Argelander-Institut für Astronomie

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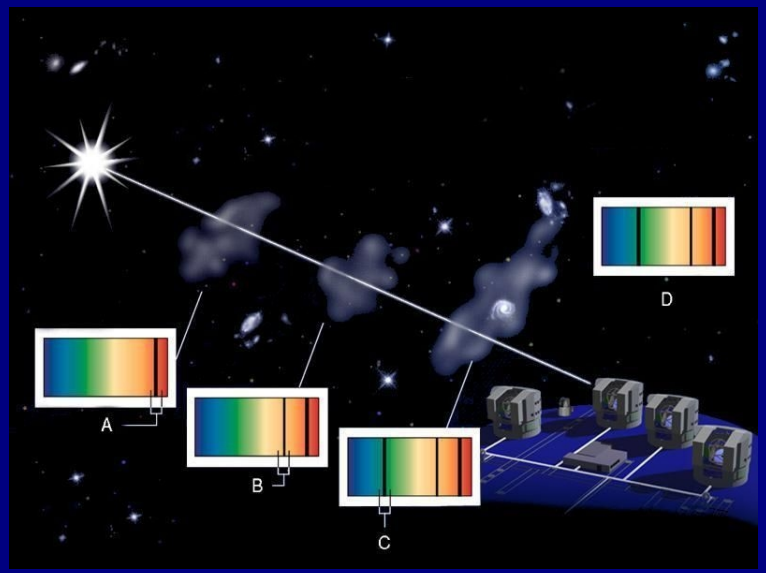
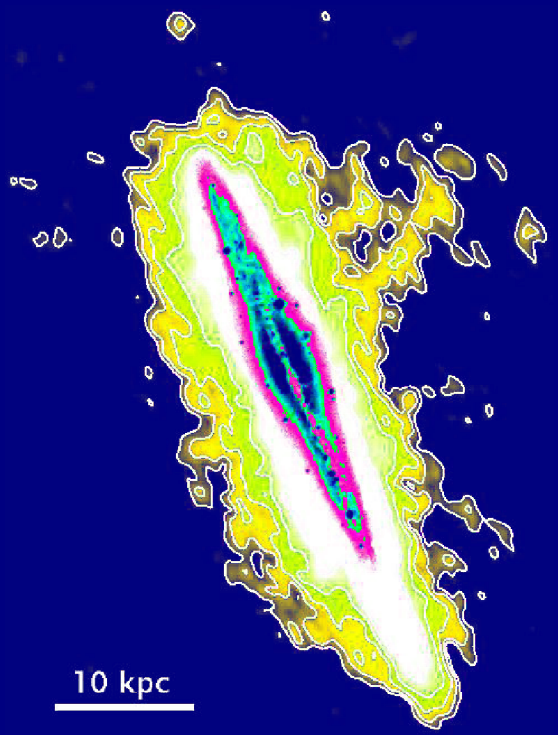
Analysis of galaxy halos using HI 21-cm emission and QSO absorption spectroscopy

