



Gas and Dark Matter in the Sculptor Group

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Astronomy
Research



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- ★ NGC 300
 - ▶ HI observations
 - ▶ Ram-pressure interaction
 - ▶ Origin of outer gas disc

- ★ NGC 55
 - ▶ HI observations
 - ▶ Population of high-velocity clouds

- ★ Science relevant to **WALLABY** and **MHONGOOSE** projects.
 - ▶ See talks by *Bärbel Koribalski* and *Erwin de Blok* later this afternoon.



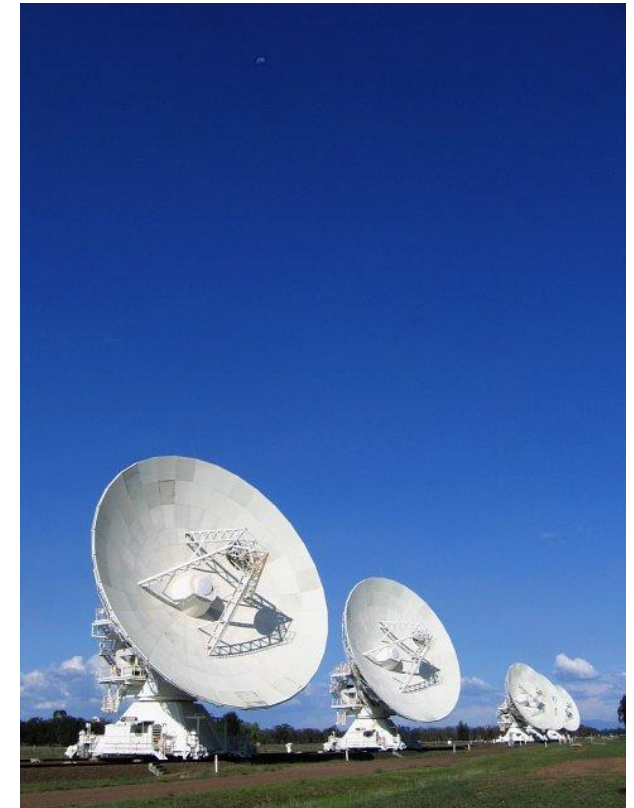
Australia Telescope Compact Array, Narrabri

★ ATCA HI observations of Sculptor group galaxies

- ▶ Array configuration: EW 352 / EW 367
- ▶ Covered area: $2^\circ \times 2^\circ$
- ▶ Number of pointings: 32
- ▶ Integration time: 96 h per galaxy
- ▶ Angular resolution: $90'' \times 180''$ (≈ 1 kpc)
- ▶ Velocity resolution: 4 km s^{-1}
- ▶ 5σ HI sensitivity: 10^{19} cm^{-2} , $10^5 M_\odot$

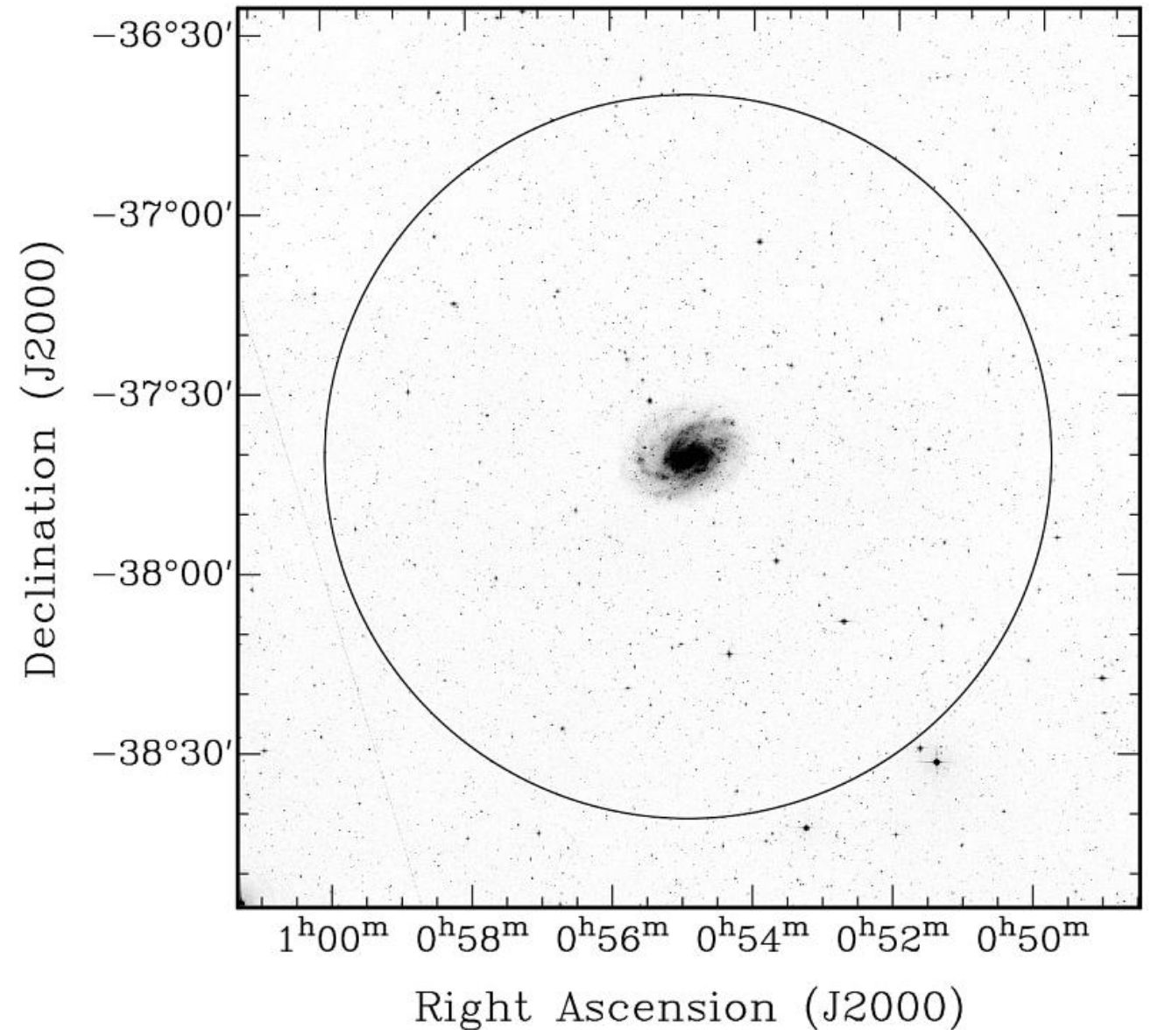
★ Status

- ▶ NGC 300
 - Westmeier, Braun & Koribalski 2011, MNRAS, 410, 2217
- ▶ NGC 55
 - Data taken and analysed (Westmeier et al., in prep.)
- ▶ NGC 247 / 7793
 - Observations ongoing

