

The EVLA at the Bottom of the Main Sequence



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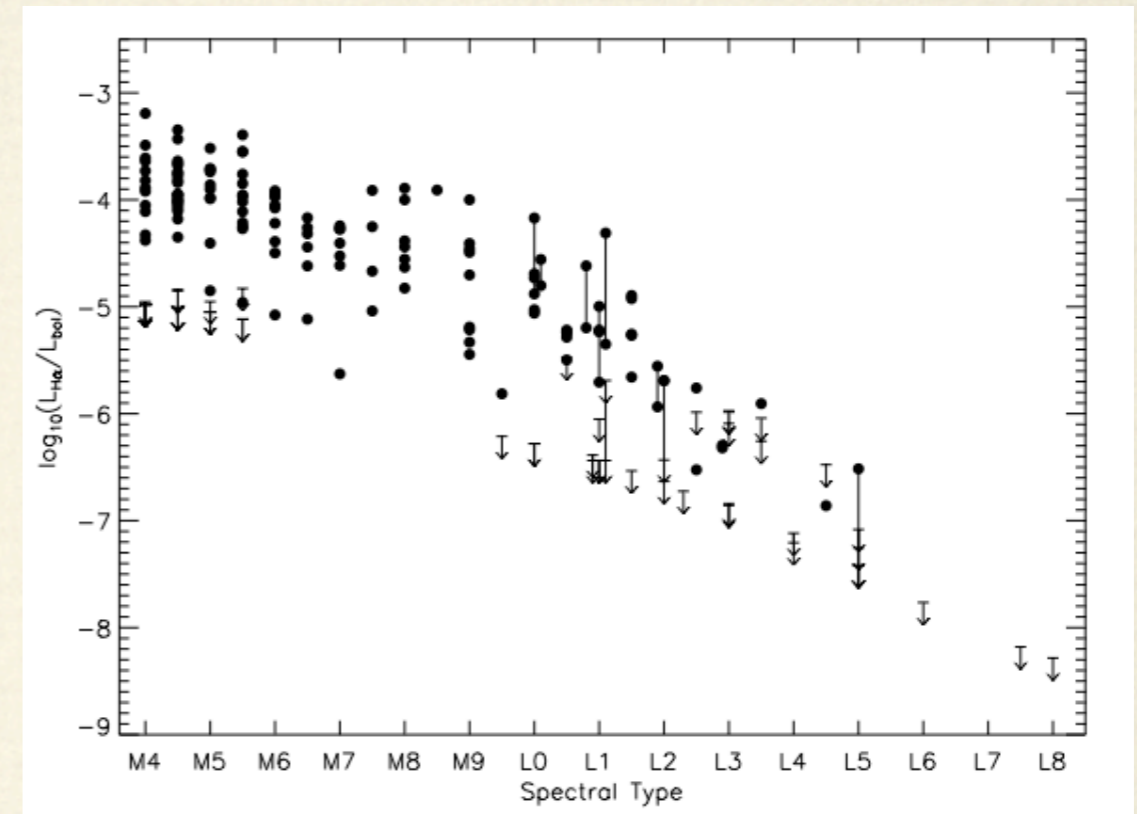
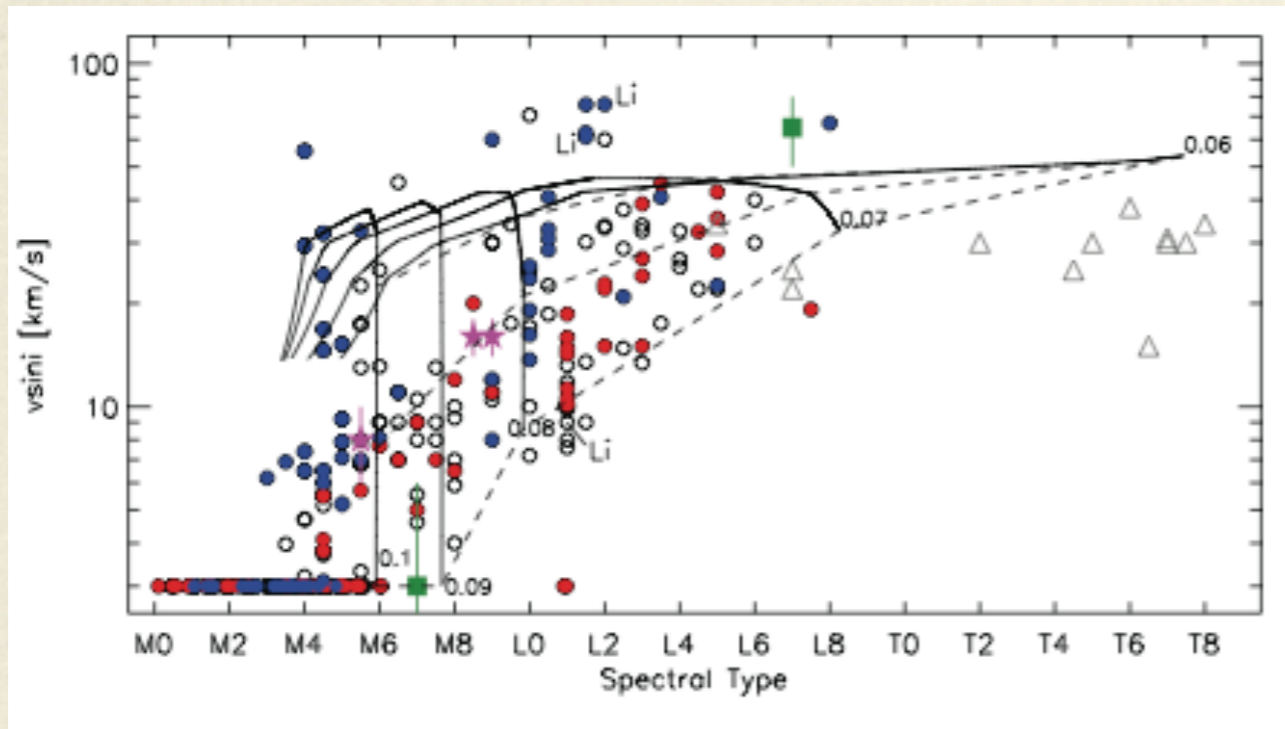
Space Telescope Science Institute

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Ultracool Dwarfs

- ❖ spectral types of \sim M7 and cooler: where it gets interesting
- ❖ magnetic activity signatures in ultracool dwarfs
- ❖ radio emission and its implications
- ❖ UCDs as radio light bulbs
- ❖ prospects for EVLA: major questions to answer/
kinds of observations to plan

