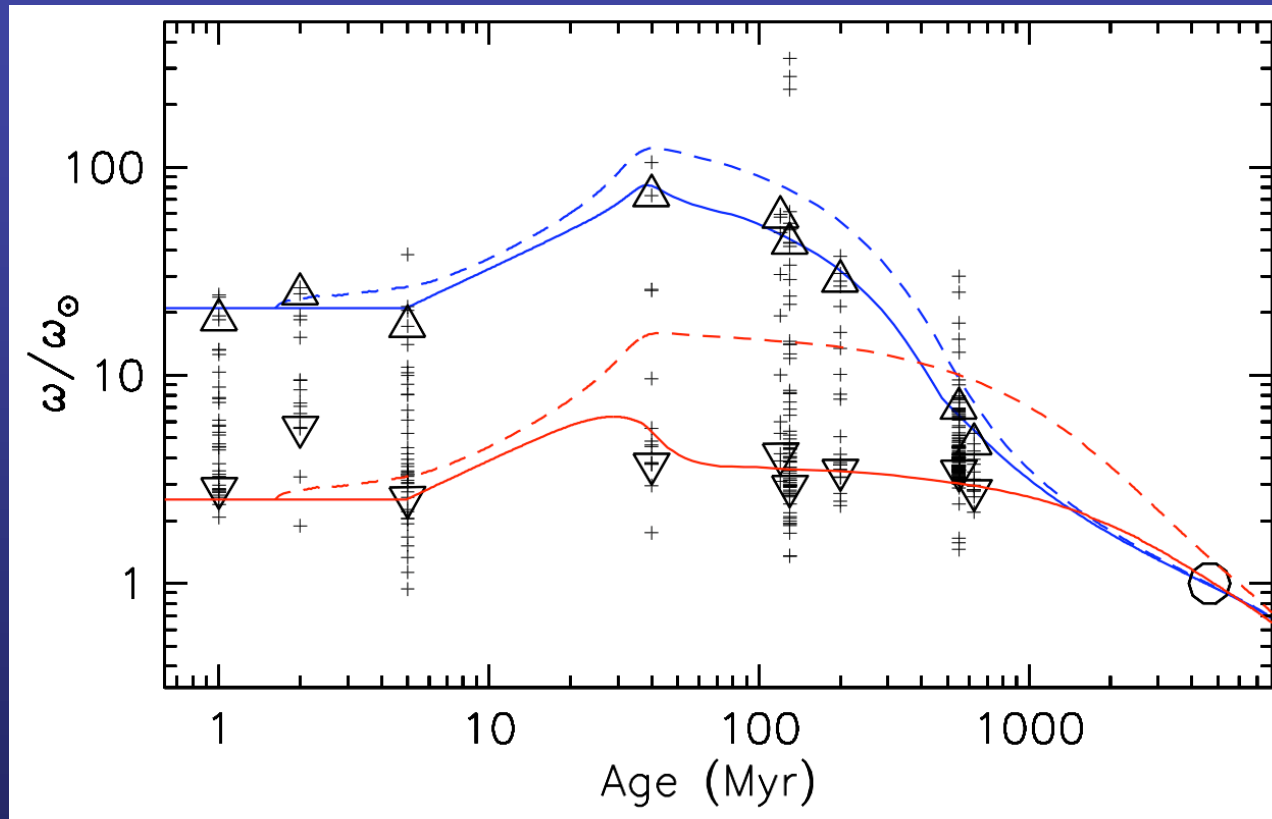


- Central layers



# Rotational history of exoplanet host stars

- Rotation rates of solar-type stars

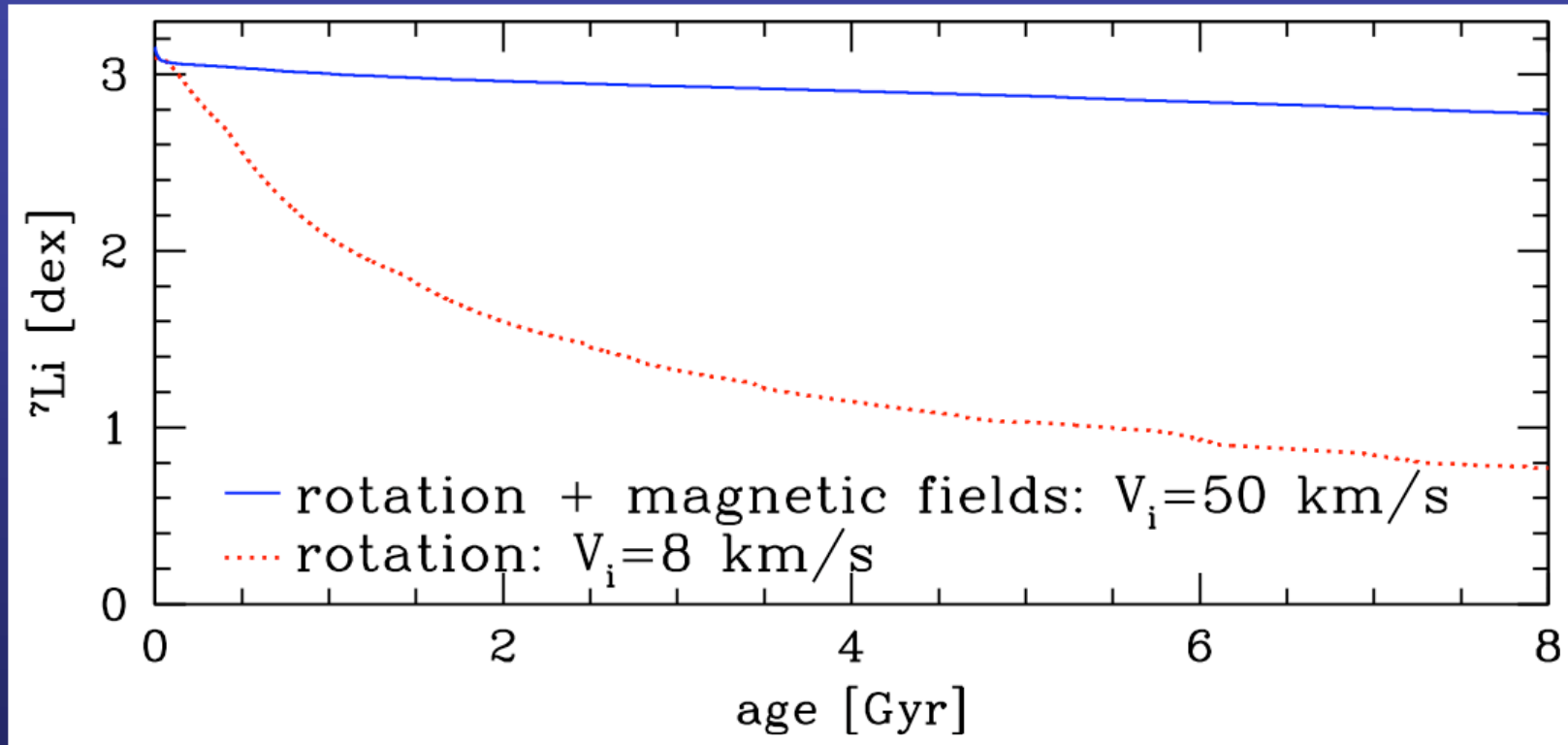


Bouvier 2008

- fast rotators : little differential rotation
- slow rotators : strong differential rotation

# Rotational history of exoplanet host stars

- Lithium depletion in slow and fast rotators



- fast rotators : high Li abundances
- slow rotators : more Li-depleted

# Rotational history of exoplanet host stars

- Disk lifetime: if longer then ...

- Lower rotation on the ZAMS  
*disk locking*

- Higher Li depletion  
*efficient mixing associated to differential rotation  
in slow rotating solar-type stars*

