

HI in galaxies

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The Radio Universe @ Ger's (wave)-length, 4-7 November 2013

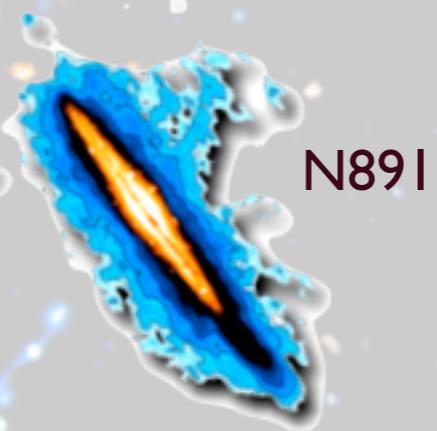
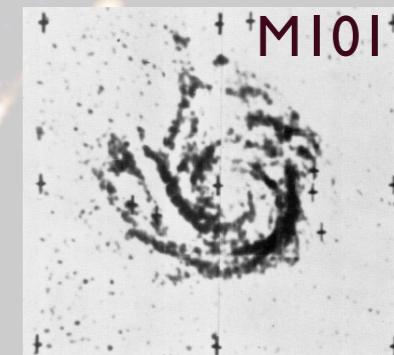
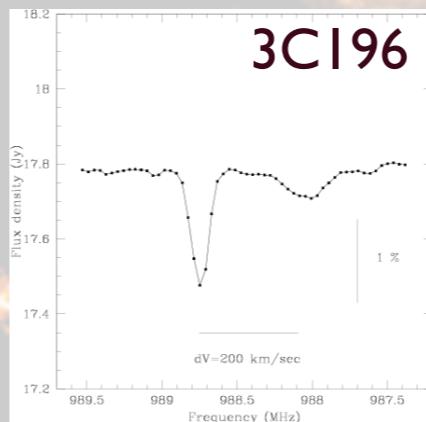


Ger's HI work

A bit of history

Recent results

Future outlook



N891



APERTIF



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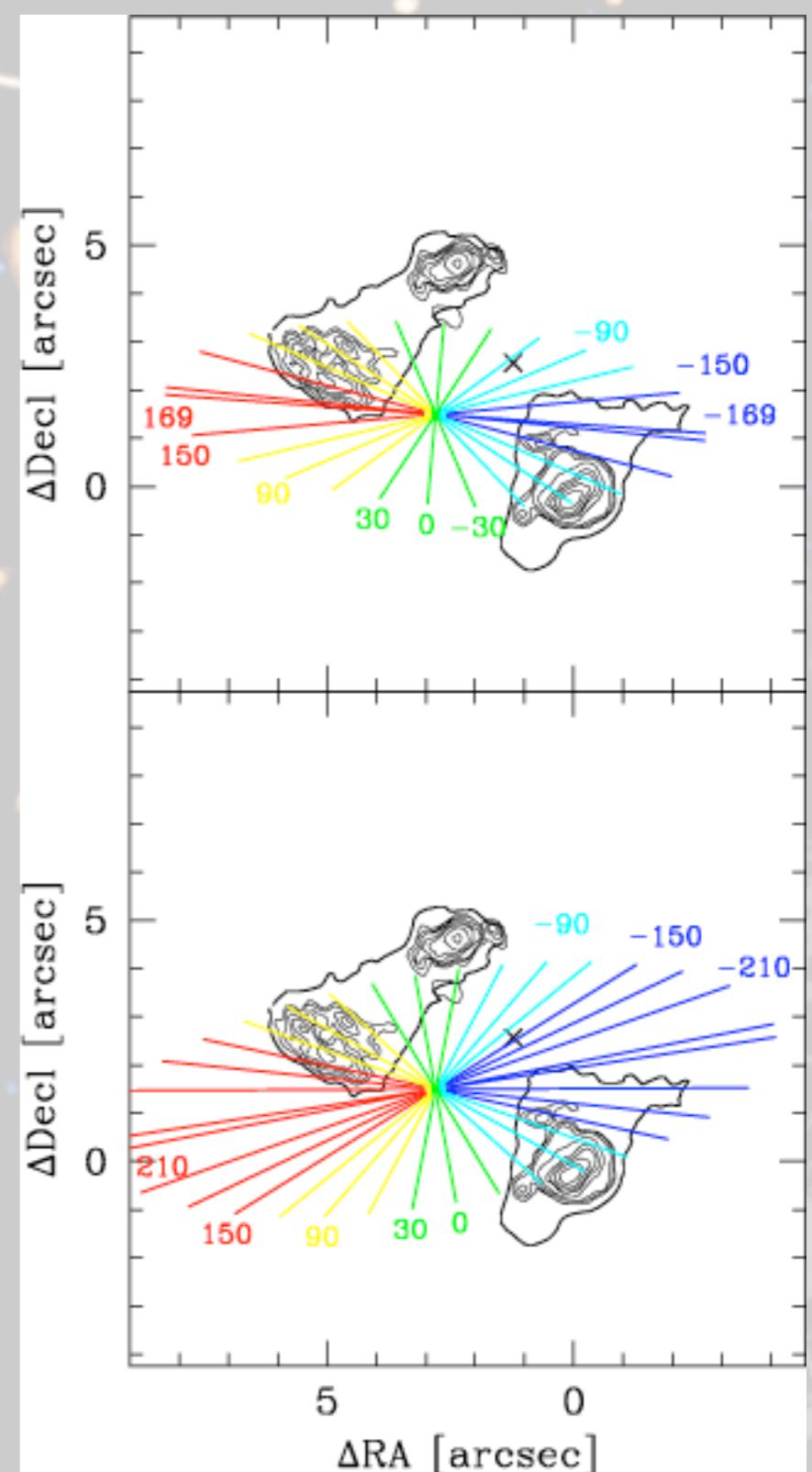
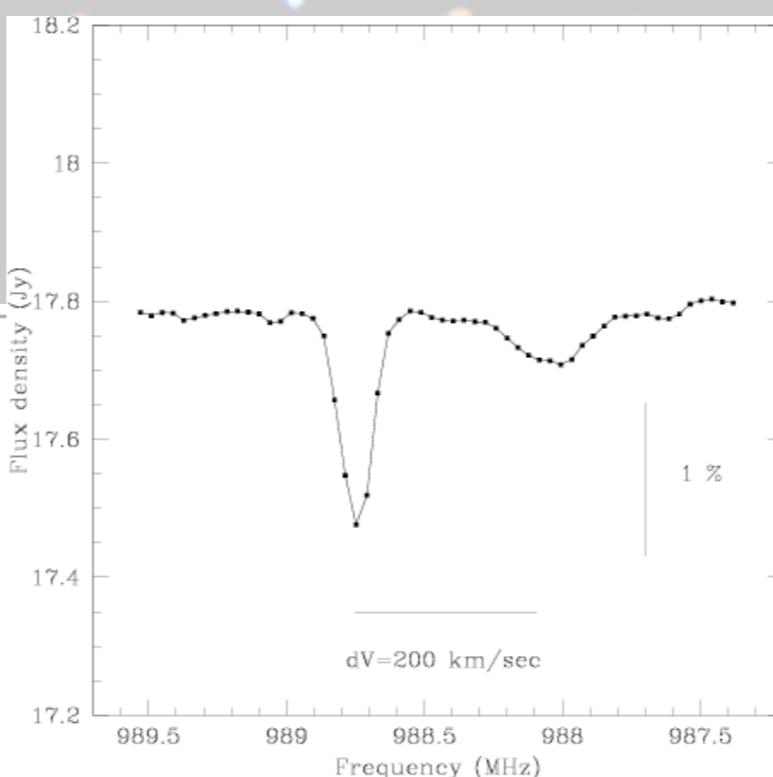
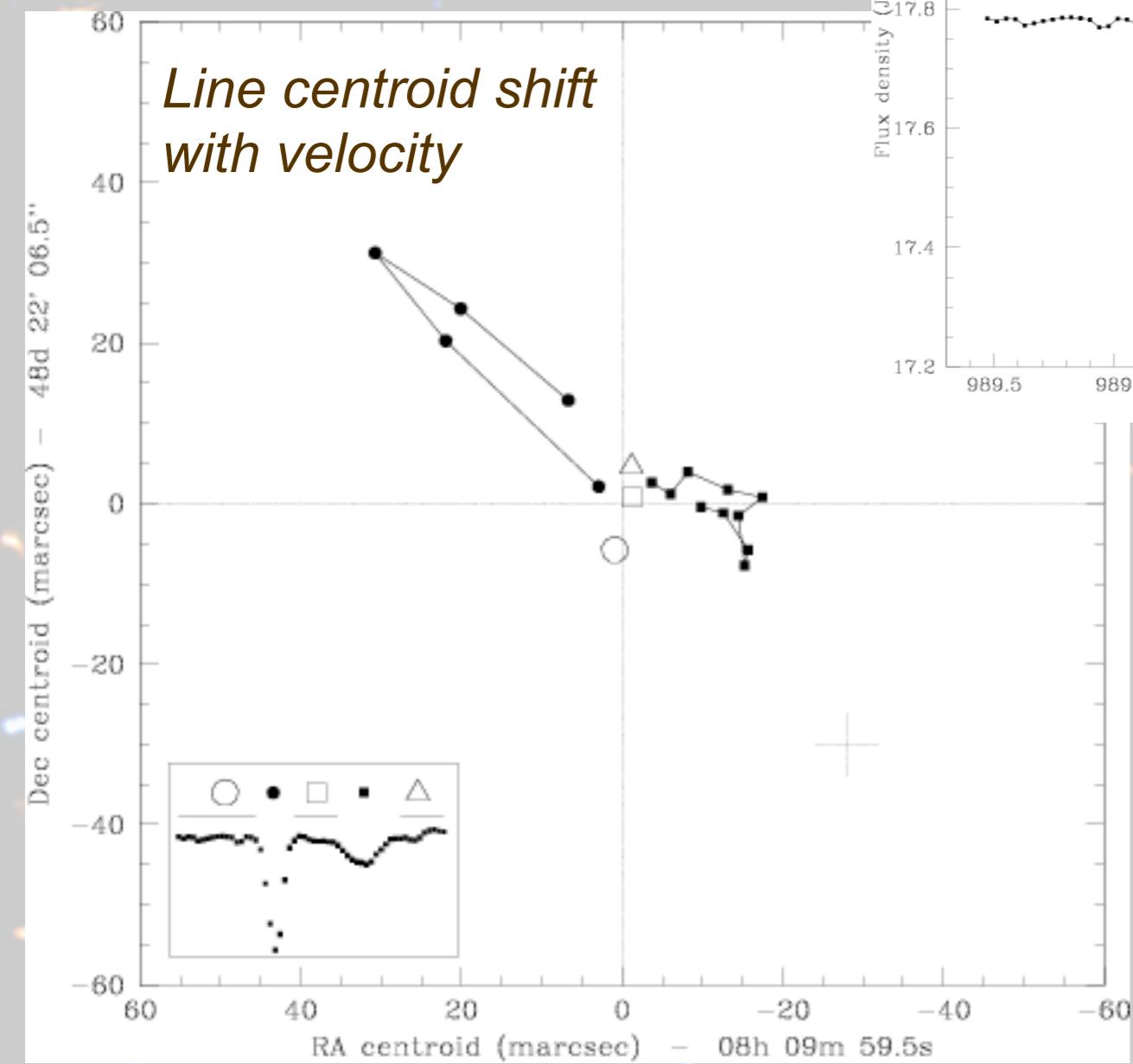
Ger's HI work

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- Briggs, F.H., de Bruyn,A.G., Vermeulen, R.C. 2001., A&A 373, 113-121.
Cold gas kinematics in an L spiral Galaxy at z = 0.437: The nature of Damped Lyman-alpha absorbers.*
- Chengalur, J.N., de Bruyn,A.G., Narasimha, D. 1999. *HI and OH absorption at z=0.89.* A&A 343, L79-L82.
- Rottgering, H., de Bruyn, G., Pentericci, L. 1999. *HI and high redshift radio galaxies. The Most Distant Radio Galaxies* 113.
- Chengalur, J.N., de Bruyn,A.G., Narasimha, D. 1999. *HI and OH Absorption towards 1830-211. Highly Redshifted Radio Lines* 156, 228.
- Moore, C.B., de Bruyn,A.G., et al. 1998. *VLBI Observations of Redshifted HI Absorption Systems at Z = 0.2-1.* BAAS 30, 1249.
- Carilli, C.L., Lane,W., de Bruyn,A.G., Braun, R., Miley, G.K. 1996. *Redshifted HI 21 cm Line Observations of Damped Ly alpha Absorption Systems.* AJ 112, 1317.
- Carilli, C.L., Lane,W., de Bruyn,A.G., Braun, R., Miley, G.K. 1996. *Redshift HI 21 CM Line Observations of Damped Ly alpha Absorption Systems.* AJ 111, 1830.
- de Bruyn,A.G., O'Dea, C.P., Baum, S.A. 1996. *WSRT detection of HI absorption in the z=3.4 damped Ly alpha system in PKS 0201+113.* A&A 305, 450.
- Chengalur, J.N., de Bruyn,A.G., Braun, R., Carilli, C.L. 1996. *A radio search for high redshift HI absorption..* BAAS 28, 1201.
- Chengalur, J.N., de Bruyn,A.G., Braun, R., Carilli, C. 1996. *A Radio Search for High Redshift HI Absorption. Cold Gas at High Redshift* 206, 279.
- Carilli, C., Lane,W., de Bruyn,A.G., Braun, R., Miley, G.K. 1996. *HI 21 cm Line Observations of Damped Ly alpha Systems. Cold Gas at High Redshift* 206, 267.
- de Bruyn,A.G. 1996. *HI at High Redshift. Cold Gas at High Redshift* 206, 171.
- Lane,W., Carilli, C.L., de Bruyn,A.G., Braun, R., Miley, G.K. 1995. *A Search for Redshifted HI 21cm Absorption by Damped Ly-alpha Absorption Systems.* BAAS 27, 1412.
- Baum, S.A., de Bruyn,A.G., O'Dea, C.P. 1993. *WSRT Detections of HI Absorption in the z=3.4 Damped Lyman alpha System towards PKS 0201+113.* BAAS 25, 1401.
- Wieringa, M.H., de Bruyn,A.G., Katgert, P. 1992. *A Westerbork search for high redshift HI.* A&A 256, 331-342.
- Wieringa, M., de Bruyn, G., Katgert, P. 1991. *A deep Westerbork search for high redshift HI.* Physical Cosmology 516.
- Sijbring, D., de Bruyn,A.G., Jaffe,W.J., Sancisi, R. 1989. *HI in the Low Velocity System of NGC1275.* ESO Conference and Workshop Proceedings 32, 107.
- de Bruyn,A.G.,Wieringa, M.H., Katgert, P., Sancisi, R. 1988. *A WSRT Search for HI at Z=3.35.* Large Scale Structures of the Universe 130, 211.
- Jaffe,W.J., de Bruyn,A.G., Sijbring, D. 1988. *HI absorption detection in the Perseus cooling flow.* NATO ASIC Proc.229: Cooling Flows in Clusters and Galaxies 145-147.



'Imaging' the HI absorption

3C196 @ $z=0.437$



Briggs, de Bruyn & Vermeulen 2001, A&A 373, 113



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Single dish HI surveys



<http://hipass.anu.edu.au>

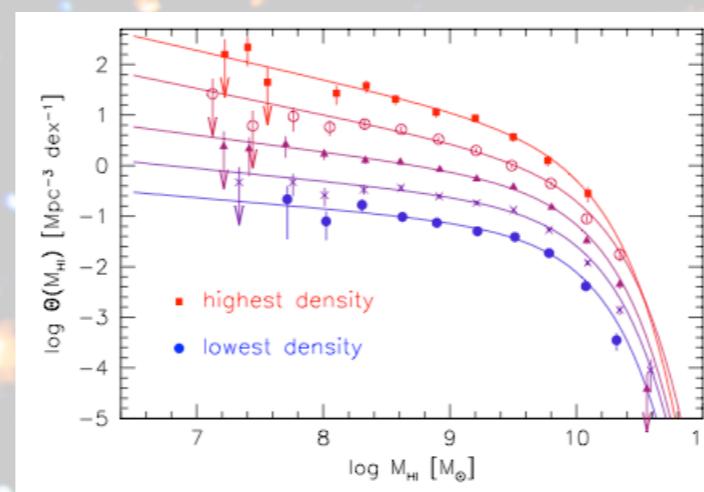
Meyer et al. 2004 MNRAS 350, 1195
Zwaan et al. 2004 MNRAS 350, 1210



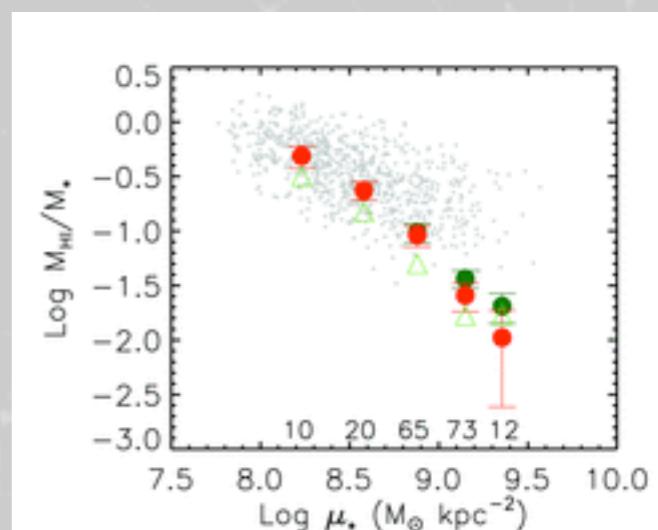
<http://egg.astro.cornell.edu>

Giovanelli et al. 2005 AJ 130, 2598
Haynes et al. 2011 AJ 142, 170

- HI source catalogues
- HI Mass Functions
- Scaling relations
- Spin-off projects: GASS, COLDGASS, BlueDISK, ...



