Broadband Radio Observations of Local Groups with ASKAP (BROLGA)

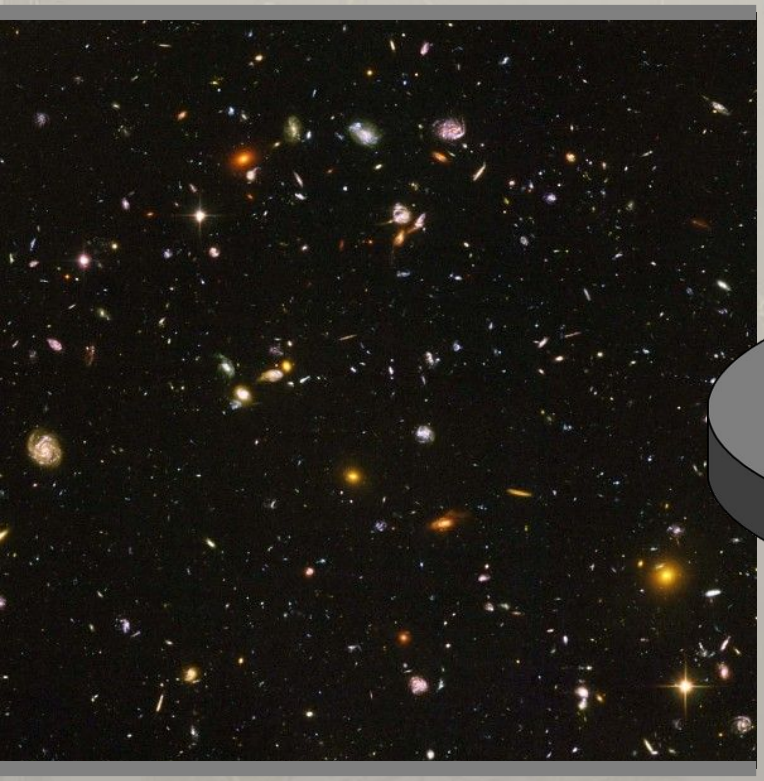
Tobias Westmeier (Australia Telescope National Facility)
on behalf of the BROLGA team

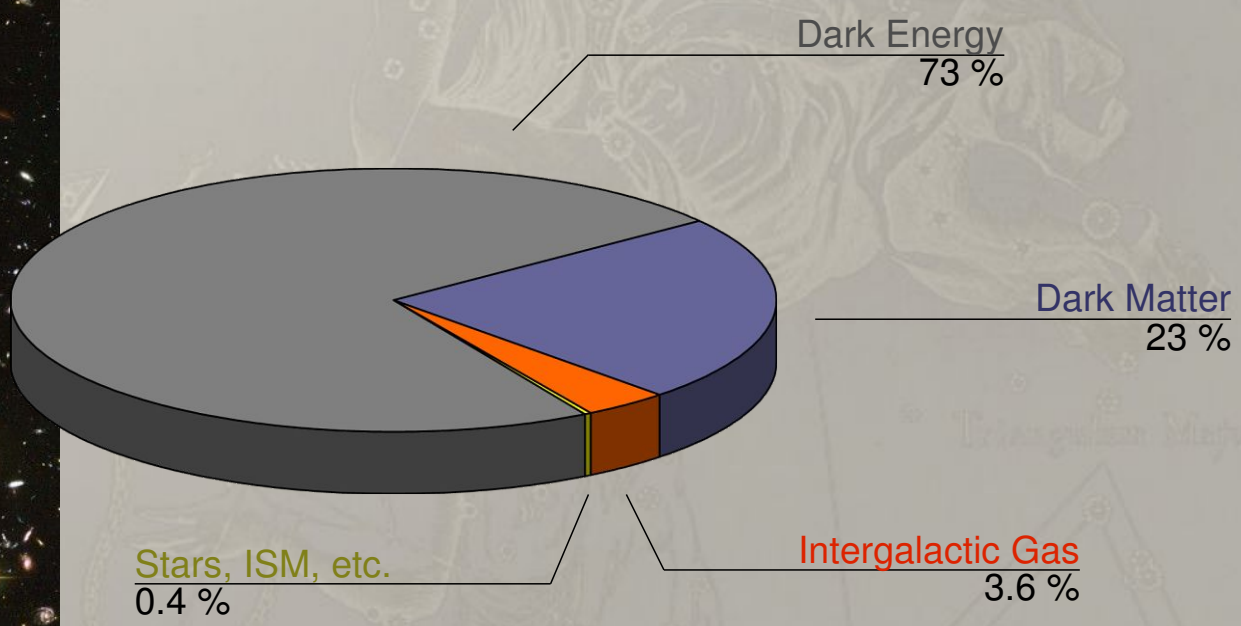
Outline of the talk

- Introduction
- Broadband Radio Observations of Local Groups with ASKAP (BROLGA)
- Results of precursor observations with ATCA
  - Tidal interaction and accretion
  - Unknown / missing / dark satellites
- Summary

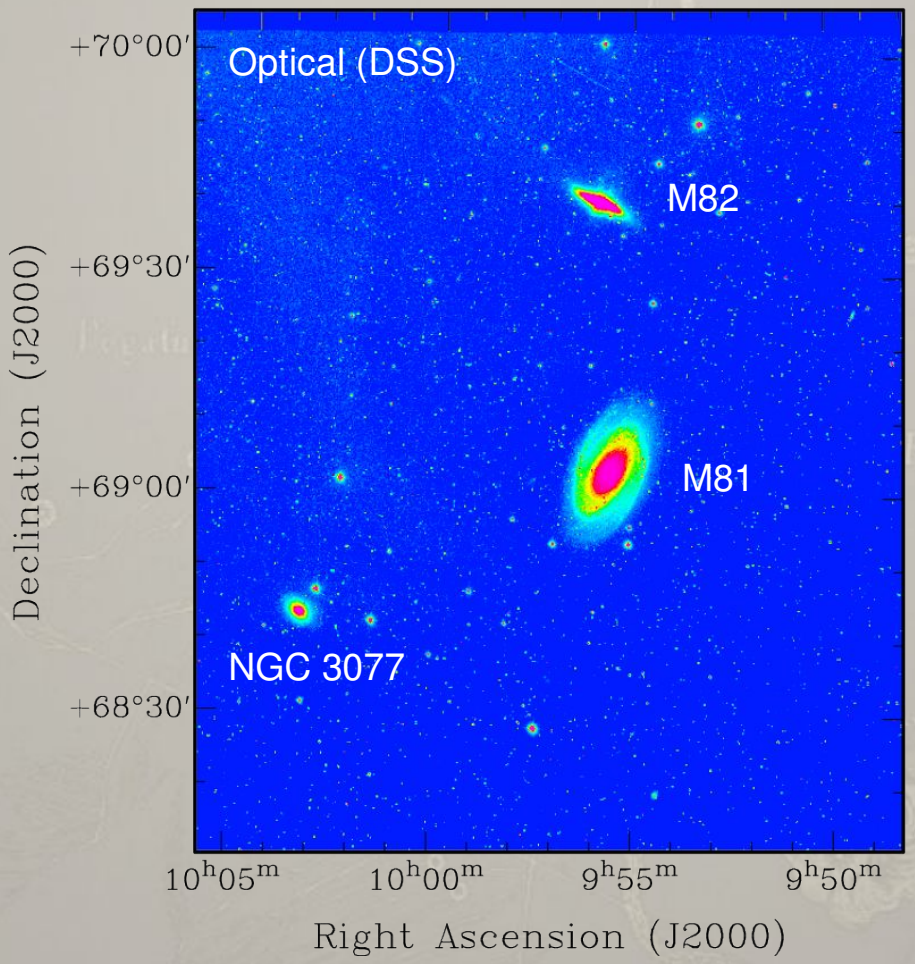
ΛCDM cosmological model

- Currently most favoured cosmological model assumes that energy density, Ω, of the universe is dominated by Dark Energy (Ω_Λ) and Cold Dark Matter (Ω_{DM})
- Numerical simulations predict hierarchical formation of structure: small DM structures formed first and then merged into larger structures (bottom-up scenario)





Introduction



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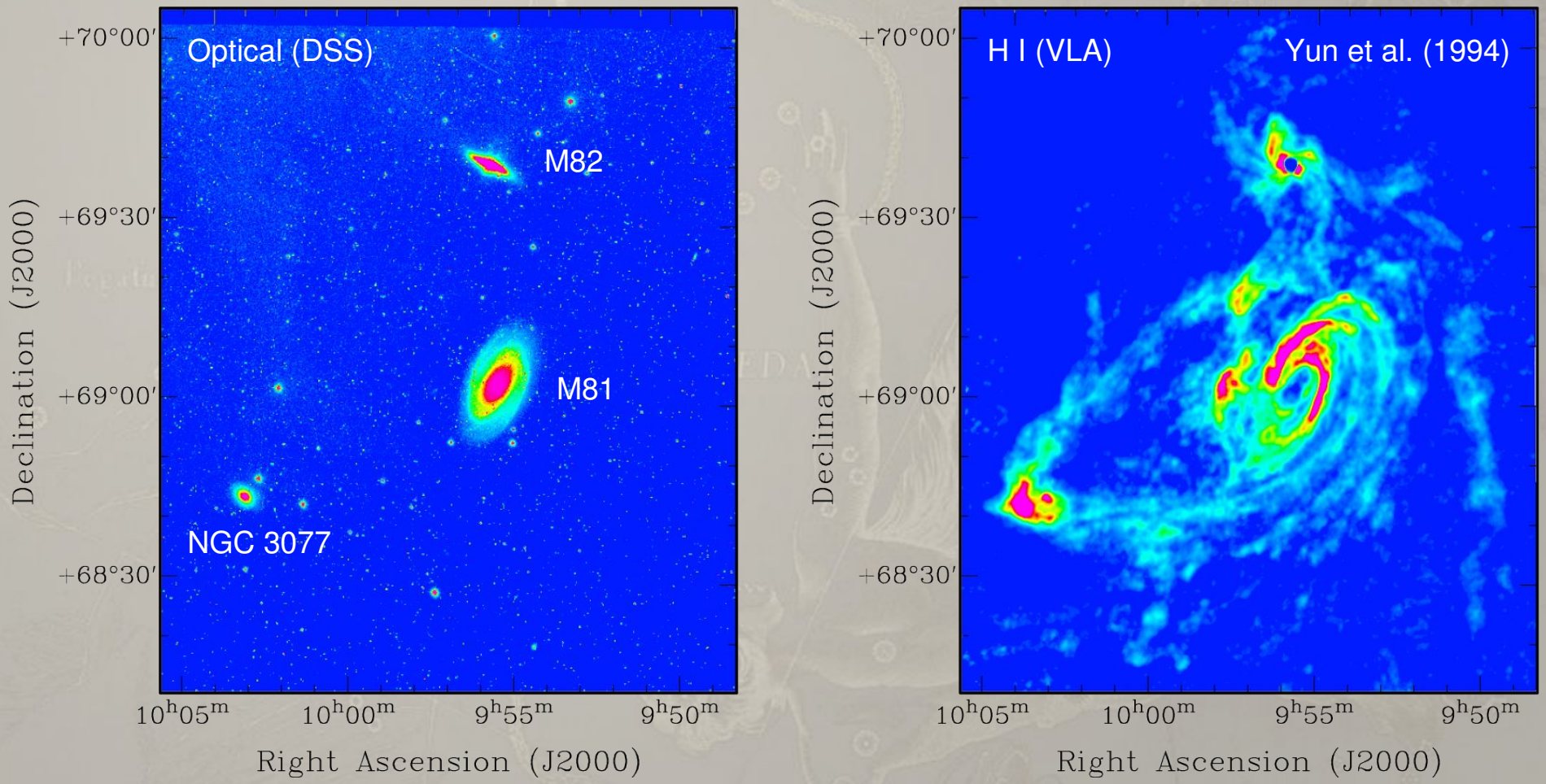


A deep, large-scale survey of nearby galaxy groups in H I will allow the systematic study of tidal interaction and structure formation in group environments.

