Document Title: Event Requirements for Simulated PSFs

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1 Introduction

The question often arises regarding the minimum number of events which are required to adequately define a simulated PSF (FAQ/IAQ). This issue has a direct impact on the simulation time required to generate a simulated PSF.

In order to adequately answer this question, I have generated a series of images of both the Crab and Cyg X-1 using PSFs derived from a varying number of simulated events. By using both sources, we hoped to study this question using a range of signal-to-noise ratios and for two different source spectra. In this way, we can attempt to answer this lingering question in a straightforward manner using real flight data.

2 The Simulated PSFs

The PSFs were generated using standard SIM tools, as described in COM-TN-UNH-DRG-036 ("The Effect of Varying Detector Thresholds on the COMPTEL Response"). The trick in this process was to control the number of events which are used in task SIMPSF to generate the final FAQ/IAQ datasets. Sinve SIMPSF uses the entire set of EVP data which is input to the program (there is no task parameter to define the number of events to use), the only way to do this was to generate a series of simulated EVP datafiles containing diferent numbers of events. The EVP files were generated using task EVPSRC, which reads in an EVP file and produces a new EVP file based on a wide selection of parameters in the TPT. (This task has far more capability that the standard EVPSEL approach.) In all cases, the PSFs were generated using the standard detector threshold thransfer functions (UNH-ISS-1008).

Two sets of PSFs were generated. One set was generated using an E^{-2} power-law input spectrum for the energy range 1-3 MeV. This was to be used for studying the Crab response in an energy range where the Crab signal was at its best. Another set of PSFs was generated using a 200 keV input spectrum for the 0.75-3.0 MeV energy range. These PSFs were to be used for studying the response of Cygnus X-1 in its most optimum energy range. These two sets of PSFs are tabulated in tables 1 and 2, respectively.

SIMPSF	*EVP*	*IAQ*	*FAQ*	*# events*
UNH-SIMPS2-3866	UNH-EVP-12245	UNH-IAQ-9307	UNH-FAQ-9260	879
UNH-SIMPS2-3867	UNH-EVP-12246	UNH-IAQ-9308	UNH-FAQ-9261	1814
UNH-SIMPS2-3868	UNH-EVP-12247	UNH-IAQ-9309	UNH-FAQ-9262	2743
UNH-SIMPS2-3869	UNH-EVP-12248	UNH-IAQ-9310	UNH-FAQ-9263	3663
UNH-SIMPS2-3870	UNH-EVP-12249	UNH-IAQ-9311	UNH-FAQ-9264	4563
UNH-SIMPS2-3871	UNH-EVP-12250	UNH-IAQ-9312	UNH-FAQ-9265	5478
UNH-SIMPS2-3872	UNH-EVP-12251	UNH-IAQ-9313	UNH-FAQ-9266	7230
UNH-SIMPS2-3873	UNH-EVP-12252	UNH-IAQ-9314	UNH-FAQ-9267	9021
UNH-SIMPS2-3874	UNH-EVP-12253	UNH-IAQ-9315	UNH-FAQ-9268	10858
UNH-SIMPS2-3875	UNH-EVP-12254	UNH-IAQ-9316	UNH-FAQ-9269	12650
UNH-SIMPS2-3876	UNH-EVP-12255	UNH-IAQ-9317	UNH-FAQ-9270	14497
UNH-SIMPS2-3877	UNH-EVP-12256	UNH-IAQ-9318	UNH-FAQ-9271	16313
UNH-SIMPS2-3878	UNH-EVP-12257	UNH-IAQ-9319	UNH-FAQ-9272	18098
UNH-SIMPS2-3879	UNH-EVP-12258	UNH-IAQ-9320	UNH-FAQ-9273	19908
UNH-SIMPS2-3880	UNH-EVP-12259	UNH-IAQ-9321	UNH-FAQ-9274	21638

Table 1: List of 1-3 MeV (E^{-2} power law) PSFs used for studying the Crab response.