HIPASSS HIMF



GASS: $M(\text{HI})/M^*$ vs. μ^*



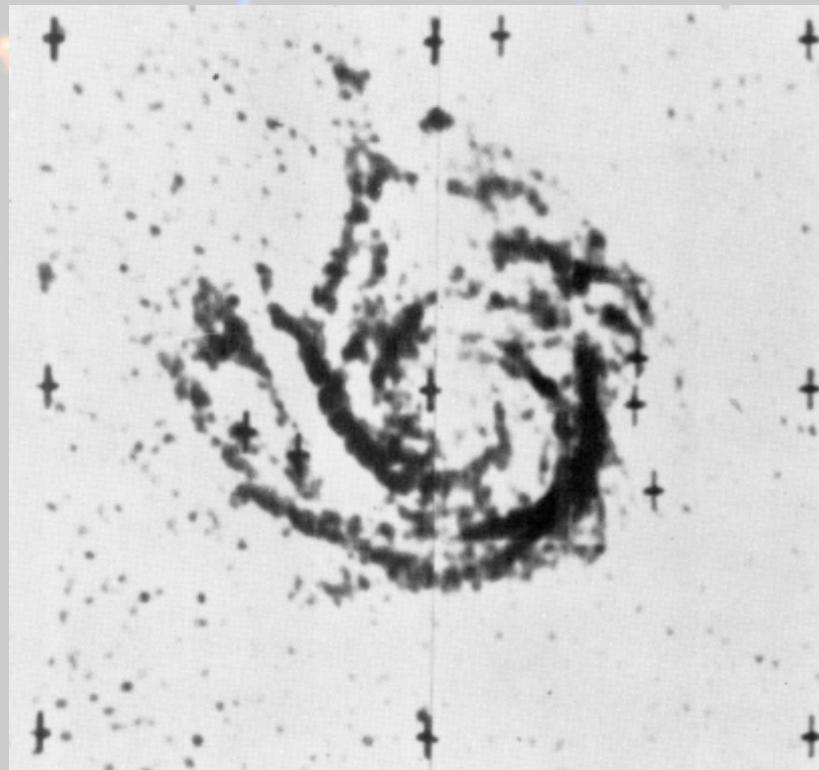
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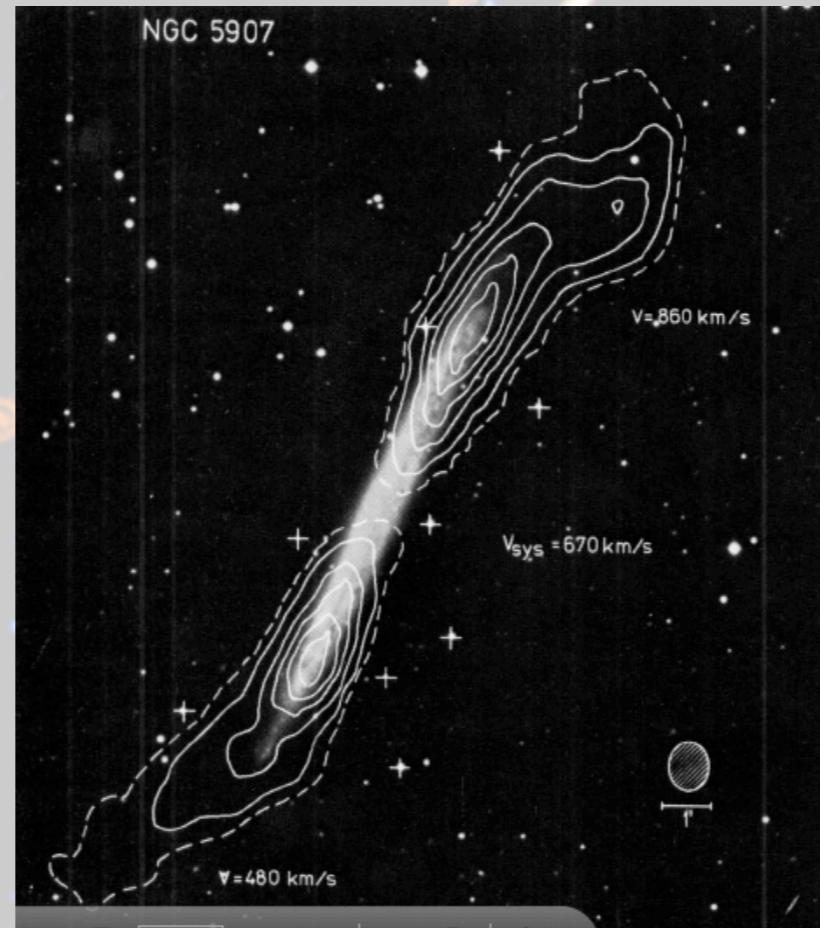
Early Westerbork work

HI shows spiral structure



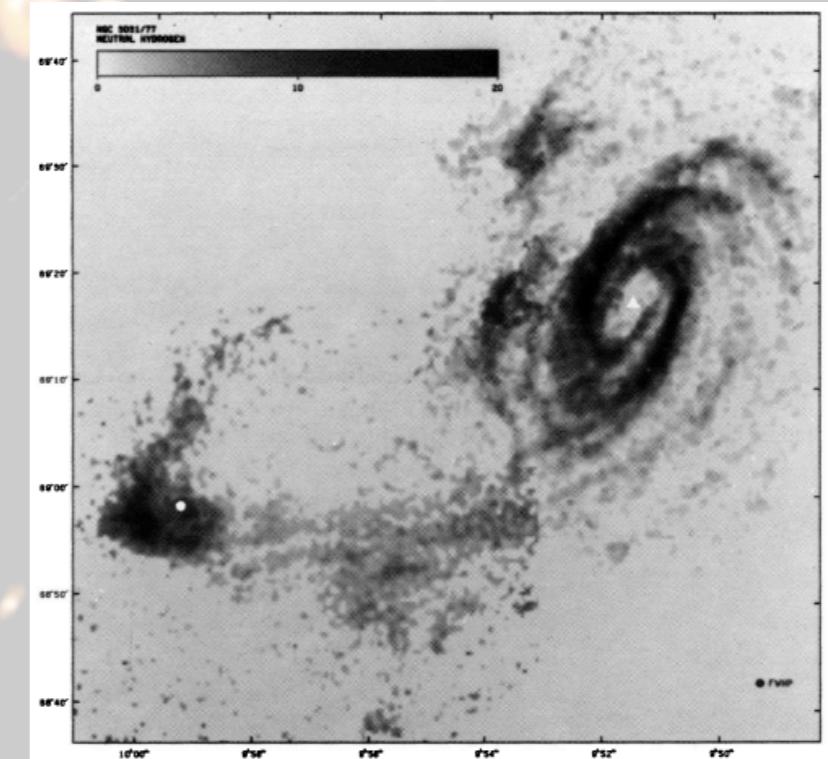
Allen et al. A&A 29, 447,
1973: HI in M 101

HI disks are warped



Sancisi A&A 53, 159,
1976: HI in NGC5907

HI traces interactions

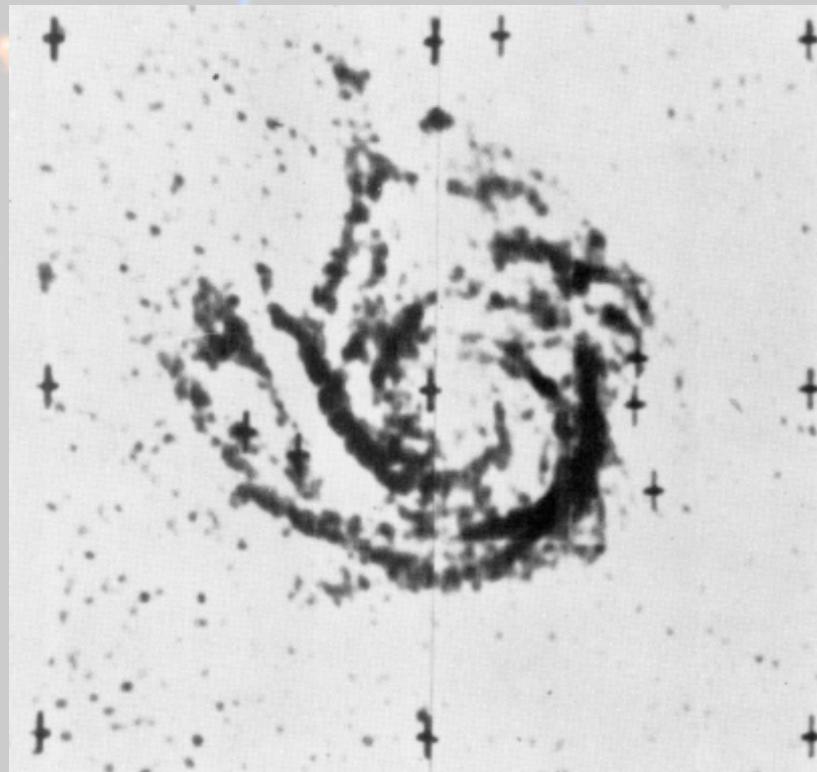


van der Hulst A&A 75, 97,
1979: HI in M81/NGC3077



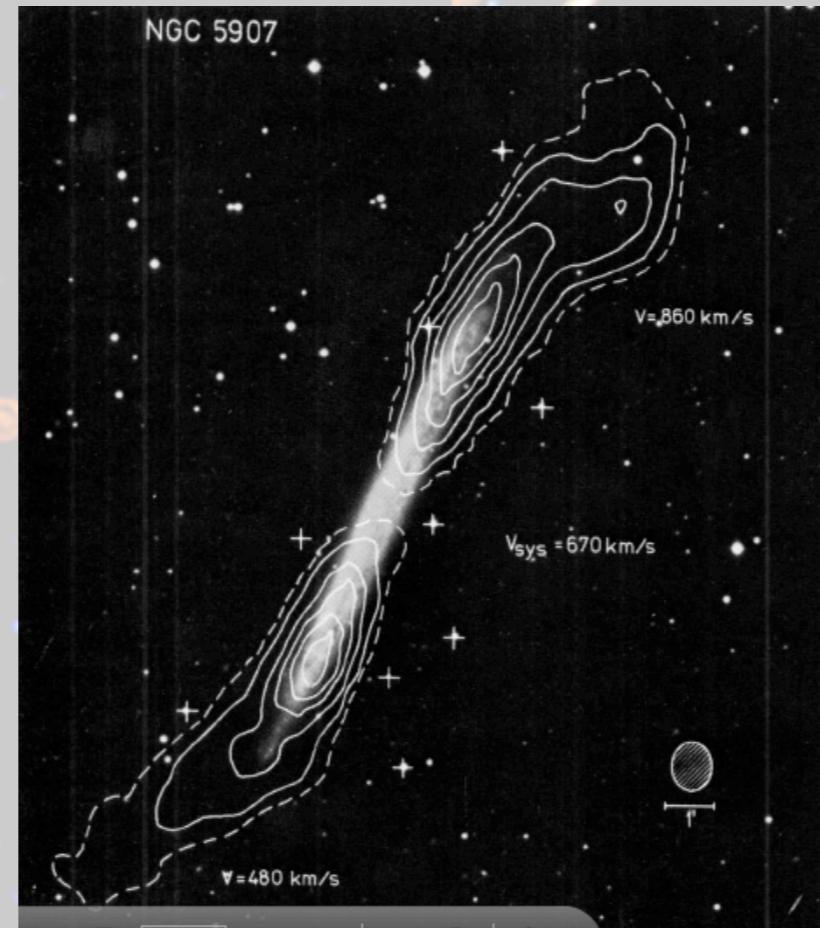
Early Westerbork work

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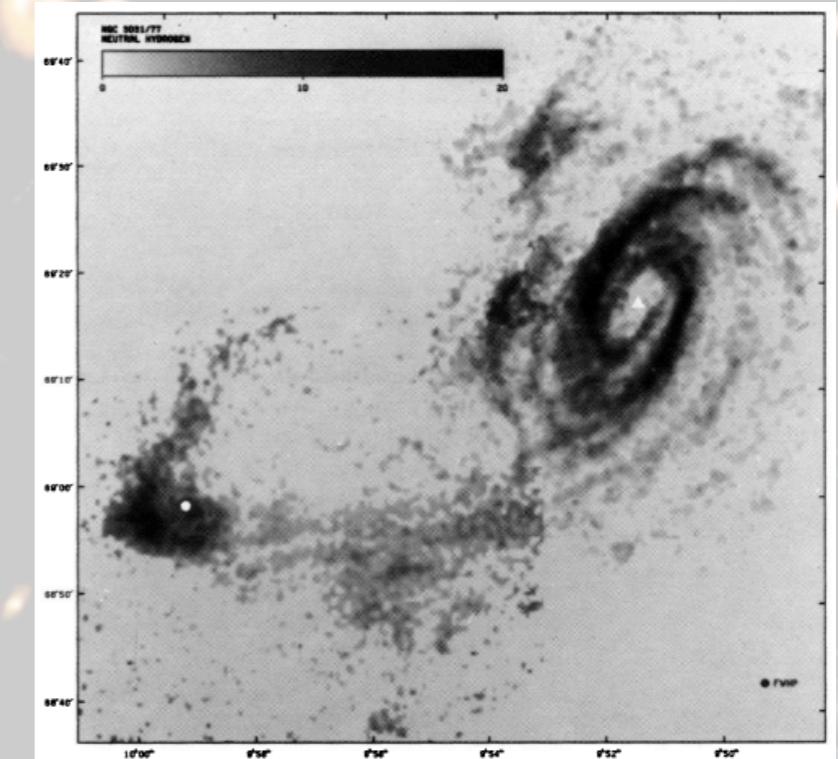
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van der Hulst A&A 75, 97,
1979: HI in M81/NGC3077

current observational state of the art:



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THINGS

Fabian, Brinks, de Blok, Bigiel, Kennicutt, Thornley, Leroy,
2008 AJ 136, 2563



Data: Walter et al 2008
Milky Way HI map: Oort et al (1958)
Milky Way art: NASA/JPL, R. Hurt (SSC)



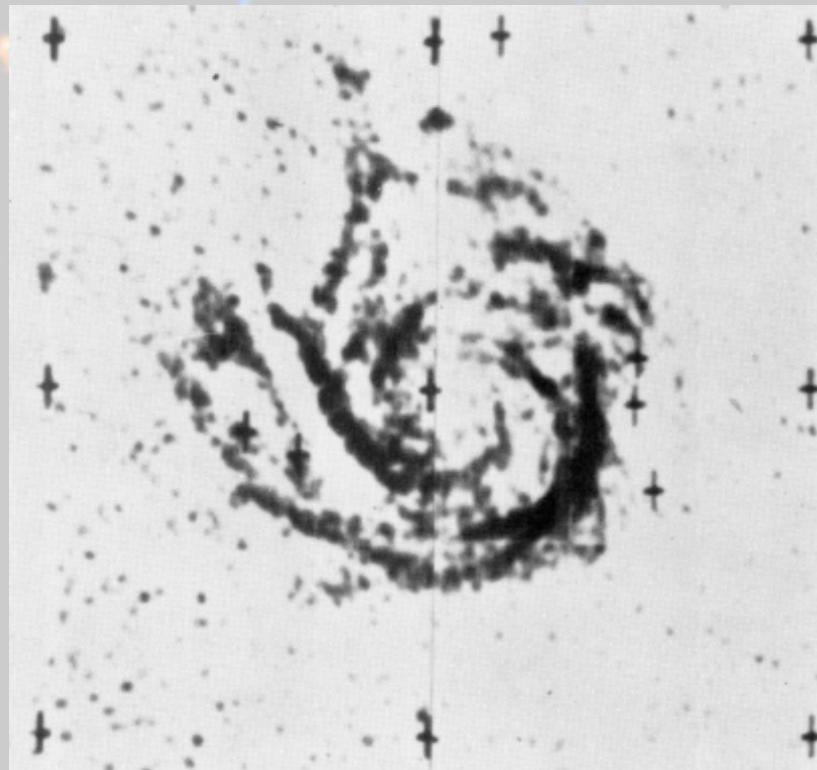
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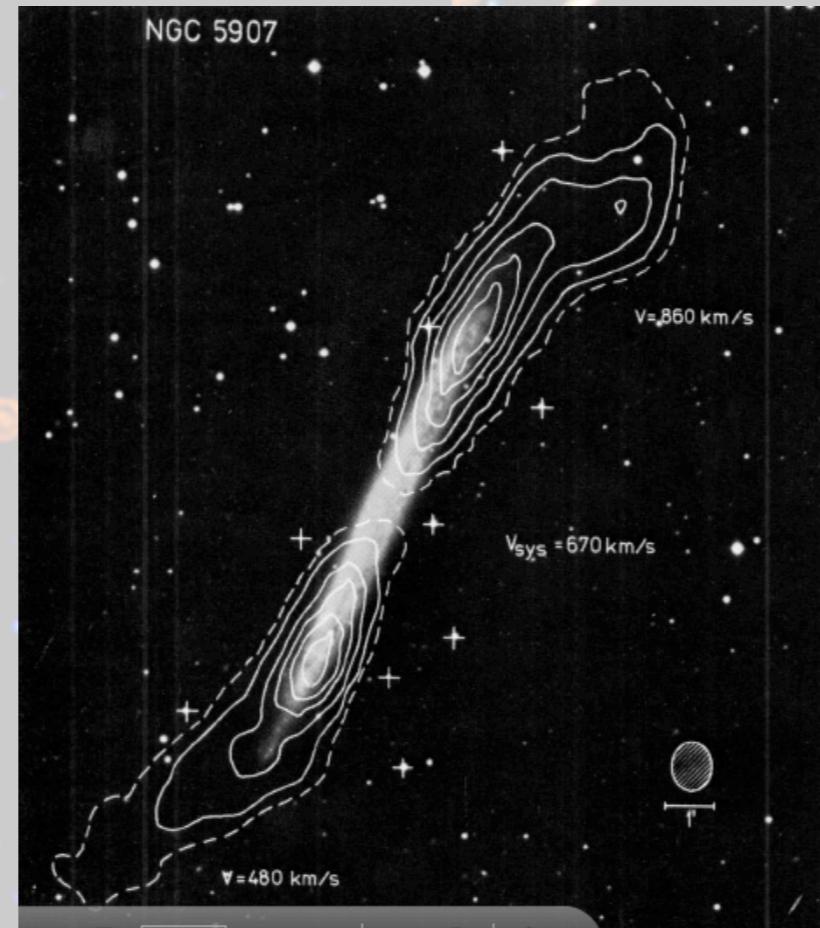
Early Westerbork work

HI shows spiral structure



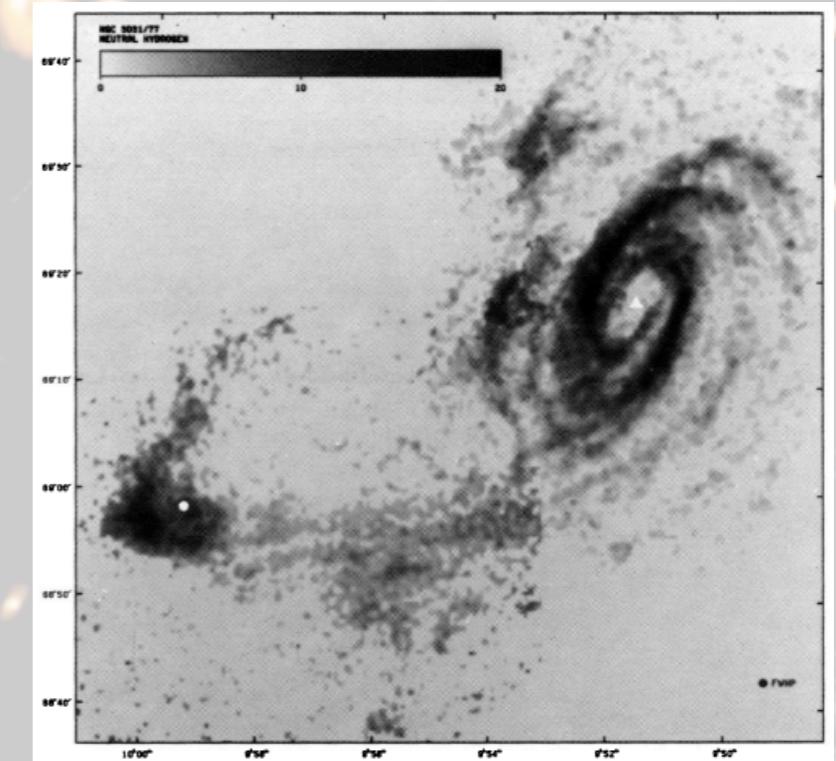
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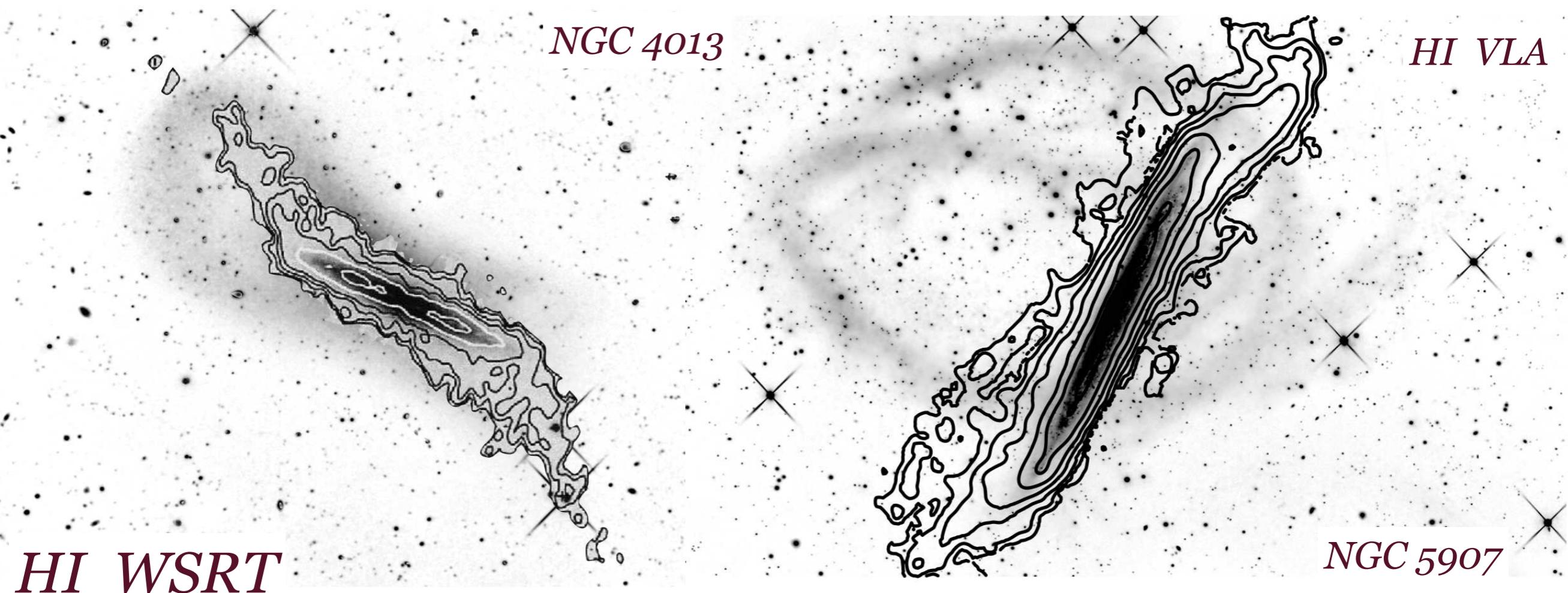


