# The Droop Effect: should it be corrected?

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## 1. Background

Droop is an extraneous electronic signal that's added to the output of every pixel and its magnitude is proportional to the mean signal (charge) on the array. Our knowledge mostly comes from it's characterization on *Spitzer* (e.g., Si:As arrays). Droop is calibrated using an empirical model, and no detector physics is involved. On *Spitzer*, the droop was corrected early in pipeline processing. The droop-corrected signal in a pixel *i* was computed using an additive correction of the form:

$$S_i^{corr} \approx S_i^{raw} - \frac{C_d}{N}\sum_{j=1}^{N} S_j^{raw}, \qquad \text{(Eq.1)}$$

where $C_d$ is the droop coefficient, and "signal" here can be either a slope that's fit to sample-up-the ramp data (i.e., a set of cumulative non-destructive reads), or, a single value (in ADU) along the ramp. The applicability to slope data is possible because a slope is just a linear combination of samples in a ramp. If the signal is a "slope", then the droop term on the right can be called a "droop current", analogous to the "dark current". The sum term must account for the total count in all electron wells, including any counts above saturation in the ADC.

For a given image, the above method implies that a single constant is subtracted from all pixels. However, if the image has an approximately uniform or slowly varying background (which is expected along most directions of the 'bright' mid-IR sky), it can be shown that the droop correction can also be approximated as a multiplicative one:

$$S_i^{corr} \sim (1 - C_d) S_i^{raw}. \qquad \text{(Eq.2)}$$

## 2. <u>Option I</u>: Correcting for Droop the Conventional Way

Under the conventional method, the droop signal $S_D$ (along with the dark current $D$) is first subtracted from a raw pixel with signal $S_{raw}$ using the additive correction method of Eq. 1. The droop (and dark) corrected pixel is then used as input to the non-linearity model $L_{(Sraw-D-SD)}$ to estimate linearized values that can then be flat-fielded with a correction factor *f*. In summary, a *true source* signal $S_{src}$ in a pixel can be recovered by first removing the instrumental signatures and then the *sky* background $S_{bgnd}$ according to:

$$S_{src} = \frac{S_{raw} - D - S_D}{f * L_{(Sraw-D-S_D)}} - S_{bgnd}. \qquad \text{(Eq.3)}$$

Note: the flat-field and linearity calibration products are created from images that are also corrected for droop.

Droop was found to contribute ~33% of the signal for the MIPS-24 array. This meant that after subtraction, the effective A/D dynamic range for true signal detection was reduced, and signals were not as far into the non-linear regime (maybe a good thing). Therefore if droop is significant for WISE, it's important to ensure (by picking a suitable gain) that dynamic range is not compromised, particularly at the faint end.

### 3. Option II: No Explicit Droop Correction: an Instrumental Background instead?

We pose the following question: is droop subject to the same electronic-well effects, e.g., responsivity and non-linearity as encountered by photoelectrons in general – i.e., from the true source + background sought for? This will be true if droop occurs in the detector substrate. If instead it occurs in the multiplexer (MUX), then the option I method is justified.

If droop contributes its share of photoelectrons (from the detector substrate), then it can be treated as part of the effective total background that is subtracted at the source photometry stage. Using the same definitions as in Eq. 3, the instrumental calibration process to recover the *true source* signal $S_{src}$ in a pixel becomes:

$$S_{src} = \frac{S_{raw} - D}{f * L_{(Sraw-D)}} - S_{bgnd} - S_D. \qquad \text{(Eq.4)}$$

This means that the droop $S_D$ is implicitly carried along in the raw signal $S_{raw}$ and that it behaves like a photoelectric signal ($S_{src} + S_{bgnd}$) in general. The sum: $S_{src} + S_{bgnd} + S_D$ is then corrected for responsivity and non-linearity in the usual way. Again, the assumption here is that droop is subject to the same responsivity and non-linear effects. This means *no prior droop correction* to the raw pixel signals $S_{raw}$ is necessary. This also includes images used to create the calibration products. Therefore, we don't need to spend resources characterizing it.

Recall that for WISE, we will be performing *relative* source photometry. The goal is for the final instrumentally calibrated frames to have no (or minimal) *systematic* pixel-to-pixel variations. This will ensure that background estimates local to sources for use in photometry do not significantly deviate from those underlying the sources.

### 4. Tests to decide on Option I vs. Option II

We assume that droop is not understood well enough to decide if option II is still viable. If not, then we will proceed to correct it using option I. Otherwise, here are some suggestions to determine if correcting for droop will make a difference to background variations and hence *relative* source photometry:

i. Using MIPS-24 data, create a high signal-to-noise flat-field with and without droop subtracted from the input image frames. Also do the same for the non-linearity calibration product. If there are *no* significant differences in the magnitude of responsivity variations and non-linearity, then the droop signal can be carried through and combined with the general sky + instrumental background (option II).

ii. Execute the MIPS-24 instrumental calibration pipeline with and without prior correcting the image frames (and input calibrations) for droop. Measure the RMS in pixel-to-pixel variations in the background in the final calibrated frames to see if droop makes a difference.

iii. In the lab (?), place a pseudo point-source signal in the corner of the array and drive it to saturation. If droop *is present*, it will elevate the signal in all other pixels. Will this 'pure' droop (+ low ambient background) signal exhibit responsivity and non-linearity variations? Or, will it originate exclusively from the multiplexer in which case the only choice is to correct it explicitly in the conventional manner (option I).

iv. If droop is present and originates from the multiplexer, can we make use of the reference pixels to estimate and correct it for the active pixels? This assumes the reference pixels respond (in a predictable manner) to the total signal in the active region. Recall that we are already using the reference pixels to correct for DC bias levels in the active region for each amplifier channel.

## 5. Summary

1. For which bands is the droop effect significant?

2. If significant, does droop occur exclusively in the multiplexer, detector substrate, or both?

3. Related to 2, is droop subject to responsivity and non-linear variations, i.e., does droop behave like a photoelectric signal?

4. If totally from the multiplexer, then I expect the answer to 3 is *no*, and the conventional (*Spitzer*) correction method applies.

5. Also, if totally from the multiplexer, can we use the reference pixels to calibrate and correct droop? Note that we already use the reference pixels to correct for DC-bias levels (at least in WISE bands 1 and 2). Maybe droop will be automatically removed too.