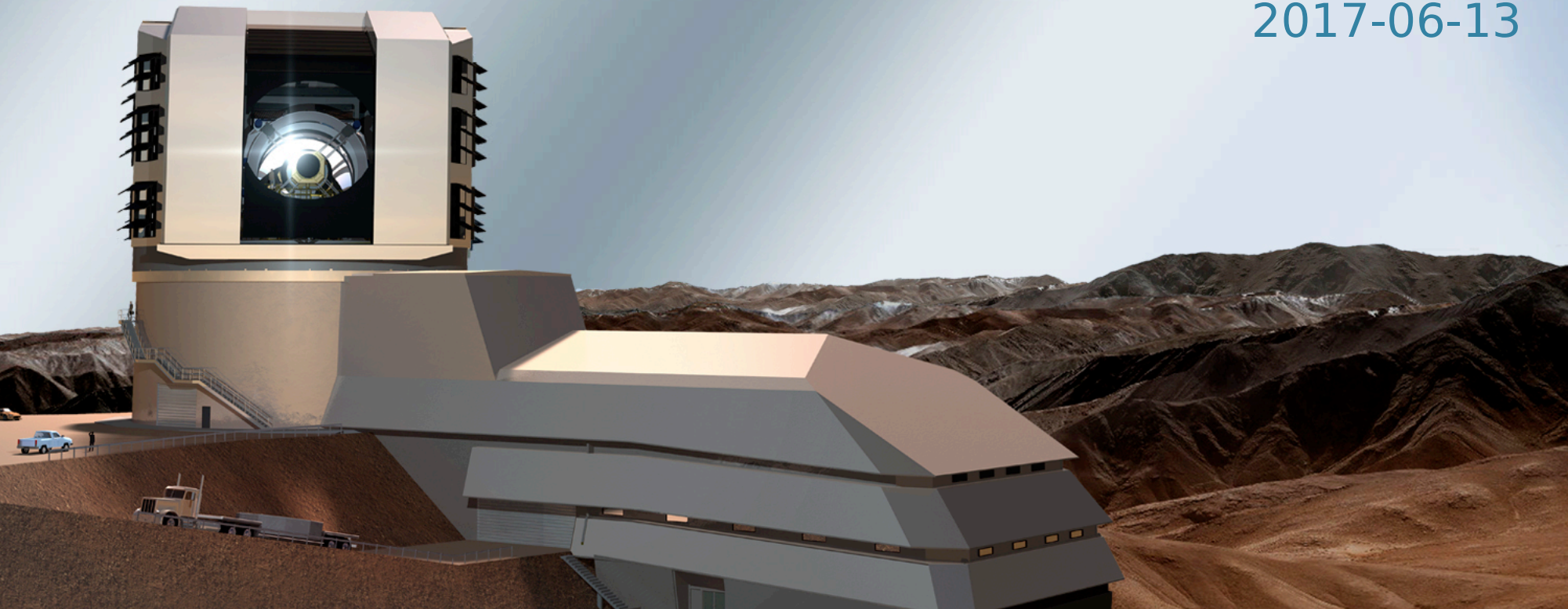
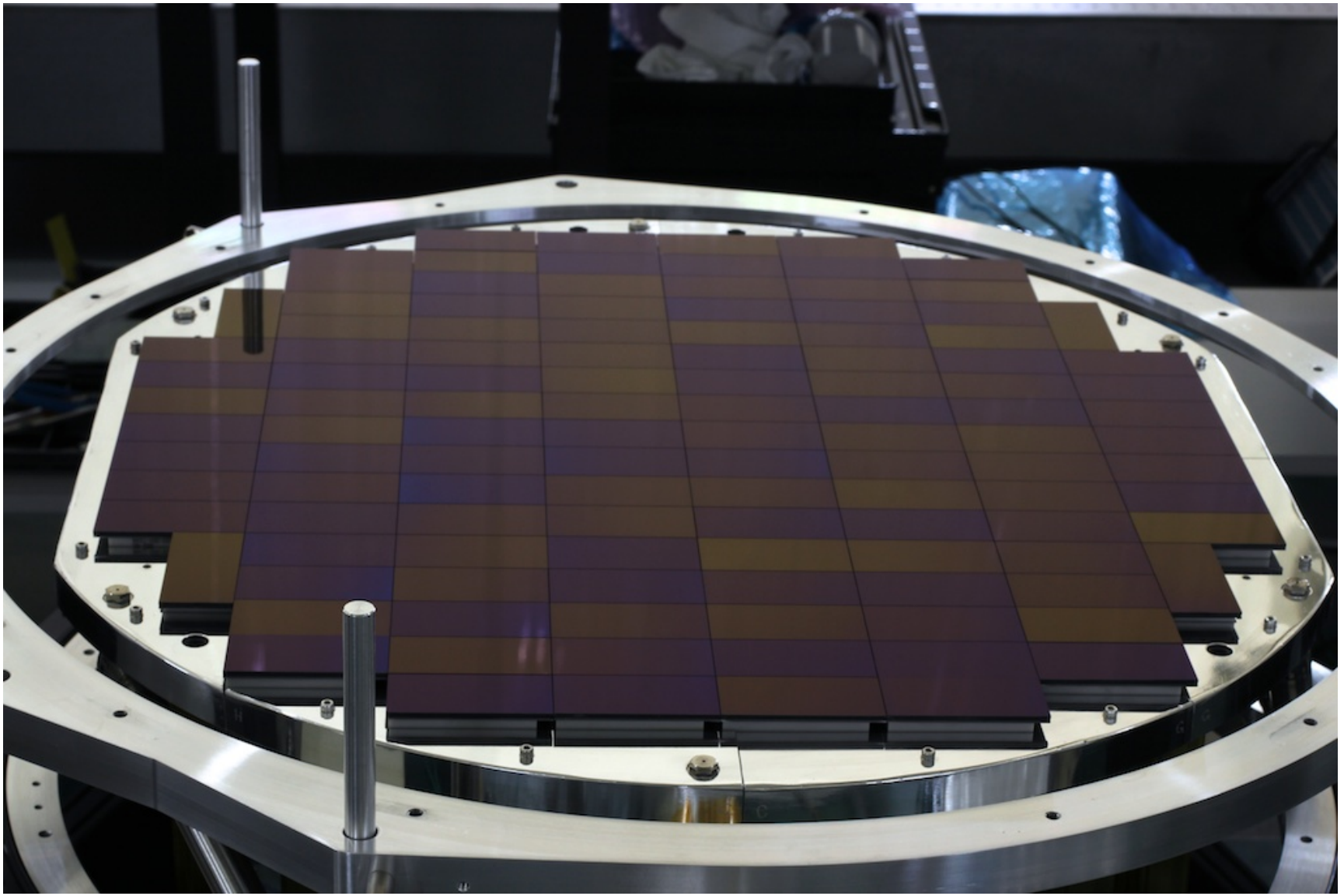
Robert Lupton
LSST Pipeline Scientist

