MHONGOOSE

MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters

MeerKAT Deep Nearby Galaxies HI Survey

Claude Carignan (UCT) & Erwin de Blok (ASTRON)

SALT/MeerKAT collaborations Workshop, November 2012

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MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters

MHONGOOSE Team

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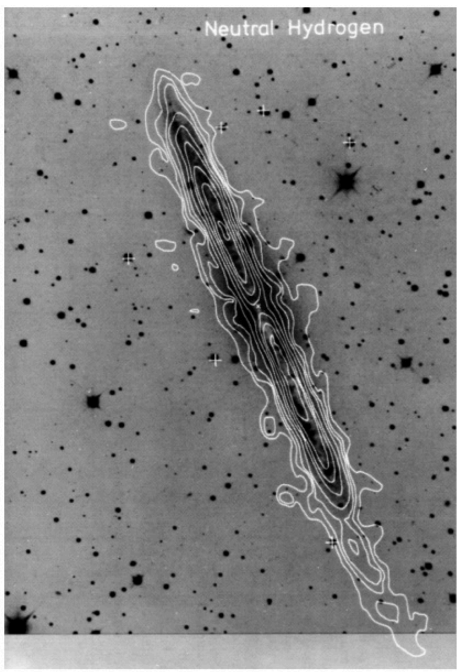
HI: what's left to do nearby ?

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

- How do galaxies get their gas ?
- How is star formation regulated ?
- How are outer disks and cosmic web linked ?

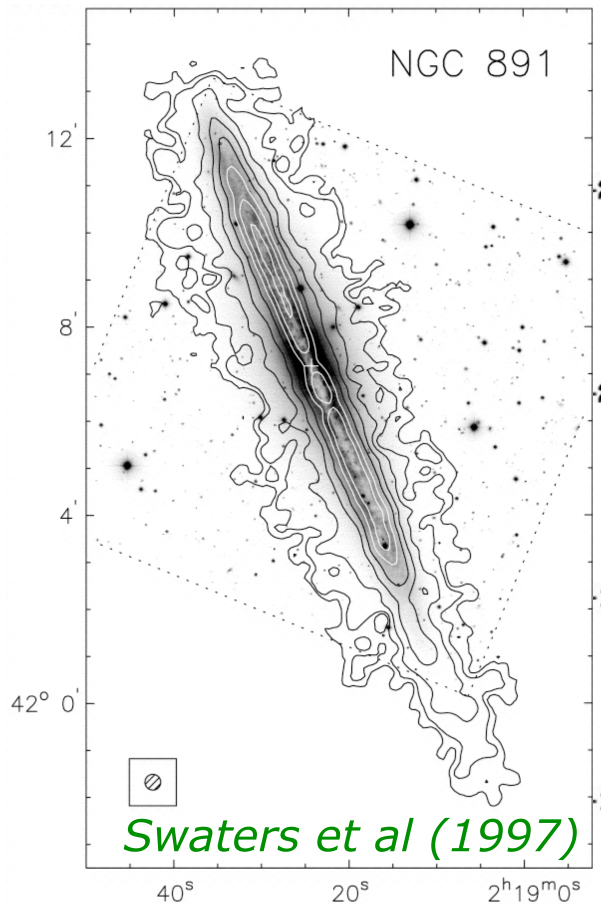
HI: what's left to do nearby ?

σ_{HI} = 5 x 10^{20} cm^{-2}



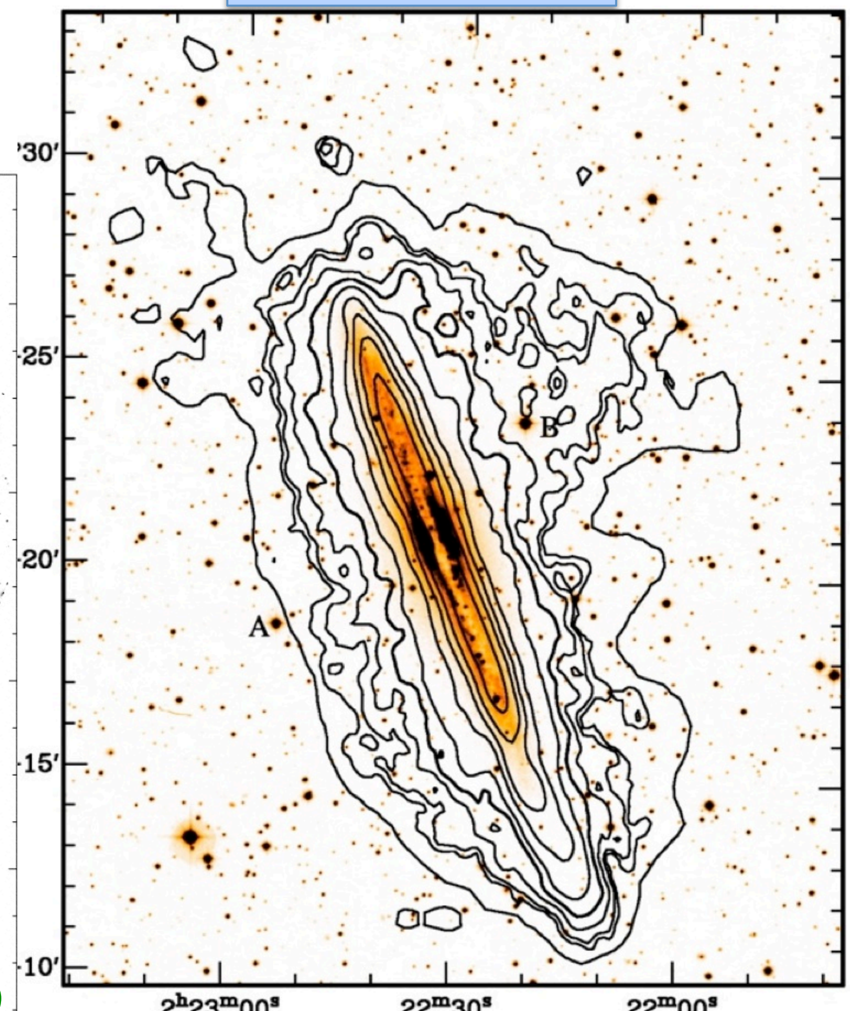
Sancisi & Allen (1979)

σ_{HI} = 1 x 10^{20} cm^{-2}



Swaters et al (1997)

σ_{HI} = 1 x 10^{19} cm^{-2}

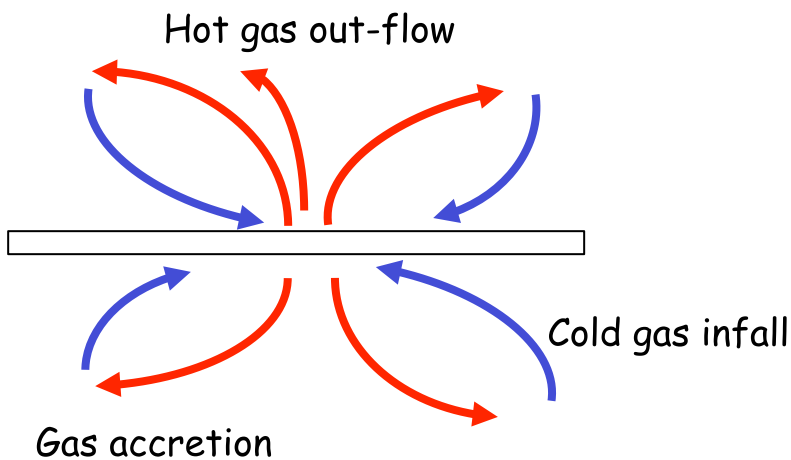


Oosterloo et al (2007)

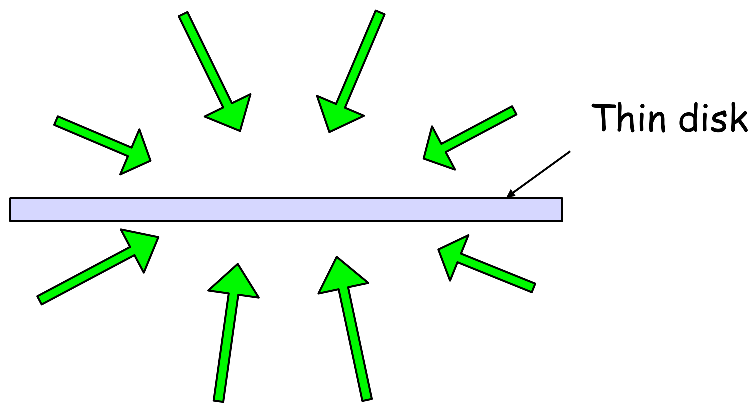
HI: what’s left to do nearby ?

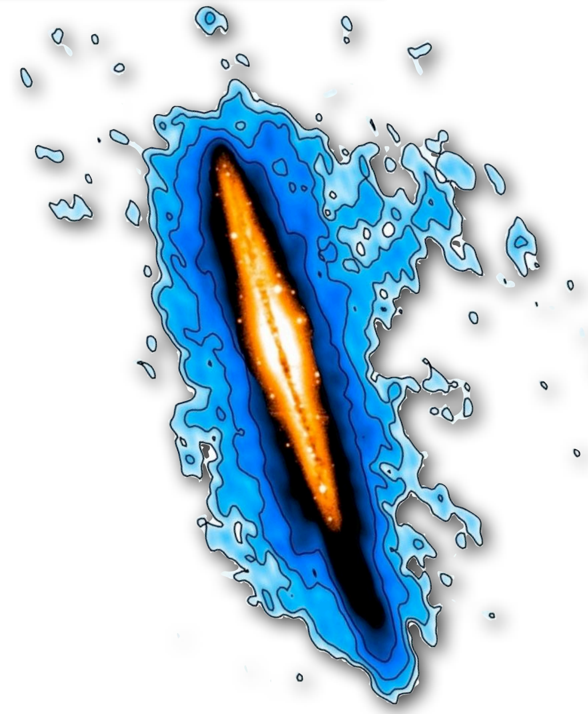
Two components

Galactic fountains



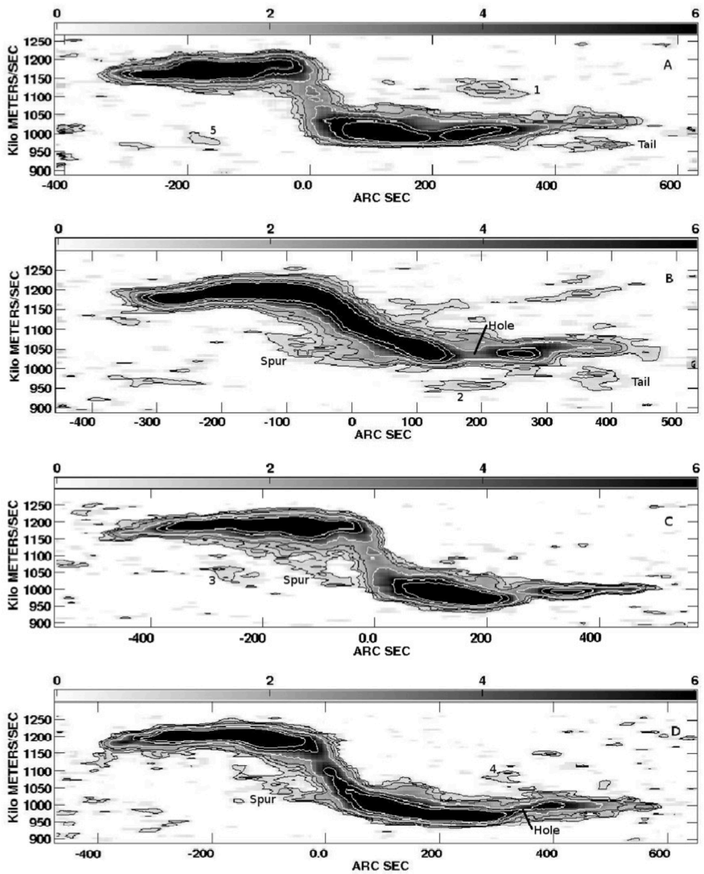
Accretion (HVC)





Ultra-deep HI observations reveal significant amount of extra-planar gas

HI: what's left to do nearby ?



