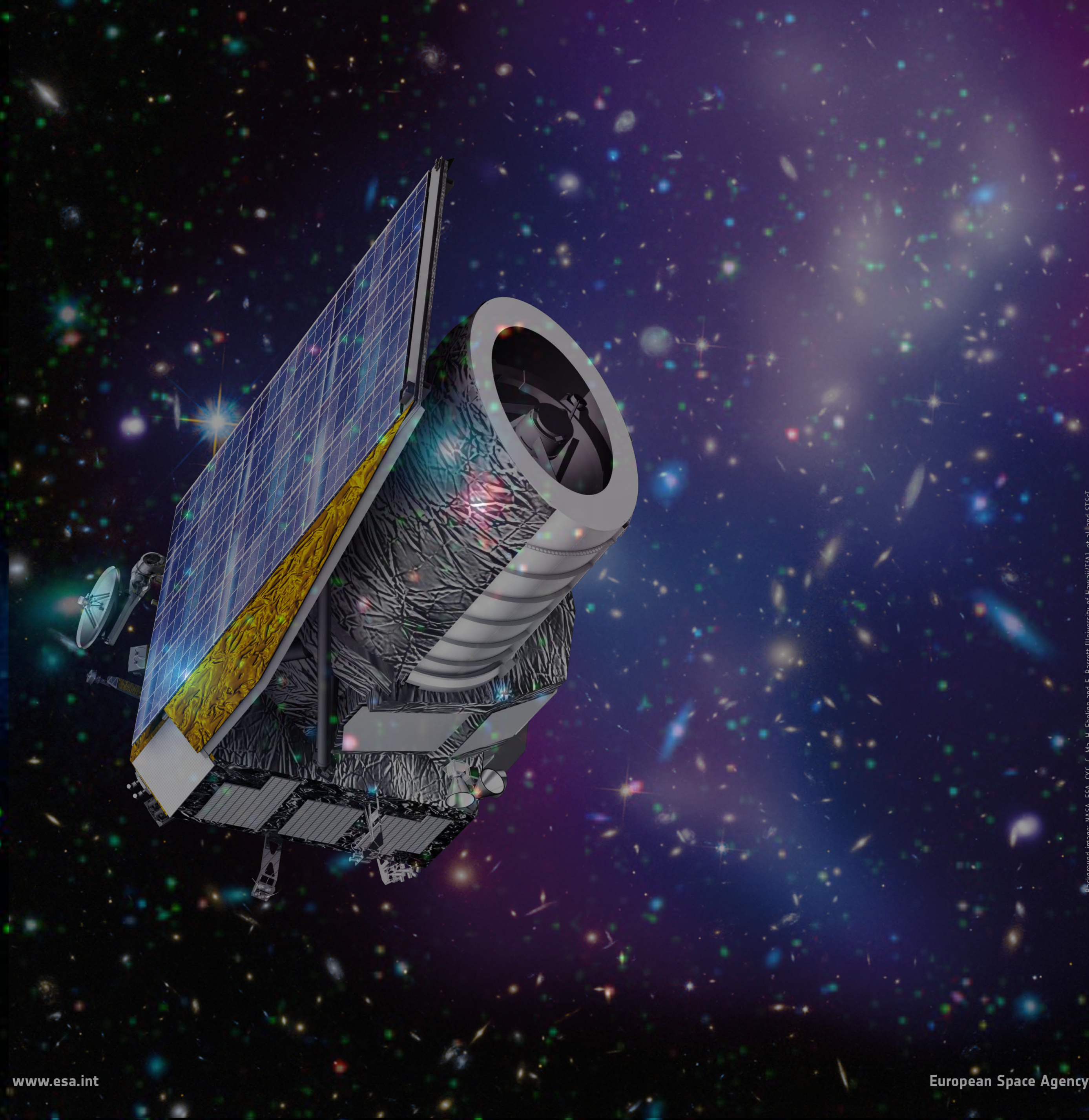


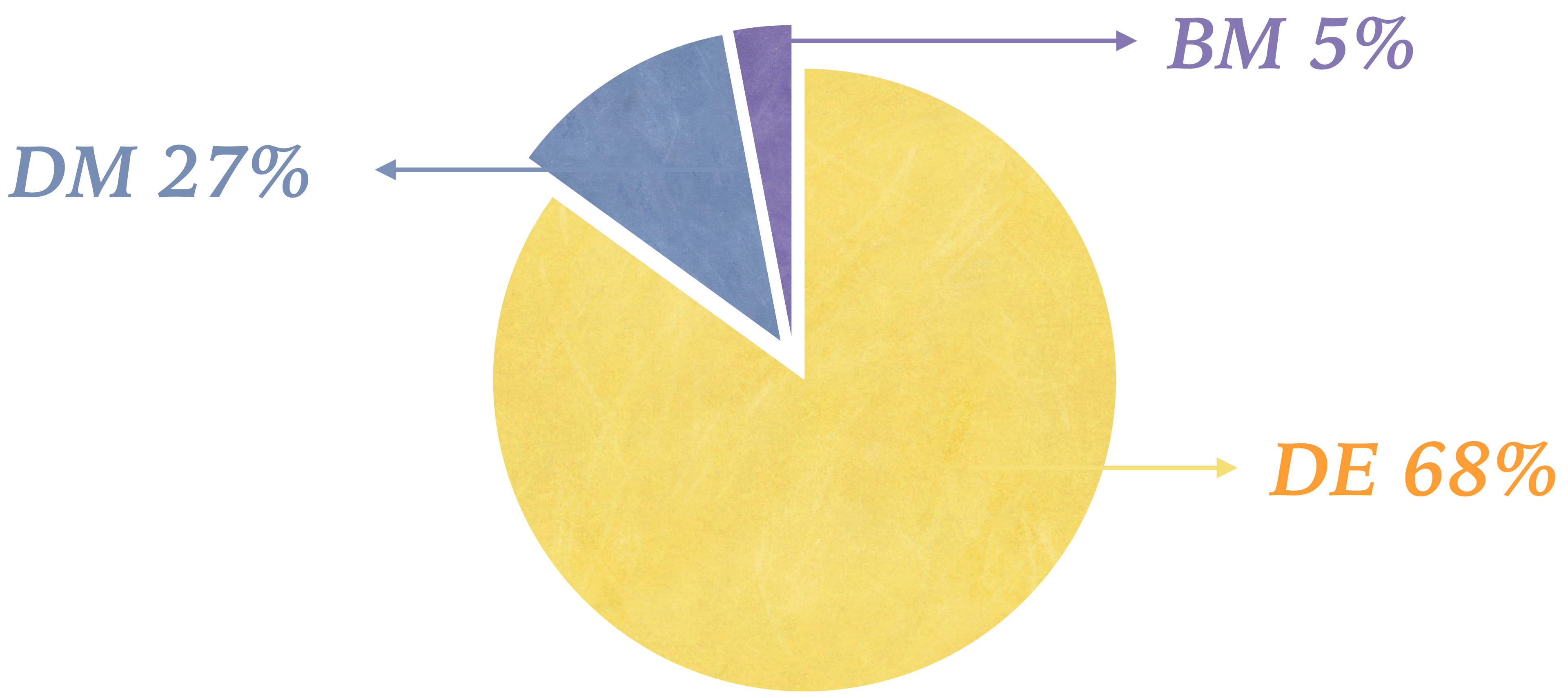
PHD STUDENT: ALEJANDRO JIMENEZ MUNOZ

SUPERVISOR: JUAN FRANCISCO MACIAS PEREZ

PREPARATION FOR THE ANALYSIS AND INTERPRETATION OF EUCLID CLUSTER COSMOLOGY

OUTLINE

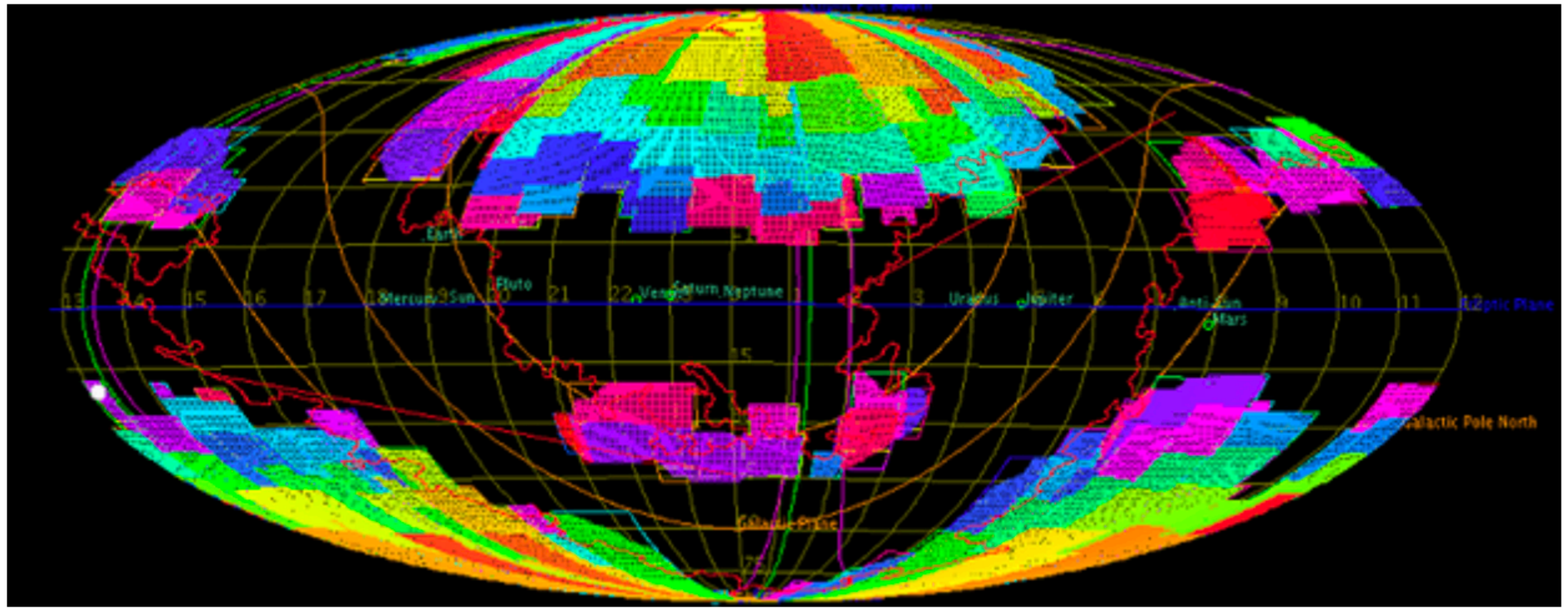
- Cosmology is the scientific study of the origin and evolution of the Universe.
- The Universe is mostly composed by Dark Matter and Dark energy and only 5% of the Universe belongs to the matter we know
- **Dark matter is responsible for the structure formation in the Universe.**
  - Example: Rotation curves of galaxies, CMB cosmological parameters estimation, mass measurement from clusters…
- **Dark energy is the responsible of the accelerated expansion of the Universe**
  - Supernovae Ia, CMB cosmological parameter estimation…
- To try to understand the Universe, spacecraft missions would be very useful, for example the Euclid mission



EUCLID

- Medium Class ESA mission expected to be launched in 2022
- Designed to study the nature of Dark Matter and Dark Energy
  - . Cosmological Probes
    - Weak Lensing (WL) - Measure cosmic shear
    - Baryonic Acoustic Oscillations (BAO) - Galaxy clustering
    - **Cluster of Galaxies - Cluster abundance**
- The Euclid system shall perform a wide survey of at least 15,000 deg^2 and a deep survey of 40 deg^2
  - Around 2 billion galaxies

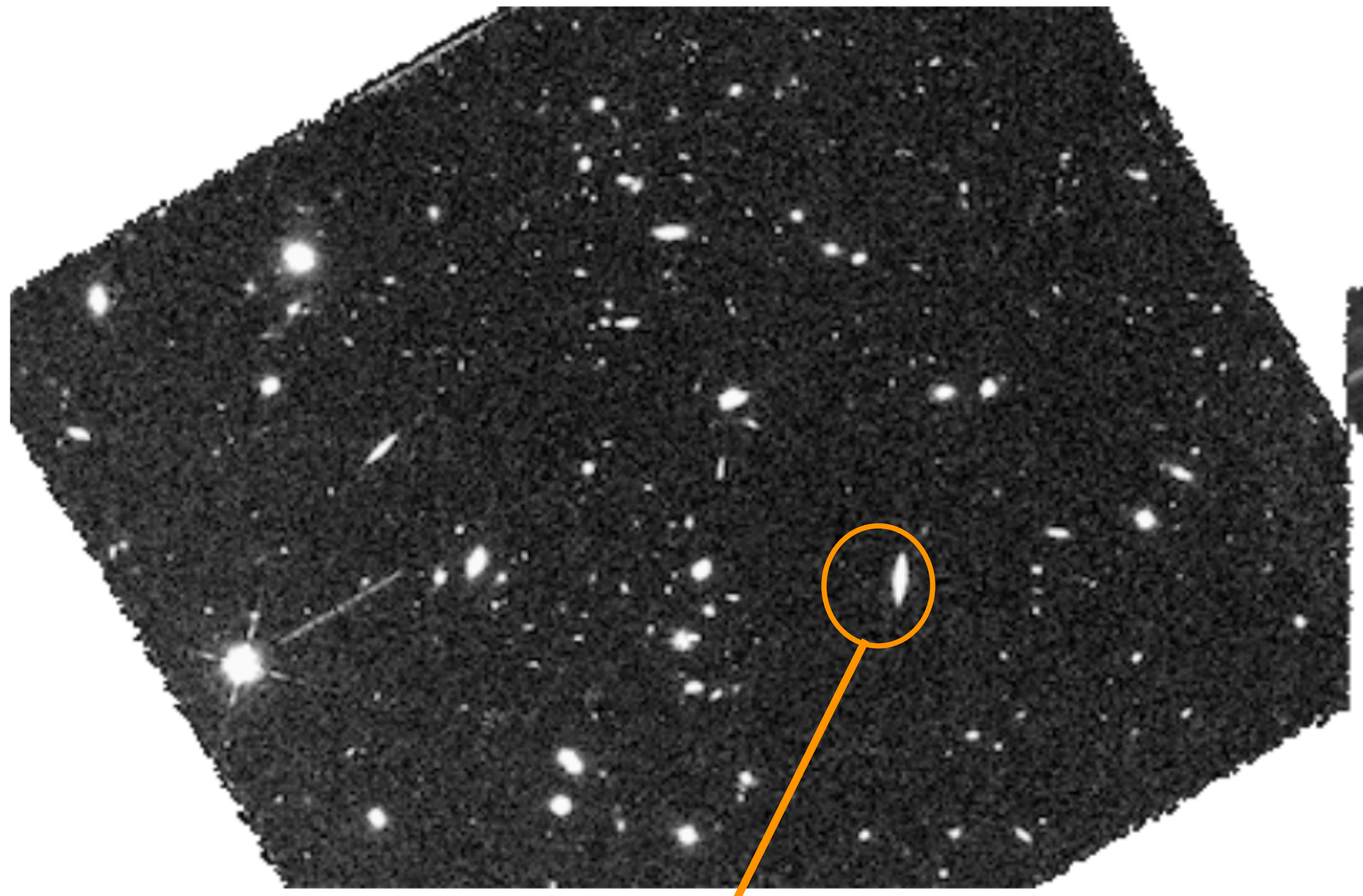
EUCLID Galactic Map coverage



EUCLID

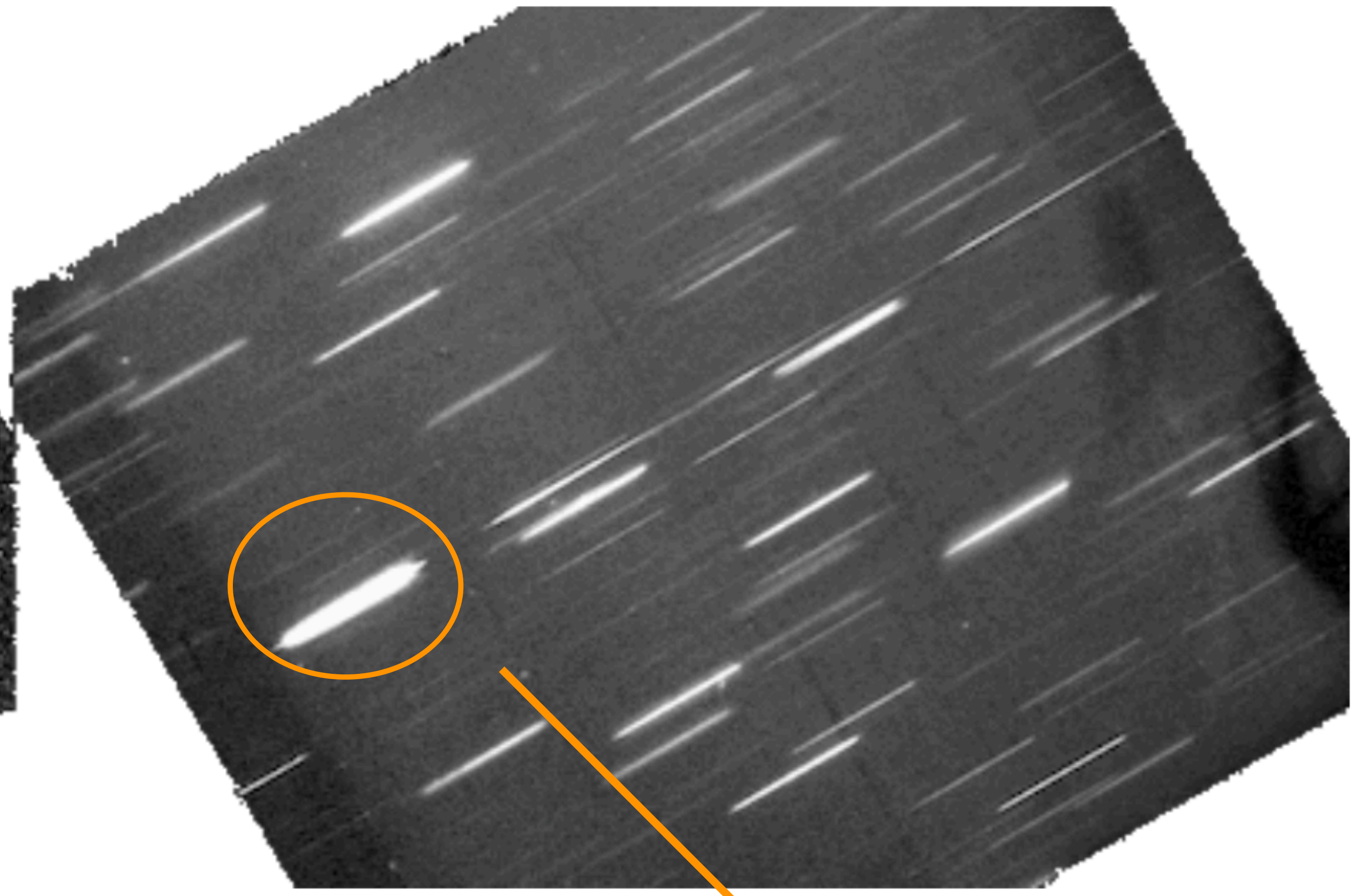
- **Visible and IR emission:**
  - **Light from stars in galaxies –> Galaxy Clusters**
  - **We need photometry and spectroscopy for galaxy properties and redshift (z) measurements**
- **Composed by two instruments with a common field of view ~ 0.54 deg2:**
  - **VIS: Visual imager (550-920nm) and a magnitude limit of** $M_{AB} = 24.5$
    - **Performing Weak Lensing with high quality**
  - **NISP: Near Infrared SpectroPhotometer.**
    - **Photometric IR images. Filters Y,J,H (920-2000nm) and a magnitude limit of** $m_{AB} = 24.5$
    - **Slitless Spectroscopy (1100-2000nm), and a magnitude limit of** $m_{AB} = 19.5$.
- **Redshift precision:** $dz/z < 0.001$; $0 < z < 2$

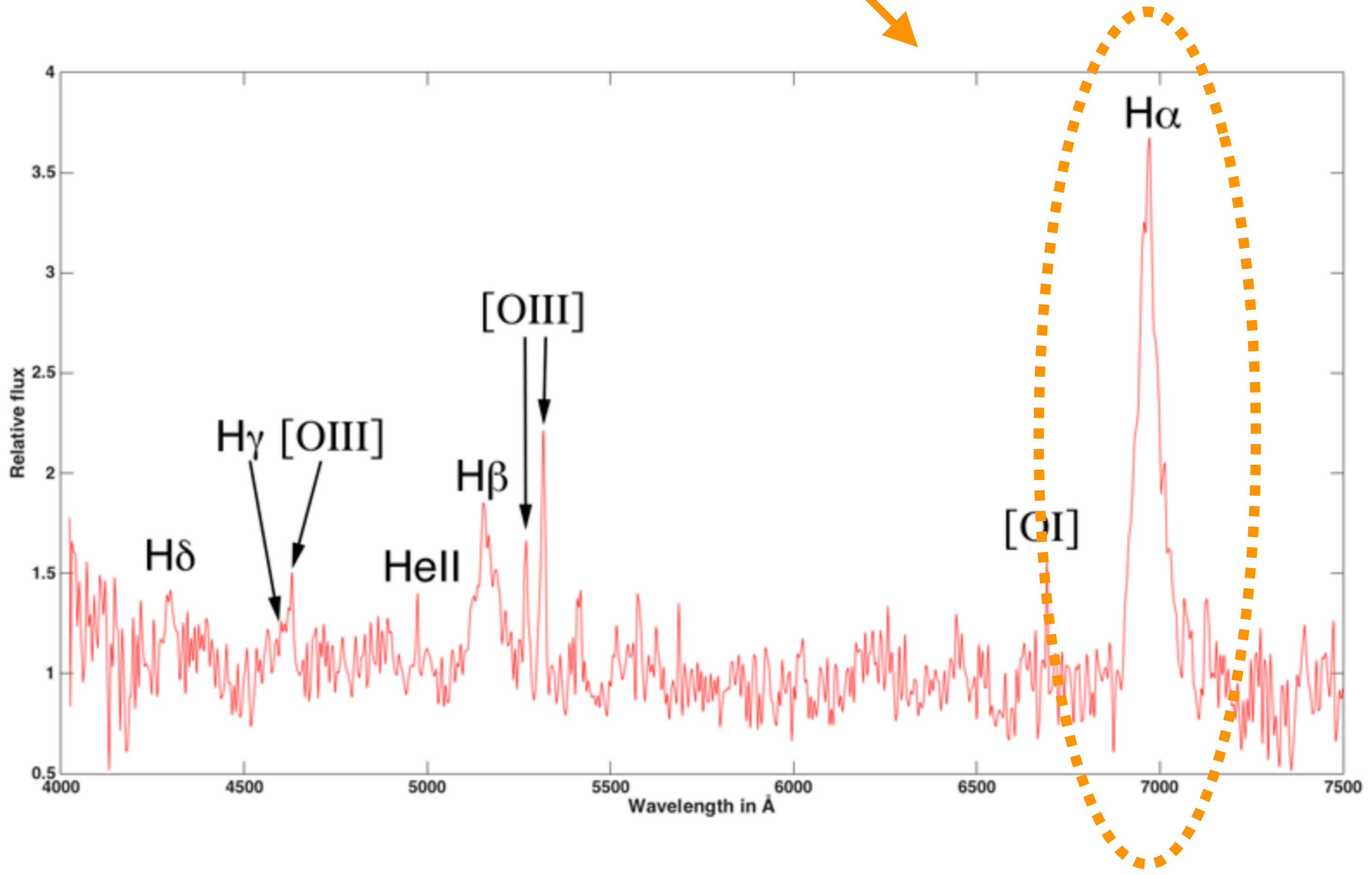
Photometry



- **Measure flux (f) and then the magnitude:** $m = -2.5 \log f + a$

Spectroscopy

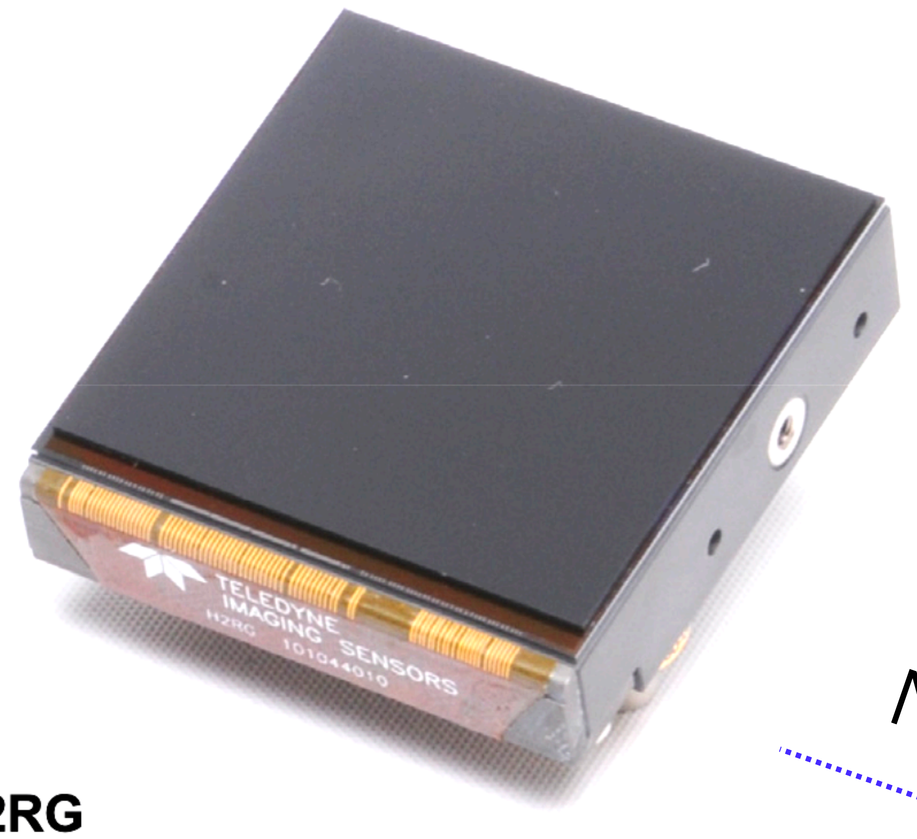




- **Measure redshift**

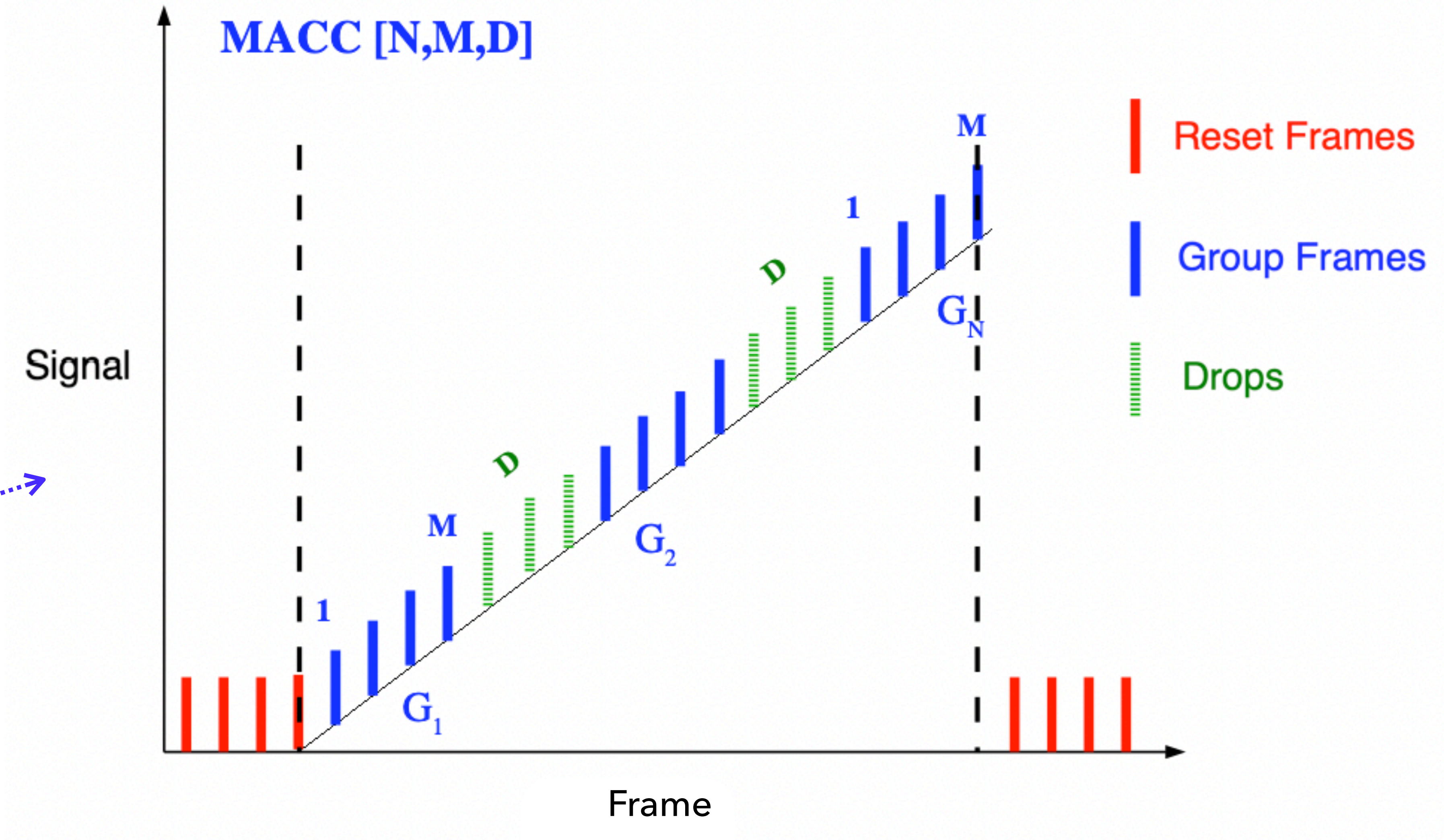
NISP READOUT MODE

- NISP - 16 H2RG detectors - Matrix of 2048x2048 pixels
- **EUCLID on-board data processing assumes a white noise approximation for the readout noise**
- **GOAL** - **Characterize the readout noise**

