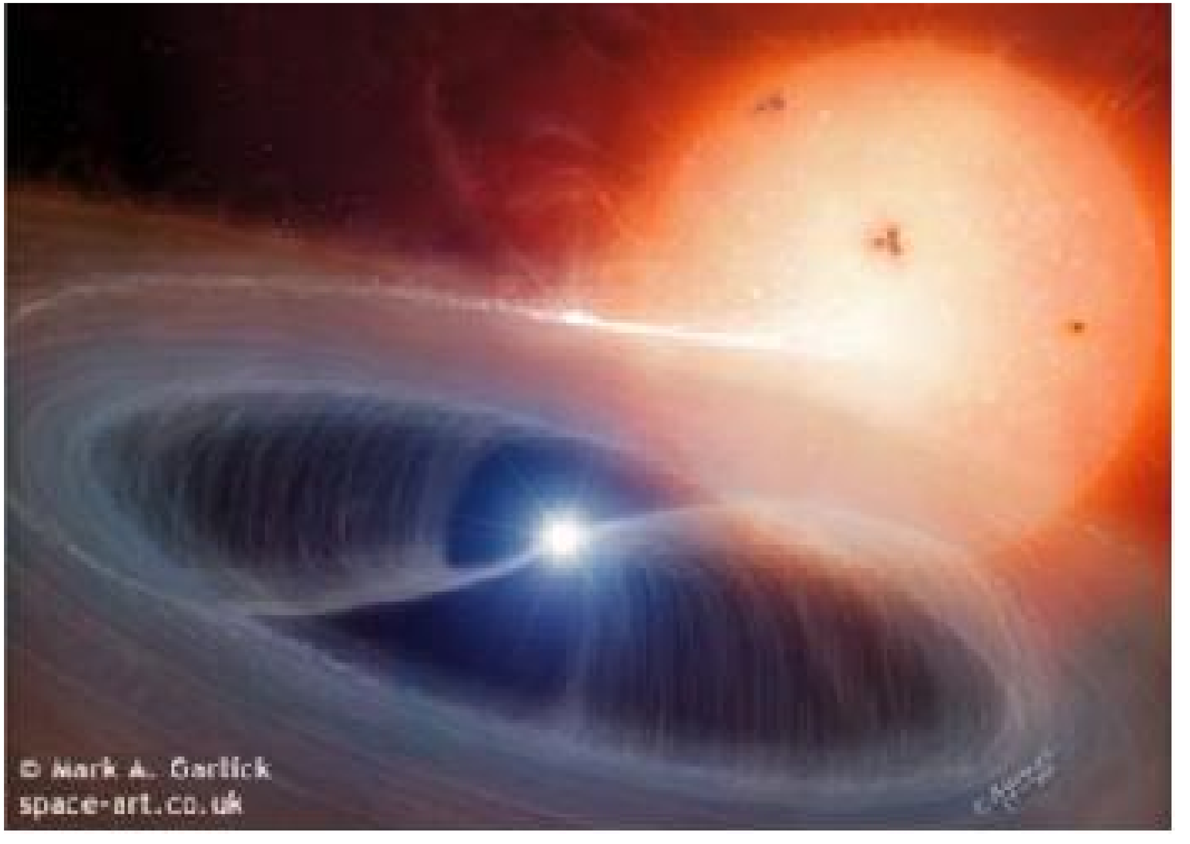
INTEGRAL/Swift observations of Cataclysmic Variables



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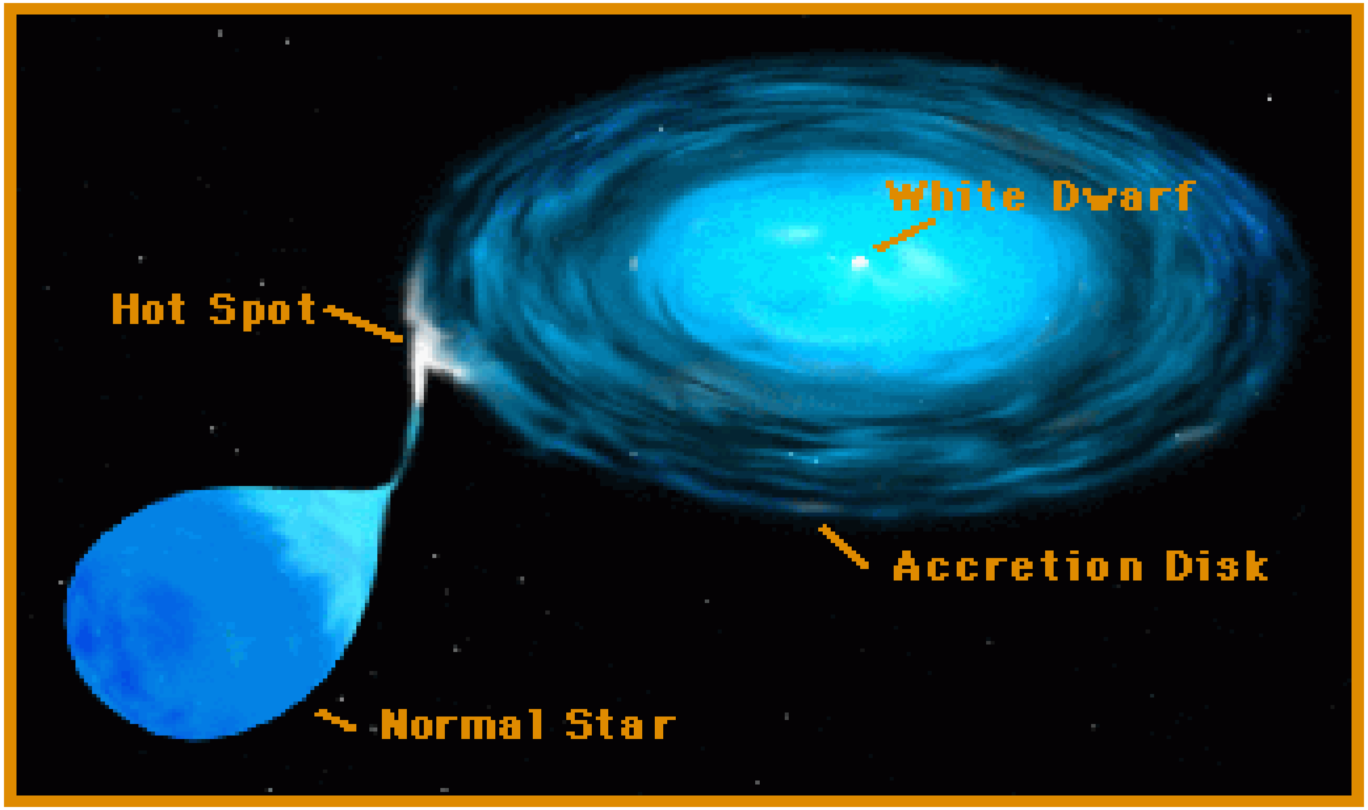
on behalf of the IBIS Survey Team

