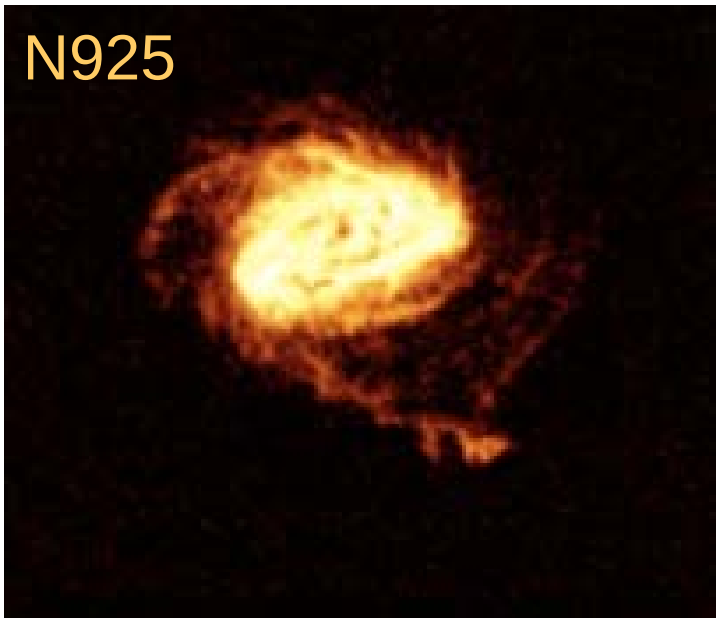
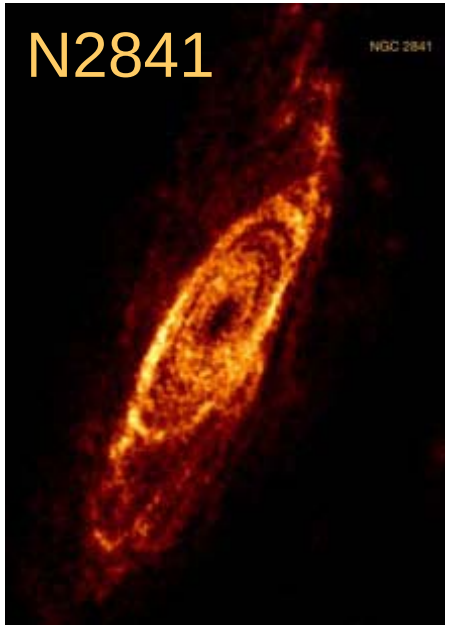
HI Signatures of galaxy evolution

Thijs van der Hulst

See: *Sancisi, Fraternali, Oosterloo & Van der Hulst*, 2008, Ann.Rev. A&A, 15, 189 and *Van der Hulst* in 'A New Golden Age for Radio Astronomy' (*arXiv:1103.1420)*





The origin of SKA in 1990, not far from here:

Radio Interferometry: Theory, Techniques and Applications,
IAU Coll. 131, ASP Conference Series, Vol. 19, 1991,
T.J. Cornwell and R.A. Perley (eds.)

THE HYDROGEN ARRAY

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University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield, Cheshire, SK11 9DL, United Kingdom

ABSTRACT The time is ripe for planning an array with a collecting area of 1 km^2 (14 times larger than Arecibo and 75 times larger than the VLA). In view of its major astronomical target I have dubbed this concept 'The Hydrogen Array', although 1μJy continuum sources will also be reliably detected. I present some initial thoughts about the issues involved.

HI to z = 10, pulsar searches and timing, continuum

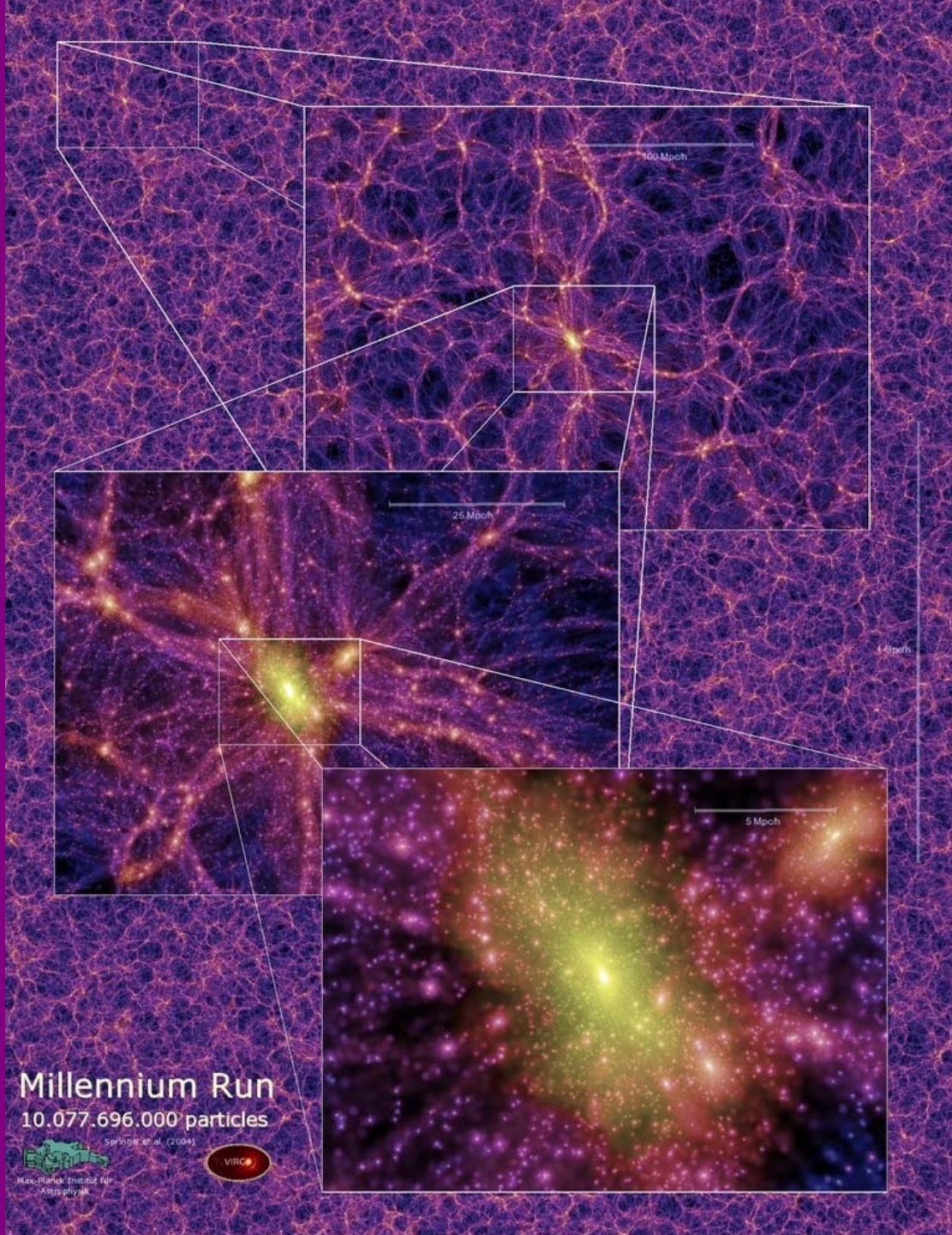
Galaxy formation

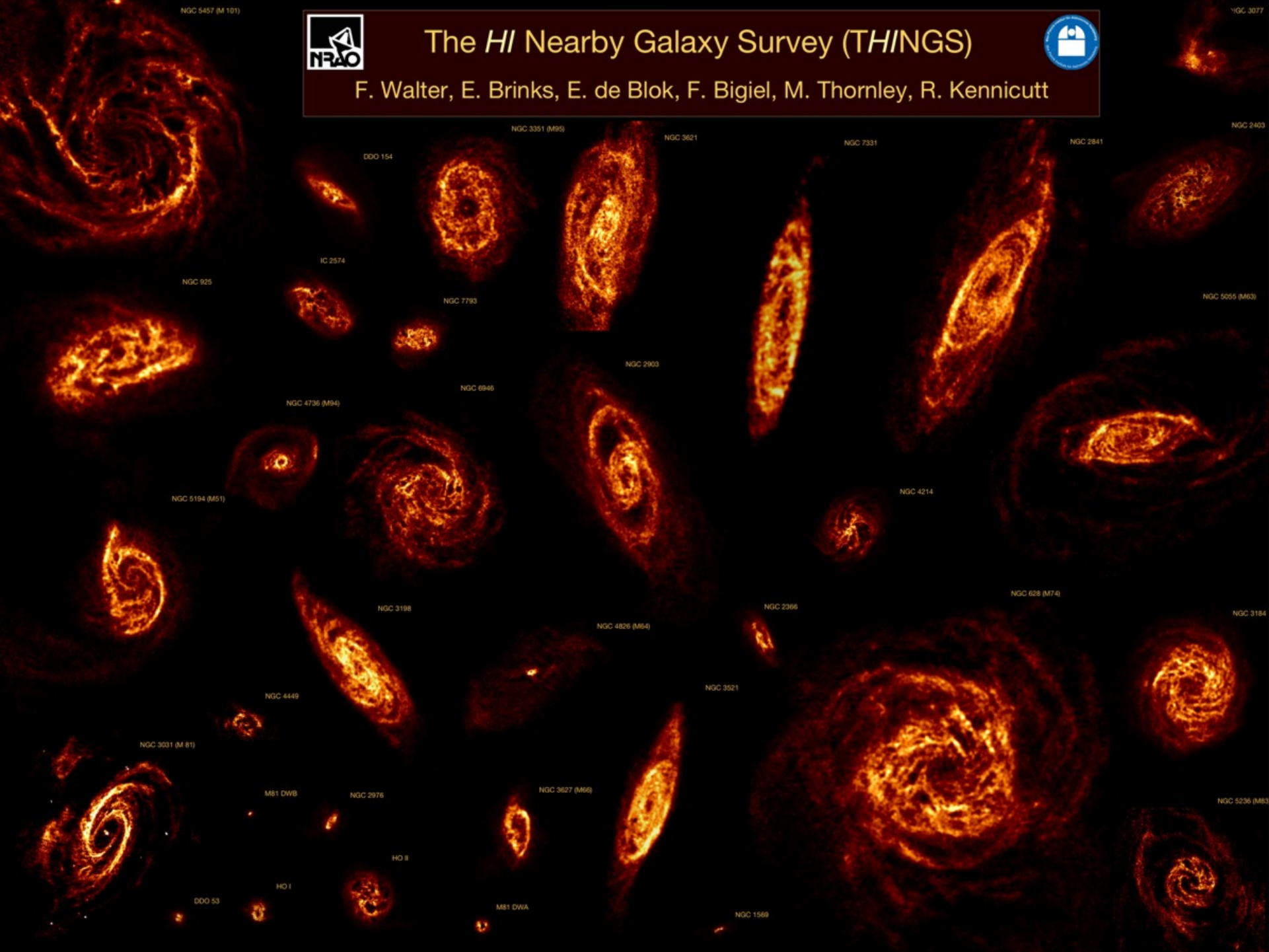
baryons flow into the DM halos and form galaxies

