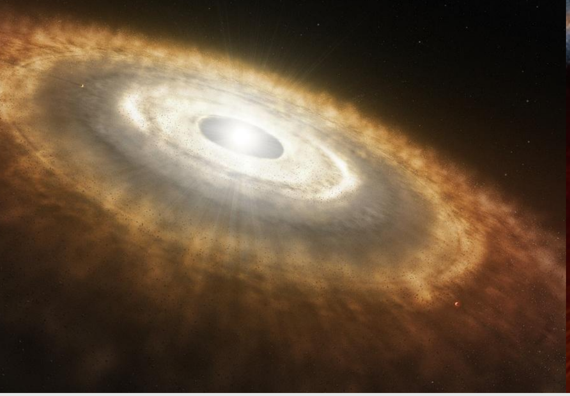


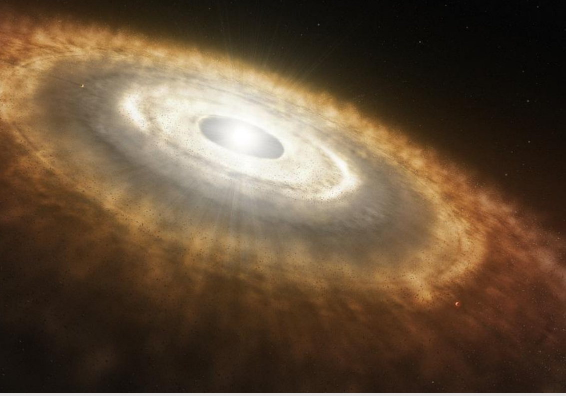
What’s so great about accreting white dwarfs?

A brief (and biased!) review

Simone Scaringi

simone.scaringi@durham.ac.uk

Durham University



1) **Why study accretion? Why accreting white dwarfs?**
2) **Aperiodic variability properties**
3) **Magnetic gating vs. Type-II bursts**
4) **Transitional accreting white dwarfs vs. tMSPs**
5) **Micronovae vs. Type-I bursts**

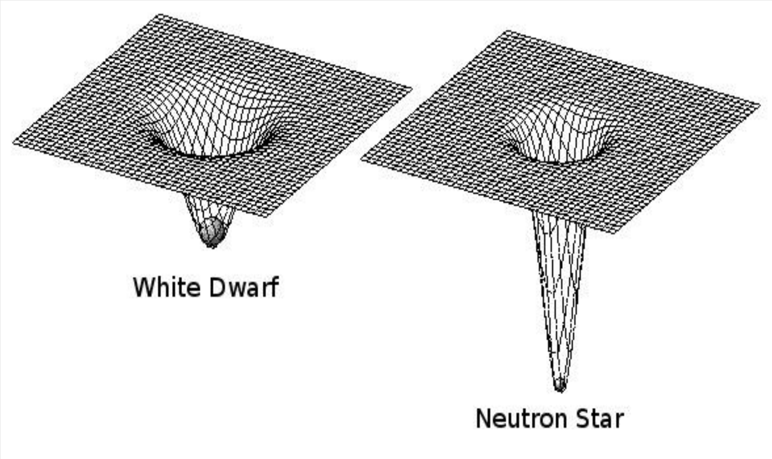
Martina Veresvarska (PhD)

Matteo Fratta (PhD)

Krystian Ilkiewicz (PD)

Accretion across the scales

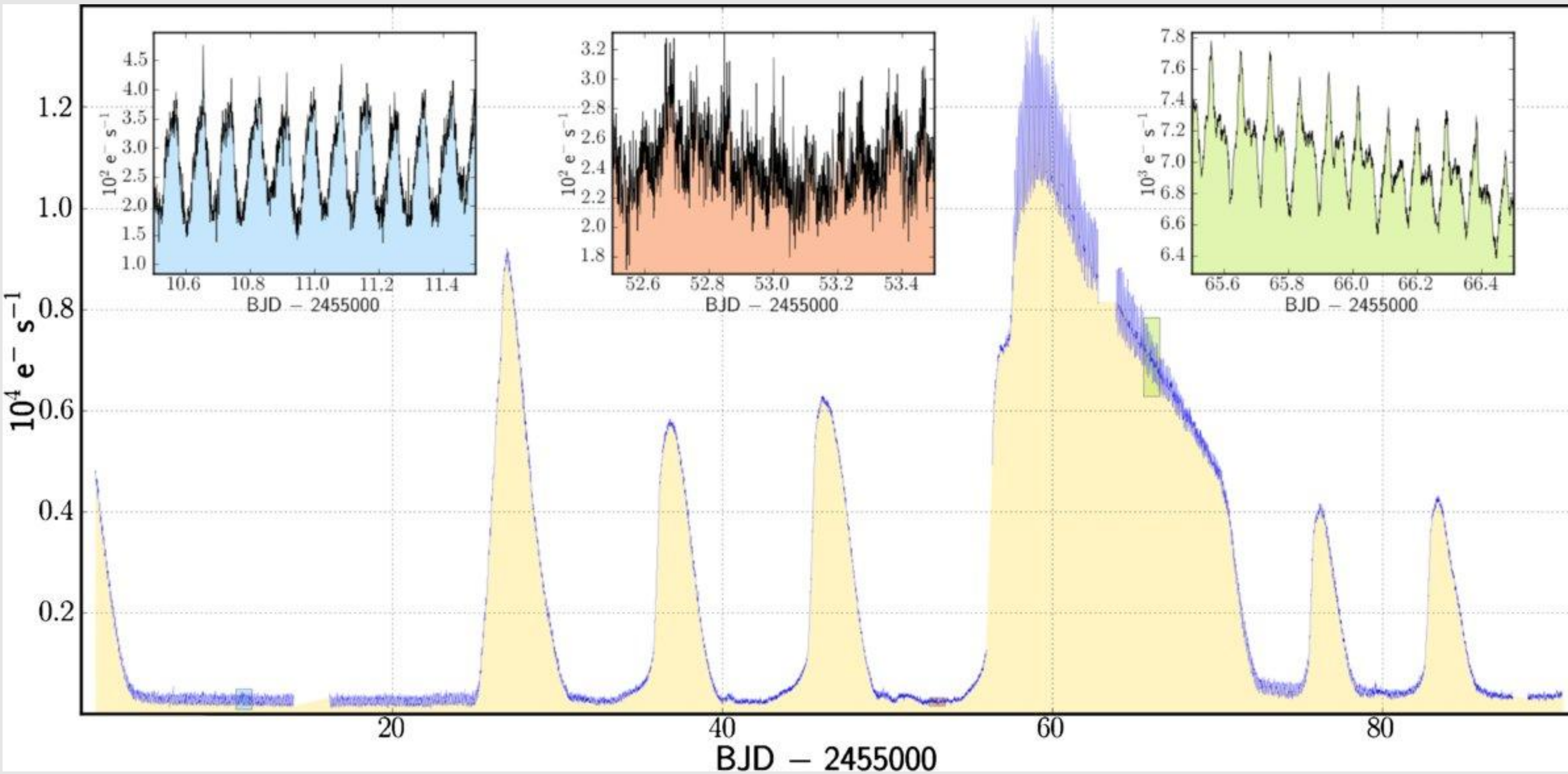
- Disk theory supposedly the same across different system types
- Disk dynamics governed by the embedded gravitational potential:



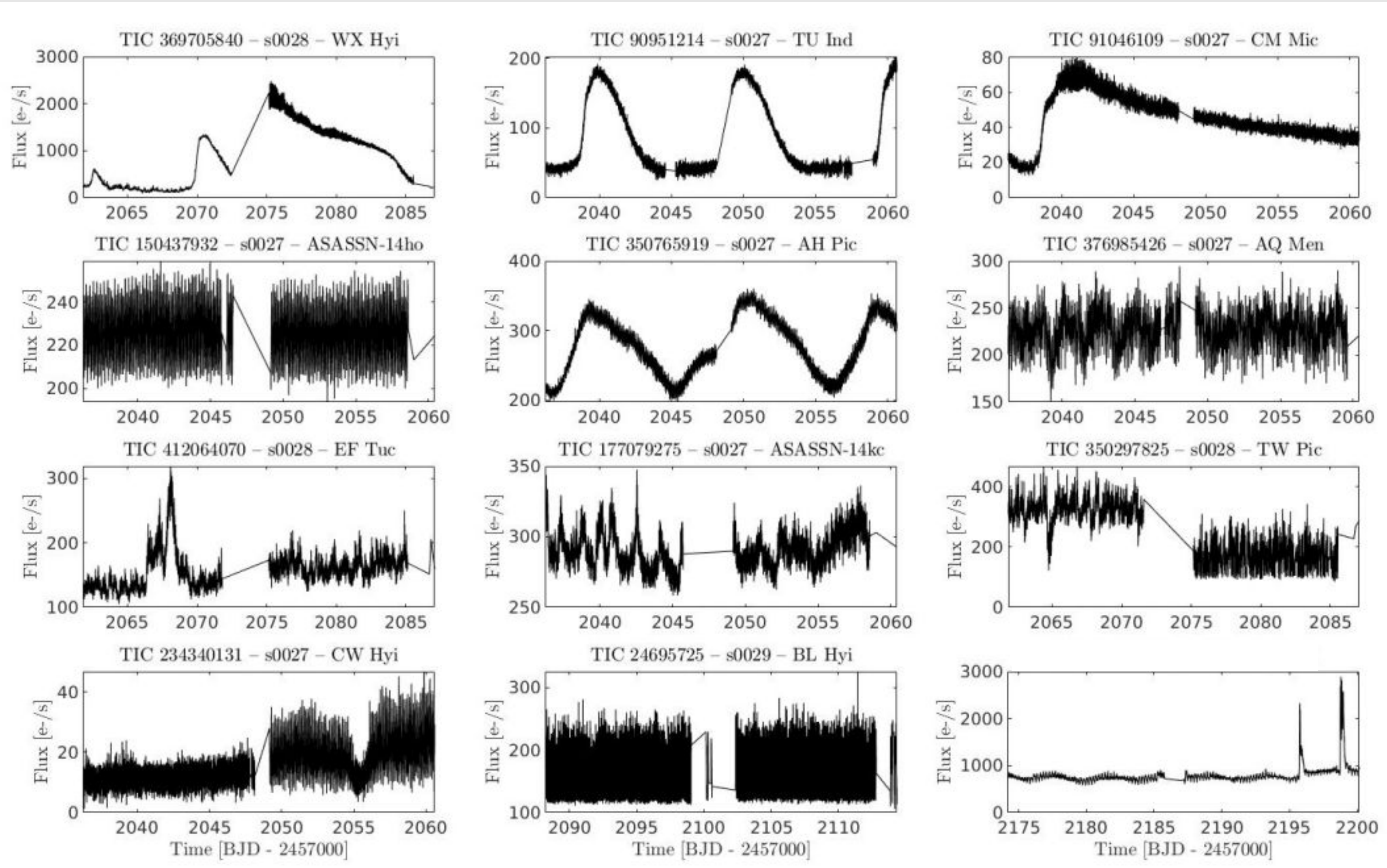
	BHs/NSs (XRBs)	WDs (CVs)	YSOs	AGN
Surface	~ km	~ thousand km	~ 10 million km	~ 10 million km
Emission	X-rays	Opt/UV	IR/Opt	UV/X-rays
t_{dyn}	~1 millisecond	~10 seconds	~2 days	~2 days
Dynamic Range	$\sim 10^7$	~300	$\sim 10^6$	$\sim 10^8$

Accretion disk instabilities

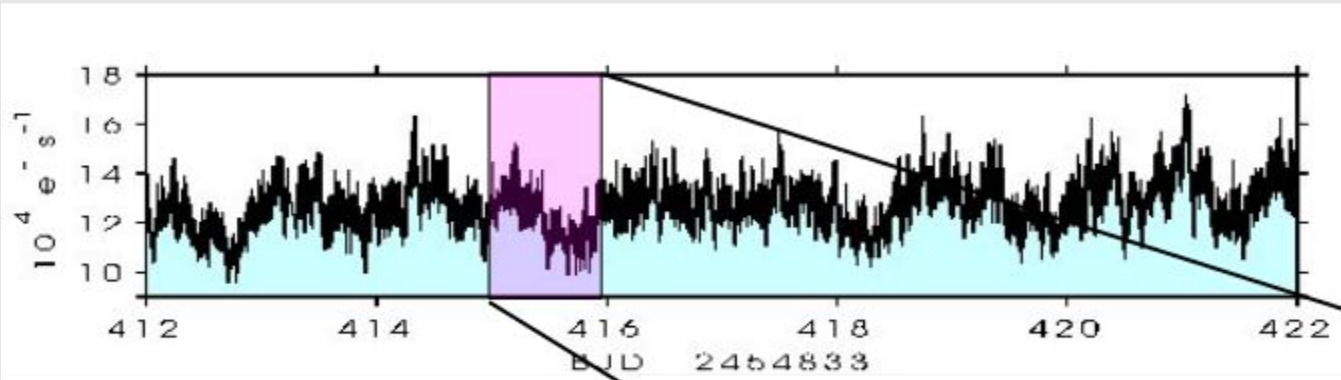
V344 Lyrae with Kepler



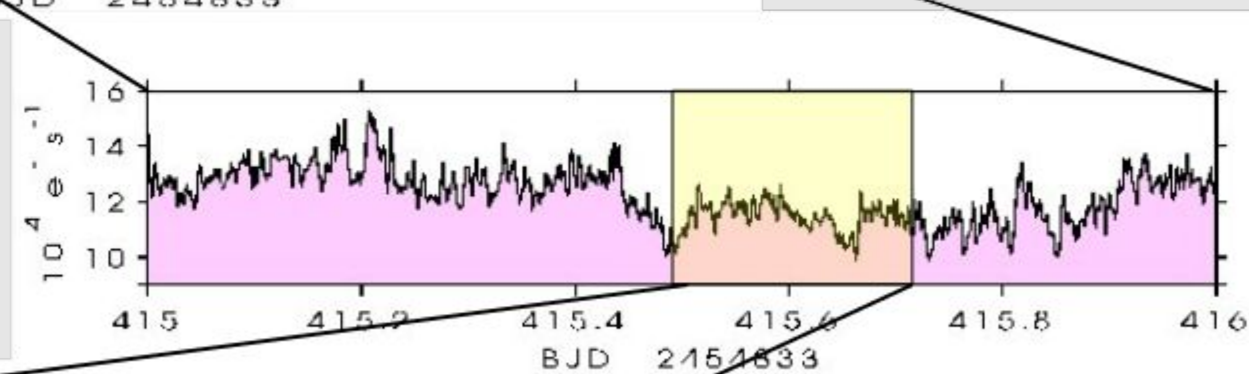
TESS atlas of AWD – Cycle 3

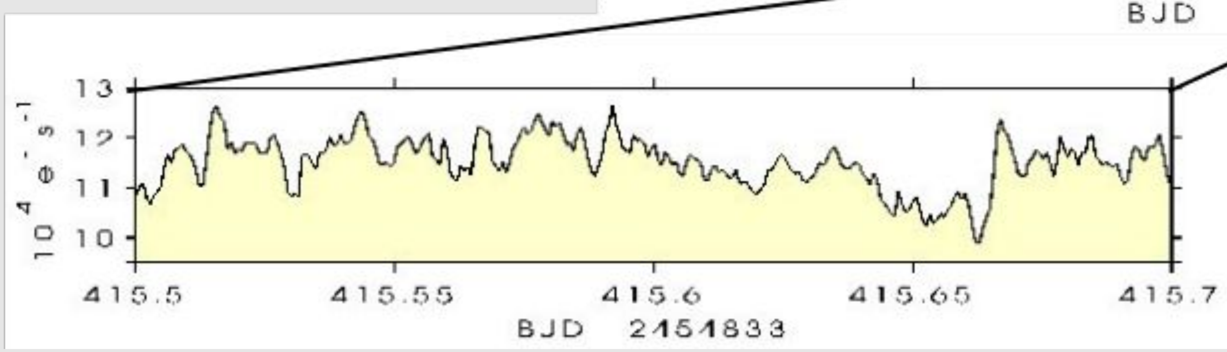


Broad-band variability



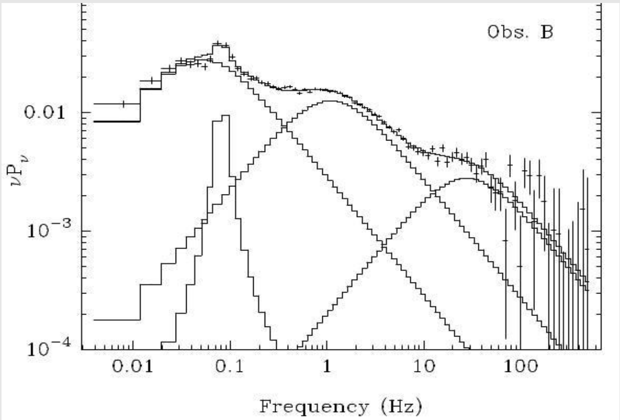
MV Lyrae
with Kepler



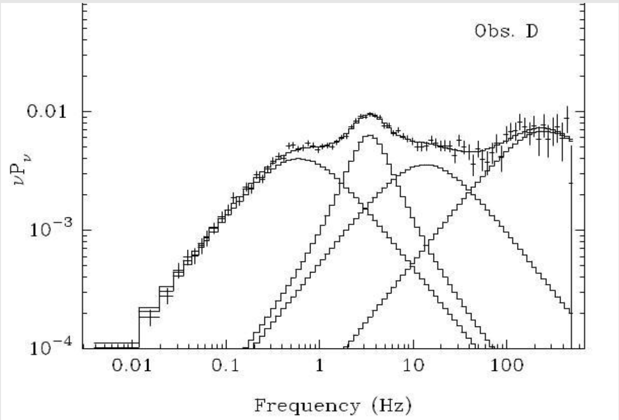


Power spectral densities:
some examples

Black hole XRB

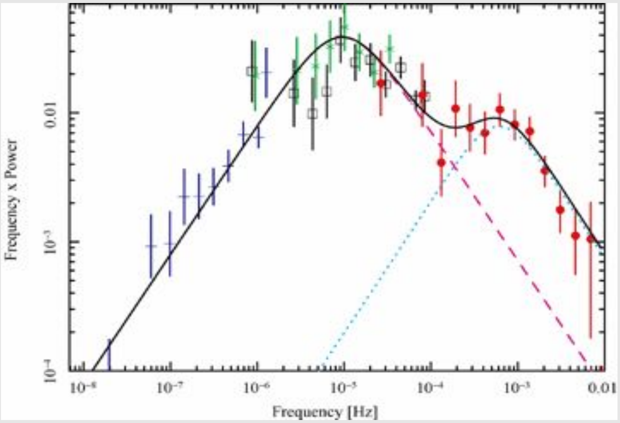


Neutron star

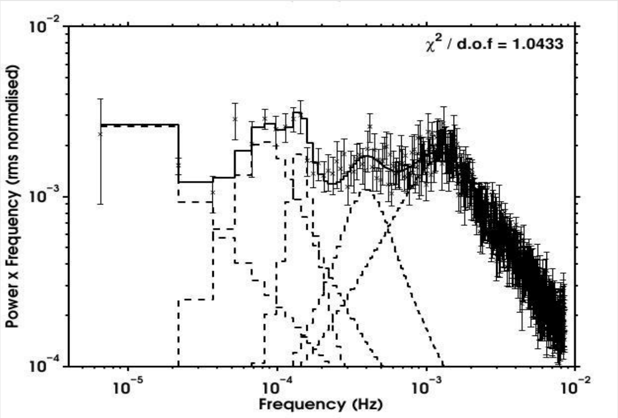


Belloni+ (2002)
McHardy+ (2007)
Scaringi+ (2012b)

AGN

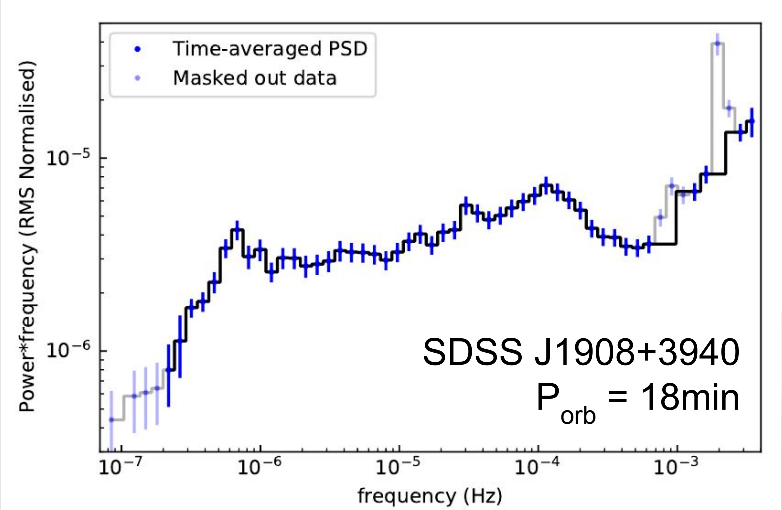


White dwarf



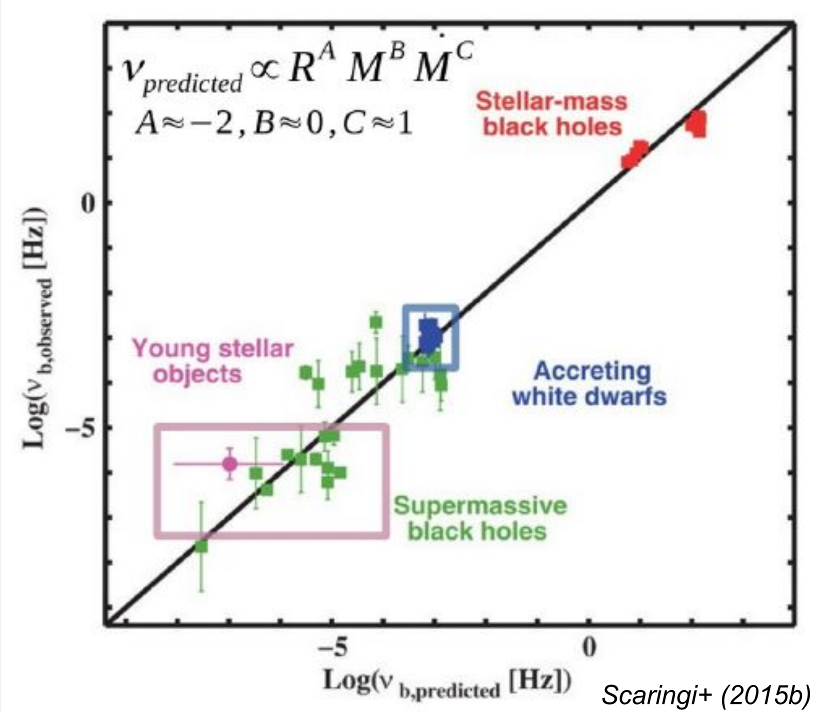
The accretion variability plane

1) Need both novalikes (high Mdot) **and** dwarf nova in quiescence (low Mdot)
2) Where is the outer disk edge?
   -> Need longer obs.



Veresvarska & Scaringi (2022, submitted)

Figure 1. Time-averaged PSD of SDSS J1908+3940 with the segment length of 60 days and masked out periodic signals in the white noise dominated high frequency regime and low frequency masked out data below the segment window length limit.

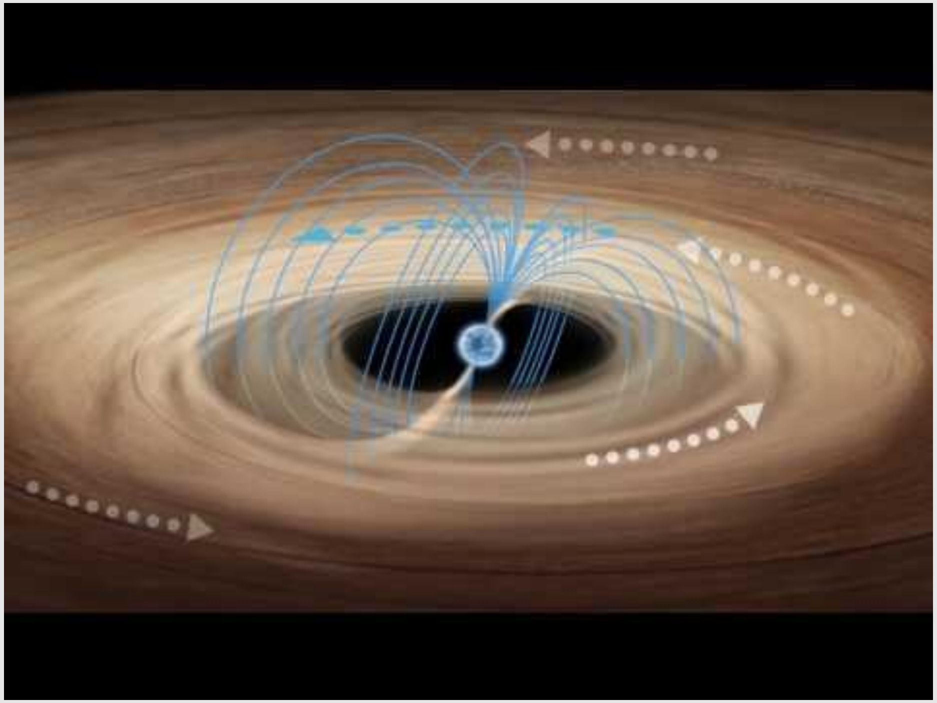


Scaringi+ (2015b)

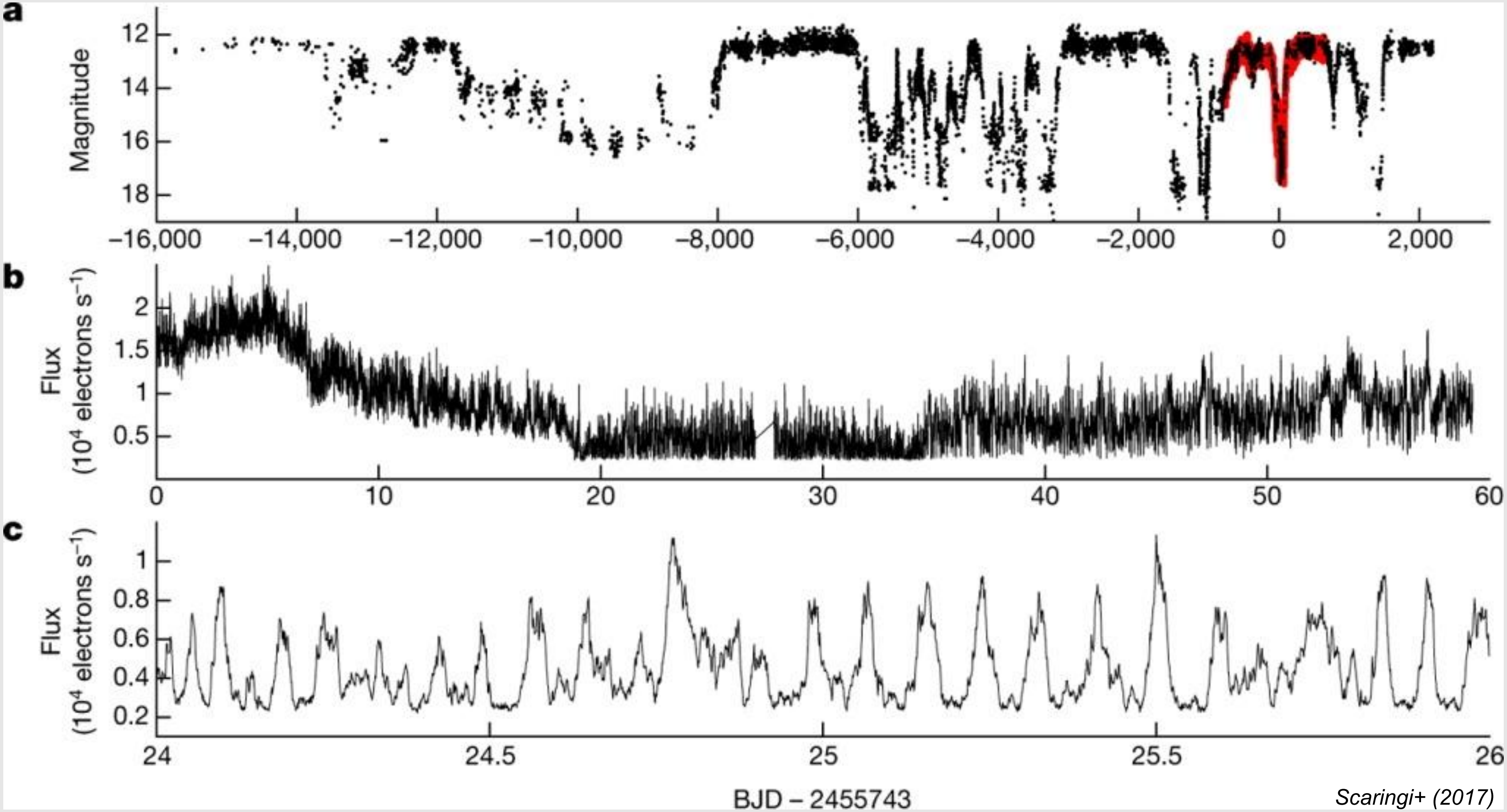
Magnetic gating

vs.

Type II X-ray bursts (a.k.a. Rapid bursters)



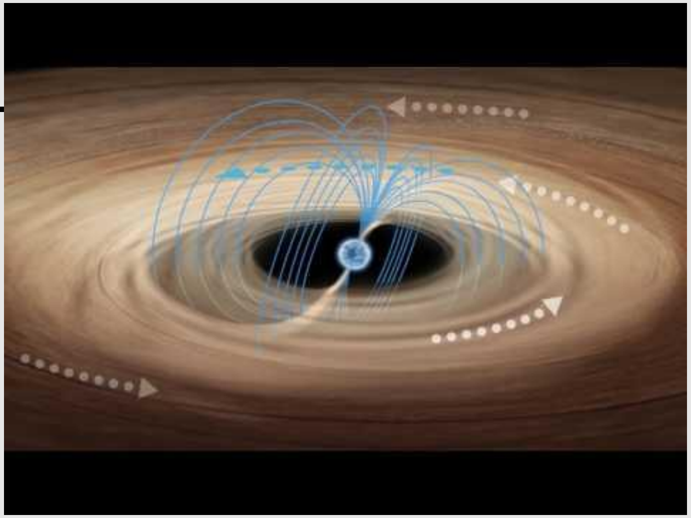
Magnetically gated accretion



Scaringi+ (2017)

Magnetically gated accretion

Type-II burst equivalent in XRBs

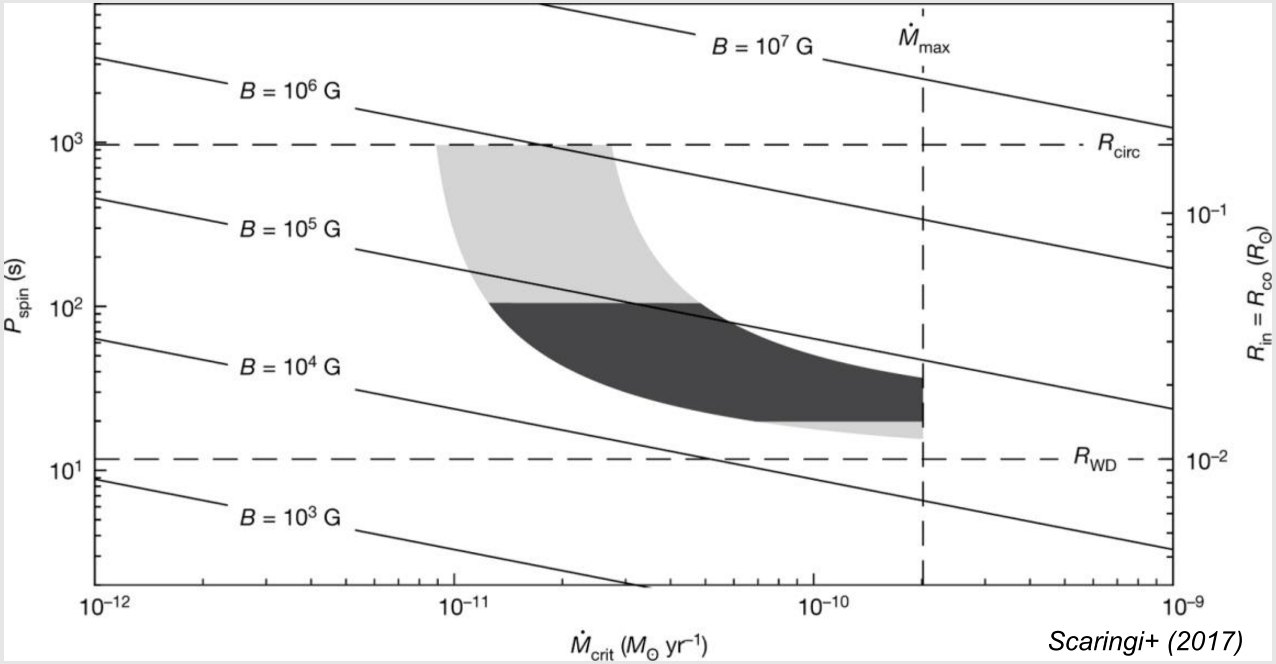


Disk-WD co-rotation radius

$$P_s^2 = \frac{4\pi^2 R_{co}^3}{GM_{WD}}$$

Critical mass transfer rate

$$\dot{M}_{crit} = \frac{\eta\mu^2 P_s}{8\pi R_{in}^5}$$



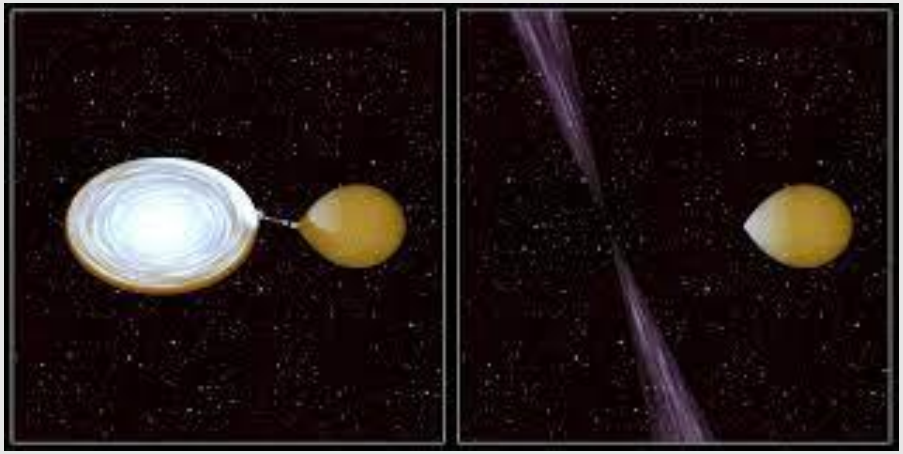
Scaringi+ (2017)

Scaringi+ (2017)
see also Littlefield+ (2022)

transitional Accreting White Dwarfs (tAWDs)

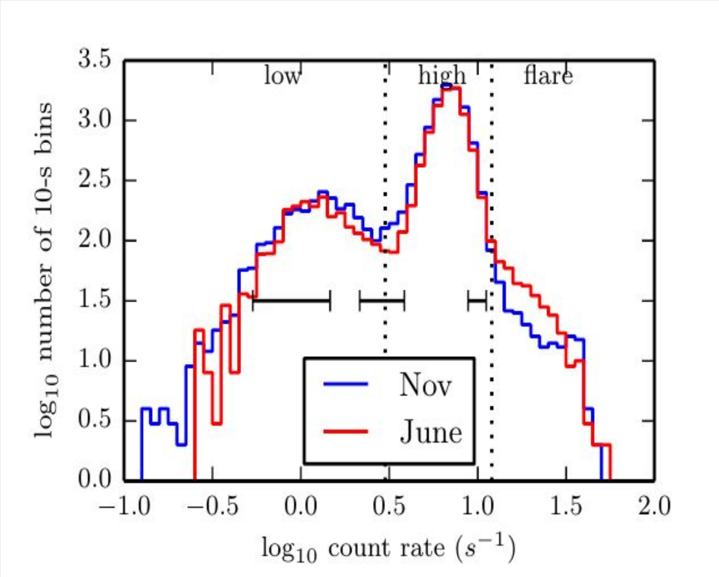
vs.

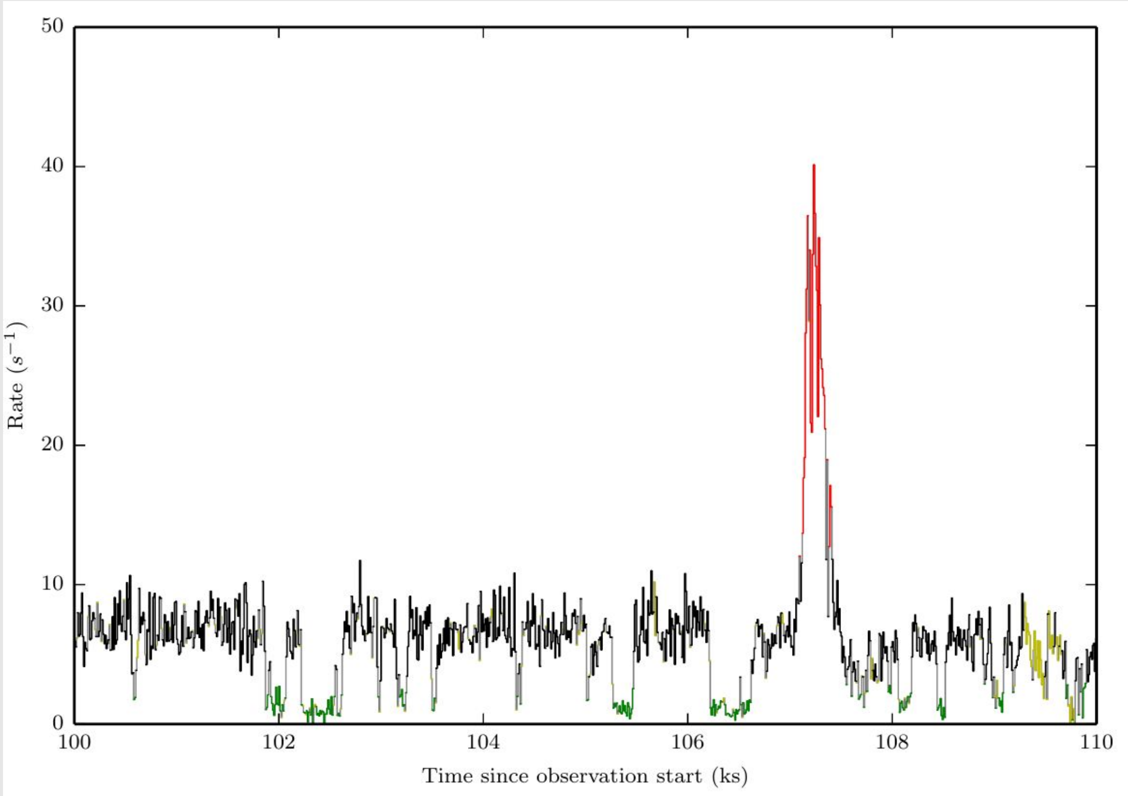
transitional Millisecond Pulsars (tMSPs)



PSR J1023+0038

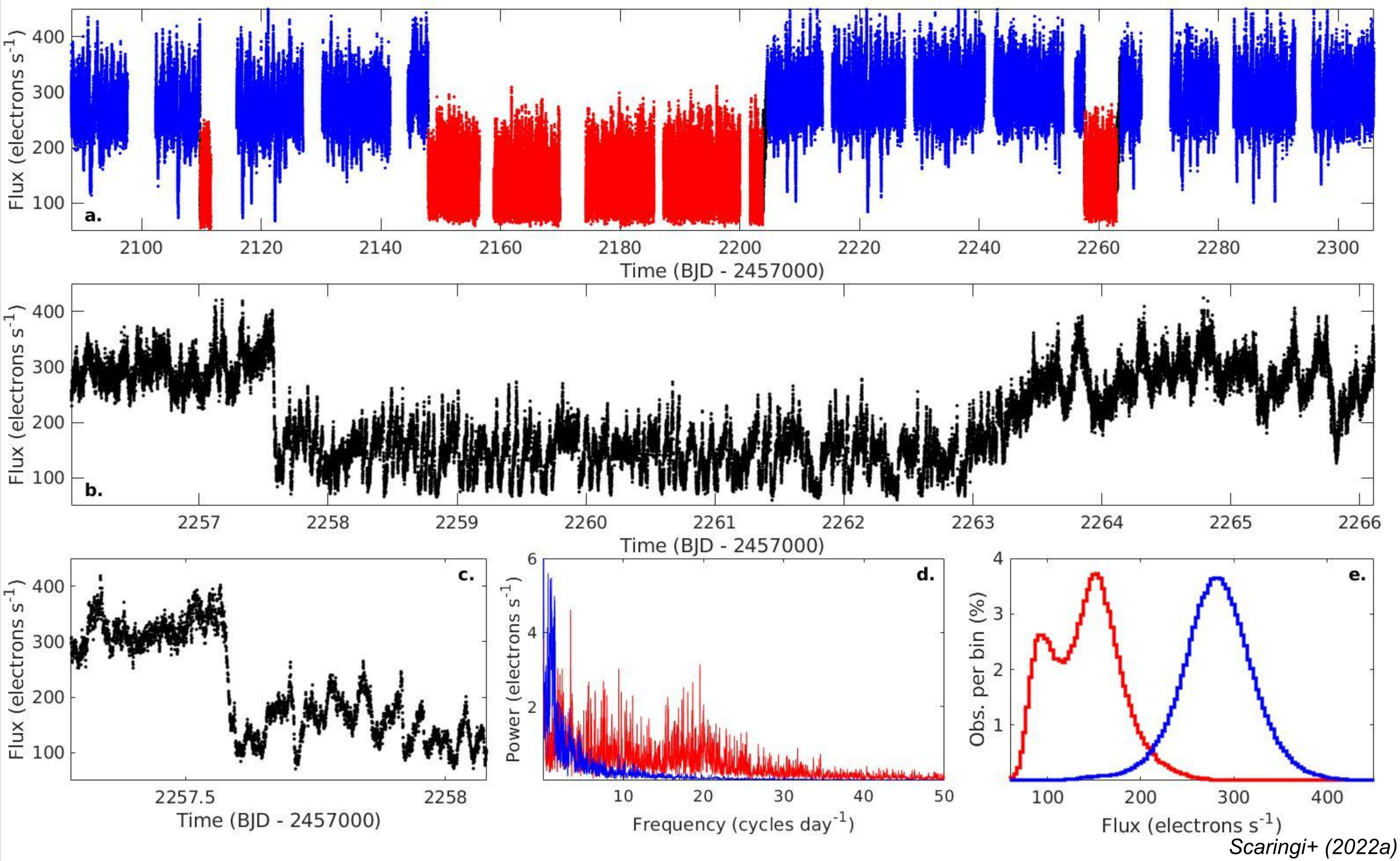
Moding caused by accretion on/off state





e.g. Archibald+ (2015)

TW Pictoris

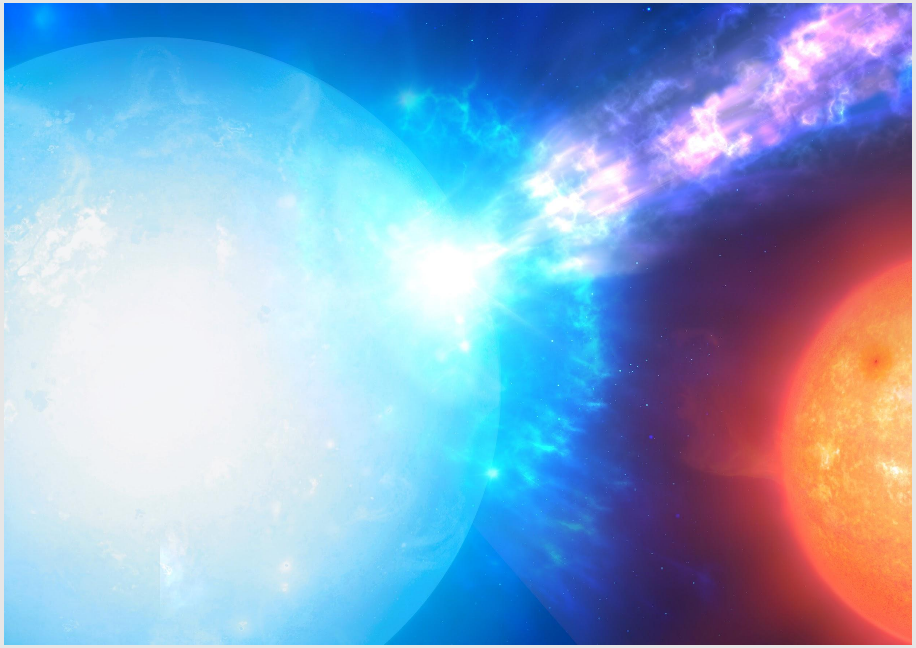


Scaringi+ (2022a)

Type I X-ray bursts

vs.

