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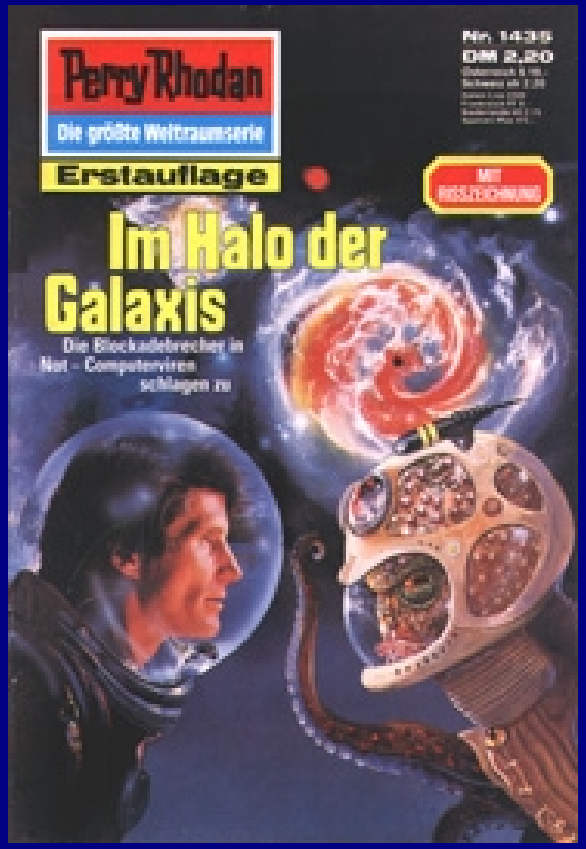
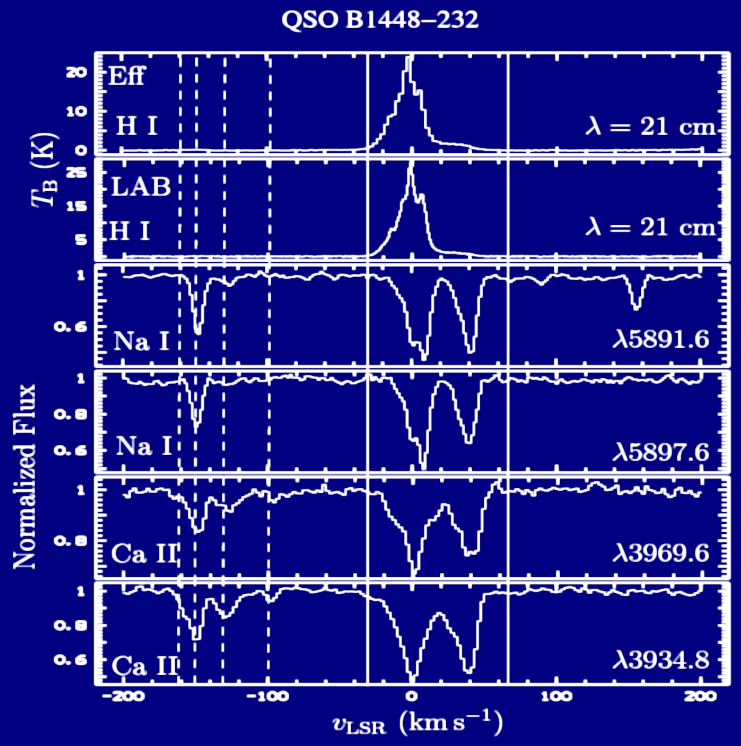
The distribution of gas in the halo of the Milky Way

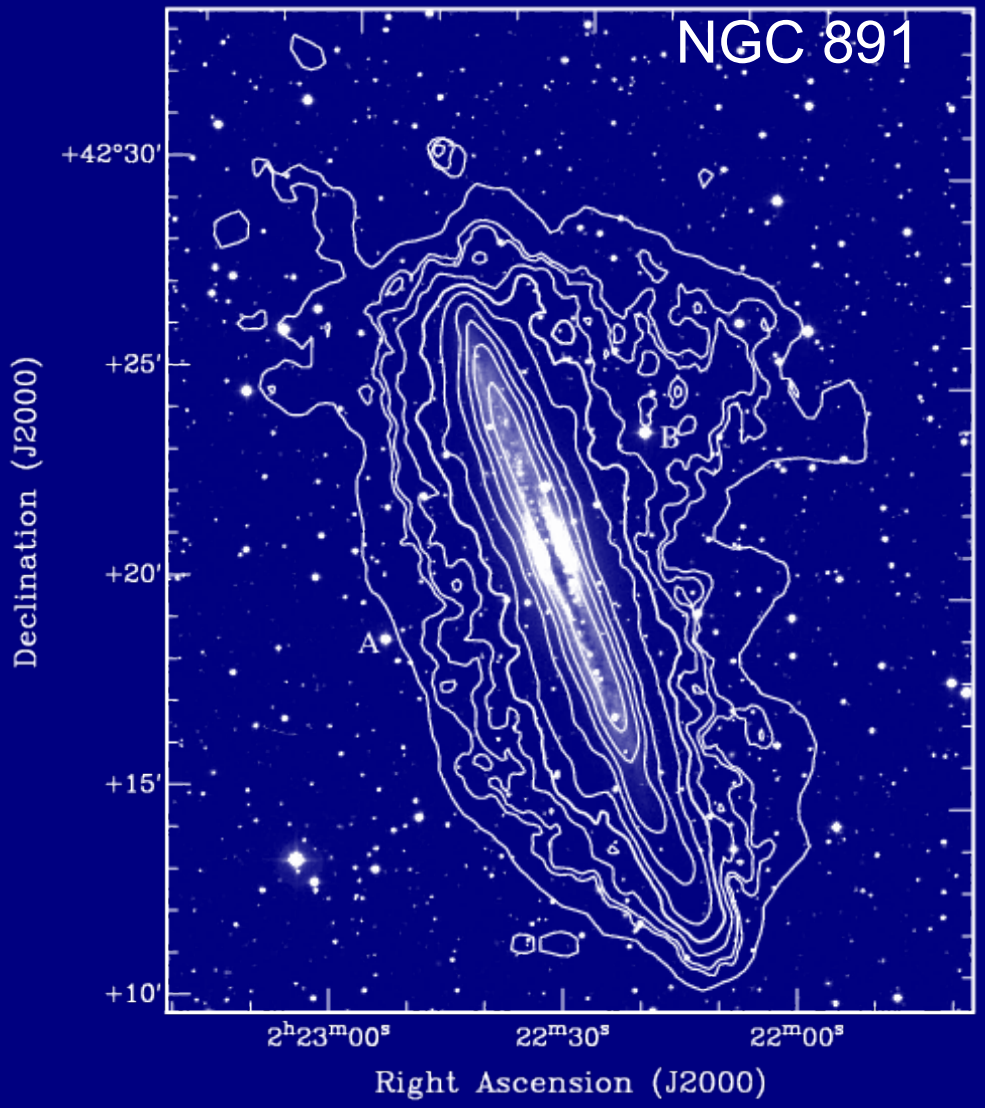
Nadya Ben Bekhti





The low-metallicity ISM, 8-12 October, 2012, Göttingen

Observations



Oosterloo et al., 2007

- Up to 30% of the total HI mass in the halo

  (e.g., Fraternali et al., 2007, Oosterloo et al., 2007)
- Streams, filaments, clouds, clumps
- Lagging halo
- Overall radial inflow