Cataclysmic Variables

CVs are close binary systems (period < day) containing a white dwarf (WD) which is accreting material from a late type star (i.e. red dwarf)

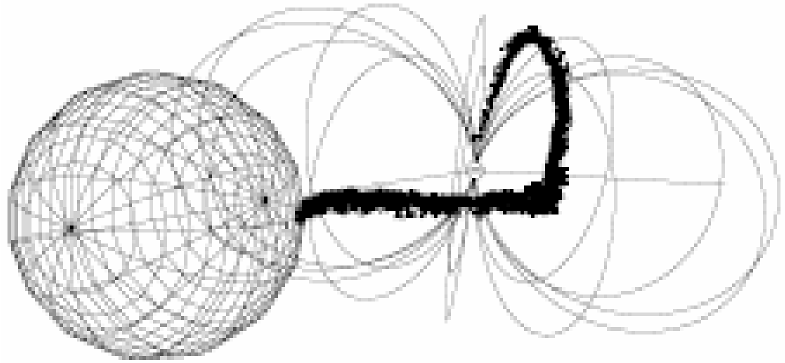
If the white dwarf is non-magnetic, the accreting material flows towards the WD through an accretion disc



If the WD has a magnetic field → Magnetic CVs (mCVs)

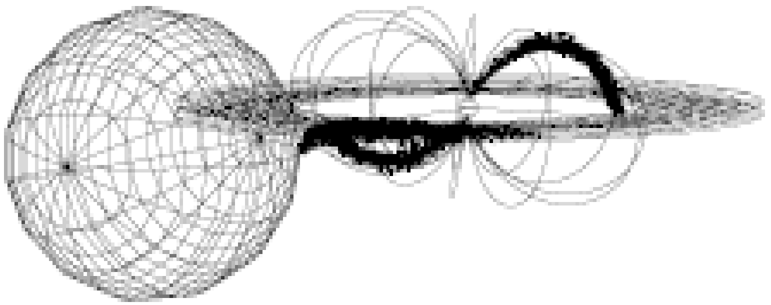
Magnetic CVs

- **Polar (AM Her star):**



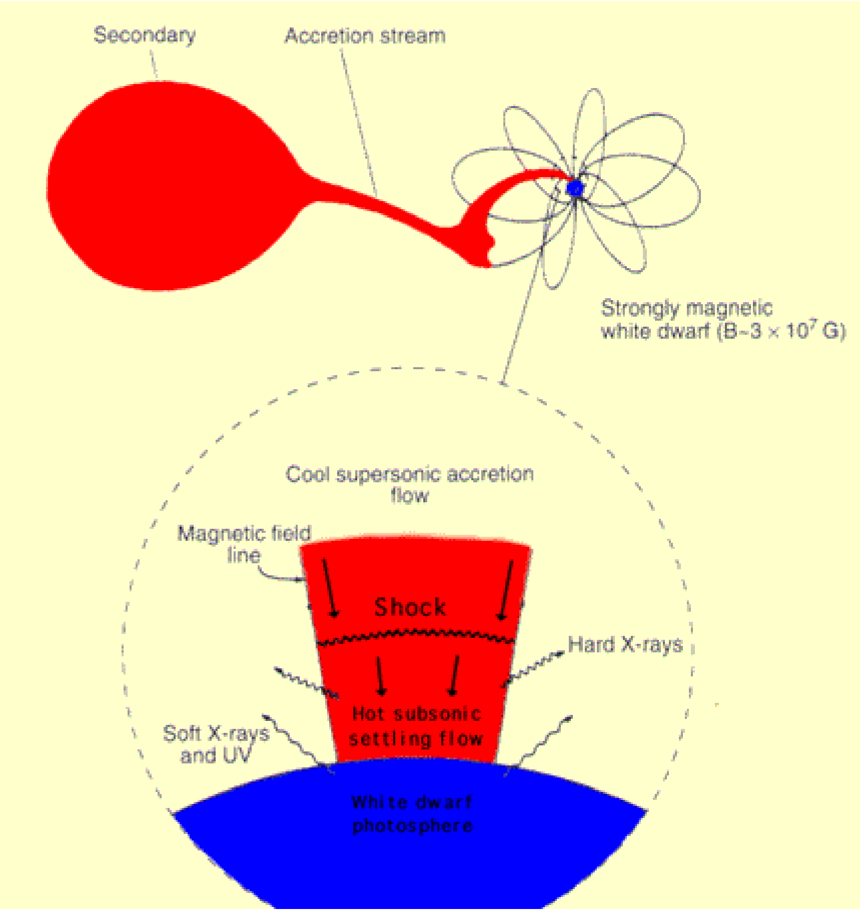
  - **highly magnetized WD ($B \geq 10^7$ G)**
  - **$P_{WD} = P_{orb}$**
  - **no accretion disc: the accreting material, channeled by the magnetic field along its lines, falls on the magnetic poles of the WD**