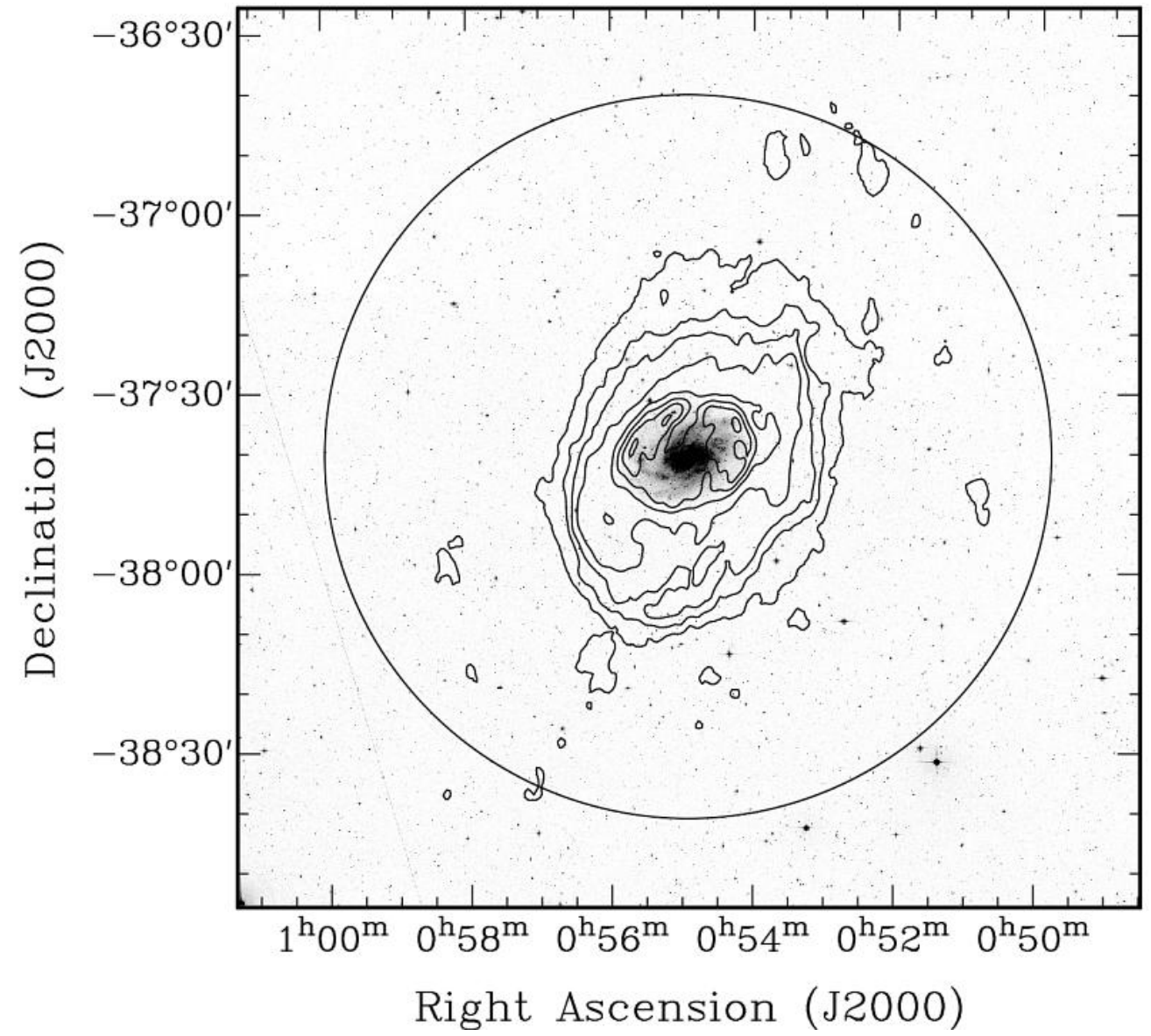
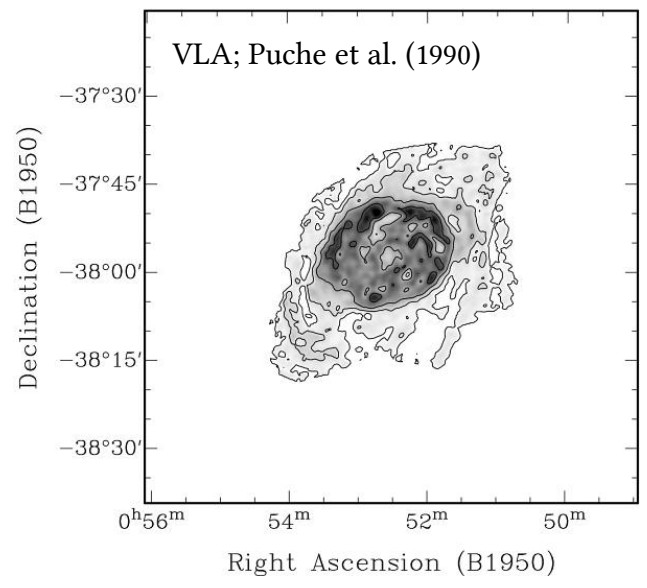


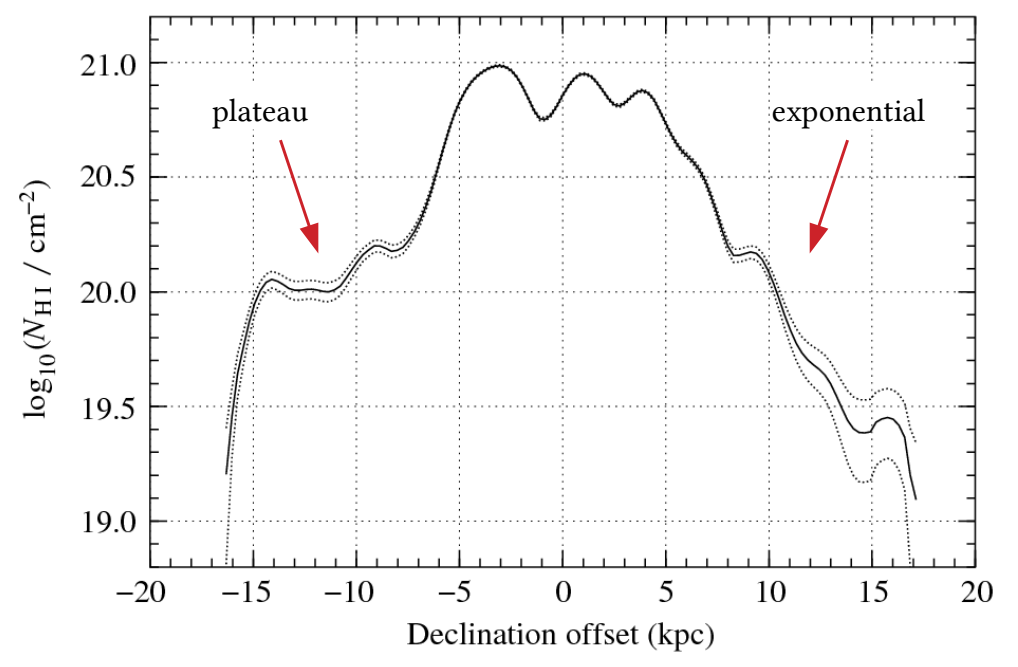
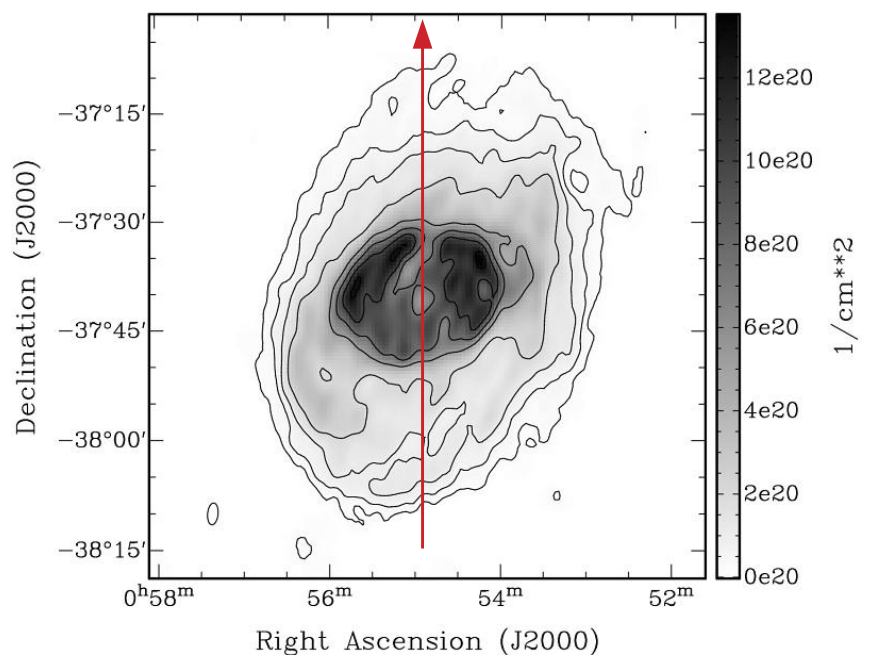
ATCA, Narrabri

★ DSS image of NGC 300



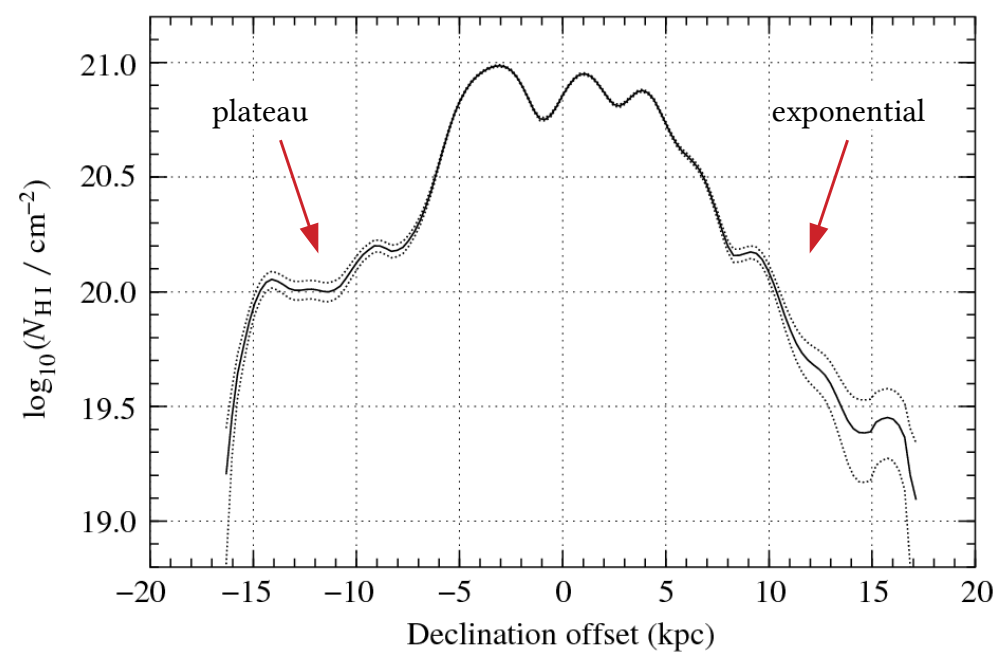
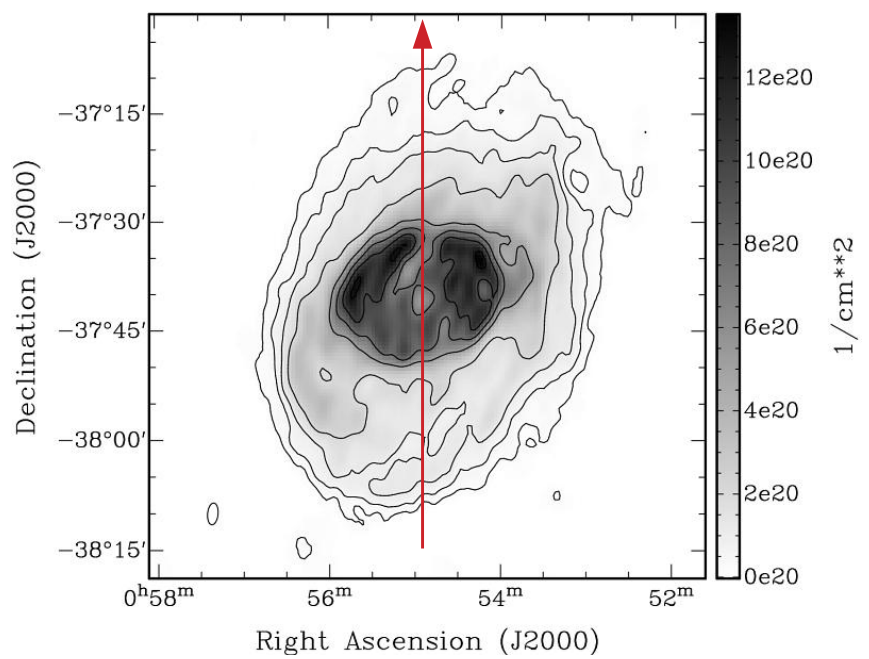
- ★ DSS image of NGC 300
- ★ HI contours
 - ▶ Lowest: 10^{19} cm^{-2}
 - ▶ Extended outer HI disc





