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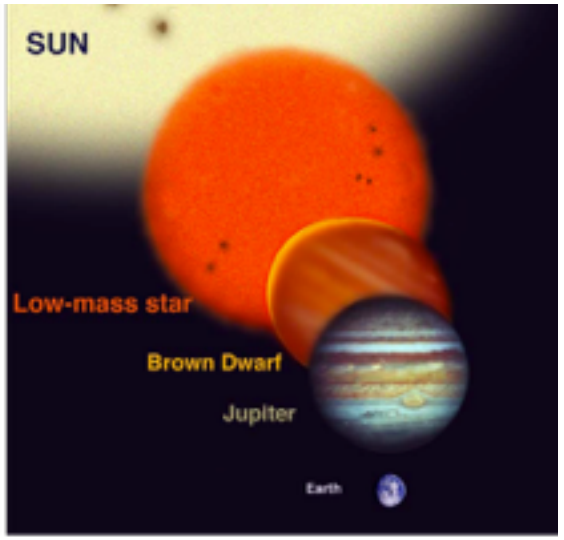
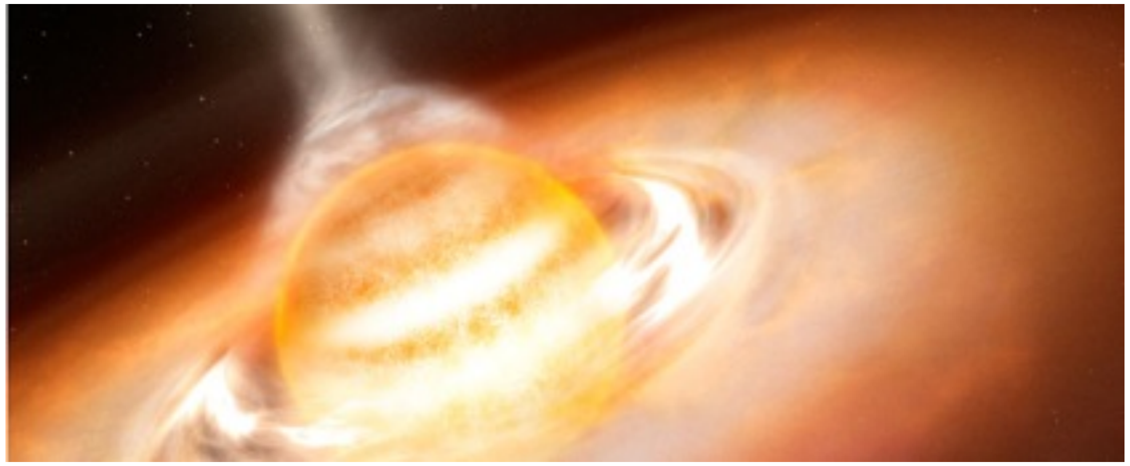
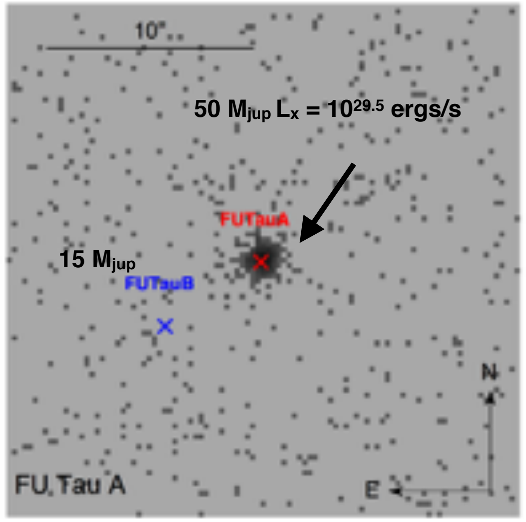