ATCA - σ_{HI} = 1 x 10^{20} cm^{-2}

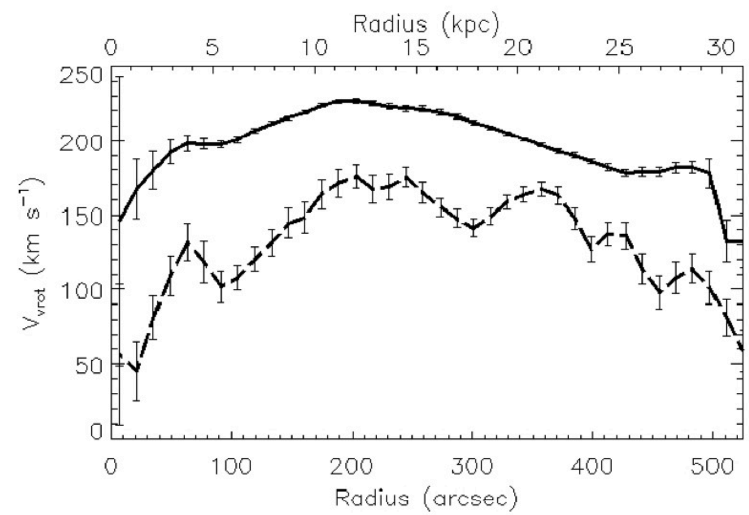
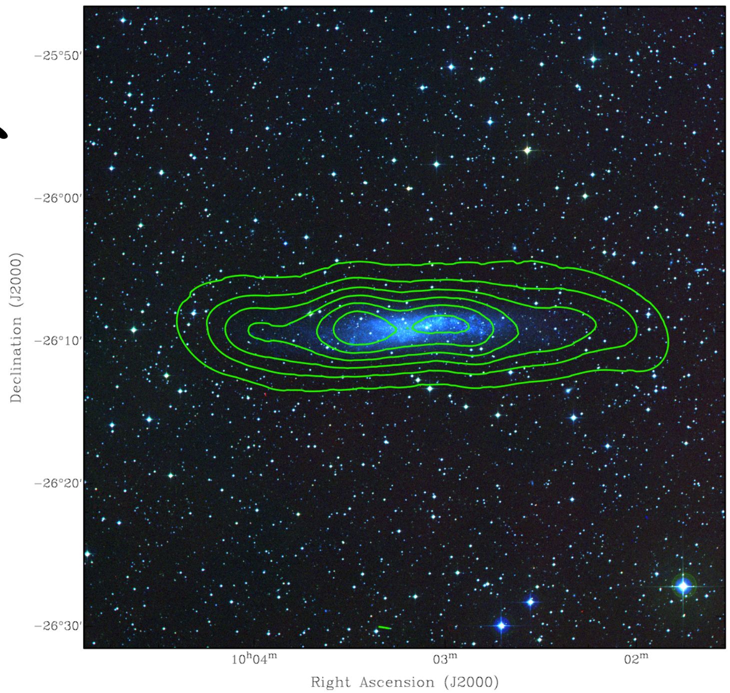
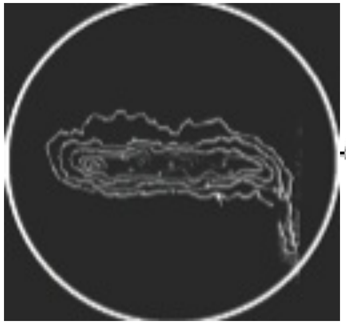


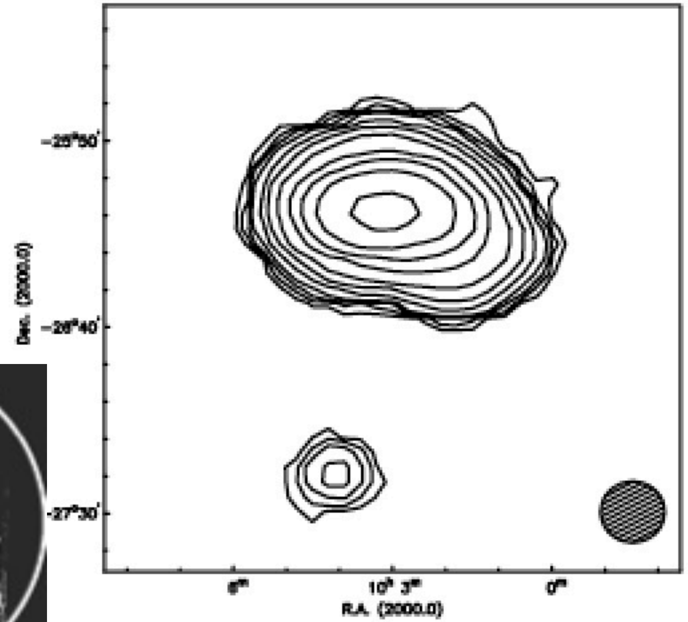
Fig. 8.— Rotation curves for both the thin disk (solid line) and the thick disk (dashed line). The average Δv between the rotation curves is about 60 $km\,s^{-1}$.

NGC 2995: Hess, K. et al. 2009
Study of galactic fountain & accretion gas

HI: what's left to do nearby ?





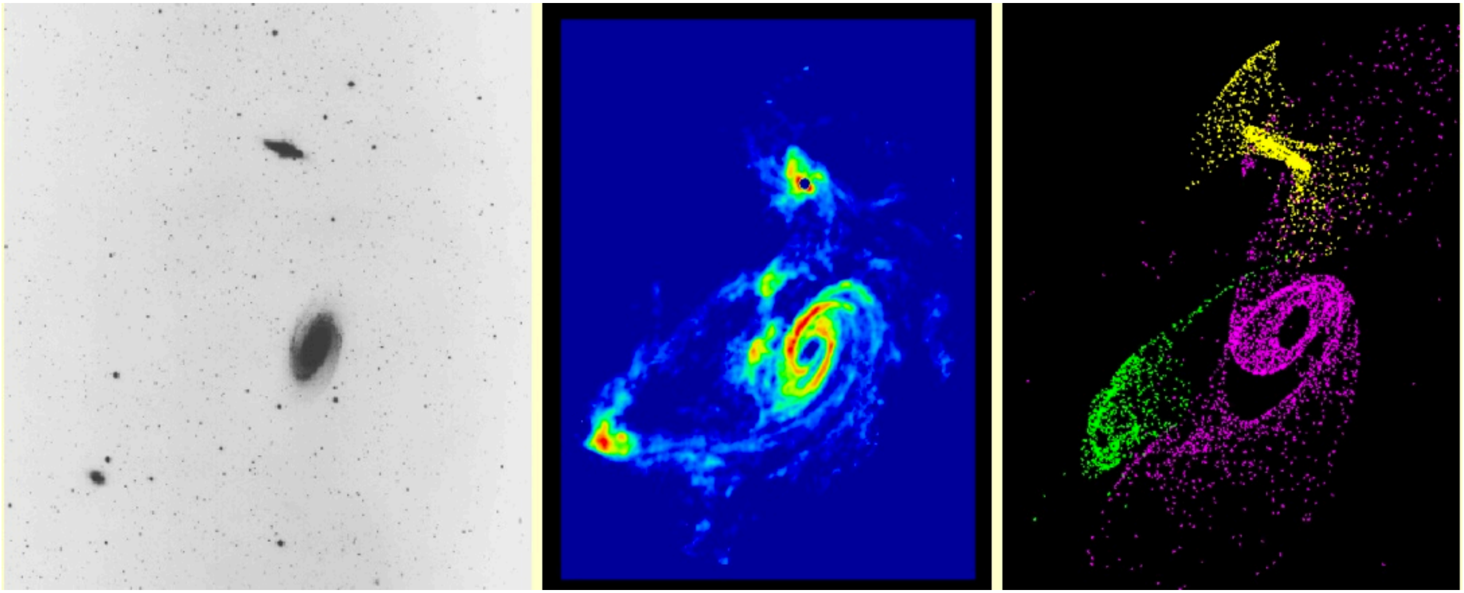


KAT 7: march 2012

VLA: Jobin & Carignan 1990

HIPASS: Barnes & de Blok 2001

HI: what's left to do nearby ?



M81 group: grav. interaction

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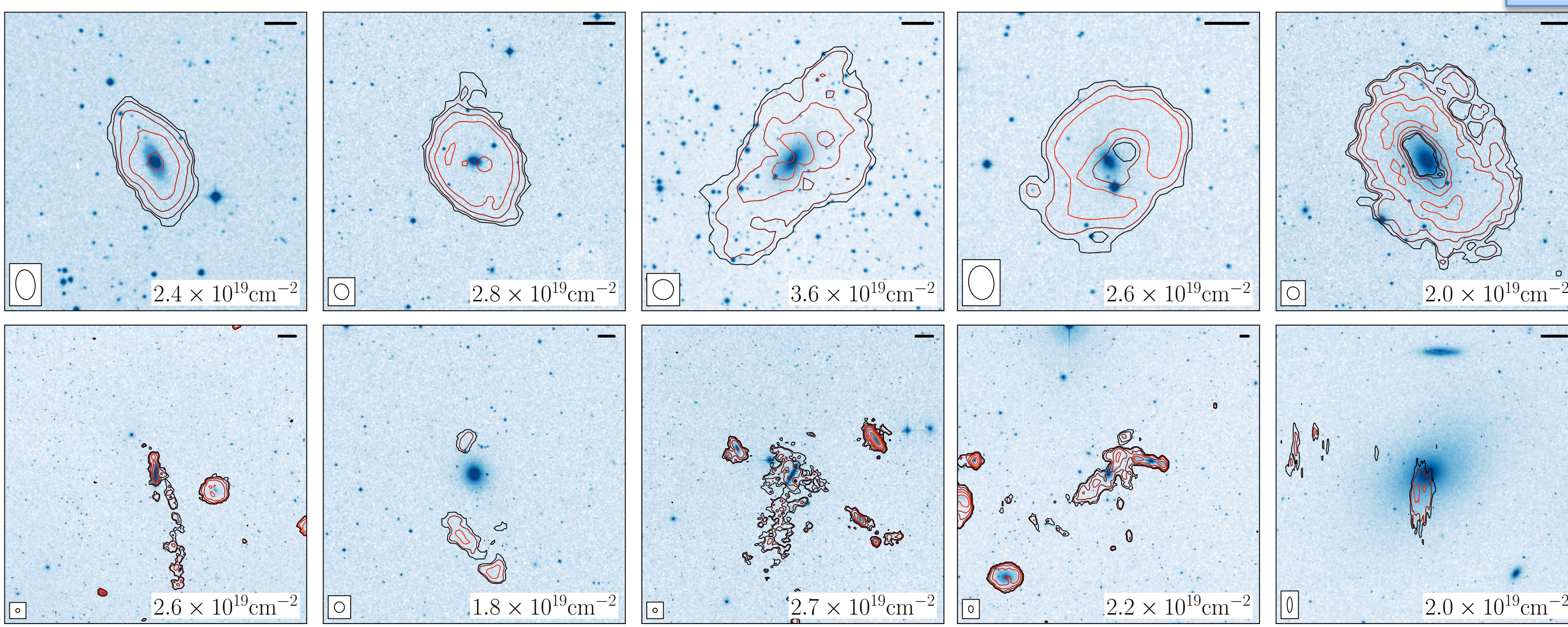
- 166 early-type galaxies, ~2000 hrs Westerbork
- sensitivity: N(HI)~10^{19} cm^{-2}, M(HI)~10^7 $M_\odot$
- 40% detection rate outside Virgo
- 1/4 of all ETGs host HI discs (10^7-10^{10} $M_\odot$)
- show the **importance of environment**

Serra et al. 2012



low density

high density (groups)

HALOGAS

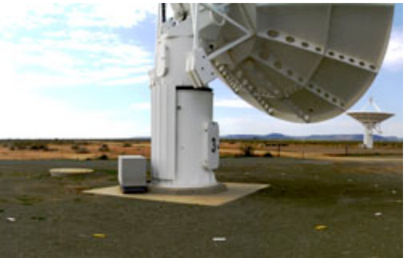
A&A 526, 2011

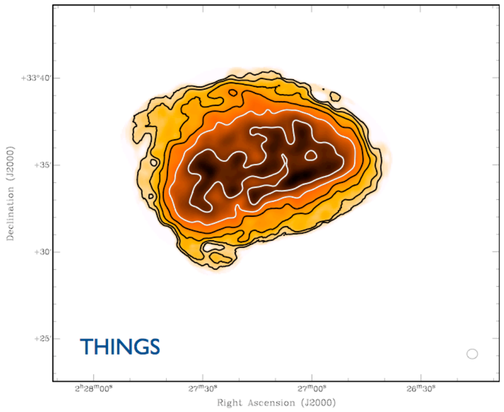
The Westerbork Hydrogen Accretion in Local Galaxies (HALOGAS) Survey

