Survey Science with the Canadian Large Adaptive Reflector: A Step towards the SKA

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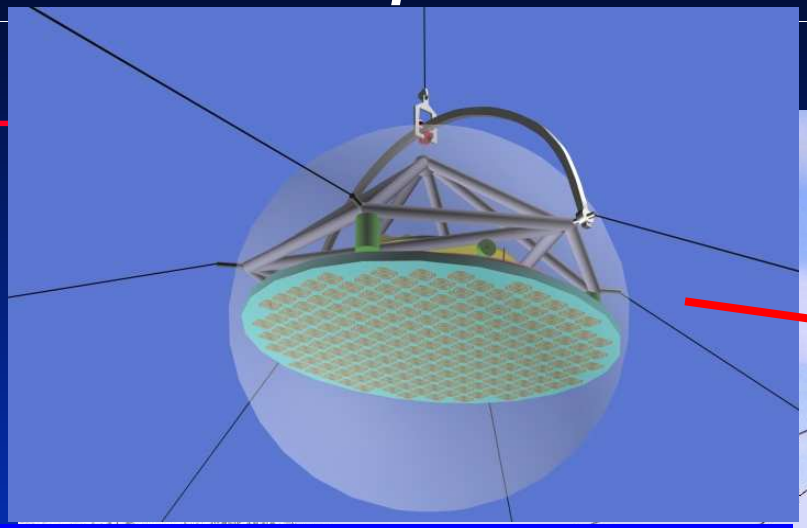
The Large Adaptive Reflector (LAR)

Canada's Concept:

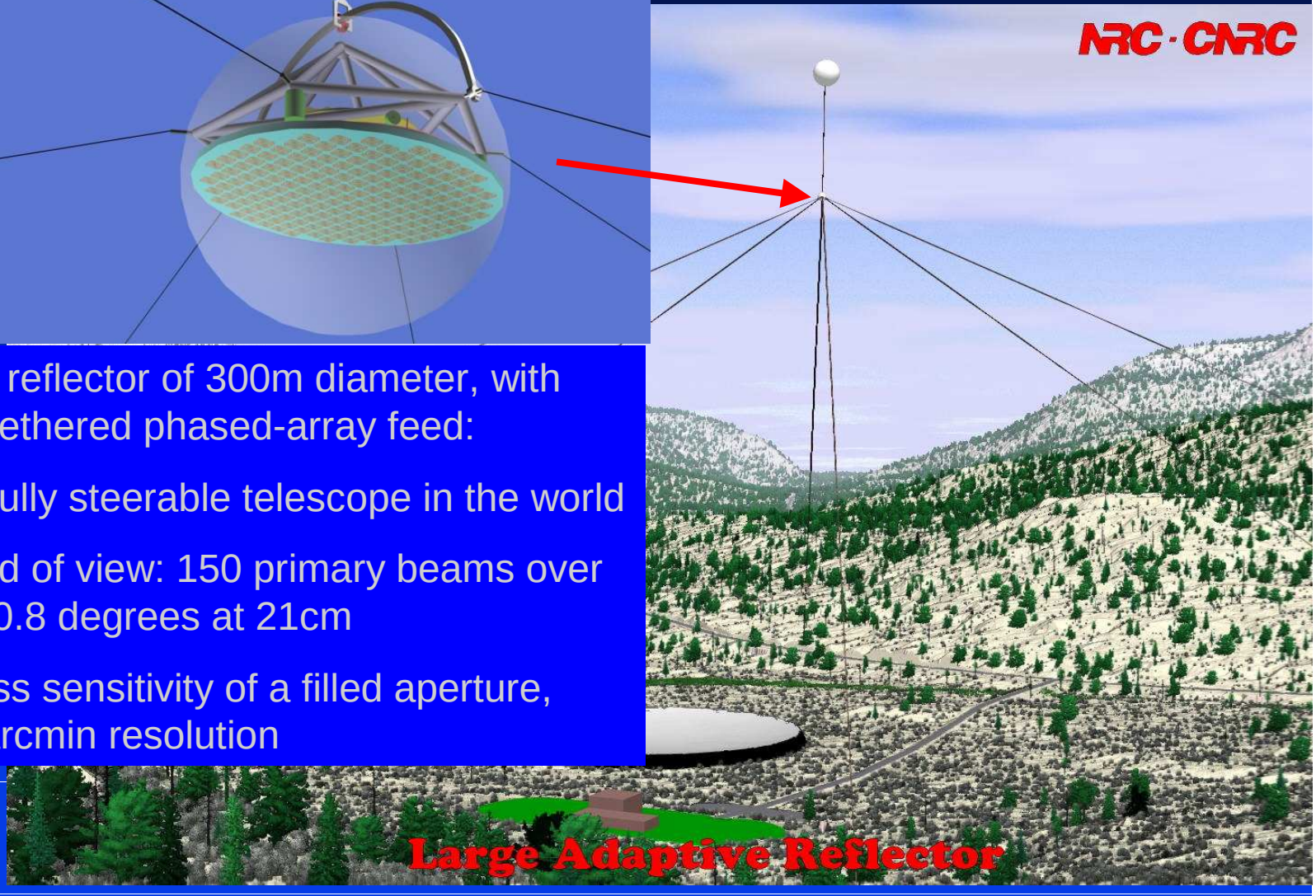


Parabolic reflector of 300m diameter, with airborne tethered phased-array feed:

-Largest fully steerable telescope in the world

-Wide-field of view: 150 primary beams over a field of 0.8 degrees at 21cm

-Brightness sensitivity of a filled aperture, with a 2 arcmin resolution



CLAR Science Surveys:

- CLAR NORTHERN SKY SURVEY:
  a three-years all-sky Northern Hemisphere survey,
  2300s per pointing
- CLAR DEEP FIELD SURVEY:
  over 50 square degrees, 100 hours per pointing

The CLAR will be equipped with several back-ends simultaneously to acquire data for each survey in different modes:

- 10000 spectral line channels over 700 MHz to 1420 MHz providing HI imaging from z=0 to 1 with sensitivity of 2 mK at a velocity resolution of 13 km/s
- 1024 spectral line channels at z=0 to provide a velocity resolution of 1 km/s to map HI in the Local Universe
- Some continuum sub-bands , and a pulsar back-end

