PARSEC-SCALE HI ABSORPTION STRUCTURE IN A LOW-REDSHIFT DLA GALAXY

ANDY BIGGS **ESO**
MARTIN ZWAAN **ESO**
EVANTHIA HATZIMINAOGLOU **ESO**
CELINE PÉROUX **MARSEILLE/ESO**
JOE LISKE **HAMBURG**

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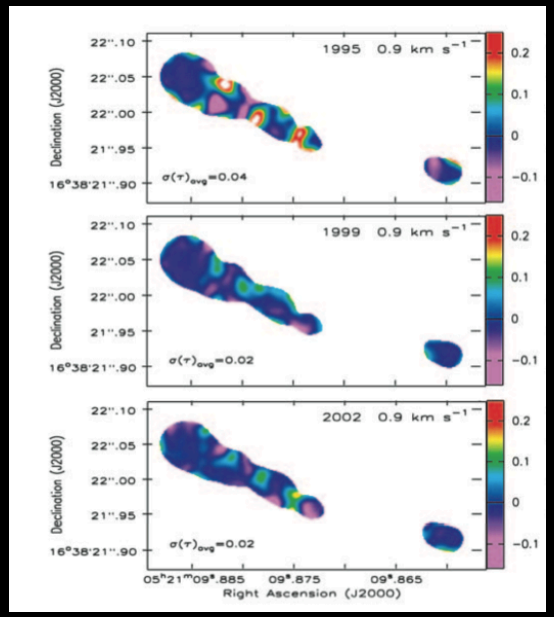
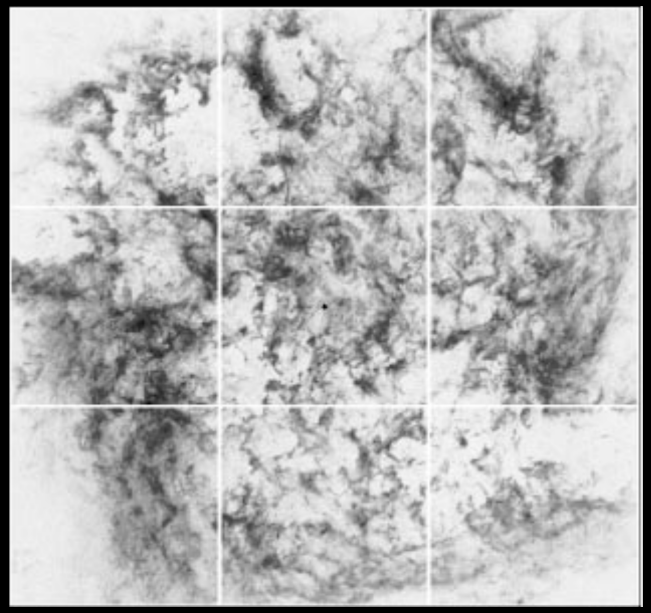
SMALL SCALE STRUCTURE IN ISM

- Structure and turbulence of the neutral medium determine size distribution of molecular clouds and affects the shape of the stellar IMF
  - Galactic HI absorption probes scales down to several AU e.g. 3C138
  - Emission studies typically probe scales > 100 pc
  - HI VLBI absorption in external galaxies probes parsec-scale structure