- **Intermediate polar (IP) (DQ Her star):**



  - **weaker magnetic field ($B \sim 10^6 - 10^7$ G)**
  - **$P_{WD} >> P_{orb}$**
  - **the accretion disc is truncated in the inner region (near the magnetosphere), resulting in an accretion curtain; thus, the accreting material follows the field lines down to the WD surface (as for polars)**
  - **part of the material can flow directly towards the WD without passing through the disc (disc-overflow)**

X-ray emission of magnetic CVs



- **Hard X-ray emission: originating from the post-shock region above the WD magnetic poles → brems with kT ~5-30 keV**

  - highly absorbed by cold material ($\sim 10^{23}$ cm^{-2}) within the accretion flow

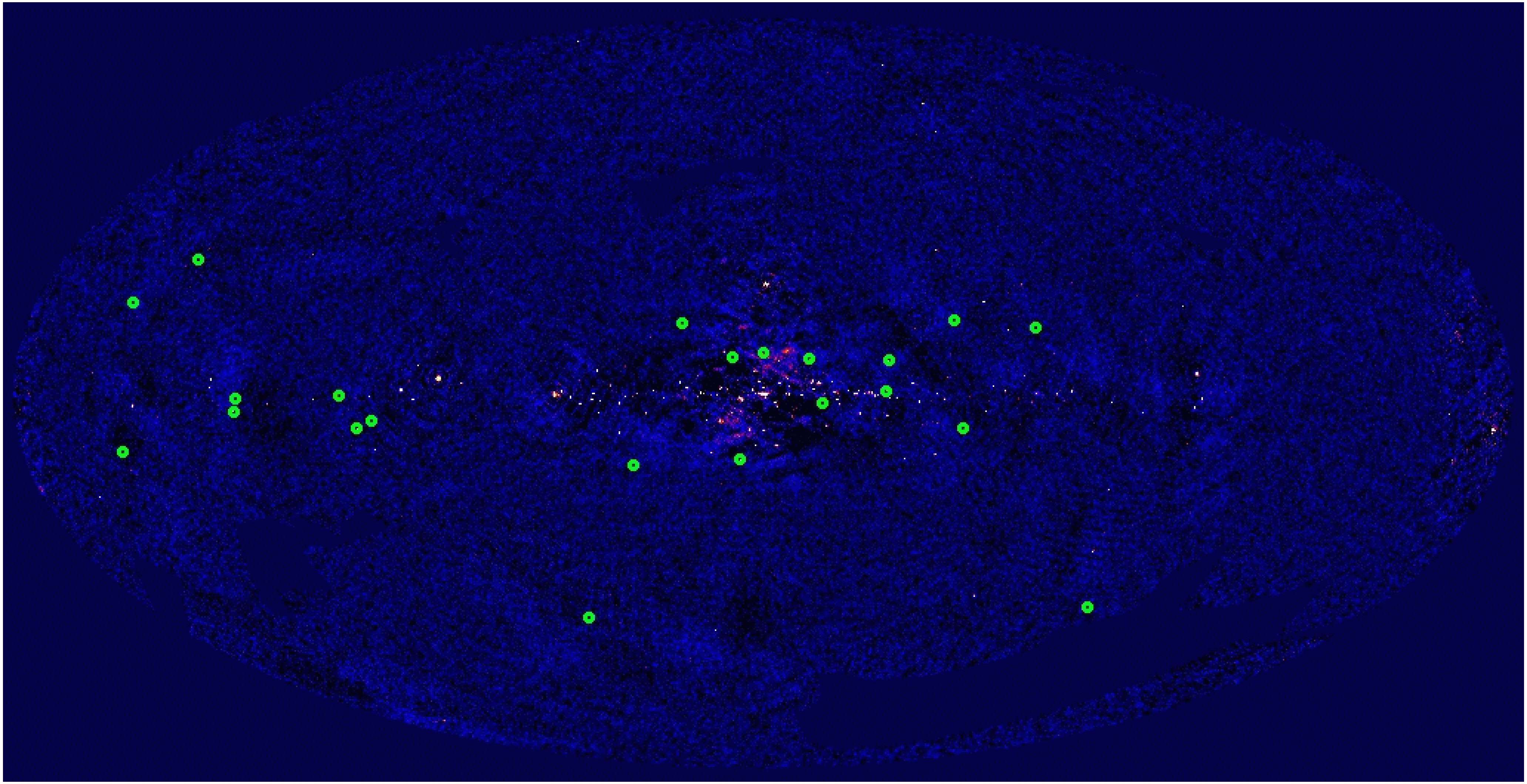
  - reflected by the WD atmosphere

- **Soft X-ray emission: due to the reprocessing in the WD atmosphere of the hard X-ray emission → bbody with kT of few tens of eV (up to ~100 eV)**

- **Fe Kα line: originating by the fluorescence from the surface of the WD and/or the pre-shock accretion flow**

