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Tracing the outer edges of galaxy disks

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
GalaxyZoo – 26 September 2013





The **H_I 21-cm spectral line** reveals the

- structure & kinematics of galaxy disks,
- nodes of star formation in the outer disk,
- signatures of tidal interactions, accretion and ram pressure stripping.

The Spiral Galaxy NGC 6946



*Evolutionary Paths in
Galaxy Morphology*

We need

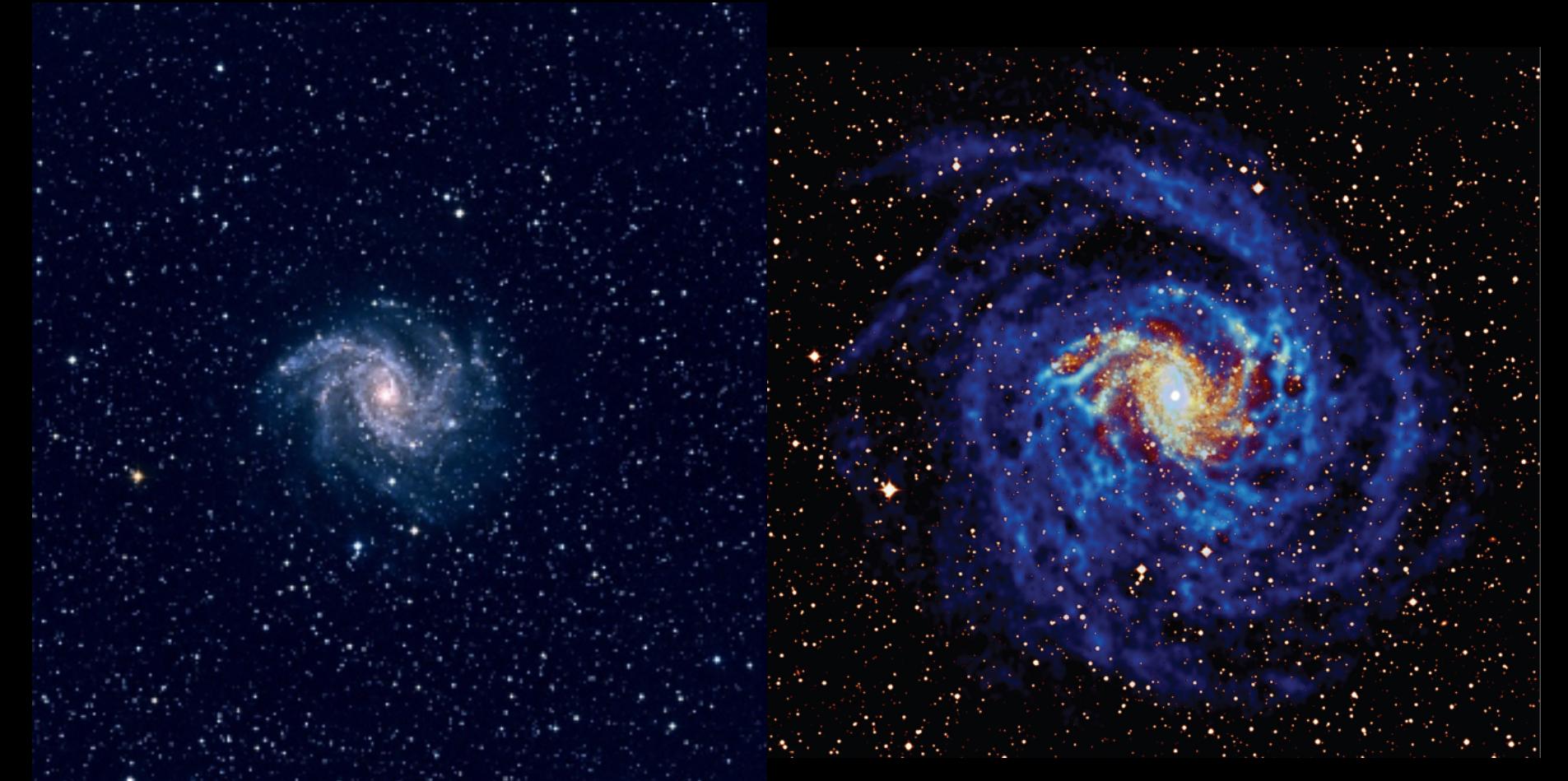
- *multi-wavelengths observations to study*
- *the morphology and kinematics of galaxies*
- *complemented by theory & simulations*

The Spiral Galaxy NGC 6946



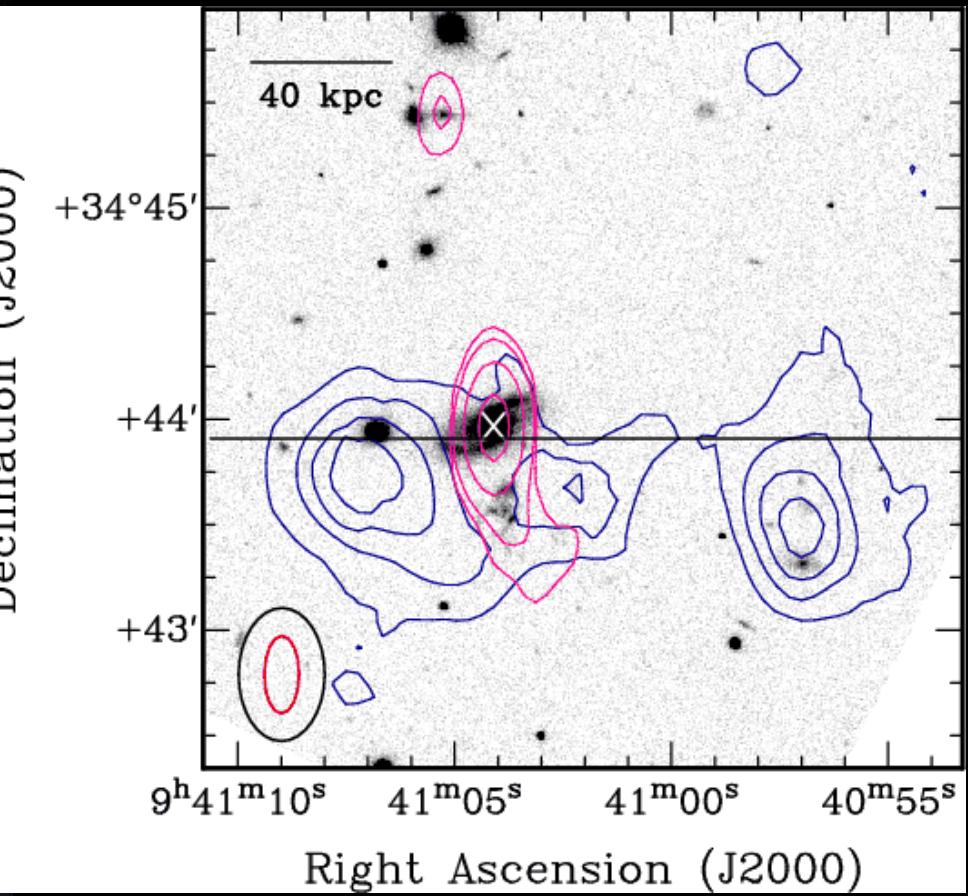
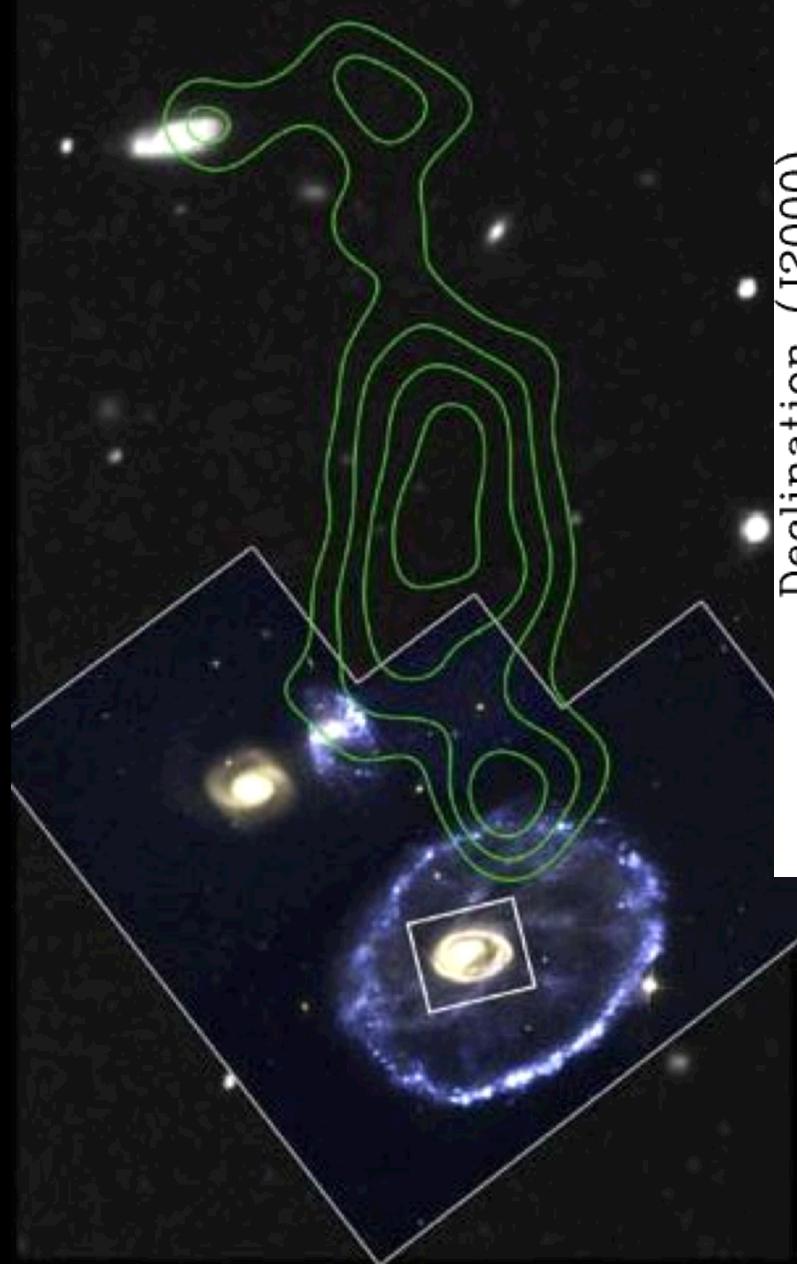
Boomsma et al. 2008

The Spiral Galaxy NGC 6946



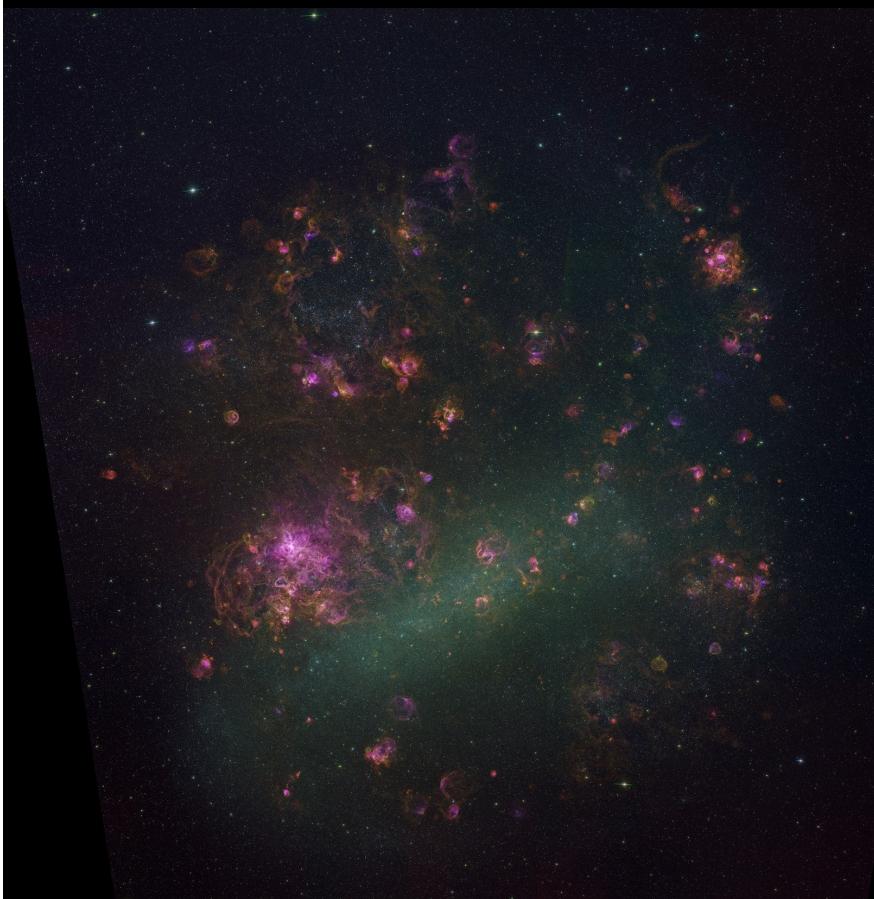
Boomsma et al. 2008

Higdon 1996



Jozsa et al. 2009

The Large Magellanic Cloud (LMC)

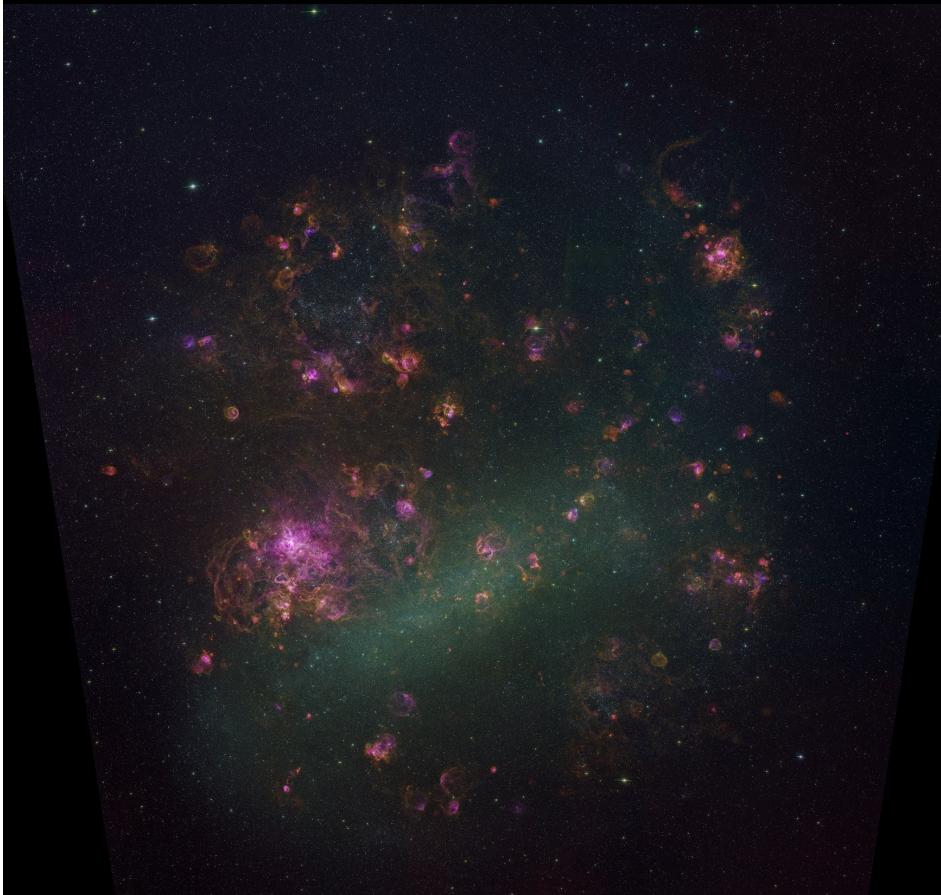


Stars & ionised gas
(Smith; CTIO)



Neutral Hydrogen
(Kim et al. 1999; ATCA)

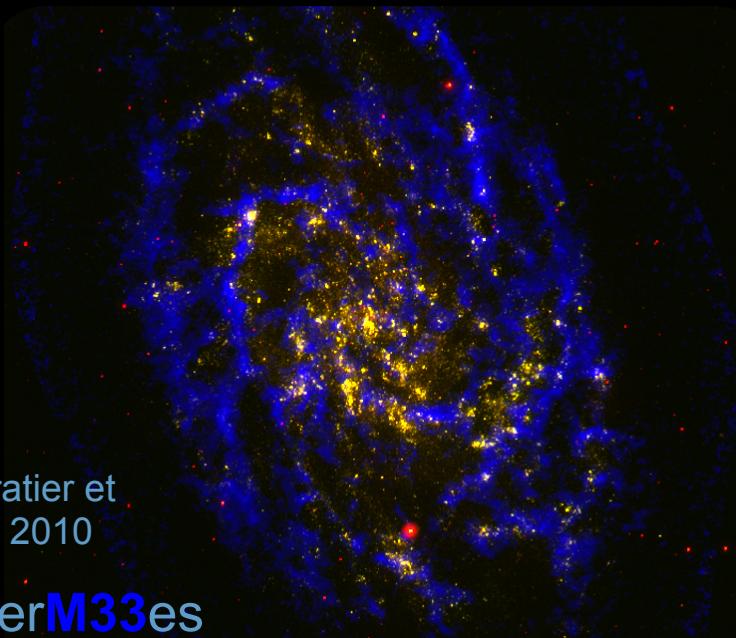
The Large Magellanic Cloud (LMC)



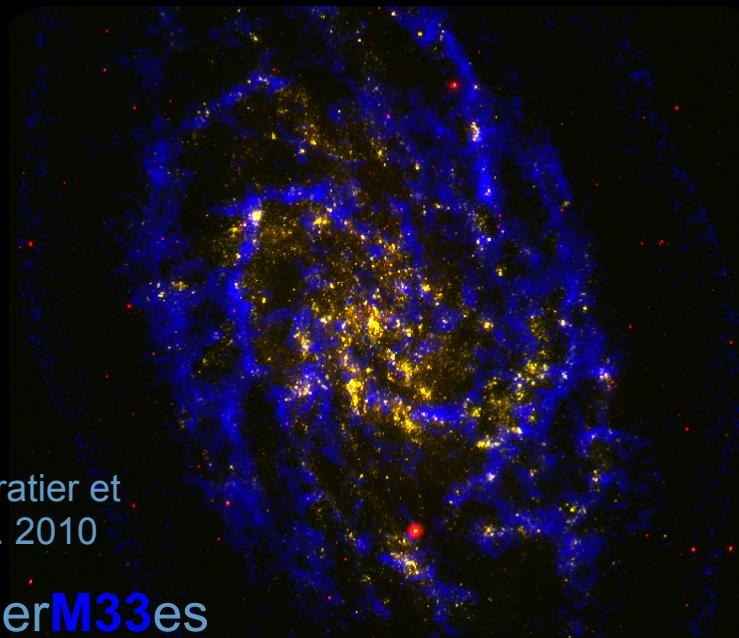
Stars & ionised gas
(Smith; CTIO)

Neutral Hydrogen
(Kim et al. 1999; ATCA and Parkes)

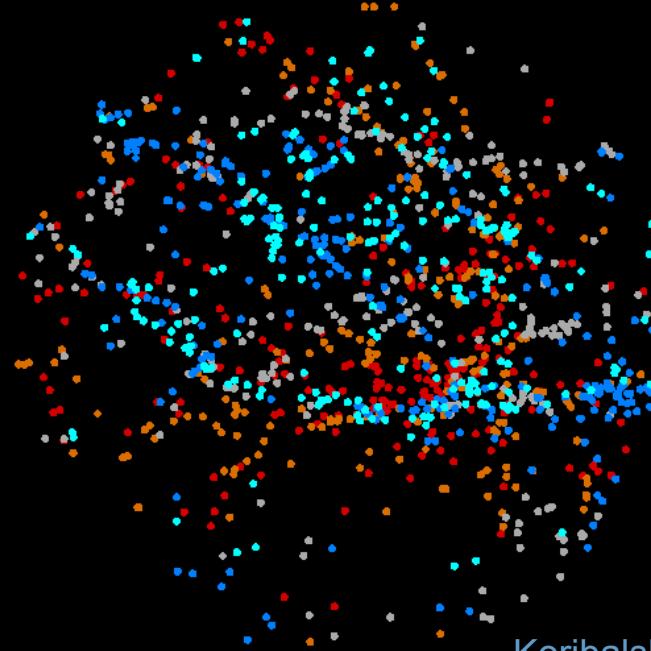
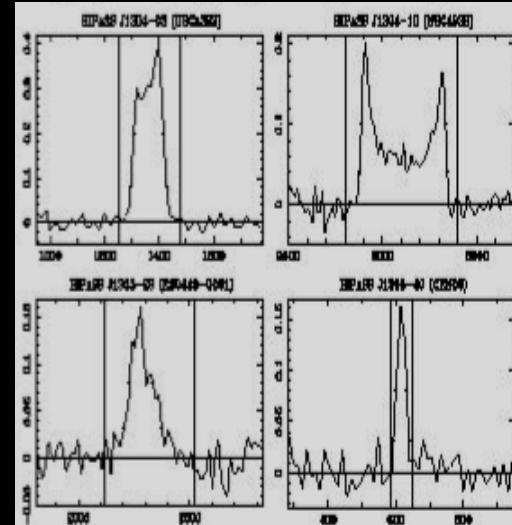
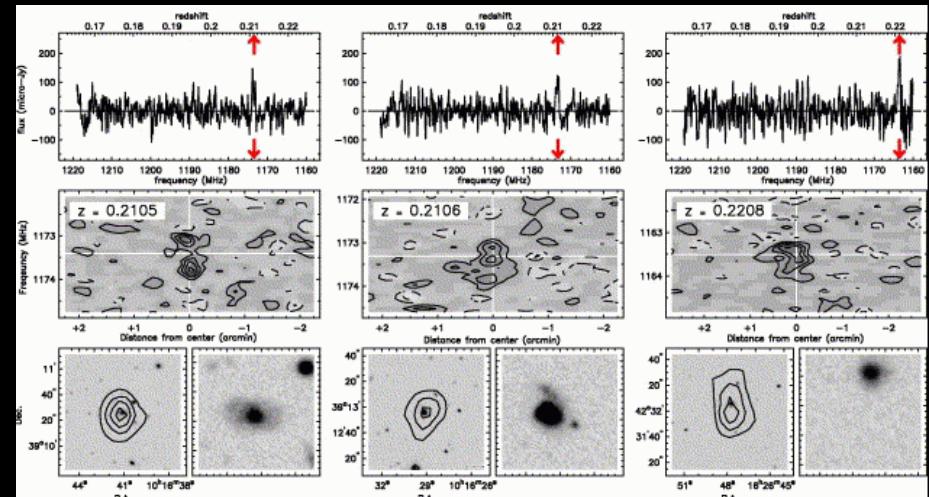
H_I in Galaxies: from z = 0



