EUCLID NIS Spectroscopic simulations

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Main contributors
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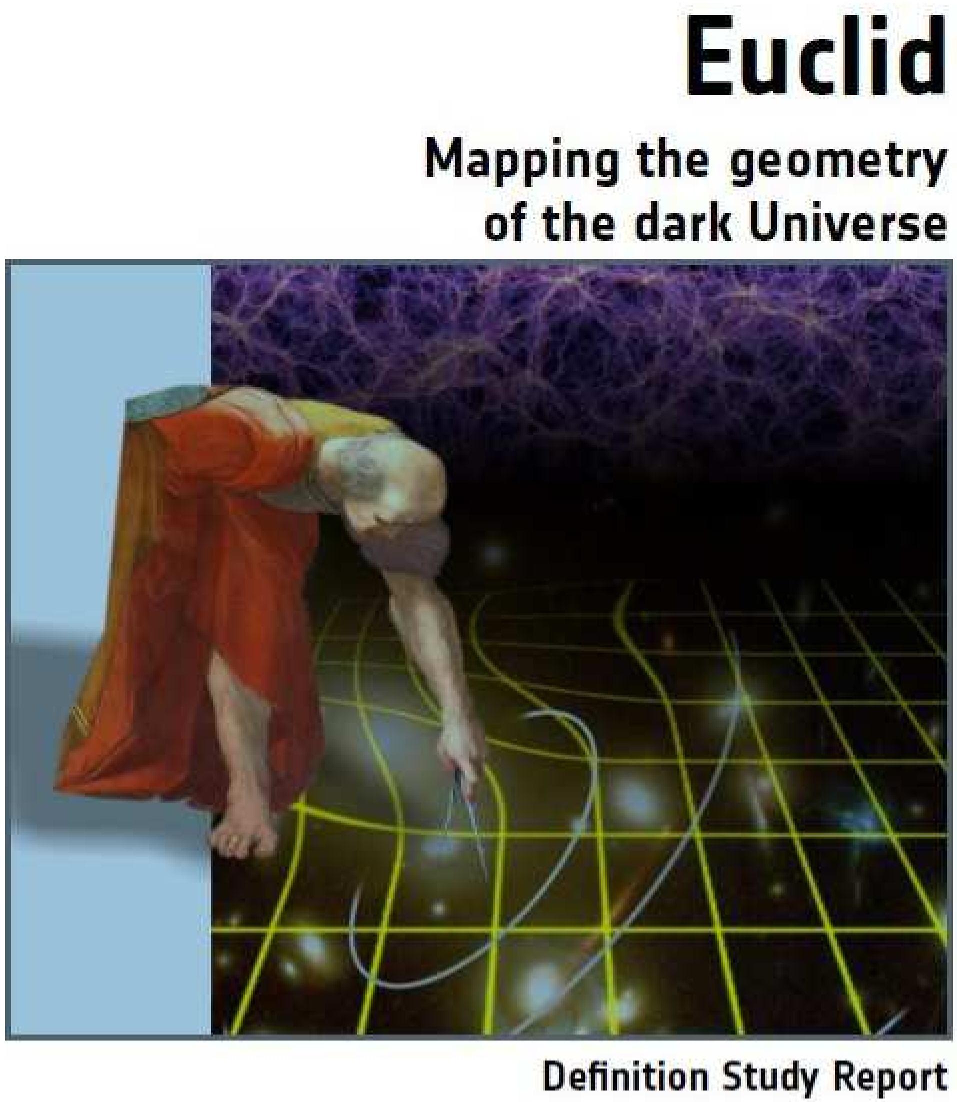
And many others from the Euclid consortium



Main Scientific Objectives

Understand the nature of Dark Energy and Dark Matter

- Reach a dark energy FoM > 400 using weak lensing and galaxy clustering (σ(wp)=0.02 and σ(wa)=0.1)
- Measure the exponent of the growth factor σ < 0.02 (distinguish General Relativity and a wide range of modified-gravity theories)
- Test the Cold Dark Matter paradigm for hierarchical structure formation
- Constrain the spectral index of primordial power spectrum, to percent accuracy (combined with Planck)

EUCLID in numbers

- Launch: 2019
- Duration 5 years
- Budget: 700 M€ (till 2027)
- 13 countries involved
- 850 people involved (450 scientists)

- **Wide Survey > 15,000 deg^2**
- **Deep Survey 40 sq. deg. (2 patches of > 10 deg^2)**
- **50 million galaxy spectra**
- **Imaging for 1.5 billion galaxies**

Instruments details

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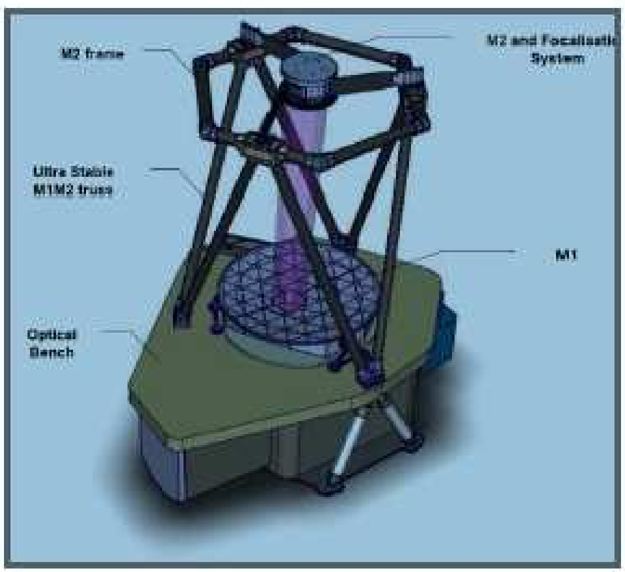
	VIS	NIP	NIS
FOV	0.7x0.7 deg2		
L coverage	5500-9000	Y,J,H	11000-20000
sensitivity	24.5, 10s extended	24, 5s pointlike	3*10-16 erg cm-2 s-1, 3.5s Unresolved line
detectors	36 4x4 CCDs	16 2kx2k HgCdTe detectors	
Pixel size	0.1 arcsec	0.3 arcsec	
Spectral Resolution			R250, 1 arcsec source



Importance of E2E simulations

- complex ambitious mission
- systematic uncertainties under full control
- Chellenging data reduction aspects
  - amount of data
  - complex analyses
  - payload related effects expected to significantly change over the mission lifetime.
- Calibration, monitoring and modeling of instrument performances
- well controlled flow of sophisticated simulations
  - evaluate and monitor performances,
  - to validate the data reduction procedures
  - to demonstrate the full control of systematics

Performance evaluation: requirements and goals

- 52 millions of galaxies over 15000 deg^2
- redshift 0.7 to redshift 2.0
- Slitless spectroscopy
- Performance verification: demonstrate we satisfy level 1/2 Requirements on redshift measurements
  - Completeness ~50% for Flux>3e-16 erg/cm2/s/A
  - Catastrophic failures < 20%
  - $\sigma_z < 0.001(1+z)$
- detection of emission lines, mainly Hα
- Redshift measurement depends on
  - instrumental parameters (PSF size, resolution, background)
  - the observing strategy adopted

Contamination

- slitless spectroscopy is affected by the confusion arising from the superposition of spectra from adjacent objects

•Almost all spectra are affected by contamination

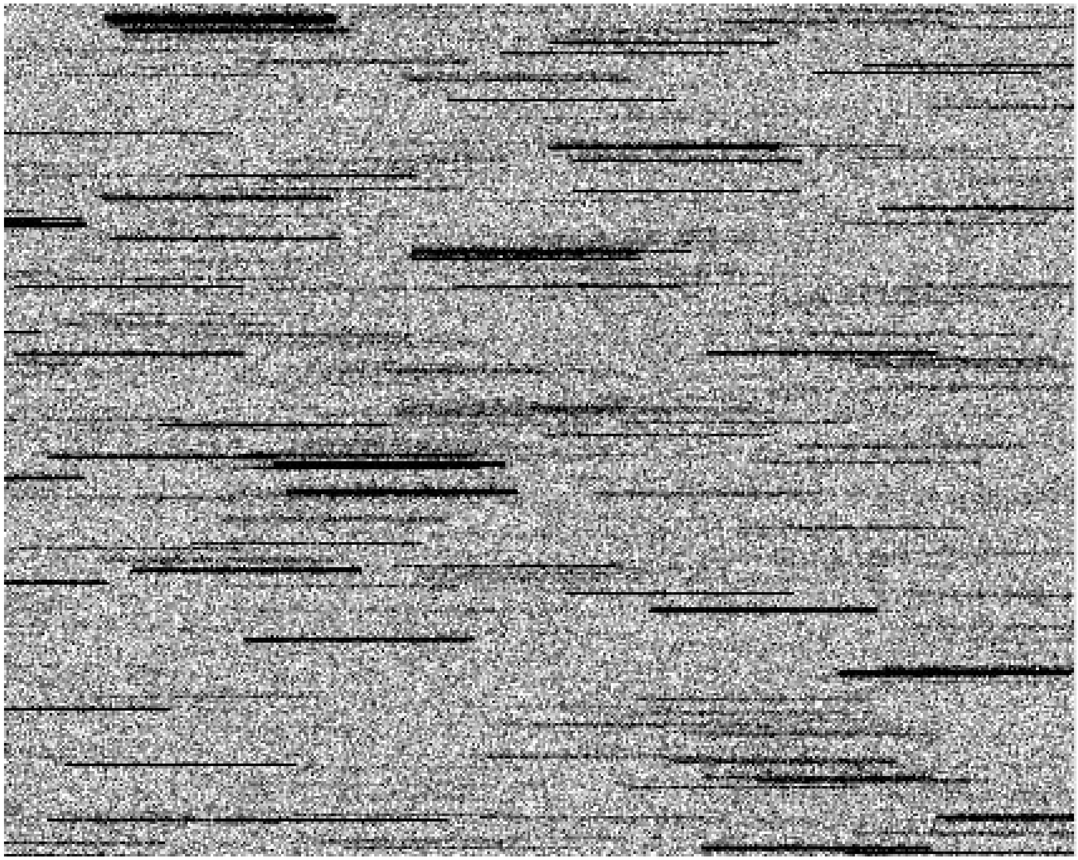
•Contamination is the main cause of redshift measurement failures.

