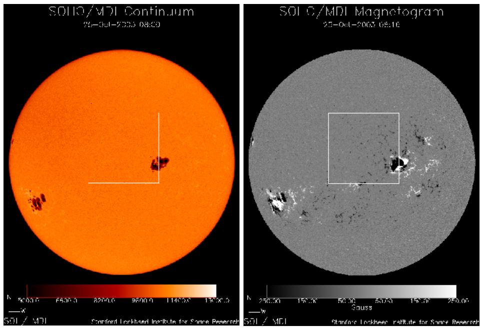
Starspot activity

Solar continuum image / Magnetogram



sohowww.nascom.nasa.gov

Sunspots:

- The number of spots varies with time over the solar magnetic cycle:
  - peaking at ~110
  - average minimum of ~5.
- Typical diameters 15 000 km or of order 1°
- Only small part of surface is covered in starspots
  - < 0.5% at maximum

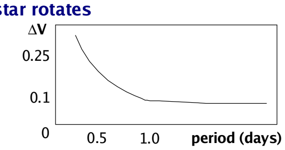
Starspots:

- Lightcurves
- Coverage measured from temperature sensitive lines such as TiO
- Indirect surface imaging

Lightcurves

Rapidly rotating single stars show variations in brightness which is attributable to cool starspots moving into and out of view as the star rotates

- measure rotation period



Eclipsing binary stars show distortions on top of eclipse events

Lightcurves show only subtle evolvution on timescales of days

Variation of lightcurves on timescales of weeks/months indicates relatively stable active regions

Temperature sensitive lines: TiO

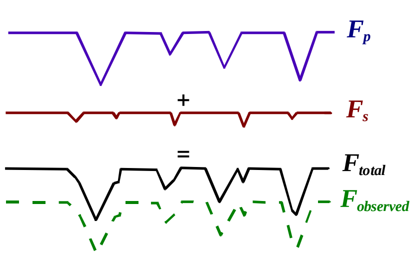
- Starspot areas defined by a two temperature model i.e. a combination of two spectra represent the stellar surface

1) The normalised photospheric spectrum F_p
2) The normalised spot spectrum F_s

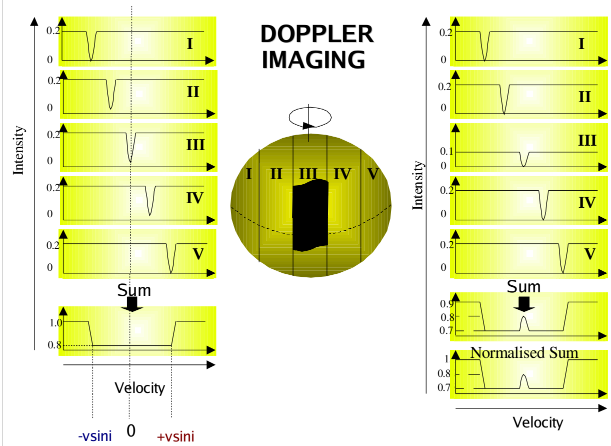
- Combine two spectra
  Fit for f_s - spot area (0-1)

  R_λ - flux correction factor

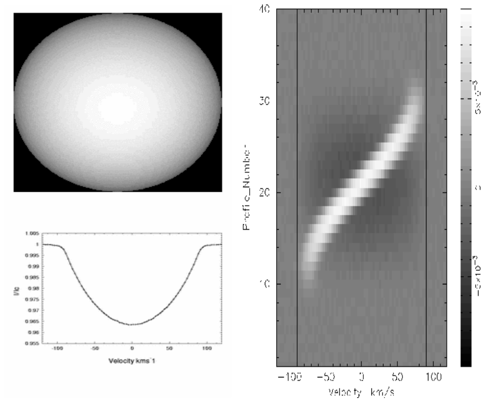
$$F_{total} = \frac{f_s R_\lambda F_s + (1-f_s) F_p}{f_s R_\lambda + (1-f_s)}$$



- Fits of 7055 A and 8860 A TiO bands indicate spot coverage values, fs = 0.15 – 0.50 for single line spectroscopic binaries
- Compare with 0.005 spot fraction for the sun

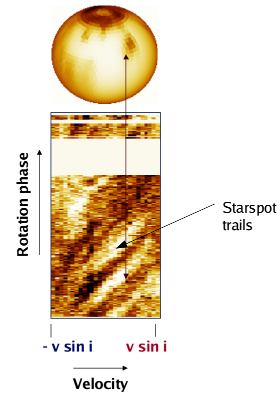


Indirect surface images of stars: Doppler imaging



The easiest target: AB Doradus

- Age < 70 Myr (cf.Pleiades)
  - Marginally pre-main sequence
- Sp. type K0Ve
- Rotation period: 12.4 h.
- v sin i = 91 km s^{-1}
- Inclination 60°



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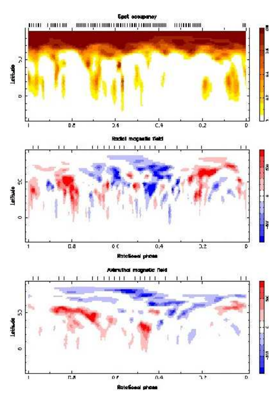
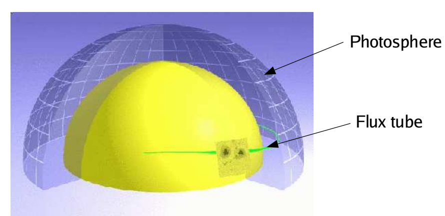
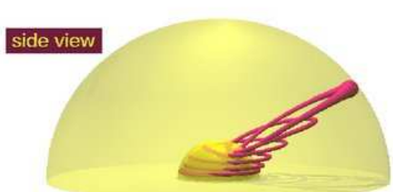


Solar flux tube emergence model

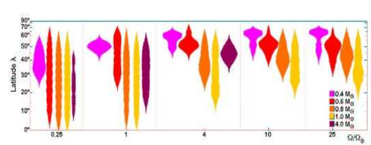
- Sun: Solar dynamo is located at the base of the convection zone
- Flux tubes rise through convective buoyancy and errupt in the photosphere to form sunspots between 5° and 40° as observed





Stars:

- Flux tube emergence models based on the solar paradigm
- The solar flux tube emergence model can be modified by increasing the rotation rate
  - i.e. From solar period of 26 days ---> 1 day periods
- Material in expanding flux ring is subject to a Coriolis force causing it to be deflected to higher latitudes
- RESULT: Young rapidly rotating stars should possess spots only at intermediate/high latitude. No spots at low latitude.



Deep convection zone and rapid rotation favour starspots at high latitudes

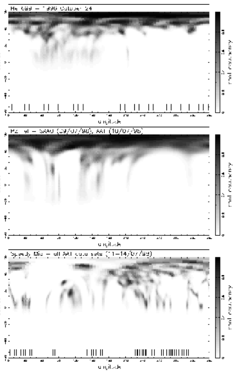
Granzer et al. Astron. & Astrophysics (2000) 255, 1087

Starspot locations as a function of spectral type

G2V
P=0.6d

K0V
P=0.9d

K3V
P=0.4d



Doppler images of main sequence stars include G dwarfs and K dwarfs which reveal cool surface features

Starspots are commonly found as:

- Small low-intermediate features
- Extensive high latitude features, including large polar caps
- At all latitudes (mainly from mid-K to M dwarfs)

Observations do not match theory as low latitude spots are excluded in the models