Activity and Kinematics of Ultracool Dwarfs

Sarah Schmidt (American Museum of Natural History/University of Washington),
Kelle Cruz (AMNH), James Liebert (University of Arizona) and I. Neill Reid (STSci)

Sample

- Our sample of ultracool dwarfs is composed of objects with spectral types M and L and includes both stars and brown dwarfs.
- To assemble our sample, we combined two different samples that span spectral types M7 to L8.
  - 51 M and 35 L dwarfs were selected from the 2MASS second release (Cruz et al. (2003), Cruz et al. (2006)) This selection is complete to a distance limit of 20 pc.
  - 30 M and 37 L dwarfs were selected from the 2MASS final release (Reid et al. (2007)). This sample is not yet complete but adds to the small number of L dwarfs within 20 pc.
- The full 2MASS selected sample discussed on this poster is composed of 153 M and L dwarfs within 20 pc.

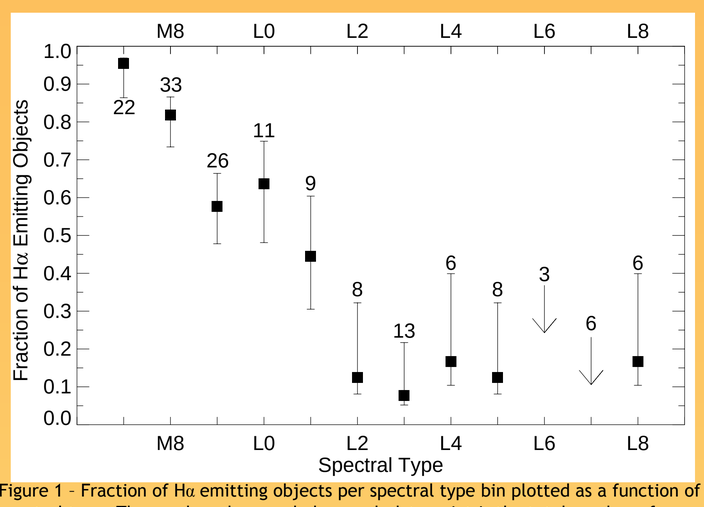

Figure 1 – Fraction of Hα emitting objects per spectral type bin plotted as a function of spectral type. The number above or below each data point is the total number of objects in each spectral type bin. The uncertainties are based on a binomial distribution. Upper limits are shown as down arrows for spectral type bins with no Hα emitting objects.

Activity

- In ultracool dwarfs, we observe chromospheric activity with the 6563 Å Hα emission line.
- Figure 1 shows the fraction of active objects per spectral type for the 2MASS selected sample.
- M7 dwarfs have the largest activity fraction, with 95% showing Hα emission. The fraction then drops sharply, with 5 of 50 dwarfs between types L2 and L8 showing Hα emission. This decline is consistent with previous results.
- Figure 2 plots relative activity strength, measured by $\log(F_{H\alpha}/F_{bolometric})$, as a function of spectral type.
- There is a strong downward trend spanning spectral types M7–L5, which is consistent with previous results.
- This suggests a correlation between effective temperature and activity strength, but the explanation for the correlation remains unclear.
- Observed variable dwarfs are labeled and plotted both in flare and relative quiescence with a dashed line connecting the different fluxes.

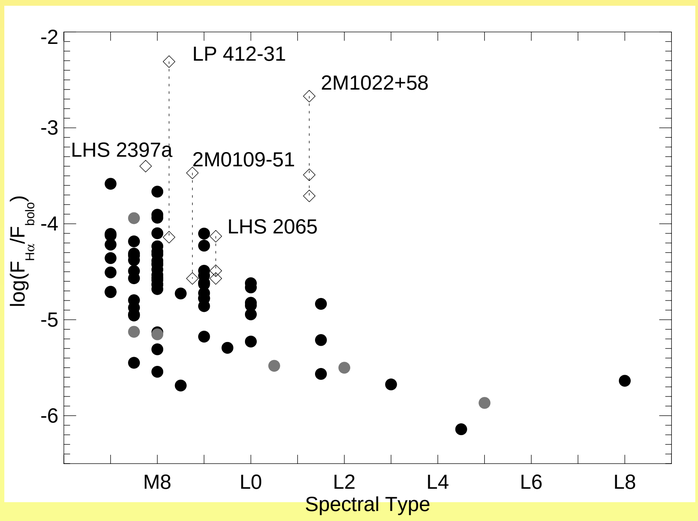

Figure 2 -- Relative Hα flux as a function of spectral type. Multiple systems *(grey)* are distinguished from single dwarfs *(black)*. For variable objects *(diamonds)*, observed peak flux and relative quiescent emission are both plotted; each variable object is labeled.

