

Exploring the neutral gas of galaxies in the Antlia cluster with MeerKAT

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Image credit: Charles James Sharp

Current picture of cluster galaxy evolution



Image credit: Cortese et al. (2021)

Examples of evolution mechanisms

Gravitational interactions



Image credit: NASA / ESA / Hubble / M. Sun

Gas outflows



Image credit: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray)

Ram pressure stripping

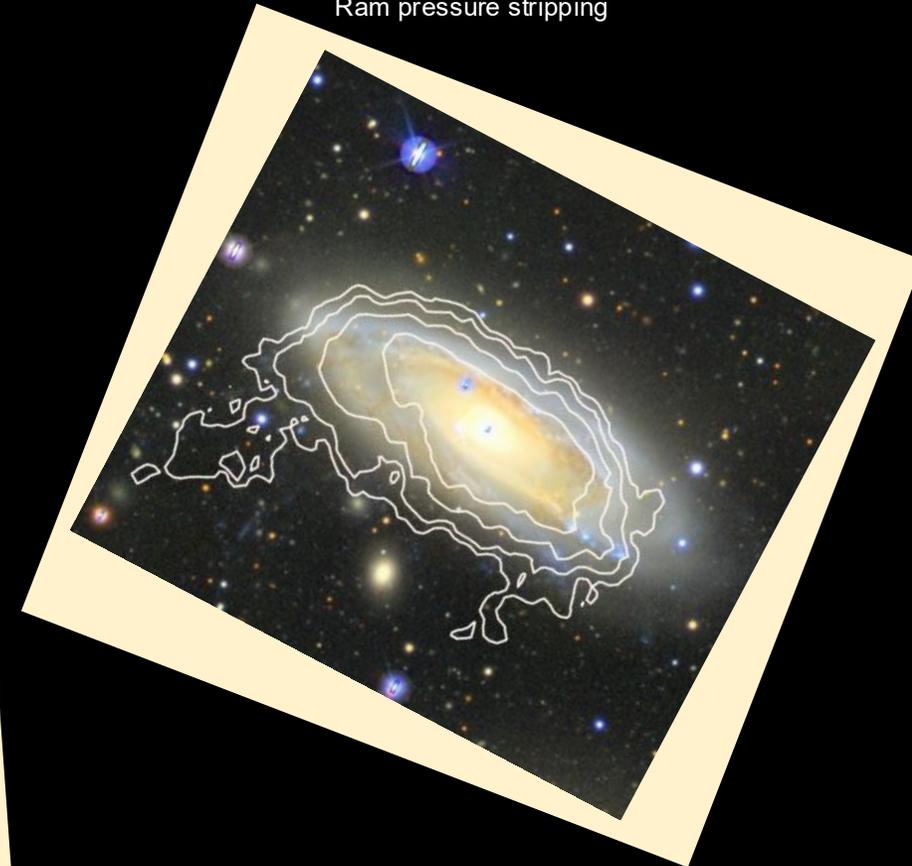


Image credit: DECam (optical); MeerKAT (radio) / Clara Cabanillas de la Casa

The Antlia cluster



Hydra
Cluster

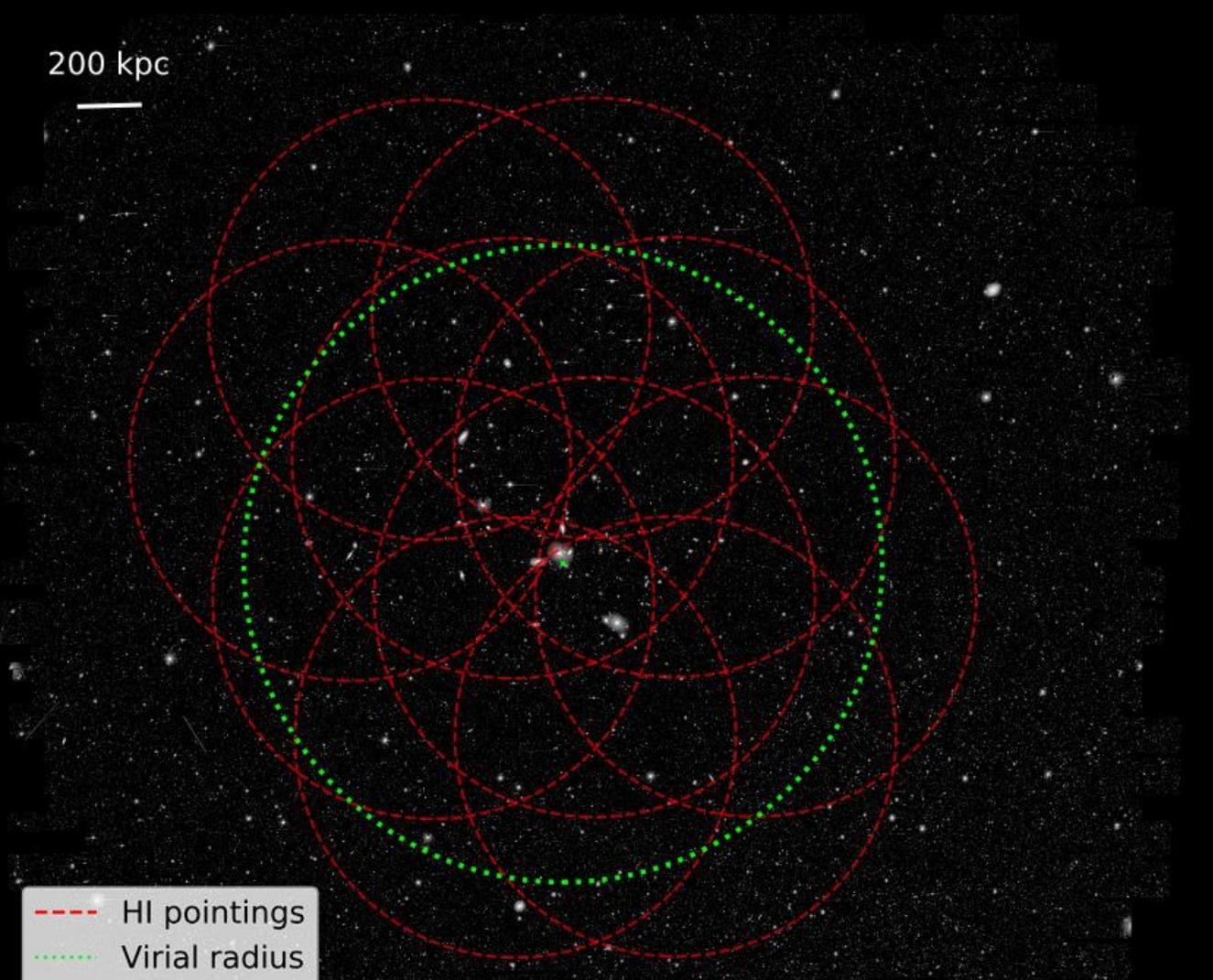


- 3rd nearest cluster (~40 Mpc).
- Low mass cluster ($\sim 10^{14} M_{\odot}$).
- Unrelaxed.
- Hydra's southern neighbor.

Data: MeerKAT + DECam

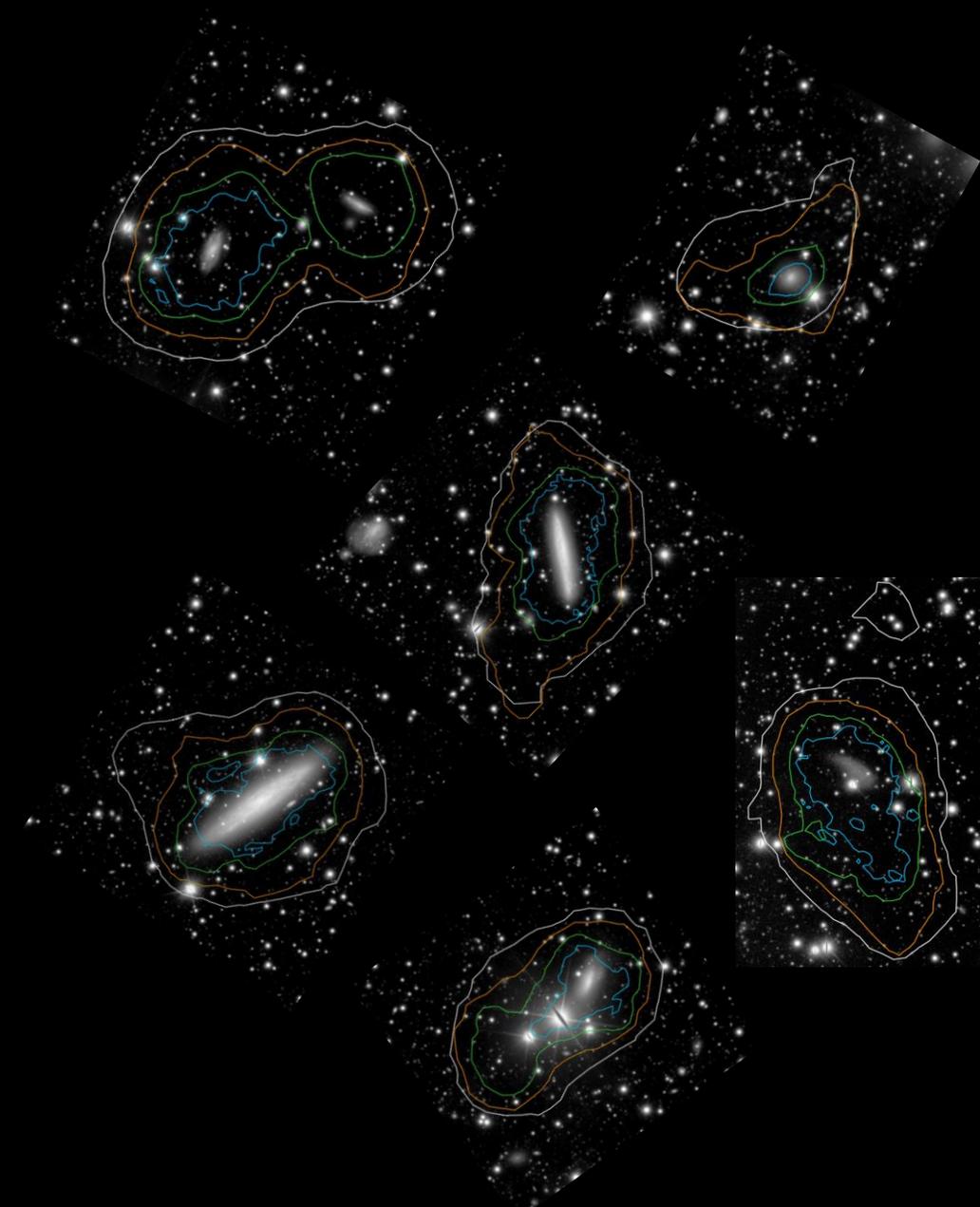
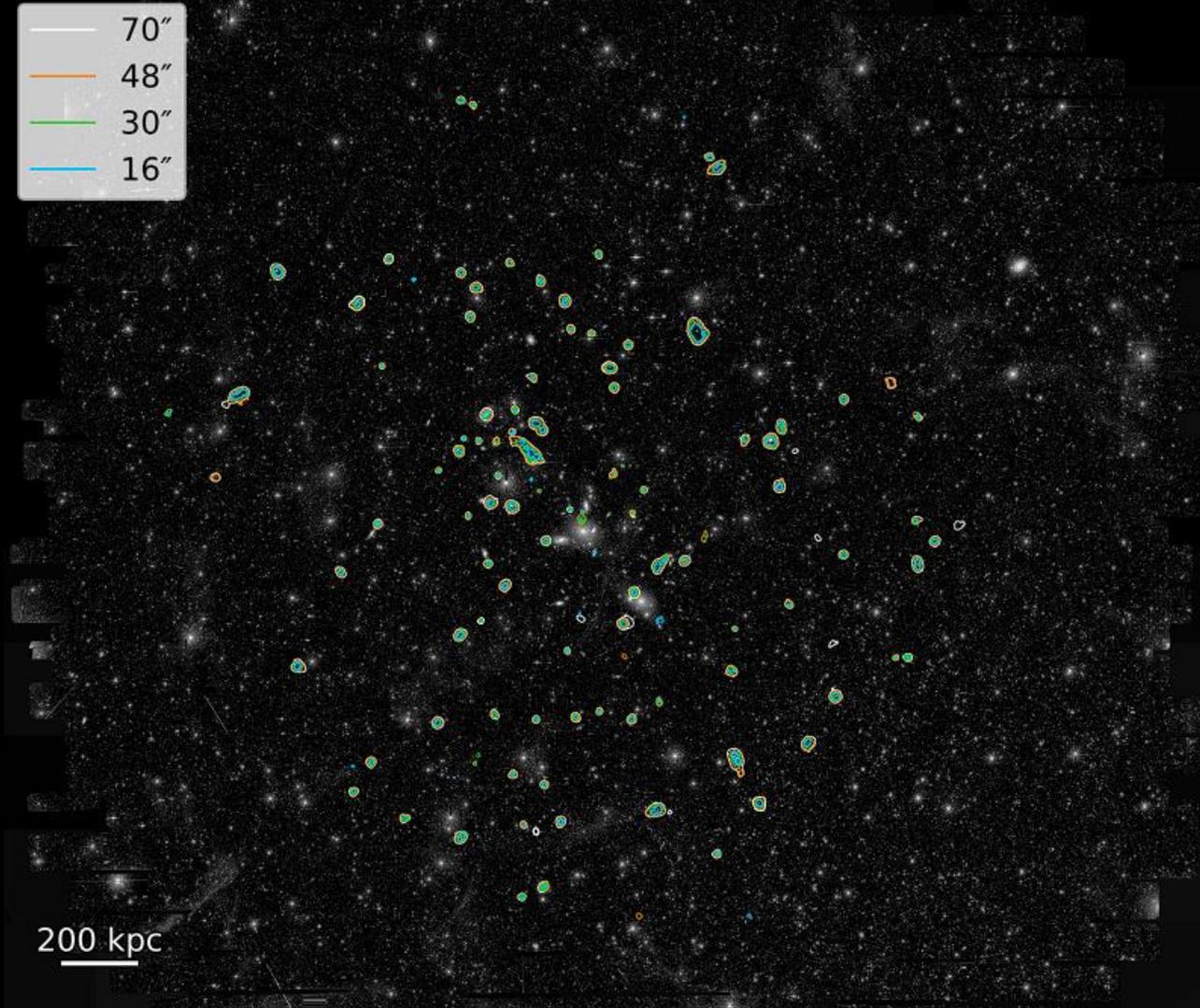