SIMPSF	*EVP*	*IAQ*	*FAQ*	*# events*
UNH-SIMPS2-3939	UNH-EVP-12261	UNH-IAQ-9380	UNH-FAQ-9333	955
UNH-SIMPS2-3940	UNH-EVP-12262	UNH-IAQ-9381	UNH-FAQ-9334	1974
UNH-SIMPS2-3941	UNH-EVP-12263	UNH-IAQ-9382	UNH-FAQ-9335	2939
UNH-SIMPS2-3942	UNH-EVP-12264	UNH-IAQ-9383	UNH-FAQ-9336	3880
UNH-SIMPS2-3943	UNH-EVP-12265	UNH-IAQ-9384	UNH-FAQ-9337	4843
UNH-SIMPS2-3944	UNH-EVP-12266	UNH-IAQ-9385	UNH-FAQ-9338	5834
UNH-SIMPS2-3945	UNH-EVP-12267	UNH-IAQ-9386	UNH-FAQ-9339	7759
UNH-SIMPS2-3946	UNH-EVP-12268	UNH-IAQ-9387	UNH-FAQ-9340	9710
UNH-SIMPS2-3947	UNH-EVP-12269	UNH-IAQ-9388	UNH-FAQ-9341	11607
UNH-SIMPS2-3948	UNH-EVP-12270	UNH-IAQ-9389	UNH-FAQ-9342	13595
UNH-SIMPS2-3949	UNH-EVP-12271	UNH-IAQ-9390	UNH-FAQ-9343	15585
UNH-SIMPS2-3950	UNH-EVP-12272	UNH-IAQ-9391	UNH-FAQ-9344	17574
UNH-SIMPS2-3951	UNH-EVP-12273	UNH-IAQ-9392	UNH-FAQ-9345	19534
UNH-SIMPS2-3952	UNH-EVP-12274	UNH-IAQ-9393	UNH-FAQ-9346	21501
UNH-SIMPS2-3953	UNH-EVP-12275	UNH-IAQ-9394	UNH-FAQ-9347	23444
UNH-SIMPS2-3954	UNH-EVP-12276	UNH-IAQ-9395	UNH-FAQ-9348	27380
UNH-SIMPS2-3955	UNH-EVP-12277	UNH-IAQ-9396	UNH-FAQ-9349	31288
UNH-SIMPS2-3956	UNH-EVP-12278	UNH-IAQ-9397	UNH-FAQ-9350	35185
UNH-SIMPS2-3957	UNH-EVP-12279	UNH-IAQ-9398	UNH-FAQ-9351	38991
UNH-SIMPS2-3958	UNH-EVP-12280	UNH-IAQ-9399	UNH-FAQ-9352	42880
UNH-SIMPS2-3959	UNH-EVP-12281	UNH-IAQ-9400	UNH-FAQ-9353	46929
UNH-SIMPS2-3960	UNH-EVP-12282	UNH-IAQ-9401	UNH-FAQ-9354	50914
UNH-SIMPS2-3961	UNH-EVP-10942	UNH-IAQ-9402	UNH-FAQ-9355	54294
UNH-SIMPS2-3962	UNH-EVP-12290	UNH-IAQ-9403	UNH-FAQ-9356	63976
UNH-SIMPS2-3963	UNH-EVP-12291	UNH-IAQ-9404	UNH-FAQ-9357	73817
UNH-SIMPS2-3964	UNH-EVP-12292	UNH-IAQ-9405	UNH-FAQ-9358	85514
UNH-SIMPS2-3965	UNH-EVP-12293	UNH-IAQ-9406	UNH-FAQ-9359	97120
UNH-SIMPS2-3966	UNH-EVP-12294	UNH-IAQ-9407	UNH-FAQ-9360	108642
UNH-SIMPS2-3967	UNH-EVP-12295	UNH-IAQ-9408	UNH-FAQ-9361	162507

Table 2: List of 0.75-3 MeV (200 keV Wien) PSFs used for studying the Cygnus X-1 response.

3 The Imaging Data

Three sets of DRI data were used as input to the imaging process. For the Crab, we took the standard (MPE) 1-3 MeV data for Viewing Period 1.0. For Cygnus X-1, we chose two sets of data. The first set covered all of the available data on Cygnus X-1 from phases 1-3 of the CGRO mission; this included all observations where Cygnus X-1 was within 40° of the COMPTEL z-axis. The second set of Cygnus X-1 data covered all of phase 1 only. These three datasets provided a range of source likelihoods from about 25 to 360. Images were generated using the standard SRCLIX, with no additional background models.

On the following pages, we tabulate the SRCLIX results for the 1-3 MeV Crab data (table 3), the 0.75-3.0 MeV Cygnus X-1 data from phases 1-3 (table4) and the 0.75-3.0 MeV Cygnus X-1 data from phase 1 alone (table 5). Also shown, in each case, are plots of the likelihood ratio and derived source counts versus the number of events incorporated into the FAQ (figures 1-3). These plots clearly show that an asymptotic level is approach by the time we get to having 20,000 events in the PSF.

