What We Can Learn and How We Should Do It

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NGC 6946 H I (WSRT) and optical (DSS)

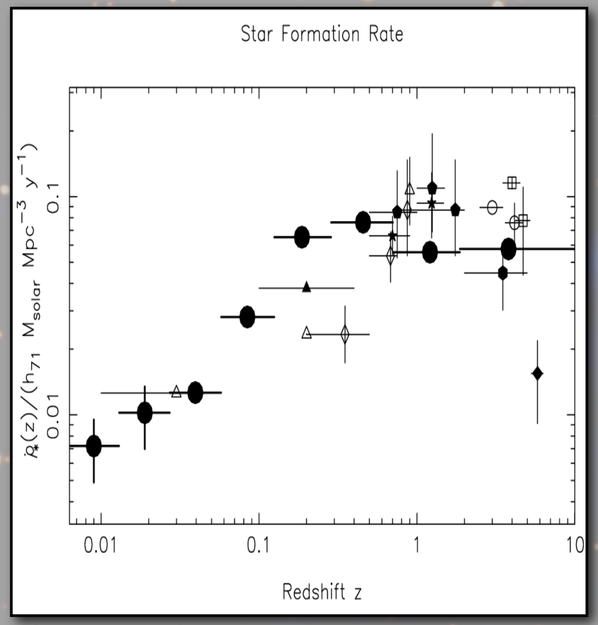
What can we learn and how we should do it

H I studies are an important part of astronomy, but progress is slowing down

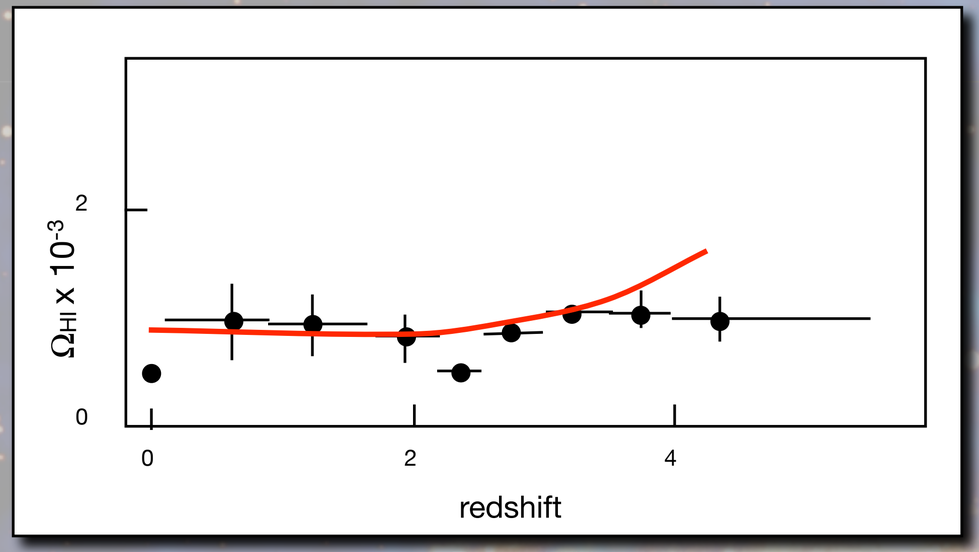
What are the opportunities offered by the new instruments?