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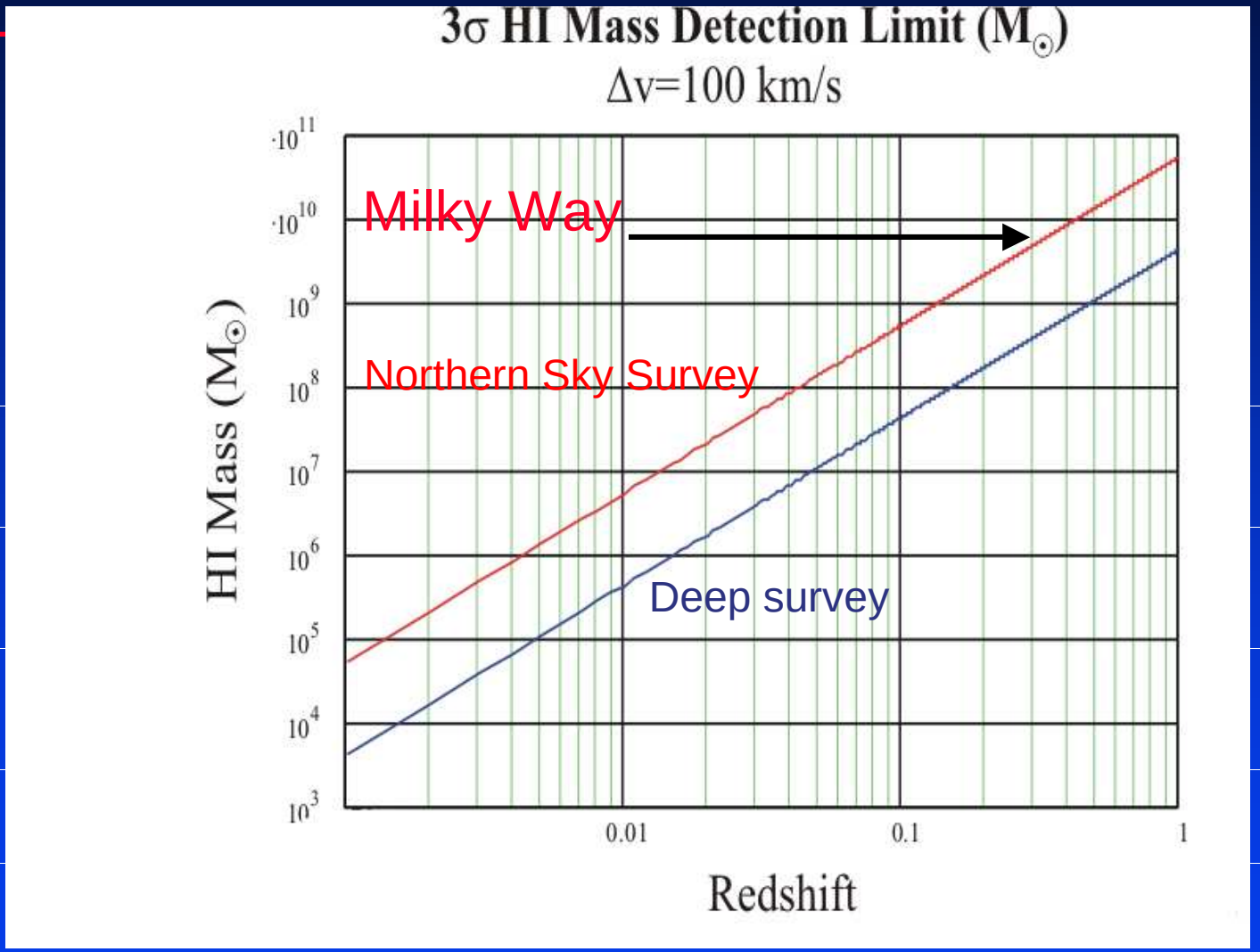
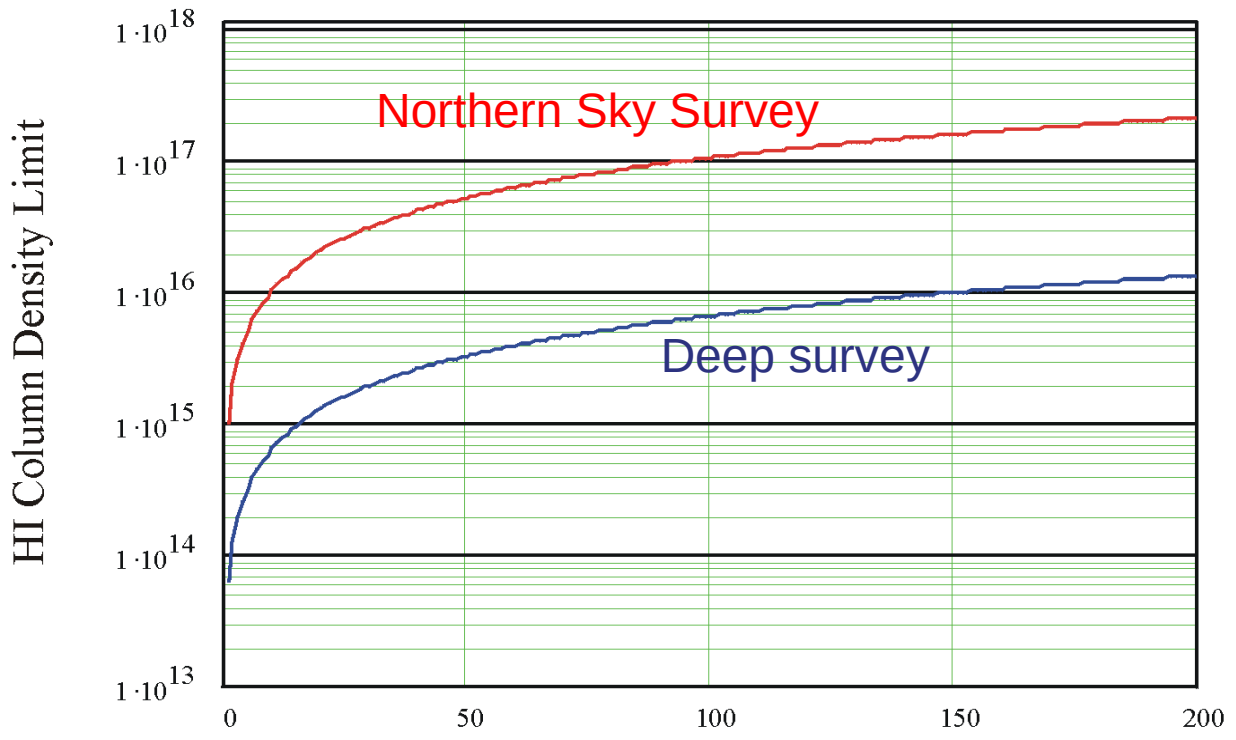
CLAR HI Mass limit as a function of Redshift



CLAR Survey HI Column Density Limit



-No such HI survey ever done in the Northern Hemisphere

- Will be 10 times deeper than HIPASS, and sample a wider redshift range at better angular resolution

Blind All-Sky Survey with the CLAR:

- Large Scale Structure:
  - Not only get redshifts for the galaxies, but also linewidths which can be used to calculate their mass to construct a galaxy mass function
  - Will tell us about galaxy populations versus environment
  - Will detect Low-Surface-Brightness galaxies and dwarf galaxies which are difficult to detect (or undetected) optically
  - Will trace the gas between galaxies, HI arms and tidal structures, revealing signs of interactions
- Detect the Cosmic Web
- Map the Reionization Epoch

