The Magnificent Seven as soft X-ray sources

Bettina Posselt

Max-Planck-Institut für extraterrestrische Physik

Astrophysikalisches Institut und Universitäts-Sternwarte Jena

In cooperation with:

S.Popov, F. Haberl, J. Trümper, R. Turolla, R. Neuhäuser

Outline

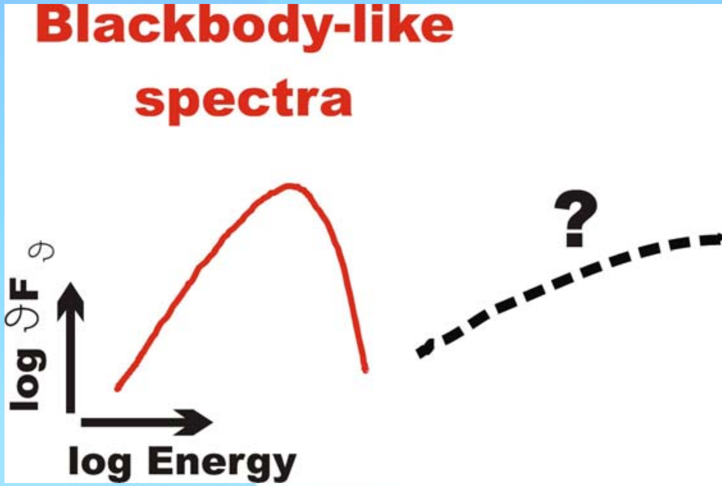
- The influence of absorption
- The inhomogenous interstellar medium
- A model ISM distribution
- Applications
- Outlook
- Summary

The Magnificent Seven in X-rays

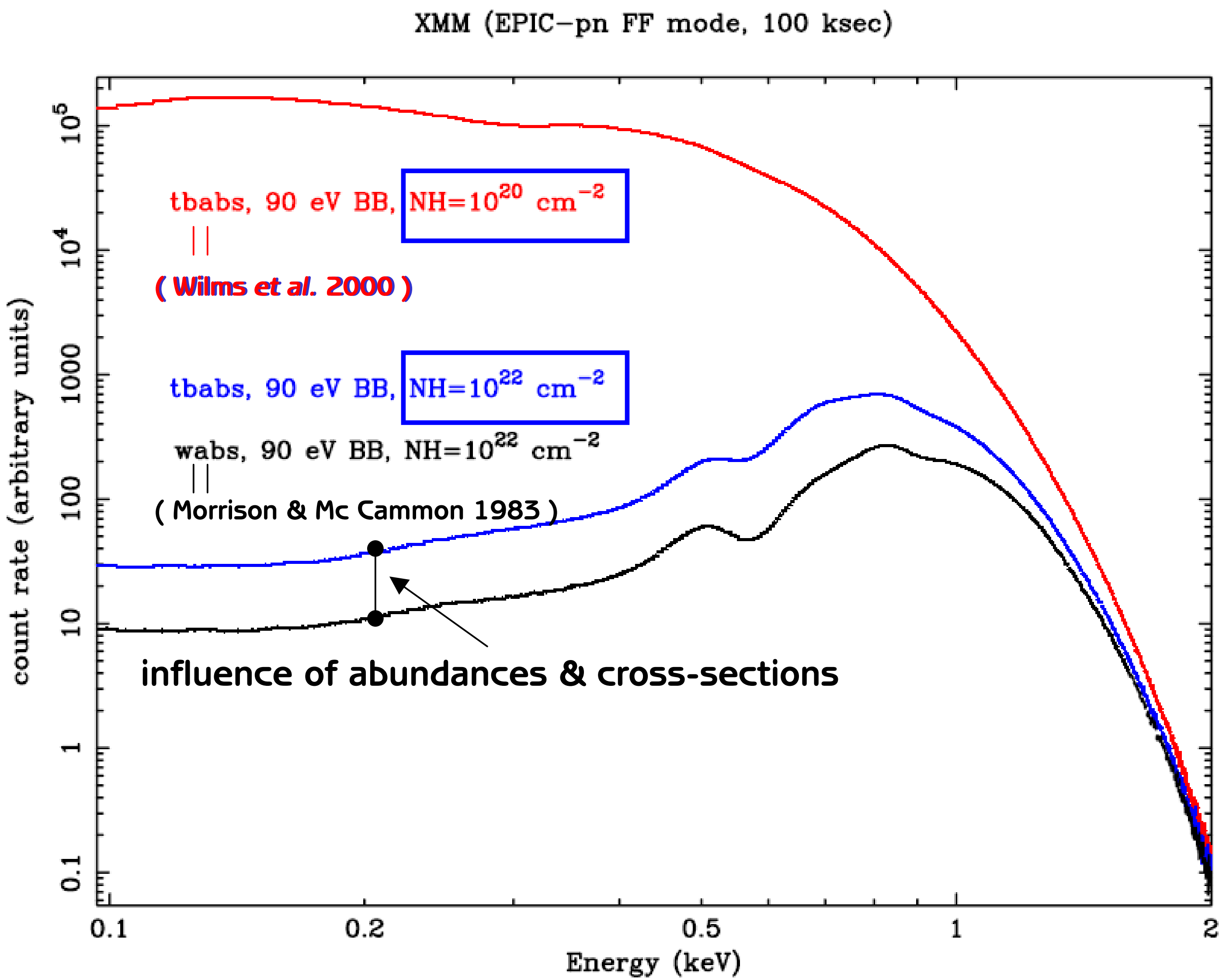
Object	EPIC PN: kT [eV]	N(H) [10^{20} cm^{-2}]	PM [mas/yr]	Lines
RX J0420.0-5022	45	1.6		
RX J0720.4-3125	85-95	1.2	97	Y
RX J0806.4-4123	96	1.0		
1RXS J130848.6+212708	86	4.3		Y
RX J1605.3+3249	96	2.0	145	Y
RX J1856.5-3754	60	0.7	332	N
1RXS J214303.7+065419	101	2.4		

