The 47 Tuc Menagerie: A Census of Binaries

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47 Tuc: Basic Facts

- Mass: $10^{6.1}$ $M_\odot$ (6th largest of ~150 in Galaxy)
- Central density: $10^{4.82}$ $L_\odot/pc^3$ (27th highest)
- Core radius: 24″=0.56 pc (46th smallest)
- Distance: 4.85 kpc (14th closest)

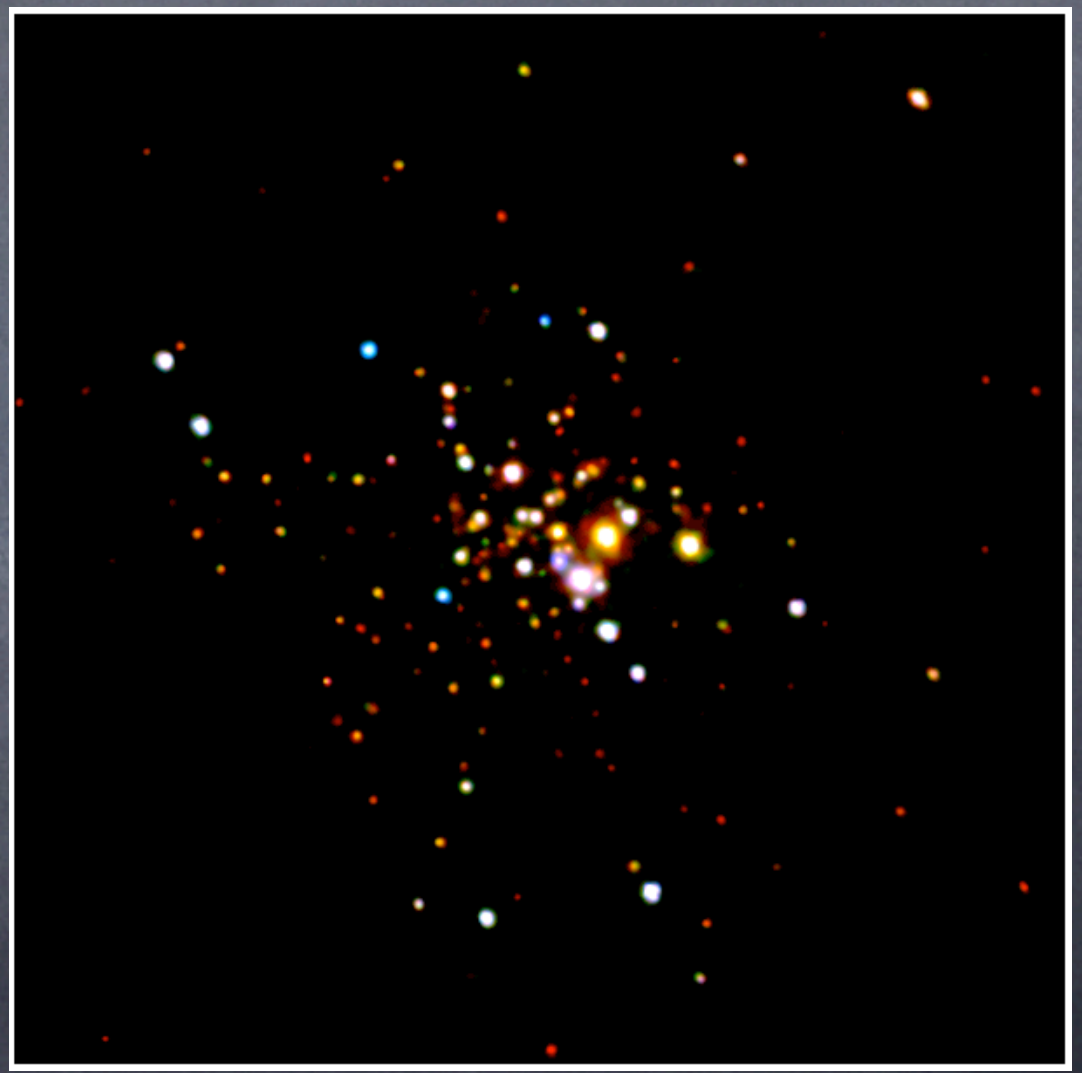
Deepest HST survey

- 8 day HST survey, Gilliland et al. 2000
- Best time-series photometry
- Monitored 46000 stars for variability

HST image of 47 Tuc

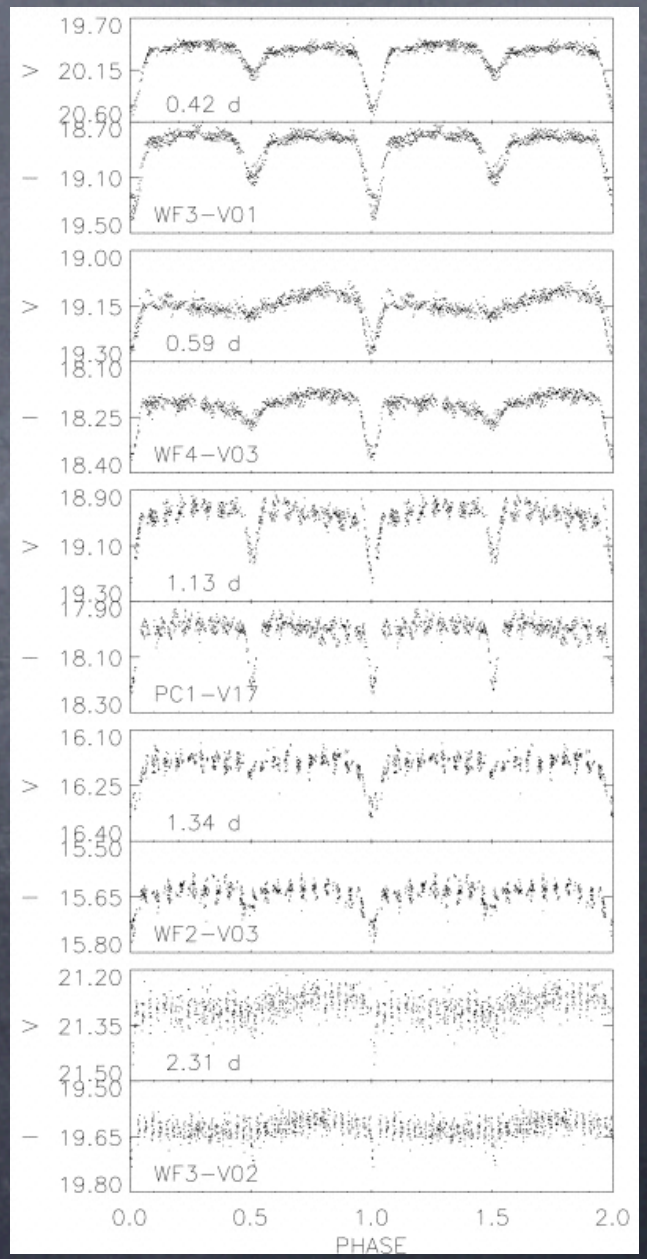
Deepest X-ray survey

- 300 ksec Chandra observation 2002, Heinke et al. 2005
- X-ray sources include CVs, qLMXBs, MSPs, and ABs



Binaries in 47 Tuc

- Albrow et al. 2001 identified:
  - 15 W Ursa Majoris (1/2 semidetached)
  - 11 detached eclipsing binaries
  - 71 BY Dra active binaries (ABs)
  - 6 "red stragglers" (mass transfer products?)



