Galaxy cluster detection with LSST : photometric calibration, bright object masks and AMICO

CSI 2024

Nathan Amouroux

Université Grenoble Alpes
UNIVERSITÉ SAVOIE MONT BLANC
LAPP
cnrs
VERA C. RUBIN OBSERVATORY
LSST Legacy Survey of Space and Time
LSST DESC Dark Energy Science Collaboration

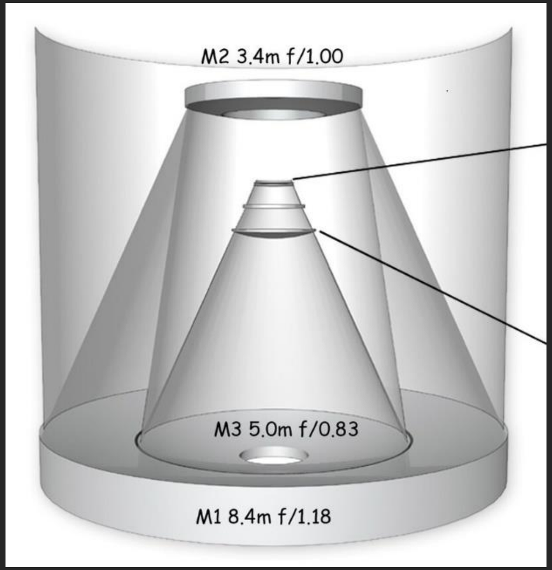
General context

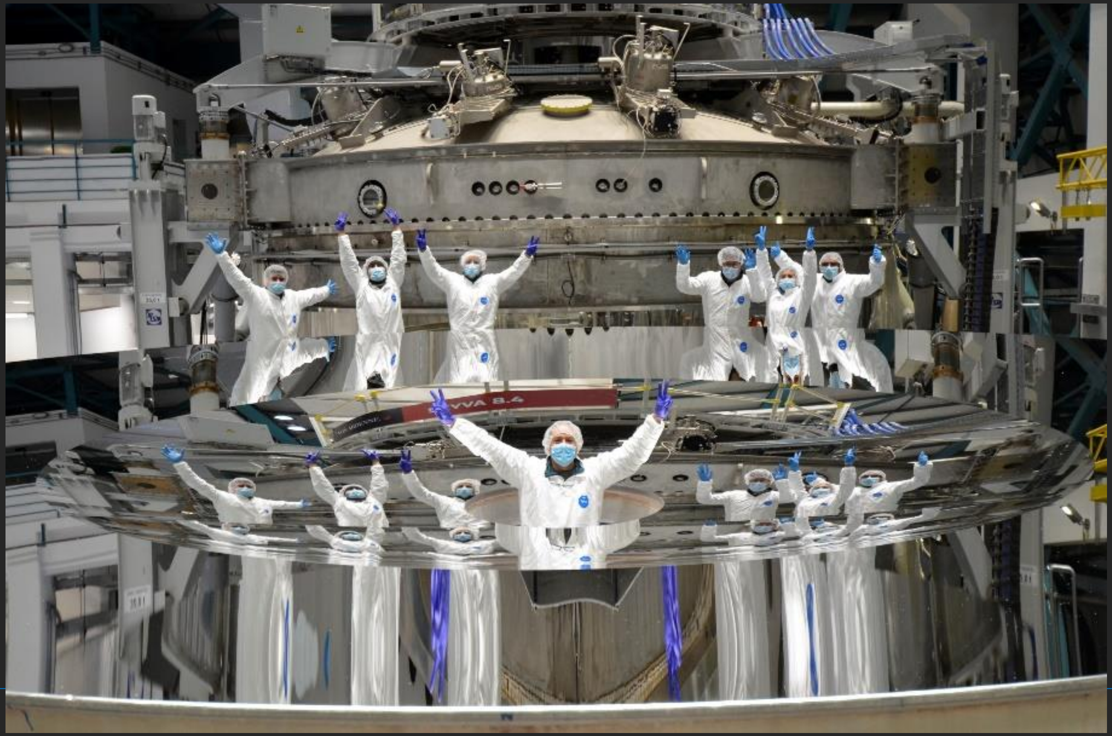
Vera Rubin Observatory

- 10 year photometric survey
- 6 bands from near IR to near UV
- 3.5 degrees field of view (x49 moons)
- Scan visible sky in 3 nights
- Objectives :
  - ➢ Solar system study
  - ➢ Milky way study
  - ➢ Transients
  - ➢ Cosmology

General context

Vera Rubin Observatory





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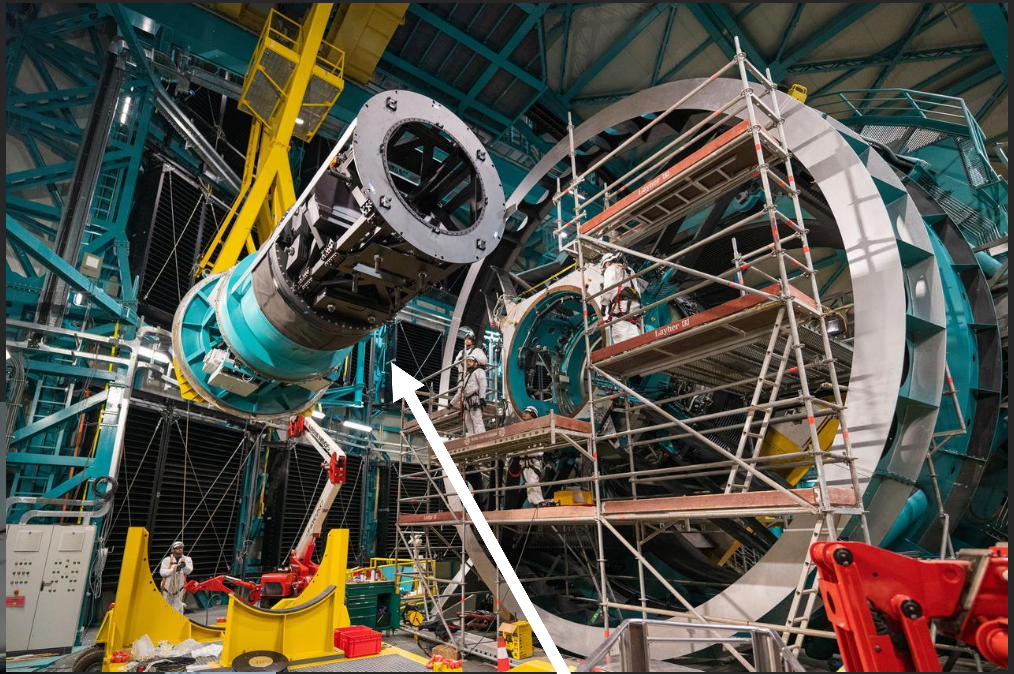

ComCam = 1/21 LSSTCam

Cosmology with LSST

- 4 probes for testing ΛCDM and its extensions:
  - Weak Lensing
  - BAO
  - Supernovae
  - Clusters