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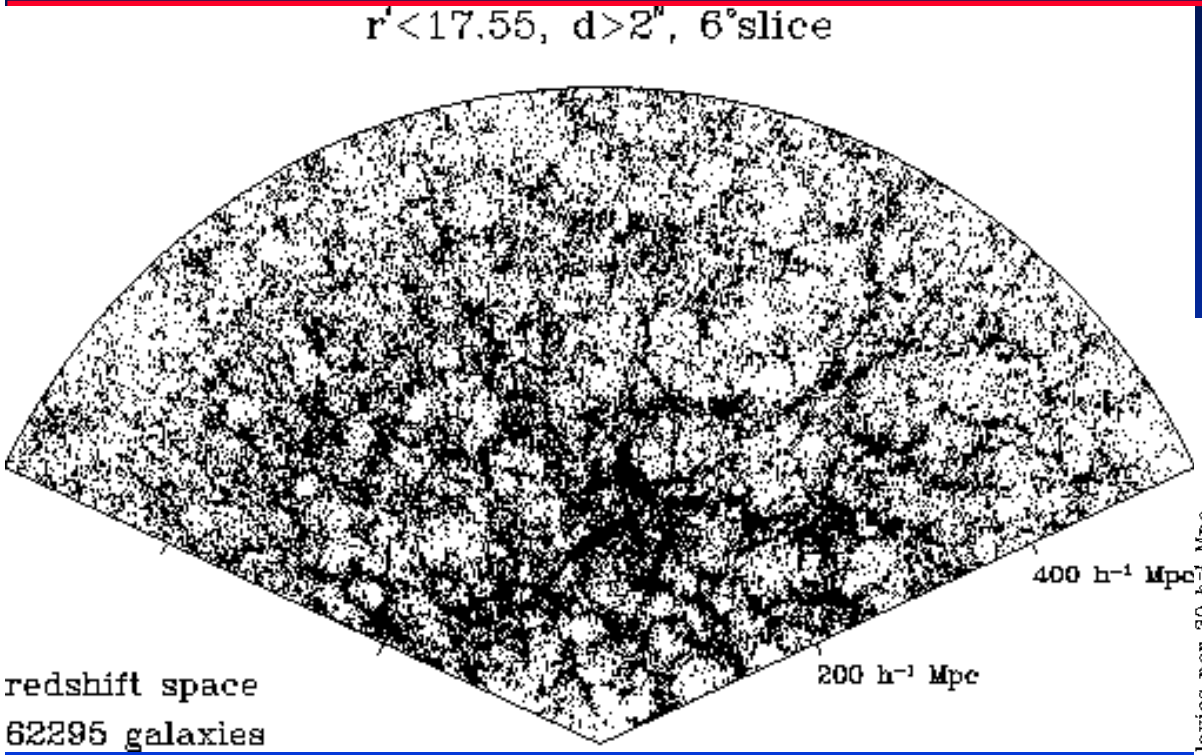
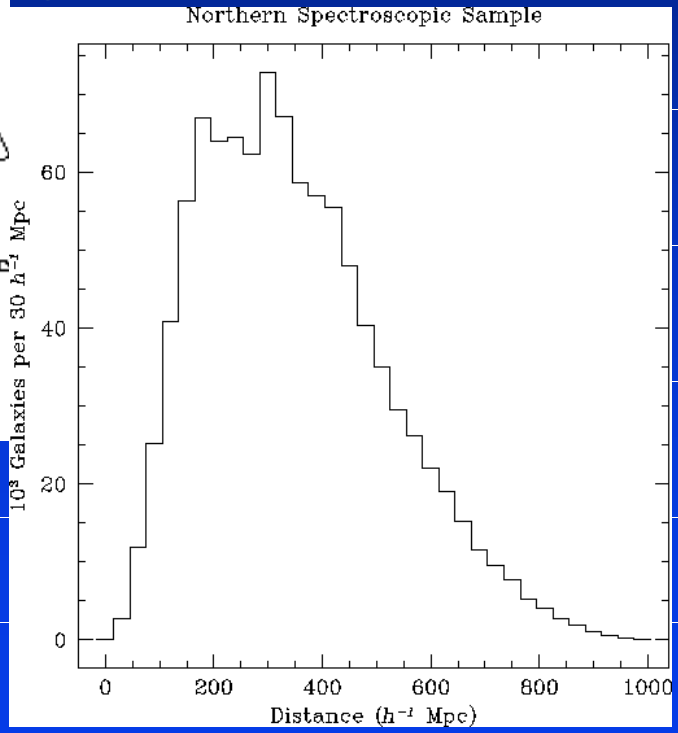
The CLAR Survey will complement optical surveys like the SLOAN Digital Sky Survey:



Large Scale Structure from distribution of optically detected galaxies to *z* about 0.2.



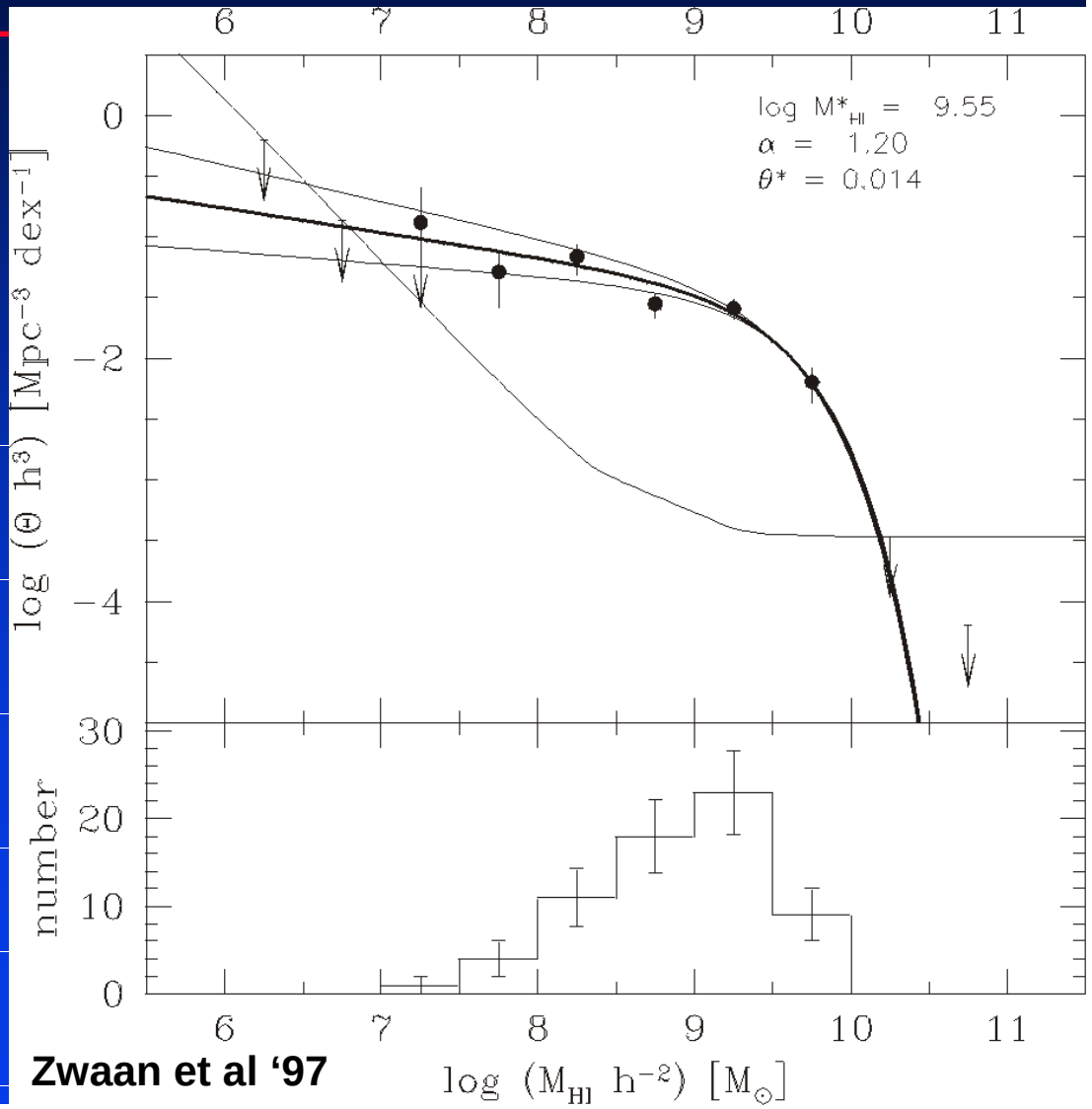
-All galaxy types are detected in HI

(E/S0s will be detectable to z= 0.3)