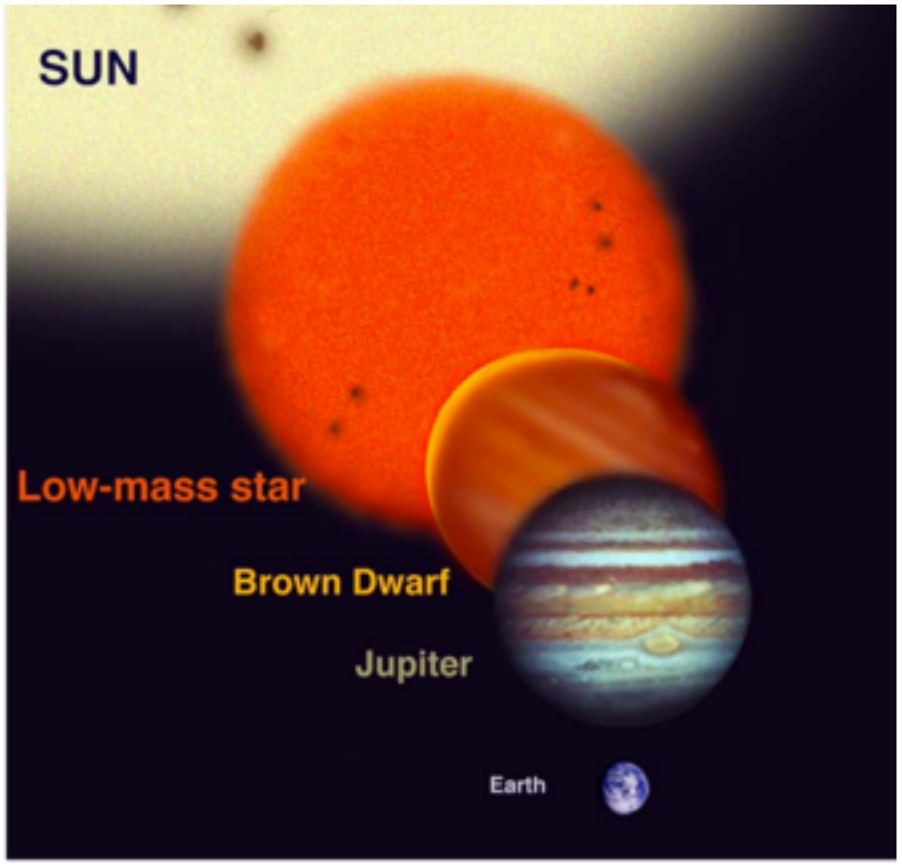


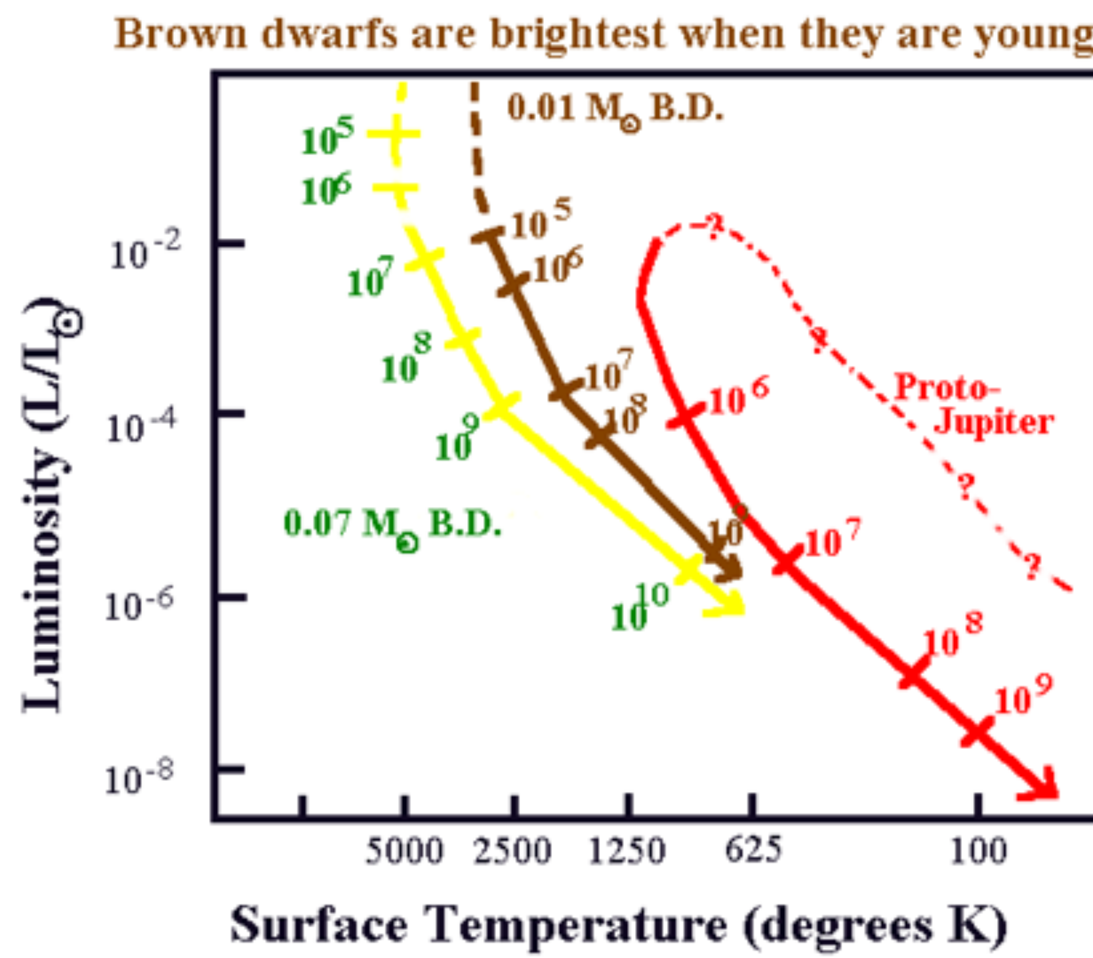


Brown Dwarfs in X-rays

Emma Whelan
(IAAT)

Brown Dwarfs





Object Type	Mass[a] ($M_\odot$)	H Fusion	D Fusion	Contains Li	D
Very low mass Star	0.1-0.075	Sustained	Evanescent	No	No
Brown Dwarf	0.075-0.065	Evanescent	Evanescent	Yes[b]	No
Brown Dwarf	0.065-0.013	Never	Evanescent	Yes	No
Planet	<0.013	Never	Never	Yes	Yes

Table 1.1: Definitions of a Very Low Mass Star, Brown Dwarf and Planet, taken from Oppenheimer, Kulkarni, & Stauffer (2000). [a] Masses given here assume that the objects have solar metalicity. [b] Brown Dwarfs in the mass range have lithium abundances that are age dependent.

cool significantly with age

WISE Survey

ratio of stars to BDs ~ 5

Formation Mechanisms

sub-stellar mass cores

Padoan & Nordlund 2004

Chabrier et al. 2014 PPVI Talk

Fragmentation of a large core and premature ejection of protostellar embryos

Reipurth & Clarke, 2001

Papers by Bate

disk fragmentation

papers by Stamatellos

action of an outflow

Machida et al. 2009

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Evidence that BDs form like Stars

borrowed from Chabrier talk at PPVI!!!