In order to evaluate the viability of a PSF, we must also look at the derived location contours to be sure that they are consistent with the (known) source location. We do that for the Cygnus X-1 data in figures 4 and 5. There we can see that even with a very few number of events, the location contours are still reasonable. We also can see that there is not much difference between the contours derived from 27,000 events in the PSF and those derived from 160,000 events in the PSF.

SRCLIX	*FAQ*	*# events*	*MLM*	*Likelihood*	*Counts*
UNH-SRCLX4-3939	UNH-FAQ-9260	879	UNH-MLM-11547	296.2	5146±321
UNH-SRCLX4-3940	UNH-FAQ-9261	1814	UNH-MLM-11548	320.3	5620±336
UNH-SRCLX4-3941	UNH-FAQ-9262	2743	UNH-MLM-11549	343.5	6061±350
UNH-SRCLX4-3942	UNH-FAQ-9263	3663	UNH-MLM-11550	344.0	6073±351
UNH-SRCLX4-3943	UNH-FAQ-9264	4563	UNH-MLM-11551	342.8	6090±352
UNH-SRCLX4-3944	UNH-FAQ-9265	5478	UNH-MLM-11552	343.4	6147±356
UNH-SRCLX4-3945	UNH-FAQ-9266	7230	UNH-MLM-11553	351.3	6280±359
UNH-SRCLX4-3946	UNH-FAQ-9267	9021	UNH-MLM-11554	353.9	6358±362
UNH-SRCLX4-3947	UNH-FAQ-9268	10858	UNH-MLM-11555	354.7	6404±365
UNH-SRCLX4-3948	UNH-FAQ-9269	12650	UNH-MLM-11556	357.6	6445±365
UNH-SRCLX4-3949	UNH-FAQ-9270	14497	UNH-MLM-11557	359.6	6446±364
UNH-SRCLX4-3950	UNH-FAQ-9271	16313	UNH-MLM-11558	359.6	6464±365
UNH-SRCLX4-3951	UNH-FAQ-9272	18098	UNH-MLM-11559	358.0	6492±368
UNH-SRCLX4-3952	UNH-FAQ-9273	19908	UNH-MLM-11560	358.8	6491±368
UNH-SRCLX4-3953	UNH-FAQ-9274	21638	UNH-MLM-11561	358.0	6504±369

Table 3: SRCLIX results for the 1-3 MeV Crab imaging (Viewing Period 1.0). The DRI data used here included MPE-DRX-15017, MPE-DRG-15700 and MPE-DRE-21486.

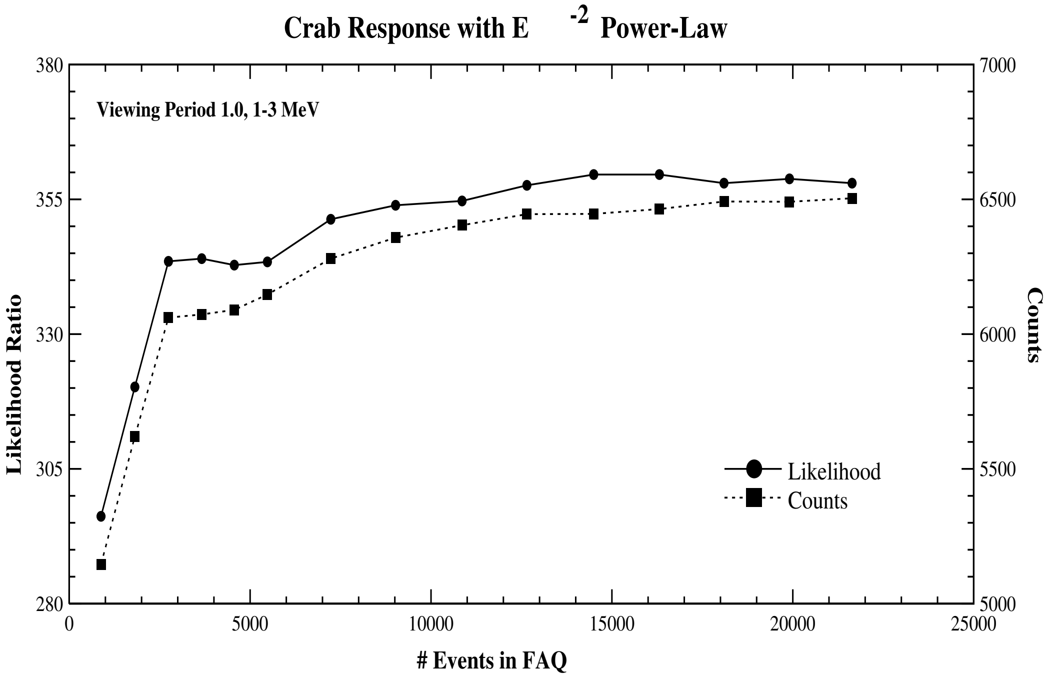

Figure 1: The imaging results for the 1-3 MeV energy interval of the Crab.

