First results from MHONGOOSE

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European Research Council
Established by the European Commission

Netherlands Institute for Radio Astronomy

university of groningen
faculty of science and engineering
kapteyn astronomical institute

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad

MHONGOOSE

A MeerKAT Large Survey Project to use ultra-deep HI observations of nearby spiral and dwarf galaxies to study cold gas accretion and the link with star formation

one of 7 LSPs
1650h (~68 days) observing time (55h per galaxy)
(300 observations of 5.5 hours)

mhongoose.astron.nl

MeerKAT HI Observations of Nearby Galactic Objects: Observing Southern Emitters

Overview

- brief science motivation
- the survey
- observations
- some science from the deep data
- some sample wide science from the shallow data
- summary

MeerKAT

- proto SKA-MID
- located in the Karoo desert, South Africa
- 64 dishes of 13.5m
- T_{sys} = 22K
- baselines 29m-8km
- 70% of baselines in a 1 km core
- high resolution *and* high column density sensitivity

Cold Gas Accretion

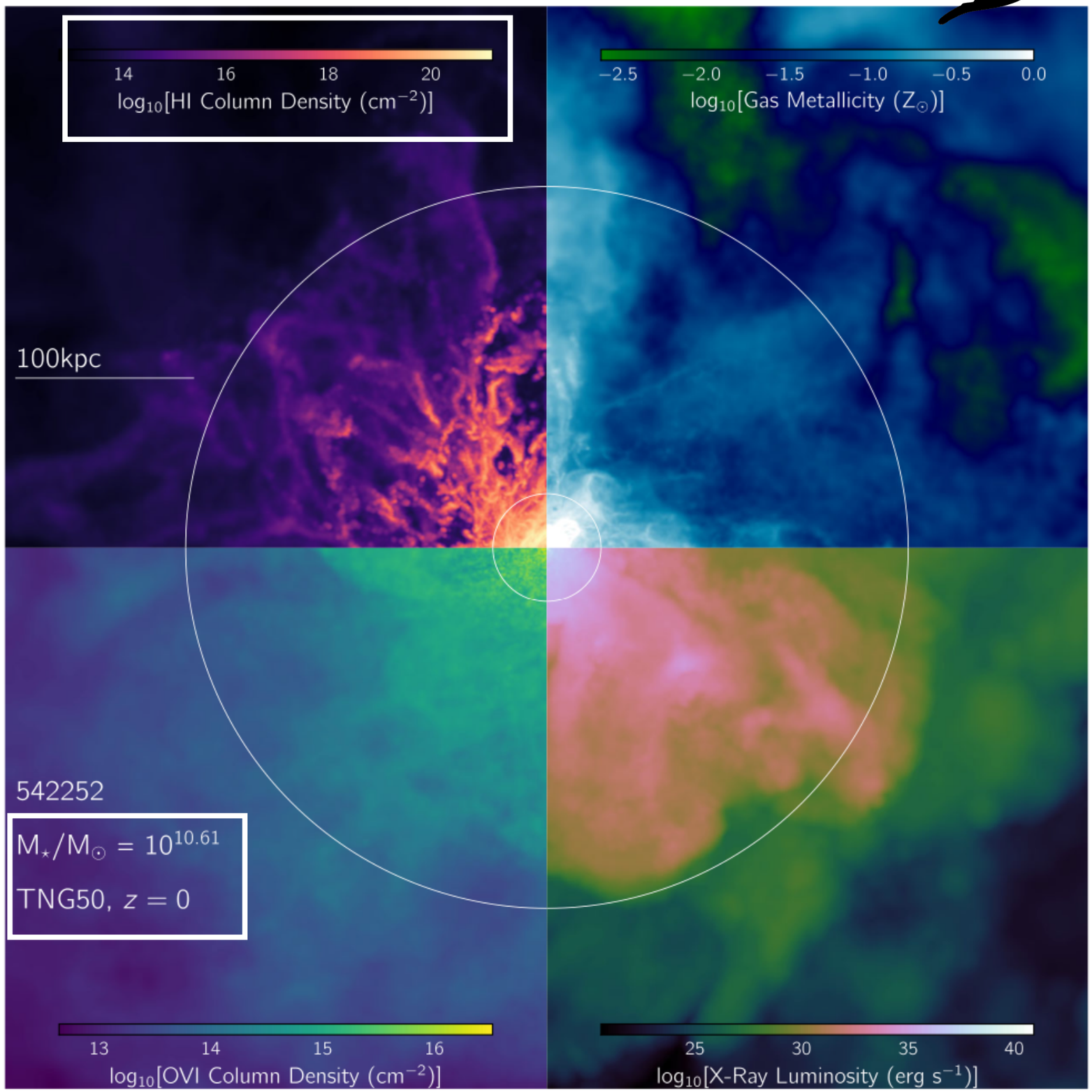
- To have galaxies form stars over their lifetime they must acquire hydrogen
- This gas most likely comes from the IGM
- Anecdotal, but circumstantial evidence
- Direct accretion of clouds and dwarfs at 10^{20} cm^{-2} order of magnitude too low to sustain star formation
- Confirmed by HALOGAS (Heald+ 2011, 2021, Kamphuis+ 2022) down to ~10^{19} cm^{-2}
- Can we see accretion happening at lower column densities in the local universe?
- Simulations predict “cold accretion” of gas

Veronese et al 2023

Talk Simone Veronese

Simulated Accretion

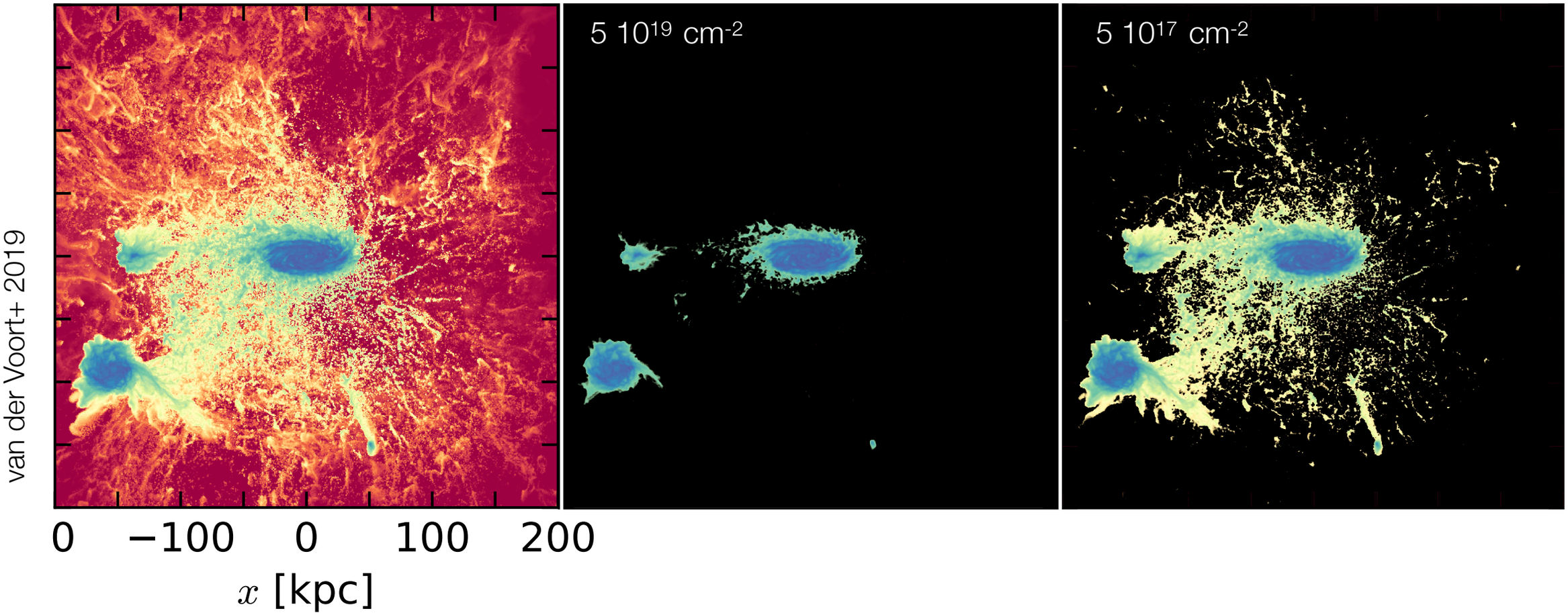
- Simulations predict “cold accretion” of 10^5 K gas out to ~100 kpc
- Can we observe HI accretion happening at lower column densities ($10^{17\text{-}18}$ cm^{-2}) in the local universe?

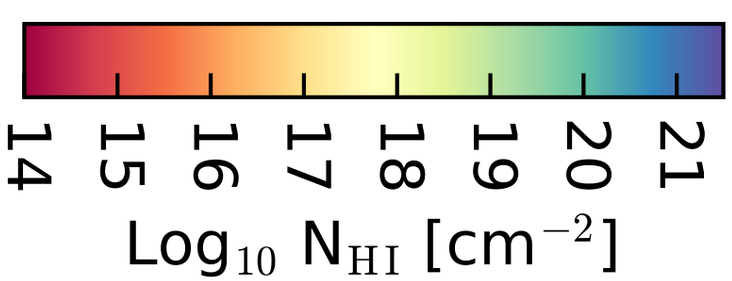


Ramesh et al. 2023

Simulated Accretion

Simulation of HI distribution





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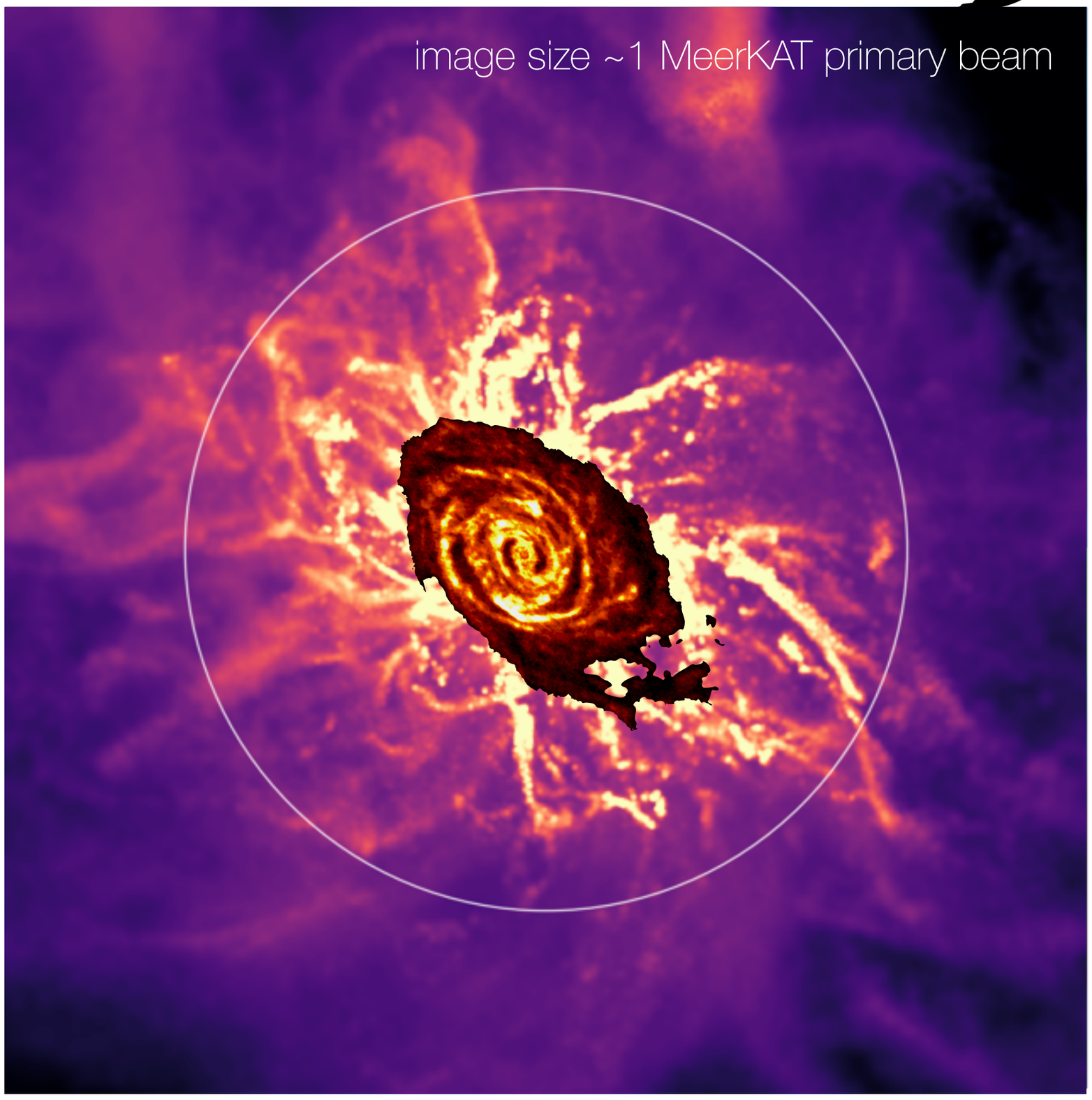


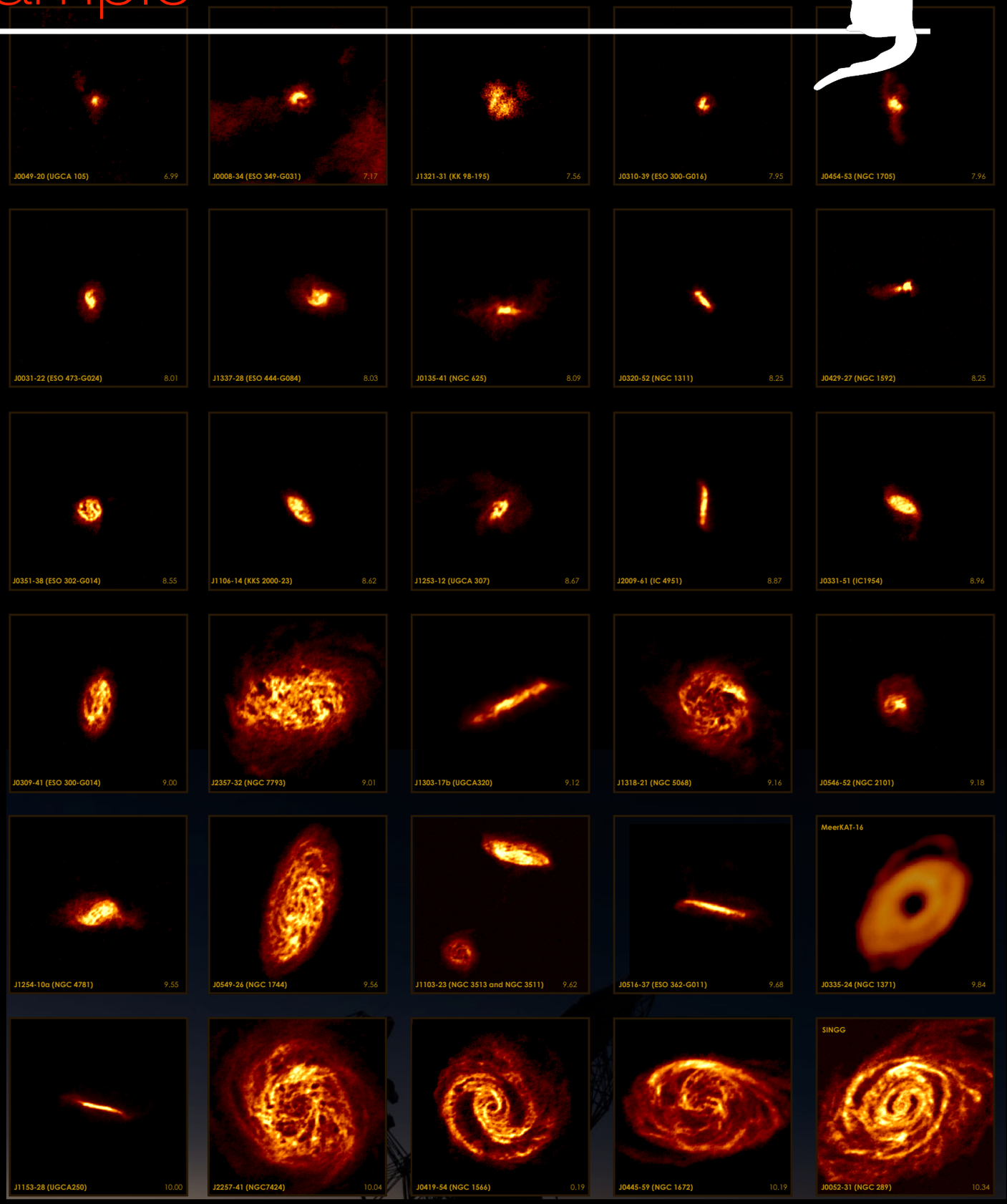
Ramesh et al. 2023

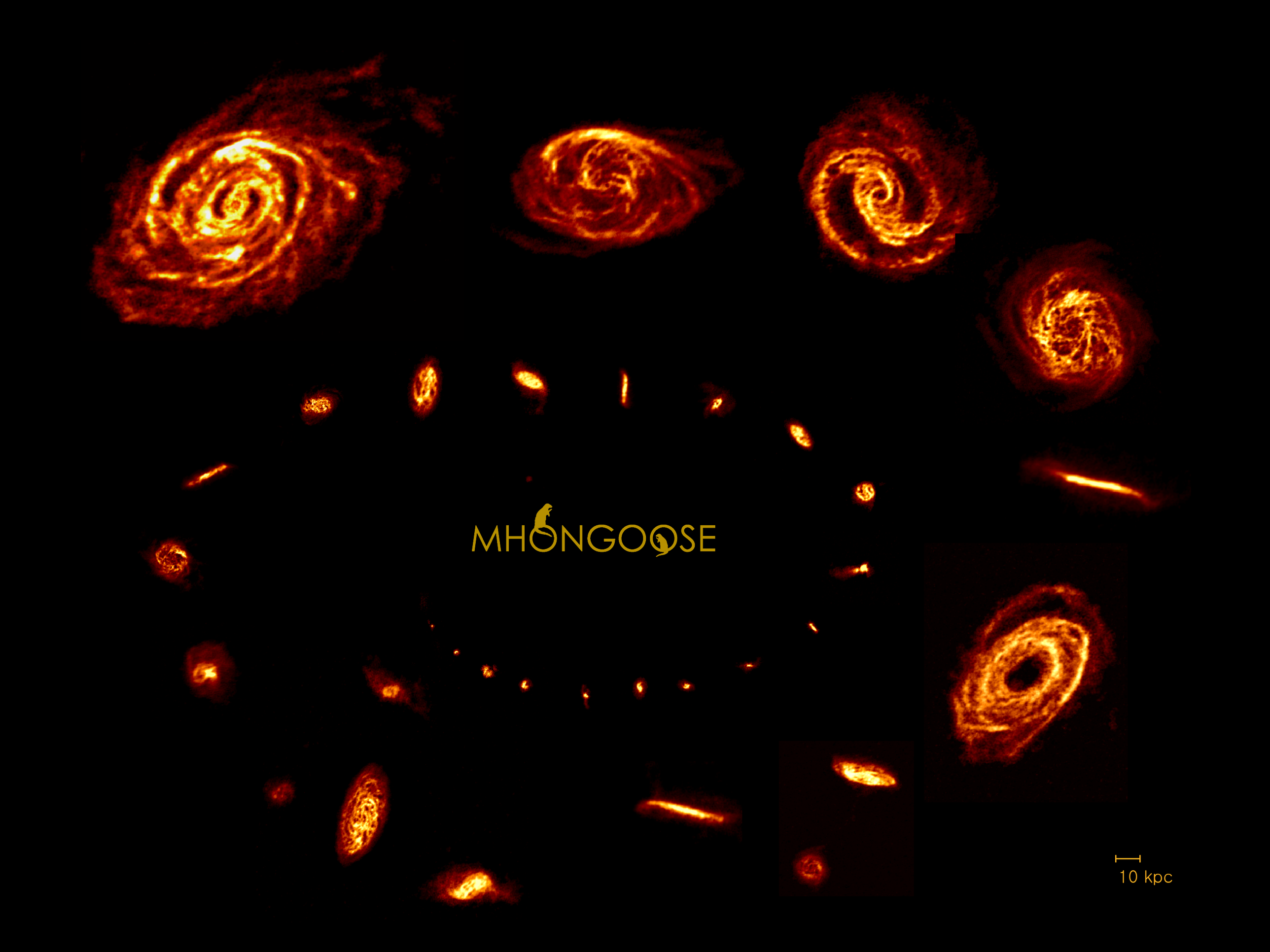
MHONGOOSE: the sample

- 30 nearby field disk and dwarf galaxies from SINGG
- M_{HI} ~ 10^{7} - 10^{11} $M_{\odot}$
- each 55h

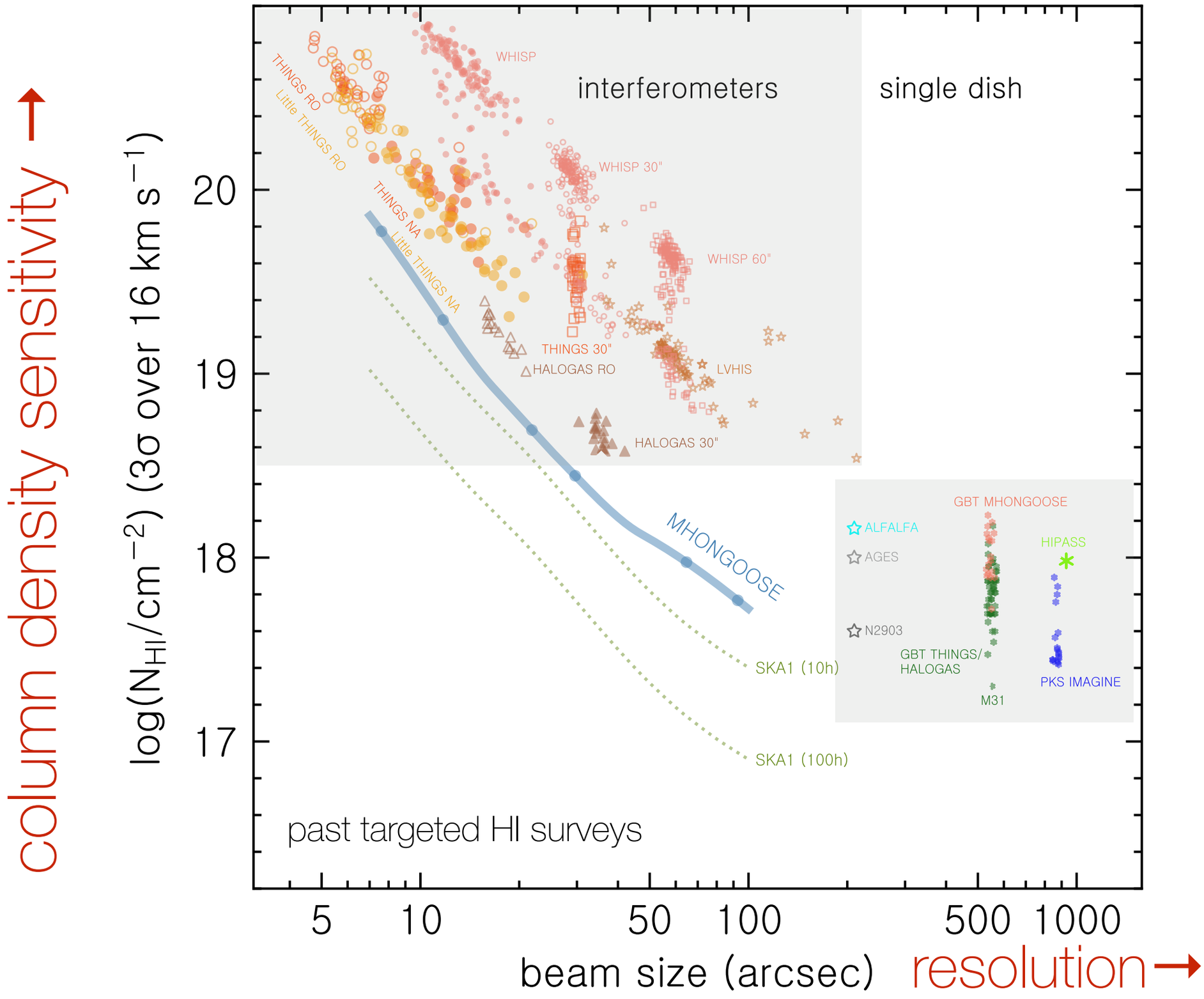
- HI @ 4 x 10^{19} cm^{-2} with 10'' resolution
- HI @ 5 x 10^{18} cm^{-2} with 30'' resolution
- HI @ 1 x 10^{18} cm^{-2} with 60'' resolution
- HI @ 5 x 10^{17} cm^{-2} with 90'' resolution
- (3σ / 16 km s^{-1})

- a factor 10 more sensitive than previous interferometer surveys
- An interferometric survey with single dish sensitivities