Nadya Ben Bekhti

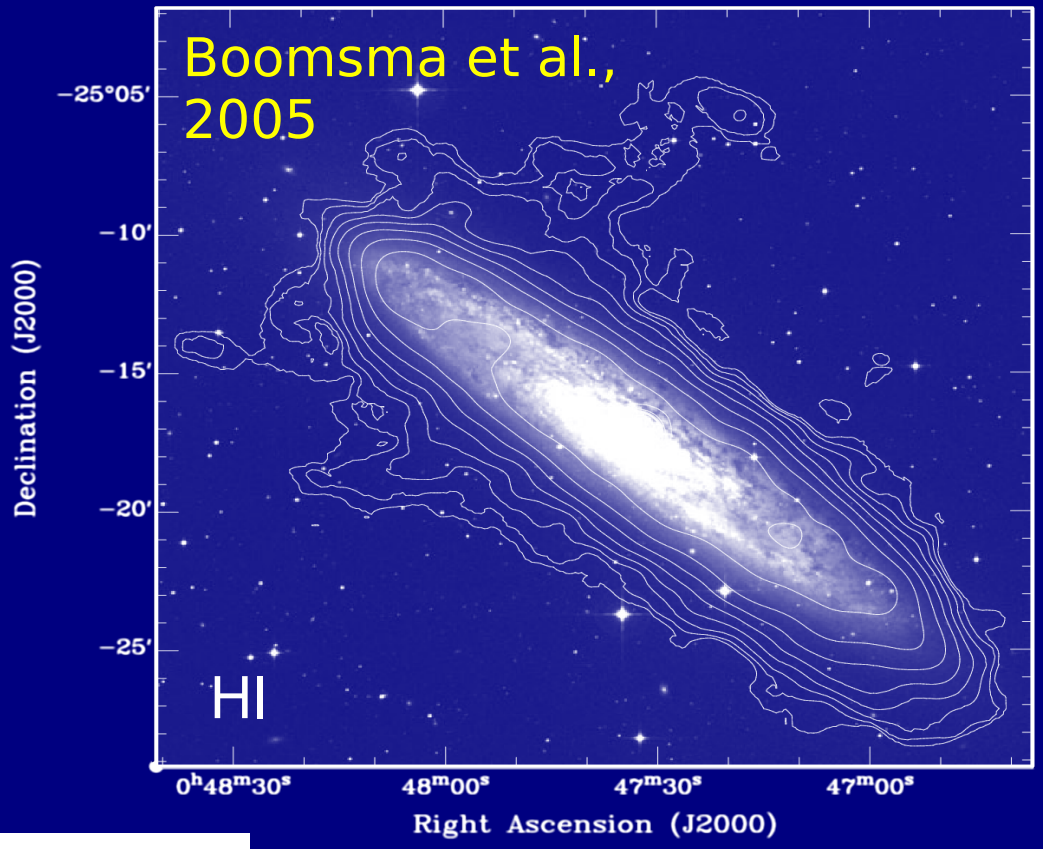


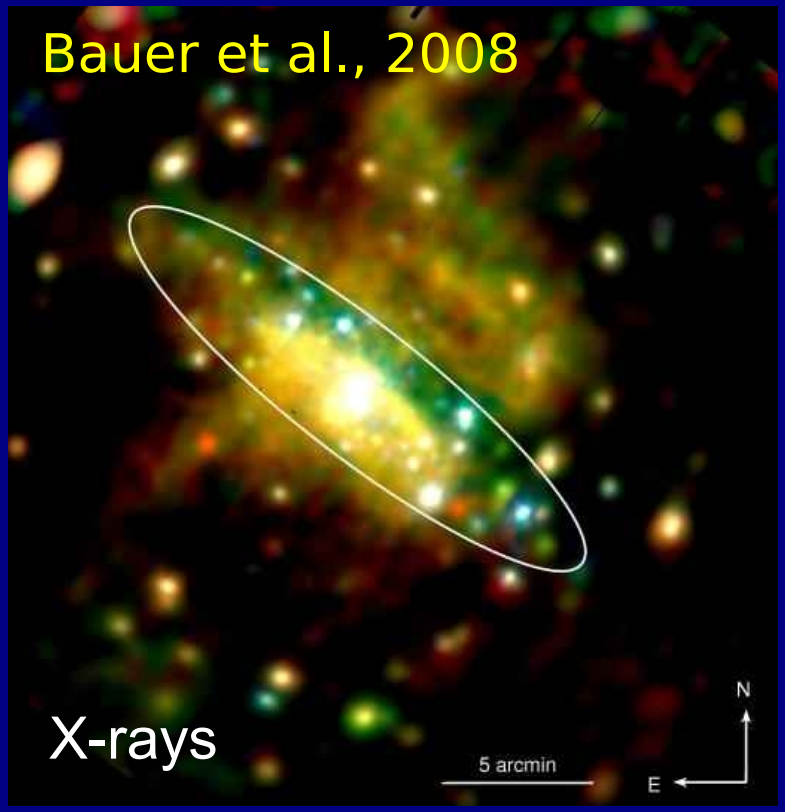


Gas in Galaxies, Kloster Seeon, 14-18 June 2011

Observations

NGC 253





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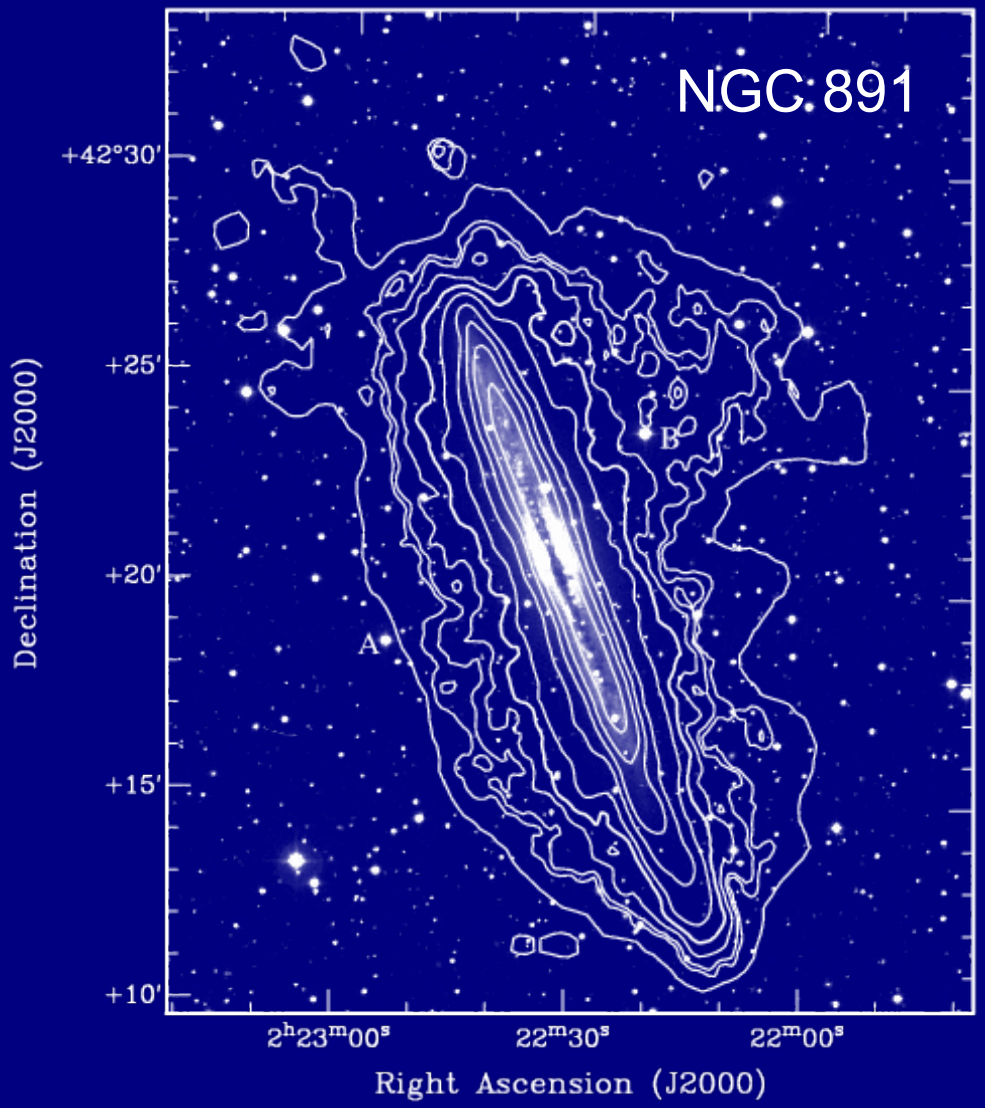
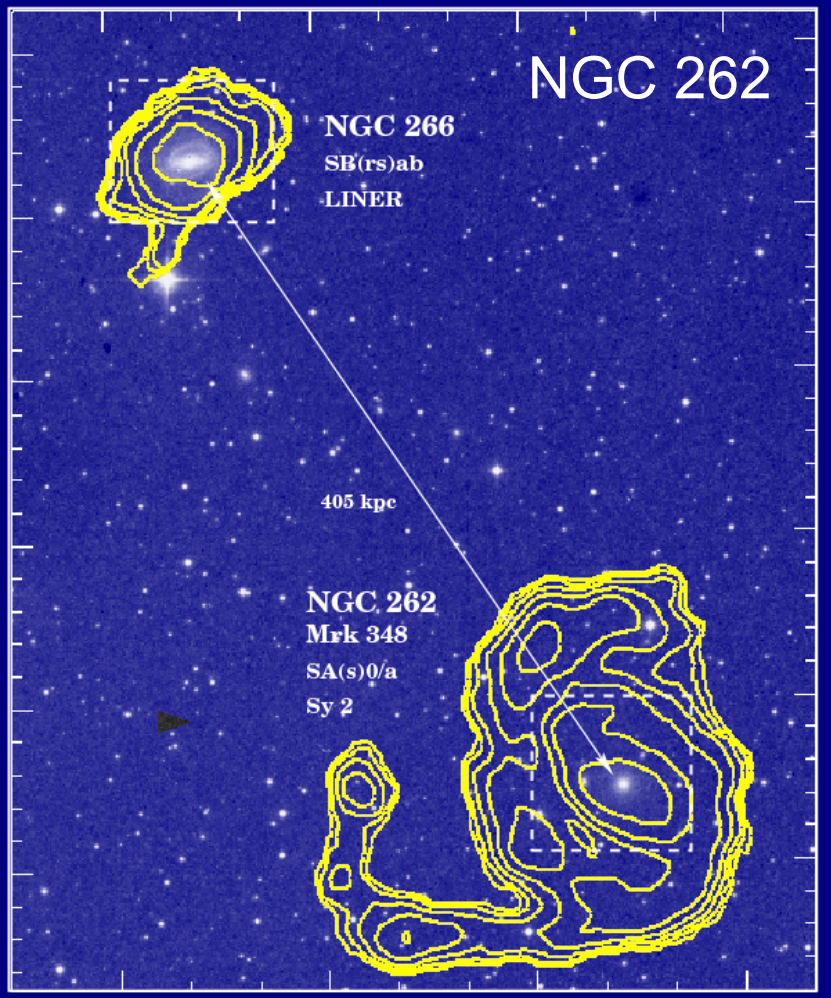
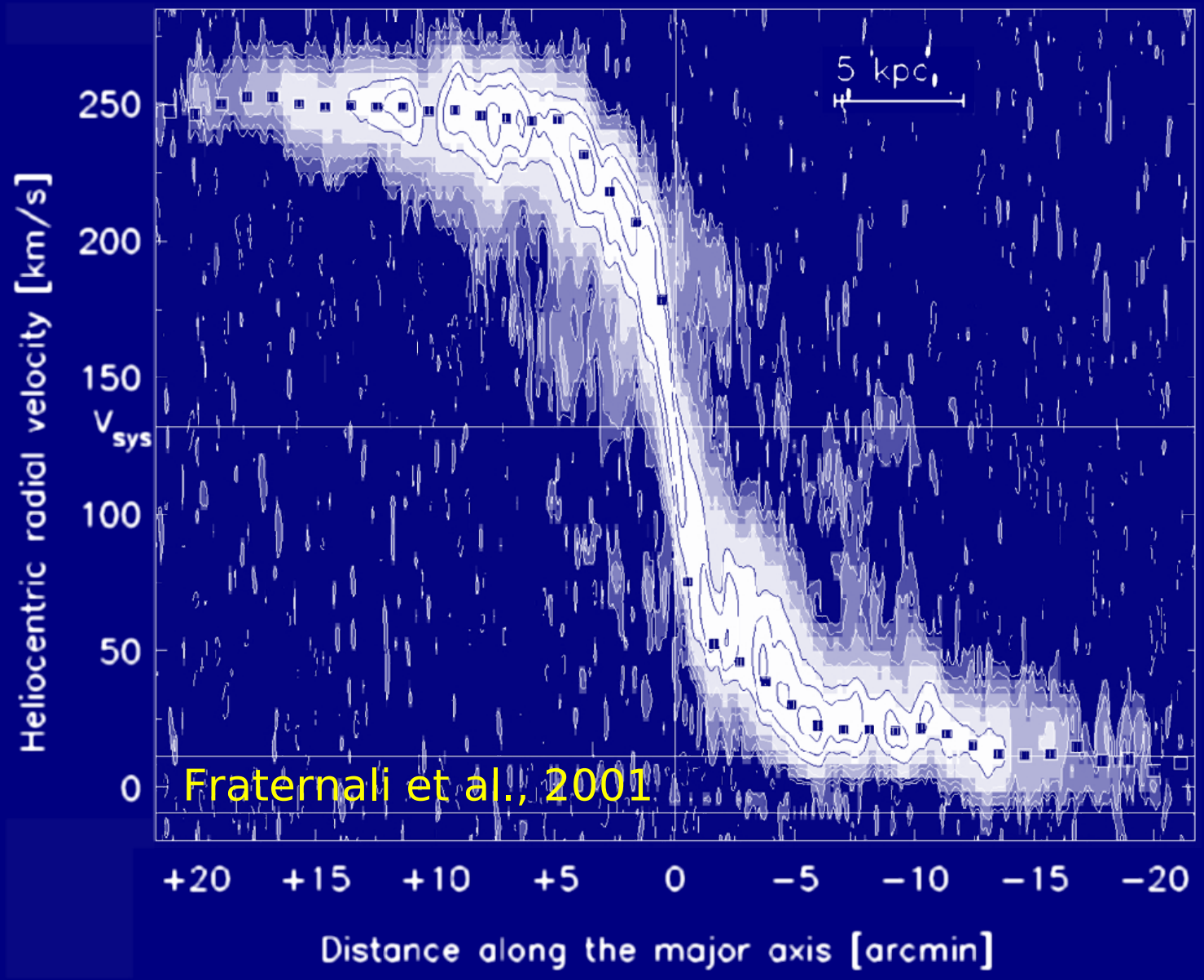