HI in Galaxies: from $z = 0$ to 0.25

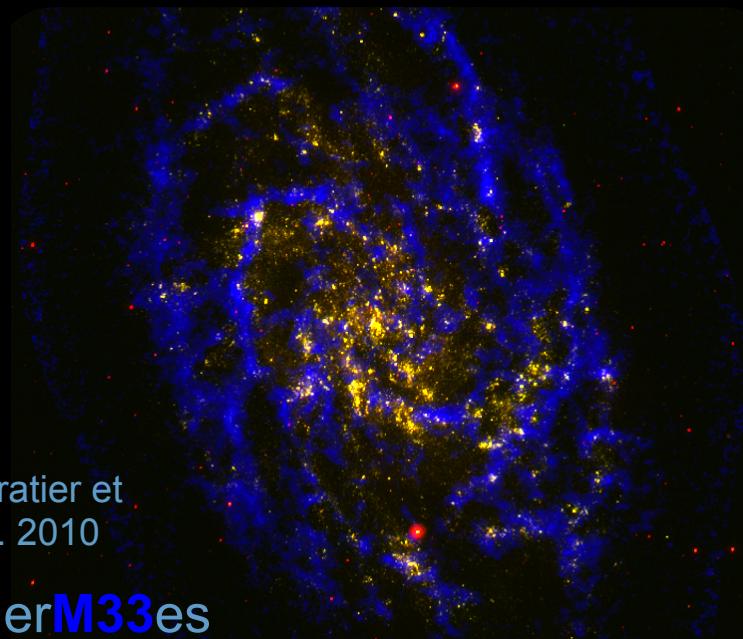


HerM33es



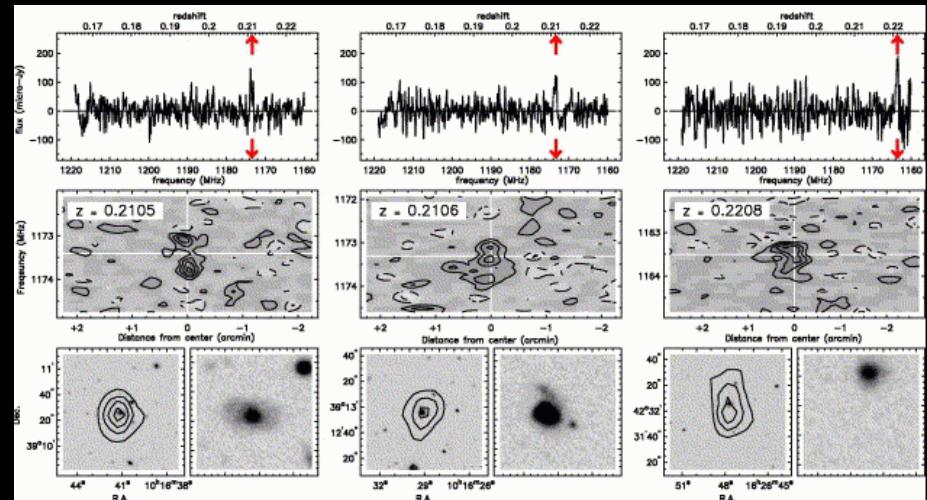
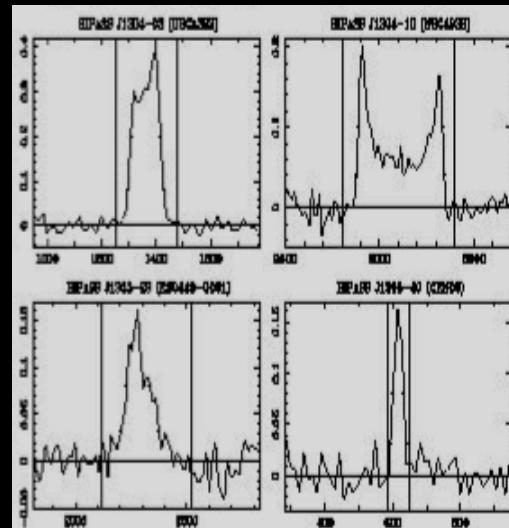
Koribalski et al. 2004
HIPASS BGC

HI in Galaxies: from $z = 0$ to 0.25



Gratier et
al. 2010

HerM33es



Verheijen et al. 2007

Currently $\approx 35\,000$ HI detected galaxies:

- Cornell archive contains HI spectra towards 9 000 optically selected galaxies; ALFALFA 40% catalog contains about 15 000 galaxies
- HIPASS & HIZOA catalogs from Parkes HI surveys contain $>6\,500$ HI-detected galaxies

SKA Pathfinder HI Surveys:

- predicted $\approx 600\,000$ HI detected galaxies from WALLABY + WNSHS ($z < 0.25$)

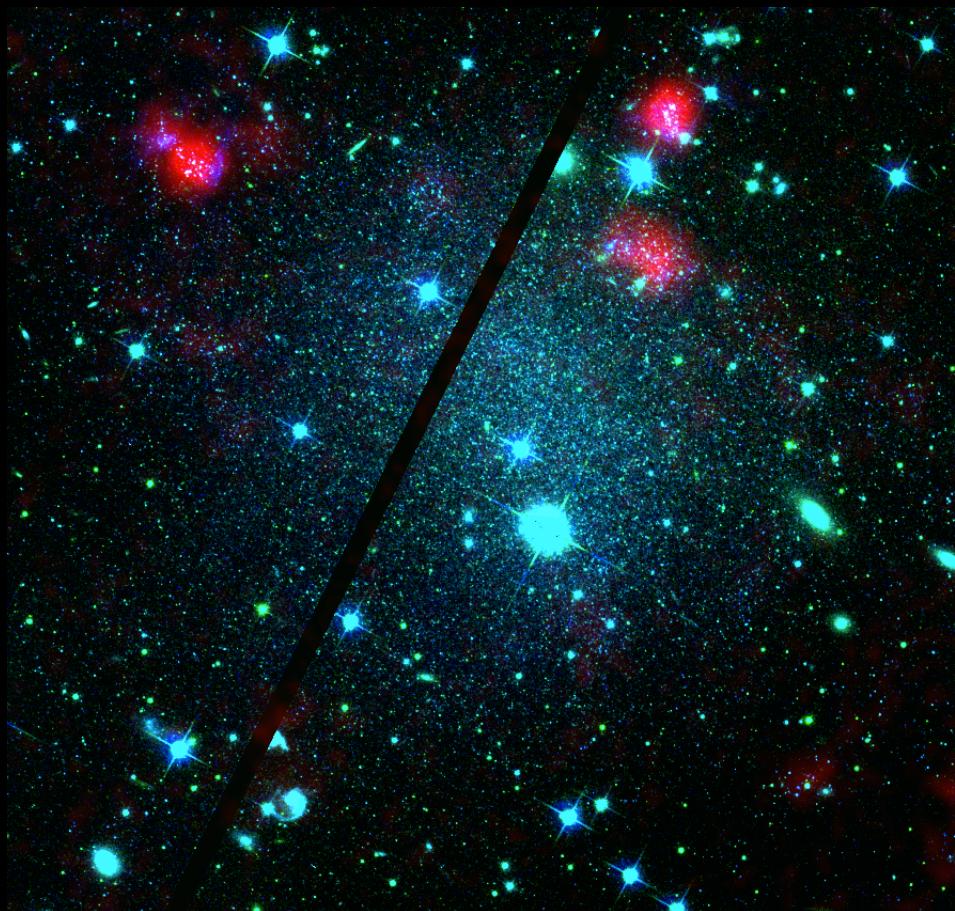
Square Kilometer Array:

- detect Milky Way like galaxy at $z=1$ (de Liski et al. 2004)

HIPASS BGC

Gas dynamics and star formation in ESO215-G?009

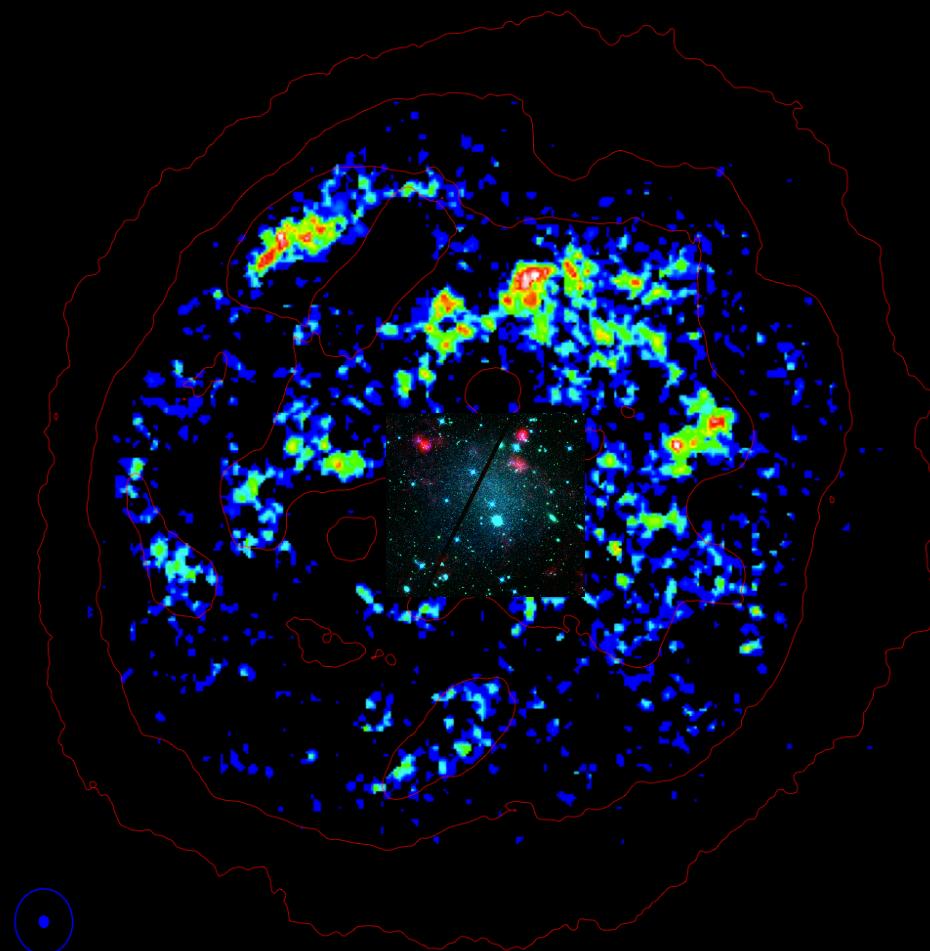
30" =
500 pc



HST (V + I), GALEX

Warren & Koribalski, in prep.

Gas dynamics and star formation in ESO215-G?009



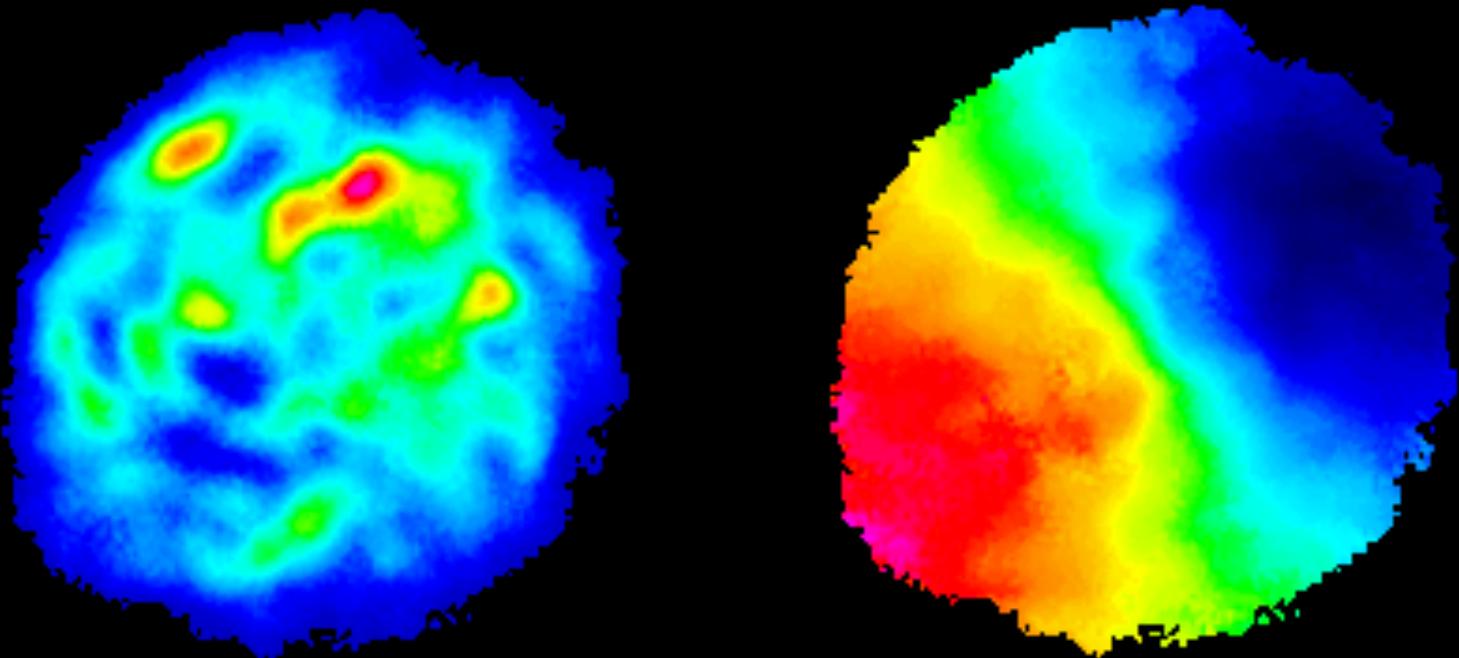
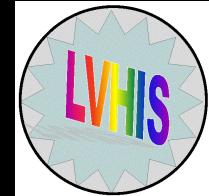
ATCA HI distribution

Warren & Koribalski, in prep.



ESO 215-G?009

(Warren, Jerjen & Koribalski 2004)

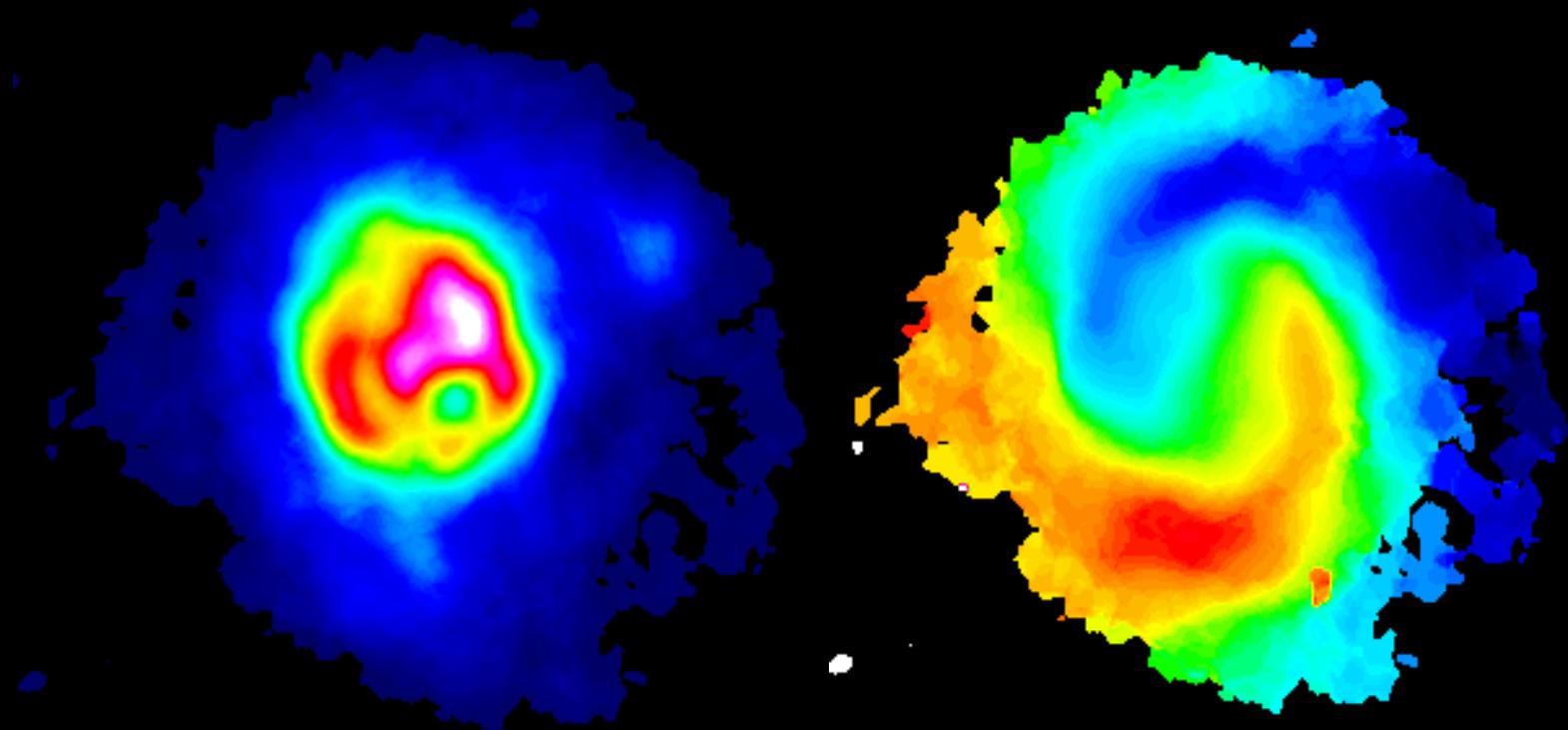


HIPASS J1057-48 $D_{\text{TRGB}} = 5.25 \text{ Mpc}$ HI diameter $\approx 12'$ (18 kpc)



ESO 223-G009

(Koribalski et al. 2013)



