Studio di oggetti ad alto redshift con HST e JWST

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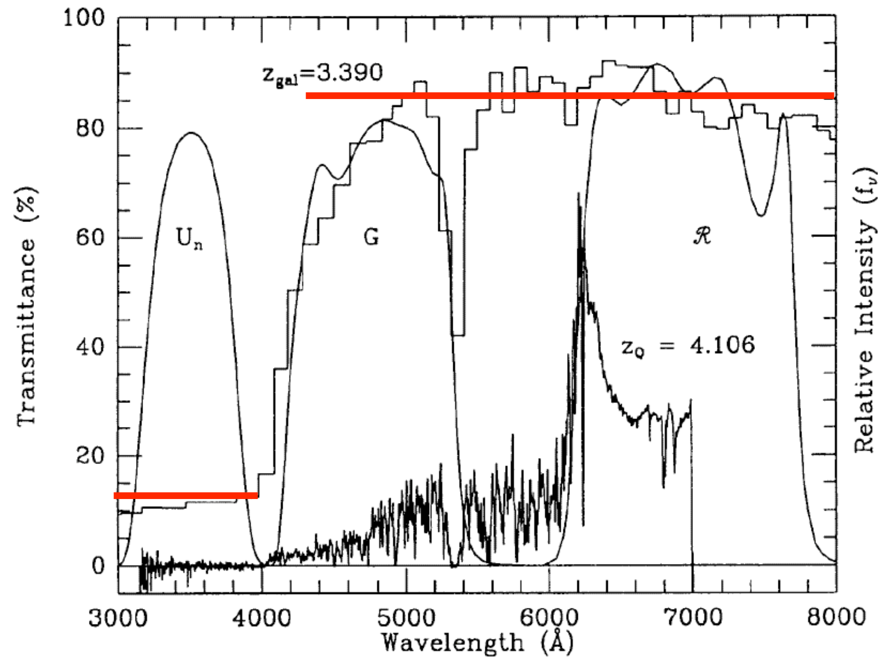
Discutero' come HST, Spitzer e JWST possono essere utilizzati per studiare l'Universo ad alto redshift. Mostrero' anche alcune delle difficolta' pratiche nell'analizzare dati profondi HST..

How to select high-z galaxies

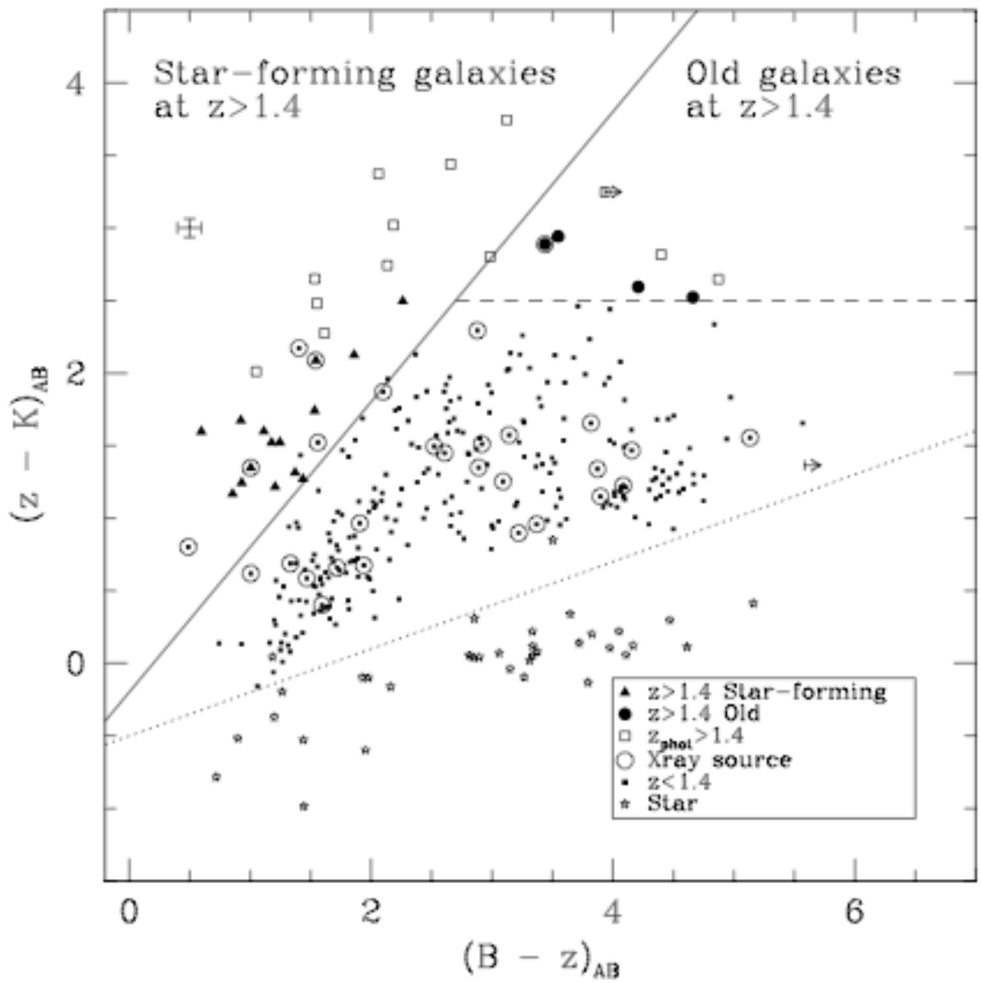
Selection of objects from an imaging survey is still the most effective way of finding high-z objects.