What is the role of the EVLA

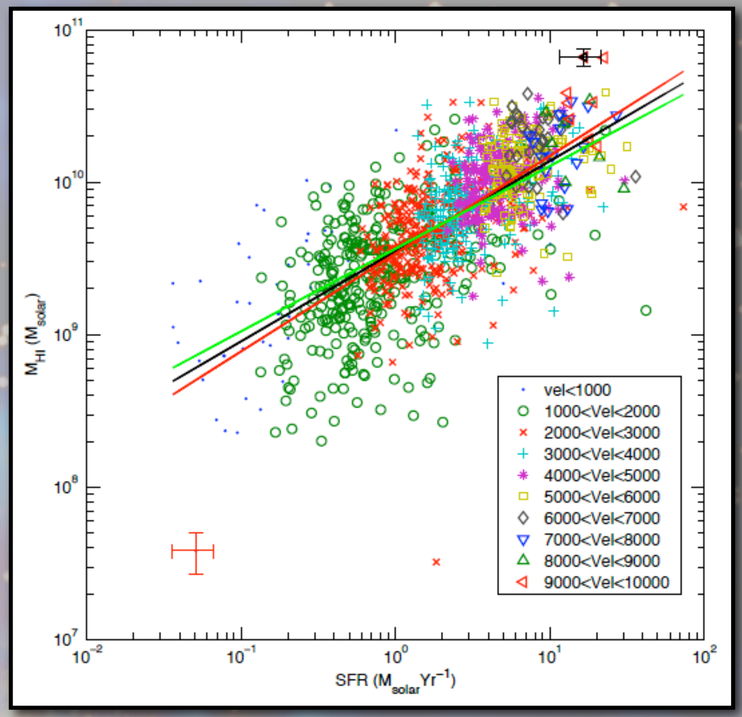
Cannot understand the evolution of galaxies without knowing about their H I



Heavens et al.



Zwaan 2006



Doyle & Drinkwater 2006

- The SFR density is a factor 10 higher at z = 1. Cosmic H I density does not track SFR
  On cosmic scales H I not 1-to-1 connected to evolution of star formation. Why???

  Short gas consumption timescales. Accretion needed.
  How does this depend on environment, mass, type, redshift?

- In a cosmological context, we do not understand the connection between gas content and star formation and on what it depends, nor the evolution of this connection.

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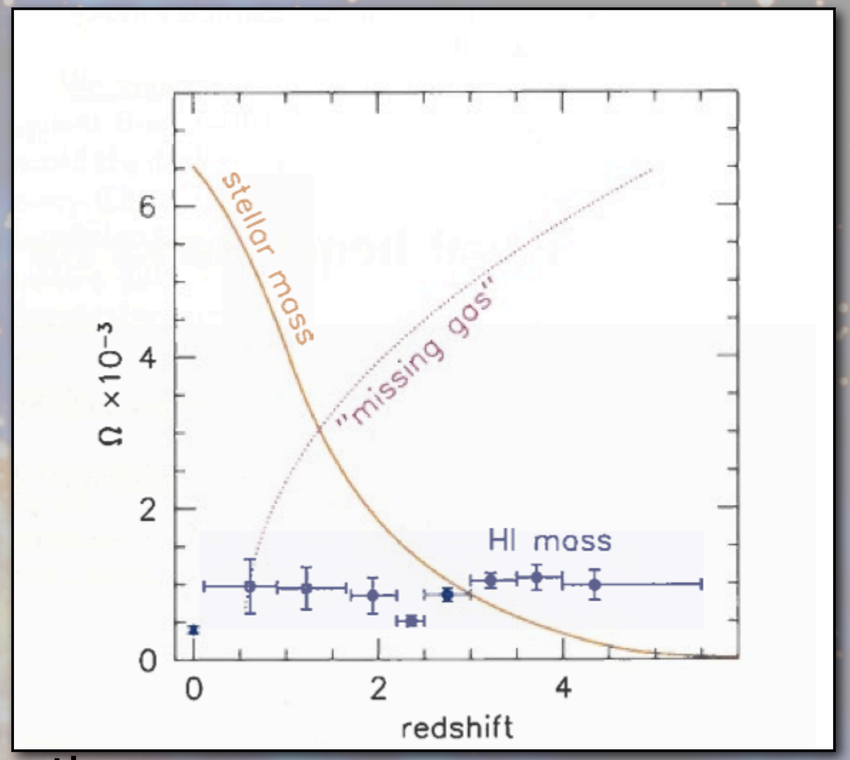
Connected to this: how do galaxies get their gas?

- We don't understand the connection gas ⇄ formation, we also don't know where the gas is coming from!

- There is not enough H I at high *z* to form all stars in the current Universe.
  Closed box cannot work

- Only 10% of baryons are in galaxies, the rest is "out there". What is the role of (cold) accretion?