Young BDs vs young star properties

(Luhman et al. 2007; Luhman ARA&A 2012)

- same radial velocity dispersion
- same spatial distribution in young clusters (see e.g. Bayo et al. '11)
- consistent with the same IMF
- wide binary BDs difficult for disk fragmentation model
- form in low-density environments (e.g. Taurus)
- accretion + disk signature (large blue/UV excess, large asymetric emission lines, H_α => natural extension of CTTs
- disk fraction around BDs ~40-60% similar to stars
- timescales for accretion around BDs ~similar to stars ~1-10 Myrs
- presence of outflows
- Observations of **isolated proto-BDs and pre-BD**

BD and star formation :
common dominant mechanism

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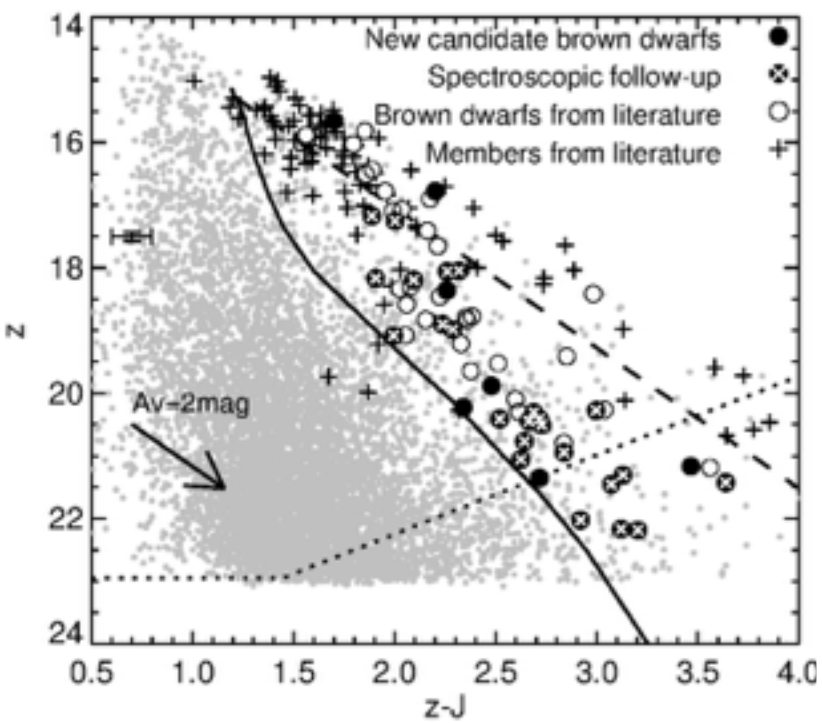
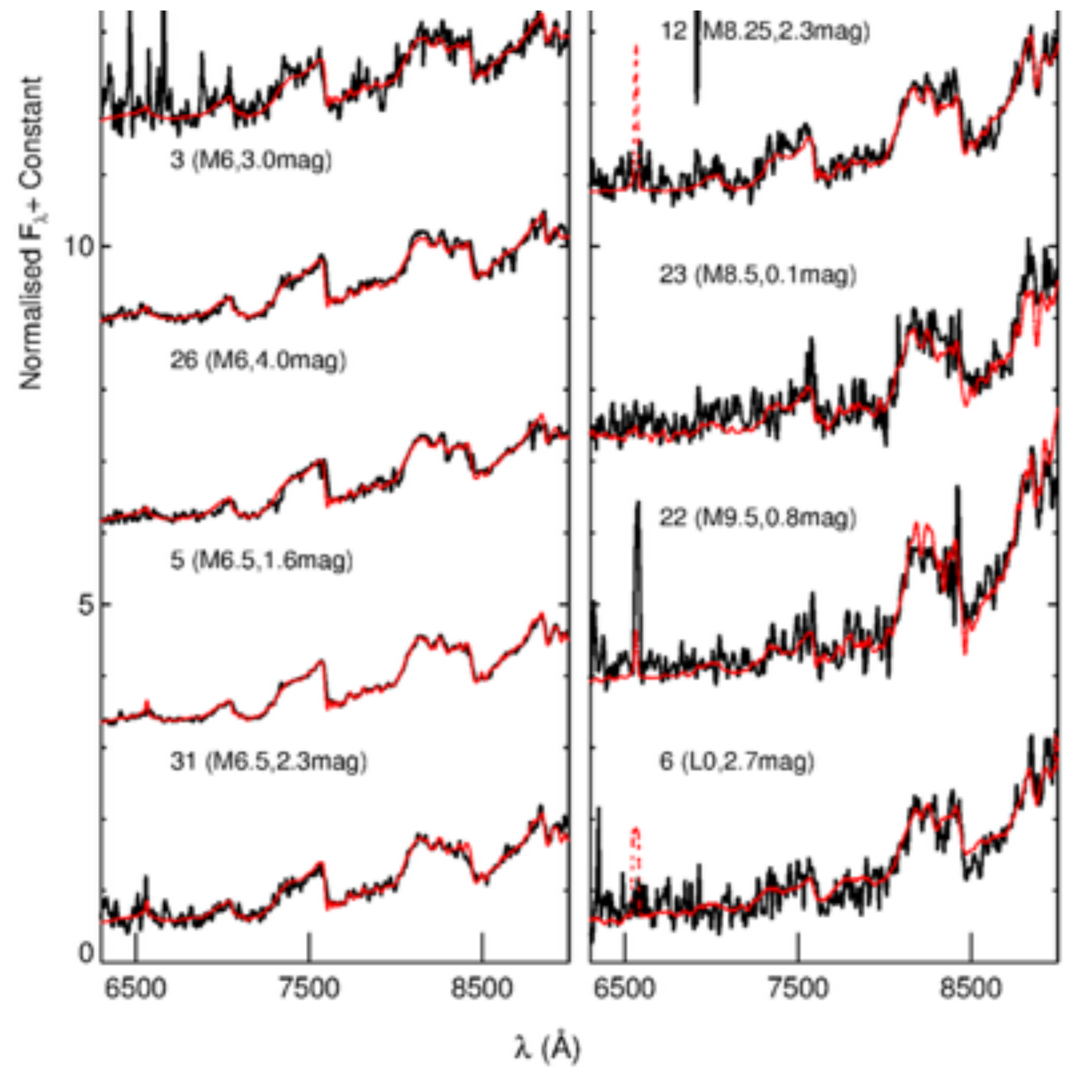
Identifying BDs

