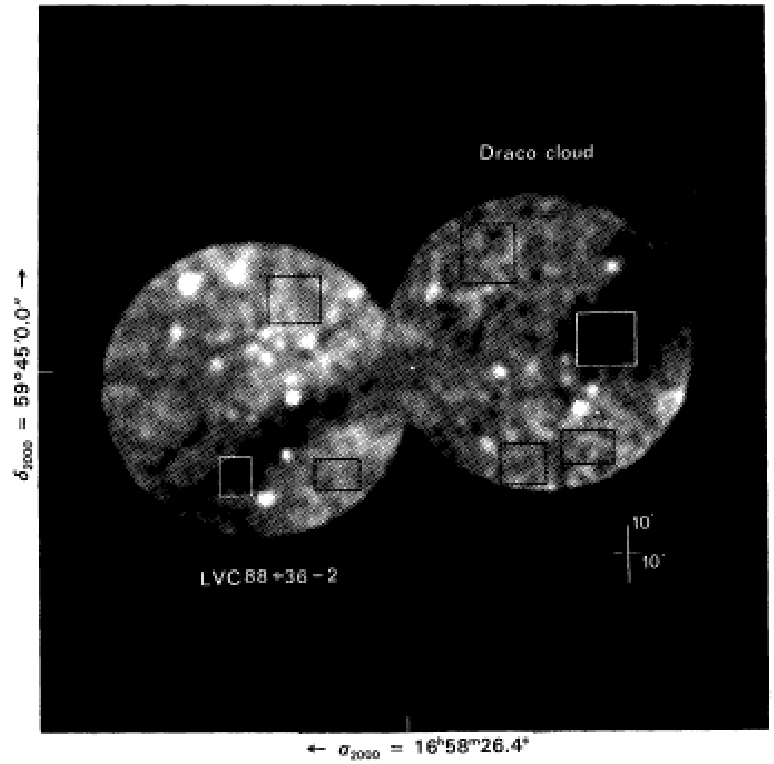
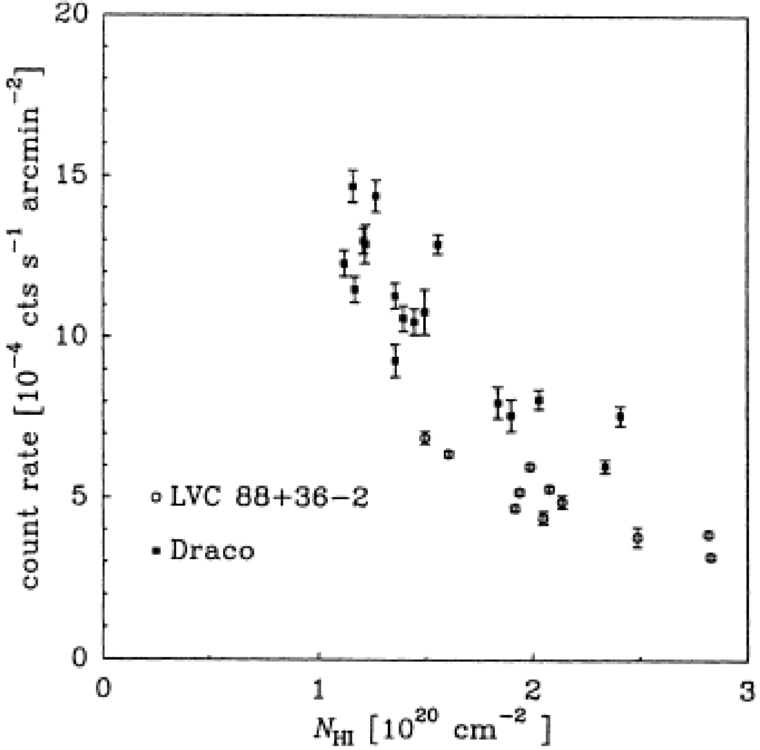
X-rays from high velocity clouds

Jürgen Kerp & Peter Kalberla
Argelander-Institut für Astronomie

X-ray shadows: Draco

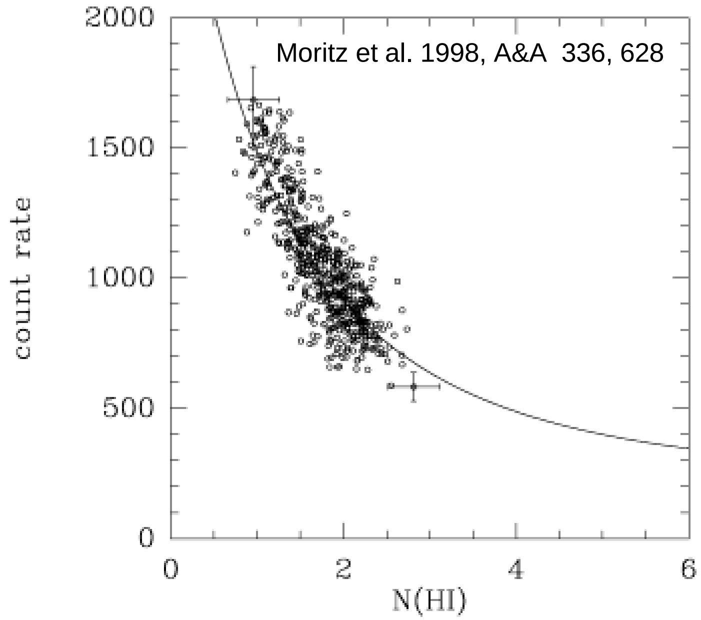




Kerp J. 1994, A&A 289, 597

X-ray shadows: Draco

- Photoelectric attenuation (1/4 keV energy regime)
- Two components
  - Local Hot Bubble
  - Distant source (galactic or/and extragalactic)