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HI Warps and capture of small satellites



Optical images from Martinez-Delgado et al. (2008/09)



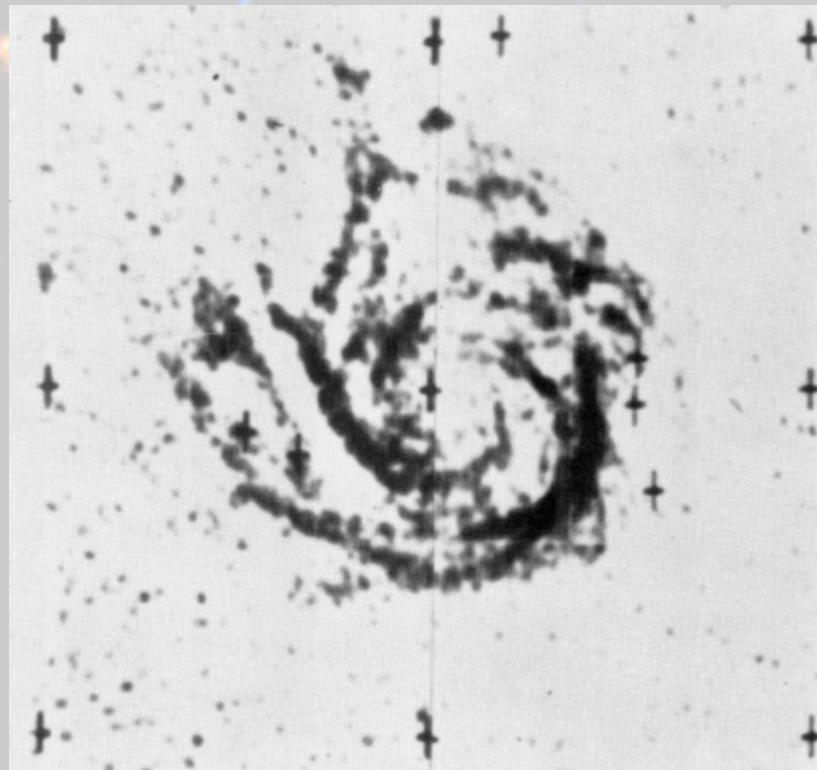
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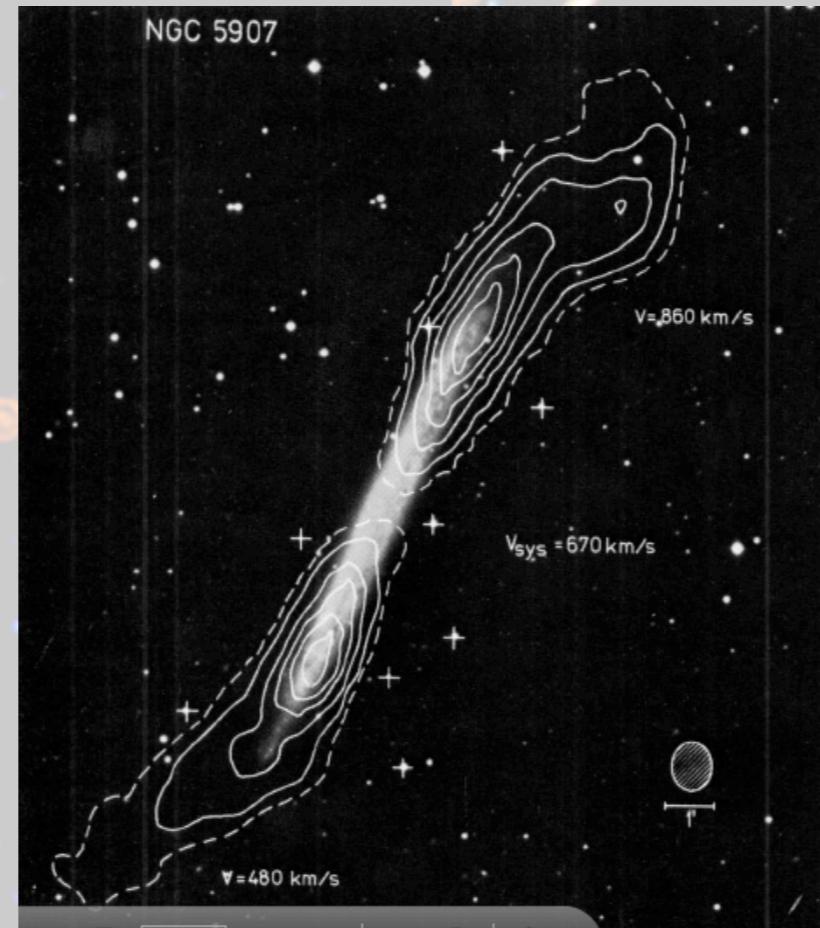
Early Westerbork work

HI shows spiral structure



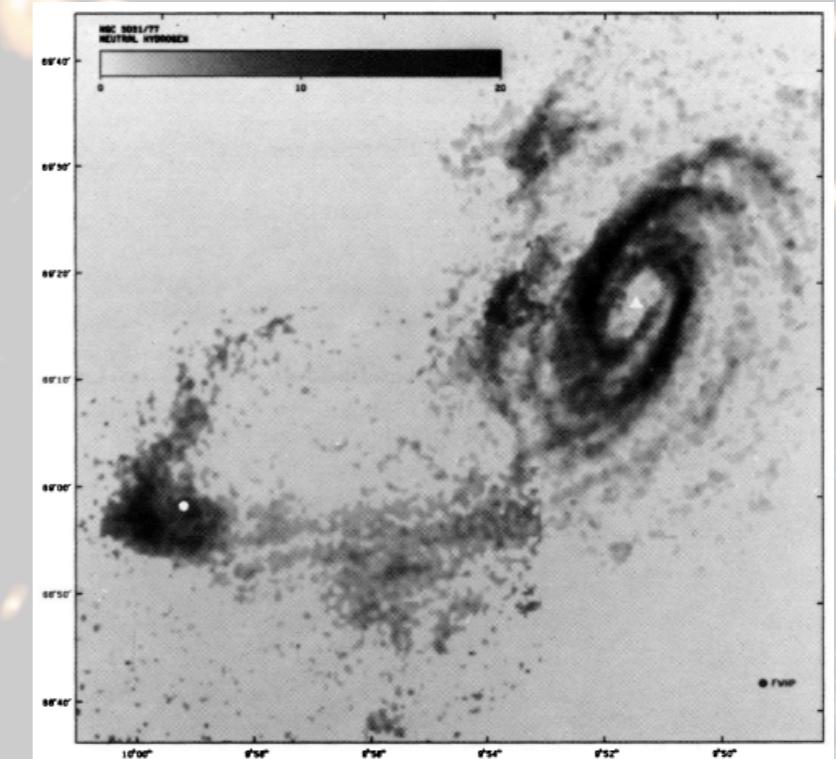
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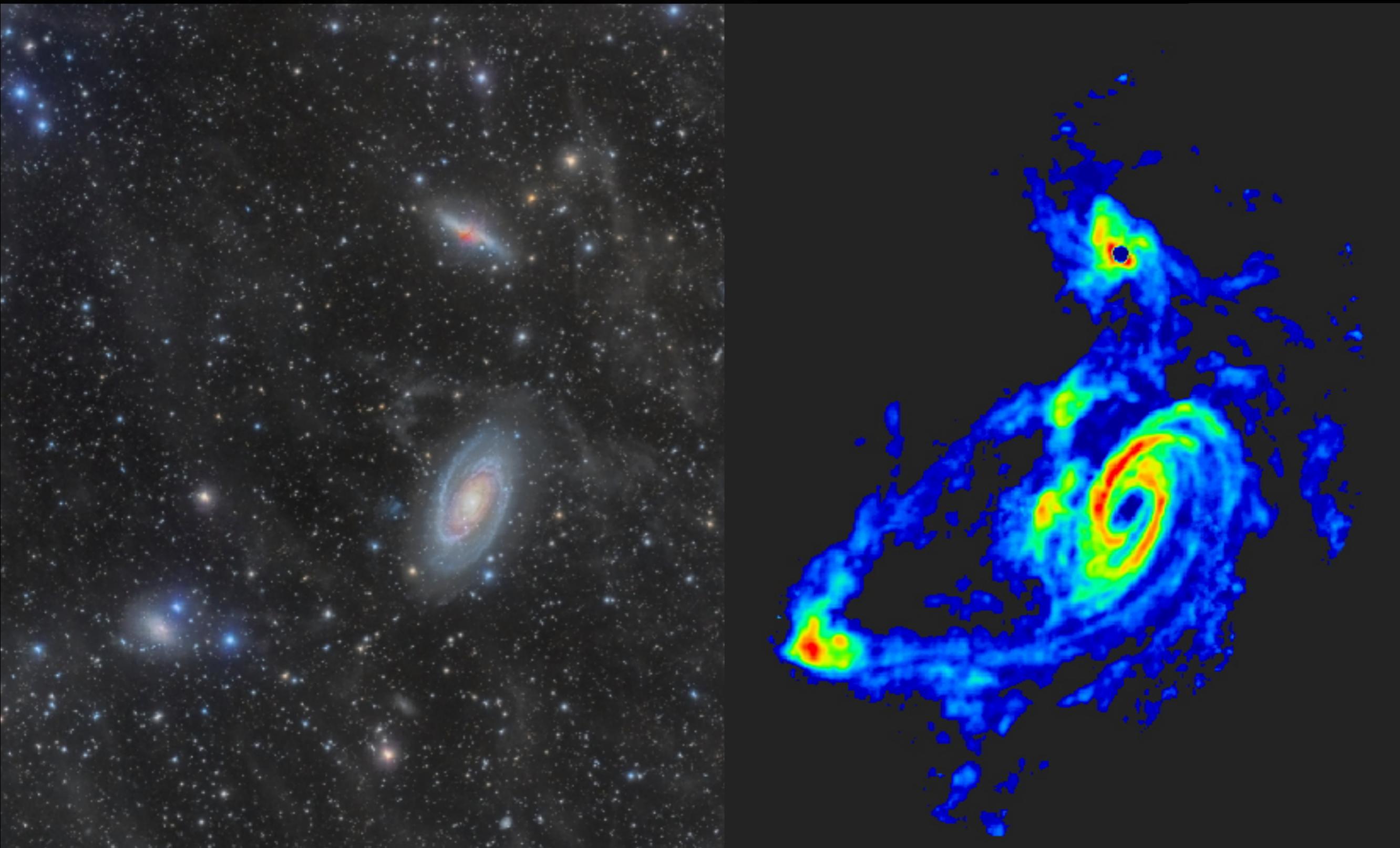
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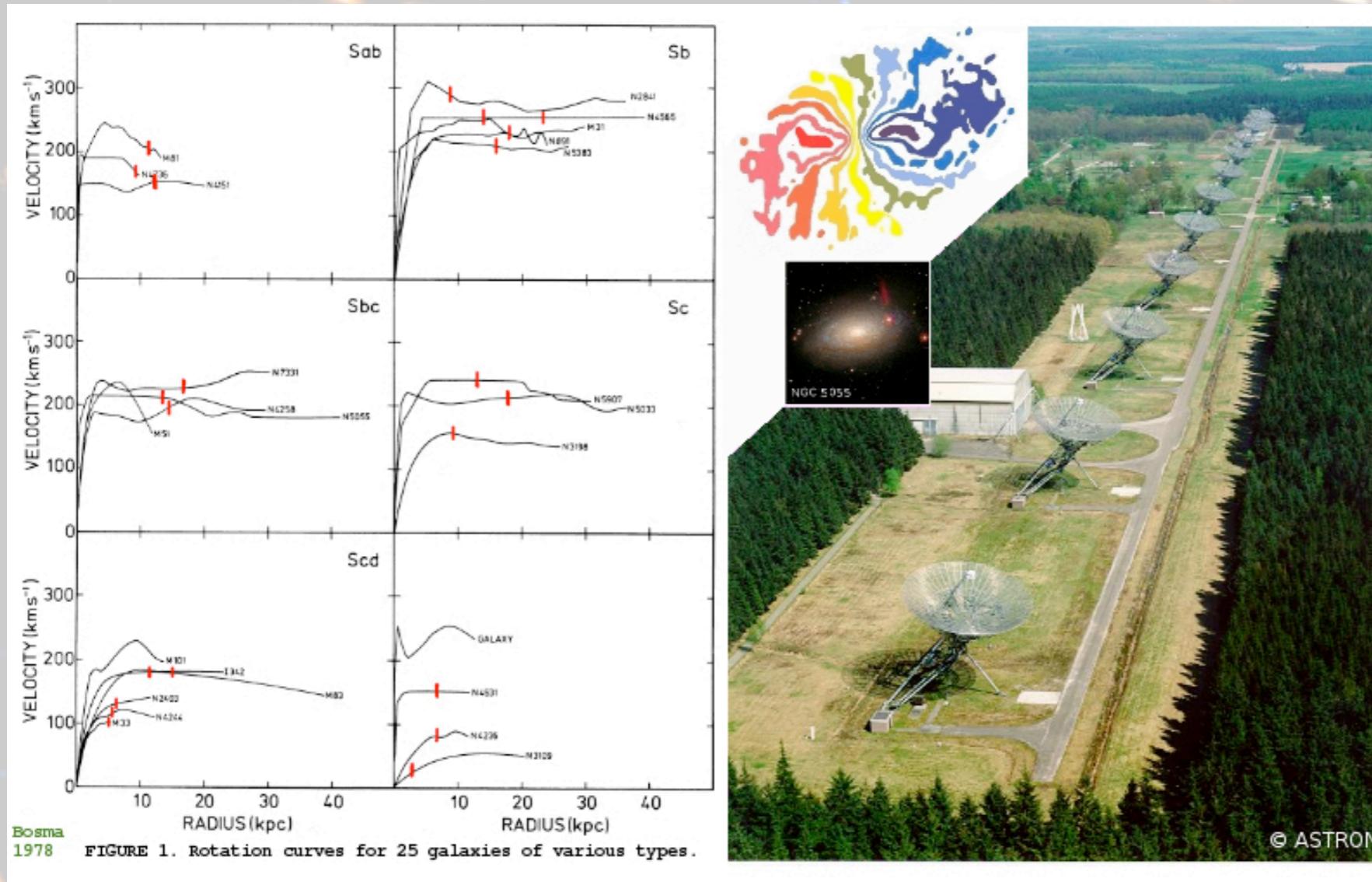


M81/M82/NGC3077

VLA HI mosaic



More early Westerbork work



Bosma, PhD thesis 1978
and 1981 AJ 86, 1791&1895

Flat rotation curves indicate the presence of dark matter leading to more thesis projects on this subject: Begeman, Broeils (three B's)



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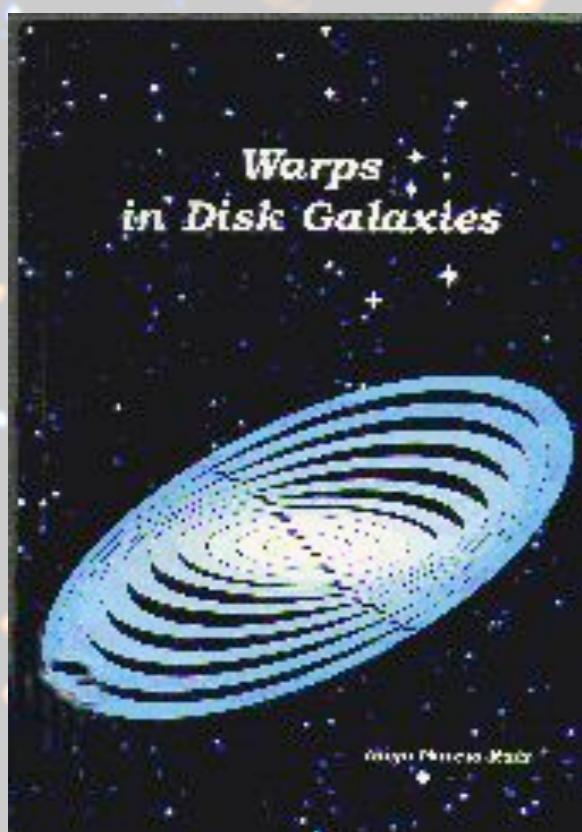


Westerbork HI Survey of Spiral and Irregular Galaxies

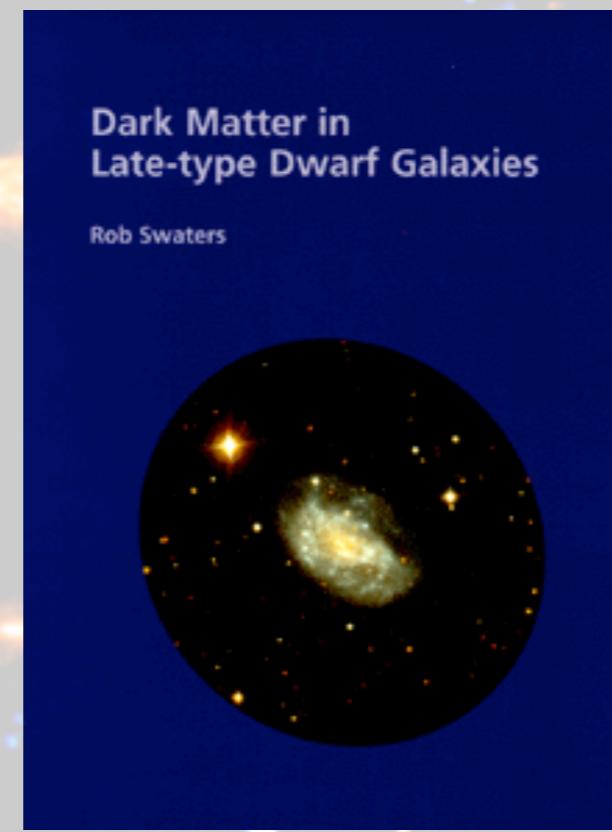
PI: T.S. van Albada

Goal: Image a thousand northern spiral and irregular galaxies in HI for:

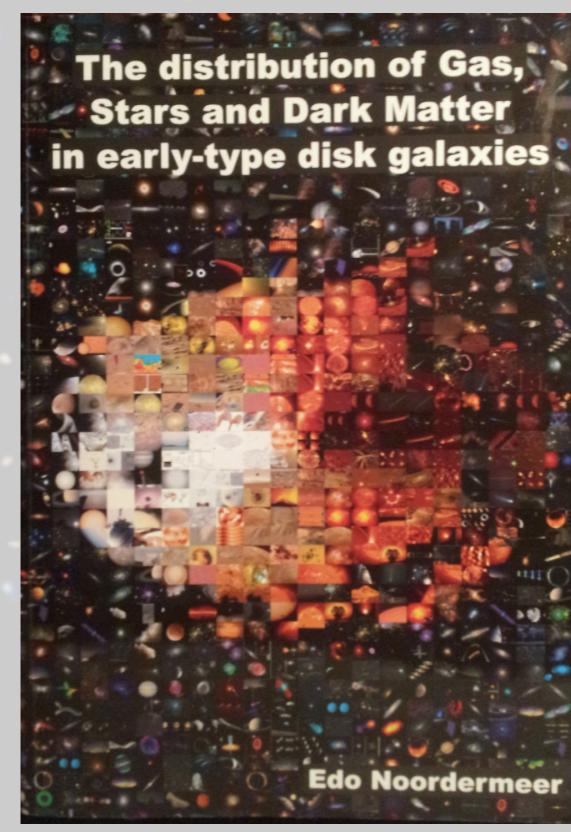
- study of the detailed distribution and kinematics of the HI disks
- study of the dynamics of galaxies using HI as a tracer



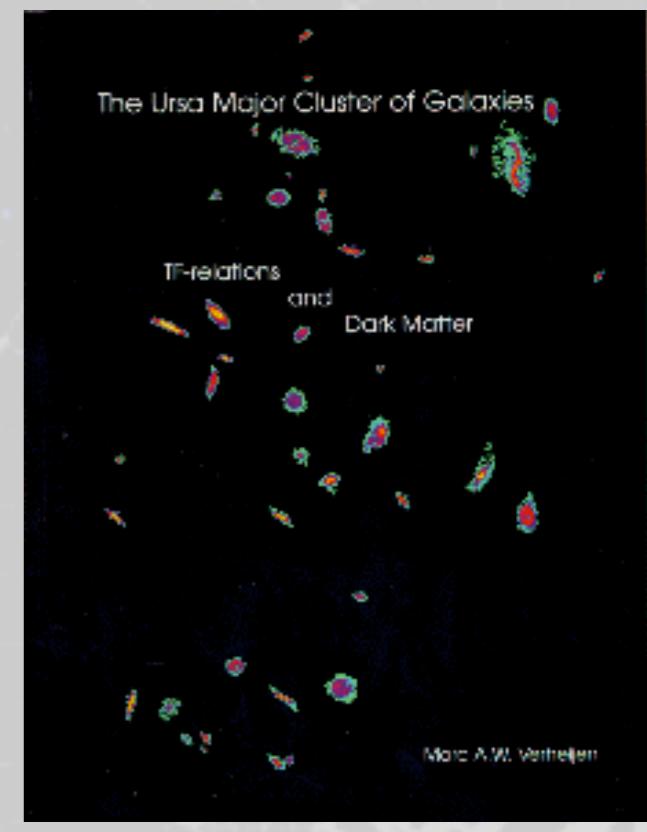
Garcia-Ruiz



Swaters



Noordermeer

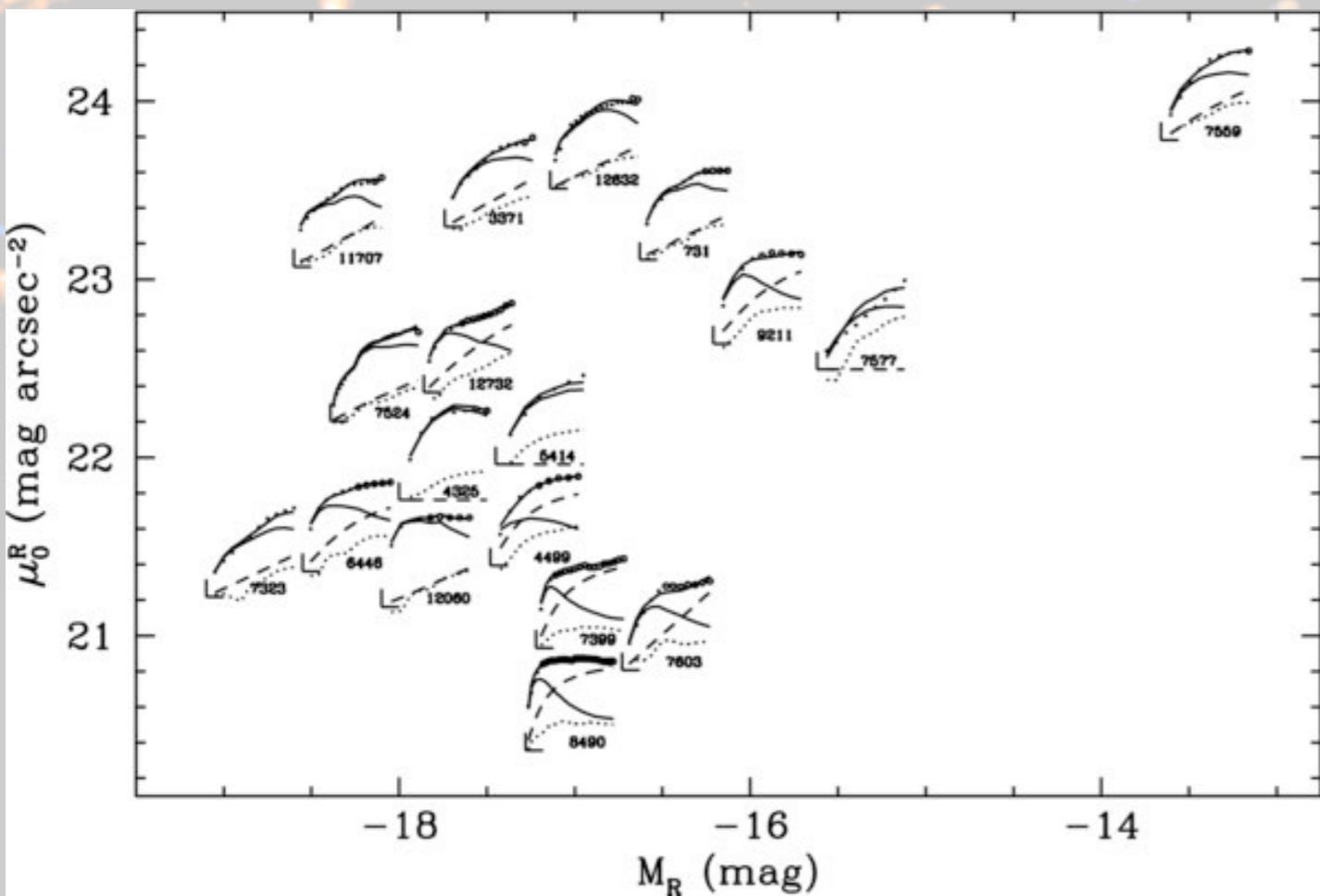


Verheijen



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WHISP results

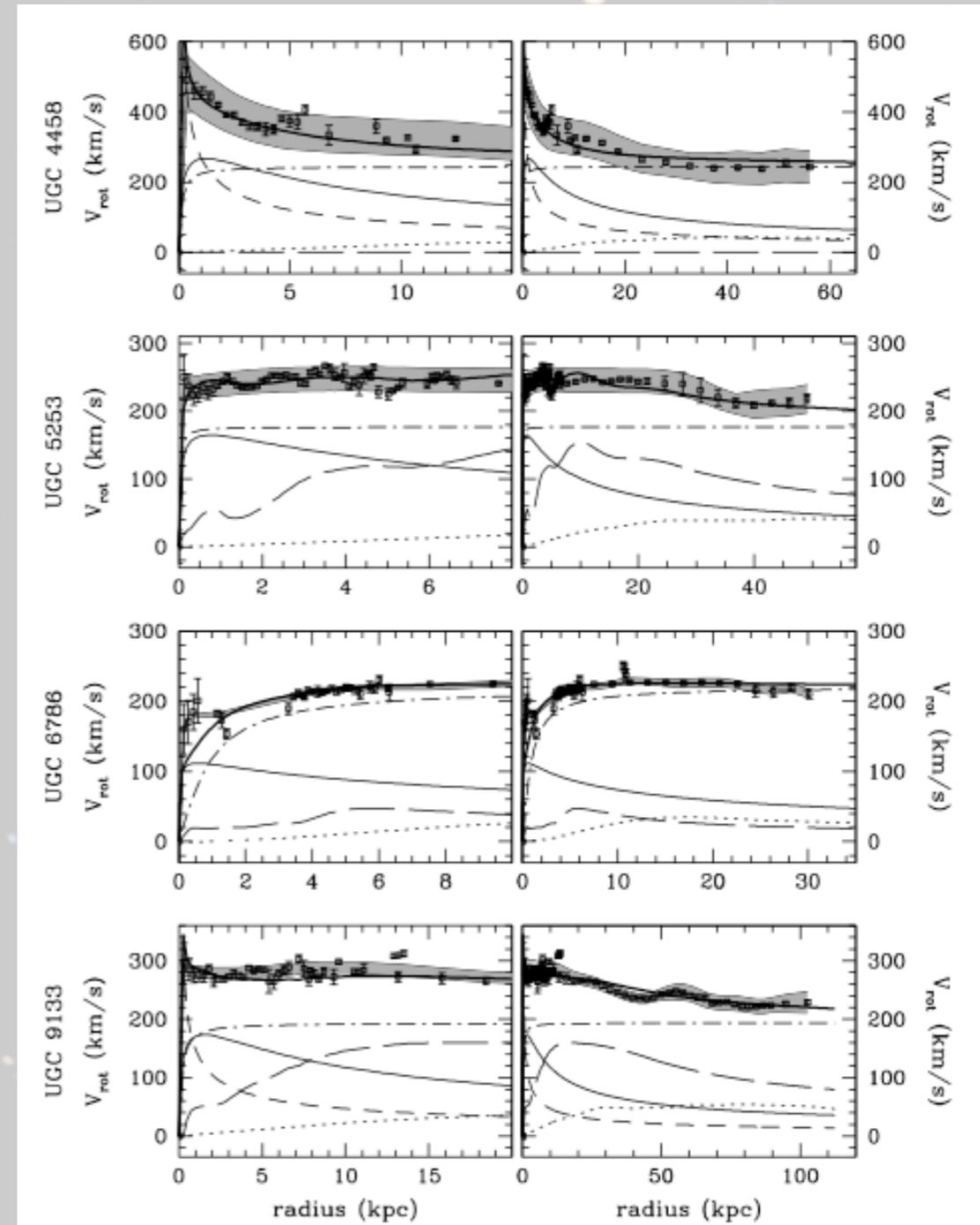


Swaters

Dark matter required in all galaxies

Most dwarf galaxies not dark matter dominated

Baryonic matter dominates in the inner parts



Noordermeer



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THINGS results

Fabian et al. 2008 AJ 136, 2563



Data: Walter et al 2008
Milky Way HI map: Oort et al (1958)
Milky Way art: NASA/JPL, R. Hurt (SSC)



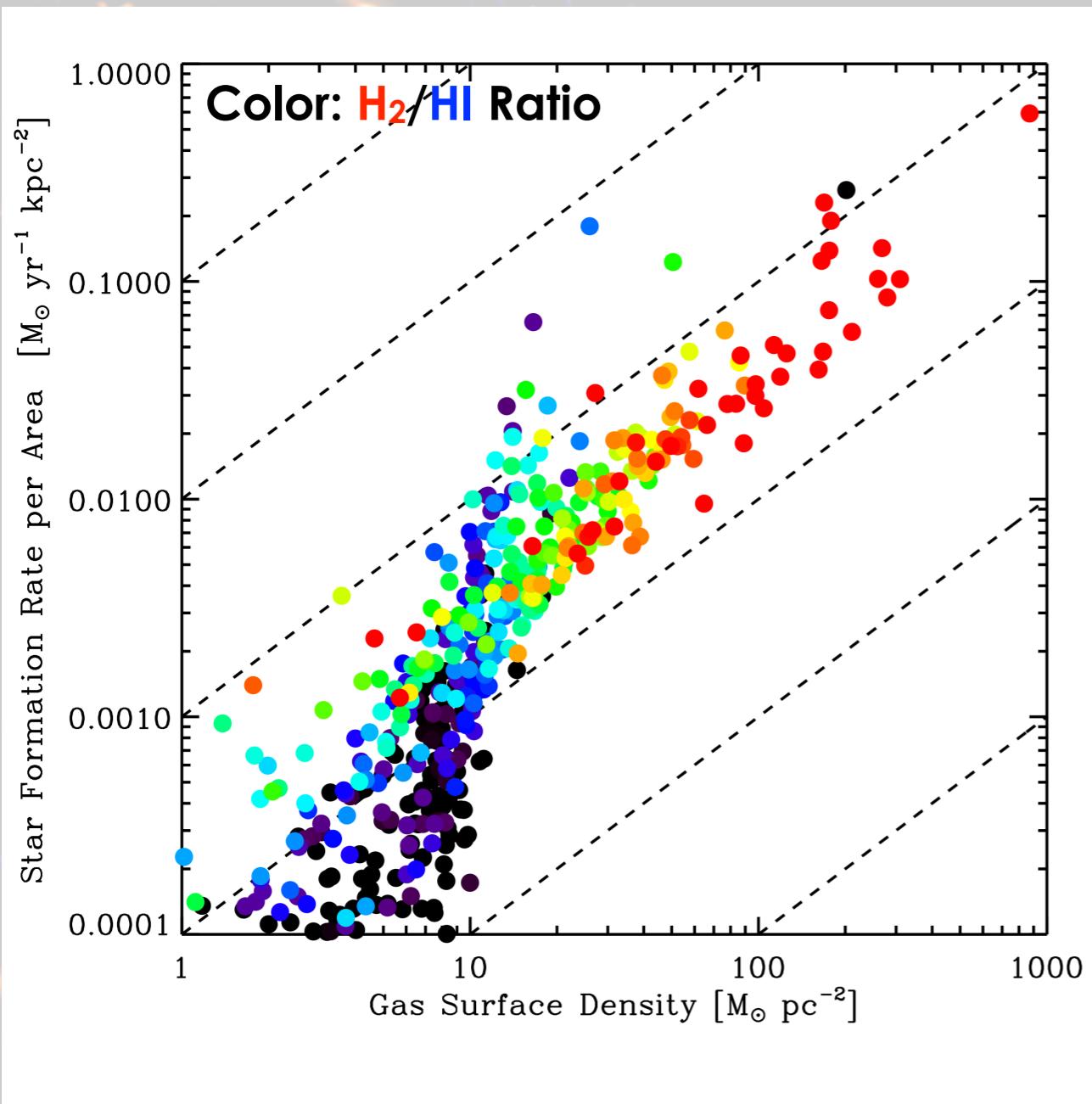
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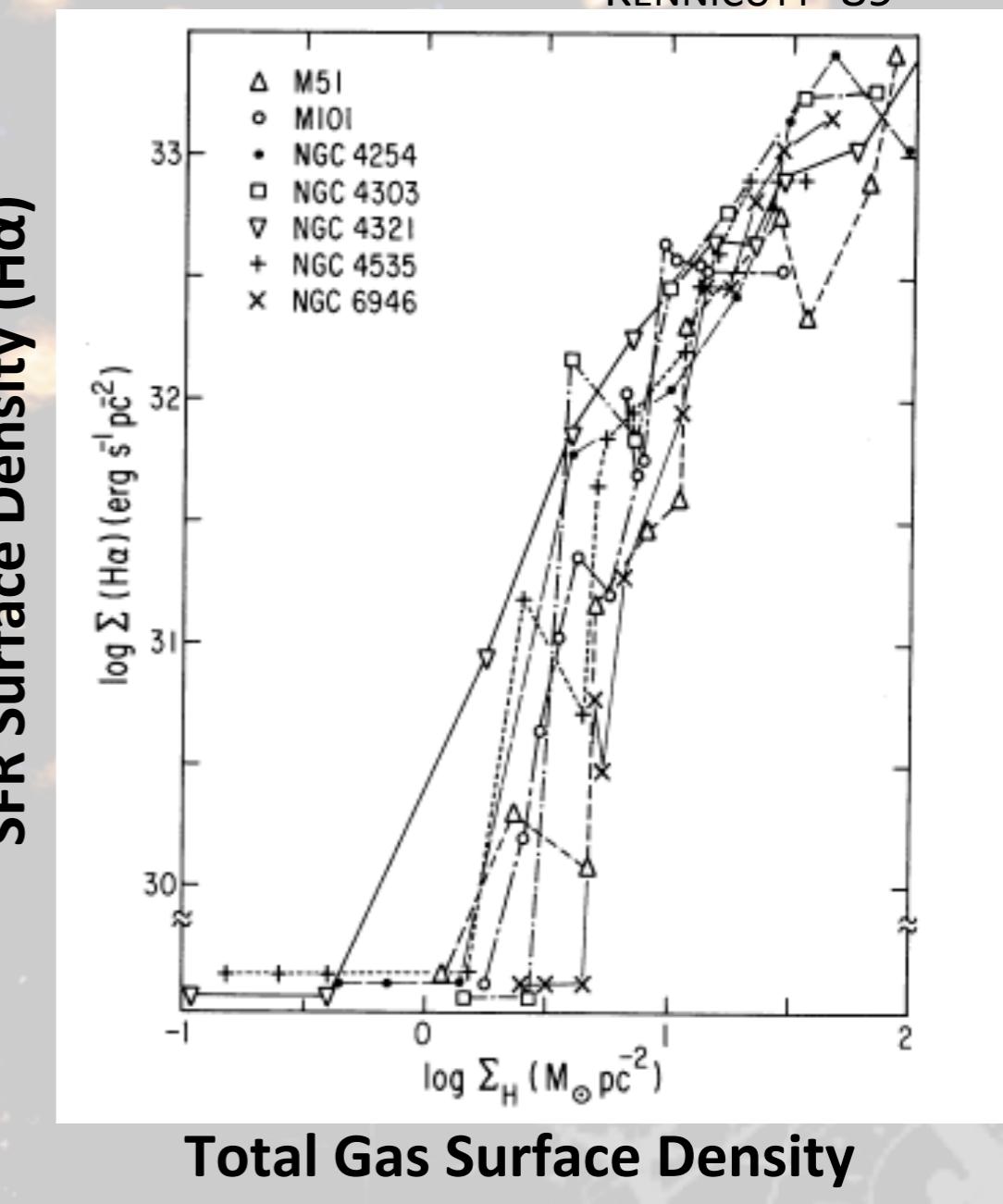