INTEGRAL observations of CVs

(From the 3th IBIS Survey, Bird et al. 2007)

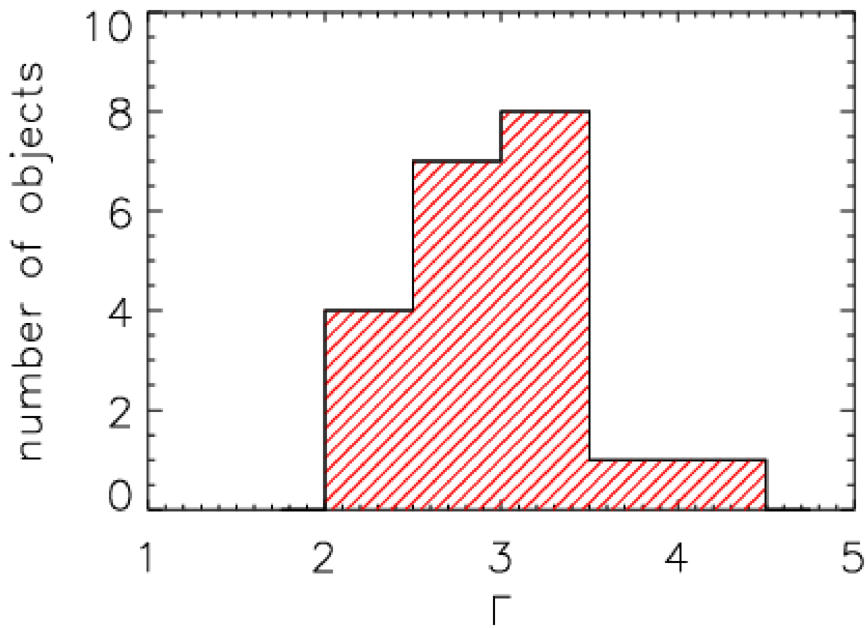


The INTEGRAL sample

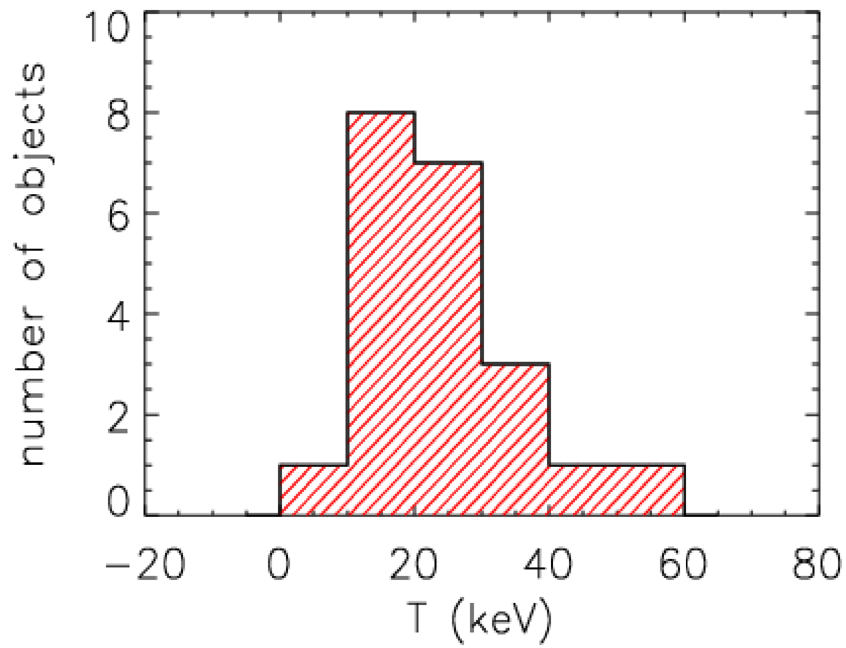
Source	RA	Dec	F(20-100) (10^{-11} erg cm^{-2} s^{-1})	Class
IGR J00234+6141	5.726	+61.706	0.6	IP
V709 Cas	7.204	+59.306	5.0	IP
GK Per	52.778	+43.934	2.5	IP
BY Cam	85.737	+60.850	3.2	IP
IGR J06253+7334	96.340	+73.602	0.7	IP
XSS J12270-4859	187.007	-48.893	2.5	IP
V834 Cen	212.249	-45.273	0.6	P
IGR J14536-5522	223.435	-55.374	1.4	P
IGR J15094-6649	227.351	-66.844	1.7	IP
IGR J15479-4529	237.050	-45.478	6.1	IP
IGR J16167-4957	244.140	-49.974	2.3	IP
IGR J16500-3307	252.491	-33.064	1.5	IP ?
V2400 Oph	258.172	-24.280	3.3	IP
IGR J17195-4100	259.906	-41.014	3.5	IP
IGR J17303-0601	262.596	-5.988	4.5	IP
V2487 Oph	262.963	-19.233	1.2	IP ?
V1223 Sgr	283.755	-31.154	7.1	IP
RX J1940.1-1035	295.058	-10.428	3.6	P
V2069 Cyg	320.906	+42.278	1.2	IP
IGR J21335+5105	323.438	+51.121	4.1	IP
SS Cyg	325.691	+43.583	3.7	DN
FO Aqr	334.478	-8.317	1.4	IP