SRCLIX	*FAQ*	*# events*	*MLM*	*Likelihood*	*Counts*
UNH-SRCLX4-3972	UNH-FAQ-9333	955	UNH-MLM-11582	67.0	7552±986
UNH-SRCLX4-3973	UNH-FAQ-9334	1974	UNH-MLM-11583	73.7	7838±972
UNH-SRCLX4-3974	UNH-FAQ-9335	2939	UNH-MLM-11584	74.4	7951±982
UNH-SRCLX4-3975	UNH-FAQ-9336	3880	UNH-MLM-11585	73.5	7974±989
UNH-SRCLX4-3976	UNH-FAQ-9337	4843	UNH-MLM-11586	76.5	8243±1004
UNH-SRCLX4-3977	UNH-FAQ-9338	5834	UNH-MLM-11587	78.1	8459±1020
UNH-SRCLX4-3978	UNH-FAQ-9339	7759	UNH-MLM-11588	77.4	8451±1023
UNH-SRCLX4-3979	UNH-FAQ-9340	9710	UNH-MLM-11589	78.3	8535±1027
UNH-SRCLX4-3980	UNH-FAQ-9341	11607	UNH-MLM-11590	77.7	8499±1026
UNH-SRCLX4-3981	UNH-FAQ-9342	13595	UNH-MLM-11591	78.0	8510±1025
UNH-SRCLX4-3982	UNH-FAQ-9343	15585	UNH-MLM-11592	78.3	8499±1022
UNH-SRCLX4-3983	UNH-FAQ-9344	17574	UNH-MLM-11593	77.5	8474±1024
UNH-SRCLX4-3984	UNH-FAQ-9345	19534	UNH-MLM-11594	77.5	8474±1024
UNH-SRCLX4-3985	UNH-FAQ-9346	21501	UNH-MLM-11595	78.4	8533±1026
UNH-SRCLX4-3986	UNH-FAQ-9347	23444	UNH-MLM-11596	77.9	8526±1028
UNH-SRCLX4-3987	UNH-FAQ-9348	27380	UNH-MLM-11597	77.7	8526±1029
UNH-SRCLX4-3988	UNH-FAQ-9349	31288	UNH-MLM-11598	77.6	8493±1027
UNH-SRCLX4-3989	UNH-FAQ-9350	35185	UNH-MLM-11599	77.8	8492±1024
UNH-SRCLX4-3990	UNH-FAQ-9351	38991	UNH-MLM-11600	78.6	8583±1031
UNH-SRCLX4-3991	UNH-FAQ-9352	42880	UNH-MLM-11601	78.4	8572±1030
UNH-SRCLX4-3992	UNH-FAQ-9353	46929	UNH-MLM-11602	78.8	8602±1031
UNH-SRCLX4-3993	UNH-FAQ-9354	50914	UNH-MLM-11603	78.2	8576±1033
UNH-SRCLX4-3994	UNH-FAQ-9355	54294	UNH-MLM-11604	77.8	8674±1048
UNH-SRCLX4-3995	UNH-FAQ-9356	63976	UNH-MLM-11605	77.8	8653±1045
UNH-SRCLX4-3996	UNH-FAQ-9357	73817	UNH-MLM-11606	77.5	8606±1041
UNH-SRCLX4-3997	UNH-FAQ-9358	85514	UNH-MLM-11607	77.8	8626±1041
UNH-SRCLX4-3998	UNH-FAQ-9359	97120	UNH-MLM-11608	78.2	8643±1041
UNH-SRCLX4-3999	UNH-FAQ-9360	108642	UNH-MLM-11609	78.2	8635±1040
UNH-SRCLX4-4000	UNH-FAQ-9361	162507	UNH-MLM-11610	78.7	8655±1039

Table 4: SRCLIX results for the 0.75-3 MeV Cygnus X-1 imaging of data from Phases 1-3. The DRI data used here included UNH-DRX-6880, UNH-DRG-7447 and UNH-DRE-10207.