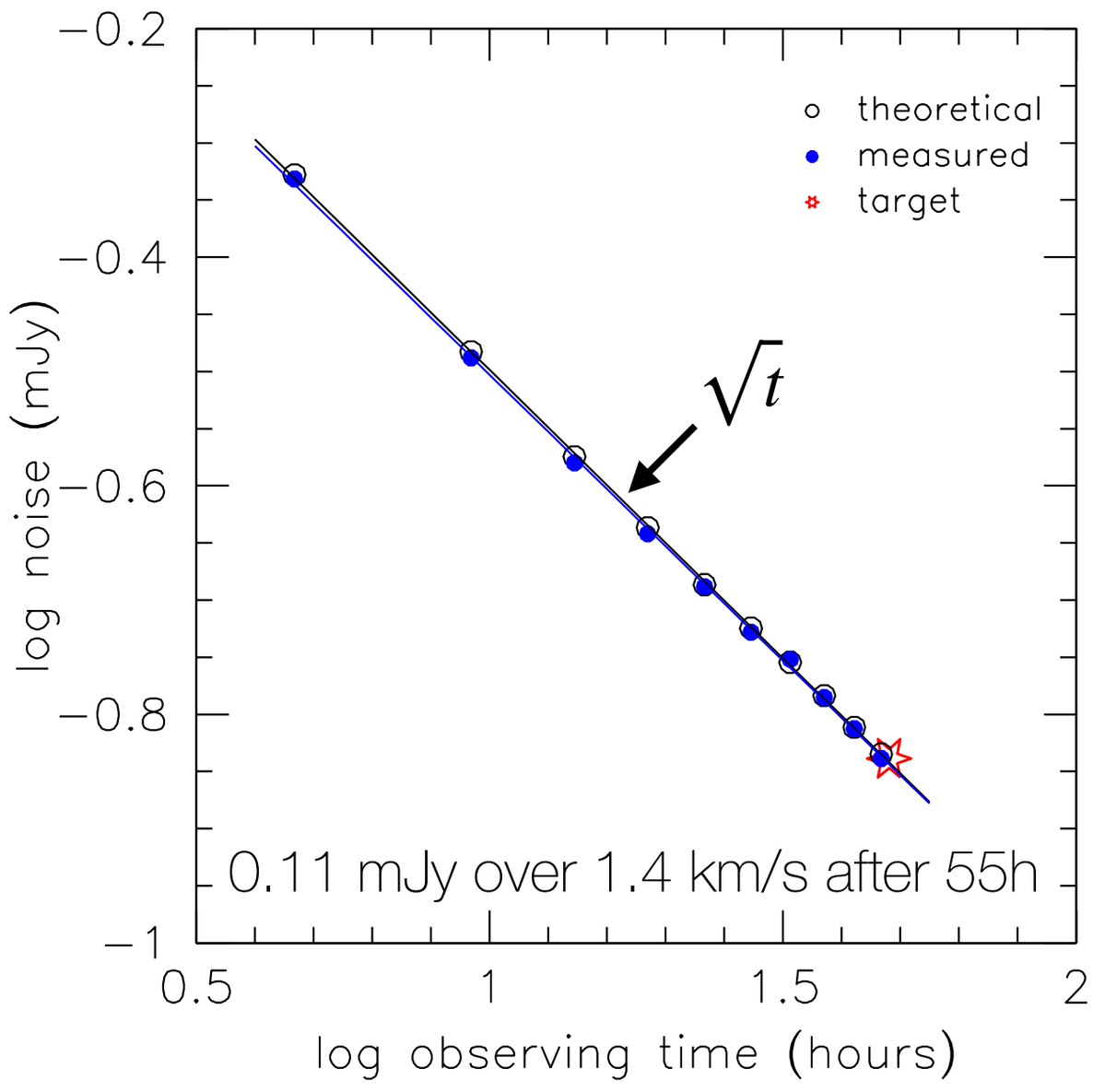

MHONGOOSE
10 kpc

MHONGOOSE depth



Work in progress

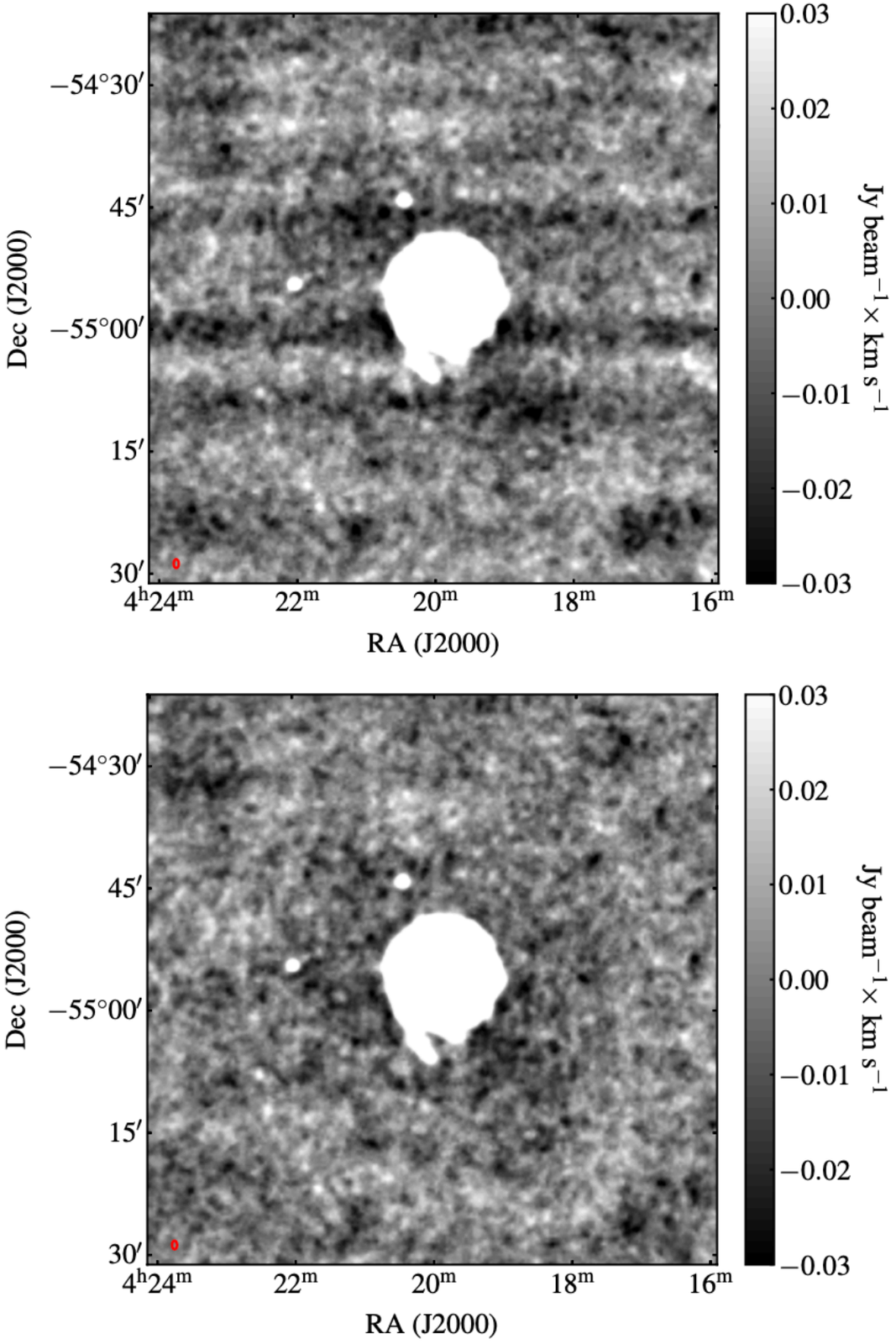
- Observations started Oct 2020
- Now 73% complete
- 14 galaxies to full depth
- Processing ongoing
- Noise well-behaved

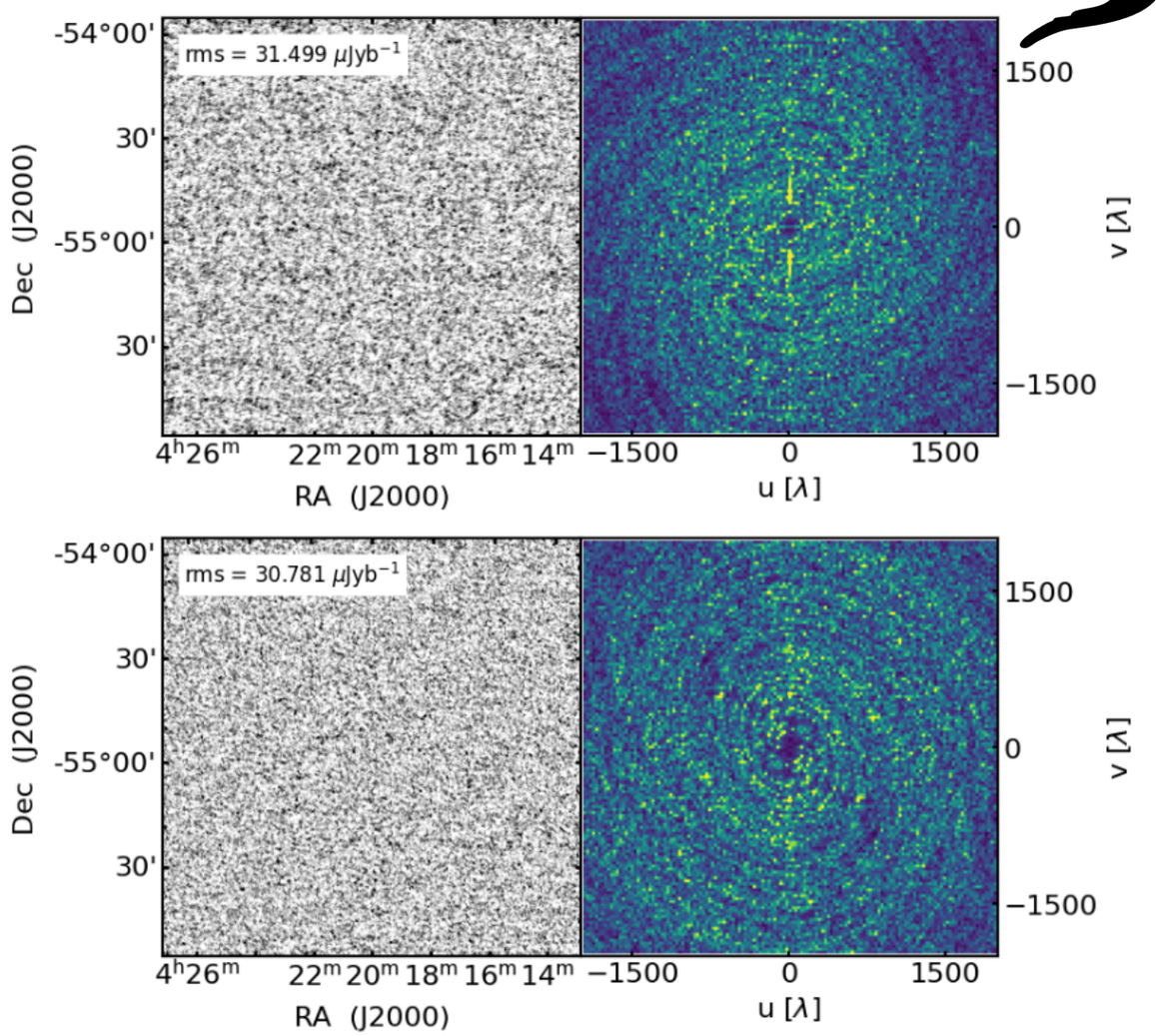


Work in progress

- Calibration and reduction in CARACal (https://github.com/caracal-pipeline/caracal)
- Pipeline produces quality control plots and reports
- Automatically uploaded to MHONGOOSE GitHub repository
- Enables rapid turn-around - check data ASAP!

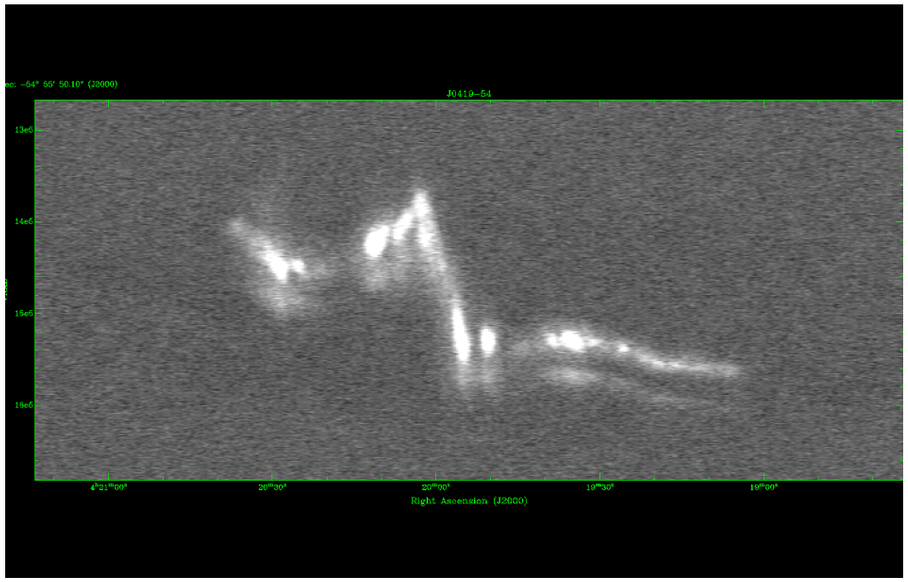
u=0

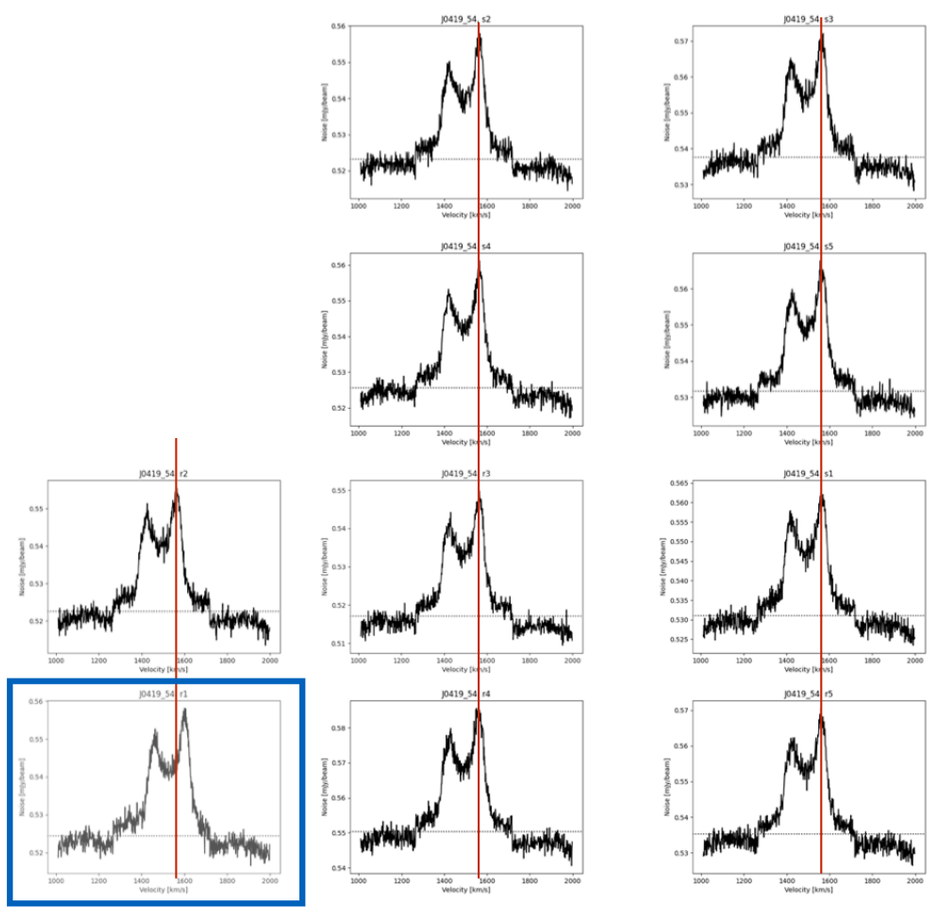


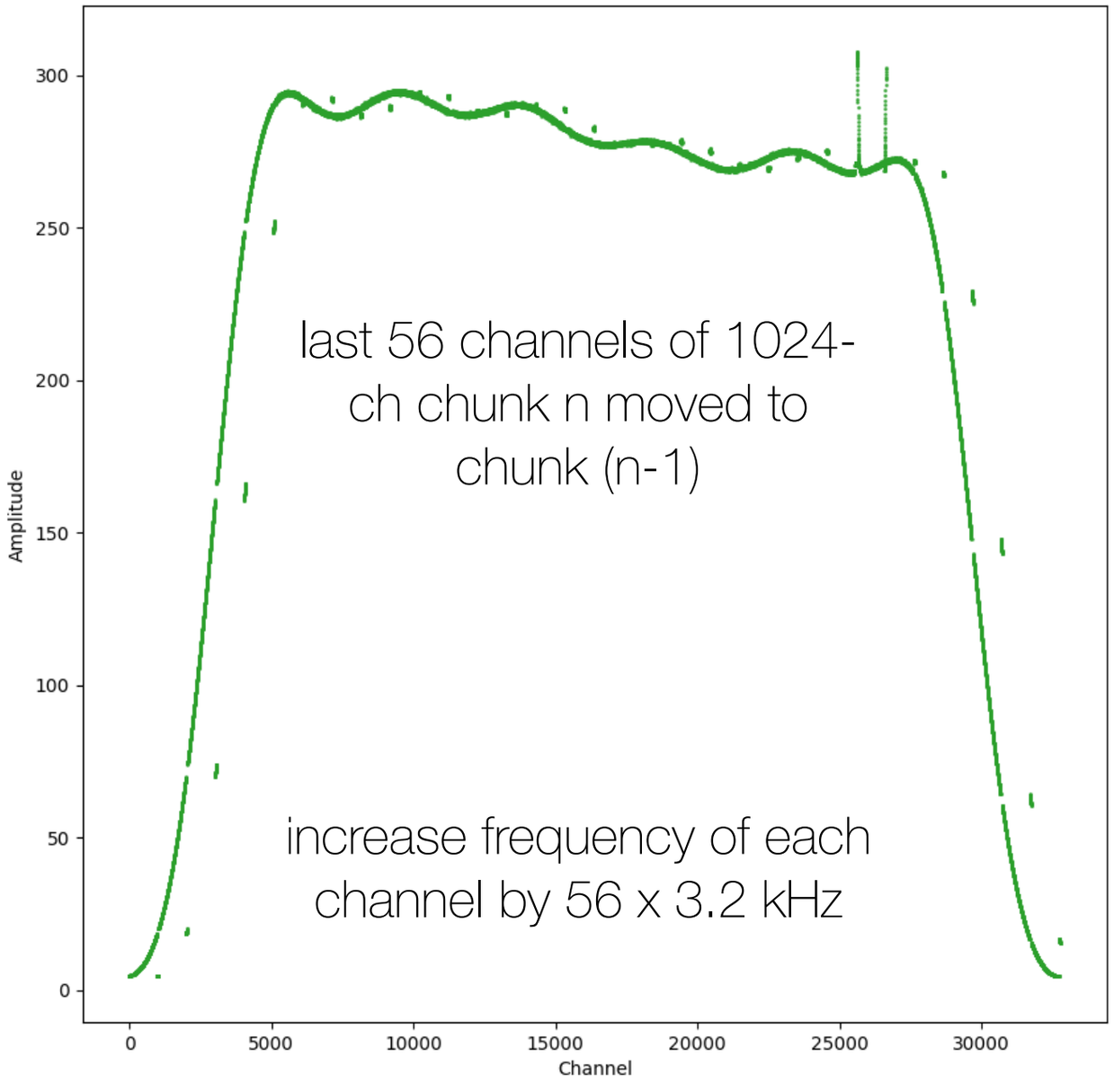


- u=0 RFI causes stripes
- implemented method to automatically remove these (Maccagni+ 2021)
- now in CARACal

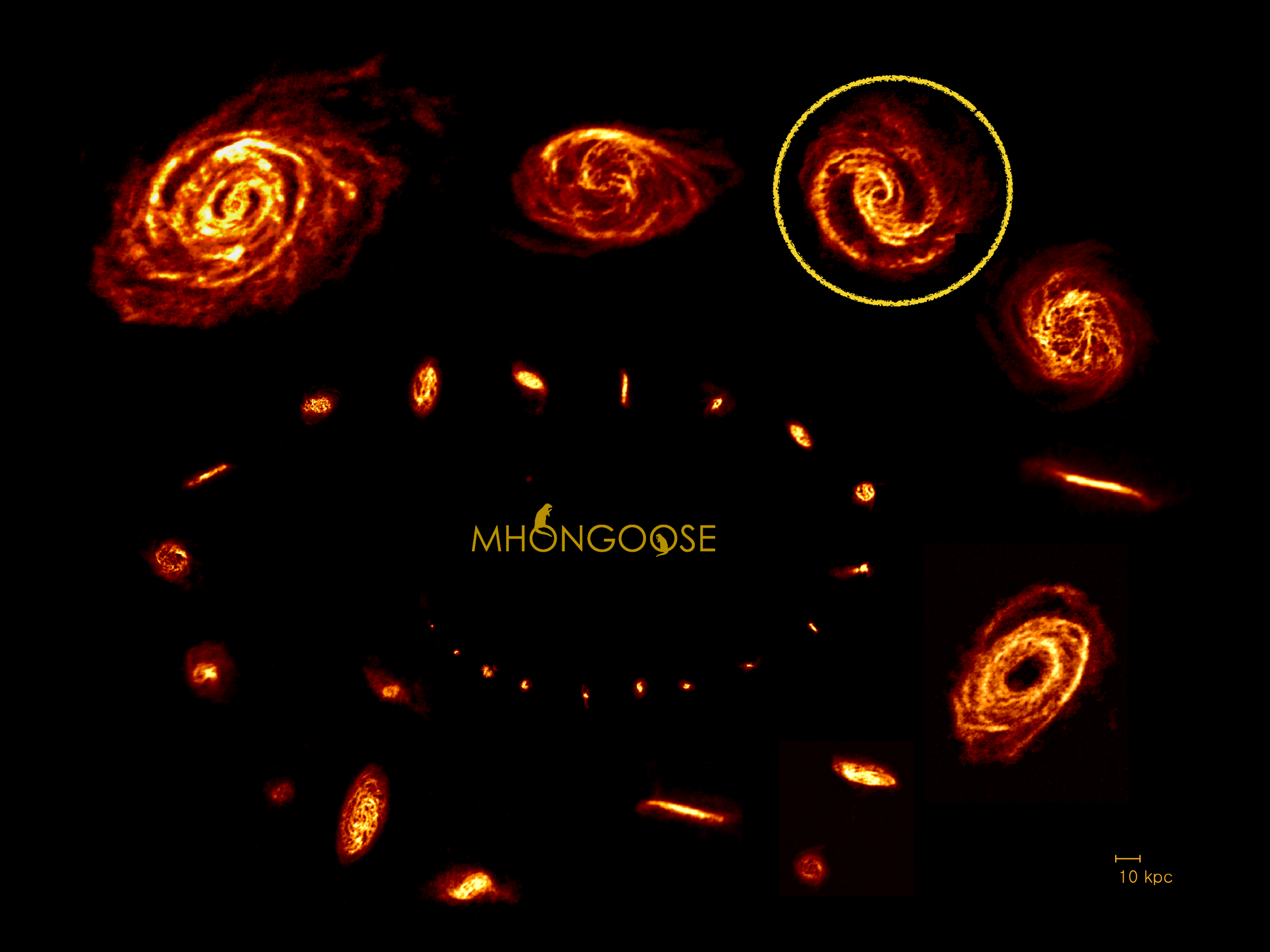
the “56 channel bug”



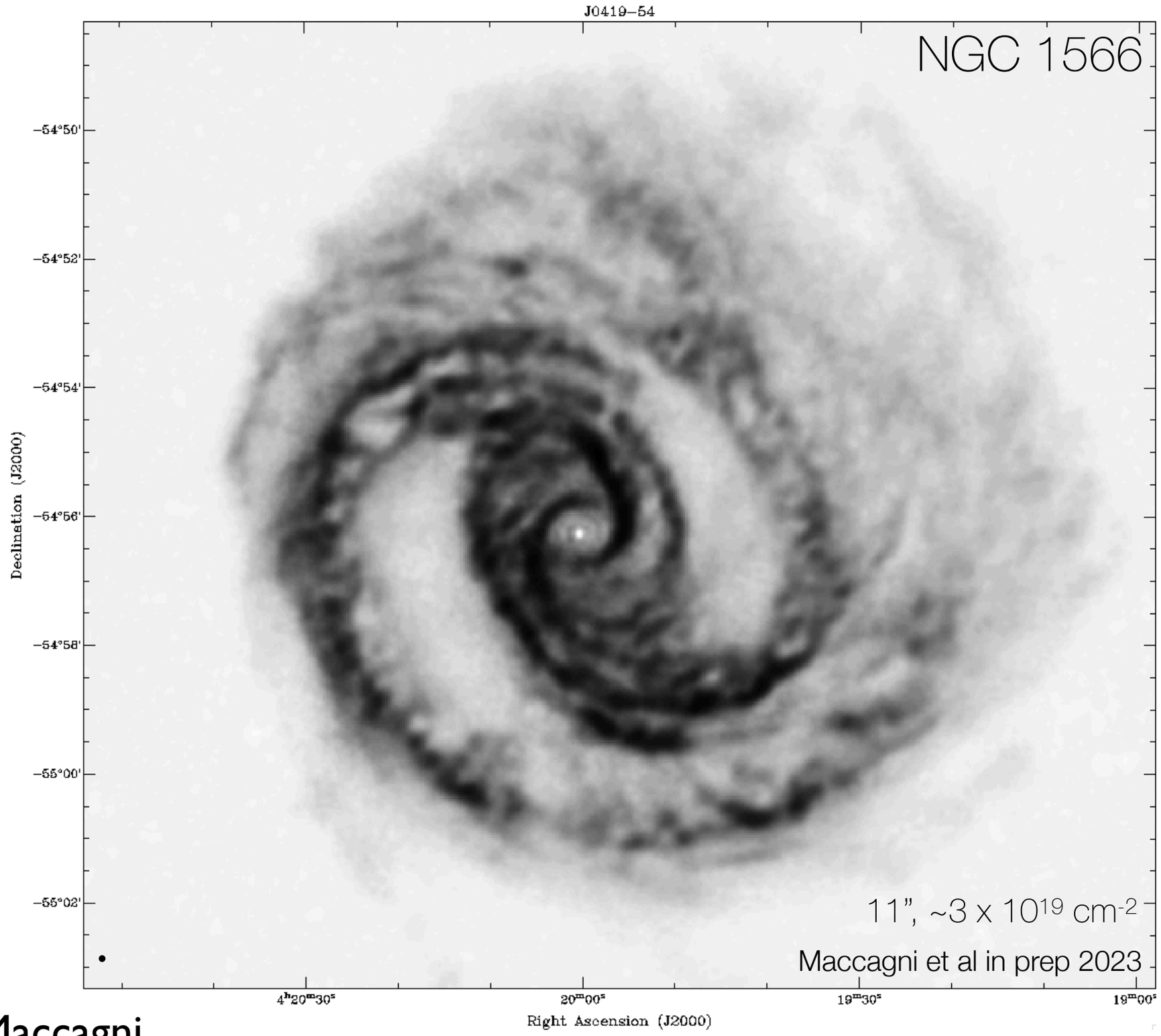




manual fix with casatools (Kleiner+, MFS)

