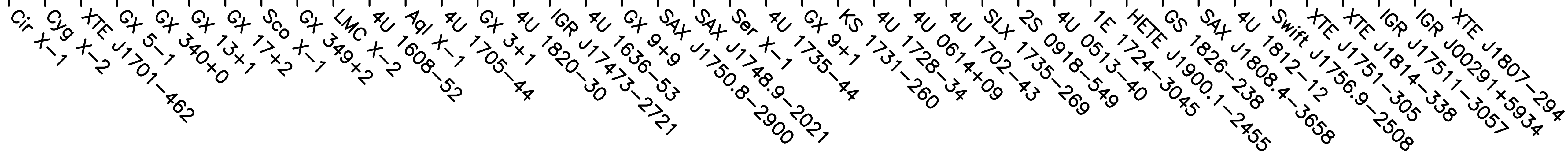
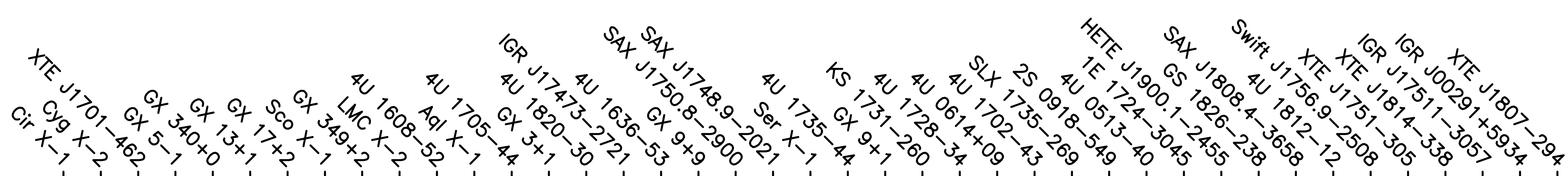
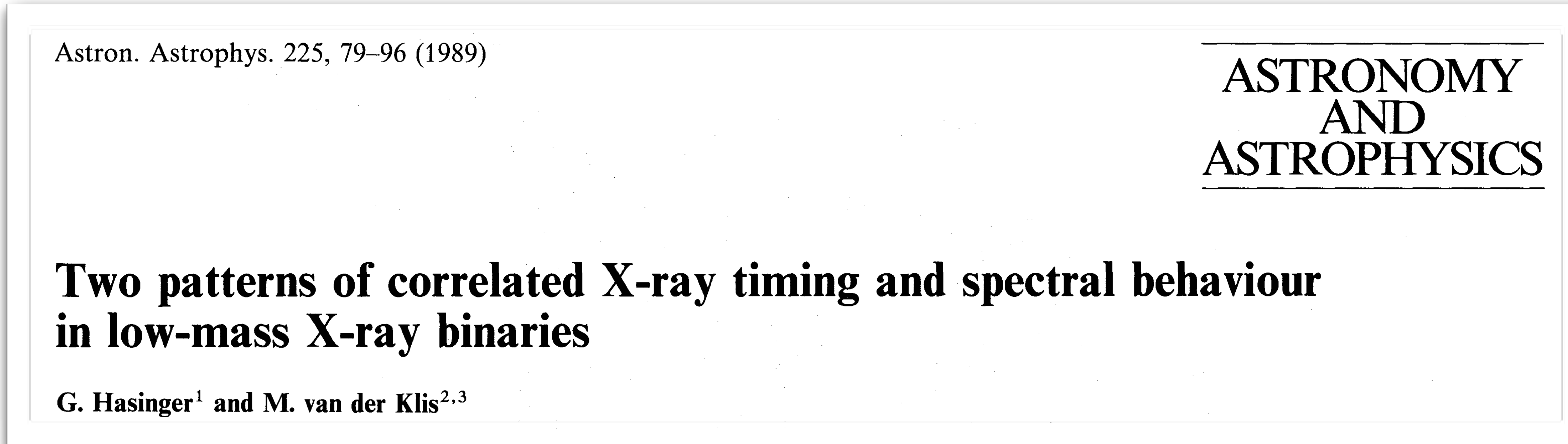


A new ranking scheme for neutron-star low-mass X-ray binaries

Joel Fridriksson, Jeroen Homan & Ron Remillard



NS LMXBs: sub-classes

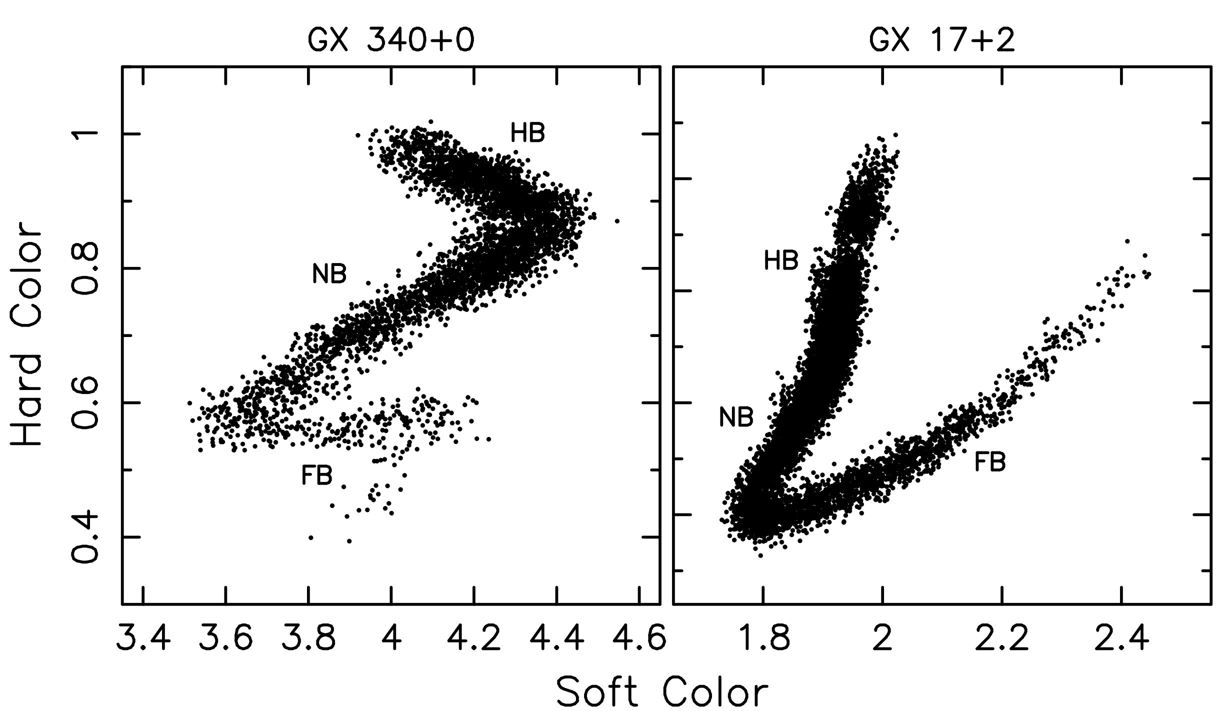

Astron. Astrophys. 225, 79–96 (1989)

ASTRONOMY AND ASTROPHYSICS

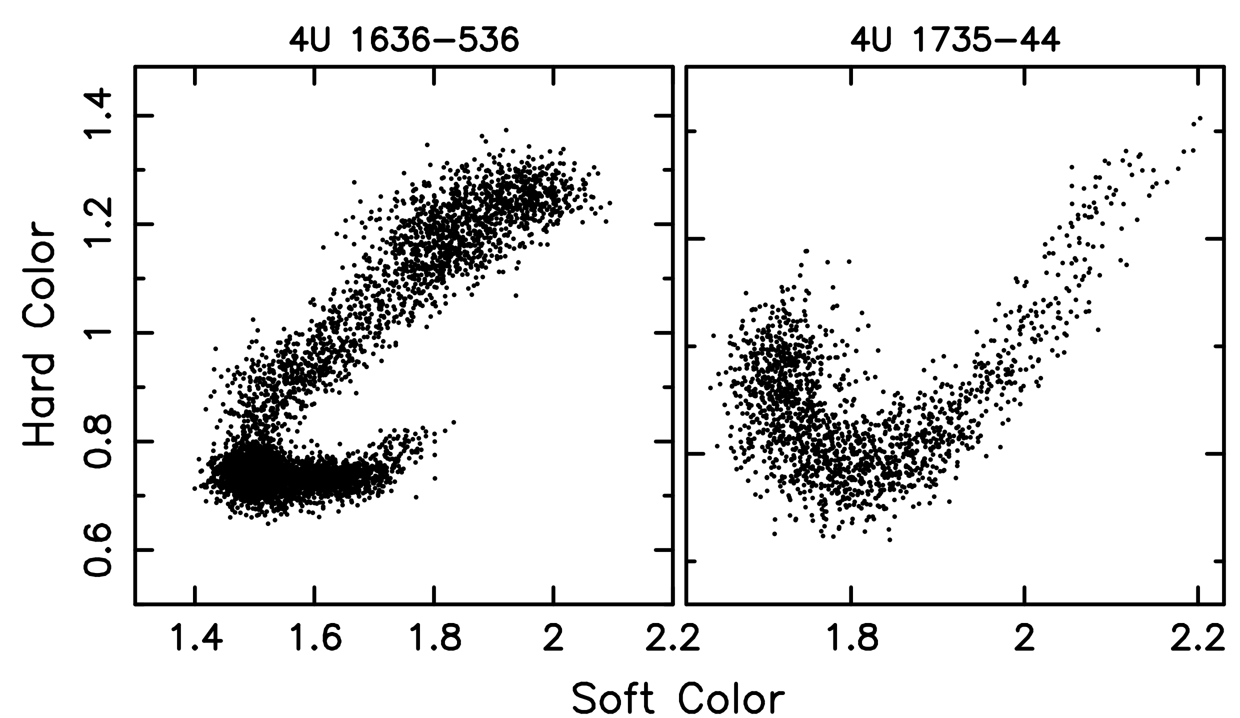
Two patterns of correlated X-ray timing and spectral behaviour in low-mass X-ray binaries