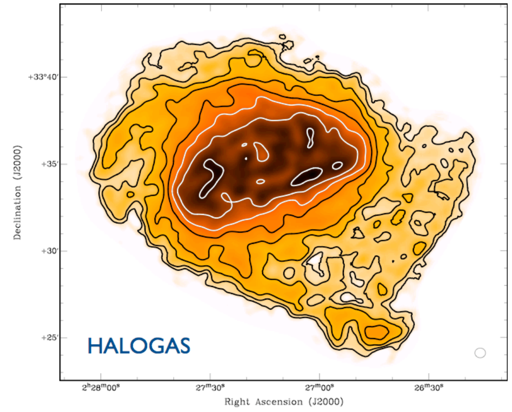
I. Survey Description and Pilot Observations

George Heald[1], Gyula Józsa[1], Paolo Serra[1], Laura Zschaechner[2], Richard Rand[2], Filippo Fraternali[3], Tom Oosterloo[1,4], Rene Walterbos[5], Eva Jütte[6], and Gianfranco Gentile[7]

- 10x12 hrs per target, to reach typical column density sensitivity of $N_{HI} = 1 \times 10^{19}$ cm^{-2} (3σ) at 30” resolution (cf. THINGS: 5×10^{19} cm^{-2})
- Survey sample includes 24 galaxies
- WSRT observations are complete as of mid-2011 ... !
- Advantage of deep WSRT observations seen at start of survey:







MHONGOOSE history

- Deadline for MeerKAT Large Programs: March 2010
- MHONGOOSE proposal:
  - 300 nearby galaxies for 8h each over uniform range in log(M_{HI}) → 2500 hours (“shallow”)
  - 30 of these ultra-deep for 200h each → 6000 hours (“deep”)

MHONGOOSE history

- Outcome of MeerKAT Large Programs TAC meeting: October 2010
- MHONGOOSE project:
  - 30 ultra-deep for 200h → 6000 hours ("deep")
  - Defining a deep sample

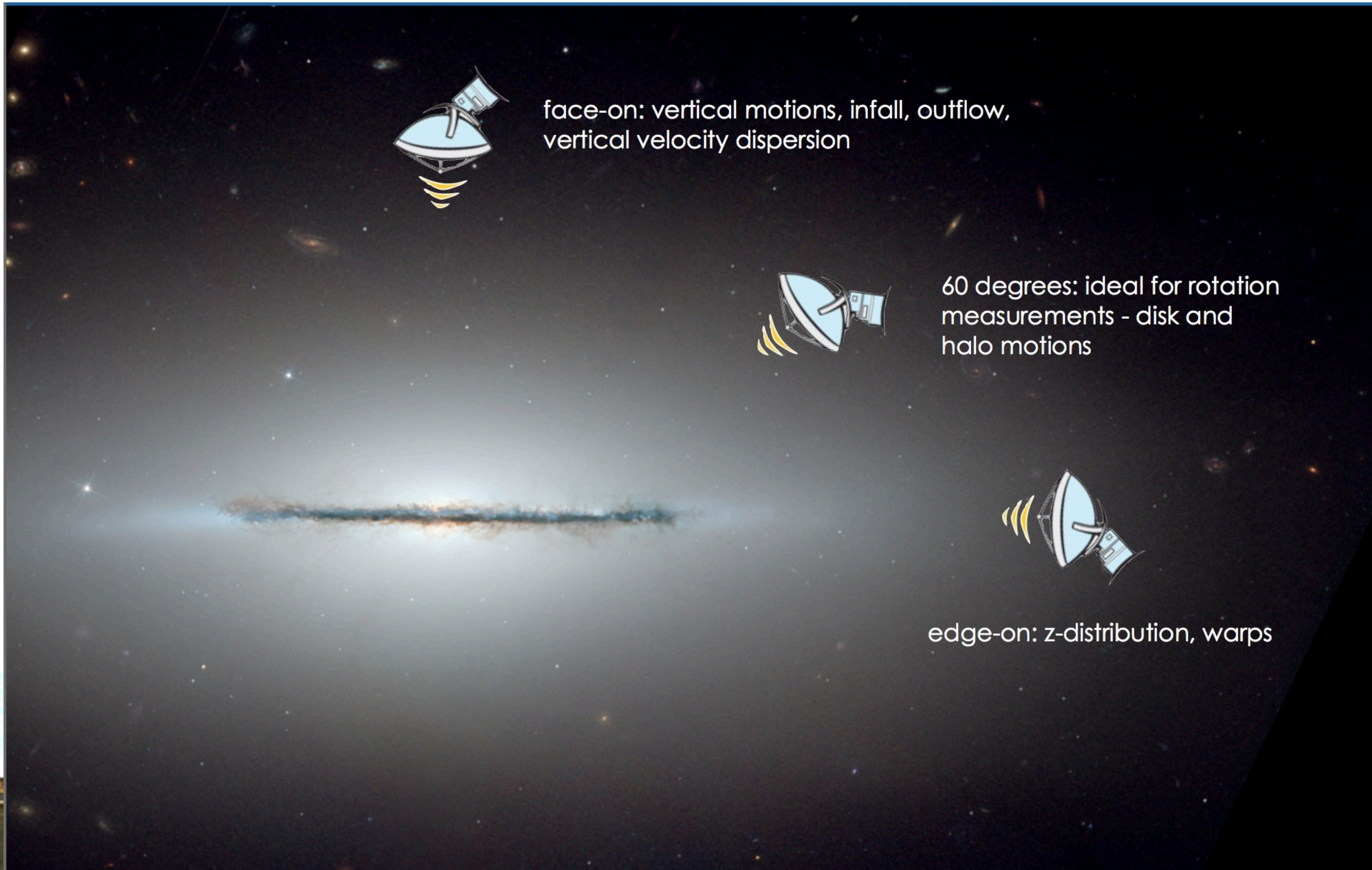
Deep Survey

- Observed 25 times longer than THINGS (200 hours per galaxy)
- Accretion, cosmic web, dynamics beyond disk
- Equivalent to HALOGAS but different parameter range
- $5\sigma = 1.25 \,.\, 10^{19}$ cm^{-2} at 30” for 16 km s^{-1} FWHM HI line at 5 km s^{-1} channel spacing or $5 \,.\, 10^{17}$ - 10^{18} cm^{-2} at 90”
- The sensitivity numbers assume the canonical MeerKAT design with 64 dishes of 13.5m, a T_{sys} of 30 K and an overall efficiency of 0.7

Selection of the sample

- Criteria for the MHONGOOSE sample:
  - HI detection
  - Extended
  - Sub-kpc resolution
  - No inclination selection

Selection of the sample



Selection of the sample

- Criteria for the MHONGOOSE sample:
  - HI detection
  - Extended
  - Sub-kpc resolution
  - No inclination selection
  - Ensure **log(M_{HI}) coverage**
  - Little foreground extinction
  - Other wavelength data (to be) available

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

- HIPASS detection

- Use homogenized non-Hubble flow distances from NED

- D < 25 Mpc

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

——— 294 objects

- HIPASS detection
- Use homogenized non-Hubble flow distances from NED
- D < 25 Mpc

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- $T > 1$ (Sa→)

