Array combination workshop:

Hands-on sessions

Bologna, Italy

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NAASC
NORTH AMERICAN ALMA SCIENCE CENTER

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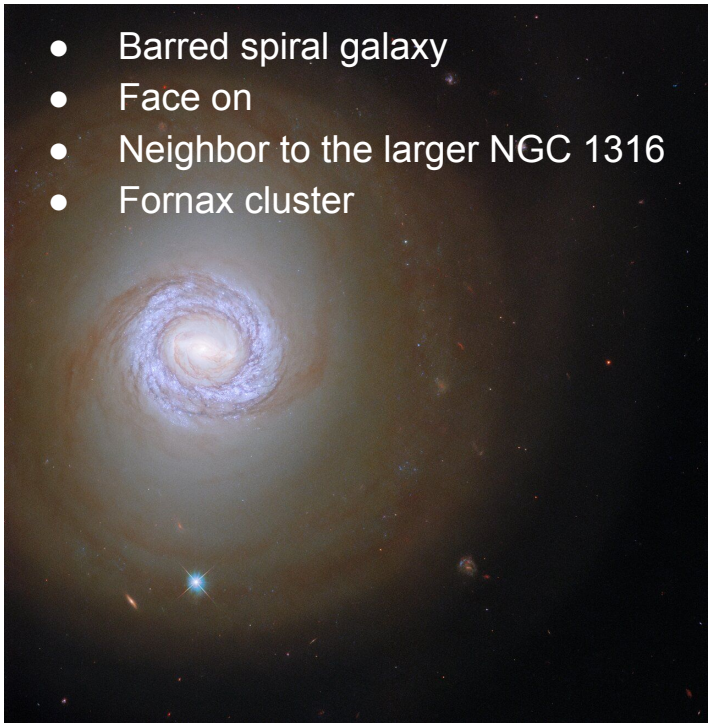
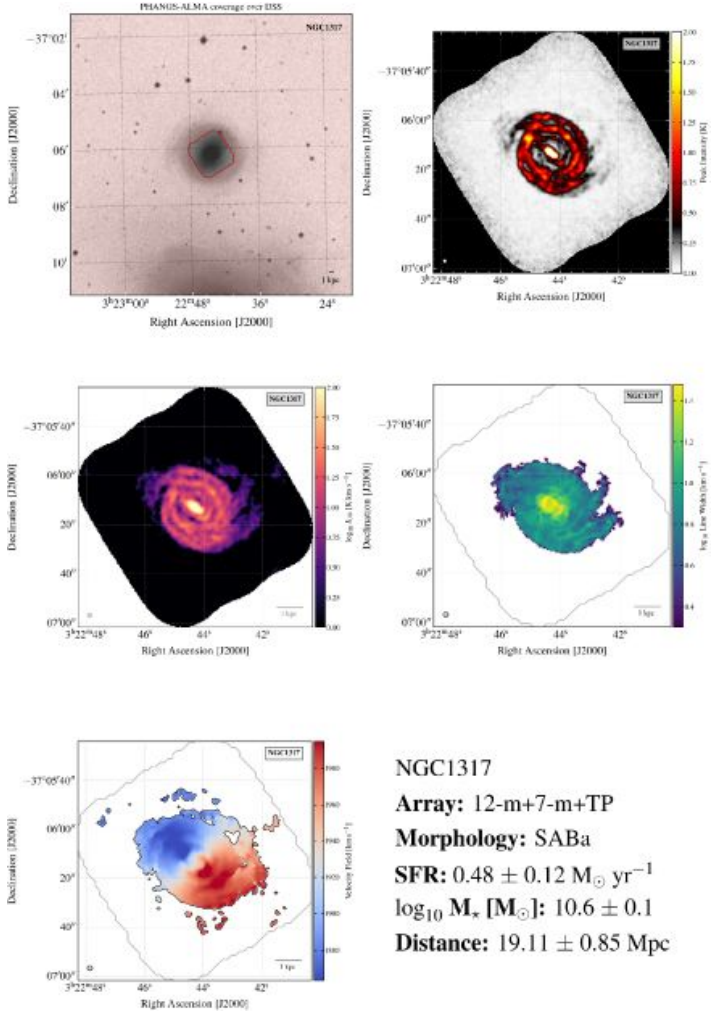
About the source: NGC 1317