THINGS results

Bigiel et al. 2010 AJ 140, 1194
Schruba et al. 2011, AJ 142, 37



Star Formation thresholds and gas phases
from pixel to pixel comparisons



from a presentation by A. Leroy



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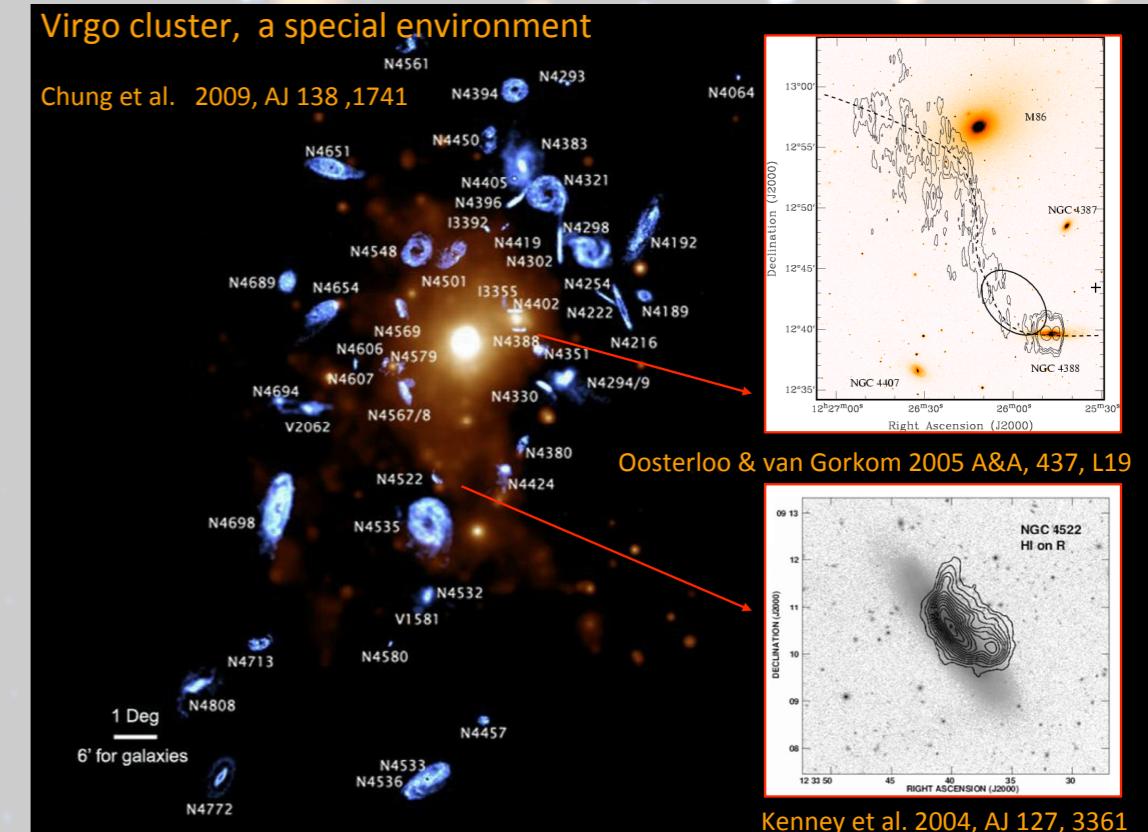
Further gleanings of WHISP and other data

(Sancisi, Fraternali, Oosterloo & v.d. Hulst. 2008, A&A Rev. 15, 189)

Gas removal mechanisms :

- *ram pressure stripping*
- *tidal stripping*

- Galactic Fountain



Evidence for accretion :

- lopsidedness of galaxies
- extraplanar gas

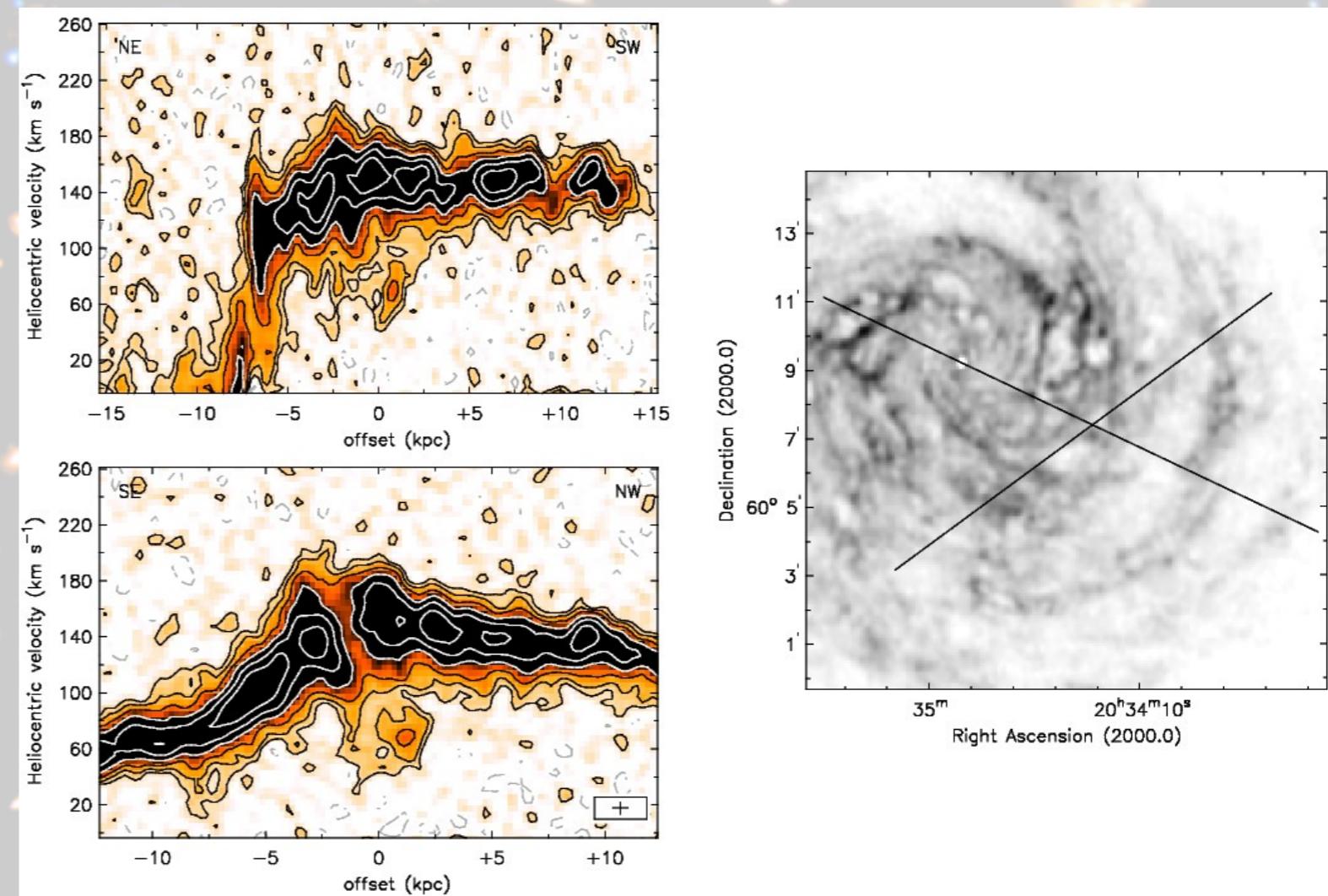
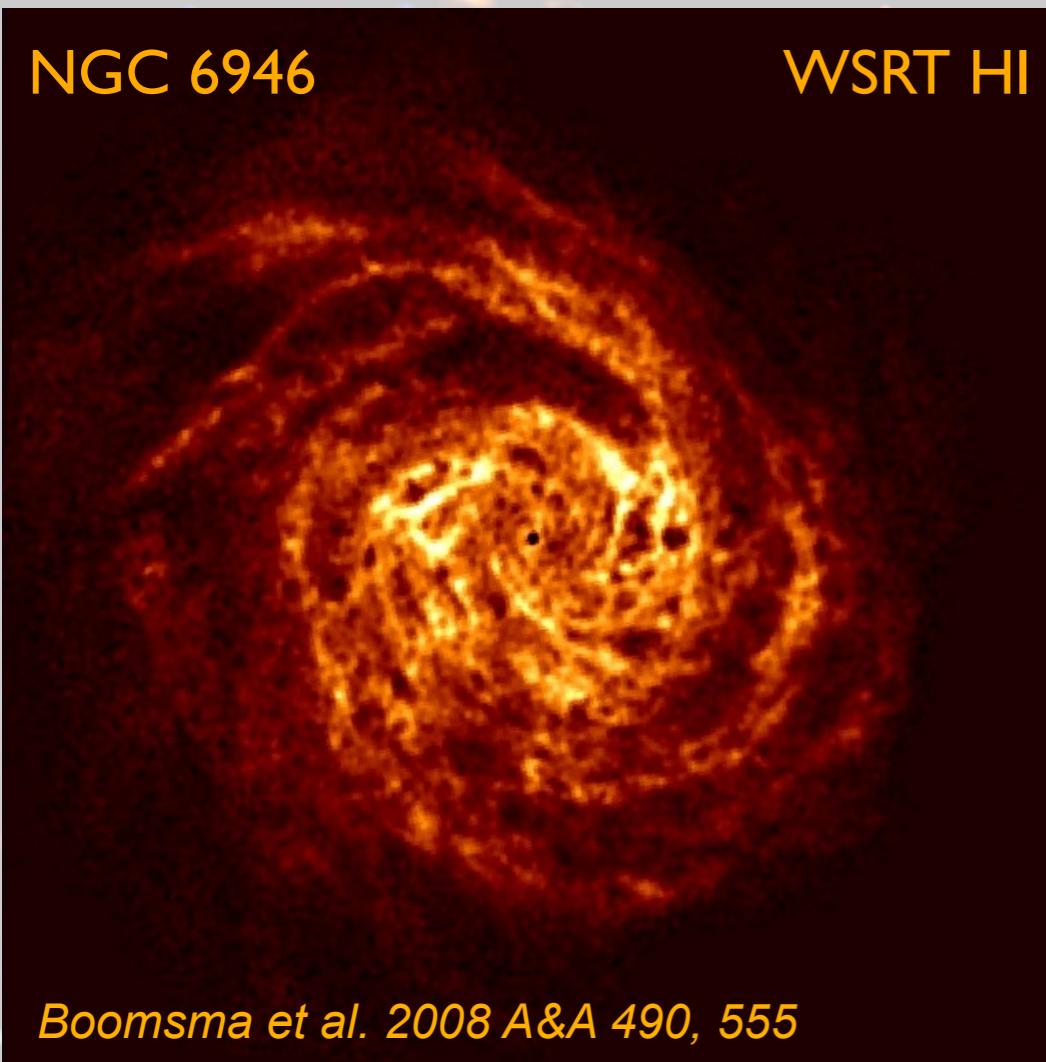


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Evidence for outflowing gas in (nearly) face on galaxies

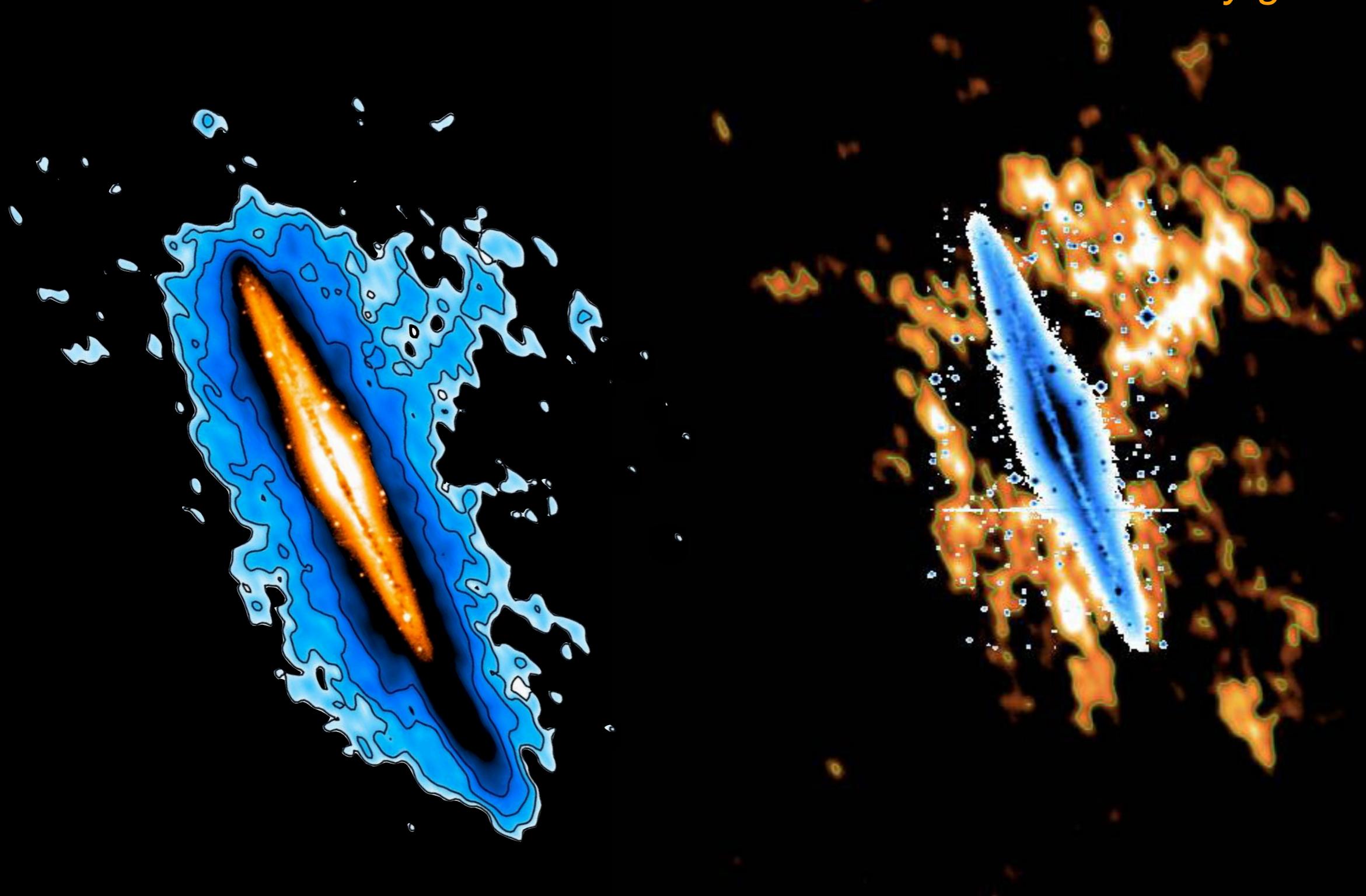


widespread *anomalous velocity* gas, associated mostly with the star forming disk, presumably a *galactic fountain*

NGC 891

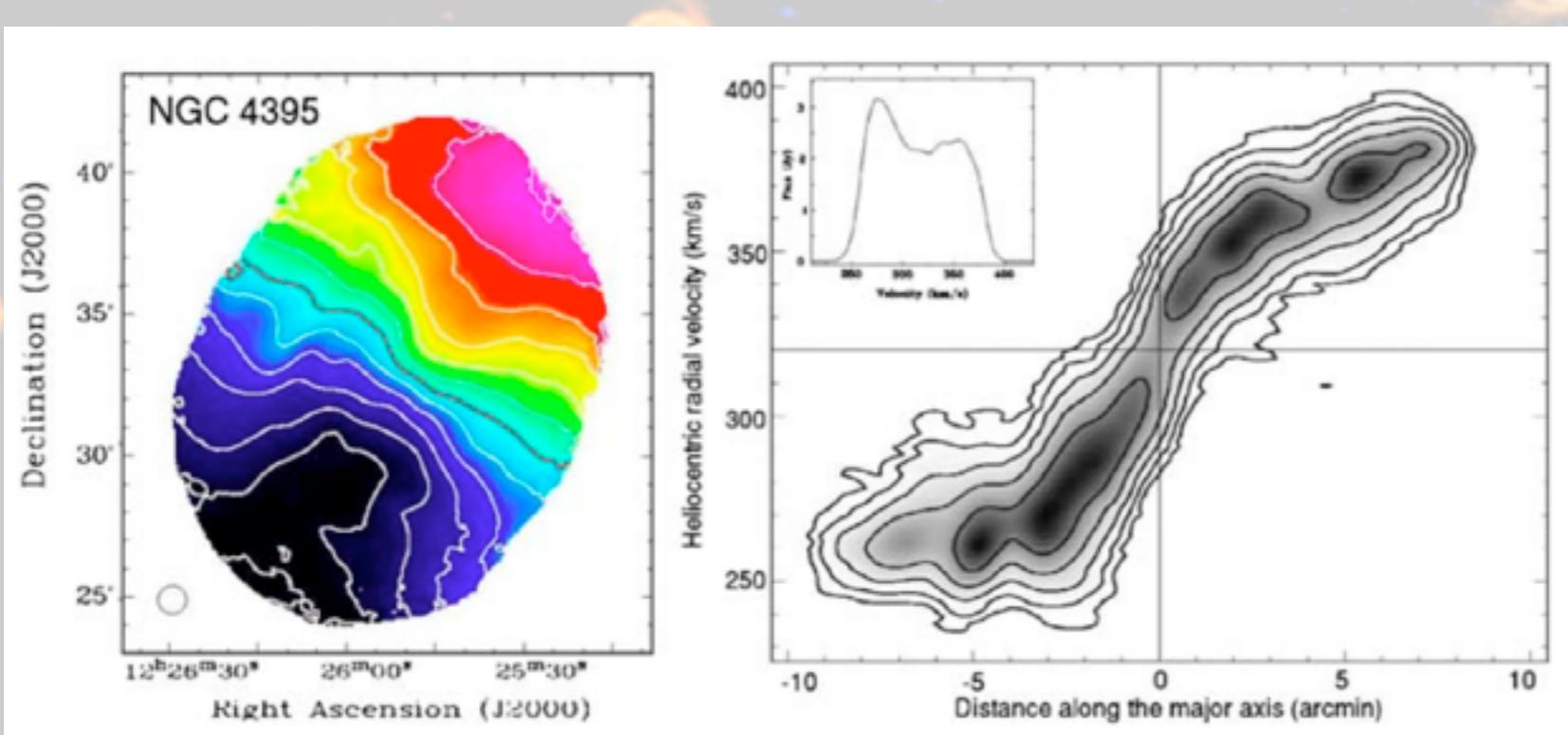
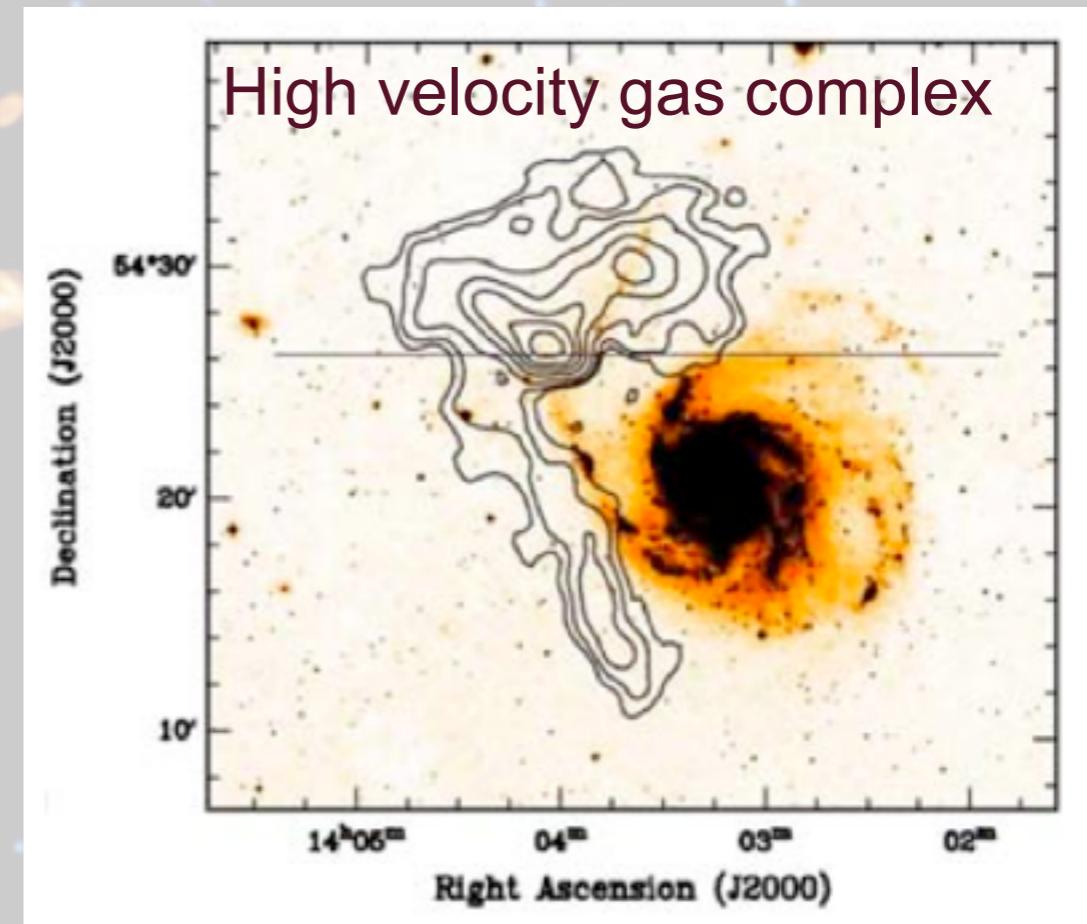
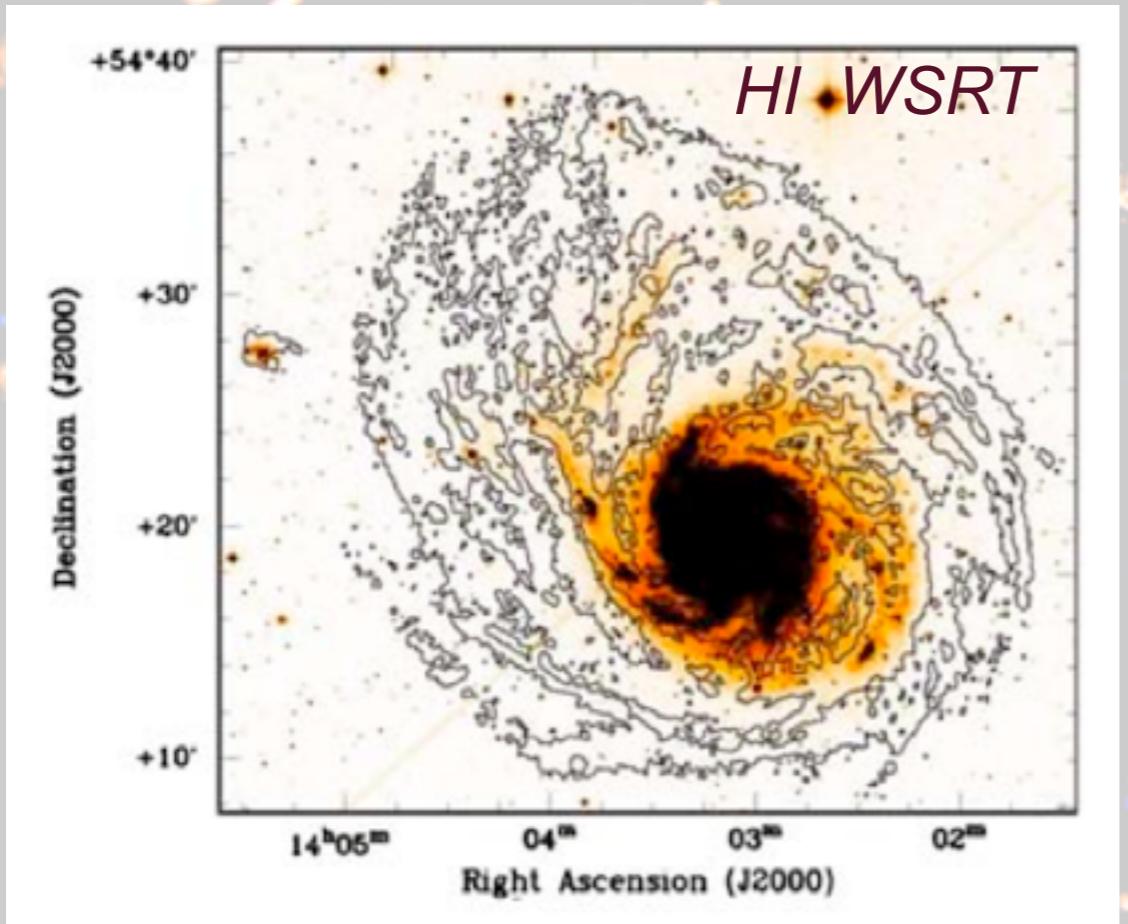
What deep ($N_{\text{HI}} < 10^{19}$) observations provide
all HI

