Flux calibration

In this document I outline how to compute flux calibration factors (FCFs) by minimizing the RMS between epochs. I then present and compare preliminary results from two regions within IC348. Lastly, I discuss possible regions where we could employ this new RMS minimization model. The IC348 maps analyzed are from the EK1 reductions, i.e. cross-correlation aligned maps.

1. Methods

Original model

For each epoch_x, where $\text{epoch}_{\text{second}} \leq \text{epoch}_x \leq \text{epoch}_{\text{last}}$ we define χ^2 as the square of the difference between each epoch_x and a FCF times epoch_x:

$$\chi^2 = \sum_{\text{pixels}} (\text{epoch}_1 - \text{FCF} \times \text{epoch}_x)^2 \tag{1}$$

By minimizing χ^2 we get an expression for the FCF:

$$\boxed{\text{FCF} = \frac{\sum \text{epoch}_1 \text{epoch}_x}{\sum (\text{epoch}_x)^2}} \tag{2}$$

New model

It was suggested to add a constant offset, K, to χ^2 to account for the variations in the background and large scale structure. The idea behind this is that we shouldn't find FCF $\rightarrow 0$ for noise dominated regions (discussed in §2.1). So, we have the new expression:

$$\chi^2 = \sum_{\text{pixels}} (\text{epoch}_1 - \text{FCF} \times \text{epoch}_x + K)^2 \tag{3}$$

By minimizing this new χ^2 with respect to the FCF and the offset constant K we get new expressions for the FCF and K:

$$\frac{\partial \chi^2}{\partial \text{FCF}} = 0 \rightarrow \text{FCF} = \frac{\sum_{\text{pixels}} \text{epoch}_1 \text{epoch}_x + K \times \sum_{\text{pixels}} \text{epoch}_x}{\sum_{\text{pixels}} (\text{epoch}_x)^2} \tag{4}$$

$$\frac{\partial \chi^2}{\partial K} = 0 \rightarrow K = \text{FCF} \times \sum_{\text{pixels}} \text{epoch}_x - \sum_{\text{pixels}} \text{epoch}_1 \tag{5}$$

Combining we get the final expression for the flux calibration factor:

$$\boxed{\text{FCF} = \frac{\sum \text{epoch}_1 \text{epoch}_x - \sum \text{epoch}_1 \sum \text{epoch}_x}{\sum (\text{epoch}_x)^2 - \sum \text{epoch}_x \sum \text{epoch}_x}} \tag{6}$$

Uncertainties

One problem that remains is how do we estimate the uncertainty in the FCF using this method?

2. Preliminary results

I tested these χ^2 models (equations 2 and 6) on both the whole field (30-arcmin PONG) and a core region (5-arcmin core) in the IC348 region.
(*Please excuse the awful screen grabbed figures in this section.*)

