Exploring ALMA data with NGC 3059

Group 1

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2023 ALMA summer school

Introduction. *PHANGS-ALMA survey*

- **P**hysics at **H**igh **A**ngular resolution in **N**earby **G**alaxie**S**
- **PHANGS-ALMA**: ALMA **CO(J=2-1)** survey of 90 nearby star-forming galaxies.
- Science motivation – demography of **molecular gas properties** in GMC scale
  - Previous surveys found global correlations between **SFR**, $\mathbf{M_{H2}}$ and $\mathbf{M_*}$
  - But there are scatters in the relations due to galaxy **type** or **location** in a galaxy
  - **Spatially resolved data** is necessary to study underlying physics

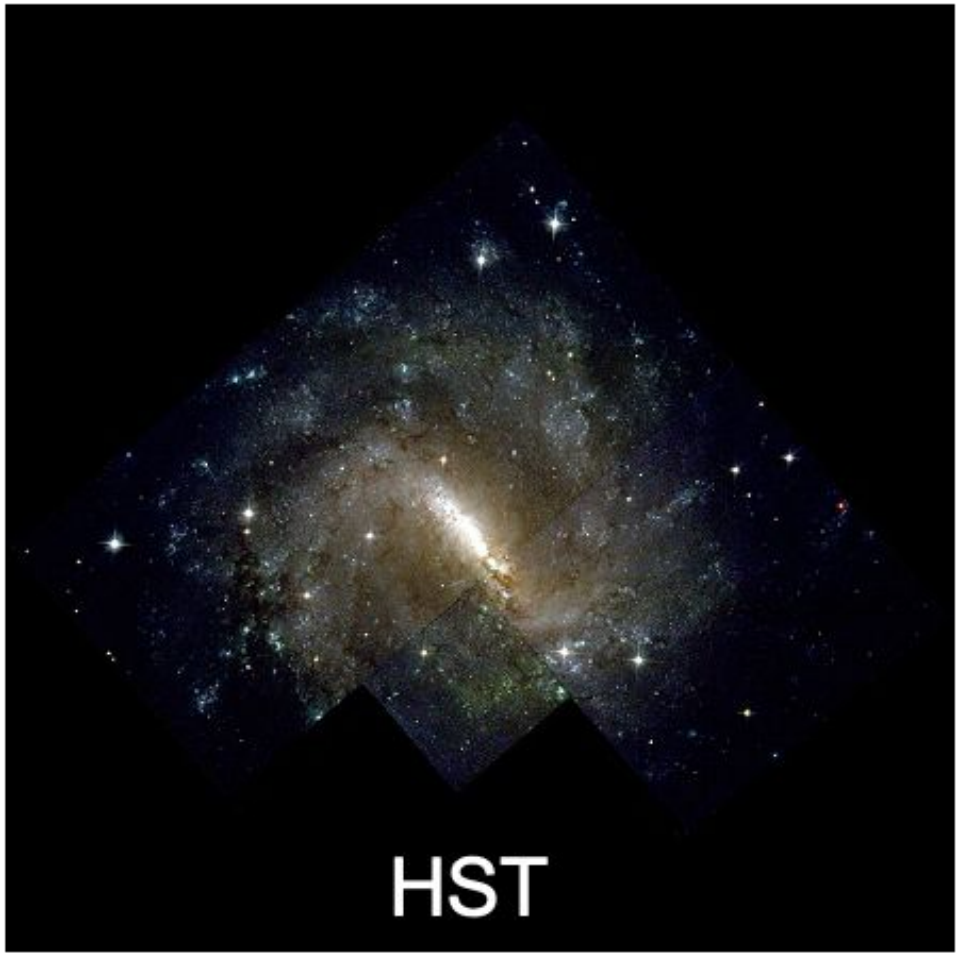
    (density distribution, self-gravity, turbulence, radiation and stellar feedback etc.)
  - High resolution (~ 1” ~ 100 pc) data → First **GMC scale molecular gas** survey
- Samples – **Nearest** (d < 20 Mpc), ALMA-accessible, massive SFGs
- **Multiwavelength** – HST & VLT/MUSE (Optical), AstroSAT(FUV), MeerKAT (radio) …

(Leroy+2021)

ALMA Data. *NGC 3059*

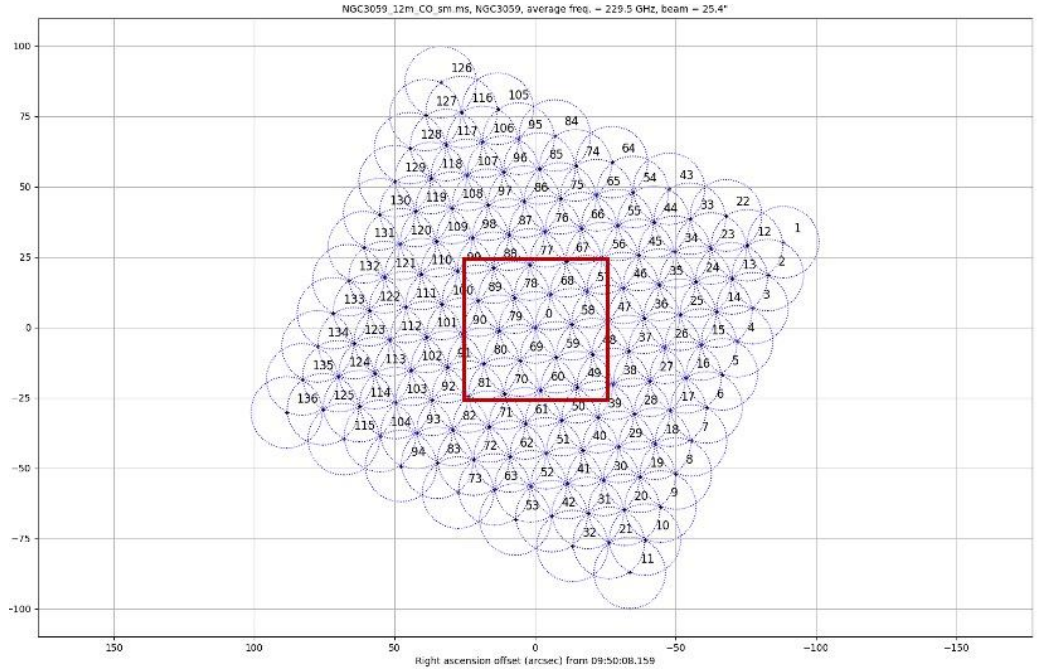
- **Barred** spiral galaxy (SBb ~ c)
- Weak bar - similar to Milky Way
- RA = 09h50m08.181s, Dec = -73d55m19.96s
- Redshift ~ 0.00424 (d ~ 20.2 Mpc)
- Inclination ~ 29.4°
- $M_{*} = 2.4 \times 10^{10}\ M_{\odot}$, SFR = 2.38 $M_{\odot}$/yr

