

HI research in the ERA of SKA pathfinders

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university of
groningen

428

*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

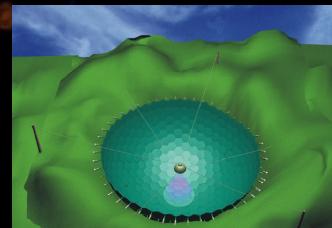
ABSTRACT The time is ripe for planning an array with a collecting area of 1 km^2 (14 times larger than Arecibo and 75 times larger than the VLA). In view of its major astronomical target I have dubbed this concept 'The Hydrogen Array', although $1\mu\text{Jy}$ continuum sources will also be reliably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

H I to $z = 10$, pulsar searches and timing, continuum

The ERA of SKA pathfinders/precursors:

(major pre-SKA investments)

ASKAP



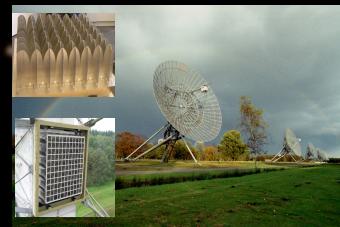
J-VLA



LOFAR

MeerKAT

WSRT-APERTIF



Wide area surveys: ASKAP, APERTIF, FAST

Deep fields: J-VLA, MeerKAT

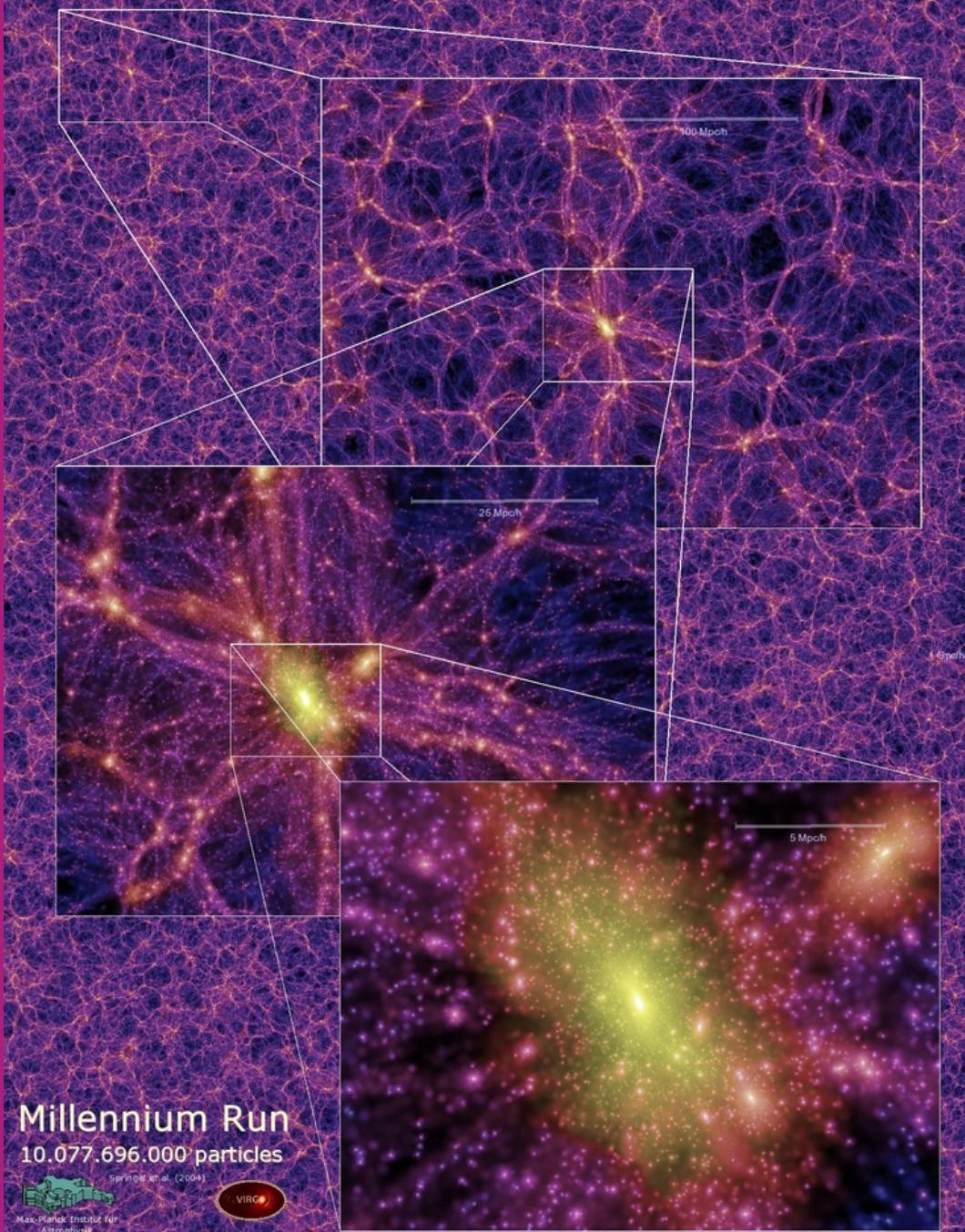
Galaxy formation

baryons flow into the
DM halos and form
galaxies

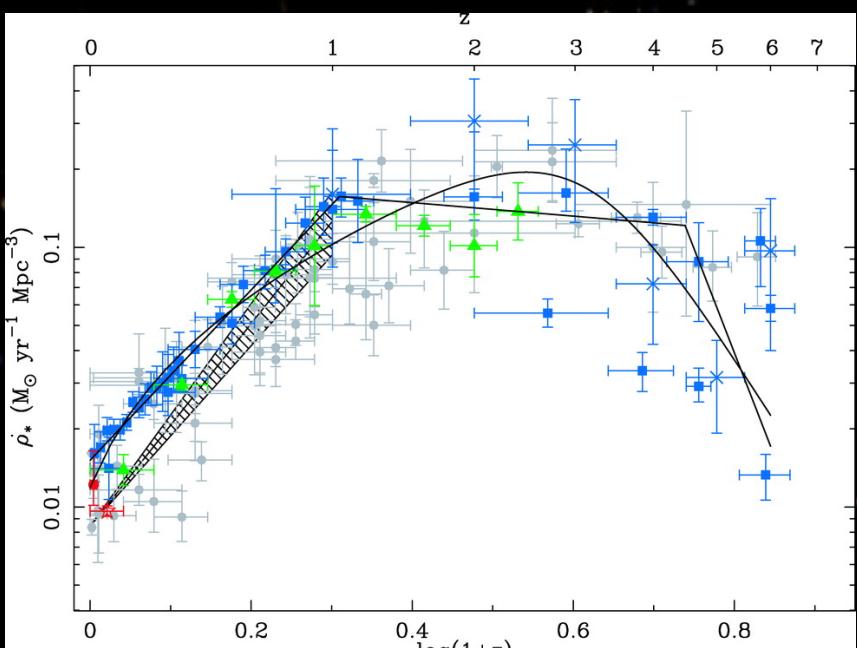
galaxies merge into
larger galaxies

gas continues to flow
in from the cosmic
web

Is this observable?



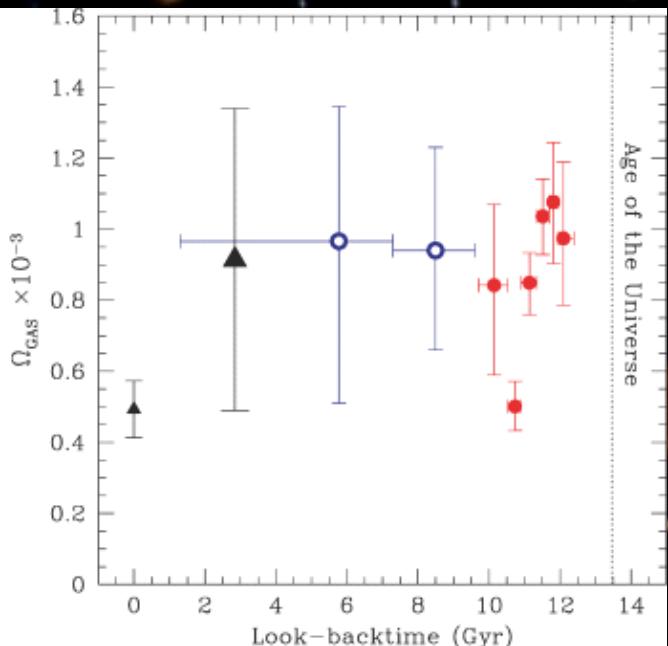
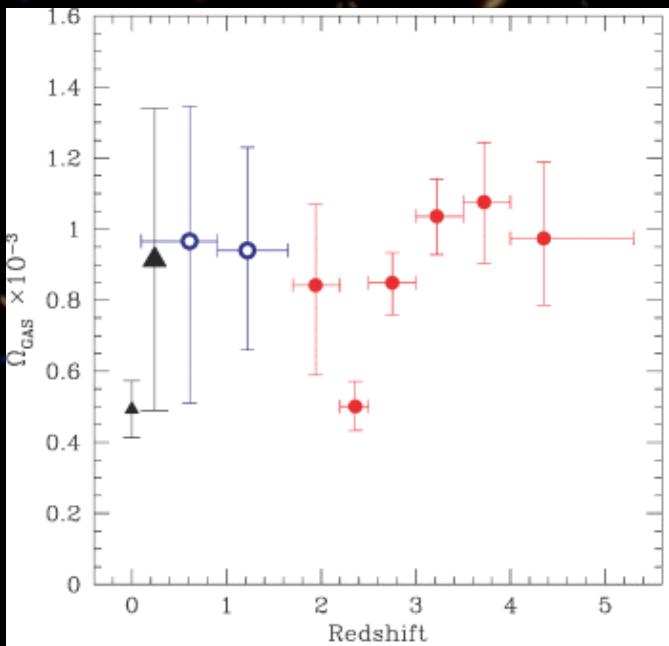
Stars



redshift

Gas

gas density

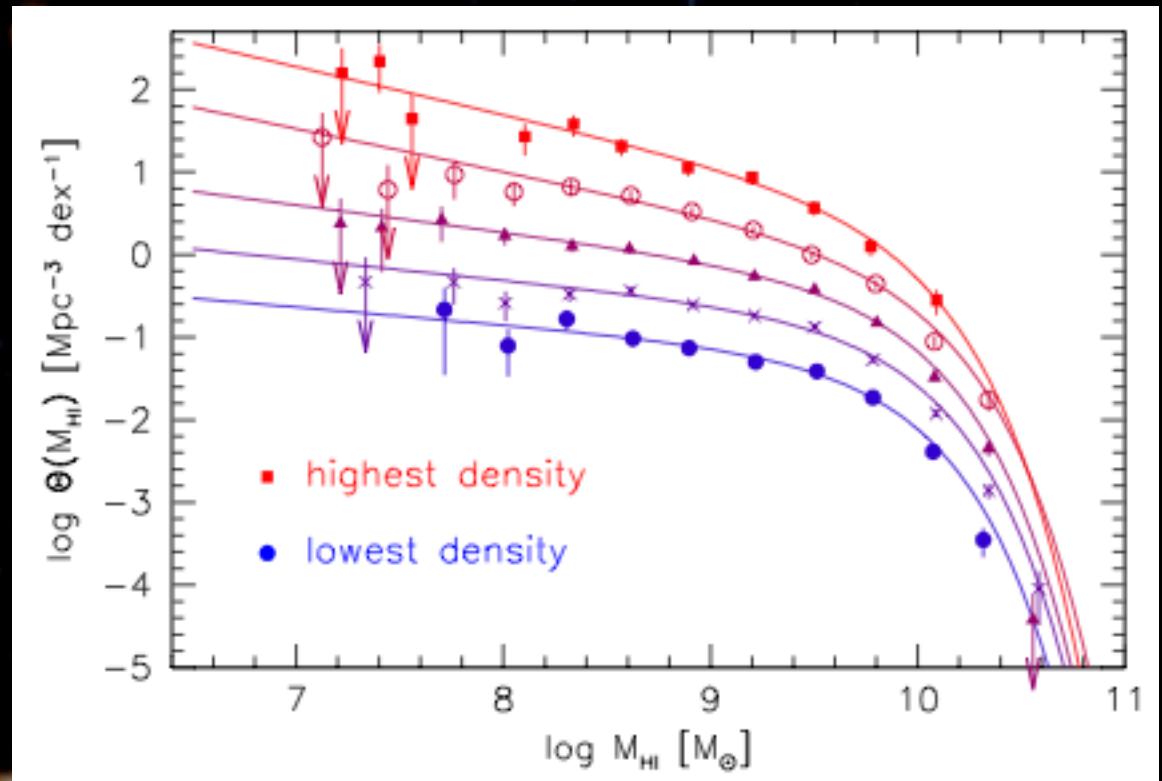


redshift

Puzzle:

star formation drops 10-fold
gas reservoir appears constant

Study the global HI content of the universe using the HI mass function



HIMF may vary with cosmic time and as a function of environment: study requires *blind, large volume* HI surveys: e.g. HIPASS, ALFALFA