$$I = I_{LHB} + I_{dist.} e^{-\sigma \cdot N_H}$$

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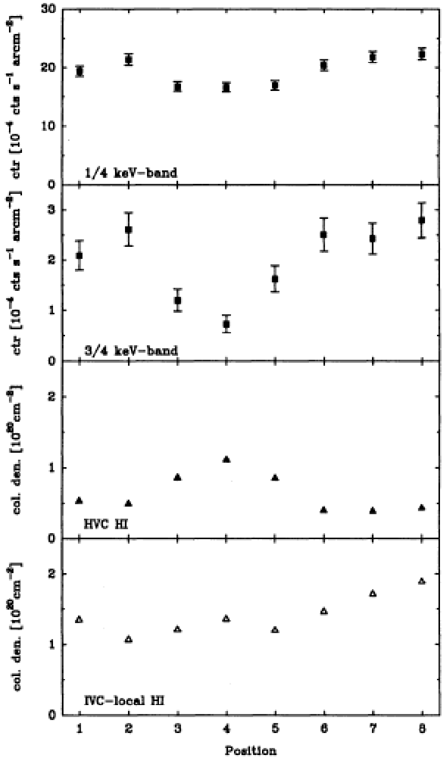
Discovery:HVC in X-ray emission

- Towards HVC 90+42 (member of the HVC complex C) Kerp et al. 1994 detected a **negative positional correlation between NH and ¾ keV** X-ray emission.
- Photoelectric absorption cross section in the ¾ keV regime **is an order of magnitude too small** to explain the negative correlation

Kerp et al. 1998,LNP 506, 457



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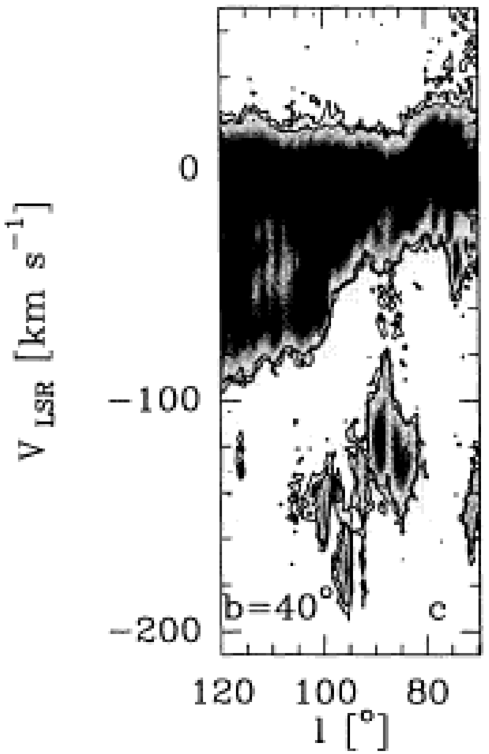
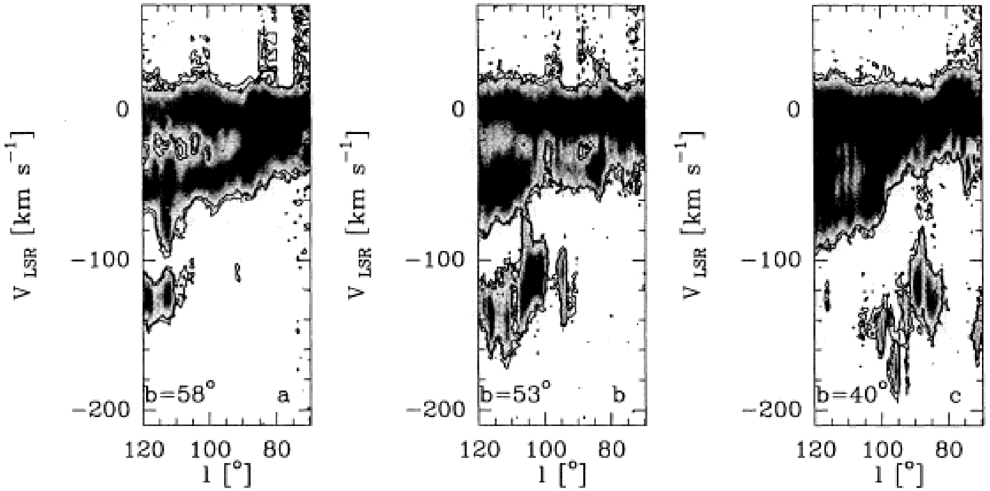
Discovery: HVCs in X-ray emission

- In the original paper we attributed the excess emission to additional heating due to magnetic reconnection (Solar corona)
- We proposed, that the HVC interacts with the high galactic altitude gas layers of the Milky Way halo
- Compressed magnetic field will spontaneously heat the interaction regions to several million degrees Kelvin

Kerp et al. 1996, A&A 312, 67



HI velocity bridges



Kerp et al. 1996, A&A 312, 67

- Using the Leiden/Dwingeloo survey Pietz et al. (1996) cataloged apparent connections between the HVC and the IVC/LVC velocity regime, which we called velocity bridges

Prediction of X-ray excess areas towards HVC complex C

- To get access to the Rosat all-sky survey, we predicted areas of excess X-ray emission in the ¼ keV energy regime, based on our list of velocity bridges.