SRCLIX	*FAQ*	*# events*	*MLM*	*Likelihood*	*Counts*
UNH-SRCLX4-4007	UNH-FAQ-9333	955	UNH-MLM-11617	22.2	2539±570
UNH-SRCLX4-4008	UNH-FAQ-9334	1974	UNH-MLM-11618	25.0	2669±565
UNH-SRCLX4-4009	UNH-FAQ-9335	2939	UNH-MLM-11619	26.7	2785±570
UNH-SRCLX4-4010	UNH-FAQ-9336	3880	UNH-MLM-11620	25.9	2771±575
UNH-SRCLX4-4011	UNH-FAQ-9337	4843	UNH-MLM-11621	25.0	2764±585
UNH-SRCLX4-4012	UNH-FAQ-9338	5834	UNH-MLM-11622	25.3	2818±594
UNH-SRCLX4-4013	UNH-FAQ-9339	7759	UNH-MLM-11623	24.2	2770±597
UNH-SRCLX4-4014	UNH-FAQ-9340	9710	UNH-MLM-11624	25.1	2843±600
UNH-SRCLX4-4015	UNH-FAQ-9341	11607	UNH-MLM-11625	25.4	2852±598
UNH-SRCLX4-4016	UNH-FAQ-9342	13595	UNH-MLM-11626	25.9	2883±599
UNH-SRCLX4-4017	UNH-FAQ-9343	15585	UNH-MLM-11627	26.0	2881±597
UNH-SRCLX4-4018	UNH-FAQ-9344	17574	UNH-MLM-11628	26.0	2883±598
UNH-SRCLX4-4019	UNH-FAQ-9345	19534	UNH-MLM-11629	26.2	2894±598
UNH-SRCLX4-4020	UNH-FAQ-9346	21501	UNH-MLM-11630	26.8	2930±599
UNH-SRCLX4-4021	UNH-FAQ-9347	23444	UNH-MLM-11631	26.8	2935±600
UNH-SRCLX4-4022	UNH-FAQ-9348	27380	UNH-MLM-11632	26.5	2922±601
UNH-SRCLX4-4023	UNH-FAQ-9349	31288	UNH-MLM-11633	26.4	2910±600
UNH-SRCLX4-4024	UNH-FAQ-9350	35185	UNH-MLM-11634	26.6	2914±598
UNH-SRCLX4-4025	UNH-FAQ-9351	38991	UNH-MLM-11635	26.9	2947±602
UNH-SRCLX4-4026	UNH-FAQ-9352	42880	UNH-MLM-11636	27.0	2956±602
UNH-SRCLX4-4027	UNH-FAQ-9353	46929	UNH-MLM-11637	26.8	2952±603
UNH-SRCLX4-4028	UNH-FAQ-9354	50914	UNH-MLM-11638	26.7	2945±603
UNH-SRCLX4-4029	UNH-FAQ-9355	54294	UNH-MLM-11639	27.3	3010±610
UNH-SRCLX4-4030	UNH-FAQ-9356	63976	UNH-MLM-11640	26.9	2986±609
UNH-SRCLX4-4031	UNH-FAQ-9357	73817	UNH-MLM-11641	27.0	2980±606
UNH-SRCLX4-4032	UNH-FAQ-9358	85514	UNH-MLM-11642	27.1	2986±607
UNH-SRCLX4-4033	UNH-FAQ-9359	97120	UNH-MLM-11643	27.4	3000±607
UNH-SRCLX4-4034	UNH-FAQ-9360	108642	UNH-MLM-11644	27.0	2978±606
UNH-SRCLX4-4035	UNH-FAQ-9361	162507	UNH-MLM-11645	27.0	2974±606

Table 5: SRCLIX results for the 0.75-3 MeV Cygnus X-1 imaging of data from Phase 1. The DRI data used here included UNH-DRX-6798, UNH-DRG-7365 and UNH-DRE-10125.