Broadband Radio Observations of Local Groups with ASKAP

Aim: Deep imaging of the 23 nearest galaxy groups in H I and radio continuum emission with ASKAP

PI: Tobias Westmeier

Team: Rainer Beck (MPIfR), Kenji Bekki (University of NSW), Nadya Ben Bekhti (University of Bonn), Erwin de Blok (University of Capetown), Robert Braun (ATNF), Ralf-Jürgen Dettmar (University of Bochum), Bjorn Emonts (ATNF), Jayanne English (University of Manitoba), Jason Fiege (University of Manitoba), Bryan Gaensler (University of Sydney), Jacqueline van Gorkom (Columbia University), Helmut Jerjen (ANU), Melanie Johnston-Hollitt (Victoria University Wellington), Gyula Józsa (ASTRON), Eva Jütte (ASTRON), Amanda Kepley (University of Virginia), Virginia Kilborn (Swinburne University), Bärbel Koribalski (ATNF), Ángel López-Sánchez (ATNF), Martin Meyer (University of WA), Erik Muller (University of Nagoya), Hiroyuki Nakanishi (Kagoshima University), Tom Oosterloo (ASTRON), Joshua Peek (UC Berkeley), D. J. Pisano (NRAO), Attila Popping (University of Groningen), Mary Putman (Columbia University), Lister Staveley-Smith (University of WA), Bart Wakker (University of Wisconsin),Tobias Westmeier (ATNF), Eric Wilcots (University of Wisconsin), Benjamin Winkel (University of Bonn), Maik Wolleben (DRAO)

The Australian SKA Pathfinder

- Number of antennas: 36 × 12 m
- Total collecting area: 4100 m² (0.3 VLA, 1.8 ATCA)
- Frequency range: 0.7 to 1.8 GHz
- Bandwidth: 300 MHz
- Field of view: 30 sq. deg. (at 1.4 GHz)
- Maximum baseline: 6 km
- Angular resolution: 10″...30″ (at 1.4 GHz)

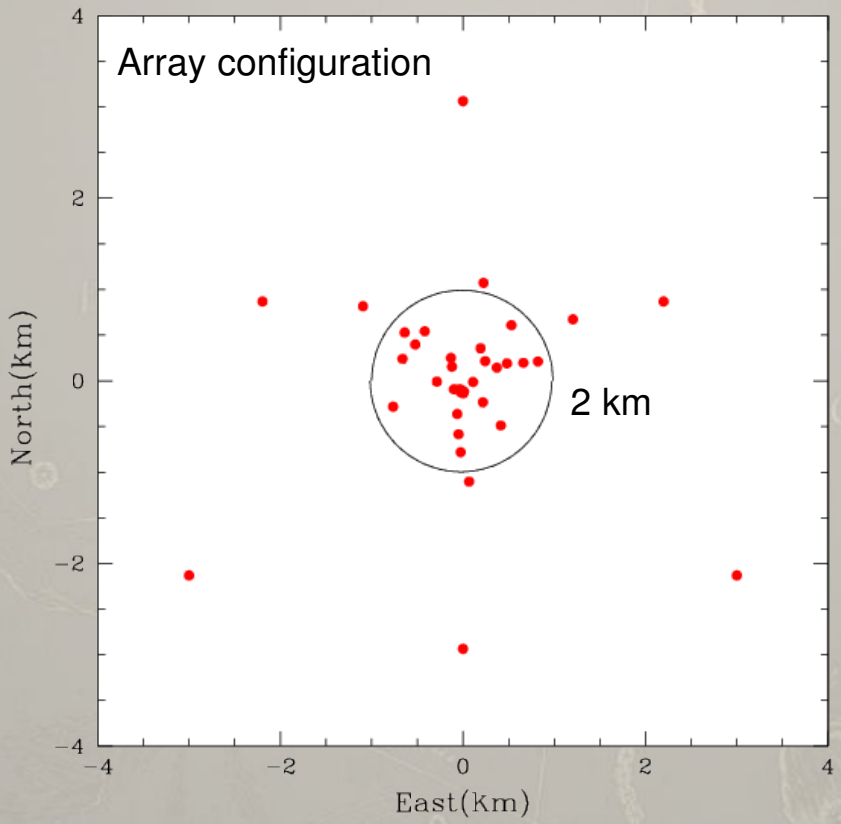
Credit: CSIRO

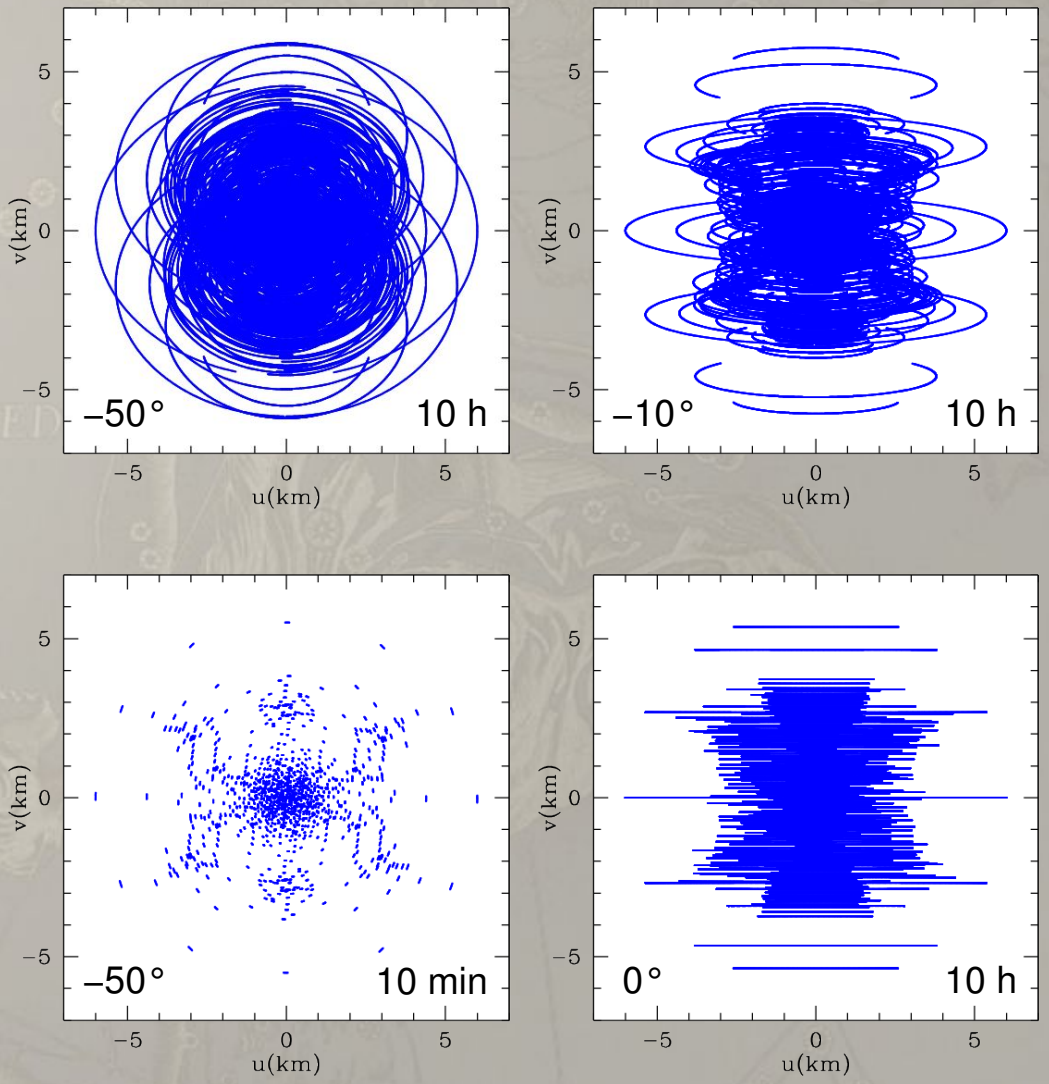
Credit: CSIRO

Murchison Radio Astronomy Observatory
Western Australia

Why is ASKAP ideal?

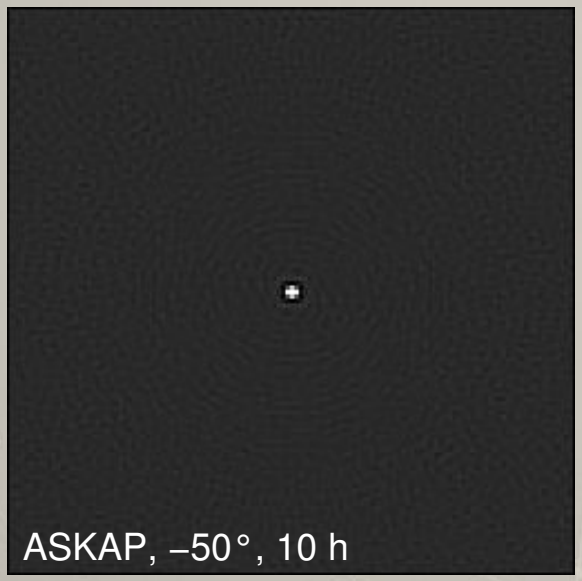
- Large field of view of 30 sq. deg. perfectly matches the angular size of nearby galaxy groups within $D \lesssim 20$ Mpc
- We can study H I and radio continuum emission simultaneously
- Excellent *uv* coverage results in low side lobe levels, important for detection of faint, diffuse extra-planar and intra-group gas

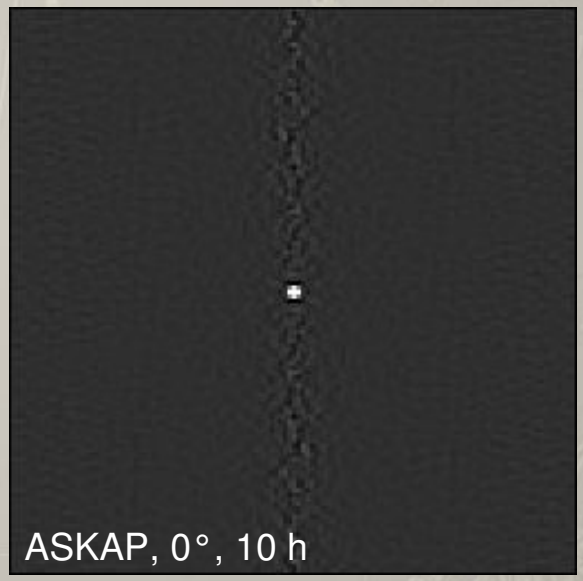


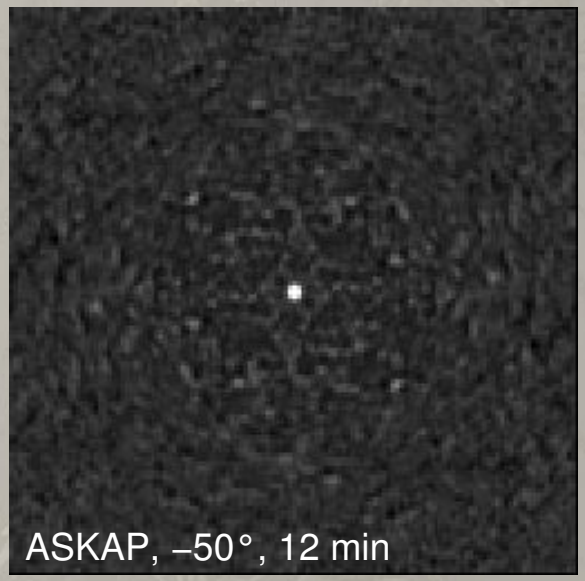


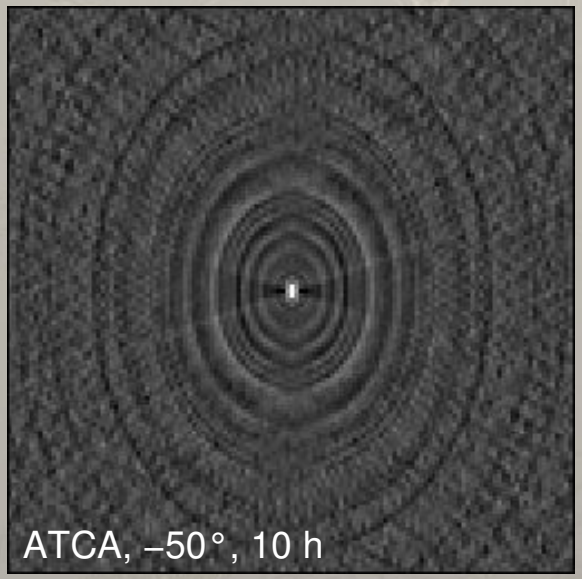
"The initial array configuration for ASKAP" (Gupta, Johnston, Feain, and Cornwell 2008)

