



Magnetic field structure in single late-type giants:

β Ceti in 2010 - 2012



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Telescopes

- ✓ Telescope Bernard Lyot, Pic du Midi, France
- ✓ Canada – France – Hawaii - Telescope

Telescope	Diameter	Instrument	Resolution	Wavelength
TBL	2 m	NARVAL	65 000	370 ÷ 1050 nm
CFHT	3.6 m	ESPaDOnS	65 000	370 ÷ 1050



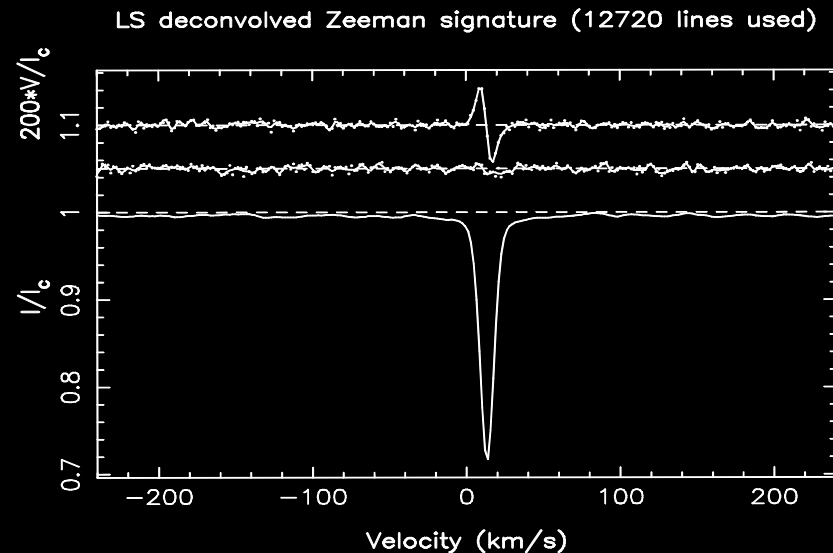
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LSD Technique

Donati et al. 1997

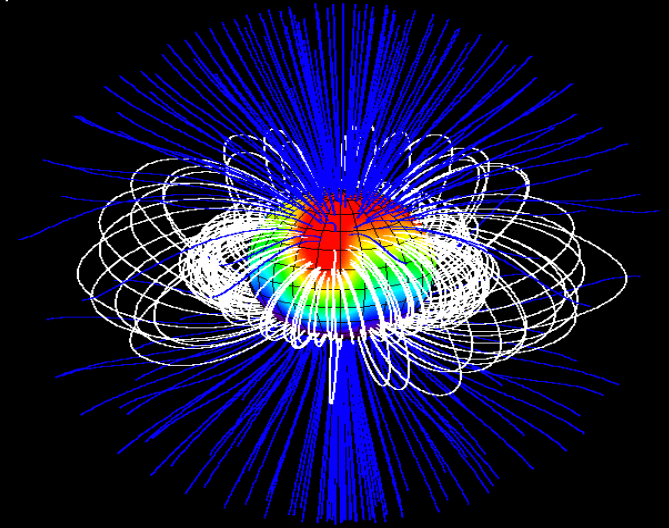
- ✓ Consist of averaging thousand of absorption lines from one spectrum
- ✓ All selected lines of the intensity spectrum have the same profile
- ✓ Improves S/N ratio
- ✓ Obtains the average photospheric profiles of Stokes I and V
- ✓ Detects weak magnetic signatures which would not be visible in individual lines





Zeeman - Doppler Imaging (ZDI)

- ✓ tomographic technique
- ✓ modeling sets of rotationally modulated circularly polarized profiles (Stokes V) of the spectral lines
- ✓ surface magnetic field is projected onto a spherical harmonics frame
- ✓ magnetic field is resolved into poloidal and toroidal components
- ✓ Stokes I profiles have a Gaussian shape
- ✓ Synthetic Stokes I and V profiles are computed and compared to the observed profiles



