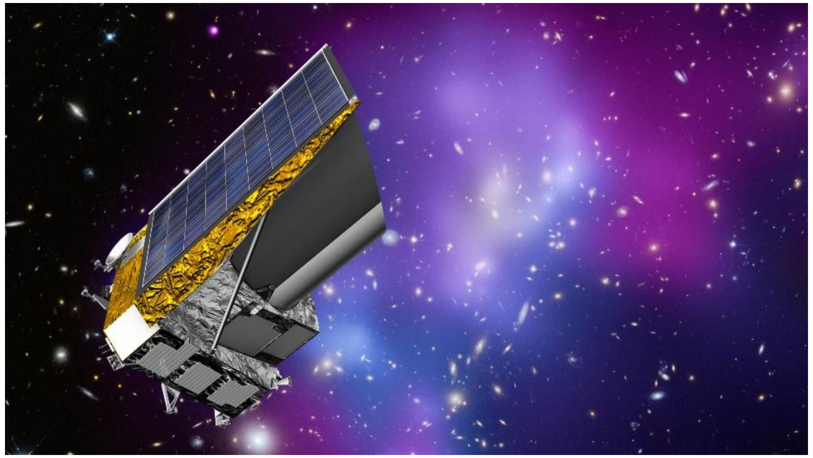
Euclid Preparation:
Performance assessment of the **NISP Red-Grism** through **spectroscopic simulations** for the **Wide and Deep surveys**

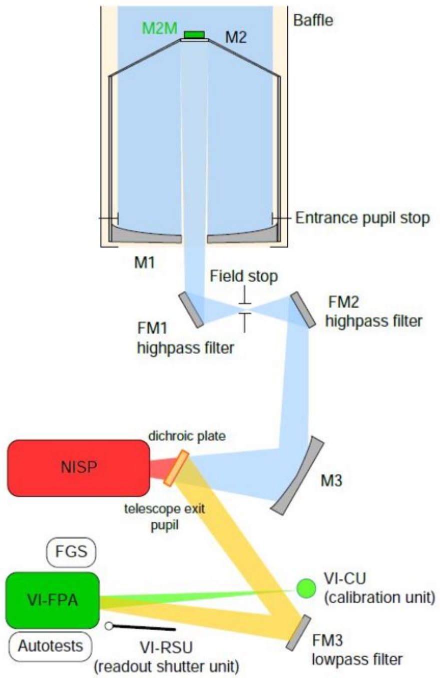


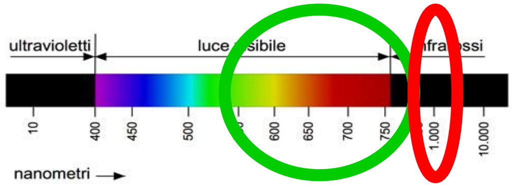
Louis Gabarra

INFN Padua, Italy

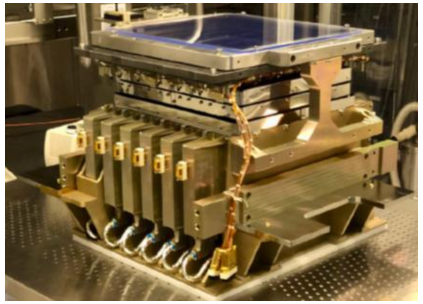
Co-authors: C. Mancini, L. Rodríguez-Muñoz, G. Rodighiero, M. Scodeggio, M. Talia, C.Sirignano, S. Dusini, L. Pozzetti, M. Moresco, D. Vergani, E. Palazzi, E. Maiorano, E. Rossetti, W. Gillard, B. Granett, M.Fumana, L. Paganin, G. Zamorani, L. Bisigello, M. Hirschmann, F. La Franca, J. Zoubian, V. Allevato, C.Laigle et al.

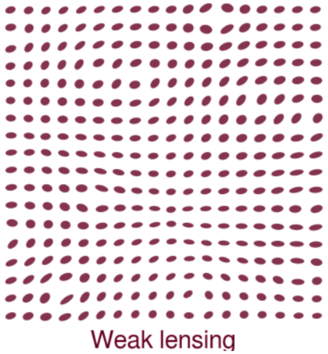
Euclid Mission: Study of the nature of the Dark Energy and Dark Matter **up to z ≈ 2**

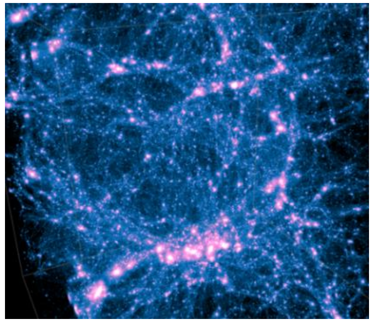




- VIS ➔ Weak Lensing* for 3D Dark Matter map (images with 0.1'' spatial resolution)

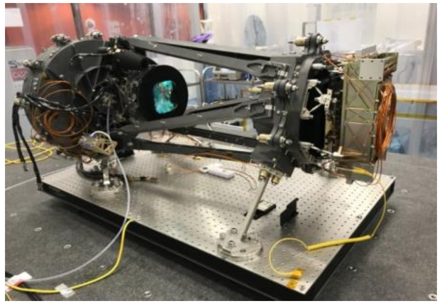


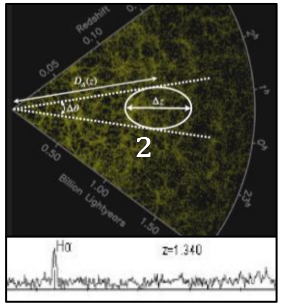


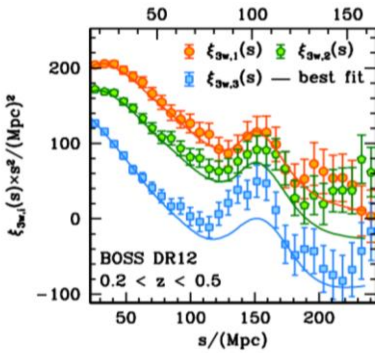


Legacy Science: Morphological parameters, masses and SFRs for billions of galaxies

- NISP ➔ Galaxy Clustering* for BAO & RSD study





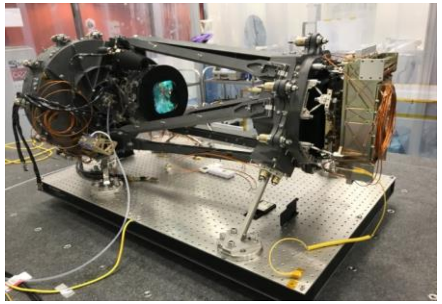


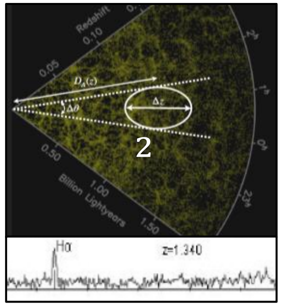
Legacy Science: Optical rest-frame spectra for 10s of millions of galaxies

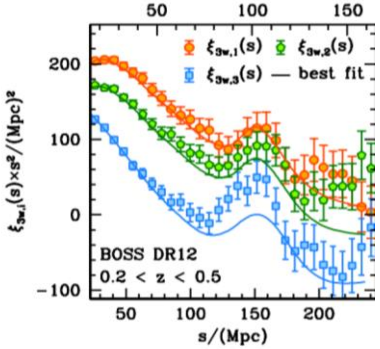
*Primary Euclid cosmological probes

Euclid Mission: Study of the nature of the Dark Energy and Dark Matter **up to z ≈ 2**

- NISP ➔ Galaxy Clustering* for BAO & RSD study





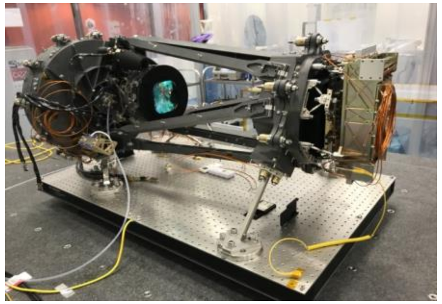


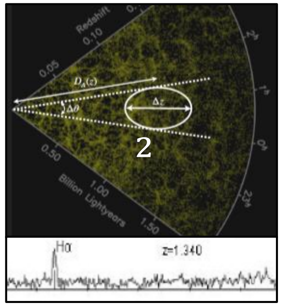
Legacy Science: Optical rest-frame spectra for 10s of millions of galaxies