Micronovae



TV Columbae

…a brief history…

THE ASTROPHYSICAL JOURNAL, **280**: 729–733, 1984 May 15

AN UNPRECEDENTED UV/OPTICAL FLARE IN TV COLUMBAE

PAULA SZKODY[1] AND MARIO MATEO[2]
Department of Astronomy, University of Washington
Received 1983 August 8; accepted 1983 November 23

ABSTRACT

We report a surprising, 2 mag, short time scale (hr) outburst of TV Col (2A 0526−328) observed simultaneously at *IUE* and optical wavelengths in 1982 November. During this "flare," the *IUE* emission lines of N V λ1240, C IV λ1550, and He II λ1640, intensified by more than an order of magnitude and developed P Cygni profiles, indicating mass loss. Continuum fits with a power law plus a blackbody from the UV through the optical showed a steepening of the UV power-law component and an increase in the temperature and size of the blackbody component during the flare activity. We discuss this unusual behavior in terms of an accretion disk instability.

Subject headings: stars: accretion — stars: dwarf novae — stars: flare — stars: individual — ultraviolet: spectra

TV Columbae

…a brief history…

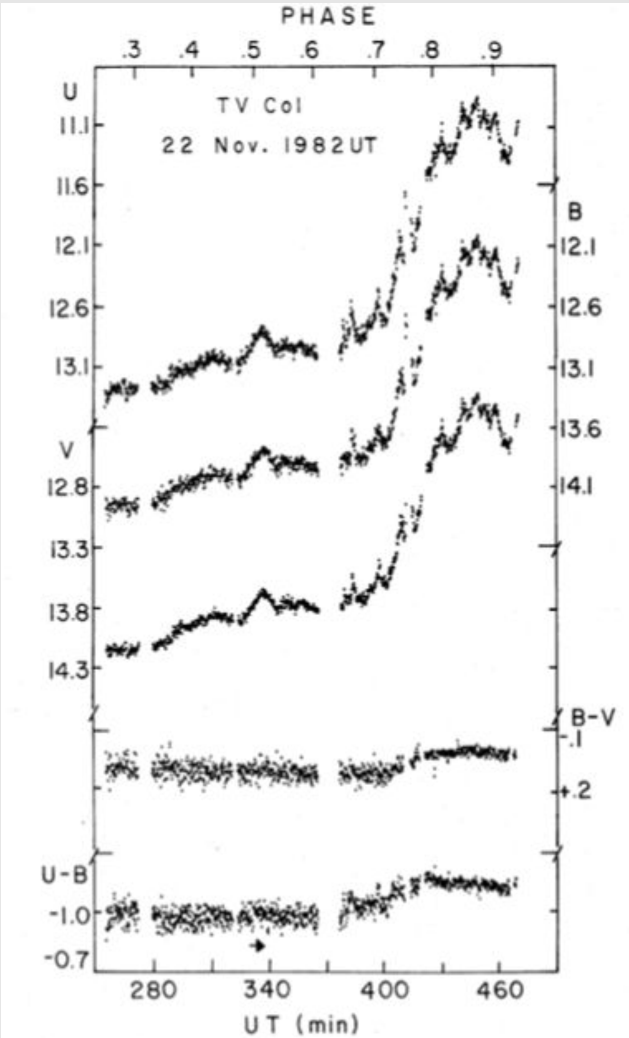
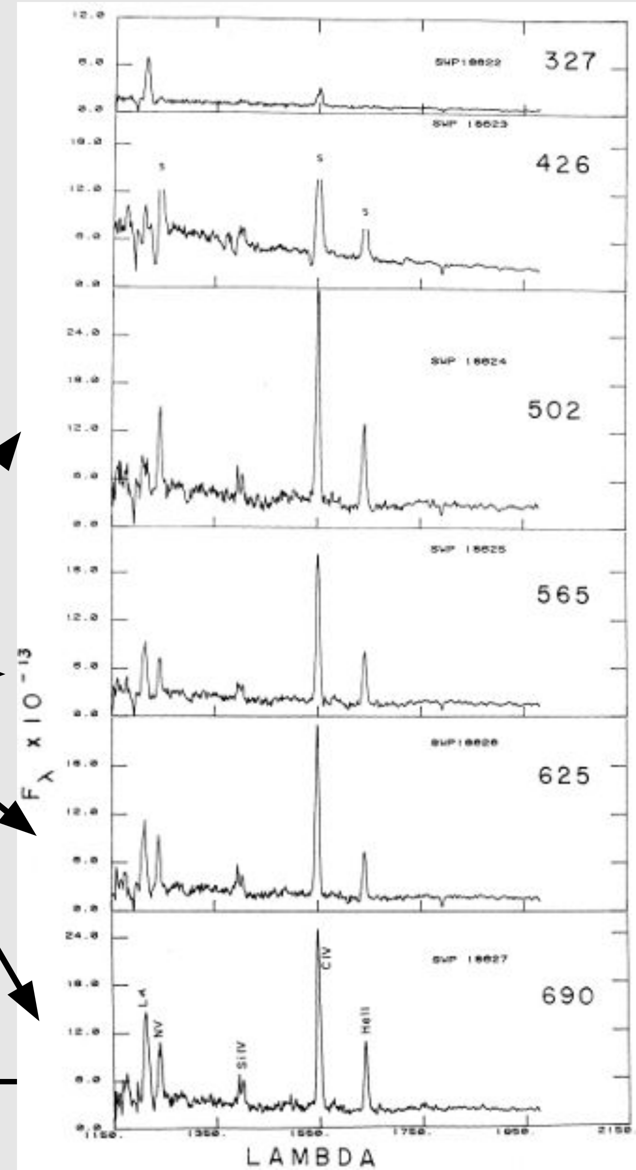


FIG. 1.—Simultaneous *UBV* photometry for 1982 November 22 UT. Each point is a 10 s integration with statistical uncertainty of less than 0.02 mag. *IUE* coverage began at the arrow and continued past the end of the optical data. Phases at the top are for the photometric variation according to the ephemeris by Hutchings *et al.* (1981).

Pre-burst

Burst maximum

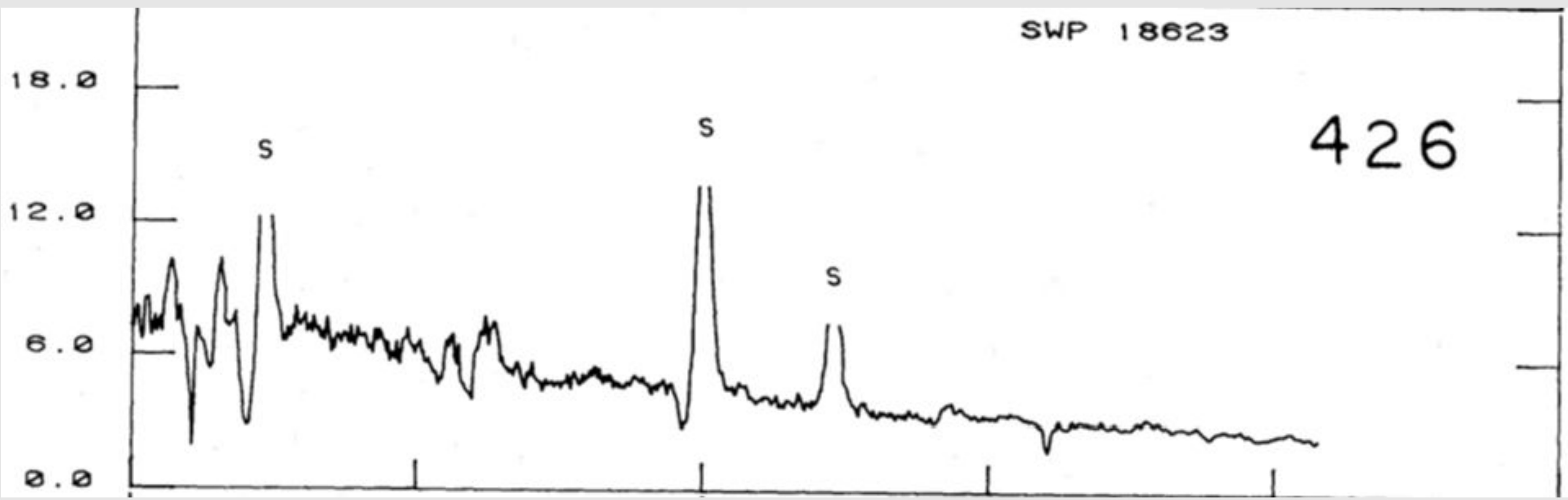
Post-burst



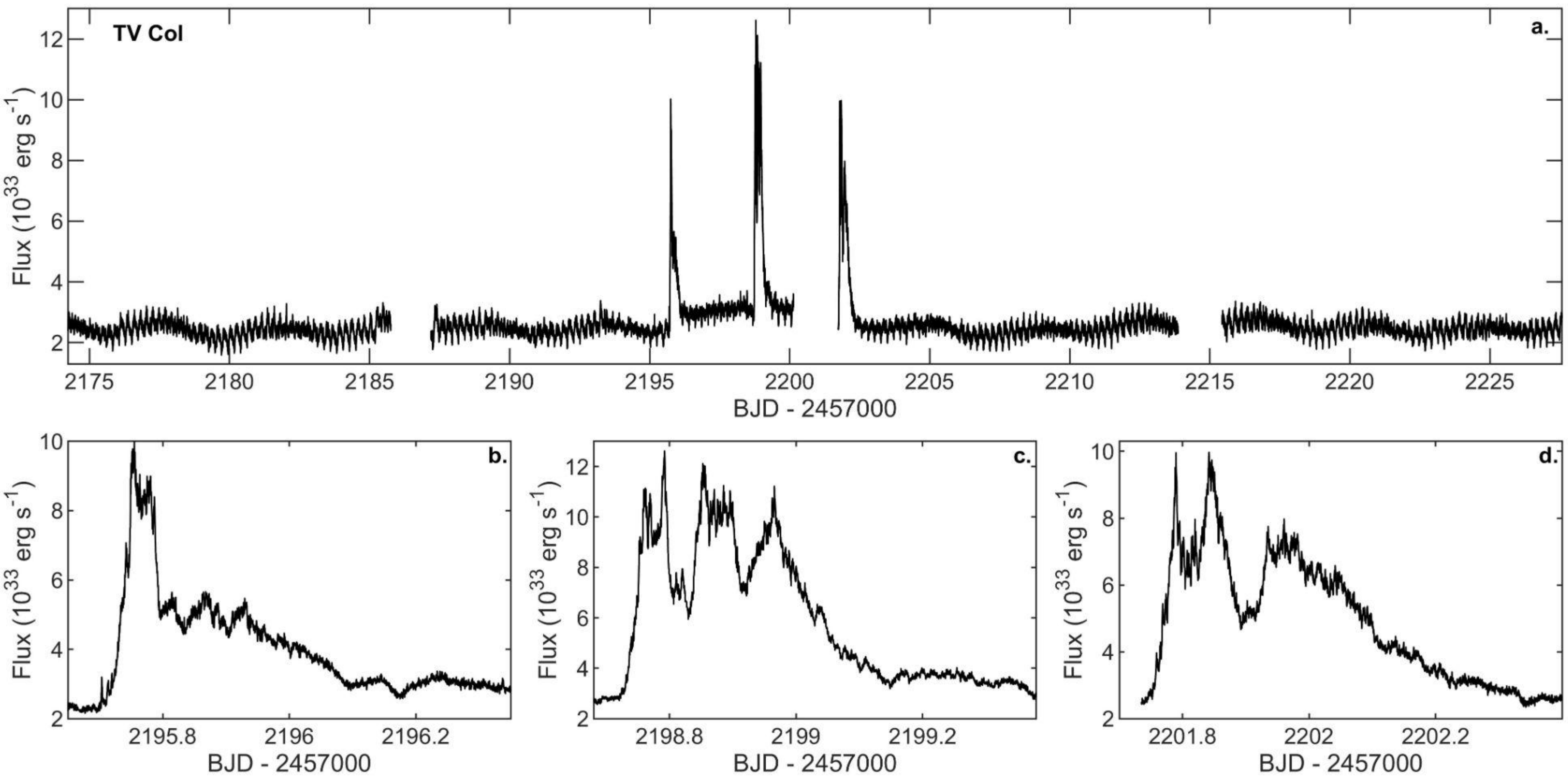
TV Columbae

…a brief history…

- High ionisation HeII and NV lines appear during burst and persist for ~1 month
- P-Cygni profile suggests outflows of >2500 km/s only at peak luminosity

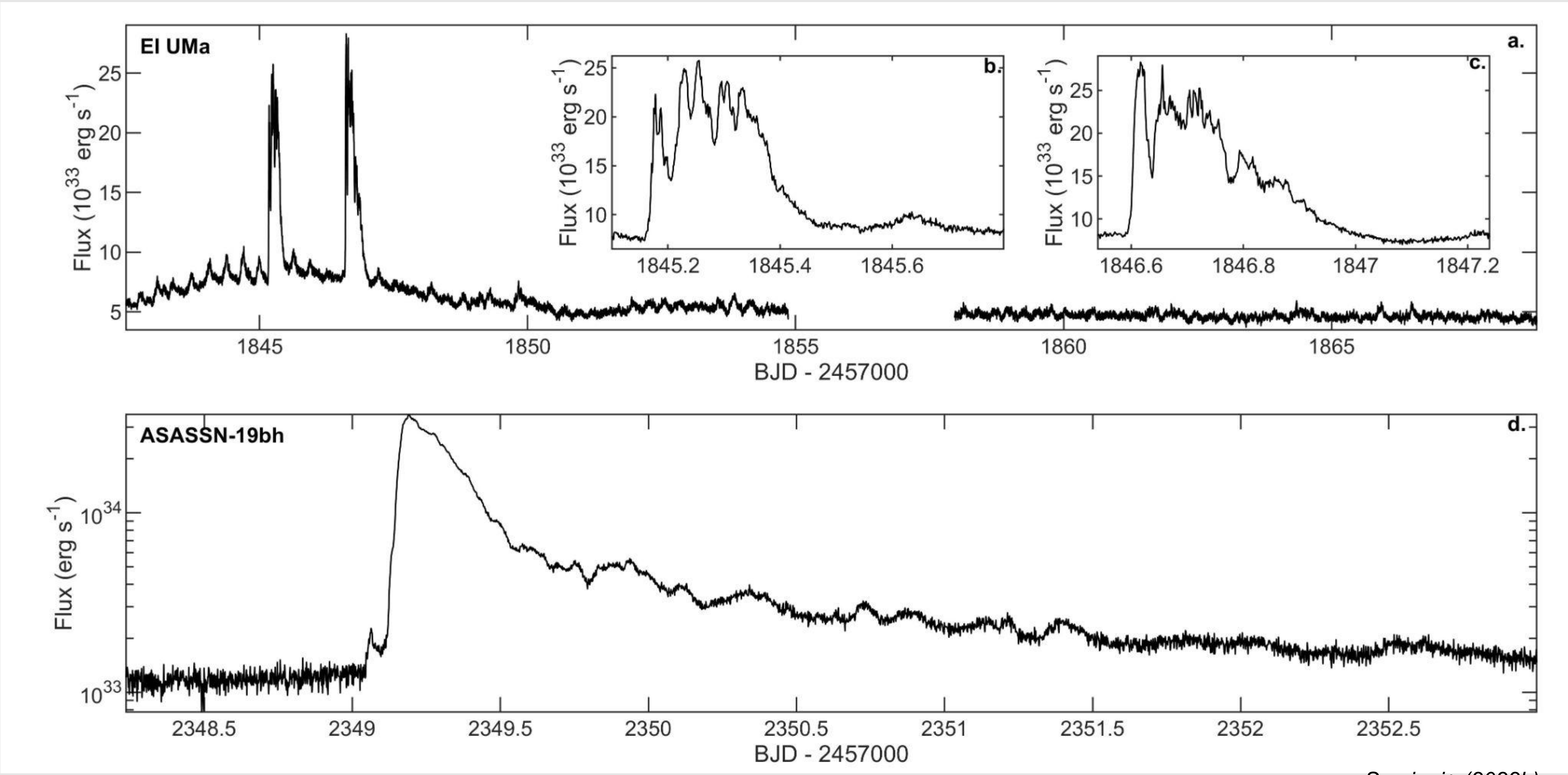


TV Columbae
…with TESS…



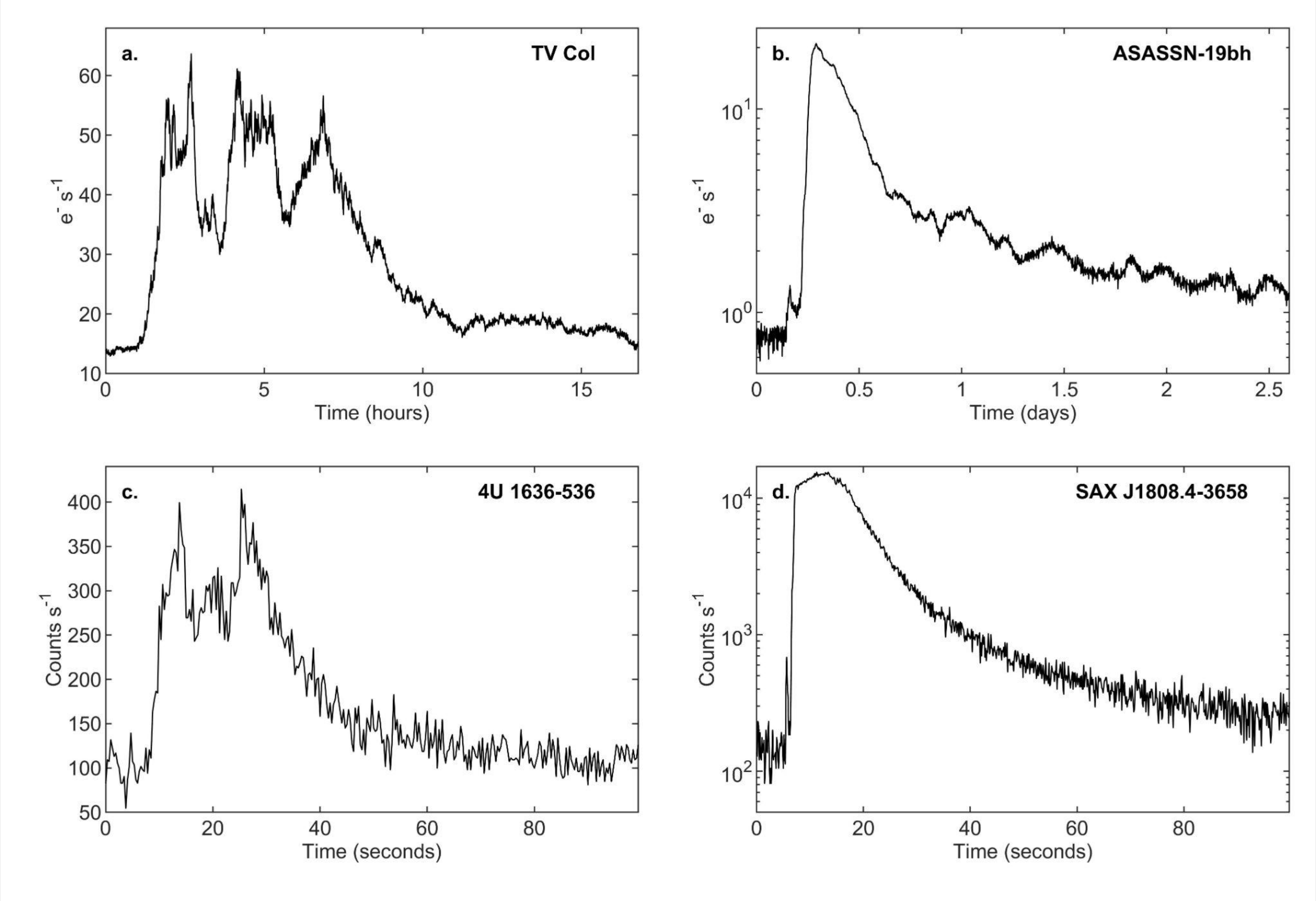
Scaringi+ (2022b)

EI UMa and ASASSN-19bh
…with TESS…



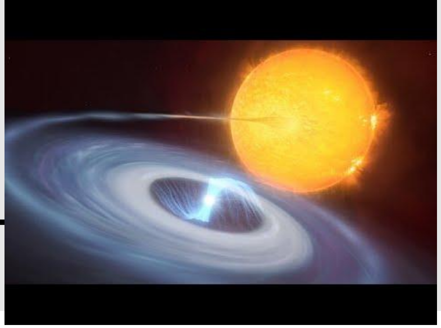
Scaringi+ (2022b)

Micronovae vs. Type I X-ray bursts



Scaringi+ (2022b)

How to trigger micronovae?

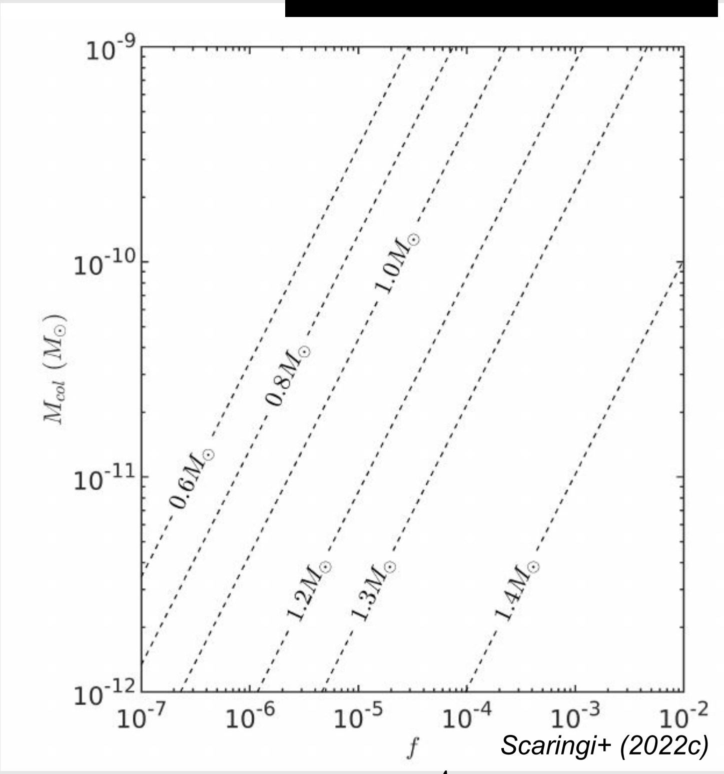


To ignite, we require:

$$P_{col} \approx P_{crit} > 10^{18} dyn\, cm^{-2}$$

As long as magnetic confinement of material holds:

$$t_{rec} = \frac{M_{col}}{\dot{M}_{acc}}$$



$$f = \frac{A_{col}}{A_{WD}}$$

Problem:

As column pushes into WD, at what depth do triggering conditions occur? (spoiler: maybe too deep)


THE FIRST
VASTO ACCRETION MEETING
19 - 23 JUNE 2023
VASTO, ITALY
Scientific Organising Committee
Enrico Bozzo (Uni. of Geneva)
Sergio Campana (INAF-Brera)
Nathalie Degenaar (Uni. of Amsterdam)
Domitilla de Martino, co-chair (INAF-Capodimonte)
Tiziana Di Salvo (Uni. of Palermo)
Chris Done (Durham University)
Boris Gaensicke (Uni. of Warwick)
Christian Knigge, co-chair (Uni. of Southampton)
Gian Luca Israel (INAF-Rome Observatory)
Lidia Oskinova (AIP Potsdam)
Simone Scaringi, co-chair (Durham University)
Jennifer Sokoloski (Columbia University)
Paula Szkody (Uni. of Washington)
Phil Uttley (Uni. of Amsterdam)
Anna Watts (Uni. of Amsterdam)
Local Organising Committee
Gisella De Rosa (STSci)
Simone Scaringi, chair (Durham University)
....
VAM
2023
Invited Speakers
Aydi E. (Michigan State)
Blaes O. (UCSB)
De Marco B. (UPC)
Ferrario L. (ANU)
Malzac J. (IRAP)
Motta S. (INAF-Brera)
Pala A. (ESO)
Parfrey K. (Trinity Dublin)
Bilous A. (Amstedam)
Coppejans D.(Warwick)
El Mellah I. (CNRS)
Grinberg V. (ESA)
Middleton M. (Soton)
Munoz-Darias T. (IAC)
Papitto A. (INAF-OAR)
Schwope A. (AIP)
THYRUS DESIGN
Con il Patrocinio del Comune di Vasto
Palazzo d'Avalos
Durham University
Photo credit: Laura Sergio
Binary illustration: Fahad Sulehria

Open questions

Broad-band variability

- **How does disk geometry/viscosity change with Mdot and radius? Do AWDs have an analogous "corona" as seen in XRBs?**

Mag. Gating

- **Why only a handful of AWDs show this? What are the "optimal" parameters to initiate mag. Gating? Does it happen in a specific evolutionary phase?**

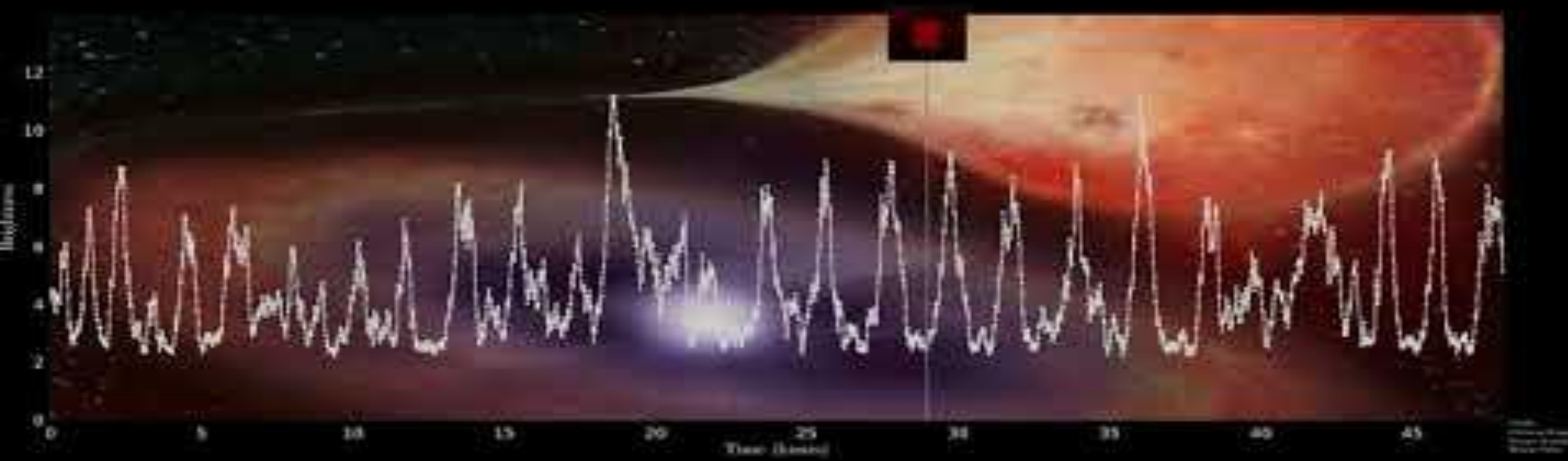
tAWD

- **What causes the abrupt drops in luminosity/sudden reduction in Mdot? Can we make direct analogies to tMSPs? How are these related to mag. Gatiting and/or evolution?**

Micronovae

- **What triggers these, and how common are they? What are the implications of common micronovae to chemical enrichment and multi-messenger emission?**

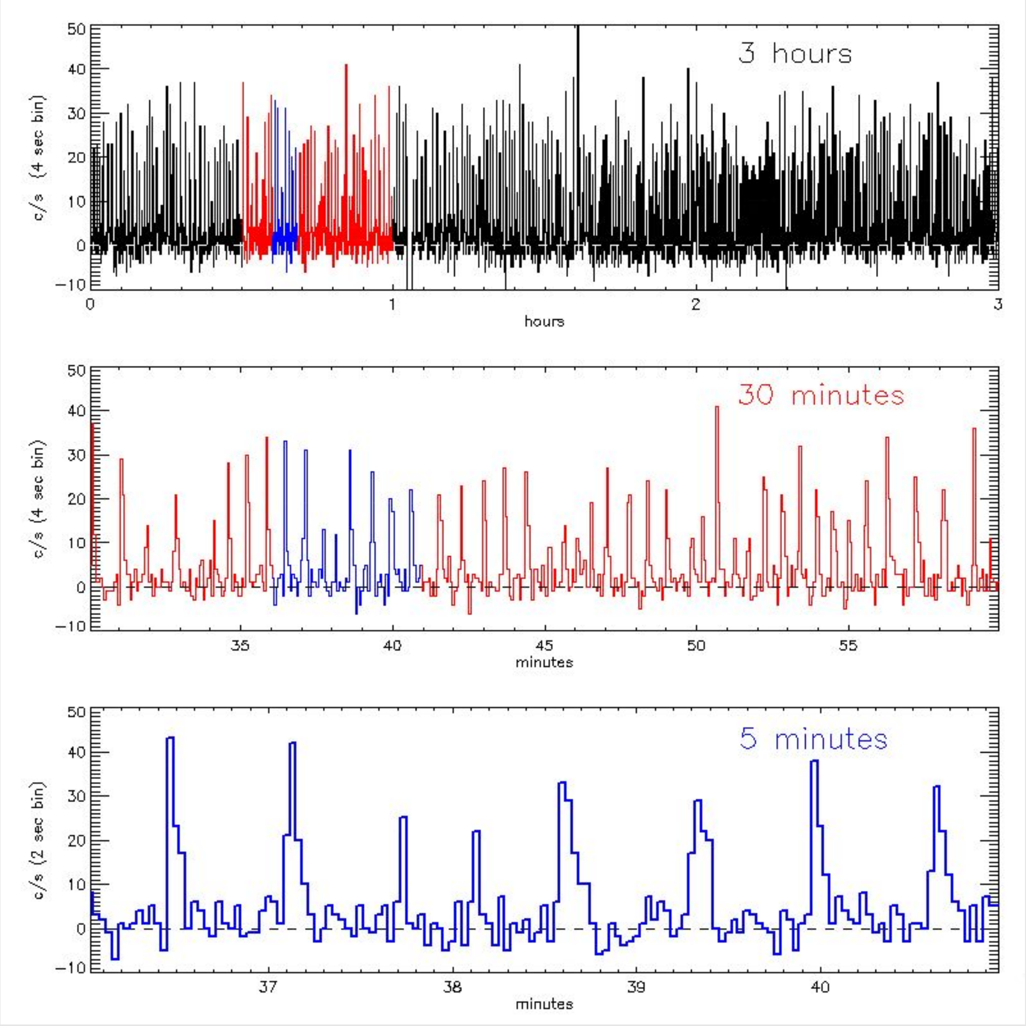
Magnetically gated accretion bursts in MV Lyrae



Rapid Bursters

- Accreting neutron stars with excess power in the kHz regime
- Only a handful known to date
- Very short bursts (few seconds)
- Best explained through magnetically gated accretion

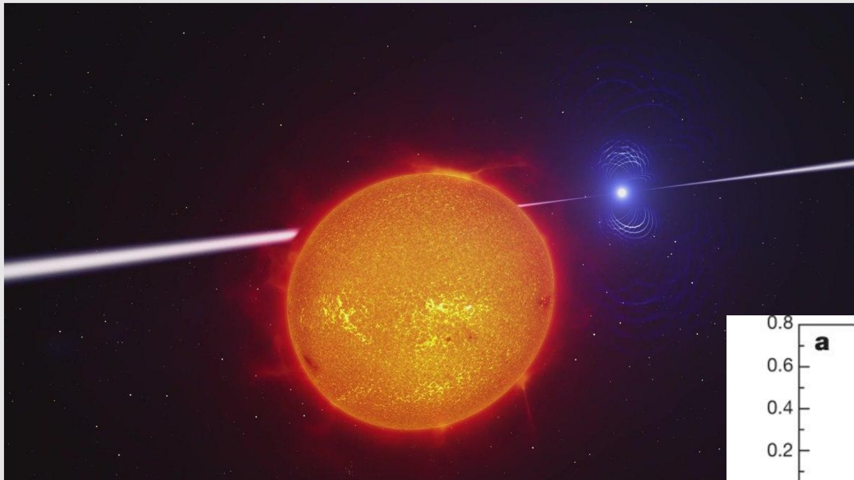
MXB 1730-335

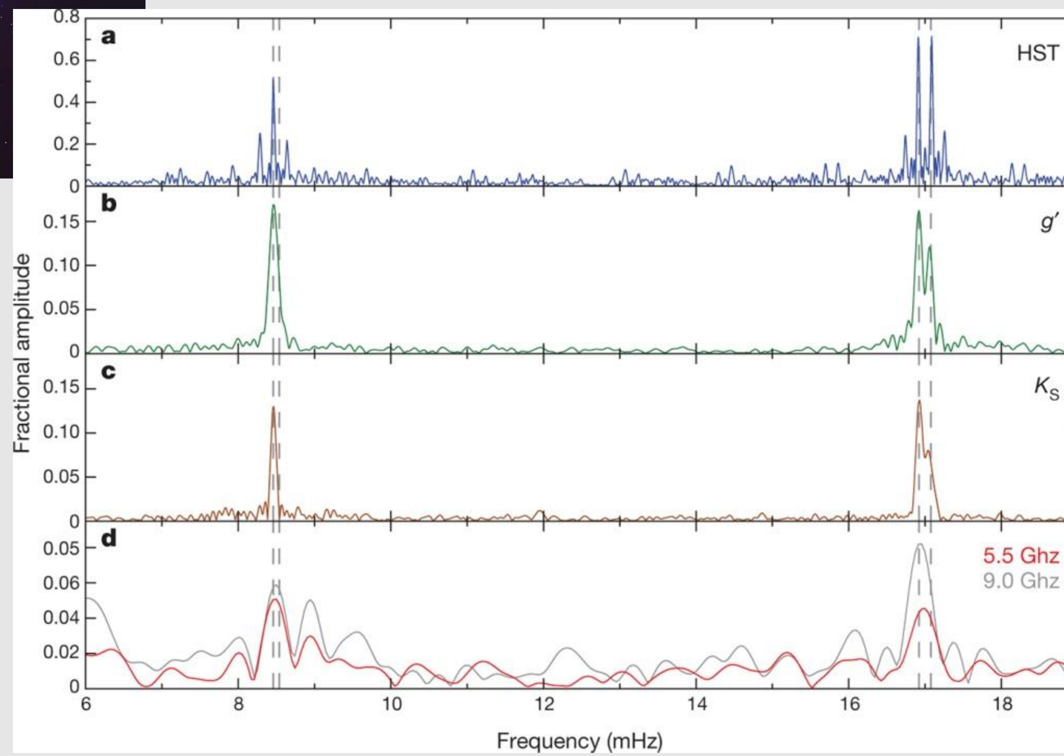


Spruit & Taam (1993), Patruno+ (2009), D'Angelo & Spruit (2010,2012), Patruno & D'Angelo (2013), Bagnoli+ (2015), van den Eijnden+ (2016), Kuulkers+ (200), etc...*

AR Sco

WD pulsar: when and how did it "turn off"?

