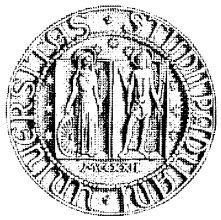
GAIA GALAXY SURVEY

A Multi-Color Galaxy Survey with GAIA



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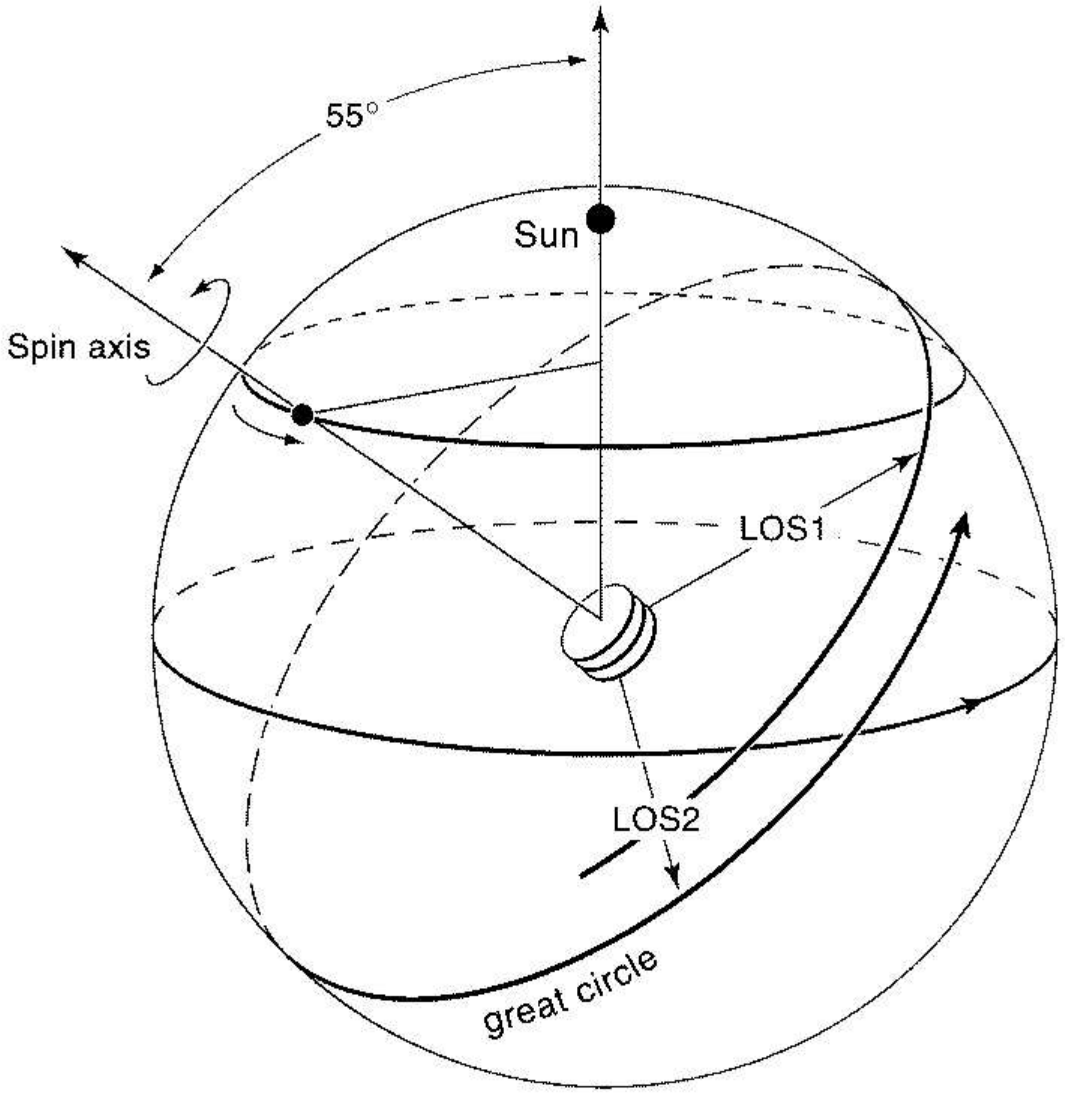
GAIA: a European Space Project *Les Houches, 14-18 May 2001*

Summary

- General Ideas on Galaxy Observations with GAIA
- Statistical Model of Galaxies
- Galaxy Detection: discrimination between point-like and diffuse objects
- Galaxy Observation: CCD binning and stacking of observations
- Simulations
- Measurement Capabilities
- Scientific Results
- Future Work

Why should we bother to observe galaxies with GAIA?



GAIA will "naturally" provide:

- All-Sky Coverage
- High Angular Resolution
- High Astrometric Accuracy
- Photometry and Spectroscopy
- Multi-Epoch Observations

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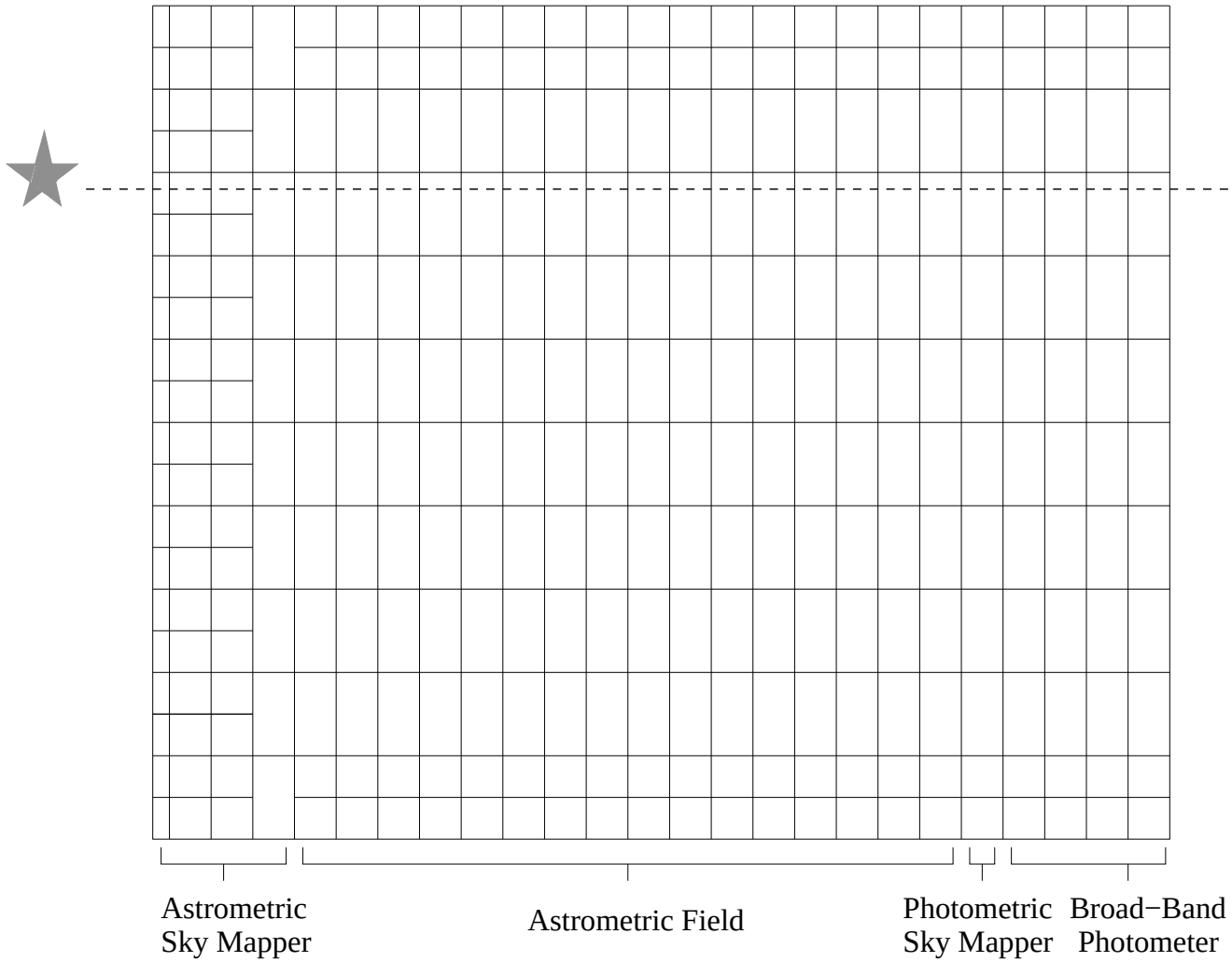
Unique "by-products"