Zwaan et al. 2005, MNRAS, 359, L30

THINGS

The HI Nearby Galaxy Survey



Data: Walter et al 2008

Milky Way HI map: Oort et al (1958)

Milky Way art: NASA/JPL, R. Hurt (SSC)

Deeper WSRT observations: Halogas project

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

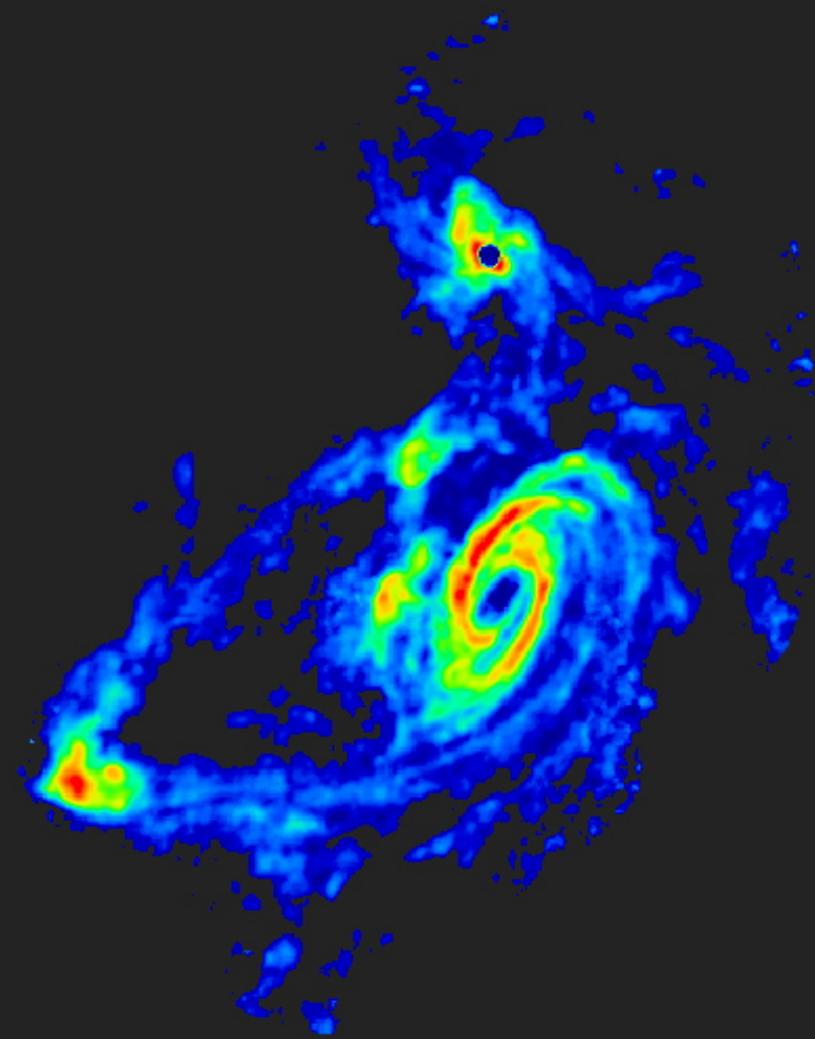


NGC 0672	NGC 0925	NGC 0949	NGC 1003	
NGC 2541	NGC 3198	NGC 4244	NGC 4258	NGC 4414
NGC 4565	NGC 5229	UGC 2082	UGC 4278	

ASTRON

M81/M82/NGC3077

VLA HI mosaic

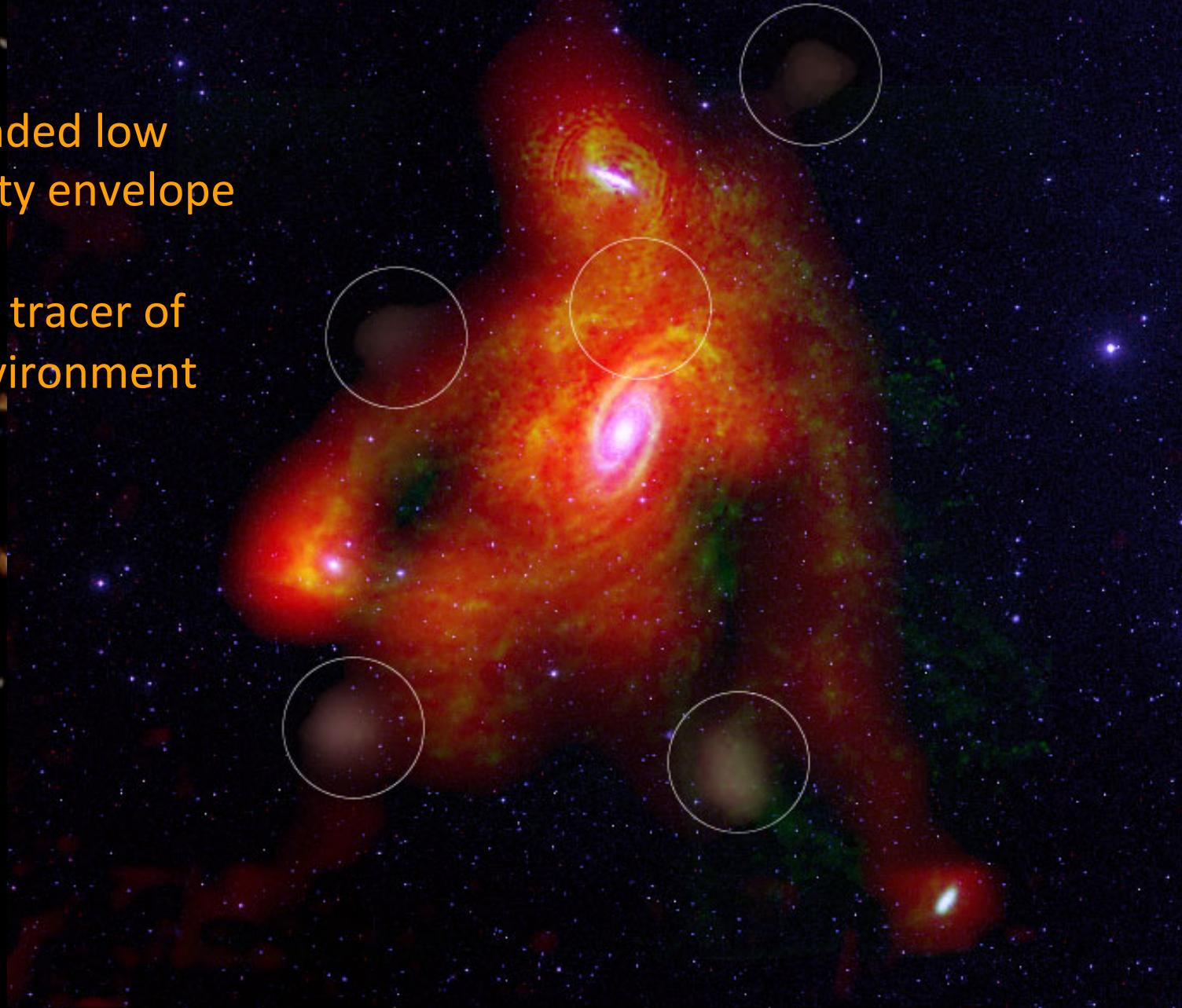


Yun et al. Nature 1994, 372, 530

M81/M82/N3077 VLA Mosaic + GBT survey

Reveals extended low column density envelope

H I is a superb tracer of the direct environment

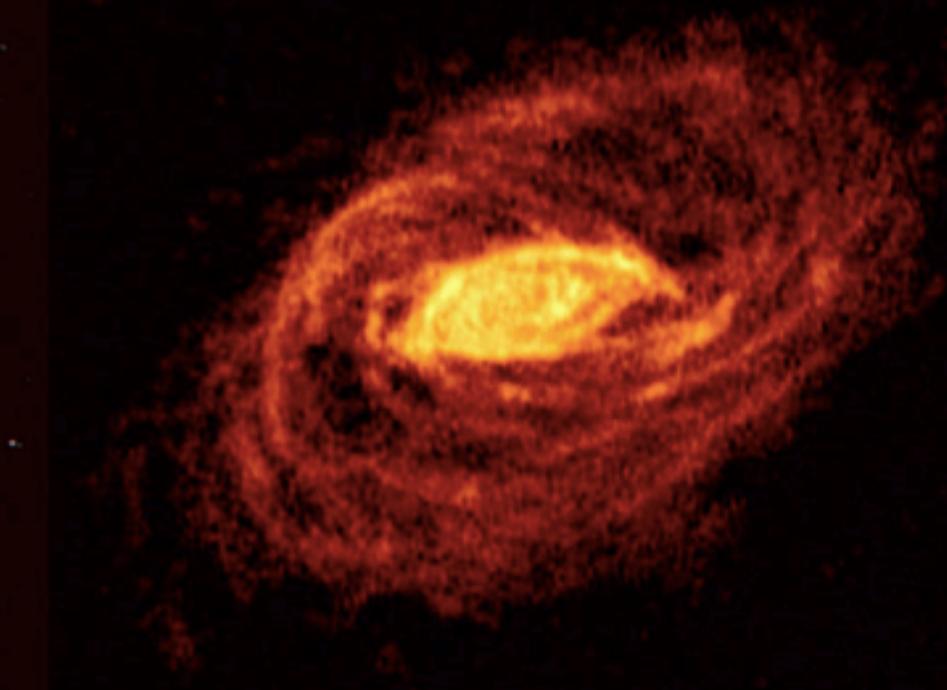


NGC 5033 warped outer disk with structure

Deep images also show structure in the outer disk



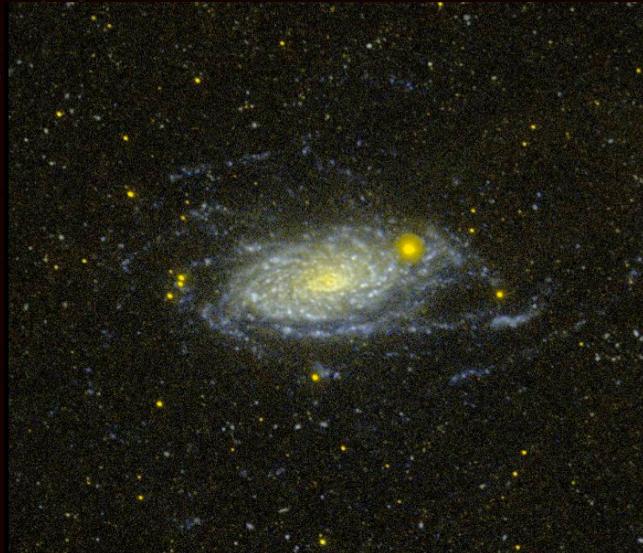
Deep optical image
(Martínez-Delgado et al.
2008, AJ 140, 962)



