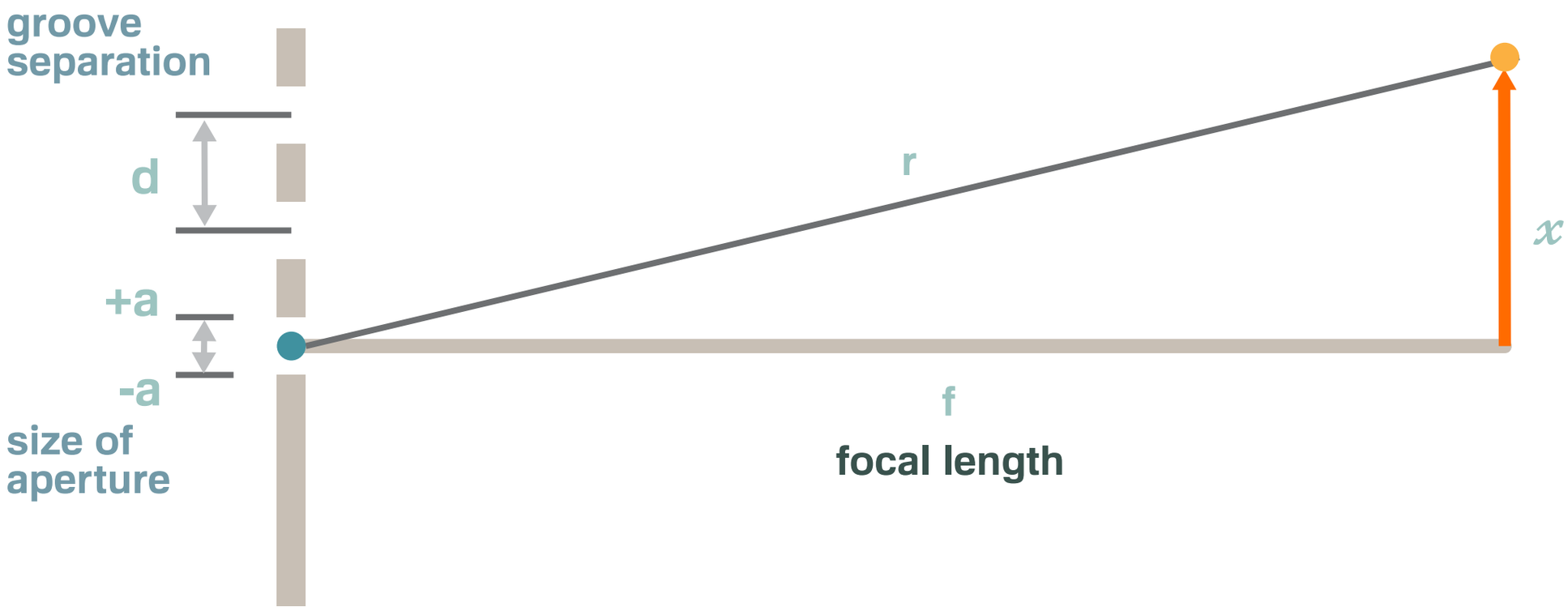
Blazed grating

1. waste no light at blocking area
2. line becomes sharper as N
3. Intensity goes up as N^2
4. energy concentrated at x=0



size of a grating

size of a spectrograph

$$\frac{\lambda}{\Delta\lambda} < mN$$

λ = 10 µm

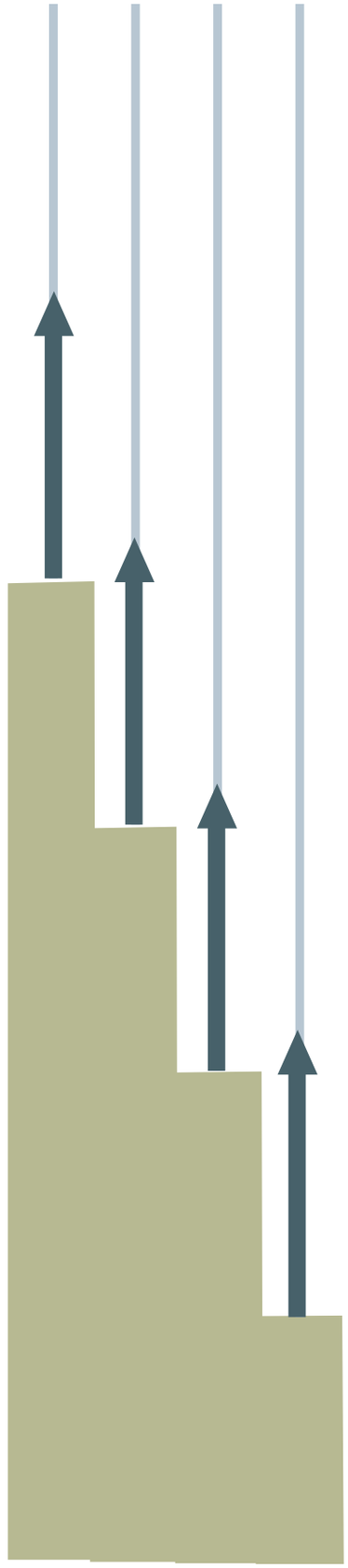
R = 100,000

m = ?

d = ?