——————— 294 objects

- HIPASS detection

——————— 194 objects

- Use homogenized non-Hubble flow distances from NED
- $D < 25$ Mpc

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

——————— 294 objects

- HIPASS detection

——————— 194 objects

- Use homogenized non-Hubble flow distances from NED
- D < 25 Mpc

——————— 139 objects

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

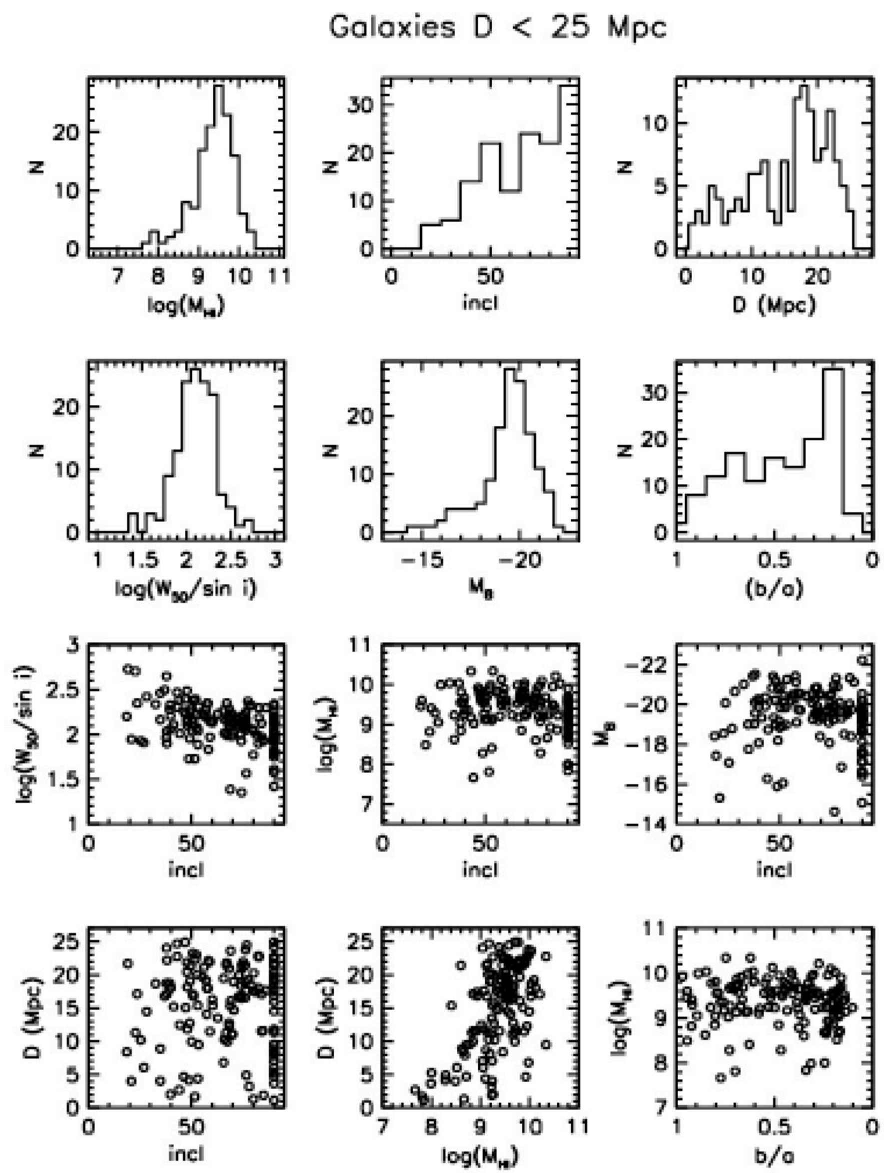
—————— 294 objects

- HIPASS detection

—————— 194 objects

- Use homogenized non-Hubble flow distances from NED
- D < 25 Mpc

—————— 139 objects



Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

294 objects

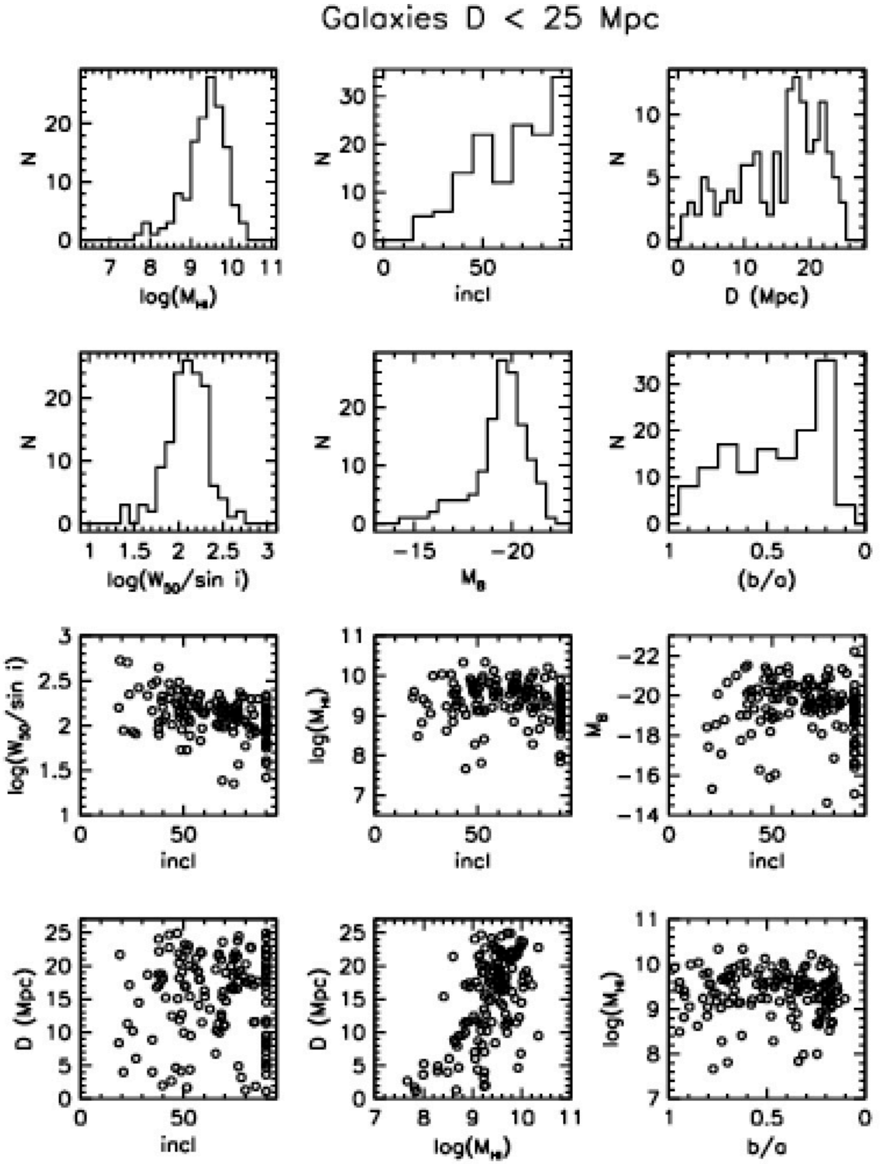
- HIPASS detection

194 objects

- Use homogenized non-Hubble flow distances from NED
- D < 25 Mpc

139 objects

How to get to 30 objects ?



Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

294 objects

- HIPASS detection

194 objects

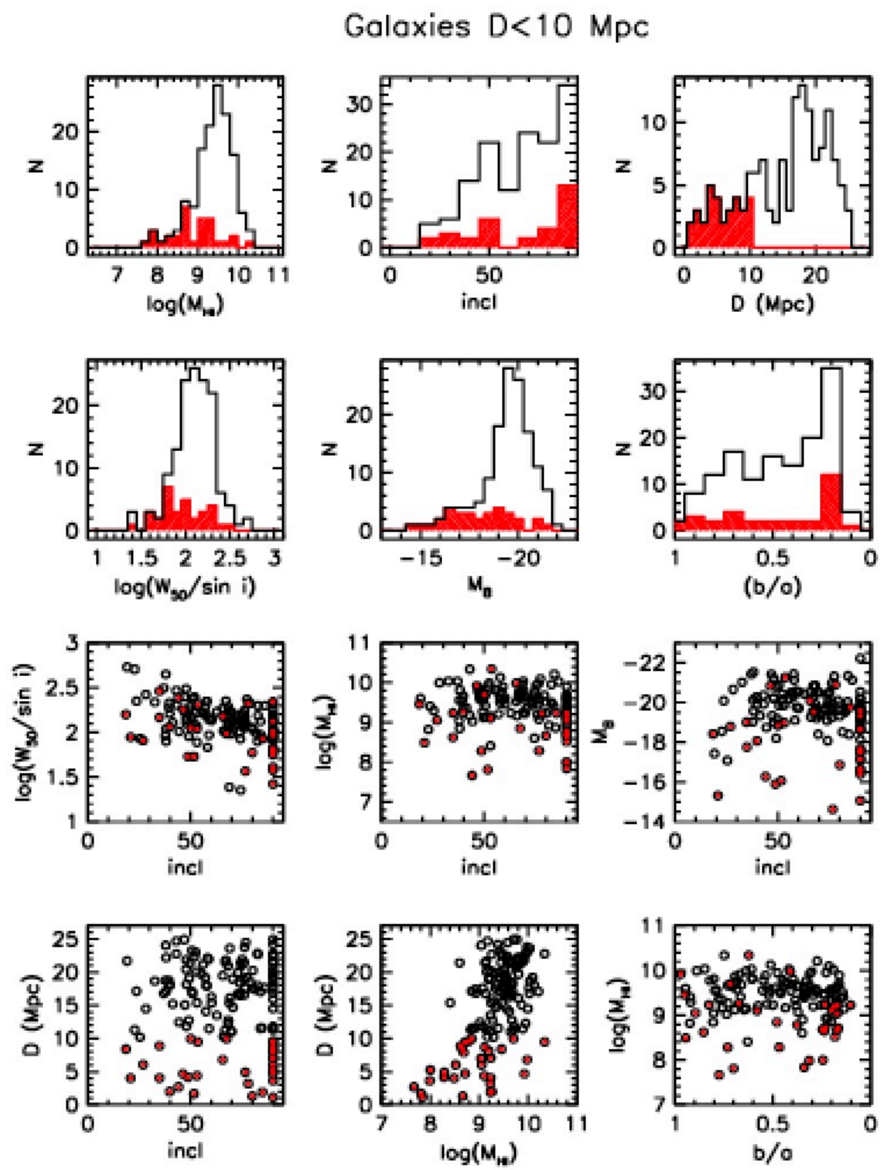
- Use homogenized non-Hubble flow distances from NED

- D < 25 Mpc

139 objects

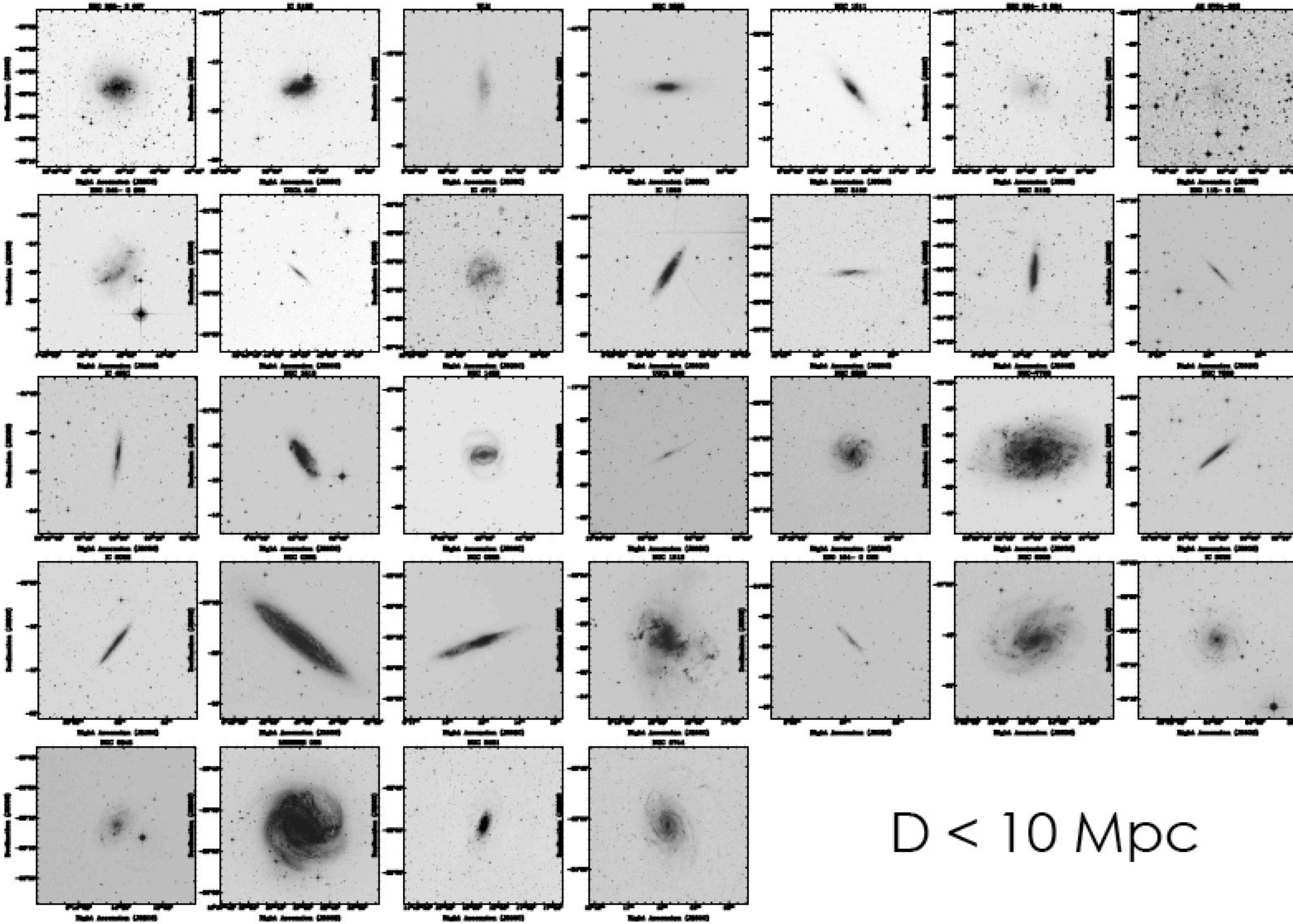
- D < 10 Mpc

32 objects



D < 10 Mpc

Name	$\log(M_{HI})$	M_B	
ESO324-024	8.283	-15.9	
IC1959	8.649	-17.57	
IC4951	8.716	-17.16	
NGC1311	8.001	-16.4	
PGC020125	8.286	-14.63	Argo
ESO245-005	8.491	-15.32	
NGC1518	8.787	-18.65	
IC4710	8.624	-17.76	
ESO471-006	8.517	-16.58	
ESO383-087	7.667	-16.27	
ESO115-021	8.715	-16.67	
IC5152	7.814	-16.06	
NGC2188	8.684	-18.66	
IC5332	9.458	-18.42	
NGC0045	9.701	-18.85	
NGC1433	8.849	-19.52	
NGC0625	7.989	-17.14	
PGC045084	9.037	-17.49	DDO161
IC5052	9.195	-19.33	
NGC5068	9.052	-18.79	
ESO154-023	9.237	-17.67	
NGC7090	9.114	-19.6	
NGC3621	9.984	-20.09	
NGC7793	9.105	-18.98	
PGC000143	7.838	-15.07	WLM
NGC1313	9.235	-19.01	
NGC5236	9.924	-20.83	
NGC6744	10.34	-21.26	
NGC3109	8.667	-16.86	
NGC0300	9.262	-18.07	
NGC0253	9.222	-20.9	
NGC0055	9.23	-19.76	



D < 10 Mpc

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- $T > 1$ (Sa→)

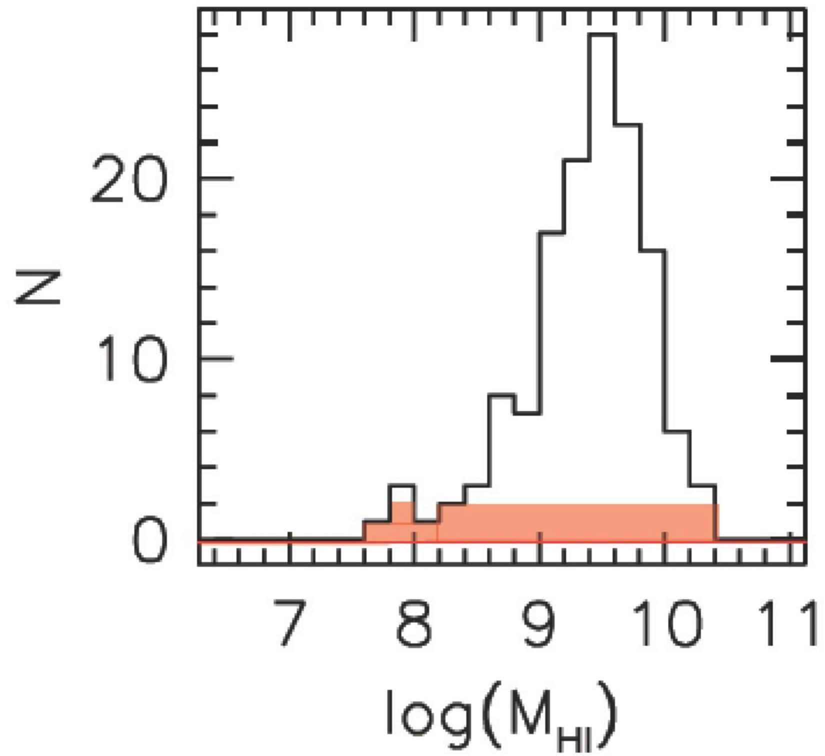
———————— 294 objects

- HIPASS detection

———————— 194 objects

- Use homogenized non-Hubble flow distances from NED
- $D < 25$ Mpc

———————— 139 objects



0.2 dex bins gives ~2 galaxies per bin

Choose 2 nearest

Selection of the sample

- $D_{25} > 3'$
- $|b| > 20°$
- $\delta < -10°$
- T > 1 (Sa→)