200 kpc



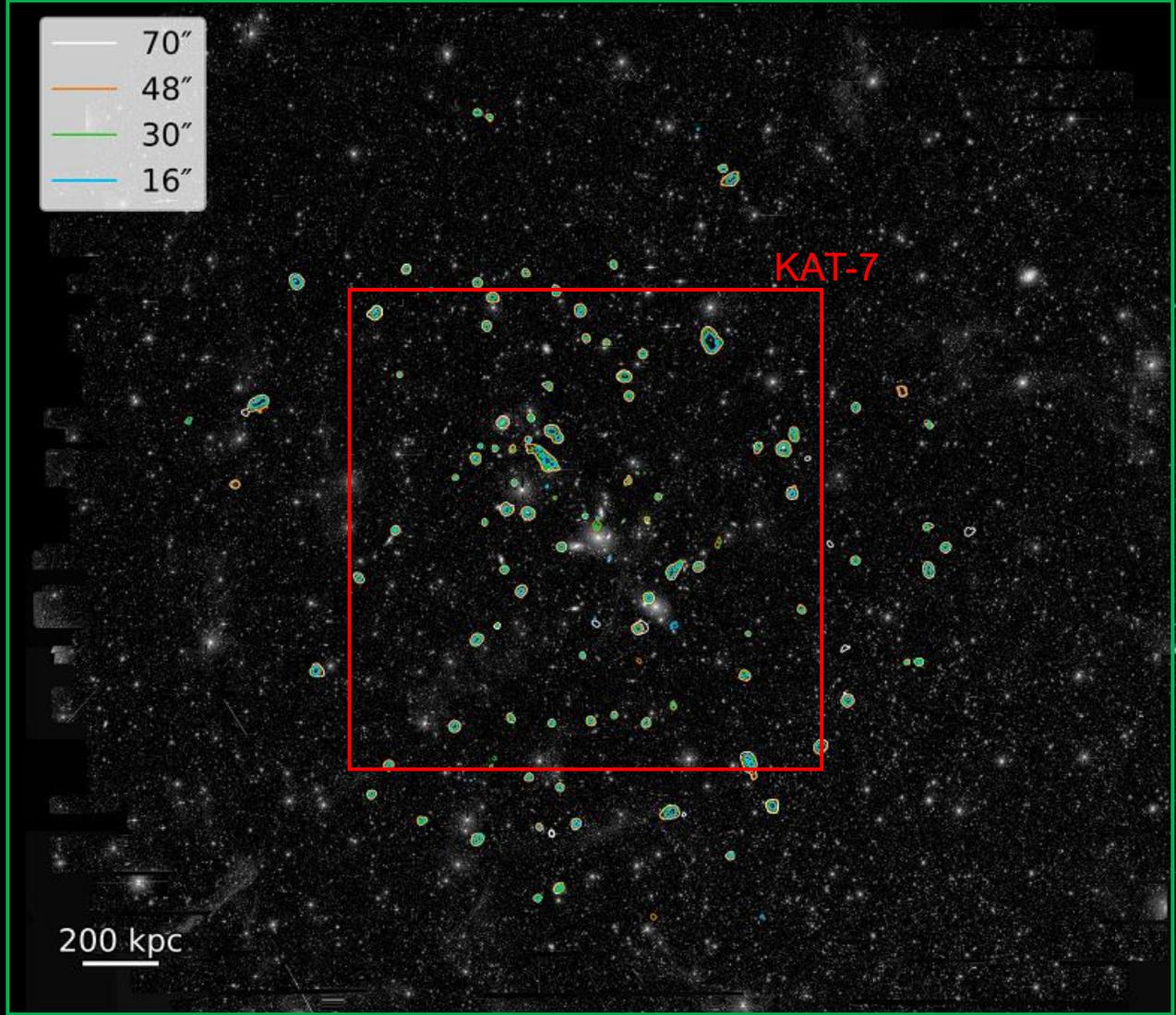
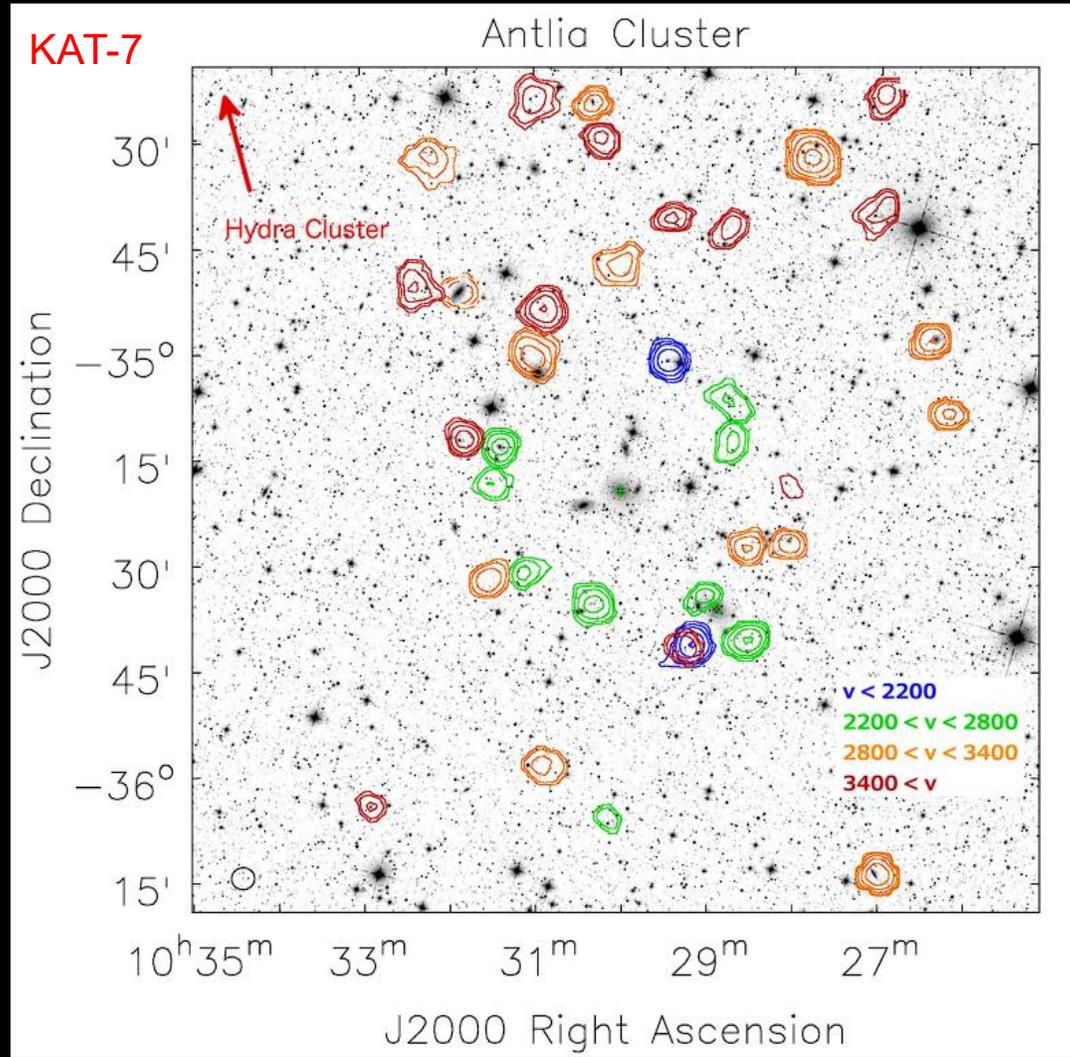
- HI pointings
- ... Virial radius

Antlia in HI



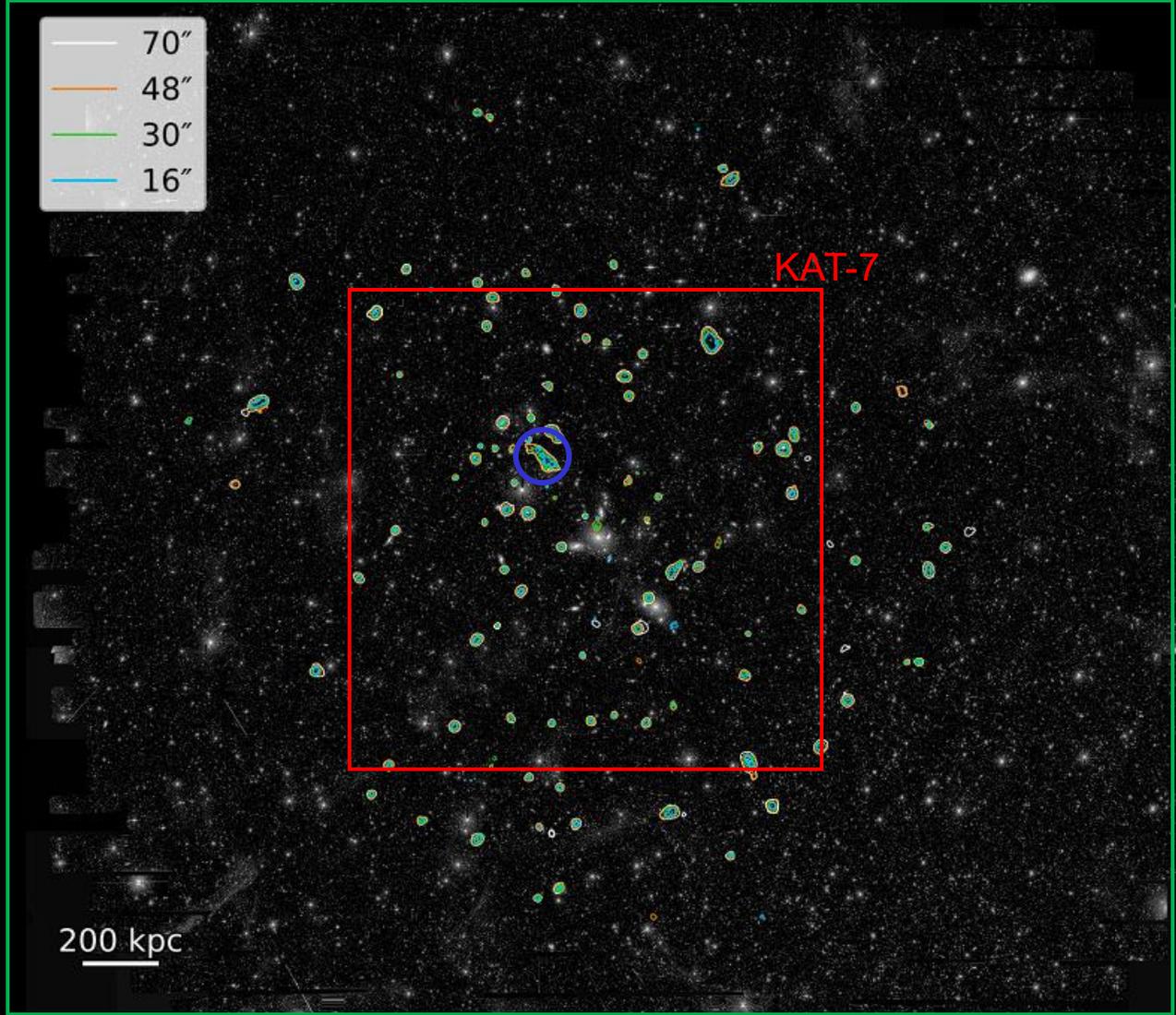
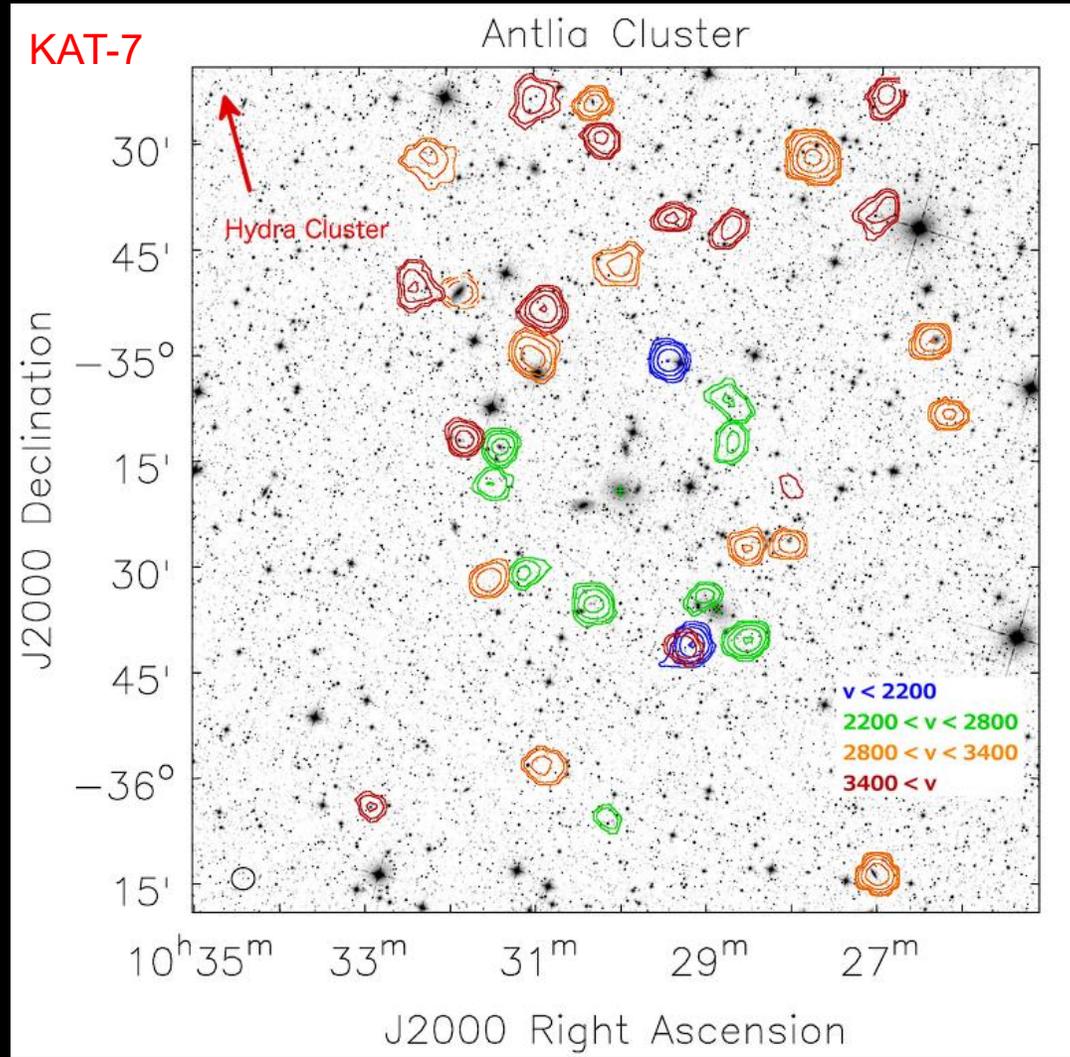
KAT-7 vs MeerKAT

MeerKAT

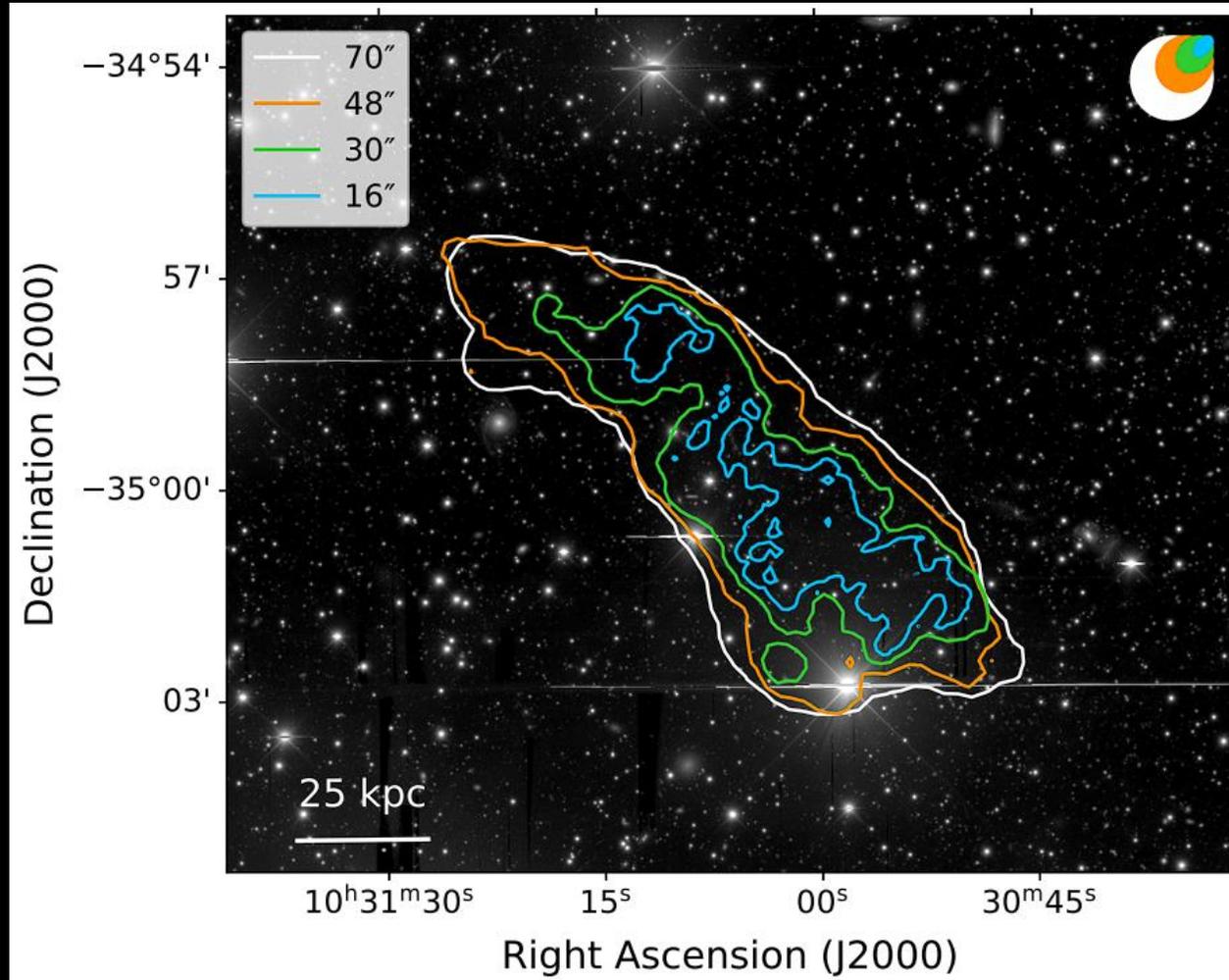


KAT-7 vs MeerKAT

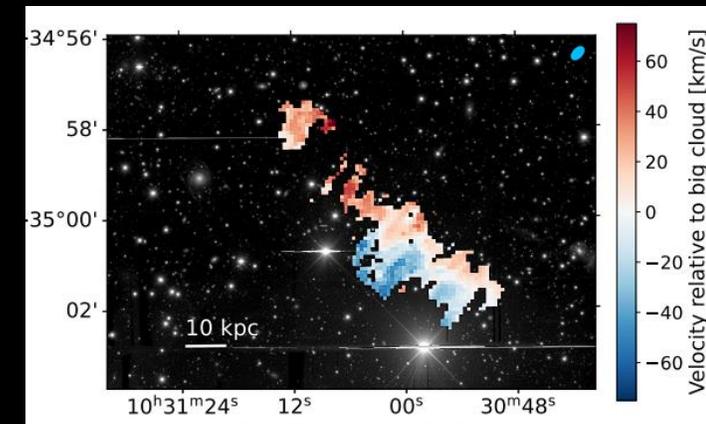
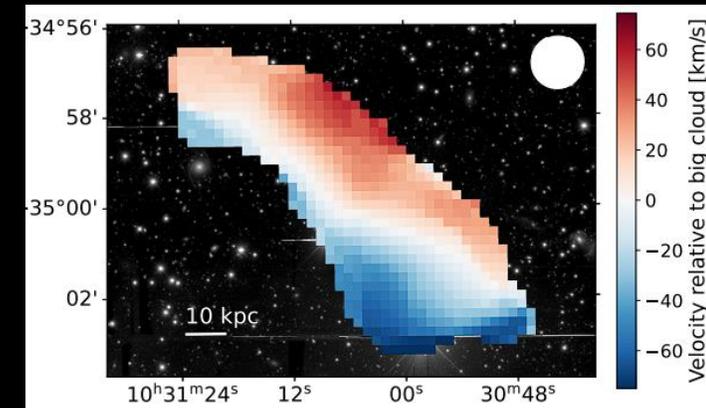
MeerKAT