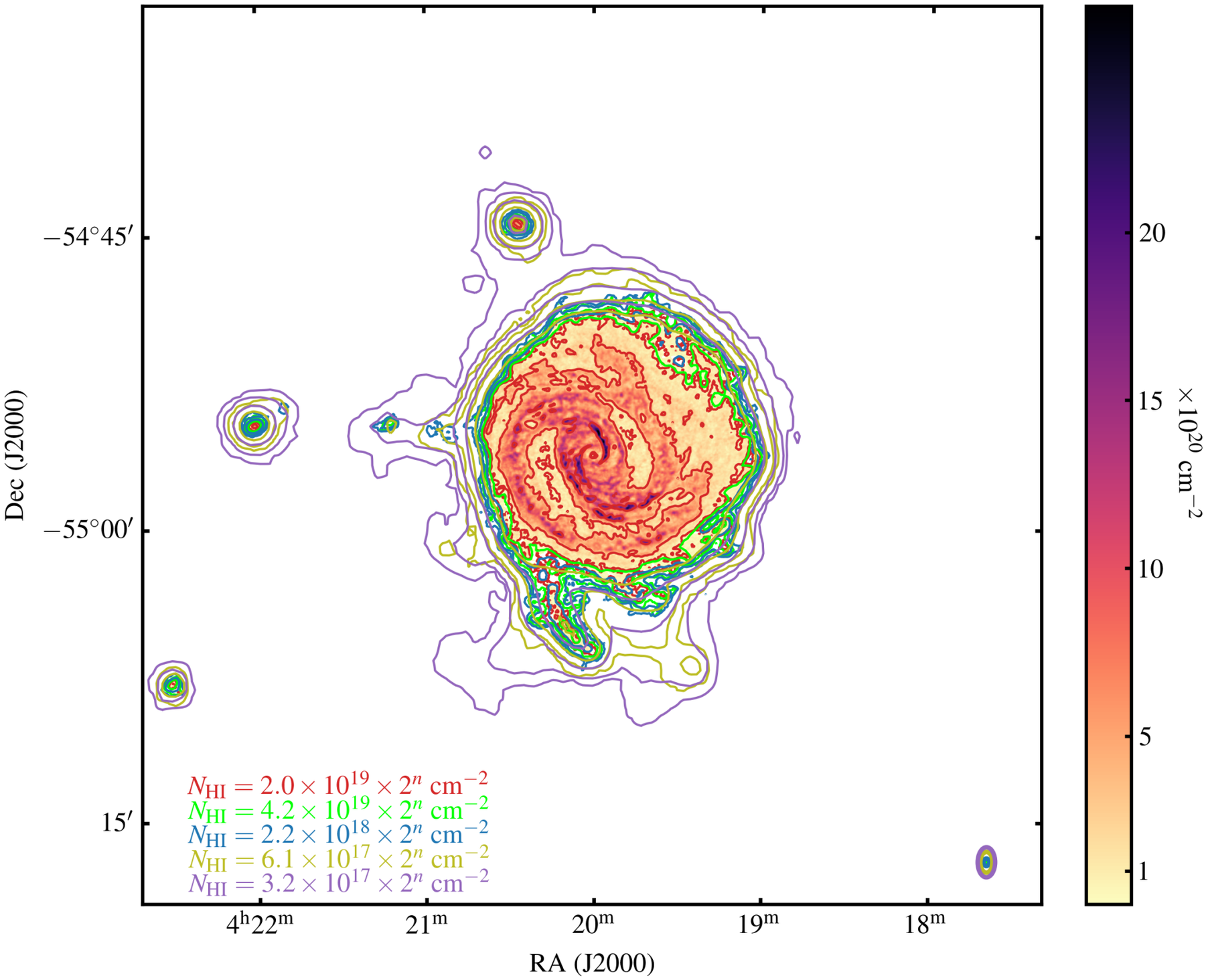

MHONGOOSE
10 kpc

First full-depth



Poster Filippo Maccagni

First results: NGC 1566



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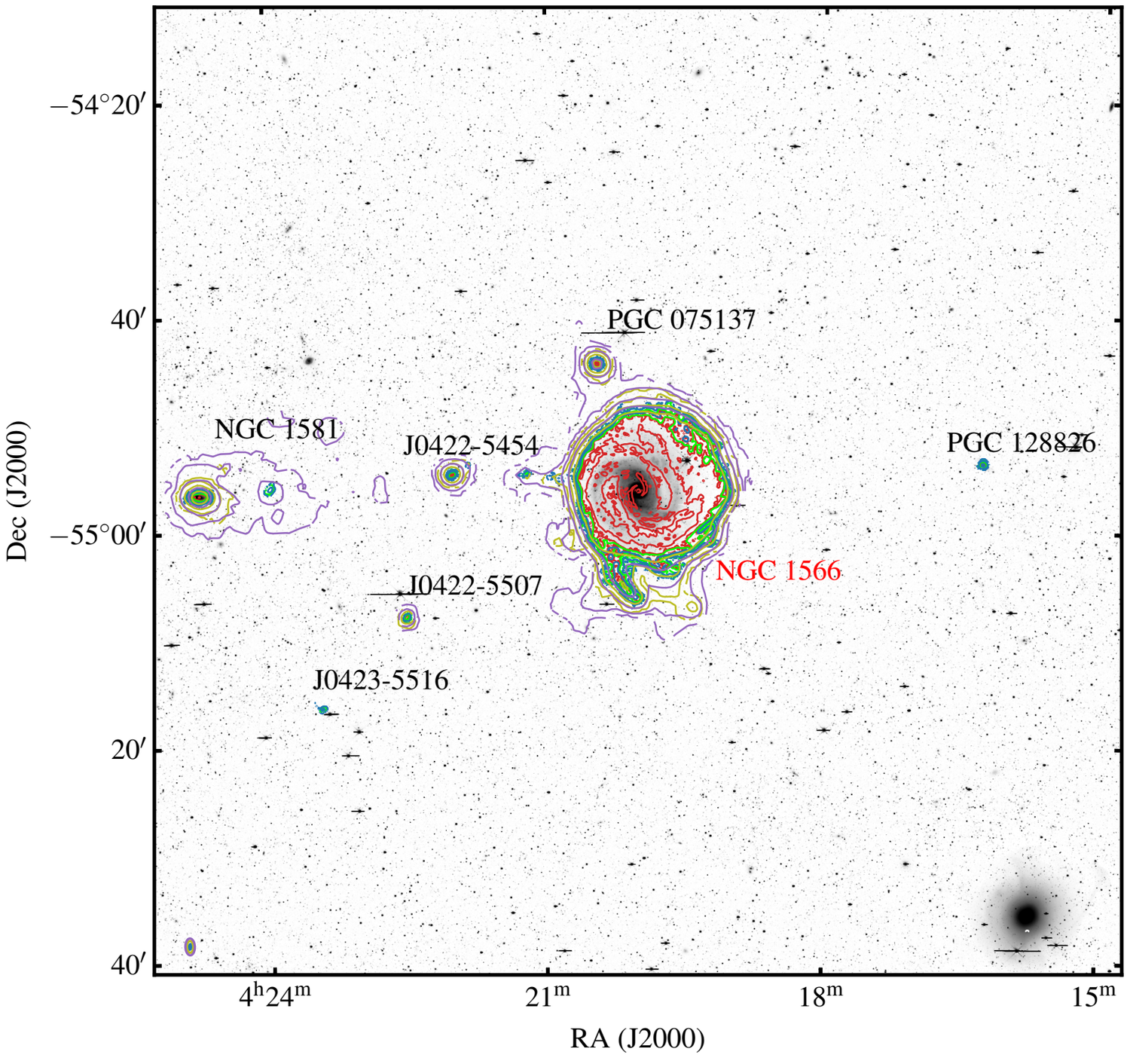

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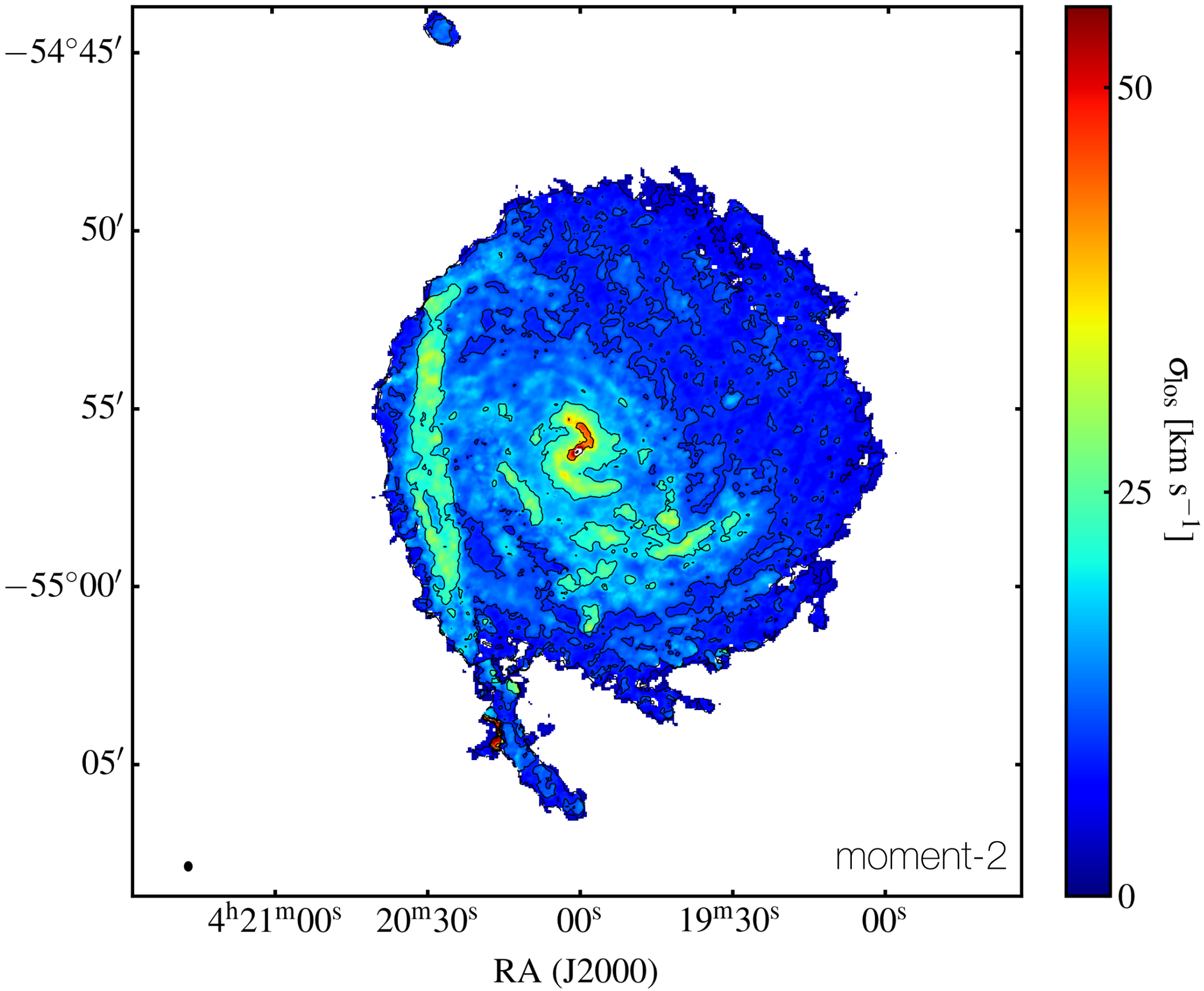
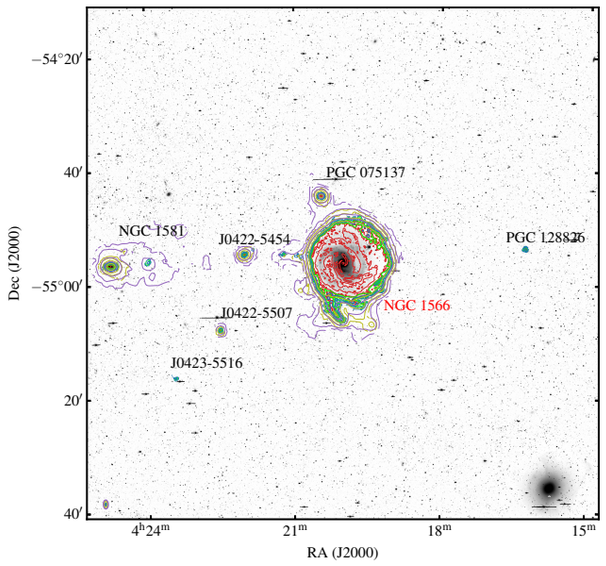
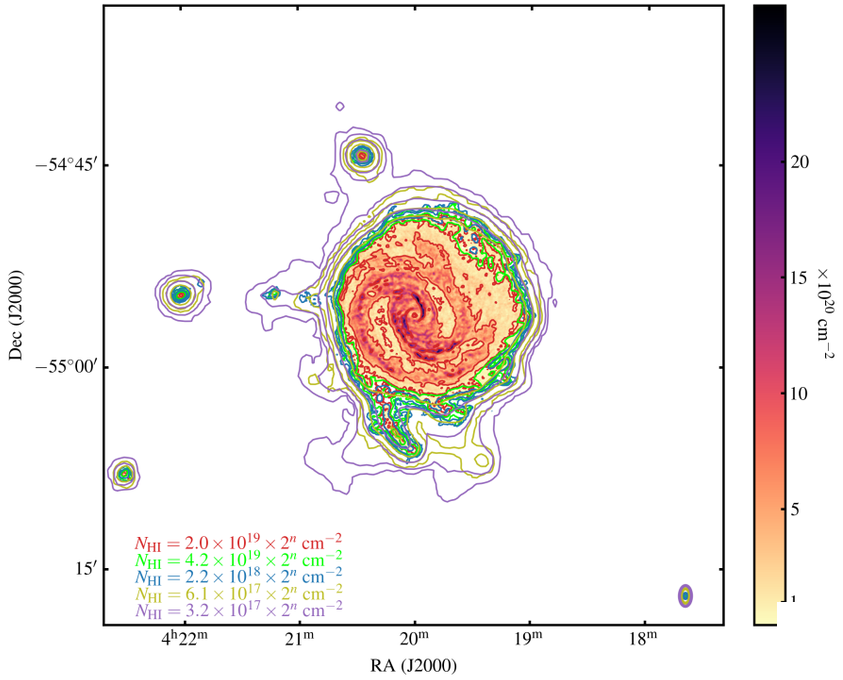
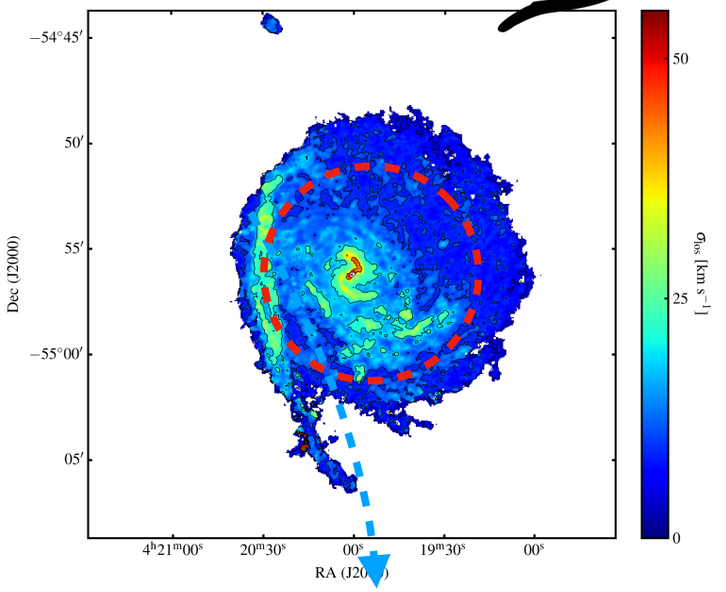


NGC 1566: HI distribution and kinematics





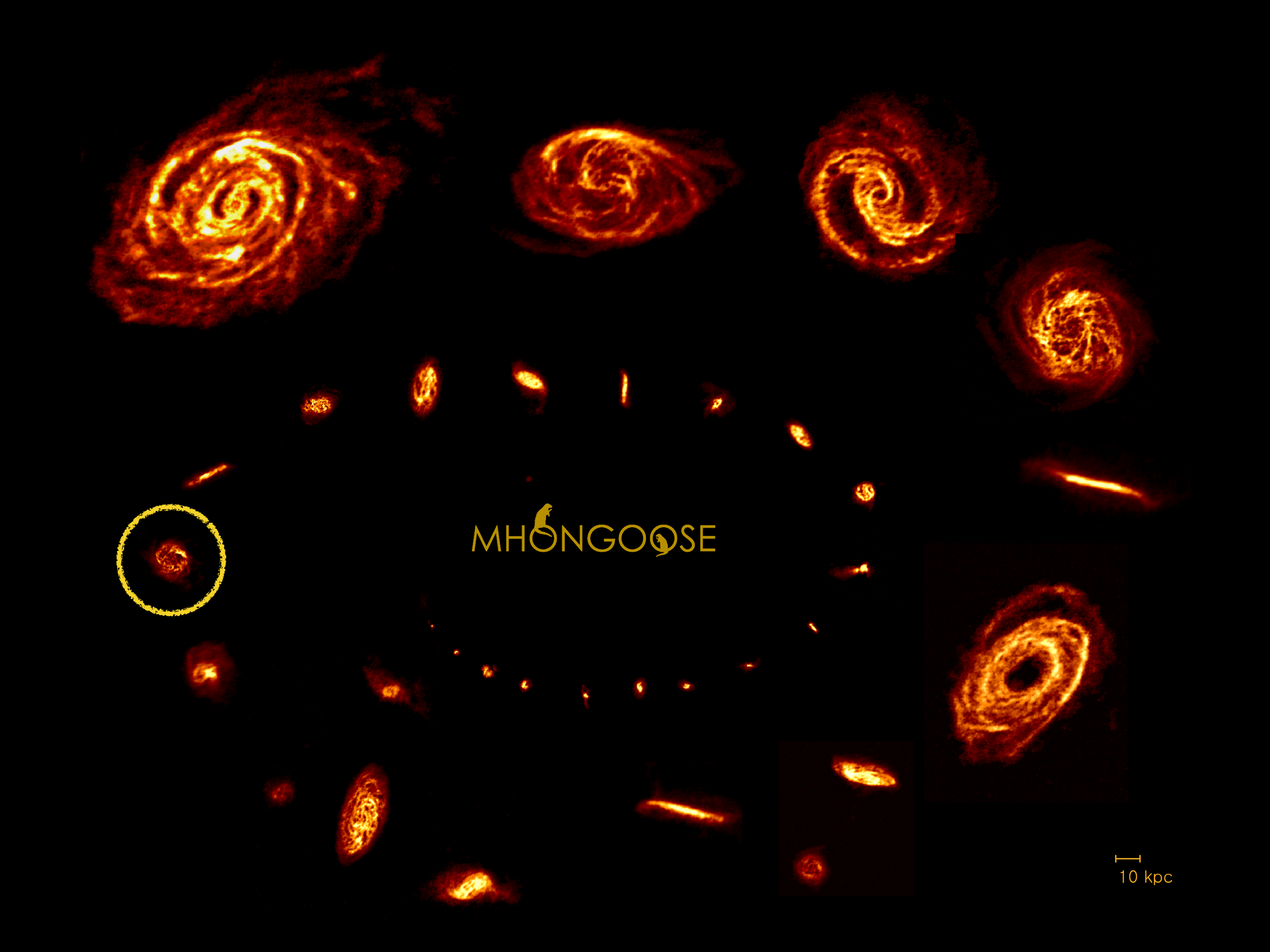


For the first time:

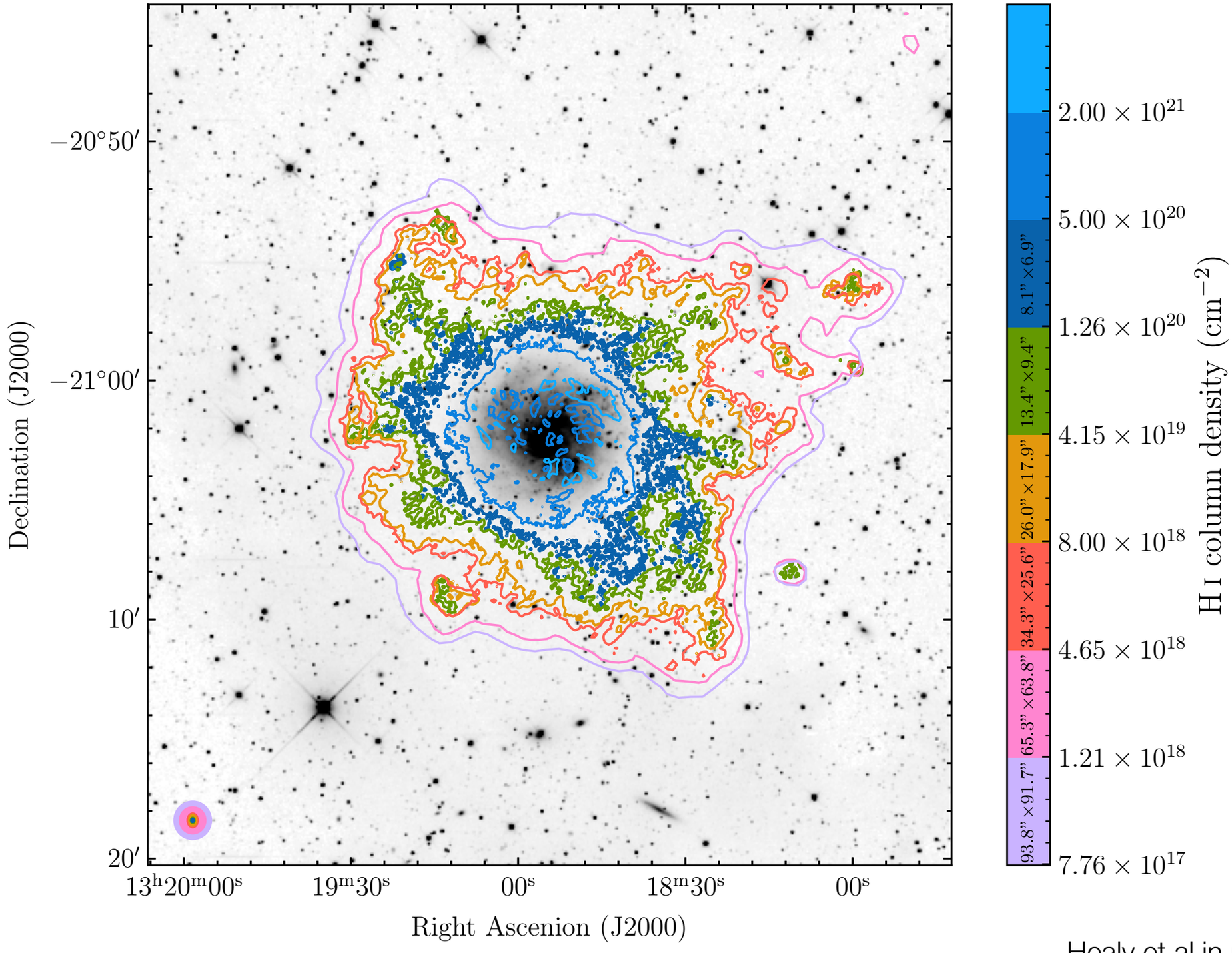
- 5 new HI detections associated with low-mass ($M_{HI} = 10^{6\text{-}7}$ $M_\odot$) galaxies
- N1566 low column density broad line-width clouds

- Eastern arm: diffuse lagging HI stream leading to broad line-width
- Diffuse gas remnant of a recent tidal interaction with PGC075137 in the north
- The lost gas may be swept up along the spiral arms and accreted into the disk