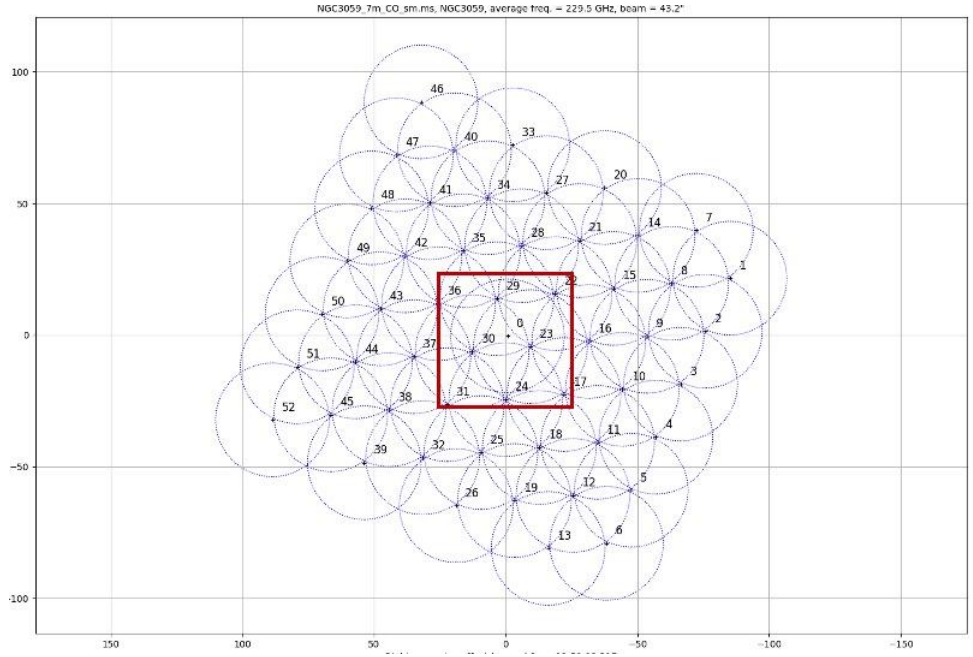
(Neumann+2023)



ALMA Data. *NGC 3059*

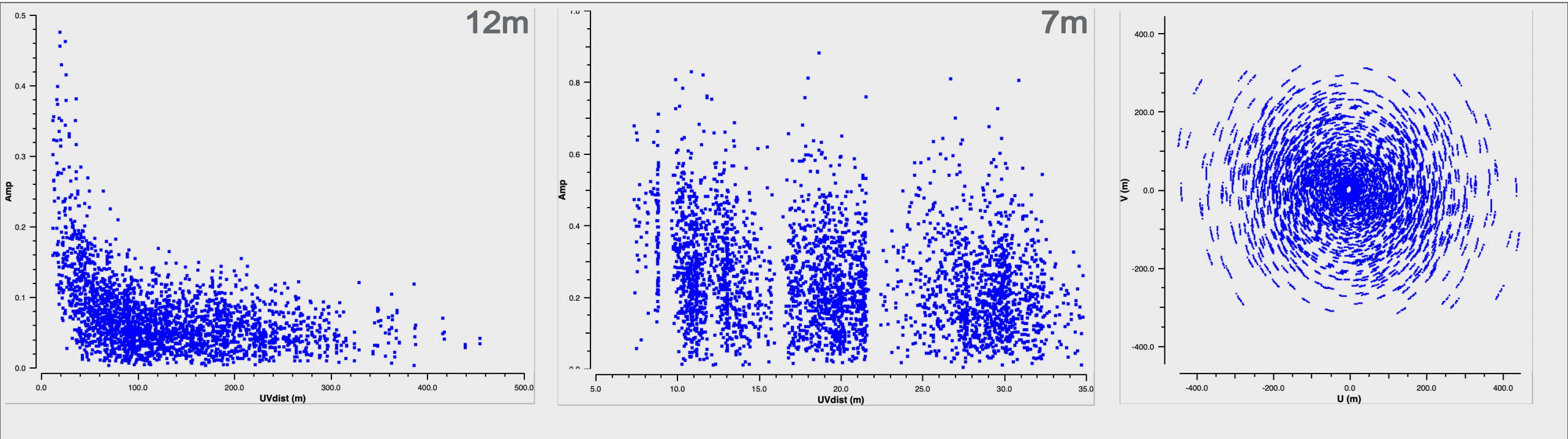
- **12m + 7m + TP** – Band 6 data, with **multiple pointings** (~140 for 12m, ~50 for 7m)
- Observed frequency ~ 229.49 GHz (rest frequency = 230.538 GHz → CO(J=2-1))
- Use cutout & channel-smoothed dataset due to computing limitation
- **.ms files** – total 40 channels & 22 pointings for 12m, 9 pointings for 7m





ALMA Data. *UV coverage*

- 12m maximum UV distance ~ 450m → **Expected beam size ~ 0.67”**
- 7m maximum UV distance = 35m → **Expected beam size ~ 8.63”**

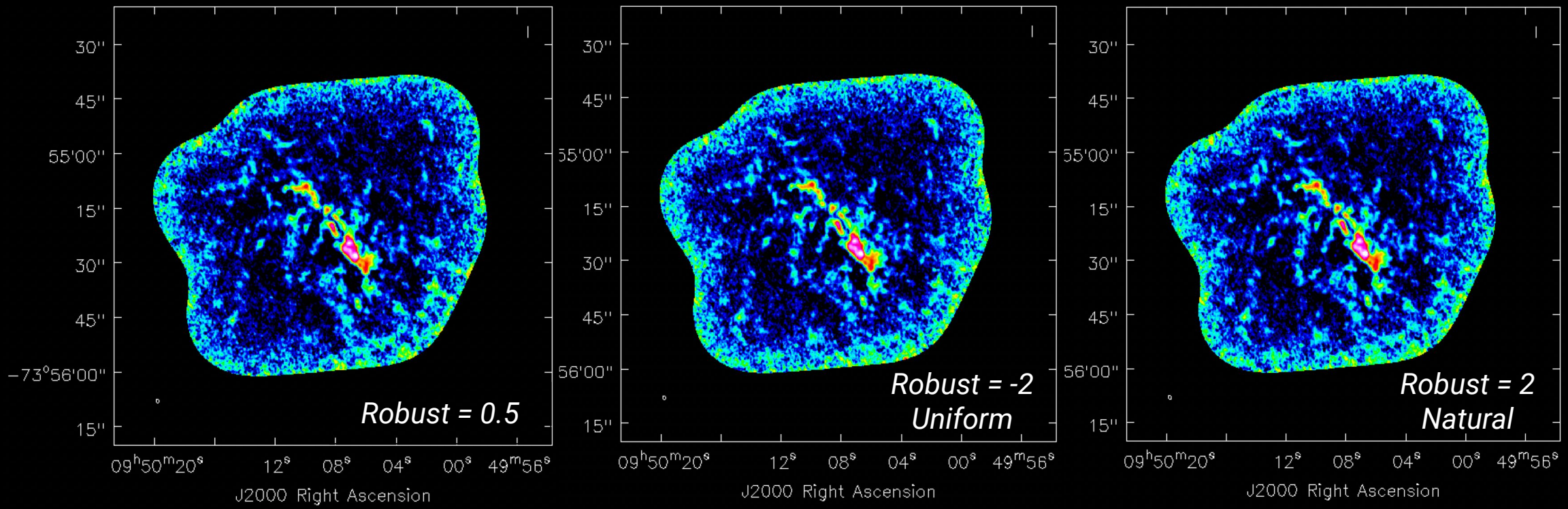


Imaging Workflow.