HSC pixels meet LSST Pipelines

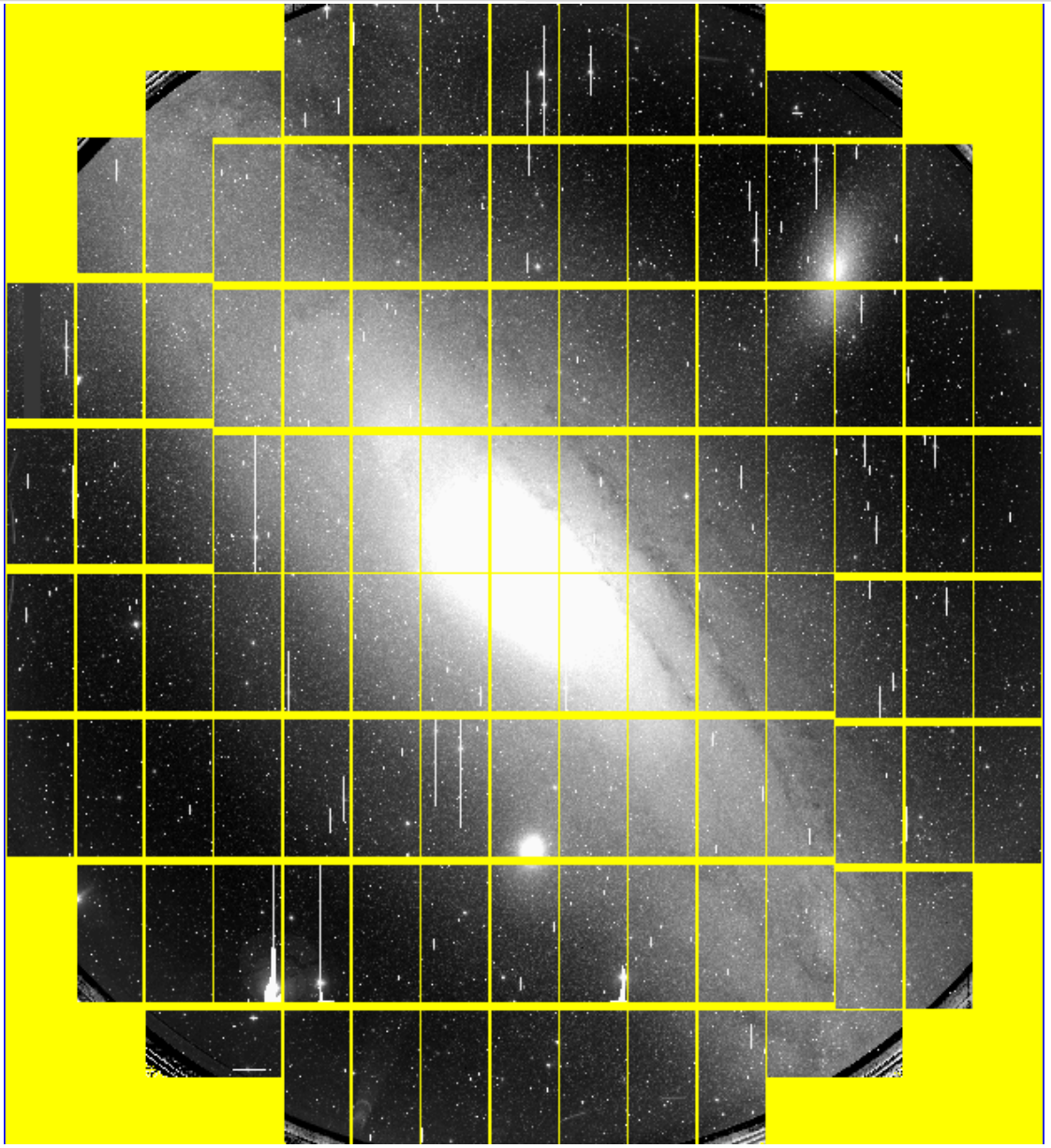
2017-06-13



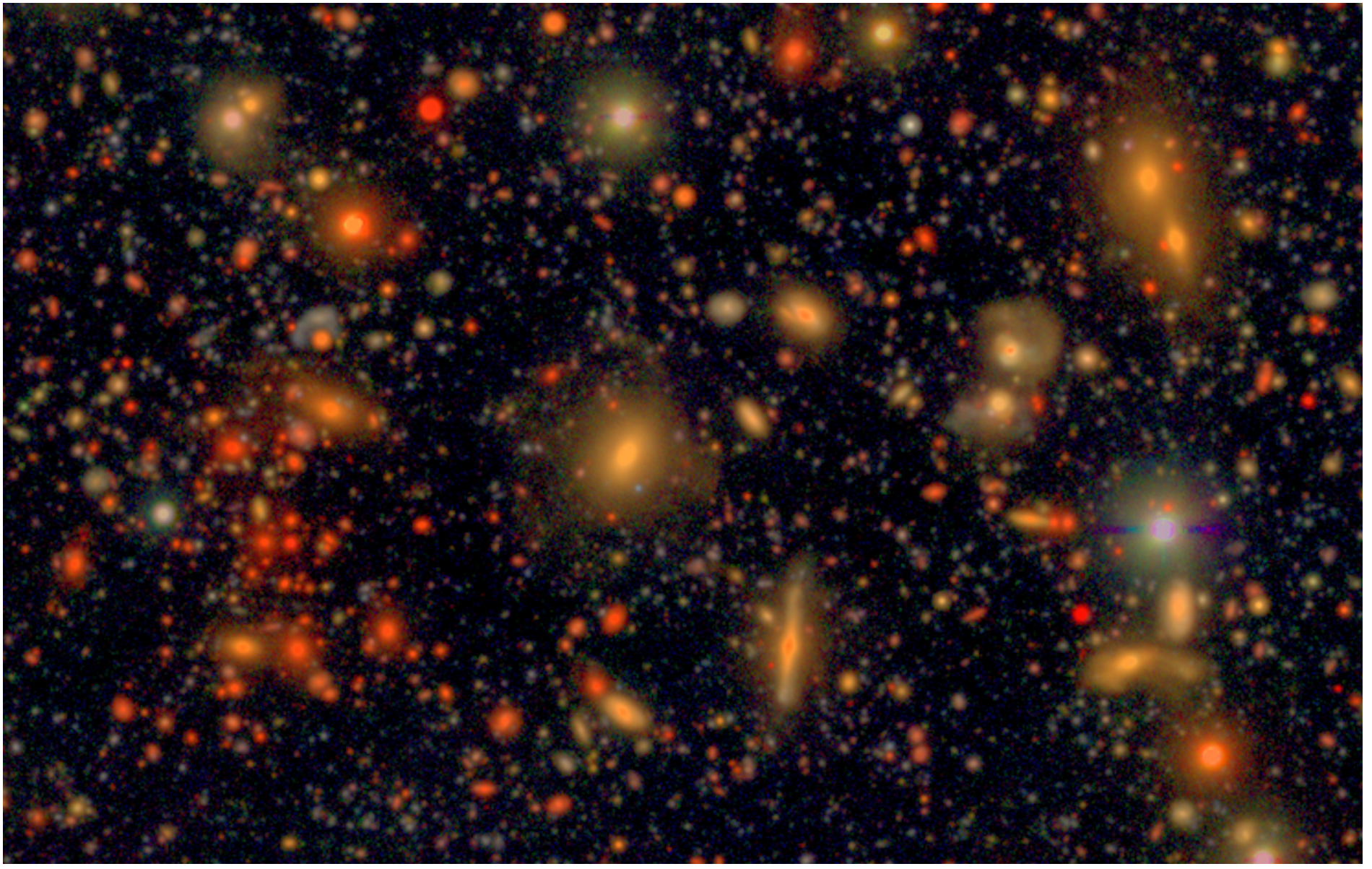
HSC’s Pixels



HSC's 1.8 deg^2 Field of View



Cosmos



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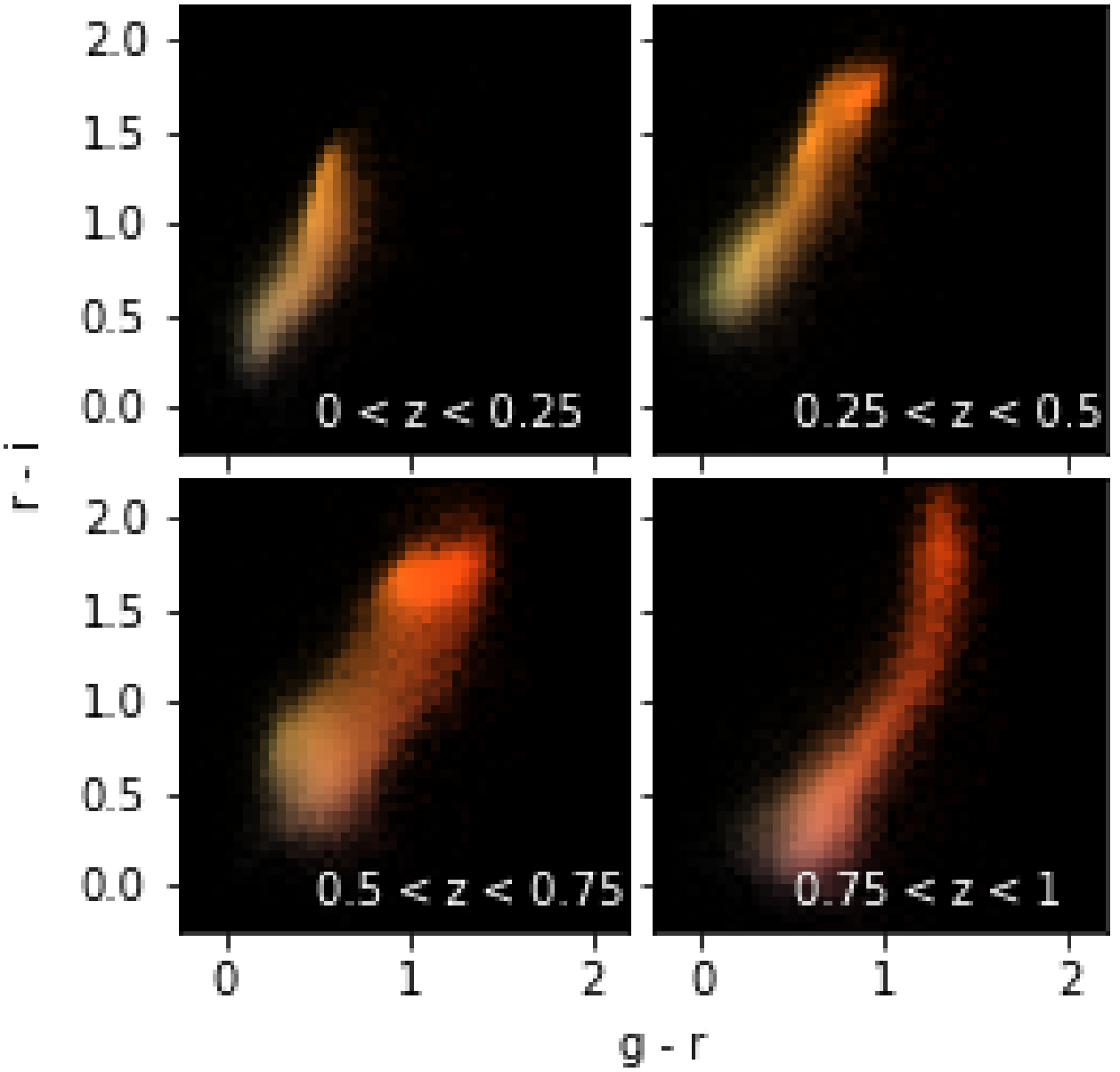

Strategy

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I’m pretty confident that we’ll have come out ahead by the time the HSC ‘SSP’ survey is done.

Create the tasks

In [6]:
```
schema = afwTable.SourceTable.makeMinimalSchema()
algMetadata = dafBase.PropertyList()

config = CharacterizeImageTask.ConfigClass()
config.psfIterations = 1
if False:
    config.measurePsf.psfDeterminer.name = "pca"
else:
    config.measurePsf.psfDeterminer.name = "psfex"

charImageTask =         CharacterizeImageTask(None, config=config)

config = SourceDetectionTask.ConfigClass()
sourceDetectionTask =   SourceDetectionTask(schema=schema, config=config)

sourceDeblendTask =     SourceDeblendTask(schema=schema)

config = SingleFrameMeasurementTask.ConfigClass()
config.slots.apFlux = 'base_CircularApertureFlux_12_0'
sourceMeasurementTask = SingleFrameMeasurementTask(schema=schema, config=config,
                                                   algMetadata=algMetadata)
```

LSST Pipelines

Process the data

In [7]:
```
butler = dafPersist.Butler("/Volumes/RHLData/hsc-v13_0")
```

In [8]:
```
dataId = dict(visit=29352, ccd=50)
exposure = butler.get('calexp', dataId)

tab = afwTable.SourceTable.make(schema)

result = charImageTask.characterize(exposure)
psfCellSet = result.psfCellSet     # we'll look at this data structure later

result = sourceDetectionTask.run(tab, exposure)
sources = result.sources

sourceDeblendTask.run(exposure, sources)

sourceMeasurementTask.run(exposure, sources)

sources.writeFits("outputTable.fits")
exposure.writeFits("example1-out.fits")
```

Outline of Data Release Pipeline

- Single `visit` processing:
  - flat fielding *etc.*
  - source detection
  - astrometric/photometric calibration
  - PSF estimation
  - deblending
  - measurement

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- Relative calibration (photometric and astrometric) of all visits on the scale of the focal plane. We're currently using PanSTARRS catalogues, but will soon switch to Gaia (at least for astrometry, maybe photometry)

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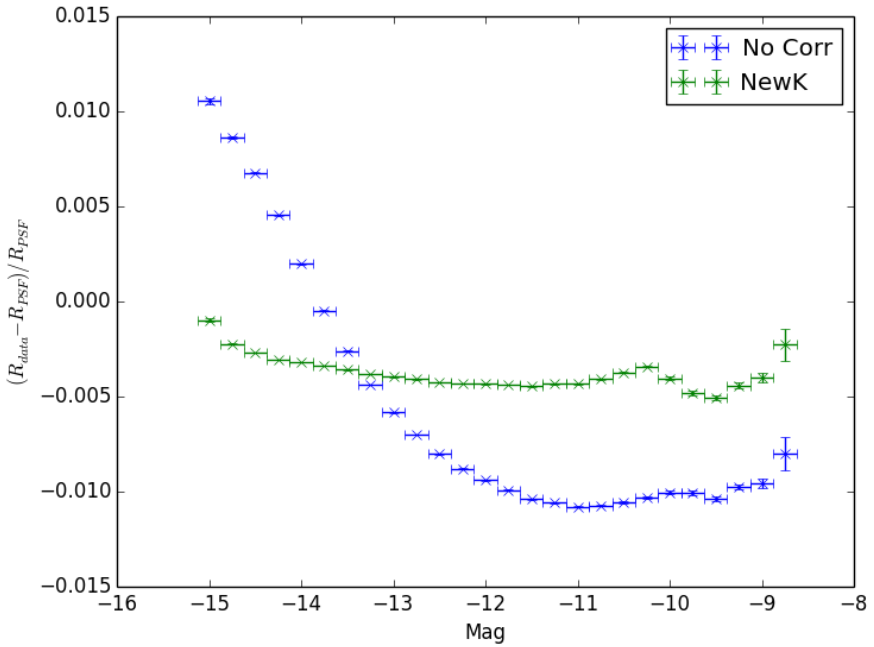

