Grism Spectroscopy For Extragalactic Astronomy, An How-To

Vicente Estrada-Carpenter
& Gaël Noirot

Postdoctoral Fellows
Saint Mary's University, Halifax

SMU Data Analytics Seminar
2022 Mar 10

OVERVIEW

Grism Spectroscopy in a nutshell

Grism data reduction & analysis with Grizli, the grism redshift and line analysis software

https://github.com/Vince-ec/grizli_example/blob/master/grizli_example.ipynb

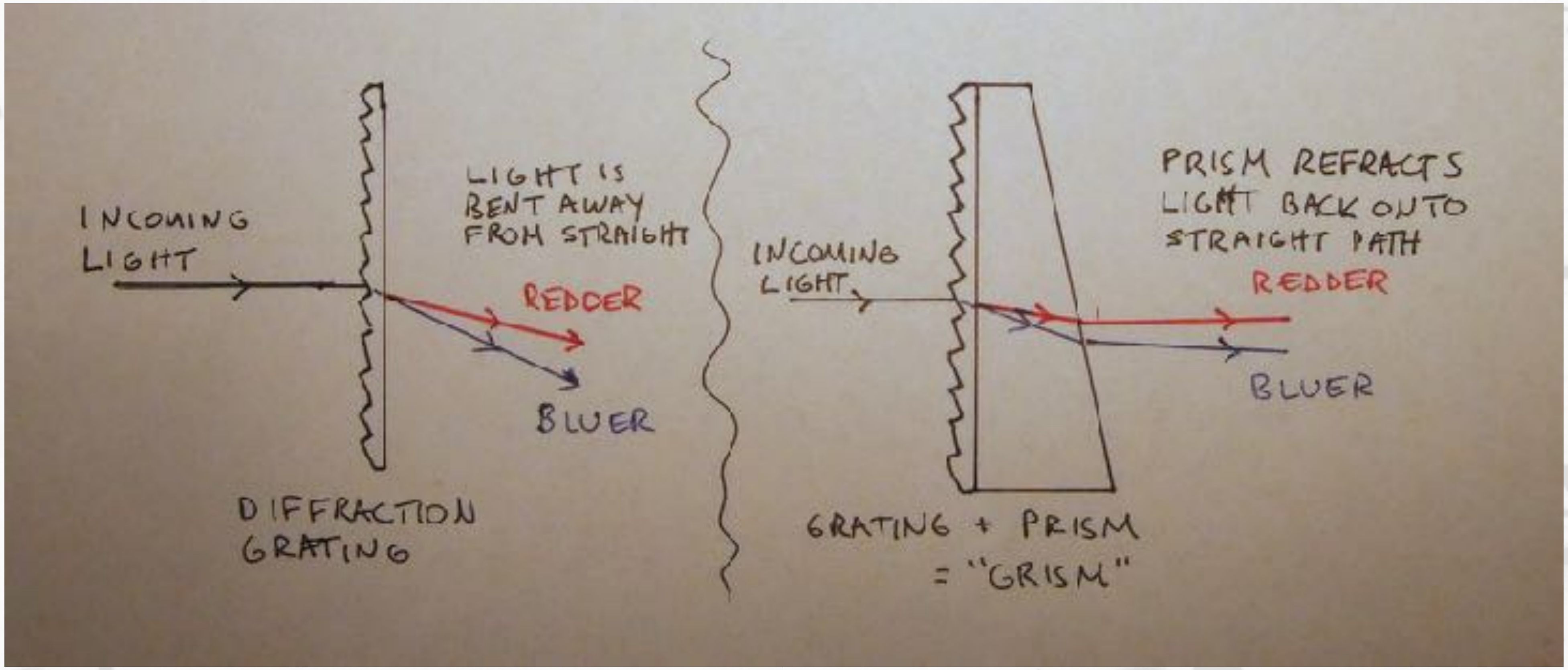
vestrada78840@gmail.com

SED fitting with Grizli and dynesty

https://github.com/gnoir0t/smu_data_analytics_seminar/blob/main/grism2D_sed_fitting.ipynb

P.S.: Notebook to JWST pipeline demo: https://github.com/gnoir0t/stsci_mos_workshop