Pietz et al. 1996, A&A 308, L37

velocity bridge	$l[^\circ]$	$b[^\circ]$	T_b[K]	$v_{\rm LSR}[{\rm km\,s^{-1}}]$
VB82+35.5	80.0 – 83.0	35.0 – 37.0	0.5	−100 ... − 30
VB89+35	88.0 – 99.5	35.0 – 37.0	0.1	−150 ... − 70
	83.0 – 88.0	35.0 – 37.0	0.06	
VB90+41	84.0 – 96.0	40.5 – 43.0	0.1	−100 ... − 40
VB96+48	91.0 – 99.0	45.0 – 50.0	0.2	−90 ... − 40
VB104+54	103.0 – 110.0	53.0 – 55.0	0.35	−100 ... − 70
VB106+62	100.0 – 110.0	61.0 – 63.0	0.2	−80 ... − 60
VB111+35	110.0 – 113.0	34.5 – 35.0	0.3	−110 ... − 85
VB112+48	111.5 – 113.5	48.0 – 48.5	0.2	−110 ... − 90
VB112+57.5	110.0 – 120.0	57.0 – 59.5	0.3	−110 ... − 70
VB115+47	114.0 – 116.0	47.0	0.25	−125 ... − 90
VB133+55	130.0 – 135.0	54.0 – 57.0	0.3	−120 ... − 70

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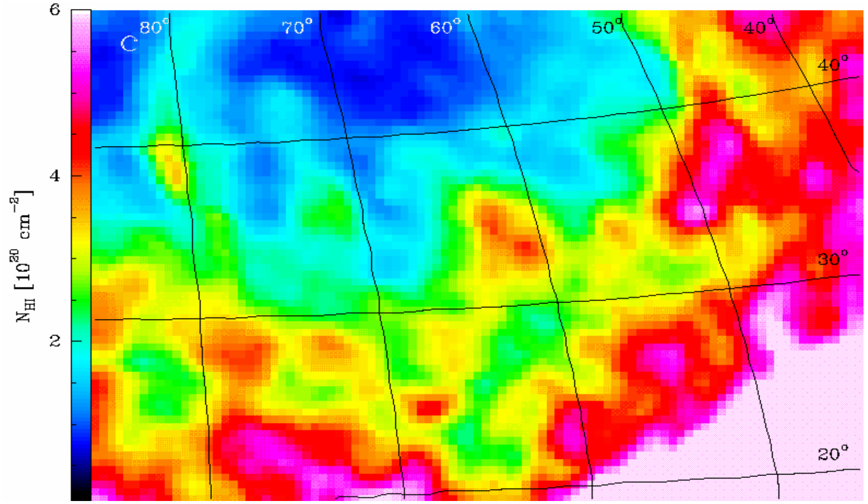
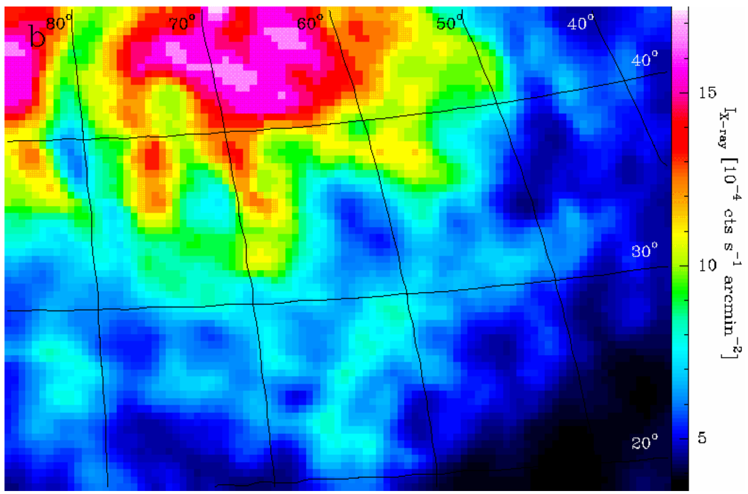
Soft X-ray radiation transfer

