Magnetic dynamos and X-ray activity in ultracool dwarfs (UCDs): surprises in the radio band

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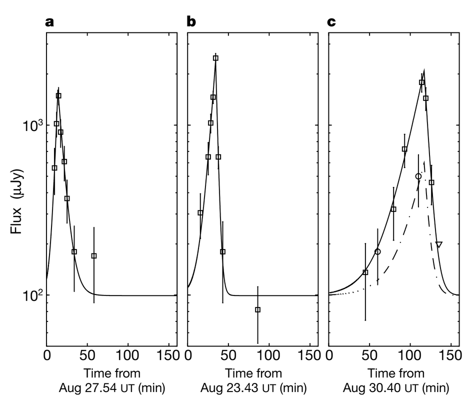
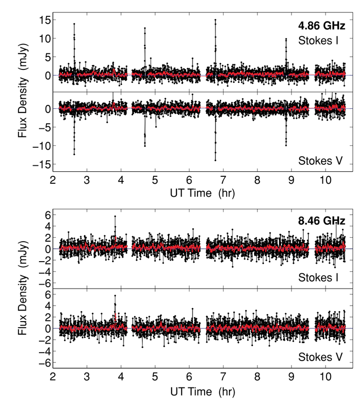
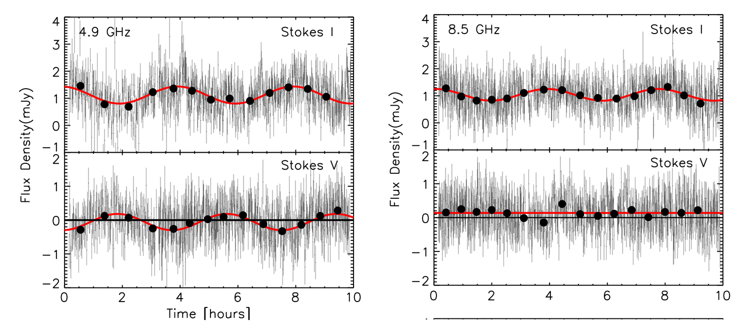
Very low-mass stars and brown dwarfs can be powerful, complex radio emitters.



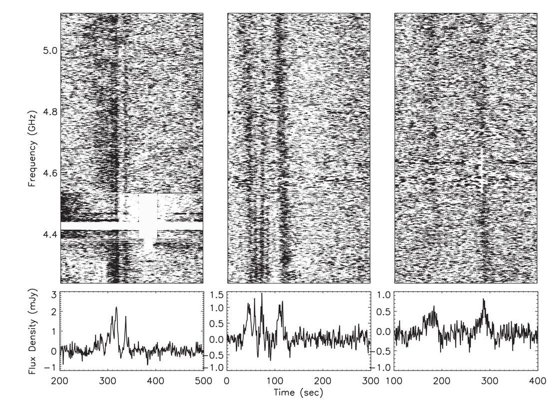
The first detection of radio emission from a brown dwarf (LP 944-20, M9; above; Berger+ 2001) was a **surprise**, since stellar scaling relations suggest that such emission should be undetectably faint.



Many radio-bright UCDs emit **periodic, bright, highly circularly polarized pulses**, as seen here in the case of 2MASS 0746+20 (Berger+ 2009).



The "quiescent" emission of UCDs can also vary nontrivially with frequency, time, and polarization. NLTT 33370 AB (M7) has an extremely flat spectrum (1 mJy across ~1–50 GHz) and varies sinusoidally with a period corresponding to the stellar rotation (above; McLean+ 2011). The circular polarization is ~20% and increases with frequency (Williams+, in prep.)



Radio emission has been detected from UCDs **as late as T6.5**, namely 2MASS 1047+21, with both bursts (above; Route & Wolszczan, 2012) and quasi-quiescent emission (Williams+, 2013).

This emission provides unique insight into magnetic activity in a novel regime.

UCD radio emission traces dissipation of the B fields, **which were generally expected to be weak prior to the first radio detection**. Stellar fields are thought to be generated in the radiative/convective transition zone, which does not exist in UCDs. Unlike in stars, the phenomenologically-important outer layers of UCDs are thought to be neutral.