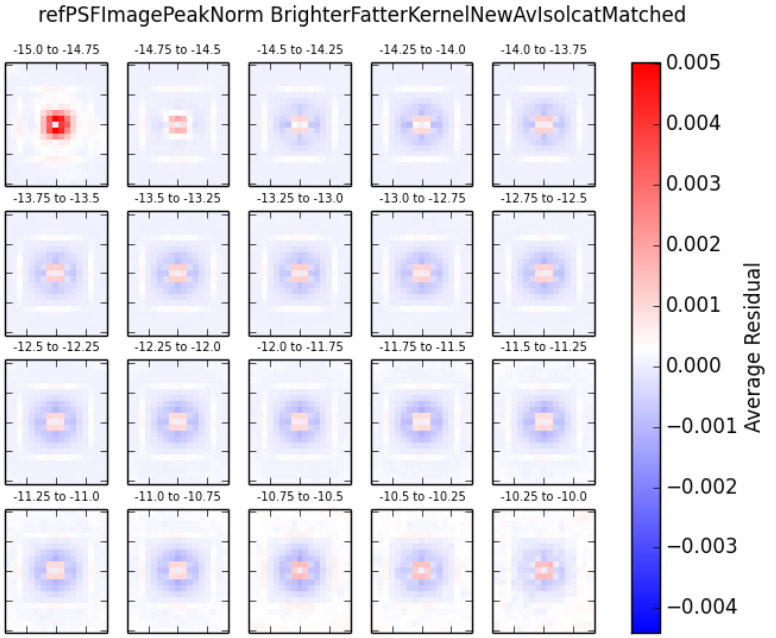

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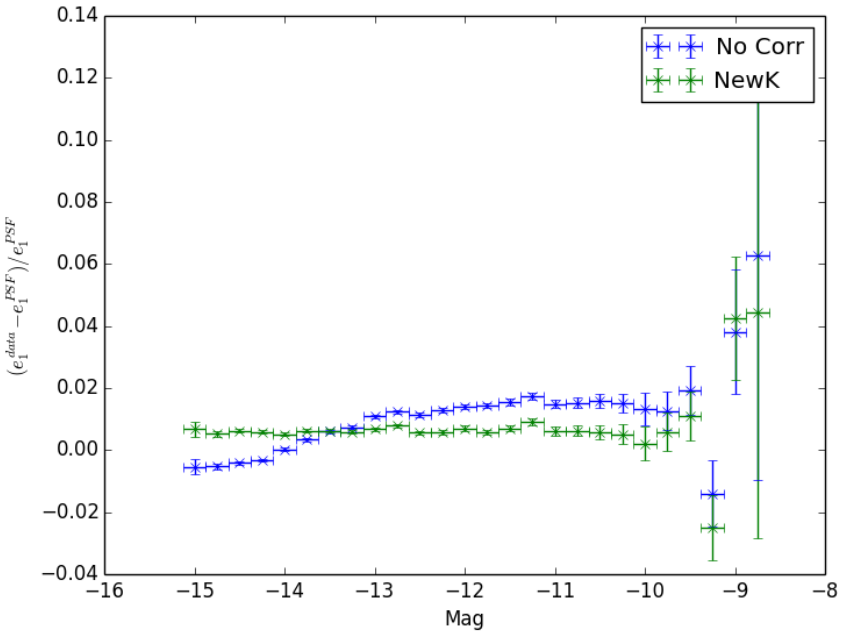
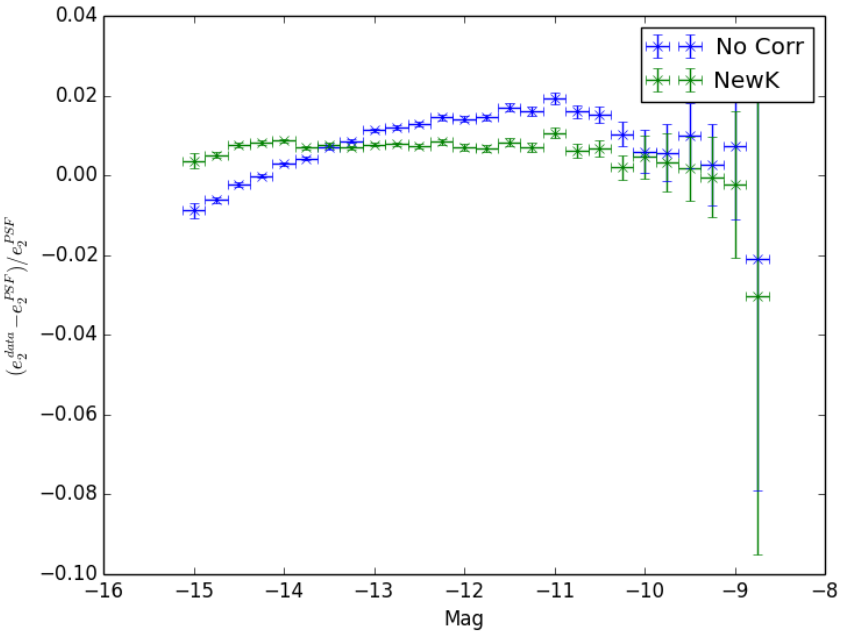


(a) The difference ϵ_1 of ellipticity of stars and the average star both with and without the correction.



(b) The difference ϵ_2 of ellipticity of stars and the average star both with and without the correction.

PSF Estimation

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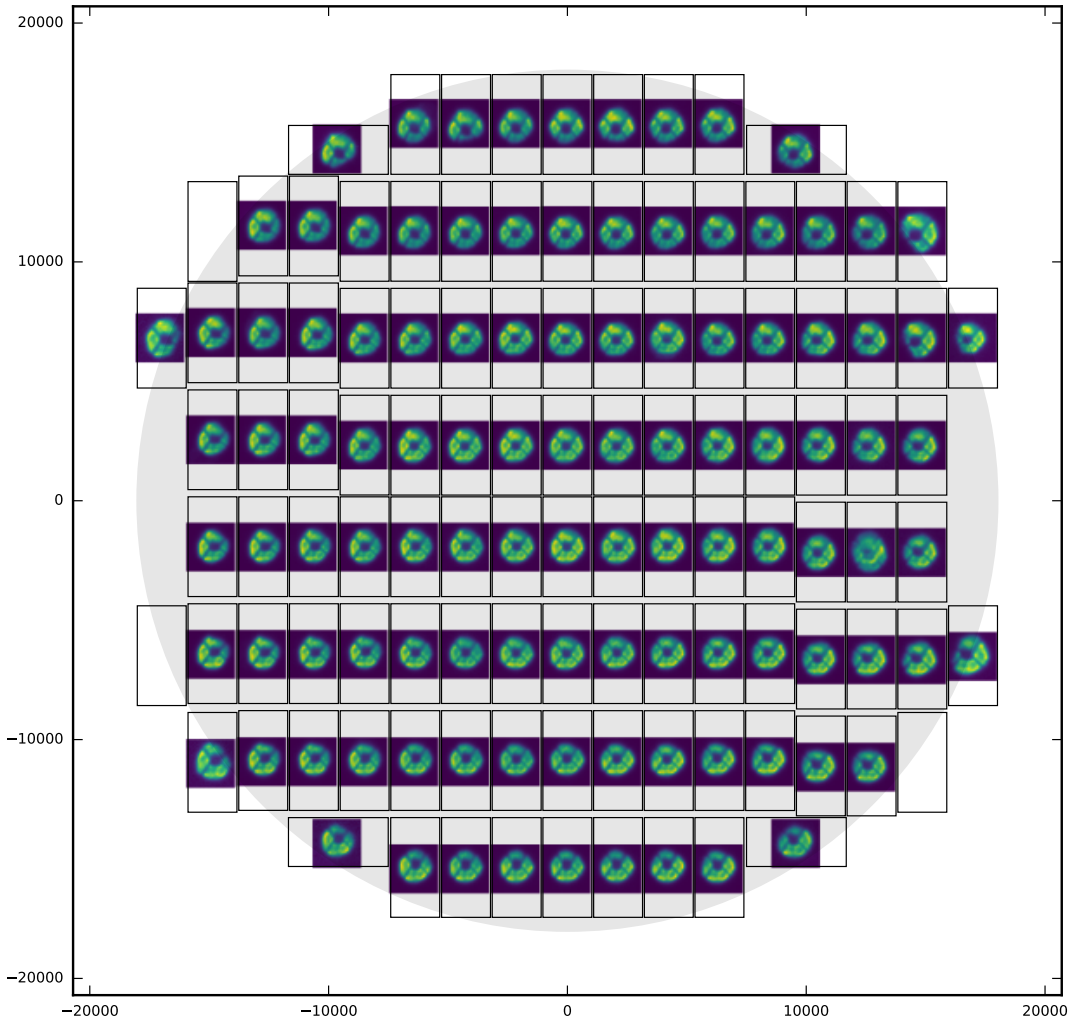
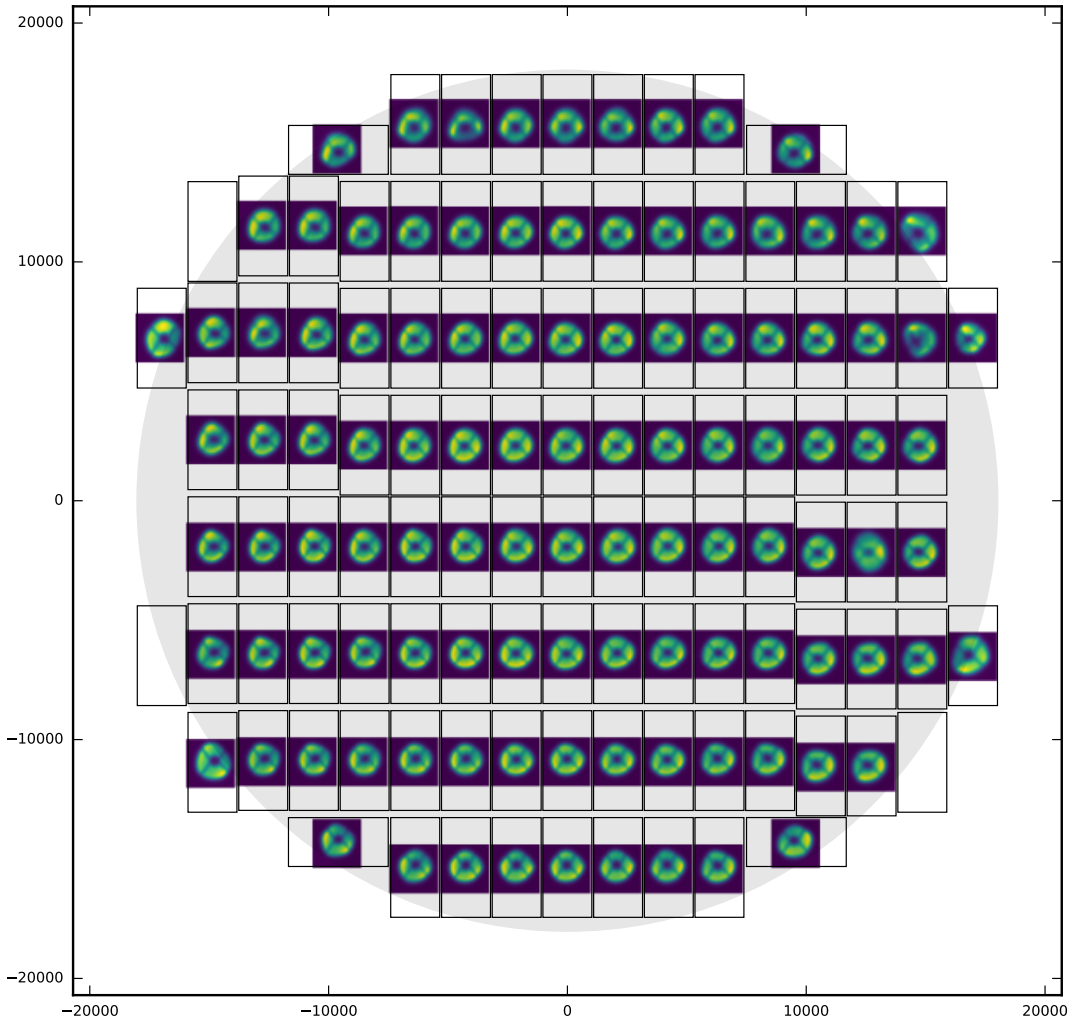
- CosmoStat@Saclay's RCA?
- Wavefront-based estimation?
- Your Code?

