NISP Spectroscopic simulations

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Performance evaluation: requirements and goals

- 52 millions of galaxies over 15000 deg$^2$
- redshift 0.7 to redshift 2.0
- Performance verification: demonstrate we satisfy level 2 Requirements on redshift measurements
  - Completeness $\sim$50%
  - Catastrophic failures < 20%
  - $\sigma_z < 0.001(1+z)$
- Slitless spectroscopy
- detection of emission lines, mainly H$\alpha$
End2End simulation pipeline: concepts

Requirements

• Use packages available at each time
• Allow for parallel development of tasks
• Possibly in different languages
• 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
• Parallel development

INSTALLATION FAR FROM TRIVIAL......

• Many external libraries
• Which are OS dependent
• Development/debugging still on going
• NOT user friendly
End2End simulation pipeline: structure

Catalog
Instrument Parameters
Observing Strategy

INPUT

 Incident spectra creation
Observed spectra creation
Spectra extraction
AXESim

Spectra combination

Redshift measure
RESS
Redshift reliability
EZ

Completeness
Purity
Dn/dz
Accuracy

IMODEL

Dispersed images
1D extracted spectra
Redshifts & flags

OUTPUT
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 but there are still gaps.
2. The two detector types have different effective fields of view, the different gaps do not coincide.
3. Mitigates the impact of cosmic defects and cosmic rays.
4. Imaging: improves the sampling.
5. Spectroscopy: the four dithers are used to implement the 2 grism*2 rolls strategy.

93.4% pixels with >3 frames.
50.9% pixels with 4 frames.
## Instrumental Parameters

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

![](chart.png)
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.


- 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

- **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 step 2: 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

- Red and blue sub-spectra for each roll angle are joined
- Array gaps and dithering strategy are taken into account
• Compare roll 0 and roll 90 spectra
• Flag spurious lines
• Combine roll 0 and roll 90 spectra allowing for gaps
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Combined after clean

Angle 0

Angle 90
Simulation pipeline step 5: redshift measurement

- 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 H\(\alpha\)
- If 1 emission line
  - assumed as H\(\alpha\).
- 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

- 90% level: $8 \times 10^{-16}$ erg/cm$^2$/s/Å
- 80% level: $4 \times 10^{-16}$ erg/cm$^2$/s/Å
- 50% level: $3 \times 10^{-16}$ erg/cm$^2$/s/Å

Wavelength (Å):

- 1.2x10^4
- 1.4x10^4
- 1.6x10^4
- 2x10^4

Flux (erg/cm$^2$/s/Å):

- 10^{-17}
- 5x10^{-18}
- 10^{-17}
- 5x10^{-18}
- 5x10^{-18}
- 5x10^{-18}
- 5x10^{-18}
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

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

- 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: $6 \times 10^{-5}$

![Graph showing redshift accuracy](image)
Simulation pipeline step 7: redshift accuracy

Predicted redshift distribution of Euclid galaxies with reliable redshift

Galaxies/deg^2/0.1 vs. redshift
End2end simulations: past, present and future use

• Demonstrate feasibility of scientific goals

• Monitor scientific performances along with instrument development and mission definition

• Will allow testing and validation of reduction and z measurement algorithms and implementations

• Will provide “as observed” data for tuning scientific exploitation
What’s missing

• Observed spectra
  – Accurate Detector Model
    • Cosmic Rays and bad pixels
    • Pixel2pixel variation of Dark current, Q.E, RON
  – PSF modelling
    • Vs. wavelength
    • Vs. X,Y position
  – Simulate 1 full FOV
    • Account for array positioning tolerances
  – ……………

• Spectra reduction
  – Real wavelength calibration
  – Realistic and optimal extraction
  – ……………

• Redshift measurement
  – Consider high redshift sources
  – Better flagging system (increase purity)
  – ……………………………
Royal Observatory Edinburgh Workshop 2011

Following the photons
Astronomical Simulations for Instruments & Telescopes
Edinburgh, 10-12th October 2011

http://www.roe.ac.uk/roe/workshop/2011/

Invited speakers:
Xavier Luri (Barcelona), Andrew Connolly (U. Wash.), Michael Davidson (Edinburgh), Bianca Garilli (Milan/LAM), Rene Gastaud (CEA/Saclay), Remy Indebetouw (Virginia), Joe Liske (ESO), Robert Lupton (Princeton), Bruce Sibthorpe (UKATC), Richard Wilson (Durham)
Conclusions

• Slitless spectra are not “so” nice
• A number of complication wrt slit/fiber spectroscopy
• Wide survey
  – 52 millions of galaxies over 15000 deg^2
  – redshift 0.7 to redshift 2.0
  – \( \sigma_z < 0.001(1+z) \)
• Deep survey
  – 40 deg^2
  – hundreds of galaxies at redshift \( z>7 \)
  – tens of quasars at \( z>8 \),
  – and more……

Lot of science to be done!