Jacobian Leverage as a Diagnostic in Radio Interferometric Calibration

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The estimation of systematic errors in radio interferometric data and the correction for such errors is termed as calibration. Modern radio interferometers are designed to have higher sensitivities and to acquire large volumes of data so that radio astronomers can study weak signals of scientific interest. Therefore, calibration also plays a role in removing bright foreground signals from the data to enable the study of such weak signals.

Fundamental limits of calibration can be studied using the Cramer-Rao lower bound (CRLB), that gives bounds on the variance of the estimated parameters. However, unlike most estimation problems, the signals of scientific interest are not in the estimated parameters: this is mainly because calibration estimates systematic errors in the data and calibration does not estimate the weak signals themselves. In contrast, the residual–which is the signal obtained by subtracting the estimated model from the data–carries information about the weak signals that is of scientific interest.

Due to the complexity of the model used in calibration that is inherently nonlinear, directly relating the variance of the estimated parameters to the variance of the residual signal is difficult. Therefore, we introduce the use of Jacobian Leverage (St. Laurent and Cook, *Biometrika*, 80-1, 1993, pp. 99-106) to study calibration as a nonlinear regression problem. Using Jacobian leverage, we can directly estimate the variance of the residual signal.

As one example, we use Jacobian leverage to study the effect of excluding short baselines during calibration of radio interferometric data. Short baselines are more sensitive to large scale diffuse structure in the sky, especially from the Galaxy. Due to the difficulty in modeling such large scale structure, only long baselines are used in calibration. However, the residual is calculated for all baselines using the estimated parameters. Using Jacobian leverage, we show that due the their exclusion in calibration, the variance of the residuals on short baselines are always higher than the variance of the residuals on long baselines. This effect should be taken into account when designing radio interferometric arrays and their calibration strategies that intend to study weak signals.