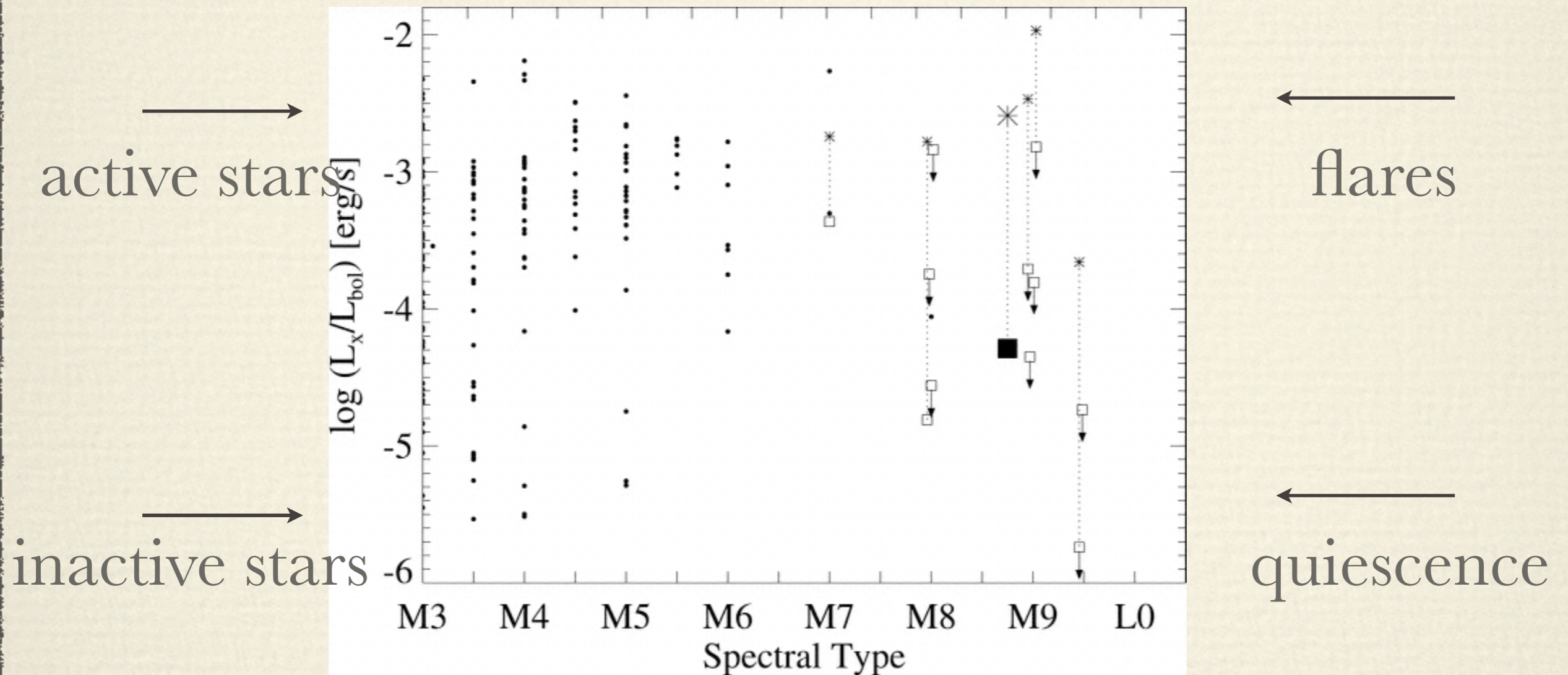
Initially, it was not expected that UCDs would display any radio emission



Reiners & Basri 2008

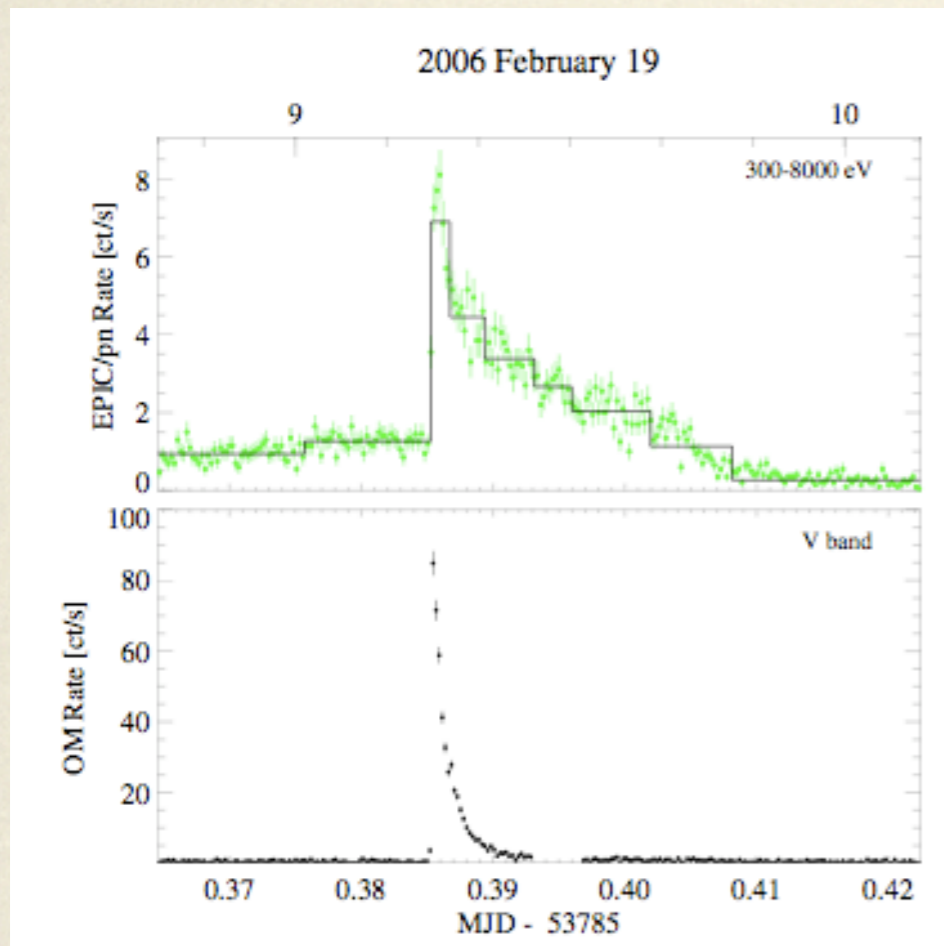
rotation-activity disconnect: nearly all objects past M7 rotate rapidly, chromospheric heating efficiency decreasing
Reiners & Basri (2008), West & Basri (2009), West et al. 2004

Decrease in coronal heating efficiency

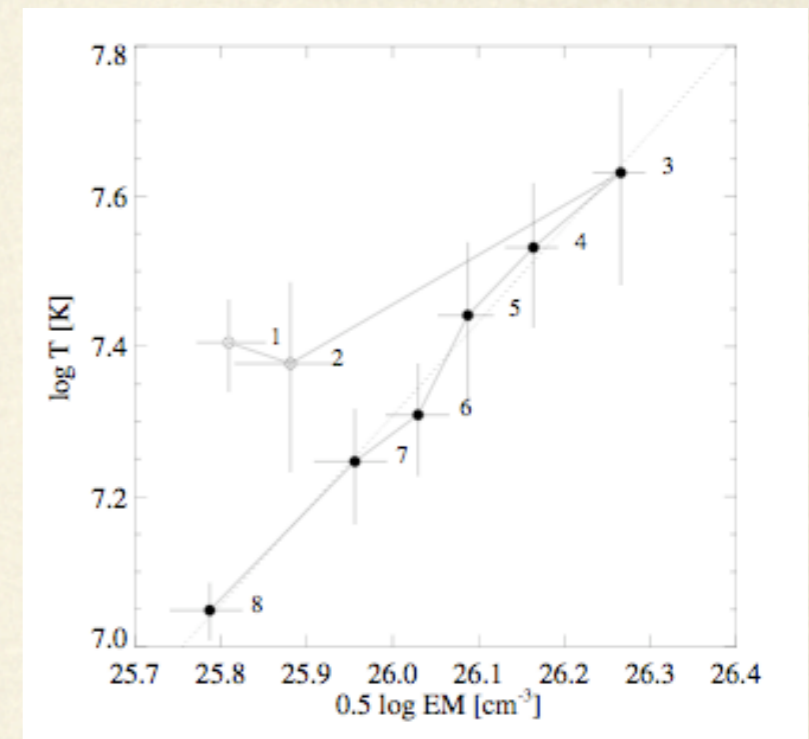


Stelzer et al. 2004

Flaring behavior of very low mass stars/ brown dwarfs is similar to dMe stars. . .