Zane et al. 2005, Schwope et al. 2005, Haberl et al. 2004

- soft blackbody-like spectra (ª90 eV)
- probable cyclotron lines
- no non-thermal spectral component
- nearby



The consequences of absorption



Hardness ratios

Especially useful at shorter exposures

$HR1_{XMM} = -0.45$

$HR1_{XMM} = +0.86$

$$HR = \frac{Cnts[band2] - Cnts[band1]}{Cnts[band2] + Cnts[band1]}$$

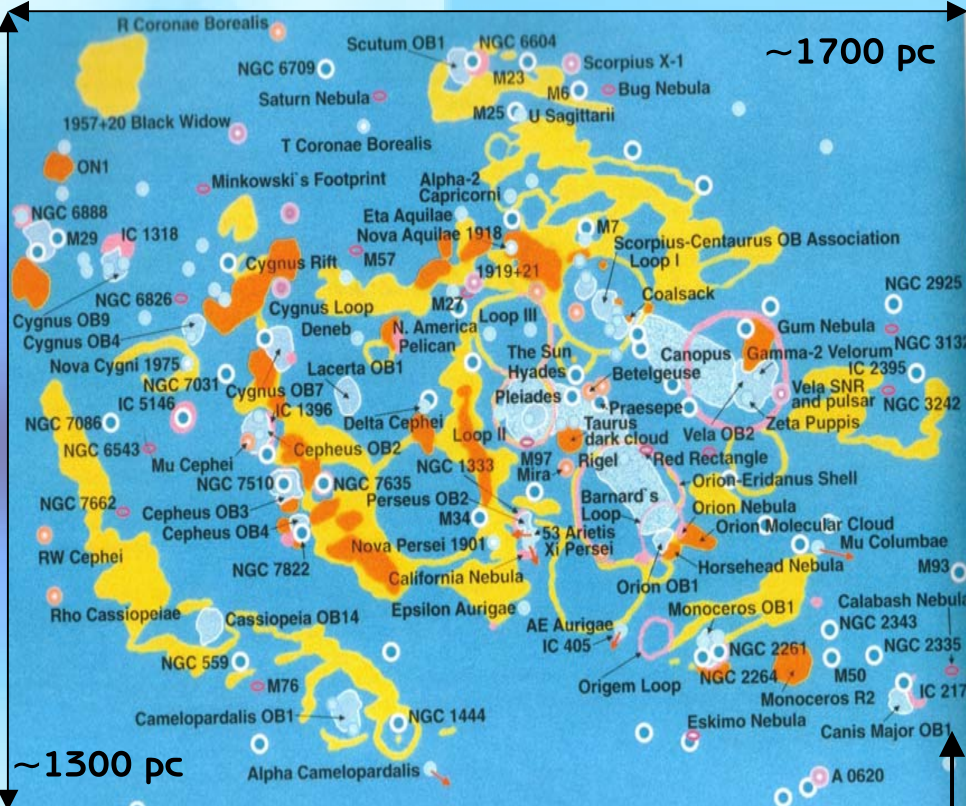
Band1 = 0.2 - 0.5 keV
Band2 = 0.5 - 2.0 keV

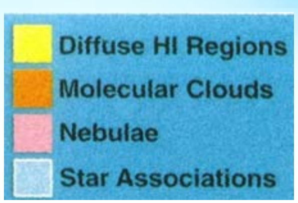
Only nearby X-ray thermal neutron stars at low N(H) found
$\Rightarrow$ more distant sources $\Rightarrow$ harder & fainter

