

ASTRONOMICAL IMAGE REDUCTION WITH



Erik Tollerud

@eteq



STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

Project Scientist, Data Analysis Tools Branch
Astropy Coordination Committee



astropy-powered
astropy.org

Easy/Basic/Lazy

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WHY python FOR THIS TASK?

- It's easy to write code at a high-level to do low-level tasks.
- It integrates well with notebooks (which are great for “quick” reduction).
- It has  **astro**py

WHAT IS ASTROPY?

The Astropy Project is a community effort to develop a **common core package** for Astronomy in Python and foster an ecosystem of **interoperable astronomy packages**.


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This means both *by*
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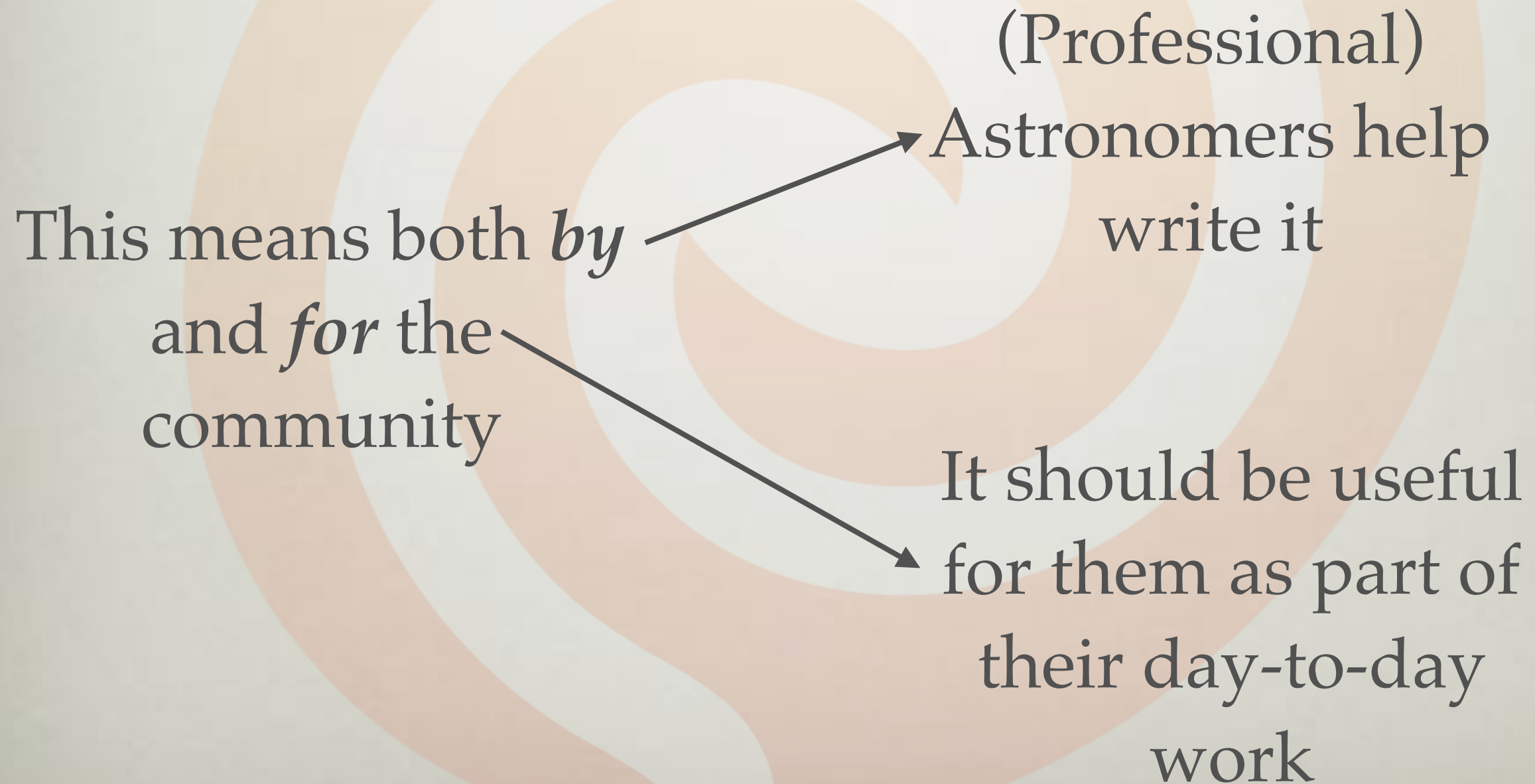
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THE ASTROPY PROJECT AND PACKAGE

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Core package “astropy” \neq “Astropy Project”

The core package is what’s in github repo *astropy/astropy*. I.e., what “pip install astropy” or “conda install astropy” gets you.

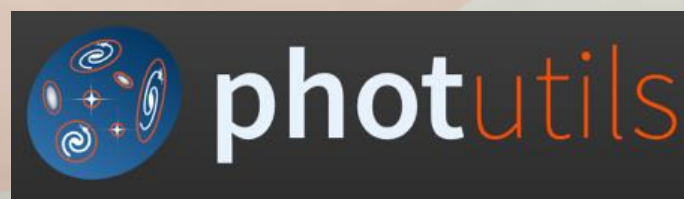
“Astropy Project” includes all the coordinated and affiliated packages and community.

WHAT UNITES AFFILIATED PACKAGES?

- A common goal and vision: reducing duplication and embracing good coding practices (testing, docs), open development
- Listing on <http://affiliated.astropy.org> (curated and reviewed by the Astropy coordination committee)
- (For many) a package template

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REMEMBER: ASTROPY IS COMMUNITY DEVELOPED

GitHub



GitHub repository page for **astropy / astropy**. The page shows a pull request titled "Allow FITS tables with time columns (not written by Astropy) to be read by io.fits #6442". The pull request is open and was created by **AustereCuriosity**. It shows 14 commits and 6 files changed. The pull request is currently in the "Open" state.

The pull request description states: "This works for Chandra files and XMM files. I have added a test for reading Chandra files. The test needs to be more detailed and will be modified soon. NOTE: The chandra file is huge, so I'll probably use another file or reduce it."

The pull request is reviewed by **taldcroft** (marked with a red X) and **mhvk** (marked with a green checkmark). The pull request is assigned to **No one—assign yourself**.

The pull request is labeled with **Affects-dev**, **Affects-release**, **Enhancement**, and **io.fits**. The pull request is also labeled with **Projects** and **Milestone** (v3.0.0).

The pull request is commented on by **astropy-bot** (bot) and **bsipocz** (Member). The bot comment says: "Hi there @AustereCuriosity - thanks for the pull request! I'm just a friendly bot that checks for issues related to the changelog and making sure that this pull request is milestone and labelled correctly. This is mainly intended for the maintainers, so if you are not a maintainer you can ignore this, and a maintainer will let you know if any action is required on your part. Everything looks good from my point of view! If there are any issues with this message, please report them here". The member comment says: "@AustereCuriosity - If you need this file, it can go into the astropy-data repository and then can be accessed as remote-data from here."

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So don't be afraid to join in!