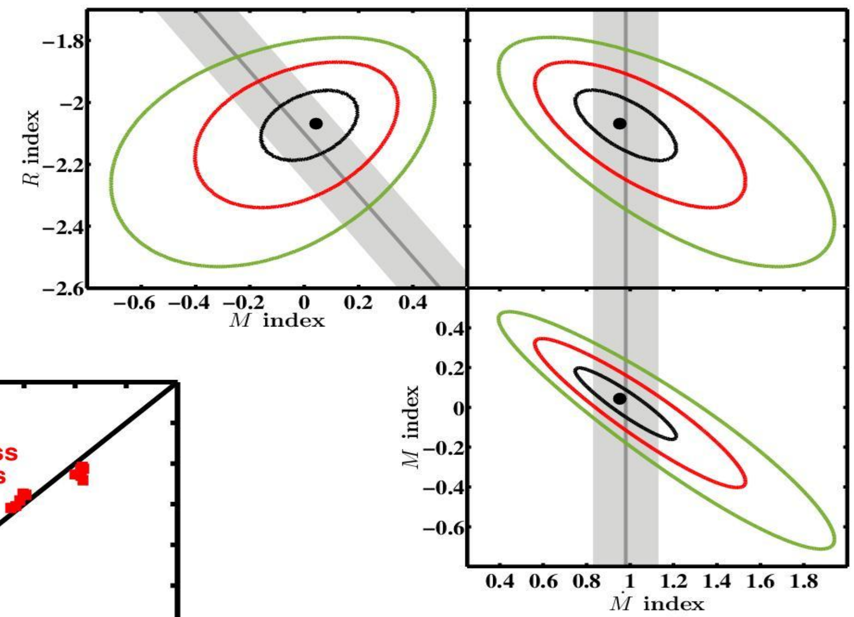


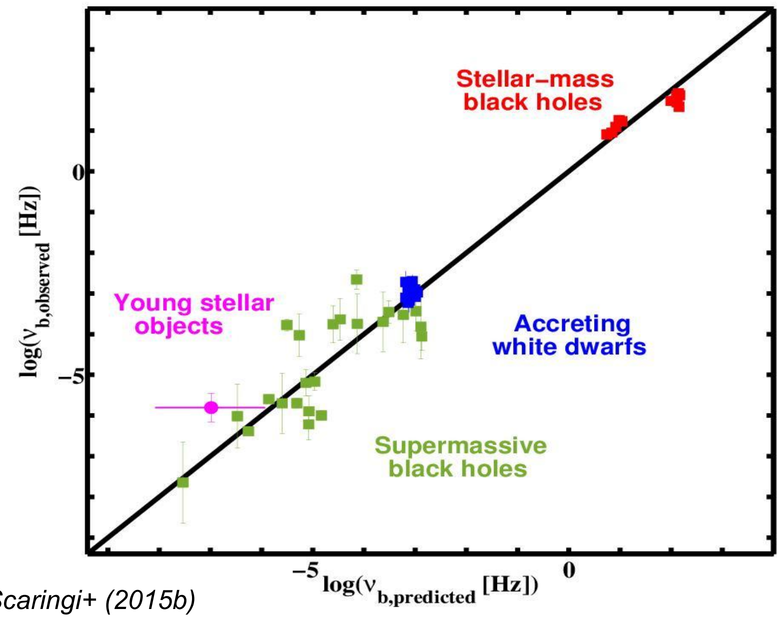


Marsh+ (2006)
Buckley+ (2017)
Singh+ (2021)

The accretion variability plane

$$\log \nu_b = A \log M + B \log R + C \log \dot{M} + D$$





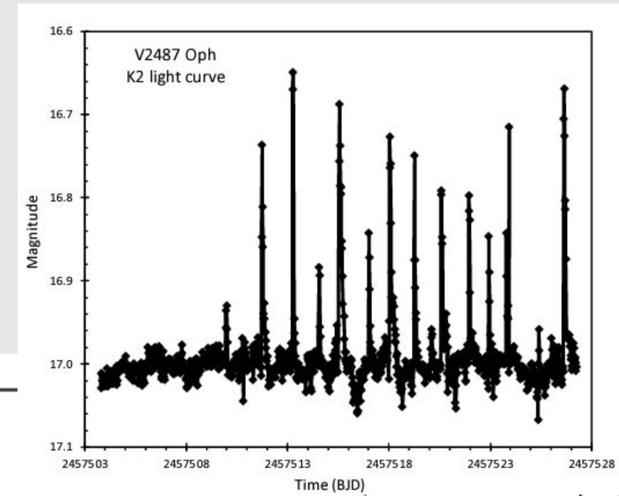
Scaringi+ (2015b)

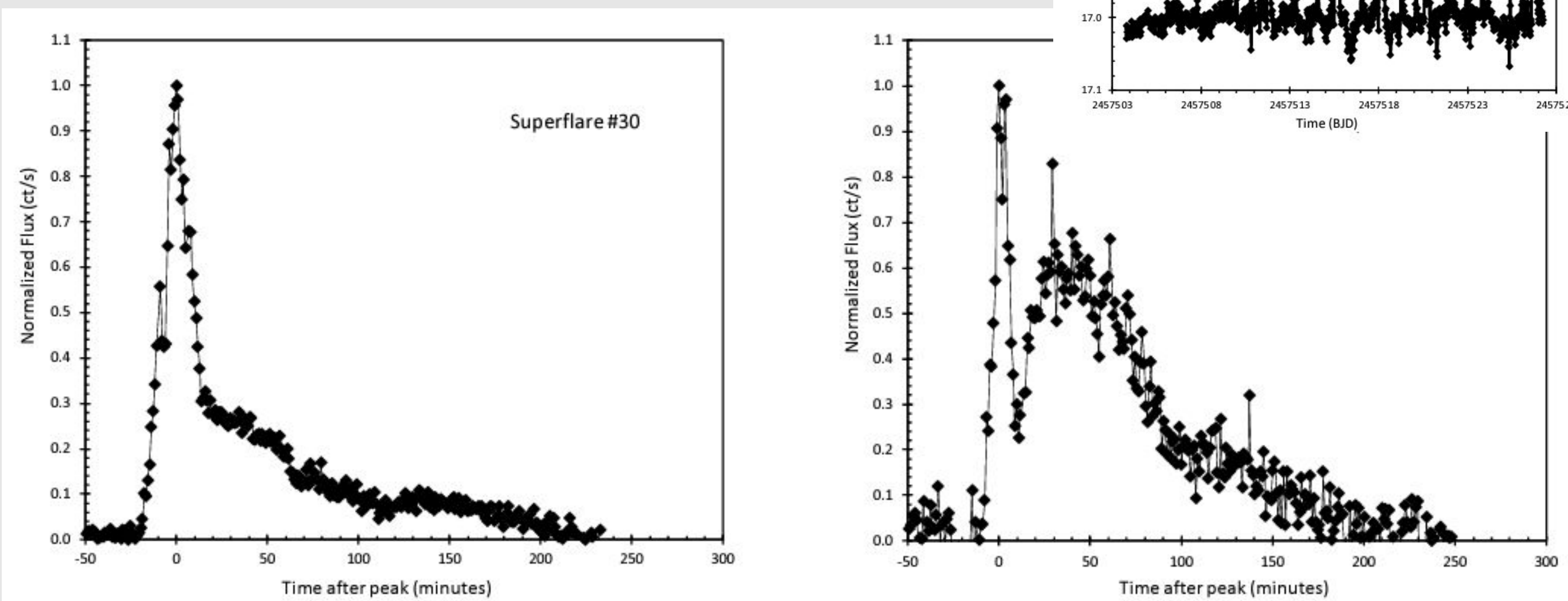
Caveat:

Frequency breaks can be wavelength dependent

V2487 Oph
…with Kepler…

- About 60 bursts observed in a Recurrent Nova
- Explained through mag. reconnection?





DW Cnc

…IP…

The return of the spin period in DW Cnc and evidence of new high state outbursts

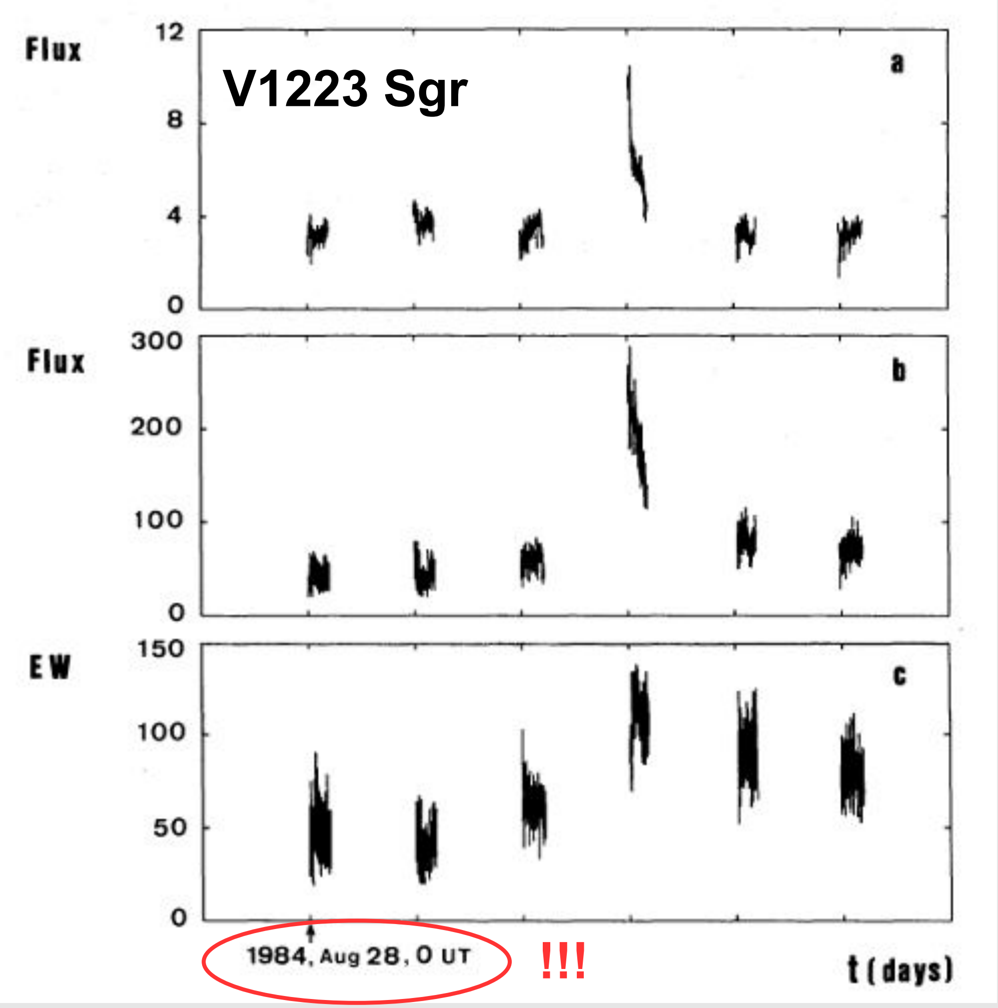
C. Duffy,[1,2★] G. Ramsay,[1] D. Steeghs,[2,8] M. R. Kennedy,[3,4] R. G. West,[2] P. J. Wheatley,[2] V. S. Dhillon,[5,6] K. Ackley,[2,7,8] M. J. Dyer,[5] D. K. Galloway,[7,8,9] S. Gill,[2] J. S. Acton,[10] M. R. Burleigh,[10] S. L. Casewell,[10] M. R. Goad,[10] B. A. Henderson,[10] R. H. Tilbrook,[10] P. A. Strøm,[2] D. R. Anderson [2]

ABSTRACT

DW Cnc is an intermediate polar which has previously been observed in both high and low states. Observations of the high state of DW Cnc have previously revealed a spin period at ~ 38.6 min, however observations from the 2018/19 low state showed no evidence of the spin period. We present results from our analysis of 12 s cadence photometric data collected by NGTS of DW Cnc during the high state which began in 2019. Following the previously reported suppression of the spin period signal we identify the return of this signal during the high state, consistent with previous observations of it. We identify this as the restarting of accretion during the high state. We further identified three short outbursts lasting ~ 1 d in DW Cnc with a mean recurrence time of ~ 60 d and an amplitude of ~ 1 mag. These are the first outbursts identified in DW Cnc since 2008. Due to the short nature of these events we identify them not as a result of accretion instabilities but instead either from instabilities originating from the interaction of the magnetorotational instability in the accretion disc and the magnetic field generated by the white dwarf or the result of magnetic gating.

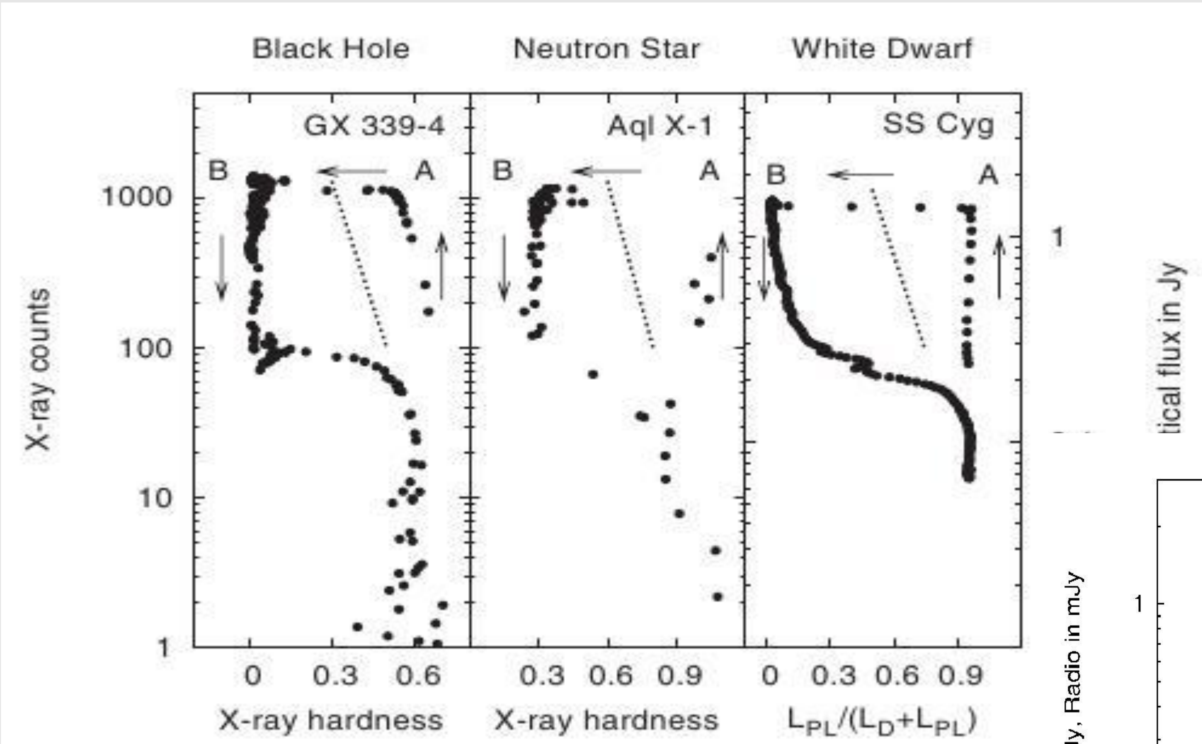
V1223 Sgr

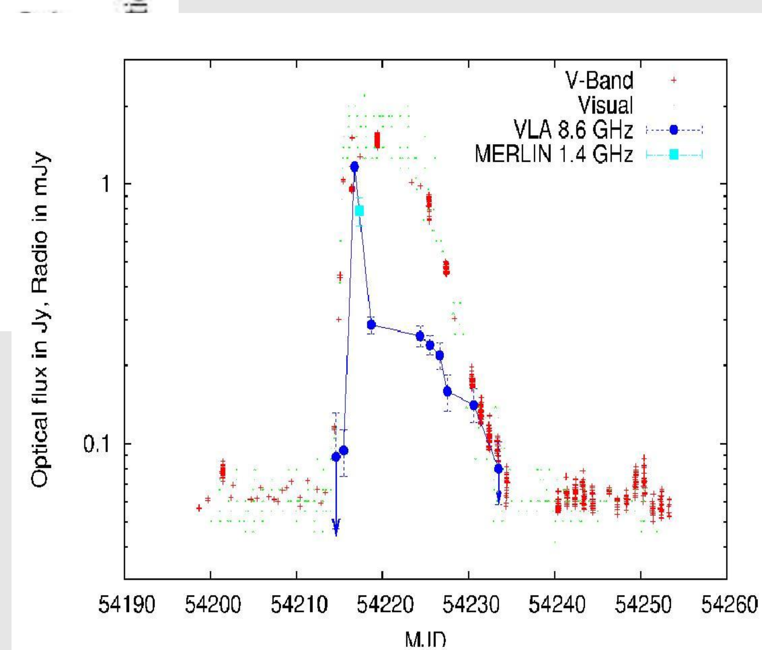
...IP...



Flux
12
8
4
0
V1223 Sgr
a
Flux
300
200
100
0
b
EW
150
100
50
0
c
1984, Aug 28, 0 UT
!!!
t (days)

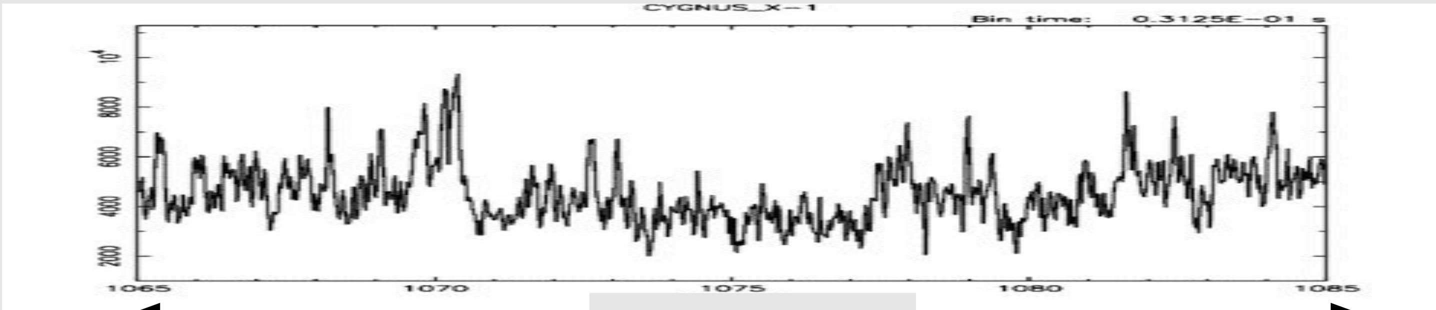
State changes + jets in WDs





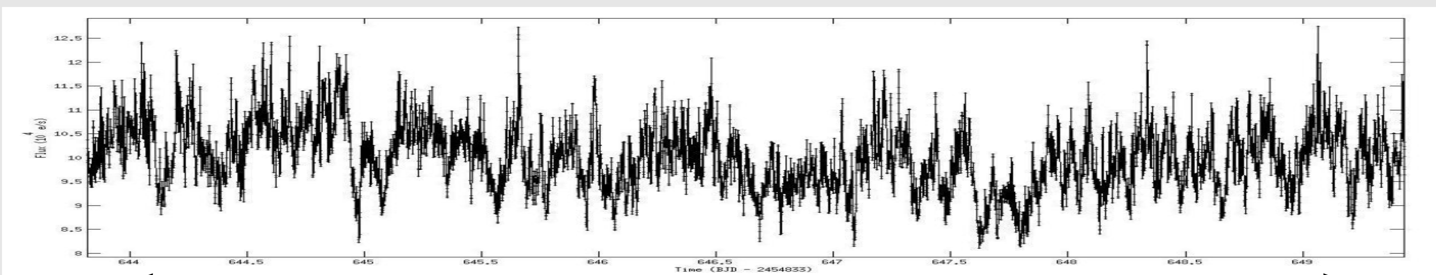
Koerding+ (2008)
Coppejans+ (2016)

Accretion-driven flickering



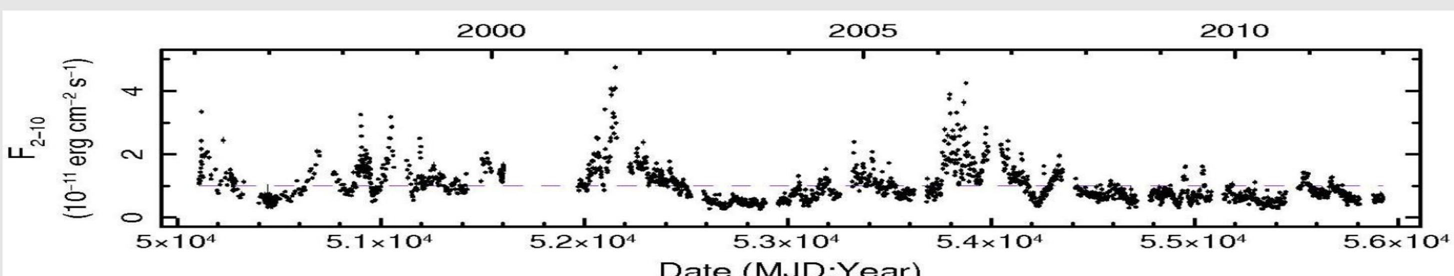
20 seconds

X-rays Cyg X-1



5 days

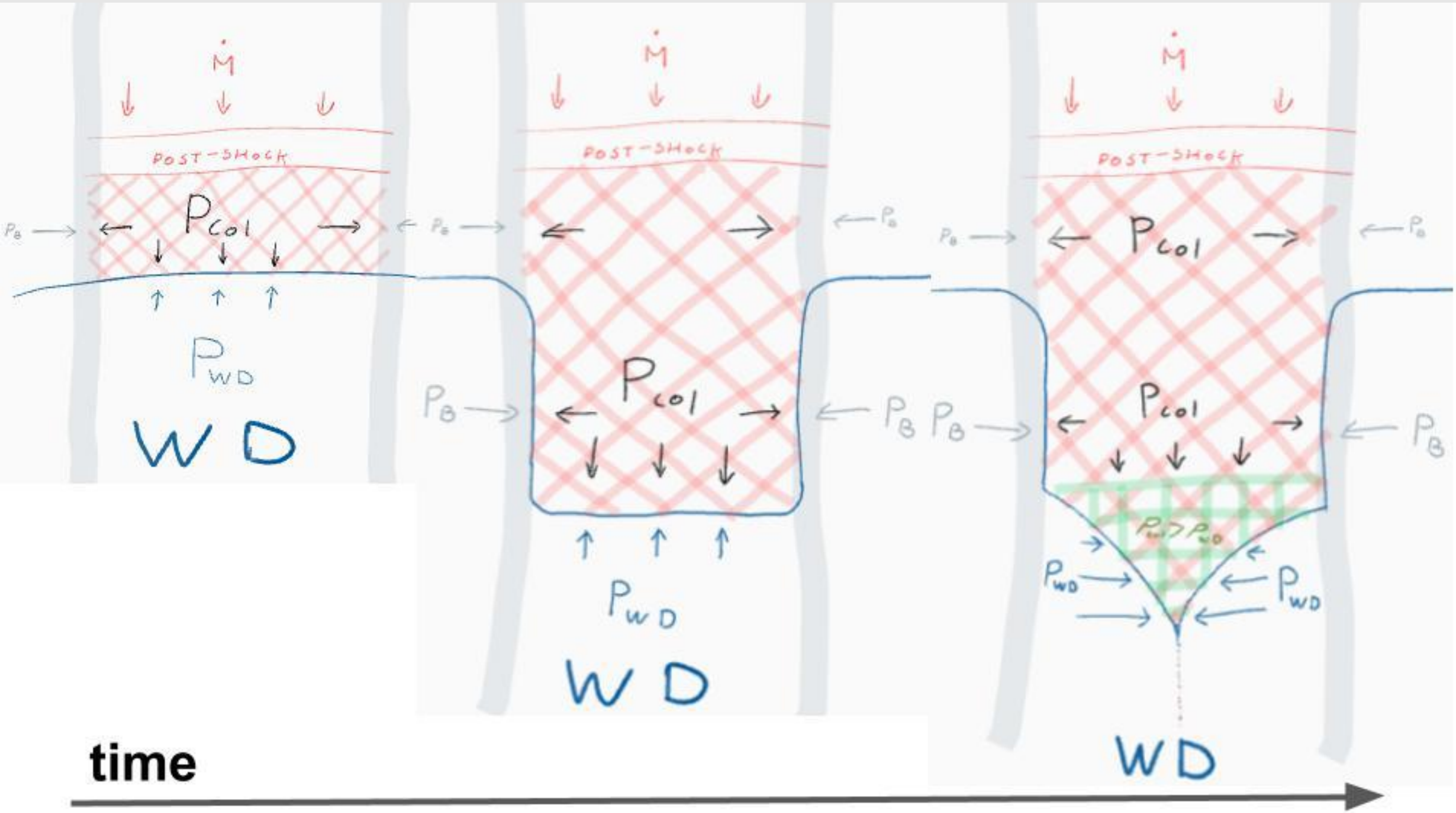
Optical MV Lyr



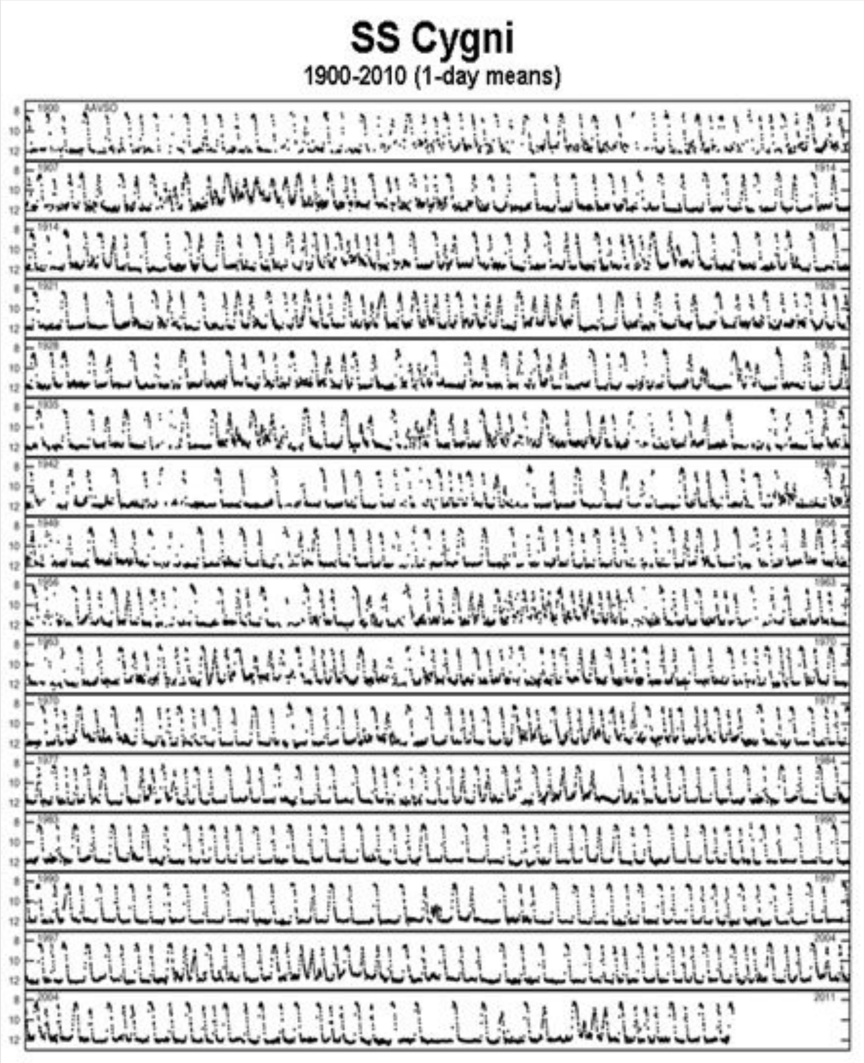
15 years

X-rays 3C 279

Density-driven Instabilities?



Accretion disk instabilities



Broad-band variability

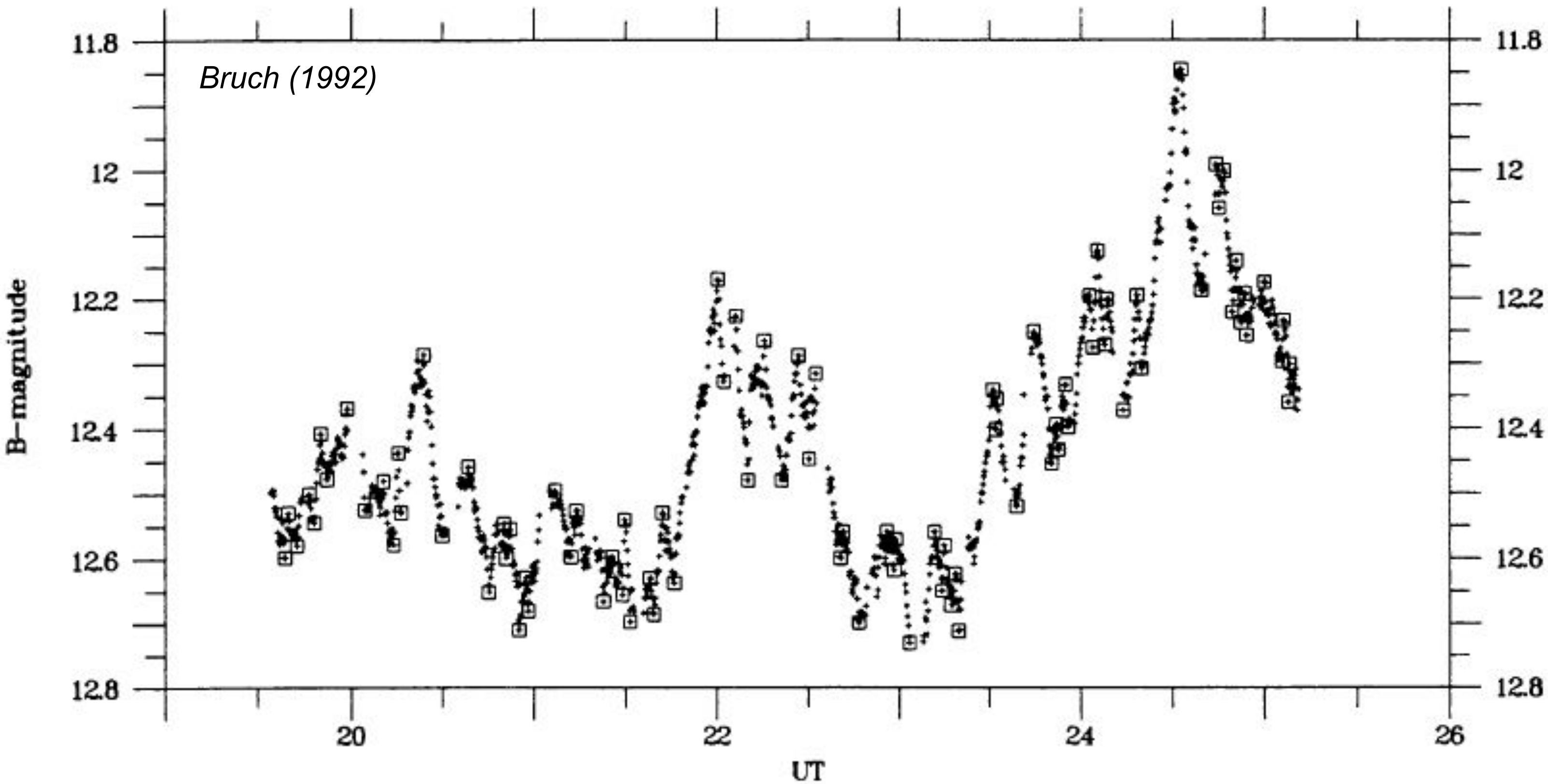
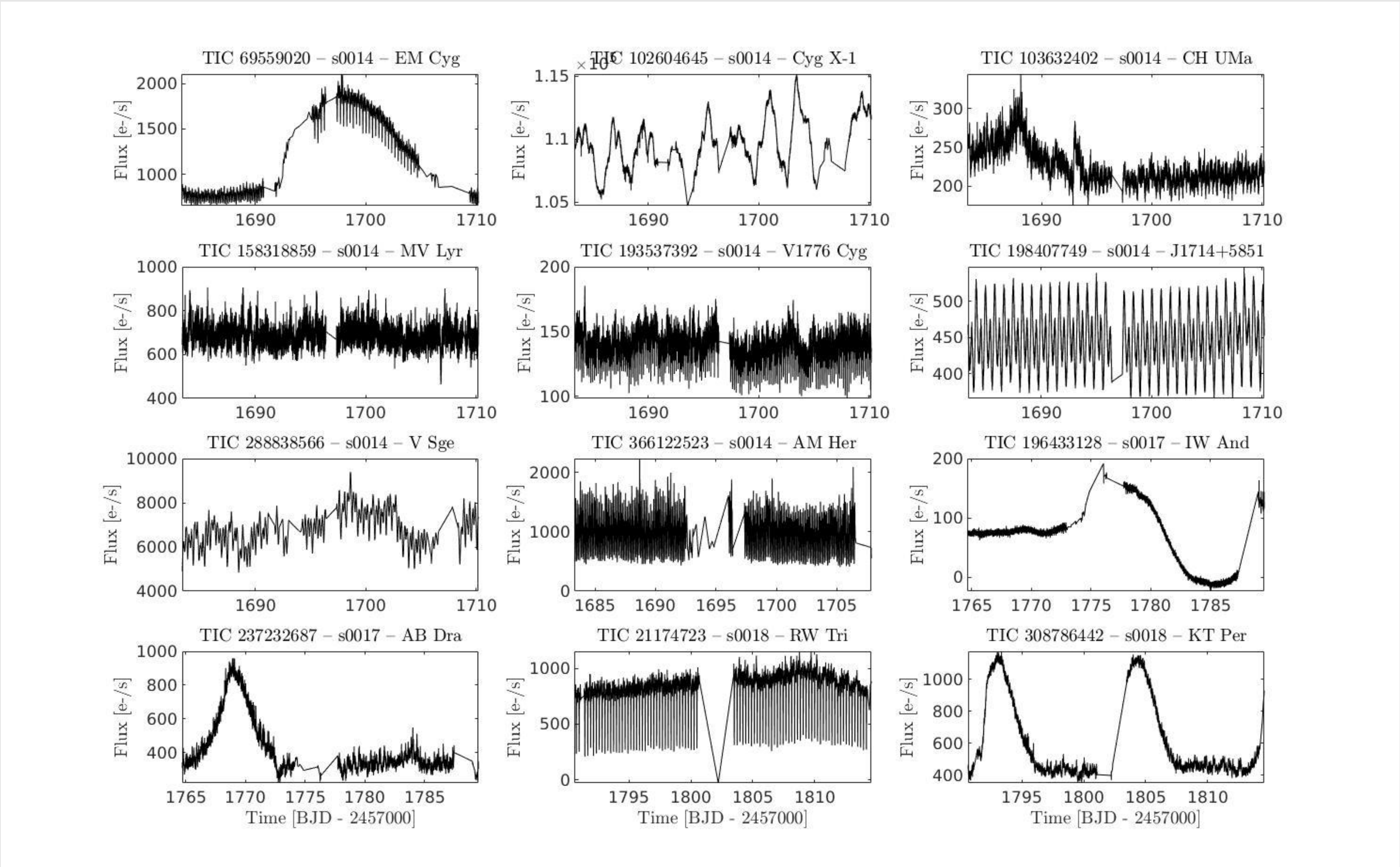


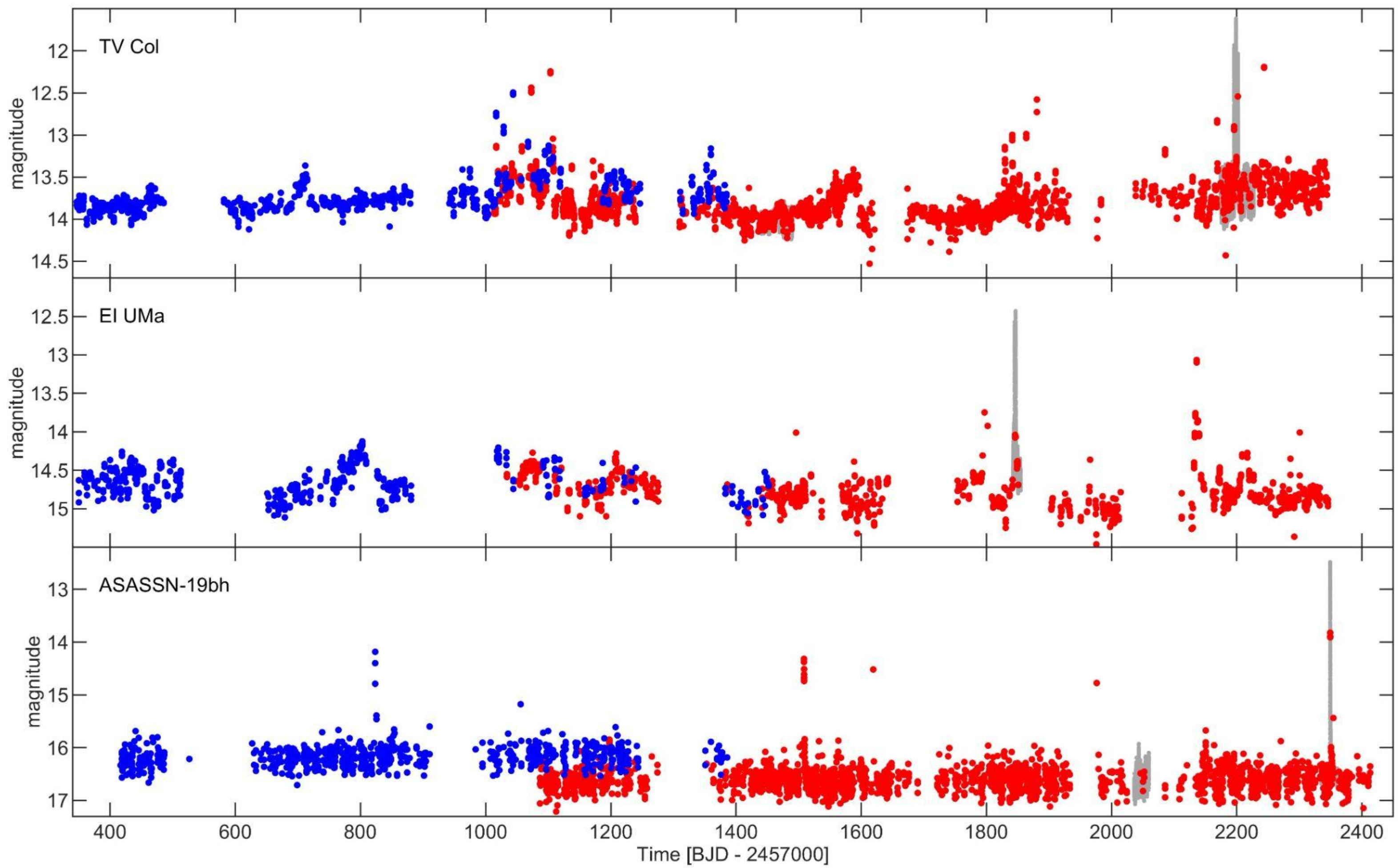
FIG. 1: Light curve of SS Cyg of 1983, Aug. 12, as an example for the formal definition of flickering flares. The base points and peaks of individual flares recognized as significant are marked by squares. The limiting amplitude for a flare was chosen to be $0\overset{m}{.}03$.