WSRT HI image
(Battaglia et al. 2005, A&A,447,49)

NGC 5033 warped outer disk with structure

UV images show star formation in the outer disk



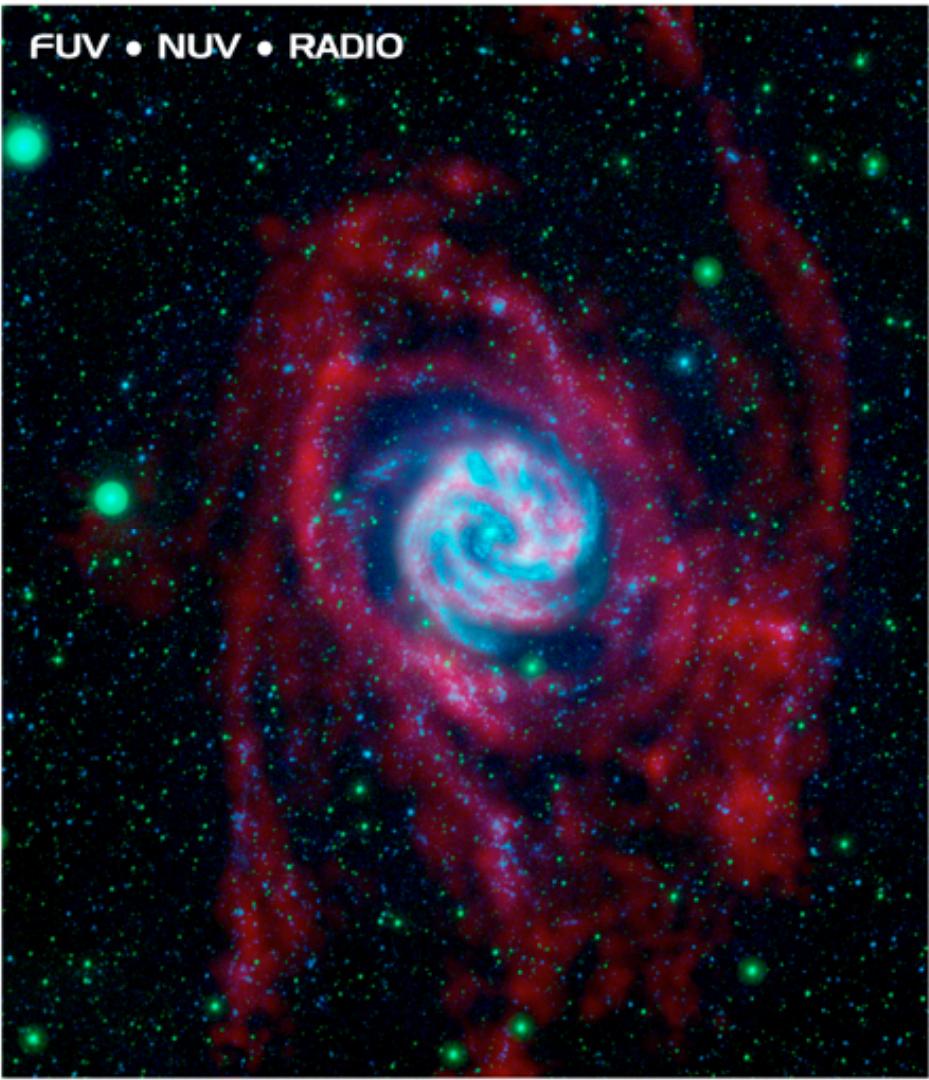
GALEX UV image
(Thilker et al. 2007, ApJS,173,538)



WSRT HI image
(Battaglia et al. 2005, A&A,447,49)

M83 its outer structure in HI and UV

FUV • NUV • RADIO



FUV • NUV



Courtesy Dave Thilker and NASA/JPL-Caltech/VLA/MPIA
See also: Bigiel et al. 2010, ApJ, 720, L31

HI traditionally a tracer of kinematics:
dark and luminous matter distribution
prominent tidal interactions

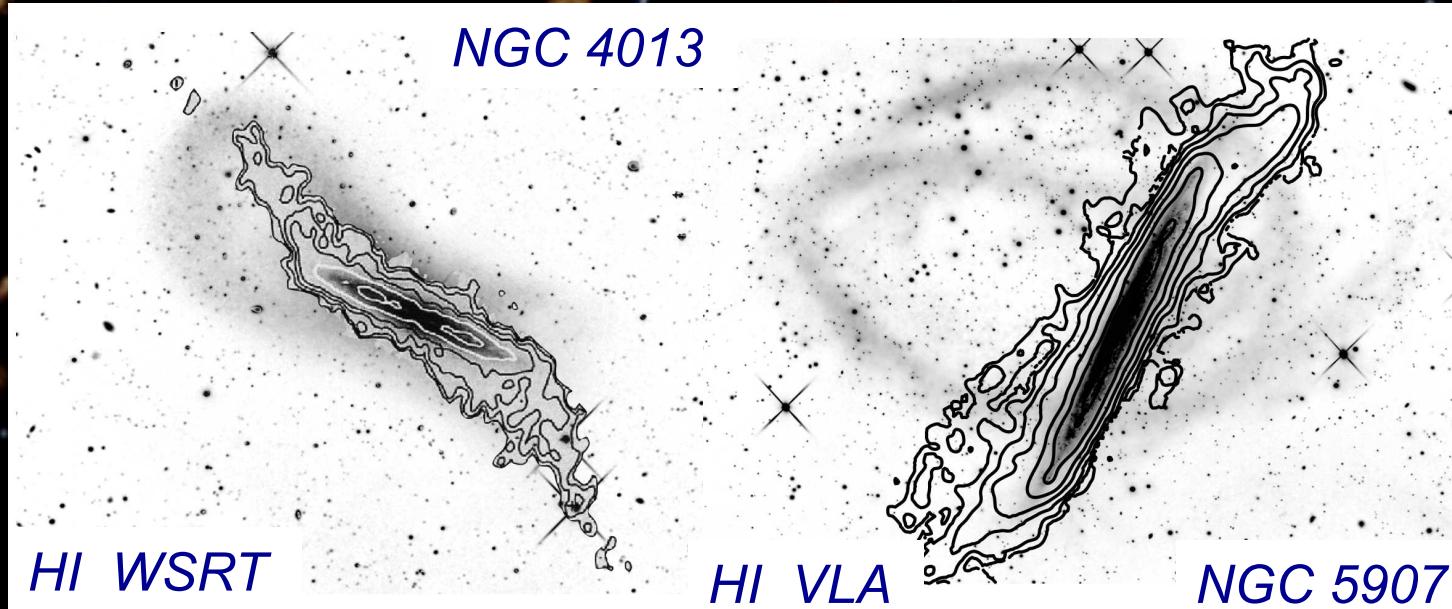
HI can tell us more:

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

Examples:

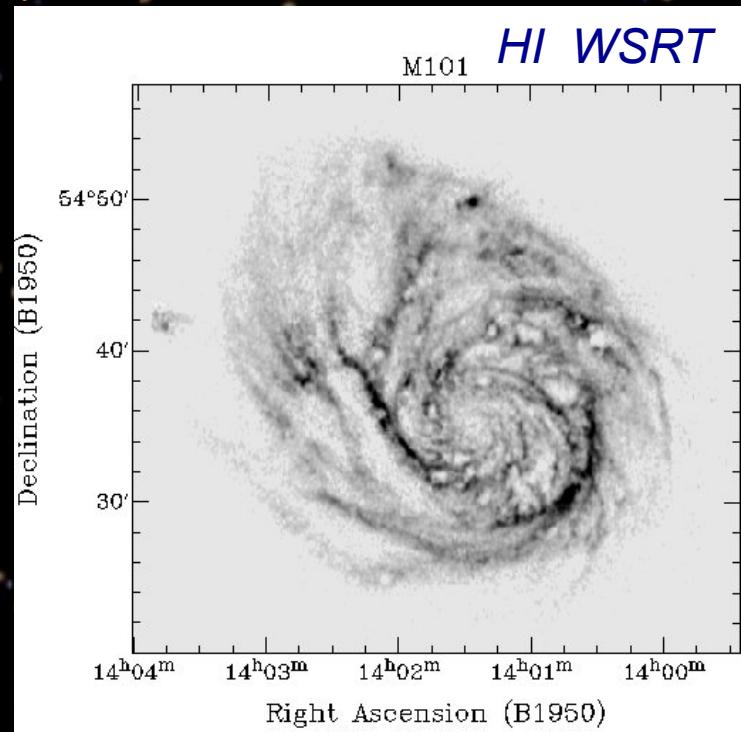
asymmetries in structure and kinematics
extraplanar gas
gas with anomalous velocities
ram pressure stripped gas

WARPS

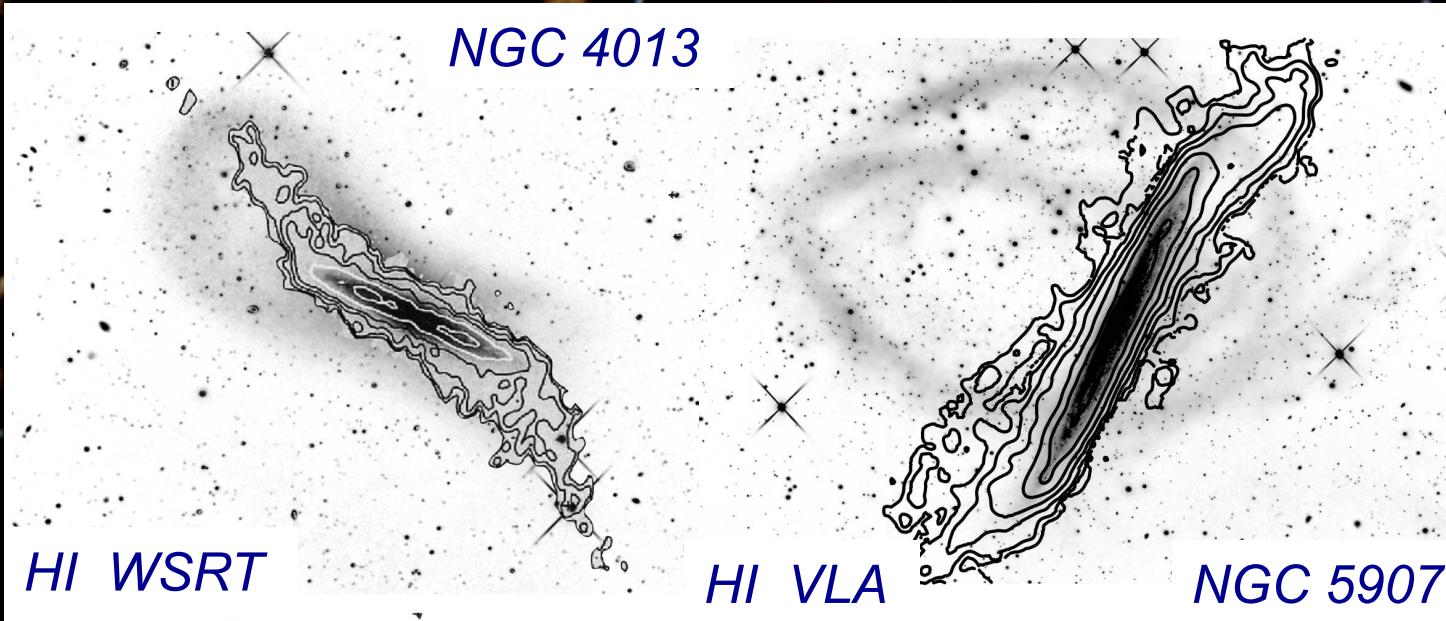


Martinez-Delgado et al. (2008/09)