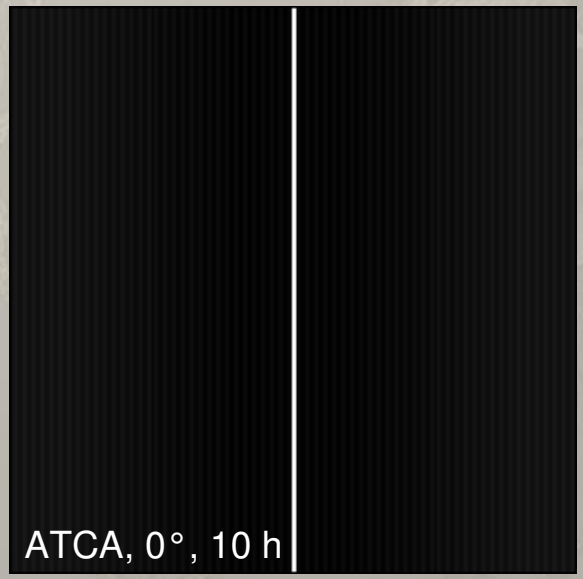
BROLGA


ASKAP, –50°, 10 h


ASKAP, 0°, 10 h


ASKAP, –50°, 12 min


ATCA, –50°, 10 h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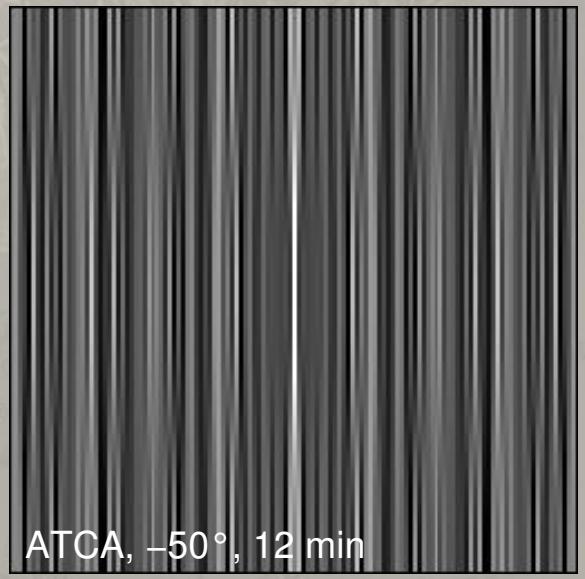
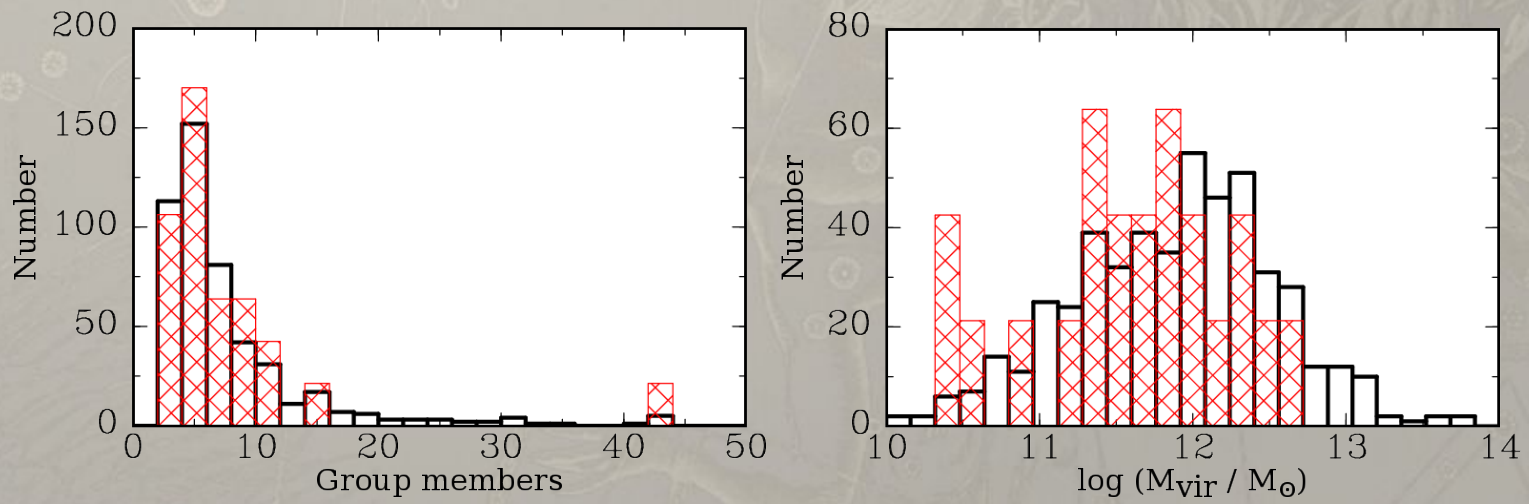

ATCA, –50°, 12 min

Strategy

- Deep imaging in H I and radio continuum of a complete, volume-limited sample of 23 groups within 18 Mpc and $\delta < 0°$ based on the LGG catalogue (Garcia 1993)
- Systematic study of groups as a function of groups mass (more than 2 orders of magnitude) and environment
- Images: (10,) 30, 90, and 180 arcsec resolution; data cubes: 4 km/s spectral resolution
- Integration time group-dependent in order to achieve constant H I mass limit, total requested integration time will be 1 year
- Sensitivity: 10^{18} cm^{-2} or 10^5 $M_\odot$ for H I (5σ), 2 μJy/beam for continuum (1σ)



Additional observations with other telescopes

- Single-dish radio observations with Parkes and Effelsberg telescope for short spacings information to map large-scale structures
- Follow-up observations of interesting galaxies with MeerKAT: high resolution (≈ 5″), high sensitivity (80 12-m antennas), but small field of view; ideal for targeted observations of individual objects
- Combination with optical data from SkyMapper to search for stellar components in tidal streams and satellites and identify tidal dwarf galaxies
- Study of optical absorption lines in the spectra of background sources (AGN, quasars) will allow us to probe different gas phases, e.g. Na I, Ca II, O VI, etc.
- Further observations / archival data at mm / sub-mm, IR, optical, UV, X-ray to probe physical conditions and star formation activity in the target groups

Credit: Shaun Amy

Major scientific aims

- Tidal interaction and accretion in group environments
  Search for tidal structures, N-body simulations, formation of tidal dwarf galaxies, etc.
- Unknown / dark / “missing” satellites
  Complete census of galaxies in groups with $M_{H\,I} \gtrsim 10^5\ M_\odot$, search for “dark galaxies”, comparison with ΛCDM, etc.
- High-velocity clouds and halo gas
  Mapping of HVCs and extra-planar gas, feedback processes between disc and halo, etc.
- Cosmic web
  Neutral component of cosmic web, role in gas accretion of galaxies, etc.
- Morphology and dynamics of galaxies in H I
  Morphology, dynamics, lopsidedness, ram-pressure stripping, star formation, AGN activity, etc.
- Magnetic fields in galaxies and the IGM
  Magnetic field strength and orientation, role of magnetic fields in galaxy interaction and evolution, etc.
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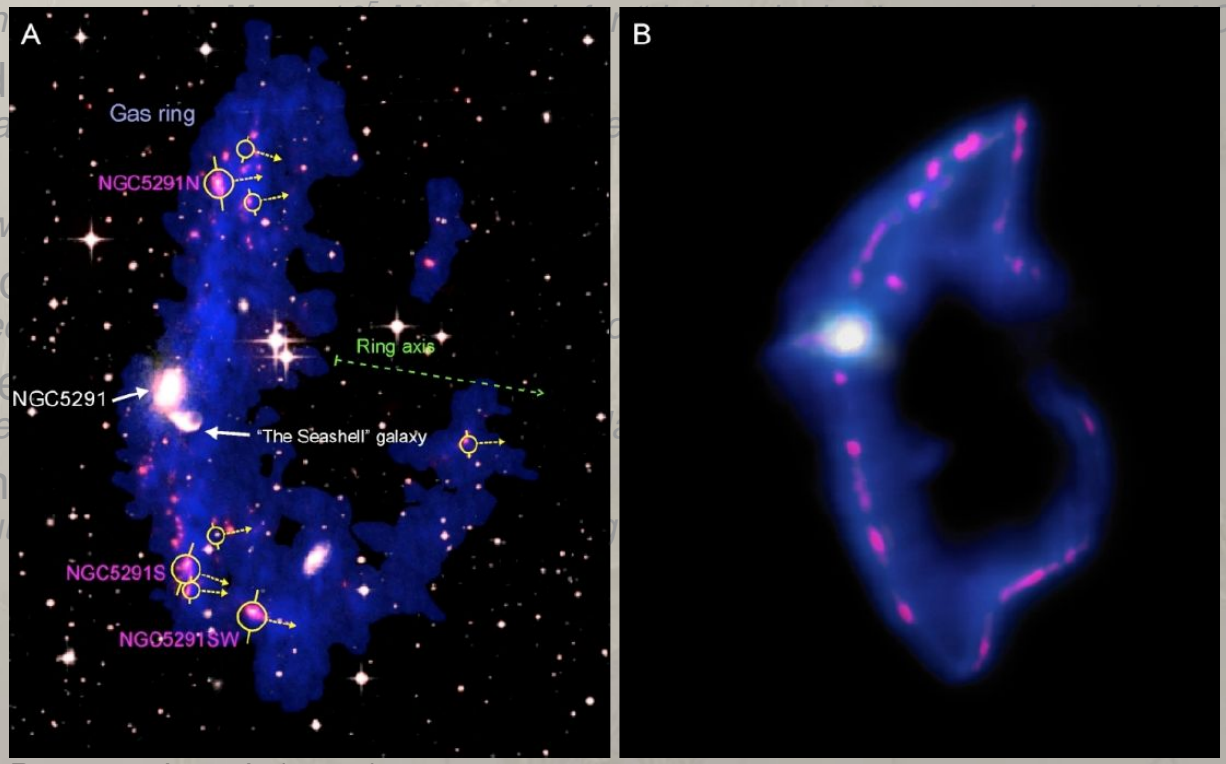

Bournaud et al. (2007)

