HI disk statistics: into the SKA era

Kristine Spekkens
Queen's University in Canada

Springel+ 2005

HI disk statistics: into the SKA era

Kristine Spekkens

Queen's University in Canada

- Untargetted HI surveys with the SKA pathfinders
- Measuring the statistics of HI galaxy structure
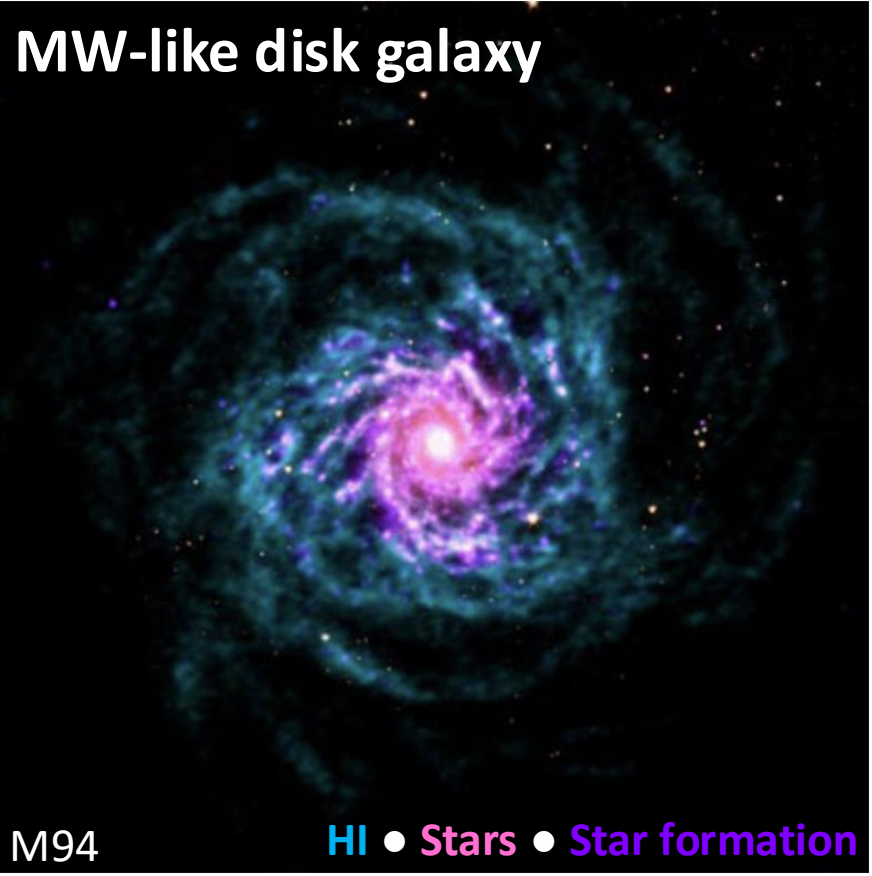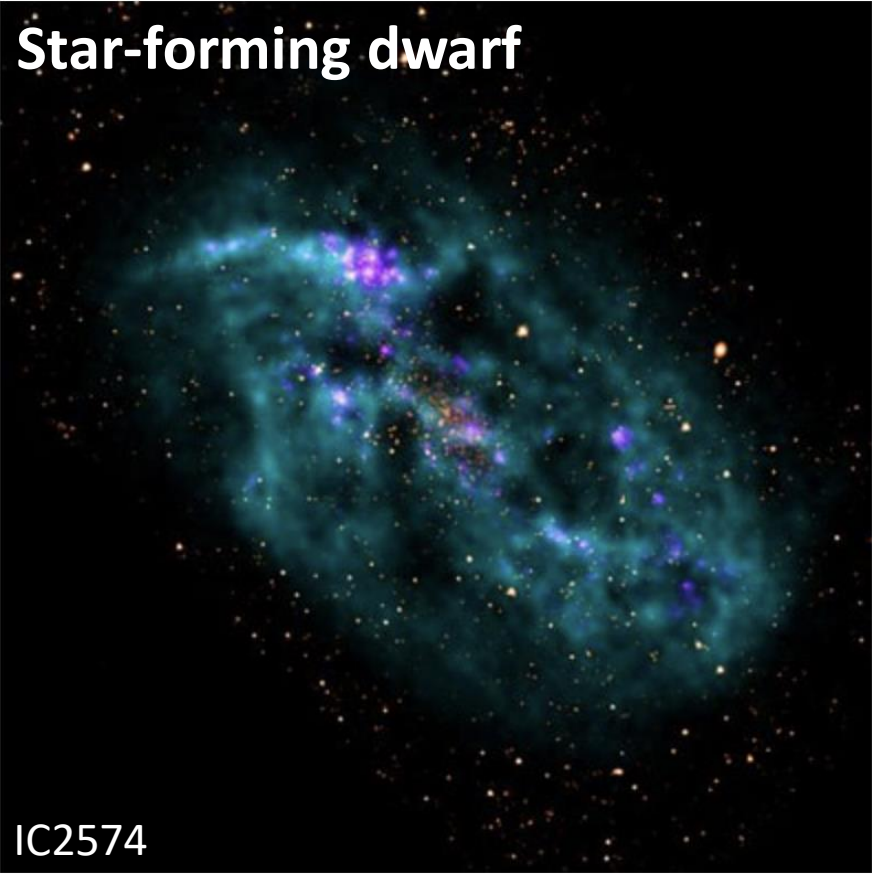- HI disk statistics through cosmic time with the SKA