**WHAT EXACTLY DO WE
MEAN BY “REDUCTION”?**

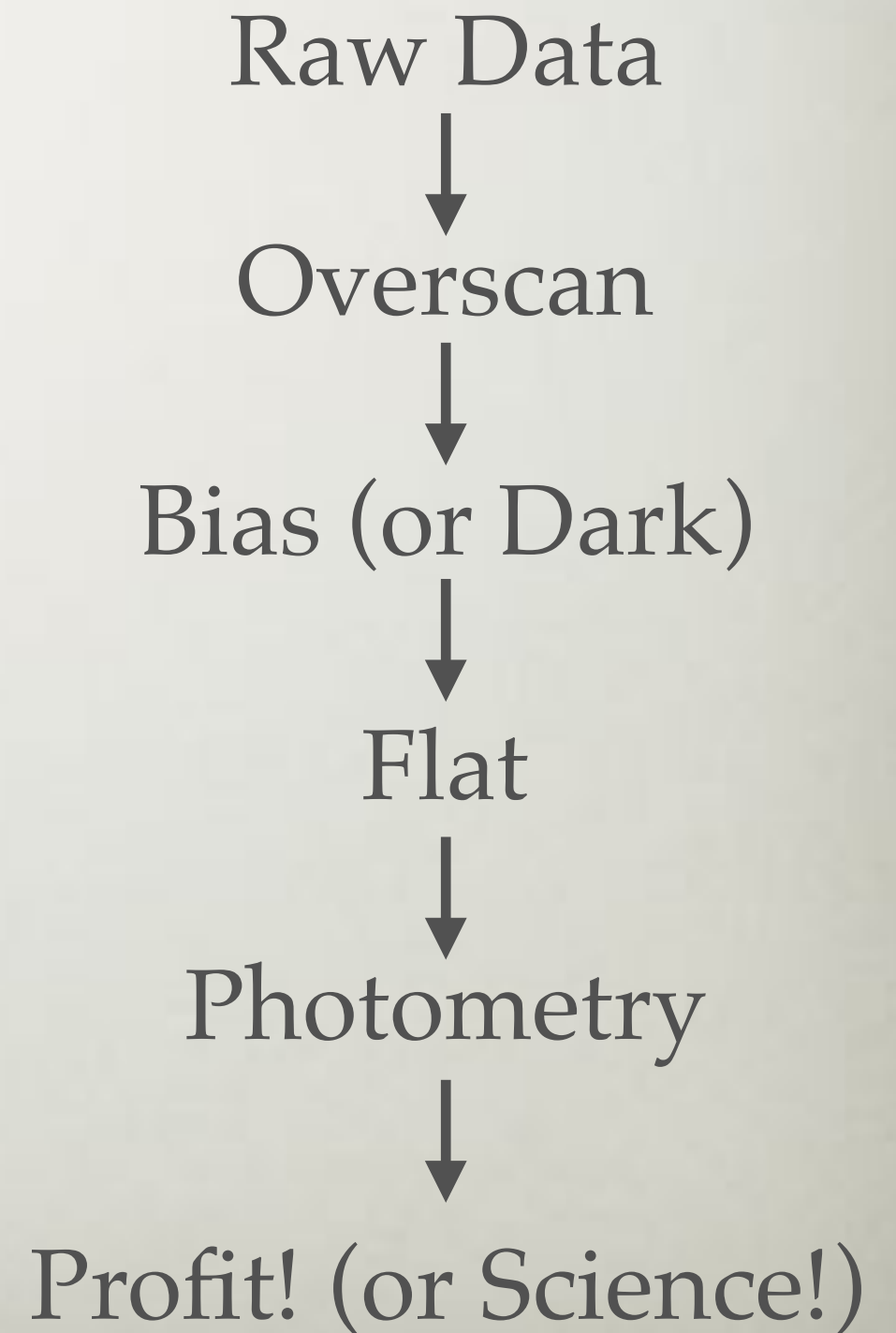
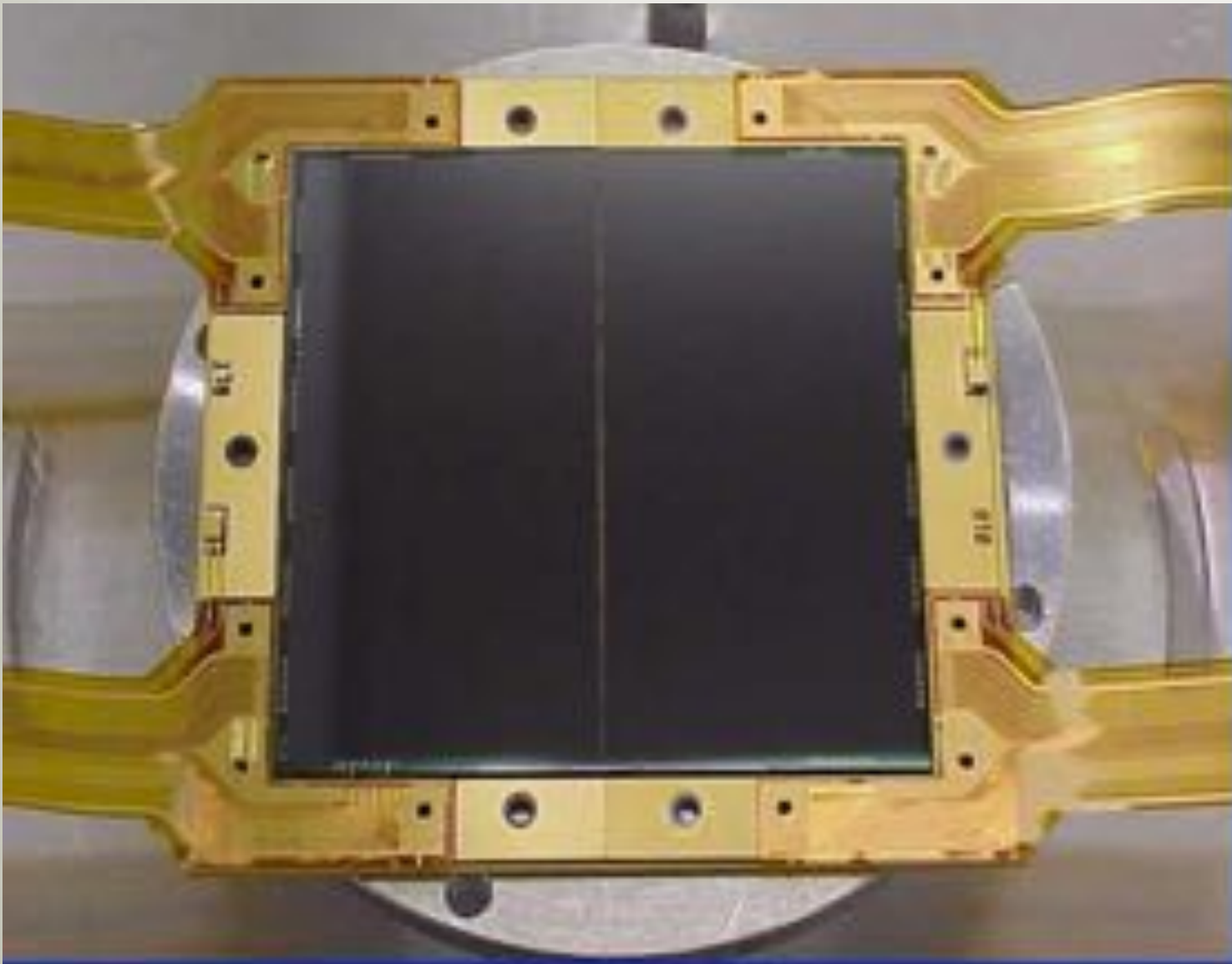
WHAT EXACTLY DO WE MEAN BY “REDUCTION”?

- At it's core: taking a lot of data and making it simpler (e.g., plotting an average).