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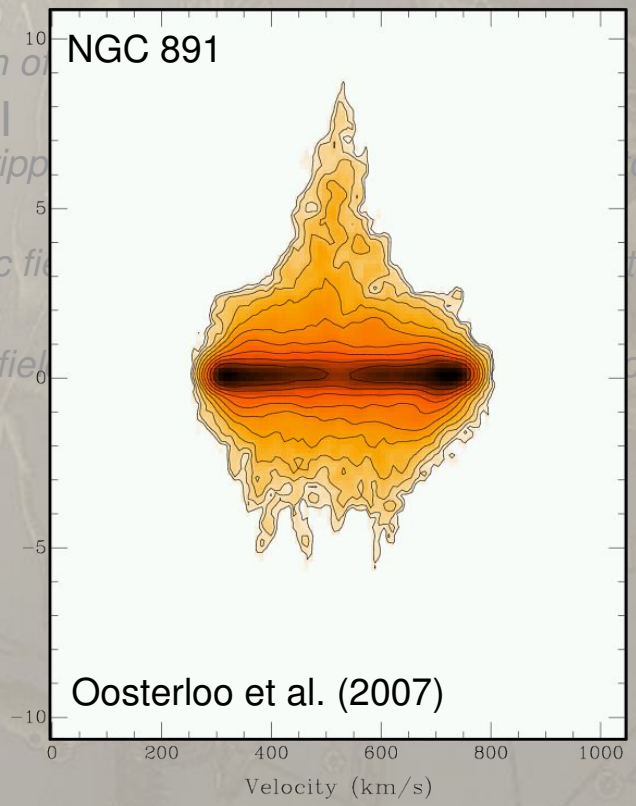

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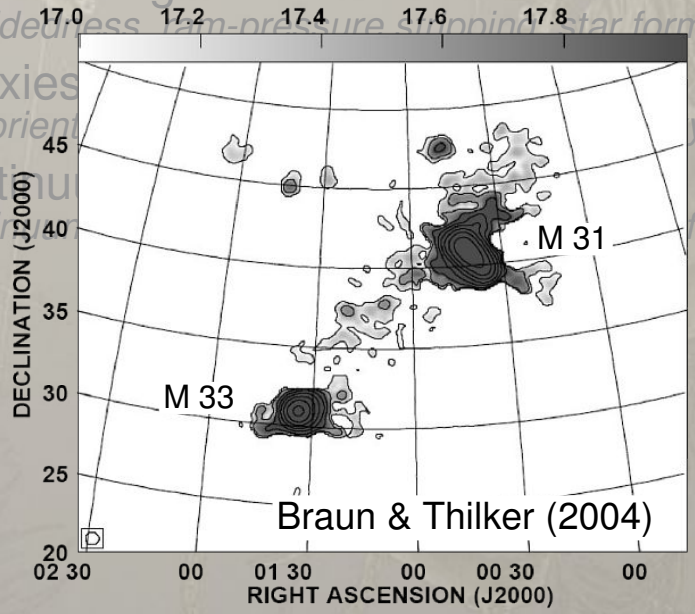

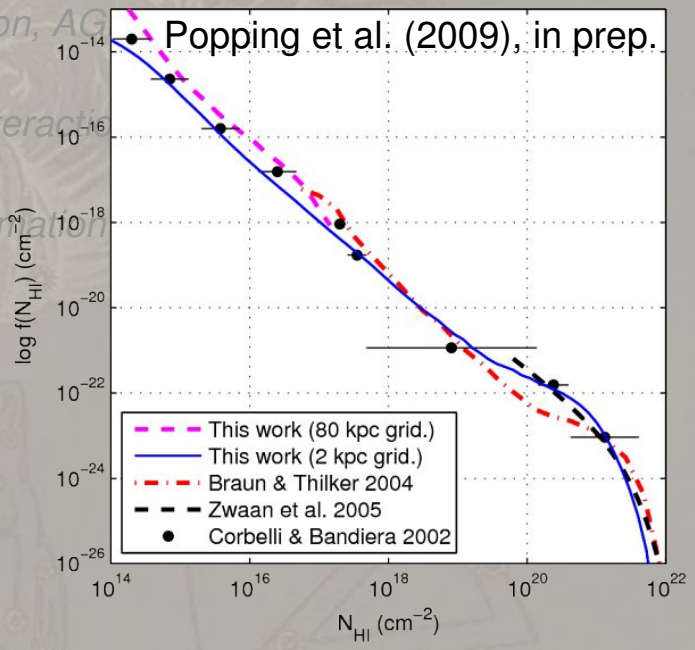

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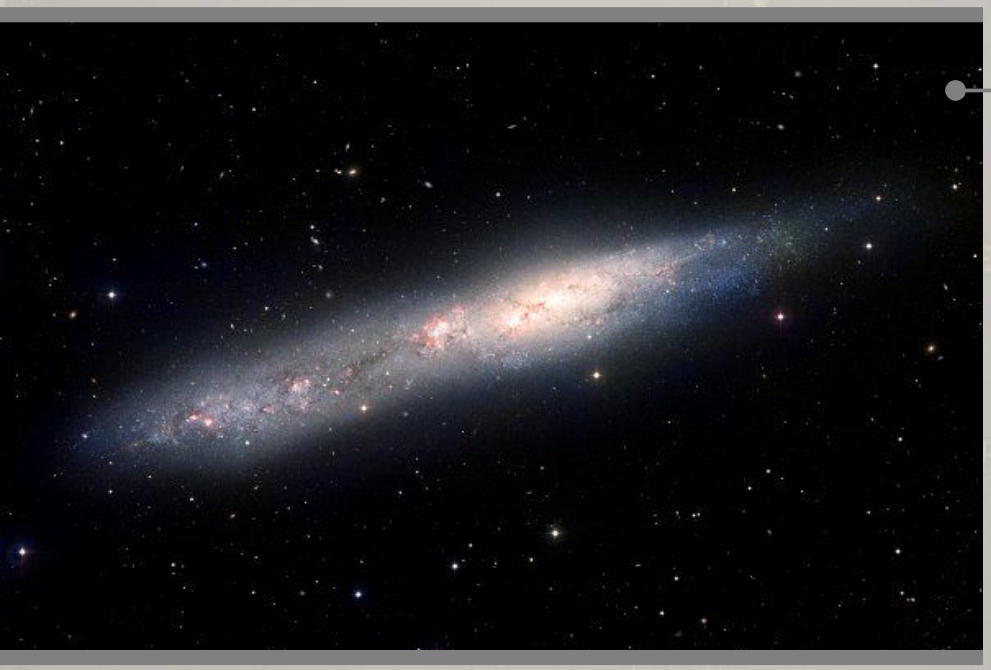
ATCA Observations of the Sculptor Group

Precursor observations of NGC 55 and NGC 300 with the ATCA

- Frequency: 1420 MHz (H I), 1384 MHz (continuum)
- Array configurations: EW352, EW367
- Number of pointings: 32
- Covered area: 2° × 2° (65 × 65 kpc²)
- Total integration time: 96 h (3 h per pointing)
- Angular resolution: 90″ × 150″ (0.8 × 1.4 kpc²)
- Velocity resolution: 4 km/s
- Sensitivity in H I: 10^{19} cm^{-2} (10^5 $M_\odot$)

ATCA Observations of the Sculptor Group



Credit: ESO

NGC 55

Type:	SB(s)m
Inclination:	81°
Velocity:	129 km/s (heliocentric)
Distance:	1.9 Mpc
Angular size:	32.4 × 5.6 arcmin
Total mass:	$1.8 \times 10^{10}\ M_{\odot}$

Credit: M. Schirmer, W. Gieren, et al., ESO

NGC 300

Type:	SA(s)d
Inclination:	45°
Velocity:	144 km/s (heliocentric)
Distance:	1.9 Mpc
Angular size:	21.9 × 15.5 arcmin
Total mass:	$2.4 \times 10^{10}\ M_{\odot}$

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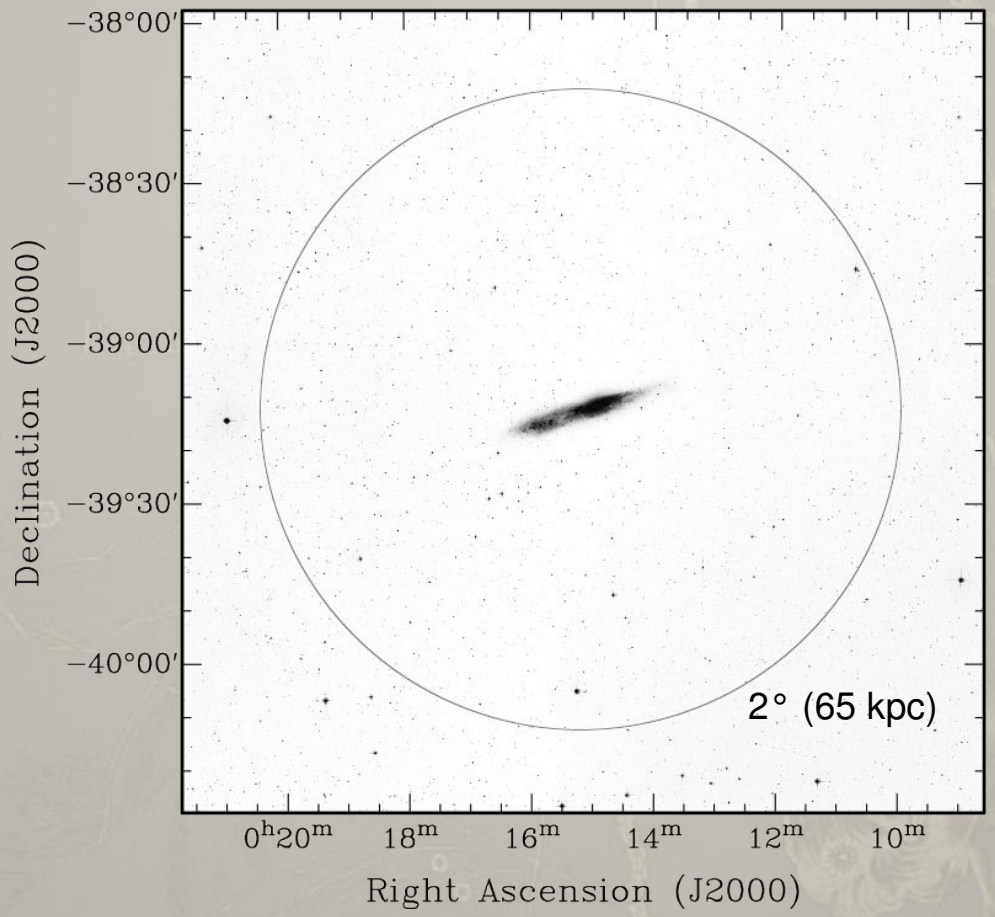
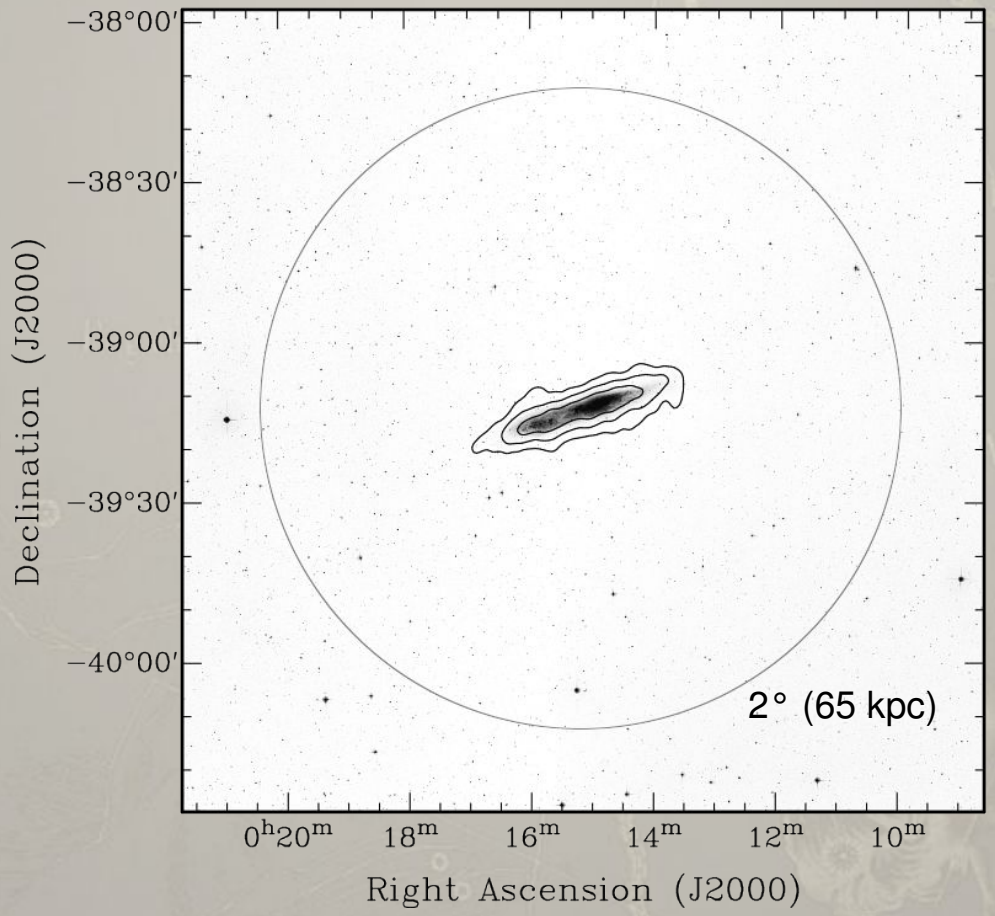