Galaxy Observing Strategy



Maximize *Science/Bit*

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- ASM detection
  - algorithm
- BBP observation
  - sample size
  - 2-D patches

Statistical Model of Galaxies

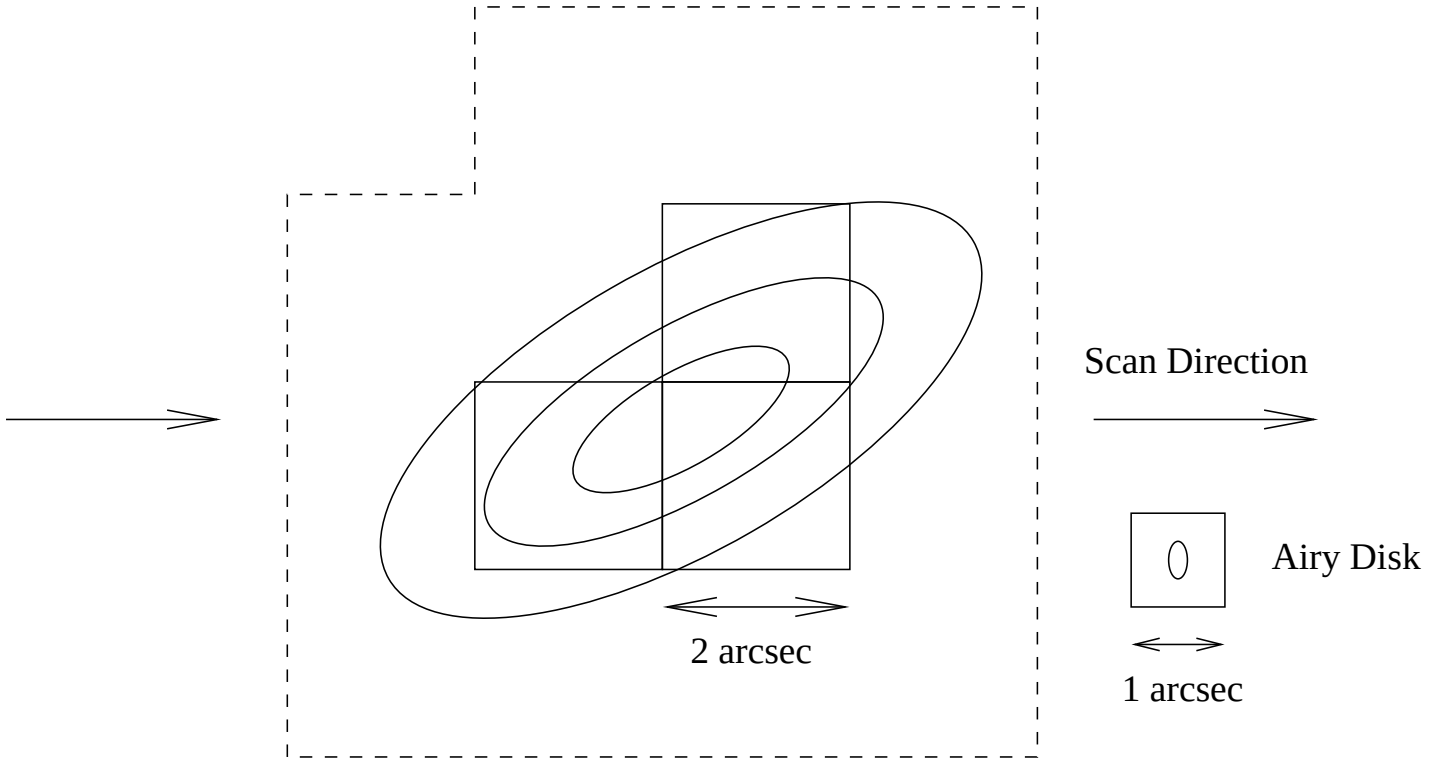
- Outputs as function of total I magnitude:
  - Differential counts: $N = N(I)$
  - Cumulative counts: $N_c = N_c(I)$
  - Effective radius: $r_e = r_e(I)$
  - Effective surface brightness for E and D: $\Sigma_{E,e} = \Sigma_{E,e}(I)$ e $\Sigma_{D,e} = \Sigma_{D,e}(I)$
  - Surface brightness radial profile for E and D:

$$\Sigma_E(r) = \Sigma_{E,e} \exp\left(-7.67\left[\left(\frac{r}{r_e}\right)^{1/4} - 1\right]\right)$$

$$\Sigma_D(r) = 0.77\,\Sigma_{D,e} \exp\left(-7.67\left[\left(\frac{1.66\,r}{r_e}\right)^{1/4} - 1\right]\right) + 2.93\,\Sigma_{D,e} \exp\left(-\frac{1.39\,r}{r_e}\right)$$

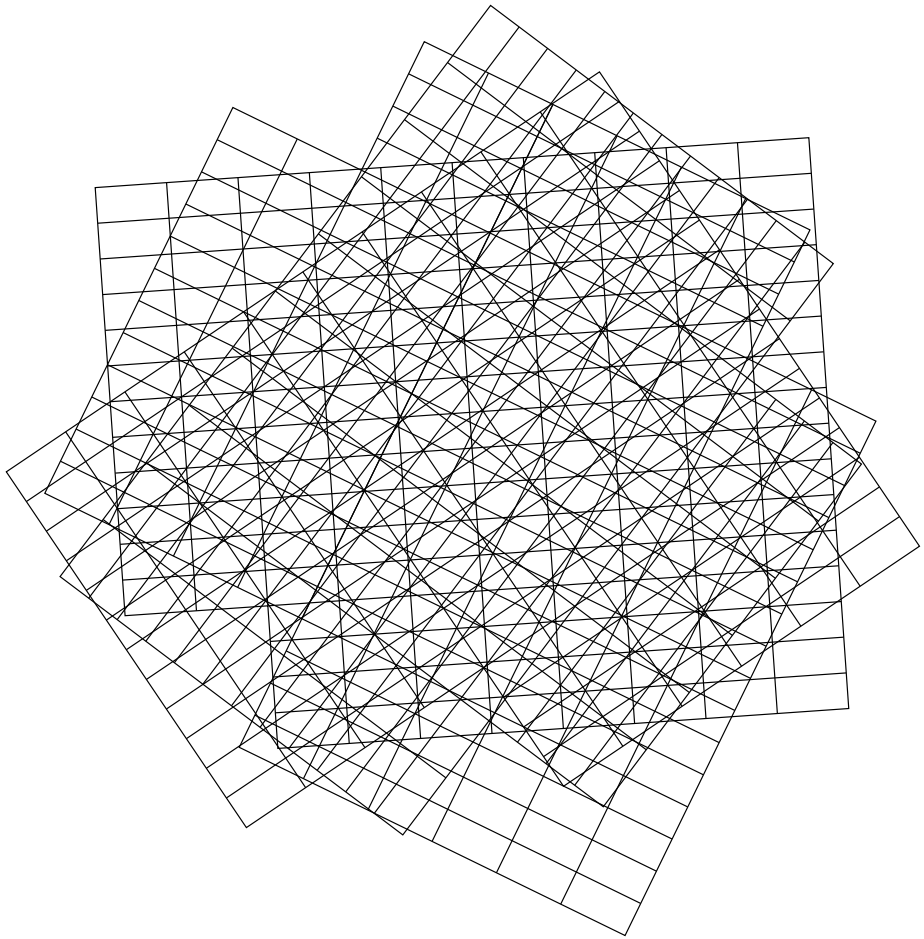
- Typical validity: within 0.2 mag/arcsec^2 up to $\simeq 4\,r_e$

Galaxy Detection



- Reliable detection at $S/N > 4$ within an area of 2×2 arcsec^2
- A galaxy of $I = 17$ would thus be detected 60% of the times
- $I \leq 17$ and $|b| > 15 \Rightarrow$ at least 3 million galaxies

Galaxy Observation: the Binning and Stacking Issues



- Binning determines angular resolution, accuracy in surface photometry and required telemetry rate
- Different observations of the same galaxy are centered and oriented differently and must be combined accordingly