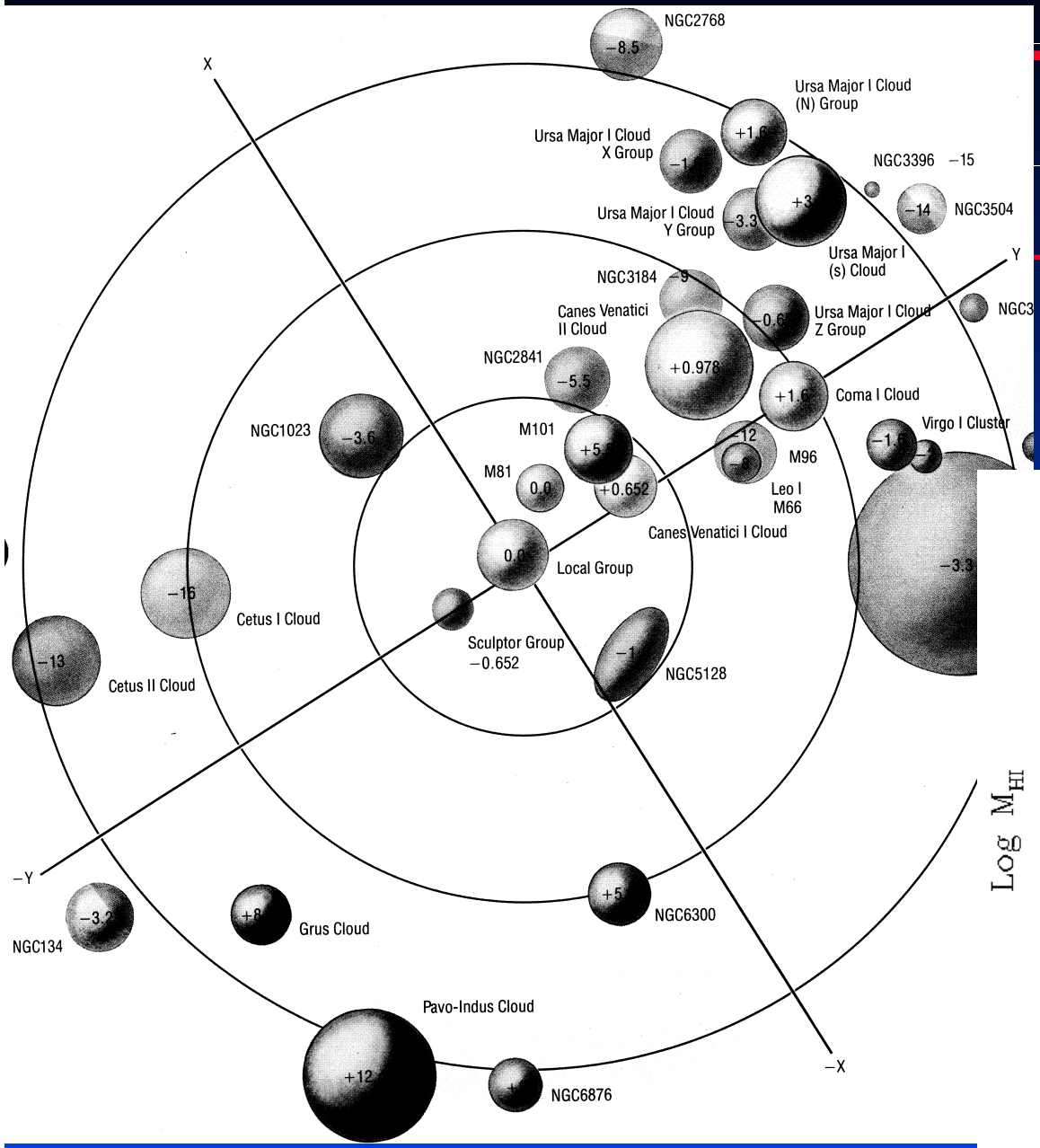
The CLAR Survey will detect the faint-end of the HI mass function:

Below 10^7 $M_{\odot}$ the HI mass function is poorly defined.

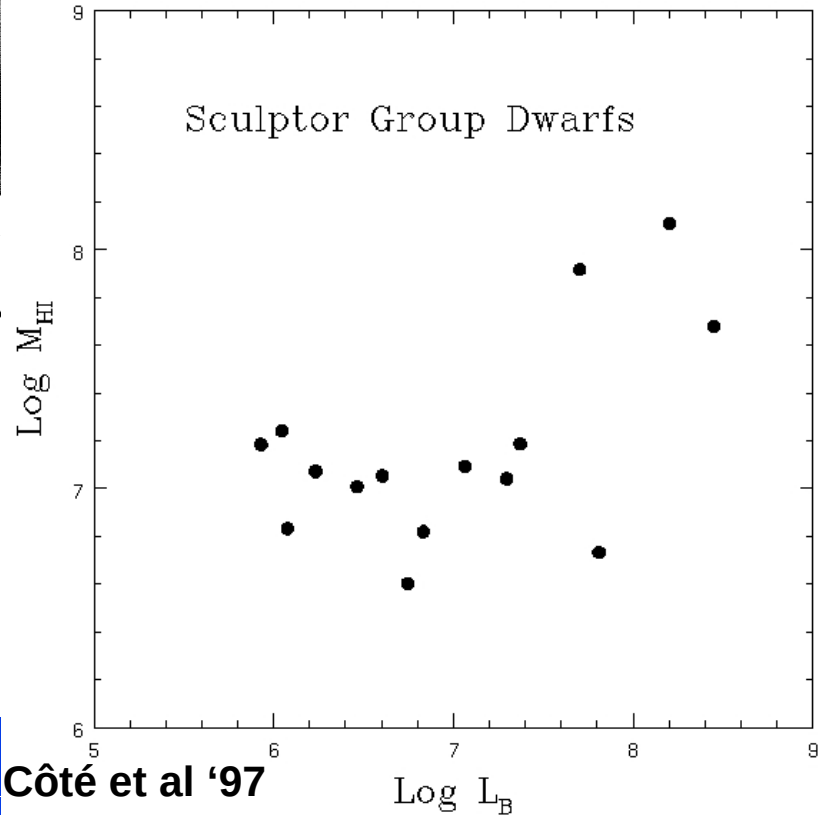
The CLAR survey will detect HI masses as low as 10^3 $M_{\odot}$ D^2_{MPC}



