Polarized skymodels in BBS (commissioner: Carlos Sotomayor)

To carry out the following task, some subbands of the data set L23954 were used. Every subband is made up of 4 channels, each channel has a width of 45.77 KHz.

Polarized point source with an arbitrary linear polarization angle (RM=0)

For this exercise the subbands L23954_SB112-SB115 were used. Initially, NDPPP was used to create independent data sets for every channel within the subband. The format of the NDPPP parset file to split the data sets is the following:

```
msin = /data/scratch/sotomayor/taskV16/L23954_SB112_uv.MS.dppp.dppp
msin.startchan = 0  # number of starting channel
msin.nchan = 1
msin.datacolumn = DATA

msout = 3csource.ms.112.0
msout.datacolumn = DATA

steps = [preflag,squash1]

preflag.type=preflagger
preflag.corrtype=auto

squash1.type = squash
squash1.timestep = 15
```

Next, point-source-model parset files were created for every individual channel. The following is an example of the format used:

```
# 3csource.mod.112.0
# (Name, Type, Ra, Dec, I, Q, U, V, ReferenceFrequency='147978210.0') = format
3CSOURCE, POINT, 03:10:00.0, +65.30.00.0, 89.5997, 7.2886, 16.3706, 0.0
```

The Q and U Stokes values were calculated using equations (1) and (2), assuming a $33°$ polarization angle ($\chi_\circ$), and 20% of degree of polarization (p)

$$Q = pI\cos(2\chi_\circ) \tag{1}$$

$$U = pI\sin(2\chi_\circ) \tag{2}$$

The stokes I values were calculated independently for each channel (to which their central frequencies are know) following the expression given for the flux densities of point sources in the folloing link: http://www.vla.nrao.edu/astro/calib/manual/fluxscale.html

BBS was then used to fill up the MODEL column of each data set with the point-source-model provided.

```
calibrate -f --key keytest --cluster-desc ~/sub7.clusterdesc --db ldb001 --db-user
postgres /data/scratch/sotomayor/taskV16/3csource.ms.112.0.gds simulation.parset
3csource.mod.112.0 .
```
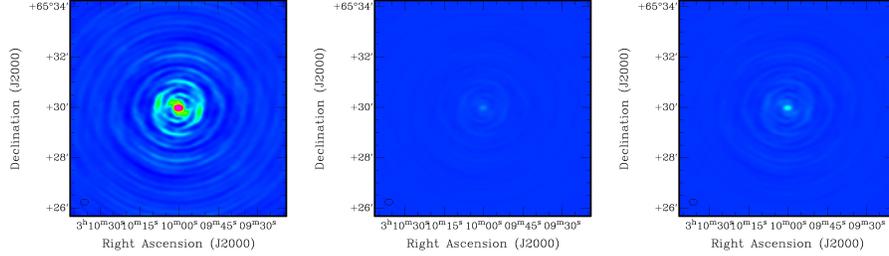
Figure 1: Stokes I (*left*), Q (*center*), and U (*right*) images of the first channel of the subband L23954_SB112.

The file that tells BBS to store the point-source-model in the MODEL column is simulation.parset. This file has the following format:

```
Strategy.InputColumn = DATA
Strategy.TimeRange = []
Strategy.Baselines = *&
Strategy.ChunkSize = 100
Strategy.Steps = [predict]
Step.predict.Operation = PREDICT
Step.predict.Model.Sources = []
Step.predict.Output.Column = MODEL_DATA
```

All the four channels of the subbands were filled up with MODEL visibilities. Before imaging, the MODEL visibilities had to be splitted to create new data sets with the MODEL visibilites only. The NDPPP file that executes the latter is:

```
msin = 3csource.ms.112.0
msin.datacolumn = MODEL_DATA

msout = 3csource.ms.post.112.0

steps = [flag1]
flag1.type=madflagger
flag1.threshold=3
flag1.timewindow=501
```

Having produced data sets with MODEL visibilities only, the final step was imaging of all four Stokes parameters. Imaging was done in CASA using the task 'clean'. In this case only I, Q, and U maps for one channel are shown in Figure (1) as the Stokes V images generated have only 0.0 Jy pixels.