Oosterloo et al., 2007

Simkin et al., 1987

Position-velocity diagramm of NGC 2403



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Observational results

- Up to 30% of the total HI mass in the halo
- Streams, filaments, clouds, clumps
- Lagging halo
- Overall radial inflow

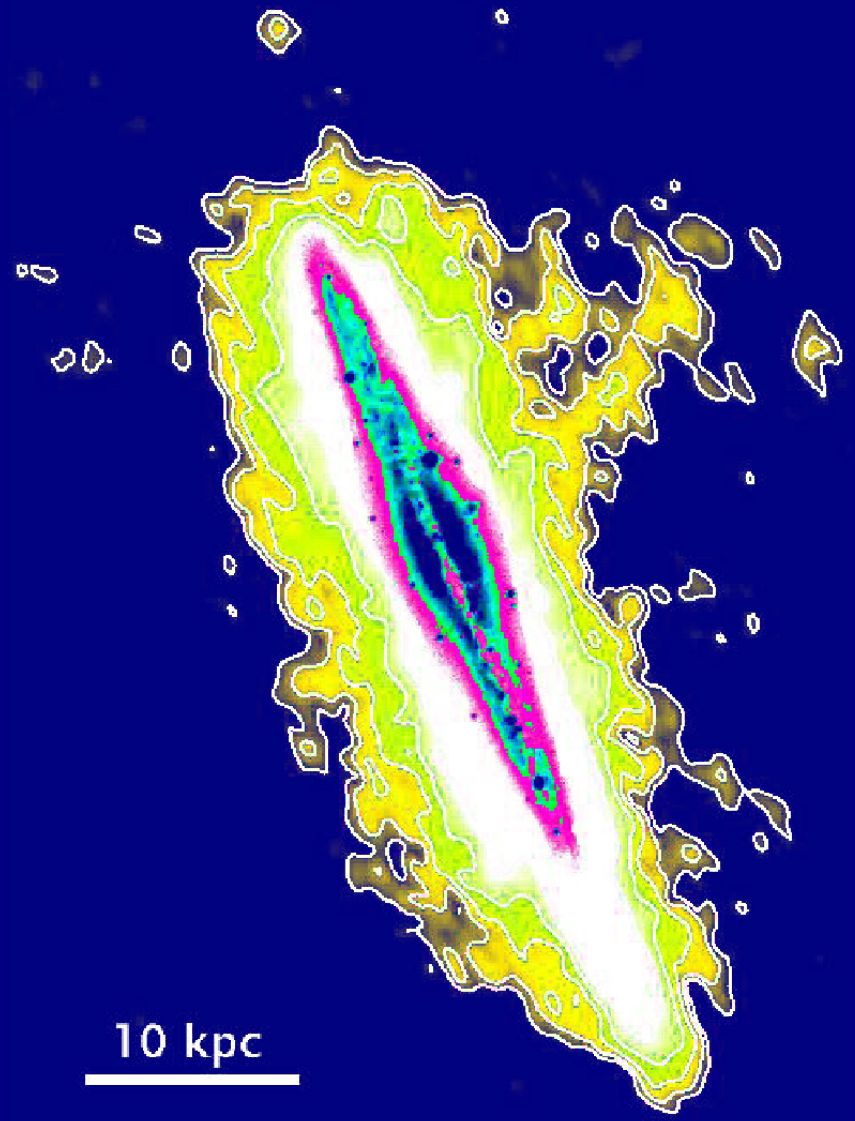
Definition of a gaseous galactic halo

Extent?