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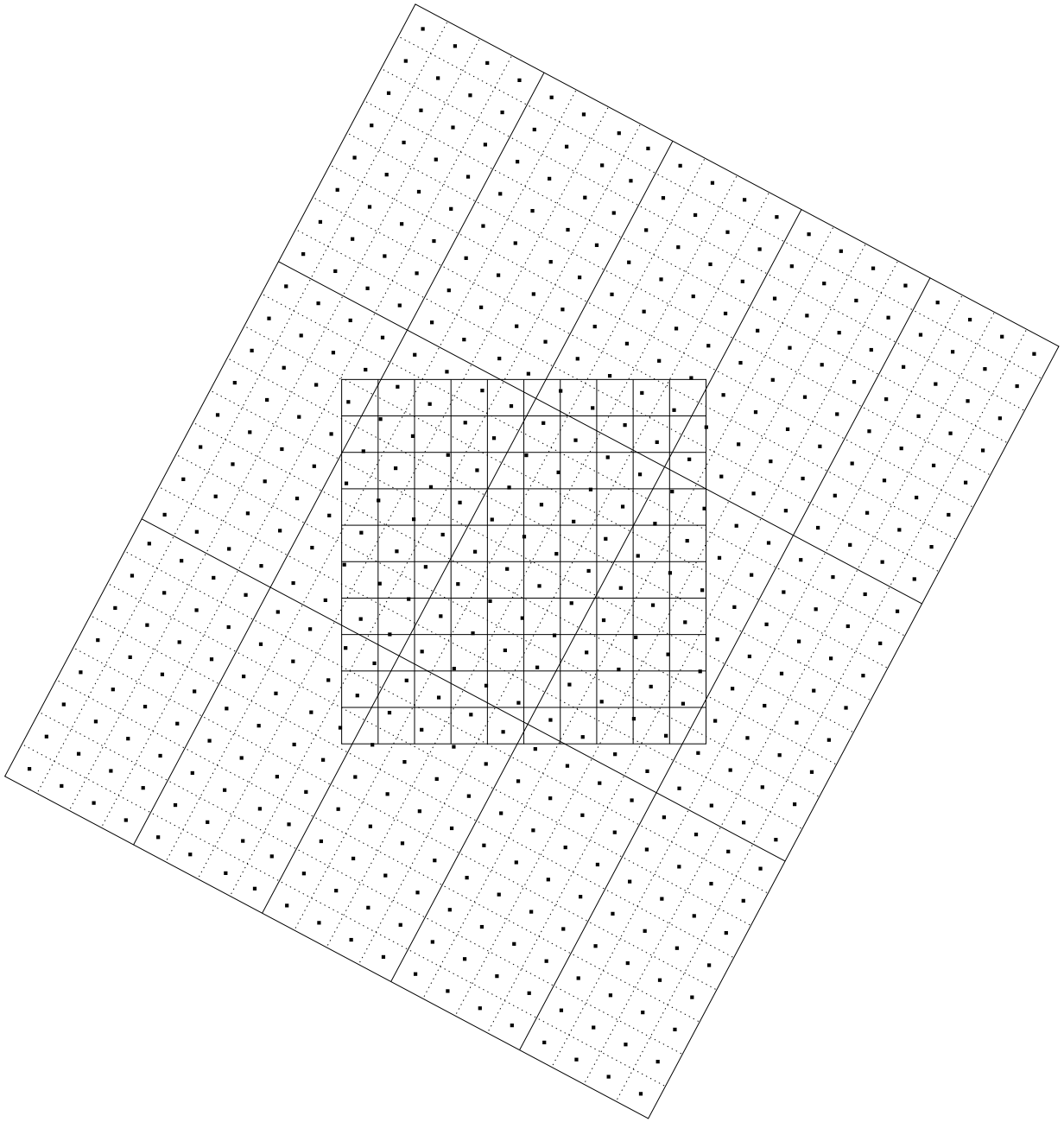
Simulations!

Stacking: Subsampling and Rebinning



- Each sample of the input image (observation) is first divided into a certain number of square subsamples, each with an equal fraction of the overall counts of the sample
- The counts of a subsample are then assigned to the pixel of the output image (flux map) containing the subsample's center
- This procedure preserves the total flux but does not recover the optical resolution which is lost due to PSF undersampling

Simulation and Stacking of Observations

Simulation

HST WFPC2 Image

⇓

- Conversion of counts
- Subpixeling
- Rototranslation
- Rebinning
- Convolution with GAIA PSF
- Addition of Poisson noise and RON