N = ?

2 **size of grating?**



CRIRES / VLT

1 - 5 µm

40 x 20 cm

reflective metal grating

EXES / SOFIA

5 - 28 µm

10 cm x 50 cm

11 kg

ESPRESSO / VLT

0.4-0.8 µm

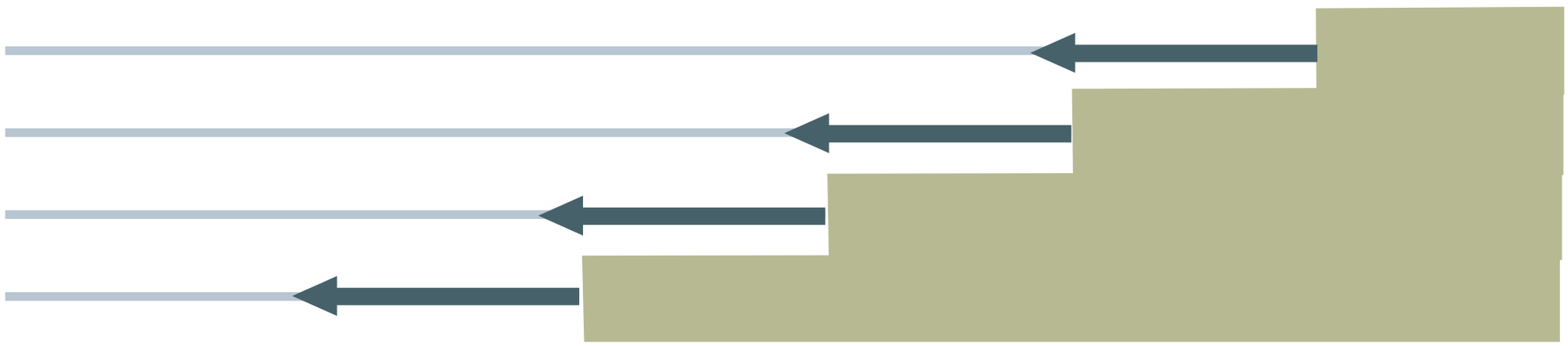
120 cm x 20 cm

50 kg

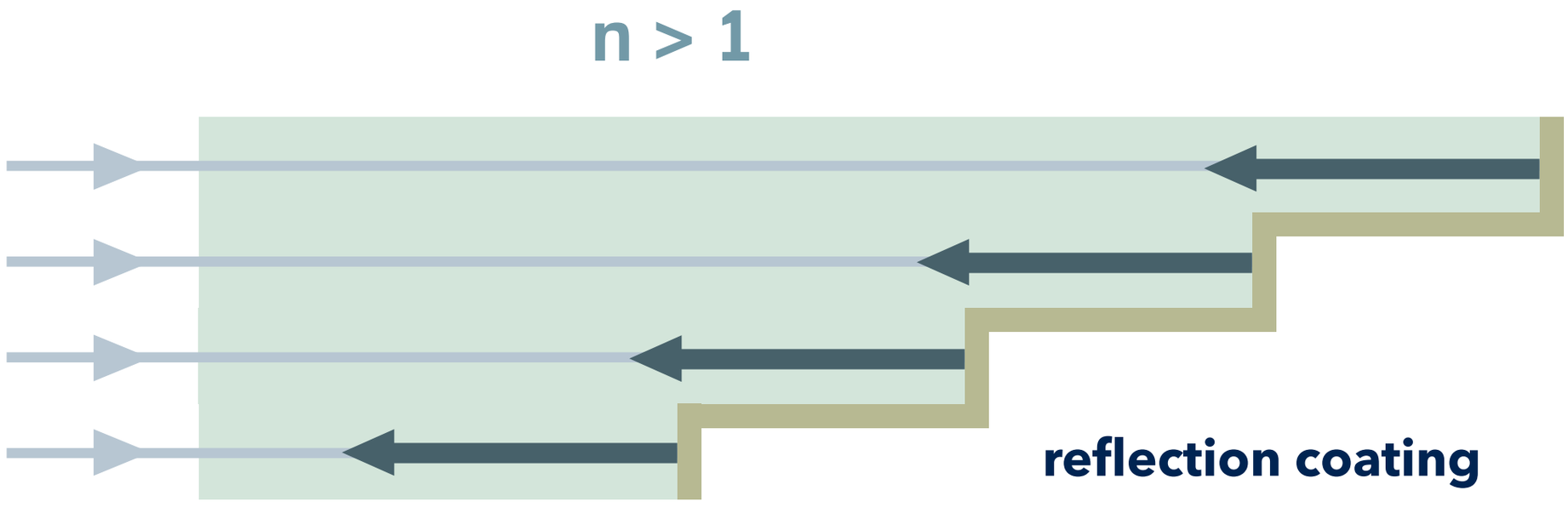
why there is no high resolution infrared spectrograph in space?

