JWST Integral Field Spectroscopy of Galaxies: Practical items for proposal preparation (mainly) for the high-z case

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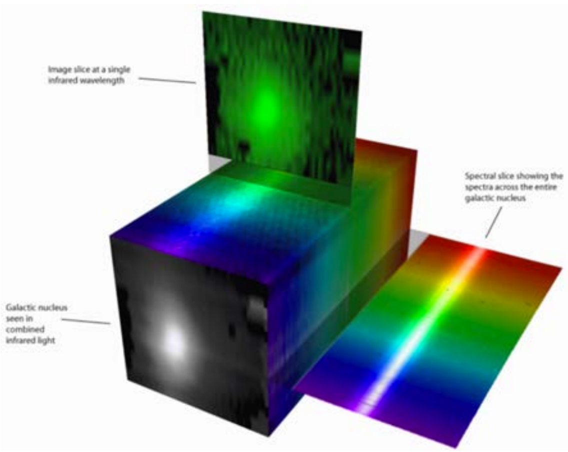
JWST IFS: Science Capability

- NIRSpec + MIRI IFUs => First time IFS in space at near- and mid-IR



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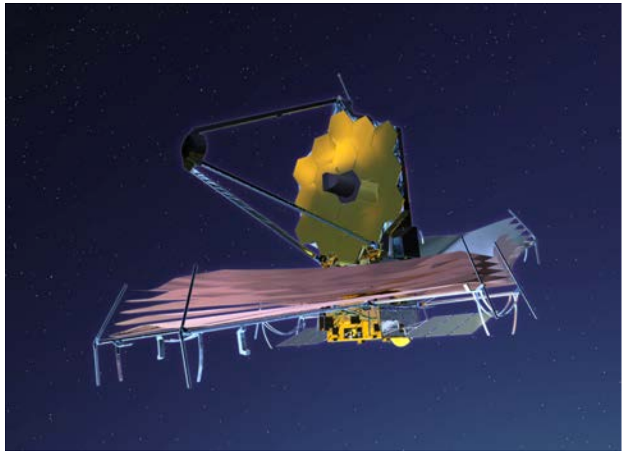


Inherent potential of IFS

JWST capabilities

- IFS at high sensitivity (orders of magnitude improvement)
- IFS over a continuous spectral coverage (0.6 – 28.8 microns)
- IFS at high angular resolutions (~ 0.1”-0.6”)
- IFS with a very stable PSF

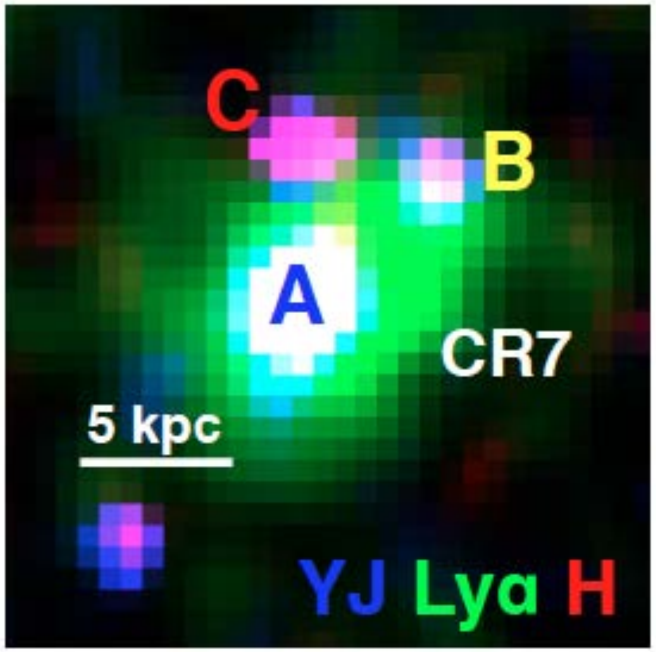
JWST IFS Science Capability : Physical coverage and resolution

