# HARMONI view of high-redshift QSO hosts


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## Abstract

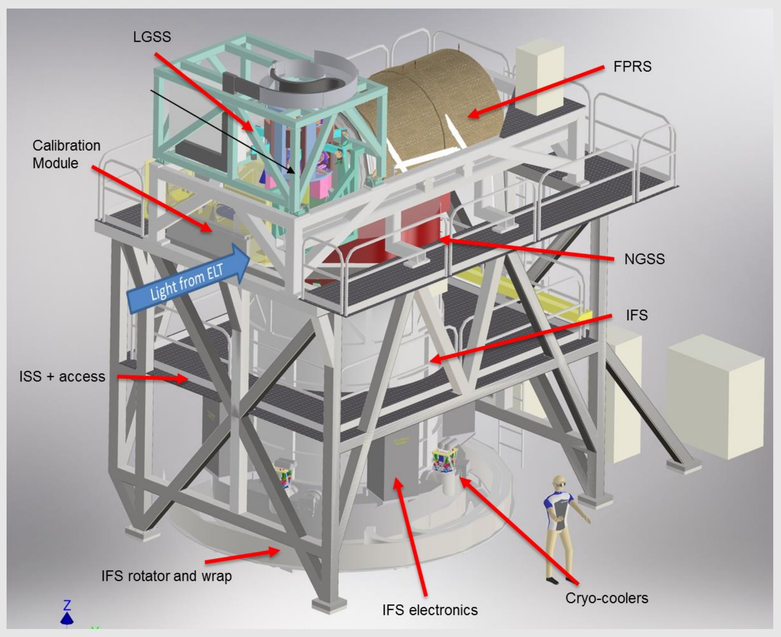

We present preliminary results on the capabilities of HARMONI[1], the first light integral field spectrograph for the ELT[2], for high-redshift QSO hosts studies.

We performed simulations of HARMONI observations of QSOs at z=1.1 assuming two host-galaxy morphologies. As input for the simulation we combined MUSE observations of two nearby galaxies and a theoretical QSO spectrum which were redshifted and dimmed to z=1.1. We used the coarsest HARMONI spatial scale, R=7500 in the J-band, and LTAO on standard seeing conditions. This setup allowed simultaneously observe emission (Hβ+[OIII]) and absorption lines (e.g. MgI) to estimate the QSO and host galaxies parameters.

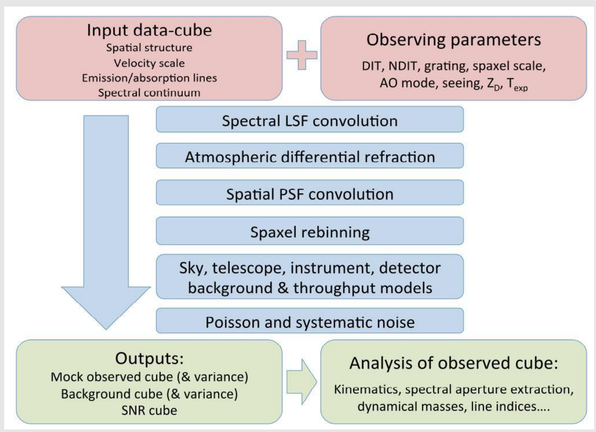

## HARMONI Instrument Description

**HARMONI** is composed of:

- Calibration Module
- Laser Tomographic AO system (LGSS)
- Single Conjugate AO system (NGSS)
- PreFocal Relay System (PFRS)
- Integral Field Spectrograph (IFS) including
  - 3,5 m diameter cryostat operating at 140K
  - Preoptics providing pupil cold stop and 4 spatial scales
  - Integral Field Unit with Field Splitter, Relay systems and Image slicer
  - 4 spectrographs including 42 gratings for multi-spectral resolution
  - 12 detectors