Poster Filippo Maccagni

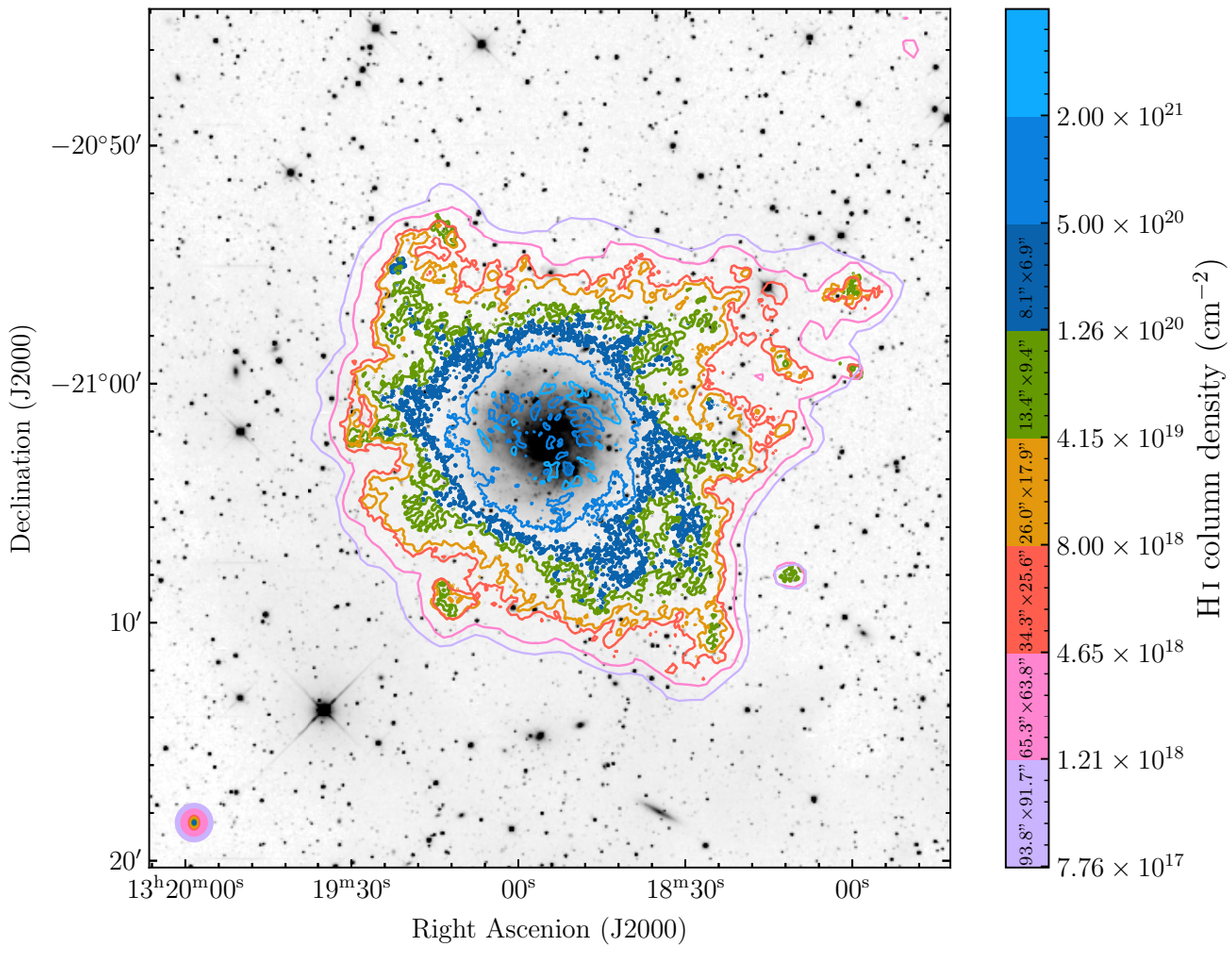

MHONGOOSE
10 kpc

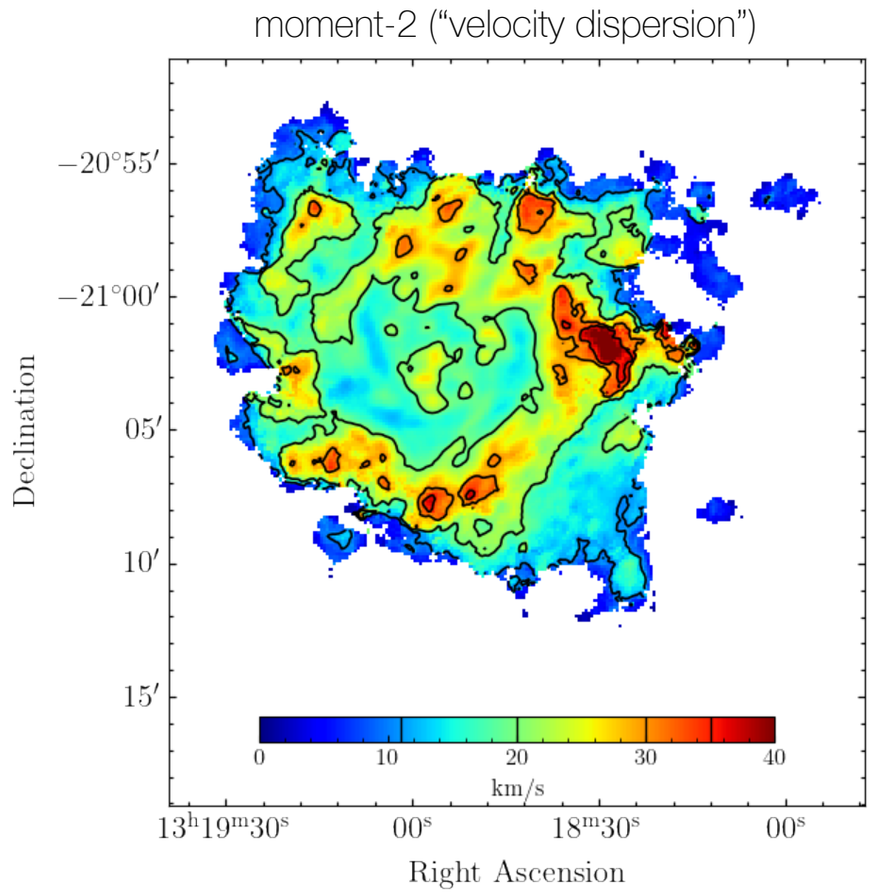
NGC 5068



Healy et al in prep 2023

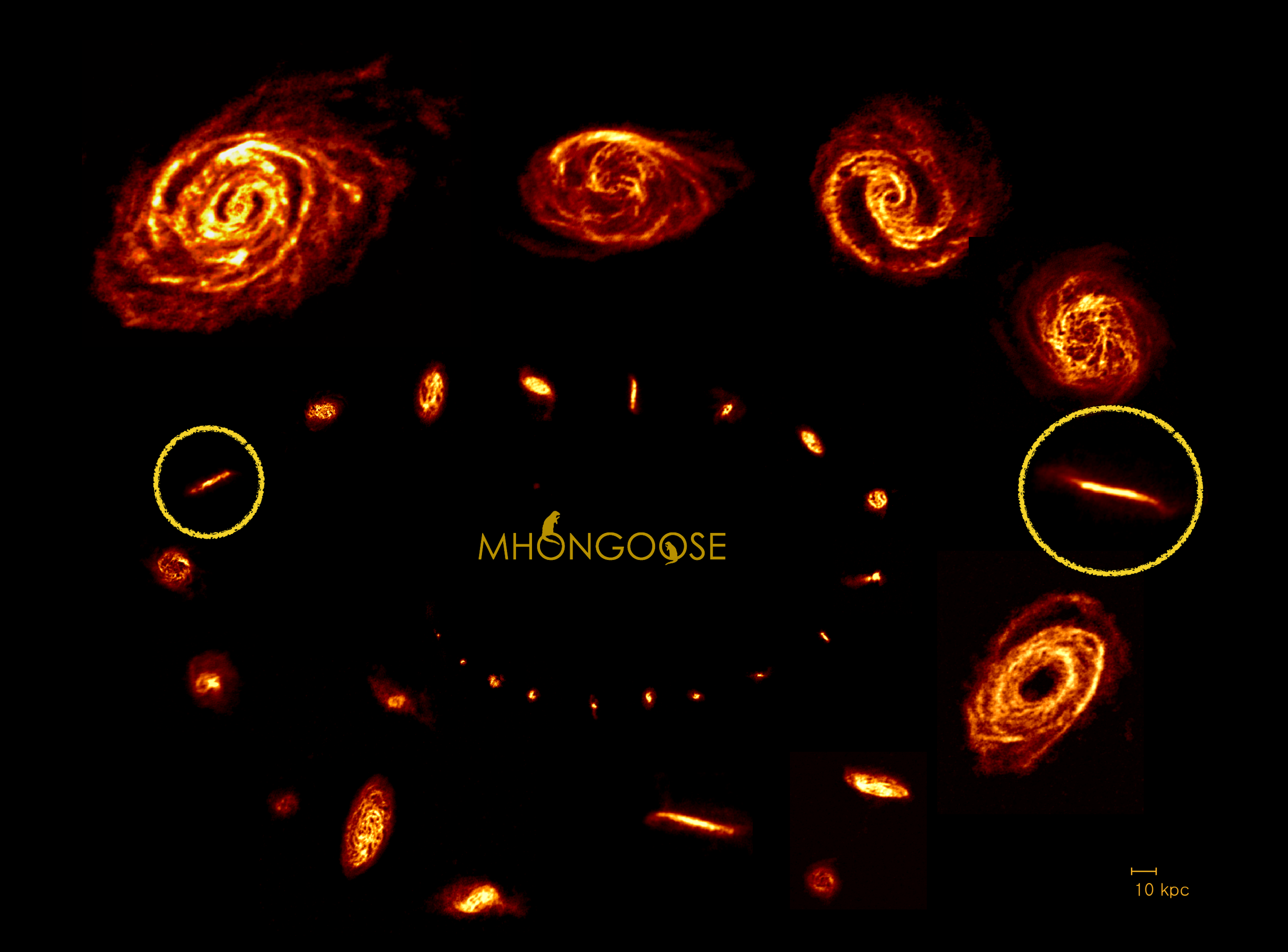
First results: NGC 5068





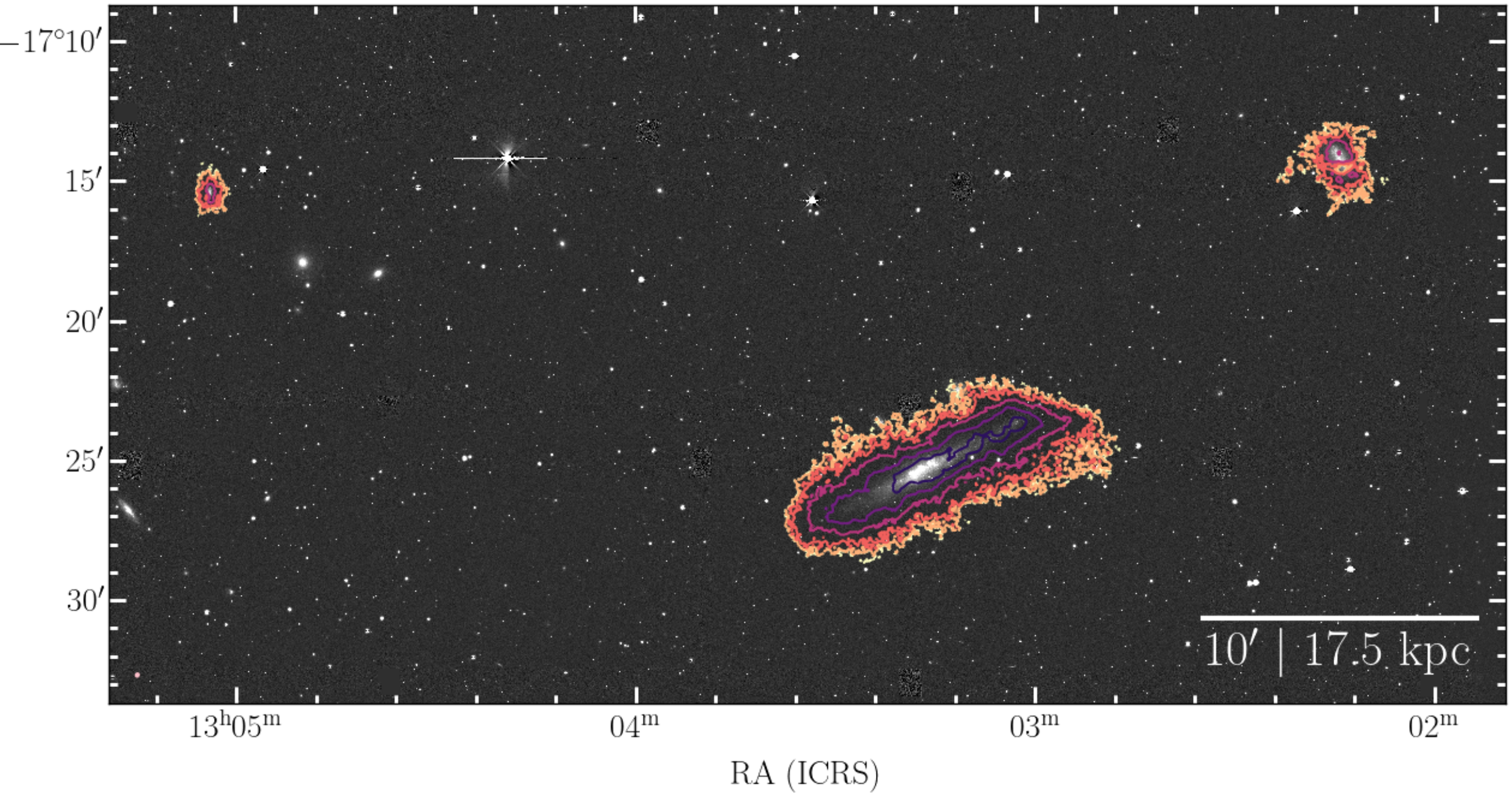
- High velocity dispersion "ring" in outer parts
- No evidence for dwarfs infall
- Accreting gas clouds?

Talk Julia Healy


MHONGOOSE
10 kpc

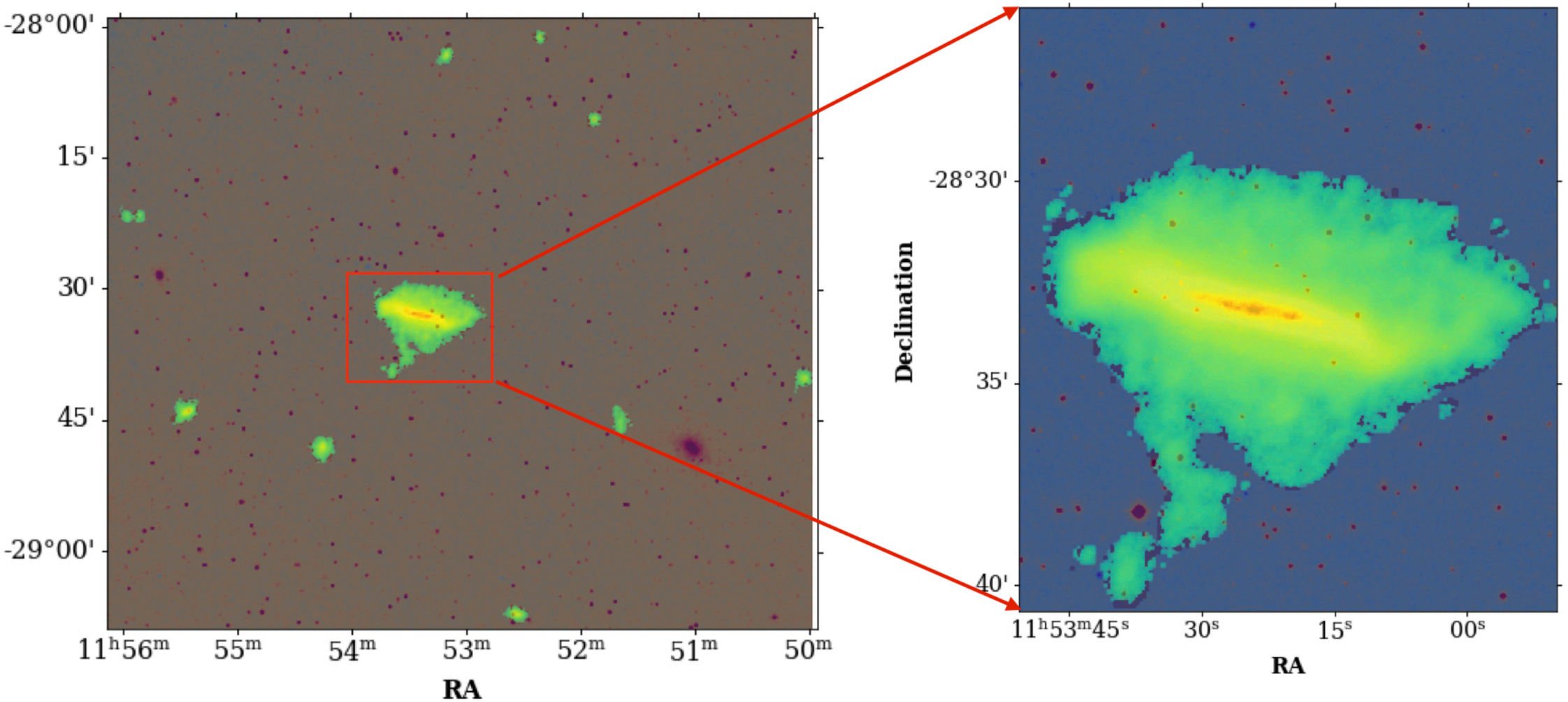
The extra-planar gas in UGCA320 (J1303-17b)

Talk by Nikki Zabel



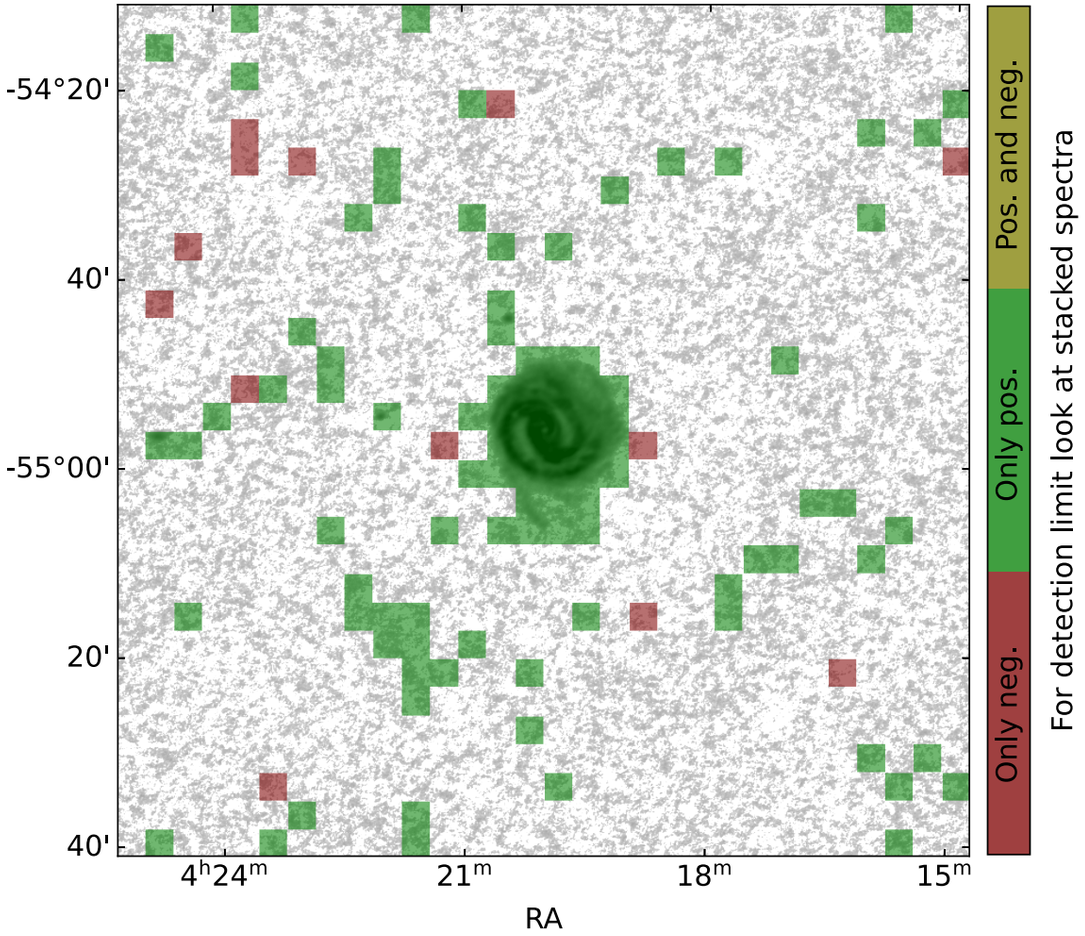
The extra-planar gas in UGC250 (J1153-28)

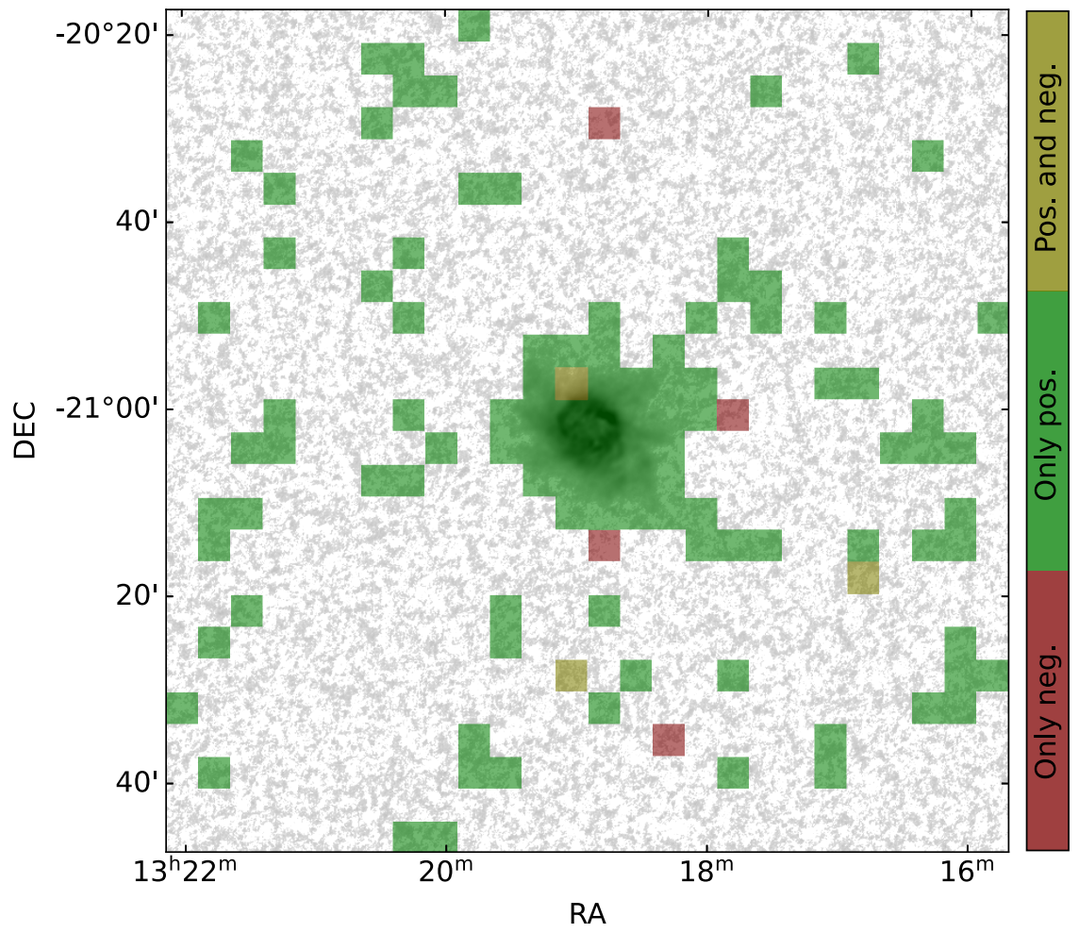
Talk by Sushma Kurapati
(Friday break-out session)



Stacking the MHONGOOSE data

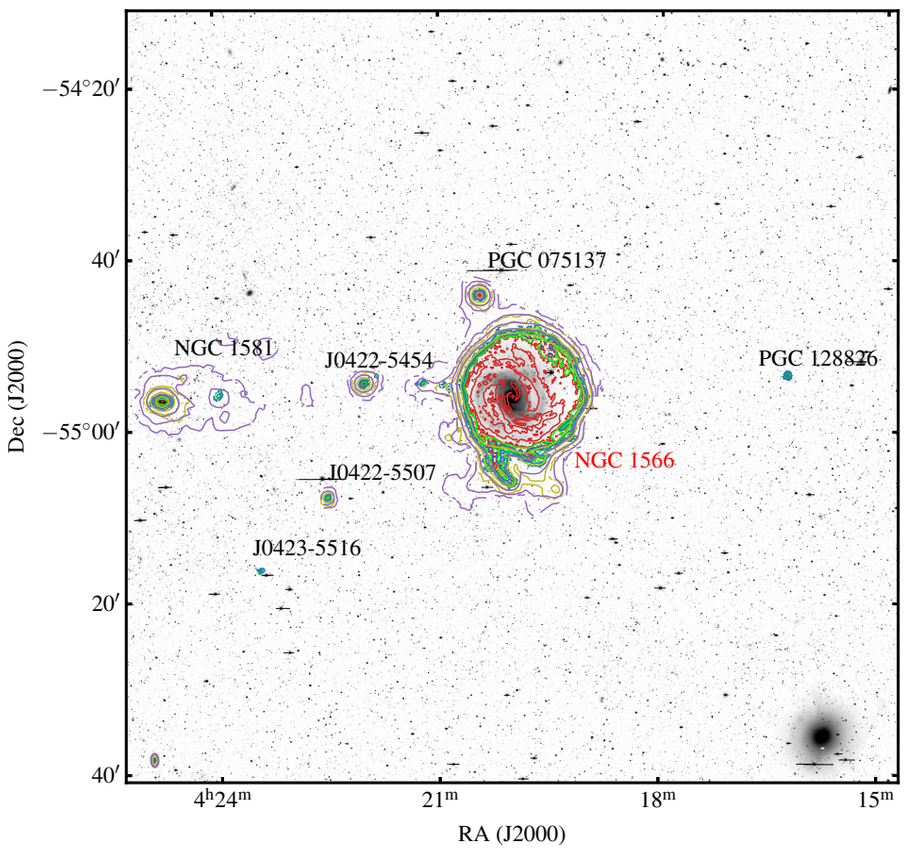
Talk by Simone Veronese
(Friday break-out session)