DSS image of NGC 55

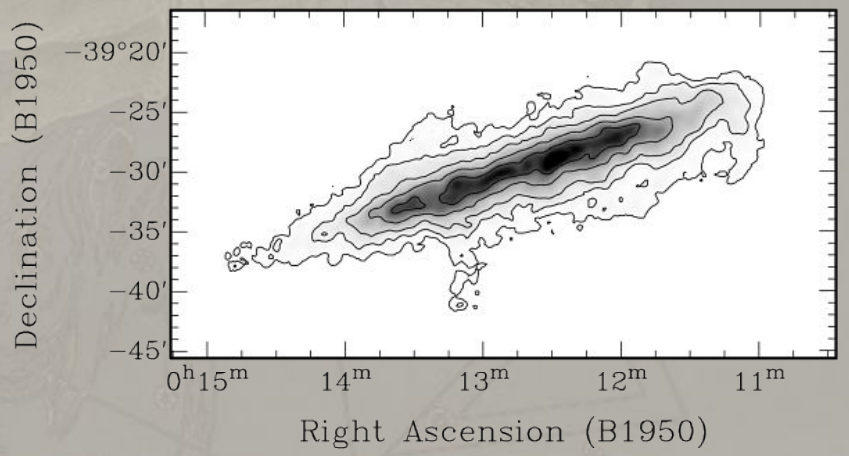
ATCA Observations of the Sculptor Group



DSS image of NGC 55

Lowest H I contour: 3×10^{20} cm^{-2}

Comparison: VLA data (Puche et al. 1991)



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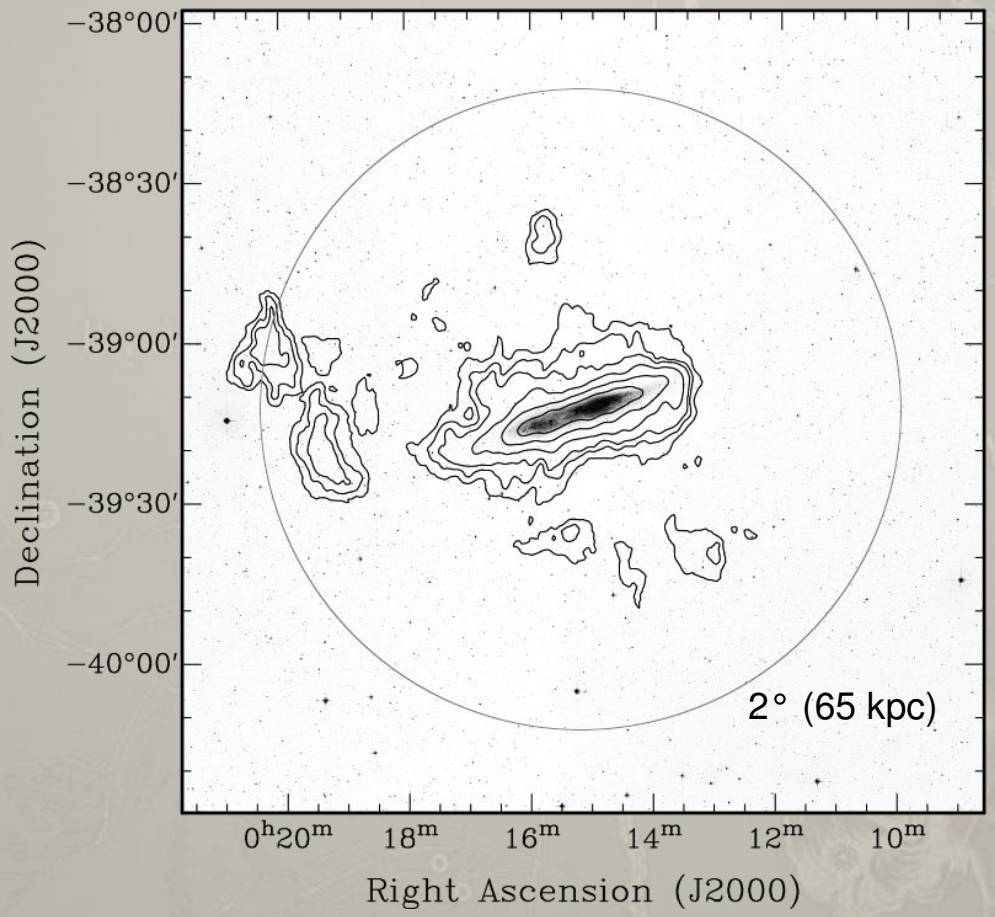
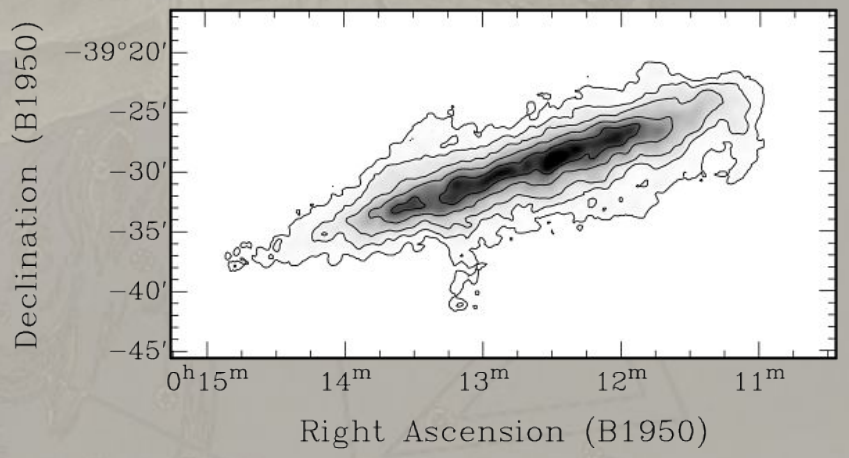


DSS image of NGC 55

Lowest H I contour: 1×10^{19} cm^{-2}

Very extended gaseous halo and several isolated H I clouds!

Comparison: VLA data (Puche et al. 1991)



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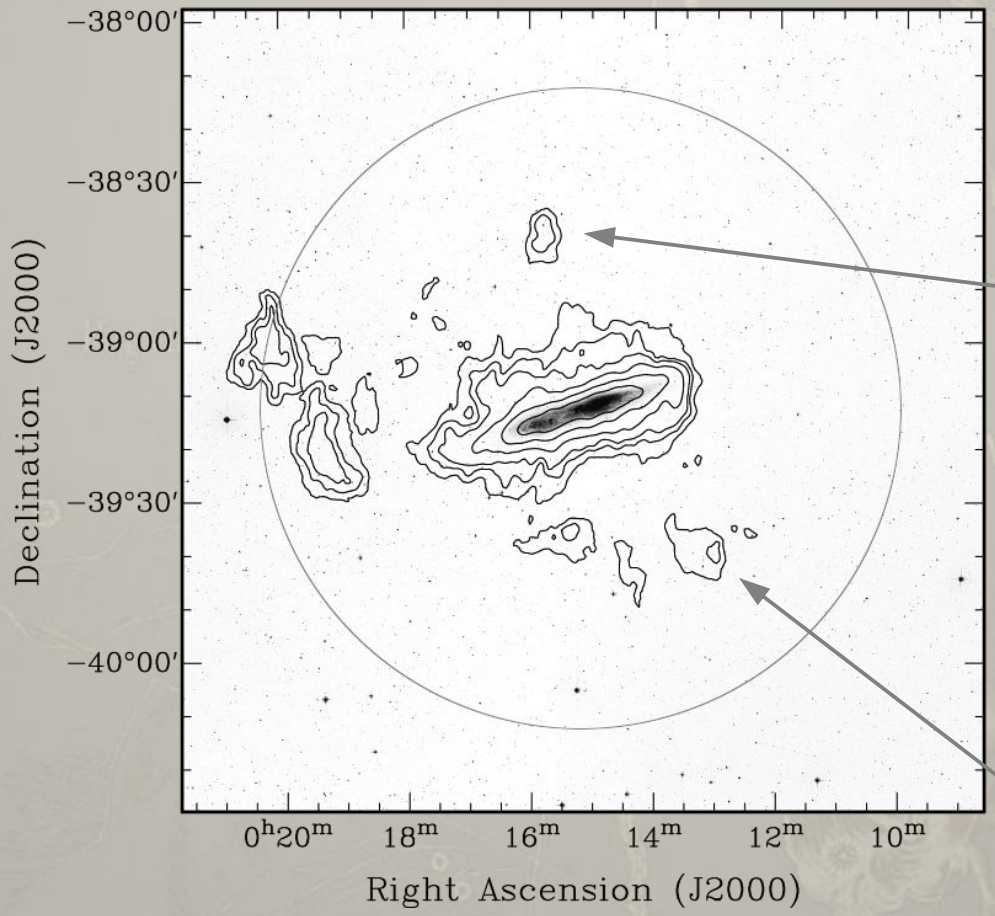
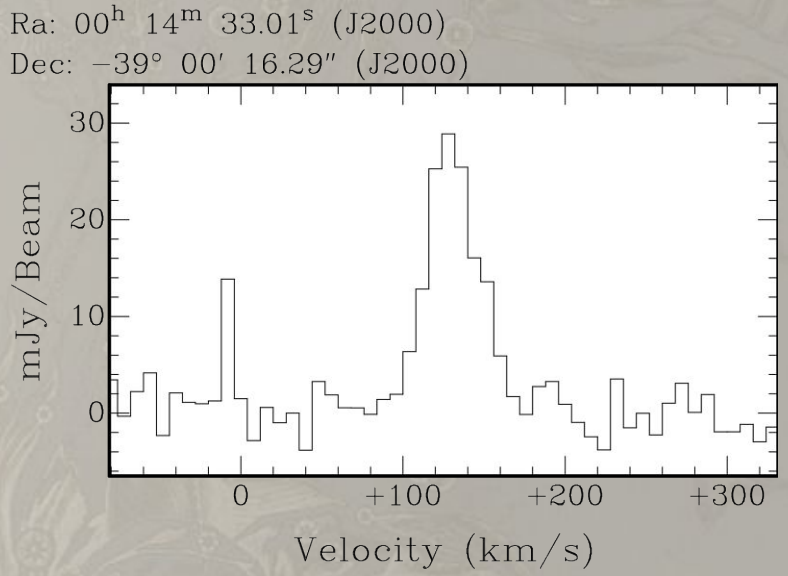
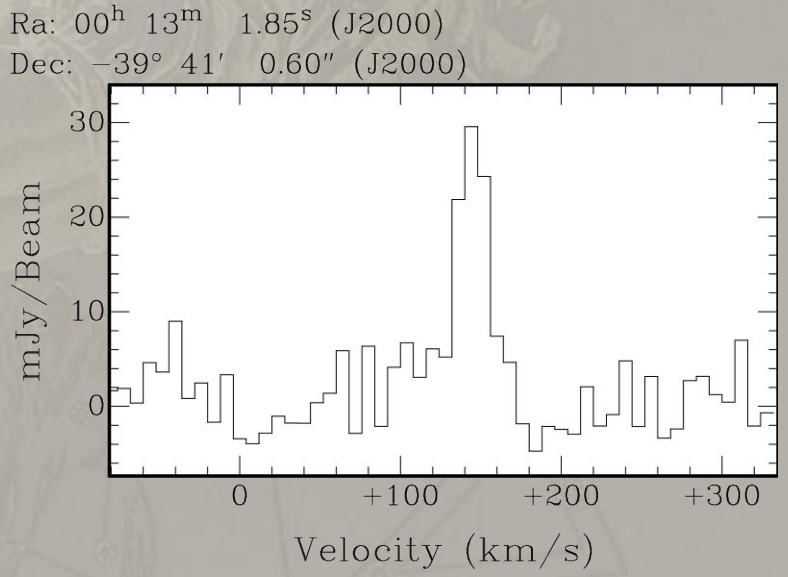
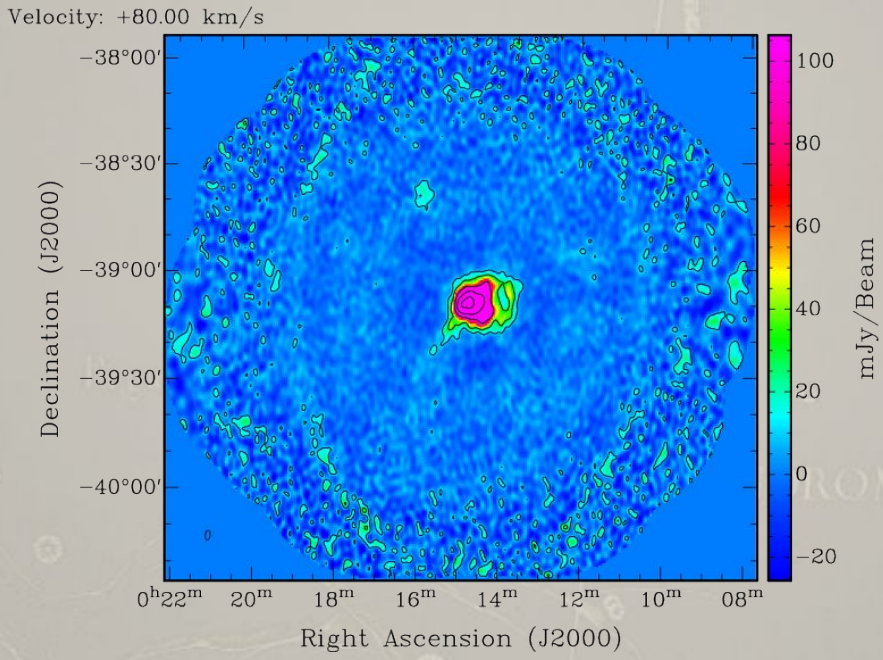