LOPSIDEDNESS

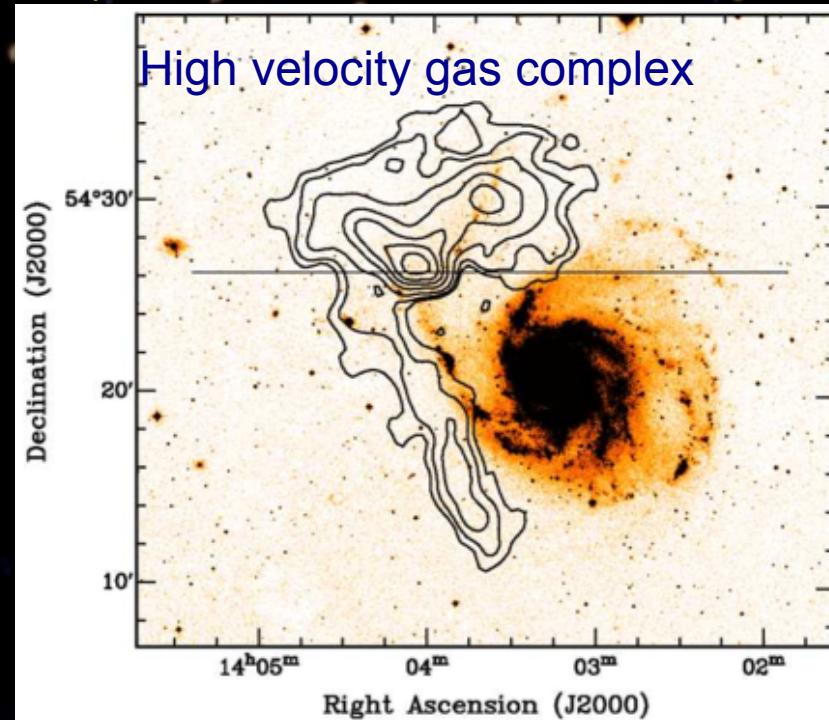
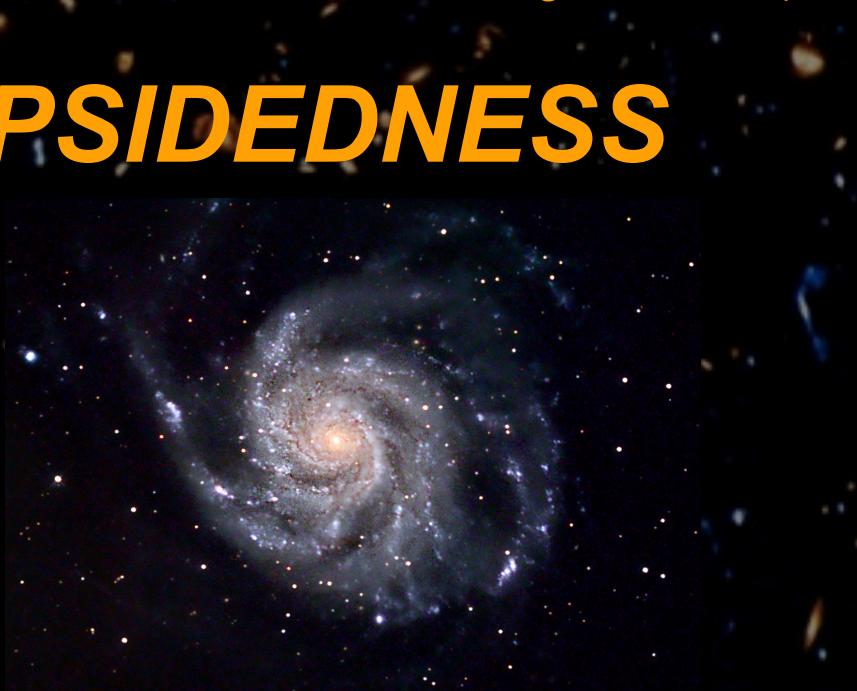


WARPS

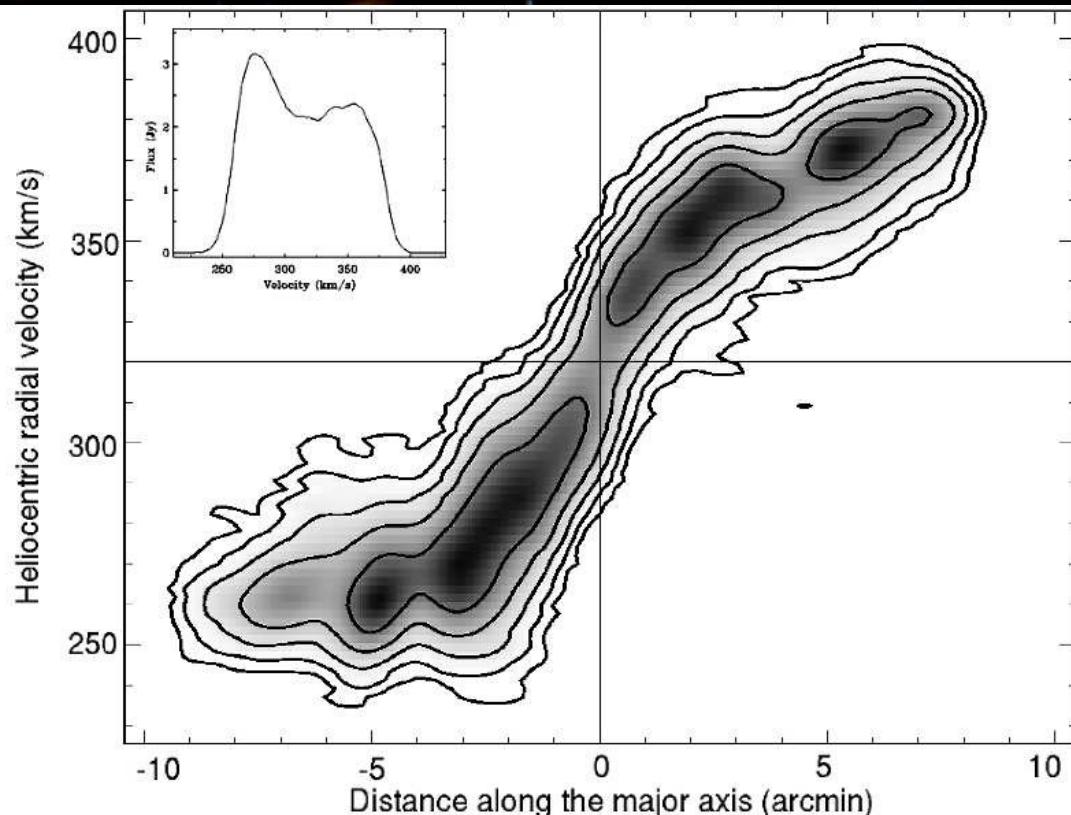
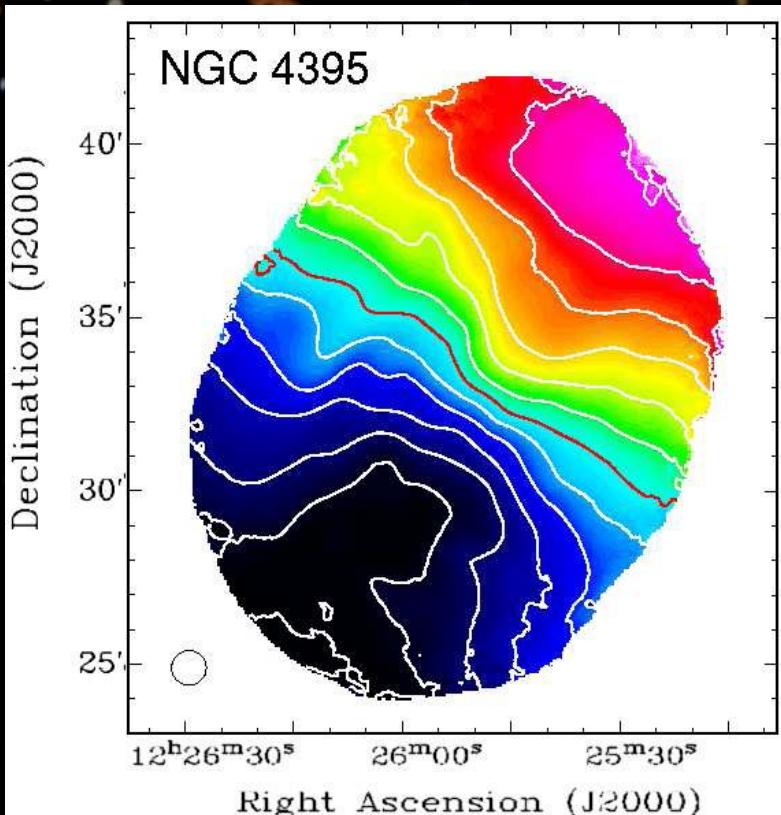


Martinez-Delgado et al. (2008/09)