Donati et al. 2006

Semel 1989

Donati & Brown 1997

Donati et al 2003

Donati et al 2006



Parameters for β Ceti

- ✓ Rotational period – 217 days

Petit et al 2002

maximum entropy principles
synthetic ZDI Stokes V profiles

- ✓ $V \sin i = 3 - 4 \text{ km/s}$

- ✓ Inclination angle $i = 40^\circ - 80^\circ$

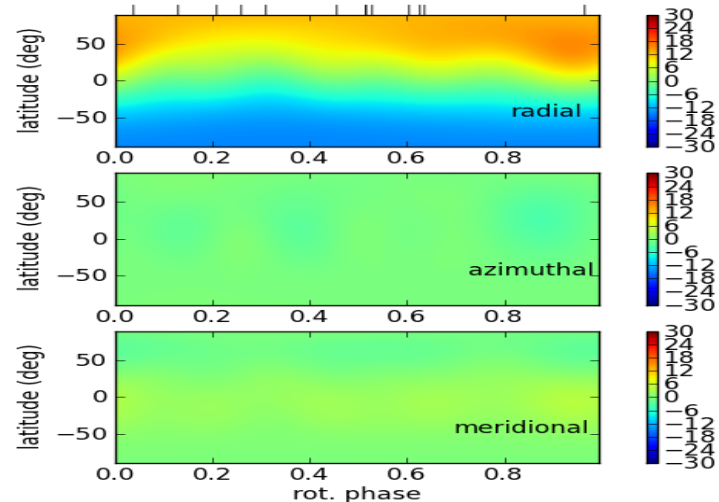
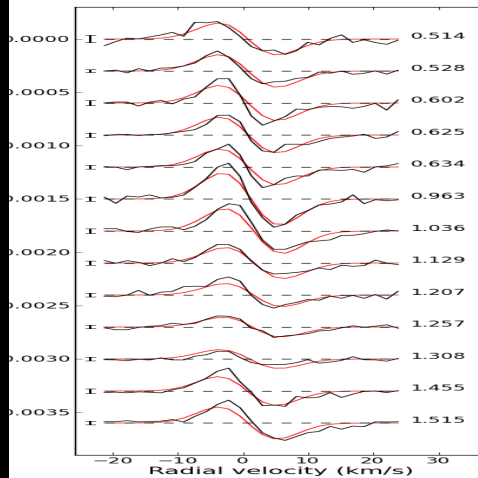
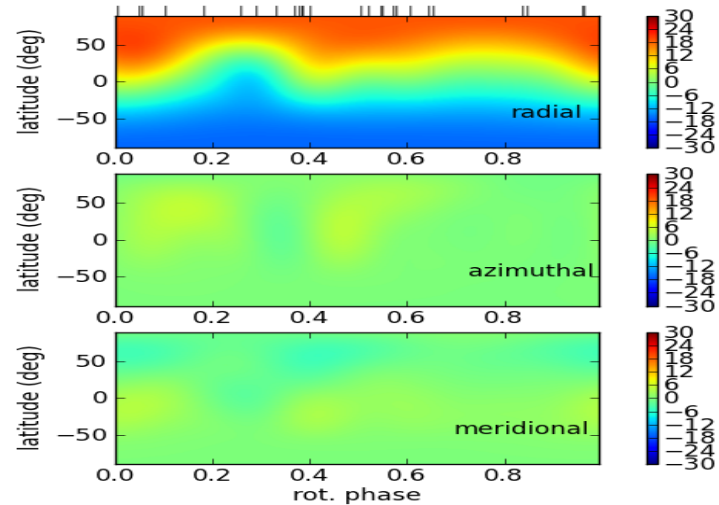
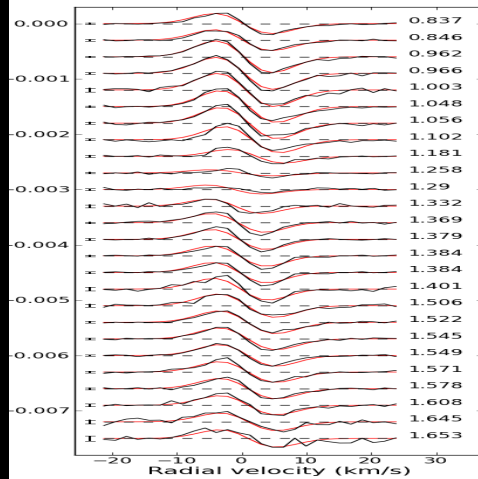
$$i = 60^\circ$$

→ The Best Magnetic Model → maximum entropy method (Donati 2001, Morin et al 2008)