Eclipsing Lightcurves, Albrow 2001

Binary fraction in 47 Tuc

- Albrow et al. infer fb=13% from observed eclipsers
  - Assume flat dist in log P to 50 years
- Ivanova et al. 2005 model binary destruction, predicting current fb=7-8%.
  - Wide binaries destroyed, so observed Albrow eclipsers indicate fb~6%
  - Imply initial fb ~50-100%

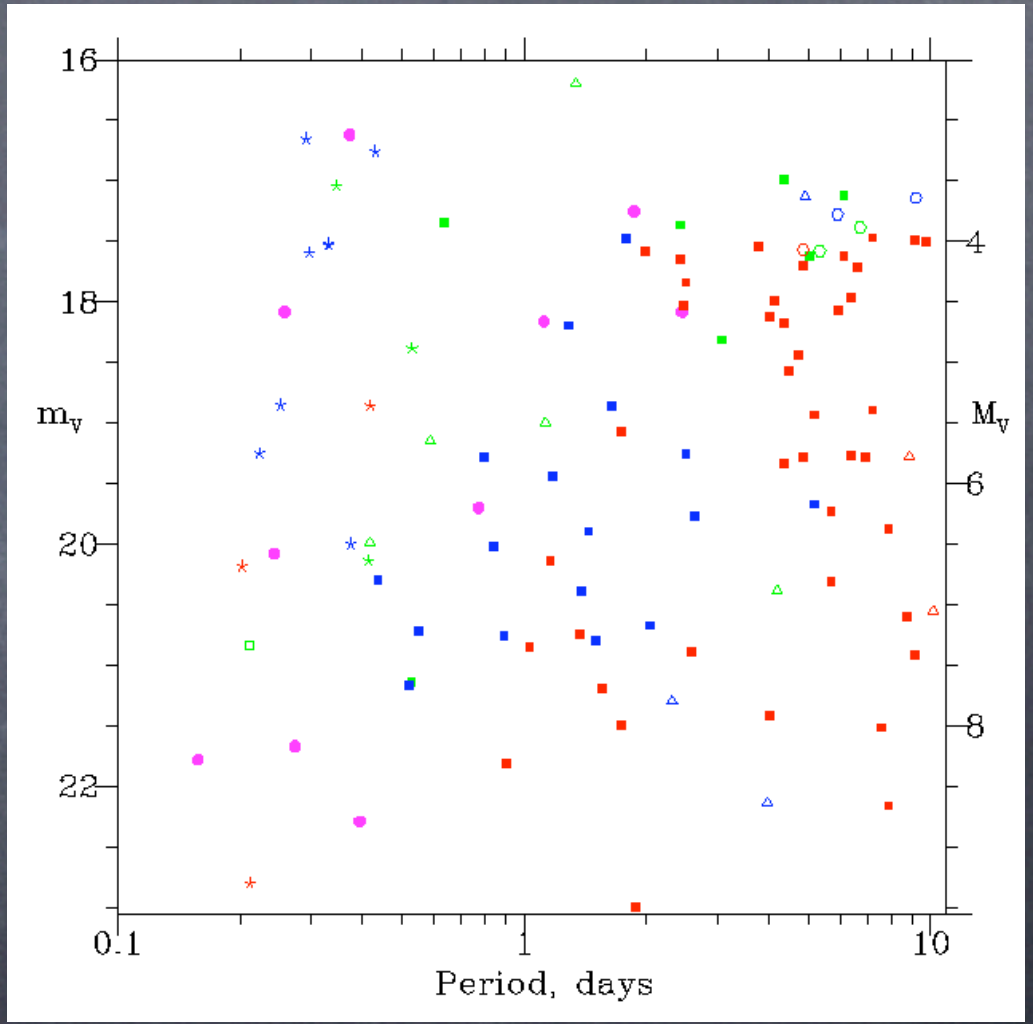
Observed contact binary frequency

- Galactic disk: 0.4% (Rucinski 1997)
- M5 halo (log ρ_c=3.91): 0.17% (Yan & Reid 1996)
- M71 (log ρ_c=3.04):0.07% (Yan & Mateo 1994)
- 47 Tuc core: 0.034% observed (Albrow 2001)
- 47 Tuc halo: 0.017% (Weldrake 2004)

Consistent with binary destruction in globular clusters

MS Binaries in 47 Tuc

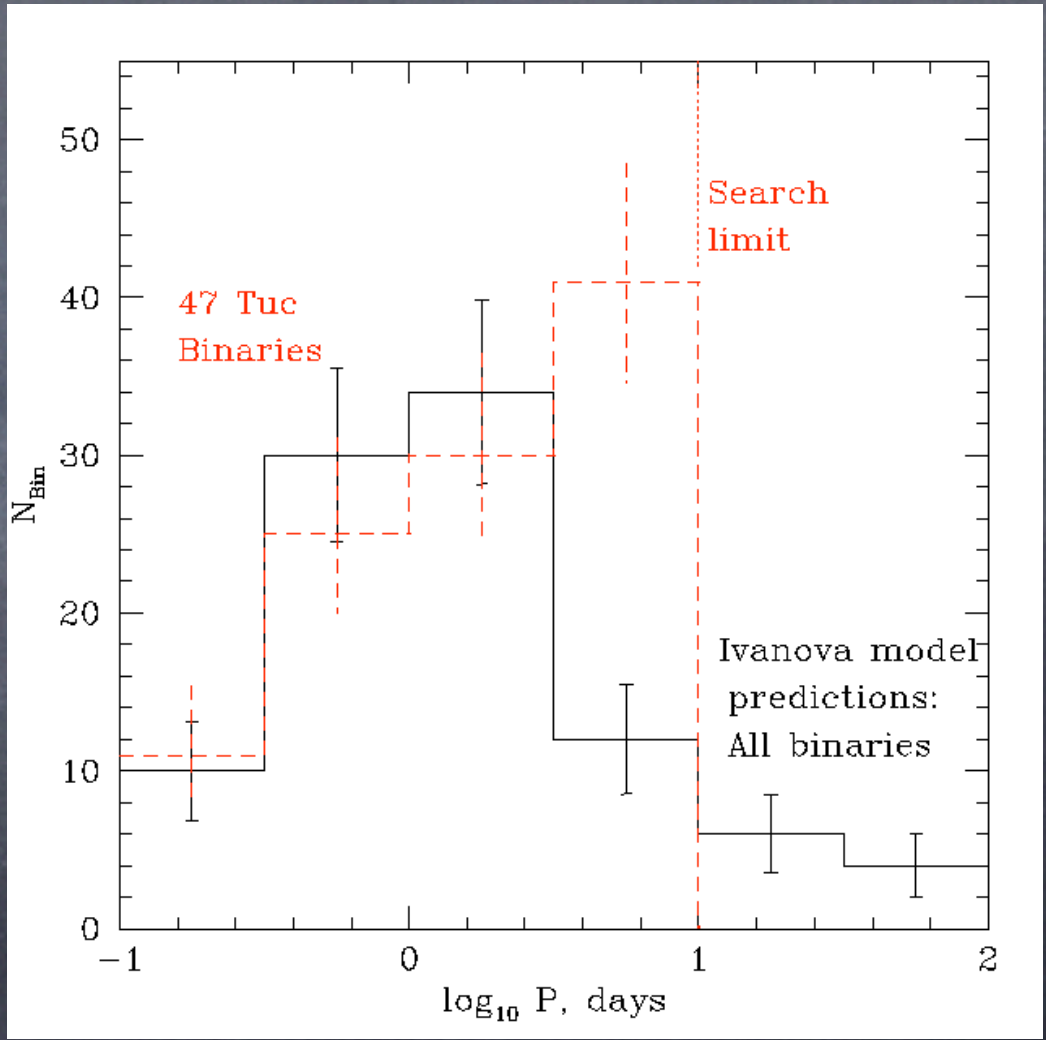
- For P<4 days, 73% of optically identified ABs X-ray detected
- 62% of X-ray ABs previously identified with HST
- For M_p>0.6, P<4 days, we know most binaries