Measurements

- We measured new proper motions and examined spectra for Hα emission for the 2MASS selected sample of M and L dwarfs.
- Hα emission is an indicator of the presence and strength of chromospheric activity in these ultracool dwarfs.
- Proper motions were measured using DSS I and II as the first epoch and 2MASS coordinates as the second epoch.
- V_{tan} was calculated with distances that were estimated using the method described in Cruz et al. 2003.

Variable Activity

- The M7 dwarf 2M1028−14 was observed during an amazing flare event with many emission lines; the flare spectrum and a comparison quiescent spectrum are shown below in Figure 3.
- During the flare event, we measure an Hα EW of 97 Å and a strongly enhanced flaring continuum. In quiescence, 2M1028-14 shows Hα emission of ~25 Å.
- The flare event elevates the 6000 to 10000 Å continuum to such an extent that the slope becomes blue. It is unknown whether the strongest M flare stars have red continua that turn blue because flare continua are not typically studied at these wavelengths.
- More observations of these known flare stars in the optical would provide direct comparison, as would ultraviolet observations of 2M1028−14 in flare.

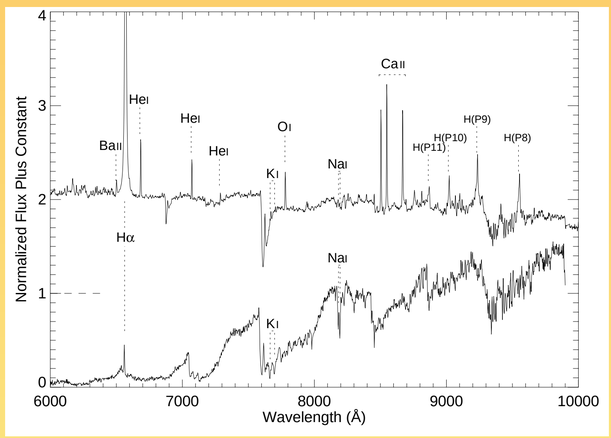

Figure 3 –Spectacularly flaring 2M 1028−14, an M7, shown both in flare and relative quiescence. The dashed line marks the constant added to the flare spectrum. Various emission lines are labeled.

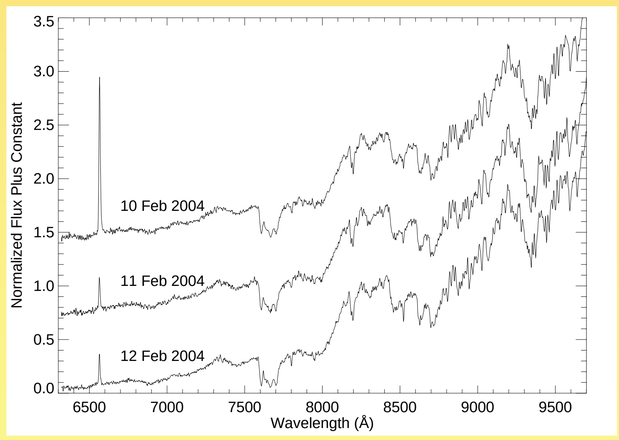

Figure 4 – 2M1022+58, an L1 dwarf with strong, variable activity. The three spectra are offset by constants marked by the dashed lines. The Hα equivalent width was 128 Å on the first night and ~25 Å on the two successive nights. No other emission lines are visible.