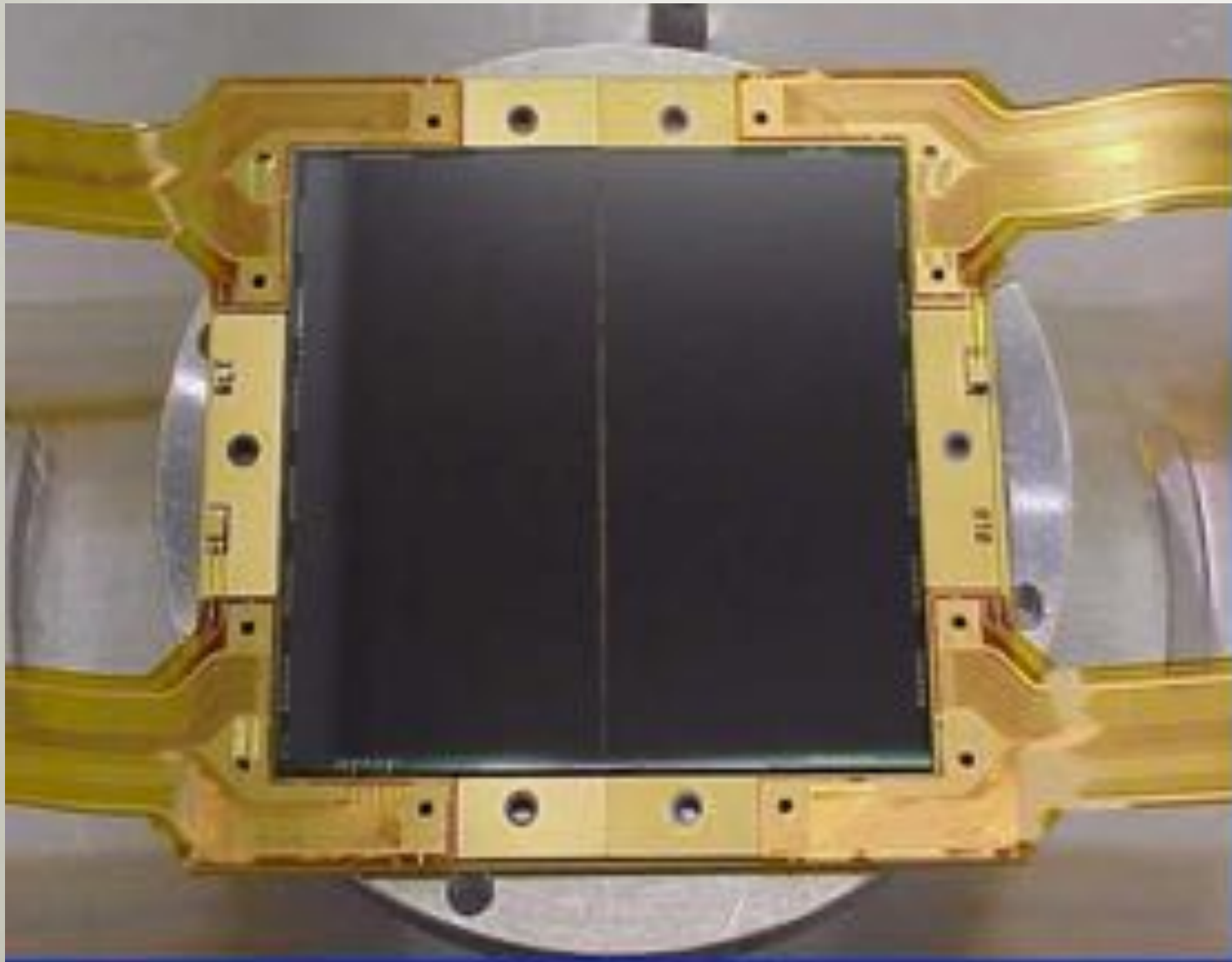
WHAT EXACTLY DO WE MEAN BY “REDUCTION”?

- At it's core: taking a lot of data and making it simpler (e.g., plotting an average).
- In astronomy, usually we really mean “analysis”: raw images / spectra -> something scientifically interpretable. For images that usually means “how much light from each object I see”.

LET'S NARROW THE FOCUS: CCD IMAGES



LET'S NARROW THE FOCUS: CCD IMAGES



Raw Data



Overscan



Bias (or Dark)