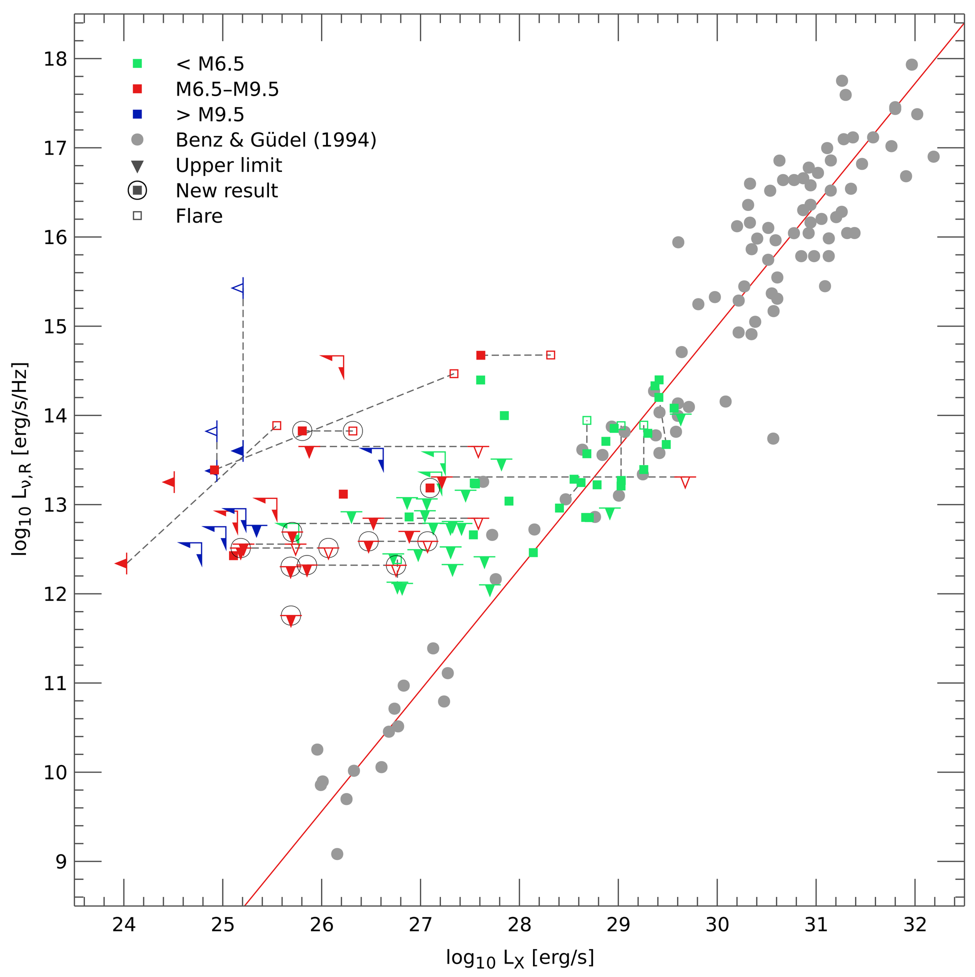
UCD radio emission is usually interpreted in terms of synchrotron and auroral electron cyclotron maser processes. Maser emission directly measures **B** and **shows kG field strengths**; other analysis probes electron densities, emission region size, and the field topology.

$$\nu_B = \frac{eB}{2\pi m_e c}$$

$$\nu_m \propto n_e^{0.23} R^{0.23} B^{0.77}$$

$$f_c \propto B^{0.51} \nu_m^{-0.51}$$

Radio/X-ray flux ratios imply that UCD magnetic processes differ greatly from those in Sun-like stars.



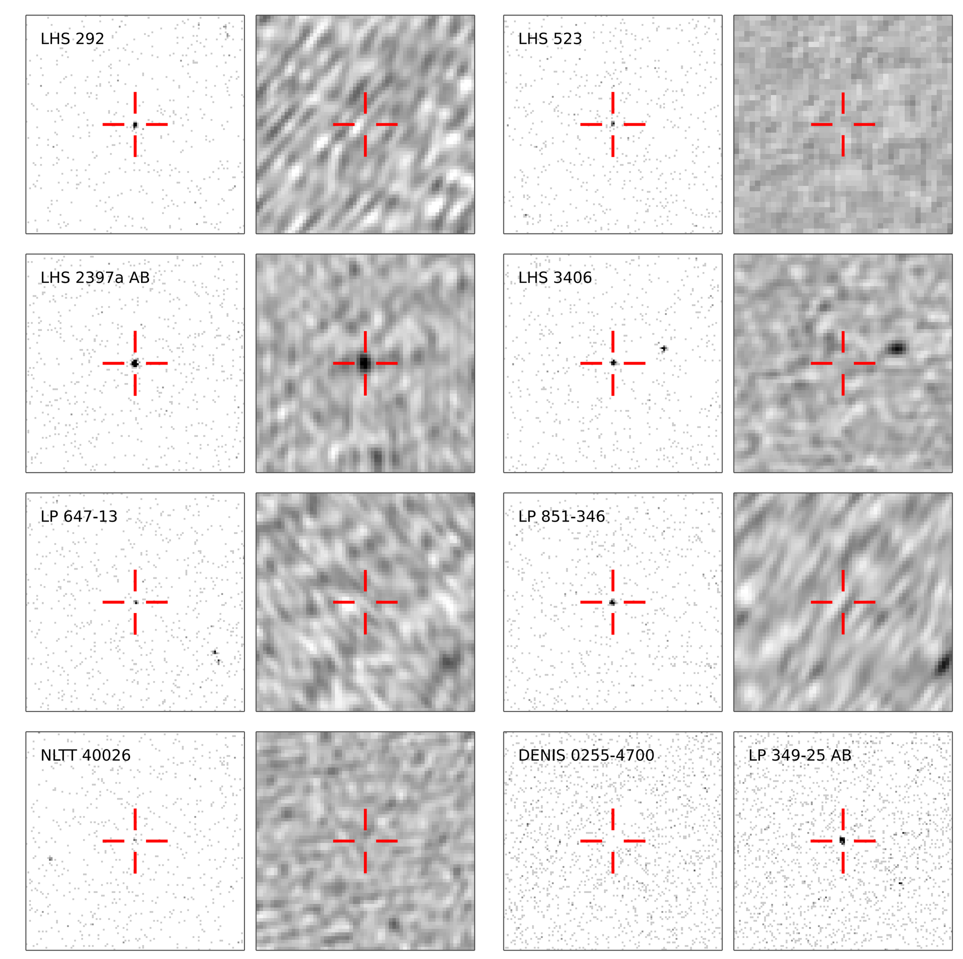
A quantitative way of analyzing the unusual nature of UCD magnetism is to consider the "Güdel-Benz" (1993) relation between X-ray and radio luminosities in Sun-like magnetic systems. At left **(from Williams+, arxiv:1310.6757)**, these are compared for both Sun-like magnetic systems (gray, following the relation) and ≥M dwarfs (colors). Lines connect multiple measurements of the same source.