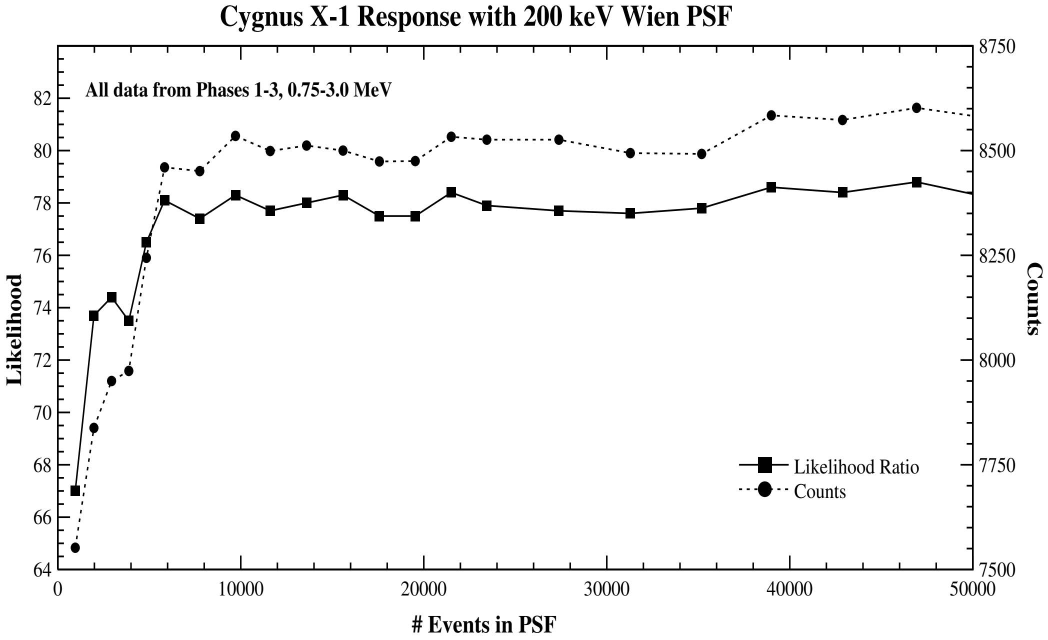

Figure 2: The imaging results for the 0.75-3.0 MeV energy interval of Cygnus X-1 for the sum of all data from phases 1-3.

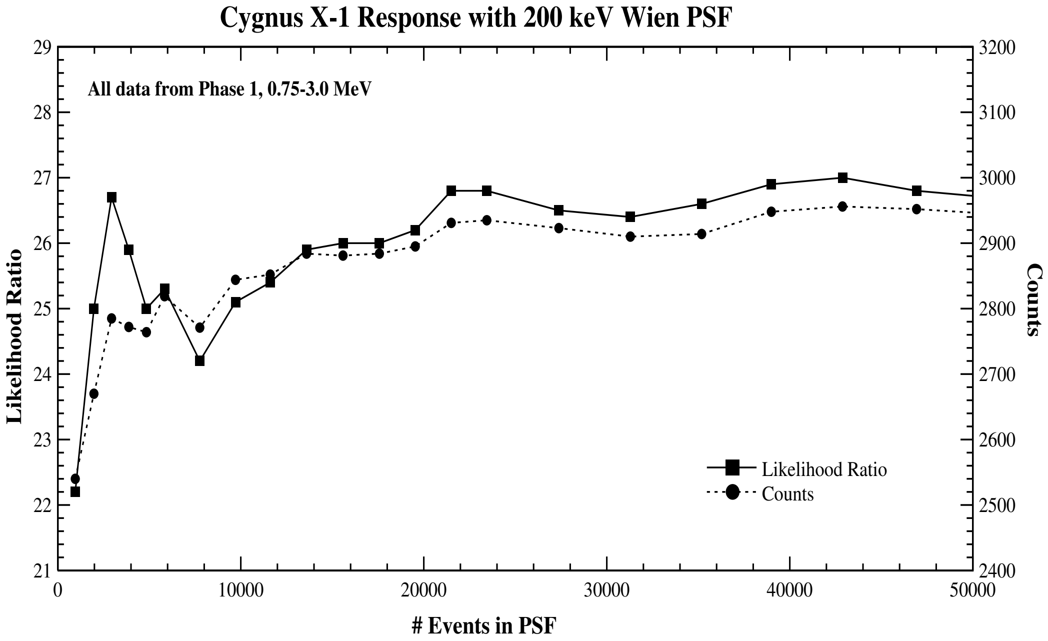

Figure 3: The imaging results for the 0.75-3.0 MeV energy interval of Cygnus X-1 for the sum of all data from phases 1.