G. Hasinger[1] and M. van der Klis[2,3]

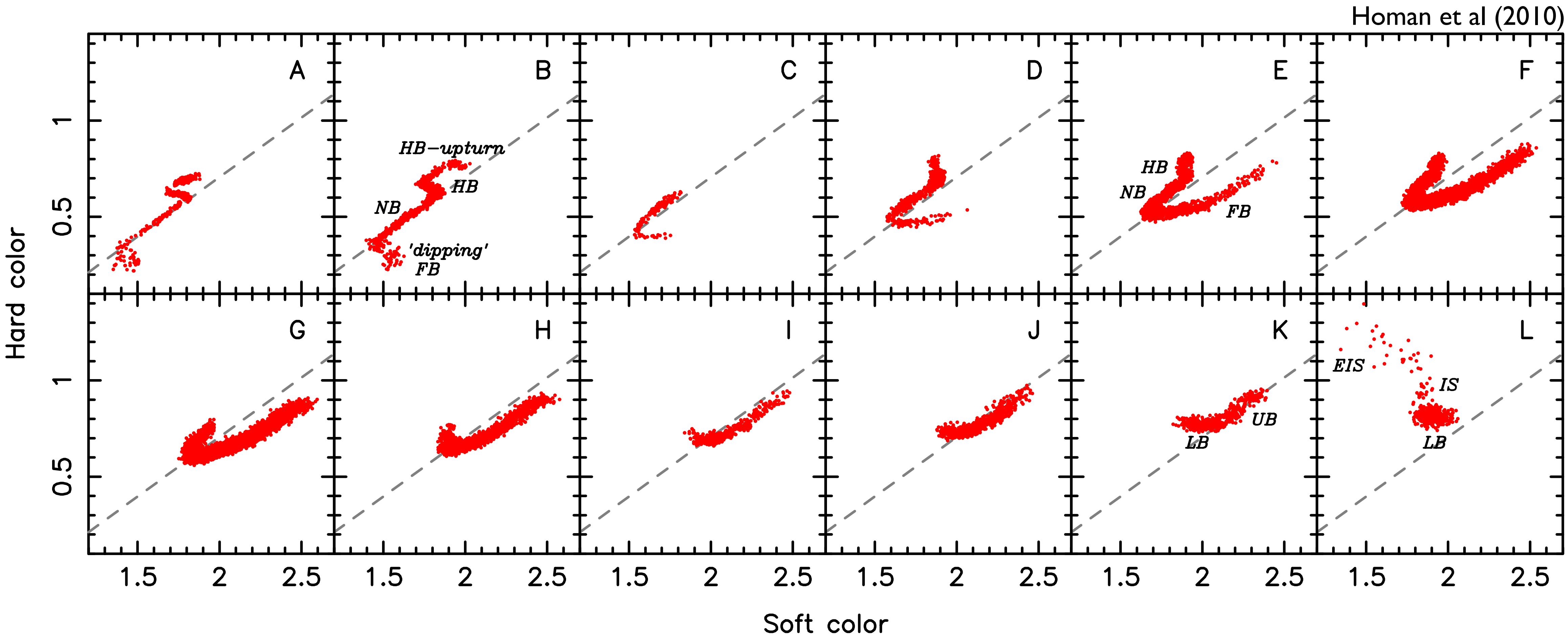
Z sources

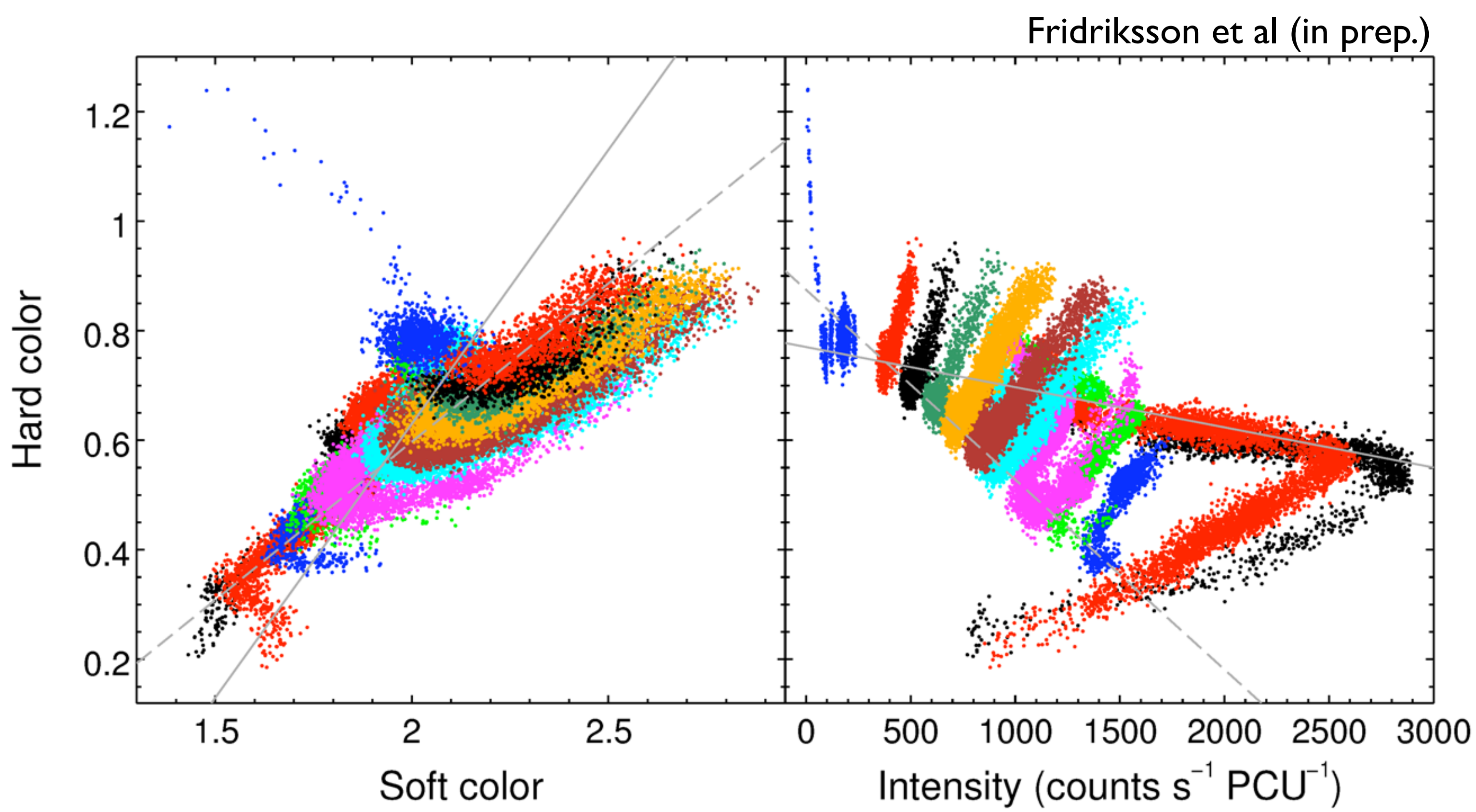


Atoll sources

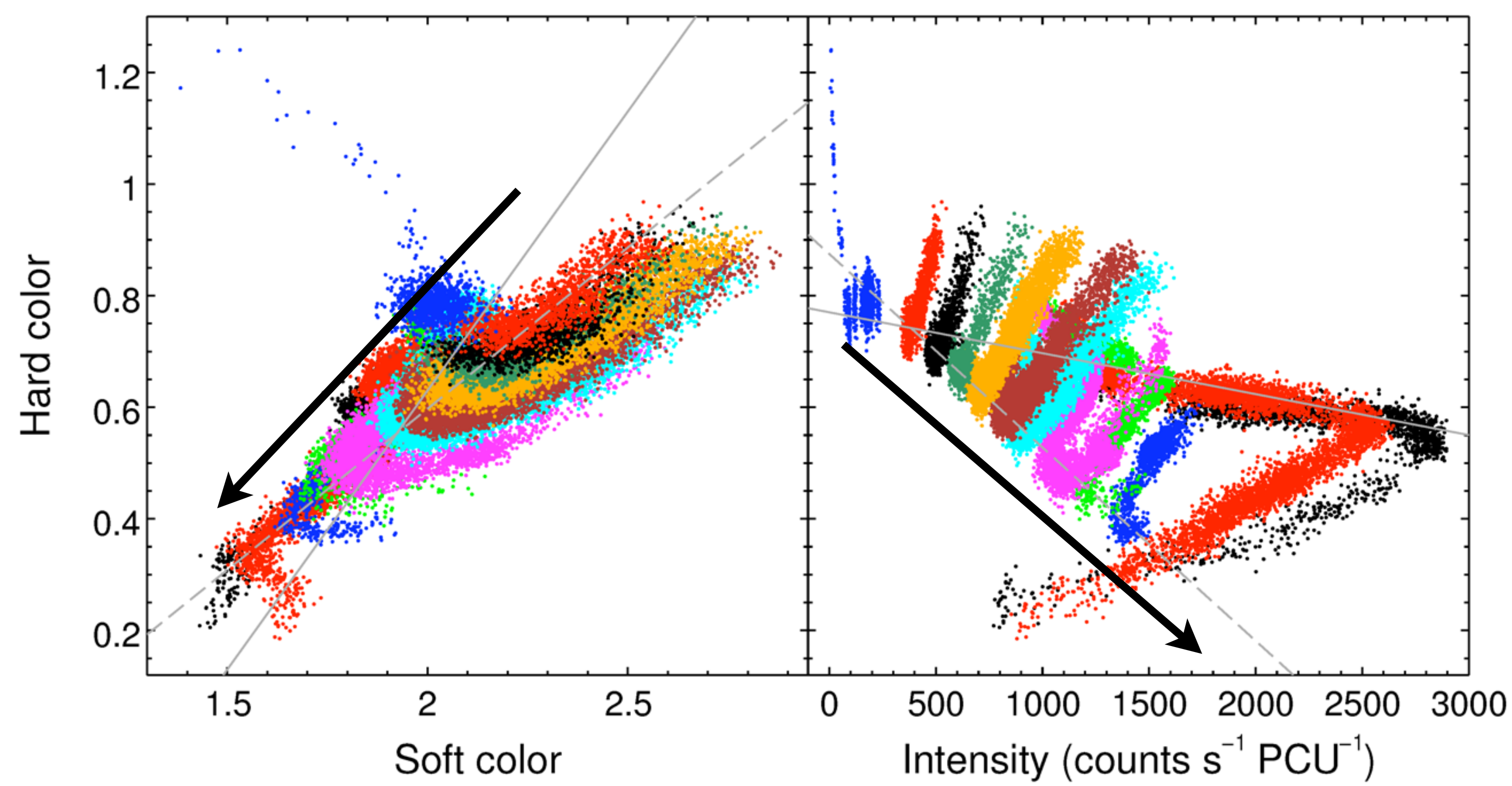


XTE J1701-462



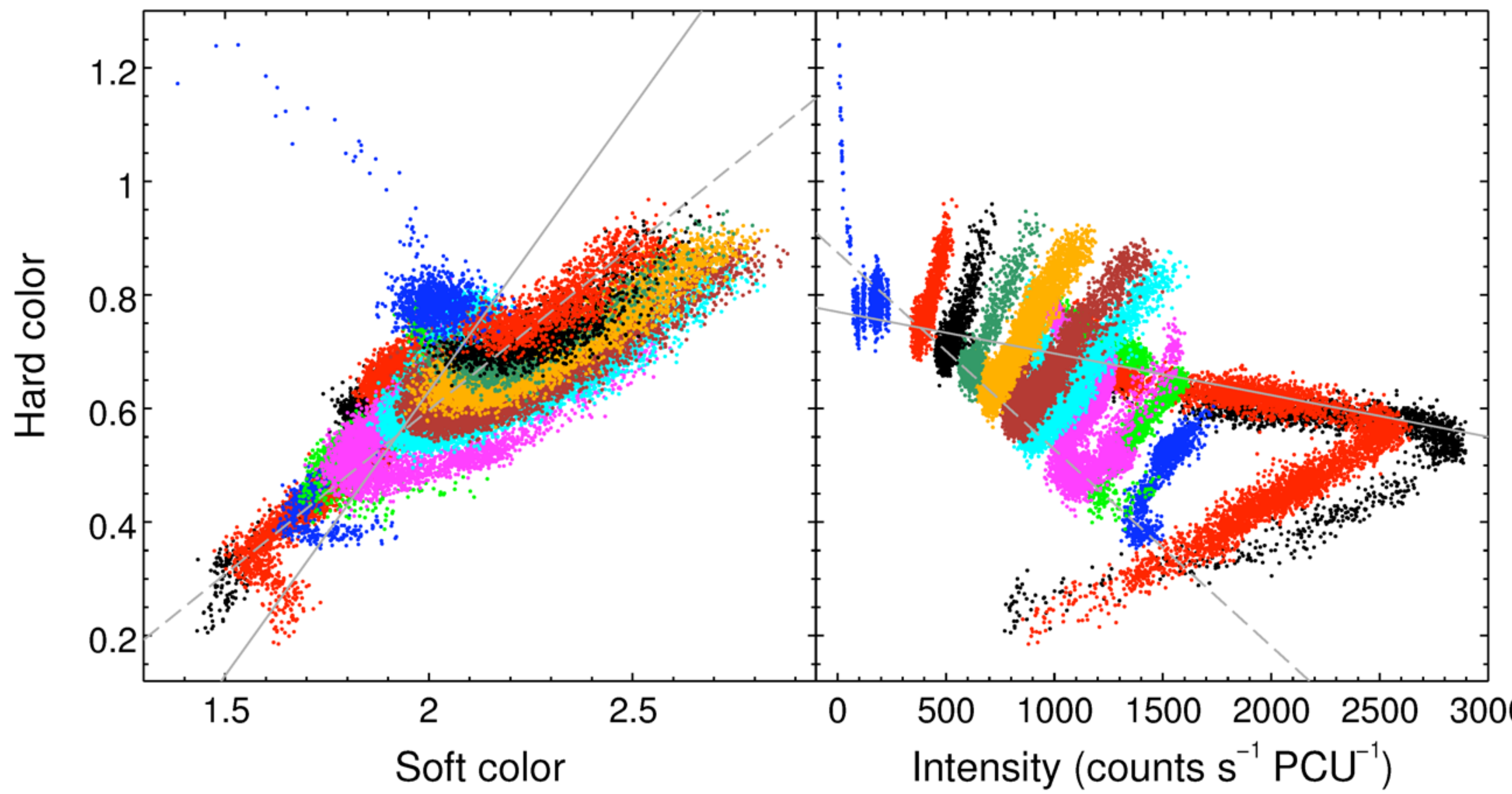


XTE J1701-462



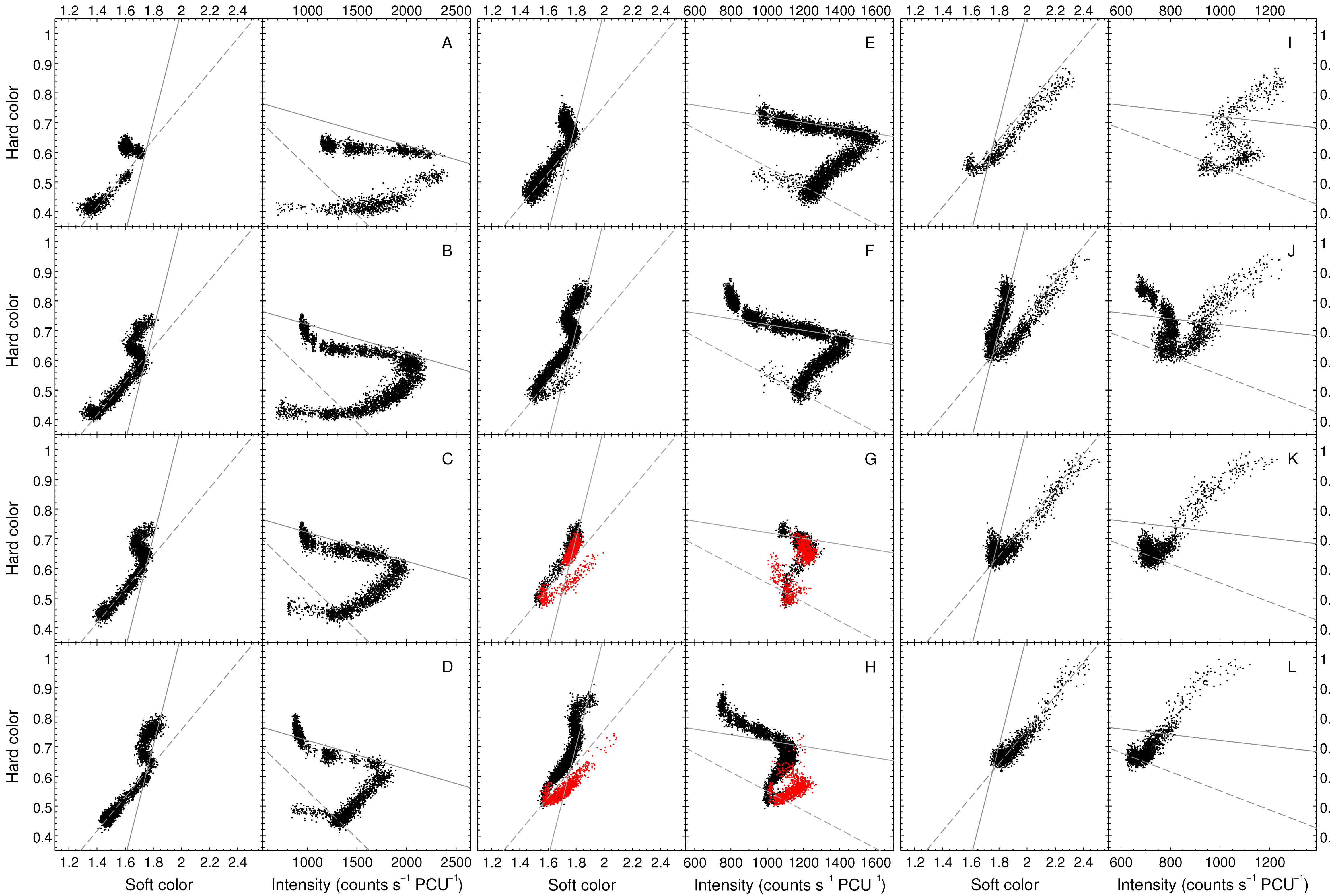
- Evolution from Eddington to quiescence
- $\dot{M}$-ranked sequence of CD/HID tracks (Lin et al. 2009)