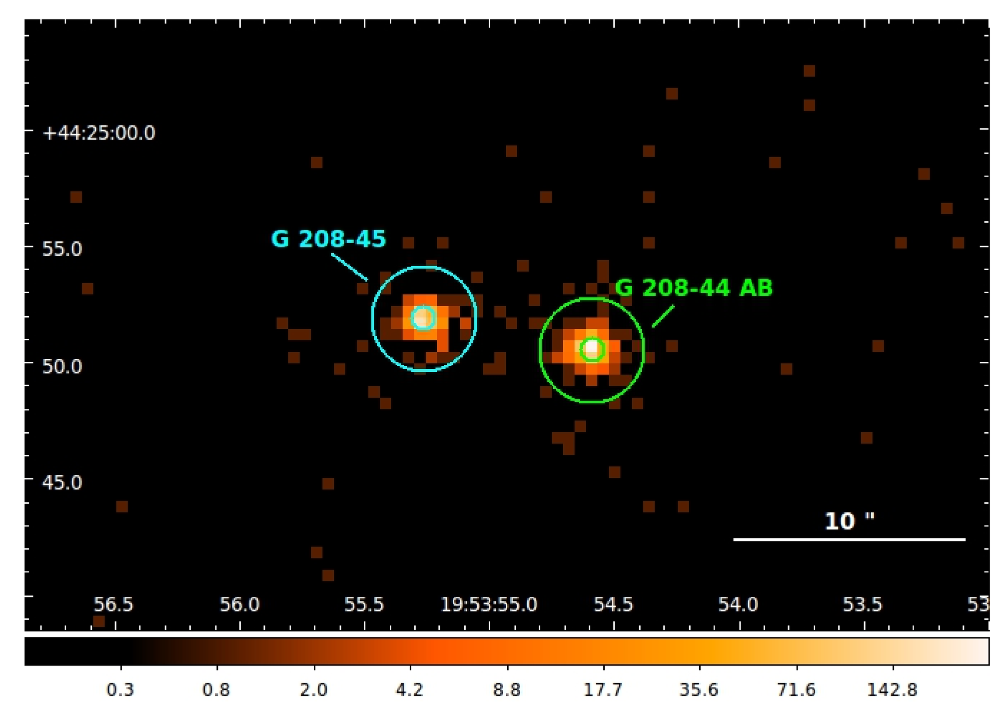
The Güdel-Benz relation holds across a wide range of luminosities and emitter types, from solar flares to active binaries. It has been used to argue that the underlying magnetic dissipation mechanisms are fundamentally similar across this whole range.

Some UCDs diverge from the relation by ≳4 dex — hence the surprisingness of the original radio detection of LP 944-20. This can be taken to support the interpretation that their magnetic processes operate in a new, substantially different regime.

This plot is derived from a living database of UCDs with both X-ray and radio measurements, built by combining both results in the literature and new analysis. More info on request!

New VLA and Chandra data show more Sun-like results.