	NIRSpec	MIRI
FoV	3” x 3”	~ 4” x 4” - 8” x 8”
Sampling	0.1”	0.2” – 0.6”

High-z galaxies 3” ~ 20 kpc (@ z 4-6)

– The FoV covers the entire galaxy, which is sampled on ~ (sub) kpc scales

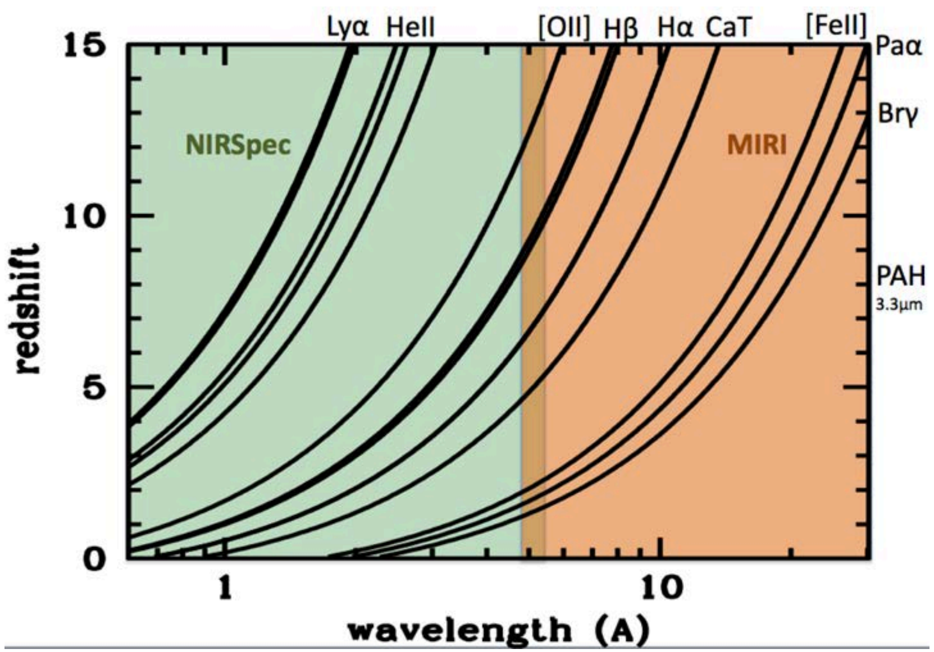
CR7 @ z=6.6



NIRSpec FoV

JWST IFS Science Capability: Spectral range and R

	NIRSpec	MIRI
Spectral range	0.6-5.3 mu	4.9-28.8 mu
Spectral R	100 (0.6-5.3) 1000 (0.7-5.2) 2700 (0.7-5.2)	3000