TESS atlas of AWD – Cycle 2

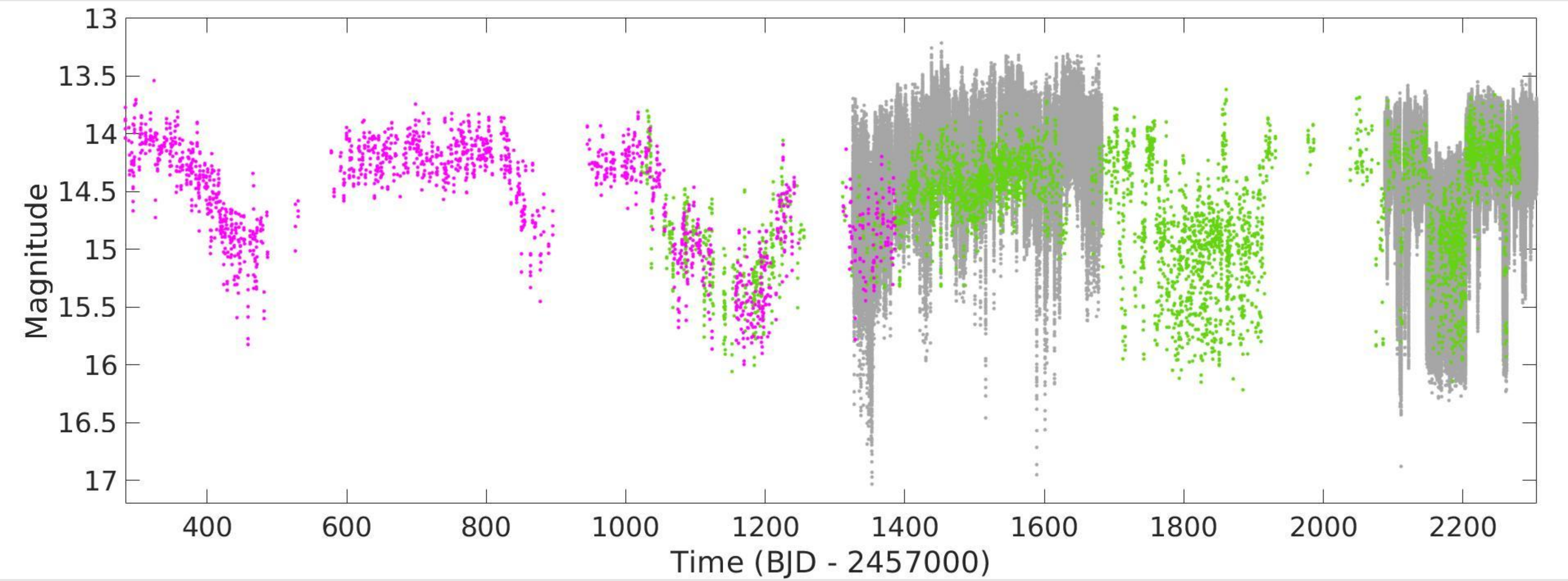


TV Col, EI UMa and ASASSN-19bh

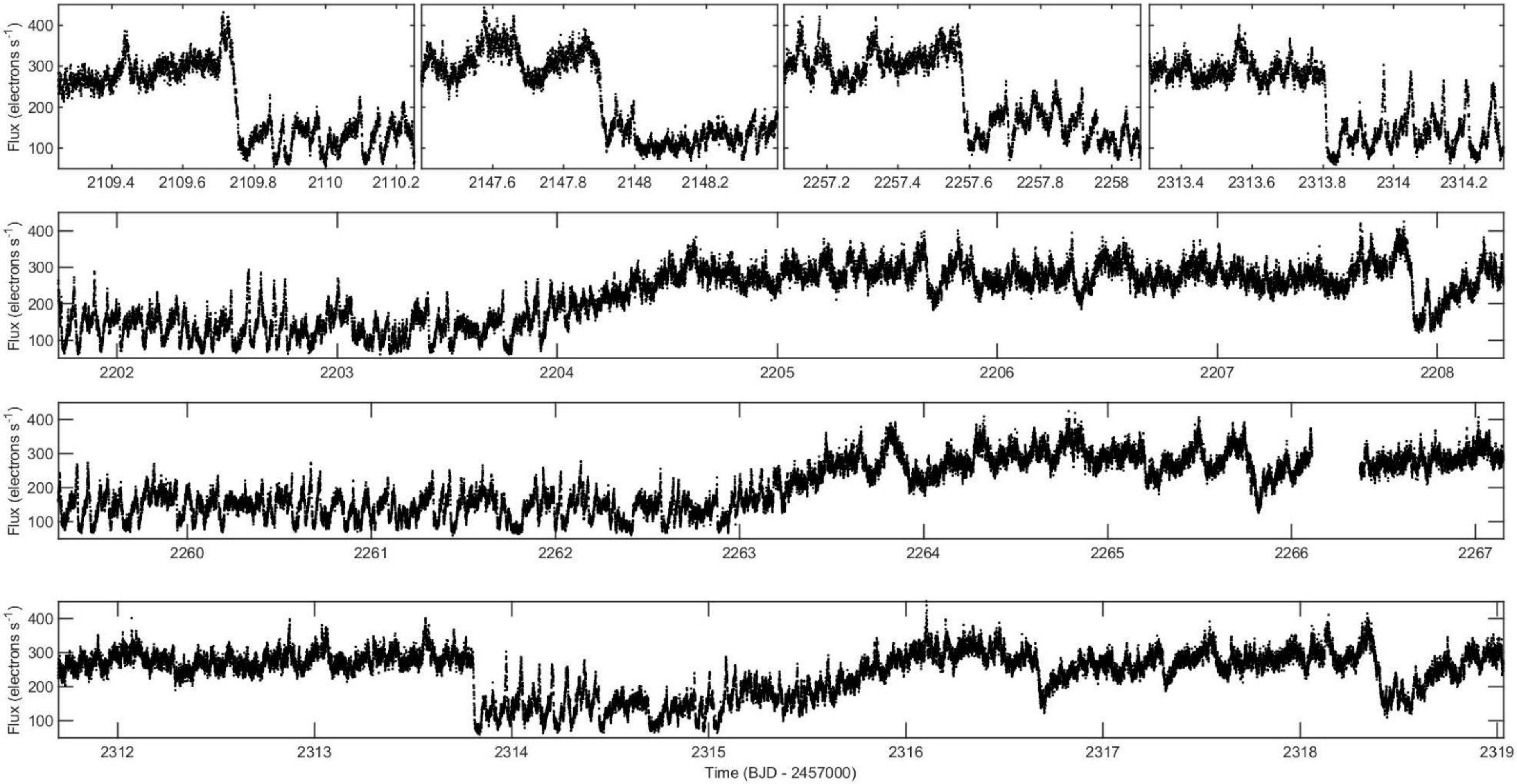
…with ASASSN…



TW Pictoris
including Cycle 1 and ASAS-SN

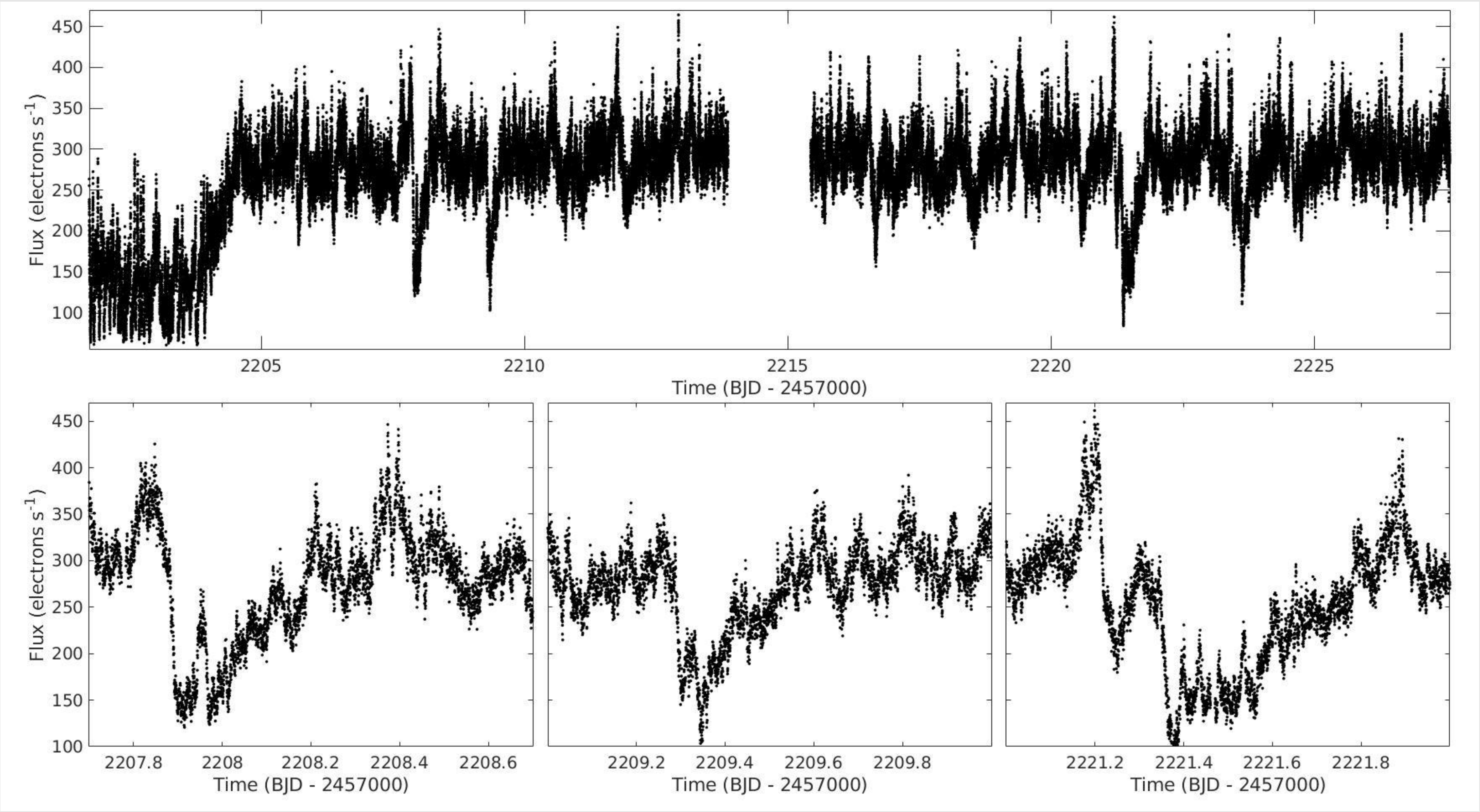


TW Pictoris

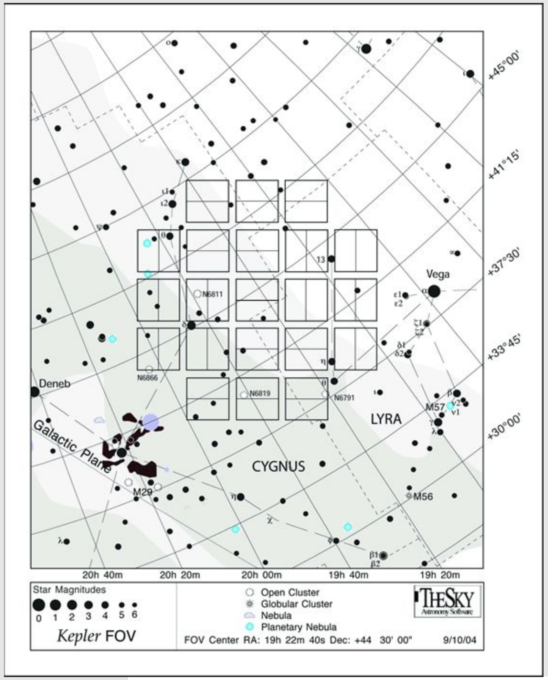


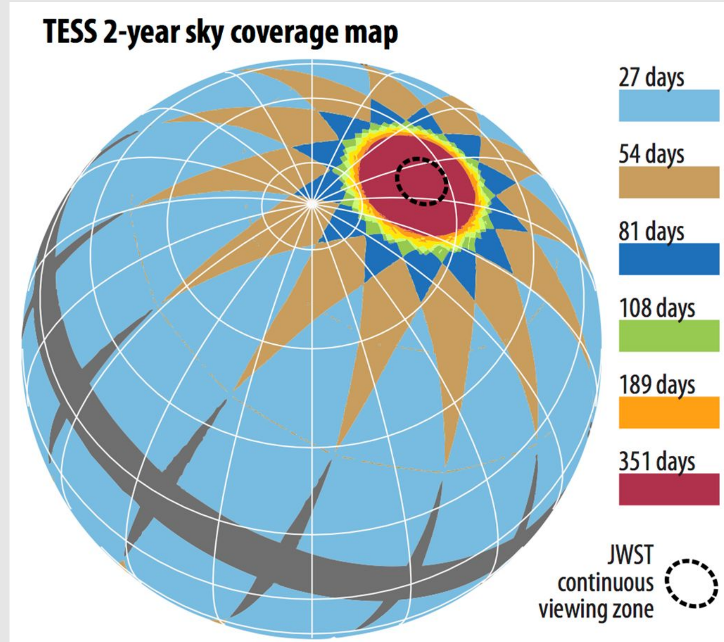
Scaringi+ (2021)

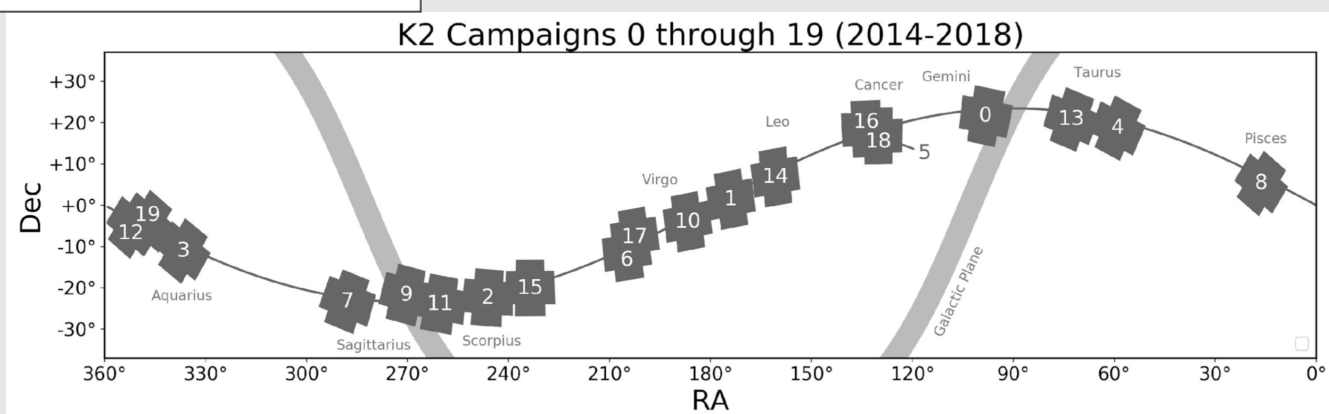
TW Pictoris



Flux (electrons s^{-1})
Time (BJD - 2457000)
2205
2210
2215
2220
2225
2207.8
2208
2208.2
2208.4
2208.6
2209.2
2209.4
2209.6
2209.8
2221.2
2221.4
2221.6
2221.8

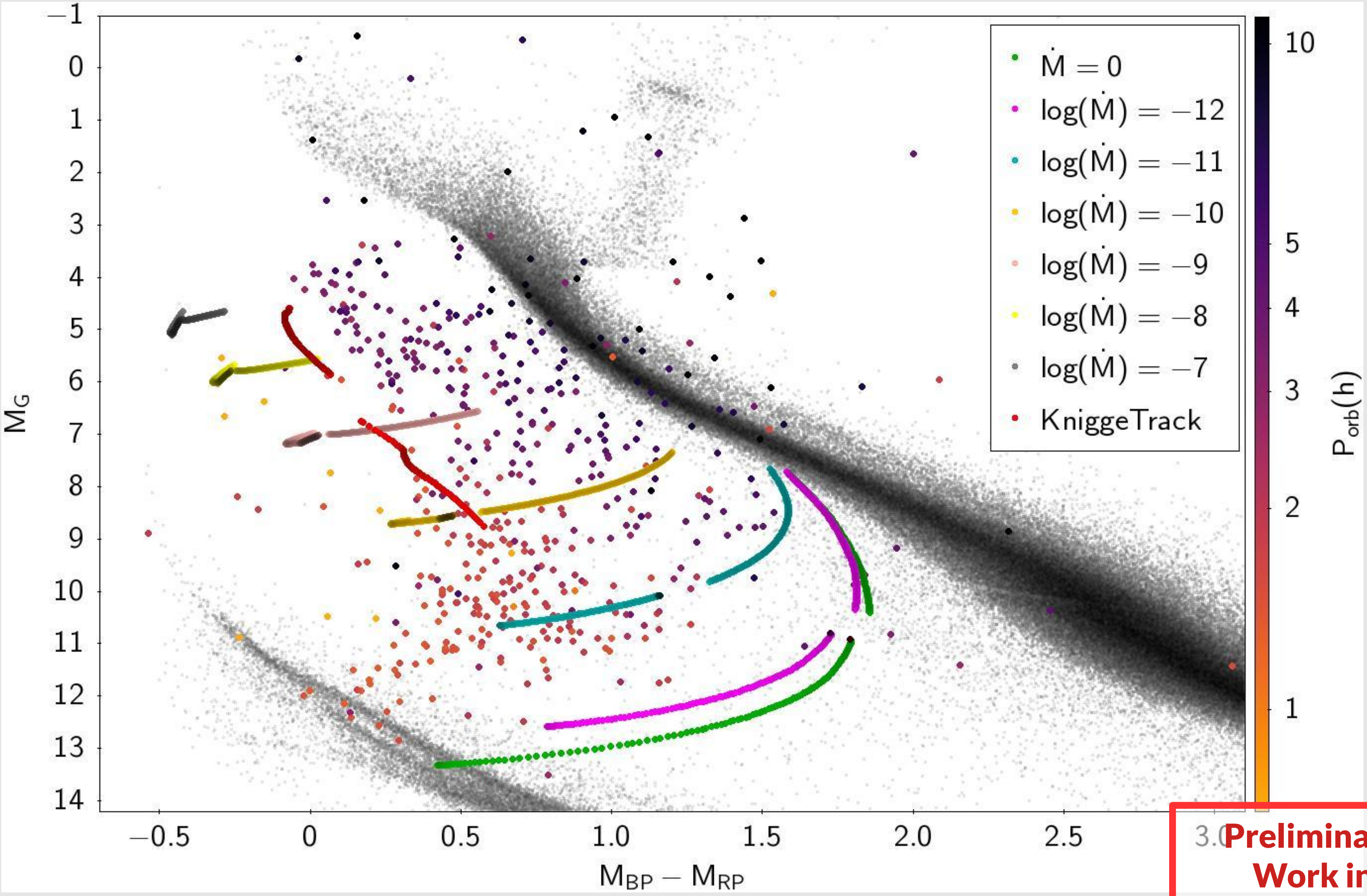

Vega
Deneb
LYRA
CYGNUS
Galactic Plane
M29
M56
M57
+45°00'
+41°15'
+37°30'
+33°45'
+30°00'
20h 40m
20h 20m
20h 00m
19h 40m
19h 20m
Star Magnitudes
0 1 2 3 4 5 6
Open Cluster
Globular Cluster
Nebula
Planetary Nebula
TheSky
Kepler FOV
FOV Center RA: 19h 22m 40s Dec: +44 30' 00"
9/10/04


TESS 2-year sky coverage map
27 days
54 days
81 days
108 days
189 days
351 days
JWST continuous viewing zone


K2 Campaigns 0 through 19 (2014-2018)
Dec
RA
+30°
+20°
+10°
+0°
-10°
-20°
-30°
360°
330°
300°
270°
240°
210°
180°
150°
120°
90°
60°
30°
0°
Aquarius
Sagittarius
Scorpius
Virgo
Leo
Cancer
Gemini
Taurus
Pisces
Galactic Plane
19
12
3
7
9
11
2
15
17
6
10
1
14
16
18
5
0
13
4
8

AWD laboratories

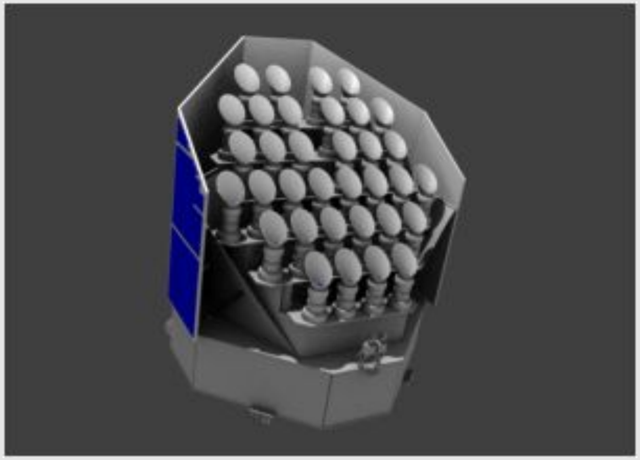
can we infer Mdot using Gaia distances?

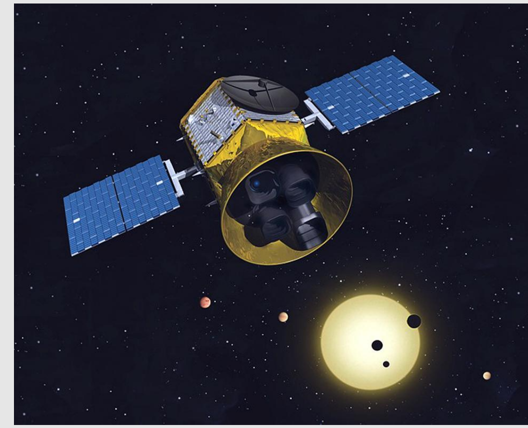


see also Abril+ (2020)

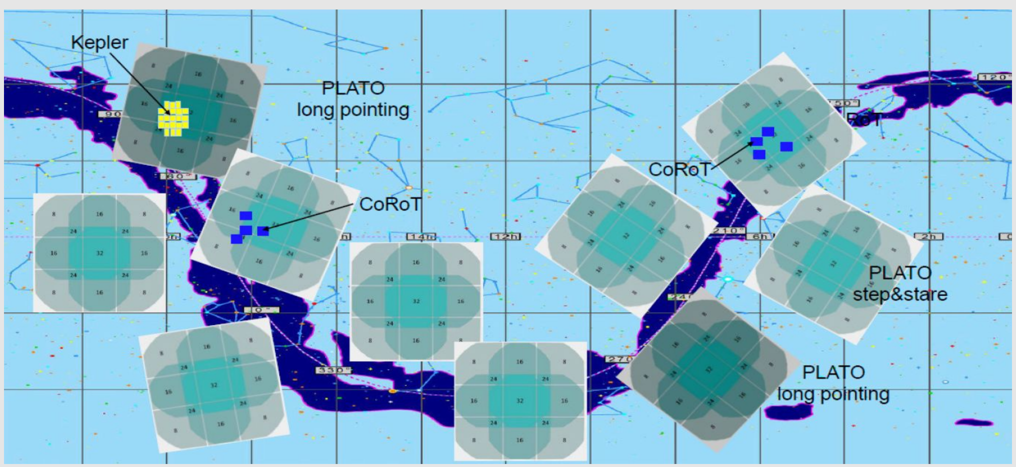
Preliminary Work in progress!

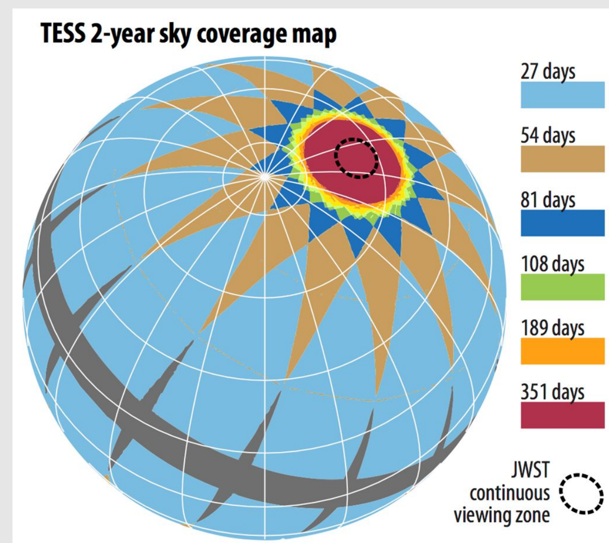
What next?
PLATO & TESS



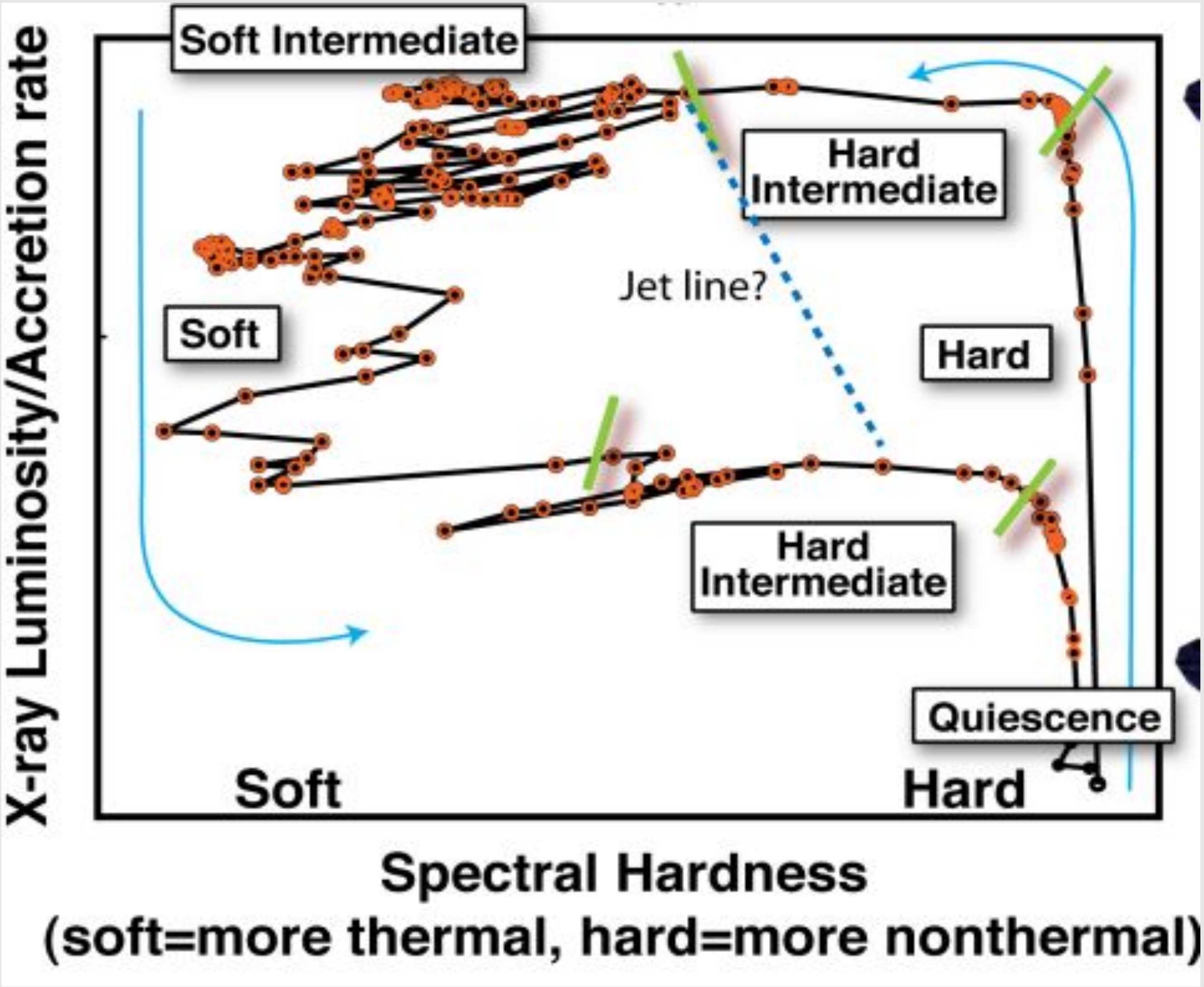


Launch 2024

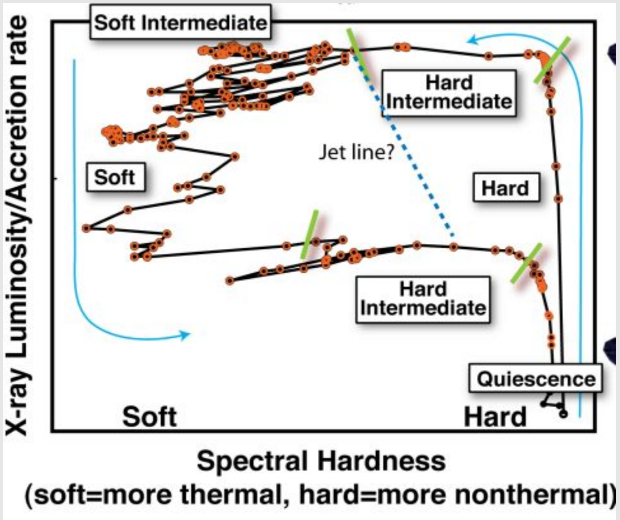


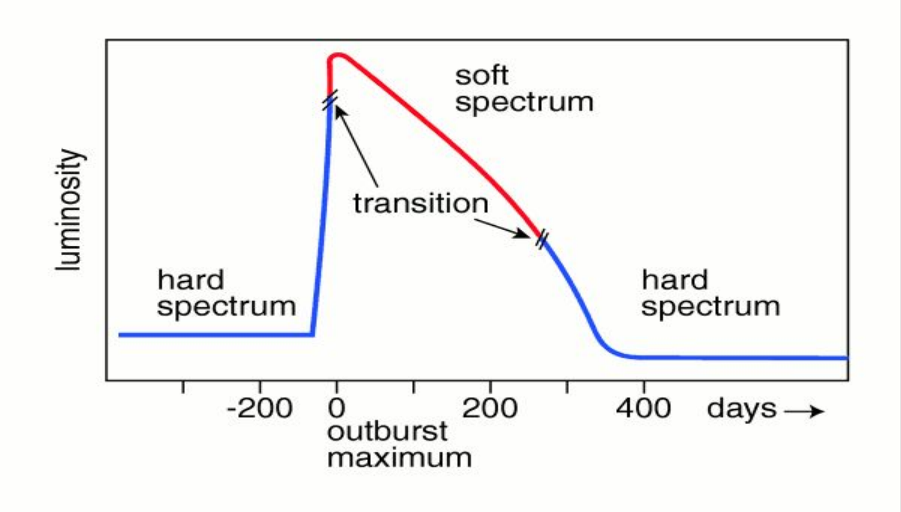


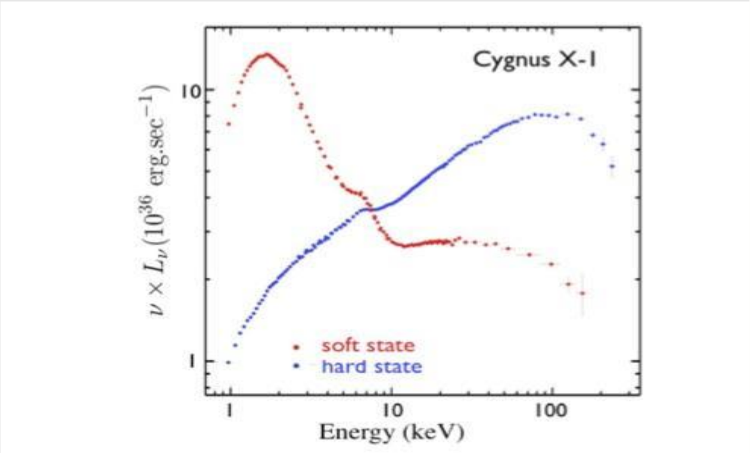
State changes in XRBs

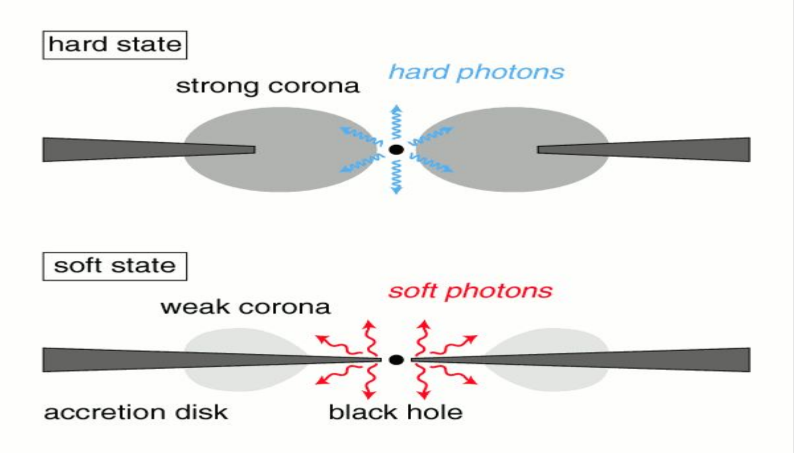


State changes in XRBs



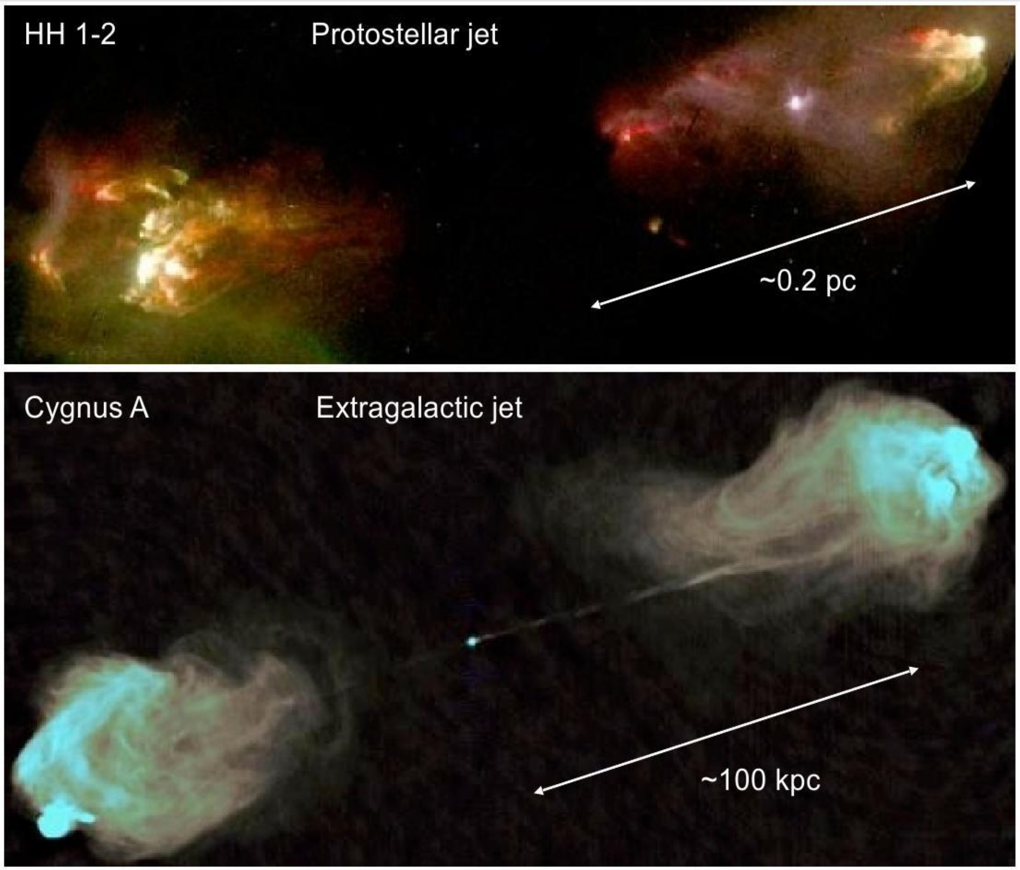


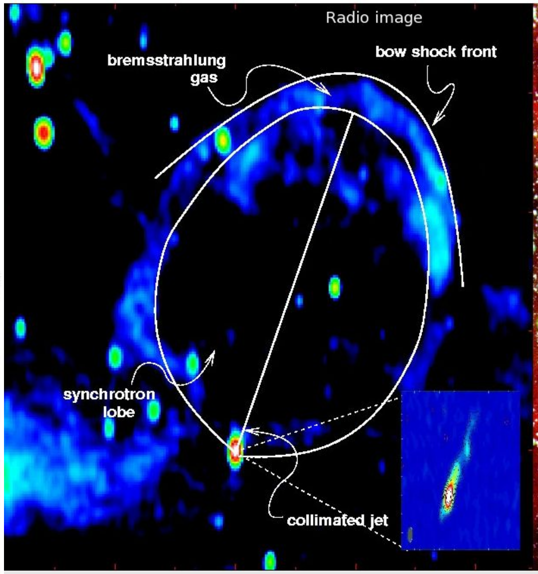




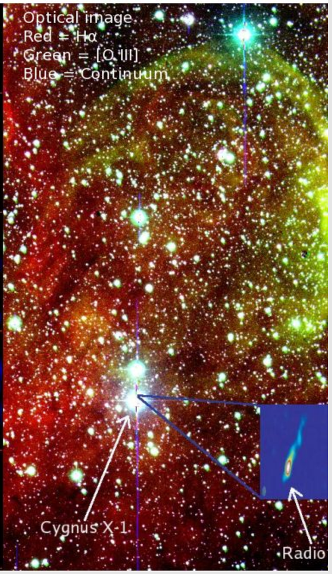
Fender+ 2004, Meyer+ 2005, Meyer-Hofmeister+ 2005, Belloni+ 2005, etc...

Jets launching:
ubiquitous mechanism?





Gallo+ (2005)



Russel+ (2007)

AGN states

AGN population studies show similar HID diagrams to XRBs and AWDs
(caveat selection effects!)

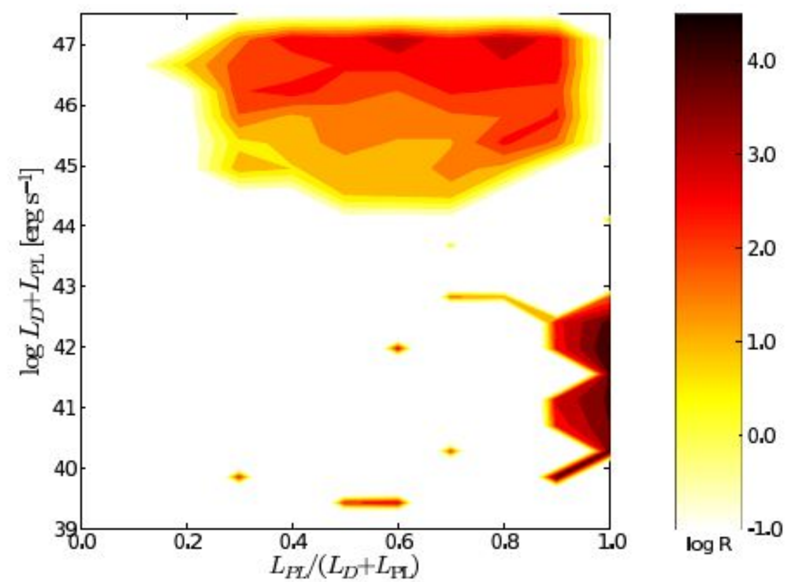
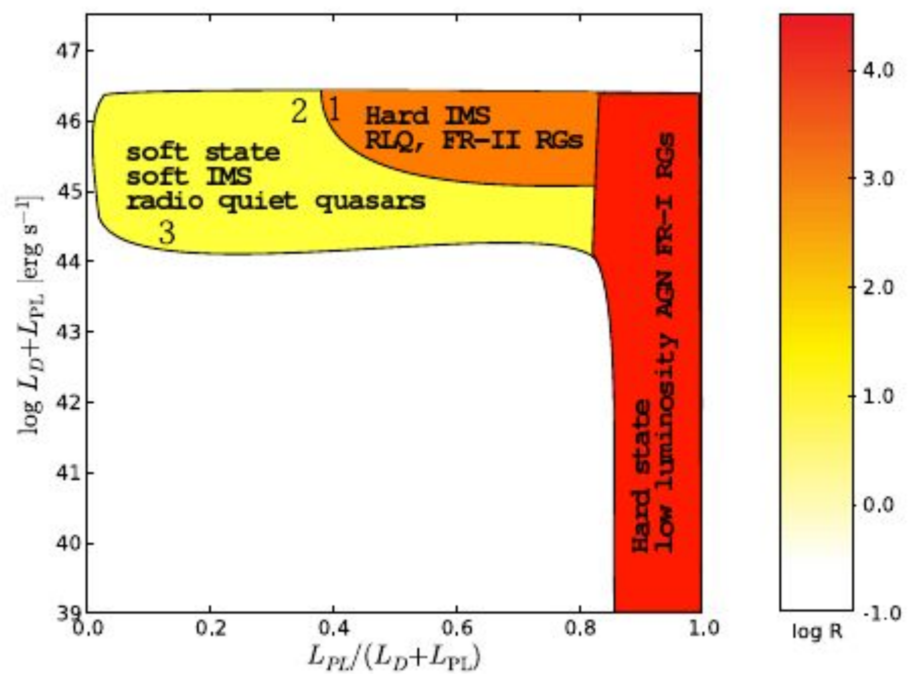
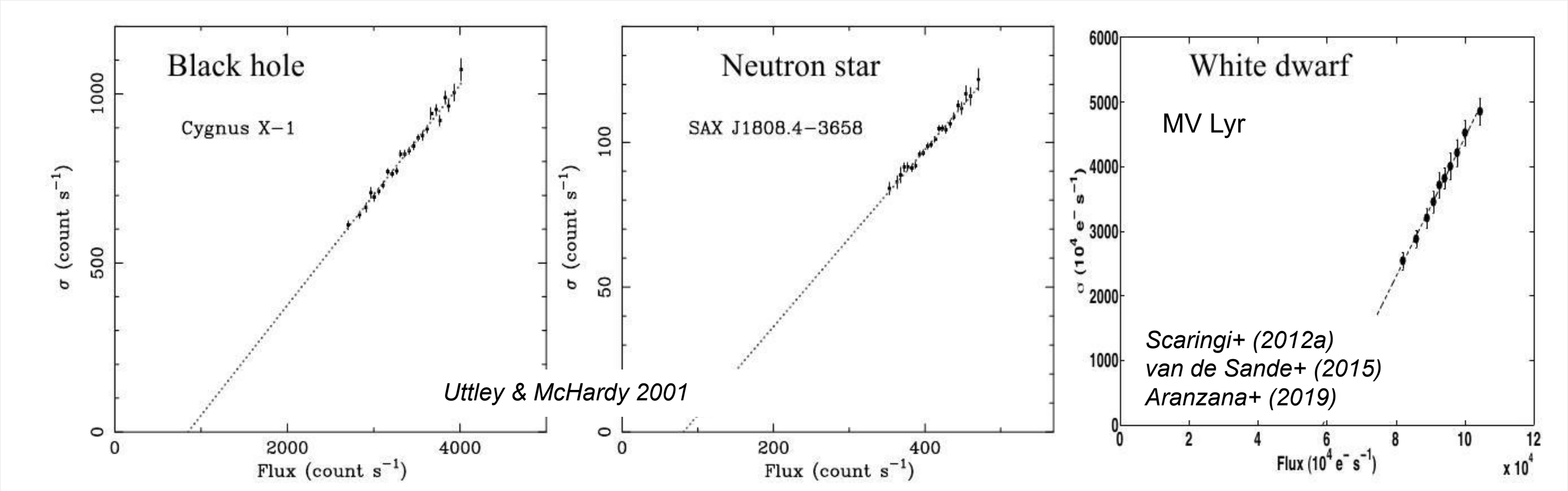


Figure 7. DFLD showing the average radio loudness for SDSS quasars and LLAGN from the Ho (1999) sample. Note that the gap between LLAGN and Quasars is an artefact of our sample selection.