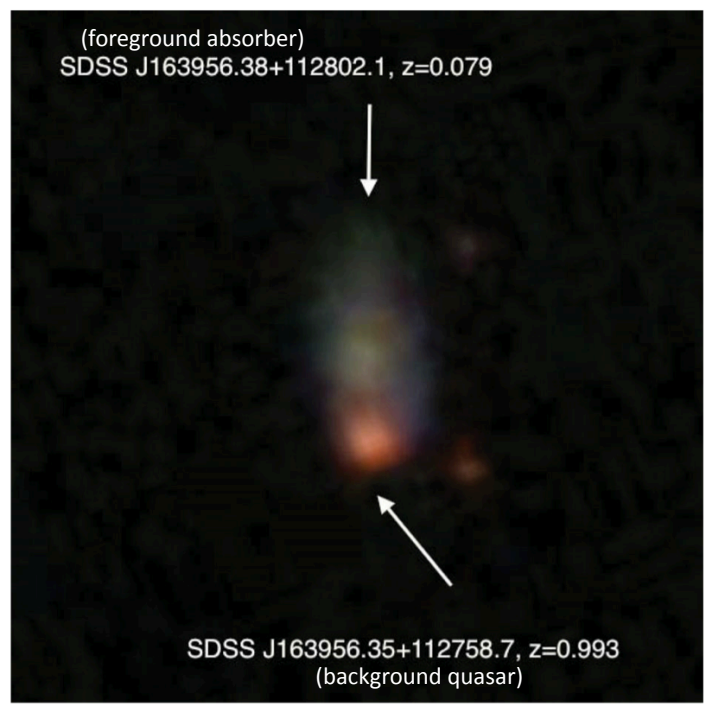


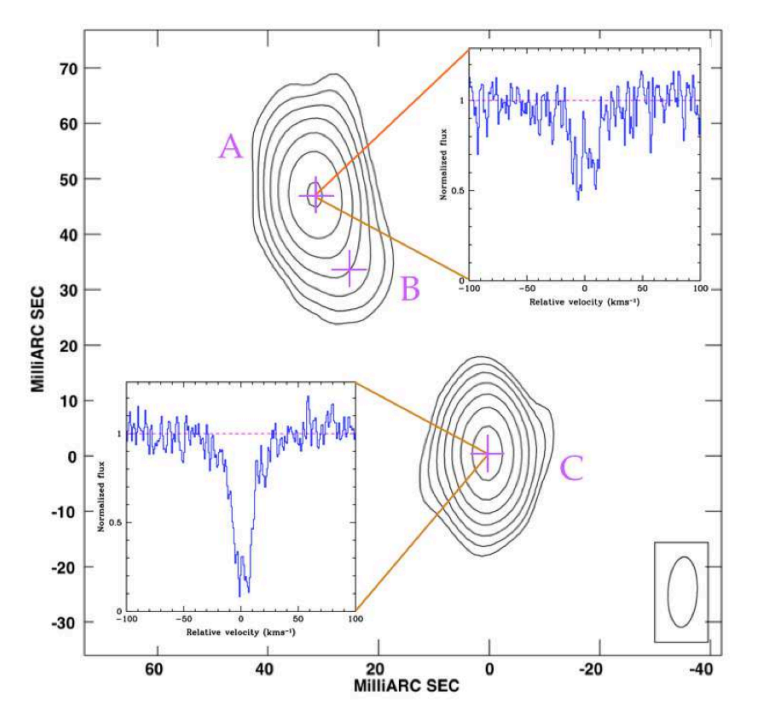
Brogan et al. 2004



Elmegreen et al. 2000

ISM OF EXTERNAL GALAXIES WITH VLBI

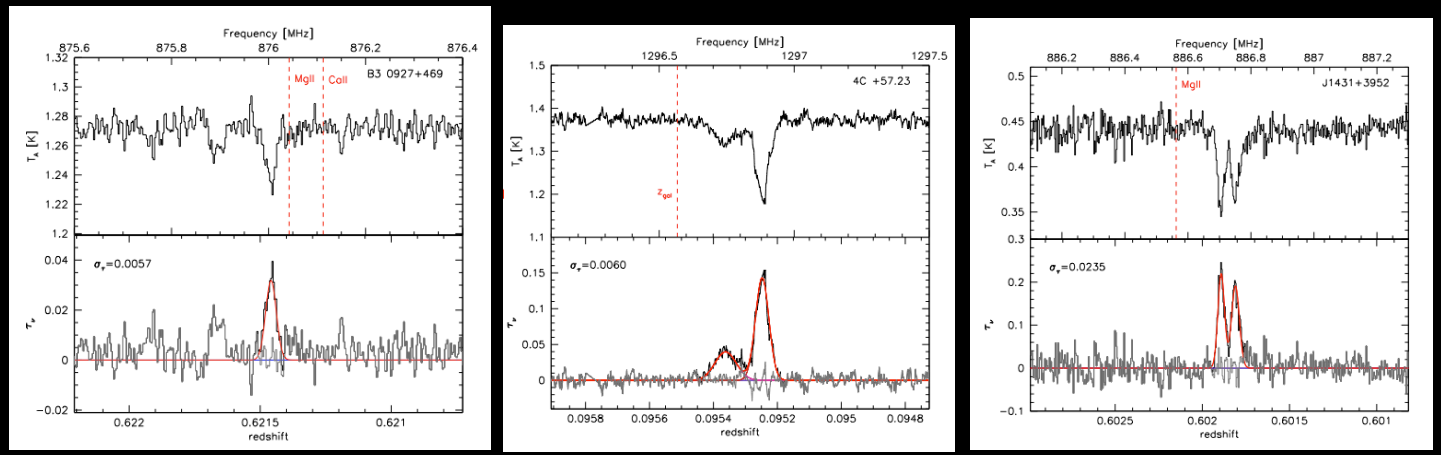




- VLBA HI spectrum shows significant differences between components separated by ≈ 90 pc
- Srianand et al. (2013) conclude that the cold absorbing gas is patchy on scales of 30-100 pc

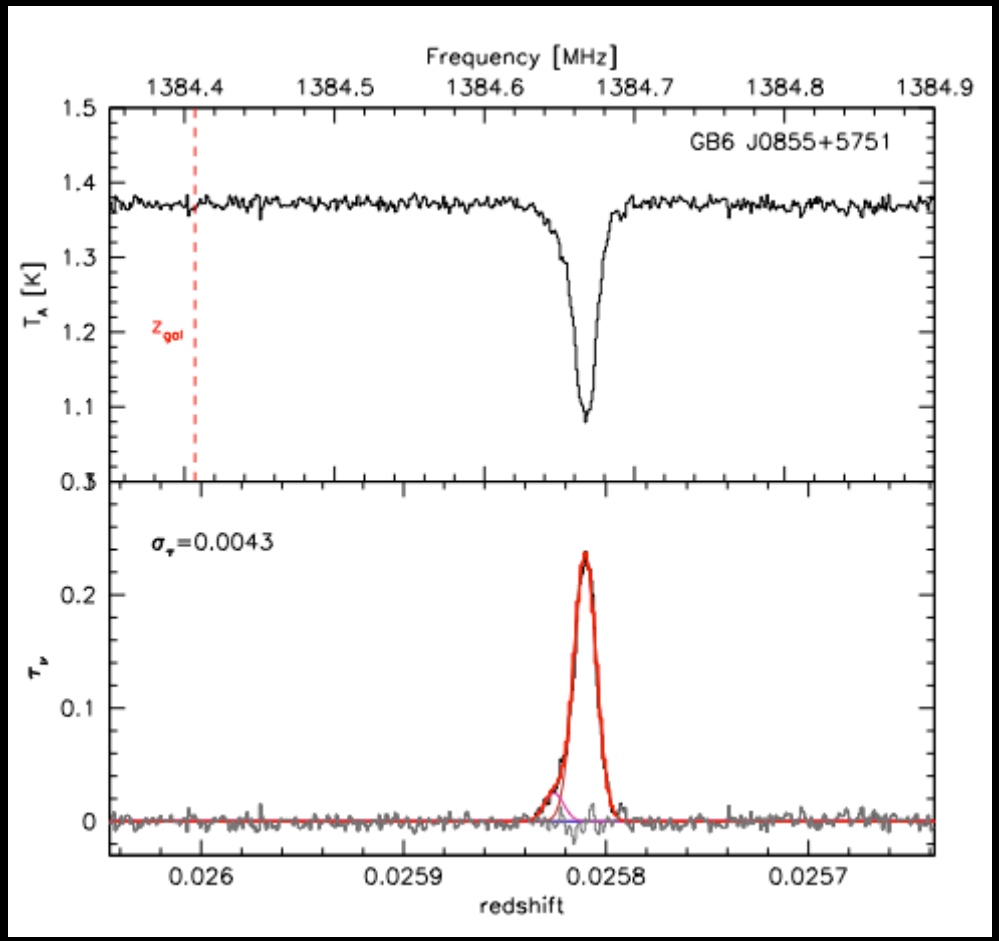
THE PARENT GBT HI SURVEY

- Small impact parameter radio-loud quasar-galaxy pairs
  - Select candidates from MgII, CaII, Ly-α absorbers, SDSS
  - Cross correlate with FIRST sources (S1.4GHz > 200 mJy and r < a few")
- 4 out of 24 candidates detected in HI
  - At least five lost due to RFI