- Barred spiral galaxy
- Face on
- Neighbor to the larger NGC 1316
- Fornax cluster

ESA/Hubble & NASA, J. Lee and the PHANGS-HST Team



Leroy *et al* 2021 *ApJS* 257 43

Phangs

presents

About the project: PHANGS-ALMA, 2017.1.00886.L

Team webpage

Data on the ALMA Science Archive

PHANGS-ALMA data release on CANFAR

Relevant survey papers:

Leroy et al 2021, ApJS, 255, 19 *PHANGS-ALMA Data Processing and Pipeline*

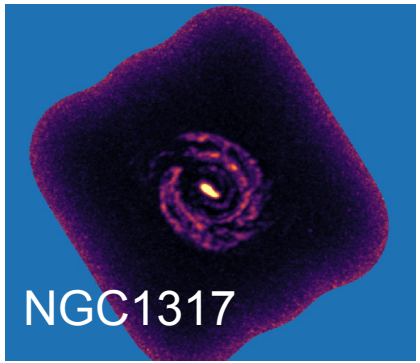
Leroy et al 2021 ApJS 257 43 *PHANGS-ALMA: Arcsecond CO(2-1) Imaging of Nearby Star-forming Galaxies* (covers the CO J=2-1 used here)

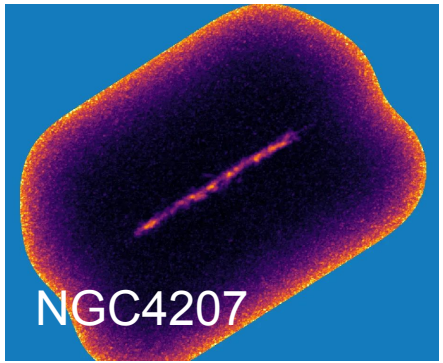
MANY more publications from this collaboration

How I chose the target (NGC1317)

This might be helpful to understand as you help users/collaborators/yourself with other data combination challenges.

- Relatively small mosaic (23 pointings with 12m array)
- Bright CO emission with different features seen in 12m, 7m and TP images
- Quite beautiful already in the ALMA Science Archive previews!
- NGC4207 is another option we may look at.





How I prepared the data for this workshop

Baselines	Split	Concat	Mosaic	Image
Check on baselines, in case you eventually want to split some of them out (e.g. to save space, highlight certain structures).	Select the SPW that you want. Average over 20 channels (to make it smaller). Do this for all 3 EBs of 12m data, and 7m data.	Concat the 12m EBs into a single measurement set.	Check on the mosaic pattern for each dataset.	Do a quick tclean (niter=0) of the 12m data and 7m data. Determine some tclean parameters (i.e. imsize, cell, start, nchan, phasecenter)
% au.getBaselineStats	% split	% concat	% au.plotmosaic	% tclean

About the data that we will use for imaging

You should have already downloaded all the files uploaded here (Google drive link)

DC2024datasets.tar

→ DC2024datasets/

2017.1.00886.L_**12m**/uid___A002_Xd9668b_Xd4/concat12m.ms/

2017.1.00886.L_**7m**/uid___A002_Xc53e4e_X2579/uid___A002_Xc53e4e_X2579.ms.split/