$M \sim 0.1 M_{\text{sun}}$, $R \sim 0.1 R_{\text{sun}}$, SO
 $g \sim 10 g_{\text{sun}}$
 expect coronal scale height to be much smaller



LP412-31 (M8 V) observed with XMM-Newton; Stelzer et al. (2006)

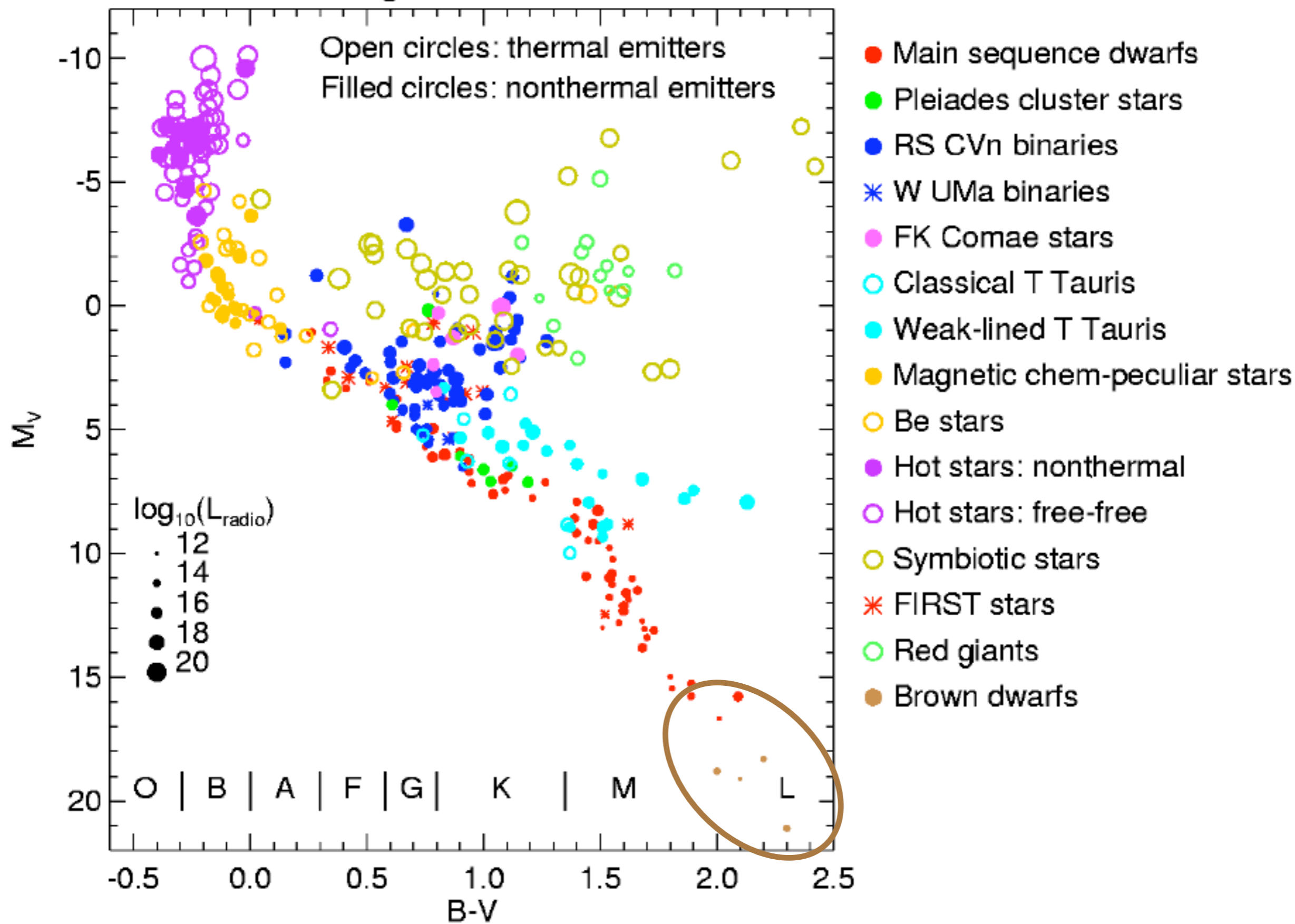
- flare optical delta $V=6$ magnitudes, among the largest stellar optical flare enhancements
- total flare energy 10^{32} ergs, typical of the largest solar flares

loop modelling using 1D HD solar flare loop models gives scale size for flaring X-ray emission $\geq R_{\text{star}}$, where $R_{\text{star}} \sim 0.1 R_{\text{sun}}$

Dynamo & Magnetic fields

- ❖ stars become fully convective at spectral types of M3-4; wasn't thought that turbulent dynamos could sustain large-scale magnetic fields
- ❖ initially thought that large resistivity of cool, dense, neutral atmospheres would prevent buildup of magnetic stresses, large scale magnetic fields
- ❖ quite strong magnetic fields (f^*B) of up to 4 kG have been detected from a handful of very low mass stars/brown dwarfs (Reiners & Basri 2007) using near IR spectroscopy of FeH