Anomalous velocity gas



Kinematic lopsidedness

Sancisi, Fraternali, Oosterloo & v.d. Hulst. 2008, A&A Rev. 15, 189



J. Kamphuis, PhD, 1993

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



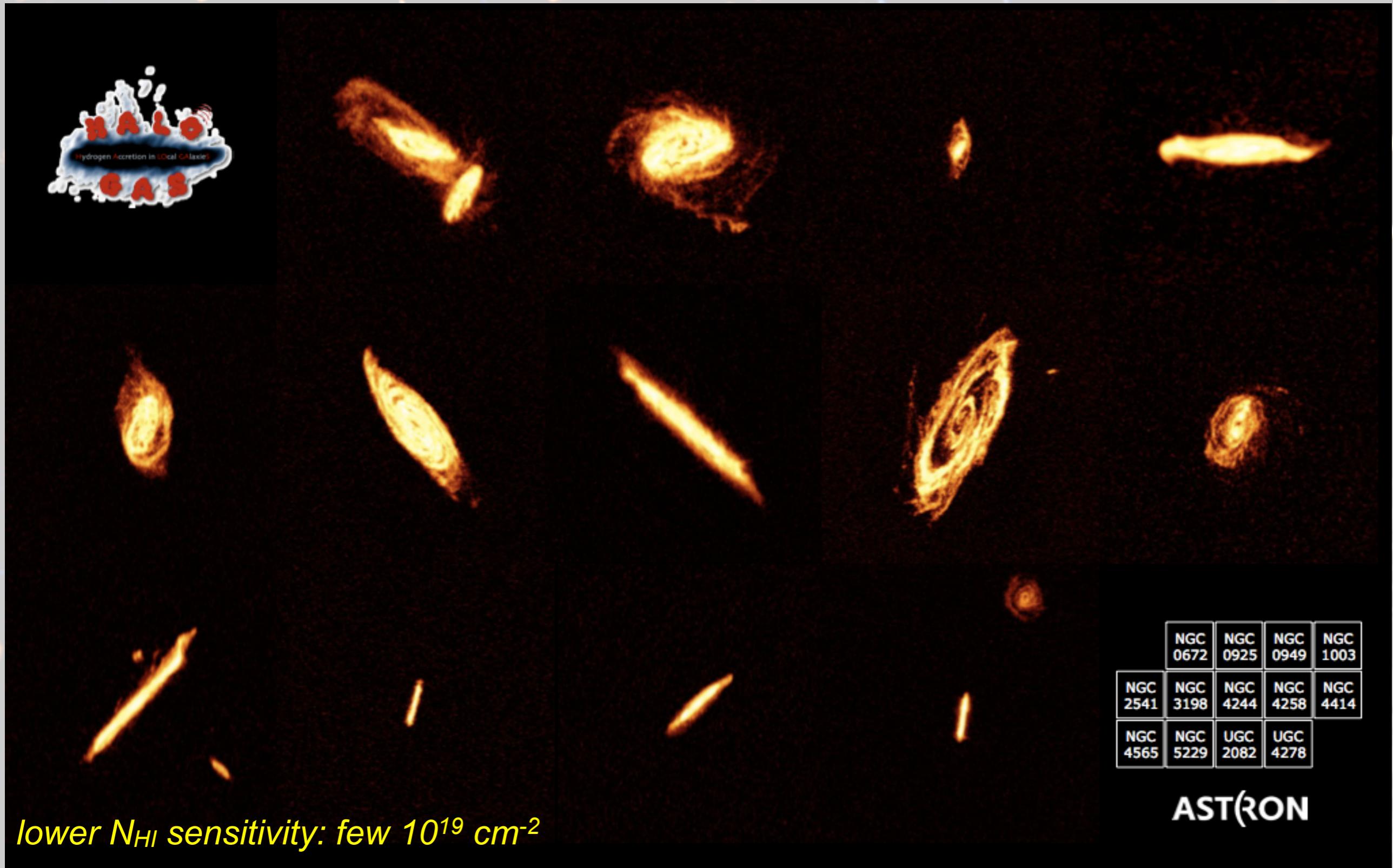
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HALOGAS

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



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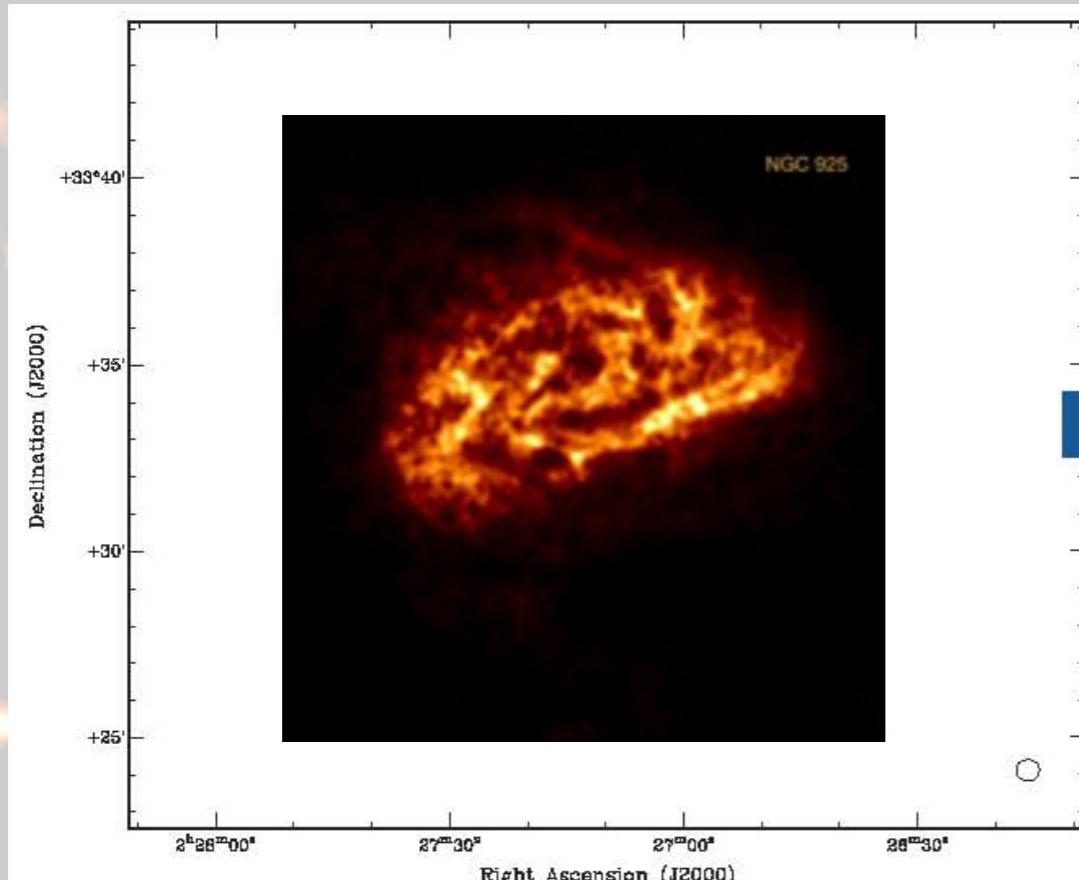
HALOGAS

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

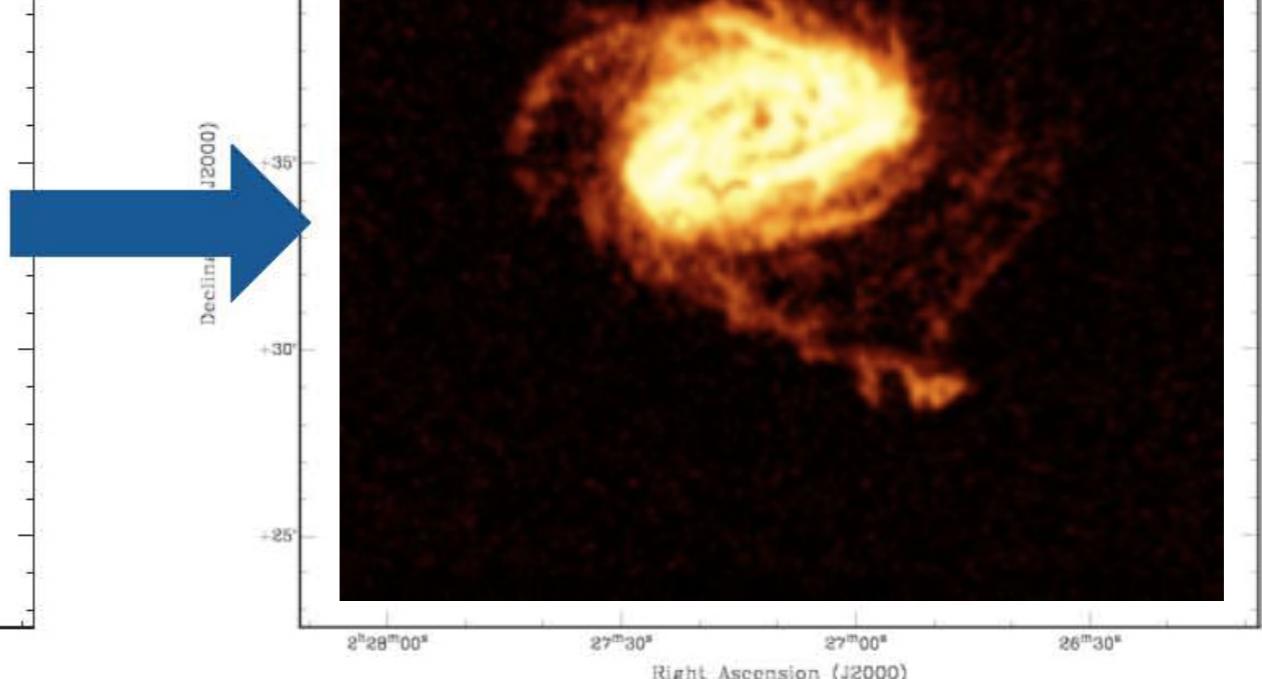
HALOGAS provides a database of the deepest available HI observations of nearby galaxies - complementary to THINGS