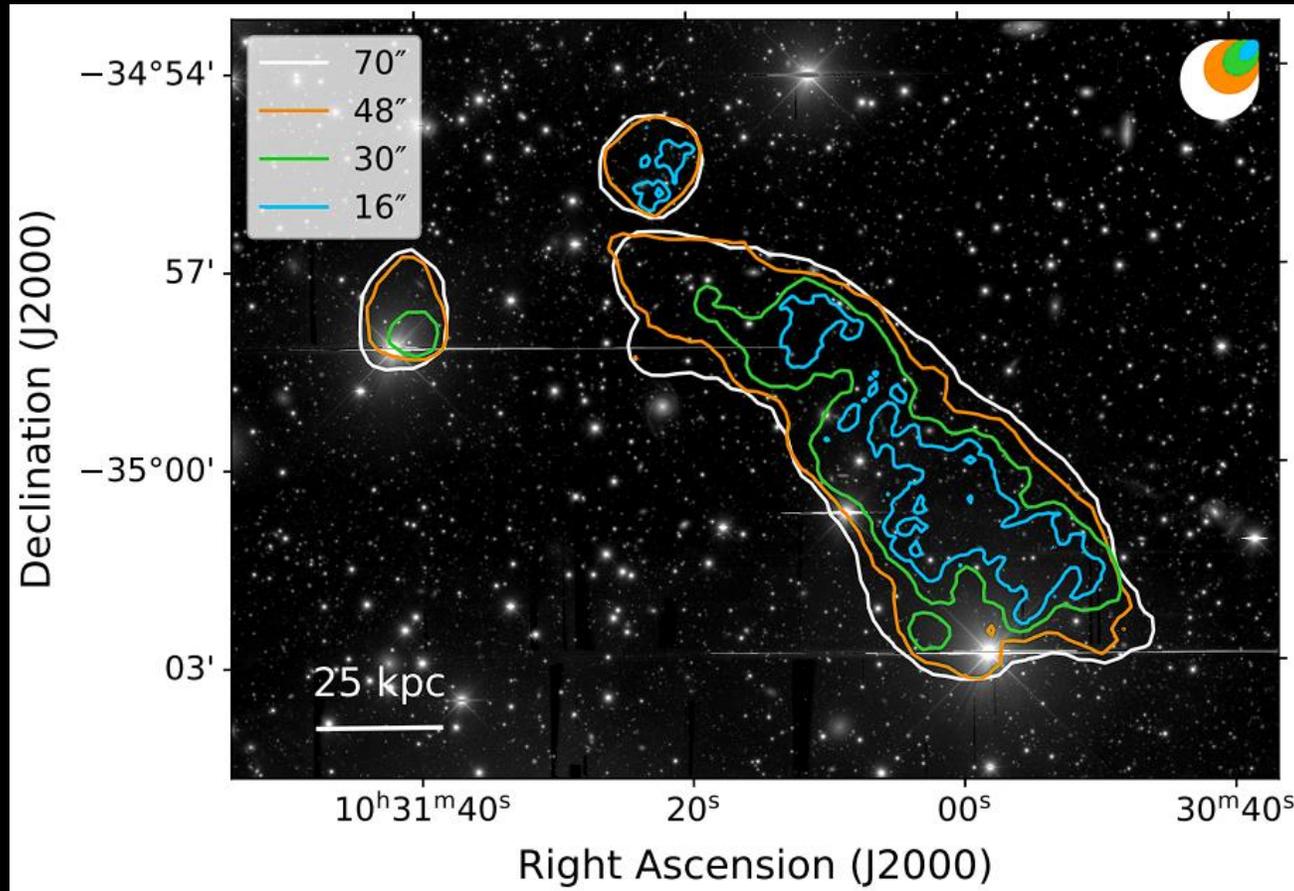
The Big HI Cloud



- HI mass of $\sim 5.76 \cdot 10^8 M_{\odot}$.
- Rotates like a galaxy.

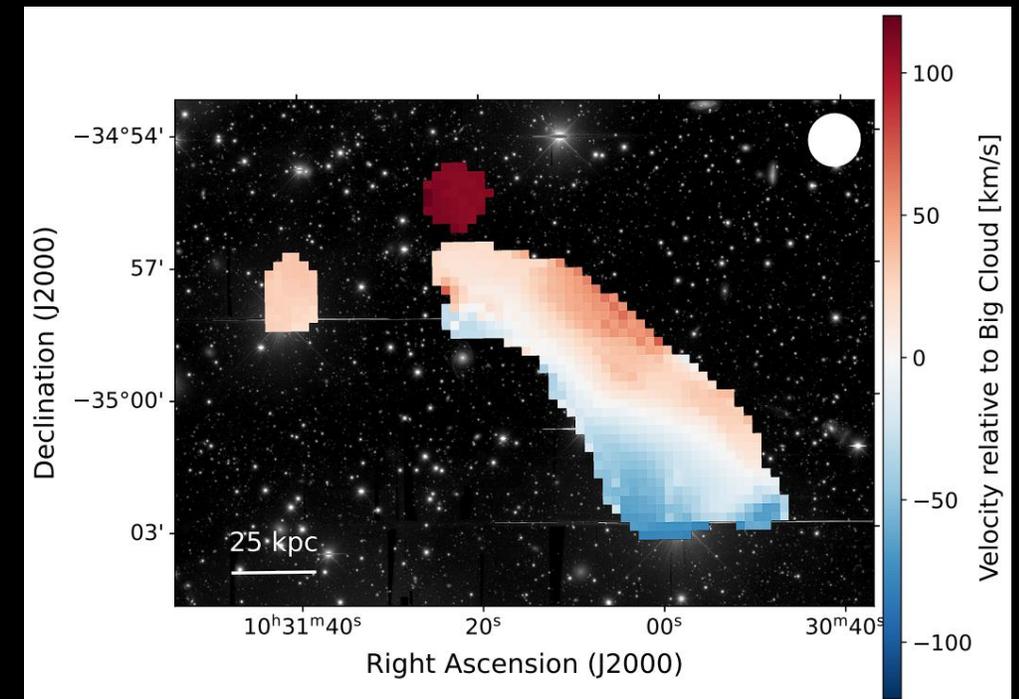


The Big HI Cloud + the small clouds

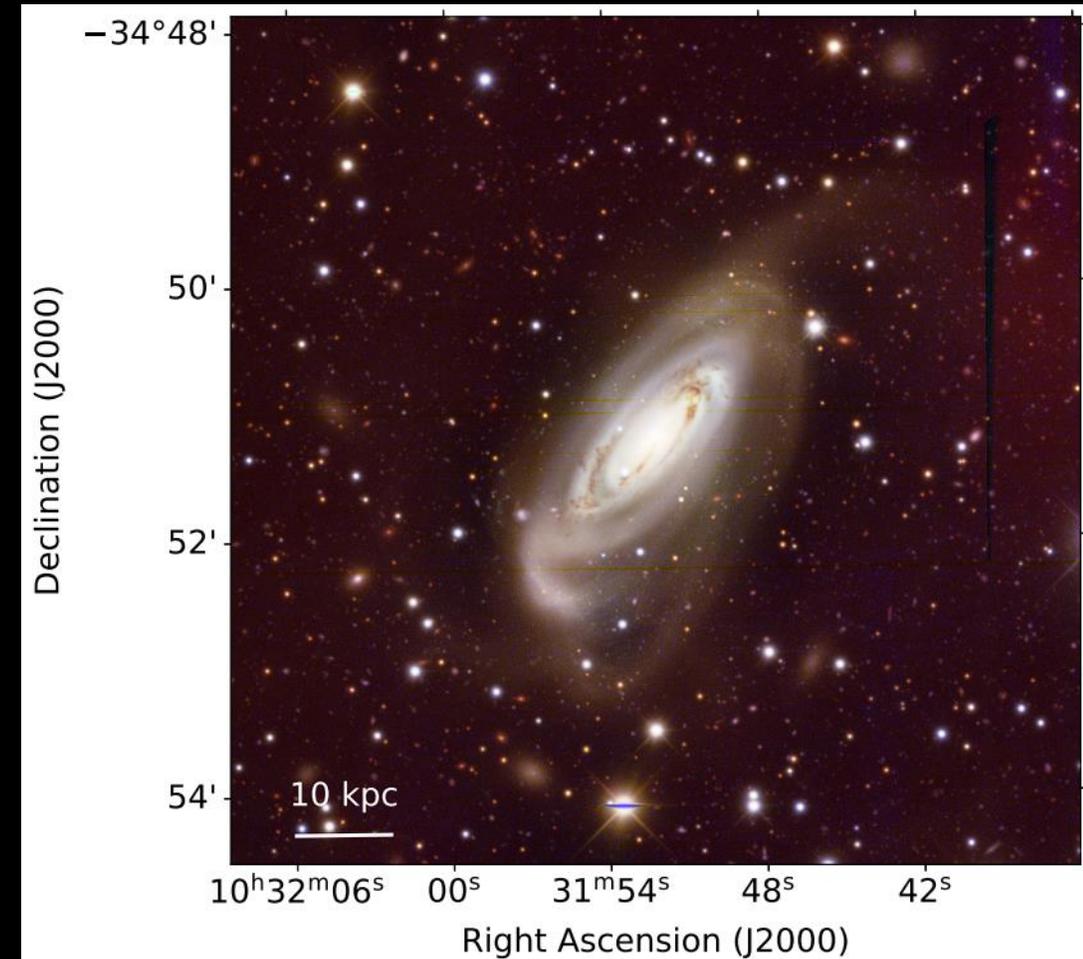
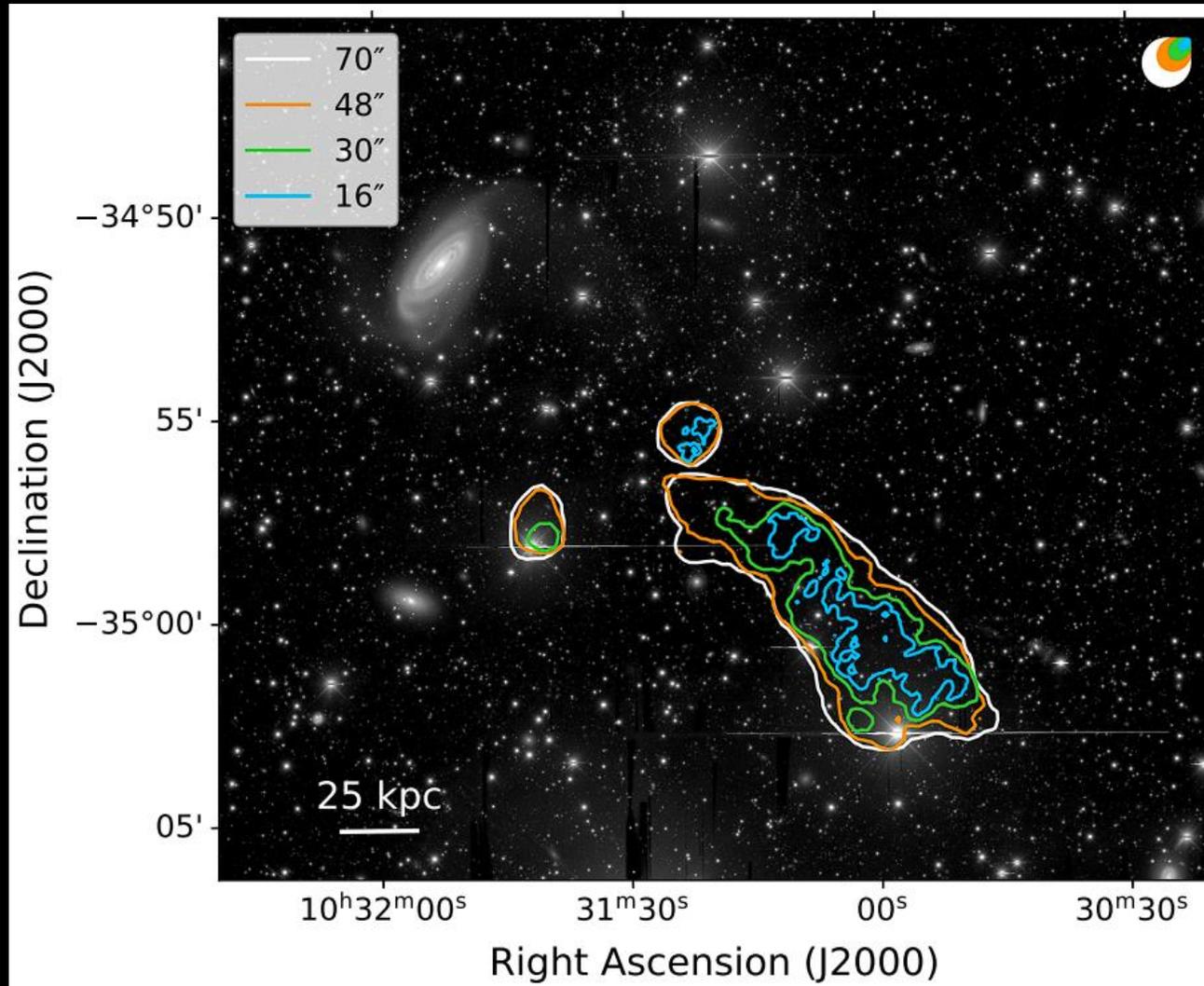


Two smaller clouds nearby:

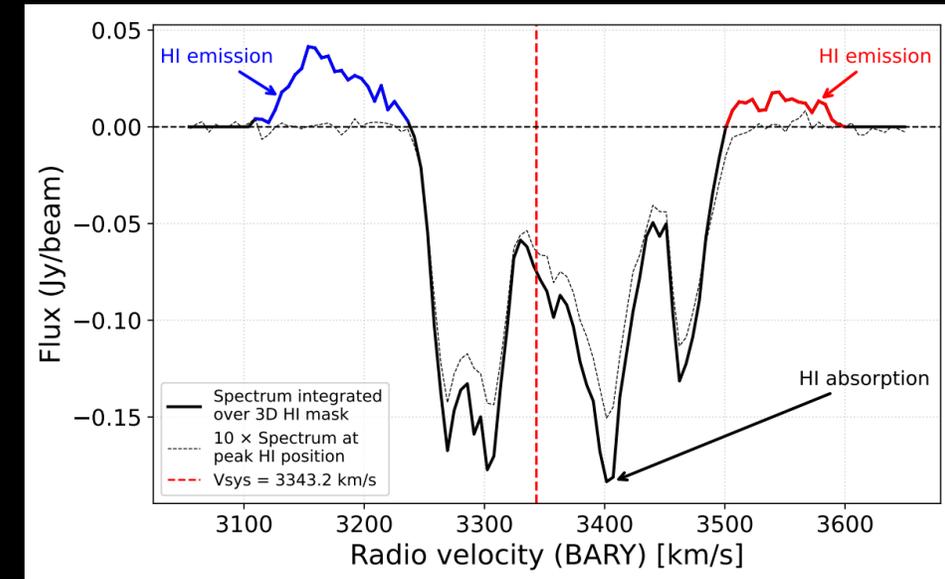
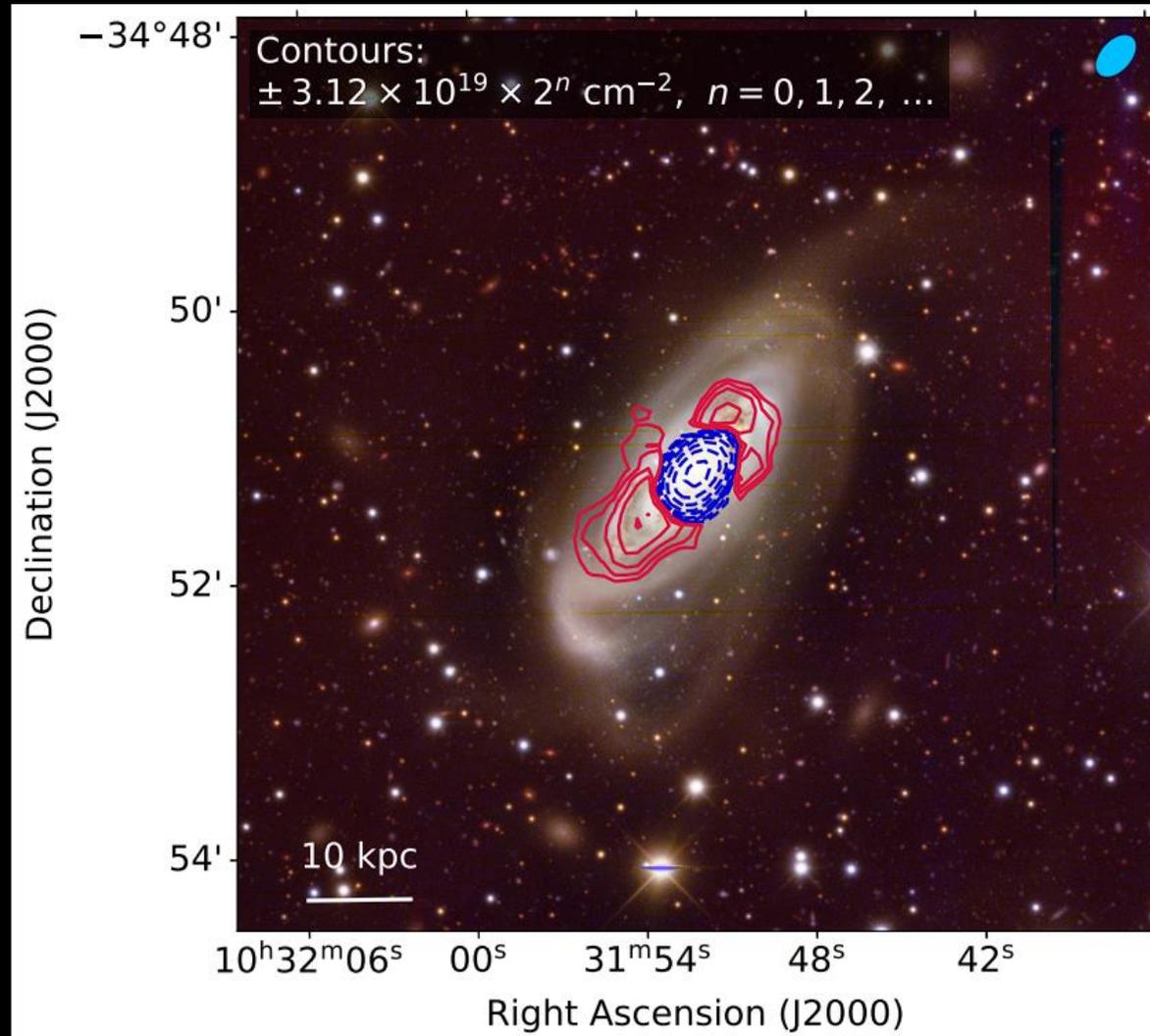
- Small cloud 1: $\sim 1.19 \cdot 10^7 M_{\odot}$.
- Small cloud 2: $\sim 1.17 \cdot 10^7 M_{\odot}$.