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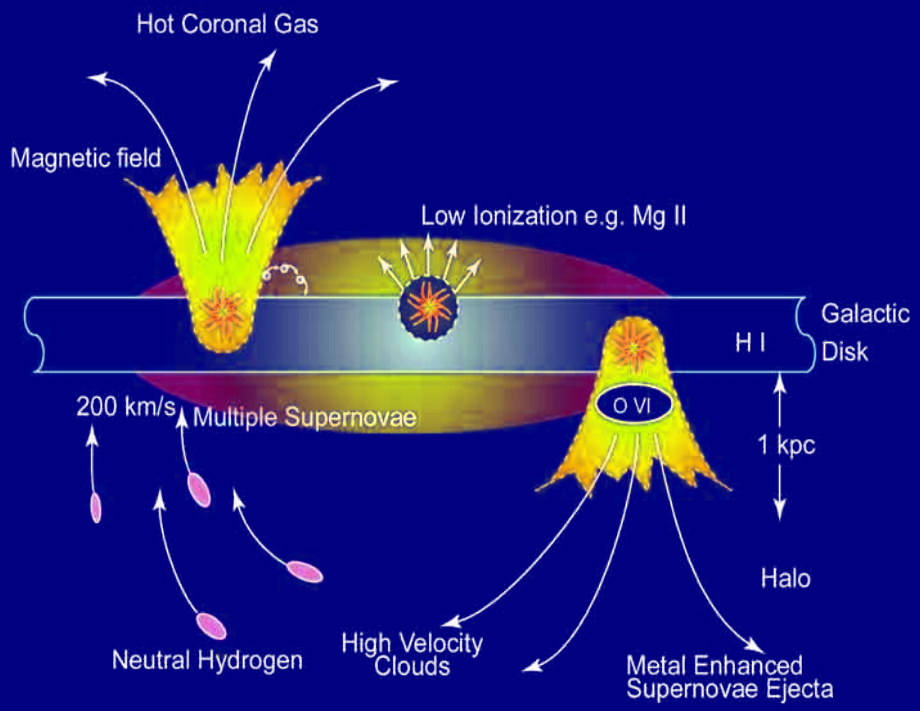
Origin of the halo gas

Galactic origin



http://satrec.kaist.ac.kr/fims/

Extragalactic origin

The Milky Way halo

Intermediate- and high-velocity clouds

- Inconsistent with galactic rotation
- IVCs
  - d ≲ 2 kpc
  - Metal abundances 0.7 to 1.0 solar
- HVCs
  - d ≲ 50 kpc
  - Metal abundances 0.1 to 1.0 solar

(Wakker et al., 2001, 2007, 2008, Richter et al., 2001, Thom et al. 2006)

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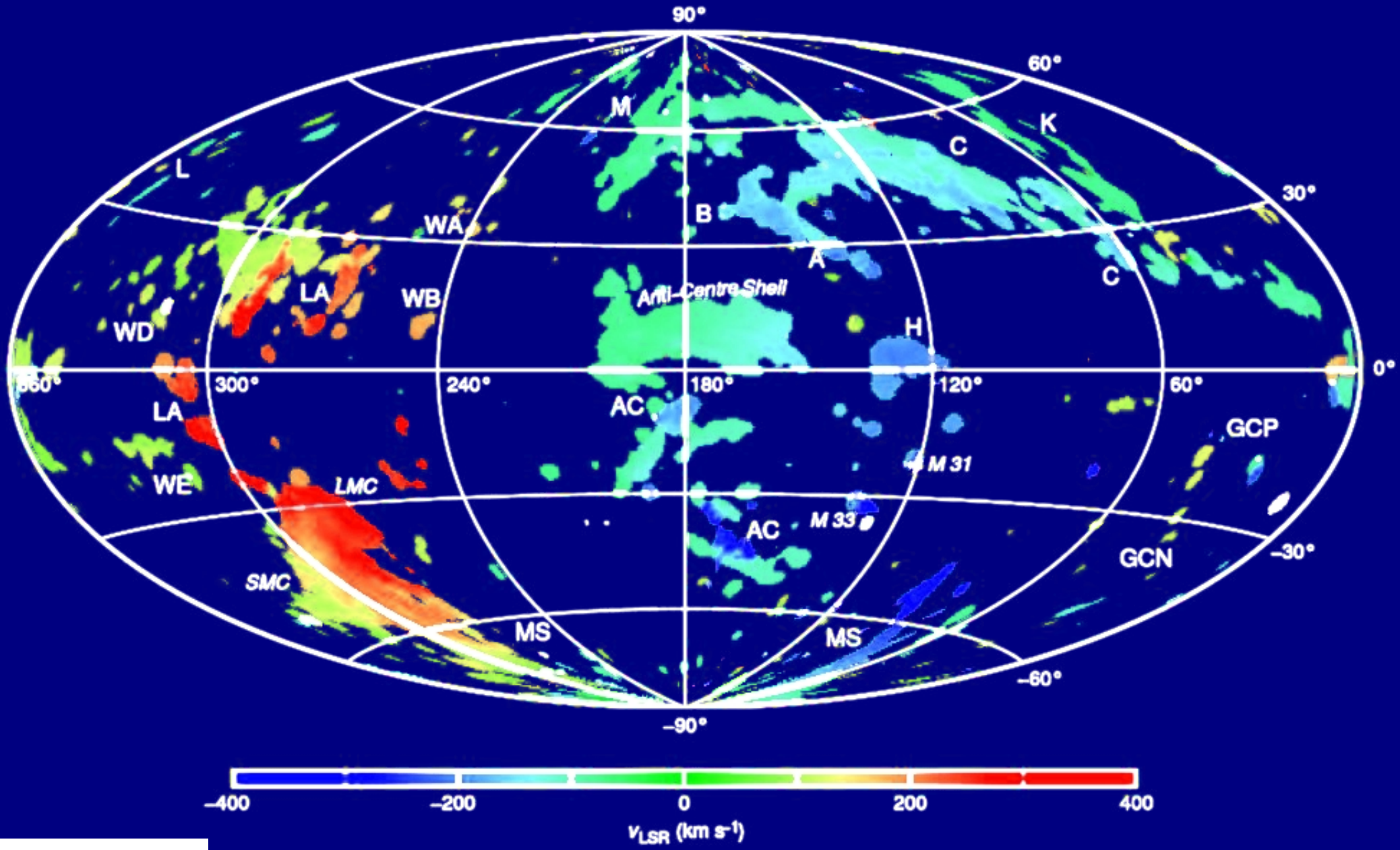
The high-velocity sky



T. Westmeier

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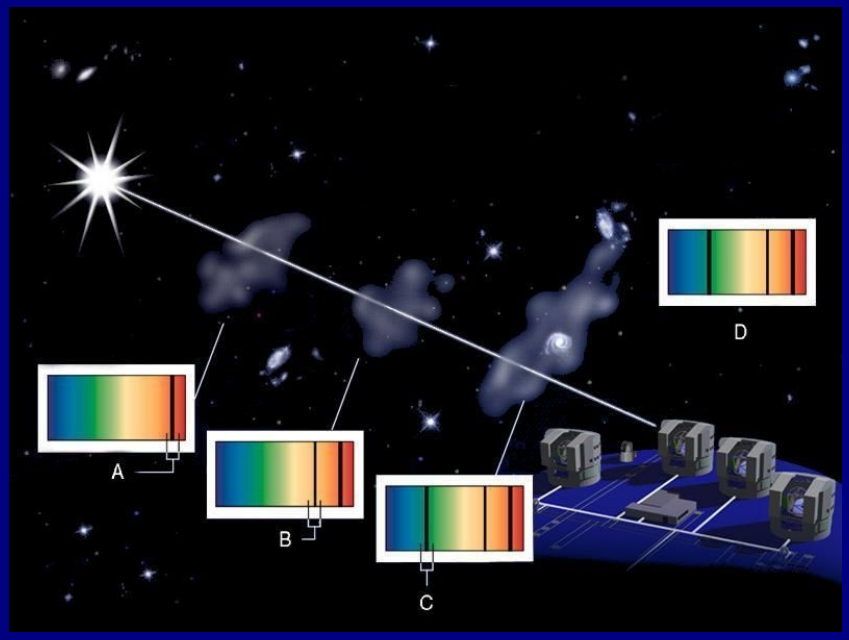
Limitation of 21-cm surveys

- Detection limit $N_{HI} \approx 10^{18}\,cm^{-2}$
- Low angular resolution

Solution:

QSO absorption line spectroscopy

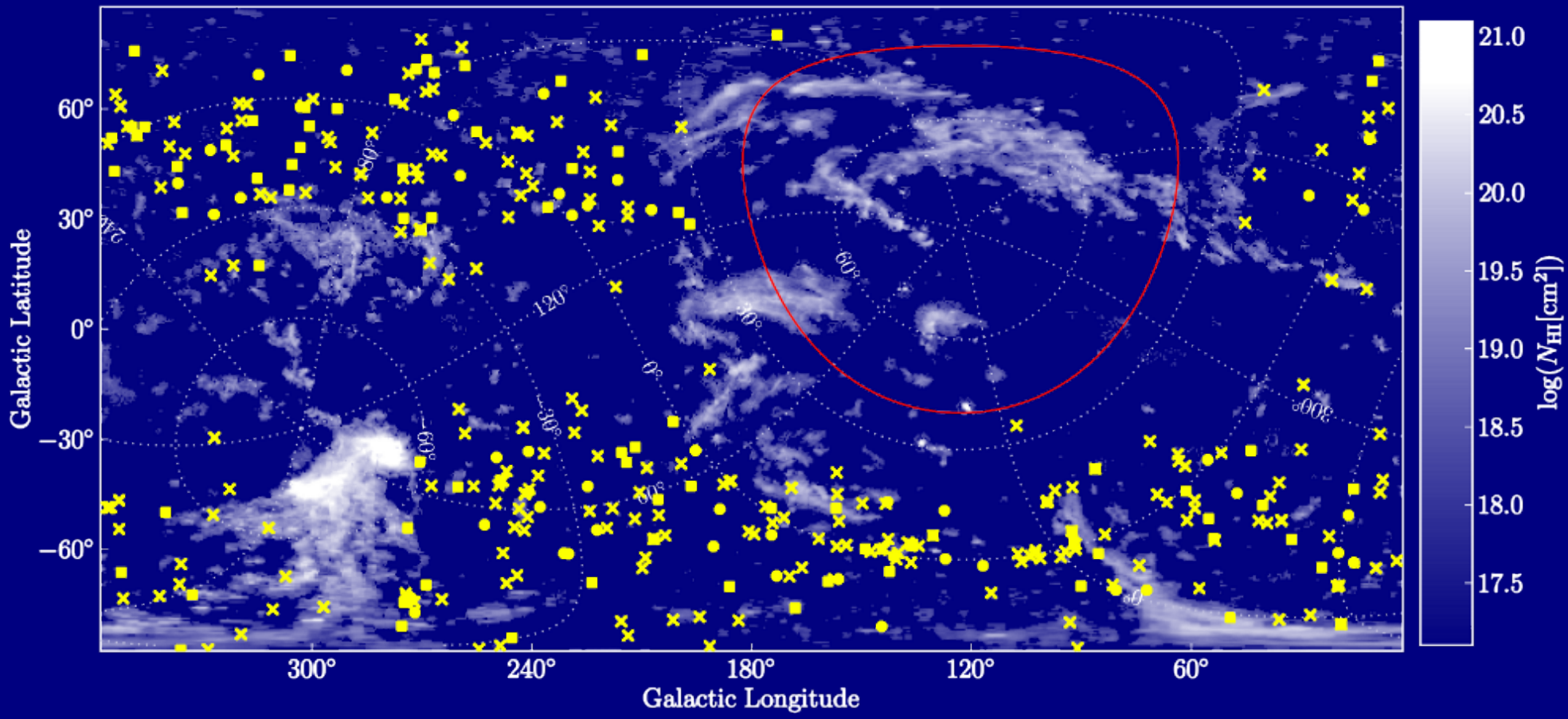


Ed Janssen, ESO

Observed sight lines

HVC all-sky map

408 in total



Ben Bekhti et al., A&A,2012

UVES (ESO archive)
EBHIS (Winkel et al., 2010, Kerp et al., 2011)
GASS (McClure-Griffiths et al., 2009, Kalberla et al., 2010)

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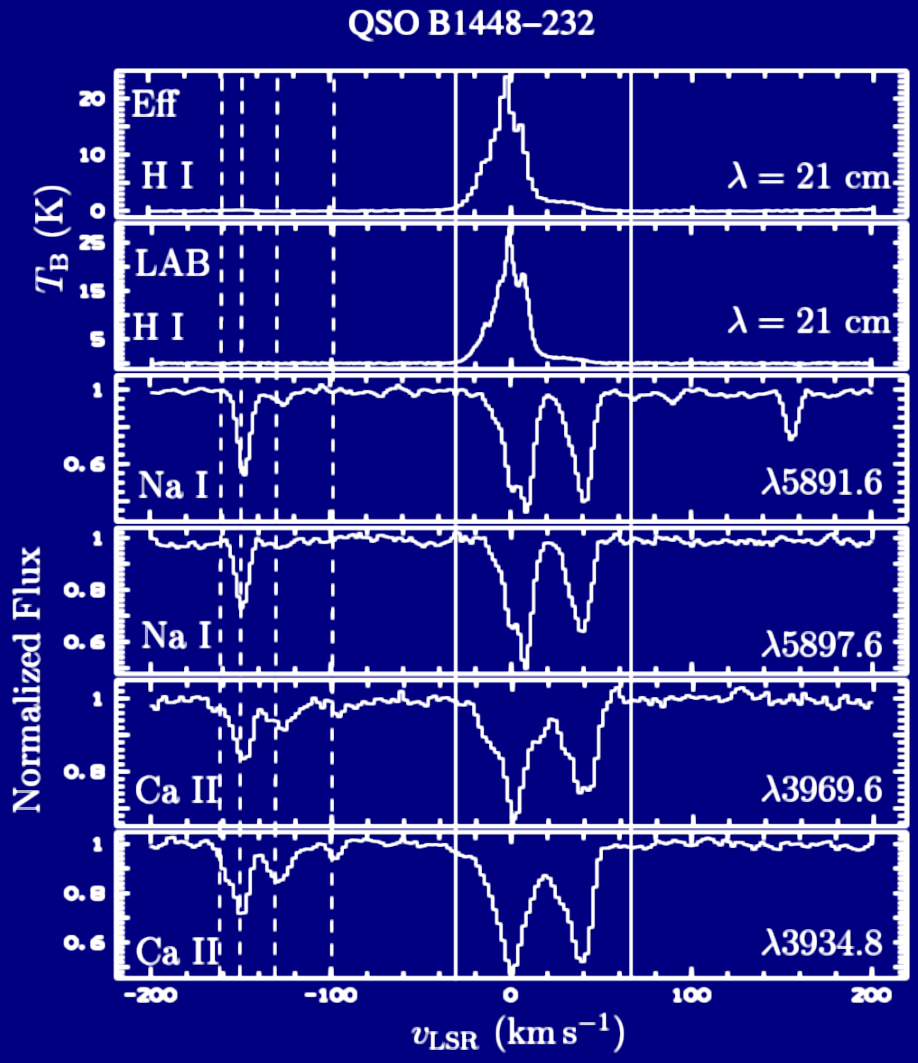
Emission and absorption spectra



Ben Bekhti et al., 2008, 2012

Typical parameters:

Absorption

- $\log(N_{CaII}/cm^{-2}) \approx 10.5...13.5$
- $\log(N_{NaI}/cm^{-2}) \approx 10...13.3$

