Averaging over Baseline with Position Shift

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Abstract—**This memo discusses the details of shifting the phase tracking center of a radio interferometer dataset while averaging over baseline. This is essentially making a single pixel dirty image which can be useful for exploring time dependent effects.**

Index Terms—**Interoferometric Synthesis**

I. INTRODUCTION

IT is sometimes useful to average visibility data over baseline, possibly with a shift in position from the original pointing center. This in essence is a single pixel dirty image. Such averaging can be useful in determining the response of the interferometer array to a dominate point source as a function of time and/or frequency. Alternately, this technique can be useful for following the time and/or frequency behavior of said dominant source. This memo describes the implementation of this software in the Obit [1][1] package. The details were lifted from AIPS.

II. AVERAGING OVER BASELINE

Averaging over baseline using the pointing center in the input dataset is pretty trivial. The corresponding complex visibilities in each time/polarization/frequency cell is averaged over baseline, possibly with weighting. This the equivalent of making a single pixel dirty image; the response to celestial emission has the shape of the naturally weighted synthesized beam centered on the delay/phase tracking center in the data. The response to emission away from this position contributes only through the sidelobes of the psf.

If the celestial emission of interest is not at the phase tracking center, then the data must be rotated to shift the tracking center to the position of the object of interest. This occurs as a phase rotation (ϕ) to the complex visibility as a function of the u,v,w coordinates:

$$\phi = -(dxyzc \cdot uvw_\nu)$$

in radians, uvw_ν is the visibility coordinate vector (u,v,w) in wavelengths at the frequency (ν) in question and $dxyzc$ is a rotation vector for which the dot product with uvw_ν gives the phase shift.

The rotation vector $dxyzc$ for -SIN projection is implemented in the routine from the ObitSkyGeom class:

```
/**
 * Finds coordinate shift from ra,dec to
 * xra, xdec and phase terms for
 * -SIN projection.
 * Adapted from the AIPSish SHISIN.FOR.
```

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[1]http://www.cv.nrao.edu/~bcotton/Obit.html

```
 * \param  ra      Initial RA in degrees
 * \param  dec     Initial Declination in degrees
 * \param  rotate  Image rotation in degrees
 * \param  xra     Shifted RA in degrees
 * \param  xdec    Shifted Declination in degrees
 * \param  dxyzc   (out) Phase term for Position
 *                 offsets in x,y,z (2pi turns)
 */
void
ObitSkyGeomShiftSIN (odouble ra, odouble dec,
                     ofloat rotate, odouble xra,
                     double xdec, ofloat dxyzc[3])
{
  ofloat maprr, xshift, yshift;
  odouble xxshft, yyshft, dzctmp;

  maprr=rotate * DG2RAD;

  /*  l, m */
  xxshft=cos(DG2RAD*xdec)*sin(DG2RAD*(xra-ra));
  yyshft=sin(DG2RAD*xdec)*cos(DG2RAD*dec) -
    cos(DG2RAD*xdec)*sin(DG2RAD*dec)*
    cos(DG2RAD*(xra-ra));

  /*  undo rotation */
  xshift=( cos(maprr)*xxshft+sin(maprr)*yyshft);
  yshift=(-sin(maprr)*xxshft+cos(maprr)*yyshft);

  /* Phase shift parameters */
  dxyzc[0]=xshift;
  dxyzc[1]=yshift;
  dzctmp=1.0-(dxyzc[0]*dxyzc[0])-
         (dxyzc[1]*dxyzc[1]);
  dzctmp=sqrt dzctmp);

  /* Prepare phase calc; mult by 2pi */
  dxyzc[0]=2.0*G_PI*dxyzc[0];
  dxyzc[1]=2.0*G_PI*dxyzc[1];
  dxyzc[2]= .0*G_PI*(dzctmp - 1.0);

} /* end  ObitSkyGeomShiftSIN */
```

III. OBIT IMPLEMENTATION

The average over baseline capability is implemented in two Obit tasks, DftPl which plots selected data versus time and AvgBL which creates an output UV data set with averaging over baseline and potentially in time segments. Both allow data selection and calibration and allow specifying a shift in the phase tracking. An example output of DftPl is shown in Figure 1 which illustrates the varying antenna response as the

source position in the beam rotates with parallactic angle. The shift needed is given by:

$$\Delta\alpha = (\alpha - \alpha_0)cos(\delta)$$

$$\Delta\delta = (\delta - \delta_0)$$

in arcseconds where (α_0, δ_0) is the phase tracking center of the input data and (α, δ) is the desired position.