immersion grating

high dispersion spectrograph



immersion grating



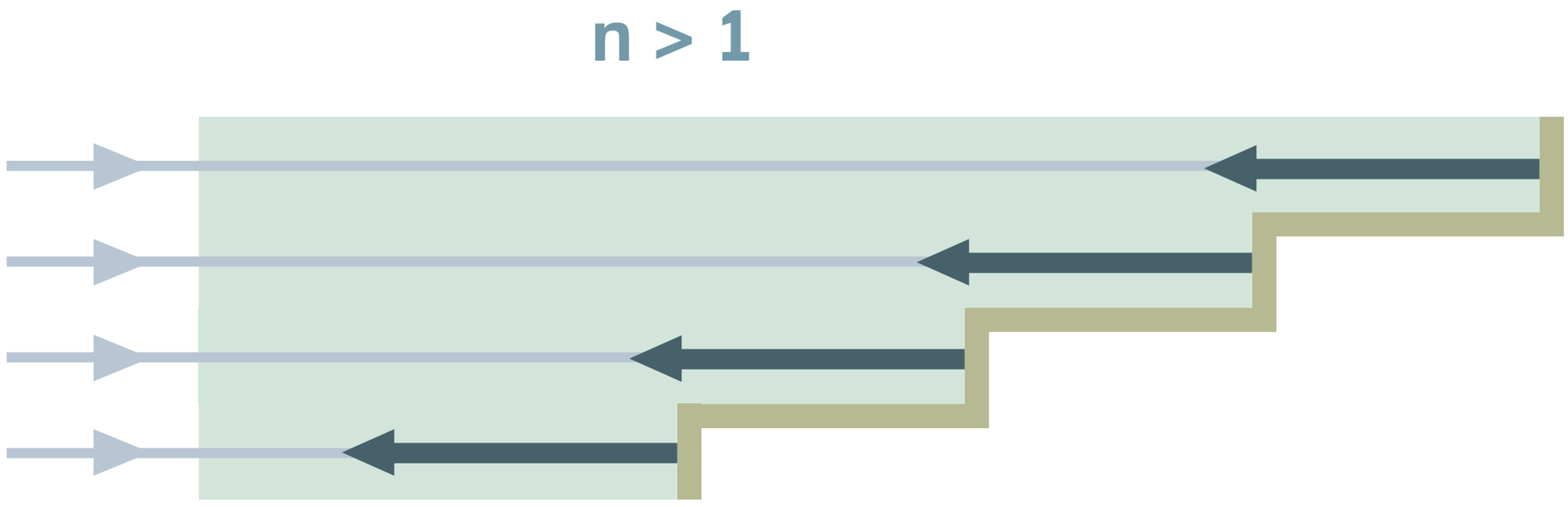
immersion grating

METIS / ELT

3-10 µm

15 cm x 15 cm

n ~ 3.4



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CRIRES / VLT

1 - 5 µm

40 x 20 cm

reflective metal grating

type of spectrograph

long slit

conventional

slit

type of spectrograph

long slit

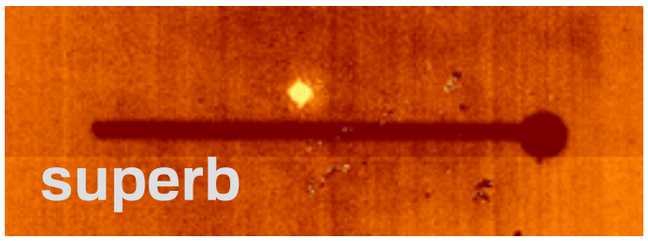
conventional

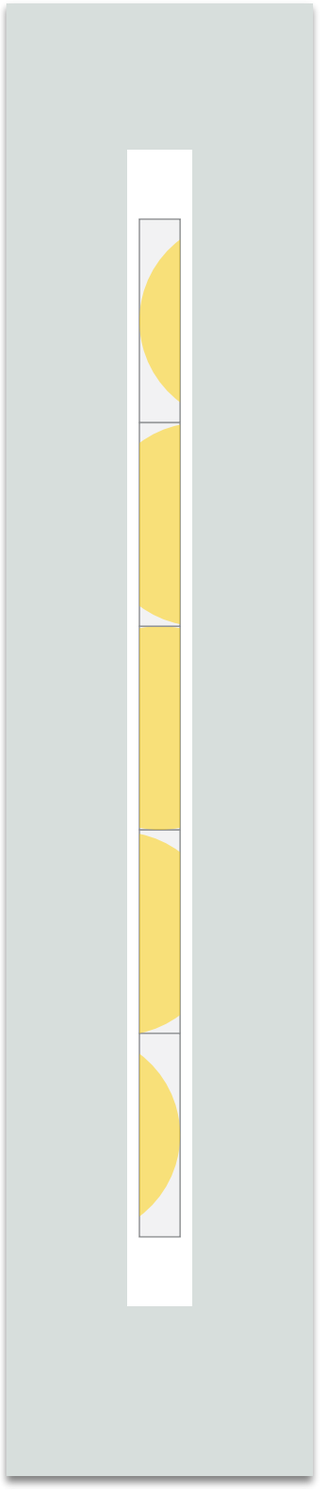
slit

takes time to collect spatial info

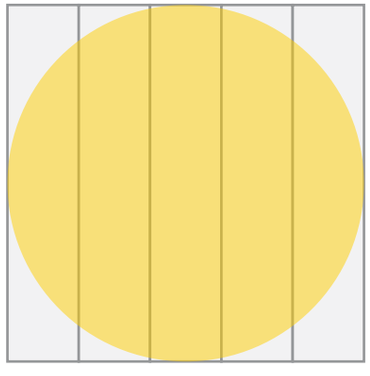
slit throughput (bad seeing)

