Rotation and Activity in the Coolest Stars

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One of the most reliable conclusions about magnetic activity in convective dwarfs has been the “rotation–activity connection”. It has been convincingly demonstrated (eg. Noyes et al. 1984) that the level of stellar activity as measured by non-radiative heating in upper stellar atmospheres is a clear function of the rotation rate of a star. The more rapidly the star rotates, the more chromospheric and coronal emission is seen. The popular dynamo mode for solar-type stars at present involves a dynamo which operates primarily at the interface between the bottom of the convection zone and the radiative core. It has been an issue for some time whether fully convective stars show some change in their activity, which might be expected when the radiative core is absent altogether. We present measurements of Hα equivalent width and v sin i made using the Keck HIRES echelle on two samples of very late-type dwarfs. The first is largely drawn from the list of the coolest field dwarfs by Kirkpatrick, Simons & Henry (1995) and were observed by the UCB team. The second contains a number of the faintest Pleiads, and were mostly observed by the CIT team. A description of the typical observation mode and reductions can be found in Basri & Marcy (1995).

We find that Hα is never in absorption in either sample of stars. All of them are M6 or later, so the contrast between chromosphere and photosphere is maximized. Our observed equivalent widths imply a much smaller surface flux than is found in earlier M dwarfs. As has been noted by Stauffer et al. (1995), the Hα emission in the latest Pleiads does not continue the rise in equivalent width seen towards cooler stars at earlier spectral types, but levels off. They did not know if this was a rotational effect. We find that the Pleiads are almost all very rapid rotators, so that this change in Hα is not due to the usual connection between rotation and activity. Stauffer et al. also find that the faintest Hyads have about the same levels of Hα emission as the faintest Pleiads. This implies that the rotational evolution of these stars is probably different than for earlier spectral types, where the Hyads are seen to have lost much of their activity. What about older stars?

Basri & Marcy (1995) found that the very cool field M dwarf BRI 0021 has extremely rapid rotation, and no sign of the Hα line at all. They hypothesized that the relation between rotation and activity breaks down in the latest M stars, and that their ability to lose angular momentum via braking due to a magnetic wind can be severely compromised. Only for 10% or so of early M field stars is v sin i measurable, while in our sample there are few stars for which it is not easily found. The connection between rotation and activity, which holds strongly from
F to mid-M stars, is no longer the rule for stars later than M6. Indeed, two of the most rapidly rotating cool field stars have among the weakest Hα emission. The extremely rapid rotation implies rotation periods down to a few hours, and for at least one case Martín et al. (1996) find that a star with a slower projected rotation velocity (LHS 2924) actually has a very short rotation period too.

This may not true for all the coolest stars; some of them do exhibit relatively strong Hα emission and may be slow rotators. What is clear is that the Hα surface fluxes are definitely weaker than for earlier M stars, and that rapid rotation no longer guarantees strong emission. It is not yet clear whether the Hα emission strengths are well correlated with coronal activity, or whether our results for Hα can be taken as good proxies for the magnetic field itself. It is possible that the atmospheric or magnetic conditions are such that either Hα emission is not promoted or magnetic winds are suppressed (cf. Basri & Marcy 1995). We can speculate that only a turbulent dynamo operates in the coolest stars, and that those which start with sufficiently rapid rotation actually suppress the production of magnetic fields.

Table 1. Rotation and Activity in Late M Stars

<table>
<thead>
<tr>
<th>Star</th>
<th>Sp.T.</th>
<th>v sin i (\text{km s}^{-1})</th>
<th>Hα Eq.W. (\text{Å})</th>
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<tr>
<td>BRI 0021-0214</td>
<td>M9.5+</td>
<td>40</td>
<td>&lt; 0.2</td>
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<td>4.2</td>
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<td>CTI 115638.4</td>
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<td>11</td>
<td>3.7</td>
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<tr>
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<td>8.5</td>
<td>4.3</td>
</tr>
<tr>
<td>LHS 2065</td>
<td>M9</td>
<td>10.5</td>
<td>8.4</td>
</tr>
<tr>
<td>LHS 2345</td>
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<td>&lt; 5</td>
<td>15.8</td>
</tr>
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<td>18</td>
<td>20.5</td>
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<td>4.9</td>
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<td>9</td>
<td>1.5</td>
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<td>8</td>
<td>5.5</td>
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<tr>
<td>VB 10</td>
<td>M8</td>
<td>&lt; 5</td>
<td>4.3</td>
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</table>

References

Martín, E.L., Zapatero, O. & Rebolo, R. 1996, this volume