-Lyman-break: it is based on the absorption of Lyman continuum (and Lyman α) photons. In order to select young star forming galaxies one generally requires 2 color criteria.

Red U-G guarantees the presence of a break. Blue or flat G-R guarantees a young starforming SED.



- BzK: the Lyman break technique is incapable of finding quiescent objects or objects that are star forming but have an older stellar component.



-Lyman α excess: based on the fact that a source with a strong Lyman α emission will show in a narrow band filter centered at the wavelength of Lyman α an excess of counts compared to the surrounding continuum. At z=3 and 4 only 30 per cent of LBG have Lyman α in emission. Similarly not all Lyman-selected galaxies satisfy a Lyman break criterion. Thus the two techniques are complementary.

- non-color selected spectroscopic survey: this is the least biased method but also the most time consuming.

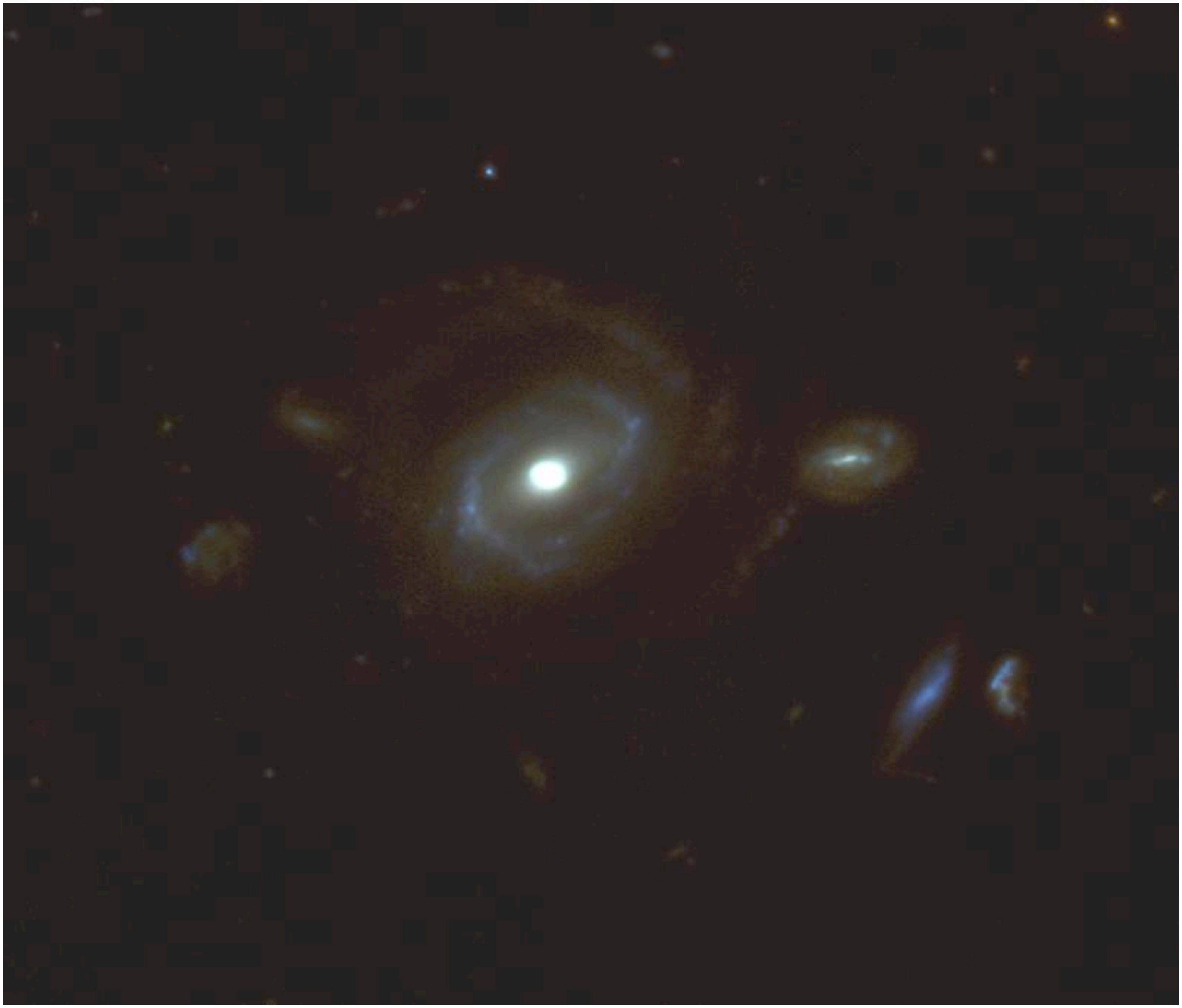
The main continuum features to identify and study stellar populations at high z are:

- Lyman break : generally present as it is caused, in part, by intervening neutral Hydrogen

- 4000Å break : present only in older populations. At $z>1.5$ it moves in the near-IR.

- 1.6 μm “peak” : not a very sharp peak, it is at this wavelength that the M/L ratio of a stellar population shows the smallest variation with age and metallicity. At $z>1.1$ it moves in the Spitzer/IRAC range.

--> IRAC/Spitzer very effective in identifying older populations.