294 objects

- HIPASS detection

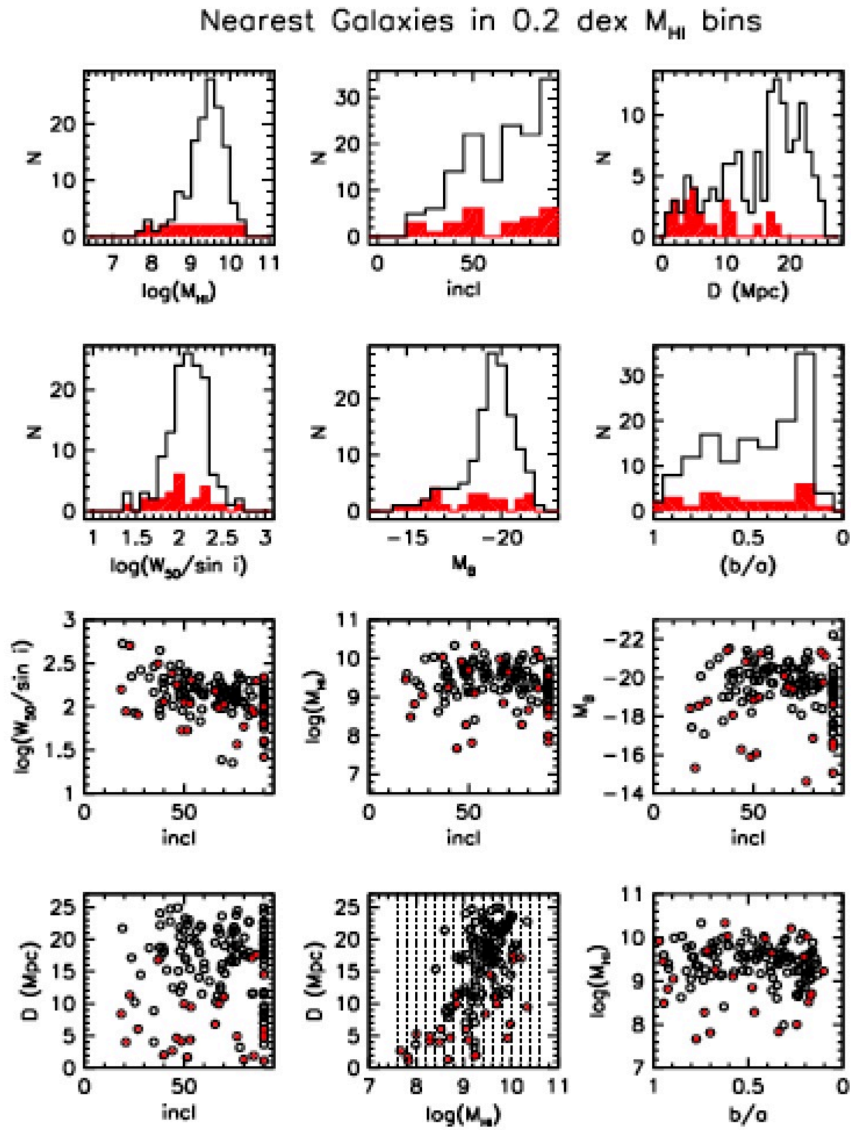
194 objects

- Use homogenized non-Hubble flow distances from NED
- D < 25 Mpc

139 objects

- 2 nearest per 0.2 dex M_{HI} bin

26 objects



Nearest in 0.2 dex M_{HI} bins

Name	$\log(M_{HI})$	M_B	
ESO383-087	7.667	-16.27	
PGC000143	7.838	-15.07	WLM
IC5152	7.814	-16.06	
NGC1311	8.001	-16.4	
ESO324-024	8.283	-15.9	
PGC020125	8.286	-14.63	Argo
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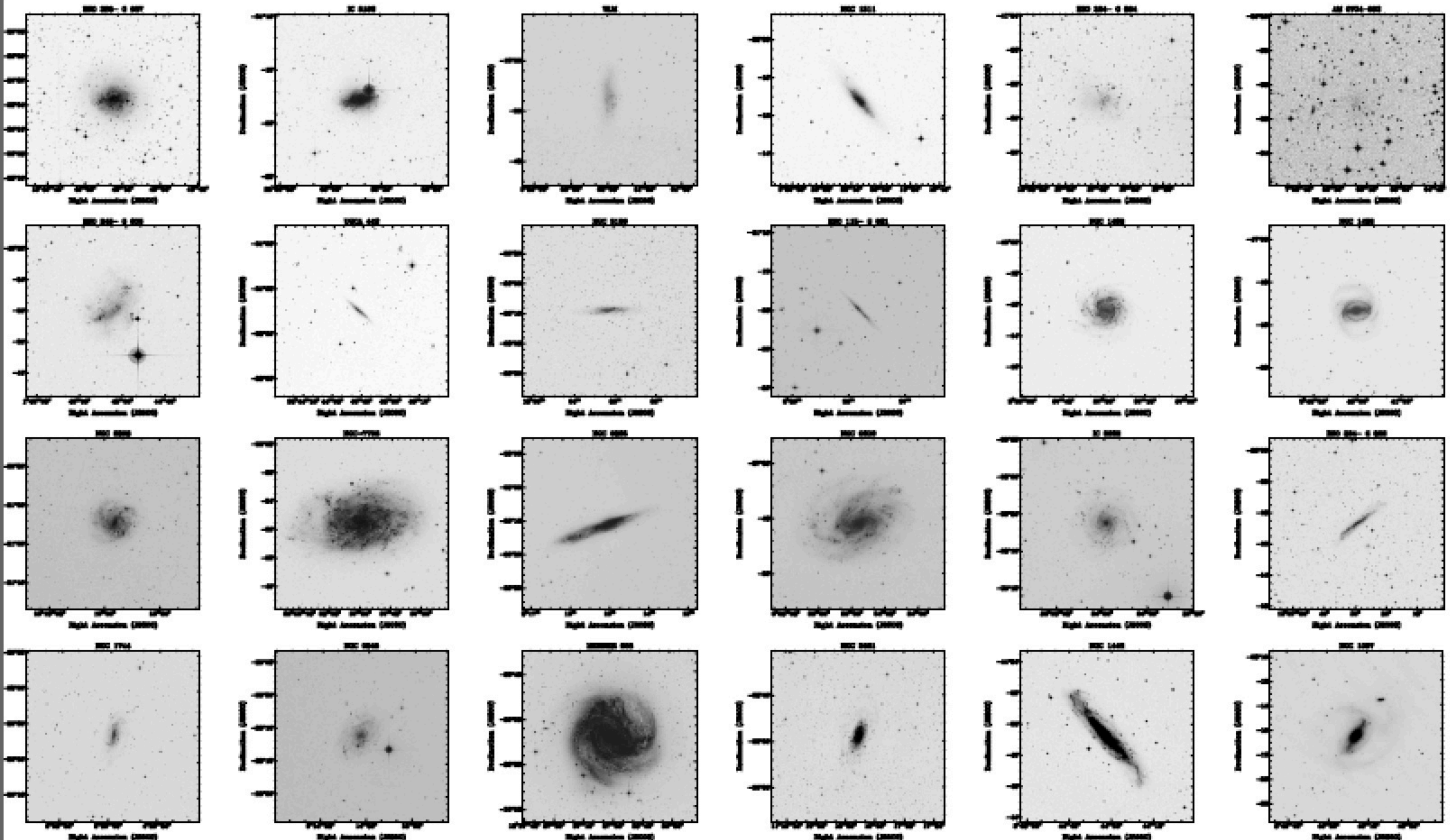
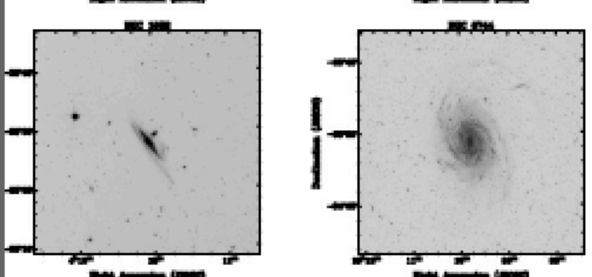
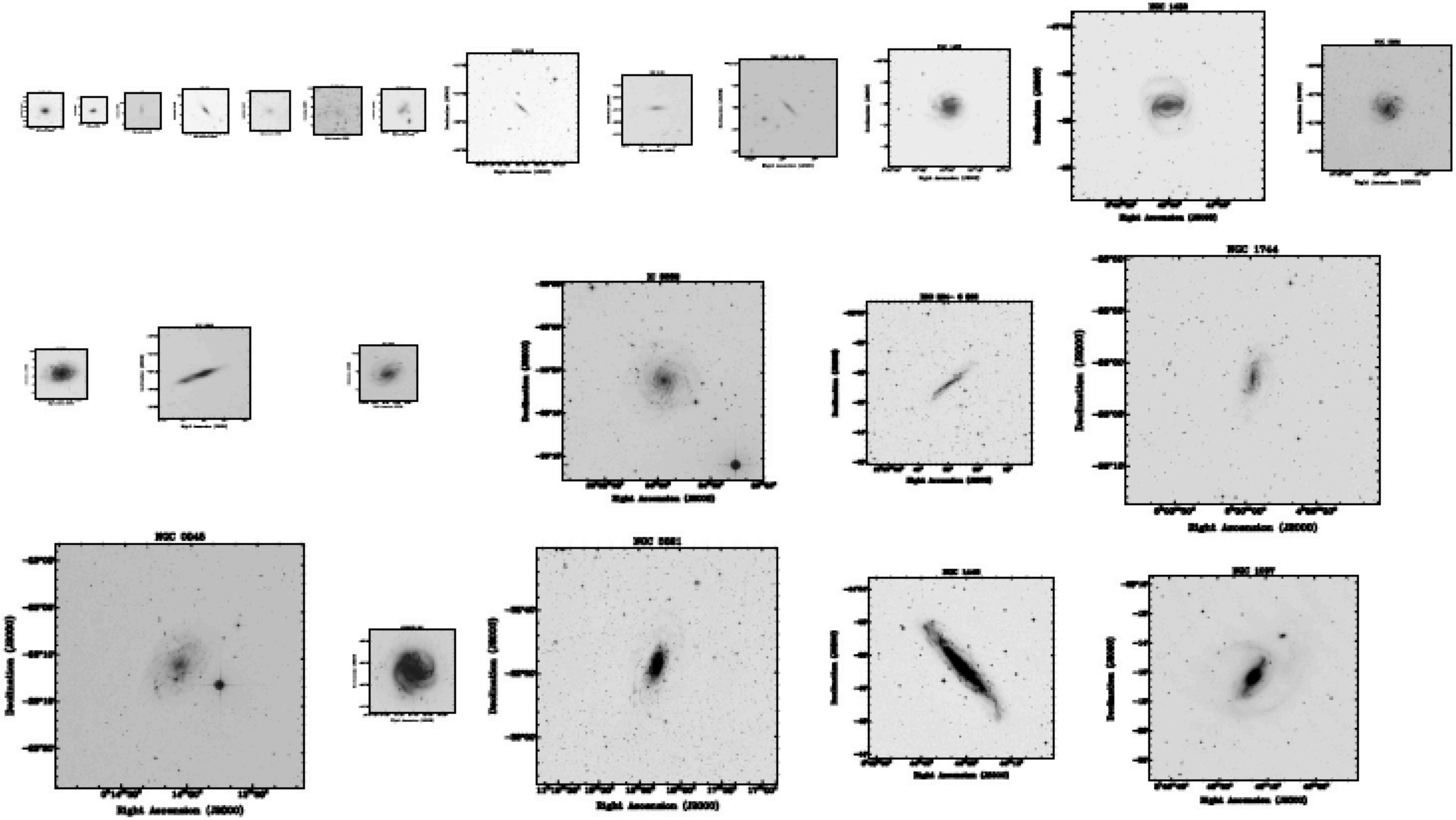
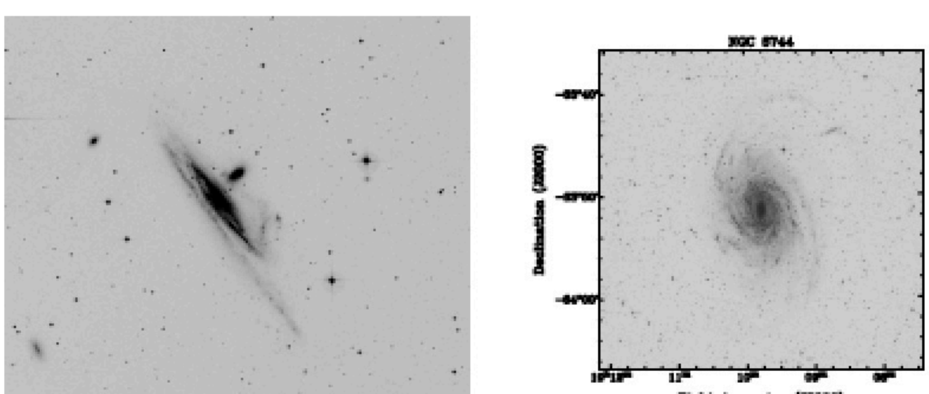
ESO471-006	8.517	-16.58	
NGC3109	8.667	-16.86	
ESO115-021	8.715	-16.67	
NGC1433	8.849	-19.52	
NGC1493	8.821	-18.55	
NGC7793	9.105	-18.98	
NGC5068	9.052	-18.79	
NGC0055	9.23	-19.76	
NGC0300	9.262	-18.07	
IC5332	9.458	-18.42	
ESO324-023	9.56	-18.62	
NGC0045	9.701	-18.85	
NGC1744	9.645	-19.41	
NGC5236	9.924	-20.83	
NGC3621	9.984	-20.09	
NGC1097	10.03	-21.42	
NGC1448	10.03	-21.12	
NGC6744	10.34	-21.26	
NGC1532	10.21	-21.34	