The cloud's origin? → NGC3281

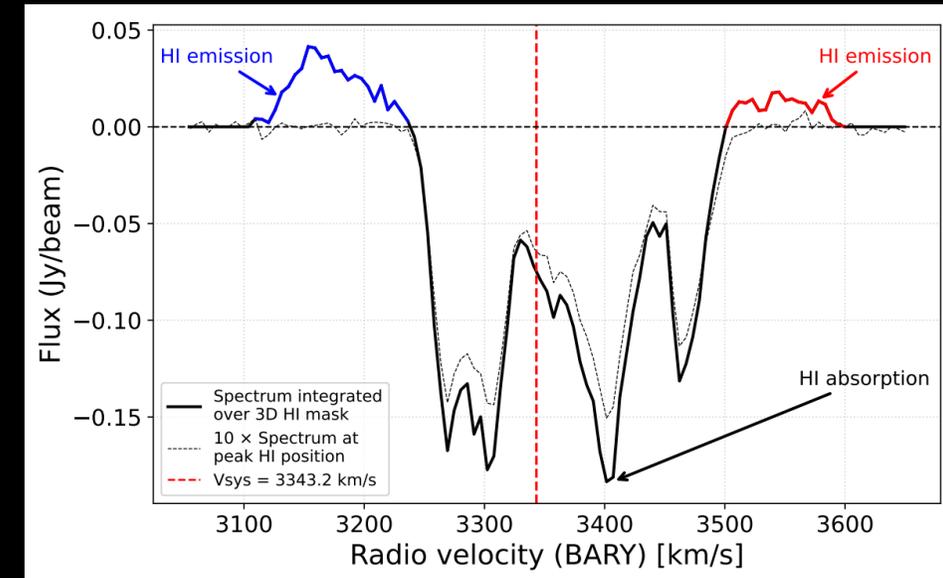
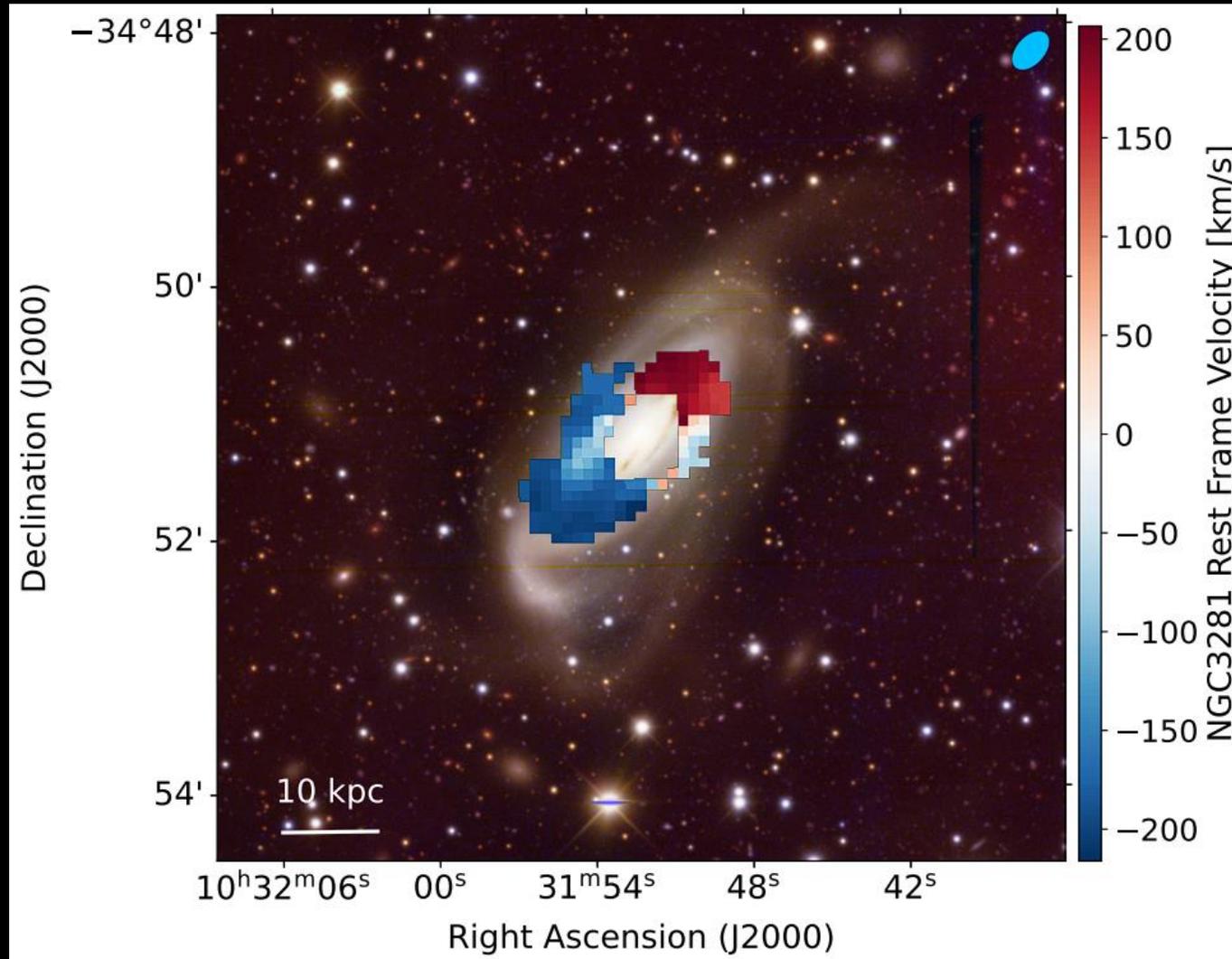


NGC3281: HI emission and absorption



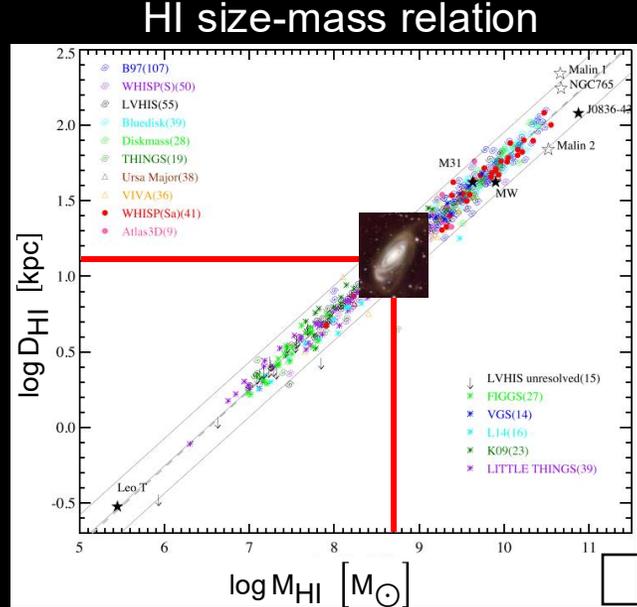
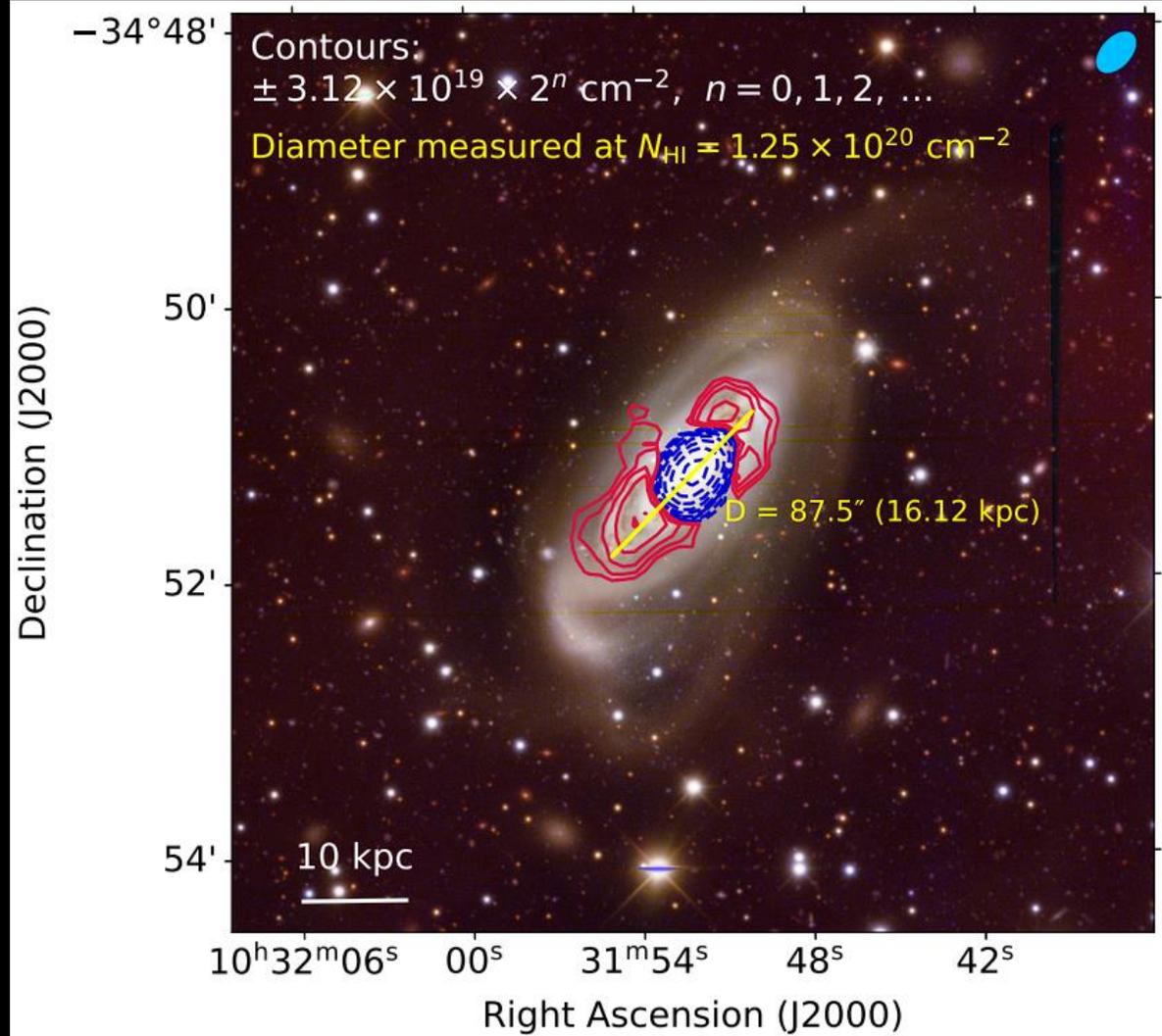
- HI emission on both sides of the galaxy.
- Most of the emission is seen on the southern side.
- Lack of extended emission past the optical disk.
- Redshifted HI absorption suggests inflow.

NGC3281: HI moment 1 emission



- The southern part is blueshifted and the northern part is redshifted.
- Same rotational orientation as the big cloud.

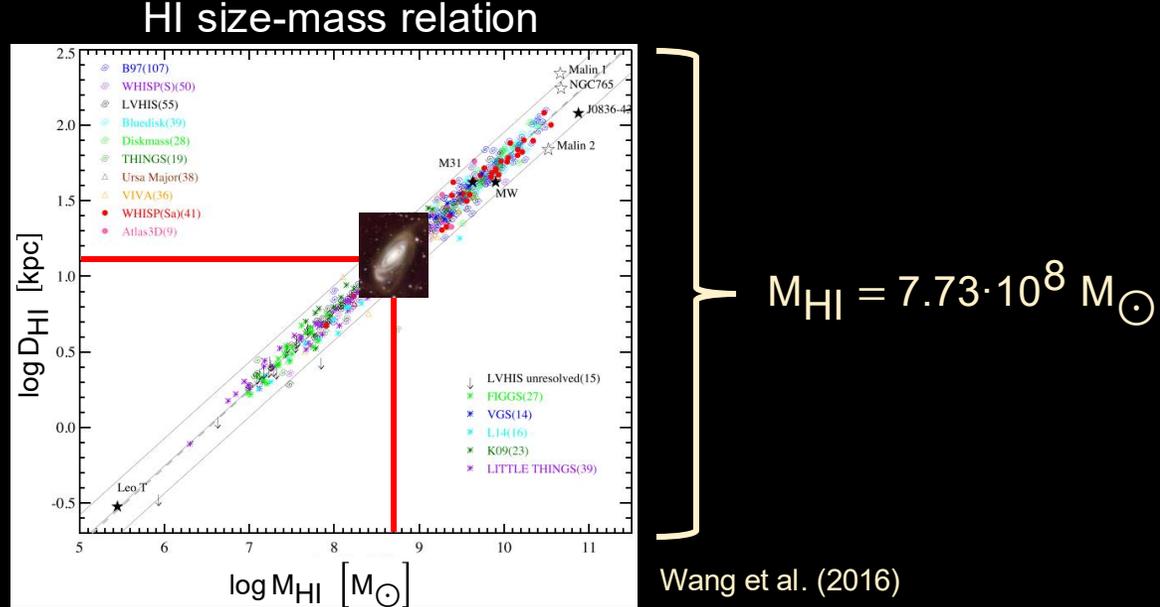
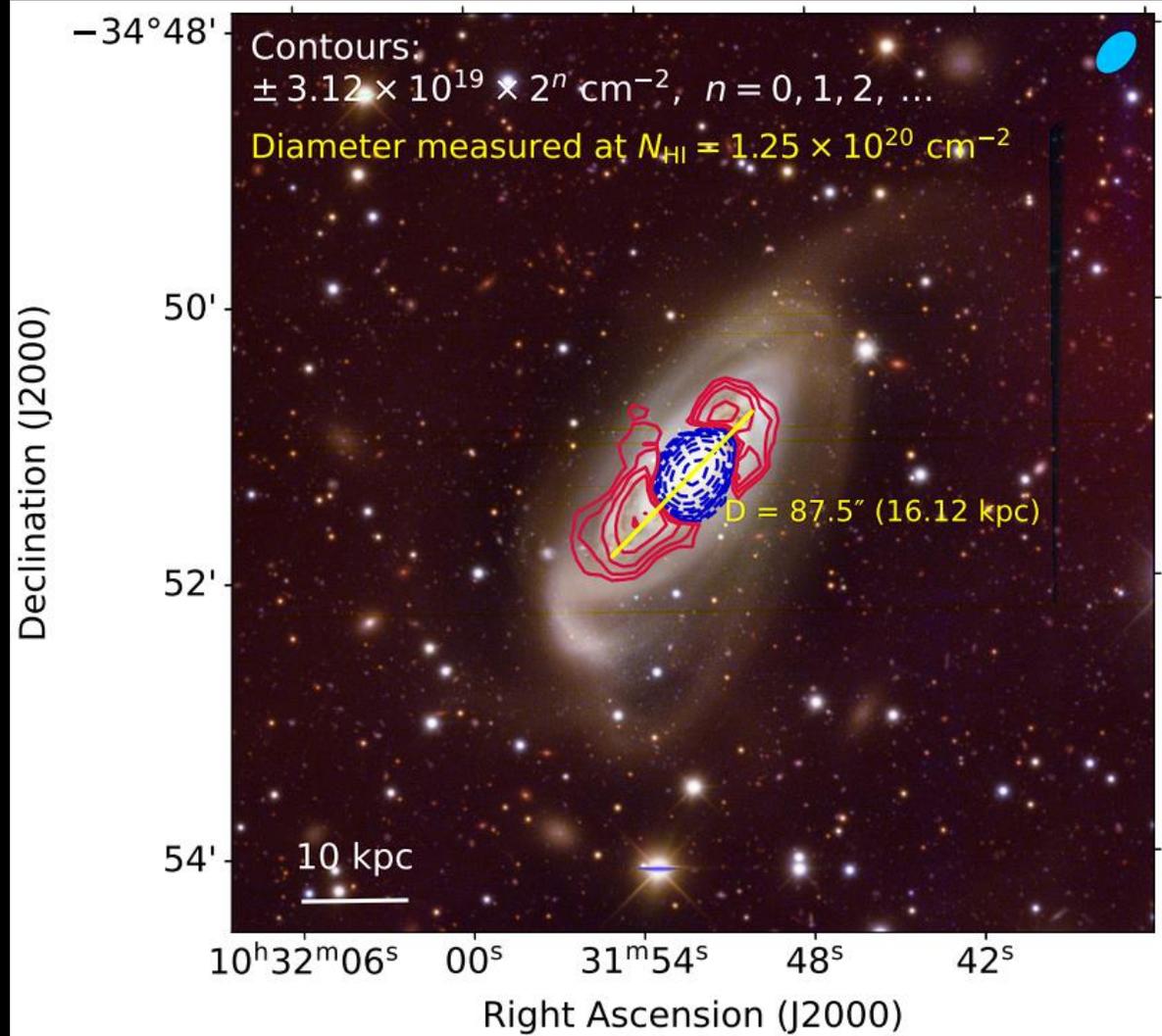
NGC3281: HI mass estimation



