Subtraction of background stars //SF interference (A feasibility study)

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Conclusions; Good knowledge and modelling of the Star-field is essential. Data will get heavily distorted by background stars.The background subtraction needs further improvements. .The star fields for the observing candidates have to be carefully investigated.

Introduction

In practice there will always be faint stars (and galaxies) within the CHEOPS field and in view of the large PSF they will intersect each other as well as the target star. The usual way of handling such a situation would be PSF-fitting and if we know the positions and (approximately) the brightness of these field objects it should be possible to apply such a photometric reduction scheme. However, there are complications: the PSF is different from one frame to another (because of pointing jitter) and in addition it varies with radial distance from the central object. And, moreover, each star has a trail moving with it. This means that we should really try to model the images as well as possible. For that we need two things

1. **A well known star field. As Bastien has shown, current catalogues do not provide neither the photmetric quality nor the coverage close to the target (I.e where they are most harmful). This means that we should carry out dedicated ground-based observations for providing the required information.**
2. **In order to reconstruct the pointing jitter we need the position files from the ACS (as it is planned to calculate the centroid for each frame it is just a matter to add this in the housekeeping data)**

To test how well this may work we first generate data for a bright target placed in a realistic field (we generate more or less populated fields based on Bastien's report) and then we make a second "model" run of the same field (except the target) without any noise using the calculated jitter (i.e. not exactly the input jitter). We also apply some uncertainty in the FF and the brightness of the field stars. Then we subtract the model images from the generated ones and use the residuals for the photometry. The result is relatively encouraging.

Star field generation

Assuming that the brightness distribution is independent of the line of sight (number of stars doubling for each magnitude step) and also assuming that the fainter stars statistically get cooler we can generate a representative star field. We are aware that this can be much better done by using a stellar population model for the galaxy, but for nitial tests it should be OK The following IDL routine is used:

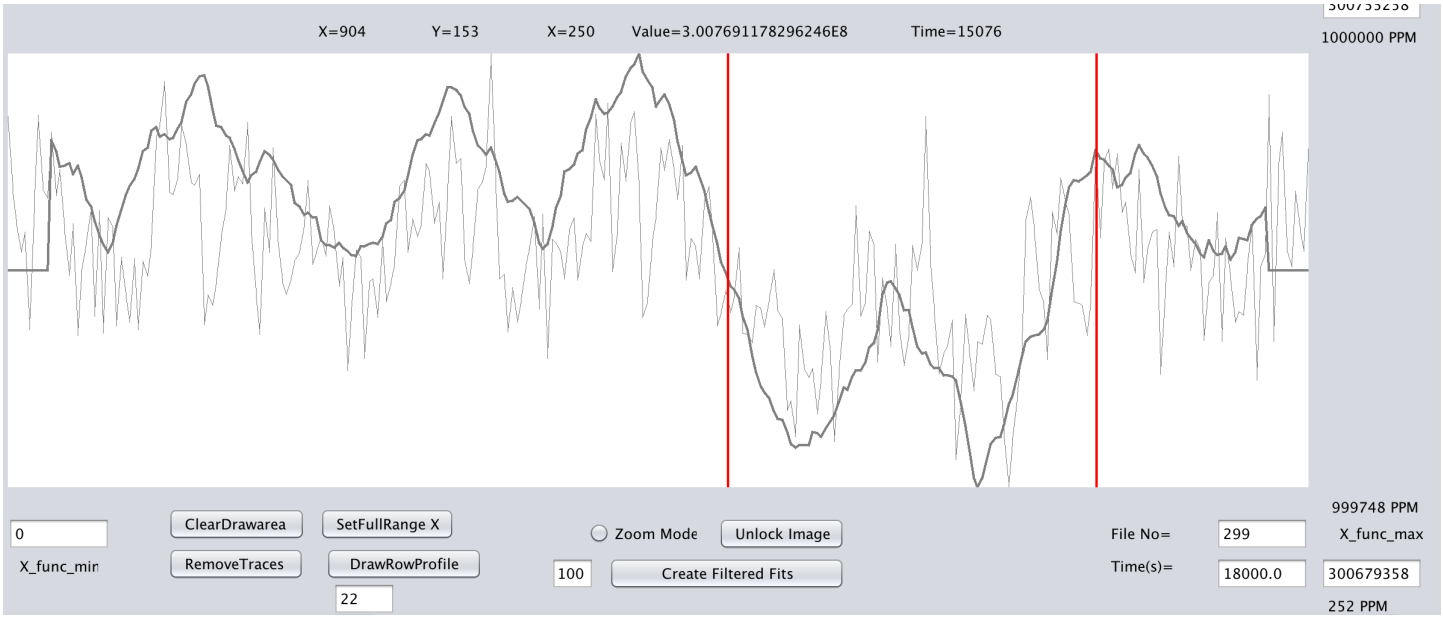
```
Pro CHEOPS_fieldStars, list, 'listfile' , num ;num = numbers of stars within a box 281x281" and V<20
;based on the average field as described by Bastien Courcol
list=fltarr(5,num) ; star num, V, Teff, x, y
t0=systime(1)
wait,0.1
seed=systime(1)-t0
pos=281.*randomn(seed,num,num,/uniform)-140.
```

```
list(0,*)= findgen(num)
list(3,*)=pos(0,*)
list(4,*)=pos(1,*)
q=fltarr(11) ; distribution function of magnitudes
for n=0,10 do q(n)=n^2
qq=10*q ; for better statistics
s=round(total(qq))
hink=fltarr(2,s) ; a basket for picking stars
seed=systime(1)-t0
count=0
 for n=0,10 do begin
  for j=0,qq(n)-1 do begin
   hink(0,count)=9.+n+randomn(seed,/uniform) ;magnitudes
   hink(1,count) = (5000. - n*150) + 200.*randomn(seed,/normal) ; teff
   count=count+1&
   endfor
endfor

for n=0,num-1 do begin
    z=fix(s*randomn(seed,/uniform))
    list(1,n) = hink(0,z)
    list(2,n) = hink(1,z)
endfor

openw,10,listfile
printf,10,list
close,10

end
```