Springel+ 2005

HI in disk galaxies

Star-forming dwarf

MW-like disk galaxy

HI is more abundant than stars in dwarfs →

← HI disks extend farther into halos than the stars

THINGS, Walter+ 08

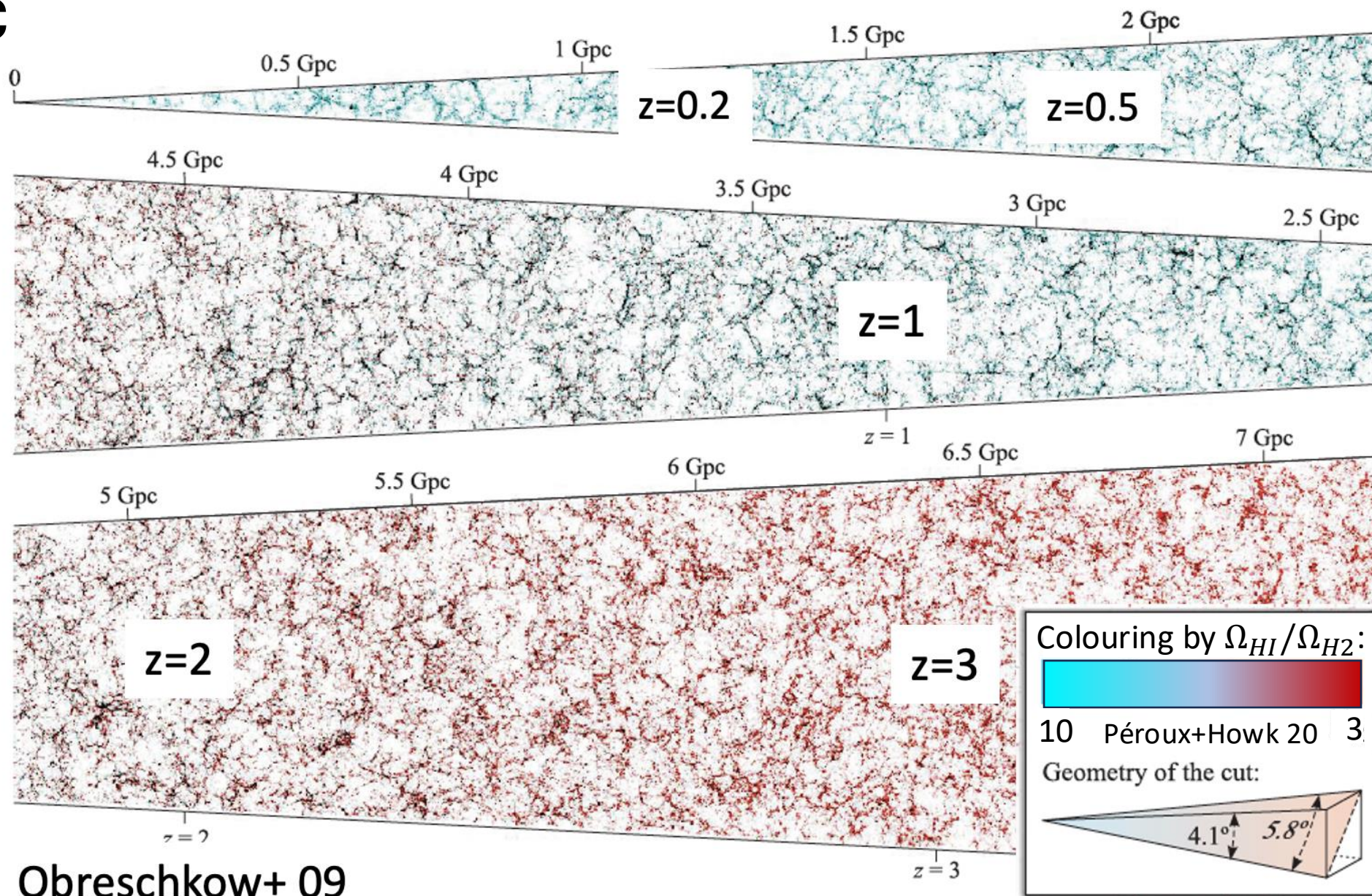IC2574

M94

HI ● **Stars** ● **Star formation**

The HI morphology and kinematics of galaxy populations probe the interplay between baryons and dark matter

HI disk statistics: rotation curve shapes and diversity

(a)

V (km/s) 10^2

10^1

Literature compilation

$\Sigma*,e$

1000

100

10

$M_\odot\ pc^{-2}$

10^0 10^1 10^2

R (kpc)

McGaugh 20
Lelli+ 16

SPARC
Spitzer Photometry & Accurate Rotation Curves

sims

obs

- APOSTLE: gas V_ϕ, pressure support corrected
- APOSTLE: V_{circ}
- APOSTLE: modeled mock observations, pressure support corrected
- LITTLE THINGS
- THINGS

100

V_{circ} (2 kpc) [km s^{-1}]

10

1:1

$10^8 M_\odot$ $5\times10^8 M_\odot$ $10^9 M_\odot$

Oman+ 15,
Dutton+19,
Frosst+ 22

Oman+ 19

10   V_{max} [km s^{-1}]   100

Tension with predictions, but selection functions unknown.

The cosmic HI census

0

0.5 Gpc

1 Gpc

z=0.2

1.5 Gpc

2 Gpc

z=0.5

4.5 Gpc

4 Gpc

3.5 Gpc

3 Gpc

2.5 Gpc

z=1

z = 1

6.5 Gpc

7 Gpc

5 Gpc

5.5 Gpc

6 Gpc

z=2

z=3

z = 2

z = 3

Obreschkow+ 09

Colouring by Ω_{HI}/Ω_{H2}:

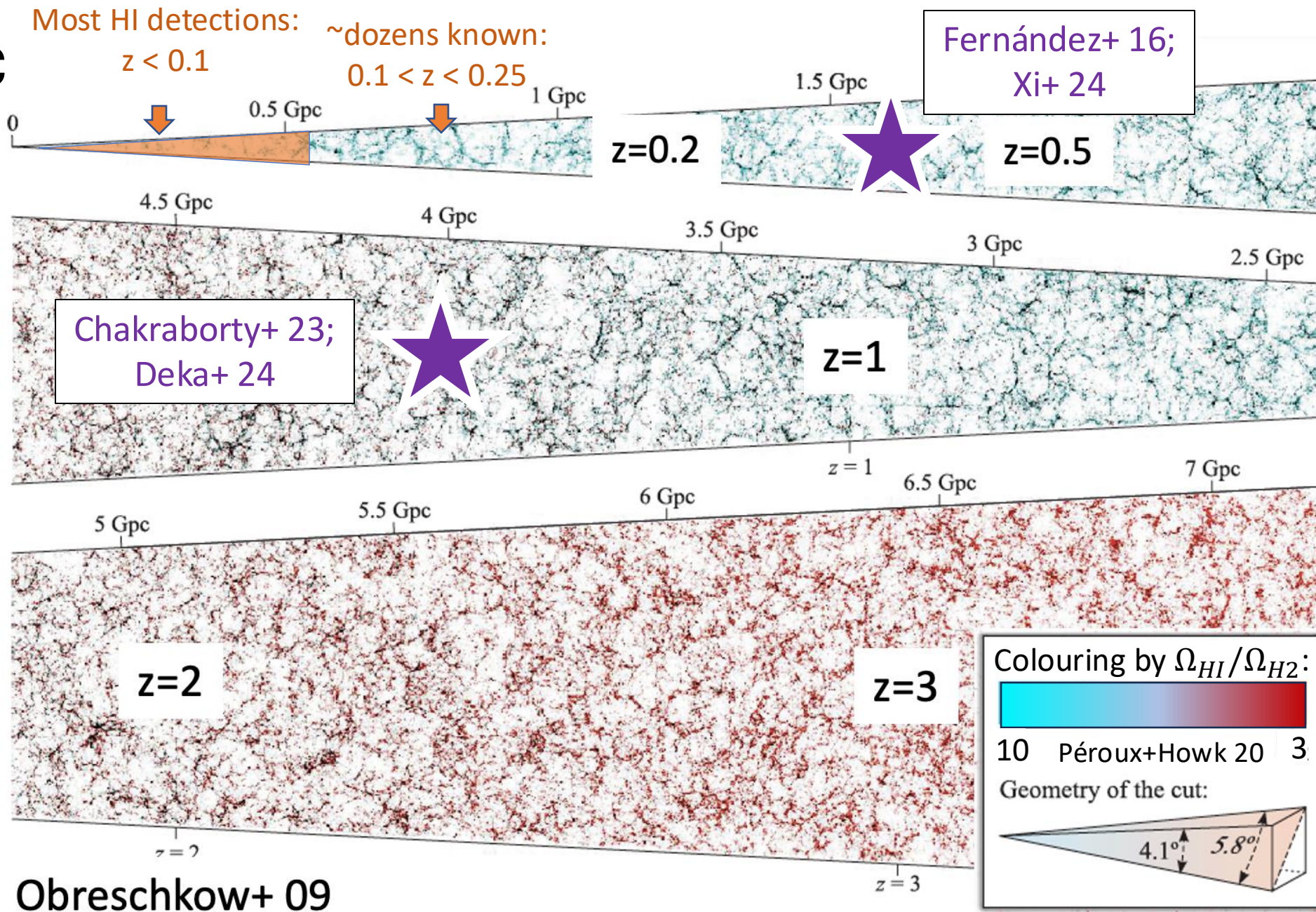10   Péroux+Howk 20   3

Geometry of the cut:

4.1°   5.8°

(universal ratio of atomic to molecular gas)

