Astrophysical aspects of Lobster Eye X-ray telescopes

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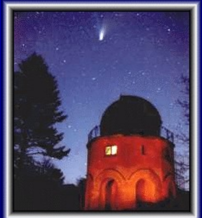


Talk: AXRO, Dec 5–8, 2011

General prospects of monitoring (…and implications for Lobster) (I)

Monitoring enables to:

- **identify the type of object – even sampled (e.g. with data binning) monitoring is meaningful**
- **place the events (e.g. outbursts) in the context of the long-term activity of a given object (system)**
- **establish a representative ensemble of events (e.g. outbursts) in**
  - **(a) a given object (system),**
  - **(b) in a type of objects (systems)**

Investigation of these items is important for our understanding of the physical processes involved.

General prospects of monitoring (…and implications for Lobster) (II)

- Monitoring of a large part of the sky is needed – wide-field (tens of square degrees FOV) monitors are desirable.

Reasons:

- most transients (e.g. objects with outbursts) were discovered only in outburst, not in quiescence before this event – a lot of 'sleeping' transients thus exist.

- monitoring is also inevitable for search for rare, unexpected and unique phenomena

The most promising types of objects located in our Galaxy to be detected by Lobster monitor:

Accretion of matter from a donor onto the compact object:

- **High-mass X-ray binaries (HMXBs)**
- **Low-mass X-ray binaries (LMXBs)**
- **Cataclysmic variables**

Spectral components in the X-ray region proposed for monitoring with Lobster (so it is possible to study them):

- **blackbody component (inner disk region in X-ray binaries, surface of the compact object)**
- **inverse Compton scattering (Comptonizing cloud in X-ray binaries)**
- **bremsstrahlung emission (accretion regions (e.g.**

Mechanisms for the long-term activity in X-ray binaries and cataclysmic variables (CVs)

- **Changes of the mass transfer rate d*m*/d*t* from the donor onto the compact object** (timescale: days, weeks, months, years)

- **Thermal-viscous instability of the accretion disk** (timescale: days, weeks, months)

- **Hydrogen burning on the white dwarf (in CVs) :**

Episodic:

– **classical nova explosion** (timescale: weeks, months)

– **recurrent novae** (timescale: weeks, months)

Steady-state:

– **supersoft X-ray sources** (timescale: days, weeks, months)

High-mass X-ray binaries (HMXBs)

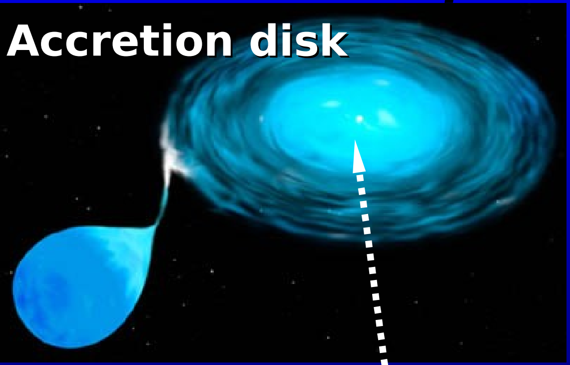
Persistent X-ray sources
Transient X-ray sources (e.g. brightenings caused by the periastron passages)

Sources of X-ray emission detectable by the monitors:

- **Disk (if exists) embedding the compact accreting object – thermal emission**
- **Close vicinity of the compact object: inverse Compton scattering, bremsstrahlung (X-rays)**
- **Colliding winds: inverse Compton scattering, bremsstrahlung (X-rays)**

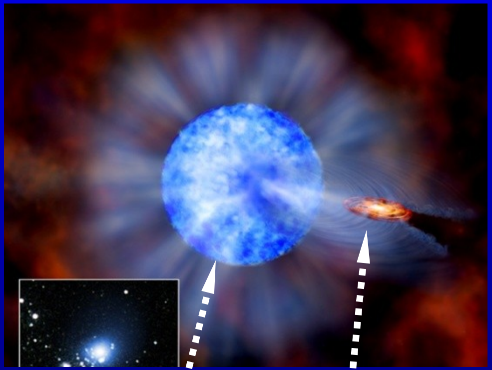
Accretion modes:

Roche lobe overflow



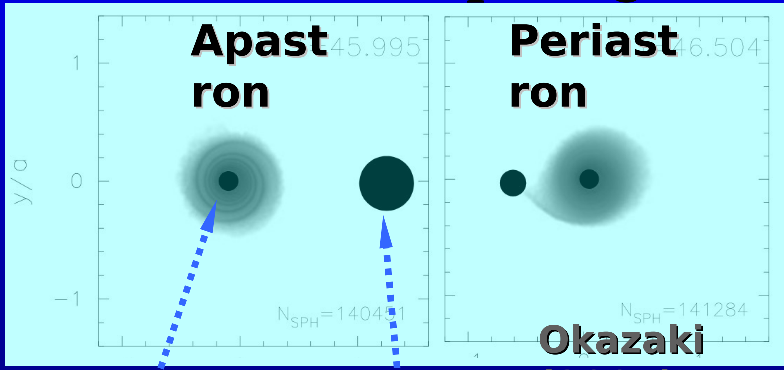
Donor, filling its lobe
Compact object (NS, BH, WD)

Wind accretion



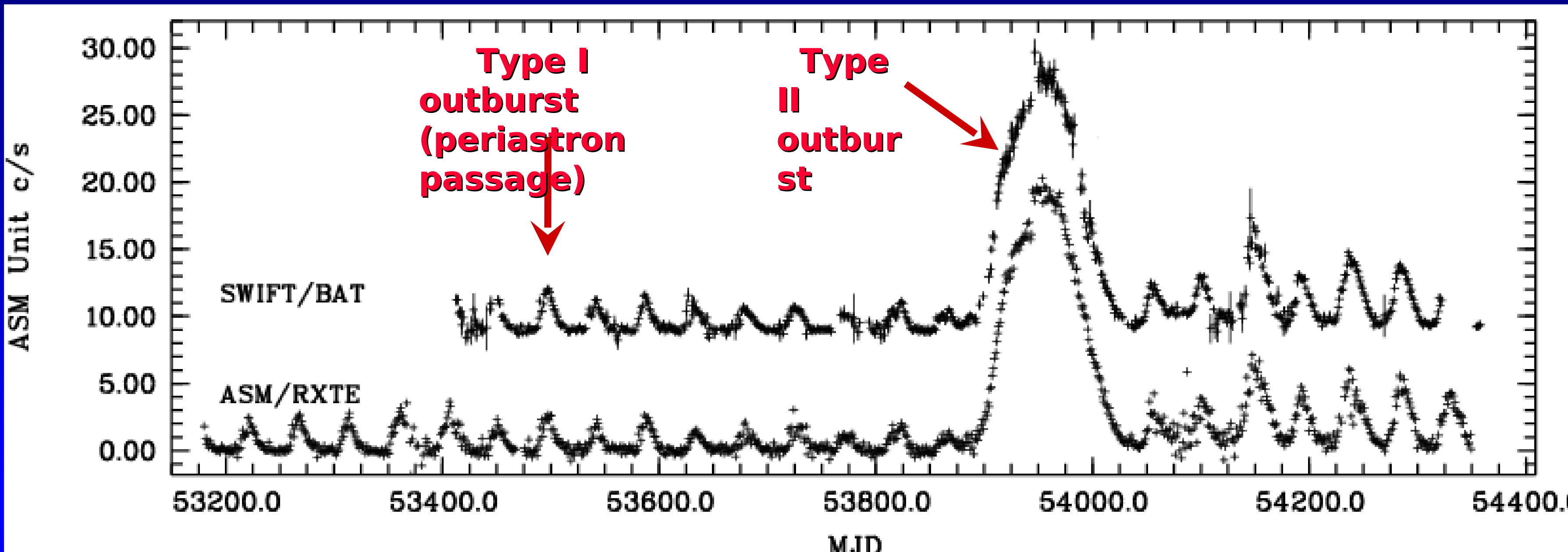
Donor, underfilling its lobe
Compact object (NS, BH, WD)