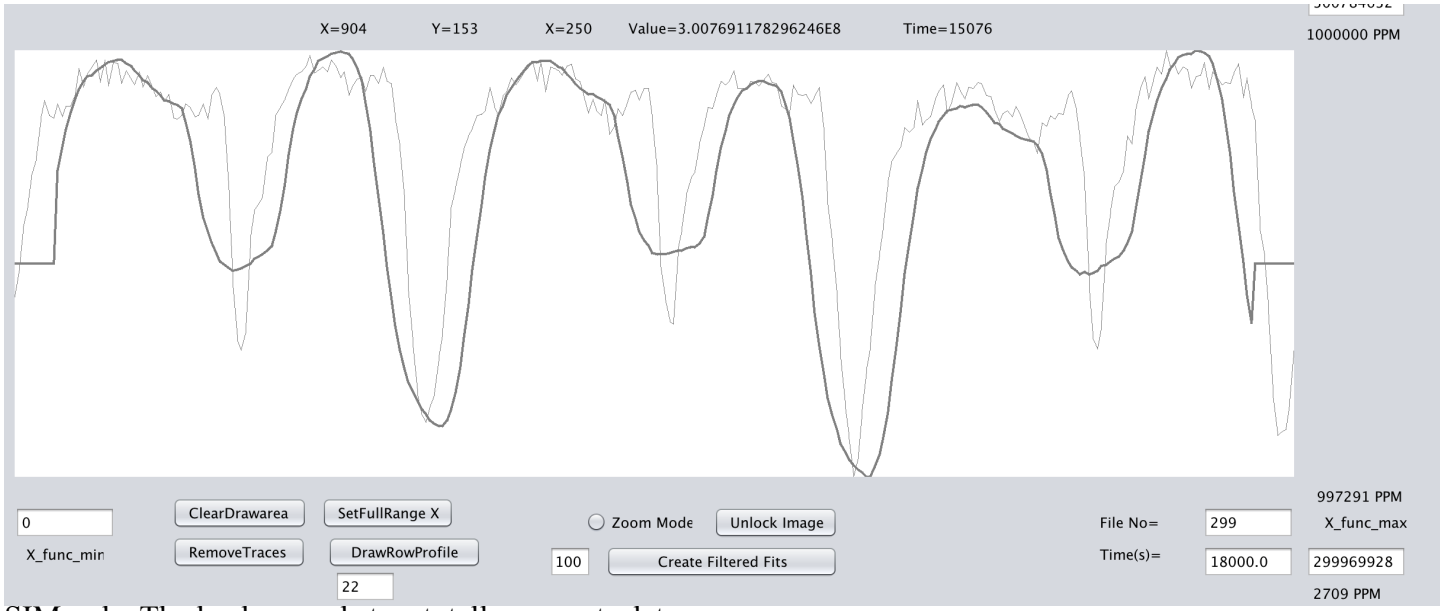
The following star field (generated by the code above) is used for the simulation SF25 simulation