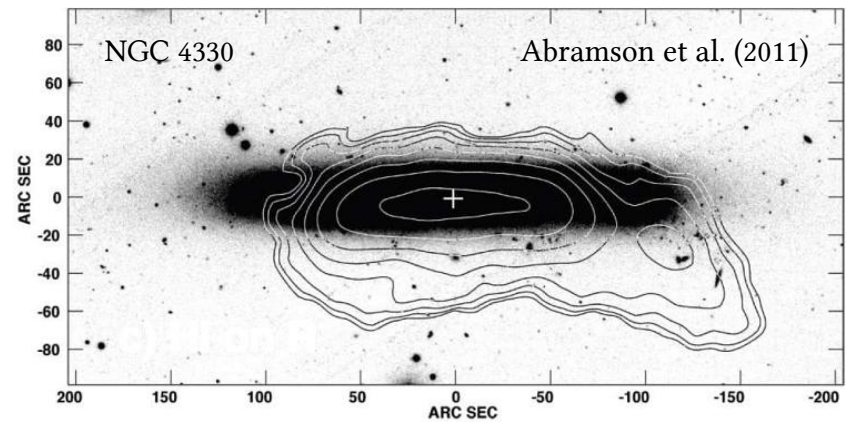
★ HI column density distribution

- ▶ Notable **asymmetries** in the outer HI disc:
 - South-eastern edge sharp and smooth.
 - North-western edge extended and frayed.



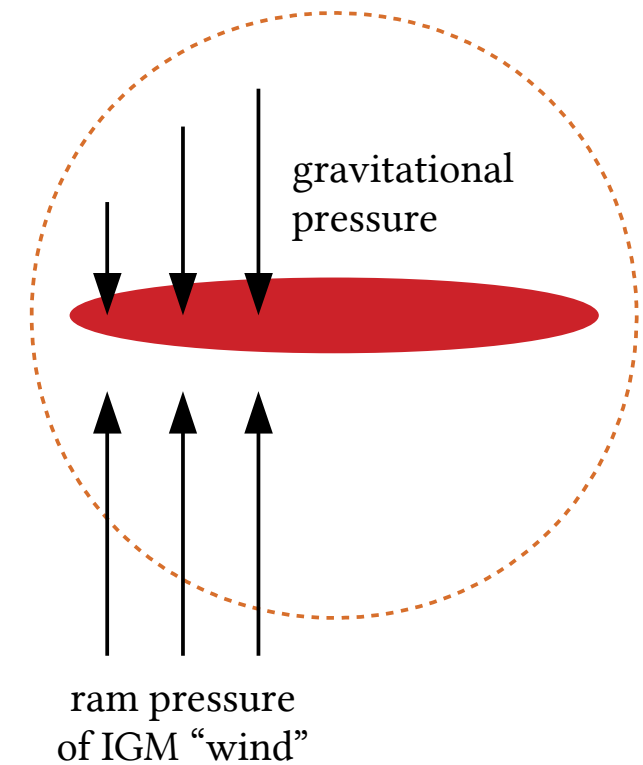
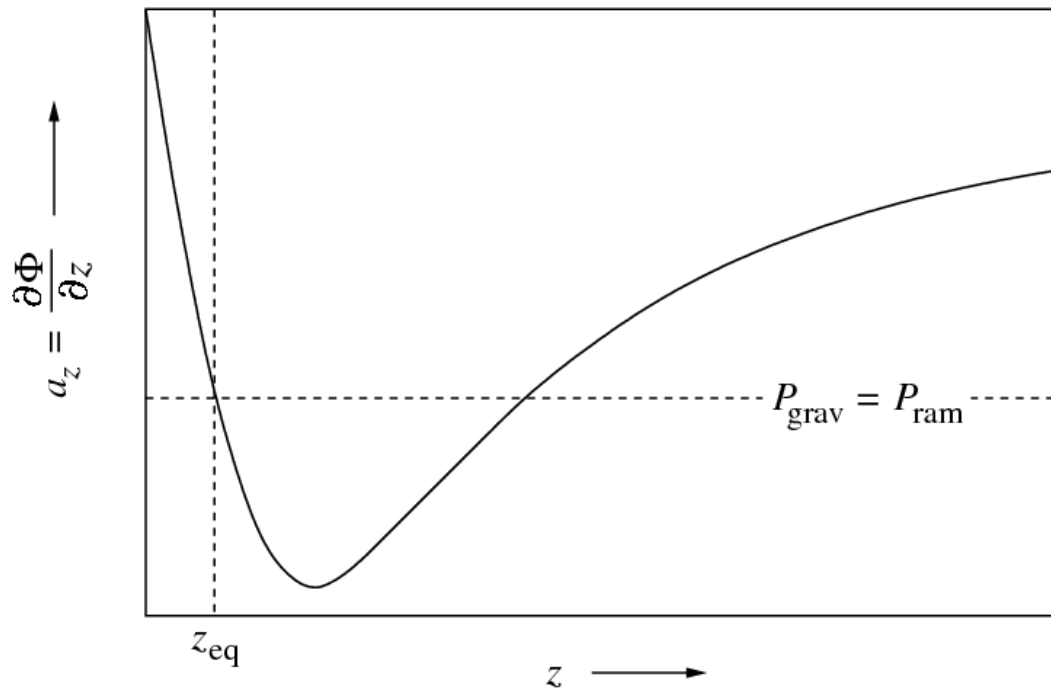
★ HI column density distribution

- ▶ Notable **asymmetries** in the outer HI disc:
 - South-eastern edge sharp and smooth.
 - North-western edge extended and frayed.
- ▶ Possible explanation:
 - Distortion of disc by **ram pressure** of IGM in the Sculptor group.



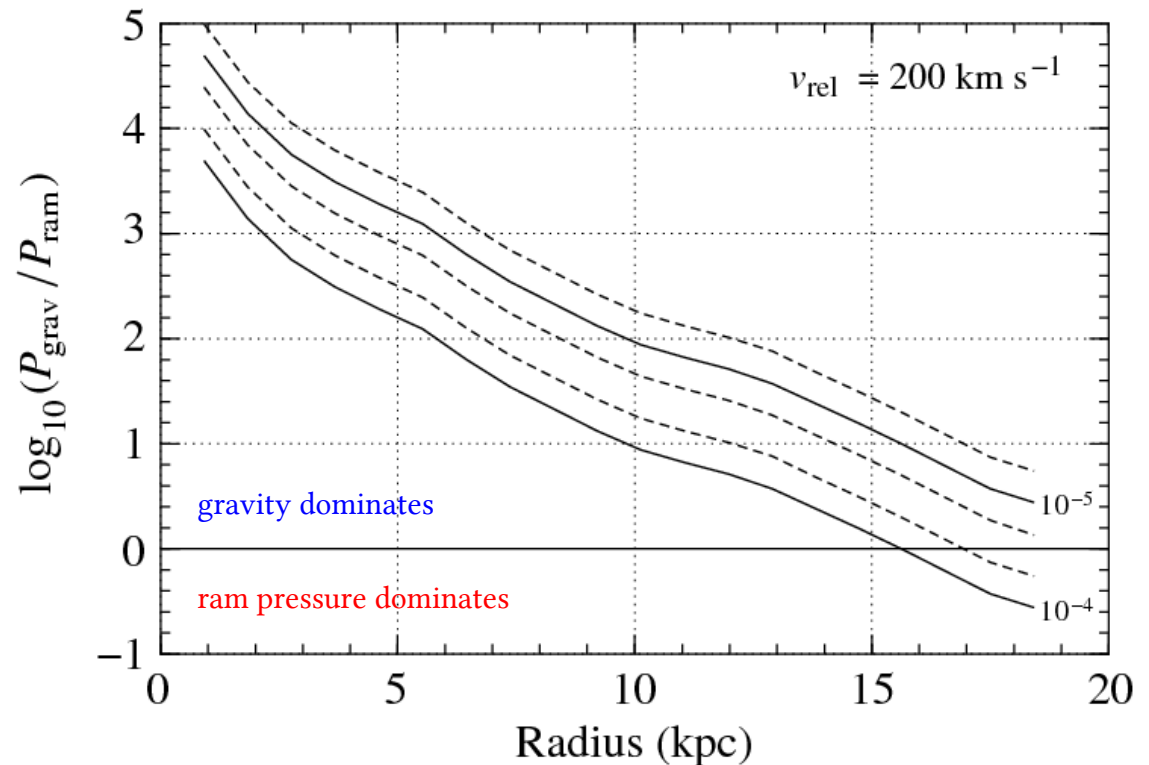
★ Ram-pressure stripping

- ▶ Ram pressure: $P_{\text{ram}} = \rho_{\text{IGM}} v^2$
- ▶ Gravitational pressure: $P_{\text{grav}} = \Sigma_{\text{gas}}(r) \times |\partial\Phi(r)/\partial z|_{\text{max}}$
- ▶ Face-on situation, but valid for inclination angles of up to 60° (Rödiger et al. 2005).