Figures taken from Alves de Oliviera A&A, 2013,A&A, 549, 123



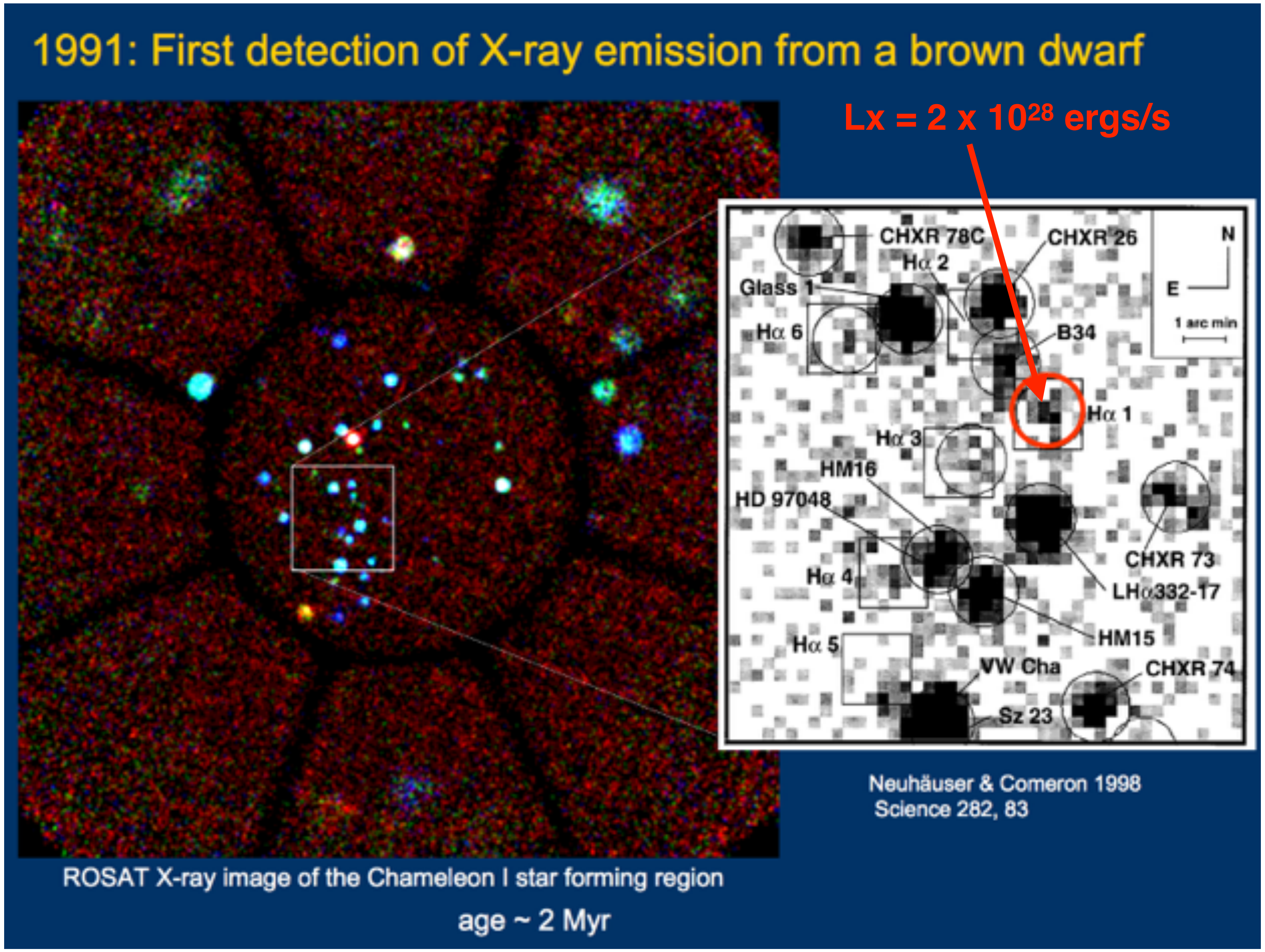


Identified using photometry and spectra.

Spectra used to determine spectral type and thus mass and temp.

Very few dynamical mass estimates exist.

Detection of X-ray Emission from Young BDs



Also see Neühauser et al. 1999, A&A, 343, 833
Comeron et al. 2000 A&A, 359, 269
Mokler & Stelzer, 2002 A&A, 391, 1025

Searched for BDs in X-rays in Pleiades, ρ-Oph, σ-Orionis, Taurus-Auriga

Only a handful of detections

Problems with ROSAT:
detection limits too low
bad spatial resolution
not many confirmed BDs

Figure borrowed from T. Preibisch talk

Detection of X-ray Emission from Young BDs

Chandra Orion Ultradeep Project (COUP)

Preibisch et al. 2005, ApJS, 160, 582

9/34 BDs detected as X-ray sources in survey of the ONC

The physical conditions in the atmospheres of the young brown dwarfs are very similar to those in late M stars