The cosmic HI census

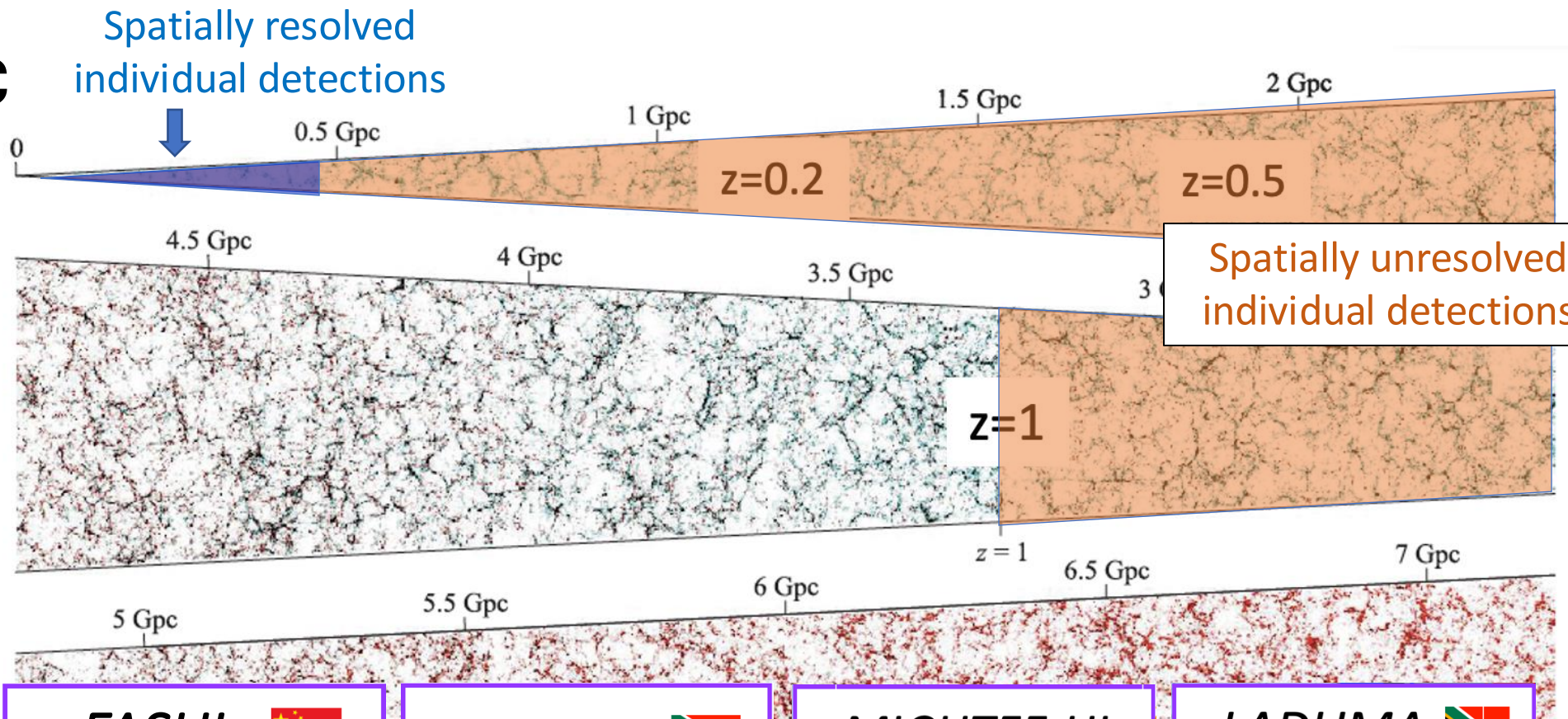## Today:

HI out to z~0.1, targetted maps within 100 Mpc.

Few individual galaxy detections at z > 0.3.

Most HI detections: z < 0.1

~dozens known: 0.1 < z < 0.25

Fernández+ 16; Xi+ 24

Chakraborty+ 23; Deka+ 24

z=0.2

z=0.5

z=1

z=2

z=3

0.5 Gpc

1 Gpc

1.5 Gpc

2.5 Gpc

3 Gpc

3.5 Gpc

4 Gpc

4.5 Gpc

5 Gpc

5.5 Gpc

6 Gpc

6.5 Gpc

7 Gpc

z = 1

z = 2

z = 3

Colouring by Ω_{HI}/Ω_{H2}:

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Obreschkow+ 09

The cosmic HI census

→ 2030:

SKA pathfinders

Tens of thousands of survey hours.

Spatially resolved individual detections

Spatially unresolved individual detections

0.5 Gpc   1 Gpc   1.5 Gpc   2 Gpc

0   z=0.2   z=0.5

4.5 Gpc   4 Gpc   3.5 Gpc   3 Gpc

z=1

5 Gpc   5.5 Gpc   6 Gpc   6.5 Gpc   7 Gpc

z=1

WALLABY

ASKAP, ~20,000 deg^2

30", z < 0.26 (S)

$M_{HI,20Mpc} \sim 10^7$ Mo

Widefield

FASHI + CHORD

FAST/CHORD

~20,000 deg^2

~5', z < 0.35 (N)

$M_{HI, 20Mpc} \sim 10^6$ Mo

Widefield

MALS + Apertif

MeerKAT/WSRT

~1,000 deg^2

~10", z <0.2

$M_{HI, 20Mpc} = 10^{6.8}$ Mo

Medium-deep

MIGHTEE-HI + Fornax

MeerKAT, ~60 deg^2

10", z < 0.4

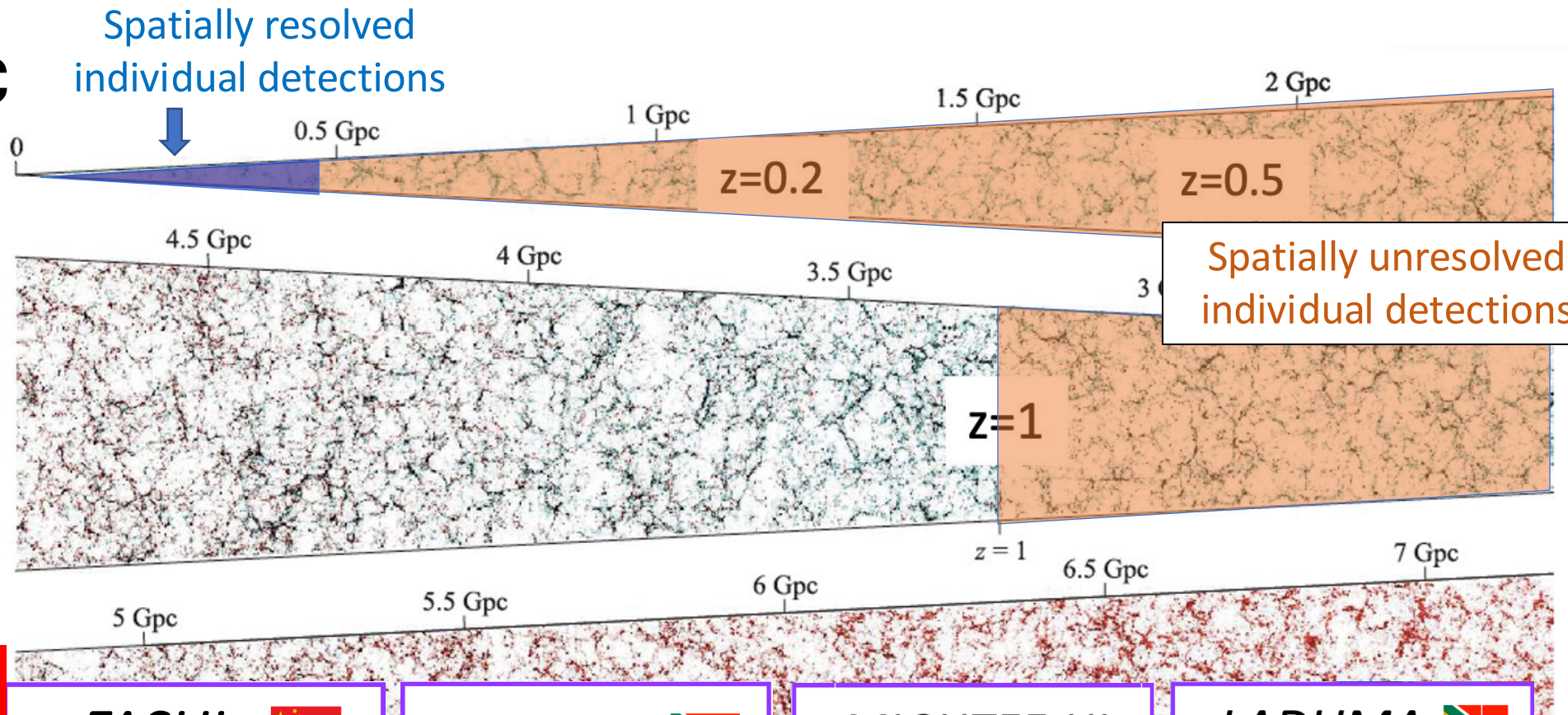$M_{HI, 20 Mpc} = 10^{5.8}$ Mo

Deep fields

LADUMA + DINGO + CHILES

MeerKAT/ASKAP/VLA

~30 deg^2

6-30", z < 1

$M_{HI, 20 Mpc} = 10^5$ Mo

Deep pencil beam

The cosmic HI census

→ **2030:**

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Spatially resolved individual detections