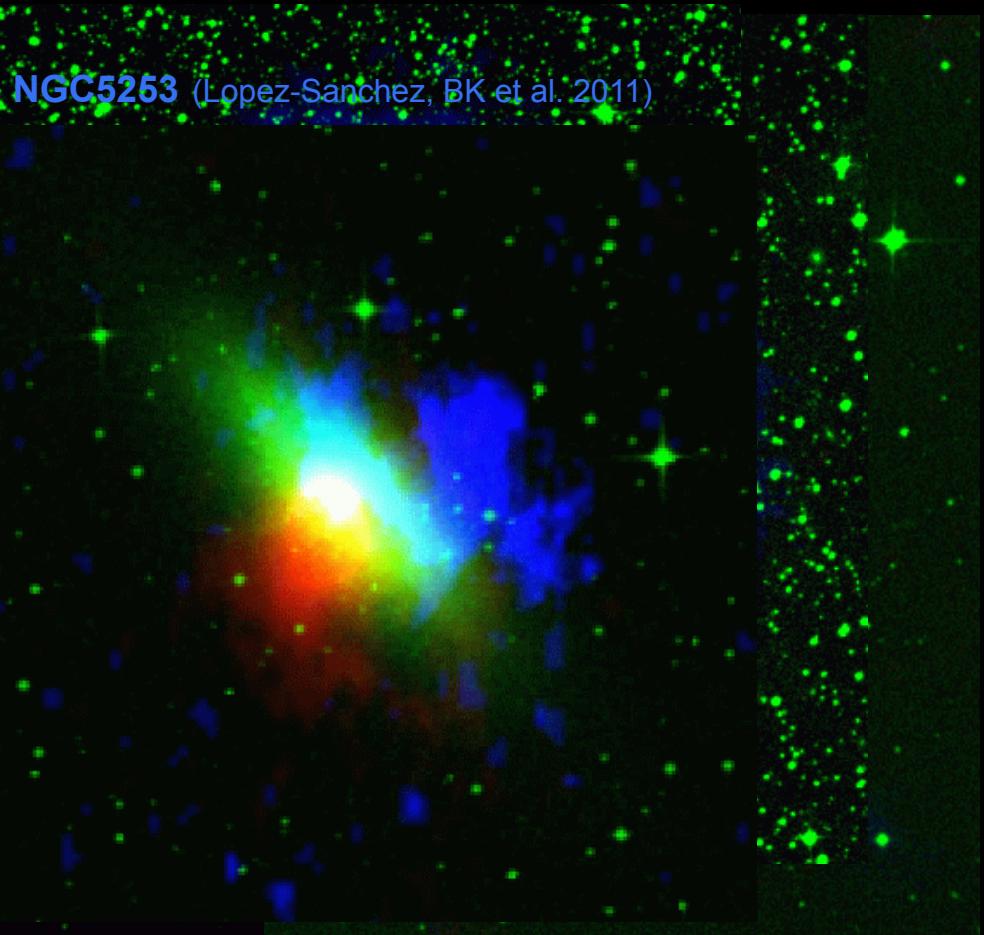
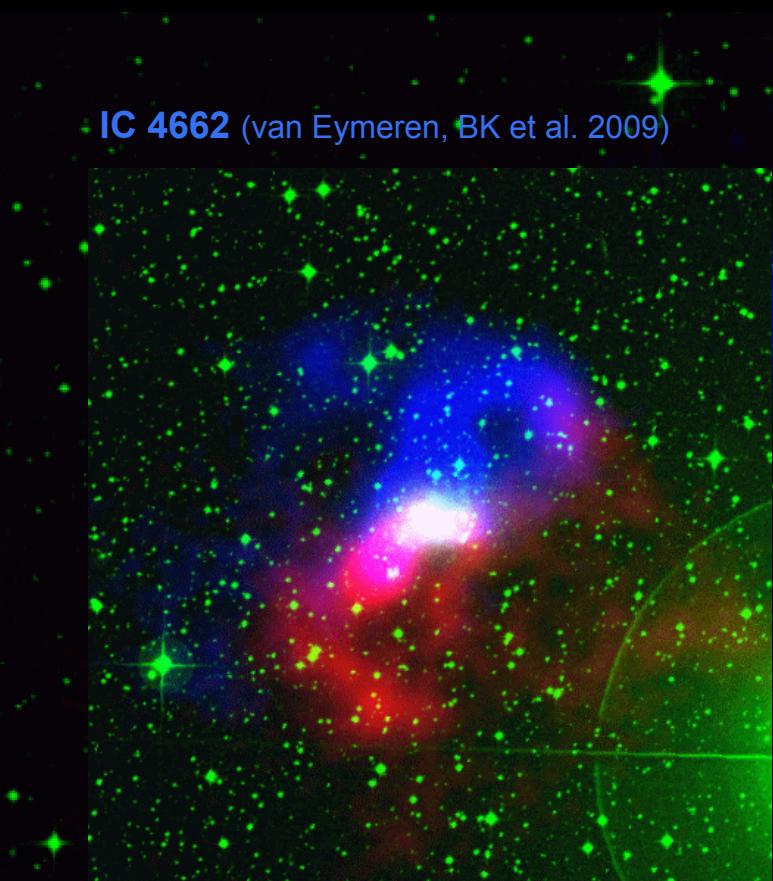
HIPASS J1501-48

$D_{\text{TRGB}} = 6.17 \text{ Mpc}$

$M_{\text{HI}} = 8.4 \times 10^8 M_{\odot}$

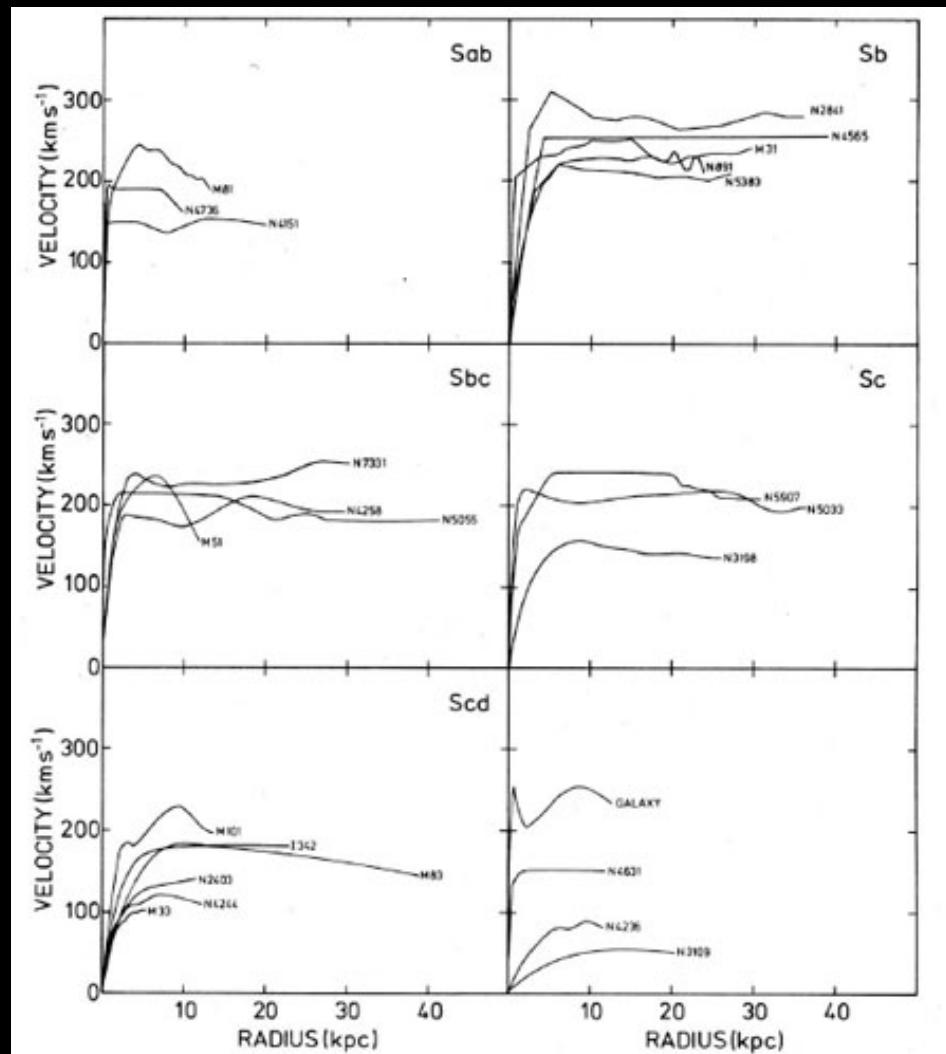
HI Galaxy Dynamics

IC 4662 (van Eymeren, BK et al. 2009)

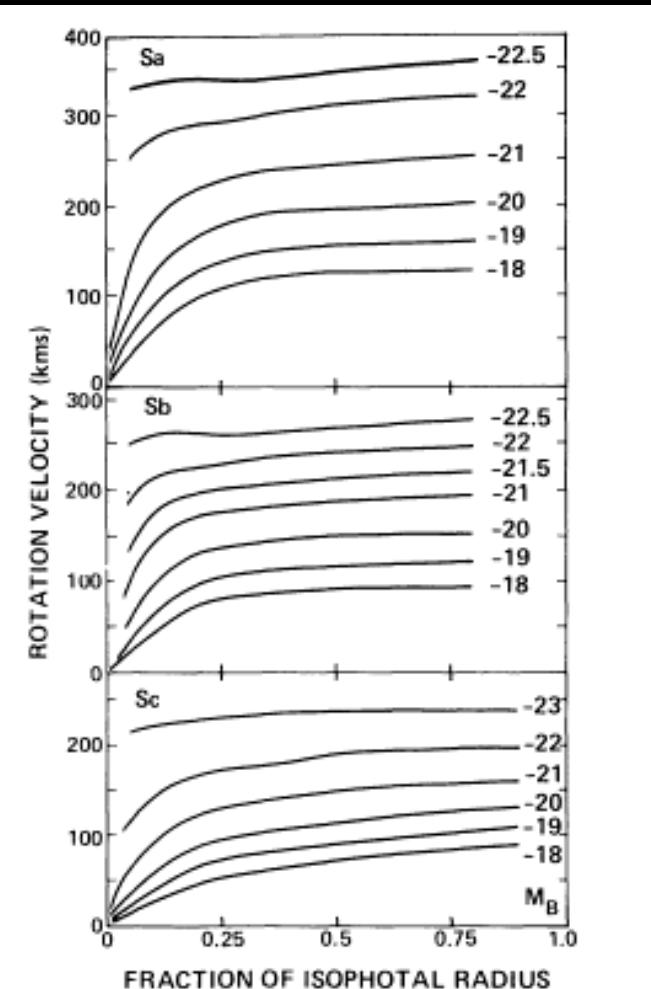


LVHIS galaxies (gas + stars)

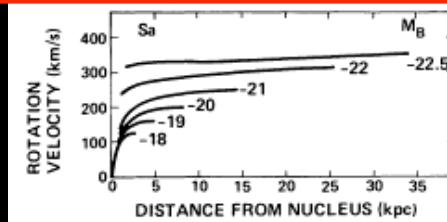
Galaxy Rotation Curves

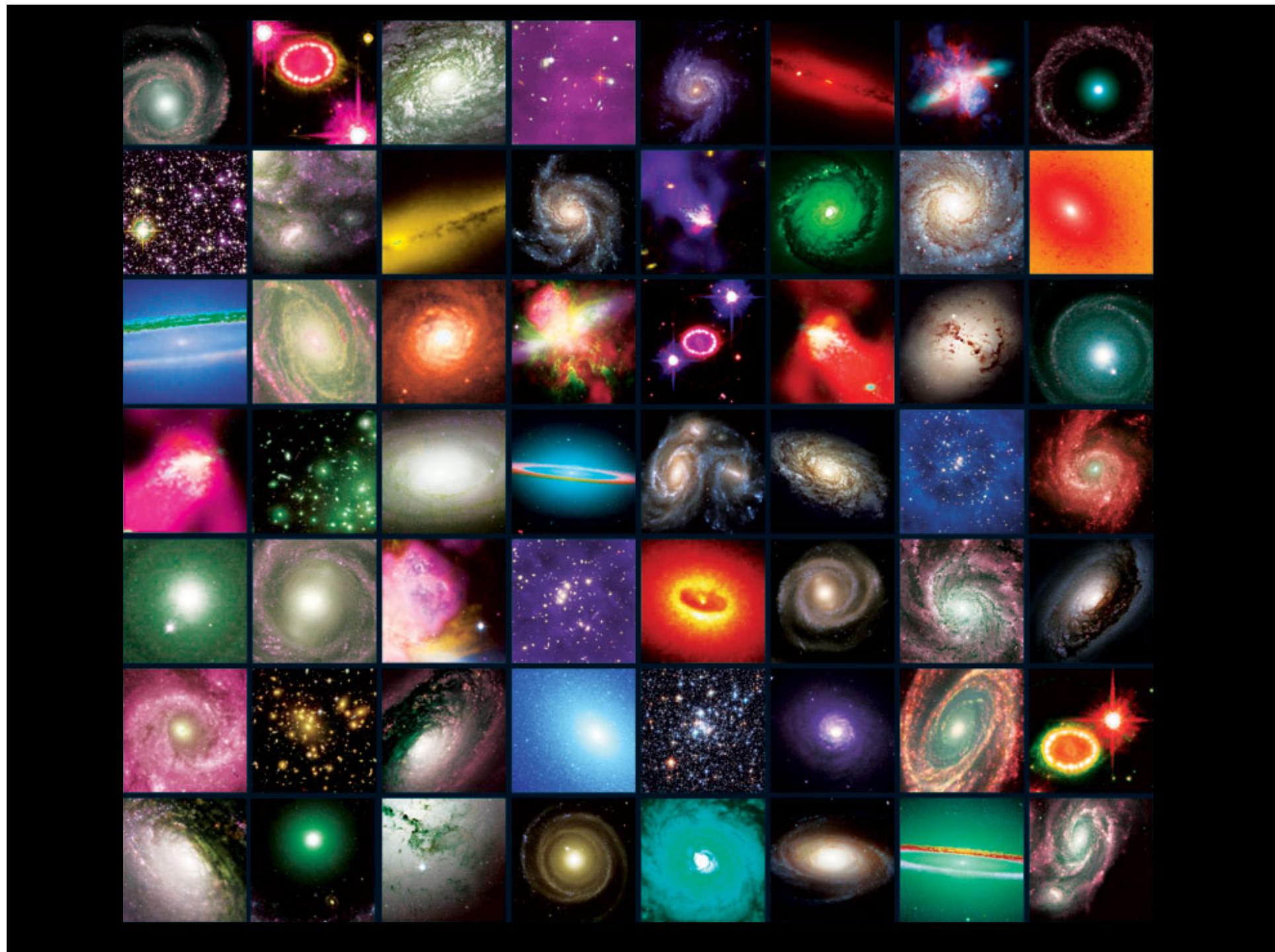


Bosma et al. 1982

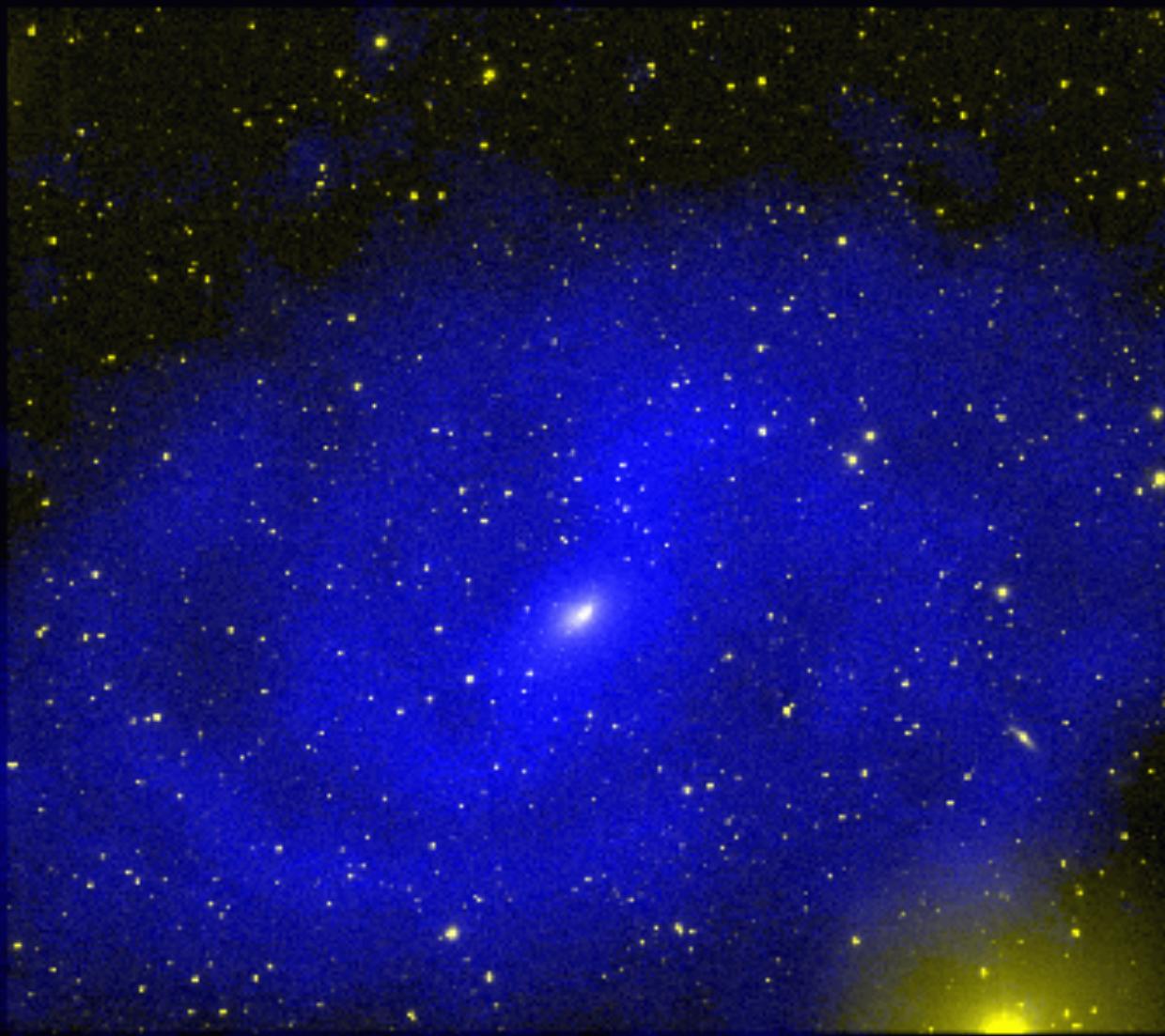


Rubin et al. 1985



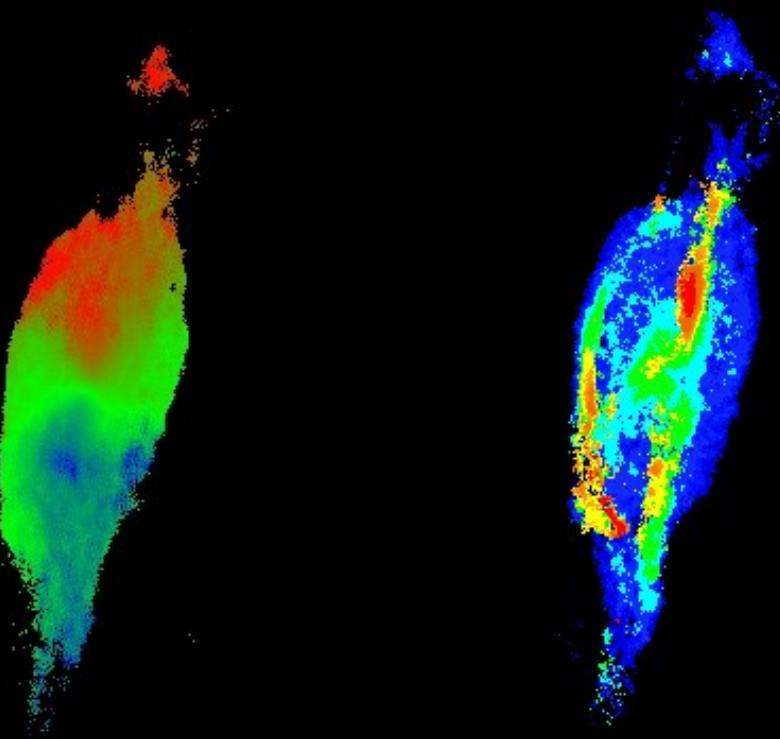
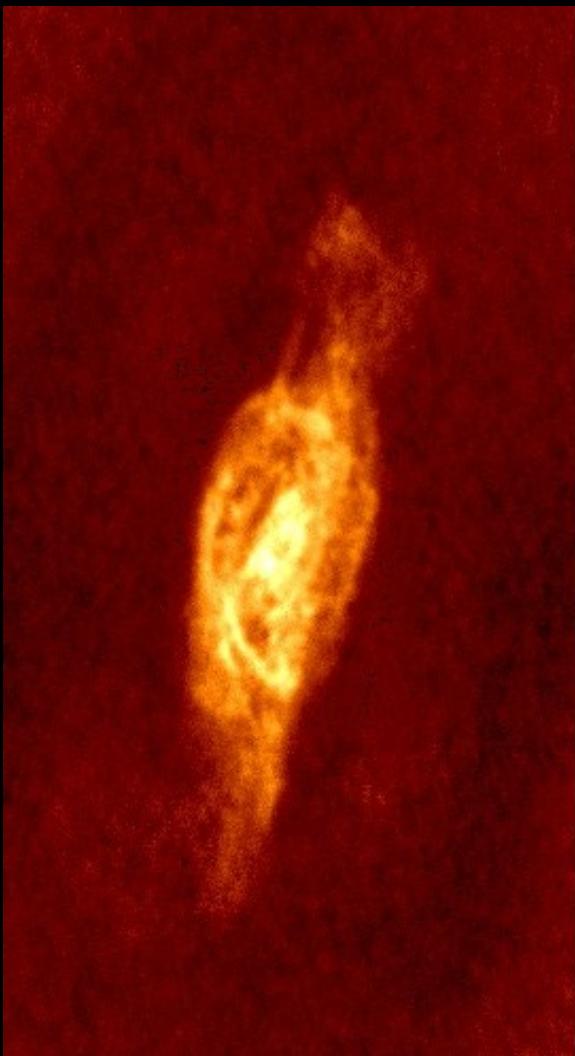