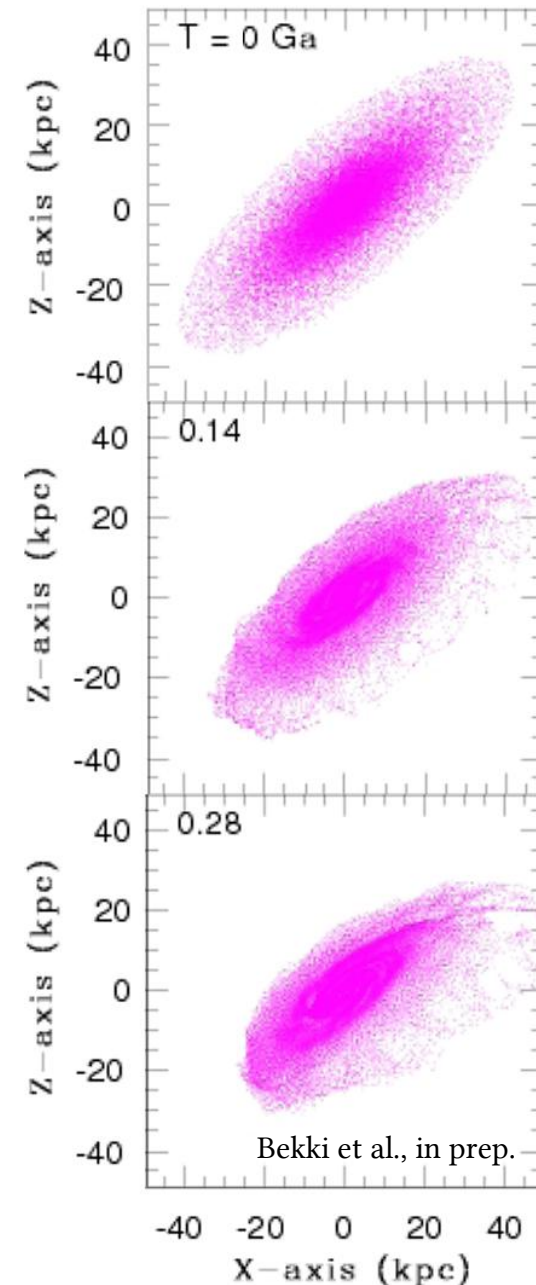
★ Effects of ram pressure

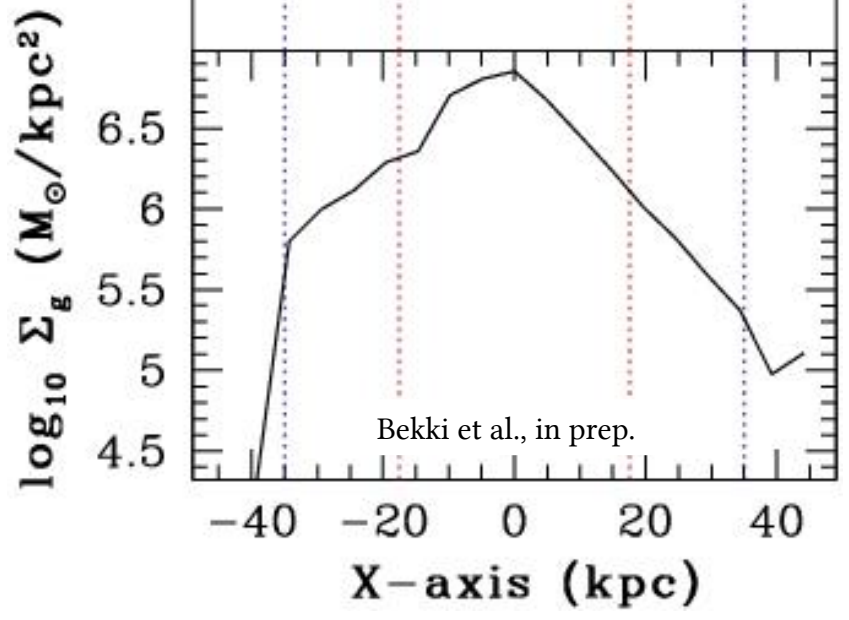
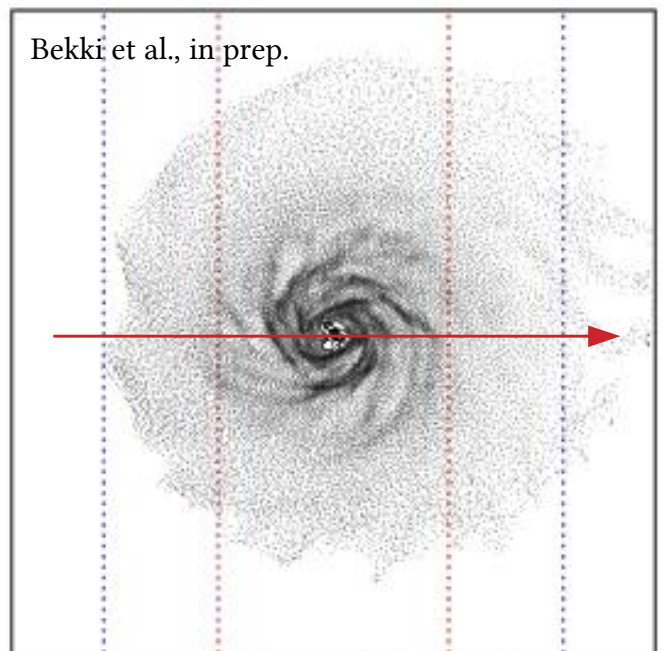
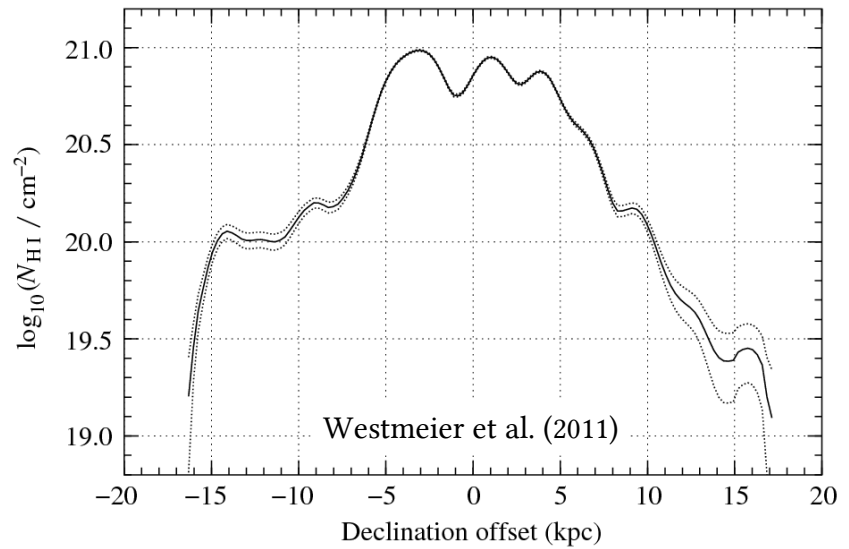
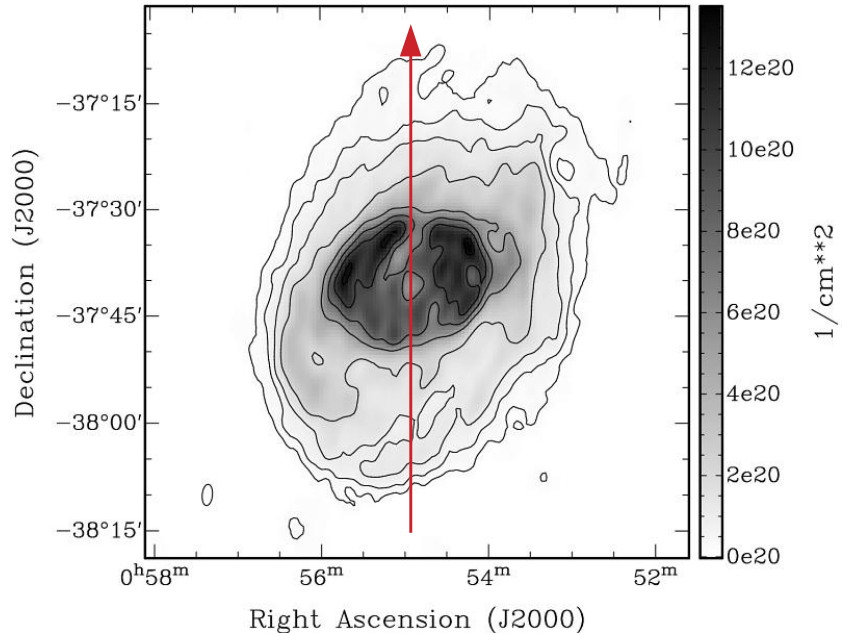
- ▶ Ram pressure does occur in **groups** (not just clusters) under reasonable assumptions on
 - the IGM density: $10^{-4} \dots 10^{-5} \text{ cm}^{-2}$
 - the relative velocity: $100 \dots 300 \text{ km s}^{-1}$
- ▶ Ram pressure affects the outer gas disc of galaxies and possibly contributes to **warping**.
→ *U-shaped warps?*
- ▶ A systematic study of ram-pressure stripping (*observations + simulations*) can be used to constrain the **IGM density** in galaxy groups.