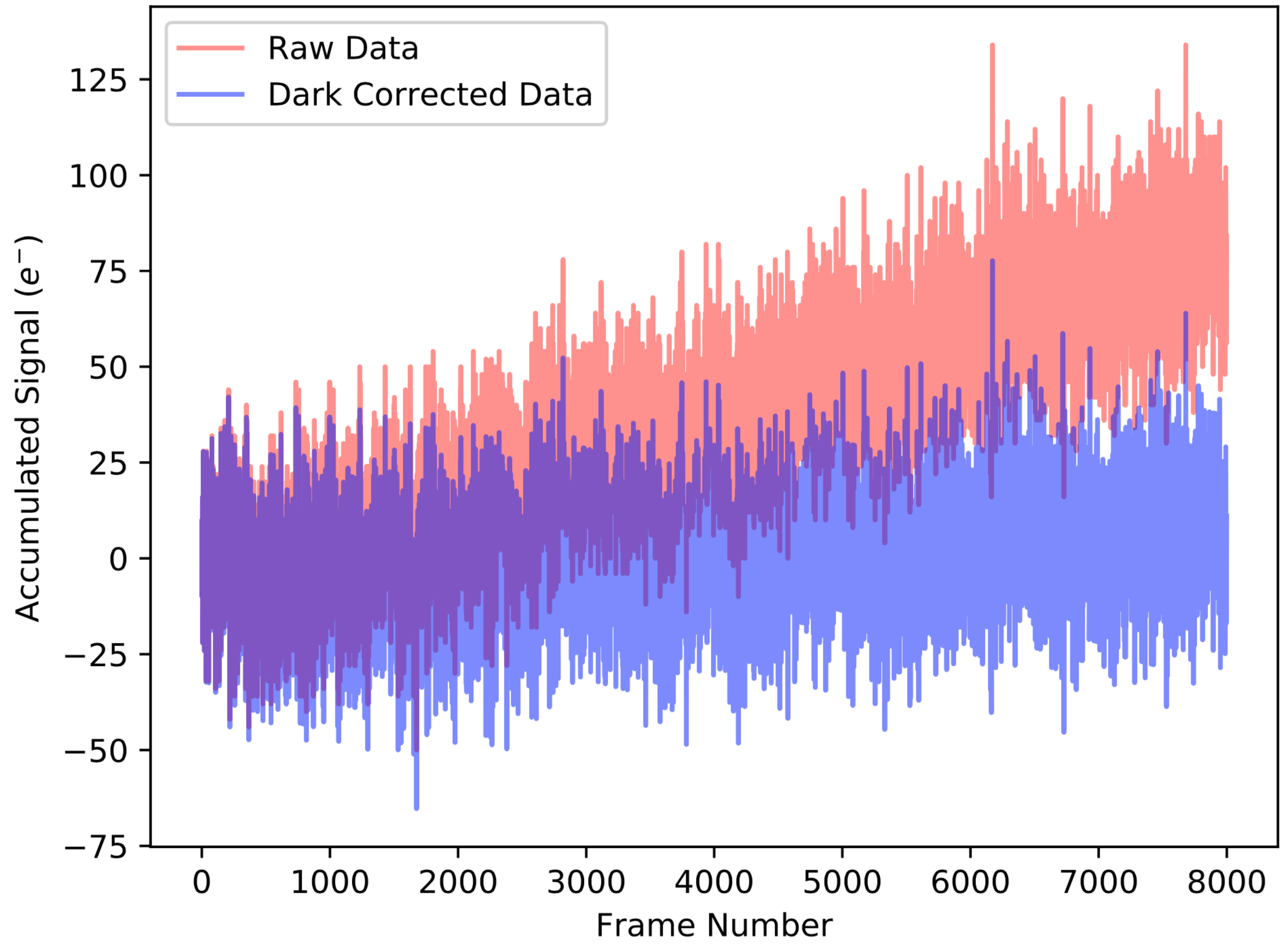


H2RG

How to acquire data (Readout mode)



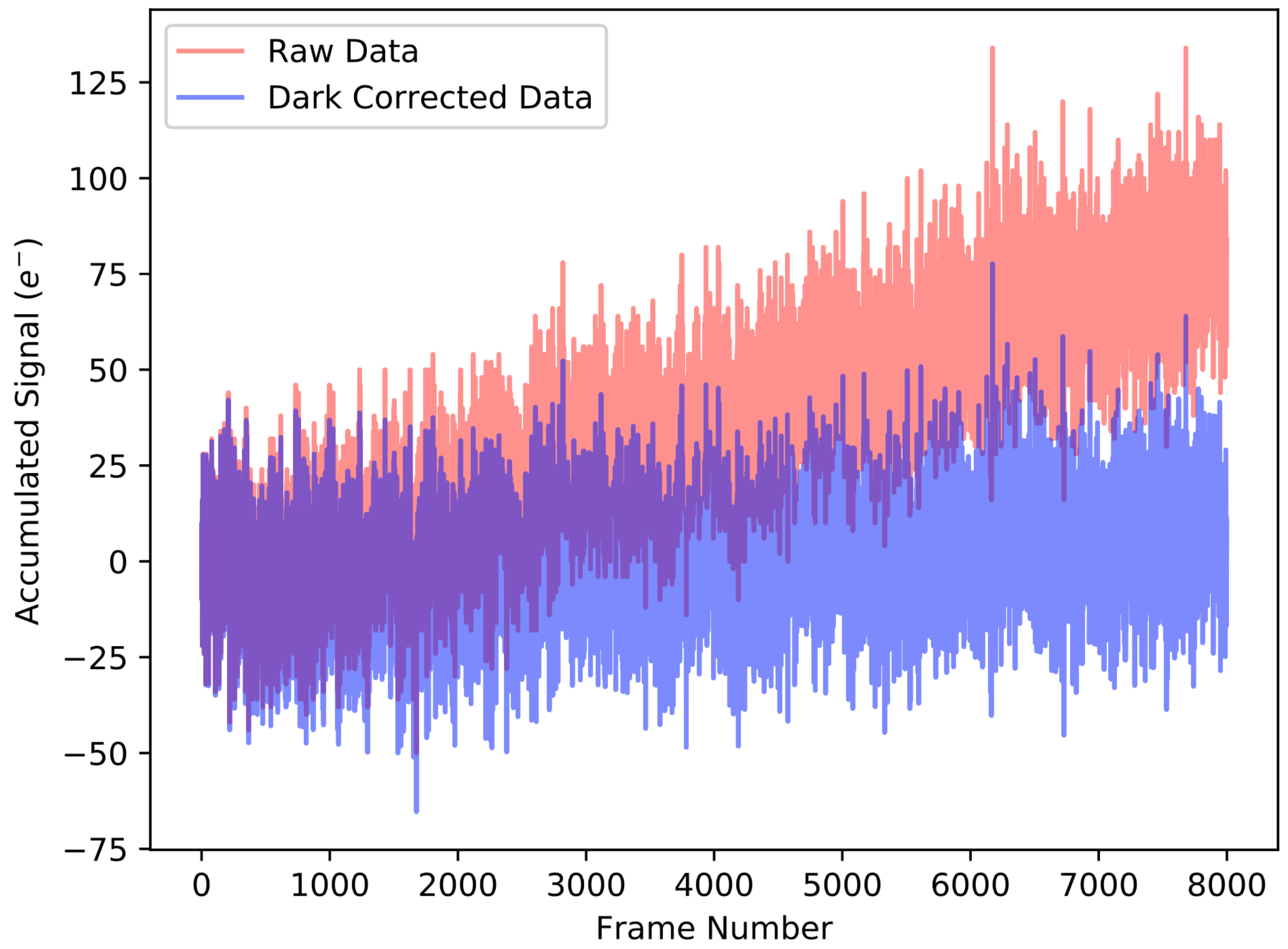
NISP detector real data

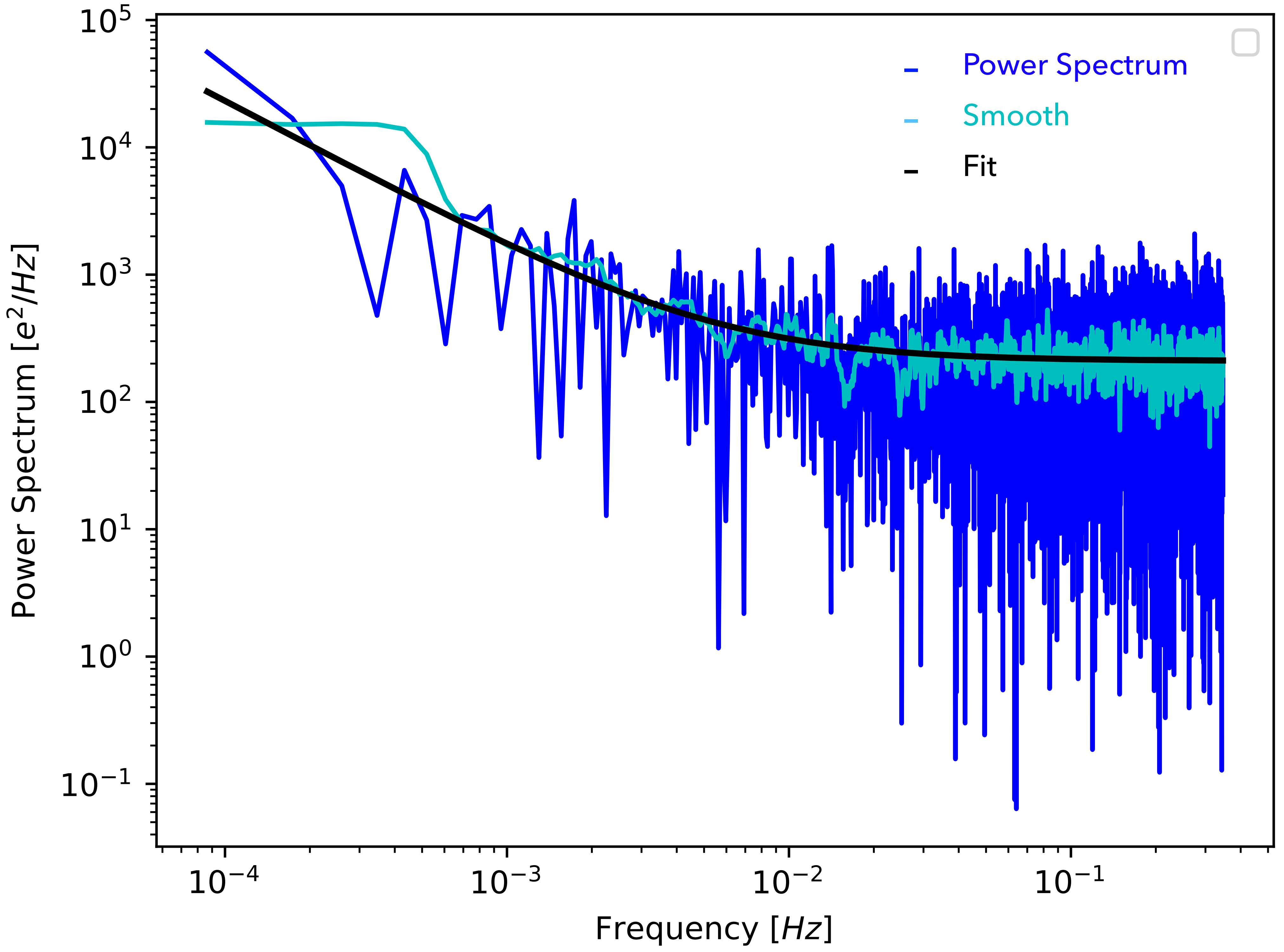


- 1 ramp = 1 pixel
- Non-destructive frames
- Signal = Photon flux (Dark) + Poisson Associated noise + Readout noise
- Dark Flux is accumulated in the frames -> slope
- We remove the dark flux for keeping only the readout noise

NISP READOUT NOISE CHARACTERIZATION

- **After Dark Correction we proceed to characterize the readout noise**



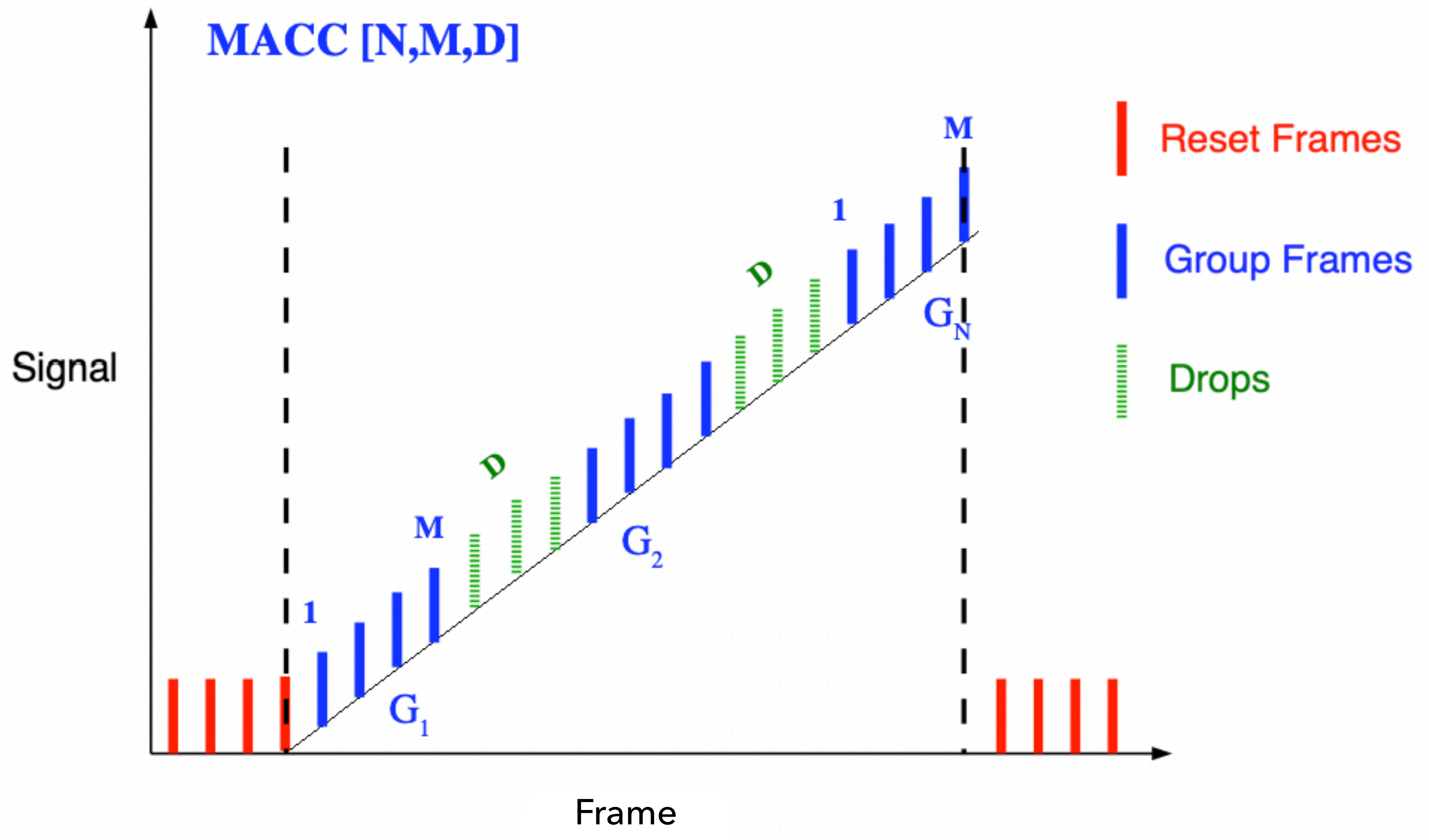


Readout noise model

- $\mathbf{P(f)} = \frac{\sigma^2}{2}\left(1 + \left(\frac{\mathbf{f}}{\mathbf{f_{knee}}}\right)^{\alpha}\right)$ - Power Spectrum
- Fitting procedure and obtaining $\sigma, \mathbf{f_{knee}}, \alpha$
- α -> slope due to the excess of noise at low frequencies
- $\mathbf{f_{knee}}$ -> where the slope begins
- σ - > The amplitude of the flat part of the spectrum

Average best fit values

- **We perform the fit for the 2048x2048 pixels**
- $\sigma = 19.70^{+1.11}_{-0.78}\ \mathrm{e^-/\sqrt{Hz}}$
- $\mathbf{f_{knee}} = 0.0052^{+0.0018}_{-0.0013}\ \mathrm{Hz}$
- $\alpha = 1.24^{+0.26}_{-0.21}$



Maximum Likelihood Flux Estimator

- $$L = \frac{1}{\sqrt{2\pi |D|}} \exp\left[-\frac{1}{2} (\Delta G - g) D^{-1} (\Delta G - g)^T \right]$$
- g is the expected flux
- Covariance Matrix depends on the Readout Noise
- We perform Monte Carlo simulations of the $(1/f)^{\alpha}$ - like noise to obtain the covariance matrix

Group Definition in MACC mode

$$G_k = \frac{1}{M} \sum_{i=1}^{M} S_i^{(k)}$$

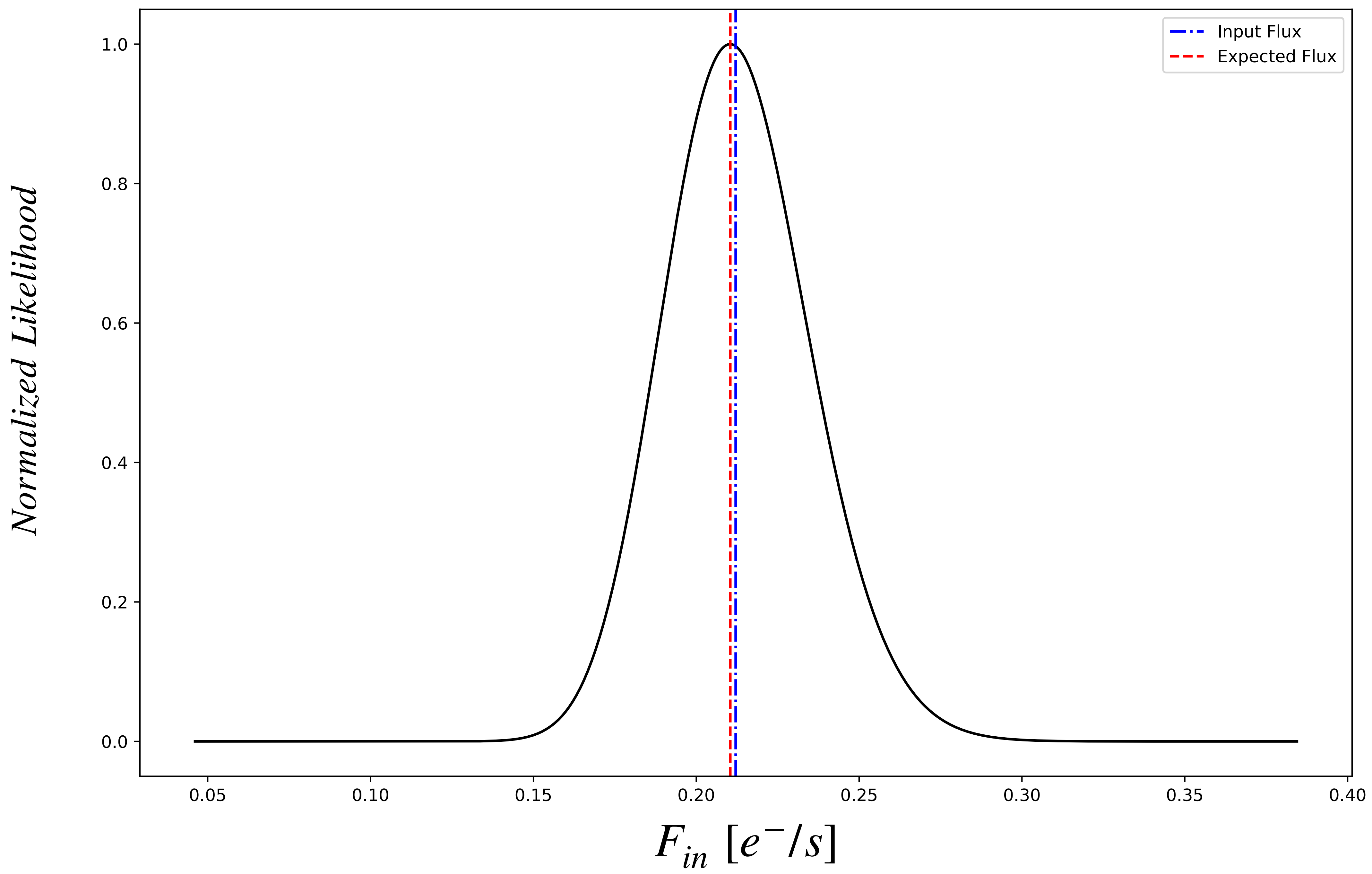
$f_i^{(k)}$ – Associated Poisson Uncertainty

$\rho_i^{(k)}$ – Readout Noise – $(1/f)^{\alpha}$ – like noise

Group differences: $\Delta G_k = G_{k+1} - G_k$

Group differences Covariance Matrix:

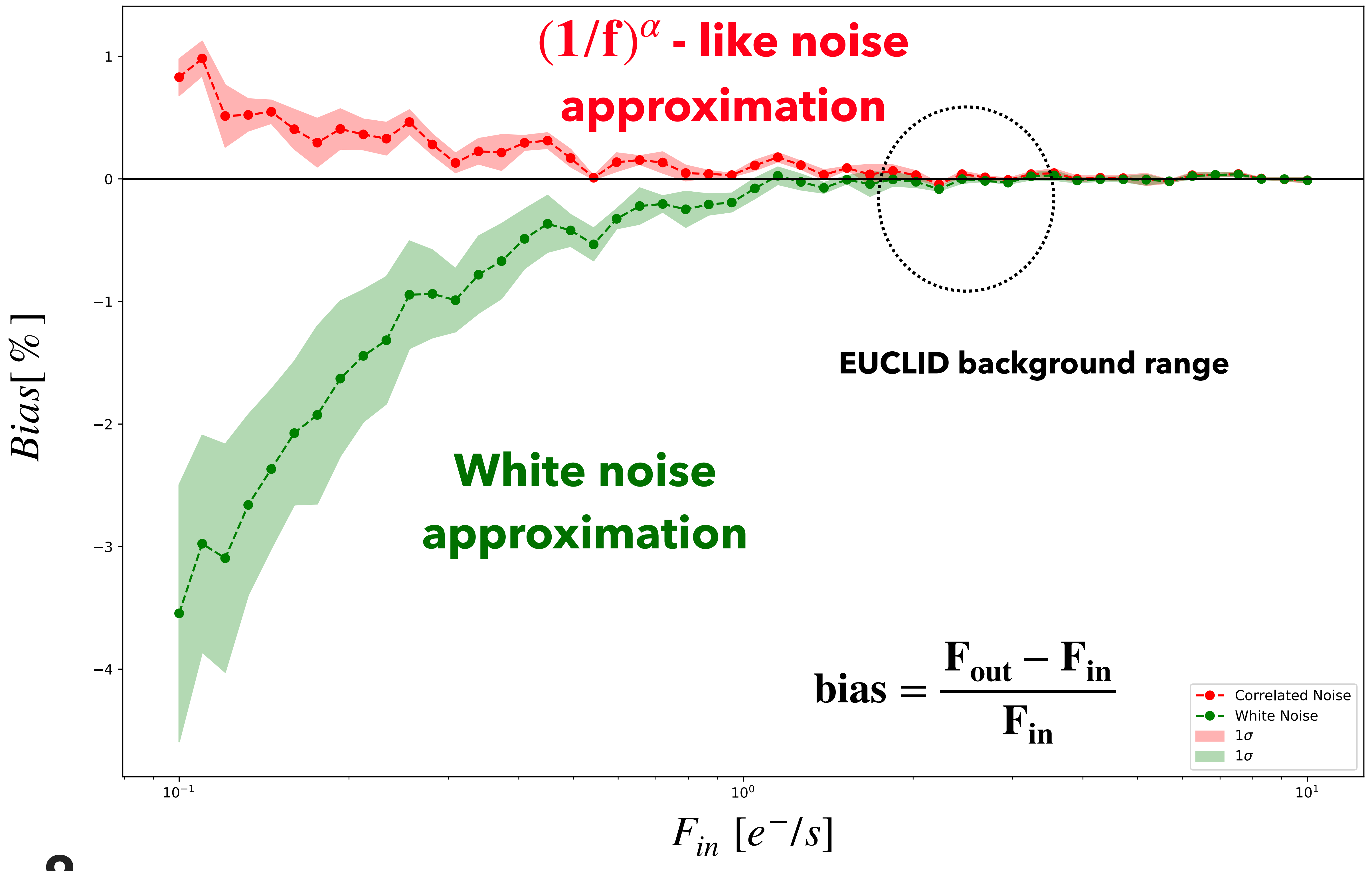
$$D = E[(\Delta G_k - E[\Delta G_k])(\Delta G_L - E[\Delta G_L])]$$



$$bias = \frac{F_{out} - F_{in}}{F_{in}}$$

EXPECTED ON BOARD FLUX BIAS AND CONCLUSION

- **To measure the flux on board EUCLID assumes a white noise approximation for the readout noise**
- **We evaluate the bias induced for this approximation**



Conclusion

- **The NISP detectors data show correlated readout noise**
- **We find that the flux bias can be up to four times larger than when accounting for the correlation in the readout noise**
- **This bias is negligible with respect the expected uncertainties for typical sky background signals**
- **we expect no significant in the on-board fluxed measured by EUCLID**
- **Paper submitted to internal referees**

Implication of correlated readout noise for flux measurements with the EUCLID NISP instrument

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Received July 1, 2020 / Accepted –

Abstract

The EUCLID satellite, to be launched by ESA in 2022, will be a major instrument for cosmology for the next decades. EUCLID is composed of two instruments: the Visible (VIS) instrument and the Near Infrared Spectrometer and Photometer (NISP). In this work we describe the implications of correlated readout noise in the NISP detectors for the final in-flight flux measurements. Considering the Multiple Accumulated (MACC) readout mode, for which the UTR (Up the Ramp) exposures frames are averaged in groups, we derive an analytical expression for the noise covariance matrix between groups in the case of correlated noise. We also characterize the correlated readout noise properties in the flight NISP detectors using long dark integrations. For this purpose, we assume a $(1/f)^{\alpha}$-like noise model and fit the model parameters to the data, obtaining typical values of $\sigma = 19.70^{+1.11}_{-0.78}$ e$^-$/ $\sqrt{Hz}$, $f_{knee} = 0.0052^{+0.0018}_{-0.0013}$ Hz and $\alpha = 1.24^{+0.26}_{-0.21}$. Furthermore, via realistic simulations and using a maximum likelihood flux estimator we derive the bias between the input flux and the recovered one. We find that using our analytical expression for the covariance matrix of the correlated readout noise we disminish this bias by up to a factor of four with respect to the white noise approximation for the covariance matrix. Finally, we conclude that the final bias on the in-flight NISP flux measurements should still be negligible even in the white noise approximation, which is taken as a baseline for the EUCLID onboard processing.