Spatially unresolved individual detections

2 Gpc

1.5 Gpc

1 Gpc

0.5 Gpc

0

z=0.2

z=0.5

4.5 Gpc

4 Gpc

3.5 Gpc

3 Gpc

z=1

5 Gpc

5.5 Gpc

6 Gpc

6.5 Gpc

7 Gpc

z = 1

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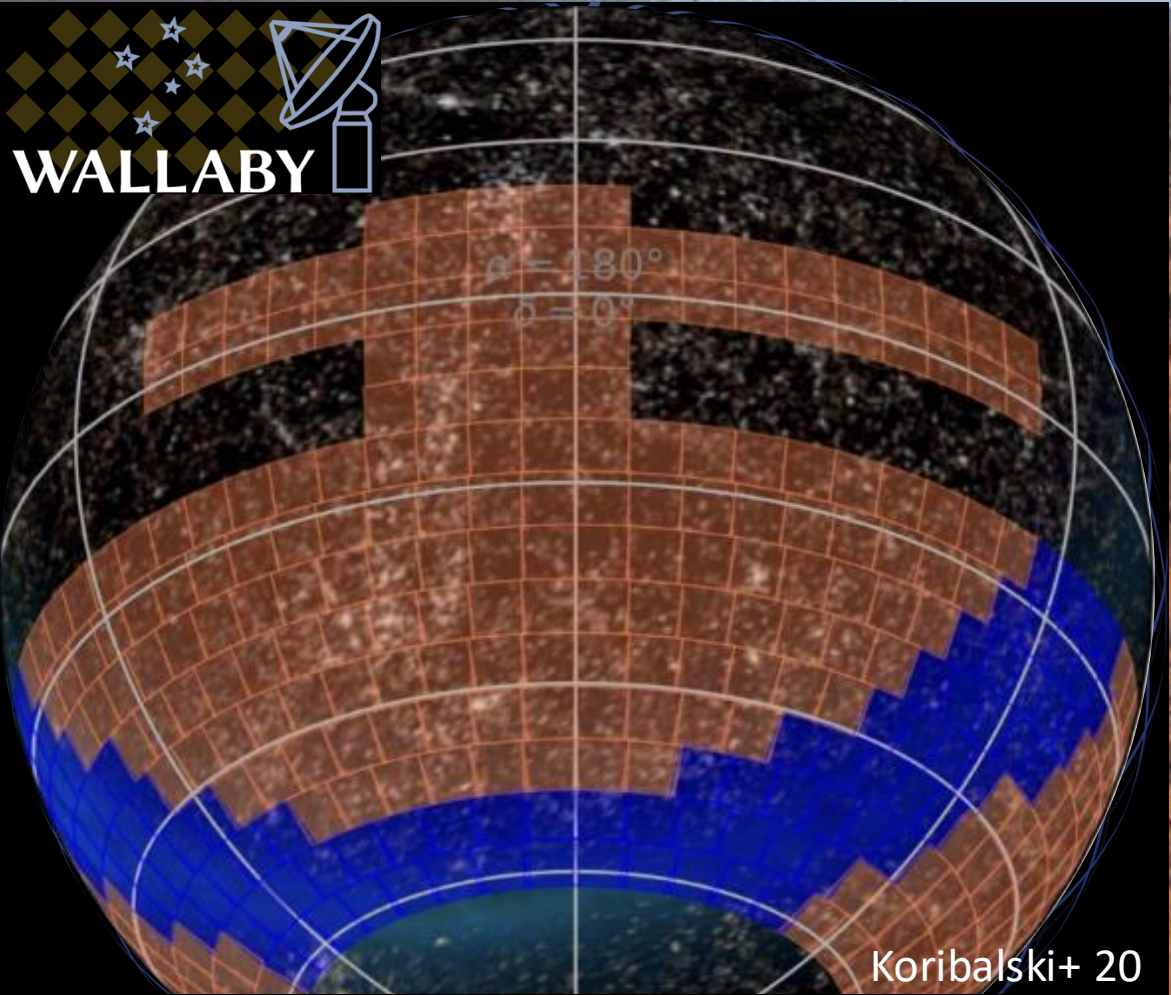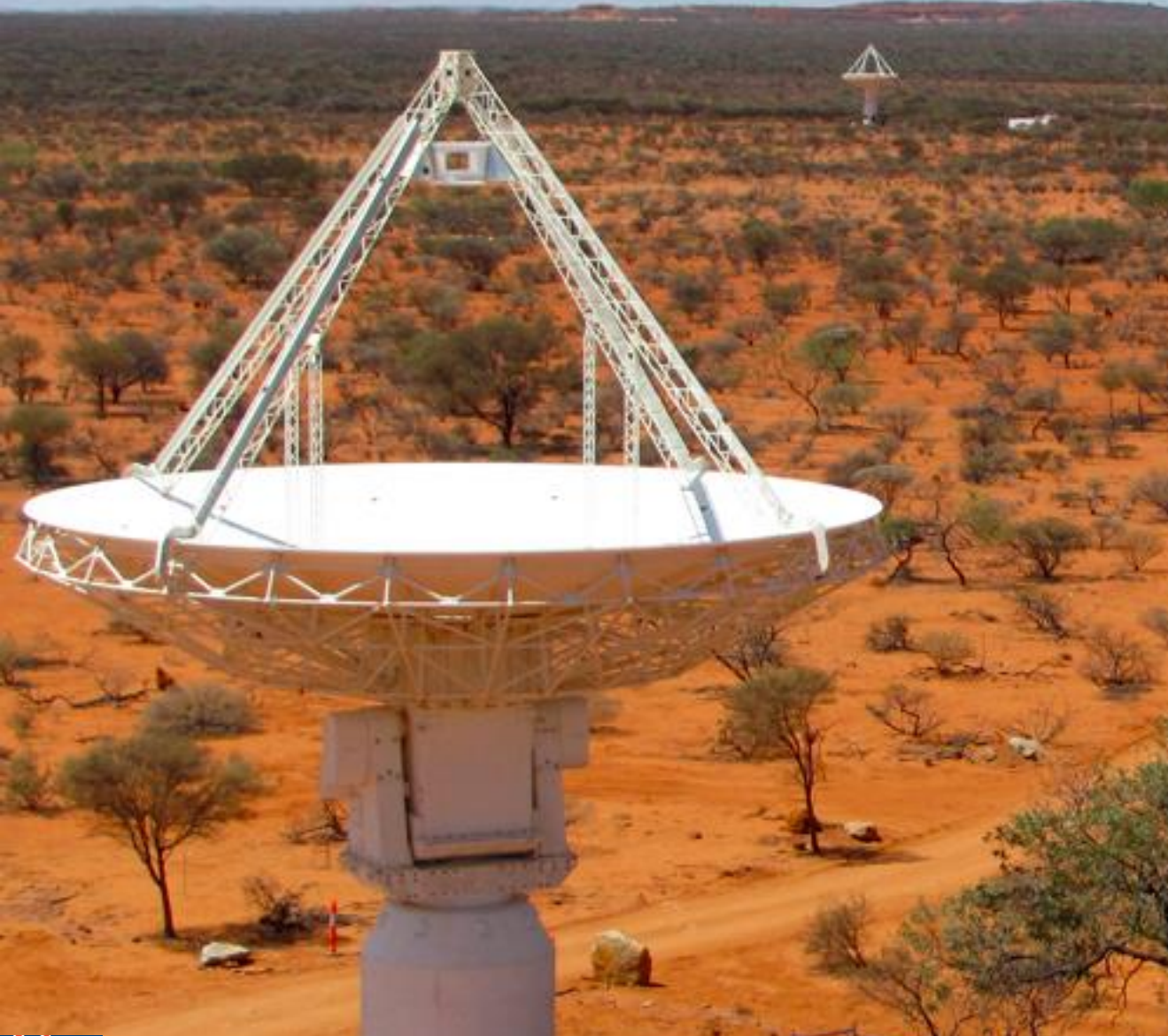MeerKAT/ASKAP/VLA