Origin?

Filling factor?

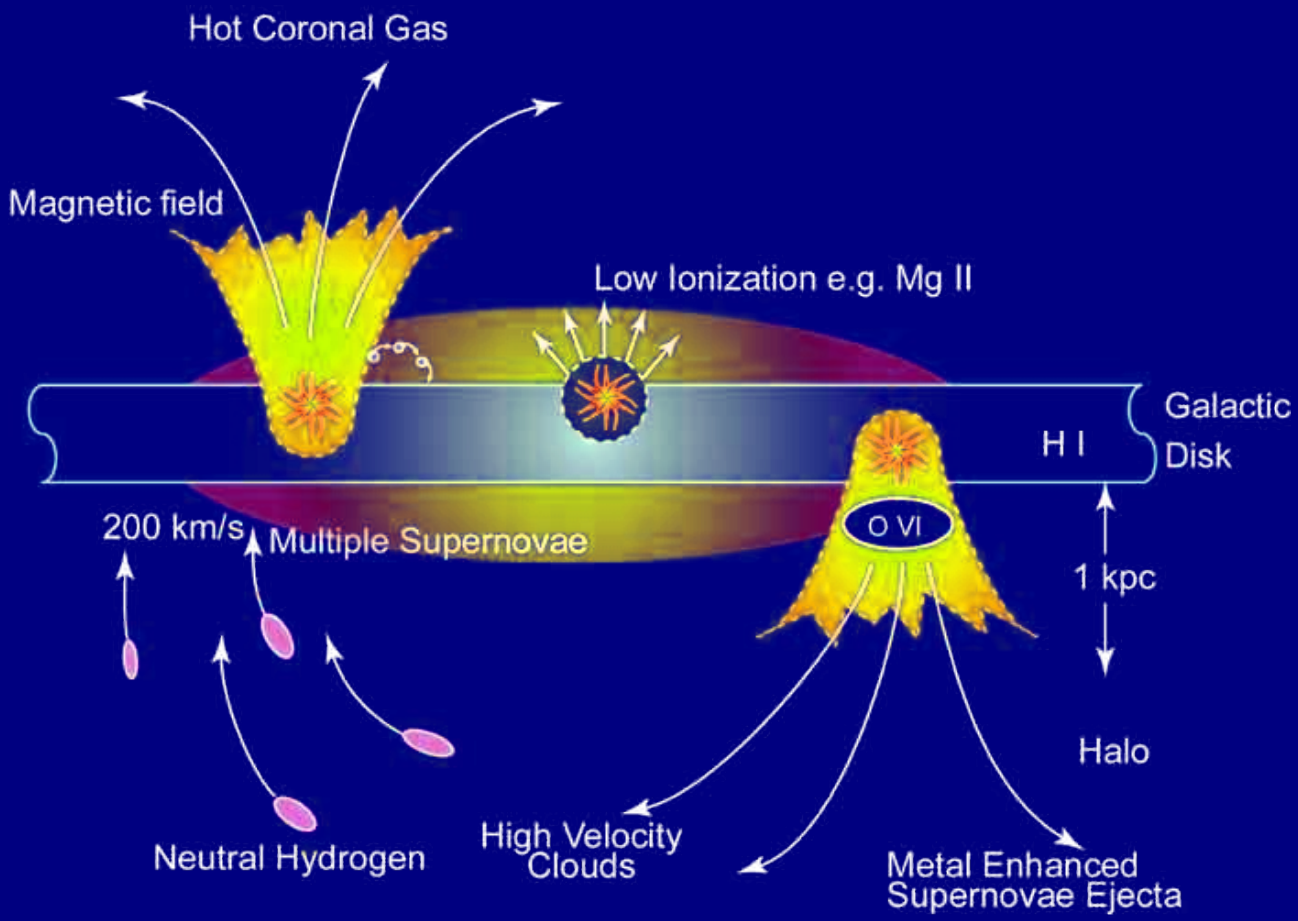
Diffuse or clumpy?



Origin of the halo gas

Galactic origin

- Galactic fountains
- Winds



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

Extragalactic origin

- Primordial
- Gaseous streams (merging, tidal interaction)
- Accretion (remnants of earlier mergers)

Halo gas is the result of complex phenomena involving internal and external processes

