What can we do with SKA1? (what's left of it)

Tom Oosterloo (Dwingeloo & Groningen)

Science input to re-baselining process

Science Review Panel

1. Produce list of science priorities (September 2014)

Science Goal	SWG	Objective	SWG Rank
1	*CD/EoR*	Physics of the early universe IGM - I. Imaging	1/3
2	*CD/EoR*	Physics of the early universe IGM - II. Power spectrum	2/3
4	*Pulsars*	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection	1/3
5	*Pulsars*	High precision timing for testing gravity and GW detection	1/3
13	*HI*	Resolved HI kinematics and morphology of ~10^10 M_sol mass galaxies out to z~0.8	1/5
14	*HI*	High spatial resolution studies of the ISM in the nearby Universe.	2/5
15	*HI*	Multi-resolution mapping studies of the ISM in our Galaxy	3/5
18	*Transients*	Solve missing baryon problem at z~2 and determine the Dark Energy Equation of State	=1/4
22	*Cradle of Life*	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc	1/5
27	*Magnetism*	The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields	1/5
32	*Cosmology*	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.	1/5
33	*Cosmology*	Angular correlation functions to probe non-Gaussianity and the matter dipole	2/5
37 + 38	*Continuum*	Star formation history of the Universe (SFHU) – I+II. Non-thermal & Thermal processes	1+2/8

Table 2. List of highest priority SKA1 science objectives, grouped by SWG, but otherwise in arbitrary order.

Does not mean they are all equal!!!

Science input to re-baselining process

December 2014

2. Critical look at proposed surveys (TAC-like)

3. See to what extent a science goal formulated for one telescope can be achieved with another

4. Access impact of individual options. No re-design allowed

January 2015

5. Access impact of scenarios (combinations of options), taking into account that even among HPSO's, some are more important than others (EoR, Pulsar GW)

SRP did not consider Technical Risk, but SEAC and SKAO did

6. Make recommendations to Director

Almost all science can still be done with re-baselined SKA1
but ambitions have to be re-baselined as well…..

The re-baselining

- Going from 256k channels to 64k gives about half of required cut (zoom-mode will be available)

- Two-site decision: part of Mid will have to be built, i.e. 0% Mid is not an option

- Re-baselined SKA1 should still offer transformational capabilities (> factor 3 improvement)
  - Mid is ~4-5x more sensitive than MeerKat, ~2-6 x more sensitive than JVLA
    - 50% Mid is nice, but not transformational
    - 50% Low is 8x LOFAR

- Not building Low or Survey is not sufficient to bring cost down to 650 M€
  - even if one element is not built, the remaining two still have to be de-scoped
  - only two parameters that really have impact:
    - number of stations (collecting area)
    - length of maximum baseline (resolution)

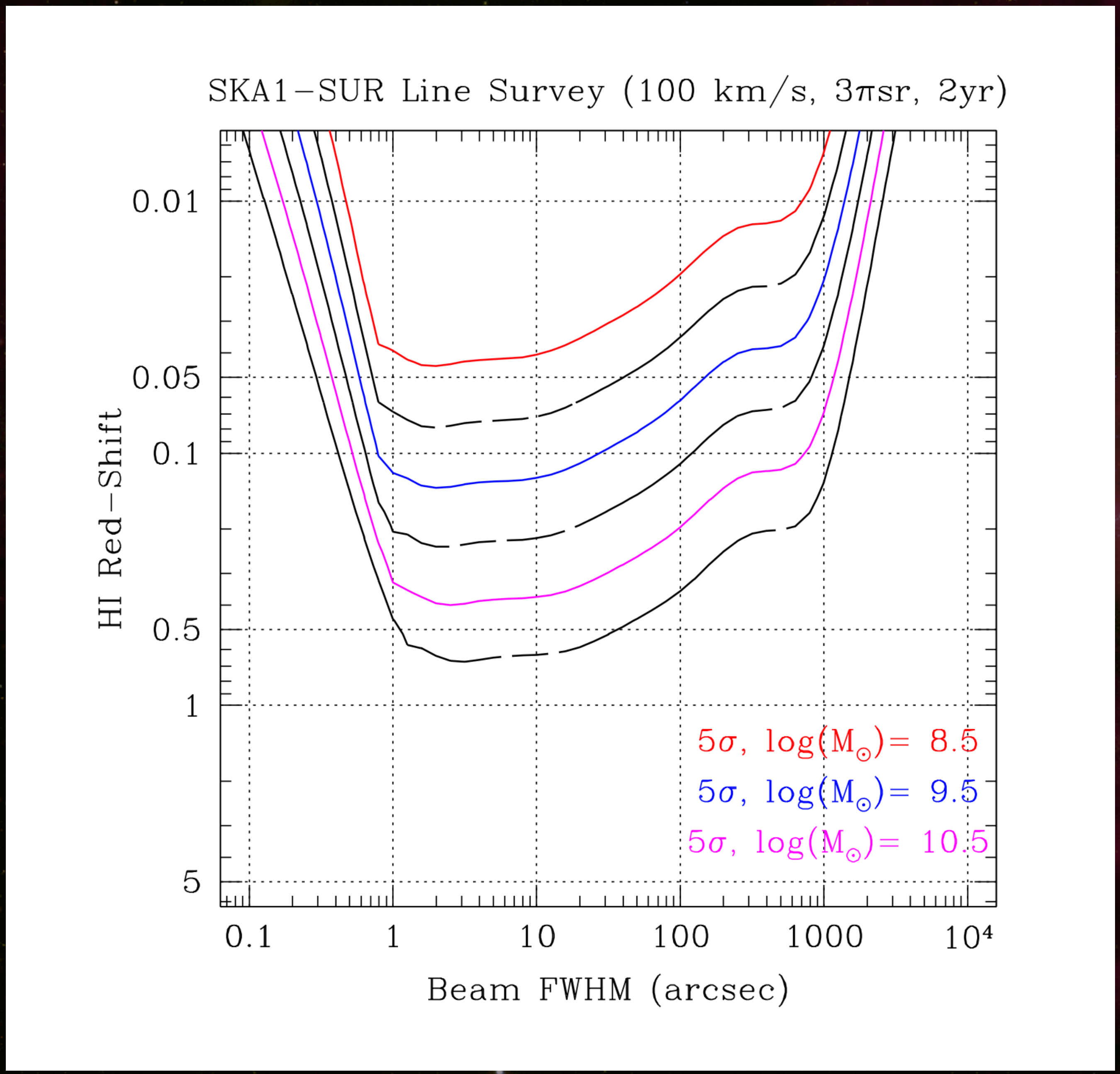
- 7 options were discussed.
  Consensus (SRP, SEAC & SKAO) that only one of them makes sense
  SKA Board agrees

  70% Mid, baselines up to 150 (120) km. 50% of pulsar beams
  50% Low, baselines up to 80 km. Inclusion of pulsar search capability
  0% Sur. PAFs in AIP
  ASKAP operations part of SKA1 (at some point)
  64k channels instead of 256k
  Band priority: 2 - 5 - 1

We're back to Memo 125

Less than half of what we were hoping for….. Is the glass 2/3 empty or 1/3 full???

2/3 empty



The resolution of Survey is high for large-area shallow surveys!!!

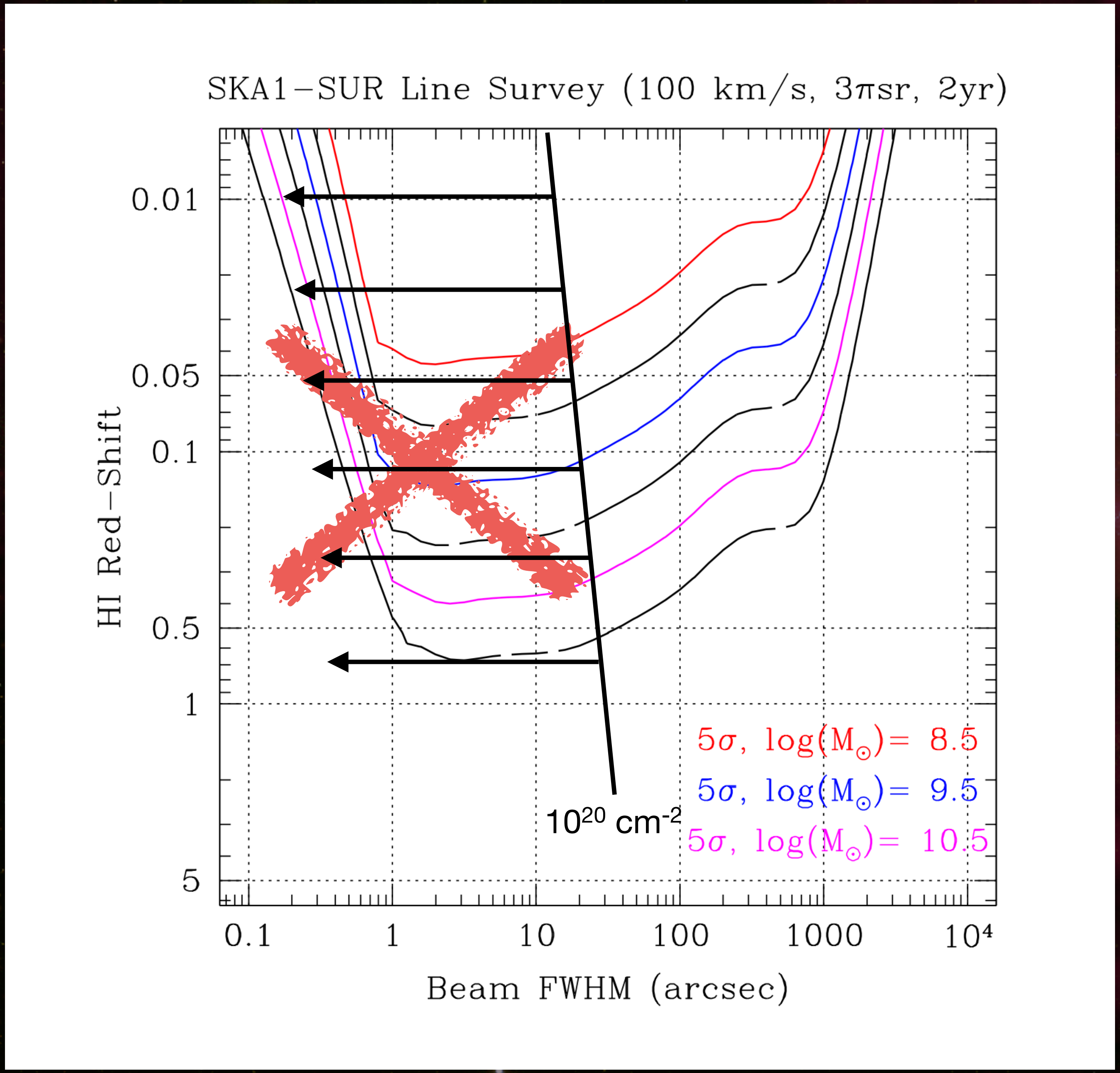
A large-area survey would only be modest improvement over Apertif/ASKAP unless most observing time of Survey would be dedicated to this

Niche for Survey:
medium-deep over few x 100 deg^2.
Faster than MID

Would increase Chiles and Laduma samples, at similar resolution, by a large factor
(same A/T, larger FoV)

Impact on Galactic HI absorption surveys

2/3 empty



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Impact on Galactic HI absorption surveys

1/3 full !!!

