ULIRG reduction steps

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1 Steps of analysis

- Download data for ULIRGs from `http://archive.stsci.edu/hst/search.php` with project id 13655.

Table 1: A sample long table.

filename	instrument	channel	filter	galaxy
ULIRG 1				
jcmc11cwq_flt.fits	ACS	SBC	F125LP	IRASF10594+3818
jcmc11dtq_flt.fits	ACS	SBC	F125LP	IRASF10594+3818
jcmc12jyq_flt.fits	ACS	SBC	F125LP	IRASF10594+3818
jcmc11cxq_flt.fits	ACS	SBC	F140LP	IRASF10594+3818
jcmc11dsq_flt.fits	ACS	SBC	F140LP	IRASF10594+3818
jcmc12jzq_flt.fits	ACS	SBC	F140LP	IRASF10594+3818
jcmc11deq_flt.fits	ACS	SBC	F150LP	IRASF10594+3818
jcmc11dhq_flt.fits	ACS	SBC	F150LP	IRASF10594+3818
jcmc12k0q_flt.fits	ACS	SBC	F150LP	IRASF10594+3818
jcmc11ctq_flt.fits	ACS	SBC	F165LP	IRASF10594+3818
jcmc11e6q_flt.fits	ACS	SBC	F165LP	IRASF10594+3818
jcmc12jxq_flt.fits	ACS	SBC	F165LP	IRASF10594+3818

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Table 1 – continued from previous page

filename	instrument	channel	filter	galaxy
jcmc13pnq_flt.fits	ACS	WFC	F775W	IRASF10594+3818
jcmc13ppq_flt.fits	ACS	WFC	F775W	IRASF10594+3818
jcmc13pmq_flt.fits	ACS	WFC	FR782N	IRASF10594+3818
jcmc13prq_flt.fits	ACS	WFC	FR782N	IRASF10594+3818
ULIRG 2				
jcmc21qtq_flt.fits	ACS	SBC	F125LP	IRASF12447+3721
jcmc21rdq_flt.fits	ACS	SBC	F125LP	IRASF12447+3721
jcmc22f0q_flt.fits	ACS	SBC	F125LP	IRASF12447+3721
jcmc21quq_flt.fits	ACS	SBC	F140LP	IRASF12447+3721
jcmc21rcq_flt.fits	ACS	SBC	F140LP	IRASF12447+3721
jcmc22f1q_flt.fits	ACS	SBC	F140LP	IRASF12447+3721
jcmc21qvq_flt.fits	ACS	SBC	F150LP	IRASF12447+3721
jcmc21rbq_flt.fits	ACS	SBC	F150LP	IRASF12447+3721
jcmc22f5q_flt.fits	ACS	SBC	F150LP	IRASF12447+3721
jcmc21qsq_flt.fits	ACS	SBC	F165LP	IRASF12447+3721
jcmc21req_flt.fits	ACS	SBC	F165LP	IRASF12447+3721
jcmc22exq_flt.fits	ACS	SBC	F165LP	IRASF12447+3721
jcmc23gsq_flt.fits	ACS	WFC	F775W	IRASF12447+3721
jcmc23gvq_flt.fits	ACS	WFC	F775W	IRASF12447+3721
jcmc23grq_flt.fits	ACS	WFC	FR782N	IRASF12447+3721
jcmc23gxq_flt.fits	ACS	WFC	FR782N	IRASF12447+3721
ULIRG 3				
jcmc31n3q_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc31n8q_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc31nbq_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc31ngq_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc32nwq_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc32o1q_flt.fits	ACS	SBC	F125LP	IRASF13469+5833
jcmc31n4q_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc31n7q_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc31ncq_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc31nfq_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc32nxq_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc32o0q_flt.fits	ACS	SBC	F140LP	IRASF13469+5833
jcmc31n5q_flt.fits	ACS	SBC	F150LP	IRASF13469+5833
jcmc31n6q_flt.fits	ACS	SBC	F150LP	IRASF13469+5833

