Independent testing of ALMA's Flux Calibration Accuracy using stable YSOs

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Introduction

- ALMA observations are typically flux calibrated using variable quasar sources which must be monitored with more stable solar system objects to provide an accurate calibration (Remijan et al. 2020).
- The nominal flux calibration accuracy in band is 10% in bands 6 and 7, and becomes larger (smaller) for the higher (lower) frequency bands (Braatz 2020).
- Using ALMA observations of bright and stable protostars (PIDs: 2018.1.00917.S, 2019.1.00475.S), we are able to independently test the accuracy of ALMA's flux calibration.

Methods

- Using the ALMA Atacama Compact Array, 4 stable and 3 variable protostars previously identified by the JCMT Transient Survey (Herczeg et al. 2017) are monitored for continuum flux changes in Band 7 (343.5 GHz/0.85mm).
- For each of the 7 epochs taken to date, we use point source models of the each stable calibrator protostar to measure a flux scale relative **correction factor to the mean (MCF, Figure 1)**.
- Our correction factors for each epoch agree to ~3%. The mean across calibrators is taken as the **relative flux correction factor (rFCF)** for each epoch.

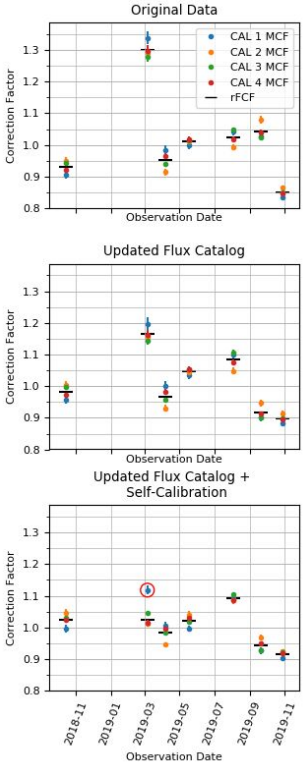

Figure 1: Mean correction factors (MCFs) to the flux scale for each epoch.

Time Domain Accuracy

- Using the original pipeline-calibrated ALMA data, we find the rFCFs for each epoch have a standard deviation of ~14%, while the rFCF needed for the second epoch is a significant outlier **(Figure 1a)**.
- Some delay is possible between the monitoring observations of the ALMA quasar calibrators and their ingestion into the calibration catalog. Updating the catalog months after the observations were taken, the rFCFs have a standard deviation of ~9% **(Figure 1b)**.
- Phase decorrelation may systematically bias the protostar calibrator flux in some epochs. Upon applying phase self-calibration, the rFCFs have a standard deviation of ~5% **(Figure 1c)**.

Spectral Window Accuracy

- Our protostar calibrators are bright enough to measure a correction factor in each spectral window independently.
- In **Figure 2**, we show the MCFs for each spectral window and epoch normalized to the overall rFCF.
- Across all of our observing epochs, we find an ~1% variation in the flux scale between spectral windows. This can be a significant source of additional uncertainty for in-band spectral index measurements and line flux ratios due to the small frequency "lever-arm" the spectral windows.

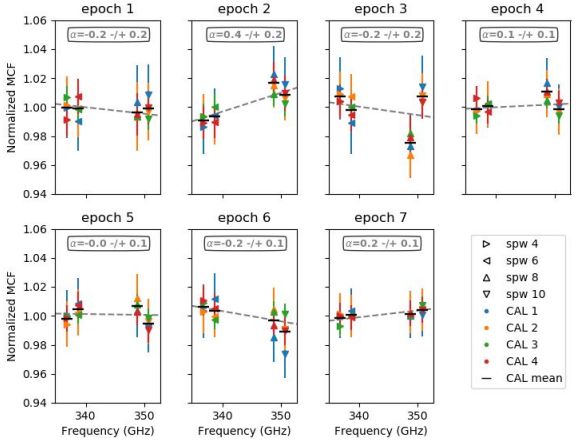

Figure 2: Mean correction factors for each epoch and spectral window normalized to the rFCF for each epoch.

Conclusions

- ALMA ACA observations of bright and stable protostars can provide a relative flux calibration **accuracy of ~3%**.
- Without an up to date calibration catalog or accounting for phase-decorrelation, the ALMA observations may provide an accuracy **poorer than nominal**.
- We find **a ~1% variation in flux scale between spectral windows**, which may affect science goals requiring comparing line or continuum fluxes within an ALMA band.
- We provide additional suggestions for obtaining ALMA observations with high relative or absolute flux calibration accuracy in Francis et al. 2020.