⇓

GAIA BBP Simulated Observation

Stacking

GAIA BBP Simulated Observation

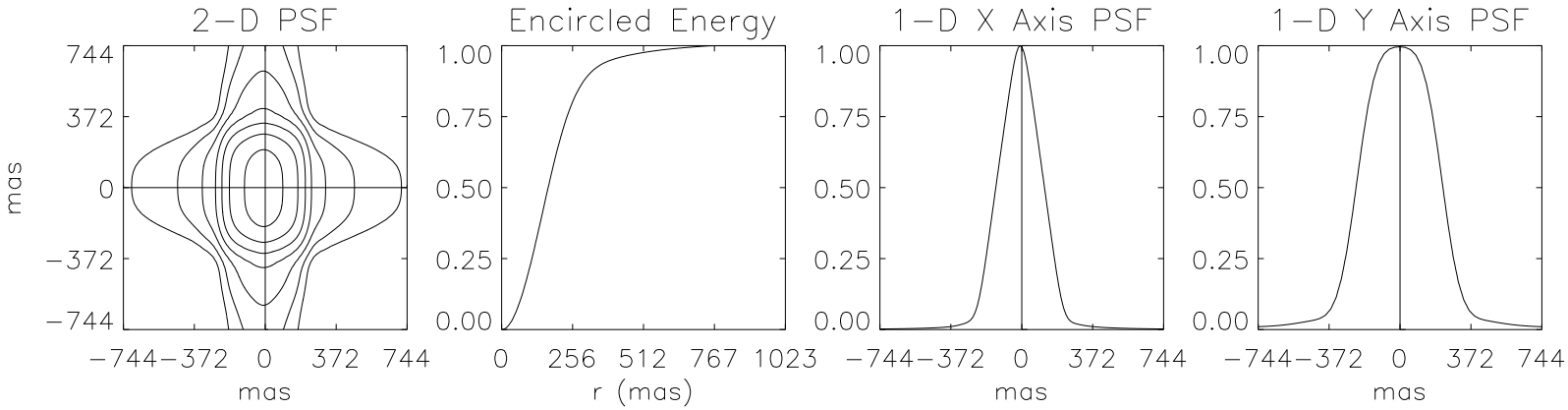
⇓

- Subsampling
- Counter-rototranslation
- Rebinning

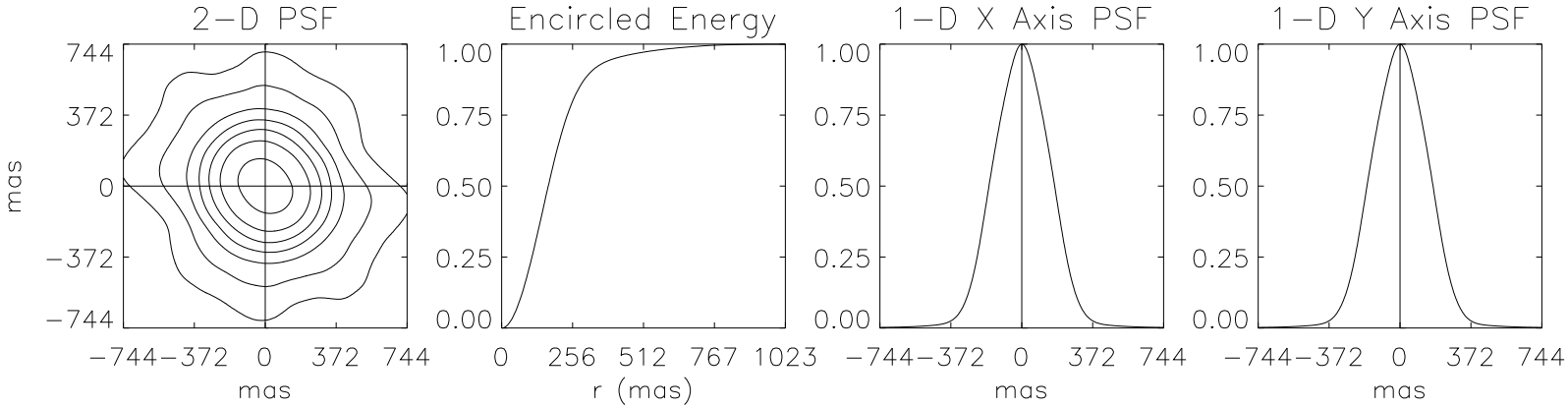
⇓

Simulated GAIA BBP Flux Map

Point Spread Function

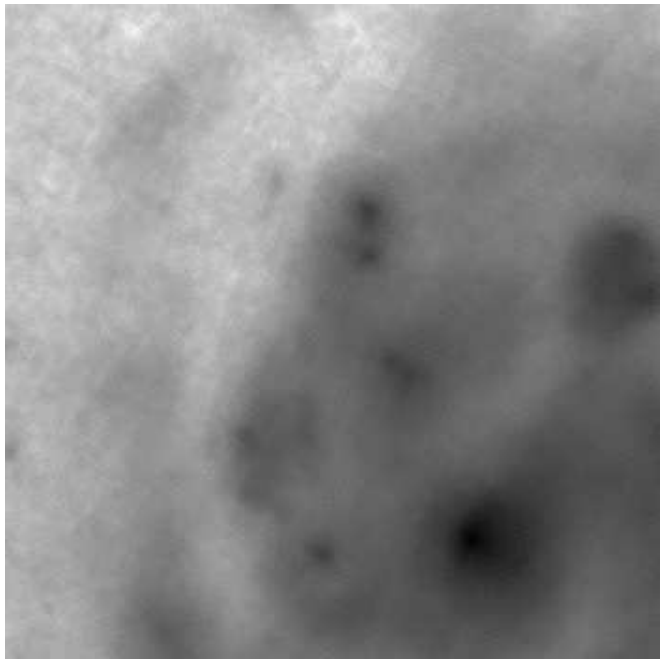


1-scan PSF

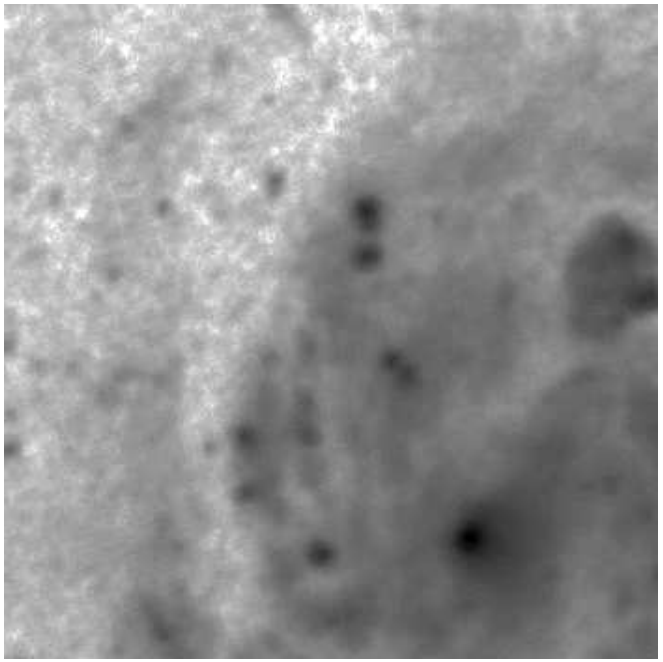


50-scan PSF

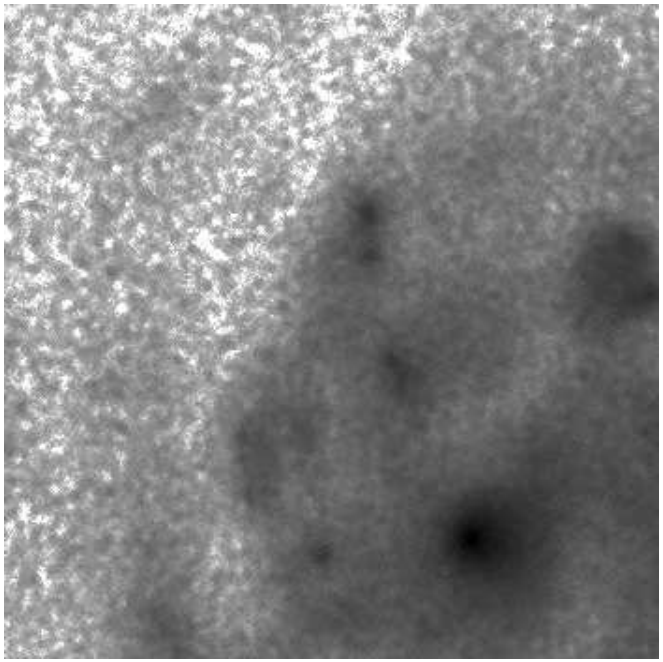
Angular Resolution and Sample Size



6×8



6×4



6×2

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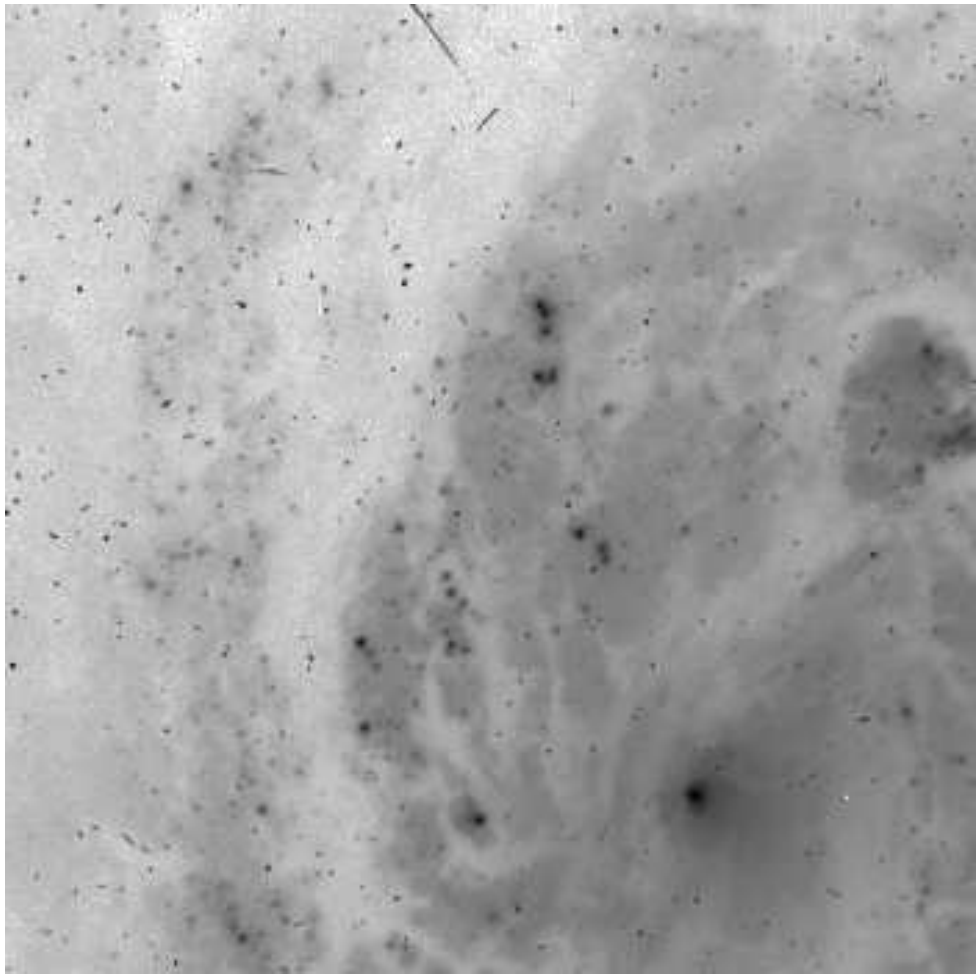
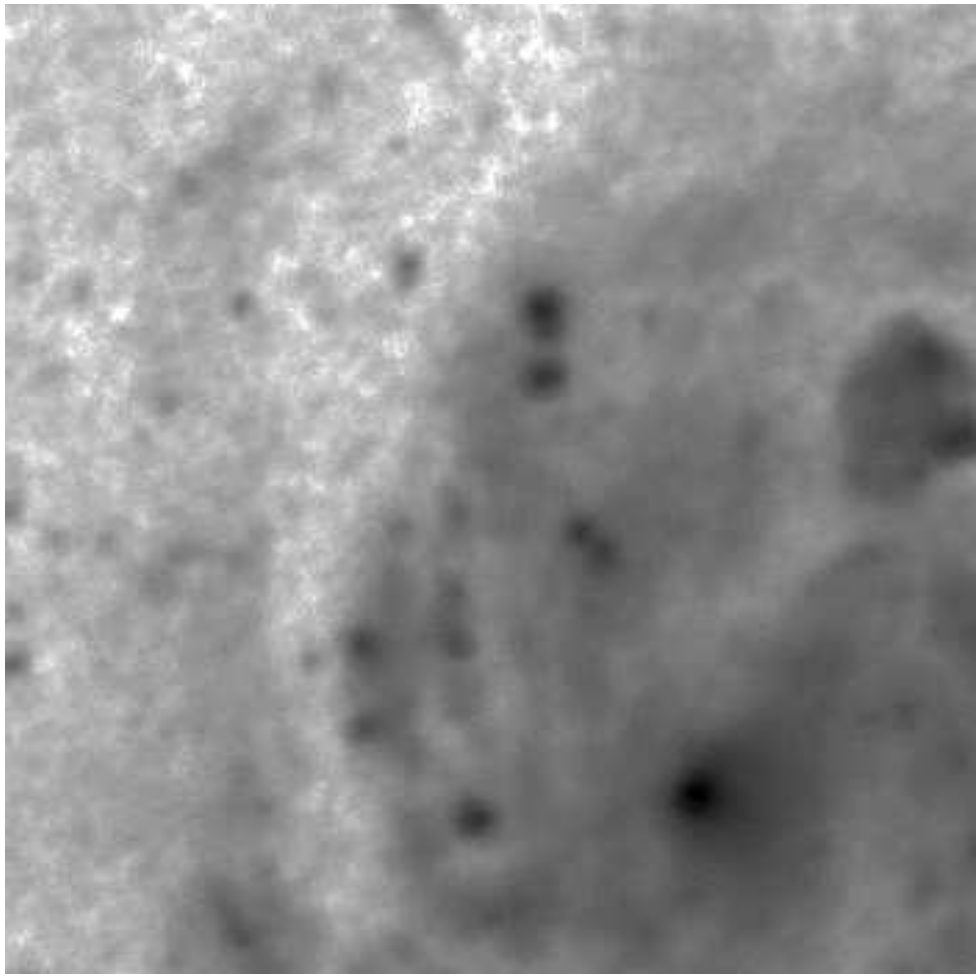
- Optimal binning of 6×4 pixel $= 223.2 \times 446.4$ mas^2