- Giant exoplanets formation  
and/or migration

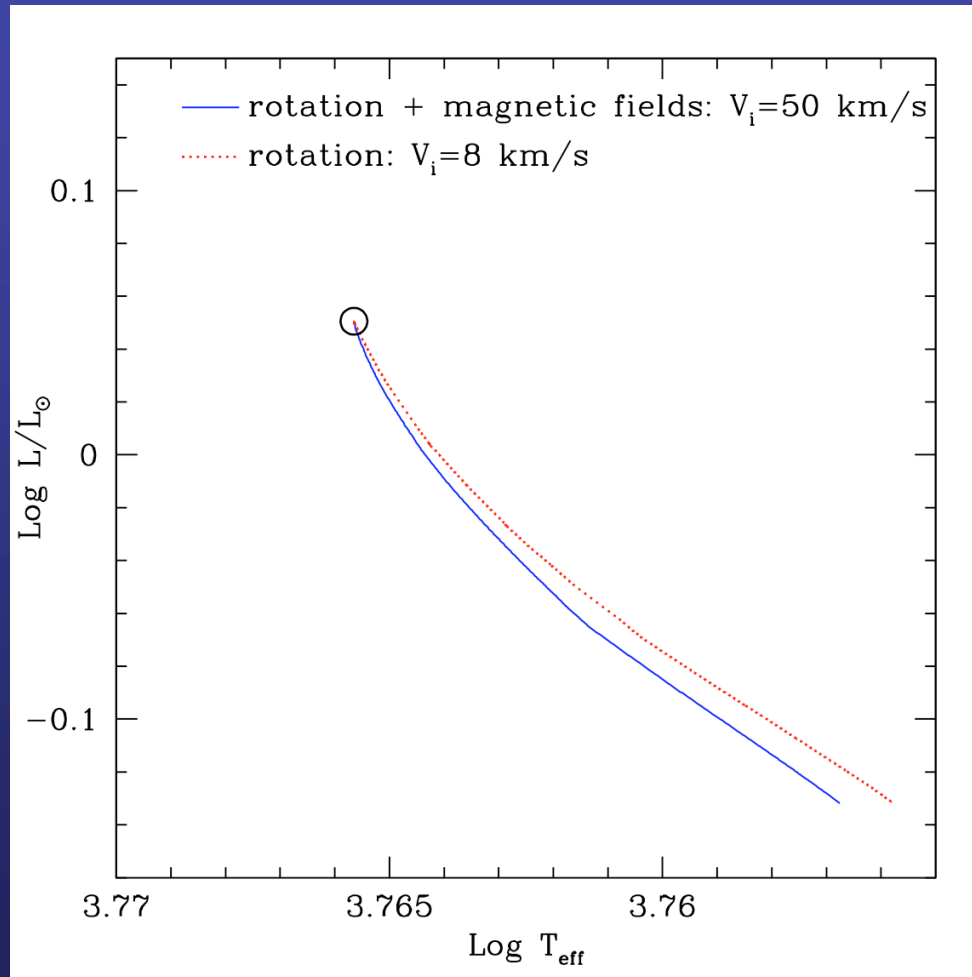
- Other correlations?  
*asteroseismic observables*

Observations in the  
Pleiades (Soderblom et  
al. 1993)

Observations by  
Israelian et al. (2004)  
(see also Meléndez et  
al. 2009)