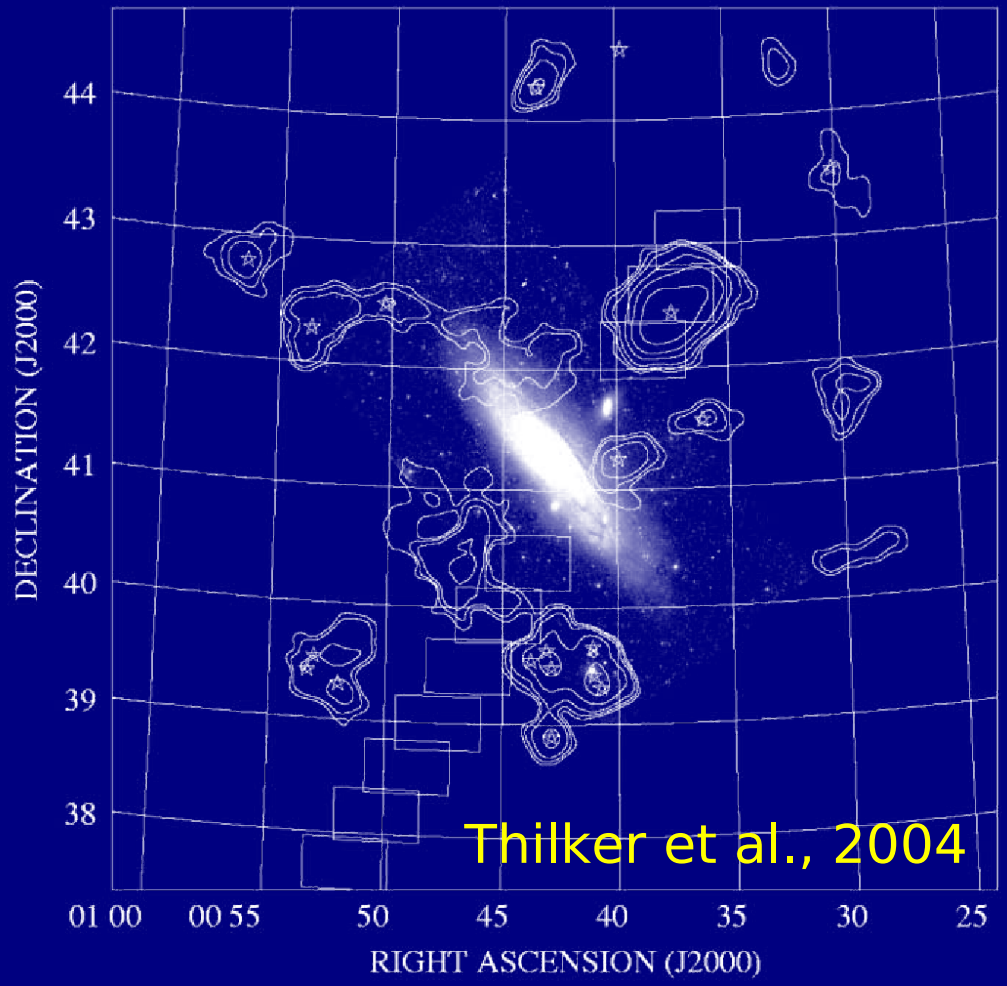
1. Studying the evolution of galaxies

- Halos: up to 30% of the total HI mass in a galaxy
- Material exchange
  → Circulation is fundamental for galactic life circle
- HI gas interacts and influences the host galaxy
  → Constant star formation rates

2. Studying the Intergalactic Medium

- Halos: interface between galaxies and the IGM
  → linking galaxies to the IGM
- λCDM cosmology predicts: most of the baryonic matter in the local universe is in the IGM (White & Frenk, 1991)
- Studying the halo: efficient way to probe the IGM near galaxies

M31



Westmeier et al. 2008:

- Lack of clouds beyond 50 kpc
- Detection limit: $8 \times 10^4\ M_\odot$
- $M_{clouds} = 10^5$ to $10^6\ M_\odot$

→ Area filling factor of f~30%

The Milky Way halo

Intermediate- and high-velocity clouds

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

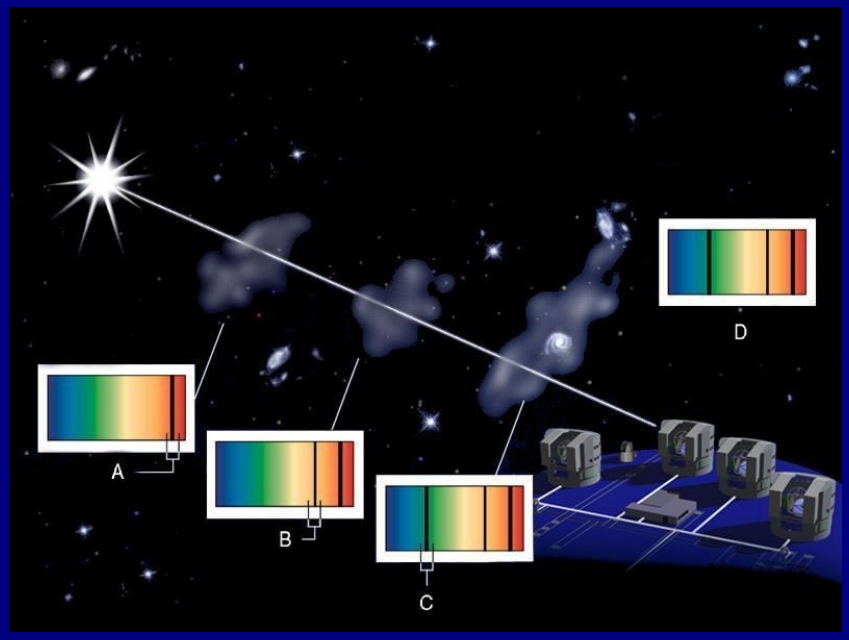
(Wakker et al., 2001, 2007, 2008, Richter et al., 2001, Thom et al. 2006)