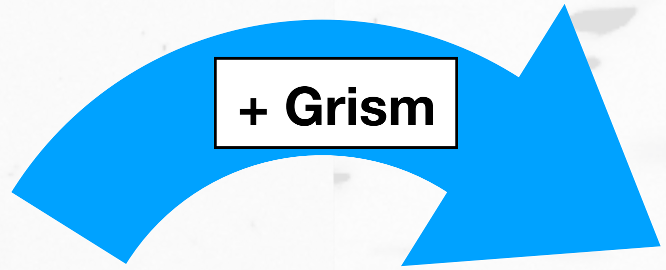
Principle



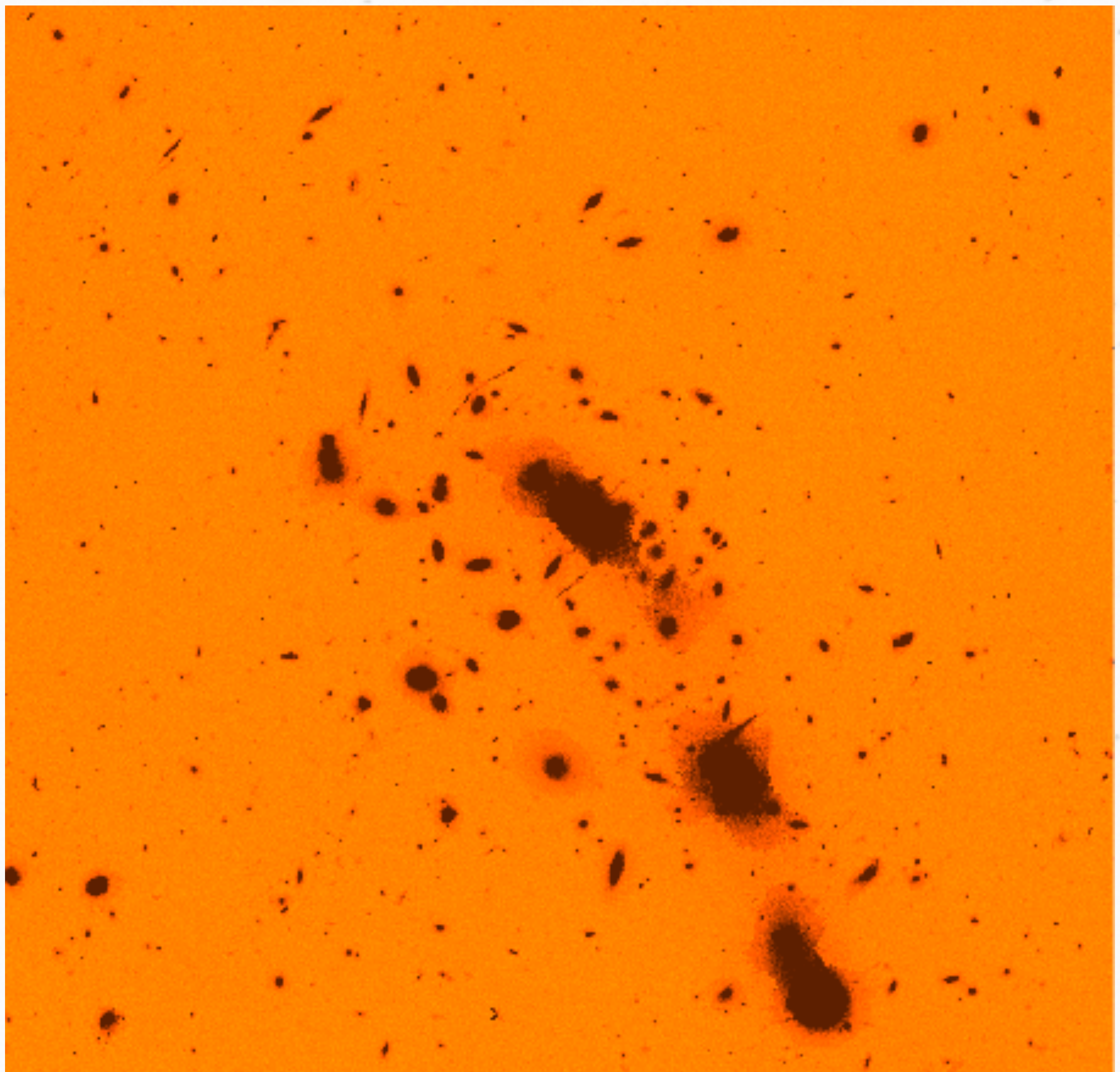
B. Weiner, https://clear.physics.tamu.edu/research/html_codes/why_grism.html

- No beam deviation.
- Slit**<u>less</u>**: - Avoids pre-selection of targets (no need to place slits),
  - all light sources have a spectrum,
  - no flux slit-loss!