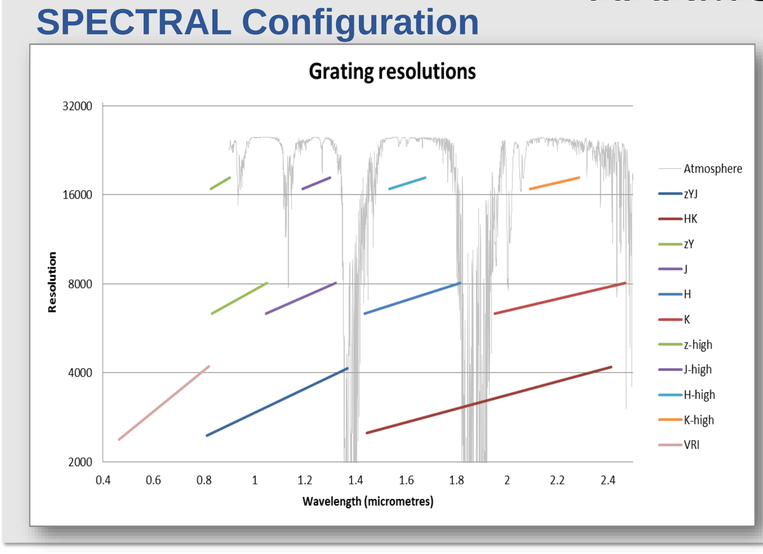

## HARMONI Simulator - HSIM



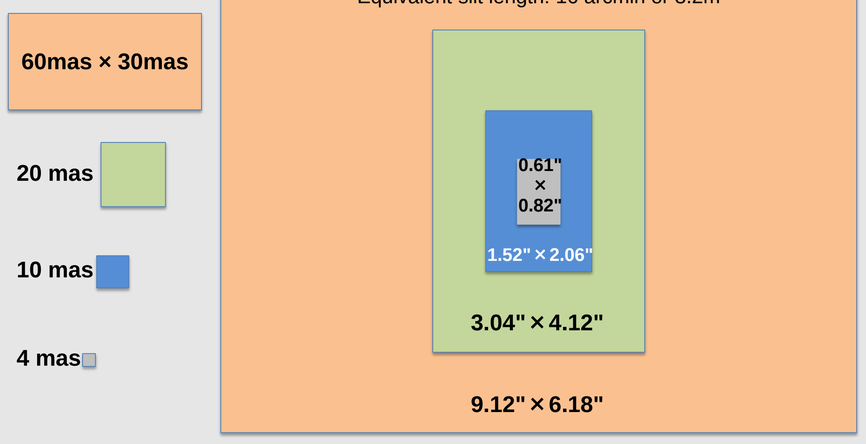

HSIM[3] simulator available to the community
http://harmoni.physics.ox.ac.uk

## HARMONI configurations

### SPECTRAL Configuration




### SPATIAL Configuration




## HSIM input

**Input data-cube**

**QSO + host** at Z~ 1.1

**Data-cubes** ~180x180x2300

**Sampling** Spatial: 10 mas/px Spectral: 2Å/px

**FoV** ~ 1,8´´x 1,8´´

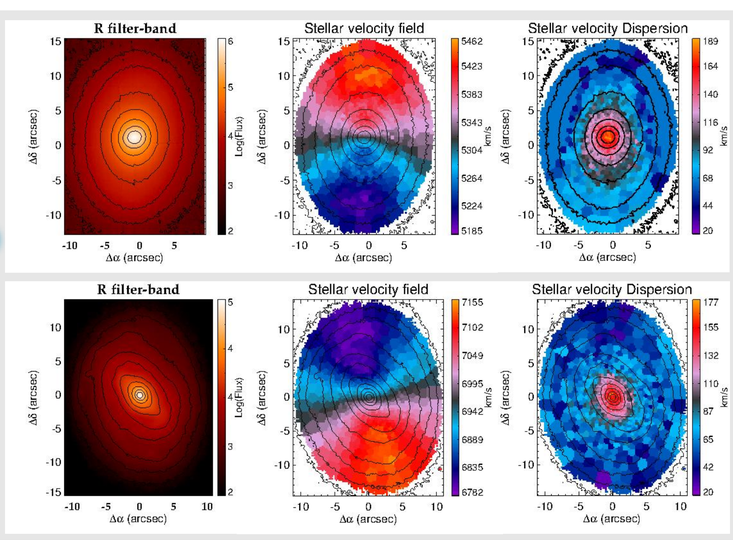
**Observing parameters**

| | | | |
|---|---|---|---|
| DIT | 900s | AO | LTAO |
| NDIT | 12 | Seeing | 0",67 |
| $Z_D$ | $20^0$ | Grating | 7500 |
| $T_{exp}$ | 3h | Scale | 30x60 |

**The QSO**
Theoretical quasar spectrum
Shifted to host object redshift + Same MUSE sampling + Best-case[6]: $\log(L_{[OIII]})=42$
Spectral redshifted and brightness dimming[5] to Z~1.1