Kerp et al. 1999, A&A 342, 213

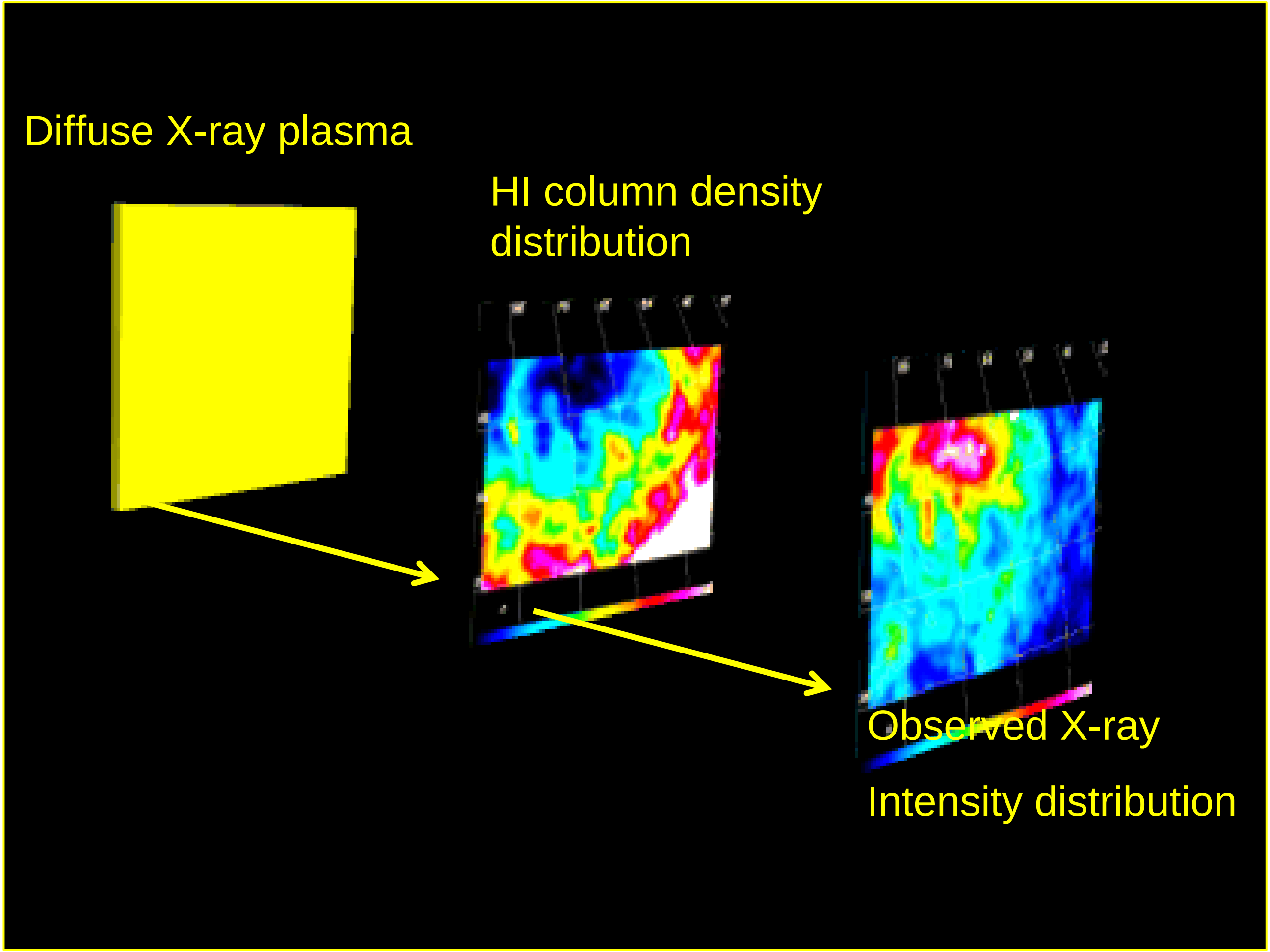




N_{HI} distribution
v_{LSR}=[-100;100]kms^{-1}

¼ keV SXRB distribution

Soft X-ray radiation transfer



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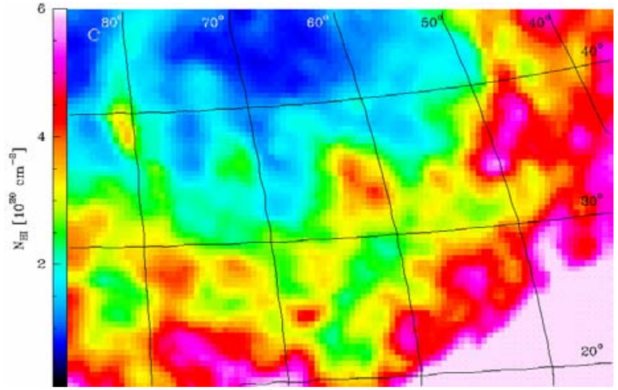
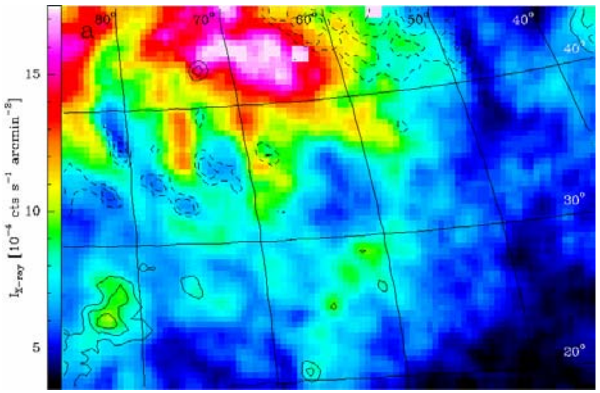
Soft X-ray radiation transfer