GRISM SPECTROSCOPY



JWST NIRISS **direct** image



NIRISS F115W simulation of MACS J0416.1-2403

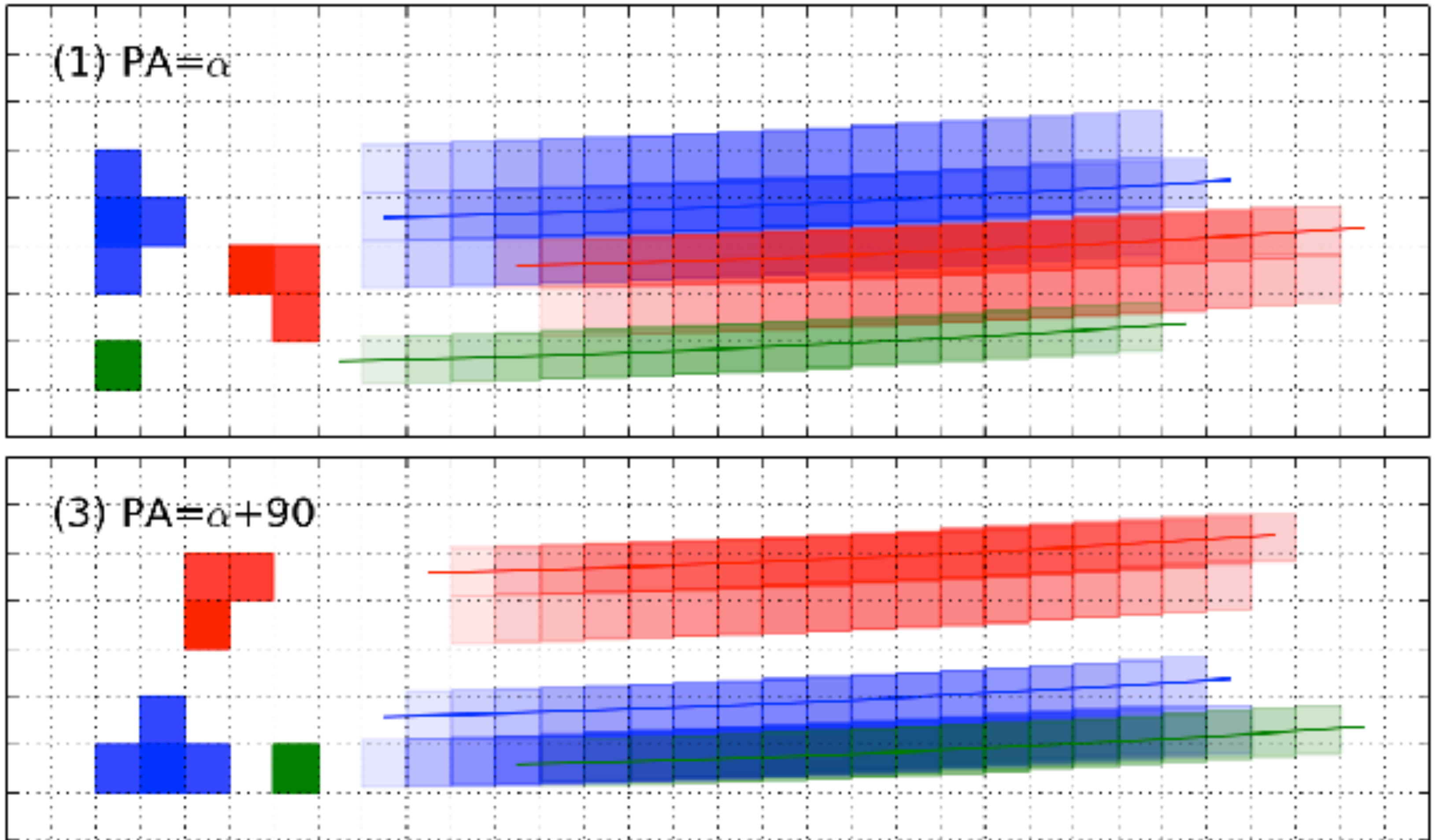
JWST NIRISS **grism** image

NIRISS G150C w/ F115W

https://jwst-docs.stsci.edu/jwst-near-infrared-imager-and-slitless-spectrograph/niriss-observing-modes/niriss-wide-field-slitless-spectroscopy

- Several hundreds of galaxies
- Several hundreds of spectra!

Contamination

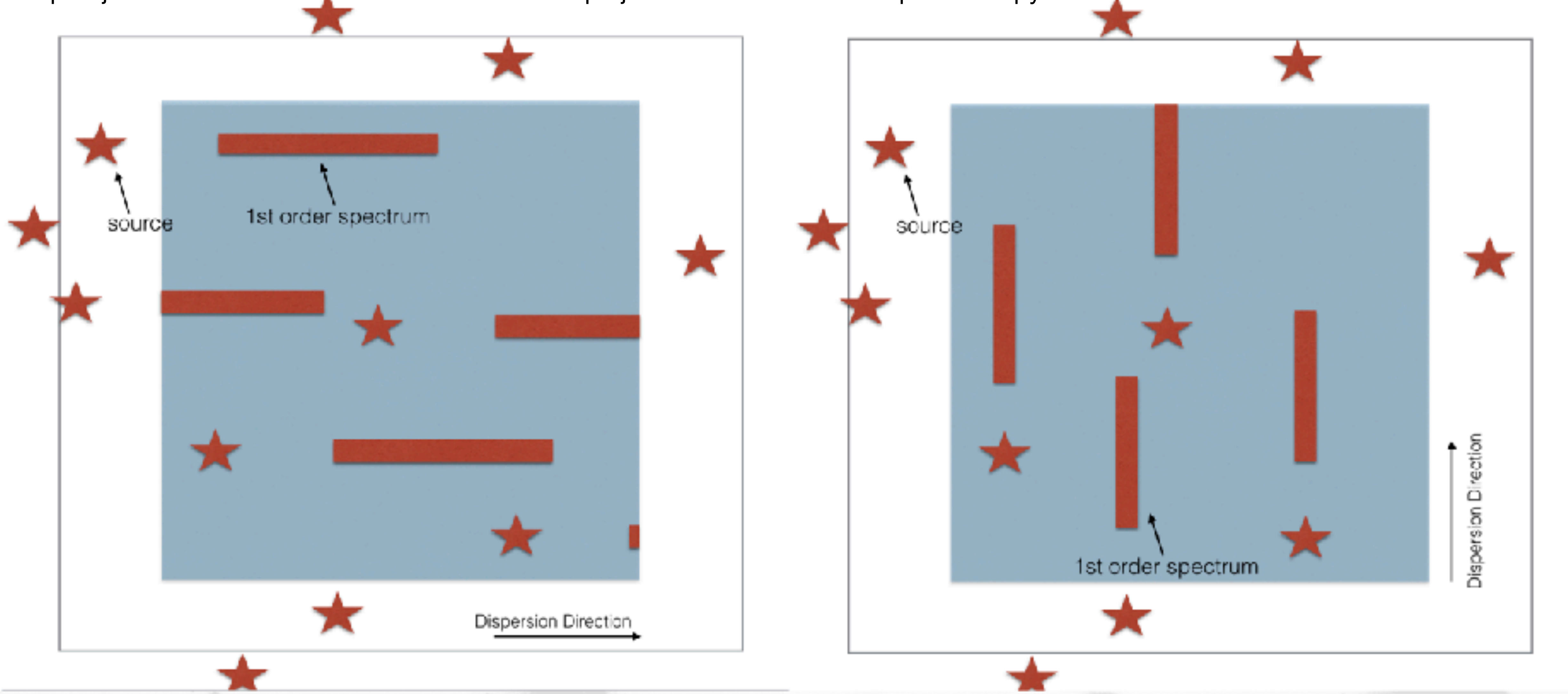


https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-wide-field-slitless-spectroscopy