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Table 2. List of highest priority SKA1 science objectives, grouped by SWG, but otherwise in arbitrary order.

Plan is to devote 50-70% of the observing time to KSPs

➪ 4000-6000 hr per year available on Mid for ALL surveys combined
~1500 hr per year specifically for HI work

Very significant potential for commensal surveys (i.e. > 1500 hr/year)
magnetism, cosmology (all-sky) and continuum (1-300 deg^2)

SKA Key Science meeting (Stockholm 24-27 Aug)
initiate the development of objectives, collaborations, leadership and explore commensal surveys

PHISCC should pursue this actively!!!!

What do we get?

SKA Mid (single pointing) will be

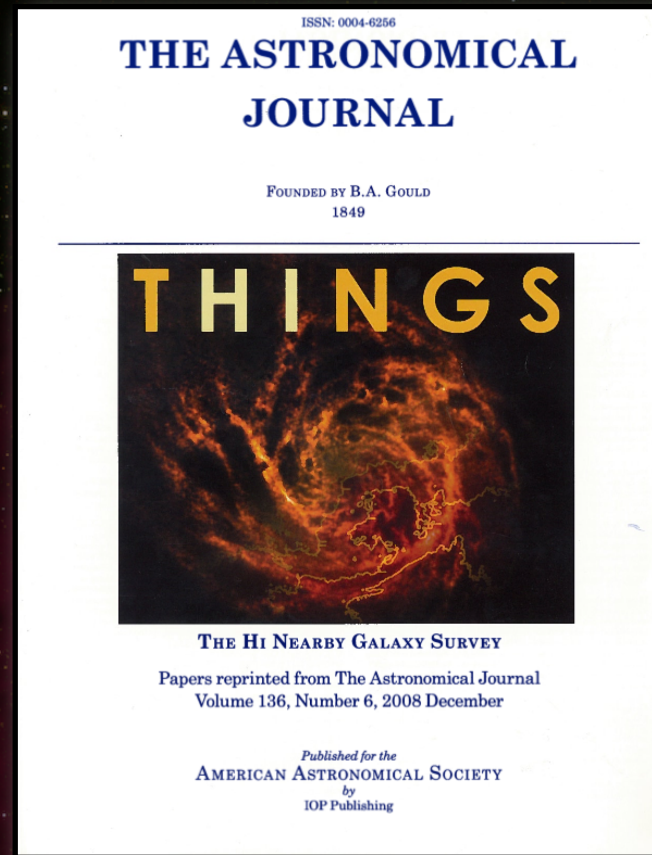
~15x faster than JVLA
  CHILES in 70 hrs
  1 THINGS galaxy in < 1 hr

~10x faster than MeerKat
  Laduma ~ 500 hr
  Monghoose galaxy in 20 hr

~50x faster WSRT
  Halogas in 2 hr

all with better uv coverage and/or resolution.
pulsar core: good surface brightness sensitivity

SSpeed ~5 x ASKAP (z=0)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THE ASTRONOMICAL JOURNAL

FOUNDED BY B.A. GOULD
1849

THINGS

THE HI NEARBY GALAXY SURVEY

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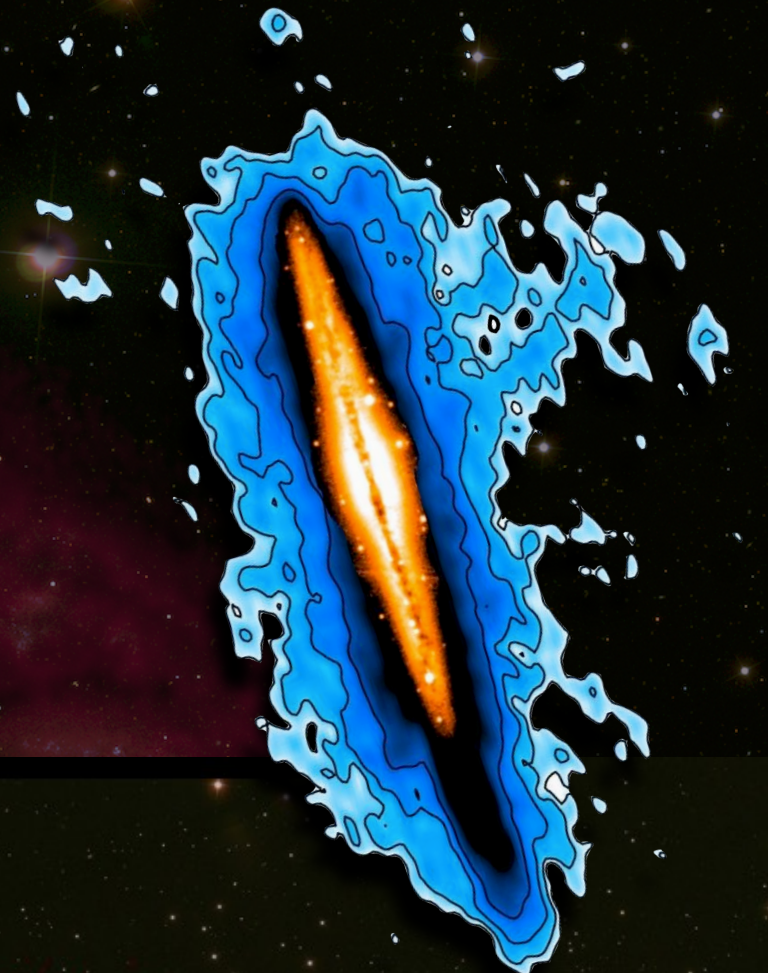
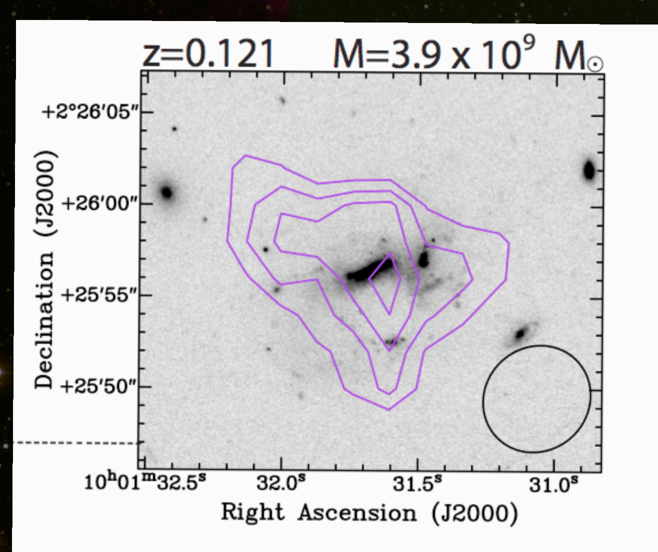




Galaxy evolution

Current state:

- ALFALFA/HIPASS: single dish — z < 0.1, all unresolved
- Apertif/ASKAP: 15-30 arcsec — z < 1 (< 0.25), low-z resolved (some)
- Chiles: 5-10 arcsec — z < 0.5 (0.2-0.3), resolves galaxies out to z ~ 0.3
- Laduma: 8-16 arcsec — z < 1.2 (0.3-0.4), mostly unresolved

Deep integrations will detect galaxies well below $M_\star$
Global Statistics out to large z