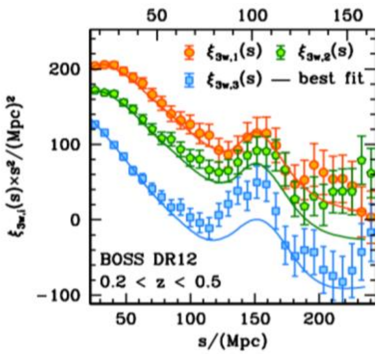
The Near Infrared Spectrometer and Photometer (NISP)

Spectroscopic requirement for the Cosmological probe **(#1/2): The spectral calibration**

- NISP ➔ Galaxy Clustering* for BAO & RSD study



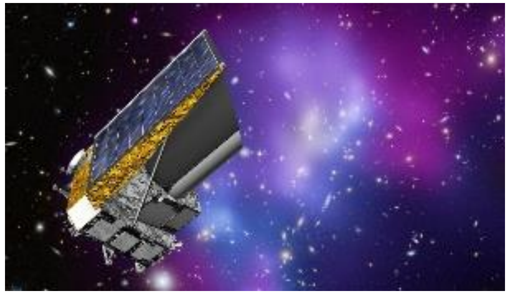


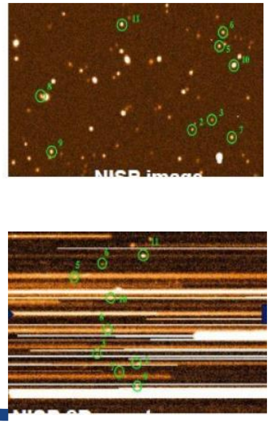


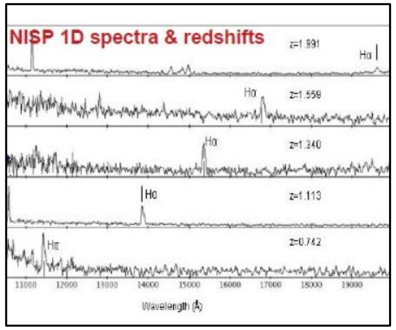
Legacy Science: Optical rest-frame spectra for 10s of millions of galaxies

Spectroscopic redshift accuracy requirement at

$$\sigma_z/(1+z) \le 0.002$$







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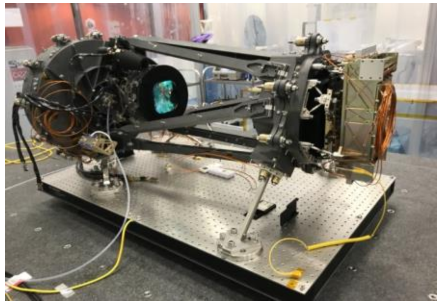
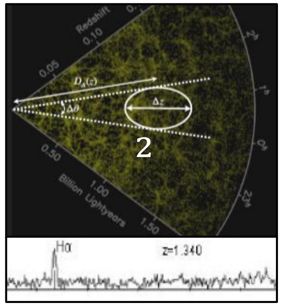
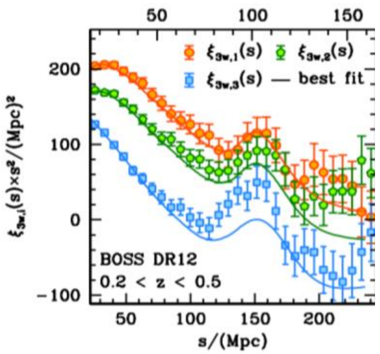
Spectroscopic requirement for the Cosmological probe **(#1/2): The spectral calibration**

➢ NISP ➔ Galaxy Clustering* for BAO & RSD study







Legacy Science: Optical rest-frame spectra for 10s of millions of galaxies

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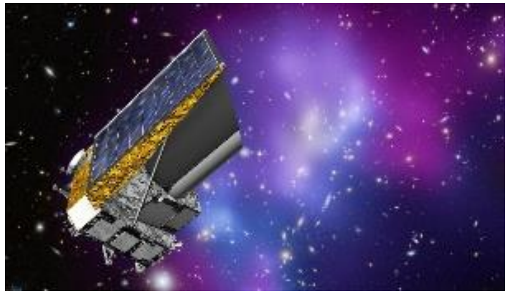
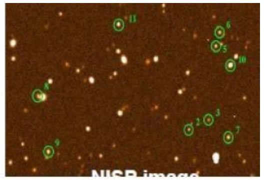
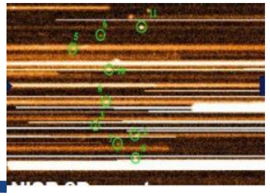
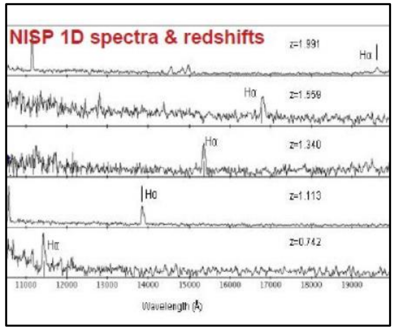






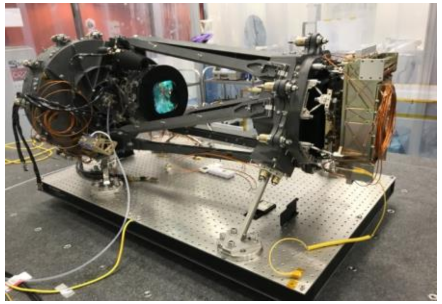


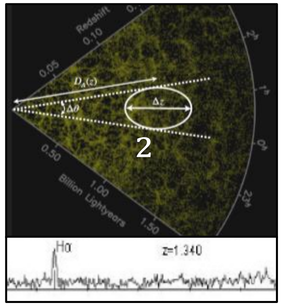
Spectral dispersion = **13.7 Å/px** + $\sigma_z/(1+z) \leq 0.002$ **translates in σ(λ) < 1 pixel!**

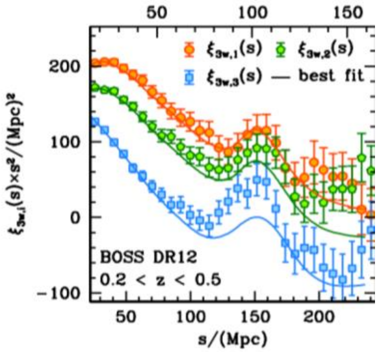
The Near Infrared Spectrometer and Photometer (NISP)

Spectroscopic requirement for the Cosmological probe **(#2/2): The detector sensitivity**

➢ NISP ➔ Galaxy Clustering* for BAO & RSD study

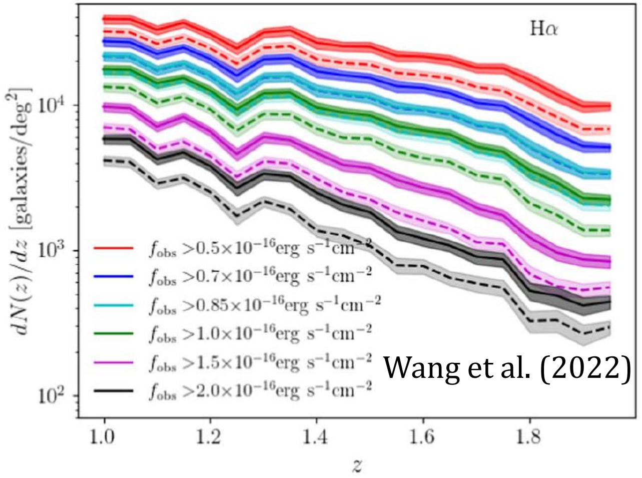






Legacy Science: Optical rest-frame spectra for 10s of millions of galaxies

Galaxy number density required of 1700 deg^{-2}



Wang et al. (2022)

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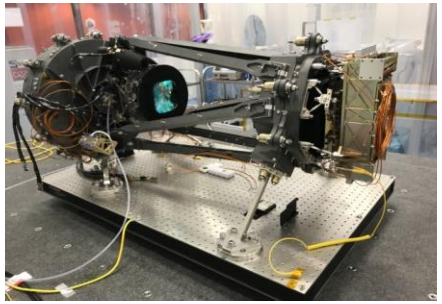