  - No B-field, no viewing angle involved
- Can it be used to get a relative ranking for other NS LMXBs?

XTE J1701-462



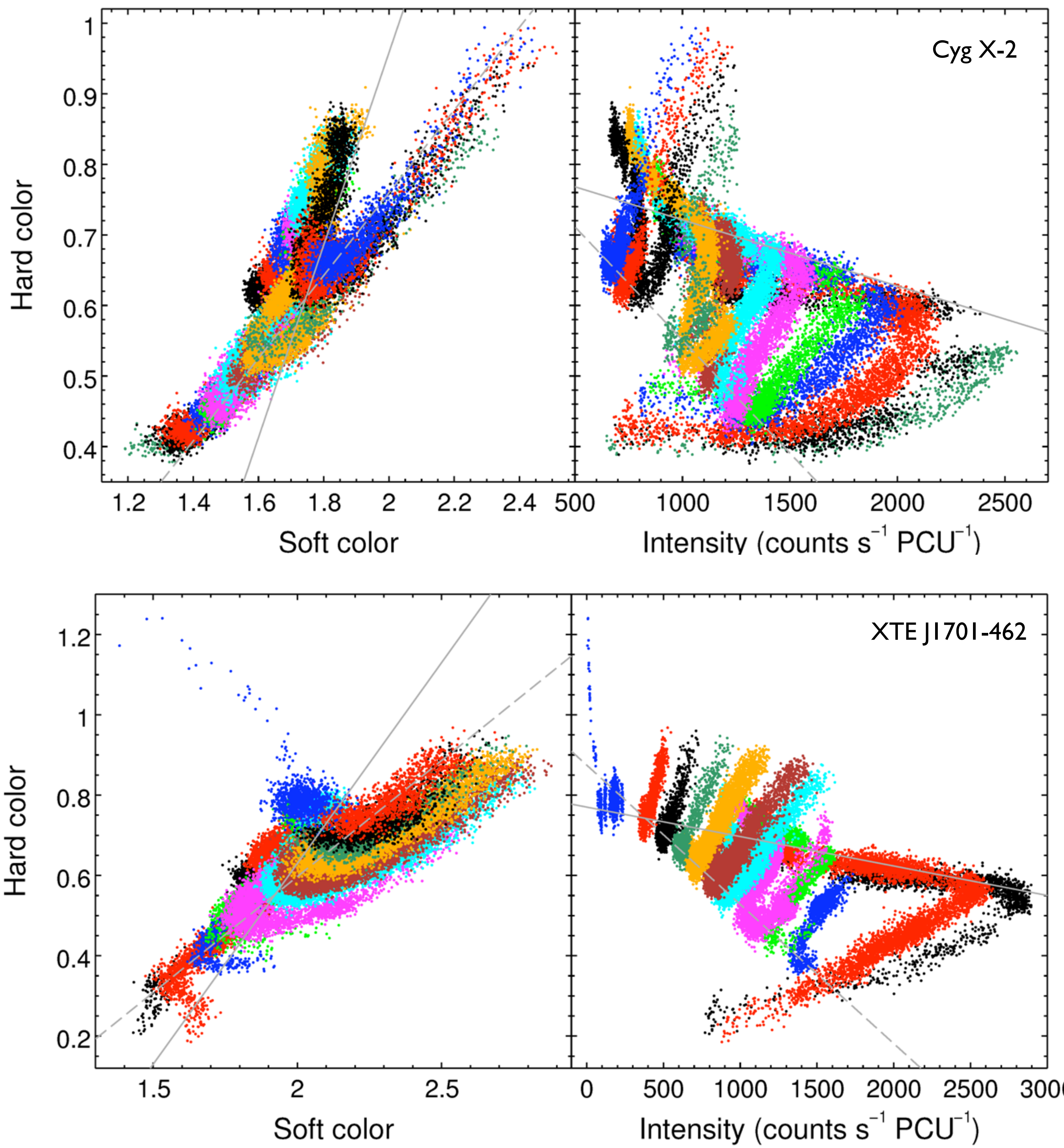
- Can we find similar behavior in other sources?
- At low luminosities: yes, atoll transients
- At high luminosities: unsure
    - Investigate sources with strong secular changes:
    - Cyg X-2, Cir X-1, and GX 13+1

