Low-level accretion in transitional MSPs and connection with very faint X-ray binaries

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EWASS 2015 - June 25, 2015
Very faint X-ray binaries

- Several transients with peak $L_X = 10^{34}-10^{36}$ erg/s around the Galactic center
- As numerous as bright LMXBs there (Degenaar+09, +10)
3 Weird aspects

1: Low peak Lx, low integrated Lx.

2: Time-averaged accretion rates very low
   suggestions that exotic systems (brown dwarf donor, IMBH accretor)
   needed (King & Wijnands 2006)

3: Several maintain continuous accretion
   rates too low to keep disk ionized, for months to years.

We argue (at least) 2 kinds of VFXBs; short orbital-period systems with short
outbursts, and magnetospherically-choked accretion, lasting longer.
VFXBs: Short outbursts

- Defining peak luminosity $L_x = 10^{34} - 10^{36}$ erg/s
- Many outbursts only a few weeks long (~6 with shorter outbursts identified)
- Suggests small disk & short orbital period

Degenaar+09
VXFBs: Bright outbursts

- Some VXFBs have shown both faint and bright ($>10^{36}$ erg/s) outbursts.
- Type 1 X-ray bursts prove NS nature.

Degenaar+09
Quasi-persistent VFXB{s}

- several stay at $L_X=10^{34}-10^{36}$ for years
- Nature unknown: Some can be slow pulsars, symbiotics, CVs
- At least one has shown bursts, proving NS nature, $L_X \sim 10^{34}$

Degenaar+12

Arnason+15
Lightcurves

- Modeling outburst decay based on disk-instability model:
  - Exponential decay while irradiated
  - Linear decay afterwards

- This fits some LMXBs but not all

Observed lightcurve and fitted model (Powell+07)

Predicted lightcurve (King & Ritter+98)
Fitting VFXB lightcurves

- We fit 3 short outbursts of VFXBs with Exp+linear decay model
- Decay well-described by model: suggesting consistency of VFXB short outbursts with models
- Comparison with well-known systems suggests $P_{\text{orb}} \sim 1$ hour (Heinke+15)

CXO J174540-290005
(Data: Koch+14, Fit: Heinke+15)
Quasi-persistent VFXBs

- Quasi-persistents break standard disk theory
- Below 20-30 minutes, UCXBs can keep disks stably accreting; but $L_X > 10^{35}$ erg/s.
- At short periods, GR sets minimum Mdot.
- LMXBs with stable accretion at few*10^{34} erg/s need new physics

UCXBs vs. evolution prediction (dotted) & stability lines. Transients as triangles, dots persistent. (Heinke+13)
A possible answer: Transitional MSPs?

- Some quasi-persistent VFXBs show intermediate $L_x$; like tMSPs (Degenaar+14, Arnason+15, Linares+14)
A possible answer: Transitional MSPs?

- Similar flaring behaviour is observed in VFXBs and tMSPs

PSR J1023+0038
Swift & NuSTAR lightcurve, 100 s bins
7e32<\(\text{L}_x\)<1e34
Relatively hard (1.1<\(\Gamma\)<1.7)
Tendulkar+14

NGC 6652 B
Chandra lightcurve, 100 s bins,
5e33<\(\text{L}_x\)<~1e35
Hard (\(\Gamma\)=1.3±0.1), Stacey+12
Conclusion

- Behaviour of transient VFXBs can be described by disk instability models.
- However, behaviour of quasi-persistent VFXBs requires new physics.
- Behaviour of quasi-persistent VFXBs are similar to tMSPs:
  - Staying in intermediate states (~few*e33 erg/s)
  - Similar flaring behaviour
- We suggest quasi-persistent VFXBs might be tMSPs

Thank you