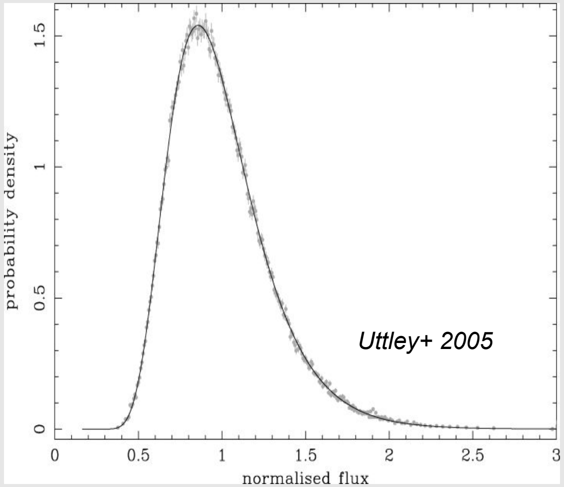


Koerding+ (2006)

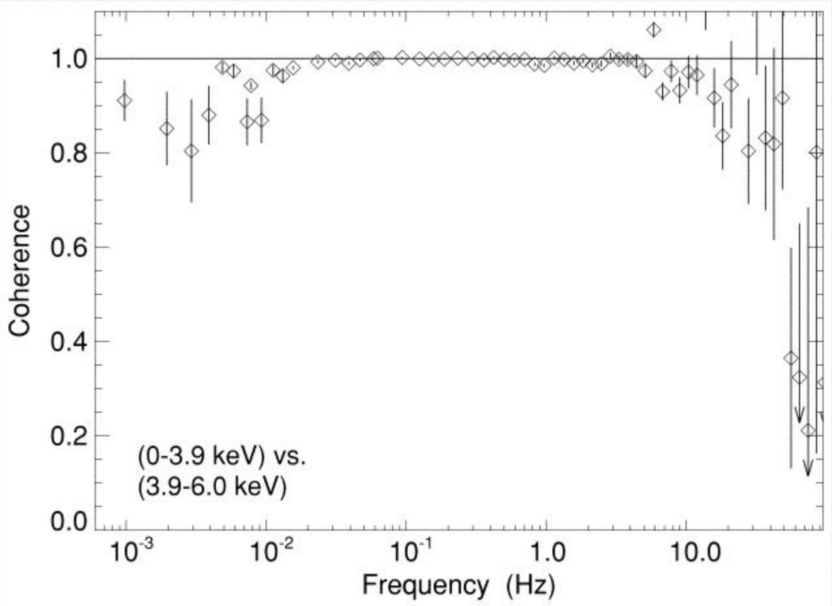
The rms-flux relation

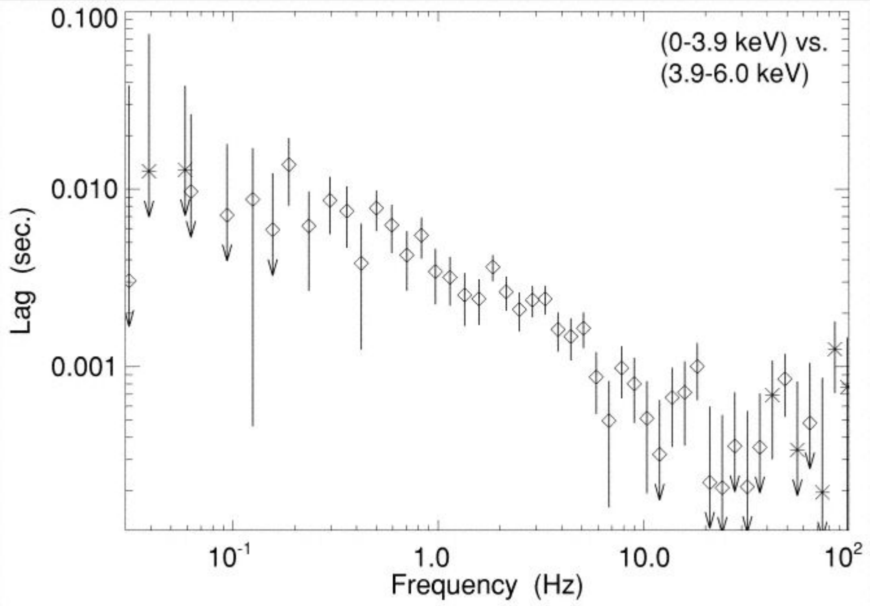


- Flux distributions are log-normal
- → Additive processes ruled out!
- Observed lightcurves must be the result of *multiplicative* processes



Coherence & Fourier-dependent lags



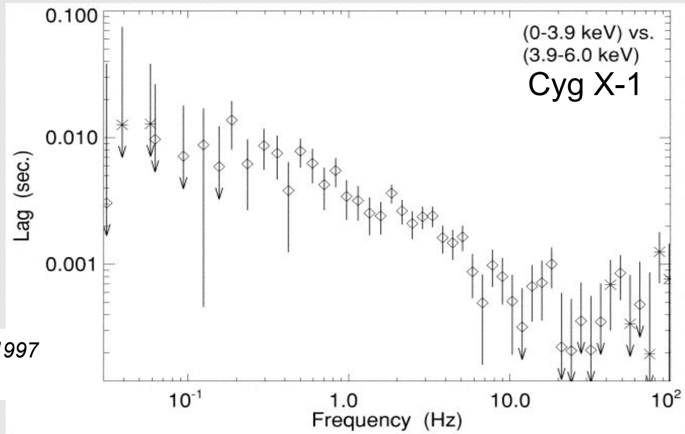


Fourier frequency-dependant measure of the linear correlation between 2 time series observed simultaneously in two energy channels

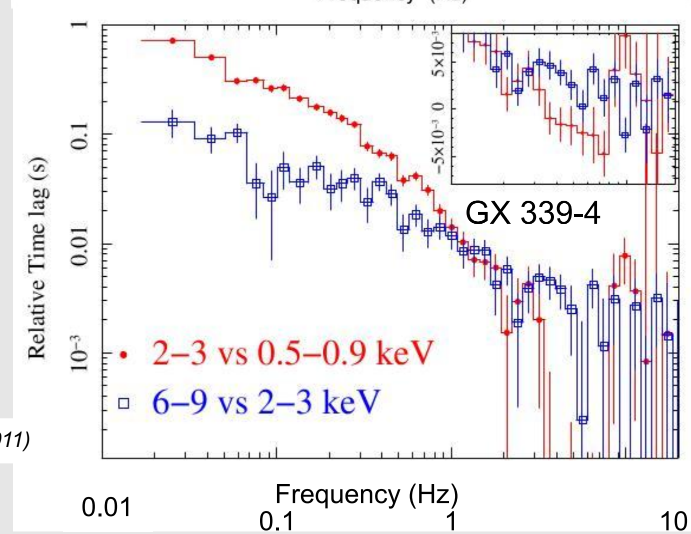
Nowak & Vaughan 1997
Nowak+ 1999

Fourier-dependent time lags

XRBs

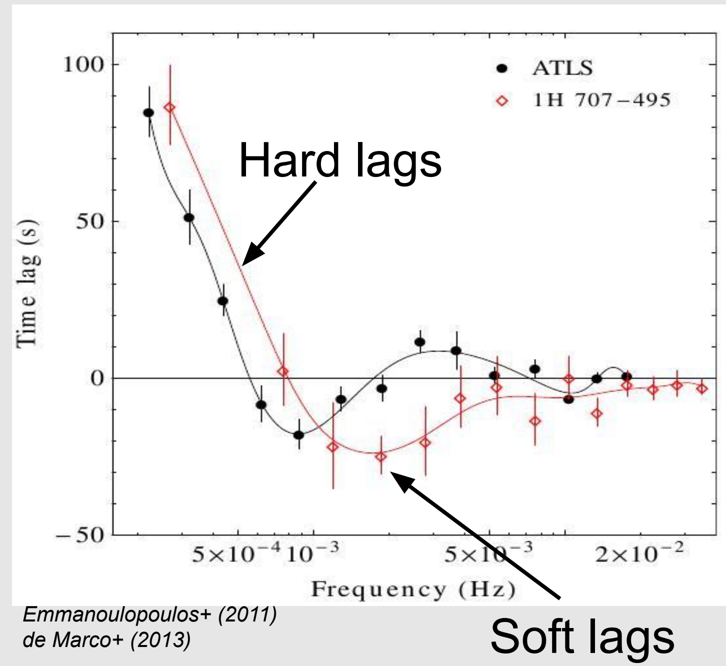


Nowak & Vaughan 1997
Nowak+ 1999



Uttley+ (2011)

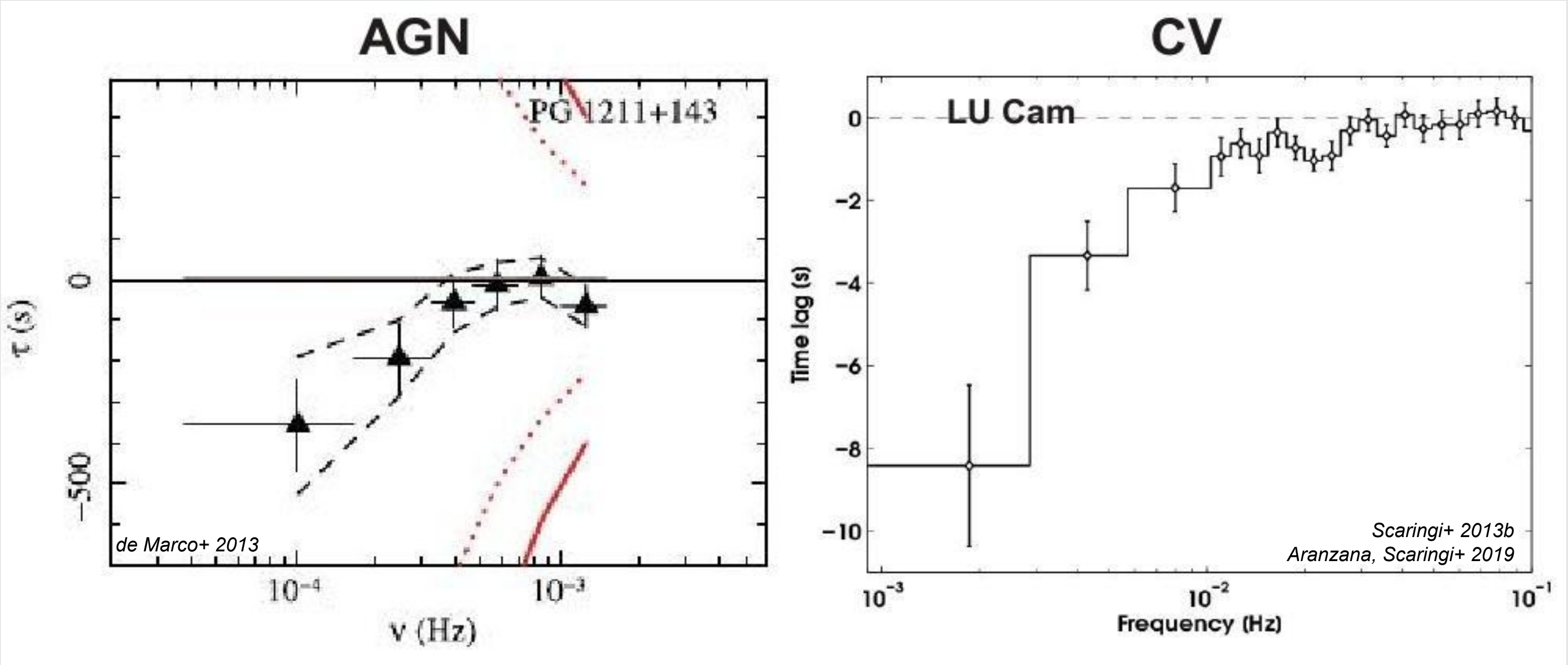
AGN



Emmanoulopoulos+ (2011)
de Marco+ (2013)

Fourier time-lags in CVs

Soft lags hard | **Red lags blue**

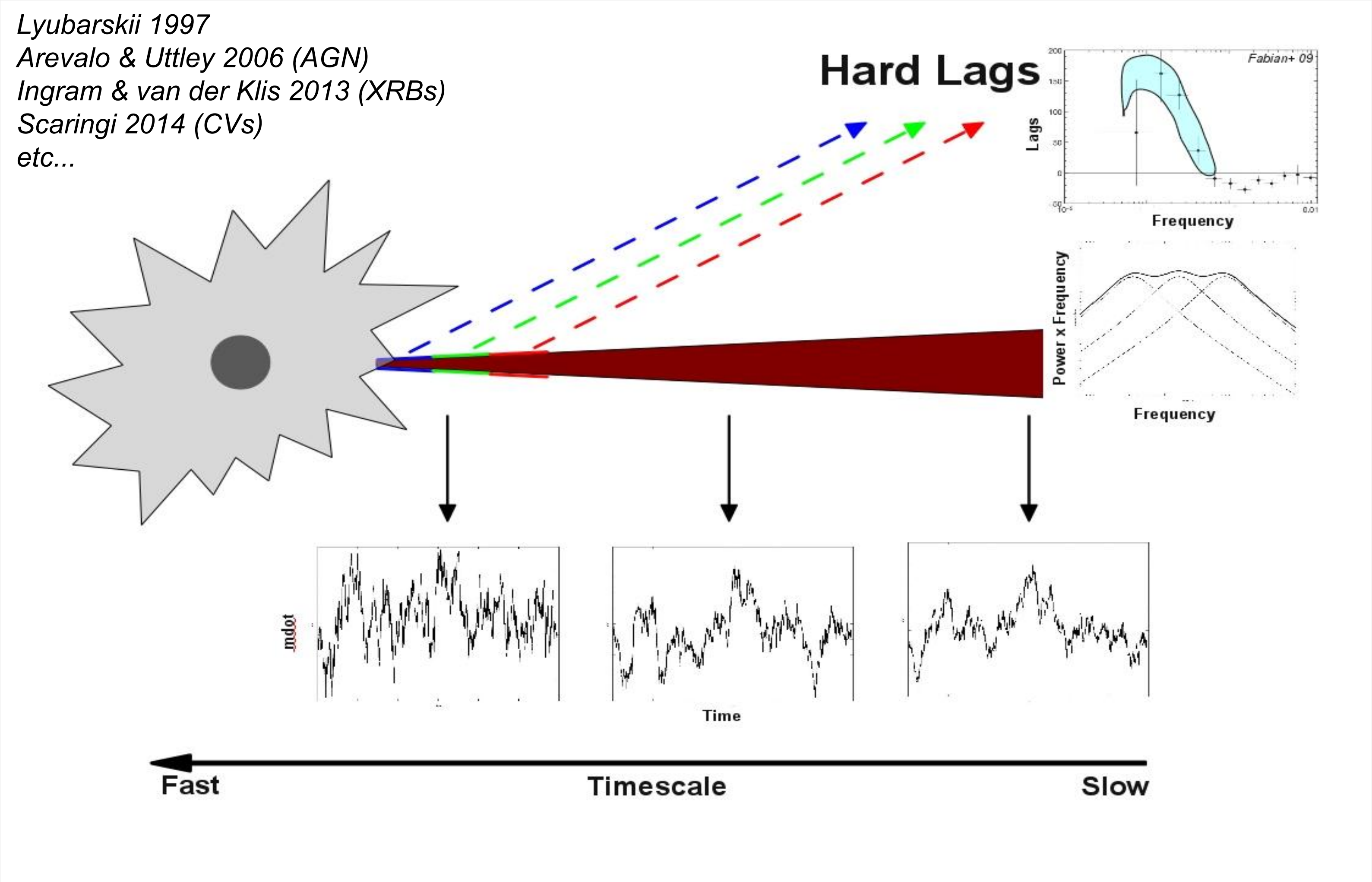


Time-scale consistent with time-travel delay

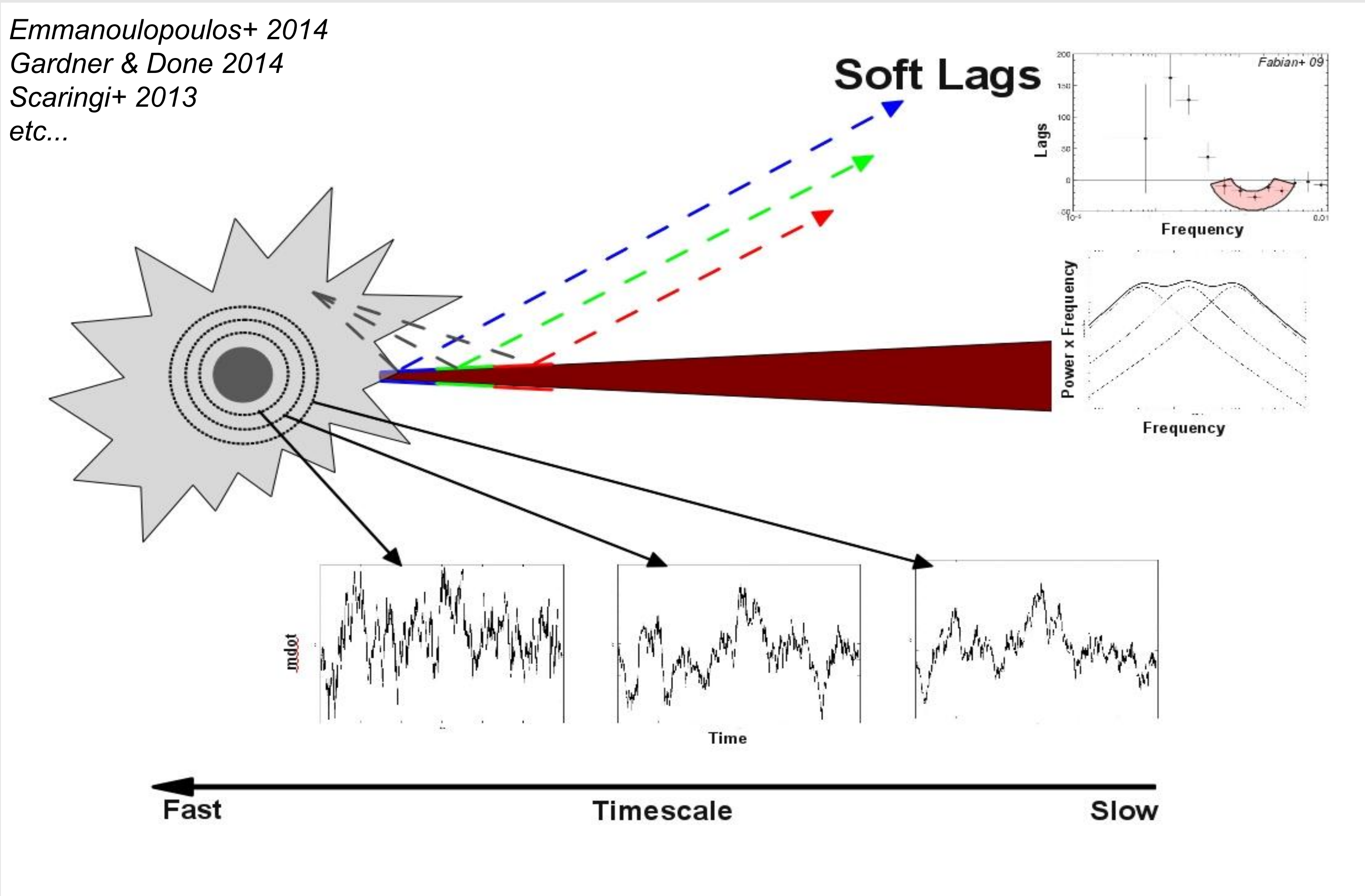
Time-scale longer than time-travel delay: *disk thermal reprocessing?*

...see also Bruch 2015

Fluctuating Accretion disks

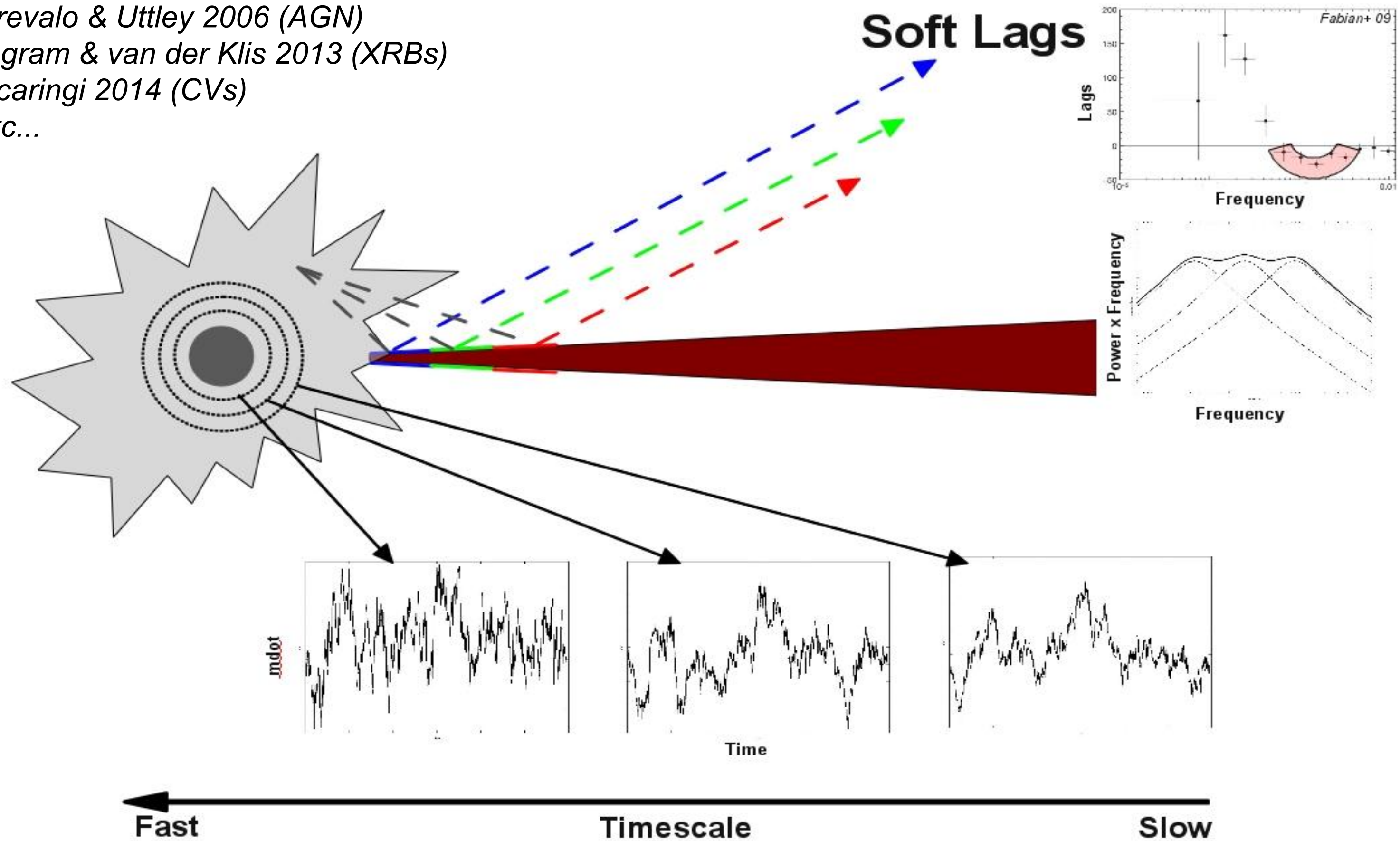


Fluctuating Accretion disks

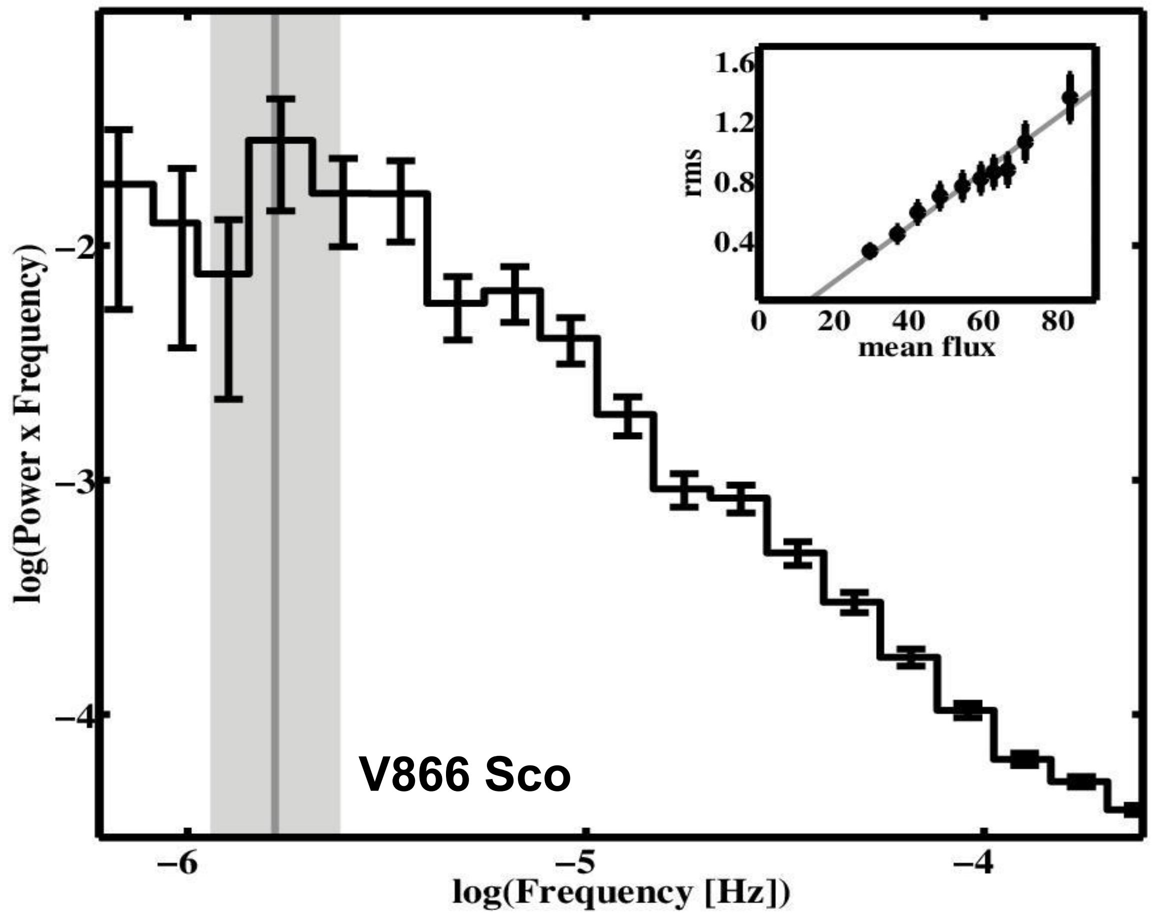


Fluctuating Accretion disks

Lyubarskii 1997
Arevalo & Uttley 2006 (AGN)
Ingram & van der Klis 2013 (XRBs)
Scaringi 2014 (CVs)
etc...

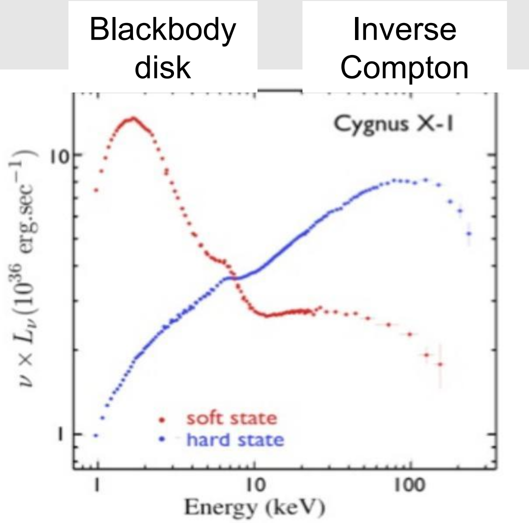


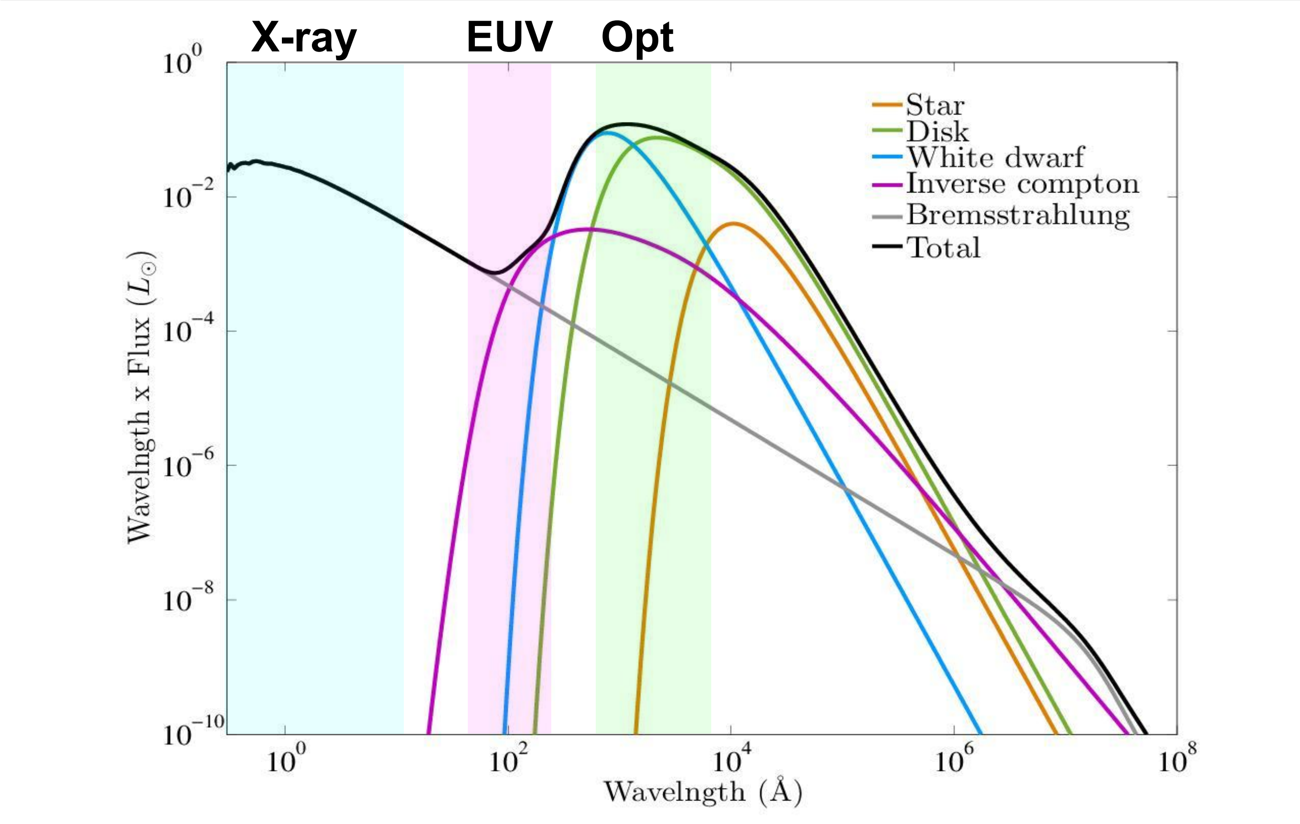
YSOs join the family!



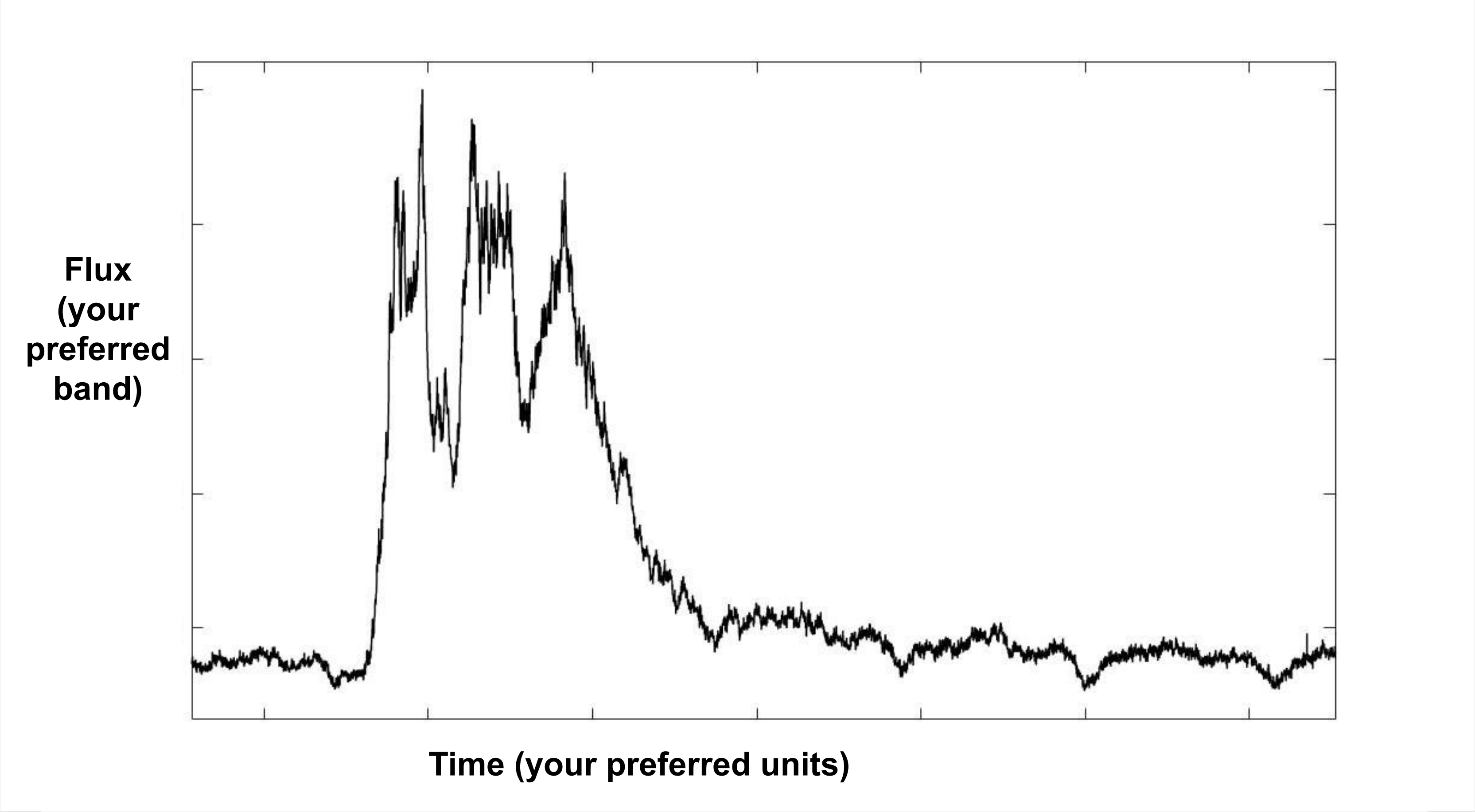
Scaringi+ (2015b)

Fluctuating Accretion disk:
how can we test for "corona" in CVs?

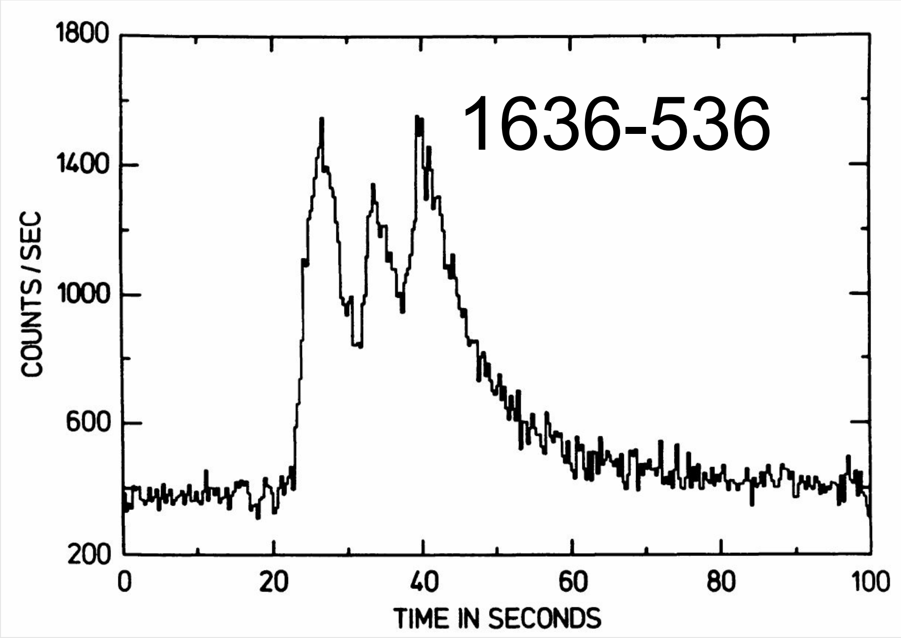


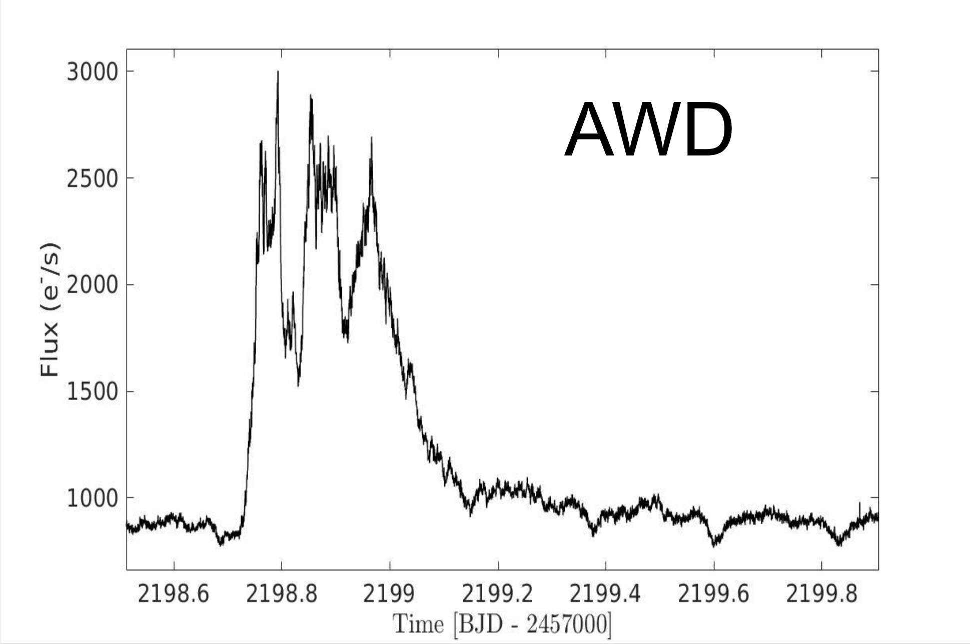


What is this?

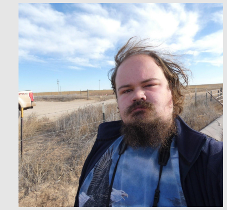


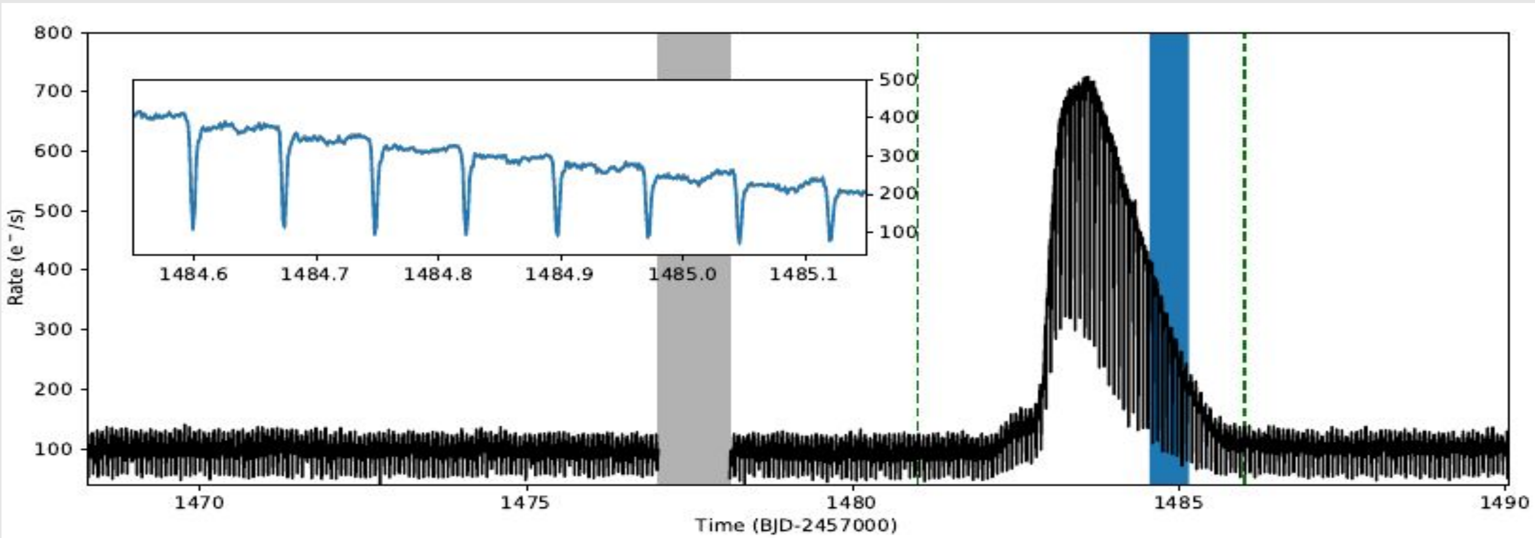
Type I X-ray bursts in AWDs?





