Astro Fit 2
Astronomy Fellowships in Italy

Marie Skłodowska-Curie Actions

A Census of Hard X-ray Magnetic Cataclysmic Variables

Federico Bernardini

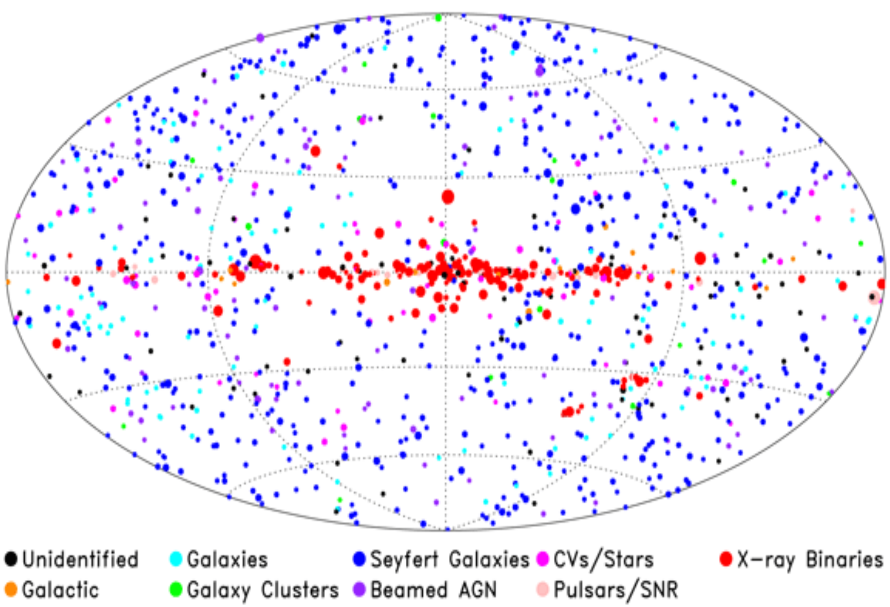
INAF – Observatory of Rome

Collaborators:
D. de Martino (NA), K. Mukai (NASA-Goddard), M. Falanga (ISSI-Bern), N. Masetti (BO), G.L. Israel (RM)

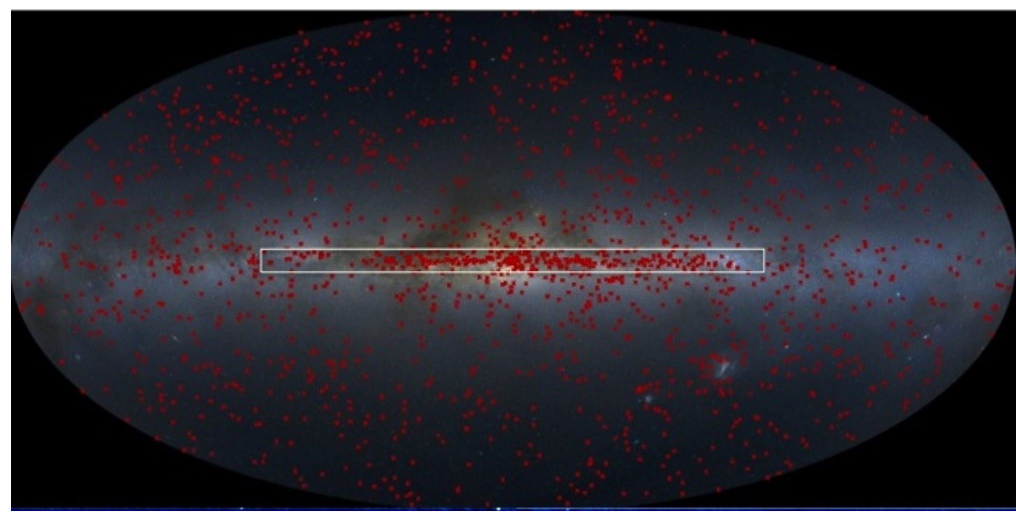
Hard X-ray catalogs

- 20% of galactic sources are Cataclysmic Variables
- Accreting White Dwarf from low mass companion
- 25% of all CVs are magnetic systems

BAT

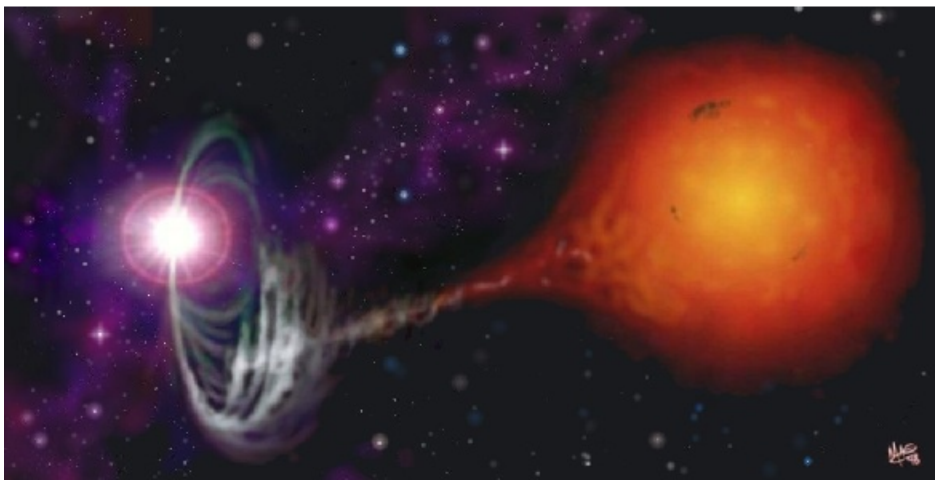


IBIS/ISGRI+BAT

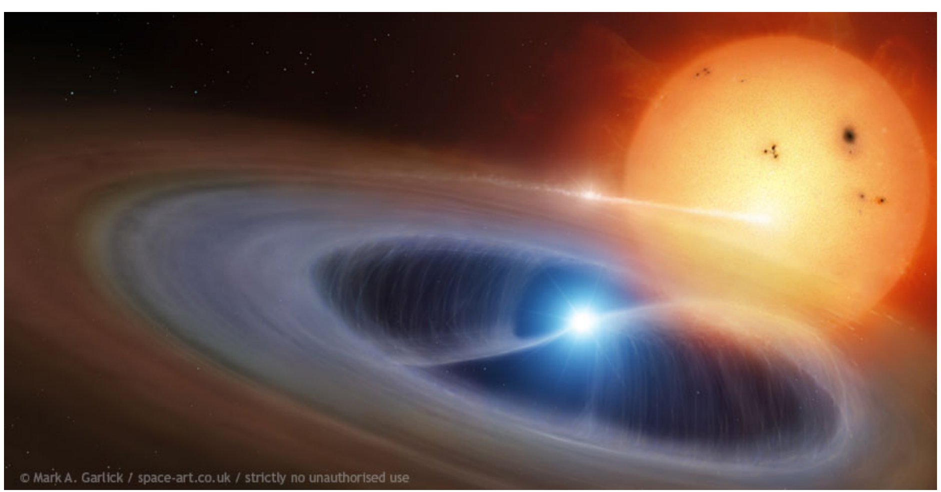


Magnetic CVs

- If the magnetic field is strong enough to regulate the accretion flow the system is defined Magnetic



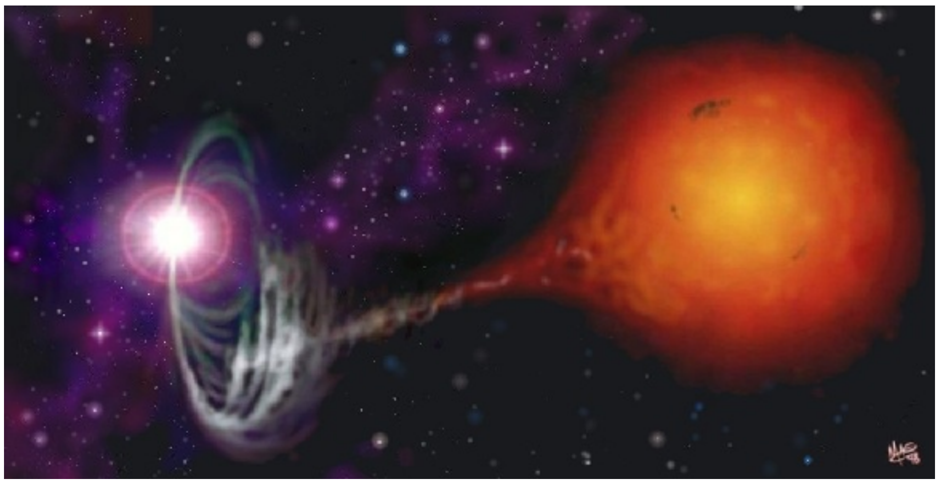
Polars
$B=10^7$-10^8 G



Intermediate Polars (IPs)
$B \leq 10^6$ G (?)