Periastron passage



Donor, underfilling its lobe
Lobe size of the compact object

V2246 Cyg / EXO 2030+375 (HMXB)

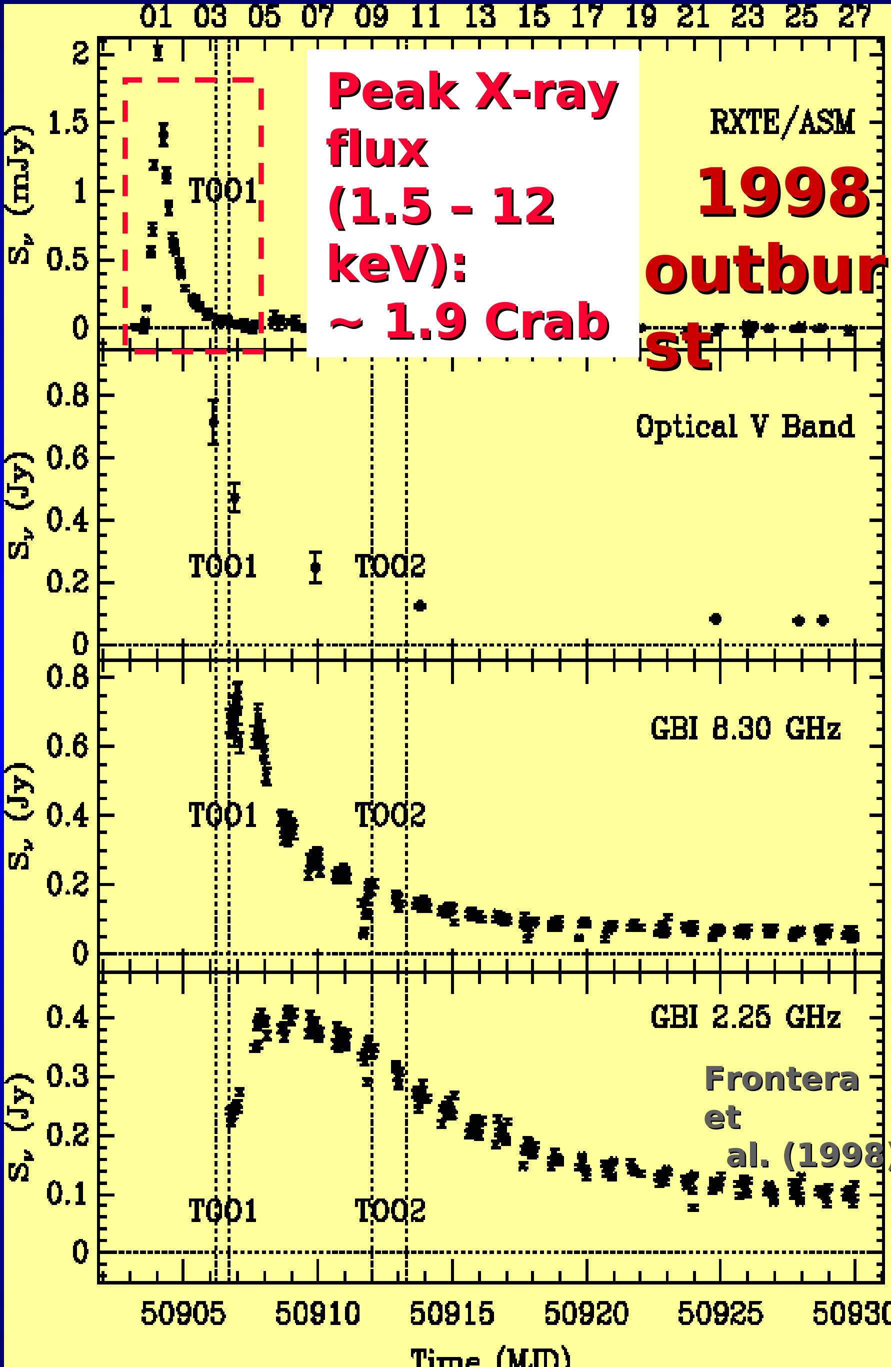


transient accreting X-ray pulsar
NS + B0Ve
Orbital period: 46.02 days (eccentric orbit)
(e.g. Motch & Janot-Pacheco 1987)

Baykal et al. (2008)

Two types of outburst:

Type I – lower X-ray luminosities ($L_X \sim 10^{36}$ erg s^{-1}), generally repeated in each orbital period cycle



Unexpected very bright outburst from a "boring" object

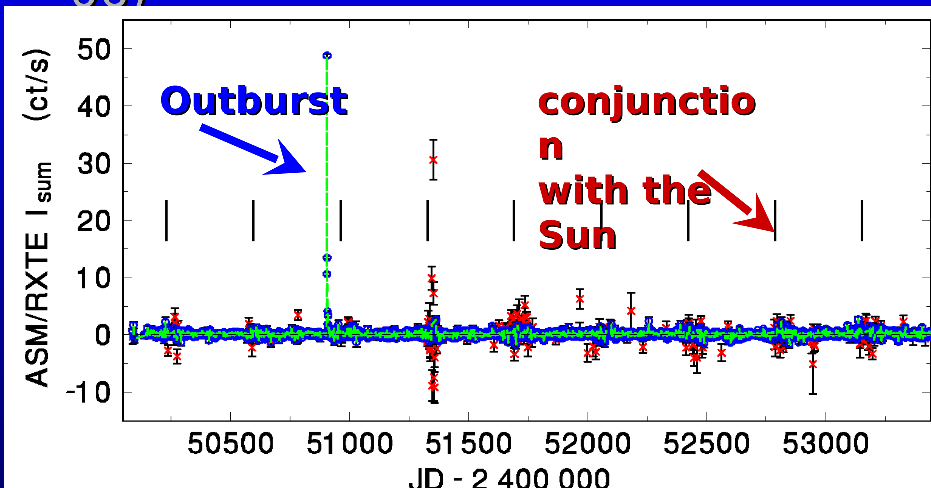
CI Cam / XTE J0421+560 (HMXB)