Spitzer

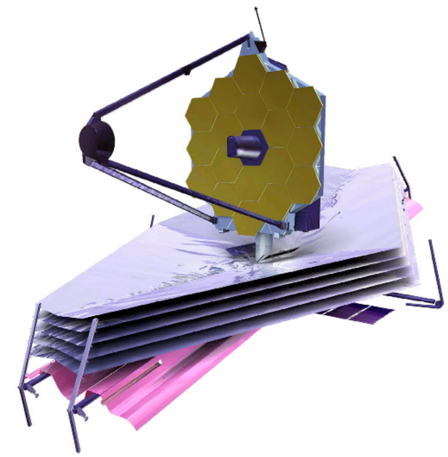
Spitzer it's a satellite with a predetermined life because of the presence of cryogen. It is expected that the cryogen will have been exhausted in about a year. After that the telescope will warm up and operations with MIPS and the long channels of IRAC will not be possible.

However, IRAC will still be usable at 3.5 and 4.5μm and various groups have recommended an extended mission.

If this is approved, the limiting factor will become communications as Spitzer is in a drift away orbit.

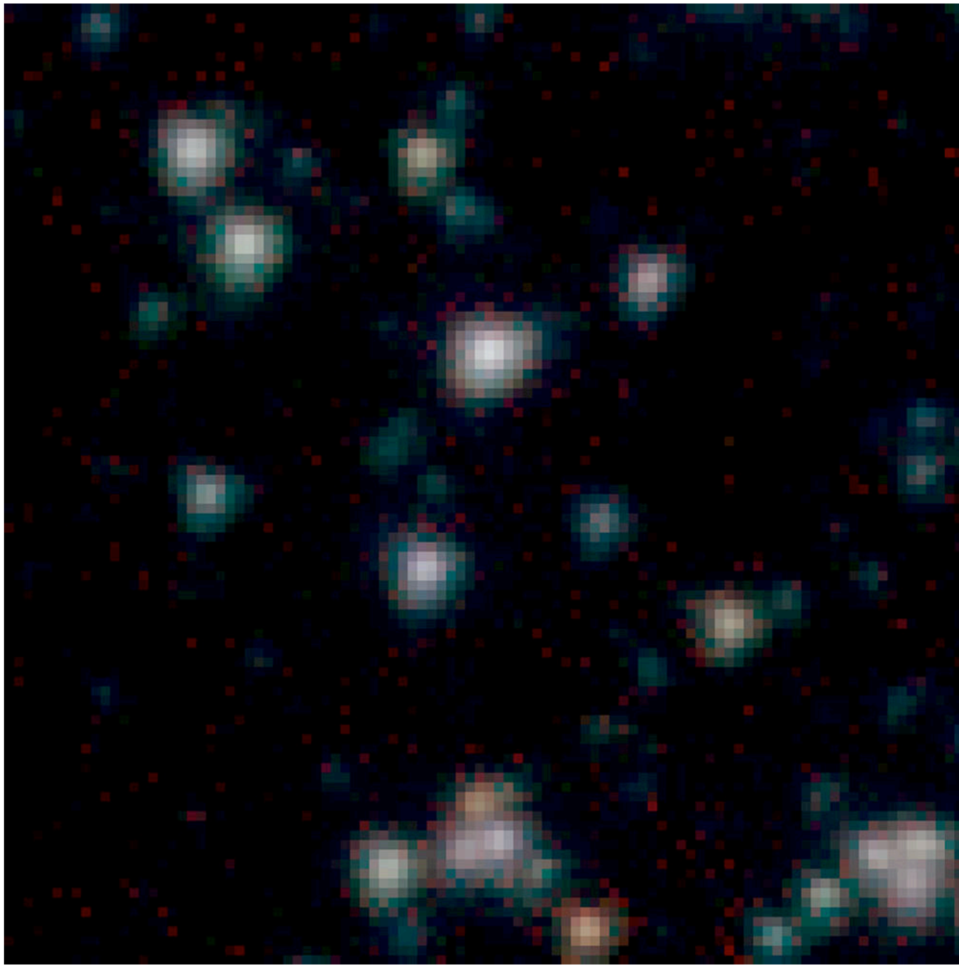
JWST will enable imaging and spectroscopy up to 28 μm.

NIRcam : near-IR camera 0.6-5 μm
NIRspec : near-IR spectrometer 0.6-5 μm
MIRI : mid-IR imagers and spectrograph 5-28 μm
FGS-TF : tunable filter 1.3-4.8 μm