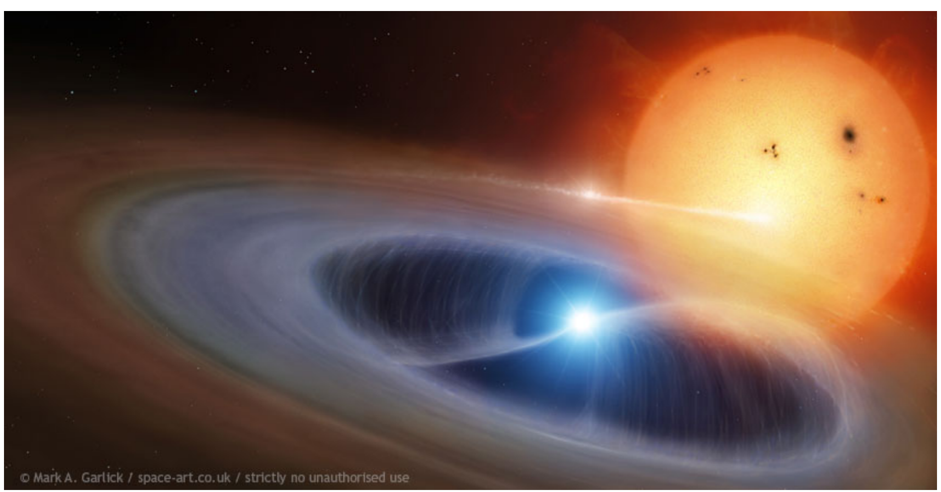
Polars and IPs

- Accretion: intense X-ray and Optical emission
  Periodic emission at spin and orbital period



Polars

$P_{spin} = P_{orb}$ [hrs]

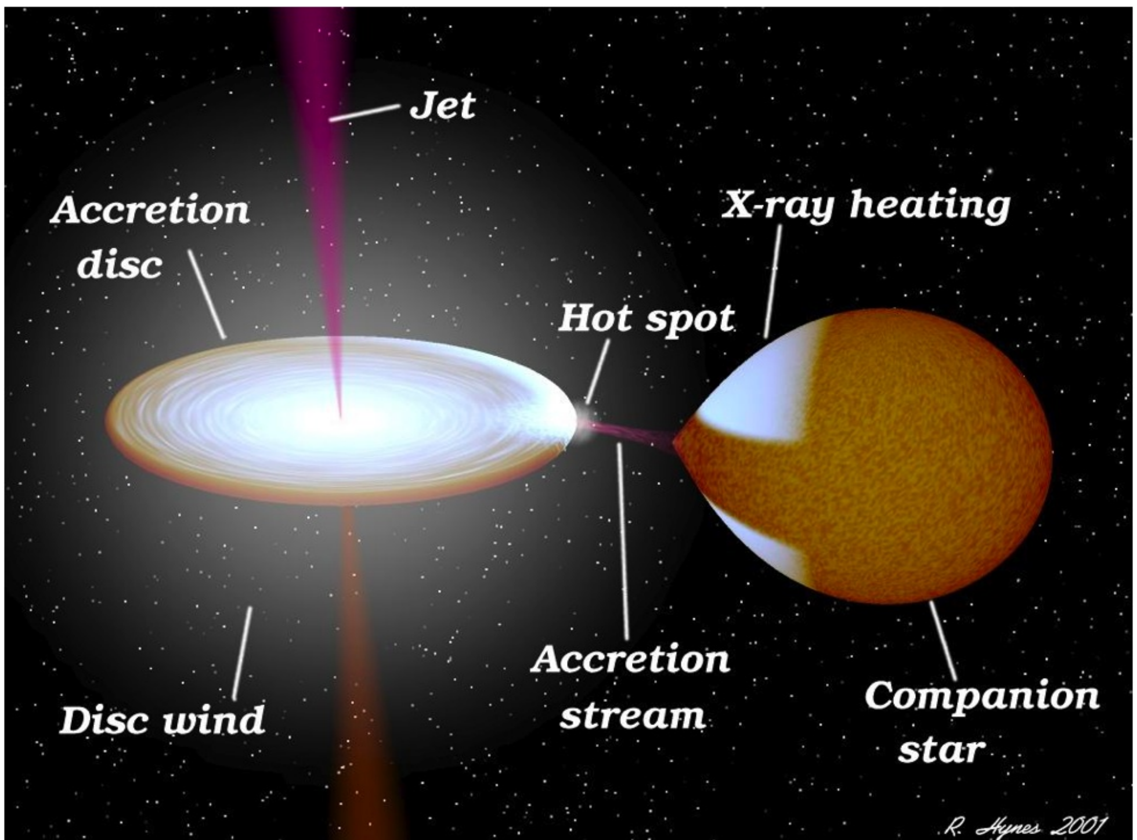


Intermediate Polars (IPs)

P_{spin} [min] < P_{orb} [hrs]

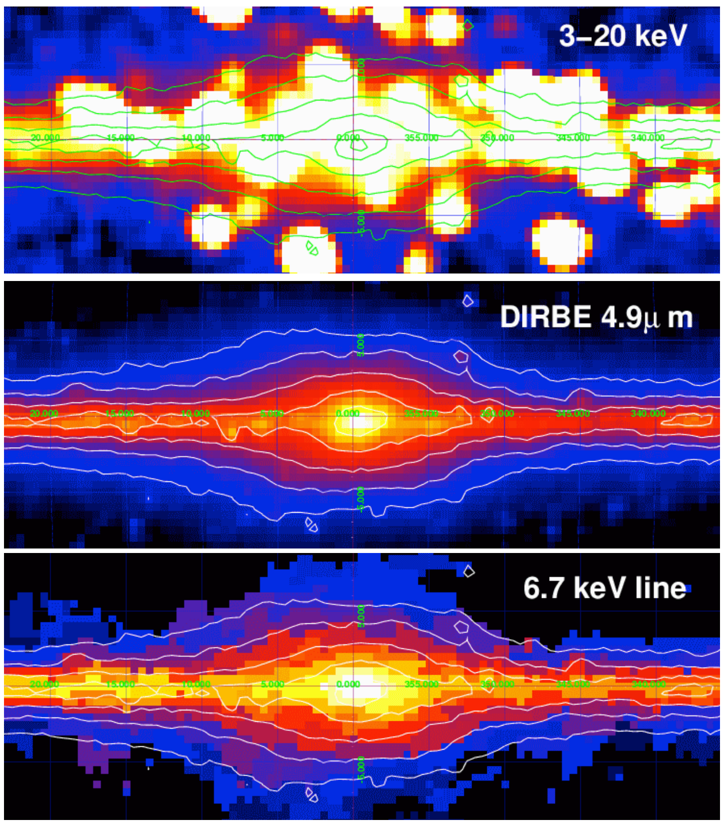
Importance of AWDs

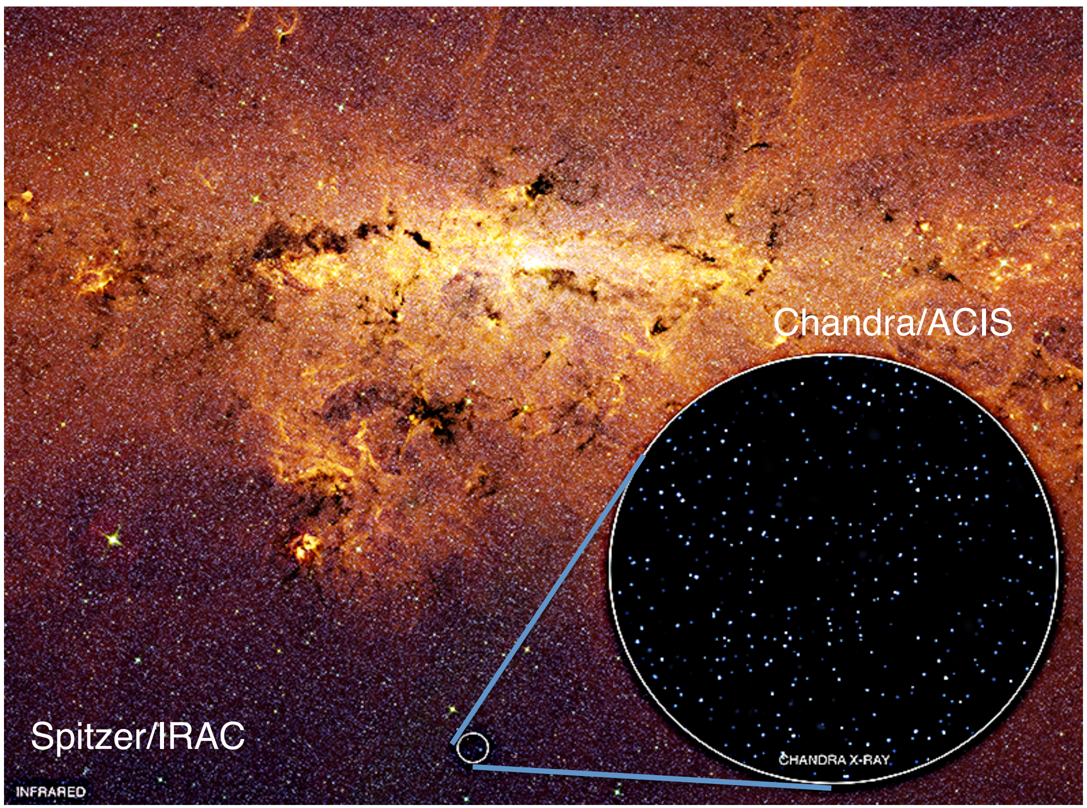
- Close-by, numerous (~1300 CVs), variable
  Universality of accretion at all scales
  AWD perfect laboratory



Why do we study magnetic CVs?