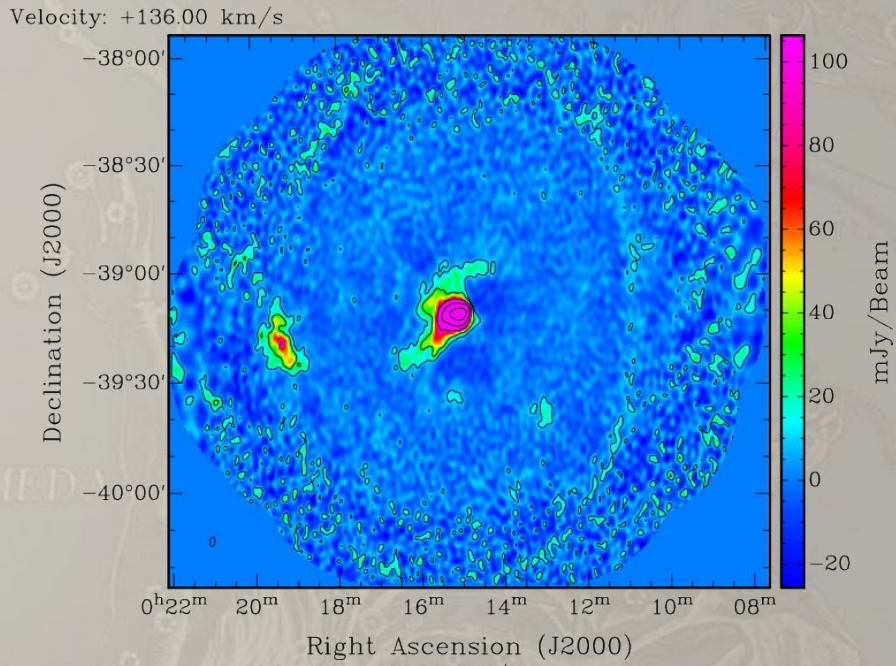


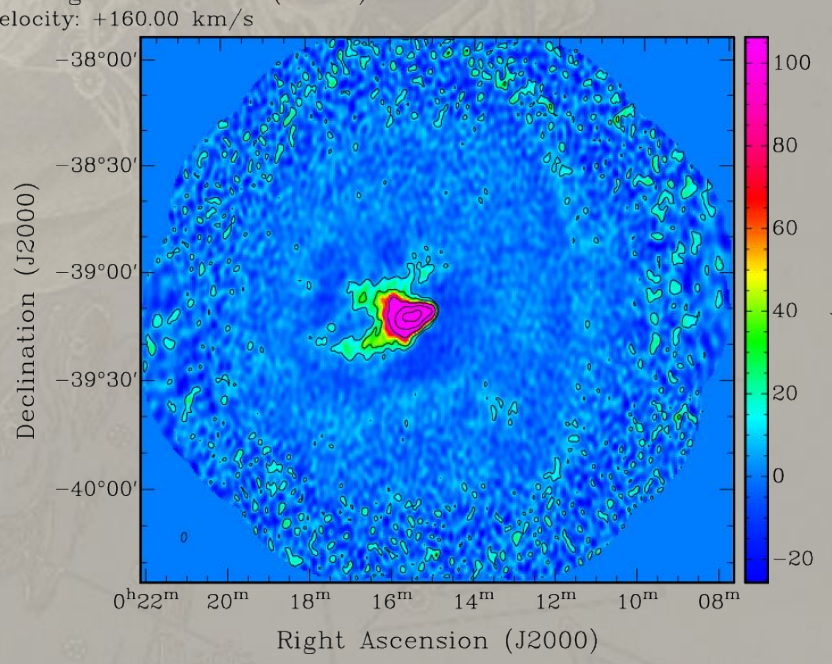


BROLGA will be by another order of magnitude more sensitive!

ATCA Observations of the Sculptor Group







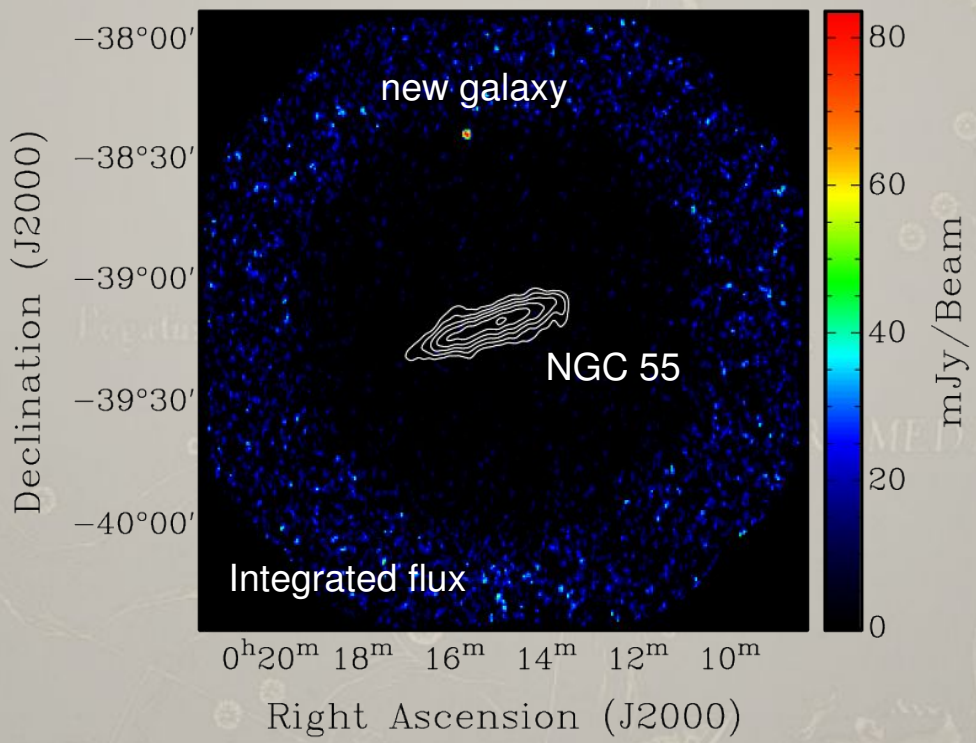
Channel maps

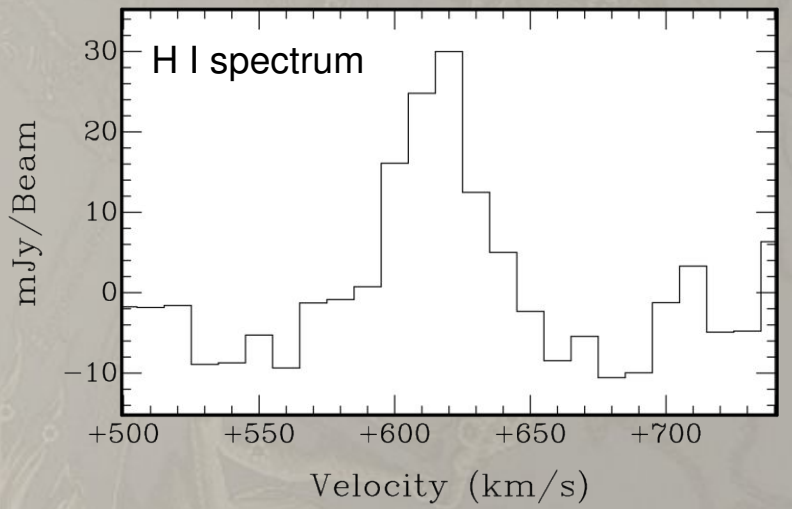
H I image of NGC 55 looks very distorted