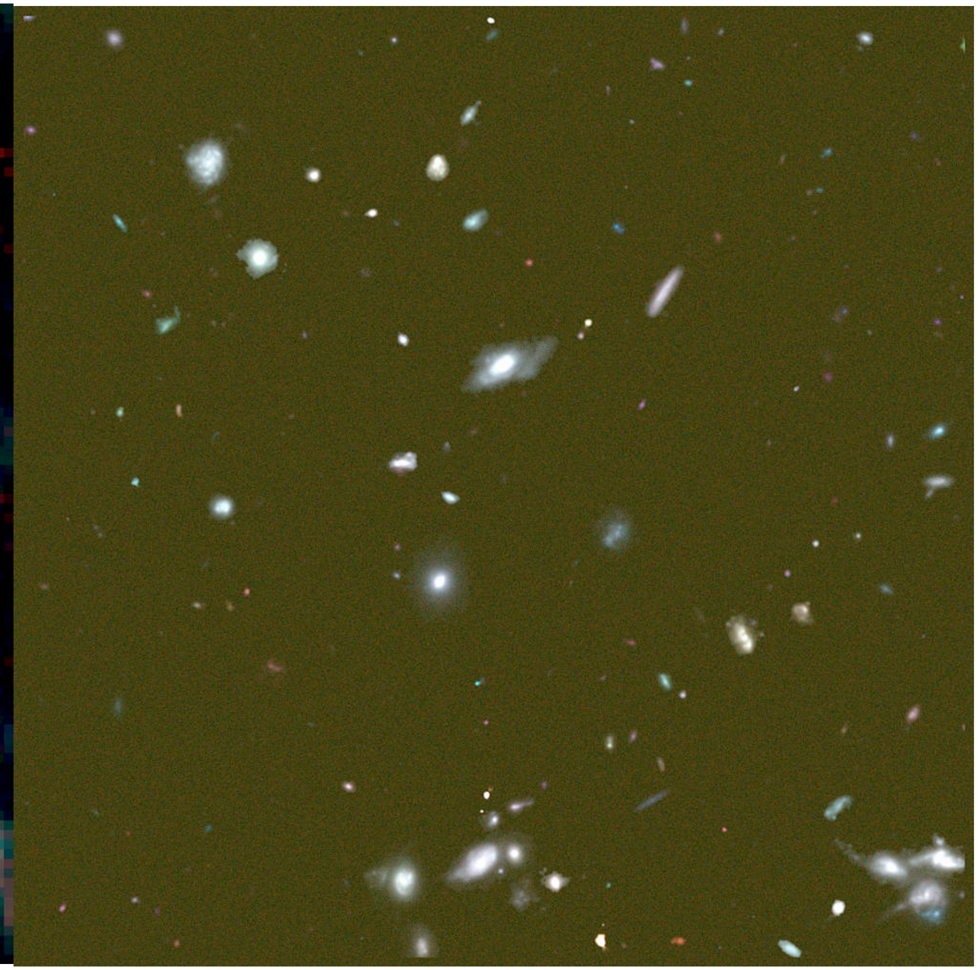


One application is the measurement of metallicity of a galaxy using R_{23} = ([OII]+[OIII])/Hβ and Hα/[NII]. These line span the interval 3727-6584Å. At redshift 6 the interval is redshift to 2.6-4.6μm. Thus, JWST will be able to measure metallicity for objects up to z=6 using the multi-object capability of NIRSpec. For individual objects MIRI will be able to obtain spectra to much high redshift.

Confronto tra una immagine infrarossa di galassie distanti ottenuta con il telescopio spaziale Spitzer (a sinistra) con una osservazione durata 75 ore e della stessa area vista da JWST con una osservazione di 50 minuti di durata (destra)



Spitzer, 25 hour per band (GOODS collaboration)



JWST, 1000s per band (simulated)

Imaging techniques

- Image combination, dithering, drizzle

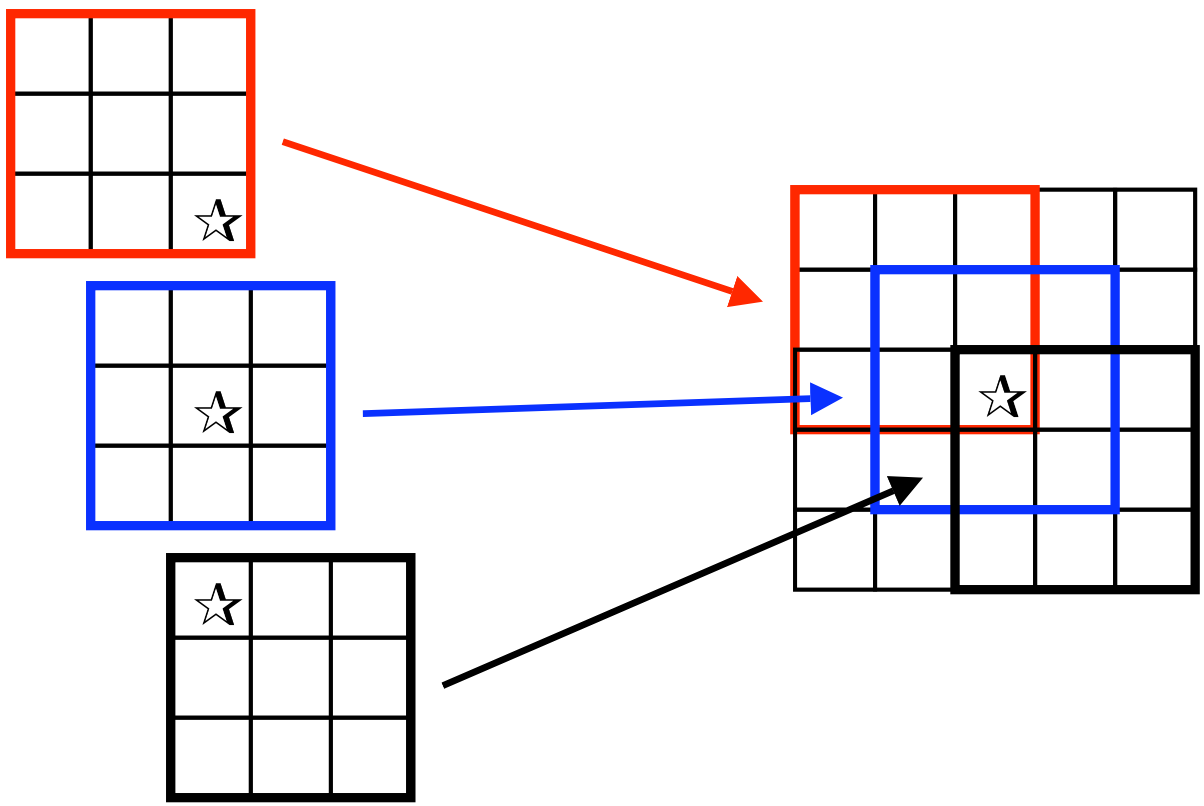
- Catalog extraction, simulations

Dithering:

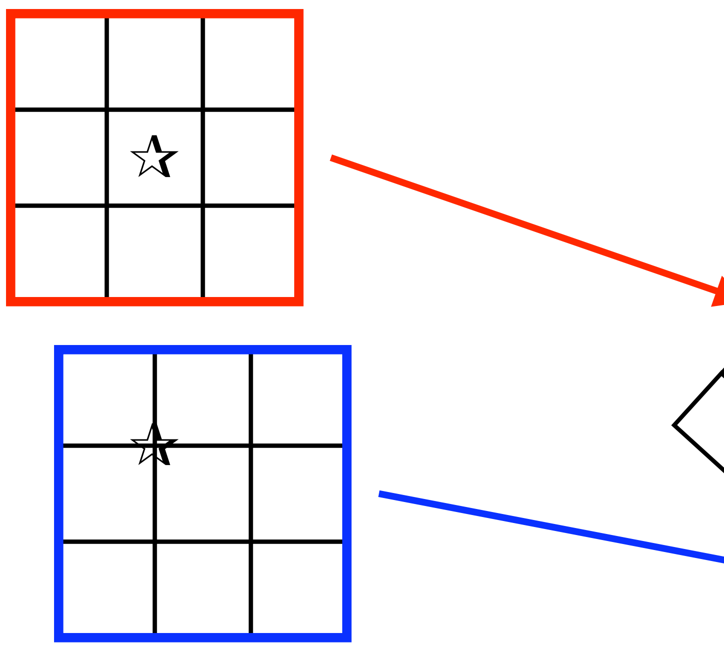
- it is generally convenient to obtain deep imaging data using a dithering technique. This consists in changing the pointing by small angles around the desired pointing so that each object will fall on different pixels. This will allow one to obtain data which can be calibrated more accurately (as one is averaging over flat fielding errors).
- for instruments that undersample the PSF (as it is typical for HST cameras) one will want to sample by dithering sub-pixel positions so as to be able to obtain a better sampled image.

Drizzling:

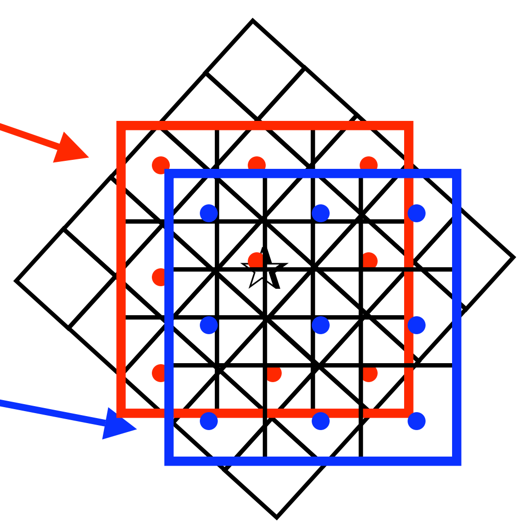
- drizzling is a technique to combine dithered data developed by Fruchter and Hook for the HDF.
- for data with no geometric distortion drizzle includes as special cases shift and add and interlacing. However, it is in practical cases superior to both and it can be effective in the presence of geometric distortion.



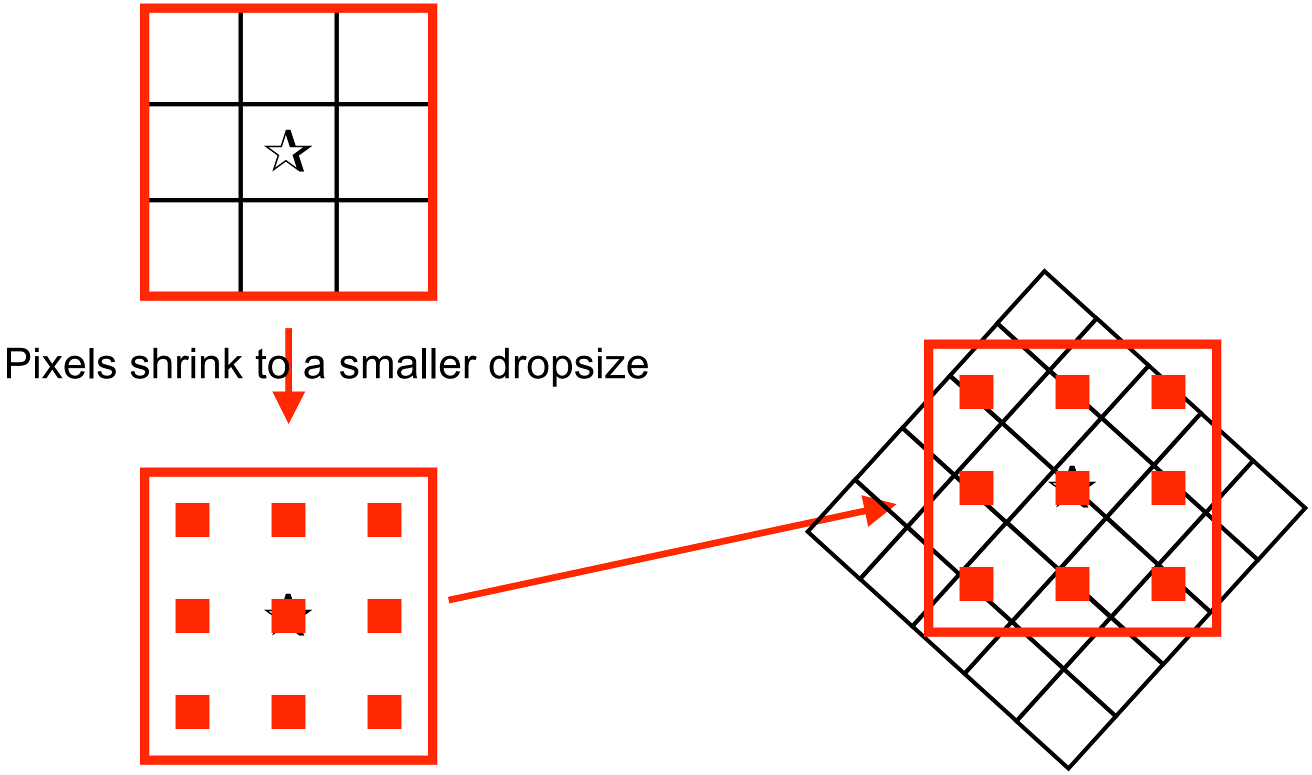
Shift-and-add: images are aligned to the nearest pixel.
No geometric distortion, no subpixel sampling.