Radio H-R Diagram: Radio Luminosities

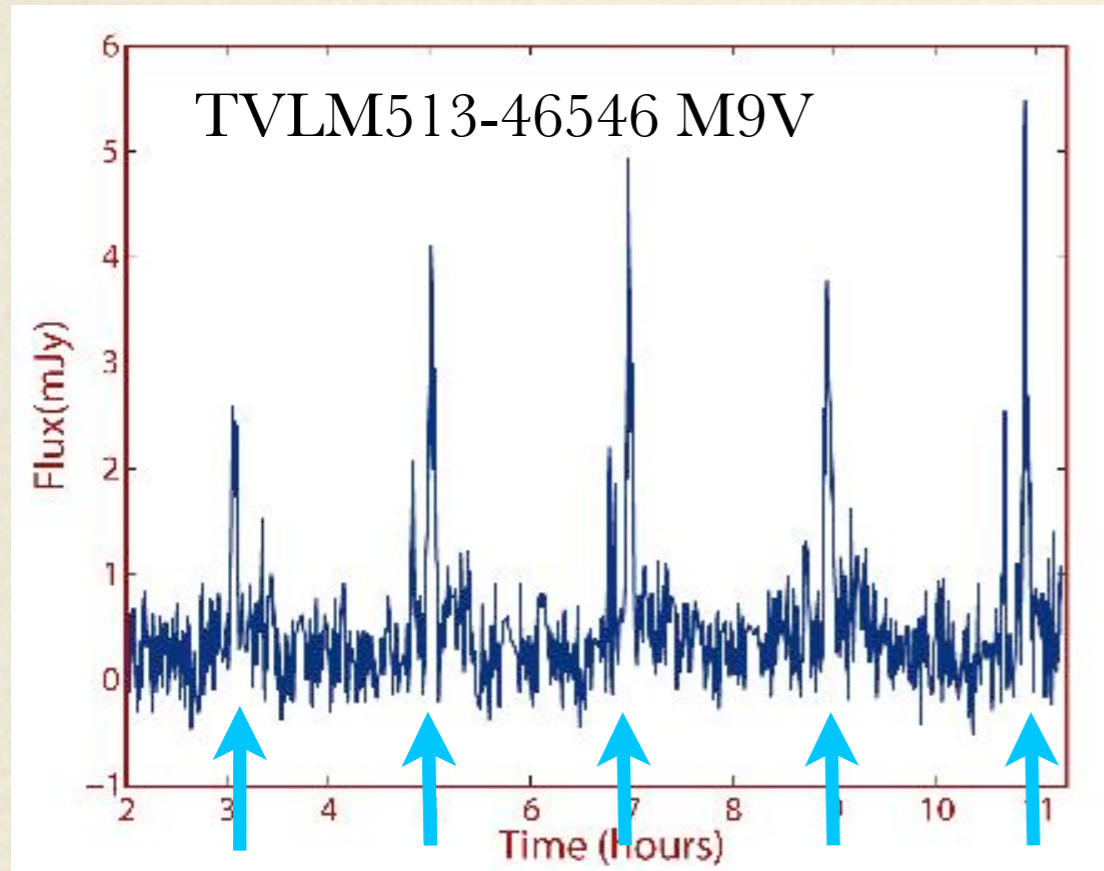


Radio Observations of UCDs

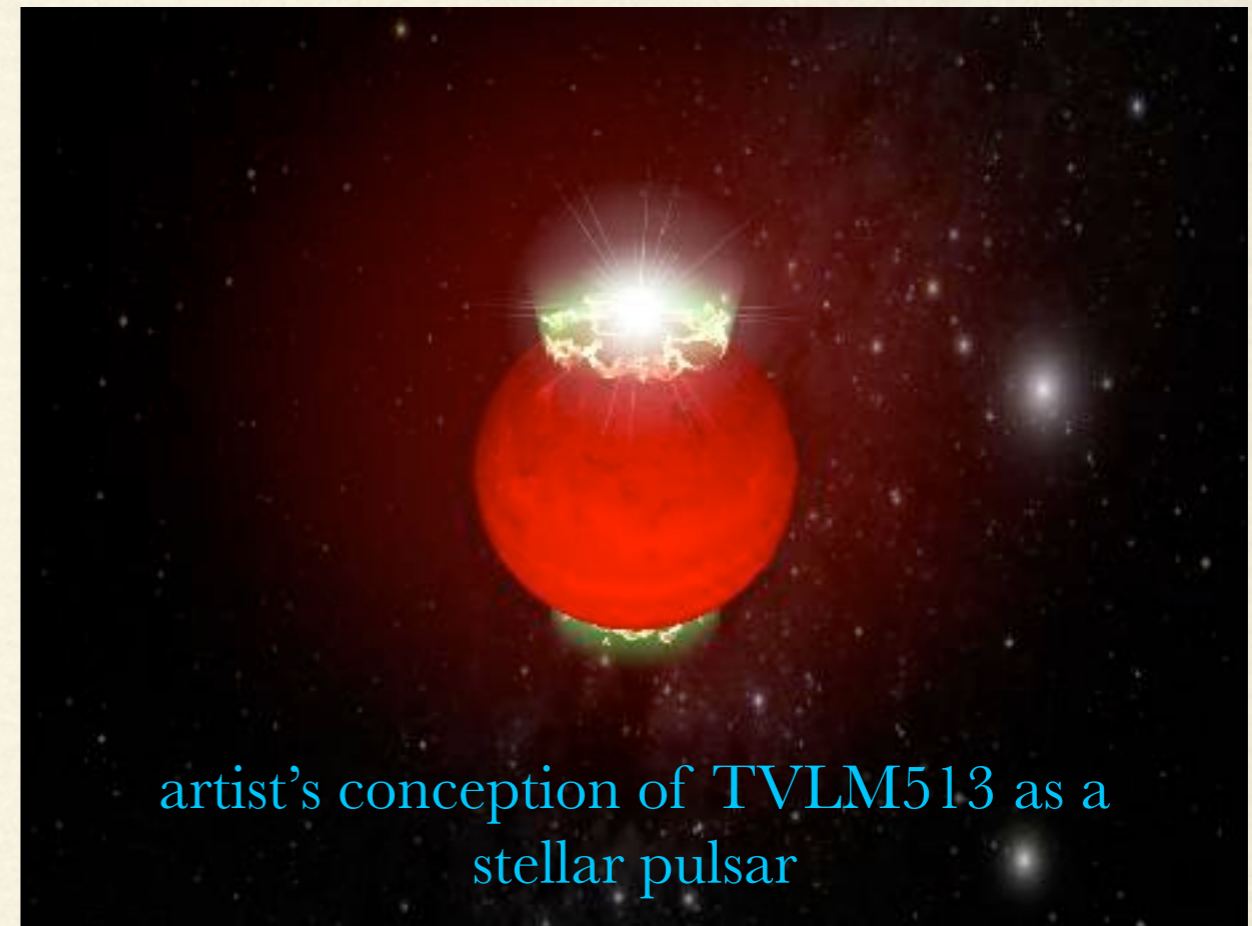
- ❖ low detection fraction: only $\sim 10\%$ (still small number statistics)
- ❖ concentration near M8-M9 (obs. bias)
- ❖ variability is a key factor: periodic & aperiodic
- ❖ rotation/inclination effect?

Pulsating radio behavior on VLM stars/brown dwarfs shows different radio emission behavior