Zwaan et al '97

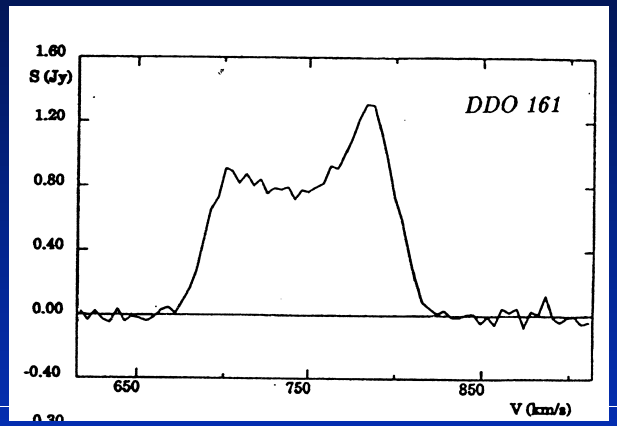


There are potentially a large number of low-mass dwarf galaxies to be detected in the nearby Universe



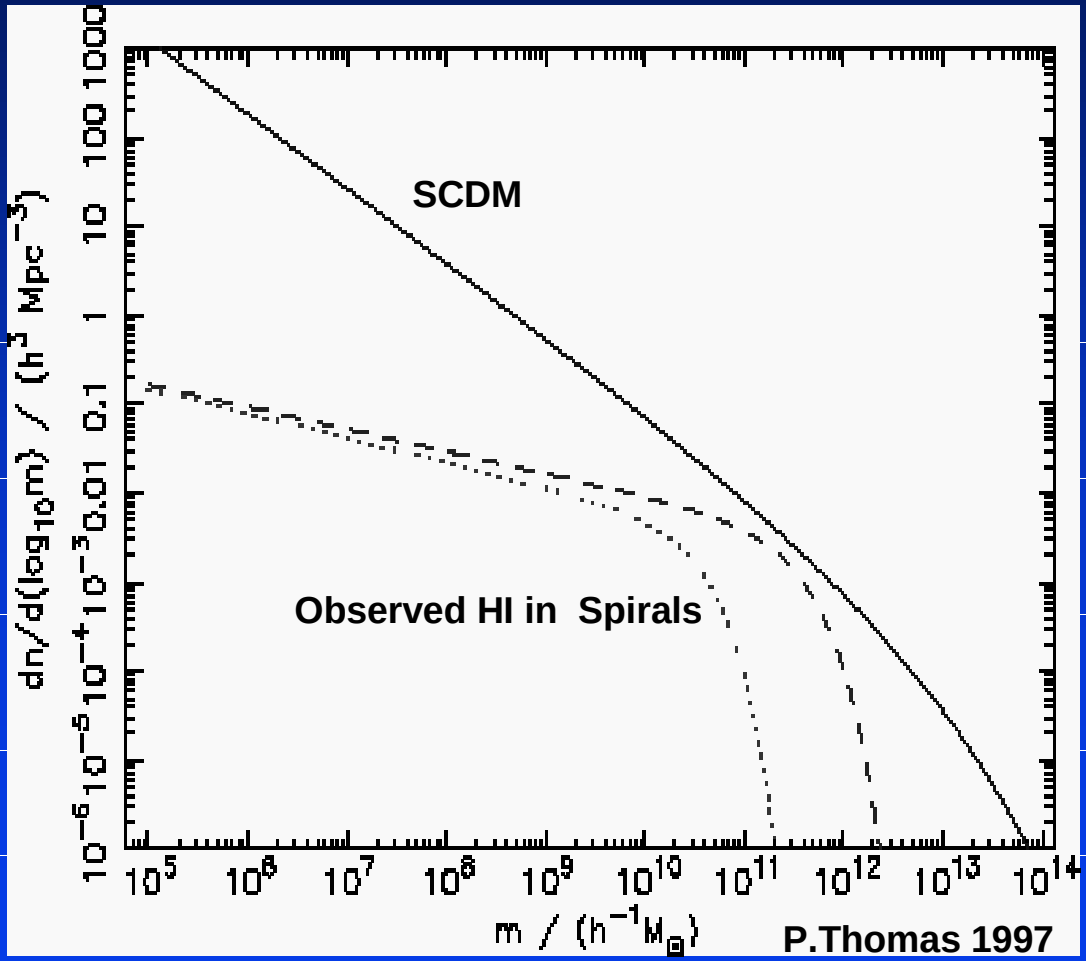
Côté et al '97

The CLAR Survey will provide a galaxy mass function:



The global profile will give the 20% Width, which will give an estimate of the maximum rotation velocity

$$M_{DYN} = R\ V^{2}_{MAX}\ /\ G$$



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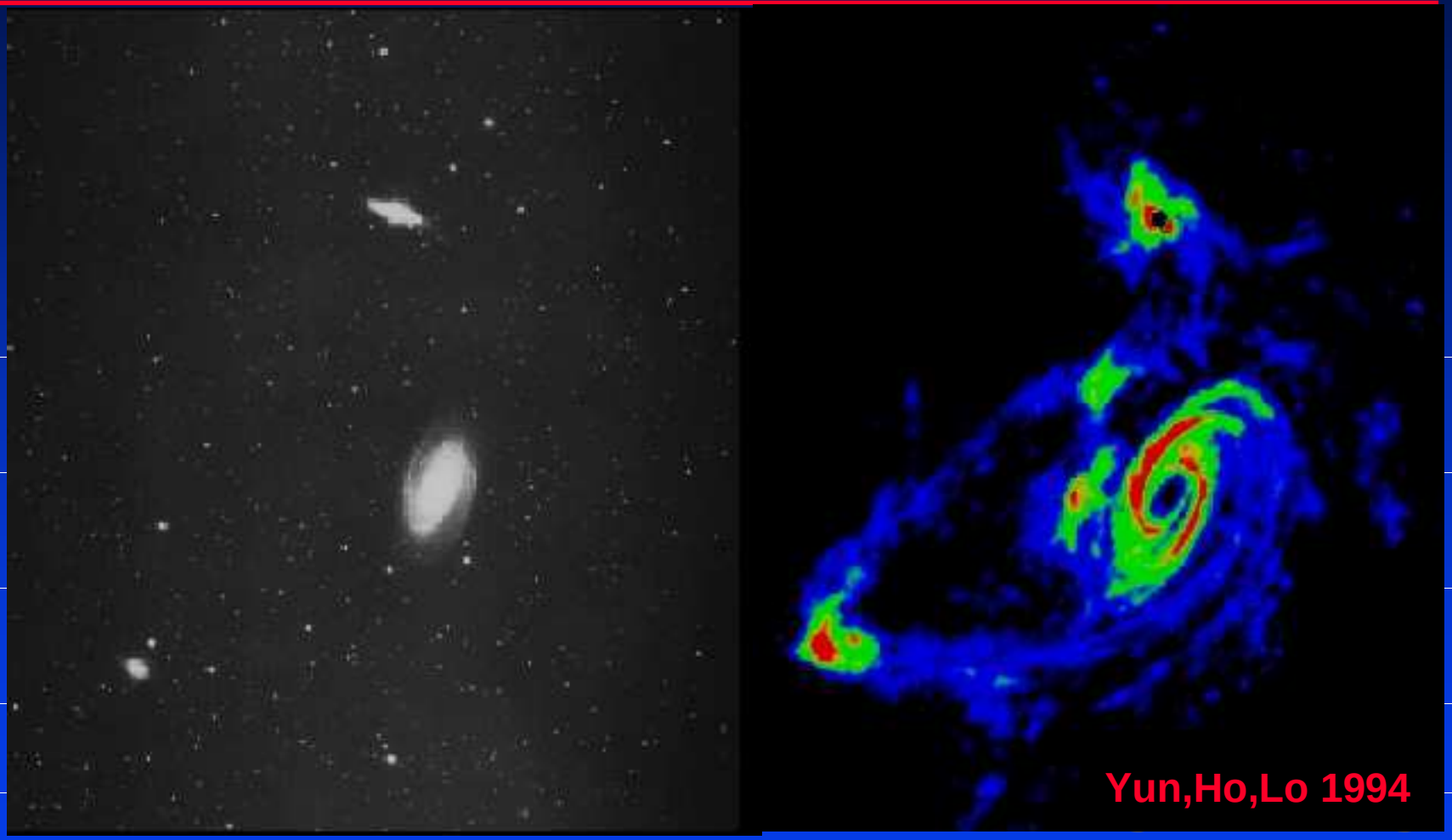
The CLAR Survey will trace galaxy interactions, and HI gas in the IGM:

M81 and dwarfs seen in optical and in HI



The CLAR Survey will map the Cosmic Web:

Spectra of QSOs show large number of Lyα absorption lines.