HALOGAS strength: detecting faint diffuse emission

THINGS strength: imaging small-scale structure



THINGS



HALOGAS

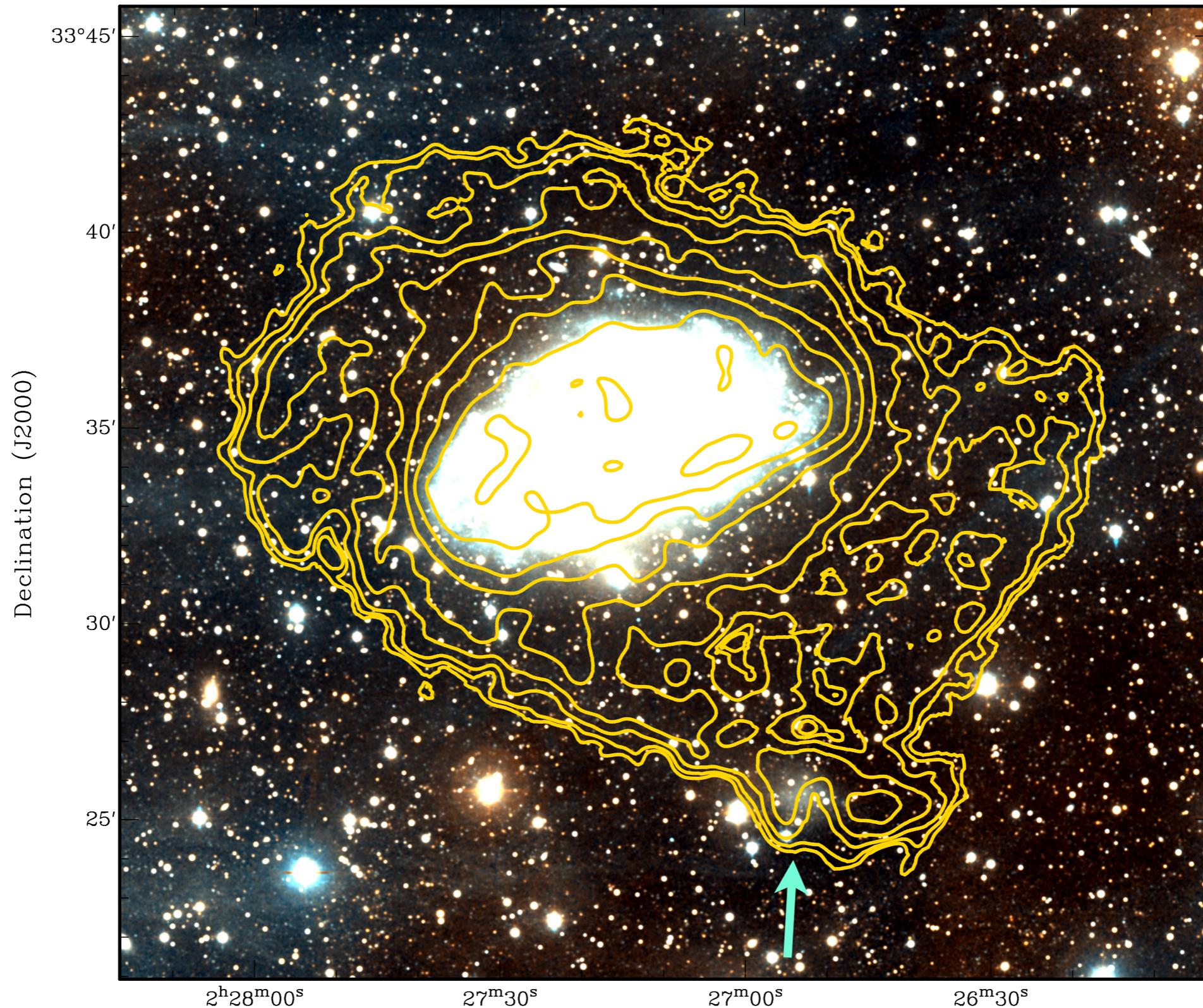


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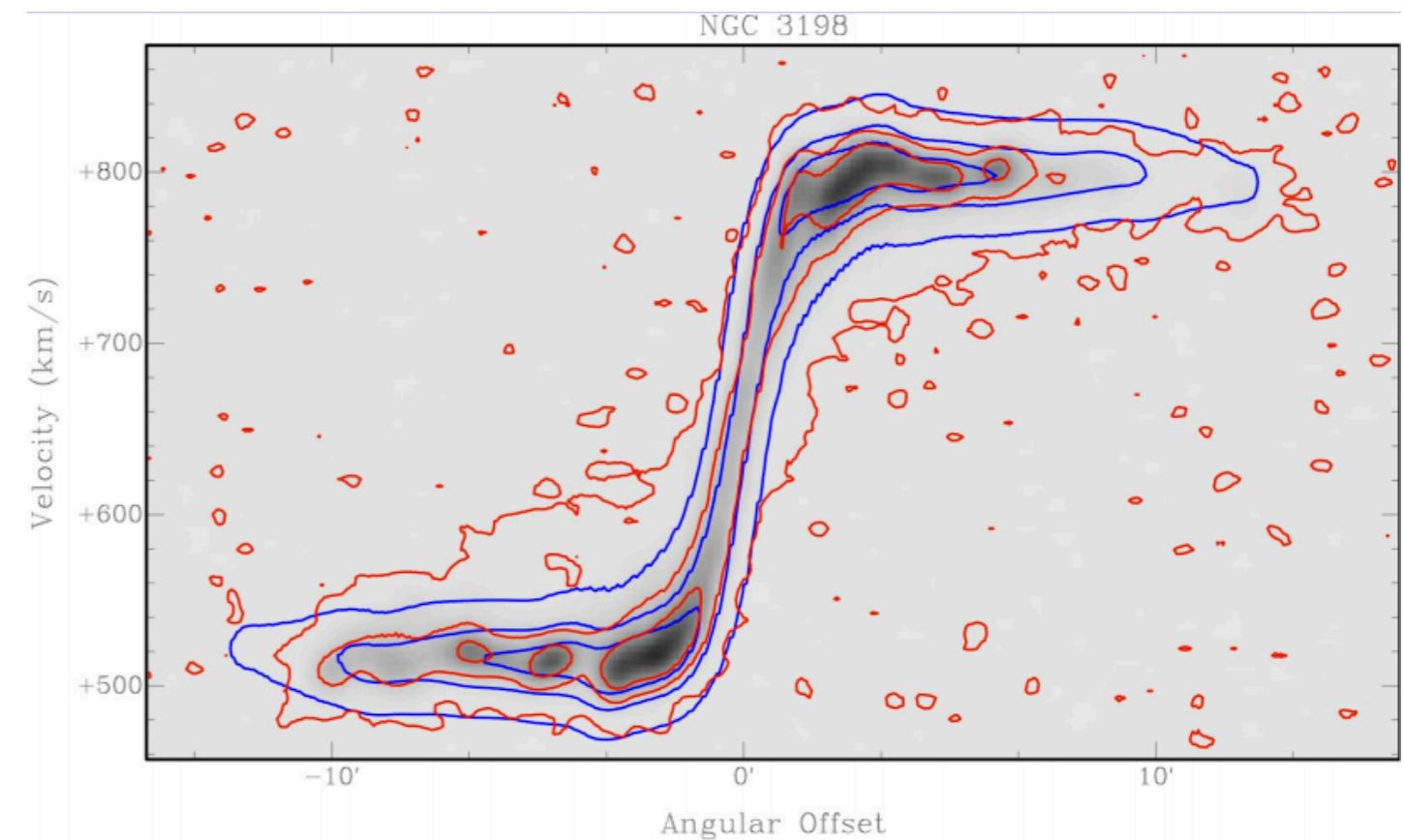
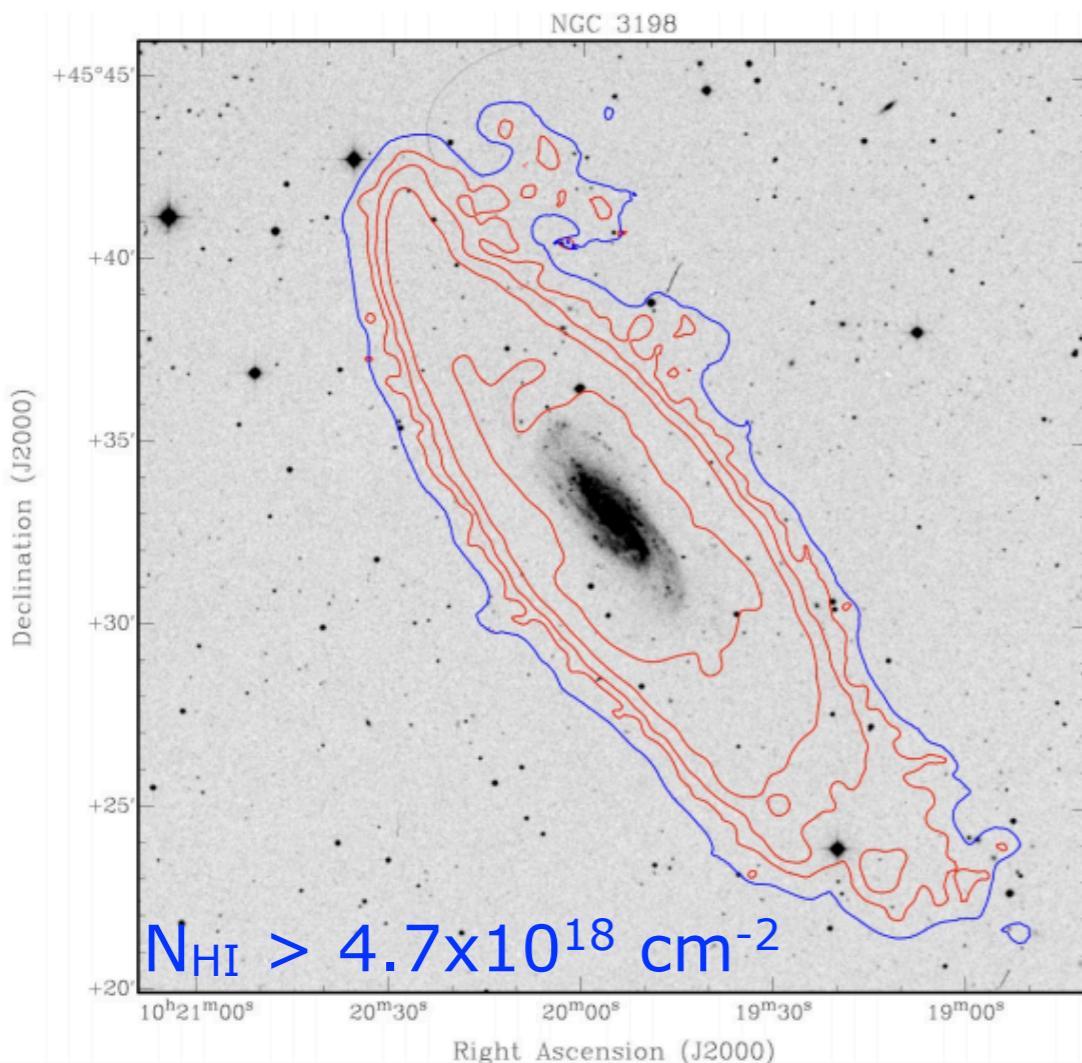
- Powerful combination of deep optical and HI reveals tidal remnants



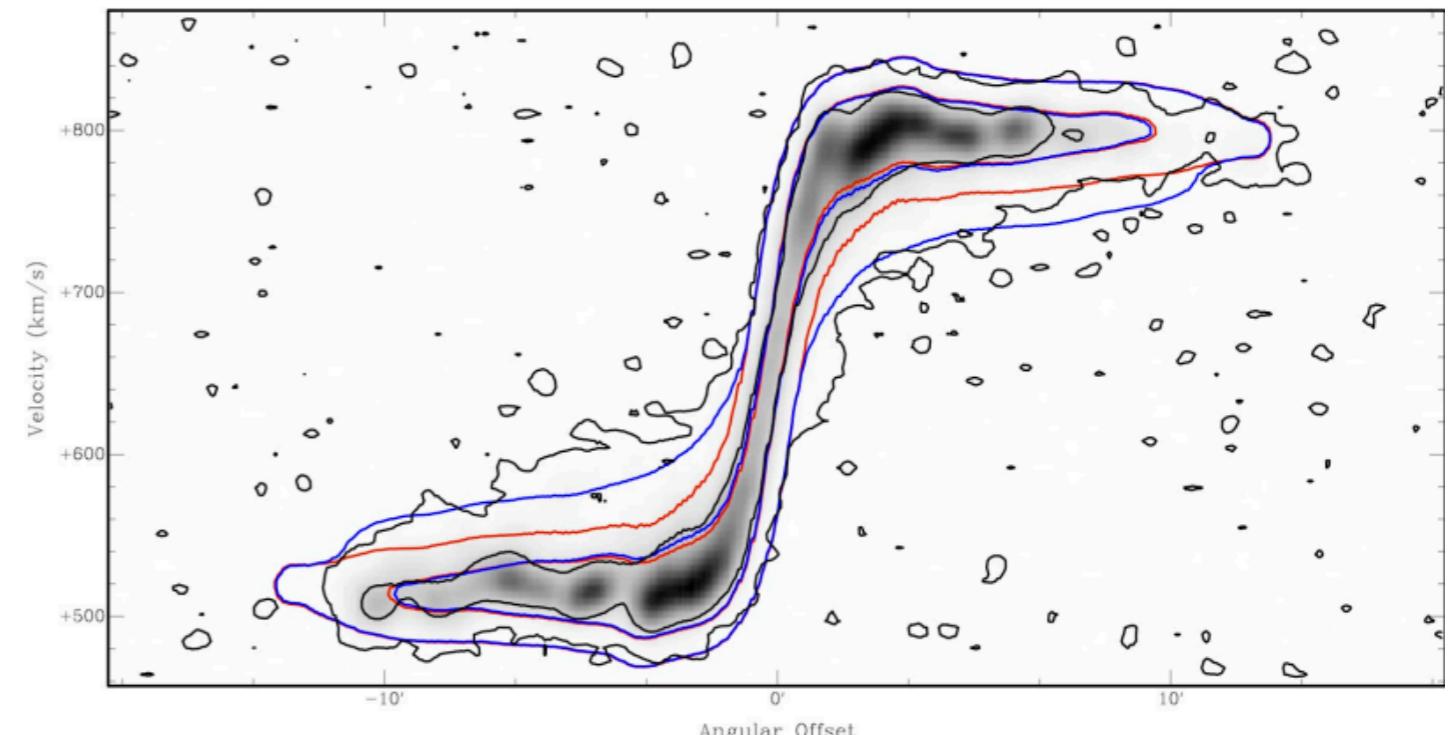
NGC 3198 (Gentile+ 2013)

- Key result:

- lagging halo (~ 30 km/s) containing estimated $\sim 10\%$ of HI mass from disk-halo separation

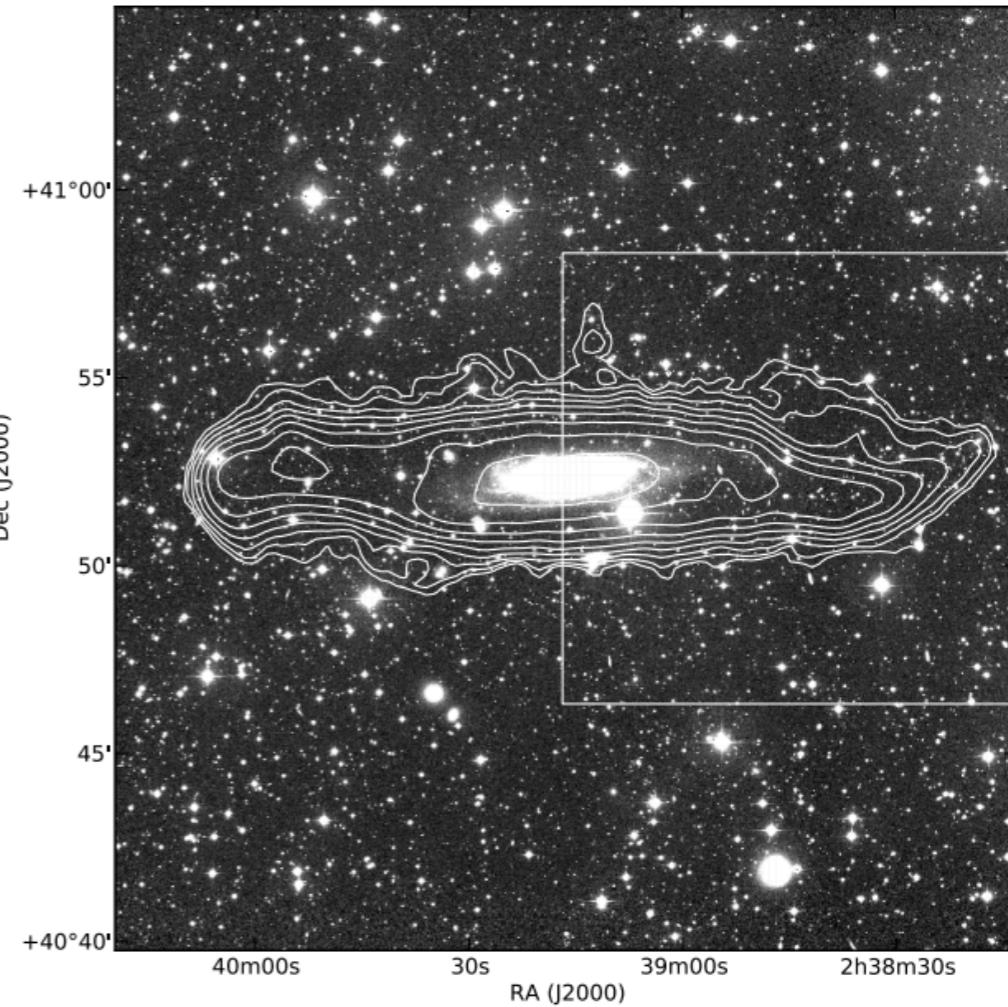
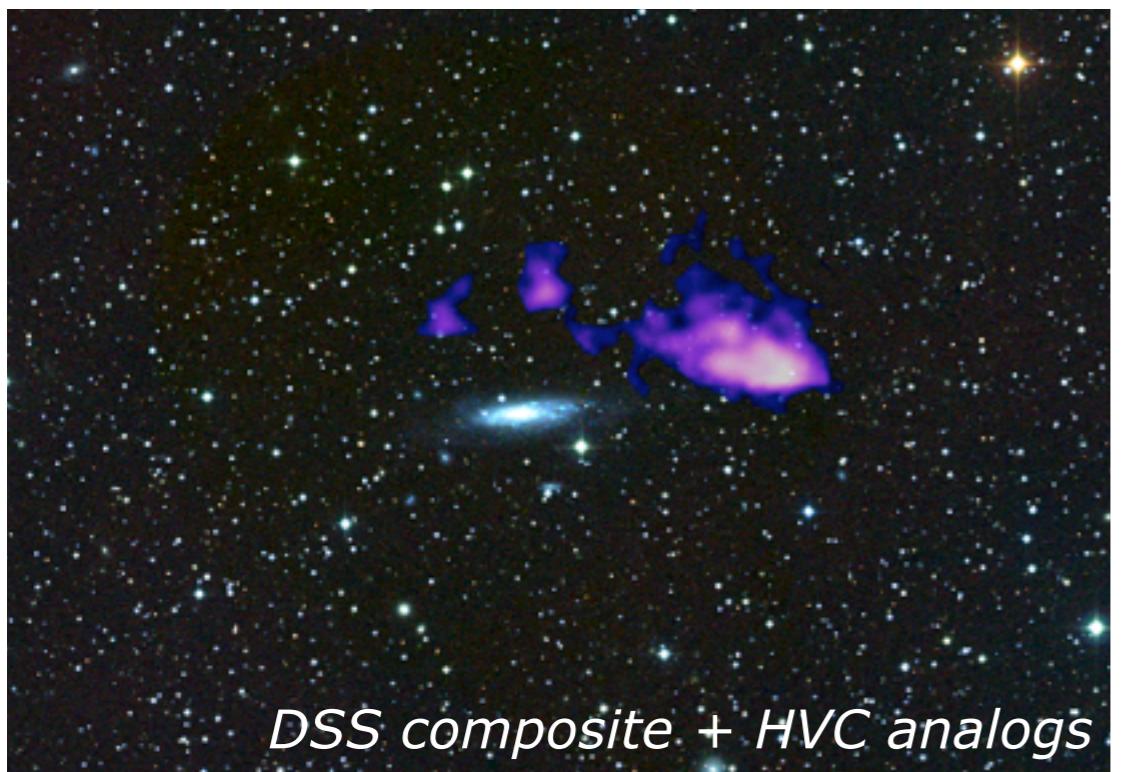


Thin disk model



Lagging halo model

- Key results:
- HVC analogs detected at 11 Mpc distance
- Contributing $\sim 4 \times 10^6 M_{\odot}$ of the HI in the system
- over a dynamical time, these features contribute $\sim 2\%$ of SFR



