RM-SYNTHESIS DEMO

Marco Iacobelli (ASTRON)

LOFAR Data School, 21st Sept 2018

Overview

- Tutorial topics
  - General notes about RM-synthesis code
  - Input data preparation & inspection
  - Output data inspection
- Tutorial goals
  - Inspection of input/output data
  - Editing (both manual and automatic) of imaged data
  - Setup of an RM-synthesis run
  - Wide field imaging of data

CEP3 login and usage

- 6 working nodes reserved: lof006 lof010 lof012 lof[015 016 017]
- 25 active user accounts: lods01...lods27
- 1 active reservation with id=lofar_school2018_114
- Work in couples!
  - Username=lodsXX | working node=lof0XX
  - Accounts from lods01 to lods05 => lof006
  - Accounts from lods06 to lods10 => lof010
  - Accounts from lods06 to lods10 => lof012
  - Accounts from lods11 to lods15 => lof015
  - Accounts from lods16 to lods20 => lof016
  - Accounts from lods21 to lods25 => lof017

Log in to the LOFAR portal: **> ssh -Y lodsXX@portal.lofar.eu**
Log in to the head node: **> ssh -Y lodsXX@lhdhead.offline..lofar**
Activate a dummy session using the reservation id and the your node:
srun -A lofar_school2018 –reservation=lofar_school2018_114 -N 1 -w lof0XX -u bash -i

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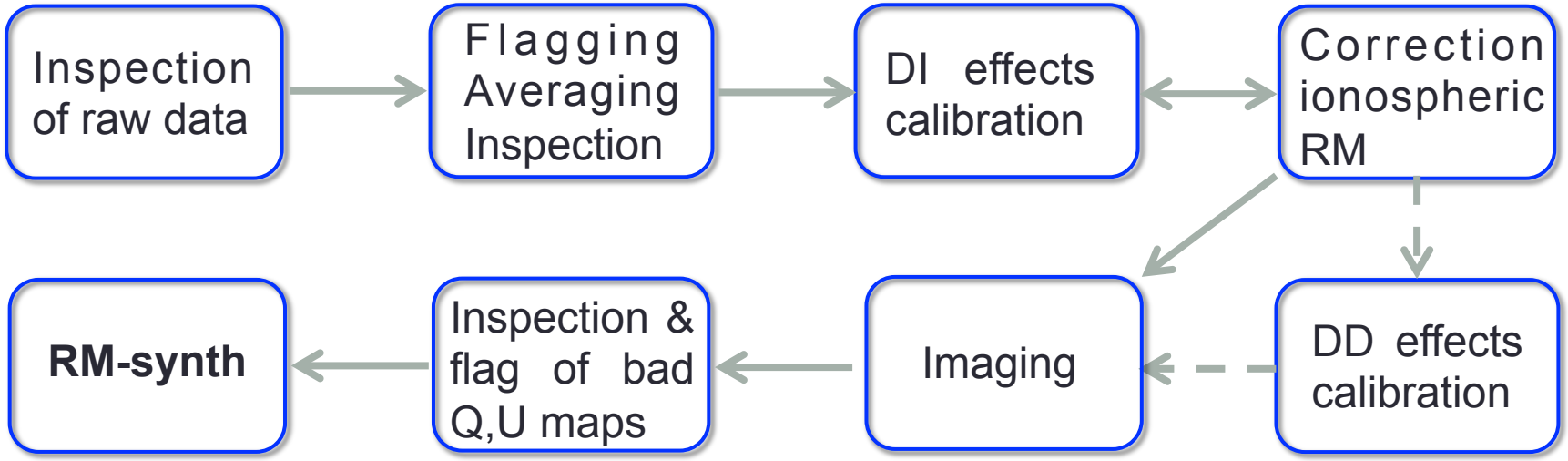
Now, open a new terminal tab (keep the previous one open too!) and type: **> ssh -Y lodsXX@portal.lofar.eu**
> ssh -Y lodsXX@lhdhead.offline.lofar
> ssh -Y lodsXX@lof0XX

- Verify that graphics forwarding works: **> geany**

Input data preparation

- How to get there . .