HSC Wavefronts



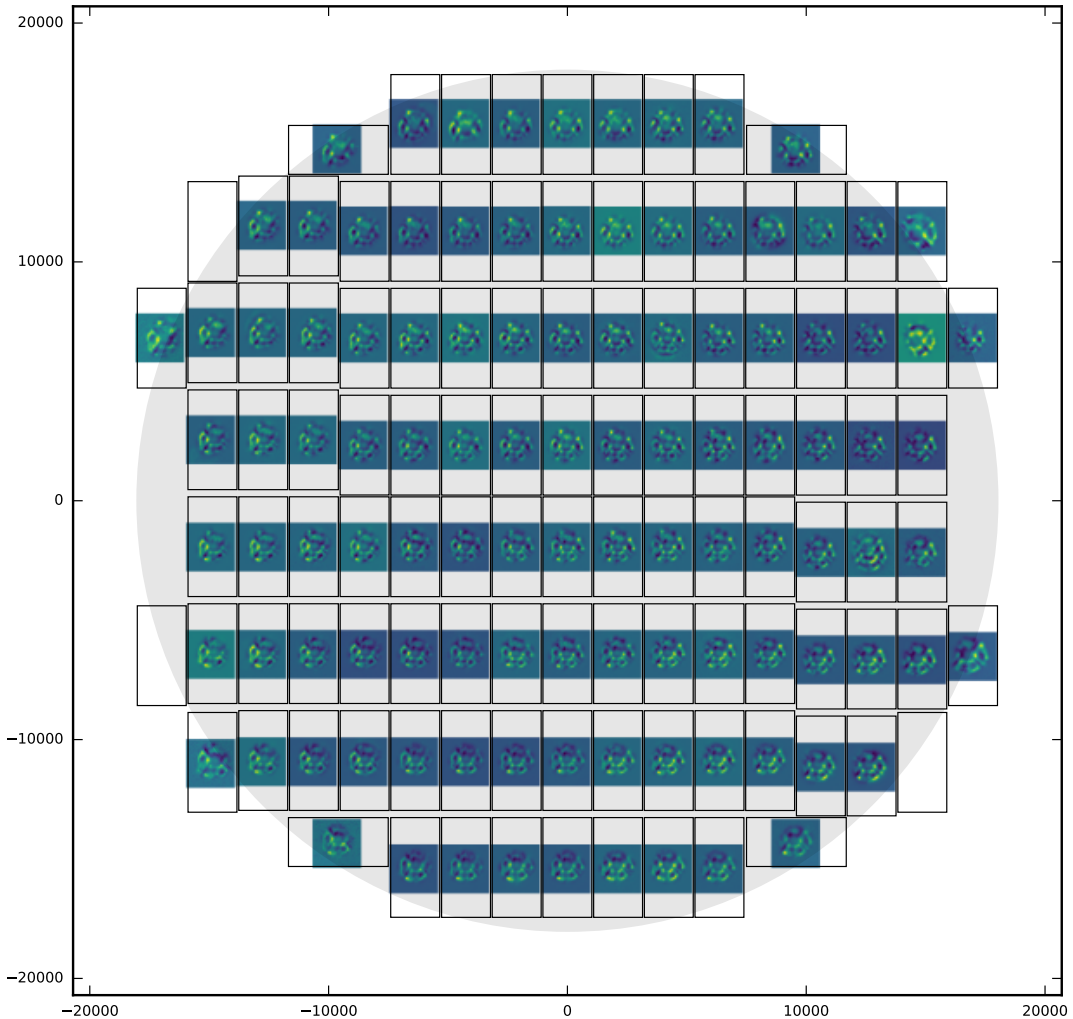
Data

HSC Wavefronts



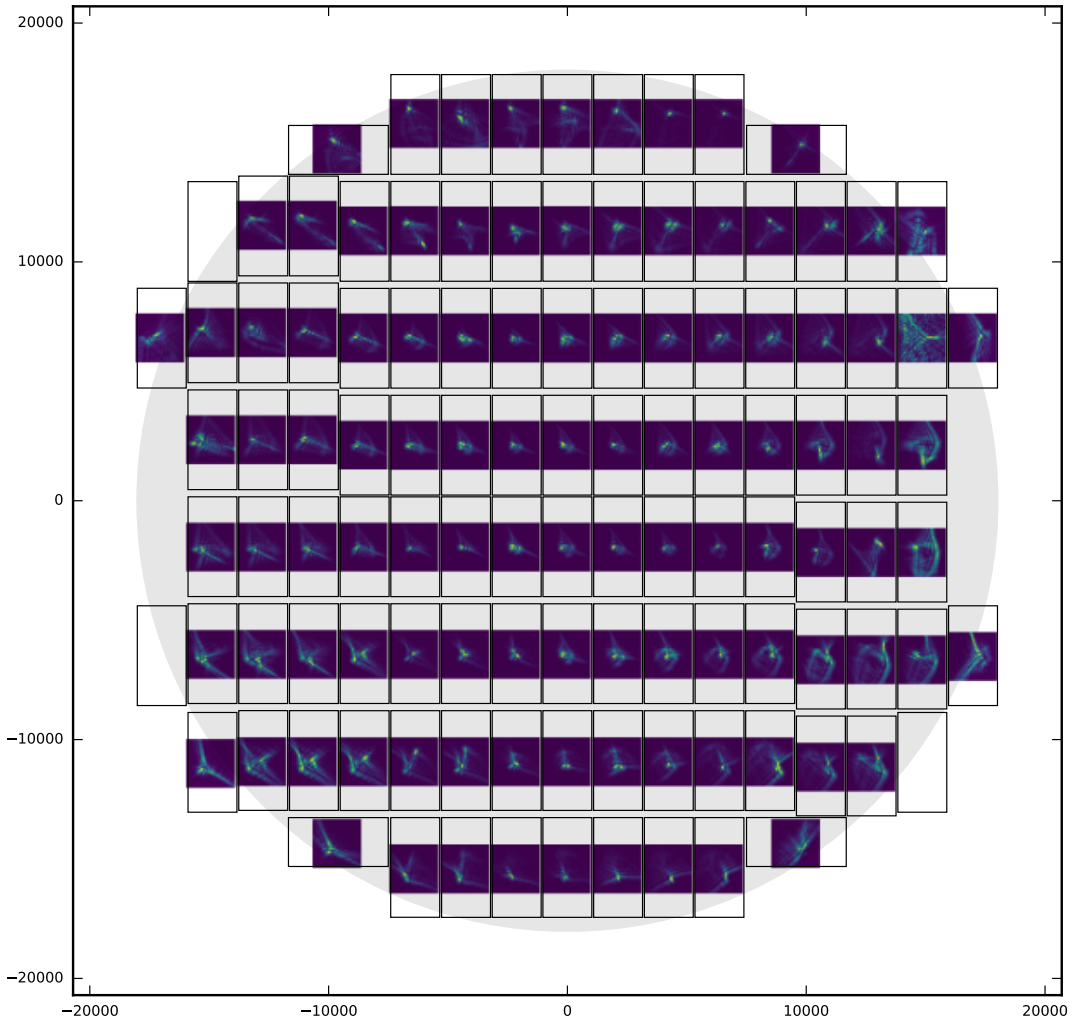
Model

HSC Wavefronts



Residual

HSC Wavefronts



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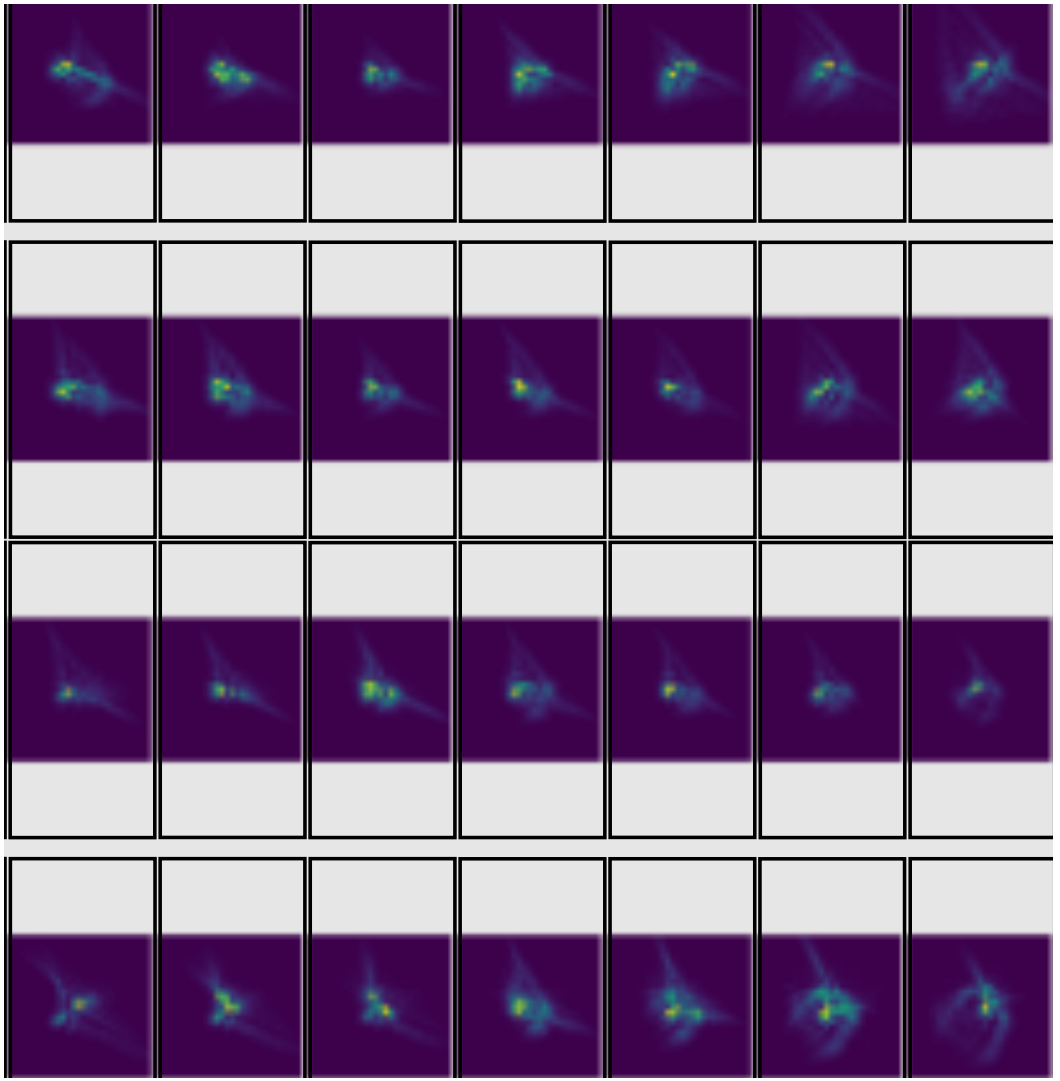

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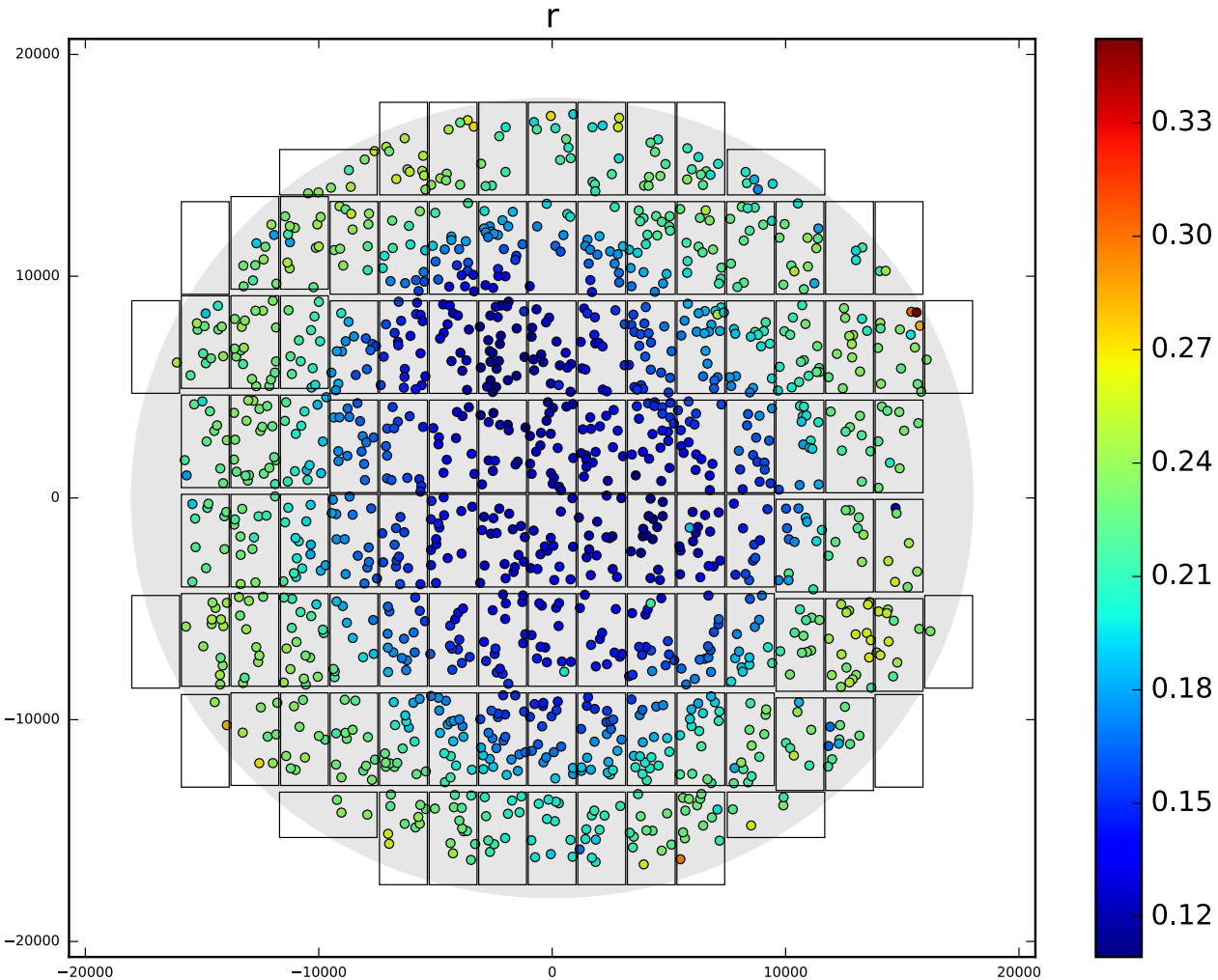
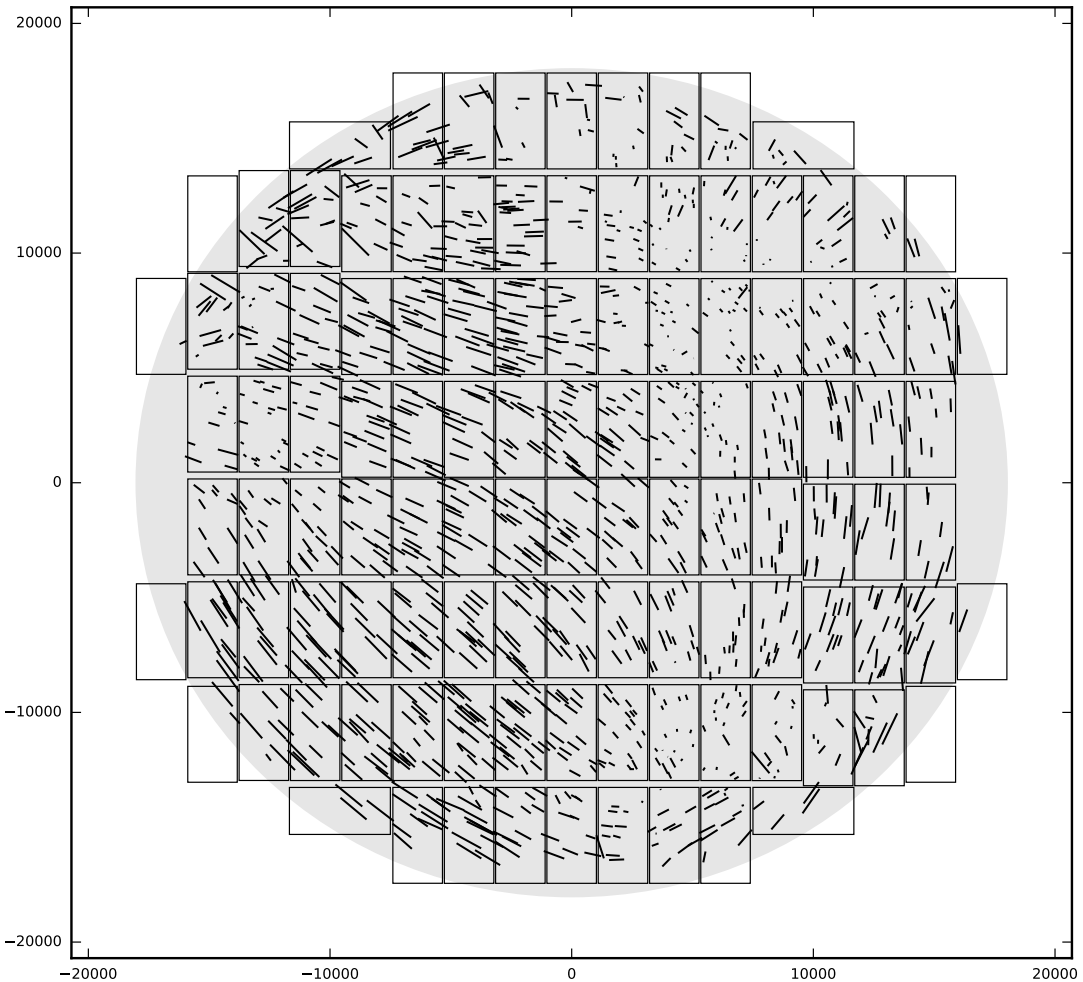


PSF radius

HSC Wavefronts



e_1, e_2

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- Coadd source detection:
  The primary detection is on the scale of the PSF resulting in a set of pixels — a `Footprint`. Each `Footprint` has one or more Peaks and these sets of Peaks define our objects.

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  The primary detection is on the scale of the PSF resulting in a set of pixels — a `Footprint`. Each `Footprint` has one or more Peaks and these sets of Peaks define our objects.
- Association and deblending:
  Synthesize a list of unique objects by merging Peaks from each band.
  Output a list of uncharacterized deblended (*i.e.* isolated) `Objects`.