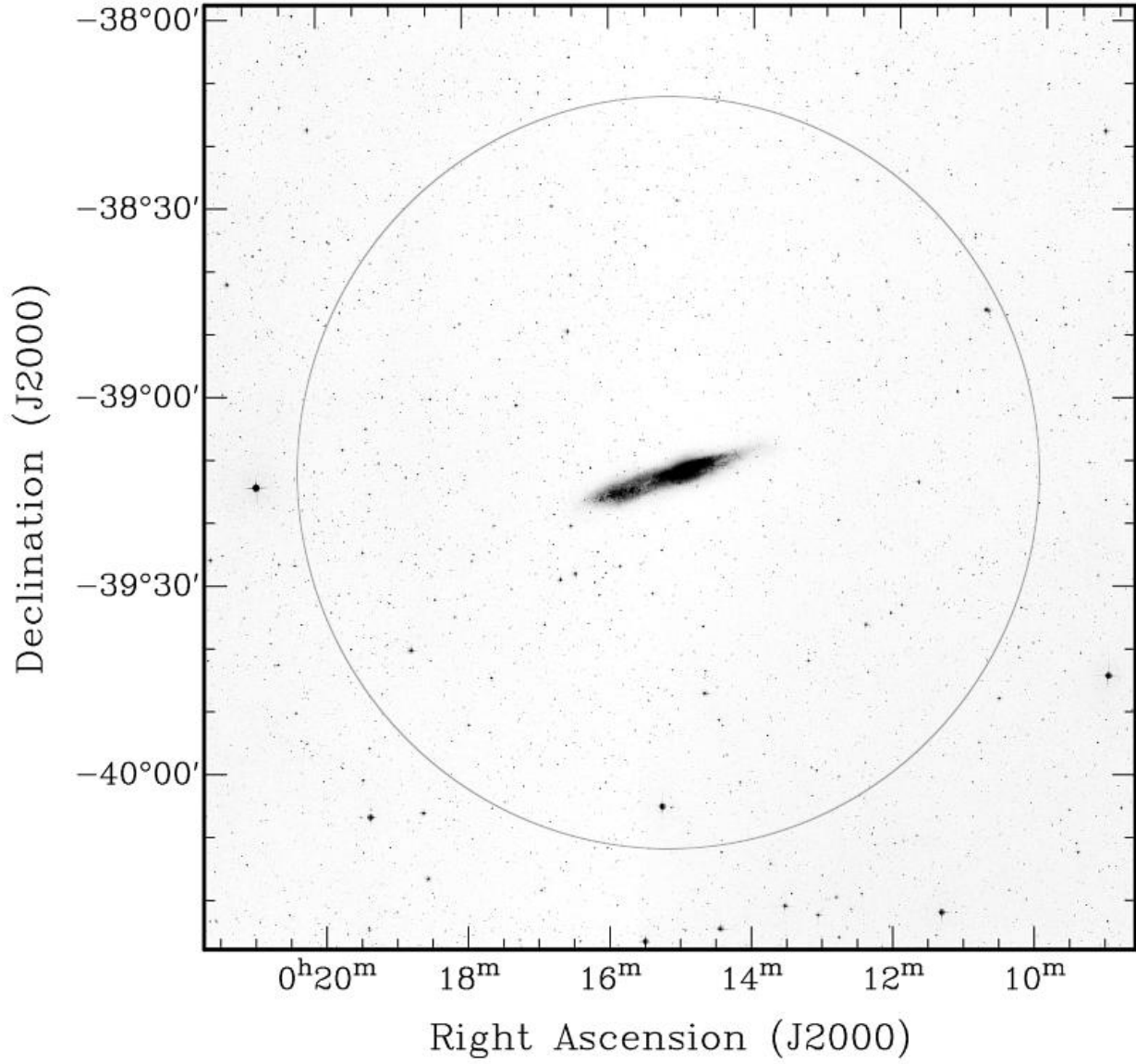
★ Numerical simulations

- ▶ Run by *Kenji Bekki* at ICRAR.
- ▶ Using smoothed-particle hydrodynamics.
- ▶ Galaxy:
 - Gas-rich, MW-type spiral galaxy
 - Stellar mass: $M_{\star} = 6 \times 10^{10} M_{\odot}$
 - Gas mass: $M_{\text{gas}} = 0.1 M_{\star}$
 - Gas disc radius: $R_{\text{gas}} = 3 R_{\star}$
- ▶ IGM:
 - Temperature: $T_{\text{IGM}} = 10^6 \text{ K}$
 - Density: $\rho_{\text{IGM}} = 10^{-4} \text{ cm}^{-3}$
 - Rel. velocity: $v \approx 250 \text{ km s}^{-1}$
- ▶ Aims:
 - Compare effects of ram pressure with observations.
 - Study effects of ram pressure on galaxy **evolution**.
 - Estimate **density** of the IGM in Sculptor.