StarNO	Mag	Temp	x_pix	y_pix
0.000000	7	5500	0	0
0.00000	12.7529	4438.38	-23.1042	-114.158
1.00000	17.3260	3573.80	-39.0465	-70.5821
2.00000	13.0263	4431.76	-17.3684	136.097
3.00000	19.8884	3798.31	-64.3218	63.8408
4.00000	16.8838	3963.05	-47.7662	97.6068
5.00000	18.4253	3758.81	-69.1525	-95.1053
6.00000	17.9680	3757.73	18.7365	-7.57529
7.00000	19.4433	3427.67	-6.12267	-10.1092
8.00000	19.6689	3458.58	-50.2908	128.470
9.00000	16.7789	3804.31	64.3811	138.011
10.0000	19.2937	3243.84	126.260	78.2993
11.0000	15.0773	4073.76	-50.4234	-117.032
12.0000	16.8724	3974.87	55.5780	-35.9664
13.0000	19.8158	3695.62	93.0161	-27.0850

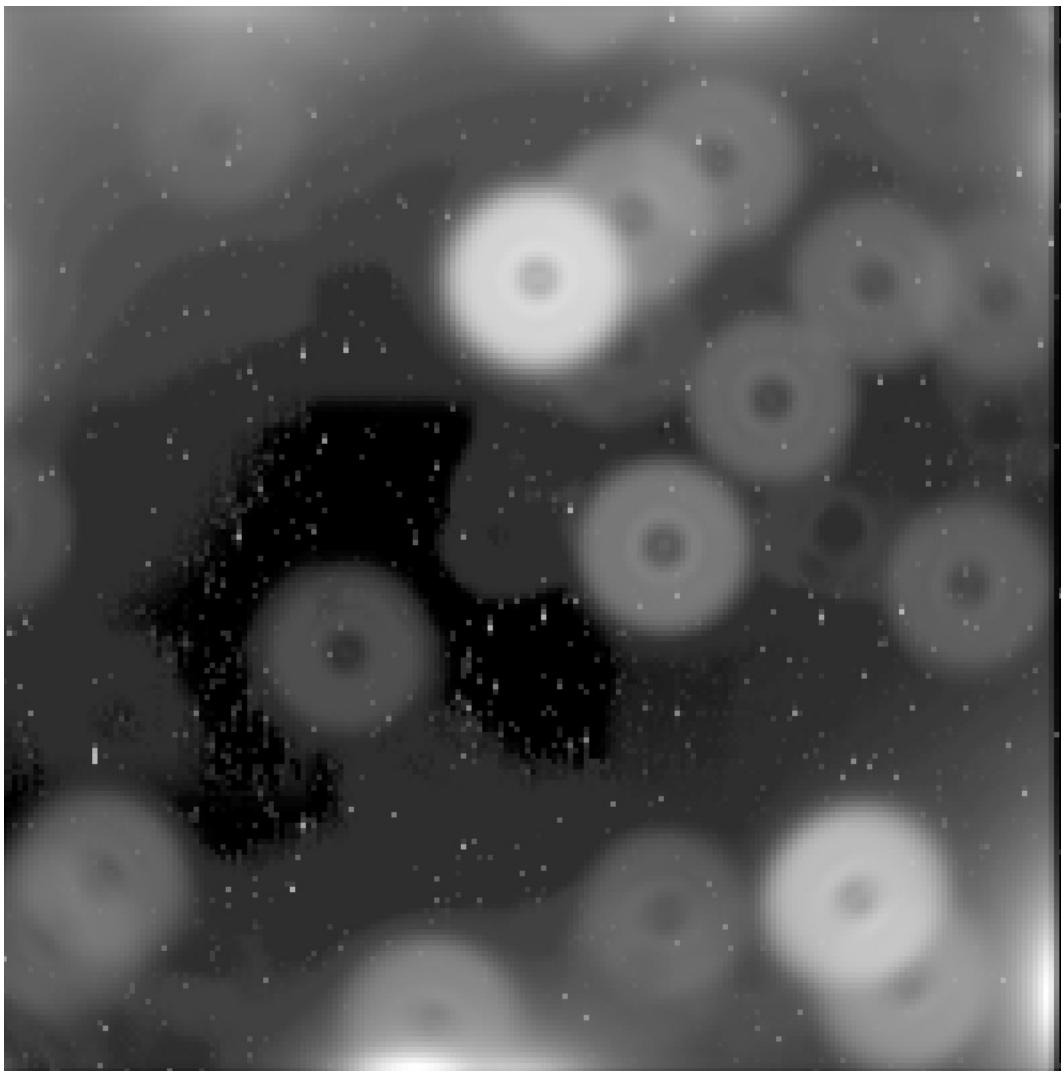
14.0000	17.7796	4167.78	48.2977	117.915
15.0000	18.9649	3711.78	45.1940	-137.373
16.0000	19.5059	3500.71	138.621	-61.4572
17.0000	15.0652	4407.35	95.5066	-131.751
18.0000	19.5951	3794.86	137.314	55.2547
19.0000	16.1664	3958.60	-95.1081	-104.890
20.0000	18.3871	3510.02	133.510	5.88814
21.0000	19.5131	3401.72	-27.1245	134.588
22.0000	15.3758	4434.90	95.0840	122.803
23.0000	17.0560	3650.88	-122.071	83.4941
24.0000	19.5987	3658.87	-65.2205	-74.786