# Rotational history of exoplanet host stars

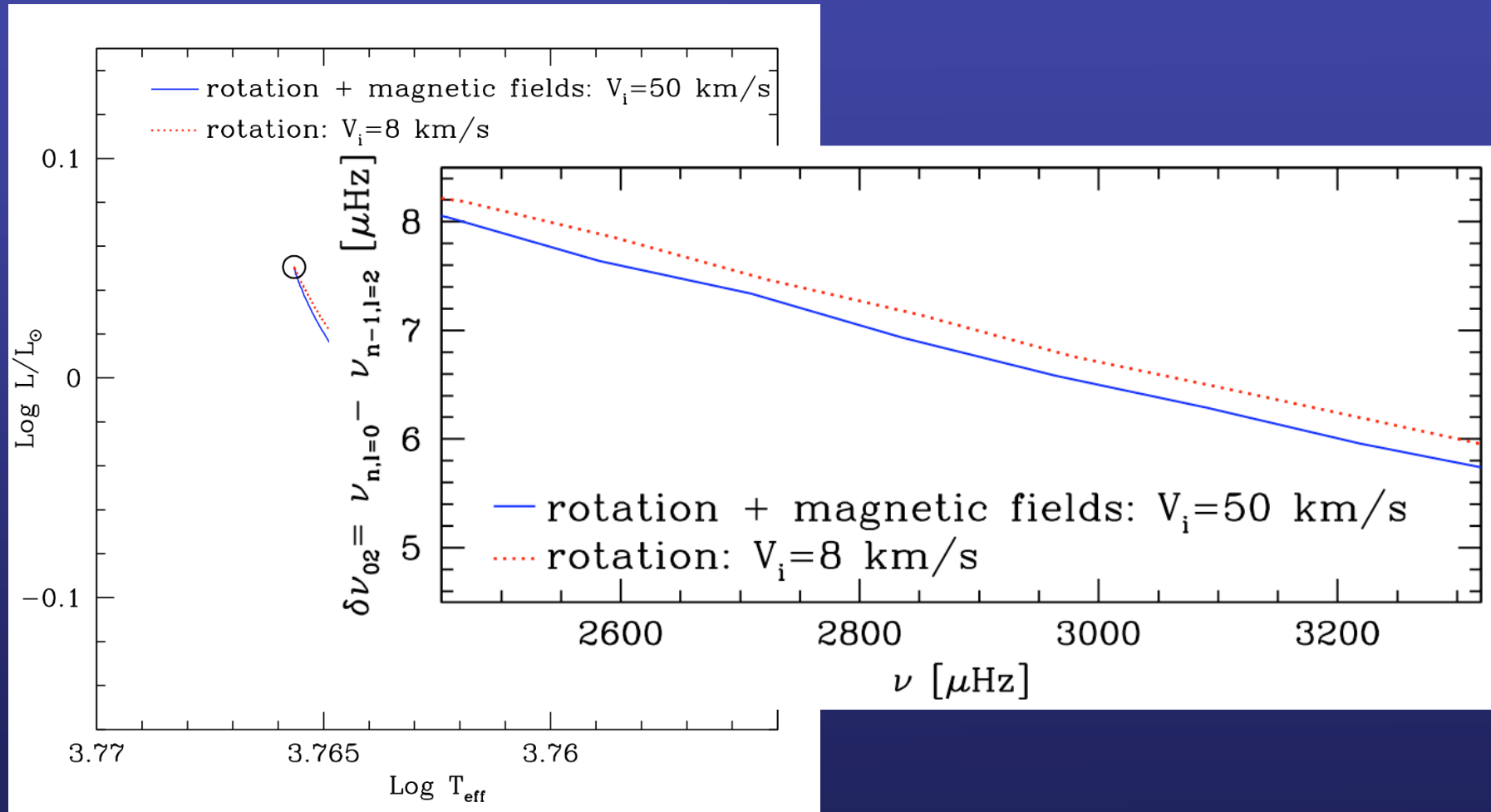
- Asteroseismic observables



- slow rotators : increase of the small separations

# Rotational history of exoplanet host stars

- Asteroseismic observables



- slow rotators : increase of the small separations

# Rotational history of exoplanet host stars

- Disk lifetime: if longer then ...

- Lower rotation on the ZAMS  
*disk locking*

- Higher Li depletion  
*efficient mixing associated to differential rotation  
in slow rotating solar-type stars*

- Giant exoplanets formation  
and/or migration

- Larger values of the asteroseismic  
small separations

Observations in the  
Pleiades (Soderblom et  
al. 1993)

Observations by  
Israelian et al. (2004)  
(see also Meléndez et  
al. 2009)

Predicted by rotating  
models

# Conclusion

- Effects of rotation
  - increase of  $T_{\text{eff}}$ ,  $Y_s$ ,  $X_c$  and of the main-sequence lifetime
  - effects on the asteroseismic observables
- Effects of magnetic fields
  - mixing is strongly reduced (solar-type stars  $\neq$  massive stars)
- Rotational history of planet host stars
  - lithium abundances and presence of giant planets related to the rotational history of the star (Bouvier 2008; see also Castro et al. 2009)
  - change of the asteroseismic properties of slow/fast rotators