In order to confirm that the polarization angle in every channel is the one initally provided, 33°, the central pixel of all the Q and U maps were used to perform the following calculation:

$$\chi = 0.5\tan^{-1}(U/Q) \tag{3}$$
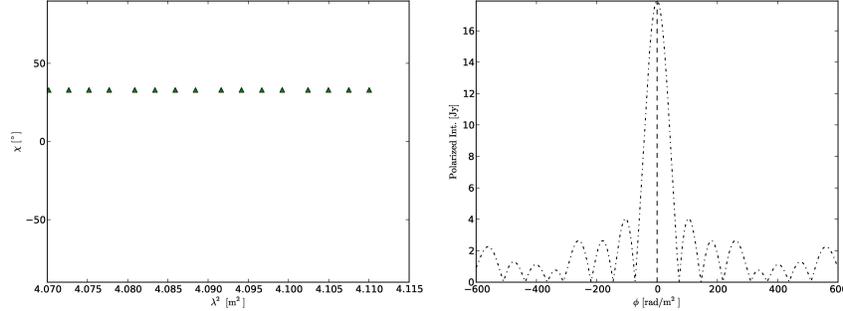
Figure 2: Polarization angles of all the 16 channels remains constant, as expected (*left*). The Faraday Depth spectrum shows one component at 0 rad/m^2 (*right*).

As shown in Figure (2) the polarization angle for all the channels, as expected, is constant, 33°. Additonaly, after running RM-Synthesis in the Q and U channels available, a peak, as expected, at 0 rad/m^2 is visible.

Polarized point source with a RM!=0

The procedure used in this case is basically the same as above. All the parset files from the previous case were used; however, in this case we assume a RM value different from 0. Therefore, the stokes Q and U values provided in the models are going to change from channel to channel. Equations (4) and (5) define this change of Q and U due to a non-zero value of RM. The subbands used in this case were 12, L23954_SB104-SB115.

$$Q = pI\cos(2(\chi_\circ + \mathrm{RM}\lambda^2)) \tag{4}$$

$$U = pI\sin(2(\chi_\circ + \mathrm{RM}\lambda^2)) \tag{5}$$

For this case a RM value of 25.5 rad/m^2 was used. After following the steps indicated in the previous case (RM = 0), it can be seen in Figure (3) that Q and U actually vary due to our input polarized point-source-models.

In order to verify that the expected variation, given by equations (4) and (5), occurs in all the channels, all the central pixel values of all the images available are ploted vs. frequency (Figure (4)).

Finally, as Q and U are changing, we expect to see also a different angle of polarization for every channel that was generated. After using equation (3), it can be seen in Figure (5) that χ is a linear funcion of λ^2; this is due to the fact that RM is constant. In Figure (5) it is also shown the Faraday Depth spectrum produced using the 48 sets of Q and U images. It is clear that only one component is present in the spectrum and that this falls exactly in the value expected and given, 25.5 rad/m^2.