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Table 1 – continued from previous page

filename	instrument	channel	filter	galaxy
jcmc31ndq_flt.fits	ACS	SBC	F150LP	IRASF13469+5833
jcmc31neq_flt.fits	ACS	SBC	F150LP	IRASF13469+5833
jcmc32nyq_flt.fits	ACS	SBC	F150LP	IRASF13469+5833
jcmc32nzq_flt.fits	ACS	SBC	F150LP	IRASF13469+5833
jcmc31n2q_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc31n9q_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc31naq_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc31nhq_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc32nvq_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc32o2q_flt.fits	ACS	SBC	F165LP	IRASF13469+5833
jcmc33dcq_flt.fits	ACS	WFC	F775W	IRASF13469+5833
jcmc33deq_flt.fits	ACS	WFC	F775W	IRASF13469+5833
jcmc33dkq_flt.fits	ACS	WFC	F775W	IRASF13469+5833
jcmc33dbq_flt.fits	ACS	WFC	FR782N	IRASF13469+5833
jcmc33dgq_flt.fits	ACS	WFC	FR782N	IRASF13469+5833
jcmc33diq_flt.fits	ACS	WFC	FR782N	IRASF13469+5833
		ULIRG 4		
jcmc41e1q_flt.fits	ACS	SBC	F125LP	IRASF14202+2615
jcmc41edq_flt.fits	ACS	SBC	F125LP	IRASF14202+2615
jcmc92t9q_flt.fits	ACS	SBC	F125LP	IRASF14202+2615
jcmc41e2q_flt.fits	ACS	SBC	F140LP	IRASF14202+2615
jcmc41ecq_flt.fits	ACS	SBC	F140LP	IRASF14202+2615
jcmc92taq_flt.fits	ACS	SBC	F140LP	IRASF14202+2615
jcmc41e5q_flt.fits	ACS	SBC	F150LP	IRASF14202+2615
jcmc41eaq_flt.fits	ACS	SBC	F150LP	IRASF14202+2615
jcmc92tbq_flt.fits	ACS	SBC	F150LP	IRASF14202+2615
jcmc41dxq_flt.fits	ACS	SBC	F165LP	IRASF14202+2615
jcmc41eeq_flt.fits	ACS	SBC	F165LP	IRASF14202+2615
jcmc92t8q_flt.fits	ACS	SBC	F165LP	IRASF14202+2615
jcmc43nrq_flt.fits	ACS	WFC	F775W	IRASF14202+2615
jcmc43ntq_flt.fits	ACS	WFC	F775W	IRASF14202+2615
jcmc43nqq_flt.fits	ACS	WFC	FR782N	IRASF14202+2615
jcmc43nvq_flt.fits	ACS	WFC	FR782N	IRASF14202+2615
		ULIRG 5		
jcmc51p0q_flt.fits	ACS	SBC	F125LP	IRASF22206-2715
jcmc51peq_flt.fits	ACS	SBC	F125LP	IRASF22206-2715

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Table 1 – continued from previous page

filename	instrument	channel	filter	galaxy
jcmc52i5q_flt.fits	ACS	SBC	F125LP	IRASF22206-2715
jcmc51p1q_flt.fits	ACS	SBC	F140LP	IRASF22206-2715
jcmc51pdq_flt.fits	ACS	SBC	F140LP	IRASF22206-2715
jcmc52i6q_flt.fits	ACS	SBC	F140LP	IRASF22206-2715
jcmc51p3q_flt.fits	ACS	SBC	F150LP	IRASF22206-2715
jcmc51pcq_flt.fits	ACS	SBC	F150LP	IRASF22206-2715
jcmc52i7q_flt.fits	ACS	SBC	F150LP	IRASF22206-2715
jcmc51oyq_flt.fits	ACS	SBC	F165LP	IRASF22206-2715
jcmc51pgq_flt.fits	ACS	SBC	F165LP	IRASF22206-2715
jcmc52i4q_flt.fits	ACS	SBC	F165LP	IRASF22206-2715
jcmc53tjq_flt.fits	ACS	WFC	F775W	IRASF22206-2715
jcmc53tlq_flt.fits	ACS	WFC	F775W	IRASF22206-2715
jcmc53tiq_flt.fits	ACS	WFC	CLEAR1L	IRASF22206-2715
jcmc53tnq_flt.fits	ACS	WFC	CLEAR1L	IRASF22206-2715

1.1 Dark and sky subtraction

- We work with 'FLT' images in this process. Because we want to avoid noise arising from drizzling process.

- We assume that the spatial structure observed in the galaxy frame other than the main galaxy itself originates from the dark current. We start by considering all the 20 dark exposures and select the dark exposure based on our minimization process. The image frame and corresponding dark frames should differ only by a scaling factor, which is a function of exposure time and the temperature of the detector (A^T_{Exp}). In addition to A^T_{Exp}, we also include a constant K, which takes care of sky subtraction in the image. We assume that the sky value is a constant and there is no spatially varying sky.