Here the final pixel size is $1/\sqrt{2}$ the initial one.



Interlacing: images are aligned to the nearest pixel. Can produce subpixel images, output can be statistically independent. No geometric distortion.



Drizzling: works in the presence of geometric distortion and can produce subpixels images. Output will generally be correlated (unless point kernel is used).

When sufficient input images are available the point kernel is preferred. With few images it can produce pixel to pixel variations in depth that are undesireable.

Casertano et al. HDFS paper characterize correlated noise when the drop size is not zero.

$$PSF_{out} = PSF_{in} \circ \text{dropsize} \circ \text{input\_pixel\_size}$$

Thus, even with the point kernel (dropsize=0) the output PSF can be no smaller in FWHM than the input pixel size.
→reducing the output pixel by more than a factor of two leads to no measurable improvements.
→For the UDF we adopted 30mas as final pixel size instead of 50mas for uniformity with GOODS and after having verified that the image quality was identical.

Catalogs

Once the final image (and its weight map) has been produced one is generally interested in producing an object catalog.

For galaxies this is more complex than it is for stars because the intrinsic shaper of the object is unknown.

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Method:

- the image is scanned to identify statistically significant objects e.g. sources with a minimum number of pixels above a minimum flux threshold
- identified objects are grown to include additional flux from their halos/envelopes by adding lower statistical significance pixels
- tests are carried out to understand which objects have to be split in subcomponents or merged into one object.
- a local background is determined through suitable filtering.

Some tips:

-because of correlations one cannot trust the errors given by Sextractor even if carefully produced weight/rms maps are used.

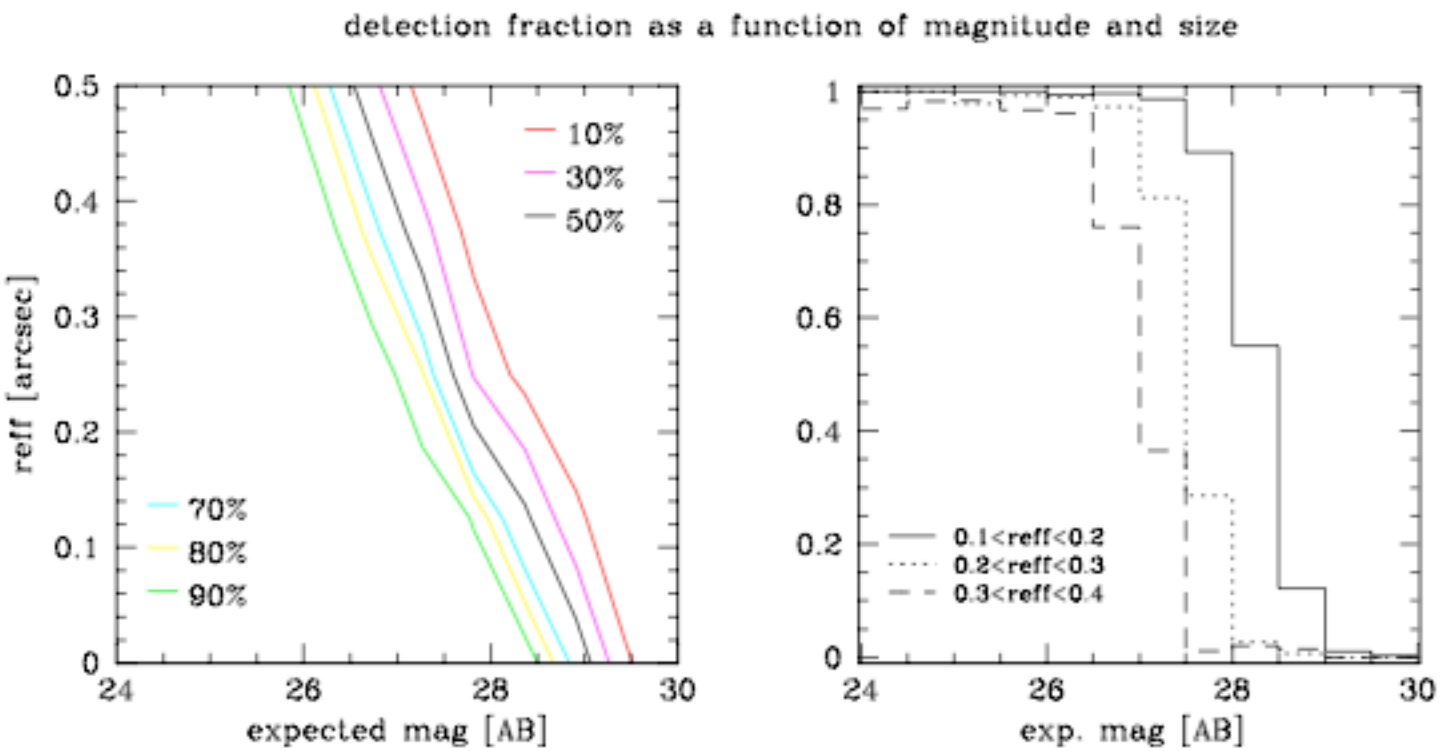
- it is often necessary to rescale the weight map by determining the effective noise over areas representative of the galaxies one is interested in. This can be done by measuring fluxes in randomly placed apertures (avoiding objects) and computing the rms, or by tracking how the rms on the image scales with a block averaging scale or by running and autocorrelation analysis.
- In the presence of correlated noise it will not be possible to adjust the errors for a generic object and one will have to be happy with a correct rescaling for the objects of interest.