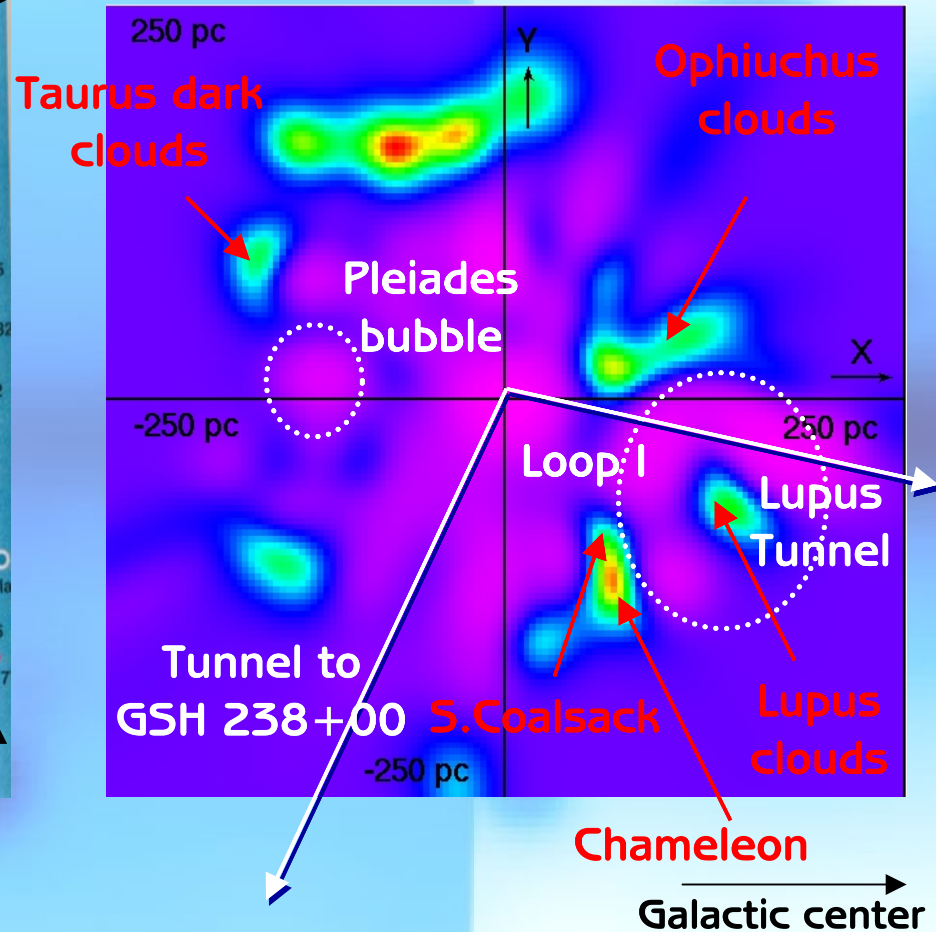
The inhomogenous Interstellar Medium

Henbest & Couper 1994

Lallement *et al.* 2003
Breitschwerdt *et al.* 2005



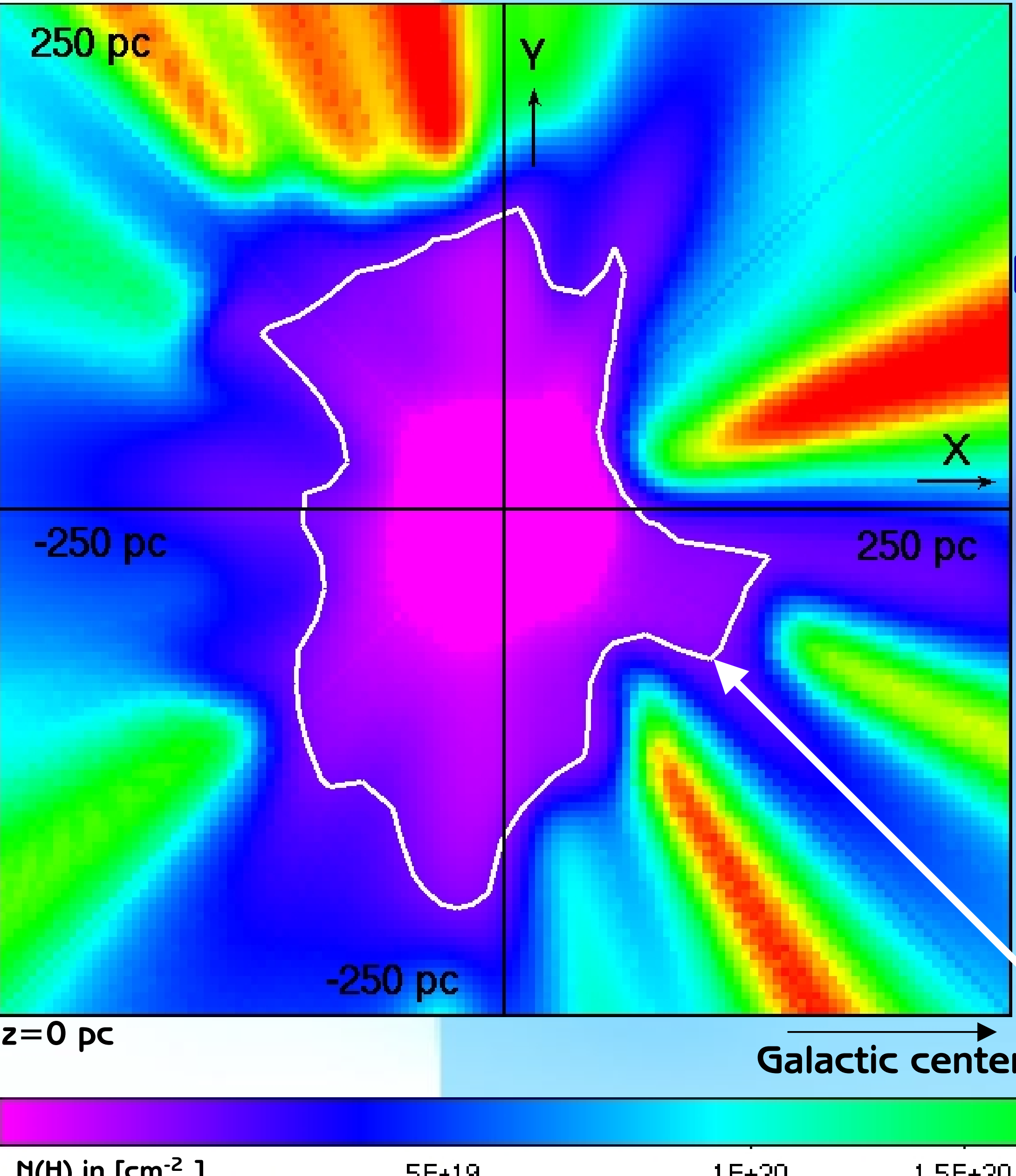




Within one kpc
around the sun

The close
solar neighbourhood

A model for N(H) – 1. The solar neighbourhood



Lallement *et al.* 2003 :