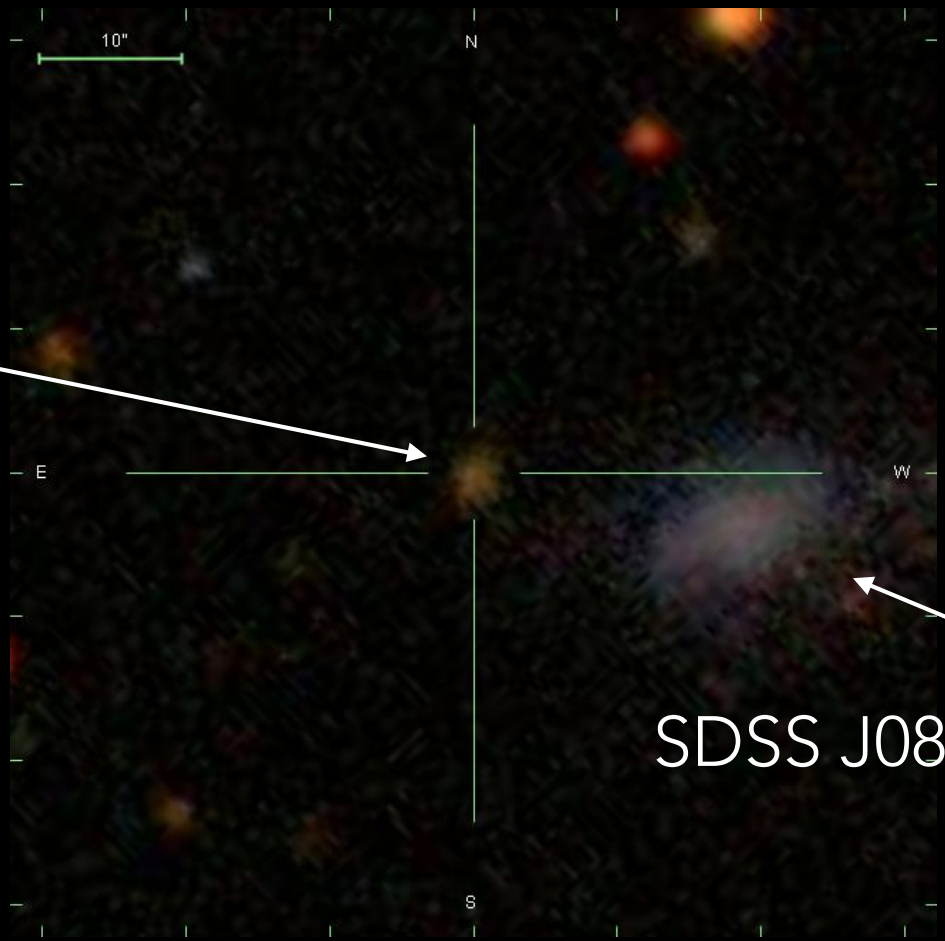
Zwaan et al. 2016

J0855+5751 GBT HI SPECTRUM



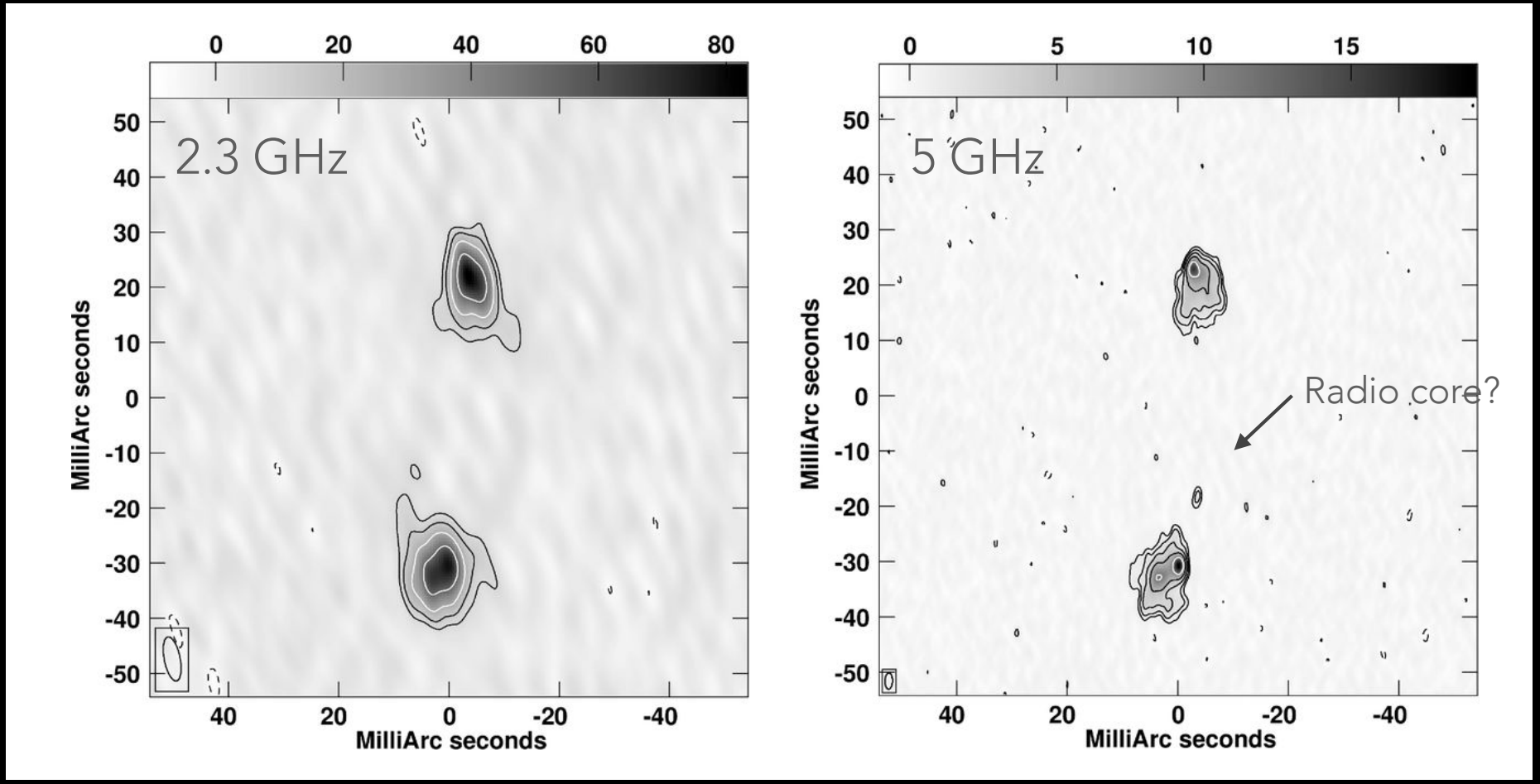
- Two components with σ = 1.5 km/s separated by ≈ 4 km/s