Flat

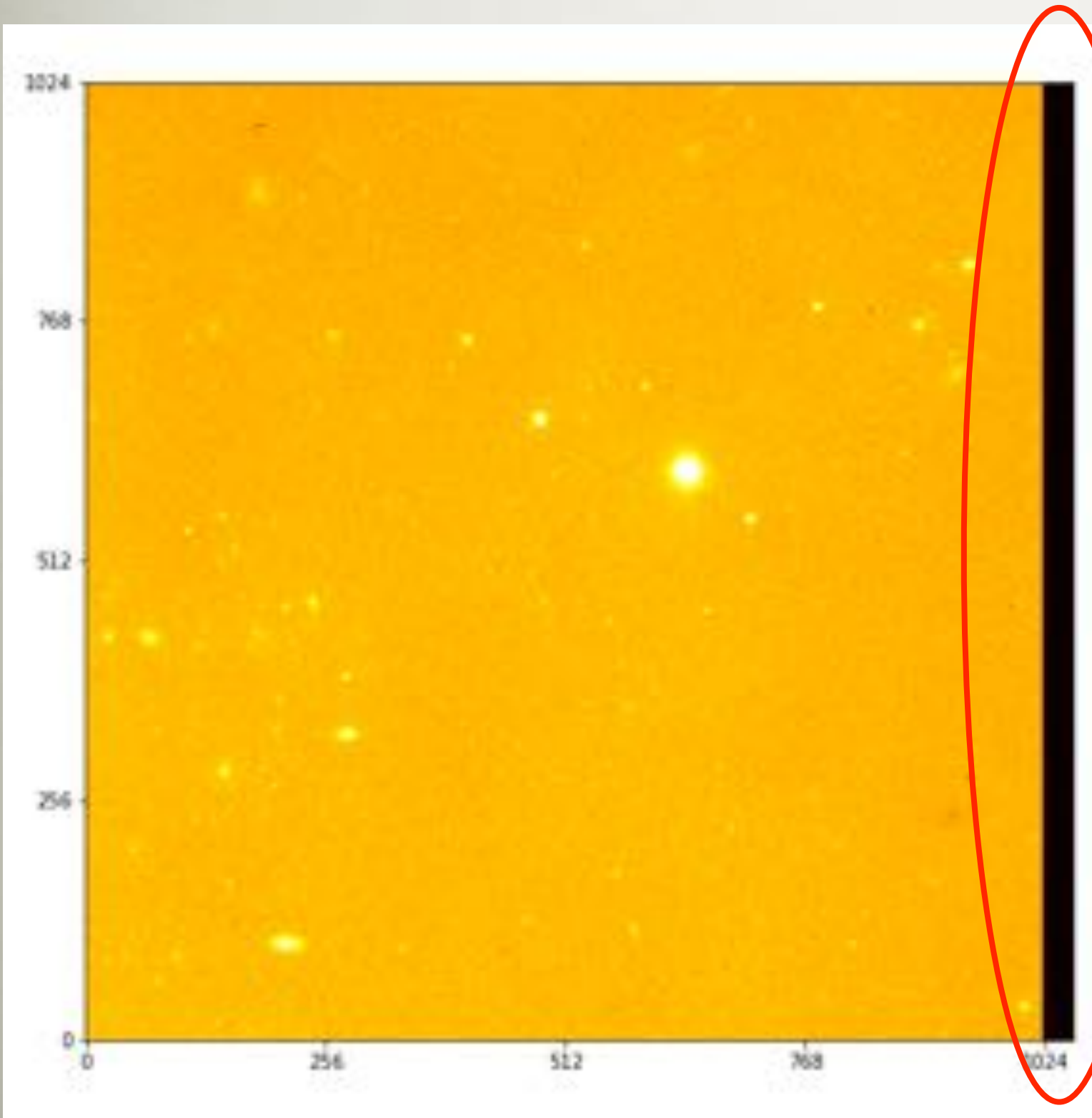


Photometry



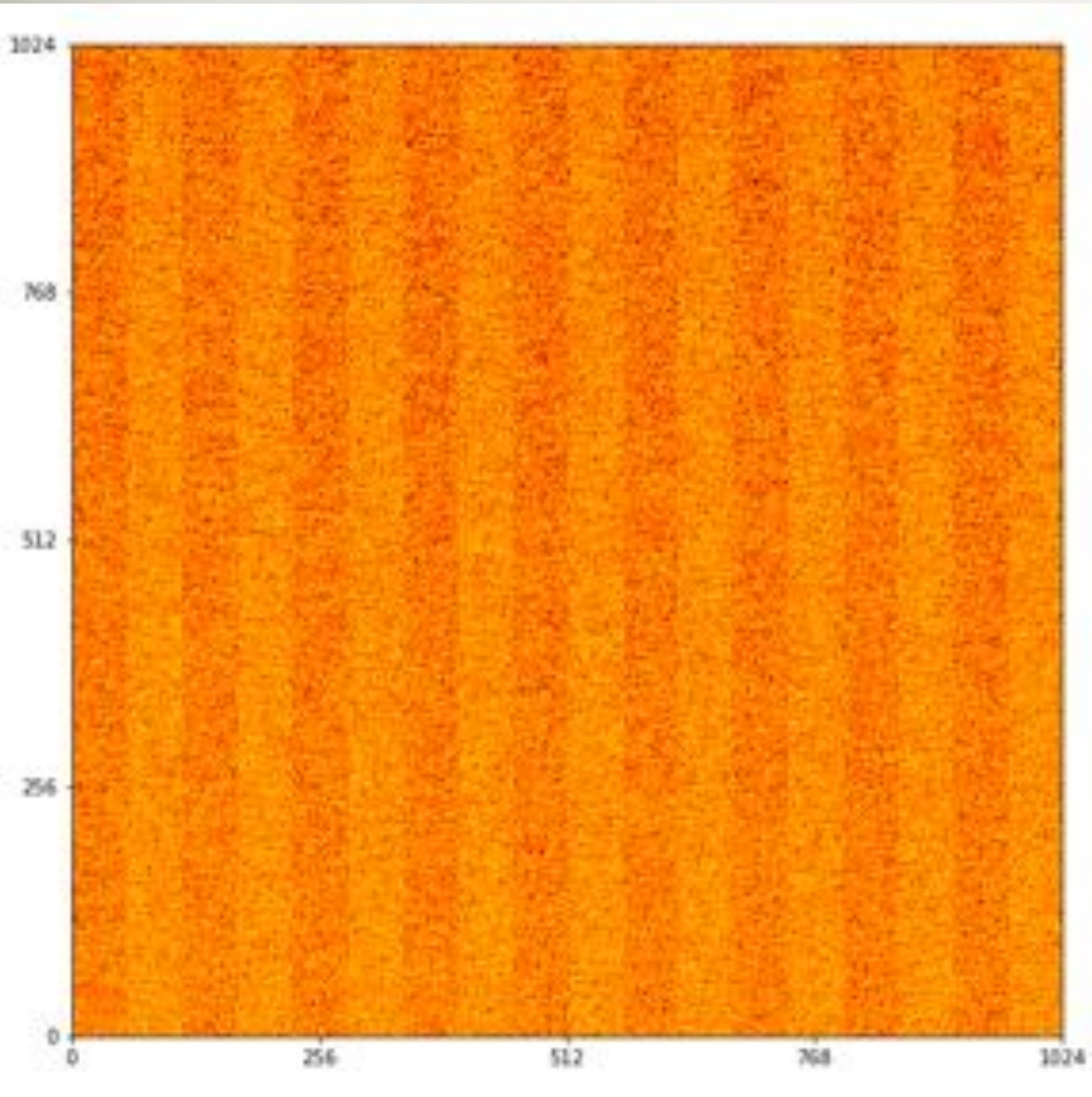
Profit! (or Science!)

OVERSCAN



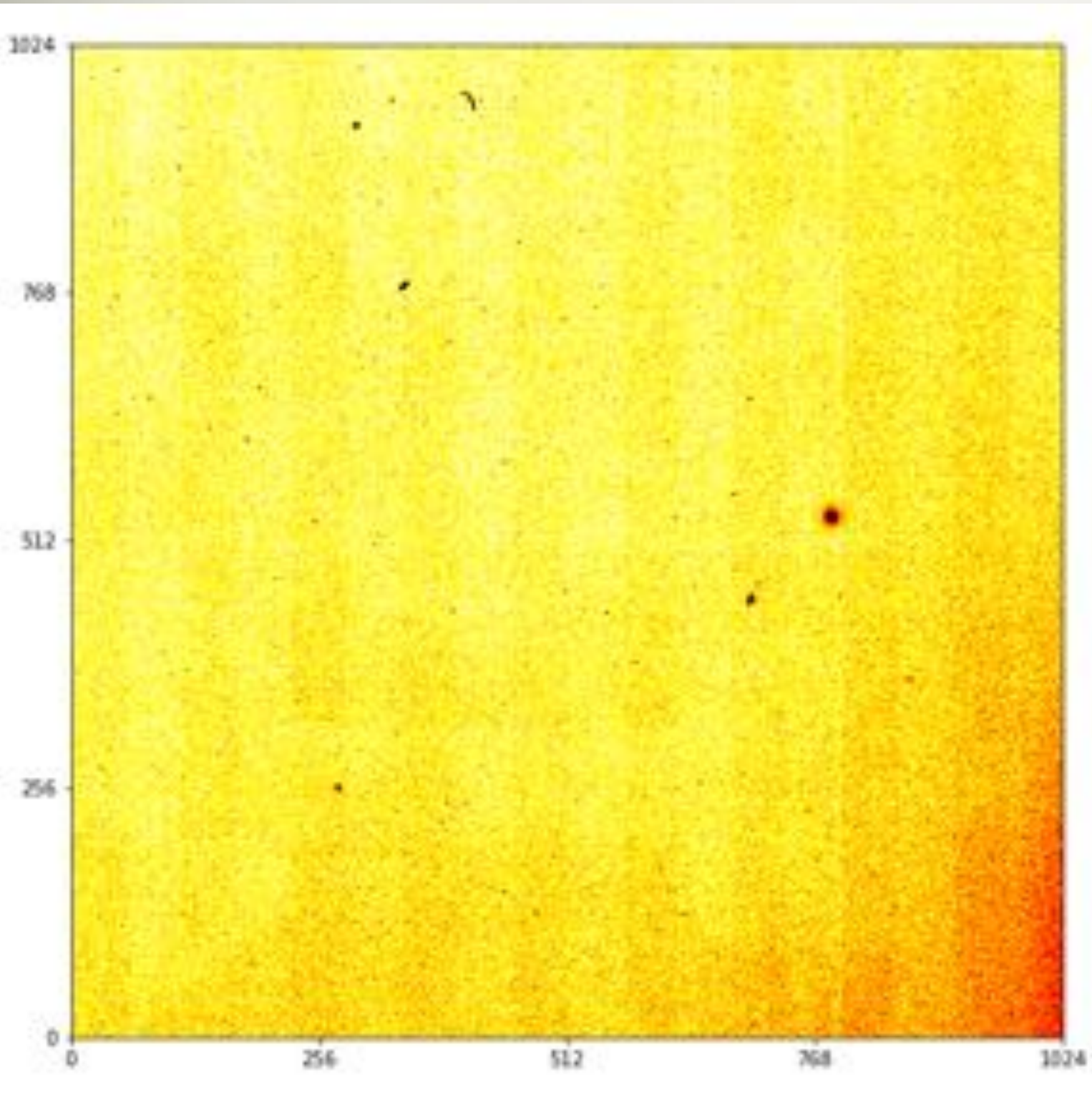
- A “fake” part of the image where the readout electronics were run past the end of the chip.
- Subtracting this removes the column-by-column bias.