•Reducing confusion produced by overlapping spectra is the first concern when devising observing strategy

Example of 2D dispersed image without any contamination reduction strategy, may 2009

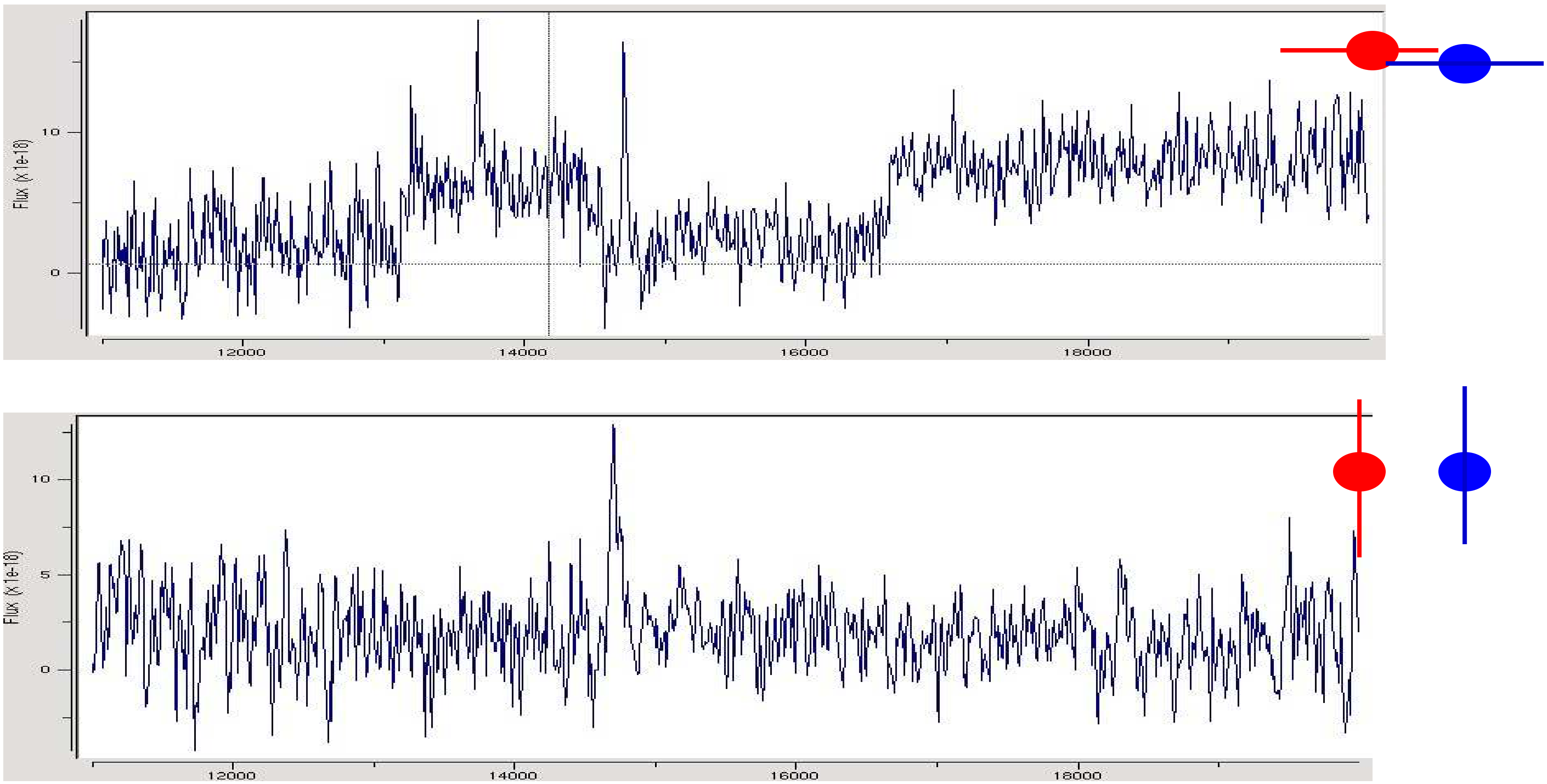
Observing strategy 1

1. Split the total wavelength coverage into two separate observations, using *red* and *blue* grisms
   – The resulting shortening of each spectrum significantly reduces the percentage of overlaps.



Observing strategy 2

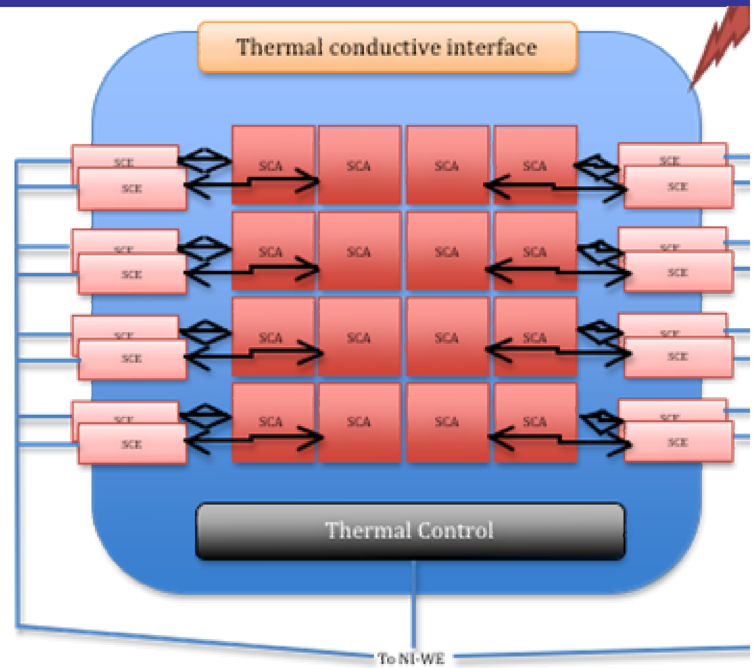
2. for each band two independent exposures are taken, with the dispersion rotated by 90 deg.
   – Allows to recognize contaminant lines



Observing strategy 3

Dithering

1. Detectors (VIS and NISP) close-butted but there are still gaps
2. The two detector types have different effective fields of view, the array formats are different gaps do not coincide.
3. mitigates the impact of cosmetics defects and cosmic rays
4. Imaging: improves the sampling
5. Spectroscopy: the four dithers are used to implement the 2 grism*2rolls strategy



Observing strategy 3

Dithering
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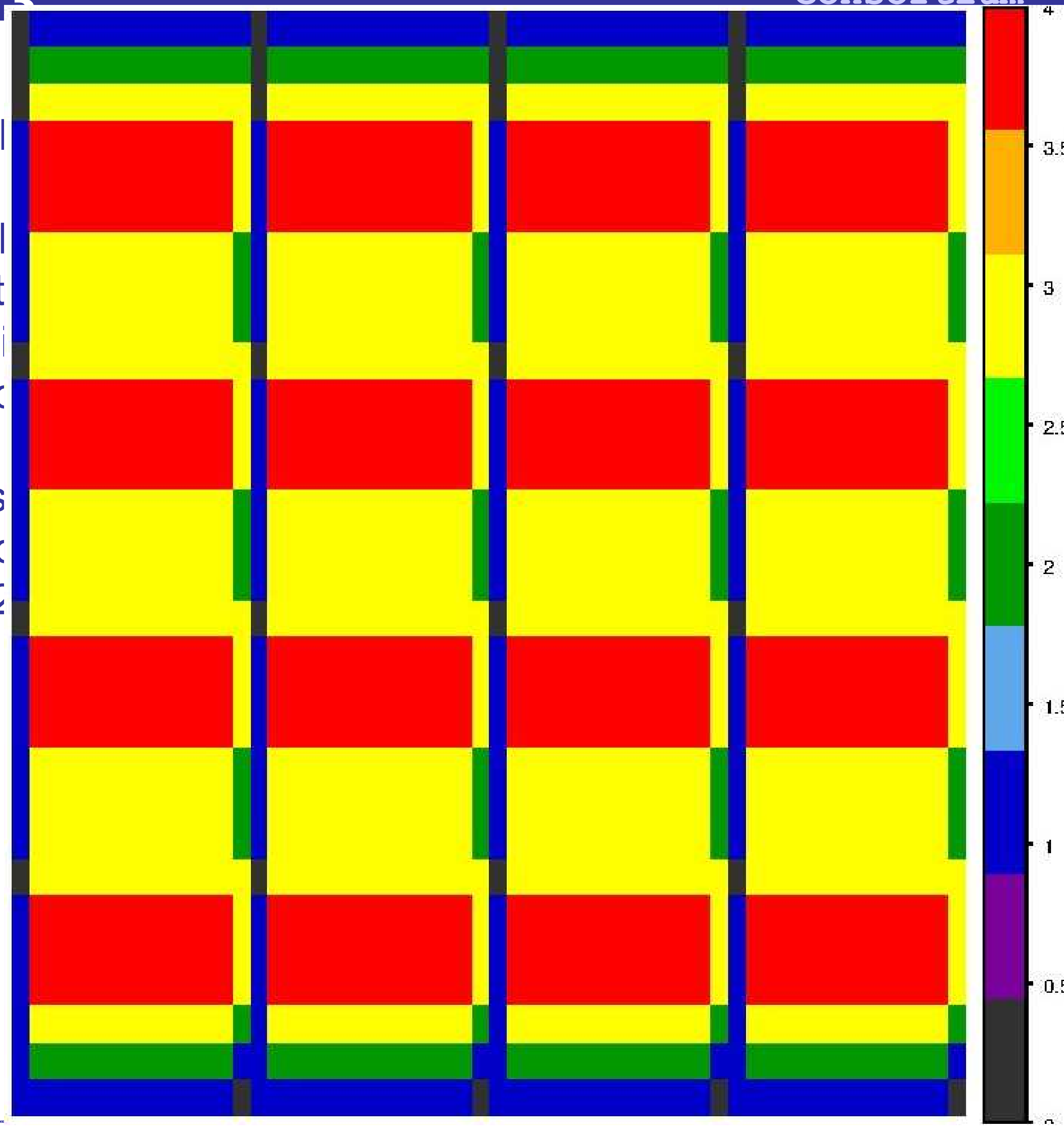
   effective fields of view, t
   different gaps do not co
3. mitigates the impact of c
   and cosmic rays
4. Imaging: improves the s
5. Spectroscopy: the four c
   implement the 2 grism*2

93.4% pixels with >3 frames
50.9% pixels with 4 frames



End2End simulation pipeline: concepts

Goals

- evaluate completeness and purity of the resulting spectroscopic sample.
- Provide dn/dz to compute cosmological quantities

Requirements

- Use packages available at each time
- Allow for parallel development
- Preferably in different languages
- Allow for easy plug-in
- Scalable (desktop, cluster,….)

