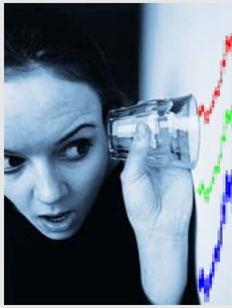
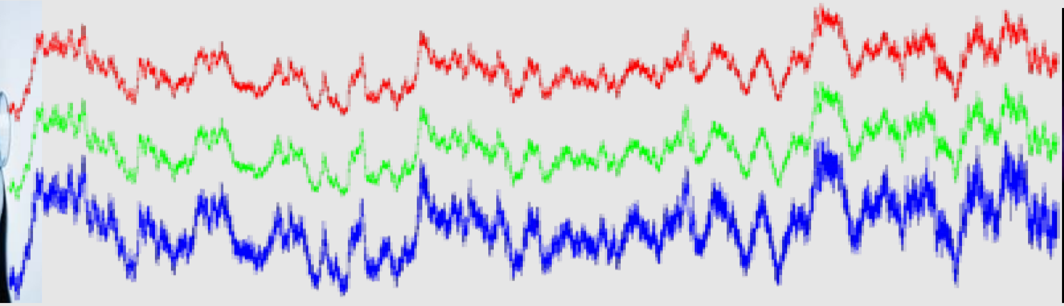
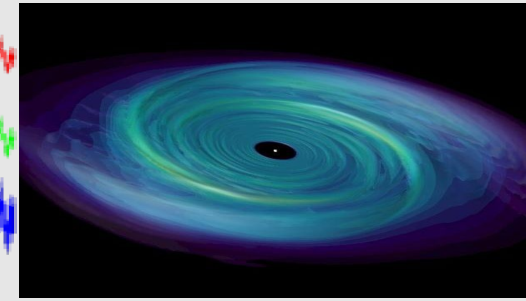






Eavesdropping on accretion disks:

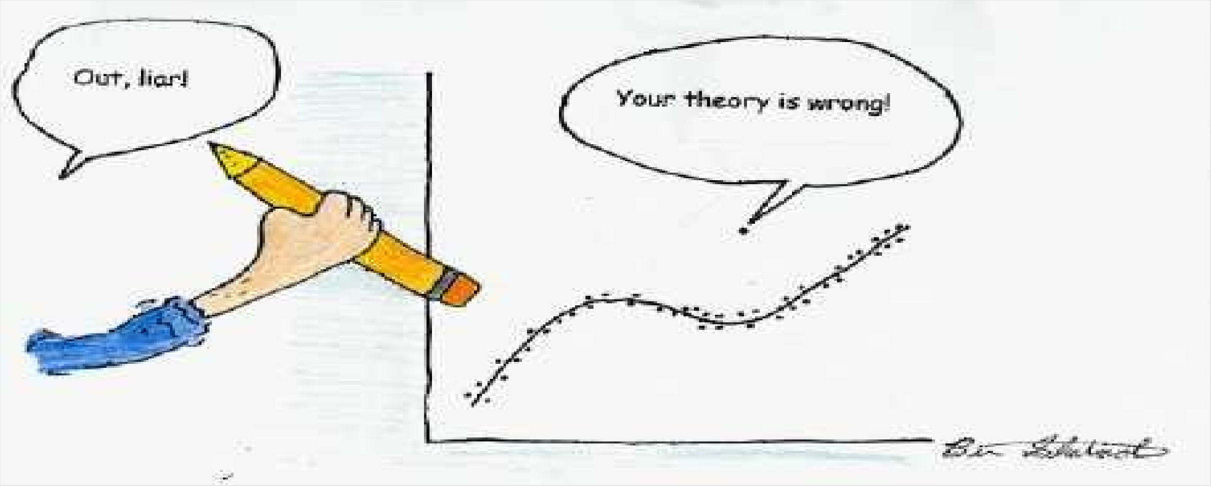
Broad-band variability properties of cataclysmic variables and their connections to XRBs/AGN

Simone Scaringi

E. Körding, P. Uttley, C. Knigge, P.J. Groot, C. Aerts, P. Jonker, M. Still

Overview

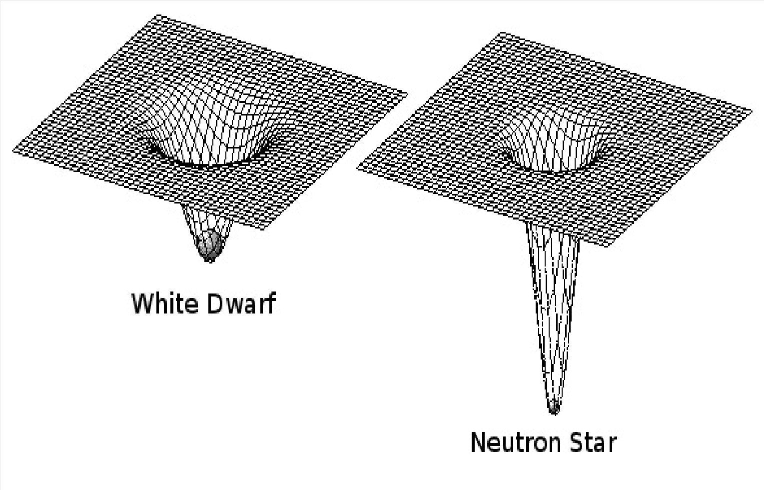
- Why look at CVs?
- The first timing connection: the rms-flux relation
- QPO evolution in CVs
- Coherence and Fourier time-lags in CVs
- Future work / Making sense?



Why look at CVs?

- Observationally both XRBs and CVs exhibit large-amplitude outbursts
- Theoretically explained through thermal/viscous instabilities in the accretion disks (Shakura & Sunyaev 1973)
- Radio emission/jets observed in conjunction with spectral changes (Koerding et al. 2008)
- Accretion disk dynamics governed by the embedded gravitational potential

CVs offer a unique laboratory to study accretion in the absence of strong gravity and strong X-ray emission!



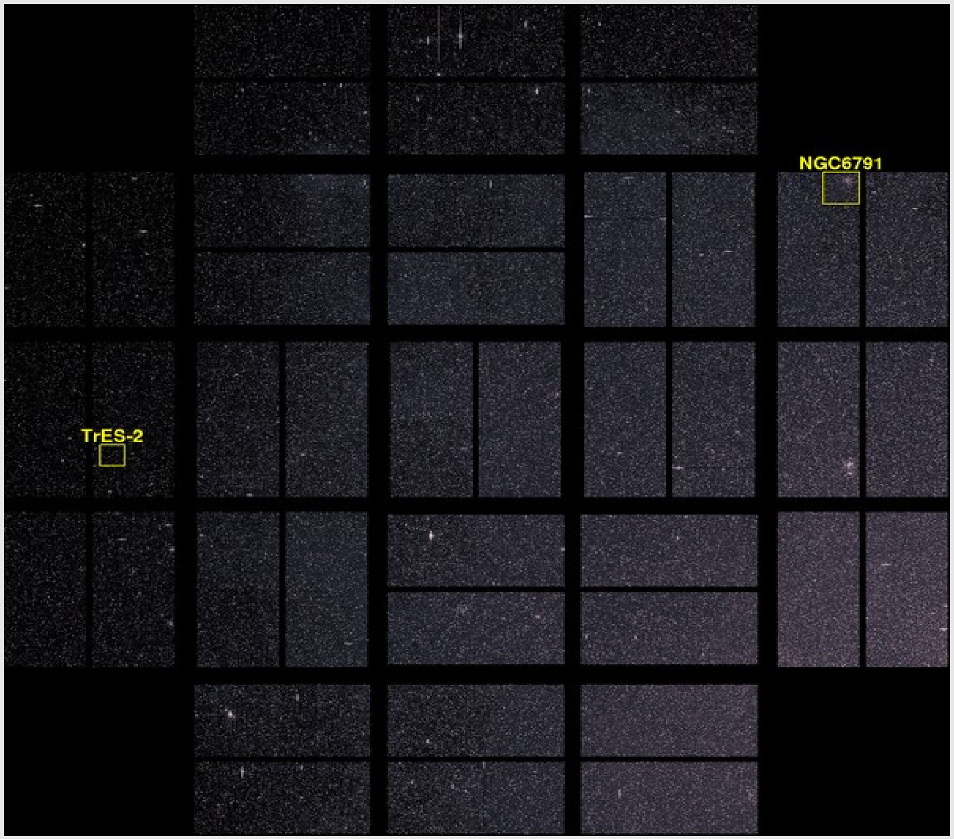
Why look at CVs?
(with Kepler)

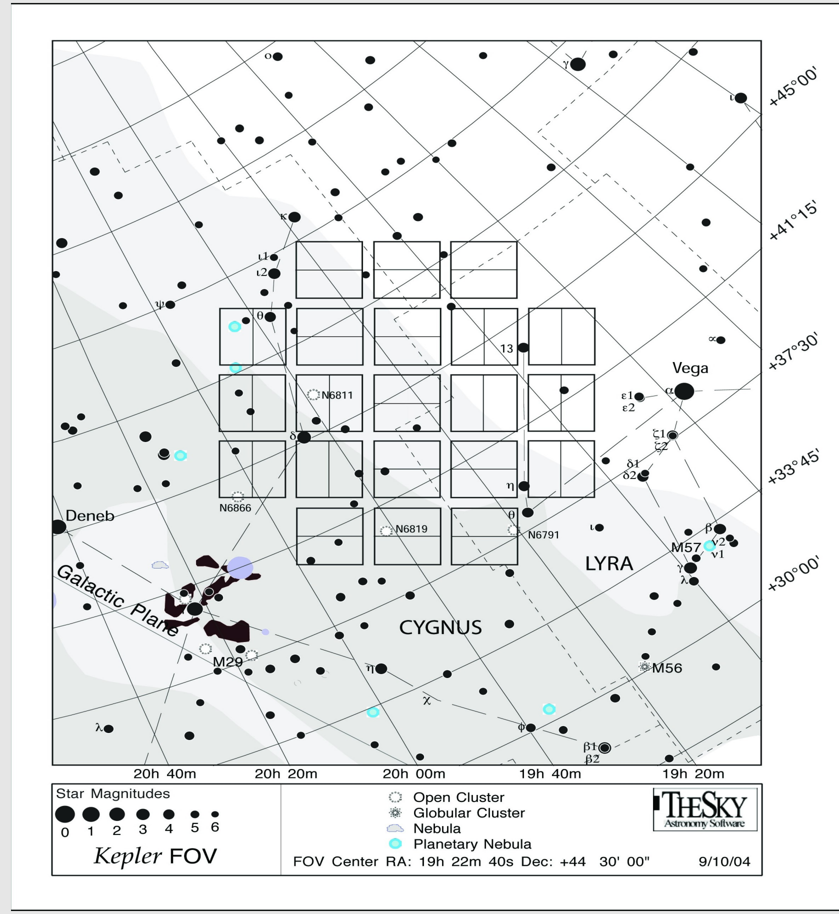
32 CCDs → 95 Megapixels!