Cosmology with LSST

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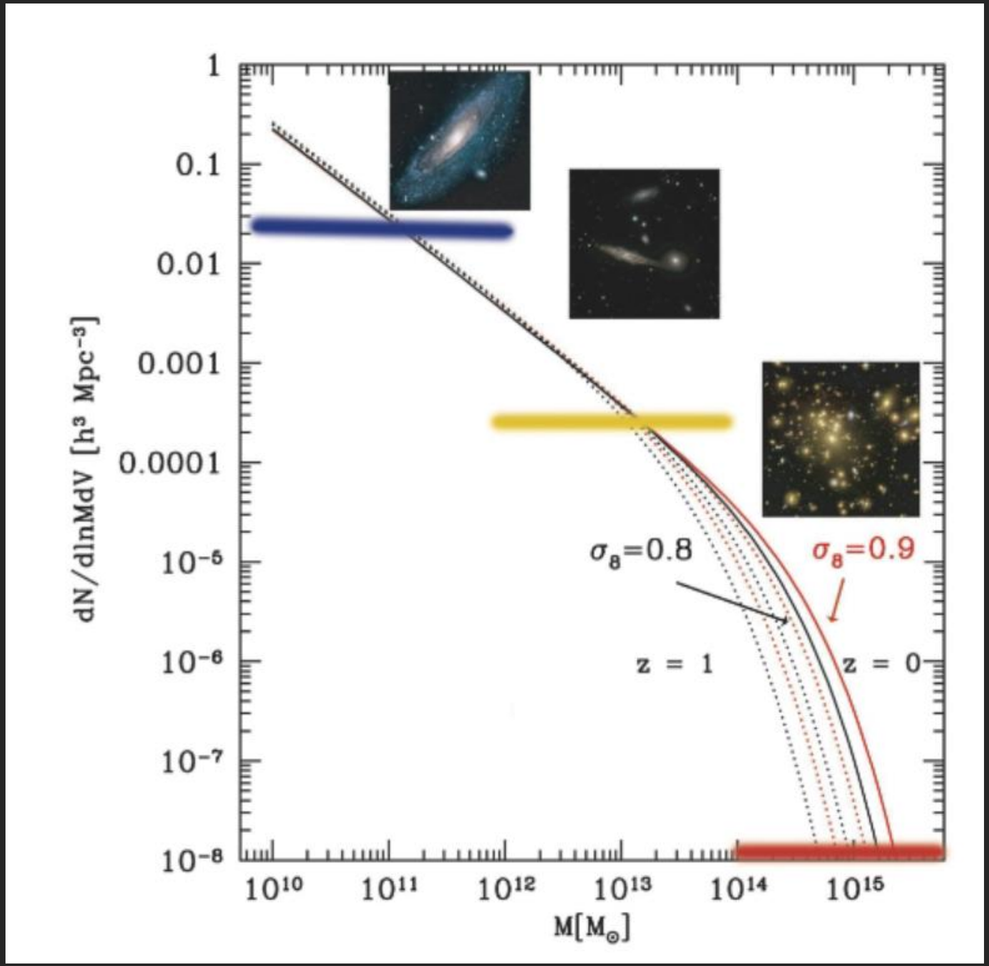
- Abundance = Counting clusters in bins of mass and redshift
- Ingredients to constrain cosmological parameters:



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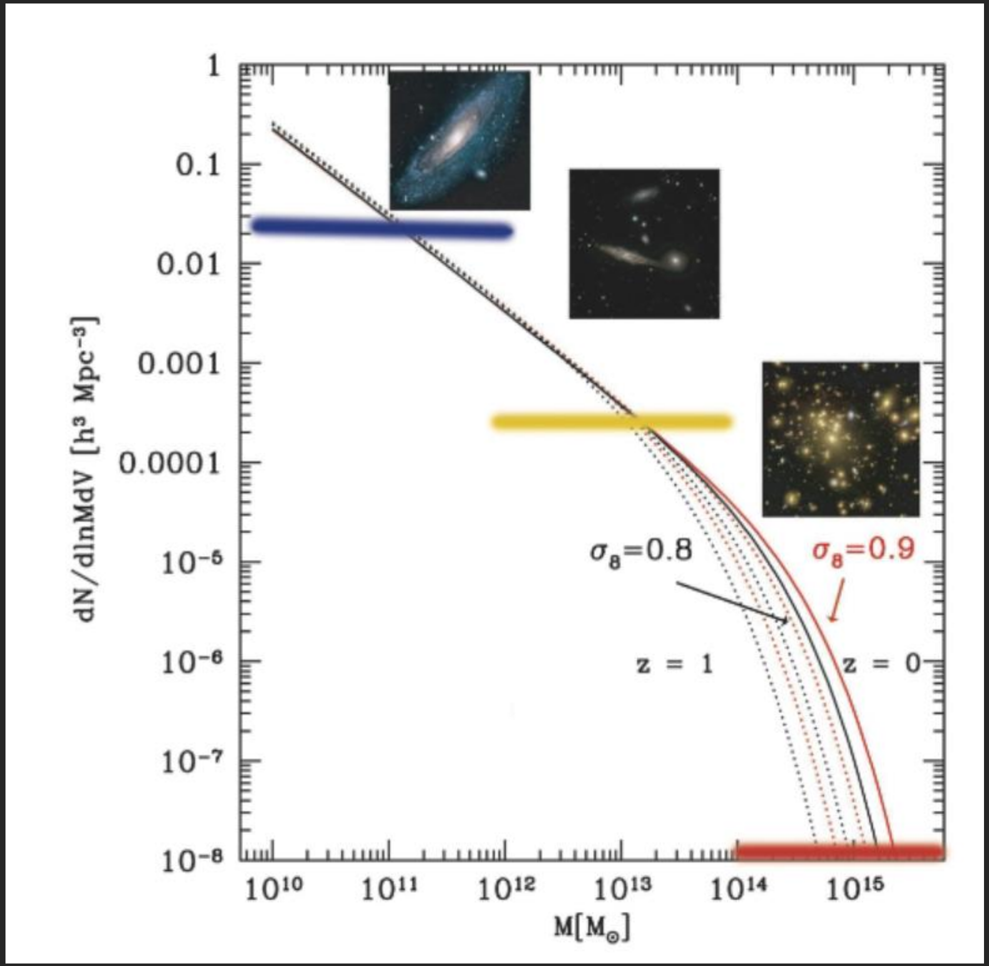