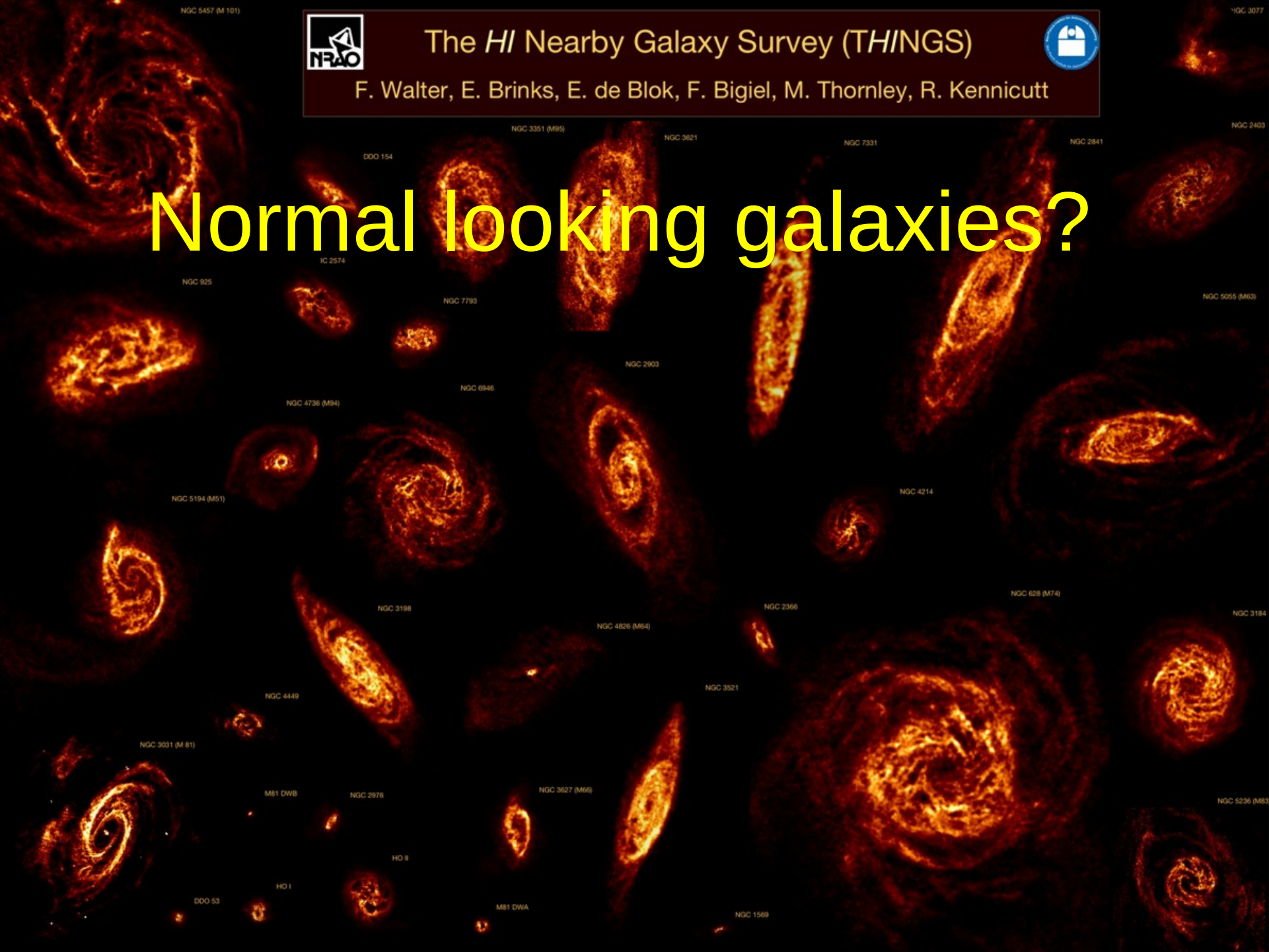
galaxies merge into larger galaxies

gas continues to flow in from the cosmic web

can we observe this?

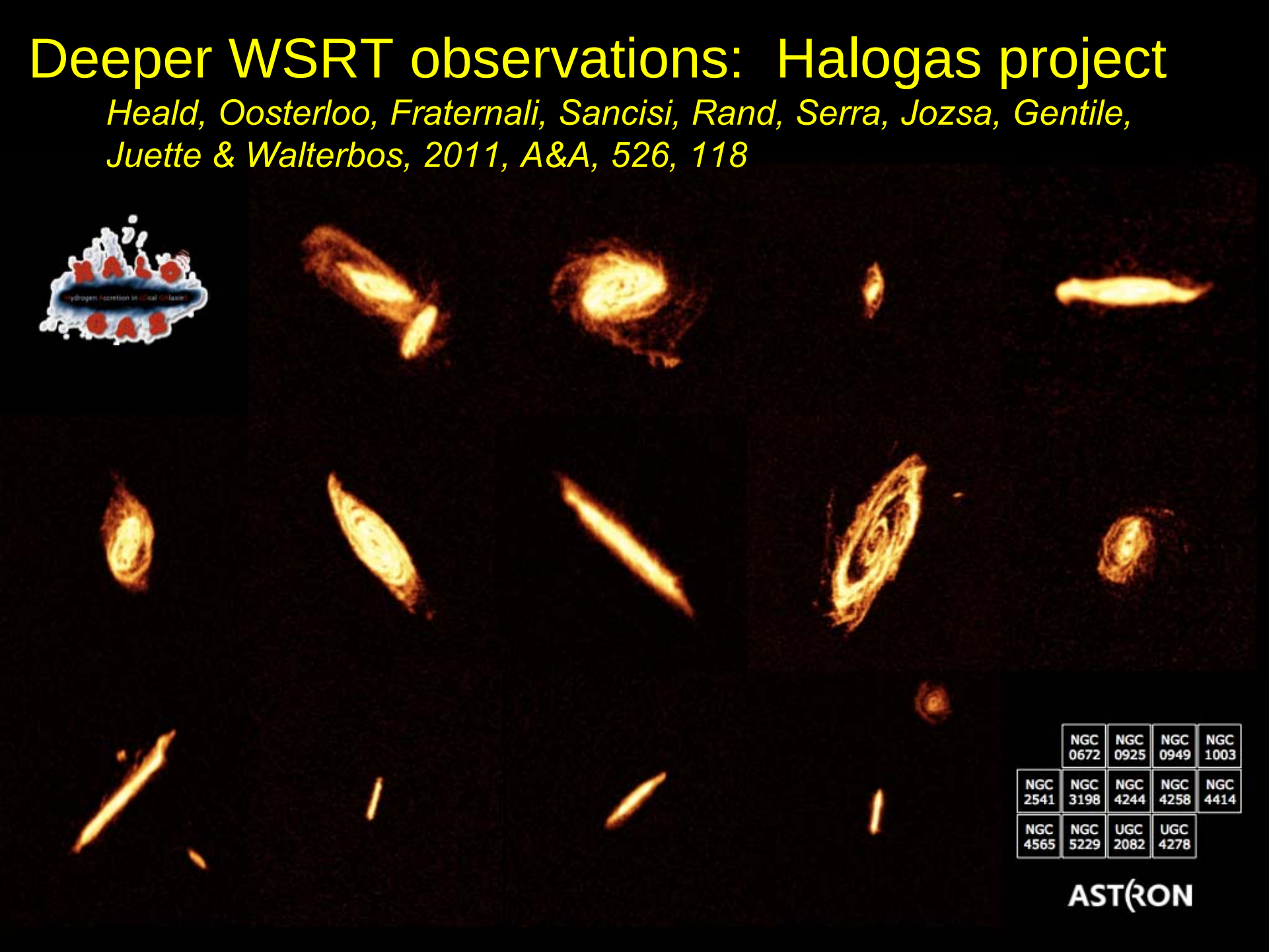



The HI Nearby Galaxy Survey (THINGS)
F. Walter, E. Brinks, E. de Blok, F. Bigiel, M. Thornley, R. Kennicutt
NRAO
NGC 5457 (M 101)
NGC 3077
NGC 3351 (M95)
NGC 3621
NGC 7331
NGC 2841
NGC 2403
DDO 154
IC 2574
NGC 925
NGC 7793
NGC 5055 (M63)
NGC 2903
NGC 6946
NGC 4736 (M94)
NGC 5194 (M51)
NGC 4214
NGC 628 (M74)
NGC 3198
NGC 2366
NGC 3184
NGC 4826 (M64)
NGC 4449
NGC 3521
NGC 3031 (M 81)
M81 DWB
NGC 2976
NGC 3627 (M66)
NGC 5236 (M83)
HO II
HO I
DDO 53
M81 DWA
NGC 1569


The HI Nearby Galaxy Survey (THINGS)
F. Walter, E. Brinks, E. de Blok, F. Bigiel, M. Thornley, R. Kennicutt
Normal looking galaxies?

Deeper WSRT observations: Halogas project

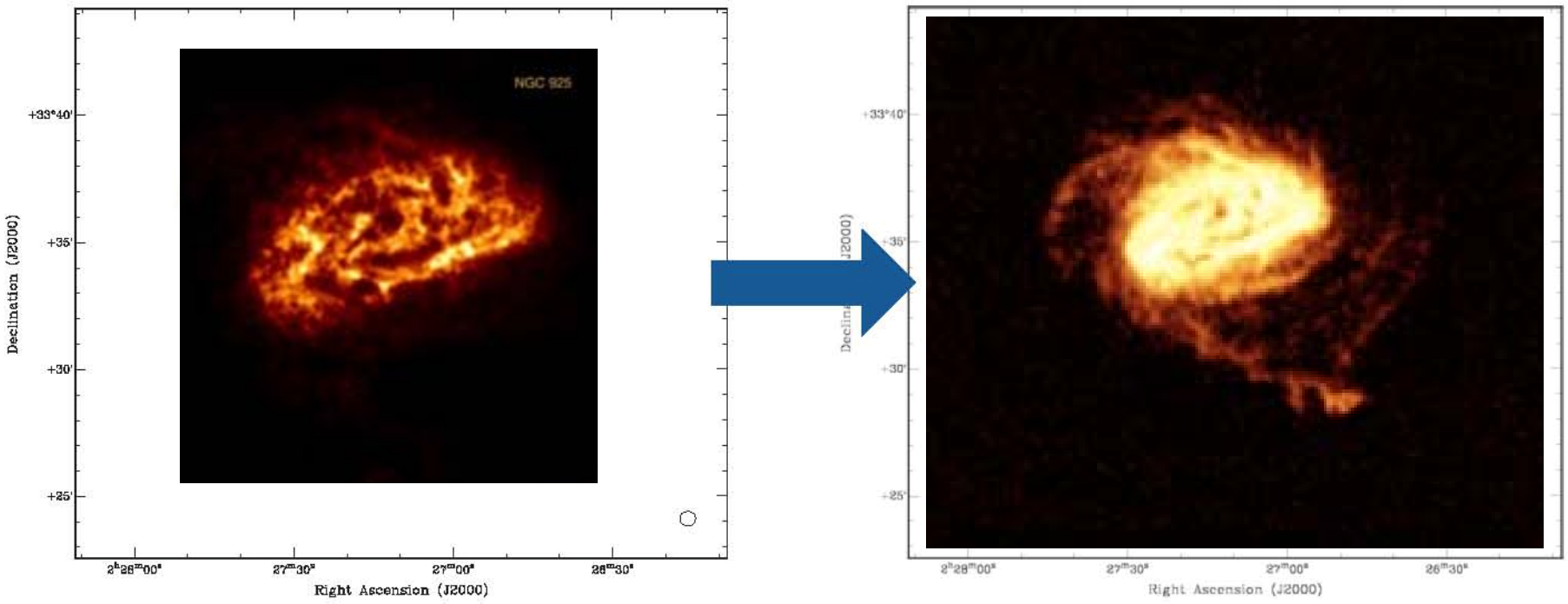
Heald, Oosterloo, Fraternali, Sancisi, Rand, Serra, Jozsa, Gentile, Juette & Walterbos, 2011, A&A, 526, 118