constant $I_{distant}/I_{LHB}$ X-ray intensity distribution

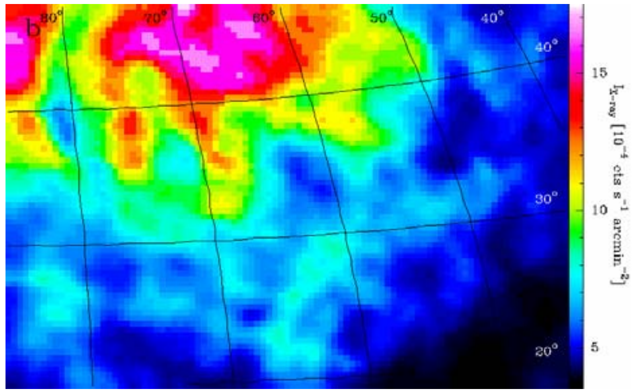


(c) J. Kerp

N_{HI} distribution
v_{LSR}=[-100;100]kms^{-1}



ROSAT 1/4 keV all-sky survey data



modelled SXRB distribution

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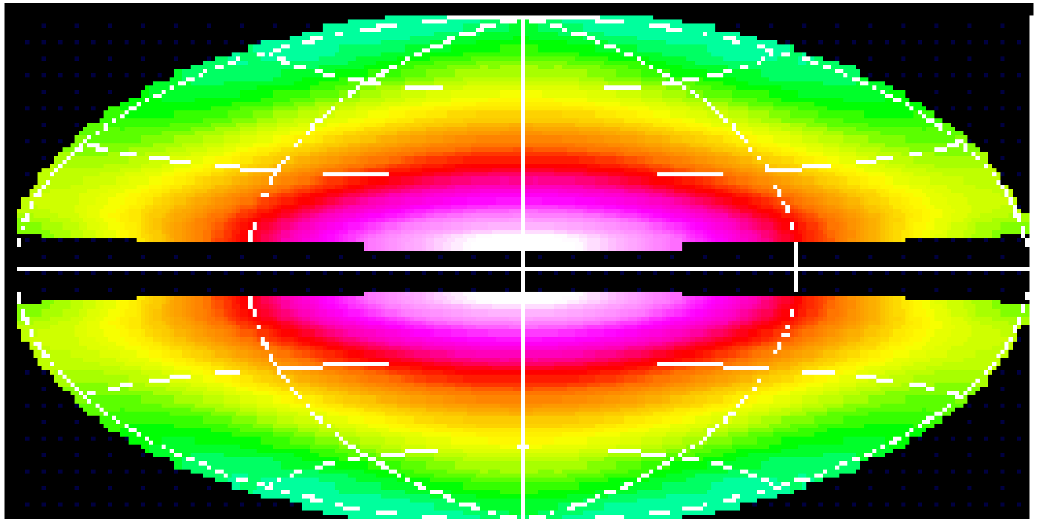
The X-ray Halo: Bonn model



Pietz, Kerp, Kalberla et al. 1998, A&A 332, 55

Kalberla 2003 presented a self consistent model of the Milky Way halo gas assuming, that the dark matter distribution is traced by the distribution of the coronal gas. **Kalberla et al. this conference**

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The X-ray Halo: Bonn model

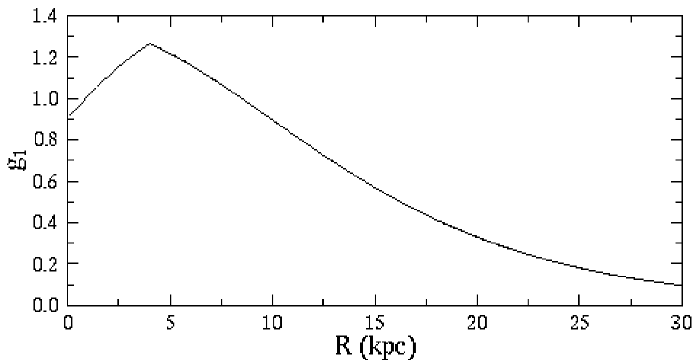
Vertical scale height 4.4 kpc

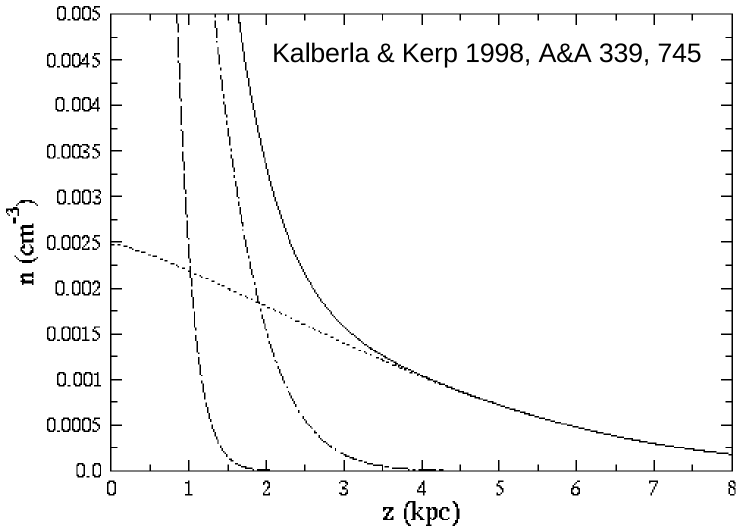
Radial scale height 15 kpc

Galactic halo plasma temperature 1.5 10^6 K (Pietz, Kerp, Kalberla et al. 1998, A&A 332, 55).

On large angular scales (several tens of degrees) the constituents of the Galactic halo can be described by a hydrostatic equilibrium model. (Kalberla & Kerp, A&A 1998 in press).

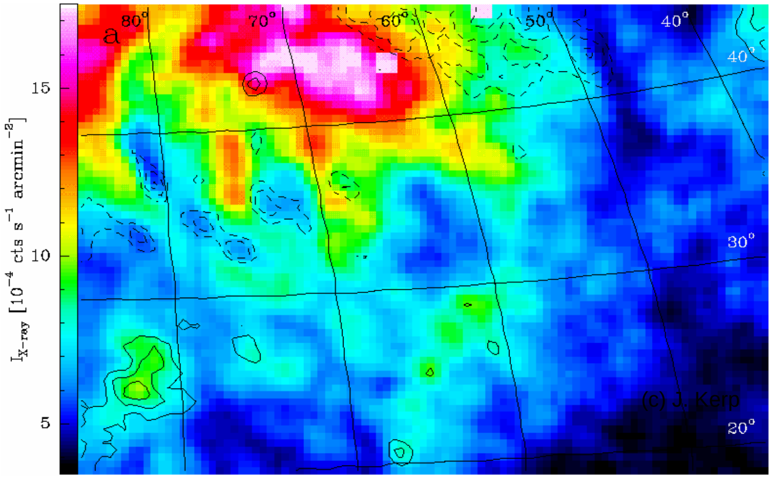
The hydrostatic equilibrium model is consistent with γ-ray, X-ray, the distribution of the WIM and radio continuum data.