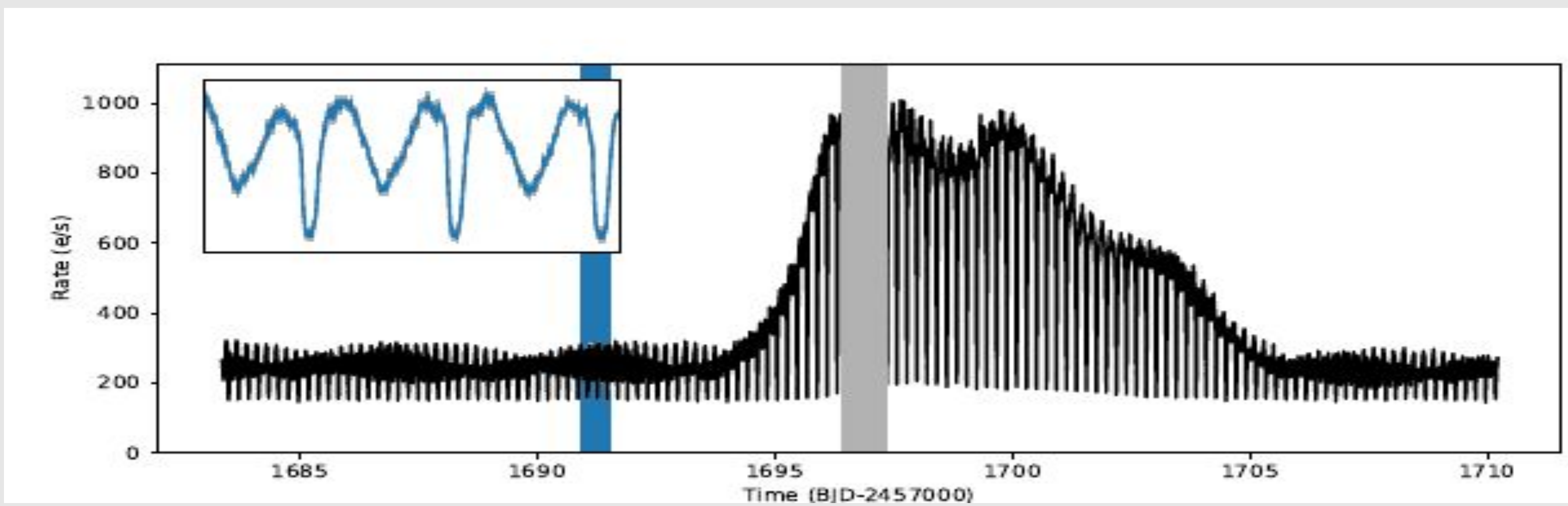
Z Cha & EX Dra





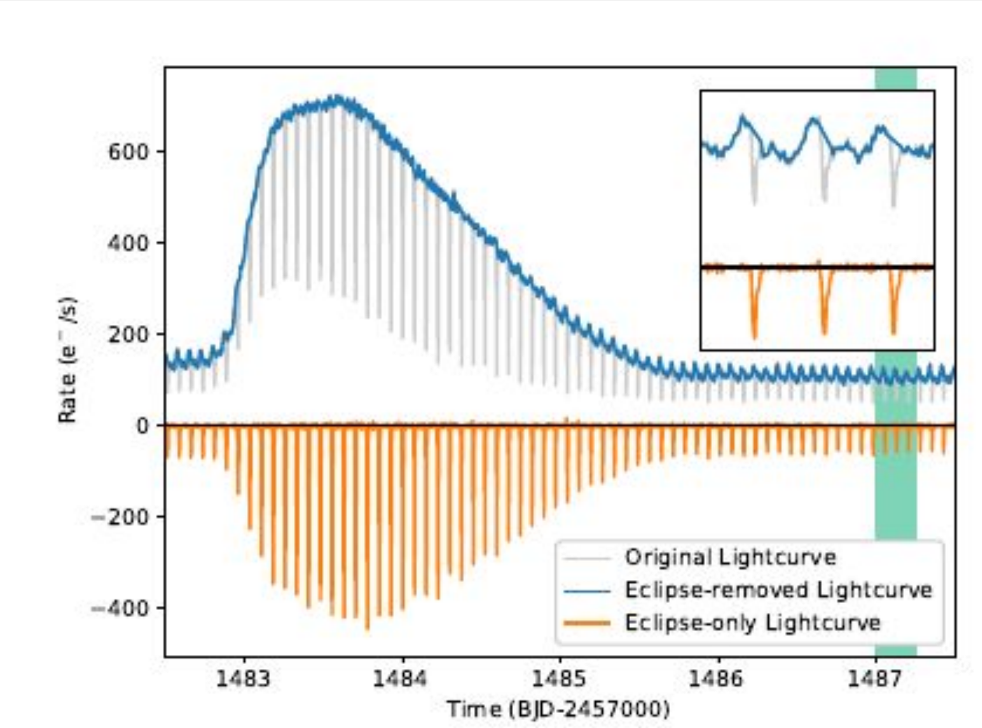
Z Cha

EX Dra

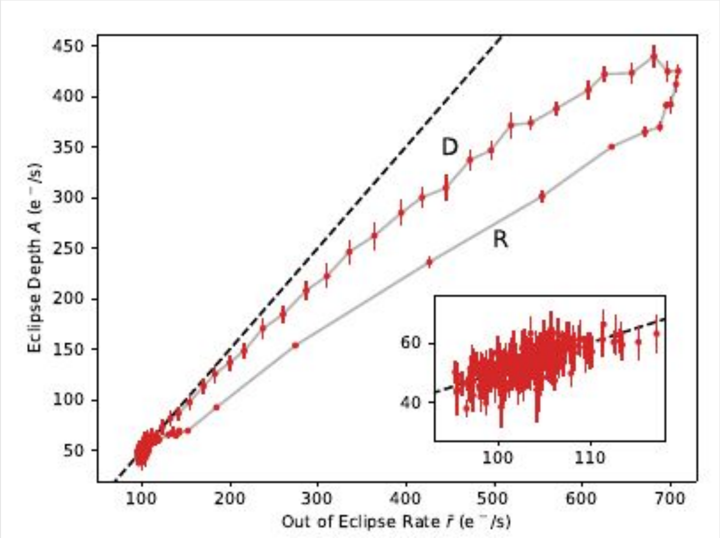


Court+ (2019)
Court+(2020)

Z Cha
Outside-in outburst evolution



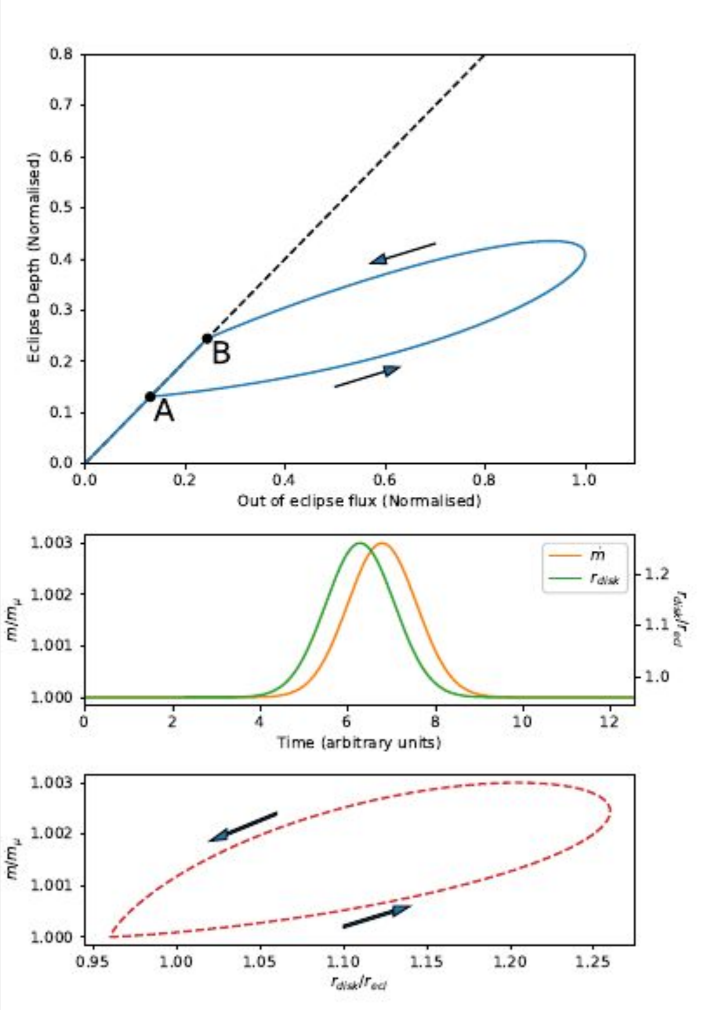
Clear hysteresis during dwarf nova outburst evolution



Court+ (2019)
Scaringi+ (2013)

Z Cha

Outside-in outburst evolution



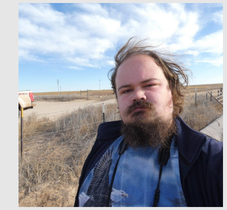
$$L(\dot{M}, R_{\rm out}) = \frac{1}{2}\int_{R_{\rm in}}^{R_{\rm out}} \sigma 2\pi R T^4(R)\,{\rm d}R$$
$$\propto \dot{M}\left(\frac{2\sqrt{R_*}}{3R_{\rm out}\sqrt{R_{\rm out}}} - \frac{1}{R_{\rm out}} + \frac{1}{3R_*}\right)$$

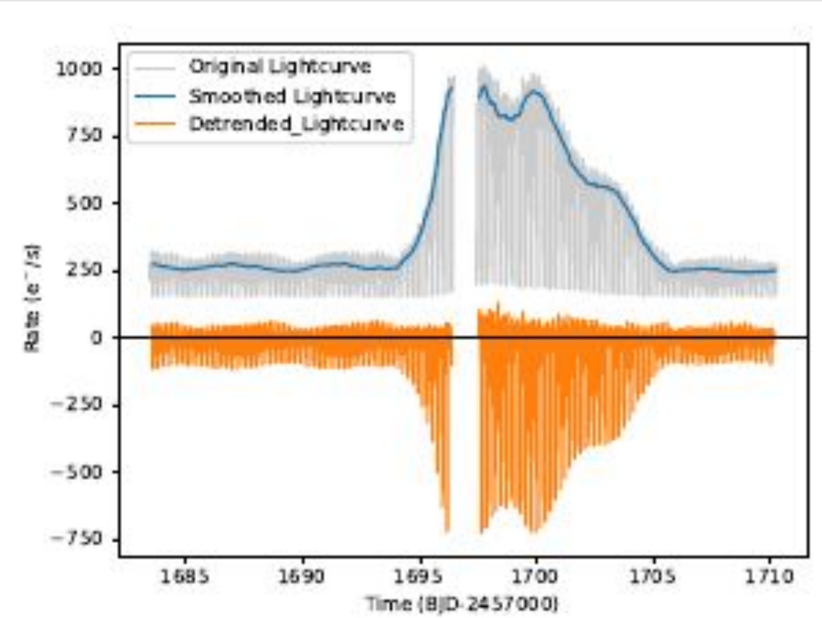
Hysteresis must be caused by outer disk size increasing **before** mass transfer rate increase → outside-in outburst

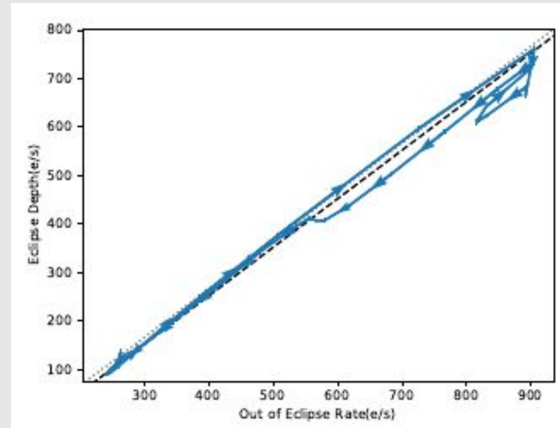
Court+ (2019)

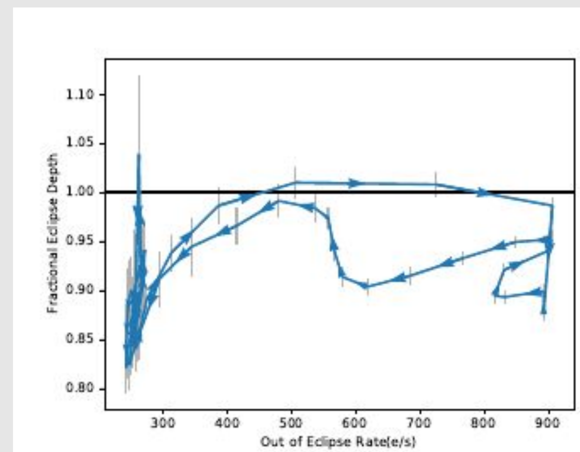
EX Dra

Inside-out outburst evolution







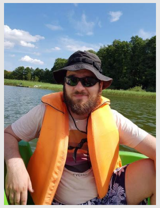


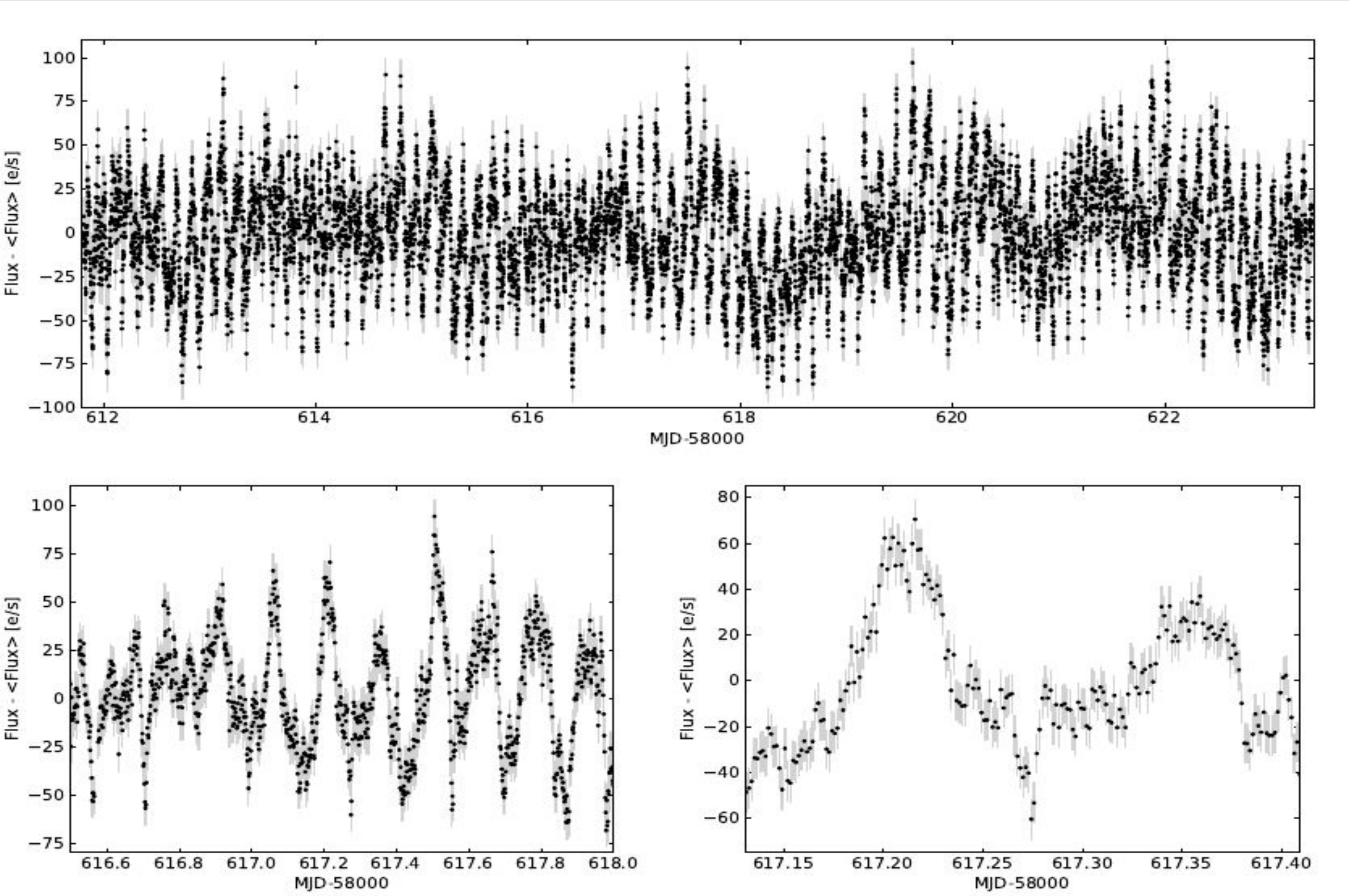
Hysteresis must be caused by mass transfer increasing **before** outer disk radius
→ inside-out outburst

Court+ (2020)

AQ Men

exploring the tilted disk

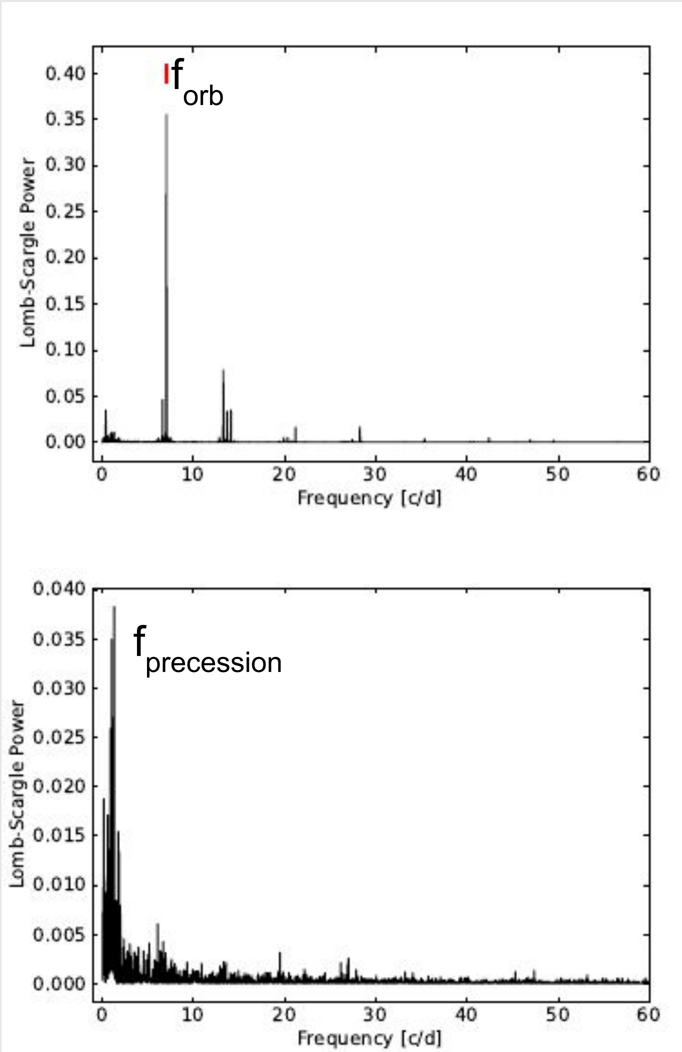




Ilkiewicz+ (2021)

AQ Men

exploring the tilted disk

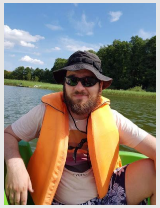


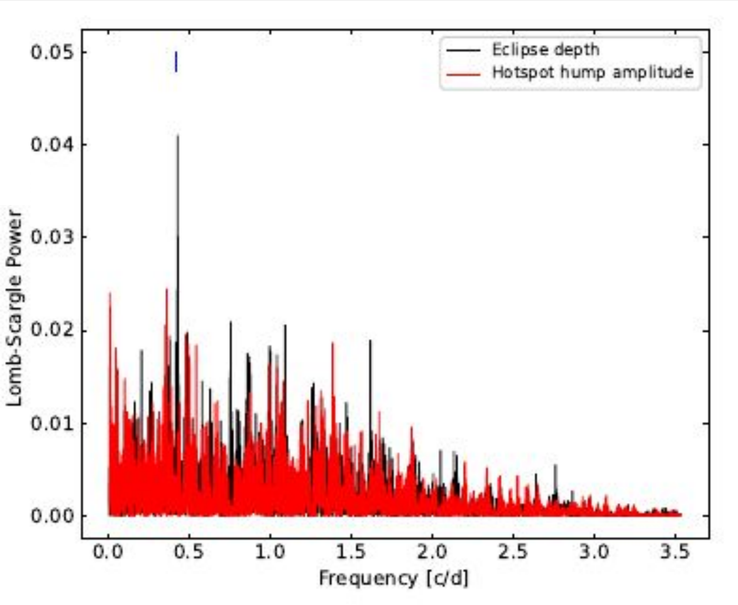
ID	Frequency [c/d]	Amplitude [e/s]	MJD_0
ω_0	7.06869(13)	24.66(17)	58667.68379(16)
$2\omega_+$	13.29413(28)	11.25(17)	58667.67647(18)
ω_+	6.64591(34)	9.42(17)	58667.71802(42)
N	0.42093(41)	7.78(17)	58668.449(8)
$2\omega_0$	14.13860(41)	7.70(17)	58667.64725(24)
$2\omega_0$-N	13.71513(44)	7.28(17)	58667.70072(27)
$4\omega_0$	28.27526(60)	5.29(17)	58667.68000(18)
$3\omega_0$	21.20627(62)	5.10(17)	58667.69222(25)
ω_-	7.4890(10)	3.42(17)	58667.69220(11)
$2\omega_0$-3N	12.8742(11)	3.08(17)	58667.7019(7)
$3\omega_+$	19.9415(11)	3.11(17)	58667.65870(43)
$3\omega_0$-2N	20.3658(11)	2.91(17)	58667.69293(45)
ω_0-2N	6.2228(12)	2.84(17)	58667.7486(15)
$6\omega_0$	42.4152(12)	2.71(17)	58667.66454(24)
$5\omega_0$	35.3431(13)	2.56(17)	58667.67009(30)
$4\omega_0$-2N	27.4305(14)	2.32(17)	58667.68465(42)
$7\omega_0$-6N	46.9523(15)	2.11(17)	58667.68200(27)
$7\omega_0$	49.4830(17)	1.89(17)	58667.68073(29)
$2\omega_0$+N	14.5574(19)	1.68(17)	58667.6597(11)
$4\omega_+$	26.5834(21)	1.53(17)	58667.68059(65)
$3\omega_0$-N	20.7830(21)	1.51(17)	58667.67364(84)
$6\omega_0$-5N	40.3054(24)	1.36(17)	58667.66312(49)
$8\omega_0$	56.5535(29)	1.09(17)	58667.67454(44)
$6\omega_0$-4N	40.7268(32)	0.99(17)	58667.66489(66)

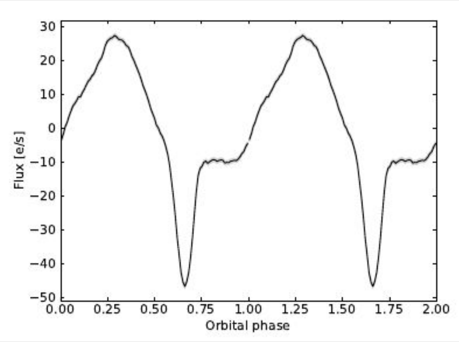
Ilkiewicz+ (2021)

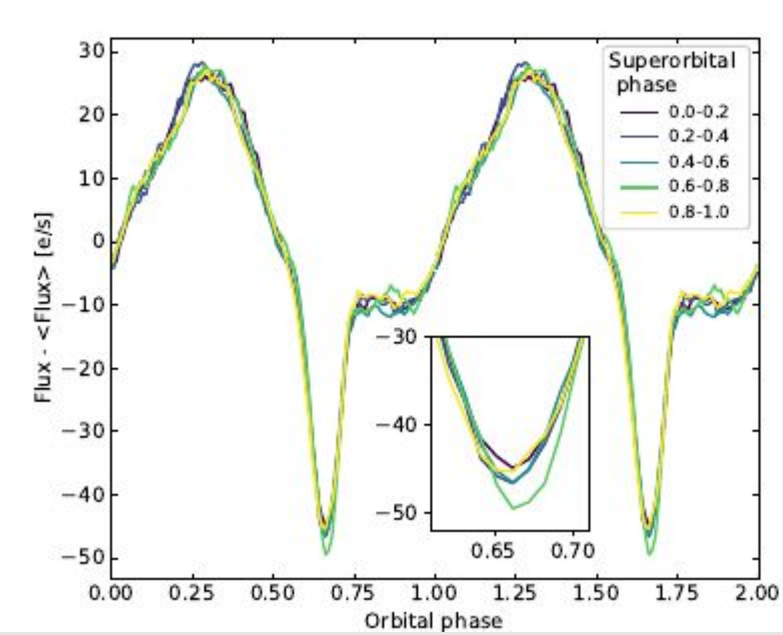
AQ Men

exploring the tilted disk





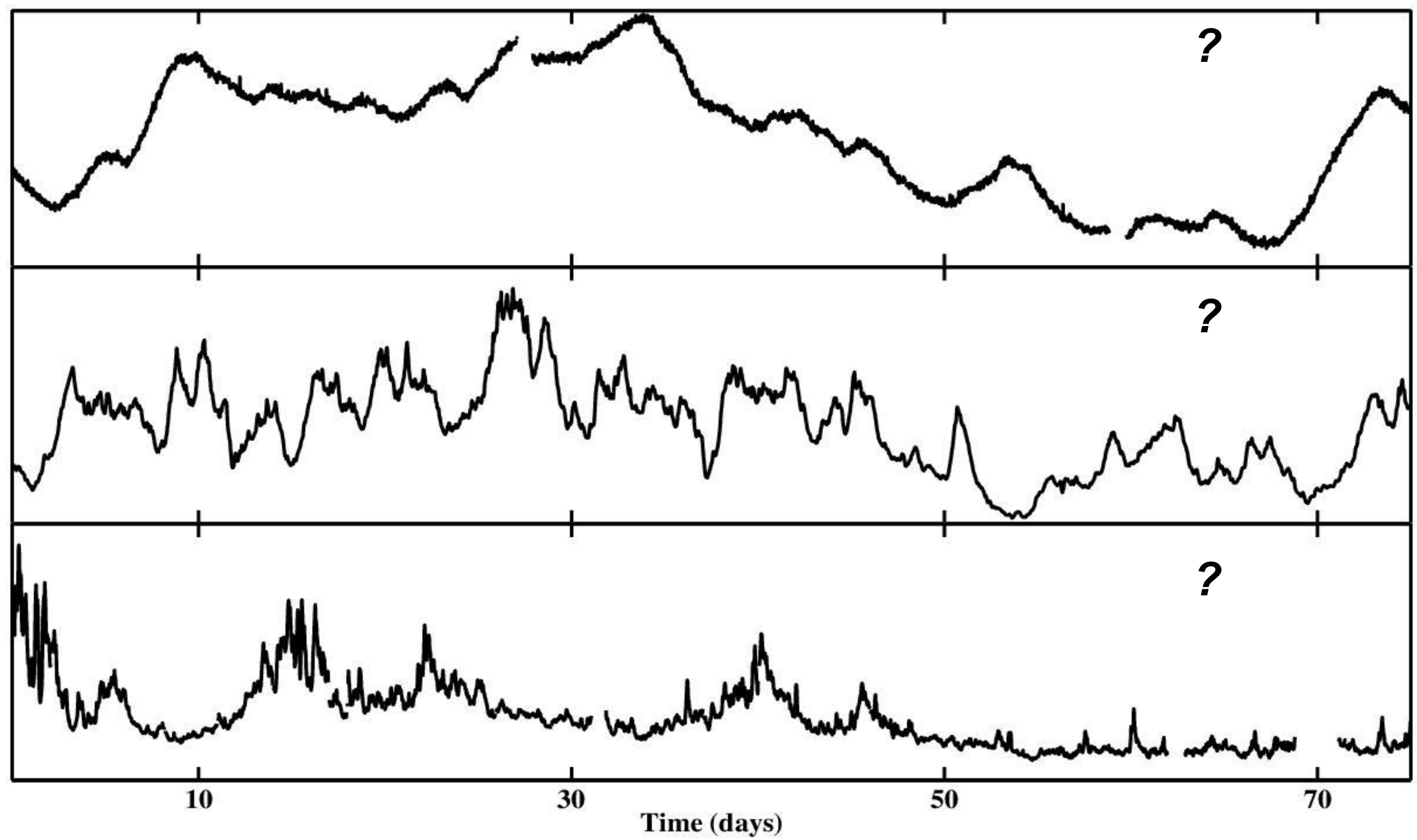




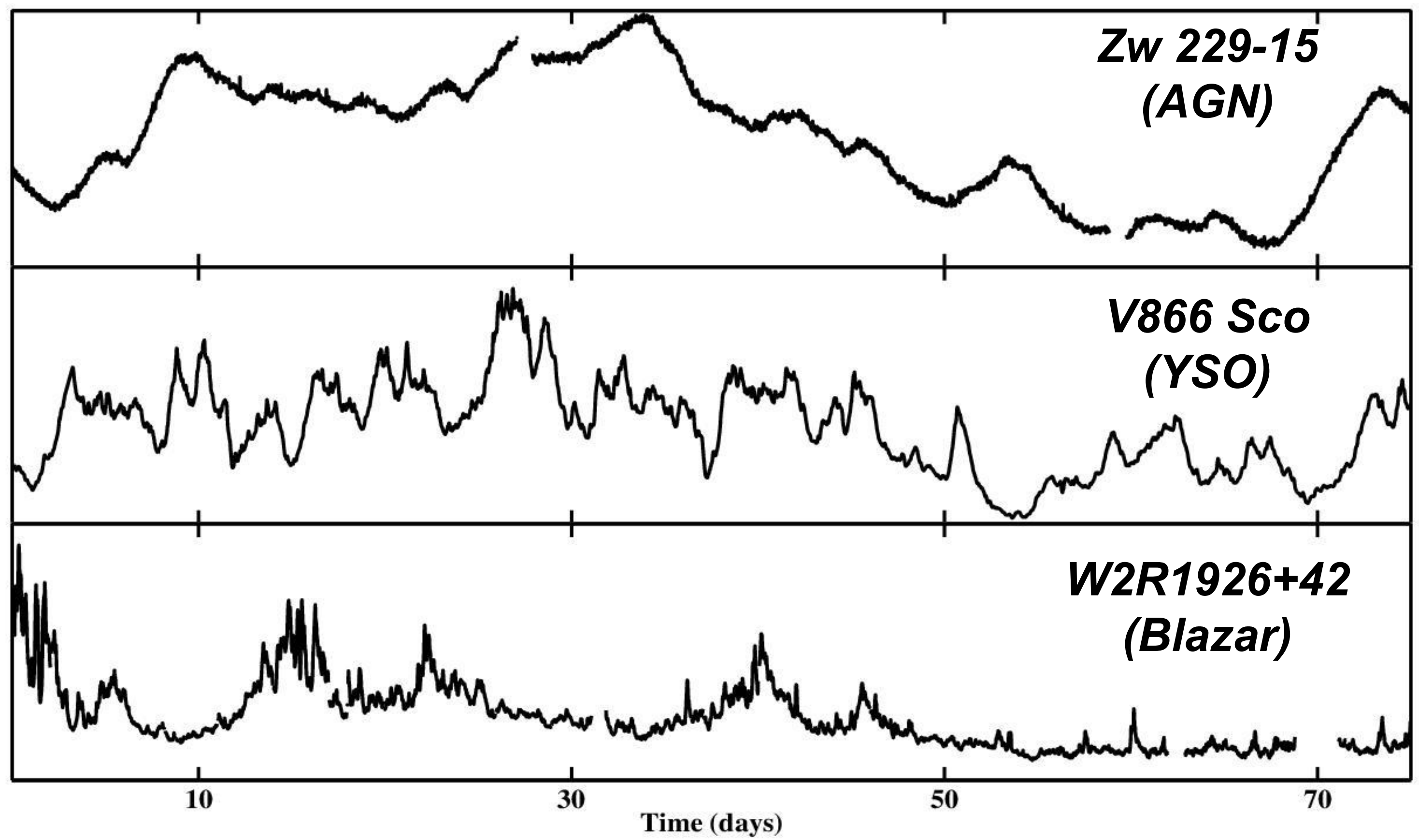
Eclipse depth variations on tilted disk precession period

Ilkiewicz+ (2021)

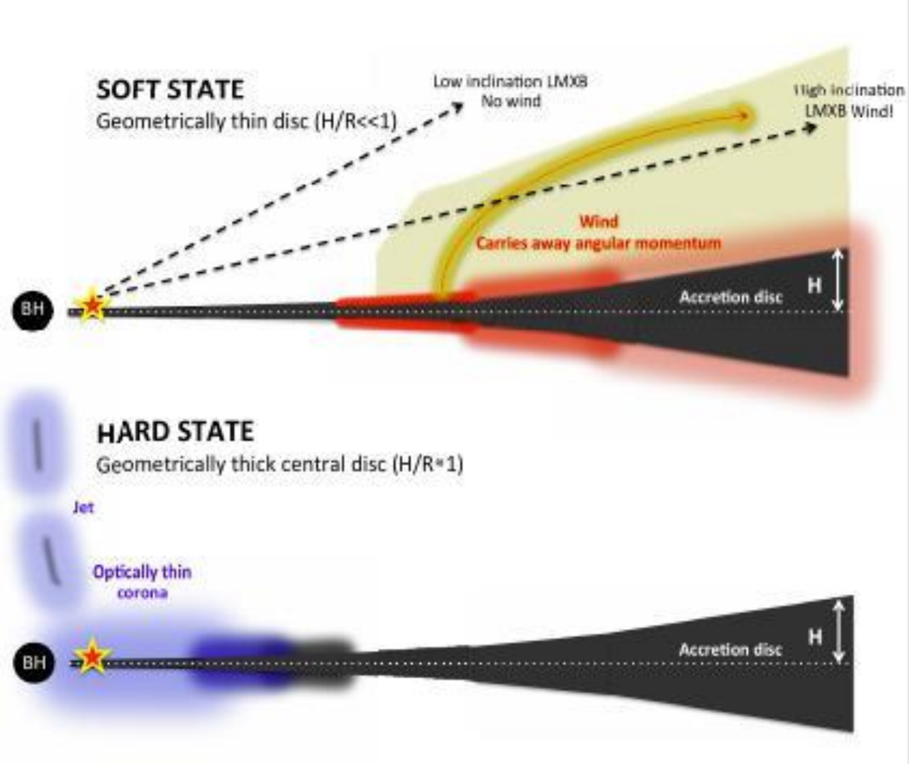
Accretion-driven flickering

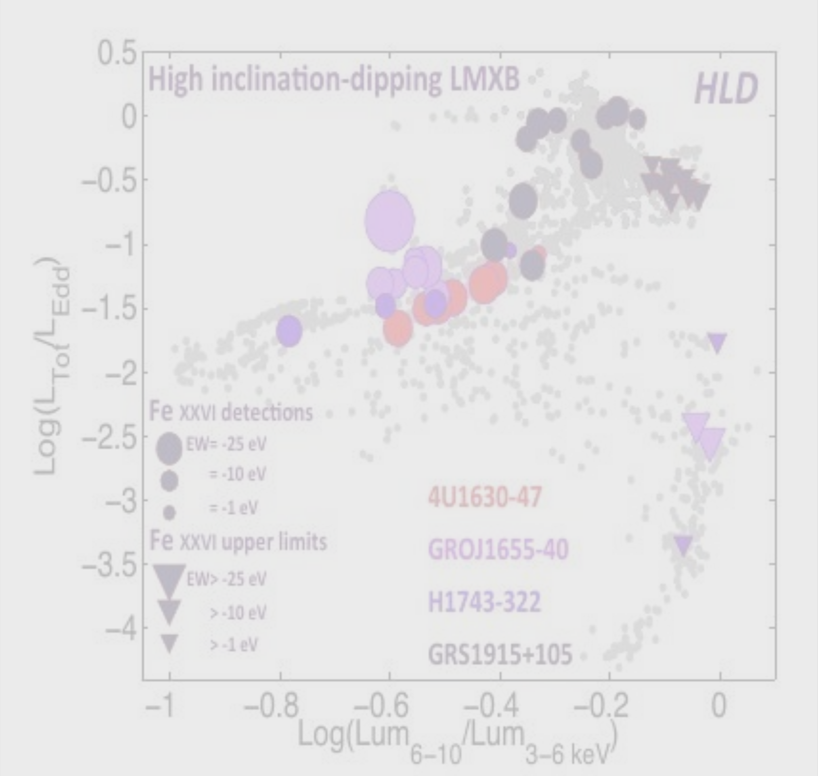


Accretion-driven flickering



State changes + disk winds

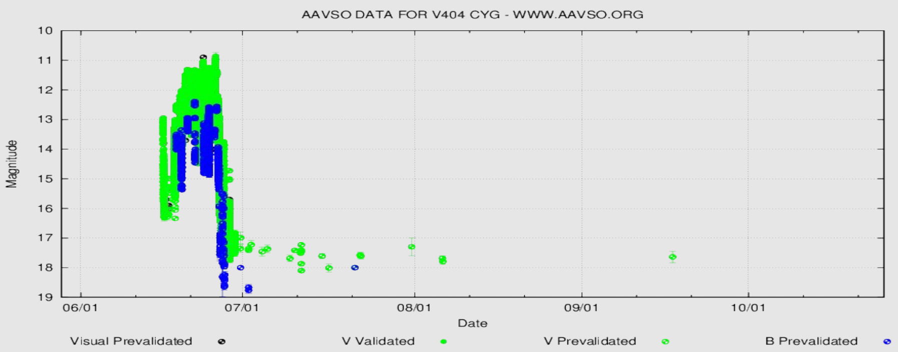




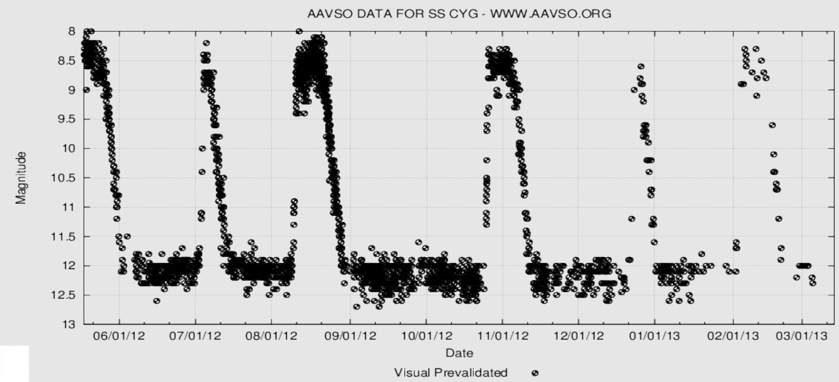
Ponti+ (2012)

What about accreting WDs?