- Galactic "diffuse" X-ray emission: hard sources
  Majority should be mCVs at $10^{30} < L_X < 10^{34}$ erg/s
  What are those with $L_X \sim 10^{29-30}$ erg/s ?

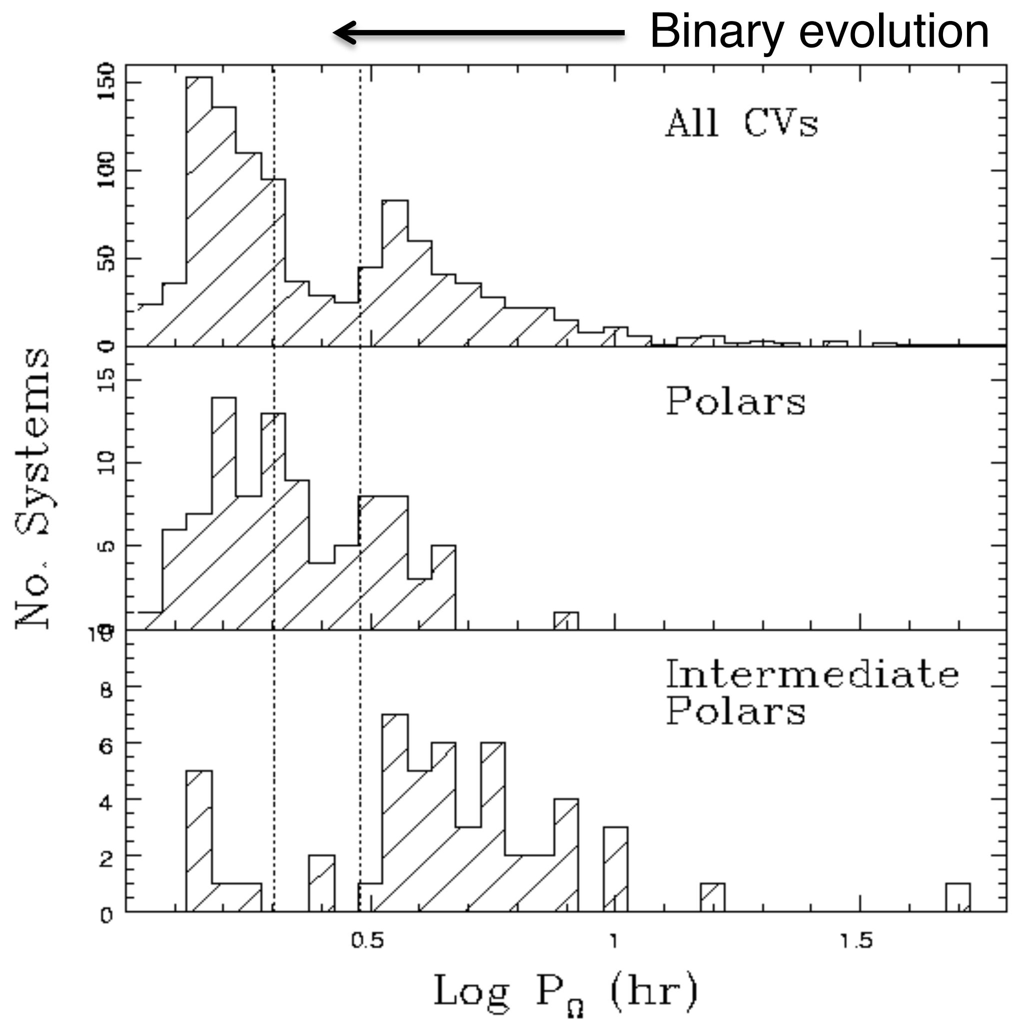




Revnivtsev 2006,2009, Hong 2012, Hailey 2016 + more

Why do we study magnetic CVs?

- We want understand their evolution
  What is the link between Polars and IPs?



Credit de Martino

Open questions

- Galactic “diffuse” emission (buldge, disc, center)
  What are the source producing it exactly?
  Is there a still uncovered population of low-L CVs?

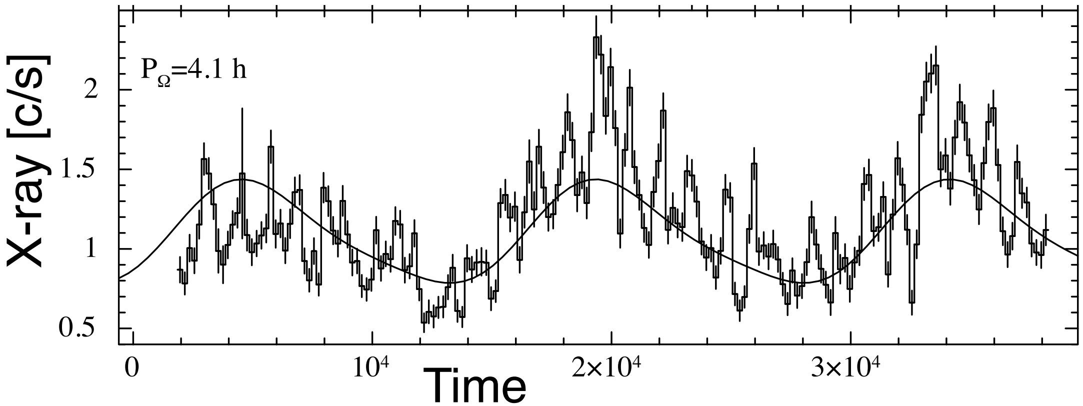
- Binary evolution
  Do long-period IPs evolve into Polars if similar B?

- Magnetic CVs
  Why are they hard X-ray emitters?
  What is the true population of mCVs?

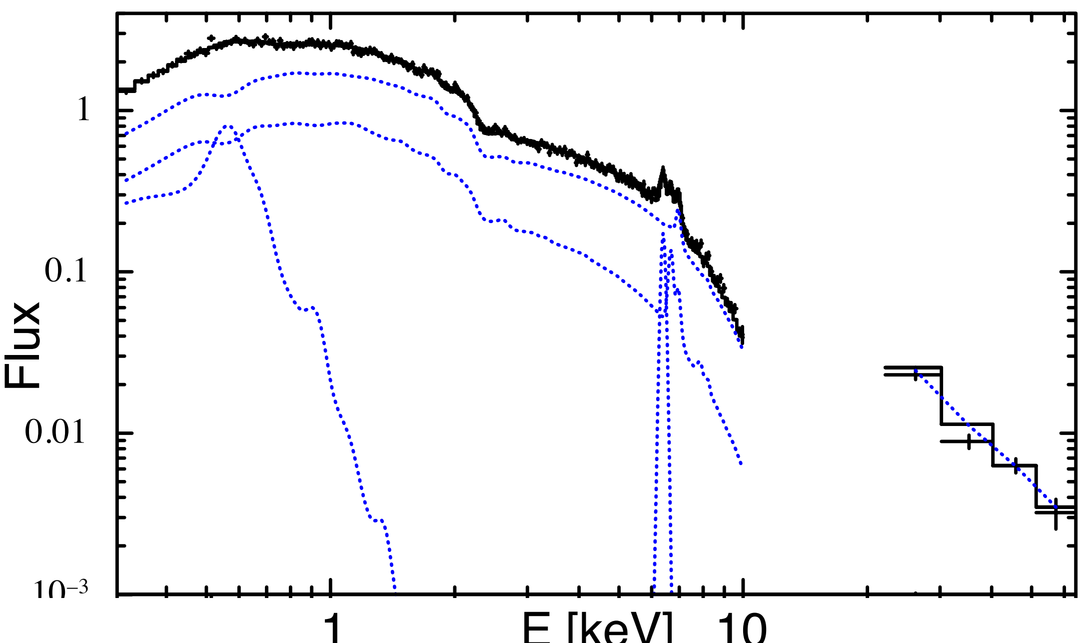
→ Volume (or at least flux) limited sample of mCV

XMM-Newton program

- Opt. follow-ups provide suitable candidates
- Unambiguous identification resides in the X-rays



P_{spin} , P_{orb}



Multi-T optically thin
6.4 keV Fe-line

Bernardini et al. 2012--2017

What do we learn from XMM data?