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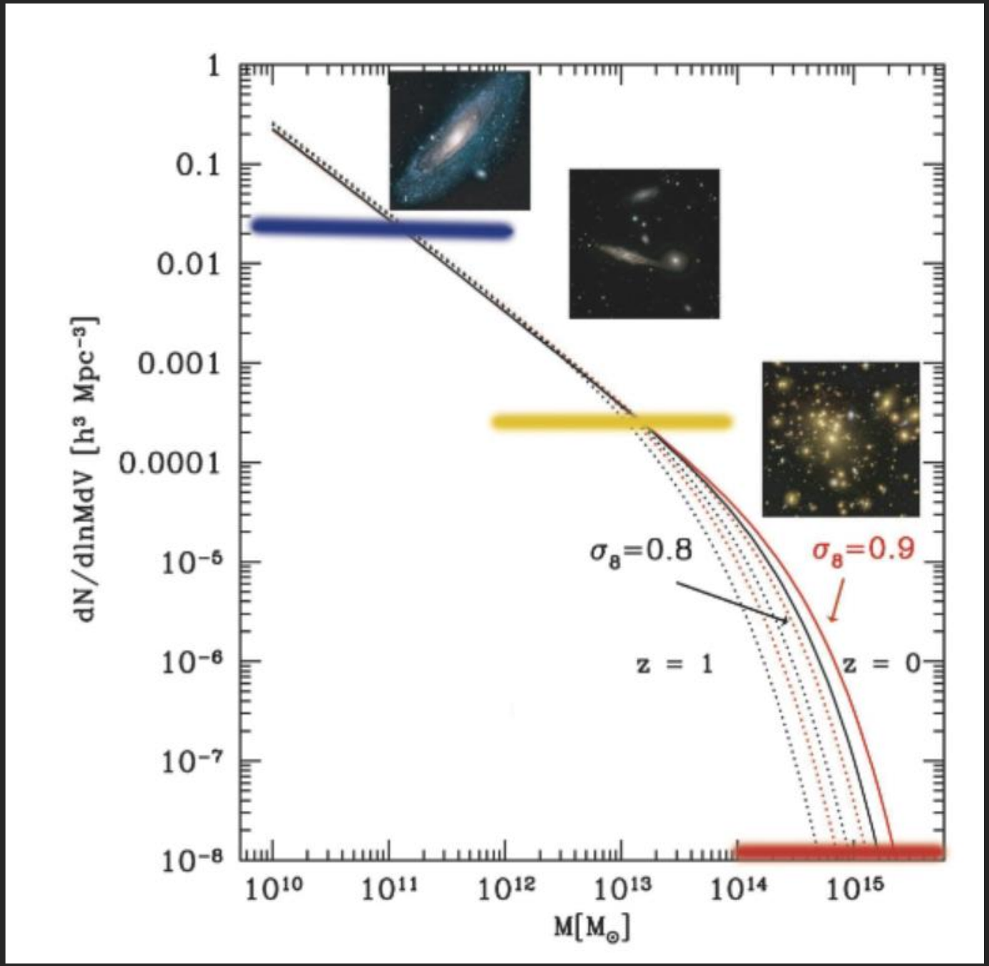

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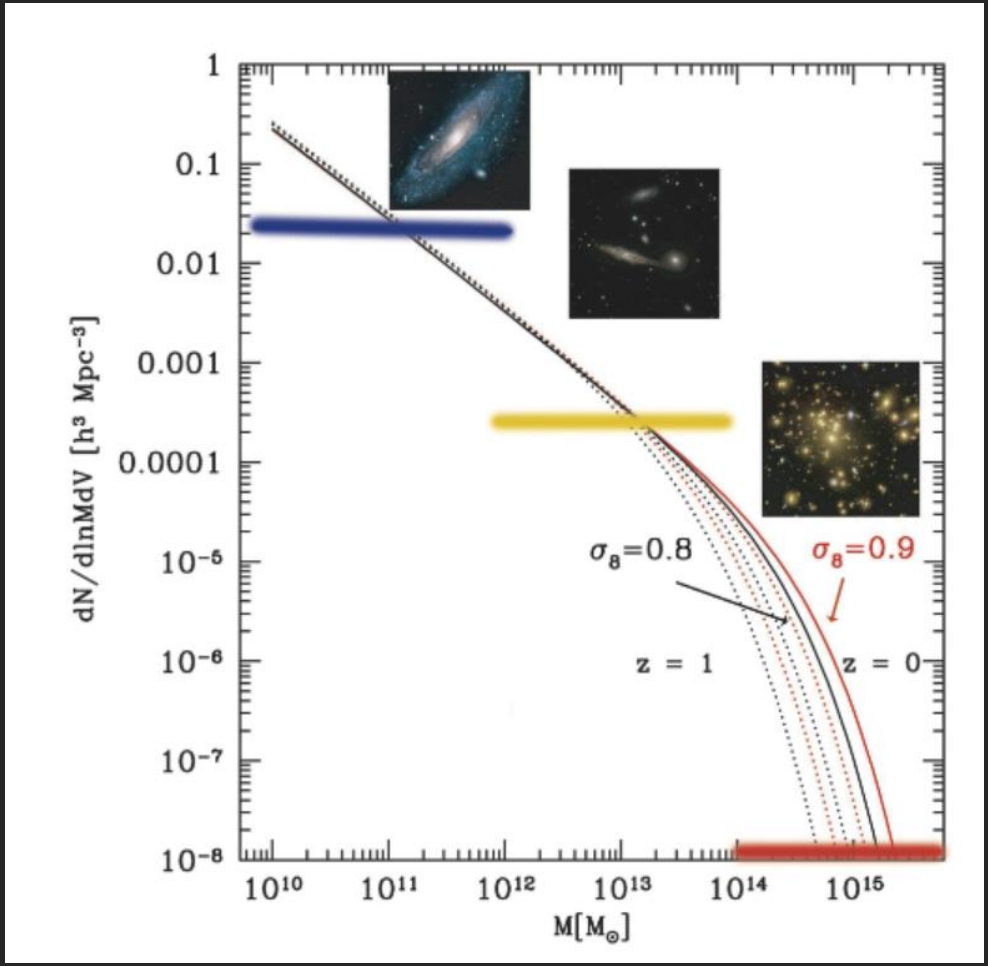
  3) Cluster detection algorithms



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Three projects :

I) Collimated Beam Projector (CBP)

II) Bright object masks

III) Galaxy cluster detection algorithms

I) Collimated Beam Projector

Collimated Beam Projector

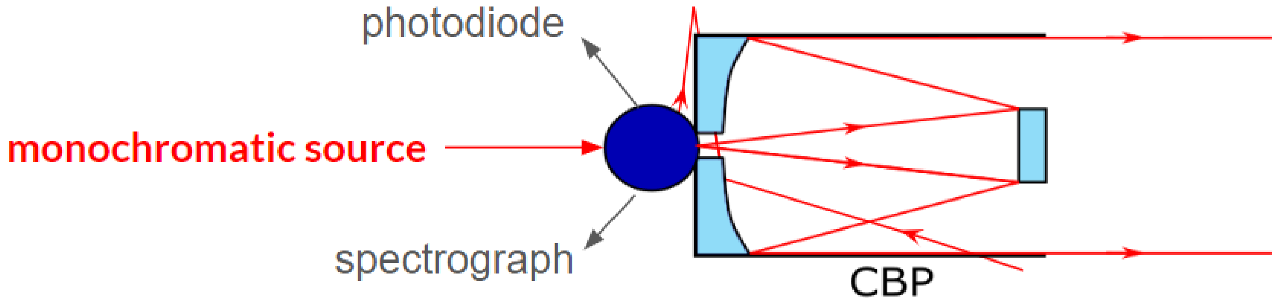
CBP general principle

The goal is to mimic a **monochromatic** star of **known flux**, to **calibrate** the **response** of an instrument and its filters. **Final goal: filter positions known at 0.1nm.**

Context : SNIa cosmology

The **Collimated Beam Projector (CBP)** must be able to shoot:

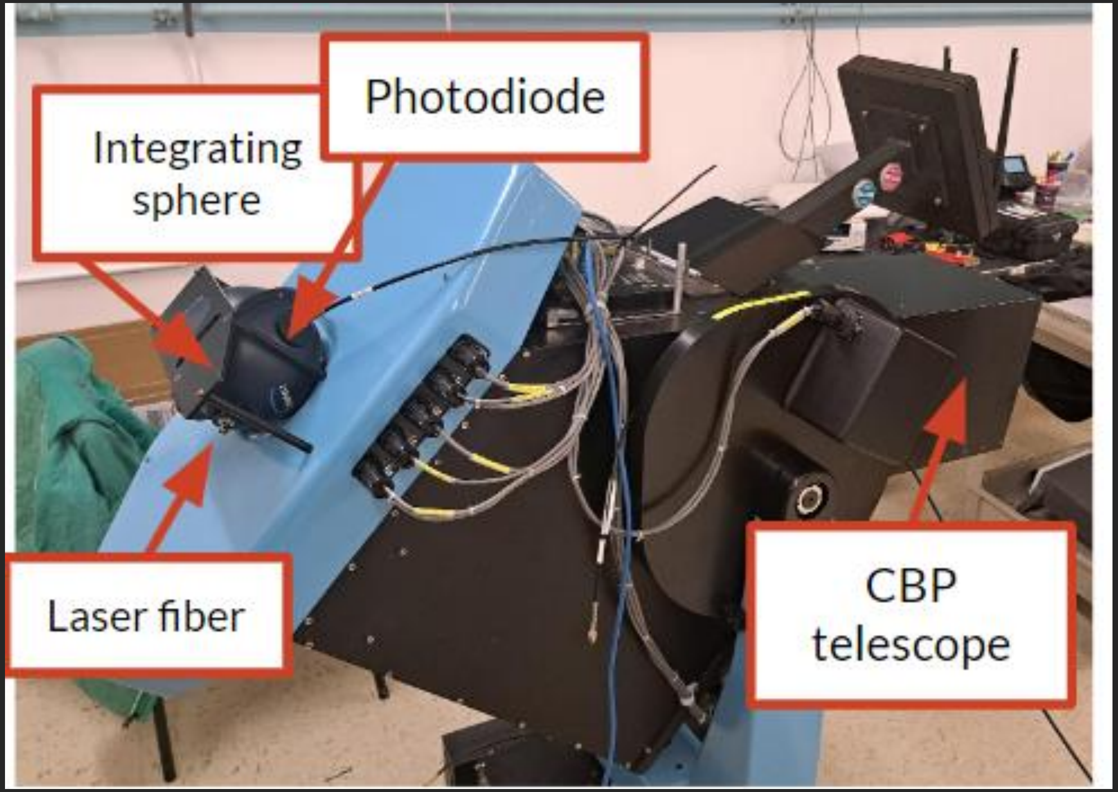
- a known quantity of photons → **photodiode**
- at a known wavelength → **monochromatic source and spectrograph**
- in a parallel beam → point source at focal point of a **telescope**