INTEGRAL spectral analysis results

Power law model

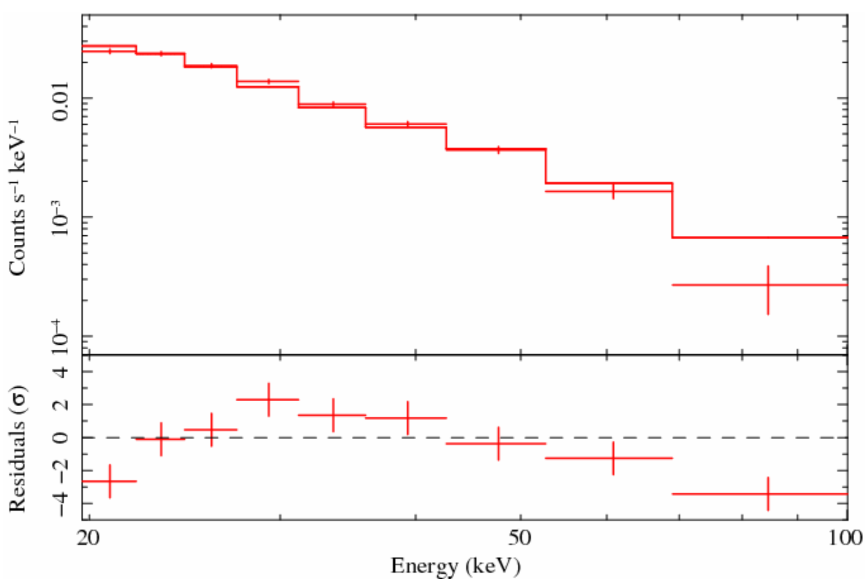


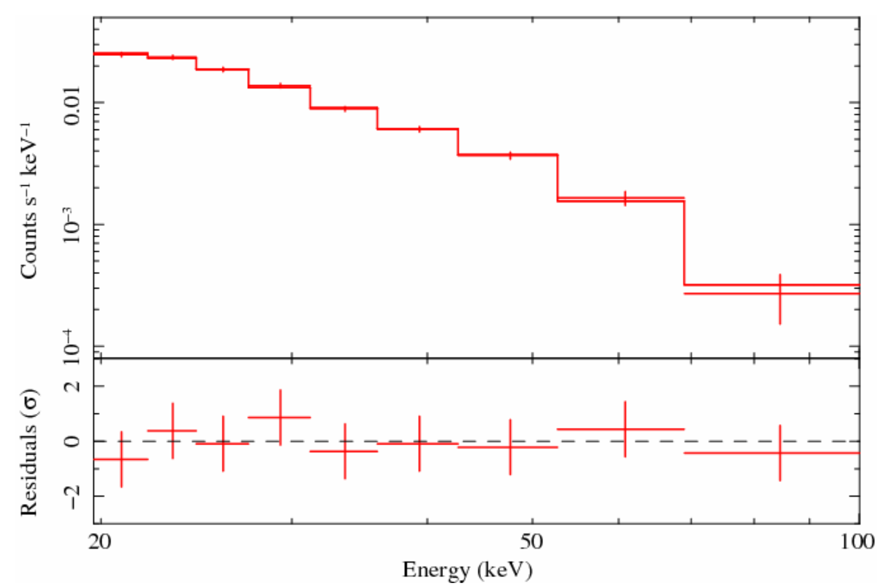
Bremsstrahlung model



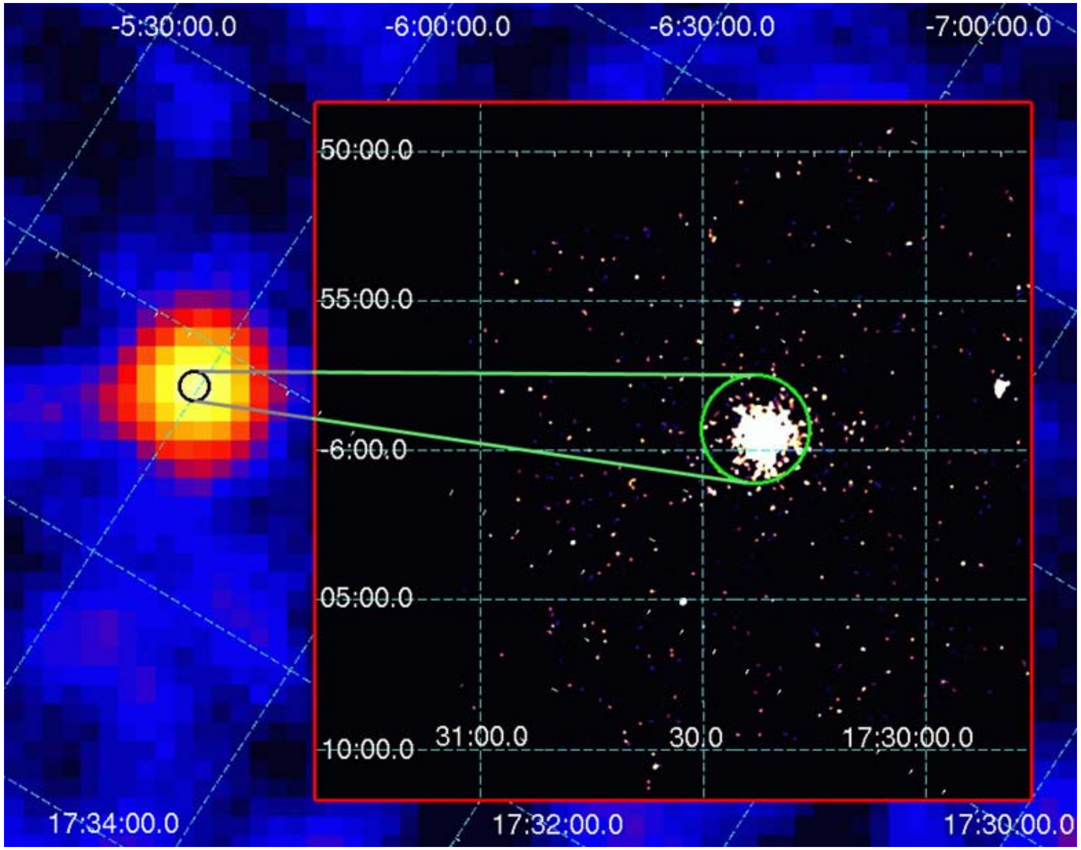
$\langle\Gamma\rangle = (2.97 \pm 0.10)$

$\langle kT\rangle = (21.7 \pm 1.0)$ keV