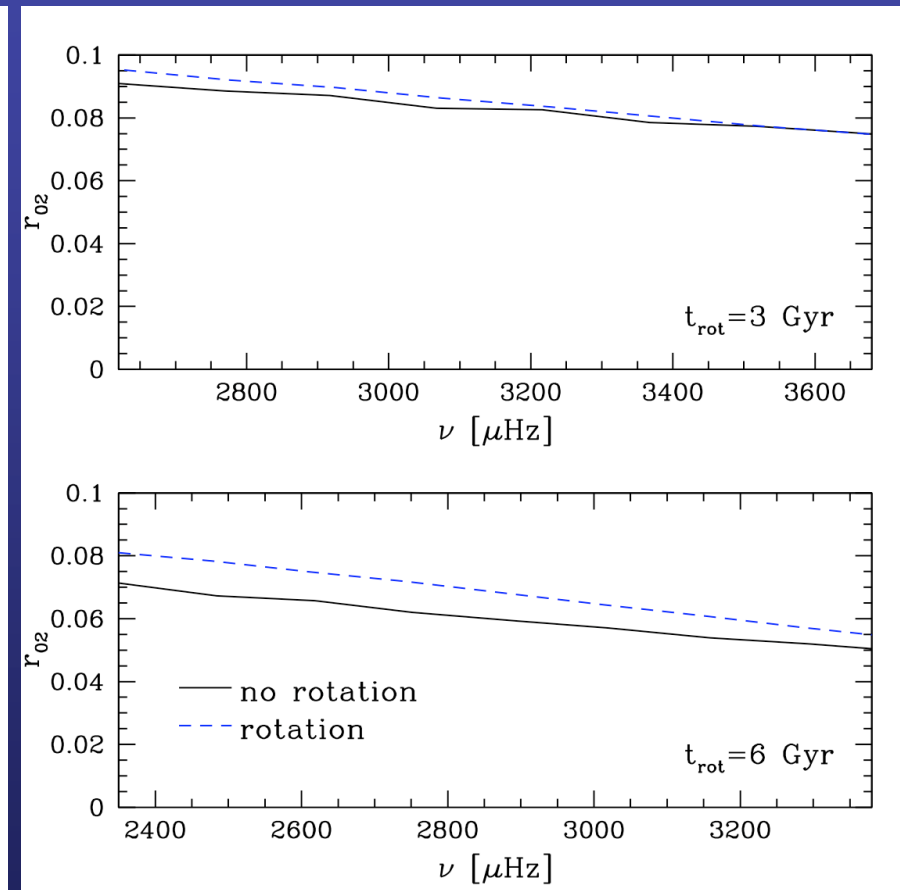
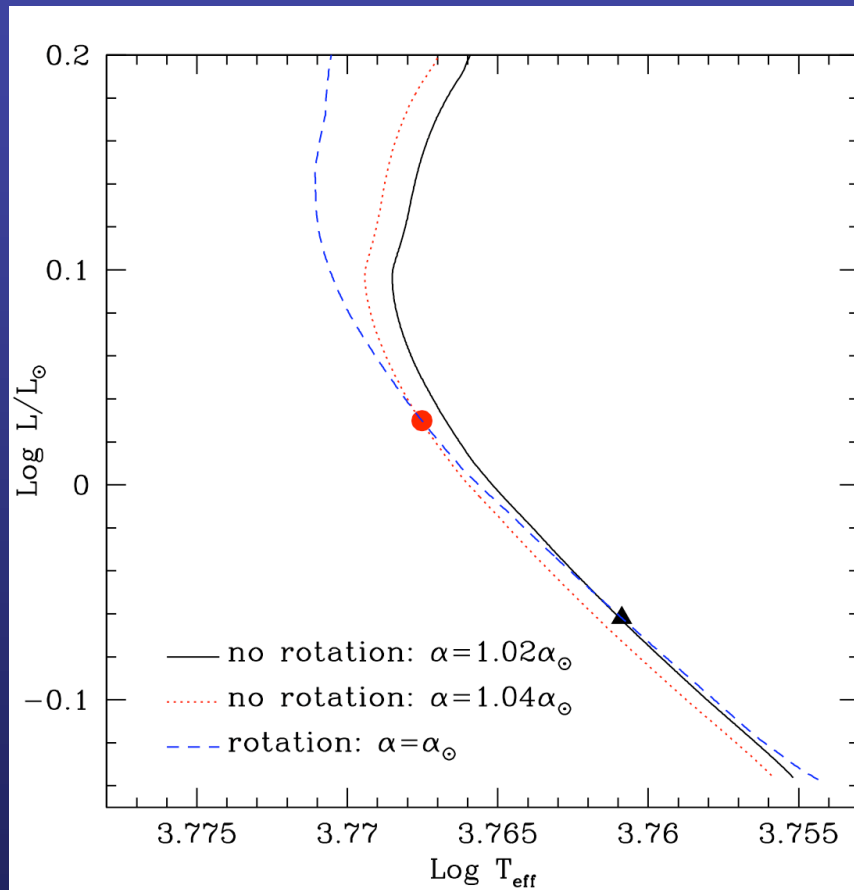
*Complementarity between spectroscopic and asteroseismic observations to constrain transport processes in stellar interiors*





# Effects of rotation

- Models with the same location in the HR diagram



# Effects of rotation

- Asteroseismic diagnostics: central layers
  - Test of the horizontal turbulence prescription

