Reducing 3-mm data of SgrA*

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This experiment was part of a global campaign to monitor the galactic centre source SgrA* over a period of 7 days. Observations were conducted by both satellite and ground-based telescopes, mainly in x-rays and at millimetre wavelengths. SgrA* is a 3×10^6 solar mass black hole, and is a point source to ATCA resolutions. However there is a variety of extra emission in the galactic centre region at 3mm, which we want to resolve out. To achieve this, the array requested for the observation was the 6A array. Using this array, only the SgrA* is present in the three spacings.

This practical session involves reducing one nights ATCA 3-mm data of this experiment.

Start the exercise with

```
% cd /DATA/NELLE_2/synwork
% mkdir mydir
% cd mydir
% unsetenv MIRDEF
% miriad
```

To load RPFITS data into *MIRIAD*, we use the `atlod` task. Currently the 3-mm system does not have a noise calibration source. `atlod` currently makes some checks and corrections to the data based on information derived from the noise calibration source. To drive `atlod` in a manner to account for the lack of calibration source, use the "`mmrelax`" option, and to leave out the "`xycorr`" option. The `reweight` and `birdie` option are standard ones for continuum processing.

```
Task:   atlod
in       = ../*.C1019
out      = c1019.uv
options  = mmrelax,reweight,birdie
```

As the 3-mm system at the ATCA is still somewhat immature, a number of "fixes" need to be done to the data. It is most convenient to do these as early as possible. These are all packaged together into a single task – `atfix`. Operations performed by `atfix` include:

- Fill in antenna locations: Currently the ATCA system fails to record the position of off-line antennas into the output RPFITS file. The location of these antennas is important for compact configurations, where *MIRIAD* needs to flag shadowed data. For this observation, there is no shadowing, and so fixing this up is irrelevant. All the same, we will fix this.
- The effective position of the antennas differ between the centimetre wavelengths and 3-mm. The reason for this is poorly understood. As the nominal antenna positions in the system are those determined from centimetre observations, a correction has to be made to the data to correct for the wrong baseline length at 3-mm. Unfortunately for this experiment, no 3-mm solution was available for the baselines. Hence this correction cannot be applied. However this is of no consequence, as the observation was of a point-source only, and position (phase) information was not relevant.
- The antenna efficiency is a function of elevation. This causes the antenna gain to change. `options=gainel` corrects for this.
- At all ATCA bands except 3-mm, system temperature is continuously measured using an injected noise source. At 3mm, system temperature is measured using the so-called "chopper wheel" method (as discussed in Rick Forster's talk). This measurement gives a so-called "above atmosphere" measurement of system temperature. This is the effective system temperature when including both atmospheric emission (adding to the noise) and atmospheric attenuation (attenuating the astronomical signal). The observer has to explicitly request a 3-mm system temperature measurement – the measurement is not continuous. This results in correcting for the system temperature correction being a little more messy than at other bands, and so often it is not applied on-line (unlike at the other bands). `options=tsys` corrects the data for the system temperature measurements.

`atfix` can also correct the data for the atmospheric opacity. This is *not* relevant to 3-mm observations, as the system temperature measurement already takes this affect into account. Correcting for atmospheric opacity is, however, relevant for 12-mm observations, where the system temperature measurement does not account for atmospheric opacity.

```
Task:   atfix
 vis      = c1019.uv
 out      = c1019.fuv
 array    = 6a
 mdata    =
 dantpos  =
 options  = tsys,gainel
```

It is interesting to see the change in the "system sensitivity" as a function of time. This is a result of the deformations in the antennas with elevation, and is measured as the Janskys it takes to raise the system temperature by 1 K. Plot this with `varplt`.

```
Task:   varplt
 vis      = c1019.fuv
 device   = /xs
 yaxis    = jyperk
```

You might also plot the system temperatures

```
Task:   varplt
 vis      = c1019.fuv
 device   = /xs
 yaxis    = systemp
```