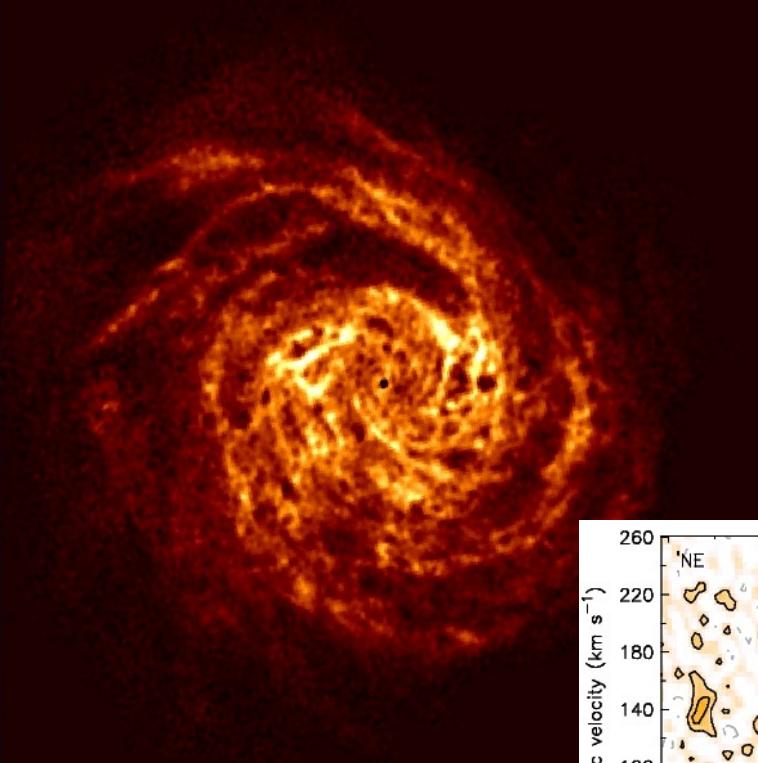
LOPSIDEDNESS



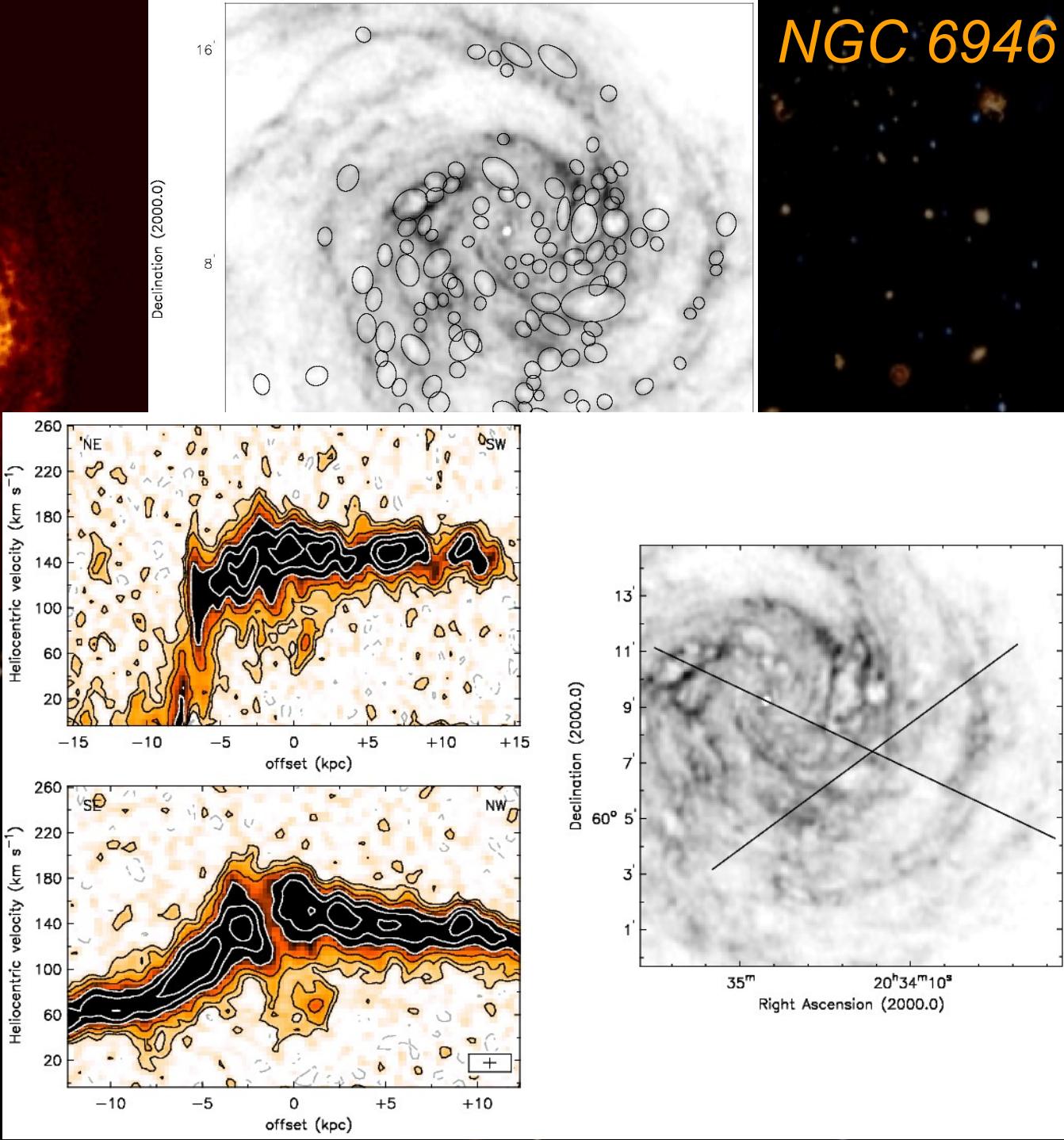
KINEMATIC LOPSIDEDNESS

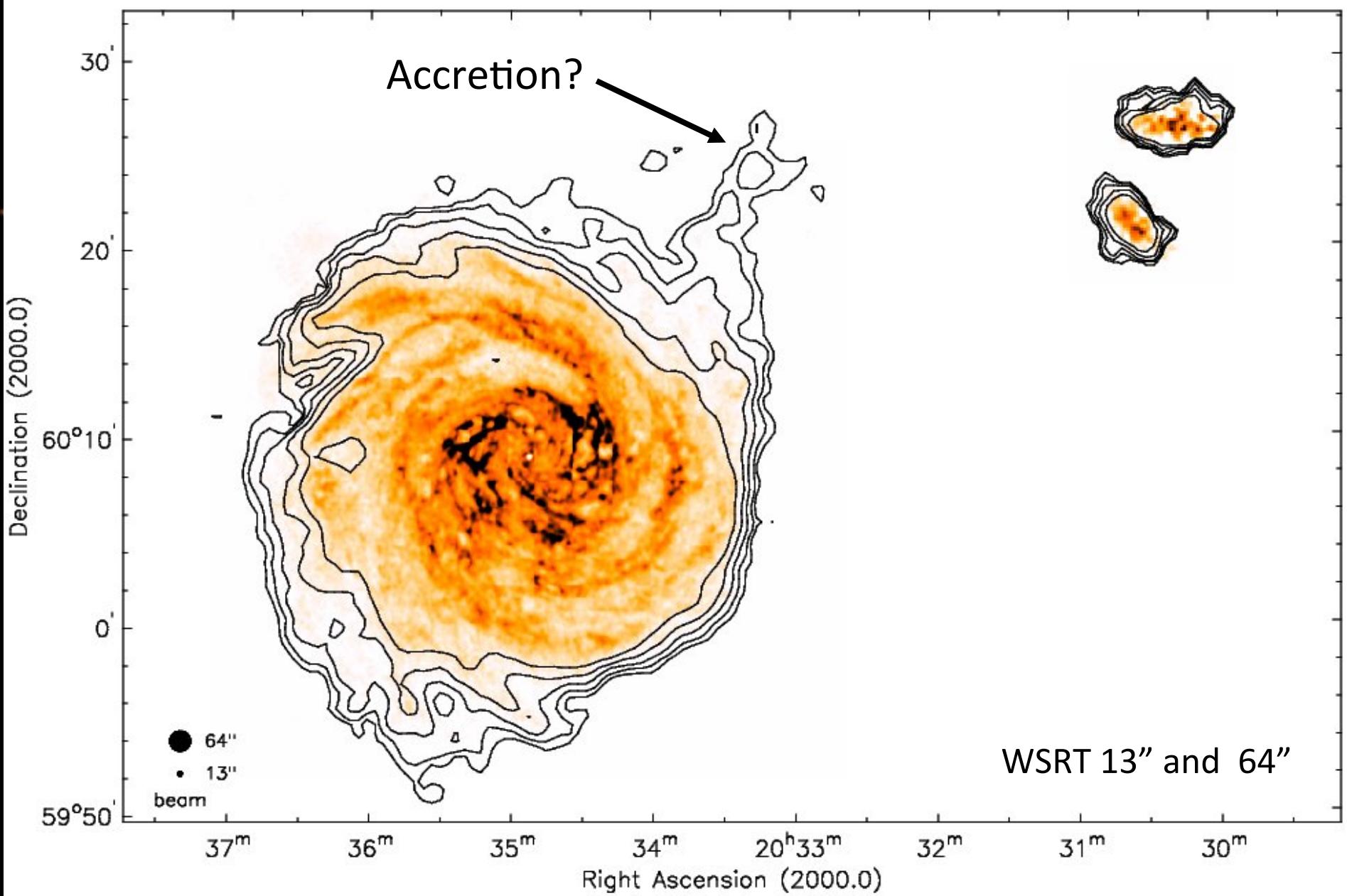


NGC 6946



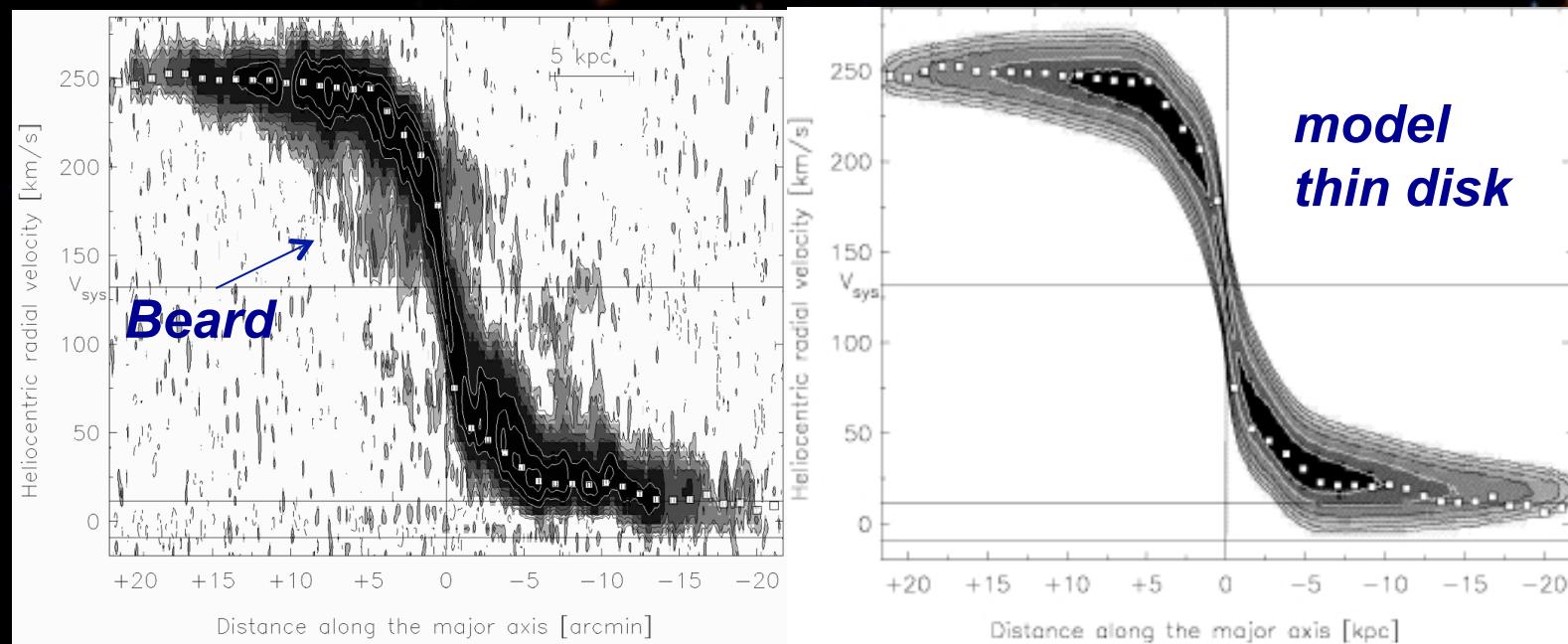
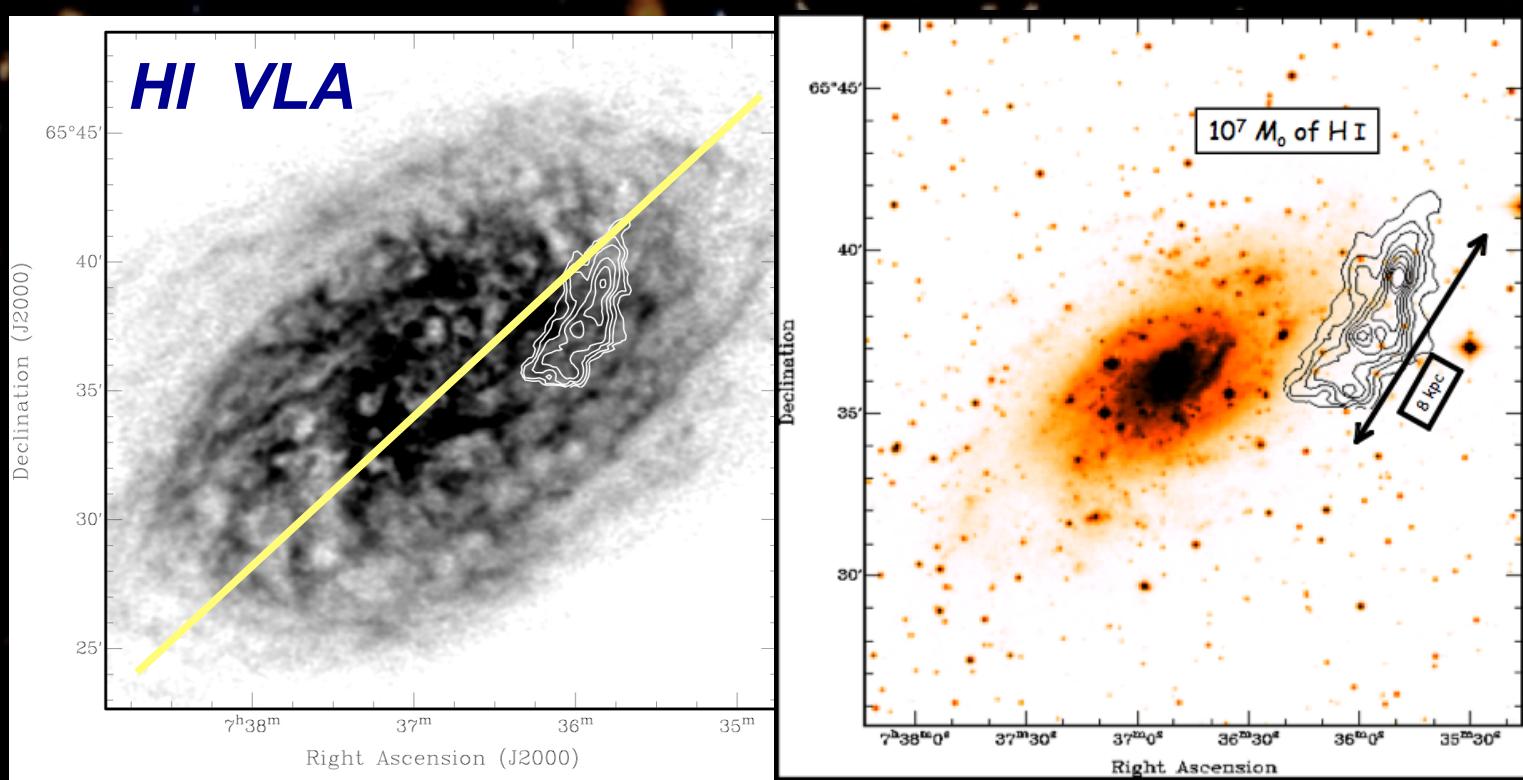
"HIGH VELOCITY CLOUDS"
*(total amount:
~ $3 \times 10^8 M_{\odot}$)*