Analysis of SF25 as reference field. Red lines indicates the transit..
Main PSF



SIM only. The background stars totally corrupts data.



Back-ground stars 100

Generated Star-field 100 background stars.

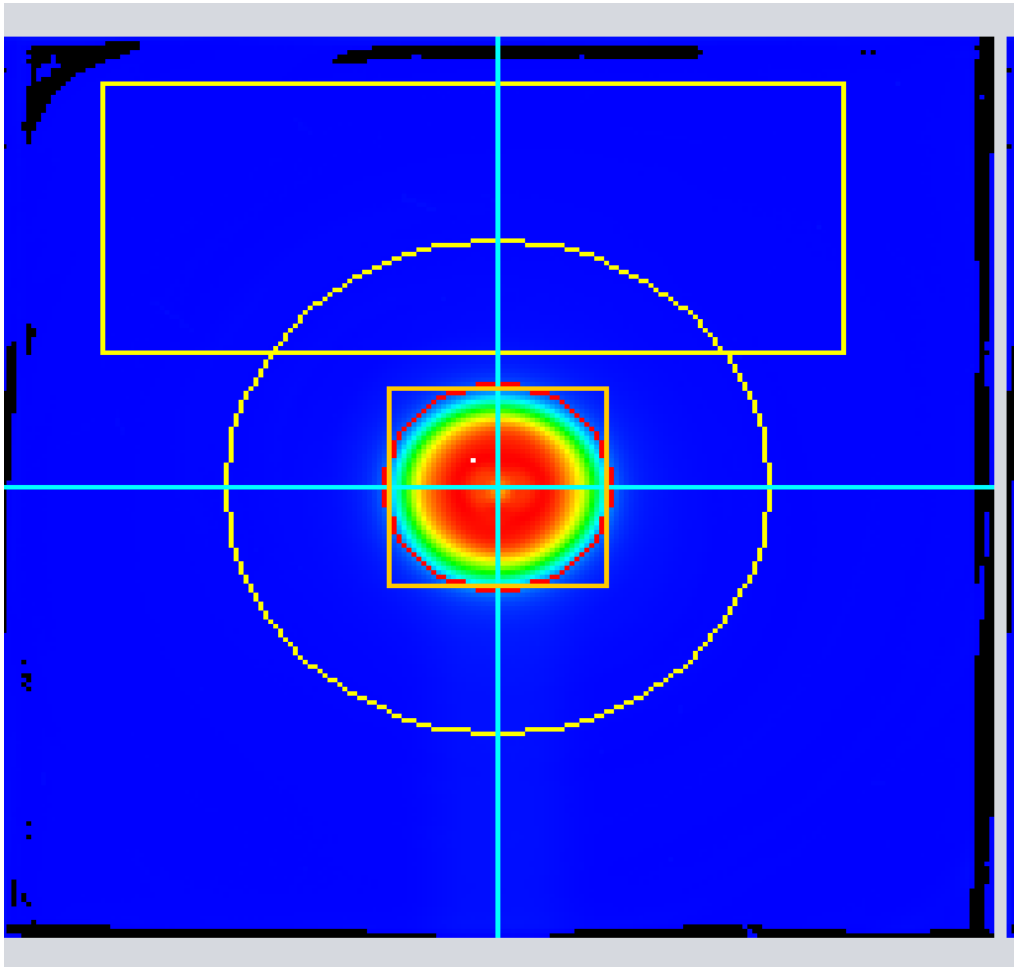
StarNO	Mag	Tempp	x	y
0.00000	7	5500	0	0
0.00000	12.7529	4438.38	-23.1042	-114.158
1.00000	17.3260	3573.80	-47.7662	97.6068
2.00000	13.0263	4431.76	-50.2908	128.470
3.00000	19.8884	3798.31	55.5780	-35.9664
4.00000	16.8838	3963.05	138.621	-61.4572
5.00000	18.4253	3758.81	133.510	5.88814
6.00000	17.9680	3757.73	-65.2205	-74.7861
7.00000	19.4433	3427.67	57.6468	80.0237
8.00000	19.6689	3458.58	76.1902	22.9414
9.00000	16.7789	3804.31	-99.2838	4.59988
10.0000	19.2937	3243.84	-3.09348	-138.430
11.0000	15.0773	4073.76	-79.9874	-60.6275
12.0000	16.8724	3974.87	-81.6225	137.359
13.0000	19.8158	3695.62	12.5337	20.6272
14.0000	17.7796	4167.78	47.7849	43.2250
15.0000	18.9649	3711.78	-111.489	99.3135