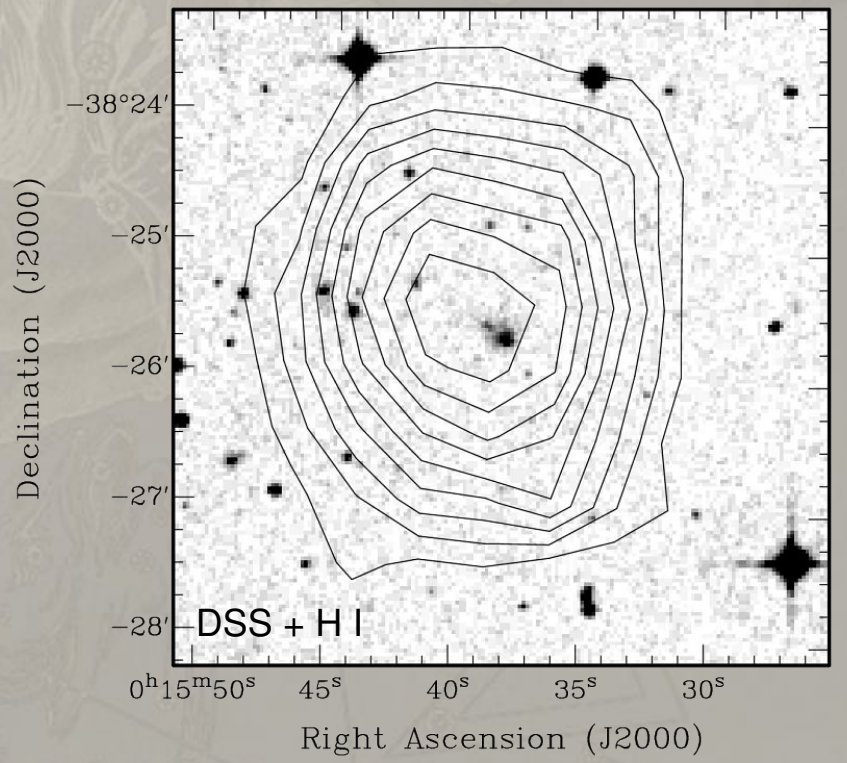
Extended regions of extra-planar gas as well as isolated gas clouds

Symmetric gaseous arms suggest strong tidal distortion

ATCA Observations of the Sculptor Group







- "New" galaxy in the NGC 55 field with faint and unusual optical counterpart
- First ever velocity measurement: v_{rad} = 610 km/s
  $D = v_{rad} / H_0 \approx 8$ Mpc $\Rightarrow$ New local galaxy!
  $M_{H\,I} \simeq 1.5 \times 10^7\ M_\odot$
- BROLGA will deliver a complete census of galaxies and satellites down to $M_{H\,I} \simeq 10^5\ M_\odot$

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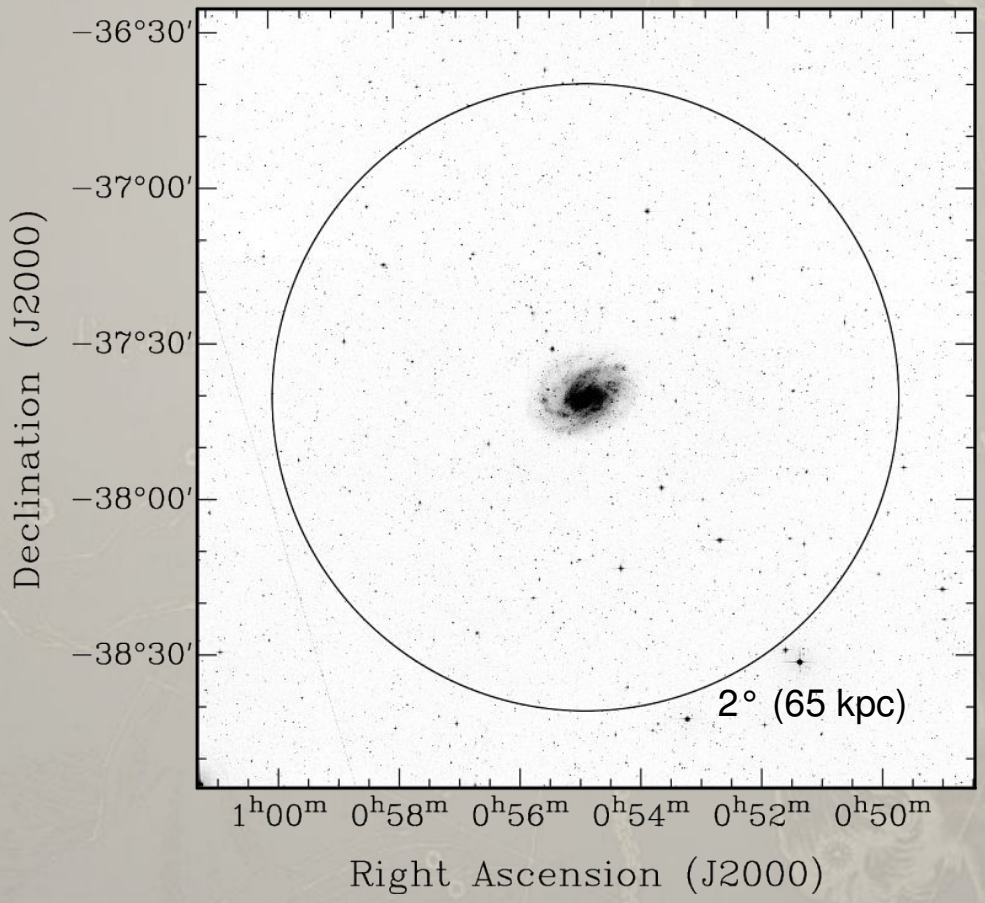
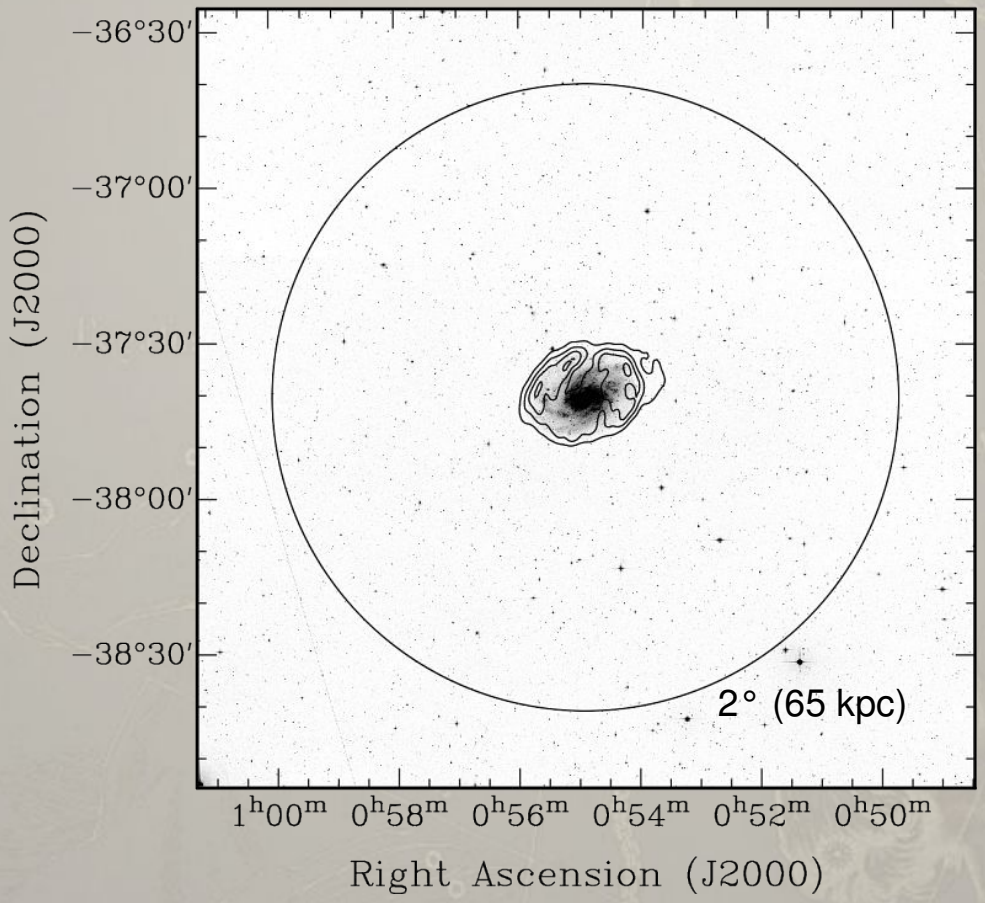


DSS image of NGC 300

ATCA Observations of the Sculptor Group



DSS image of NGC 300

Lowest H I contour: 5×10^{20} cm^{-2}

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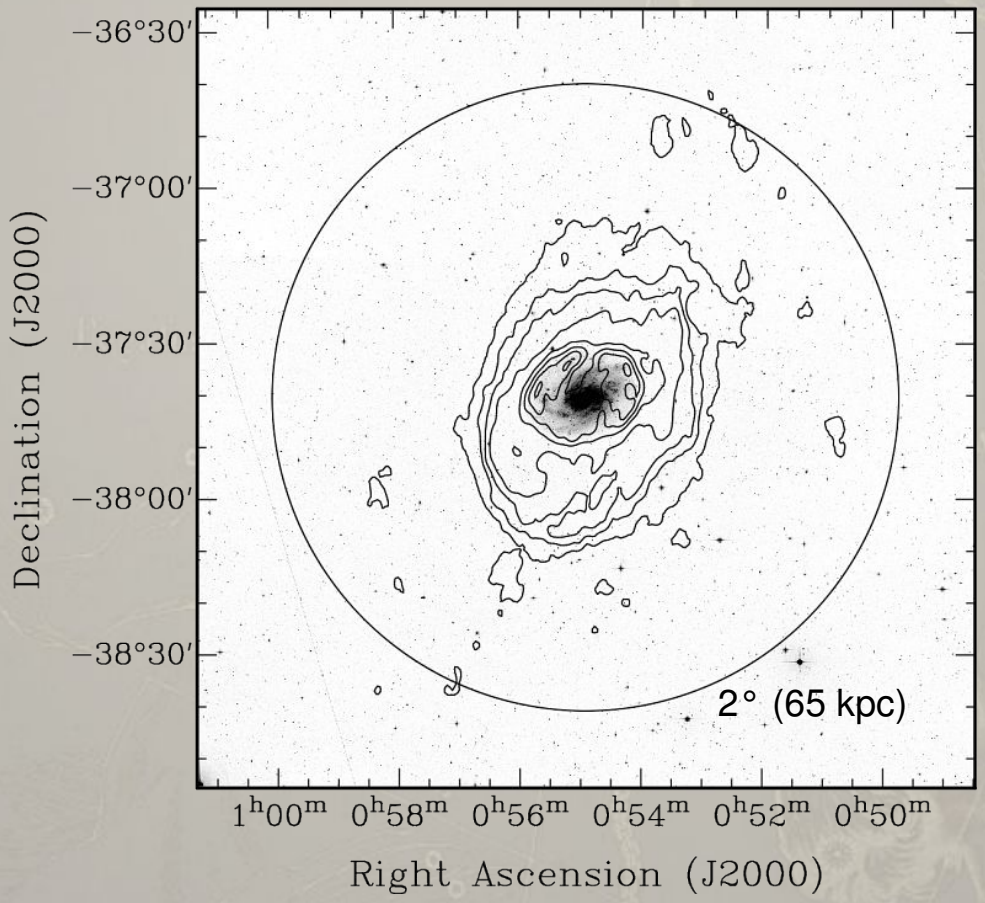
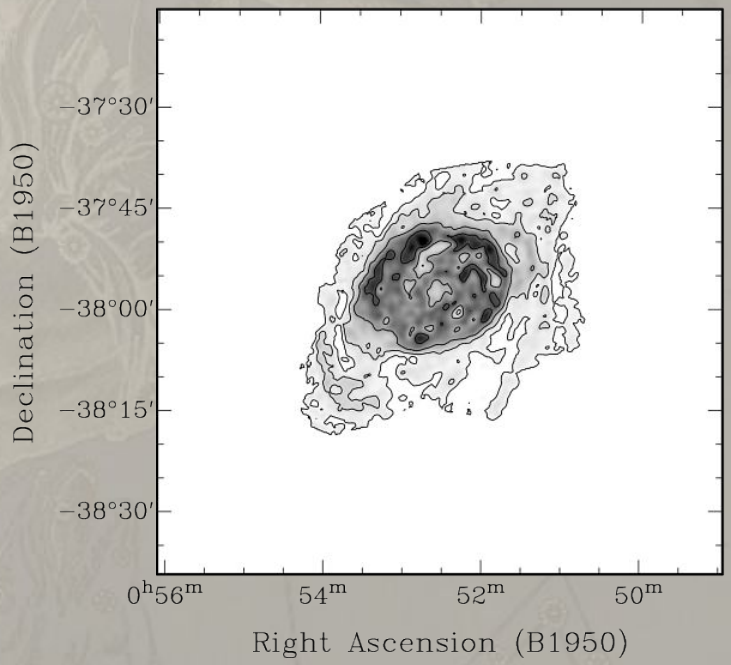