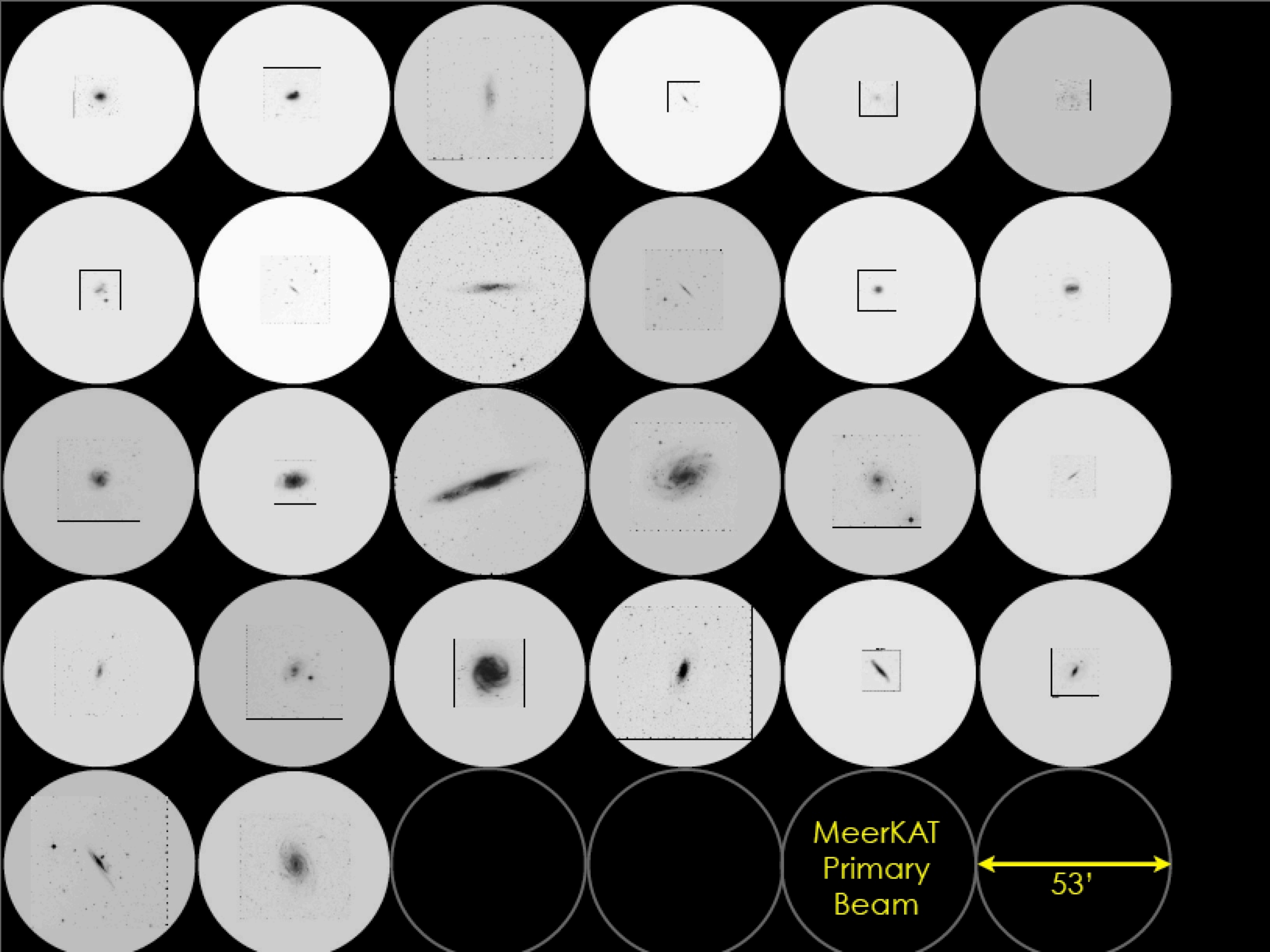


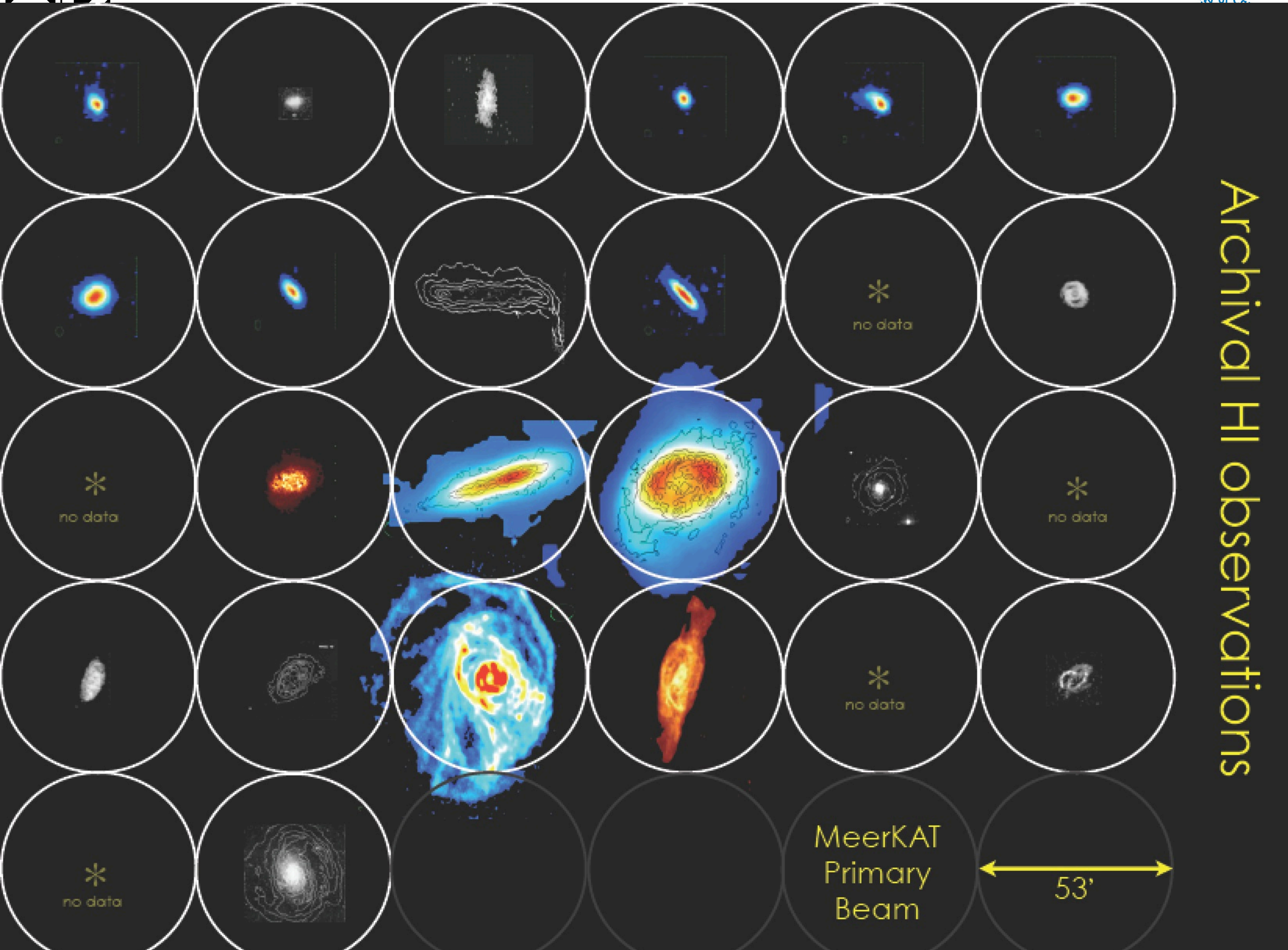
Nearest in 0.2 dex M_{HI} bins





Nearest in 0.2 dex M_{HI} bins; relative physical sizes


MeerKAT
Primary
Beam
53'


Archival HI observations
no data
no data
no data
no data
no data
MeerKAT
Primary
Beam
53'

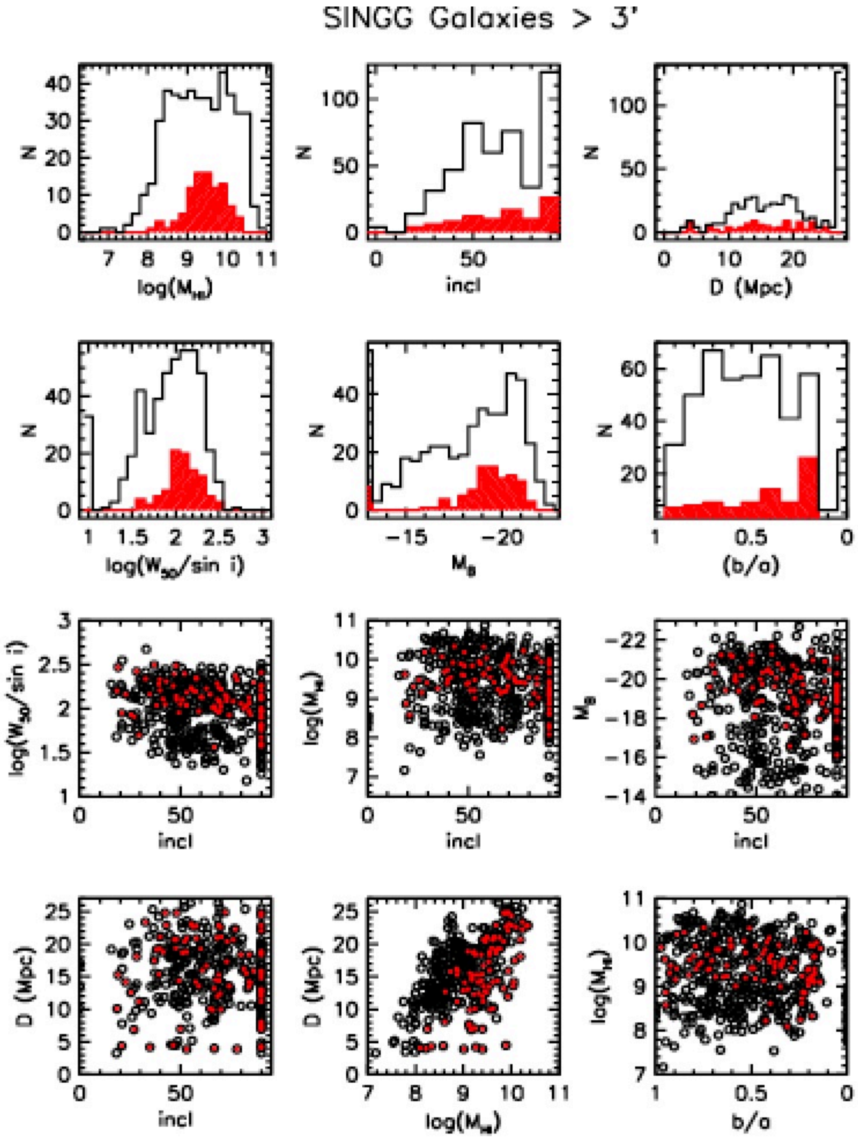
SINGG sample

- Survey for Ionization in Neutral Gas Galaxies (Meurer et al 2006)
- *HIPASS based*
- *S_p > 50 mJy*
- *| b | > 30°*