BIAS



- An unexposed image is required.
- Catches pixel-by-pixel bias variation.
- Sometimes replaces overscan, but otherwise must be overscan-corrected.
- Sometimes “darks” used also / instead

FLATS

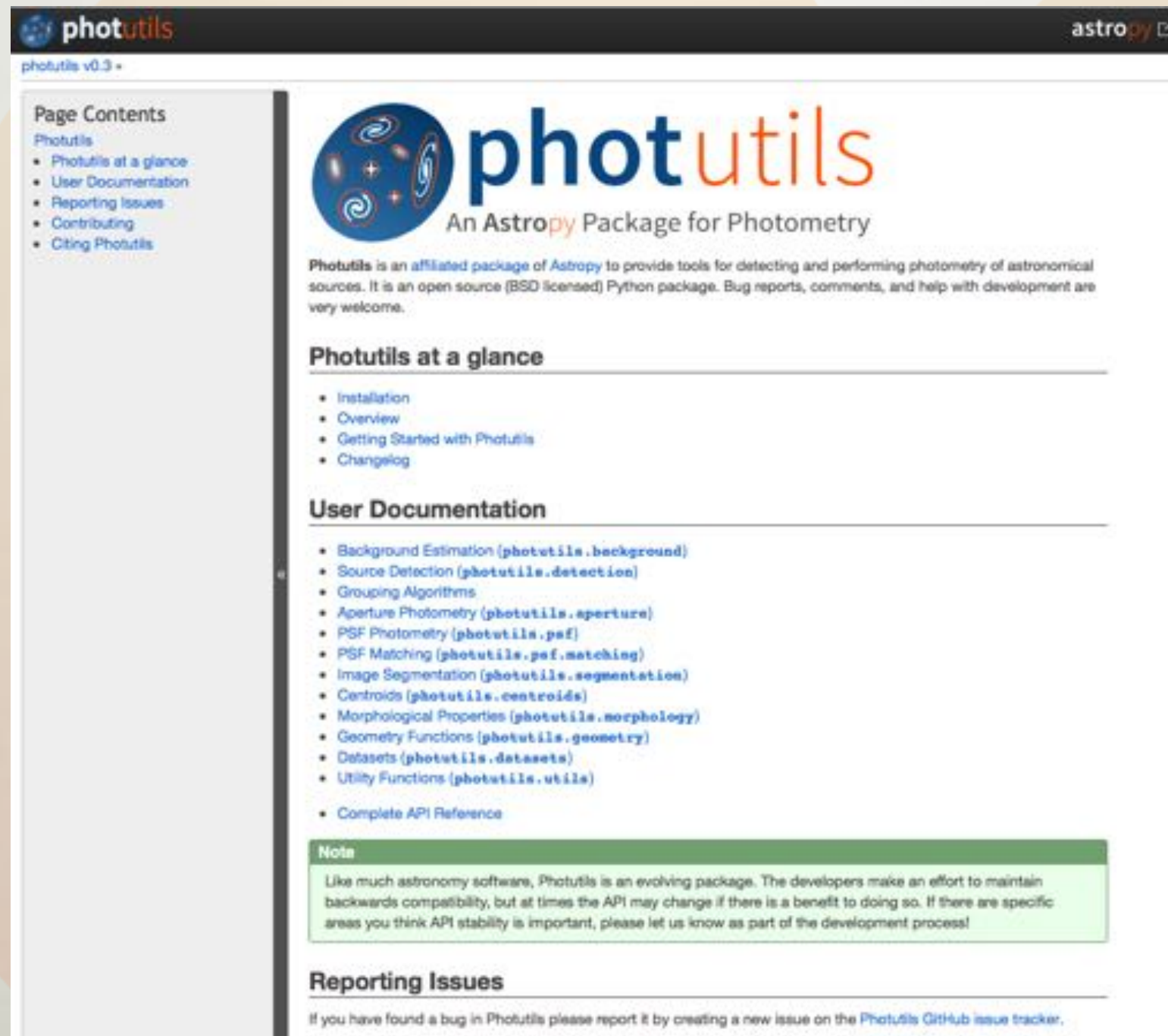


- An exposure of a lit (often de-focused) screen is required.
- Removes optical and pixel-to-pixel sensitivity artifacts.
- Filter-dependent
- Must have better S/N than science exposures!

PHOTOMETRY

- The aforementioned corrections yield an image that *should* be proportional to the light actually coming from the sky.
- To truly reduce the data to a table of “how much light is coming from all the things”, need to measure the “total” from each object from that image.
- Measuring light: “photometry”