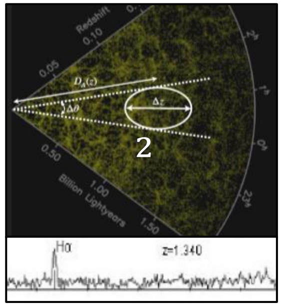

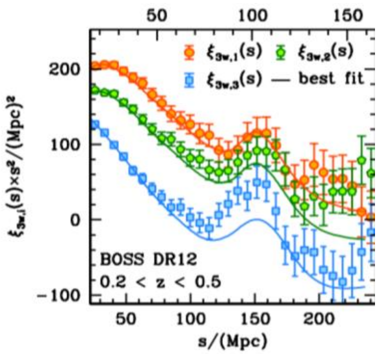

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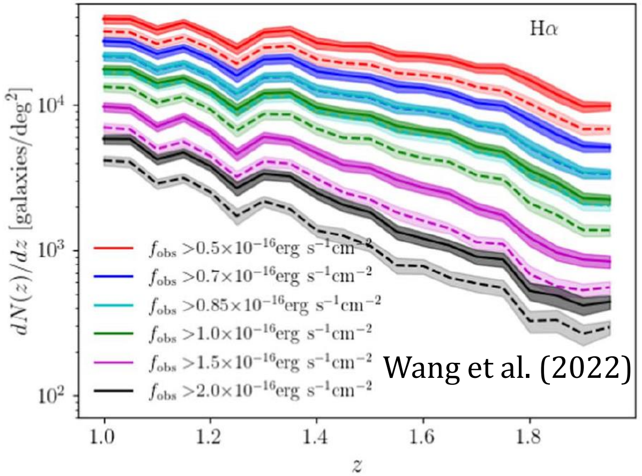

	Wide Survey	Deep Survey
AREA (deg^2)	15,000	40
IMAGING (VIS-NISP-P)	VIS H(AB)$\leq$24.5 NISP-P H(AB)<24	H(AB)$\leq$26.5 NISP H(AB)<26
SPECTRO (NISP-S)	Red grism - Flux(line)$\geq 2 \times 10^{-16}$ CGS H(AB)$\leq$19.5 4 frames of 553.0 s	Red grism Blue grism Flux(line)$\geq 6 \times 10^{-17}$ CGS H(AB)$\leq$21.5 5×4 frames of 553.0 s

Why will **Euclid spectroscopy** provide **unprecendeted data**?

- Poorly sampled **redshift range 1.5 < *z* < 2** due to:
  - **Optical strong emission lines** are too blue to be observed with **classical optical spectrographs**
  - Absorption and emission from **atmosphere in the NIR**
    - ➔ It includes the ***redshift desert*** *- 1.4 < z < 1.8* - Soon to be a forest!

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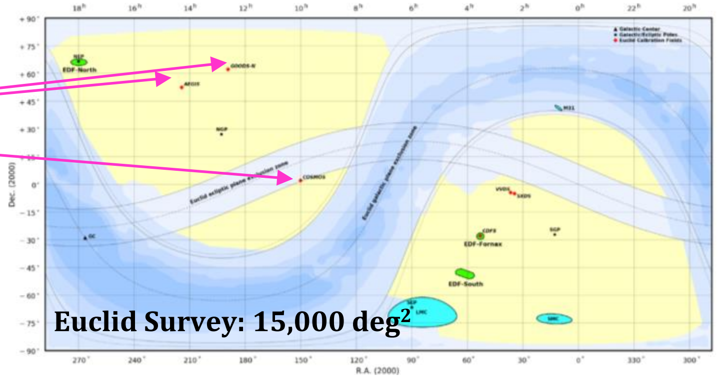

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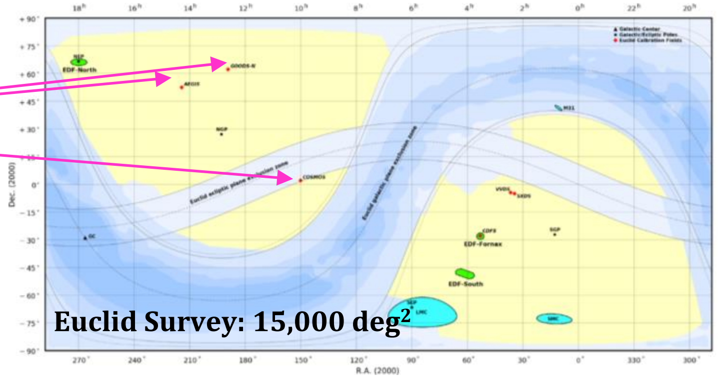
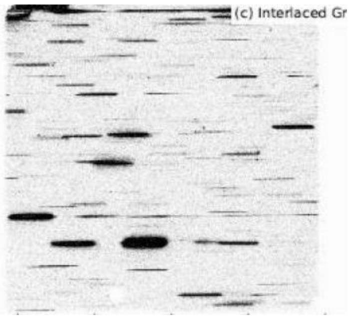
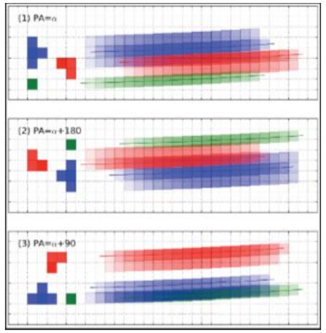


- **Slitless spectroscopy:**
  - **PROS:**
    - Untargeted pointing
    - Full FoV spectroscopy ➔ **Dispersed image**
    - Easy to build and operate
  - **CONS:**
    - **Overlapping** of spectra ➔ 4 Grism orientations
    - **Spectral convolution with galaxy shape**





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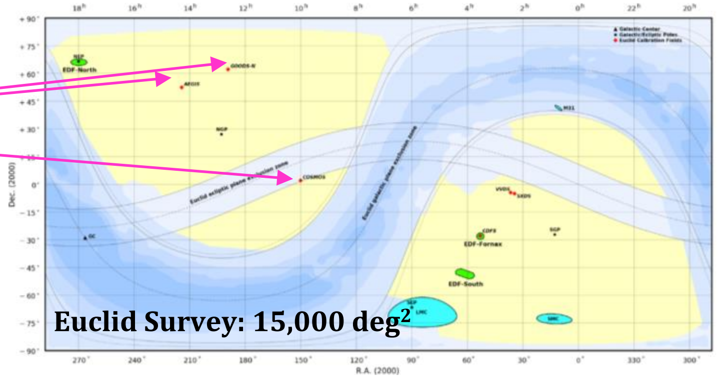

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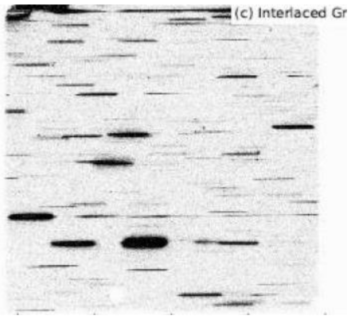

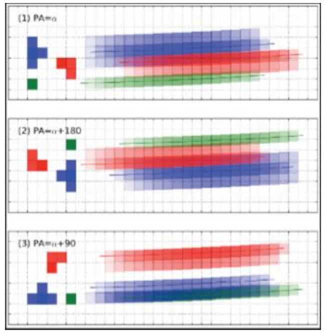

➔ PILOT RUN simulations to estimate NISP's capabilities

Objectives of the **PILOT RUN**
⇔ Simulating thousands of **Star Forming galaxies at 0.3 ≤z ≤2.5**

- To **develop** a solid methodology to build **synthetic spectra including emission lines**
- Simulating **thousands** of RGS spectra to **assess**:
  1. The **NISP simulator** (SIM/TIPS) **+ spectral extraction** (SIR) performance
  2. The **NISP/RGS performance** for the **Wide & Deep field surveys**
  3. The **effect of the galaxy shape** on the quality of the slitless spectra

	Wide Survey	Deep Survey
AREA (deg^2)	15,000	40
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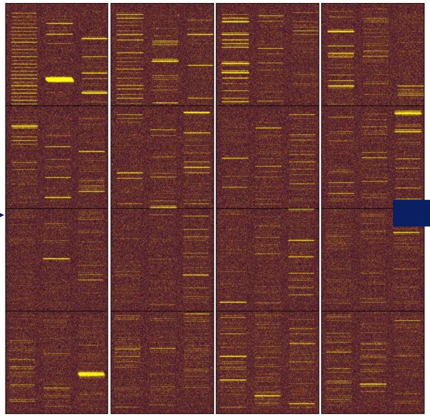
For 0.25” radius source at SNR = 3.5