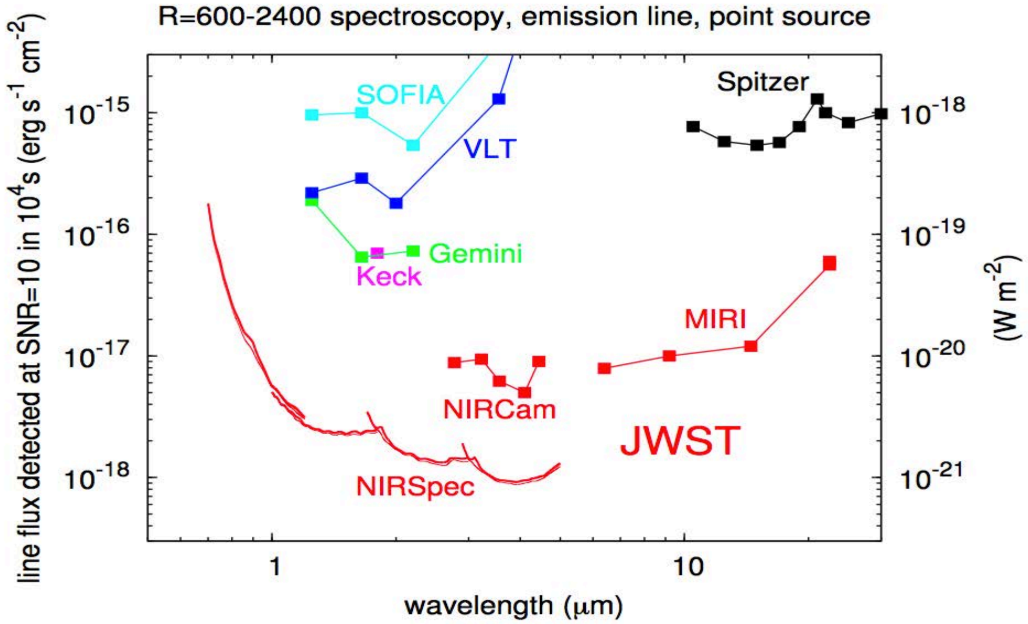


High-z galaxies

- NIRSpec (e.g.):
  - Hbeta out to z ~ 10
  - Halpha out to z ~ 7
- MIRI (e.g.):
  - Halpha for z > 6.5
  - Paalpha for z > 1.6
  - PAH (@3.3) out to z ~ 7.5

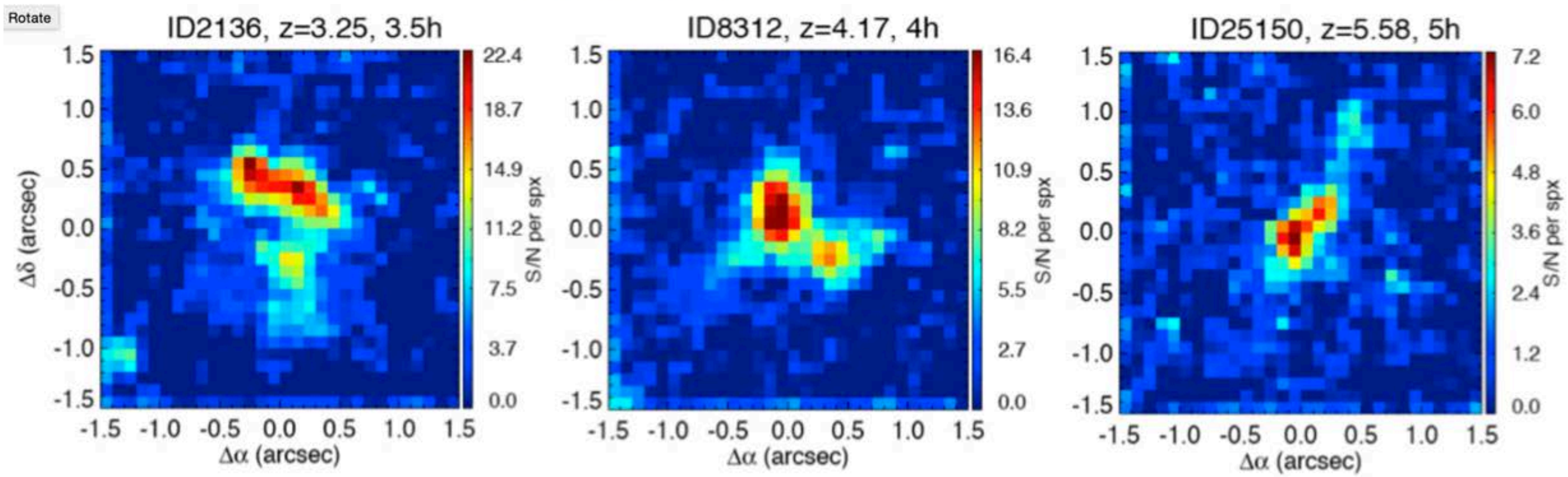
(Velocity resolution: ~ 100 km/s)

JWST IFS Science Capability: Sensitivity



High-z galaxies:

Thanks to these sensitivities It will be possible to study the internal structure of (the most massive and extended) high-z galaxies by means of IFS with reasonable exposure times (i.e. hours)



Disclaimer: Refer to STScI ETC for updated sensitivities

JWST IFS Science Capability

- JWST IFUs very powerful and sensitive …

… but maneuvering and mechanisms overheads can be significant

- Then, it is important to identify an observational strategy to optimize the efficiency of the proposal, i.e. maximize the fraction of clock time that goes into on-target exposure time

- It follows some comments on practical matters when preparing a proposal.