Deblender

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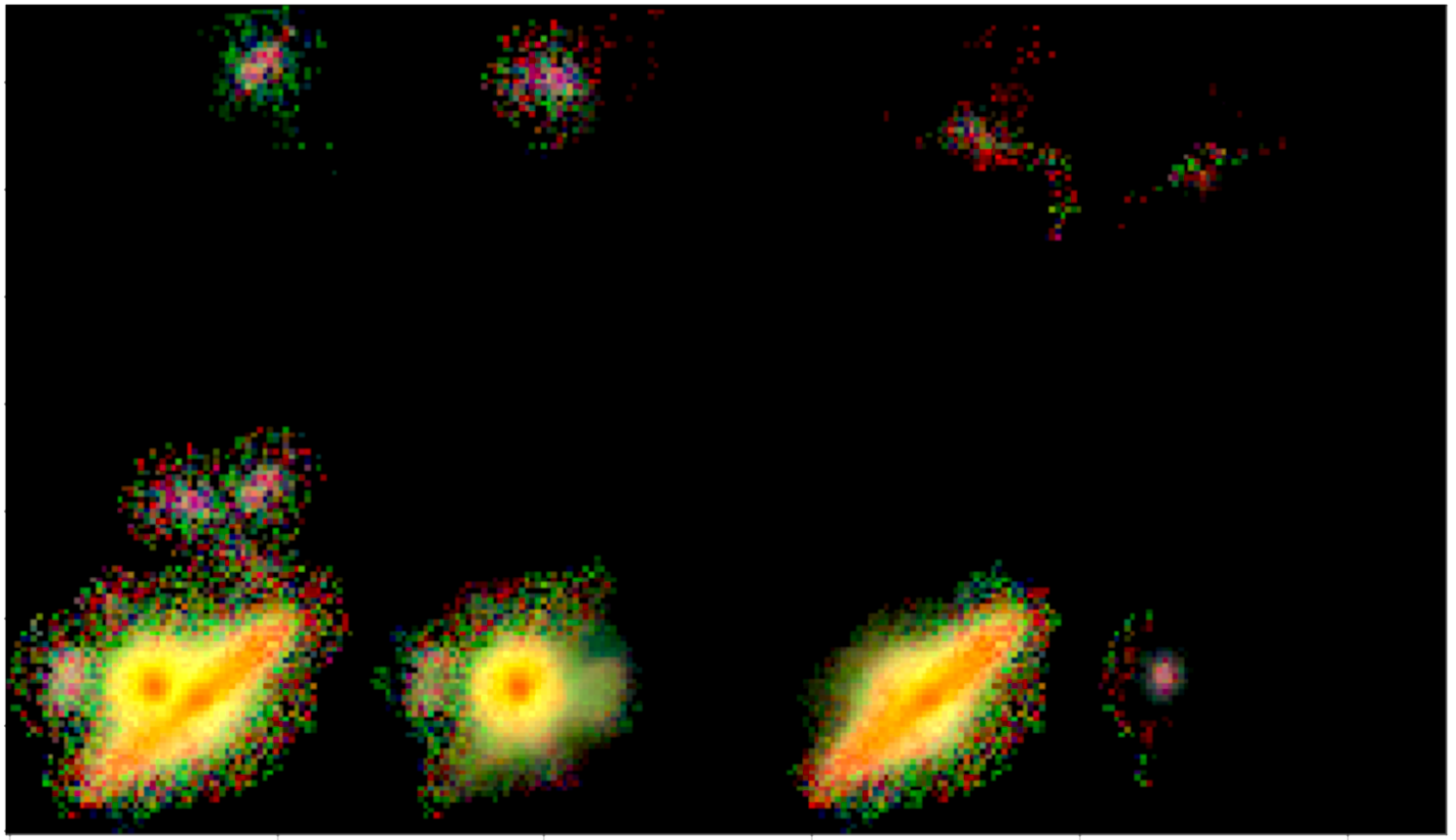

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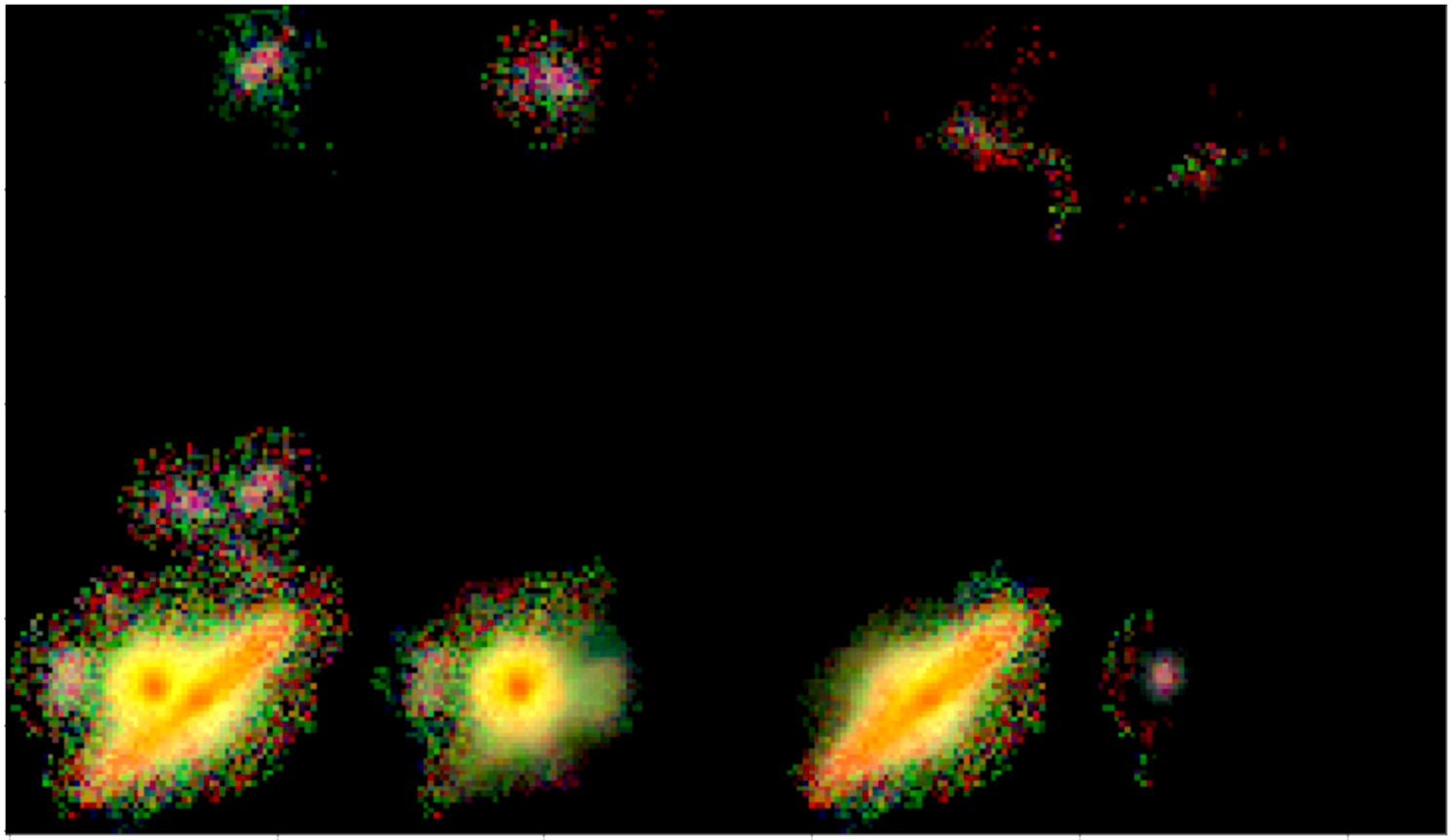

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  Measure `Object` properties such as:
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- Forced Photometry:
  Measure fluxes for every `Object` on every visit keeping all non-photometric parameters fixed

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The only options that I know of:

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- Use a direct mean of the pixel values. But this allows the junk to leak into the coadd.
- Make use of the differences between images to remove the junk, then use a mean

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- Remove the junk that's in only one image (leaving the cores of bright objects)
- Calculate a direct mean of what's left, a "Safe Clipped Coadd"