Key words. Infrared detectors – HgCdTe detectors – Signal processing – covariance matrix – noise correlations

OUTLINE

I. *Cosmology and The EUCLID mission*

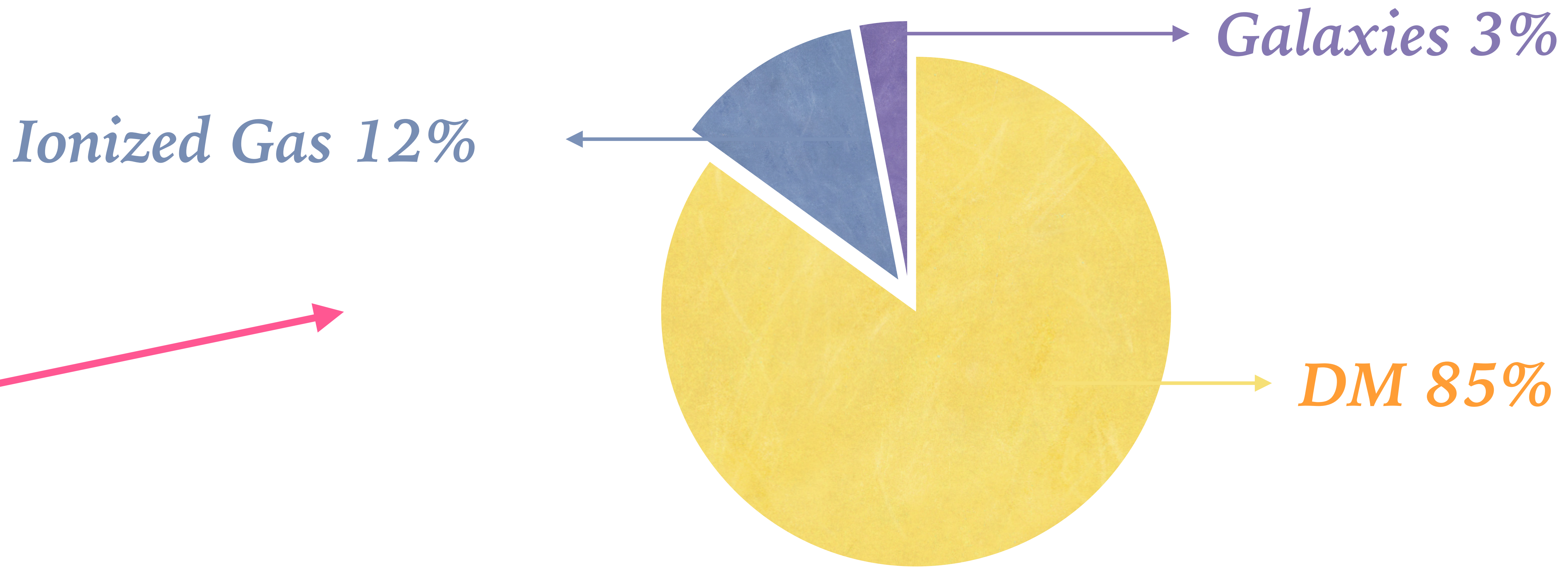
II. *EUCLID detector performance*

IV. *Towards more realistic cluster simulations*

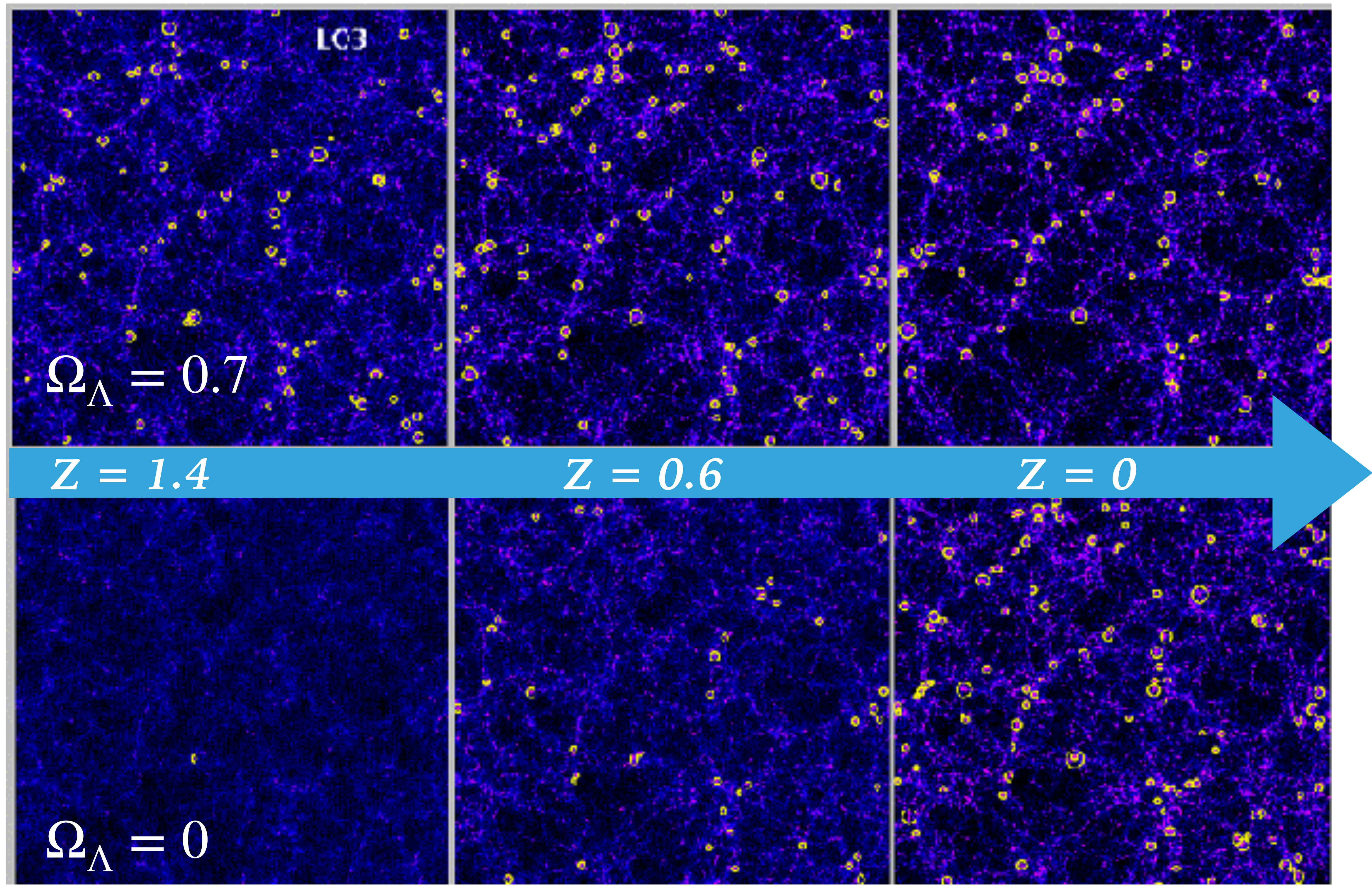
V. *Conclusion and Perspectives*

GALAXY CLUSTERS AND COSMOLOGY

- Clusters are formed by gravitational collapse
  - Largest gravitationally bound structures (Virialized)
  - Self-similarity, scaled copies of each others
- Dominated by DM (~85%), and formed by ionized gas (ICM) and Galaxies



- $10^{13} M_\odot < M_{cluster} < 10^{15} M_\odot \;;\quad 0 < z < 3$
- Various cluster observables:
  - **Optical and IR: Light from Galaxies**
  - X-Ray: Bremsstrahlung emission
  - mm λ: SZ (Sunyaev–Zeldovich) effect, Inverse Compton of CMB γ and ICM e-
- Mass and redshift distribution of cluster (Cluster number counts) is sensitive to cosmological parameters.



S. Borgani & L. Guzzo + 2001

CLUSTER NUMBER COUNTS

Cluster number counts

Catalog Selection Function (SF)

$$\frac{dN}{dz} = \int d\Omega \int \widehat{X}(z, M, l, b) \frac{dn}{dz\,dM\,d\Omega} dM$$

volume

Halo Mass Function (HMF)

- **The Selection Function is the Instrumental Capability to detect a cluster. Thus it is the Probability of finding a cluster.**
- **How to compute it?**
  - **Simulated Mock Catalogue**
  - **Cluster injection method - The one we will use**

DETERMINE SELECTION FUNCTION

MOCK simulations

- Given a synthetic catalog of galaxies from numerical simulations (MOCK catalog)
- Apply detection algorithm
- Compared the Clusters from MOCK and detection algorithm catalog
- PROBLEM: Depends on simulations

Cluster Injection

- From Survey Data we apply detection algorithm
- Study properties of detected clusters
- Simulate a cluster catalogue with this properties
- Inject it into the Survey Data
- Reapply Detection algorithm and look for the clusters we have defined

COMPUTE COMPLETENESS

- $N_{detected}$ **is the number of clusters we have after checking with the detection algorithm**
- N_{true} **are the "true" clusters**

$$C = \frac{N_{detected}}{N_{true}}$$

SELECTION FUNCTION DETERMINATION: CLUSTER INJECTION METHOD

- **We apply the cluster injection method using the EUCLID MOCK Catalog.**
- **Generate a catalogue from a simple 3D model of the cluster:**
  - Construct bins of mass and redshift
  - Simulate galaxies using the galaxy density profile, $n(r/R_{200})$, and the galaxy luminosity function, $\phi(m)$
  - We assign a sky position to each cluster and to each galaxy within the cluster to generate a catalogue
- **This method has some advantages:**
  - We keep the catalogue properties
  - It could be used in the real data with some modifications

LUMINOSITY FUNCTION

- *We compute the Luminosity Function for the actual EUCLID simulations*
- *We create bins*
  - *Mass*
  - *Redshift*
- *Schechter Function (LF)*
- *We perform the MCMC fit in the Luminosity Function (LF)*

Luminosity Function

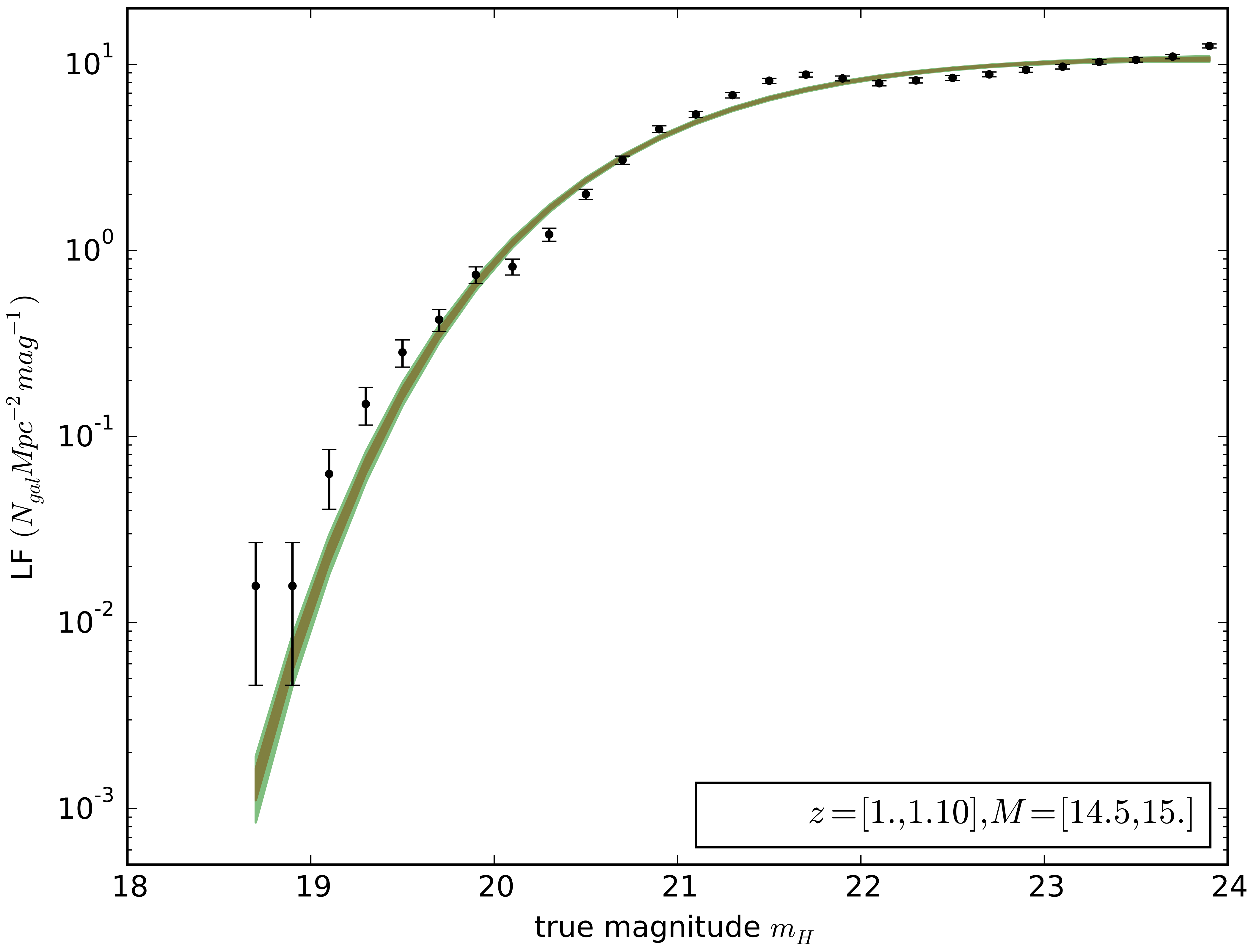
Faint-end slope

Normalization

$$\phi(m) = 0.4\log(10)\phi^{\star}10^{0.4(m^{\star}-m)(\alpha+1)}\exp(-10^{0.4(m^{\star}-m)})$$

Characteristic magnitude

Driver et al. 1994

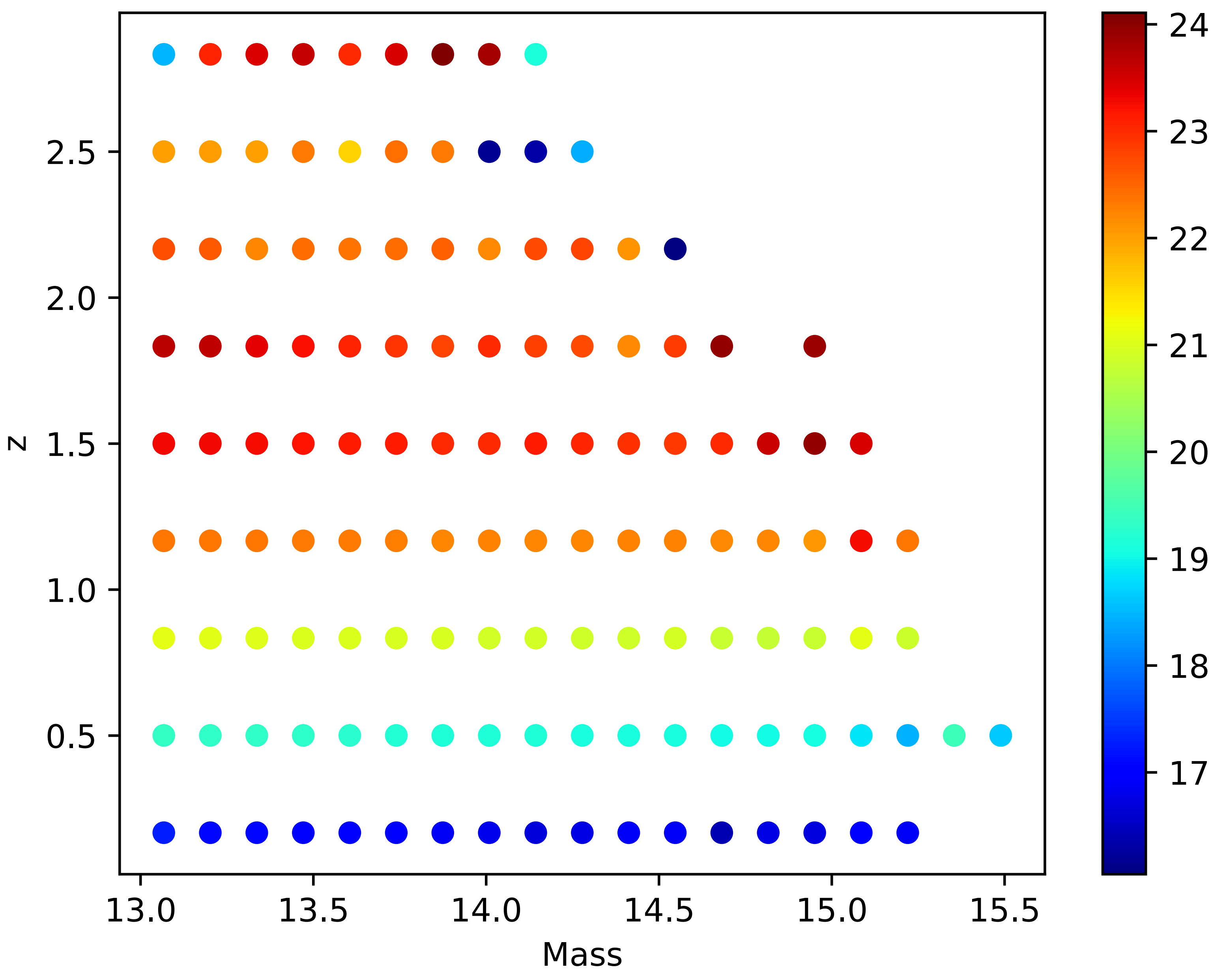


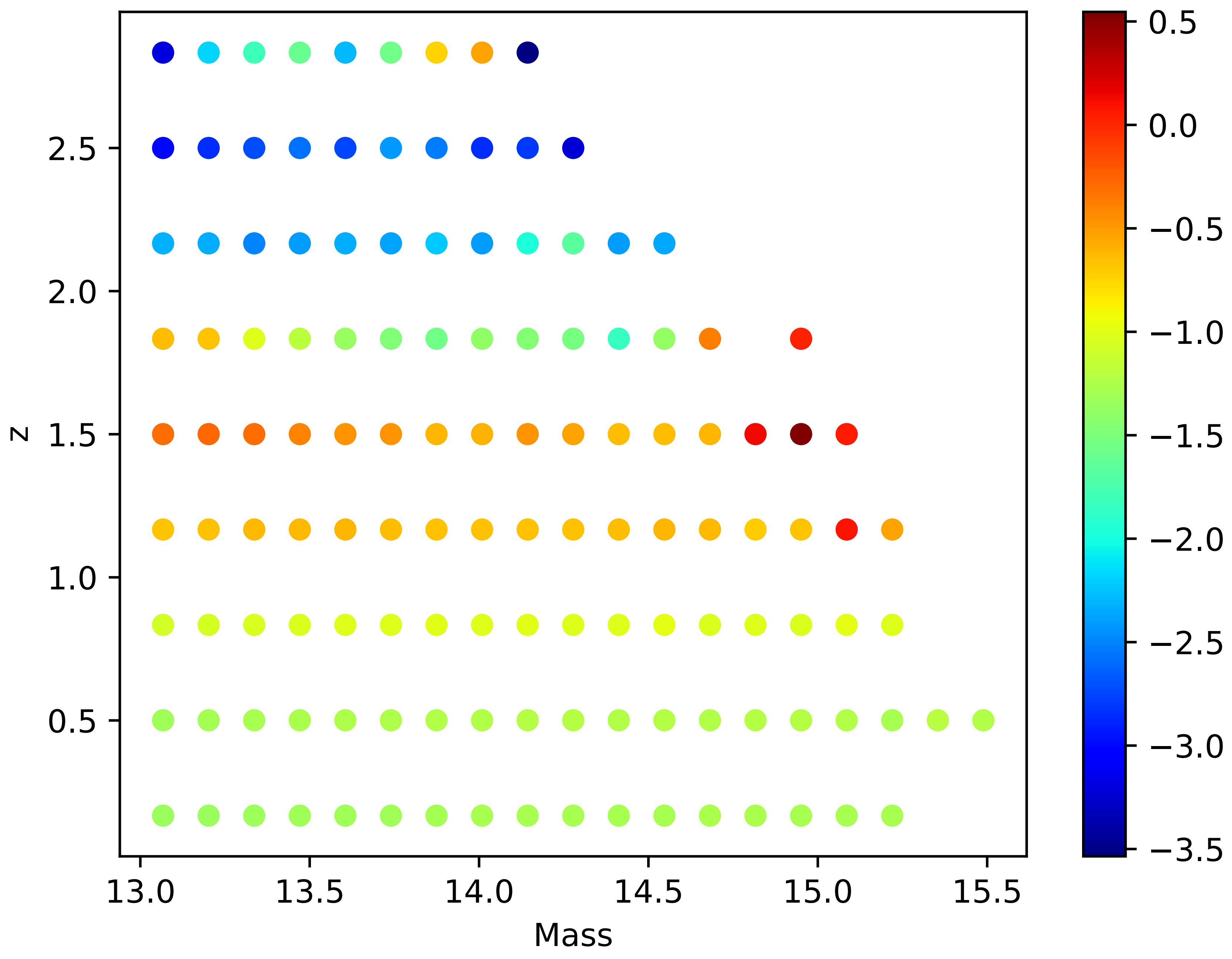
PARAMETERS EVOLUTION WITH THE MASS AND REDSHIFT

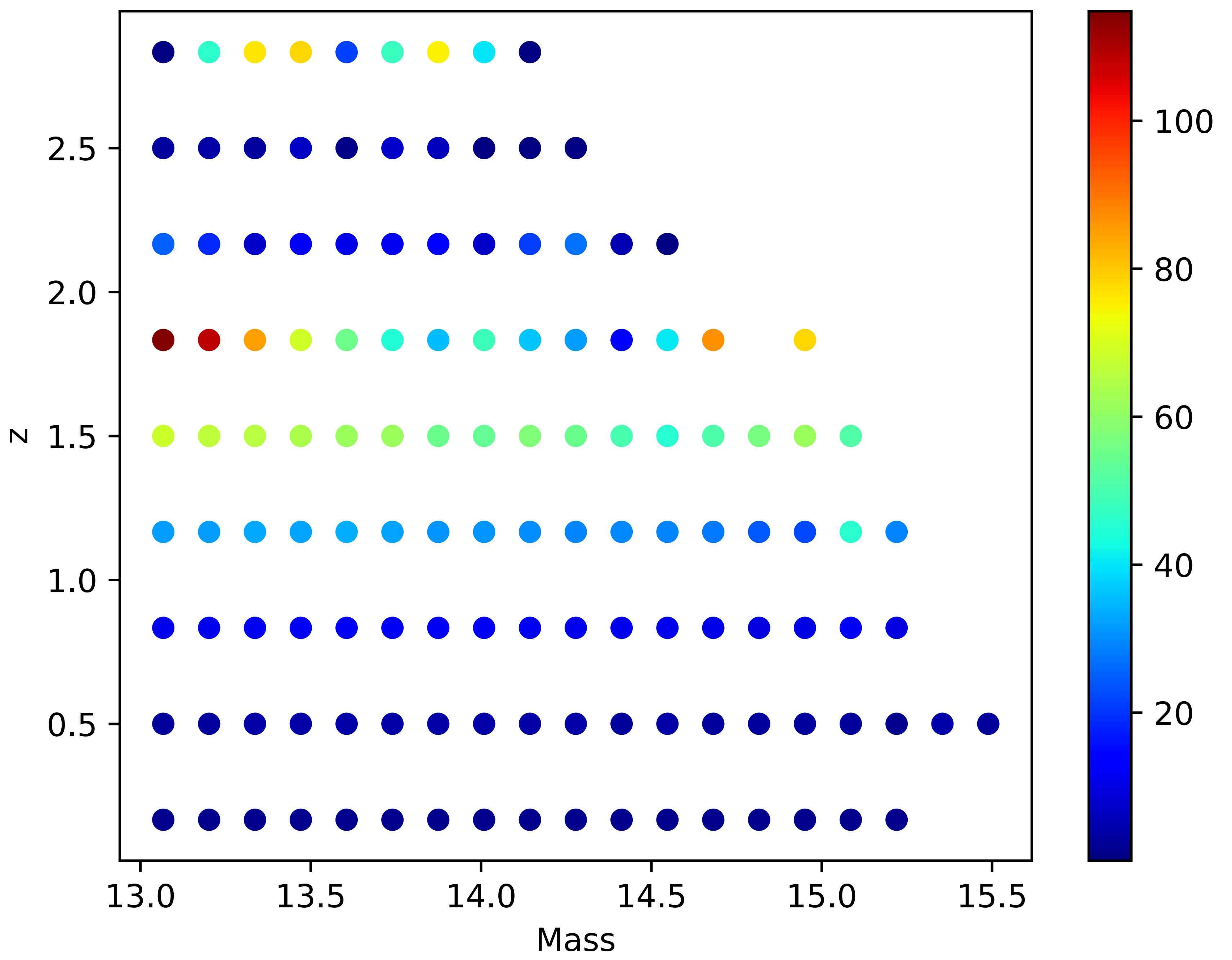
Characteristic magnitude m^*

Faint-end slope α

Normalization ϕ^*







- Characteristic magnitude, m^*, shows evolution with redshift, but not with cluster mass
- Faint-end slope, α, shows evolution with redshift but not with cluster mass
- Normalization, ϕ^*, does not show any clear evolution

PROFILE DISTRIBUTION OF THE RADIAL NUMBER DENSITY OF GALAXIES

- *We compute the Density Profile for the actual EUCLID simulations*
- *We create bins*
  - *Mass*
  - *Redshift*
- *Theoretical 3D NFW model. We add a truncation parameter due to resolution problem in the outer region of the cluster due to the simulations.*
- *We perform the MCMC fit in the projected Profile distribution (NFW) function*

2D projected NFW function

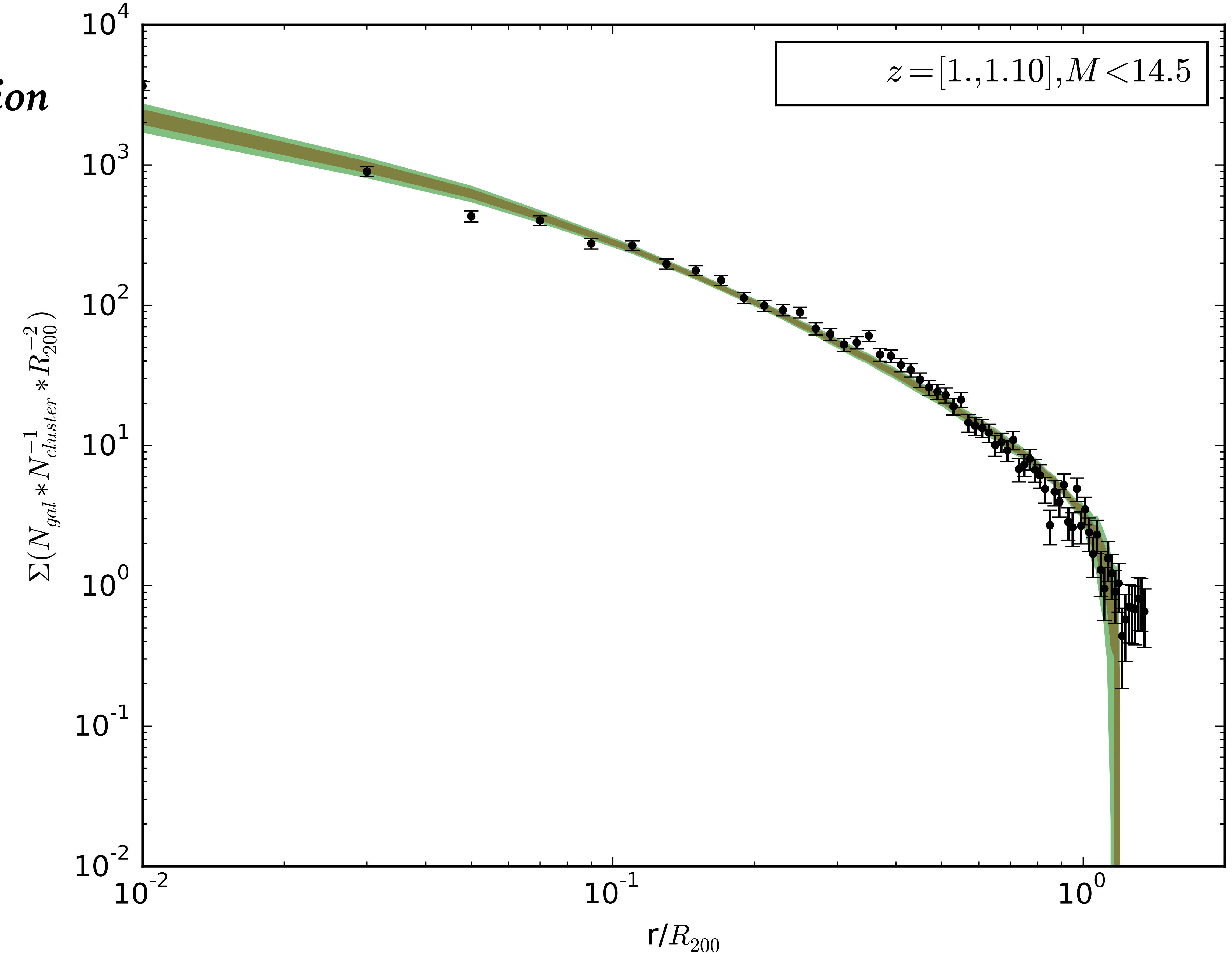
Normalization

$$n(r/R_{200}) = \frac{n_0}{(cr/R_{200})(cr/R_{200}+1)^2}\mathscr{H}(r_{max} - r)$$