atmospheric diffraction



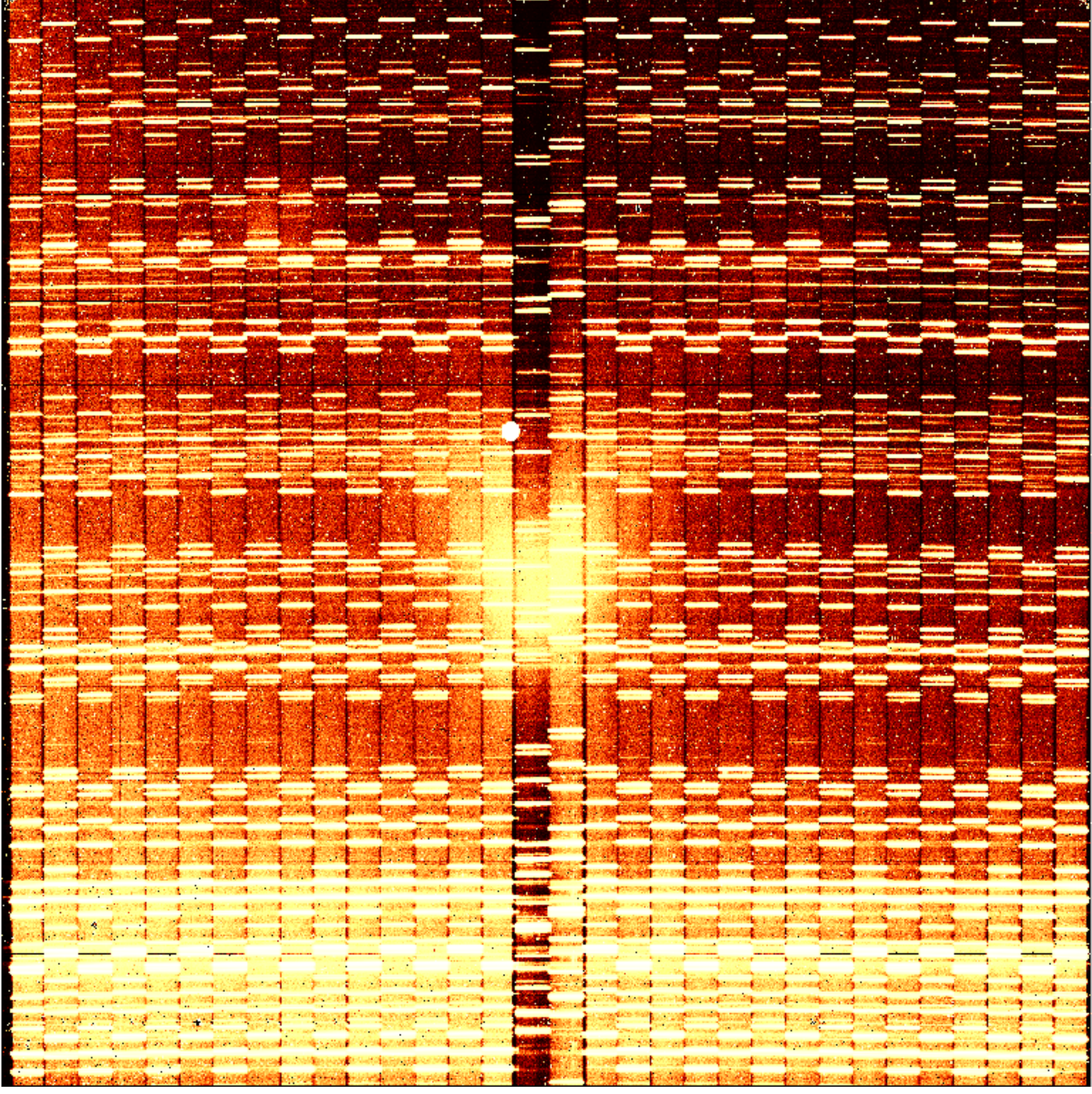


extended source



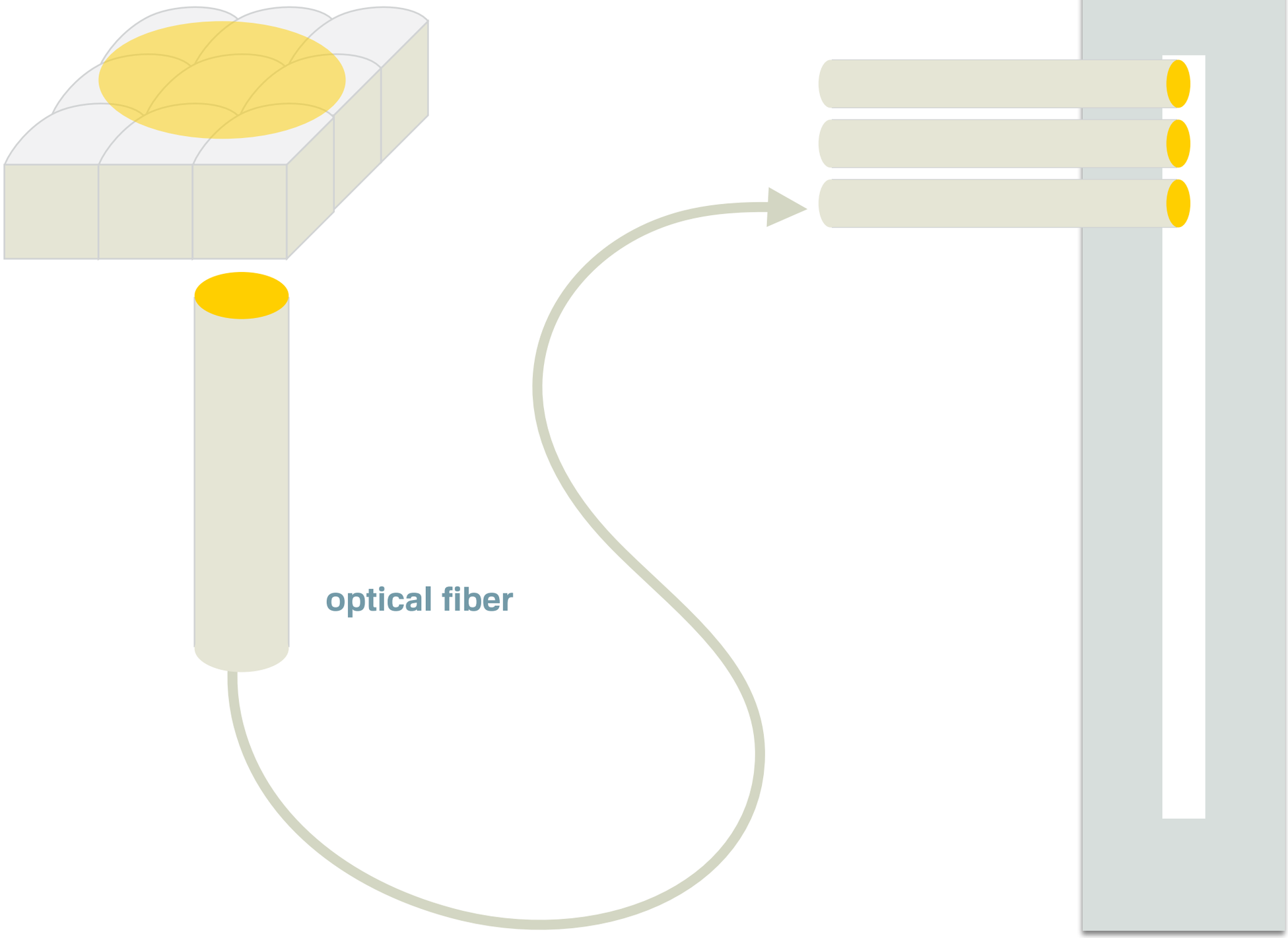
IFU integral field unit