$M_{\text{HI}} = 7.73 \cdot 10^8 M_{\odot}$

Wang et al. (2016)

NGC3281: HI mass estimation



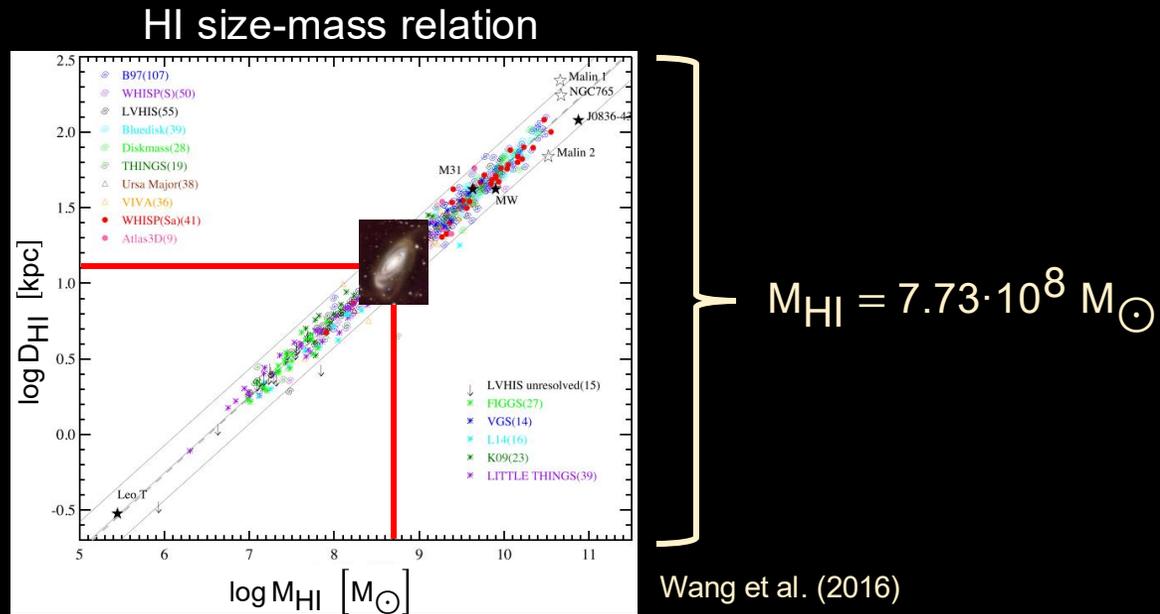
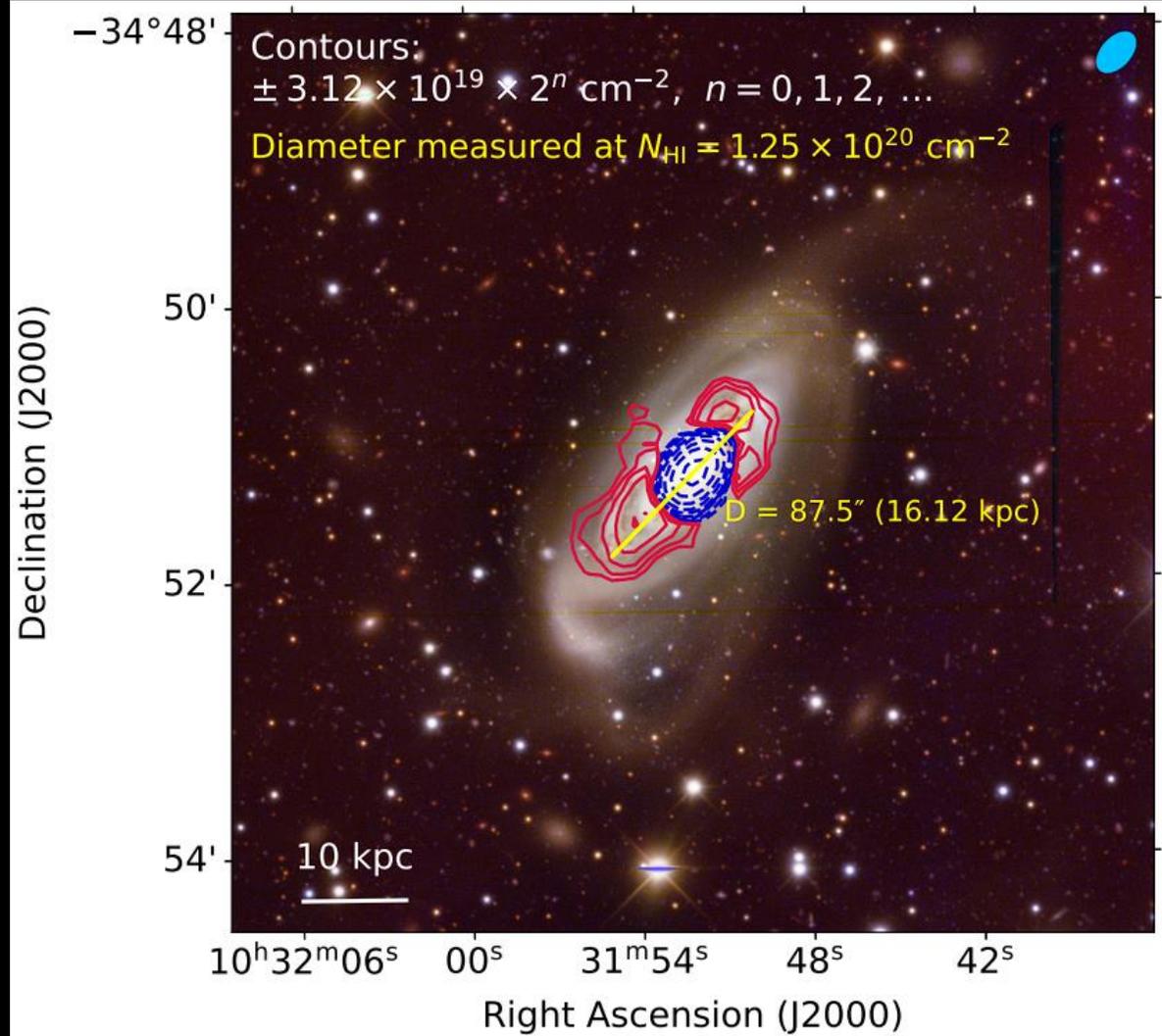
Expected "healthy" HI from D_{25} method (Boselli & Gavazzi 2009):

$$\log(h^2 M_{\text{HI,exp}}) = c + d \log(h D_{25} / \text{kpc})^2$$

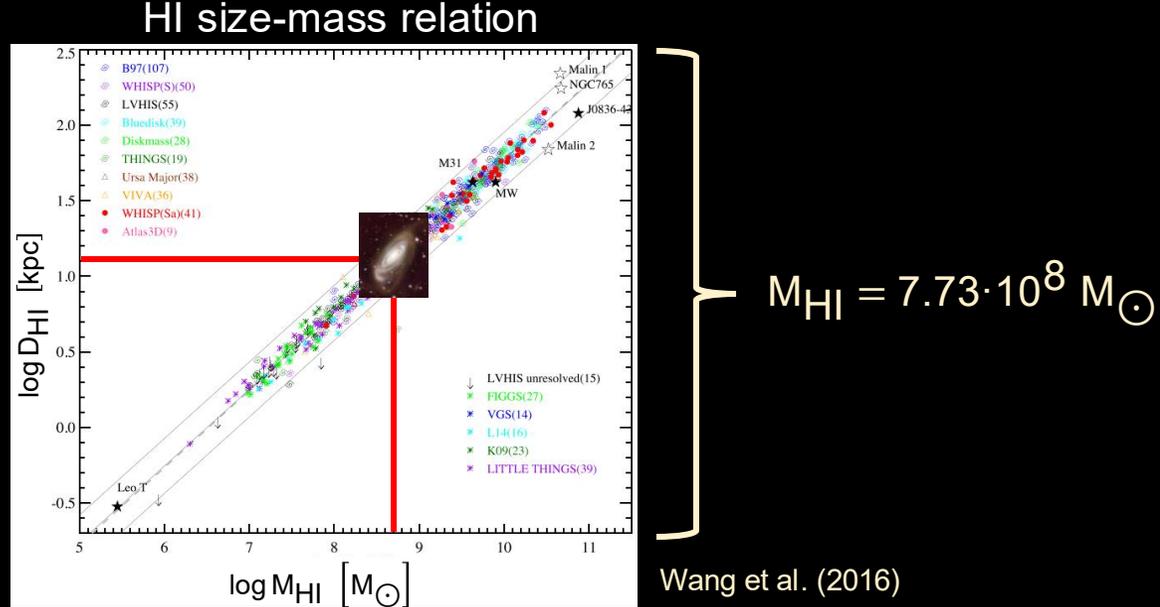
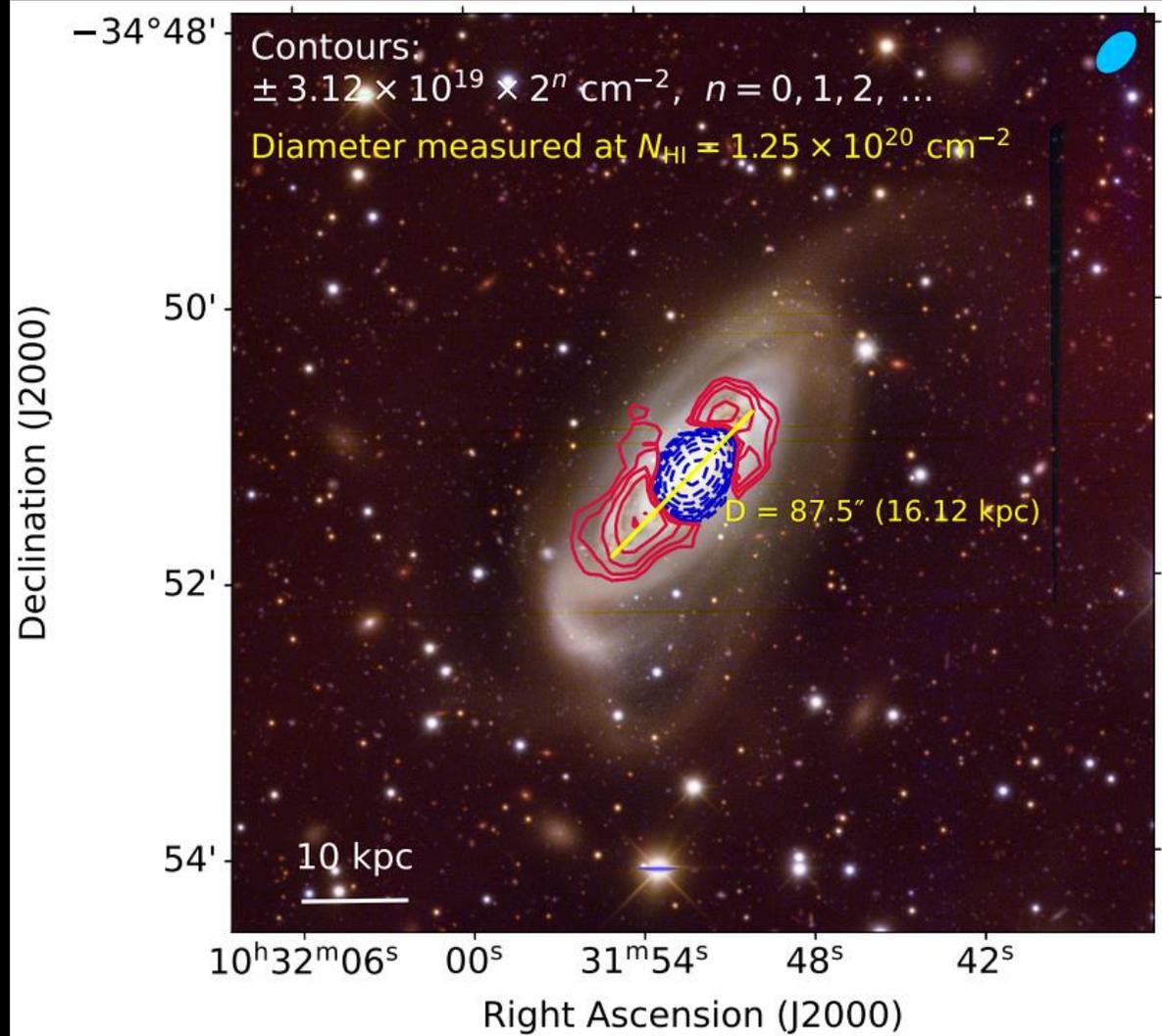
$\rightarrow M_{\text{HI,exp}} = 4.86 \cdot 10^9 M_{\odot}$

$c = 7.75$
 $d = 0.59$ } Sab
 $D_{25} = 34.2 \text{ kpc}$
 $h = 0.7$

NGC3281: HI mass estimation



NGC3281: HI mass estimation



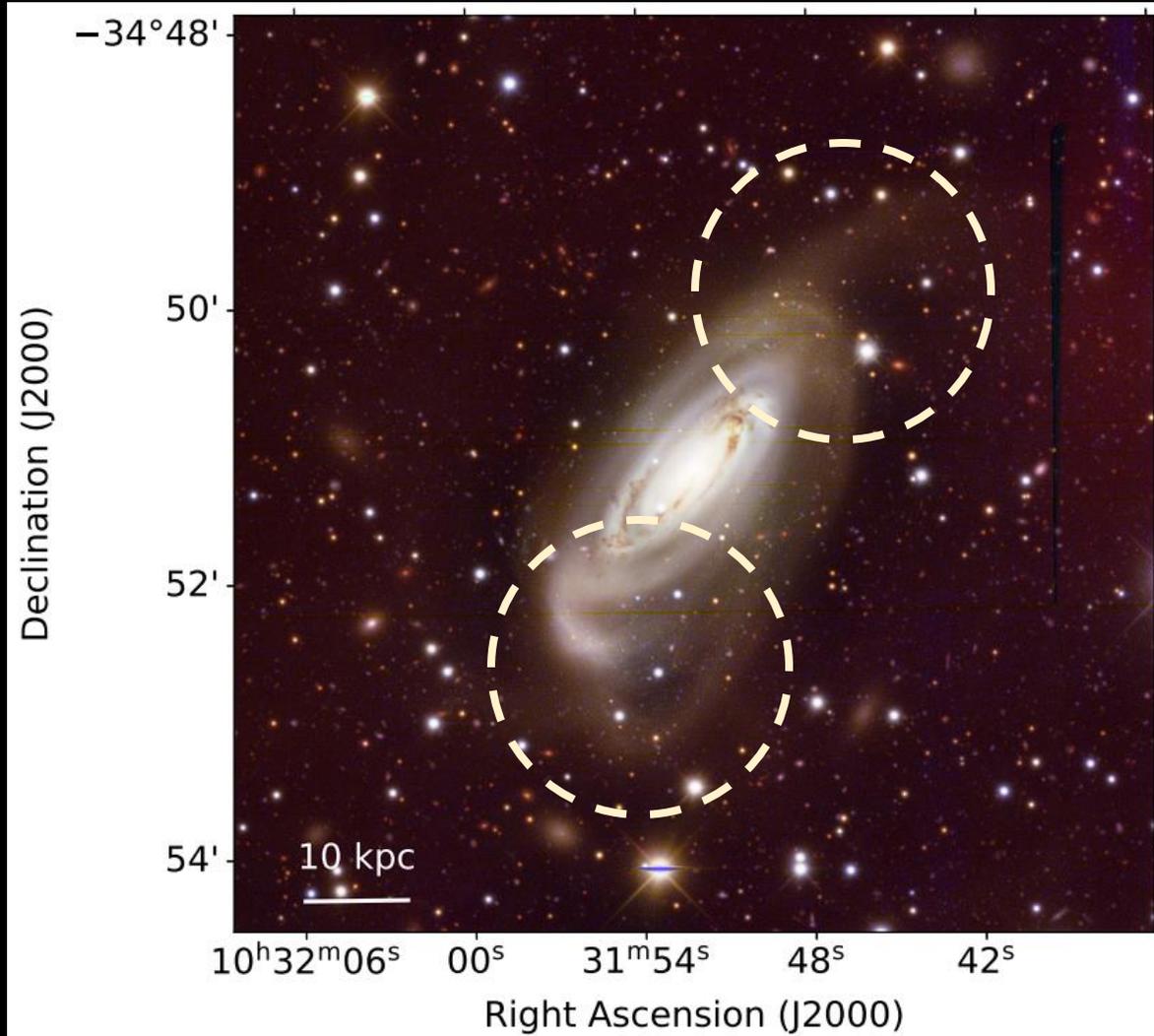
Final expected "healthy" HI:

$$2.18 \cdot 10^9 M_{\odot} \leq M_{\text{HI,exp}} \leq 7.86 \cdot 10^9 M_{\odot}$$

