# The magnetic topology of young Suns

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Collaborators:

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Cosmic Magnetism, Kiama, June 10th 2010

### Why study stellar magnetic fields?

Magnetic fields play a crucial role in a star's evolution.

 The young Sun was MUCH more magnetically active than it is today.

 Our key question:
How do young Suns generate magnetic fields?



Solar magnetogram (SOHO)

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### Generating magnetic fields

- Differential rotation and convection form a dynamo process.
  - The intensity and distribution of magnetic fields provides a window onto this underlying dynamo.



The solar dynamo (NASA)





#### Detecting magnetic fields

- High-resolution spectropolarimeters such as SEMPOL on the Anglo-Australian Telescope (AAT), split incoming light into right- and left-hand circularly polarised light.
- From this we get a Stokes V polarisation spectrum.





- Differing magnetic field orientations have different Stokes V signatures as the star rotates.
- The longitude, latitude and orientation of field lines can be determined.



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#### LSD and ZDI (or how LSD helps us see the stars)

- Zeeman signatures are typically extremely small, ~0.1% of the continuum level.
- Therefore we use LSD (Least-Squares Deconvolution, Donati et al. 1997) to increase the S/N of the Zeeman signature.



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# Reconstructing the magnetic field

- A time series of Stokes V LSD profiles is inverted to recover the magnetic topology.
- The radial, azimuthal, & meridional field can be reconstructed.
- ZDI recovers the global magnetic field topology of a star.





### Magnetic fields on young Suns

- The young Sun-like star HD 141943 was observed at the AAT with SEMPOL.
- HD 141943 has a large azimuthal magnetic field on its surface.
- Could a distributed dynamo be operating in the star?



vsini ~ 35

Marsden et al. (submitted)



### Polarity reversals on Fares et al. (2009) Mature Stars



- Polarity reversals are reported on the mature (~1 Gyr) late-F star Tau Boo with a magnetic cycle length of ~2 yr.
- However, Tau Boo hosts a "Hot Jupiter". Could this be influencing the star's magnetic cycle?



### Young Suns: I

Marsden et al. (2006), Jeffers & Donati (2008), Jeffers et al. (submitted)



- HD 171488 is a young (30 50 Myr) early-G star observed at 4 epochs from Sep 2004 through to Nov 2007.
- The most striking feature is the polar ring of azimuthal field occurring at all epochs, but no polarity reversal!



#### Young Suns: II

Marsden et al. (in prep.)



- HR 1817 is a young Sun-like star observed at 4 epochs.
- A ring of azimuthal field is seen, but it weakens in 2007.
- In 2009 the polar radial field appears to reverse polarity, but not the azimuthal field.



#### Comparison to theory



#### Brown et al. (2009)

#### Attempted reversal

- Recent models of young Suns show "wreaths" of azimuthal field, similar to the rings we see, but at a lower latitude.
- The models also undergo "attempted" magnetic reversals.
- Could this be what happened on HR 1817 in 2007?



#### Differential rotation (DR)

- We can include a Sunlike differential rotation law in the imaging :  $\Omega(I) = \Omega_{eq} - d\Omega \sin^2 I$ ,  $\Omega_{eq} =$  equatorial rotation.  $d\Omega =$  shear from equator to pole (the differential rotation).
- $d\Omega$  and  $\Omega_{eq}$  are found using  $\chi^2$ -minimsation.



Marsden et al. (submitted)



# The differential rotation of young Suns

- Young Sun-like stars show increasing dΩ with decreasing convective zone depth (i.e. with increasing mass).
- For young stars more massive than the Sun there appears to be a LARGE jump in the level of differential rotation.





#### Summary of results

- The young Sun-like stars appear to have a ring of azimuthal field around the pole, similar to the models of Brown et al. (2009) but at higher latitudes.
- Could these regions of azimuthal field indicate that a distributed dynamo operates in young Suns?
- No evidence yet that young Suns undergo full polarity reversals as does today's Sun.
- Young stars heavier than the Sun show a large increase in differential rotation.



#### What we don't know!

- How could a distributed dynamo operate?
- Do young Suns undergo full (or even "attempted") magnetic polarity reversals?
- Do all young stars heavier than the Sun have a large differential rotation?
- Does high differential rotation imply short magnetic cycles?
- Do young stars even have regular stellar cycles or does their magnetic activity vary chaotically?
- When/how did the regular solar dynamo develop?



# Thank you for your patience!

## Questions?

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