Input data preparation

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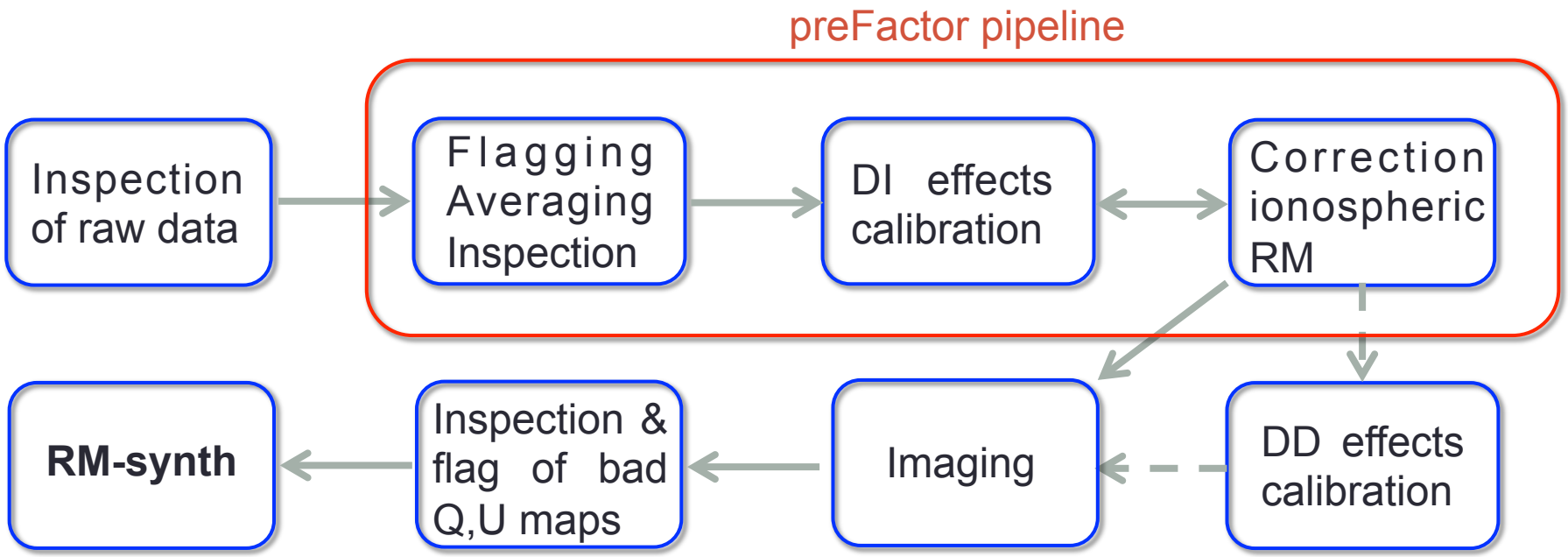

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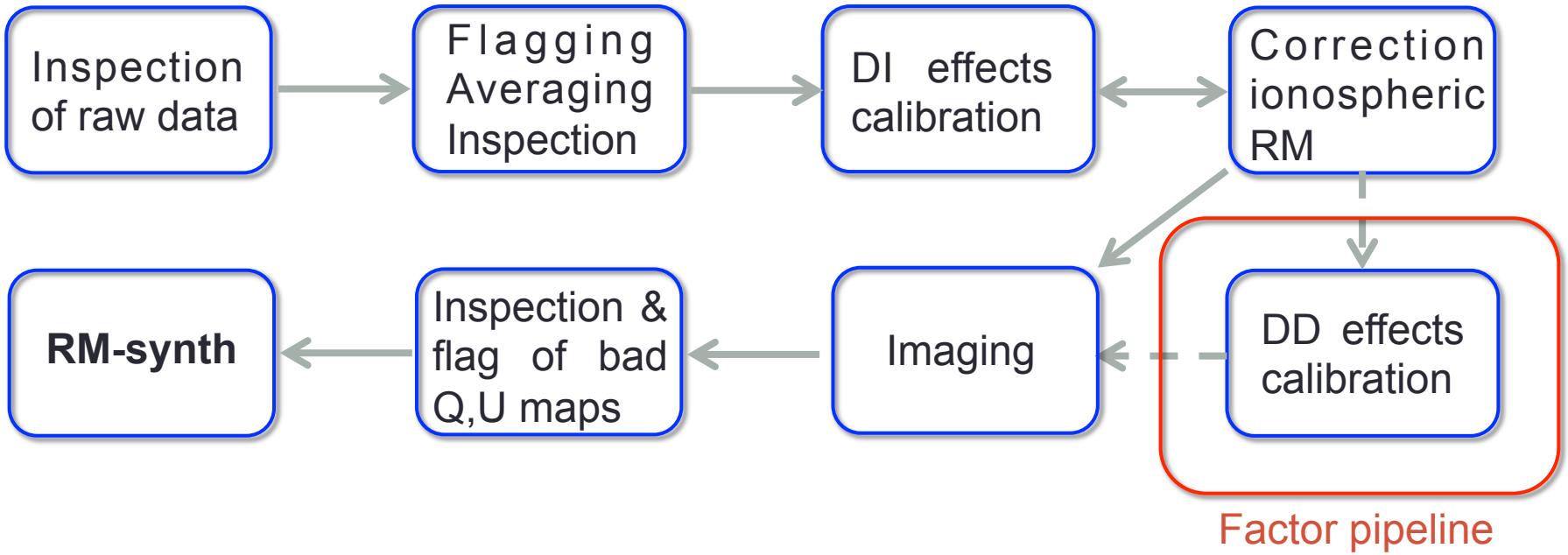