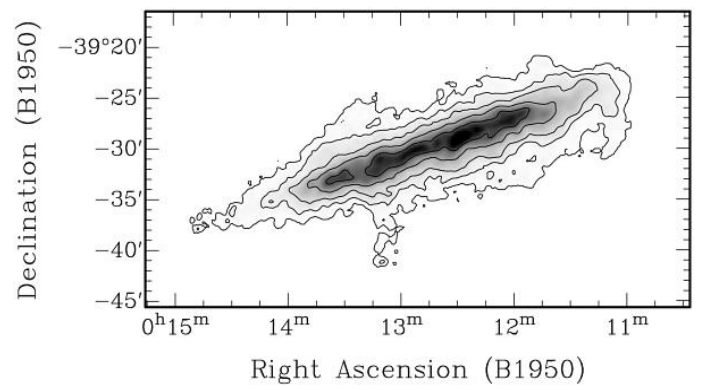




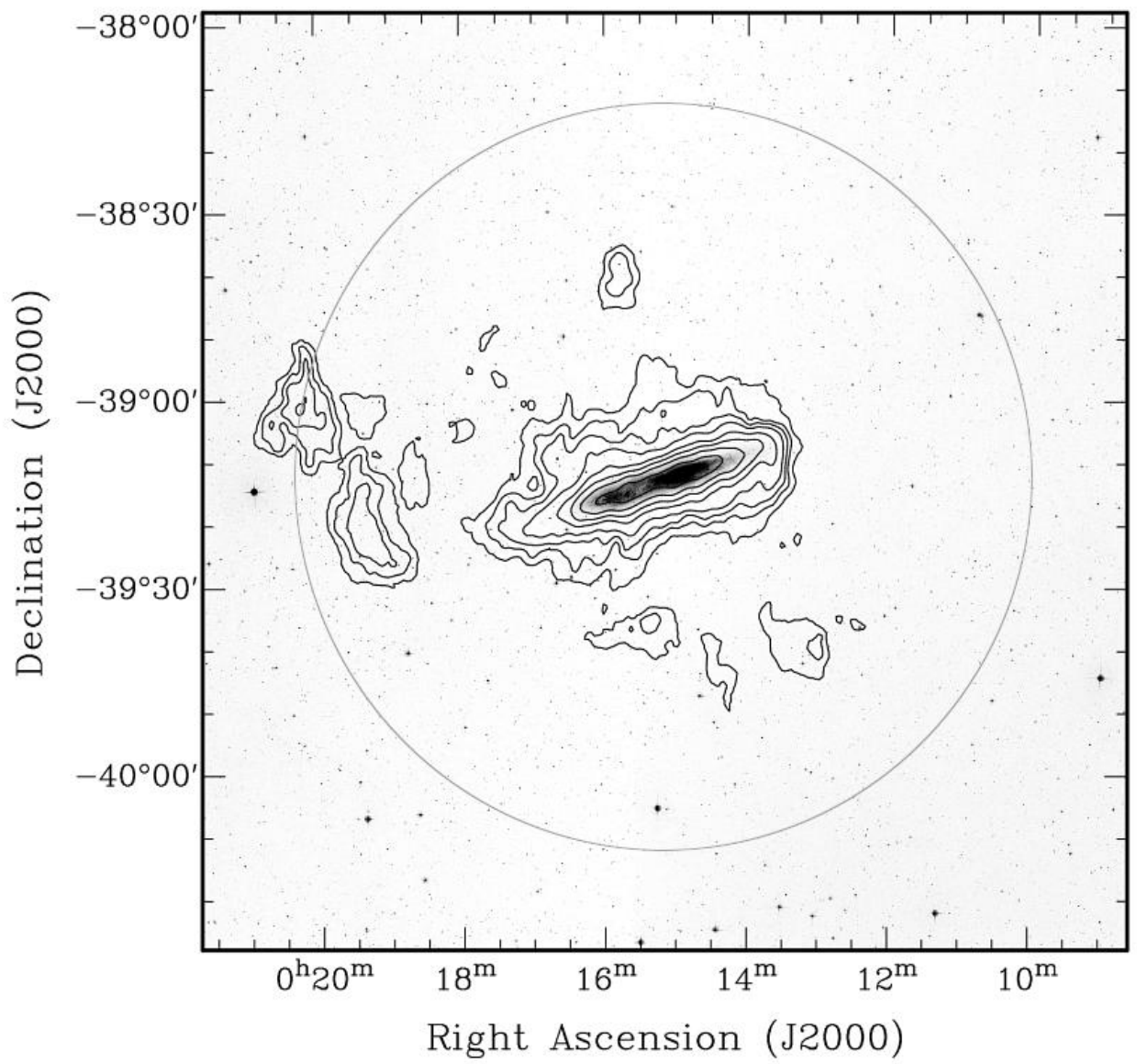
★ DSS image of NGC 55

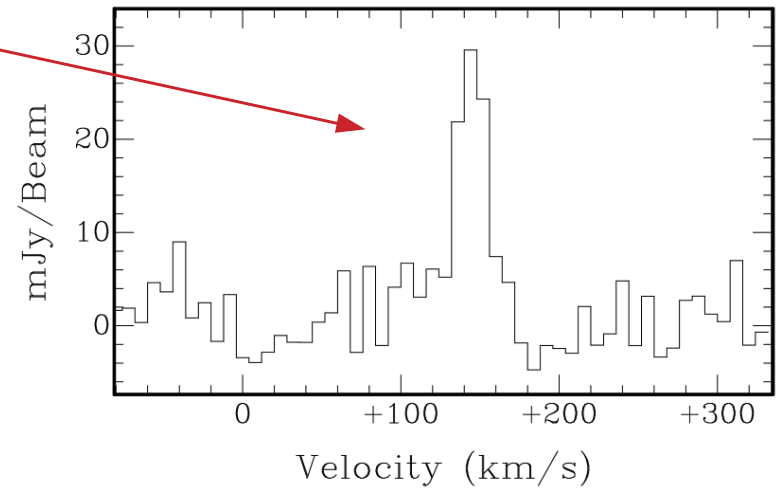
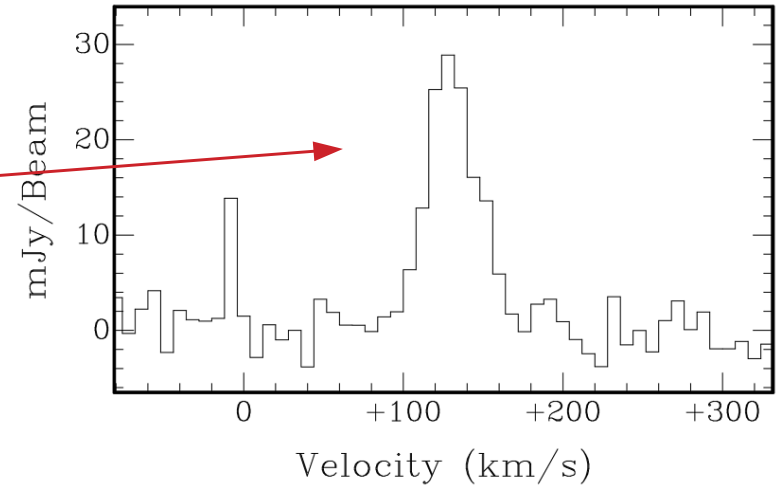
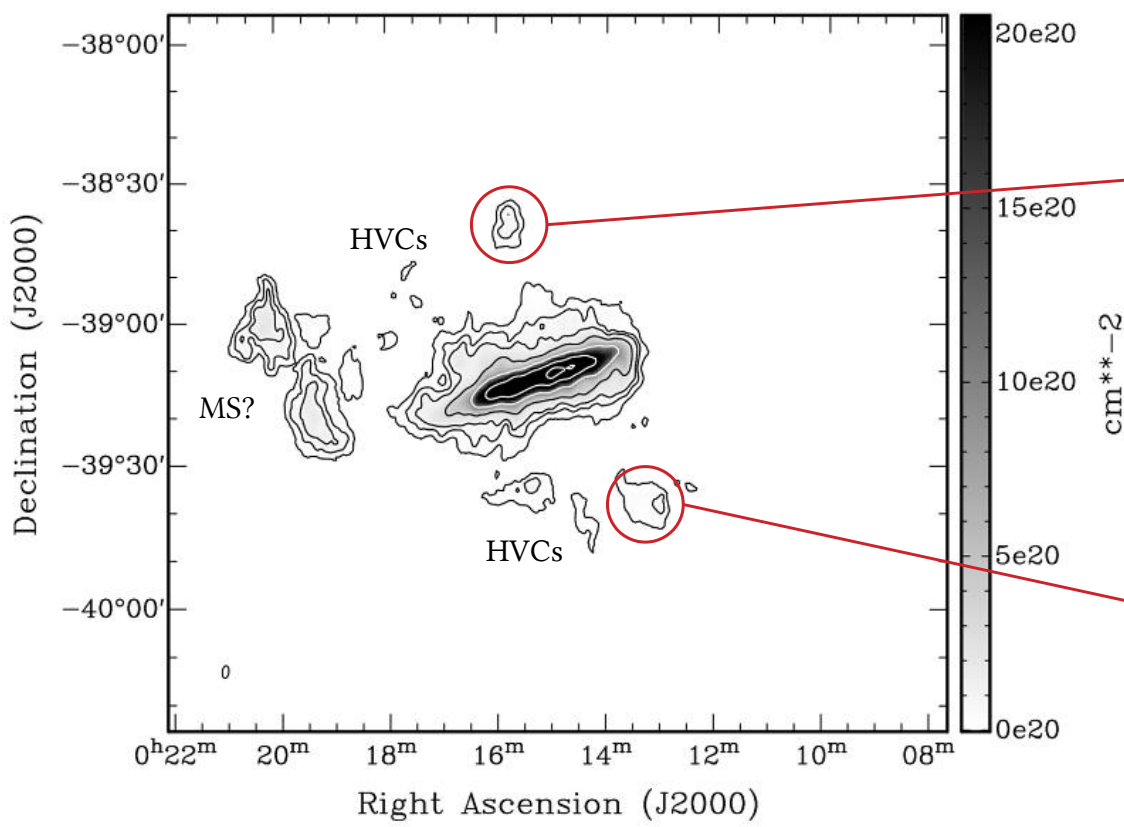


- ★ DSS image of NGC 55
- ★ HI contours
 - ▶ Lowest: 10^{19} cm^{-2}
 - ▶ HI disc looks very distorted
 - ▶ Several isolated gas clouds / HVCs