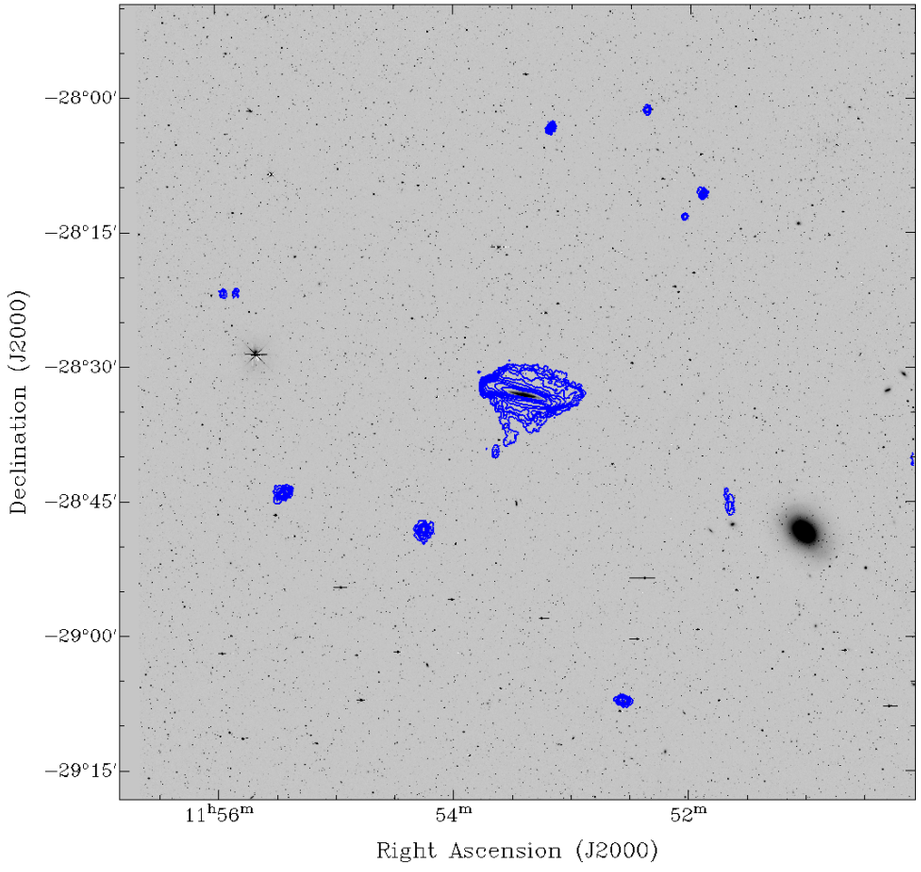




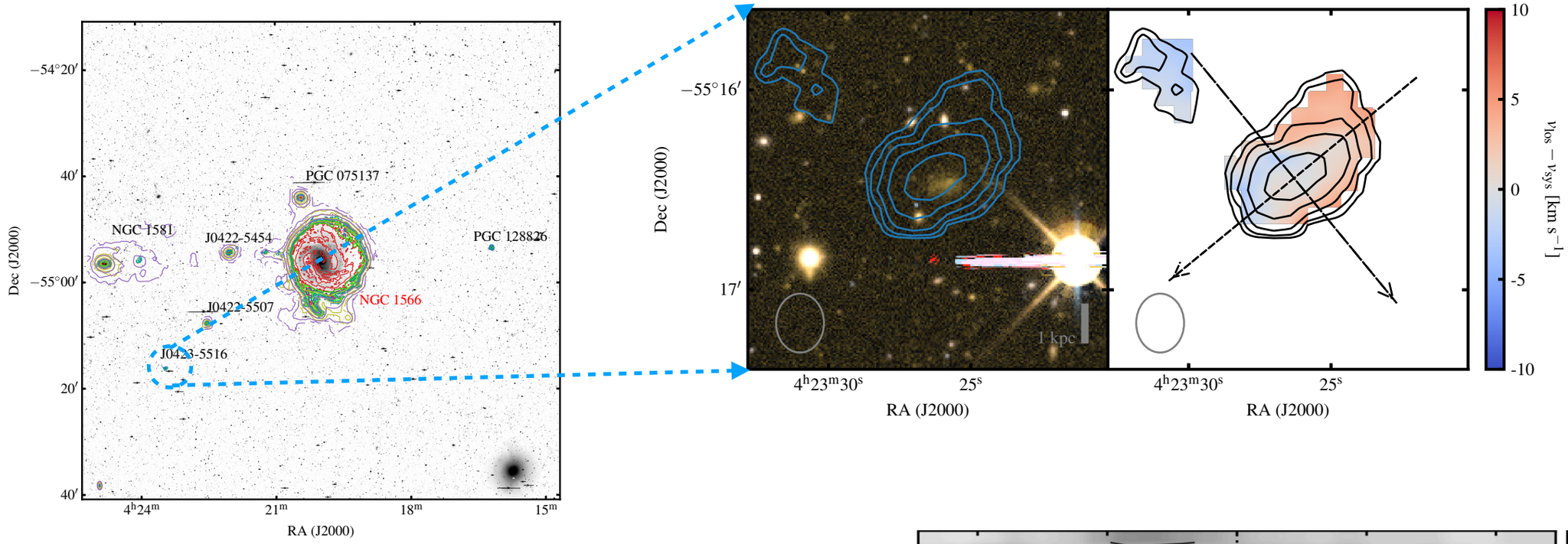
Dwarf galaxies

- MHONGOOSE surveys 30 deg^2 in different galaxy environments from isolated to groups
- Sensitivity to very low HI masses: $M_{HI} = 4 \times 10^5\ M_\odot$ (for 3σ/30 km/s @ 17.8 Mpc)
- Combination with deep photometry (VST, $\mu_g > 26$ mag/arcsec^2)
- Discovery and study of dwarf galaxies beyond the Local Group
- Do Local Group science outside the Local Group

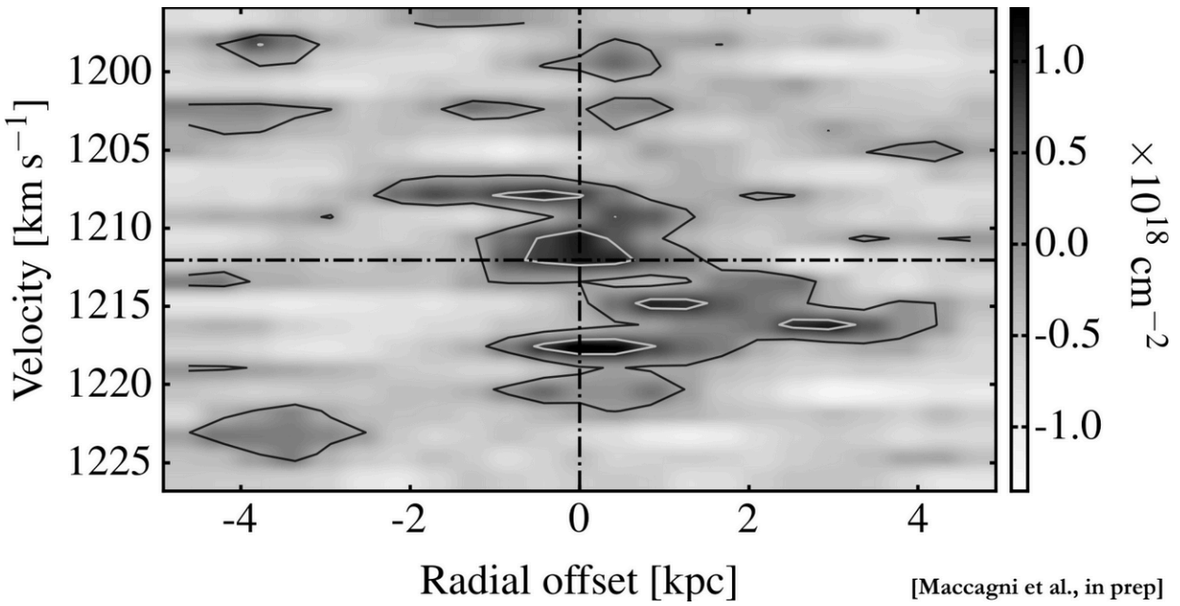




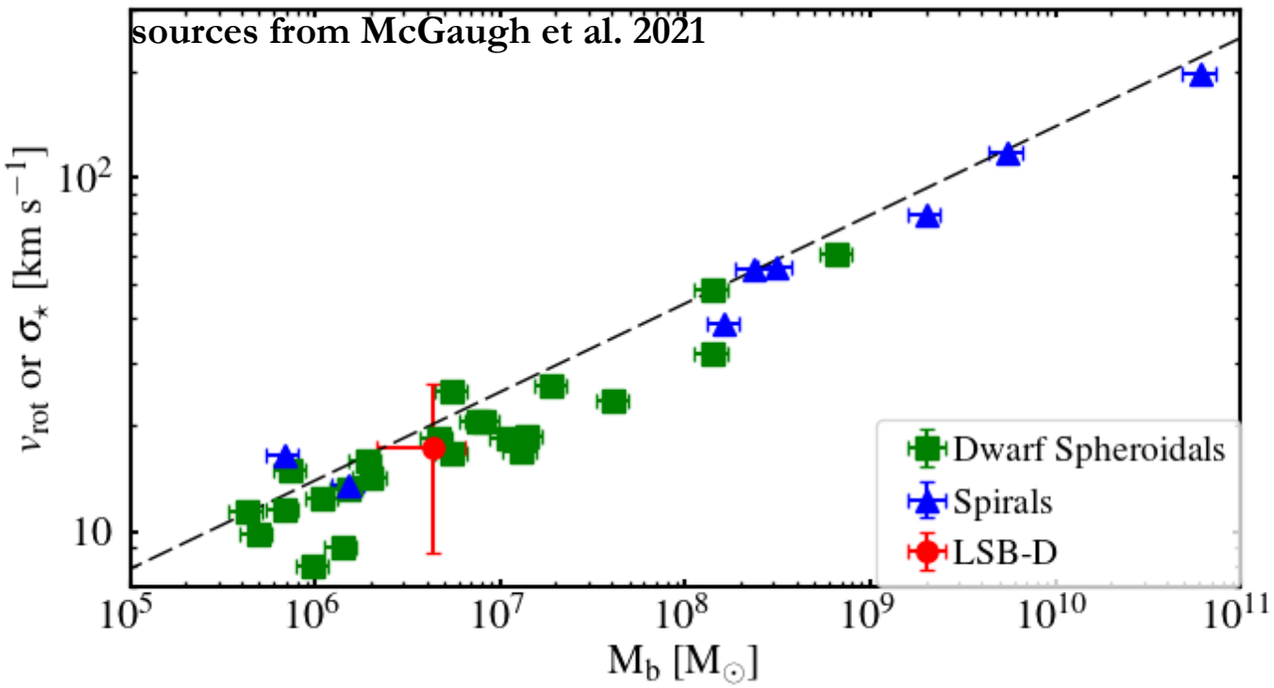
LSB-D - a low-mass galaxy in Dorado

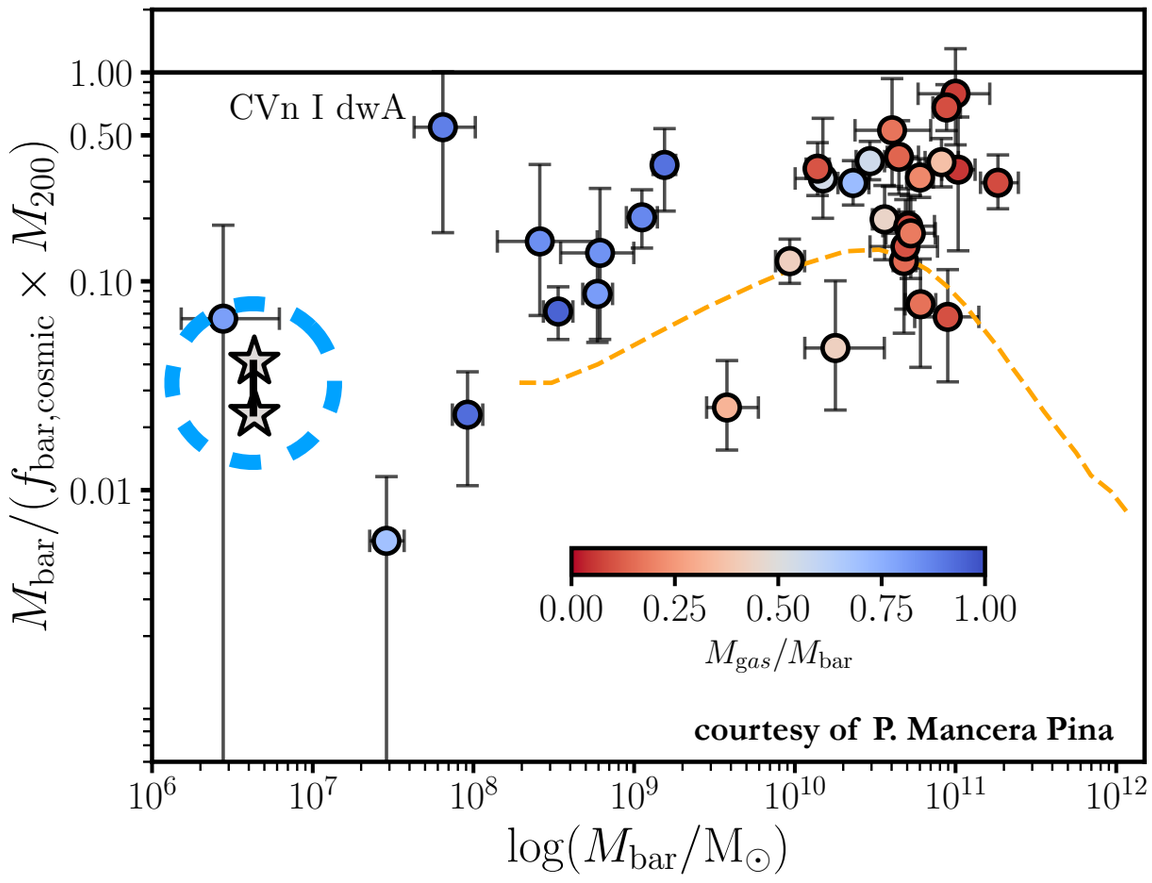


- HI observations + deep photometry, VEGAS, $\mu_g > 26$ mag/arcsec^2)
- Low-surface brightness galaxy in Dorado
- $M_{HI} = 1.67 \times 10^6\ M_\odot$; $M_\star = 2.3 \times 10^6\ M_\odot$
- $M_{bar} = 4 \times 10^6\ M_\odot$
- HI is rotating, but also non-circular component



LSB-D - a low-mass galaxy beyond the LG



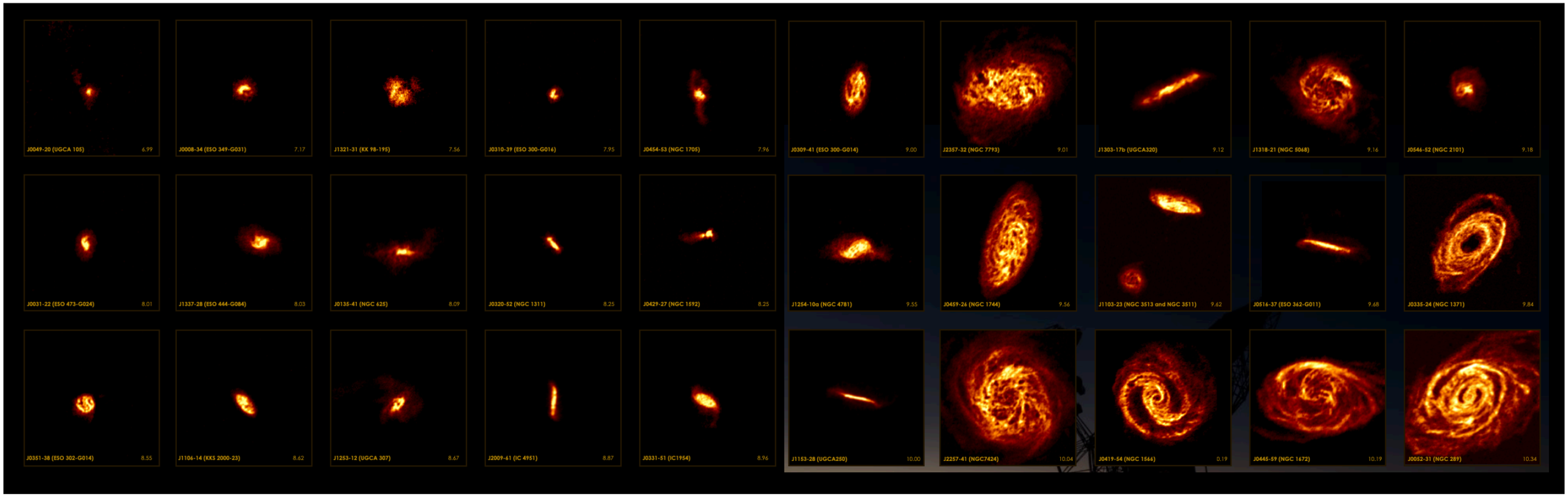


- LSB-D is on the baryonic Tully-Fisher relation highlighting its universality down to very small sources also beyond the Local Group
- LSB-D is dark-matter dominated: M_{bar} ~1.3 % M_{dyn}
- Constrain uncertainties on the low-mass end of the baryon-mass halo relation

Cosmological view on the evolution of dwarf galaxies beyond the Local Group

Single-track data release

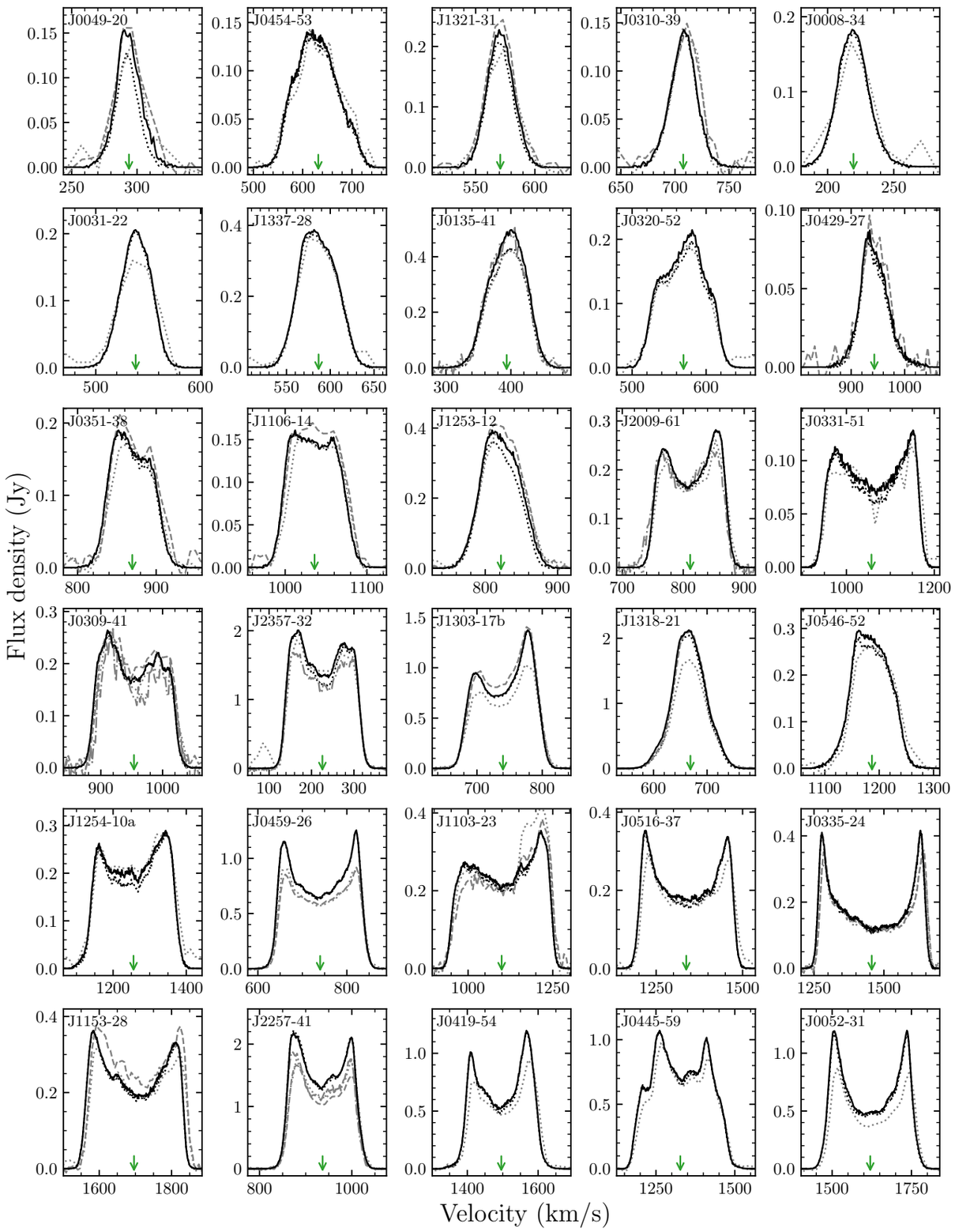
- Previous was based on internal data deep release of 10 galaxies
- In the next few months public data release of moment maps of single tracks of entire sample
- Zeroth, first and second moment maps
- Two resolutions: robust = 0.5 (~10”) and robust=1.5 (~30”)

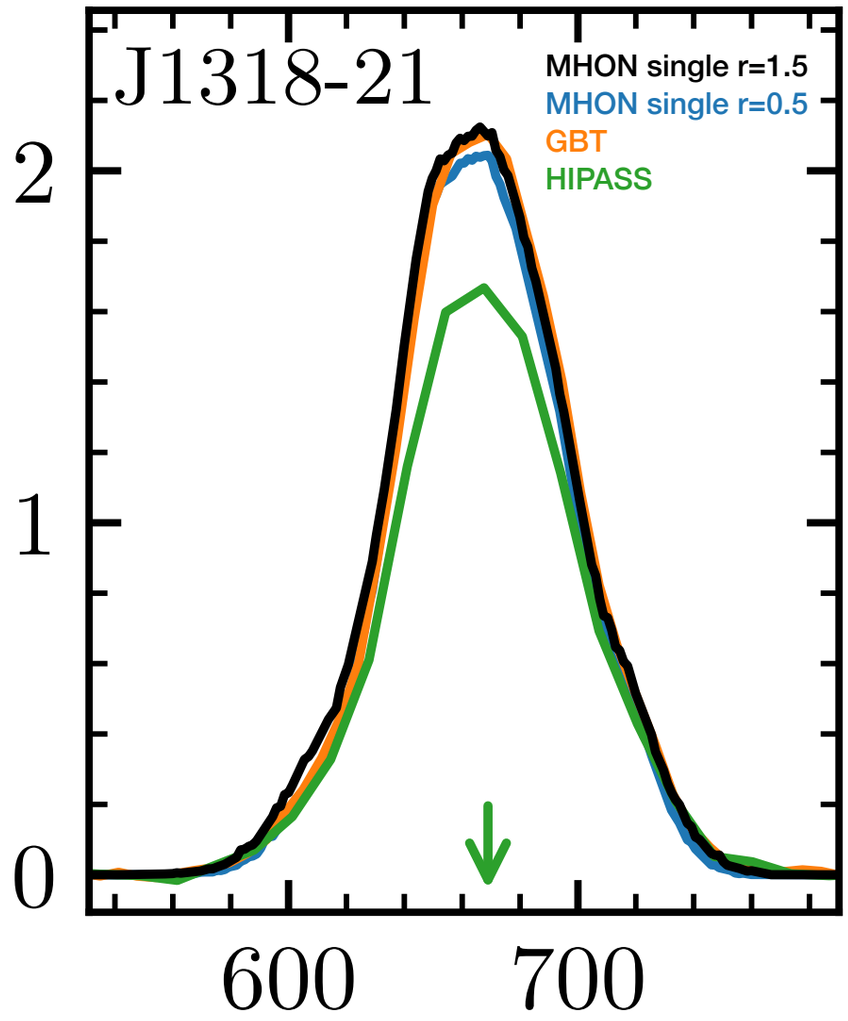


Some single-track survey science

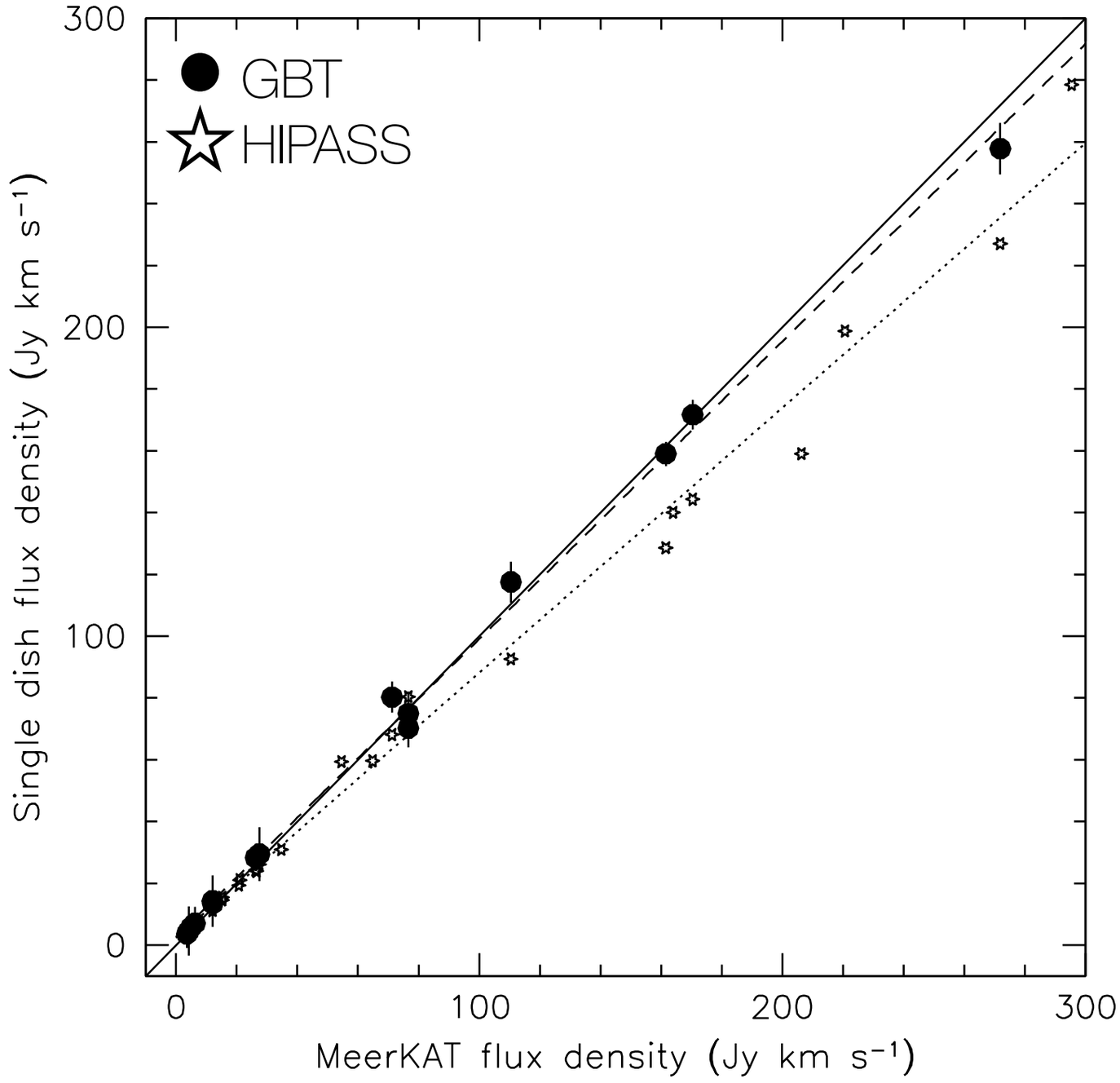
- Global HI profiles: comparison with single dish and deep
- Dwarfs and companions
- Moment plots