Emission

- $\log(N_{HI}/cm^{-2}) \approx 18.3...20.3$

Area filling factor f~30%

Velocity distribution

Slight excess towards negative velocities, probably due to infall

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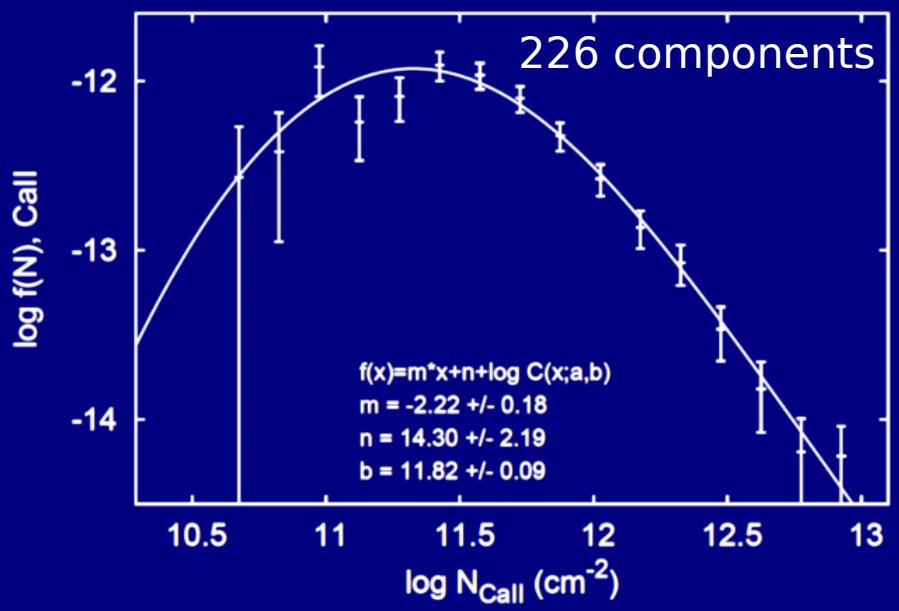
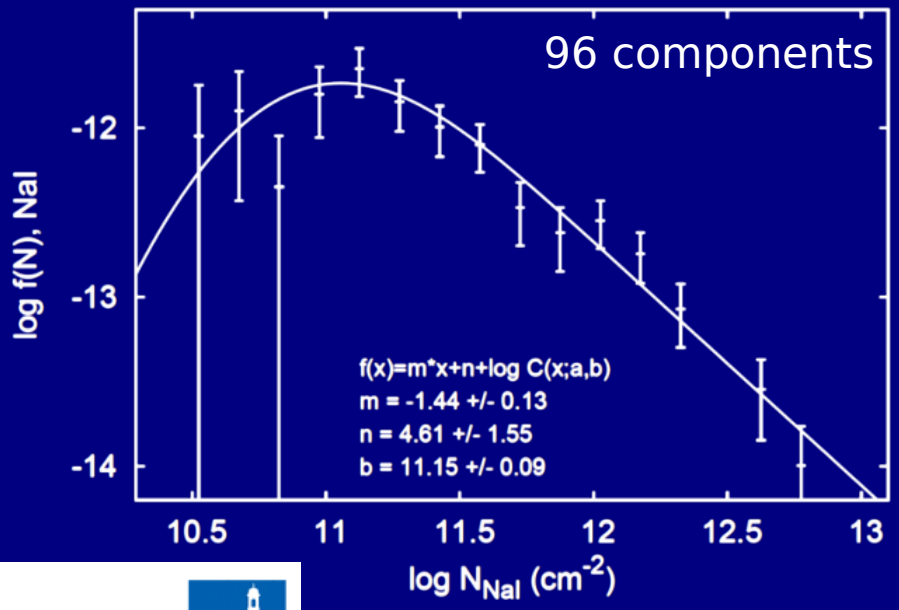
Column-density distribution function





f(N)=m/ΔN

Power law multiplied by completeness function
Ben Bekhti et al., 2012

β = -2.2 +/- 0.2 (CaII)
β = -1.4 +/- 0.1 (NaI)

CaII at z< 0.5 (Richter et al., 2011)
β = -1.7 +/- 0.1

MgII absorbers (Churchill et al., 2003)
β = -1.6 +/- 0.1

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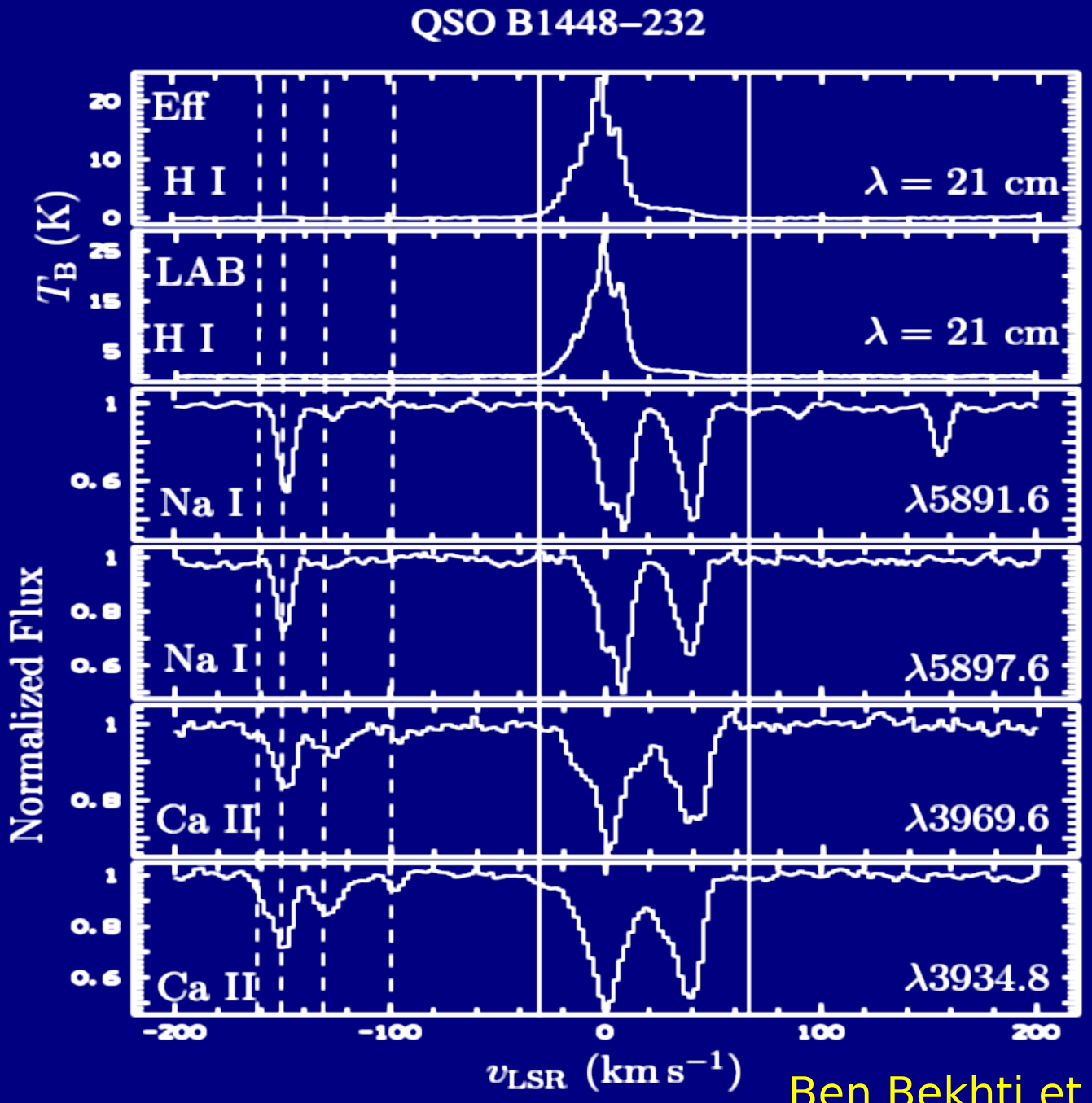