- Source contamination is an issue, especially in crowded fields
- Can be mitigated using multiple orientations, or careful modelling of the spectral traces

Out-of-field sources and spectra

https://jwst-docs.stsci.edu/methods-and-roadmaps/jwst-wide-field-slitless-spectroscopy



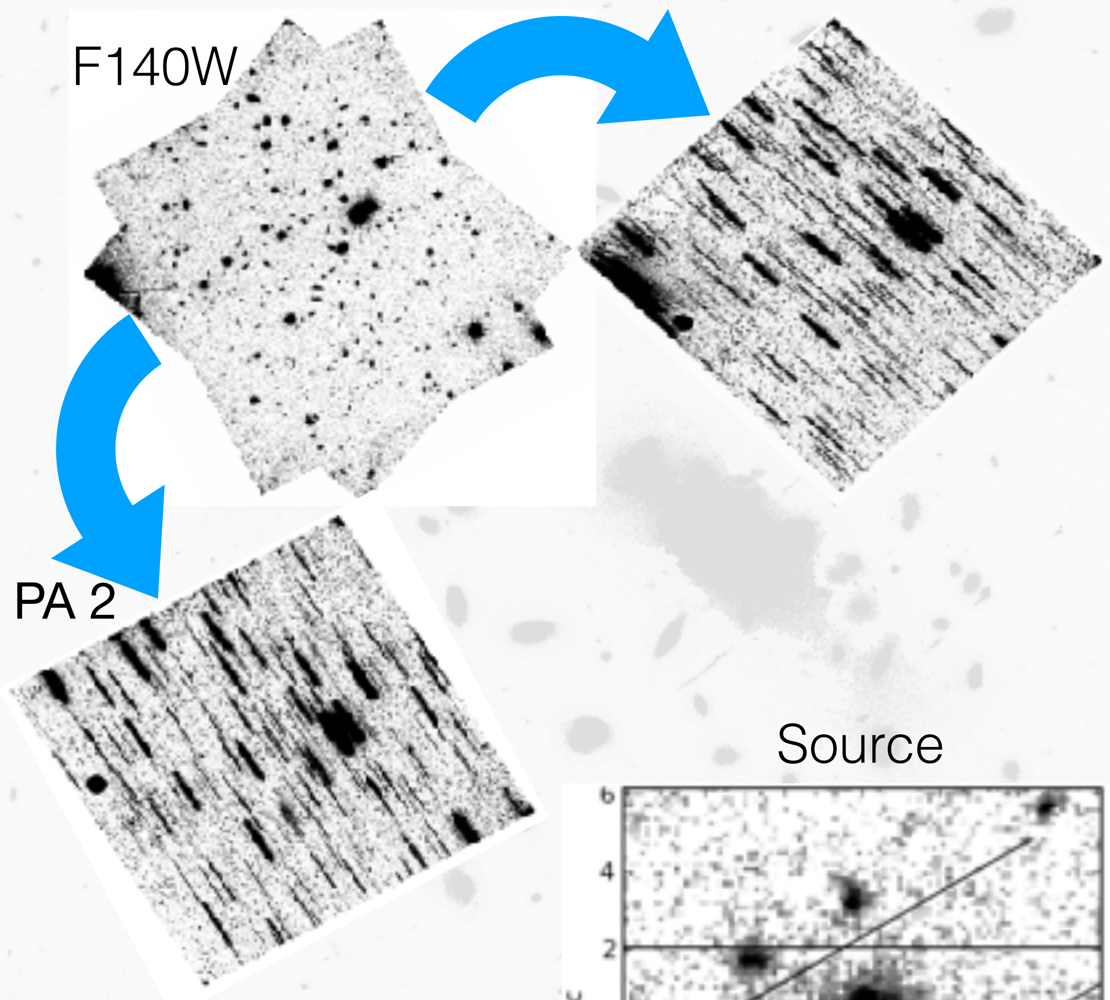
- Dispersing element FoV larger than detector
  —> some sources have no or only partial spectrum
    - can be mitigated with multiple orientations