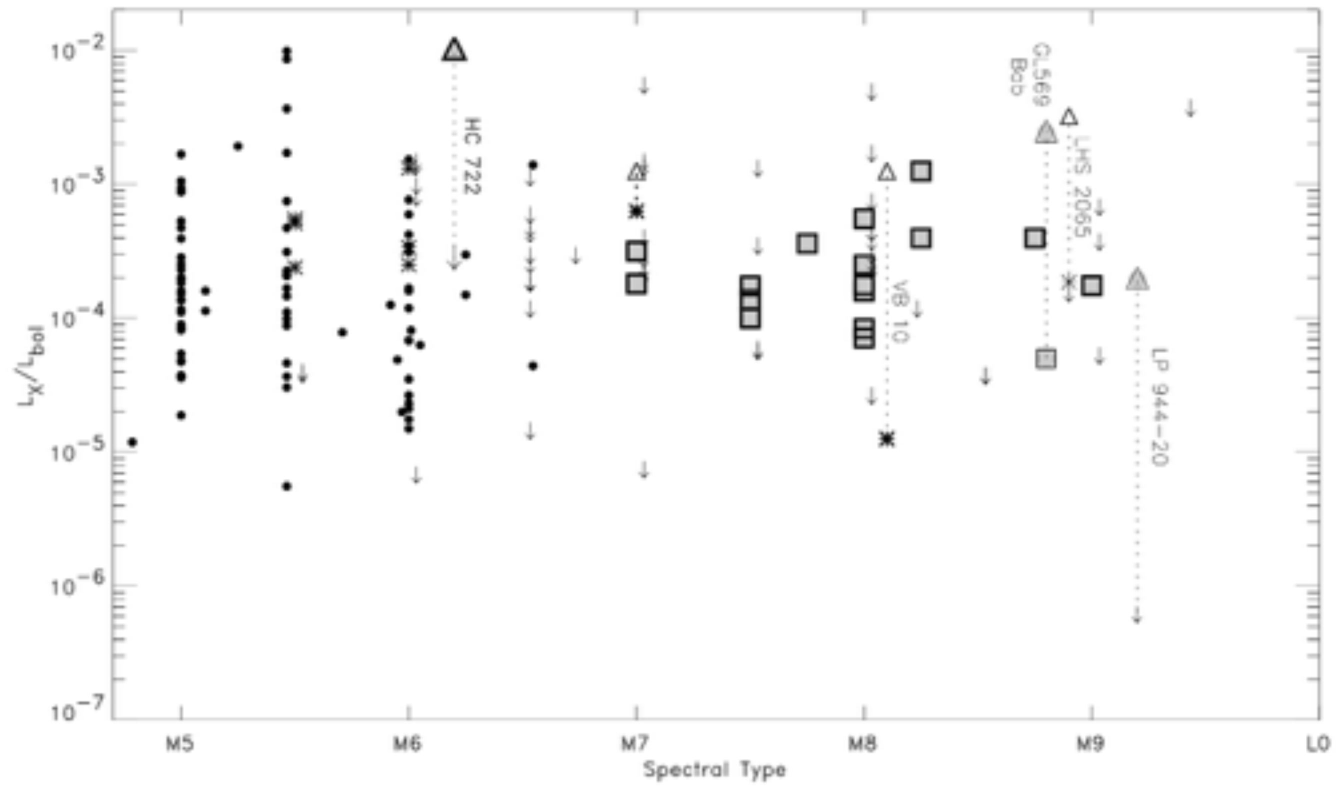


Fig. 8.— Fractional X-ray luminosity versus spectral type for objects of type M5 or later. The solid dots show stars in the COUP optical sample. Data for late M field stars from Fleming et al. (1993) are shown as asterisks. The BDs in the ONC from the SHC04 sample and other X-ray detected young BDs (as discussed in §2) are shown by grey filled squares.

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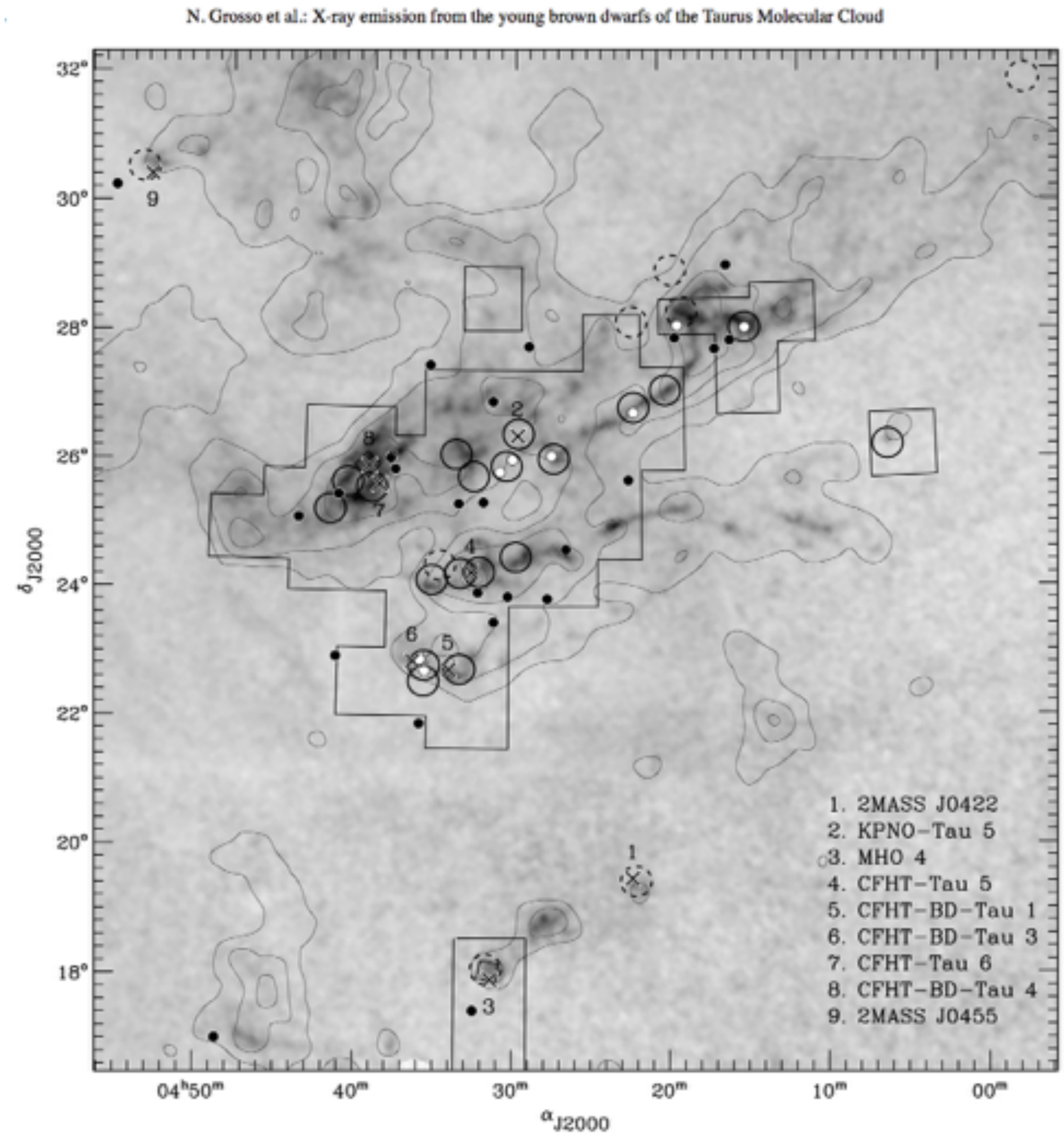
Detection of X-ray Emission from Young BDs