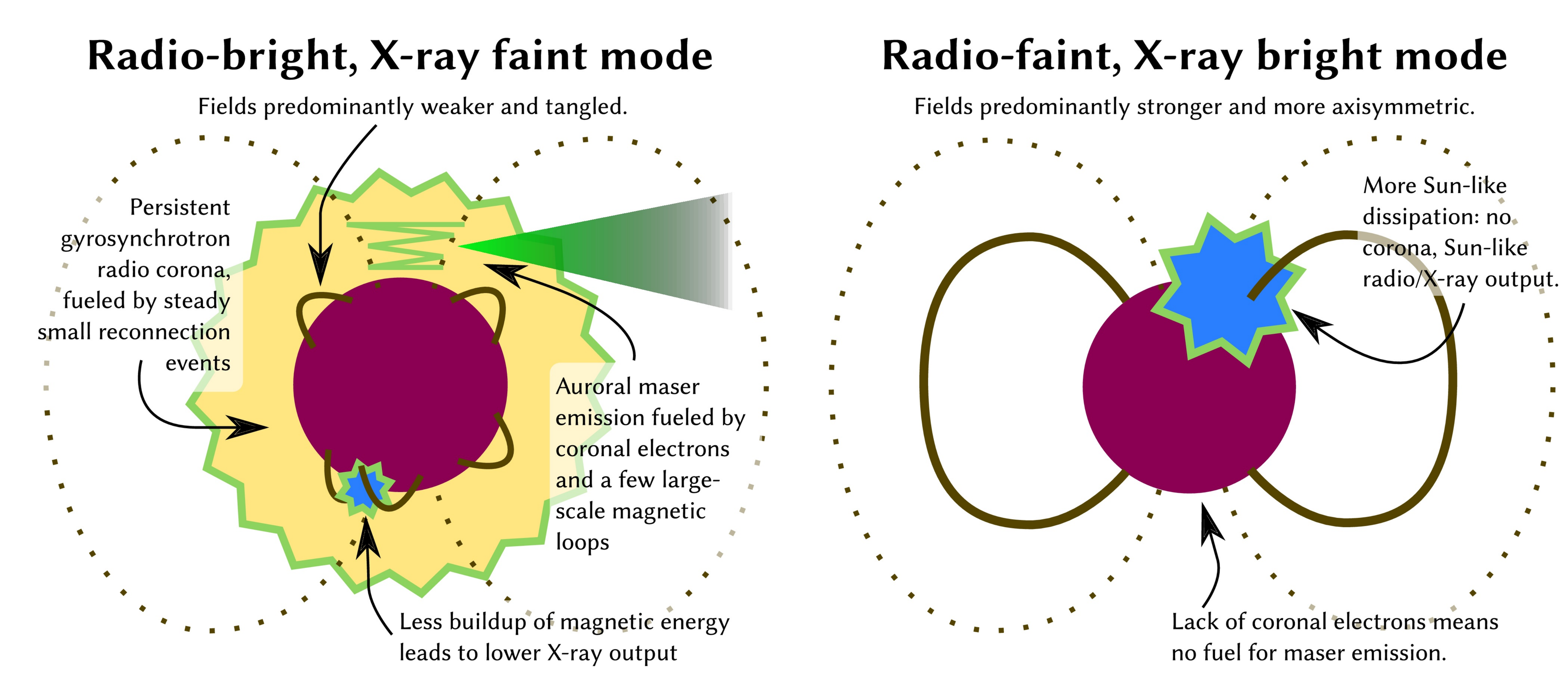
We obtained new VLA and Chandra observations of seven UCDs with late-M spectral types. At upper left (**from Williams+, arxiv:1310.6757**), we show cutouts of these objects in both the X-ray (white backgrounds) and radio (gray backgrounds) bands. The lower-right of the plot also shows Chandra data for two previously-unpublished objects. Previously-unpublished Chandra observations of another system (G 208-44AB/45, below; **from Williams+, arxiv:1310.6757**) was also analyzed. The high X-ray detection fraction (100% of the newly-observed sources) is unusual and doubles the number of UCDs with X-ray detections.

Only one of the targets was detected in the radio. **The new data strongly support previous indications (e.g. Stelzer+ 2012) of a bimodality in UCD properties in light of the Güdel–Benz relation**: while some objects are extremely radio-overluminous, others are not and could in fact be consistent with the relation (see circled points in figure below left).

We performed standard analyses of the X-ray spectra and lightcurves, finding typical results. About half of the detected systems show statistically significant indications of X-ray flaring over the course of the observations (~20 ks in most cases).

A bimodal magnetic dynamo may explain the data.

In Williams+ (**arxiv:1310.6757**), we offer a toy model for understanding the bimodal behavior, basing on Zeeman-Doppler Imaging results from Morin+ (2010) that suggest a bimodality in the magnetic field topology. **This picture is also motivated by our results relating the rotation and X-ray activity of our targets, as described in the adjacent poster by Cook+ and arxiv:1310.6758.**



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