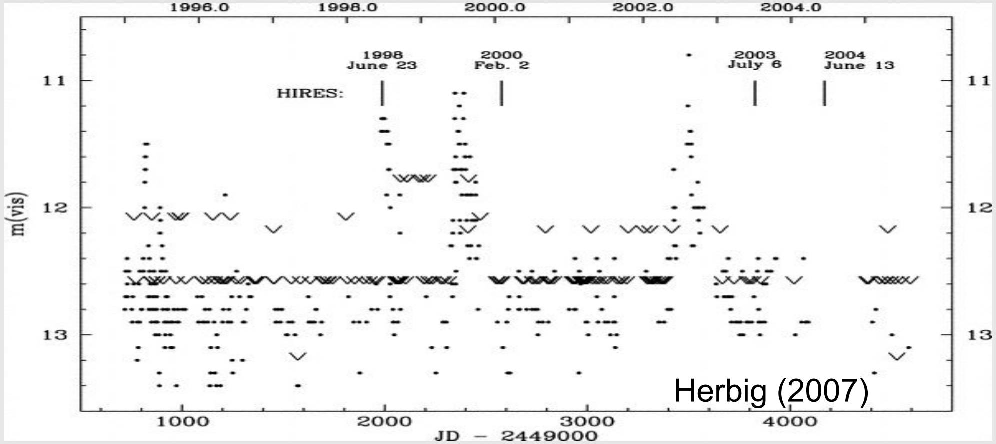
Accretion disk instabilities



V404 Cyg
Black hole



SS Cyg
White dwarf

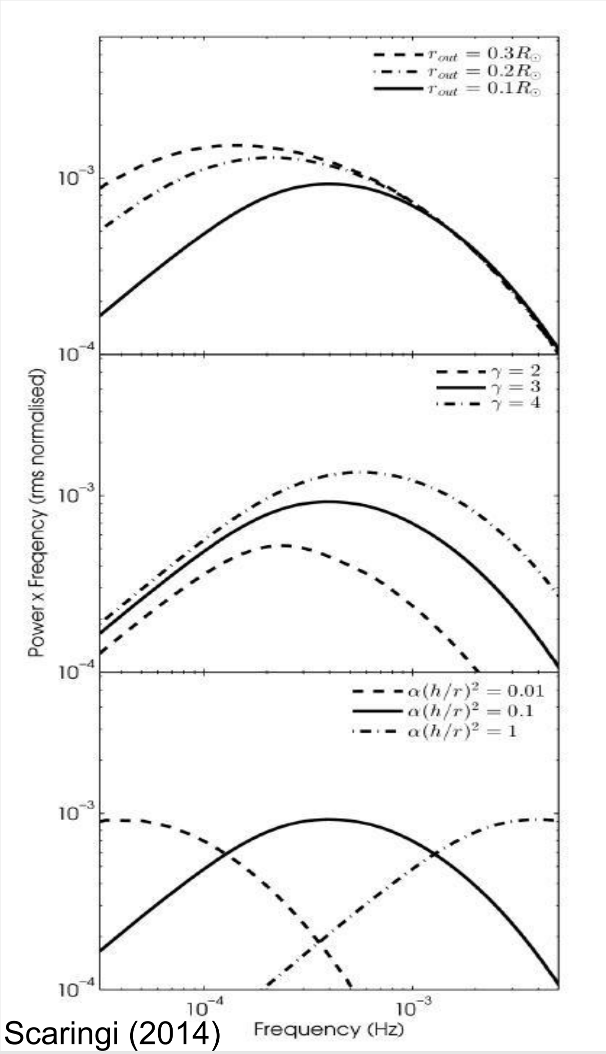


EX Lupi
Young-stellar object

Fluctuating Accretion disks

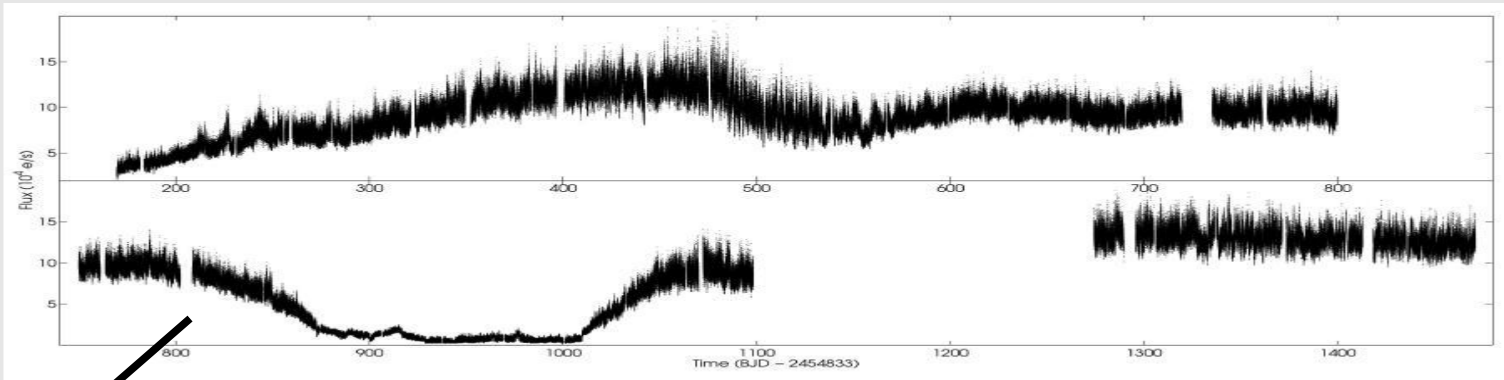
1) Fix $M_{WD} \rightarrow R_{WD}$ (mass-radius relation)
2) Set $r_{in} = R_{WD}$
(assume disk extends to WD surface)
3) Fit **4 free parameters**:

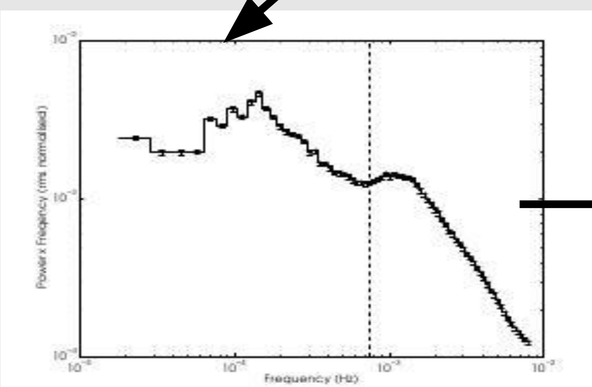
- r_{out} = outer disk radius
- $\alpha(h/r)^2$ = viscosity and disk scale height
- γ = emissivity index
- F_{var} = fractional variability per radial decade

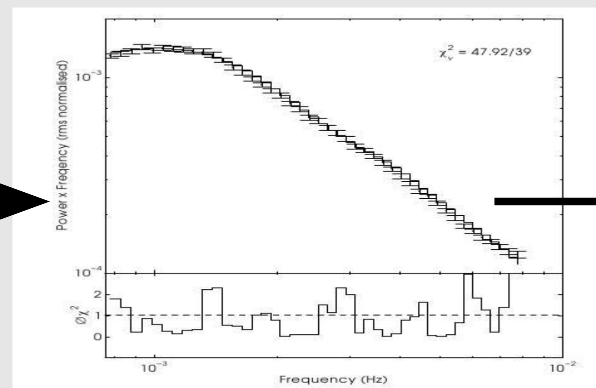


Scaringi (2014)

Fluctuating Accretion disk:
what generates the variability?







$M_{WD}(M_\odot)$	$\equiv 0.73$
$r_{in}(R_\odot)$	$\equiv 0.0105$
$r_{out}(R_\odot)$	$0.117^{+0.029}_{-0.020}$
γ	$0.853^{+0.047}_{-0.041}$
$\alpha(h/r)^2$	$0.705^{+0.289}_{-0.182}$
F_{var}	$0.220^{+0.001}_{-0.001}$

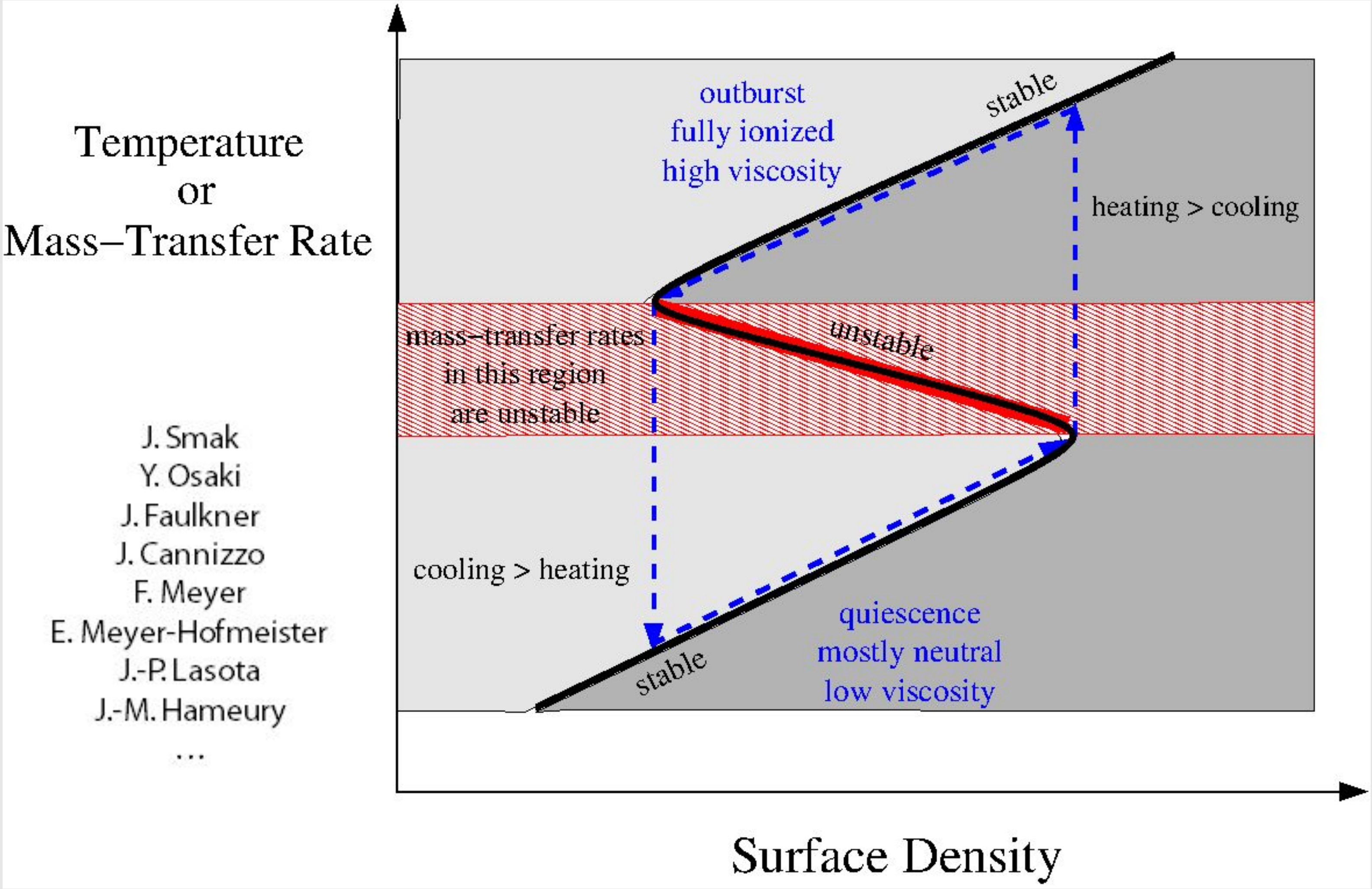
Scaringi (2014)
see also Dobrotka+ (2015,2016)

Geometrically thick disk close to the WD with large viscosity parameter?

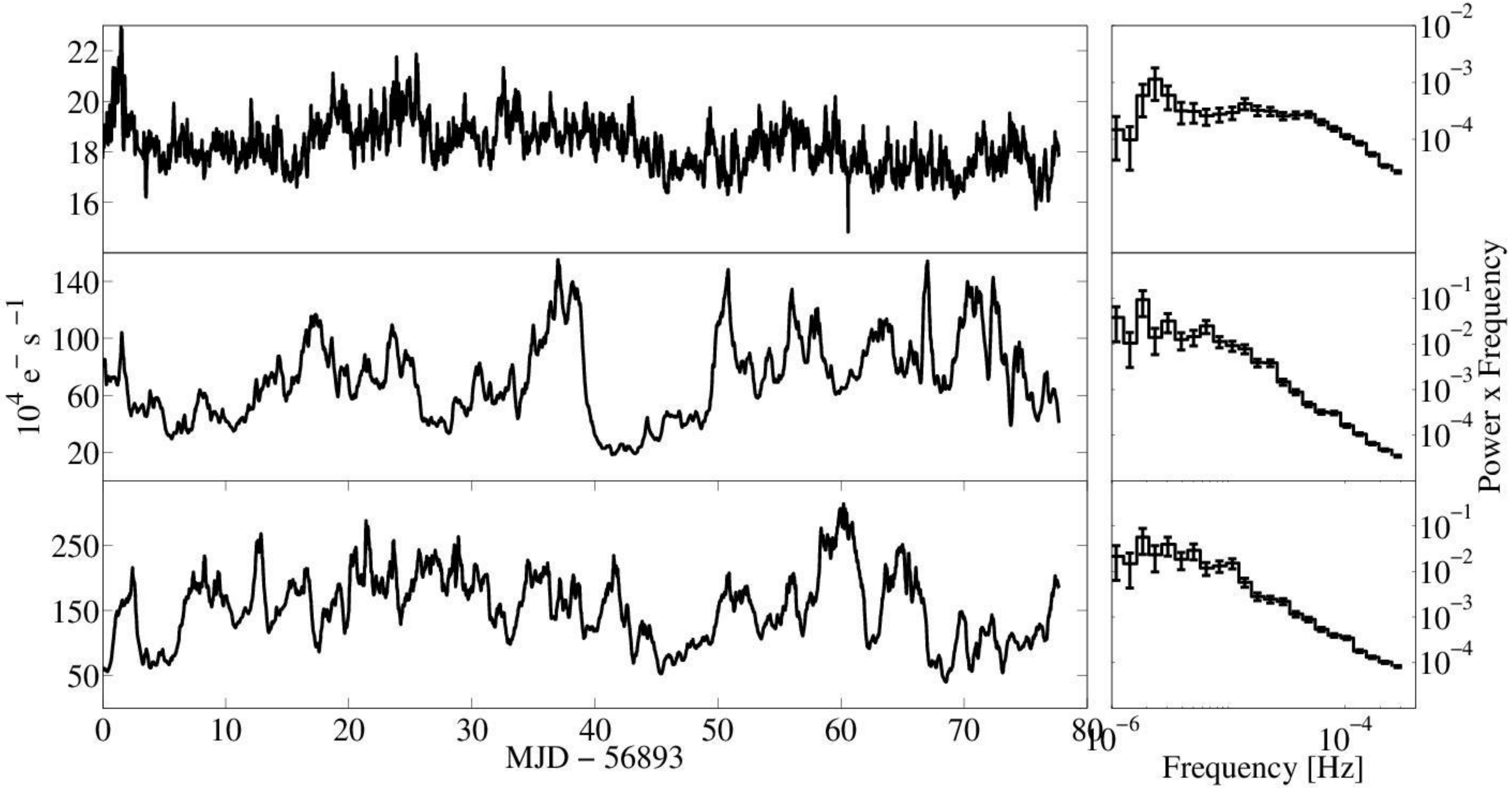
also inferred from eclipse mapping studies:

Feline+ (2005), Wood+ (1986,1992), Groot+ (2000,2004), Baptista&Bortoletto (2004), etc...

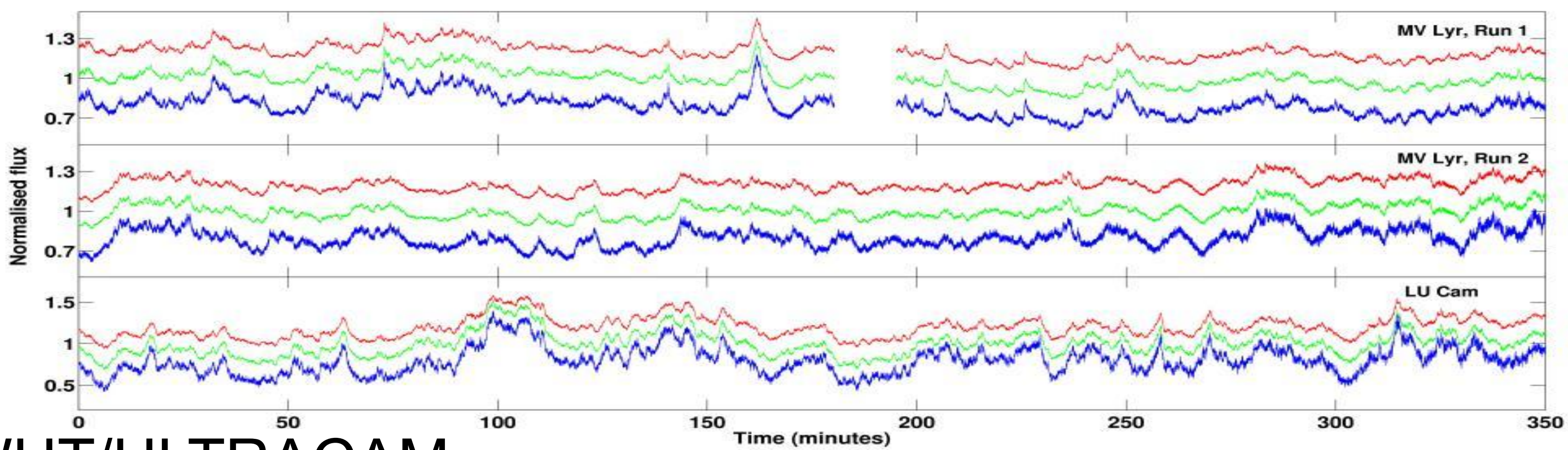
The Disk Instability Model



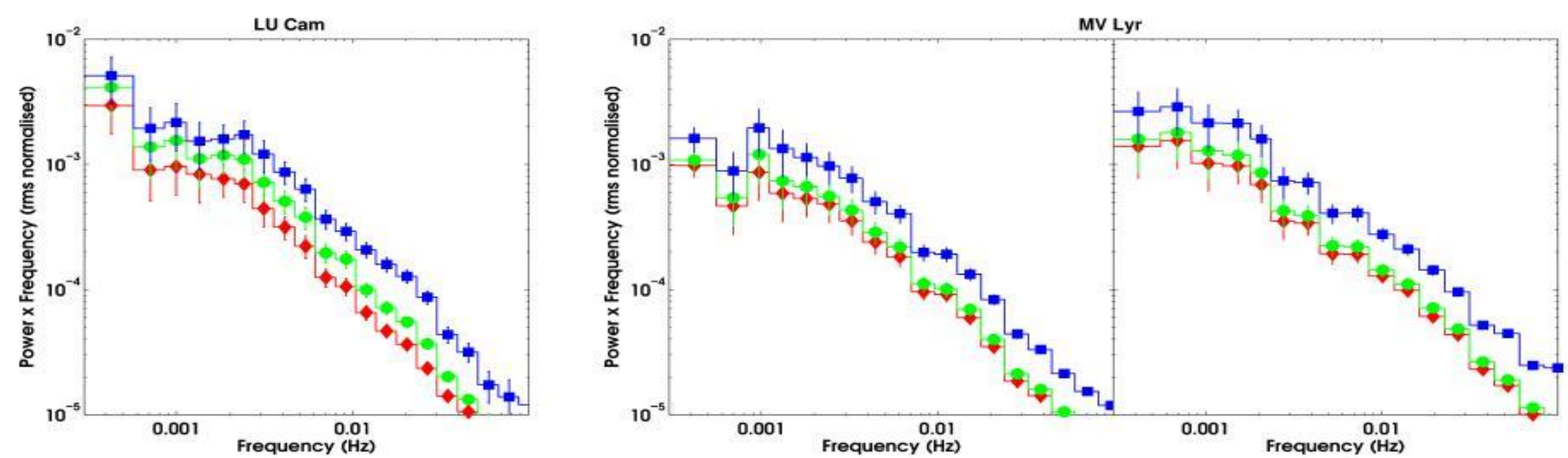
Accretion-driven flickering:
YSO variability



Fourier time-lags in CVs



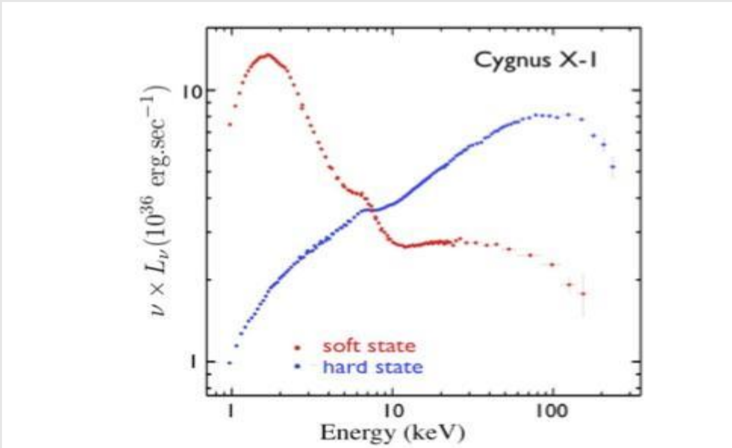
WHT/ULTRACAM

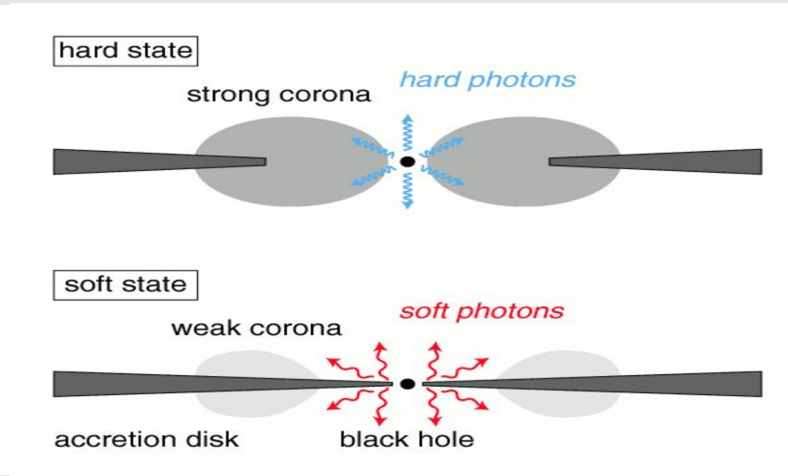


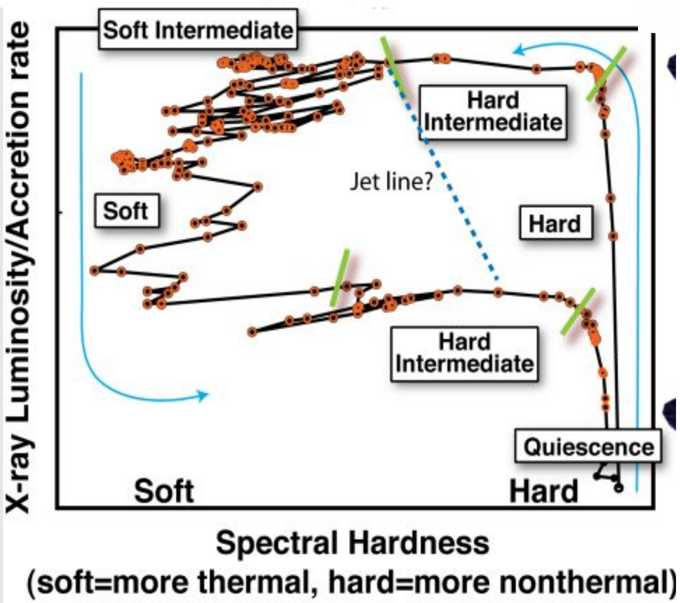
u'
g'
r'

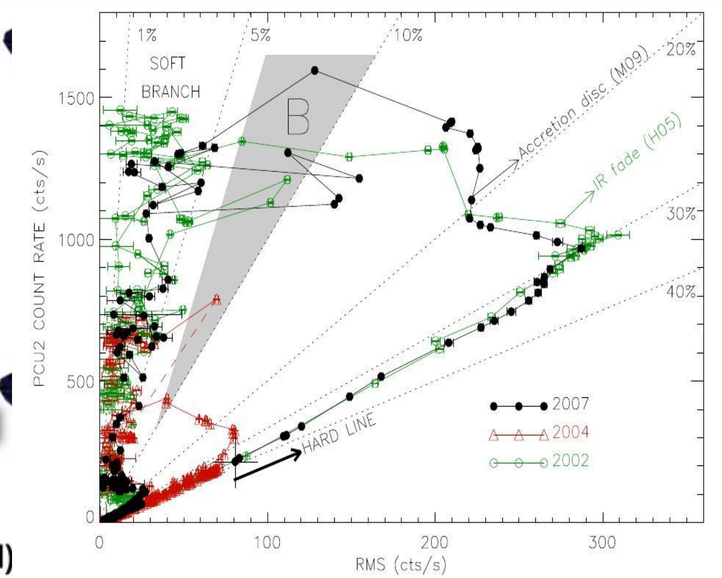
•Scaringi+ 2013b

Fluctuating Accretion disk:
what generates the variability in XRBs?

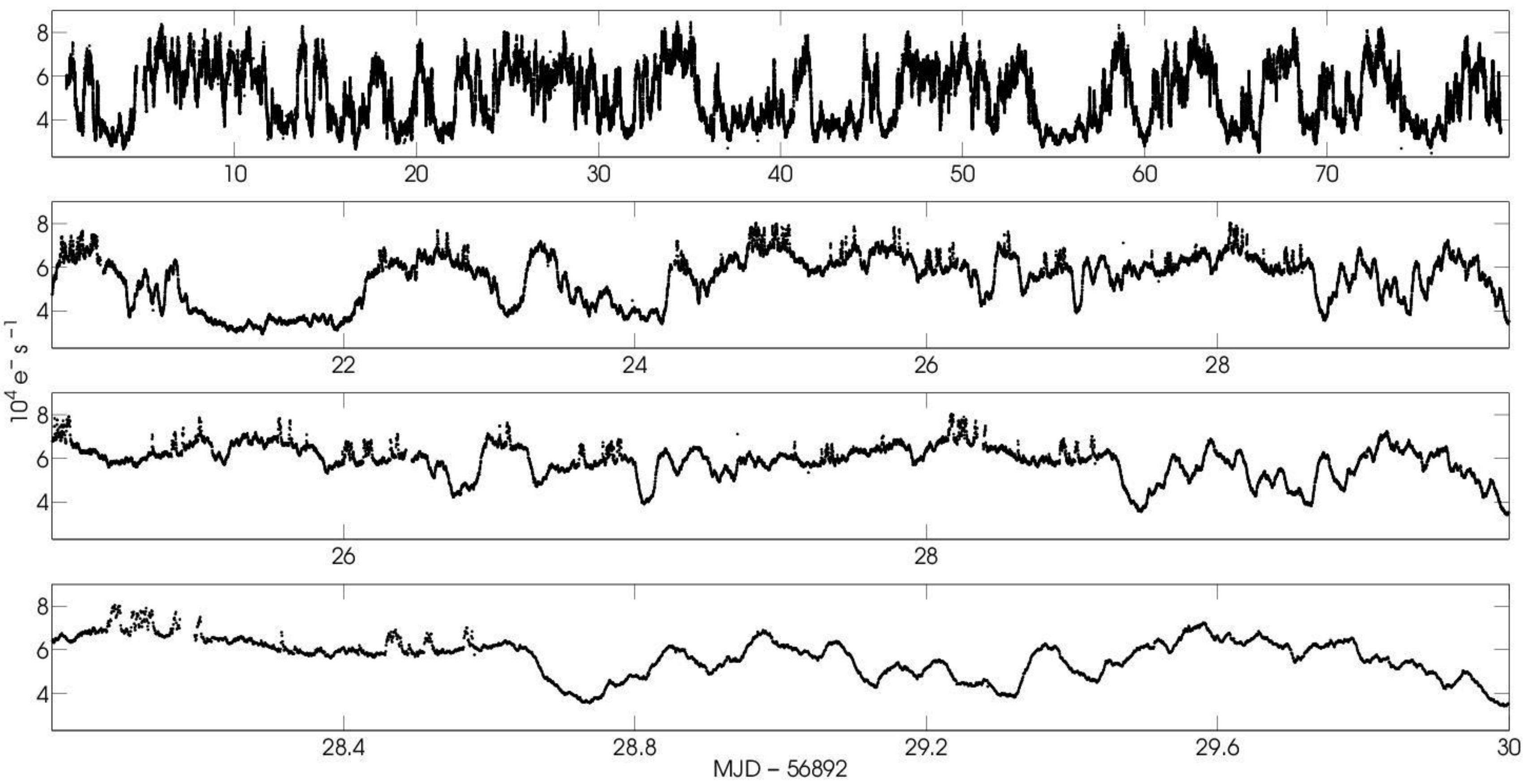




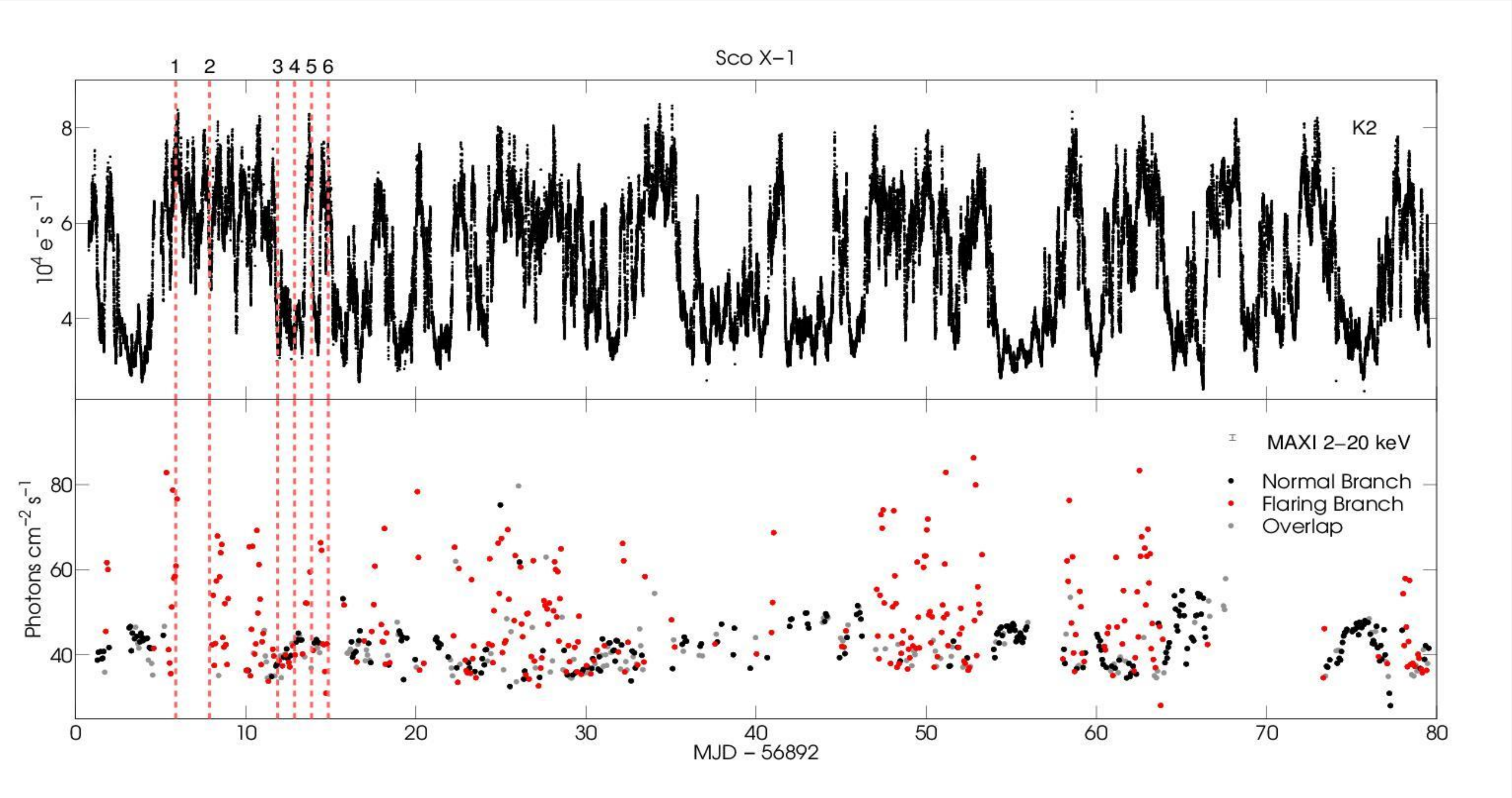




Sco X-1 with *K2*

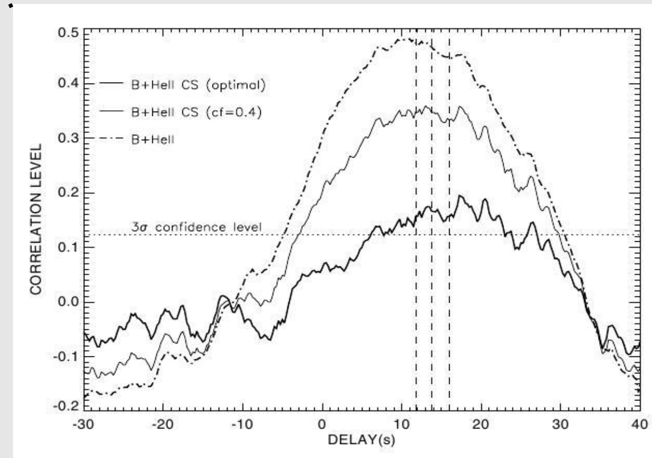


Sco X-1 with *K2*

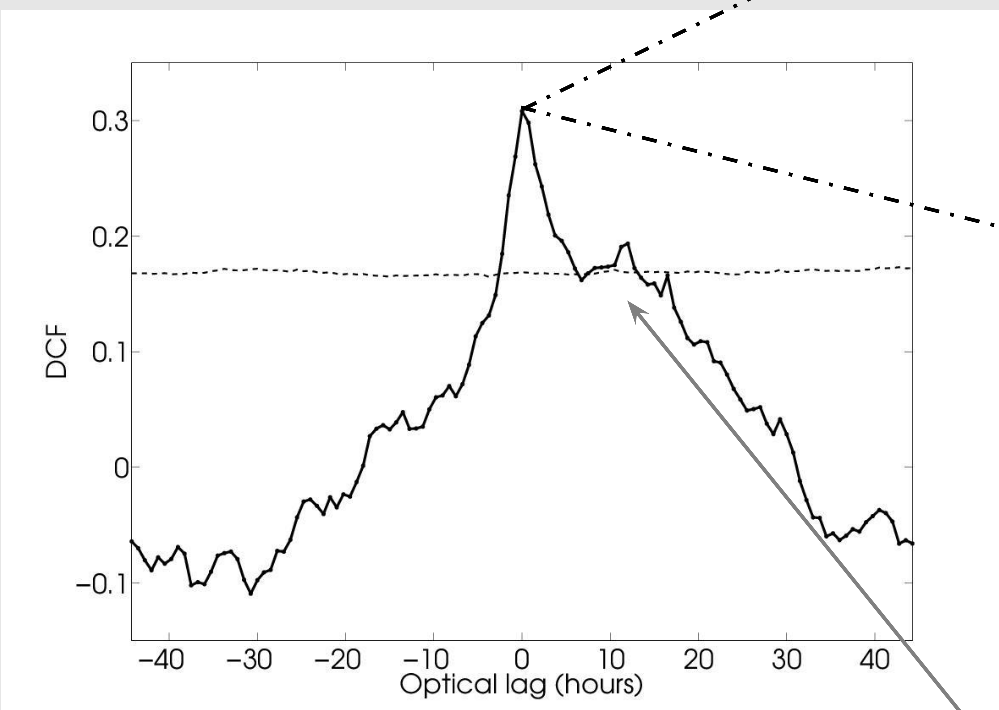


Scaringi+ (2015a)

X-ray/optical DCF



Munoz-Darias+ 2007



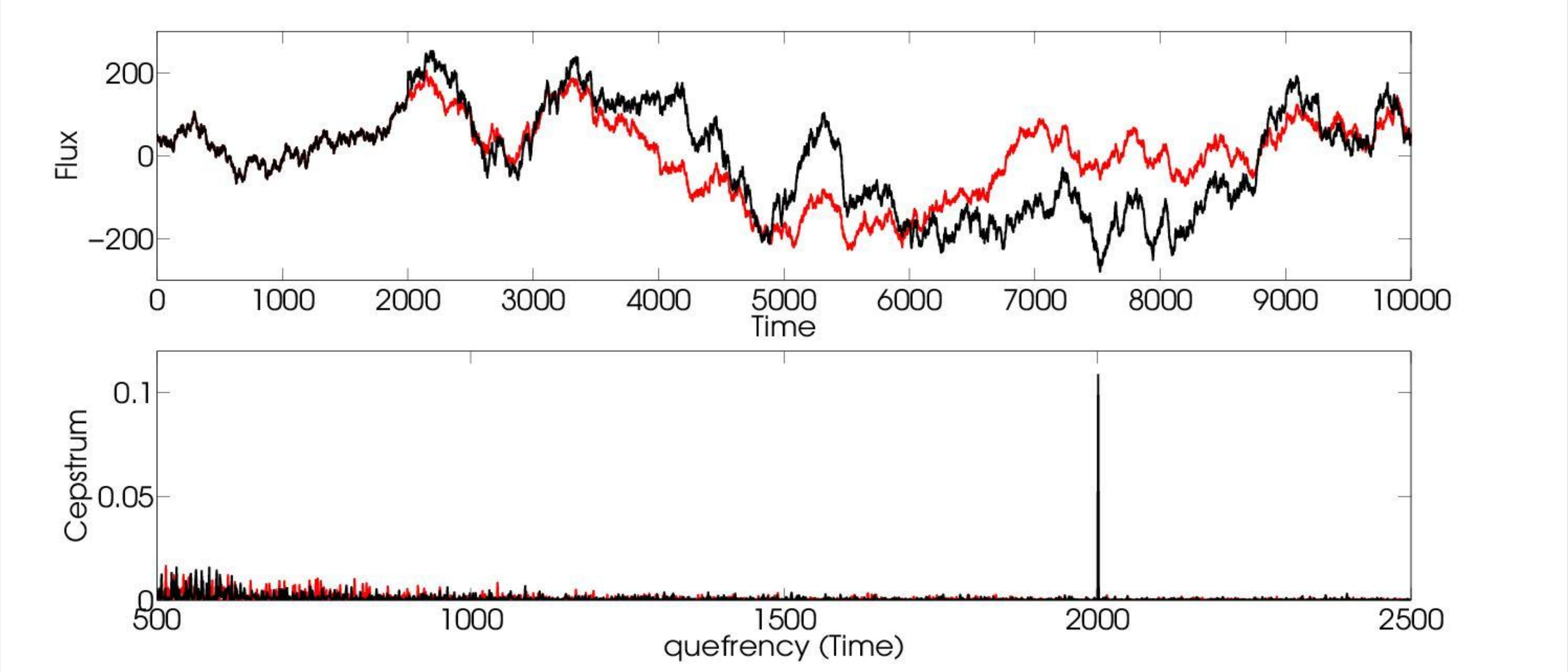
Scaringi+ (2015a)

Broad ~12 hour optical lag

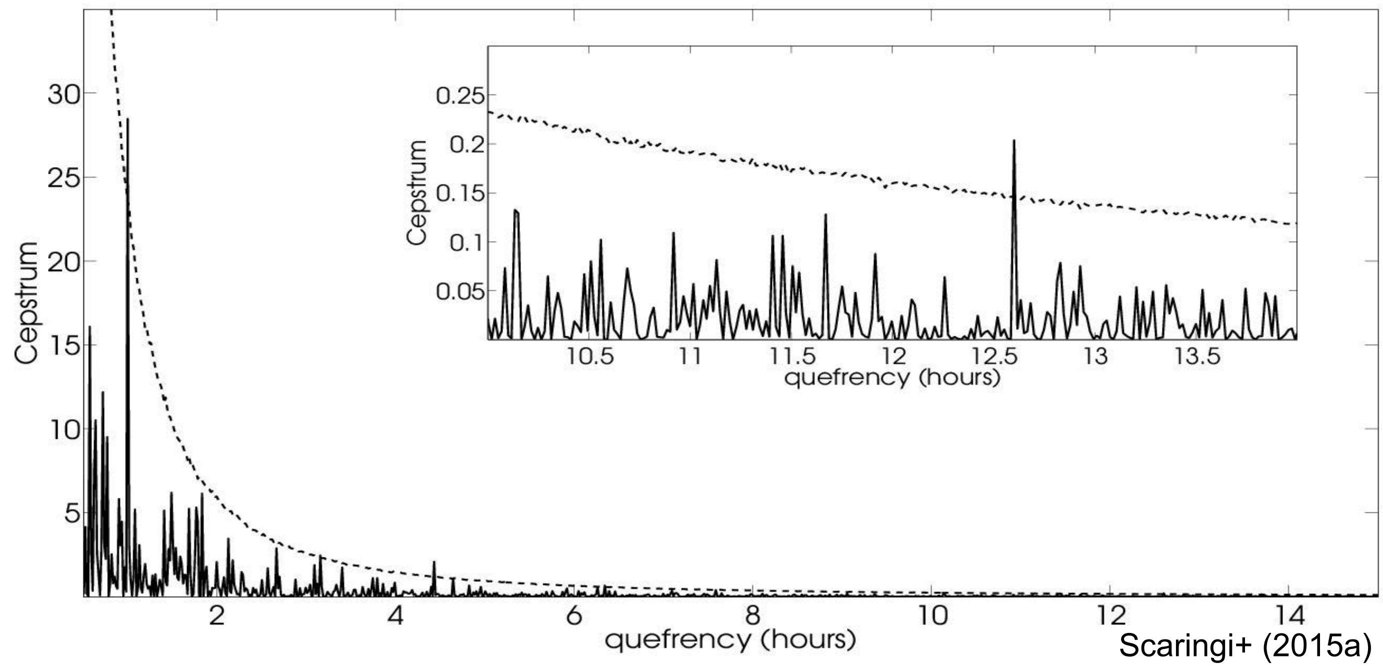
The Cepstrum

- Used to find echoes in time-series data
- Developed for earthquakes/bomb explosion studies

$$\text{power cepstrum of signal} = \left|\mathcal{F}^{-1}\left\{\log(|\mathcal{F}\{f(t)\}|^2)\right\}\right|^2$$



The Cepstrum

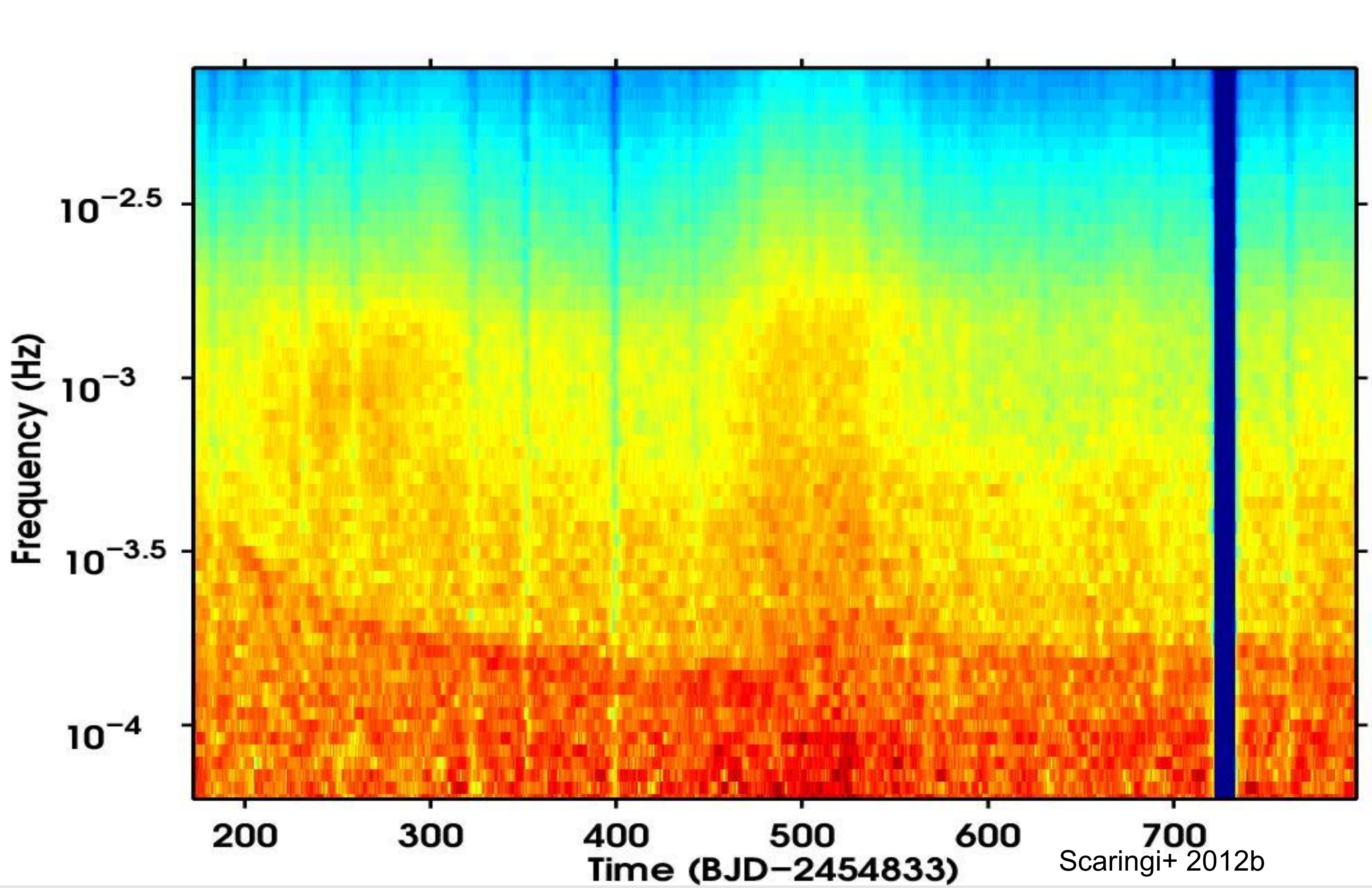


Scaringi+ (2015a)