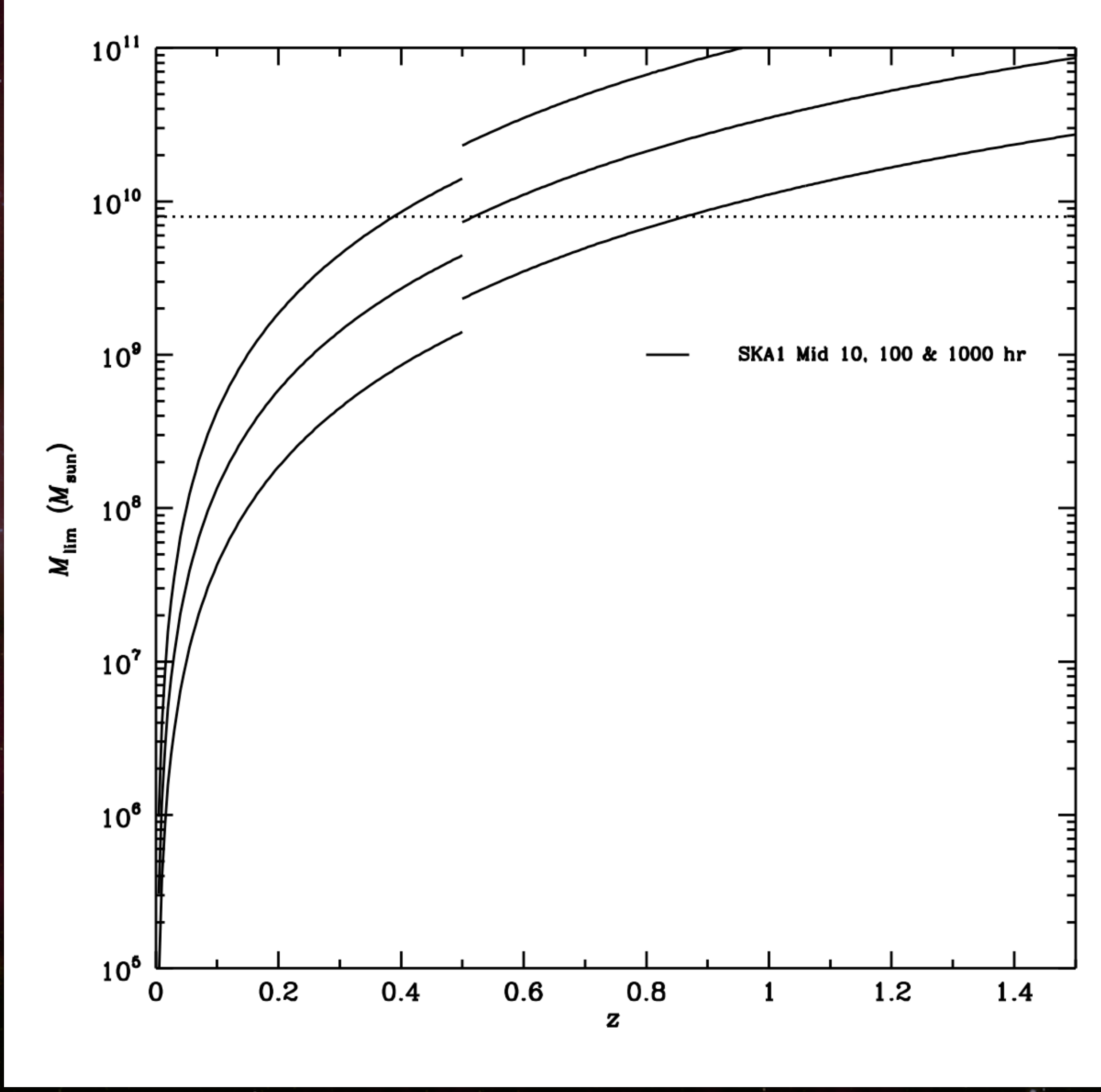
SUR only z < 1.2

Can study larger part of galaxy population out to reasonable redshifts

Could do several CHILES/LADUMA surveys (cosmic variance)

or go deep on a single field

Big worry: performance of Band 1



Detection limit (unresolved)

Galaxy evolution

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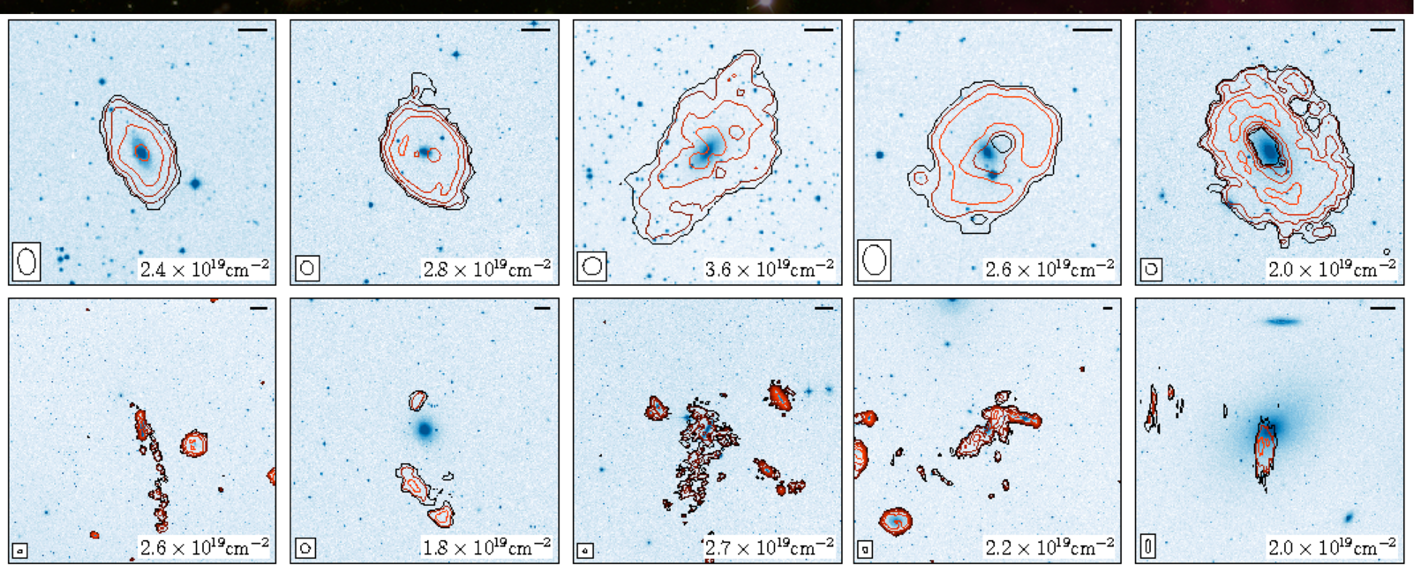
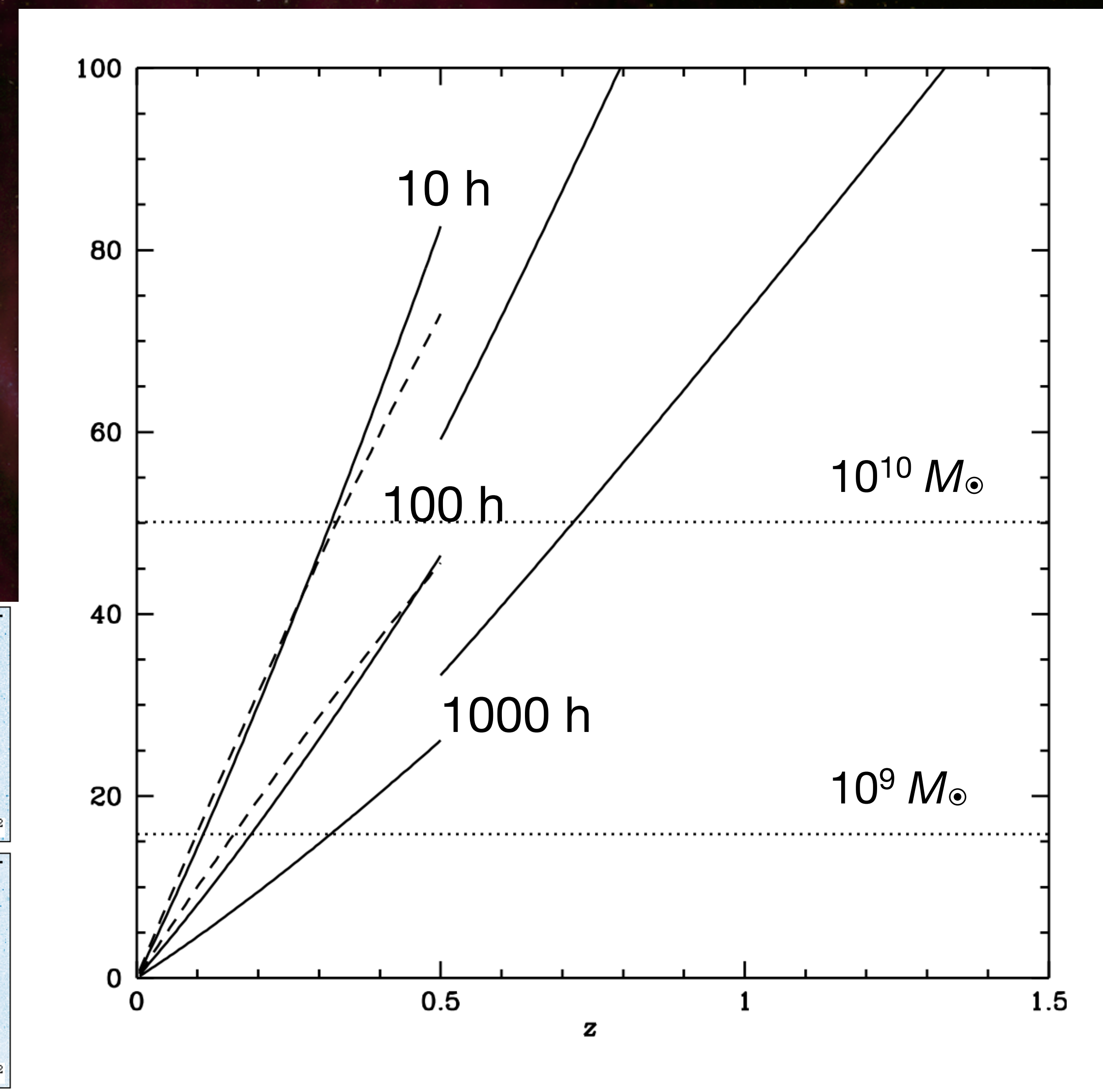
- Apertif/ASKAP: 15-30 arcsec — $z < 1$ (< 0.3), low-z resolved (some)
- Chiles: 5-10 arcsec — $z < 0.45$ (0.2-0.3), resolves galaxies out to $z \sim 0.3$
- Laduma: 8-16 arcsec — $z < 1.2$ (0.3-0.4), mostly unresolved

Deep integrations will *resolve* many galaxies

Role environment

Kinematics; Angular momentum





physical resolution of detecting 10^{20} cm^{-2}

Galaxy evolution

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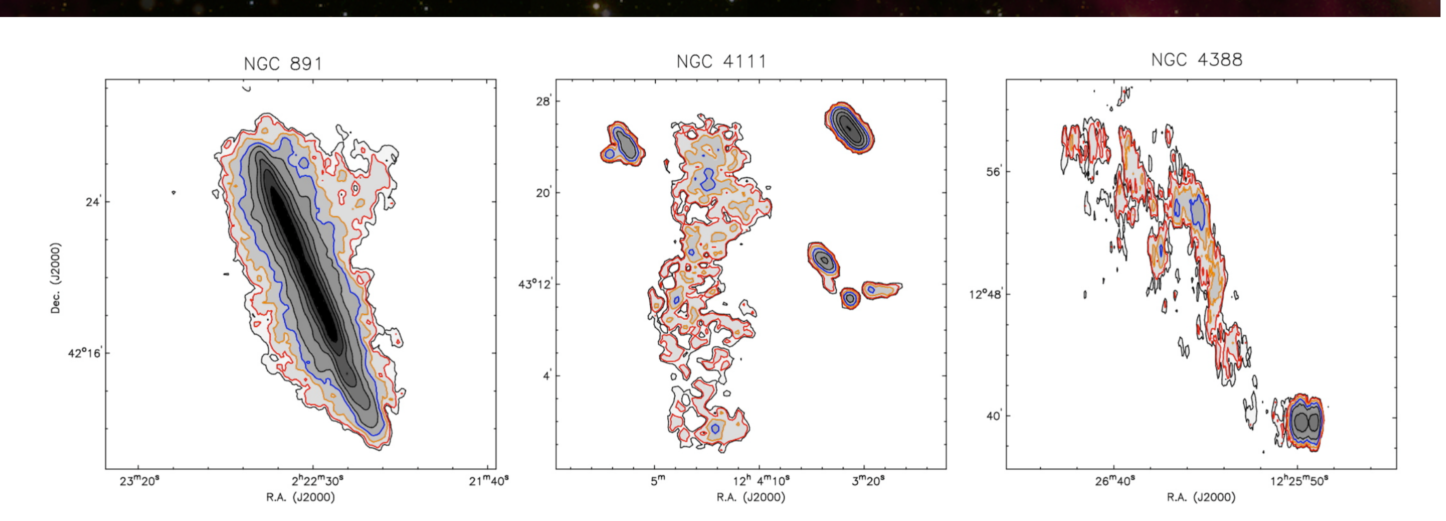
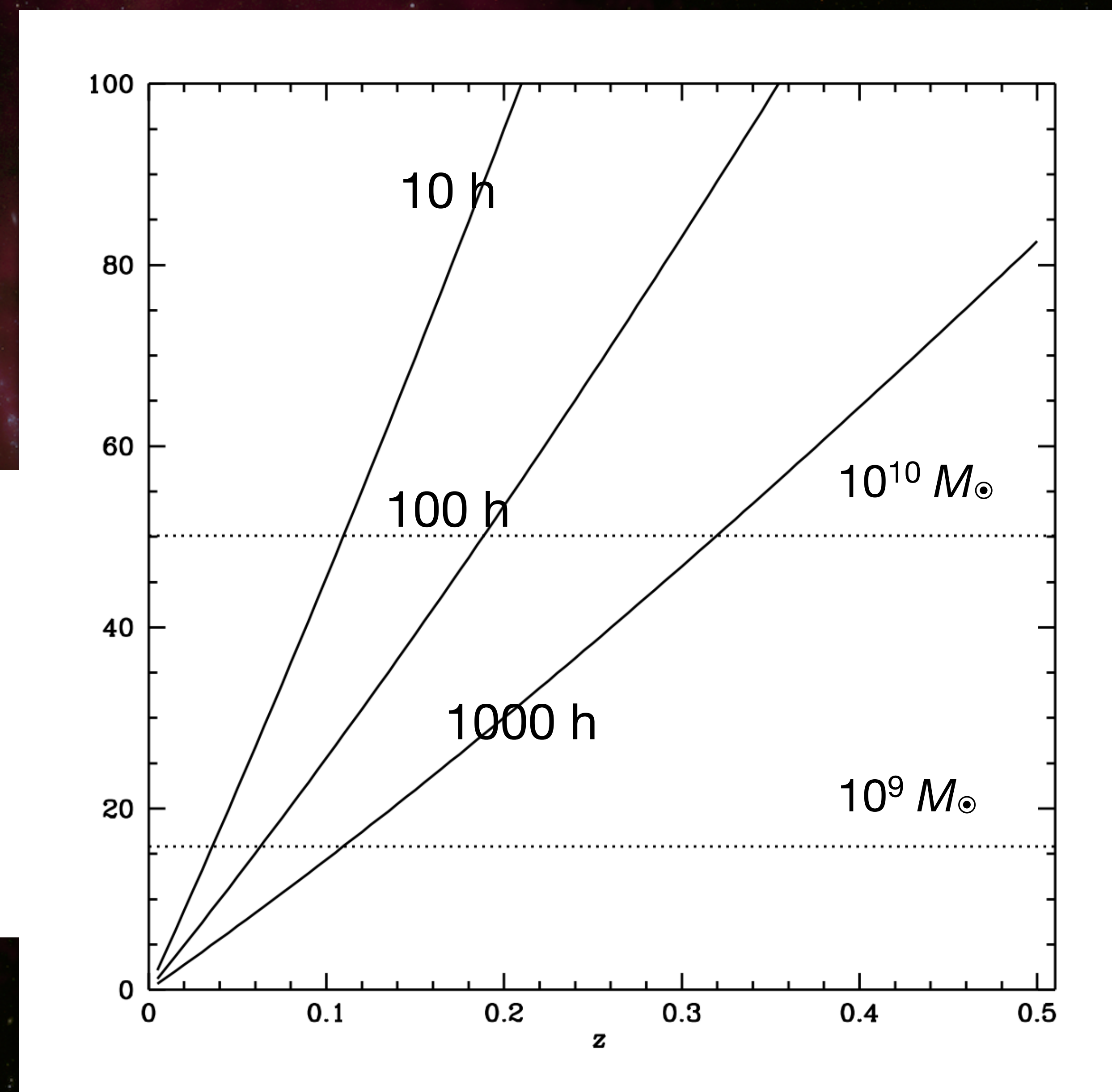
- Laduma: 8-16 arcsec — z < 1.2 (0.4), mostly unresolved