468 objects

- δ < -10°
- D_{25} > 3'
- D < 25 Mpc

93 objects



SINGG sample

- Survey for Ionization in Neutral Gas Galaxies (Meurer et al 2006)
- *HIPASS based*
- $S_p > 50$ *mJy*
- *| b | > 30°*

468 objects

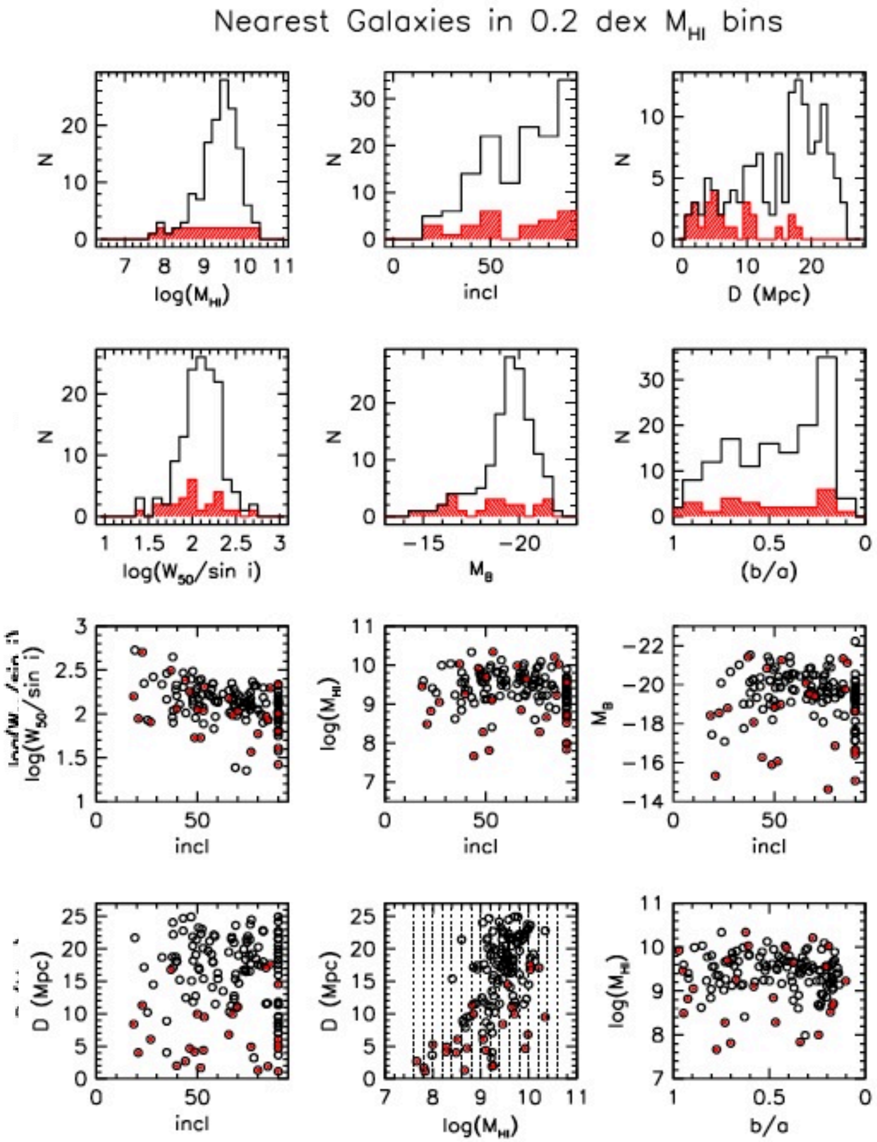
- δ < -10°
- $D_{25} > 3'$
- D < 25 Mpc

93 objects

- Nearest 2 per bin

24 objects

- Misses out on low HI masses

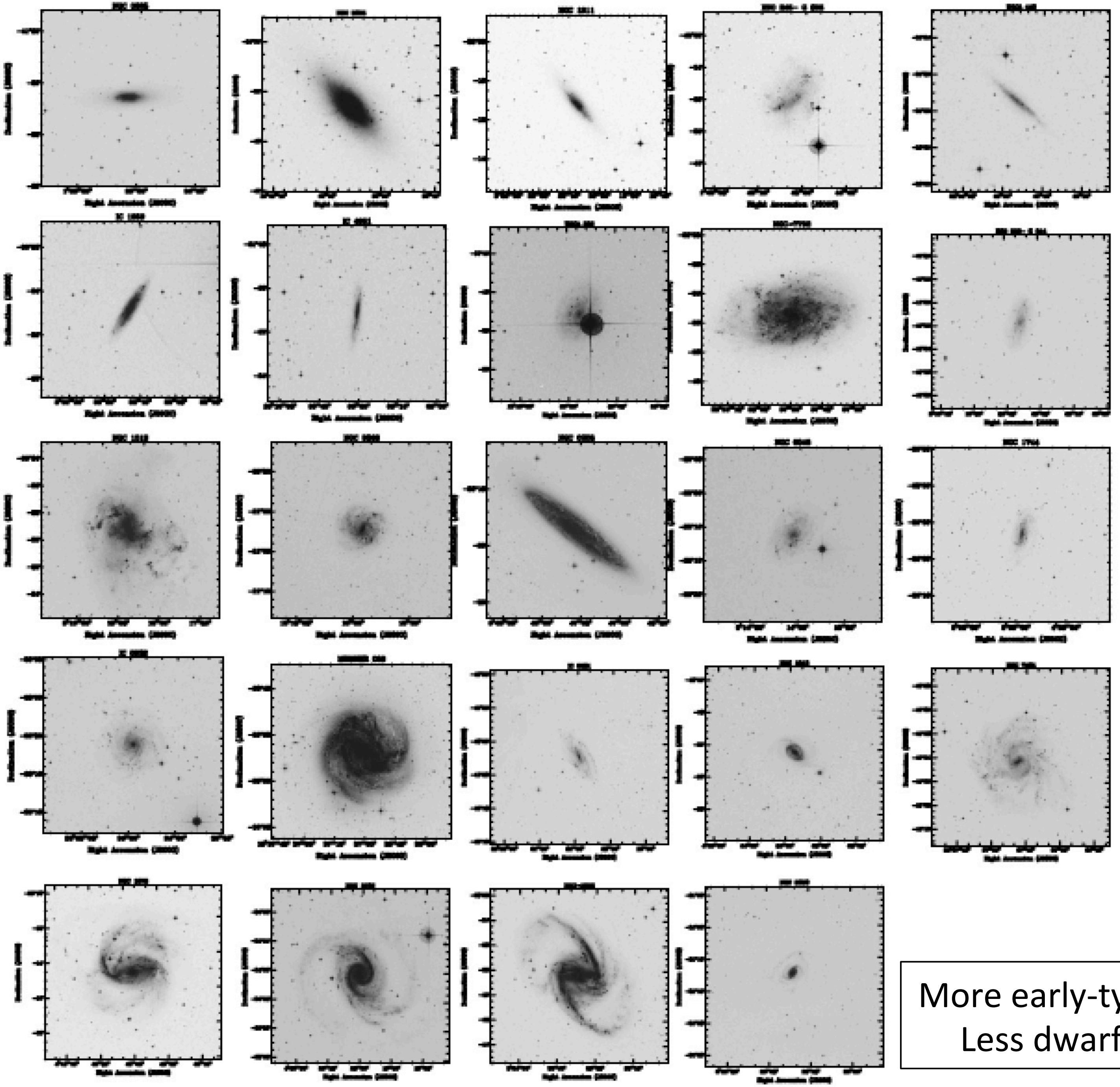


SINGGS Extended Sources

Name	log(M_{HI})	M_B
NGC0625	8.09	-16.12
NGC5253	8.22	-16.58
NGC1311	8.25	-16.4
ESO471-006	8.33	-16.58
ESO245-005	8.58	-16.58
IC1959	8.61	-17.57
IC4951	8.87	-16.96
PGC045652	8.87	-16.93
NGC7793	9.01	-18.89
ESO300-014	9	-17.89
NGC1313	9.26	-19.42
NGC5068	9.16	-19.61
NGC0253	9.4	-20.97
NGC0045	9.4	-18.77
NGC1744	9.56	-18.66
IC5332	9.62	-18.2
NGC5236	9.89	-20.83
IC5201	9.84	-19.37
NGC1512	9.93	-19.06
NGC7424	10.04	-19.62
NGC1672	10.19	-20.73
NGC1566	10.19	-21.23
NGC1365	10.33	-21.69
NGC0289	10.34	-20.19

XX = also in 10 Mpc HIPASS
XX = also in binned MHI HIPASS

SINGGS Nearest in 0.2 dex M_{HI} bins



More early-types
Less dwarfs

Overall strategy

- Collaboration with SINGG/SUNGG/Wallaby
  - Shallow observations of ~200 galaxies
  - Deeper follow-up of ~60 galaxies with ATCA/GMRT
  - Select 30 galaxies for MeerKAT deep survey
    - 200 hours corresponds to ~M_{HI}^* at $z = 0.1$

MHONGOOSE update

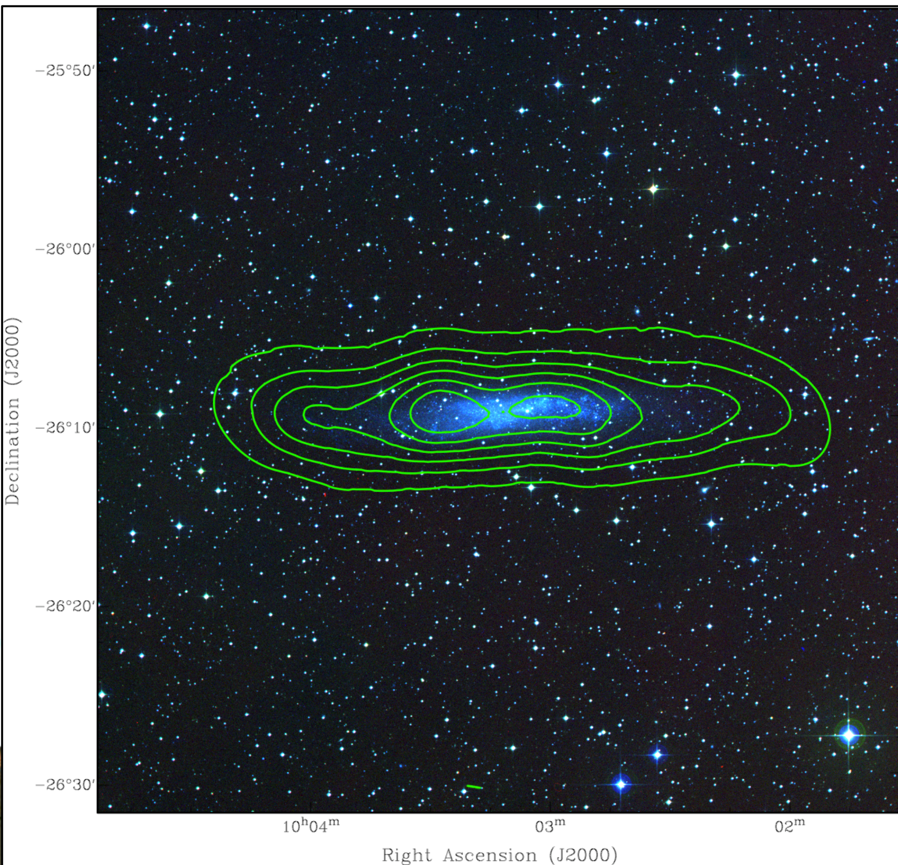
- Work in the past year has concentrated on defining a precursor sample for MHONGOOSE
- Sample of 90 galaxies has been defined using SINGG/SUNGG database (PI: Gerhardt Meurer)
- SINGG/SUNGG were drawn from HIPASS in a similar manner as MHONGOOSE
- Advantage is that multi-wavelength observations are readily available
- First HI data cube obtained by KAT 7 (NGC 3109)