Studying the Milky Way halo

21-cm HI data → EBHIS + GASS

QSO absorption line spectroscopy

- Absorption-selected sample

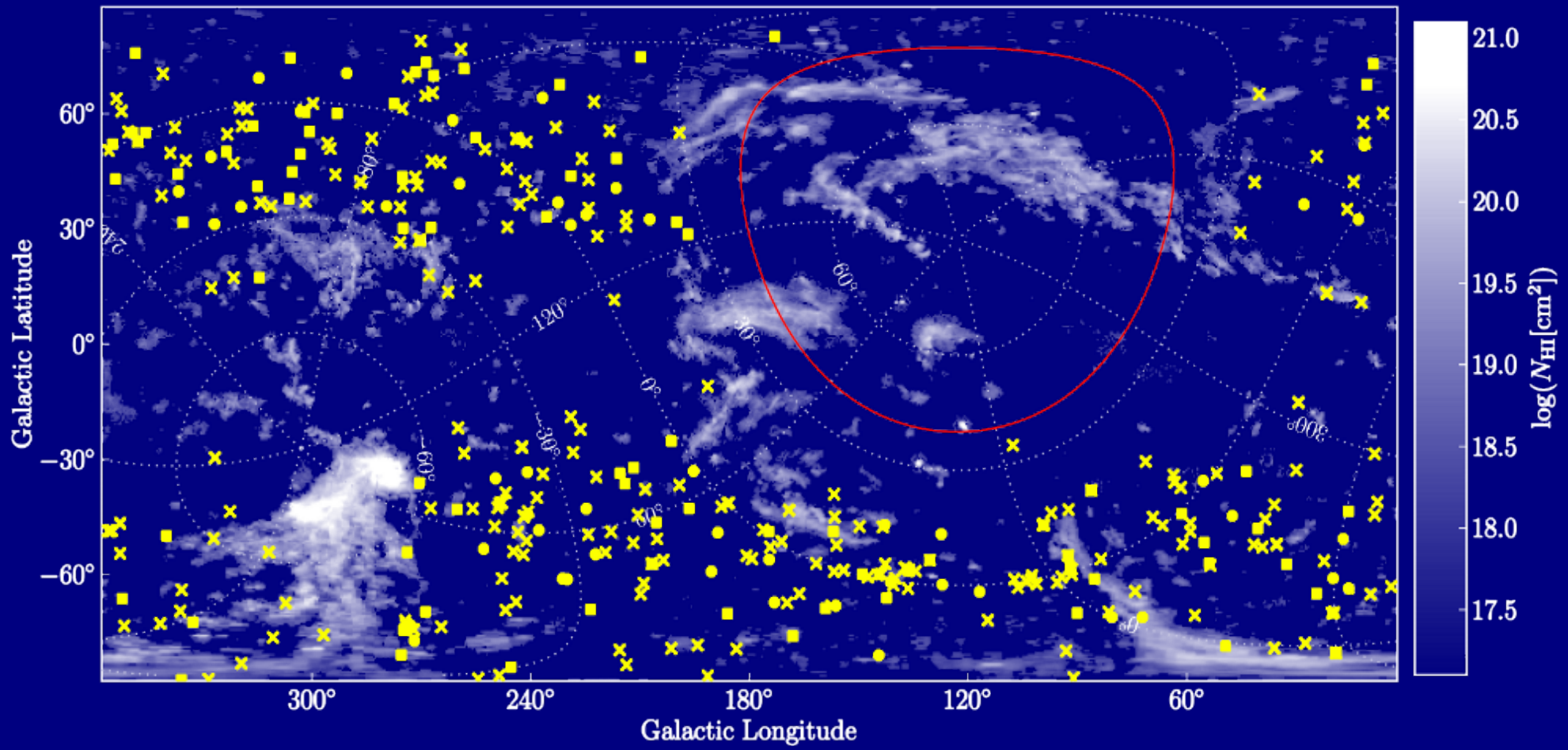


Ed Janssen, ESO

Observed sight lines

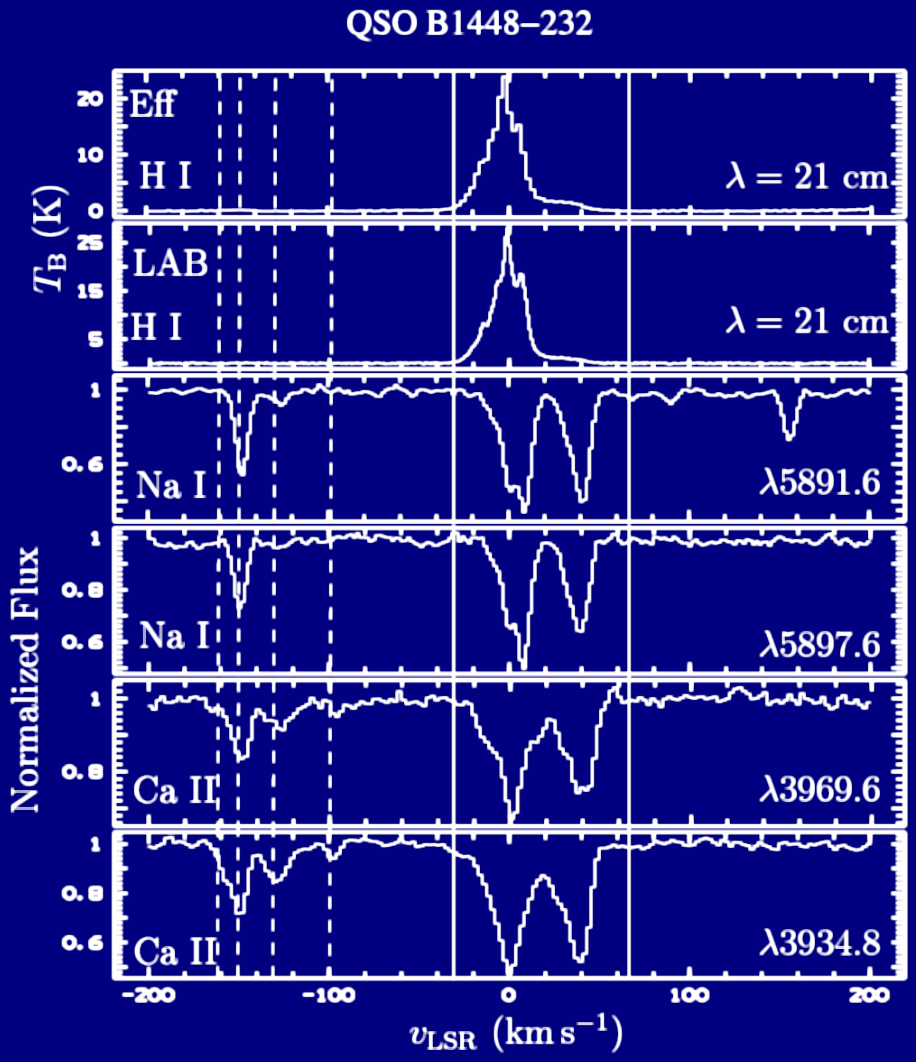
HVC all-sky map

400 in total



Ben Bekhti et al., in prep.

Emission and absorption spectra



Ben Bekhti et al., 2008

Typical parameters:

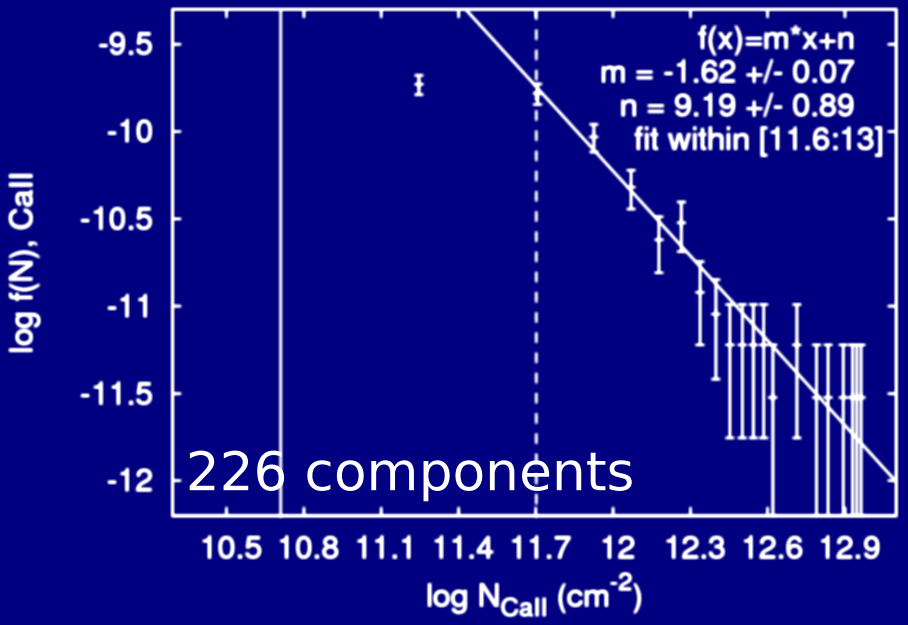
Absorption

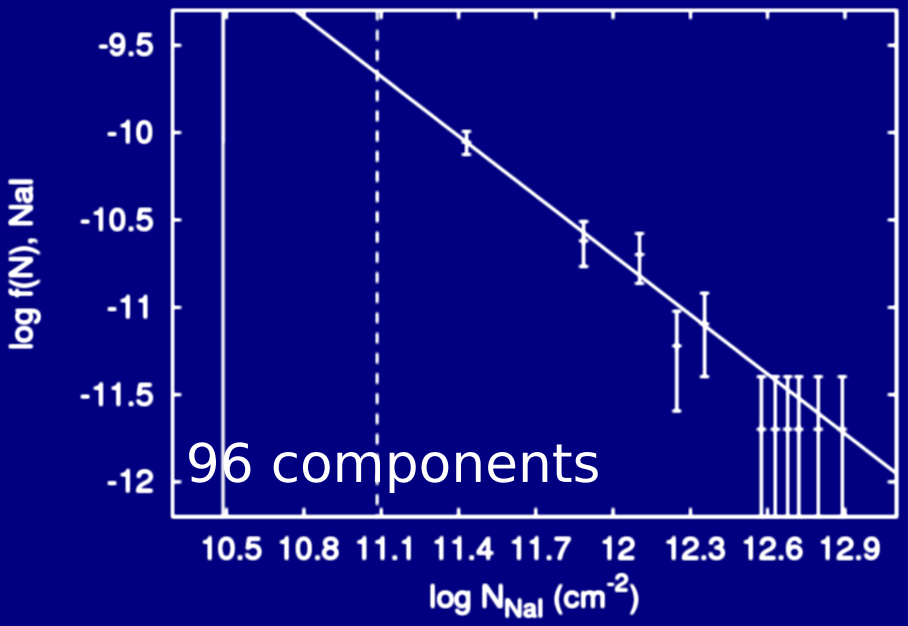
- $\log(N_{CaII}/cm^{-2}) \approx 11...12.5$
- $b \leq 7$ km/s

Emission

- $\log(N_{HI}/cm^{-2}) \approx 19...20$
- $b \leq 20$ km/s

Area filling factor f~30%





CaII/NaI column densities

Column-density distribution function

$f(N)=m/\Delta N$

Power law, N^{β},with

Ben Bekhti et al., 2008

$\beta = -1.62 +/- 0.1$ (CaII)

$\beta = -1.14 +/- 0.07$ (NaI)

MgII absorbers

Churchill et al., 2003

$\beta = -1.6 +/- 0.1$

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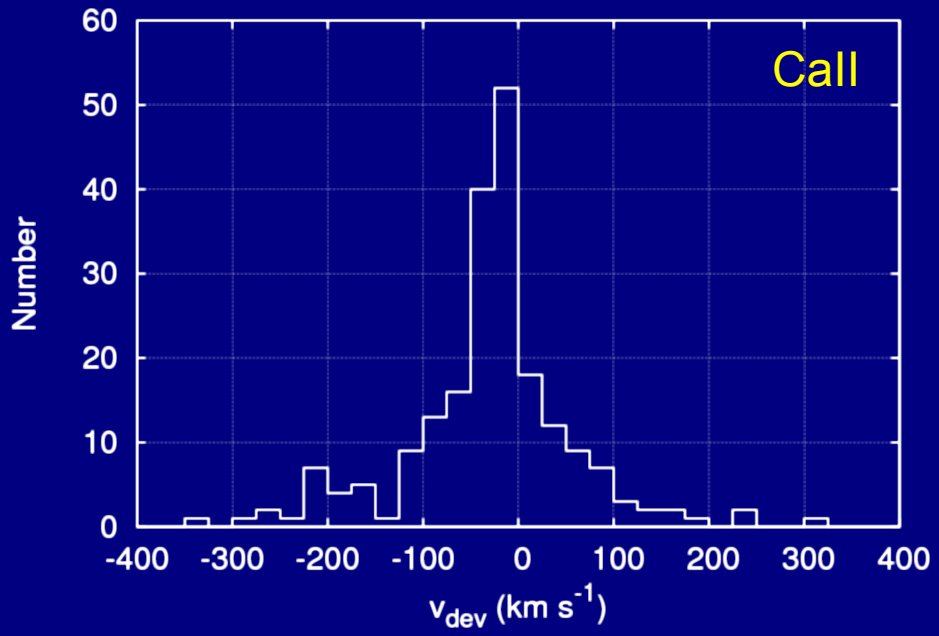
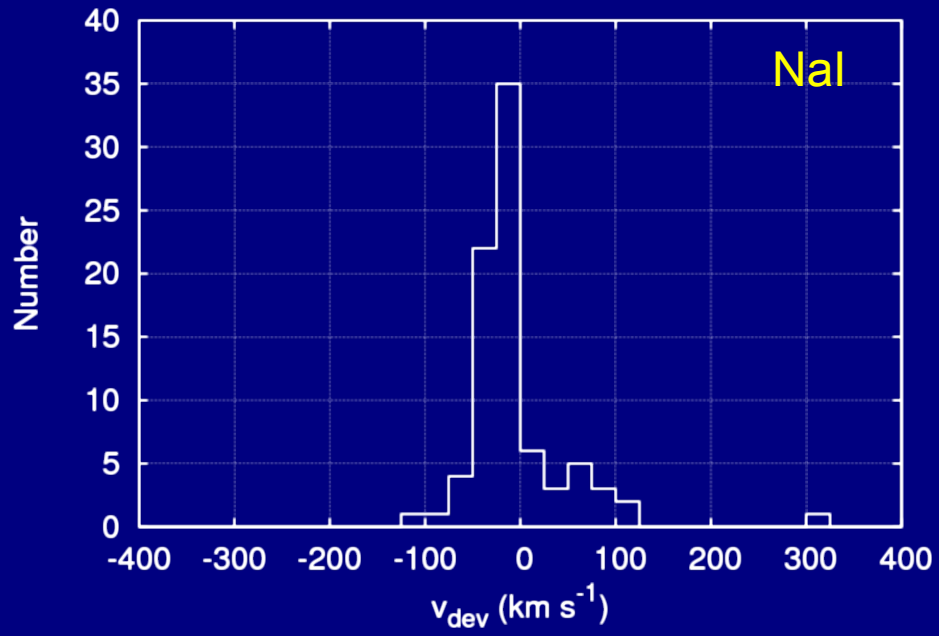
Velocity distribution