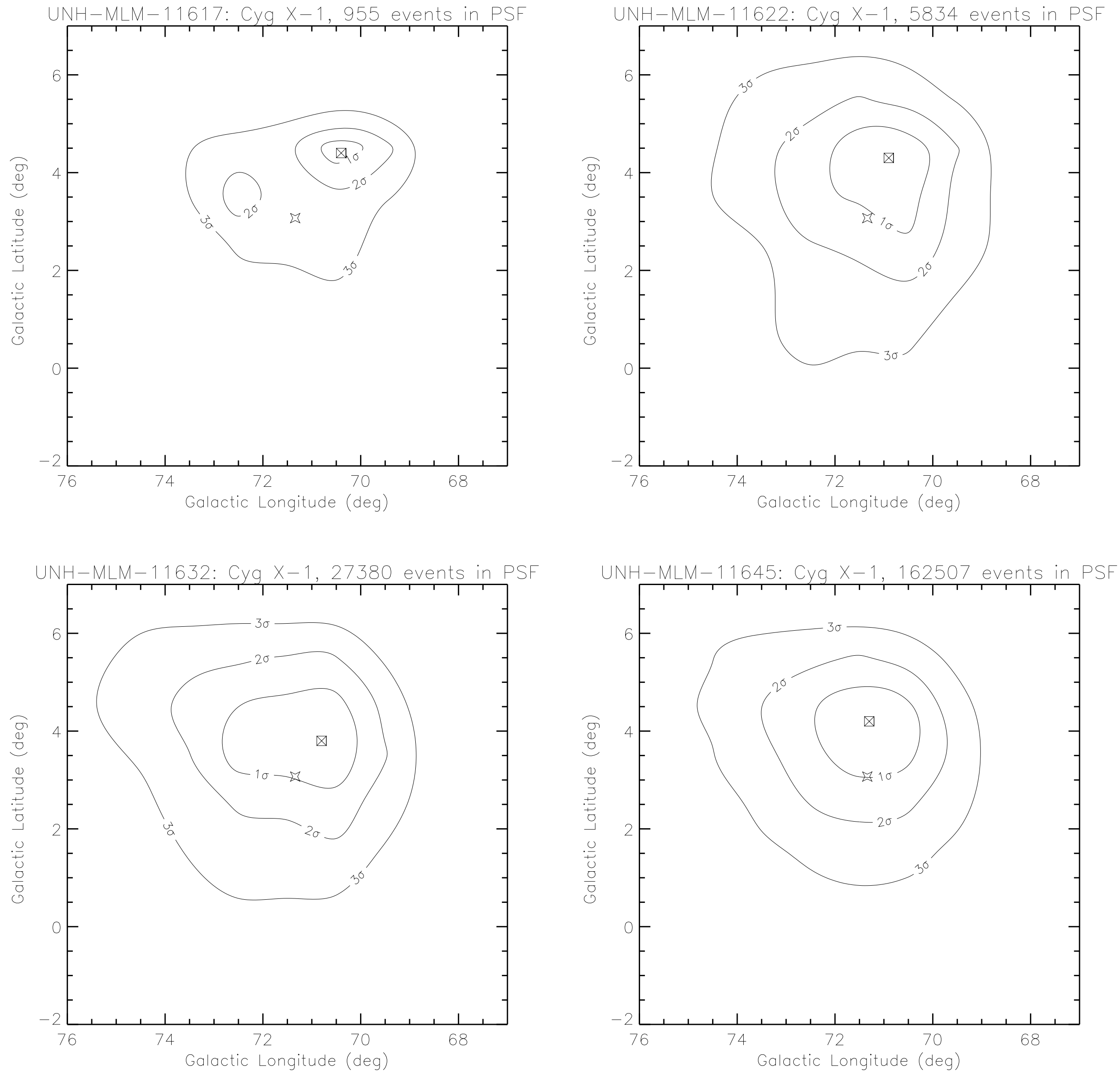

Figure 4: Location contours derived from the Cygnus imaging of the Phase 1 data for various number of events in the PSF. In each case, the maximum likelihood position is denoted by the small box and the location of Cyg X-1 is denoted by a star. Note that even with a very few number of events, the location contours are reasonably consistent with the known source location.