The HALOGAS project

- Will provide a large database of the deepest available HI observations of nearby galaxies - complementary to THINGS (HALOGAS strength is detecting faint diffuse emission; THINGS strength is small-scale structure)

example: ***NGC 925***



HI traditionally a tracer of kinematics:

dark and luminous matter distribution

HI can tell us more:

we need to look carefully to recognise the evidence for processes governing the acquisition and removal of gas

Examples:

asymmetries in structure and kinematics
extraplanar gas
gas with anomalous velocities

HI *observations in the local universe*

- ***Extended HI*** *disks with outer* ***spiral*** *structure*

- *Large number of* ***WARPED*** *and* ***LOPSIDED*** *disks*

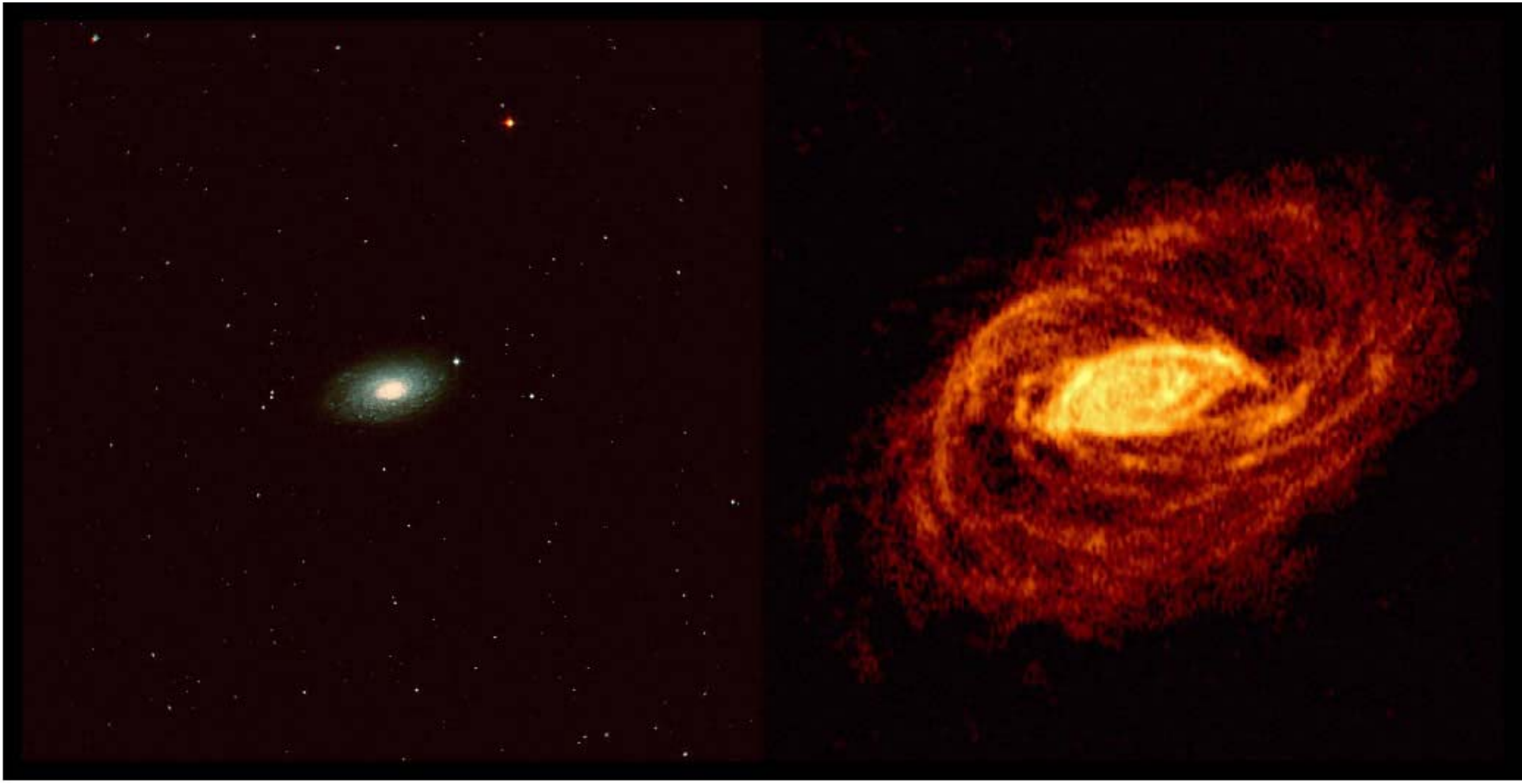
- *Large reservoirs of* ***extra-planar*** *gas*

- ***Lumpy HI*** *structures (****clouds, tails, filaments****) around galaxies*

Result of recent minor ***mergers****,* ***accretion, outflows, stripping***

EXTENDED HI (note the spiral structure)

optical **NGC 5055** *neutral hydrogen WSRT*

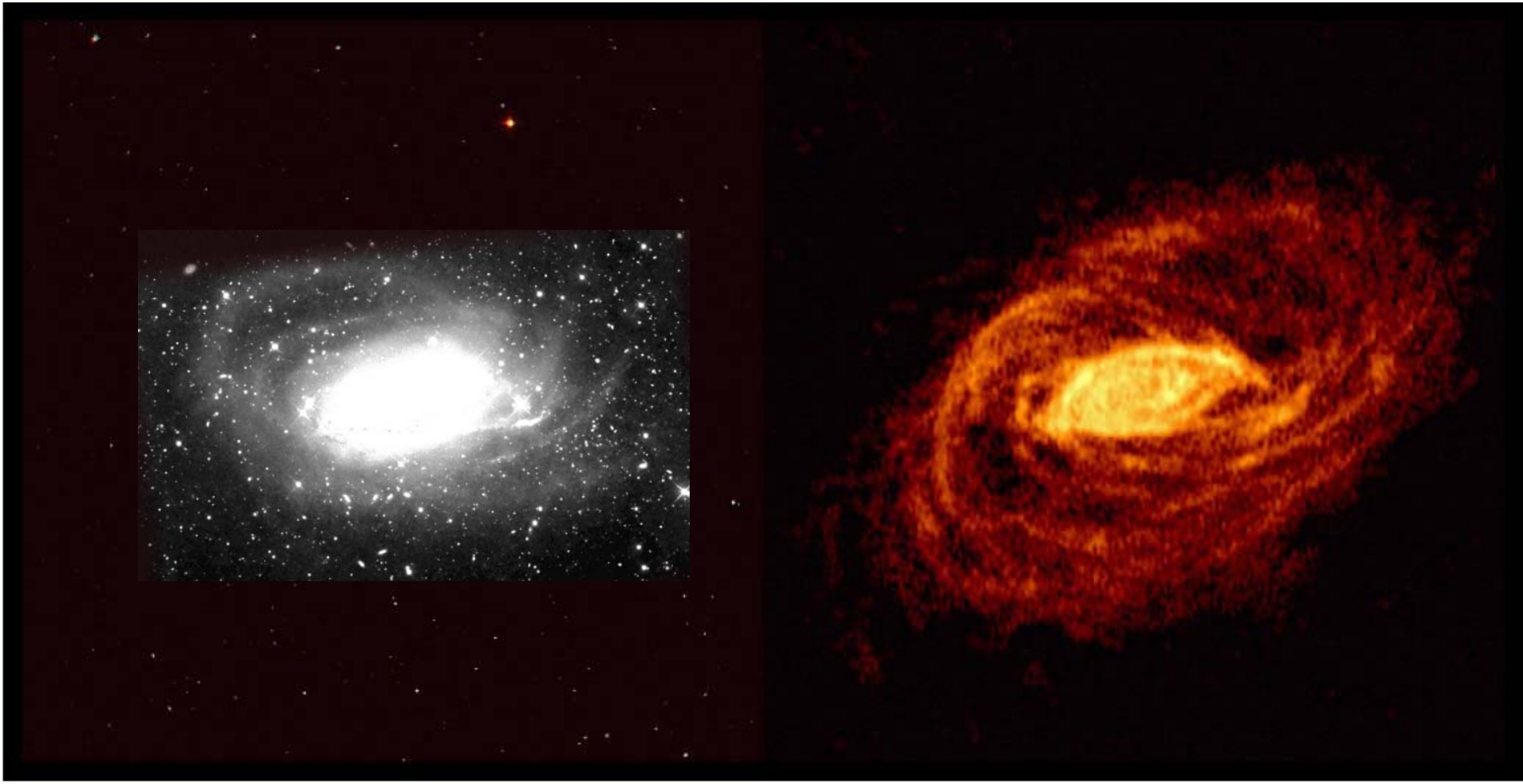


same scale

Battaglia et al. 2005

EXTENDED HI (note the spiral structure)