The Blue Compact Dwarf (BCD) Galaxy NGC 2915



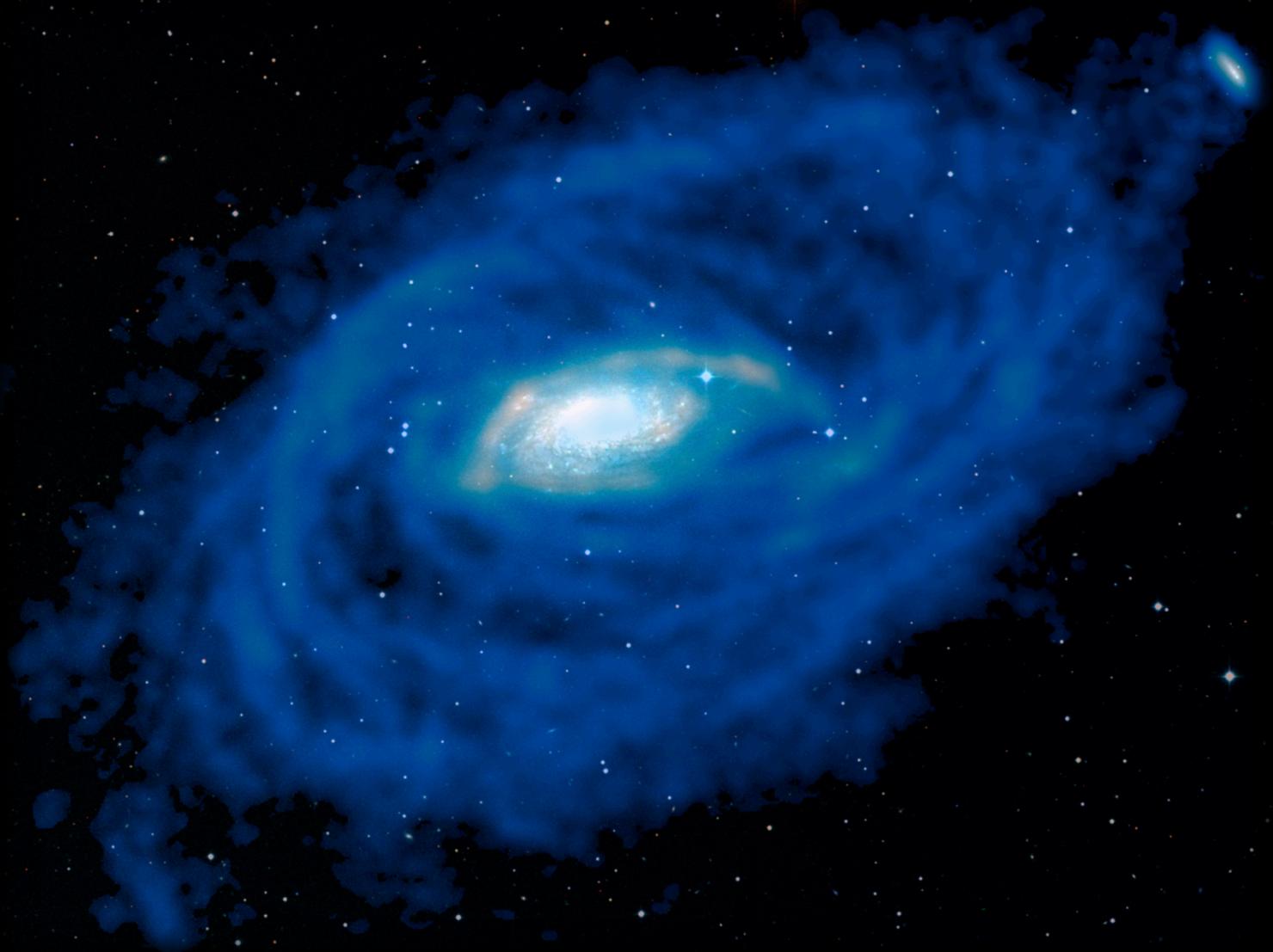
Meurer et al. 1996

The Spiral Galaxy NGC 3621



Walsh et al.; Koribalski et al. 2013

The Spiral Galaxy NGC 5055



Patterson et al. 2011

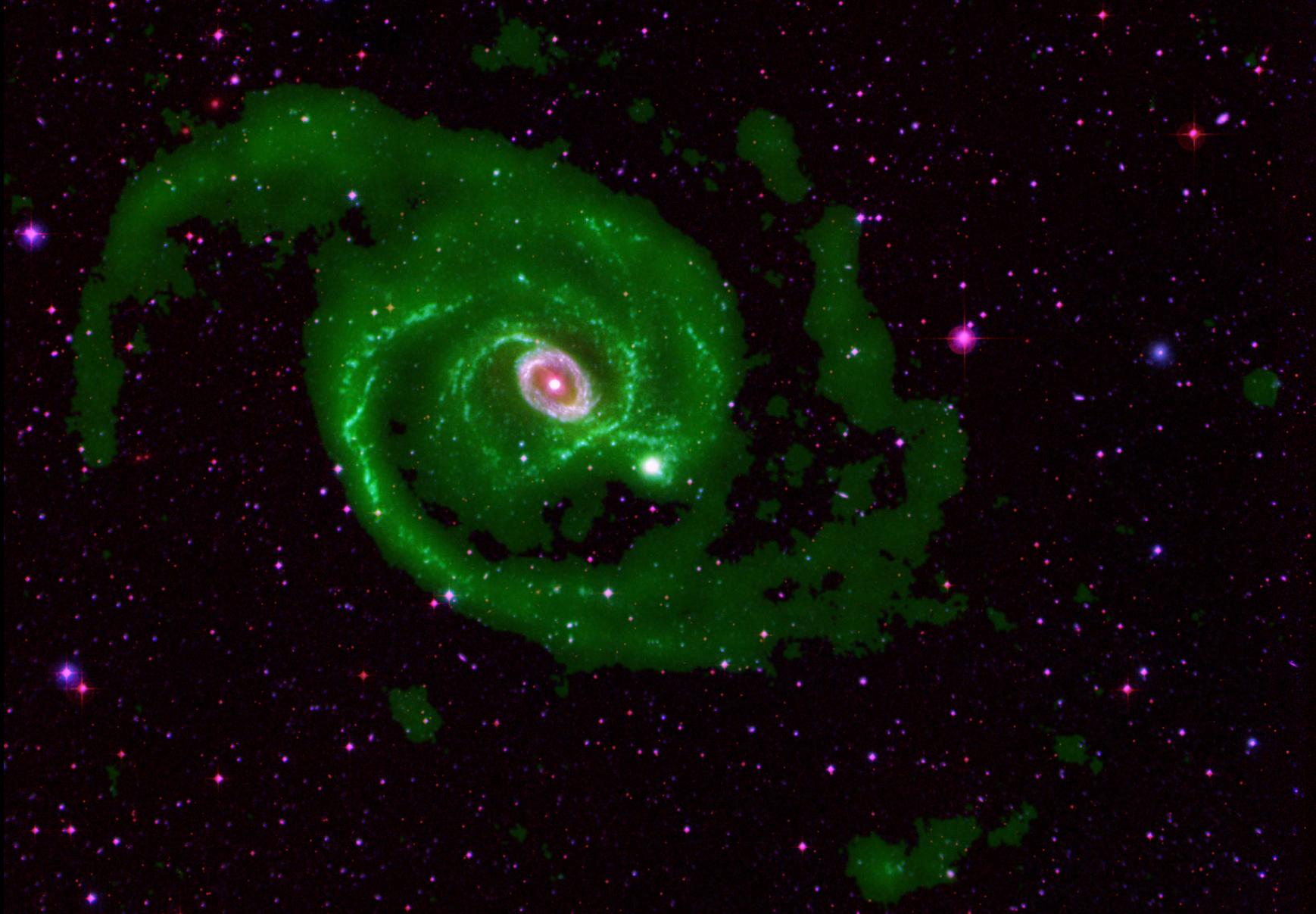
The Sculptor Group Spiral Galaxy NGC 300



Westmeier et al. 2011

NGC 1512 / 1510 (Koribalski & Lopez-Sanchez 2009)

5'
13.8 kpc

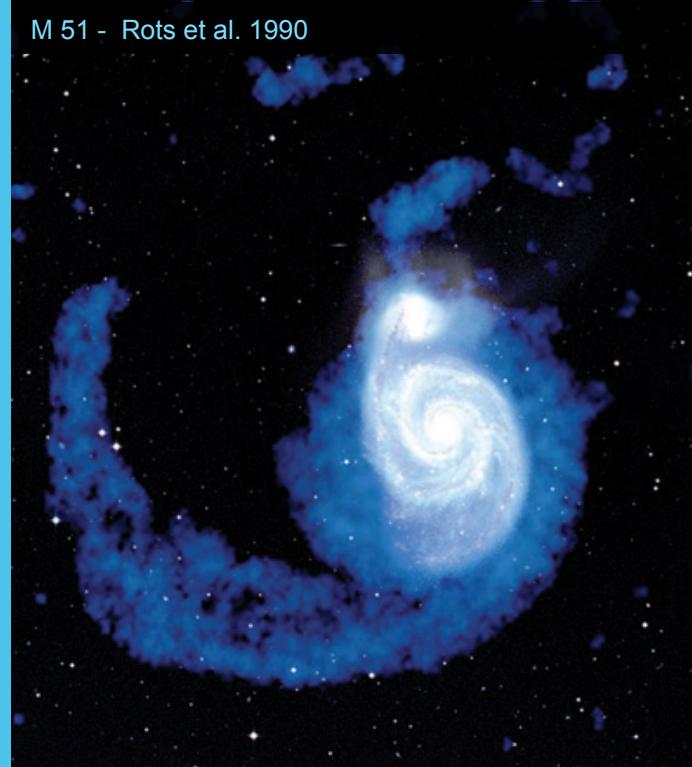
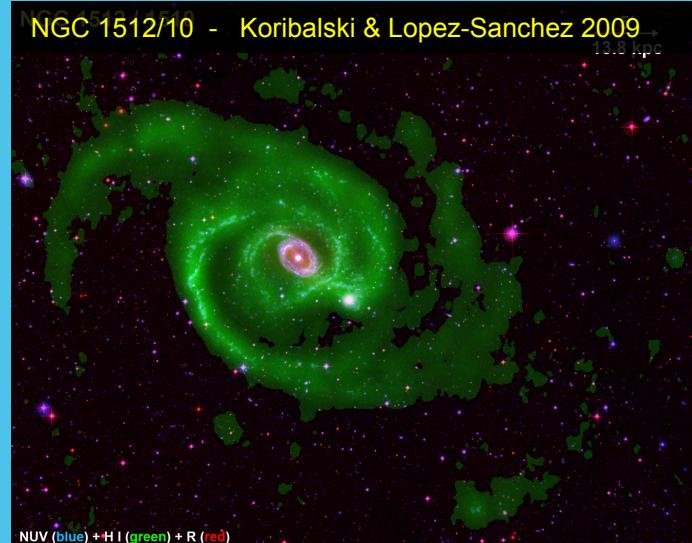


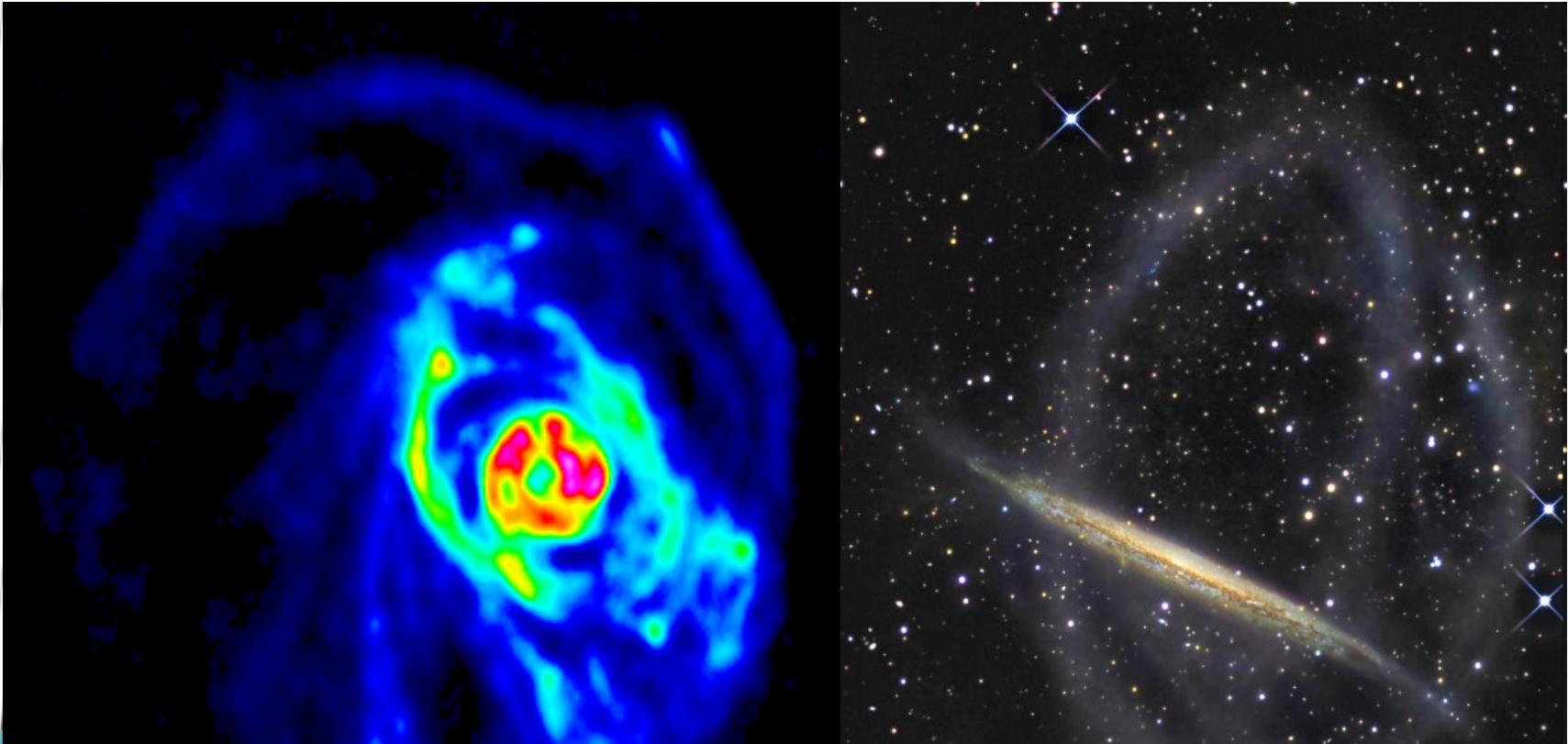
NUV (blue) + B (green) + R (red)

Individual Galaxies

The HI 21-cm spectral line reveals

- the radial extent of galaxies
- rotational velocity & total mass
- dark matter content
- extraplanar gas & environment
- star formation in the outer disk
- tidal tails, plumes & filaments





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The Local Volume HI Survey (LVHIS)

Dr. Bärbel Koribalski
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The Local Volume ($D < 10$ Mpc)

Aim: a census of the LV galaxies (550+)

study in all wavelengths (HI, CO, H α ; optical, IR, UV imaging, radio continuum, ...) on all scales, derive scaling relations, etc.

Focus: HI observations (~300+ galaxies)

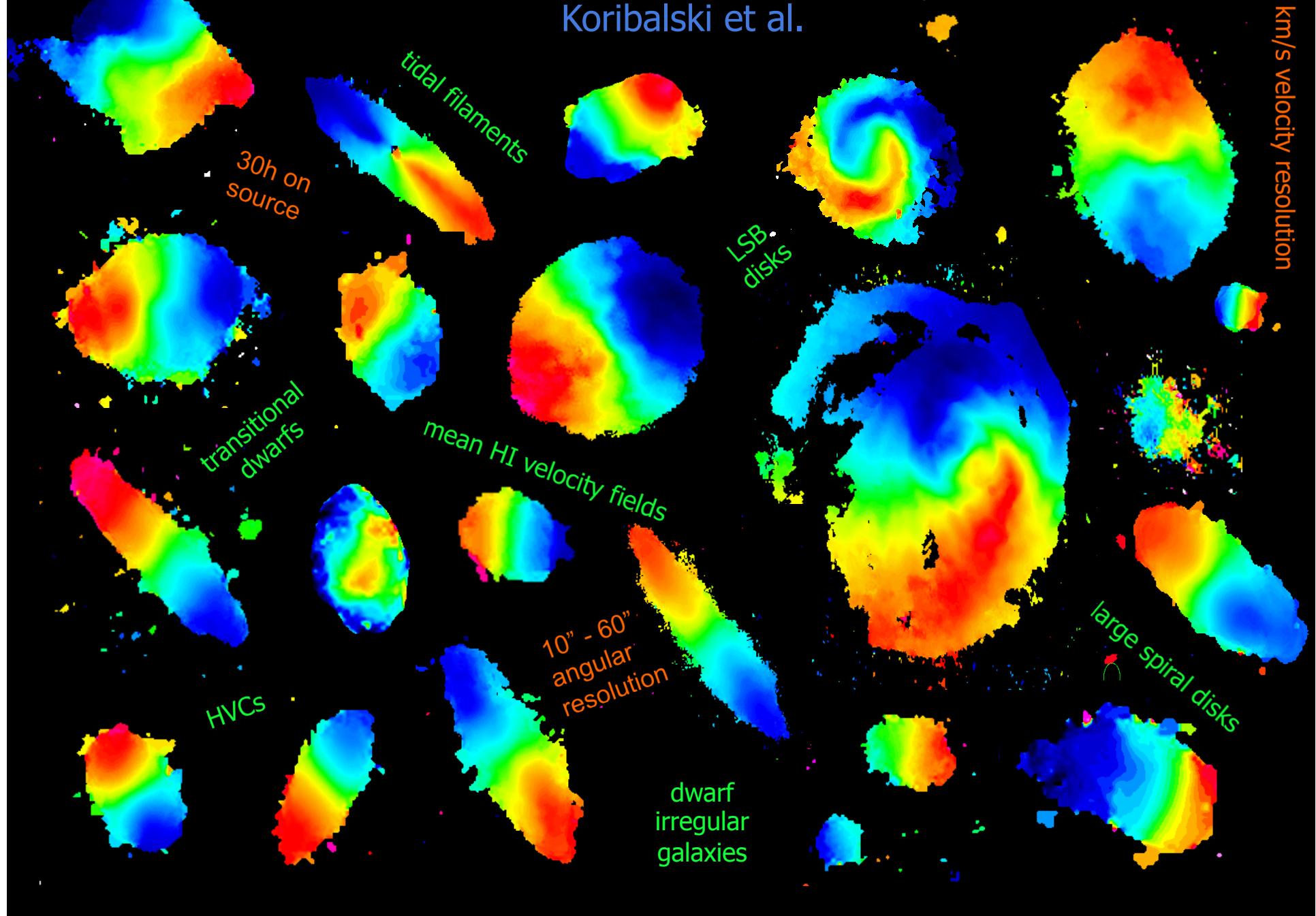
ATCA-LVHIS (80), THINGS (30), Little THINGS (42), FIGGS (60), VLA-ANGST (29), WHISP, WSRT-LVHIS (20+), HALOGAS, BlueDisks, ... and in future: WALLABY

Essential: accurate distances !