Deep integrations will do Halogas-kind work well beyond Local Volume

Role environment & accretion



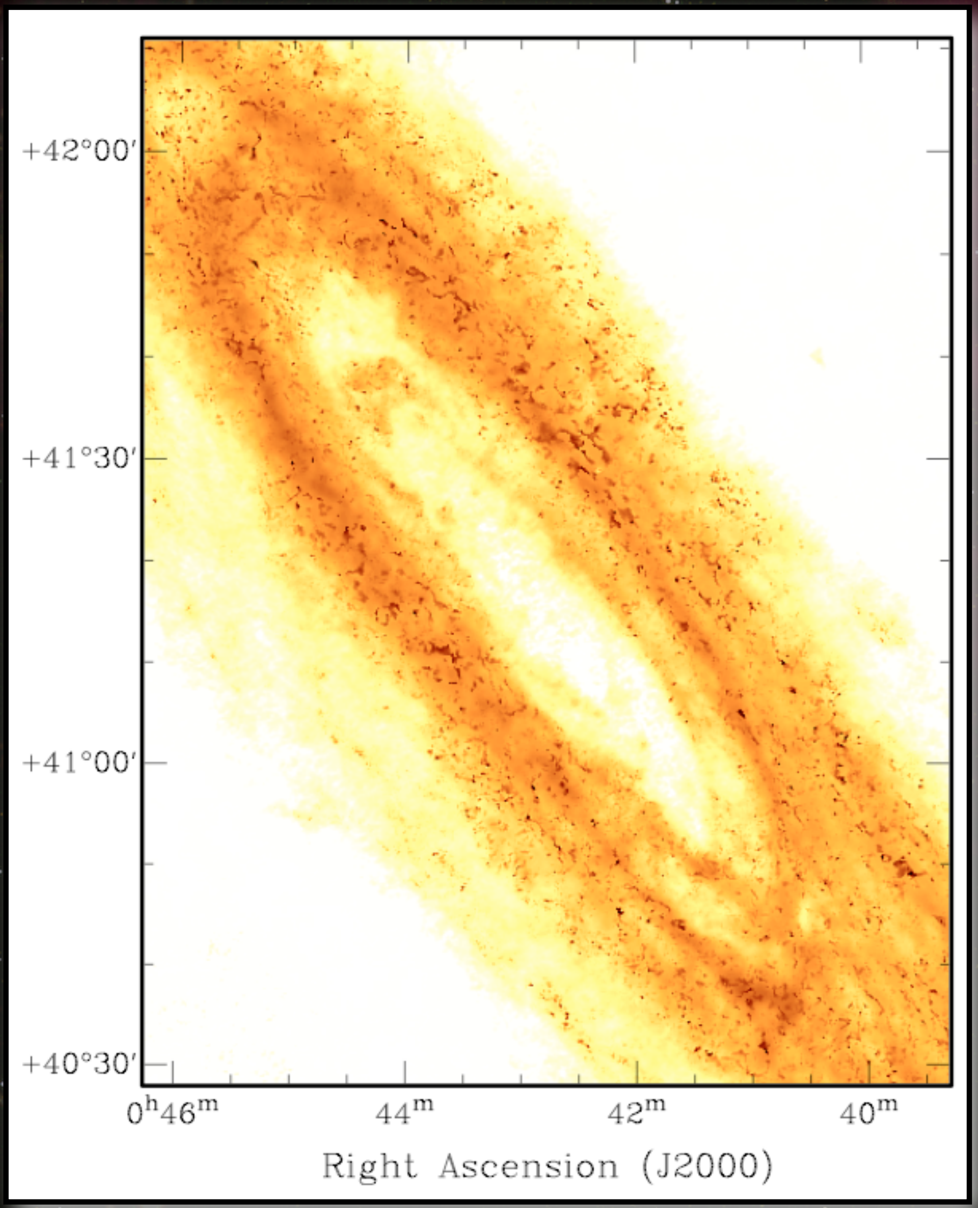


physical resolution of detecting 10^{19} cm^{-2}

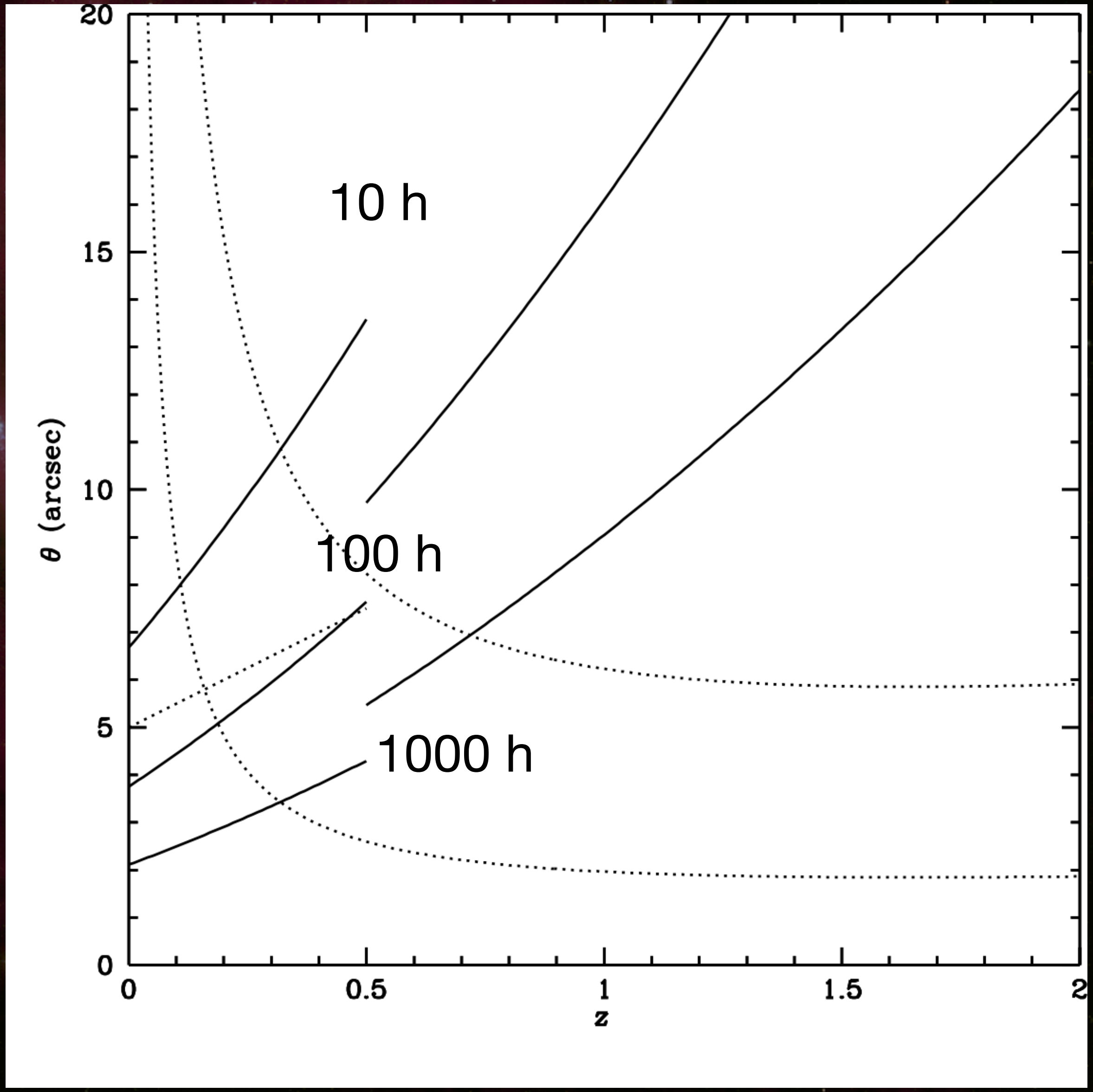
Nearby galaxies

- Current state:
  - THINGS: scaling relations for star formation at 500 pc resolution, ~ few x 10^{20} cm^{-2} (B-array)
  - Monghoose: same as above at ~ 1 kpc resolution (MeerKat)

4 arcsec at 5 Mpc is 100 pc: ISM-star formation (ALMA)
and disk-halo interaction at small scales



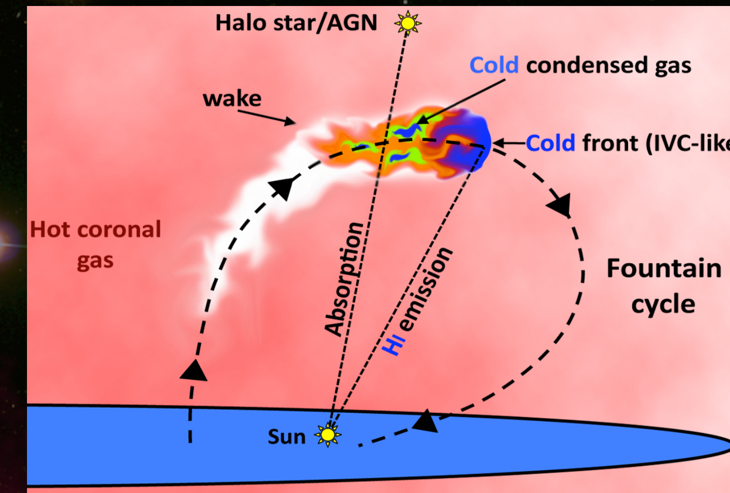
HI in M31 with 100 pc resolution (Braun; WSRT)



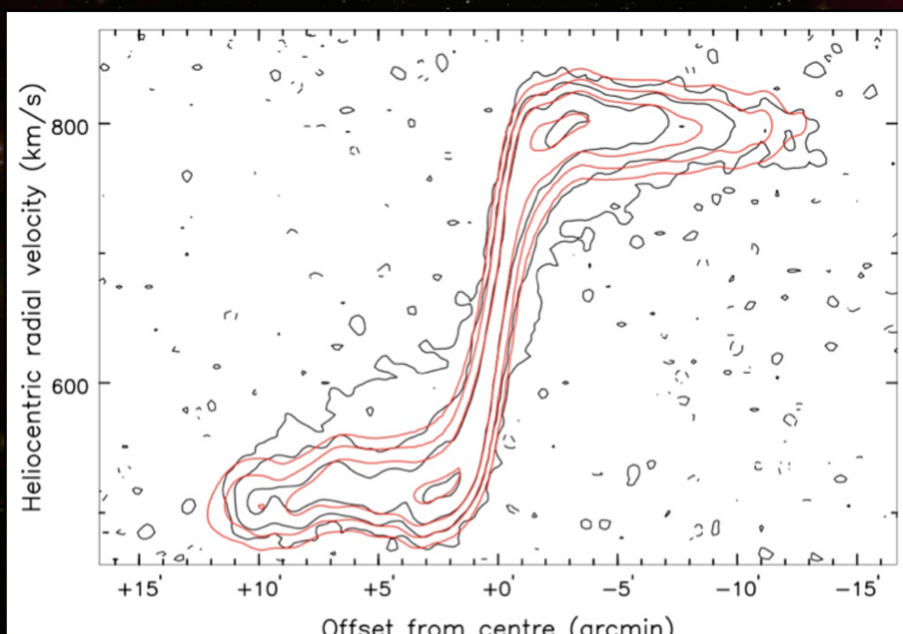
angular resolution of detecting 10^{20} cm^{-2}

