

*A Compendium of
Claimed and Confirmed
Magnetic Stars
of Spectral Type B2 and Earlier*

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Why massive stars?

- High mass = High luminosity
 - High $L \longrightarrow$ radiatively driven winds
 - Mass loss + magnetic field = circumstellar material
- Magnetic fields affect massive star evolution
 - Herbig Ae/Be progenitors of Ap/Bp
 - Progenitors of white dwarfs and magnetars
- Origin of magnetic fields still a mystery
 - Fossil fields
 - Dynamo

Indirect Indicators

UV line variability

- Stellar wind lines of C IV, Si IV, and N V
- Dipole fields -- **magnetically trapped material**
- Cyclical: **Discrete Absorption Components (DACs)**
- Timescales \approx Rotation period

Photometric variability

Chemical Peculiarities

- Magnetic field causes **lack of mixing** on the surface

X-rays

- Variable **hard X-ray emission** not explained by instability driven wind shocks

Detection Techniques

- Spectrograph + Polarimeter : Stokes I and V spectra
- Technique: **wavelength difference $\propto B_{\ell}$ ($\lambda_L - \lambda_R$)**
- LSD (Least Squares Deconvolution) - for weak lines, summing of all observable lines improves the magnetic signal
- Difficulties: rotational broadening and pulsation affects line profiles.
- Higher spectral resolution/Higher SNR = Detection of weaker and complex fields

Literature search:

- 29 candidate/detected massive magnetic stars
- Type B3 to O6
- 3 stars with no Stokes V detection
- 11 He Strong stars
- 6 Pulsators; 1 SPB star
- 5 O type stars
- 6 fast ($v \sin i > 100$ km/s) rotators
- 3 stars with fields more complex than a dipole

14 of 29 stars are on the Target List :

Spectral Type: B2

HD 37776 (V 901 Ori) -Vp

HD 37479 (σ Ori E) - Vp

HD 3360 (ζ Cas) - IV

HD 200775 (V 380 Cep) - Ve

HD 184927 (V 1671 Cyg) - Vp

HD 36982 (LP Ori) - V

HD 37490 (ω Ori) - IVe

HD 163472 (V 2052 Oph) - IV/Vp

Spectral Type: B1

OI 201

W 601 - e

HD 47777 (NGC 2264-83) - III

HD 37017 (V 1046 Ori) - Vp

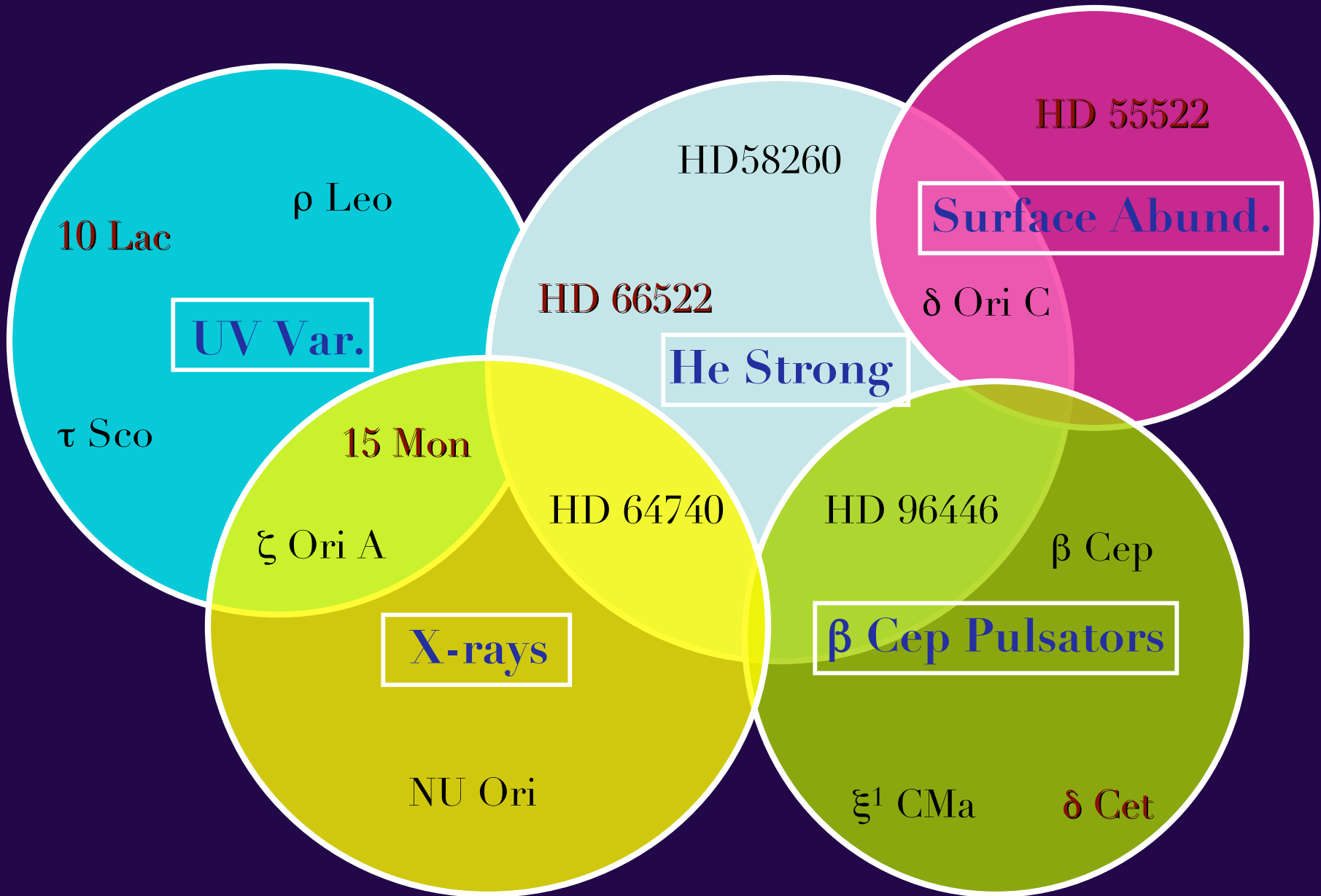
Spectral Type: O6-O4

HD 37022 (θ^1 Ori C) - V

Spectral Type: O6.5f?pe-O8fp

HD 191612

What do we know about the remaining 15?