CASE: JWST IFS observations of high-z galaxies (e.g. z > 3)

Comments on practical items
Case: IFS of high-z galaxies

- Some things to consider:
  - Target selection: if possible, close on the sky
  - Planning for NIRSpec + MIRI IFU combined observations ?
  - Target acquisition
  - Spectral coverage: # of settings and gap
  - Background
  - Dithering / Nodding

Target selection: If possible, select your targets close on the sky

- The initial telescope slew is very costly (1800sec)
- But if your targets are in close proximity on the sky, the overheads associated to the slews are greatly reduced

  E.g.:

  - 5 targets all over the sky: Slew overheads = 5 x1800 s = 2.5h
  - 5 targets within 1 deg.: Slew overheads = 1800+4x~300s = 0.8 h

For high-z IFU observations in cosmological fields this will imply important savings, if the targets are properly grouped/ selected

Target Acquisition

- Telescope pointing accuracy heavily dependent on the astrometry of the guide star. The goal ~ 0.1" (work in progress, then TBC), i.e. about or smaller than a spaxel.

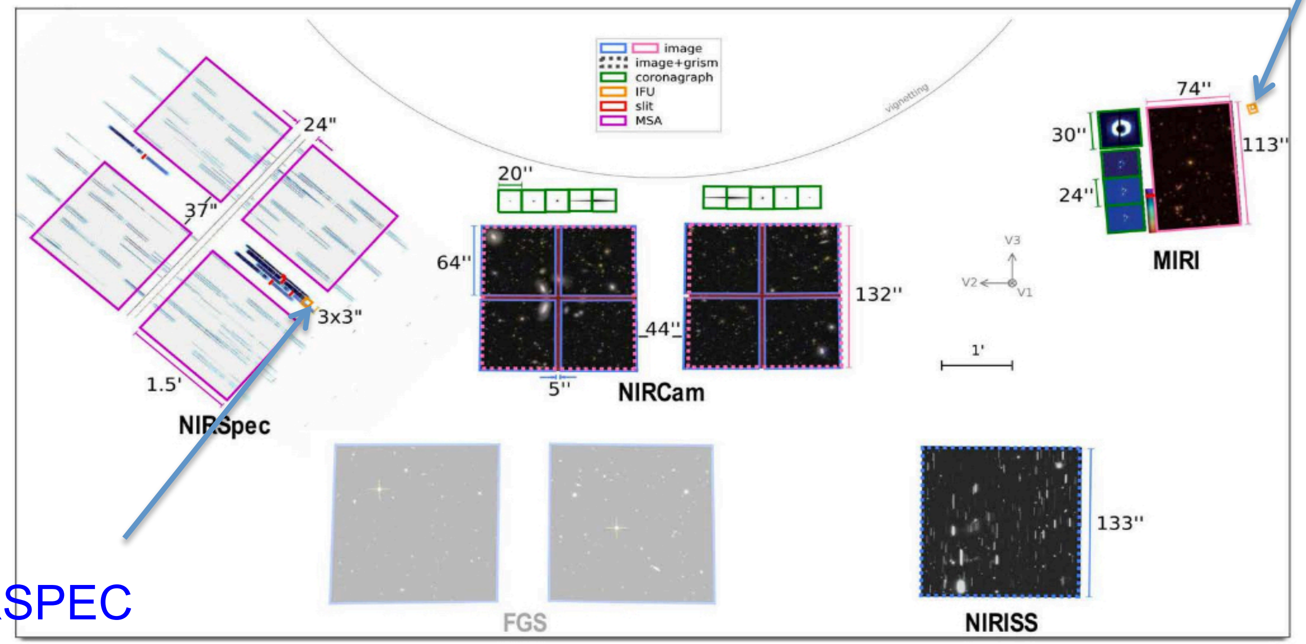
- High-z targets are typically small wrt FoV, then target acquisition may not be needed (but tbc, and also depending on the uncertainties of the targets' coordinates)

