Magnetic Cataclysmic Variables in the XMM-Newton Era

D.de Martino
INAF-Osservatorio Astronomico di Capodimonte Napoli

&
G.Anzolin, J.-M.Bonnet-Bidaud, M.Falanga, B.Gaensicke, F.Haberl, N.Masetti, G.Matt, M.Mouchet, K.Mukai

Outline

Open questions for MCVs:

- MCV-CV evolution & incidence of magnetism in WDs
- Role in Population of Galactic X-ray Sources
- Accretion & Emission processes: role of fundamental parameters

Results from X-ray Observations:

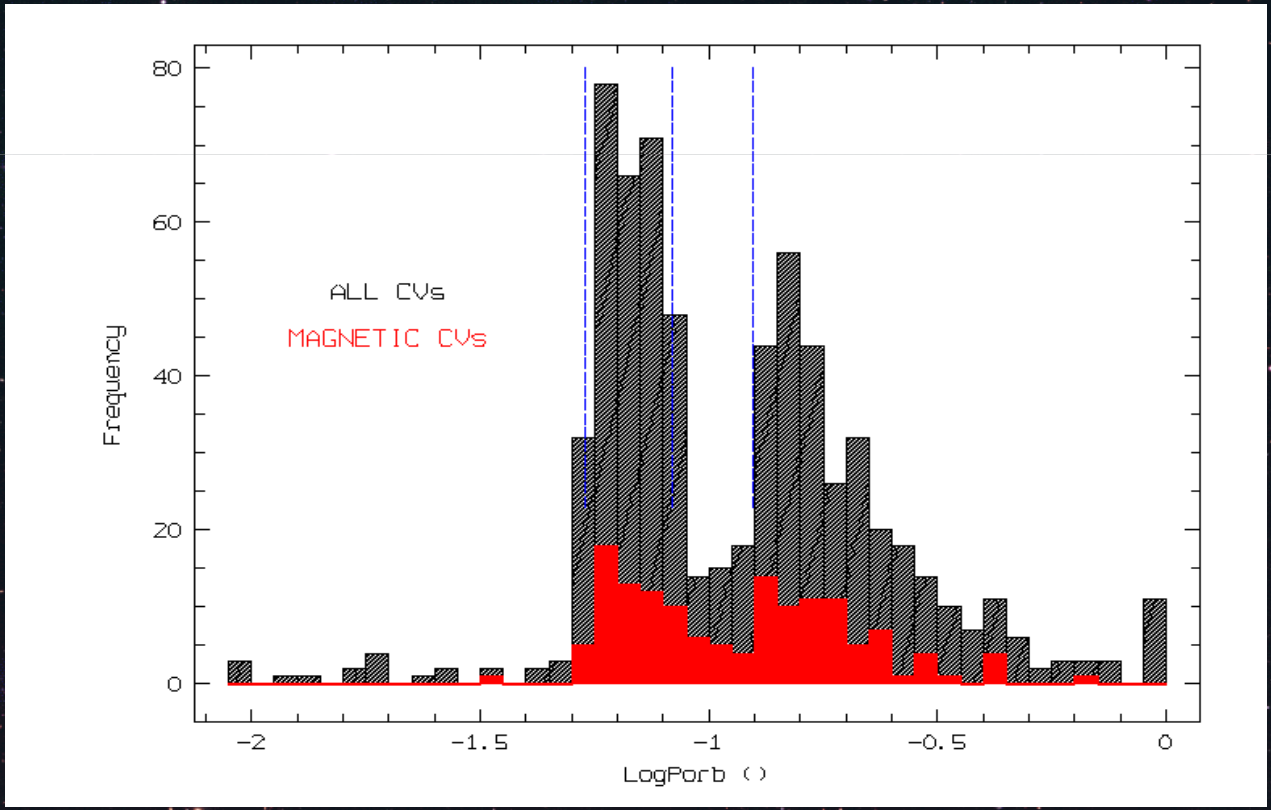
- Increasing memberships of MCVs
- New X-ray properties of MCVs

Perspectives:

- Future X-ray facilities

Questions on MCV Evolution

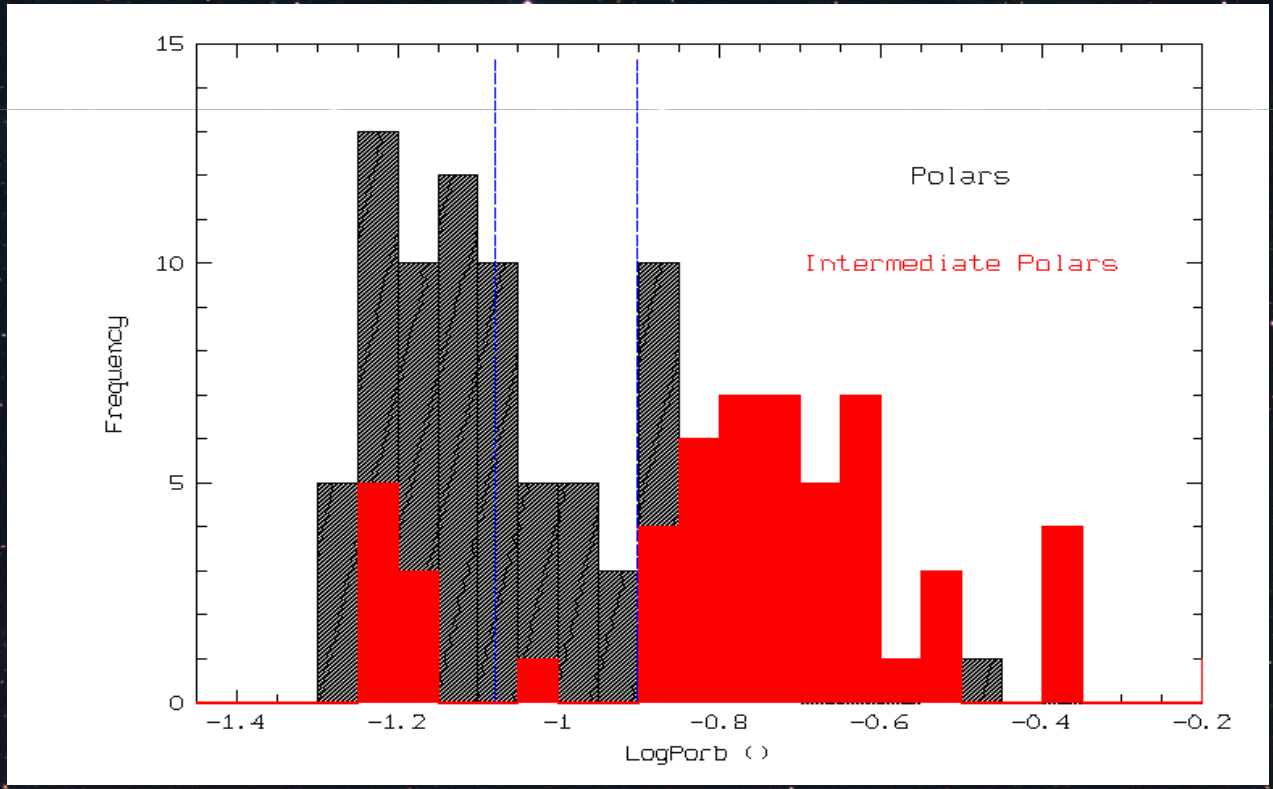
MCVs ~25% of all CVs against MWDs ~10% of all WDs