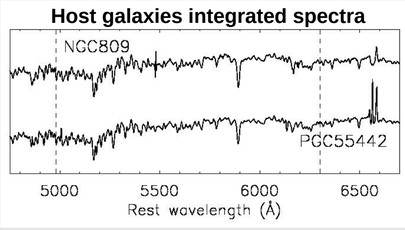
**The host galaxies**
Nearby galaxies from AMUSING Project[4]
MUSE data-cube → 0.2 ´´/px + 1.25 Å/px spatial + spectral samplings
Spectral redshifted and brightness dimming[5] to Z~1.1. Data cube resized accordingly

## Two host galaxies



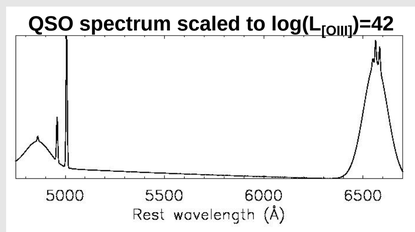

| | NGC809 | PGC55442 |
|---|---|---|
| Type | Lenticular | Spiral |
| Ø ["]/[kpc] | 88.7 / 33.35 | 63.1/33.21 |
| Mag (H) | 10.72 | 10.98 |
| $V_{sys}$ (Km/s) | 5367 | 7068 |

**Host galaxies integrated spectra**




## QSO spectrum

**QSO spectrum scaled to $\log(L_{[OIII]})=42$**




QSO continuum: exponential function[7]
+
Gaussian profiles for bright emission lines[8,9]

## Simulated HARMONI observations

**HSIM Output data-cube**

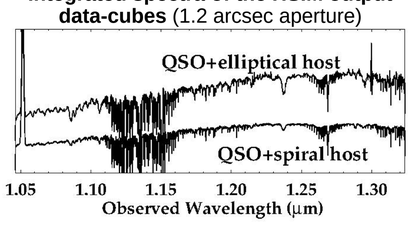
**HARMONI observation of QSO + host** at Z~ 1.1

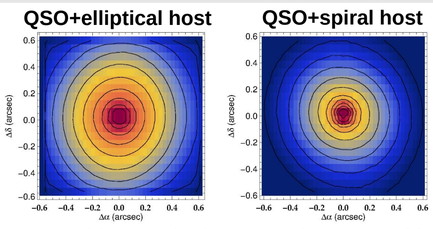
**Data-cubes** ~60x30x3325

**Sampling** Spatial: 30x60 mas/px Spectral: 0.83 Å/px

**FoV** ~ 1,8´´x 1,8´´

**Integrated spectra of the HSIM output data-cubes** (1.2 arcsec aperture)

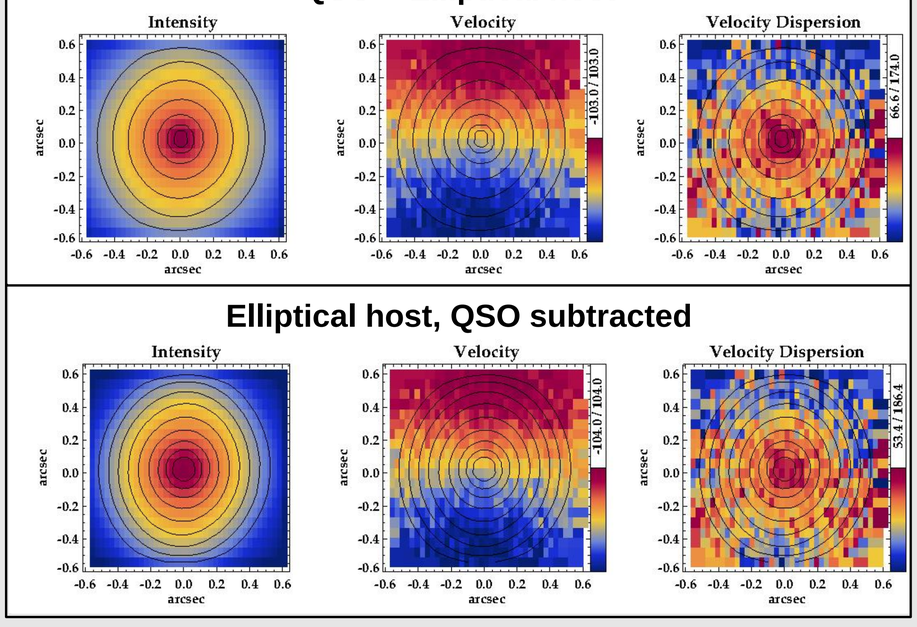



Integrated images in the spectral range 1.198-1.126 μm obtained from simulated HARMONI observations.