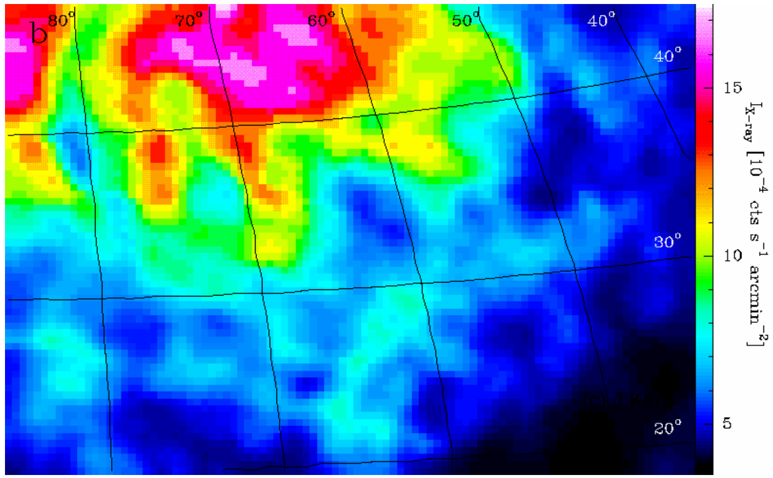


Soft X-ray radiation transfer

Kerp et al. 1999, A&A 342, 213



ROSAT 1/4 keV all-sky survey map



Modelled ROSAT map based on the Leiden/Dwingeloo HI 21-cm line data.

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Soft X-ray radiation transfer

Phase	Column density	location	area coverage
WNM	0.3×10^{20} cm^{-2} < N_{HI} < 3×10^{20} cm^{-2}	full sky	100%
IGM	N_{HI} < 0.001×10^{20} cm^{-2}	full sky	100%
CNM	N_{HI} > 2×10^{20} cm^{-2}	full sky	< 30%
MM	N_{HI} >> 10^{21} cm^{-2}	Galactic Plane	< 10%

The Warm Neutral Medium (WNM) is most important for the soft X-ray radiation transfer.

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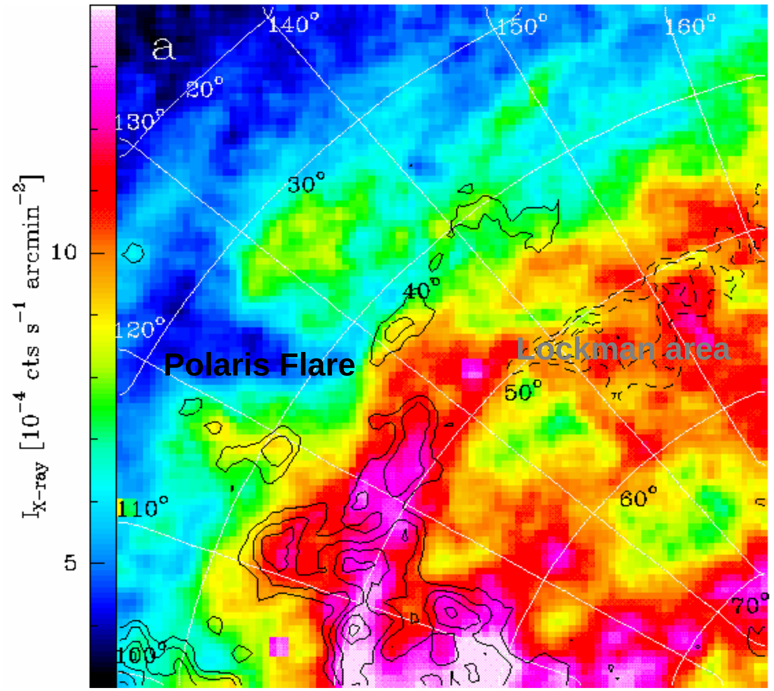
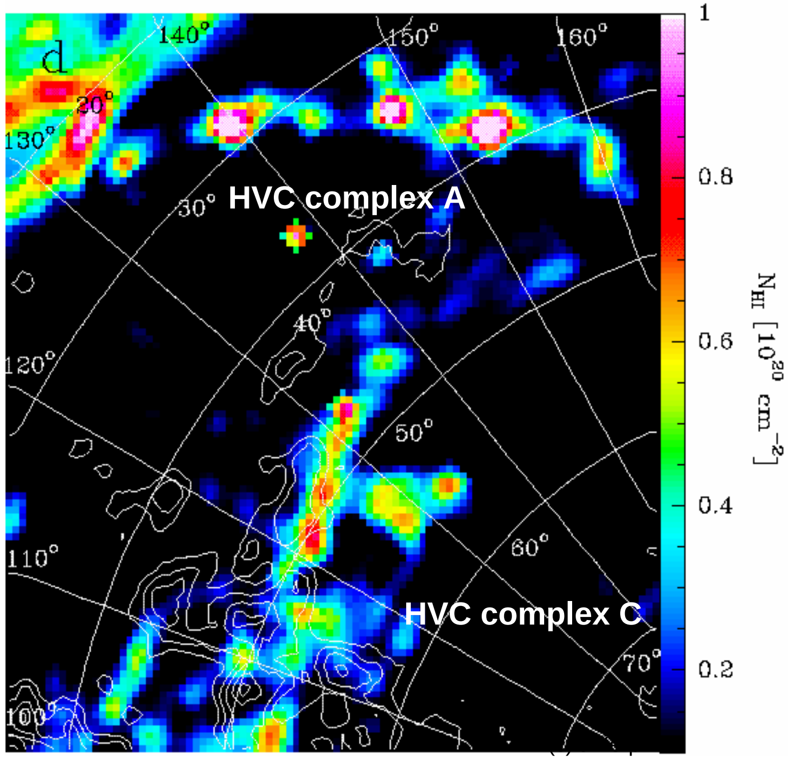
HVC complex C and A