Zwaan 2006

The connection between star formation, H I and accretion, over time.
is one of the main issues to address in the coming years through large, deep surveys of the H I in the local and "distant" Universe

Gas is not accreted by eating dwarfs

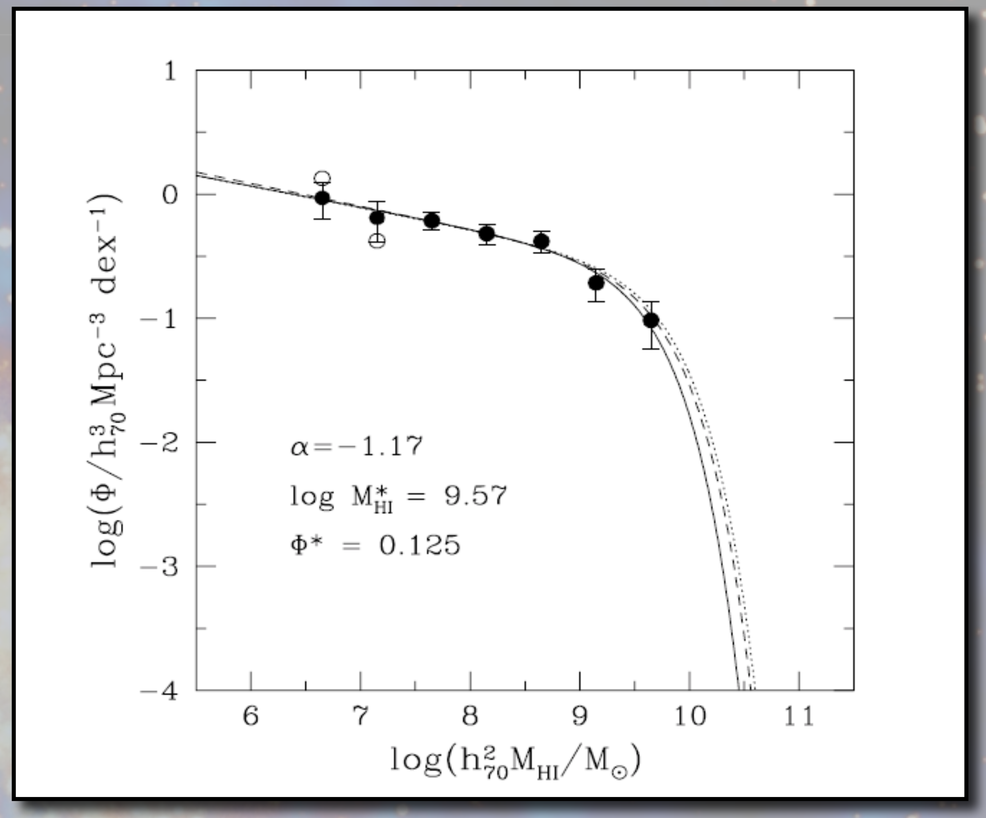
- Galaxies have to accrete H I continuously

But:

- Most H I in galaxies is already in large galaxies

- Large galaxies cannot remain gas rich by accreting gas-rich dwarfs

Was accretion of dwarfs ever important?
How does mass function evolve with redshift?