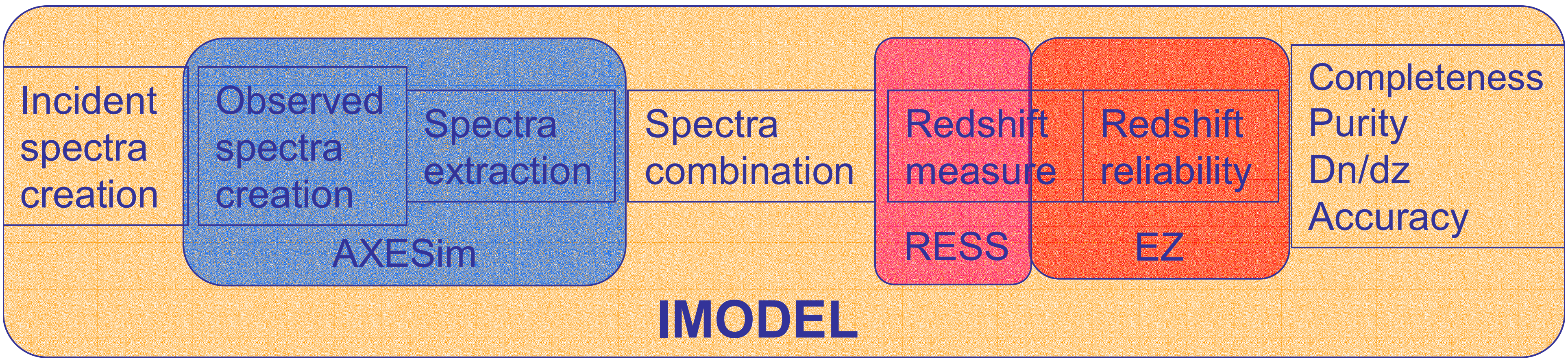
S/W Architecture

ONE s/w environment (FASE, OTICON 9.2) allowing to

- Plug-in external modules in any language
- Scalability: desktop, cluster, grid
- Parallel development

End2End simulation pipeline: structure

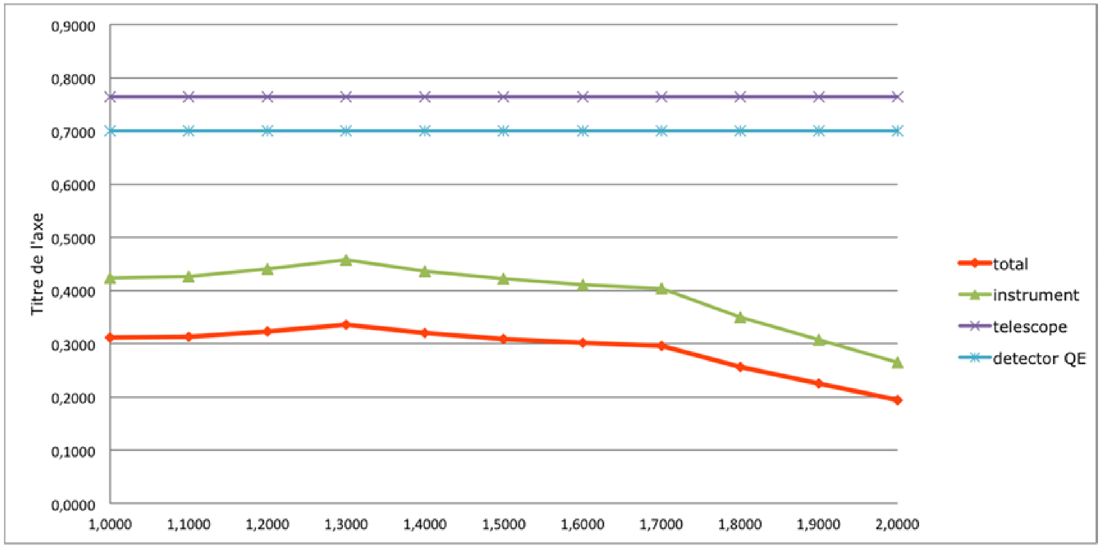
Catalog
Instrument Parameters
Observing Strategy
INPUT



Dispersed images
1D extracted spectra
Redshifts & flags
OUTPUT

Instrumental Parameters

Parameters	Value in IPRR
Instrument parameters	
Grism bands (nm)	Blue=1100-1457 Red=1445-2000
Plate scale	0,3''
Dispersion/pixel	9.8A/pix
transmission	See curve
PSF, EE in radius (asec)	Blue EE50= 0,2'' EE80 = 0,45'' RedEE50=0,225'' EE80 = 0,55''
Detector total noise	9e
Zodi noise (entrance)	aldering
Extra noise	20 % of zodiacal noise
Array size	16x 2040x2040
Gap x/gap y	3/6 mm
Survey parameters	
Exposure time	540s
Dither pattern	4 dithers
Observational strategy	2 rolls, 2 bands
Exposure time	540s
Field Overlap	no



Observational strategy

The input catalog

- realistic description of galaxy clustering both on the sky and in redshift;
- correct description of galaxy spectral properties (i.e. their Spectral Energy Distribution), as a function of both environment and redshift.

COSMOS IRAC catalog (Ilbert et al. 2010, ApJ 709, 644)

- Coverage: 2 deg^2
- Galaxy parameters: sky coordinates, magnitudes, galaxy size, stellar mass, Star Formation Rate (SFR), metallicity (via SED fitting)
- SFR converted into H-α line flux, taking into account dust
- metallicity used to compute line ratios (Hα vs. [OII], [OIII] doublet, Hβ, SII, NII).

Each galaxy assigned

- a spectral type (Specific Star Formation Rate)
- a matching spectral template (Bruzual and Charlot)

Simulation Pipeline step 1: incident spectra

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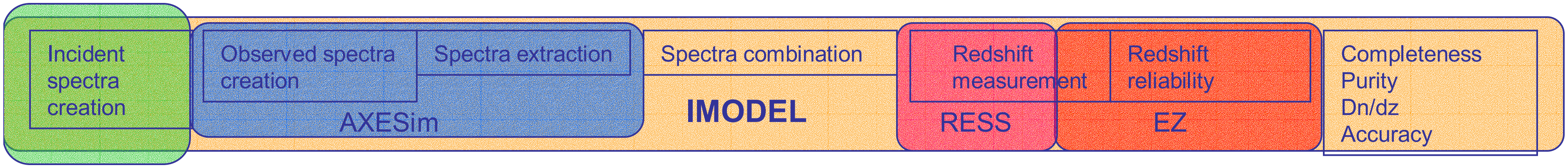
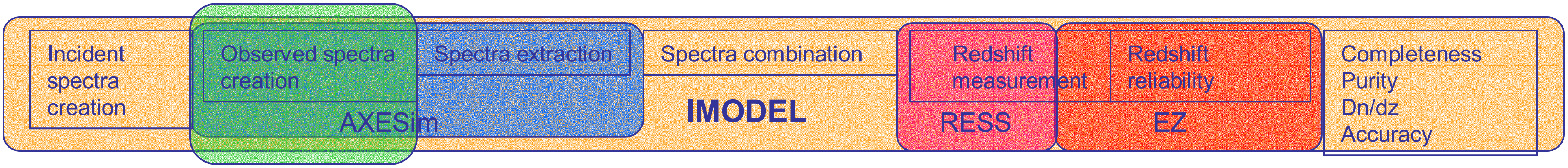
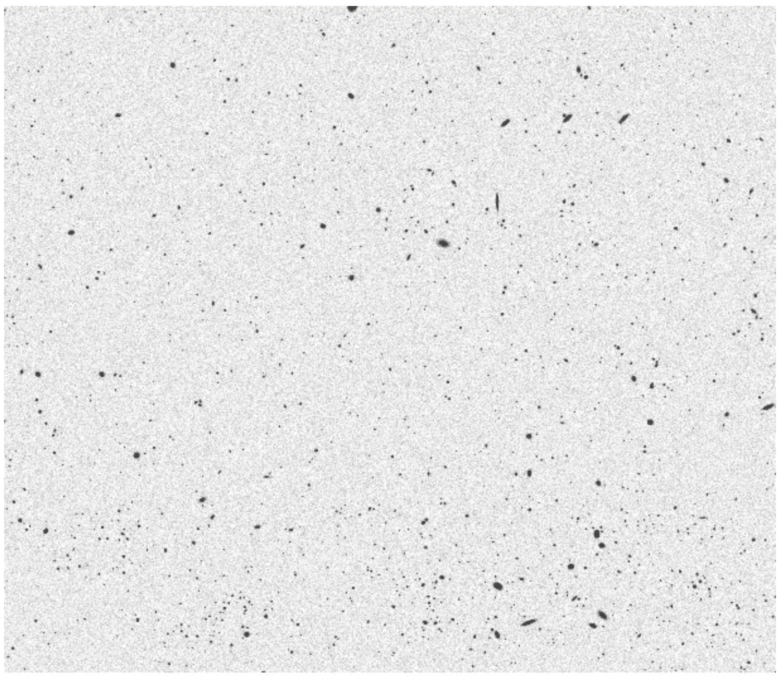