- In order to remove the contribution from galaxy itself, we find a circular radii R_{95} [1] of the galaxy by following these steps:-

  - First, we subtract a constant sky value from one of the F125LP frames.

[1]Radius at which the total flux falls to 95% of the total flux

- Next, we find the brightest pixel in one of the F125LP frames.
- Then we perform aperture photometry with circular apertures to find out the radius at which the total flux in the exposure falls to 95% of the total flux of the galaxy.
- We mask a circular region on the image centered at pixel position (512, 512) and radius that covers the R_{95}

  We mask a circular region on the image centered at central pixel of SBC filed of view (i.e. (512, 512)) and radius that covers R_{95} radius of the galaxy. For all the following analysis, we work with the masked image of the galaxy. We mask the same region in dark exposures.

- Out of 20 dark exposures, we select the best dark, by identifying the scaling factor and sky value that minimizes the aperture photometric residuals between the image frame and the scaled dark frame.

In the following, we explicitly write the scaling factor as the product of two terms:

$$A^T_{Exp} = A^T * A_{Exp} = A^T * \frac{exp_{gal}}{exp_{dark}} \tag{1}$$

where, A^T depends on the detector temperature only, and $\frac{exp_{gal}}{exp_{dark}}$ accounts for the different exposure times (which are known). We find A^T and K by minimizing the residual between the fluxes in the scaled dark exposures and the galaxy image.

$$f^{out}_g(i,j) = f^{in}_g(i,j) - A^T * \frac{exp_{gal}}{exp_{dark}} * f^k_{dark}(i,j) - K \tag{2}$$

Where $f^{in}_g(i,j)$, $f^{out}_g(i,j)$, $f^k_{dark}(i,j)$ are counts at pixel position (i,j) in the input and output galaxy images and k^{th} dark exposure. A^T and K are the parameters that are to be determined using minimization process. There is a total of 20 dark exposures so $k \in [1, 20]$.

Minimization of the residuals of two images i.e. using minimizing function as

$$F[A^T, k, K] = \sum_{i,j} (f^{out}_g(i,j)[A^T, k, K])^2$$

does not work as the distribution of pixels with non-zero counts are is very sparse which leads to minimum value of A^T and K as zeros. Therefore, we use a minimizing function[2] dependent on radial variation.

$$G[A^T, k, K] = \sum_{r<r_0} |f_g^{out}(r)| \tag{3}$$

where

$$f_g^{out}(r) = \frac{1}{2\pi r \Delta r} \sum_{(i,j):r_{i,j} \in [r-\Delta r/2<, r+\Delta r/2]} f_g^{out}(i-i_0, j-j_0) \tag{4}$$