image slicer



IFU

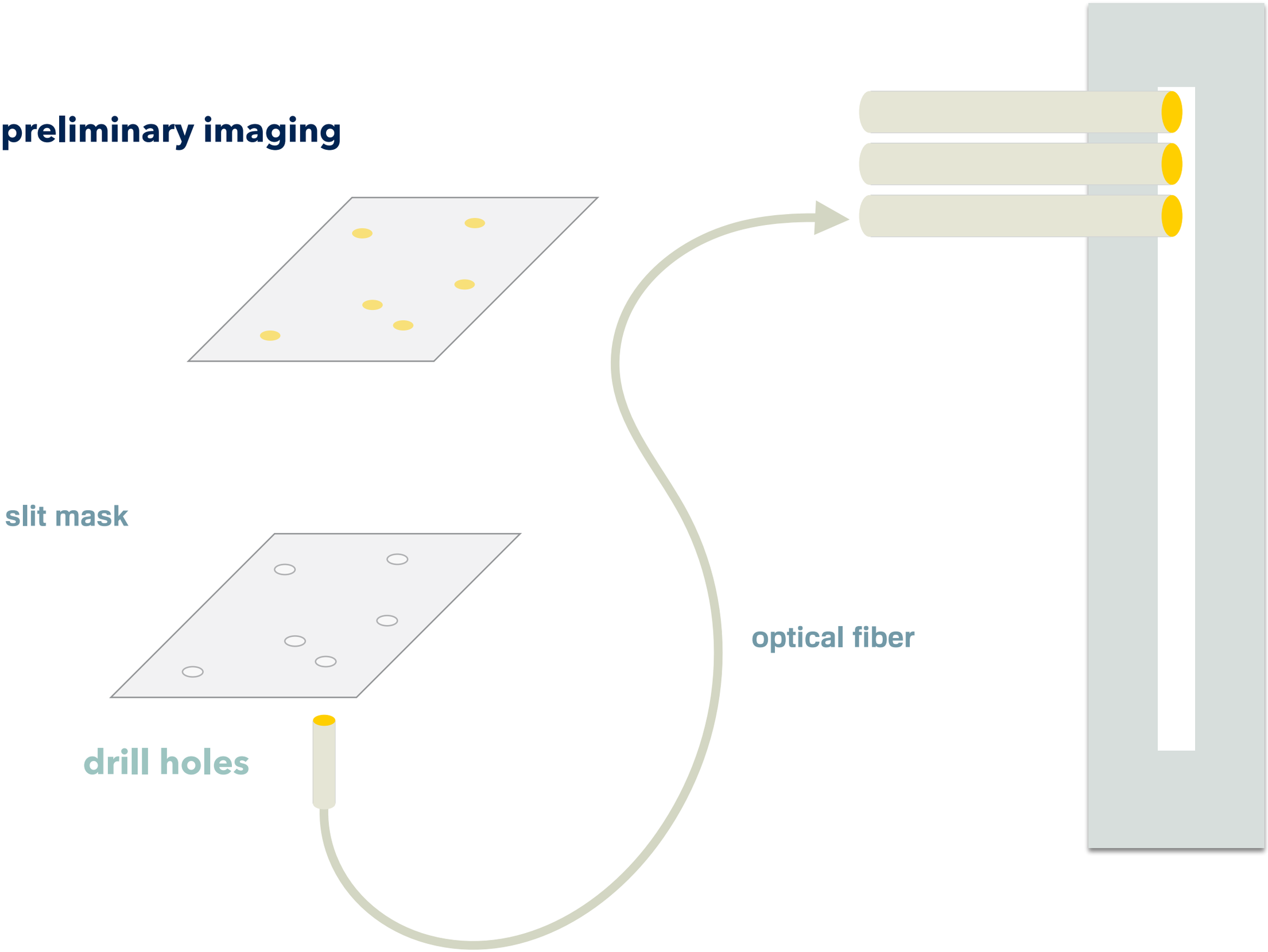
lenslet array



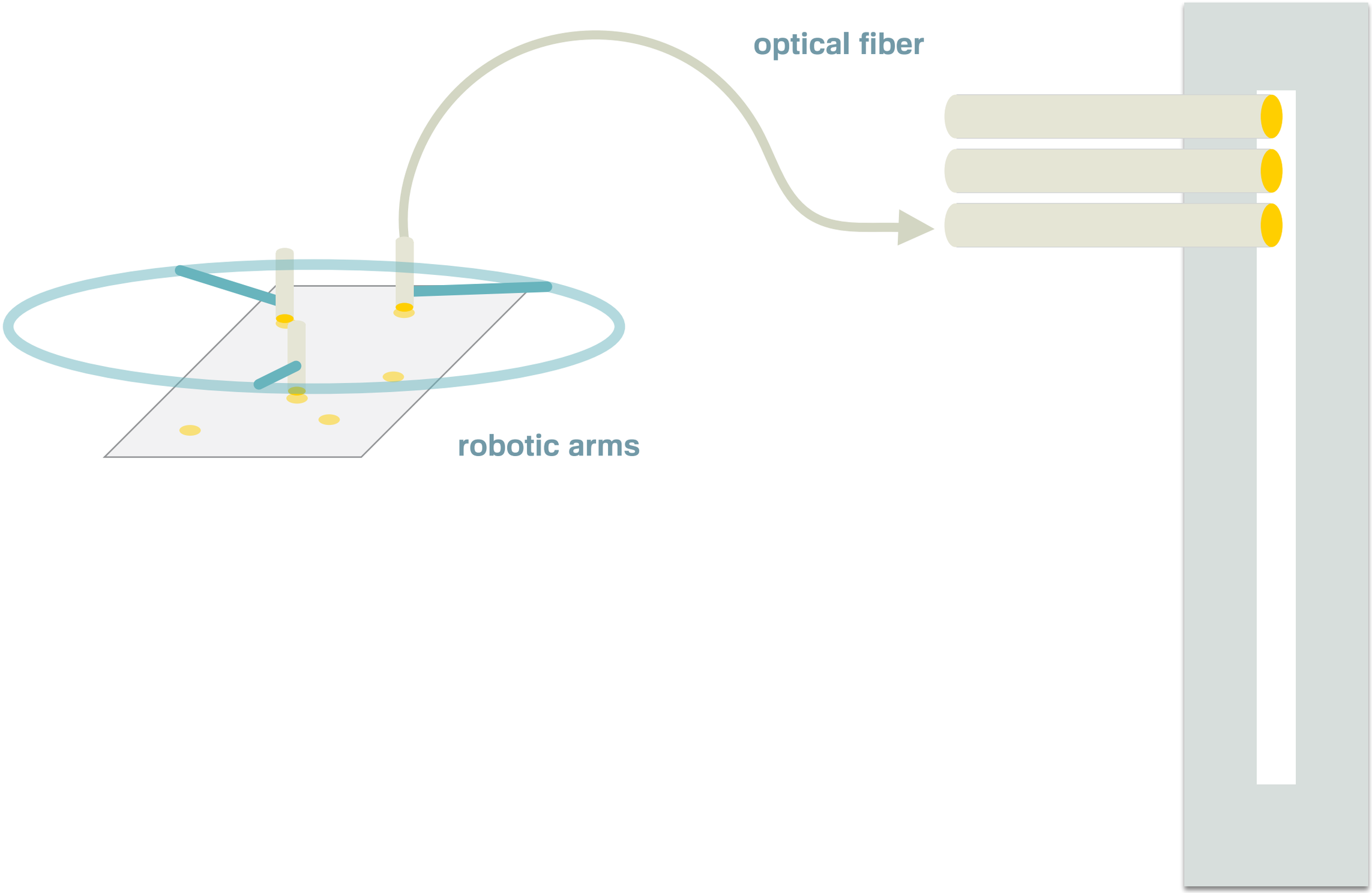
optical fiber