Whole field

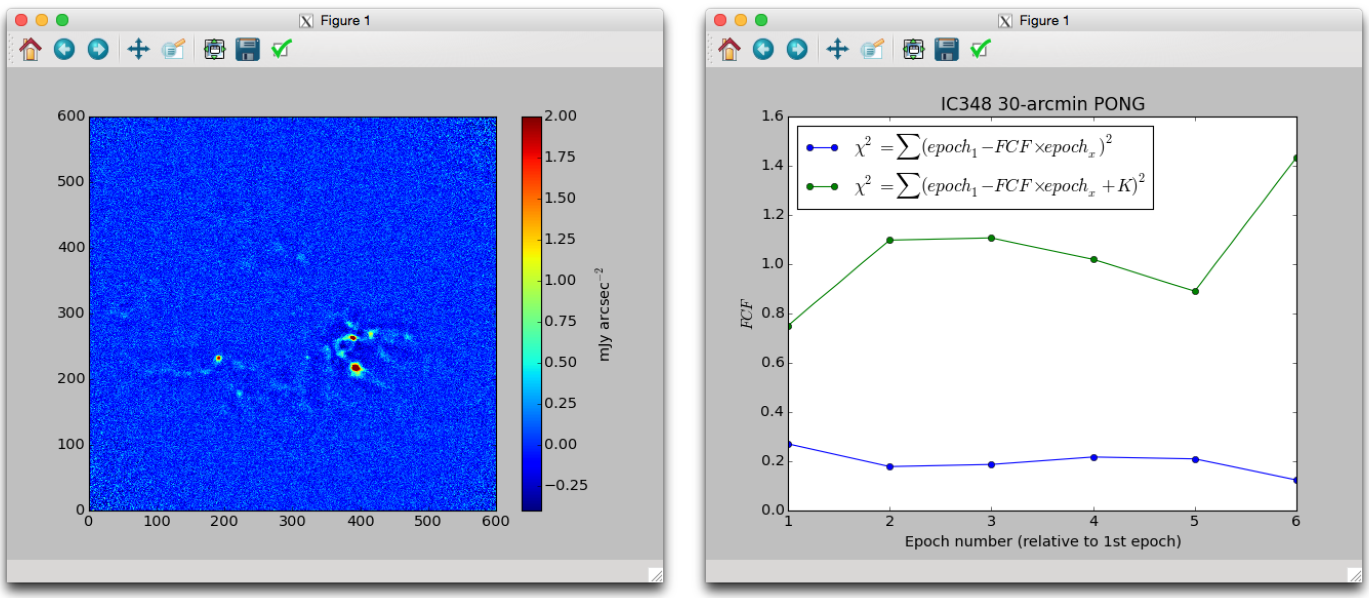

Figure 1: Whole field from IC348 of the **left** and FCF as a function of epoch number on the **right**.

By employing the χ^2 model without the offset K for the entire field I find the FCF's to be quite low, $0.1 < \text{FCF} < 0.3$. This doesn't make sense, the FCF's should be near 1 ± 0.3. This is likely due to the noise in the map, which dominates in area over bright compact sources. When summing up all the pixels in nosey regions we get an average flux of ~ 0, so this FCF method shouldn't work over the entire map. Namely, we should find $\text{FCF} \to 0$ for a noise dominated map.

The χ^2 model with the offset K for the entire field shows somewhat reasonable FCF's, $0.8 < \text{FCF} < 1.4$. These FCFs are not necessarily correct, however they are more reasonable than what was found for χ^2 without the offset. There seems to be a suspiciously large large scatter in FCFs using this method for the entire field. I need to compare these FCFs to Steve's results to get a sense of how accurate they really are (*in progress*).