CVn survey; Kovac et al 2007

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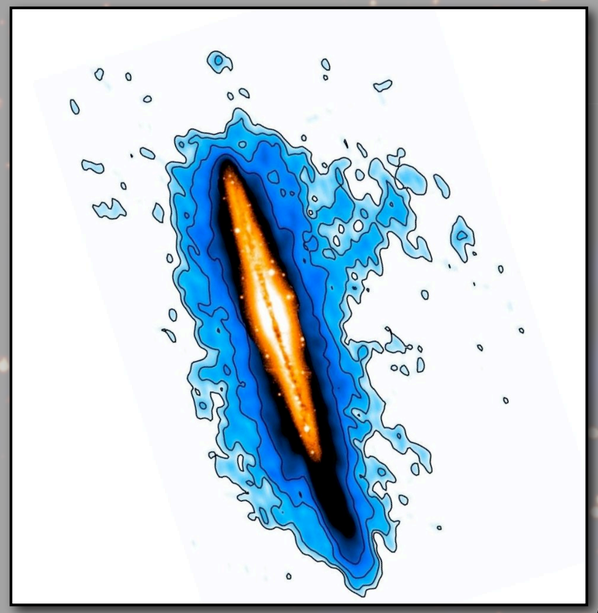
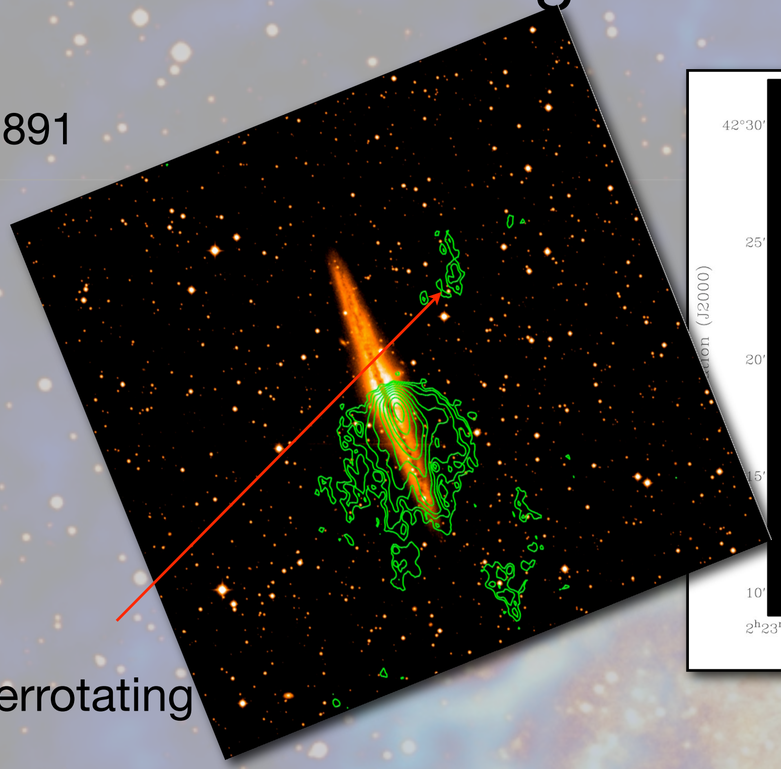
H I halos are the interface between galaxies and IGM?

Model of cold accretion
(Maccio, Moore & Stadel)