Hallinan et al. 2007

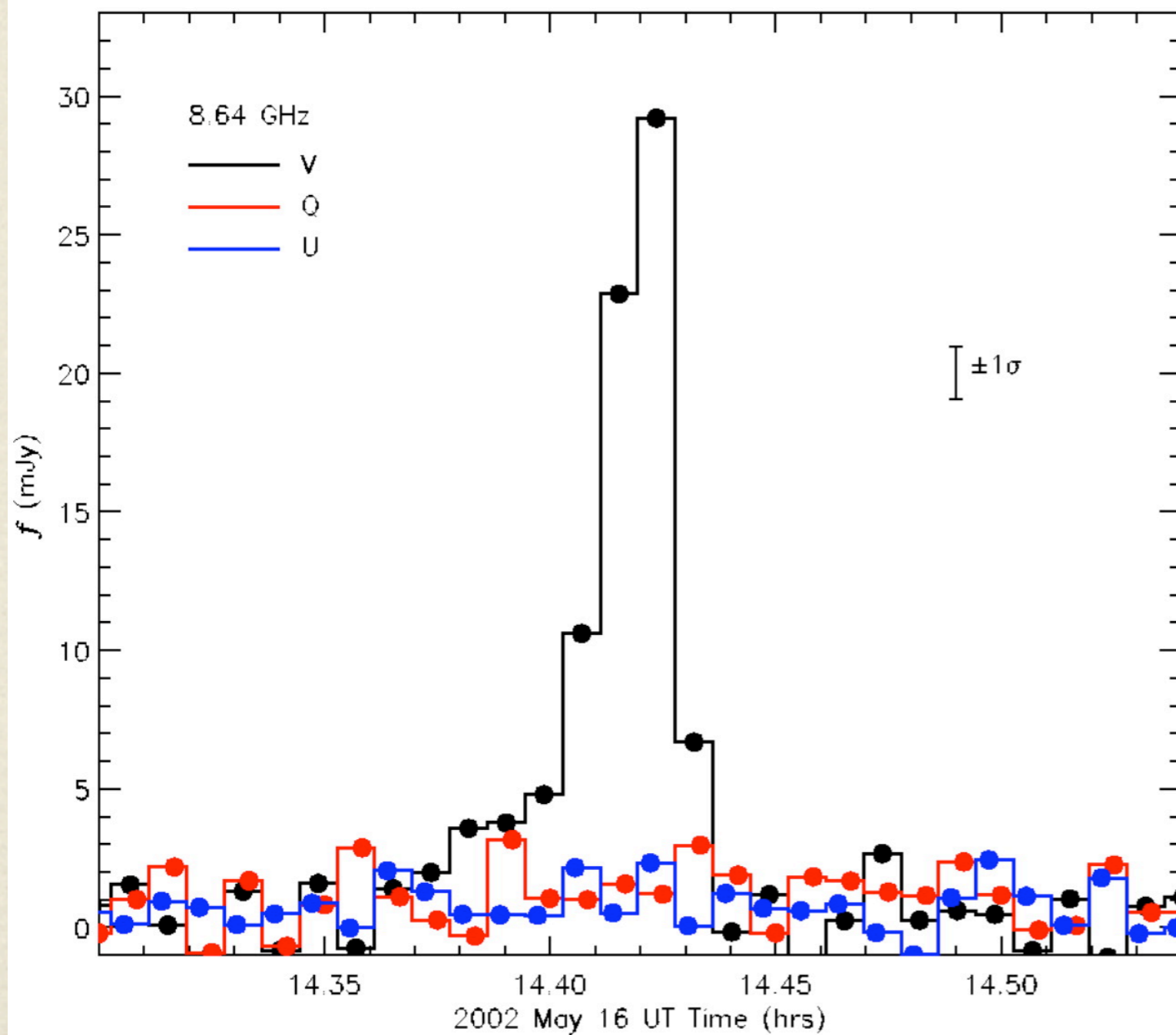


0.1 M_{sun} , 0.1 R_{sun} star with $P_{\text{rot}} \sim 2$ hours, showing pulsating radio bursts



radius constraint: brown dwarfs as radio light bulbs to probe fundamental properties

Aperiodic radio variability

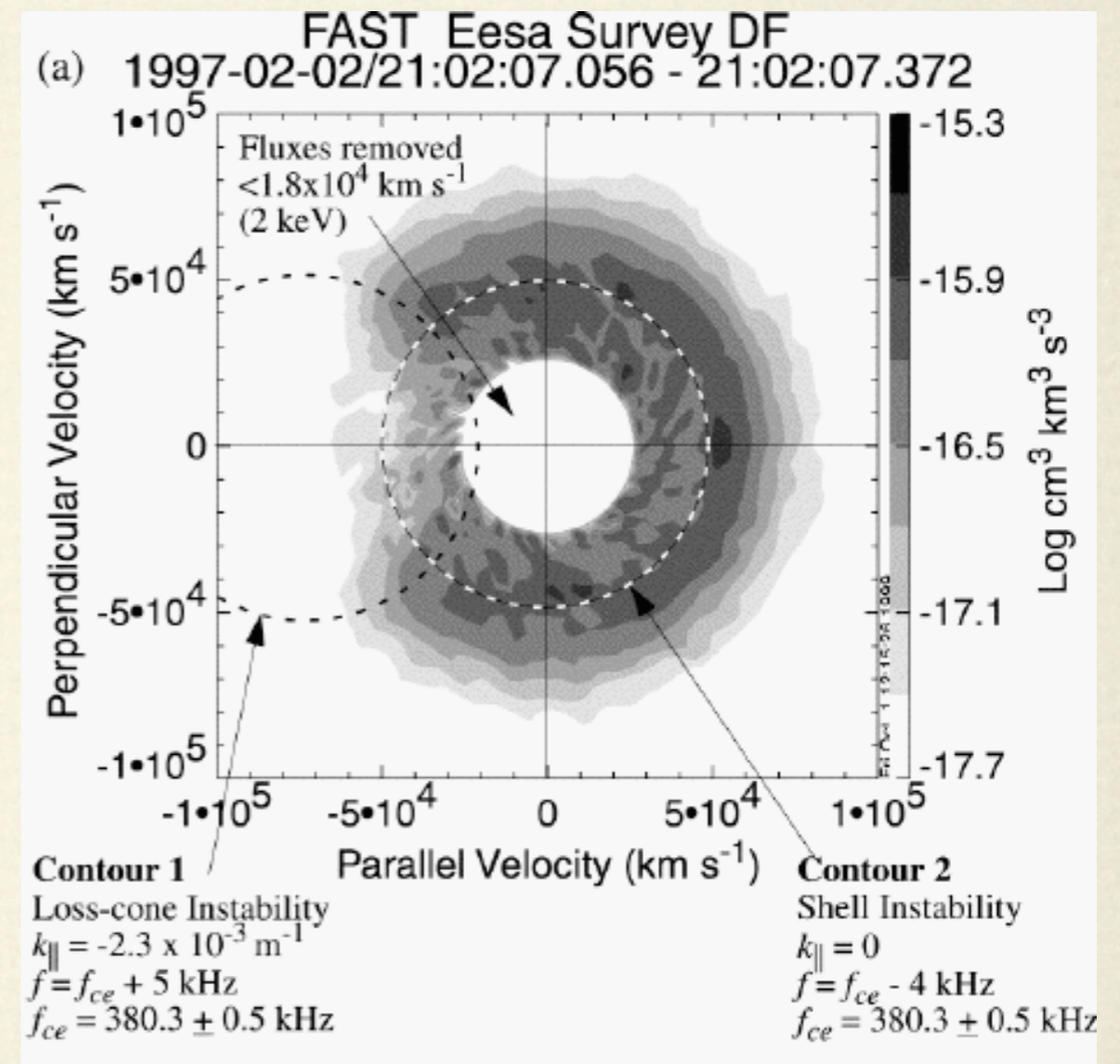


Large flux density events accompanied by significant ($>50\%$) circular polarizations