~30 deg^2

6-30", z < 1

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Deep pencil beam

Resolving HI disks with WALLABY on ASKAP

Koribalski+ 20

Southern hemisphere HI survey,
30" + 5km/s resolution

Australian SKA Pathfinder (ASKAP)

CSIRO

Resolving HI disks with WALLABY on ASKAP

Koribalski+ 20 - 3π sr prediction

int. S/N > 10
int. S/N > 5
ALFALFA
HIPASS

resolution elements across disk
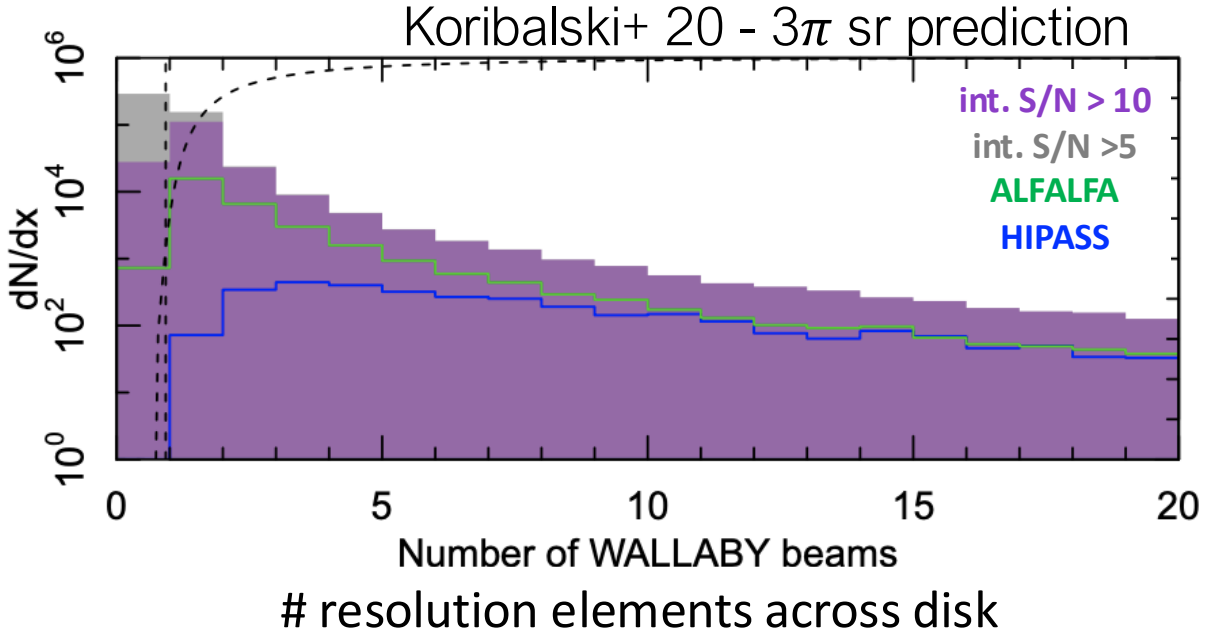
WALLABY will spatially resolve
>8,000 HI disks.

Statistics! Selection function!

Wang+ 22

Full survey now underway!
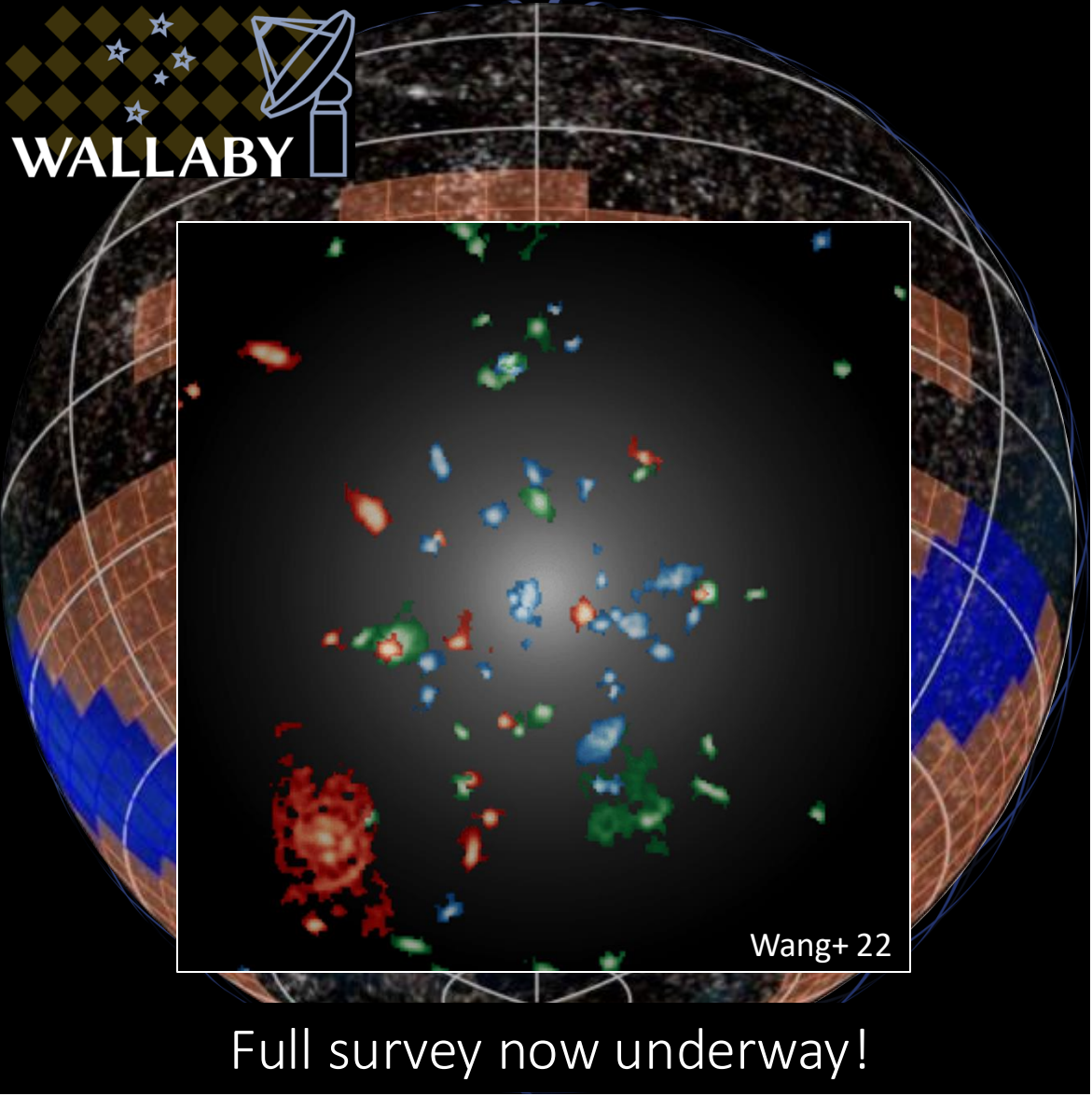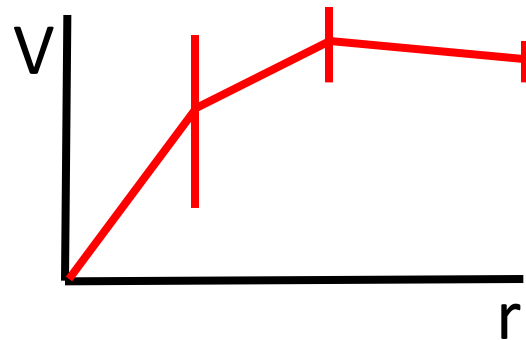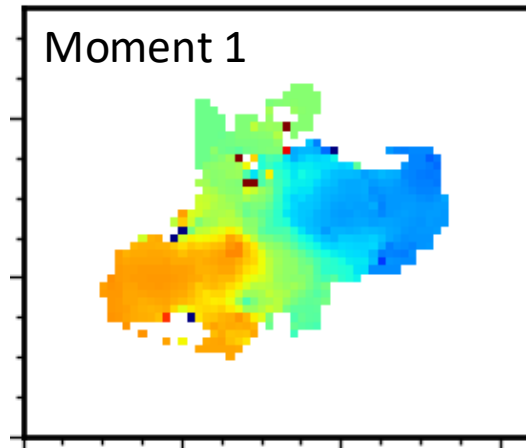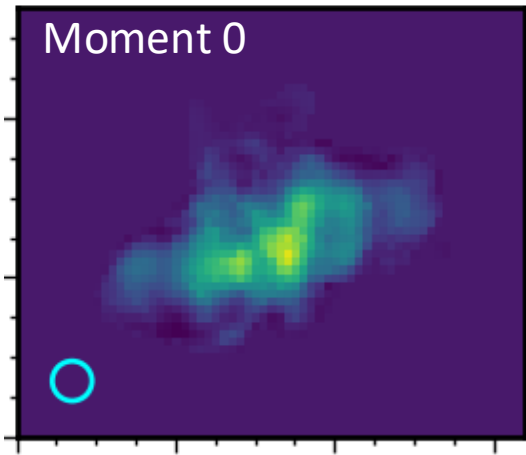
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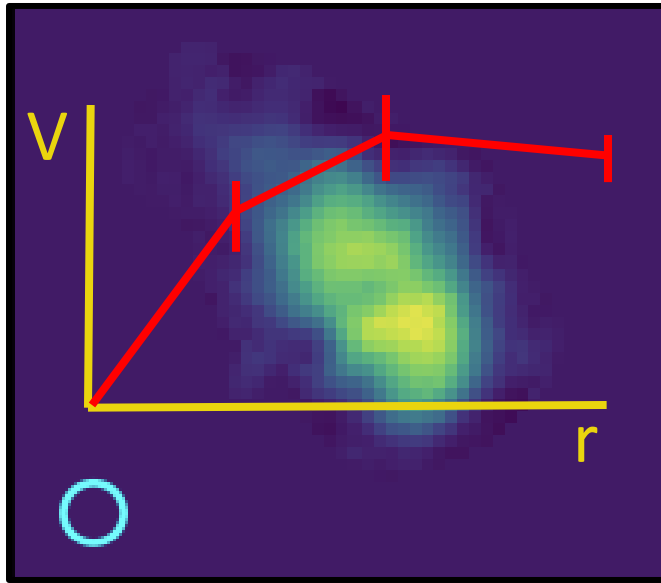
3D rotating disk models are required to extract physical structure such as rotation curve and disk geometry.