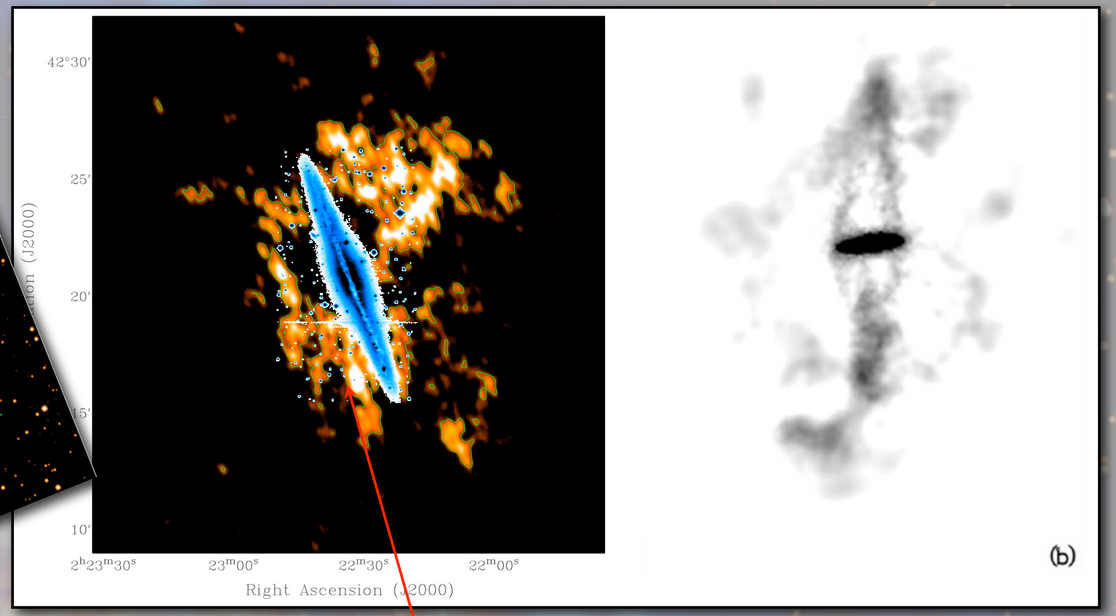


Oosterloo et al 2007
16x12 hr WSRT

NGC 891



Counterrotating cloud



extended non-rotating outer halo at level of 10^{19} cm^{-2}, more than 20 kpc above disk

- Lower halo corresponds to galactic fountain but outer halo has no kinematic relation to disk
- Can explain outer halo by accretion of gas from IGM
- Only very few cases known because deep observations are needed
- Deep H I observations of nearby spirals may help to understand the relation with IGM
- Study the low column density H I in nearby Universe to see how this connects to IGM

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How we should do it?

Several new instruments available in a few years which will focus on H I

EVLA
Apertif
ASKAP
MeerKat
ATA
Fast

Important to focus on what an instrument can do best,
leave the rest to others

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New facilities at L band in 2012

Apertif (NL): 14 dishes of 25 m, focal plane array, FoV 9 degree^2
MeerKat (ZA): 80 dishes of 12 m, single feed, FoV 1 degree^2
ASKAP (AUS): 36 dishes of 12 m, focal plane array, FoV 30 degree^2

All have bandwidths of ~300 MHz and 16000 (or more) channels
cover H I over z=0-0.2 in one observation with good spectral resolution (few km/s)

	EVLA	Apertif	MeerKat	ASKAP	WSRT
A/T	2	1	1.3	0.5	1
FoV	1	30	4	120	1
Bandwidth	3	2	2	2	1
Survey Speed Shallow	4	30	7	30	1
Survey Speed Deep	12	60	14	60	1
SB Sensitivity	+	o	o	o	o

Relevant for EVLA: these are survey instruments, a project of 1000 hrs is considered small

