Understanding Stellar Birth Through the Photometric and Spectroscopic Variability of T Tauri Stars

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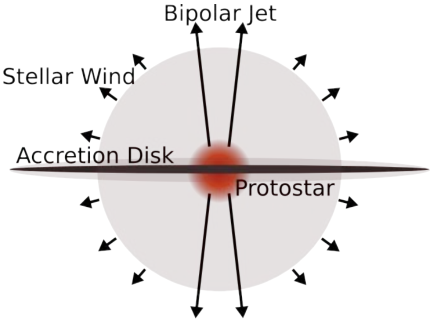
T Tauri Stars

- Stellar Formation
- Observational Characteristics
  - Optical variability
  - Late spectral type (F-M)
  - Infrared excess
  - Ultraviolet excess
  - Lithium absorption lines
  - Balmer emission lines
  - P Cygni line profile
- Physical Characteristics
  - Hot and cool spots
  - Typically $M < 3M_{\odot}$
  - Age $\approx 2-3$ million years
  - Accretion disk (CTTS only
  - Stellar outflow (wind, jet)



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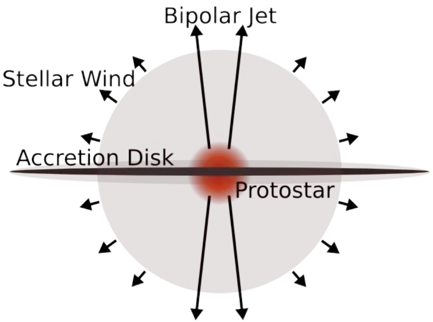

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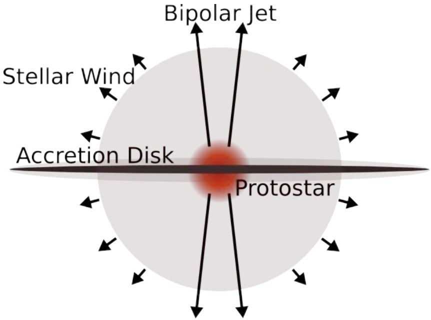

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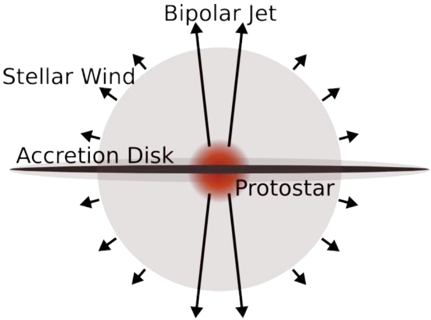

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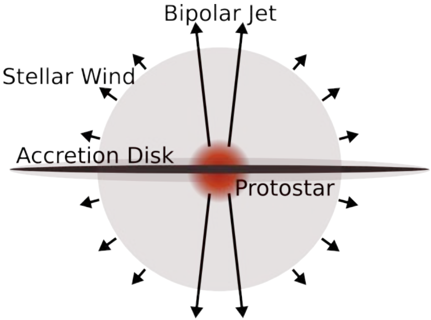

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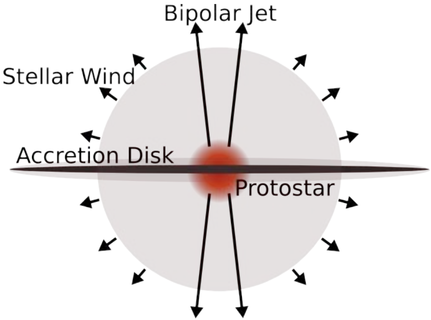

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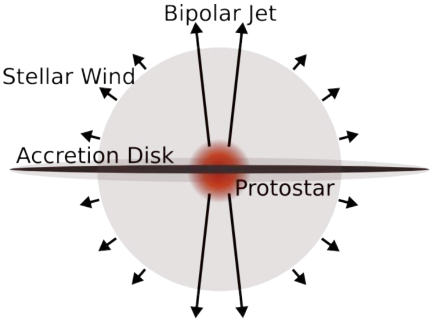

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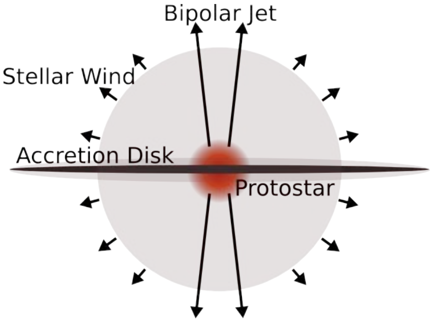
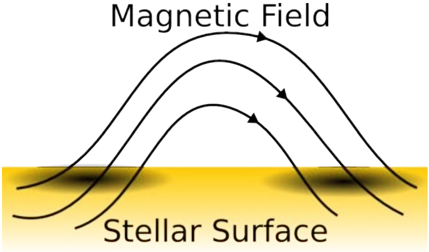
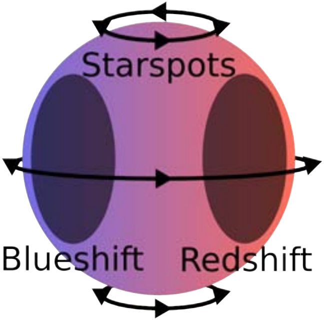