Rogstad 74; Bosma 78; Begeman 87; Sicking 97; Jozsa+ 07; KS+Sellwood 07; Kamphuis+ 15, Bekiaris+ 16; di Teodoro +Fraternali 15; Davies+ 17; Oh+ 19; Varidel+19; Deg, KS+22
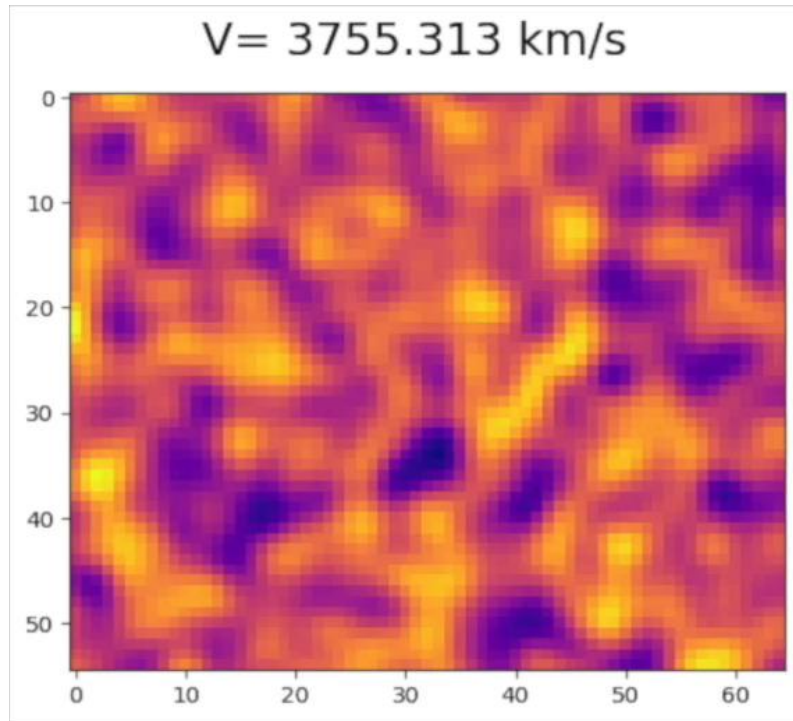

Wang+ 22

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Moment 0

Moment 1

V

r
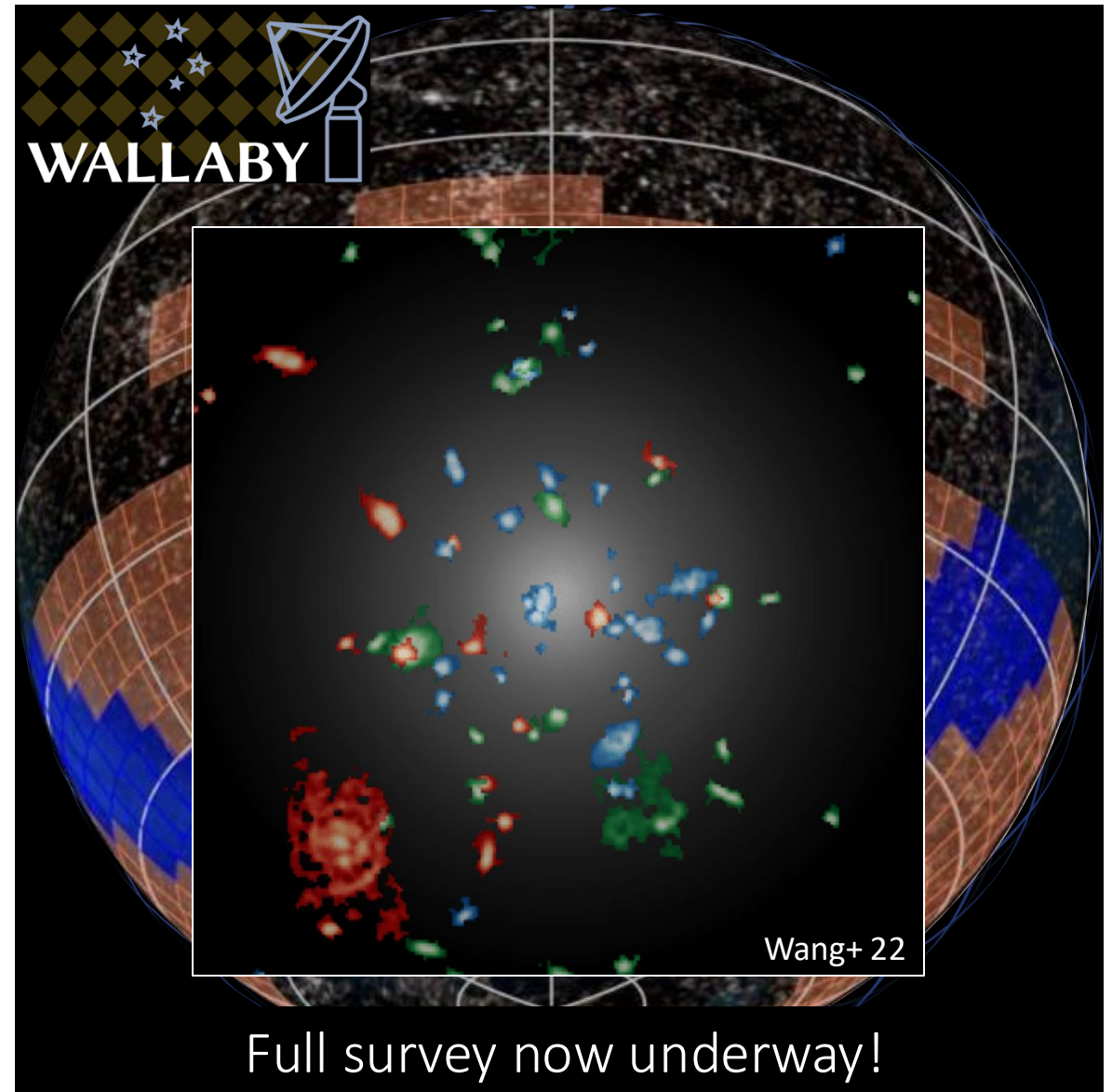
Challenge: most resolved WALLABY detections are in a S/N + resolution regime on the edge of modellability – generic to untargetted surveys.

