Wesleyan University The Honors College

AU Mic: The Journey Begins

by

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Table 1: Observation Information

	26 March 2014	18 August 2014	24 June 2015
Antennas:	32	35	37
Baselines (m):	14–437	20–1268	30–1431
On-source time (min):	35	35	33
Flux calibrator:	Titan	J2056-472	Titan
Bandpass calibrator:	J1924-2914	J2056-4714	J1924-2914
Phase calibrator:	J2101-2933	J2101-2933	J2056-3208
pwv (mm):	0.6	1.6	0.7

AU Mic was observed with ALMA on three dates: 26 March 2014, 18 August 2014, and 24 June 2015. All observations were configured with four spectral windows, and employed ALMA's 12m antennas and Band 7 receivers. Within each observation, AU Mic was observed in seven-minute segments.[1] One spectral window was centered around the CO $J = (2-1)$ transition at a frequency of 230.538001 GHz, with a total bandwidth of 1.875 GHz and a channel spacing of 488 kHz. The remaining three spectral windows were configured to detect continuum emission with central frequencies of 228.5, 213.5, and 216.0 GHz, total bandwidths of 2 GHz, and channel spacings of 15.6 MHz.

Information regarding each of the three observations can be found in Table 1. The short-baseline March observation was intended to provide information about AU Mic's disk on large spatial scales; in contrast, the subsequent long-baseline August observation was intended to trace the small scale structure of the disk. During the August observation, the quasar J2057-3734 was observed to test the quality of the gain transfer. Due to subpar quality, the August data were supplemented with a second night of long-baseline observations in June of 2015. The quality of the gain transfer was determined with observations of the quasar J2101-2933. During the last segment of the June observation (04:23:38-04:29:58

[1]Extraneous?

Table 2: Subtracted point-source fluxes

Time (UTC)	Point-source Flux (μJy)
03:45:0-04:20:0 (no flare)	$(4.1 \pm 0.2) \times 10^2$
4:23:38-4:24:00	$(9.2 \pm 1.7) \times 10^2$
4:23:38-4:24:00	$(1.146 \pm 0.010) \times 10^4$
4:25:00-4:26:00	$(3.59 \pm 0.10) \times 10^3$
4:26:00-4:27:00	$(1.58 \pm 0.10) \times 10^3$
4:27:00-4:28:00	$(4.50 \pm 1.0) \times 10^2$
4:28:00-4:29:00	$(4.60 \pm 1.0) \times 10^2$
4:29:00-4:29:58	$(5.20 \pm 1.0) \times 10^2$

UT), the host star flared—flare fluxes can be found in Table 2.

Calibration, reduction, and imaging were carried out using the `CASA` and `MIRIAD` software packages. Standard ALMA reduction scripts were applied to the datasets: phase calibration was accomplished via water vapor radiometry tables, and system temperature calibrations were performed to account for variations in instrument and weather conditions. Flux and bandpass calibrations were subsequently applied.

The authors travelled to the NRAO facility in Charlottesville, VA in October 2015 to further process the data; in particular the trip was intended to allow on-site correction of the 24 June flare. Tasks used to reduce the data at the NRAO facility were all part of the CASA package. An elliptical gaussian was fit to a small region around the star in the image plane of each dataset using the task `imfit`; the equatorial coordinates of the the model gaussian centroid were used to define the star position. Each observation was then phase shifted using the task `fixvis` so that the the pointing center was the same as the star position fit. The peak flux of the model gaussian was also subtracted from the location of the star in the visibility domain so that only the disk remained.

The 24 June dataset required additional reduction due to the flare. While for the other dates we were able to fit a single point source to account for the stellar component over the entire observation, the flare required that the dataset be split into one minute bins between 04:23:38 and 04:29:58 in order to account for the variable flux of the host star. For each of these bins, we used the task `uvmodelfit` to fit a point source to the long baseline visibilities, which we subsequently subtracted from each bin in the visibility domain. Subtracted point fluxes can be found in Table 2.

The June date pointing center, defined by the centroid of the elliptical gaussian fit to the star, was visibly offset from the surrounding disk; this could be explained if the flare referenced above were not symmetric with respect to the star. The offset was remedied by redefining the pointing center as follows. Because the star is known to be located at the center of the disk, we can use information provided by the brightness distribution of the disk to infer the star position. We do so by selecting the brightest pixel on each side of the disk from the clean component map (the `.model` file produced by `tclean`), and redefining the star/pointing center as the mean of the two pixel positions. This yields offsets of $(0.01'', -0.05'')$ for the March observation, $(0.01'', 0.00'')$ for the August observation, and $(0.00'', 0.09'')$ for the June observation. Given the good agreement between the calculated star position and the image center for the two non-flare dates (March and August), we conclude that the 'pixel' method represents a viable way to accurately determine star position. We apply this correction and redefine the image center via `fixvis`. For consistency, we apply the phase shift to all three dates.

Due to the high proper motion of AU Mic, the pointing centers of the three dates differ by a not-insignificant amount. When datasets with different pointing centers are cleaned together with `tclean`, the pointing center of the first dataset is taken as the new pointing center, and the data are combined in in the *uv* plane with each subsequent dataset offset from the first as given by their relative pointing centers. In the case of AU Mic, this leads to an image of the disk composed of three observations offset with respect to each other. To remedy this, we use the task `concat`, which combines datasets with their pointing centers aligned so long as the pointing centers do not differ by more than the value of `dirtol`. We set `dirtol` to $2''$, a value larger than AU Mic's proper motion over ALMA's ~ 1 year observation baselines.