- Options for TA
  - NIRSPec:
    - Standard TACQ: Thought for the MOS, very powerful but implies large oveheads. (1200sec)
    - No-TA ("Point&Stare"): Current implementation implies extra activities, which add overheads
    - WATA method planned for Cycle 1. Uses the target or a nearby source obs. through a slit. (~ 600sec)
  - MIRI:
    - Standard TACQ: (600sec)
    - No-TA ("Point&Stare"): planned for Cycle 1

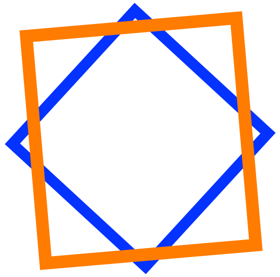
- Several options (available or planned) with different levels of accuracy and overheads. The observer needs to optimize for the specific case, but for high-z sources no-TA seems to be an appropriated option (if pointing accuracy goal is reached)

NIRSpec + MIRI IFU observations ?

- If you plan to use the both NIRSpec and MIRI IFUs for your observations consider that:
  - NIRSpec & MIRI IFUs are separated by about 13.5 arcmin in the JWST focal plane, so
    - Extra slew
    - Guide star will be different for NIRSpec and MIRI (1 GS is ~300 s, so total ~600 s)
  - The relative orientation of the FoVs is different (~40 degrees)
  - PA constrains may conflict:
    - MIRI typically uses the Imager simultaneously ➔ PA constrains to avoid bright sources
    - NIRSpec : Also may also require a specific PA to avoid bright sources in the MSA



Credit: STScI

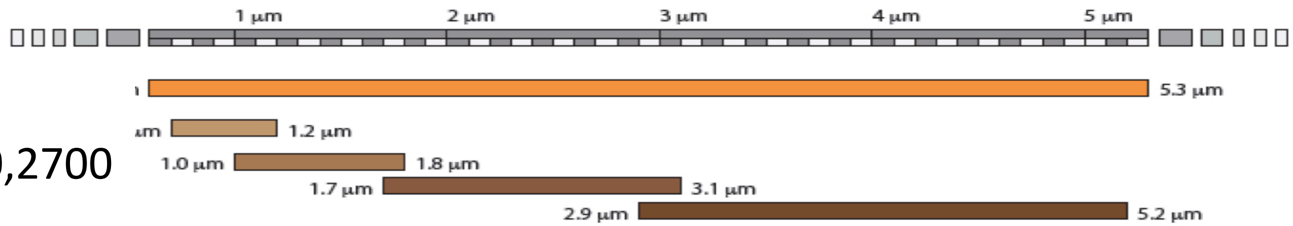


Spectral Configurations and R

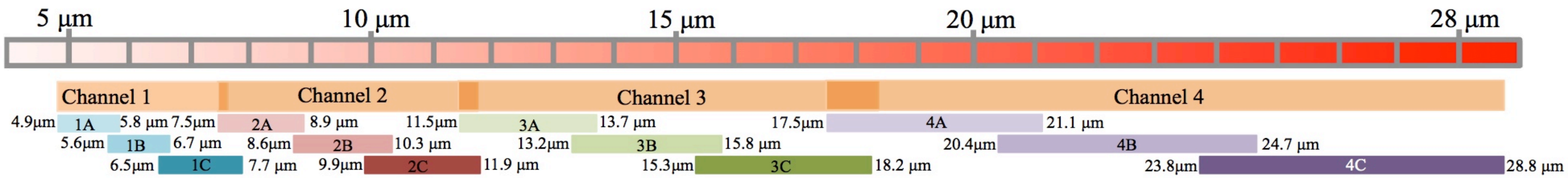
- NIRSPec
  - At low R (100), 1 setting for the whole range (0.6-5.3μm)
  - At R=1000, 2700, 4 settings to cover (0.7-5.2μm)