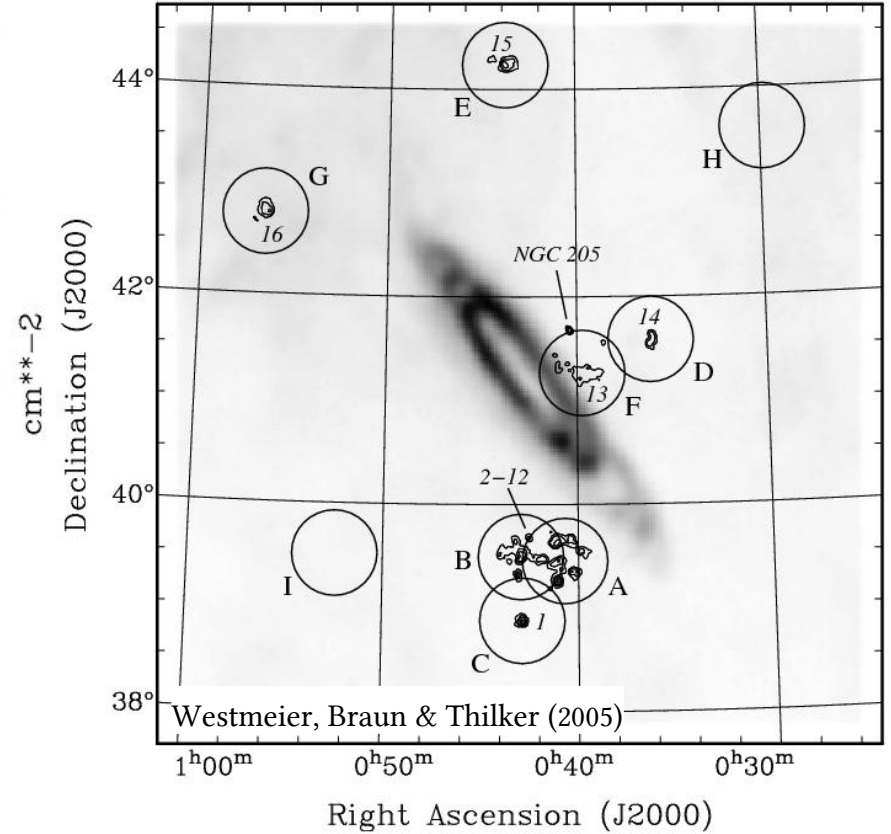
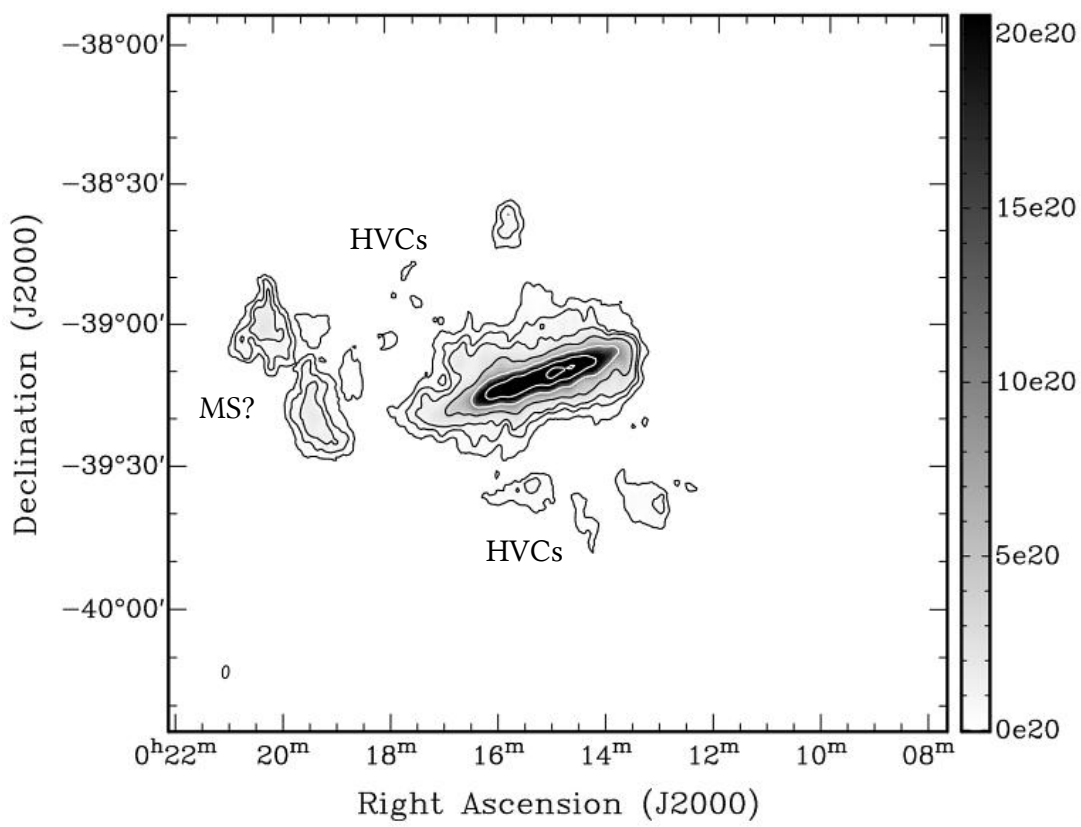
VLA image, Puche et al. (1991)





★ Isolated HI clouds

- ▶ Significant detections
- ▶ HI masses of a few times $10^6 M_{\odot}$



★ Isolated HI clouds

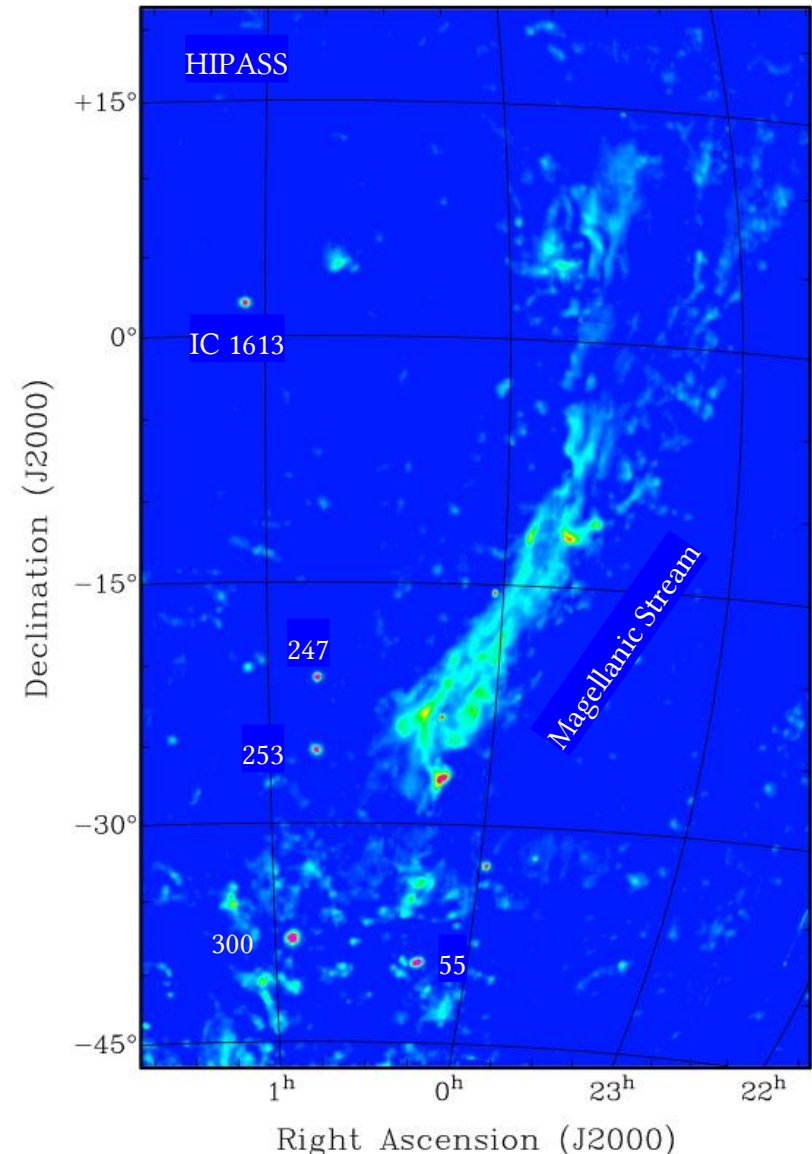
- ▶ Significant detections
- ▶ HI masses of a few times $10^6 M_{\odot}$
- ▶ Origin not yet clear, but HI masses comparable to HVCs around Milky Way and Andromeda (*e.g. complex C; Wakker et al. 2007; Thom et al. 2008*).

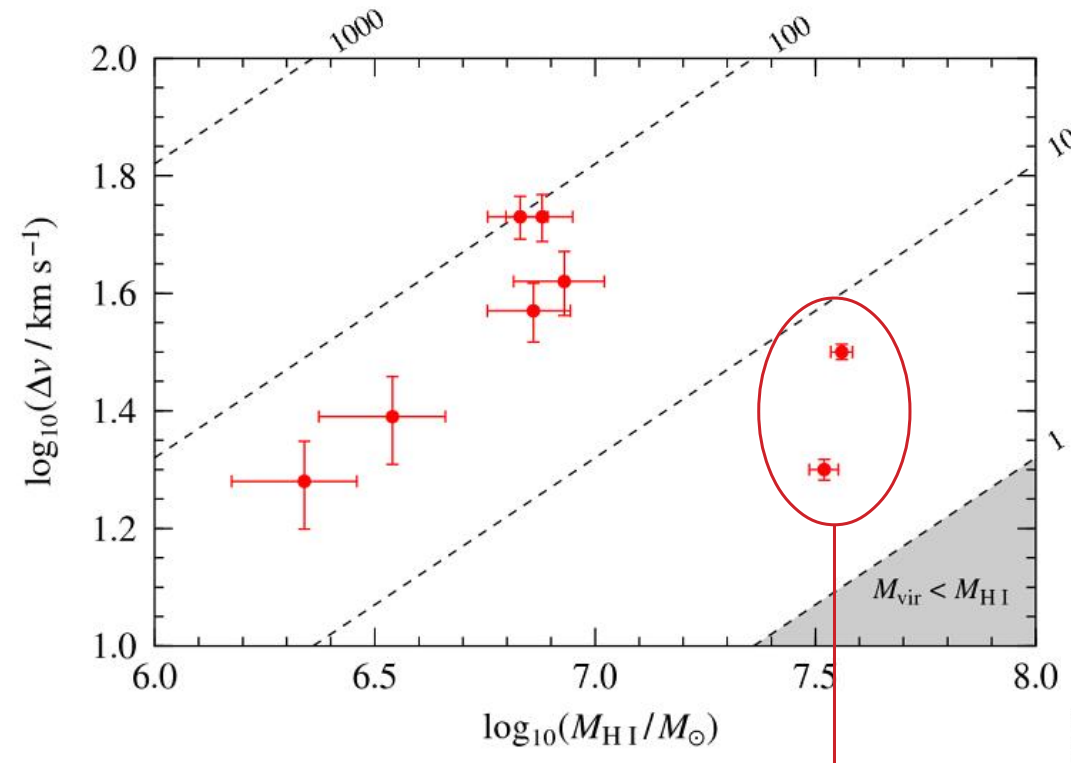
★ NGC 55 or foreground?