- Individual imaging of 12m & 7m
  - **tclean** with **specmode='cube', gridder='mosaic'**
  - Change robust parameter and compare
- 12m+7m combined imaging
  - Make concatenated ms files using **concat** task
- Add TP image to 12m+7m
  - **Feathering** technique
  - Change TP image to mock visibility **(tp2vis)**
- Moment 0, 1, 2 maps for all cleaned images

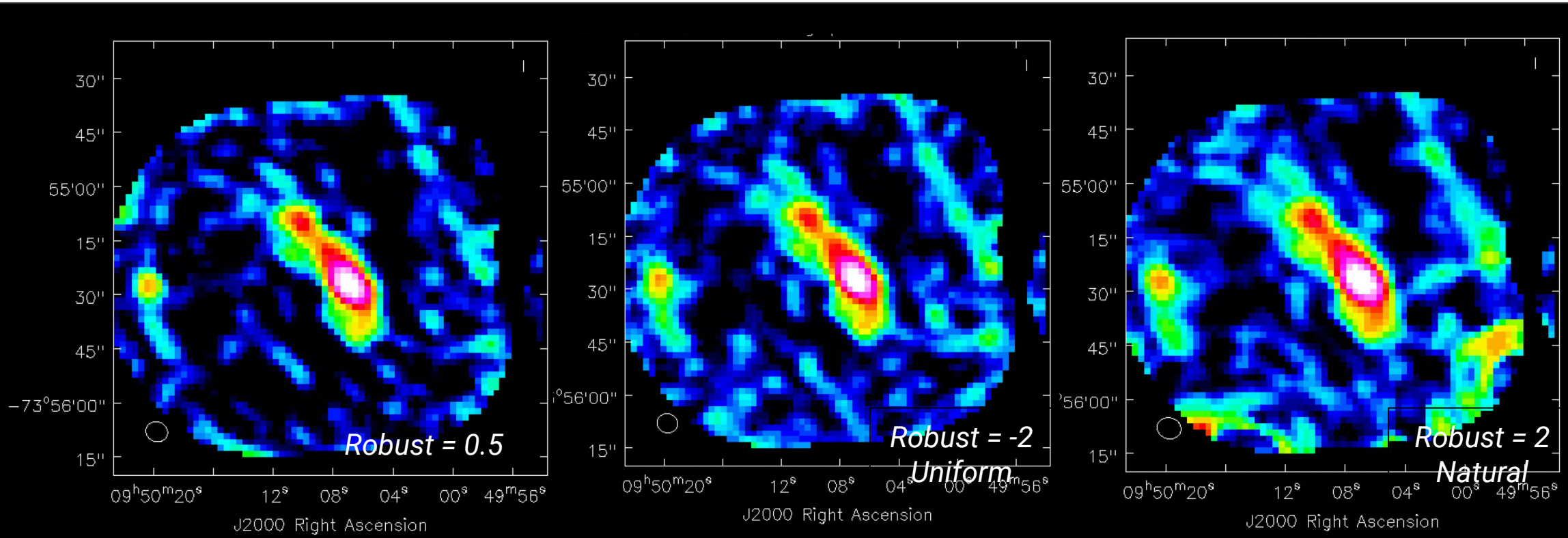
Result. *12m data imaging*

- Mom0 maps of Interactive cleaning (robust =0.5) - Auto cleaning (robust = -2 & 2)
- Beam size: 1.12”×0.84” - **1.10”×0.83”** - 1.16”×0.86”
- RMS: 2.15 - 2.22 - **2.10** mJy/beam (In the same central region at channel 4)



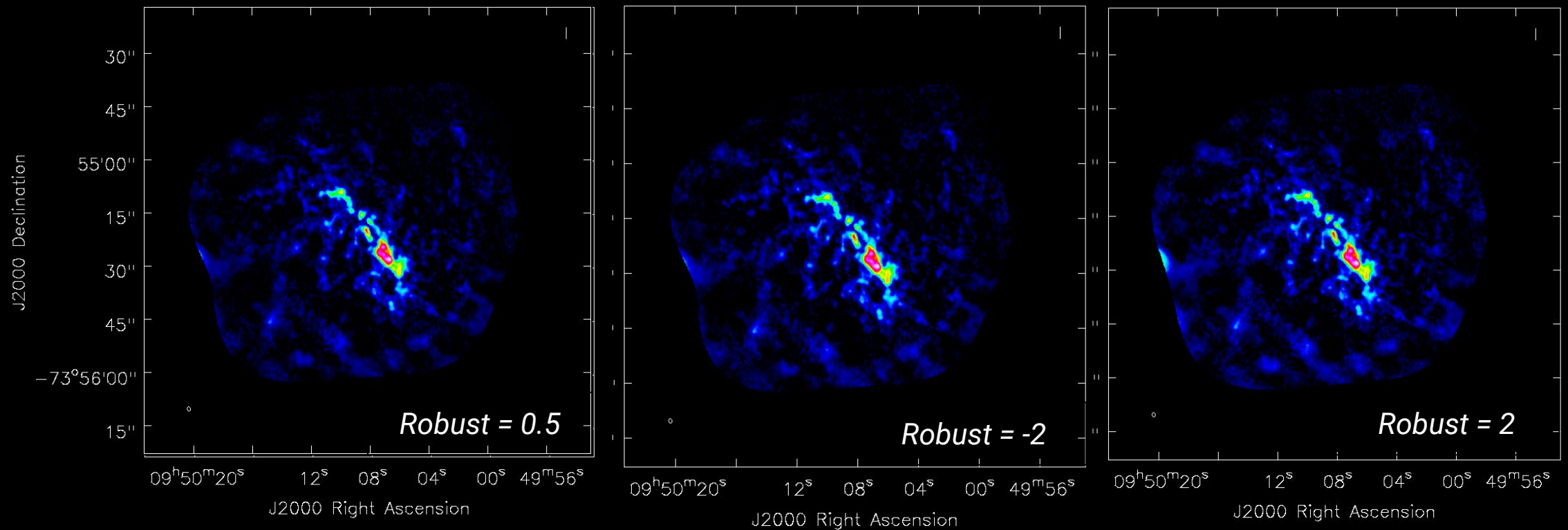
Result. *7m data imaging*

- Mom0 maps of Interactive cleaning (robust =0.5) - Auto cleaning (robust = -2 & 2)
- Beam size: 6.13”×5.48” - **5.82”×5.39”** - 6.72”X5.83”
- RMS: 7.18 - 9.28 - **6.79** mJy/ beam (In the same central region at channel 4)