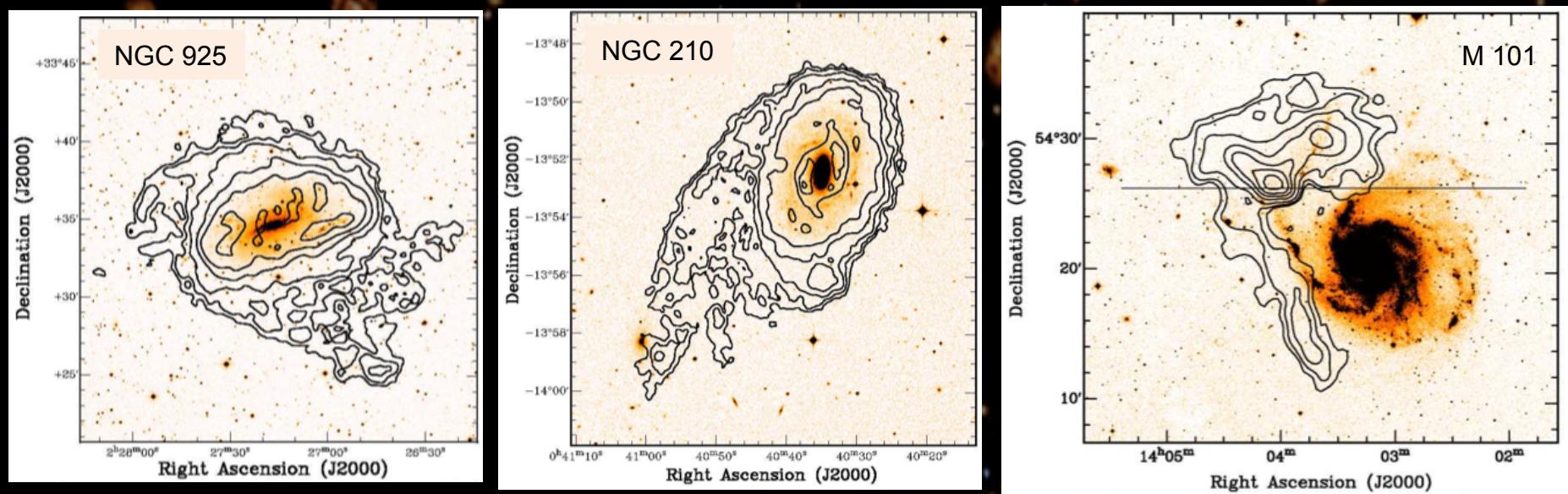
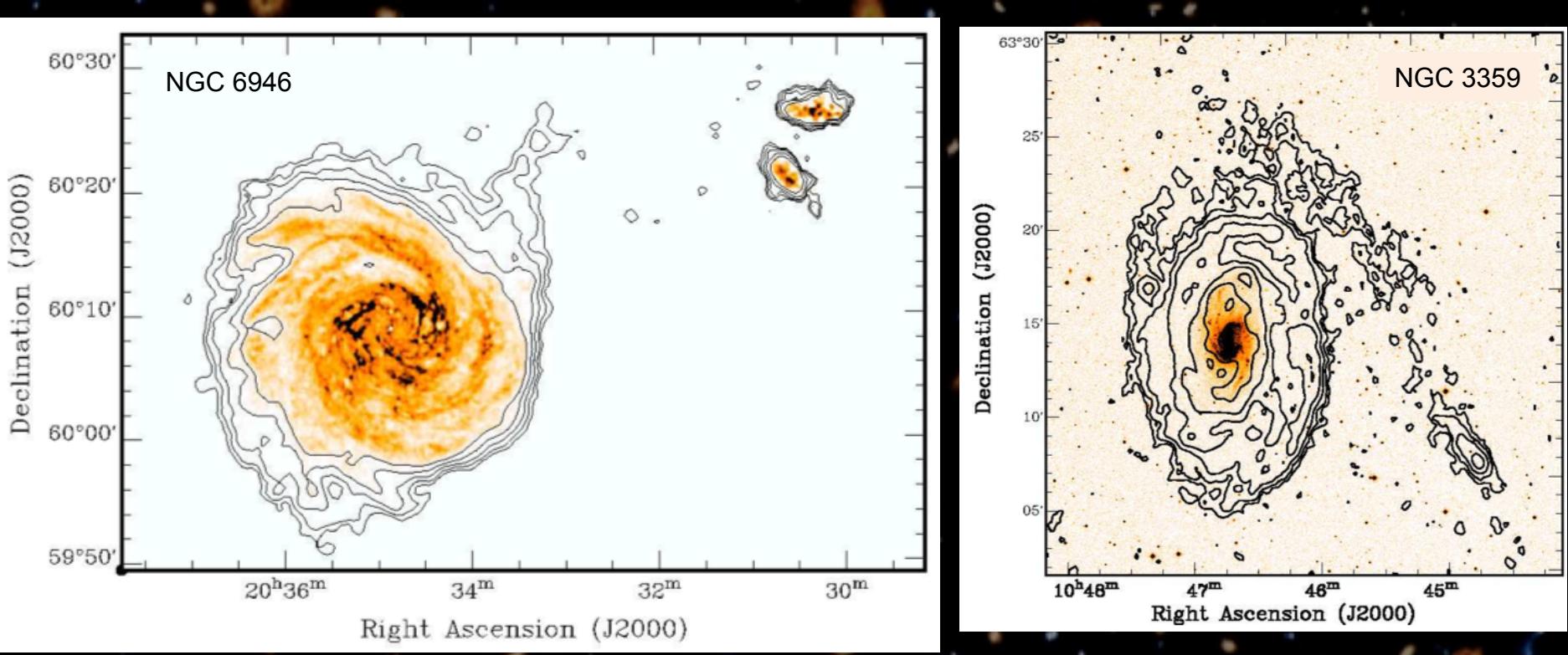