- X-ray Power Spectra – Accretion diagnostic

$\omega \approx \Omega$ → Stream-fed Polars

ω → Disc-fed IP

ω-Ω → Stream-fed IP

ω, ω-Ω → Disc-overflow IP

- Pulses vs Energy – Absorption/geometry diagnostic

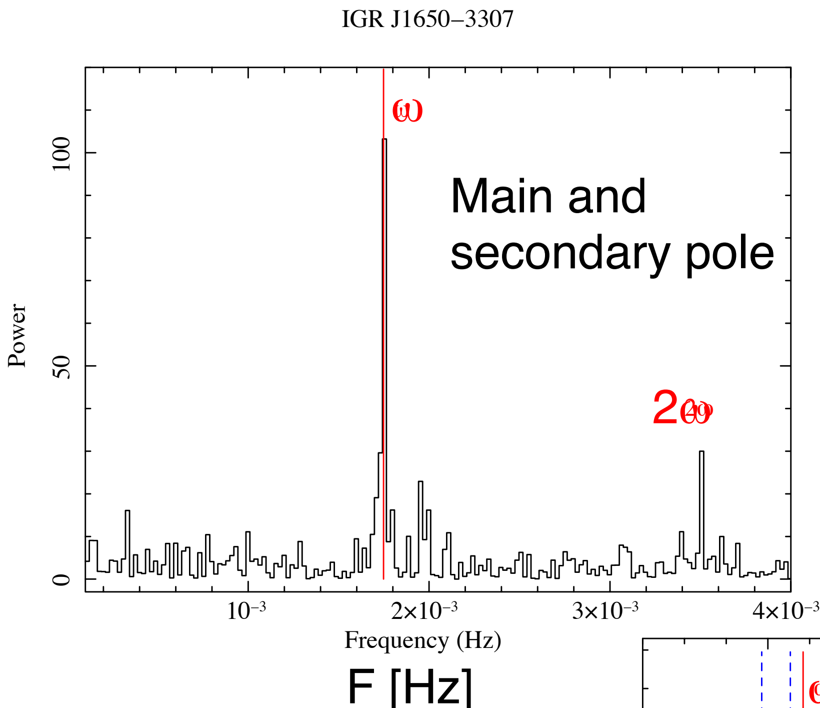
Ampl. decreases with E -> local photoelectric absorption

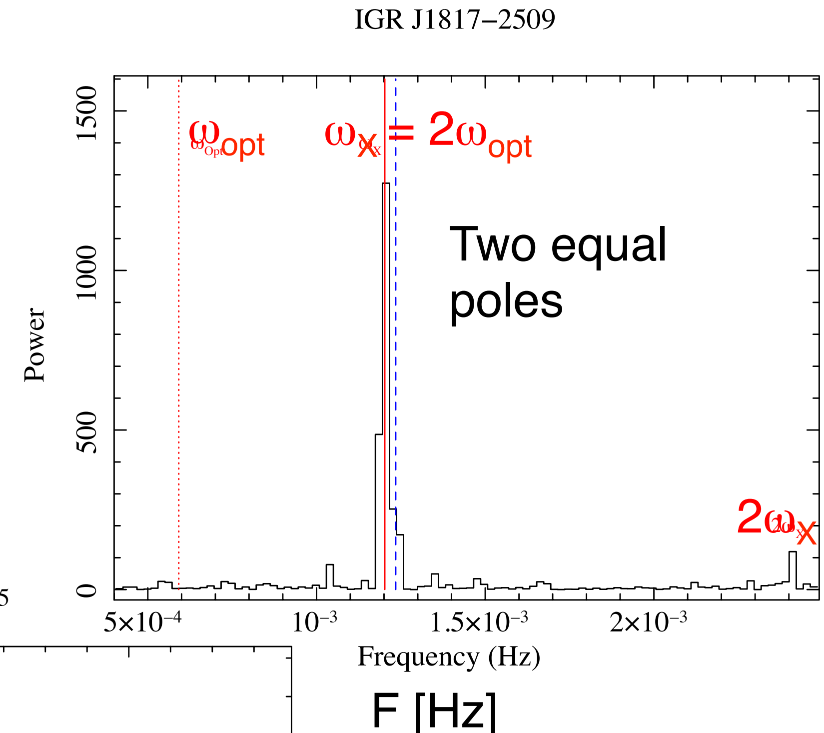
Shape changes -> Additional emission components

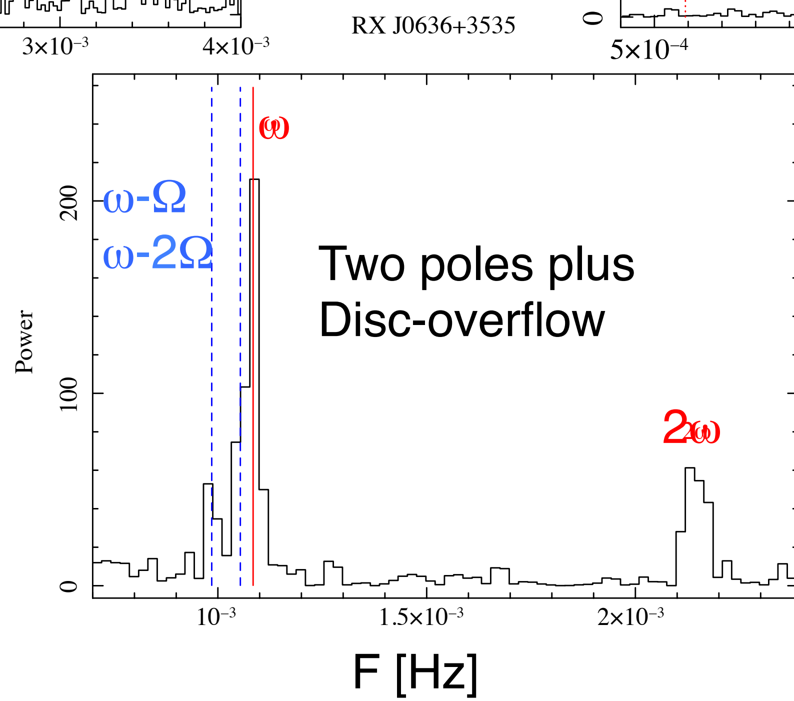
- Broad-band energy spectra – Physical Parameters