PHOTUTILS: COMMUNITY PHOTOMETRY TOOLS



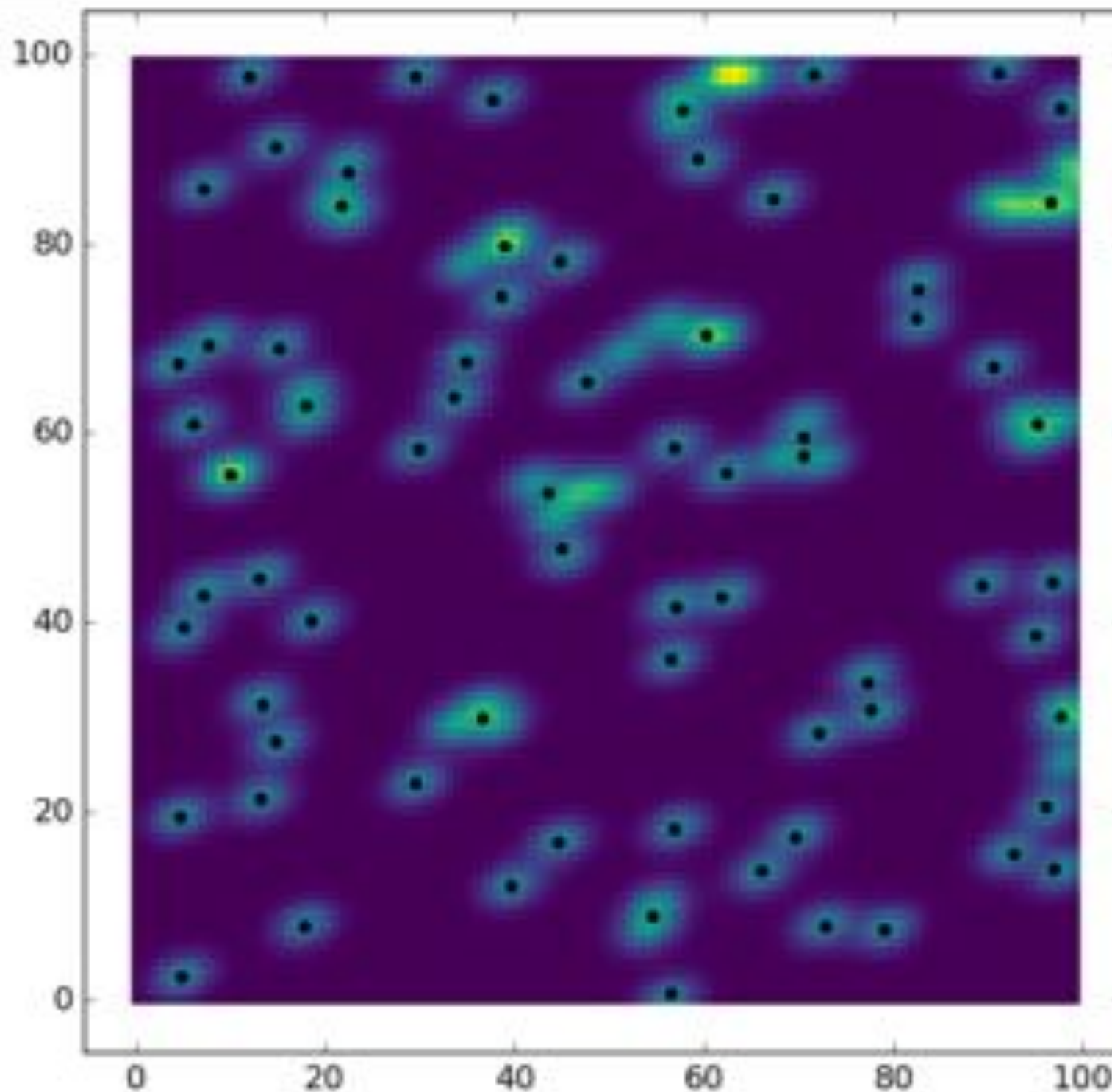
The screenshot shows the photutils website. At the top, there's a header with the 'photutils' logo on the left and the 'astropy' logo on the right. Below the header, the version 'photutils v0.3' is displayed. The main content area is divided into two columns. The left column, titled 'Page Contents', lists the following items: 'Photutils', 'Photutils at a glance', 'User Documentation', 'Reporting Issues', 'Contributing', and 'Citing Photutils'. The right column contains the main content. It starts with the 'photutils' logo and the text 'An Astropy Package for Photometry'. Below this, a paragraph states: 'Photutils is an affiliated package of Astropy to provide tools for detecting and performing photometry of astronomical sources. It is an open source (BSD licensed) Python package. Bug reports, comments, and help with development are very welcome.' This is followed by a section titled 'Photutils at a glance' with a bulleted list: 'Installation', 'Overview', 'Getting Started with Photutils', and 'Changelog'. Next is the 'User Documentation' section with a bulleted list of topics: 'Background Estimation (photutils.background)', 'Source Detection (photutils.detection)', 'Grouping Algorithms', 'Aperture Photometry (photutils.aperture)', 'PSF Photometry (photutils.psf)', 'PSF Matching (photutils.psf.matching)', 'Image Segmentation (photutils.segmentation)', 'Centroids (photutils.centroids)', 'Morphological Properties (photutils.morphology)', 'Geometry Functions (photutils.geometry)', 'Datasets (photutils.datasets)', 'Utility Functions (photutils.utils)', and 'Complete API Reference'. A green box labeled 'Note' contains the text: 'Like much astronomy software, Photutils is an evolving package. The developers make an effort to maintain backwards compatibility, but at times the API may change if there is a benefit to doing so. If there are specific areas you think API stability is important, please let us know as part of the development process!'. The final section is 'Reporting Issues', which includes the text: 'If you have found a bug in Photutils please report it by creating a new issue on the Photutils GitHub issue tracker.'

<http://photutils.readthedocs.io>

PHOTUTILS: OBJECT-FINDING

```
In [21]: star_finder = photutils.findstars.SAOStarFinder(threshold=bkg_var/2, fwhm=5)
found_stars = star_finder(im)

plt.imshow(im)
plt.scatter(found_stars['xcentroid'], found_stars['ycentroid'], color='k')
None
```



PHOTUTILS: OBJECT-FINDING

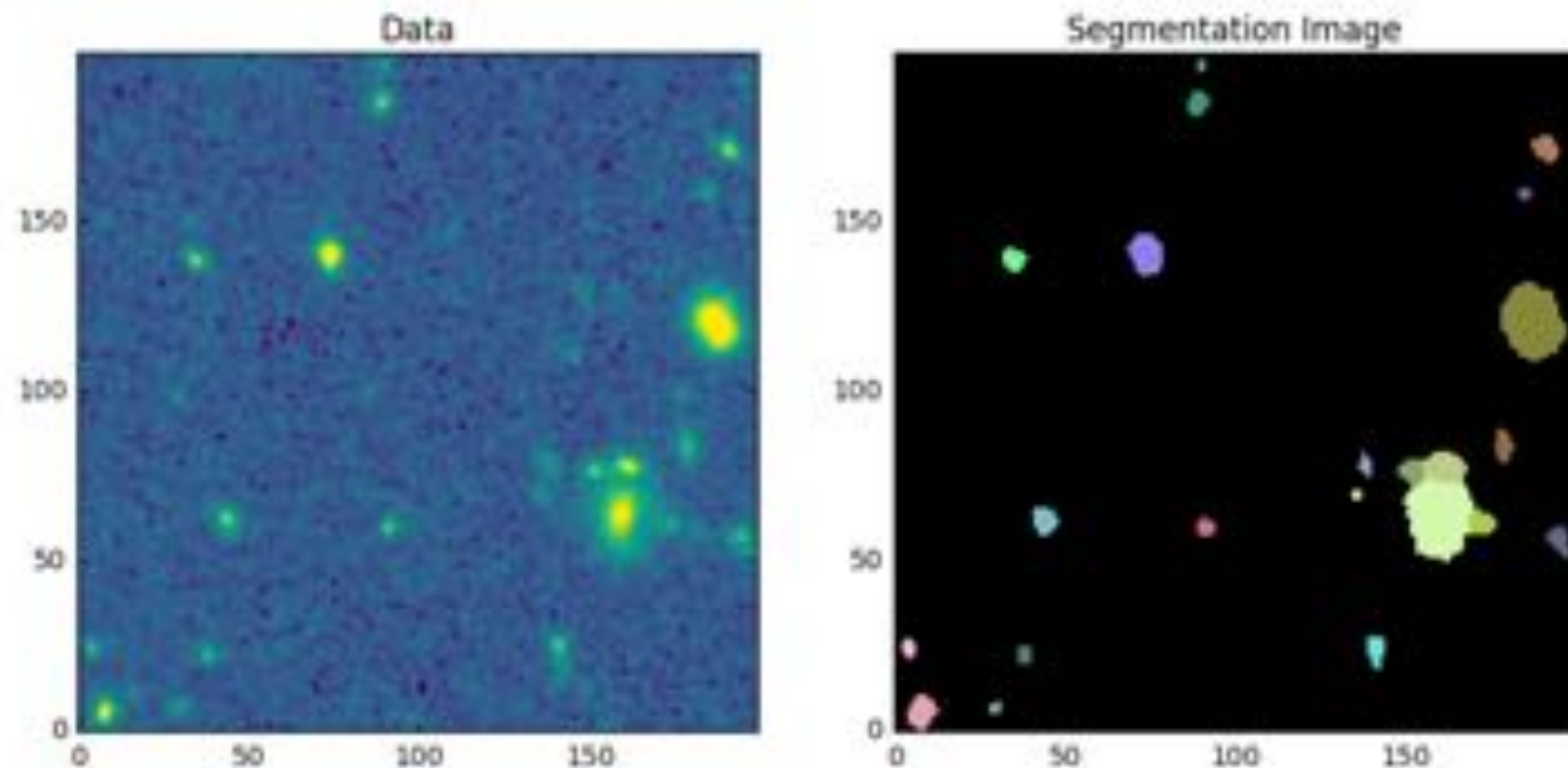
```
In [41]: from photutils import deblend_sources

segm2 = deblend_sources(data, segm, npixels, filter_kernel=kernel,
                        contrast=0.001, nlevels=32)

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 8))
ax1.imshow(scale_image(data, scale='sqrt', percent=99.5))
ax1.set_title('Data')
ax2.imshow(segm2, cmap=rand_cmap)
ax2.set_title('Segmentation Image')

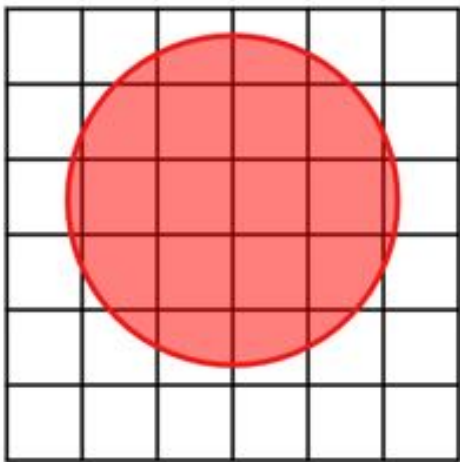
print('Found {} sources'.format(segm2.max))
```