MOS multi-object spectroscopy

preliminary imaging

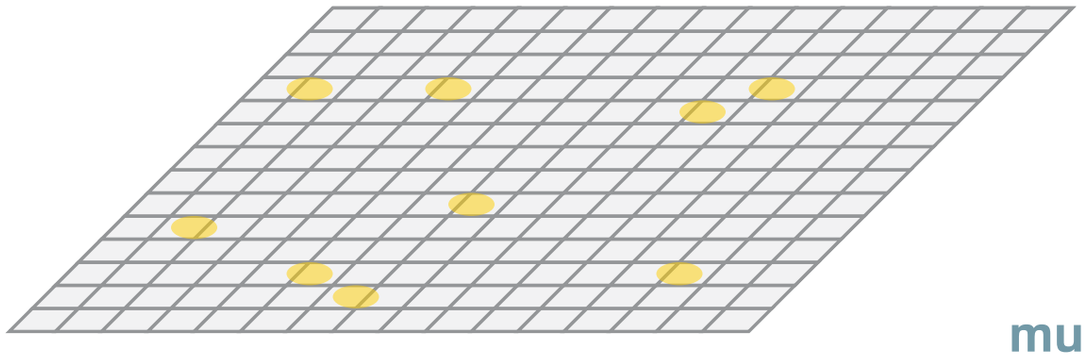


MOS multi-object spectroscopy