The absorbing gas could be related to:

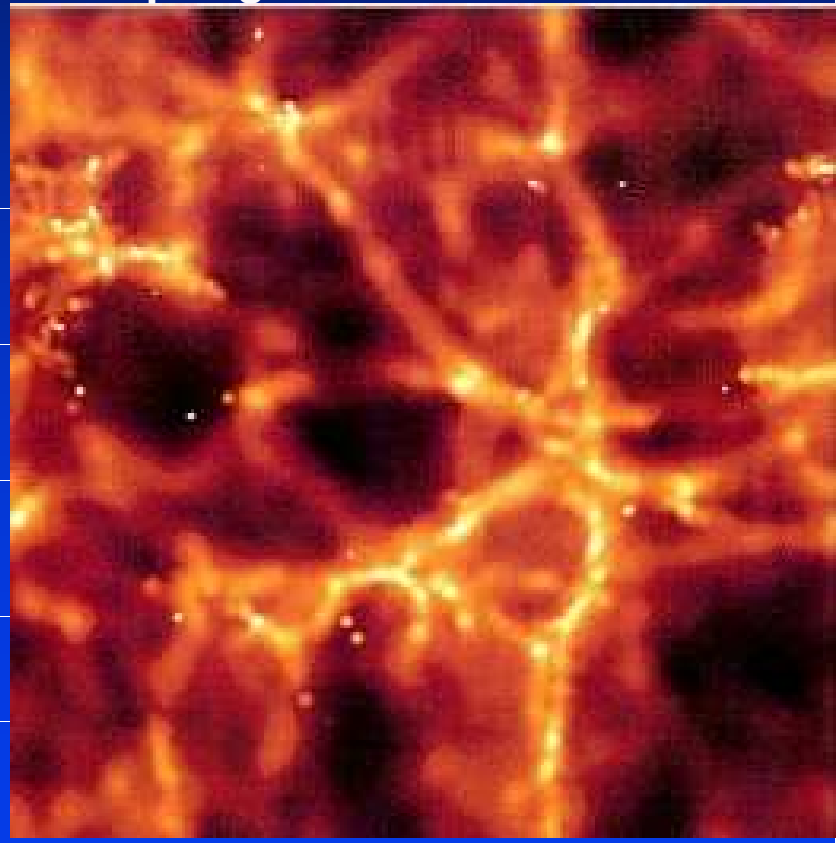
huge diffuse HI halos of galaxies,

halos of undetected LSBs or dwarf galaxies,

intragroup gas,

the Cosmic Web: gaseous filaments and sheets connecting overdense regions where galaxies formed

N-body simulations from Springel et al 2001

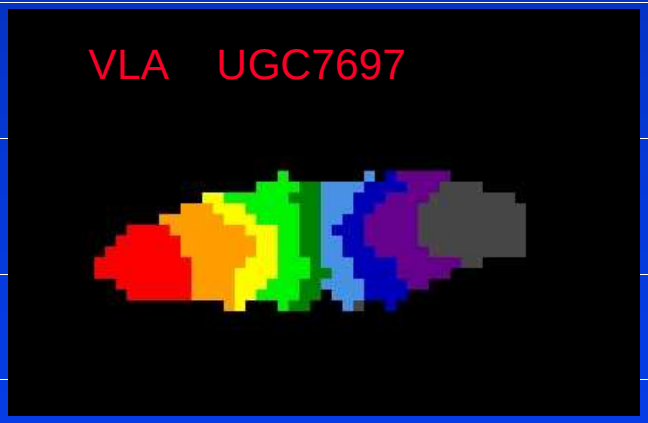


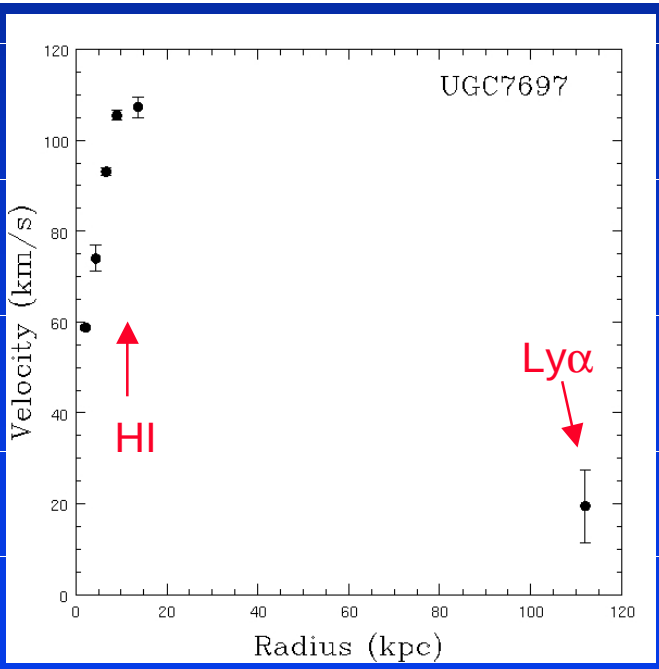
At least some Lyα lines seem associated with galaxy halos:

Côté et al 2001:

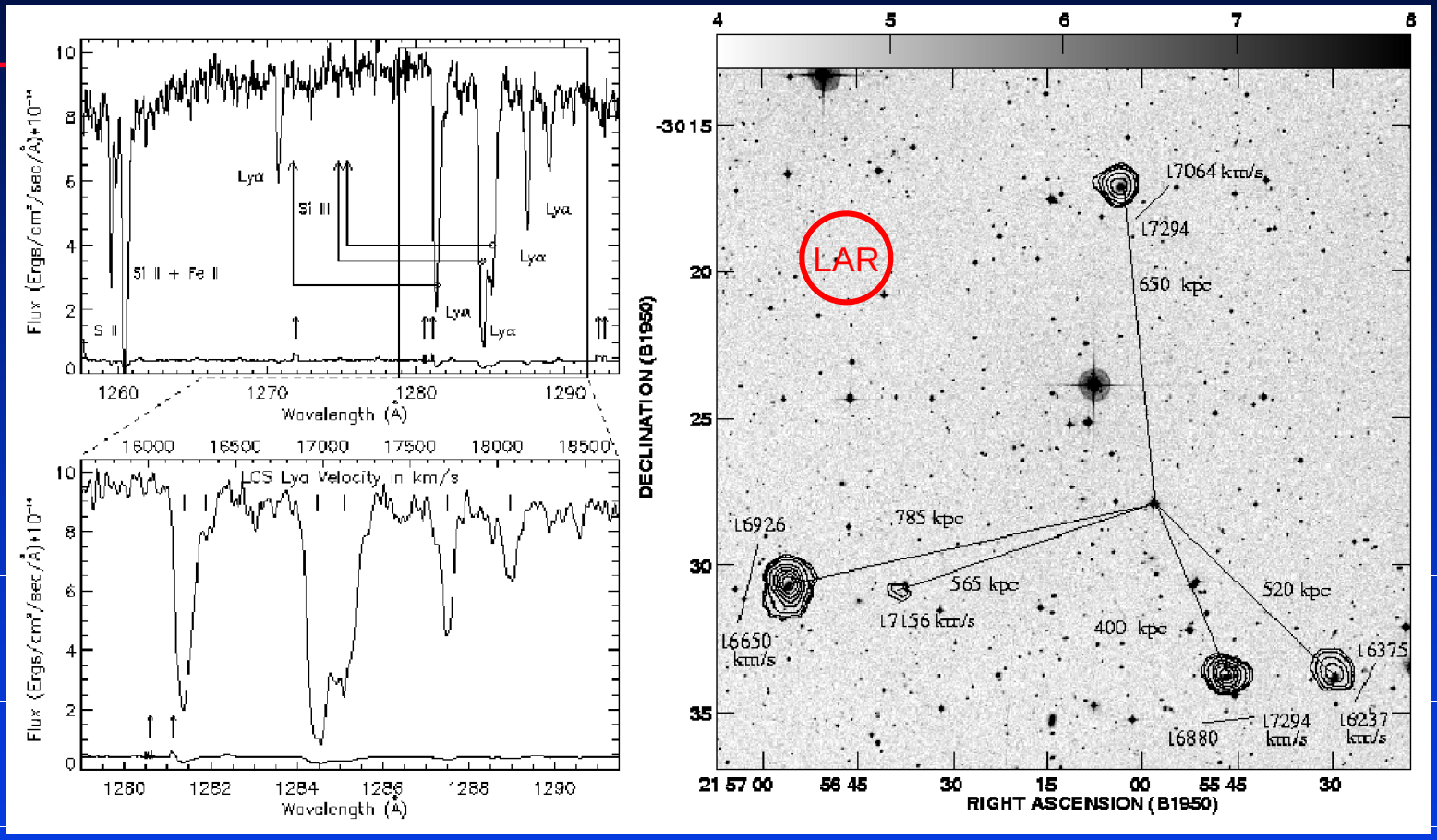
For 5 QSO-Galaxies with separations of 40 to 160 kpc, the velocities of the galaxies agree very well with that of the Lyα line in the HST QSO spectra

QSO-Galaxy	ρ (h_{75}^{-1}kpc)	V_{gal} (km s^{-1})	$V_{Ly\alpha}$ (km s^{-1})
PG1259+593-UGC8146	41	669	700
PG0804+761-UGC4238	100	1544	1564
TON1542-UGC7697	112	2536	2553
MRK876-NGC6140	155	910	913
PG1309+355-NGC5033	163	875	893





Some Lyα lines are not associated with galaxy halos:



Absorbing System at *cz* = 17,000 km/s

$N_H = (2 – 5) \times 10^{16}$ cm^{-2}

Shull et al '99

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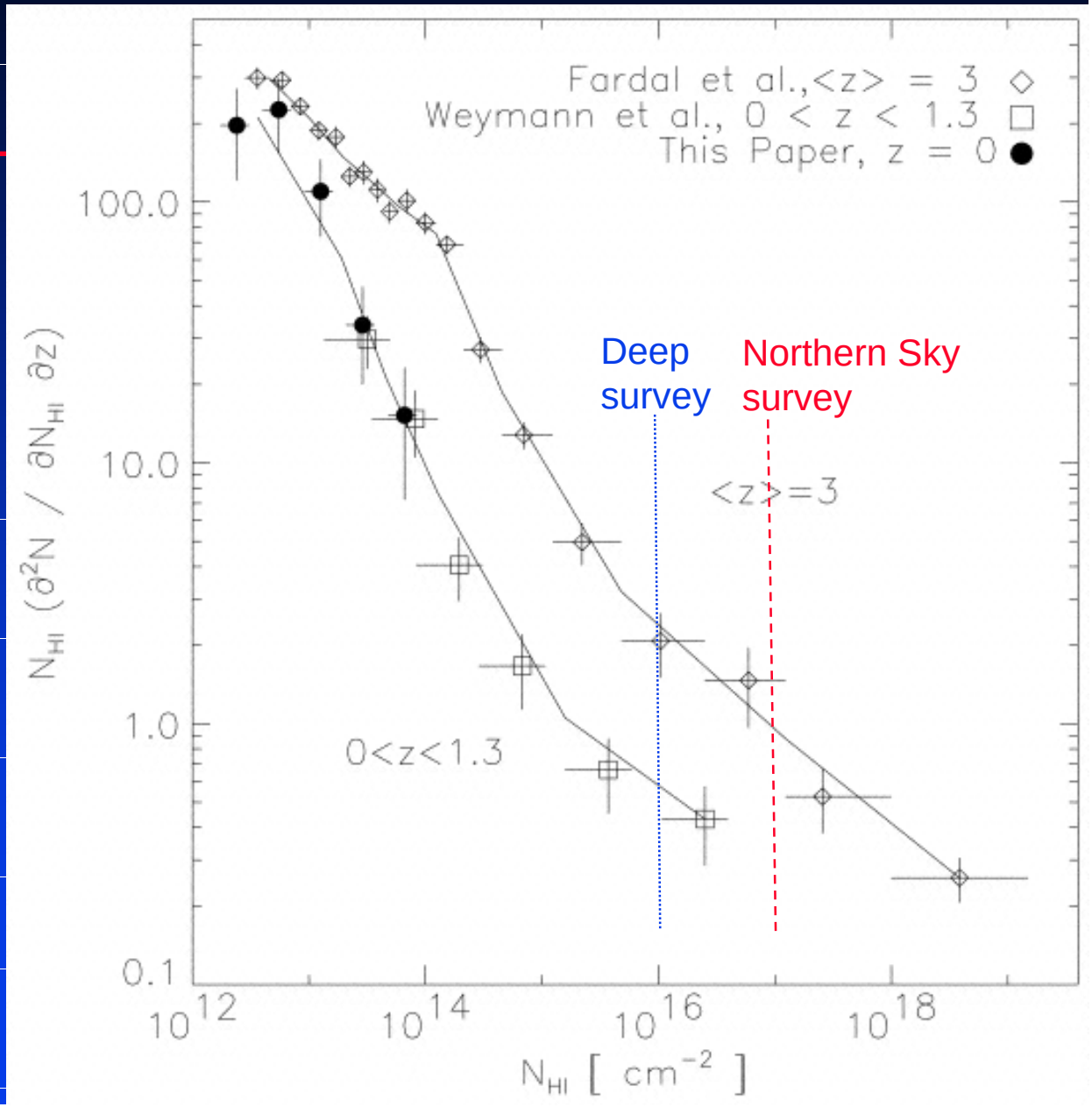
Many measured Lyα lines will be within the range of detection in emission for the CLAR surveys limiting HI column densities.