Kerp et al. 1999, A&A 342, 213

(c) J.Kerp



colours: ROSAT1/4 keV data
contours: regions of too strong or too weak X-ray emission (>3 sigma)

colours: HVCs v_{LSR}=[-450;-100]kms^{-1}
contours: 1/4 keV excess emission

Physical properties of the X-ray excess regions

Kerp et al. 1999, A&A 342, 213

complex	*l*-range [°]	*b*-range [°]	E_{det}(1/4 keV) [10^{-10} erg cm^{-2} s^{-1}]	E_{rad}(1/4 keV) [10^{34} erg s^{-1}]	EM [cm^{-6} pc]	n_e [cm^{-3}]	sigma(mean)	sigma(max)
C	143 - 148	42 - 45	4,2	5,0	0,054	0,03	5,0	6,3
C	129 - 135	41 - 44	3,3	4,2	0,041	0,03	5,8	7,8
C	119 - 130	46 - 51	5,6	6,7	0,022	0,01	6,3	8,5
C	116 - 122	39 - 43	3,3	3,9	0,034	0,02	5,6	8,2
C	110 - 116	41 - 46	3,8	4,5	0,032	0,02	7,1	10,2
C	110 - 117	46 - 53	6,8	8,1	0,033	0,02	7,7	11,2
C	110 - 116	54 - 58	2,0	2,4	0,022	0,02	5,5	7,8
C	97 - 111	50 - 53	6,4	7,6	0,031	0,02	6,5	9,0
C	99 - 105	35 - 39	5,6	6,7	0,044	0,02	6,6	11,0
C	89 - 96	41 - 45	3,3	3,9	0,024	0,02	6,7	10,6
D	80 - 84	23 - 27	2,0	2,4	0,028	0,02	6,6	10,1
GCN	34 - 40	-31 - -28'	4,6	5,4	0,034	0,02	2,5	5,3

HVC impact: enhance cooling

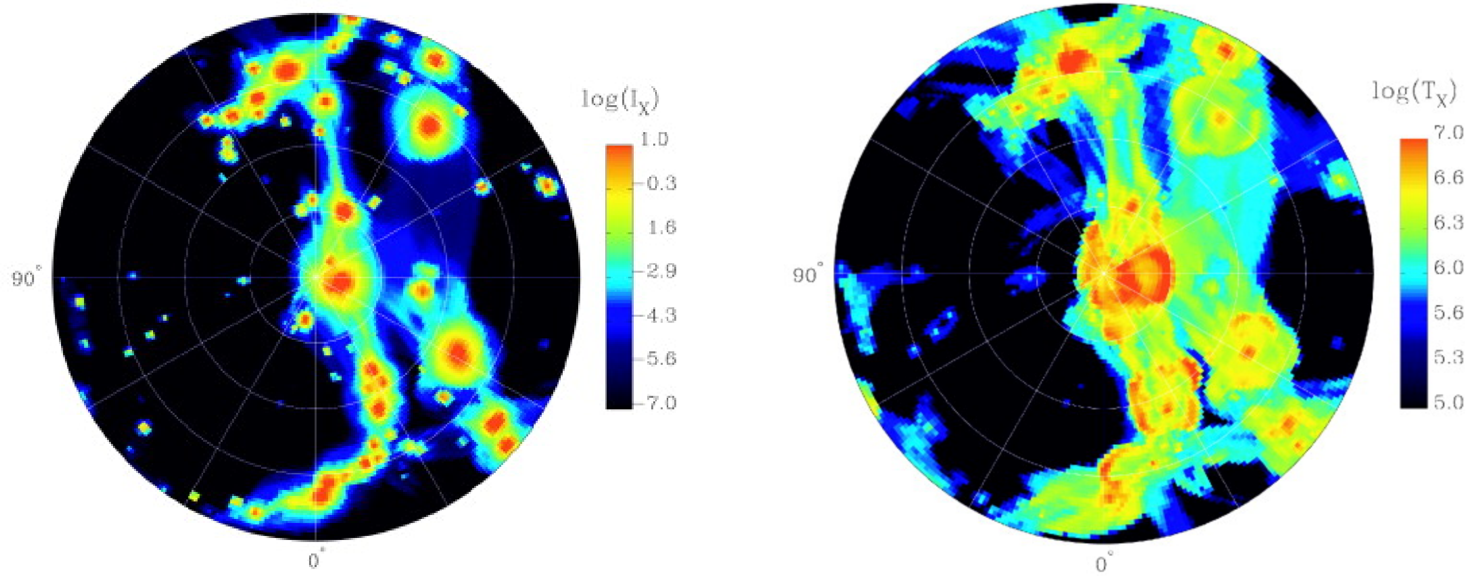
- A detailed re-analysis of the ROSAT pointed PSPC data indicate, that the excess X-ray emission can be attributed to enhances cooling rather than heating.
- The emission measure is up to two orders of magnitude higher than of the undisturbed X-ray halo
- Assuming a galactic altitude of about 4 kpcs, the electron density in the interaction region is enhanced by a factor of about three
- This implies a strong shock, not sufficient to produce X-rays by itself but enhanced cooling