Albrow; X-ray & Albrow; Edmonds

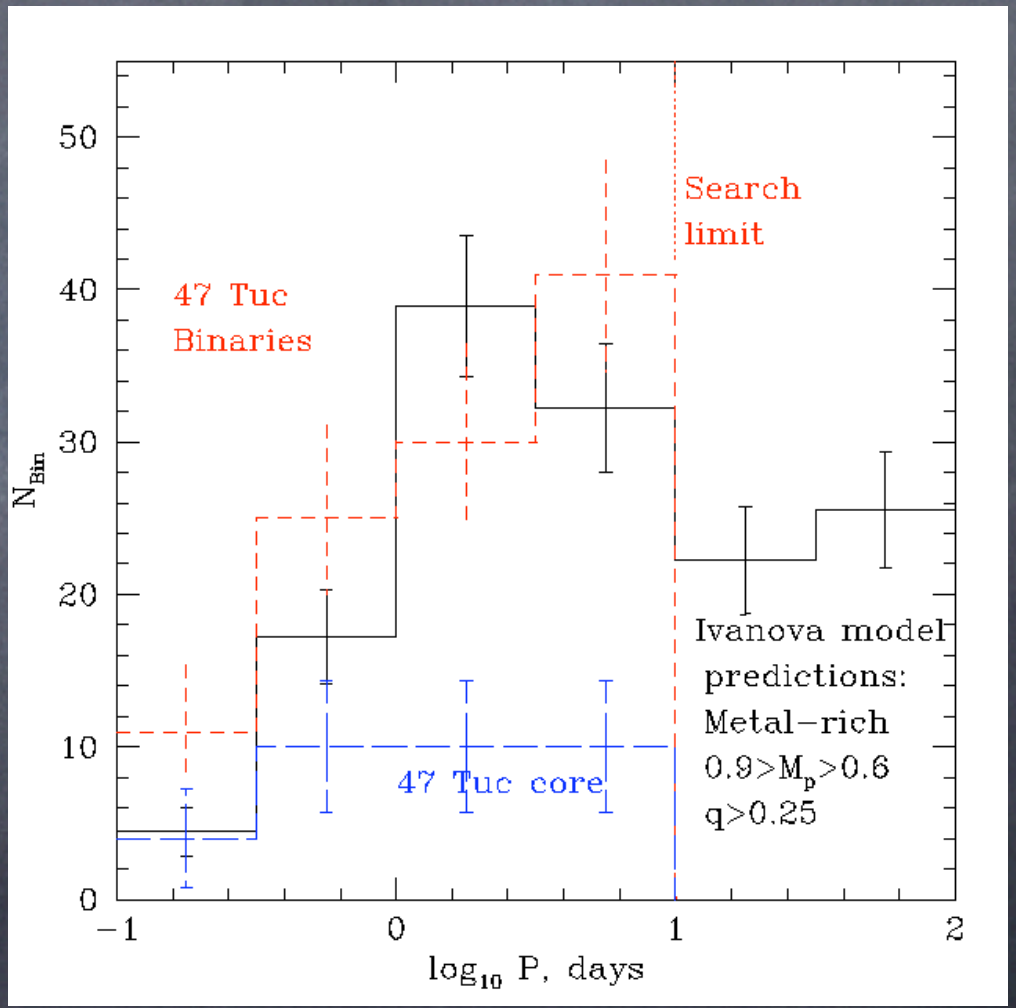
Periods too long?

- More binaries at P>4 days than predicted by current models? (Ivanova et al. 2005)



Possibly consistent

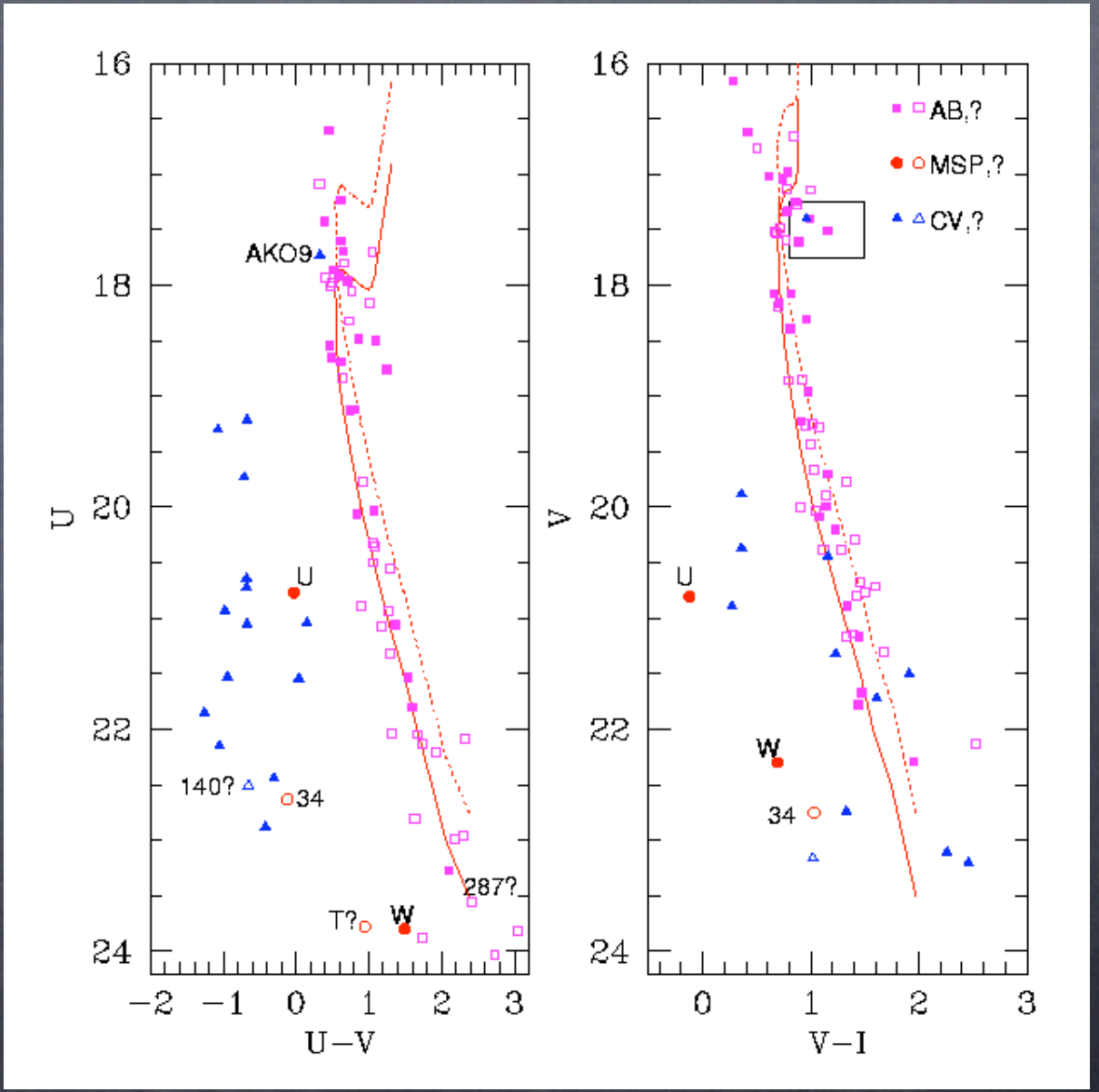
- Discrepancy diminishes if only appropriate (mass, mass ratio) binaries from Ivanova models plotted