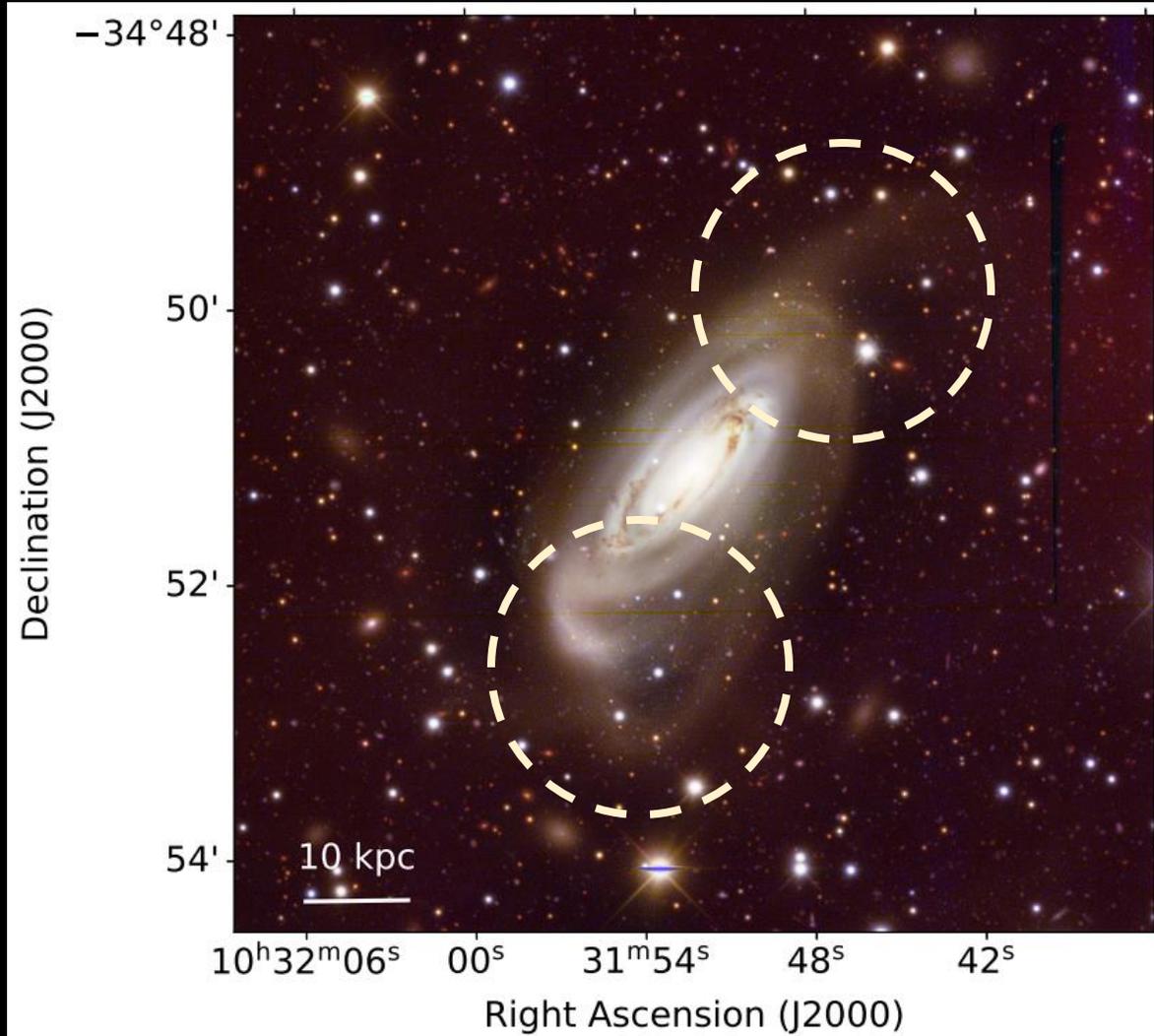
$$\text{Missing HI fraction} = \frac{M_{\text{HI,exp}} - M_{\text{HI}}}{M_{\text{HI,exp}}} \sim 52 - 93\%$$

$M_{\text{HI,clouds}} \parallel 7 \cdot 10^8 M_{\odot}$
 Could account for ~9-43% of the missing HI.

NGC3281: Disturbed optical morphology



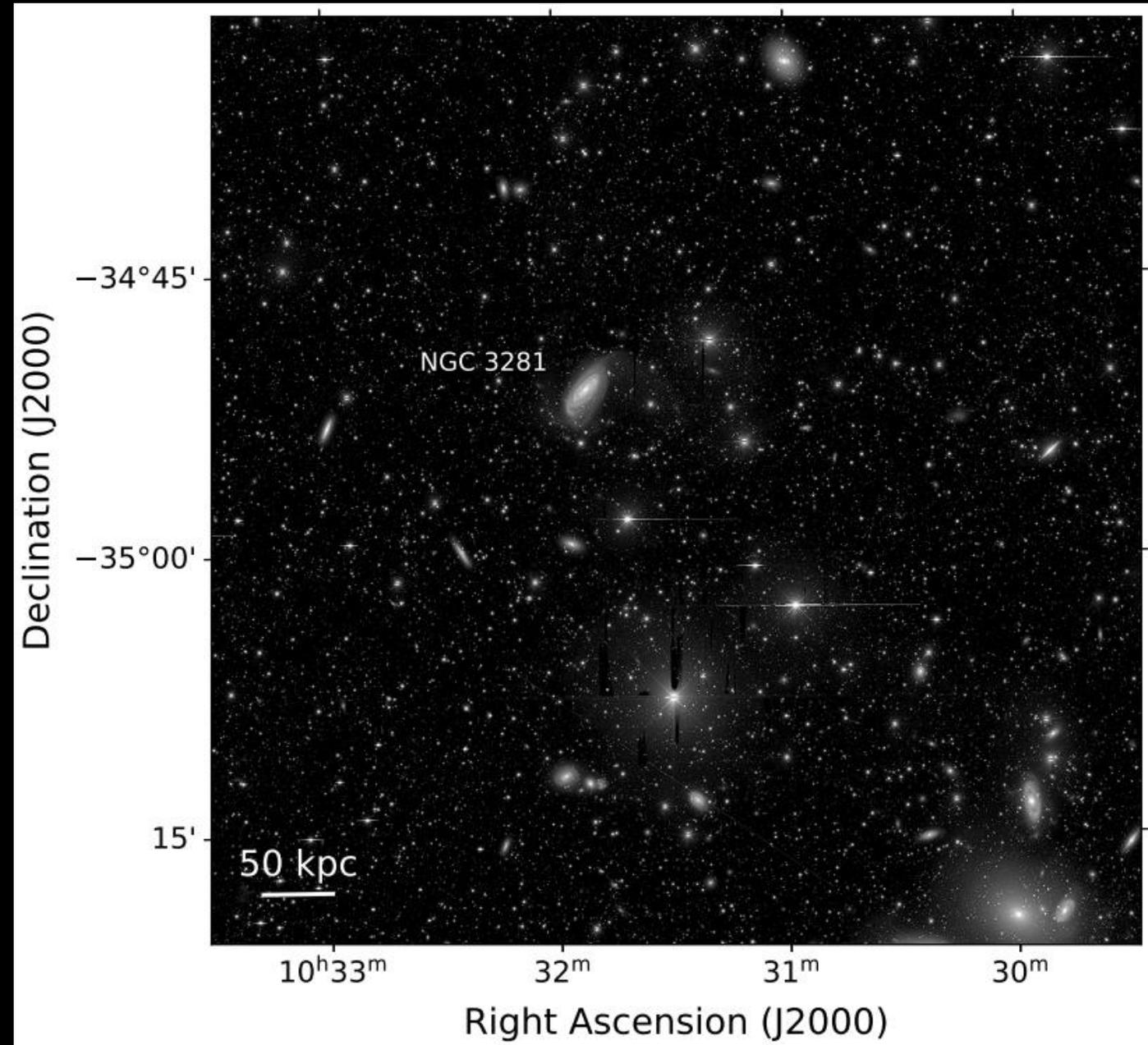
NGC3281: Disturbed optical morphology



Let's look for
the culprit

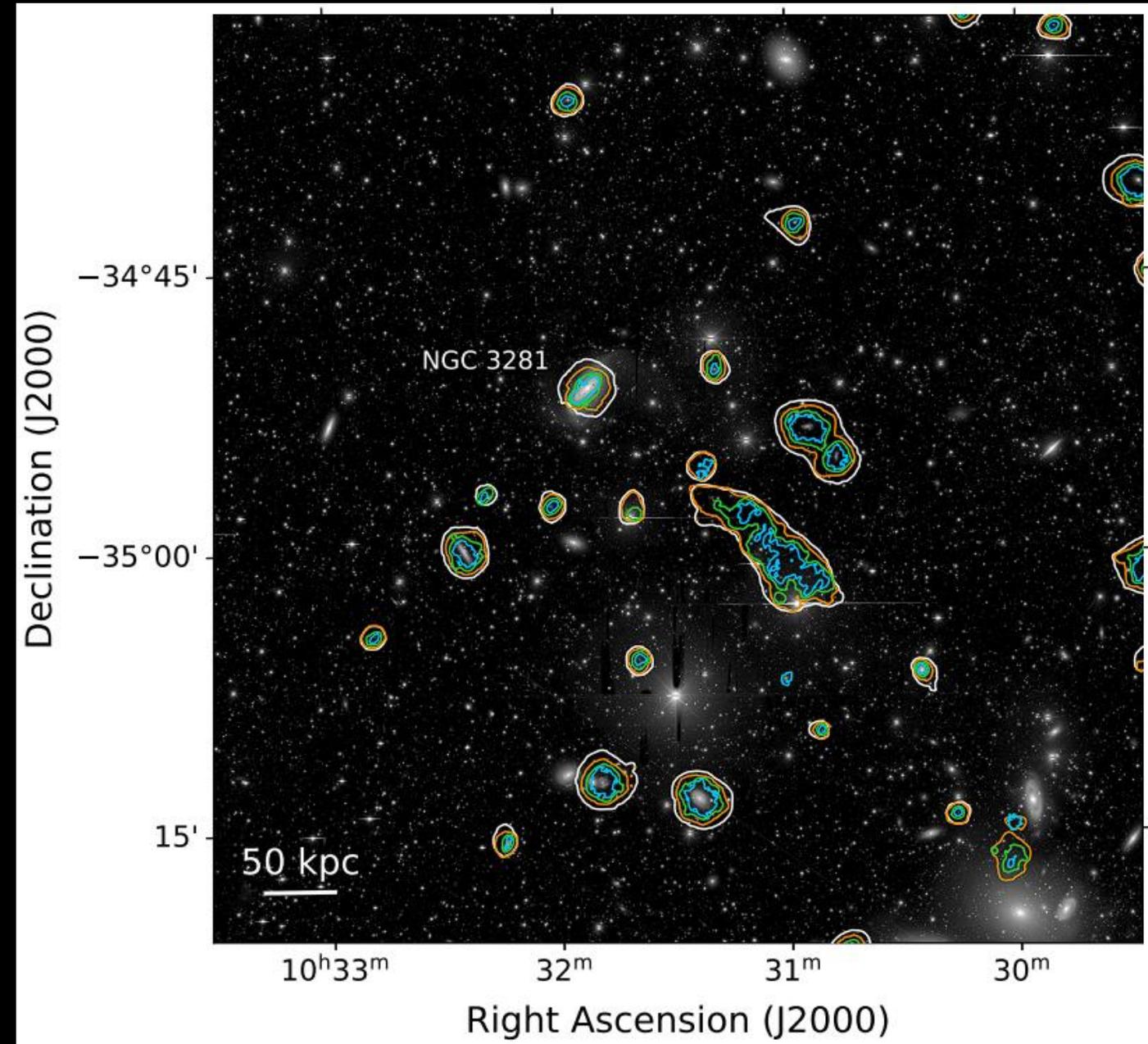


Around NGC3281

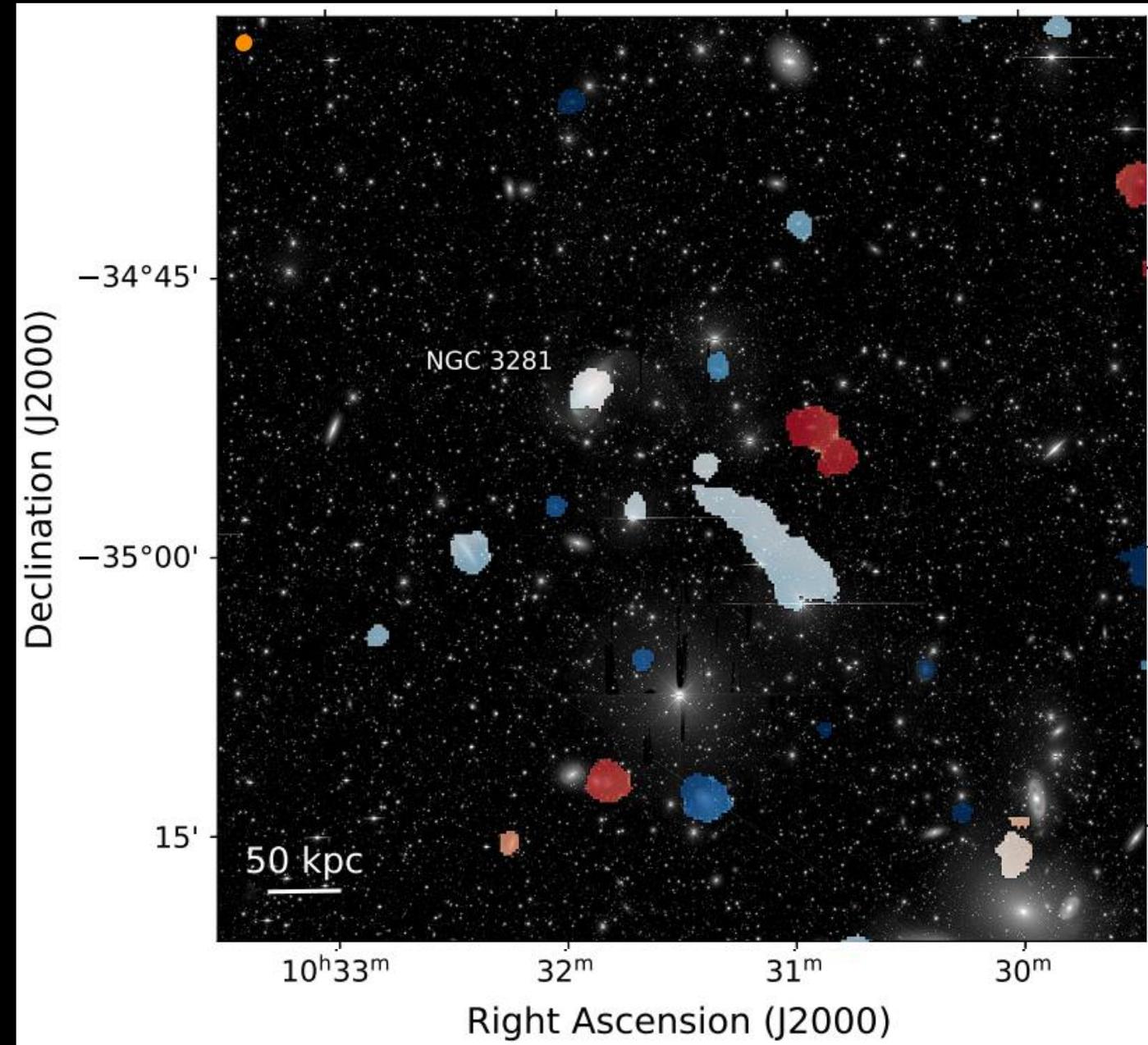
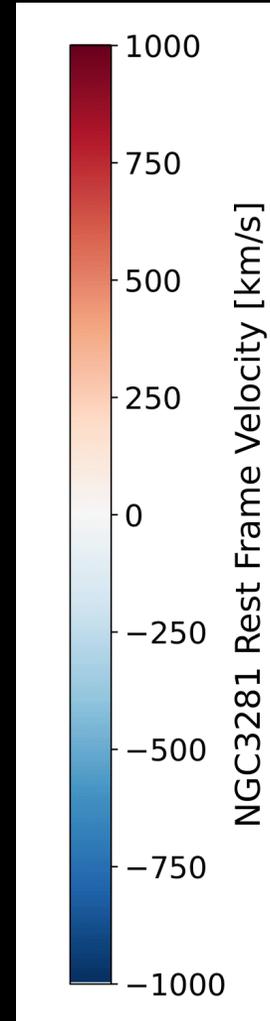