Burgasser & Putman (2005) burst from M8V DENIS1048-3956

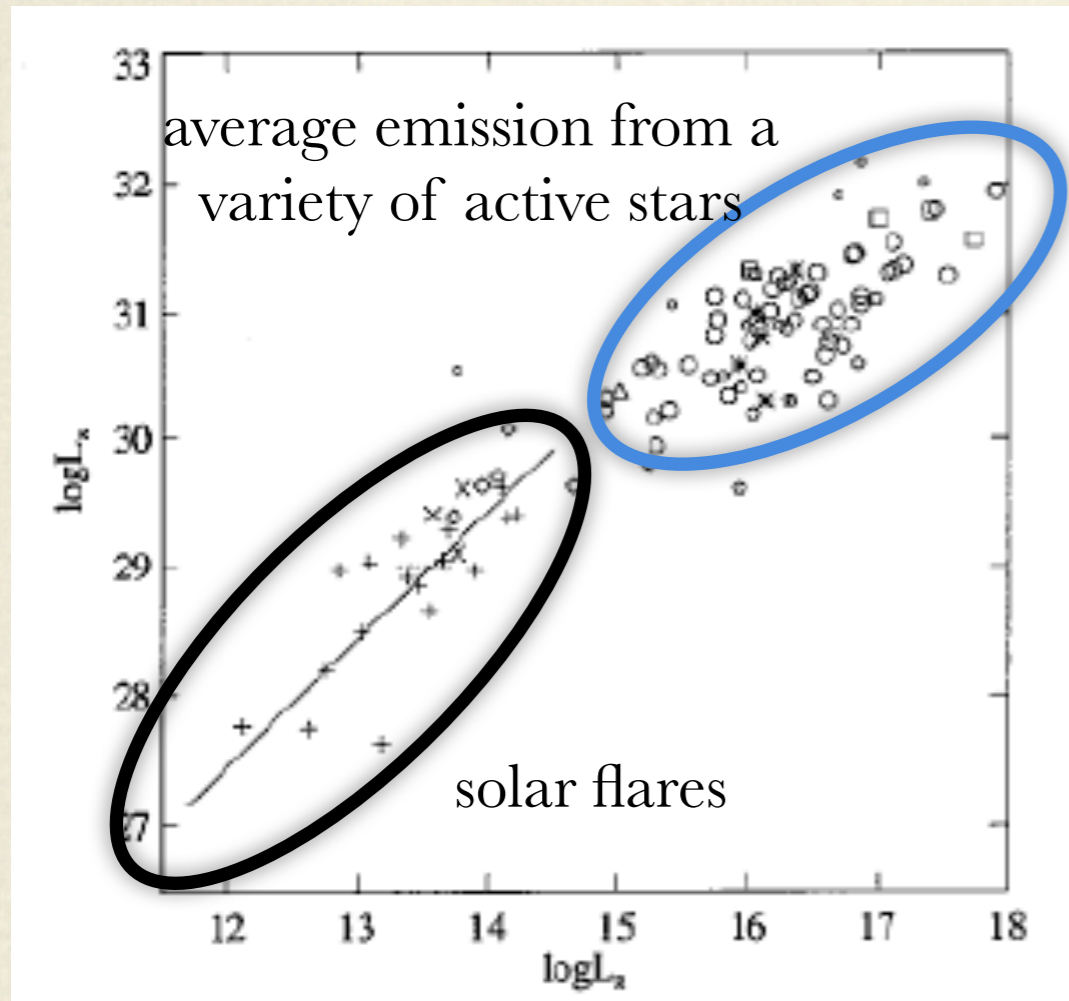
cyclotron maser instability

- wave-particle resonance between EM radiation & magnetized electrons
 - requires anisotropy in e^- distribution function: $\partial f / \partial p_{\perp} > 0$
 - occurs where $v_B / v_p > 1$ ($v_B \sim 2.8 B_3$ GHz, $v_p \sim 9 (n_e / 10^{12})$ GHz)
 - coronal loops & converging magnetic geometry provide a ready format for loss-cone distribution of electrons.
- Observations of auroral kilometric radiation (AKR) show that shell or horseshoe distribution is dominant driver of instability. Requires magnetic field-aligned electric fields.



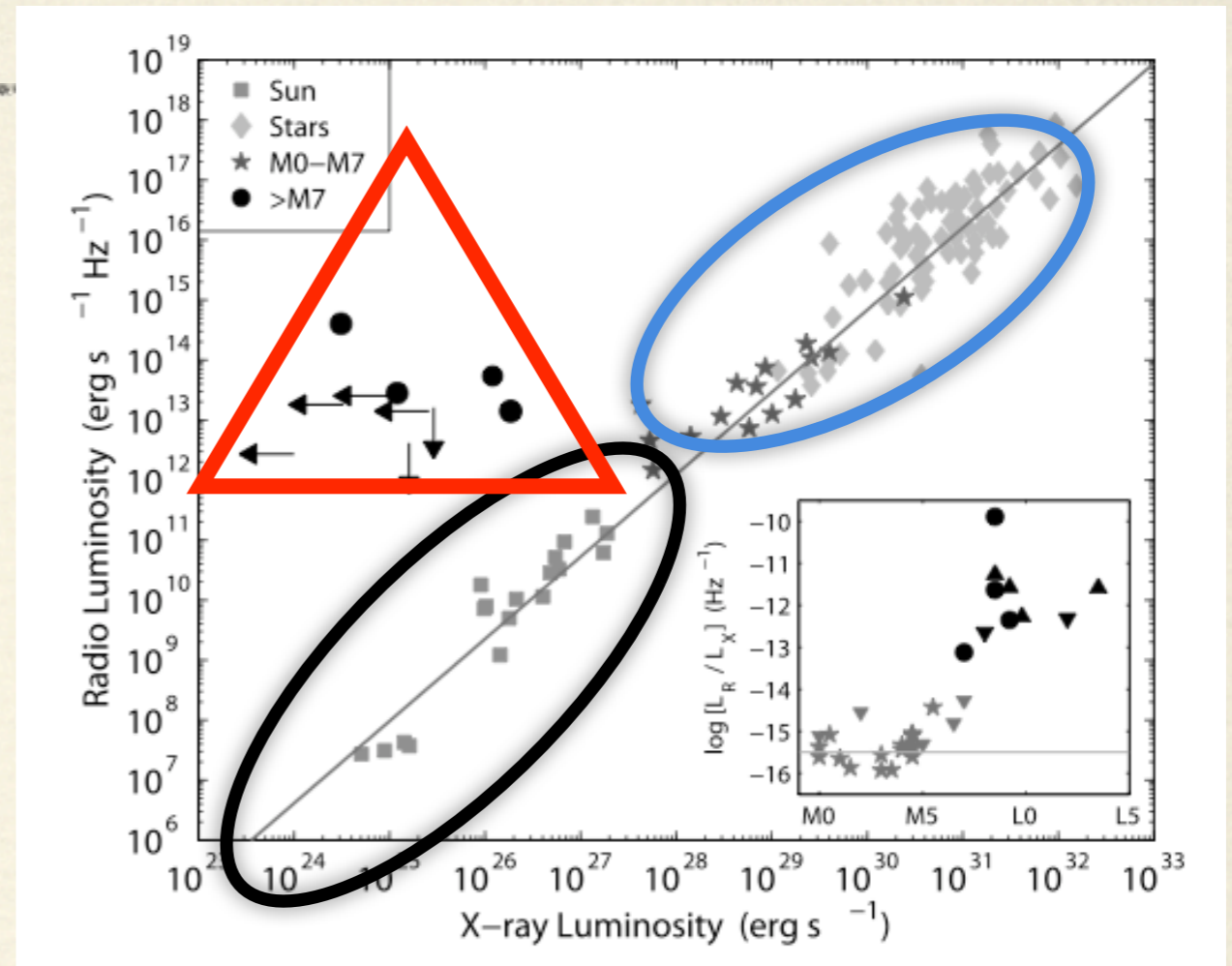
Ergun et al. (2000) AKR in situ measurements of electron distribution function, showing the horseshoe distribution

X-ray/Radio (dis)connections



Güdel & Benz (1993)

common energy reservoir from which particle acceleration (L_r) and plasma heating (L_x) are both produced; extension from solar flares to average stellar conditions implies similarity in physical process