Questions on MCV Evolution

Current census: Polars (62%) IPs (38%)

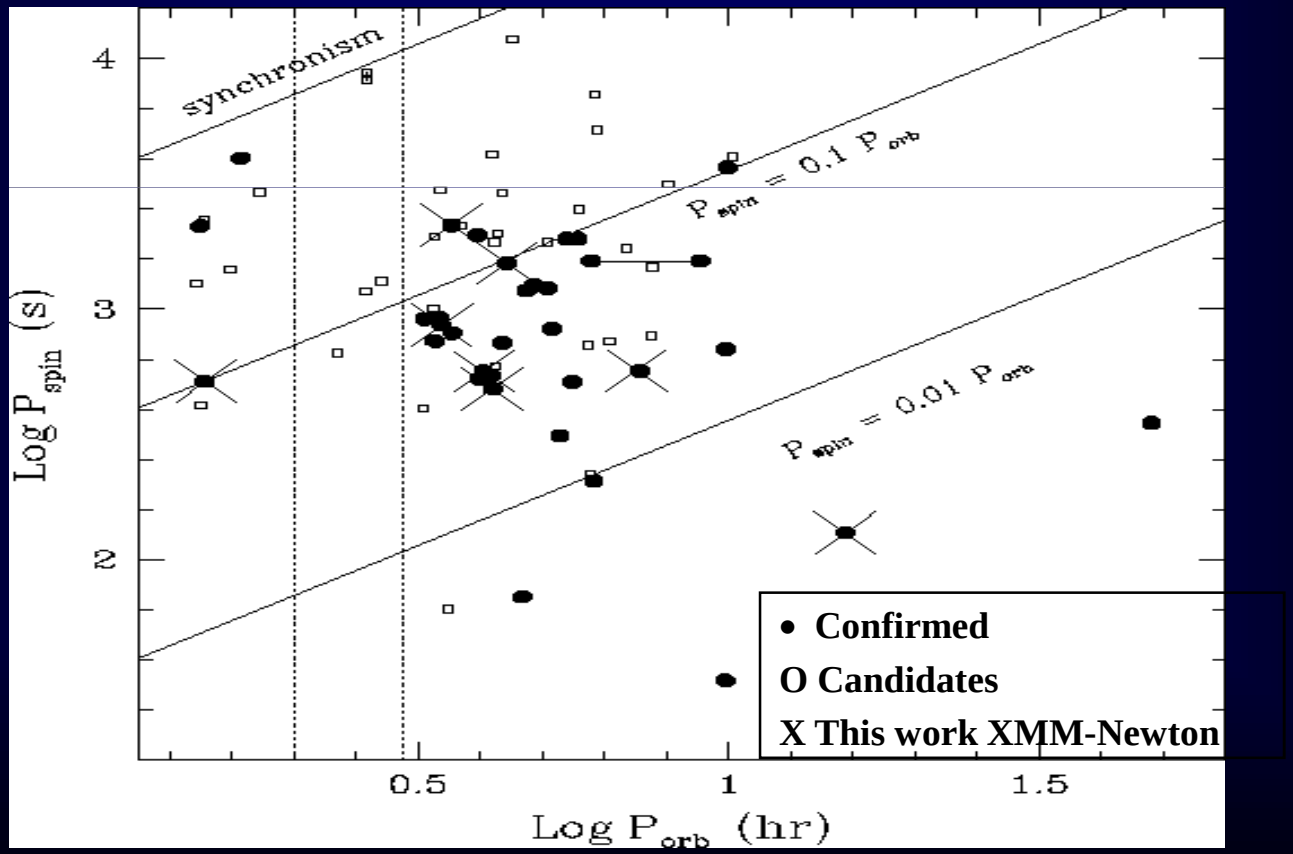
- Selection effects on IPs: Soft X-ray Surveys, long Porb?
- IP candidates increased ~ 50% in the last 4 yrs!



Do IPs evolve towards synchronism?

Wide range of asynchronisms:

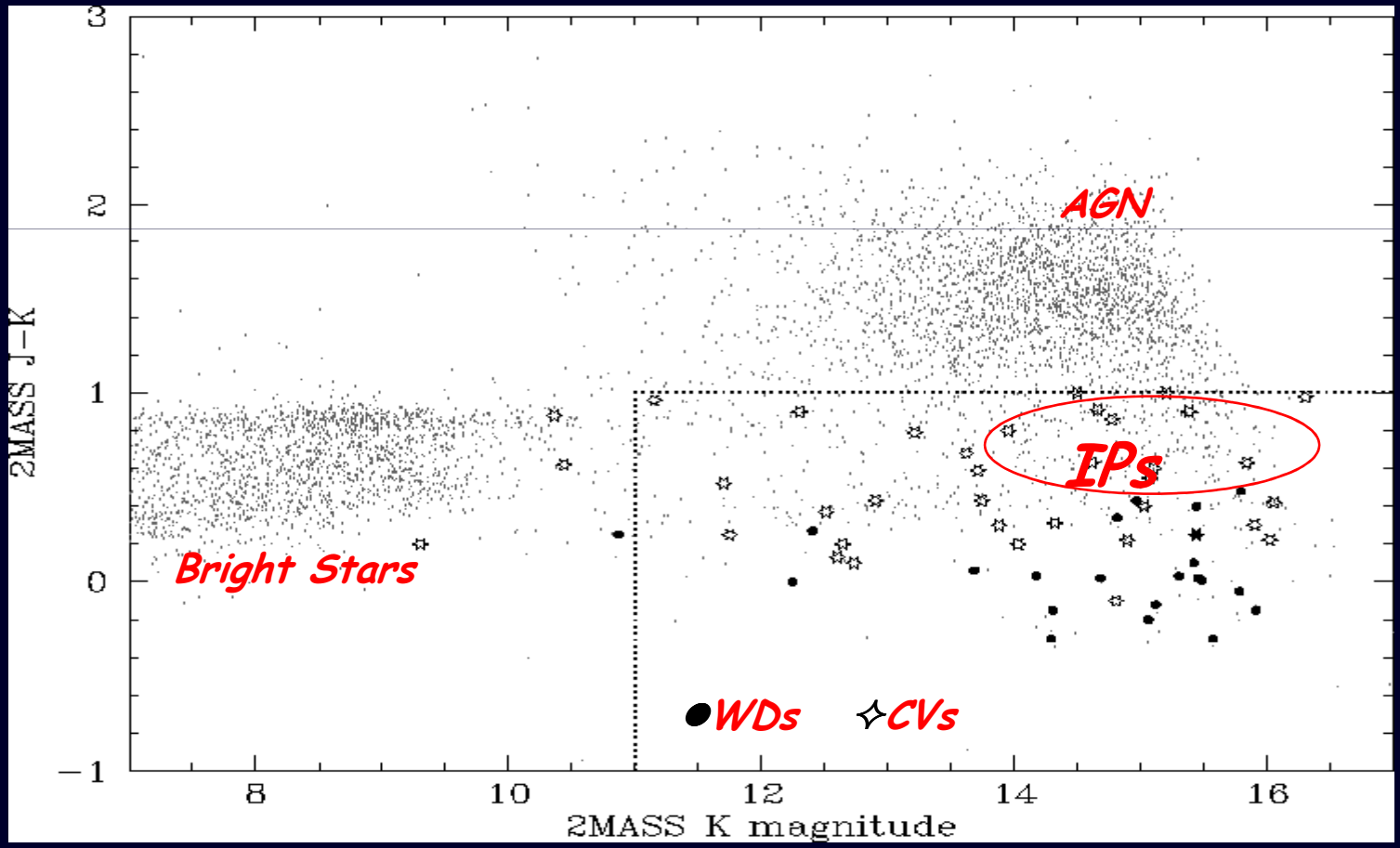
- Clustering close to Pspin/Porb=0.1 **but new** candidates at high & low degree of asynchronism
- **50% of the class still to be confirmed in the X-rays!**