Around NGC3281

Let's turn on
the HI



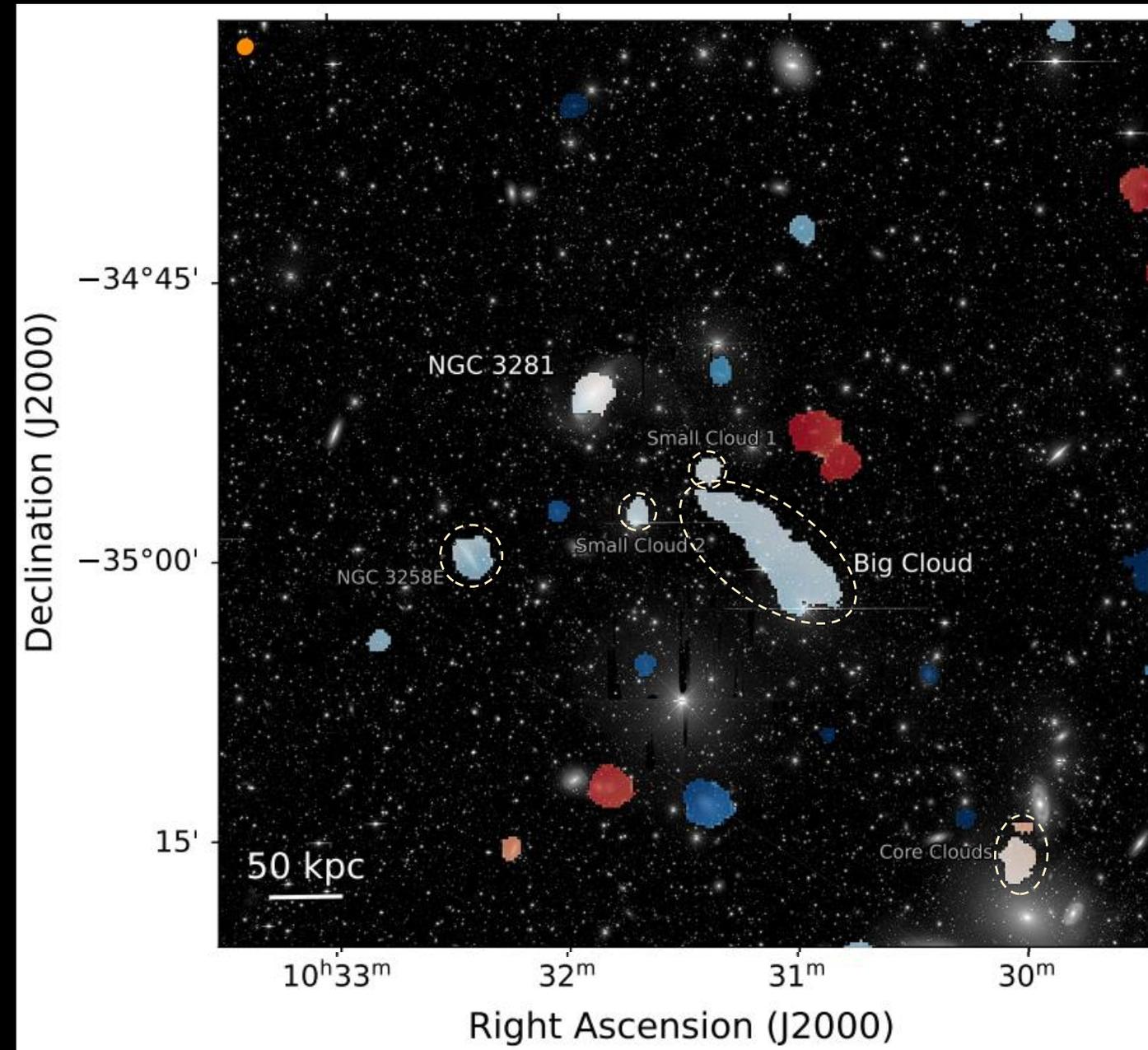
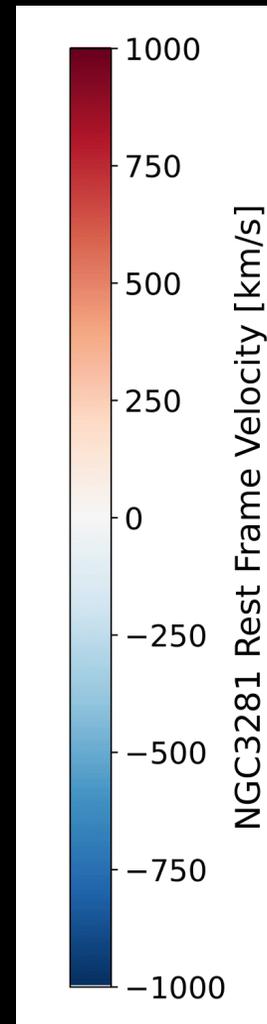
Around NGC3281: Moment 1 map



Around NGC3281: Moment 1 map

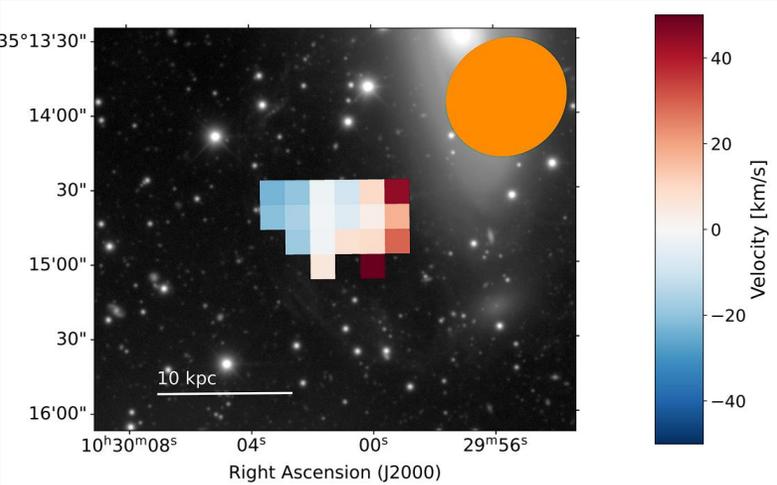
Velocity map reveals 6 sources at similar redshift to NGC3281:

- One galaxy: NGC3258E
- The big HI cloud
- The two small HI clouds
- Two clouds near the cluster core

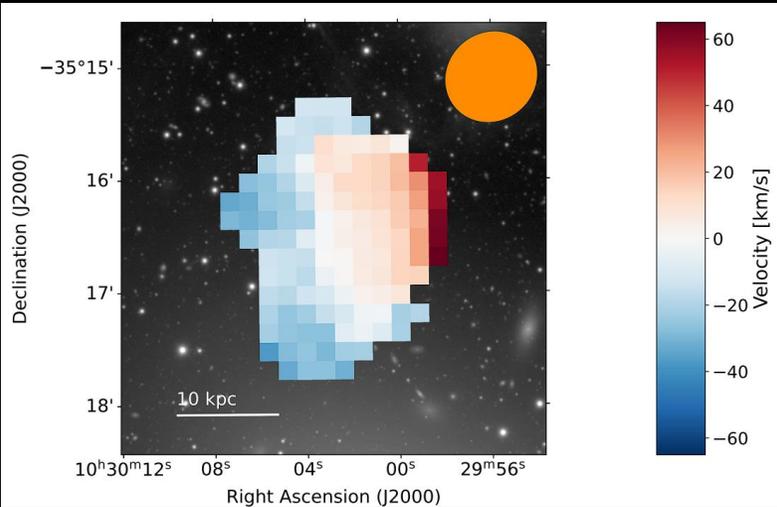


The core clouds

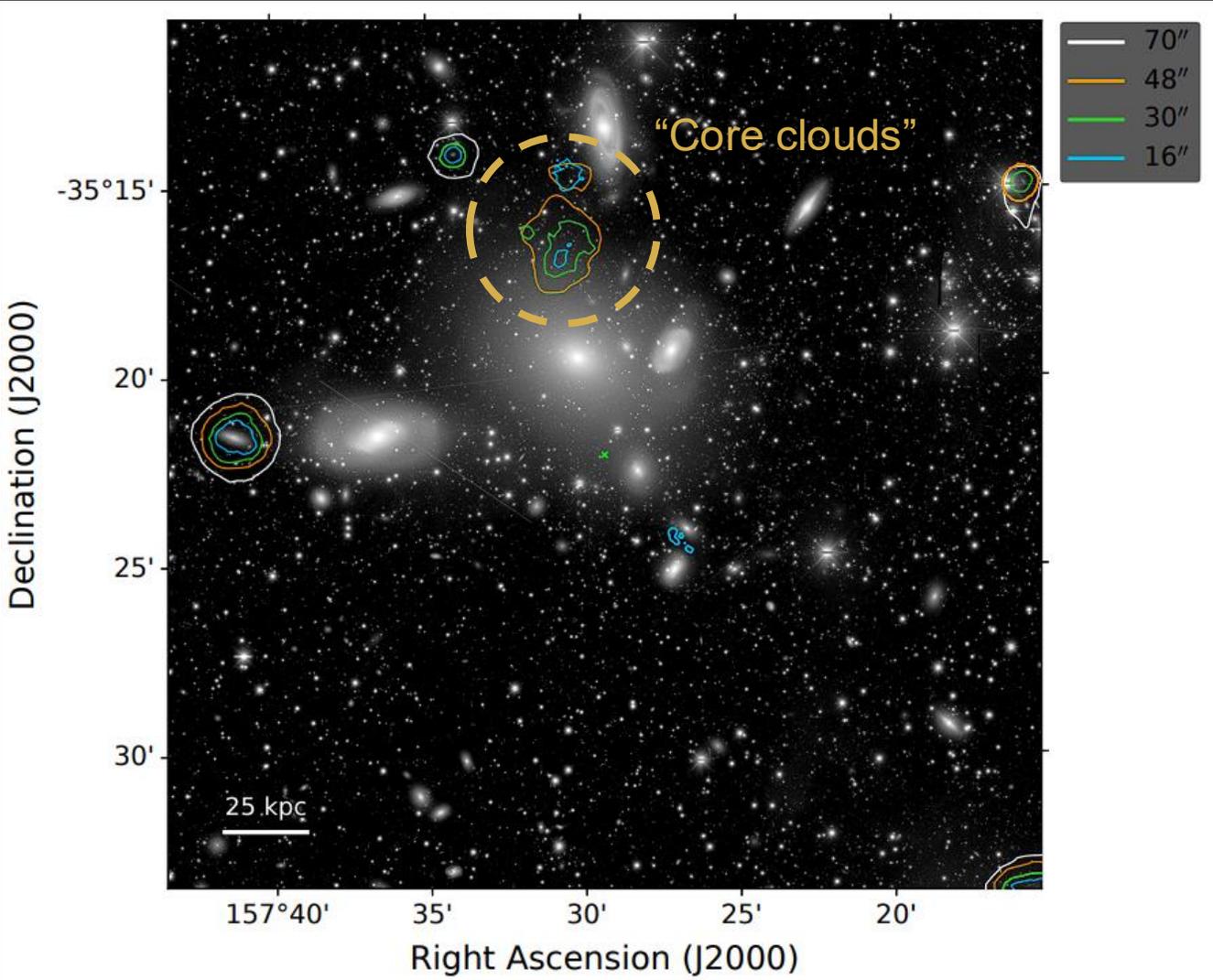
MeerKAT



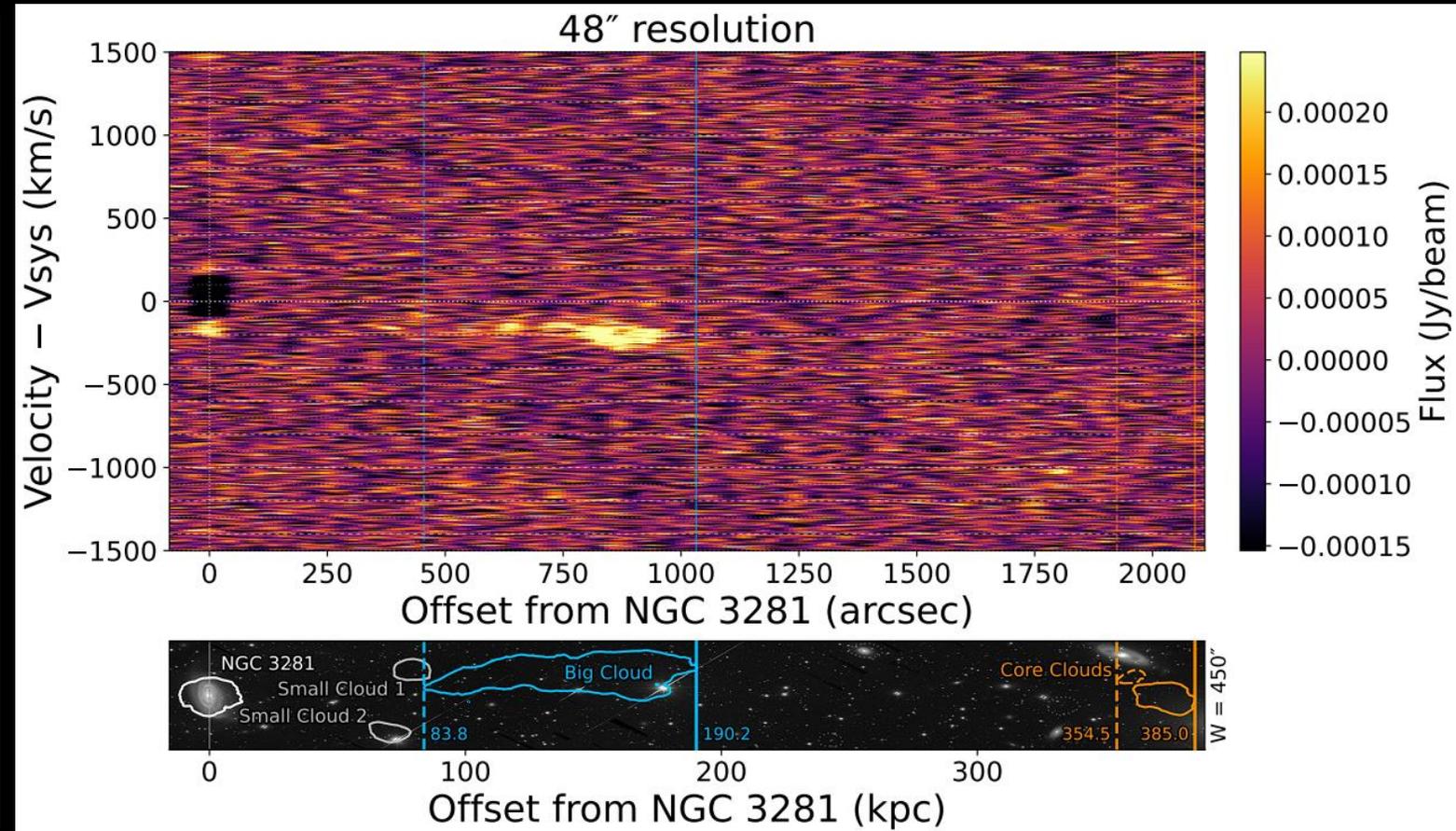
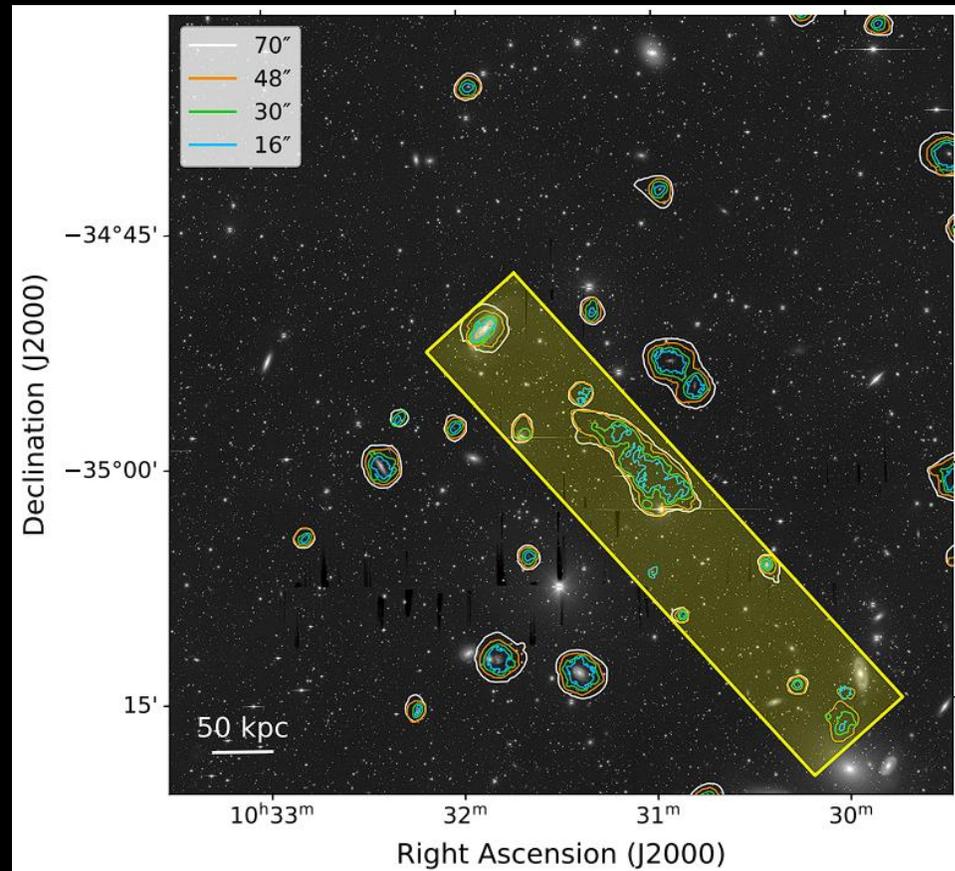
Core cloud 1:
 $\sim 7.34 \cdot 10^6 M_{\odot}$



Core cloud 2:
 $\sim 5.85 \cdot 10^7 M_{\odot}$



Position-velocity (PV) diagram



Our Hypothesis: NGC 3281 falls rapidly through the center of the cluster → the cluster core gravitationally perturbs NGC 3281 → HI gas loosens up and gets stripped → ram pressure stripping stretches the HI cloud.

