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Making Movies from Radio Astronomical Images with AIPS

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Abstract

We present a detailed recipe for making movies from multi-epoch radio observations of astronomical sources. Images are interpolated linearly in time to create a smooth succession of frames so that a continuous movie can be compiled. Here, we outline the procedure, and draw attention to specific details necessary for making a successful movie. In particular, we discuss the issues pertaining specifically to making polarization movies. The procedure described here has been implemented into scripts in NRAO's AIPS package (Brandeis AIPS Movie Maker – BAMM) that are available for public use (http://www.astro.brandeis.edu).

1 Introduction

We have long been interested in presenting sequences of polarization sensitive VLBI (Very Long Baseline Interferometry) images as "magnetic movies" to show the evolution of the parsec-scale magnetic field in the jets of blazars. Early VLBI polarization experiments revealed complex magnetic field structure in these sources with dynamic polarization properties on short time scales (e.g. Brown, Roberts & Wardle, 1994) and intra-day variability has been observed in some sources (Gabuzda et al. 1989, 2000a,b). Now, instruments such as the NRAO[1] Very Long Baseline Array (VLBA) and the Very Large Array (VLA) are routinely used to rapidly monitor changes in source structure in a variety of radio sources, making movies of these objects possible.

Here we present our method for making total intensity and/or polarization movies from multi-epoch radio observations. We focus especially on the issues specific to polarization sensitive images. This procedure has been implemented in a script in NRAO's AIPS package, and we have applied it to make some "superluminal magnetic movies" (section 3).

2 Methodology

In this section, we discuss our procedures for creating movies from a series of radio *images*[2] obtained at differing epochs. We have implemented this procedure into an AIPS script in the form of a RUN file named BAMM (Brandeis AIPS Movie Maker; see section 3). In order to fill in "gaps" in the sequence, we interpolate between adjacent images to create a smooth succession of *frames* to combine into a movie. We

[1]The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.
[2]Throughout our discussion, we refer to the original AIPS files as *images* and to those files interpolated from the *images* using our procedure as *frames*.

favor interpolating linearly between successive epochs over more sophisticated weighting schemes in which non-adjacent images are factored into the interpolation since linear interpolation is simple and well defined. Also, we caution against applying this method to data undersampled in time as one may be misled by the results (e.g. "strobing" effects).

2.1 Making the Movie Frames

The data assumed here are AIPS image files derived from UV data using the same cell sizes and field of view. Calibrated I, Q, and U images[3] are read into NRAO's AIPS reduction package and the following procedures are followed.

2.1.1 Total Intensity Movies

1. All the images need to be restored to a common beam size. We restore the CLEAN components of each image onto a blank image with the task RSTOR. In order to avoid false interpretation of moving features due to effects of changing resolution, we use the largest beam amongst the images for all frames.

2. Images are then aligned relative to a common stationary (total intensity) feature, and a common image size (field of view) is chosen. The stationary feature can be, for instance, the (presumed) stationary core of a quasar jet or a bright feature in a maser source. We use the task LGEOM to perform this step.

3. Restored and aligned images are linearly interpolated with the task COMB to output a user specified number of frames at evenly spaced epochs. The number of frames determines the time elapse between the resultant movie frames and the weighting given to adjacent images in the interpolation.

A total intensity movie can now be compiled from these frames (section 2.2).

2.1.2 Polarization Movies

Here, we discuss additional steps necessary for making polarization movies. Proceed with steps 1 & 2 from section 2.1.1, this time using all three Stokes (I, Q, and U) images. Stokes V (circular polarization) images can be treated identically to I images as described in section 2.1.1. After aligning the I images, the corresponding Q and U (and V) images must be shifted by the same amount.

1. If rotations to the tick-marks that illustrate the orientation of the electric field vectors need to be made[4] (e.g. accounting for Faraday rotation by adding a correction angle, θ, or changing the tick-marks to show the orientation of the magnetic field vectors[5]), the total polarized intensity ($p = \sqrt{Q^2 + U^2}$) and electric field vector orientation ($\chi' = \frac{1}{2}\arctan\frac{U}{Q} + \theta$) images at each epoch are made first from the restored and aligned Q and U images with the task COMB. This is done in order to avoid the problem of having tick-marks rotating improperly later.