Ben Bekhti et al., 2008

HI results from VLA and WSRT

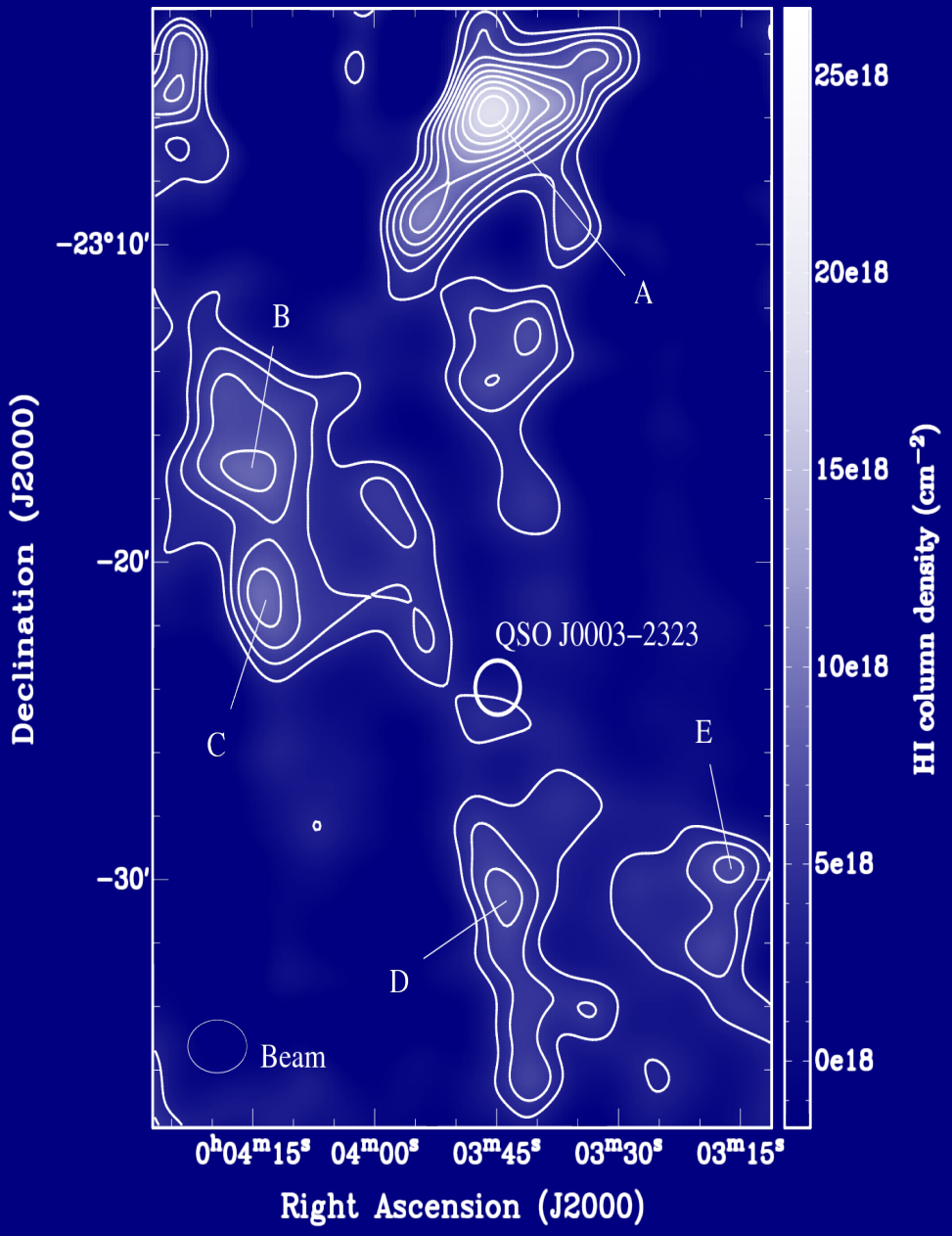
$N_{HI}=10^{18}...10^{19}cm^{-2}$

$\Delta v_{FWHM}=2...13$ km/s

$70 \leq T_{max} \leq 3700$ K

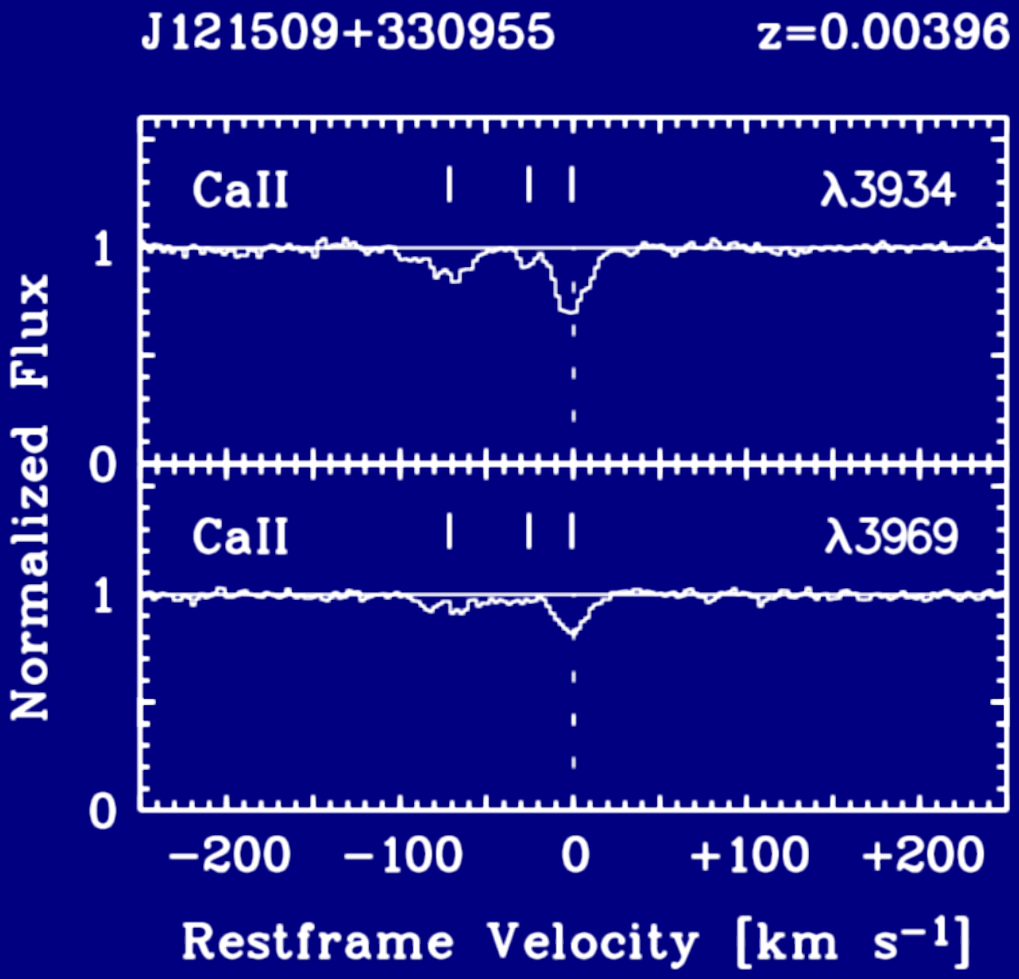
$\Phi \leq 5'$

Cold, compact, clumps in all observed directions



Ben Bekhti et al., 2009

CaII absorbers around other galaxies



- 23 intervening systems ($z < 0.5$)
- log N(CaII) = 11 – 13
- Same properties as Milky Way HVCs

→ Radial extend: 55 kpc

Richter et al., A&A, 2011

Conclusions

- Extended gaseous 21-cm HI halos are just the tip of the iceberg
- Structures on all scales: AU to kpc
- The HI gas is mostly made of discrete clouds with typically f~30%
- Neutral gas halos are common for low and high redshift galaxies

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Outlook

- Multi-wavelength studies
- Halos of galaxies at different z
- Revised view on HVCs:

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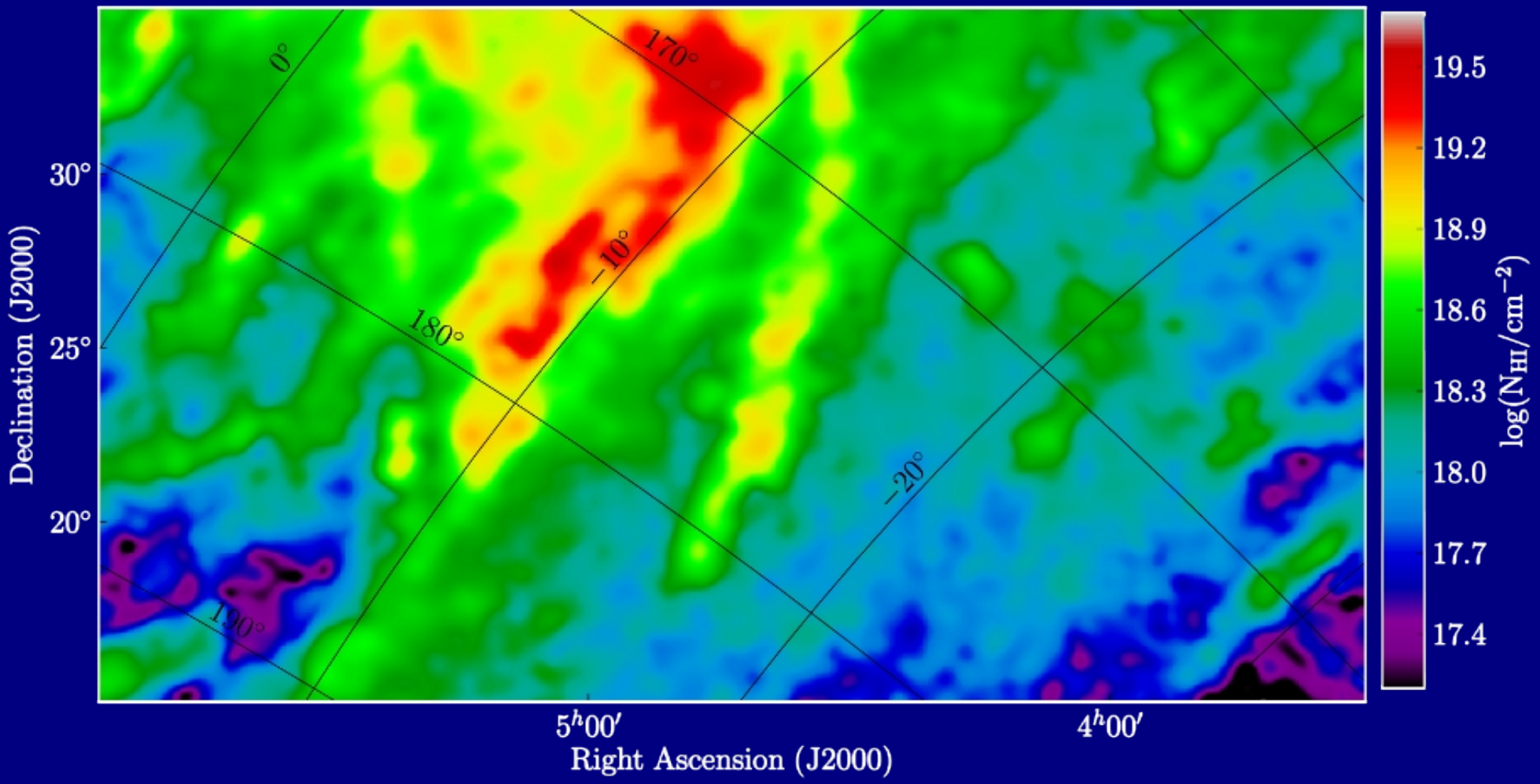
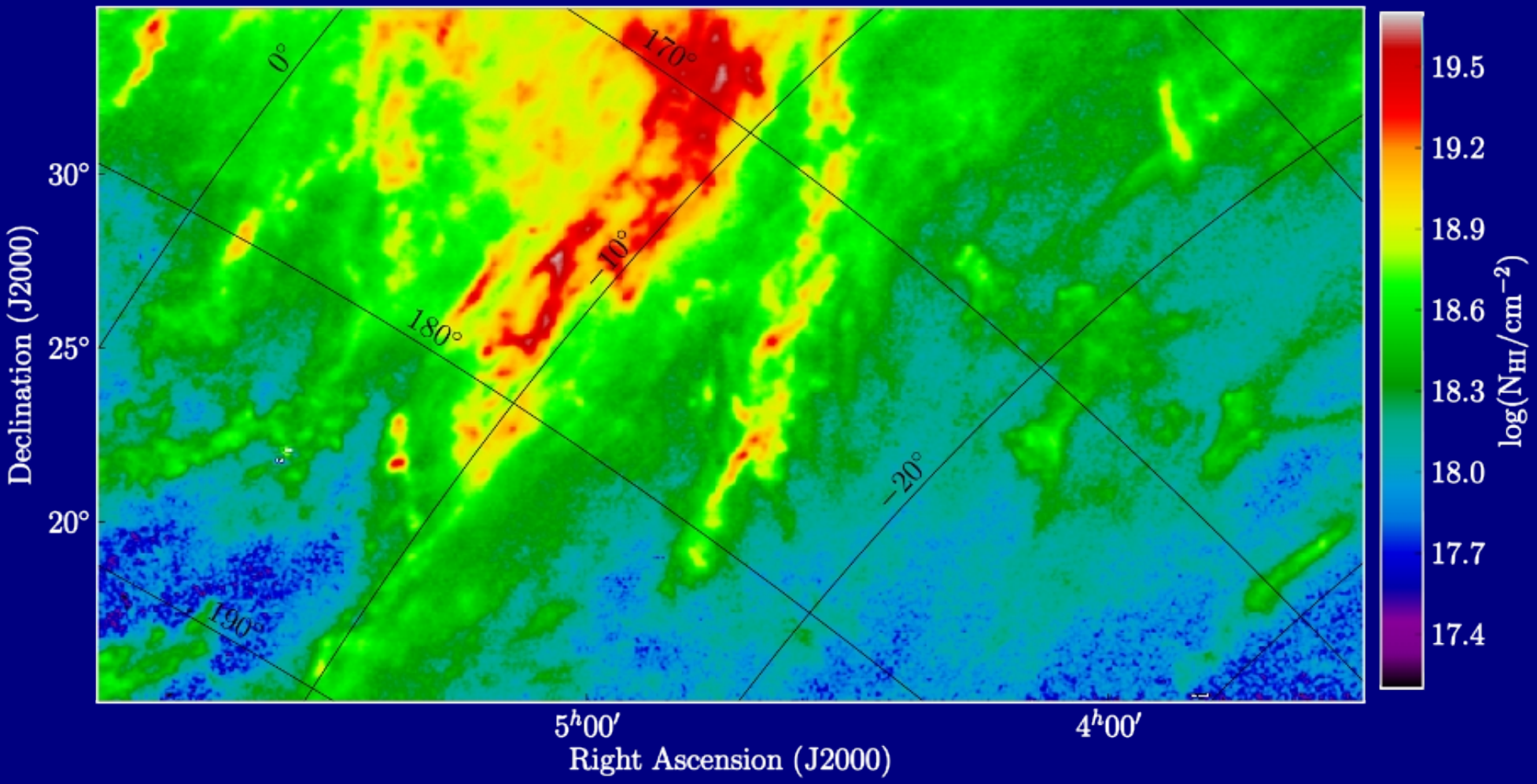
LAB: Leiden/Argentine/Bonn Survey