Swift-XRT/IBIS observations



Why follow-up observations performed with the X-ray telescope (XRT) on board Swift are important:

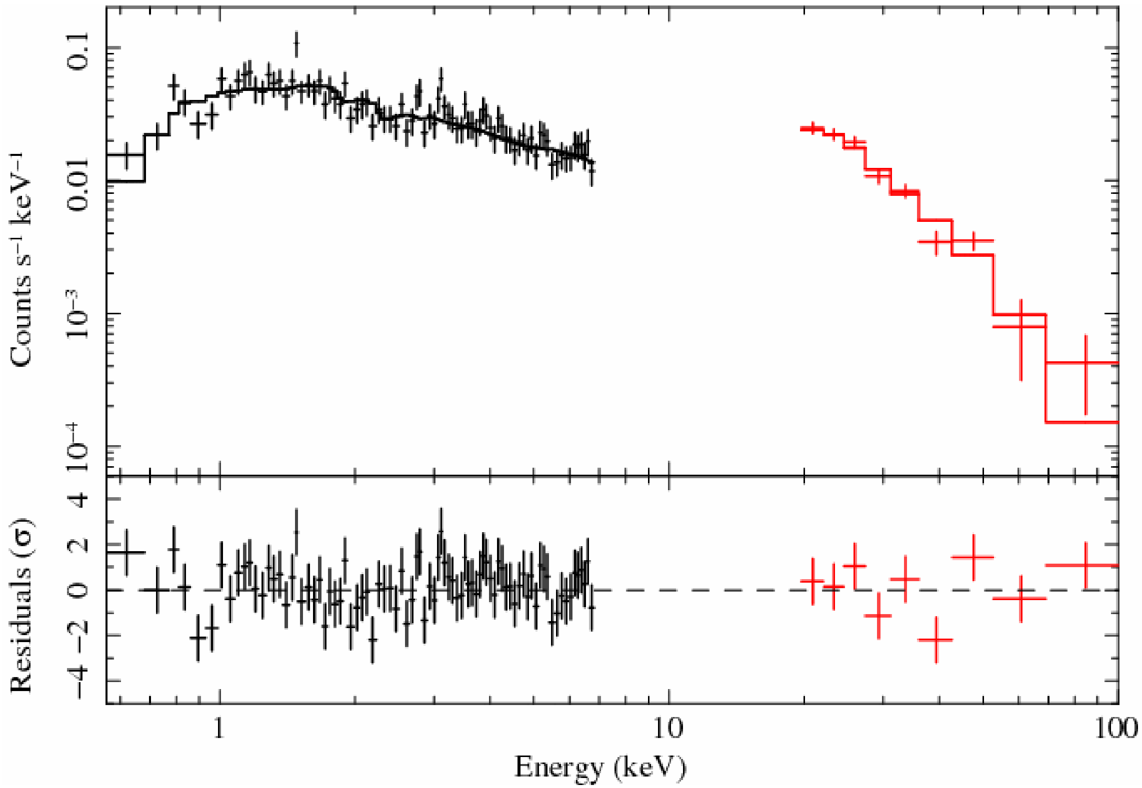
- **thanks to the positional accuracy of XRT (few arcsec) the INTEGRAL position is refined → this is necessary in view of optical follow-up**