Cyg X-2



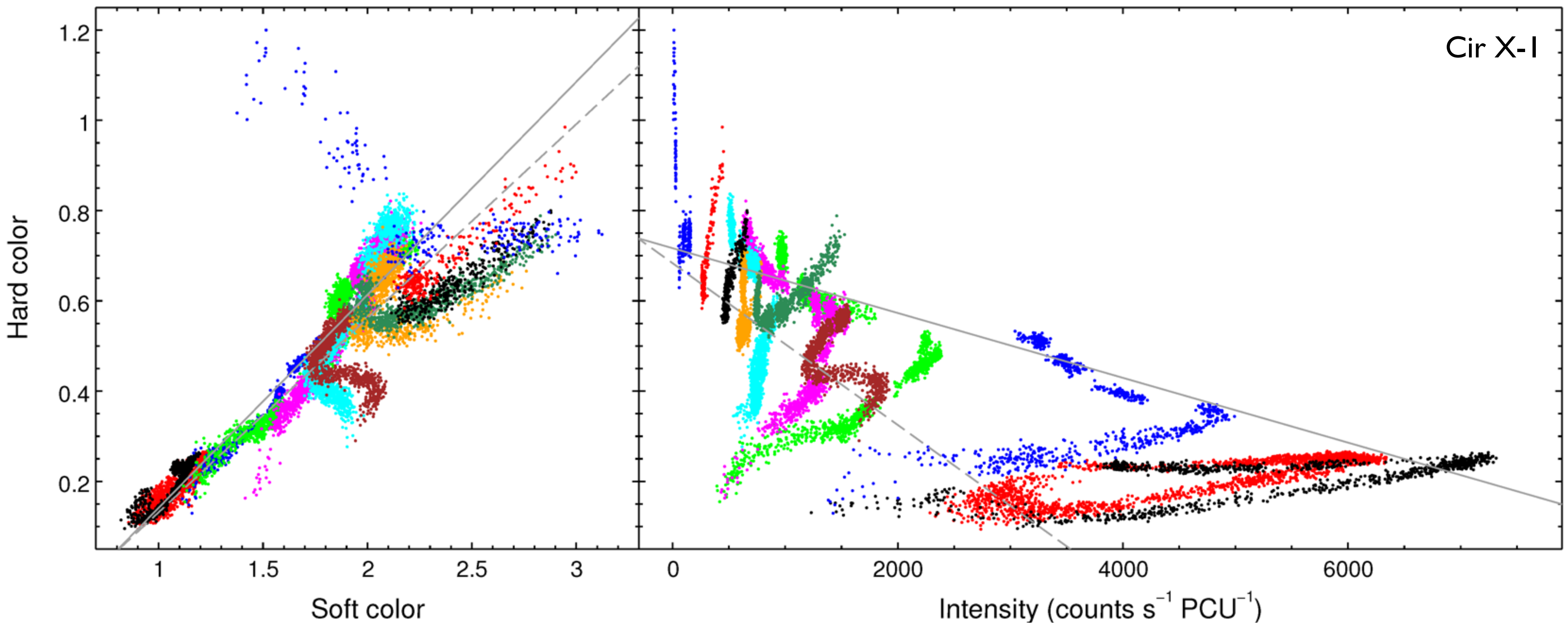
Cyg-like Z ↔ Sco-like Z

Cyg X-2

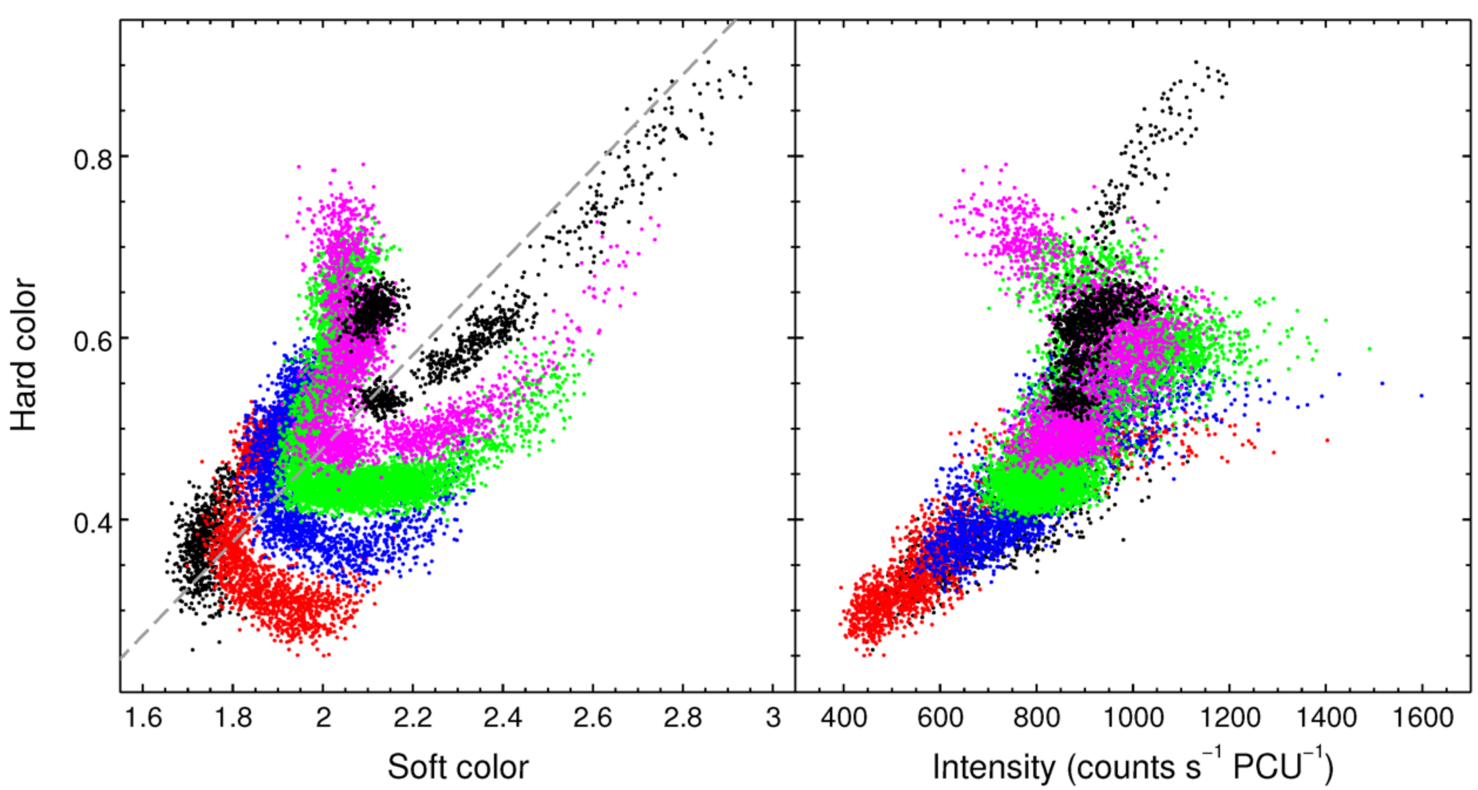


Cyg X-2
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})
XTE J1701-462
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})

Cir X-1 & GX 13+1



Cyg-like Z ↔ atoll

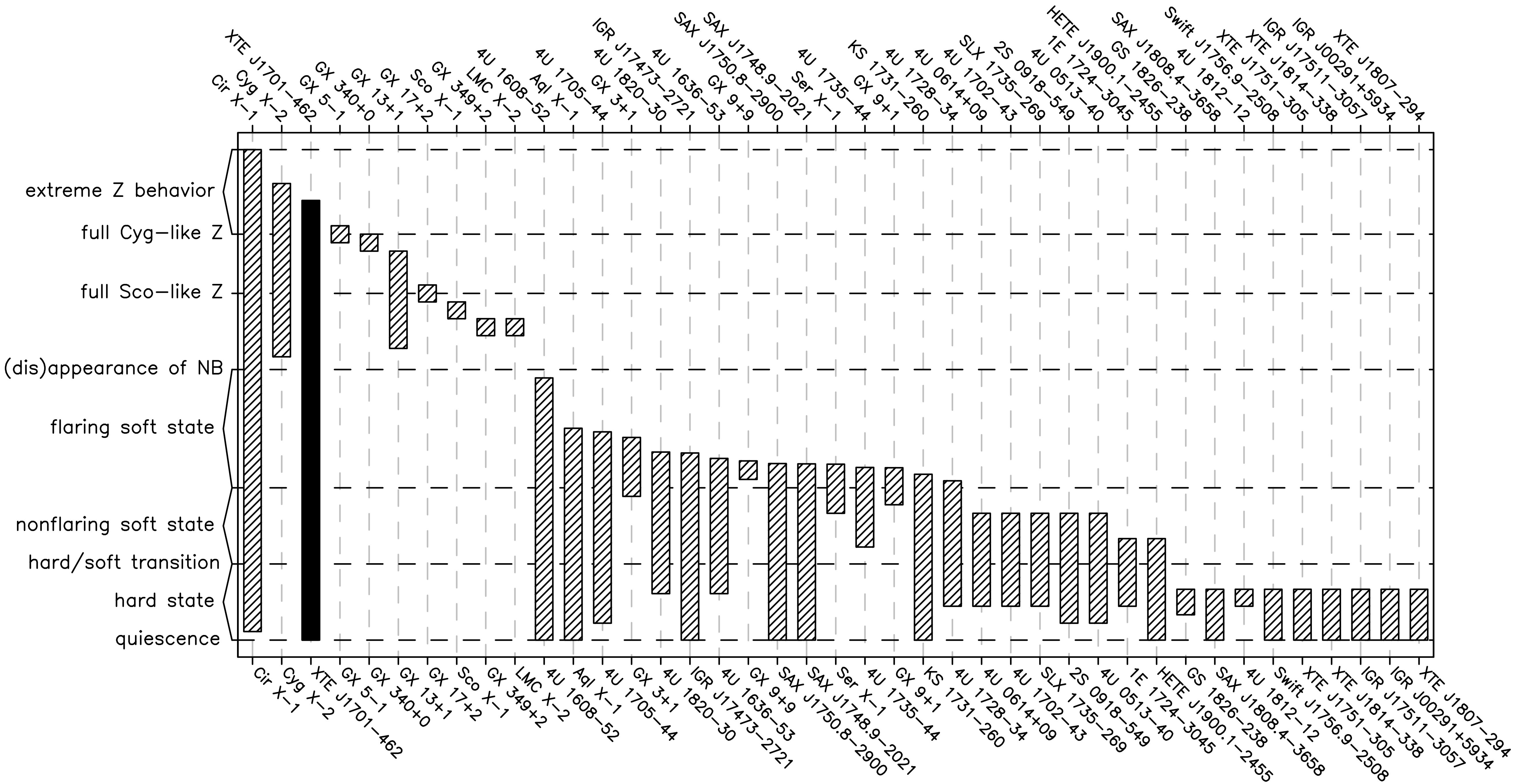


Cyg-like Z ↔ Sco-like Z

NS LMXBs

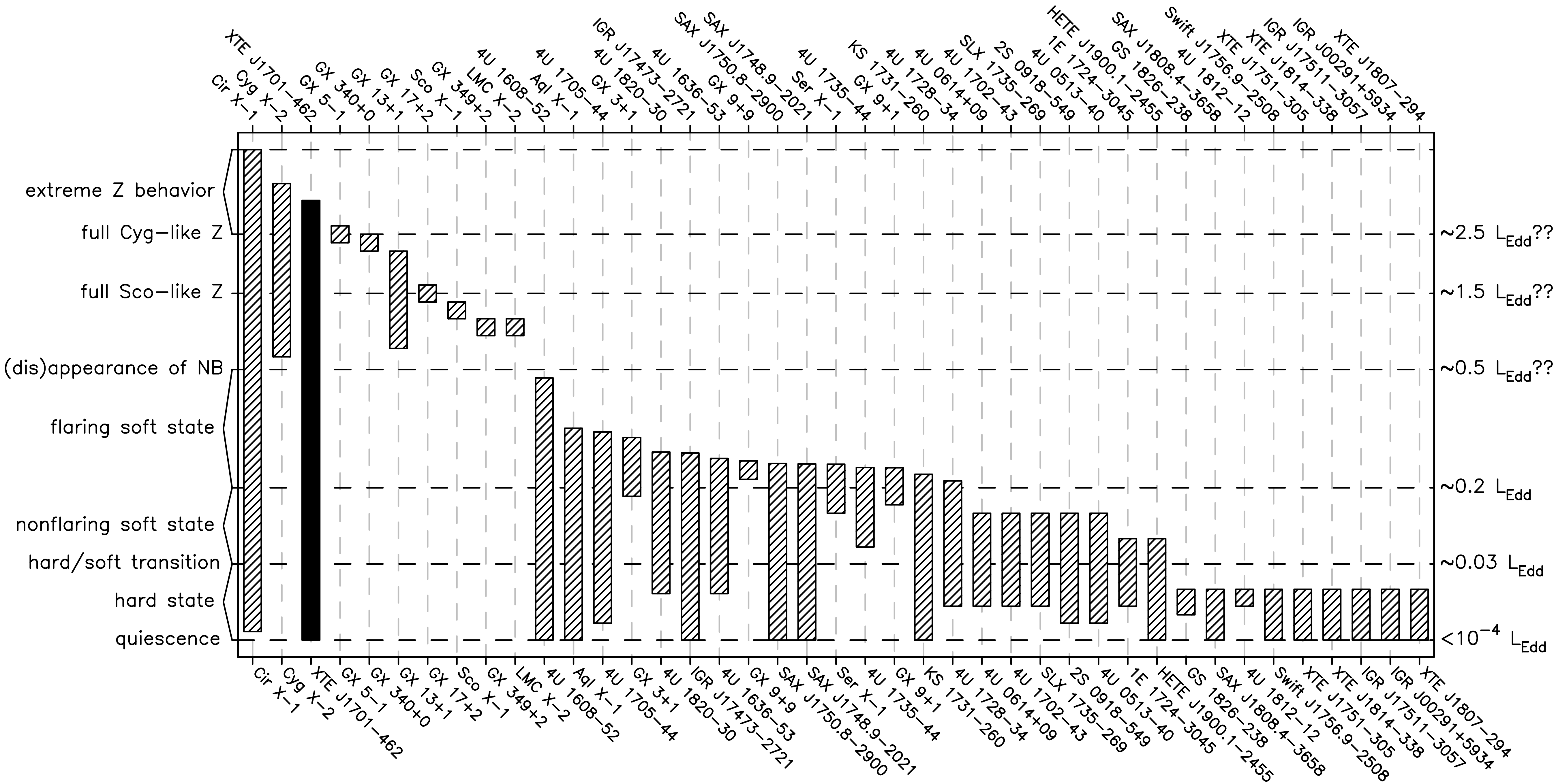
- Conclusion: XTE J1701-462 is not alone. Behavior might be representative of NS-LMXBs
- Next step: rank 40+ NS-LMXBs based on CD/HID morphology (150+ ks, no dipping/eclipsing sources)
- Ranking criteria: presence & orientation of Z/atoll states/branches
- Assumption: luminosity (mass accretion rate) determines CD/HID morphology