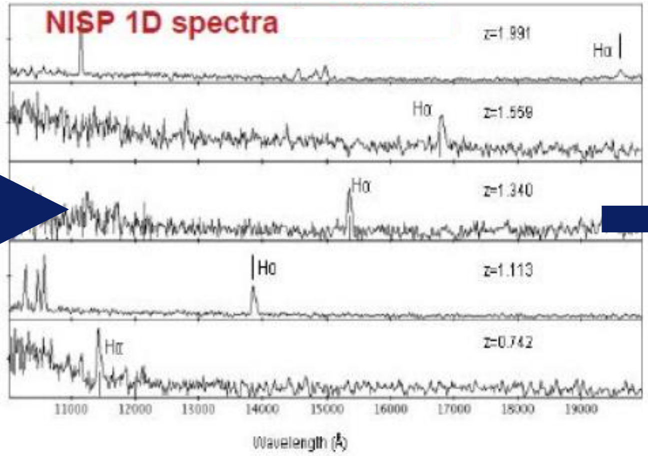
Construction of the **INPUT spectral library**

Euclid simulator



2,496 sources are distributed on a grid to avoid **mutual contamination**

Euclid spectral extraction pipeline



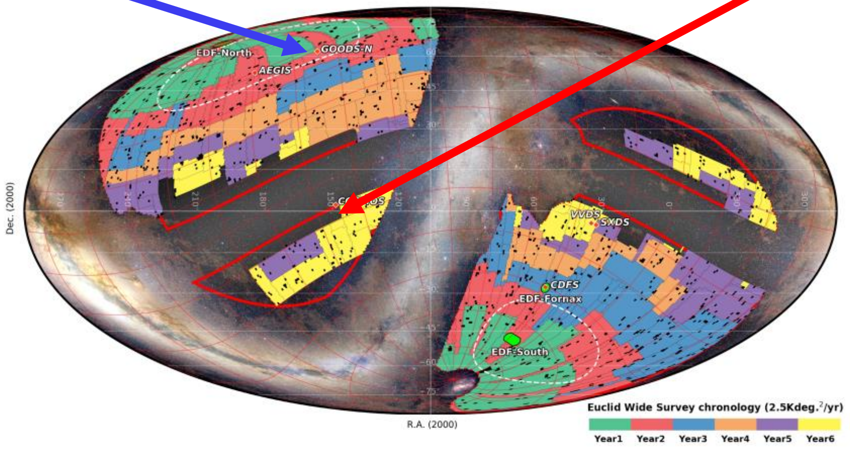
Analysis of the **extracted spectra**

Description of the simulation datasets (1/2): Simulating the **Euclid Wide and Deep** surveys

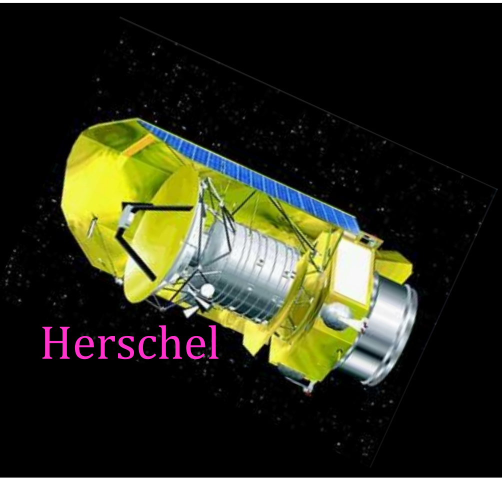
- Starting from publicly released **multiwavelength photometry** catalogs**: from UV to far-IR!**

GOODS-North field
BARRO et al. (2019)
➔ **Deep Field simulations**

COSMOS field
Laigle et al. (2016)
➔ **Wide Field simulations**



Scaramella et al. (2022)



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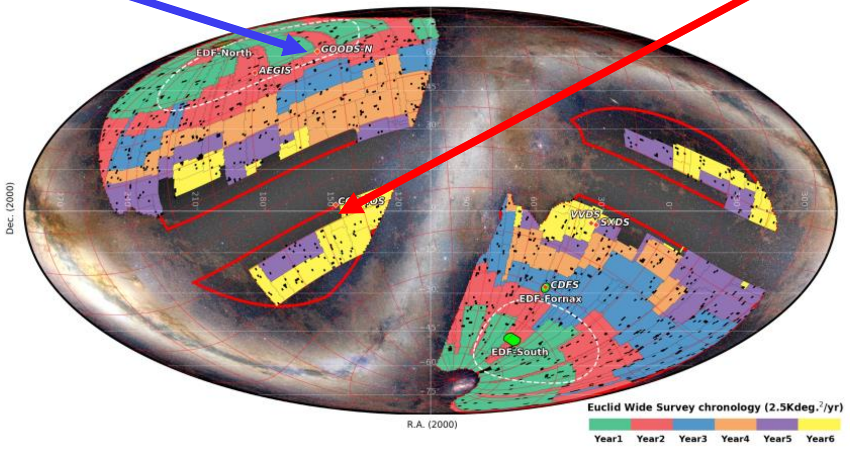

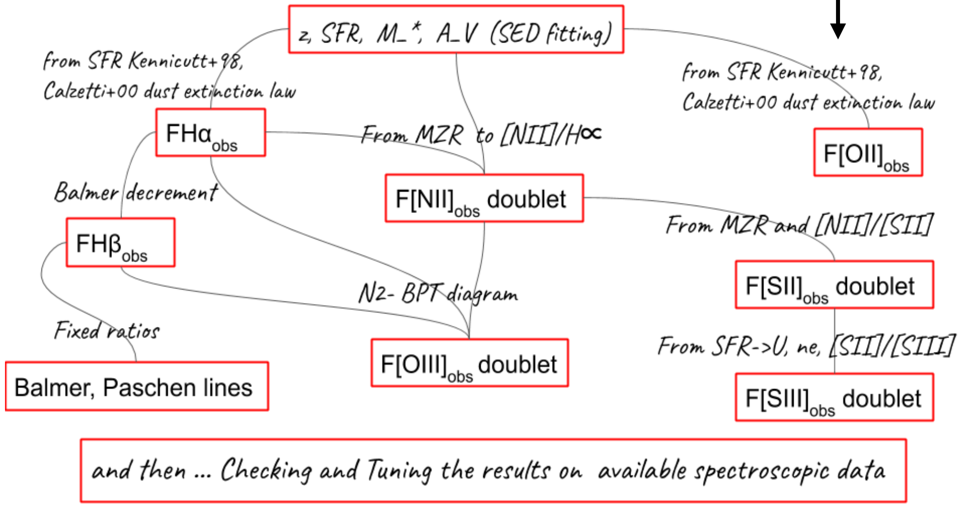

* Fields scheduled for deep observations for photometric redshift calibration and colour gradient calibration purposes

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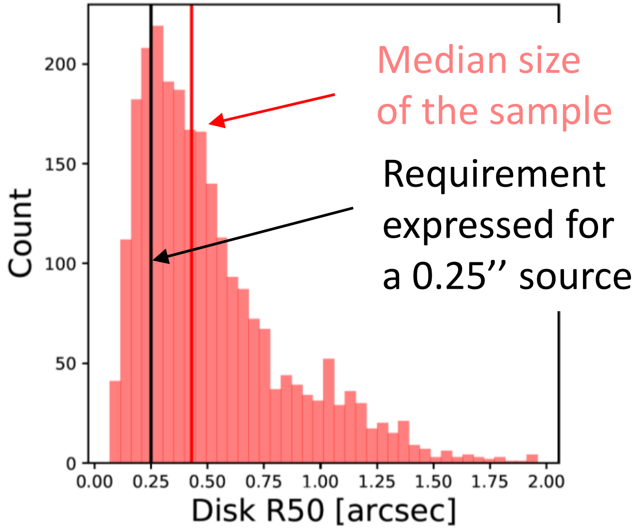