## Analysis of the HARMONI observed data-cubes

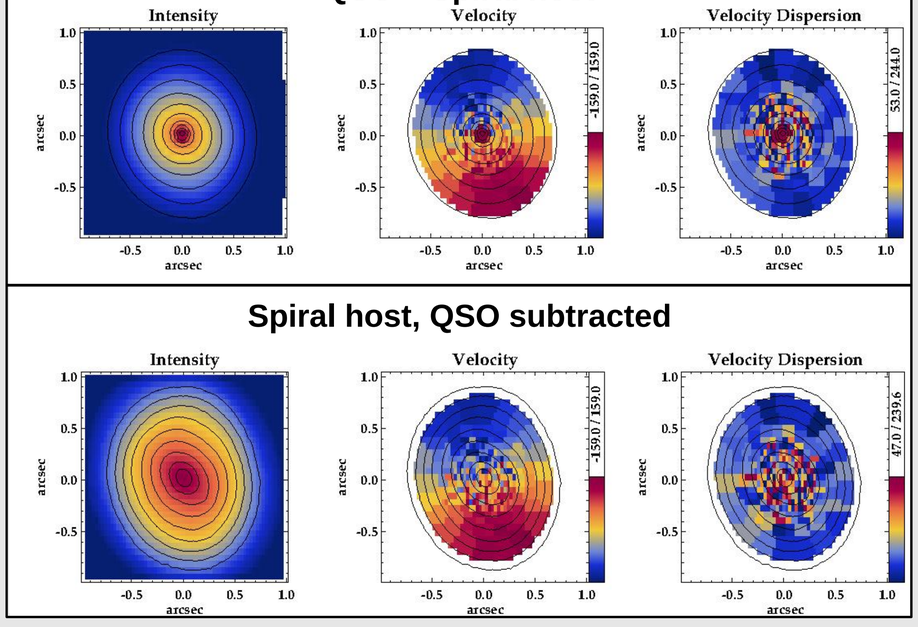
### QSO + Elliptical host




### Elliptical host, QSO subtracted




### QSO + Spiral host




### Spiral host, QSO subtracted




Upper panels show the intensity, velocity, and velocity dispersion maps of the stellar component for two QSO+host galaxies at Z=1.1 obtained from the HARMONI observed data-cubes using PPXF[10]. Bottom panels present the same maps derived from the HARMONI data-cubes after the QSO subtraction using an optimal PSF (HSIM output for a point-source QSO HSIM input).

**Results:** Stellar kinematic parameters can be estimated.
A proper subtraction of the PSF (QSO removal) would revel the morphology of the host galaxy.

## Conclusions

- Our simulations indicate that HARMONI will obtain high quality observations of QSO+host objects using reasonable observing times of about three hours/object.
- PSF reconstruction and QSO removal are key to measure the host galaxy parameters.
- HARMONI observations are key to unveil the co-evolution of galaxies and their central black-holes.

## Next steps

- Complete a set of QSO+host galaxy simulations using different redshifts, QSO/host brightness ratios and host morphologies, and exploring other spectral wavelength ranges.
- Explore different methodologies for subtracting the central QSO and improve the estimation of the QSO and host galaxy properties.

## References


[1] Thatte et al. SPIE, 9908E, 1XT (2016)
[2] https://www.eso.org/sci/facilities/eelt
[3] Zieleniewski et al. MNRAS, 453, 375 (2015)
[4] Galbany et al. MNRAS, 455, 4087 (2016)
[5] Plank Collaboration, A&A, 594, 13 (2015)
[H0=67.9 km/s/Mpc, ΩM=0.31 and $\Omega_\Lambda$=0.69]
[6] Zakamska et al. AJ, 126, 2125 (2003)
[7] Neugebauer et al. ApJS, 63, 615
[8] Davison & Netzer, Rev.Mod.Phys, 51, 715 (1979)
[9] Wills et al. ApJ, 415, 563 (1993)
[10] Capellari MNRAS, 466, 798 (2017)