NGC 2403

Anomalous
gas
 $3 \times 10^8 M_\odot$

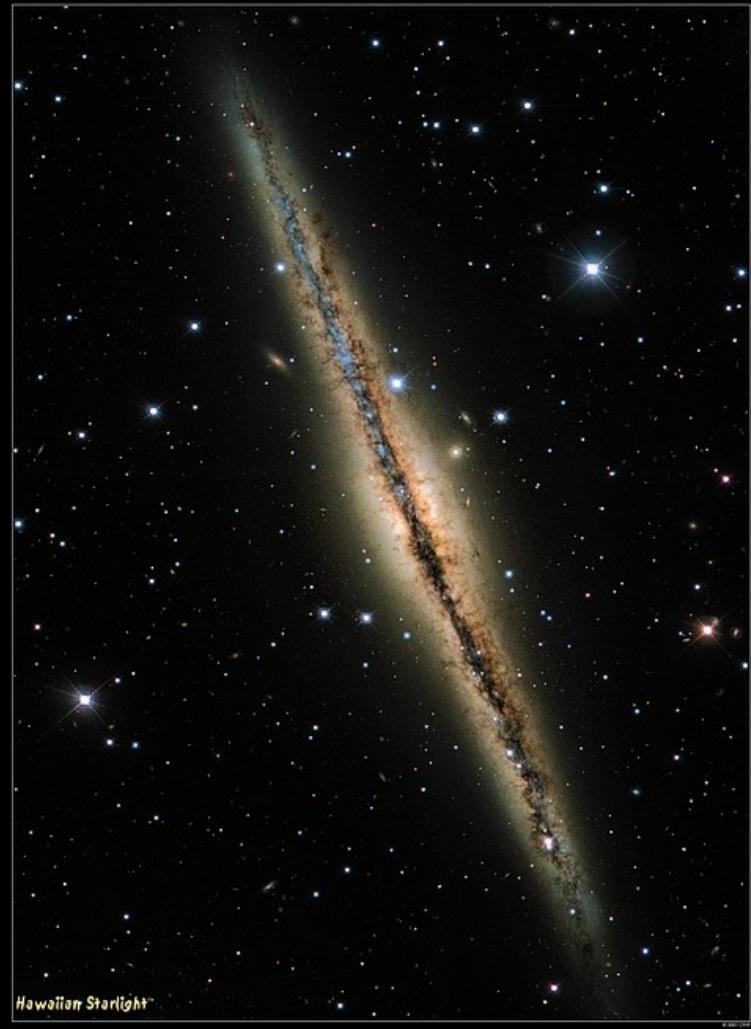


Fraternali,
Oosterloo
et al. 2001
ApJ 562, 47



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

optical



Hawaiian Starlight™

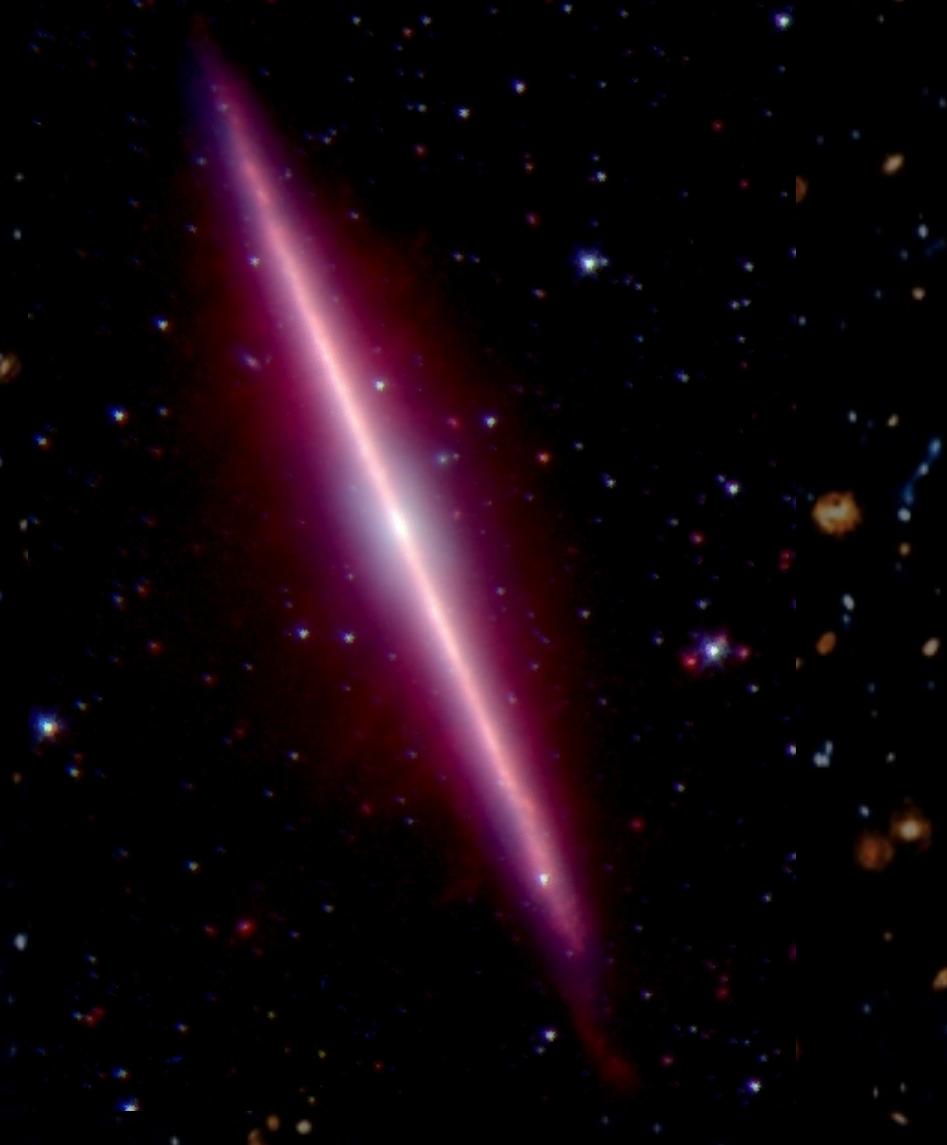
Edge-On Spiral
Galaxy NGC 891
From Mount Keck - Hawaii

NGC 891 is a spiral galaxy, seen edge-on, about 30 million light years away from our galaxy. It is extremely flat, and about twice as long as it is wide. The galaxy has a very prominent central bulge, and a very faint outer disk. The outer disk is composed of many small, irregularly shaped stellar systems. Many spiral galaxies can be seen in the background, most of them thousands of light years away.

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CFHT
CANADA-FRANCE-HAWAII TELESCOPE
www.cfht.hawaii.edu

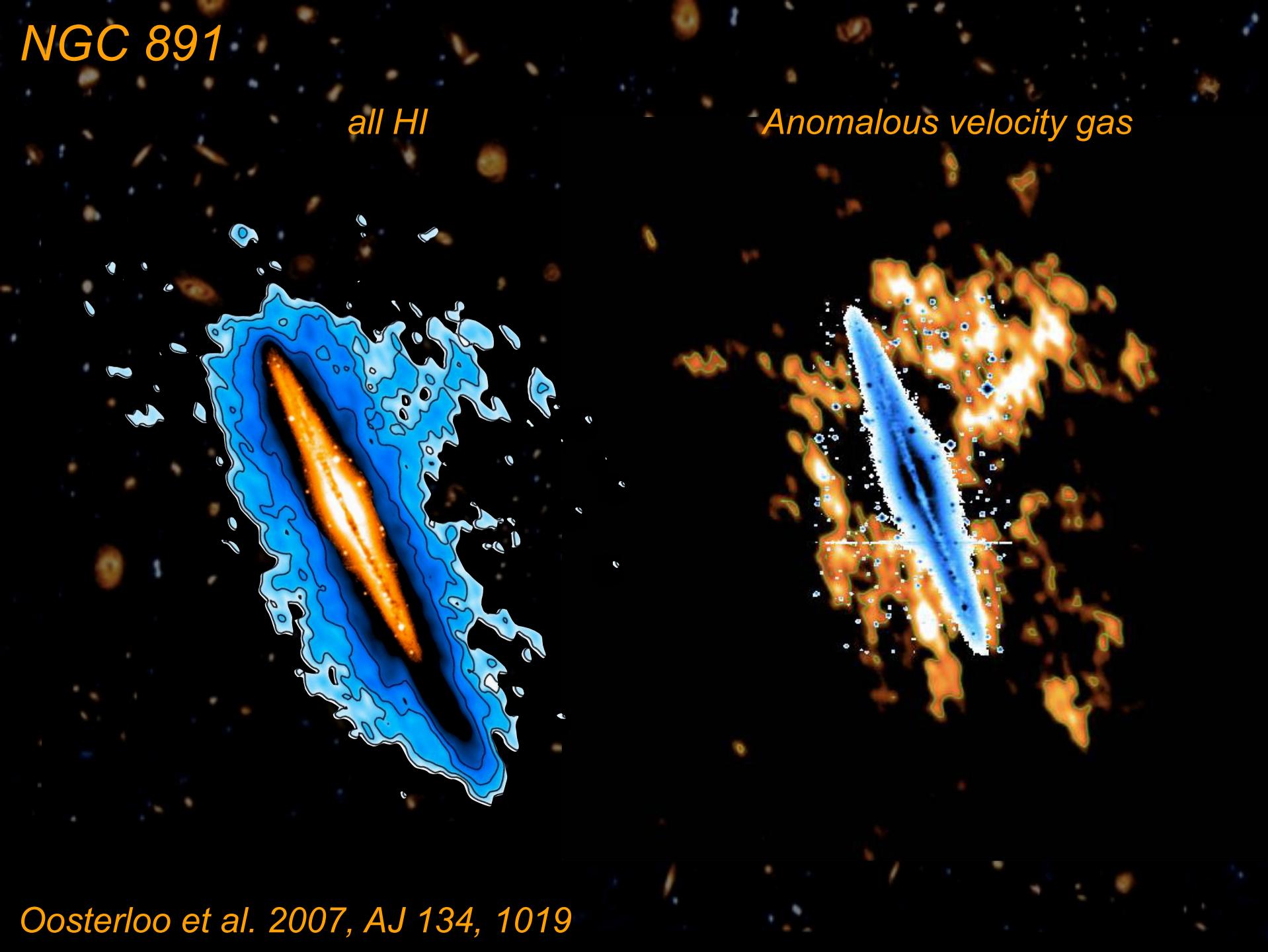
near infrared



NGC 891

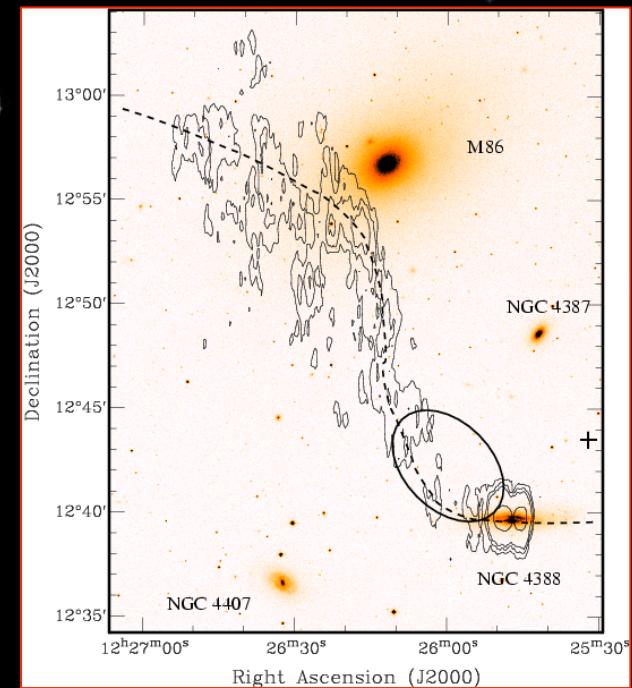
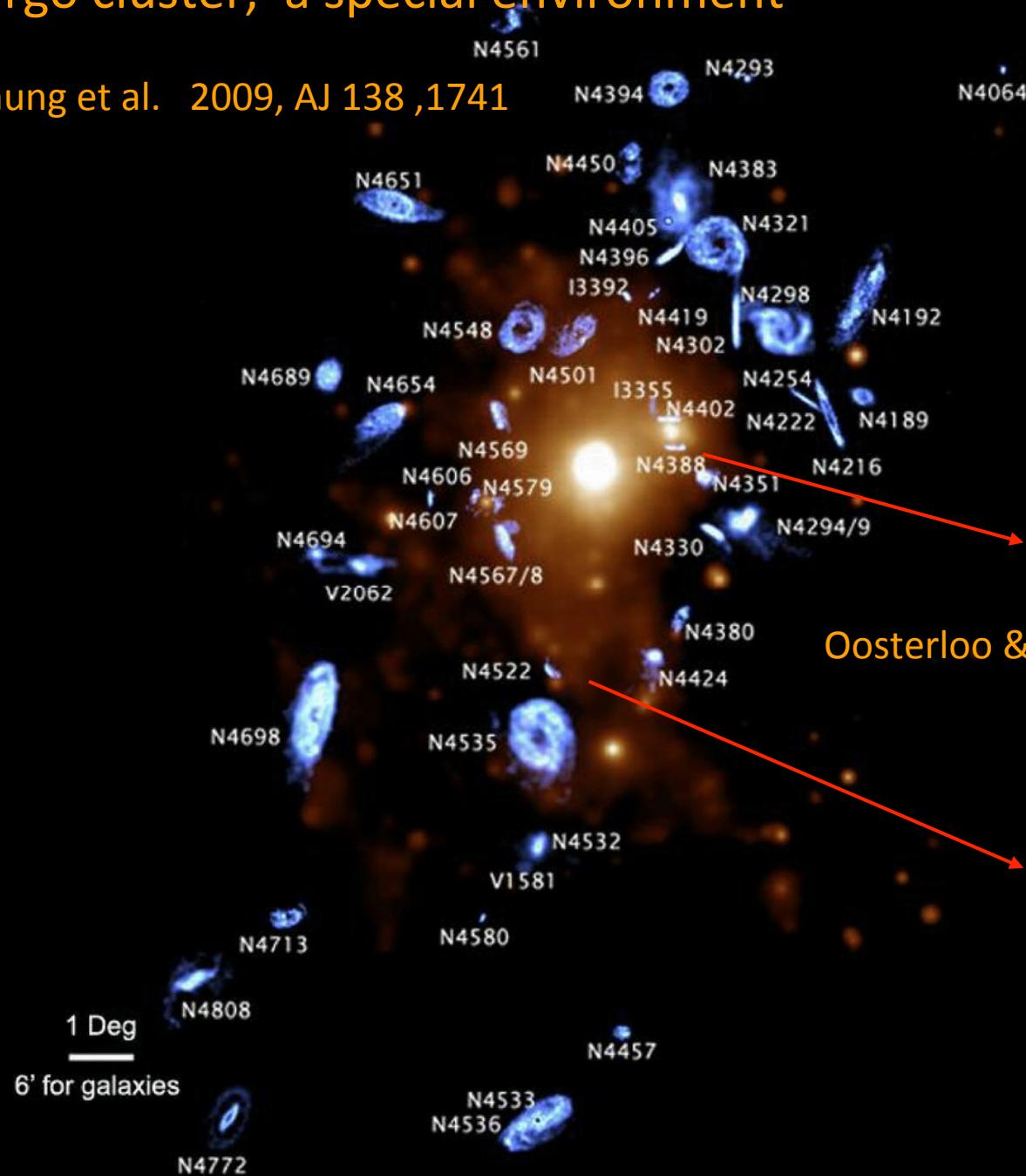
all HI