Flux Maps of M100



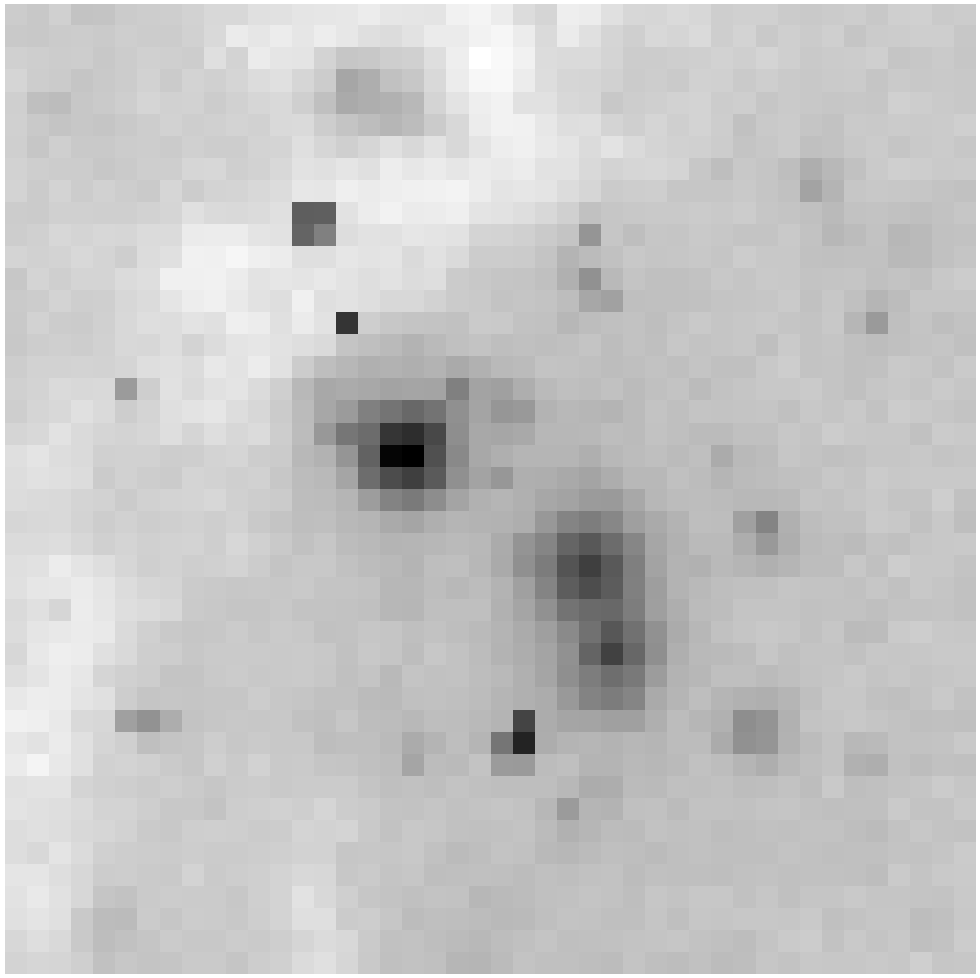
Original Image (HST WFPC2, 900 s)



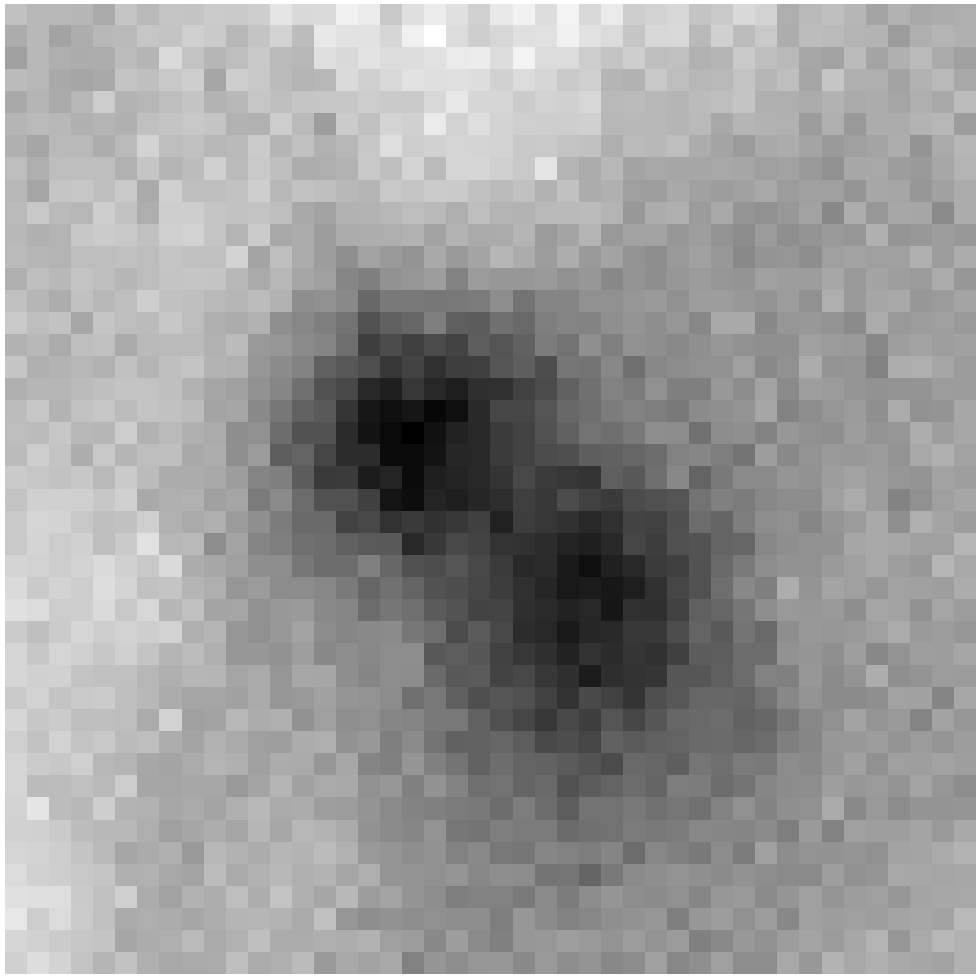
Simulated Flux Map (GAIA BBP, 43.09 s)