IP candidates from Surveys

- **X-ray & nIR detection:**

ROSAT – 2MASS colours efficient in **IP** detection
(Gaensicke et al. 2005)



IPs from Surveys

- HARD X-ray Surveys:

RXTE , INTEGRAL & SWIFT detect CVs most MCVs of IP type (Revnistev et al. 2004; Barlow et al. 2006; Bonnet-Bidaud et al.2007; Mukai et al.2007; Shafter et al. 2008)

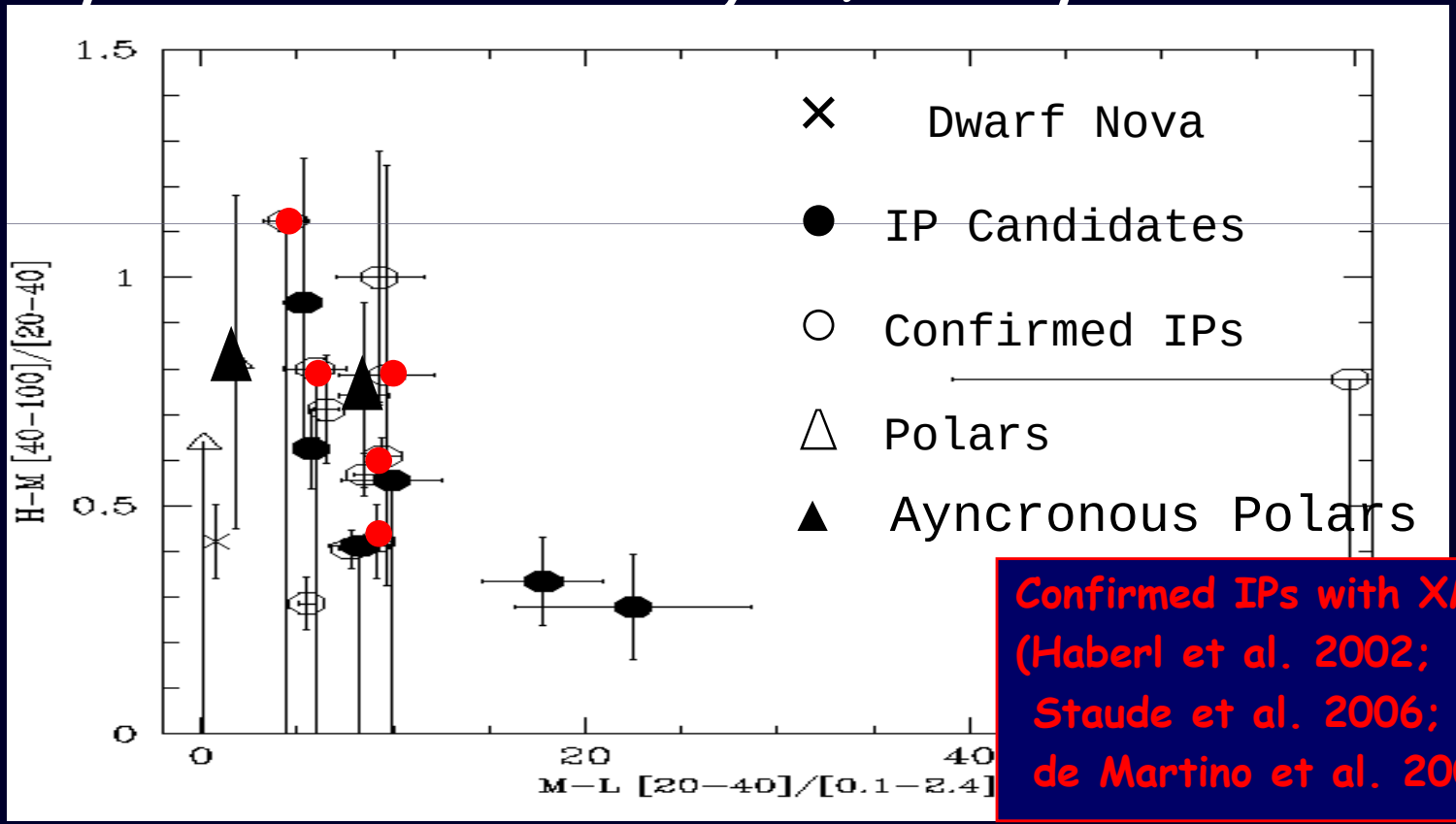
Hard (>20keV) X-ray emission was already detected in bright IPs by GINGA & BeppoSAX

Asynchronism: a common characteristics of hard X-ray CVs

·INTEGRAL IBIS/ISGRI catalogue:421 sources (Bird et al. 2007

-About 5% are CVs (Masetti et al. 2006; Mukai et al.2006, Bodaghee et al. 2007; Bonnet-Bidaud et al. 2007)

-Hard spectra with wide range of absorption



Confirmed IPs with XMM-Newton
(Haberl et al. 2002;
Staude et al. 2006;
de Martino et al. 2006,2008)

Do MCVs play a role in Galactic Populations?