- **by combining XRT and IBIS spectra it is possible to analyse the X-ray emission of mCVs over a wide energy band (~0.5-100 keV)**

IGR J16167-4957

3 Swift observations (Sep 2005 – Feb 2007) for a total effective EXPO = 11 ksec

Best-fit model: soft black-body + hard optically thin emission (brems) attenuated by a complex absorber (one totally and one partially covering the source)



$$\chi^2/\nu = 1.08$$

$$N_H = \left(0.96^{+0.26}_{-0.22}\right)\times 10^{22}\,cm^{-2}$$

$$N_{Hpc} = \left(94.0^{+41.5}_{-35.2}\right)\times 10^{22}\,cm^{-2}$$

$$C_f = 0.87^{+0.11}_{-0.34}$$

$$kT_{bb} = 95^{+20}_{-16}\ \textit{eV}$$

$$kT_{brems} = 16.7^{+6.6}_{-4.5}\ \textit{keV}$$

$$F(2-10) = 1.7\times 10^{-11}\ \textit{erg cm}^{-2}\ \textit{s}^{-1}$$

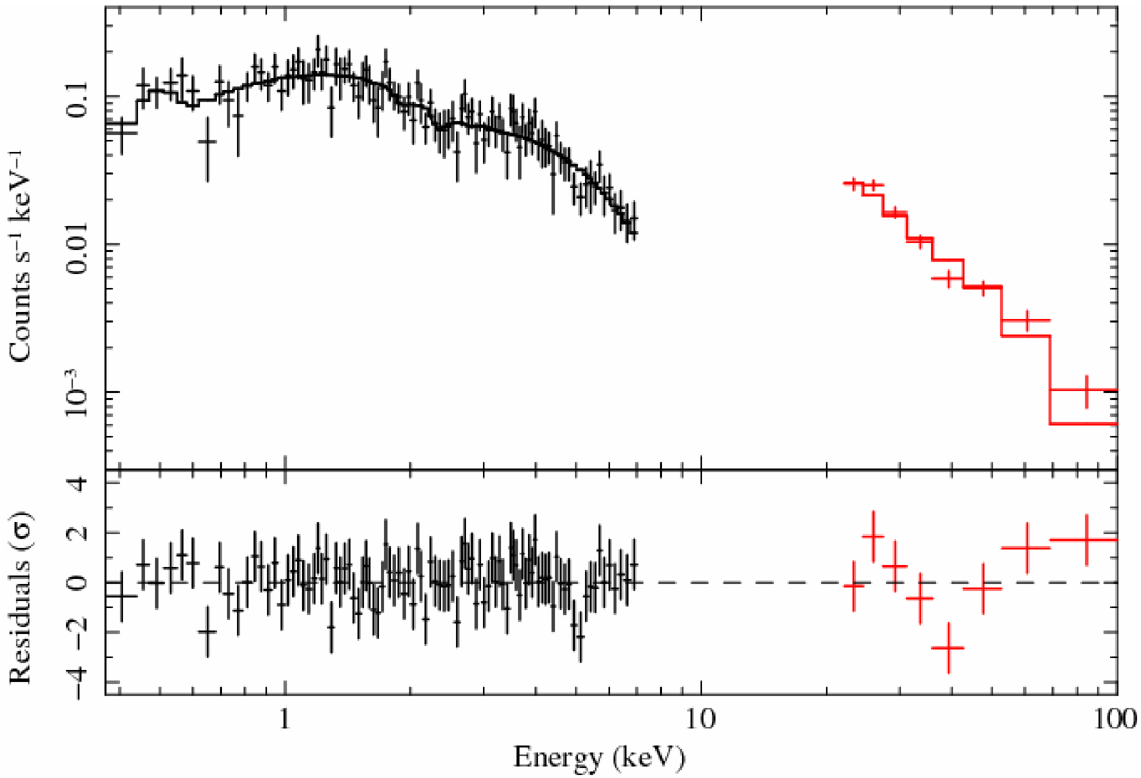
$$F(20-100) = 2.3\times 10^{-11}\ \textit{erg cm}^{-2}\ \textit{s}^{-1}$$

$$Const_{IBIS/XRT} = 0.75^{+1.74}_{-0.36}$$

IGR J17195-4100

3 Swift observations (Oct 2005 – Jun 2007) for a total effective EXPO = 6 ksec

Best-fit model: soft black-body + hard optically thin emission (brems) attenuated by a simple absorber (totally covering the source)