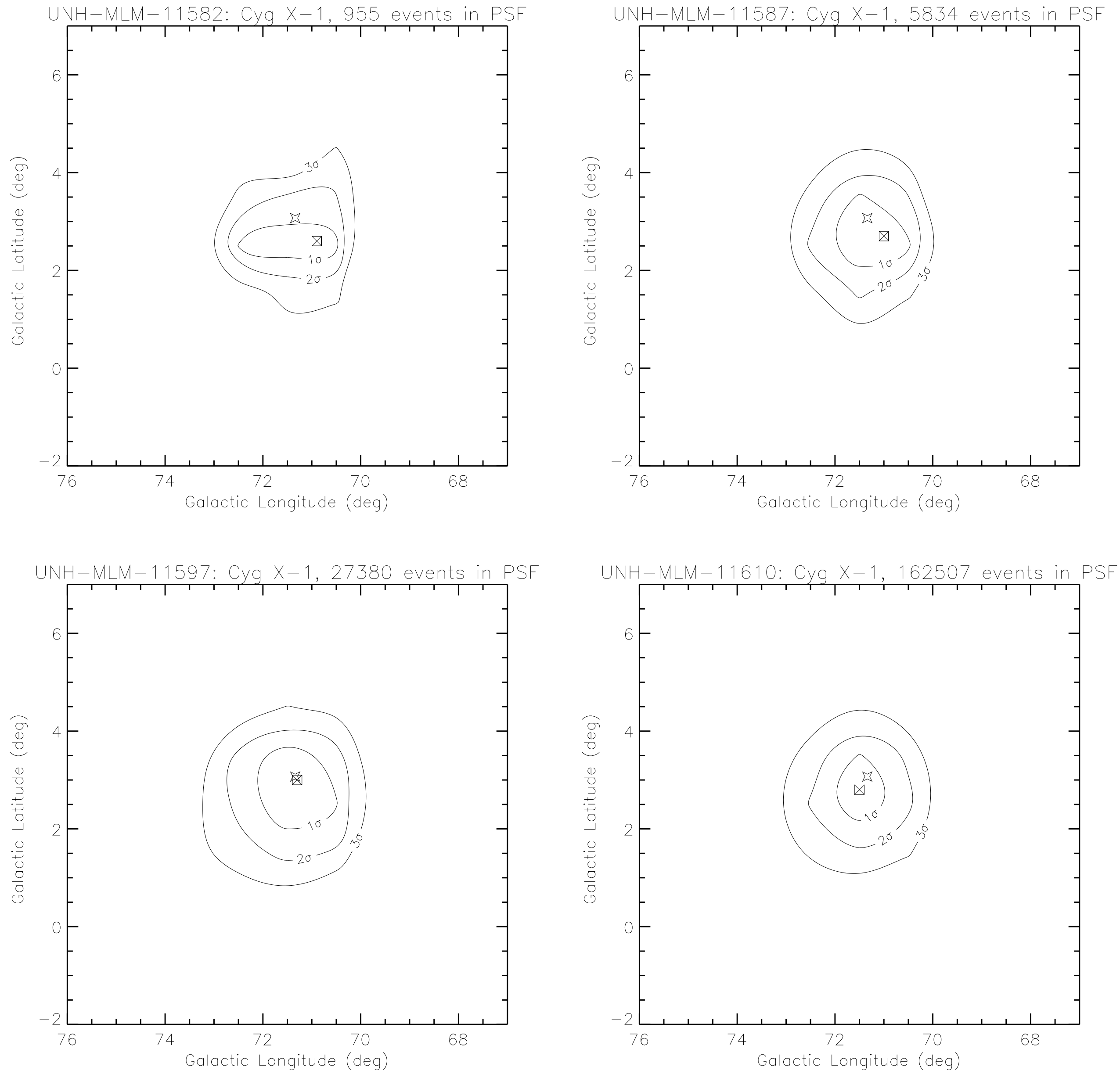

Figure 5: Location contours derived from the Cygnus imaging of the Phase 1-3 data for various number of events in the PSF. In each case, the maximum likelihood position is denoted by the small box and the location of Cyg X-1 is denoted by a star. Note that even with a very few number of events, the location contours are reasonably consistent with the known source location.

4 Summary

Using real flight data, we have studied the SRCLIX imaging results which are derived from real flight data using PSFs derived from a range of event numbers. We have done so for three different levels of signal-to-noise ratio and for two different spectral shapes. In all cases, the resulting likelihood ratio, the derived number of source counts and the derived location contours were used in the evaluation.

The results of this study indicate that a simulated PSF derived from 20,000 events should provide more than sufficient definition for obtaining the proper imaging results for a point source. (Even as few as 10,000 events may be sufficient.) This conclusion is, to first order, independent of the source signal-to-noise and the assumed spectral shape.