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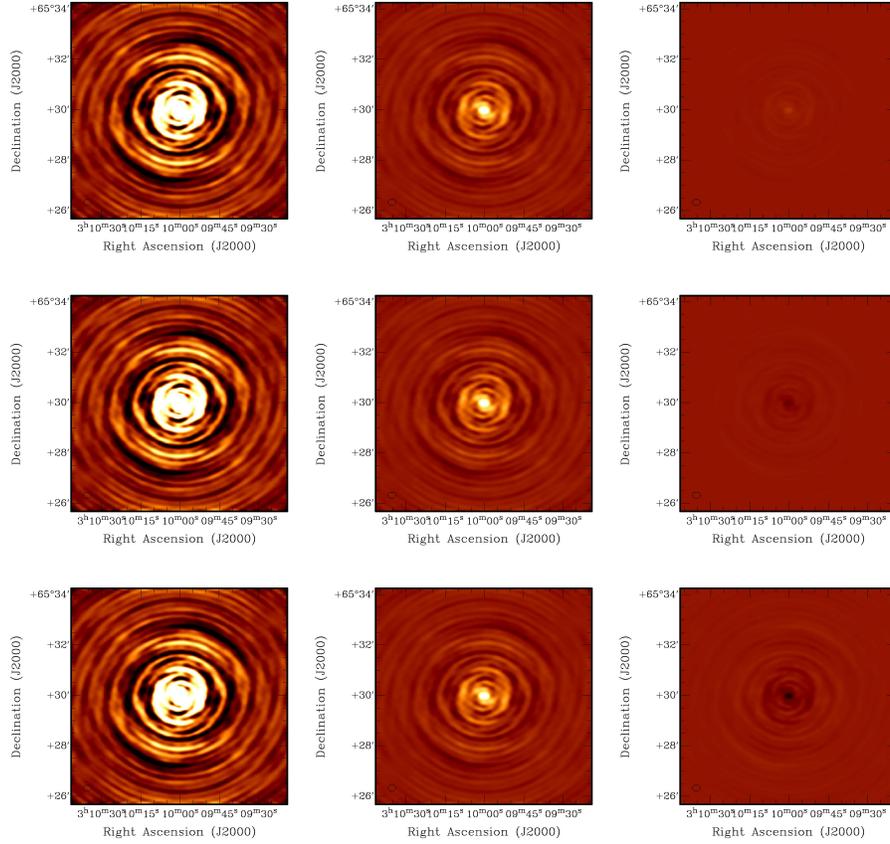
Figure 3: Stokes I(*left column*), Q(*center column*), and U(*right column*) maps of the first three channels (each channels is a row) from the subband L23954_SB104. It is clearly visible in the Stokes U images that the polarization vector changes due to a non-zero RM.
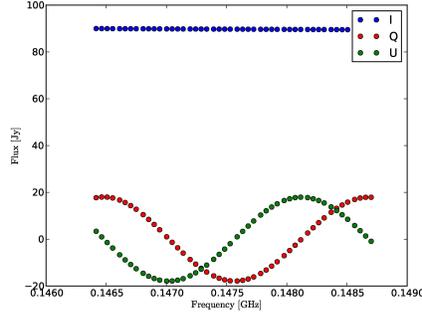
Figure 4: Stokes I, Q, and U values (taken from the central line of sight) of the 48 sets (channels) of images available.
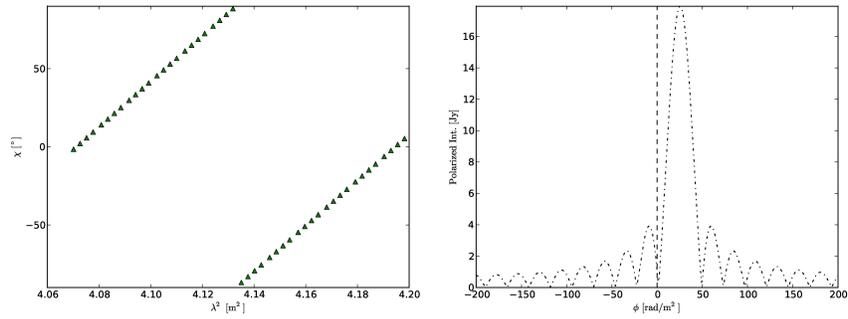
Figure 5: Linear variation of the polarization angle due to the RM of 25.5 rad/m^2 (*left*). Faraday Depth spectrum after using the 48 sets of Q and U images (*right*).
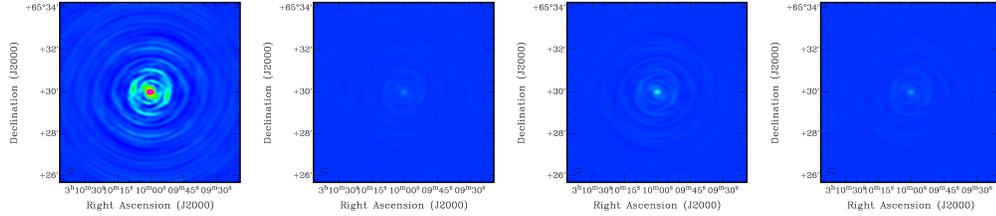
Figure 6: Stokes I(*left*), Q(*left center*), U(*right center*), V(*right*) maps.

Polarized point source with circular polarization

For this case, only the first channel of the subband L23954_SB112 was used. In order to provide a value to the model in Stokes V, a percentage of circular polarization of 10% was chosen. The model, therefore, is the following:

```
# 3csource.mod.112.0
# (Name, Type, Ra, Dec, I, Q, U, V, ReferenceFrequency='147978210.0') = format
3CSOURCE, POINT, 03:10:00.0, +65.30.00.0, 89.5997, 7.2886, 16.3706, 8.9599
```

All the steps to produce the Stokes I, Q, U, and V images are the same as in the first case (RM=0). In Figure (6), we can see that all the maps have the correct intensity values given our polarized point-source-model.