Slight excess towards negative velocities, probably due to infall

HI results from VLA and WSRT

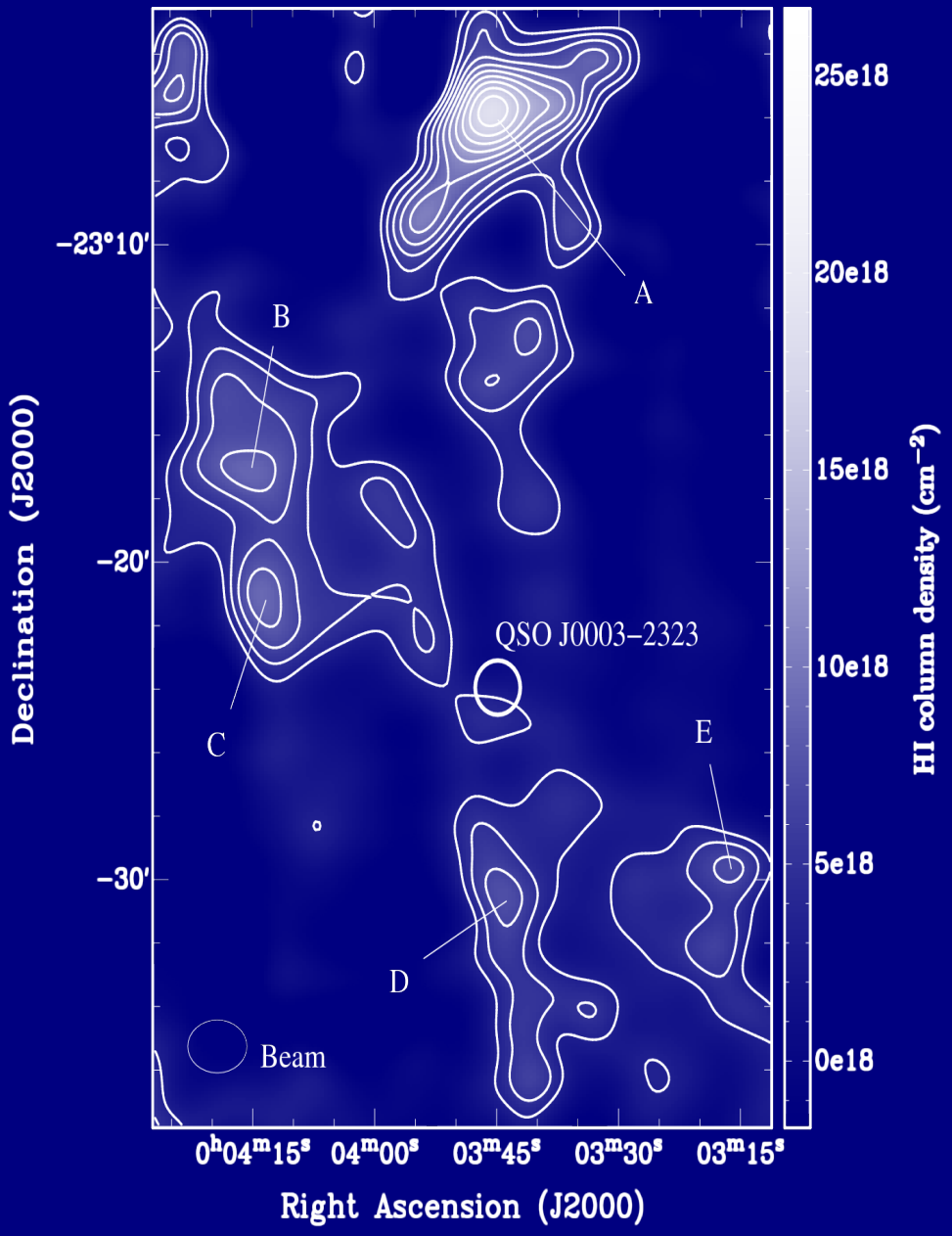
$N_{HI}=10^{18}...10^{19}cm^{-2}$

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

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

$\Phi \leq 5'$

Cold, compact, clumps in all four directions



Ben Bekhti et al., 2009

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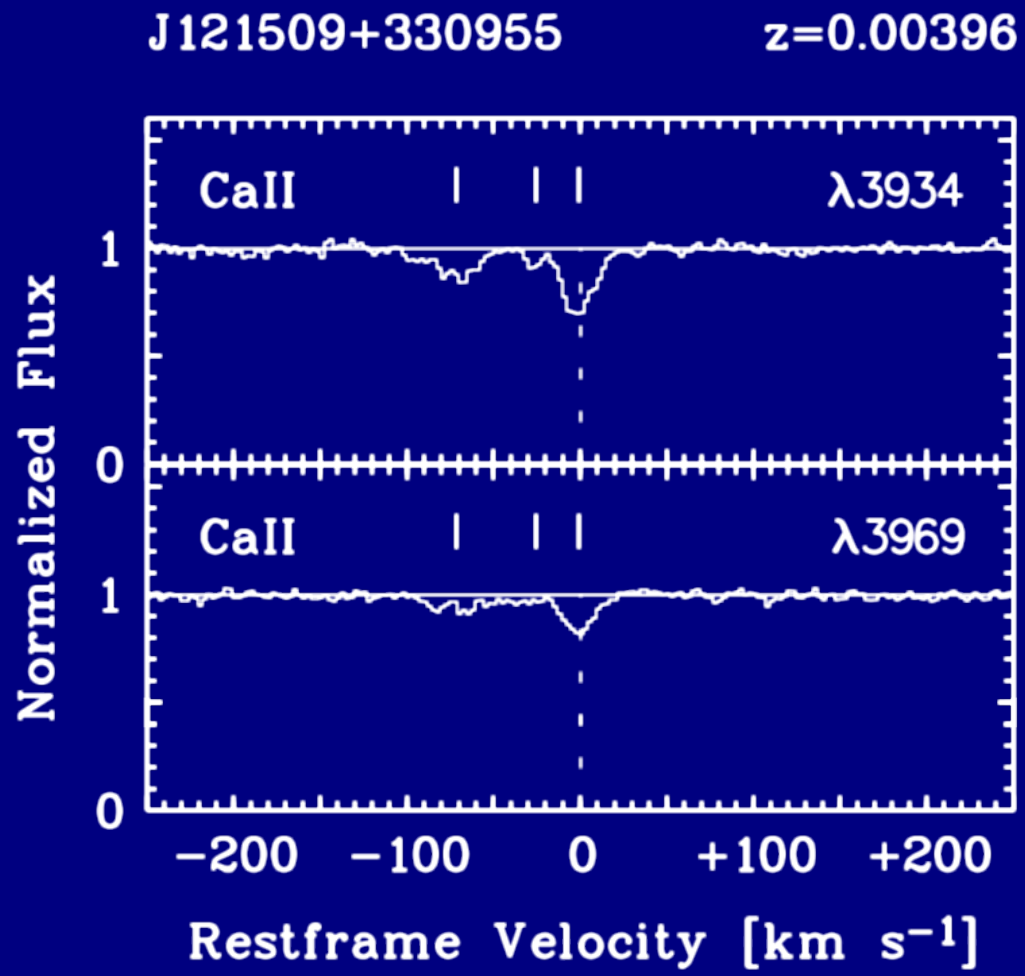
CaII absorbers around other galaxies



- 23 intervening systems ($z < 0.5$)
- log N(CaII) = 11 – 13
- Same properties as Milky Way HVCs
- dN/dz (CaII) = 0.117

→ Radial extend: 55 kpc

Richter et al., 2011

Conclusions

- Extended gaseous 21-cm HI halos are just the tip of the iceberg
- Structures on all scales: AU to kpc
- Streams, clouds, clumps, and filaments do not have a common origin
- The HI gas is mostly made of discrete clouds with typically f~30%
- Neutral gas halos are common for low and high redshift galaxies

Open questions

- How much HI gas is in galaxy halos?
  → Extent, radial distribution
- Evolution effects:
  → Accretion rate → const. SFR
- How does the gas cycle work?
- What role do magnetic fields play?
- Is the accretion cold or warm?
- Stable or transient objects?

Outlook

Multi-wavelength studies

Combining:

- Absorption line studies in the Optical and UV
  → COS
- High-resolution & sensitivity data:
  EBHIS, GASS, WSRT, ATCA, ASKAP, LOFAR
  → SKA
- Simulations