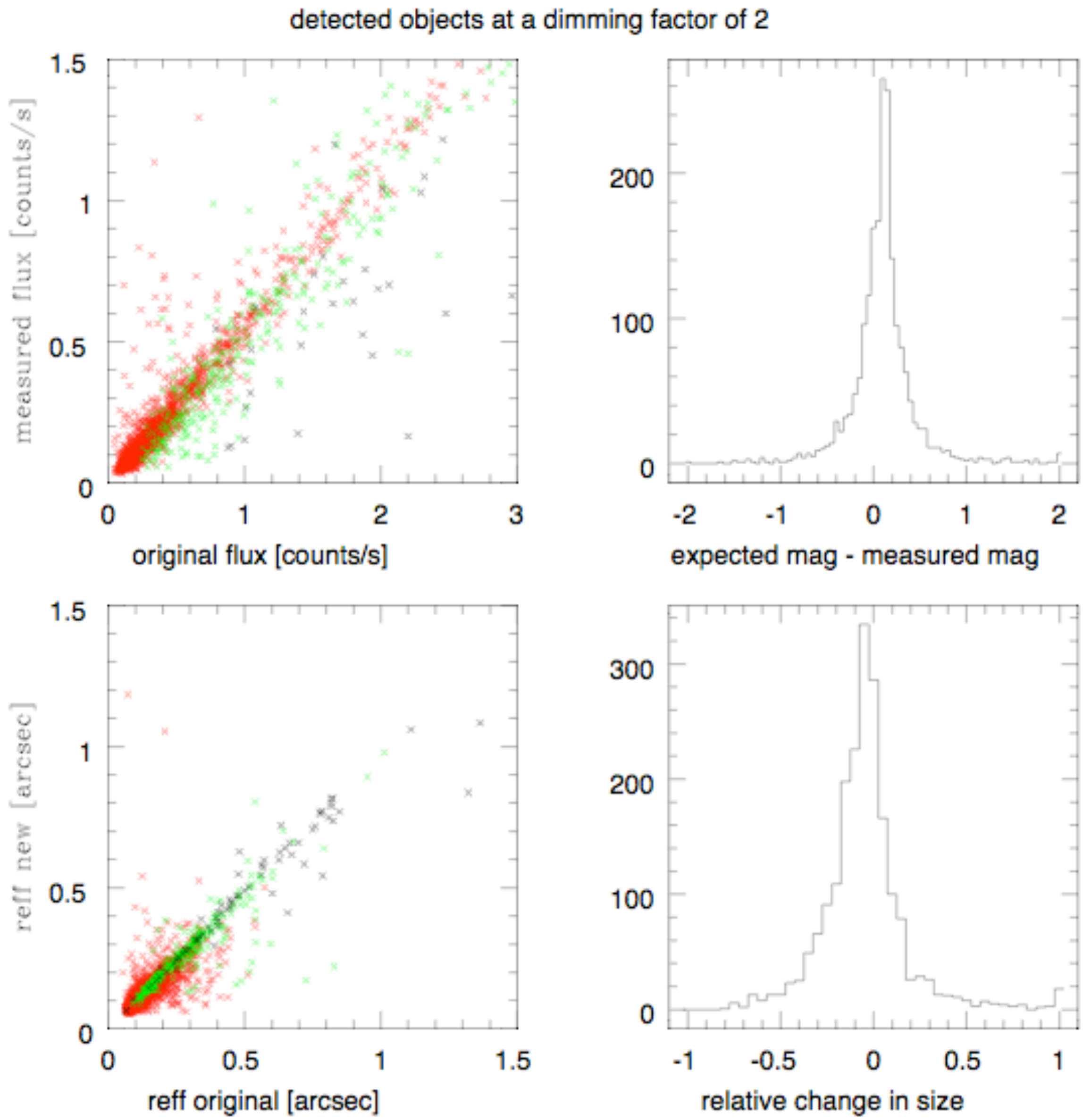
-Sextractor has biases so one has to rely on extensive simulations in order to:

- Determine the effective error for each class of object
- Determine whether magnitude biases are present. This is often the case as Sextractor will introduce a non-linear bias where faint objects will appear fainter than they are.

-Simulations will be necessary to determine the level of completeness and one can use the same set for completeness and bias anaysis

- There are two schools of thought on simulations: using real objects properly rescaled or using simulated objects. Both have advantages and disadvantages and it's probably a good idea to try both.