optical **NGC 5055** *neutral hydrogen WSRT*

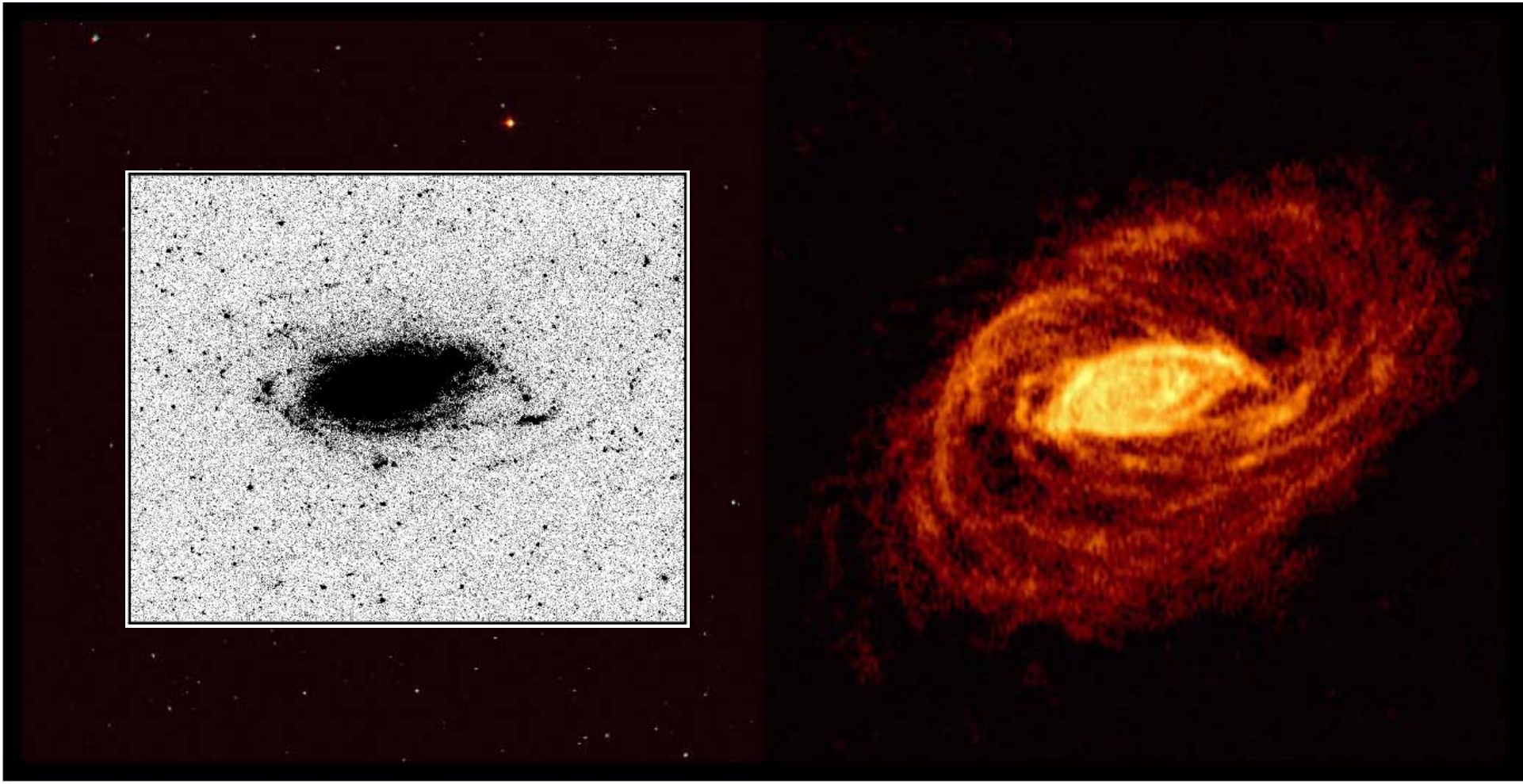


same scale

Battaglia et al. 2005

EXTENDED HI (note the spiral structure)

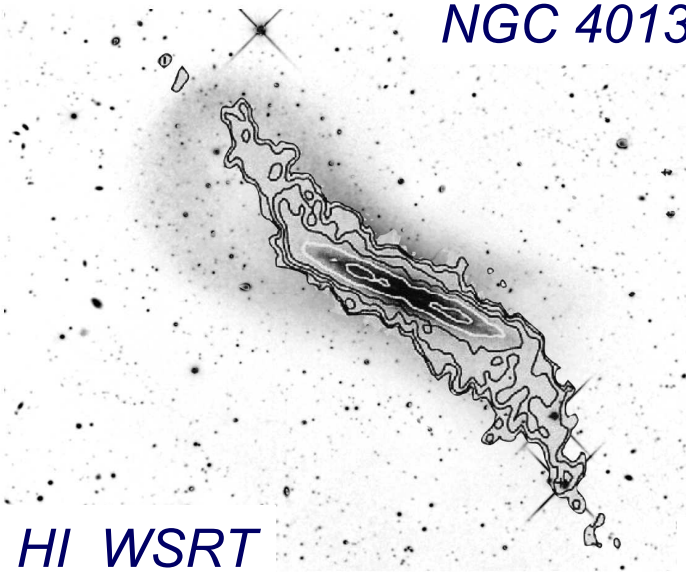
GALEX **NGC 5055** *neutral hydrogen WSRT*

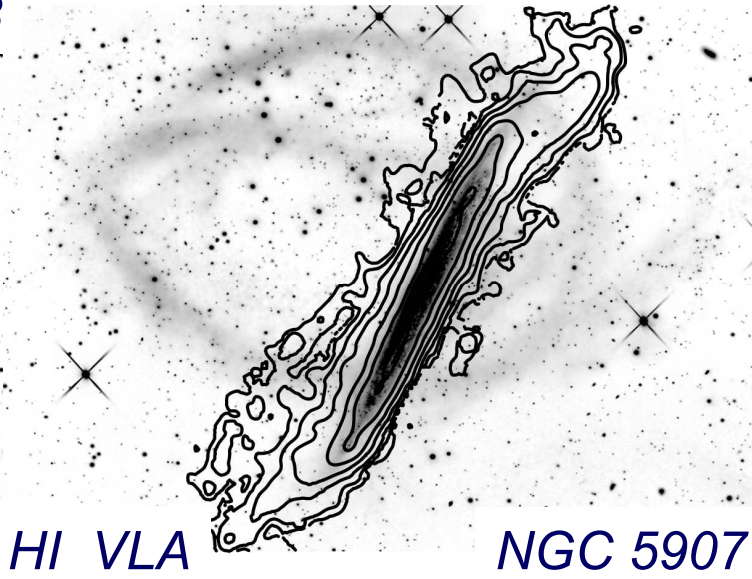


same scale

Battaglia et al. 2005

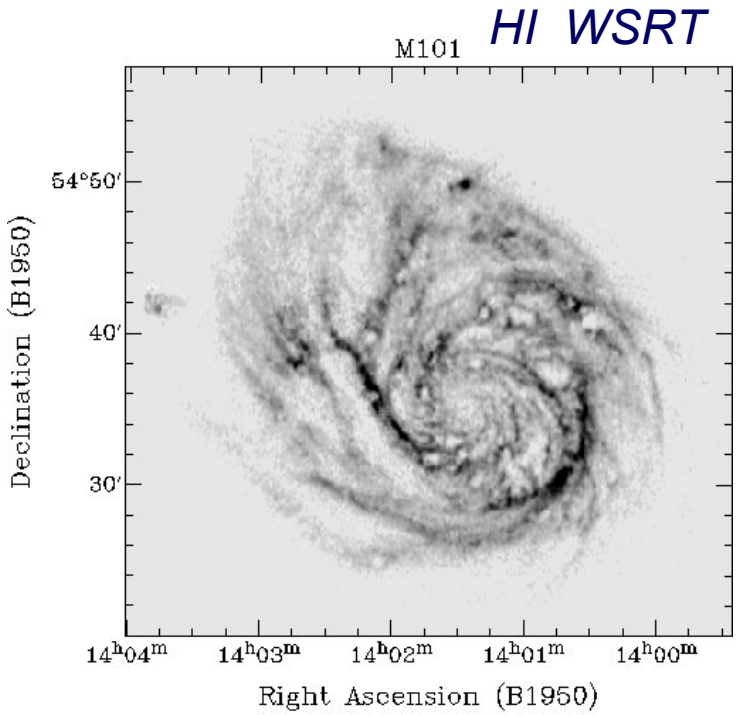
WARPS



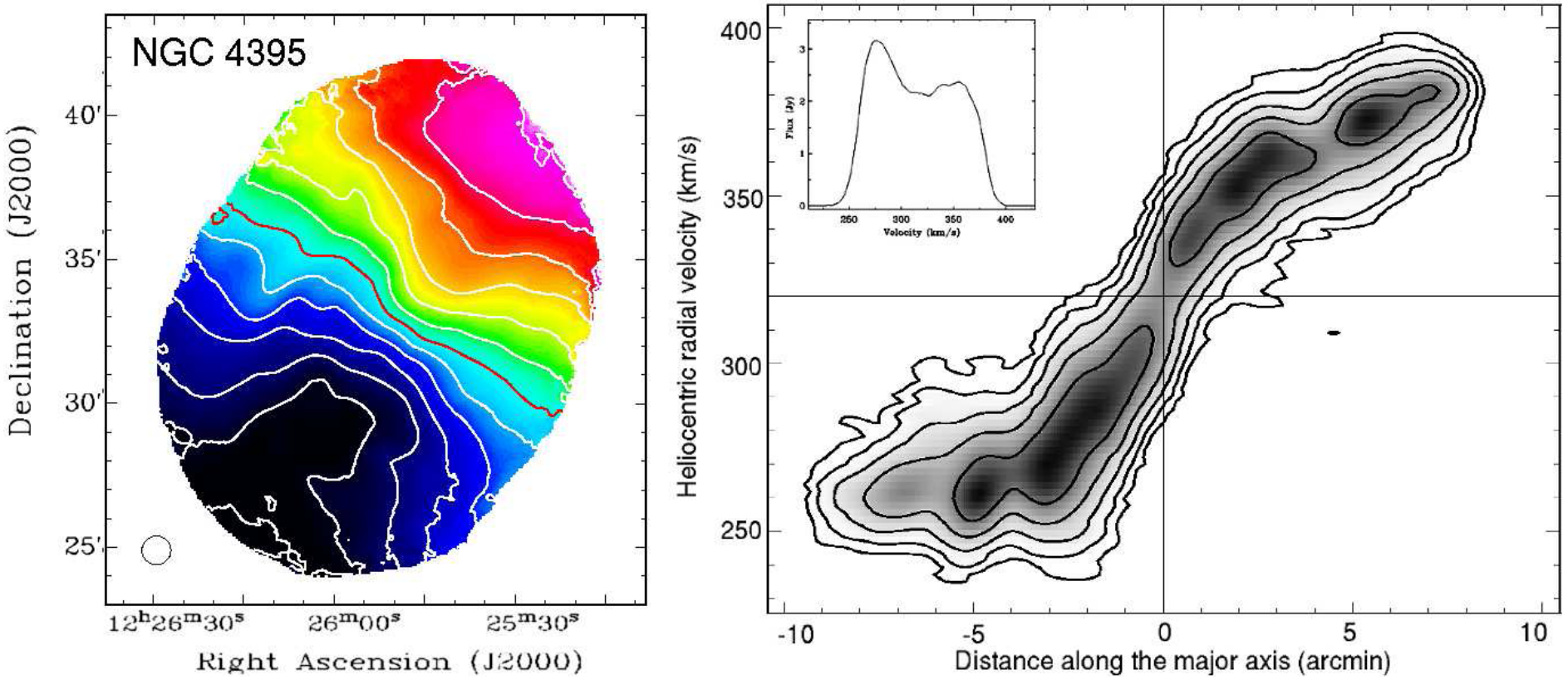


Martinez-Delgado et al. (2008/09)