$$\chi^2/\nu = 0.9$$

$$N_H = (0.43^{+0.12}_{-0.11}) \times 10^{22}\, cm^{-2}$$

$$kT_{bb} = 86^{+10}_{-8} \ \ eV$$

$$kT_{brems} = 28.4^{+5.9}_{-4.6} \ \ keV$$

$$F(2-10) = 2.4 \times 10^{-11} \ \ erg\ cm^{-2}\ s^{-1}$$

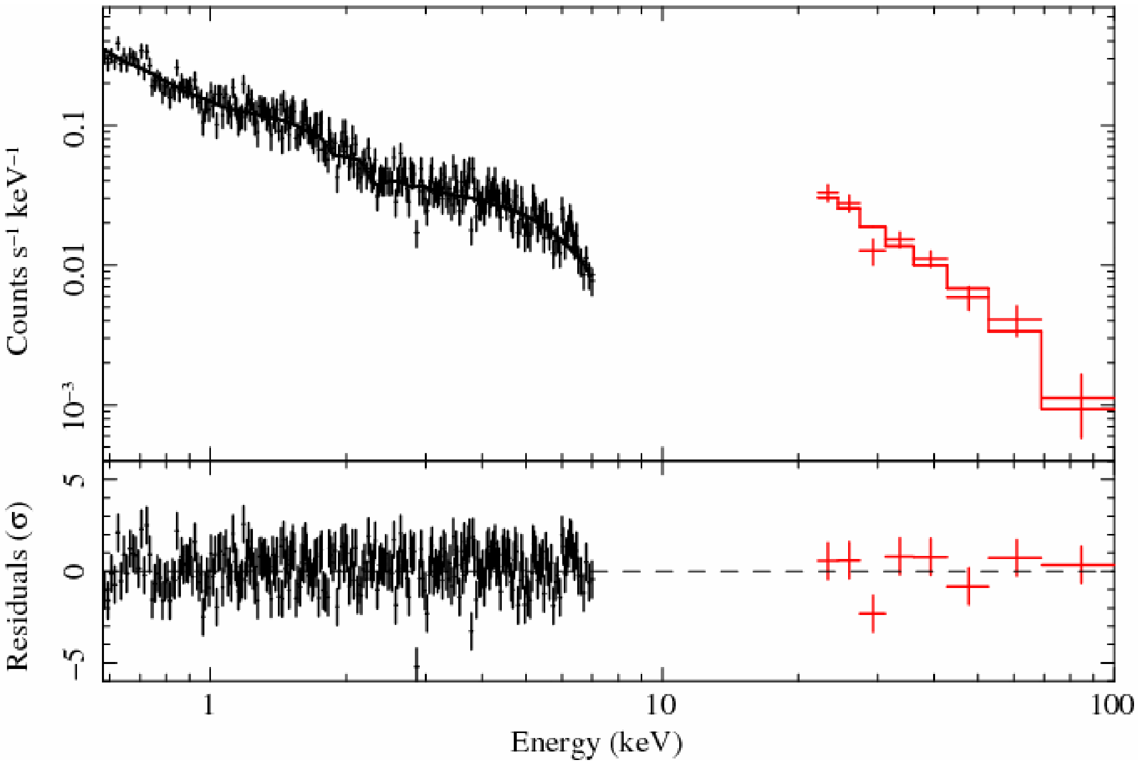
$$F(20-100) = 3.5 \times 10^{-11} \ \ erg\ cm^{-2}\ s^{-1}$$

$$Const_{IBIS/XRT} = 1.40^{+0.38}_{-0.29}$$

IGR J17303-0601

5 Swift observations (Feb 2007) for a total effective EXPO = 25 ksec

Best-fit model: soft black-body + hard optically thin emission (brems) attenuated by a complex absorber (one totally and one partially covering the source)



$$\chi^2/\nu = 1.2$$

$$N_H = \left(0.064^{+0.004}_{-0.005}\right)\times 10^{22}\,cm^{-2}$$

$$N_{Hpc} = \left(29.4^{+15.7}_{-10.4}\right)\times 10^{22}\,cm^{-2}$$

$$C_f = 0.47^{+0.04}_{-0.10}$$

$$kT_{bb} = 92^{+7}_{-5}\ \ eV$$

$$kT_{brems} = 30.7^{+7.3}_{-5.5}\ \ keV$$

$$F(2-10) = 1.8\times 10^{-11}\ \ erg\ cm^{-2}\ s^{-1}$$

$$F(20-100) = 4.4\times 10^{-11}\ \ erg\ cm^{-2}\ s^{-1}$$

$$Const_{IBIS/XRT} = 1.53^{+0.62}_{-0.44}$$

The 6.4 keV iron line is significant at ~95% confidence level

$$EW = 83^{+60}_{-65}\ \ eV$$

Conclusions

- INTEGRAL has detected several mCVs (mostly IPs)

- IBIS spectra are better modelled with a brems with <kT> ~22 keV (agreement with Swift/BAT data, Ajello et al. 2007)

- By combining XRT and IBIS data it is possible to perform a broad band spectral analysis that is crucial in determining the different components which characterize the X-ray emission

- The results of the spectral analysis of 3 new IPs are consistent with those reported in literature for known IPs (i.e. RX J0558, RE 0751 and RX J1712, De Martino et al. 2004; UU Columbae, De Martino et al. 2006; V 709 Cas, De Martino et al. 2001)

Future work

- complete the XRT/IBIS analysis of the remaining 7 sources followed-up by Swift so far

V709 Cas
GK Per
XSS J12270-4859
IGR J14356-5522
IGR J15479-4529
IGR J16500-3307
FO Aqr

- timing analysis

- search for periodicities in the light curves (i.e. P_{WD}, P_{orb} and $P_{syn} = P_{WD} - P_{orb}$)

- investigate the spectral behaviour of pulsations (i.e. analyse the spectra at maximum and minimum of the pulse cycle) to get information on the accretion and on the contribution of the WD poles to the X-ray emission