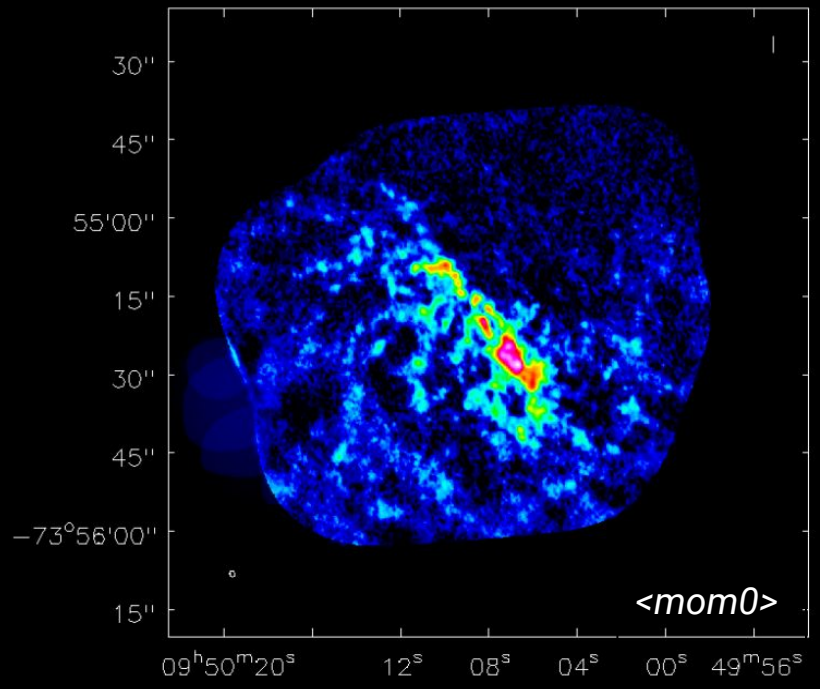
Result. *12m+7m combined imaging*

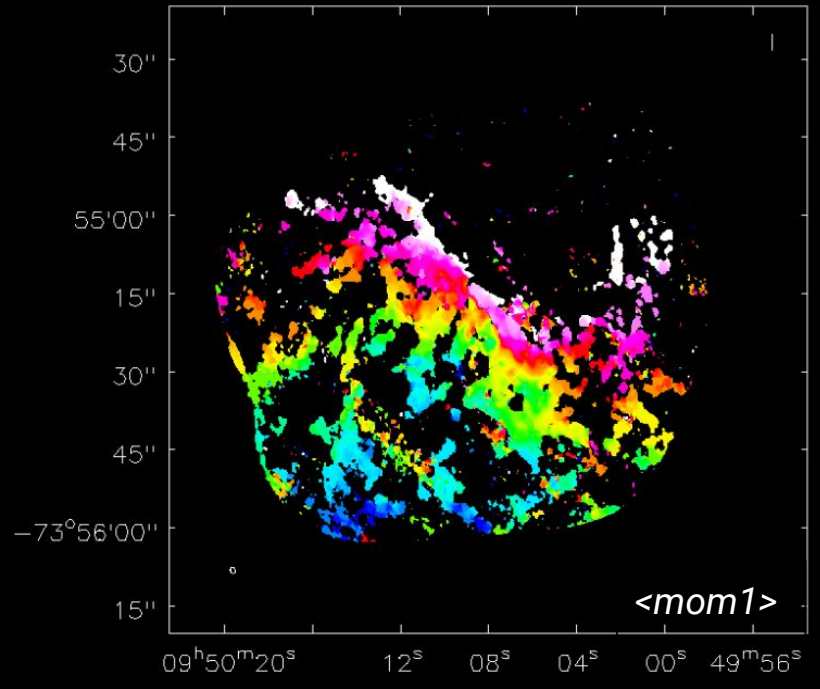
- Mom0 maps of Interactive cleaning (robust =0.5) - Auto cleaning (robust = -2 & 2)
- Beam size: 1.19”×0.90” - **1.19”×0.90”** - 1.23”×0.91”
- RMS: 2.04 - 2.12 - **2.02** mJy/ beam (In the same central region at channel 4)

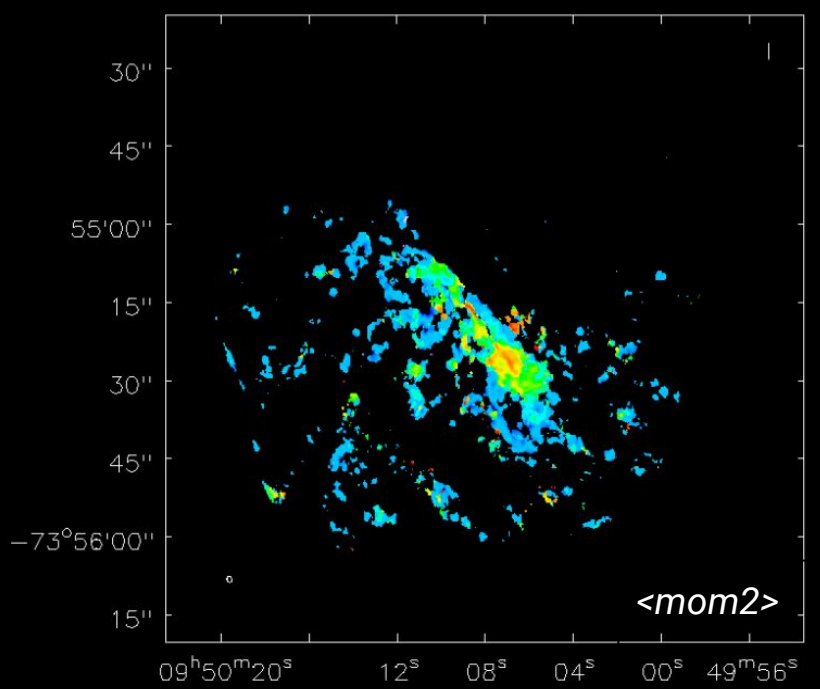


Result. *Add TP image (Feathering)*

- 12m + 7m + TP using feathering (moment 0, 1, 2 maps)