Remarkable system: **supergiant B[e] + compact object (black hole)** **(e.g. Lamers et al. 1998; Barsukova et al. 2002)**

Orbital period: **19 d** (Barsukova et al. 2005 **(eccentric orbit)?)**

Outburst:

- **thermal instability of a small, wind-fed accretion disk (analogous to outbursts of soft X-ray transients** (Simon et al. 06)



Low-mass X-ray binaries (LMXBs) | Cataclysmic variables (CVs)

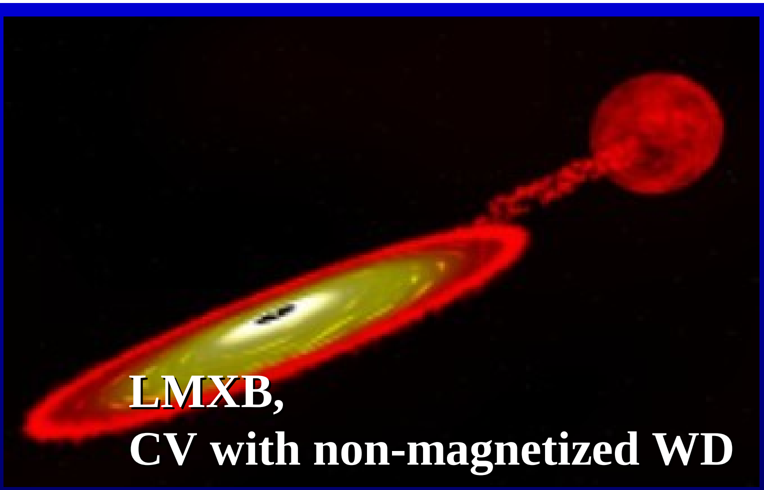
LMXBs: - persistent
- transient: soft X-ray transients (outbursts caused by a thermal-viscous instability of the accretion disk)

CVs: - outbursts of dwarf novae
- episodes of the high and low states

<u>Sources of X-ray emission detectable by the monitors:</u>

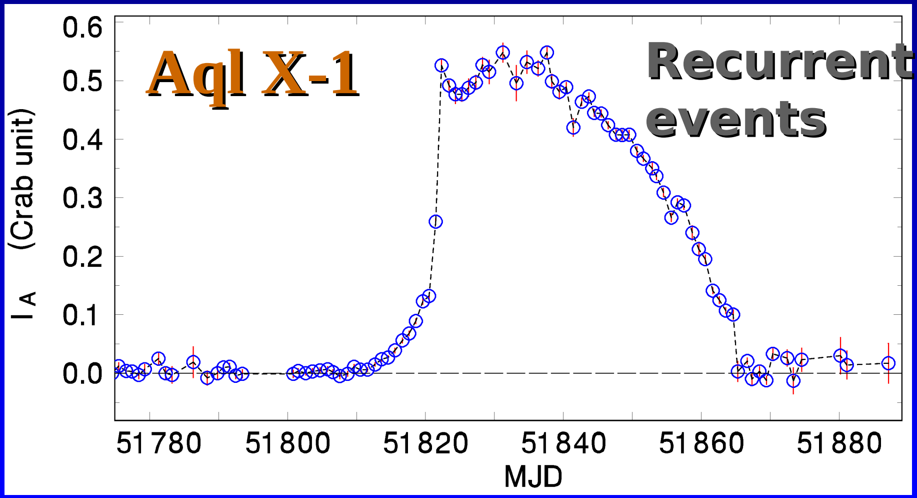
- Inner disk region – thermal radiation (far UV in CVs, soft X-rays in LMXBs)

- Close vicinity of the compact object
  - CVs: bremsstrahlung (X-rays)
  - LMXBs: Comptonizing cloud (inverse Compton scattering – hard X-rays)

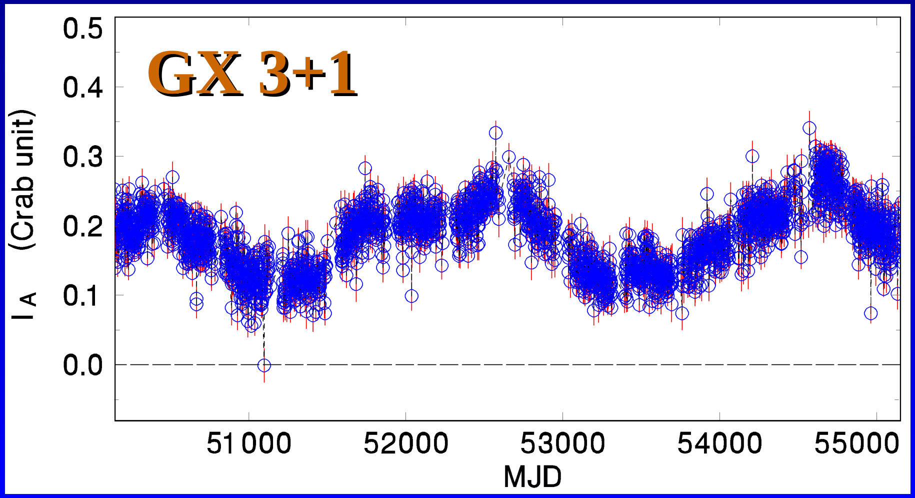


Examples of transient and persistent LMXBs

Outburst of a transient source



Fluctuations of a persistent source



in soft X-rays – ASM/*RXTE* data (one-day means)