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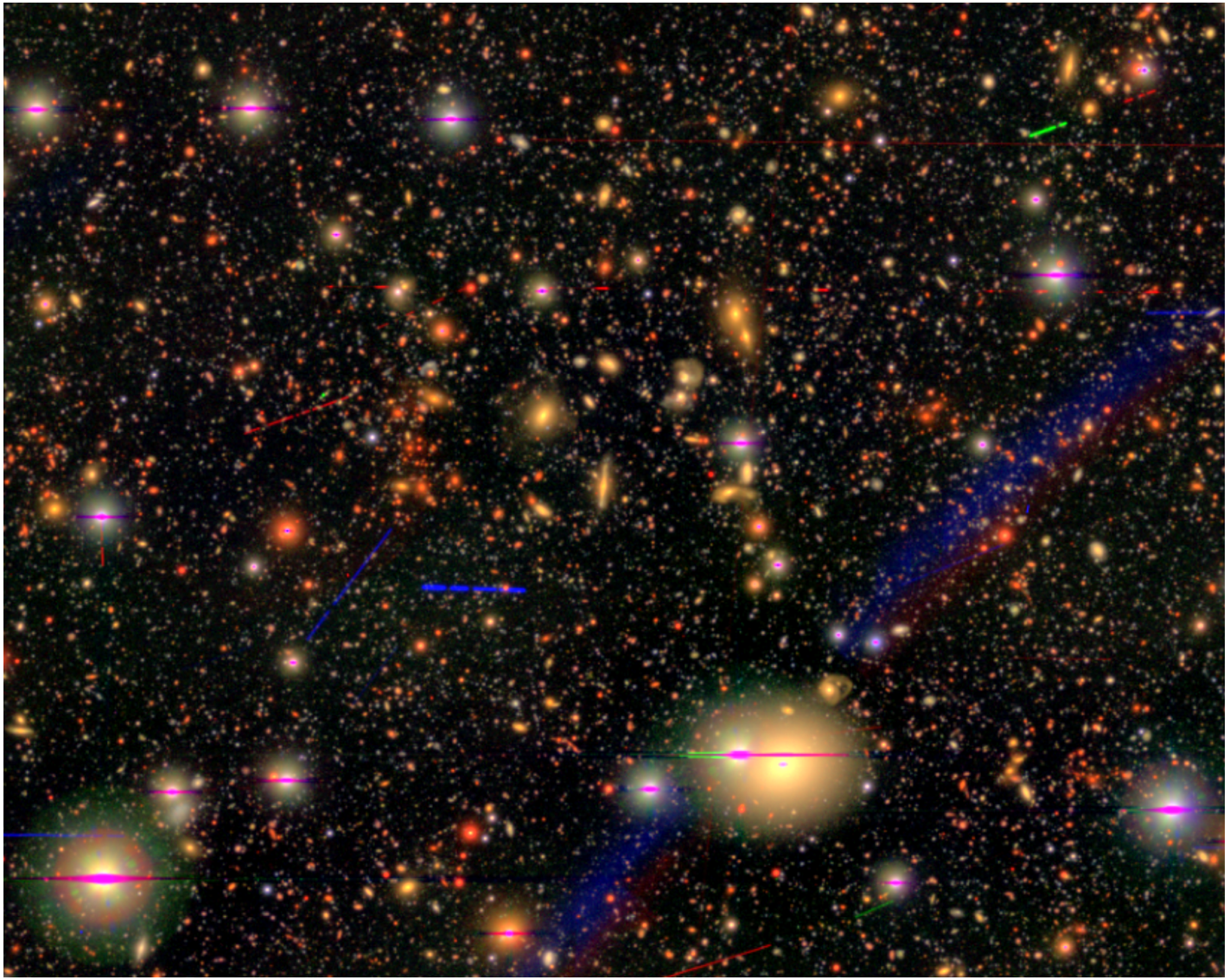
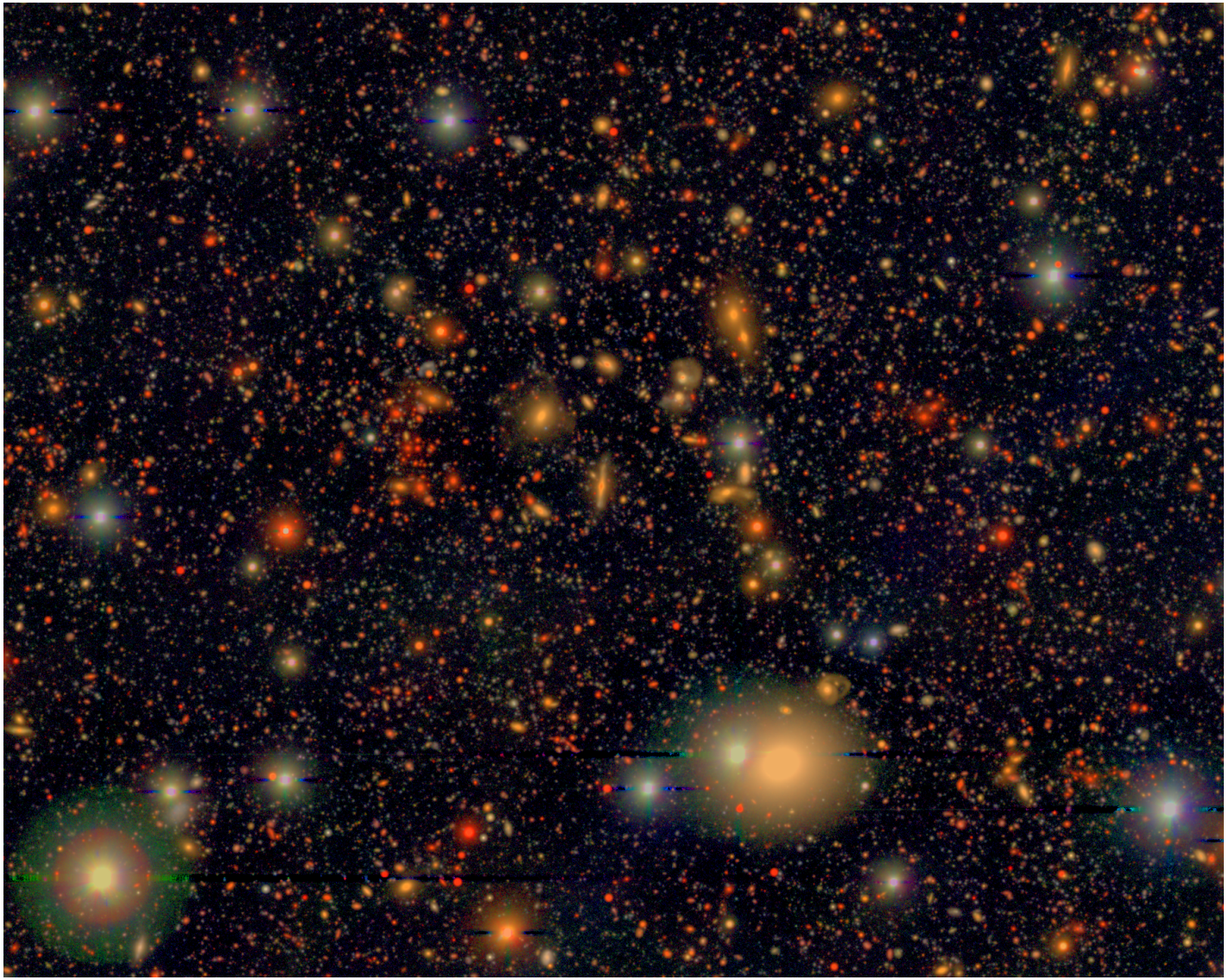
As Nick Kaiser pointed out in 2001 (PSDC-002-011-00), and Zackay, Ofek, and Gel-Yam recently rediscovered, you can build a coadd with optimal properties by down-weighting components that are suppressed by the images' PSFs, and then flattening the noise.
We don't currently use these coadds for HSC (it's a bit complicated with a spatially varying PSF)

Safe-Clipping Coadds



PSF-matched Coadds



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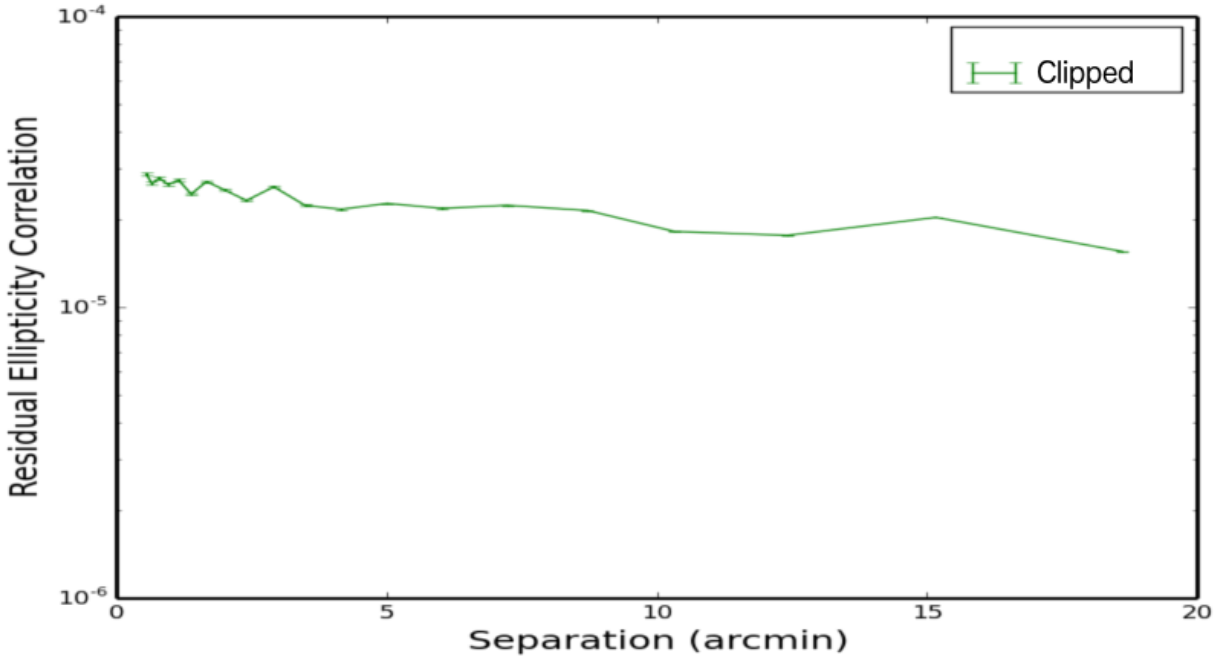
Courtesy Bob Armstrong σ Clipped



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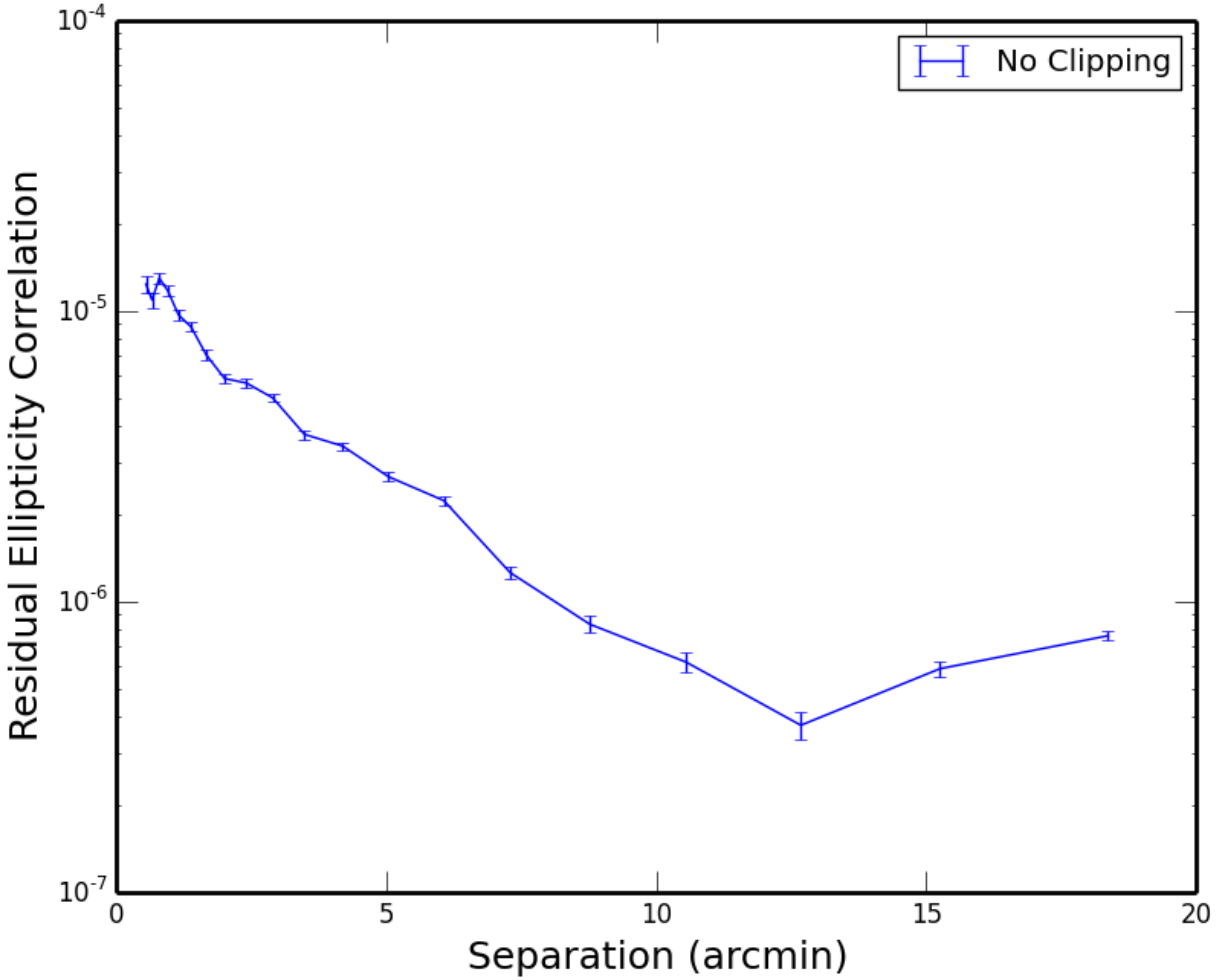

