Magnetic dynamos and X-ray activity in ultracool dwarfs (UCDs): constraining the role of rotation - arXiv:1310.6758

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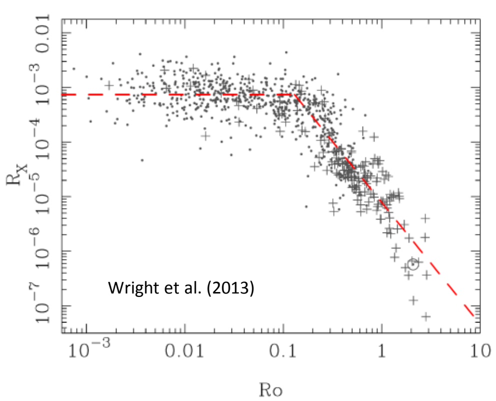
Overview: We analyze the **X-ray activity-rotation** relation in **ultracool dwarf** stars (UCDs). Our motivation is to understand the underlying magnetic dynamo of these fully-convective objects. Our sample of 38 UCDs includes **7 new X-ray observations**, 3 unpublished archival measurements, and an exhaustive search of the literature. We find X-ray activity to be **anticorrelated** with rotation, although this is not likely due to "centrifugal stripping". We speculate that an unobserved third parameter may drive the observed anticorrelation.

Magnetic activity: solar-type stars vs. UCDs

Rotation and (Super?)Saturation

In solar-type stars, magnetic activity indicators increase with faster rotation until reaching **saturation** levels ($L_X/L_{bol} \approx 10^{-3}$; e.g., Pizzolato et al. 2003; Wright et al. 2011).

The figure below emphasizes these two regimes, showing the X-ray activity ($R_X = L_X/L_{bol}$) versus the **Rossby number (Ro**; the rotation period divided by the convective overtime time).



Supersaturation effects have been observed in solar-type stars. Some of the fastest rotators show decreased activity ($L_X/L_{bol} \approx 10^{-3.5}$; Randich et al. 1996; Wright et al. 2011). One possible explanation is a decrease in coronal volume from **centrifugal stripping**.

How are magnetic fields generated?

Magnetic fields in solar-type stars (F,G,K) are generated at the tachocline – the **αΩ dynamo**.

Ultracool dwarfs (UCDs; spectral type later than M6), however, are fully convective and cannot generate magnetic fields in the same manner.

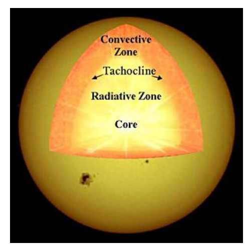


Image courtesy of NASA

Surprisingly , UCDs have been detected in both radio and X-ray bands … **they are magnetically active**! (Berger et al. 2001, Hallinan et al. 2006)

Objectives

- Increase the number of ultracool dwarfs with measured X-ray activity
- Identify all UCDs with published X-ray and rotation measurements in the literature
- Isolate role of rotation from complicating effects of temperature and spectral type
- Identify magnetic properties of UCDs and how they may relate to other stellar parameters

A complete catalog and new X-ray observations

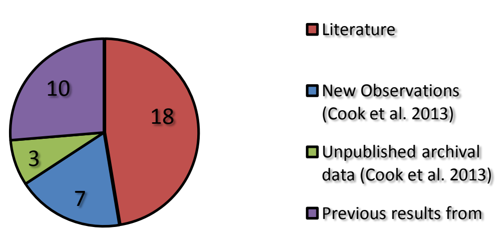
Our sample is comprised of **38 UCDs**, all of which have measured rotational velocities and have been observed in X-ray bands, including:

- Seven (7) new ***Chandra*** observations of late-M dwarfs.
- Three (3) previously-unpublished measurements from the *Chandra* archives.

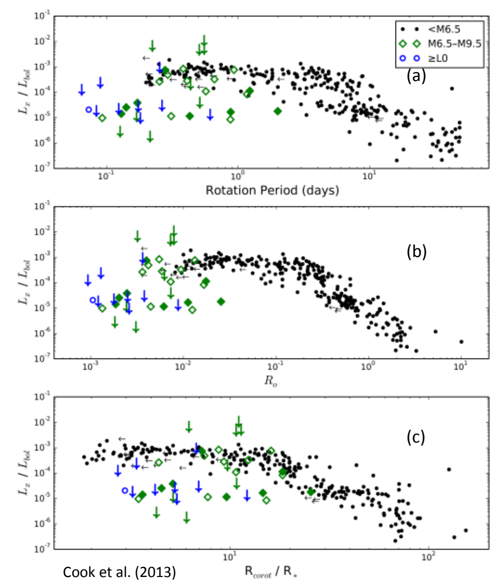
All X-ray luminosities have been converted to a standard **0.2-2.0 keV** band. Conversion factors were calculated using *Chandra* PIMMS and an APEC plasma model.

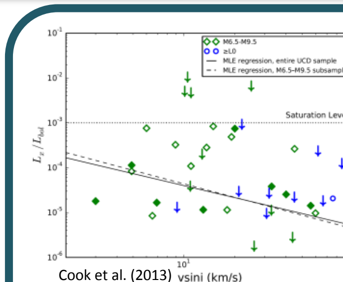

The *Chandra* X-ray Observatory

UCD X-ray and Rotation Measurements



Activity-Rotation: explaining the breakdown

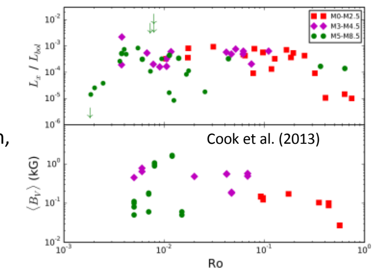




X-ray activity is anticorrelated with rotation velocity in all UCDs, as well as in M6.5-M9.5 stars.

X-ray emission could be connected to **large-scale magnetic topology**.

Late-M topologies (green, lower) are bimodal:
•Strong ⟨B_V⟩⇒ dipolar
•Weak ⟨B_V⟩⇒ tangled
(Morin et al. 2010; Gastine et al. 2013)



Lower data from: Donati et al. (2008),Morin et al. (2008, 2010)

X-ray activity vs. (a) rotation period, (b) Rossby number, and (c) normalized corotation radius (strength of centrifugal forces). Included are samples of Pizzolato et al. (2003) and James et al. (2000).

Important results:

- UCDs are all rapid rotators in terms of rotation period and Rossby number.
- There is a large number of UCDs with significantly suppressed X-ray activity ($L_X/L_{bol} \approx 10^{-5}$).
- In (c): UCDs with suppressed X-ray emission have same centrifugal forces as saturated solar-types. **This suggests that centrifugal stripping is not responsible for "supersaturation" in these UCDs.**

Conclusions

See our full results and conclusions in Cook et al. (2013)

- We've presented a complete sample of UCDs with X-ray and rotation measurements, including 7 new observations.
- UCDs range widely in X-ray activity levels (**10^{-3} – 10^{-5}**). **Activity is anticorrelated with rotation**, but centrifugal stripping is not to blame.
- The wide dispersion is likely the result of a confounding third parameter; we speculate that **large-scale topology** is responsible.
  Dipolar fields ⇒ saturated X-ray activity, slower rotation
  Tangled fields ⇒ suppressed X-ray activity, faster rotation

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