1.2 combining FLT files using astrodrizzle

- **INTERMEDIATE files**
- **parameters**
- **Example command**

1.3 psfmatch

- **INTERMEDIATE files**
- **parameters**
- **Example command**

1.4 PHOTFLAM factor

- **INTERMEDIATE files**
- **parameters**
- **Example command**

[2]Refer to appendix A

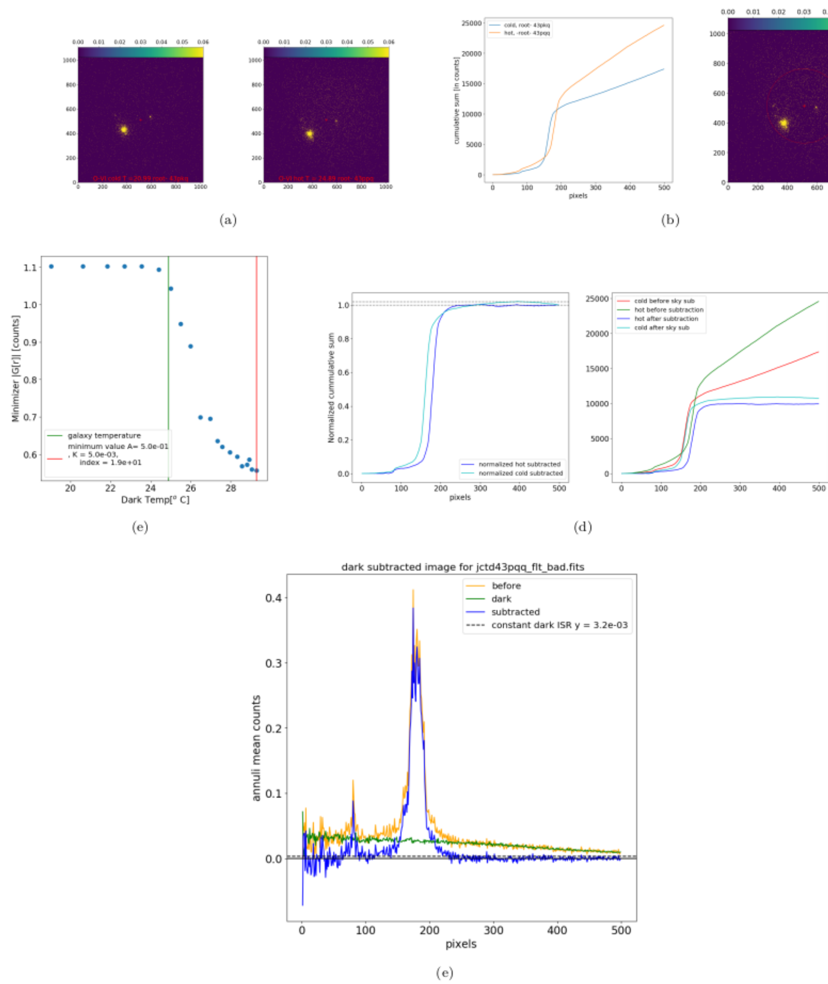

Figure 1: The figure shows the results of applying the dark subtraction method to a sample image (a) Two cold and hot frames. We correct for dark subtraction in hot frame., (b) Cumulative sum profile for FLT files at two different temperature. (c) Minimizer value as a function of temperature of darks (d) Dark subtracted cumulative radial profiles for hot frame before and after subtraction, (e) Radial profile for galaxy in circular apertures centered at (512, 512).

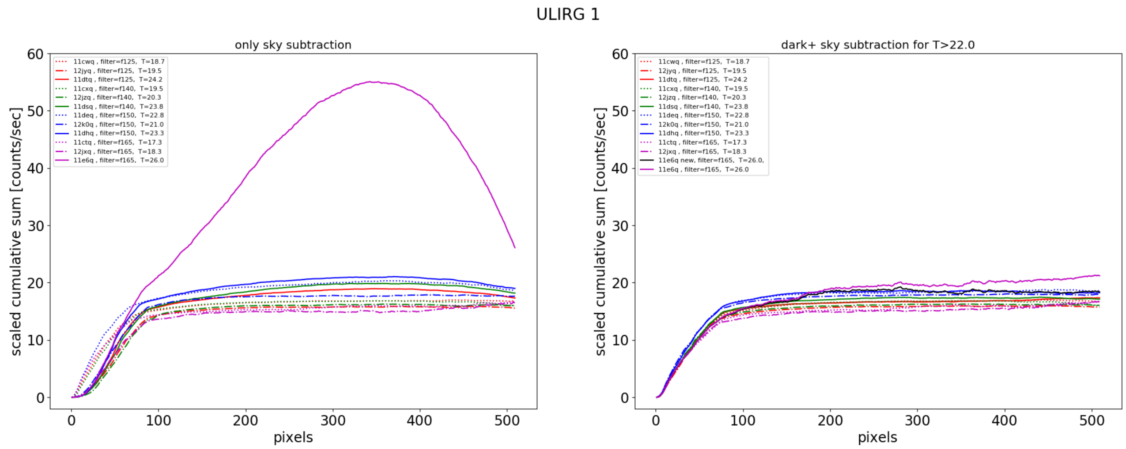

Figure 2: The figure shows circular aperture photometry on each of the exposure for ULIRG 1 before and after sky+dark subtraction.