- The accuracy in surface photometry is of 0.15 mag/arcsec^2 at $\mu_V = 19.5$ mag/arcsec^2

Angular Resolution of Flux Maps: a detail of M100



Original Image (HST WFPC2, 900 s)



Simulated Flux Map (GAIA BBP, 43.09 s)

- The angular resolution is better than 0.4 arcsec

Measurement Capabilities

- An astrometric and photometric galaxy survey
- A limiting magnitude of $I \simeq 17$, corresponding to $z \simeq 0.1$ or $d \simeq 400$ Mpc
- A coverage of at least 75% of the sky down to low Galactic latitudes
- A sample of at least 3 million galaxies
- Multi-color observations (up to 4 broad bands)
- Multi-epoch observations (on average 85 observations in 5 years)
- An angular resolution better than 0.4 arcsec
- An accuracy in surface photometry of 0.2 mag/arcsec^2 at $\mu_I = 20$ mag/arcsec^2

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- Complementary with future surveys

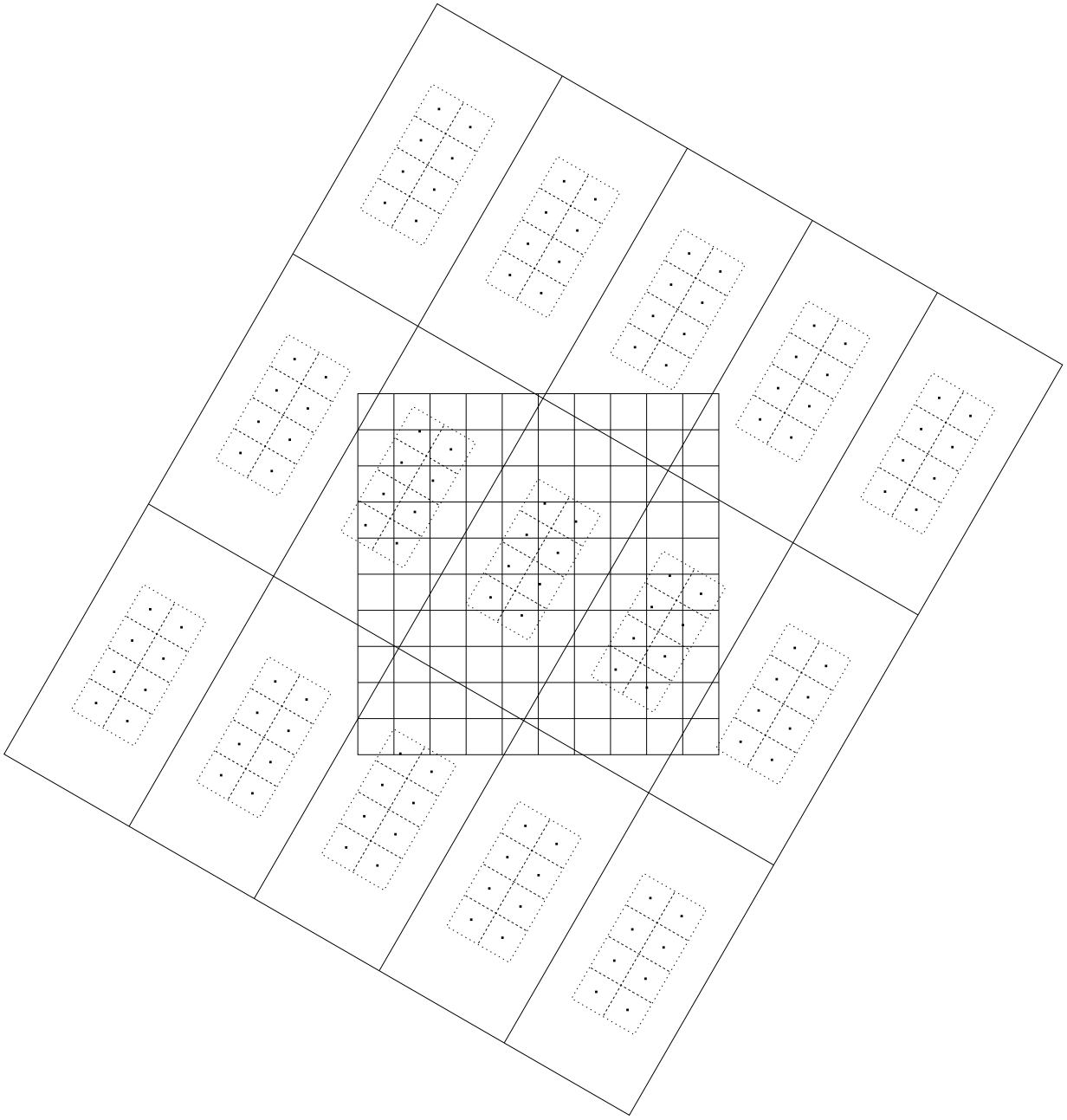
Scientific Results

- Spatial Distribution
  - Large-scale structure in the Local Universe
  - Peculiar motions in the Local Group
  - Detection of astrometric "jitter" in galactic nuclei
- Surface Photometry
  - Bright galaxies: detailed analysis of morphology
  - Faint galaxies: statistical analysis of photometric structure in the inner regions
  - Mapping of star-forming regions and dust lanes
  - Detection of photometric variability in galactic nuclei

Future Work

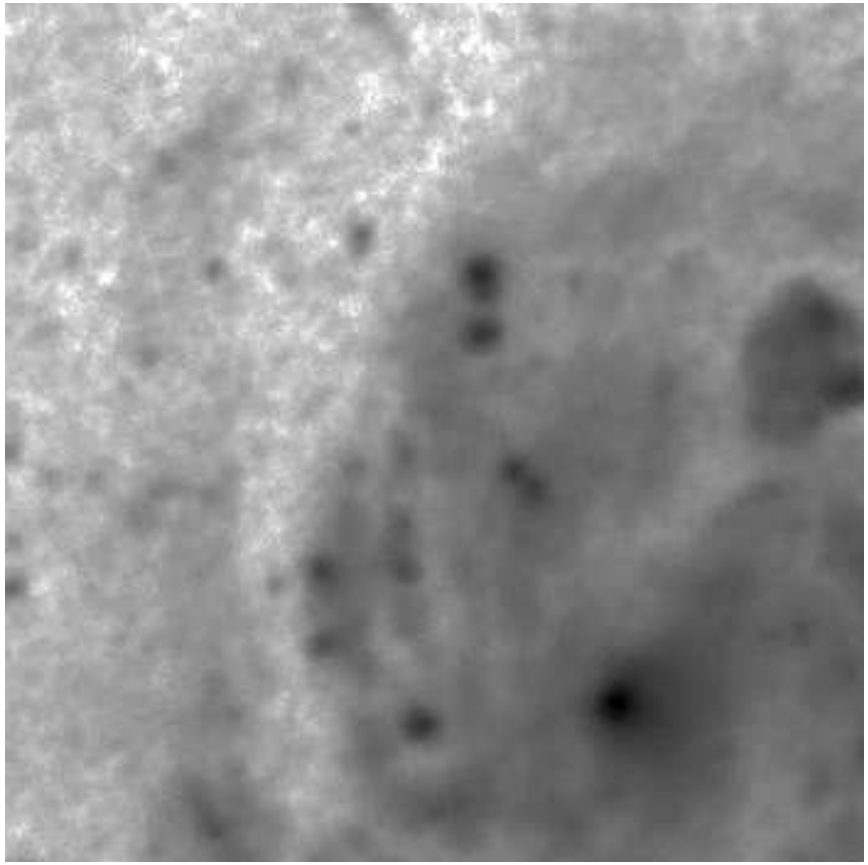
- Detection algorithm development
- Optical resolution recovery
- Physical modeling of astrophysical systems
- Simulation on Synthetic Images
- Galaxy observations in PSM (AF17) and Spectro?
- ! Scientific Case Discussion !

