Magnetic properties of low mass stars: new discoveries and future prospects

Denis Shulyak
Georg-August University, IAG, Göttingen, Germany

A. Reiners (IAG, Germany), A. Engeln (IAG, Germany), L. Malo (CFHT, USA),
R. Yadav (Cambridge, USA), J. Morin (Montpellier, France),
O. Kochukhov (Uppsala, Sweden)

AASTCS 5, Palm Springs, 7–12 May 2017
M dwarfs

- Cool MS stars
  \[ T_{\text{eff}} = 2400 - 3800 \text{ K} \]
  \[ M = 0.6 - 0.1M_\odot \]
  70% by number
  40% by mass
- Solar like activity: X-ray, \( H_\alpha \), Ca II H & K
- Promising targets to search for Earth-size planets

© NASA’s Goddard Space Flight Center
M dwarfs

- **Stellar dynamos**
  Stars with $M < 0.35M_\odot$ become fully convective (different dynamos?)

© NASA/CXC/M.Weiss
Measuring magnetic fields: two approaches

- **Polarimetry:**
  - Stokes-$\mathbf{V}$: geometry, polarity (ZDI)
  - Cannot detect small scale fields of opposite polarity

- **Spectroscopy:**
  - Stokes-$\mathbf{I}$: total magnetic flux density (Zeeman broadening)
  - Cannot see polarity of the field

Polarimetry and spectroscopy provide important constraints for models of stellar dynamos.
Results from polarimetry: confusogram

© Morin et al. (2010)
Saar & Linsky (1985)
First detection of the magnetic field in an M dwarf star AD Leo

![Graph showing flux versus wavelength for Ti I 4480.95 cm⁻¹ with g = 2.500, B = 3600 G, f = 0.68 for AD Leo, B = 2900 G, f = 1.0 for SUNSPOT, and another line for 61 CYG A.]
Spectroscopy

Relative analysis of atomic line profiles (Fe I 8468.4 Å)
Spectroscopy

Reiners & Basri (2006, 2007)

Empirical analysis of FeH lines (without radiative transfer)

Simplest solution ever: estimate $\langle B \rangle$ by simple interpolation between the spectra of two reference stars with known $\langle B \rangle$
Spectroscopy

Reiners & Basri (2006, 2007)
Empirical analysis of FeH lines (without radiative transfer)
Simplest solution ever: estimate $\langle B \rangle$ by simple interpolation between the spectra of two reference stars with known $\langle B \rangle$

These “known $\langle B \rangle$” are actually from Johns-Krull & Valenti (2000), i.e. derived from the relative analysis of line shapes and thus limited to the max. field of EV Lac ($\approx 3.9$ kG).
Combining Stokes-\(V\) and Stokes-\(I\) from POLARBASE

© Morin et al. (2010)
Combining Stokes-$V$ and Stokes-$I$ from POLARBASE

© Morin et al. (2010)
Main goal

Measure total (unsigned) magnetic flux from Stokes-I data

Wing-Ford $F^4 \Delta - X^4 \Delta$ transitions ($\lambda \lambda 990 - 995$ nm)
Main goal

Measure total (unsigned) magnetic flux from Stokes-I data

Wing-Ford $F^4 \Delta - X^4 \Delta$ transitions ($\lambda\lambda\,990 - 995$ nm)
Main goal

Measure total (unsigned) magnetic flux from Stokes-I data
Main goal

Measure total (unsigned) magnetic flux from Stokes-I data

Remove telluric with MOLECFIT
Main goal

Measure total (unsigned) magnetic flux from Stokes-I data

Remove telluric with MOLECFIT

Ti I

AASTCS 5, Palm Springs, 7–12 May 2017
Ti lines in NIR

WX UMa, $\nu \sin i = 6 \text{ km s}^{-1}$, $\langle B \rangle = 7.3 \pm 0.5 \text{ kG}$

© Shulyak et al., in press
Ti lines in NIR

WX UMa, $v \sin i = 6 \text{ km s}^{-1}$, $\langle B \rangle = 7.3 \pm 0.5 \text{ kG}$

© Shulyak et al., in press
Ti lines in NIR

In stars with large $v \sin i$ we rely on the effect of magnetic intensification of spectral lines.

V374 Peg, $v \sin i = 35 \text{ km s}^{-1}$, $\langle B \rangle = 5.2 \pm 1.0 \text{ kG}$

© Shulyak et al., in press
What is so peculiar about stars with strong fields?
Future work

Calar Alto high-resolution search for M dwarfs with Exoearths with Near-infrared and optical Echelle Spectrographs
Future work

Stokes-I between 0.5 - 1.7 µm (R ≈ 82 000)
Future work

Stokes-I between 0.5 - 1.7µm ($R \approx 82\,000$)
Future work

Derive stellar parameters for the whole sample.

J23096−019 (M3.5 V)
Teff = 3464K, log g = 4.97, [Fe/H] = −0.10, vsini = 3.00 km/s

© Passegger et al., submitted
Future work

Sample of $\approx 300$ M dwarfs, $\approx 70$ transits per star.
Future work

Sample of \( \approx 300 \) M dwarfs, \( \approx 70 \) transits per star.
Summary

- Combining results from Stokes-V and Stokes-I.
- Observing dynamo bistability in both Stokes-I and Stokes-V (need to constrain better with larger sample).
- WX UMa managed to generate the strongest to date magnetic field of $\langle B \rangle \approx 7.0$ kG.
- Analysis of the full CARMENES sample.