Grosso et al. 2007, A&A, 468, 391

XEST Data
The XMM-Newton Extended Survey of the TMC
Güdel et al. 2006a

1. 2MASS J0422	Acc = Y, $L_x = 2 \times 10^{28}$ erg/s
2. KPNO−Tau 5	Acc = Y, $L_x = 0.8 \times 10^{28}$ erg/s
3. MHO 4	Acc = Y, $L_x = 8 \times 10^{28}$ erg/s
4. CFHT−Tau 5	Acc = N, $L_x = 12 \times 10^{28}$ erg/s
5. CFHT−BD−Tau 1	Acc = N, $L_x = 14 \times 10^{28}$ erg/s
6. CFHT−BD−Tau 3	Acc = N, $L_x = 0.6 \times 10^{28}$ erg/s
7. CFHT−Tau 6	Acc = Y, $L_x = 2.8 \times 10^{28}$ erg/s
8. CFHT−BD−Tau 4	Acc = Y, $L_x = 24 \times 10^{28}$ erg/s
9. 2MASS J0455	Acc = ?, $L_x = 0.2 \times 10^{28}$ erg/s



Conclusion: Accreting and non-accreting brown dwarfs have a similar X-ray fractional luminosity.

Detection of X-ray Emission from Young BDs

Grosso et al. 2007, A&A, 468, 391

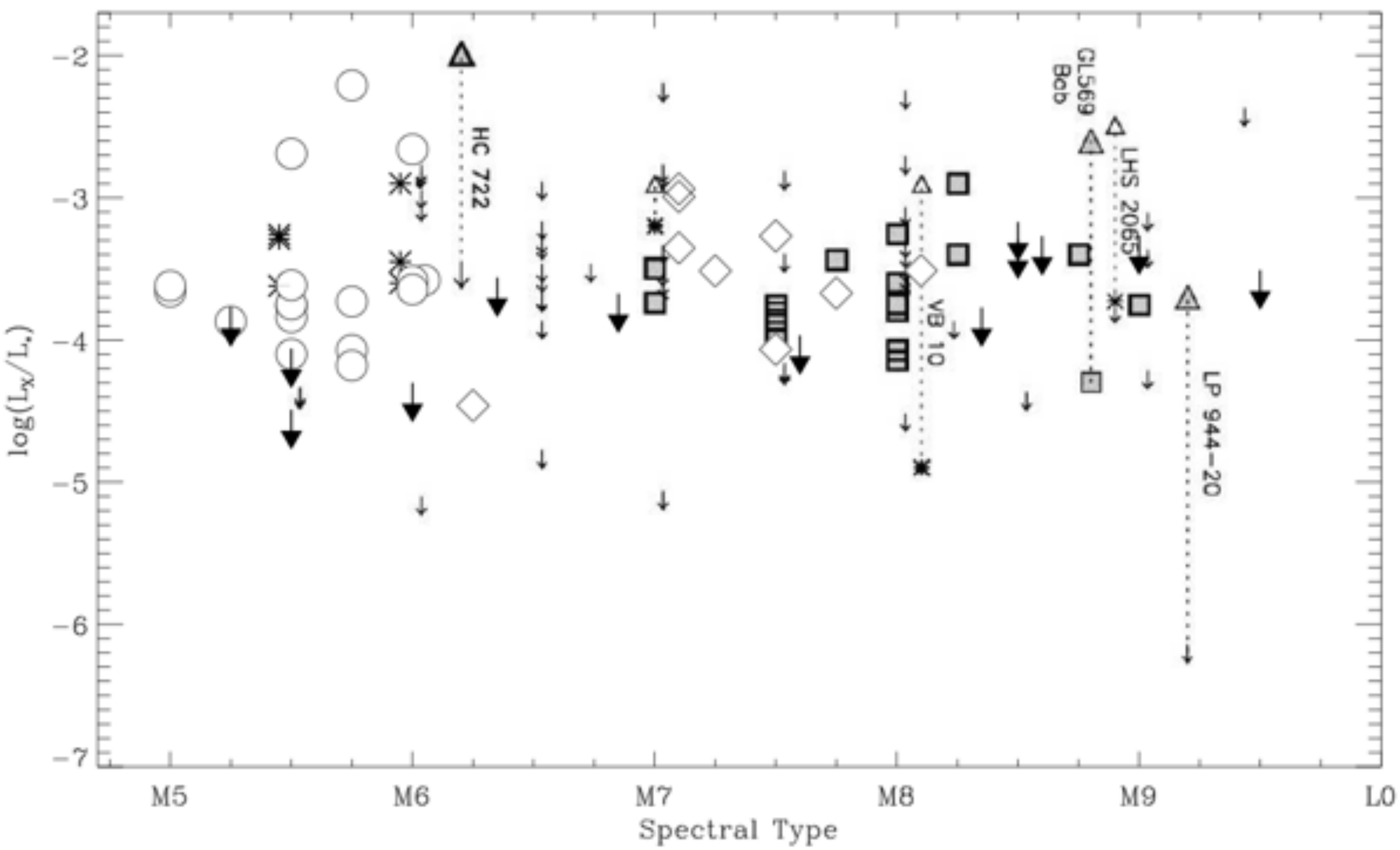


Fig. 14. X-ray fractional luminosity vs. spectral type for objects of type M5 and later. Detections of late M field stars from Fleming et al. (1993) are shown as asterisks. The circles show low-mass stars of the TMC detected in X-rays (Güdel et al. 2006a). Diamonds and thick arrows show BDs in the TMC. The other X-ray detected BDs (see Preibisch et al. 2005b, and references therein) are shown by gray filled squares. For very cool objects with strong flares, the values at flare peak are shown by triangles, connected by dotted lines to the quiescent emission. Some symbols have been slightly moved in spectral type to avoid overlaps.