CHANDRA Survey of GC (Muno et al. 2003;2004; Ruiter et al 2005):

- 1500 over 2000 Faint Sources: Lx < 10^{31} – 10^{33} erg/s
- Hard spectra: kT > 8keV & Fe H-like and He-like emissions
- Affected by local absorption
- Variable: Periods 300sec – 4.5hrs

IPs proposed to be dominant population

RXTE & INTEGRAL surveys of Milky way (Sazonov et al. 2006; Revnivtsev et al. 2006, 2008):

- XLF [2-10keV] at L<10^{34}erg/s from Coronal (65%) and CVs (35%)
- XLF of CVs [2-12keV] similar to XLF[16-60keV]

Galactic Ridge emission at E>20keV dominated by MCVs

MCV Properties

POLARS:

- PHASE LOCKED -> NO DISC
- STRONGLY POLARIZED in OPTICAL/nIR-> B ~10-230 MG
  (but isolated MWDs have 0.1-1000MG !)
- HARD (10-20keV) & SOFT BB (30-50eV) X-RAY COMPONENTS

IPs:

- ASYNCHRONOUS -> DISC/ DIRECT /HYBRID
- UNPOLARIZED (B <5MG) exceptions are 6 systems (B>5MG)
- HARD (>20keV) SOURCES but 4 ROSAT discovered with SOFT BB

MCV Properties

QUESTIONS:

- Are IPs a still hidden population of MCVs?
- Are the SOFT X-ray & Polarized IPs the true Polar progenitors?
- Do all IPs possess a SOFT X-ray component?
- Why asynchronous CVs are so hard X-ray emitters?

High Sensitive X-ray broad-band observations to:

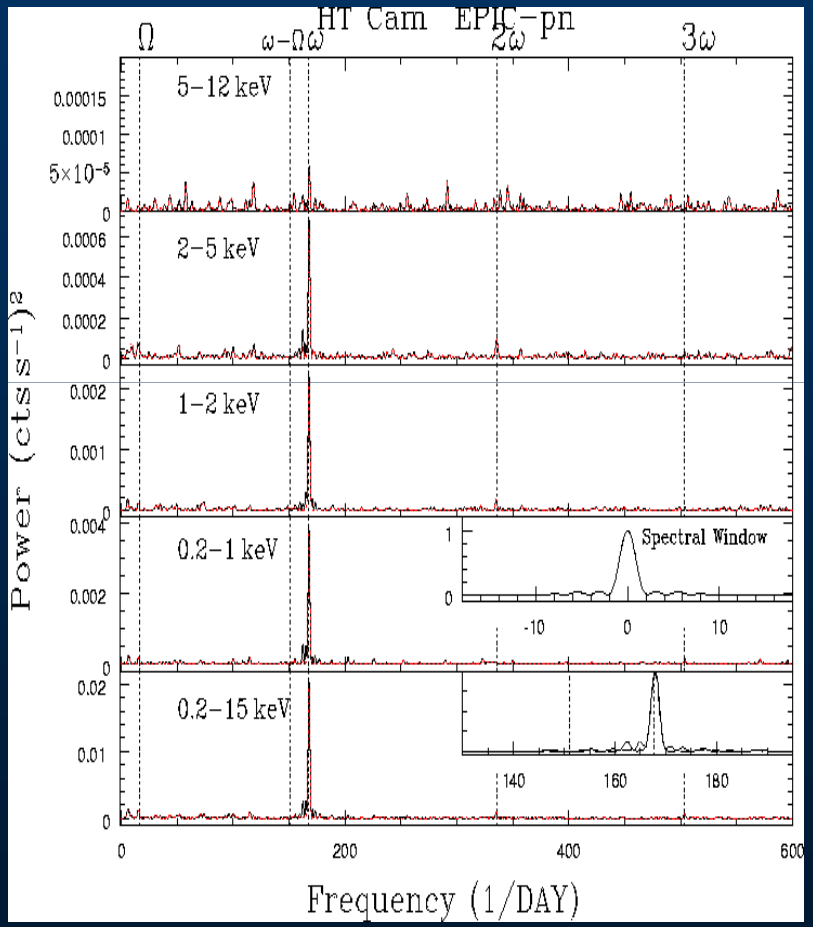
- Confirm IP Membership
- Characterize soft and hard X-ray emissions

The Role of XMM-Newton

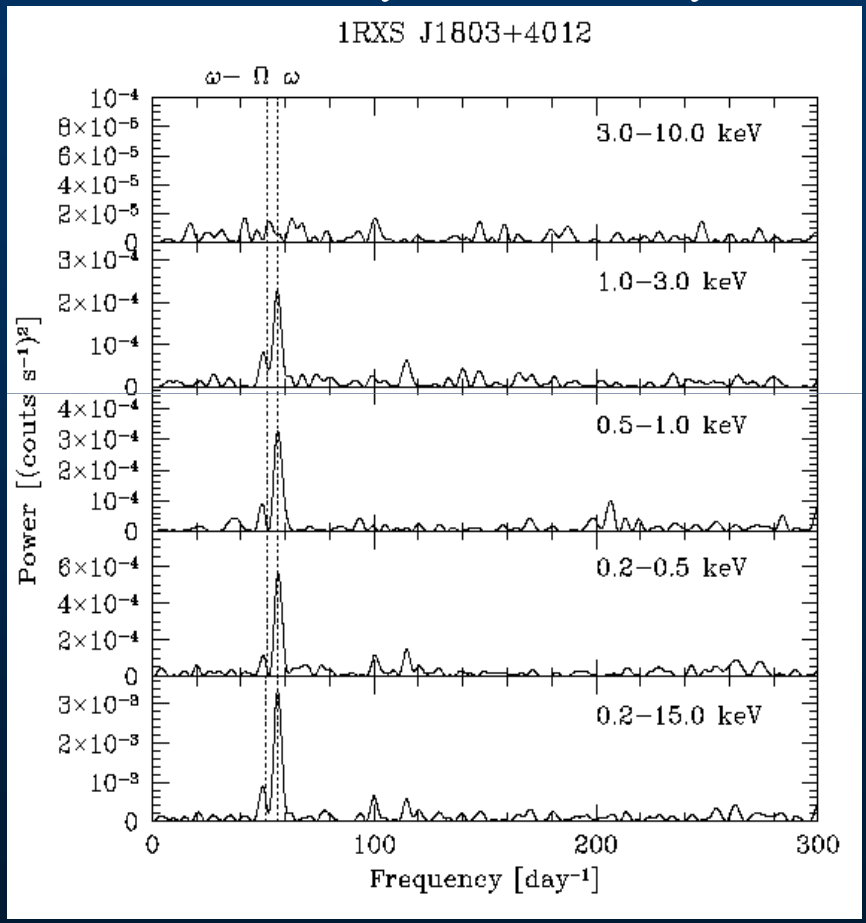
- **X-Ray Power Spectra:** -Secure membership identification
  - Accretion mode diagnostic
  - $\omega \rightarrow$ Disc
  - ω -$\Omega \rightarrow$ Direct (no disc) accretion
  - ω ω-Ω,$\Omega \rightarrow$ Disc overflow(Hybrid)
- **Energy dependent X-Ray & Optical/UV Light curves @ dominant P:**
  - Geometry and magnetic field complexity
  - Primary & Reprocessed radiation
  - Absorption effects
- **X-Ray spectra:** - Pre-shock & Post-shock diagnostic
  (Multi-Temperature, density, velocities & Mdot)