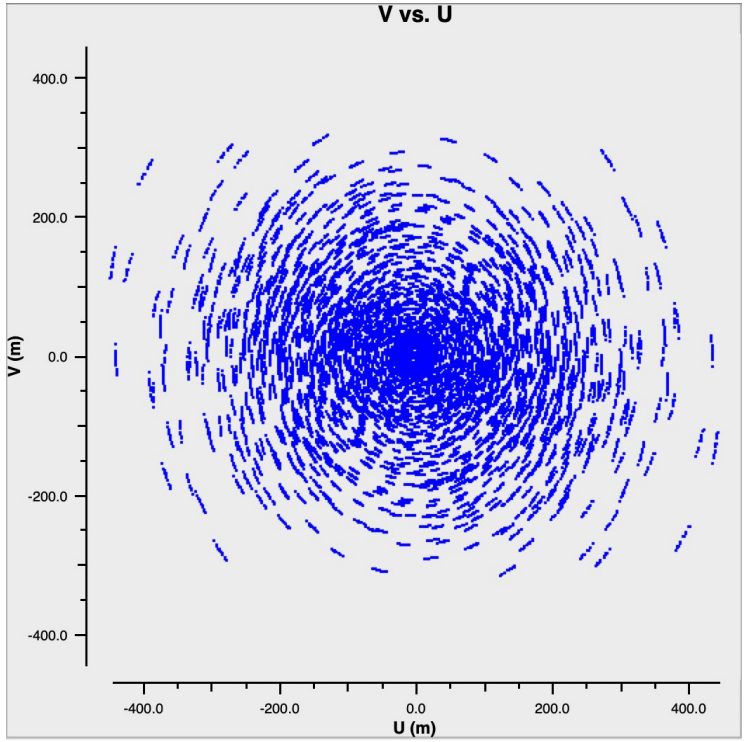


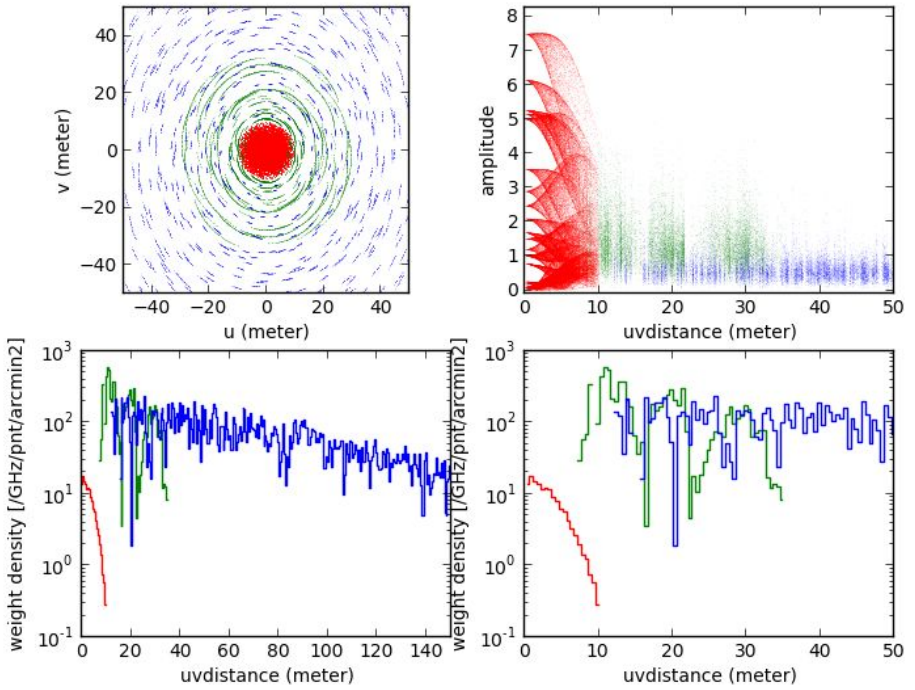




Result. *Add TP image (tp2vis)*

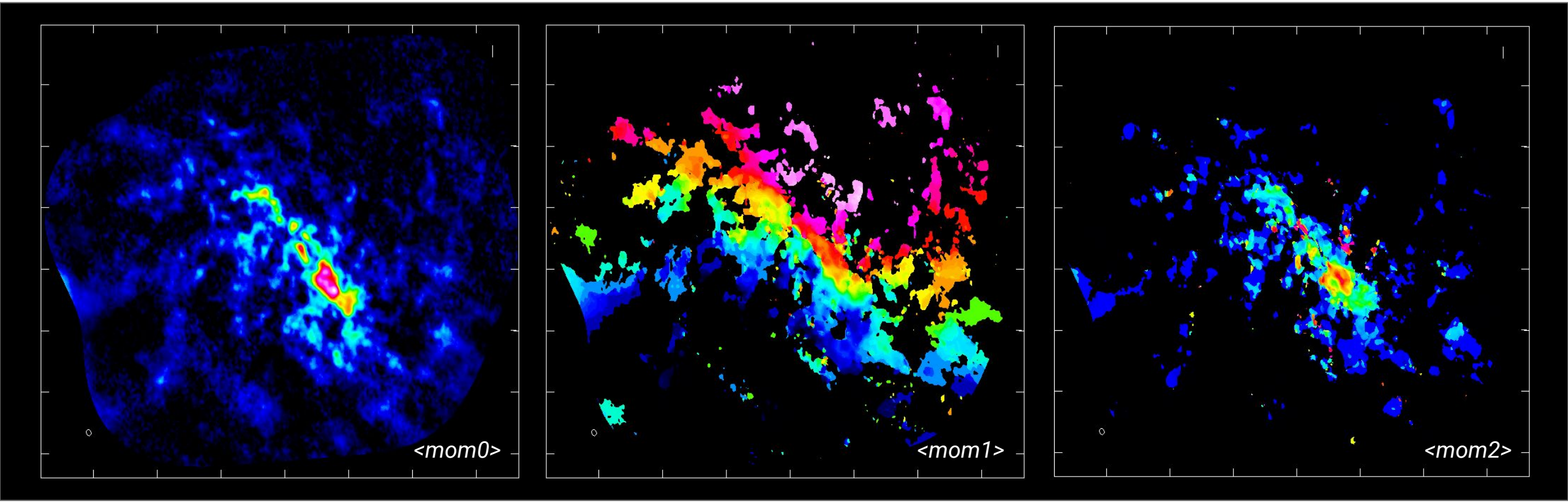
- TP is **single dish** data, which is **not** visibility measurements
- tp2vis python code → generate **mock visibility files** based on TP image *(Koda+2019)*
- By using mock ms. files, we add TP to 12m+7m dataset, and make image





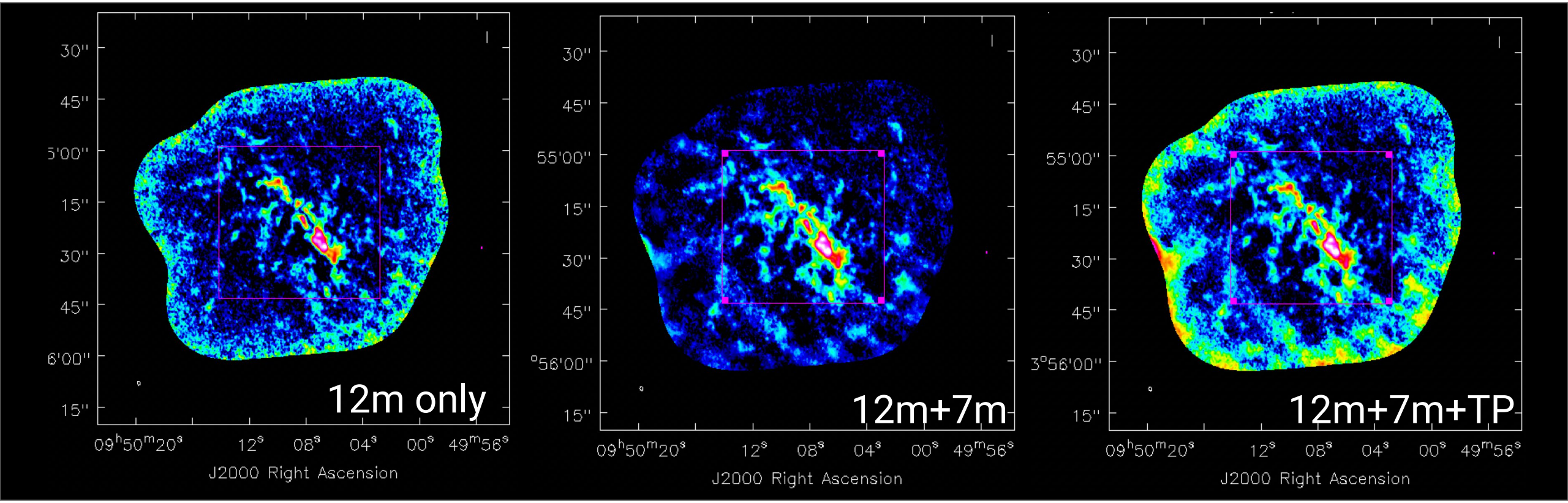
Result. *Add TP image (tp2vis)*

- 12m + 7m + TP using tp2vis (moment 0, 1, 2 maps)