HVC impact: local structure formation

- Within the framework of structure formation, the HVC impact is totally consistent with the accretion of gas by the Milky Way.
- The accreted gas masses are in the order of 10^7 to 10^8 solar masses, a single dwarf galaxy
- The absence of primordial matter towards all HVC complexes studied so far implies processed gas => consistent with dwarf galaxy matter

Bonn X-ray halo: window to the early universe in X-rays

surface brightness 0.5 to 2.0 keV emission-weighted temperature



Kravtsov et al. 2002, ApJ 571, 563

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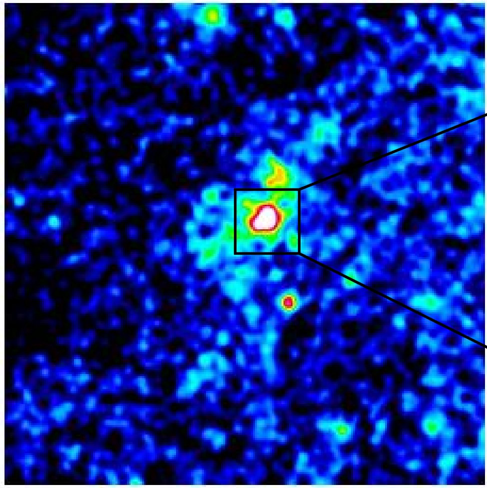
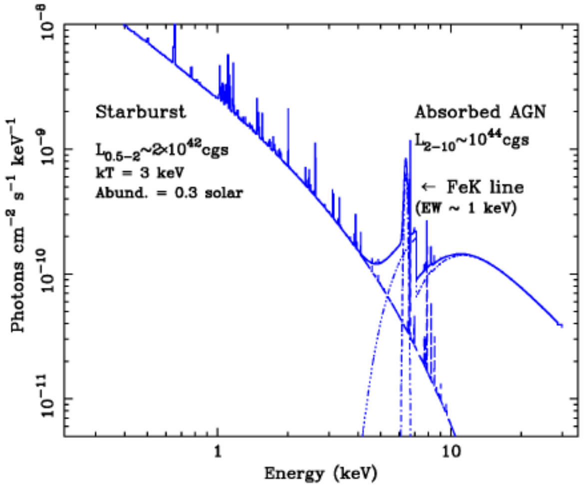
Bonn X-ray halo: window to the early universe in X-rays





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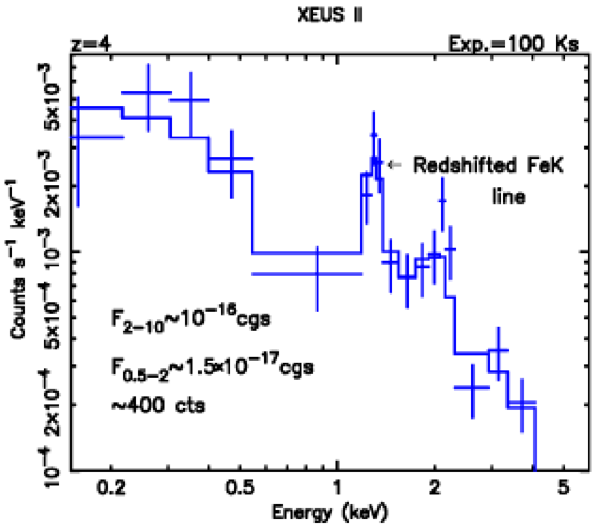

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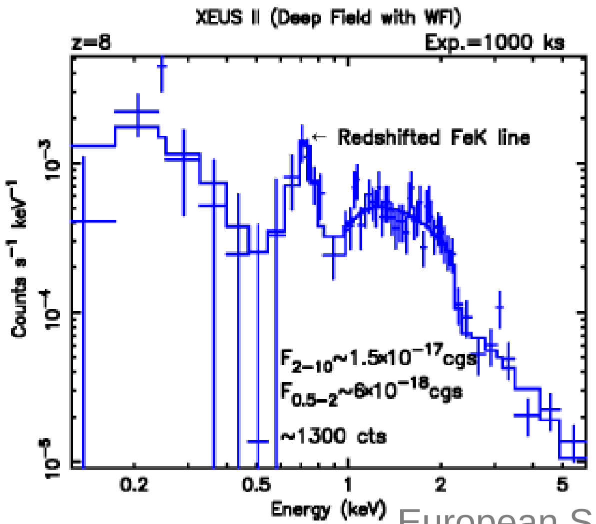

z=8

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Summary

- Soft X-ray emission is associated with HVCs of complex C, D and GCN
- The volume electron density is enhanced by an order of magnitude while the plasma temperature is about the same of the Milky Way X-ray halo.
- The soft X-ray radiation transfer can be modelled quantitatively in particular accounting for the WNM gas.
- This knowledge opens the window to the the early universe emission
  - Warm Hot Intergalactic Medium in emission
  - Highly redshifted X-ray emission of the first galaxies and AGNs