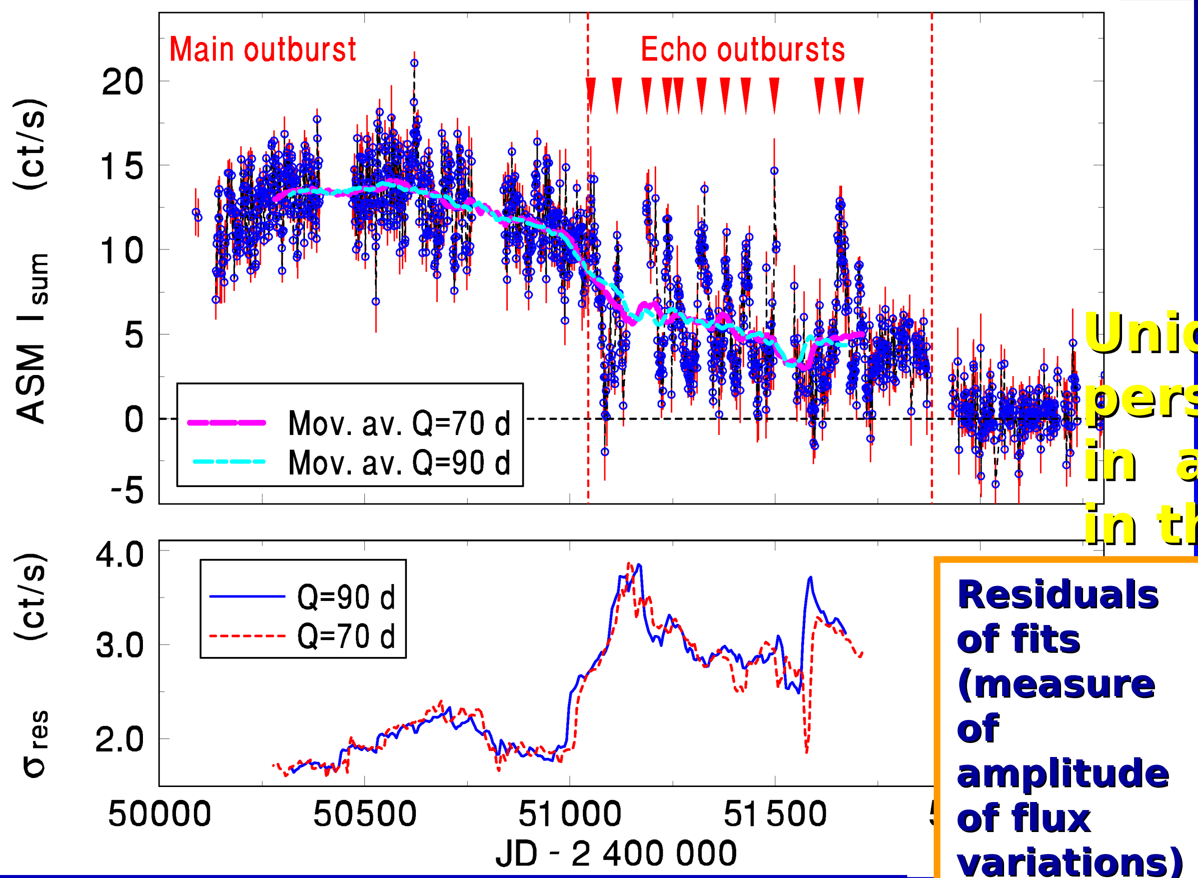
ctivity of the types of source in the 1.5-3 keV band

sen band is similar to the band of the peak sensitivity of the proposed
escope.

es are re-calculated into Crabs - proposed sensitivity of Lobster o
ellite is better than ~0.1 Crab

of these light curves are gradual enough (except the rising branch of
in discernible even after further smoothing and/or binning (to increase

Transition of a LMXB: persistent – transient – quiescent



Quasi-persistent
KS 1731–260

Unique transition betwe persistent and transient ty in a given source observ in the real time

Residuals of fits (measure of amplitude of flux variations)

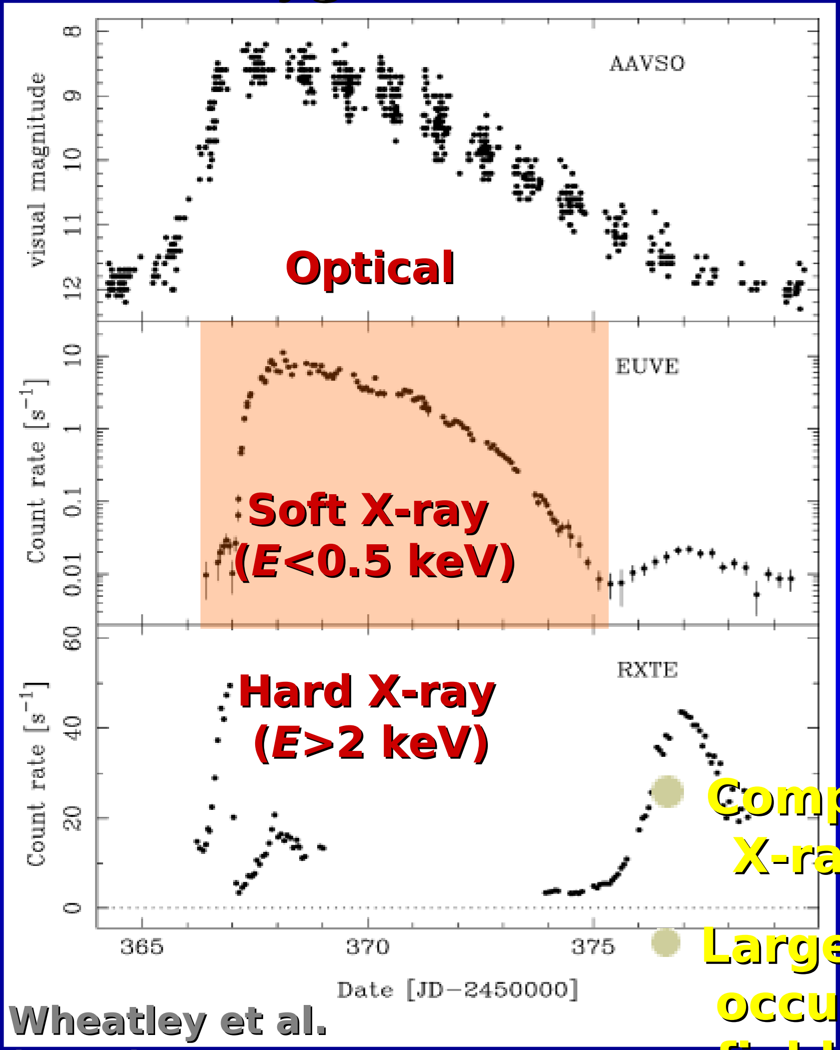
data (1.5-12 keV) (one-day means)

5 ct/s - peak intensities of KS 1731-260 in the high state: 0.23 Crab

of the standard deviation of intensity can reveal the behavior of the s (series of echo outbursts in this case) - approach useful also when t g. echo outbursts) cannot be distinguished in the data