Input data preparation

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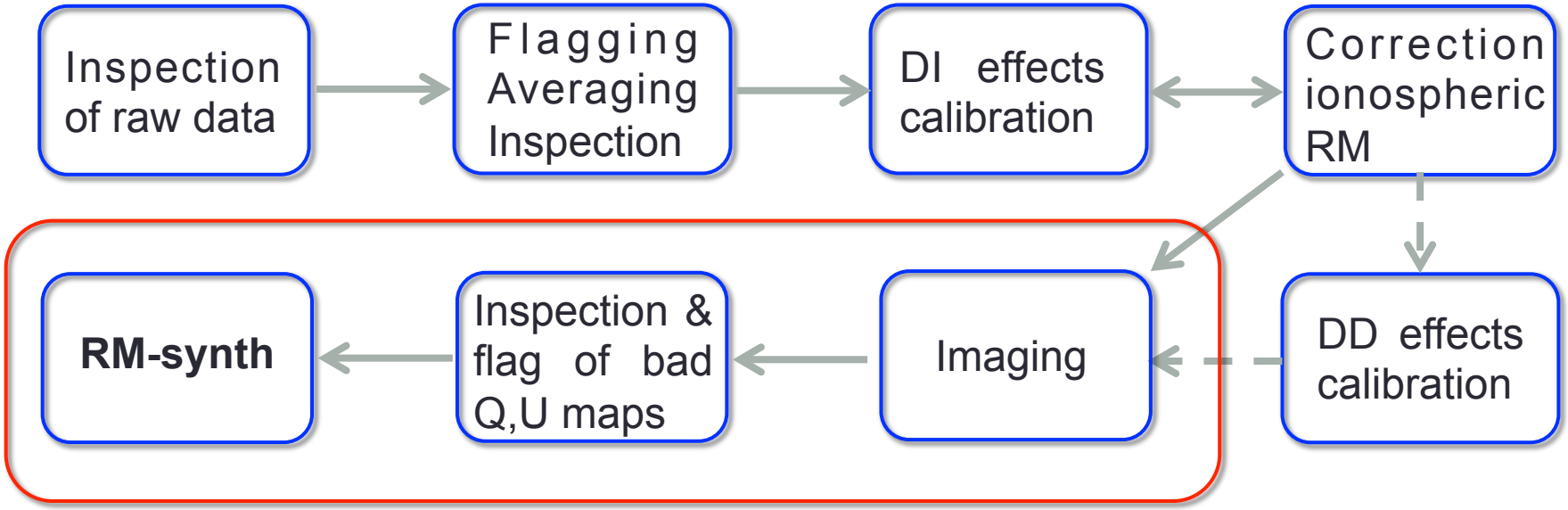


Input data preparation: imaging

- See imaging lecture L9 and tutorial T4
  - Which Stokes parameters ? **I Q U V**
  - Which parameters ? Npix, cellsize, pol clean