Anomalous velocity gas

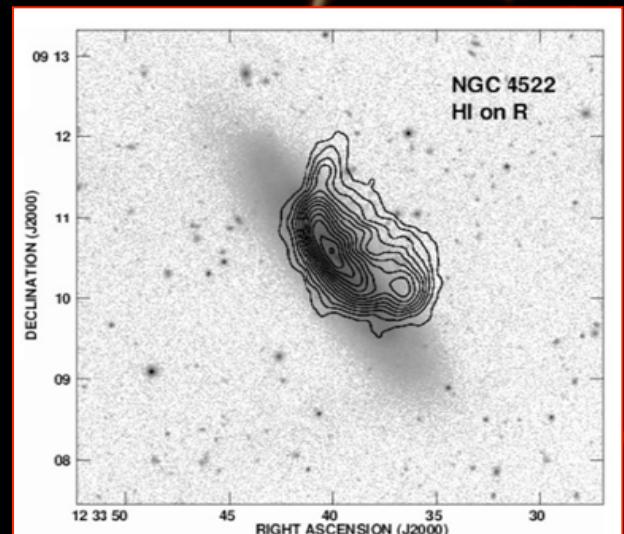


Virgo cluster, a special environment

Chung et al. 2009, AJ 138, 1741



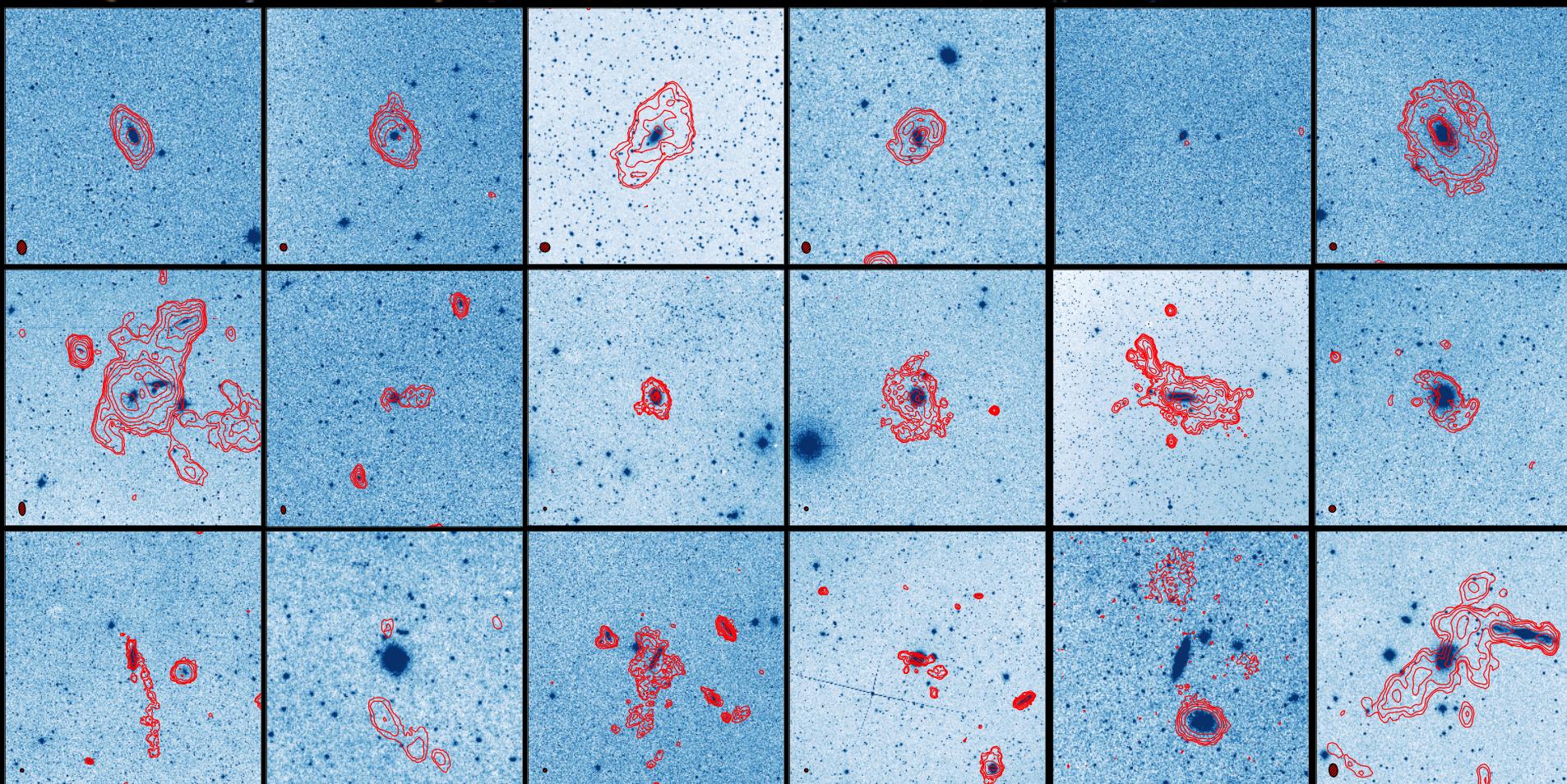
Oosterloo & van Gorkom 2005 A&A, 437, L19



Kenney et al. 2004, AJ 127, 3361

Atlas3D: HI in early type galaxies

(Cappellari et al. 2011, MNRAS, 416, 1680)



Emerging picture:

We can use the HI to diagnose

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

but requires ***resolved*** imaging with
adequate ***sensitivity*** of ***many***
galaxies in different ***environments***

ASKAP HI science:



- Widefield ASKAP L-Band Legacy All-Sky Blind Survey (WALLABY)
- The First Large Absorption Survey in HI (FLASH)
- Deep Investigations of Neutral Gas Origins (DINGO)

MeerKAT HI science:

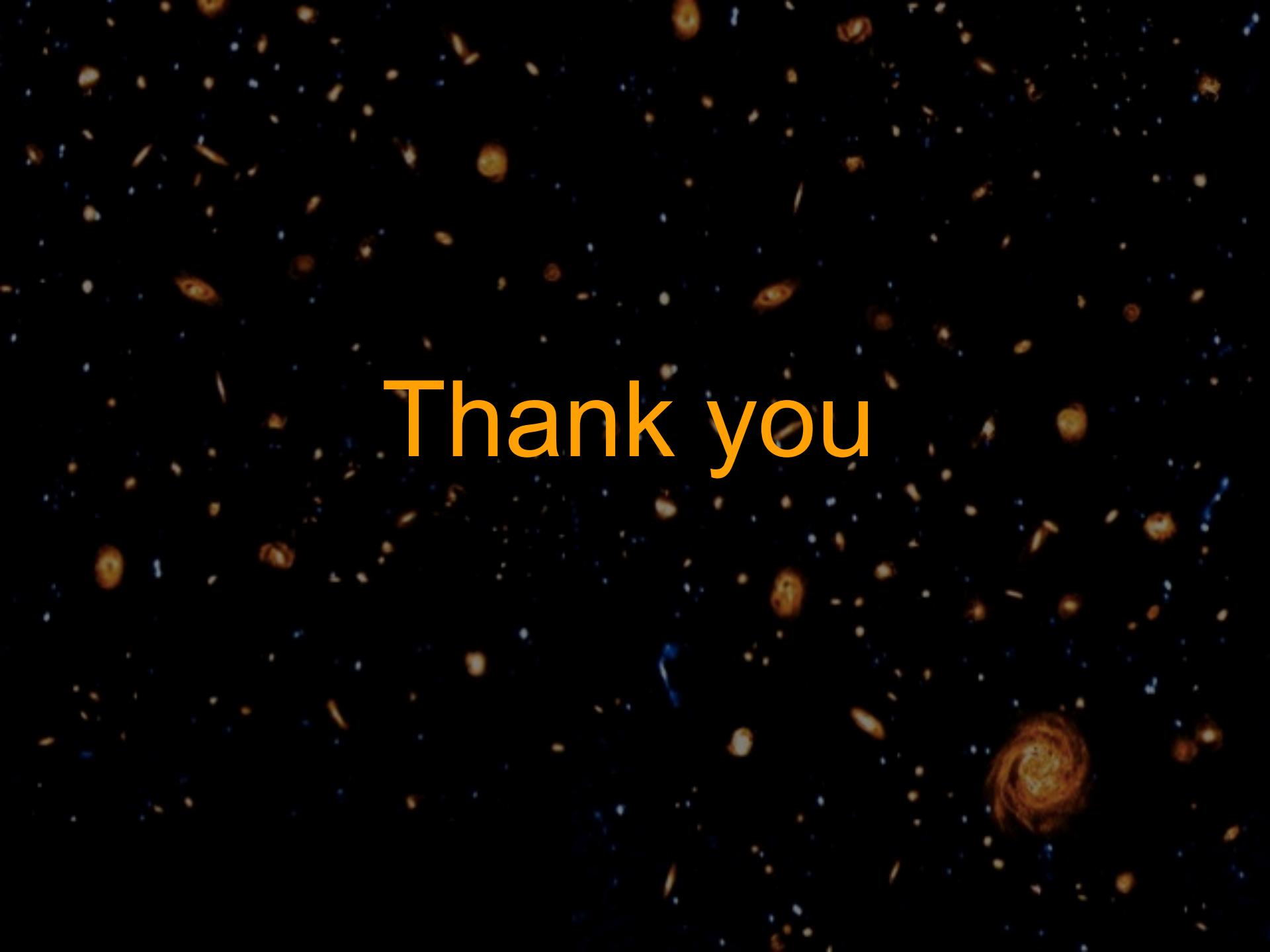


- LADUMA: ultra Deep HI survey (two proposals combined) 5000 hr on a single field (high priority)
- MHONGOOSE: MeerKAT HI observations of Nearby Galactic Objects: Observing Southern Emitters 6000 hr for 30 objects (medium priority)
- A MeerKAT HI Survey of Fornax 2450 hr (medium priority)
- MeerKAT HI Absorption Survey Line Survey 4000 hr (medium priority)

APERTIF HI science:



- Westerbork Northern Sky HI Survey (WNSHS)
- A Medium-Deep Survey (few 100 deg²)
- A Deep APERTIF HI Survey (DASH)
- Blind HI Absorption Line Survey (NN)

A dense field of galaxies against a dark background.

Thank you