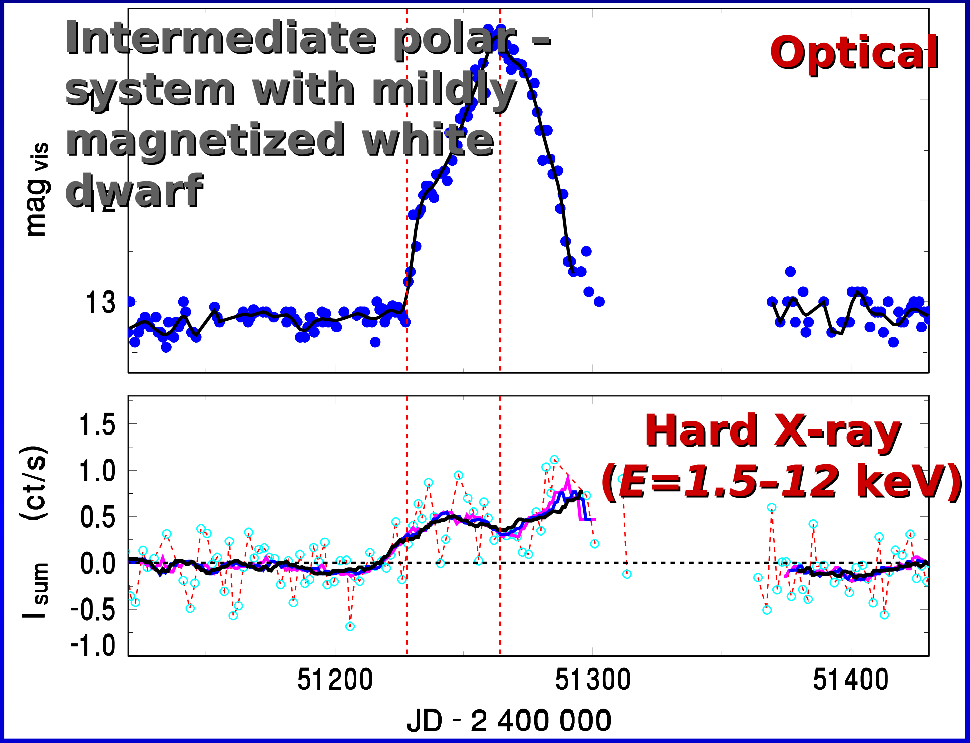
Outbursts of dwarf novae in X-rays

SS Cyg / 3A 2140+433



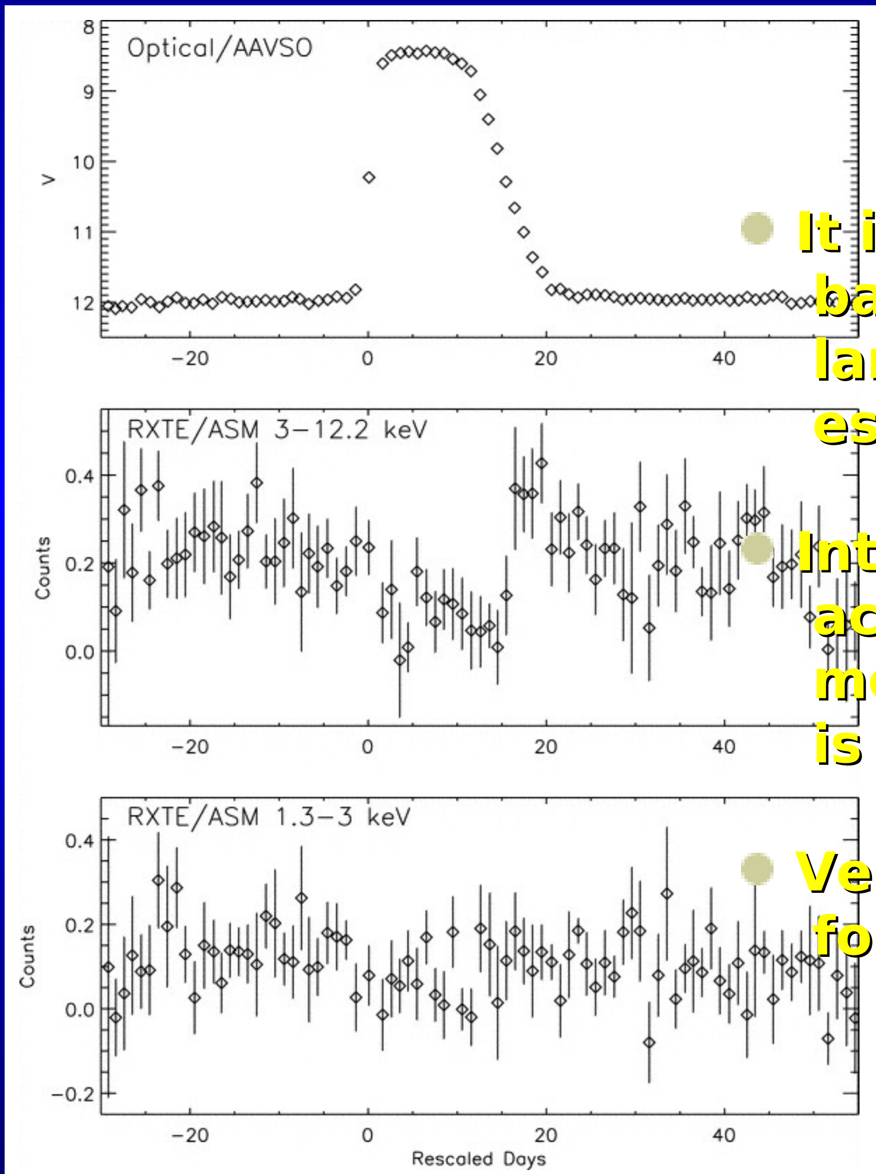
Wheatley et al. (2003)

GK Per / 1A 0327+43



- Complicated relation between the optica X-ray profile of outburst (varies from CV t
- Large structural changes of the emission re occur during outburst (depend on the ma field of the white dwarf)
- Strong brightening often only in very soft X-rays (but it may differ from system

Outbursts of dwarf novae in X-rays – comparison of hard X-ray and optical profiles in outburst



SS Cyg

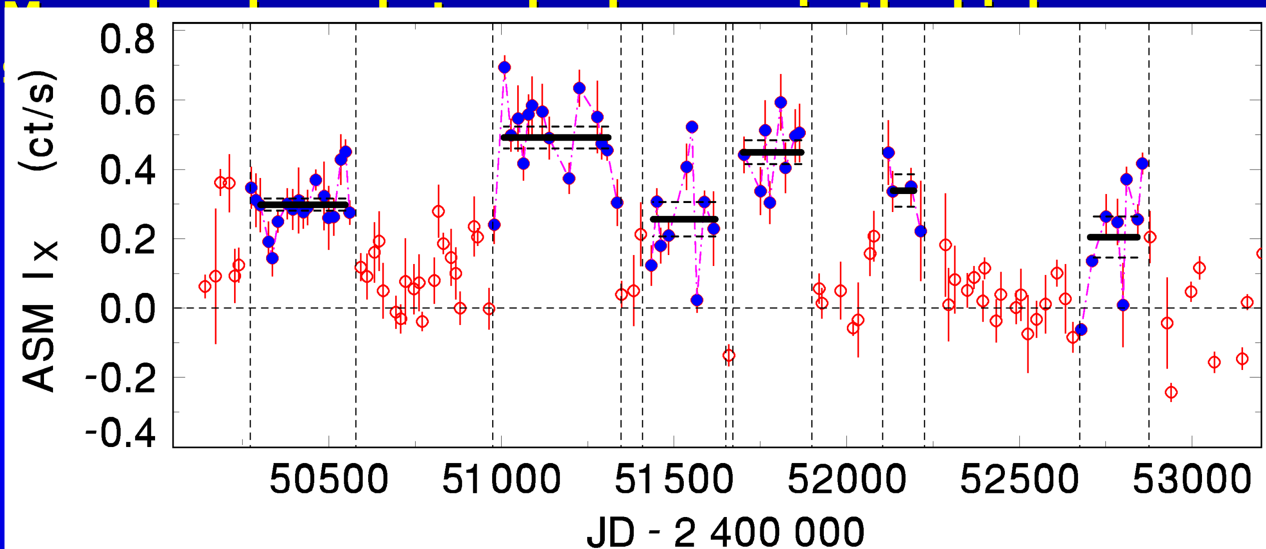
- It is important to chose proper spec band for X-ray monitoring to obse large-amplitude X-ray variations – especially true for cataclysmic varia
- Intense optical outburst may not accompanied by a brightening even medium X-rays: a decrease of the fl is observed in this CV.
- Very soft X-ray band is recommend for monitoring of this type of object