Global HI profiles

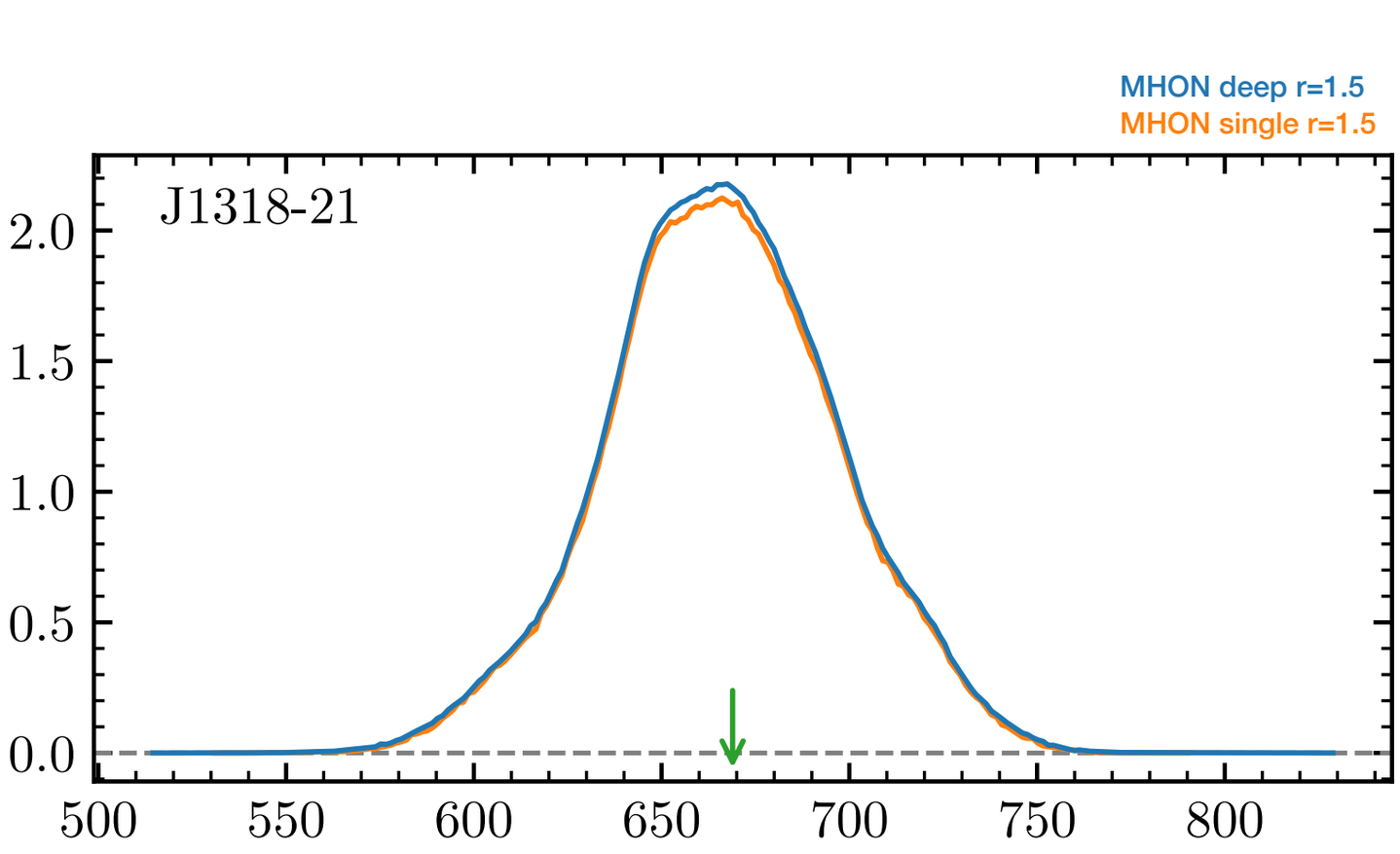


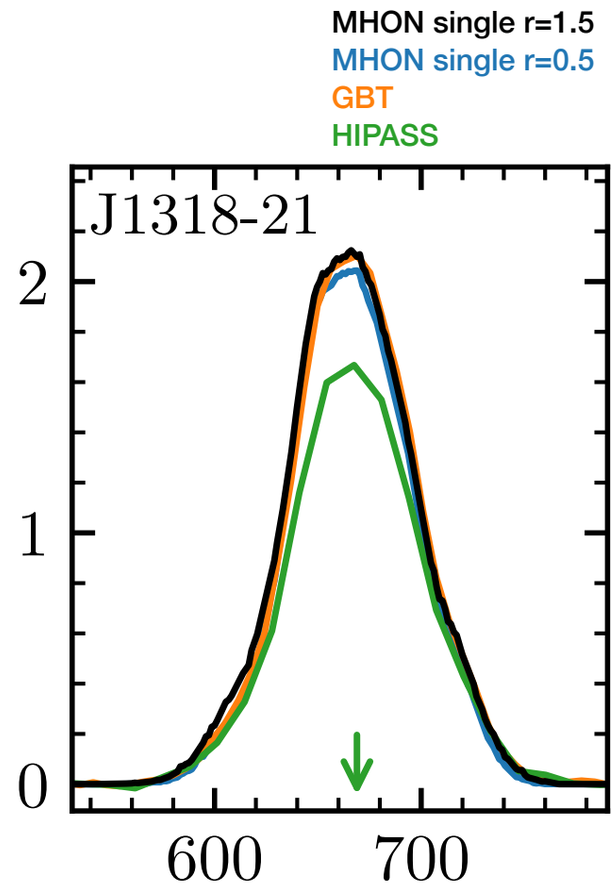


Global HI profiles

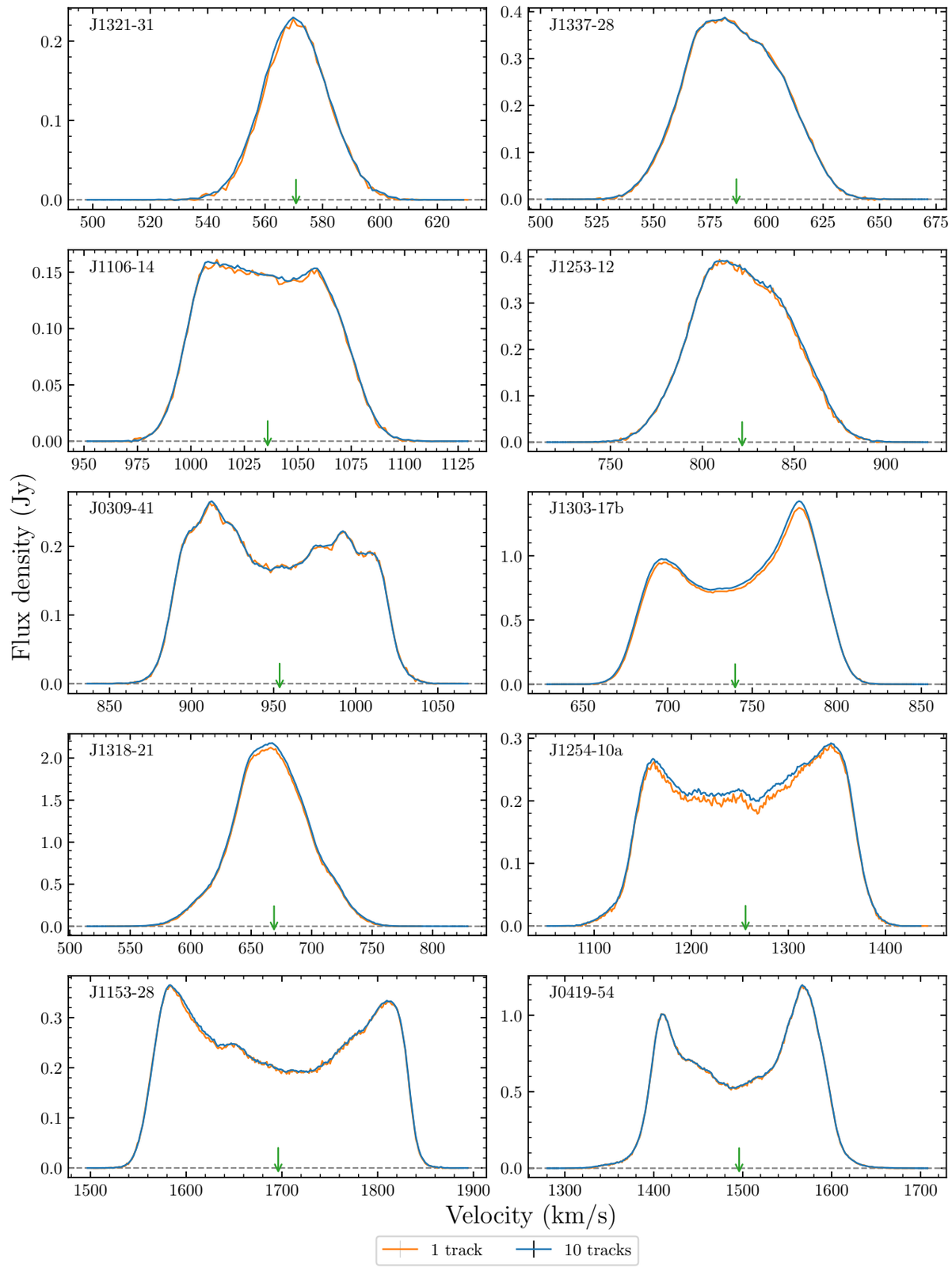


Global HI profiles: 1-track vs 10-track



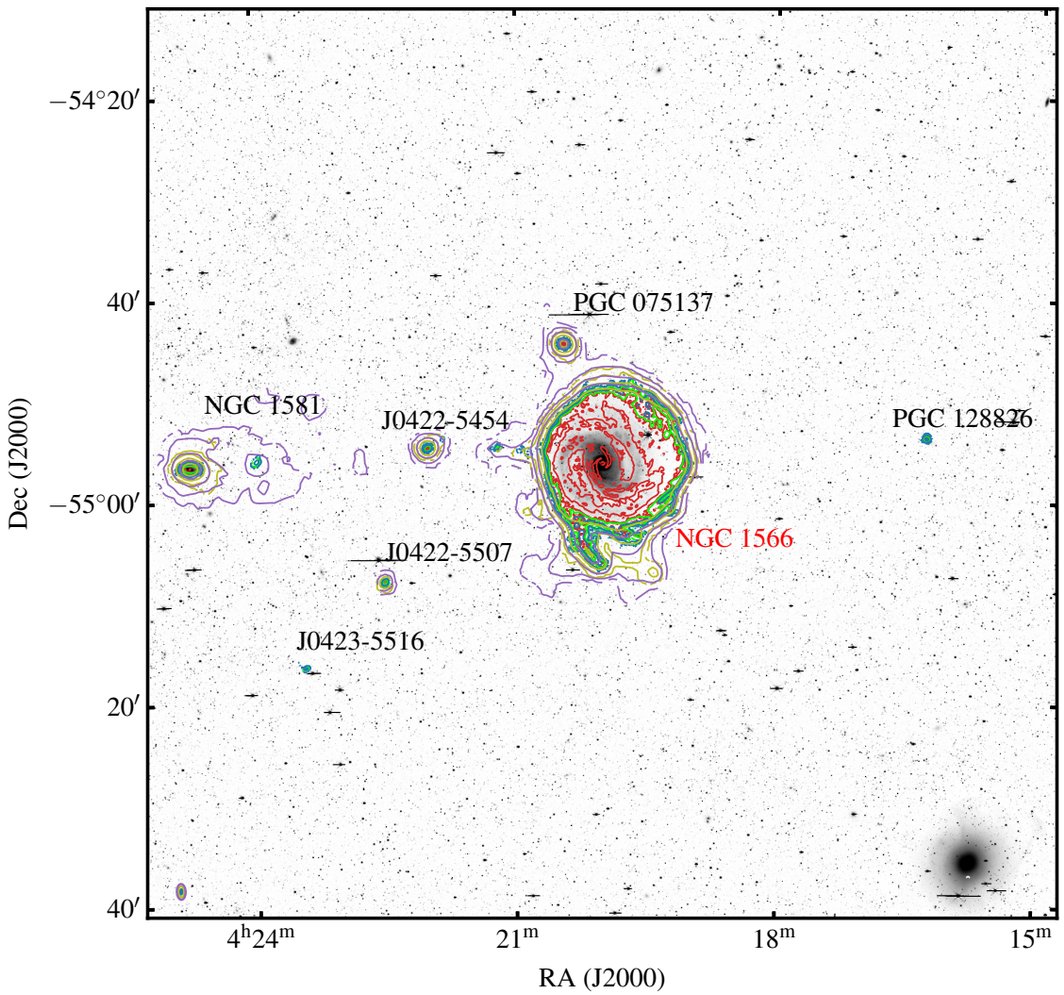


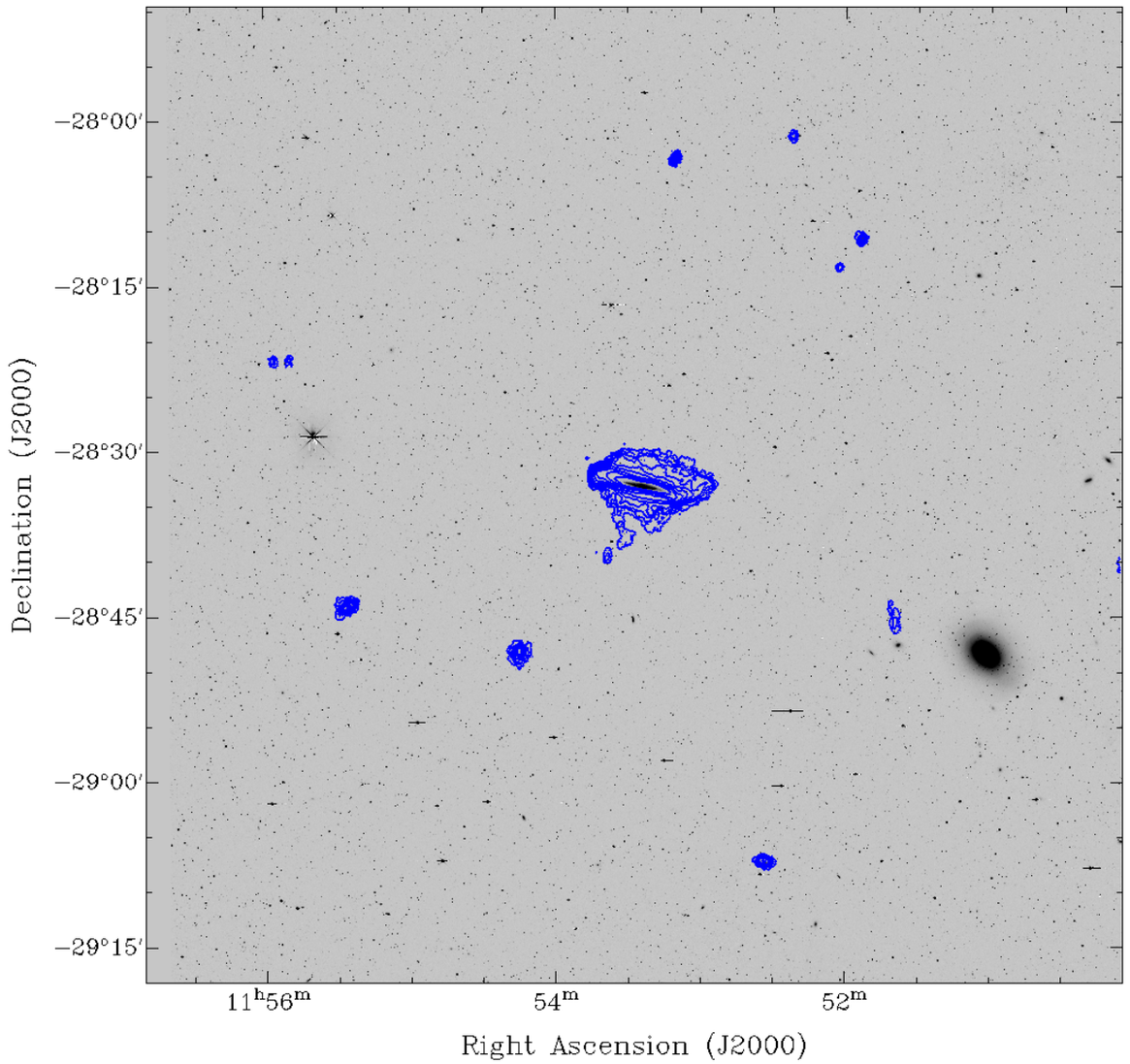
Global HI profiles: 1-track vs 10-track



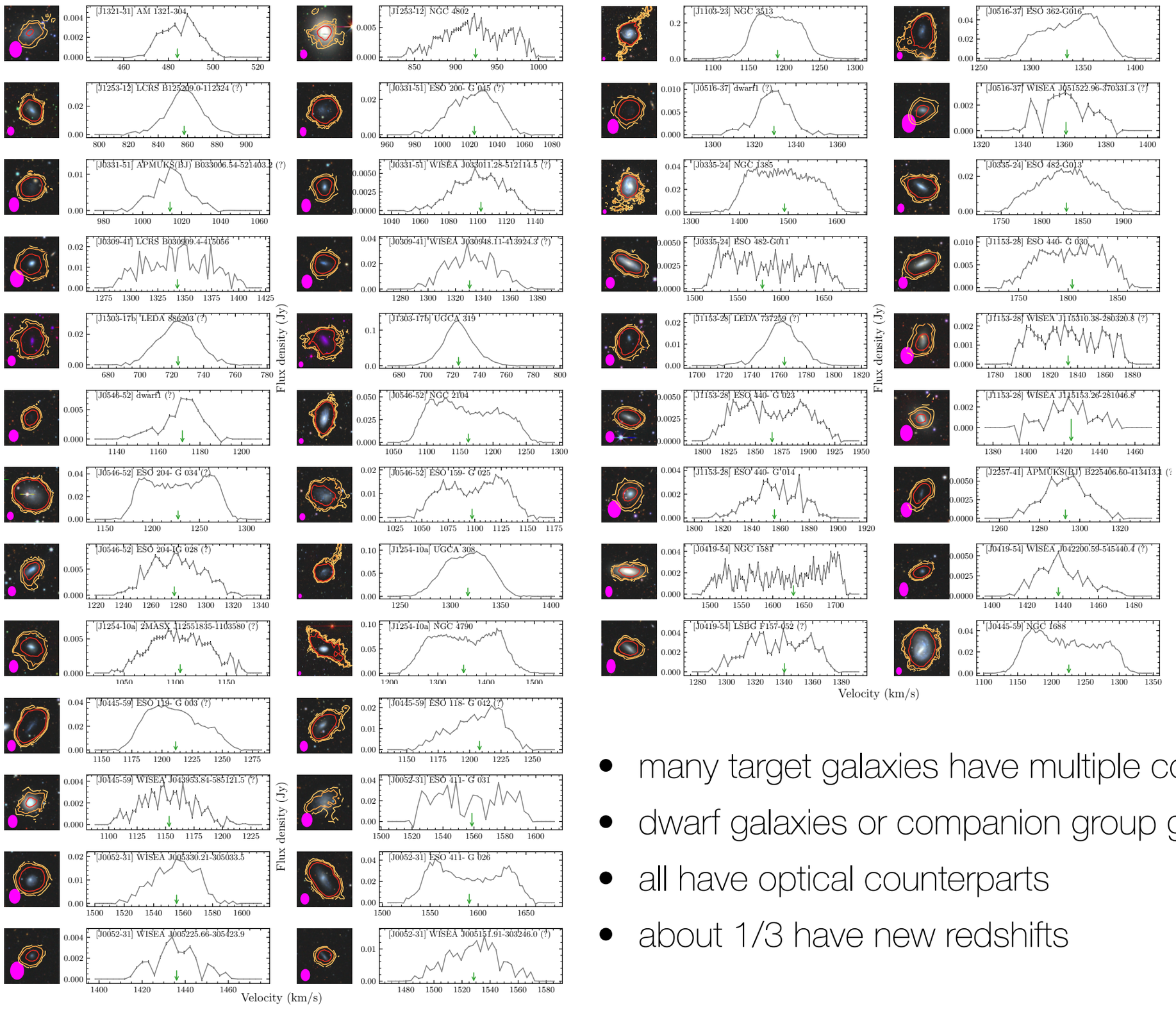
- 10-track always detects (slightly) more flux
- varies from <1% to 4.5% extra
- this may not sound much, but:
  - if we assume the flux is spread evenly over the disk
  - then the equivalent extra column density varies from 2 x 10^{17} cm^{-2} to 8 x 10^{18} cm^{-2}
  - consistent with our detection limits
- establishing presence of low-column density from global HI profiles (interferometer or single dish) is not trivial