Optical IDs of X-ray Sources

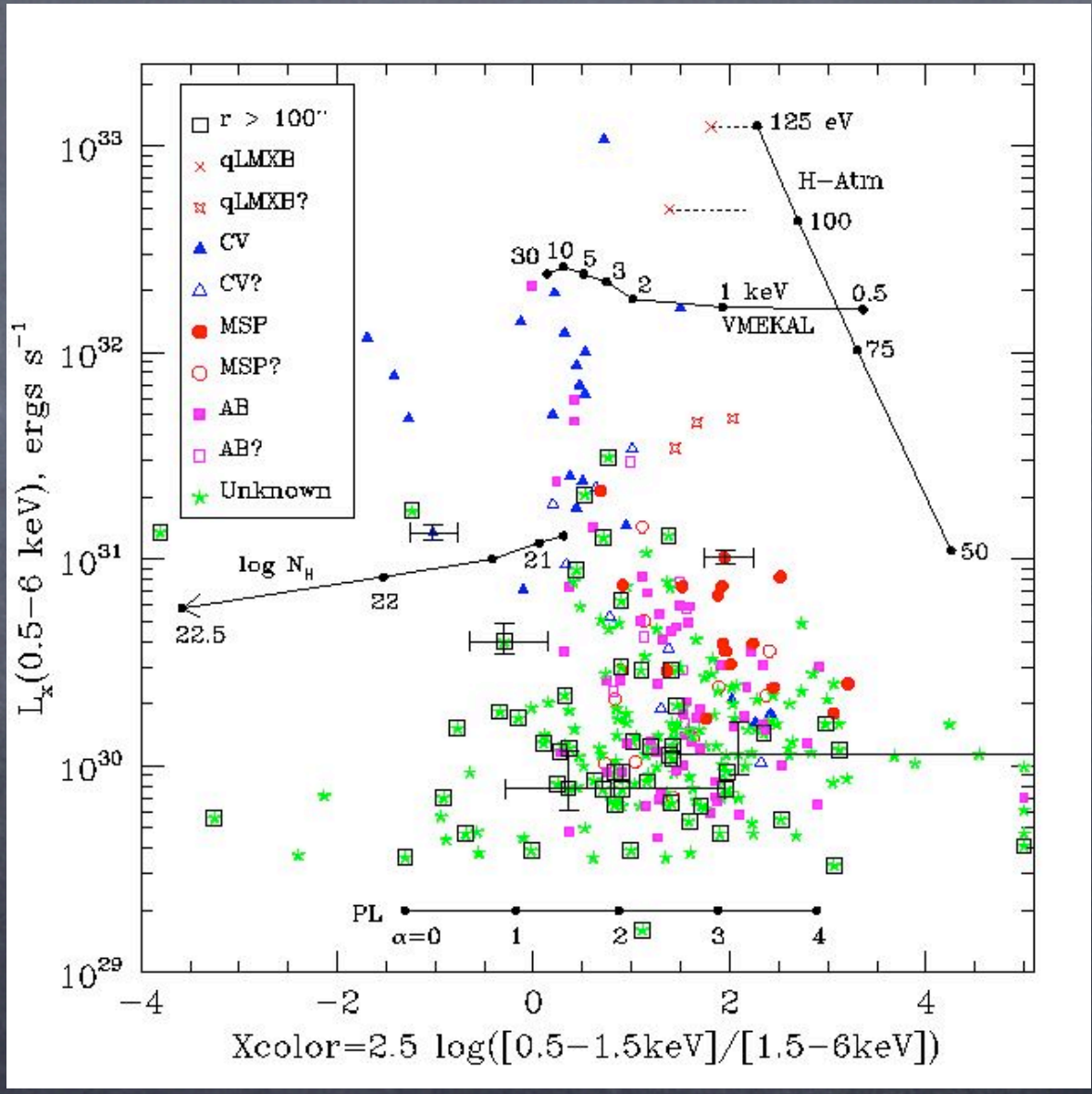
- Optical IDs from X-ray:
  - 22 CVs
  - 60 ABs
  - 3-5 MSPs
  - 2 qLMXBs