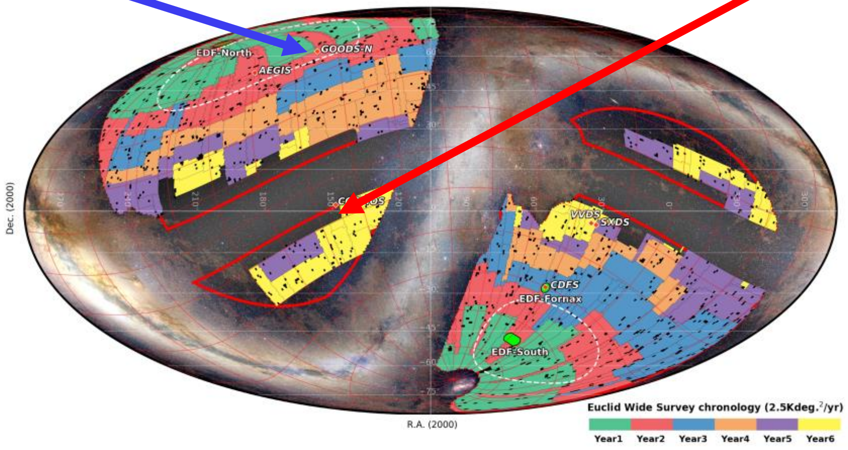

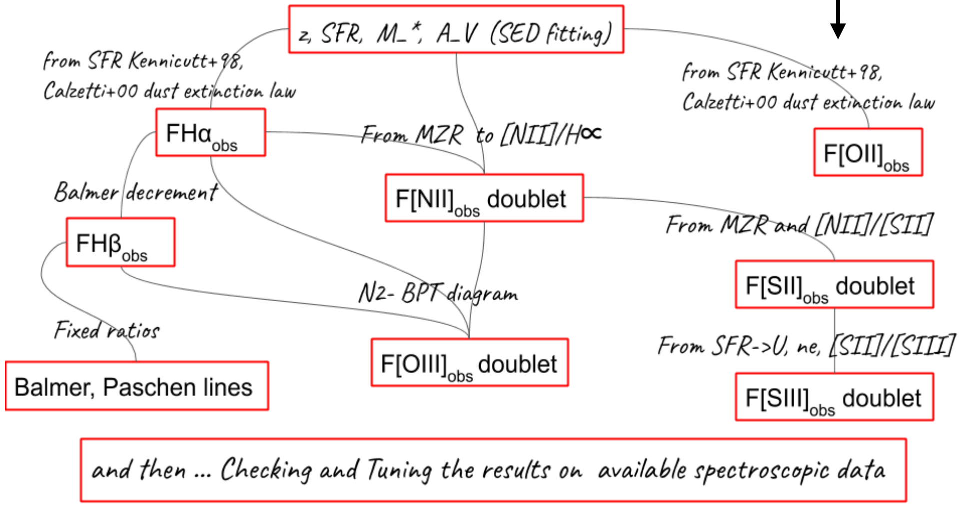

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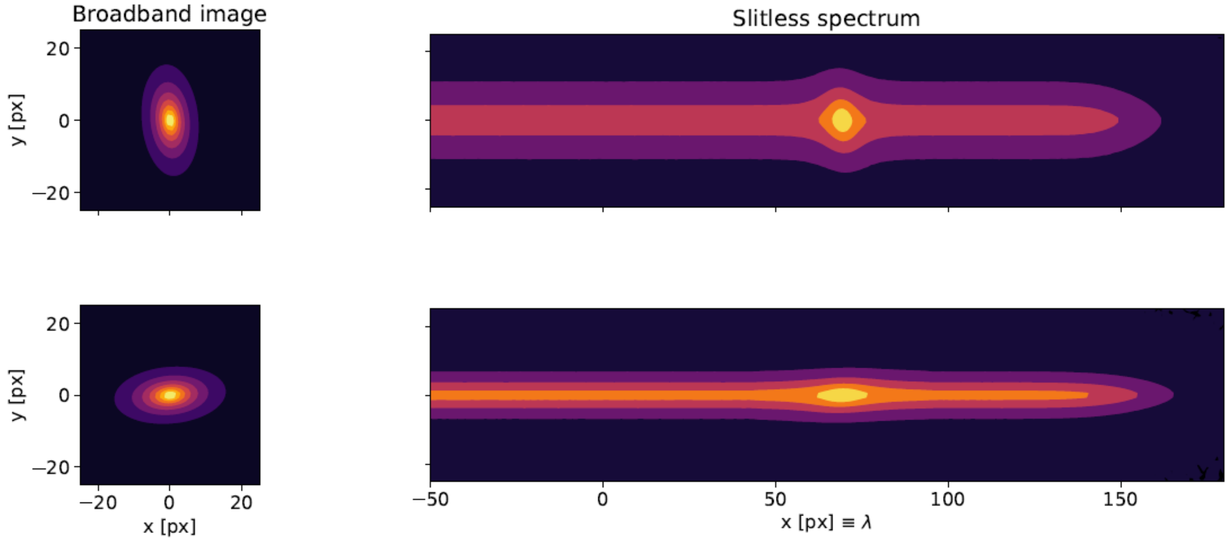
Probing the **effect of the galaxy shape** on the quality of the slitless spectra
Simulating **thousands of times** the **same galaxy** with varying **Disk R50**

- Simulating **thousands of times** the **same galaxy**, i.e. same incident spectra
- Galaxy located at **z = 1.6 ➔ Hα** (6e-16 CGS) and **[OIII]5008** (3e-16 CGS) fall in the RGS passband
- We change the morphological parameters **ONE AT A TIME**:

4 datasets of 1248 sources

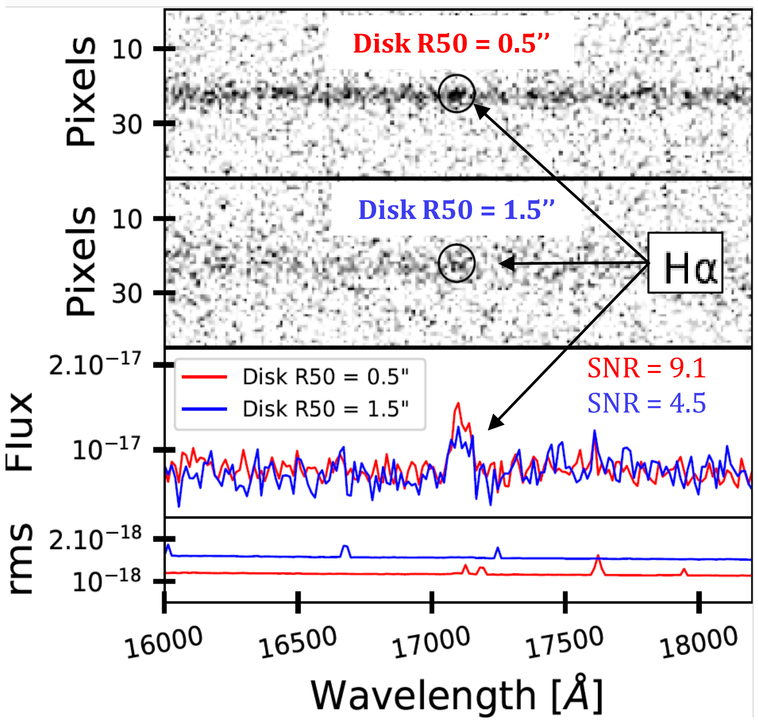
1) Changing the **inclination**, i.e. from edge-on to face-on (from 0° to 90°)
2) Changing the **position angle** of the disk to the dispersion axis (from 0° to 90°)
3) Changing the **Bulge fraction** (from 0 to 1)
4) Changing the **disk size** (from 0.01'' to 2'')



PhD thesis, Outini (2019)