SDSS IMAGE



- Impact parameter ≈ 7 kpc

PREVIOUS VLBI OBSERVATIONS



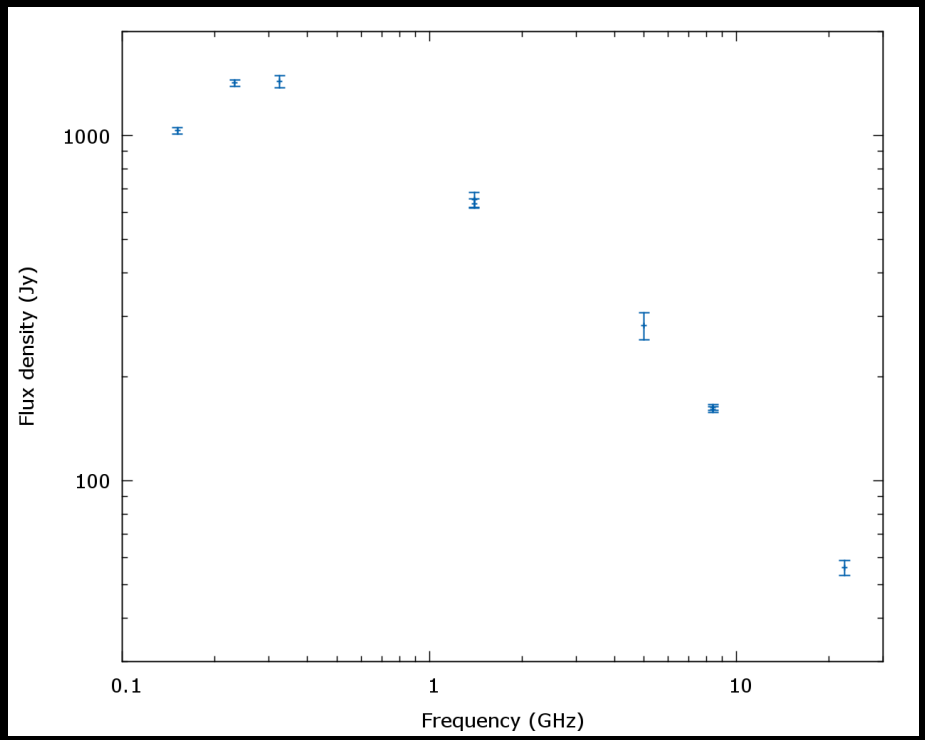
VLBA Calibrator Survey
(Beasley et al. 2002)

VLBA Imaging and Polarimetry Survey
(Helmboldt et al. 2007)

Re-reduced from archival data

J0855+5751 PROPERTIES

- We measure redshift with WHT
  - $z = 0.541\,86$
- Projected size < 0.5 kpc
- Radio SED peak ≈ 300 MHz
- Unpolarized
- J0855+5751 fulfils many criteria of CSS/GPS sources