Current focus is on automated 3D models with statistical uncertainties – a new regime.

V= 3755.313 km/s

Westmeier+ 22
Deg+ 22
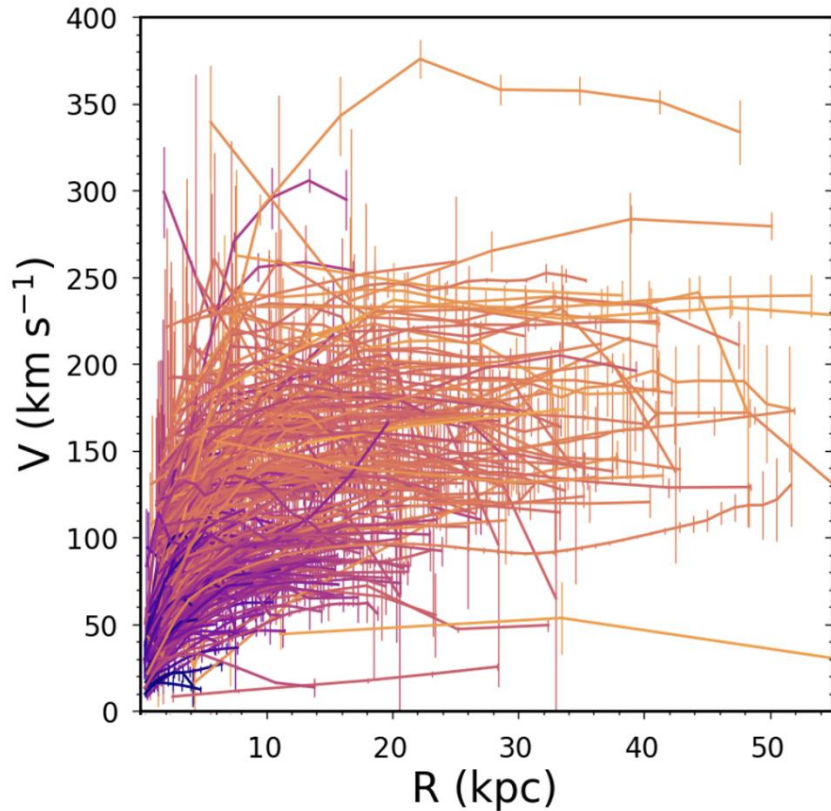Murugeshan+ 24

WALLABY TWG5: kinematics pipeline

WALLABY

CanDIAPL

cirada.org
CIRADA
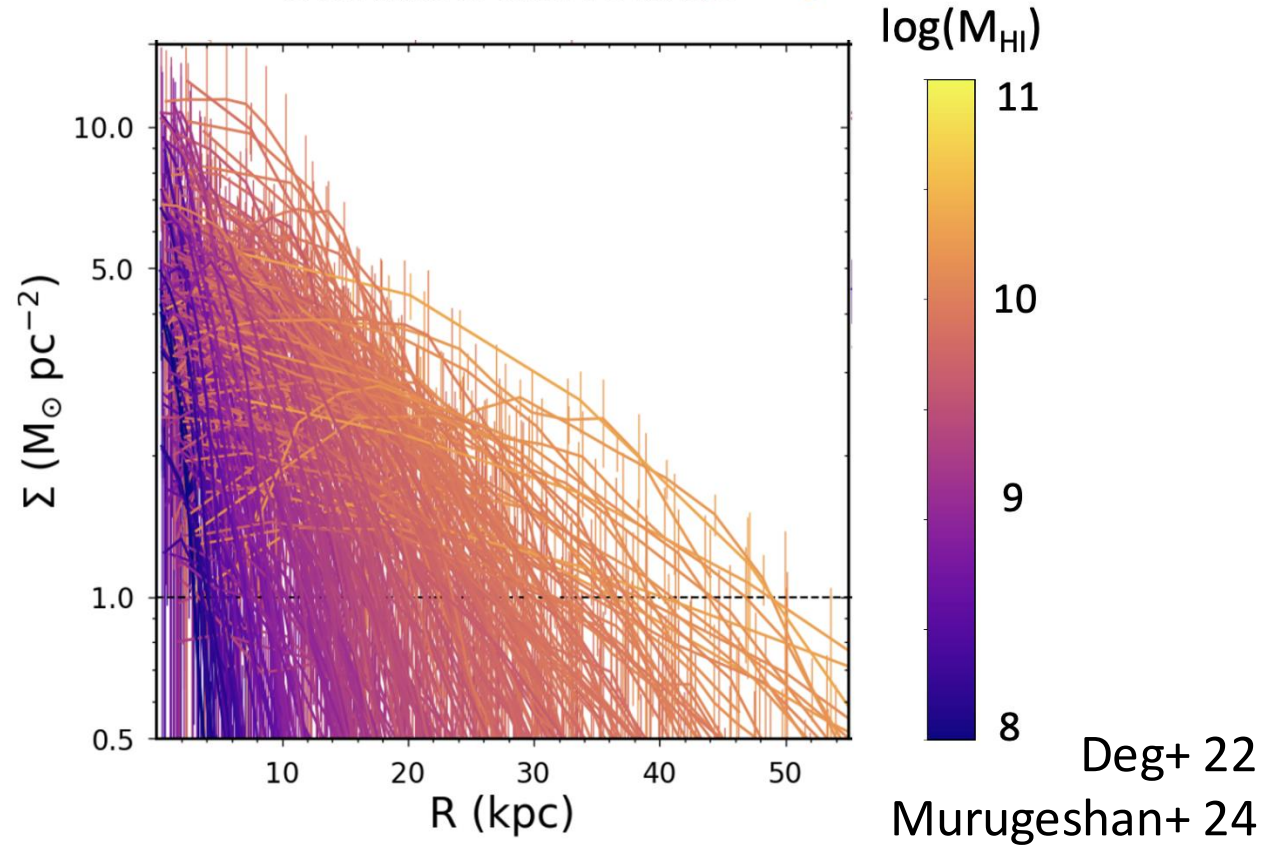CANADIAN INITIATIVE FOR RADIO ASTRONOMY DATA ANALYSIS

Resolving HI disks with WALLABY on ASKAP

Where we are now:

Deg+ 22

Murugeshan+ 24

Homogeneous models of 236 untargetted HI detections now available – the largest collection of its kind

Resolving HI disks with WALLABY on ASKAP

WALLABY
SPARC
MIGHTEE-w50
MIGHTEE-vout

BTFR

$\log(M_{gas} + M_{stars},$ solar masses)

V_{HI} (km/s)