Found 22 sources

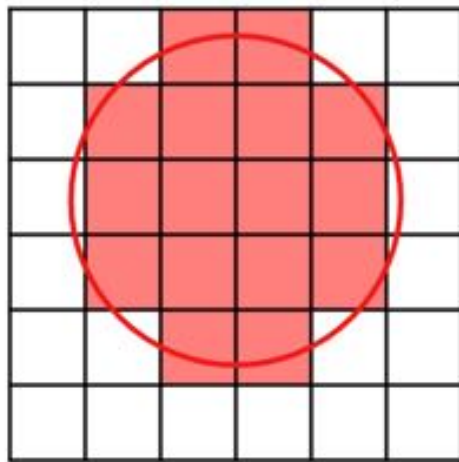


PHOTUTILS: APERTURE PHOTOMETRY

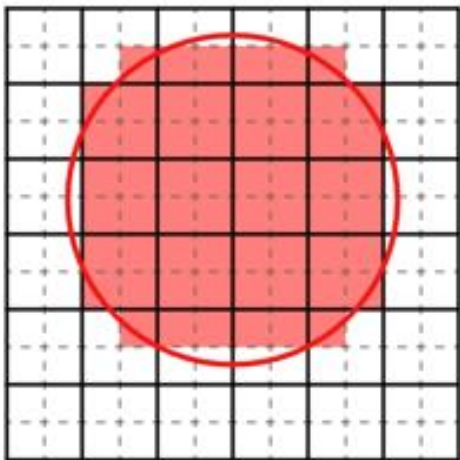
method = 'exact'



method = 'center'



method = 'subpixel'
subpixels = 2



```
In [41]: from photutils import CircularAnnulus

positions = [(90.73, 59.43), (73.63, 139.41), (43.62, 61.63)]

aper = CircularAperture(positions, r=3)
bkg_aper = CircularAnnulus(positions, r_in=10., r_out=15.)
apers = [aper, bkg_aper]
```

Now, perform the photometry.

```
In [42]: phot = aperture_photometry(data, apers)
phot.rename_column('aperture_sum_0', 'aperture_sum')
phot.rename_column('aperture_sum_1', 'annulus_sum')
phot
```

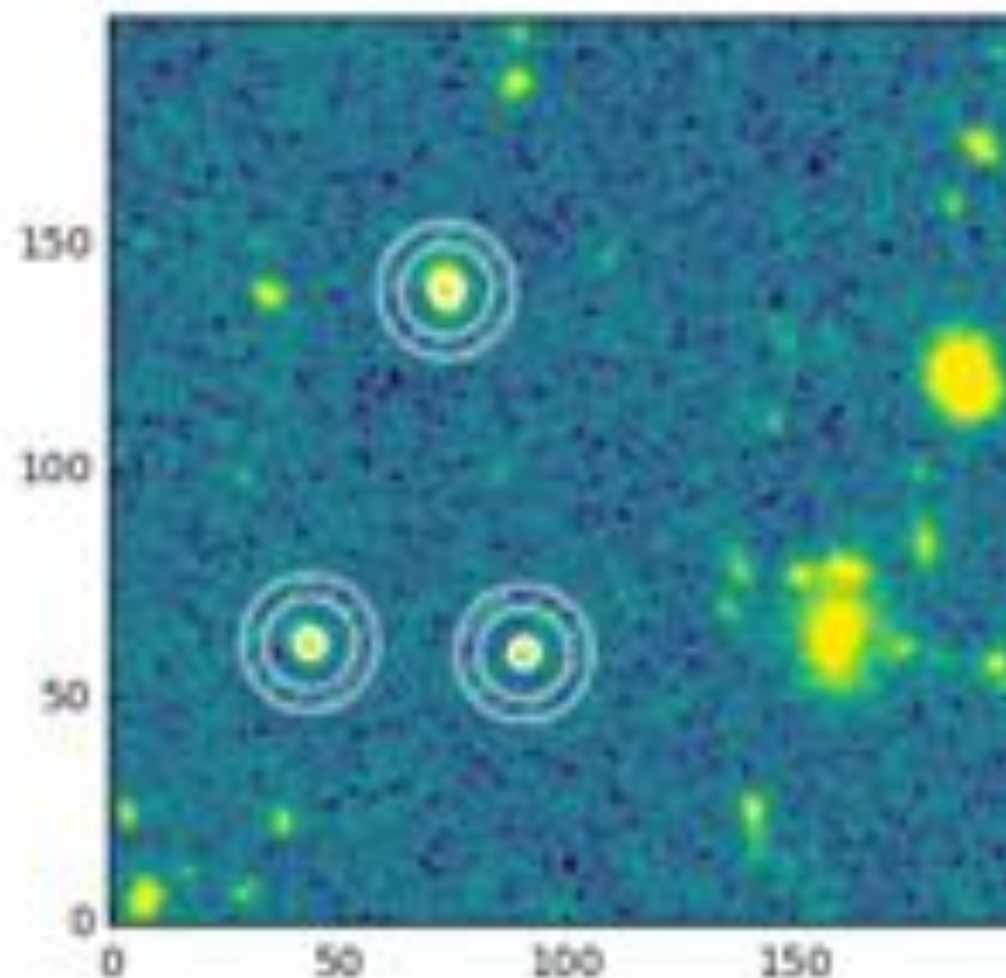
Out[42]: <QTable length=3>

id	xcenter	ycenter	aperture_sum	annulus_sum
	pix	pix		
int64	float64	float64	float64	float64
1	90.73	59.43	0.0866436609693	0.0199107563833
2	73.63	139.41	0.393646538117	0.0358905306285
3	43.62	61.63	0.130109734904	0.0160684757391