LOPSIDEDNESS



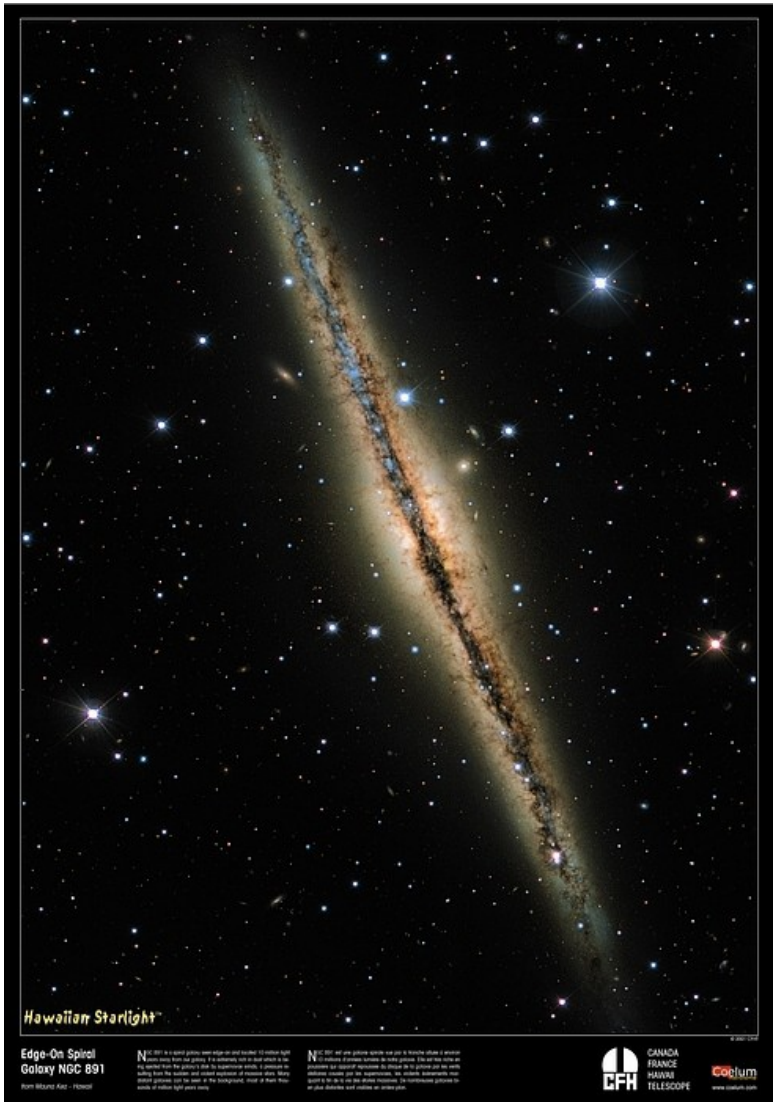
KINEMATIC LOPSIDEDNESS



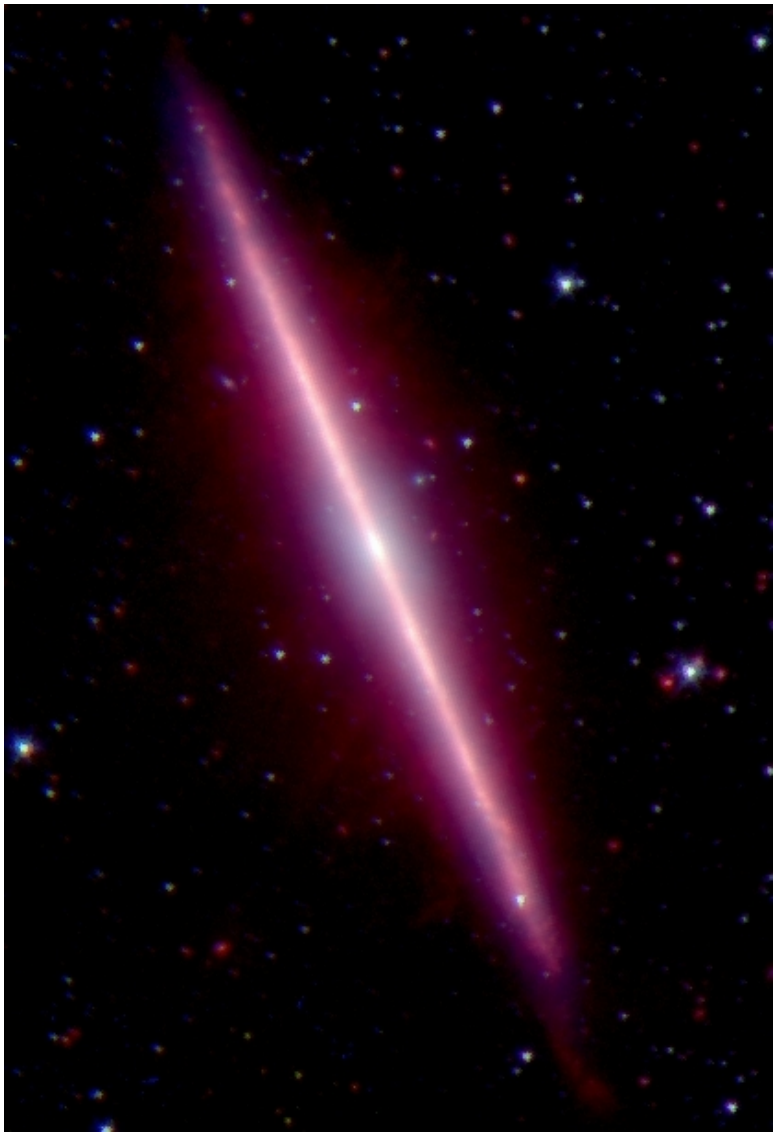
Heald and Oosterloo, 2008, ASP Conf. Series 396, 267