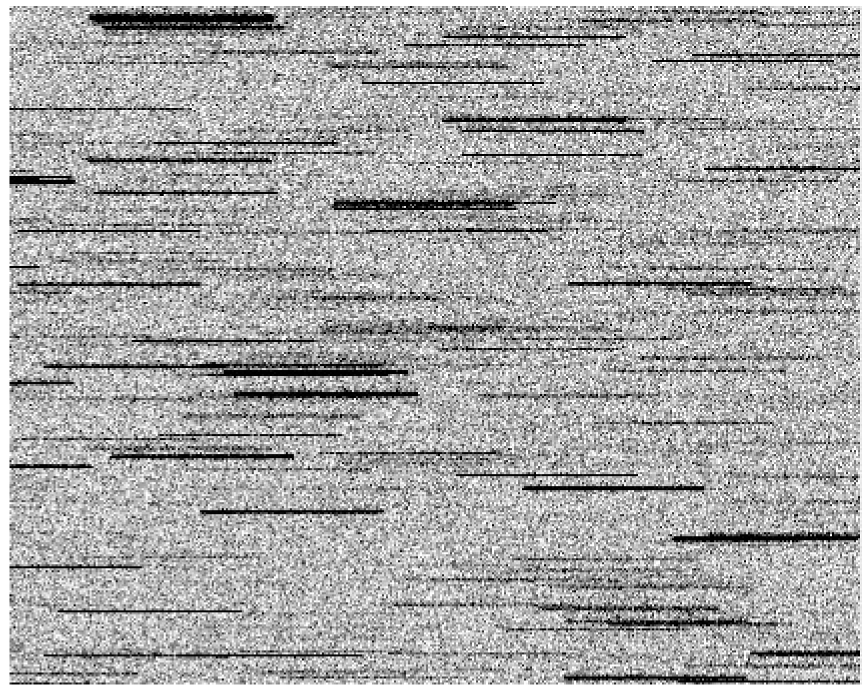
- Galaxy spectra:
  - Scale template (continuum only) to object magnitude.
  - H-α line added upon (flux and equivalent width from input catalog)
  - standard set of lines added ([OII], Hβ, [OIIIa], [OIIIb], [NII] and [SII]); fluxes computed from Hα flux using standard lines ratios depending on the morphological type and metallicity
- Stars added to the galaxy catalog, according to the observed star surface density: |b|=60 and |b|=30.
- Star spectra:
  - Pickles stellar template corresponding to the spectral and luminosity type
  - Rescaled to object magnitude.

Simulation pipeline step2: observed spectra

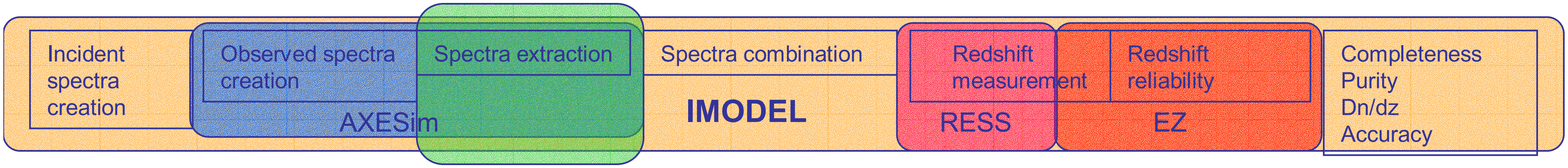


- Carried out by aXeSIM (M. Kümmel,J.R. Walsh, H. Kuntschner,2010, http://axe.stsci.edu/axesim/)
  - direct image
  - dispersed image
  - One simulation per dither per array





Simulation pipeline step3: spectra extraction



- Spectra are extracted from the single 2D images (1 per dither per array)
- 1D spectral extraction by aXeSIM itself.
  - Not detection
  - s/w “knows” where source is
  - s/w “knows” how large source is
  - Not optimal but optimistic extraction

Simulation pipeline step 4: spectra joining

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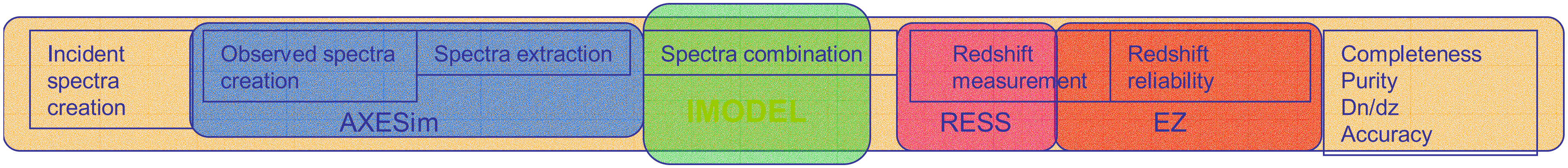
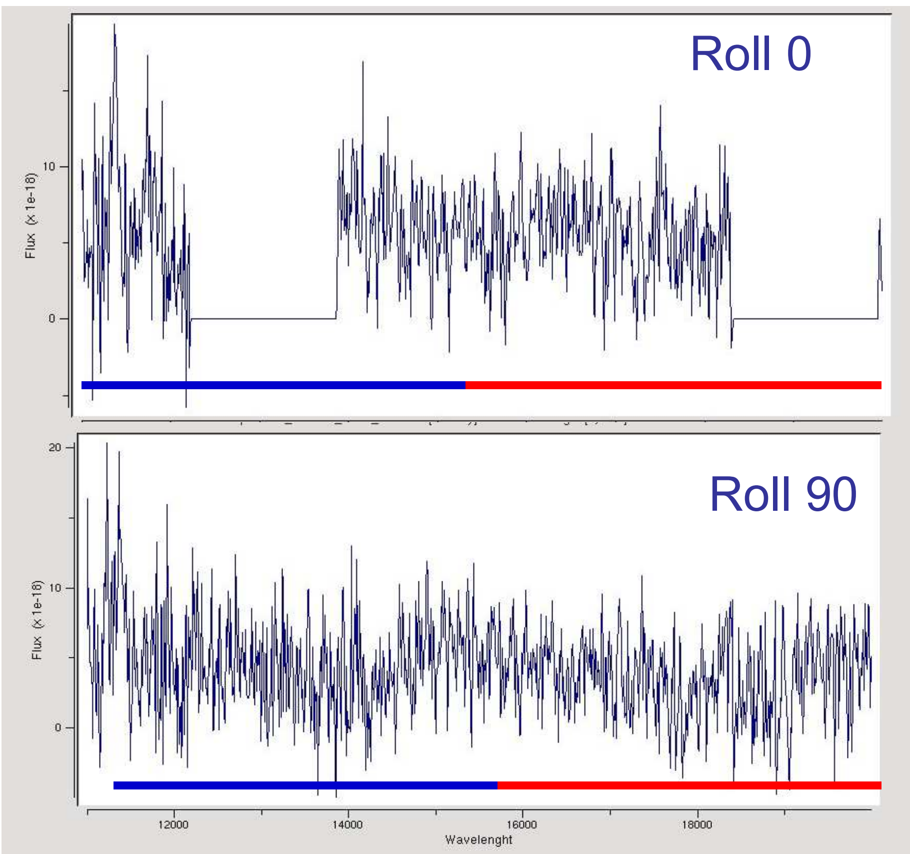
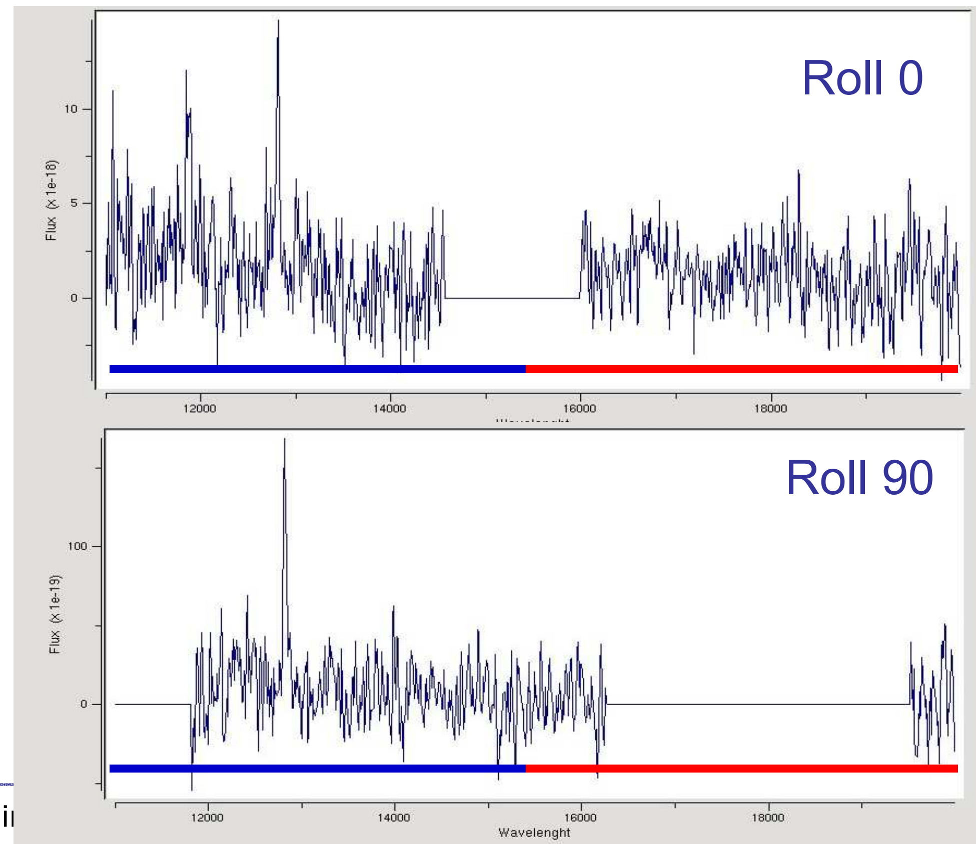


- Red and blue sub-spectra for each roll angle are joined
- Array gaps and dithering strategy are taken into account