Na D absorption lines toward 1000 sight lines at d<350 pc

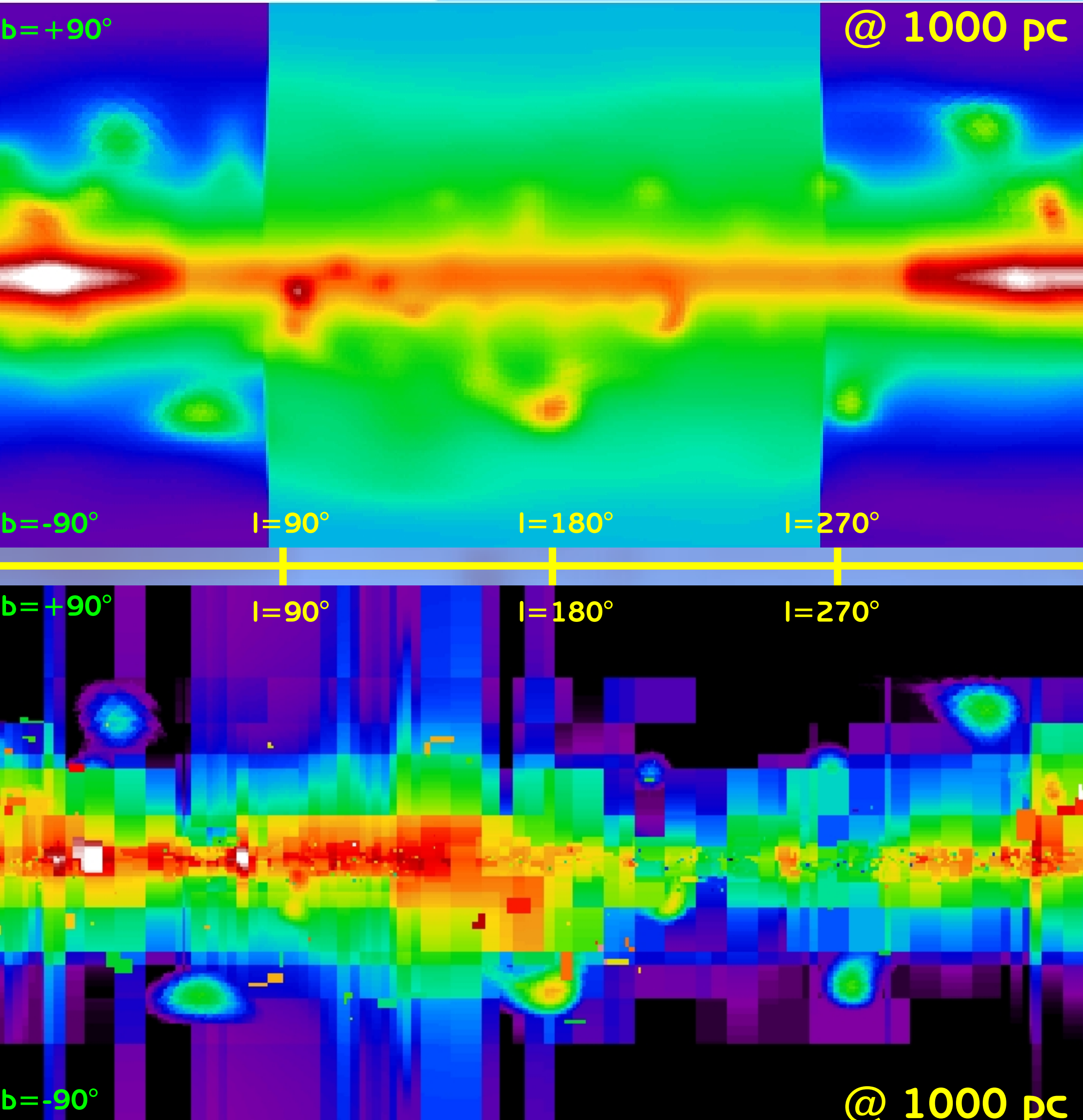
line widths ⇒ N(Na)⇒ n(Na) by inversion method (Vergely 2001)

Ferlet *et al.* 1985
n(Na) ⇒ N(Na) ⇒ N(H)

Drawbacks :

- Na is no perfect H tracer, especially for H_2; a priori n(Na)
- Possible underestimation by 30% comparing to Na UV lines
- Not applicable for *log* N(Na)<11

A model for N(H) – 2. Radii larger than 230 pc



Analytical model:

Exponential density factors for H I & H_2 according to

Popov *et al.* 2000,
Zane *et al.* 1995, Bochkarev 1992,
Dickey & Lockman 1990

Test:

- **Open Cluster extinctions**
  Piskunov *et al.* 2006
- **Pulsar PSR B0656+14**

Extinction model:

Combined extinction surveys

Hakkila *et al.* 1997

E(B-V) $\Longrightarrow$ N(H)

Paresce *et al.* 1984,
Predehl & Schmitt 1995,

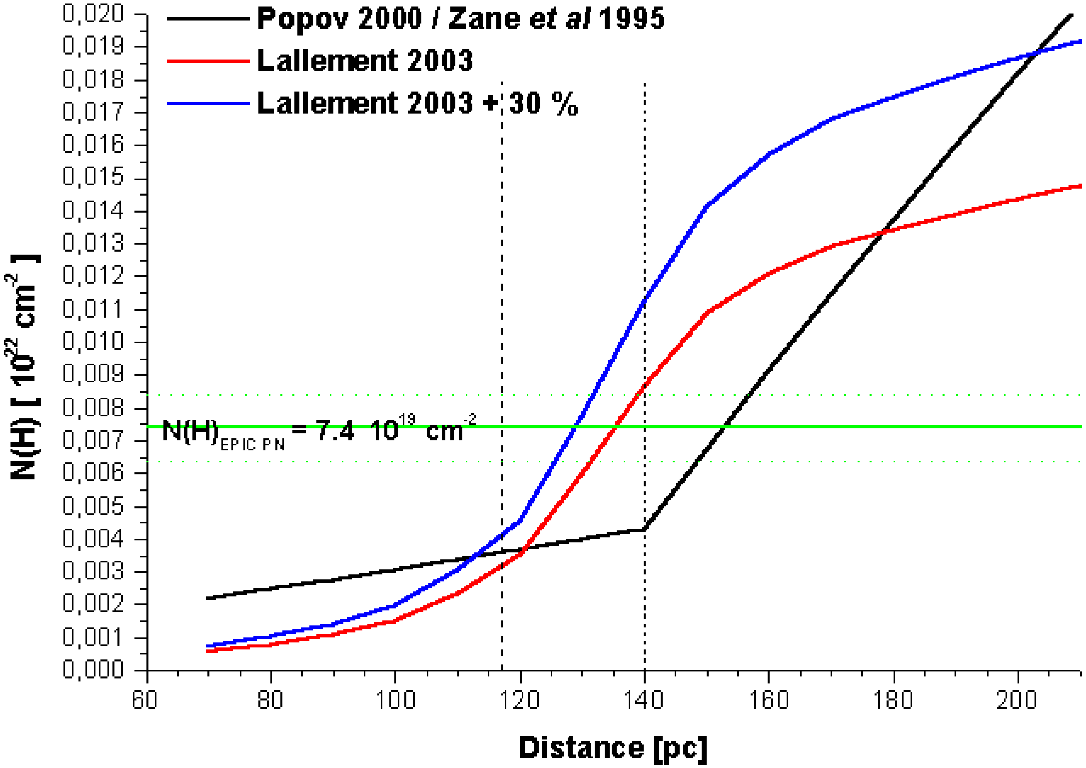
Application 1 – check distances

In the direction of
RX J1856.5-3754
(l=359°, b=-17°)

For EPIC PN : 130 – 140 pc
(see talk by F. Haberl)

Kaplan et al. 2002 : 140 ± 40 pc
Walter & Lattimer 2001: 117 pc

towards R CrA
@ 130 pc : 0.7 10^{20} cm^{-2}
@ 140 pc : 1.0 10^{20} cm^{-2}



	N(H) [$10^{20}cm^{-2}$]	Hom. N(H)	Lal+analyt	Lal+Hak	Distances [pc]
RX J1856.5-3754	0.7	140 pc	135 pc	135 pc	130 - 140
RX J0420.0-5022	1.6	3.6 d_{140}	2.5 d_{135}	n.a.	...340
RX J0720.4-3125	1.2	1.2 d_{140}	2.0 d_{135}	1.8 d_{135}	240 - 270
RX J0806.4-4123	1.0	2.5 d_{140}	1.8 d_{135}	1.8 d_{135}	235 - 245
RBS 1223	4.3	1.3 d_{140}	n.a.	n.a.	-
RX J1605.3+3249	2.0	1.2 d_{140}	3.0 d_{135}	n.a.	... 410
RBS 1774	2.4	2.3 d_{140}	3.1 d_{135}	n.a.	... 420