NGC 891 *edge-on galaxy: extra-planar gas?*

optical

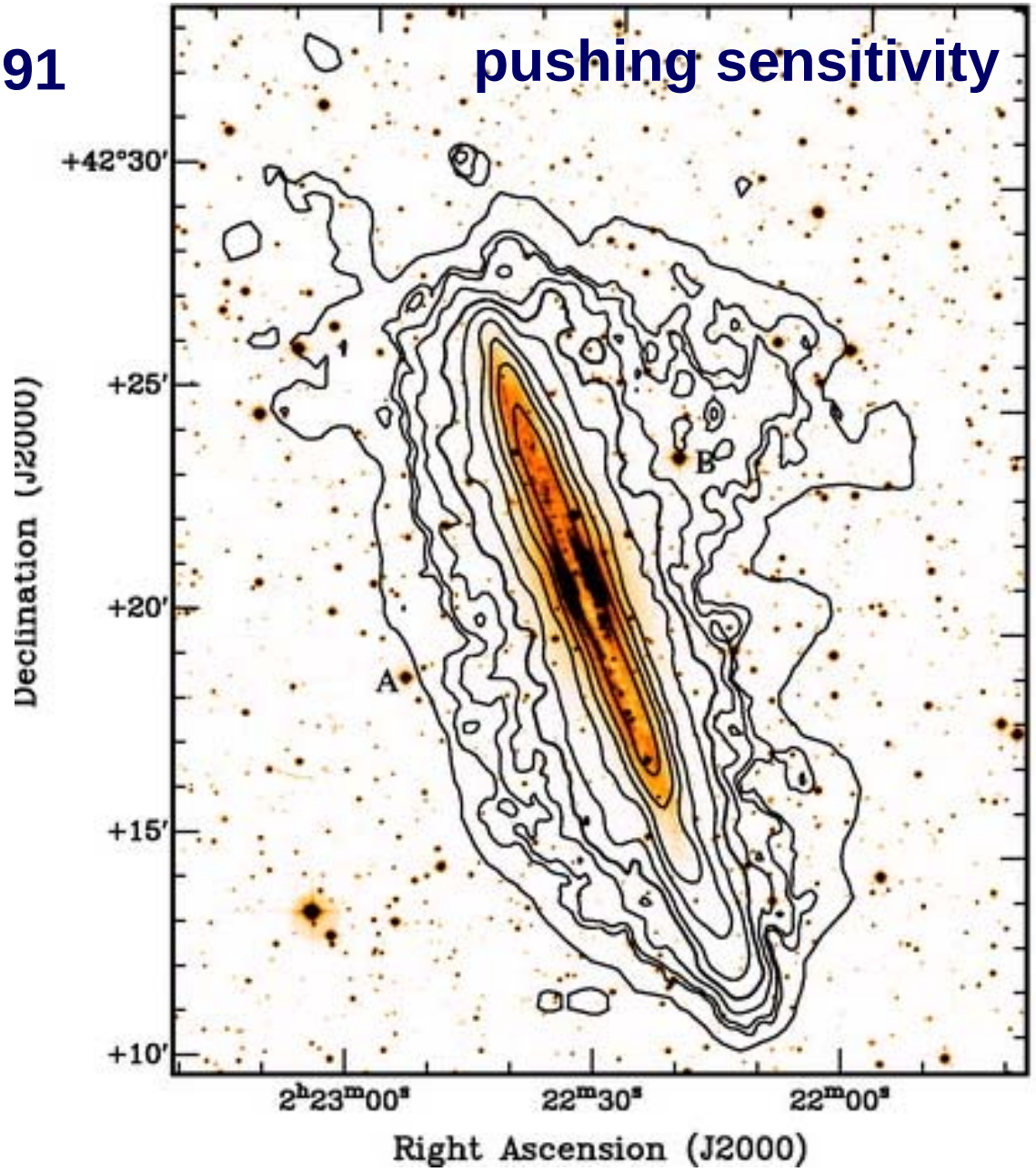


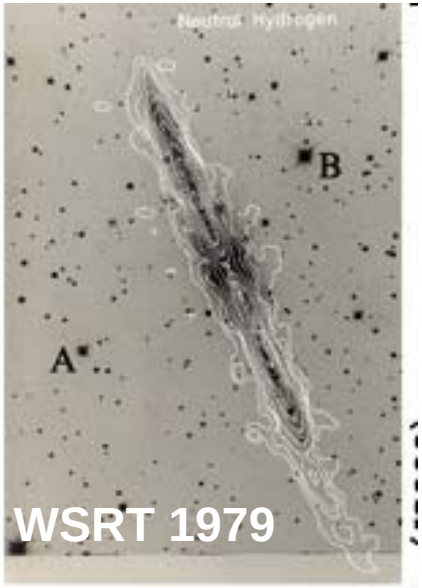
near infrared

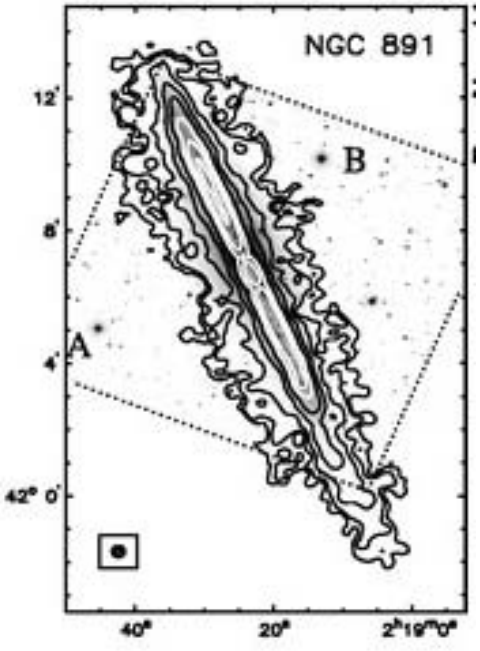


NGC 891

pushing sensitivity







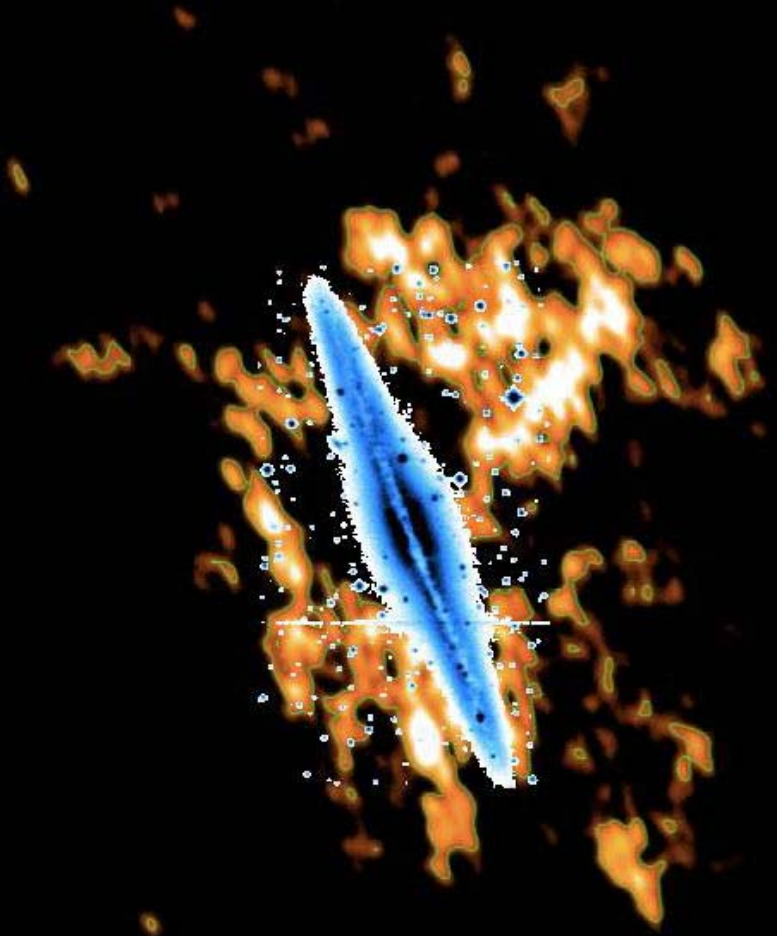
WSRT 1997

Oosterloo et al. 2007, AJ 134, 1019

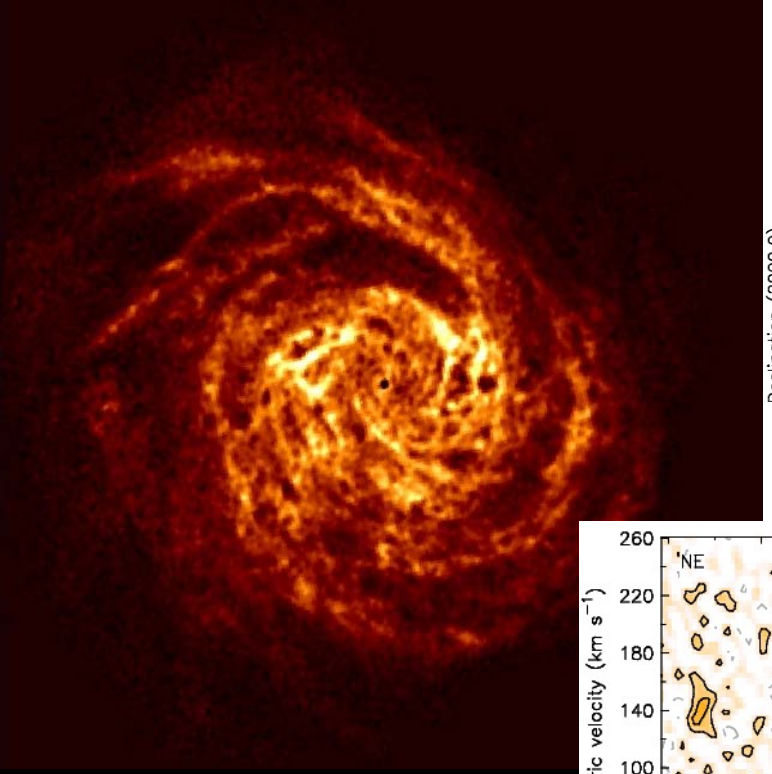
NGC 891

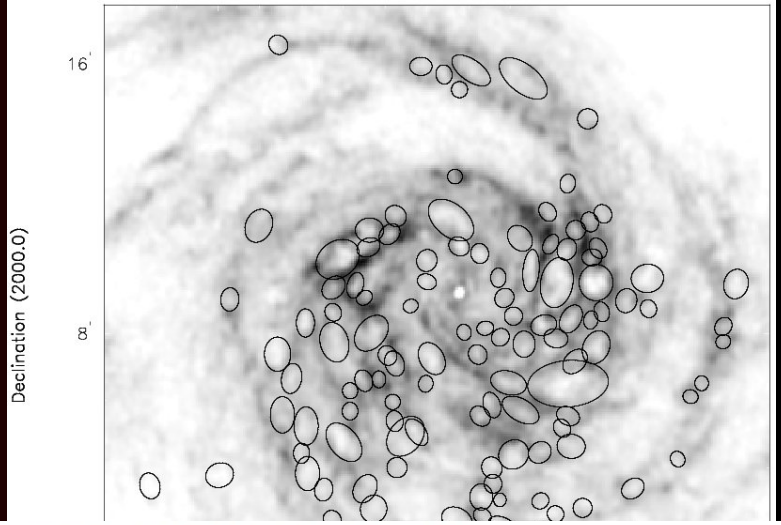
Anomalous HI not corotating

~ 1 x 10^8 $M_\odot$



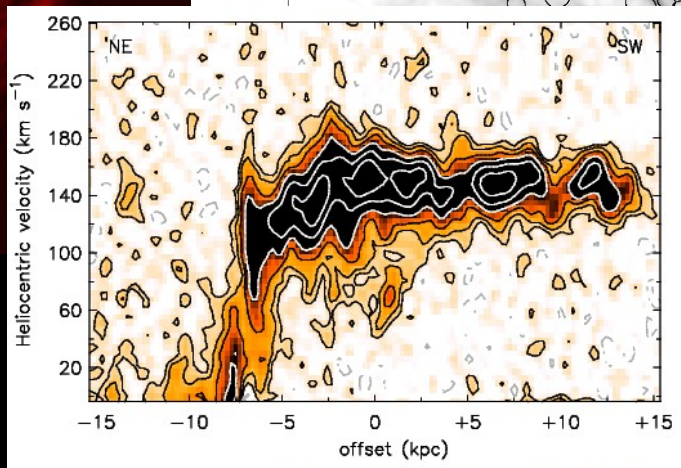
Oosterloo et al., 2007, AJ 134, 1019

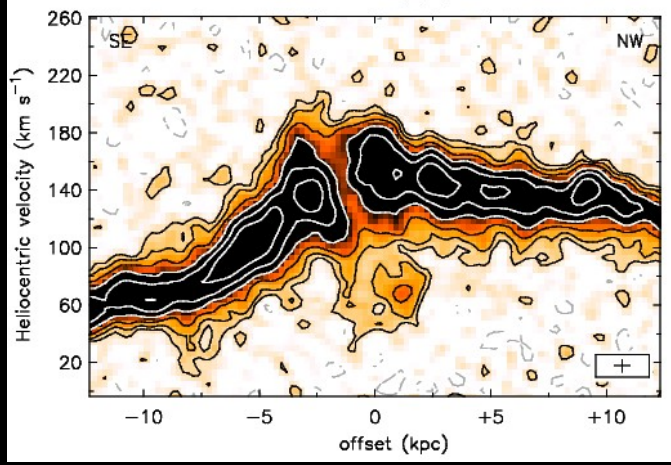


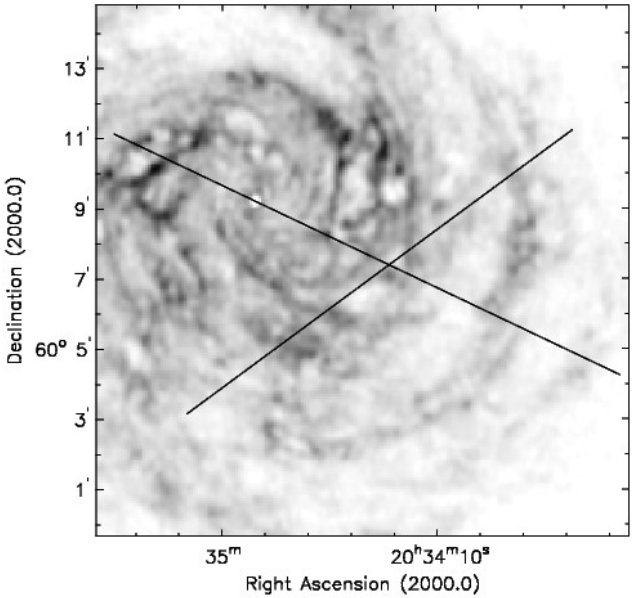


NGC 6946

"HIGH VELOCITY CLOUDS" (total amount: ~3x10^8 $M_\odot$)