Deg, KS+ 24
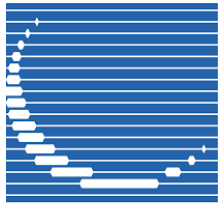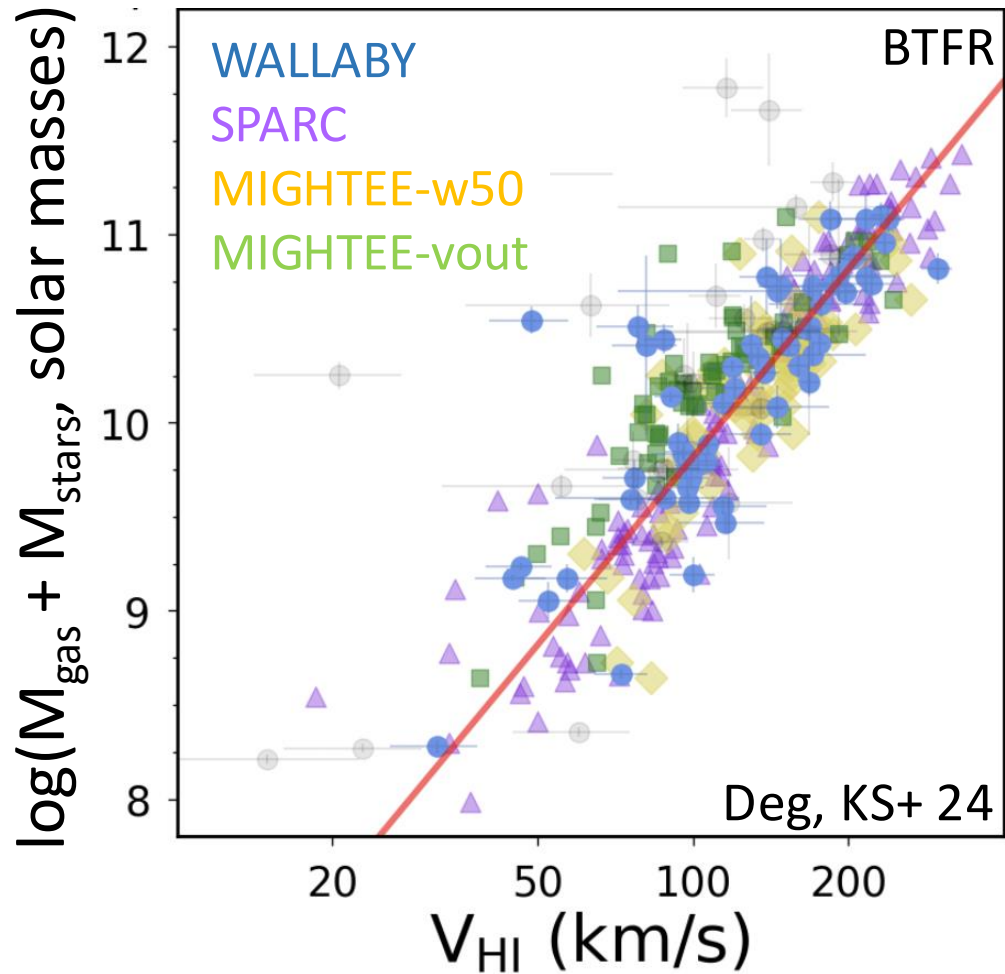
Scaling relations for HI disks and some interesting model failures...

NGC 4632
Deg, Palleske, KS+ 23

A polar ring of gas -
galaxy evolution caught in the act!

ASKAP, CSIRO, Subaru

Spatially resolving galaxies: column density sensitivity

The SKA will image HI disks at resolutions as high as ~1", and at column densities as deep as $\log(N_{HI})$~17, in ~tens of hours.

HI disks: $\geq 1e20$ atoms/cm^2

de Blok+ 24

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Obreschkow+ 09

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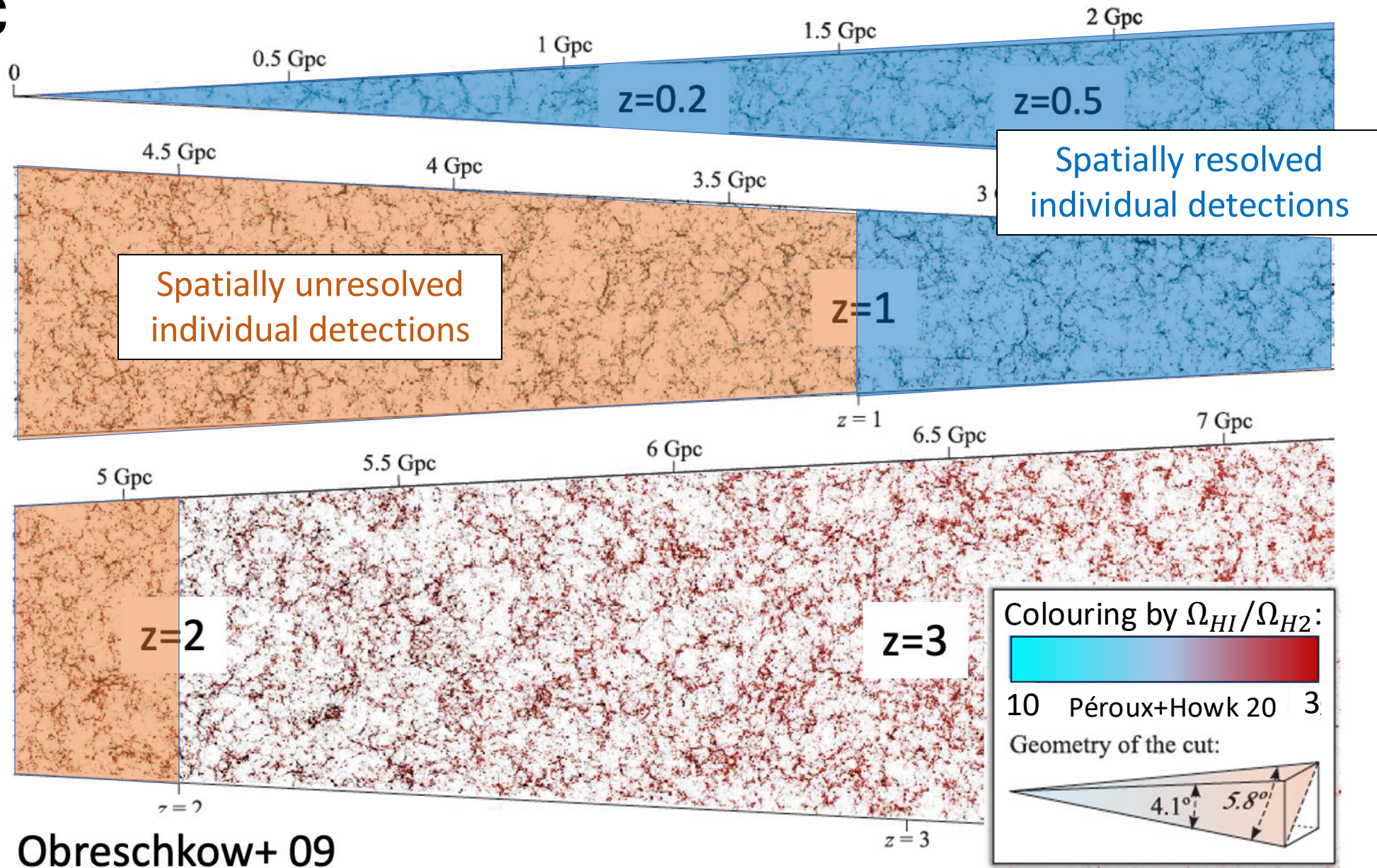
~30 deg^2

6-30", z < 1

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Deep pencil beam

The cosmic HI census

## SKA Key Science:

~10,000hr pencil beam SKA KSP: HI detecctions out to z ~ 2, HI disk maps [log(M_{HI}) > 10] to z ~ 1: AM buildup across cosmic time.

Staveley-Smith + Oosterloo 15; Blyth+ 15; Meyer + 15; Obreschkow+ 15; Power+15

Spatially resolved individual detections

Spatially unresolved individual detections

Colouring by Ω_{HI}/Ω_{H2}:

10   Péroux+Howk 20   3

Geometry of the cut:

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Obreschkow+ 09

Population studies of HI disks place important constraints on the interplay between baryons and dark matter.
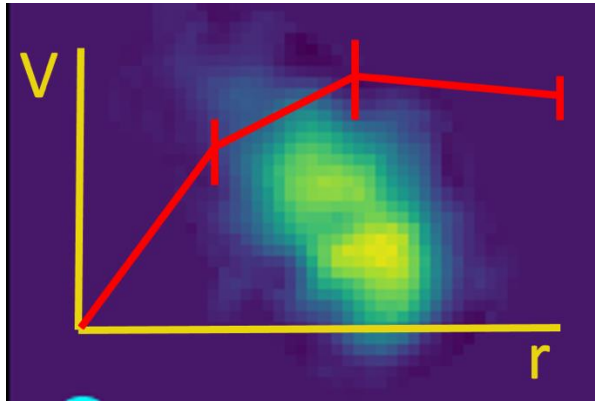
WALLABY on ASKAP is delivering the first statistical samples of local HI disks → modelling challenges are generic to untargeted surveys.

A large KSP on SKA could map HI disks out to z~1: AA4 (but not AA*?) is the only facility being built or planned that can do this.
We should update this forecast!

An SKA KSP