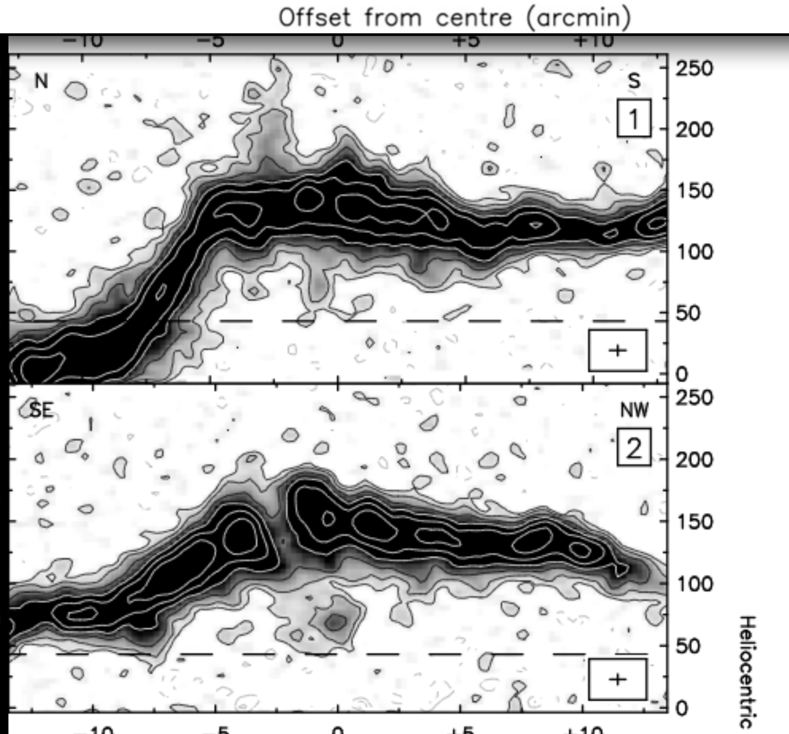
Nearby galaxies

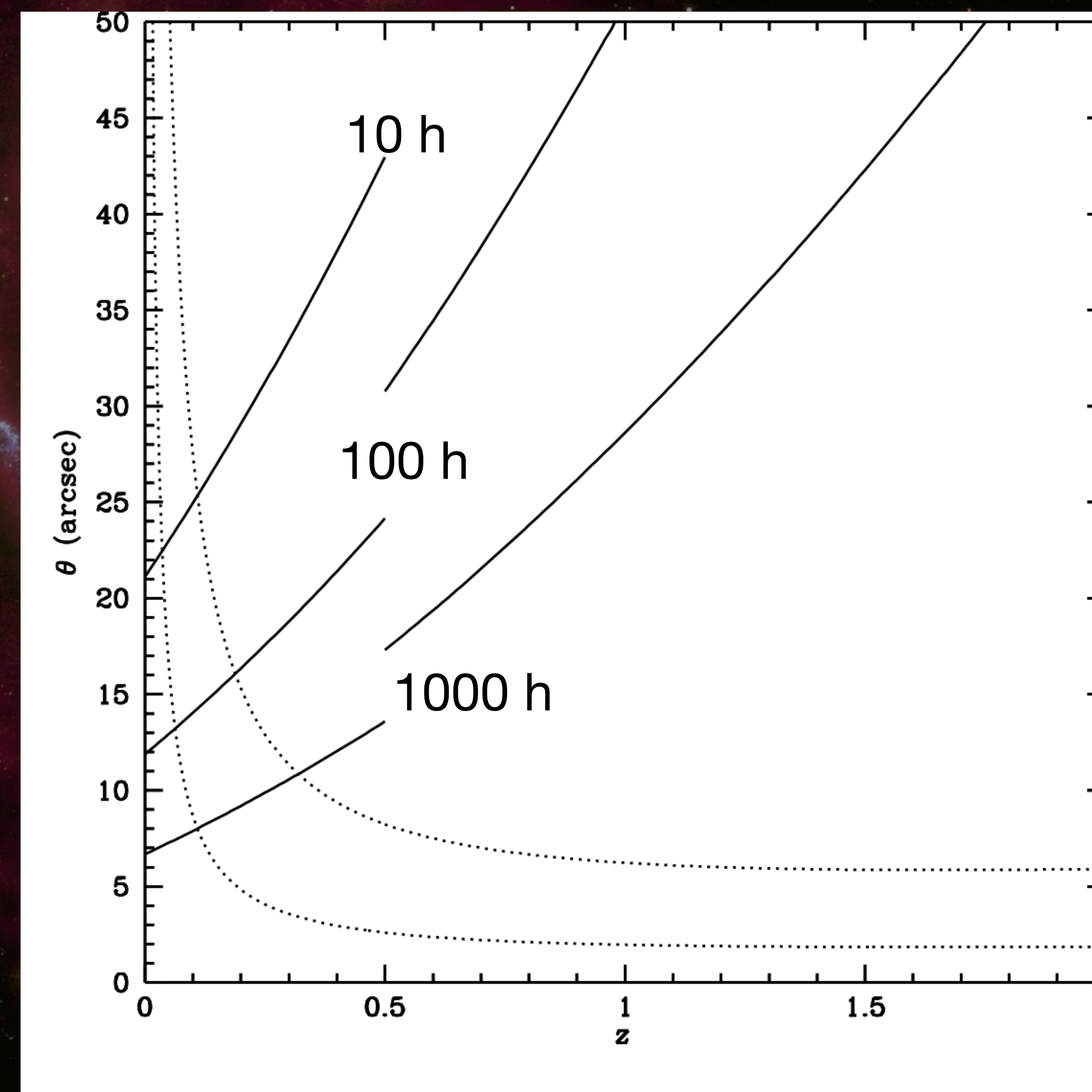
- Current state:
  - Halogas: extra-planar gas at 30-60 arcsec resolution
  - Monghoose: same as above at ~ 1 kpc resolution (MeerKat)



Mid: details of disk-halo interaction at small scales, accretion



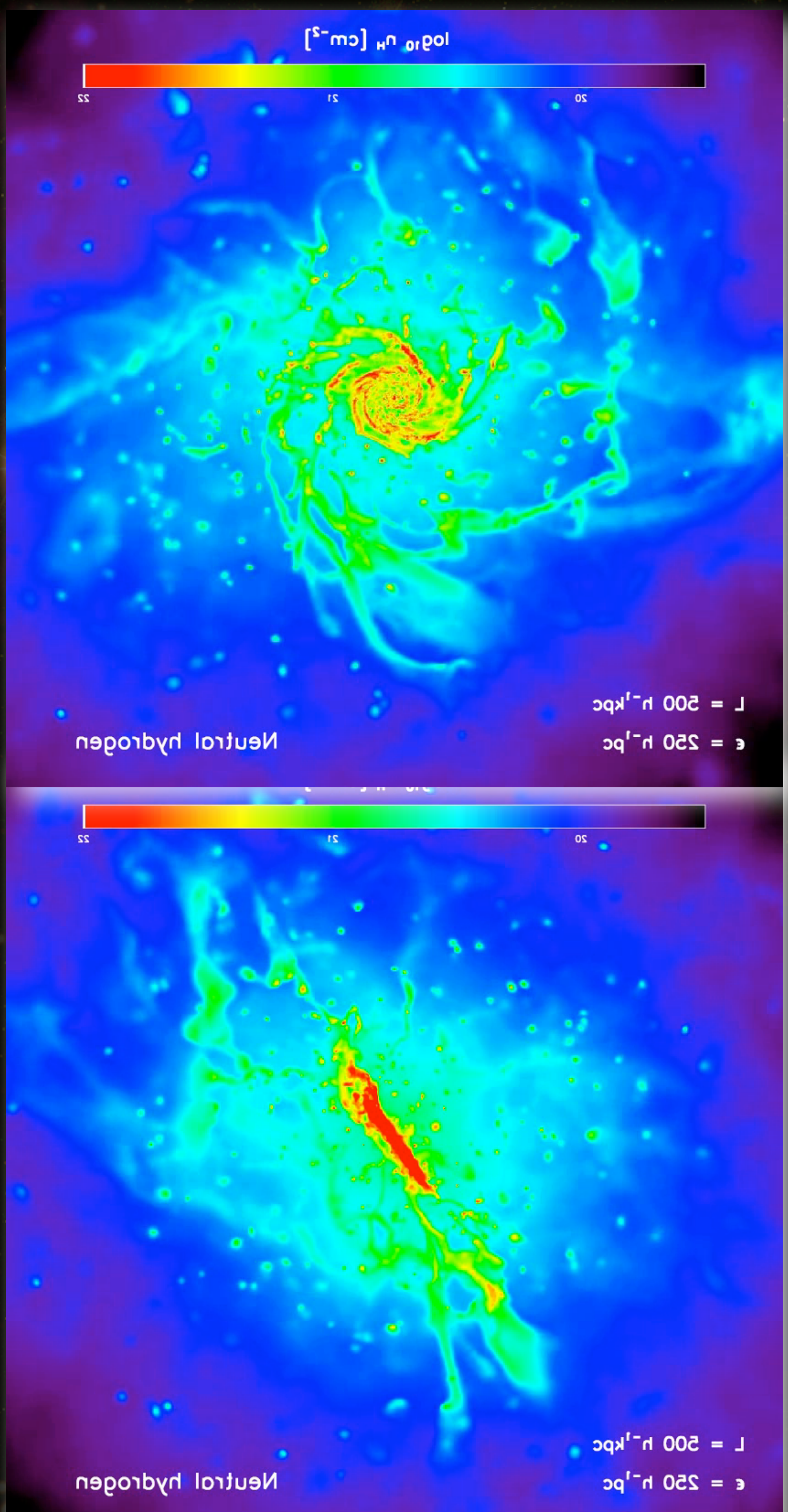


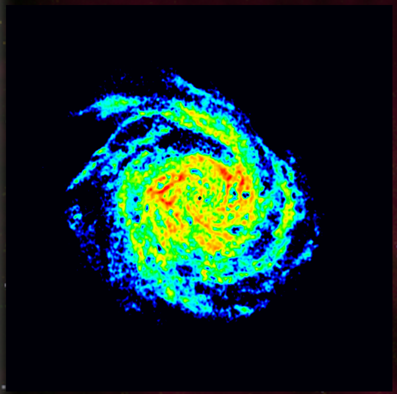


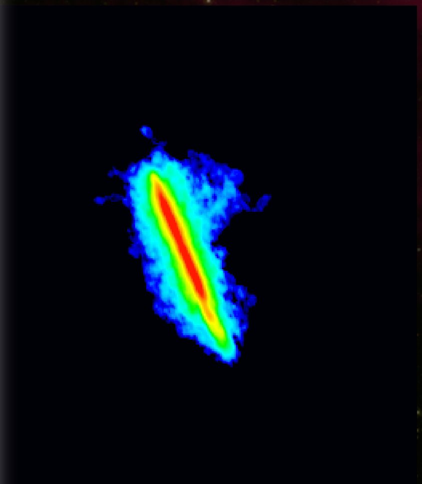
angular resolution of detecting 10^{19} cm^{-2}