Drizzling: Subsampling and Rebinning

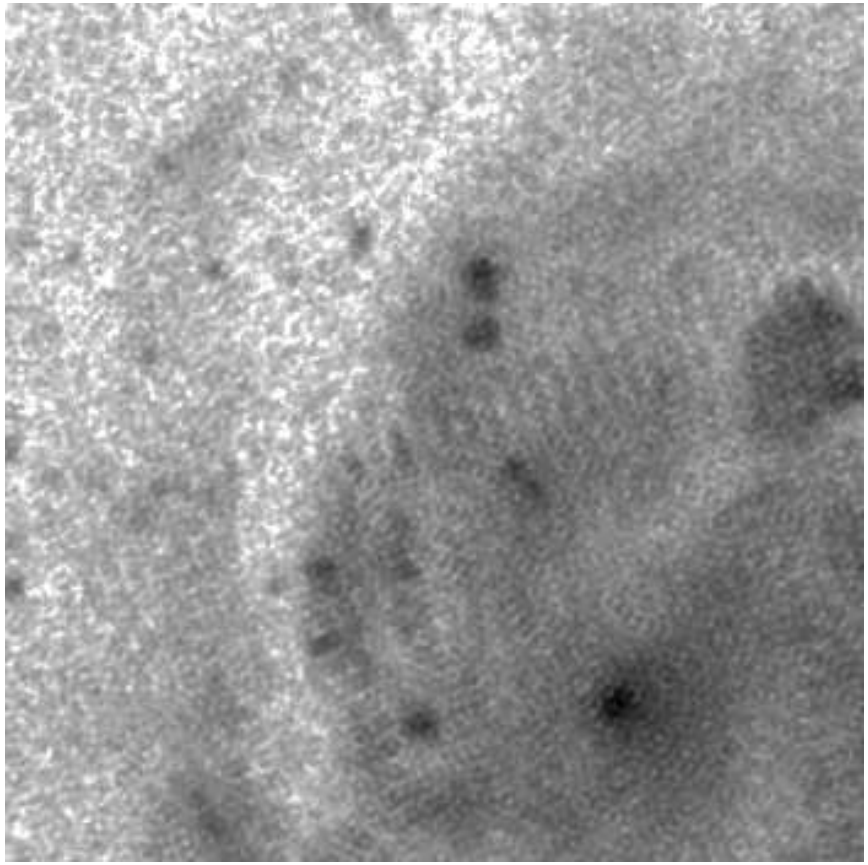


- Samples are shrunken of a factor two along both directions before dividing them into subsamples and creating the flux map
- This procedure may improve the angular resolution but also produce artifacts

Drizzling: Flux Map



Stacking



Drizzling

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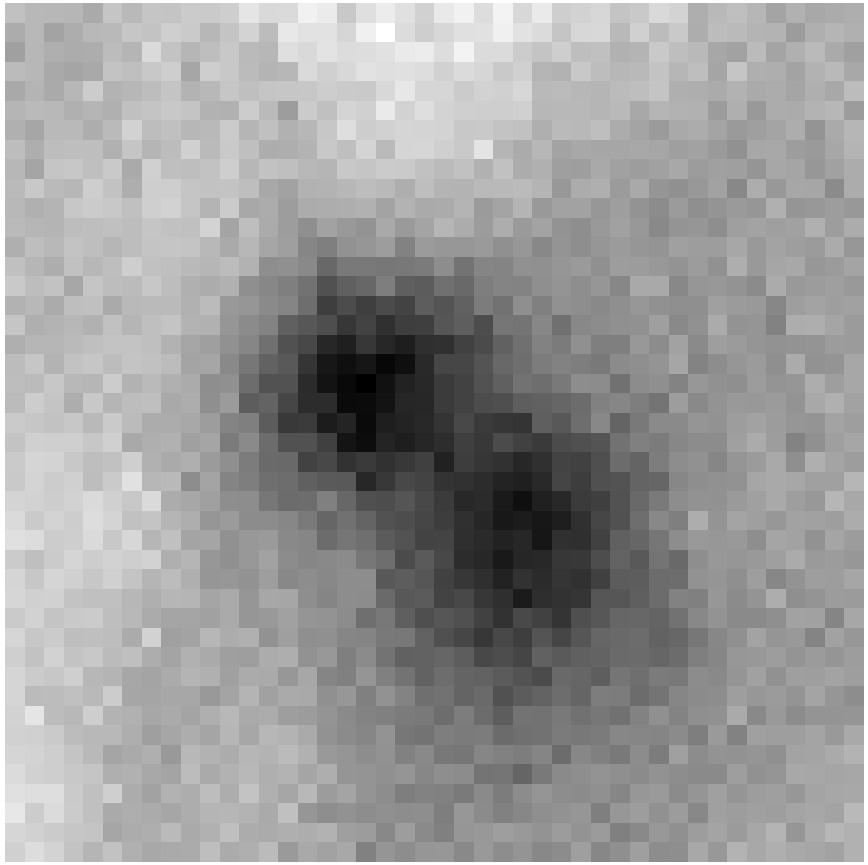
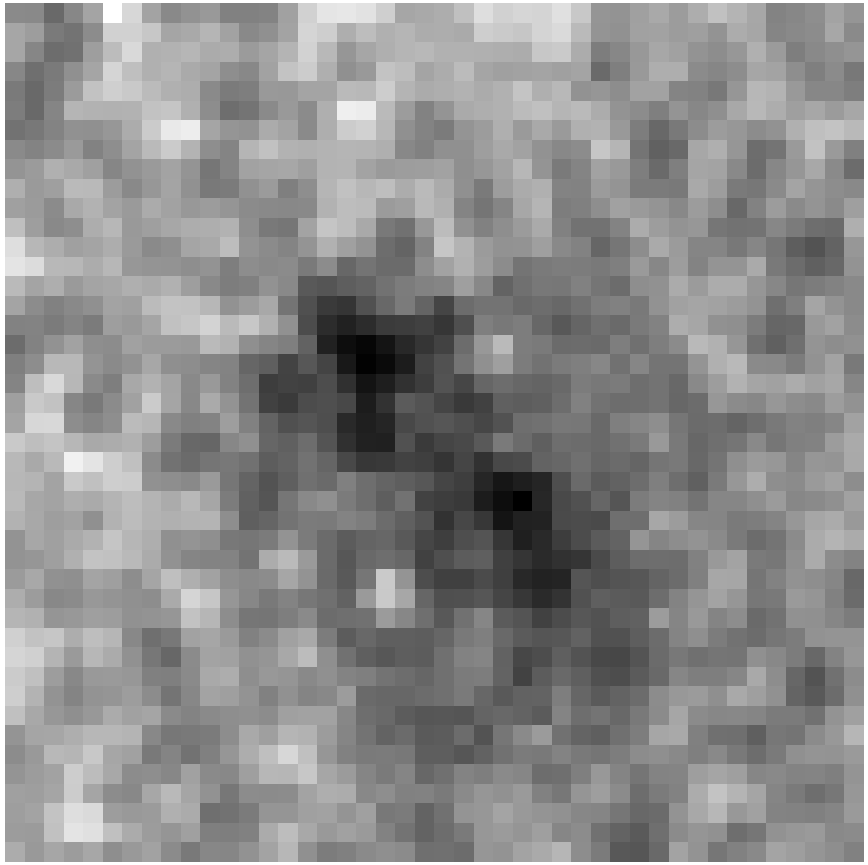
- Artifacts can be easily seen