  - Simplest way, a single parameter with no polarization cleaning

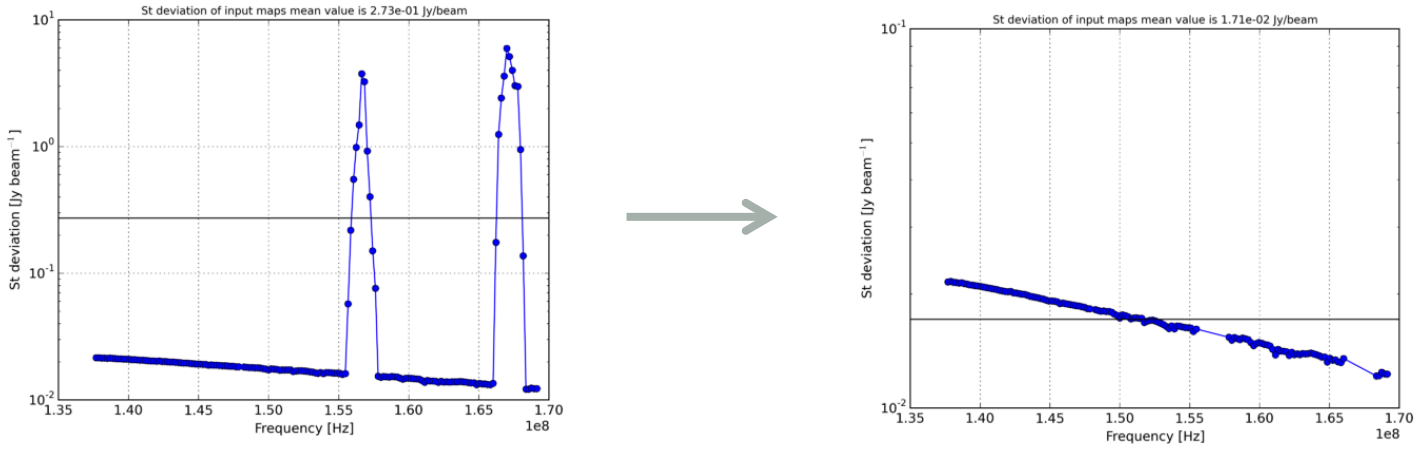
> wsclean –name 10_deg_SB221_StokesU -size 1200 1200 -scale 30asec -weight briggs 0.0 -pol U -niter 0 -threshold 0.005 -mgain 0.8 -beamsize 165asec ../L123685_SB221_uv.DPPP.postionRMcorr

  - Cleaning is performed in sum over channels of Q_ch^2 + U_ch^2. When doing RM-synthesis, this is the most sensible option.

> wsclean -pol QU -join-polarizations -join-channels -squared-channel-joining -channels-out 100 ...

Input data preparation: inspection

- Flagging of bad maps
  - Removal of **Q U** maps with anomalous variance is an option
  - Which Stoke parameter refer the plots below ?
  - Why a non flat variance ?



- Weighting of maps
  - Assign a weight to each **Q U** maps based on the inverse of their variance is also an option

General notes about pyrmsynth code

- Several software tools available. In this tutorial we will use some of the main software tool developed for LOFAR and low frequency data processing
  - https://github.com/mrbell/pyrmsynth A package that performs fast RM Synthesis and RM CLEAN imaging while still providing the flexibility of a Python interface.
  - The code works on sets of FITS files.
  - Each FITS file contains images from a single sub-band, or some other subset of the observed frequencies.
  - As a default, the code assumes all Stokes parameters (IQUV) to be saved in one FITS file. However it can also handle separately saved Q and U FITS files.
  - Collect all FITS files in a directory so the software will read them all in, stack them into a single data cube, and perform RM synthesis along each line of sight.

General notes about pyrmsynth code

- Command-line tool, input as a parset, output as feedback on screen.
- To source main software packages, type:

  > module load lofar

  - Which packages you loaded ?