Navarro et al. 1996

Concentration

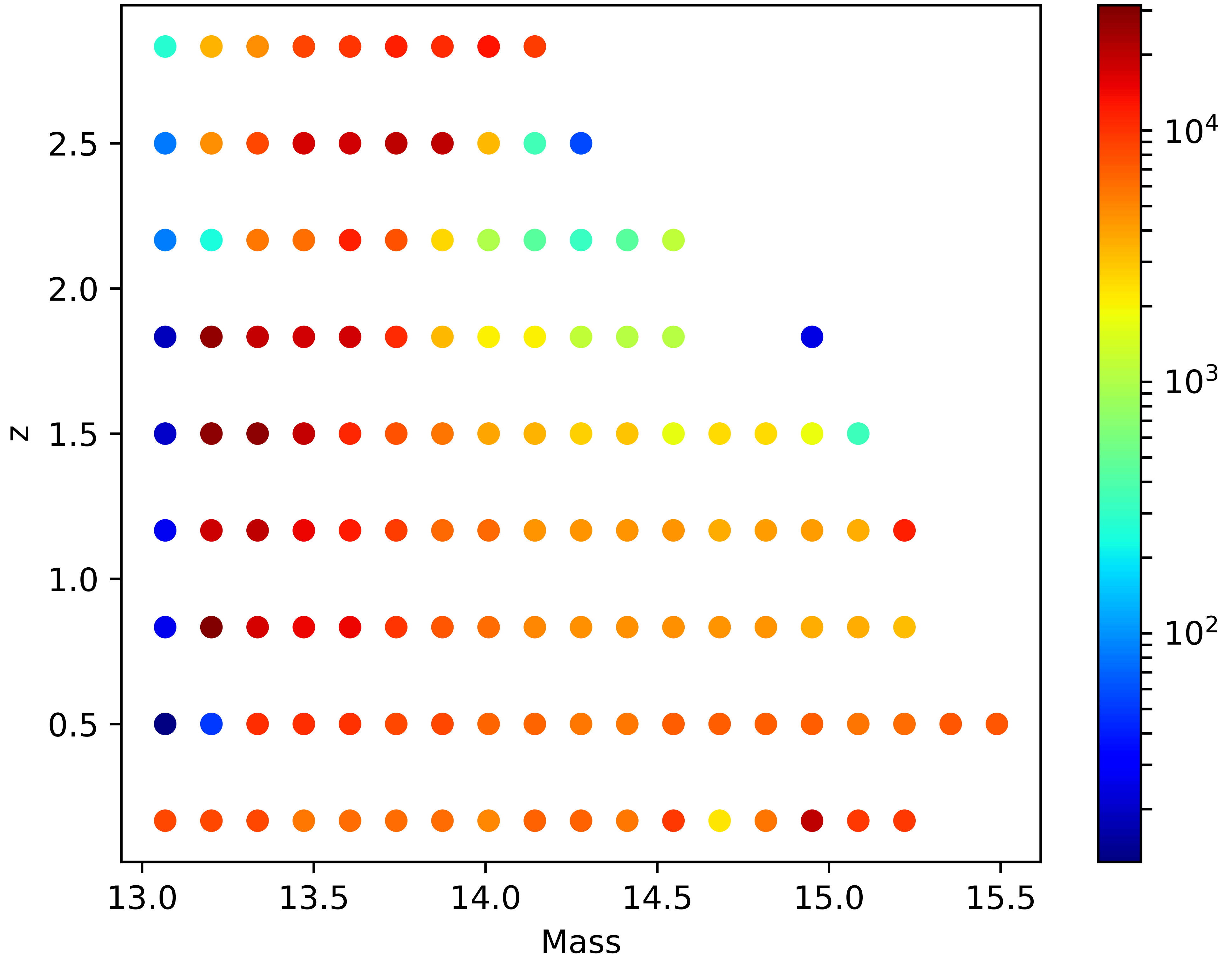
Truncation radius

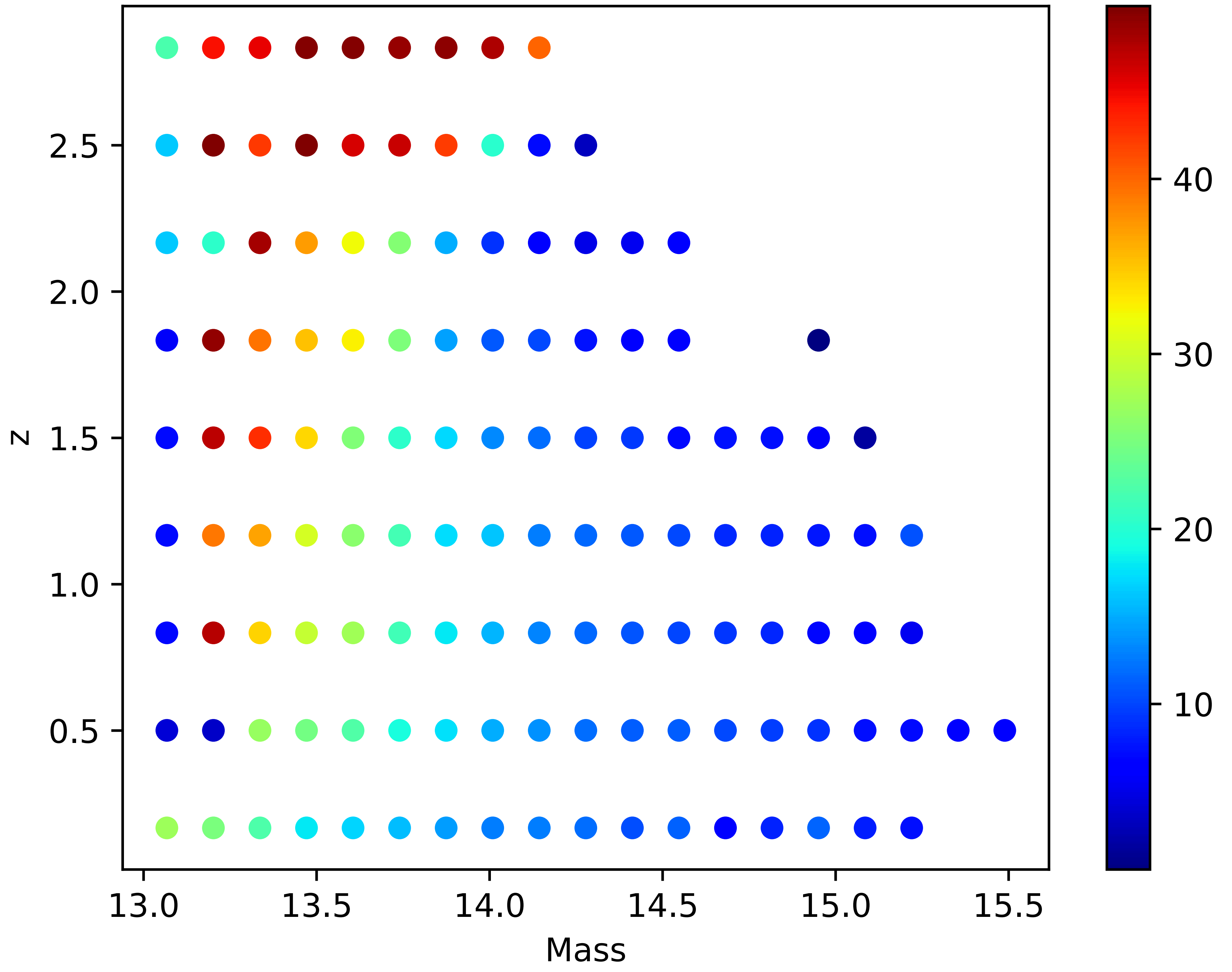


PARAMETERS EVOLUTION WITH THE MASS AND REDSHIFT

NORMALIZATION, n_0

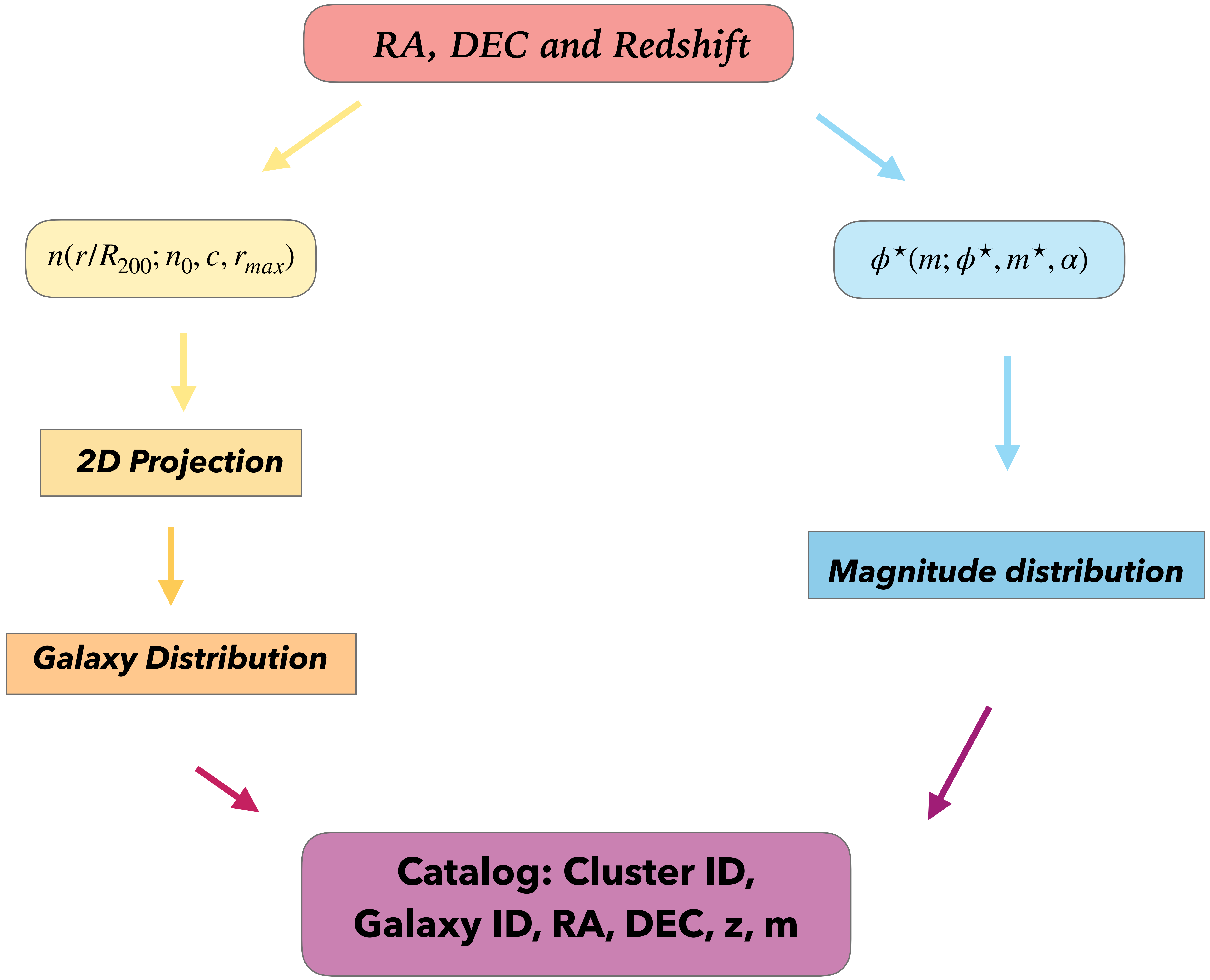
CONCENTRATION, c



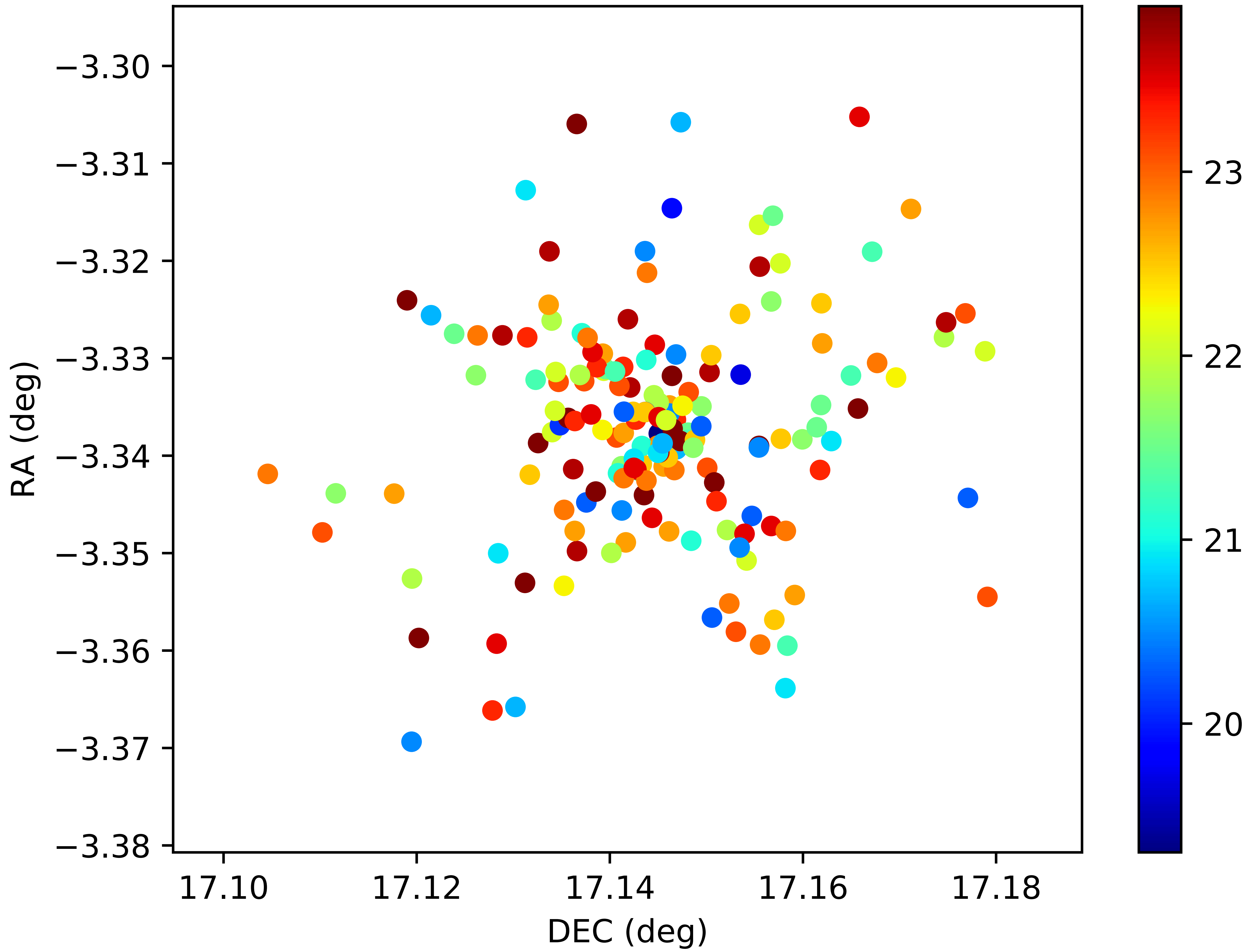


- Concentracion, c , shows evolution with cluster mass and also with redshift
- For normalization, n_0, the evolution is difficult to interpret

CLUSTER SIMULATION



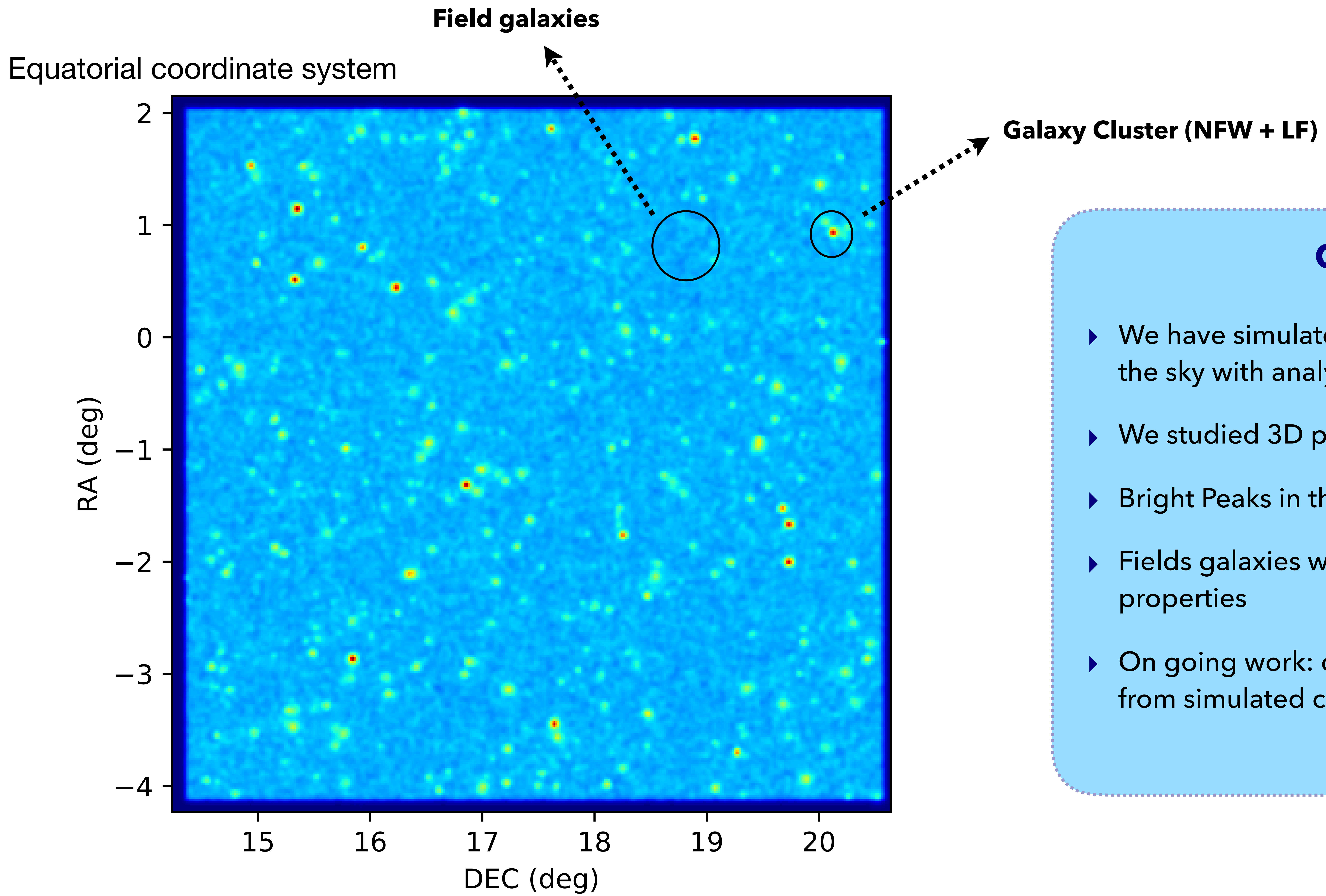
EXAMPLE OF A SIMULATED CLUSTER



Simulated Cluster properties

- Cluster is more populated in the center
- Bright of galaxies showed in the colorbar
- The brightest galaxy is in the center
- There is no correlation between the magnitude of galaxies and their radial distribution

SIMULATED SKY



Conclusion

- We have simulated a projection of galaxies on the sky with analytical methods
- We studied 3D properties of clusters (NFW + LF)
- Bright Peaks in the figure are clusters
- Fields galaxies with the same cluster galaxy's properties
- On going work: obtaining the Selection Function from simulated catalog

OUTLINE

I. Cosmology and The EUCLID mission

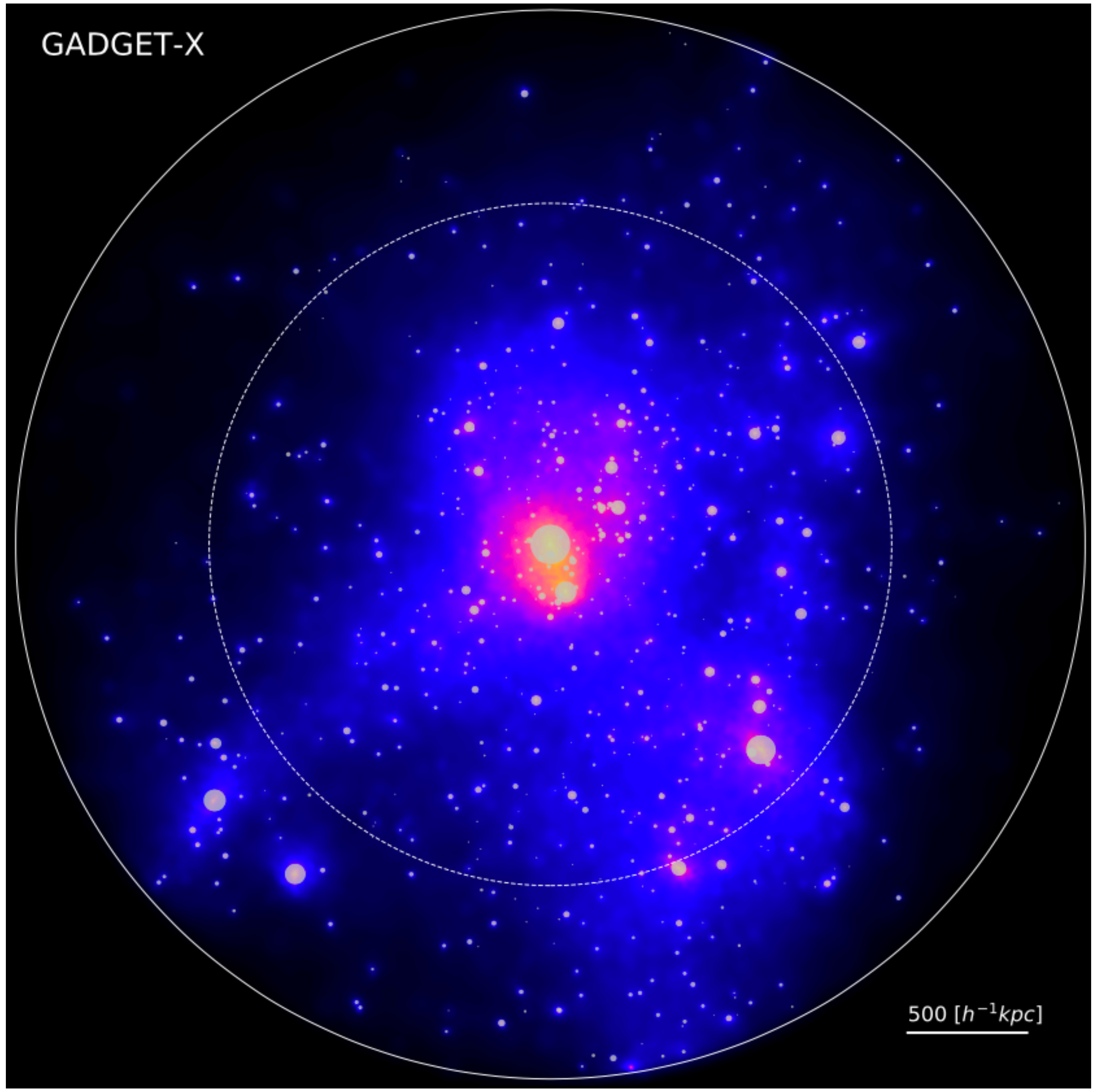
II. EUCLID detector performance

III. Preparation to cluster cosmology with EUCLID

V. Conclusion and Perspectives

THE 300 PROJECT

- **EUCLID catalogue is done with semi analytical models.**
- **Solving numerical simulations for baryonic component are called Hydrodynamical Simulations.**
- Catalogue created by Hydrodynamical re-simulations of Galaxy Clusters
- Fundamental equations of gravitation, hydrodynamics and perhaps radiative cooling and transfer are solved for a large number of points
- Resolution: $m_{DM} + m_{gas} = 1.5 \times 10^9 h^{-1} M_{\odot}$

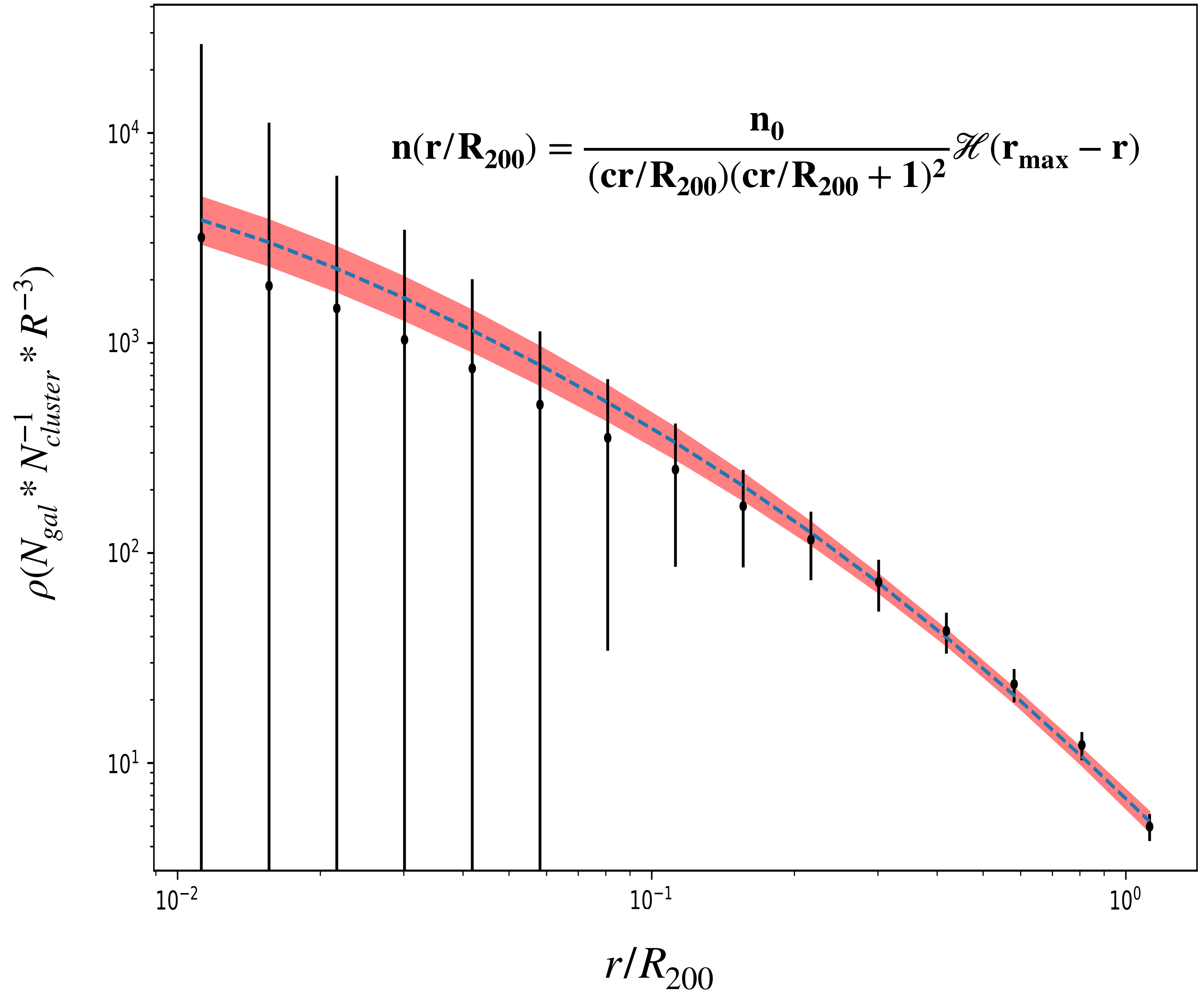


Blue color - Dark matter density
Red color - galaxy brightness
Symbol size - proportional to stellar mass

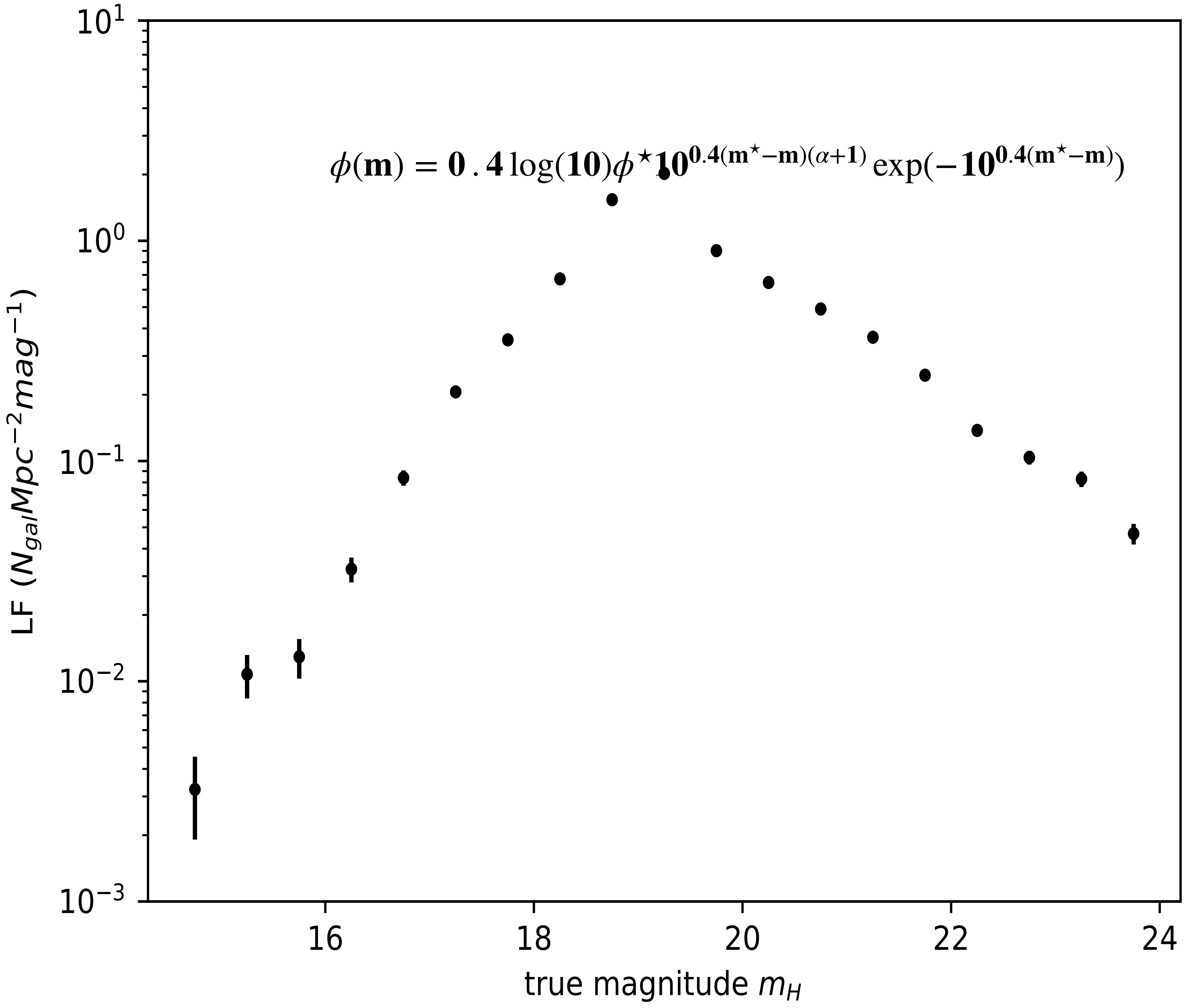
THE 300 PROJECT: DENSITY PROFILE DISTRIBUTION

- We perform the same analysis as for the EUCLID Catalogue
- We study the distribution of the number of galaxies as a function of the radial distance as the magnitude distribution

Number Density profile

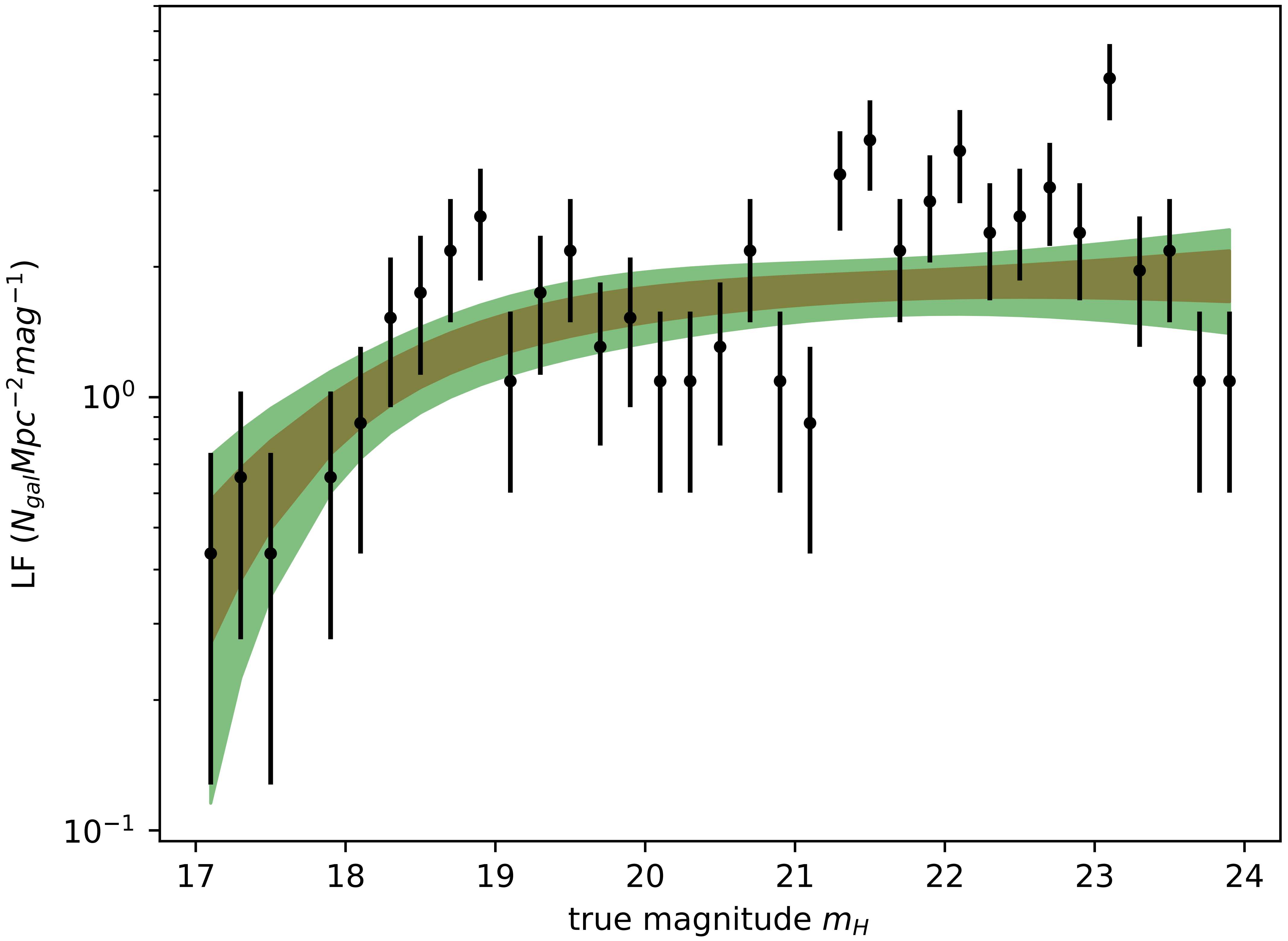


Luminosity function



- **There is no enough resolution for faint galaxies**

Luminosity function for ONE cluster



Conclusion

- The Schechter Model for the HD cluster gives a good fit to the data
- On going work: HD Dark Matter simulations with better resolution than the EUCLID ones.
- **Example of resolution for a 1 Gpc box**
  - **Millenium (EUCLID) -> 5200^3 particles**
  - **The 300th -> 3840^3 particles**
  - **The 300th HD -> 7680^3 particles**
- The 300th HD has enough resolution for checking NFW model in the inner region and performing a better fit