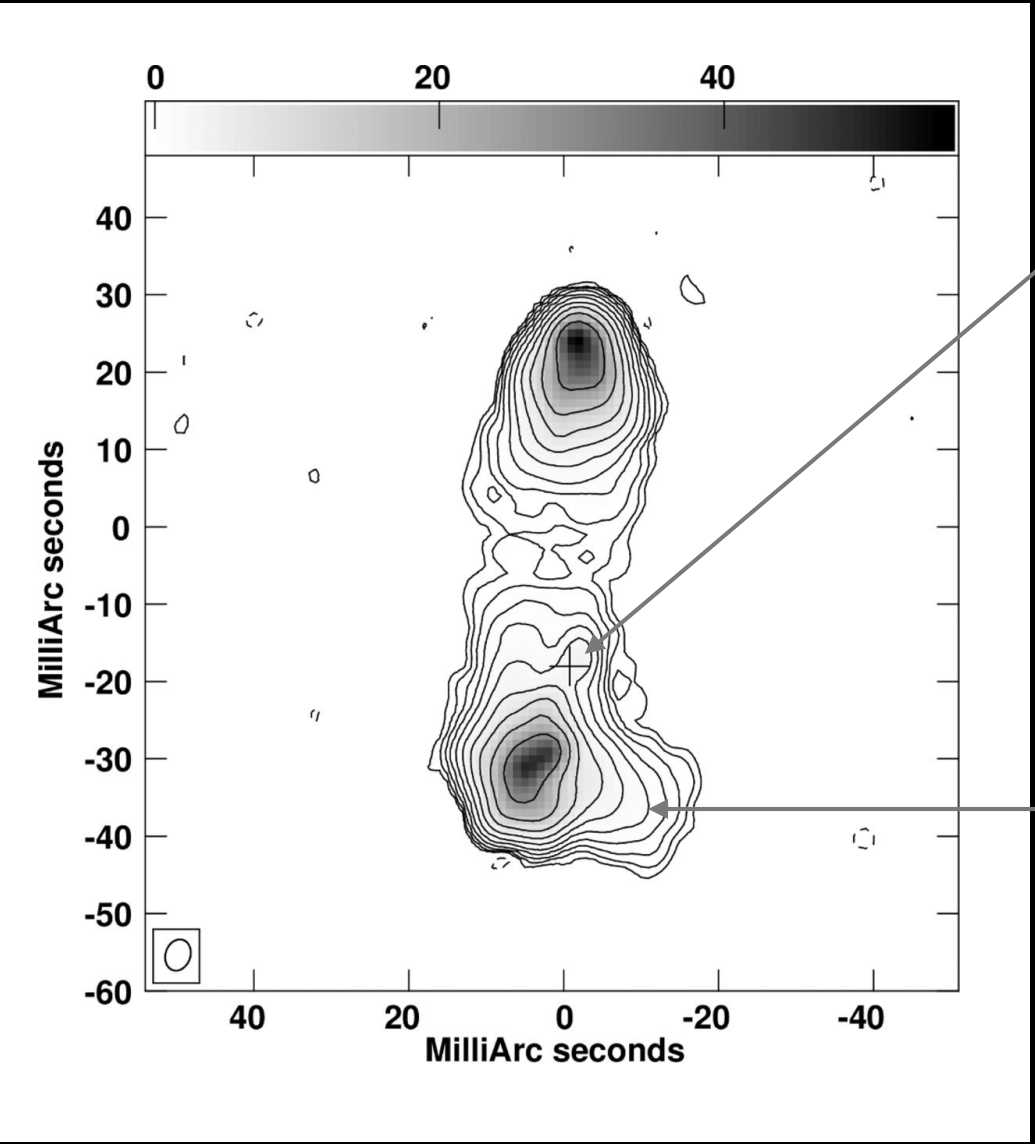


NEW GLOBAL VLBI OBSERVATIONS

- EVN + VLBA
  - Angular resolution@ 1385 MHz: 4 mas = 2 pc at z = 0.026
- In-beam phase calibrator!
  - J0854+5757 = 0850+581
  - 8′ from target (not usable for Wb)
- Used 4 x 2 MHz subbands
  - Continuum sensitivity = 18 μJy/beam
- One subband for HI line
  - Spectral resolution = 200 m/s, sensitivity of 1.4 mJy/channel

Goal was to investigate ISM on scales between 2-30 pc

CONTINUUM IMAGE



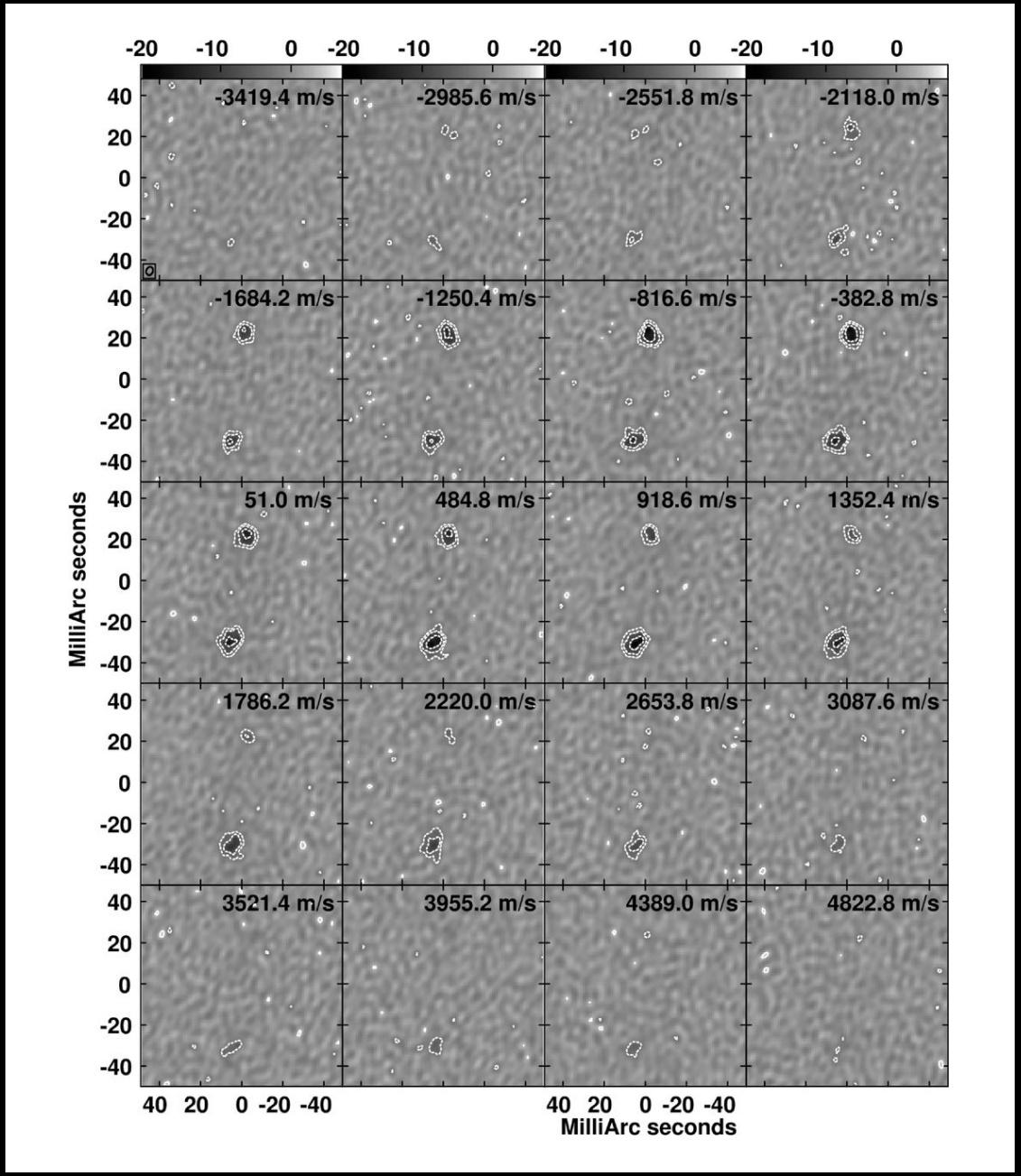
Core component seen in 5 GHz map

C-band peak flux = 2.1 mJy/beam
L-band peak flux = 3.4 mJy/beam
$\alpha \approx -0.4$