IDs in GO-8267 HST field



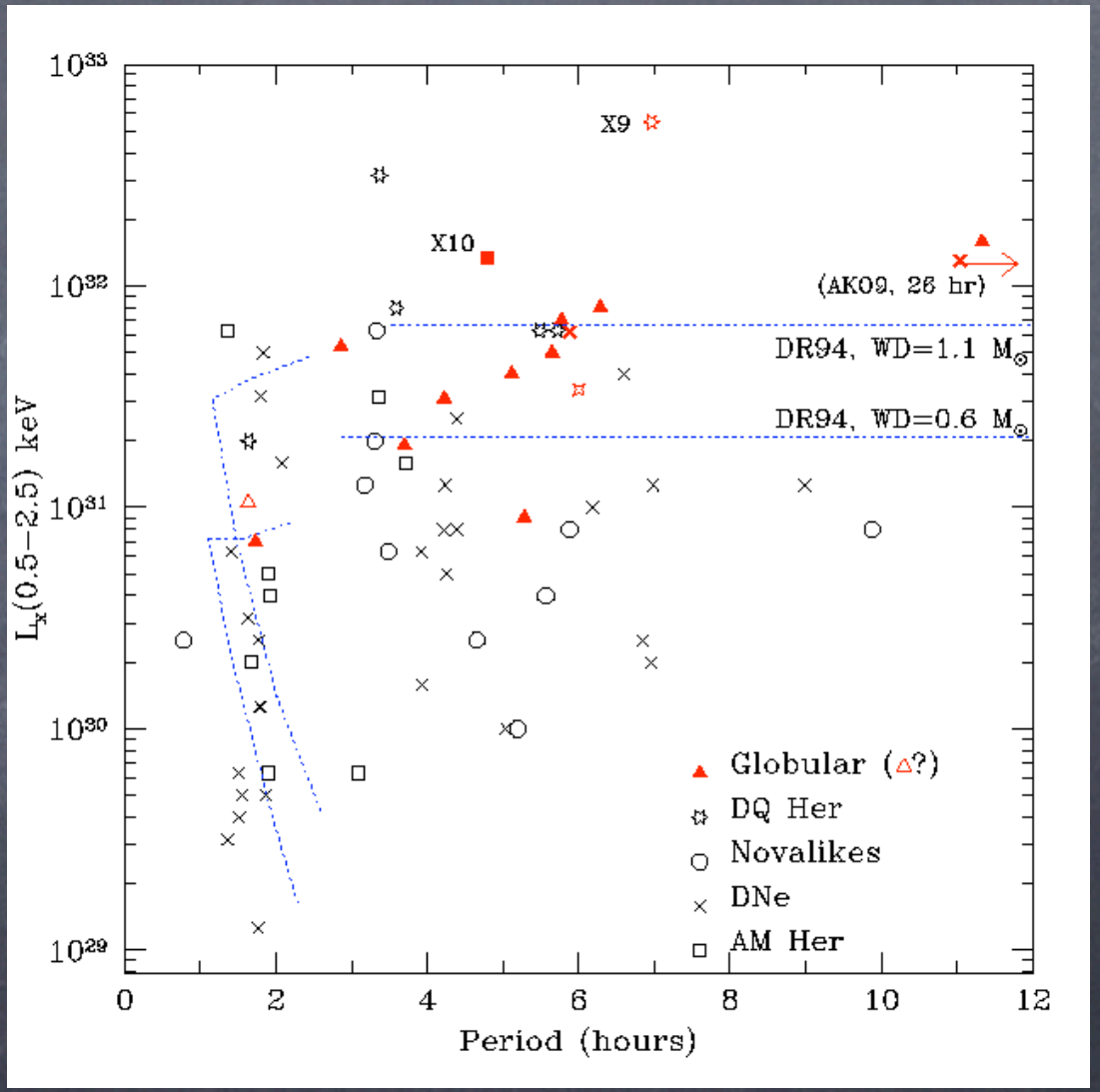
47 Tuc X-ray CMD

- 3 faint, hard qLMXBs
- Many faint X-ray sources still unidentified; ABs, CVs, MSPs



CVs in Clusters, Field

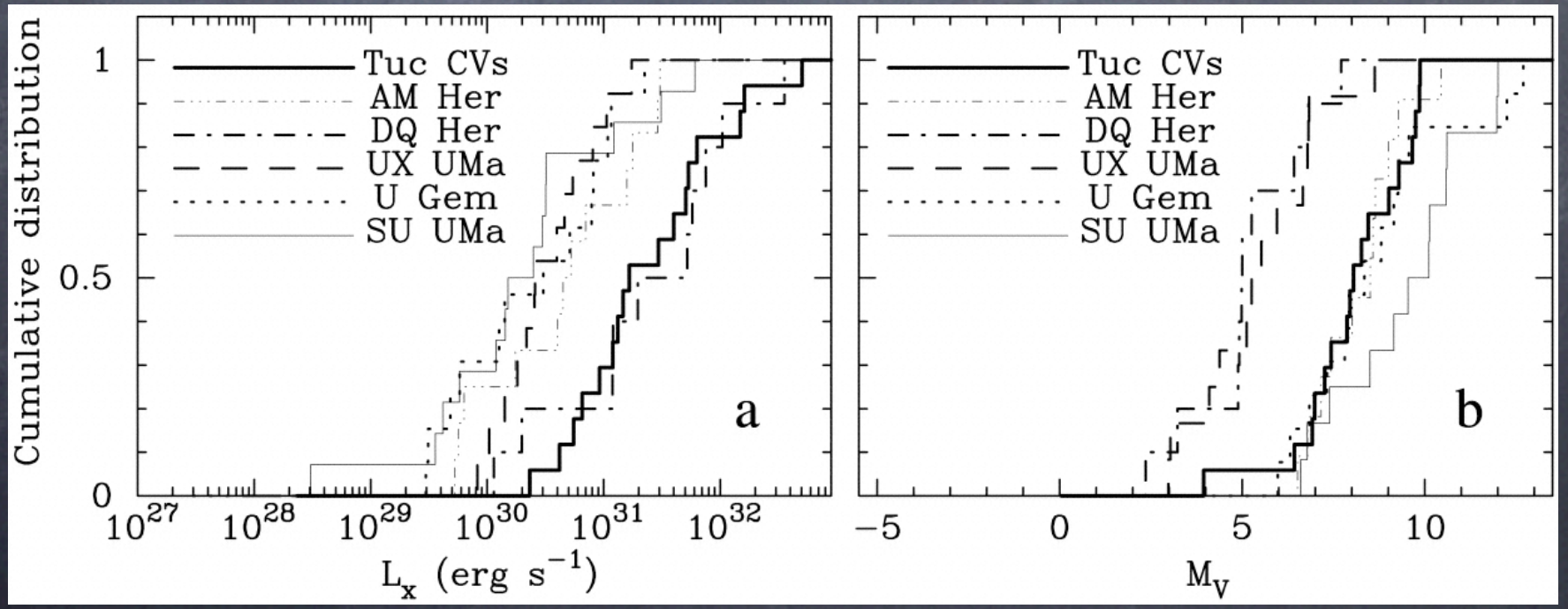
- Periods known for 8-11 CVs in 47 Tuc, 5 CVs in other clusters
- Novae not strongly overabundant compared to field (Townsley04)



See Edmonds et al. 2003

Magnetic CVs?