Simulation pipeline step 5: redshift measurement 1

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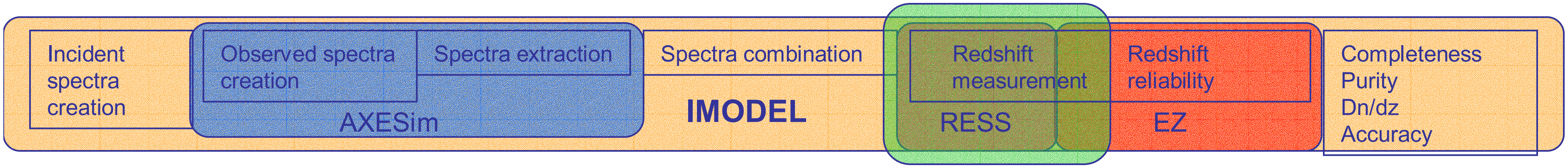
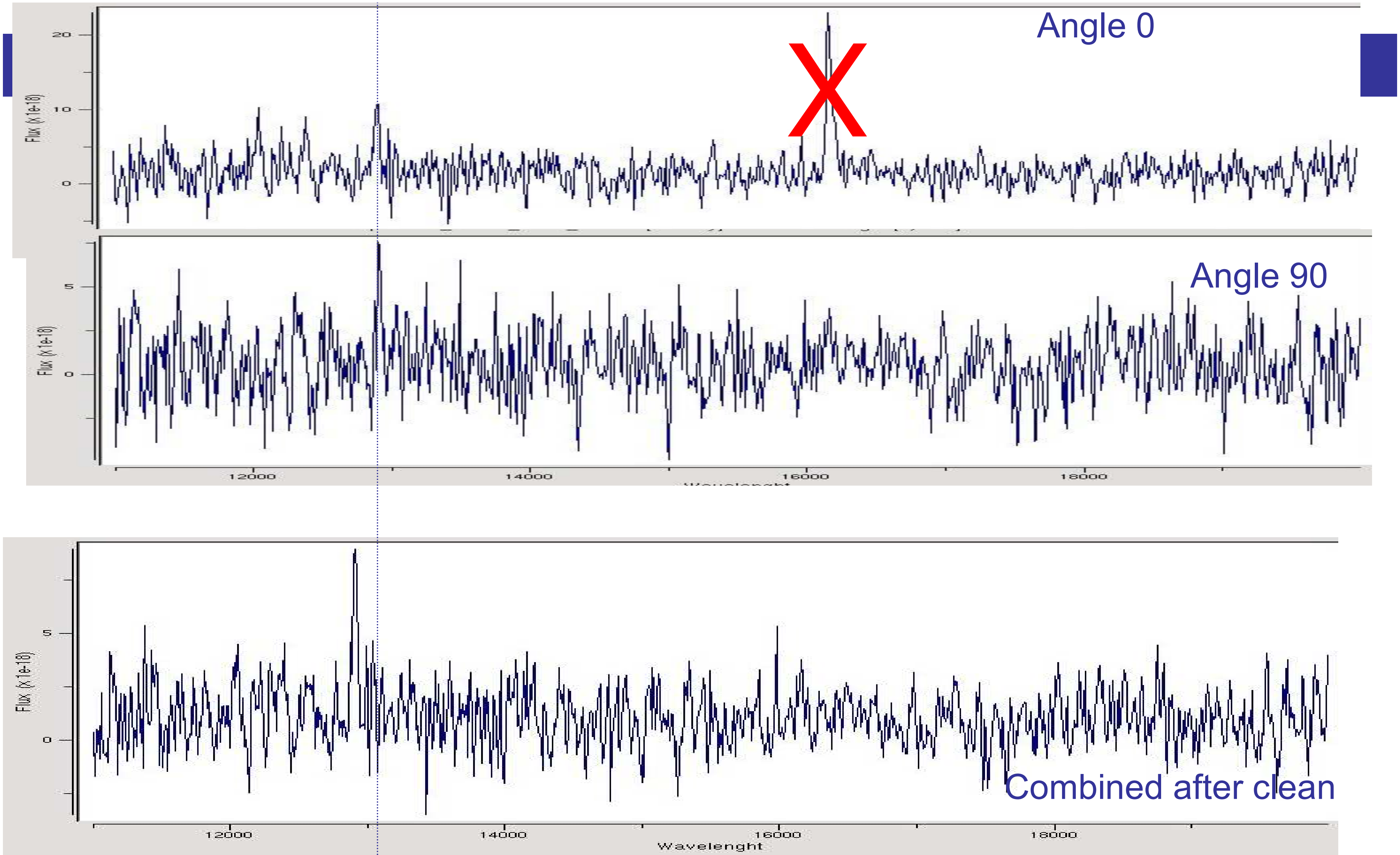
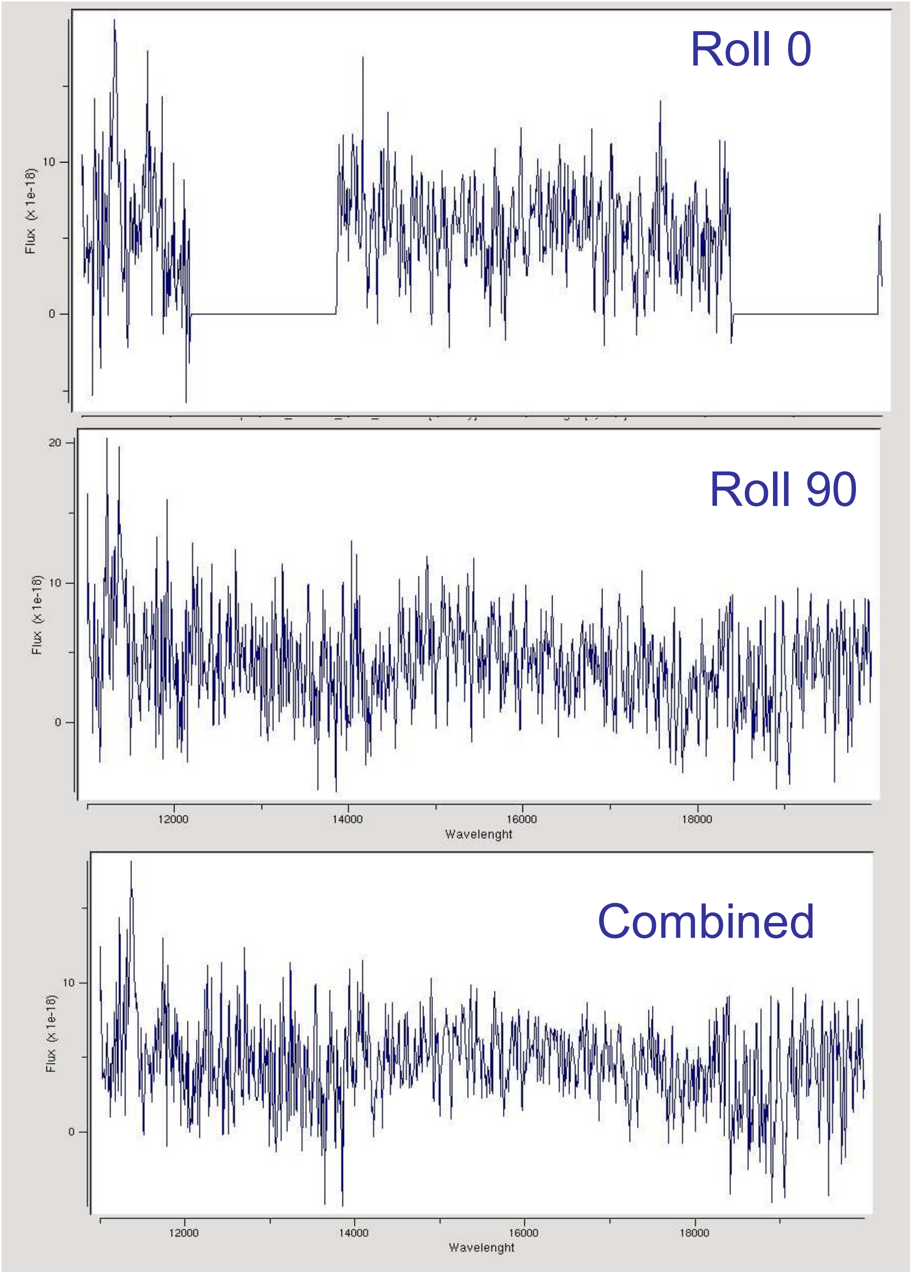
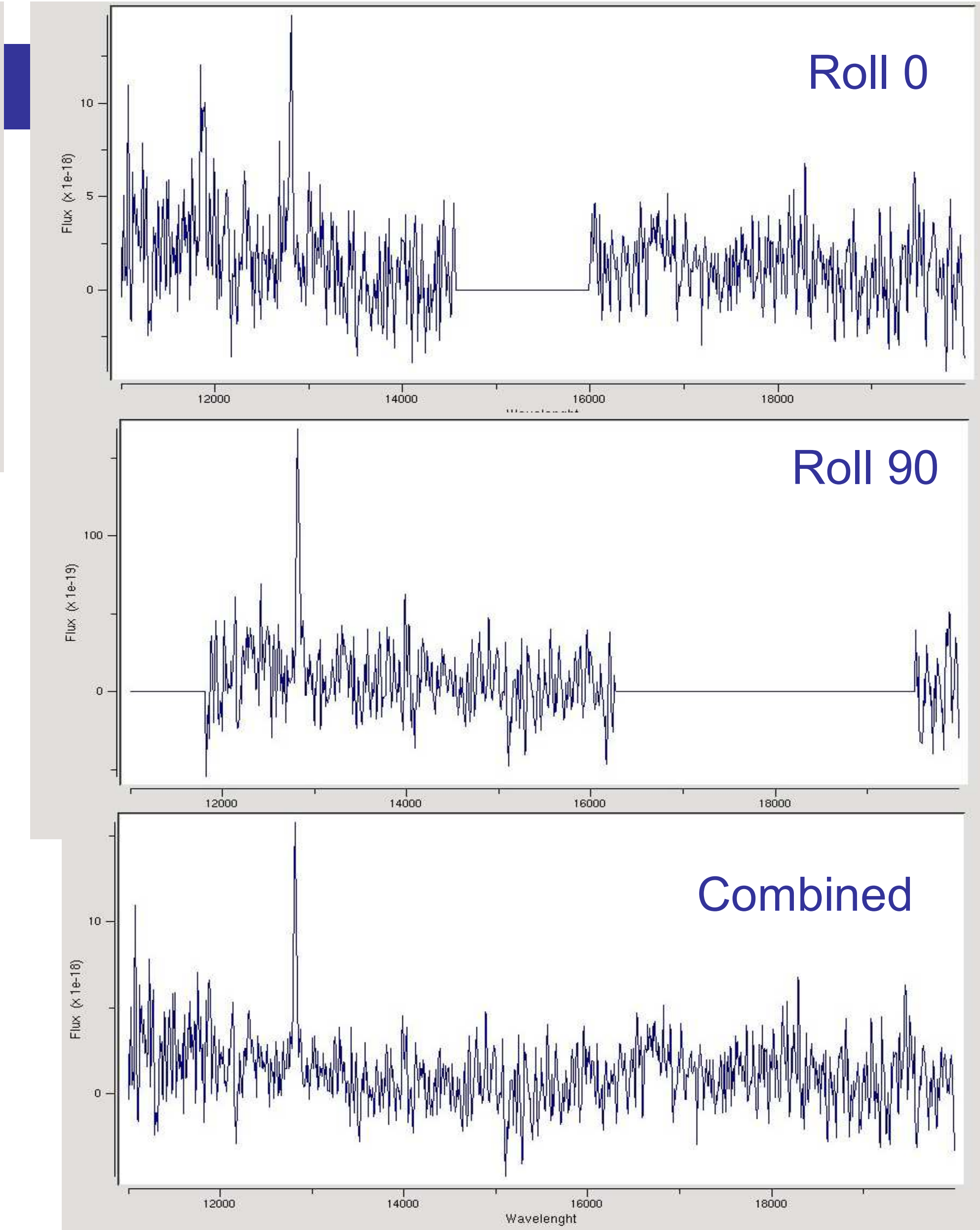