Averaged outburst data

McGowan et al. (2004)

AM Her / 3A 1815+498 (polar)

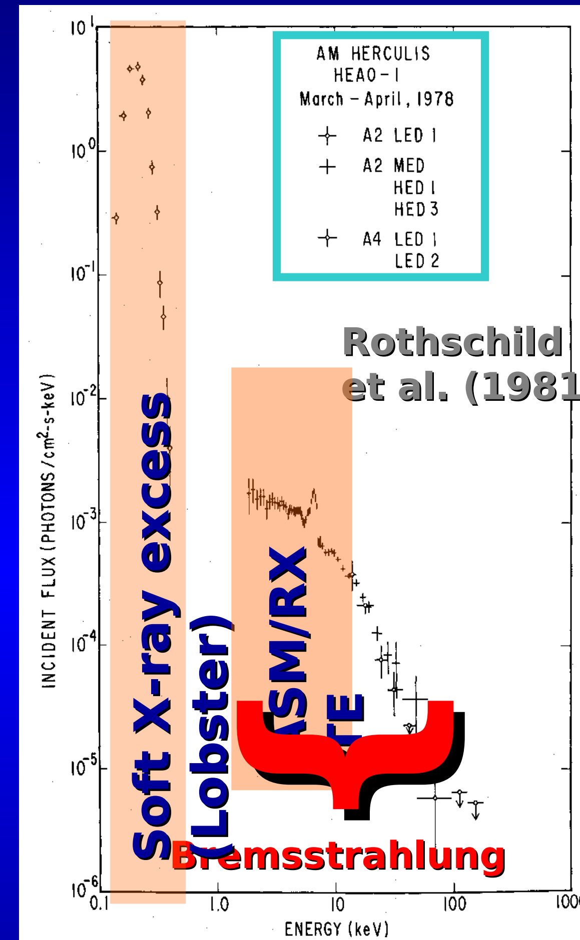
Example of the X-ray light curve of a polar in the individual high-state episodes (15-day means of data).



ASM/RXTE data (1.5 – 12 keV)

Faint X-ray source:

1 Crab =75 ct/s – peak intensities of AM Her in high state: ~ 0.01 Crab



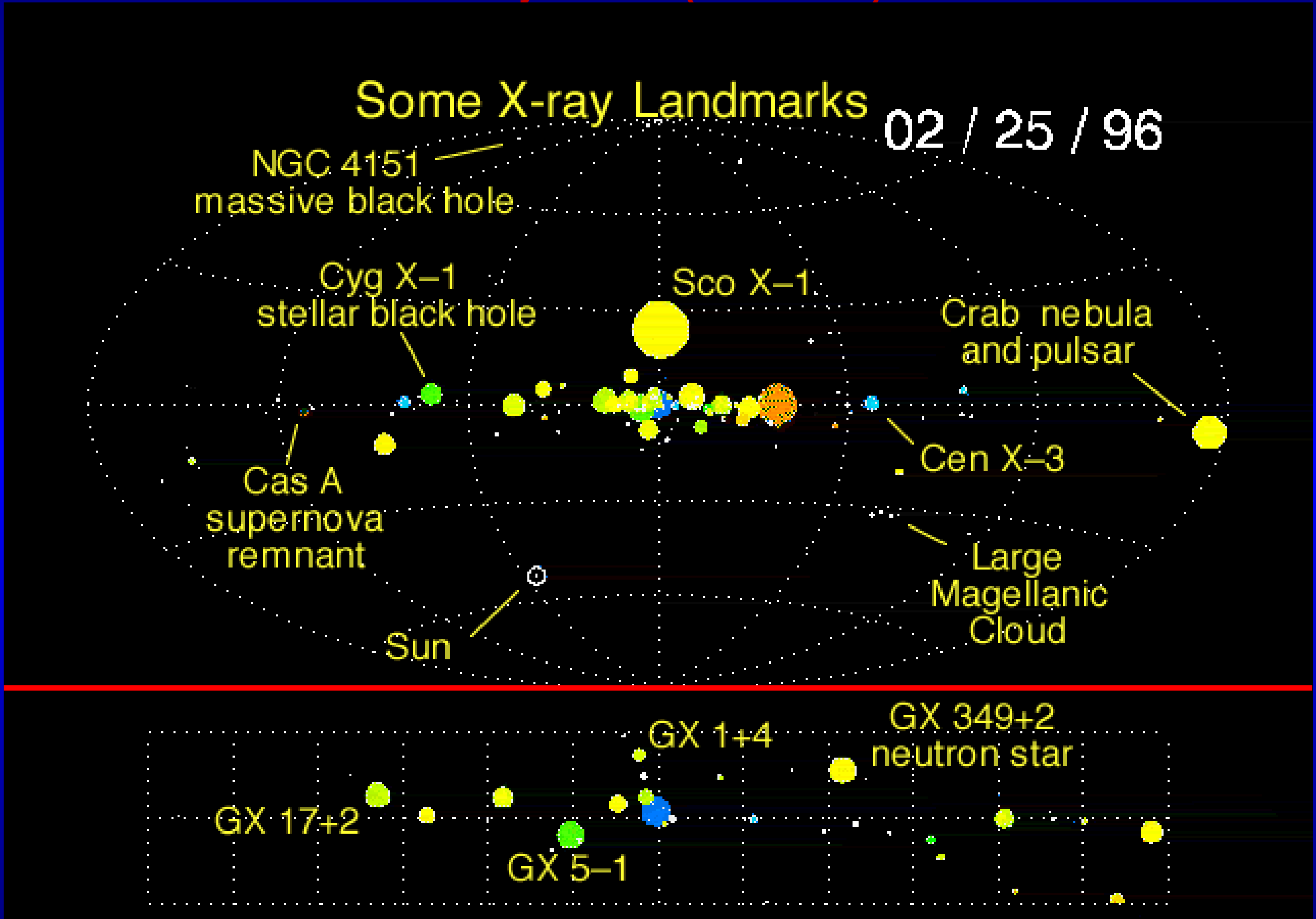
X-ray spectrum of AM He in the high state. Lobste is expected to monito mainly soft X-ray exces (E < 1 keV).