  > python rmsynthesis.py rmsynth.parset

```
[iacobelli@lhd001]$ python pyrmsynth.py -h
Usage: rmsynth.py <input parameter file>

Options:
  --version             show program's version number and exit
  -h, --help            show this help message and exit
  -p, --plot_rmsf       Plot the RMSF as soon as it is computed.
  -V, --stokes_v        Produce a Stokes V cube after reading the fits files.
  -s, --separate_stokes
                        Indicate that the Stokes Q and U input images are
                    stored in separate FITS files.
  -f, --freq_last       Indicate that NAXIS4 is the frequency axis.
  -r, --rest_freq       Indicate that the frequency for an image is given in
                        the RESTFREQ header keyword.
```

General notes about pyrmsynth code

- How to set it up

Useful to focus on objects

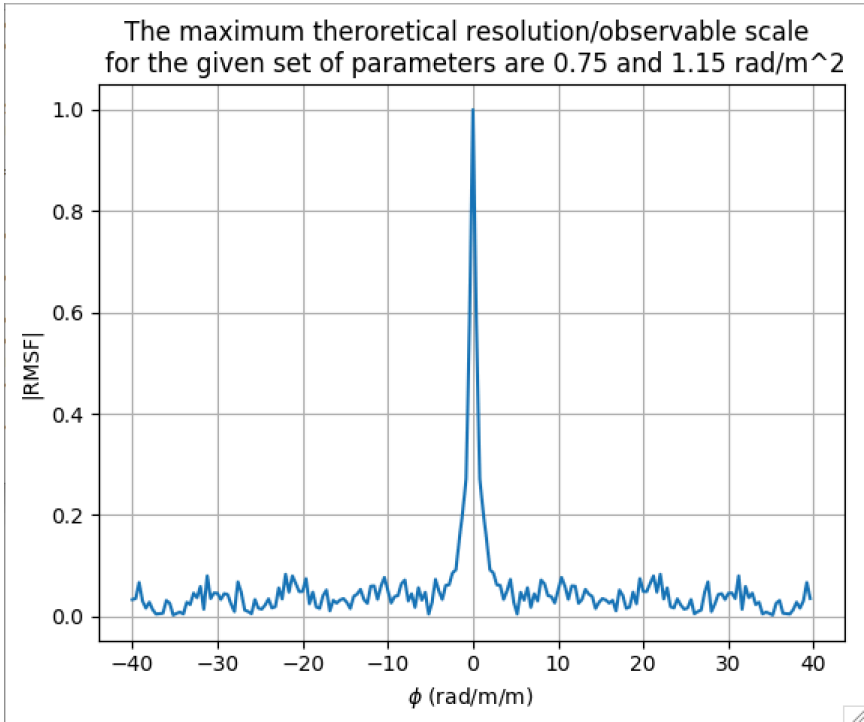
Useful to speed up runs

Useful to optimize S/N

```
% parameter file for rmsynthesis python code
% capable of running standard RM Synthesis as well as RM Clean

% Parameter file format:
% Comments can be added on their own lines, starting with a %, this must be followed by a space
% Parameters are given as keyword value pairs, with spaces as delimiters

% ra and dec min and max of the subimage to process, given in pixels
% a value of -1 means to use the bound of the image
dec_min -1 %200
dec_max -1 %400
ra_min -1 %200
ra_max -1 %400

% Define the phi axis, dphi in rad/m/m
phi_min -25 %-100
nphi 100 %200
dphi 0.25 %1

% Mask file. Pixels with non-zero values in the image will be used for RM Synthesis
% Comment the following line out if you don't wish to use a mask
% Mask image must have the same number of pixels as the Stokes-Q and U images
% irrespective of the ra, dec min and max values. The mask file should be
% located in the input_dir
%imagemask ./mask.fits

% Clean parameters. gain is the loop gain, niter is the number of clean iterations,
% cutoff sets the value of the max of the residual image at which point the procedure stops, defined in Jy
do_clean False
gain 0.1
niter 100
cutoff 0.0001

% weighting parameter. Give the name of the weight file (located in the input_dir).
% If you leave it out, all channels will be given a weight of 1.0.
%do_weight weight.txt

% spectral index option. Give directory or global average value. If wanted,
% specify reference frequency.
% alpha 0
%ref_freq

% Detection threshold on polarized intensity map
%threshold 0.1

% output file
outputfn /data/scratch/iacobelli/M33_DATA_CSonly/RMSYNTHESIS/
% directory where the input fits file can be found
input_dir /data/scratch/iacobelli/M33_DATA_CSonly/RMSYNTHESIS
```