Conclusion: The X-ray fractional luminosity for brown dwarfs and late M stars the same

Detection of X-ray Emission from Young BDs

FU Tau A+B, FU Tau A ⟶ strong accretor, outflow, disk, wide separation, isolated

Stelzer et al. 2010, MNRAS, 408, 1095

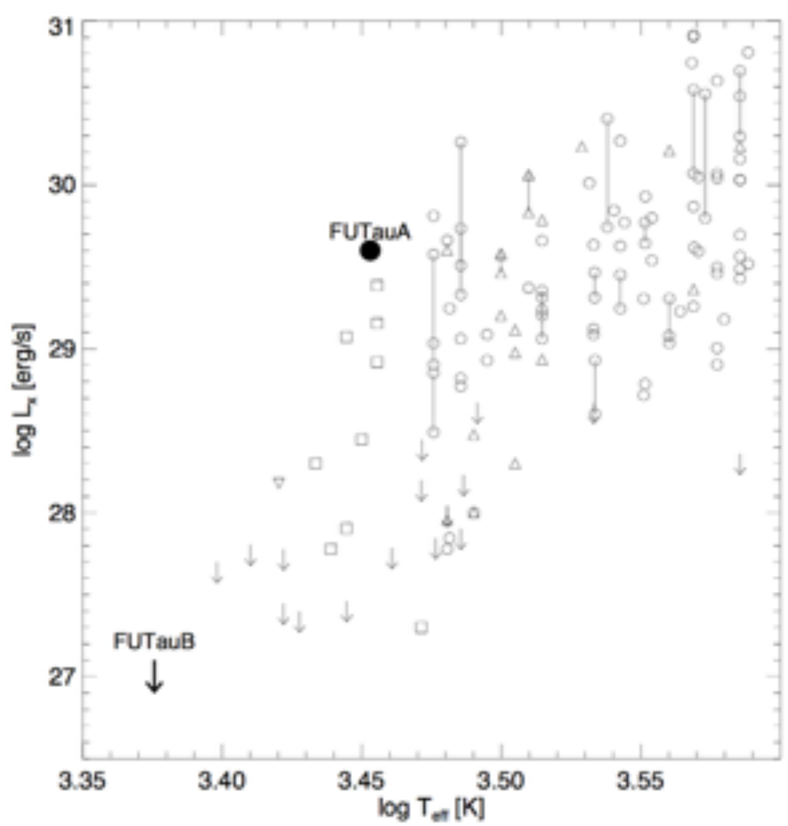


Table 1. X-ray parameters of the FU Tau binary.

Object	Offax [′]	Counts in 0.3 − 8 keV	Expo [sec]	log L_x [erg/s]	log $\left(\frac{L_x}{L_{bol}}\right)$
FU Tau A	0.29	603.8 ± 24.6	54153	29.7	−3.2
FU Tau B	0.39	< 4.7	54053	< 27.2	< −3.8

Bolometric luminosities from Luhman et al. (009a).

it has a coronal component but softer x-ray emission dominates

accretion origin

observations of such wide binaries important for constraining models

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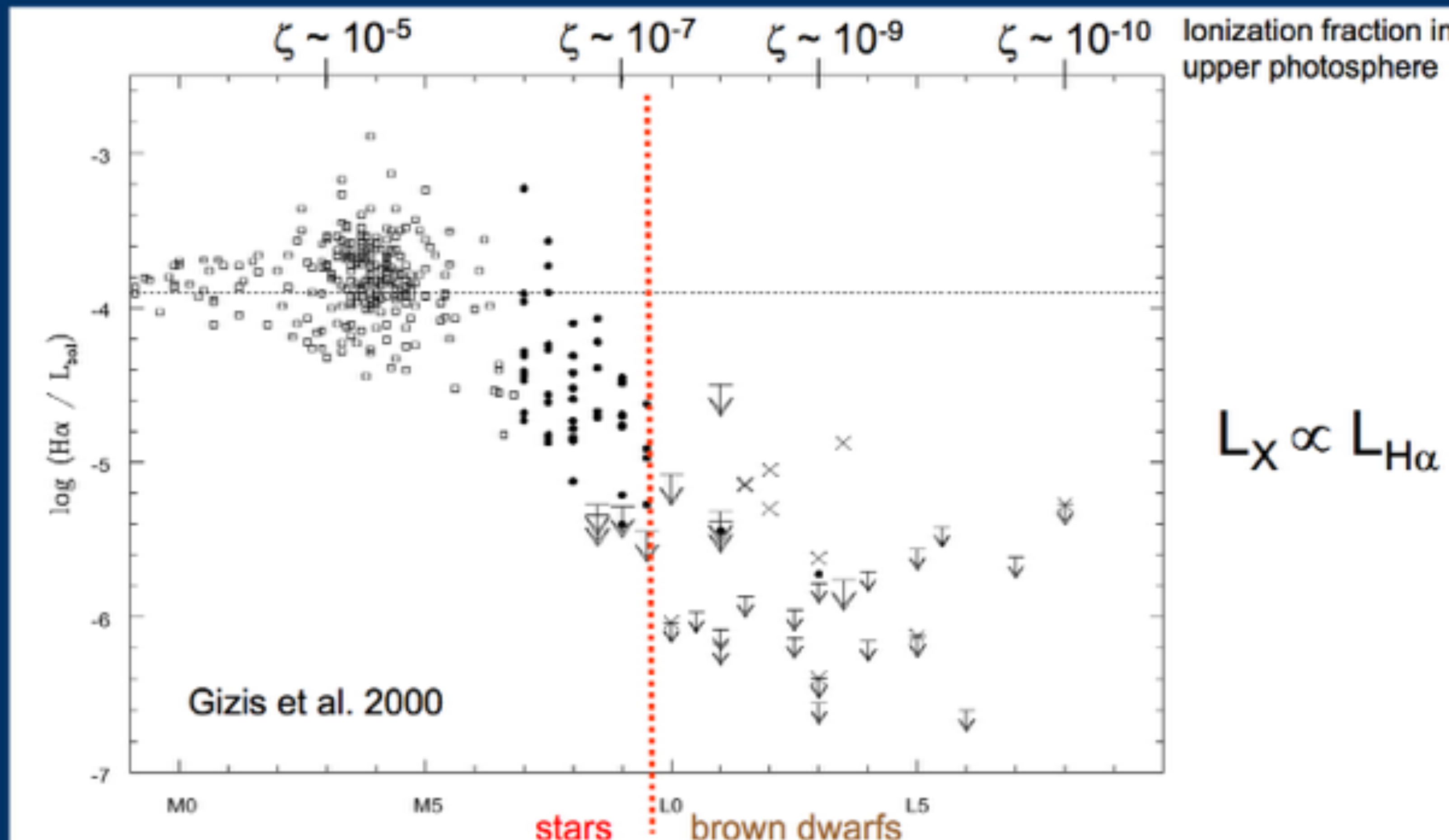
Evidence of Break at M9 L0 boundary