16.0000	19.5059	3500.71	-25.6192	-34.5022
17.0000	15.0652	4407.35	132.351	135.989
18.0000	19.5951	3794.86	110.592	-69.5660
19.0000	16.1664	3958.60	-109.225	51.2890
20.0000	18.3871	3510.02	34.8613	-93.6229
21.0000	19.5131	3401.72	-133.747	67.1125
22.0000	15.3758	4434.90	-88.5609	-71.4295
23.0000	17.0560	3650.88	-27.4839	104.131
24.0000	19.5987	3658.87	-85.3594	114.744
25.0000	17.1416	3797.87	-124.945	139.893
26.0000	19.5992	3543.48	-76.0422	-33.1061
27.0000	12.4640	4257.65	114.939	-87.4152
28.0000	18.6815	3564.64	139.537	-13.0510
29.0000	17.7432	3489.11	89.5829	19.1013
30.0000	19.5211	3591.18	3.50790	-126.905
31.0000	19.3480	3544.48	-109.112	-106.219
32.0000	18.1453	3492.43	37.2243	-3.63730
33.0000	18.8307	3724.11	108.959	82.1873
34.0000	15.8980	4206.51	-54.0679	79.2058
35.0000	15.5450	4173.15	24.5414	-70.5009
36.0000	15.5543	4445.81	19.3553	56.2464
37.0000	17.3391	4084.30	5.77296	13.6545
38.0000	19.8501	3231.44	-19.6892	-13.2661
39.0000	19.4279	3868.70	18.1705	139.743
40.0000	19.8622	3539.46	42.9812	4.74721
41.0000	18.6903	3706.31	11.1685	-61.5591
42.0000	18.4009	3932.08	-112.601	139.730
43.0000	13.5935	4308.86	70.2466	-85.4913
44.0000	16.6932	3679.33	20.5152	-81.0427
45.0000	15.2088	4231.48	-115.610	93.9166
46.0000	17.8525	3846.72	7.37492	140.205
47.0000	14.3823	4420.07	122.838	69.9669
48.0000	17.1101	3663.67	34.0620	104.796
49.0000	18.7661	3921.80	-95.4574	-96.5140
50.0000	18.0421	3948.33	-94.6156	41.9044
51.0000	14.2801	4523.68	27.4887	-1.77045
52.0000	19.2770	3044.69	56.4628	-4.93576
53.0000	16.5796	3711.69	12.9211	-128.627
54.0000	16.9544	3775.80	112.309	99.2922
55.0000	15.3543	3976.57	2.02937	130.181
56.0000	19.5287	3294.76	16.5405	93.9238
57.0000	16.7253	3922.45	140.989	132.874
58.0000	19.1200	3354.07	-109.318	131.861
59.0000	18.9466	3598.51	90.1630	129.058
60.0000	17.2252	4068.45	-44.0264	87.9248
61.0000	19.8378	3637.72	-34.1550	-128.180
62.0000	19.4279	3868.70	-116.022	-77.9046
63.0000	18.8477	3572.88	122.446	74.1021
64.0000	15.3763	4358.63	13.6978	106.283
65.0000	17.2047	3626.29	138.627	-73.3853
66.0000	19.1017	3680.13	14.9153	-78.3972
67.0000	16.1152	3557.07	-32.5250	-19.9556