Drizzling: a detail of M100



Stacking

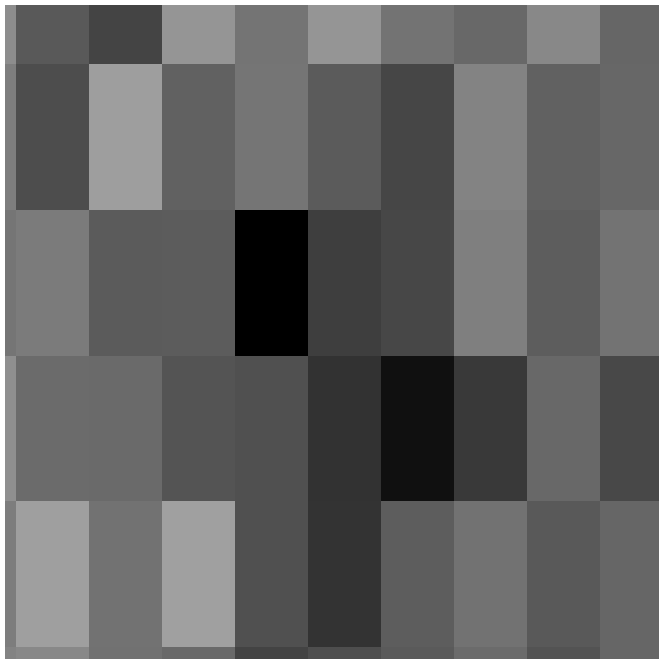


Drizzling

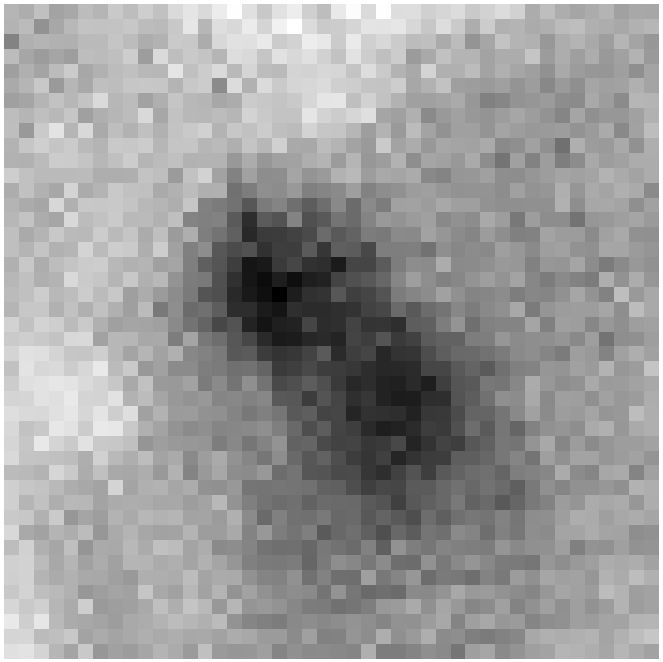
$\Downarrow$

- Interesting but needs refinement

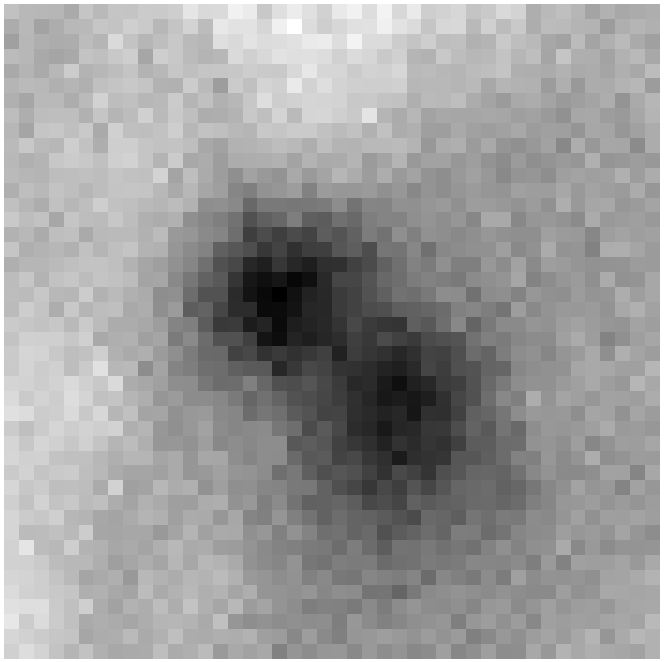
Angular Resolution and Number of Scans



1 scan



20 scans



50 scans

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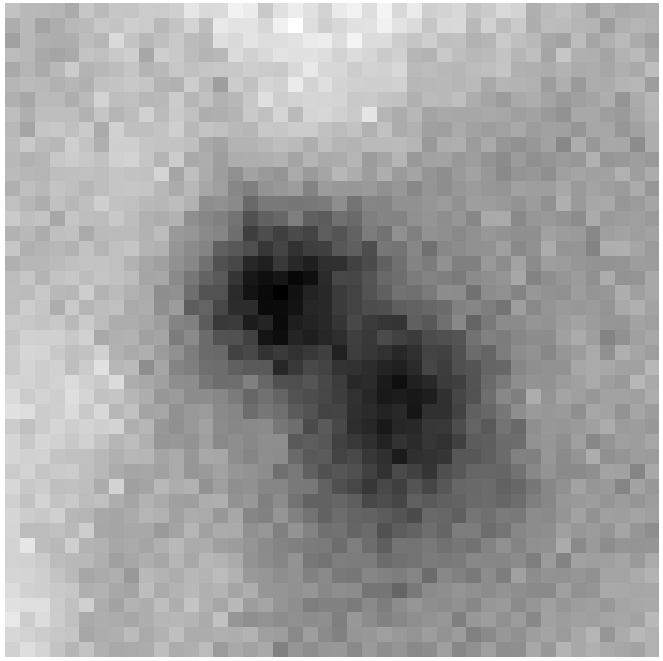
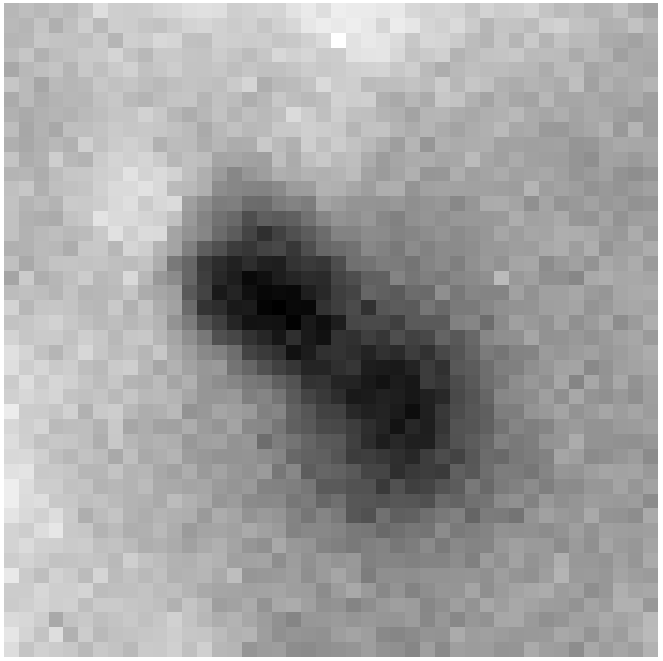
- Studies of bright features could be carried out even at the 20-scan level

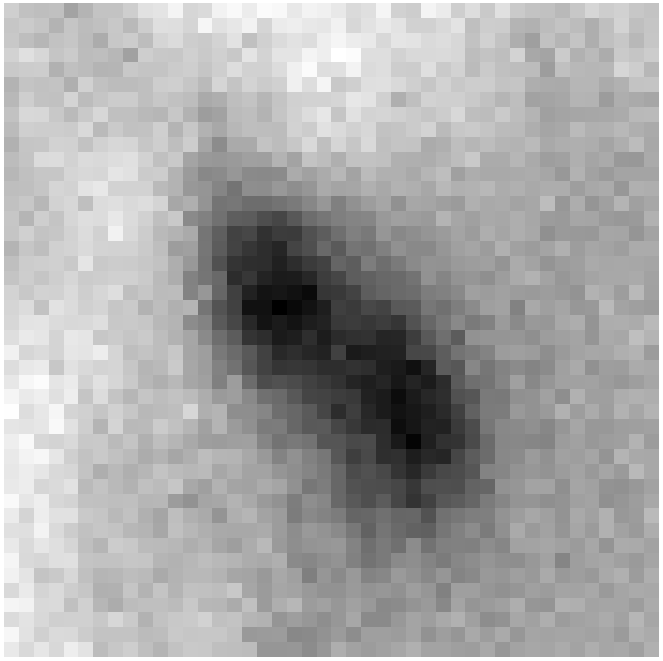
Non-Random Scan Directions



180 degrees



90 degrees



45 degrees

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- Not an issue!