Shock temperature -> M_{WD}

X-ray power spectra of IPs

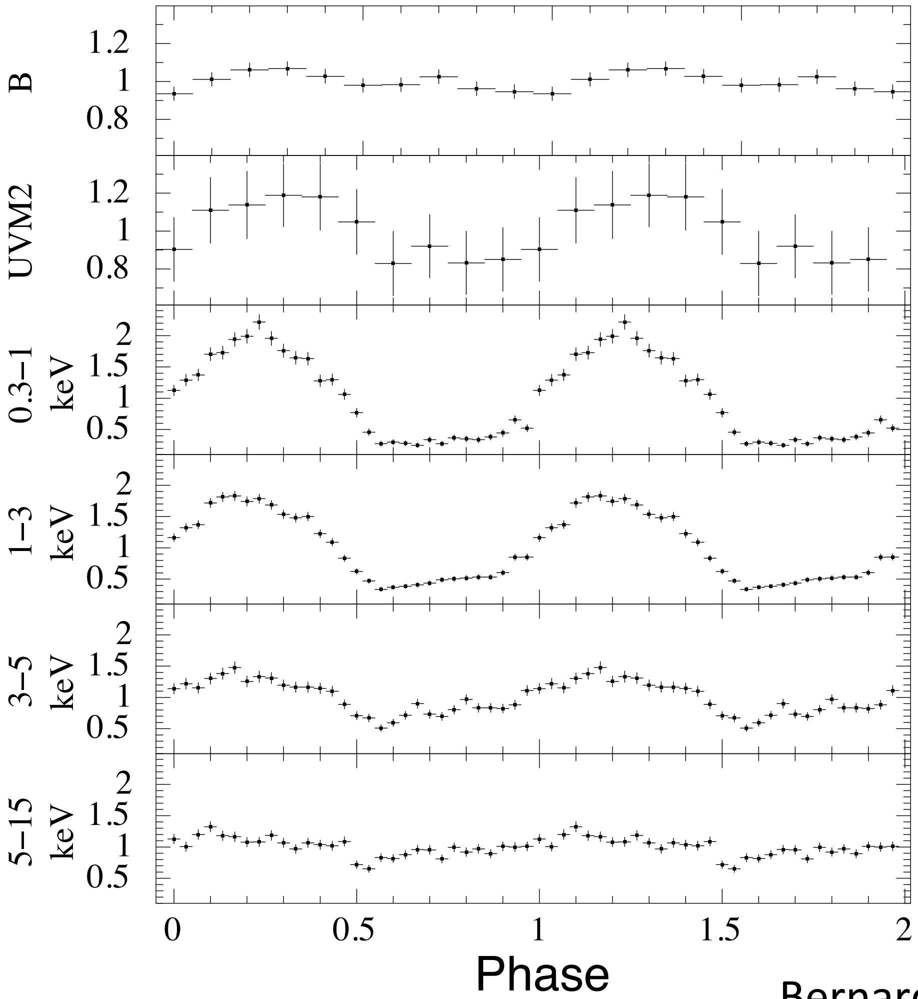






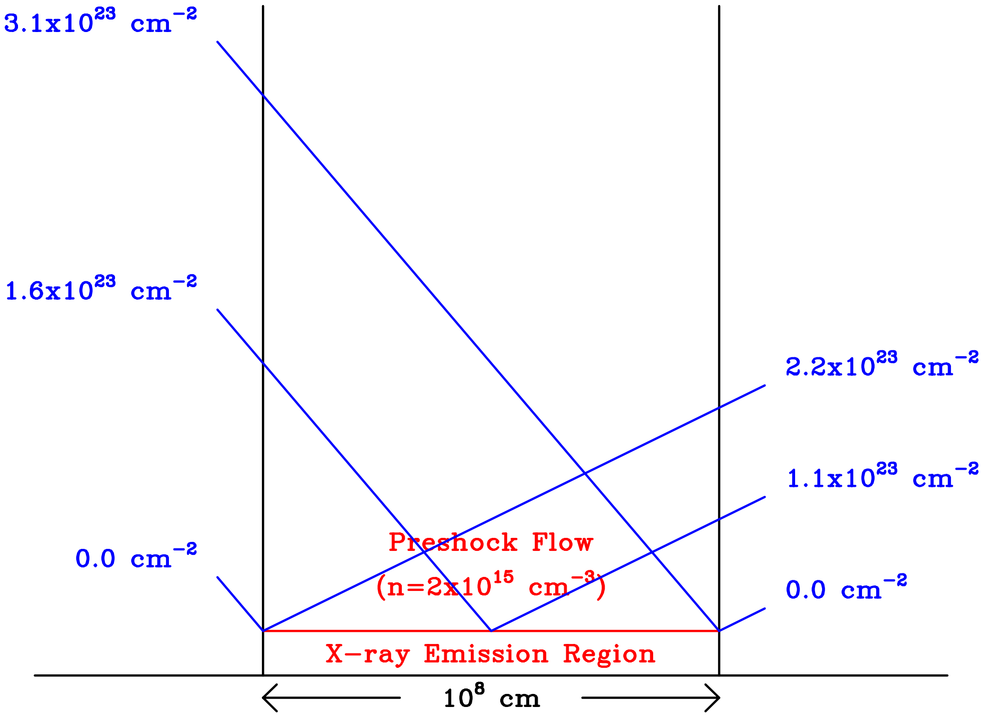
Bernardini et al. 2012

Pulses vs Energy



N_H >> ISM

Accretion flow is cool (not ionized)