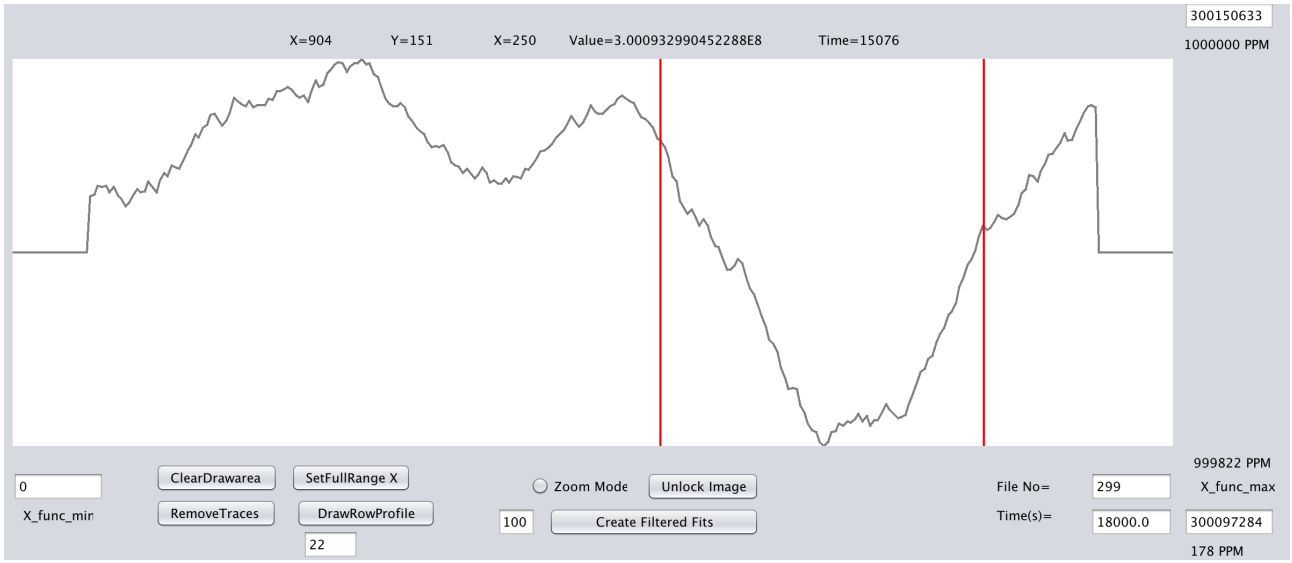
68.0000	19.0996	3241.30	-64.0589	-94.9726
69.0000	13.7078	4564.15	-4.93687	-118.184
70.0000	19.3189	3497.38	-76.9866	80.4076
71.0000	17.8085	4111.33	-2.49939	3.18787
72.0000	14.2619	4300.48	-19.4955	-89.7123
73.0000	16.5928	3814.71	-106.567	35.7308
74.0000	18.5128	3738.38	-90.9944	97.6857
75.0000	17.3010	3616.80	40.6583	-82.0025
76.0000	17.1135	3533.13	82.8871	79.9012
77.0000	19.4457	3536.87	76.9981	33.0113
78.0000	13.6680	4785.17	44.1223	119.660
79.0000	17.6124	3795.78	-85.9245	-84.2112
80.0000	15.0017	4305.39	47.8838	24.7980
81.0000	18.7747	3283.24	-58.9666	-76.7756
82.0000	17.2900	3927.46	5.83952	102.701
83.0000	19.0004	3329.79	-137.448	6.18755
84.0000	16.5015	3860.52	-14.2226	136.726
85.0000	14.8695	3884.25	39.3217	69.6880
86.0000	11.4885	4642.34	4.60939	49.3363
87.0000	16.1947	3988.35	20.0737	36.1195
88.0000	14.2647	4167.03	22.7672	59.5915
89.0000	12.3160	4215.94	60.7606	-68.6307
90.0000	15.6520	4188.19	91.4585	42.6199
91.0000	14.1156	4350.38	-137.005	58.7670
92.0000	18.6390	3570.15	-37.9675	70.7487
93.0000	16.1441	4106.97	-131.280	132.427
94.0000	15.1931	4145.24	67.8278	45.8116
95.0000	17.9447	3549.78	7.60121	124.347
96.0000	19.8418	3366.39	-19.1793	-44.2693
97.0000	15.3612	4195.89	83.9471	-10.9932
98.0000	17.1793	4037.82	59.8942	-0.210999
99.0000	19.1573	3569.71	-124.843	-107.193