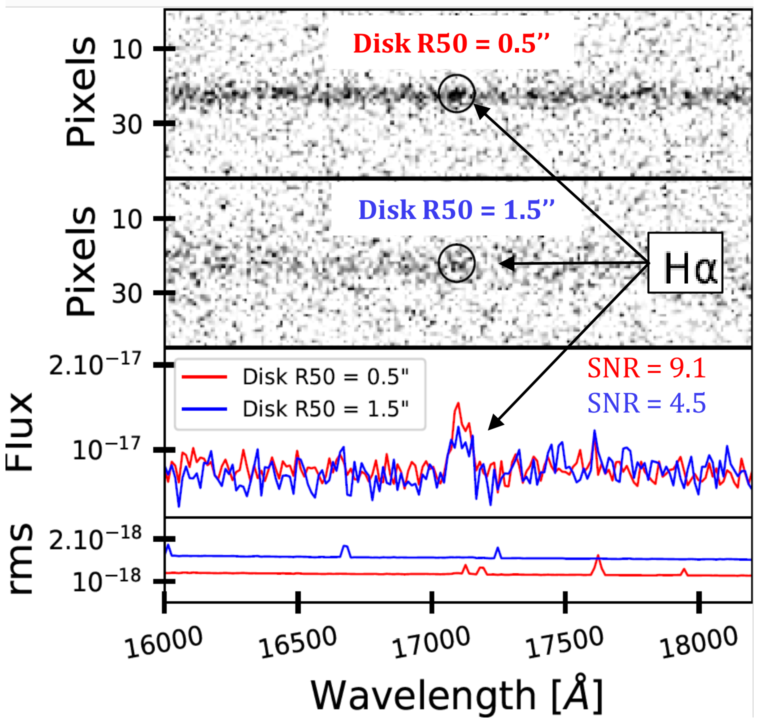
Probing the **effect of the galaxy shape** on the quality of the slitless spectra
Simulating **thousands of times** the **same galaxy** with varying **Disk R50**

Noise & FWHM
at two different **Disk R50**
(0.5'' and 1.5'')

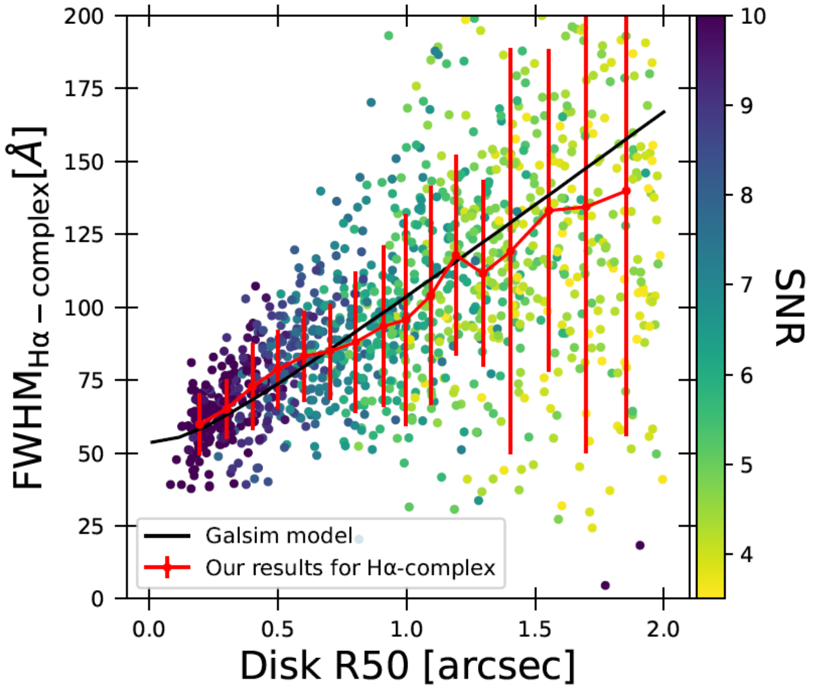


Probing the **effect of the galaxy shape** on the quality of the slitless spectra
Simulating **thousands of times** the **same galaxy** with varying **Disk R50**

Noise & FWHM
at two different **Disk R50**
(0.5'' and 1.5'')



Spectral resolution
Versus **Disk R50**



The **spectral resolution** degradation
as the Disk R50 increases

Probing the **effect of the galaxy shape** on the quality of the slitless spectra
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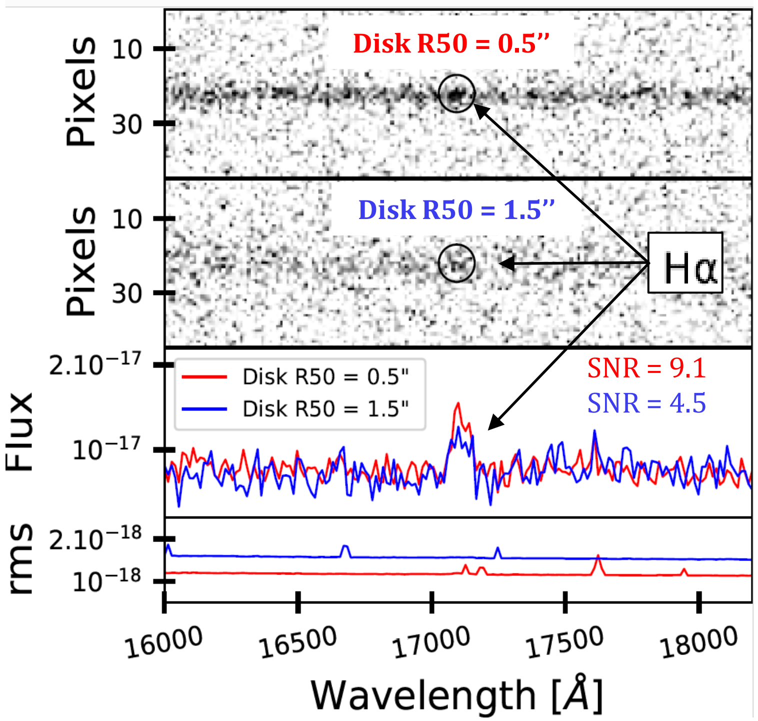
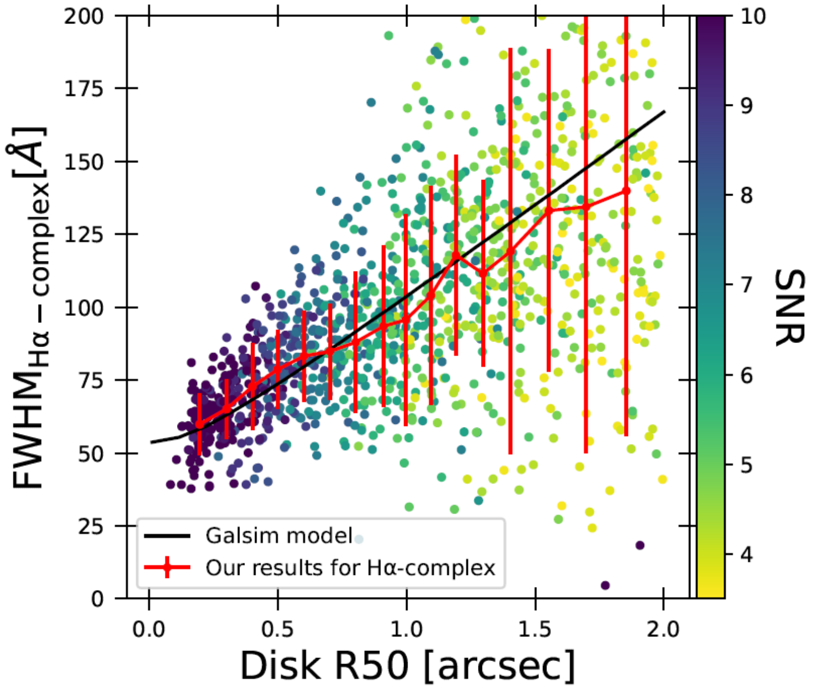
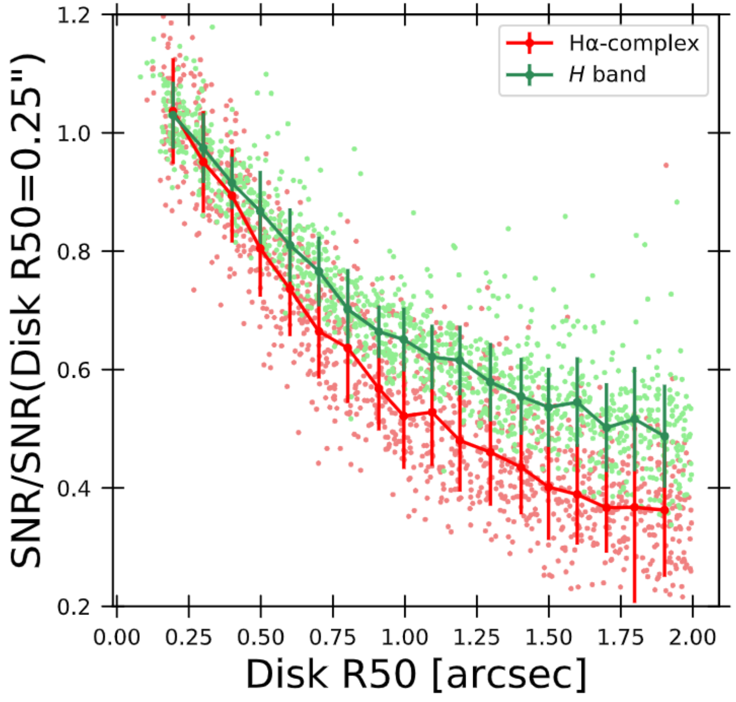