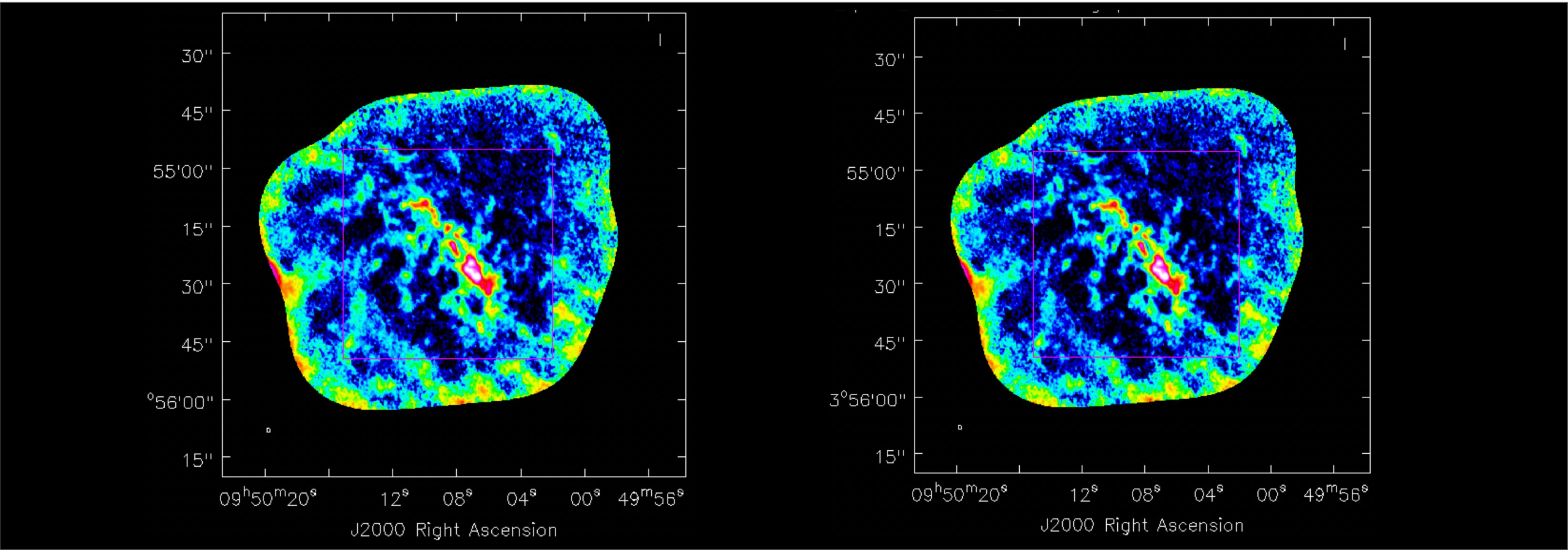
Discussion. *Why low resolution data are necessary?*

- Some emissions are extended so they can be “resolved out” in 12m data
- Mean intensity in the box: 0.36 (12m) < 0.46 (12m+7m) < 0.48 (12m+7m+TP) Jy/beam km/s



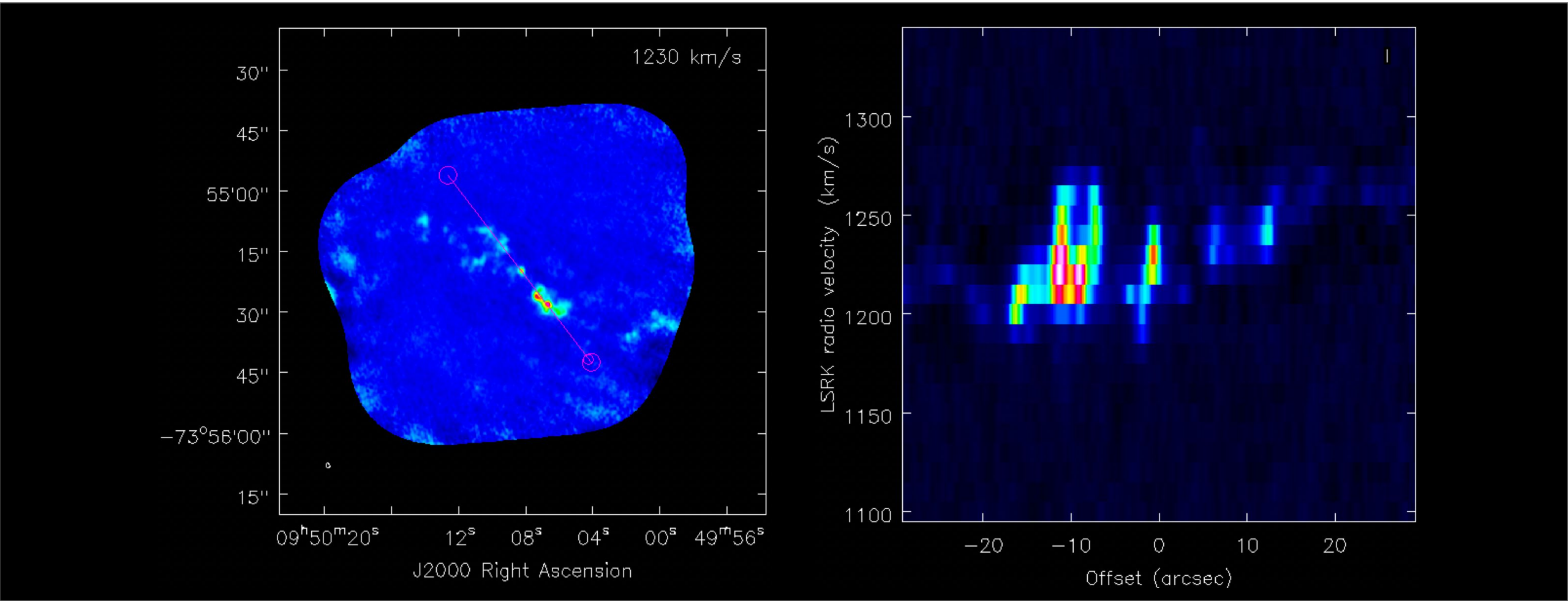
Discussion. *Feather vs tp2vis*

- Mean in mom0 maps: 0.451 (Feather) vs 0.413 (tp2vis) (unit: Jy/beam km/s)
- RMS : 2.23 (Feather) vs 2.23 (tp2vis) (unit: mJy/beam)