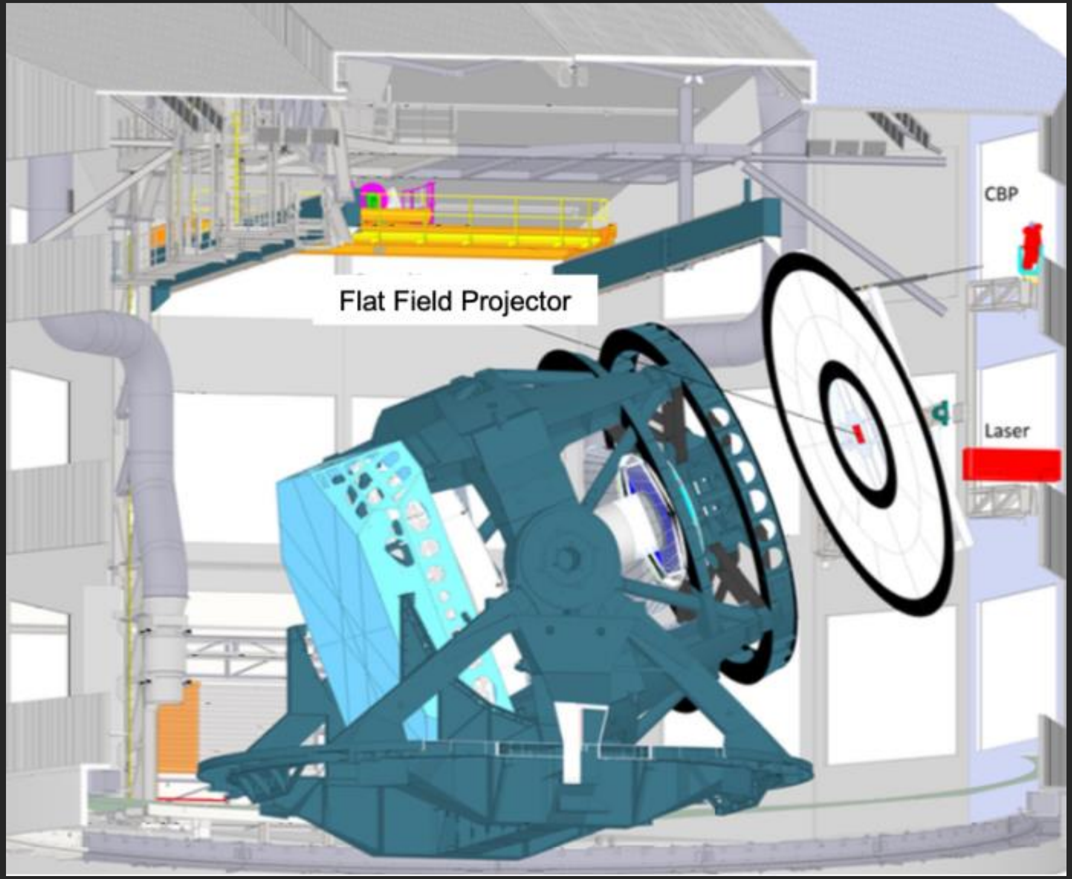


J. Neveu, LSST-France 15/12/2023

Collimated Beam Projector

CBP general principle

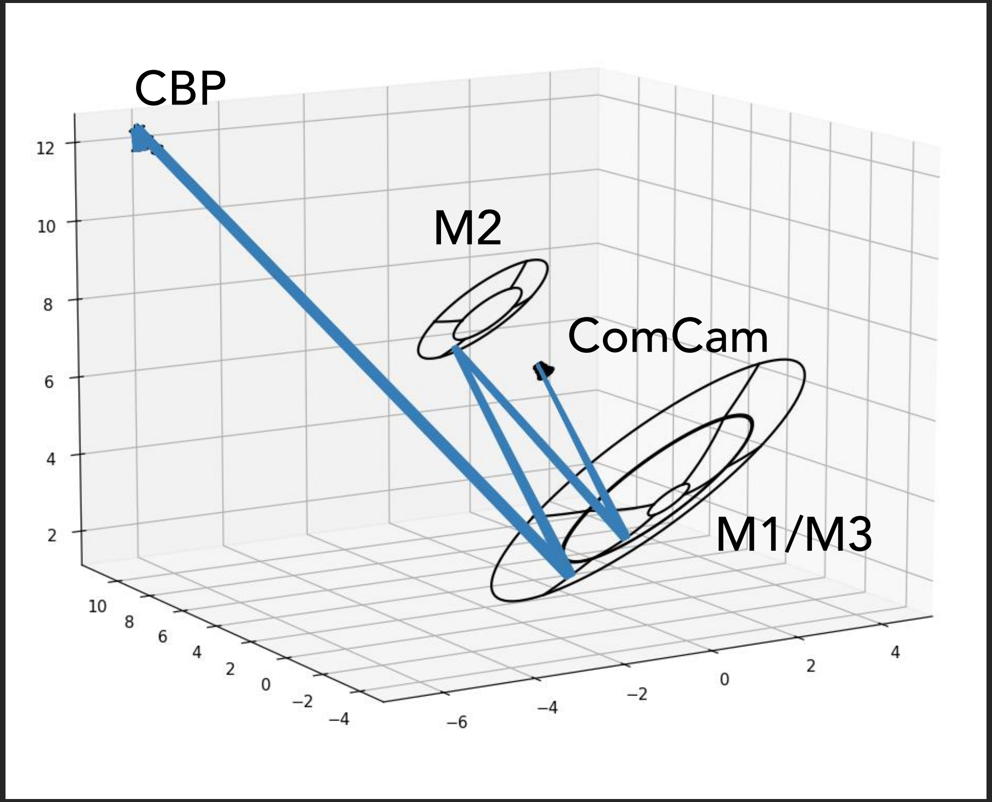




Collimated Beam Projector

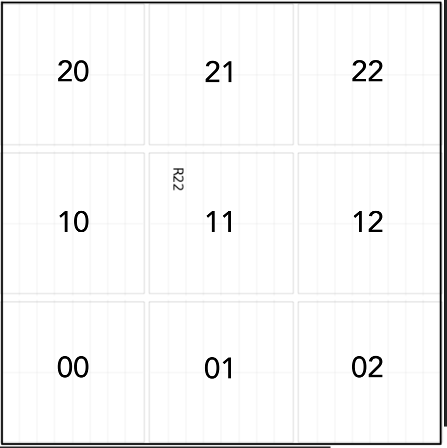
Batoid

- Geometrical simulation
- Load instruments via configuration files
- Set optics reflectiveness
- Set photons wavelenght, position and initial direction to create beams
- Propagate photons through the telescope



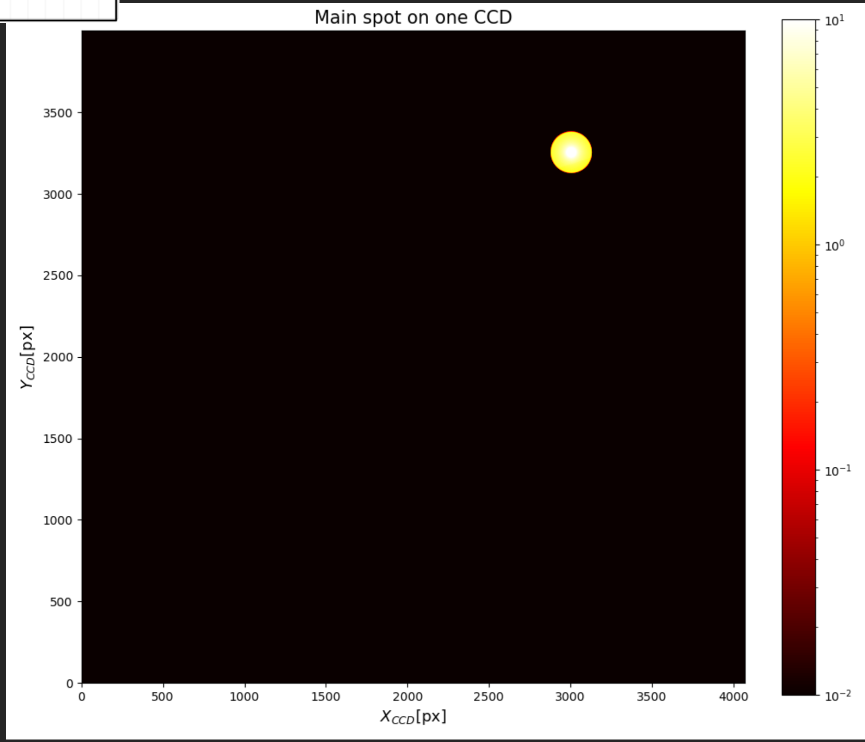
3D projection of ray propagation with batoid

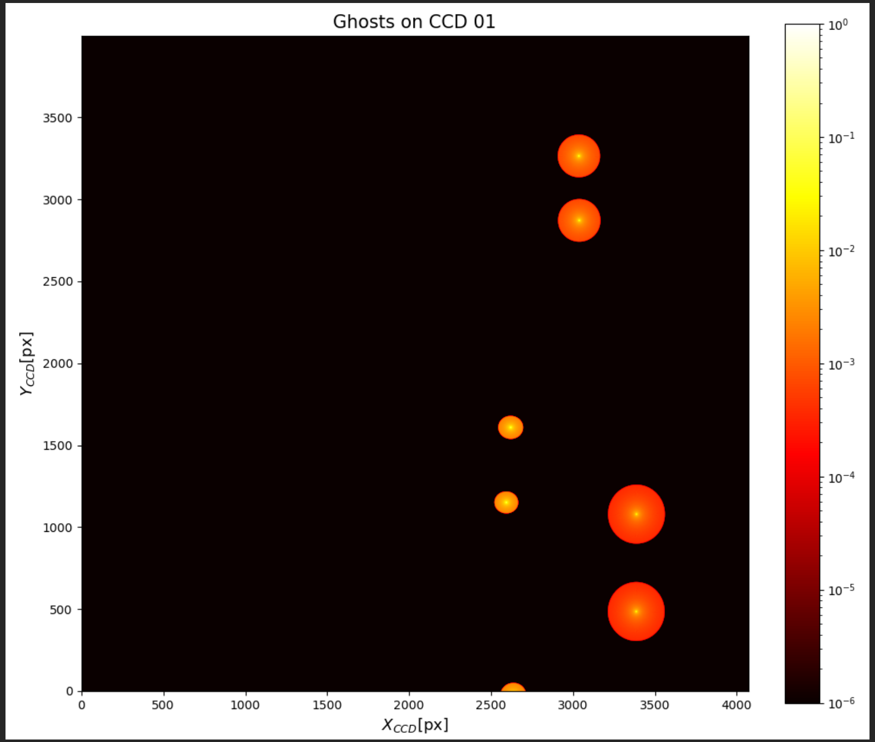
→ Output = photons physical position on detector + path + their flux (in %)