member.uid___A001_X1284_X2889.NGC1317.spw17.I.**sd**.im.fits

TP data

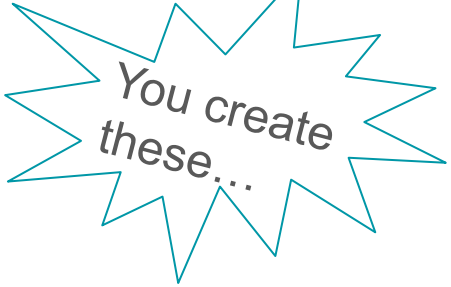
This version came from the PHANGs collaboration

tpfits = tpdir+'ALMA_TP.NGC1317.CO21.image.VLSRK.fits'

if you don't have this one, use the one from the ALMA Science Archive:

tpfits = ‘member.uid___A001_X1284_X2889.NGC1317.spw17.I.sd.im.fits’

About the images we will use for assessment



imagefits/

NGC1317_12m7m_CO.image.fits

NGC1317_Feather_CO.image.fits

NGC1317_MACF_CO.image.fits

NGC1317_sdint_sdgain1.joint.cube.image.fits

NGC1317_TP_CO.regrid.imt.depb.fits

NGC1317_12m7m_CO.image.sm.fits

NGC1317_Feather_CO.image.sm.fits

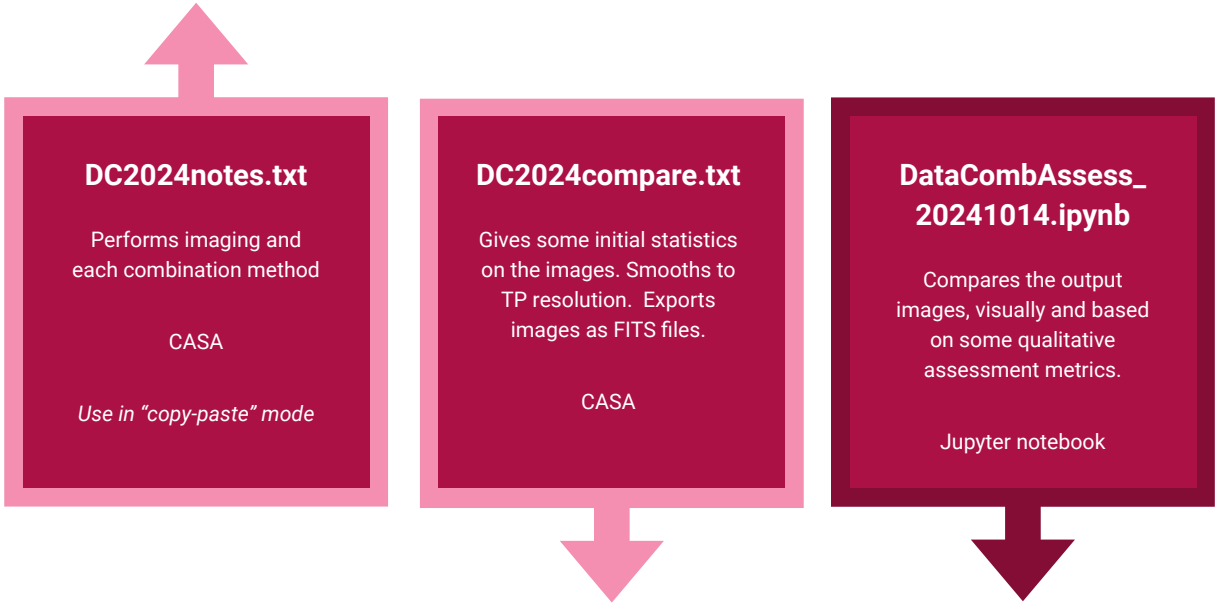
NGC1317_MACF_CO.image.sm.fits

NGC1317_sdint_sdgain1.joint.cube.image.sm.fits

^^ images created in DC2024notes.txt, and then into FITS in DC2024compare.txt

^^ created in DC2024compare.txt

About the scripts that we will use



Overview of steps for the tutorials

Wednesday

Look through script

Generate the 12m + 7m image

Imaging the interferometry data

CASA: DC2024notes.txt

Thursday

Run combinations

Feather
(look for "### FINALLY, run feather.")