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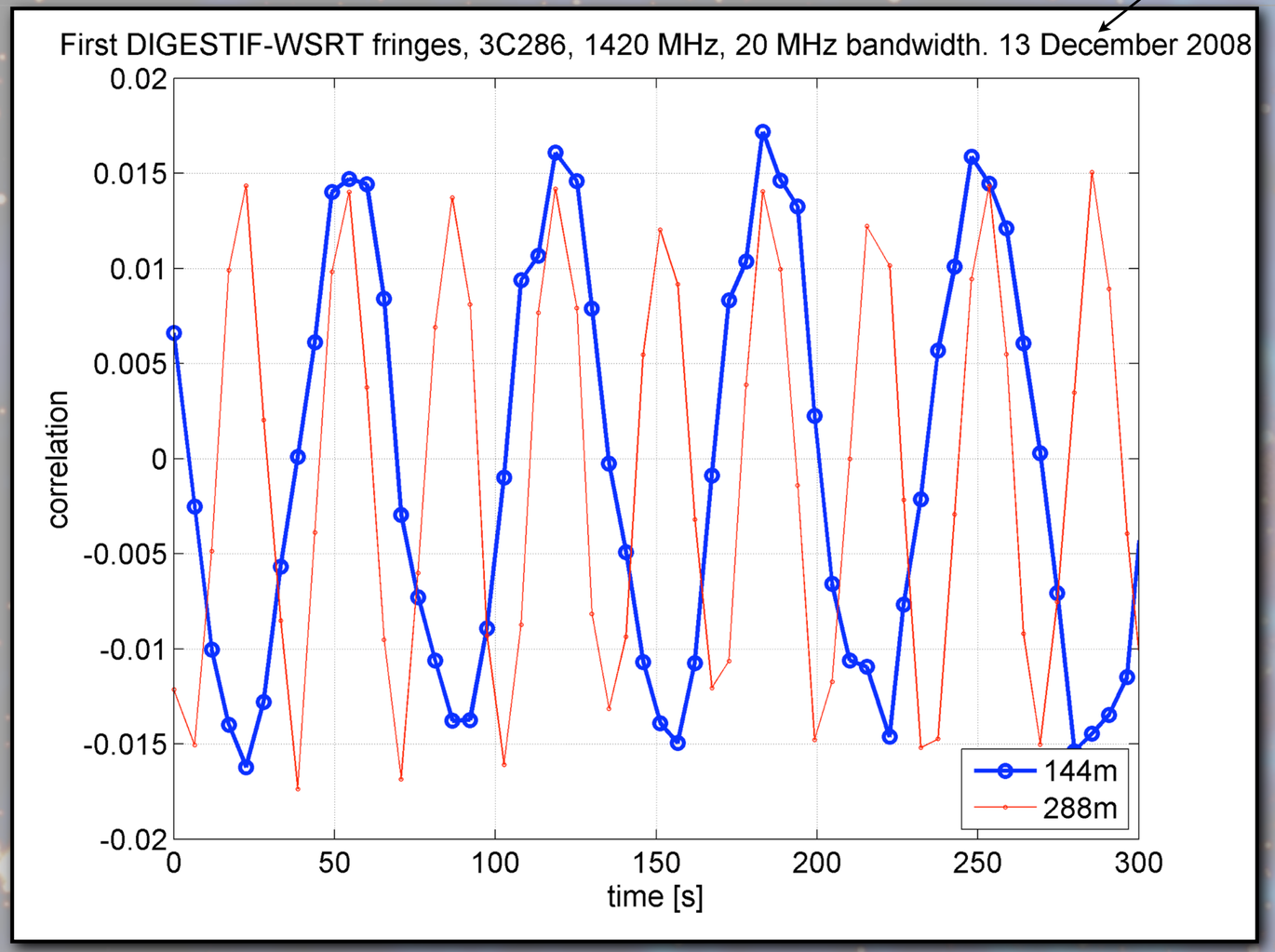
Latest result: first fringes on astronomical source between WSRT dish with FPA and “old” dish



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Apertif , ASKAP, MeerKat

- Major new opportunity: can image the entire sky at high resolution, high sensitivity and out to large distances

- Current state: we know about H I in ~10^4 galaxies, ~100 above z = 0, mostly single dish (3’-15’)

- In 2014: 10^6 galaxies, out to z = 0.6, most above z = 0.1, with 15 arcsec resolution.

- Can start addressing evolution of H I in galaxies and connection to star formation evolution

In parallel with

- Can detect 10^5 $M_\odot$ out to 5 Mpc. Over entire sky, so enough volume to study the smallest H I galaxies, and smaller

- H I absorption survey out to z = 1. ~1000 detections

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What should the EVLA (not) do?

	EVLA	Apertif	MeerKat	ASKAP	WSRT
A/T	2	1	1.3	0.5	1
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Niches for EVLA:

- Very deep integrations of small fields. Go for highest *z*
- Deep integrations of nearby spirals. Interface galaxies - IGM
- Deep searches for low column density H I in nearby Universe with compact array configurations

note: 100 h with EVLA = 1 min with SKA

Only worth doing if willing to spend large amounts of observing time

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Optimum resolution for deep H I work