Core region vs. Whole map

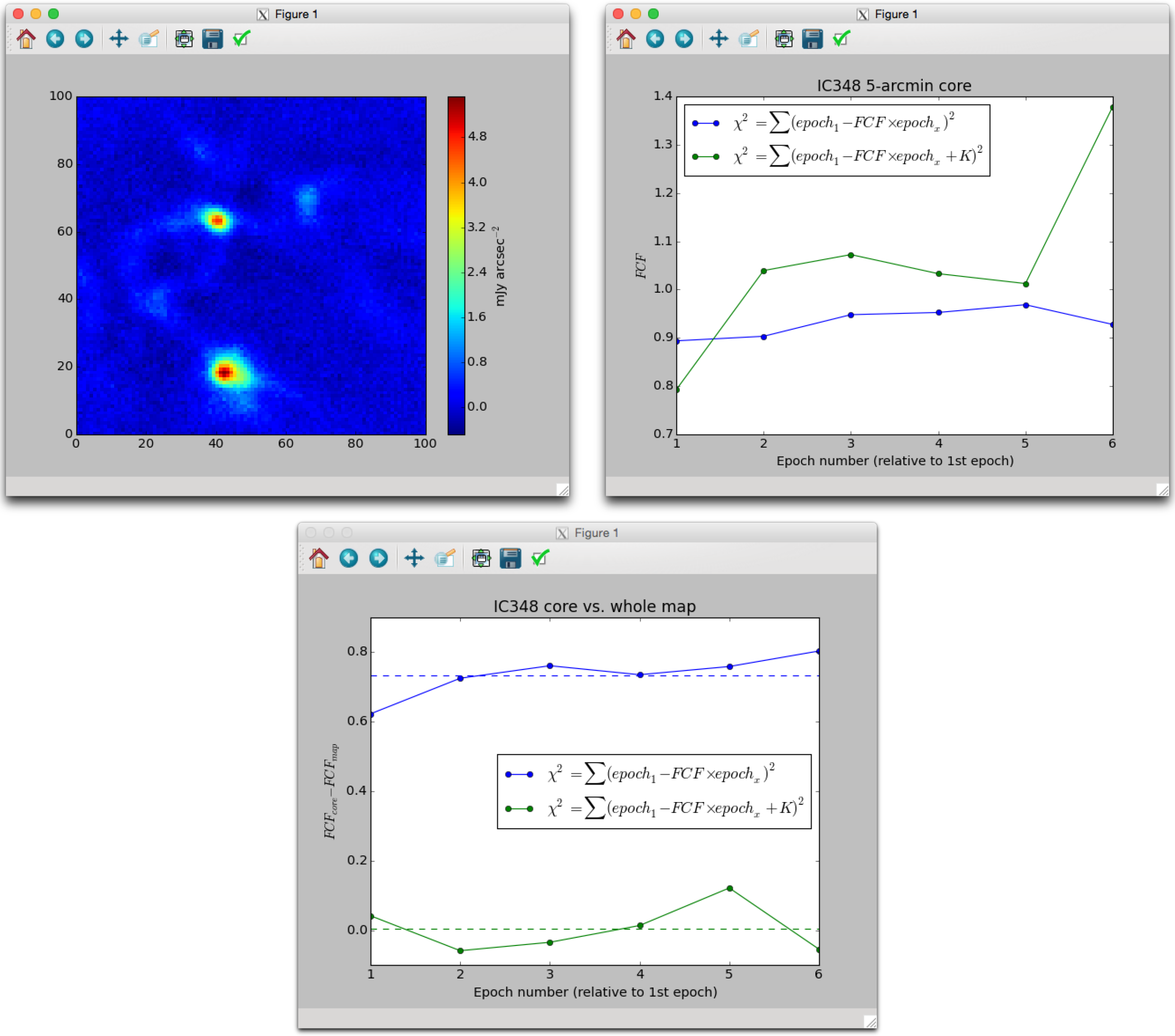

Figure 2: Core region from IC348 of the **left** and FCF as a function of epoch number on the **right**. Comparing the FCFs derived from the core versus the whole map on the **bottom**.

I applied the same χ^2 analysis to a 100×100 px^2 box about the two centre compact sources of IC348. I found the FCFs derived from χ^2 without the offset to be consistently bellow 1. As seen in Figure 2 this region is still largely dominated ($\sim 90\%$) by diffuse structure. So as we'd expect, these FCFs should be constantly underestimated using the original model.

Interestingly, the FCFs computed from the χ^2 with the offset in the core region are similar to those computed for the entire field. I find the mean residuals $\langle \text{FCF}_{\text{core}} - \text{FCF}_{\text{map}} \rangle \approx 0$ for the FCFs derived by the χ^2 with the offset, whereas $\langle \text{FCF}_{\text{core}} - \text{FCF}_{\text{map}} \rangle \gg 0$ for the FCFs derived by the χ^2 without the offset. This gives me confidence that $\chi^2 = \sum(\text{epoch}_1 - \text{FCF} \times \text{epoch}_x + K)^2$ is a more accurate and more stable model.

3. Regional ideas

Now that I have a possibly reliable and stable model to compute FCFs, I need to apply the model to sensible regions of each map to get reliable FCFs.

1$^{\text{st}}$ idea – SNR cut

Define a flux cut, say $S_{850} > 3\sigma_{850}$. This result in maps with only significant detections. I'd then employ χ^2 model for the $> 3\sigma$ maps for all pixels that align with each other over all epochs. In principle, this could work, but I'm not sure how well. This would get rid of all noisy regions and leave us with only $> 3\sigma$ detections, but how reliable are these sources we detect? This might work as it would get rid of all noisy regions, however it might leave some "fake" large scale structure which doesn't appear in other epochs, due to weather fluctuations and variations in the dish.

2$^{\text{nd}}$ idea – Over all sources

Apply the χ^2 FCF model to all compact sources within the field, identifiable over all epochs. This might only be okay if there are enough sources to make the sum of their fluxes statistically stable over all epochs. Namely, given there is some variability between epochs individual sources will vary in fluxes, but we'd need enough sources in the map to compensate for the sources "going off" with "dormant" sources. e.g. we'd need $\langle S_{850} \rangle_{\text{all epochs}} \approx$ constant. I know there were some issues with using all compact sources within the field. I believe Steve suggested this might not be a good idea as the point spread function changes epoch to epoch. And sources embedded within diffuse structure would vary in shape epoch to epoch. These problems would also arise in the SNR cut suggestion, as you would likely detect all of these same compact sources.

3$^{\text{rd}}$ idea – Steve's pairs

I would instead use all of the same pairs Steve has been using for his analysis, but apply the my χ^2 FCF model. This wouldn't really count as a completely independent study, but could be worth pursuing anyways.

4$^{\text{th}}$ idea – How do FCFs translate?

Attempt this χ^2 FCF model within both small and large scale structure reductions and see how the FCFs compare.