R100

R1000,2700



- MIRI
  - All at R=3000, 3 settings for the whole range (5 -28.8μm) with four non-contiguous sp. ranges

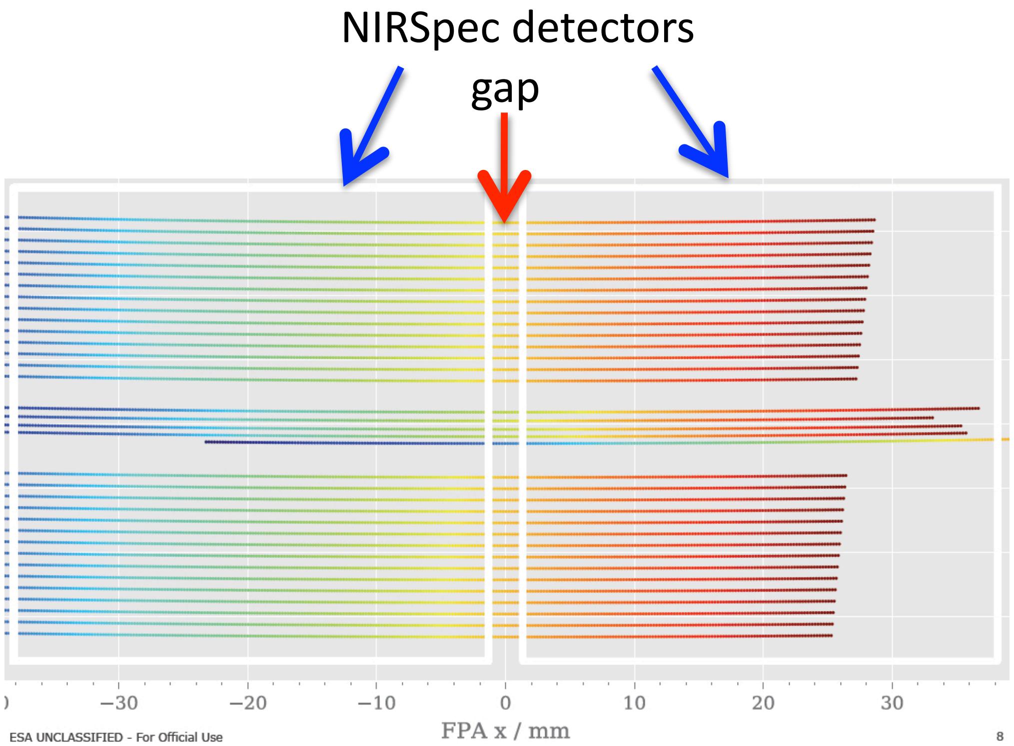


For minimizing settings, think about location of spectral features needed for you science.

Relevant for target selection. E.g., for a z= 2.2 target one needs 2 grating settings to observe from Hbeta to Halpha in high-R with NIRSpec, but all is obtained with a single setting for a z=2.6 target.

NIRSpec gap

- There is a gap between the two NIRSpec detectors
  - check that the there is not an important feature there !
- For the IFU this affects the R=2700 mode only (i.e. not relevant for R1000 and R=100)