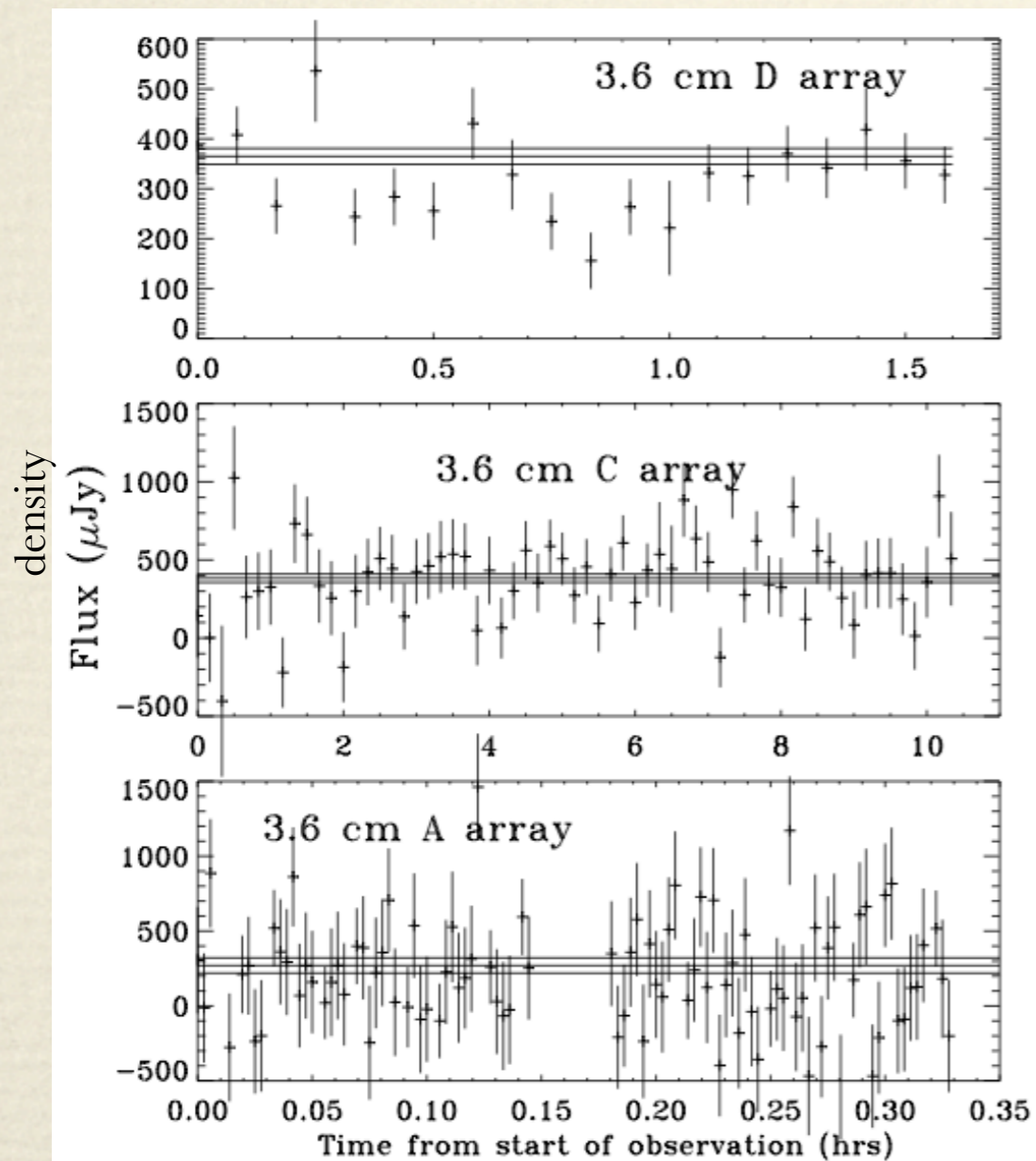


Berger et al. (2008)

VLM stars/brown dwarfs are very radio-luminous compared to this relation, implying (1) decrease in coronal heating efficiency (L_x) and more efficient particle acceleration, or (2) change to different radio emission mechanism

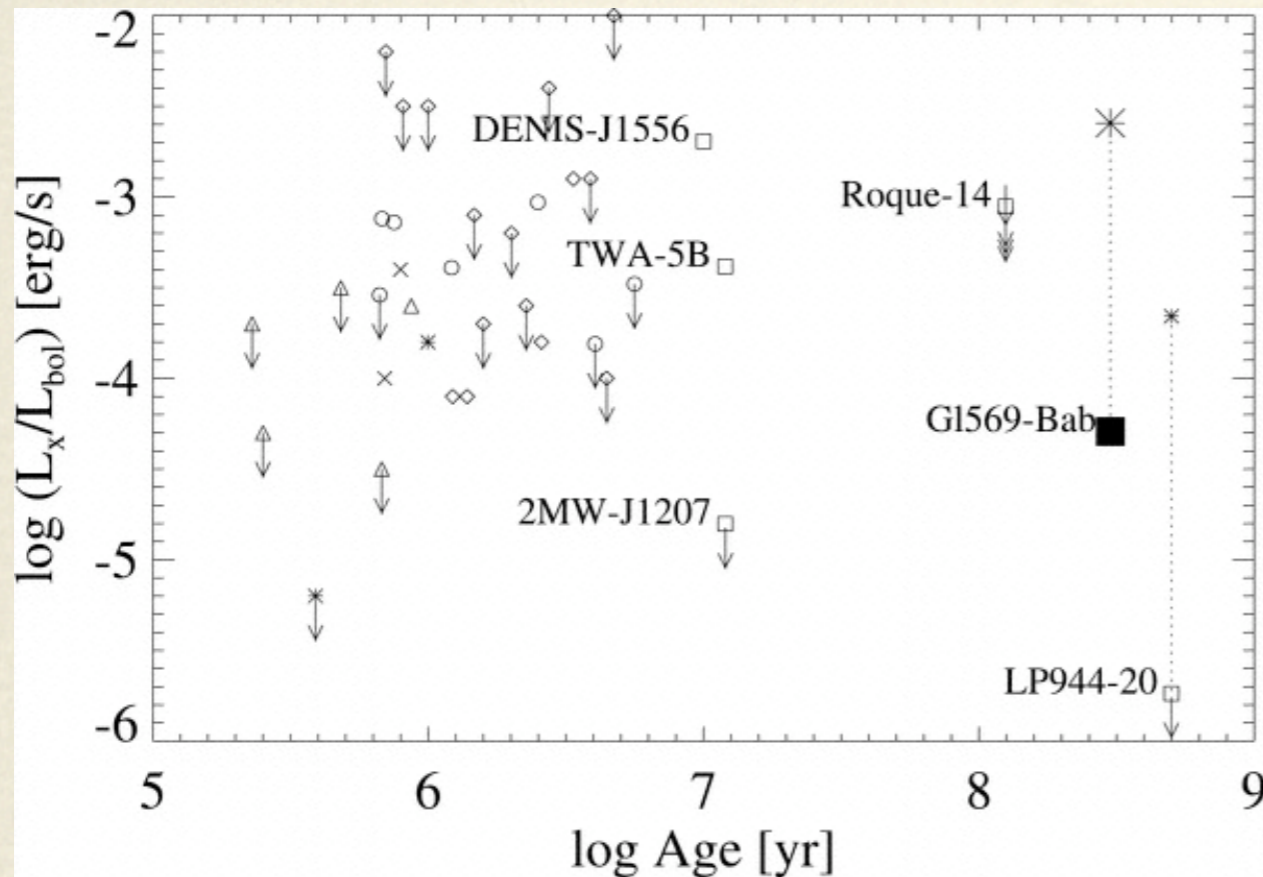
lack of variability

Osten et al. 2009



- ❖ LP 349-25, M8V+M9V
- ❖ single frequency detection
- ❖ followup at two epochs reveals similar 3.6 cm flux density, 6 cm flux densities
- ❖ no evidence for short term or significant long term variability
- ❖ no reason to invoke coherent mechanism
- ❖ what is the origin of quiescent radio emission from UCDs?