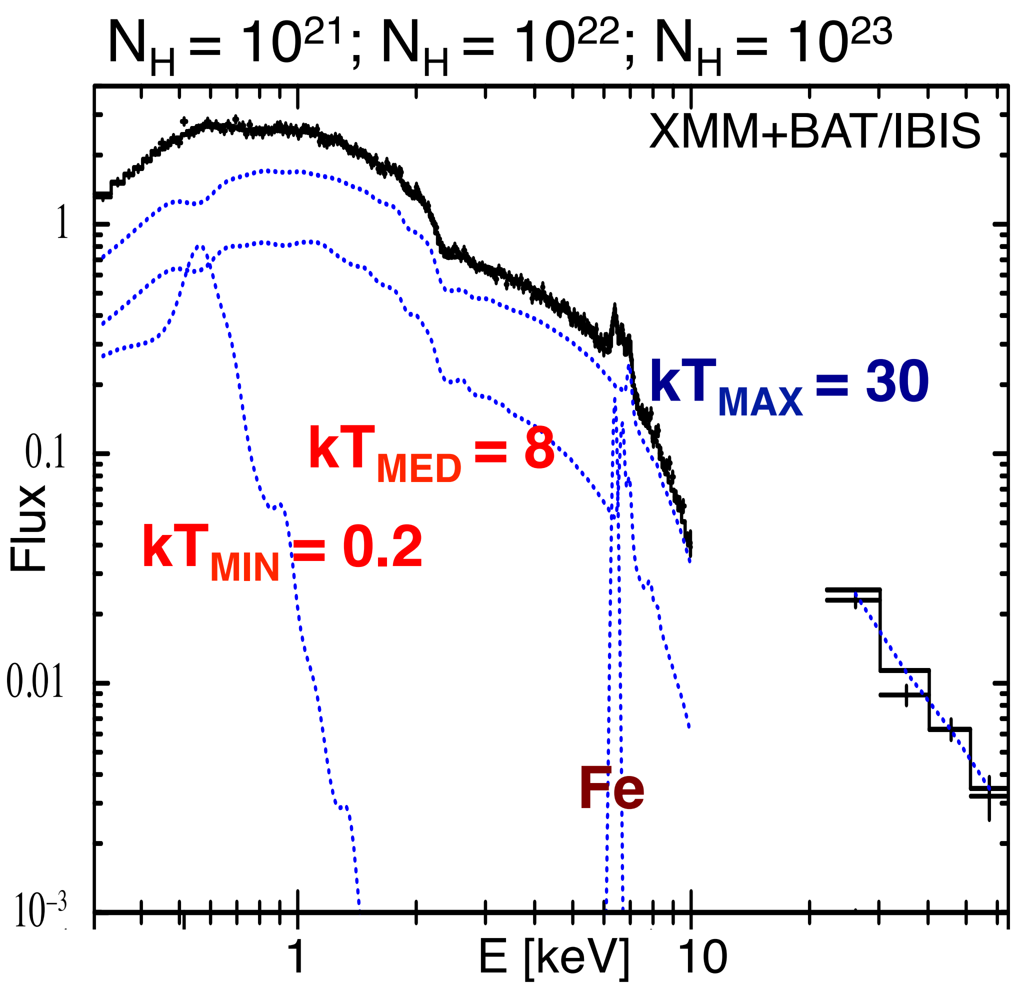
Mukai 2017

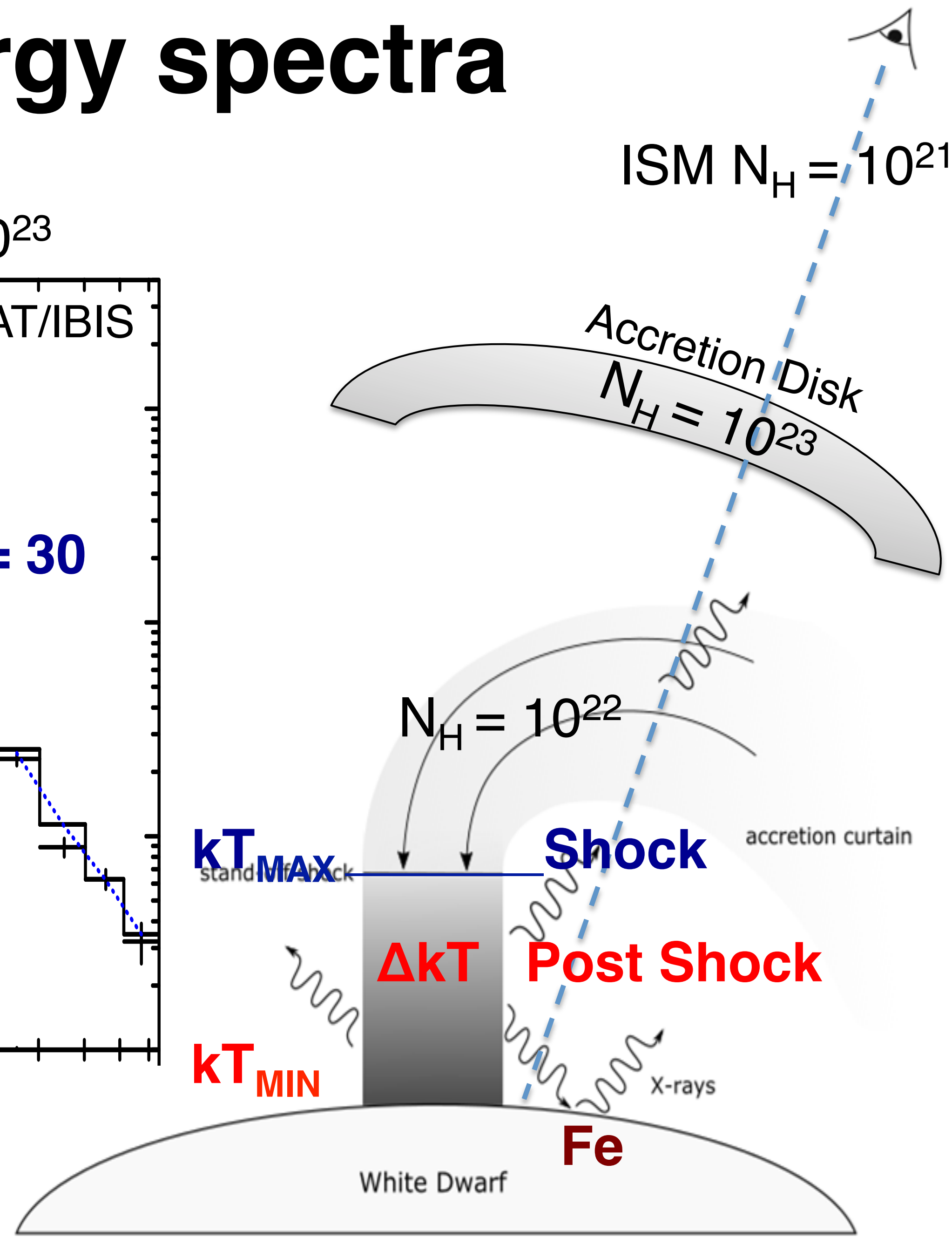
Bernardini et al. 2012

Amplitude vs E -> localized photoelectric absorption

Phasing -> Geometry of the emission components

Broad-Band energy spectra

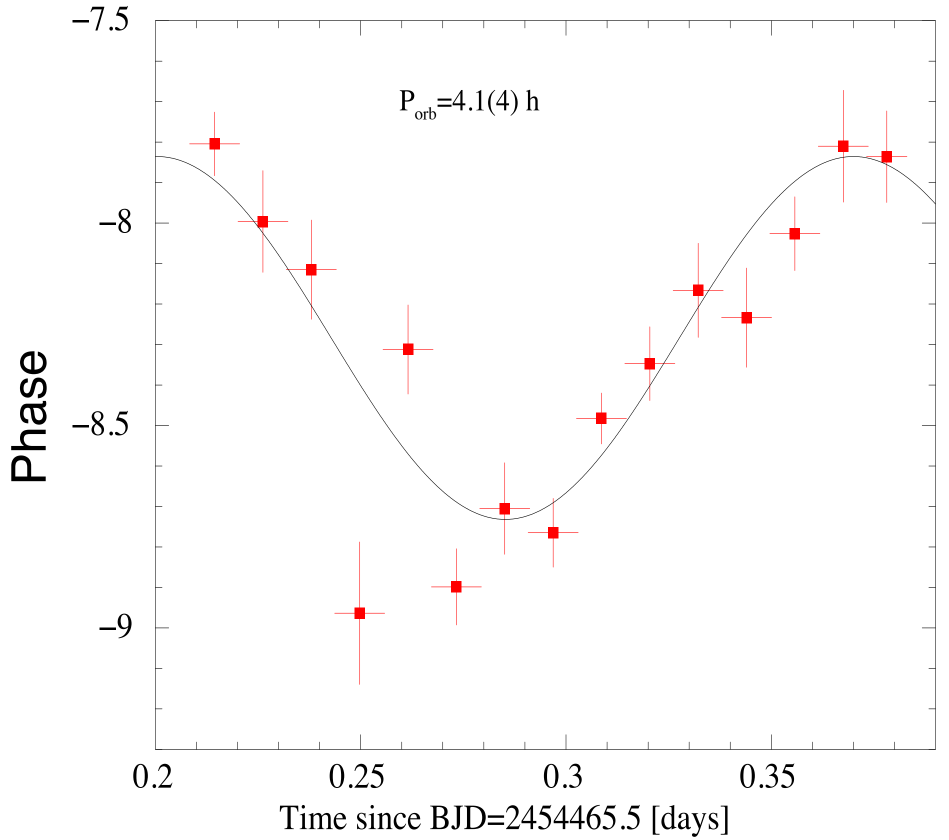




Other techniques

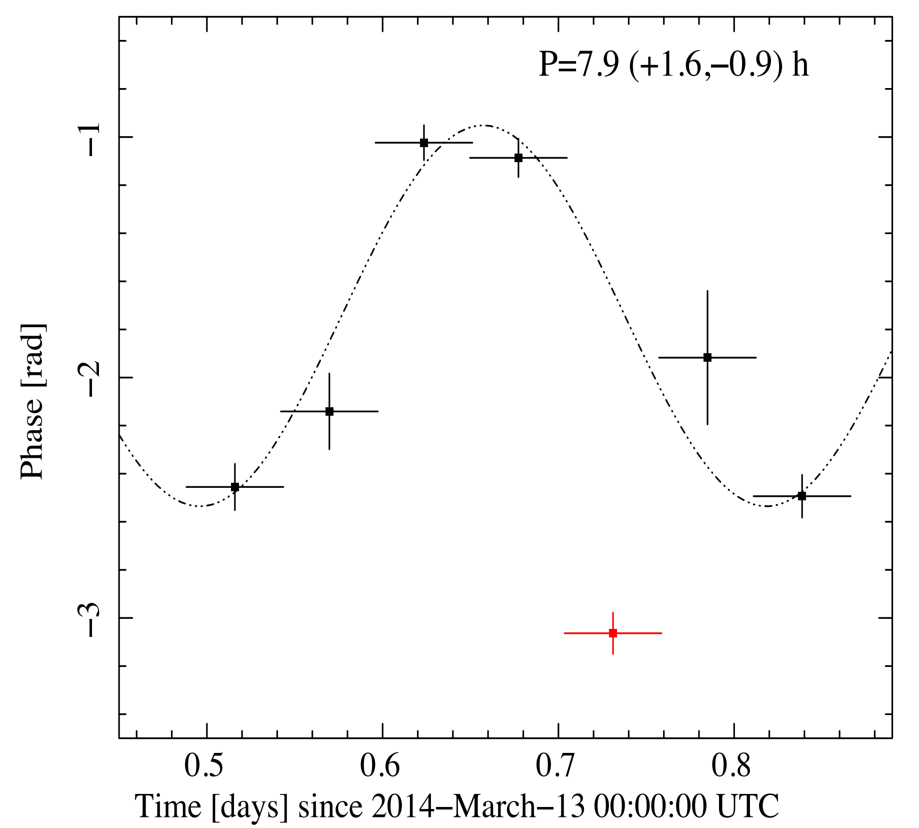
- Orbital period not easy to detect
  Phase-fitting technique -> P_{orb}

