Magnetic Activity in Low Mass Stars

... Does it Depend on Rotation?
Dr. Suzanne Hawley, U Washington (ITP 3-12-02) Is There an Empirical Connection Between Rotation and Activity in Low Mass...
AD Leo Flares March 2000

UV (1200-1700 Å)

UV counts (STIS)

UT - 10 March 2000

UT - 11 March 2000

UT - 12 March 2000

UT - 13 March 2000

C IV During Flare 8 (Hawley et al. 2002)

Time (sec)

Velocity (km s⁻¹)

Peak counts

Peak velocity

Chromospheric evaporation/condensation

Fisher (1989)
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\[ E_U \sim E_X \]

\[ E_{Hy} \sim E_{CaK} \]

\[ E_{Hy} \sim 0.05 E_U \]

Hamley & Pettersen 1991

\[ E_{(flare)} \sim 100 (L_{quiet}) \]

Lacy, Moffett, and Evans

Liebert 2MASSJ0149 \[ H \alpha \geq 100 \times \text{quiet} \] (M9.5)

Fleming VB10 \[ \text{X-rays} \geq 100 \times \text{quiet} \] (M8)
The four initial Keck II digital spectra of 2M0149, observed on 1997 December 7, ordered by increasing time from the top; the bottom panel is one of several similar spectra taken at later times (see text) when the object was observed in quiescence. Detected emission lines from Table 1 are labeled in the top frame. The Hα line in all but the bottom spectrum is truncated in the plot.
Radio flare (8.4 GHz)  
2M0036 - L3.5

Fig. 3. — Lightcurve of the 8.46 GHz emission from 2MASS J0036+18 on 2001, Oct 9.13 UT, with 35.6-min bins. We find a flare and persistent emission, which appears to be strongly variable. The steep decline in flux during the first twenty minutes of the observation, and the shallow rise during the last sixty minutes possibly signal two additional strong flares. The solid line is an exponential model. The inset shows the circularly polarized flux (diamonds) and the total flux (squares). The fraction of circular polarization near the peak of the flare is n~0.65%. The negative values indicate left-handed circular polarization (see Table 3).

Benner (2002)

Fig. 6. — (a) Ratio of radio to bolometric luminosities for detected flares from M and L dwarfs. Symbols are as in Figure 5. With the exception of Proxima Centauri (M5.5), the radio activity appears to cluster around log(Lradio/Lbol) ~ -6. This possibly indicates a saturation effect. (b) Ratio of radio to bolometric luminosities for persistent emission from the detected sources, and upper limits which are similar to or lower than these detections. The dashed line is a linear fit to the detections, while the dotted line includes the upper limits. In both cases there is an increase in log(Lradio/Lbol) with spectral type. The same ratio for Hα emission drops significantly beyond M7. These observations indicate that the radio and Hα emission are probably uncorrelated at the bottom of the main sequence. The upper limits that violate the relation, and have measured rotational velocities, have v sin i < 10 km sec^-1. This result is discussed in detail in §6 and Figure 7.

Benner (2002)
Activity Effects on TiO (7050) Subbands

Figure 3

Figure 9a

- Activity Effects on TiO (7050) Subbands

Figure 9b

- Activity Effects on TiO (7050) Subbands

Figure 9c

- Activity Effects on TiO (7050) Subbands

Hawley et al. 1996 (PMSU2)

Gizis et al. (2000)
Fig. 1. — $L_{\text{Hα}}/L_{\text{bol}}$ versus $v \sin i$ for M4 and M5 dwarfs (from Defrance et al., 1998). Upper limits in Hα emission and $v \sin i$ marked by arrows (though actual equatorial velocity may be higher).

Fig. 2. — $v \sin i$ versus Spectral Type, for M3 to L5 dwarfs. Overlapping objects marked with spines. Horizontal line is at 15 km s$^{-1}$, below which we define objects as slow rotators. Vertical line marks spectral type L1.5, above which all objects rotate rapidly. 'Li' marks objects with Lithium; these are confirmed brown dwarfs.
Is There an Empirical Connection Between Rotation and Activity in Low Mass Stars?

Threshold ~ 10 km/s? "Saturation"?

\[ \log \frac{L_{\text{H}\alpha}}{L_{\text{bol}}} \]

\[ \text{vsini} \] (kms\(^{-1}\))

M5 - M8.5

\[ \log \frac{L_{\text{H}\alpha}}{L_{\text{bol}}} \]

M5 - L6

Mohanty & Basu (2002)

Schematic:
- Turbulent
- Shell
- Strong connection, convection weakens, red zone forms?
- Atmosphere = neutral, inhibits magnetic heating?
- Primordial
- Complete convection
- Dust formation in atmosphere

Speculative:
- Rotation important for dynamo?
- Rotation not needed for dynamo?
- Rotation inhibits convection?
- Rotation contributes to dust dynami
Questions

- What causes activity effects on TiO bands and colors?
- Is Hα best diagnostic for late M-L dwarfs?
  ⇒ need chromospheric models
- Why does activity last longer at lower mass (M3-M7 range)? [Answer is NOT rotation!]
  ⇒ need turbulent dynamo theory
- Does dust formation inhibit convection and/or form radiative zone, preventing field from reaching surface? [M8-L range]
  ⇒ need atmosphere calculations, incorporate turbulent dynamo
  Or atmosphere becomes neutral preventing heating?
- Is there an age effect in late M-early L dwarf activity? Difference between stars and brown dwarfs? Or just depends on T of atmosphere?
  ⇒ need more data
- Primordial or acoustic fields important?