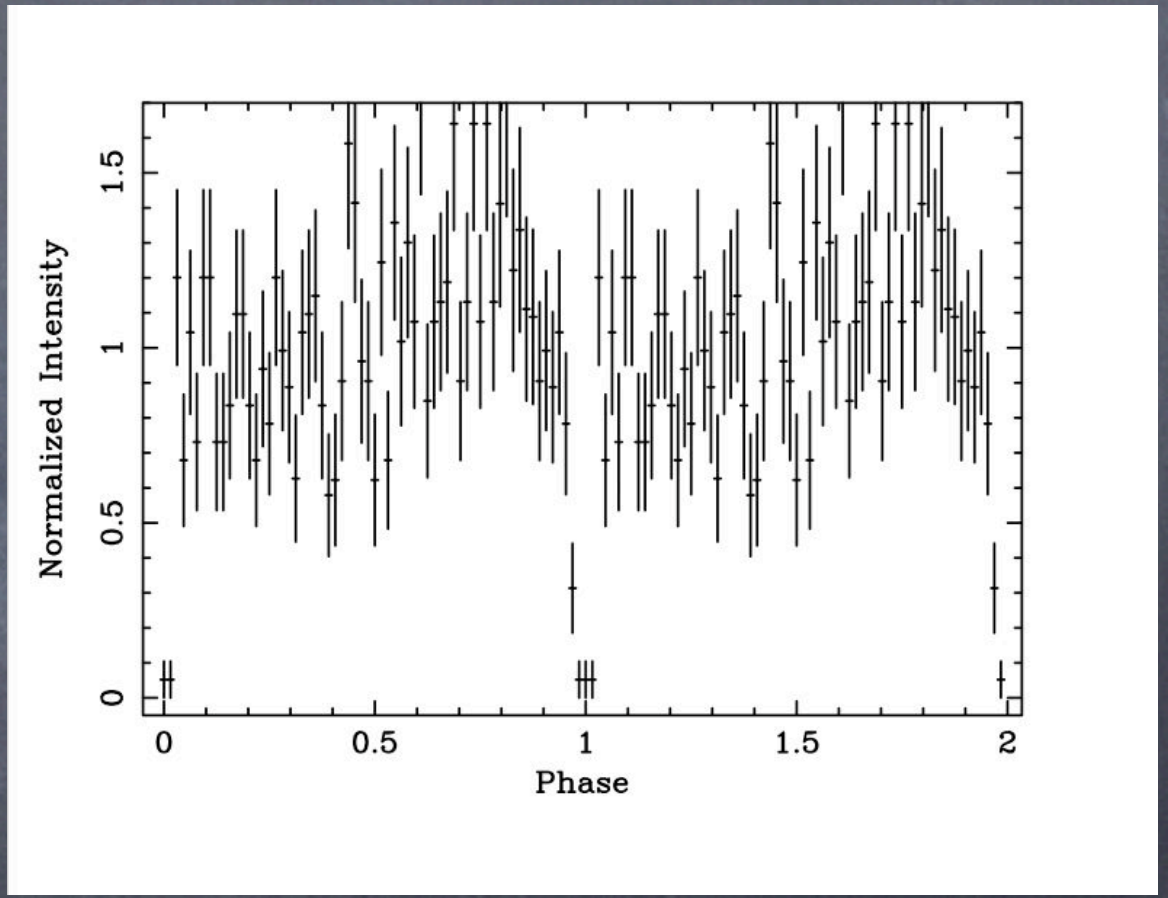
- CVs in 47 Tuc are X-ray bright (like DQ Her magnetic systems), but dim in visible light (like U Gem dwarf novae).
- Are the WDs more massive?



Edmonds et al. 2003

Quiescent LMXBs

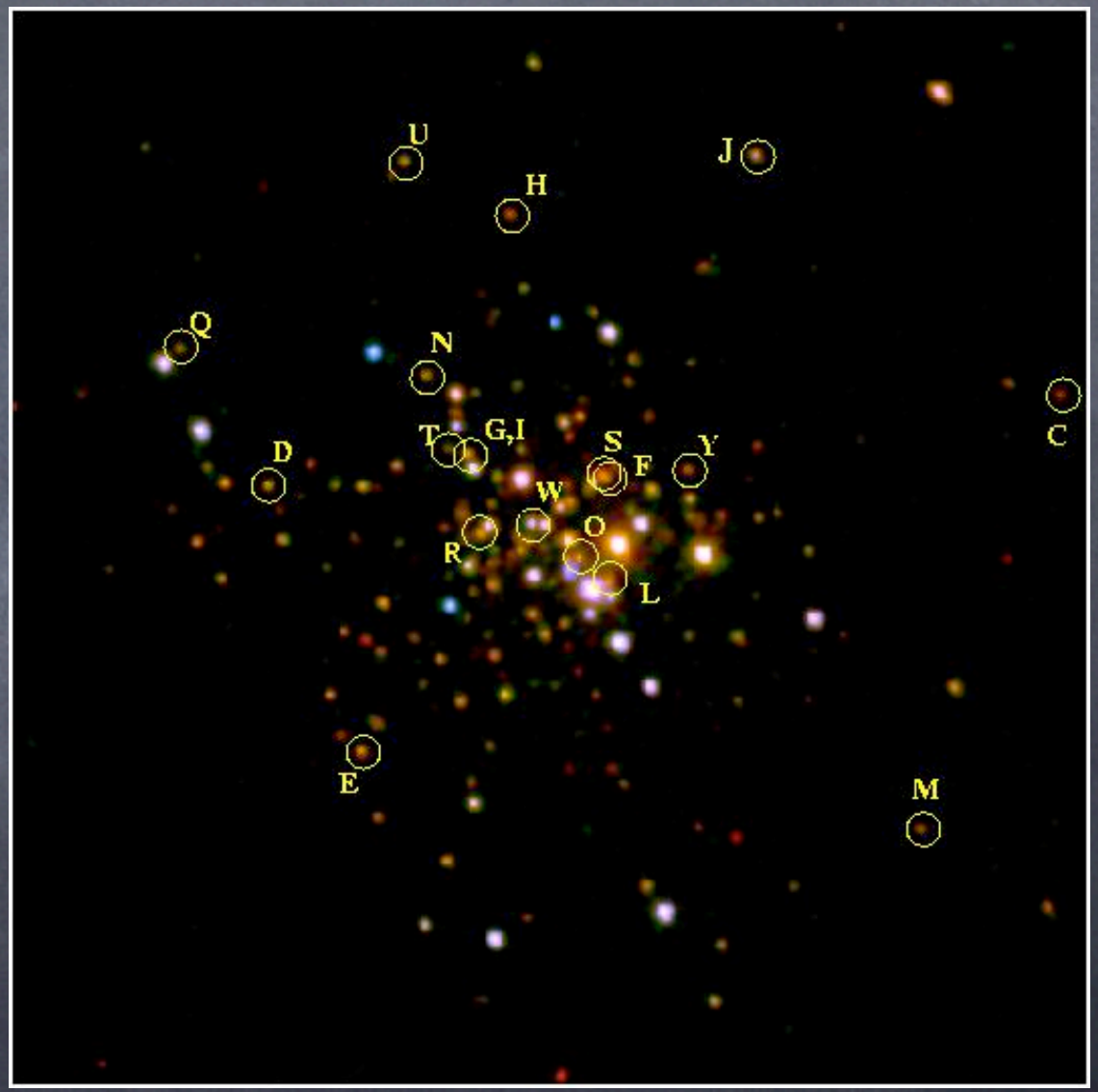
- Identified through blackbody-like (cooling neutron star) X-ray spectral component
- 5 known in 47 Tuc
- Two periods from eclipses, 3.1 & 8.7 hrs