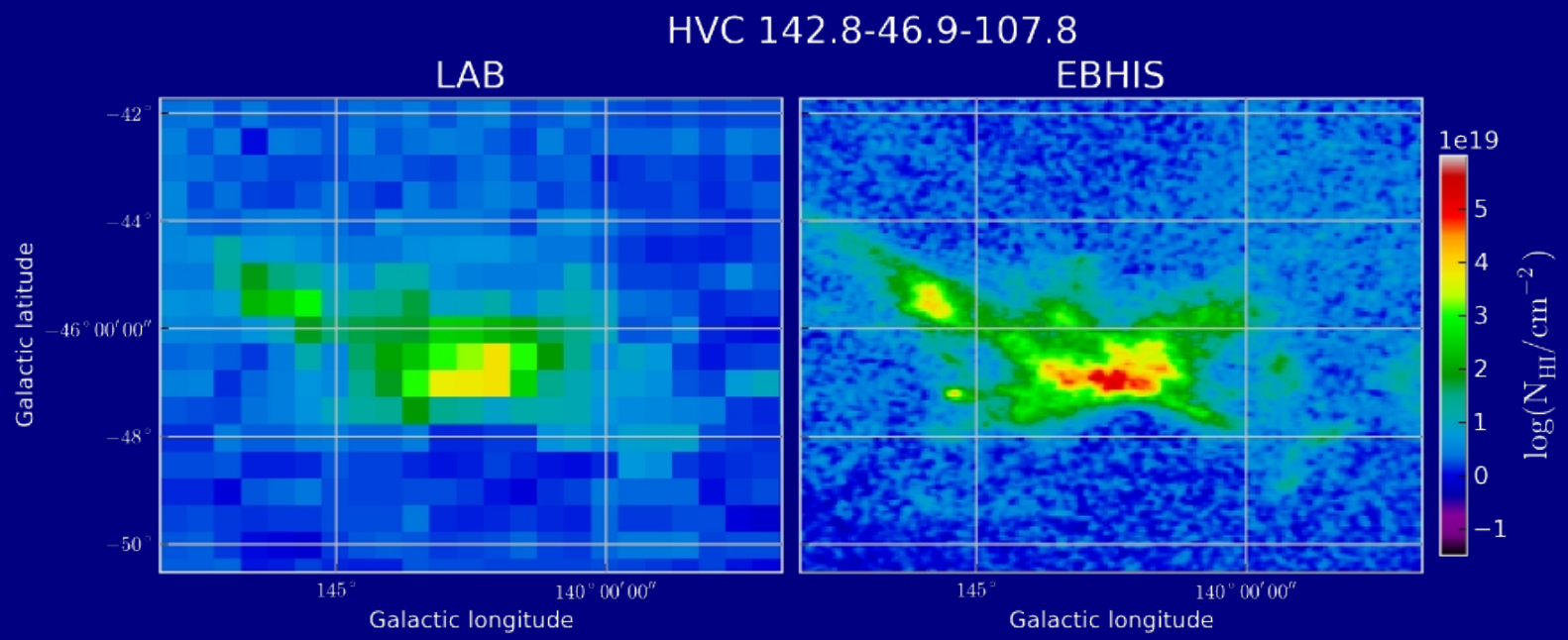


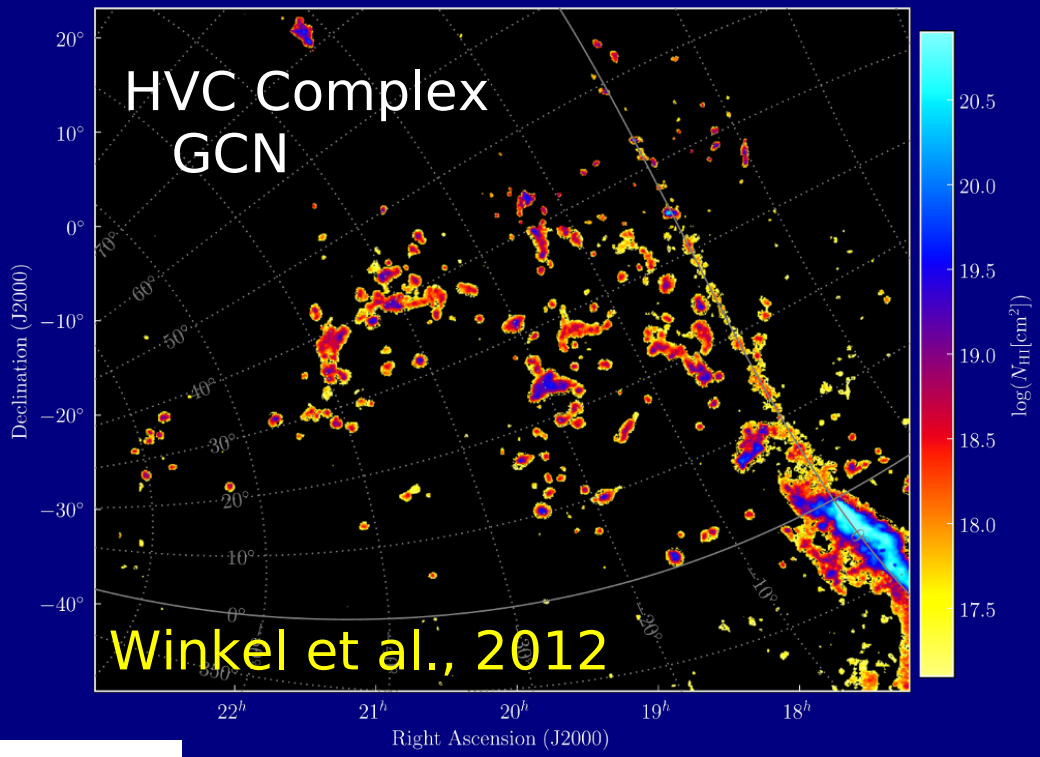
(Kalberla et al., 2005)

EBHIS: Effelsberg-Bonn HI survey



(Winkel et al., 2010, Kerp et al., 2011)


HVC 142.8-46.9-107.8
LAB
EBHIS
Galactic latitude
Galactic longitude
Galactic longitude
1e19
5
4
3
2
1
0
−1
log(N_HI/cm^−2)


HVC Complex
GCN
Winkel et al., 2012
Declination (J2000)
Right Ascension (J2000)
log(N_HI[cm^2])
20.5
20.0
19.5
19.0
18.5
18.0
17.5

Effelsberg-Bonn HI Survey

EBHIS

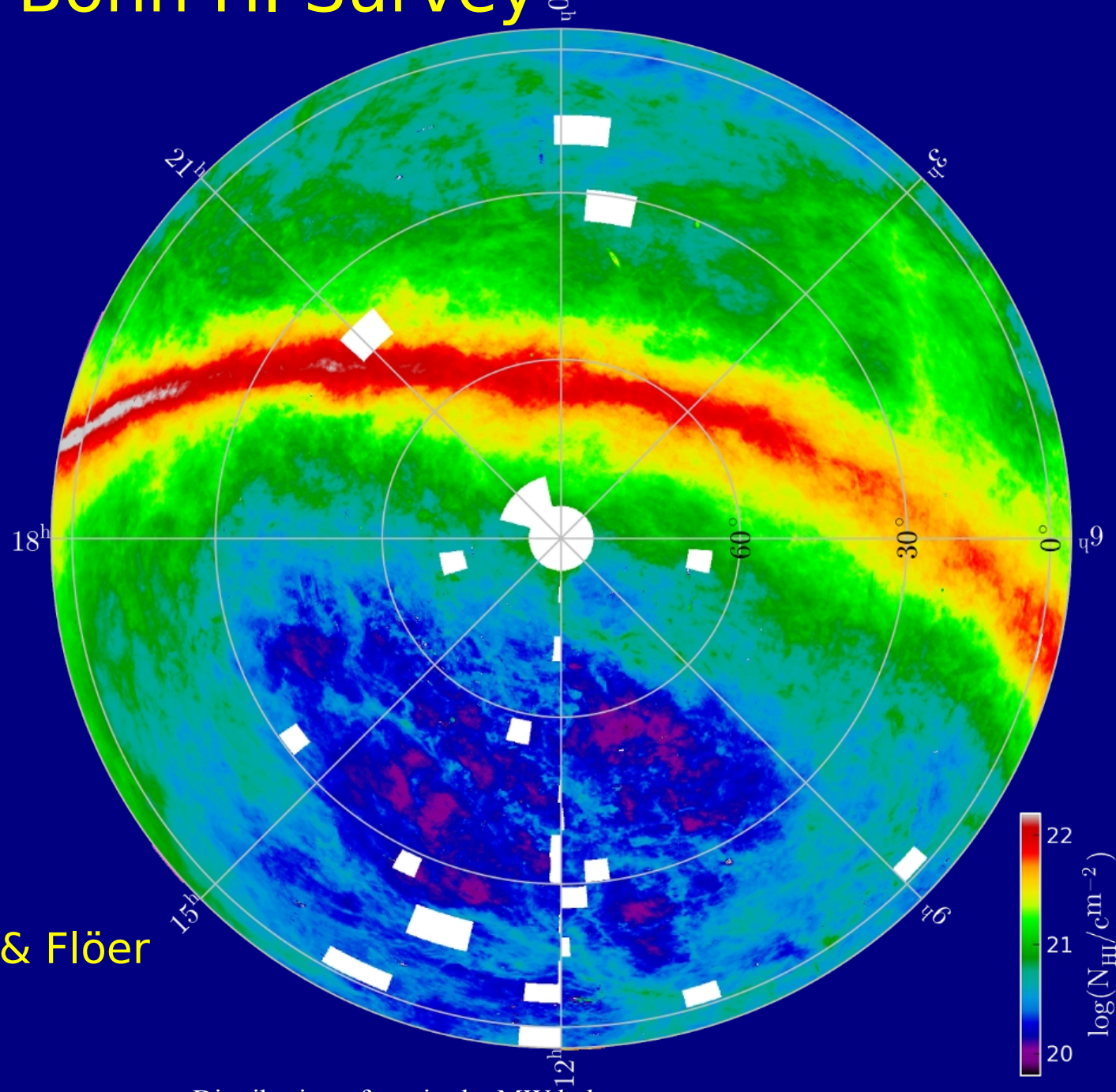


Image: Winkel & Flöer

Distribution of gas in the MW halo

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Thank you!