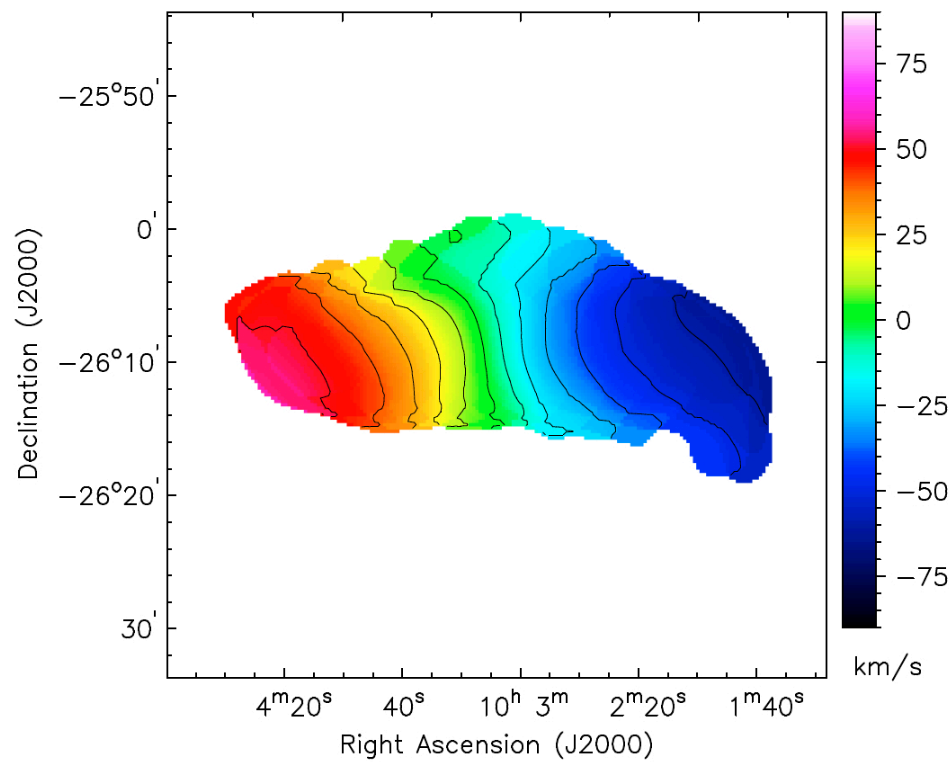
HI with KAT 7

Major milestone for South Africa's KAT-7 telescope

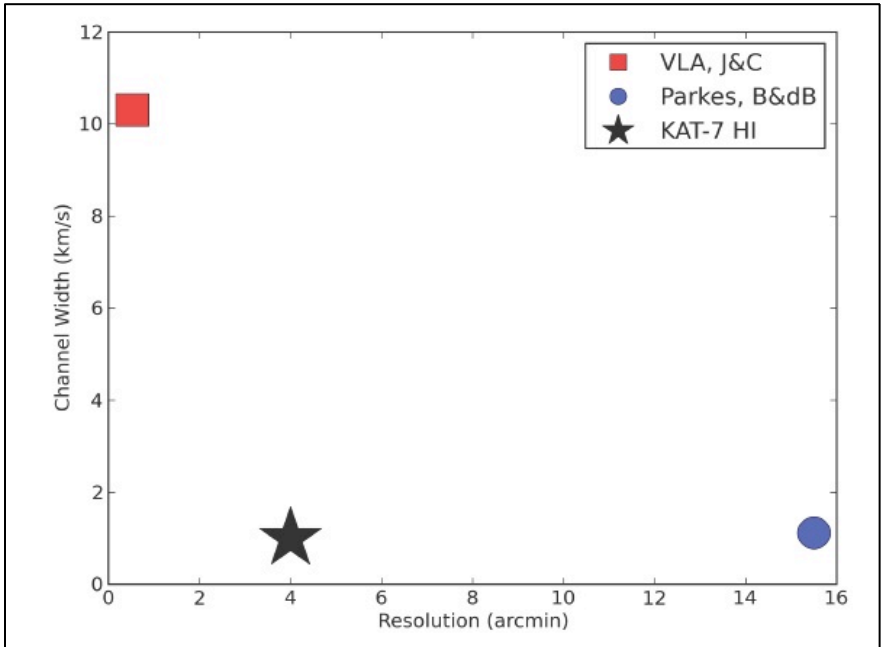
- First atomic hydrogen spectral line images of a nearby galaxy

Carnarvon, 13 March 2012. South Africa's KAT-7 telescope has reached a major milestone by being able to observe the 21 cm spectral line of hydrogen from a nearby, small spiral galaxy – NGC 3109 – that is 4.3 million light-years away from Earth.





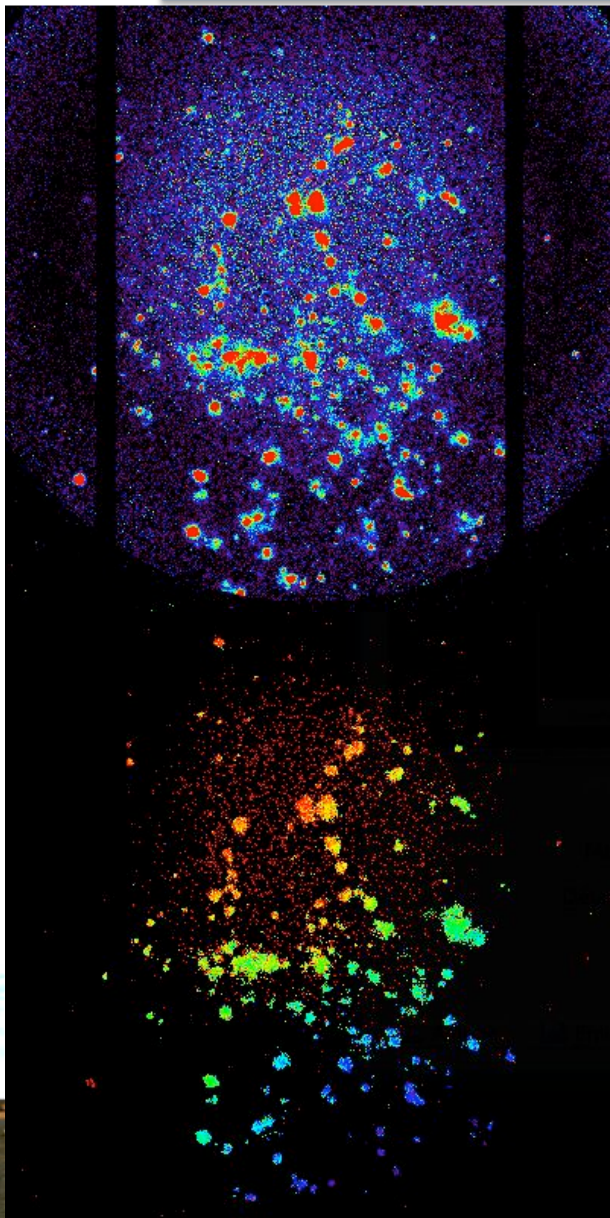
HI with KAT 7



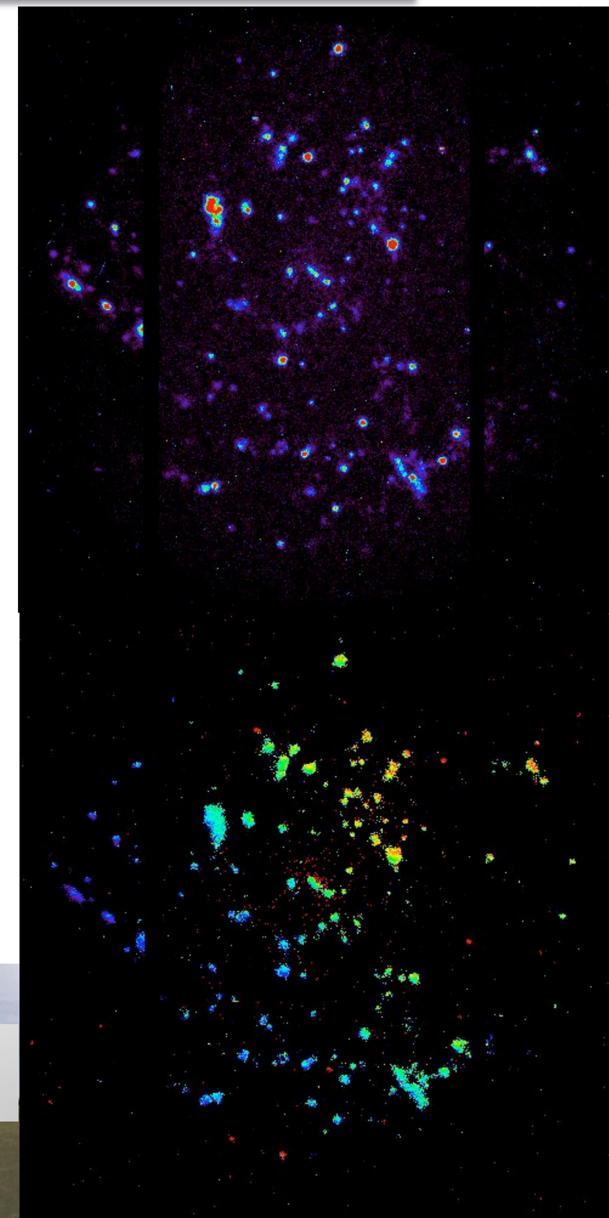
Mode	# Bands	Band Bandwidth	Channel Bandwidth	Available
Wideband	1	256 MHz	390.625 kHz *	Yes
8k Wideband	1	256 MHz	48.8 kHz **	Yes
OH Spectral Line	1	400/32 = 12.5 MHz ***	1.5 kHz	~ Jun 2012
OH Spectral Line	1	400/128 = 3.1 MHz ***	381 Hz	~ Jun 2012
HI Spectral Line	1	>= 33.4 MHz	<= 4.8 kHz	~ Oct 2012

Table 1: Expected correlator modes for KAT-7 commissioned before the end of 2012.

Hα Fabry-Perot on SALT



SALT FP
Medium
Resolution
Data
September 2012



NGC 7424

NGC 7793

MHONGOOSE update

- First HI data cube obtained by KAT 7 (NGC 3109)
- Commissioning of HI line mode – KAT 7 commissioning team in collaboration with B. Frank (PhD, UCT) & D. Lucero (post-doc, UCT)
- SALT Hα Fabry-Perot follow-up of MHOGOOSE deep survey candidates (medium resolution)
- ANU 2.3m (WIFES – 38” x 25” IFS) observations of candidates - PI: G. Meurer, in coll. with M. Mogotsi (PhD, UCT)

MHONGOOSE sample questions

- Covering large range in galaxy properties essential
- Important to have resolution, however choosing large angular diameter galaxies removes low HI masses from sample
- Preliminary LVHIS-like survey of larger number of objects
- Questions:
  - Can/should the size limit be optimised?
  - Should a lower size or distance limit be considered?
  - Is mosaicing a better investment than multiple single galaxies observations?
  - Is the accretion question relevant for $M_{HI} < 10^{7.5}\ M_{\odot}$?
  - Is there an optimum mass/size scale where we should observe?
  - Coordination with other HI/multi-λ surveys

website: mhongoose.astron.nl