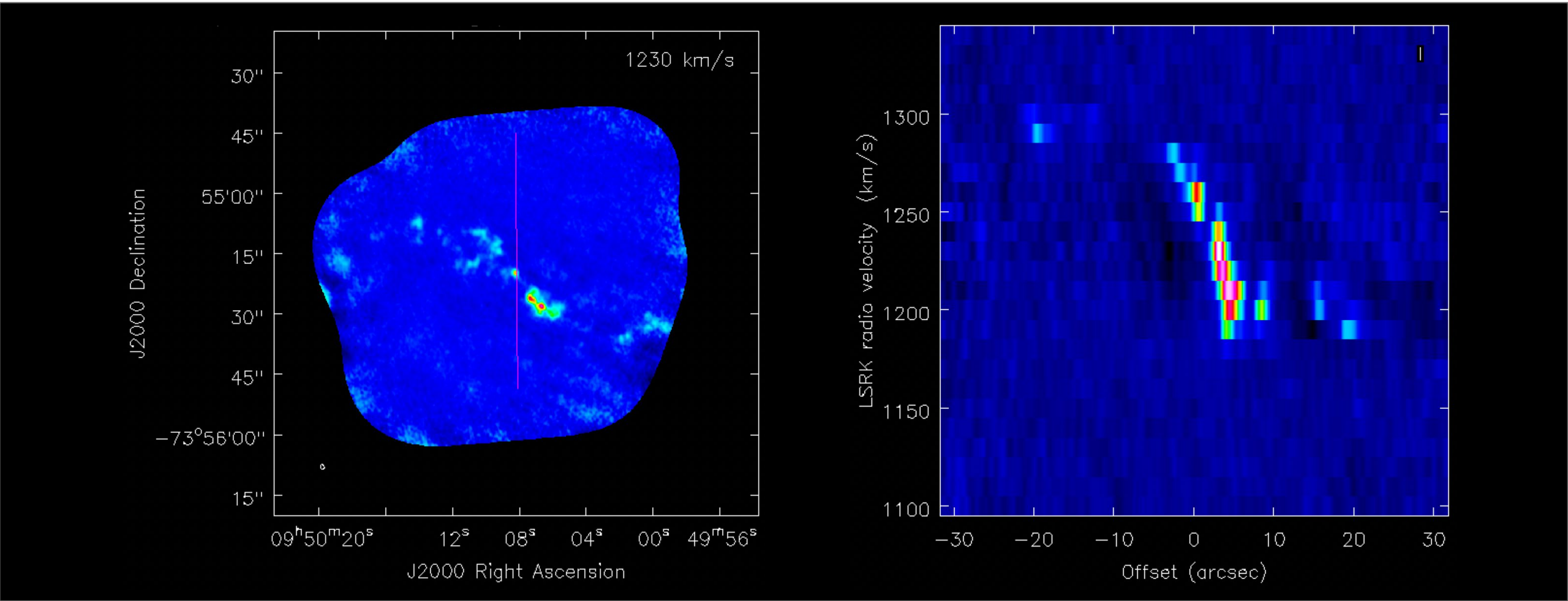
Discussion. *PV diagram*

- Kinematically disturbed region along the bar → turbulence? inflow? feedback?