- On 2004 Feb 10, we observed the L1 dwarf 2M1022+58 with an Hα EW of 128 Å. The next two nights, Hα emission was at ~25 Å. These spectra are shown above in figure 4.
- As seen in figure 2, the quiescent emission is remarkably strong at $\log(F_{H\alpha}/F_{bol}) = -3.5$, which is evidence that 2M1022+58 is not a flaring dwarf but is in a permanent state of strong chromospheric activity.
- The Hα strength is enhanced by approximately an order of magnitude at peak flux, but there are no other emission lines present.

Flare Rate

- During spectroscopic observations of the 2MASS selected sample, five (4M and 1L) dwarfs were observed in flare.
- If all late-M dwarfs are equally likely to flare, we estimate that each spends 4/81 (~5%) of its time in flare. This is consistent with previous results.
- Similarly, we find a flare rate of 1/70 (~2%) for L dwarfs. This rate is a lower limit due to the difficulty of observing weak Hα in these faint objects.

Kinematics

- The 2MASS selected sample is characterized by a mean velocity of V_{tan} = 31.3 km s^{-1} and a velocity dispersion of σ_{tan} = 20.8 km s^{-1}. Two outliers (V_{tan}>100 km s^{-1}) are excluded from the kinematics.
- To investigate an activity/age relation for ultracool dwarfs, we plot velocity histograms for the active and inactive populations in the 2MASS selected sample.
- The inactive dwarfs have a slightly higher velocity dispersion than the active dwarfs (σ=19.0 km s^{-1} compared to σ=22.9 km s^{-1}) which suggests that the inactive dwarfs are an older population.
- However, a K-S test between the distributions indicates that there is no significant difference between the populations.

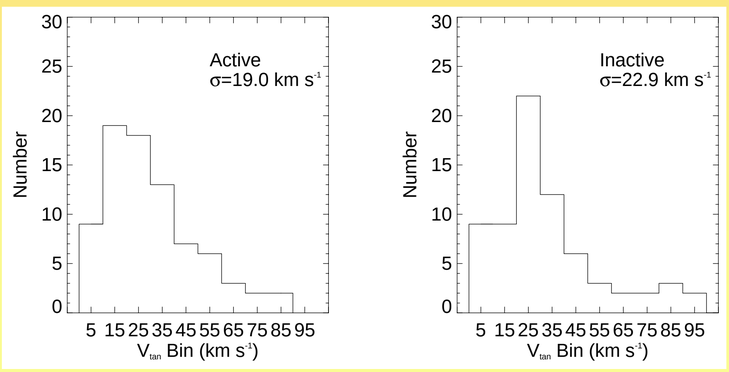

Figure 5 – Velocity distributions for the active and inactive populations of the 2MASS selected sample of ultracool dwarfs. The active dwarfs have a velocity dispersion of σ=19.0 km s^{-1} while the inactive dwarfs have a slightly higher velocity dispersion of σ=22.9 km s^{-1}.

Summary

- We measured new proper motions and examined spectra for Hα in the 2MASS selected sample of M and L dwarfs.
- With the exception of two outliers, the velocity distribution of the 2MASS selected sample is consistent with thin disk kinematics.
- Consistent with previous results, we find that activity strength declines with later spectral type for types M7 and later; the correlation extends through L5 dwarfs.
- We find the activity fraction to peak at spectral type M7 and decline through mid-L dwarfs for the 2MUPM sample.
- The late-M dwarfs in our sample have an estimated flare rate of ~5%. We put a lower limit of ~2% on the flare rate of L dwarfs.
- Velocity distributions suggest that the active population is marginally older than the inactive population.
- The L1 dwarf 2M1022+58 shows unexpectedly strong Hα emission both at observed peak flux and in relative quiescence. The explanation for the absence of other emission lines in the flare spectrum remains unclear.
- The M7 dwarf 2M1028−14 shows an amazing flare spectrum with many emission lines. More observations are needed to compare this object to earlier M-type flares.

References

Cruz, K.L., Reid, I.N., Liebert, J., Kirkpatrick, J.D., & Lowrance, P.J. 2003, ApJ, 126, 2421
Cruz, K.L., et al. 2006, accepted to AJ
Reid, I.N, et al. 2006, in prep

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