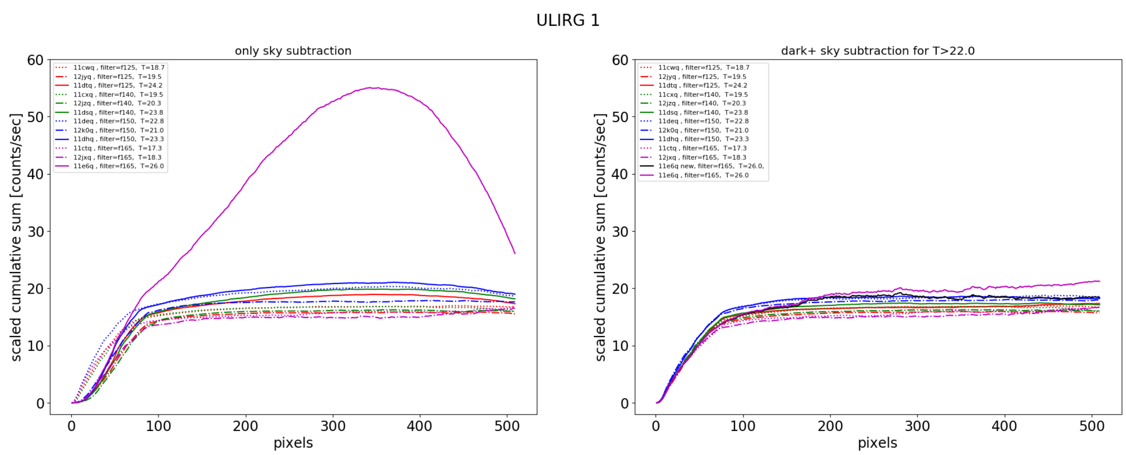

Figure 3: The figure shows circular aperture photometry on each of the exposure for ULIRG 1 before and after sky+dark subtraction.

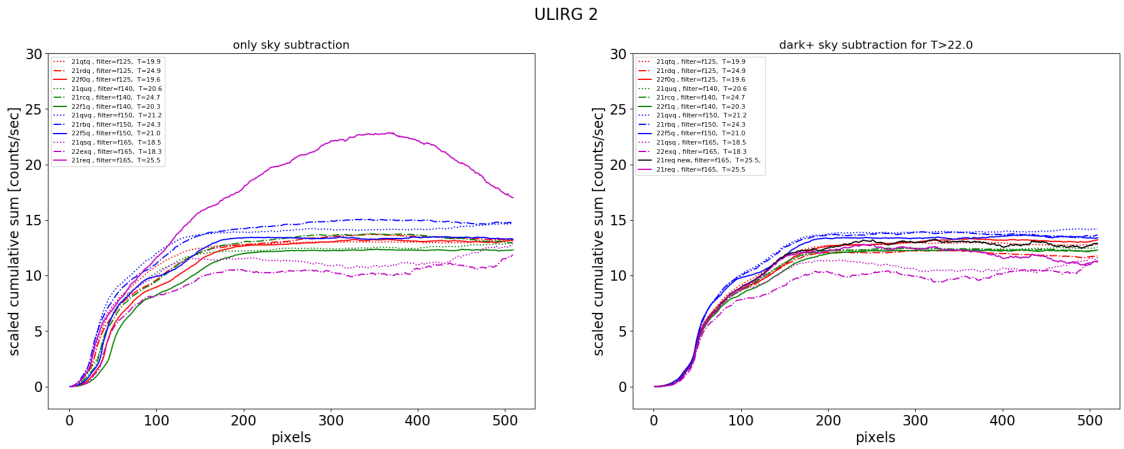

Figure 4: The figure shows circular aperture photometry on each of the exposure for ULIRG 2 before and after sky+dark subtraction.