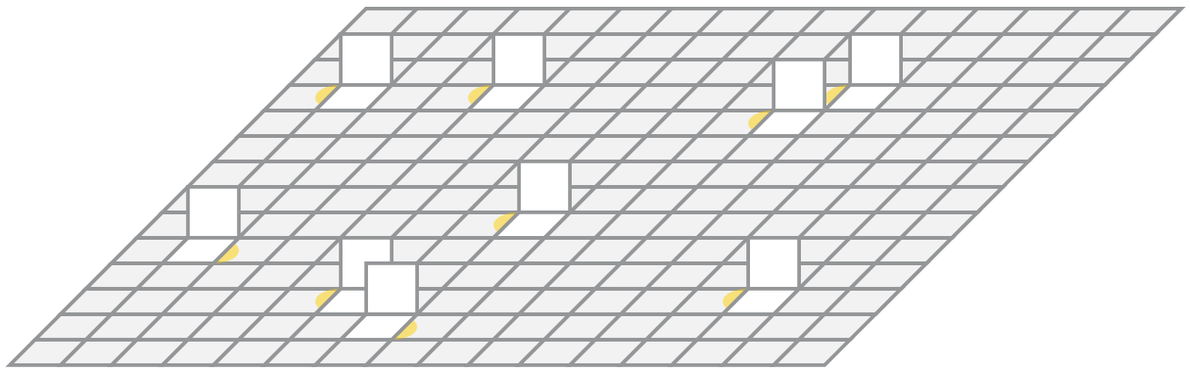


MOS multi-object spectroscopy

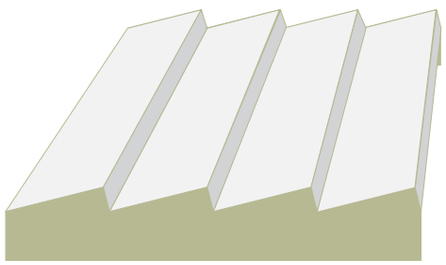
preliminary imaging



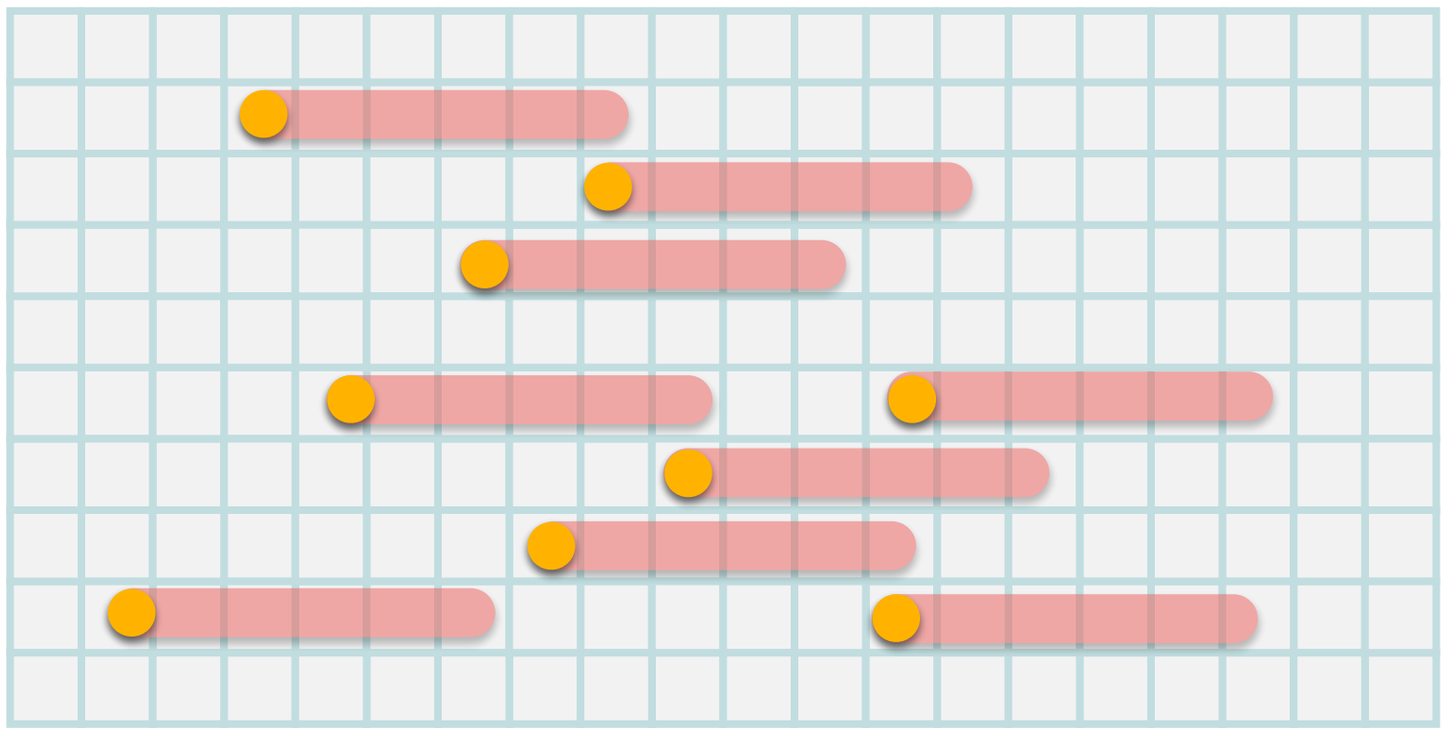