g of data can significantly increase the signal/noise n some types of objects

aint sources can be detected by monitoring if only sis of the mean levels of intensity is considered

Composed view of X-ray sky

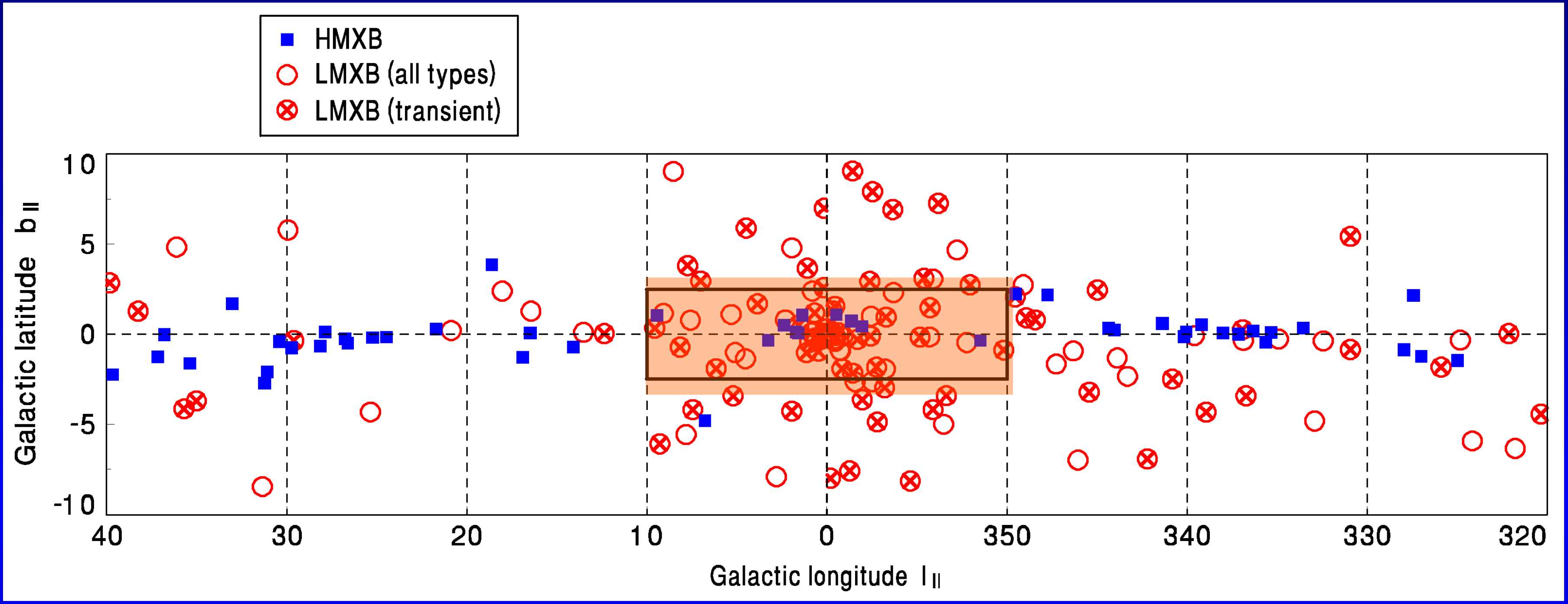
All-Sky Monitor (ASM/*RXTE*)



View toward the Galactic center

Most detected objects are binary systems with mass-accreting neutron star or black hole.

Space distribution of most X-ray binaries

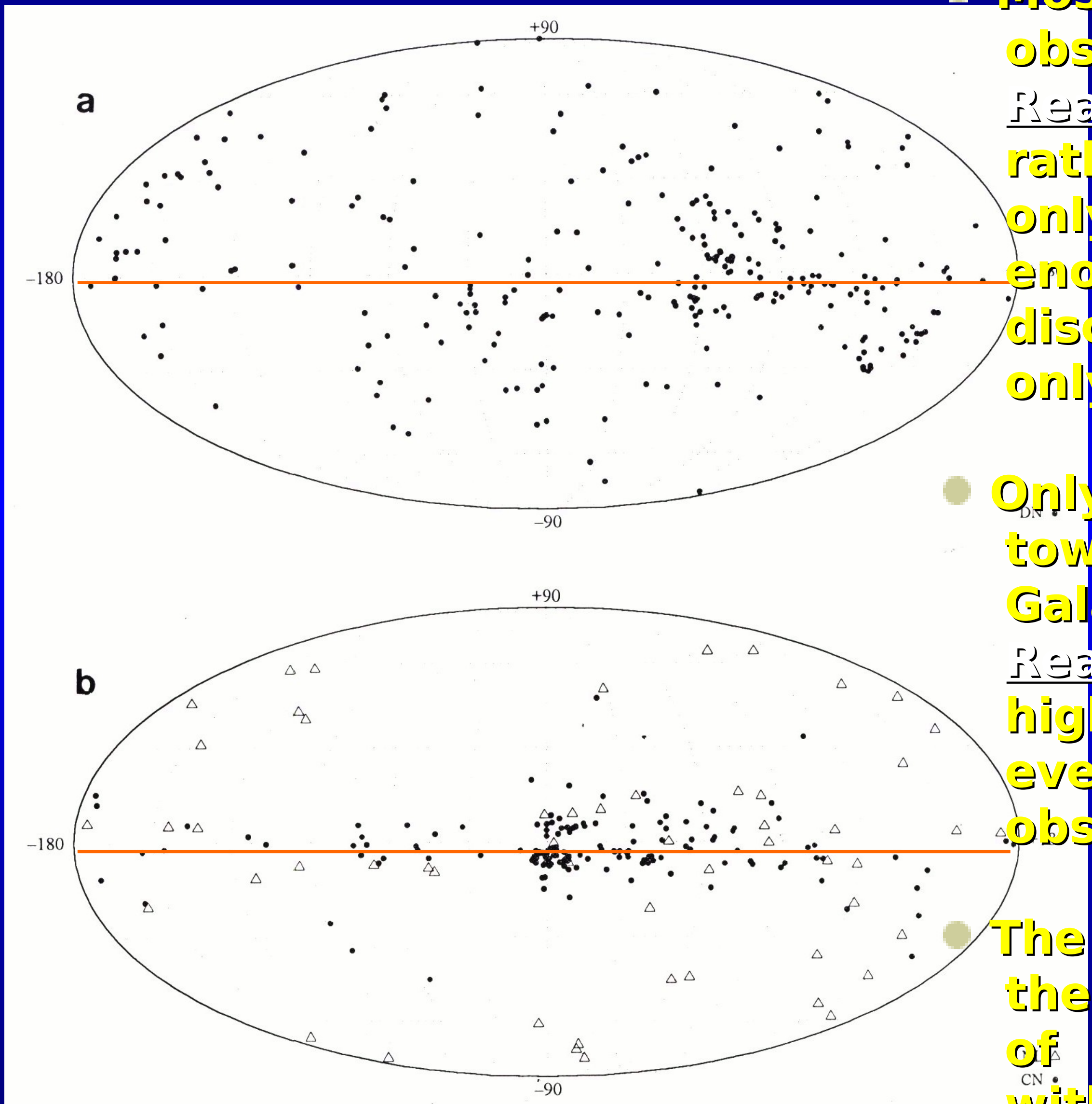


d of the center of the Galaxy (20 x 80 deg). The positions of known LMX
MXBs (Liu et al. 2007, 2006) are marked. The field proposed for the r
ter is marked by the oblong – it contains a number of the already know