SF 100

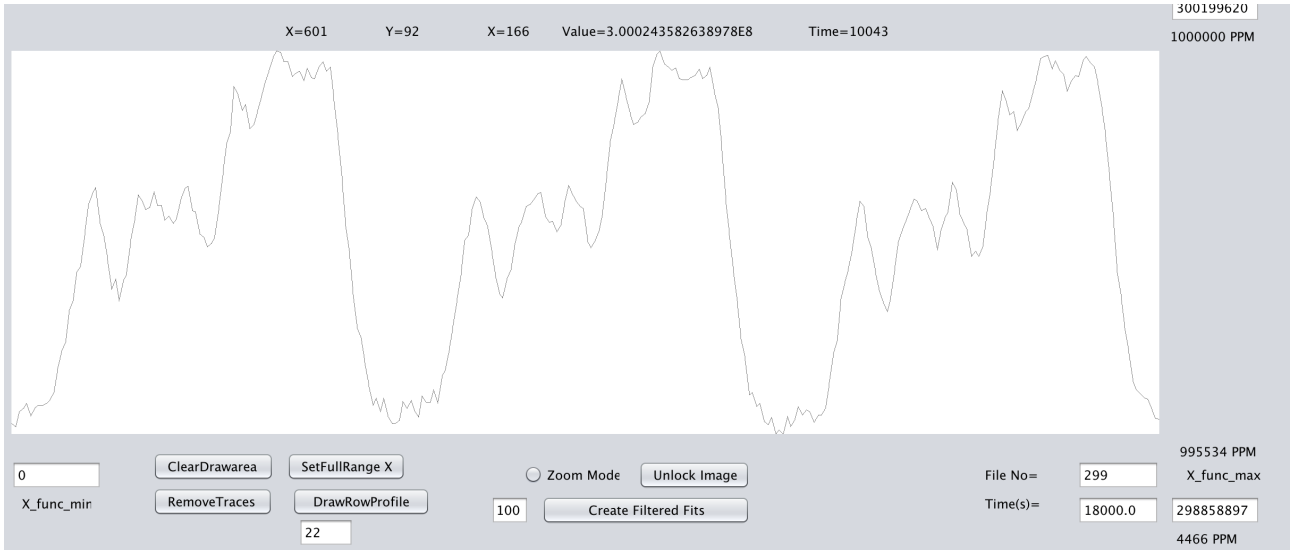
The selection of background is hard and needs further refinement.



A rather large background is defined. I use the square above the centre to somewhat minimise the effect of the readout trails.



SIM-MODEL run Red lines indicate expected transit.



Heavily distorted. No subtraction of background stars.

Procedure for removing background stars.
Both analysis are performed using the built in software in the DFS.

The SIM-MODEL.Uses a bit of pre-processing before applying ring photometry analysis.