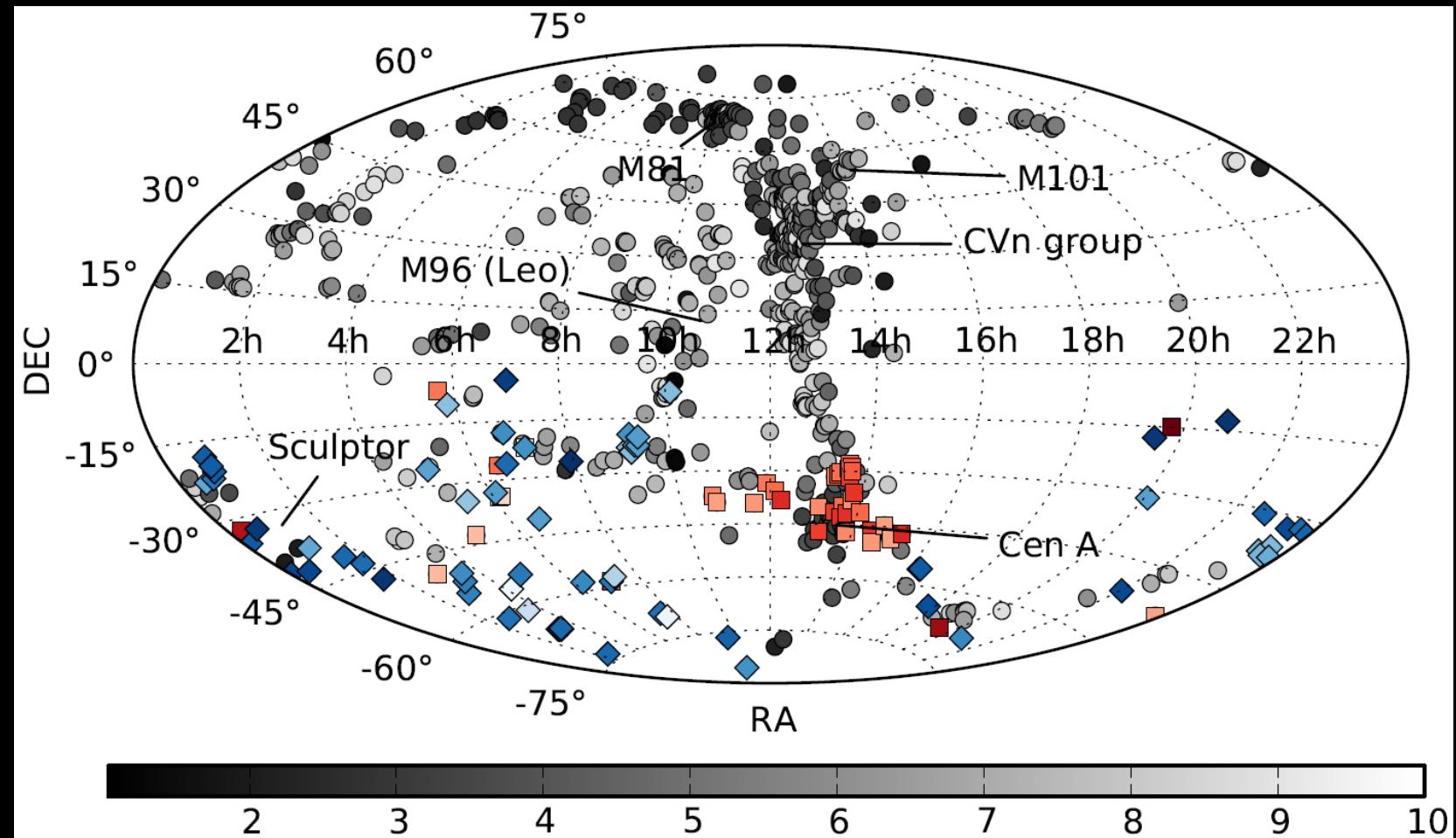
[www.atnf.csiro.au / research / LVHIS](http://www.atnf.csiro.au/research/LVHIS)

The Local Volume HI Survey (LVHIS)

Koribalski et al.



The Local Volume HI Survey (LVHIS)



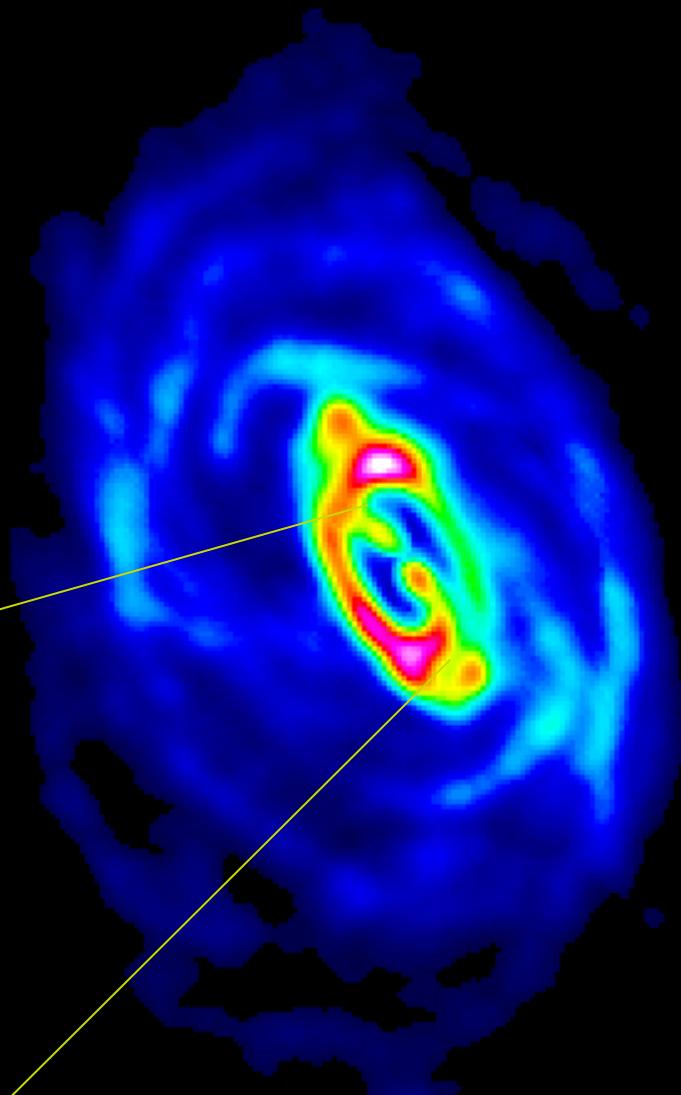
Deep H-band survey: see poster by Tye Young et al.

The Circinus Galaxy (HIPASS J1413-65)

= one of the largest nearby galaxies



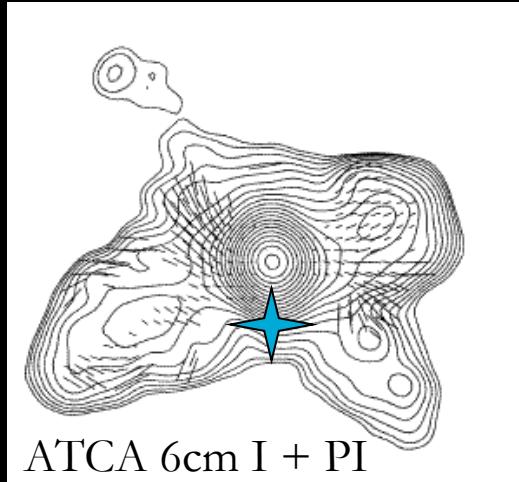
2MASS infrared



ATCA HI distribution

The Circinus Galaxy (HIPASS J1413-65)

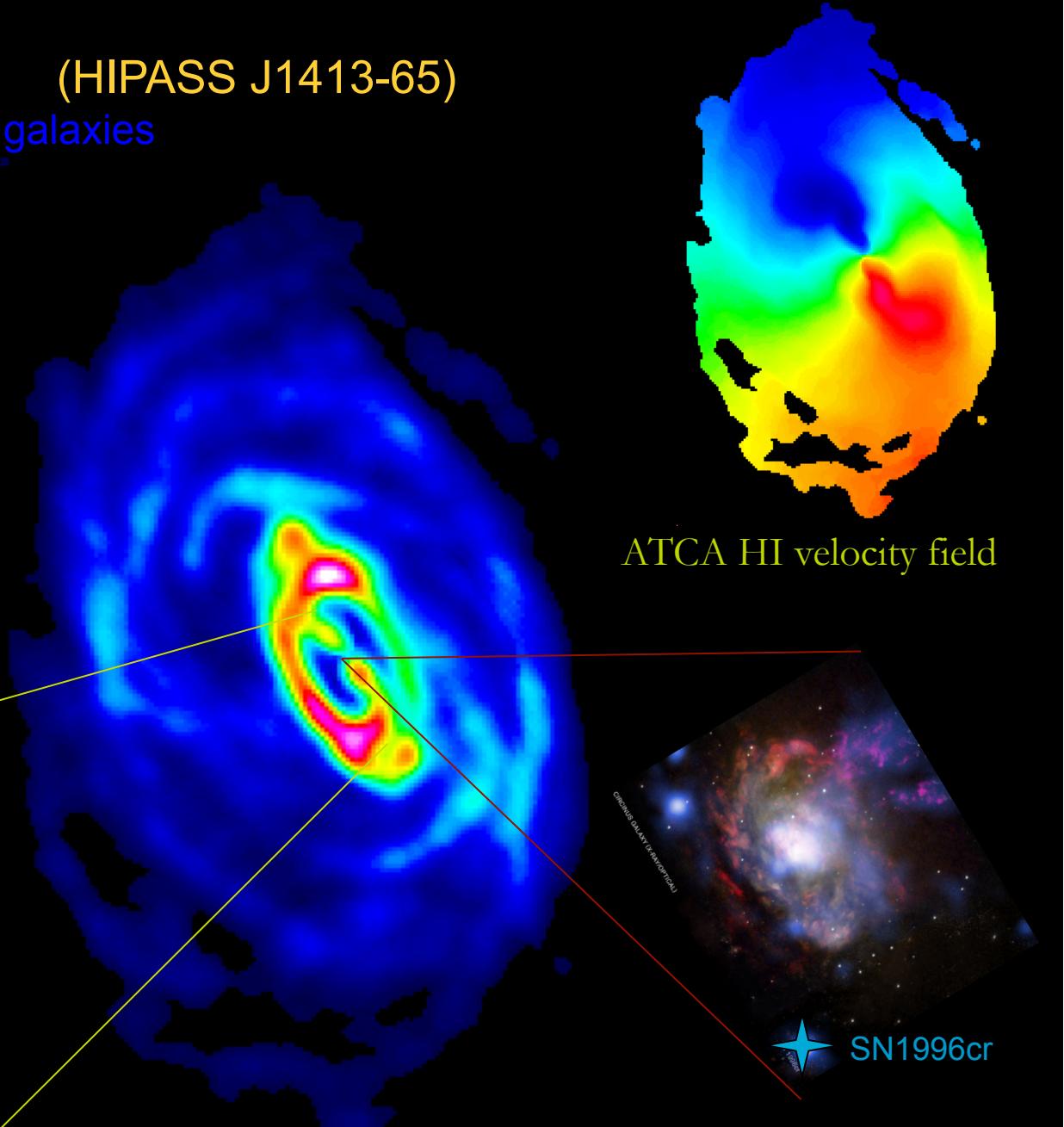
= one of the largest nearby galaxies



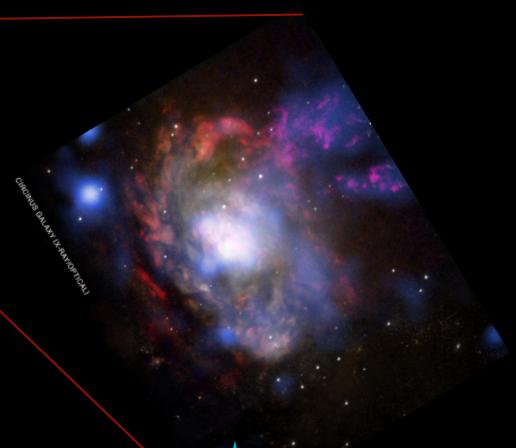
ATCA 6cm I + PI



2MASS infrared



Chandra X-ray + H α

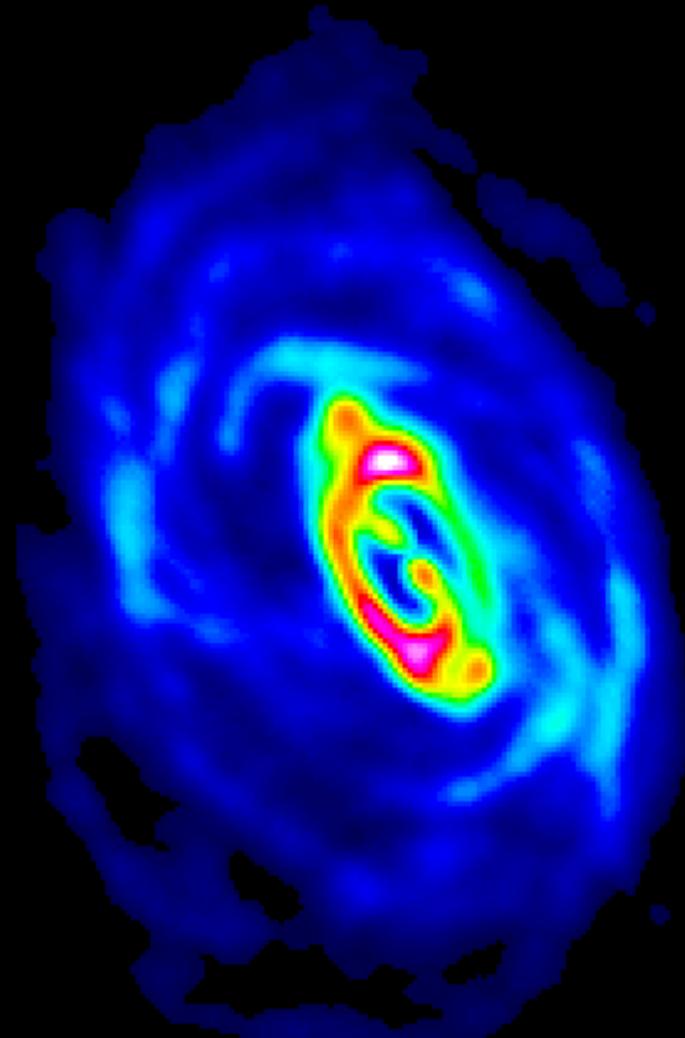


SN1996cr

The Circinus Galaxy (HIPASS J1413-65)

= one of the largest nearby galaxies

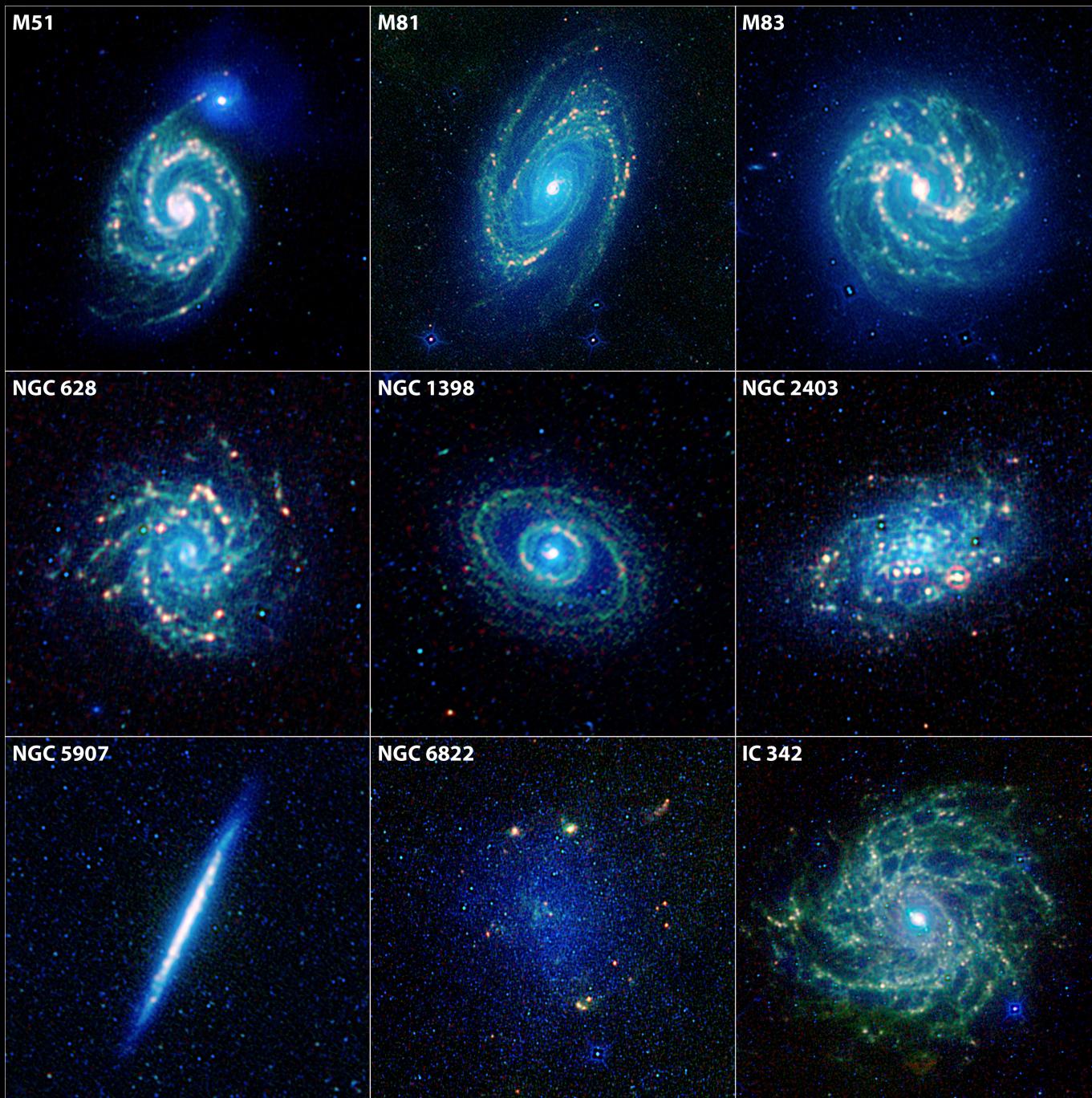
- $D \approx 4.2$ Mpc
 - HI extent > 70 kpc
 - $M_{\text{HI}} = 6 \times 10^9 M_{\odot}$
-
- Jones et al. 1999
 - Curran et al. 2008
 - For al. 2012