- Compare roll 0 and roll 90 spectra
- Flag spurious lines
- Combine roll 0 and roll 90 spectra allowing for gaps


Angle 0
X
Angle 90
Combined after clean
Flux (x1e-18)
Wavelenght
12000
14000
16000
18000


Roll 0
Roll 90
Combined
Flux (x 1e-18)
Wavelenght
12000
14000
16000
18000


Roll 0
Roll 90
Combined
Flux (x 1e-18)
Flux (x 1e-19)
Wavelenght
12000
14000
16000
18000

Simulation pipeline step 5: redshift measurement

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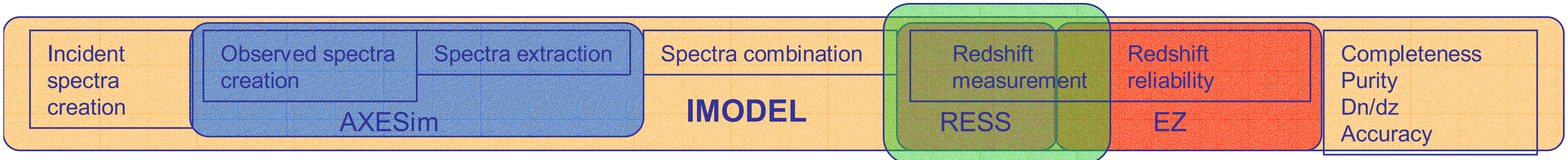
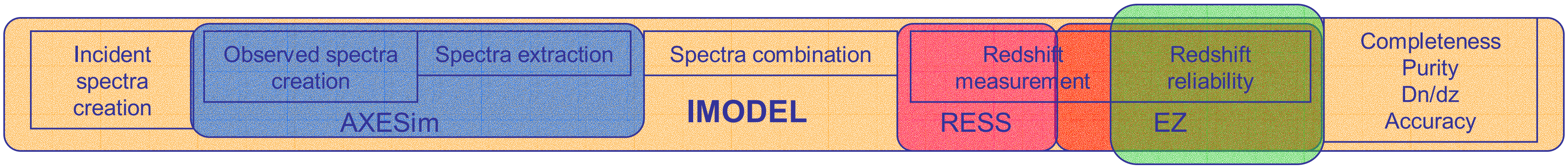


- Compare roll 0 and roll 90 spectra
- Flag spurious lines
- Combine roll 0 and roll 90 spectra
- Blind search for emission lines
- If >1 emission line:
  - Check if give concordant redshift
  - if not, strongest line assumed as Hα
- If 1 emission line
  - assumed as Hα.
- If no emission lines
  - standard cross-correlation technique

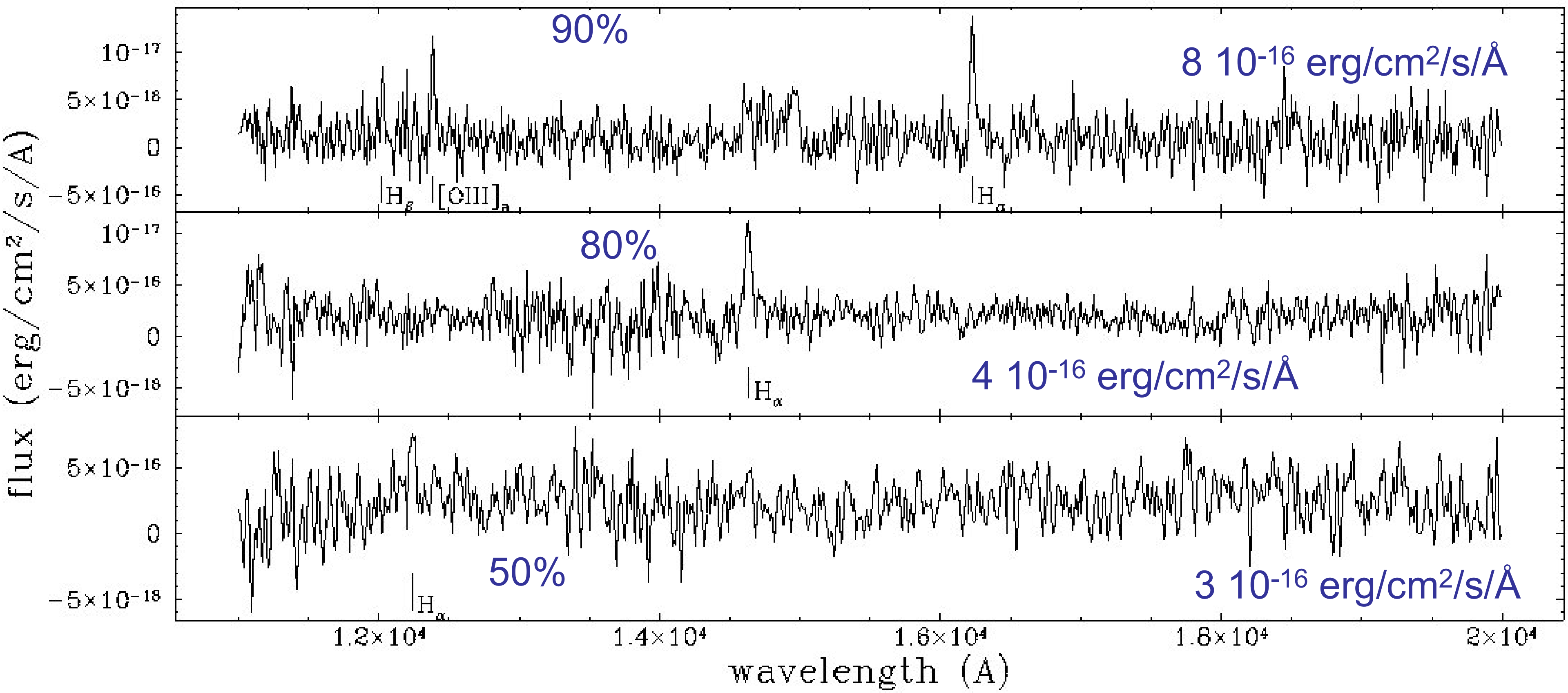
Simulation Pipeline step 6: Redshift reliability



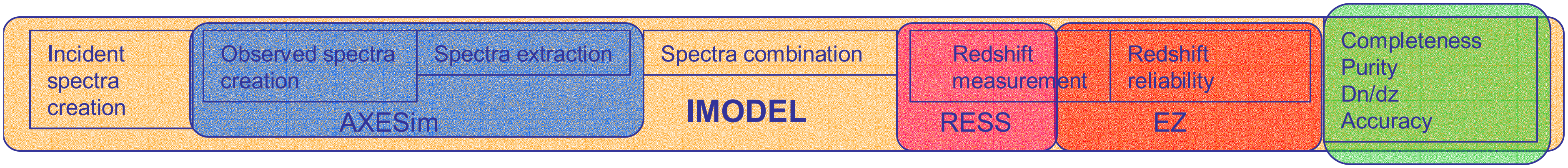
- assign a reliability flag to each measure (EZ,Garilli et al. 2010, PASP 122, 827):given the redshift, *back* search on spectrum all expected emission lines (Hα, SII, OIII, Hβ…)
  - If all expected lines are found **reliability 90%**
  - If only one line is found
    - High S/N: **reliability 80%**
    - Low S/N: **reliability 50%**
  - No emission line found **reliability 0%**

- *Good* spectra: reliability >=50%

Simulated spectra



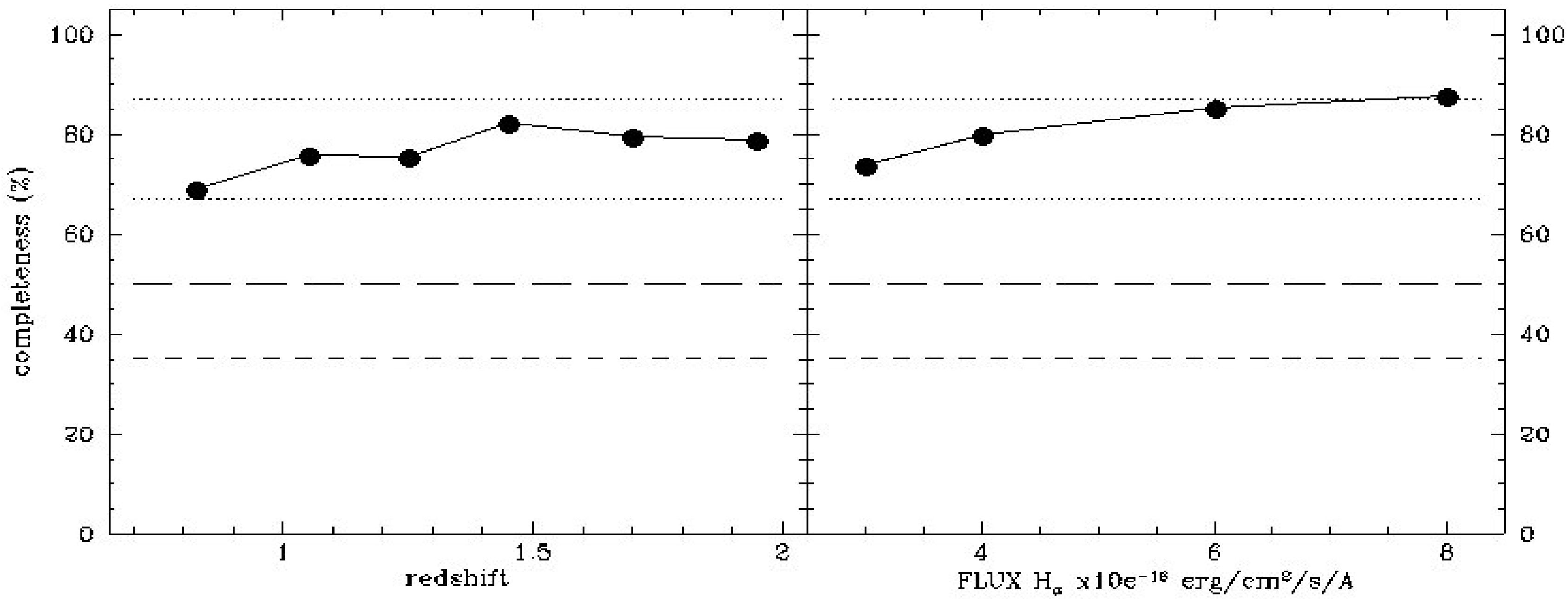
Simulation pipeline step 7: Completeness and Purity