Kepler

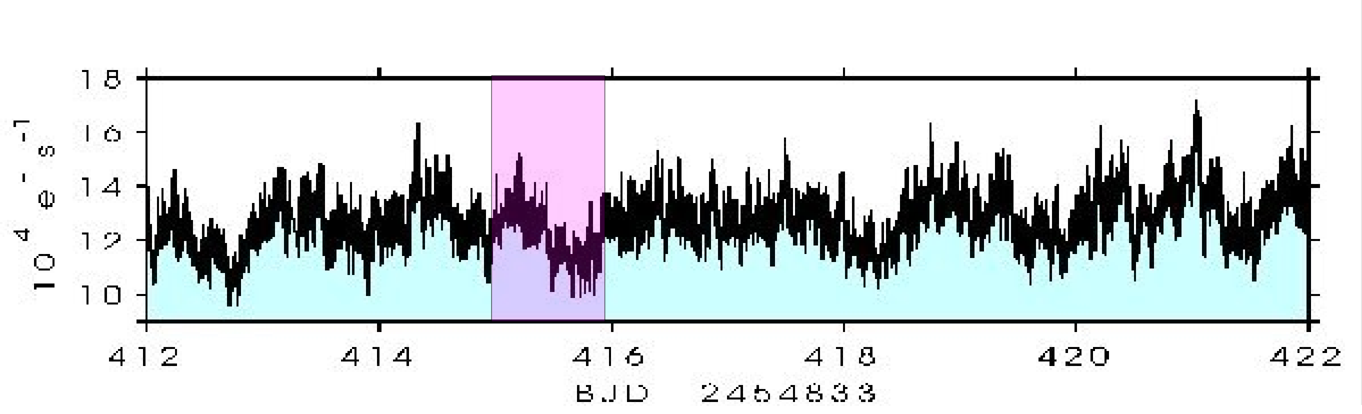
Why look at CVs?
(with Kepler)