Philipp Richter, Benjamin Winkel, Uli Klein, Michael Murphy, Peter Kalberla, Jürgen Kerp and the EBHIS team, Verena Lüghausen, Vivien Thiel and Robert-Bosch-Stiftung

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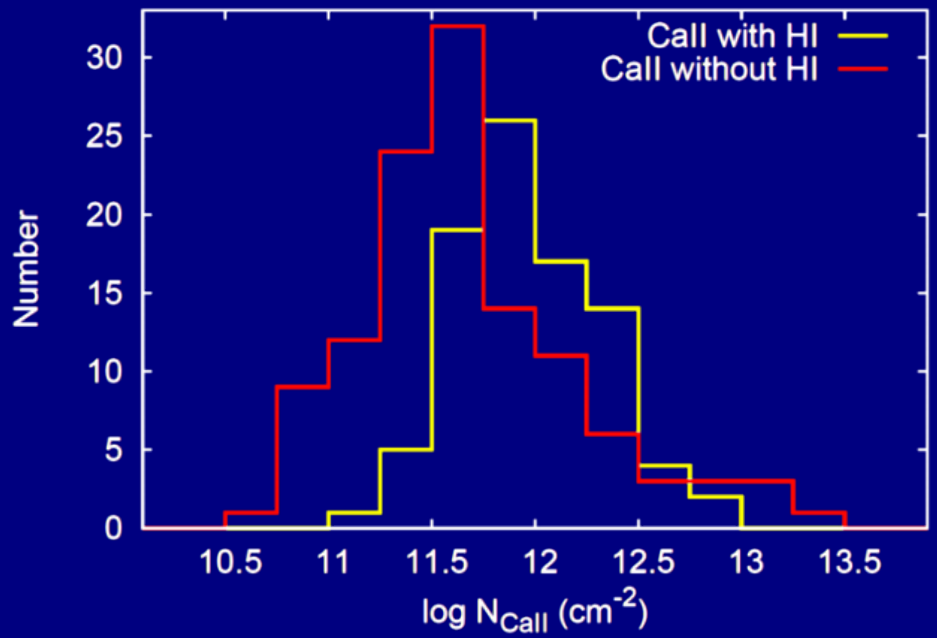
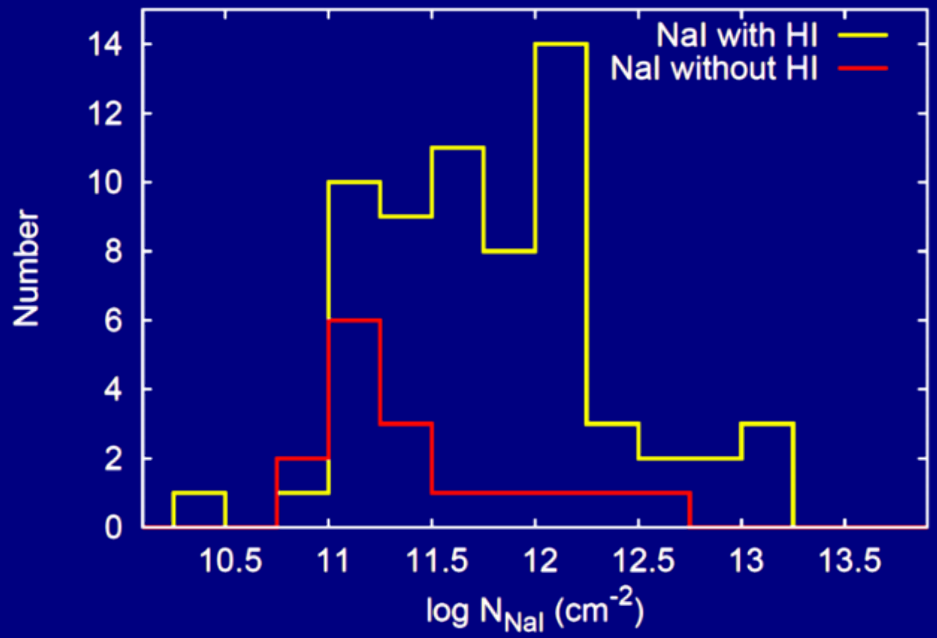
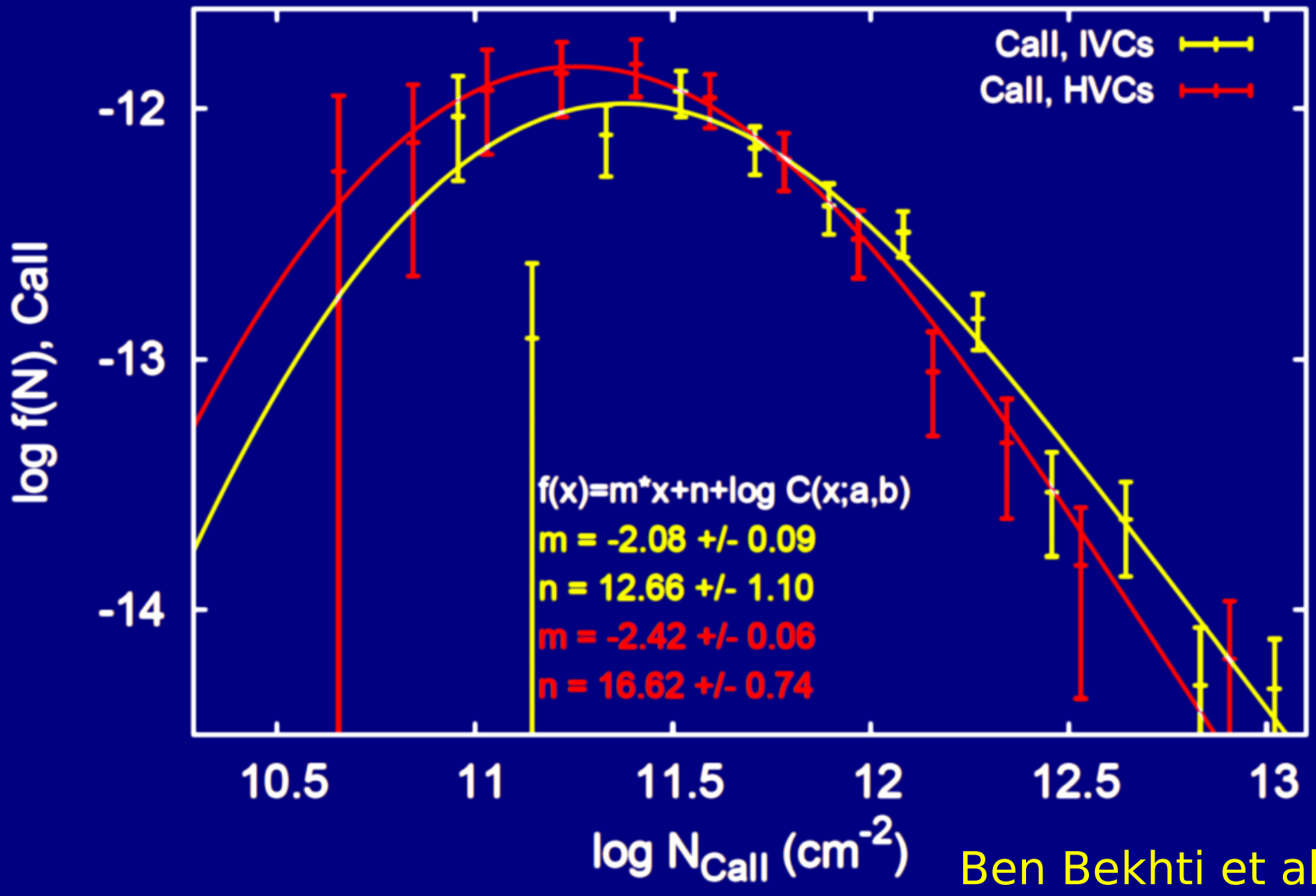




Column densities of CaII/NaI absorbers with and without HI

Ben Bekhti et al., 2012

Column density distribution for IVC and HVC gas



Ben Bekhti et al., 2012