The CLAR surveys will reveal for the first time the structure of the gas giving rise to these Lyα lines, and its connection to galaxies.



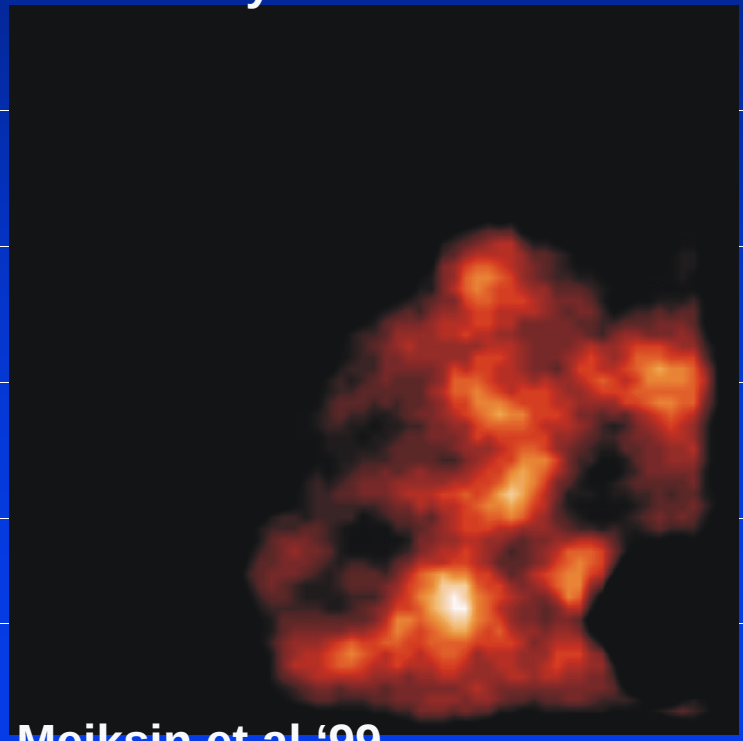
The CLAR Survey will map the reionization epoch:

If the reionization epoch occurred at $5 < z < 20$, it should be detectable as a 'step' in the radio spectrum between $70 < \nu < 240$ MHz.

For z=8 ν=160 MHz, CLAR beam=18'

If the reionization is caused by a large number of stars well-distributed in space the step will be sharp and well synchronised over the sky. If it is due to widely-spaced QSOs, it will appear irregular over the sky.

Simulation of HI emission around a newly formed QSO at z=8.5, once the region is heated above T_{CMB} by soft X-rays. The peak intensity is 16 mK, detectable by the CLAR in a few hours



Meiksin et al '99

The CLAR: an important step towards the SKA

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targets/regions suitable for follow-
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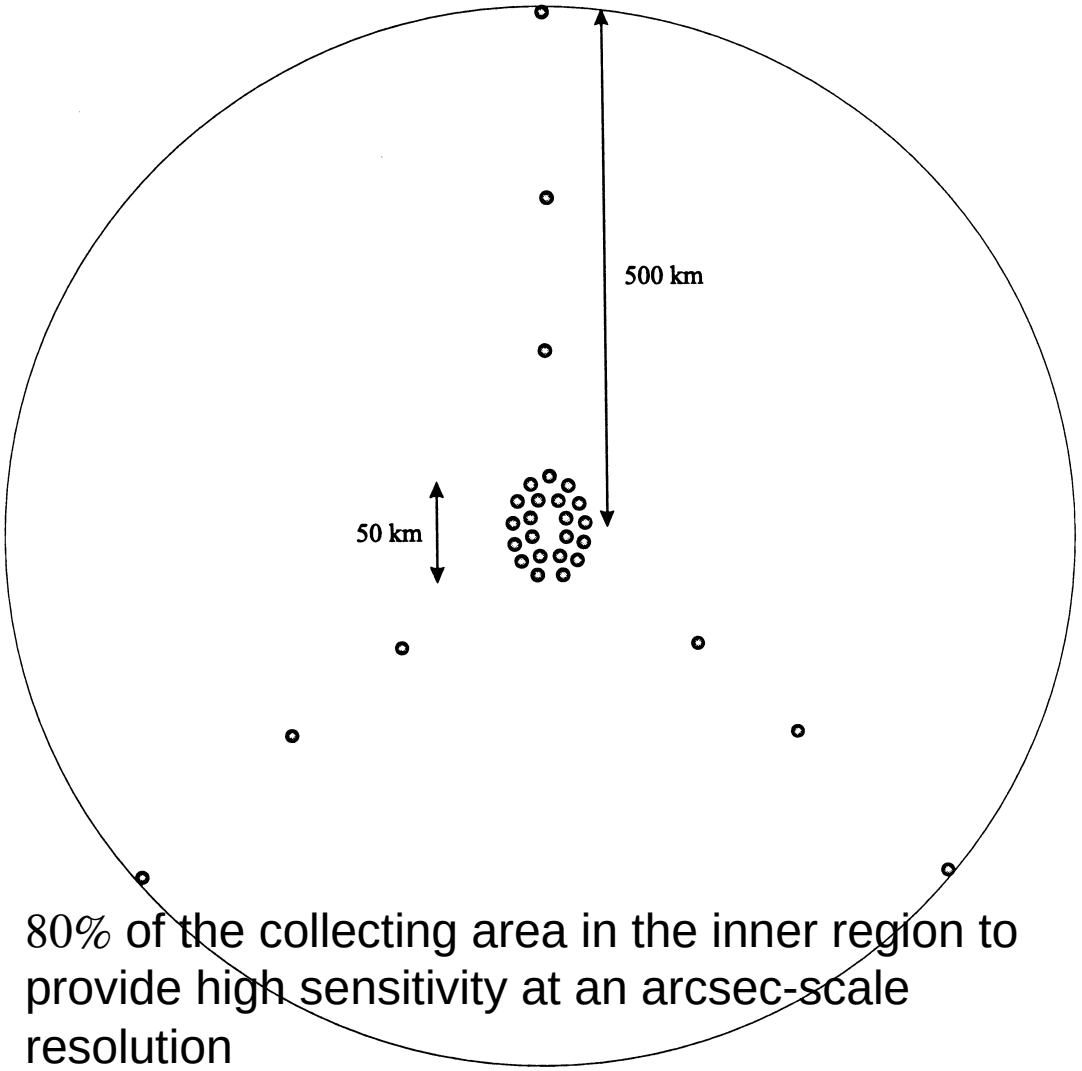

80% of the collecting area in the inner region to provide high sensitivity at an arcsec-scale resolution

The CLAR: an important step towards the SKA

-The CLAR surveys are the necessary first step to provide targets/regions suitable for follow-up with the SKA, and to assure that the SKA surveys are designed in an optimal way.

(with a SKA in the south there would still be a Δdec ~40^{o} overlap)

-The biggest gain with the SKA will be in resolution, not (much) in sensitivity. We will have to wait for the SKA for:

Galaxy Dynamics: rotation curves of galaxies up to z=0.2, for dark matter studies and Tully-Fisher peculiar velocities

Galaxy Evolution: HI imaging of galaxies and mergers at z>1

formation of structure in the early universe z=2-3

➡ **The design of the SKA and its science surveys will benefit from the knowledge derived from the CLAR surveys**

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