  —> some spectra correspond to sources not imaged in the direct images
    - problematic for the wavelength calibration of these spectra
    - can be mitigated with dithering or if other imaging data exist for these sources

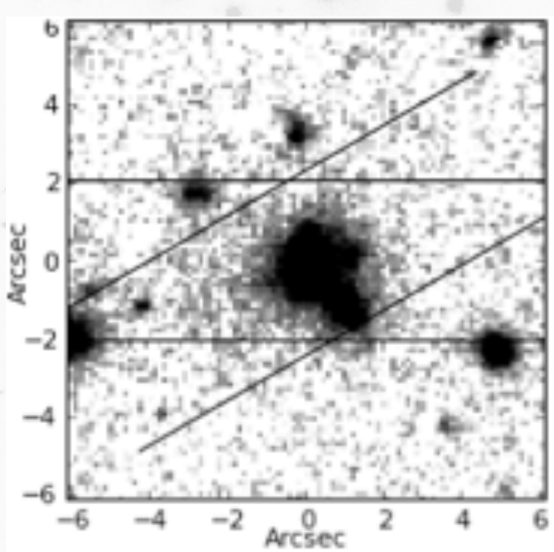
GRISM SPECTROSCOPY

Example

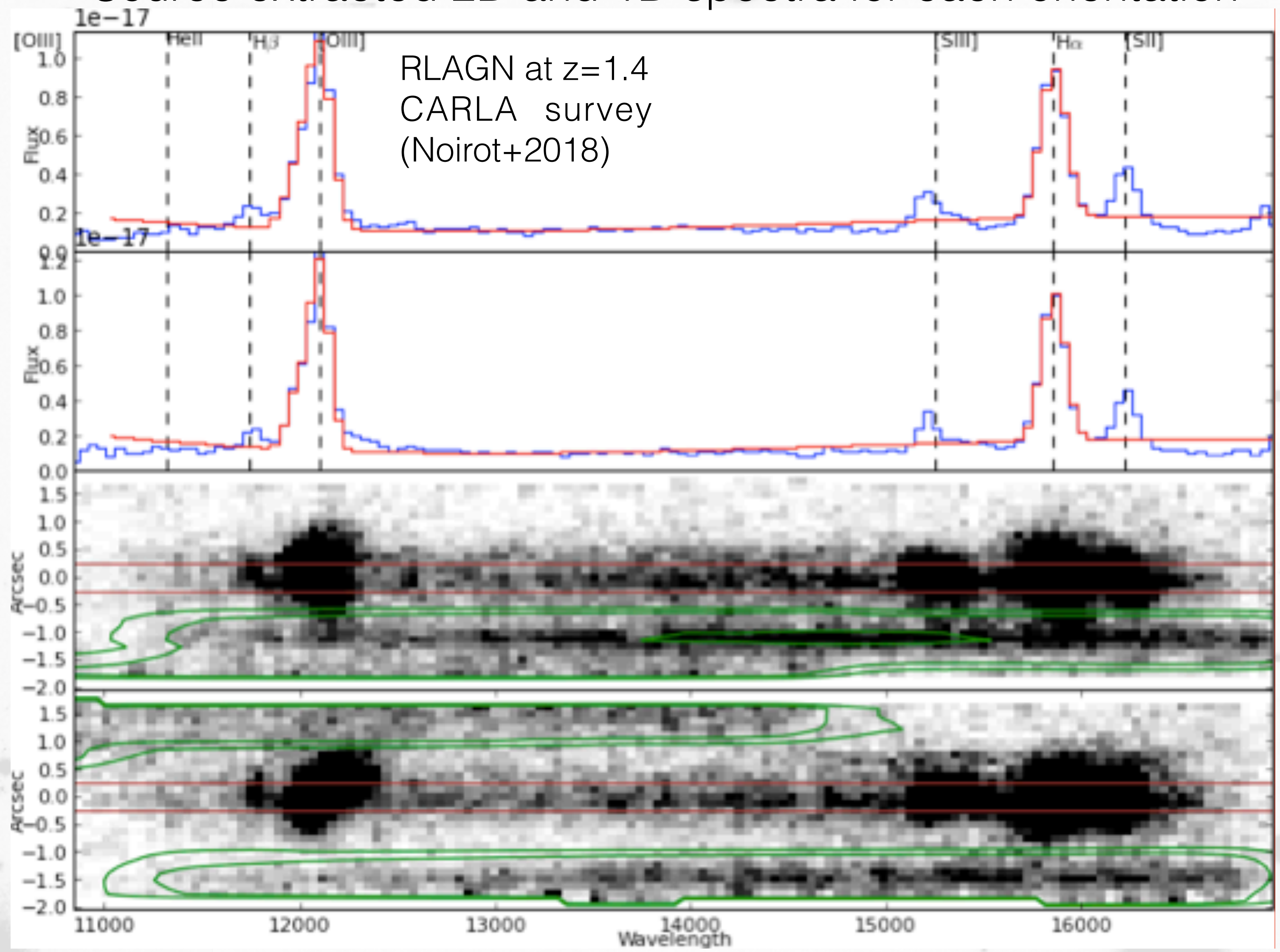
HST G141, R=130, λ=1.1-1.7μm



Source



Source extracted 2D and 1D spectra for each orientation



- Effective resolution depends on source angular size and morphology wrt the dispersion direction (spectral overlap of all adjacent pixels along the dispersion direction).

Successes of grism spectroscopy

Science highlights

Wide field slitless spectroscopy has been available on the Hubble Space Telescope (HST) using the ACS G800L, WFC3/UVIS G280, WFC3/IR G102 and G141 grisms. Scientific highlights of the usage of these HST grisms include spectral template definition, binarity and variability of the coolest brown dwarfs (Buenzli et al. 2015; Schneider et al. 2015), detailed characterization of gravitationally lensed star-forming galaxies (Brammer et al. 2012a; Wang et al. 2020), spectroscopic confirmation of $z \sim 2$ clusters (Noirot et al. 2018), age-dating passive galaxies in $z \sim 2$ clusters (Newman et al. 2014) and in the field (Whitaker et al. 2013; Estrada-Carpenter et al. 2019; Morishita et al. 2019), discovery of extreme emission line galaxies (Atek et al. 2011), statistical studies of galaxy evolution (Whitaker et al. 2014; Prusinski et al. 2021), discovering