X-ray Periodicities

Complexities in Energy dependent X-Ray Power Spectra



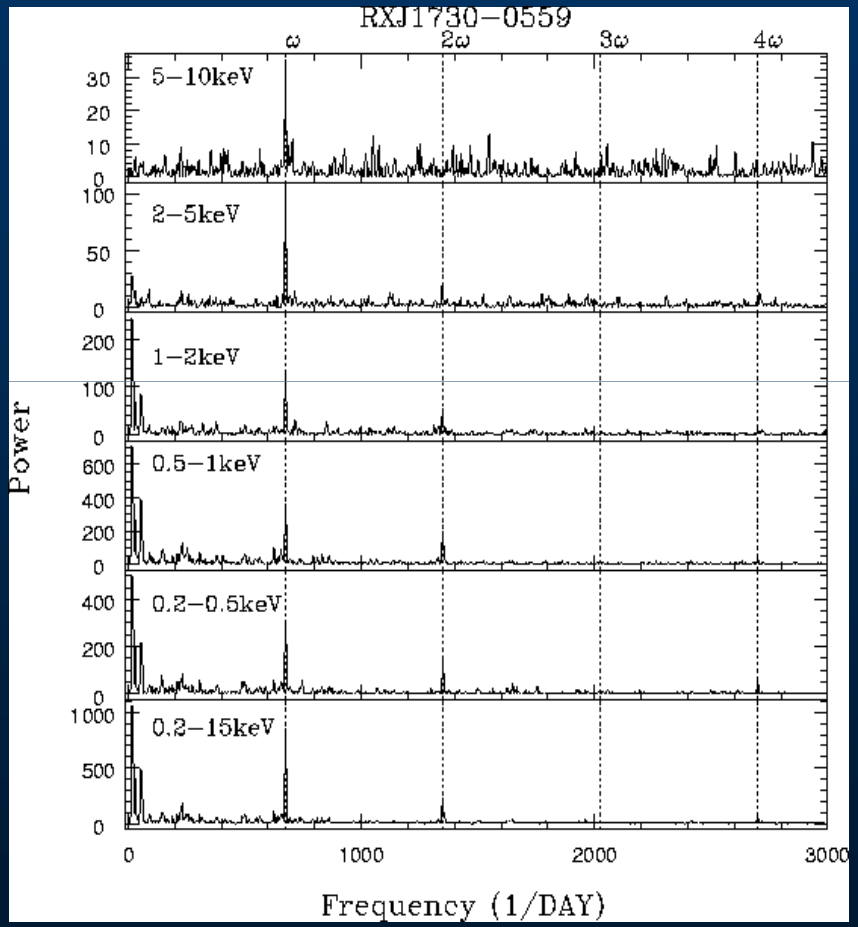
One Pole disc-fed
(de Martino et al. 2005)



One Pole Hybrid
(Anzolin et al. 2008)

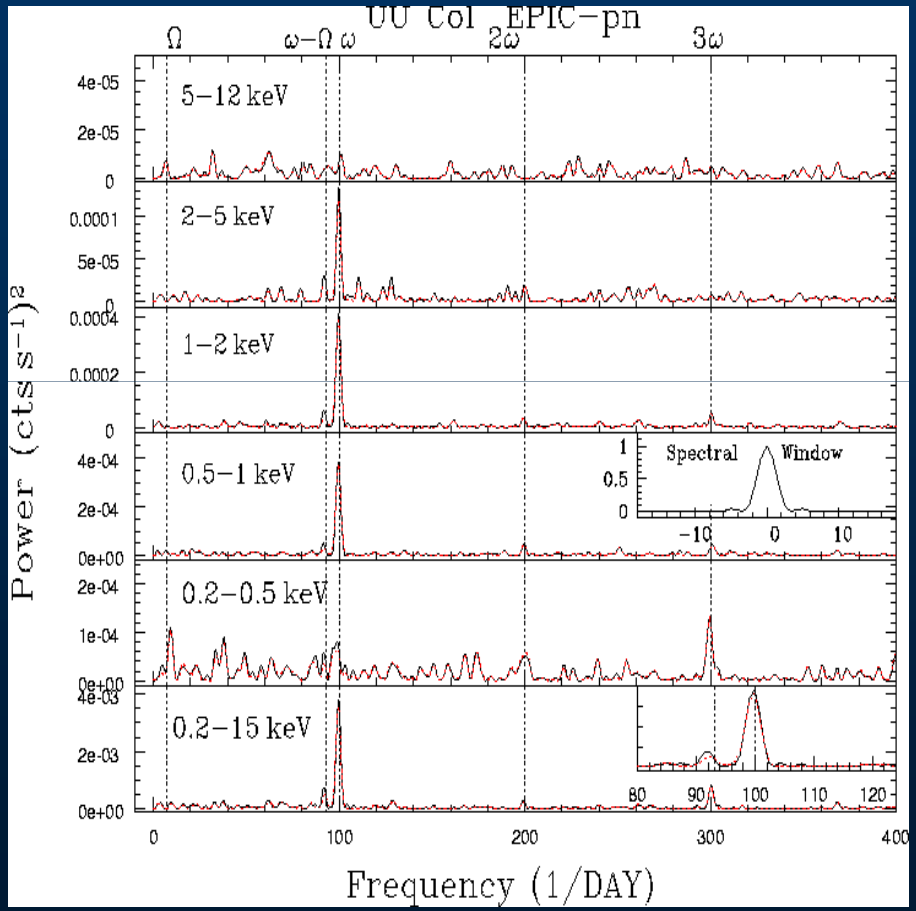
X-ray Periodicities

Complexities in Energy dependent X-Ray Power Spectra



Two Poles disc-fed

(de Martino et al. 2008)