Companion galaxies



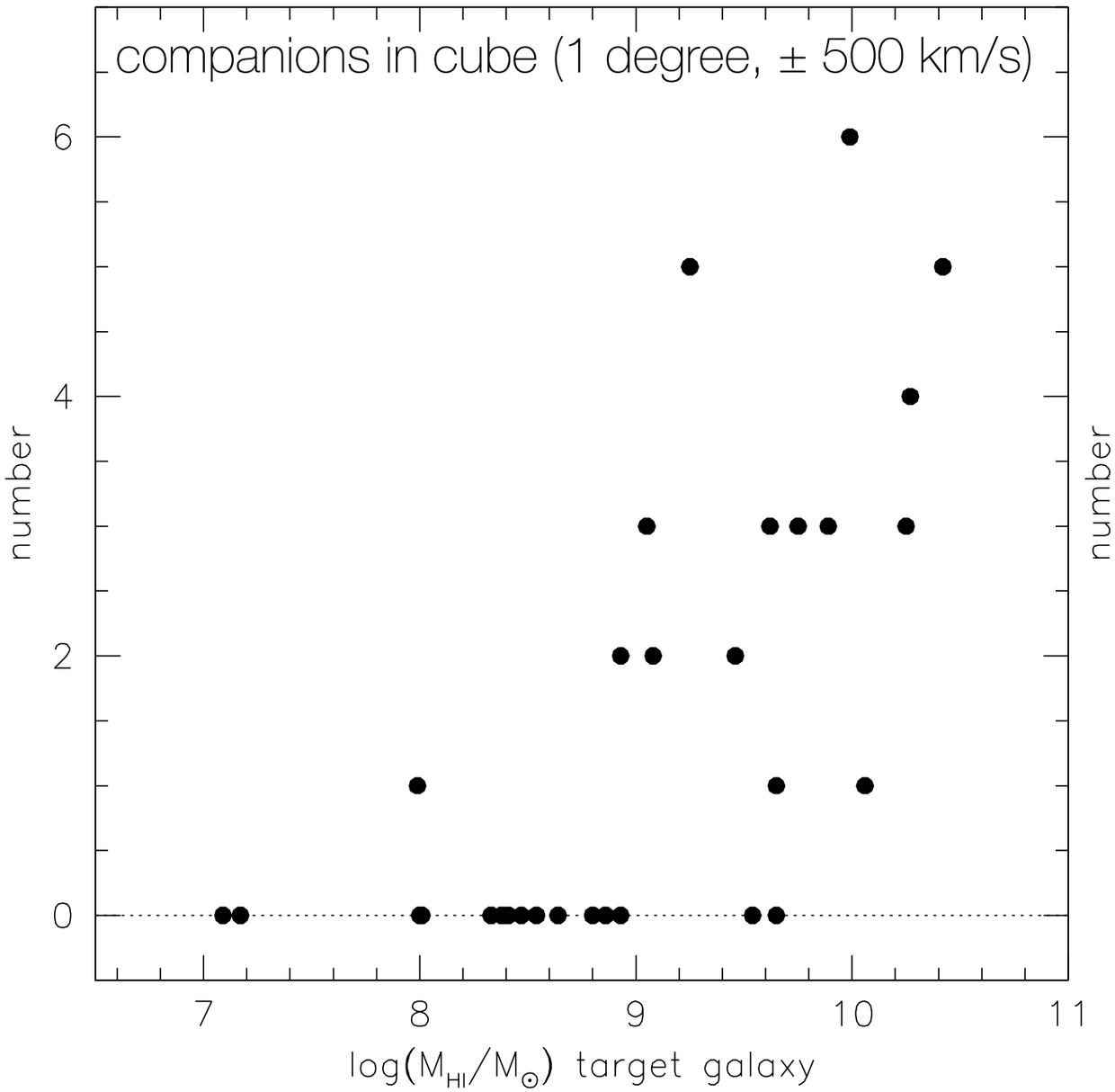


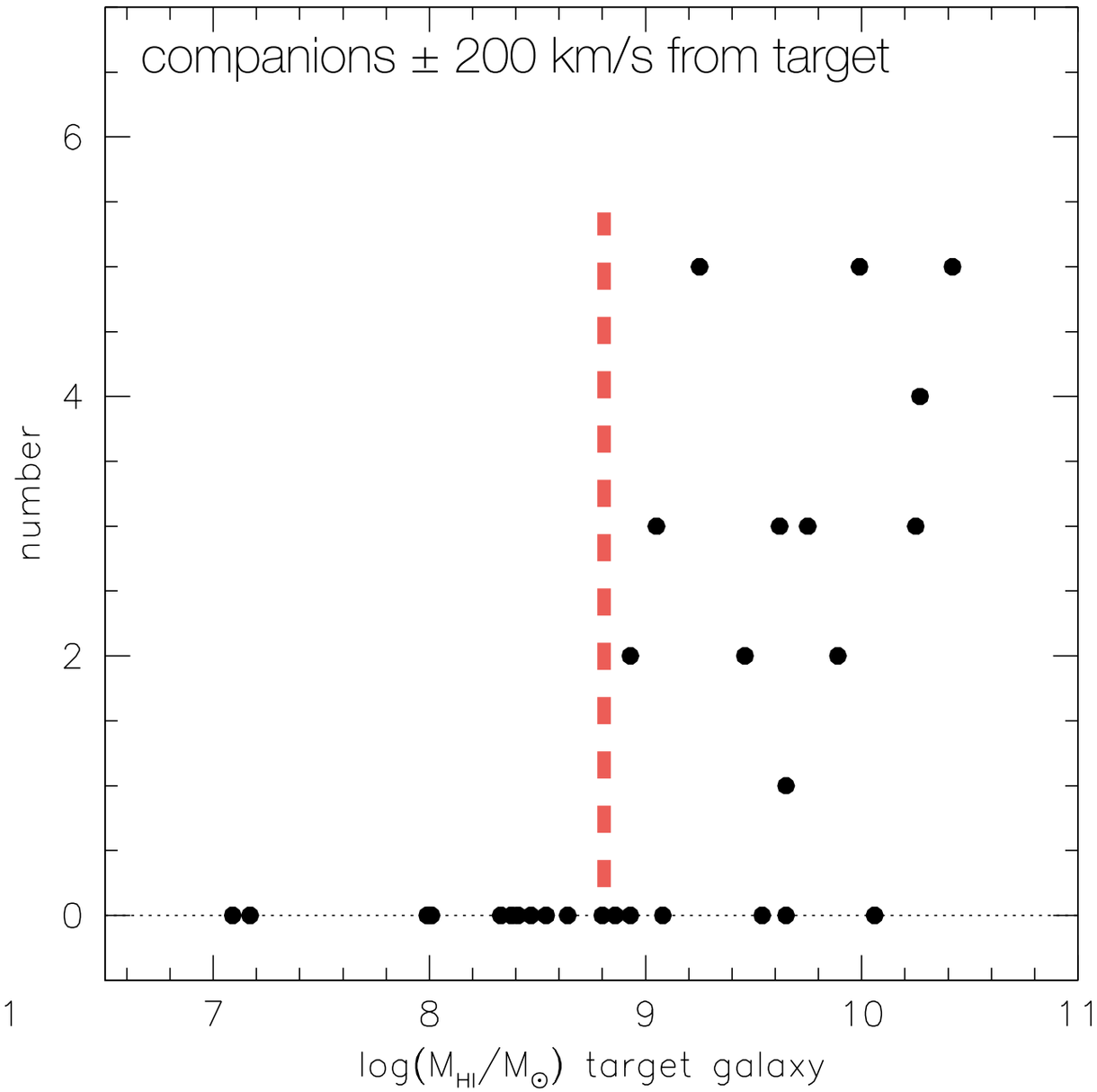
The 44 companions



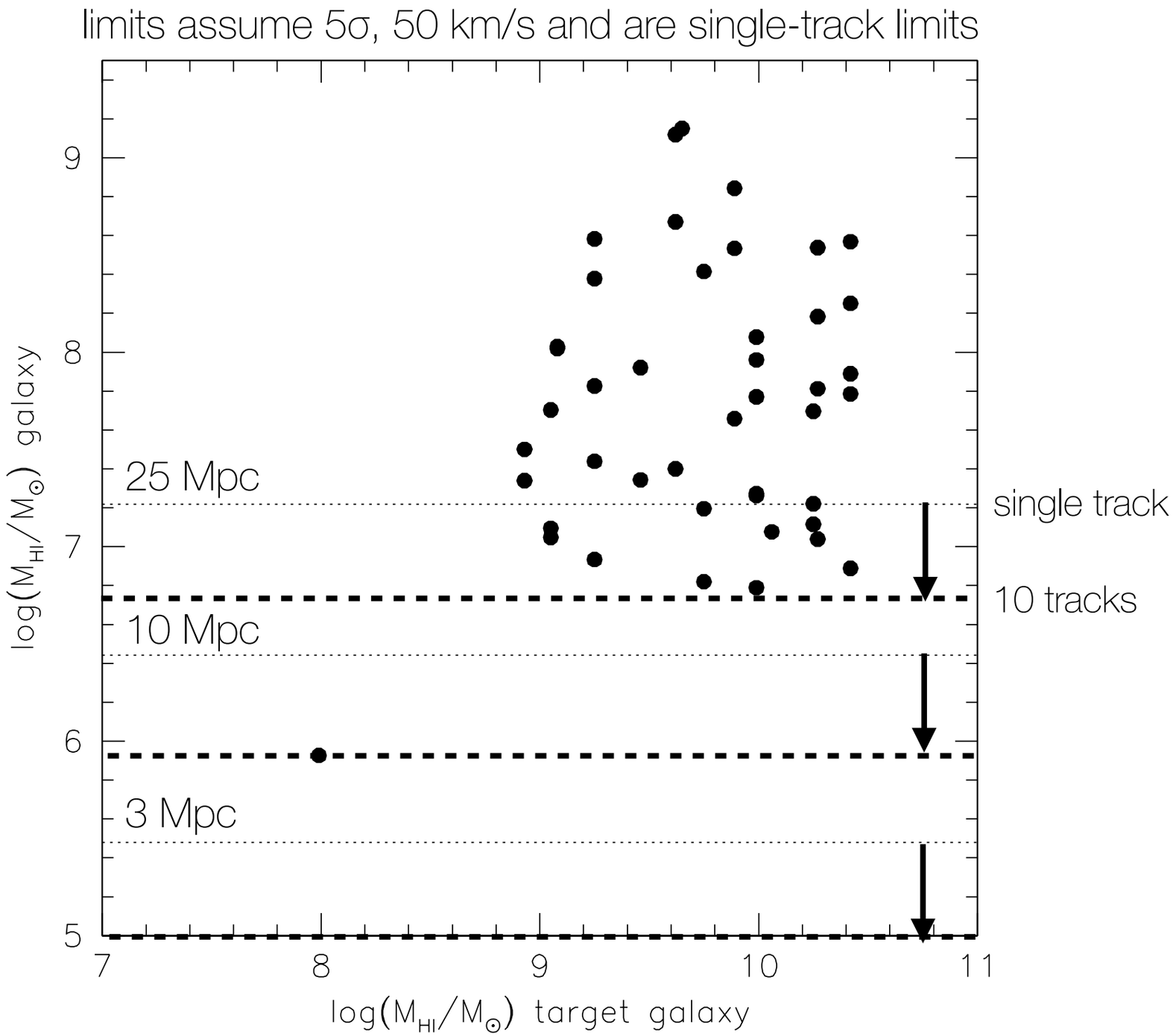
- many target galaxies have multiple companions
- dwarf galaxies or companion group galaxies
- all have optical counterparts
- about 1/3 have new redshifts

Companions of the target galaxies





Companion masses

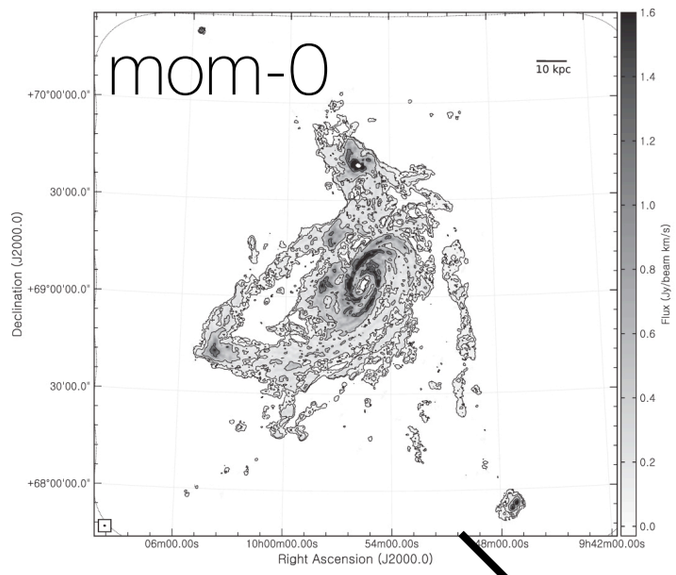


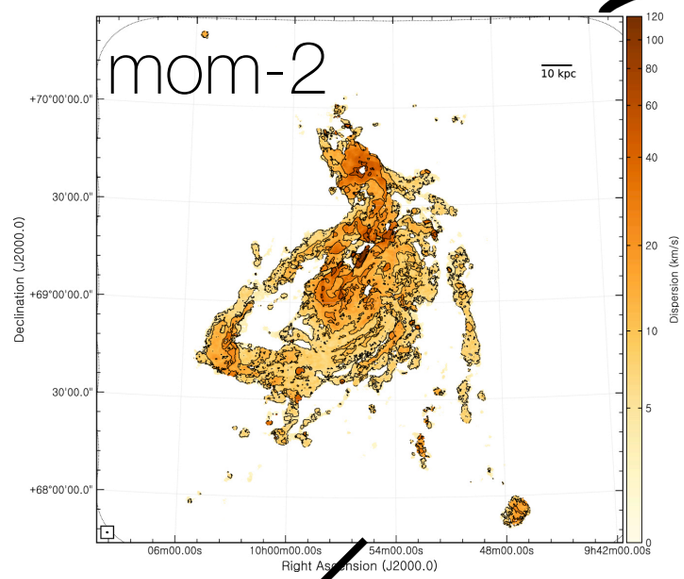
The M81 triplet moment plots

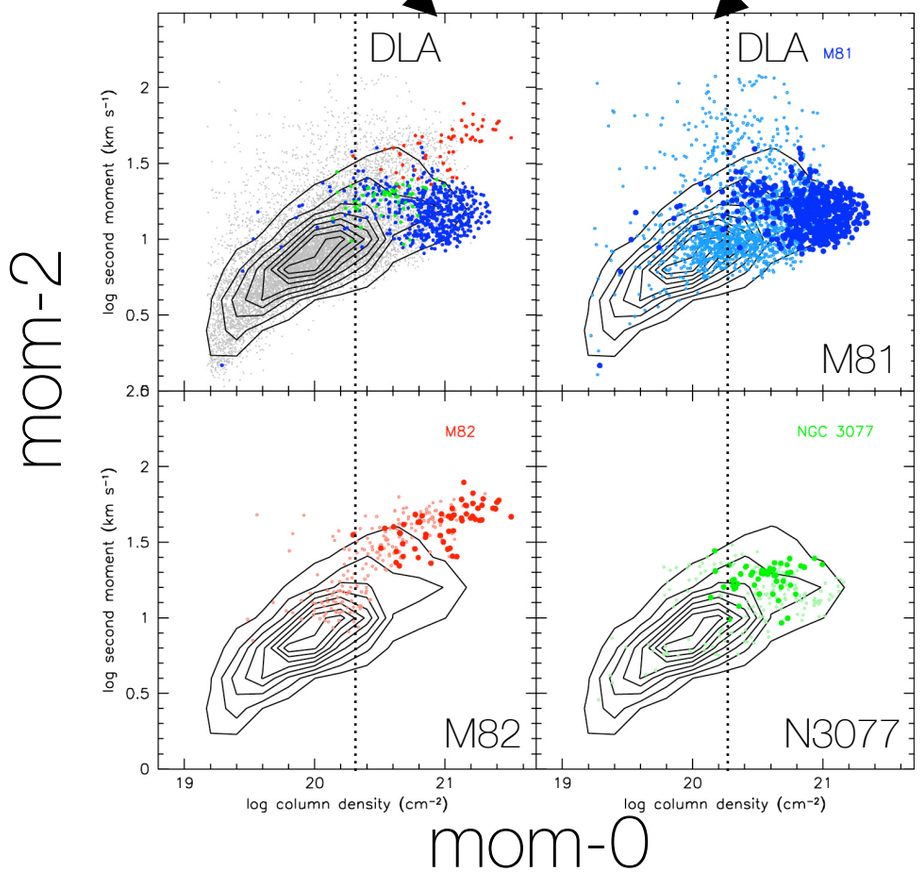
dB++ 2018

We now also include column densities below 2×10^{20} cm^{-2}, allowing us to more fully address questions such as whether the H I velocity dispersion depends on column density, and whether tidal material can be identified based purely on the column density and/or velocity dispersion.

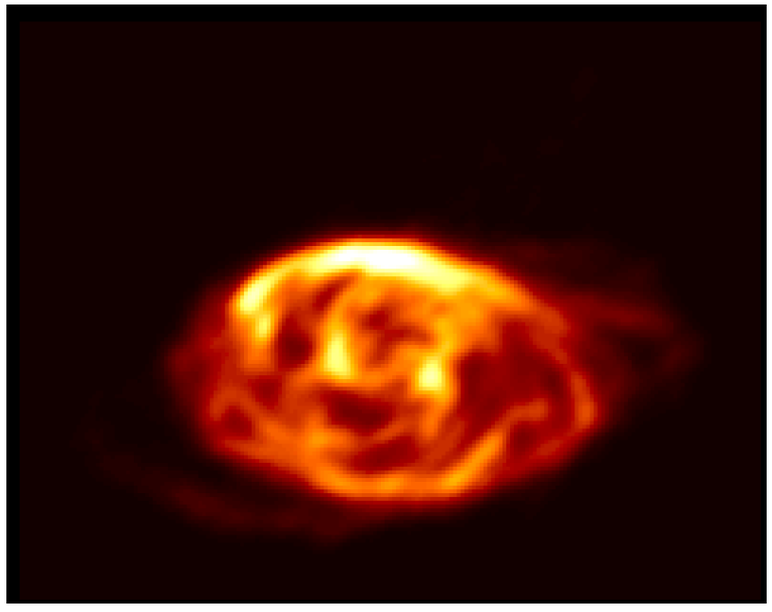
space. High velocity dispersions at high column densities most likely reflect intrinsically high dispersions, while similar dispersions at low column densities are due to the presence of multiple components at different velocities.