W37; 3.1 hour period

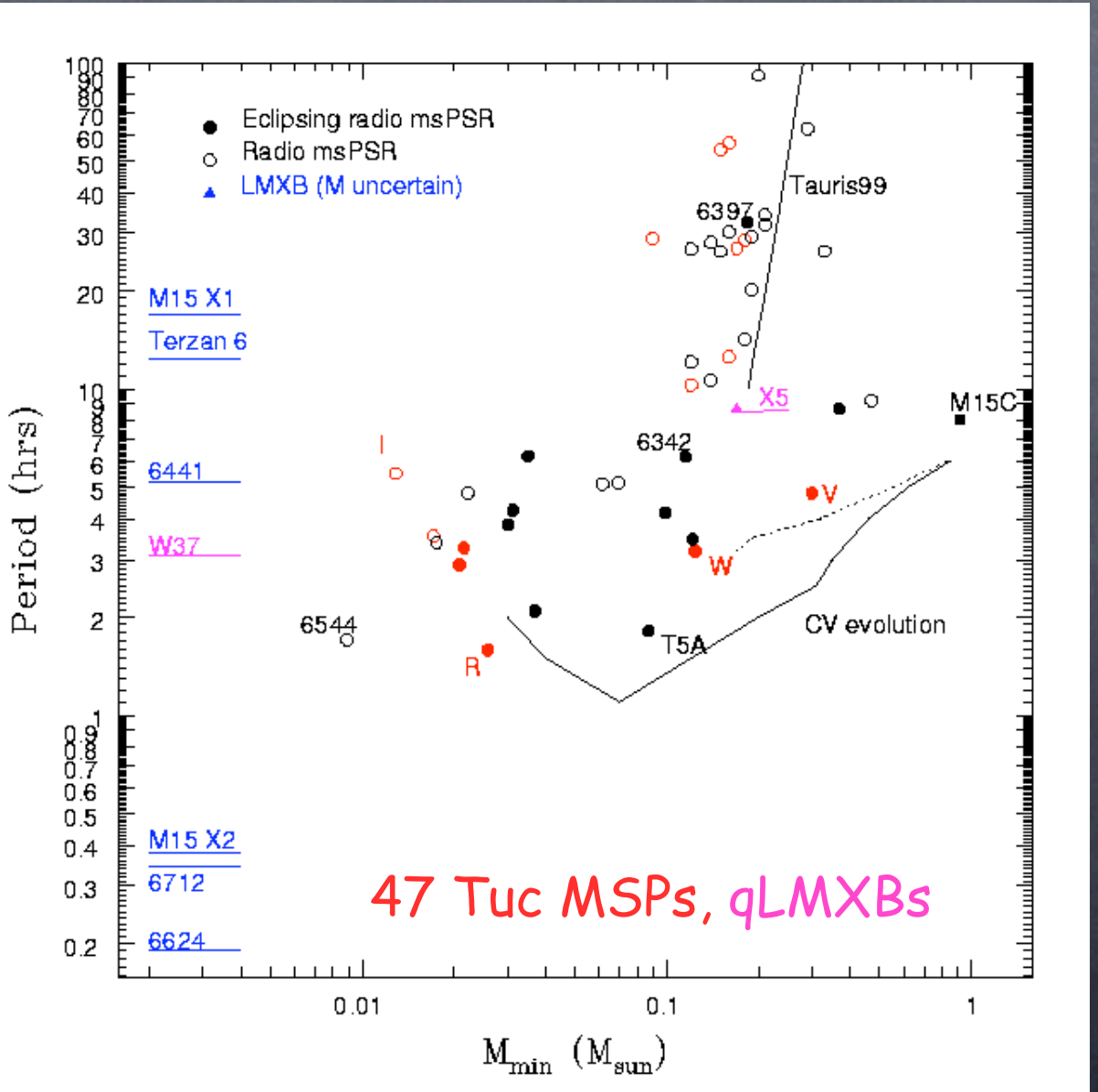
MSPs in 47 Tuc

- 22 radio MSPs discovered in 47 Tuc (Camilo 2000)
- 19 positions known, all seen in X-ray (Bogdanov 2005b)
- MSP W companion fills Roche lobe (Bogdanov 2005a)



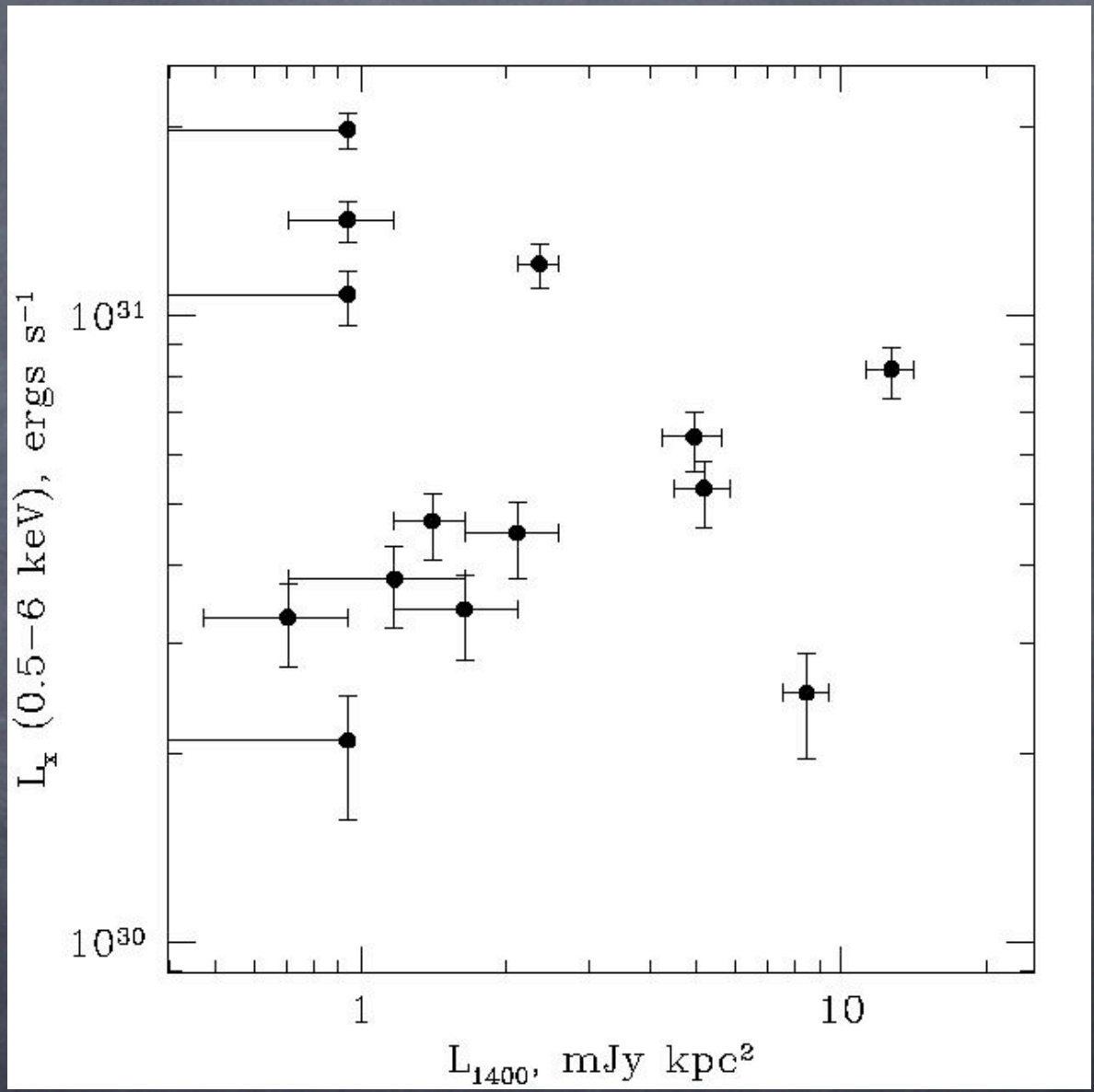
Neutron star systems

- Unusual products:
- Ultracompact LMXBs
- Very low-mass MSPs (from UC LMXBs?)
- Low-mass eclipsing MSPs; exchanges?