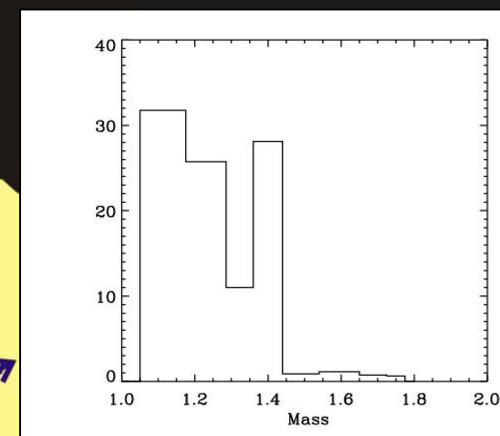
Application 2 – Population synthesis

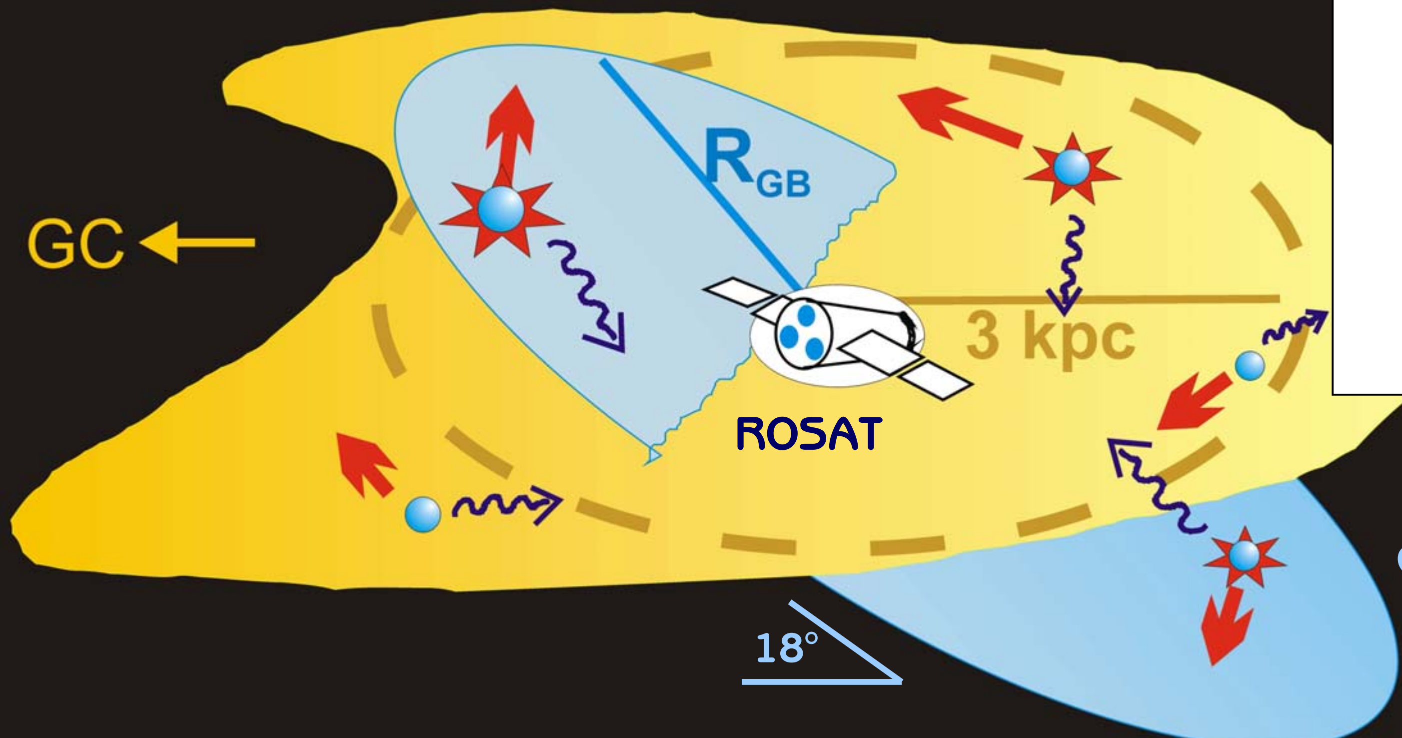
Reminder: population synthesis by Popov *et al.* 2000, 2003 :