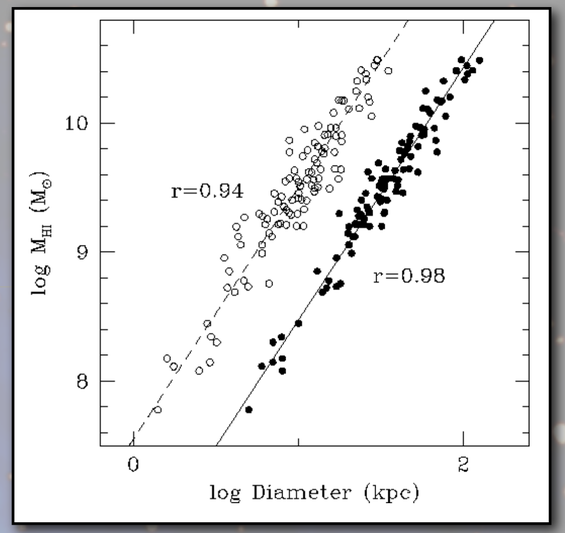
Column density averaged over disk is the same for all spirals so you can compute at which resolution you start resolving out galaxies at high *z*

size of smallest galaxy

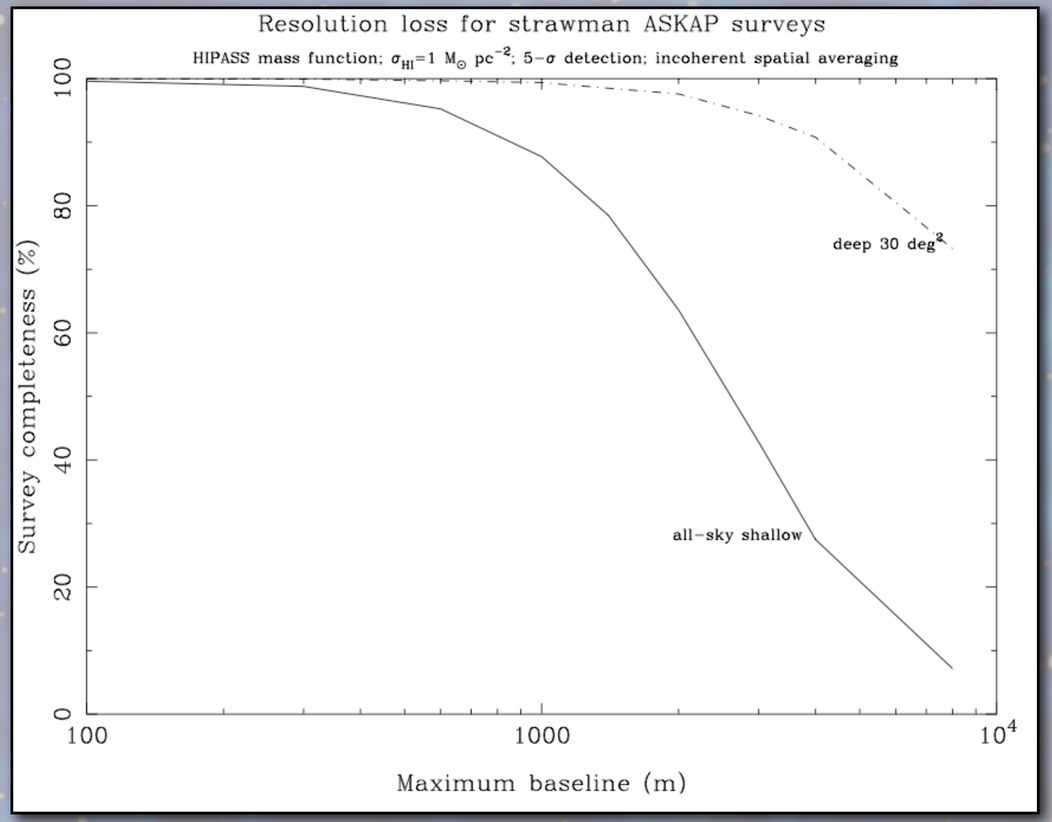
EVLA	100 hrs	100 days
z = 0	4”-7”	2”-3”
z = 0.2	5”-9”	2”-4”
z = 0.4	7”-13”	3”-5”
z = 0.6	9”-17”	4”-8”

No piggy-back with continuum surveys
H I integration times too long

See ASKAP memos of Staveley-Smith for more details



Broeils & Rhee 1997



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“The best place to find a galaxy is right next to another one”

This is not good!!!!