Nearby galaxies

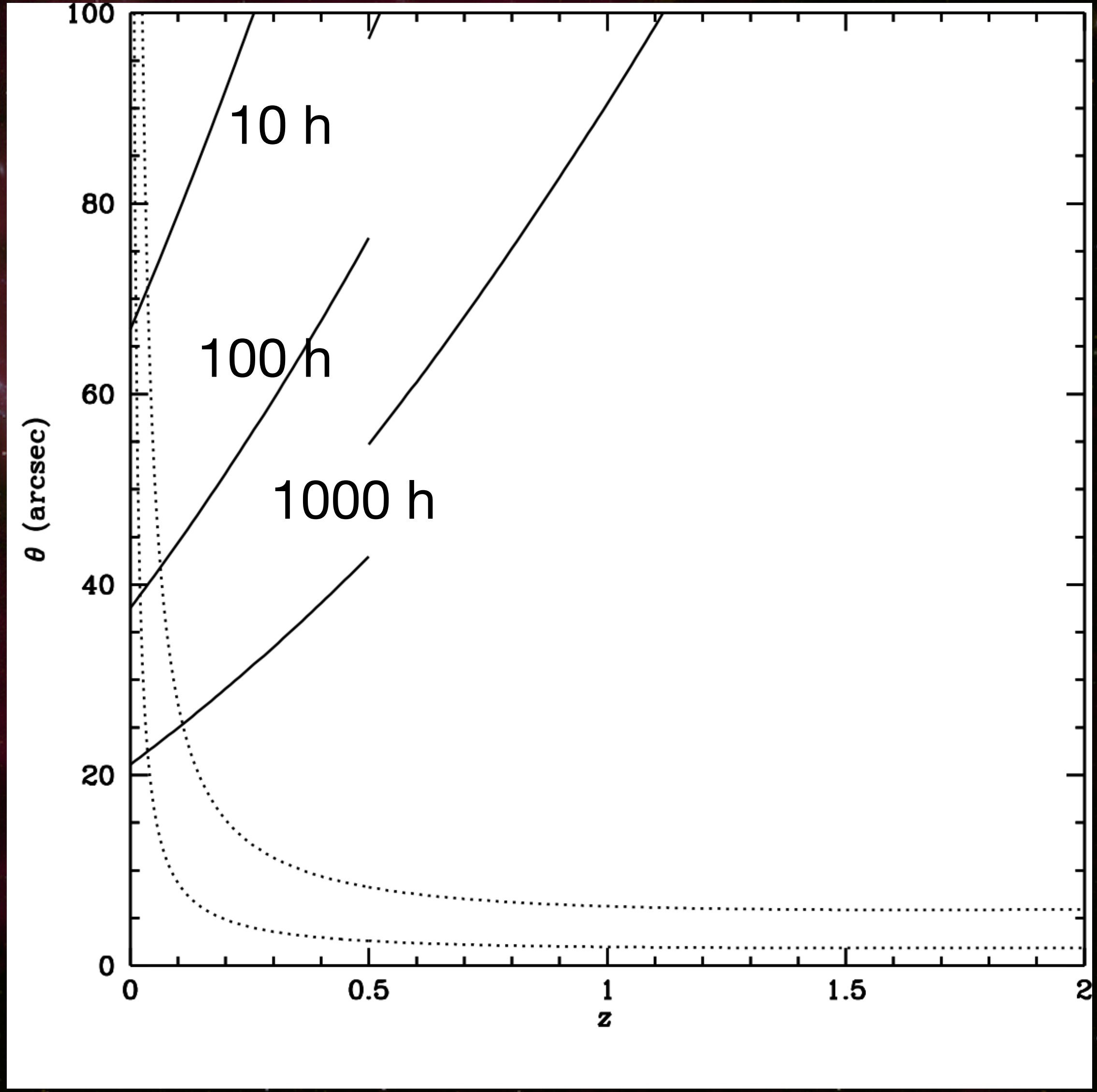
- Current state:
  - Halogas: Disk-halo interface & accretions at few kpc resolution, ~ 5 x 10^{18} cm^{-2} (WSRT)
  - Monghoose: same as above at ~ 1 kpc resolution (MeerKat)







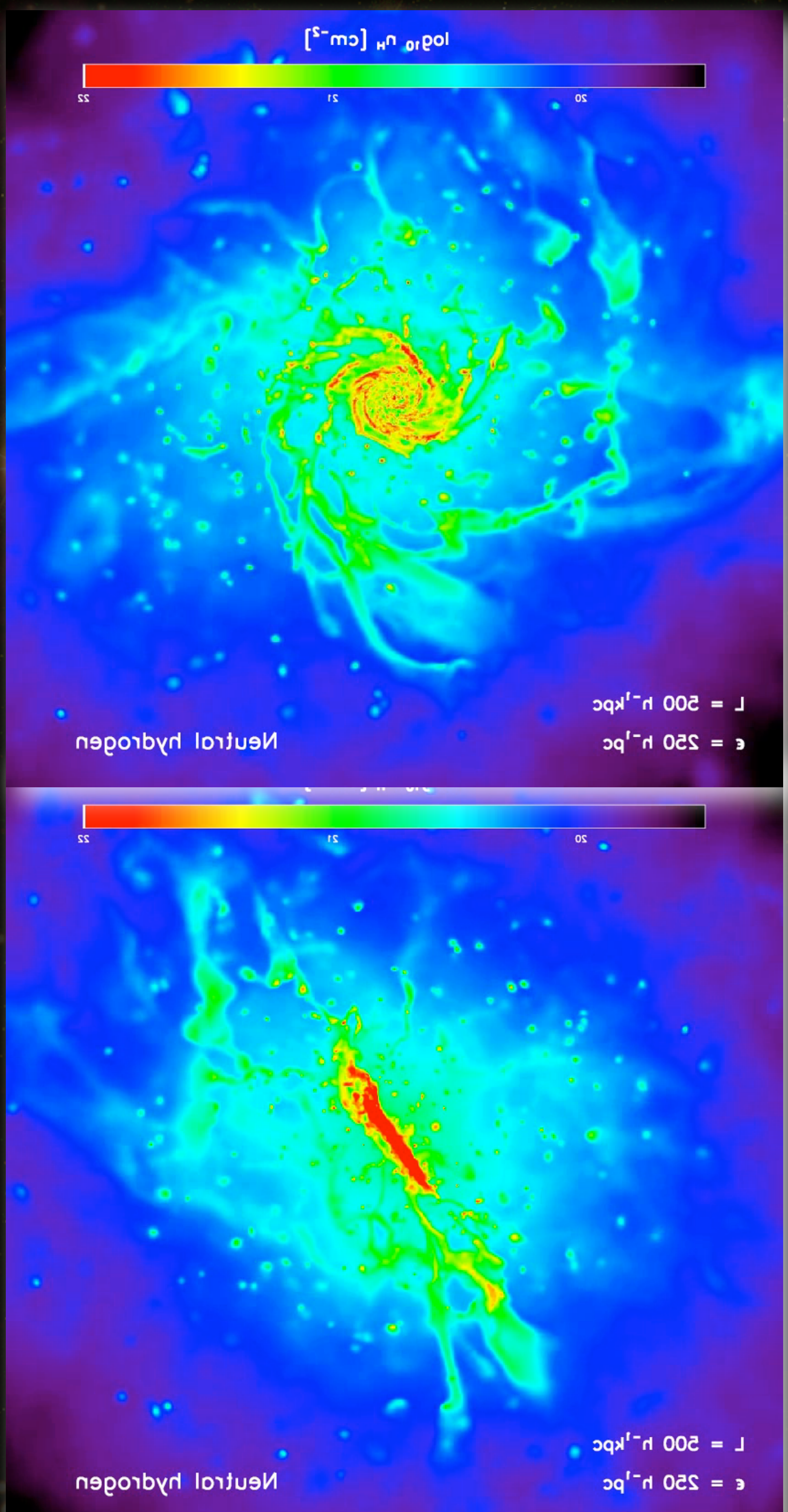
Potential for studying disk-halo-IGM interfaces

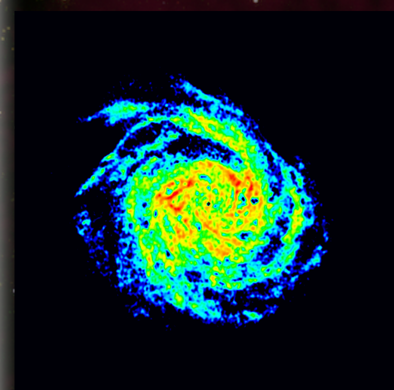


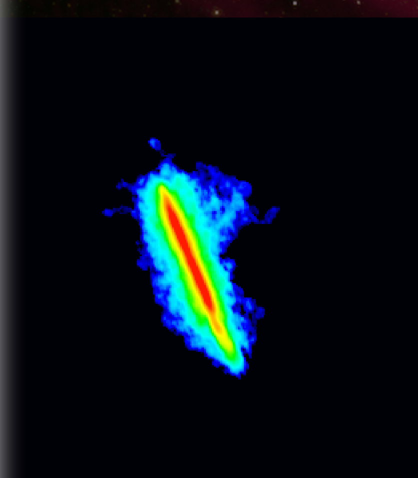
angular resolution of detecting 10^{18} cm^{-2}

Nearby galaxies

- Current state:
  - Halogas: Disk-halo interface & accretions at few kpc resolution, ~ 5 x 10^{18} cm^{-2} (WSRT)
  - Monghoose: same as above at ~ 1 kpc resolution (MeerKat)







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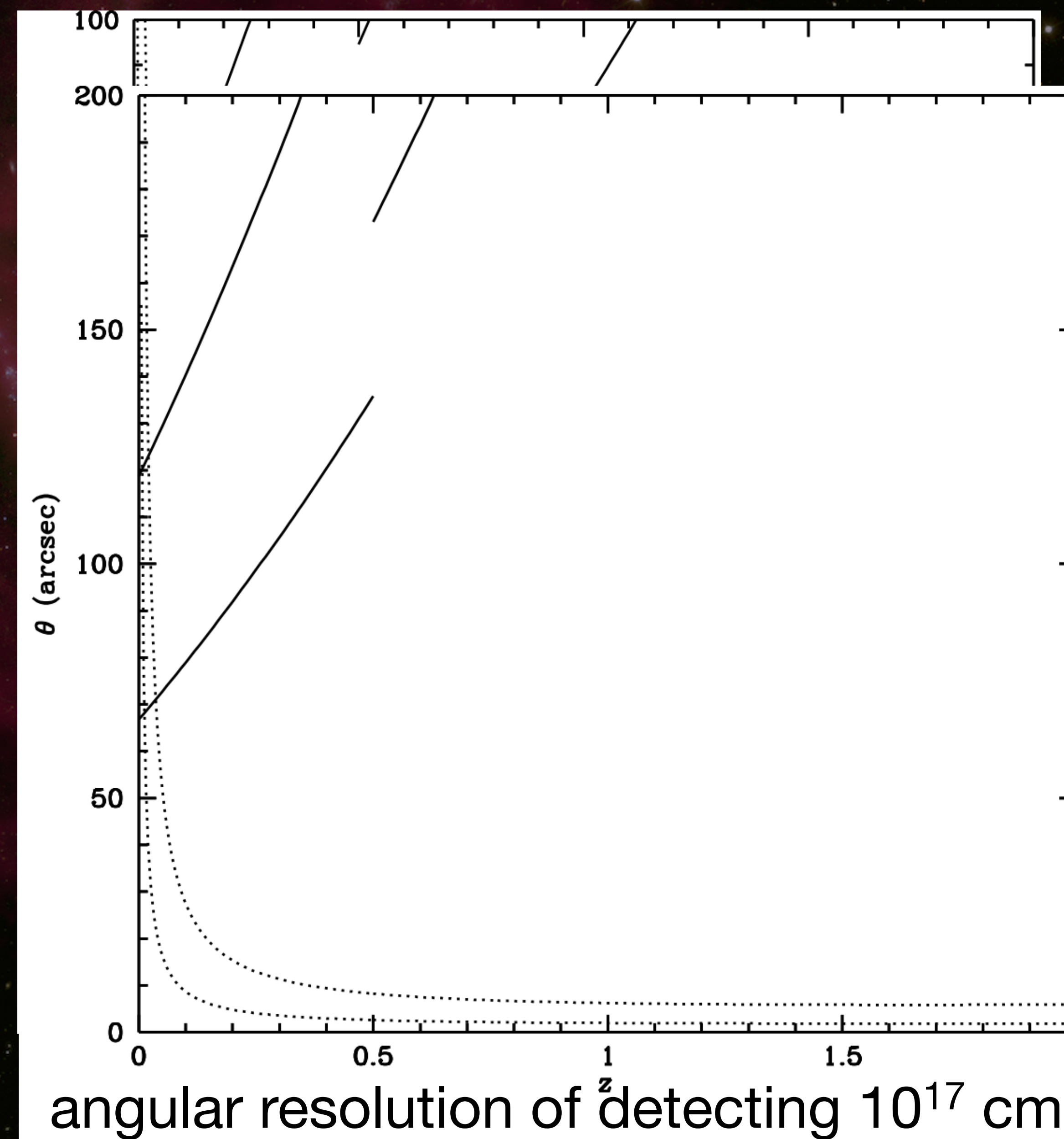