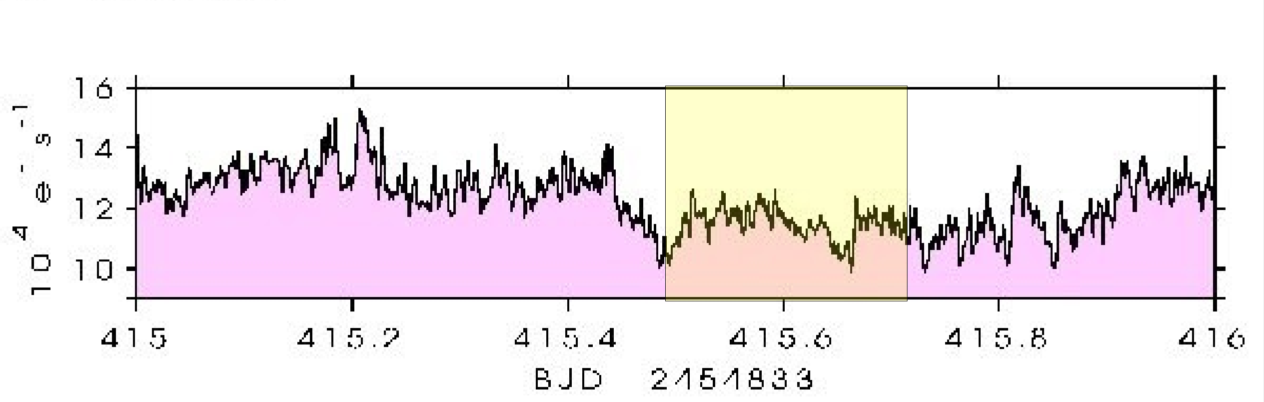
100 square degree field-of-view

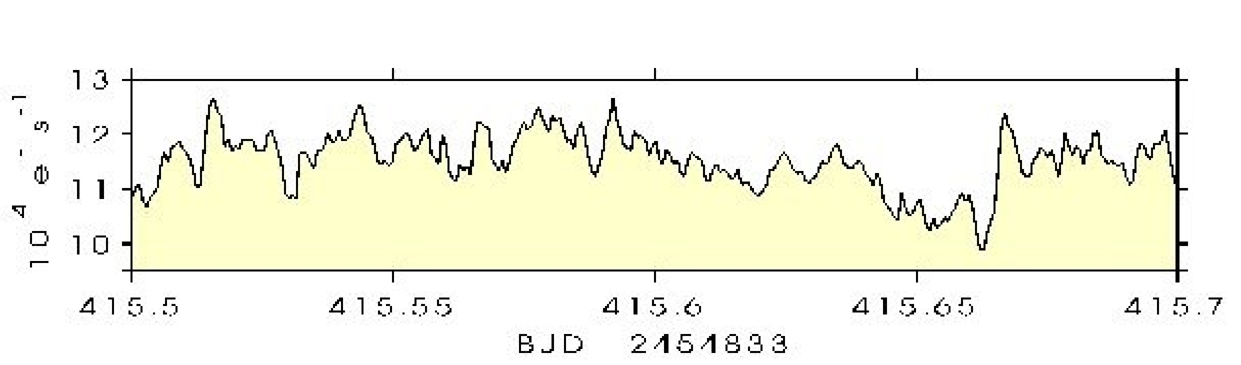




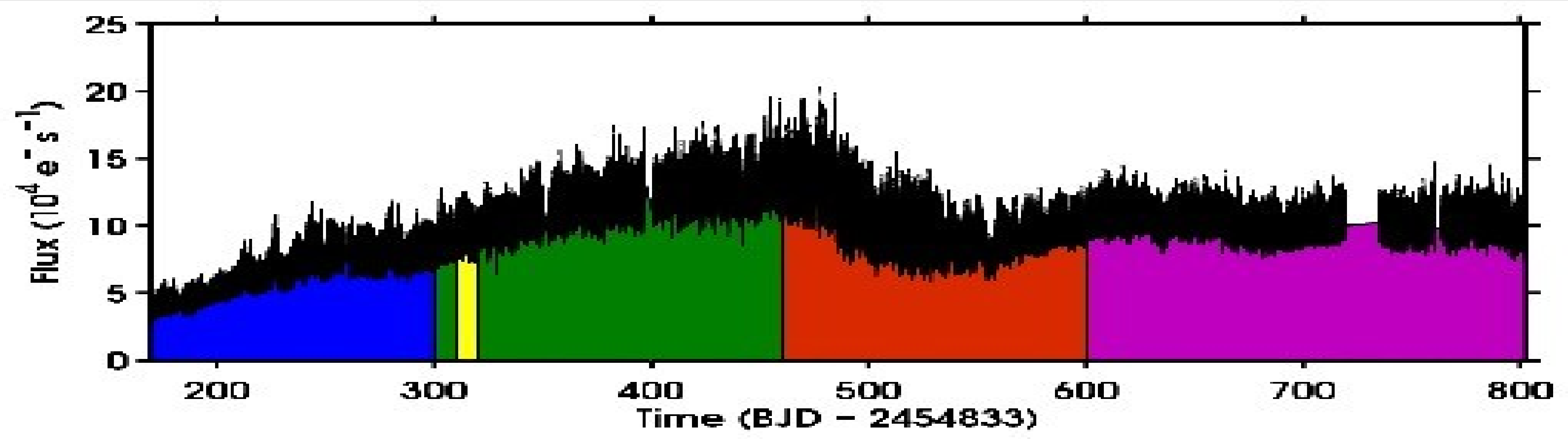
MV Lyrae with Kepler

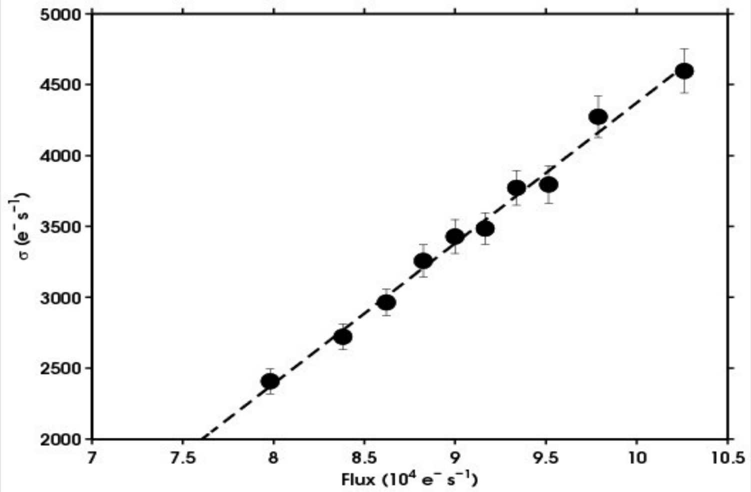


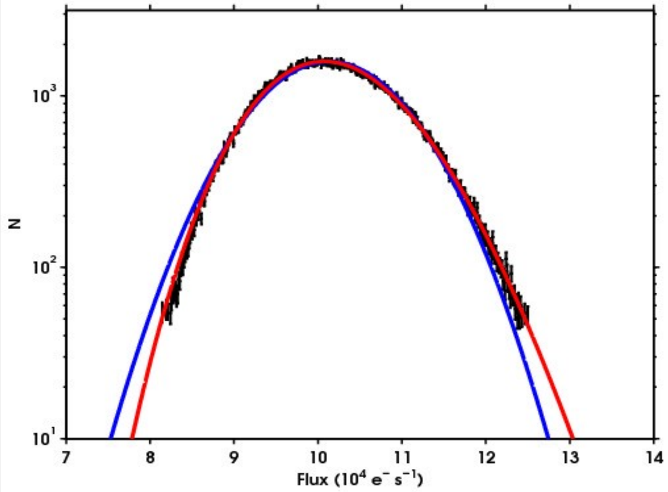




MV Lyrae with Kepler



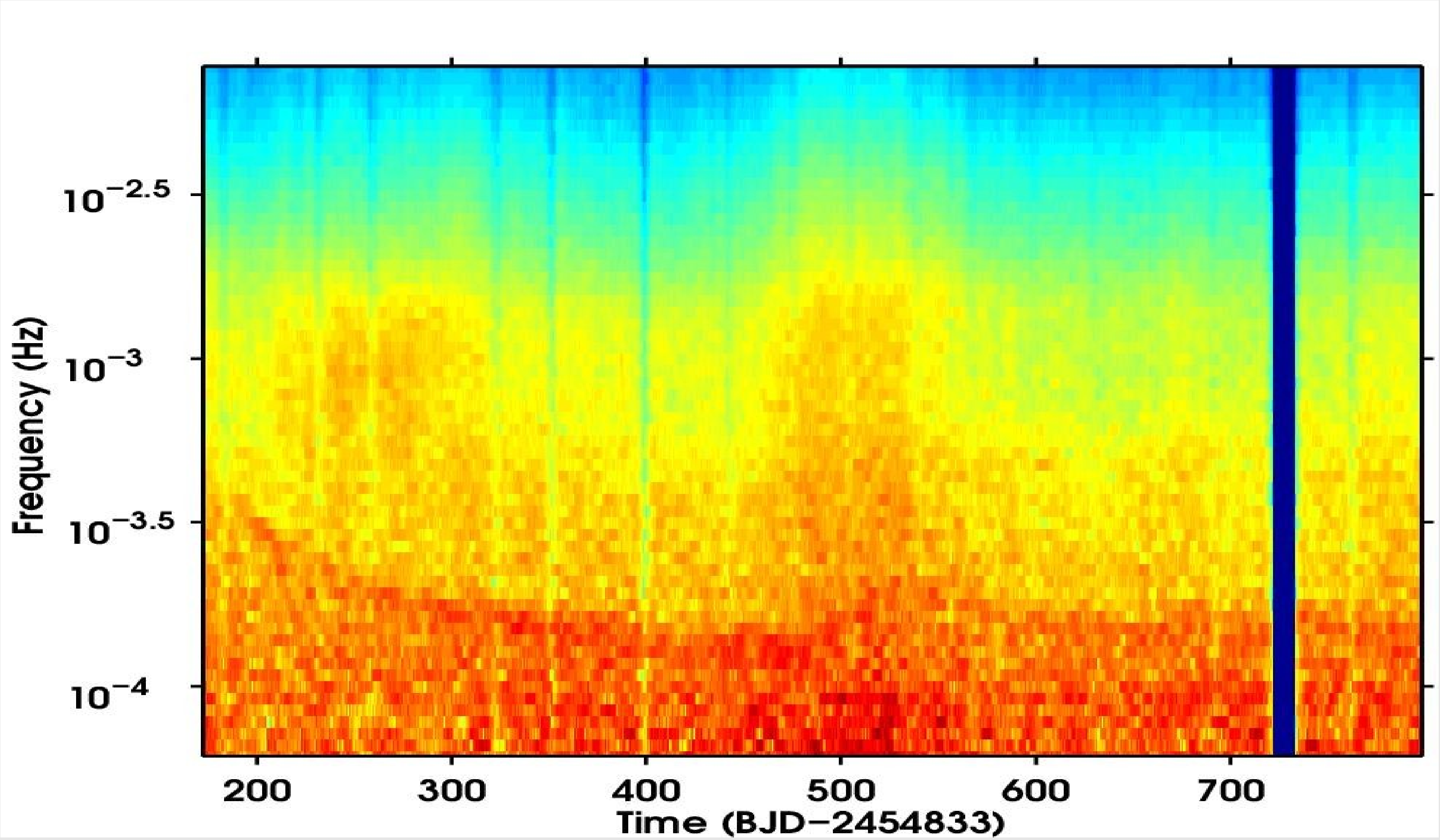




(Scaringi et al. 2012a)