Activity in Young BDs

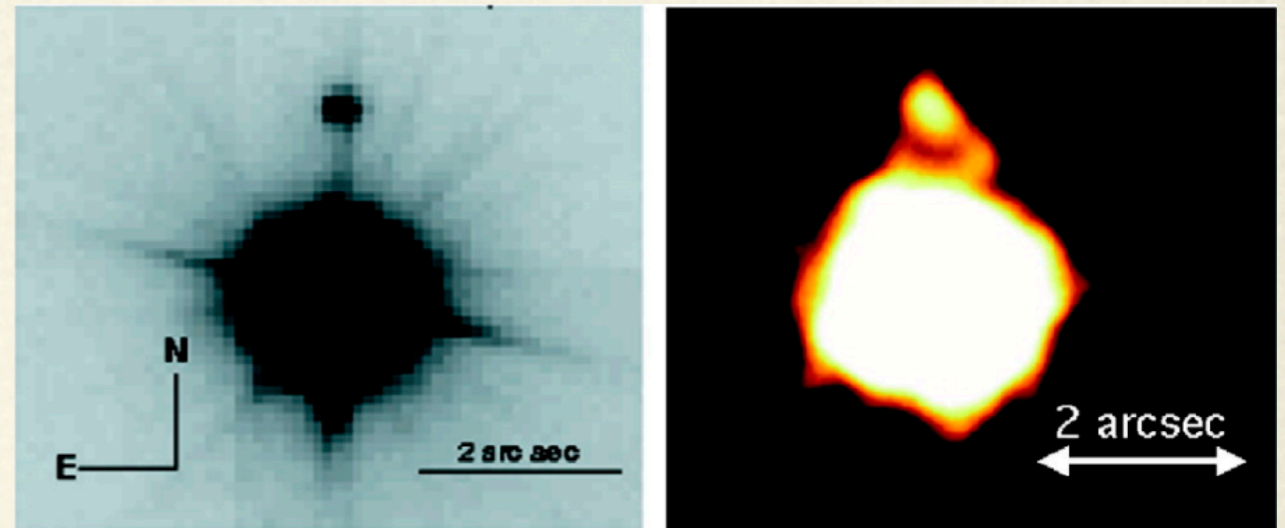


Stelzer et al. 2005

- ❖ Preibisch et al. (2005) Orion BDs (M6-M9) similar X-ray properties (L_x/L_{bol} , T_x , flare rates) to coeval low mass stars
- ❖ properties also similar to M6-M9 field stars
- ❖ T_{eff} is key, controls degree of ionization

Activity in Young BDs

Osten & Jayawardhana (2006) anomalous behavior in TWA 5B, the nearest youngest brown dwarf: X-ray detection & radio nondetection imply behavior similar to young stars and older active stars

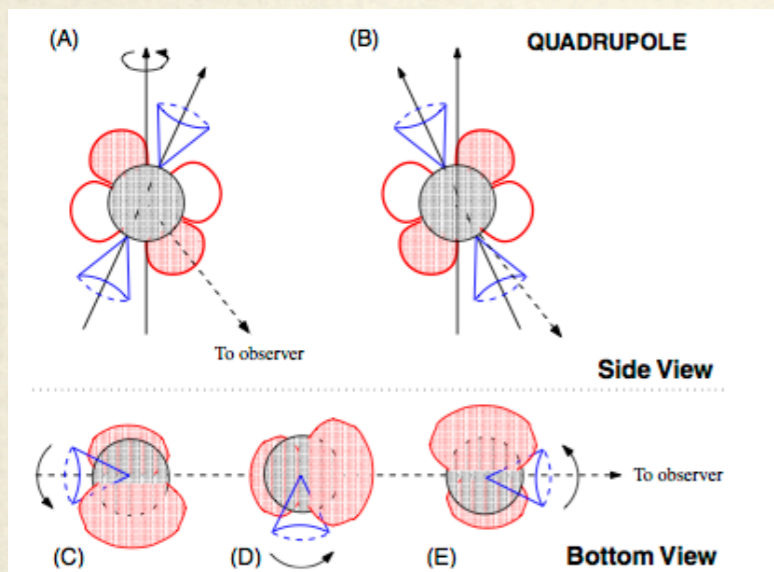


Tsuboi et al. 2003

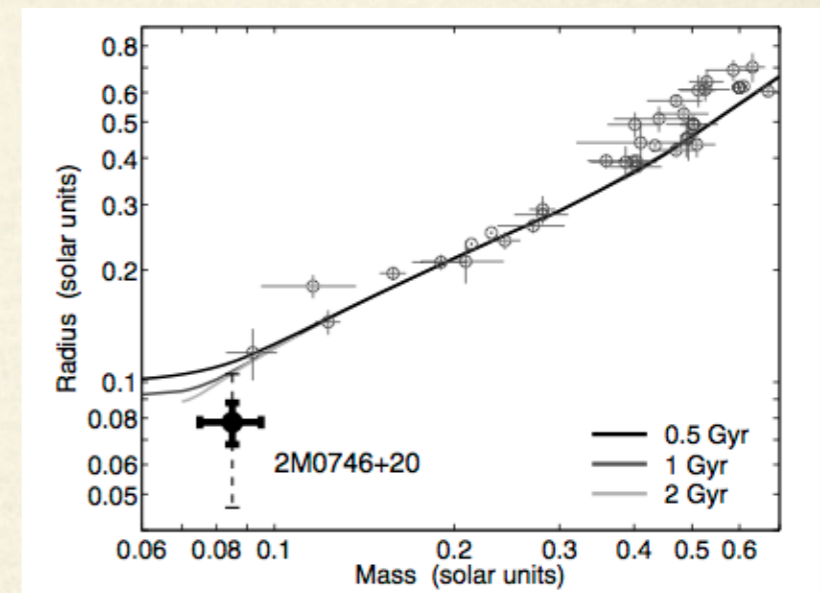
magnetic field generation in brown dwarfs is less efficient than in stars: Reiners et al. 2009 did not detect large magnetic fluxes in young brown dwarfs

Radio UCD light bulbs

- using radio emission as a light bulb to probe fundamental properties of ultracool dwarfs: $P_{\text{rot}} + v \sin i = \text{radius constraint}$



2M0746+20(L0+L1.5);
Berger et al. 2009



- binary brown dwarfs: mass prospects from HSA observations

key questions I.

- ❖ internal structure of ultracool dwarfs: do strong exterior magnetic fields imply $M(R)$ difference from models?
- ❖ sampling the rotation-age-activity relation using different activity indicators
- ❖ rotationally induced threshold for activity?

key questions II.

- ❖ two emission mechanisms? flare, quiescent
- ❖ where do accelerated particles originate? role of flares?
- ❖ behavior near M5? transition to CME-dominant flare mechanism? relation to internal structure?
- ❖ behavior in mid L? transition to jovian magnetosphere?
- ❖ radio emission controlled by rotation or inclination? if rotation, where (T_{eff}) and when (age)?

6 impossible things before breakfast. . .

- ❖ detecting T dwarfs, stellar - planetary connection
- ❖ bandwidth: avoid pitfalls of single frequency detection, spectral index constraints
- ❖ time resolution + bandwidth: dynamic spectra (dMe stars, solar corona), better constraints on plasma processes
- ❖ multi-wavelength observations: magnetic field detections, H α , X-ray
- ❖ high frequency emission, molecular masers from brown dwarfs?
- ❖ disk thermal emission from young brown dwarfs?