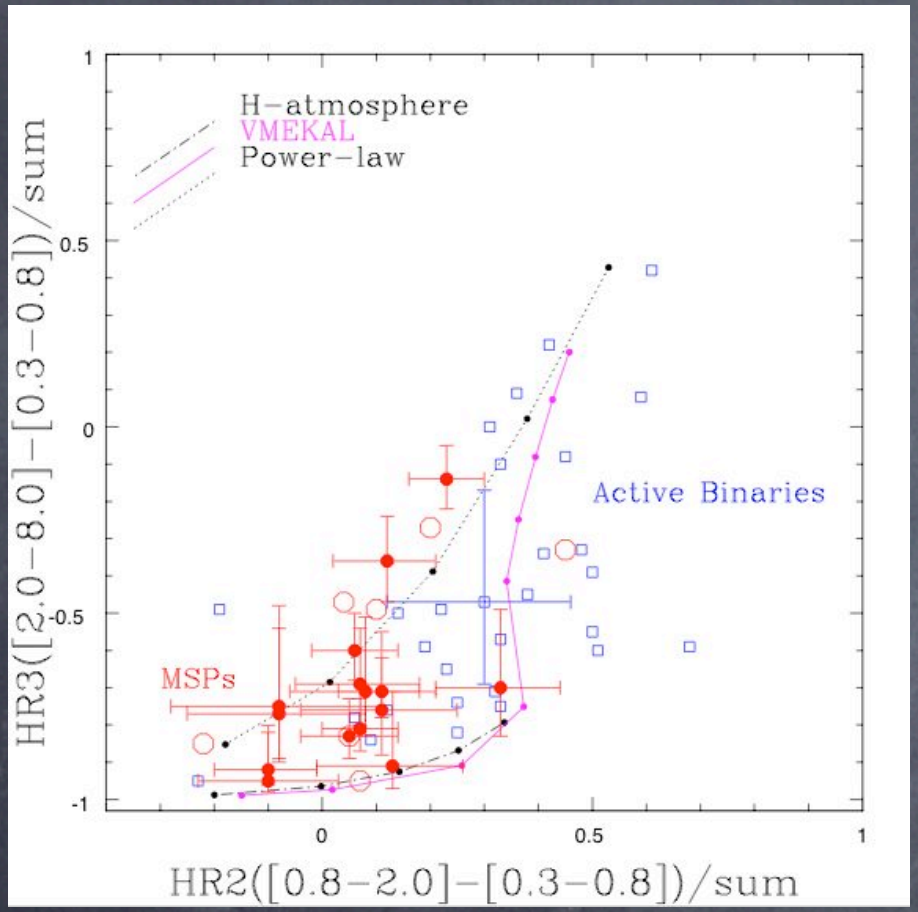


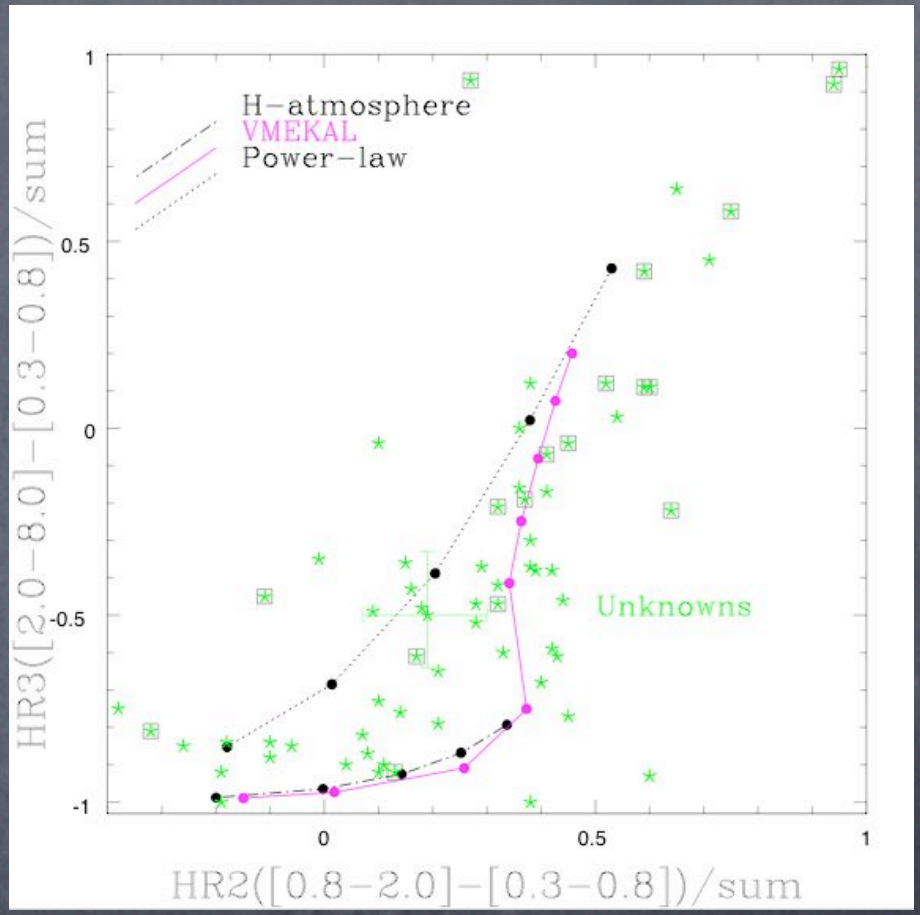
47 Tuc MSPs: X-ray vs. Radio

- No correlation between X-ray, radio flux
- Implies X-ray studies sample full MSP population



MSPs





- Comparison of X-ray colors allows statistical separation of unidentified into MSPs, ABs, predicting ~25 total MSPs (<60 @95% conf.)

Constraint on NSs in 47 Tuc

- Class of 6 eclipsing MSPs in globulars with Mc~0.1-0.2 Msun -> MS companions
- Indicates a second exchange (Freire 2003)
- 8% of MSPs doubly exchanged; implies ~8% of neutron stars singly exchanged
- Suggests total of ~400 neutron stars in 47 Tuc, needing only ~10% retention

47 Tuc: Conclusions

- X-ray Binaries: MS ABs, CVs, qLMXBs, MSPs
- Binary fraction consistent with ~7%
- 123 ABs; periods comparable to predictions
- 22 CVs; 8-11 CV periods; most above gap, high Fx/Fopt, high Lx (magnetic? massive WDs?); incomplete
- 5 qLMXBs, 2 eclipsing (8.7, 3.1 hours)
- 22 MSPs, constrained <60; imply ~400 neutron stars