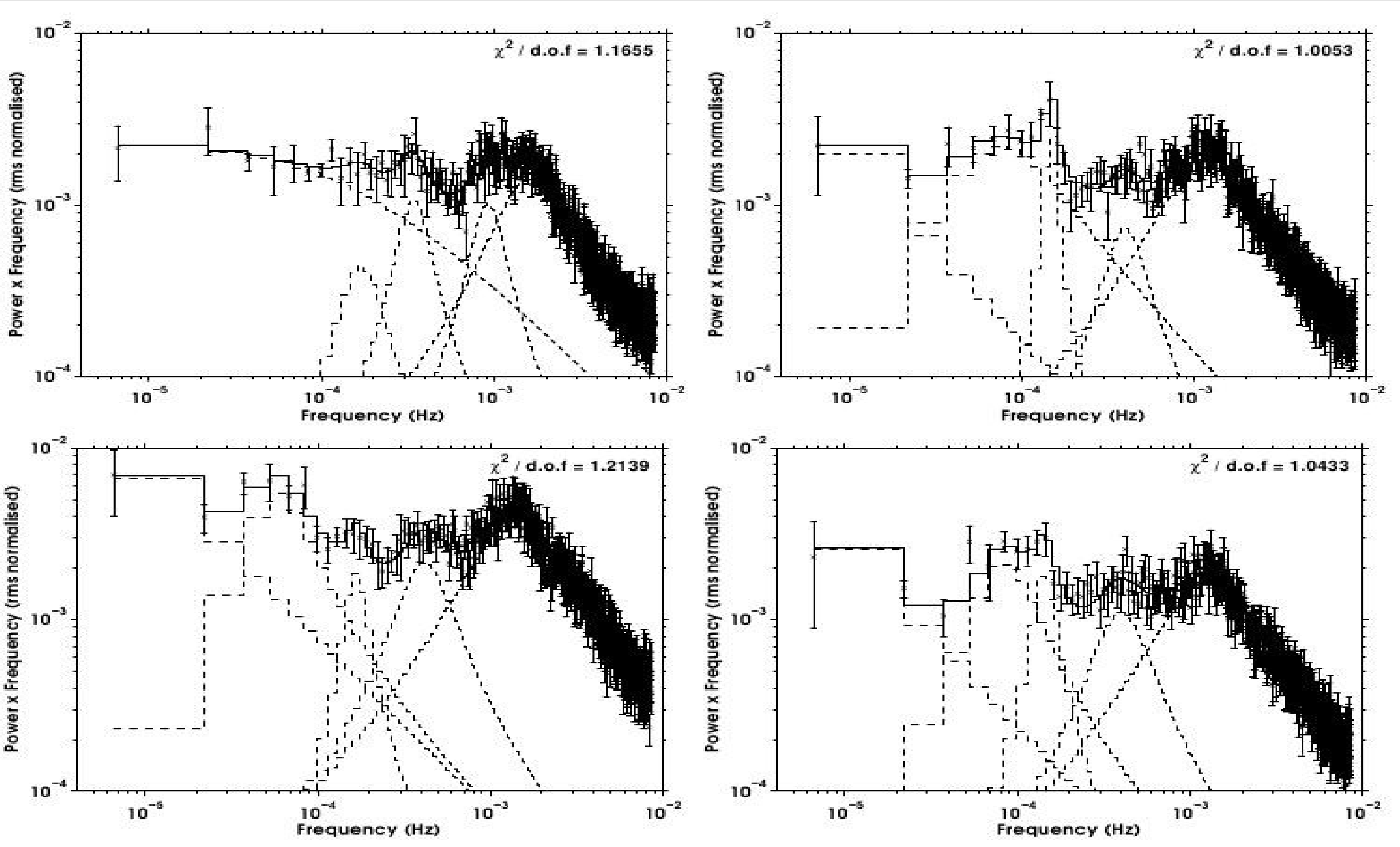
QPOs in MV Lyrae

- Dynamic PSD → 5.3 day segments with 50% overlap



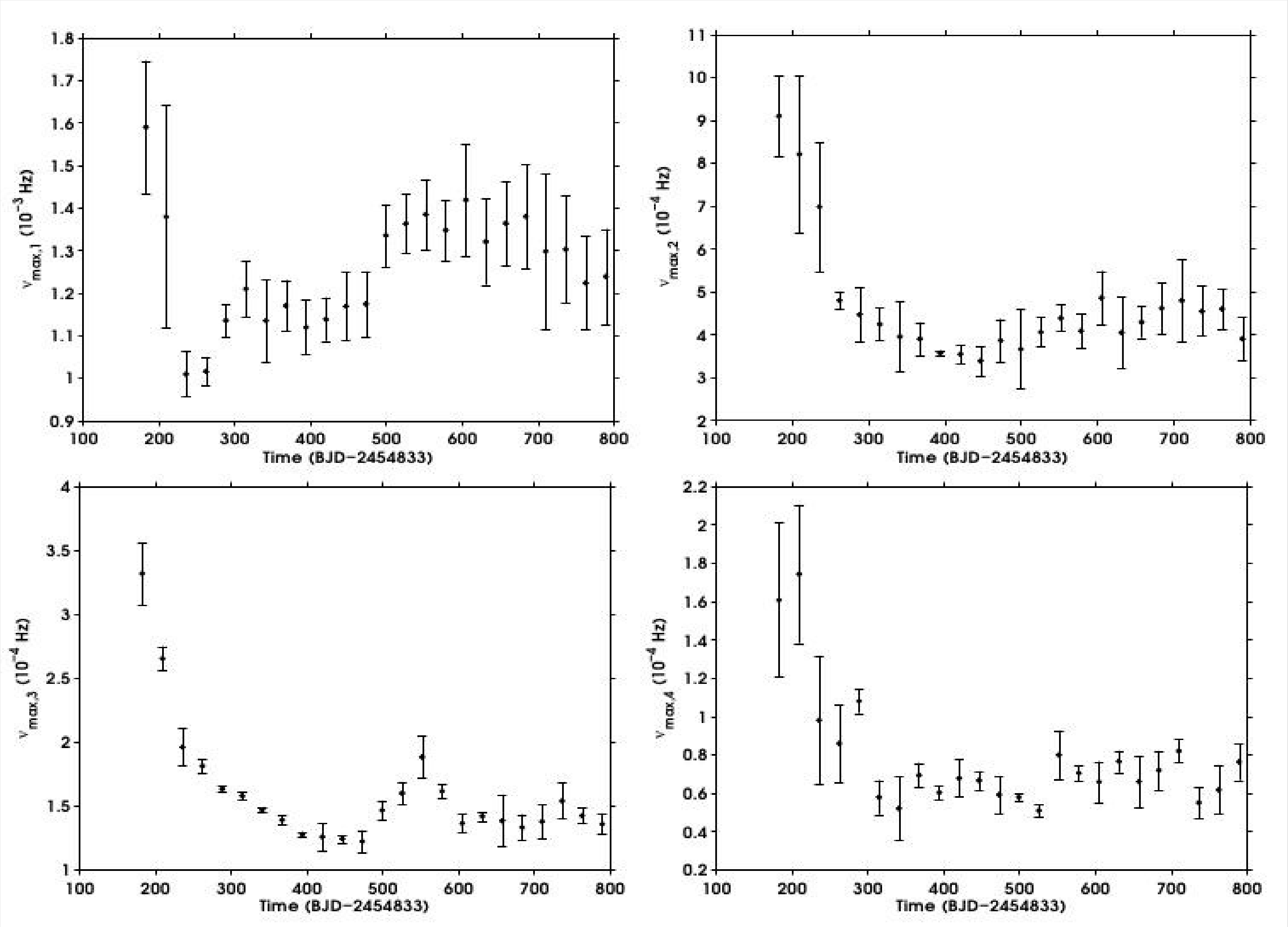
(Scaringi et al. 2012b)