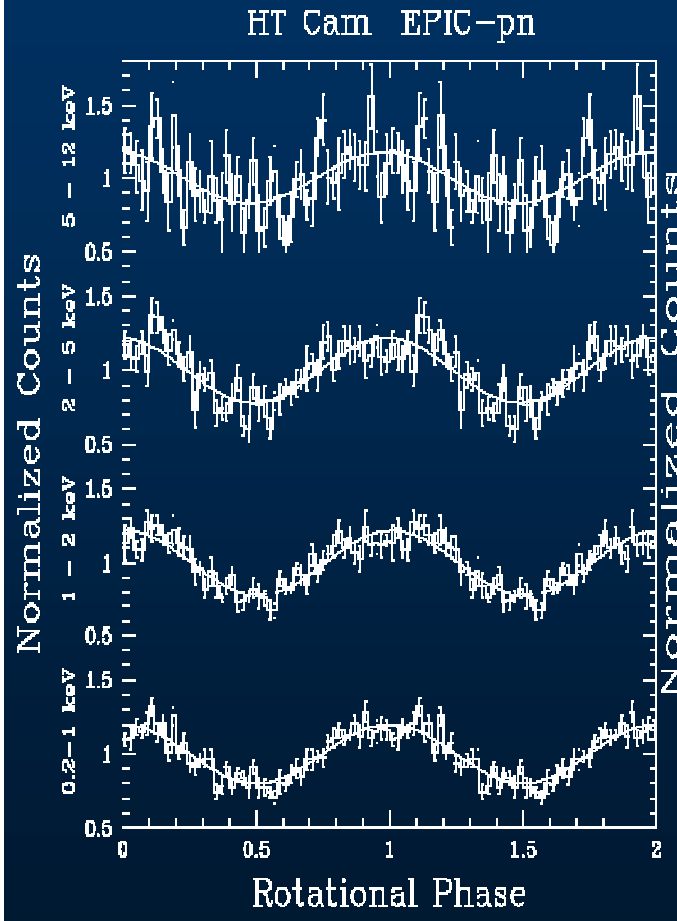


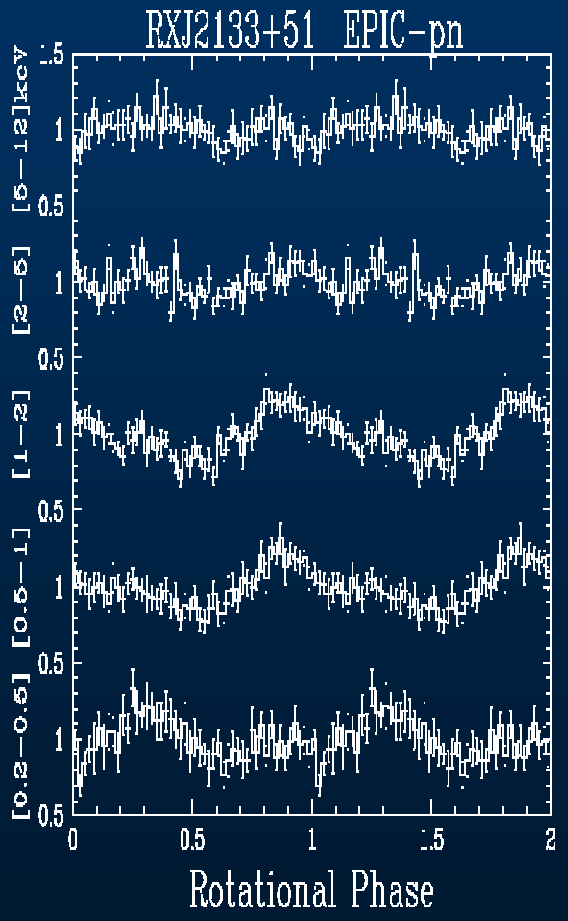
Two Pole Hybrid

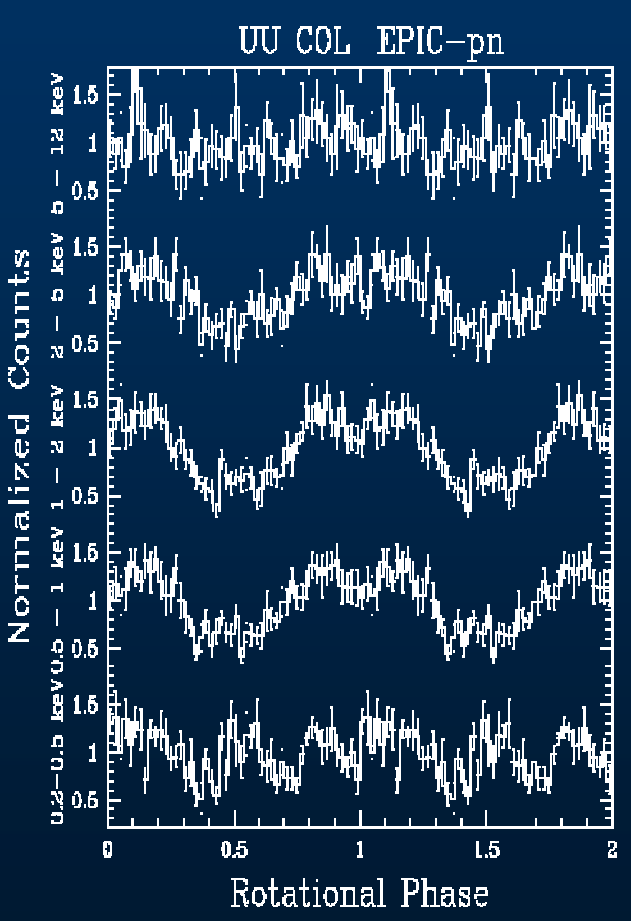
(de Martino et al. 2006)