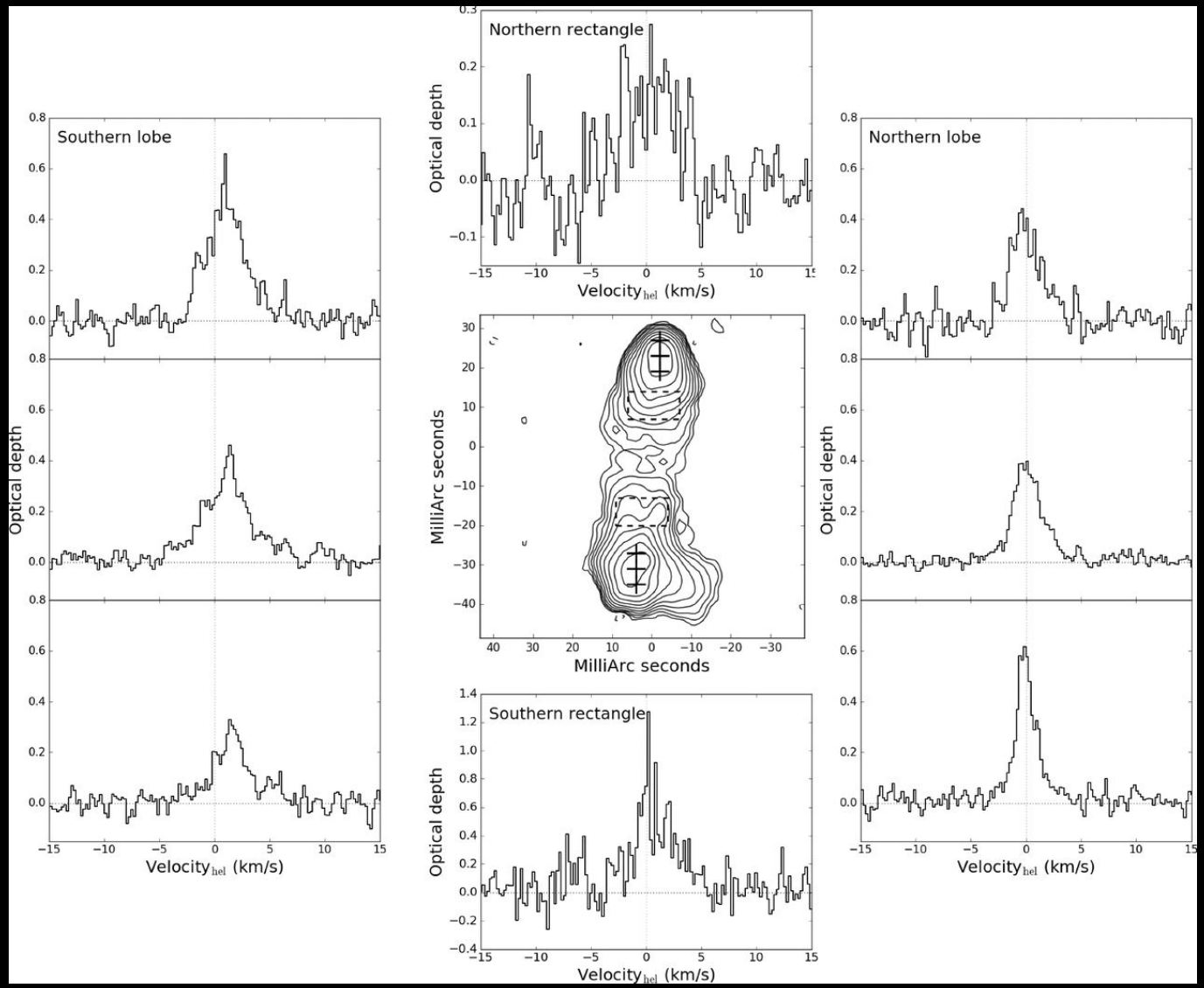
Distorted lobe with deflected jet

Interaction with ISM of host galaxy

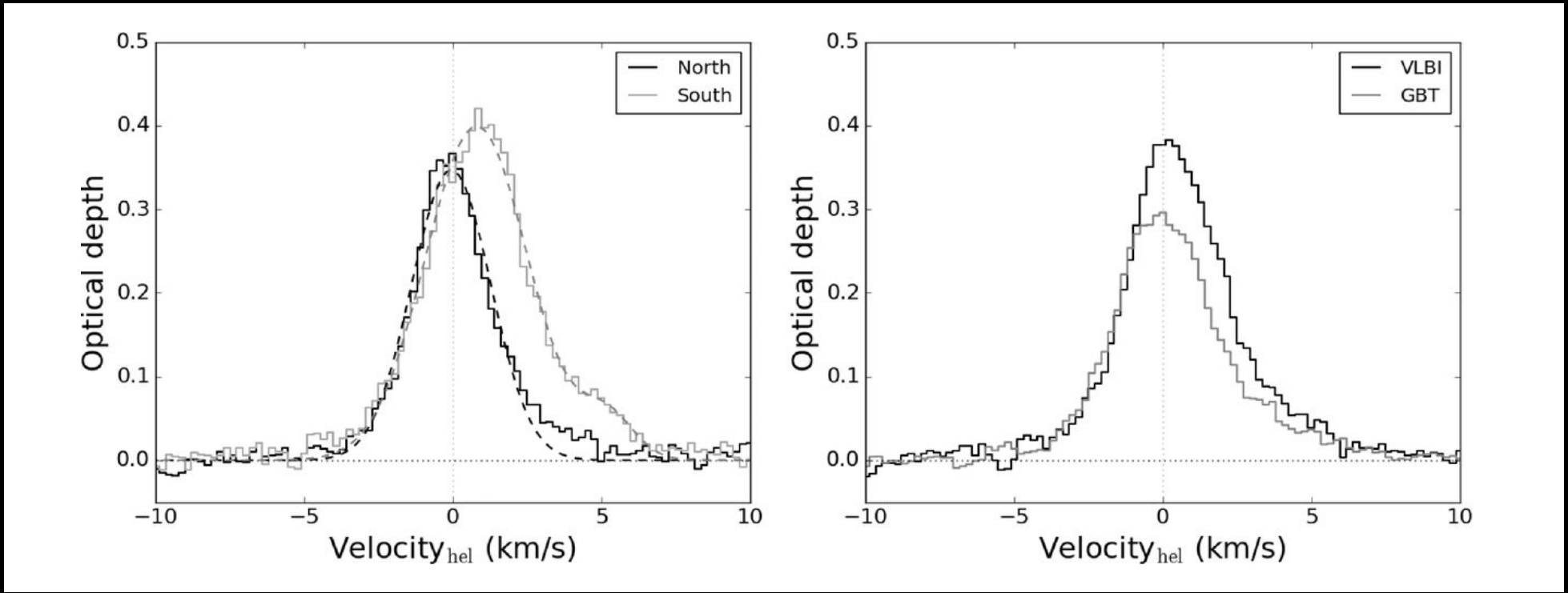
H I ABSORPTION IN THE FOREGROUND GALAXY



OPTICAL-DEPTH SPECTRA OF DIFFERENT SIGHTLINES



COMPARING BOTH LOBES



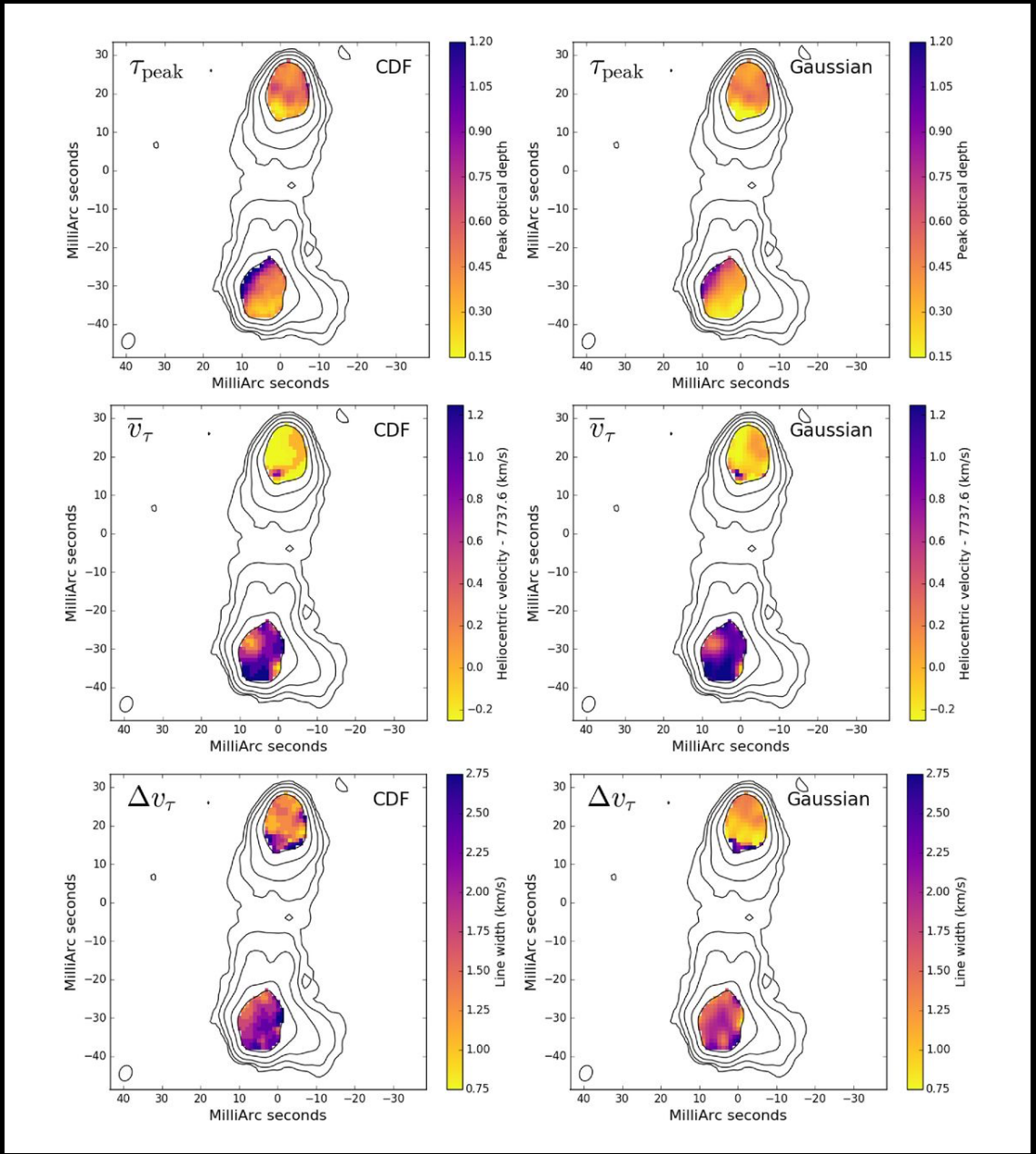