- 3 significant echoes:
- → 1 hour, 4.4 hours, 12.6 hours

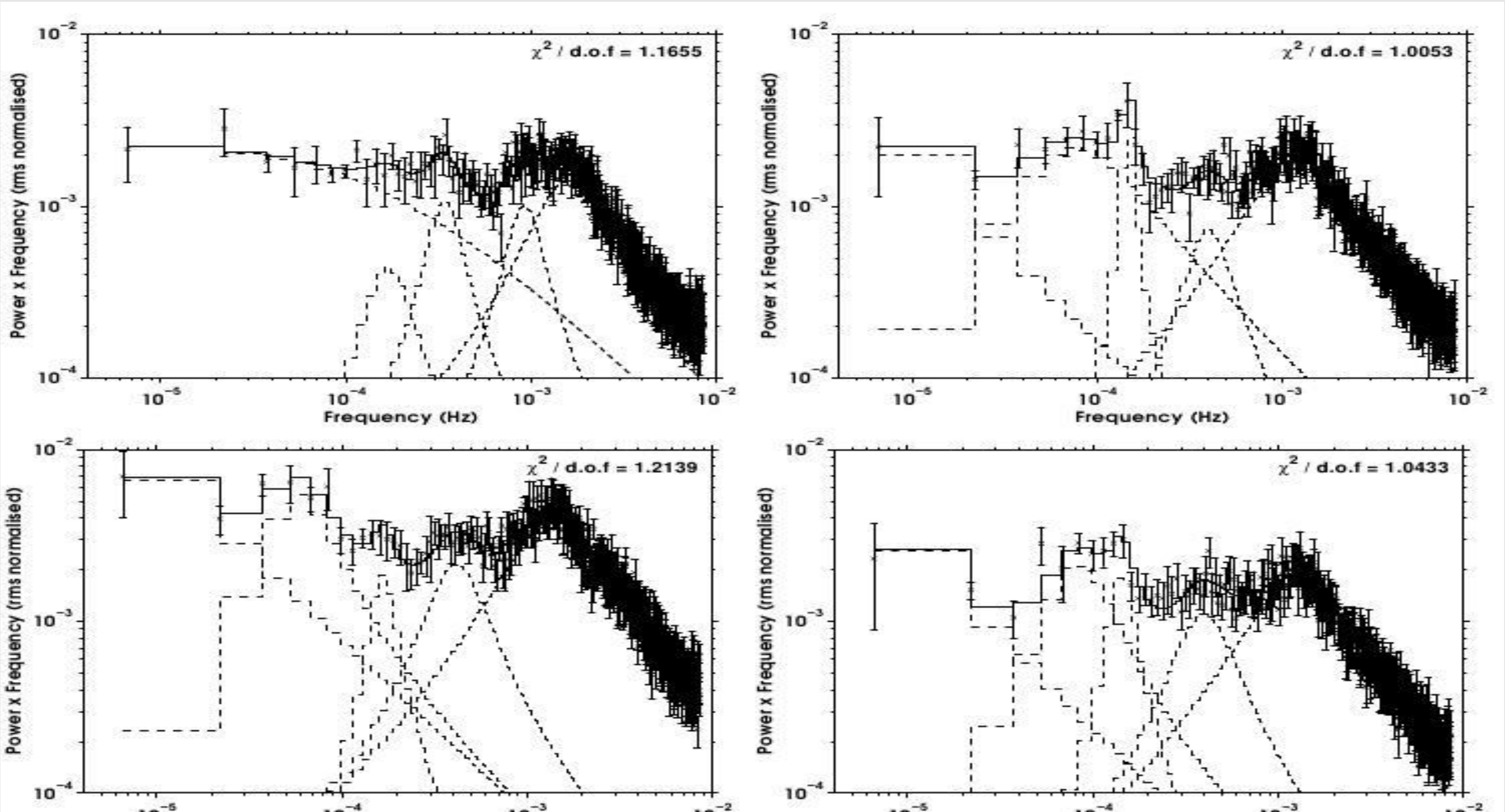
QPOs in MV Lyrae

Dynamic PSD → 5.3 day segments with 50% overlap



Scaringi+ 2012b

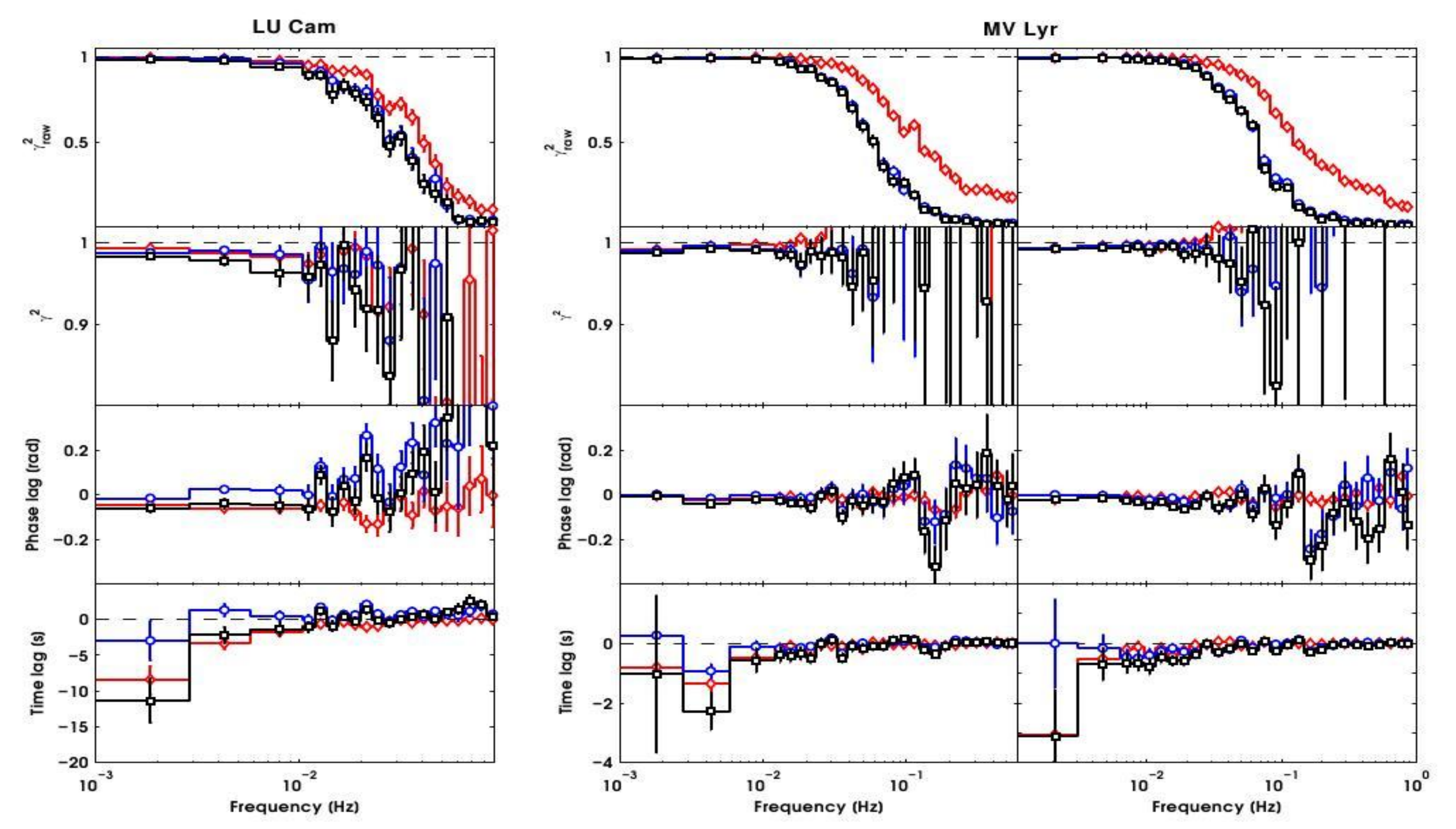
QPOs in MV Lyrae



Scaringi+ 2012b

Average of 5 independent PSDs

Fourier time-lags in CVs



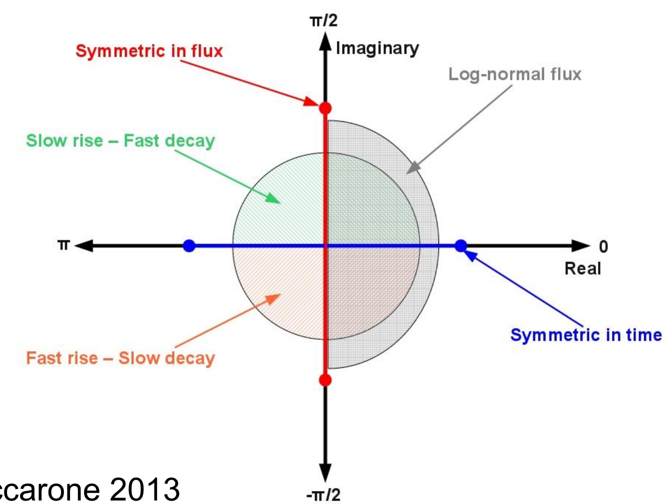
u'-r' g'-r' u'-g'

(Scaringi+ 2013b)

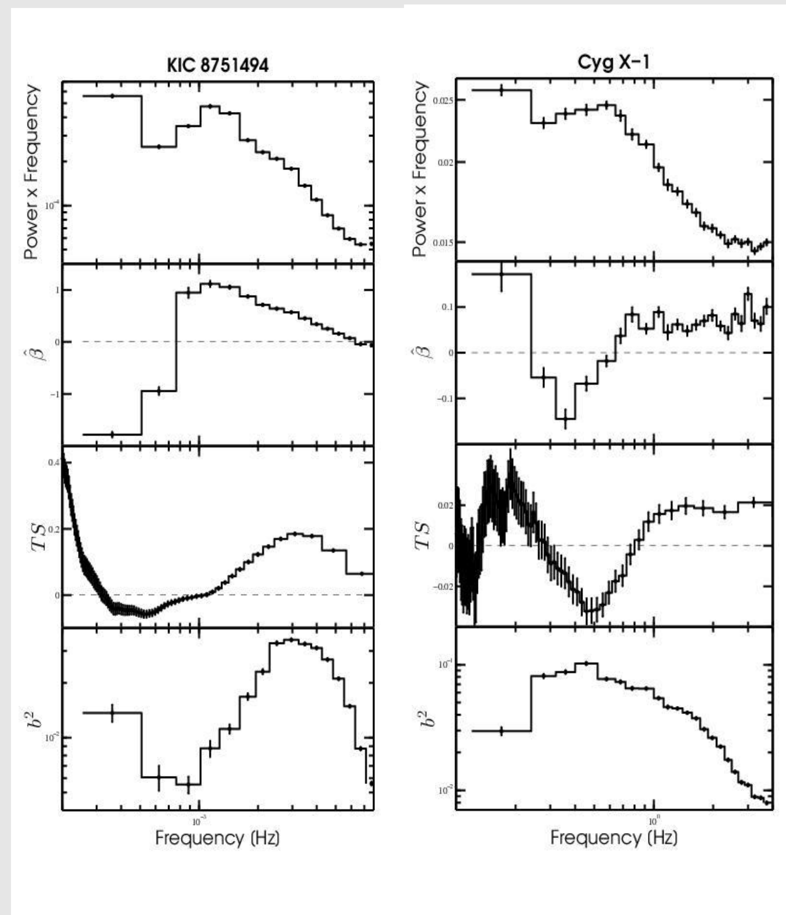
Bispectrum

For frequency pairs ***k*** & ***l***, it is defined by:

$$B(k,l) = \frac{1}{K} \sum_{i=0}^{K-1} X_i(k) X_i(l) X_i^*(k+l),$$

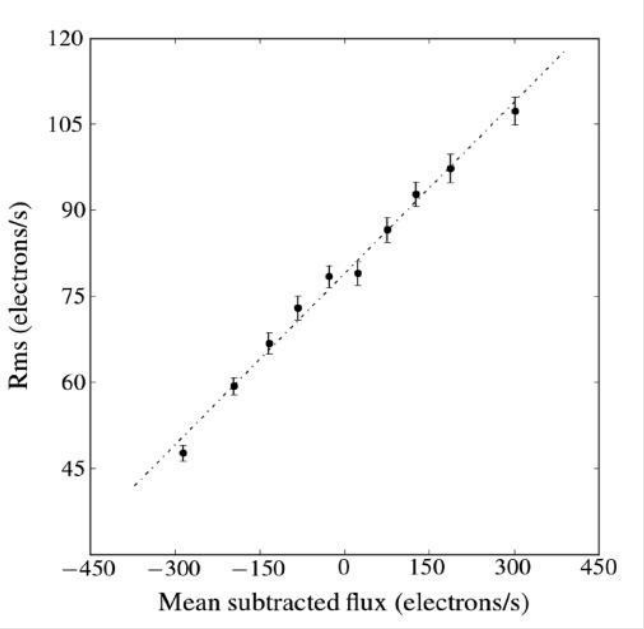


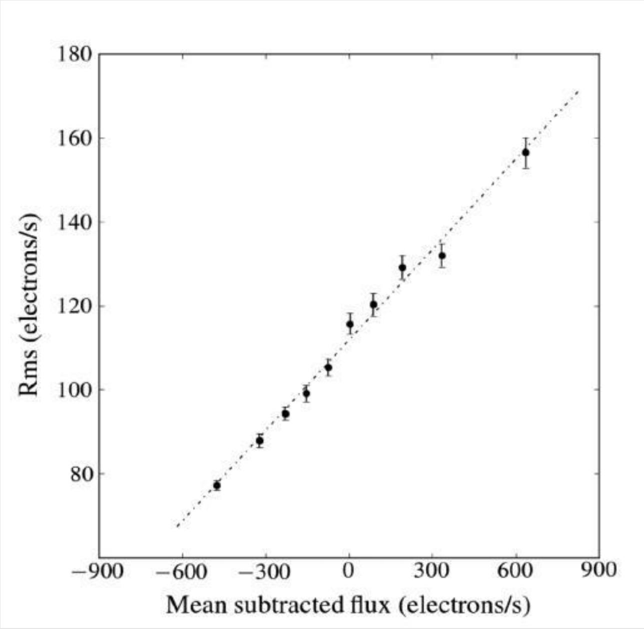
- Maccarone 2013
- Scaringi+ 2014



The rms-flux relation

All *Kepler* CVs with good enough quality data show it!





KIC 8751494
(nova-like)

van de Sande + (2015)

V1504 Cyg
(dwarf nova)

Fluctuating Accretion disk

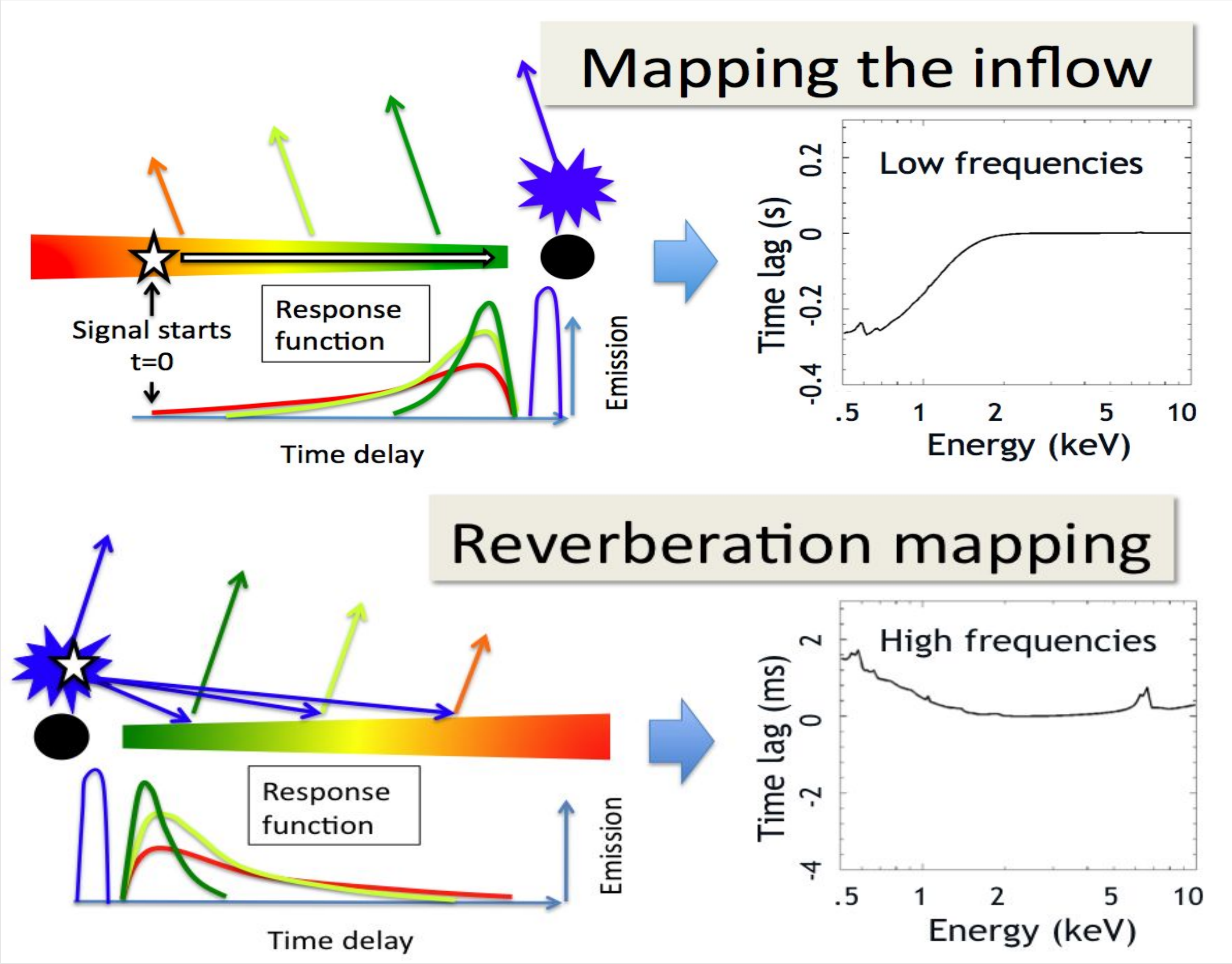
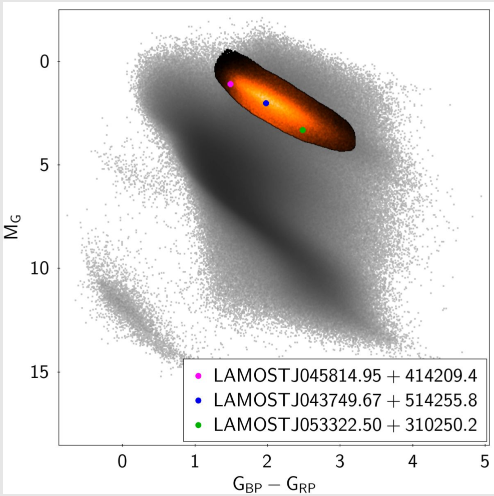
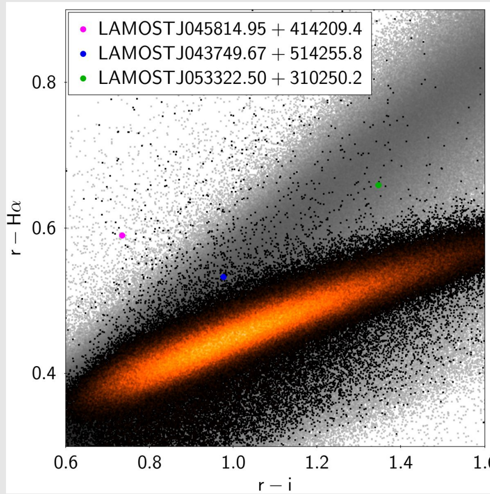


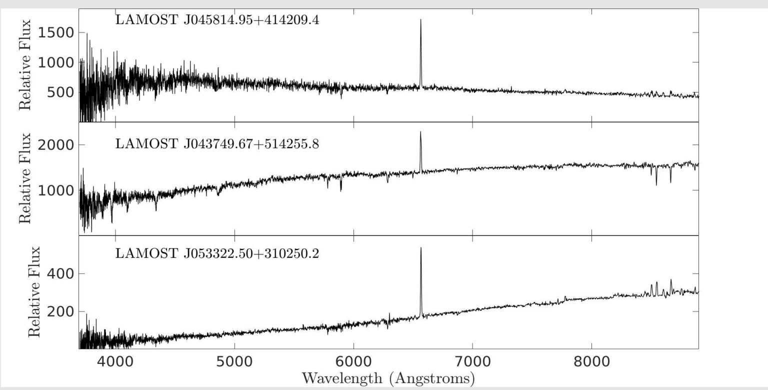
Image credit:
Phil Uttley

What next?

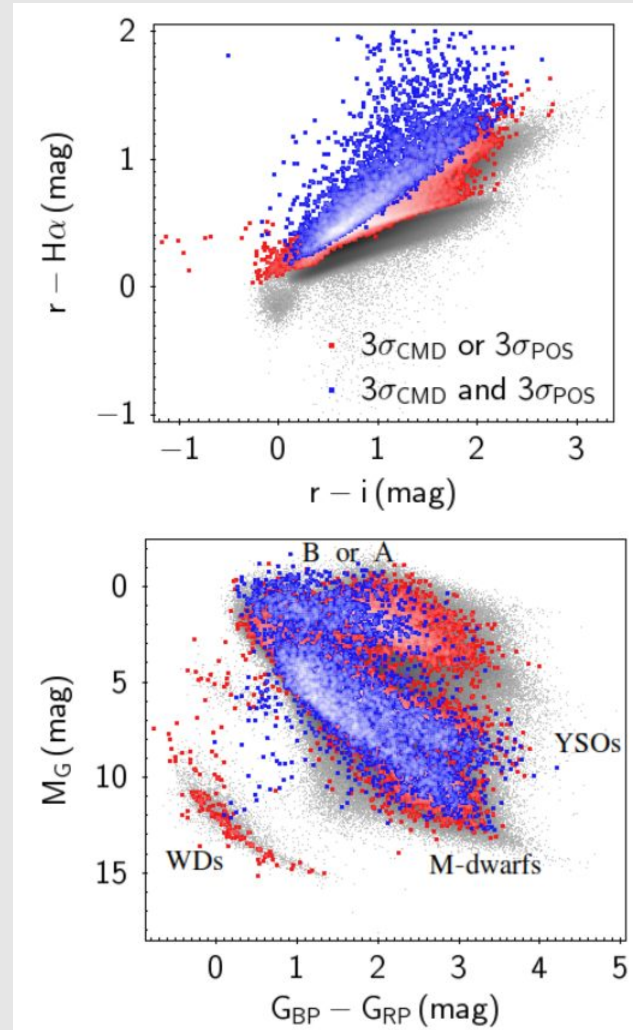
Gaia - IPHAS – UKIDSS - TESS







20,000 Ha-excess sources in northern Galactic plane

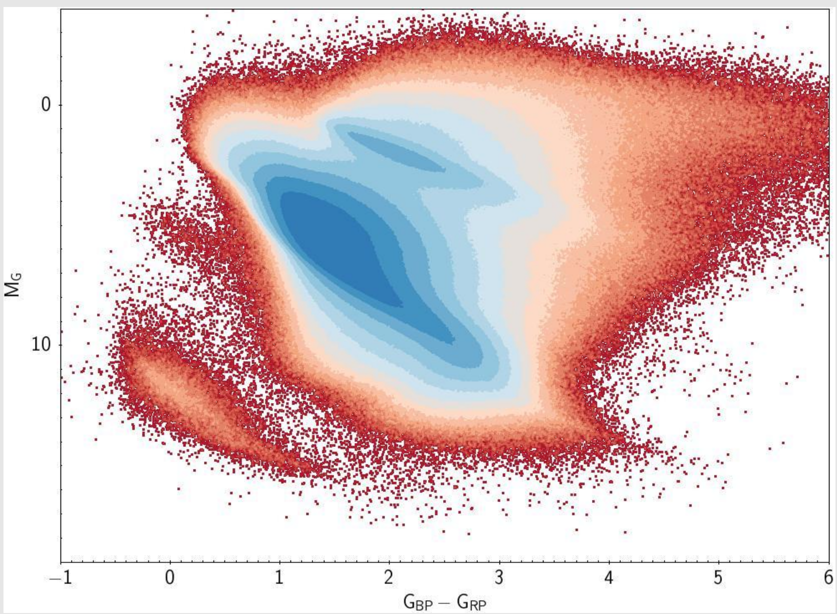


Scaringi+ (2017)
Fratta+ (2021)

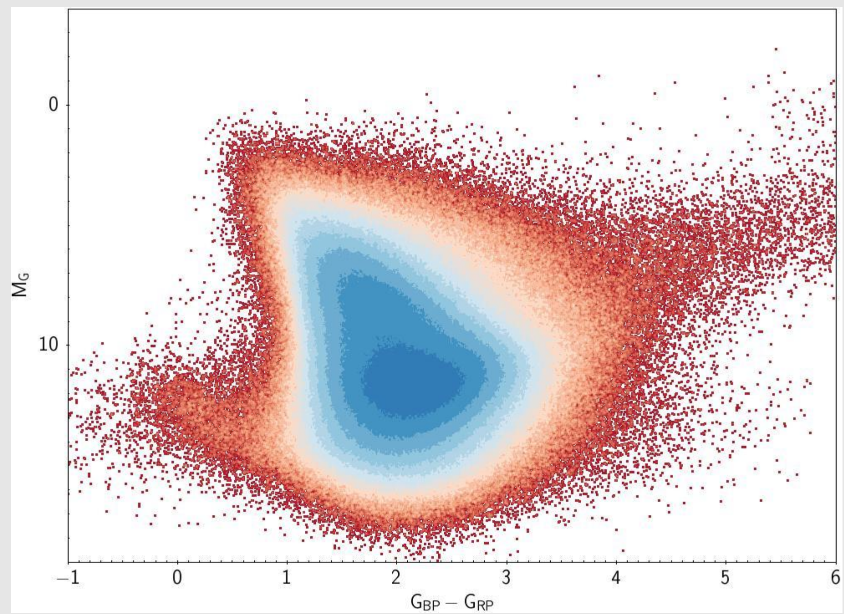
XGAPS

Gaia EDR3 - IGAPS – UKIDSS

34 million matches
Random Forest used to select “good” astrometric sources
U,g,r,i,Ha,J,H,K + Gaia



Good astrometric sources

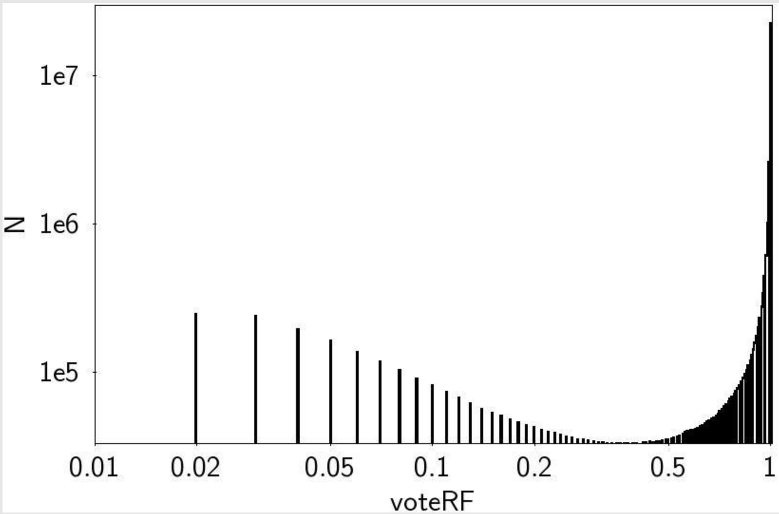


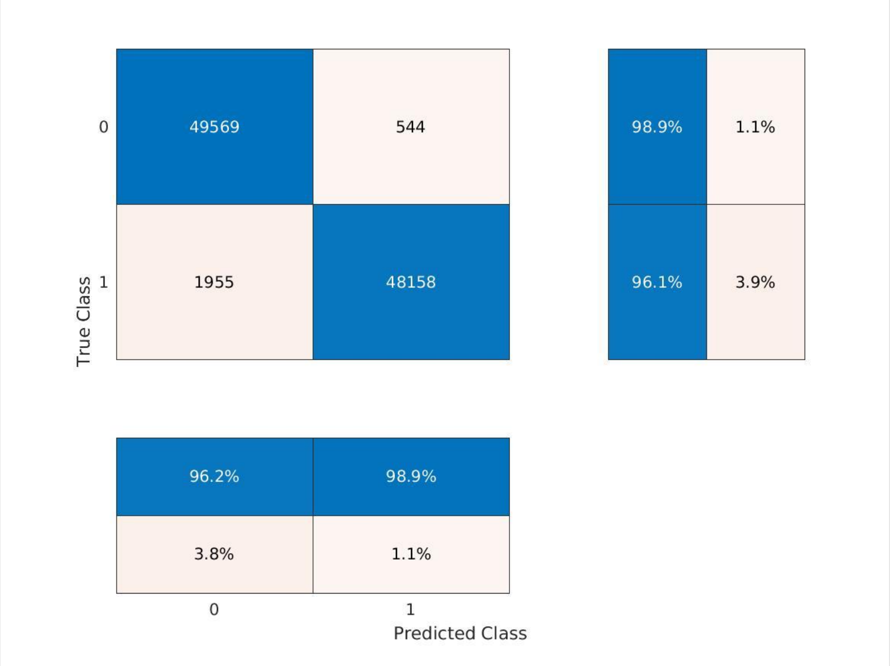
Bad astrometric sources

Scaringi+ (in prep)

XGAPS

Gaia EDR3 - IGAPS – UKIDSS - TESS

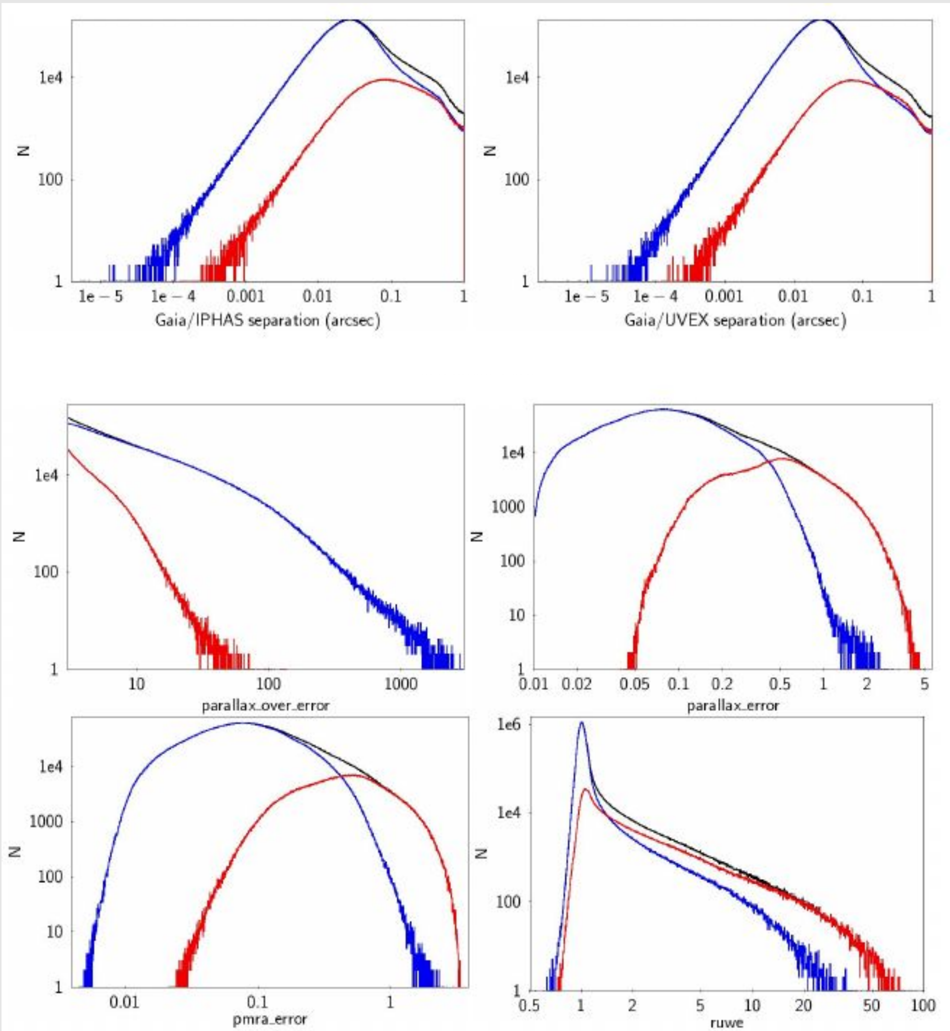




Scaringi+ (in prep)

XGAPS

Gaia EDR3 - IGAPS – UKIDSS - TESS



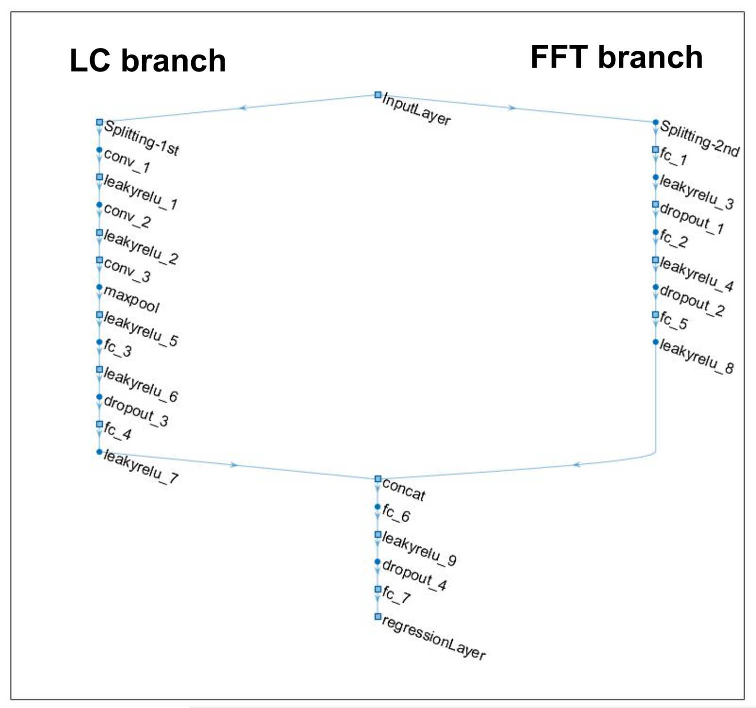
Predictor Name	Predictor Importance
pmra	11.68
pmdec	9.07
bMJD_separation_UVEX	4.30
bMJD_separation_IPHAS	4.26
ipd_frac_multi_peak	4.06
ipd_gof_harmonic_amplitude	3.61
astrometric_n_good_obs_al	2.67
astrometric_n_obs_al	2.65
scan_direction_mean_k1	2.53
parallax_error	2.42
scan_direction_mean_k2	2.24
scan_direction_mean_k3	2.22
ruwe	1.96
astrometric_excess_noise_sig	1.84
astrometric_gof_al	1.81
astrometric_excess_noise	1.74
pmdec_error	1.70
redChi2	1.64
scan_direction_strength_k1	1.57
astrometric_sigma5d_max	1.50
ipd_frac_odd_win	1.49
scan_direction_mean_k4	1.49
astrometric_n_bad_obs_al	1.42
astrometric_chi2_al	1.36
pmra_error	1.33
astrometric_n_obs_ac	0.27

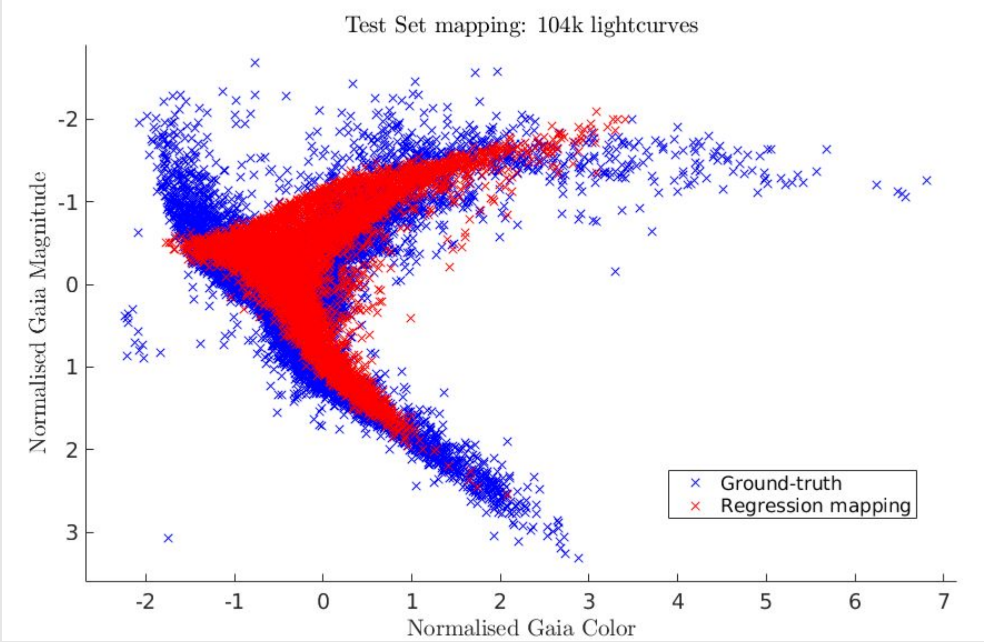
Table 1. Out-of-bag predictor importance of all predictors used for classification by the Random Forest classifier ordered according to importance.

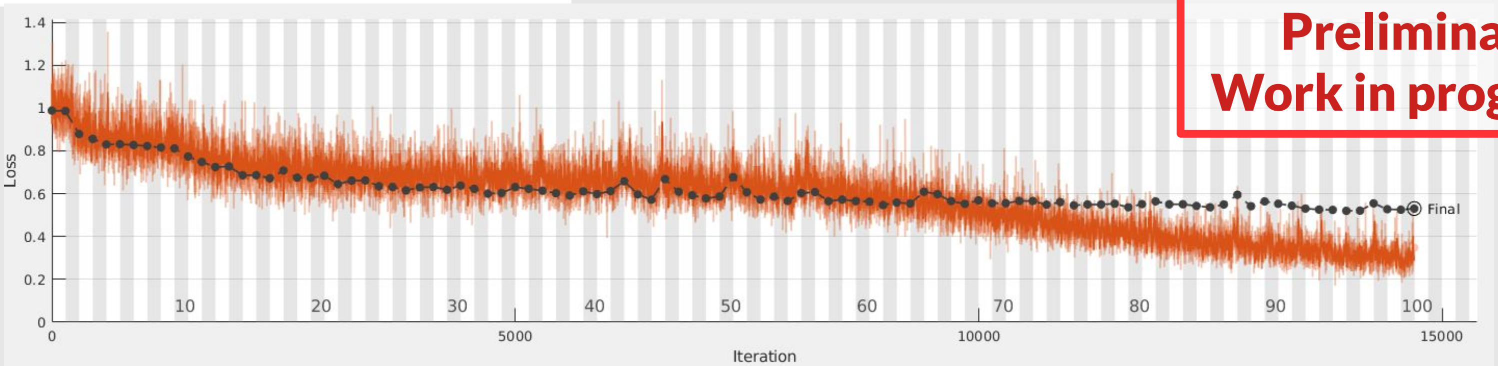
Scaringi+ (in prep)

What next?

Mapping lightcurves to the Gaia CMD and more...







Preliminary
Work in progress!