Different Types of Measurements

B_l -- Longitudinal component of the magnetic field

$\langle B_l \rangle$ -- Mean longitudinal field (measured using Regression method)

B_{eff} -- Measured longitudinal component of the magnetic field strength (integrated over the stellar disk)

B_p -- Magnetic field strength at the magnetic pole (calculated using longitudinal field, obliquity, inclination, and rotational phase)

Stars with Confirmed Fields

δ Ori C

[Bohlender et al 1987/Bohlender 1989]

- B3 Vp; He Strong
- H α variability
- He spots
- $B_{\text{eff}} = -3400$ G ($\sigma=300$ G), constant
- $B_p \sim -9 \pm 2$ kG
- $v \sin i = 30$ km/s

$$i = 10^\circ, \beta \approx 0^\circ$$

τ Sco

[Donati et al 2006b]

- B0.2 V
- periodic UV variability
- X-ray emission
- $B_\ell = -50$ to 90 G (ESPaDOnS + AAT)
- Complex field geometry
- $v \sin i = 5$ km/s

$$i = 60 \text{ to } 90^\circ$$

Stars with Confirmed Fields (cont.)

ζ Ori A

[Bouret et al 2008]

- O9.7 Ib $i = 40^\circ, \beta = (83 \pm 10)^\circ$
- UV and optical spectral variability
- X-ray emission
- $B_p = 61 \pm 10$ G (Narval + LSD)
- Complex field geometry
- $v \sin i = 110$ km/s

β Cep

[Henrichs et al 2000]

- B1 IV $i = (60 \pm 10)^\circ, \beta = (85 \pm 10)^\circ$
- H α and UV variability
- β Cep pulsator
- $B_\ell = -90$ to 90 G (Musicos + LSD)
- $B_p = 350 \pm 40$ G
- $v \sin i = 27$ km/s

Stars with Confirmed Fields (cont.)

HD 58260

[Bohlender 1989]

- B3 Vp; He Strong
- He lines variable
- $B_{\text{eff}} = 2300 \text{ G}$ ($\sigma=250 \text{ G}$), constant
- $B_p = 8.1 \pm 2 \text{ kG}$
- $v \sin i < 12 \text{ km/s}$

$$i \approx 0^\circ, \beta = 40^\circ$$

ξ^1 Cma

[Hubrig et al 2006a]

- B1 III
- β Cep pulsator
- $\langle B_\ell \rangle = 280 \pm 44 \text{ G}$ (FORS1 + Regression)
 $330 \pm 45 \text{ G}$
- $v \sin i = 20 \text{ km/s}$

Stars with Confirmed Fields (cont.)

NU Ori

[Petit et al 2008]

- B0.5 V
- Soft X-ray emission
- $B_\ell = 84$ to -321 G (ESPaDOnS + LSD)
- $B_p = 650^{+220}_{-170}$ G
- $v \sin i = 80$ km/s

ρ Leo

[Kholtygin et al 2007]

$i=85^\circ$, $\beta = 59^\circ$

- B1 Iab
- UV variability -- DACs
- $B_p = 240 \pm 50$ G
- $v \sin i = 50$ km/s

Stars with Claimed Fields

δ Cet

[Schnerr et al 2008]

- B2 IV; β Cep pulsator
- N excess
- 1 recent measurement -- Musicos + LSD
- $B_\ell = 40 \pm 28$ G ; **No Stokes V signature detected**
- Pole on view
- $v \sin i = 5$ km/s

HD 55522

[Briquet et al 2007]

- B2 IV/V
- He and Si spots
- 4 Stokes I and V spectra -- FORS1 + Regression
- $\langle B_\ell \rangle = 38$ to 554 G
- $v \sin i = 70$ km/s

Stars with Claimed Fields (cont.)

15 Mon

[Schnerr et al 2008]

- O7 V((f))
- X-ray emission
- UV variability -- DACs
- 5 Stokes V spectra (Musicos + LSD)
- **No Stokes V signature detection**
- $v \sin i = 63$ km/s

10 Lac

[Schnerr et al 2008]

- O9 V
- UV variability -- DACs
- 15 Stokes V spectra (Musicos + LSD)
- **No clear Stokes V signature detection**
- One possible detection, $B_{\ell} = 204 \pm 55$ G
- $v \sin i = 31$ km/s

Stars whose declination is too far south to observe with CFHT

HD 96446

- B2 Vp; He Strong
- β Cep pulsator
- $B_{\text{eff}} = -1650$ G, constant
- Dec = -60

HD 64740

- B1.5 Vp; He Strong
- X-ray emission
- $B_{\text{eff}} = 490$ to -890 G
- Dec = -49

HD 66522

- B2 IIIp; He Strong
- N enhancement
- Only 4 measurements
- $B_{\text{eff}} = -80$ to 1030 G
- Dec = -50

[Bohlender et al 1987]

Summary

- 12 early-type stars, not on the MiMeS target list, are observable from the CFHT.
- 4 of these stars need further observations for definite field detection (δ Cet, HD 55522, 10 Lac, and 15 Mon).
- Diversity can aid understanding of evolution of massive magnetic stars.