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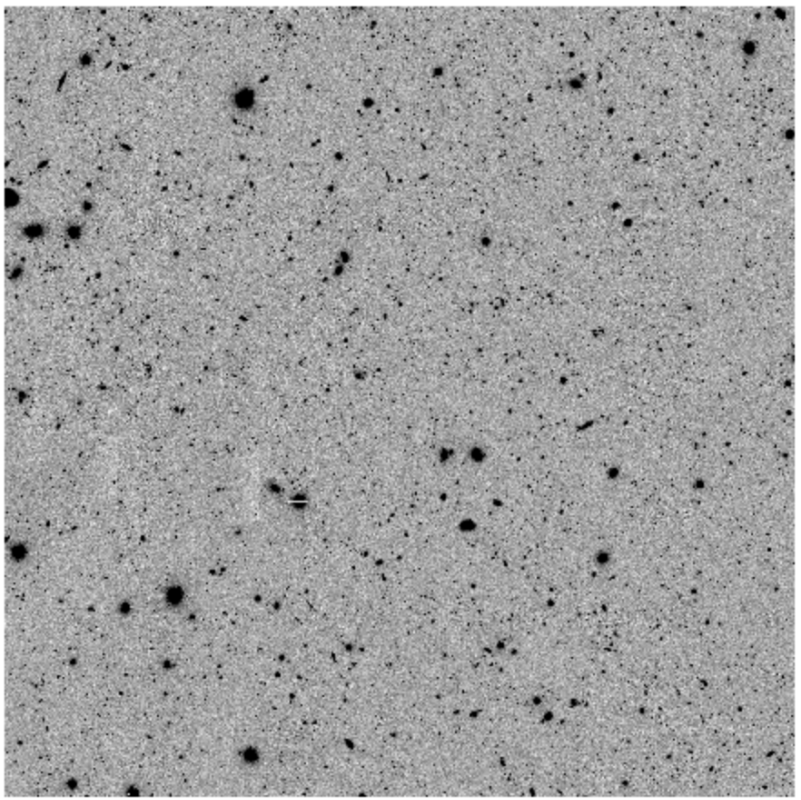
Unfortunately SQL isn't a very expressive language.
Recently many people have realised the *Jupyter Notebooks* provide a way that people can really compute close to the data.
I think it's time to move to the next phase:

Keep the Code with the Data

Processing HSC data with Jupyter

Get HSC calibrated exposure

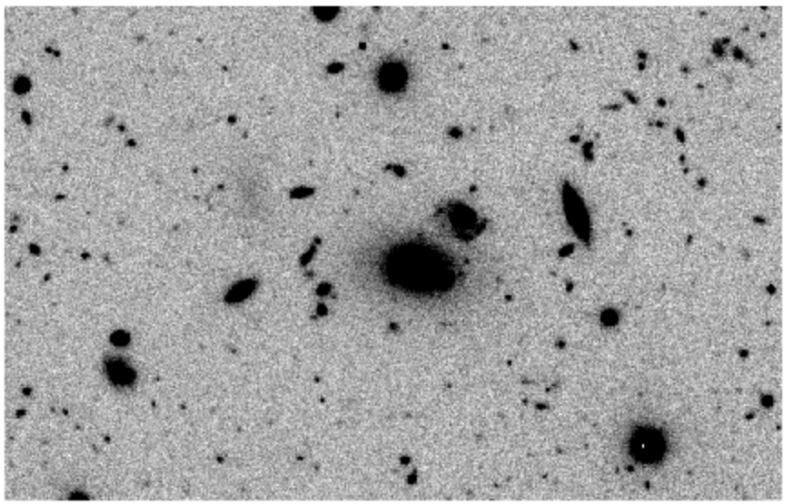
In [5]:
```
dataId = dict(tract=9348, patch='7,6', filter='HSC-I')
exp = butler.get('deepCoadd_calexp',dataId)
display_image(exp.getMaskedImage().getImage().getArray(), figsize=(8,8));
```



Processing HSC data with Jupyter

Make cutout

In [6]:
```
bbox = afwGeom.Box2I()
bbox.include(afwGeom.Point2I(2700, 3600))
bbox.include(afwGeom.Point2I(3330, 4000))
exp_cutout = exp.Factory(exp, bbox, afwImage.LOCAL)

mi = exp_cutout.getMaskedImage()
mask = mi.getMask()
mask.removeAndClearMaskPlane('CR', True)

display_image(mi.getImage().getArray());
```



Processing HSC data with Jupyter

Smooth at PSF scale

In [7]:
```
psf = exp.getPsf()
sigma = psf.computeShape().getDeterminantRadius()
ngrow = int(3*sigma)
mi_smooth = smooth_gauss(mi, sigma)
print('psf fwhm = {:.2f} arcsec'.format(sigma*0.168*2.355))
```

```
psf fwhm = 0.52 arcsec
```

Image thresholding

- Find high-threshold sources that are 6 σ above the background and create a mask plane

In [8]:
```
high_thresh = 6
fpset_high = afwDetect.FootprintSet(
    mi_smooth, afwDetect.Threshold(high_thresh, afwDetect.Threshold.STDEV), 'HIGH_THRESH', 1)
fpset_high = afwDetect.FootprintSet(fpset_high, ngrow)
fpset_high.setMask(mask, 'HIGH_THRESH')
```

- Find low-threshold sources that are 1.5 σ above the background and create a mask plane

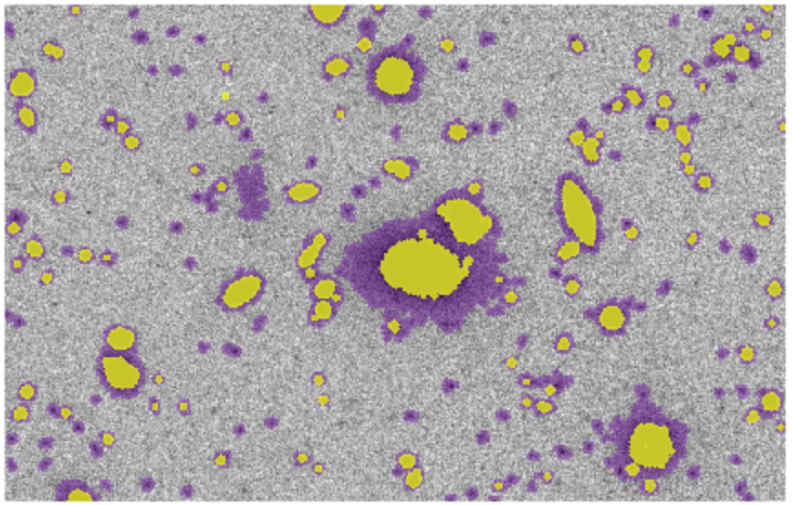
In [9]:
```
low_thresh = 1.5
fpset_low = afwDetect.FootprintSet(
    mi_smooth, afwDetect.Threshold(low_thresh, afwDetect.Threshold.STDEV), 'LOW_THRESH', 10)
fpset_low = afwDetect.FootprintSet(fpset_low, ngrow)
fpset_low.setMask(mask, 'LOW_THRESH')
```

Processing HSC data with Jupyter

Visualize segmentation maps

- low-threshold footprints are purple
- high-threshold footprints are yellow

In [10]:
```
seg_high = fpset_high.insertIntoImage(True).getArray().copy().astype(float)
seg_low = fpset_low.insertIntoImage(True).getArray().copy().astype(float)
seg_low[seg_low>0] = 1.0
seg_low[seg_low==0] = np.nan
seg_high[seg_high>0] = 1.0
seg_high[seg_high==0] = np.nan

ax = display_image(mi.getImage().getArray())
kws = dict(cmap='plasma', vmin=0, vmax=1, origin='lower')
ax.imshow(seg_low*0.2, alpha=0.4, **kws)
ax.imshow(seg_high*1.0, alpha=0.8, **kws);
```



Processing HSC data with Jupyter

Remove bright sources and associated diffuse light

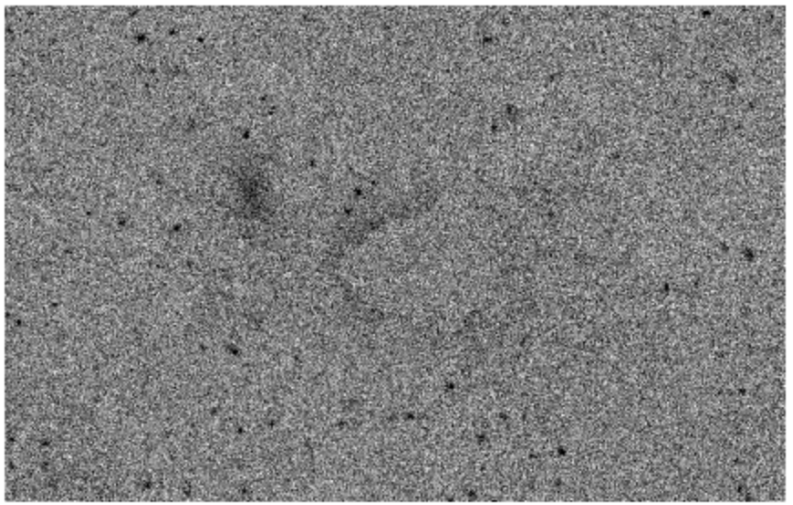
- associate a low-thresh footprint with a high-thresh footprint if more than 5% of its light is above the high threshold

In [11]:
```
max_frac = 0.05

# loop over low threshold footprints
# and save those with >max_frac high
# threshold pixels
fp_list = afwDetect.FootprintList()
for fp in fpset_low.getFootprints():
    hfp = afwDetect.HeavyFootprintF(fp, mi)
    pix = hfp.getMaskArray()
    bits_high = (pix & mask.getPlaneBitMask('HIGH_THRESH')!=0).sum()
    if bits_high/float(fp.getArea()) > max_frac:
        fp_list.append(fp)

# build a new footprint set
fpset_replace = afwDetect.FootprintSet(mi.getBBox())
fpset_replace.setFootprints(fp_list)

# create a mask plane for "cleaned" footprints
if 'CLEANED' in mask.getMaskPlaneDict().keys():
    mask.clearMaskPlane(mask.getMaskPlane('CLEANED'))
mask.addMaskPlane('CLEANED')
fpset_replace.setMask(mask, 'CLEANED')
```

Processing HSC data with Jupyter

- replace footprints associated with bright sources with sky noise

In [12]:
```
exp_clean = exp_cutout.clone()
mi_clean = exp_clean.getMaskedImage()
back_rms = mi.getImage().getArray()[mask.getArray()==0].std()
noise_array = back_rms*np.random.randn(*mask.getArray().shape)
replace = mask.getArray() & mask.getPlaneBitMask('BRIGHT_OBJECT') != 0
replace |= mask.getArray() & mask.getPlaneBitMask('CLEANED') != 0
mi_clean.getImage().getArray()[replace] = noise_array[replace]
display_image(mi_clean.getImage().getArray());
```



Processing HSC data with Jupyter

- smooth to emphasize extended low-surface-brightness structures

In [13]:
```
smoothed = smooth_gauss(mi_clean, 4)
display_image(smoothed.getImage().getArray());
```