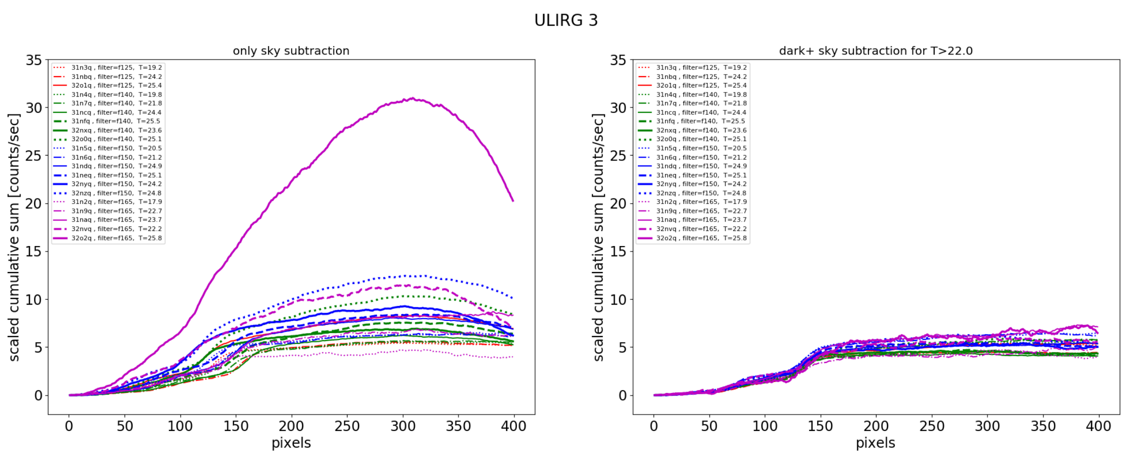

Figure 5: The figure shows circular aperture photometry on each of the exposure for ULIRG 3 before and after sky+dark subtraction.

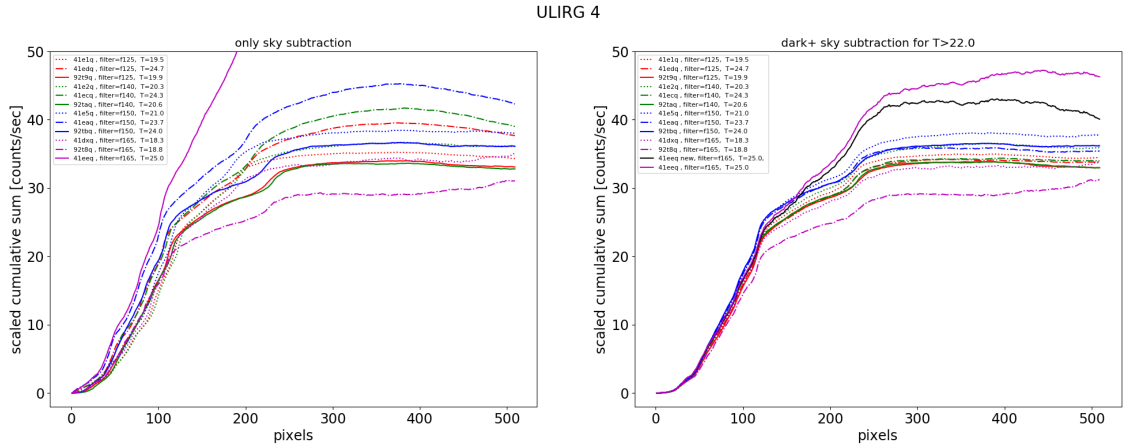

Figure 6: The figure shows circular aperture photometry on each of the exposure for ULIRG 4 before and after sky+dark subtraction.

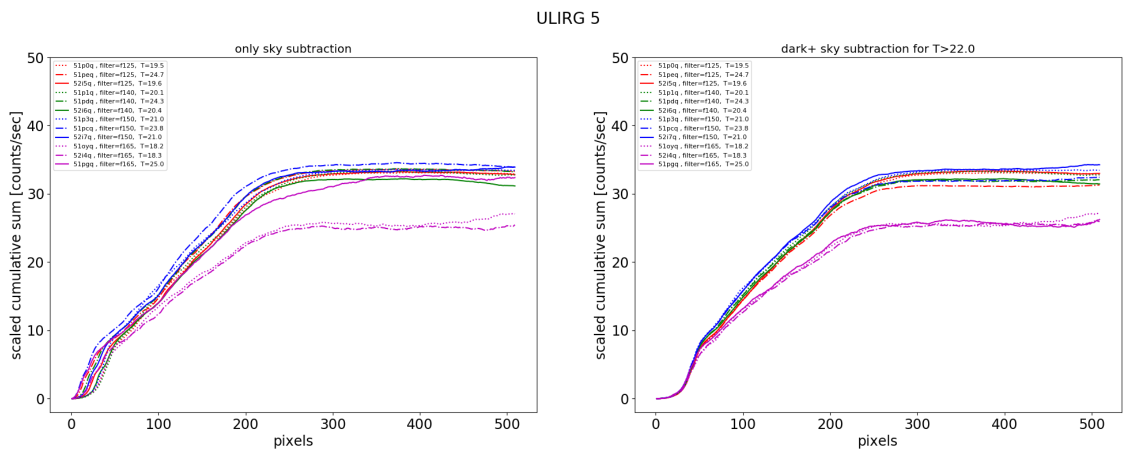

Figure 7: The figure shows circular aperture photometry on each of the exposure for ULIRG 5 before and after sky+dark subtraction.