OUTLINE

CONCLUSIONS AND FUTURE WORK

- **CONCLUSIONS**
  - We characterised the NISP detector noise and checked that the actual On-flight configuration for EUCLID works fine
  - We were able to recreate the 3D properties of a Cluster from analytical properties and generate a random catalogue
  - We checked the resolution limits of the 300th project and we studied 3D properties of the 300th clusters

- **Last thesis year perspectives:**
  - **Add random catalogue to existing data and check with matching cluster detection -> Obtaning Selection Function**
  - **Check the 300th High Definition cluster properties**
  - **Study Mass Scaling Relations for high redshift clusters: use SZ data (Planck) to calibrate the mass for EUCLID clusters**

A.JIMENEZ - MUNOZ, J.F.MACIAS-PEREZ

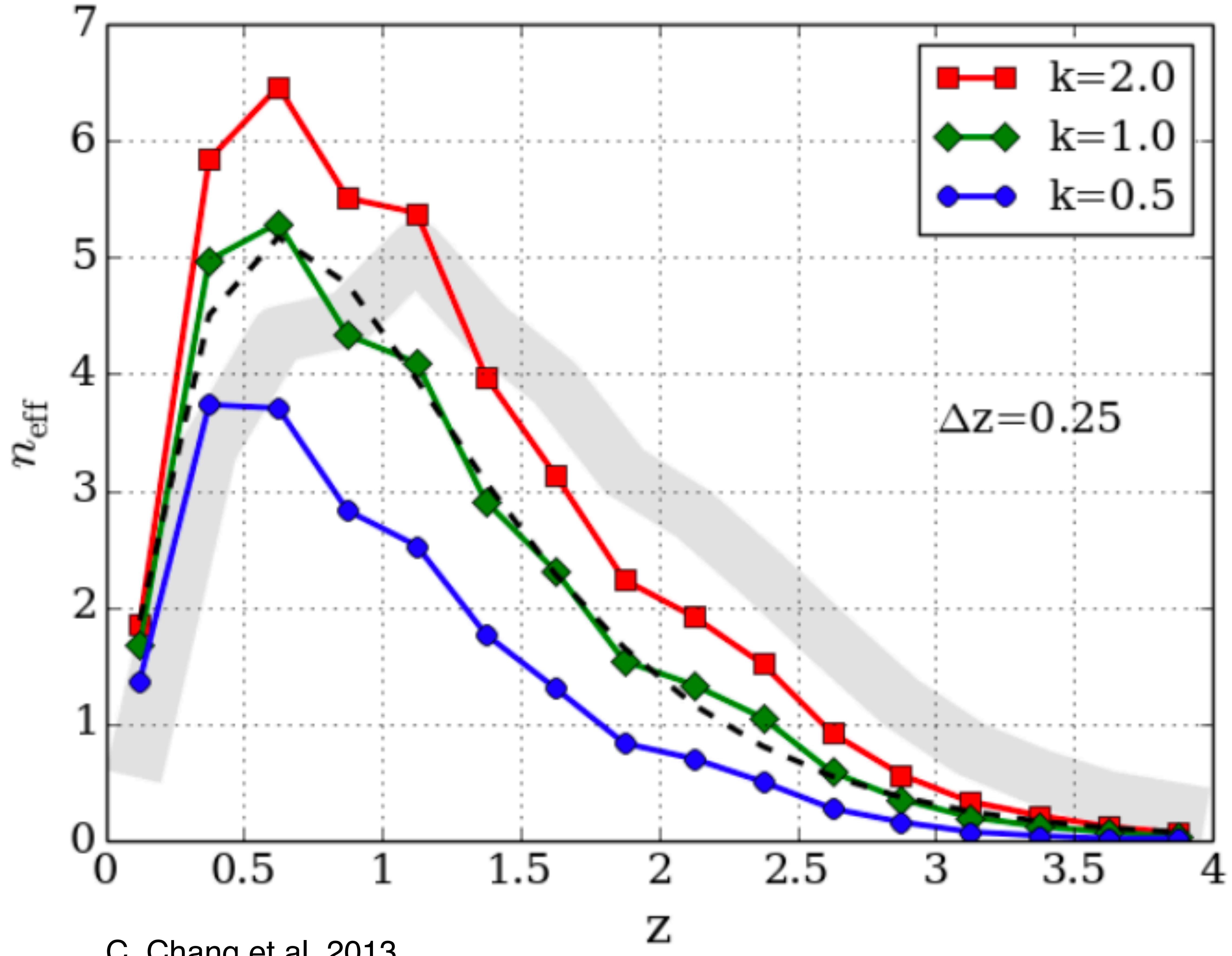
THANKS FOR YOU ATTENTION !

BACK UP

A.JIMENEZ - MUNOZ, J.F.MACIAS-PEREZ

ADDING FIELD GALAXIES

Field Galaxies Distribution



C. Chang et al. 2013

Field Galaxies

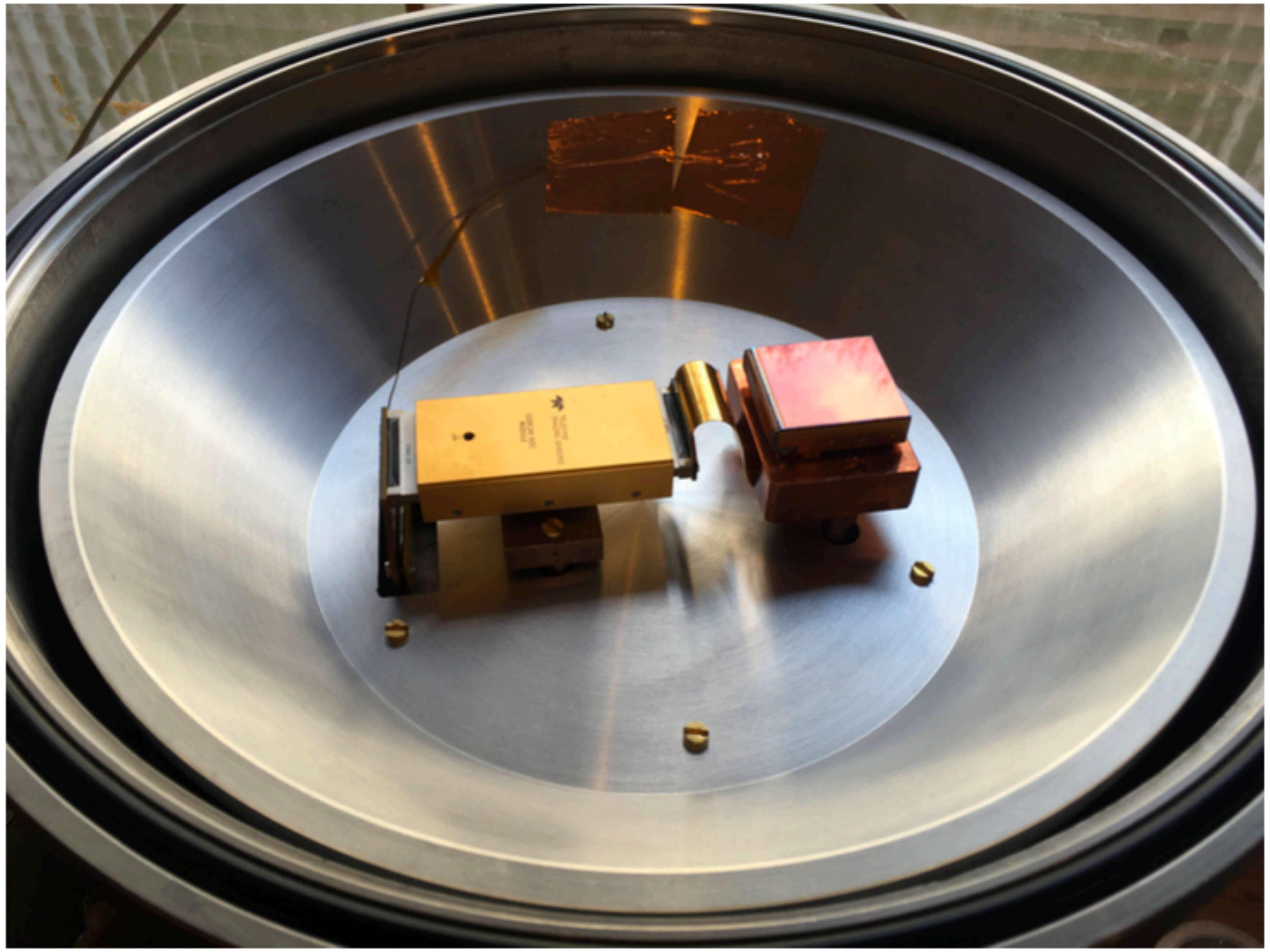
- **We add the Field Galaxies to the Cluster simulation just for a first test of the detection algorithm.**
- **For the real cluster injection method we only need the clusters.**
- **The distribution shows the number of galaxies as a function of the redshift**
- $$P(z) = z^{\alpha} \exp\left[-\left(\frac{z}{z_0}\right)^{\beta}\right]$$

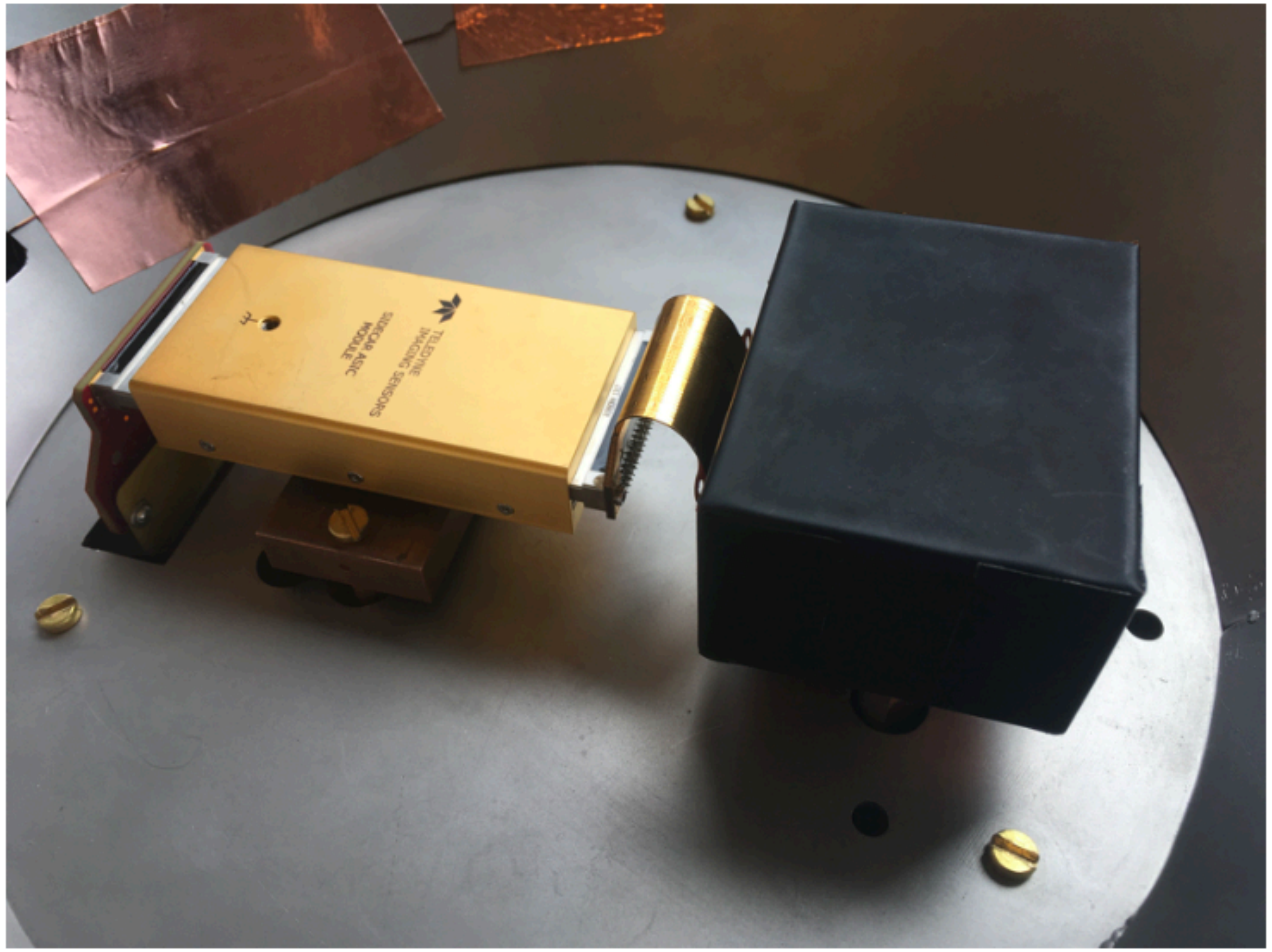
R500

$$\Delta = \frac{<\rho(r<R)>}{\rho_c(z)}.$$

$$R_\Delta \equiv \left(\frac{M_\Delta}{\frac{4}{3}\pi\rho_c\Delta} \right)^{\frac{1}{3}}$$

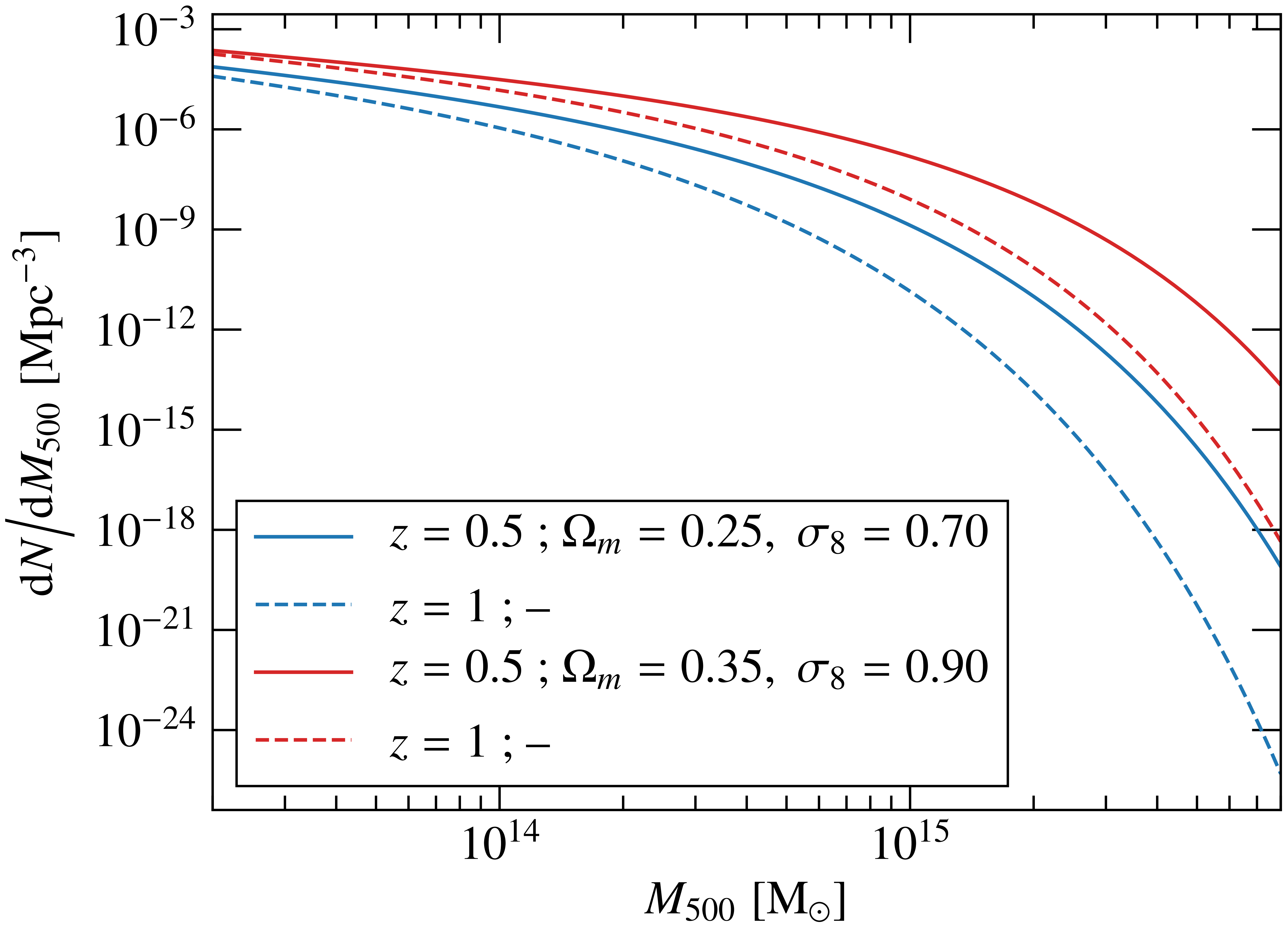
NISP





POWER SPECTRUM

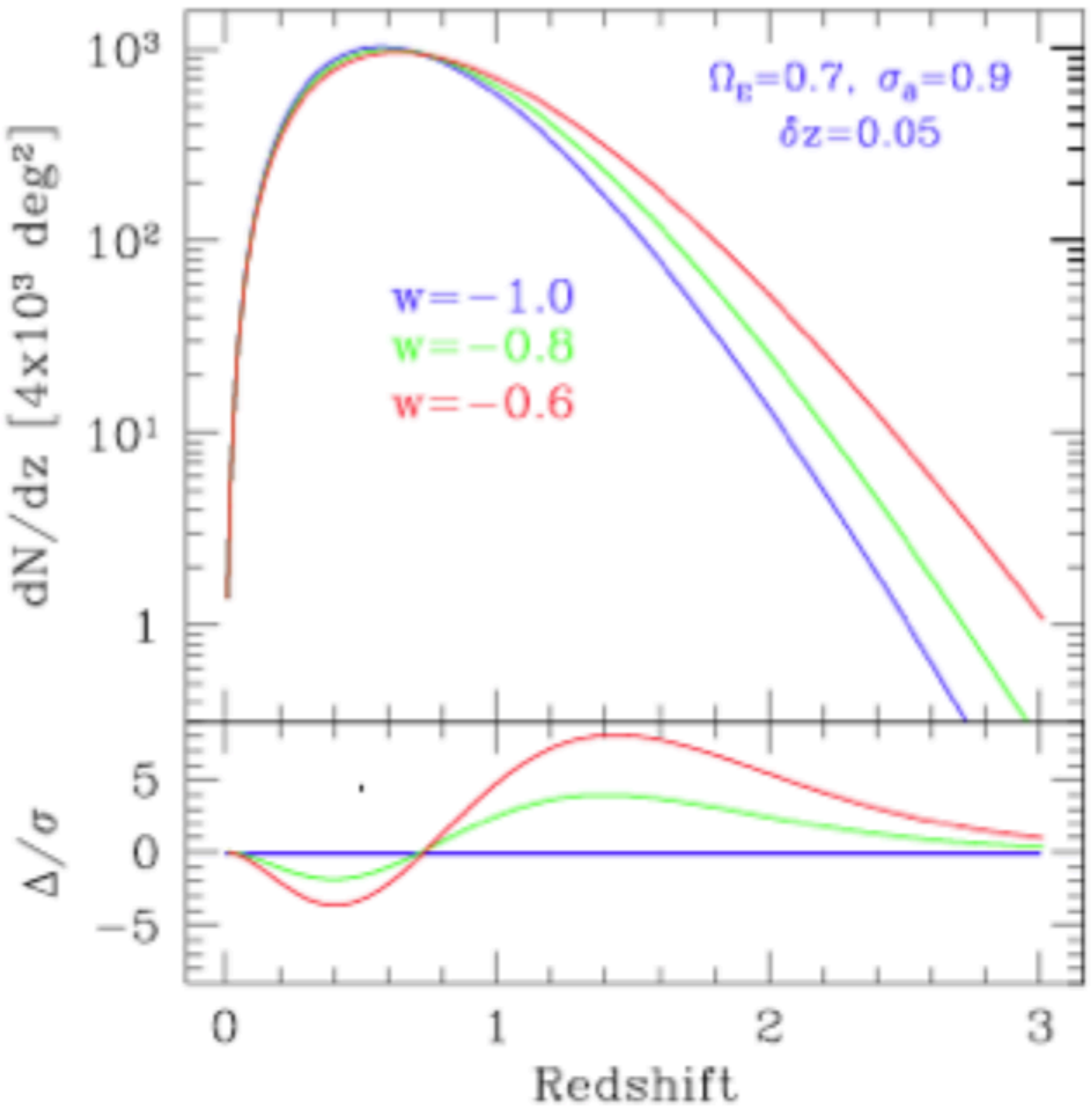
$$\frac{dN}{dz} = \int d\Omega \int \widehat{X}(z, M, l, b) \frac{dn}{dz dM d\Omega} dM$$

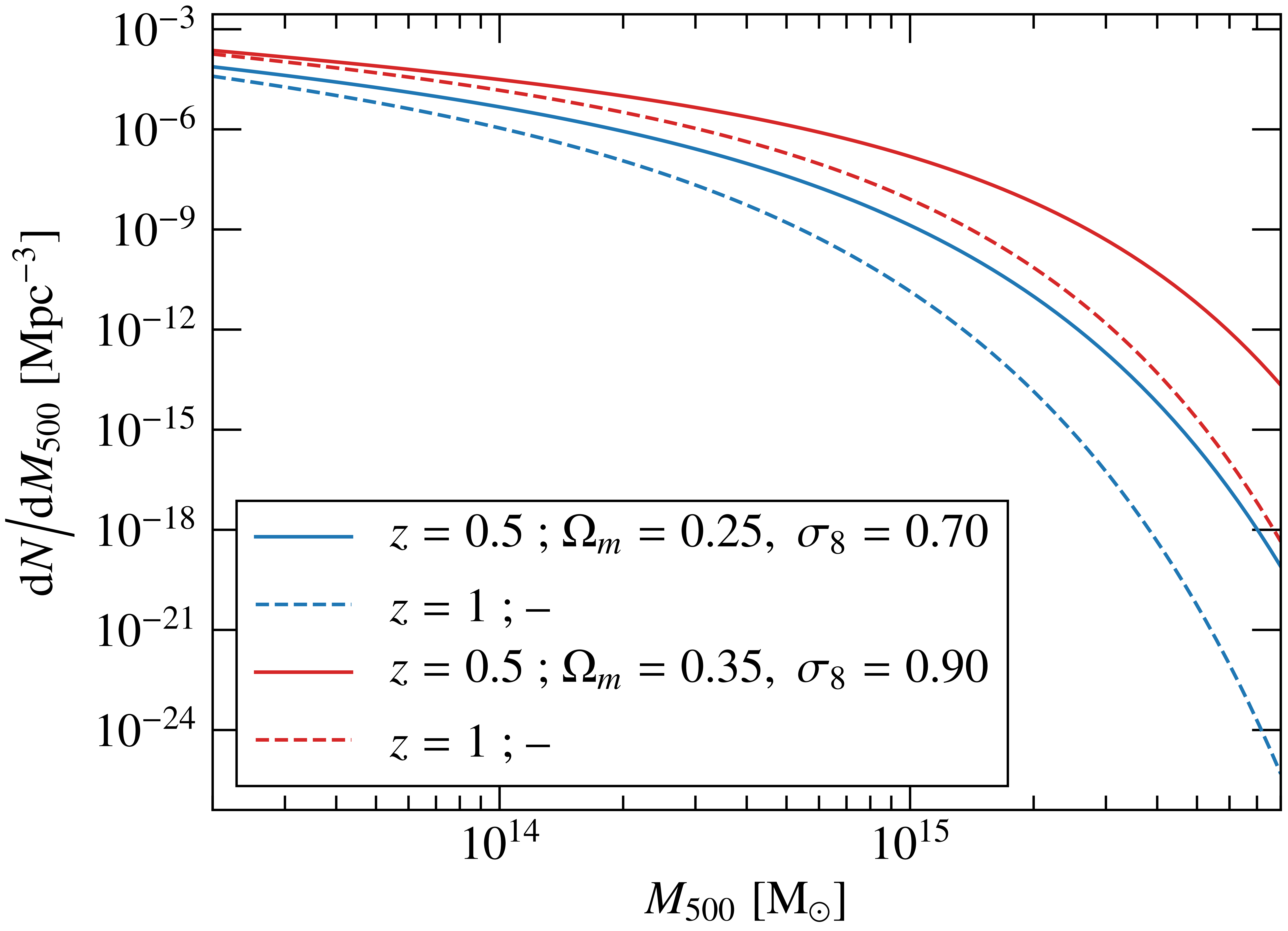


POWER SPECTRUM

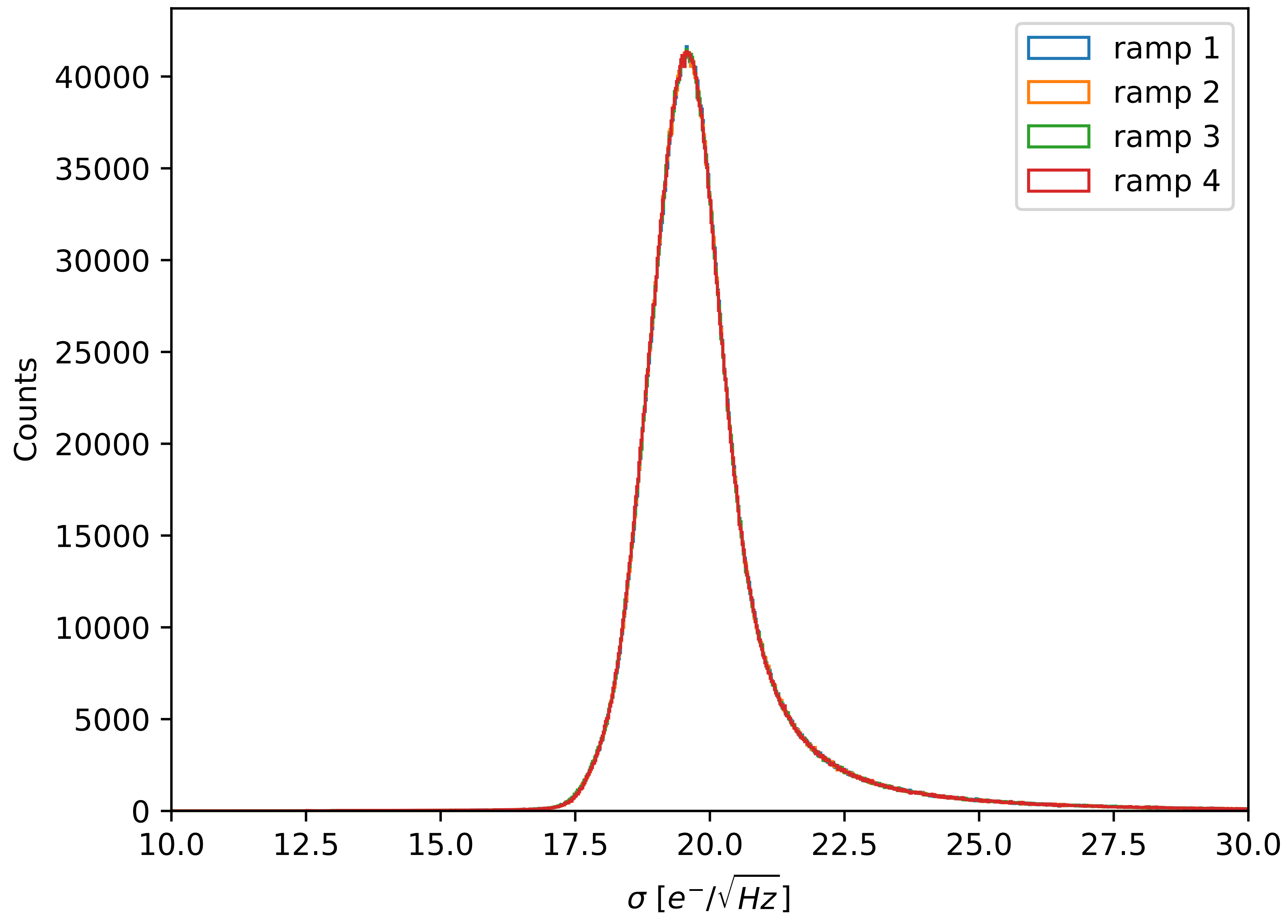
$$\frac{dN}{dz} = \int d\Omega \int \widehat{X}(z, M, l, b) \frac{dn}{dz dM d\Omega} dM$$