ATCA HI distribution



$15' = 18$ kpc



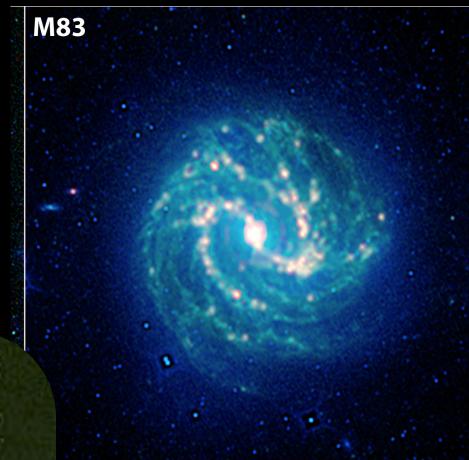


Martinez-Delgado et al. 2009

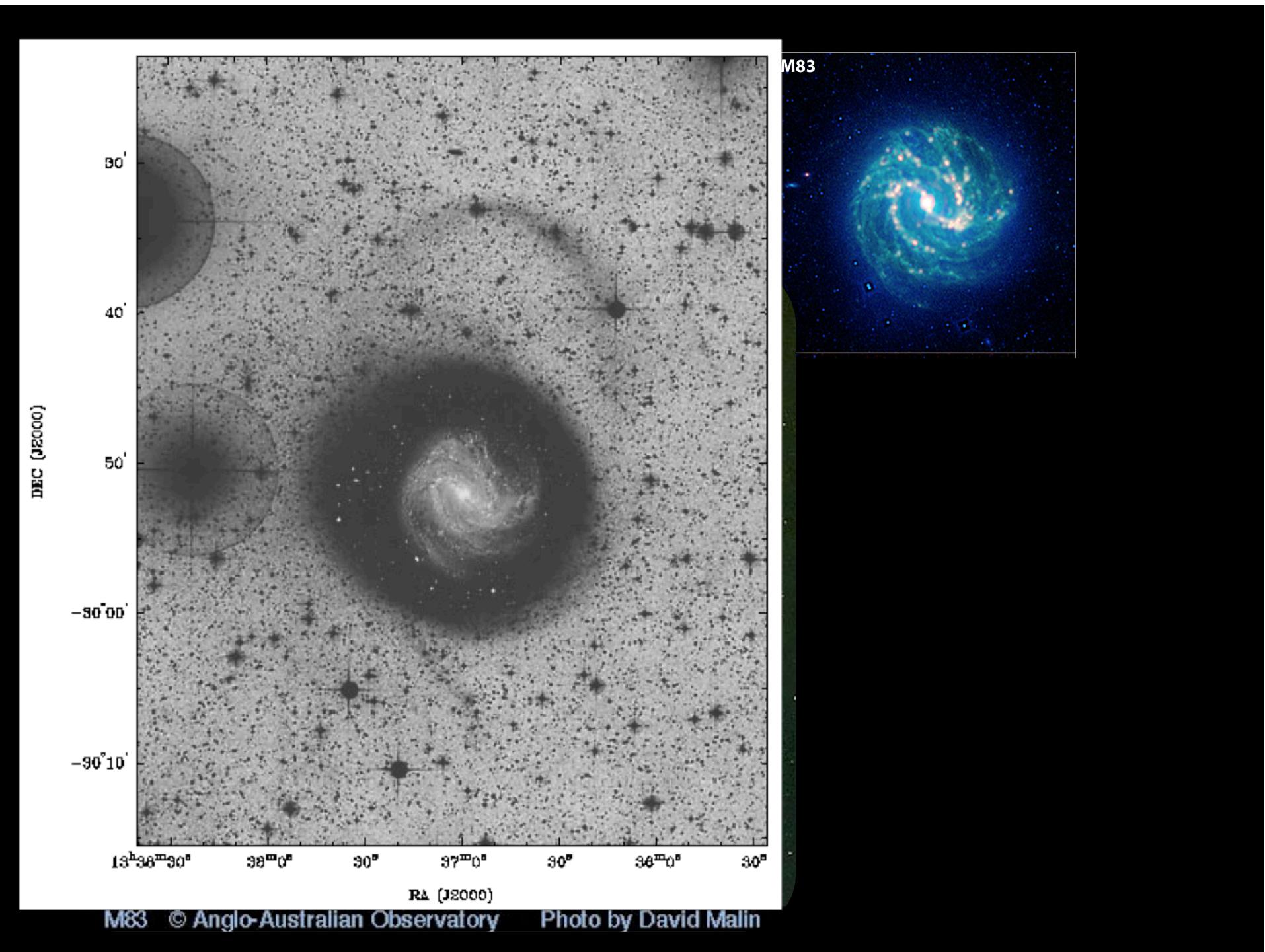
M51



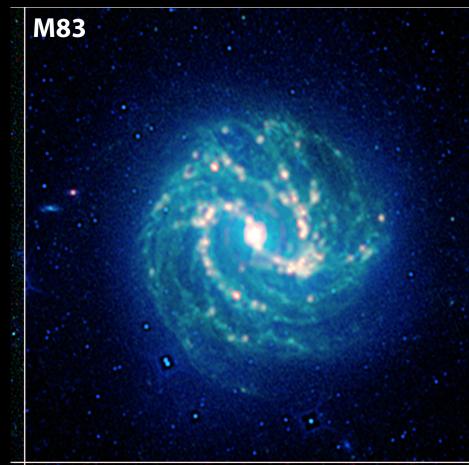
Rots et al. 1990



M83 © Anglo-Australian Observatory Photo by David Malin

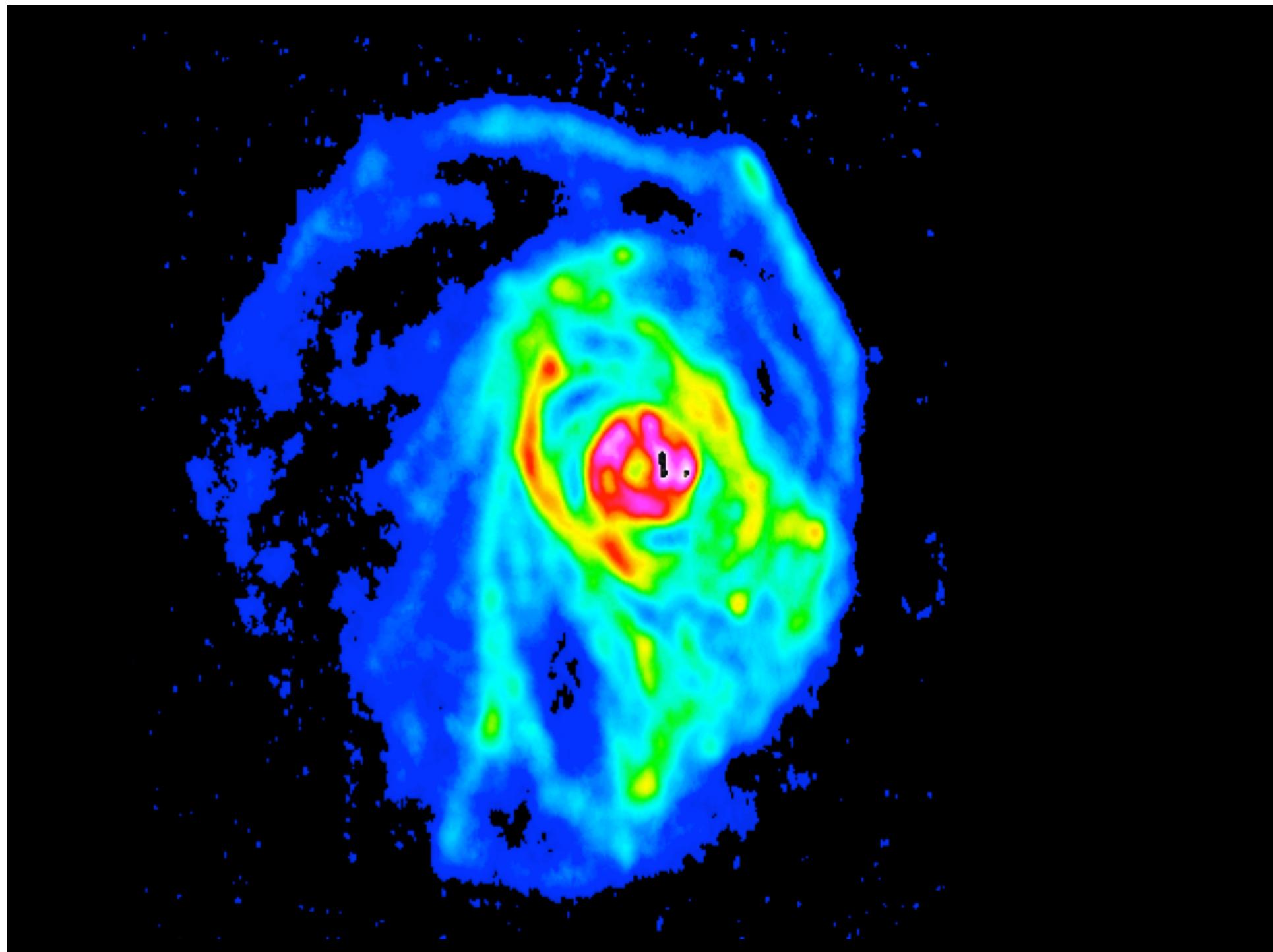


GALEX NUV+FUV; Thilker et al.



GALEX NUV+FUV; Thilker et al.





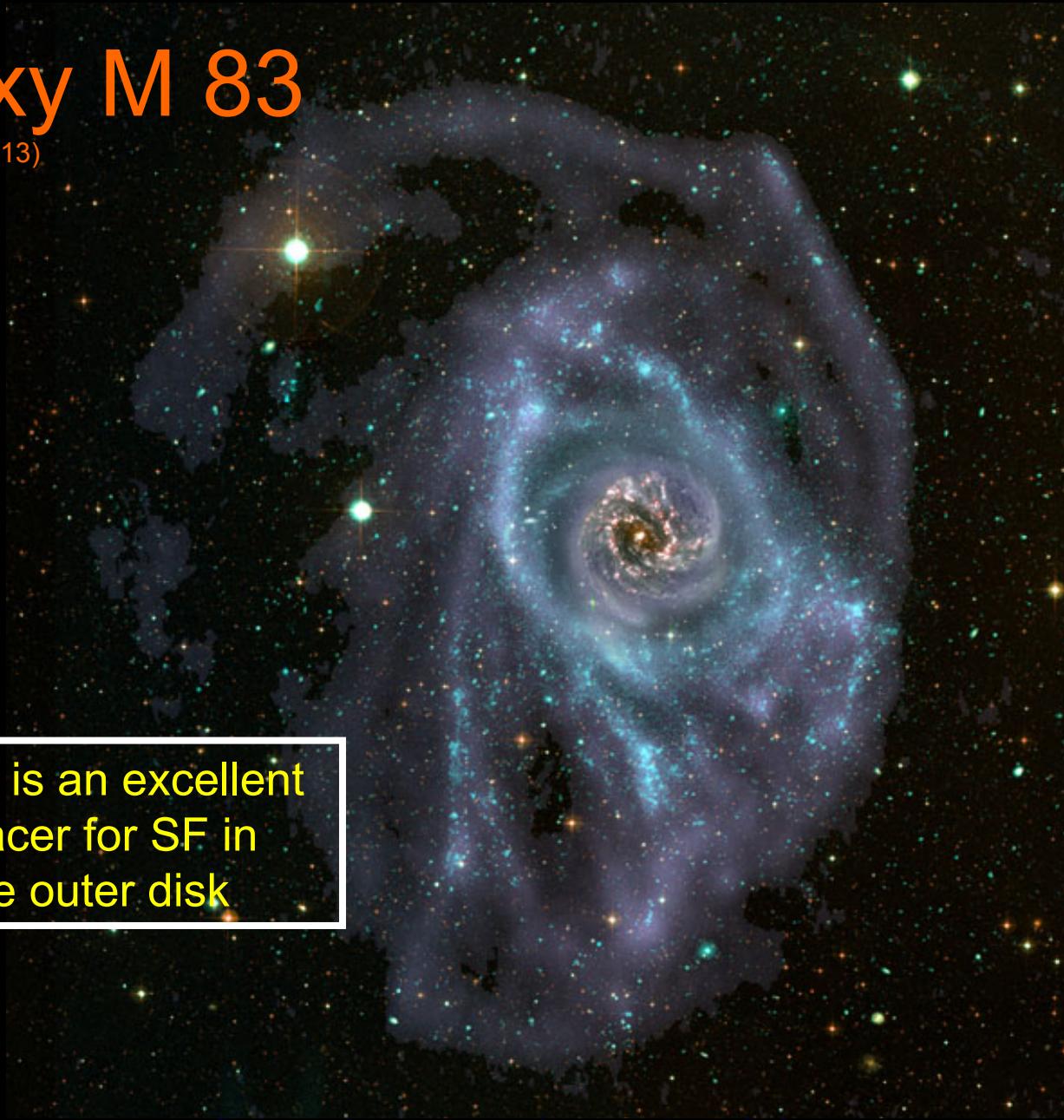
The Galaxy M 83

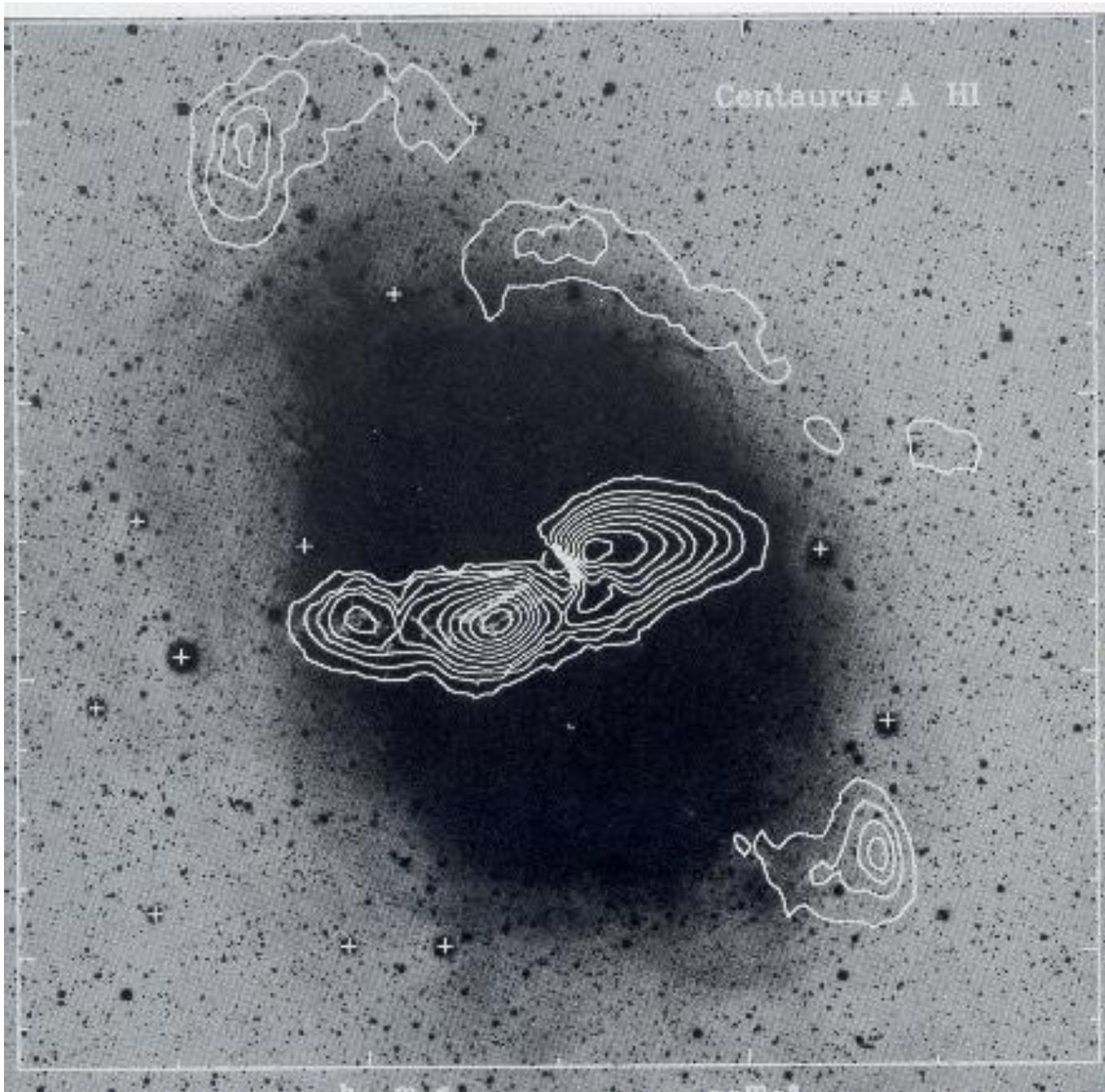
(Koribalski 2008; Jarrett et al. 2013)