the prevalence of inside-out star formation (Nelson et al. 2016), measuring galaxy properties, including Lyα absorption by the intergalactic medium, in the reionization epoch (Schmidt et al. 2016; Tilvi et al. 2016) and breaking the record for most distant spectroscopic redshift of a galaxy at $z = 11$ (Oesch et al. 2016). The 3D-HST survey alone measured $\sim$100,000 spectroscopic redshifts with the WFC3/IR grisms (Momcheva et al. 2016), vastly more than all ground-based near-IR spectroscopy combined. Given the wealth of science done with HST slitless grisms, it can be expected that NIRISS on board JWST will prove similarly productive.

(Willott+2022)

Instruments

HST/ACS	G800L (R=100; 0.6-1.0µm)
HST/WFC3	G280 (R=70; 0.2-0.8µm), G102 (R=210; 0.8-1.2µm), G141 (R=130; 1.1-1.7µm)
JWST/NIRISS WFSS	GR150C, GR150R (R=150, w/ F090W, F115W, F140M, F150W, F158M, F200W; 0.8-2.2µm)
JWST/NIRCAM WFSS	GRISMR, GRISMC (R=1600, w/ 8 medium & 4 wide blocking filters; 2.4-5.0µm)
Euclid	1 blue grism 0.9-1.3µm, 3 red grisms 1.3-1.9µm; R=380.
Roman	R=400-800; 1.0-1.9µm.

OVERVIEW

Grism Spectroscopy in a nutshell

Grism data reduction & analysis with Grizli, the grism redshift and line analysis software

https://github.com/Vince-ec/grizli_example/blob/master/grizli_example.ipynb

vestrada78840@gmail.com

SED fitting with Grizli and dynesty

https://github.com/gnoir0t/smu_data_analytics_seminar/blob/main/grism2D_sed_fitting.ipynb

P.S.: Notebook to JWST pipeline demo: https://github.com/gnoir0t/stsci_mos_workshop