X-ray Pulses

Energy dependent structured pulsations







One hard Pole

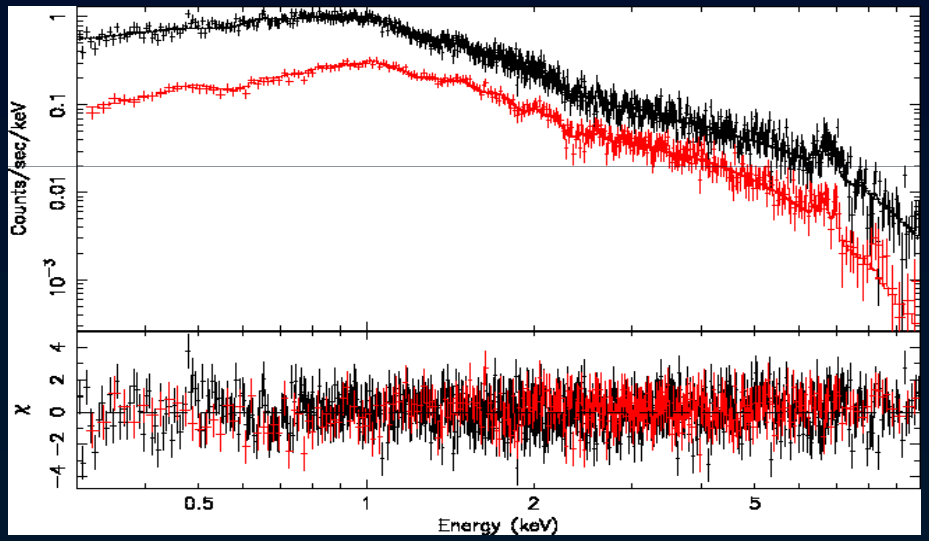
Primary hard Pole + Secondary soft Pole

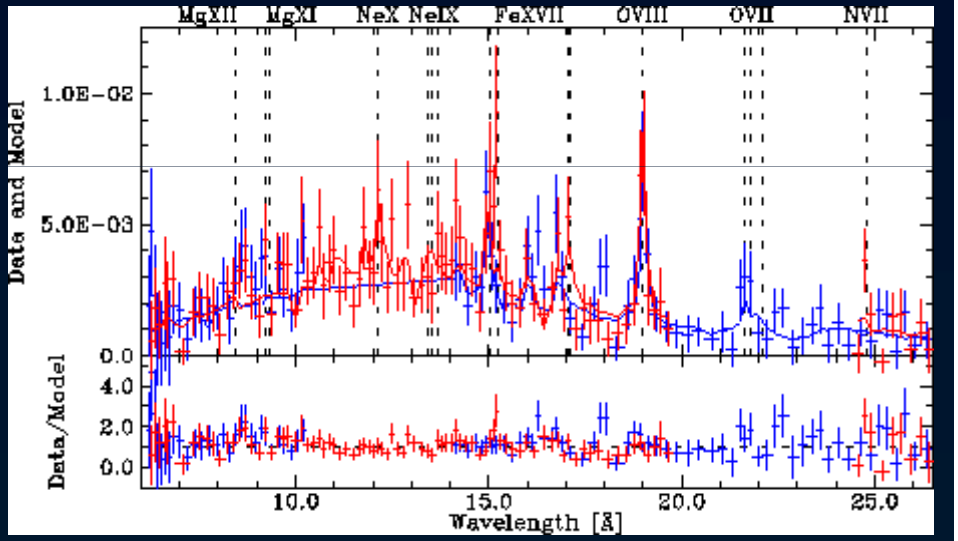
Primary hard & soft Pole + Secondary soft Pole

X-ray Spectral Properties

Starting from the simplest case of HT Cam (de Martino et al. 2005)

Multi-temperature post-shock flow :EM(T) ≈(T/Tmax)$^{\alpha}$





- kTmax=20keV; α=0.7 Az=0.6
- Absorption negligible

-He-like OVII triplet: no forbidden line -> high density limit $n_e > 5 \times 10^{12} cm^{-3}$

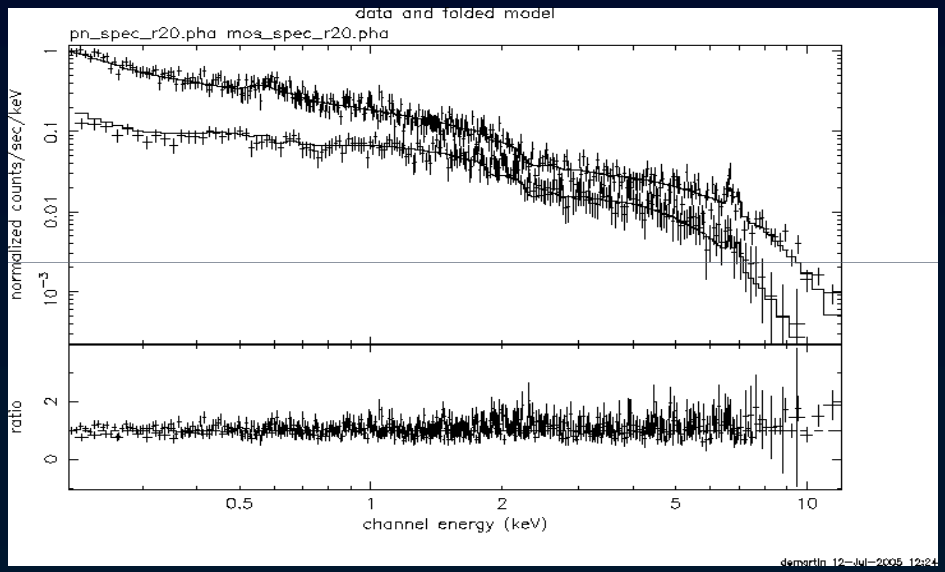
- OVII/OVIII ratio -> kTmin=0.3keV

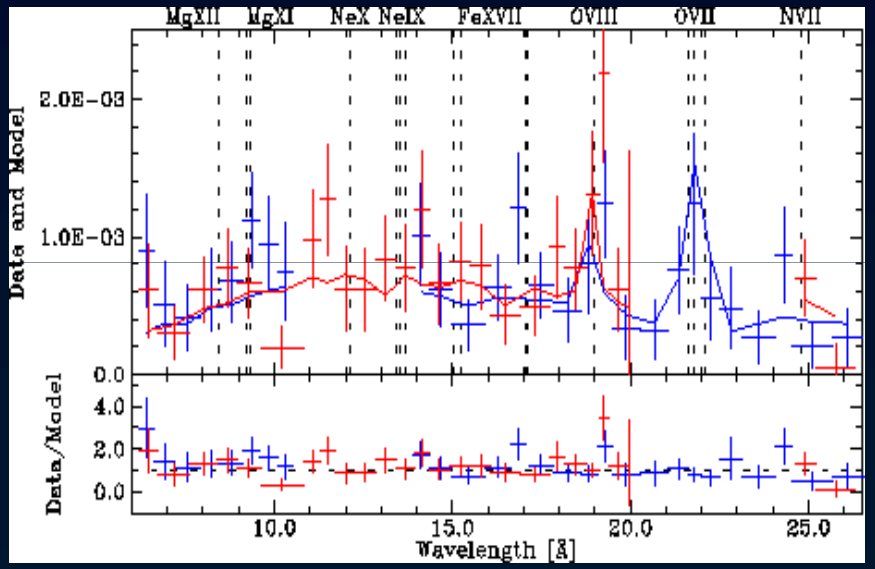
- V(OVIII)~1000km/s-> Vshock≈Vff/4

X-ray Spectral Properties

Complexities at soft energies

UU Col a Soft IP





Two temperatures: kT hot=11 keV
kT cool=0.18 keV Az=0.4

Black-Body: kTbb=50eV

Partial(51%) Dense Absorber: $1.0 \times 10^{23} cm^{-2}$

Two Temp. Plasma also found in other 2 Soft IPs (Evans & Hellier 2004, 2006)