Drop in activity at spectral type ~M9

Objects cooler than M9: predominantly neutral atmospheres → very high resistivity, rapid decay of currents prevents the buildup of magnetic free energy

→ no support for magnetically heated coronae and chromospheres

Fleming et al 2000, ApJ 533,372; Mohanty et al 2002, ApJ 571,469

Figure borrowed from T. Preibisch talk

Detection of X-ray Emission from Young BDs

Many 10's of Young BDs detected in X-rays

Mostly quiescent emission, some example of flares

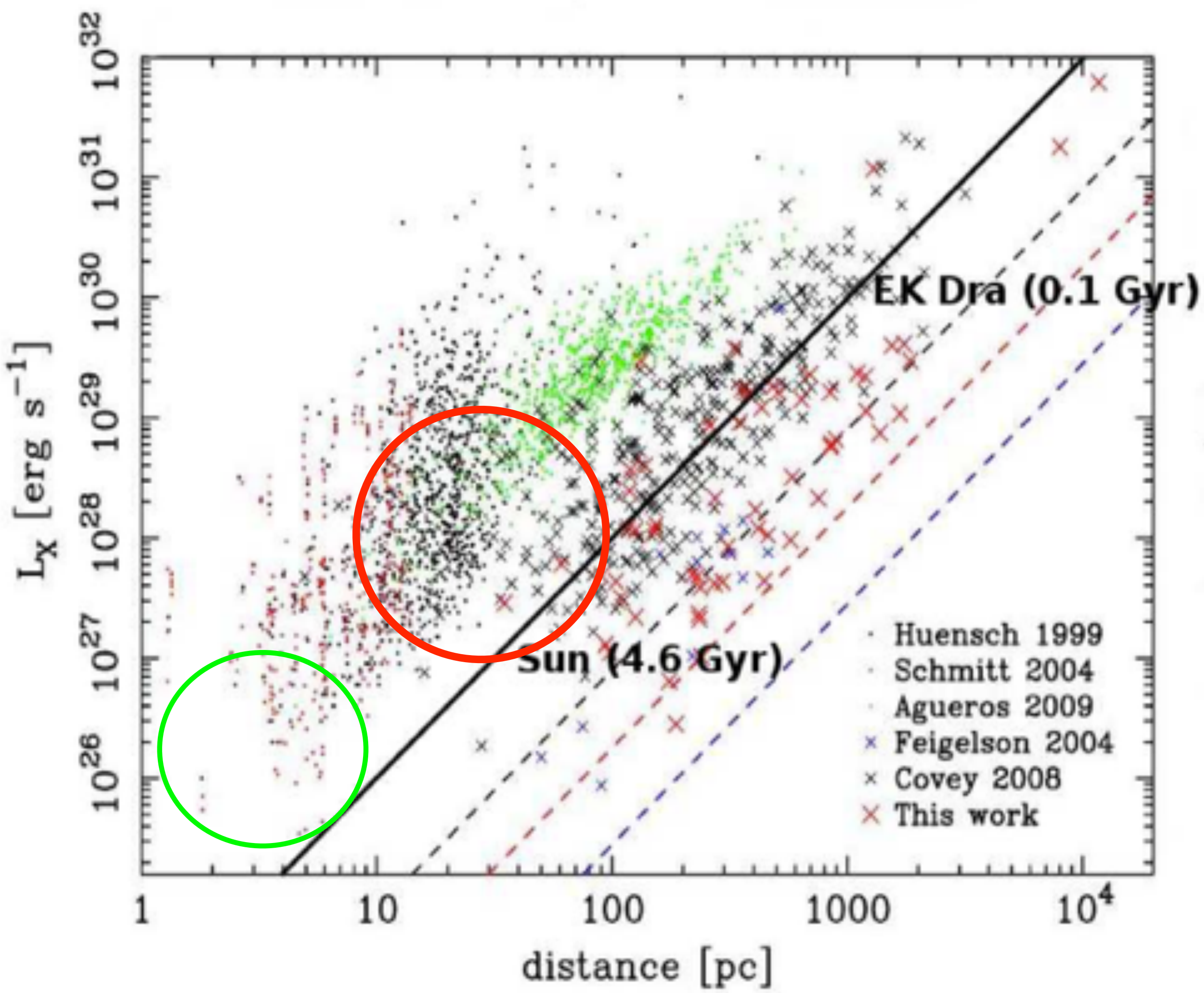
L_X in the range 10^{26} to 10^{30} erg/s

A few older BDs detected in X-rays, mainly flares, tentative evidence of quiescent emission

X-ray activity related to T_{eff} for young and old BDs

Tentative evidence of break at M9 L0 boundaries

What can e-Rosita do?



Can expect an increase in numbers of BDs detected especially nearby < 50 pc (TW Hya), field BDs

Optical and NIR data needed to confirm BD status is there

improved statistics check similarity with stars

statistics to investigate break at M9 boundary for close-by objects

In general detect more FU Tau type objects, important for constraining formation models