Spectral resolution
Versus **Disk R50**



The **spectral resolution** degradation as the Disk R50 increases

SNR emission lines & continuum
Versus **Disk R50**

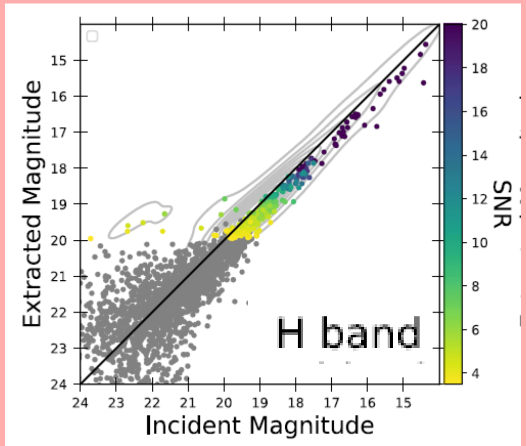


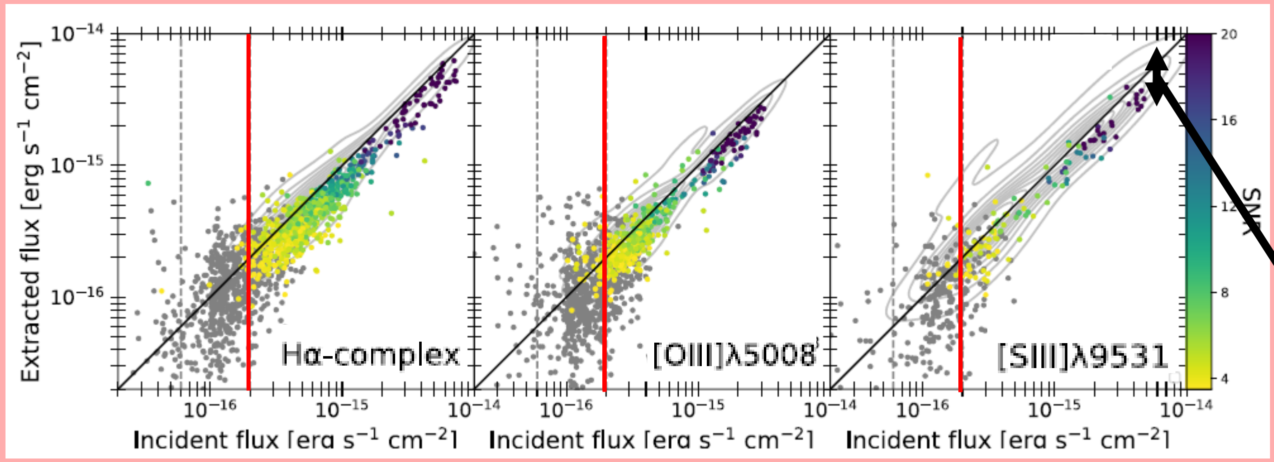
⇒ **SNR** drops by **approx. 20% as the disk R50 doubles**

Euclid Wide and Deep Field Surveys simulations:
True Versus Extracted fluxes

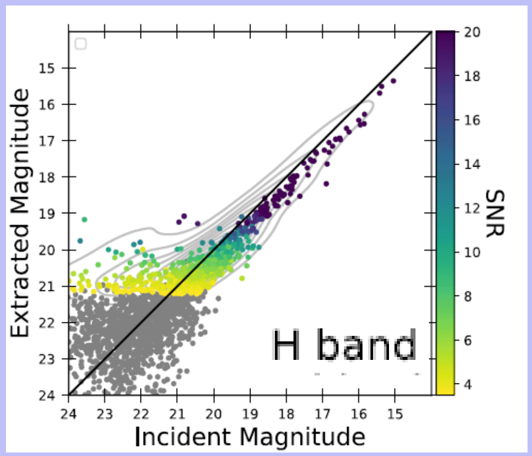
Continuum measurement | **Emission line** measurement