Intervening absorption

ASKAP & MeerKat : $z < 1.4$

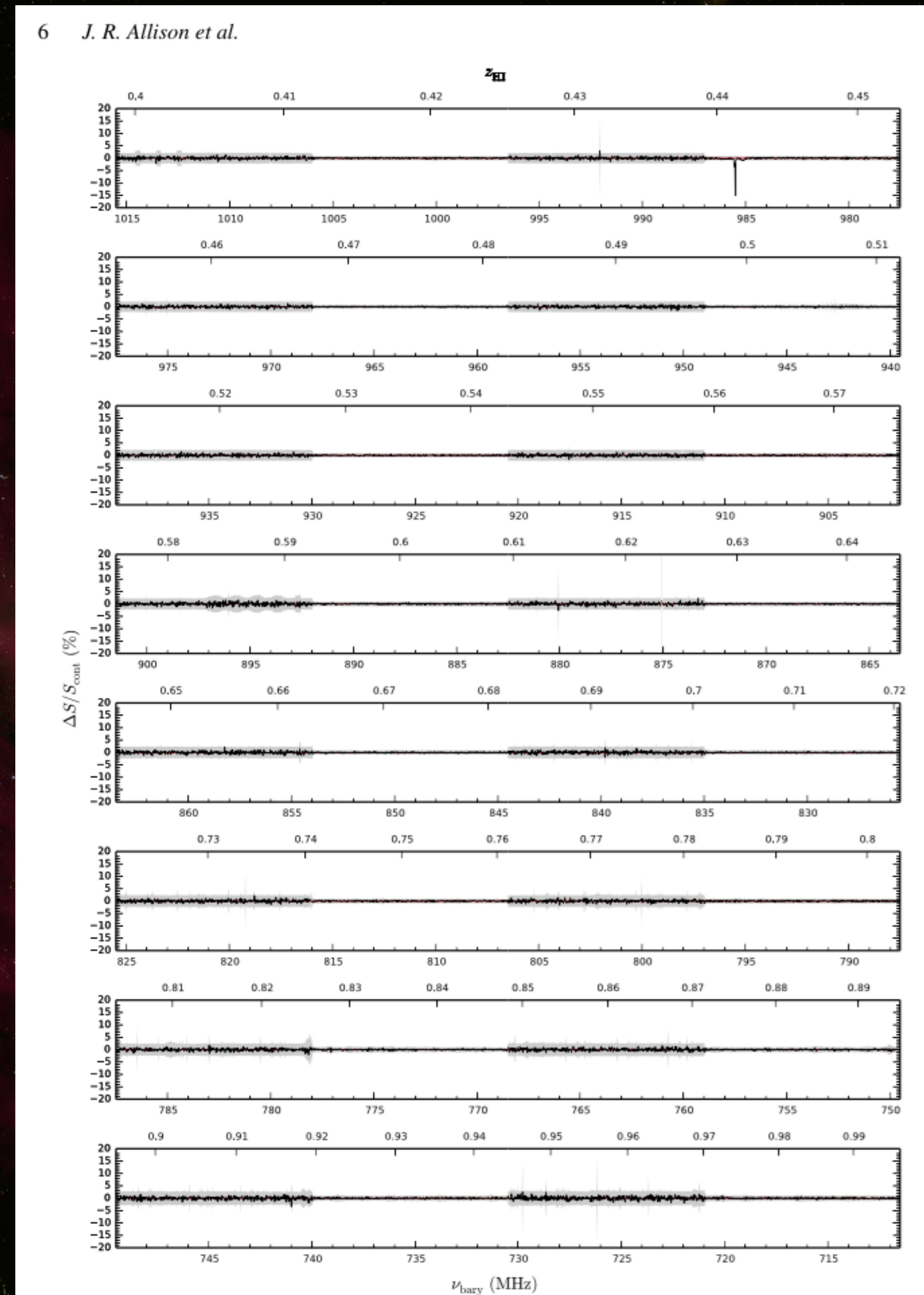
SKA1 Mid: $z < 3$

Potential not much reduced

FoV goes as $(1+z)^2$

FRBs!!

Big worry: performance of Band 1



Associated absorption

Current state:

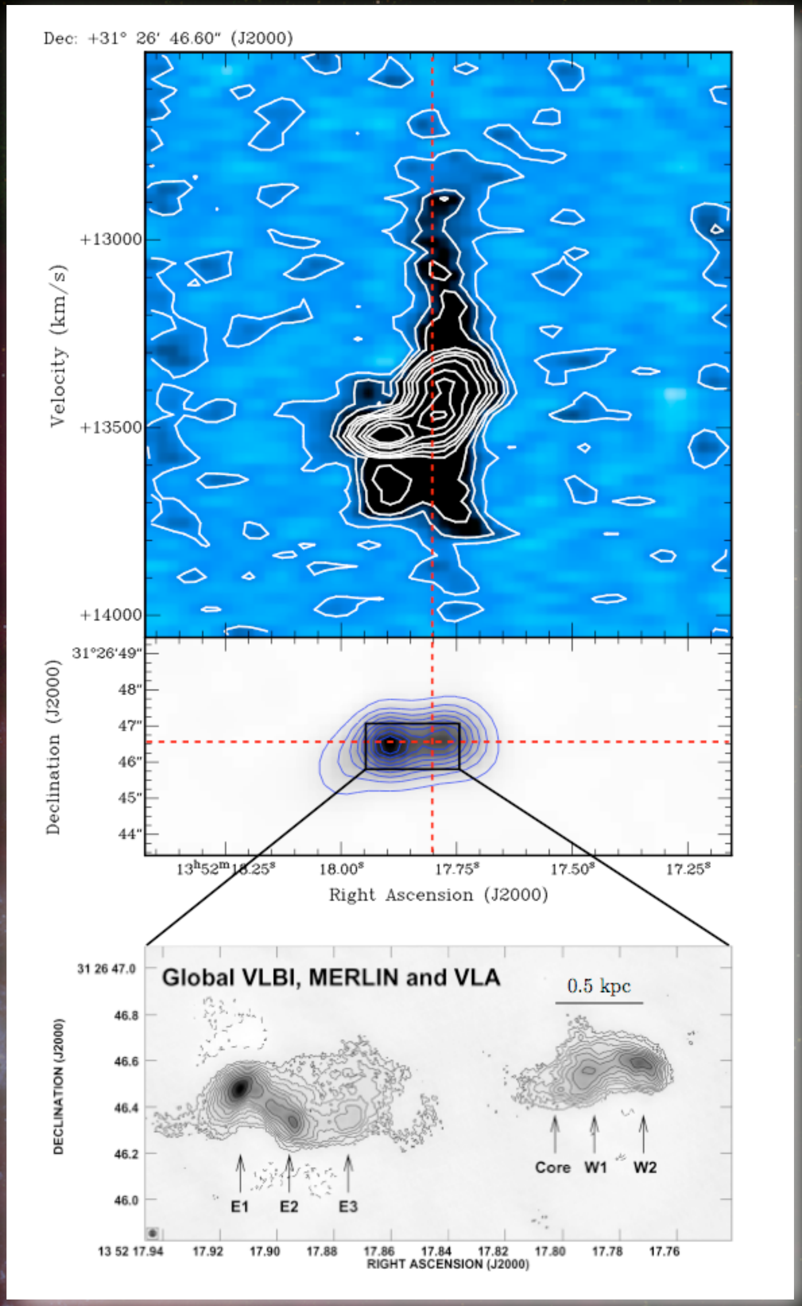
- WSRT: z < 0.2 (30% detection rate!!)
- JVLA A-array: highest resolution (1-2 arcsec), z < 0.45
- Apertif/ASKAP/MeerKat:
  surveys will find many new systems, z < 1 (0.25)
  but will be unresolved

Progress possible by:

- higher spatial resolution: 4x better than JVLA
  locate where the outflow is occurring,
  much larger volume over which sources are resolved
- explore z > 1 (completely new)

Mid should have Band 1!!!

Sensitivity is important, but not crucial



Mahony+ 2014

Conclusion

Re-baselining of SKA1 has significant impact on HI science
but there is still significant improvement compared to existing telescopes

Exploit commensal surveys

Opportunities:

Deep integration to go for the highest z, global properties
Many fields like CHILES/LADUMA
Resolved properties for large fraction of galaxy population out to z ~ 0.5
Low column density studies out to z ~ 0.1 - 0.2

100 pc resolution in nearby galaxies: disk-halo interface
very low column density observations of nearby galaxies: galaxy - IGM interface

Absorption studies for unexplored redshifts

PHISCC should be pro-active to create coherent strategy (as in SKA Book)