IV. DISCUSSION

Averaging a visibility dataset is a useful technique to evaluating time variations in either a source observed or the instrumental response to a source. Since this is in practice a single pixel naturally weighted imaging, the field of view in the average is restricted by the psf of the array being used. Shifting the phase tracking center is required if the target is offset from it in the initial data.

REFERENCES

[1] W. D. Cotton, "Obit: A Development Environment for Astronomical Algorithms," *PASP*, vol. 120, pp. 439–448, 2008.
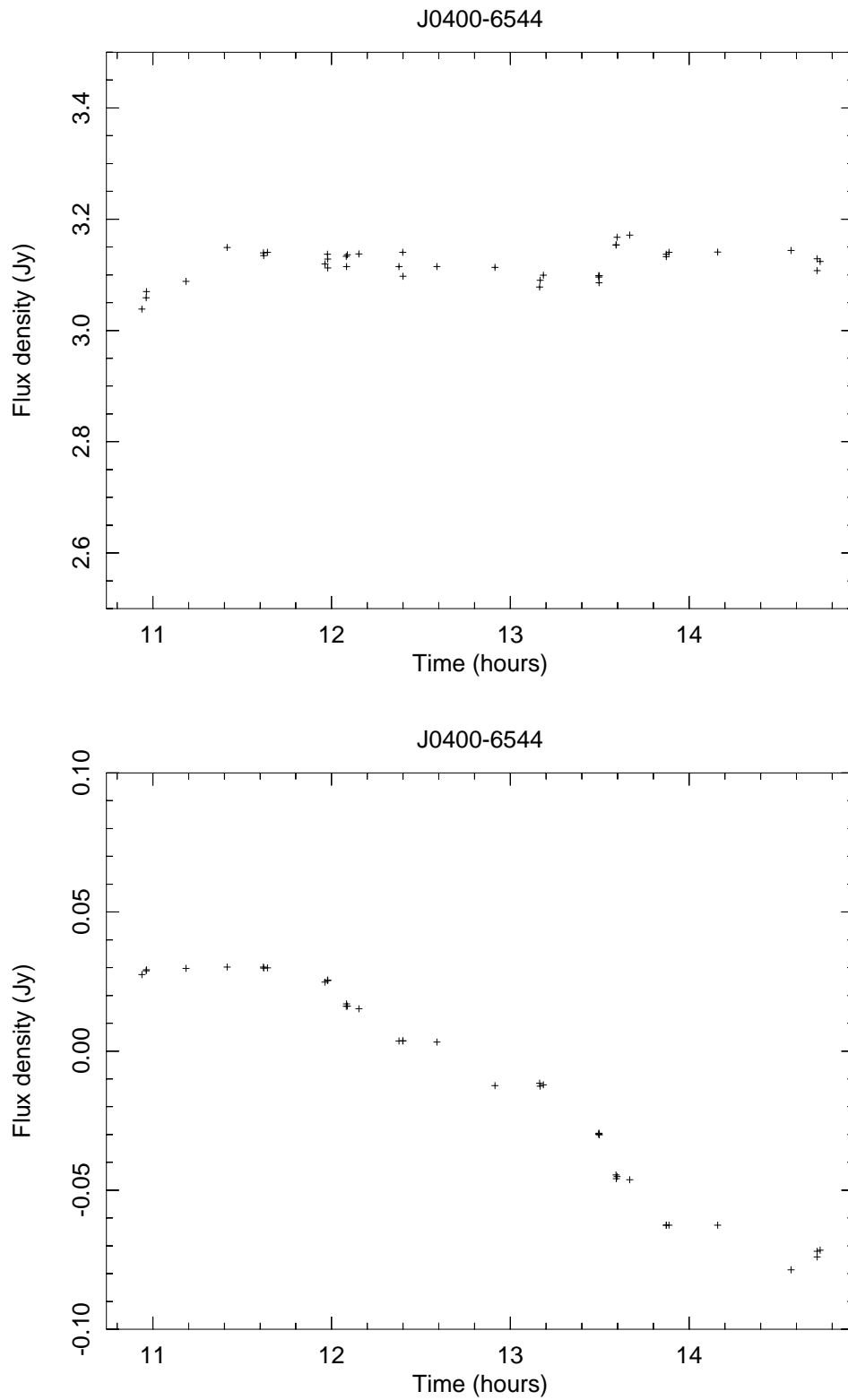
Fig. 1.   DftPl output:
Top: Average parallel polarized (XX) visibility for a set of MeerKAT data with antenna pointing offset from a bright calibrator,
Bottom: corresponding average cross polarized (XY) visibility.
The phase tracking center was shifted to the calibrator. The variation in flux density is the result of parallactic angle rotating the beam over the source.