2. The resultant p and χ' images are used to make new Q and U images[6] (eqns 1 & 2) using the task COMB, via:

[3] I, Q, and U correspond to the Stokes parameters for total intensity and linear polarization; Q and U images are only necessary for polarization movies.

[4] If not, proceed to item 3 using $Q' = Q$ and $U' = U$.

[5] Assuming negligible Faraday rotation, $\theta = \frac{\pi}{2}$.

[6] While Q and U have changed in order to rotate the tick-marks, p ($= \sqrt{Q'^2 + U'^2}$) remains unchanged.

$$Q' = p * \cos 2\chi', \tag{1}$$

$$U' = p * \sin 2\chi'. \tag{2}$$

3. Lastly, the I, Q', and U' images are linearly interpolated separately with the task COMB. These images are then used to make the I, p, and fractional polarization ($m = p/I$) movie frames. The length of the tick-marks on the p frames can be made uniform or proportional to the magnitude of m or p.

Our AIPS script, BAMM, will implement all of these steps (section 3) after the user specifies the epochs of observations and the positions of a stationary feature. The individual movie frames are ready for inspection with standard AIPS tools, or the procedure may be repeated with different parameters if the user is not satisfied with the output.

2.2 Compiling the Movies

At this point, the user is satisfied with the quality and duration of the movie frames and wishes to export them into a movie outside of AIPS. The user may proceed in a number of ways. For contour movies, frames can be written out of AIPS in postscript format. It is important that identical contour levels (in mJy/beam) be used for all the frames. The files are then converted to GIF format which can be done with software such as XV, Adobe Photoshop, or ps2gif.

For color movies, the frames can be displayed on the AIPS TV and the images are captured with the task TVCPS or even XV. Also, the frames can be exported to software packages like the Caltech VLBI package or IDL. The same display scale should be used for all the frames. Scripts to implement these steps in AIPS are available upon request. We combine the movie frames (now in a standard graphics file format) into movie clips using Adobe Premiere for export to video tape, animated GIFs, or Quicktime movies. Other formats are supported by Premiere. Also, IDL has been used to compile movies similar to ours (B.G. Piner, personal communication).

3 Application: VLBA Polarization Monitoring of 12 Blazars

We have applied our procedure to images of twelve blazars monitored at 15 and 22 GHz with the VLBA in 1996 by the Brandeis Radio Astronomy Group, yielding six epochs of polarization sensitive images separated by about two months each. Details of this monitoring program are discussed by Homan et al. (2001) and references therein. These data are sufficiently well sampled in time that a simple linear interpolation between two adjacent epochs yielded satisfactory results. The movies show clear superluminal motion, and reveal the complexity of the evolution of the magnetic field structure in these sources. These movies have provided a highly visual medium in which to show our work for scientific talks, general lectures, and are on our WWW site.[7] BAMM, instructions, other AIPS macros, and our "Superluminal Magnetic Movies" are available to the public by following the links in our WWW site or by contacting one of the authors (CCC).

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[7] http://www.astro.brandeis.edu

5 References

Brown, L.F., Roberts, D.H., & Wardle, J.F.C. 1994, ApJ, 437, 108

Gabuzda, D.C., Wardle, J.F.C., & Roberts, D.H. 1989, ApJ, 338, 743

Gabuzda, D.C., Kochenov, P.Y., Cawthorne, T.V., & Kollgaard, R.I. 2000a, MNRAS, 313, 627

Gabuzda, D.C., Kochenov, P.Y., Kollgaard, R.I., & Cawthorne, T.V. 2000b, MNRAS, 315, 229

Homan, D.C., Ojha, R., Wardle, J.F.C., Roberts, D.H., Aller, M.F., Aller, H.D., & Hughes, P.A. 2001, ApJ, 549, 840