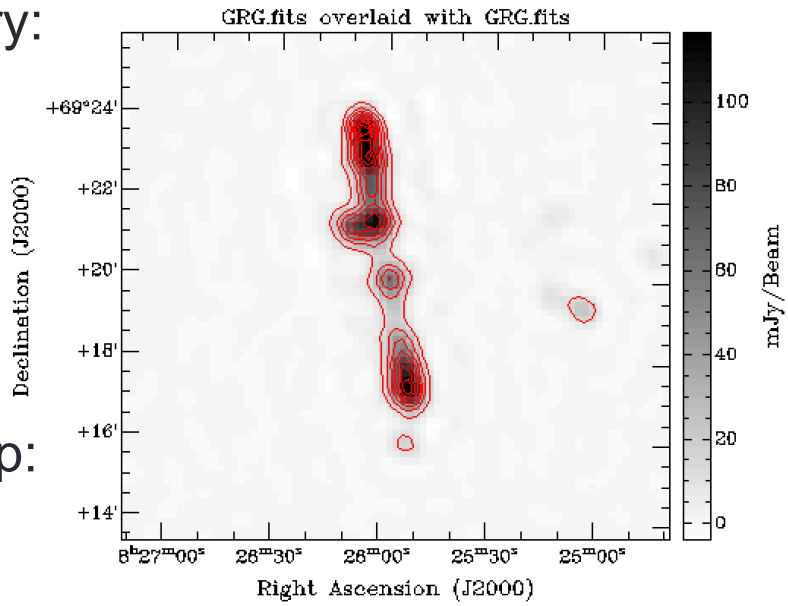
Running RM-synthesis

- Data and scripts are in /home/iacobelli/RMDEMO so first make your working directory and enter it:
  - **> cd /data/scratch/lodsXX**
  - **> python myrmsynth.py -p -s rmsynth.par**
  - While running a few useful outputs are saved and displayed:
    - the maximum theoretical resolution
    - the maximum observable scale
    - the RMSF values and profile
    - How the frequency coverage affects the RMSF side lobes ?



RM-synthesis: outputs inspection

- Data are in /home/iacobelli/RMDEMO
  - Make and access your working directory:
    > cd /data/scratch/lodsXX
  - To source fits viewer packages, type:
    > module load ds9 or
    > module load karma (for kvis)
  - First let us open the target Stokes I map:
    > ds9 GRG.fits



  - Now let us check a fits cube to find the Faraday depth range selected in the experiment.
    - Check noise distributions; Gaussian for Q,U but not for PI: why ?
    - Find the instrumental polarization component and quantify it
    - Find the GRG in both RA,DEC and FD

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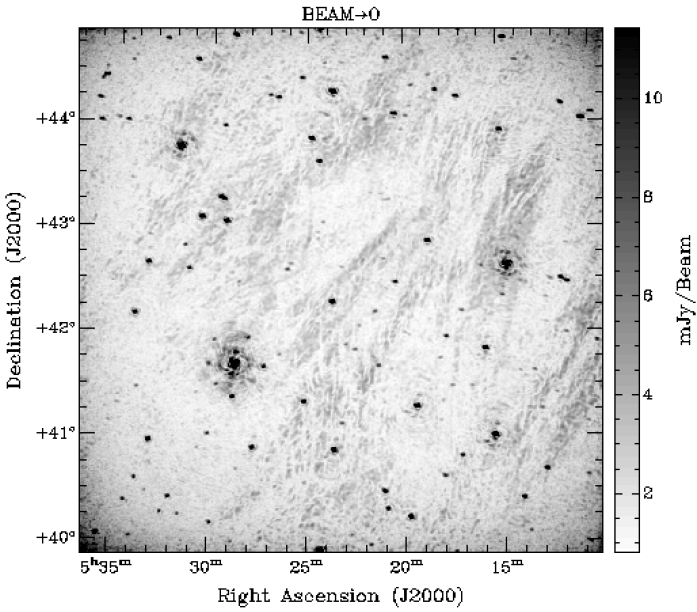

  - Collapsing RM cubes allows to portrait the content of structures in both FD and PI. Let us open a map showing the peaks of PI:
    > ds9 _polint.fits

  - Now let us check a fits cube showing Galactic foreground . .
    > ds9 _di_p.fits
    - Can you recognize how Stokes I looks like ?
    - Find the instrumental polarization component
    - Can you find any background polarized source ?

RadioNet

RadioNet has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562

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Netherlands Institute for Radio Astronomy

LOFAR