the ranking



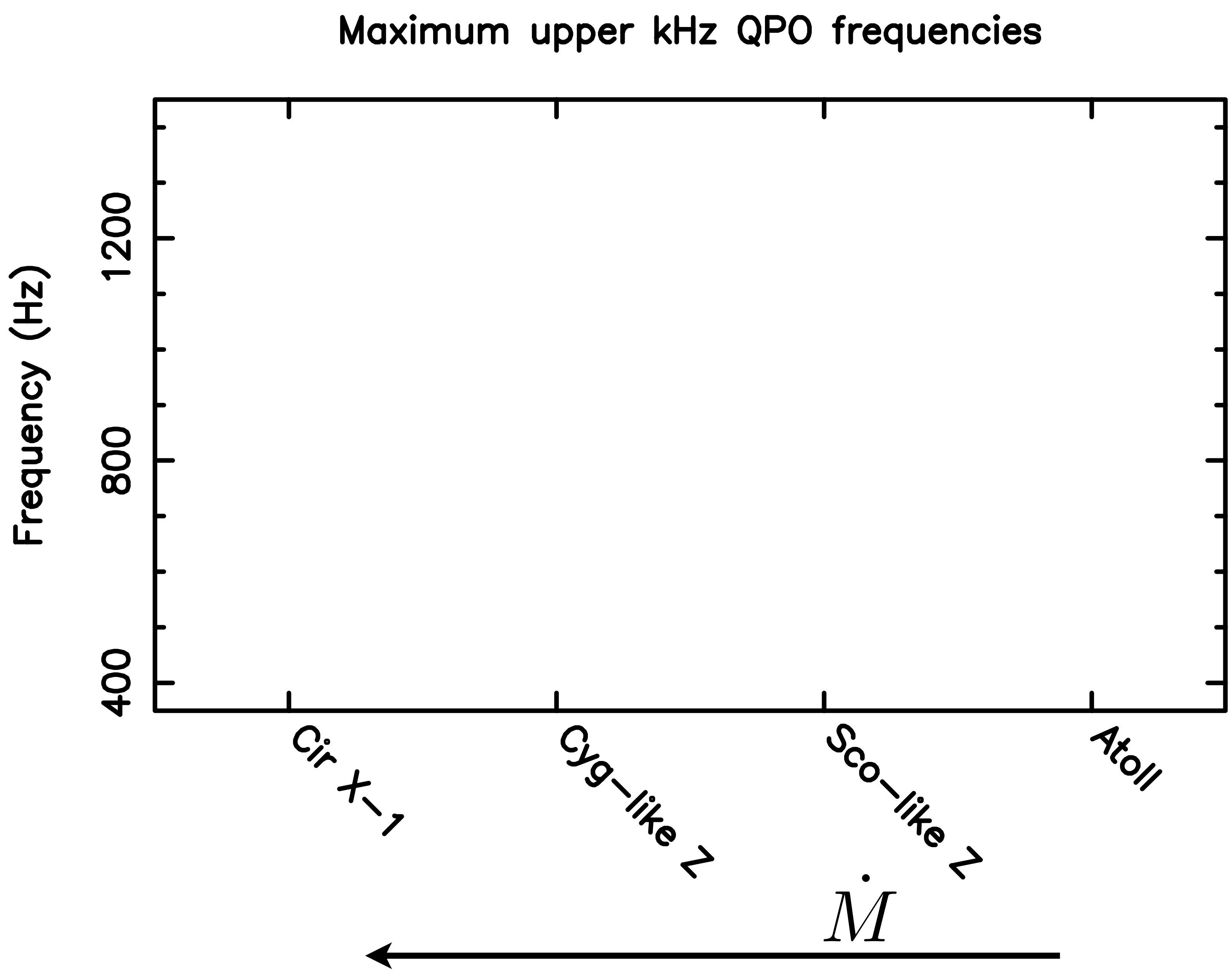
extreme Z behavior
full Cyg−like Z
full Sco−like Z
(dis)appearance of NB
flaring soft state
nonflaring soft state
hard/soft transition
hard state
quiescence
Cir X−1
Cyg X−2
XTE J1701−462
GX 5−1
GX 340+0
GX 13+1
GX 17+2
Sco X−1
GX 349+2
LMC X−2
4U 1608−52
Aql X−1
4U 1705−44
4U 1820−30
GX 3+1
IGR J17473−2721
4U 1636−53
GX 9+9
SAX J1750.8−2900
SAX J1748.9−2021
Ser X−1
4U 1735−44
GX 9+1
KS 1731−260
4U 1728−34
4U 0614+09
4U 1702−43
SLX 1735−269
2S 0918−549
4U 0513−40
1E 1724−3045
HETE J1900.1−2455
GS 1826−238
SAX J1808.4−3658
4U 1812−12
Swift J1756.9−2508
XTE J1751−305
XTE J1814−338
IGR J17511−3057
IGR J00291+5934
XTE J1807−294

the ranking



extreme Z behavior
full Cyg−like Z
full Sco−like Z
(dis)appearance of NB
flaring soft state
nonflaring soft state
hard/soft transition
hard state
quiescence
~2.5 L_{Edd}??
~1.5 L_{Edd}??
~0.5 L_{Edd}??
~0.2 L_{Edd}
~0.03 L_{Edd}
<10^{-4} L_{Edd}
Cir X−1
Cyg X−2
XTE J1701−462
GX 5−1
GX 340+0
GX 13+1
GX 17+2
Sco X−1
GX 349+2
LMC X−2
4U 1608−52
Aql X−1
4U 1705−44
GX 3+1
4U 1820−30
IGR J17473−2721
4U 1636−53
GX 9+9
SAX J1750.8−2900
SAX J1748.9−2021
Ser X−1
4U 1735−44
GX 9+1
KS 1731−260
4U 1728−34
4U 0614+09
4U 1702−43
SLX 1735−269
2S 0918−549
4U 0513−40
1E 1724−3045
HETE J1900.1−2455
GS 1826−238
SAX J1808.4−3658
4U 1812−12
Swift J1756.9−2508
XTE J1751−305
XTE J1814−338
IGR J17511−3057
IGR J00291+5934
XTE J1807−294

- Radiative stresses may play an important role:
  - Increasingly violent intensity swing at high Lx (up to factors of ~8 in 30 minutes).
  - Systematic shift in kHz QPO frequency ranges



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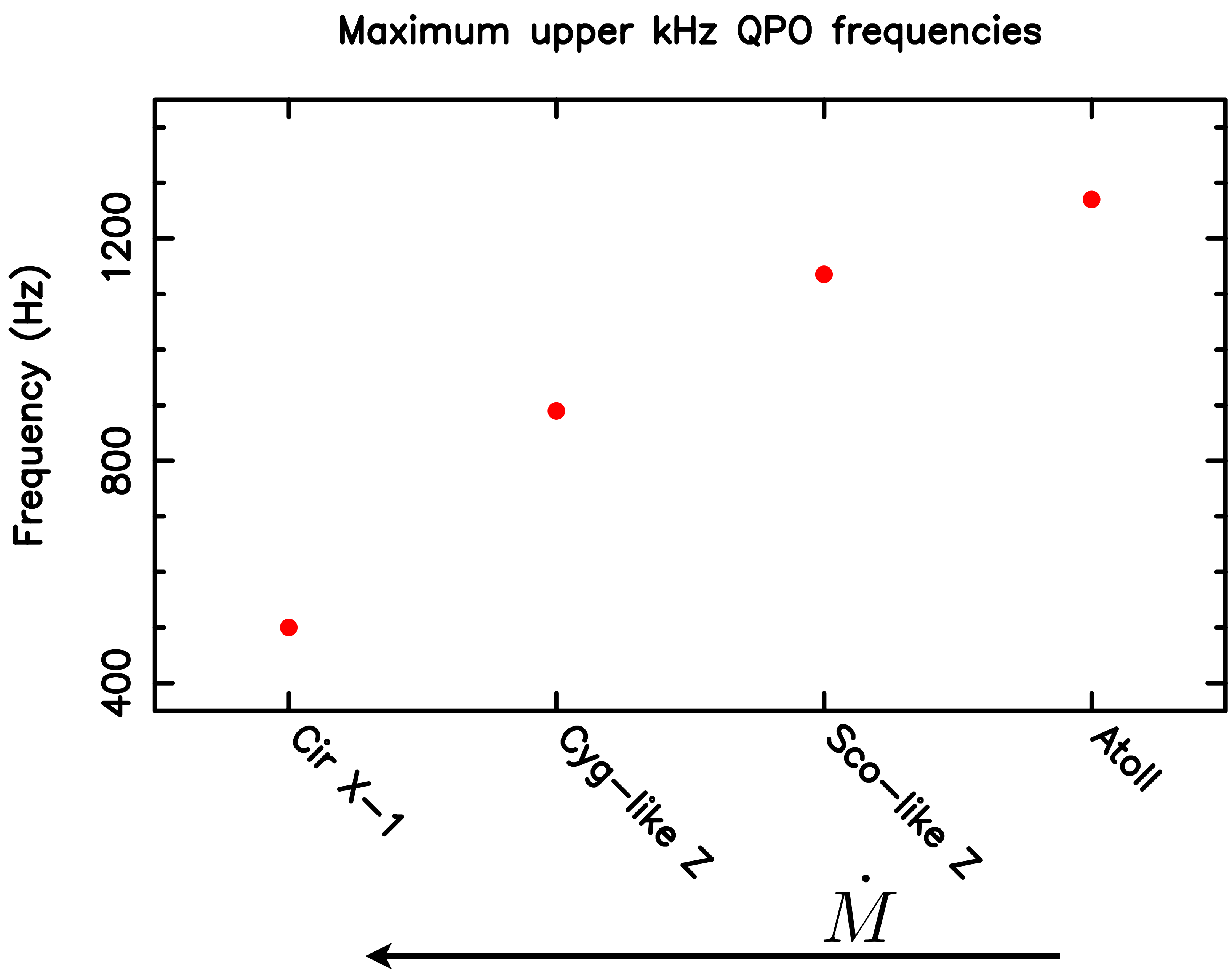
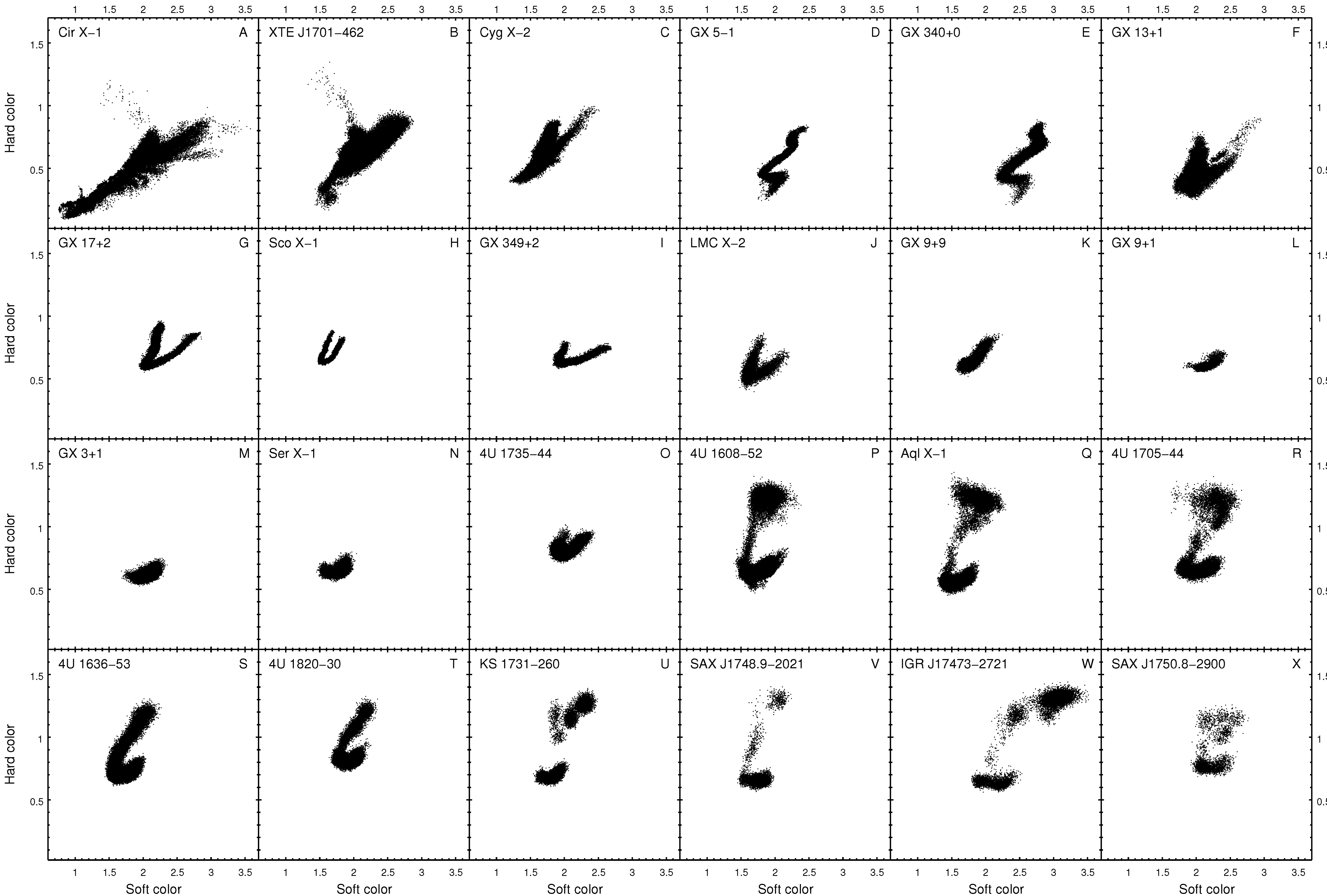
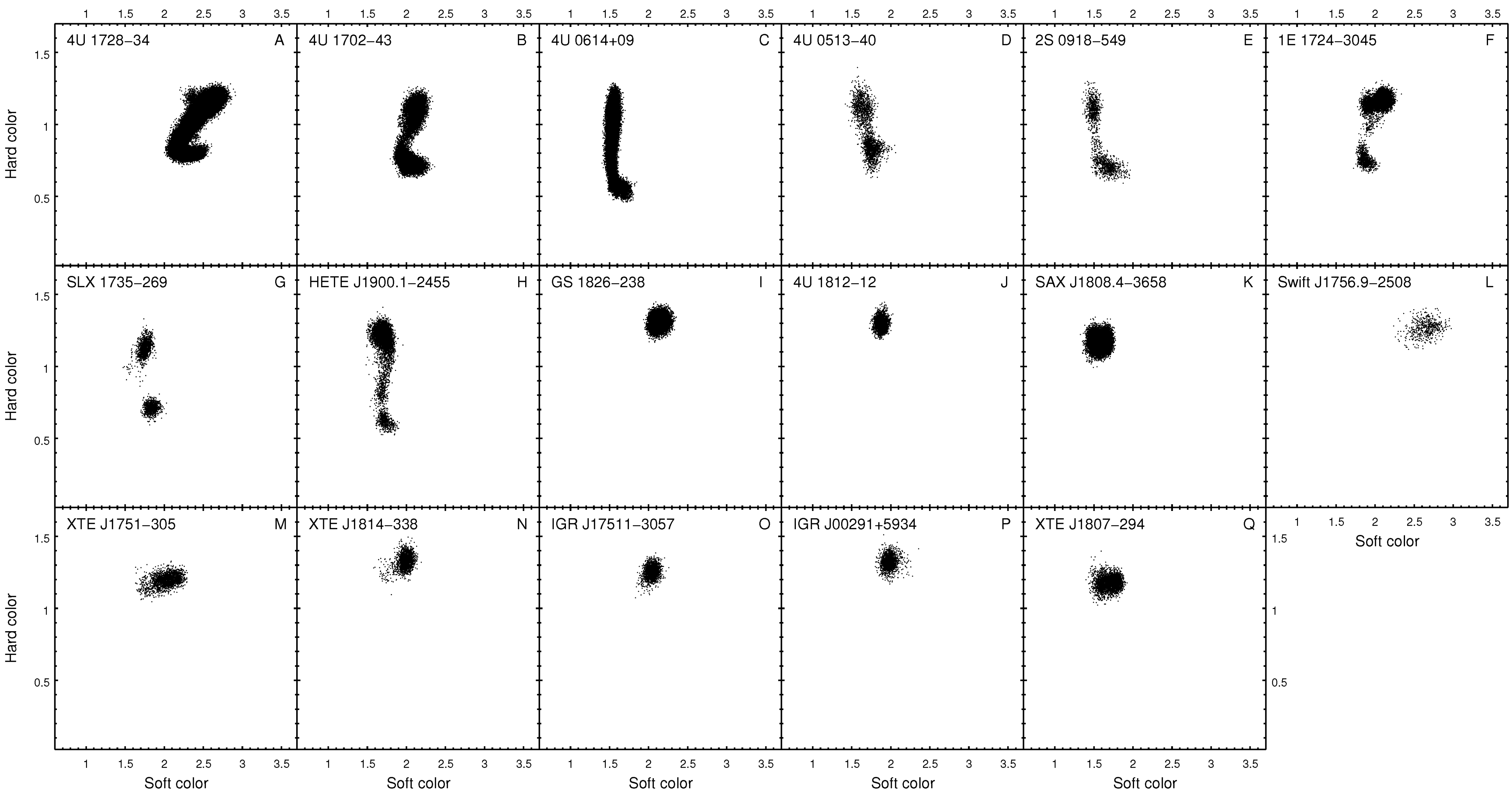
    - Increasingly violent intensity swing at high Lx (up to factors of ~8 in 30 minutes).
    - Systematic shift in kHz QPO frequency ranges