Gould Belt : 20 NS Myr^{-1}
Gal. Disk (3kpc) : 250 NS Myr^{-1}

- Cooling curves by Kaminker *et al.* 2002
- Flat mass spectrum

or



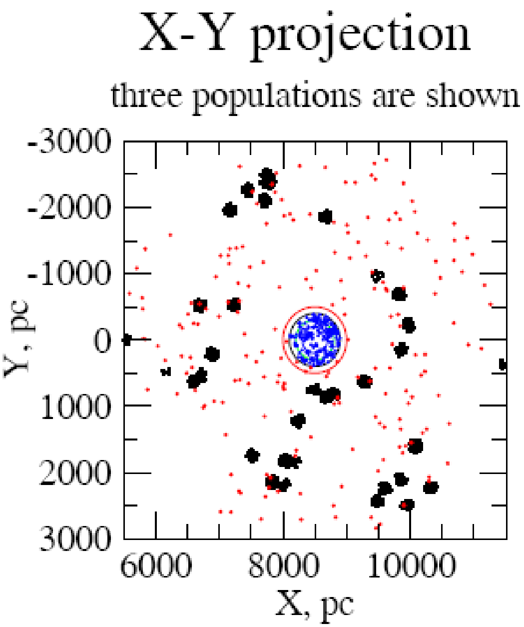


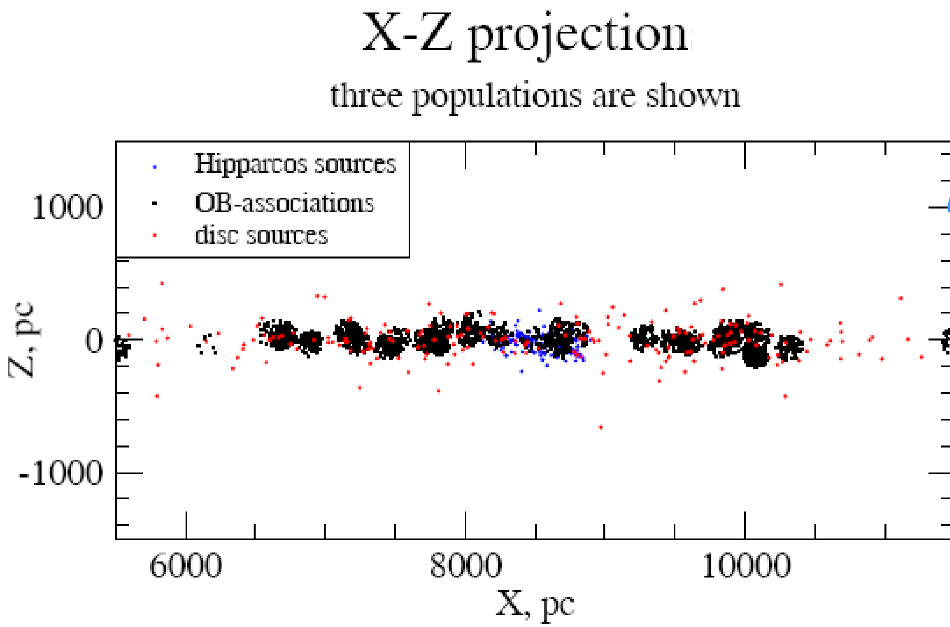
Arzoumanian *et al.* 2002

R_{GB} = 300..500 pc

Population synthesis - recent improvements

1. Spatial distribution of progenitor stars





Gould Belt:
Hipparcos stars
up to 400 pc

Age: spectral type &
cluster age (OB ass)

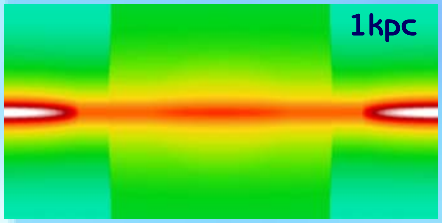
Star associations
birth rate $\sim N_{star}$

Field stars

↑ 2. Spatial distribution of ISM

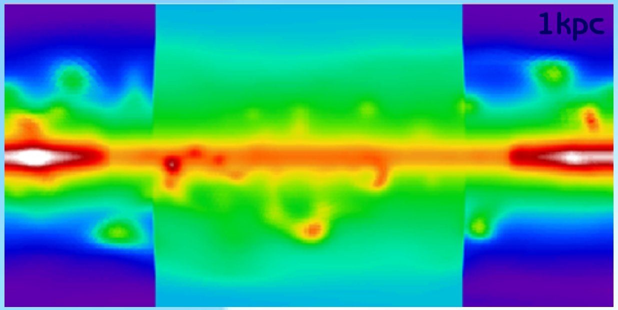
\+ new cross sections & abundances

instead of :



now :

(same scale)



Further improvements:

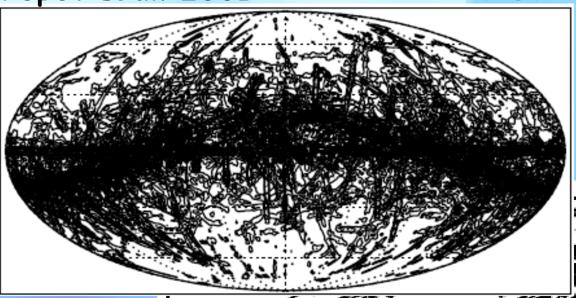
- Mass spectrum (see talk by S. Popov)
- fainter XMM EPIC PN count rates
- cooling curves (Grigorian *et al.* 2000, Popov *et al* . 2006)

First results

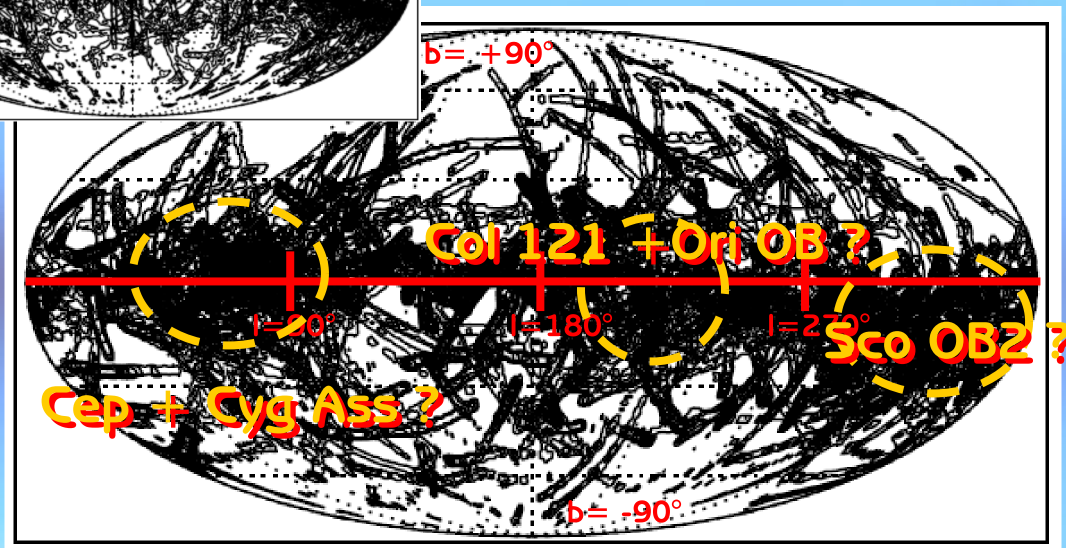
The new initial distribution of progenitor stars:

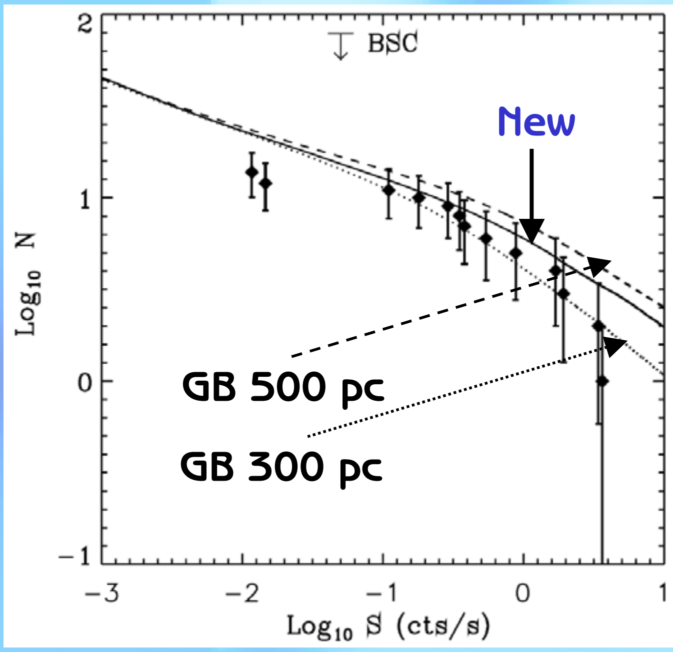
Popov *et al.* 2003

For comparison: ROSAT, old ISM distribution, masses etc. as before



Count rate > 0.05 cnts/s





Dark areas: ~ 0.001 sources / square degree

Outlook (1)

Different *log* N - *log* S curve for distinct sky regions

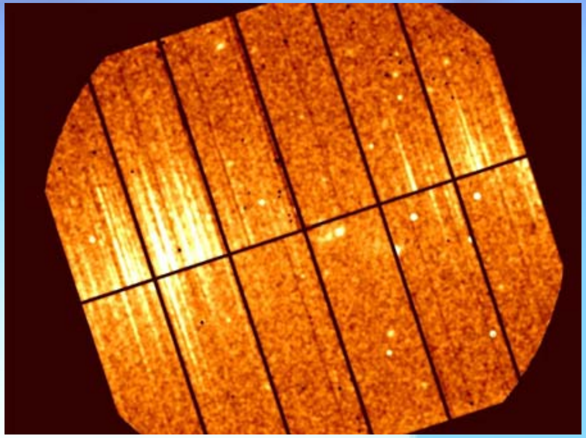
Population synthesis for fainter (XMM) sources

Outlook (2)

X-ray thermal neutron star candidate search:

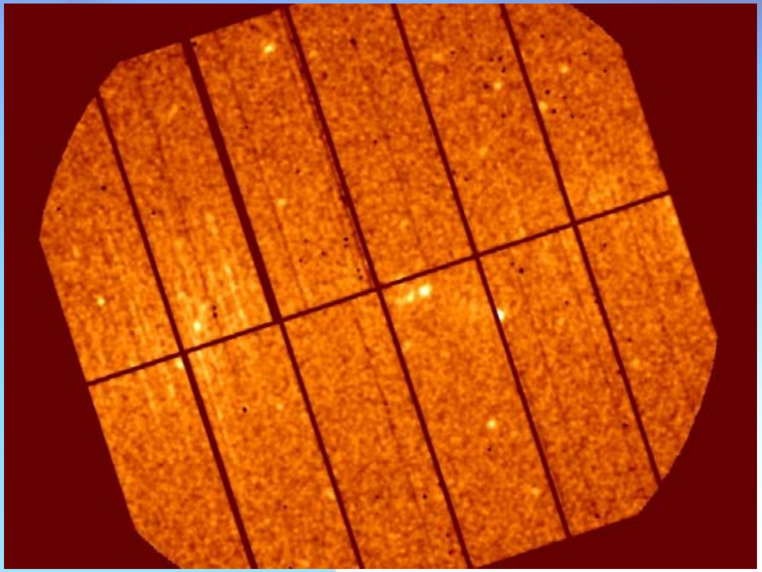
- at larger N(H) fi harder sources with XMM & ROSAT
  (difficult to distinguish from other objects)
- very faint soft XMM sources

Survey of the deepest XMM-Pointings



Special treatment at low energies

[0.15 .. 2.0 keV]



Summary

Interstellar absorption results in fainter *and* harder counterparts of X-ray thermal neutron stars

The ISM is highly inhomogenously distributed

Our N(H)-models account for it and can be used

- for distance estimations in the solar vicinity

e.g.

RX J1856 : 135 ± 25 pc

RX J0720 : 255 ± 25 pc

RX J0806 : 240 ± 25 pc

- as ingredient in population synthesis models aiming for individual *log* N-*log* S curves in distinct sky regions

Considering the spatial distribution of progenitor stars in population synthesis results in an enhancement of predicted neutron star numbers towards some lines of sight in the sky