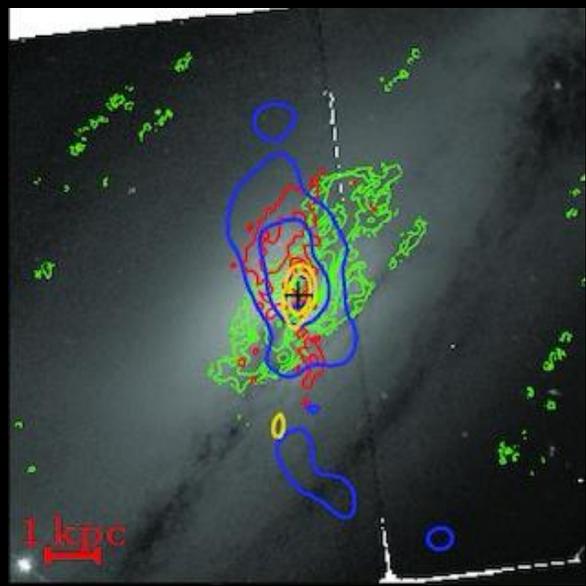
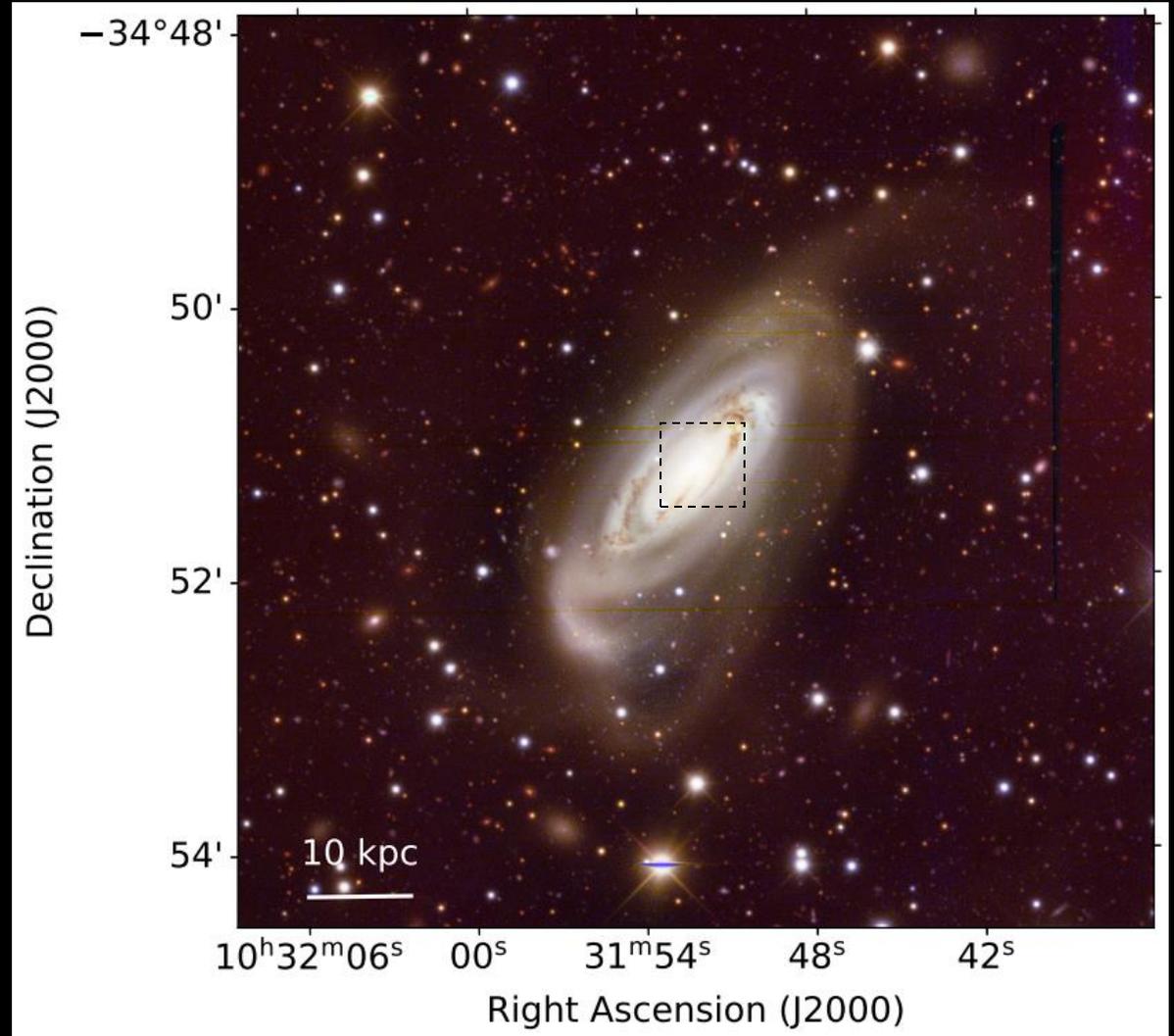
A meme featuring a man with a shocked expression, wearing an orange shirt, with the text "BUT WAIT" at the top and "THERE'S MORE!" at the bottom.

BUT WAIT

THERE'S MORE!

NGC3281: The AGN

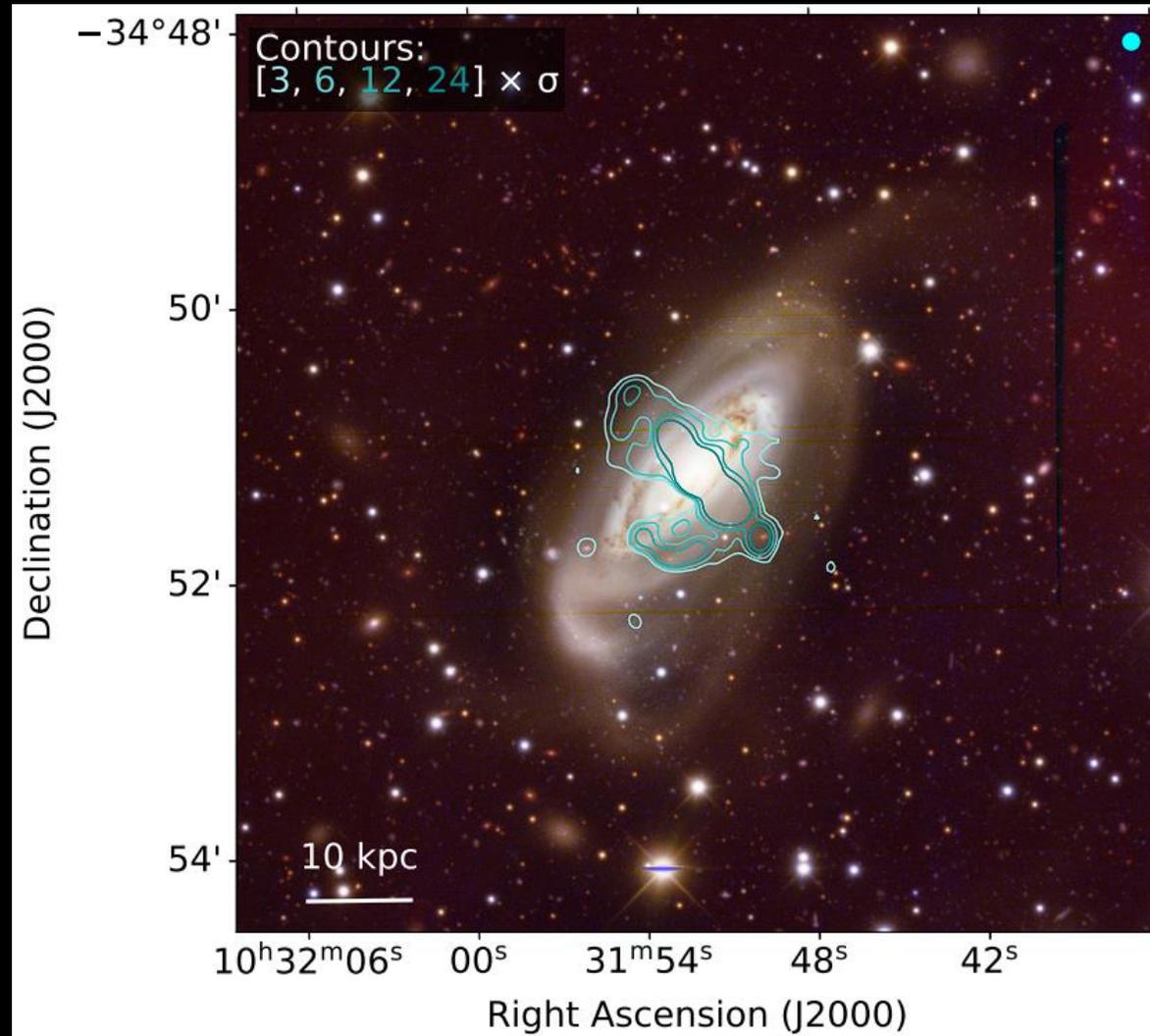
- Seyfert 2 galaxy.



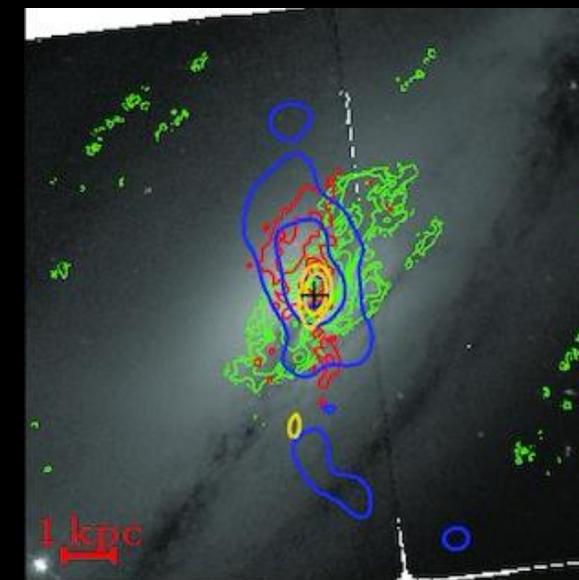
Dall'Agnol de Oliveira et al. (2023)

X-ray
 OIII
 CO
 Radio 8.6 GHz

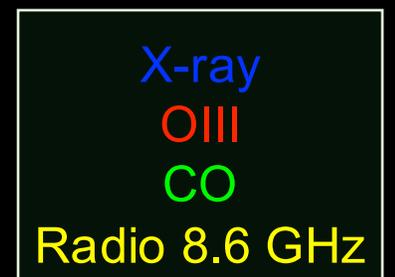
NGC3281: Radio continuum



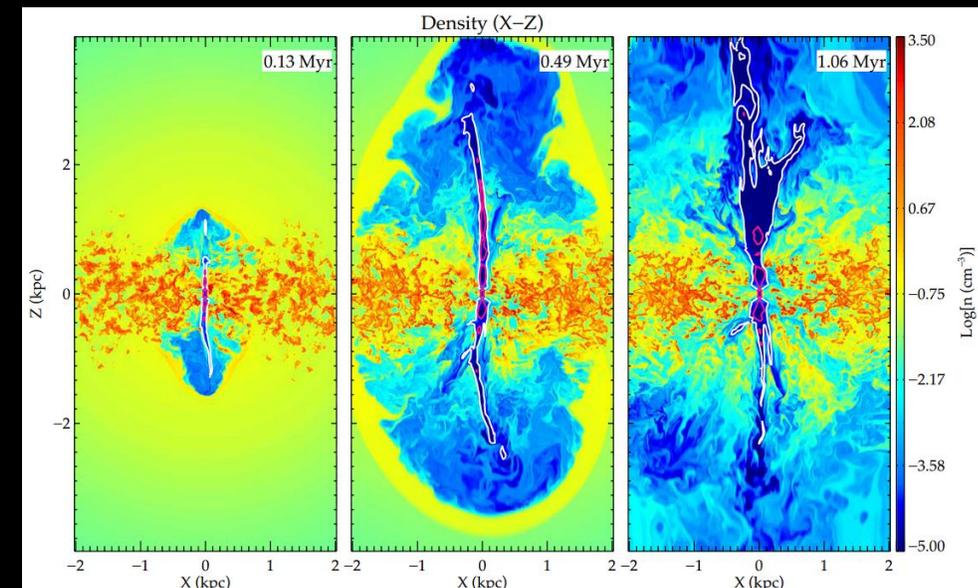
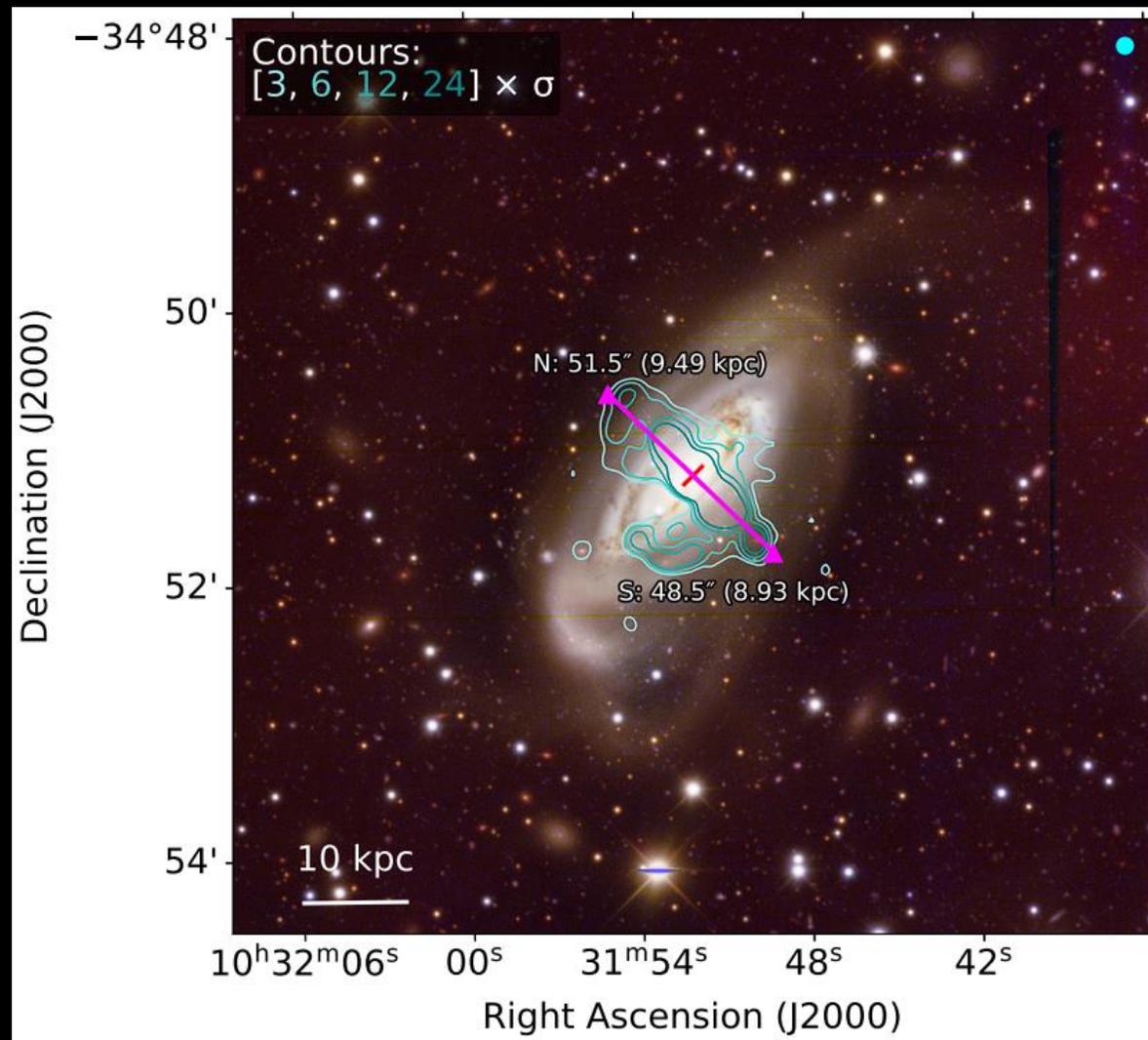
- Seyfert 2 galaxy.
- Radio continuum outflows resolved for the first time.



Dall'Agnol de Oliveira et al. (2023)



NGC3281: Radio continuum



Mukherjee et al. (2018)

- Radio continuum looks like frustrated outflows.
- Outflow length \rightarrow timescale: 20-45 Myr

Summary

- Our data allows to study in great detail galaxy evolution in Antlia:
 - 118 HI sources with masses between $\log M_{\text{HI}} = 6.57 - 9.50 M_{\odot}$.
- Study of NGC3281:
 - Evidence suggest NGC3281 underwent a combination of gravitational interactions and ram pressure stripping. Leading to HI clouds retaining the galaxy's rotational signature.
 - We estimate the Big Cloud left NGC3281 around 300-350 Myr ago.
 - These events might have activated the AGN at the galaxy's center.
- To do:
 - Estimate the ICM density and pressure profiles from X-ray observations.
 - Have fun exploring the rest of the cluster.
 - Explore the connection between Antlia and Hydra.