What’s next?

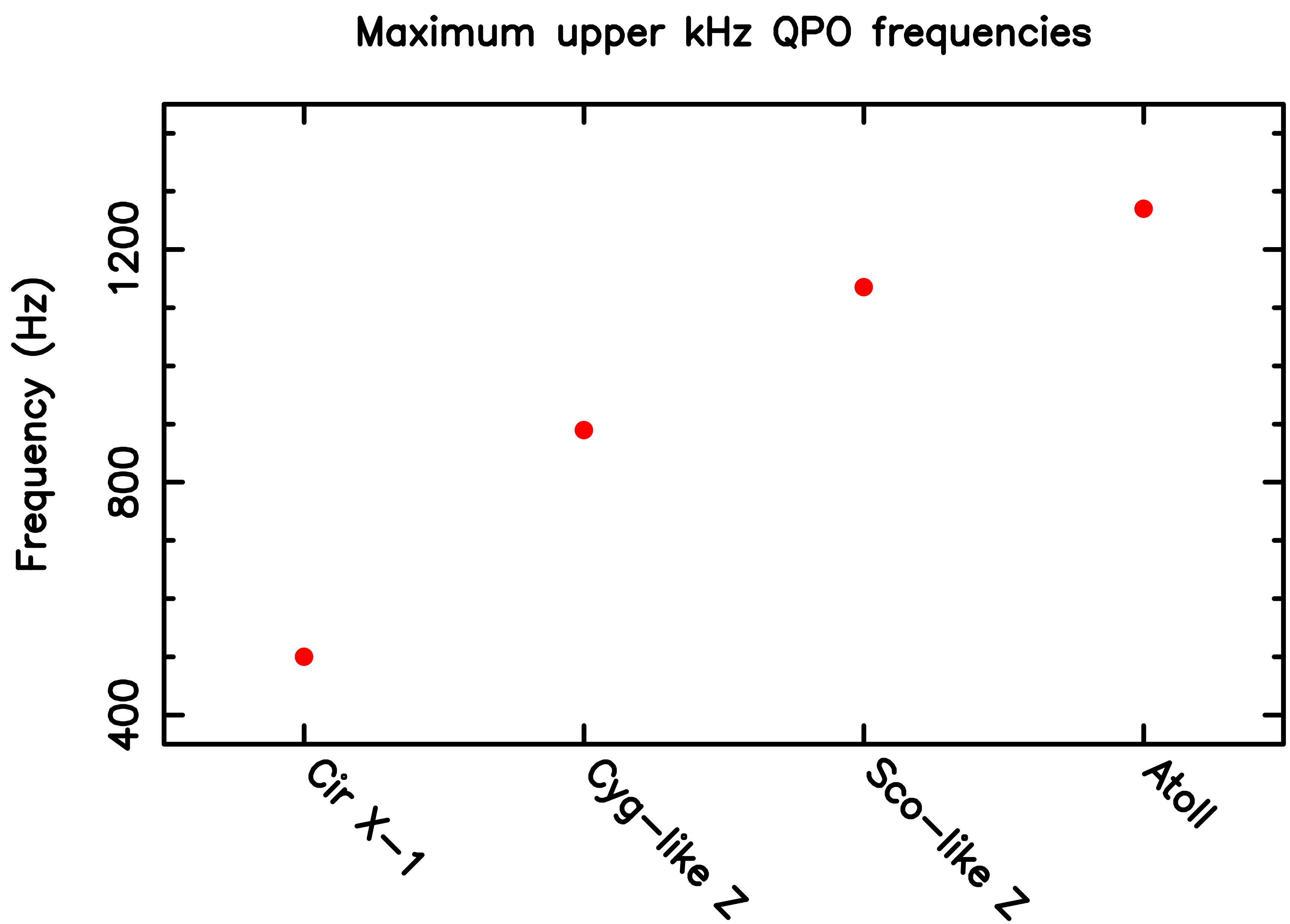
- Study variability/spectral properties across entire range of mass accretion rate
- Type I X-ray bursts
- Add more sources (<150 ks, dipping/eclipsing NS LMXBs)
- Test the ranking scheme - obtain luminosities
  - distance estimates (VLBA)
- Try something similar for black holes?


Cir X−1
A
XTE J1701−462
B
Cyg X−2
C
GX 5−1
D
GX 340+0
E
GX 13+1
F
GX 17+2
G
Sco X−1
H
GX 349+2
I
LMC X−2
J
GX 9+9
K
GX 9+1
L
GX 3+1
M
Ser X−1
N
4U 1735−44
O
4U 1608−52
P
Aql X−1
Q
4U 1705−44
R
4U 1636−53
S
4U 1820−30
T
KS 1731−260
U
SAX J1748.9−2021
V
IGR J17473−2721
W
SAX J1750.8−2900
X
Hard color
Soft color



4U 1728−34
A
4U 1702−43
B
4U 0614+09
C
4U 0513−40
D
2S 0918−549
E
1E 1724−3045
F
SLX 1735−269
G
HETE J1900.1−2455
H
GS 1826−238
I
4U 1812−12
J
SAX J1808.4−3658
K
Swift J1756.9−2508
L
XTE J1751−305
M
XTE J1814−338
N
IGR J17511−3057
O
IGR J00291+5934
P
XTE J1807−294
Q
Hard color
Soft color
1
1.5
2
2.5
3
3.5
0.5