Completeness: fraction of spectra **measured** above a given line flux limit

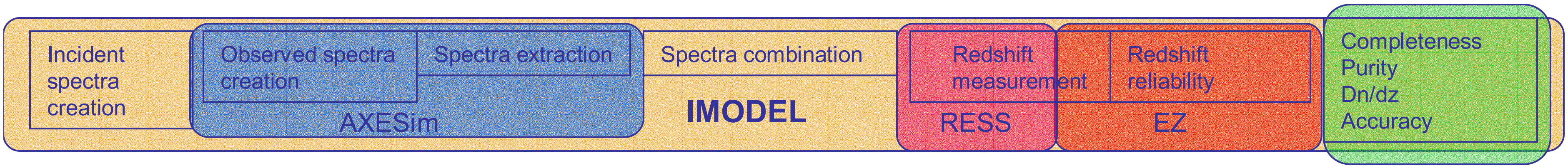
long dashed line: current goal

dotted lines: range of 20% allowed for variation



Simulation pipeline step 7: Completeness and Purity

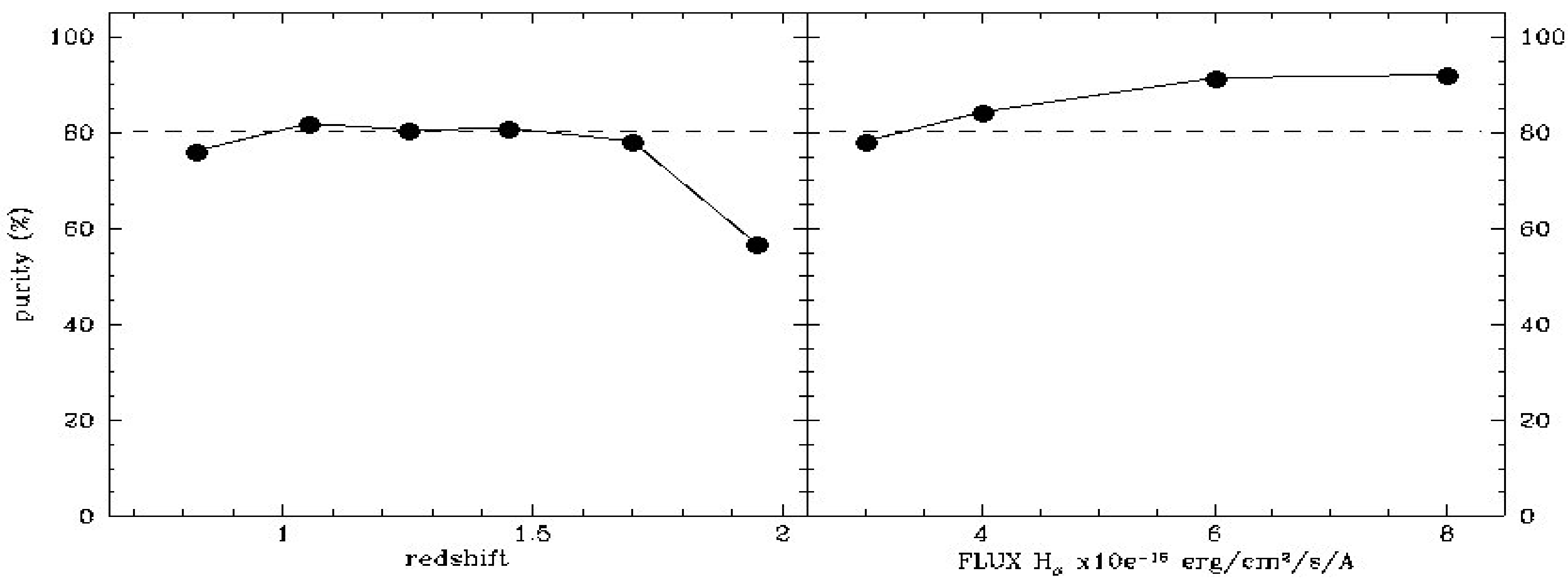
Euclid Consortium



Purity: fraction of spectra **correctly measured** above a given line flux limit. Complement to the fraction of catastrophic redshifts (required to be less than 20%)

long dashed line: current goal

Room for improvement



Simulation pipeline step 7: redshift accuracy

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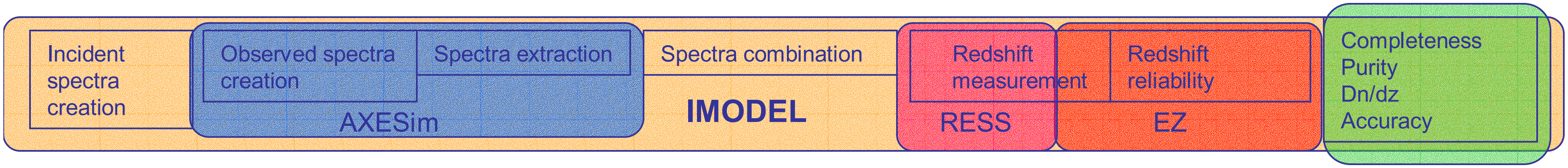
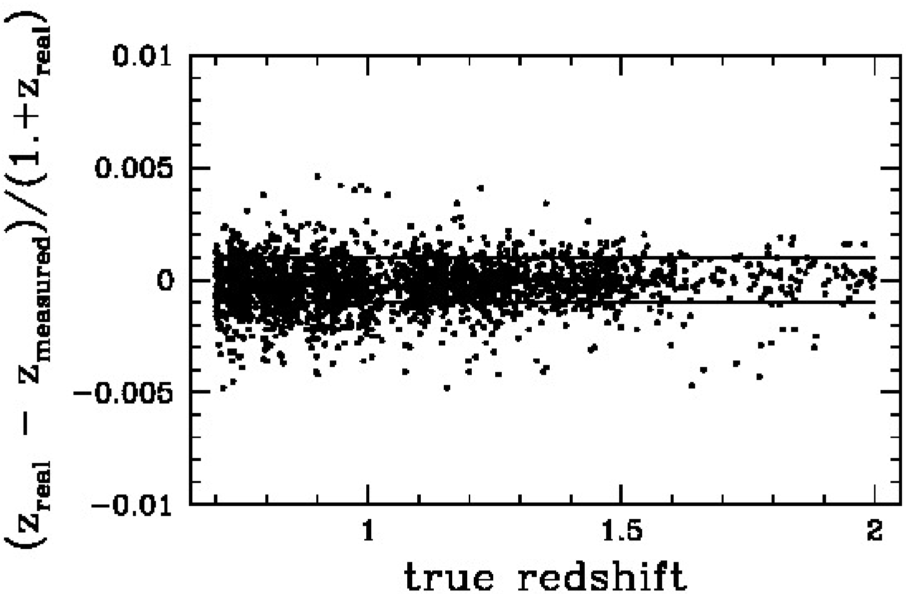
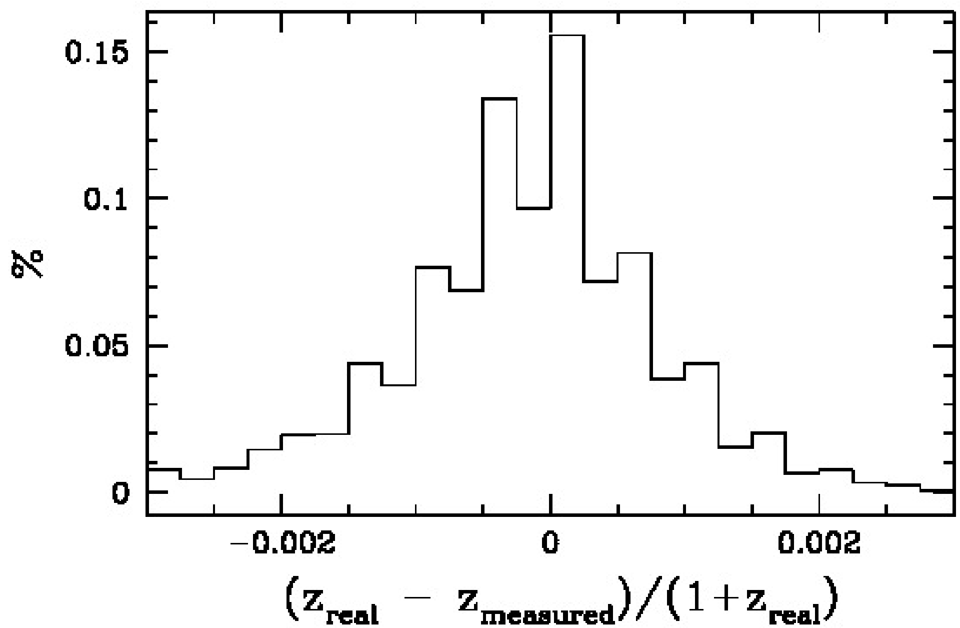
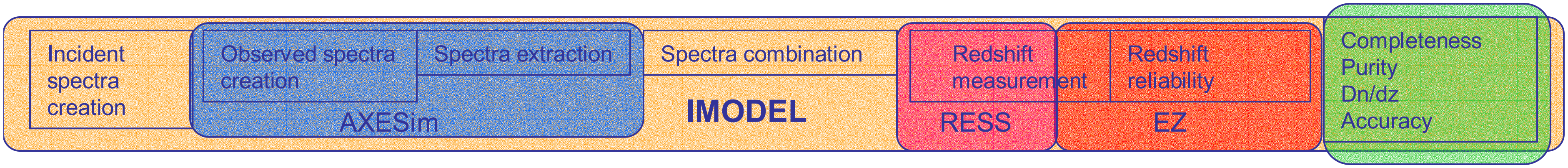