PHOTUTILS: APERTURE PHOTOMETRY

Apertures can plot themselves

```
In [46]: plt.imshow(scale_image(data, scale='sqrt', percent=99.))  
aper.plot(color='white', lw=2)  
bkg_aper.plot(color='white', lw=2, hatch='//', alpha=0.5)
```



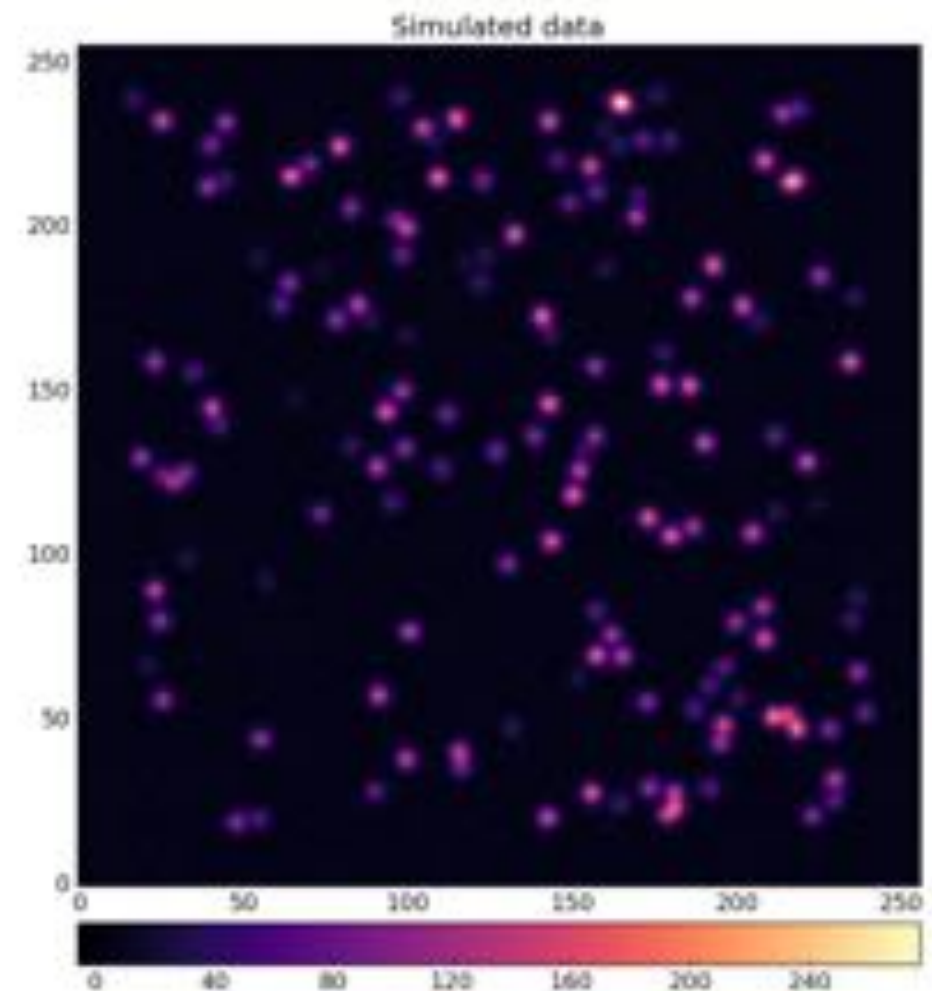
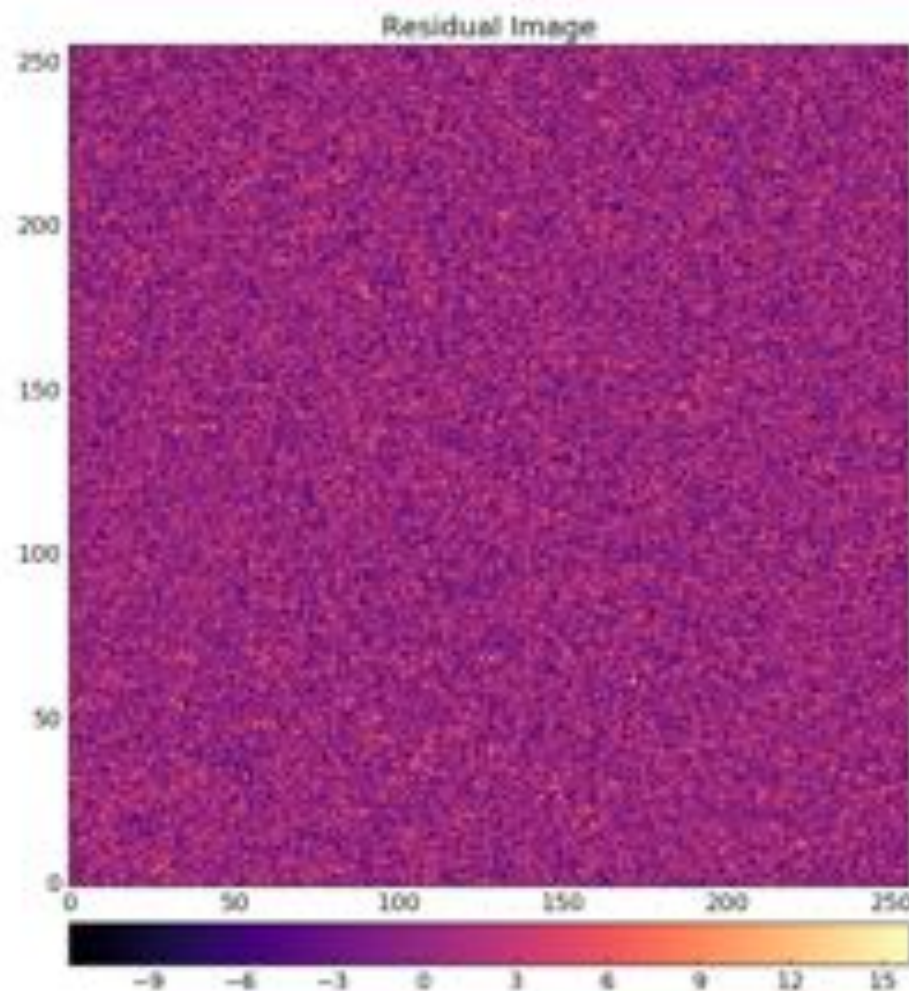
PHOTUTILS: PSF PHOTOMETRY

```
In [20]: from astropy.table import Table  
positions = Table(names=['x_0', 'y_0'], data=[starlist['x_mean'], starlist['y_mean']])
```

```
In [21]: photometry_results = basic_photometry(image=image, positions=positions)  
  
WARNING: Both positions and finder are different than None, which is ambiguous, finder is going to be ignored. [photu  
tils.psf.photometry]
```

```
In [22]: plt.subplot(1,2,1)  
plt.imshow(basic_photometry.get_residual_image())  
plt.title('Residual Image')  
plt.colorbar(orientation='horizontal', fraction=0.046, pad=0.04)  
  
plt.subplot(1,2,2)  
plt.imshow(image)  
plt.title('Simulated data')  
plt.colorbar(orientation='horizontal', fraction=0.046, pad=0.04)
```

```
Out[22]: <matplotlib.colorbar.Colorbar at 0x11488be48>
```



NOW GO DO IT YOURSELF!

LSSTC-DSFP-Sessions / Session5 / Day1 /
python_imred.ipynb

Note: substantial downloads required at
beginning... may need to share the files if you can.