QPOs in MV Lyrae

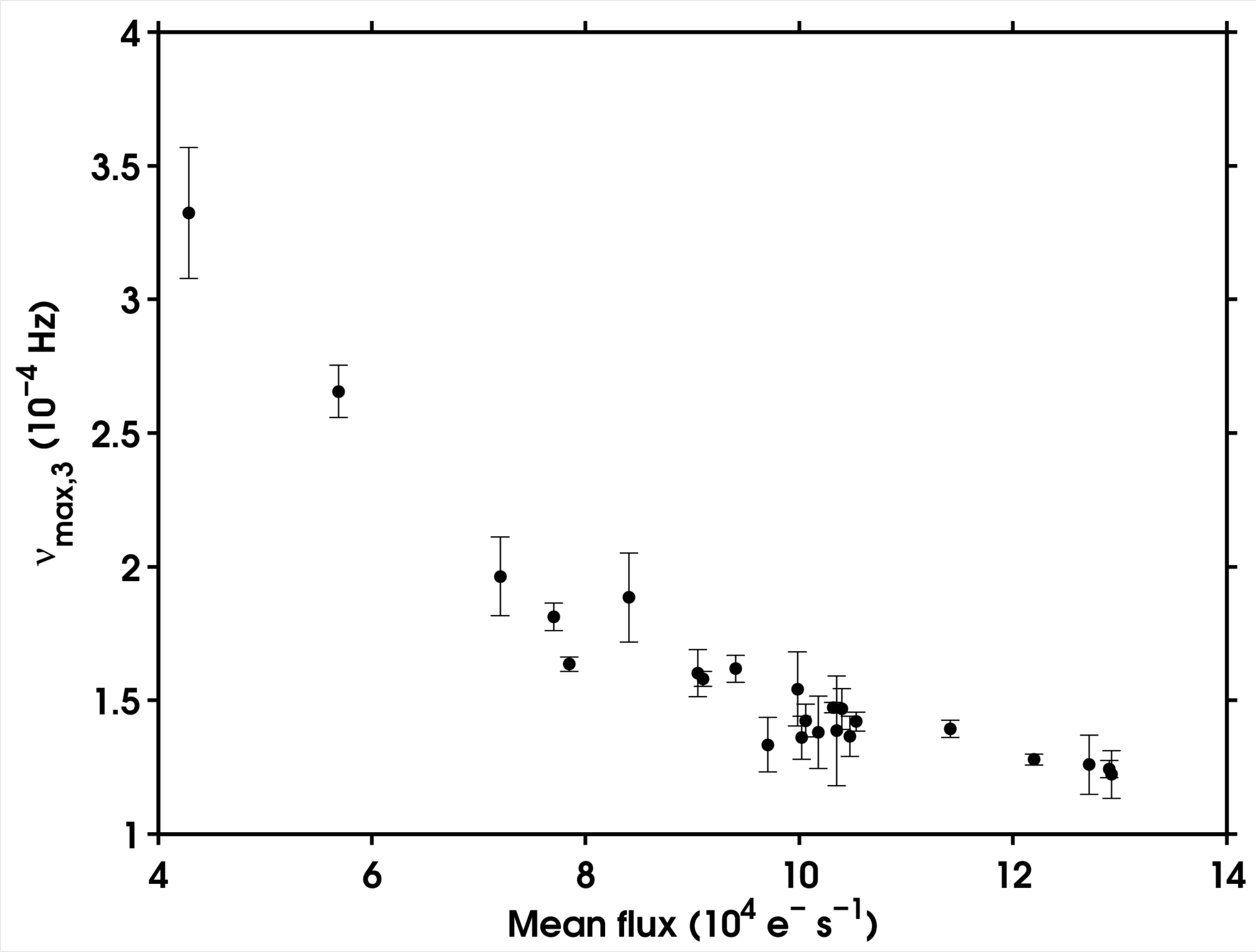


Average of 5 independent PSDs

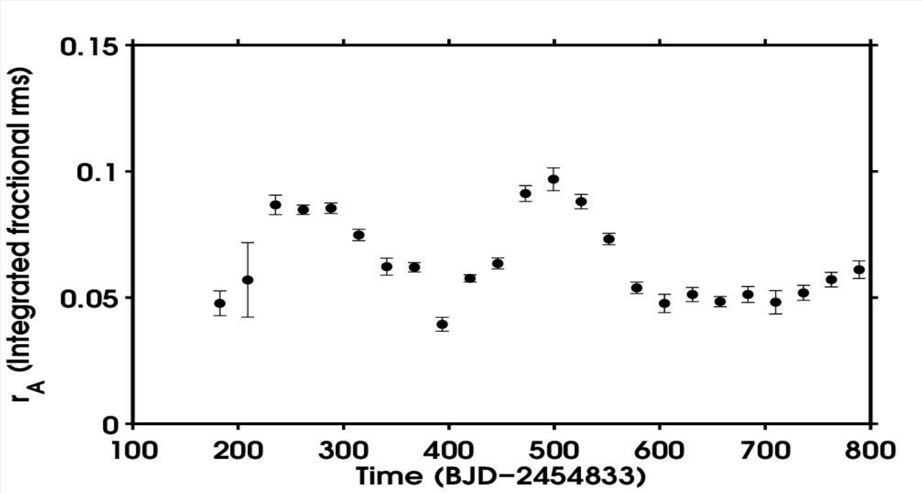
QPOs in MV Lyrae



QPOs in MV Lyrae



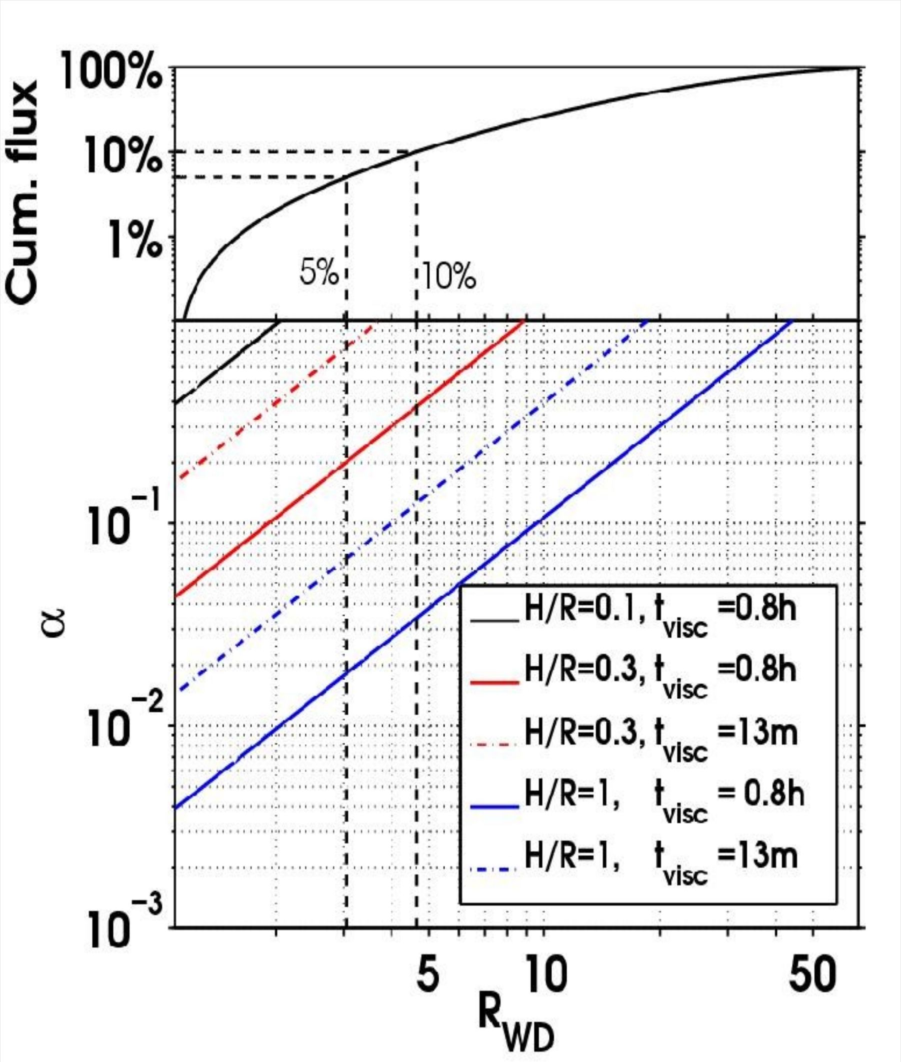
QPOs in MV Lyr



- Highest frequency Lorentzian:

  → varies between 5%-10%

  → Use this to constrain the minimum size of the emitting region



(Scaringi et al. 2012b)

Viscous or dynamical?

$$\nu_{dyn}(r) = \frac{1}{t_{dyn}(r)} = \sqrt{\frac{GM}{r^3 4\pi^2}},$$

- High frequency break
  → Accretion disk truncates at ~$10R_{WD}$
- Lowest frequency Lorentzian
  → Outer disk edge is beyond L1 point

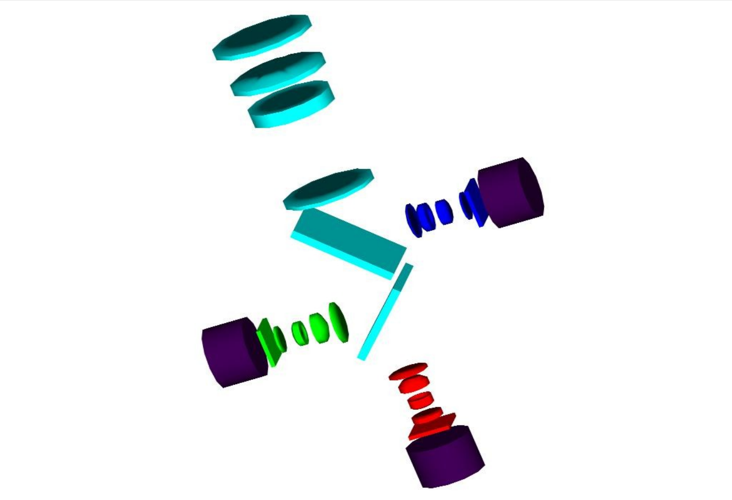
$$\nu_{visc}(r) = \alpha(H/R)^2 \nu_{dyn}(r),$$

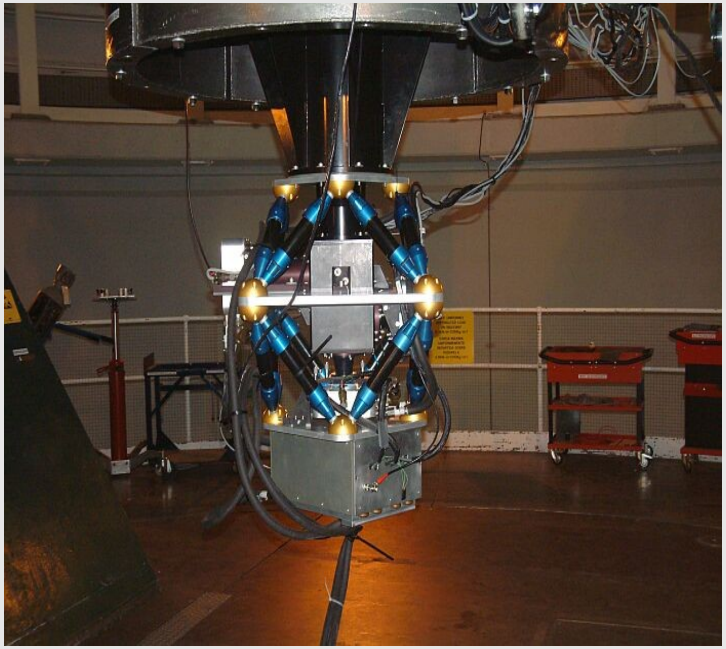
- Both high and low frequency components
  → Large $\alpha > 0.1$
  → Large $H/R > 0.3$

Coherence and Fourier time lags in MV Lyr and LU Cam

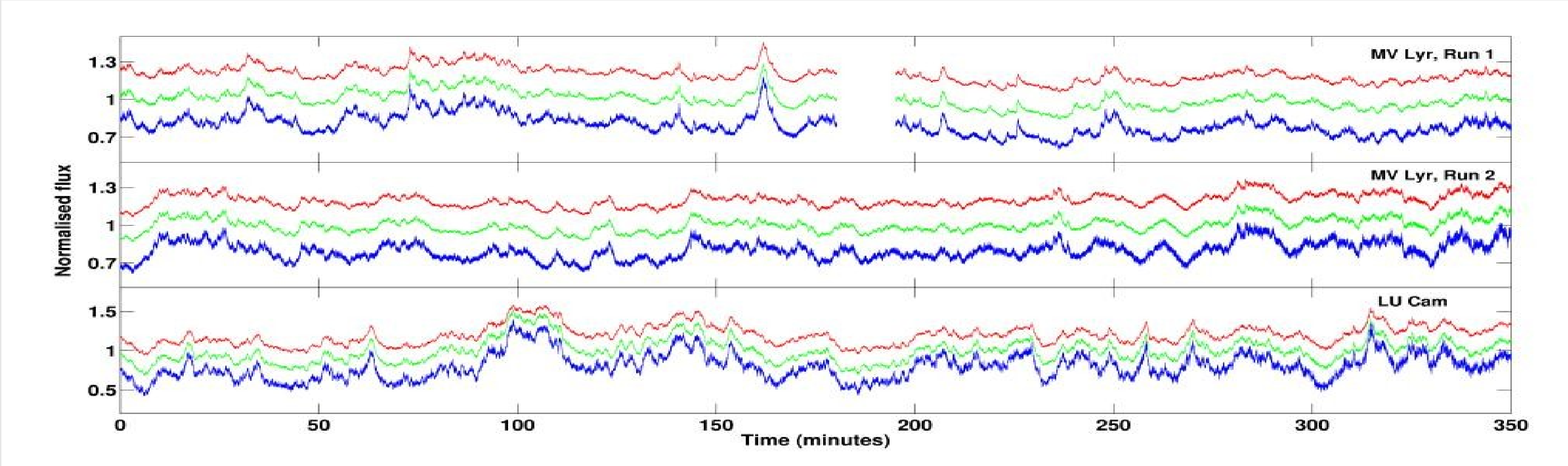
- ULTRACAM observations on the 4.2 m WHT with simultaneous *u', g', r'*
- MV Lyr → 12h, ~0.8s cadence