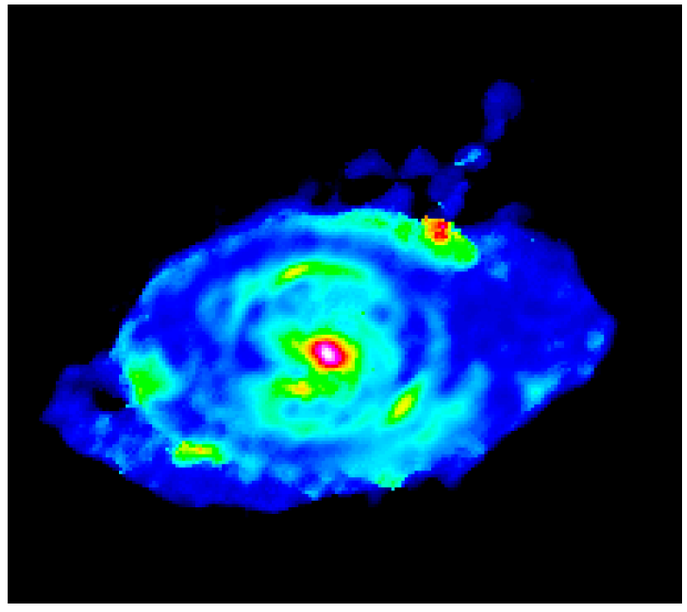




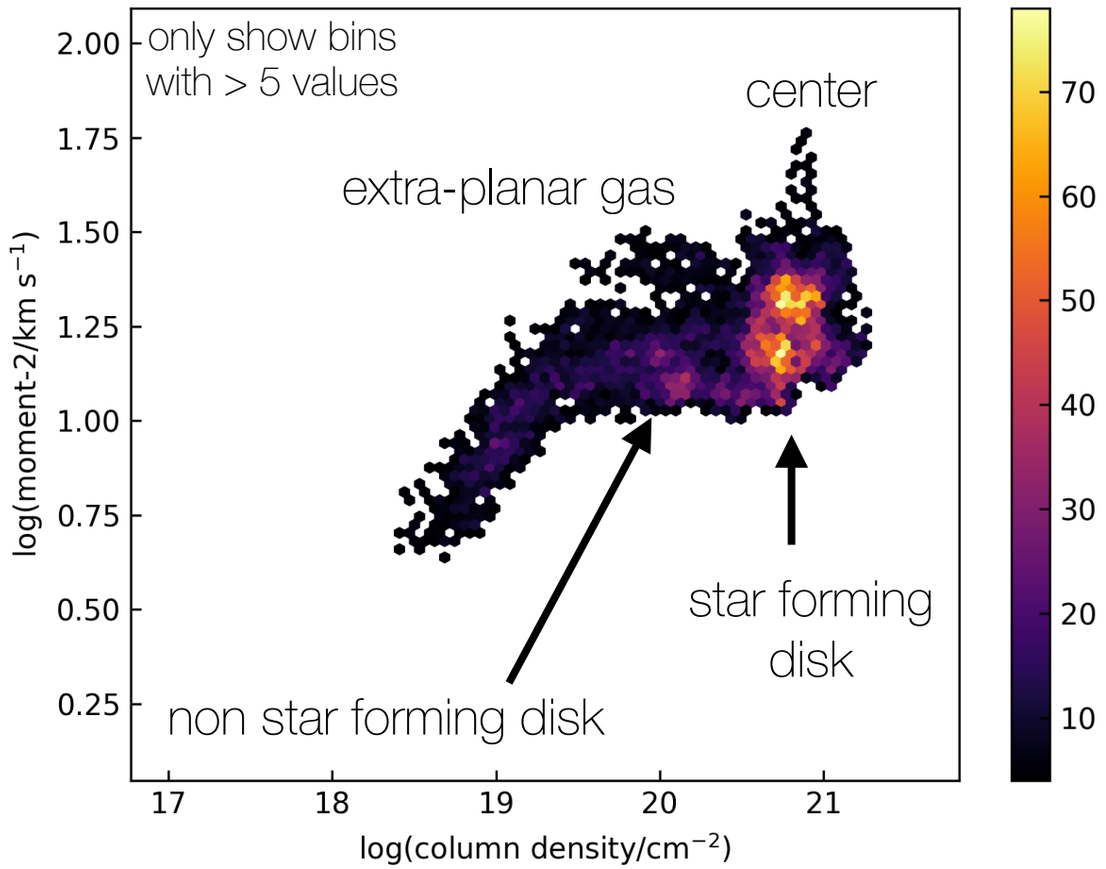


Moments with NGC 1672

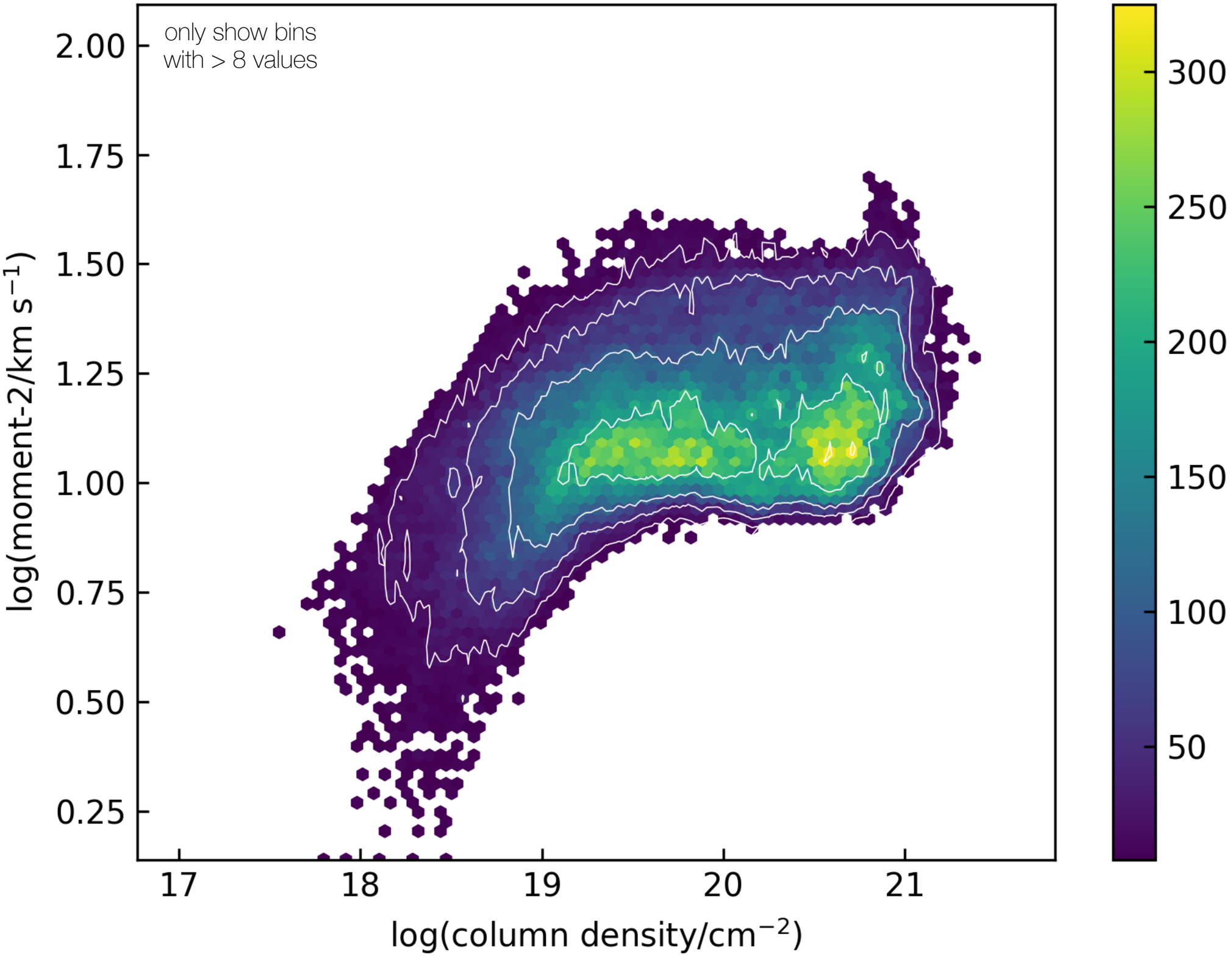




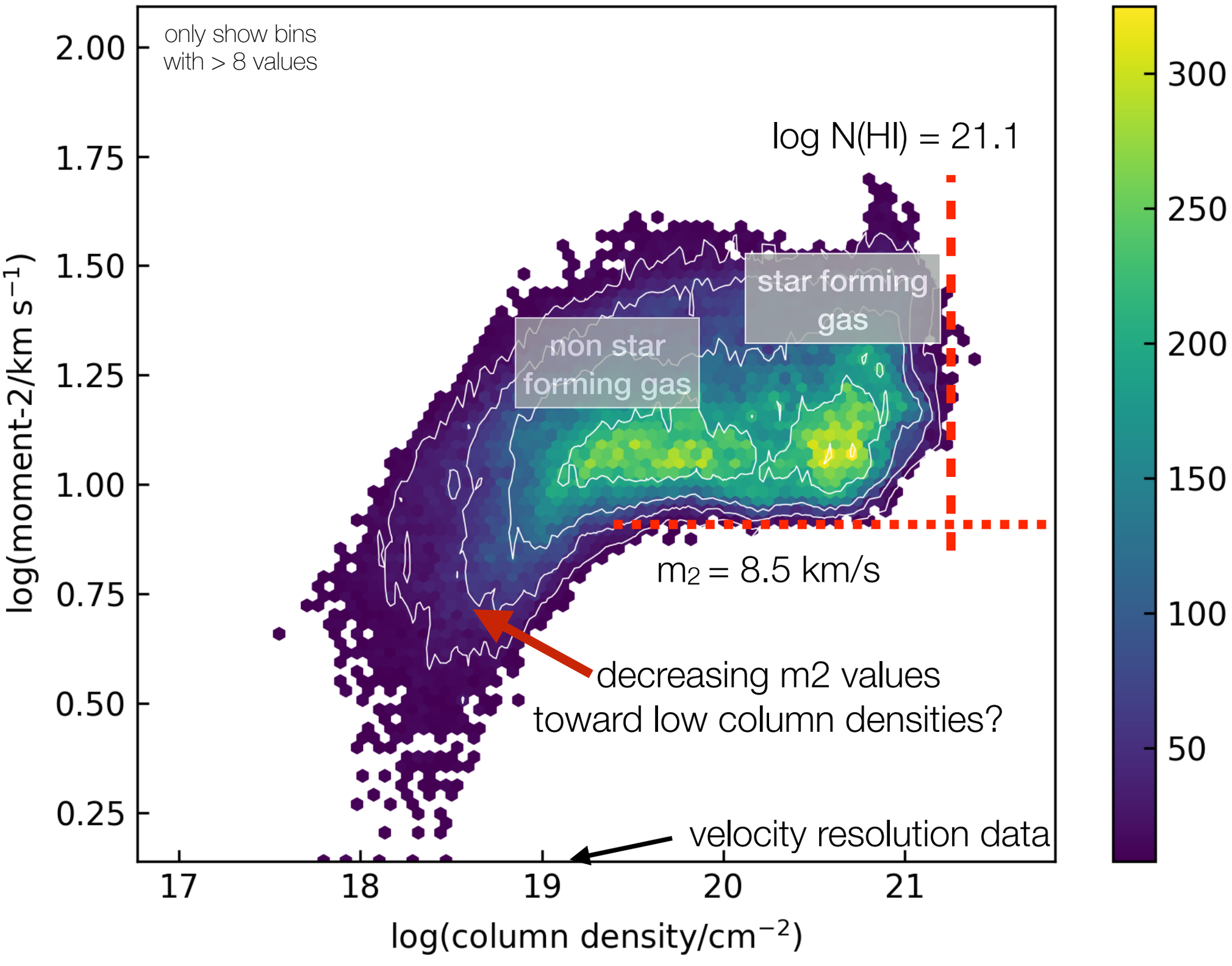
correct for inclination



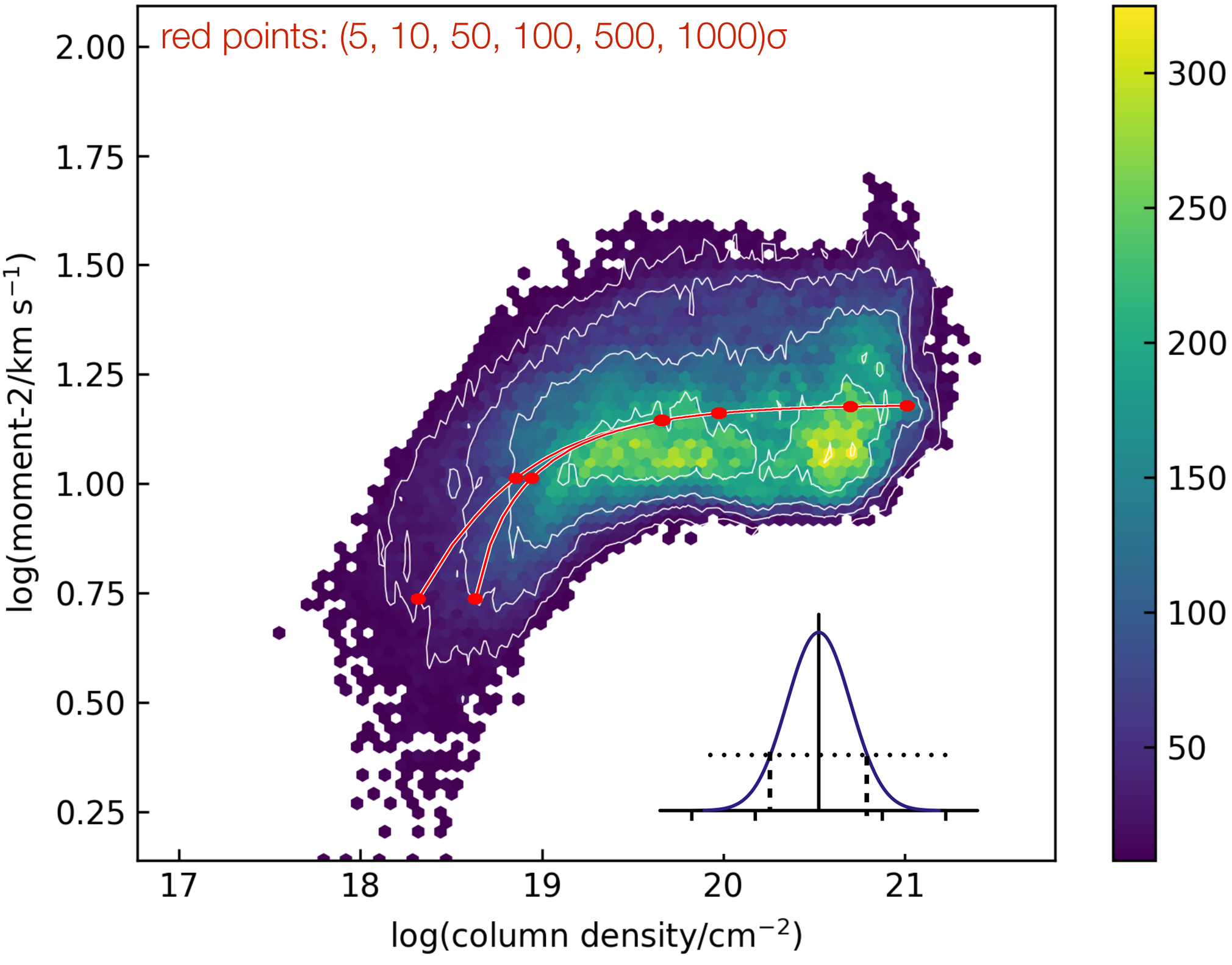
All galaxies together



All galaxies together

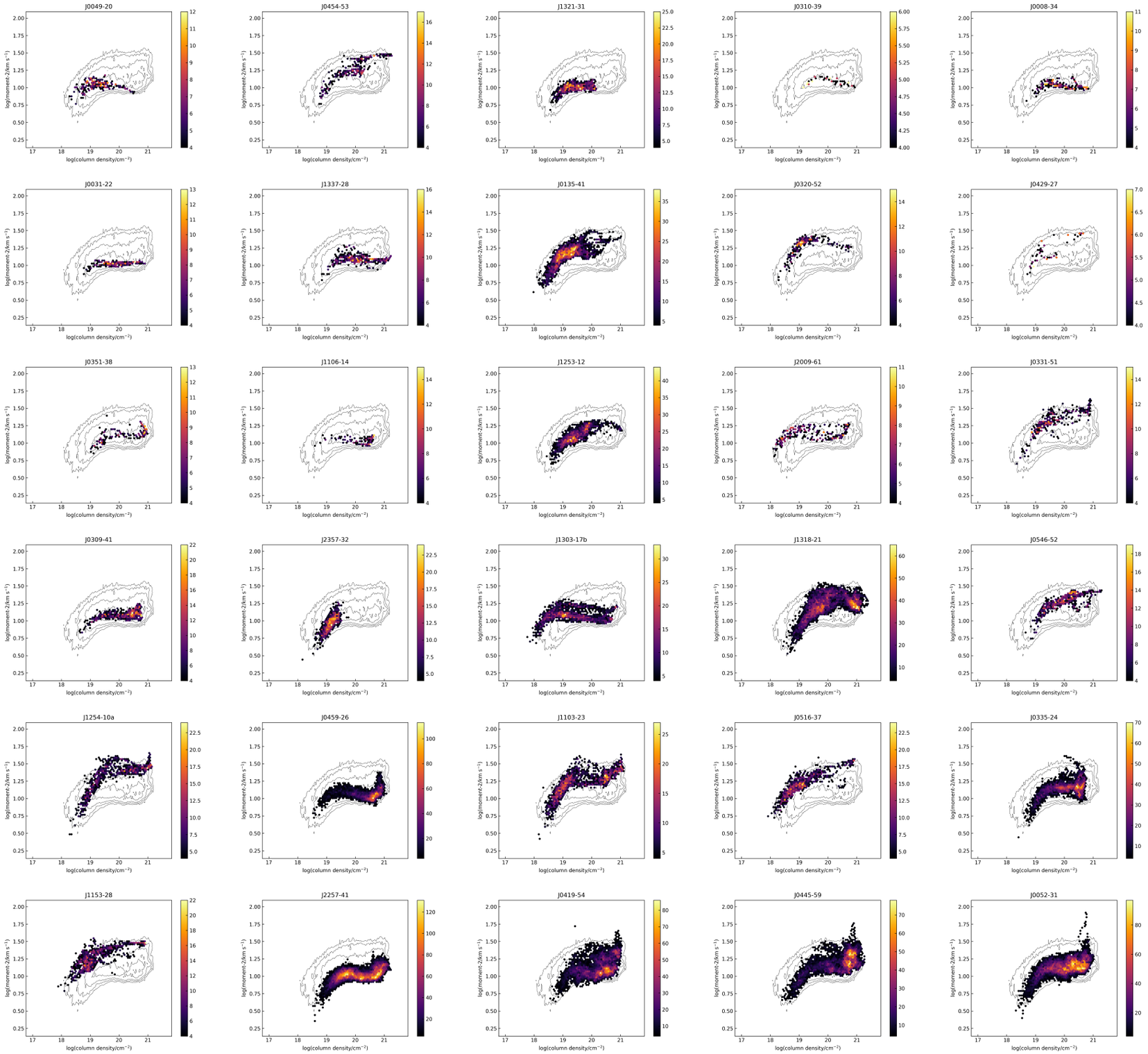


First results: NGC 1566



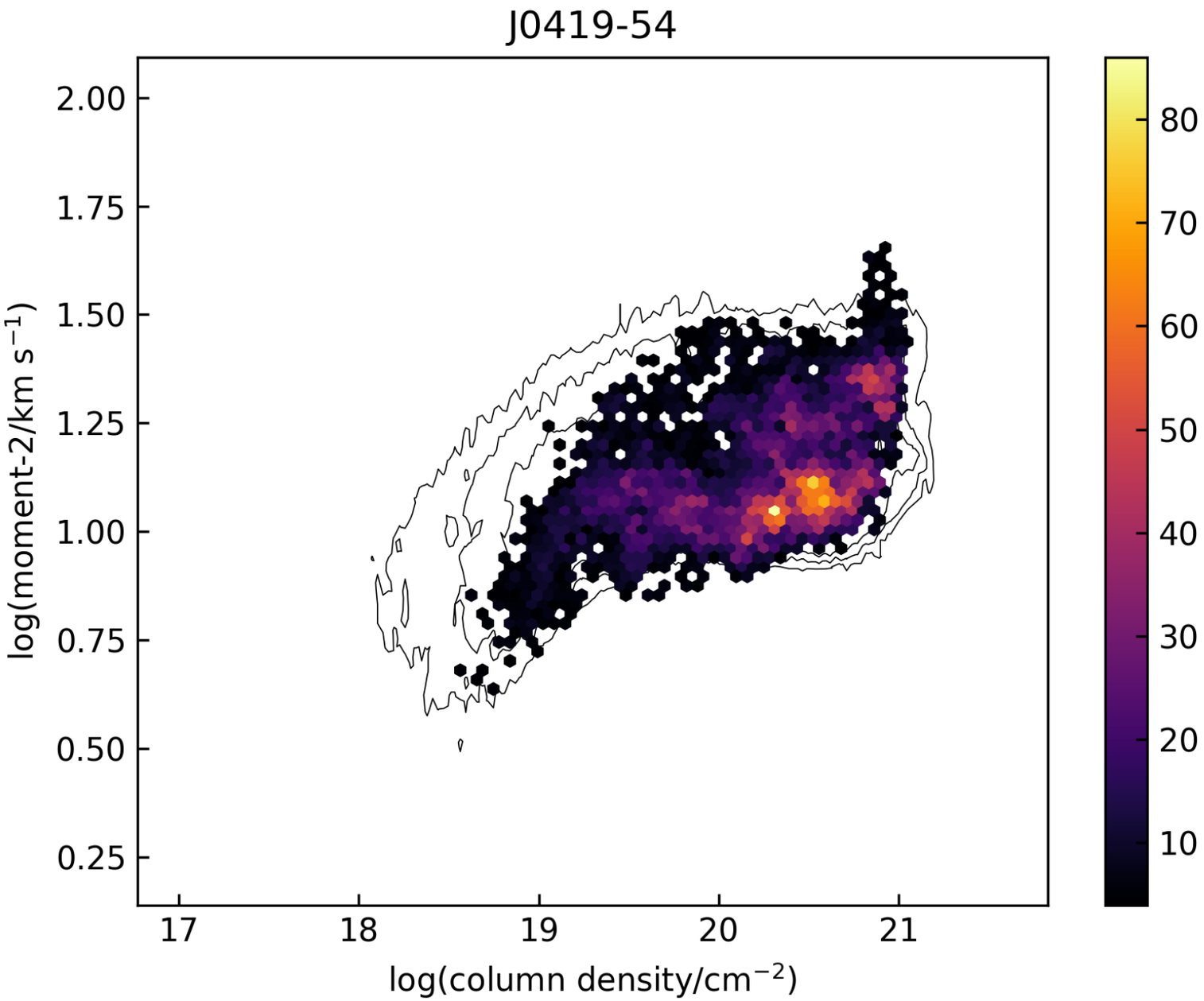
Galaxy variations

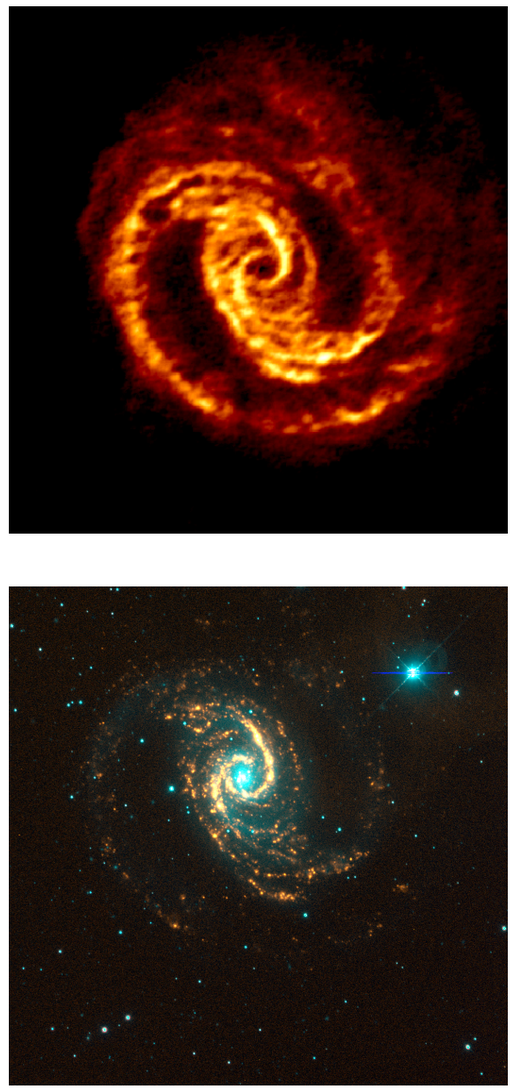
low HI mass



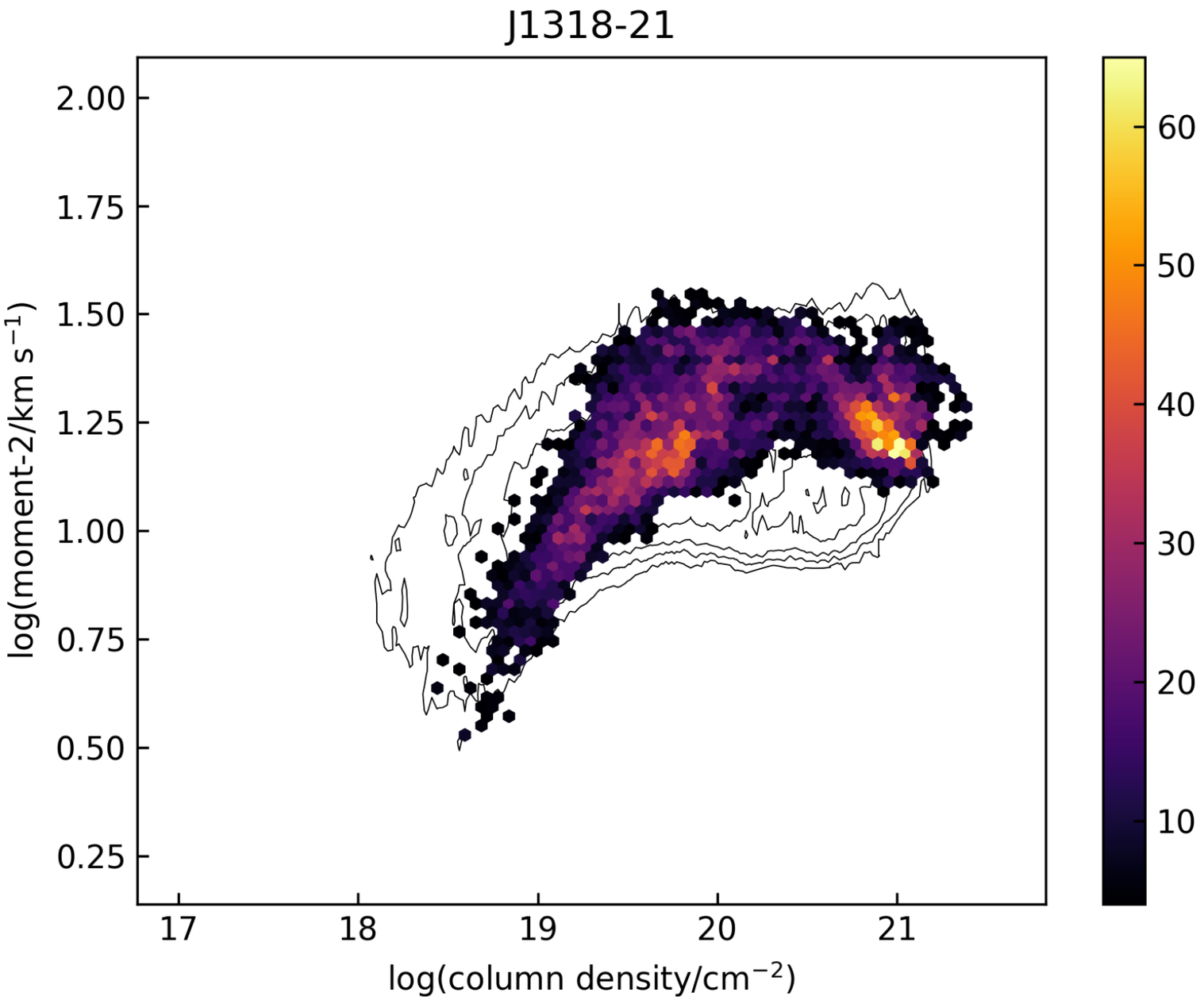
high HI mass

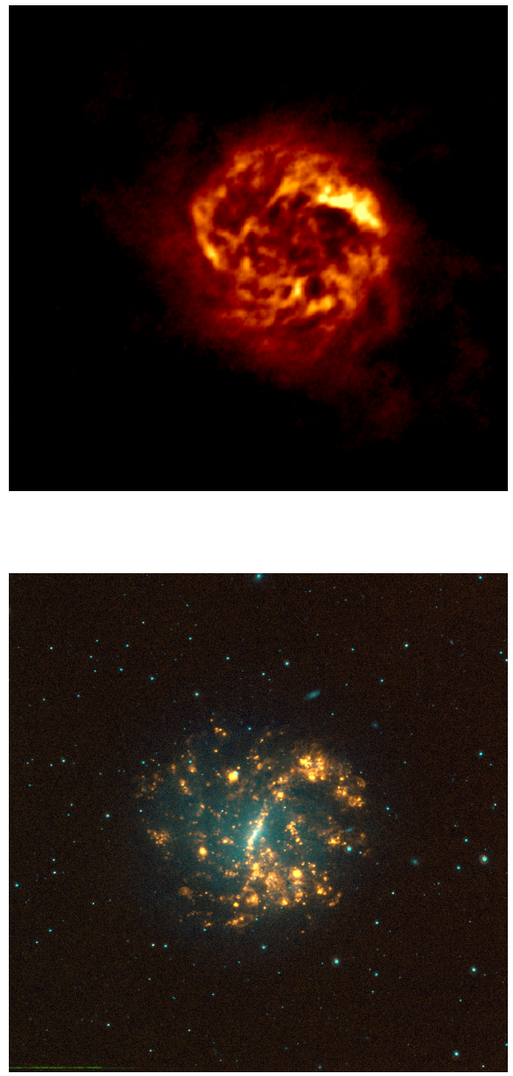
The NGC 1566 case



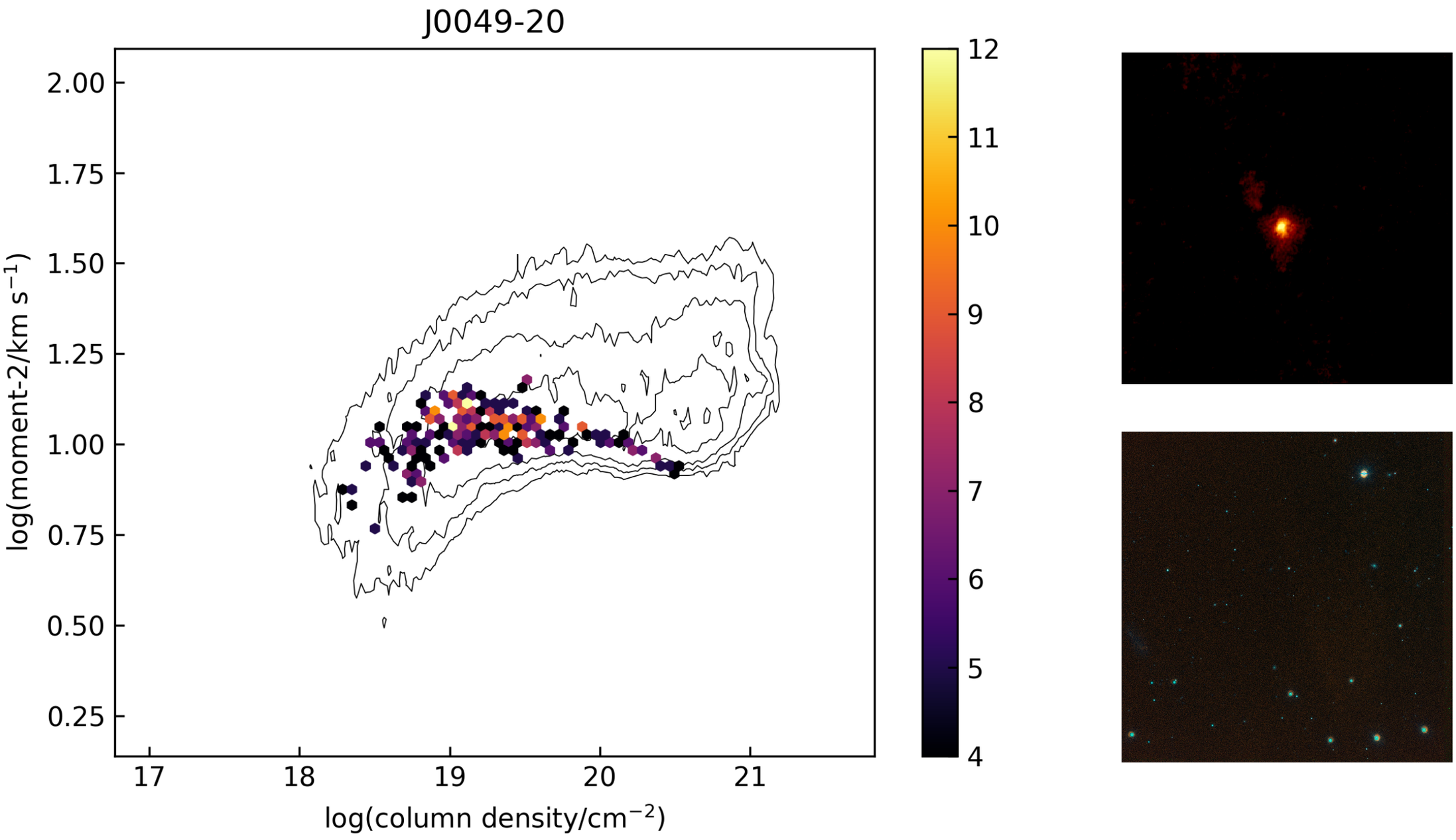


The NGC 5068 case



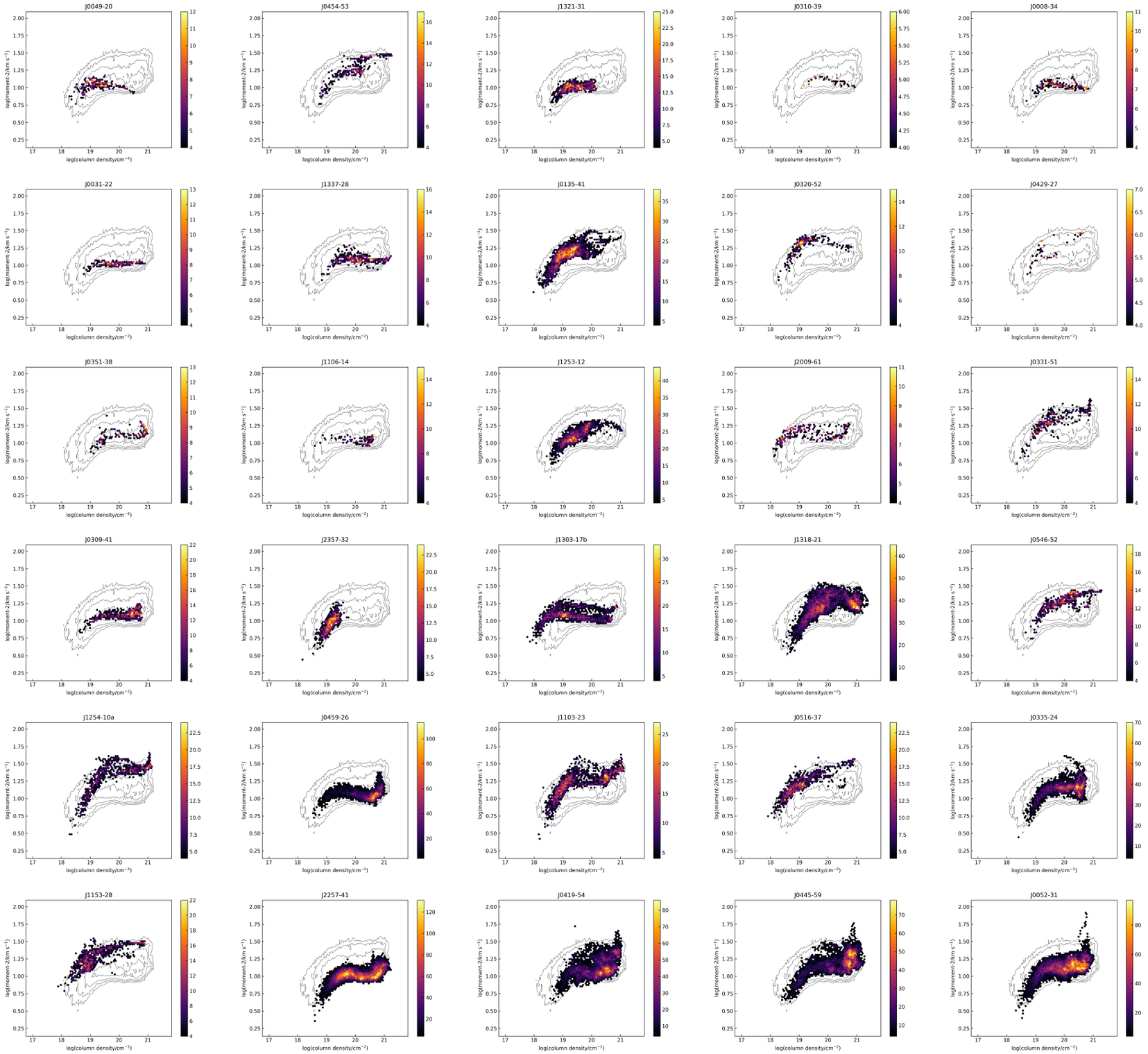


The J0049-20 case



Galaxy variations

low HI mass



high HI mass

Moments

- Moments analysis highlights some fundamental properties of galaxies
- Clear distinction between star forming and non-star forming gas
- Minimum “velocity dispersion” and confirms maximum column density
- Also shows limitations of moment maps
- To be continued on full-depth maps

Summary

- MHONGOOSE is underway
- Data quality excellent and as desired
- Deep low column density HI reveals: possible cold accretion, interaction features, a variety of dwarfs beyond the local group

This work has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 882793 "MeerGas").