XSS J0056+4548



Bernardini et al. 2012

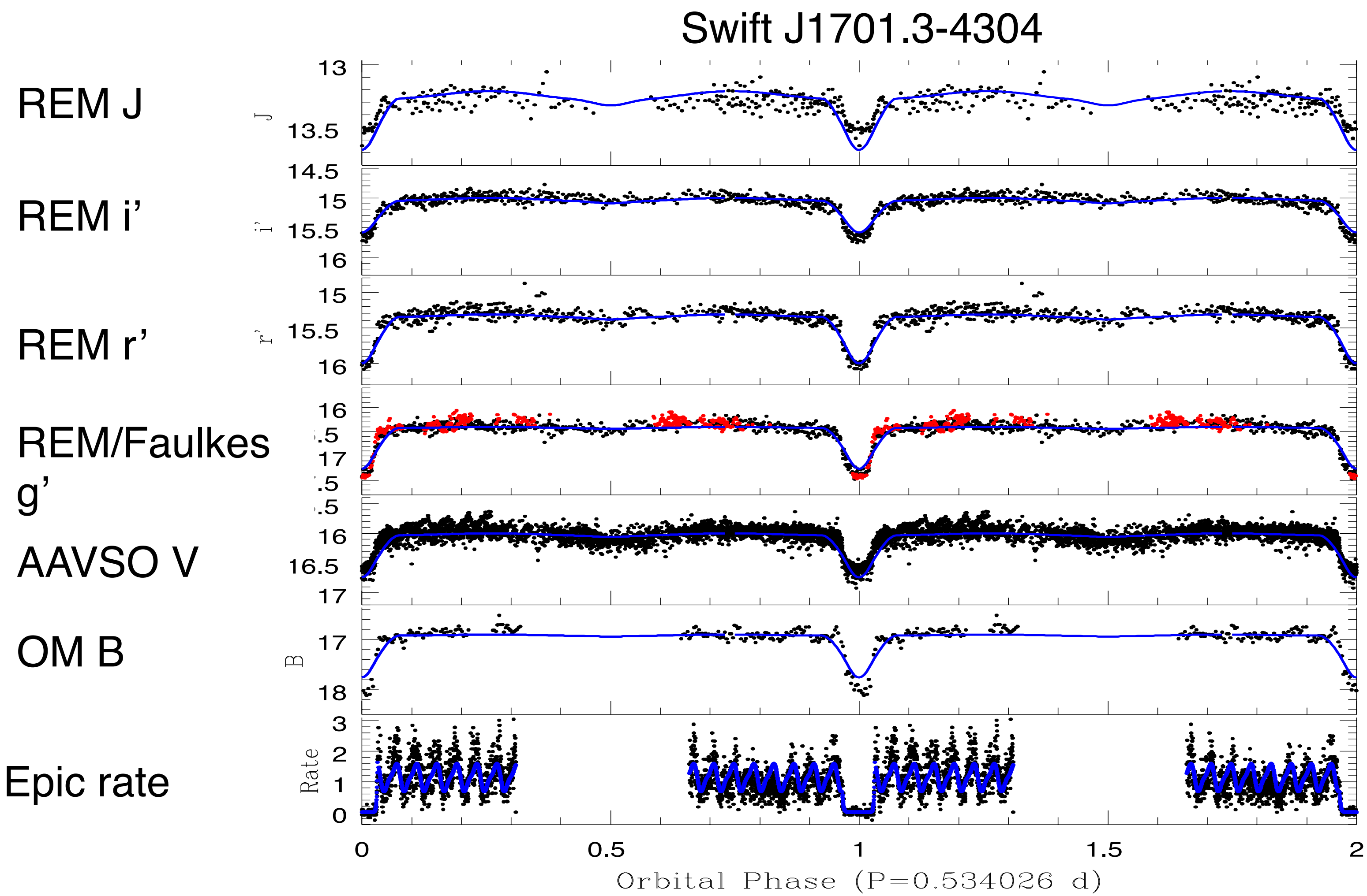
IGR J04571+4527



Bernardini et al. 2015

Some specific result

- First long-period fully eclipsing IP



P_{Ω} = 12.8 h
P_{ω}=1858.7 s

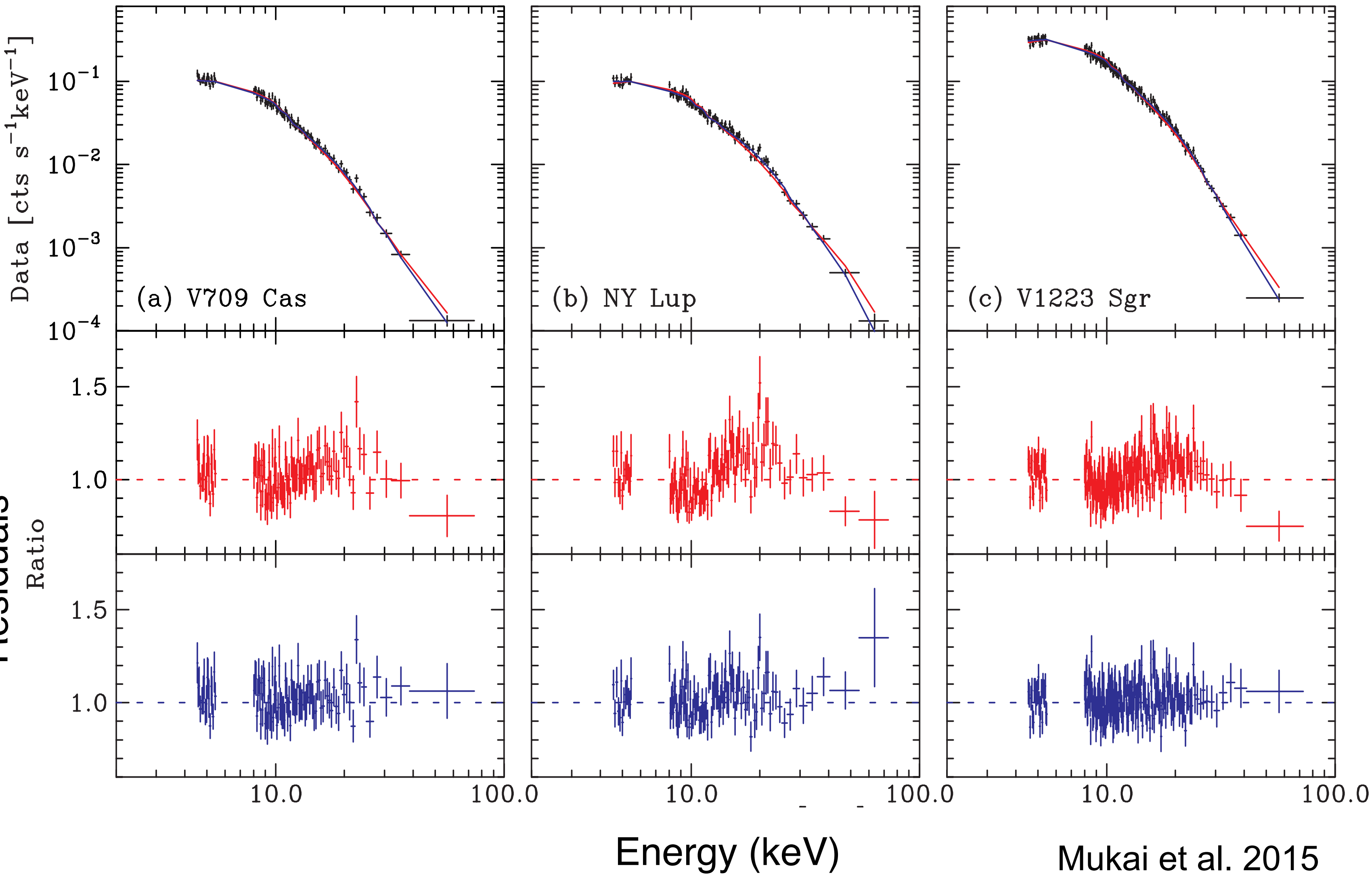
Wealth of info: q, i, T_2, a, R_2, R_X

Bernardini et al. 2017

Some specific result

- First detection of reflection in mCV

XMM+NuStar

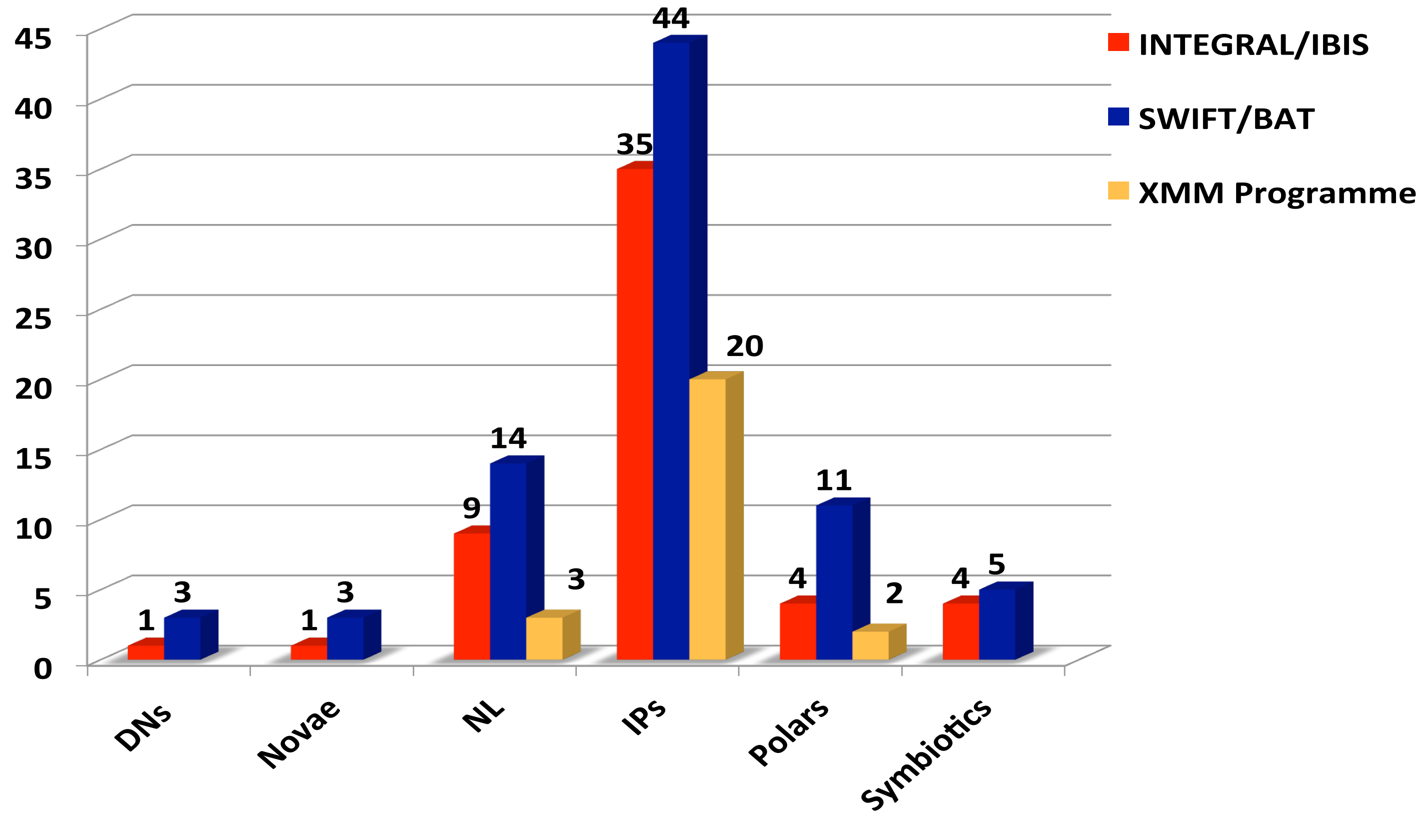


Mukai et al. 2015

General results of the program

- How many CVs are out there?

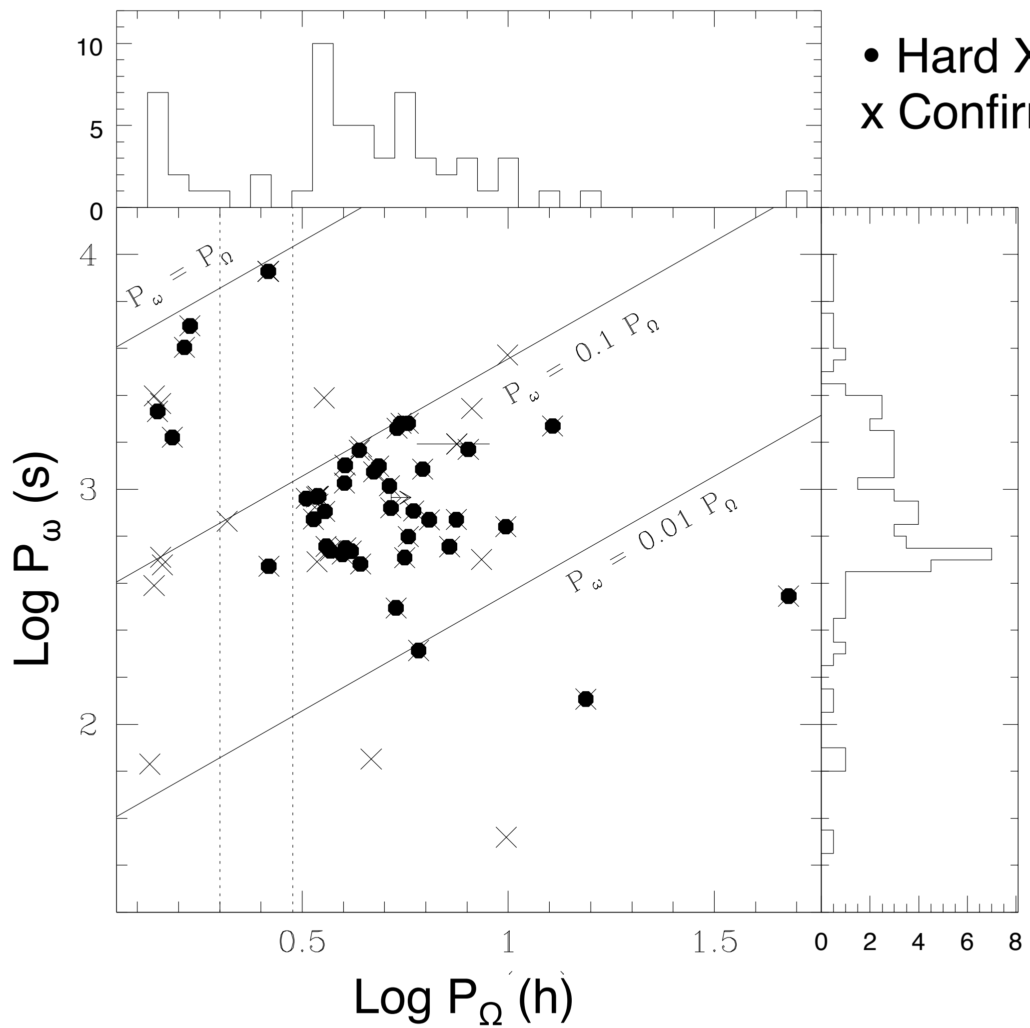
20 IPs + 2 Polar + 3 NL + 1 LMXB (transitional)