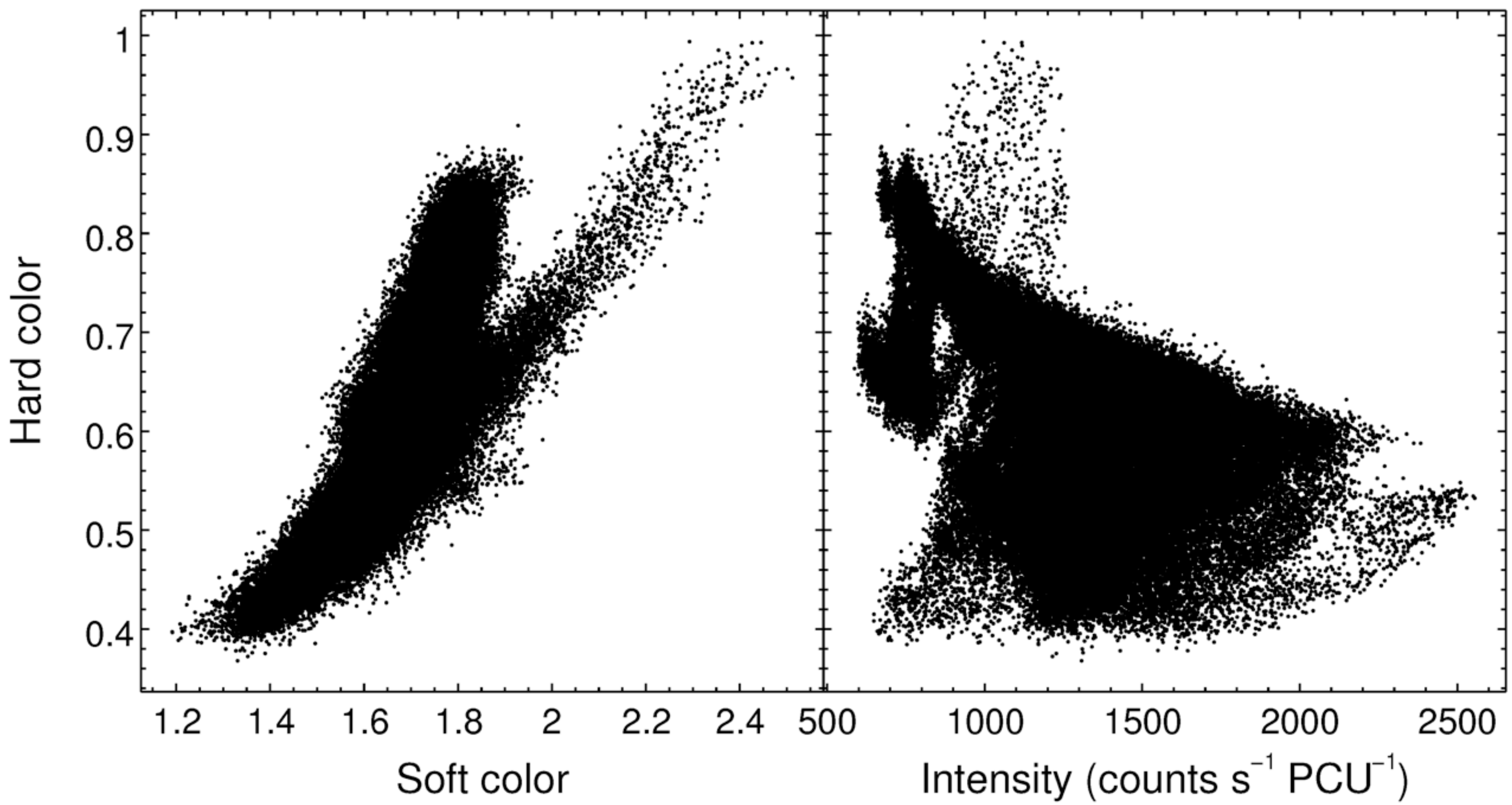
X-ray variability: kHz QPOs



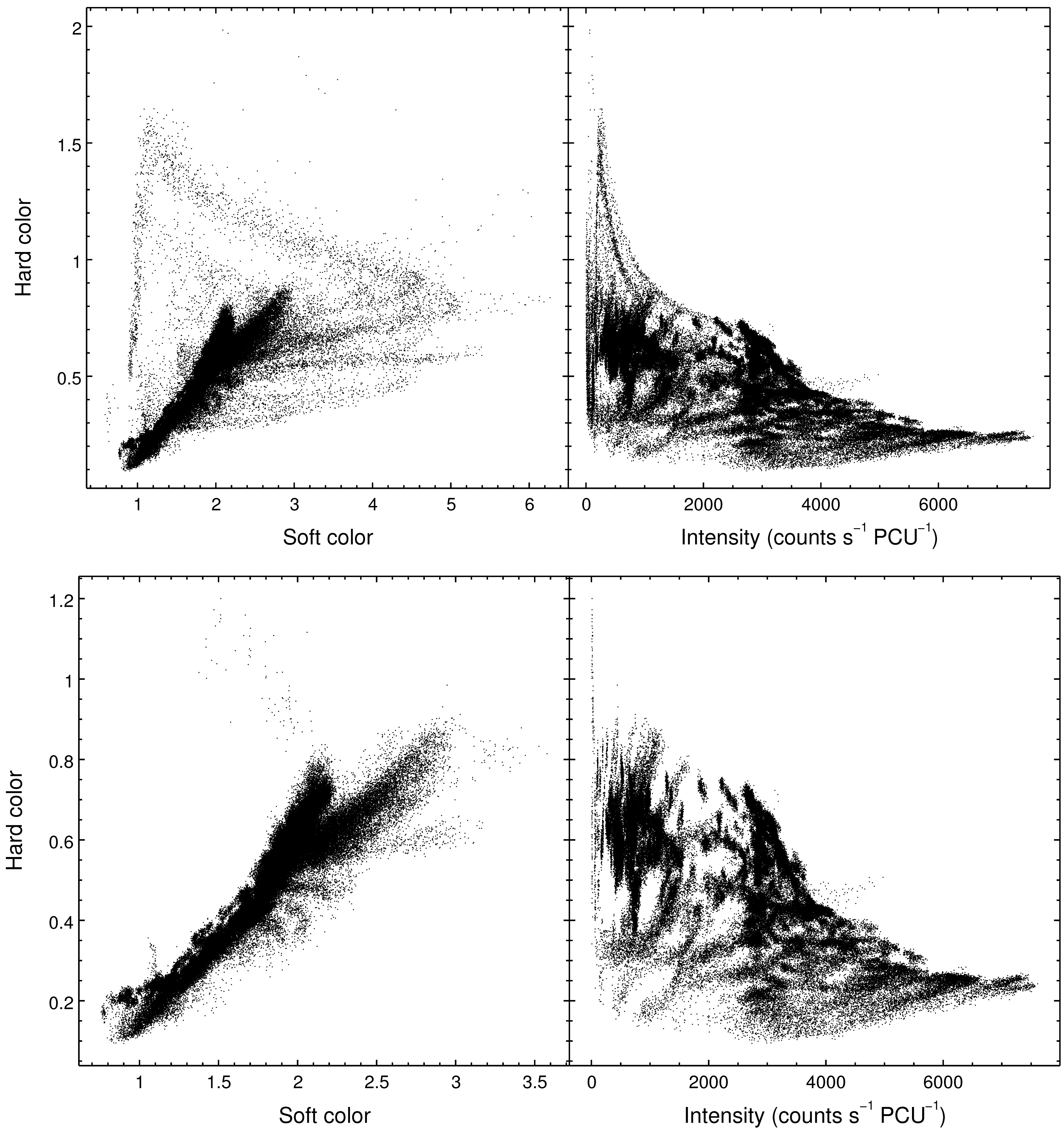
Lower mass accretion rates → higher kHz QPO frequencies

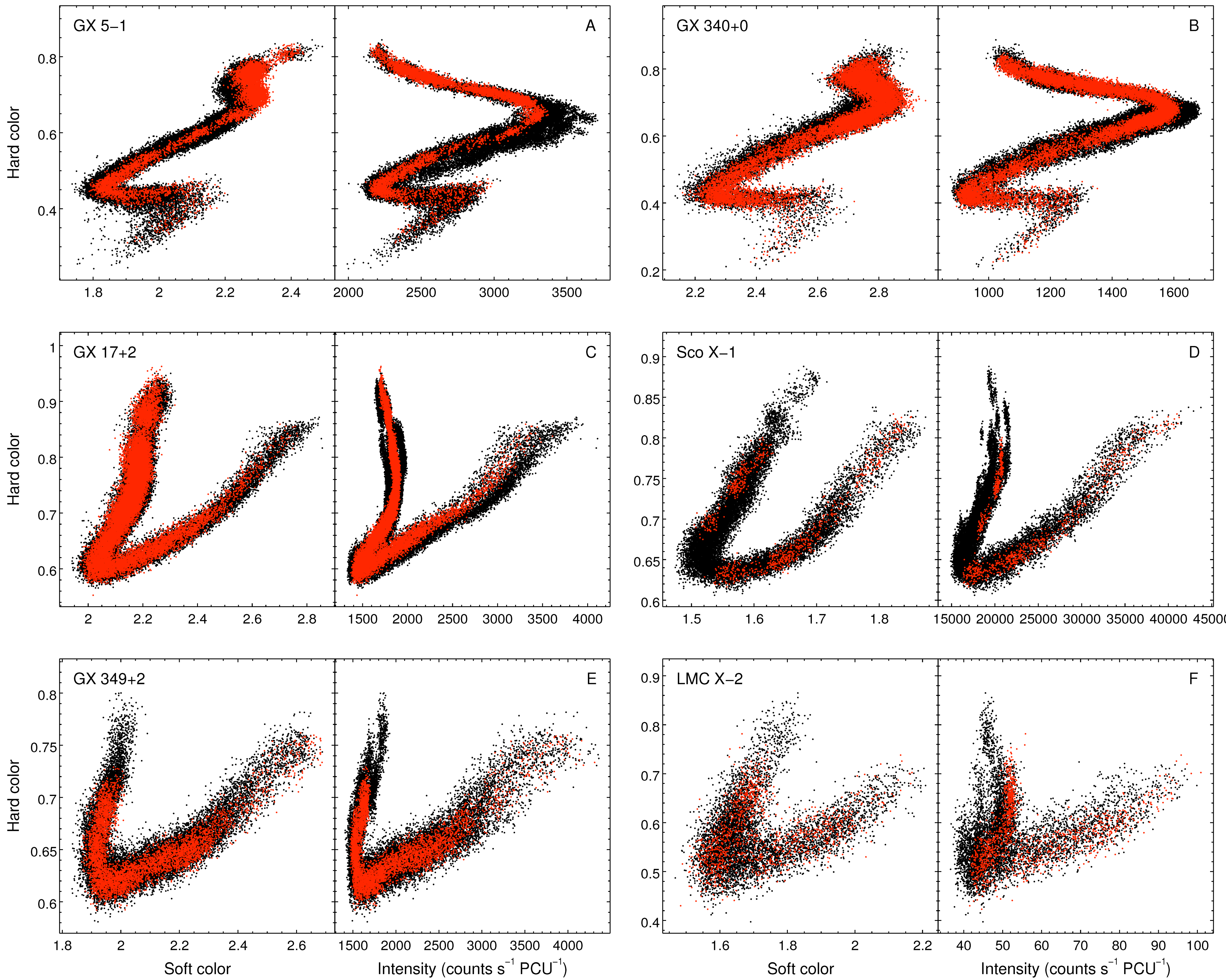
$$\nu_{K,rad} = \nu_K (1 - const \times \frac{L}{L_E})^{1/2}$$