All effects ON

SIM RUN → HK-file:CalcJitterList Is produced by calculating centre of gravity. (deviation from Detector centre)

SIM RUN

SimData0
SimData1

SimData n

Detector Trace ON
Dark Current ON
ChargeTransfer ON

Distort FF 0.001
Distort PSF OFF
Distort DARK 0.01

Model Run →

MODEL RUN

SimData0
SimData1

SimData n

Model run (using the simulator to create a model).
We make the following assumptions:

The Jitter will be known in a HK file.(Calculated on-board)
We use the calculated Jitterfile from the SIM run

The detector behaviour will be known readout-traces, charge transfer…..
The FF will be know to an accuracy of 0.1 % (a noise of 0.1 % is added to the ideal FF)
The dark will be know to 1% accuracy
The PSF is well known
The star-field should be well known
We will have orbit/and or images information and will be to determine the rotation of the PSF accurately.

NOTE I exclude the Main PSF for the model run.

The simulator could easily produce the difference between the two runs, A simple subtraction of the **Model run** from the **SIM run** produces an identical data set with normal file structure.Referred to as **SIM-MODEL**.
This data set is analysed the normal way in the DFS using the ring photometry.

SIM-run settings

Loaded PSF:psf_field1.fitsL=40401
DETECTOR
Detector trace=25 ? sec line (=2.5E-5)
Exposure image=1.0
Noise (stdev) added=3
Det Bias (added)=100
Amp of induced temp disturbance=0.005
Period of induced temp disturbance=0.00628

TRANSIT
R_star=0.8
R_planet=1
Transit start time(s)=10000
Transit Duration(s)=5000

ORBIT
Orbital Period (s)=6000
scale factor dx jitterfile=1
scale factor dy jitterfile=1
Orbit angle to Max >27.1=40

SIMULATION EFFECTS ON/OFF
SHOT NOISE: ON
DET NOISE: ON

BRIGHT LIMB: ON
COSMIC RAY: ON 1/x distribution min 100 max=80000 COSMIC RAY FOV/2=88
STAR VARIATION: ON
PLANET TRANSIT : ON
DET TRACE EFFECT: ON
DARK CURRENT EFFECT ON AIMO 47-20DarkAmp=2.38e8DarkExp=-9080
ChargeTransfer ON Transfer Time=0.001

RUN SPECIFICS
Total number of image frames=18000
Accumulation of Image frames=60
No of wiggle excursions/image=1
Resolution/wiggle point (s)=1
Total Simulation Time=18000.0
Output Format=double_64
ON BOARD FF OFF
ON BOARD FF DESTROYER: OFF
ON DEJITTER (Image stacking) OFF
ON BOARD CR identifying / time and spatial OFF
Replace data ON Board OFF
Time Filtering (only)
Sto CR info to fileOFF
CR_avg_hits=1.5% pixel area 1000 sec exposure
CR_avg_enhanced=15% pixel area 1000 sec exposure SAA Orb f Start=0.5 Orb f Finish=0.6

MODEL RUN settings

Loaded PSF:psf_field1.fitsL=40401
DETECTOR
Detector trace=25 ? sec line (=2.5E-5)
Exposure image=1.0
Noise (stdev) added=3
Det Bias (added)=0
Amp of induced temp disturbance=0
Period of induced temp disturbance=0.00628

TRANSIT
R_star=0.8
R_planet=1
Transit start time(s)=10000
Transit Duration(s)=5000

ORBIT
Orbital Period (s)=6000
scale factor dx jitterfile=1
scale factor dy jitterfile=1
Orbit angle to Max >27.1=40

SIMULATION EFFECTS ON/OFF

SHOT NOISE: OFF
DET NOISE: OFF
BRIGHT LIMB: OFF
COSMIC RAY: OFF
STAR VARIATION: OFF
PLANET TRANSIT : OFF
DET TRACE EFFECT: ON
DARK CURRENT EFFECT ON AIMO 47-20DarkAmp=2.38e8DarkExp=-9080
ChargeTransfer ON Transfer Time=0.001

RUN SPECIFICS
Total number of image frames=18000
Accumulation of Image frames=60
No of wiggle excursions/image=1
Resolution/wiggle point (s)=1
Total Simulation Time=18000.0
Output Format=double_64
ON BOARD FF OFF
ON BOARD FF DESTROYER: OFF
ON DEJITTER (Image stacking) OFF
ON BOARD CR identifying / time and spatial OFF
Replace data ON Board OFF
Time Filtering (only)
Sto CR info to fileOFF

////////STAR FIELD 100 TEST RUN settings the same as for the 25 field.