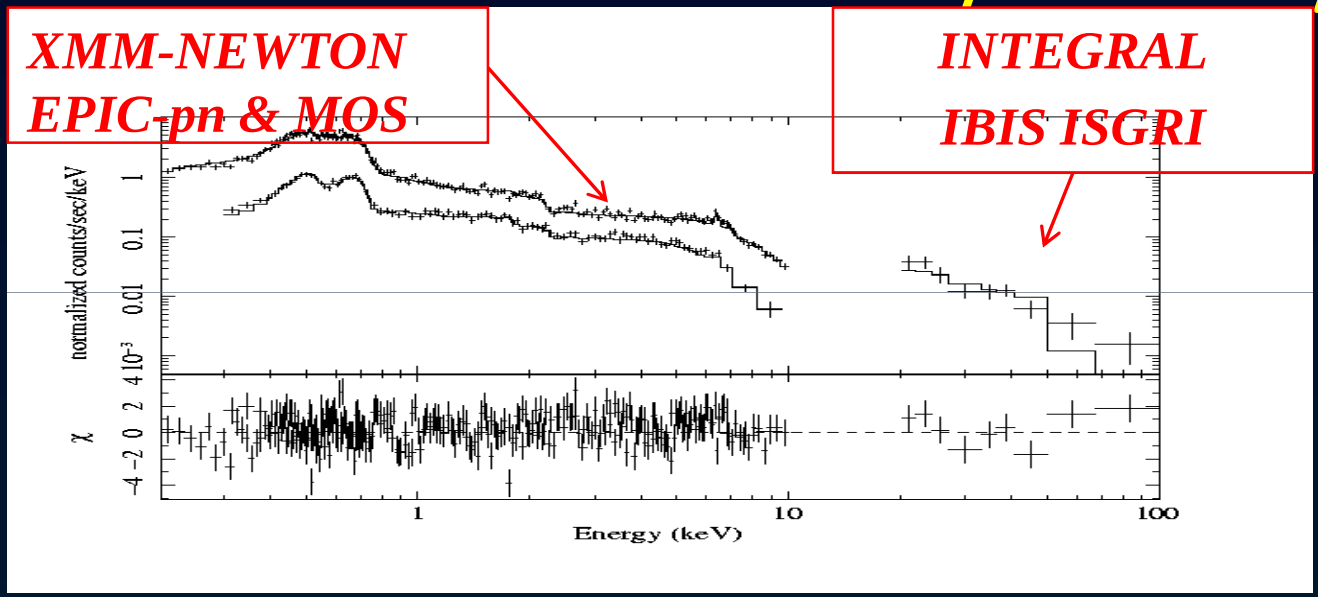
Strong lines OVIII, OVII
OVII/OVIII ratio -> kT=0.2 keV
r/f (OVII) ~28 collision dominated plasma

(de Martino et al. 2006, A&A)

X-ray Spectral Properties

…& …further complexities at soft energies

RXJ1730-0559 a hard IP with a complex Soft spectrum



Two temperatures: kT hot = 55keV
kT cool=0.17 keV Az=0.4
Black-Body: kTbb=90eV
Total Absorber: $3.6 \times 10^{21} cm^{-2}$
Partial(56%) Dense Absorber: $1.4 \times 10^{23} cm^{-2}$
OVII Absorption edge@ 0.74keV τ~1.8
Reflection: 6.4keV Fe line: EW=110eV
(de Martino et al. 2008,A&A)

3rd IP with absorption edge!
(V709 Cas - de Martino et al. 2001;
V1223 Sgr – Mukai et al. 2001)

↓

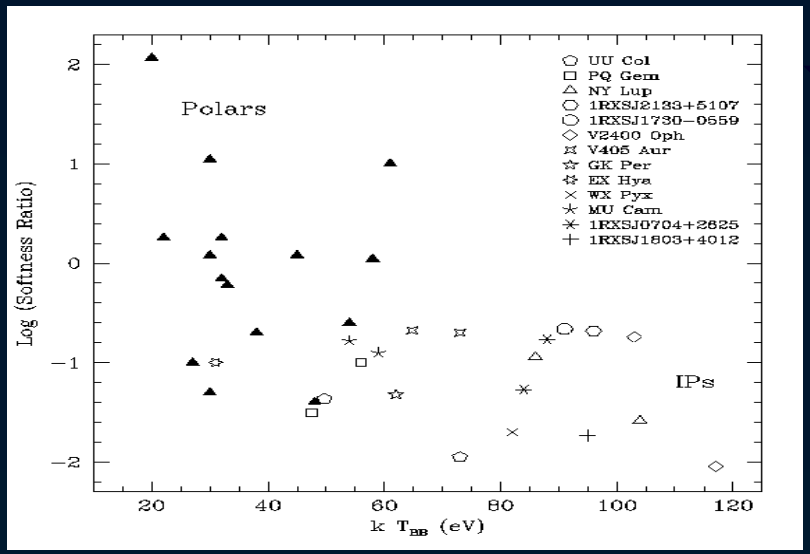
Warm absorber in IPs

SOFT IPs: An emerging class

- **ROSAT:** 4 IPs with soft BB similar to Polars (30-60eV)
- **XMM-Newton:** Current roster of 13 IPs (42% of class)

Characteristics:

- Heavily absorbed Nh ~ $10^{23}cm^{-2}$
- BB temperatures over a wider range (30-100eV)
- Soft-to-Hard Luminosity ratio lower than Polars
- WD spots smaller for hotter BBs ($f<10^{-5}$-10^{-6})



Polars: Ramsay et al. 04
IPs: Haberl et al. 02,
de Martino et al. 06,08
Evans & Hellier 07
Staude et al. 08
Anzolin et al. 08

SOFT IPs: An emerging class

Reprocessing at WD poles

- Bremsstrahlung irradiates small WD spot
- Cyclotron radiation beaming on wide area
- BB Temperature is average over spot area

(Konig et al. 2006)

- Hotter BBs for lowest field IPs
- Cooler BBs in higher field IPs
- Polarization searches to confirm the hypothesis

Why asynchronous systems are hard X-ray sources?

Radiative losses by cyclotron & bremsstrahlung forB>1MG

$Frad \approx \rho^a Te^b$

One-fluid plasma in low B and high flow rates

(Wu et al. 1994; Fisher & Beuermann 2001; Beuermann 2003)

If asynchronism is a signature of low B systems

- Bremsstrahlung is primary & Cyclotron second cooling
- Second cooling process decreases the shock height and lowers the average post-shock Temperature

Conclusions

✓ *Identification of new MCVs essential to understand :*

- *Evolution of MCVs & incidence of magnetism in WDs*
- *Role of MCVs in Galactic Populations of X-ray sources*

✓ *Fundamental role of XMM-Newton in:*

- *Identification of new faint candidates*
- *Study of temporal and spectral properties*

✓ *Increasing similarities of IPs with Polars:*

- *One or Two-poles active & secondary pole is soft*
- *X-ray soft component in most IPs but with differences*
- *X-ray spectroscopy still for a few (XEUS)*

✓ *Hard X-ray emission to be characterized:*

Role of Suzaku, Swift, INTEGRAL & in future: SIMBOLX