- ▶ Two possibilities:
 - Clouds are at the distance of NGC 55
 - Clouds are foreground and part of Milky Way or Magellanic Stream

★ Virial vs. HI mass:

- ▶ Virial mass: $M_{\text{vir}} \propto \langle v^2 \rangle R_{\text{vir}} \propto d$
- ▶ HI mass: $M_{\text{HI}} \propto F_{\text{int}} d^2 \propto d^2$
- ▶ Mass ratio: $\alpha = M_{\text{vir}} / M_{\text{HI}} \propto d^{-1}$

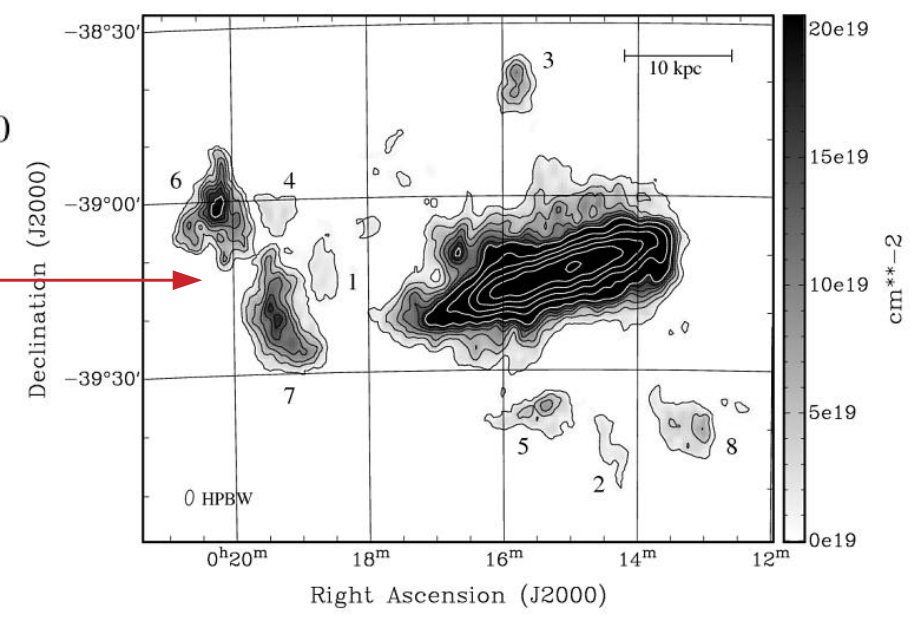




Virial-to-HI mass ratio
 $\alpha = M_{\text{vir}} / M_{\text{HI}}$

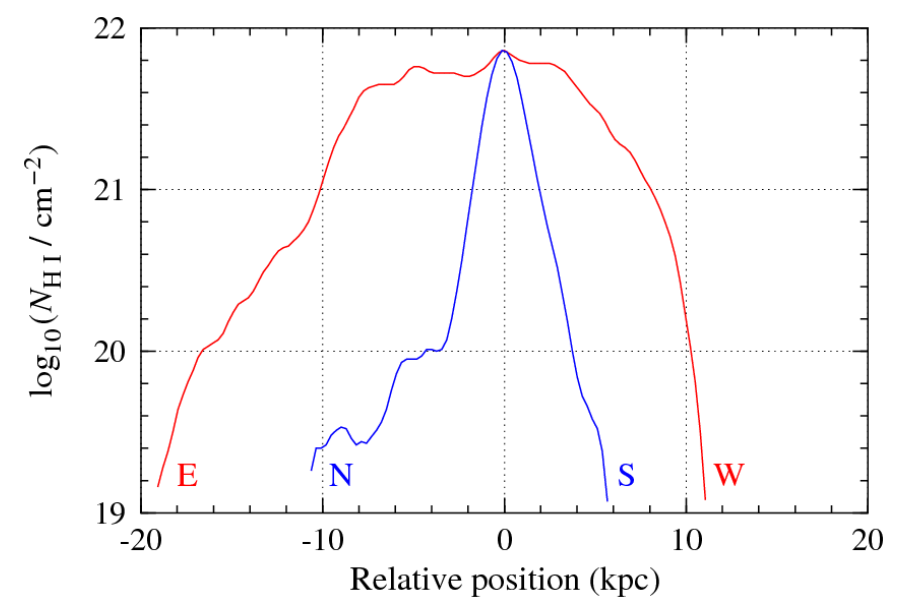
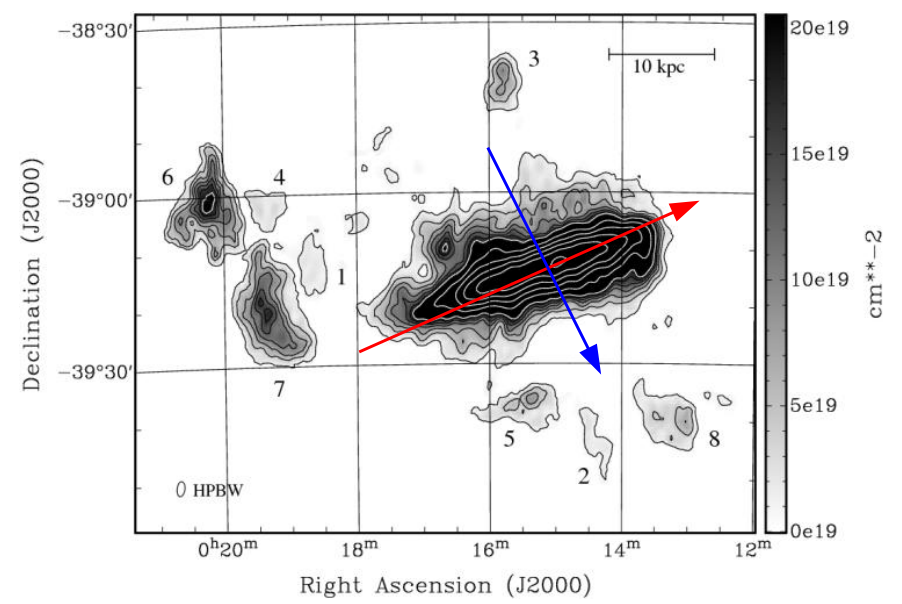
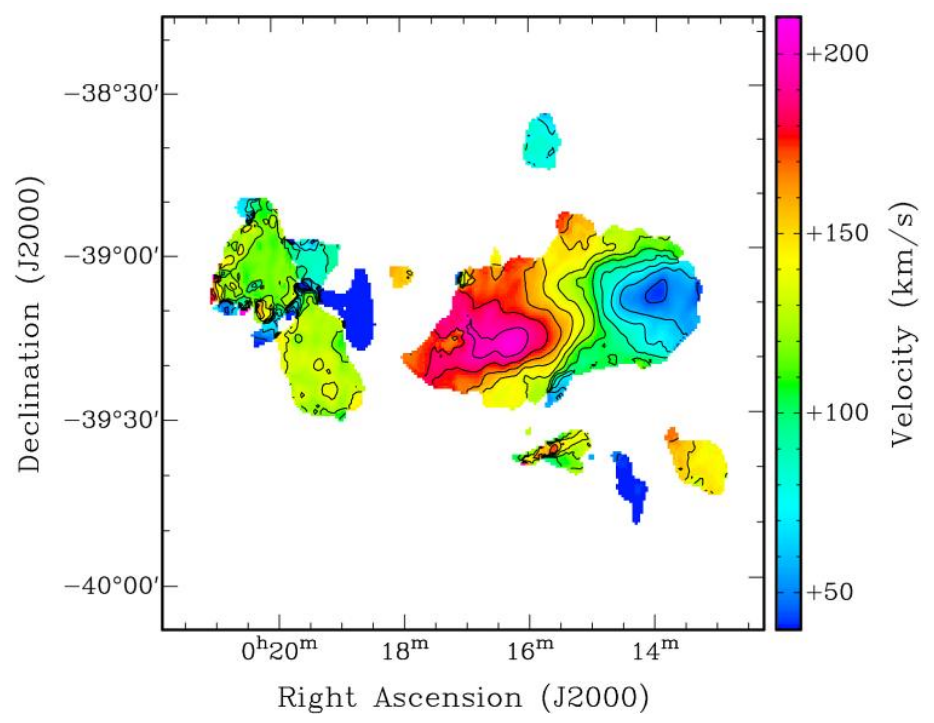
★ Result:

- ▶ $\alpha = 50 \dots 100$ for six clouds
- ▶ $\alpha < 10$ for remaining two



★ HI disc of NGC 55

- ▶ Strong **asymmetry** with very sharp edge or truncation on one side.
- ▶ Appearance of “thickness” of disc likely caused by **warping** of outer disc.
- ▶ Detailed analysis under way...



- ★ HI observations of Sculptor group galaxies with the ATCA.
- ★ NGC 300
 - ▶ Extended, twisted and warped gas disc.
 - ▶ Strong evidence of ram-pressure effects on gas disc from both observations and numerical simulations.
- ★ NGC 55
 - ▶ Discovery of population of high-velocity clouds of $M_{\text{HI}} \approx 10^{6\text{--}7} M_{\odot}$.
 - ▶ Origin of HVCs uncertain at this stage.
- ★ NGC 247 / 7793
 - ▶ Observations ongoing.
- ★ More detailed studies in the future with WALLABY and MHONGOOSE.