Collimated Beam Projector

Batoid



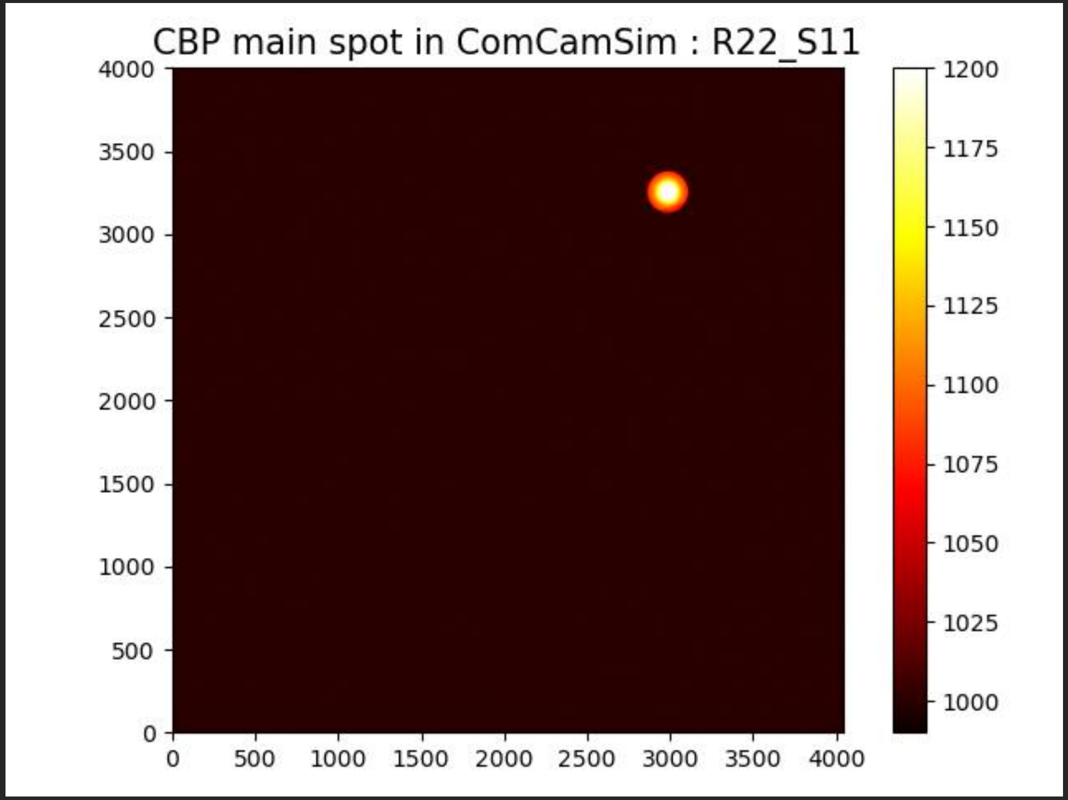


Example of one CBP star shot in the telescope : beam + its ghosts on one CCD of ComCam

Collimated Beam Projector

ImSim : Image simulation

- One spot simulated from batoid output
- Basic sensor model (not LSST) → Need to use LSST sensor model for photometry
- Arbitrary flux : need to take exposure time into account
- Next steps :
    - ➢ Setup common framework for cbp analysis
    - ➢ Analysis with real data



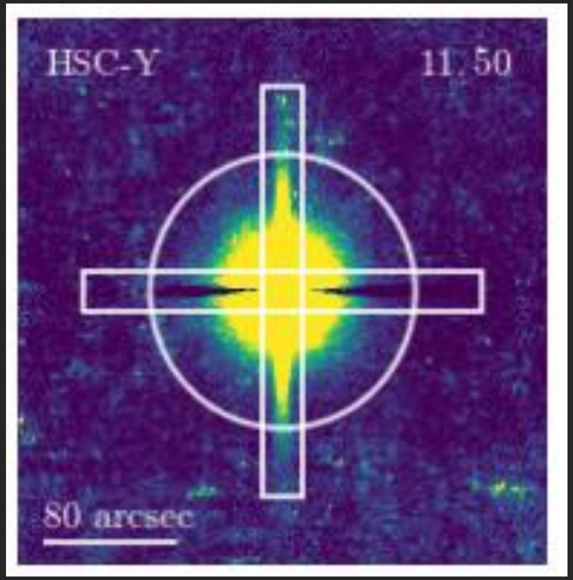
II) Bright object masks

Bright object masks

The bright stars issue

Bright stars reduce image quality by introducing optical/electronical effects

→ May induce biases in science results



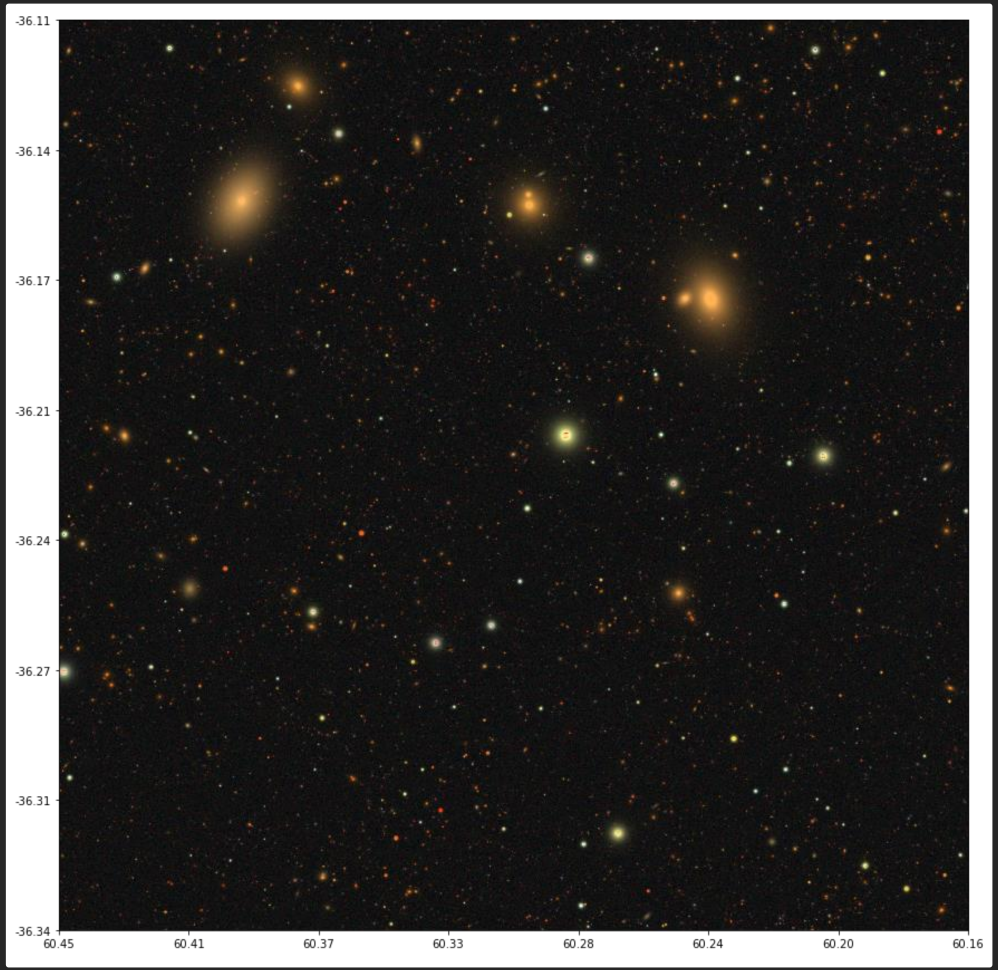
Example of a saturated star and its mask in HSC-SSP Coupon et al. 2017

→ Concerns different working groups with different needs for masks

DC2 simulation

- Objective : produce data close to LSST
- Underlined by cosmological simulation + astronomical objects from external data

  → Production of images with LSST instrumental effects
- Final catalog made by running LSST Science pipeline on the images