(both transient and persistent) concentrate toward the Galactic plan
: bulge.

necessary to monitor the whole sky to discover a transient in outburst.

Space distribution of cataclysmic variables



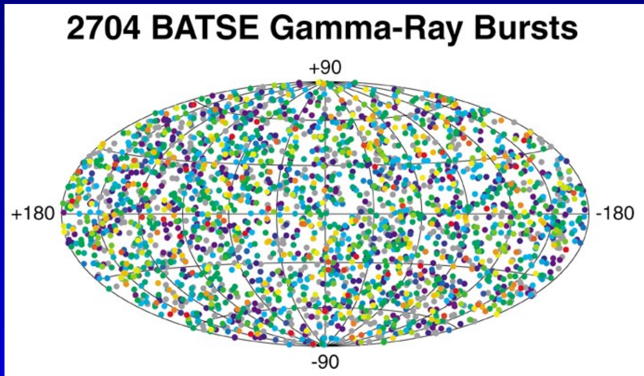
- **Most cataclysmic variables are observed all over the whole sky**
  <u>Reason:</u>
  rather low-luminosity populatio only nearby objects are brigh enough to be observed (mostl discovered in the optical band only subsequently in X-rays)

- **Only classical novae concentrat toward the Galactic plane and t Galactic bulge.**
  <u>Reason:</u>
  high optical luminosity in explos even objects at large distances observable

- **The direction toward the cent the Galaxy is suitable for monit of explosions of classical no with a wide-field monitor**

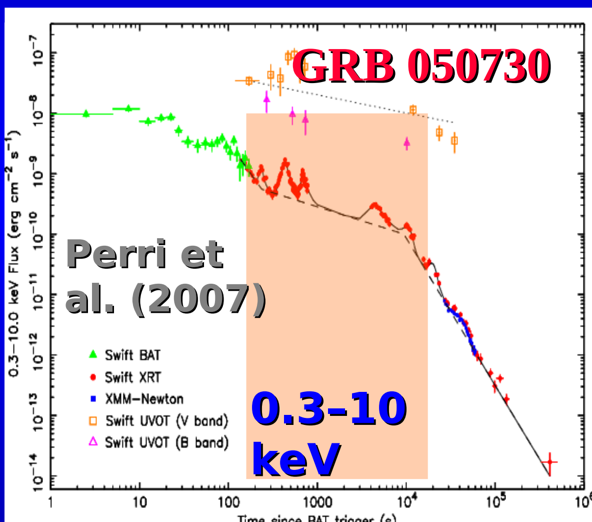
Warner (1995)

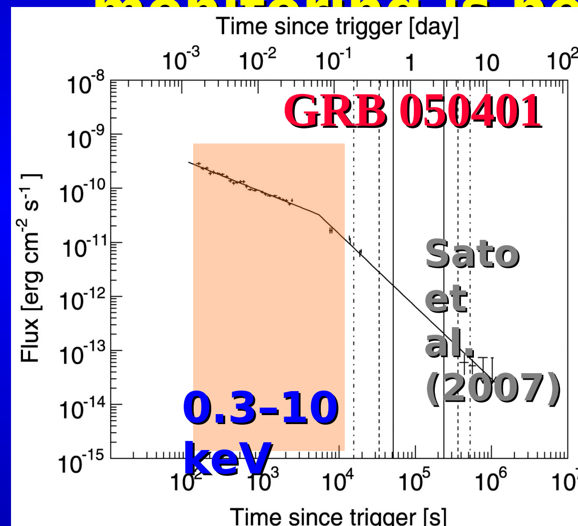
X-ray afterglows of GRBs – perspectives for lobster

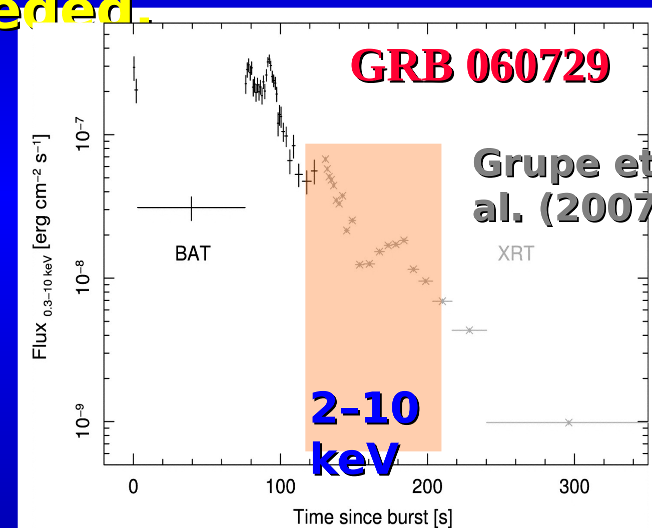


GRBs come from extragalactic objects.

GRBs are uniformly distributed in the sky – wide-field monitoring is needed.







X-ray afterglows of GRBs – soft X-ray band comparable to the propos

y afterglow can be observed even with a small monitor for several m ger

on independent of any observed GRB trigger (by another satellite) is p o X-ray flashes can be observed with Lobster)

Conclusions and confrontation with theories

tion of the Lobster monitoring needed: binary systems in our G
of various types (thermal instability of the disk, periastron p
the time-scale of days → long exposures and
n be used

ectral region – soft X-rays (*E* < 2 keV) (peak sensitivity of Lobste
trum of the suggested sources often peaks at *E* ~ 1 keV desp
r extinction.

w-frequency (low energy): interstellar extinction of X-rays (mo
e unobservable or very faint for energies *E* < 0.1 keV)
gh-frequency (high energy): X-ray flux significantly decreases
ectral profile

sults can be achieved even by investigating the X-ray light c
ctral band (i.e. without hardness ratios):
of the accretion disk, radial profile of the disk, evolution of the
g outburst, evolution of spiral arms in the disk, accretion spot i
are predicted to strongly influence the profile of the X-ray light

Acknowledgements:

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