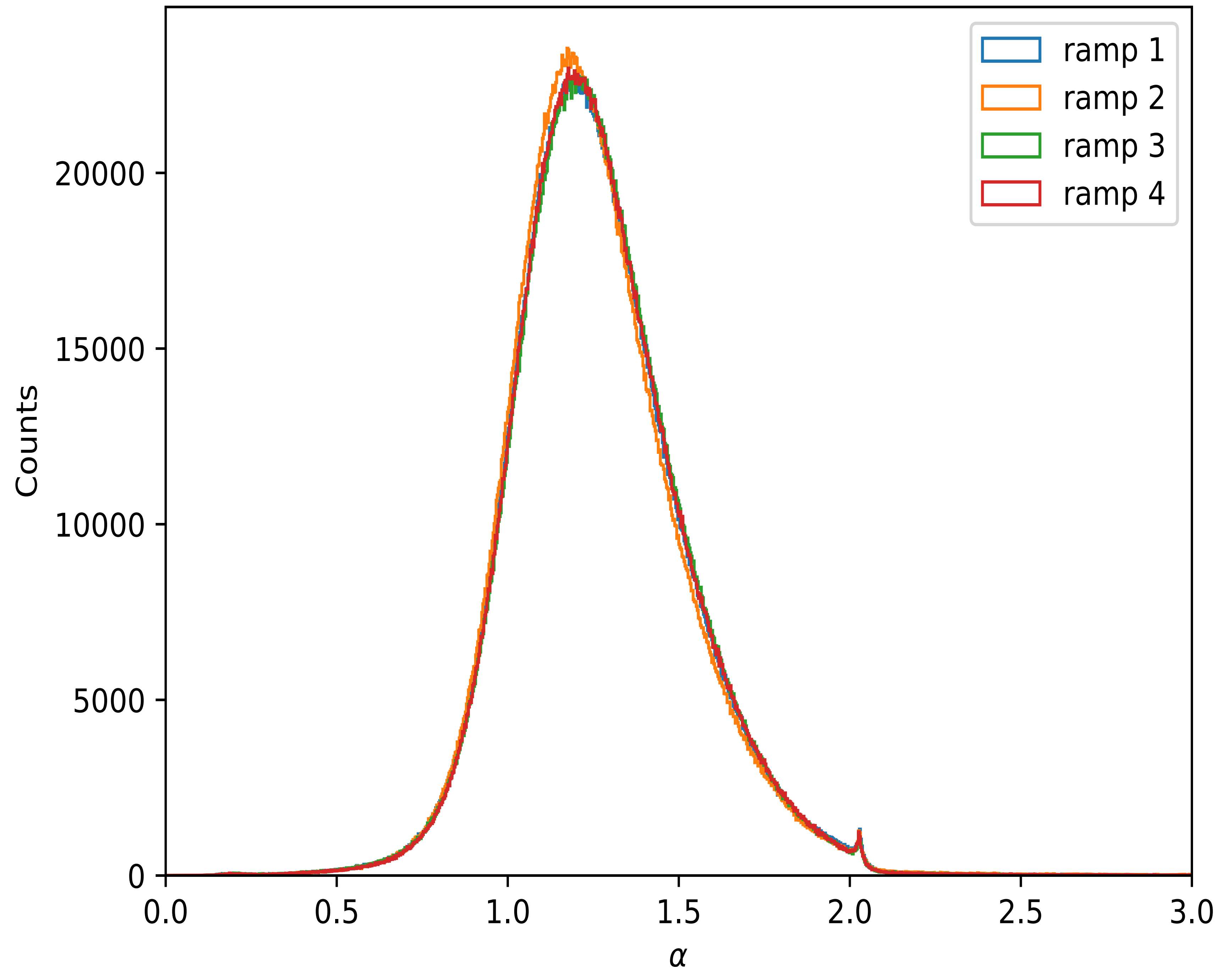
$$\frac{dn}{d\ln M} = M \cdot \frac{\rho_0}{M^2} f(\sigma) \left| \frac{d\ln\sigma}{d\ln M} \right|$$

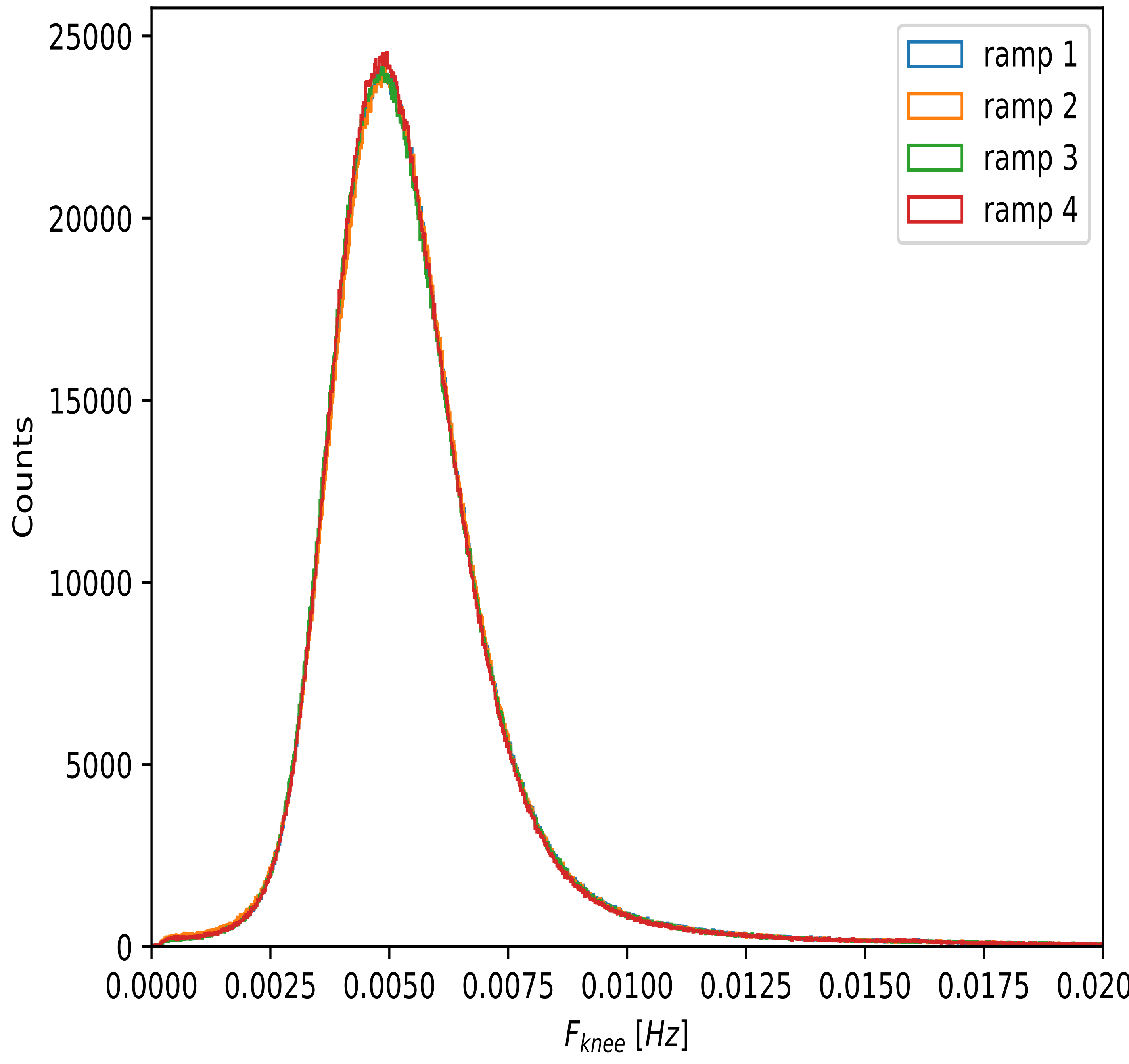




POWER SPECTRUM







OPTICAL AND IR IMAGES

- Visible and IR emission:
  - Light from stars in galaxies
- How to determine the Mass of the cluster ?
  - Richness (number of galaxies)
  - Luminosity profile
  - Gravitational lensing
  - Velocity dispersion
- Euclid Cluster Finder Algorithm

- Luminosity Function:
  - Surface density of galaxies as a function of the magnitude, $\phi(m^*)$
- Density Profile:
  - galaxy volume density distribution, $n(r)$

Name	CFC participation	Detection principle	Main reference	Cluster properties assumptions	Use of calibration field	Membership
AMASCFI	1,2,3,4	Adaptive kernel	Adami & Mazure (1999)	Typical size and $m_H^\star$ calibration	Yes	X
AMICO	1,2,3,4	Optimal filtering	Bellagamba et al. (2018)	LF and profile	No	✓
HCFA	3,4	Hierarchical finder	Díaz-Sánchez (in prep.)	Typical size only	No	✓
PZWav	1,2,3,4	Wavelet adaptive	Gonzalez (2014)	Typical size and $m_H^\star$ evolution	No	X
sFoF	1,2,3,4	Friends-of-friends	Farrens et al. (2011)	None	Yes	✓
WaZP	1,2,3,4	Wavelet	Benoist (2014)	Typical size and $m_H^\star$ evolution	Yes	✓
RedGOLD	1,2	Red sequence	Licitra et al. (2016a)	–	–	–
Voronoi	1	Voronoi tessellation	Iovino (in prep.)	–	–	–

R. Adam et al. 2019

NASA Hubble Space Telescope Image - STScI-2019-58

THE 300 PROJECT

- Fundamental equations of gravitation, hydrodynamics and perhaps radiative cooling and transfer are solved for a large number of points (arranged either on a grid or following the trajectories of the fluid flow)
- Resolution: $m_{DM} + m_{gas} = 1.5 \times 10^9 h^{-1} M_\odot$
- Fluid equations
- SPH smooth particle hydrodynamics. Fluid equations, gravity equations as a mesh

$$\rho_i = \sum_j m_j W(\frac{r_{ij}}{h_i})$$

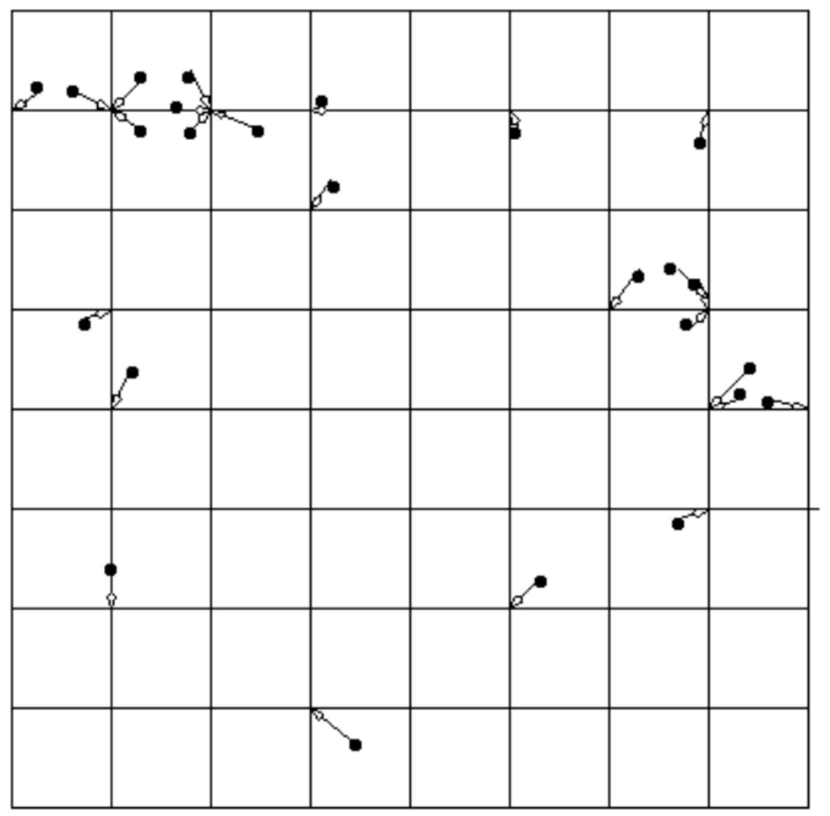
$$A_i \rho_i = \sum_j A_j m_j W(\frac{r_{ij}}{h_i})$$

$$p_i = \frac{1}{\rho_i} \sum_j p_j m_j W(\frac{r_{ij}}{h_i})$$

$$\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} = -\frac{1}{\rho} \nabla p$$

$$\frac{\mathrm{d}\vec{v}_i}{\mathrm{d}t} = -\sum_{j=1}^{N} m_j \left[f_i \frac{P_i}{\rho_i^2} \nabla_i W_{ij}(h_i) + f_j \frac{P_j}{\rho_j^2} \nabla_i W_{ij}(h_j) \right]$$

Moving Particles to Mesh Points in a Particle Mesh Method



$$\frac{\partial^2 \phi}{\partial x^2} = \rho(x)$$

$$\frac{\frac{\phi(x+\Delta)-\phi(x)}{\Delta} - \frac{\phi(x)-\phi(x-\Delta)}{\Delta}}{\Delta} = \frac{\phi(x+\Delta)+\phi(x-\Delta)-2\phi(x)}{\Delta^2} = \rho(x)$$

$$\begin{aligned}
\phi(x+\Delta)+\phi(x-\Delta)-2\phi(x) &= \sum_k \hat{\phi}(k) \{\exp(ik(x+\Delta)) + \exp(ik(x-\Delta)) - 2\exp(ikx)\} \\
&= \sum_k \hat{\phi}(k) \exp(ikx) \{\exp(ik\Delta) + \exp(-ik\Delta) - 2\} \\
&= \sum_k \hat{\phi}(k) \exp(ikx) \{2\cos(k\Delta) - 2\} \\
&= \sum_k \hat{\phi}(k) \exp(ikx) \{-4\sin^2(k\Delta/2)\} \\
&= \Delta^2 \sum_k \hat{\rho}(k) \exp(ikx)
\end{aligned}$$

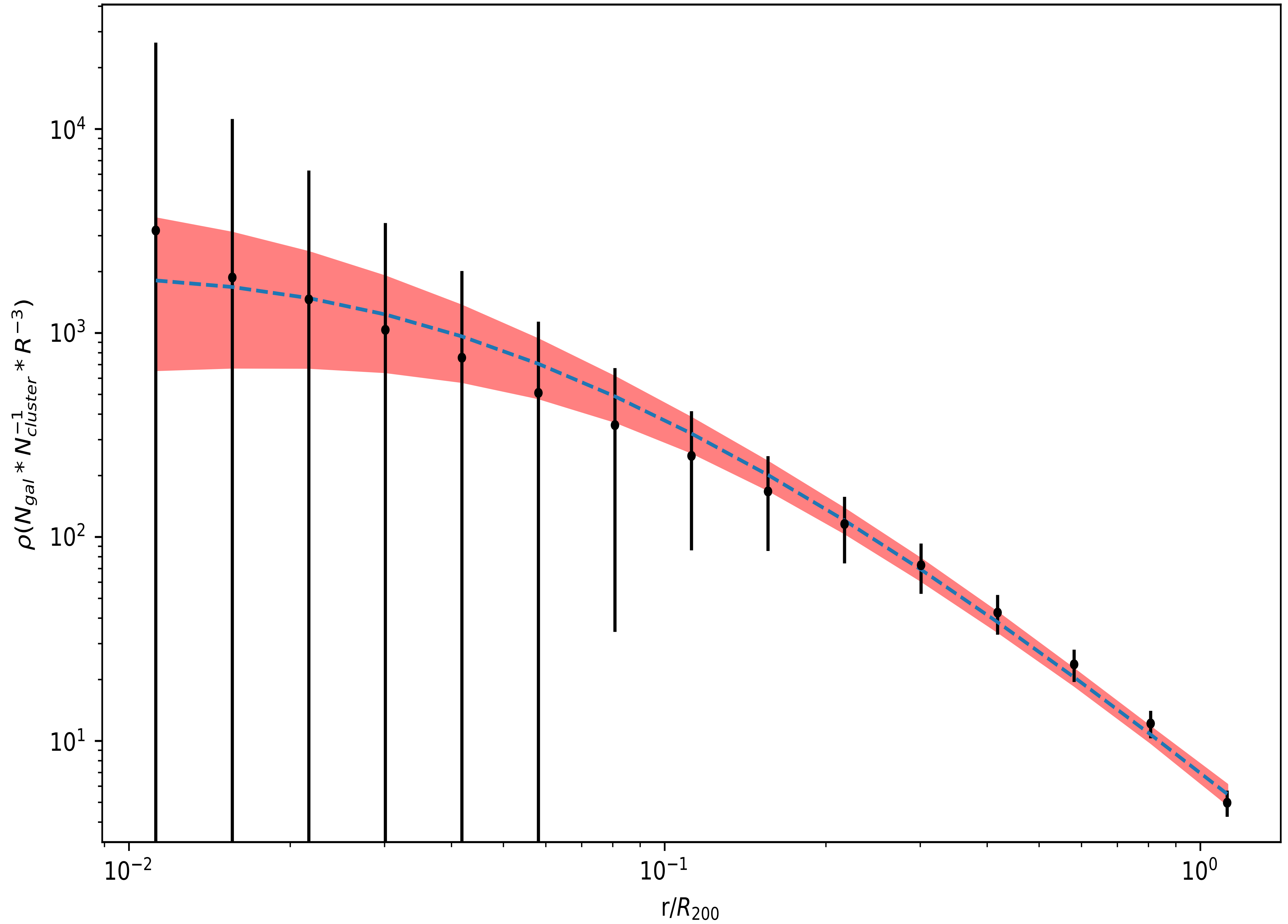
$$\hat{\phi}(k) = -\frac{\hat{\rho}(k)}{4\Delta^2 \sin^2(k\Delta/2)} \approx -\frac{\hat{\rho}(k)}{k^2}$$

3D PROFILE OF THE CLUSTER SPACE DENSITY

$$\mu = gal/vol/clusters$$

$$error = \sqrt{\mu/vol}$$

3D NFW function



Normalization

$$n(r/R_{200}) = \frac{n_0}{(cr/R_{200})^{\beta}(cr/R_{200}+1)^{\alpha}}$$

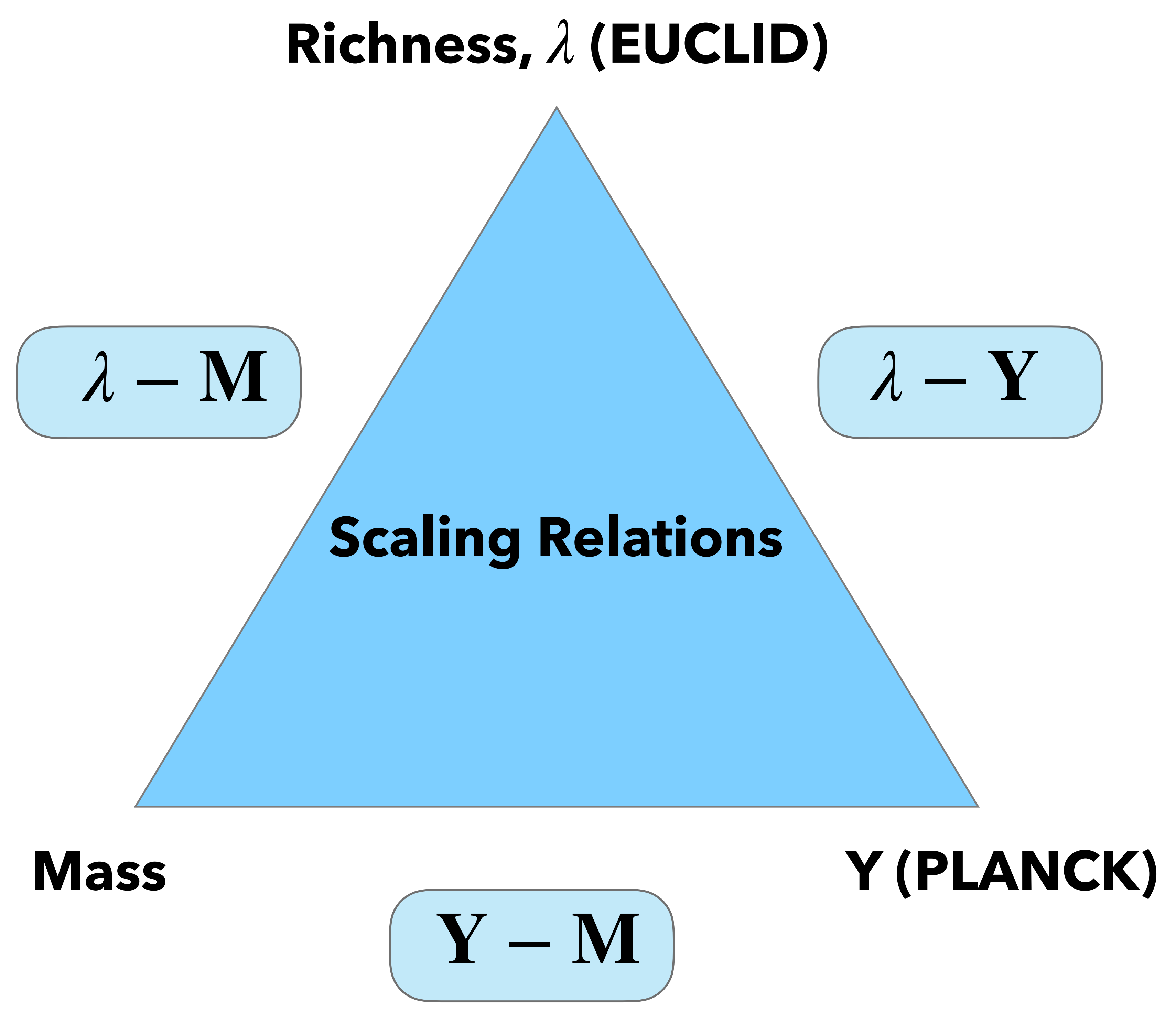
Concentration Exponent Exponent


Z = 0.4
Z = 0.5
Z = 0.6
Z = 0.4 + Dark Galaxies
Z = 0.5+ Dark Galaxies
Z = 0.6 + Dark Galaxies
$\rho(N_{gal} * N_{cluster}^{-1} * R^{-3})$
r/R_{200}


Z = 0.8
Z = 1
Z = 1.4
Z = 0.8 + Dark Galaxies
Z = 1 + Dark Galaxies
Z = 1.4 + Dark Galaxies
$\rho(N_{gal} * N_{cluster}^{-1} * R^{-3})$
r/R_{200}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

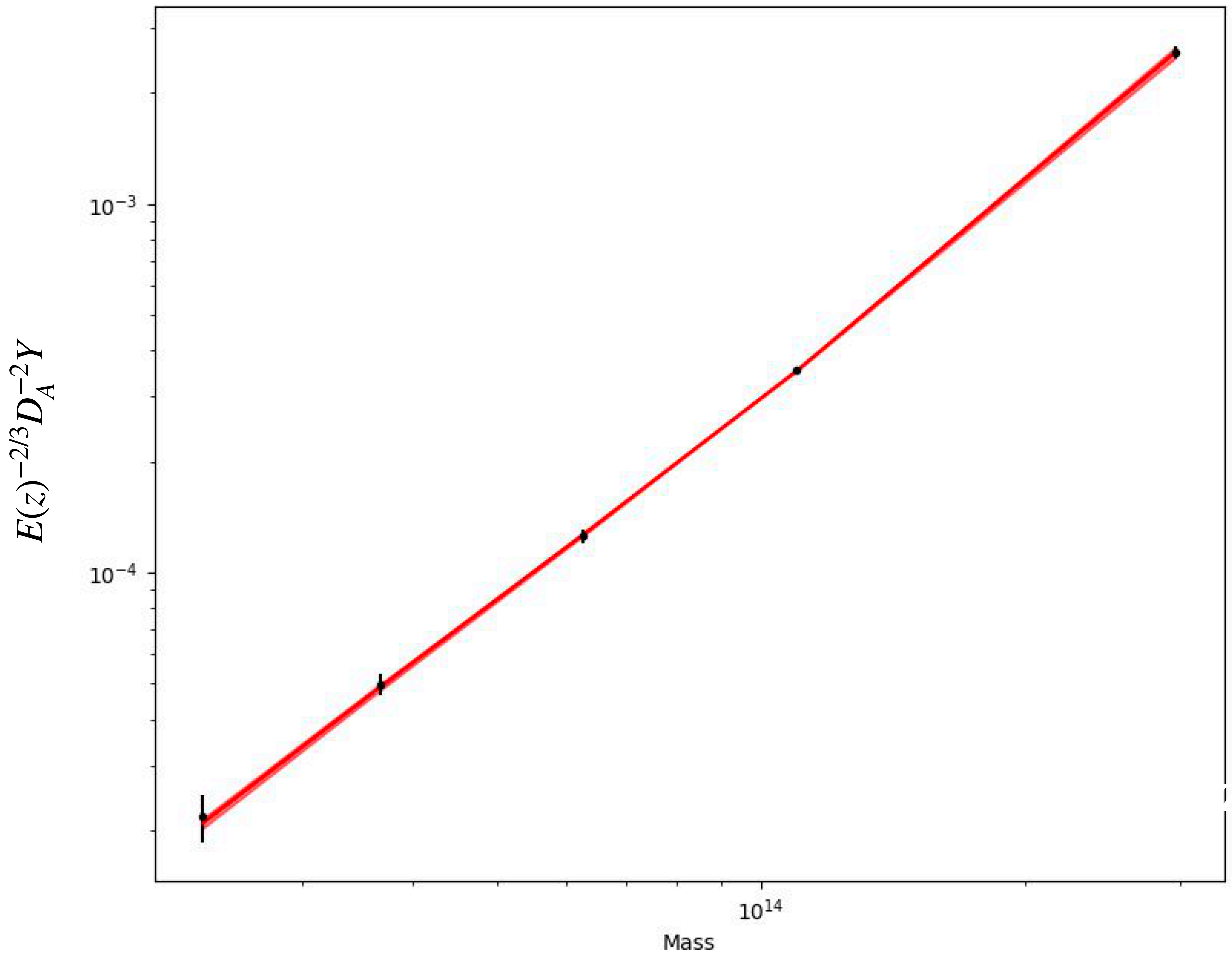
SCALING RELATIONS

- **Once we study the Selection Function, for doing Cosmology we need the mass**
- **Mass is not an observable**
- Scaling Relation: The link between two physical properties such as Mass, Number of Galaxies (Richness), SZ (Sunyaev–Zeldovich) effect…etc
- Mock EUCLID catalogue -> Richness, Mass
- SZ Sunyaev–Zeldovich effect-> Distorsion of CMB electromagnetic spectrum due to Inverse Compton Scattering with ionized gas of the cluster , $\mathbf{y} \propto \mathbf{P_e}$
- SZ is measured through the Compton Parameter, Y
- **Estimate mass of a cluster by scaling relations of observables**
    - Since we have Planck data, and the Scaling Relation of SZ effect with Mass, we will try to use this.