- HIPASS J1336-29
- $D \approx 4.5$ Mpc

HI is an excellent
tracer for SF in
the outer disk

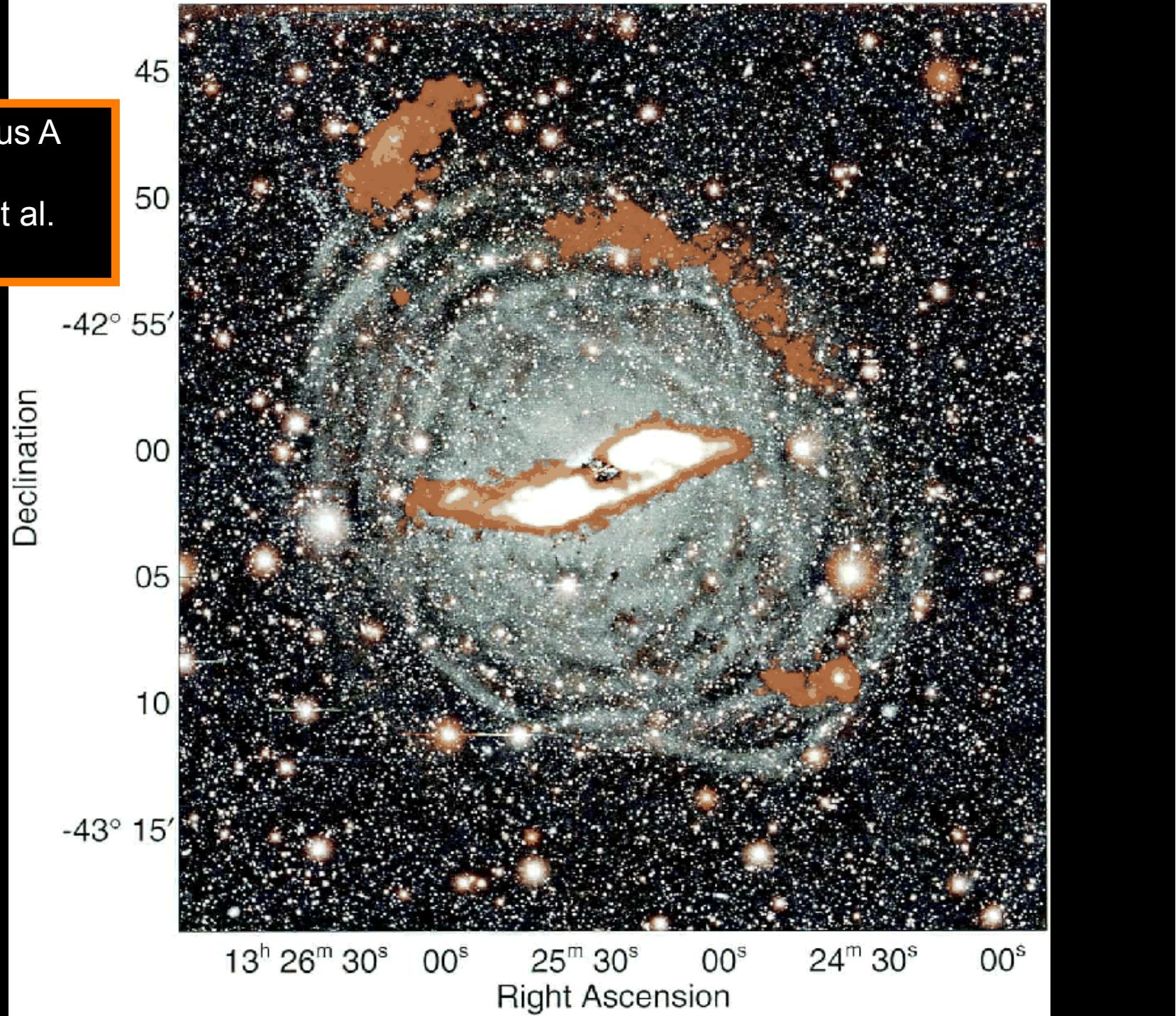
color-composite by
Angel Lopez-Sanchez



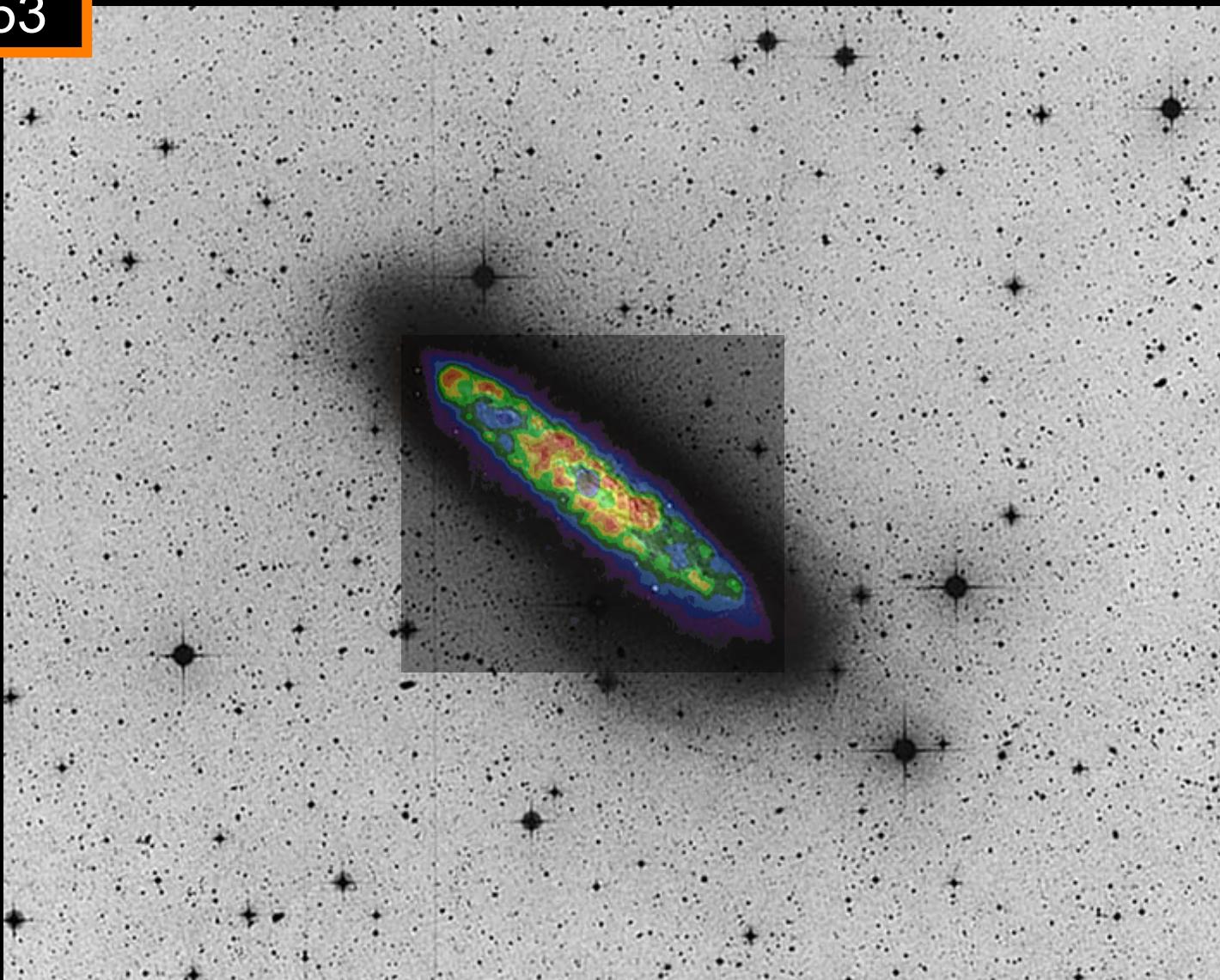


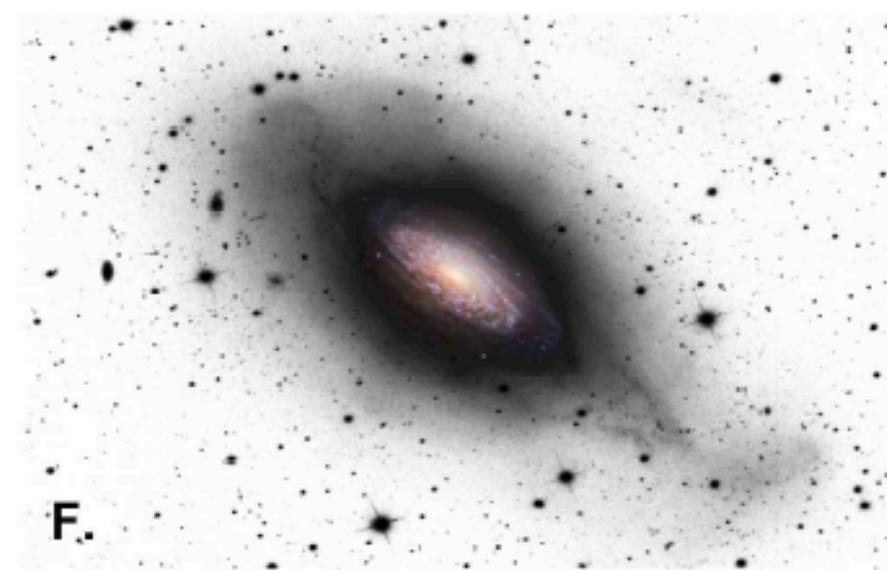
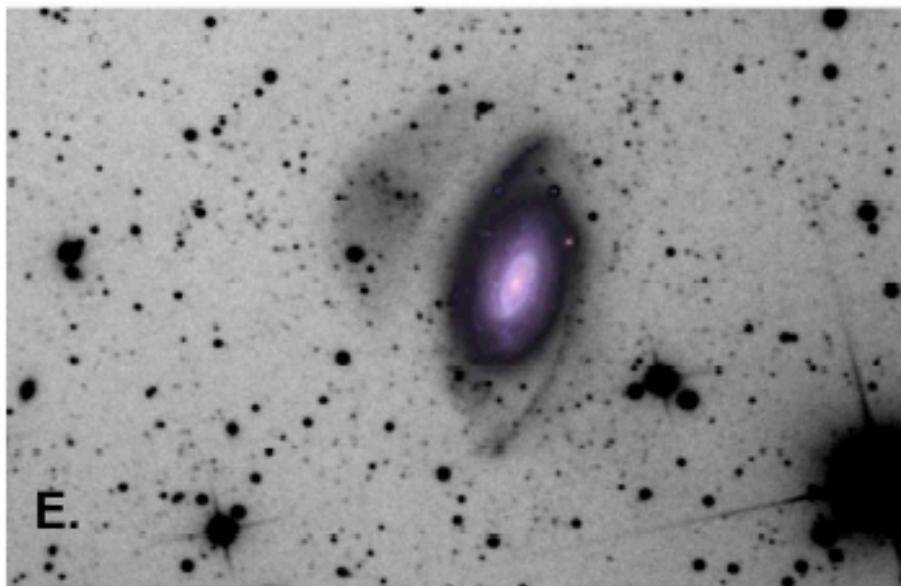
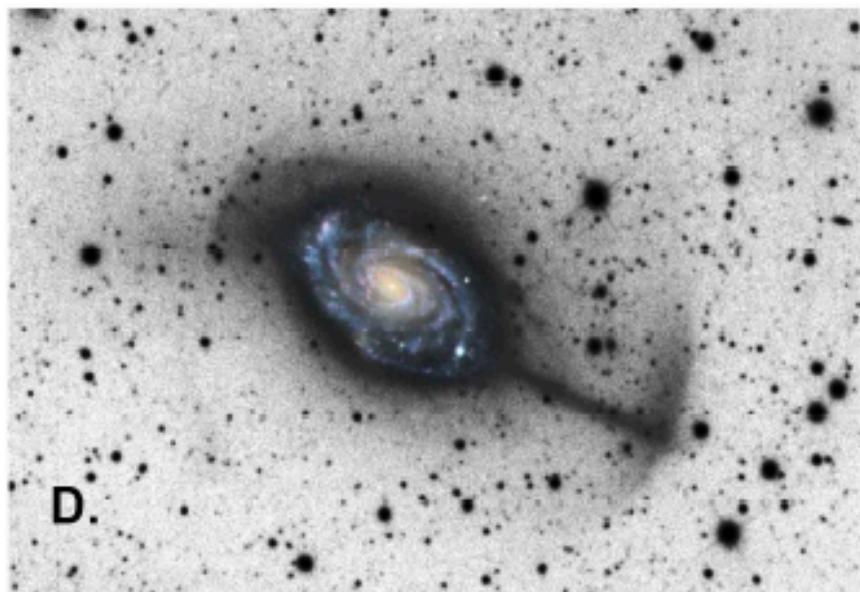
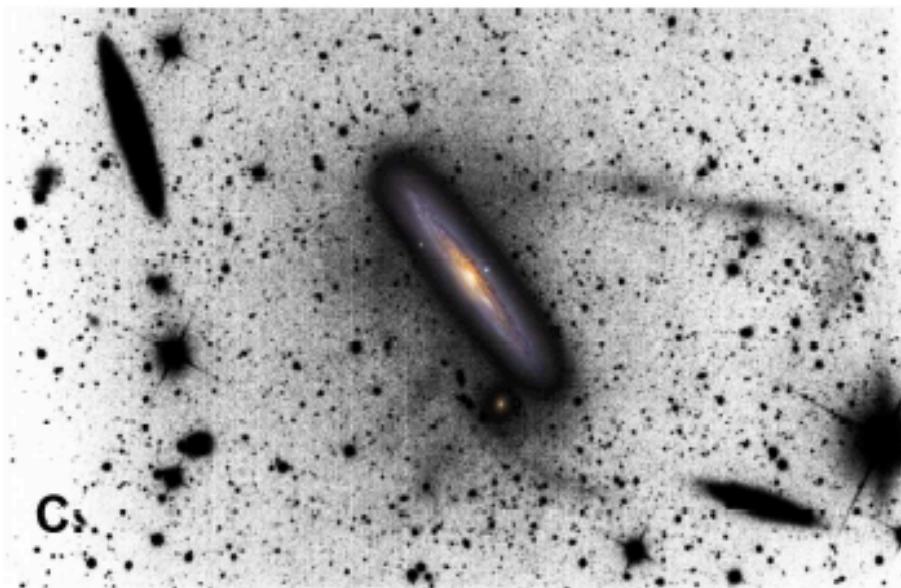
Galaxy Zoo - Tracing the edges of galaxy disks - B. S. Koribalski

Centaurus A
Struve et al.
2001

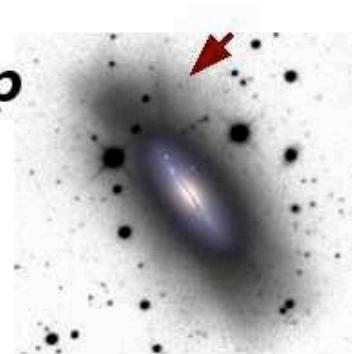
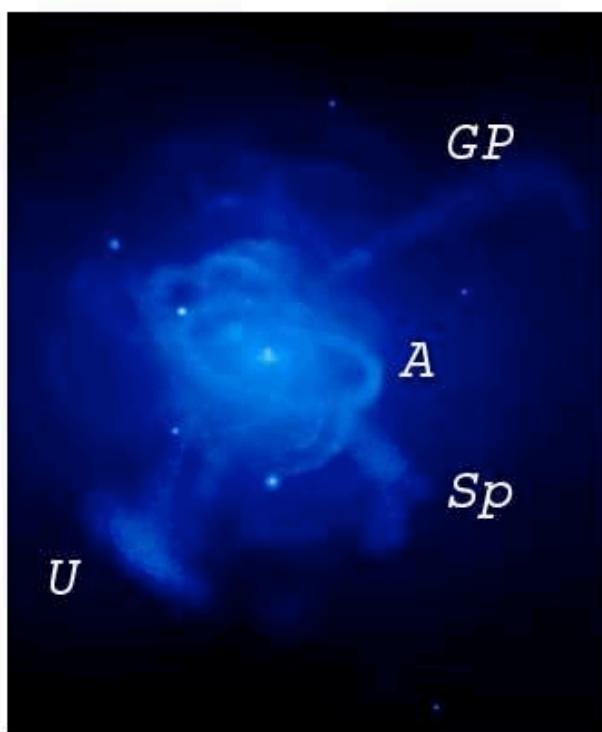
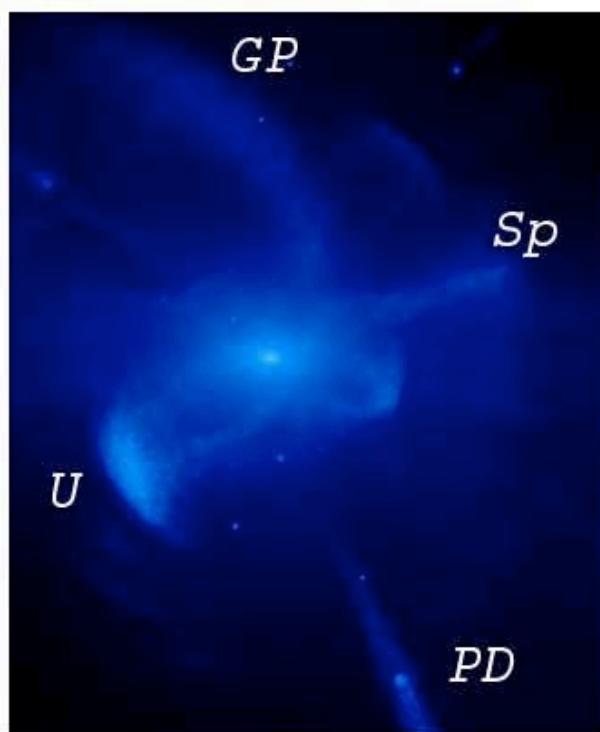
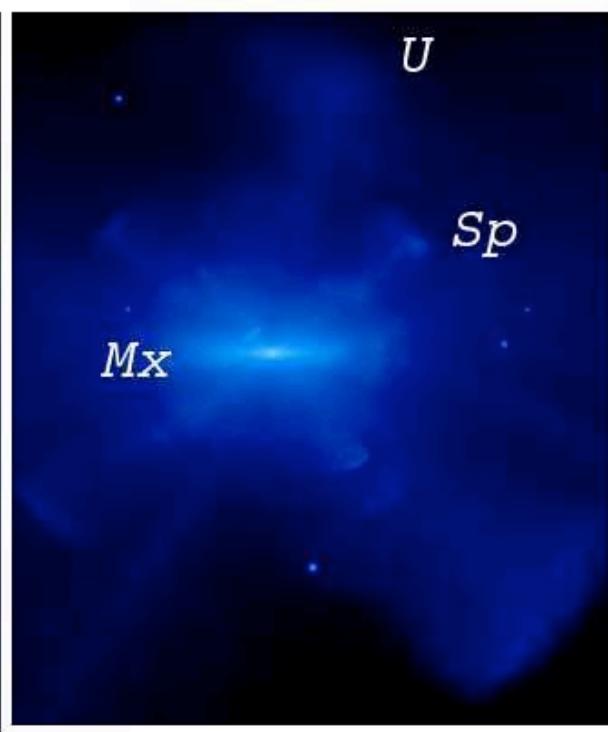
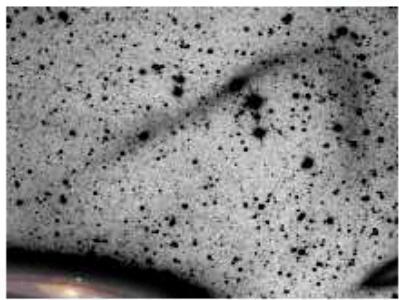
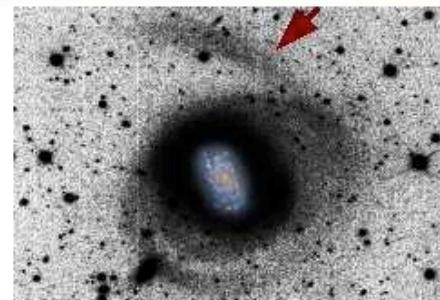


NGC 253





Galaxy Zoo - Tracing the edges of galaxy disks - B. S. Koribalski

A**Sp****U****GP****GP****U****PD****GP****Mx**

HIZOA J0836-43

$V_{\text{hel}} = 10689 \text{ km/s}$

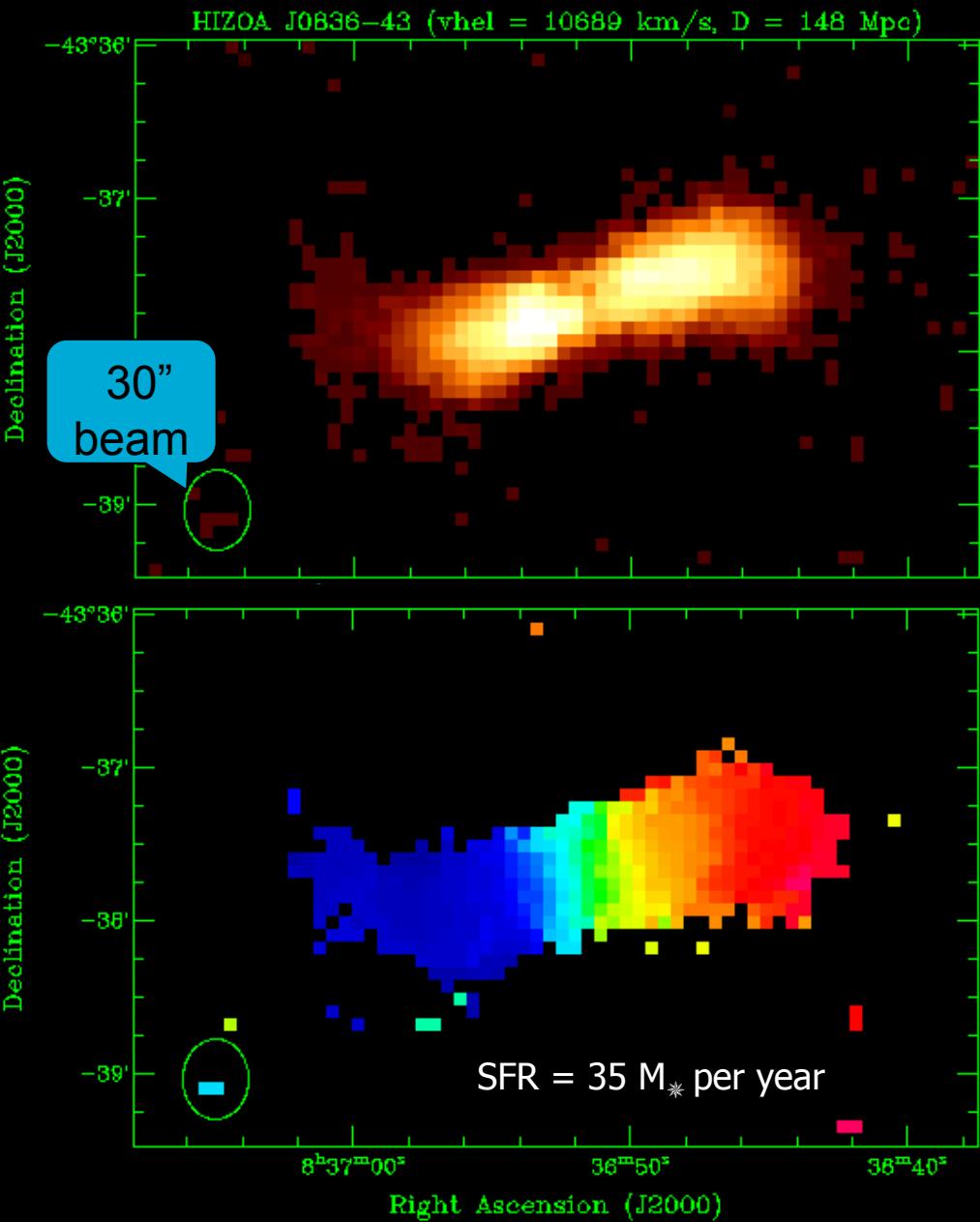
$z = 0.036$

$D = 148 \text{ Mpc}$

$M_{\text{HI}} = 7.5 \times 10^{10} M_{\odot}$

$M_{\text{dyn}} = 1.4 \times 10^{12} M_{\odot}$

Donley, Koribalski,
Staveley-Smith et
al. (2006)



HIZOA J0836-43

$V_{\text{hel}} = 10689 \text{ km/s}$

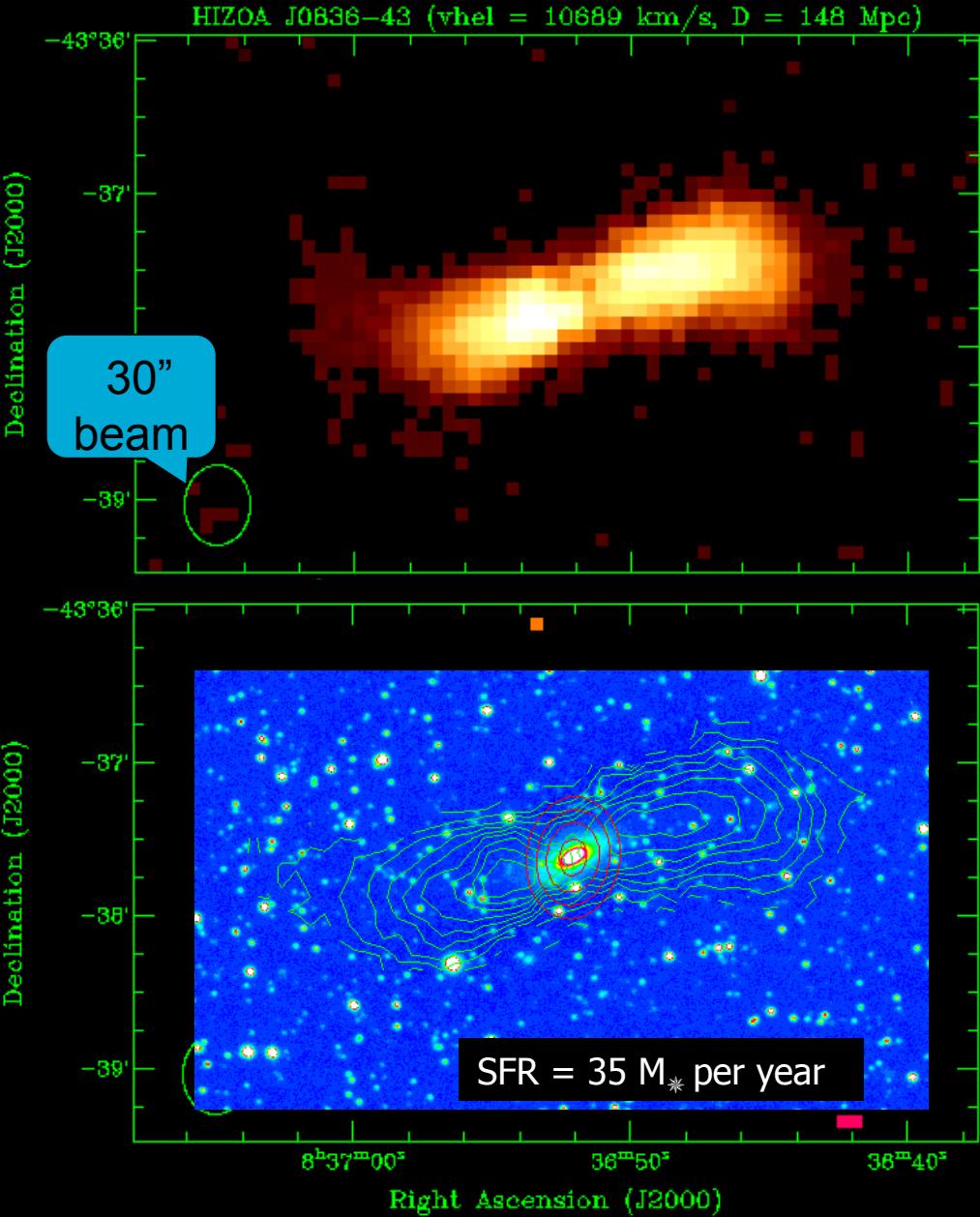
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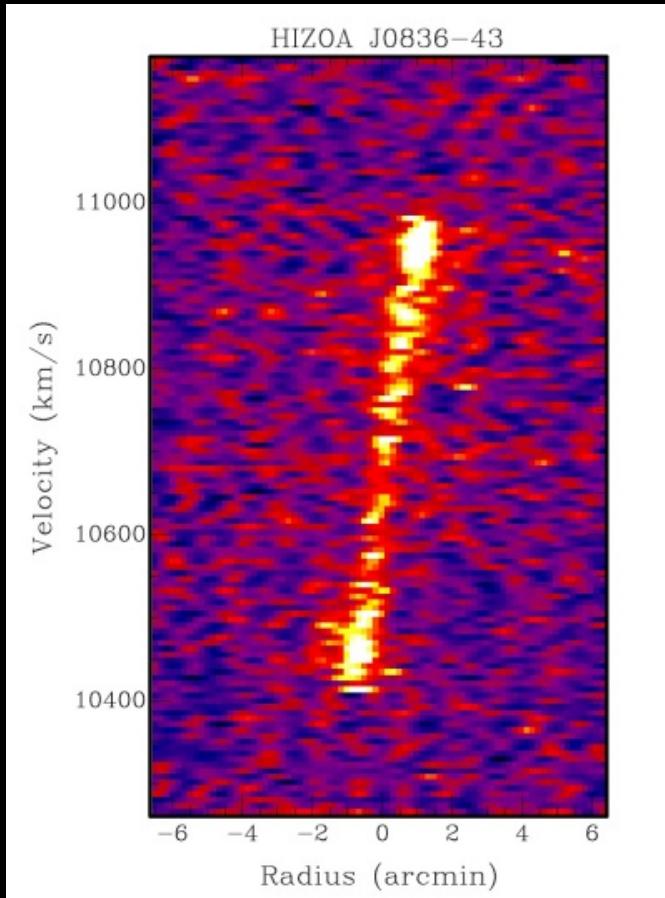
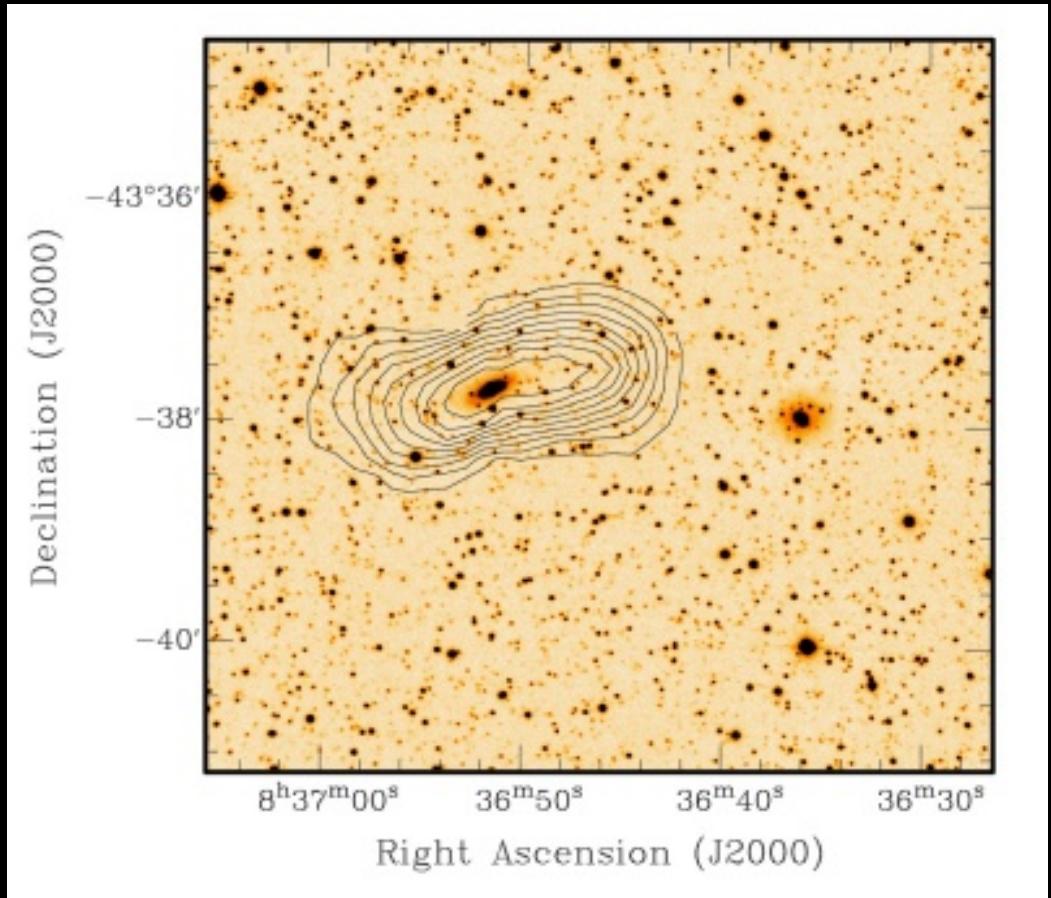
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Donley, Koribalski,
Staveley-Smith et
al. (2006)