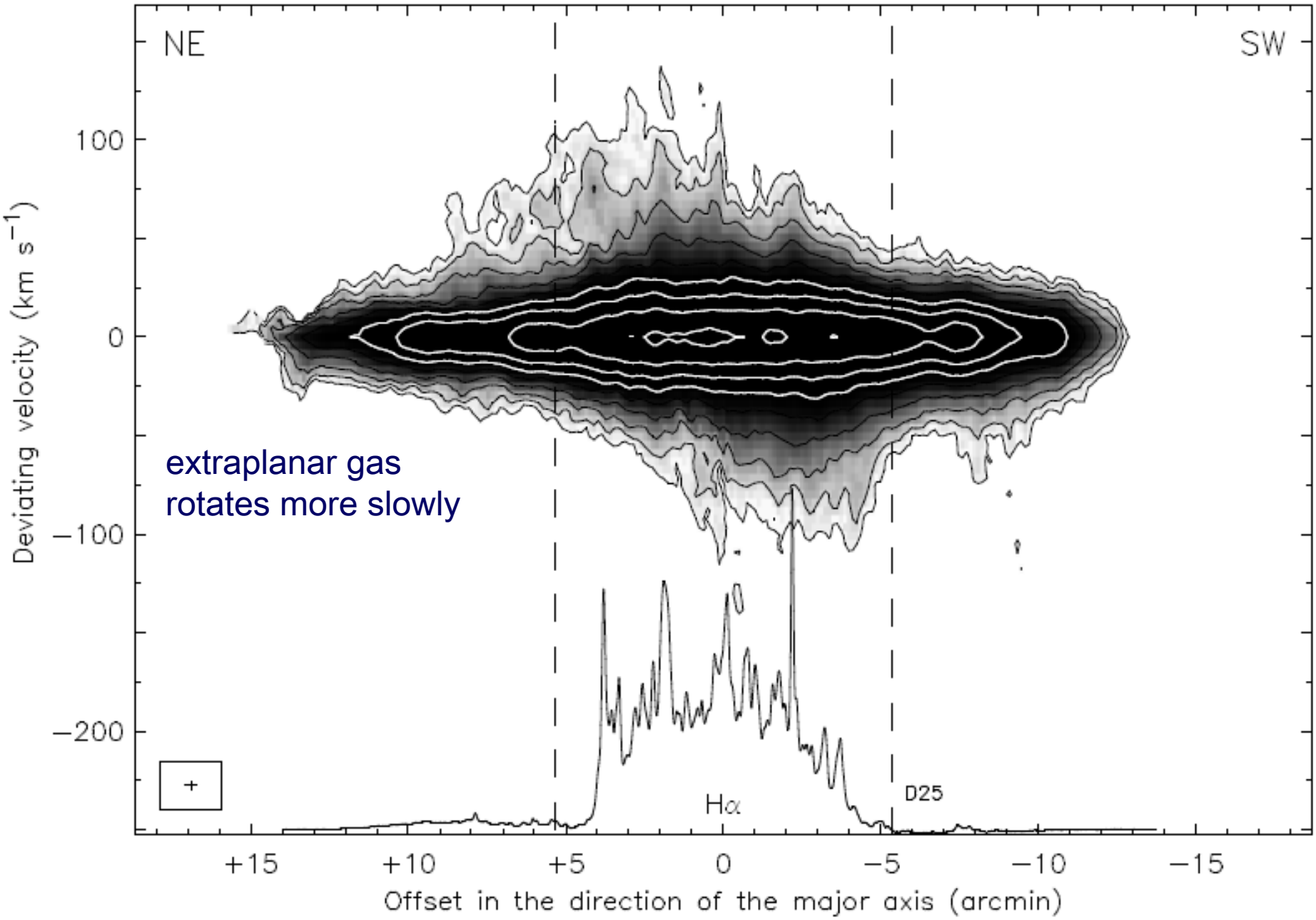






NGC 6946 extraplanar gas

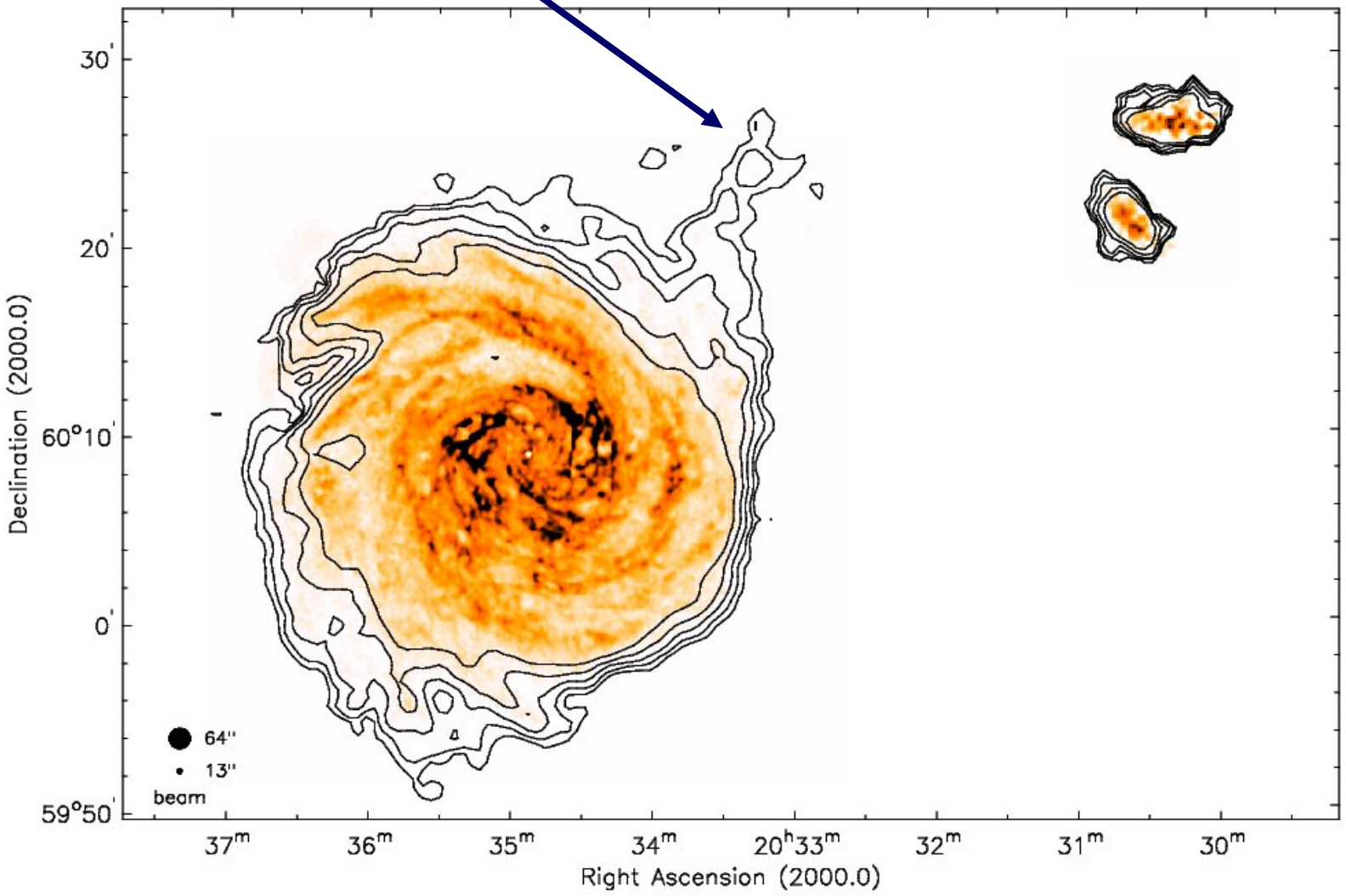
Boomsma, PhD Thesis 2007



NGC 6946

Accretion?

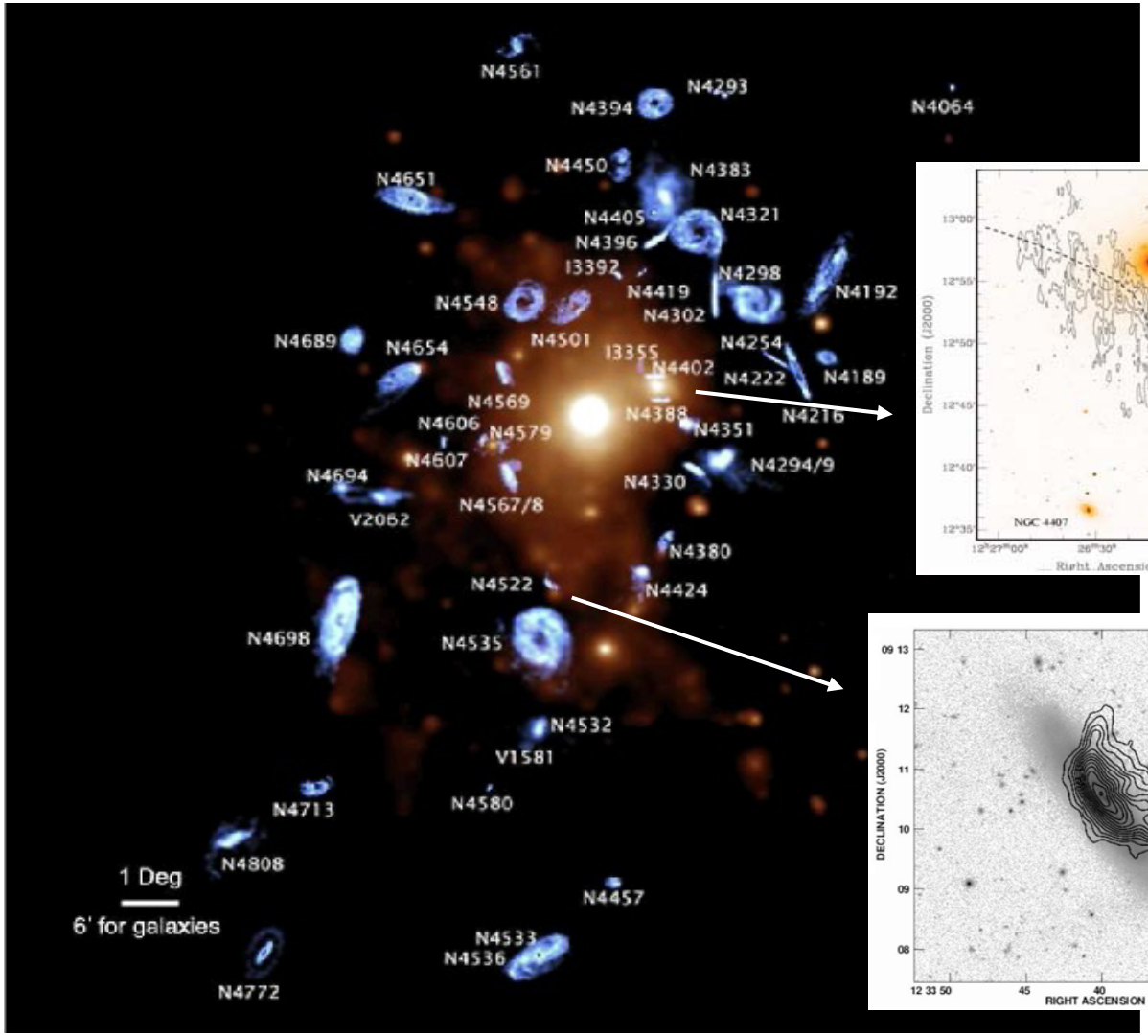
WSRT HI image



Boomsma et al. 2008, A&A 490, 555

Virgo cluster

stripping



VIVA: Chung et al. 2009, AJ 138, 1741

Emerging picture:

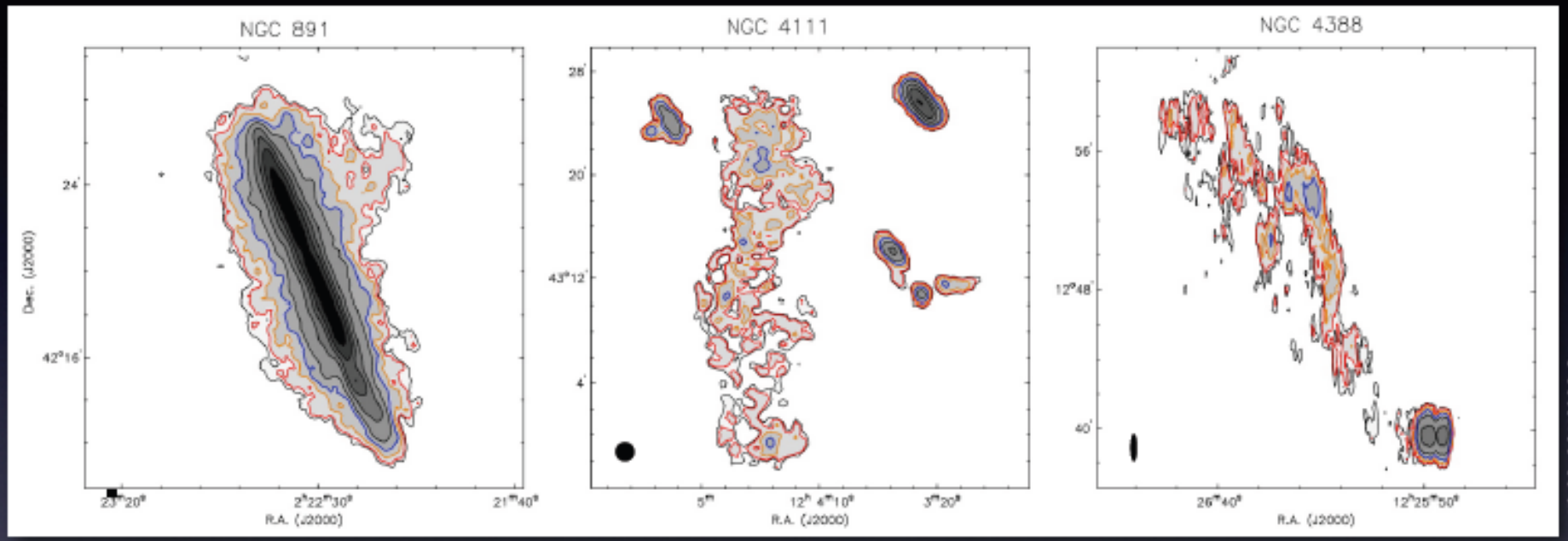
We can use the HI to diagnose

- *accretion*
- *outflows*
- *stripping*
- *tidal effects*

but require ***resolved*** imaging with adequate ***sensitivity***

accretion and depletion of gas

beam = 30"x30" | beam = 45"x45" | beam = 18"x90"



Map and measure these filaments
in various evironments at different redshifts.

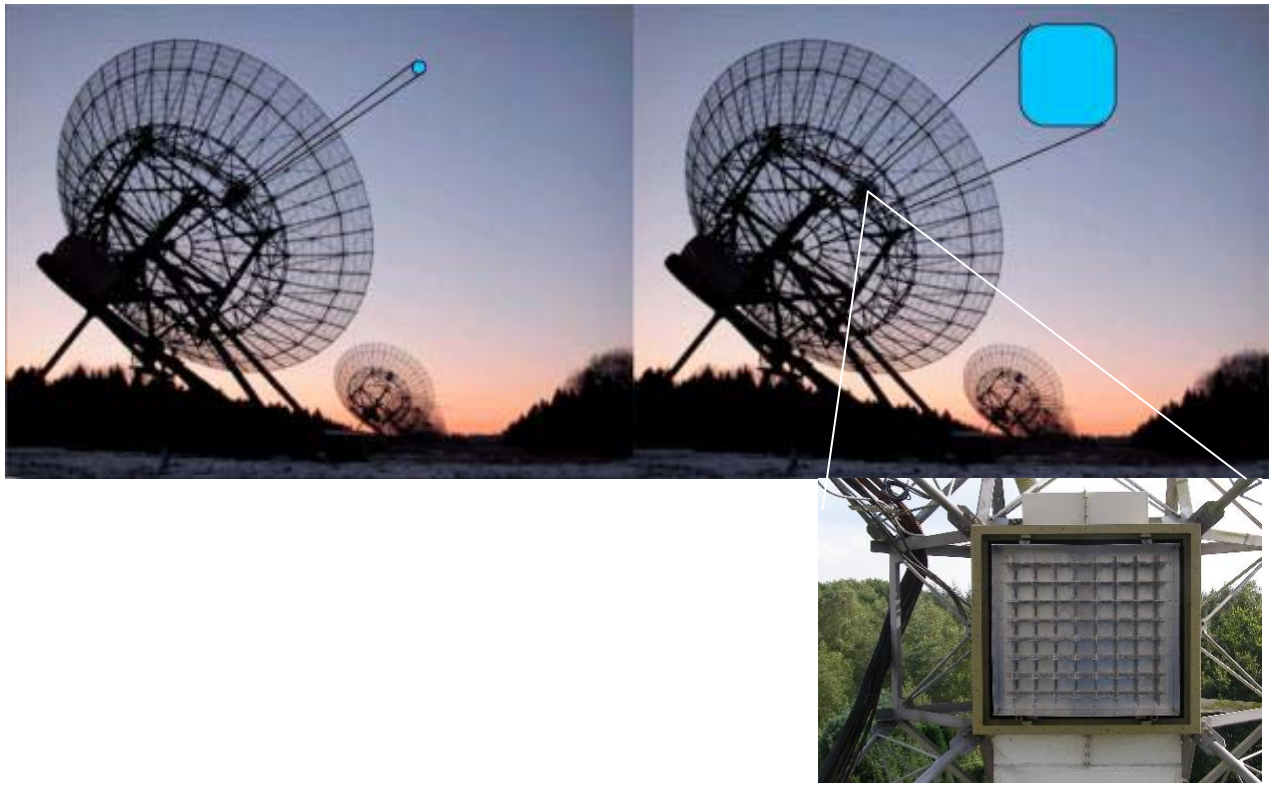
2×10^{19} (atoms/cm^2)
5×10^{19} (atoms/cm^2)
10×10^{19} (atoms/cm^2)

Non-equilibrium situations allow for lower HI column densitities.
→ enhanced sensitivities are required to detect and map the features.

Which gas depletion mechanisms dominate where?

APERTIF

12 x 25m antennas
8 sq. deg. FoV
12'' – 60'' resolution
1.0 – 1.7 GHz
300 MHz bandwidth
16348 channels



Medium Deep Survey PI M. Verheyen 500 sq.deg. 12x12 hr z = 0.0 – 0.26

HI environment of galaxies, low HI mass galaxies, HIMF evolution

Herschel-Atlas PI M. Jarvis 150 sq.deg. 24x12 hr *z* = 0.09 – 0.4

galaxy evolution as function of environment and AGN activity

DASH PI J. Brinchman 5 pointings @ 100 x 12h *z* = 0.02 – 0.3

characterize accretion from cosmic web by combining HI and Lyα data

ASKAP

36 x 12m antennas
30 sq. deg. FoV
10'' – 30'' resolution
0.7 – 1.8 GHz
300 MHz bandwidth
16348 channels

Deep Investigations of Neutral Gas Origins (**DINGO**), PI M. Meyer

evolution of HI from z = 0 to z ~ 0.5 : HI mass function and cosmic web

Target: GAMA survey area: 150 sq. deg. 500 hr
60 sq. deg. 2400 hr

MeerKAT

64 x 13.5m antennas
single pixel offset feeds
0.6 – 1.7 GHz
8 – 14 GHz (later phase)
850 MHz bandwidth
6'' – 30'' resolution

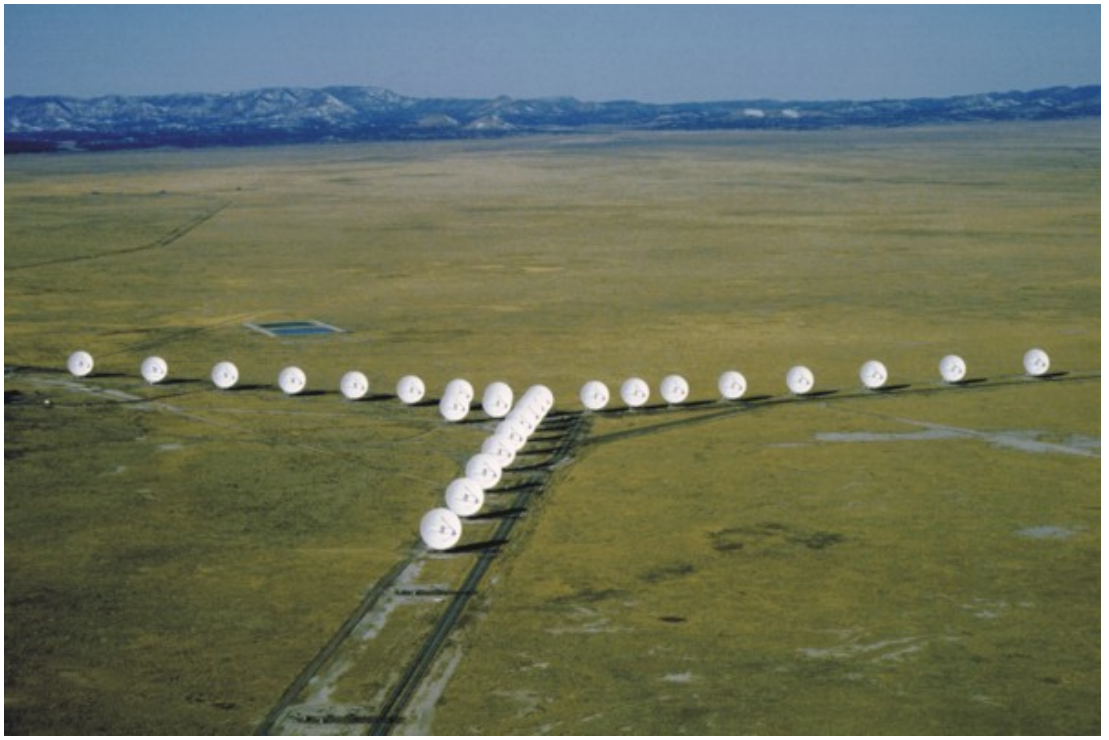
LADUMA: Looking At the Distant Universe with the MeerKAT Array,
PI S. Blyth, B. Holwerda and A. Baker, 5000 hr on one field (high priority):
HI content of galaxies from z = 0 to z = 1.2

MHONGOOSE: MeerKAT HI observations of Nearby Galactic Objects: Observing Southern Emitters, PI E. de Blok, 6000 hr for 30 objects (medium priority):
characterizing the distribution and kinematics of galaxies of different type and luminosity to low N(HI) levels.

A MeerKAT HI Survey of Fornax PI P. Serra, 11 sq.deg. Strip, 2450 hr (medium priority): *characterizing HI in the cluster (galaxies) to N(HI) ~ 10^{18} cm $^{-2}$*

EVLA (for HI)

27 x 25m antennas
1 sq. deg. FoV
4’’ – 40’’ resolution
1 – 2 GHz
1 GHz bandwidth (21cm)
> 65536 channels



Exciting times ahead !!