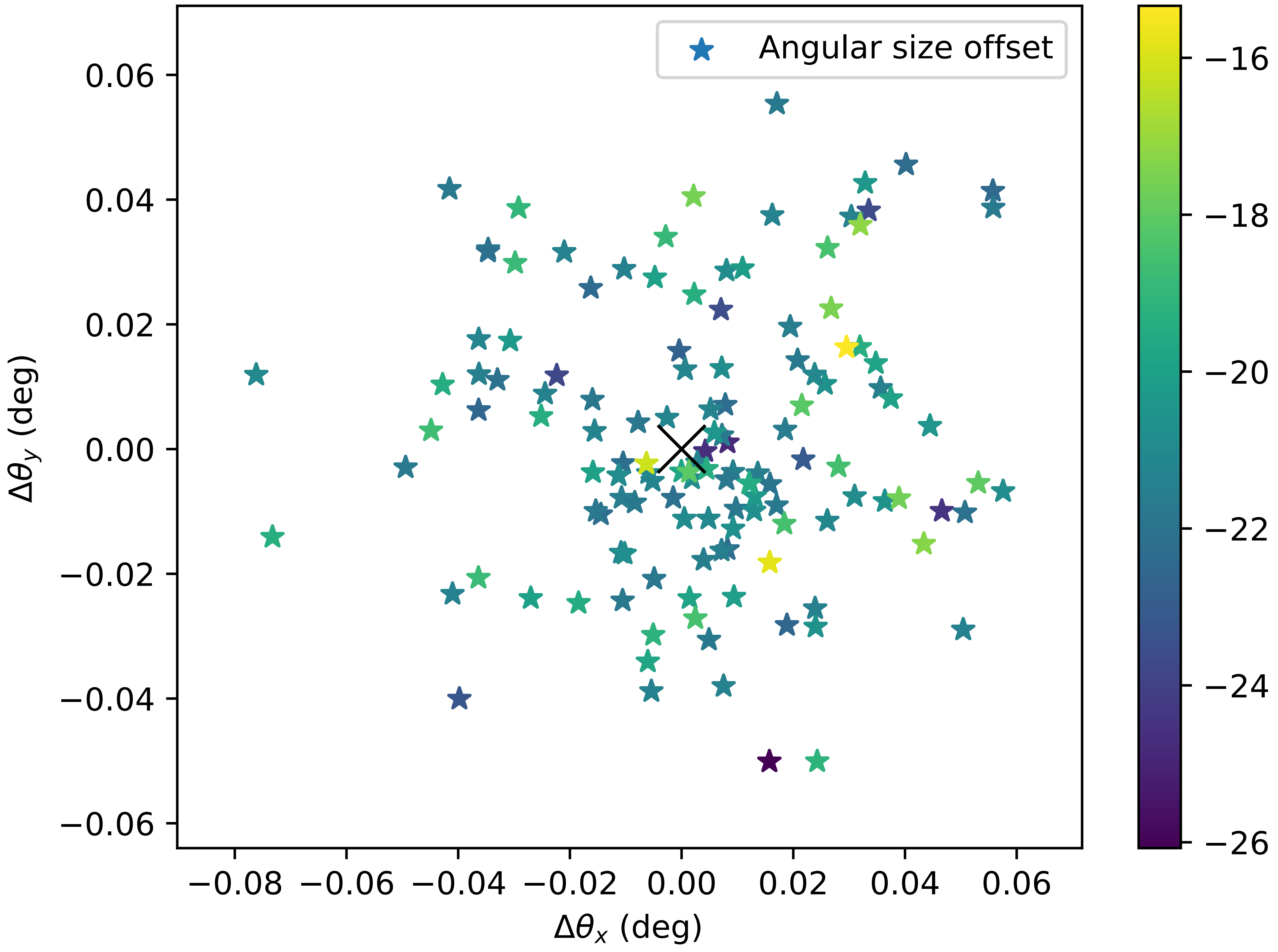


SCALING RELATIONS

- For each cluster in EUCLID we compute the Compton Parameter Y
- We create bins in Mass and Redshift
- We stacked the Y and Mass value for each cluster in a bin (black points in the figure)
- Using Planck noise maps we have a realistic approximation
- We recover the Y vs Mass Scaling Relation
- **It is possible to use Planck Data to calibration Scaling Relations for EUCLID**
- **On going work: Richness vs Mass and Richness vs SZ.**



EXAMPLE OF A CLUSTER

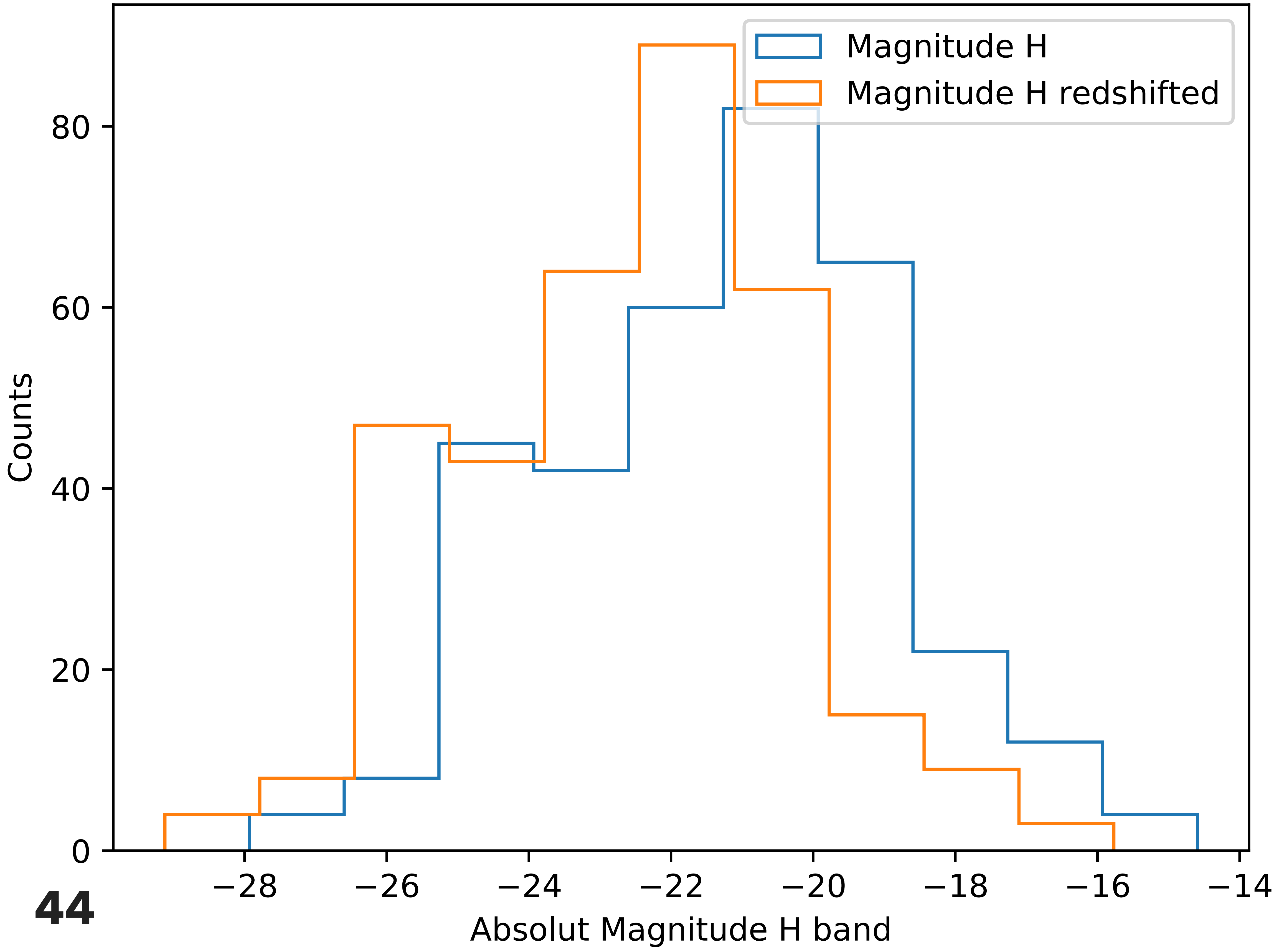


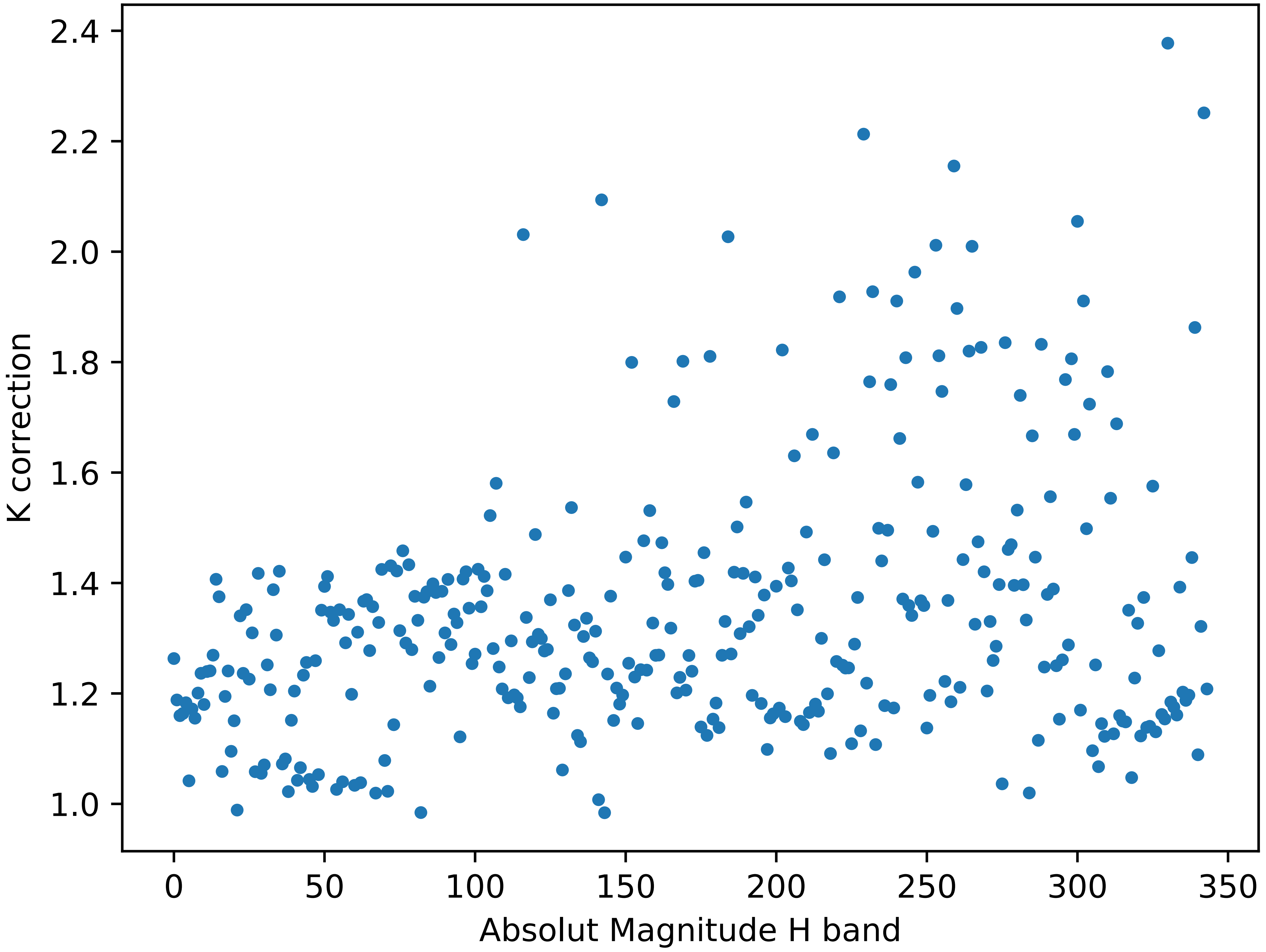
- *Considerations:*
  - *DM Particles > 20 (For having a galaxy)*
  - *Luminosity > 0 (For having stars —> A galaxy)*
  - *Only Direct substructures from the Host Halo (not sub-substructures, for first halo ~ 20)*
  - *Resolution > 0.99*
  - *h = 0.677*

K CORRECTION – HD 0323 CLUSTER

- ***Corrections from Absolute to Apparent magnitude:***
  - *K correction - a correction factor needed to convert from the observed band to the rest-frame band*
  - *μ - relationship between bolometric (ie, integrated over all frequencies) flux S and bolometric luminosity L*

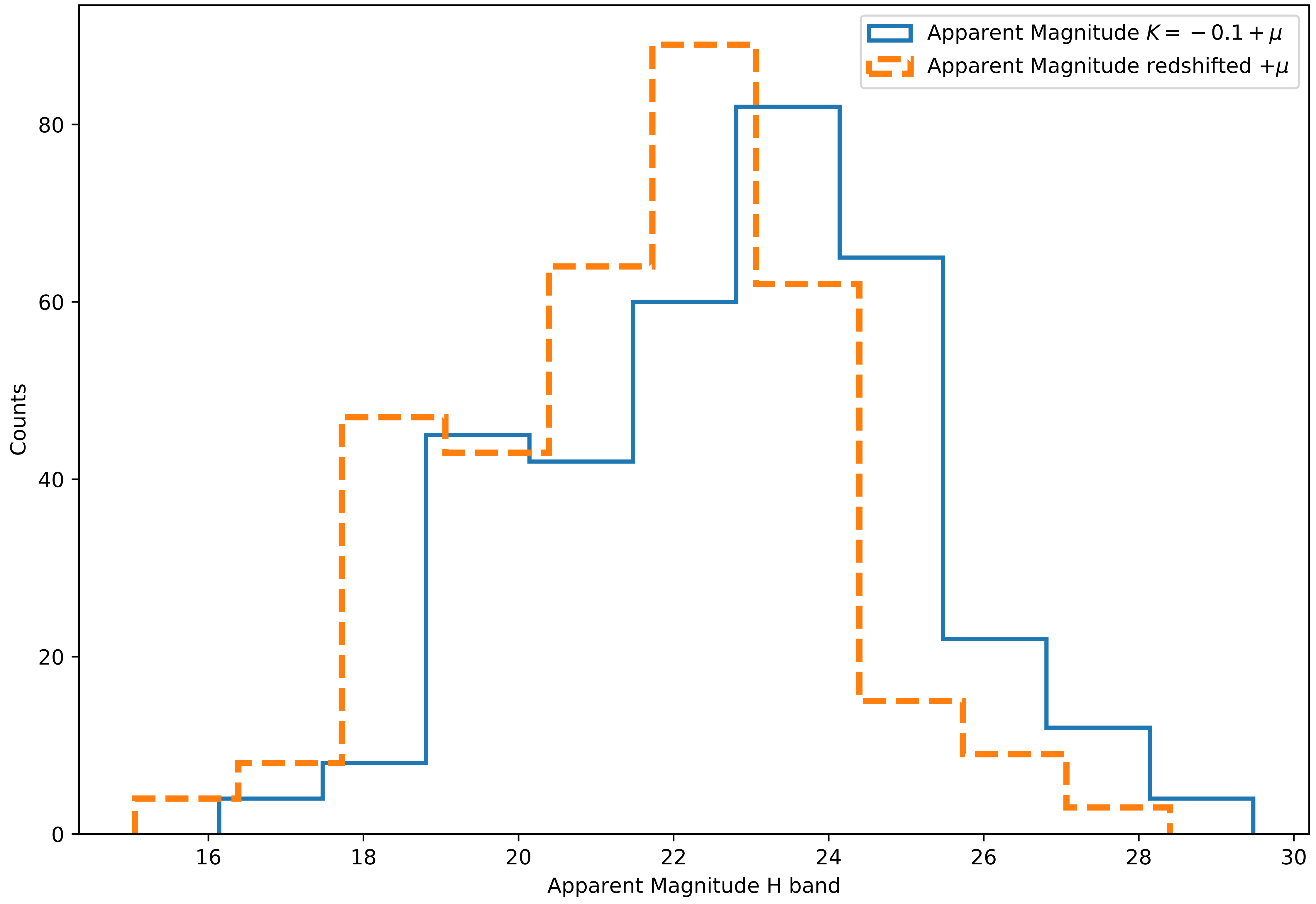
- $m_H = M_H + \mu + K_H$
- $\mu = 5 \log \frac{D_L}{10pc} \mid D_L = (1+z)^2 D_A$



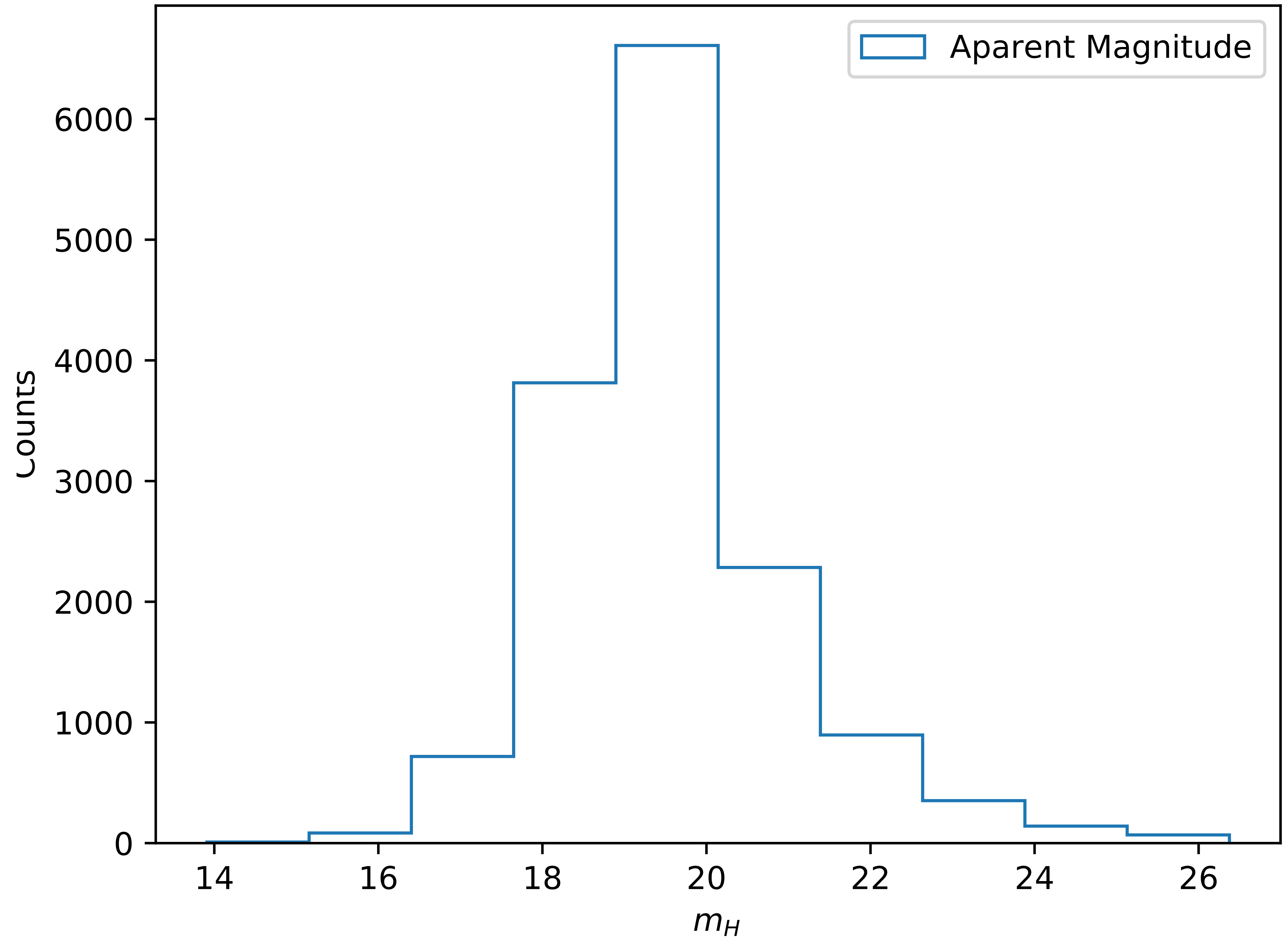


APPARENT MAGNITUDE – COMPARISON

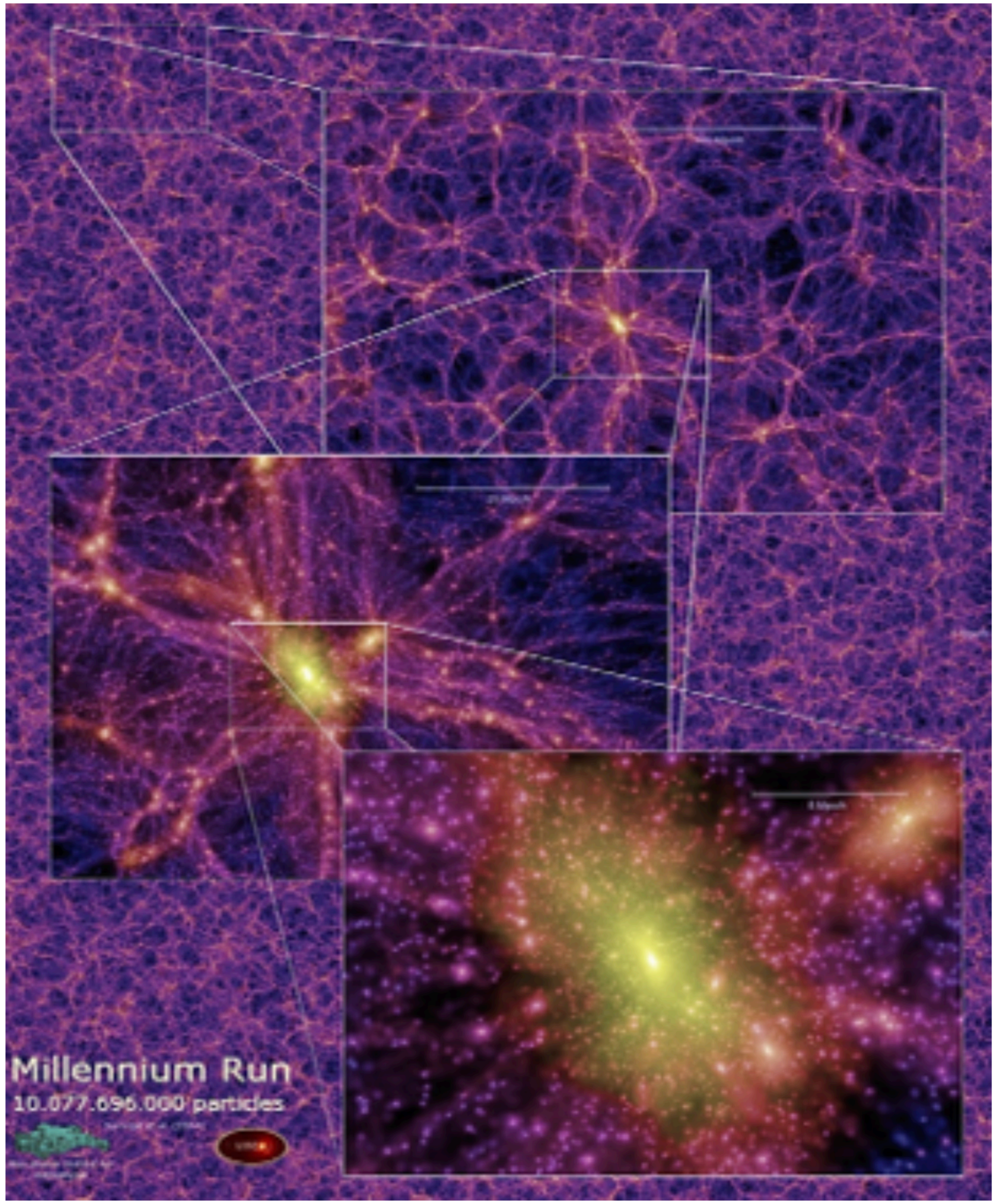
- HD CLUSTER



- 324 NON-HD CLUSTERS



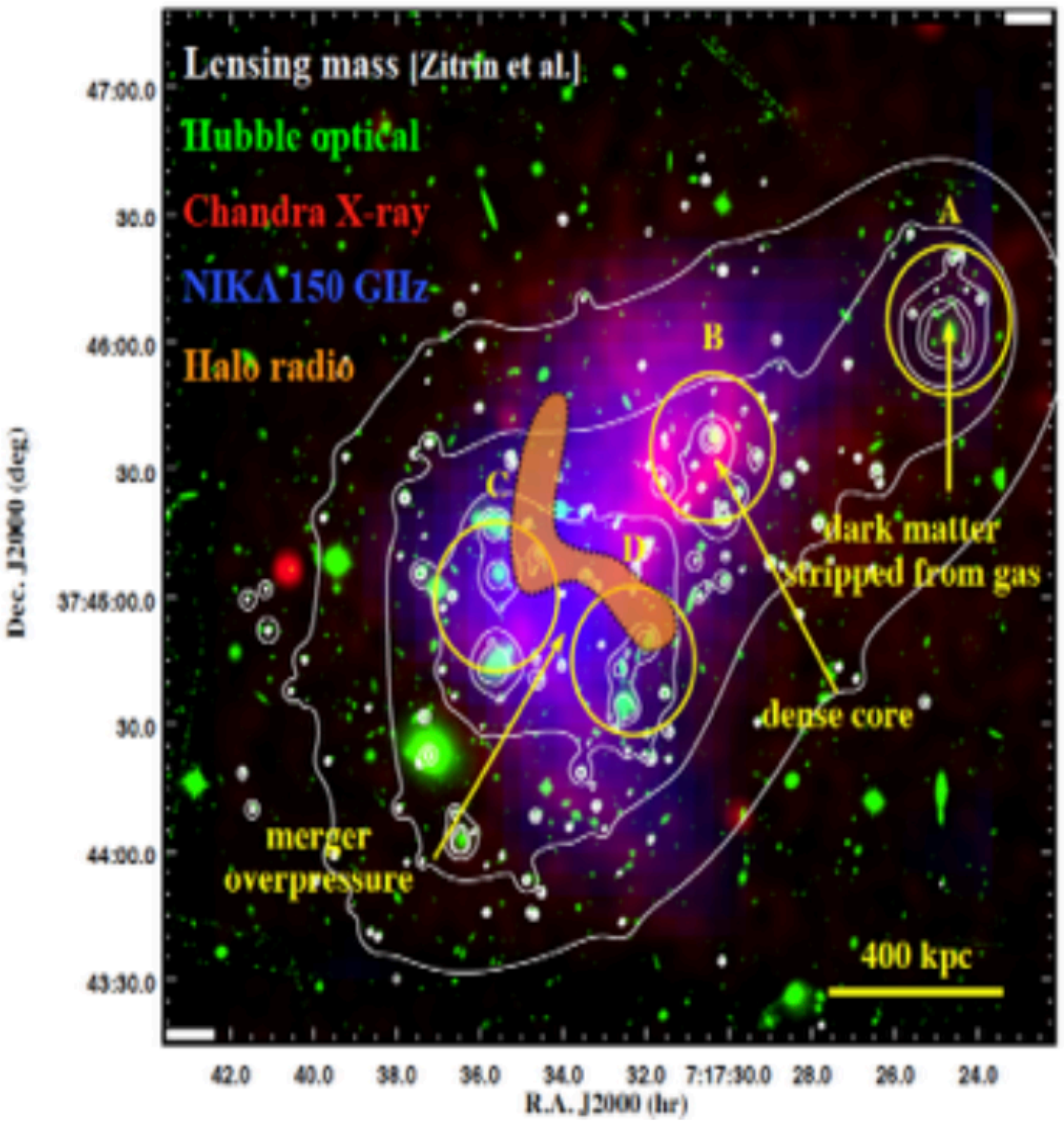
K CORRECTION – HD 0323 CLUSTER



- gravity governs large scale structure evolution via gravitational collapse
- large scale structures in the universe organise in the form of filaments and halos
- the distribution in mass and redshift of the halos is given by the mass function, which depends on cosmology (Press & Schechter 1974)
- halos are rescaled copies one of each other, their density radial distribution has a generic form (Navarro, Frenk & White 1997)
- collapse does not proceed to a point but reaches virial equilibrium
- most massive halos form last and give rise to clusters of galaxies

MULTI WAVELENGTH APPROACH

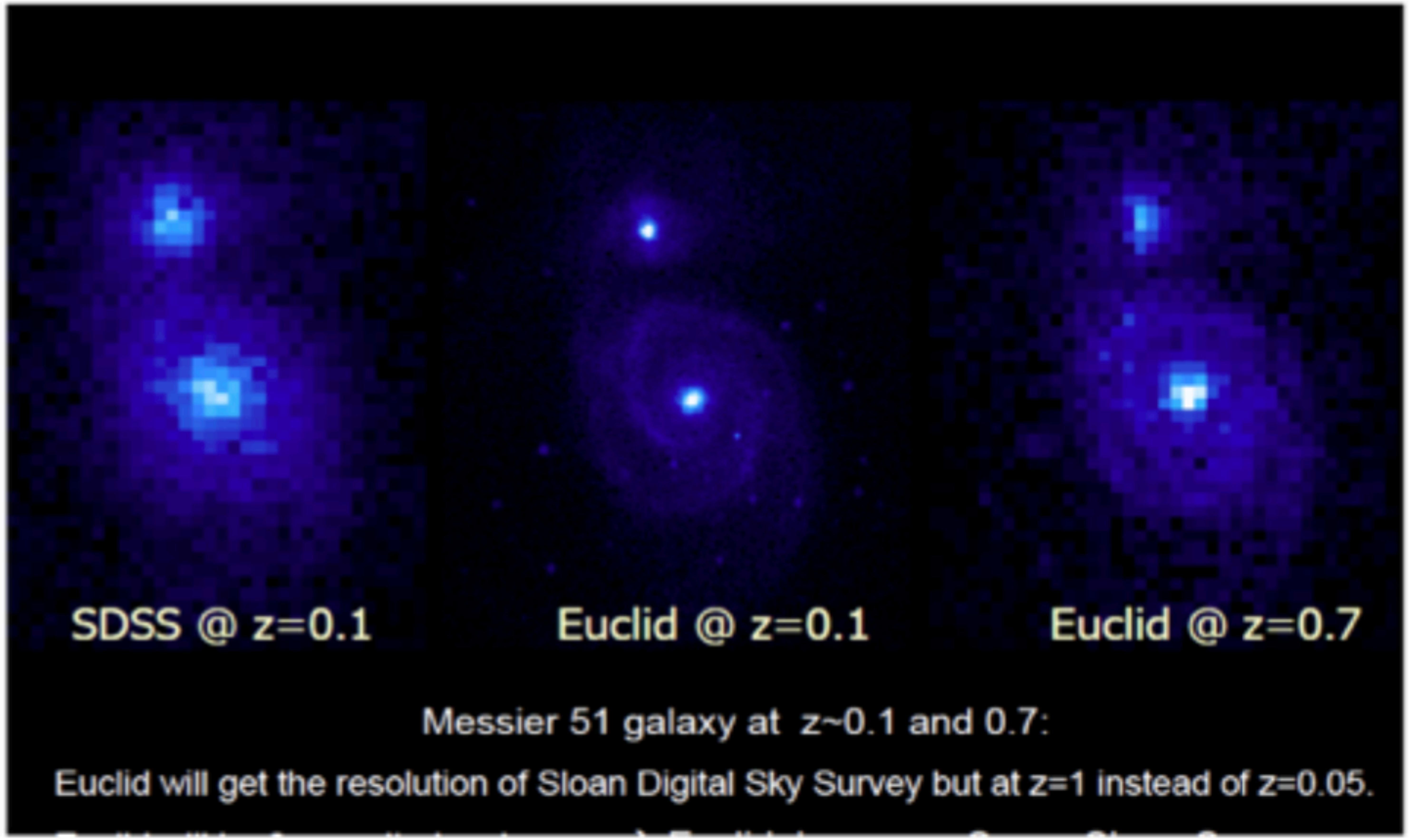
Courtesy of R. Adam, NIKA collaboration



- member optical & IR galaxy distribution (density distribution proxy and cluster detection)
  - number of galaxies, richness
  - radial profile
  - velocity dispersion
  - redshift of the cluster
- weak & strong lensing on background galaxies (density distribution)
- X-ray emission from ICM hot gas (gas density and cluster detection)
- Sunyaev-Zeldovich effect (inverse Compton scattering of hot electrons with CMB photons)
  - thermal (gas pressure and cluster detection)
  - kinetic (velocity distribution)
- radio emission (central AGN, radio halo in shocks), helps reducing bias in mass estimates