  LU Cam → 6h, ~1.3s cadence

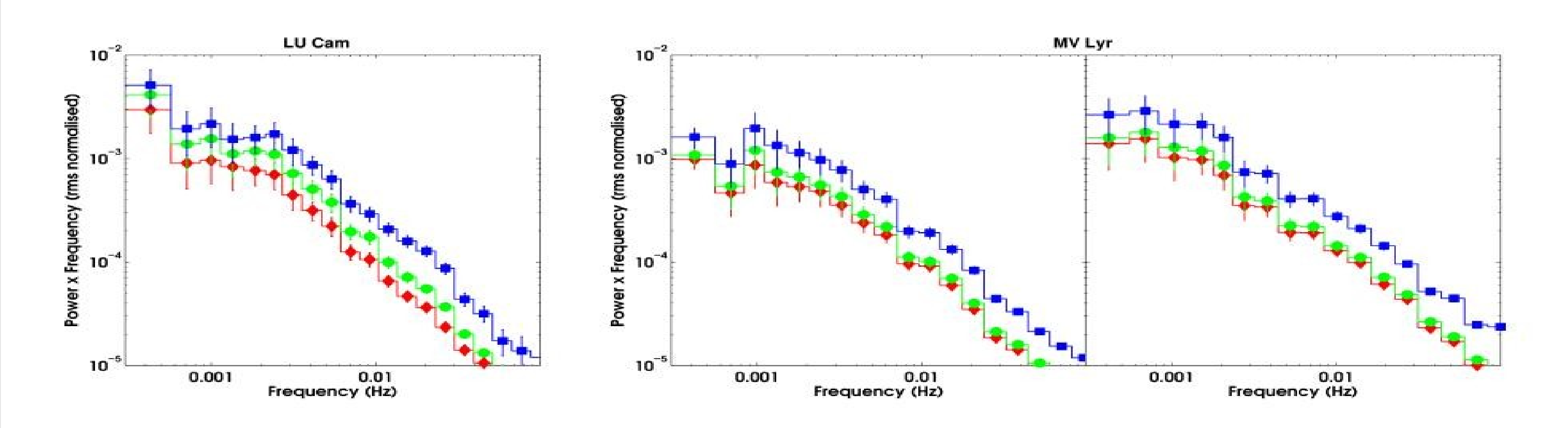




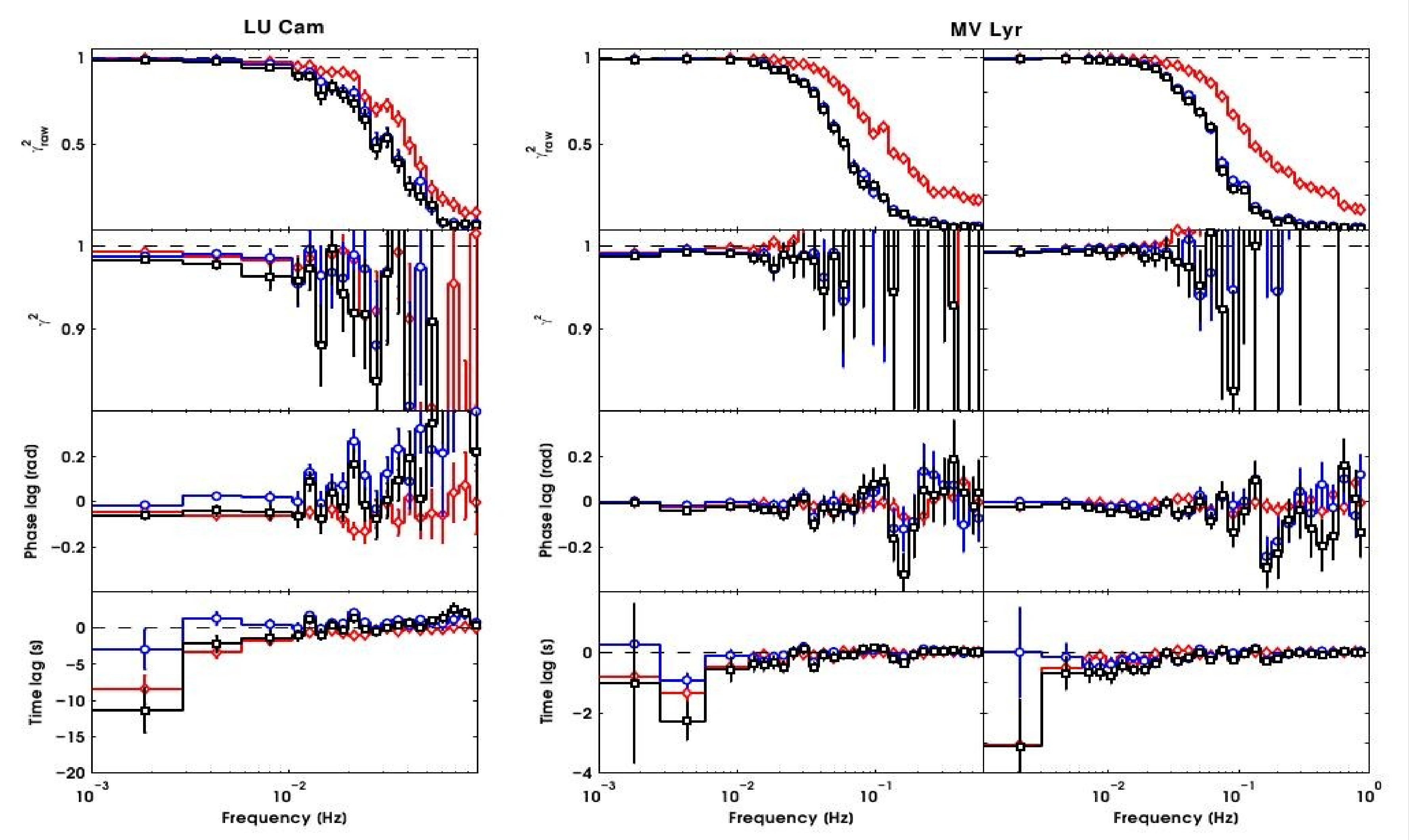
Coherence and Fourier time lags in CVs



u'
g'
r'



Coherence and Fourier time lags in CVs



u'-r' g'-r' u'-g'

(Scaringi et al. 2013)

Coherence and Fourier time lags in CVs

- Soft-lags → ~~Viscous propagation~~
- Disk reprocessing from boundary layer photons/"corona"/?

AGN - XRBs	**CVs**
High-energy photons photoionising disk surface layers	UV photons heating disk surface layers
→ Soft-lags observed as "reflection" from different disk radii (Fabian et al. 2009, De Marco et al. 2013)	→ Disk reprocesses photons and re-emits them on the thermal timescale
→ Lags interpreted as light-crossing time from central object to disk	→ Lags interpreted as thermal timescale at specific disk radius?

Future work...

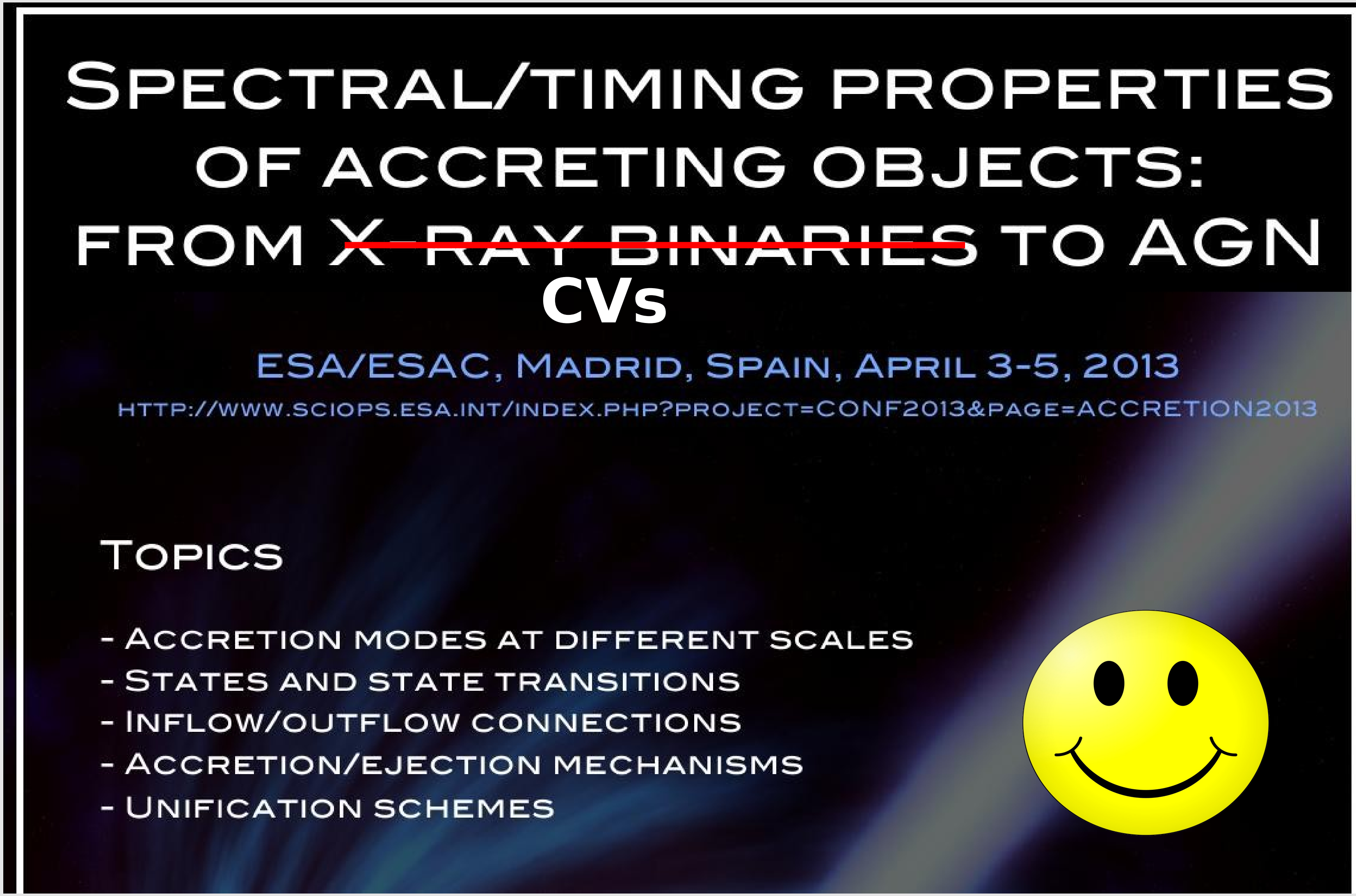
- Look at Fourier-dependent time-lags in Dwarf Nova (SS Cyg?)