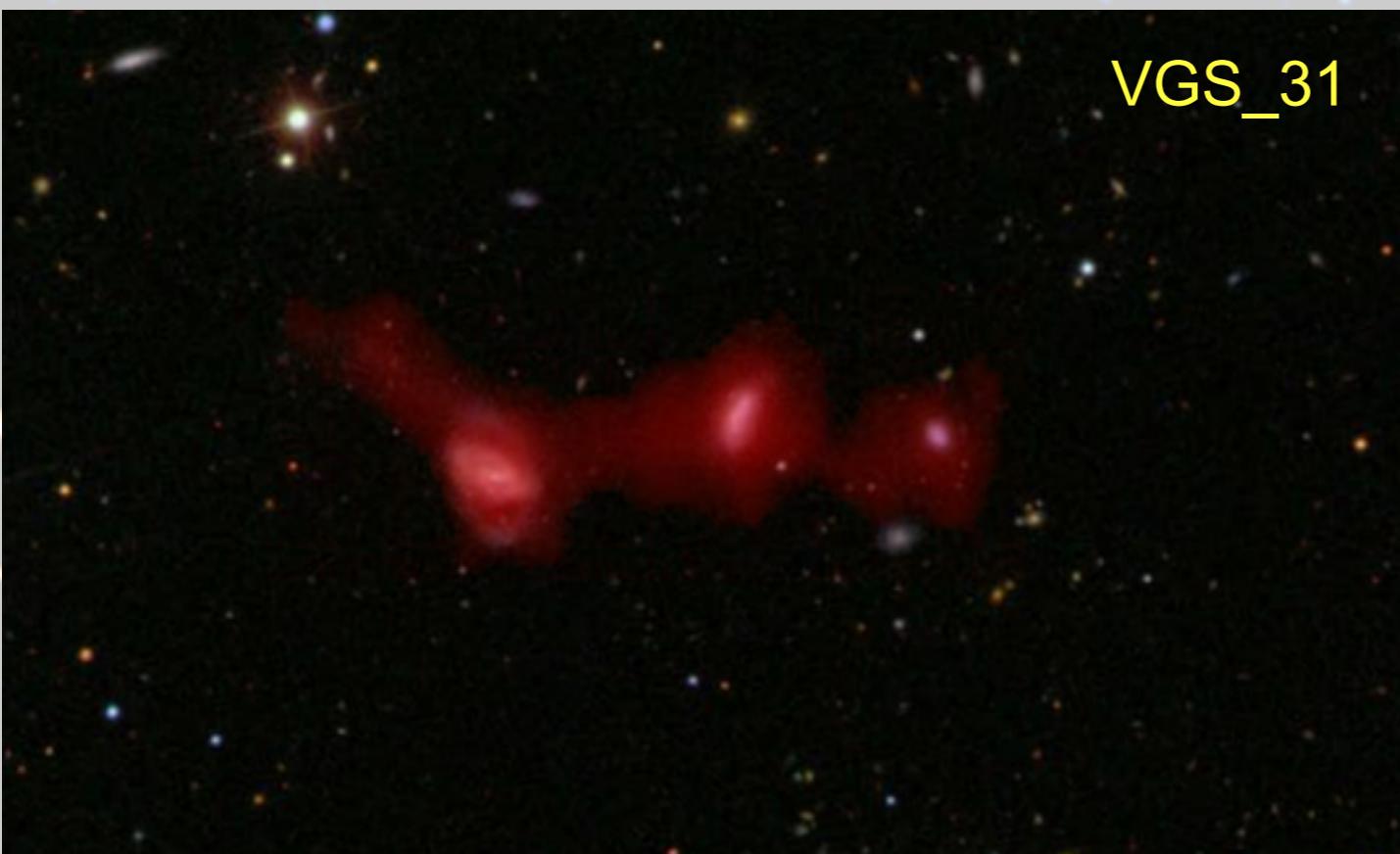
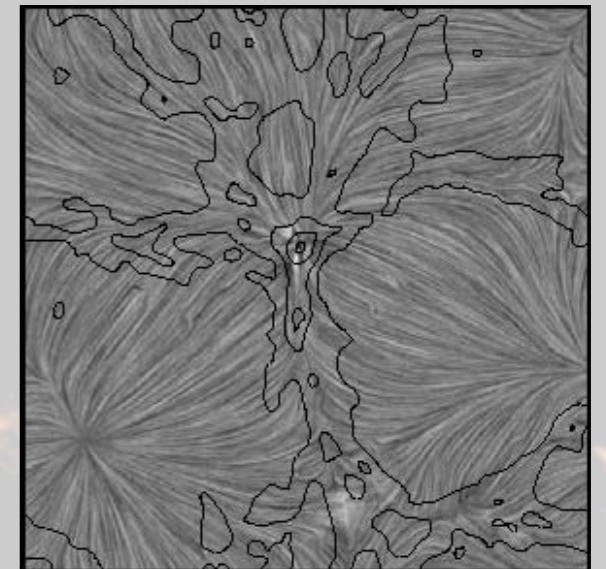
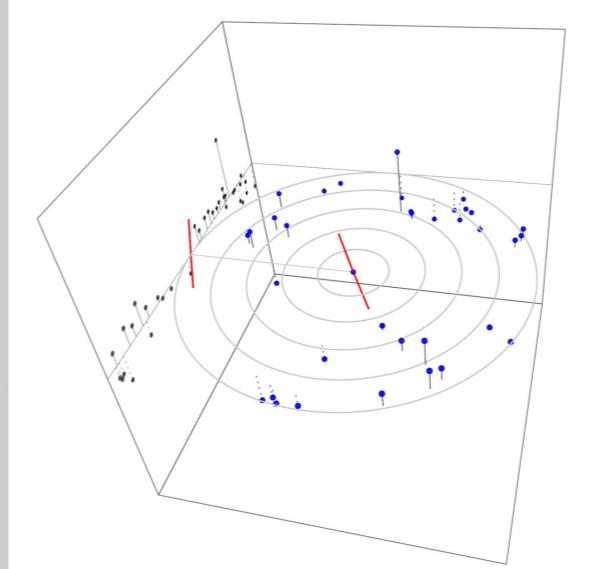
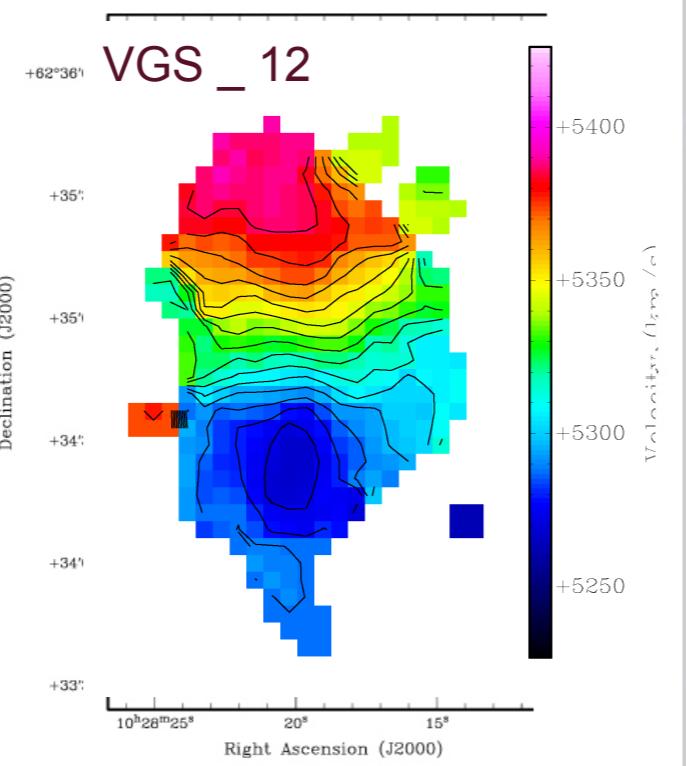
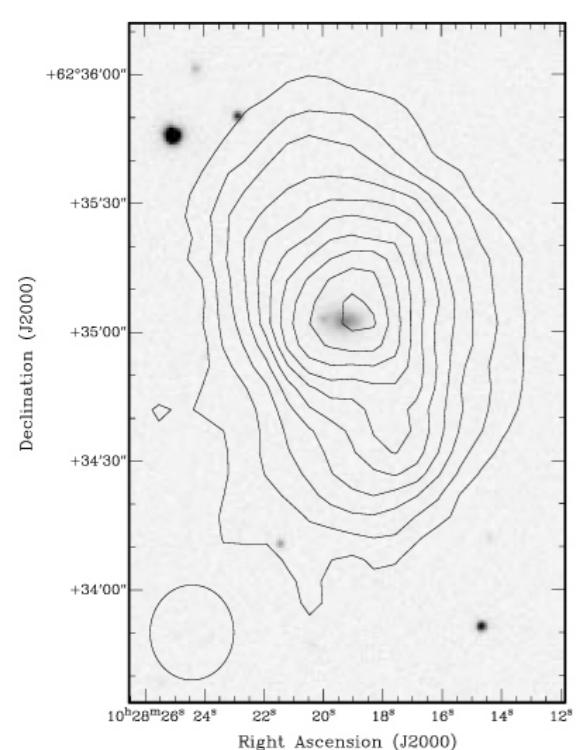
Heald et al. (in prep)

HALOGAS + HALOSTARS

Cloud	Mass	Height
1	$2 \times 10^5 M_{\odot}$	10 kpc
2	$3.3 \times 10^5 M_{\odot}$	10 kpc
3	$3 \times 10^5 M_{\odot}$	5 kpc
AC (excl #3)	$2.9 \times 10^6 M_{\odot}$	-

Galaxies in voids

(Stanonik et al. 2009, Kreckel et al. 2012, Beygu et al. 2013)



VGS_31

Huge polar disk in thin wall:
accretion in action from the
neighbouring voids?

Galaxies not different from
galaxies elsewhere: but have
systematically *small stellar mass*

Interacting group inside a void,
aligned along LSS filament?



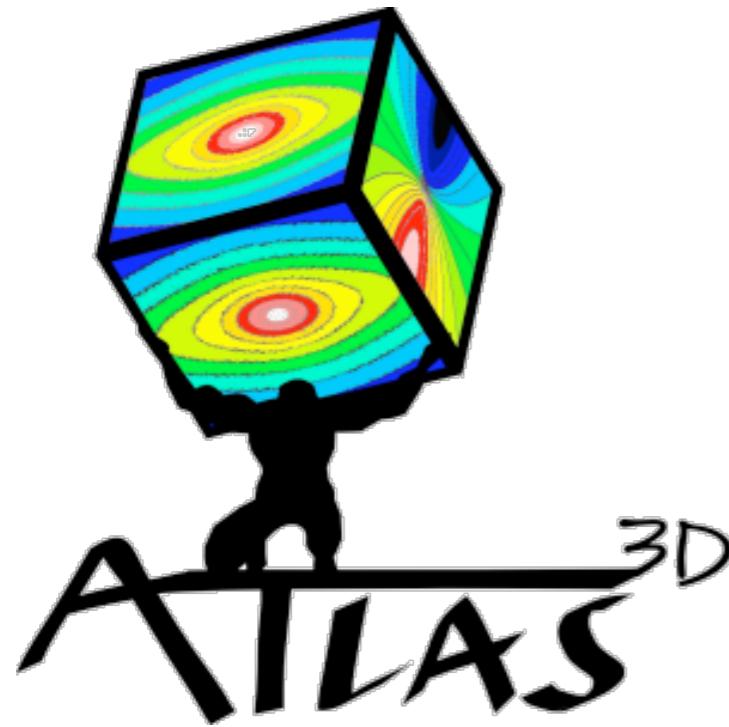
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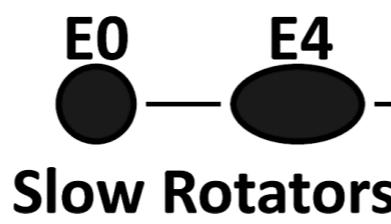


HI in early type galaxies

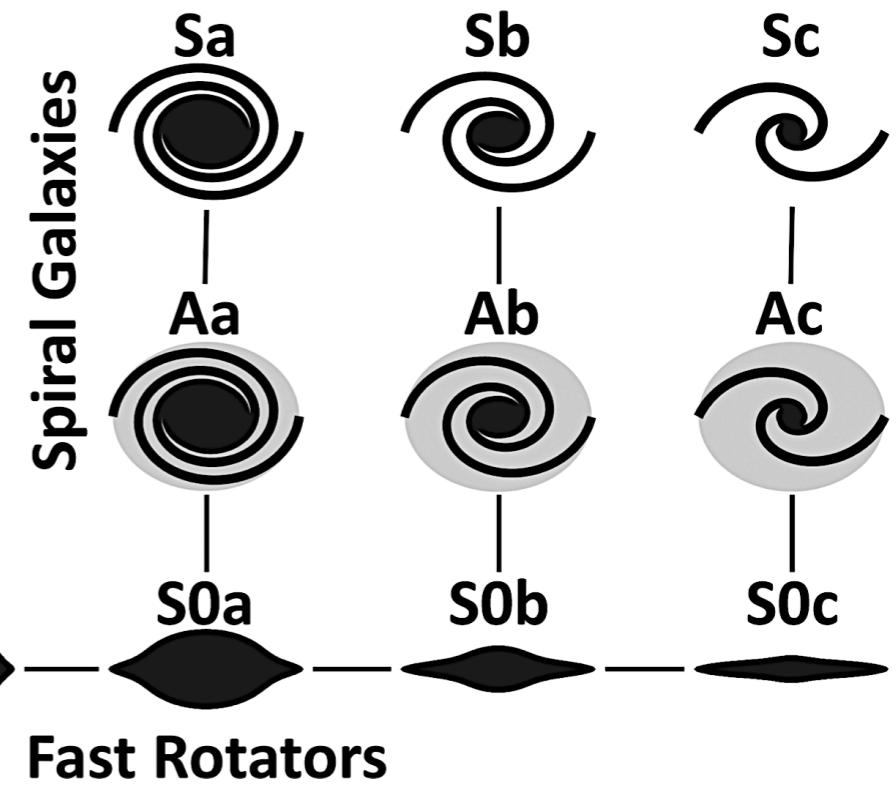
(Capellari et al. 2011, Serra et al. 2012)



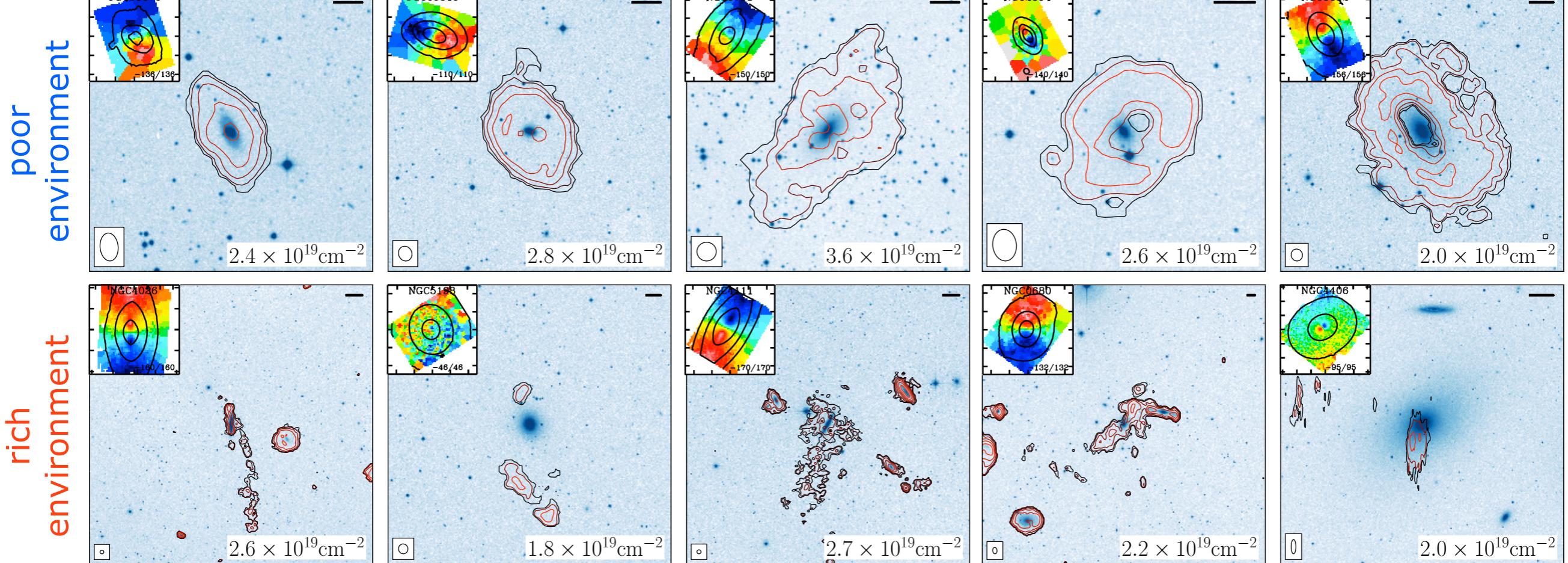
<http://purl.org/atlas3d>



Slow Rotators



Fast Rotators



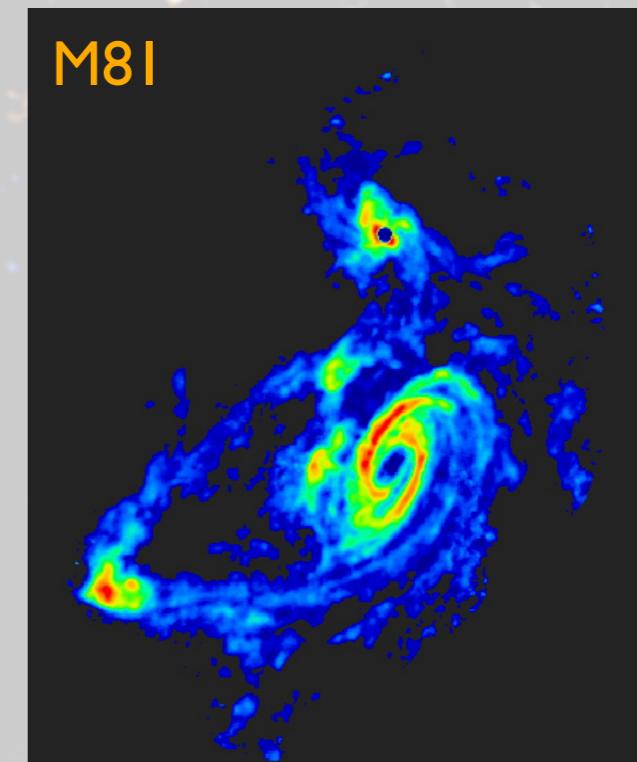
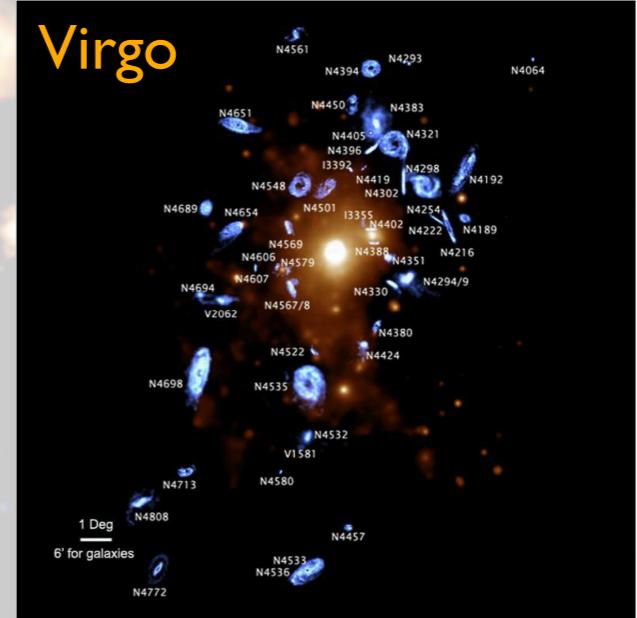
HI observations in the local universe

(Sancisi, Fraternali, Oosterloo & v.d. Hulst. 2008, A&A Rev. 15, 189)

Environment is important :

- clusters: Virgo, Coma, ...
- field: groups and filaments
- voids:

need to define environment !!

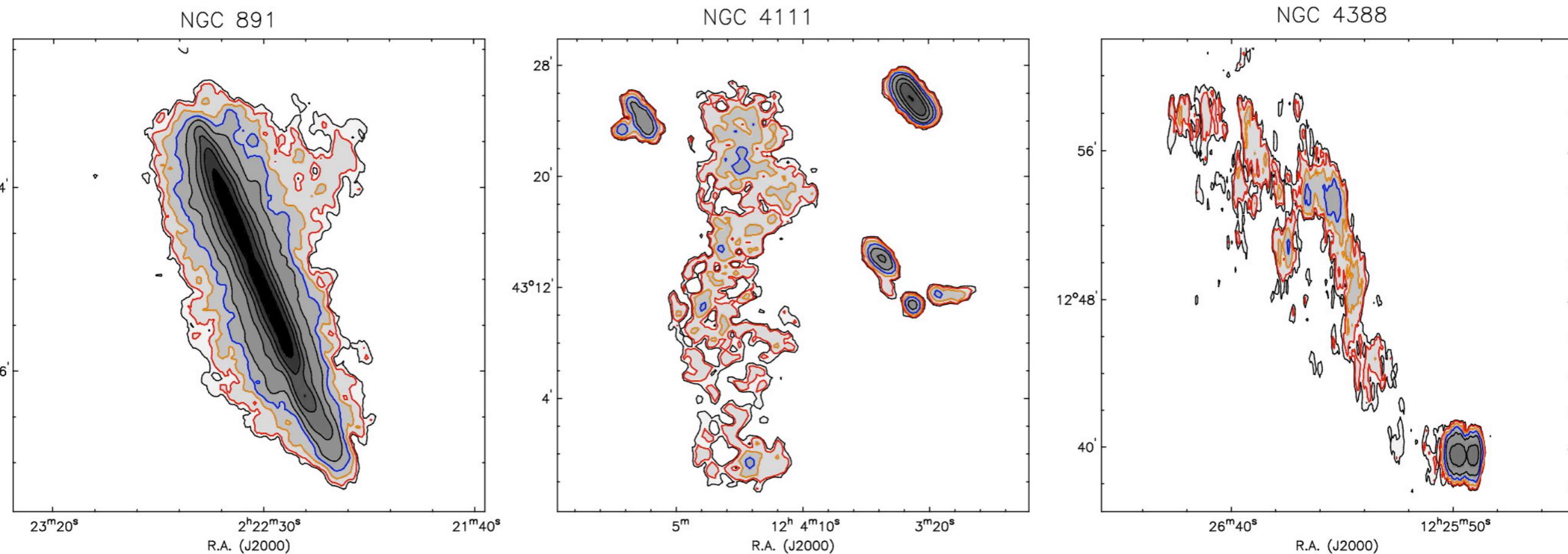


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Interesting features require N_{HI} depth



Deep integrations and low resolution
reveal large low column density structures

To find the subtle HI signatures one needs
to push to column densities of $< 10^{19}$



courtesy Marc Verheijen



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Future outlook

HII tells a lot, but need to carefully examine the signatures and combine the data with modelling

Future surveys with APERTIF, ASKAP and MeerKAT will provide key information

WSRT
APERTIF



ASKAP



wide area surveys + small area medium deep and deep surveys



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thank you



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