Multi-wavelength approach is mandatory

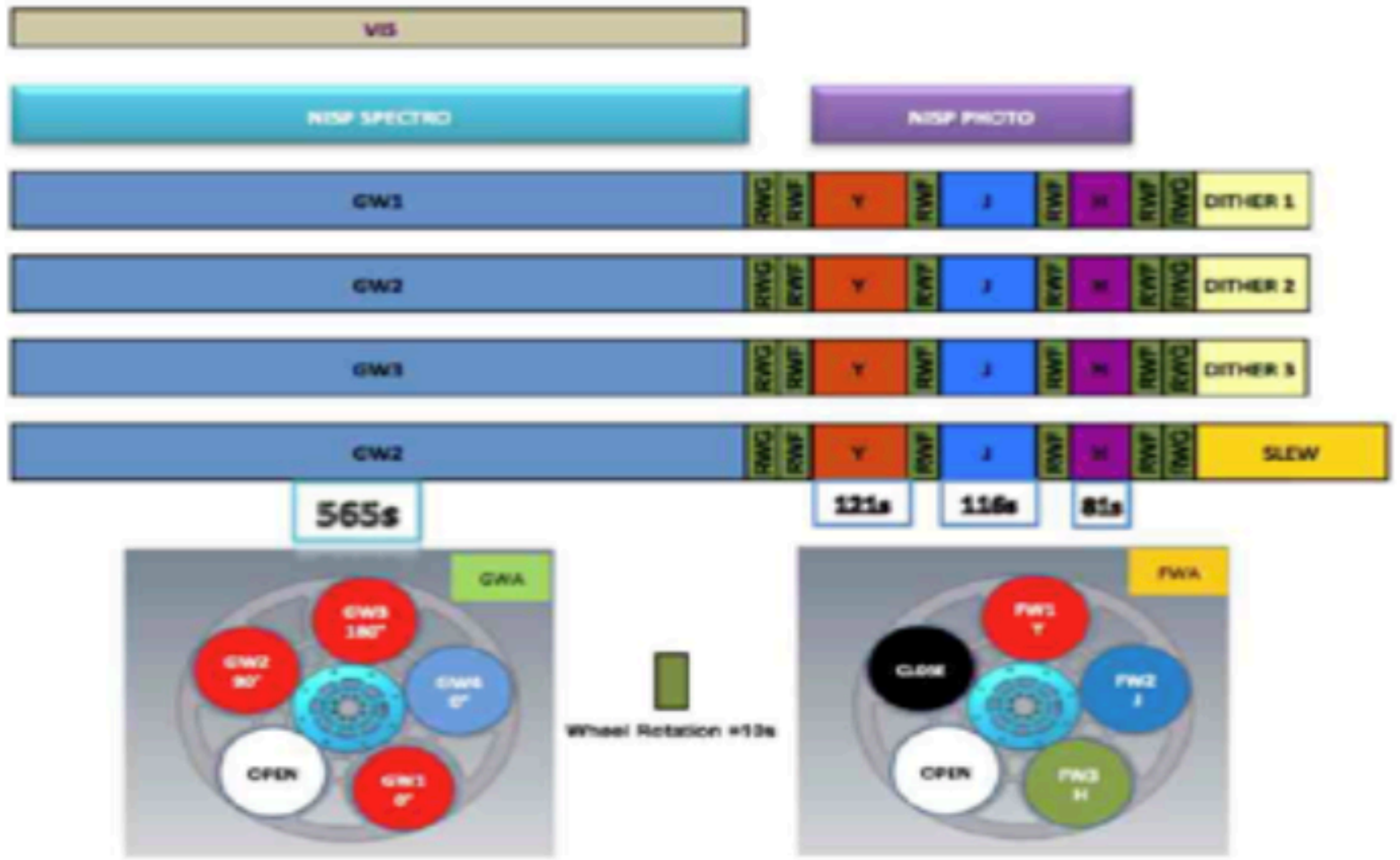
COMPARING SURVEYS

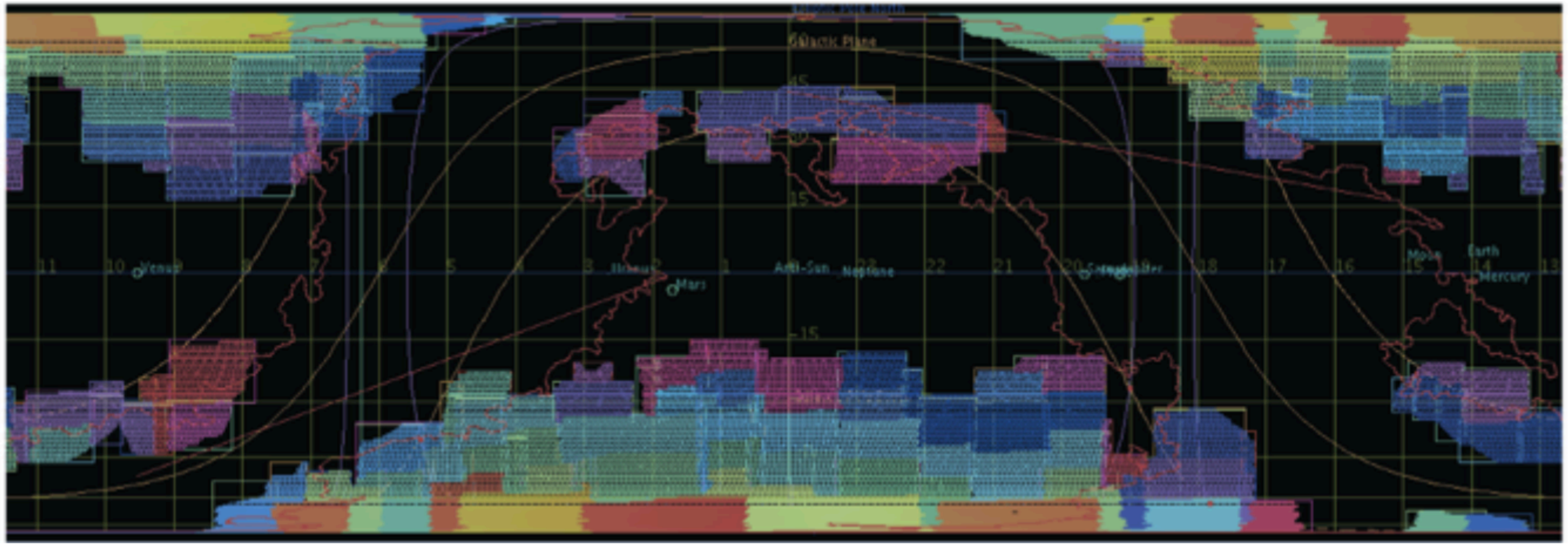


- need to use ground-based data for photo-z reconstruction of galaxies: agreement with ground-based surveys like CFHT, KIDs, LSST, DES, and others being studied

NISP CYCLE

- Observing 4 cycles of about 900 s followed by depointing (slew)
- Calibration on specific targets
- 15000 deg2 covered in 6 years

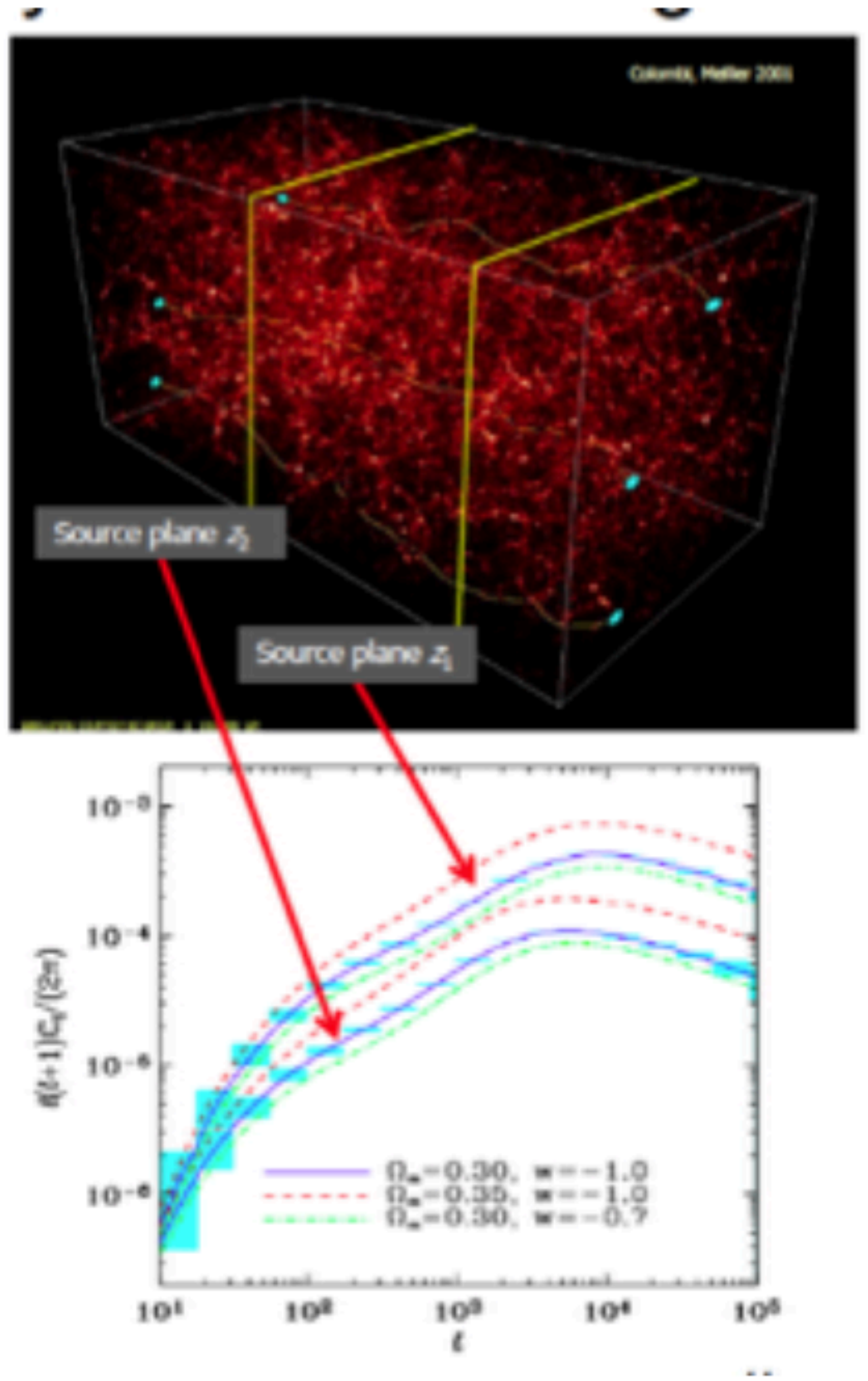




COSMOLOGICAL PROBES EUCLID

Weak lensing (WL)

- distribution of matter, expansion history, growth rate, tomography
- 3-D cosmic shear measurements $0 < z < 2$
- shape and photo-z from optical and NIR data
- 1.5 billion galaxies



Galaxy clustering (GC)

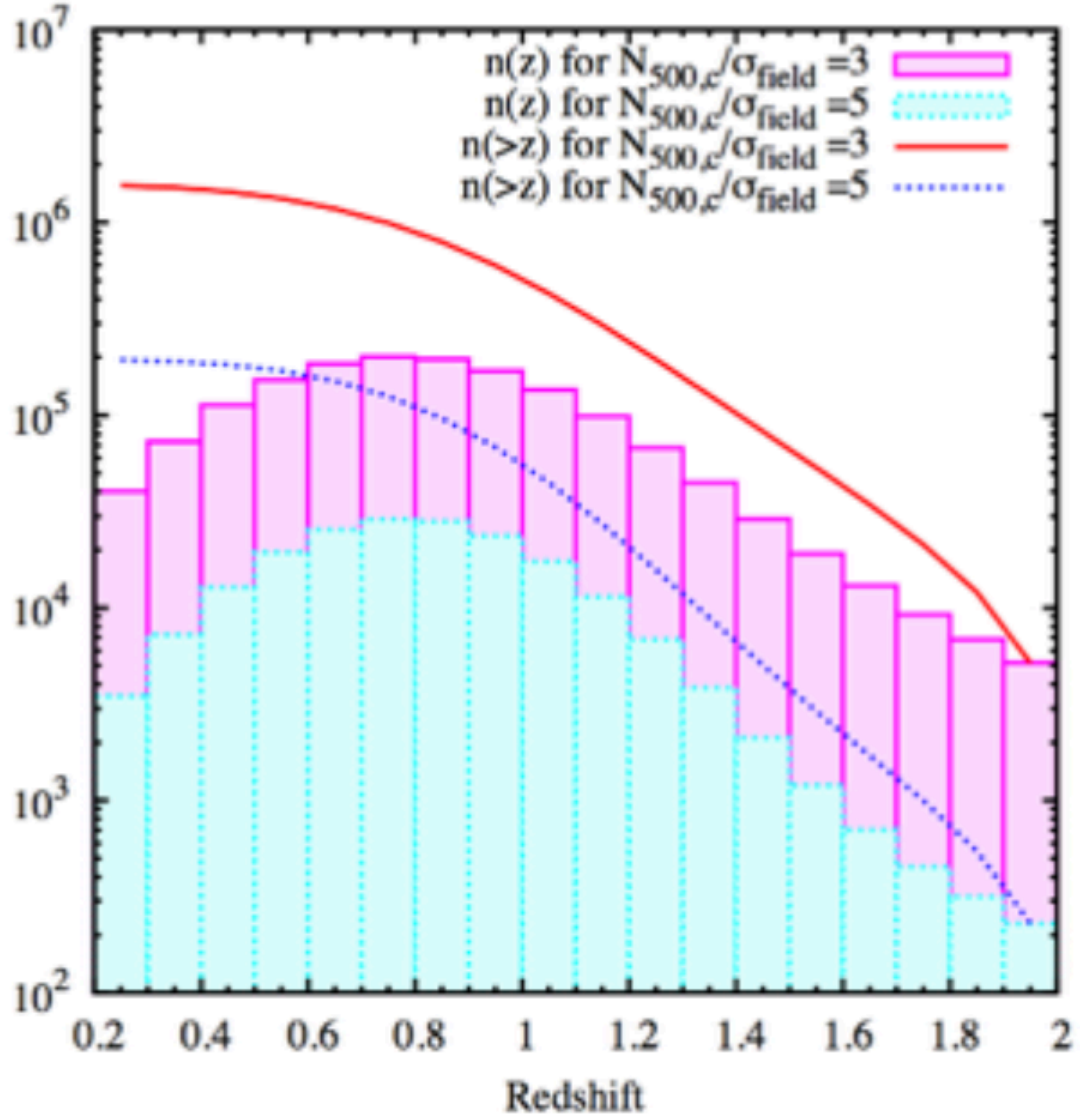
- distribution of matter, expansion history, growth rate, tomography
- 3-D position measurements $0.7 < z < 2$
- 3D distribution of galaxies from spectroscopy redshift
- measure position of 50 millions galaxies

Clusters of galaxies

- measure cluster number counts as a function mass and redshift, power spectrum statistics,
- detection of about 60000 clusters

WHY EUCLID

- ✓ Large sky coverage: covers both north and south hemisphere
- ✓ Strong statistics
- ✓ Relative well control selection function: all LCDM clusters with M > 2 10^{14} M⊙ are detected at 3 sigma up to redshift 2
- ✓ High redshift tail
- ✓ Homogeneous detection properties across the sky
- ✓ State-of-art weak lensing mass estimates
- ✓ Multi-probe analysis: richness, radial profiles, velocity dispersion with spectroscopy
- ✓ Multi-wavelength synergy with other satellite experiments: Planck, e-Rosita, Athena+



EUCLID – LSST

Euclid & **LSST**

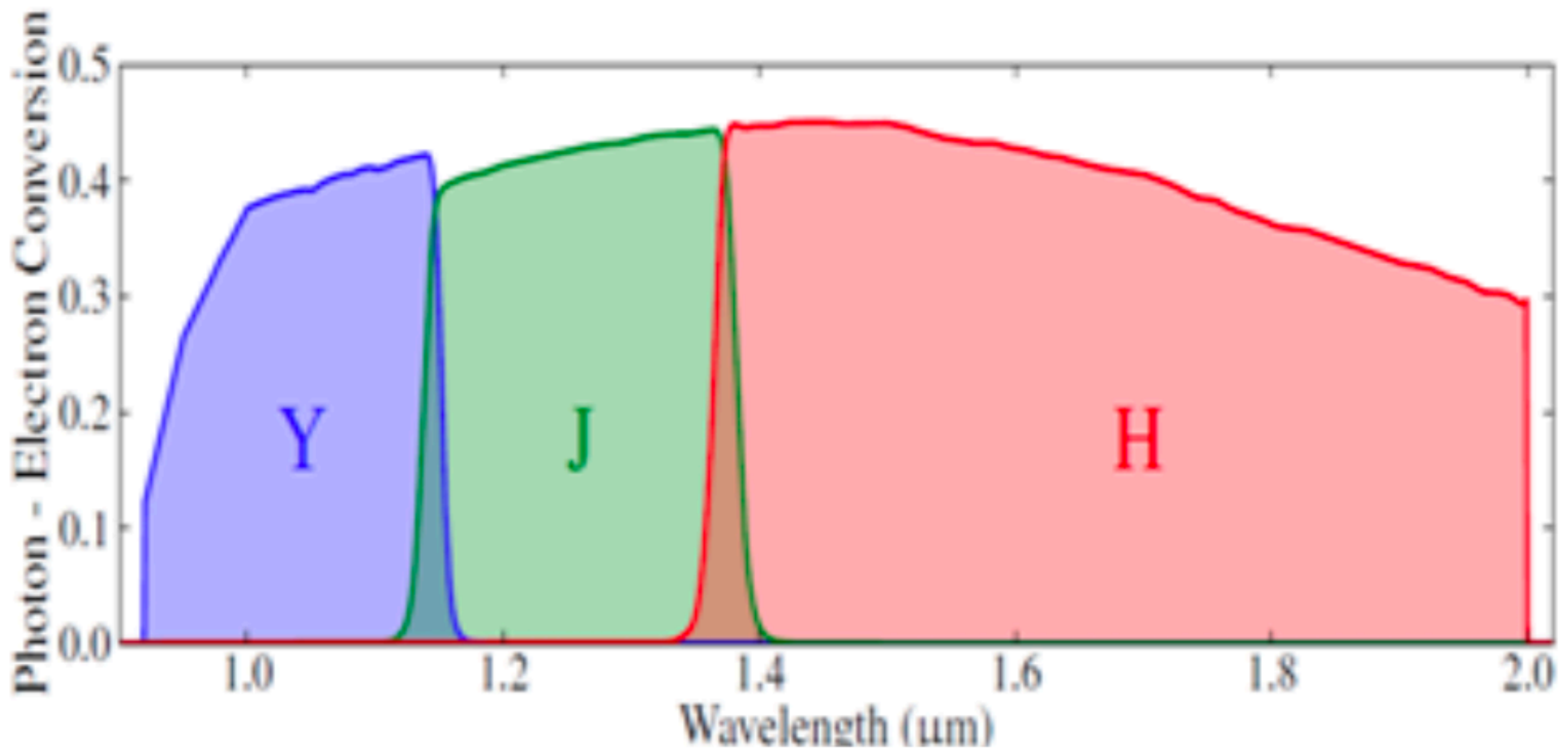
FoM ~ 1500(WL&Galaxie)-4000 (all)
~ 900 members
European lead project / ESA
Space telescope / 1.2 m mirror
Launch : 2019
Mission length : 6 years
1 exposure depth : 24 mag
Survey Area : 15 000 square degrees (.36 sky)
Filters : 1 Visible(550-900nm)+ 3 IR(920-2000 nm)
+ NIR spectroscopy (1100 – 2000 nm)

FoM > 800 (WL,BAO, SN)
~ 450 Core members + 450 to come
US lead project / NSF-DOE
Ground Telescope / 6.5 m effective mirror
1st light : 2019
Observation length : 10 years
1 exposure depth : 24 mag (i) (~27 in 10 years)
Survey Area : 20 000 square degrees (.48 sky)
Filters : 6 filters (320-1070 nm)

→2 complementary approaches to address the question of the acceleration of the Universe and the nature of the Dark Energy in the next decade.

Major contributions to both projects from French teams

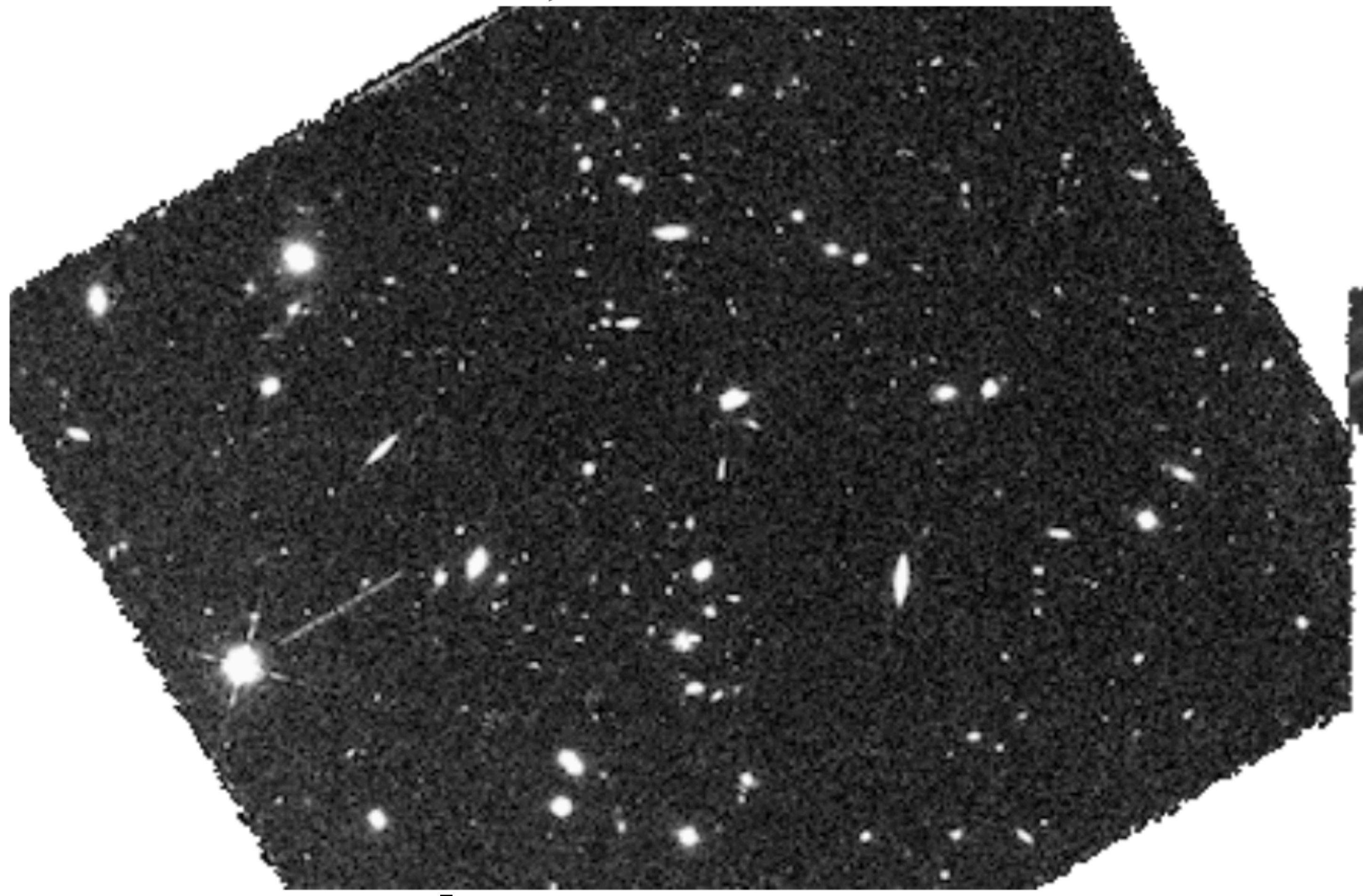
NISP



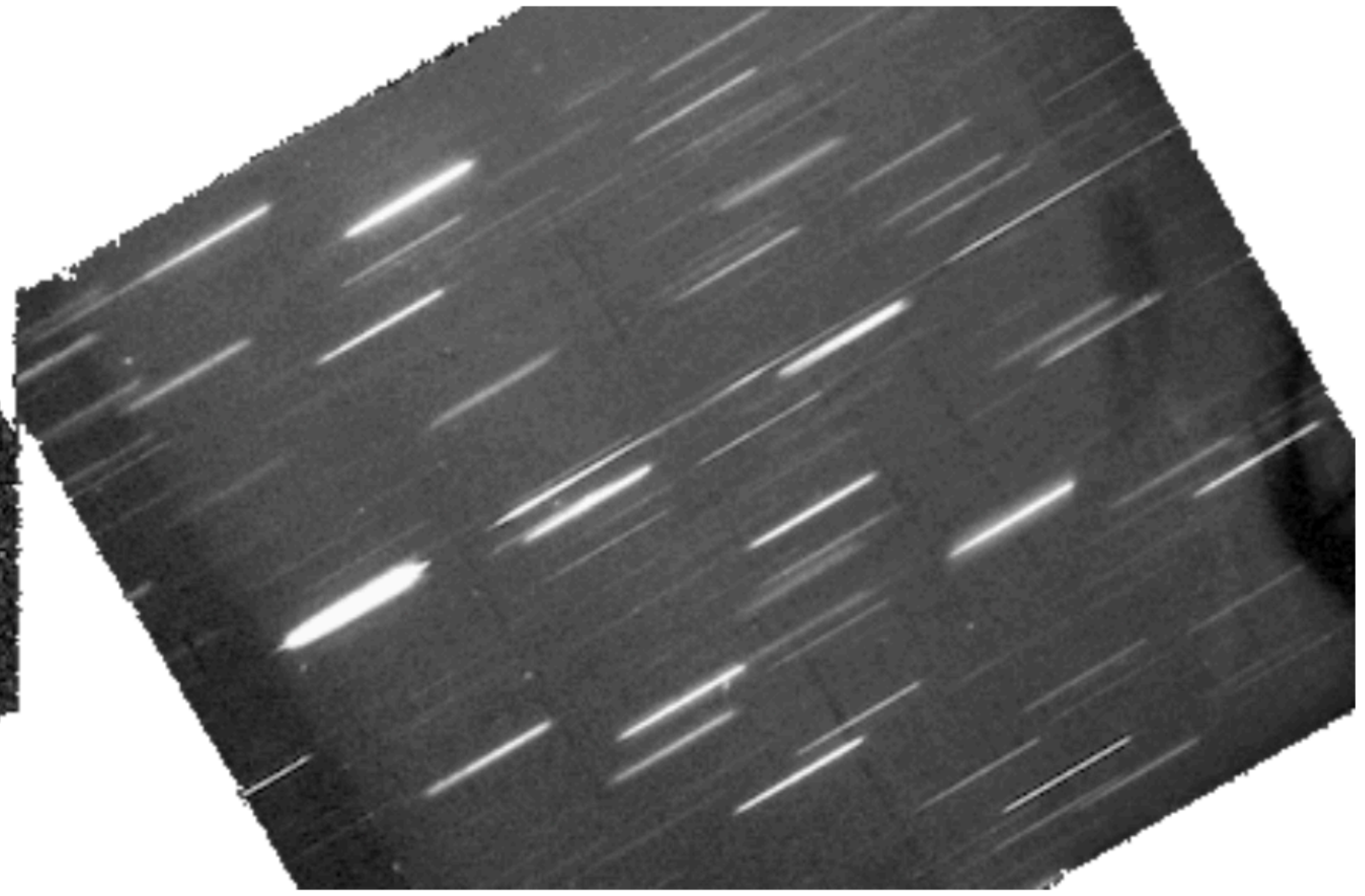
Slitless Spectroscopy up to $M_{AB} = 19.5$

Photometric IR images up to $M_{AB} = 24.5$

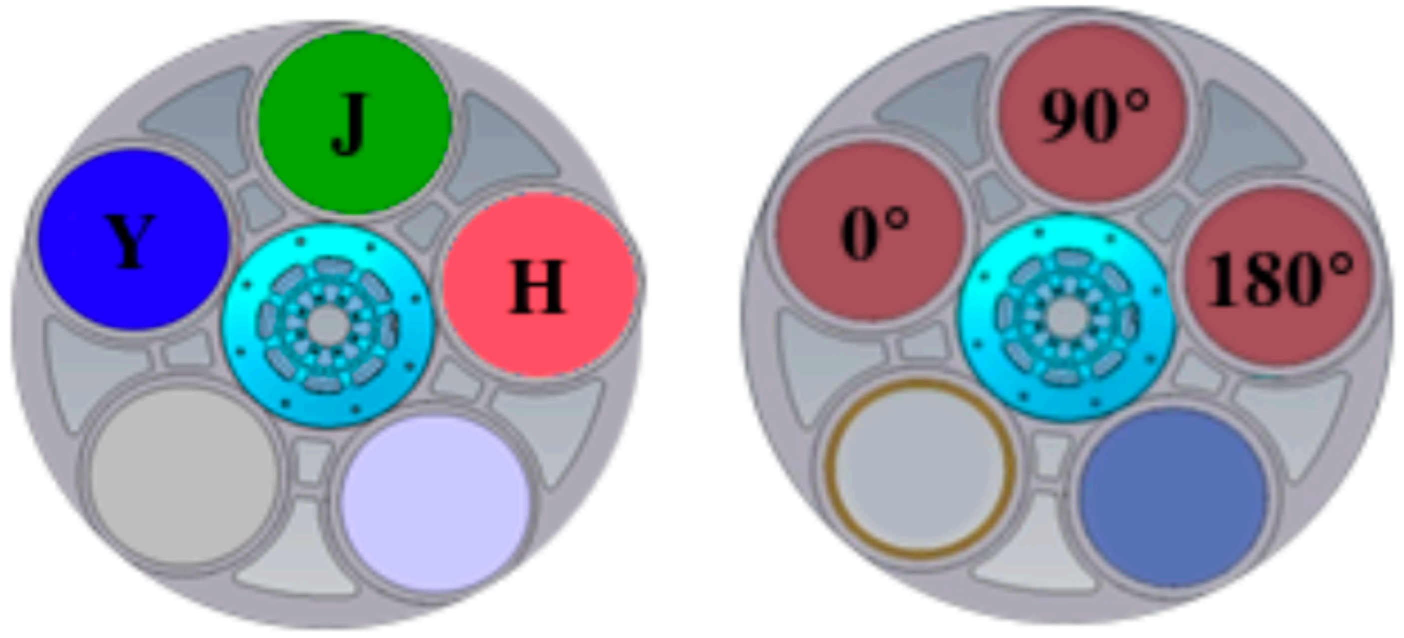
Weiner,B et al. 2012



Photometry



Slitless-Spectroscopy



NI-FWA NI-GWA

- **Photometry the peak brightness of the object through various filters. An object that is redshifted will have its peak brightness appear through filters towards the red end of the spectrum. - Far Away objects**
- **Spectroscopy - $H\alpha$ spectral line measurement**

NISP measurement cycle

1. GWA angle 1 + FWA open
2. GWA angle 2 + FWA open
3. GWA angle 3 + FWA open

Spectrometry — 560s

4. GWA open + FWA filter Y
5. GWA open + FWA filter J
6. GWA open + FWA filter H

Photometry — 270s

7. FWA closed. → Dark