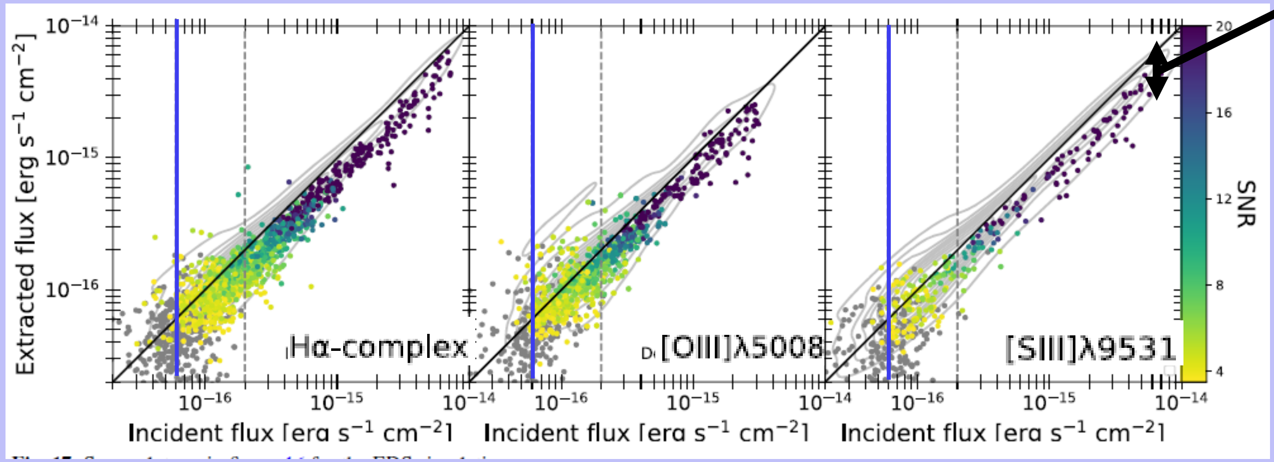
Wide Field simulation





Deep Field simulation

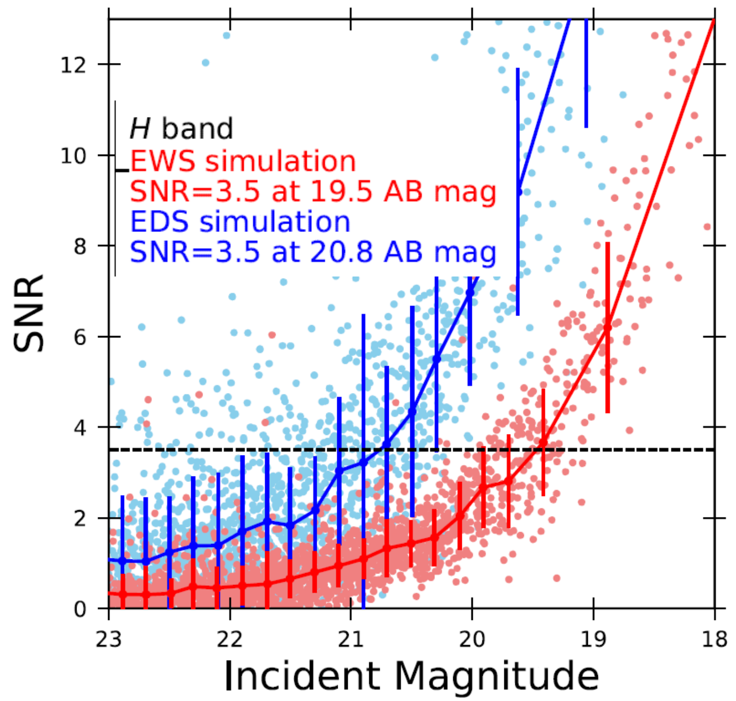




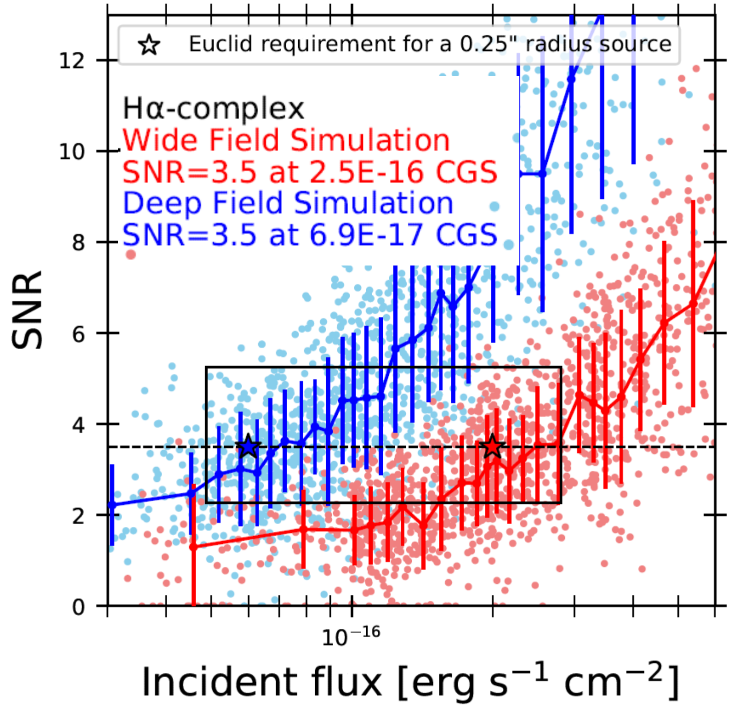
Offset expected to be **reduced** with the **optimal extraction aperture** procedure

Euclid Wide and Deep Field Surveys simulations:
Deriving the **RGS detection limit** at **SNR = 3.5**

Continuum detection limit

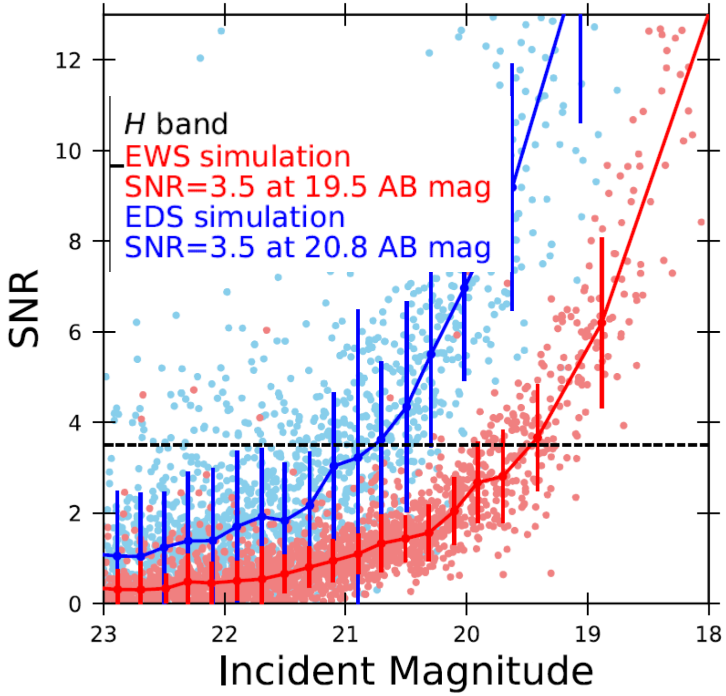


Hα detection limit

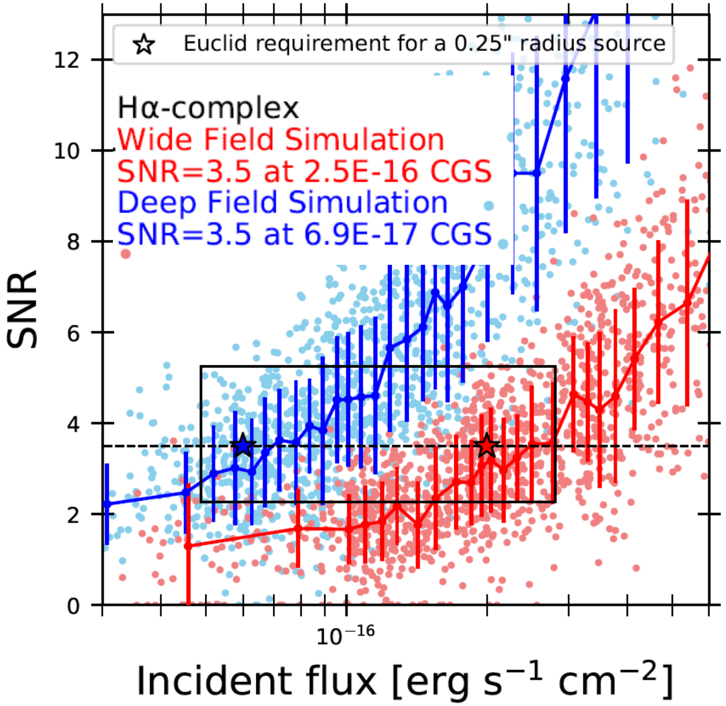


Euclid Wide and Deep Field Surveys simulations:
Deriving the **RGS detection limit** at **SNR = 3.5**

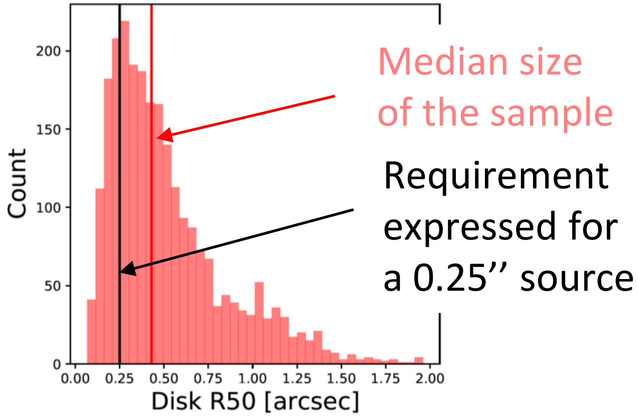
Continuum detection limit

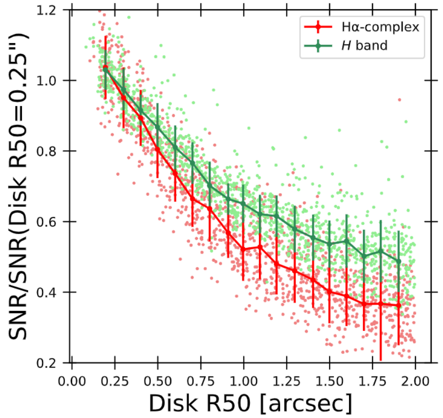


Hα detection limit



The **size effect**



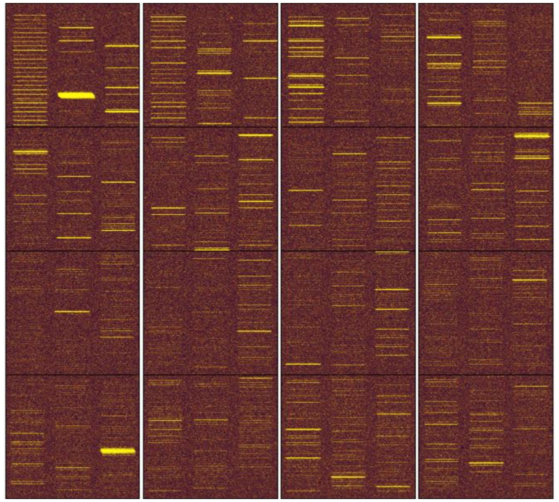


Conclusion and **NEXT STEPS**

- Validation of the **OU-SIM & OU-SIR pipeline**
- Characterization of the **degradation of the SNR as the Disk R50 increases**
  - ⇒ **SNR emission lines & continuum** drops by **approx. 20%** as the **disk R50 doubles**
- **Preliminary assessment of the NISP Red-Grism capabilities**

Simulation	Exposure time (s)	Continuum H band (mag)	Emission lines Hα (CGS)
EWS	2212	19.5 ± 0.2	$(2.5 \pm 0.6) \times 10^{-16}$
EDS	22 120	20.8 ± 0.6	$(6.9 \pm 2.8) \times 10^{-17}$

Median disk radius of the sample = 0.4’’



- **NEXT STEPS:**
  - Coming simulations
    - With a **bigger sample of simulated spectra**
    - Testing spectral decontamination and optimal extraction
    - Including the **blue grism**