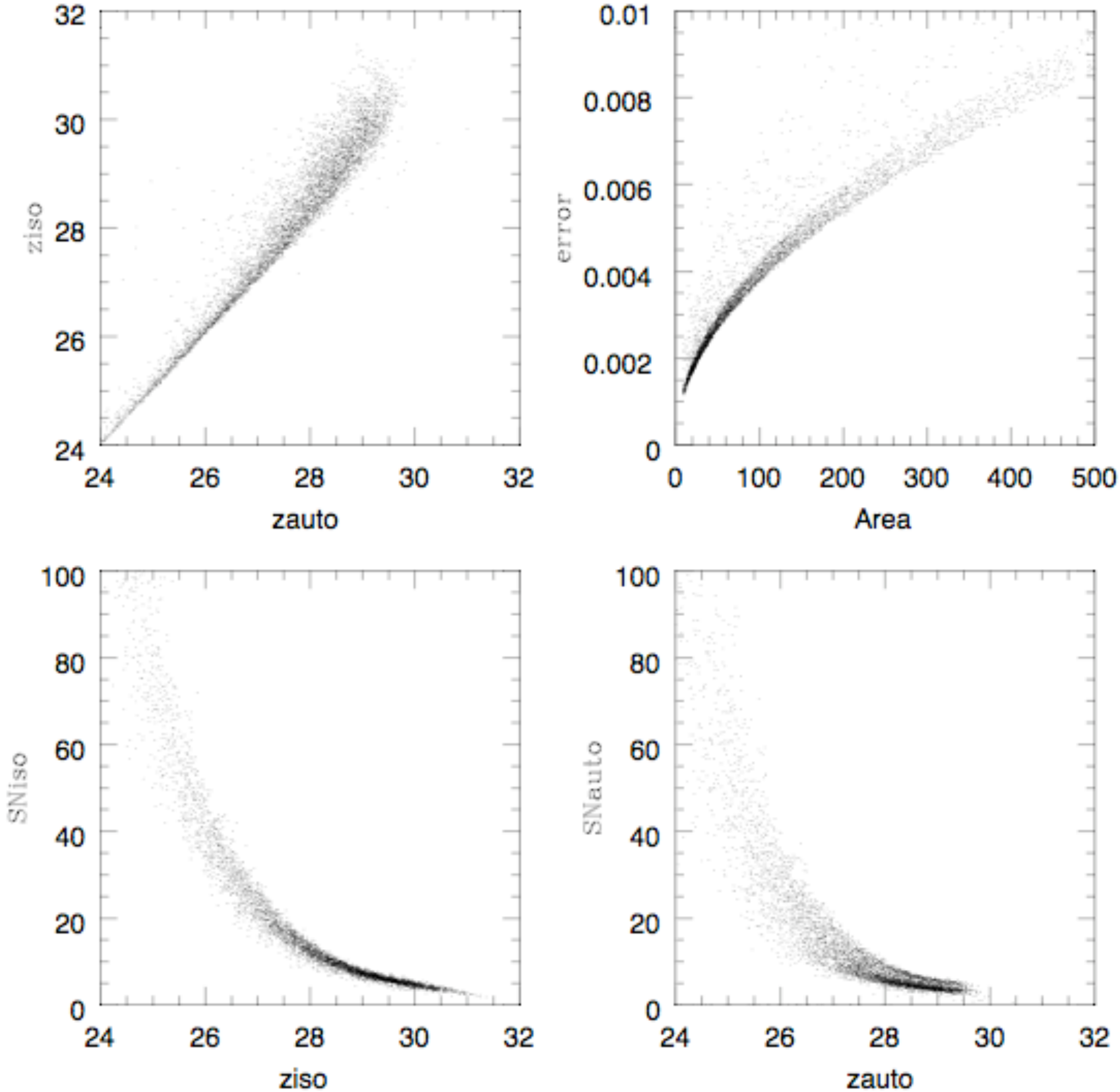

detection fraction as a function of magnitude and size
reff [arcsec]
expected mag [AB]
10%
30%
50%
70%
80%
90%
exp. mag [AB]
0.1<reff<0.2
0.2<reff<0.3
0.3<reff<0.4



detected objects at a dimming factor of 2
measured flux [counts/s]
original flux [counts/s]
expected mag - measured mag
reff new [arcsec]
reff original [arcsec]
relative change in size

-Sextractor has various magnitude outputs. Generally the best estimate for the total flux is magauto but this can still be biased by 0.3 mag.

- for colors it’s best to use the difference of magiso with image photometry done in dual image mode. This means that the isophotes are determine on one image and then are used also for determining the magiso in the second image.
- there are some relatively arbitrary parameters such as the deblending ones. Different catalogs might differ in a detail comparison simply because of their different blending. Of course changing blendings means repeating all simulations and this can be time consuming (e.g. for the UDF/UDF05 project we have a 24 (Opteron) cpu Linux cluster…



zauto
ziso
Area
error
SNiso
SNauto

New tools:

- Virtual observatory and Hubble Legacy Archive will enable studies that were previously impossible.

- Sloan Digital Sky Survey has had an enormous impact. A new generation of wide surveys is coming on line and some of them might be essential to help find targets for JWST.

Summary:

- the Lyman break technique is an effective method to find high-z galaxies but is not the only one and is not perfect.

- Sextractor is becoming the standard for producing catalogs. It is very complex and it’s too often used as a black box. Monte carlo simulations to characterize what it’s actually doing are a must!

- given the deblending uncertainties one wonders whether with JWST deep surves (which will be closer to the confusion limit) one will need a new generation of cataloguing software.