Model-assisted clean with Feather

SDINTIMAGING

CASA: DC2024notes.txt

Friday

Assessments

CASA: DC2024compare.txt
Python: DataCombAssess_20241014.ipynb

Important messages to keep in mind

An aim for this workshop, from my perspective, is to provide guidance and open the conversation about the best ways to support you, your collaborators, and the community when combining ALMA interferometry and SD data.

An ideal outcome is to take home working scripts that can serve as a template.

We may find some bugs, or room for improvement, in some of the scripts. **Please let everyone know what you find!**

I was (possibly) selected to give this tutorial because mine is the first name on the paper **"Data Combination: Interferometry and Single-dish Imaging in Radio Astronomy"** by Plunkett, Hacar, Moser-Fischer, Petry, et al. (2023). It was truly a TEAM EFFORT, so I am by no means the sole expert with ALL the answers. We'll work together 😊

First steps

Find the data

Find the file “DC2024notes.txt”

Update paths to the data files

“Copy-paste” the lines of the script

Hopefully finish with the first set of TCLEAN(s)

We’ll orient ourselves to the rest of the script while it runs.

Next steps

Finish DC2024notes.txt

Run commands in DC2024compare.txt (especially exportfits)

With the FITS files, start the assessment in DataCombAssess.ipynb

Questions and follow-up

- In 12m+7m TCLEAN, we are using briggsbwtaper, robust=0.5. Would it be better to use natural weighting?
  - George will try natural weighting to test it out.
- Difference between briggsbwtaper (experimental?) and briggs
- Do we correct TP by BL primary beam before or after feather?
- Should we use the 12m + 7m primary beam, or the 12m primary beam image?
- A lot of discussion on whether “model assisted clean” is changing the model, adding flux, identifying the mask, etc. And especially, whether this is conceptually correct.
- Sdfactor in feather – is it scaling the flux, or the weights?
  - It is scaling the flux. On the other hand, sdgain (in sdintimaging) scales weights based on relative noise in the two images.

Identified issues

- If CASA crashes on the first TCLEAN, it might be because in versions 6.5.4 and 6.6, it seems to handle the "empty" SPW identification differently. Remember, there are 3 EBs of the 12m data, and 1 EB of the 7m data. It seems that the SPWs are being assigned differently. In such a case, you might need to run MSTRANSFORM on your 12m measurement set. The script works for 6.6 (even though we told you 6.5.4, sorry!)
  - mstransform(vis=myvis12,datacolumn='all',combinespws=True,outputvis=myvis12+'.new')
- If you get a similar error/crash with SDINTIMAGING, then it's related. Again, you should have used mstransform.
- You can reduce 'growiterations' in TCLEAN to speed up the imaging.
- IF the rest frequencies don't agree, then use:
  - imreframe(imagename=tpim, output=tpim+'.reframe', restfreq='230.538GHz')
- In sdintimaging, you may need to clean deeper.
- In DataCombAssess.ipynb, make sure that the "units" package is imported (it might be missing, oops).
  - from astropy import units as u

Lessons from Day 1-2

- We already managed to crash CASA in ~50% of cases. And we did it with a “simple” task like TCLEAN. The error message doesn’t always help. It’s usually due to datasets not being aligned somehow (spatial or spectral)
  - listobs
  - Mstransform
- Some chaos is welcome. More chaos is when it’s time to reconvene.

Lessons from Day 3

- You don’t *have* to do assessment in K, but you should make sure units are equal (and not in terms of different beams)
- The “banana” shape in the spectrogram at edge channels might be due to noise in those channels, so it doesn’t necessarily mean that the result was “bad”.
- Lots of discussion about MACF – maybe it’s more complicated than this ;-)
- In addition to comparing resulting images with TP image (as “reference” image), also compare flux of small-scale emissions by comparing with simulated observations with same uv-coverage.