Velocity dispersion as narrow as 0.9 km/s

$$T_k \leq \frac{m_H \Delta v^2}{k\, 8 \ln 2} = \frac{1.2119 \times 10^2 \Delta v^2}{8 \ln 2},$$

Kinetic temperatures < 100K
Looking at the CNM

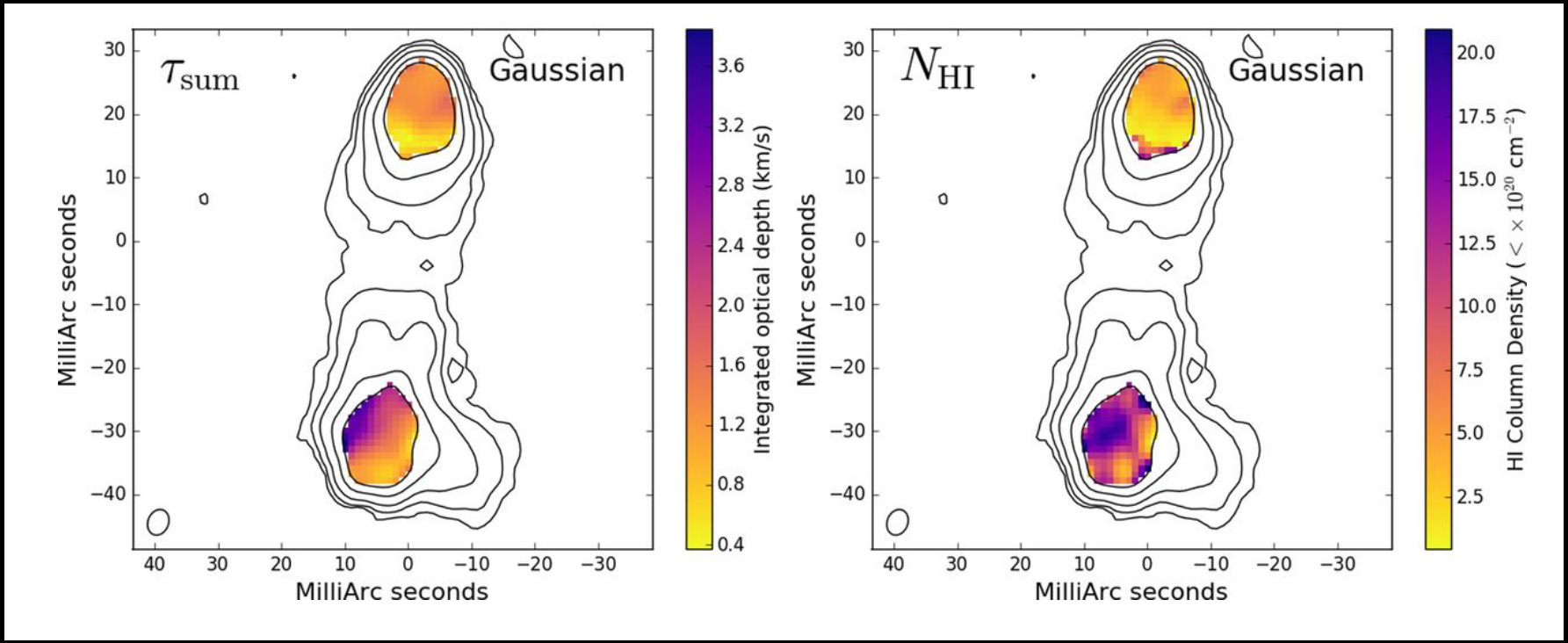
MAPS OF PEAK OPTICAL DEPTH, VELOCITY OF MAXIMUM OPTICAL DEPTH AND VELOCITY WIDTH