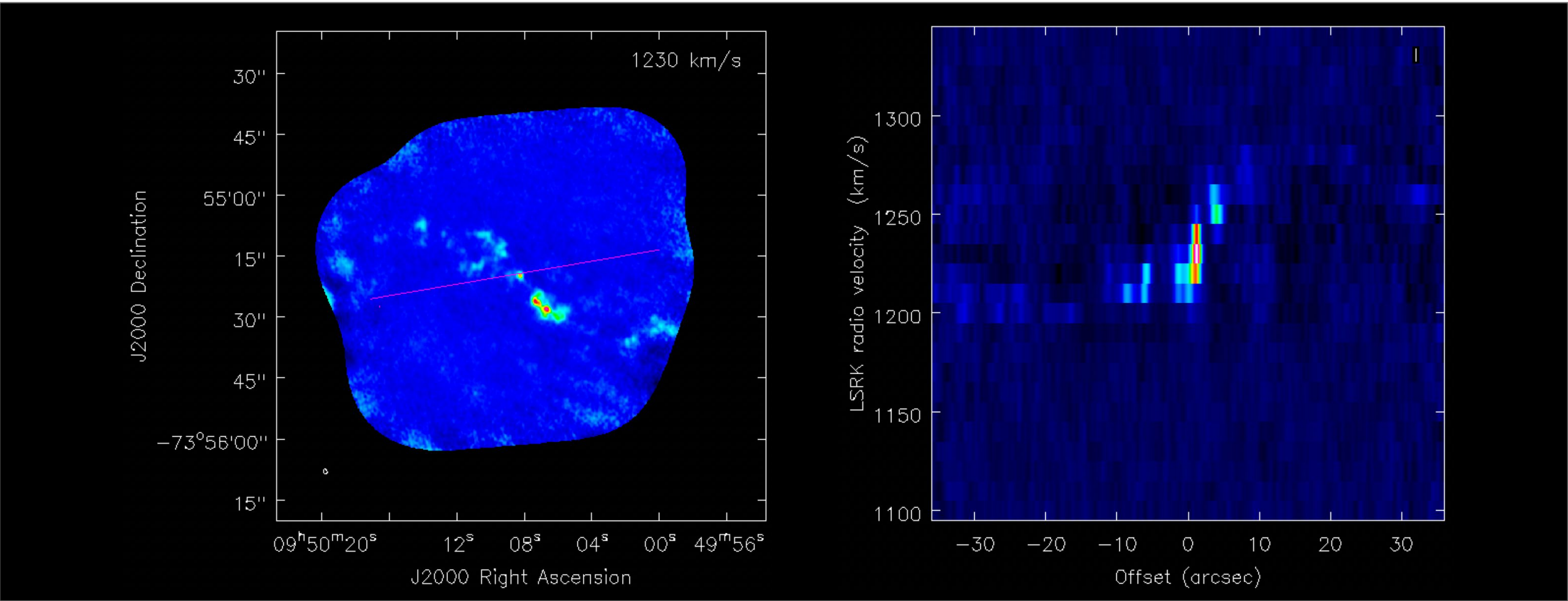
Discussion. *PV diagram*

- Following galaxy rotation



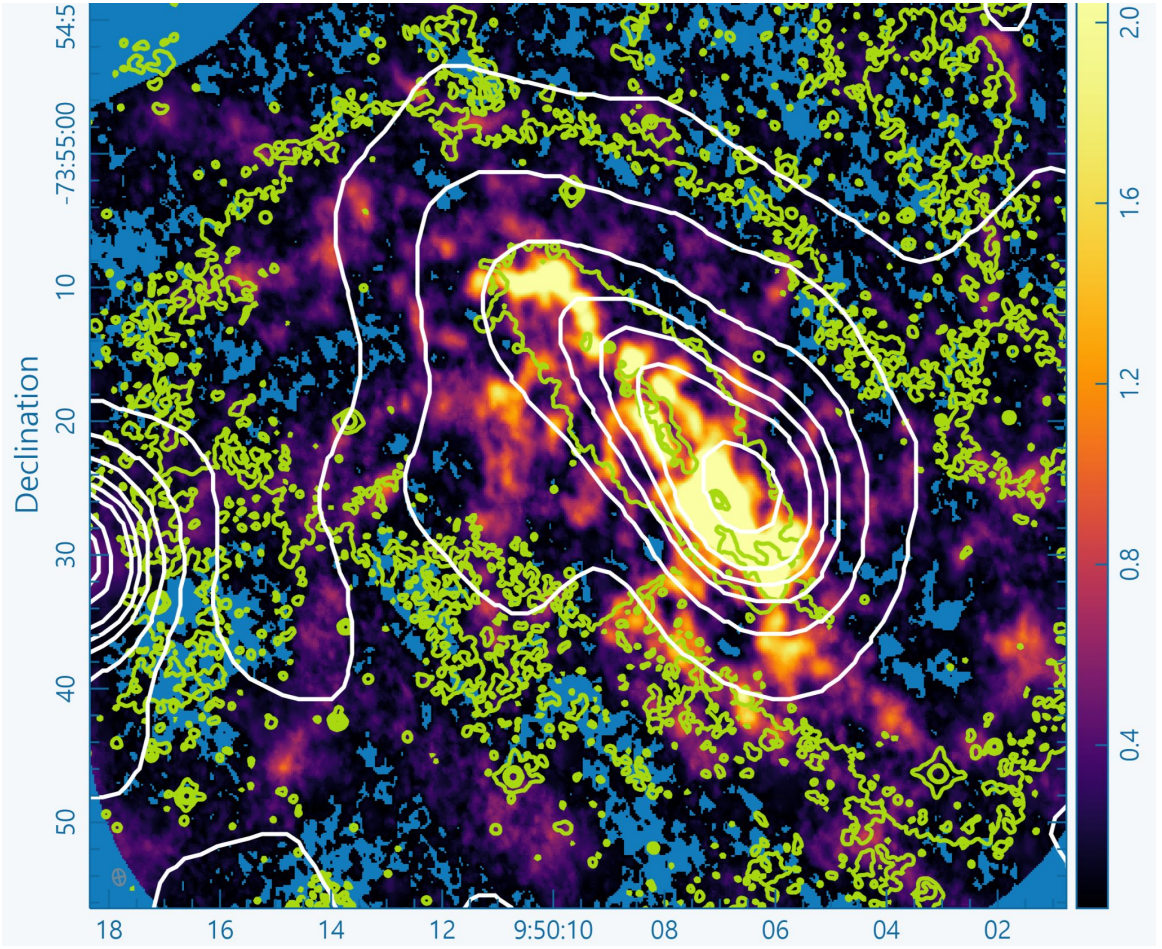
Discussion. *PV diagram*

- Following galaxy rotation



Discussion. *Overlay with Multiwavelength Images*

- ALMA CO mom0 + MeerKAT 1.28GHz (White) + HST (Light green)
- HST ~ stellar light / MeerKAT ~ synchrotron from supernova remnants (i.e., SF region)
- Cospatial component in ALMA & MeerKAT
  → SF region has a large cold gas reservoir
- Stellar emission is not bright in CO-bright region
  → strong dust extinction?

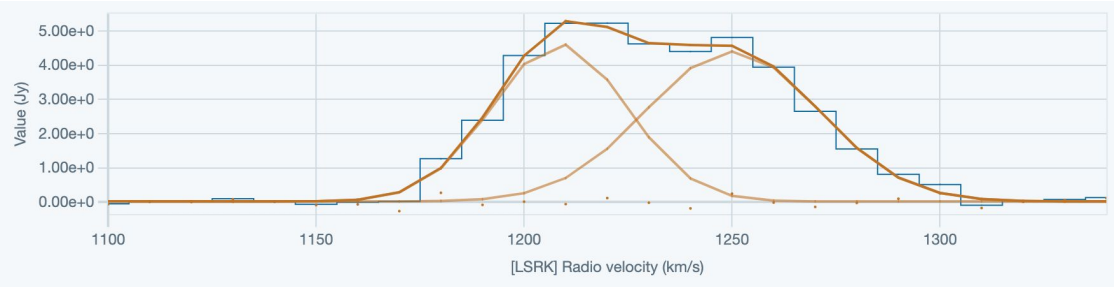


Discussion. *Molecular Gas Mass (M_{H2})*

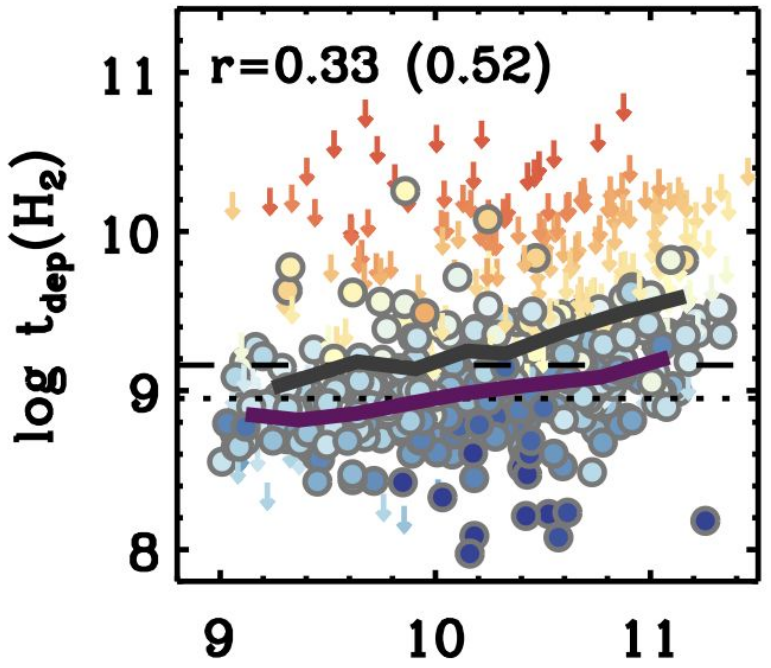
- Double Gaussian fitting using CARTA
- Total flux: 186 + 229 = 415 Jy km/s

$$L'_{\mathrm{CO}} = 3.25 \times 10^7 \, S_{\mathrm{CO}} \, \Delta v \, \nu_{\mathrm{obs}}^{-2} \, D_{\mathrm{L}}^2 \, (1+z)^{-3}.$$

(Solomon & Vanden Bout 2005)



- $M_{H2} = \alpha_{CO} \, L'_{CO} = 7.1 \times 10^8 \, M_\odot$ (α_{CO}=4.3)
- Smaller than literature ($2.4 \times 10^9 \, M_\odot$, Neumann+2023)
  - Due to CO emission outside the image?
- Gas depletion time (M_{H2}/SFR) ~ 0.29 Gyr
  - Lower than typical SFGs, but it can increase if we use full data



xCOLDGASS (Saintonge et al. 2017)

Q & A