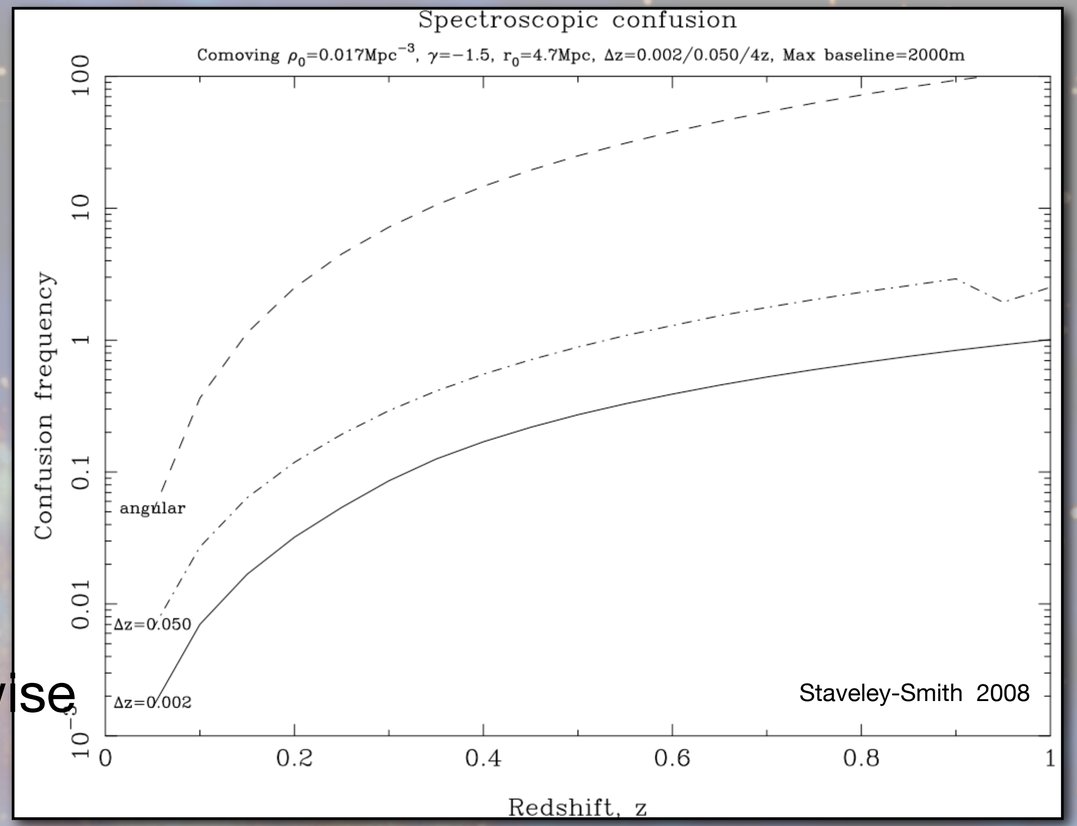
Galaxies are clustered so confusion is potentially a problem

Simulations done (for ASKAP) by Lister Staveley-Smith

For deep C-array surveys:

Need to have independent redshift information, otherwise confusion can be significant

Photometric redshifts are sufficient



Confusion by galaxies > 0.1 $M_\star$

By galaxies > 1 $M_\star$ is factor 15 down

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Summary

Important issues to address in extra-galactic H I work

- One cannot understand the evolution of galaxies without knowing about the evolution of H I in galaxies
- Investigate the H I properties as function of type, environment, mass, …
  In particular, the *evolution* of the above with redshift and the relation with evolution of star formation
- How do galaxies get their H I, interface between galaxies and IGM
- Low column density H I, Cosmic Web
- The smallest galaxies, and smaller

- Few niches for EVLA
  - Deep integrations of small fields. Go for highest *z*
  - Deep integrations of nearby spirals. Interface galaxies - IGM. Combine with high *z*?
  - Deep searches for low column density H I in nearby Universe with compact array configurations
  - Also EVLA projects will need very long integration times

Panoramic Radio Astronomy

Wide-field 1-2 GHz research on galaxy evolution

2-5 June 2009, Groningen, the Netherlands

ATNF

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