Example of a simulated DC2 image

We use this dataset in the following parts

Bright object masks

Masking methodology

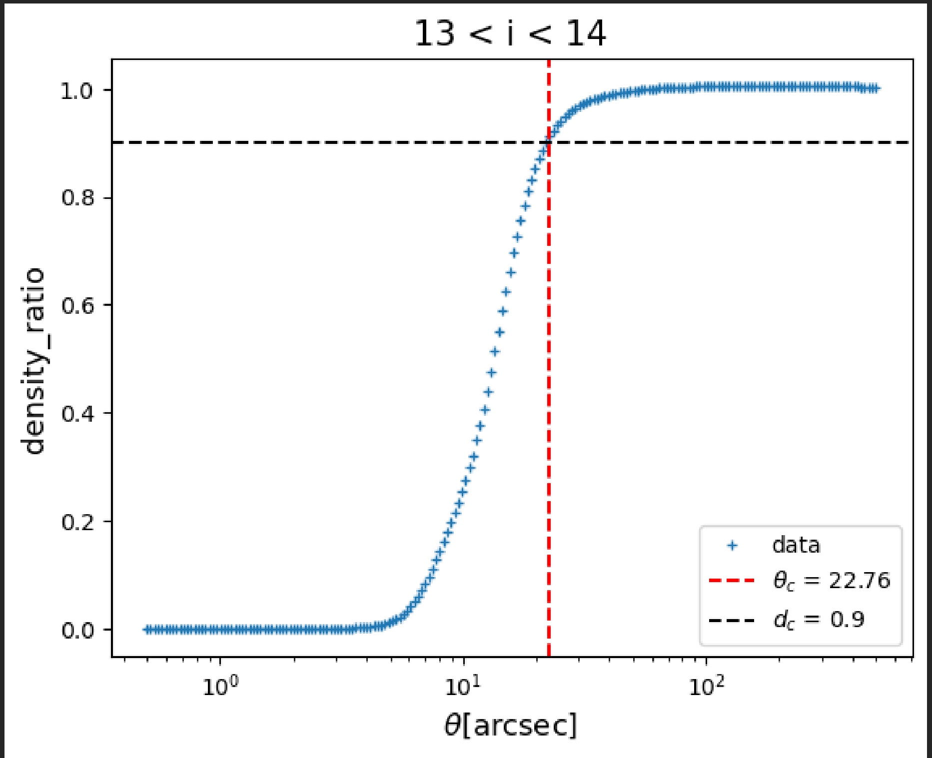
- Based on HSC-SSP method :

Not discussed here

1) Build a « bright object » sample and a galaxy sample

2) Determine disk radii to mask around bright star as a function of the magnitude using density profiles

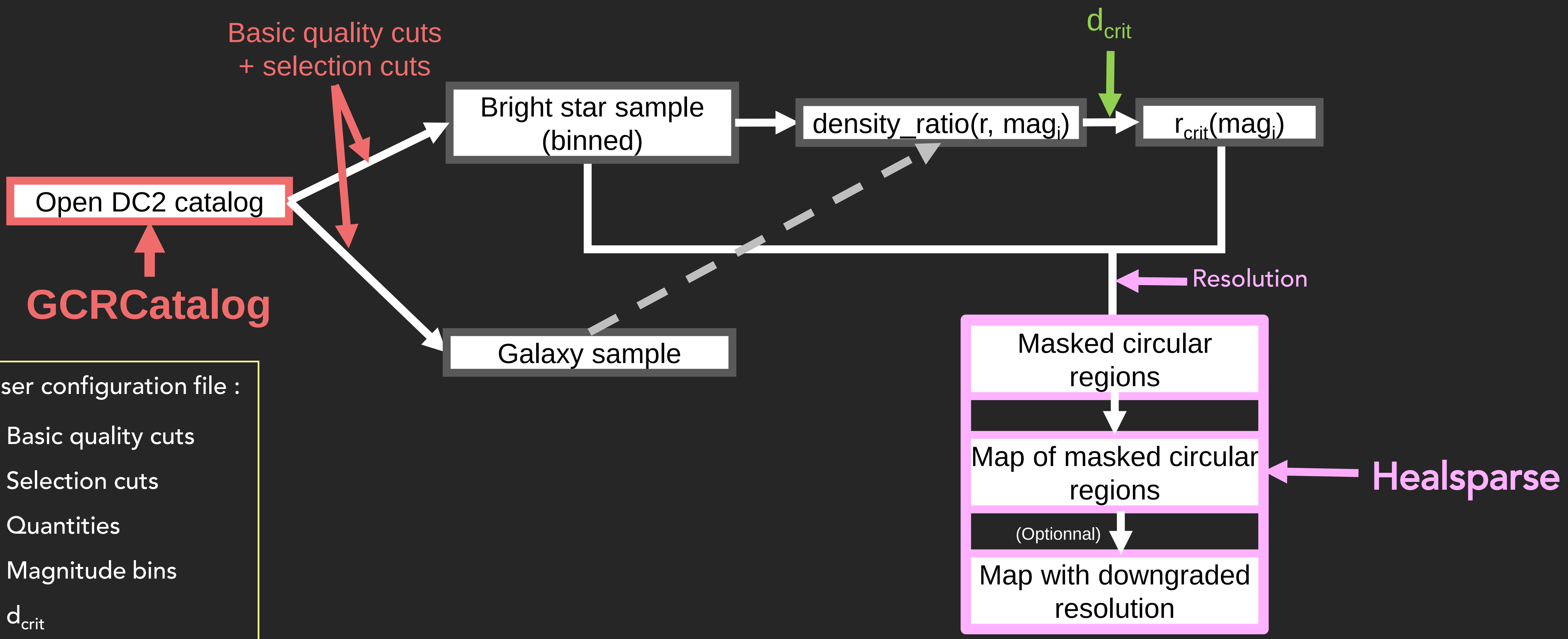
3) For each object : mask the region contained within the corresponding disk



Radiuses goes from ~50'' down to 7''