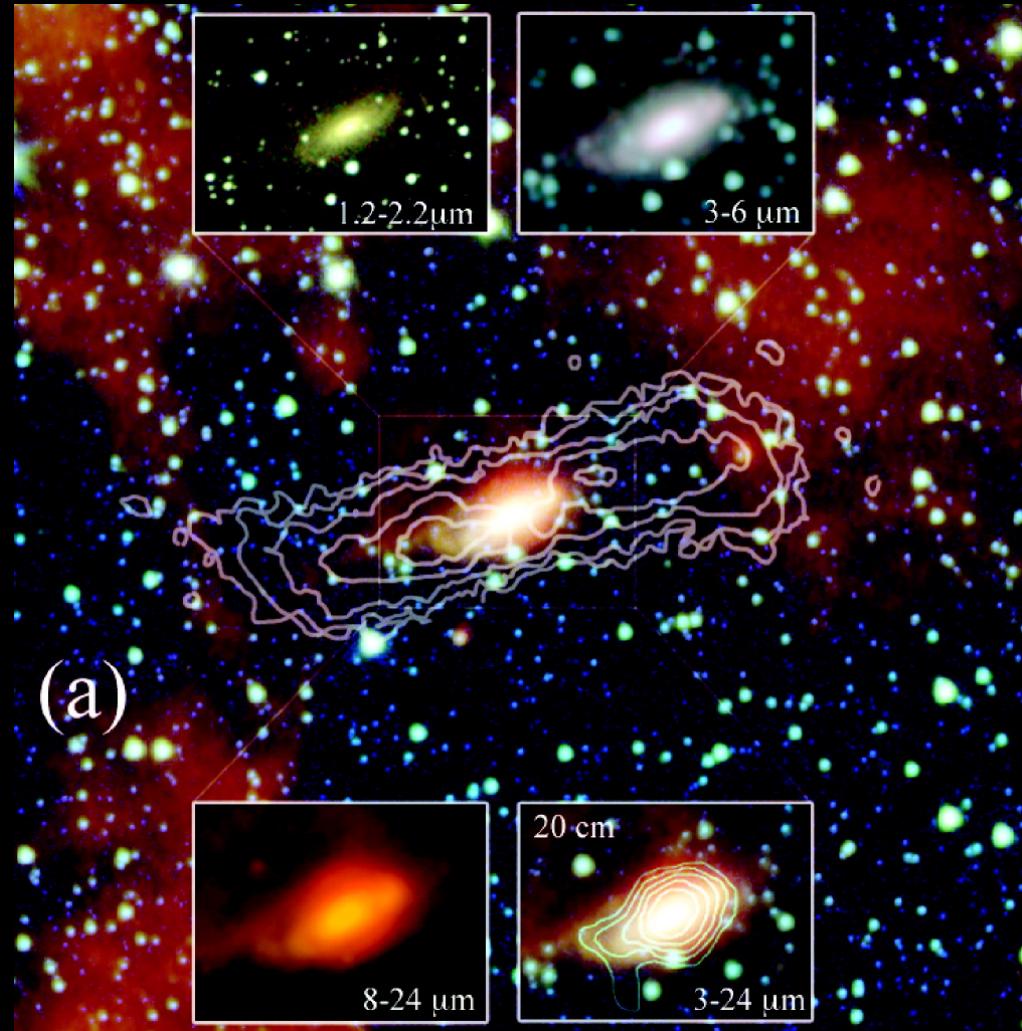


HIZOA J0836-43

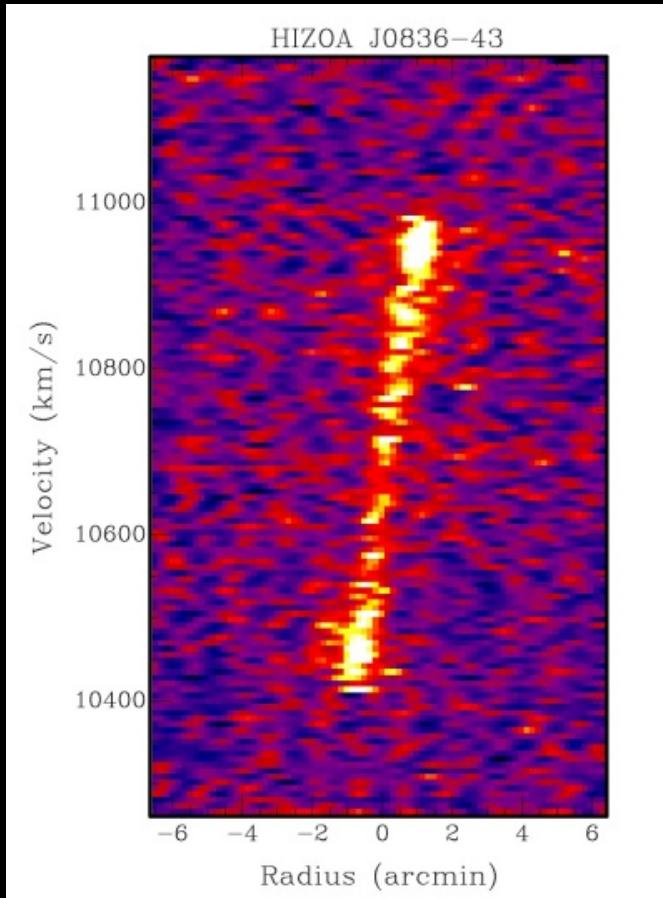


Donley, Koribalski, Staveley-Smith et al. (2006)

HIZOA J0836-43

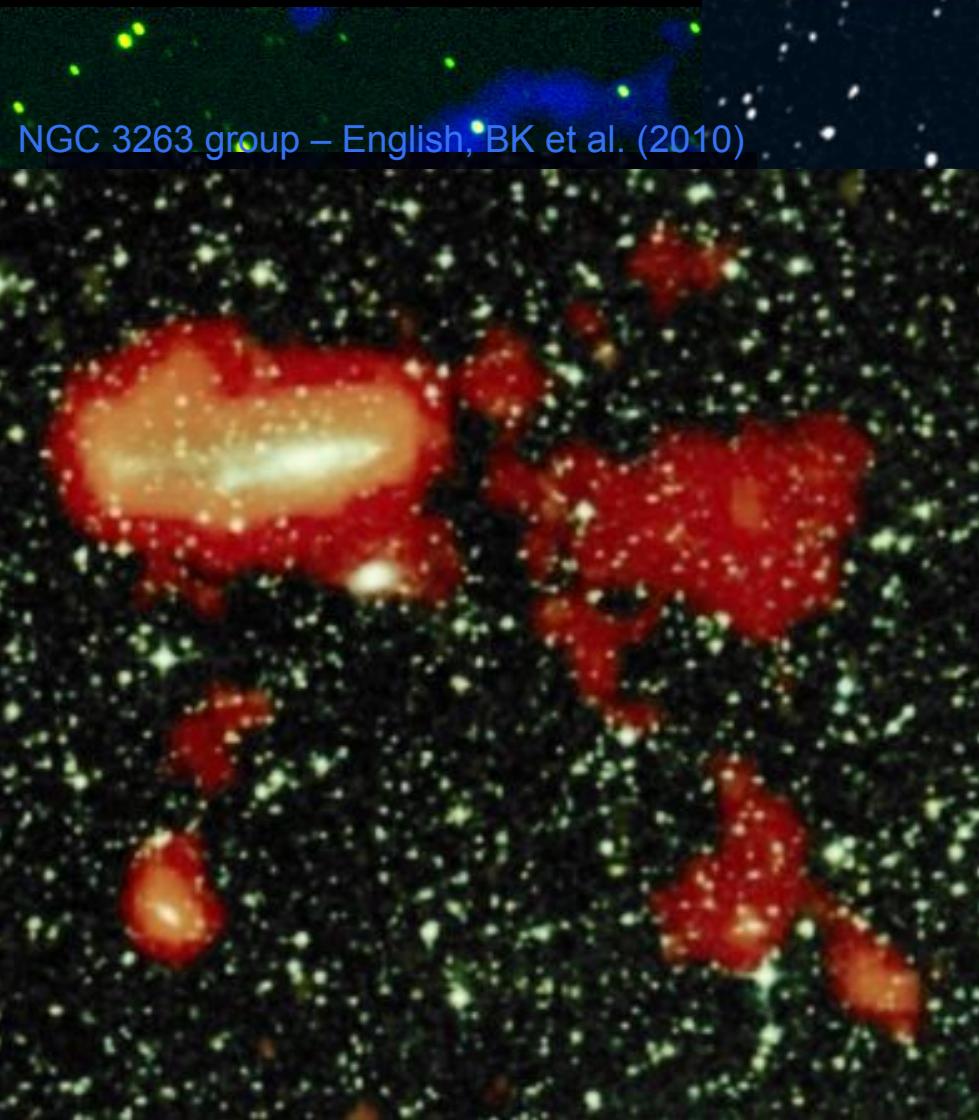


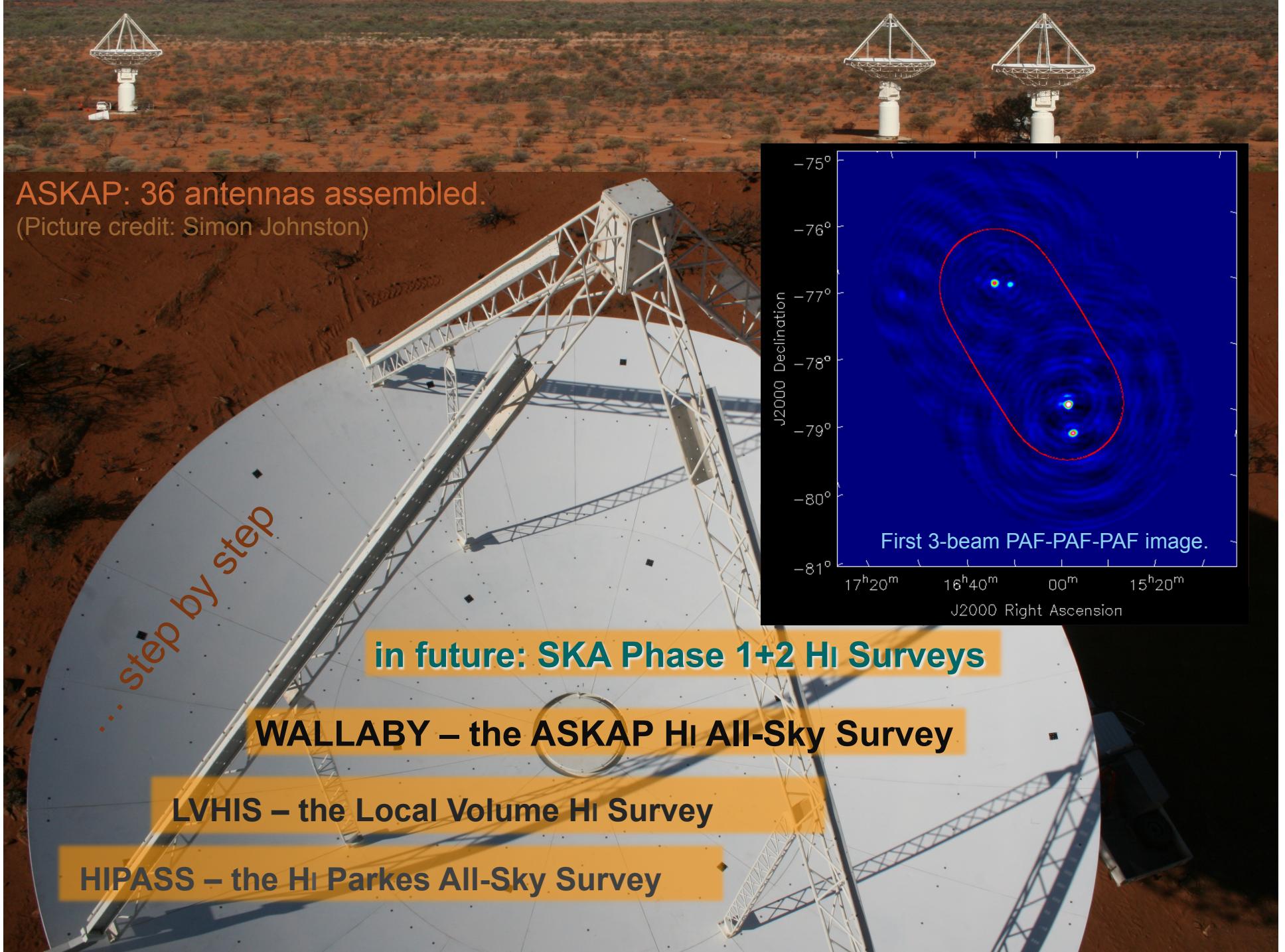
Cluver et al. (2008, 2010)



Donley et al. (2006)

H_I streams and plumes





WALLABY - the ASKAP HI All-Sky Survey

(led by B. Koribalski & L. Staveley-Smith)



ASKAP =
36 x 12-m dishes
with “radio cameras”

FOV = 30 sq degr



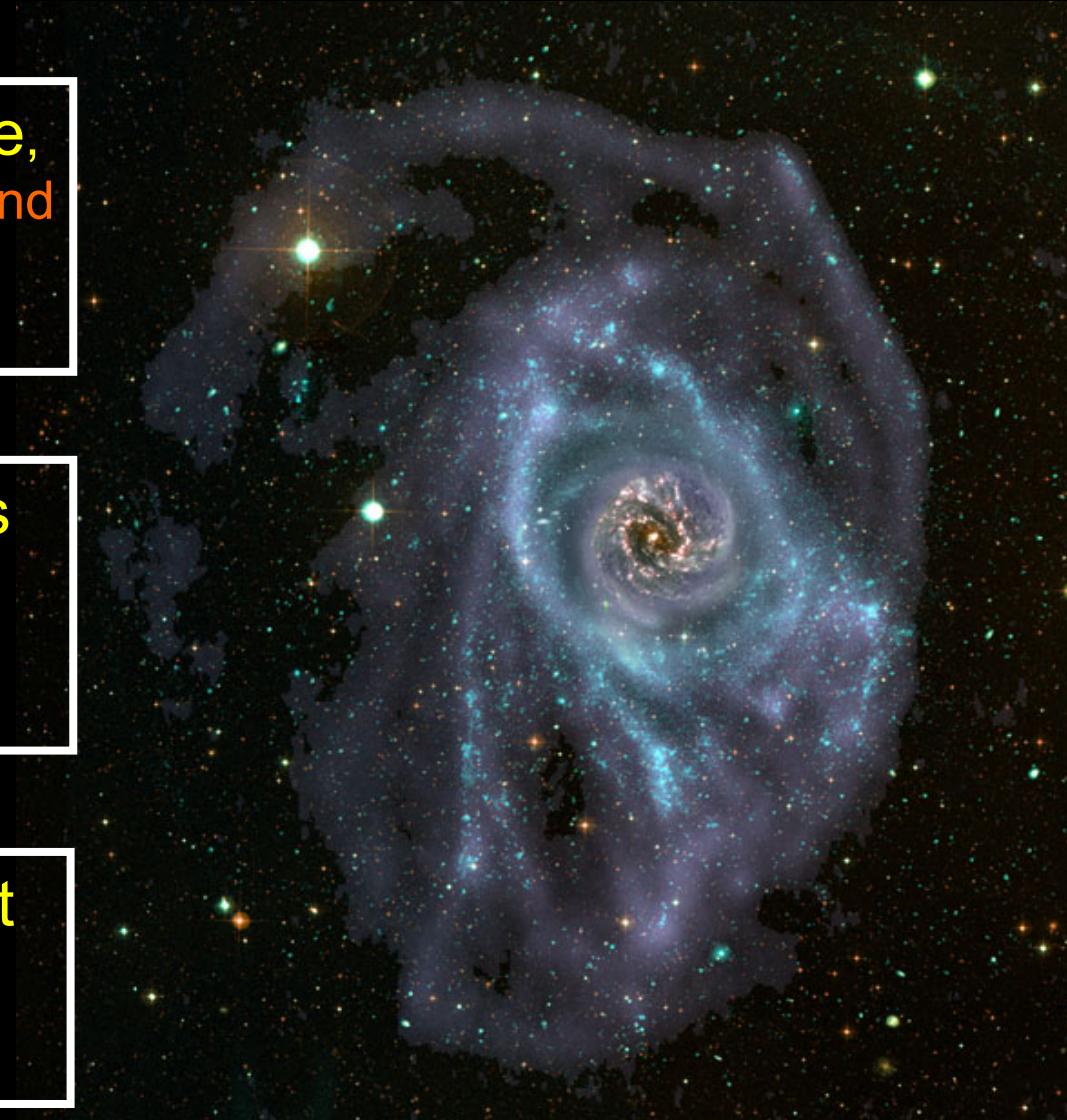
Summary

M 83: gas & stars

HI disks are large, extending well beyond the stellar disks of galaxies.

HI disk dynamics allow us to measure dark matter mass & distribution.

HI is an excellent tracer for SF in the outer disk.





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