DSS image of NGC 300

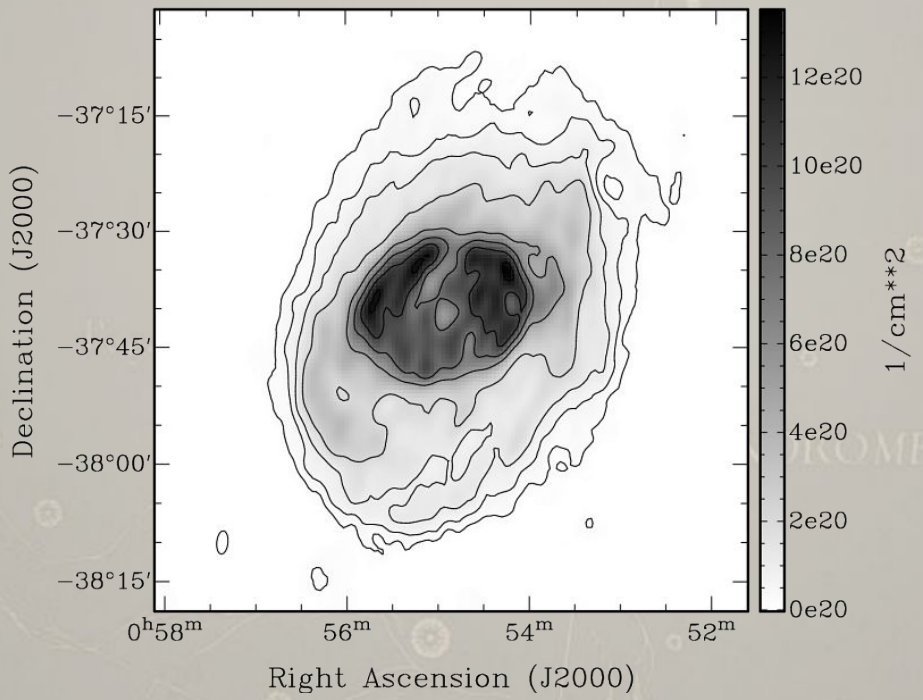
Lowest H I contour: 1×10^{19} cm^{-2}

Very extended outer disc and several isolated H I clouds!



Comparison: VLA data (Puche et al. 1990)

ATCA Observations of the Sculptor Group



Inner disc

- Aligned with optical disc
- Major axis: ≈ 20′ (11 kpc)
- Column densities: ≈ 10^{21} cm^{-2}

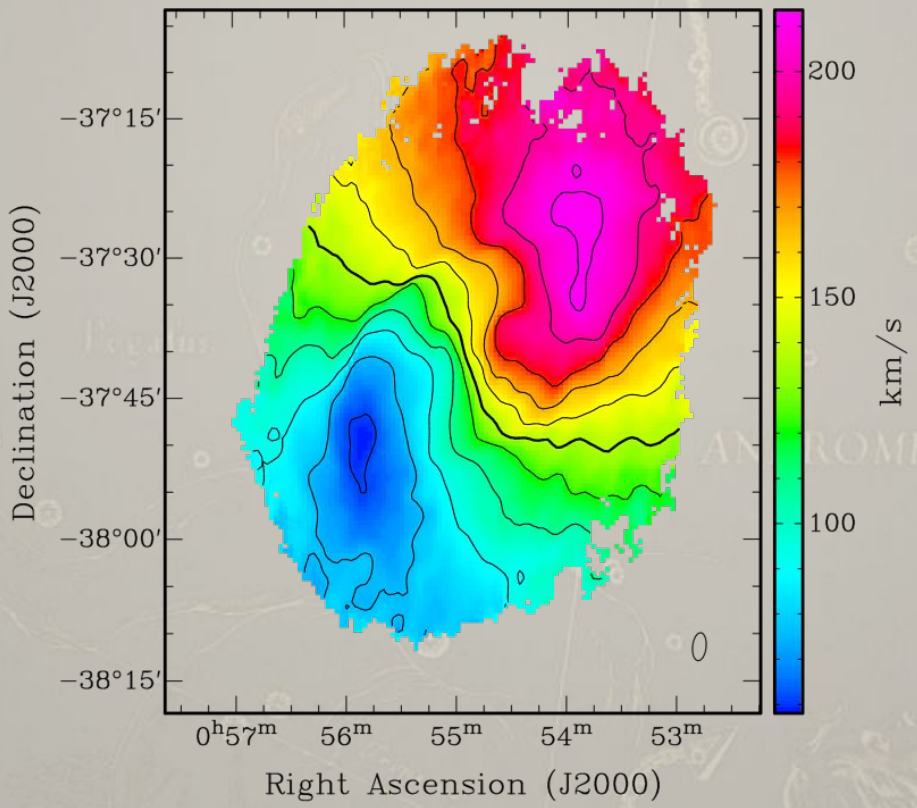
Outer disc

- Systematic change in position angle
- Major axis: ≈ 1° (33 kpc)
- Column densities: ≈ 10^{19}…$10^{20.5}$ cm^{-2}

Strong asymmetry

- South-eastern edge sharp and smooth
- North-western edge broad and ragged
- Possible explanation: ram-pressure interaction as NGC 300 is moving through intergalactic medium (or result of tidal forces?)

ATCA Observations of the Sculptor Group

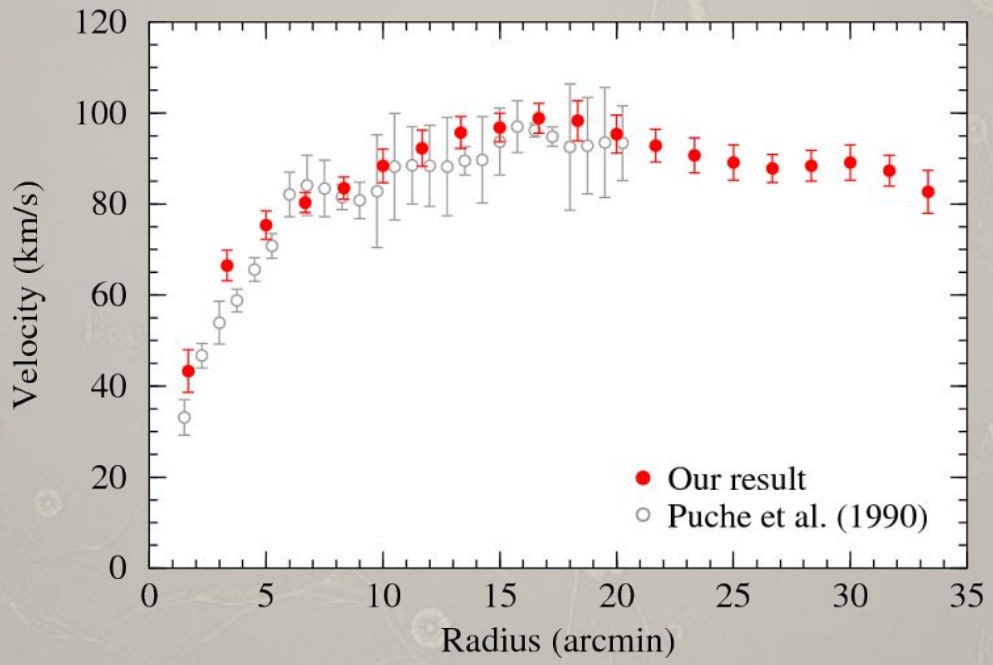


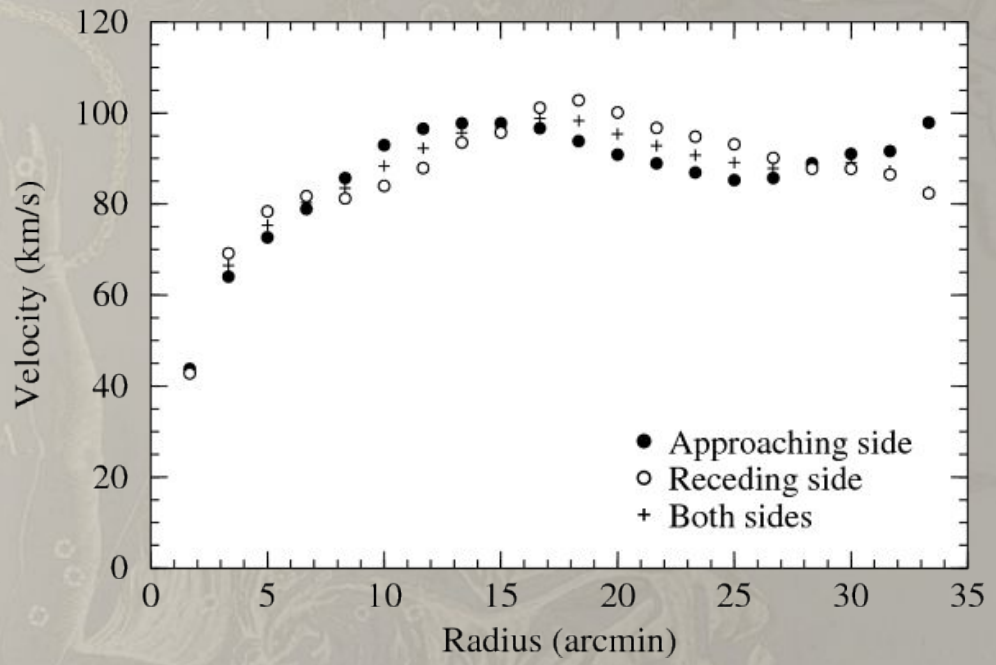
Velocity field

- Determination: position of maximum of Gauß-Hermite polynomials fitted to spectra
- Velocity field looks very distorted
- Inner disc: regular rotation consistent with orientation of optical disk
- Outer disc: gradual and systematic shift of kinematic axis with respect to inner disk

Morphology and kinematics of NGC 300 suggestive of recent tidal distortion.

ATCA Observations of the Sculptor Group





Rotation curve

- Application of GIPSY task **`rotcur`** to fit tilted rings to velocity field
- Rotation curve extends out to 0.56° (R = 18.4 kpc), much further than previous VLA data of Puche et al. (1990)
- Rotation velocity peaks at R ≈ 8.75 kpc with v_{rot} ≈ 98 km/s, then slowly decreases to v_{rot} ≈ 83 km/s

Summary

- BROLGA will study a complete, volume-limited sample of 23 nearby galaxy groups in H I and radio continuum using ASKAP
- BROLGA will allow us to study structure formation in group environments in great detail and as a function of different group parameters, e.g. mass, density, environment, etc.
- Primary science areas of BROLGA include tidal interaction and accretion, cosmic web, missing satellites and high-velocity clouds, morphology and dynamics of galaxies, polarisation and magnetic fields, etc.
- ASKAP is the ideal instrument due to its large field of view of 30 sq. deg. and excellent coverage of the *uv* plane
- BROLGA will have a 5σ H I mass sensitivity of $\simeq 10^5\ M_\odot$ and a continuum rms of 2 μJy
- BROLGA will also include data at other wavelengths (including radio, IR, optical, UV, etc.) to fully understand the physical conditions in the studied galaxy groups

Get involved!

- ASKAP Survey Science Projects are open to new members
- More information at http://www.atnf.csiro.au/projects/askap/