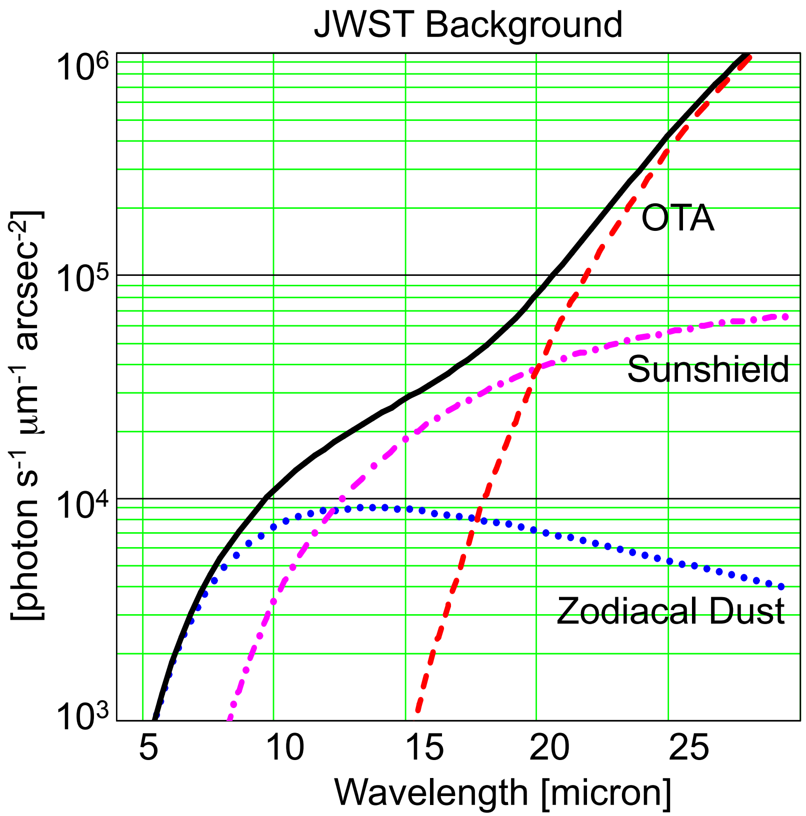


When analysing the gap effects for your observations, consider the uncertainties in the gap calculations, in the redshifts, the possible v. field, line width, etc

Background

- **NIRSpec IFU**
  - Zodiacal light: mainly relevant for R=100 observations and low wavelengths (i.e. λ< 2μm)
  - MSA-imprint: Specific of the IFU, and it may be relevant for high-z (as relative faint sources / long exposures)
    - Due to light leaking through the MSA that may contaminate the IFU spectra. Effects potentially more relevant if interested in the continuum. Actual impact TBD during commissioning.
    - Strategy: Select a PA that avoids bright sources on (critical zones of) the MSA
    - Calibration: exposure with IFU (closed), model, hybrid
- **MIRI MRS**
  - Zodiacal light: dominates at λ < 12 μm
  -- Telescope / sunshield: Important at λ > 10 μm. Dominant at λ > 15 μm

Strategy for high-z: Dither /Nod in FoV



http://www.roe.ac.uk/ukatc/consortium/miri/index.html

Dithering / Nodding

Main reasons for dithering/nodding:

- Accurate background measurements
- Good PSF sampling for NIRSPec and MIRI IFS
- Detector cosmetic/defects/characteristics
- Others: Enlarge FoV

Strategy for high-z (tbc, for specific cases)

- NIRSpec: e.g. at least 4-point dither-pattern (subpixel sampling + amplitude of 0.5-1")
- MIRI: optimise depending of high priority channel

Relative importance (in general):

MODE	IR_BACKGR. ZODIACAL	IR_BACKGR. THERMAL	INST. (MSA) LEAKAGE	PSF SAMPLING	DETECTOR COSMETIC
MIRI-CH1	++	−	−	++	+
MIRI-CH2	++	+	−	++	+
MIRI-CH3	+	++	−	+	+
MIRI-CH4	+	++	−	+	+
NIRSPEC	+−	−	+−	++	+

++ Dominant / + Relevant / +− Subject to science case / − Non relevant

Summary

- **JWST NIRSpec and MIRI IFUs are very powerful observing modes for studies of high-z galaxies thanks to their unique combination of features:**
  - Increased sensitivity by factors 100 wrt previous instruments
  - Wide spectral coverage from the optical (0.6µm) to the mid-IR (28µm)
  - Stable high-angular resolution over the entire spectral range

- **…. but overhead time may be significant. The optimization of the observations can be complex.**

- **Although still there are some uncertainties about implementation (with some items to be clarified during commissioning), important to plan in advance**