β Ceti - Magnetic Maps

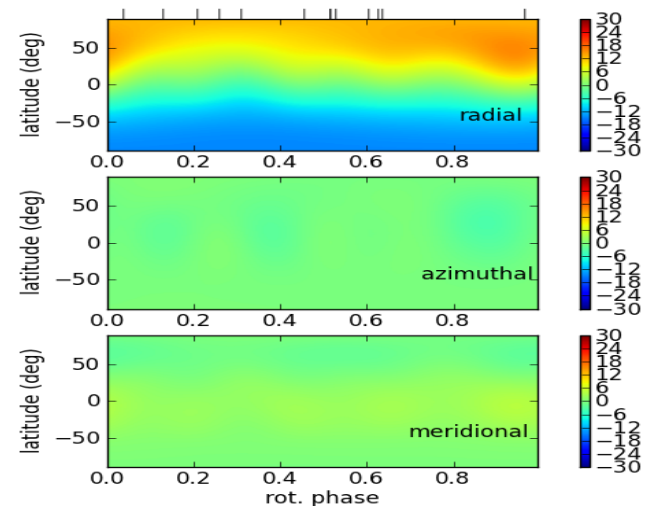
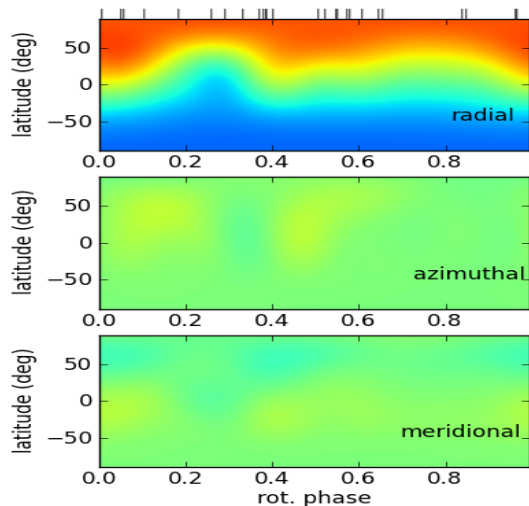
- ✓ June 2010 – December 2010
- ✓ June 2011 – January 2012
- ✓ dipolar configuration
- ✓ dominating poloidal component - 98% of the reconstructed magnetic energy





β Ceti - Magnetic Maps

	χ^2	Mean Field	Poloidal	Dipol	Axisymmetry
2010	2.2	12.1	97.7	79.3	79.3
2011 - 2012	2.4	9.8	98.5	94.0	89.1





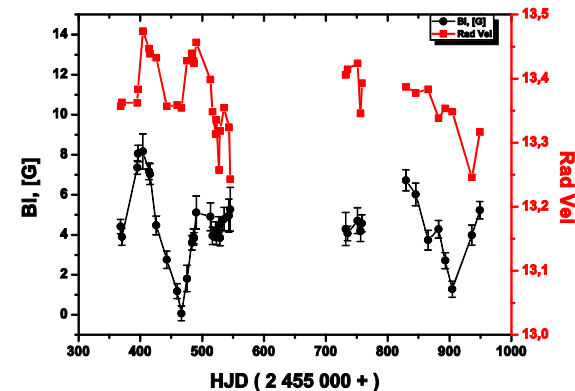
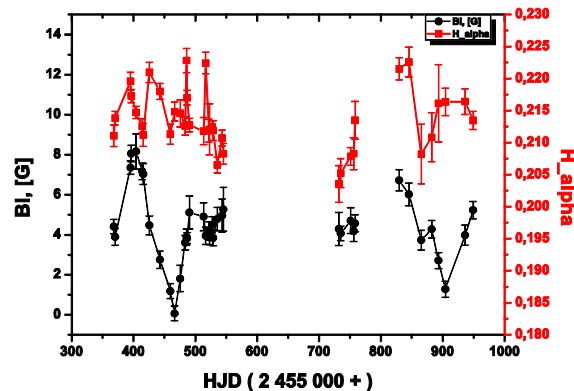
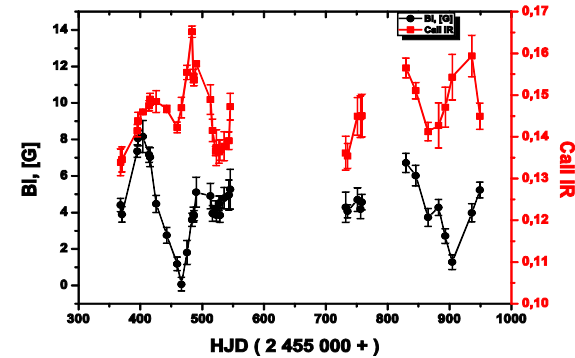
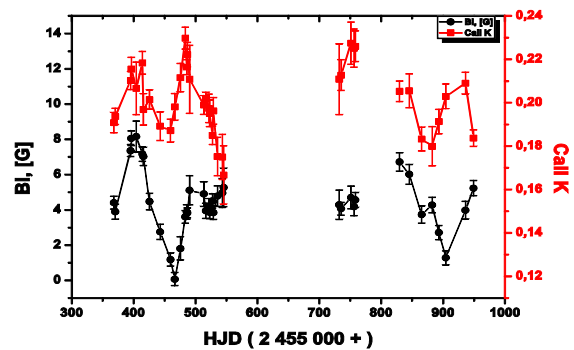
β Ceti - tracers of activity