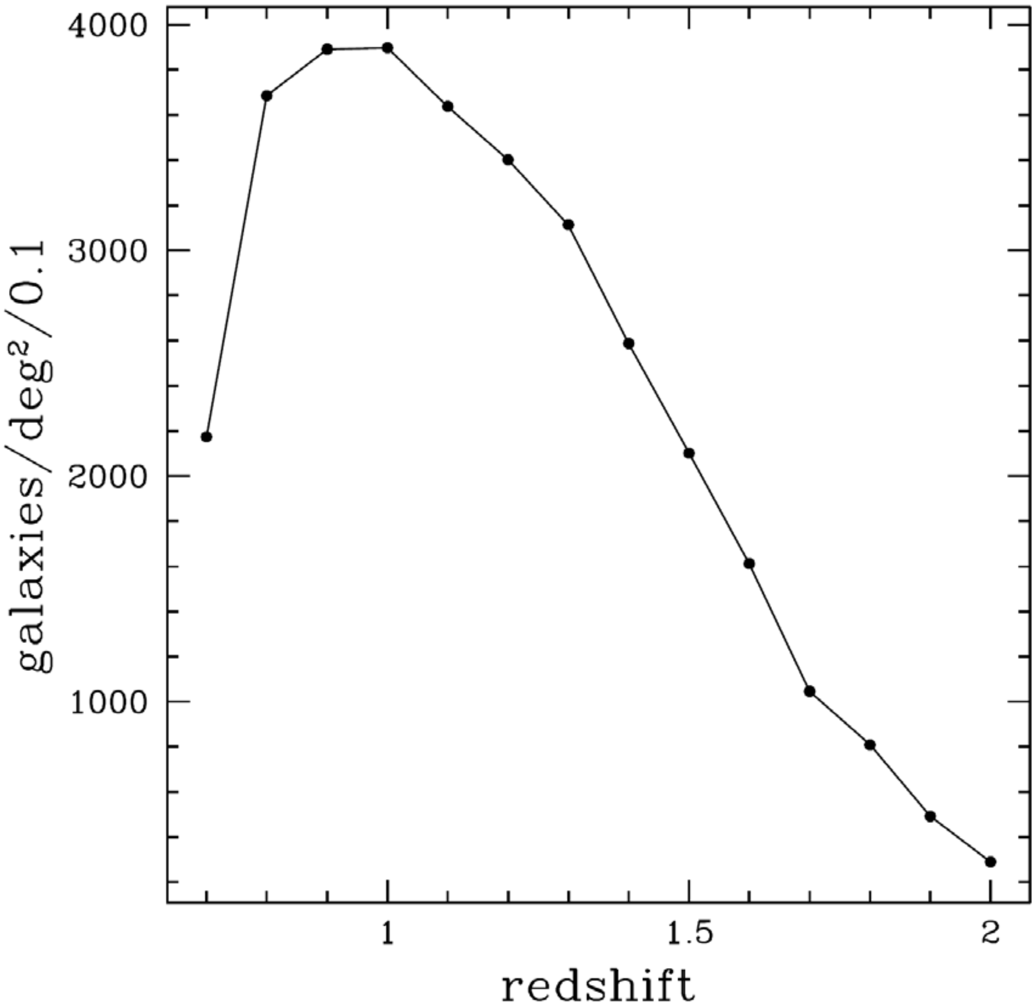
- Low statistical uncertainties and negligible systematic errors
- Thin lines: $\sigma(z)<0.001(1+z)$. 70% of the galaxies are within this limit.
- systematic offset: 6×10^{-5}





Simulation pipeline step 7: redshift accuracy





Predicted redshift distribution of Euclid galaxies with reliable redshift

Deep survey

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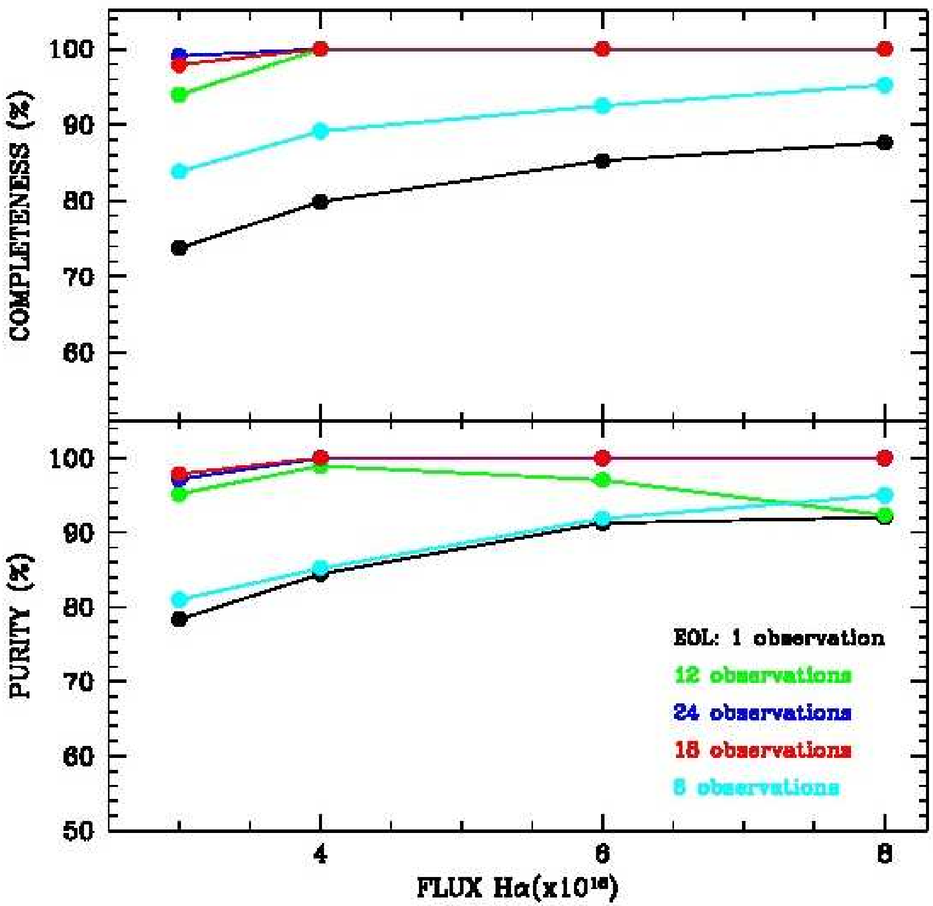

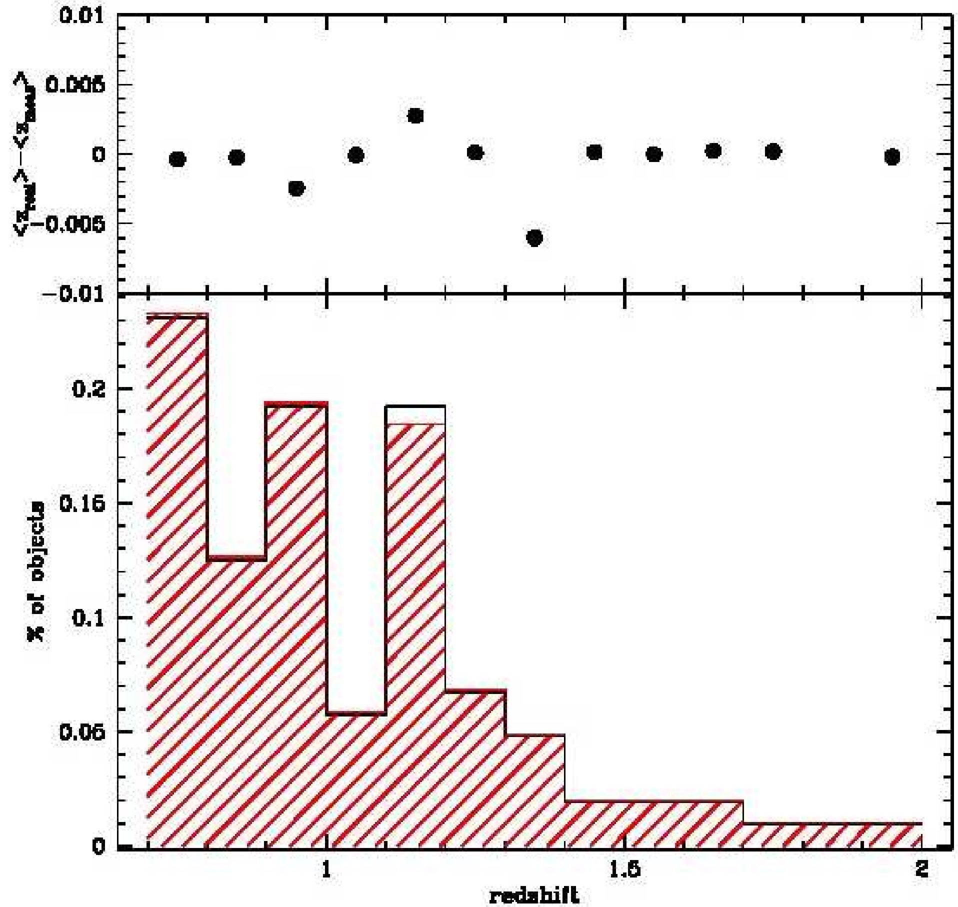

Sub-sample with a purity of 99%

mean redshift in 0.1 redshift bin known to 0.1%

End2end simulations: past,present and future use

- **Past:** Demonstrate feasibility of scientific goals
- **Present**: Monitor scientific performances along with instrument development and mission definition
- **Present**: spectra to understand primary (BAO measurements and growth factor) and legacy science (e.g. high redshift QSOs)
- **Future**: Will allow testing and validation of reduction and z measurement algorithms and implementations
- **Future**: provide "as observed" data for tuning scientific exploitation

Lot of things to be refined before ……….