Magnetically Generated Cool Spots





Photometry Variability $P \approx P_{\text{rotation}}$

Spectroscopy Fake radial velocity signature

Accretion Shocks

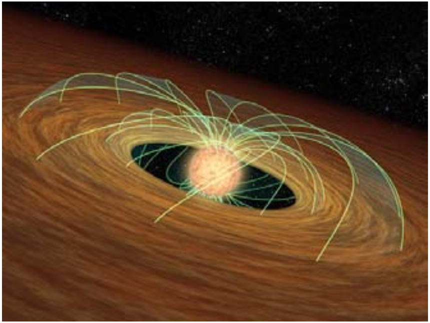


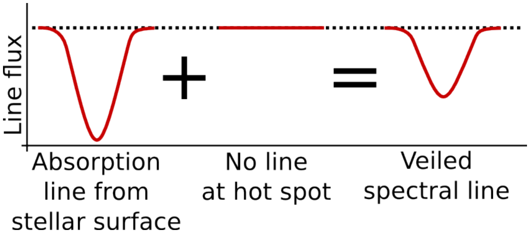
Figure: NASA. http://www.spitzer.caltech.edu/images/1641-ssc2006-15a-Stars-Can-t-Spin-Out-of-Control

Photometry Ultraviolet excess

Spectroscopy Spectral line veiling

Spectral Line Veiling

- Excitation and ionization is temperature dependent
- Equivalent width of spectral lines is temperature dependent



- Measured in units of stellar continua

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Targets

BP Tau

DN Tau

Hubble 4

- Images: Sloan Digital Sky Survey

Data

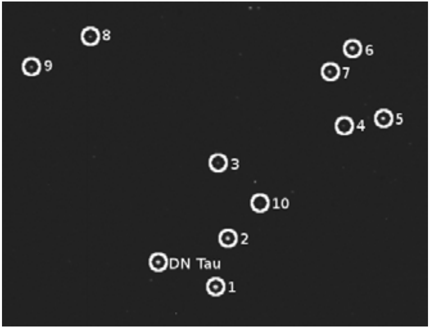
Photometry

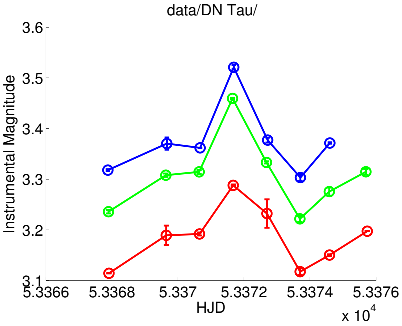
- McDonald Observatory
- BVR photometry
- 0.8m telescope
- Data from 2004-2011
- Observing runs typically 5-7 days (about 1 per year)

Spectroscopy

- McDonald Observatory
- 2.1m Otto Struve telescope
- 2.7m Harlan J. Smith telescope
- Taken simultaneously with the photometry data
- Reduced by Naved

Measuring Periodicity





- Take Fourier transform

Periodicity

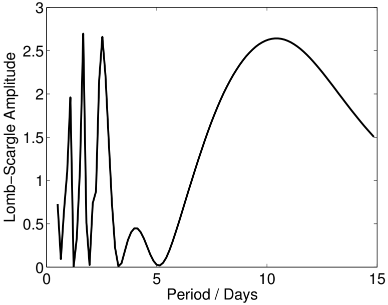
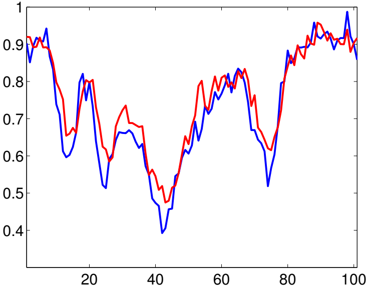


Figure: Hubble 4. Visual photometry. Nov 2007.

- No strong signals
- Not enough points

Measuring Spectral Line Veiling



- Continuum normalize
- veiled spectrum $= \frac{\text{unveiled}+\text{veiling}}{1+\text{veiling}}$
- χ^2 fit to measure the veiling

Spectral Line Veiling

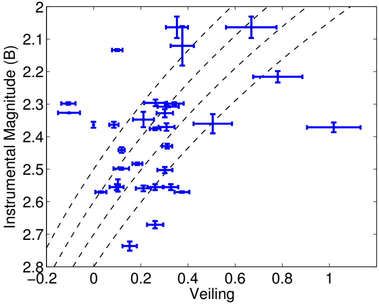


Figure: BP Tau. B photometry and spectral line veiling.

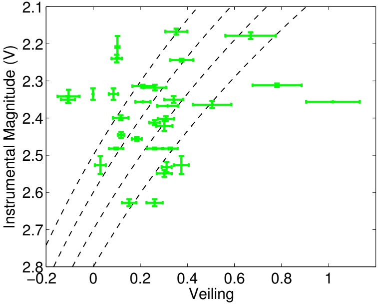


Figure: BP Tau. V photometry and spectral line veiling.

Spectral Line Veiling

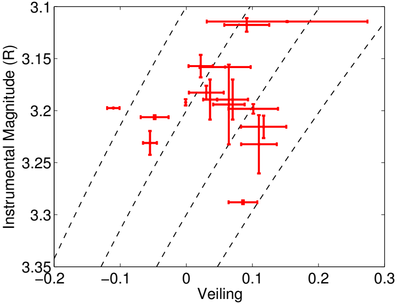


Figure: DN Tau. R photometry and spectral line veiling.

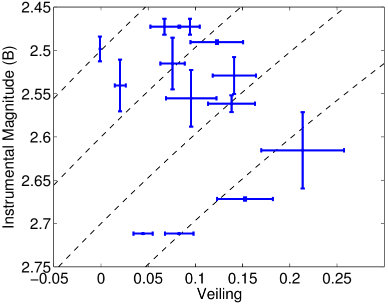


Figure: Hubble 4. B photometry and spectral line veiling.

Thank You

Questions?