  → Will the more "standard" CVs show hard-lags?

- Broad-band variability comparison of a population of CVs to XRBs/AGN

  → Known Kepler CVs ~40, and more to be found! (maybe an XRB as well?)

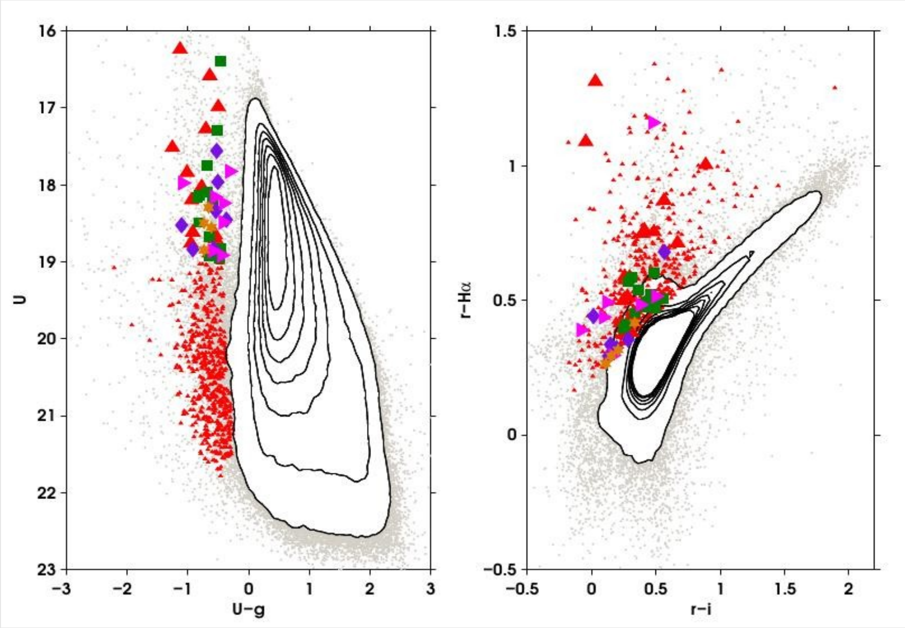
- AGNs with Kepler! (~400 in the FOV)
- Making sense of all of it!

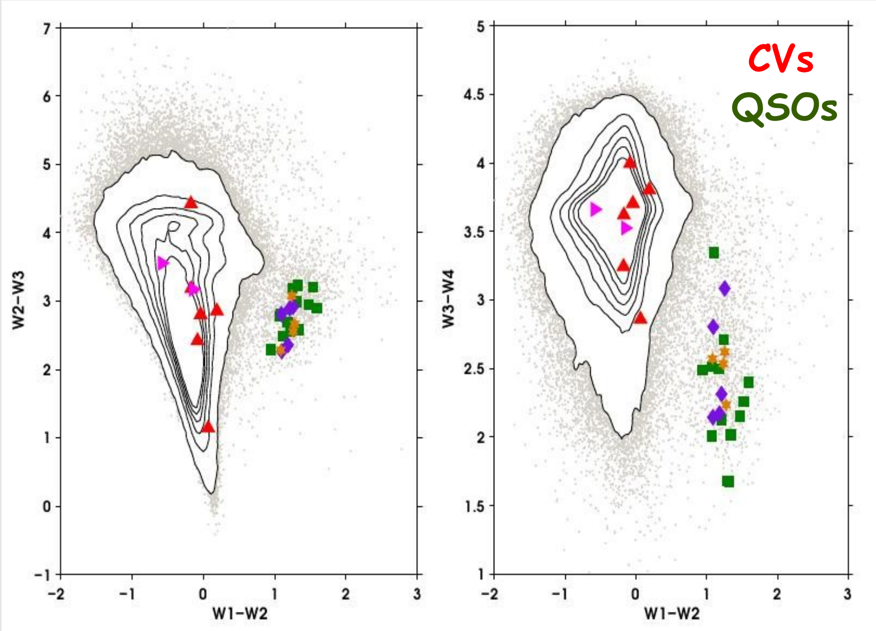

Spectral/timing properties
of accreting objects:
from ~~X-ray binaries~~ to AGN
CVs
ESA/ESAC, Madrid, Spain, April 3-5, 2013
http://www.sciops.esa.int/index.php?project=conf2013&page=accretion2013
Topics
- Accretion modes at different scales
- States and state transitions
- Inflow/outflow connections
- Accretion/ejection mechanisms
- Unification schemes

Thanks!

Kepler-INT Survey (KIS)
(U, g, r, i, Ha)

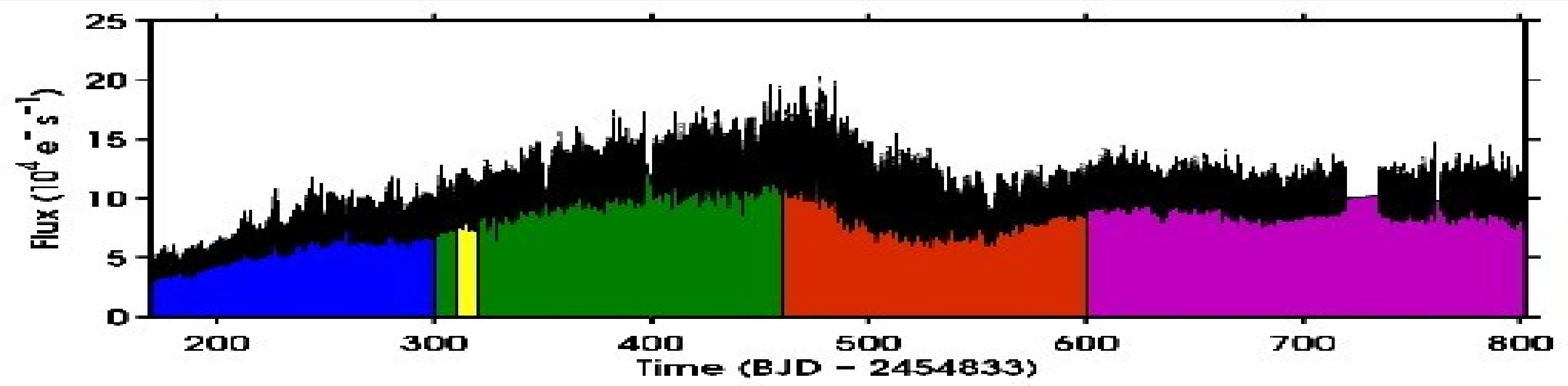
Blue excess sources + H-alpha excess sources + WISE colours



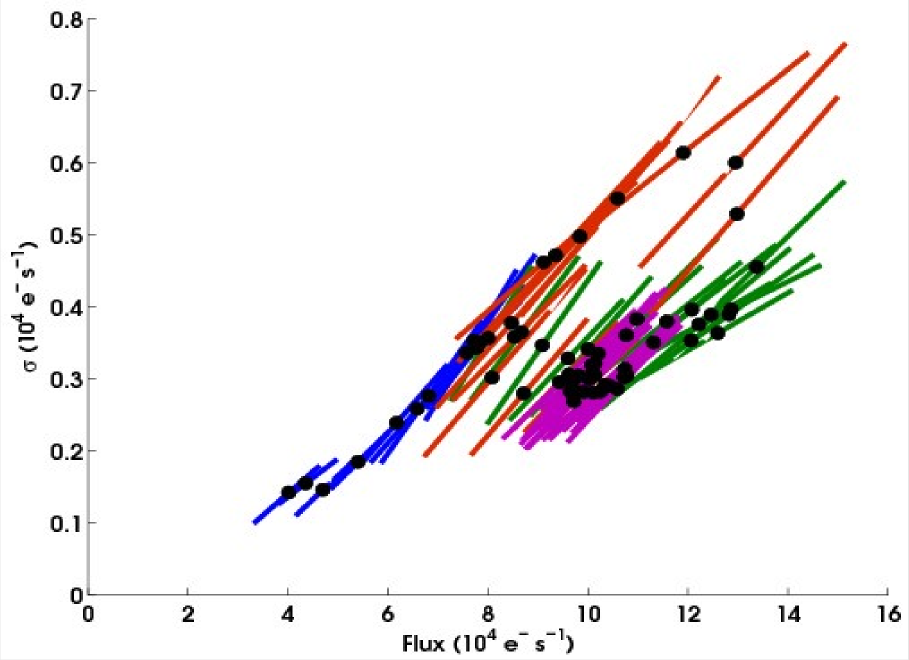


(Scaringi et al. 2012c)

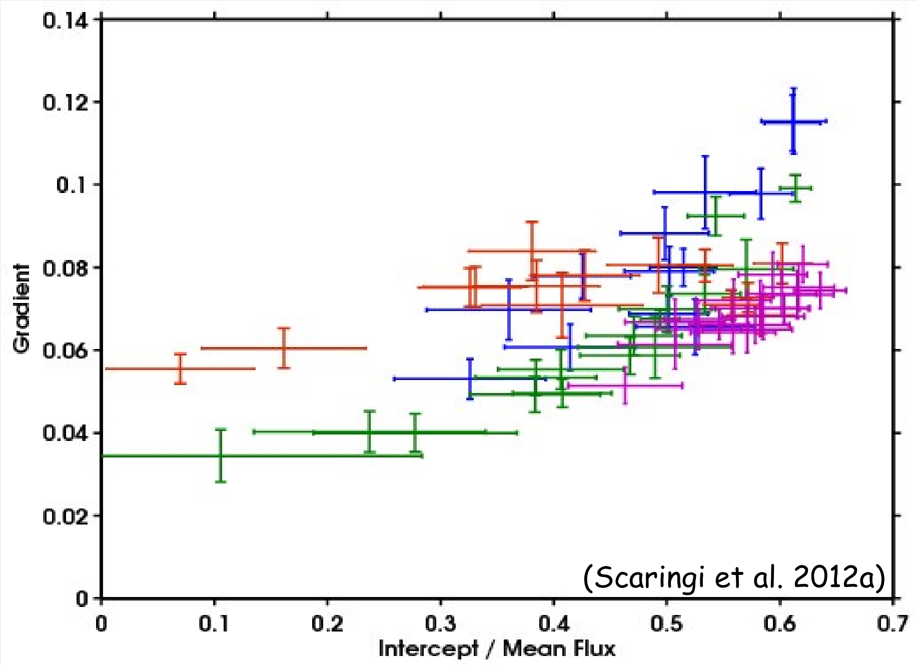
MV Lyrae



Flux (10^4 e$^-$ s^{-1})
Time (BJD − 2454833)