Left: cumulative distribution function (CDF) of the optical depth as a function of frequency

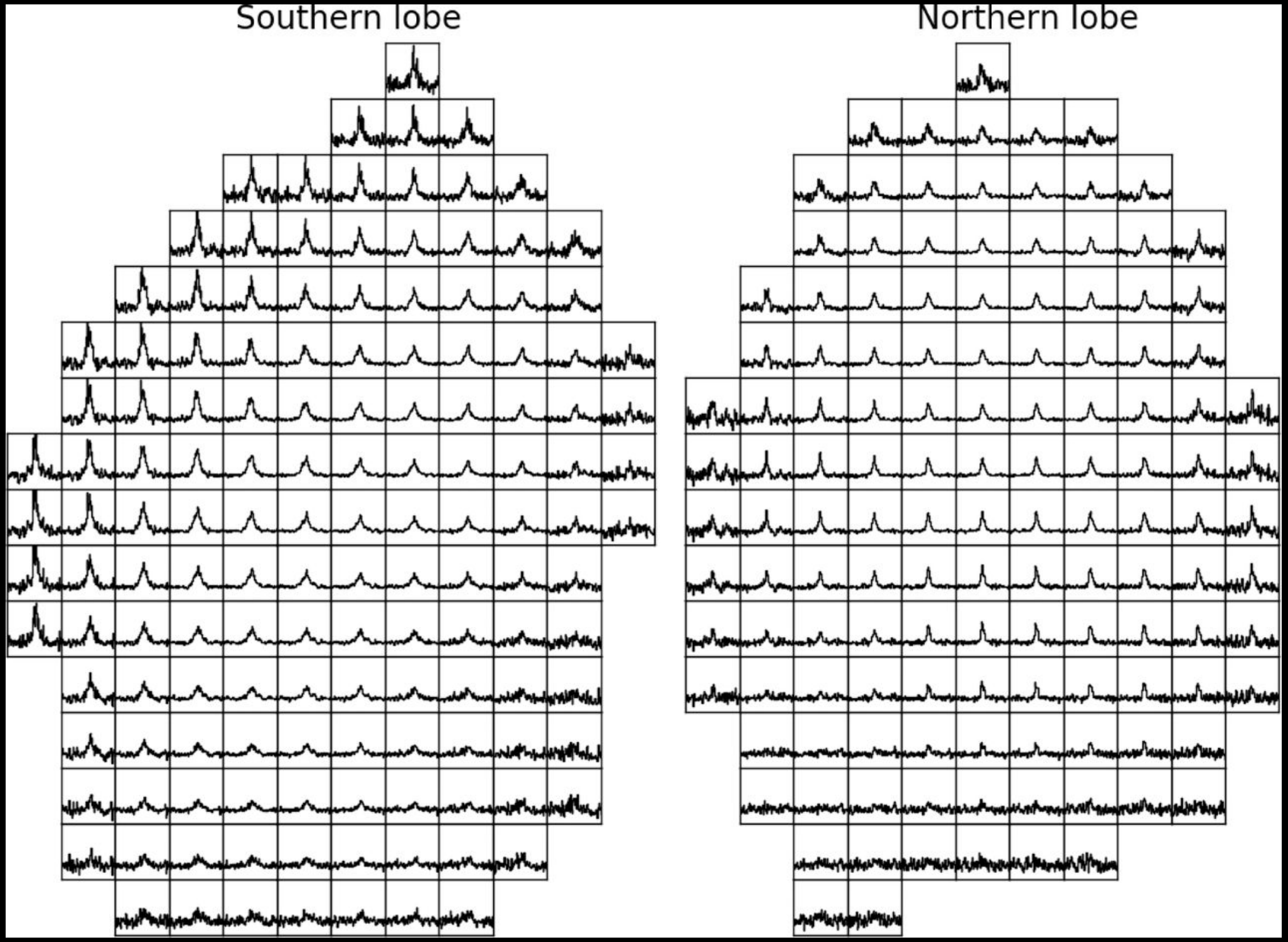


Right Gaussian fits

MAPS OF OPTICAL DEPTH AND COLUMN DENSITY



Column density maps calculated by assuming that spin temperature is equal to kinetic temperature


Southern lobe
Northern lobe

INTERPRETATION

- Large and apparently coherent variations in line width are visible
- Total τ - **and column density** - **varies by factor of 5 over 12 mas or 6.3 pc**
- We observe structure on scales **between 2 and 30 pc**
- **No sight lines that do not intercept absorbing H I gas**
- We see a single coherent cold structure of at least 35 pc, larger than the largest CNM clouds featured in the McKee & Ostriker (1977) model
- Further evidence that the **blobby sheet model of Heiles & Troland (2003)** is also appropriate for external galaxies
- We interpret peaks seen within the broader line profile as individual cold cores (blobs) located within the larger-scale sheet

IMPLICATIONS

- T_s depends on Lyα (column density) and 21-cm (optical depth)
- Assumption: same gas is probed by the optical and radio
- Kanekar et al. (2014) use smoothed H I emission maps of LMC → estimates of T_s are correct within 10%
- Our data show that H I can be unevenly distributed on smaller scales
- T_s values may significantly less reliable than suggested.