Bernardini et al. 2012 to 2017 - Credit de Martino

General results of the program

- What did we learn about IPs?



P_ω: hundreds – thousands seconds

Most at P_Ω > 3hr

Clustering at $P_\omega/P_\Omega \approx 0.05$- 0.1

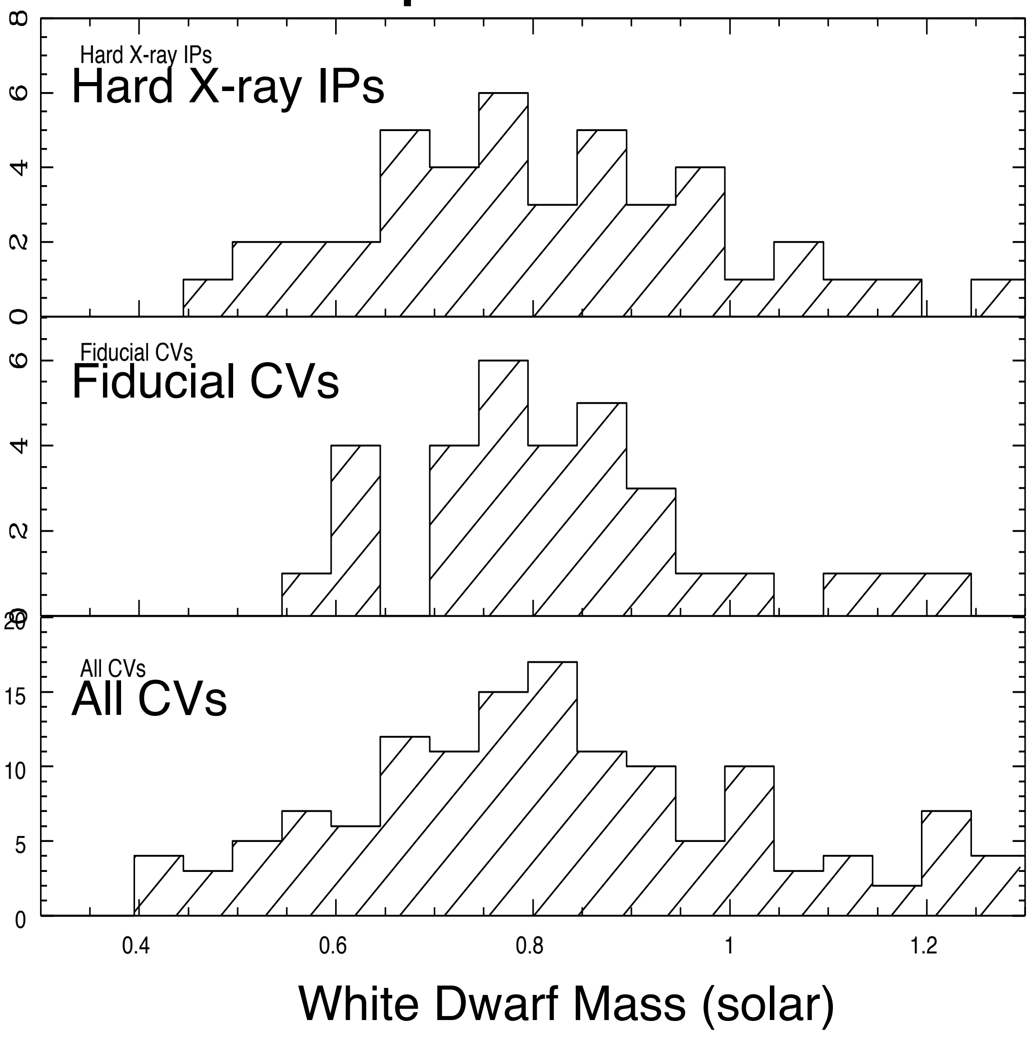
Weakly desynchronized at P_Ω < 2-3hr

46/66 detected by INTEGRAL/SWIFT

Bernardini et al. 2017

General results of the program

- Why IPs have harder X-ray spectra?
  -> Other parameters than M_{WD} play a role



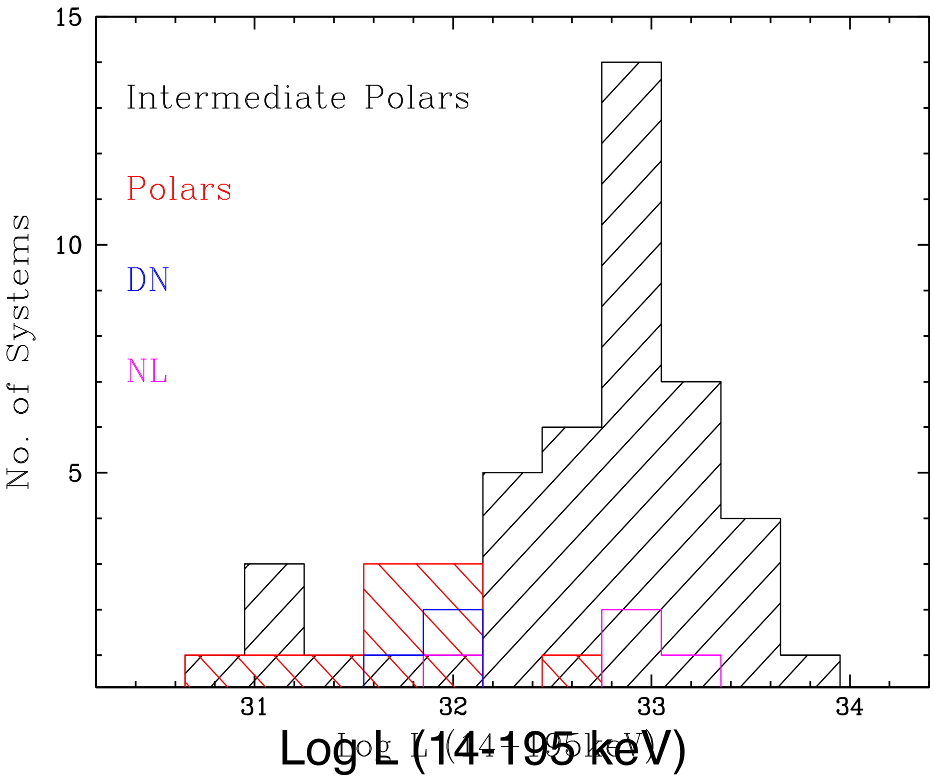
kT_{shock} => M_{WD}

$<M_{IPs}> = 0.81 \pm 0.18\ M_{\odot}$
$<M_{Fid}> = 0.82 \pm 0.15\ M_{\odot}$
$<M_{CVs}> = 0.82 \pm 0.24\ M_{\odot}$

Made using: Anzolin 08,09, Brunschweiger 09, Tomsick 16, Bernardini et al. 12,13,15,17. Credit de Martino.

General results of the program

- Is there a still uncovered population of low-L IPs?
- What is the CV and mCV space density?



IPs: $\langle Lx \rangle \sim 8x10^{32}$ erg/s (up to ~1kpc)

6 IPs at Lx ~ $0.5\text{-}5x10^{31}$ erg/s
with 4 below the 2-3h gap

Polars: Lx $\leq 2x10^{32}$ erg/s (up to 240 pc)

Low Lx: Polars, short-P_{orb} IPs, or DNs ?

These results depend on distance uncertainties
Gaia will soon provide accurate CV distance

Conclusions and Perspectives

- XMM program is an ongoing project
- Hard X-ray CVs are dominated by mCV of IP-type
- They increased by 50% thanks to hard surveys
- Hard magnetic CVs have:

  M_{WD} consistent with other CVs

  Maybe harder because moderate B & high dm/dt

- Near Future: census of hard X-ray CVs

  XMM-Program + Extras -> flux limited sample

  Unveil the true population of faint sources

  Widen our knowledge of CVs and binaries