Cyg X-2

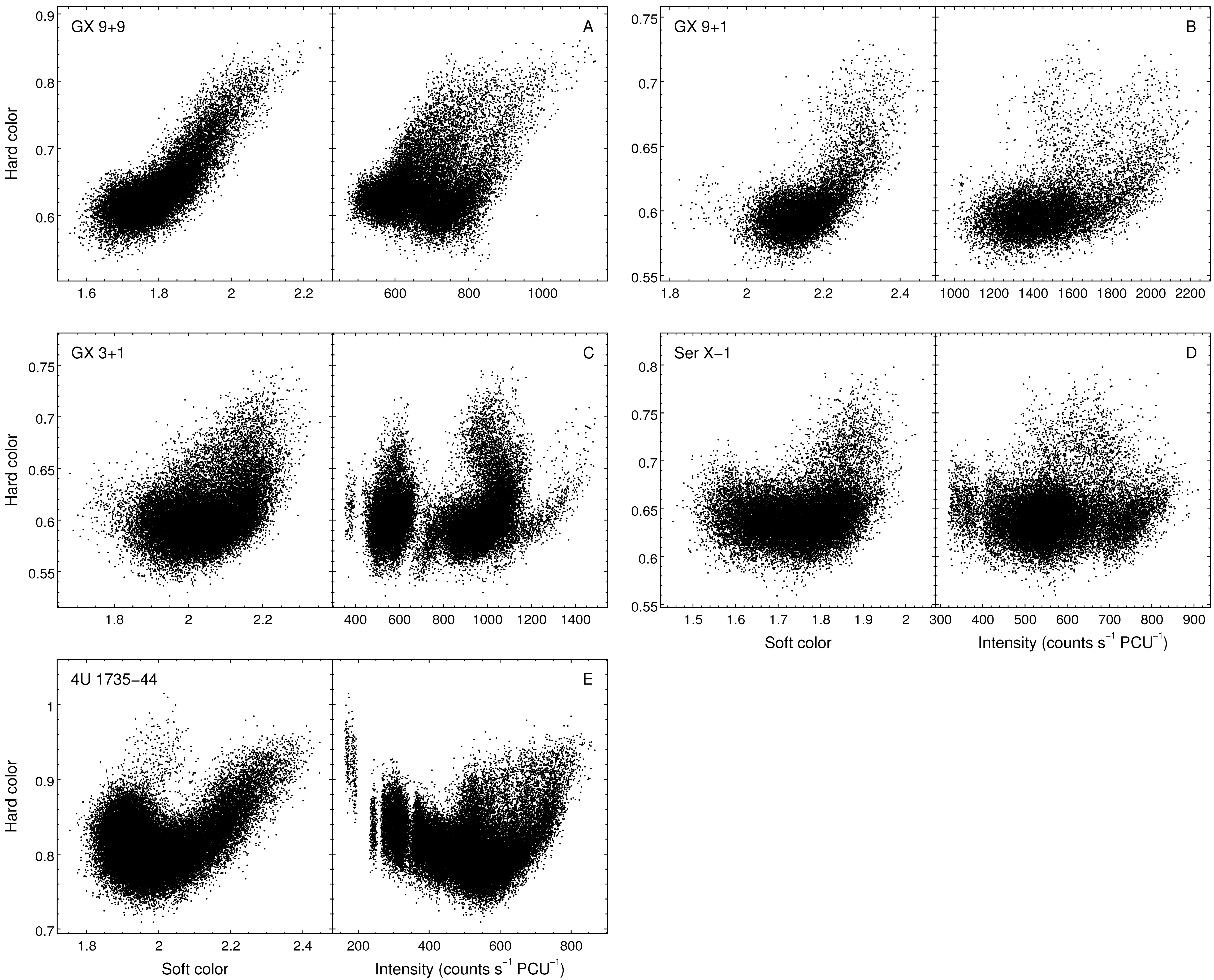


Many short (few ks) observations spread over 15 years

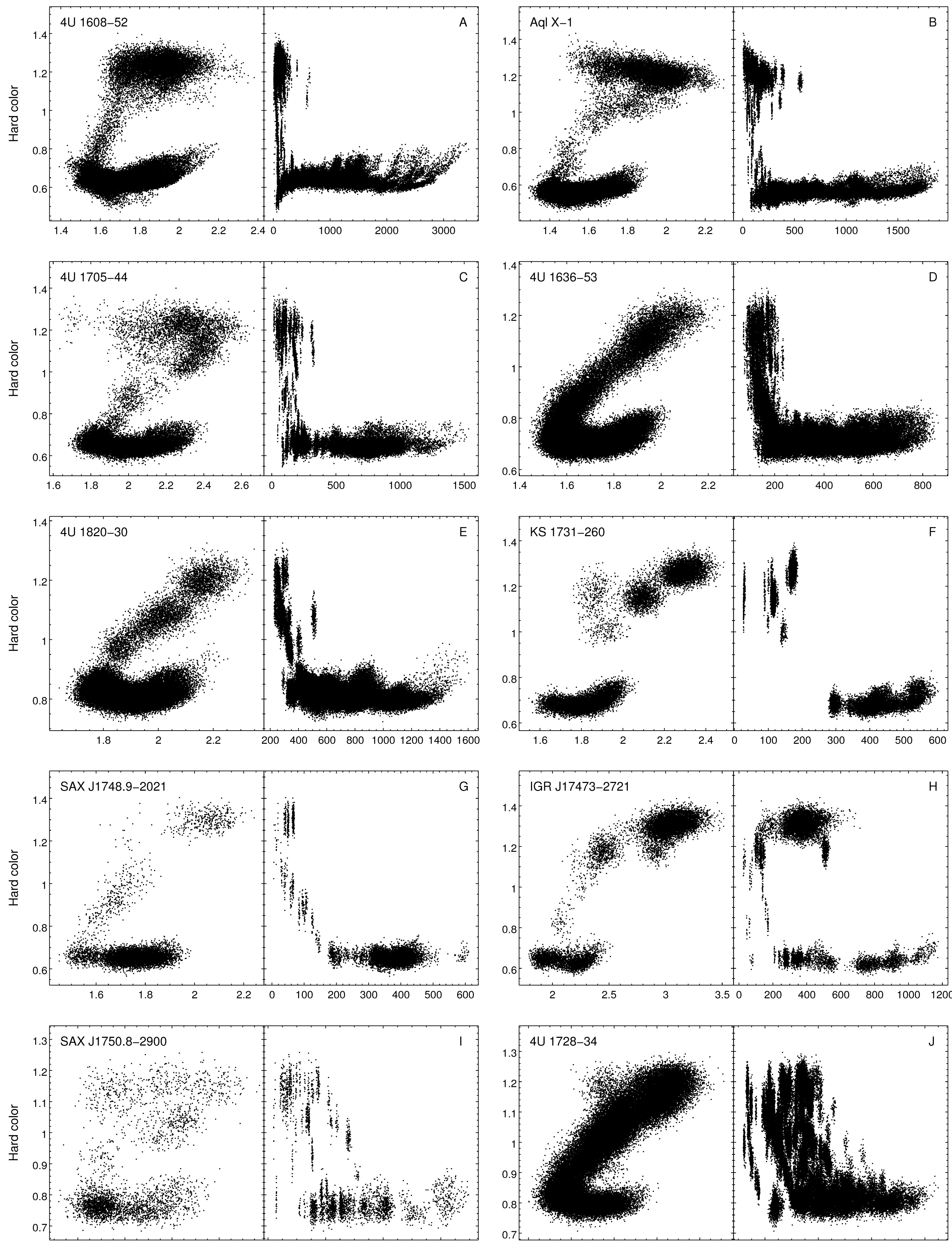

Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})



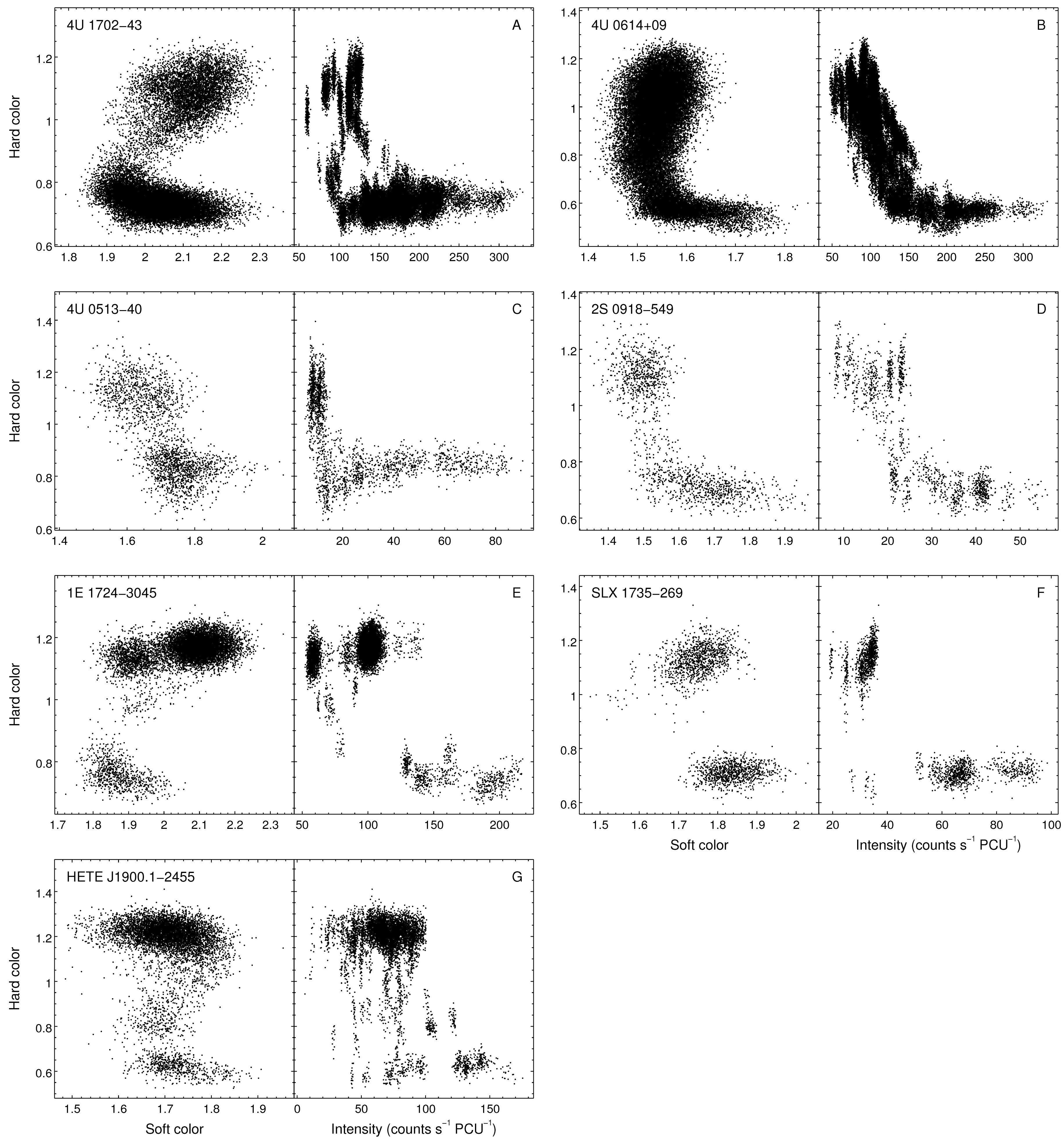
GX 5−1
A
GX 340+0
B
GX 17+2
C
Sco X−1
D
GX 349+2
E
LMC X−2
F
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})



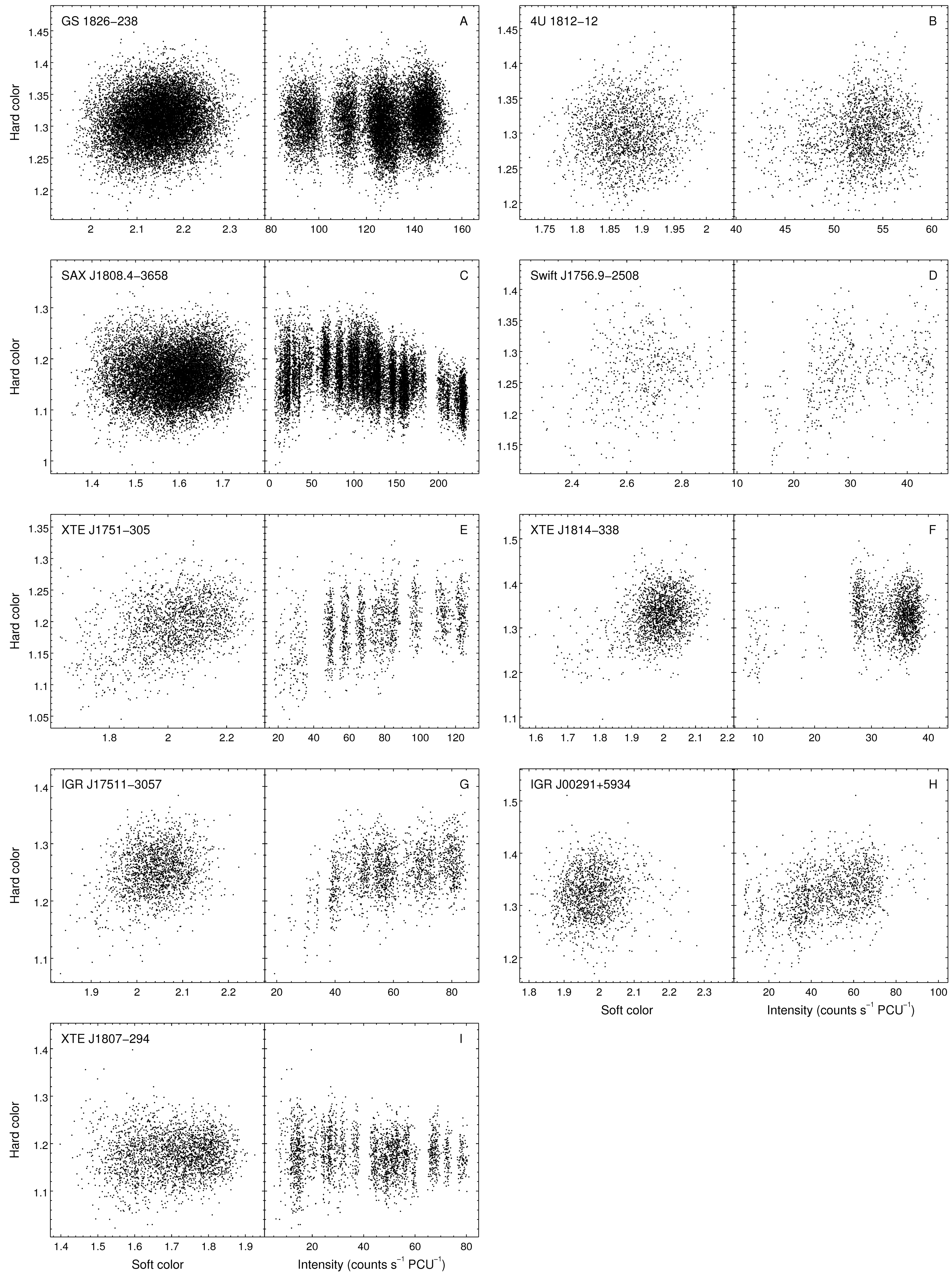
GX 9+9
A
GX 9+1
B
GX 3+1
C
Ser X−1
D
4U 1735−44
E
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})



4U 1608–52
A
Aql X–1
B
4U 1705–44
C
4U 1636–53
D
4U 1820–30
E
KS 1731–260
F
SAX J1748.9–2021
G
IGR J17473–2721
H
SAX J1750.8–2900
I
4U 1728–34
J
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})



4U 1702−43
A
4U 0614+09
B
4U 0513−40
C
2S 0918−549
D
1E 1724−3045
E
SLX 1735−269
F
HETE J1900.1−2455
G
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})



GS 1826−238
A
4U 1812−12
B
SAX J1808.4−3658
C
Swift J1756.9−2508
D
XTE J1751−305
E
XTE J1814−338
F
IGR J17511−3057
G
IGR J00291+5934
H
XTE J1807−294
I
Hard color
Soft color
Intensity (counts s^{-1} PCU^{-1})