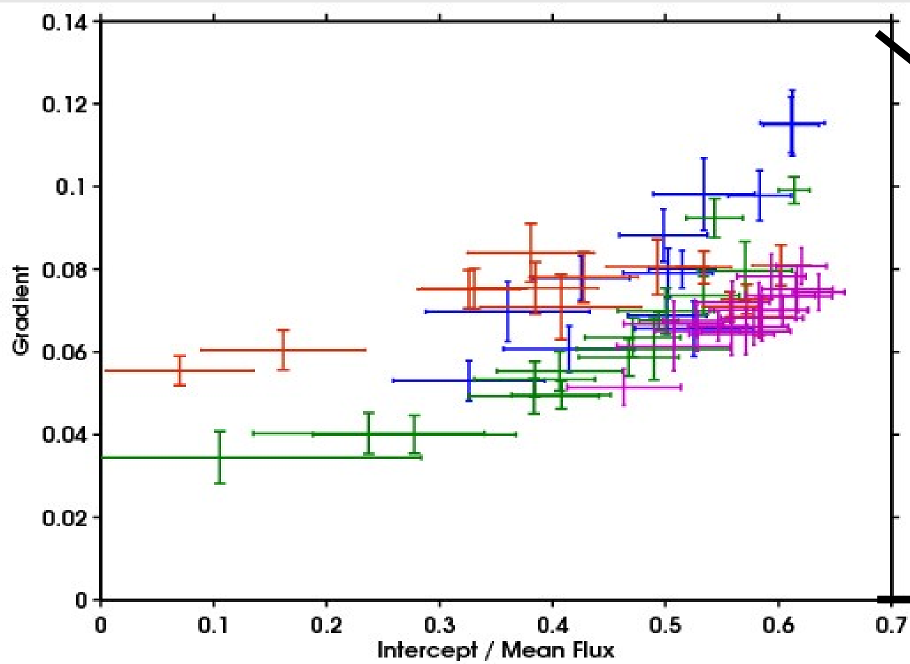


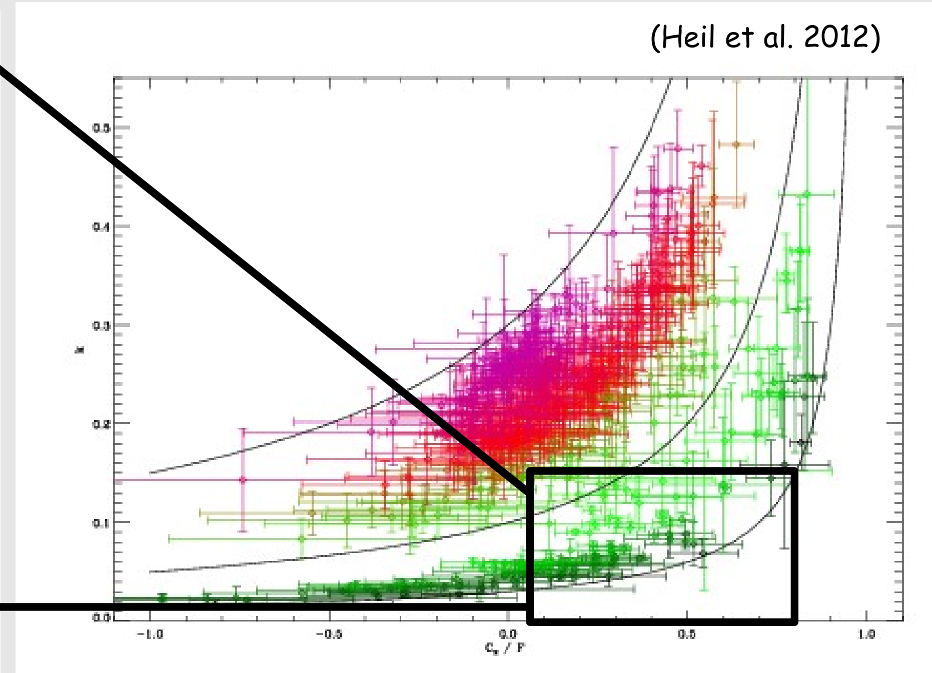
σ (10^4 e$^-$ s^{-1})
Flux (10^4 e$^-$ s^{-1})



Gradient
Intercept / Mean Flux
(Scaringi et al. 2012a)

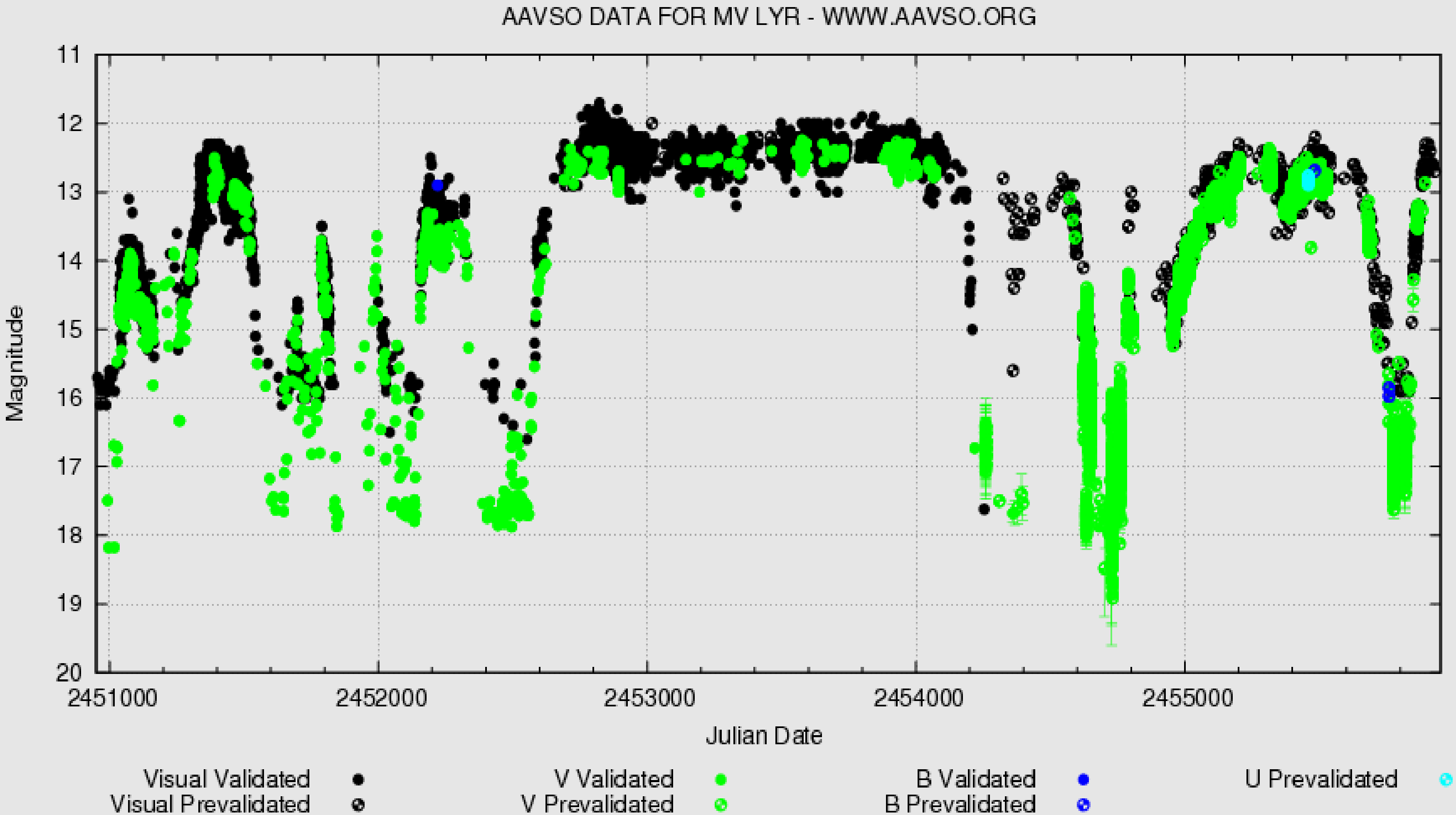
MV Lyrae vs. Black holes





- The obtained rms-flux relations are remarkably similar between BH accretors (X-rays) and WD accretors (optical)

MV Lyrae



AAVSO DATA FOR MV LYR - WWW.AAVSO.ORG
Magnitude
11
12
13
14
15
16
17
18
19
20
2451000
2452000
2453000
2454000
2455000
Julian Date
Visual Validated
Visual Prevalidated
V Validated
V Prevalidated
B Validated
B Prevalidated
U Prevalidated