Surfaced-averaged
longitudinal
magnetic field

$0.1 \div 8.2$ G

Call K :
 $0.17 \div 0.23$

H α :
 $0.20 \div$
 0.22



Call IR :
 $0.13 \div$
 0.17

RV :
 $13.24 \div$
 13.47
km/s



β Ceti – mass, evolutionary status, surface abundances

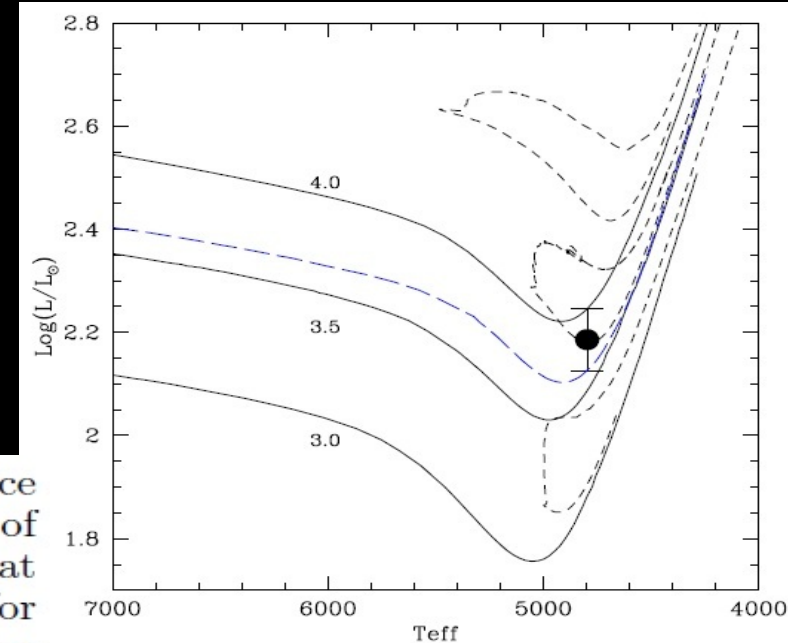
C. Charbonnel & T. Decressin

- ✓ $R = 17.98 R_{\text{sun}}$
(15 – 17)
- ✓ $M = 3.5 M_{\text{sun}}$
(2.8 – 3.2)

Lagarde et al. 2012

Table 2: Theoretical predictions for surface Li abundance and carbon isotopic ratio at the effective temperature of β Ceti on the first ascent of the red giant branch and at the clump in the $3.5 M_{\odot}$ standard and rotating models for two initial rotation velocities (50 and 140 km.s^{-1}). These numbers have to be compared with the observational values for β Ceti, namely $N(\text{Li})=0.01$ and $^{12}\text{C}/^{13}\text{C}=19\pm 2$ (see text for references and details)

	N(Li) RGB	N(Li) clump	$^{12}\text{C}/^{13}\text{C}$ RGB	$^{12}\text{C}/^{13}\text{C}$ clump
standard	1.75	1.27	67	20.6
rotation (50)	1.58	1.12	61	20.6
rotation (140)	0.53	0.007	38	18.32



- ✓ B-type main-sequence progenitor
- ✓ clump



β Ceti – Rossby Number

C. Charbonnel & T.
Decressin

✓ Def: Ro - the ratio between the rotational period $Prot$ and the convective turnover time τ_c

$$Ro = Prot / \tau_c = 1.26$$

$$Prot = 217 \text{ d}$$

$\tau_c = 172 \text{ d}$ (Hp/2 above the base of the convective envelope)

✓ Mean magnetic field of the main-sequence progenitor:

$$B (MS) = B [R / R (MS)]^2 \quad (\text{Stepien 1993})$$

$$R (MS) = 2.01 R_{\text{sun}}$$

$$R = 17.98 R_{\text{sun}}$$

$$B = 12.1 \text{ G and } 9.8 \text{ G}$$

$$\rightarrow B (MS) = 784 - 968 \text{ G}$$

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Conclusions

- ✓ Two magnetic maps of the surface magnetic field topology
- ✓ ZDI analysis : dipolar configuration with a dipole strength 12.1 G and 9.8 G for the two maps, respectively
- ✓ The large-scale magnetic field is mainly axisymmetric
- ✓ The behavior of the line activity indicators $H\alpha$, CaII K, CaII IR and the RV correlates rather well with the behavior of the longitudinal magnetic field $B_l \rightarrow$ dipole topology
- ✓ Clump position on the HRD
- ✓ $Ro = 1.26$
- ✓ $B (MS) = 784 - 968 \text{ G}$ (Aurière et al. 2007)

→ Ap star descendant



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Thank You
for your attention!