Having corrected the data for this imperfections, it is time to break it into one file per source and frequency. The observing frequencies were 90.559 and 90.688 GHz. Us the task `uvsplit` for this.

```
Task:   uvsplit
vis      = c1019.fuv
```

The result of this is a significant number of source/scan files:

```
x1253-055  )  Various calibrators used to set up the system and
t1253-055  )  do initial checks.
1921-293   )
```

For our purposes, you can ignore these. The important ones are

```
1253-055   Bandpass calibrator
x1921-293  The main reference pointing calibrator
1730-130   The secondary calibrator
t1730-130  Scans being system temperature measurements on the
           secondary calibrator
sgrastar   SgrA*
tsgrastar  Scans being system temperature measurements on SgrA*
```

The large number of files reflects the large amount of calibration needed at 3 mm. 1253-055 (Virgo A) is probably the strongest 3-mm point source in the south. This is used as a bandpass calibrator.

The reference pointing calibrator is a source that one periodically observes in "reference pointing update" mode, to tweak up the antenna pointing models. The reference pointing calibrator needs to be at least about 5 Jy, and needs to be as near as we can be to the source of interest. 1921-293 is one of the strongest sources in the southern sky at 3mm. The file `x1921-293` contains reference pointing data - which is not of interest to us (it has been processed and used by the on-line system during the course of the observation).

Its common to use the secondary calibrator (1730-130 in our case) for a flux reference during the course of the observation. To do this, we need to measure both the apparent flux of the secondary, and the system temperature in the direction of the secondary - as well as the flux of SgrA* and system temperature in this direction. Hence the scans of `t1730-130` and `tsgrastar`. These files contain no interesting astronomical data: they reflect the arcane way that the ATCA on-line system measures system temperature (again these data have been processed and used by the on-line system during the course of the observation).

The processing steps them are: bandpass calibration, and copy the solution to the secondary calibrator.

```
Task:   mfcal
 vis      = 1253-055.90559
 interval = 0.1

Task:   gpcopy
 vis      = 1253-055.90559
 out      = 1730-130.90559
```

Now it is time to calibrate the secondary, and copy the solution to SgrA*. Typically you would use a planet as a flux calibrator in work at 3-mm. This was not possible with this array – all the available planets were resolved out. Instead, we have taken as a given fact that 1730-130 has a flux density of 2.5 Jy. This may or may not be about right. However the aim of this experiment was to monitor the flux of the source over the 7 days of the campaign. Hence relative (rather than absolute) flux density is OK.

```
Task:   gpcal
 vis      = 1730-130.90559
 flux     = 2.5
 interval = 0.1
 options  = nopol,xyvary

Task:   gpcopy
 vis      = 1730-130.90559
 out      = sgrastar.90559
```

Finally, with the calibration complete, we can look for any flux variation with time.

```
Task:   uvplt
 vis=sgrastar.90559
 device=/xs
 stokes=i
 axis=time,amp
```

Note there are a few places where the fluxes look quite different. Why not look at the observing log (last pages), and see what happened at these times. Do you believe these data? I would not think so. Best flag them out – with `blflag`

```
Task:   blflag
 vis=sgrastar.90559
 device=/xs
```

The light curve shows a number of features that we do not believe. There is a dip in the flux density at 15^h – for example. By looking at 7 nights of data, its pretty clear that this is an instrumental error, rather than a change in the flux of SgrA*. Quite probably, it reflects an error in our assumed gain/elevation correction.

Having completed this, it is instructive to look at the phase of the source.

```
Task:   uvplt
 vis=sgrastar.90559
 device=/xs
 stokes=i
 axis=time,phase
```

As can be seen, this is wrapping rapidly. Why not look at the closure phase instead? `options=rms` causes the task `closure` to plot what it believes are the appropriate error bars.

```
Task:   closure
 vis=sgrastar.90559
 device=/xs
 options=rms
```