DESC DC2 bright star masks project

How it works



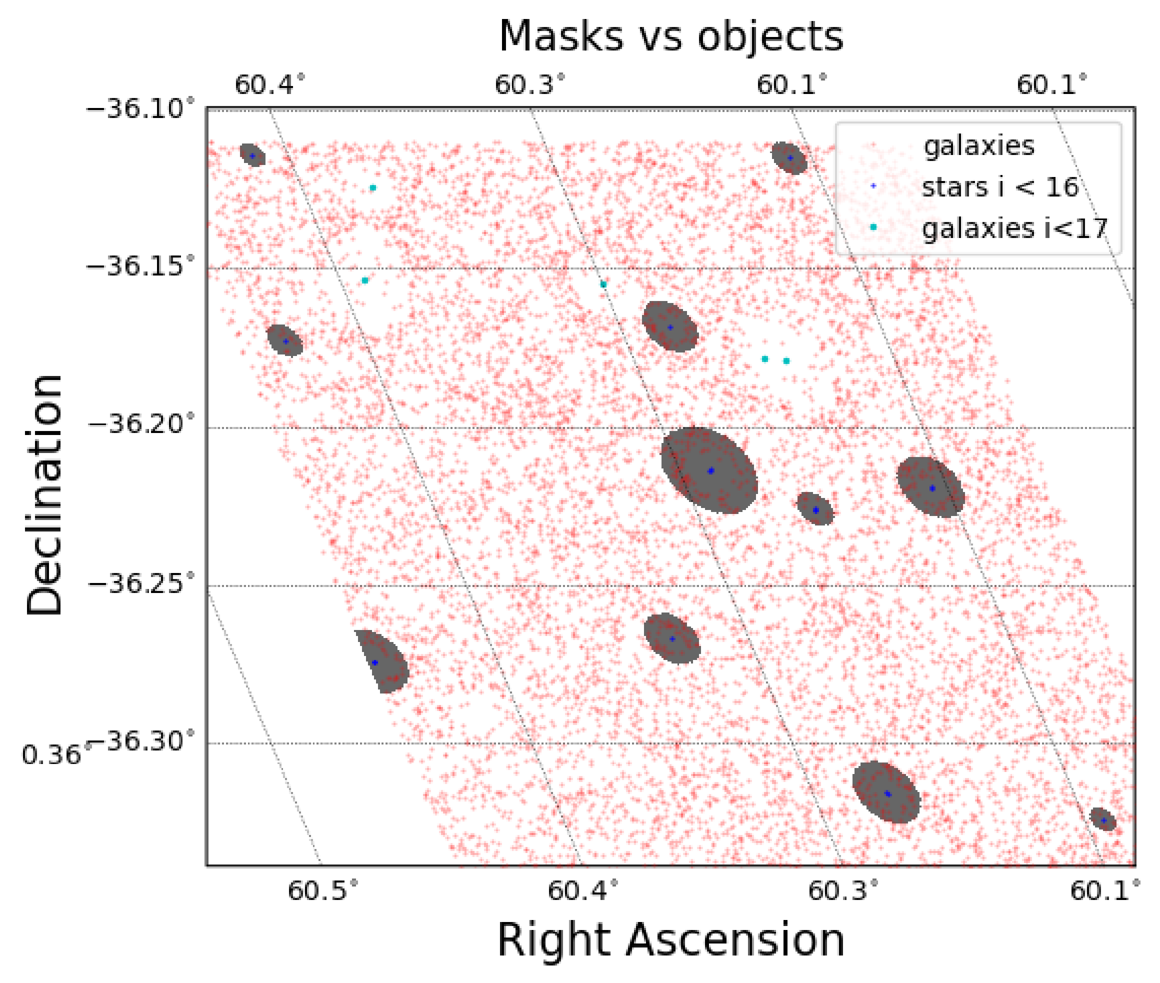
User configuration file :

- Basic quality cuts
- Selection cuts
- Quantities
- Magnitude bins
- d_{crit}
- Resolution

Parallelization over tracts → T ~ 15mins

DESC DC2 bright star masks project

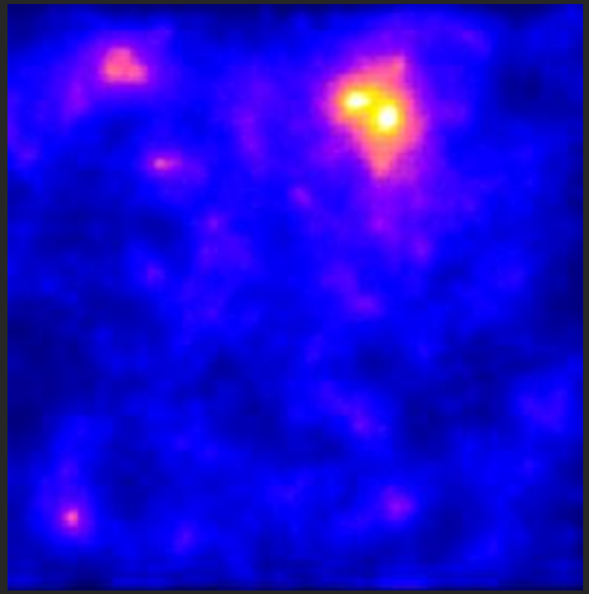
Final map



III) Galaxy cluster detection algorithms

AMICO algorithm

- AMICO = Adaptative Matched Identifier of Clustered Objects
- New algorithm to add to DESC galaxy cluster algorithms
- Optimal Filtering → Non biased signal amplitude estimator with minimal error
- 3D SNR map → cluster detection
- Galaxy member association to clusters

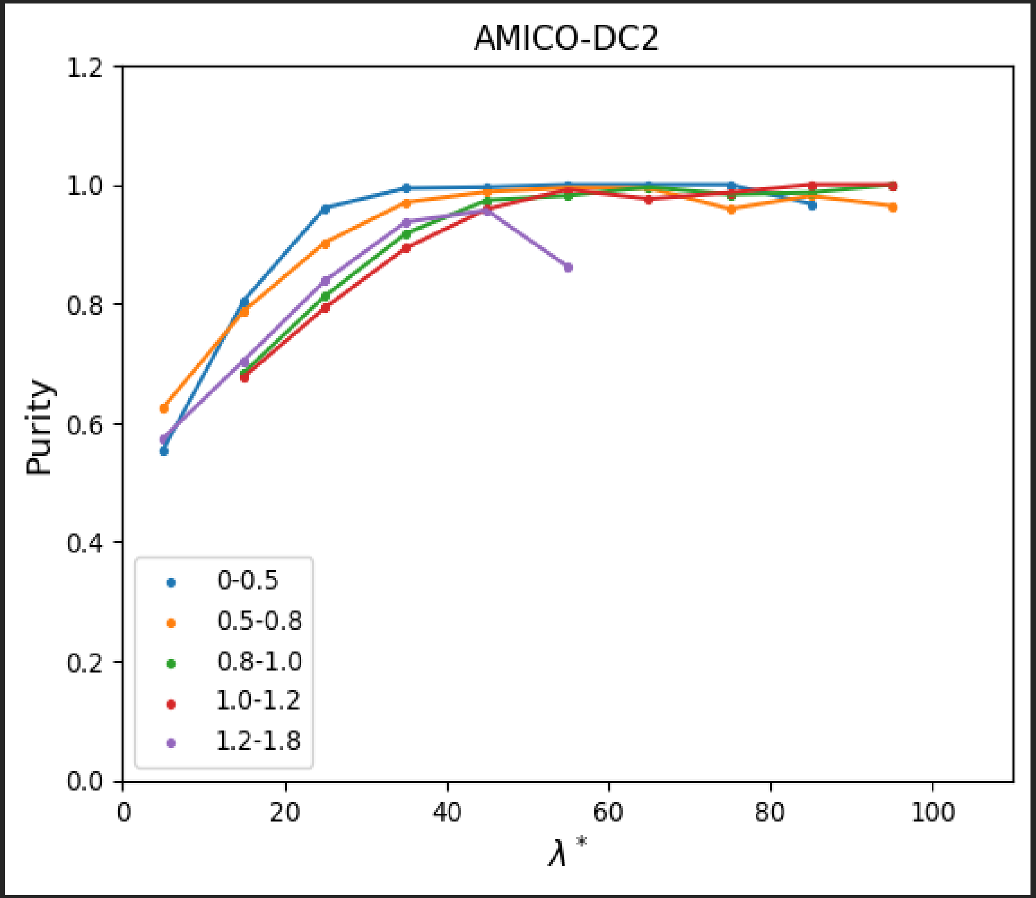


Example of SNR map on 1x1 deg^2 portion of the sky

AMICO validation

Validation / Optimization work :

- ➢Richness validation
- ➢Galaxy selection criteria
- ➢Selection functions
- ➢Tests on cosmological constraints
- ➢Mask validation



Prospects

- CBP :
  - Development of common software for CBP data analysis
  - Summit data to analyze soon
- Bright objects masks :
  - Discussion with different working groups on bright galaxy masks
  - Study on first ComCam catalogs
- AMICO :
  - Finalize DC2 analysis with AMICO
  - Looking forward to first Rubin cluster catalogs