multi-shutter array



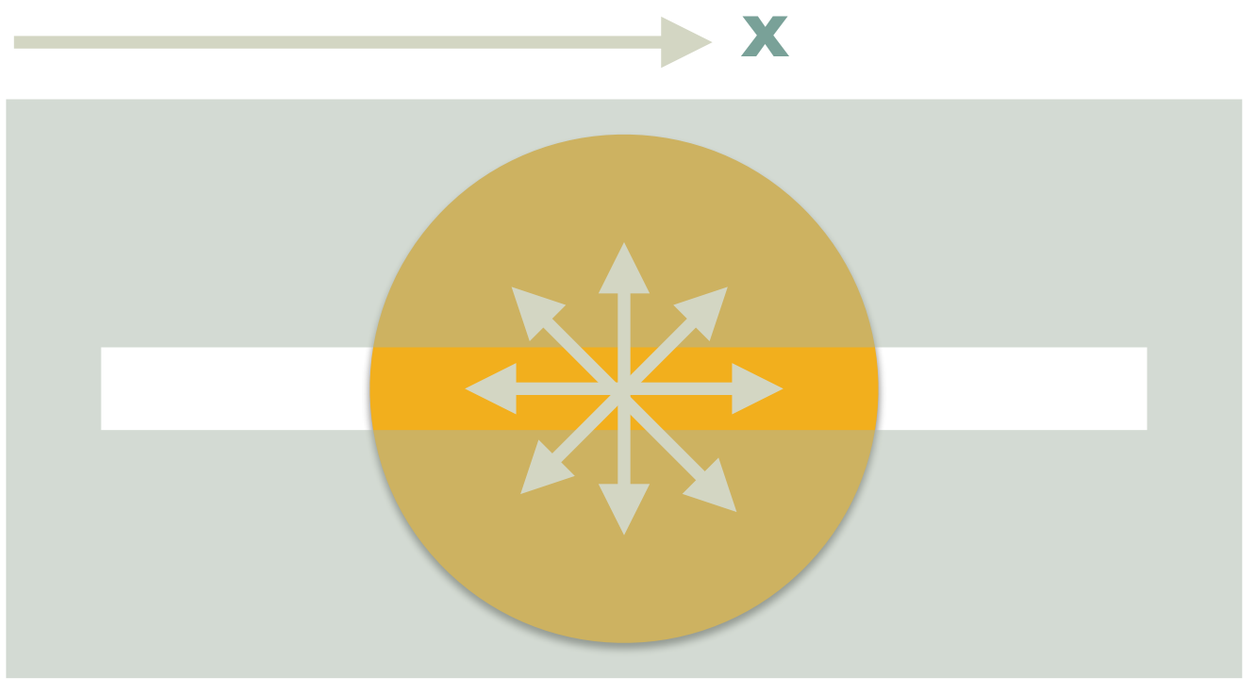
JWST / NIRSpec



objective spectroscopy



Spatial axis



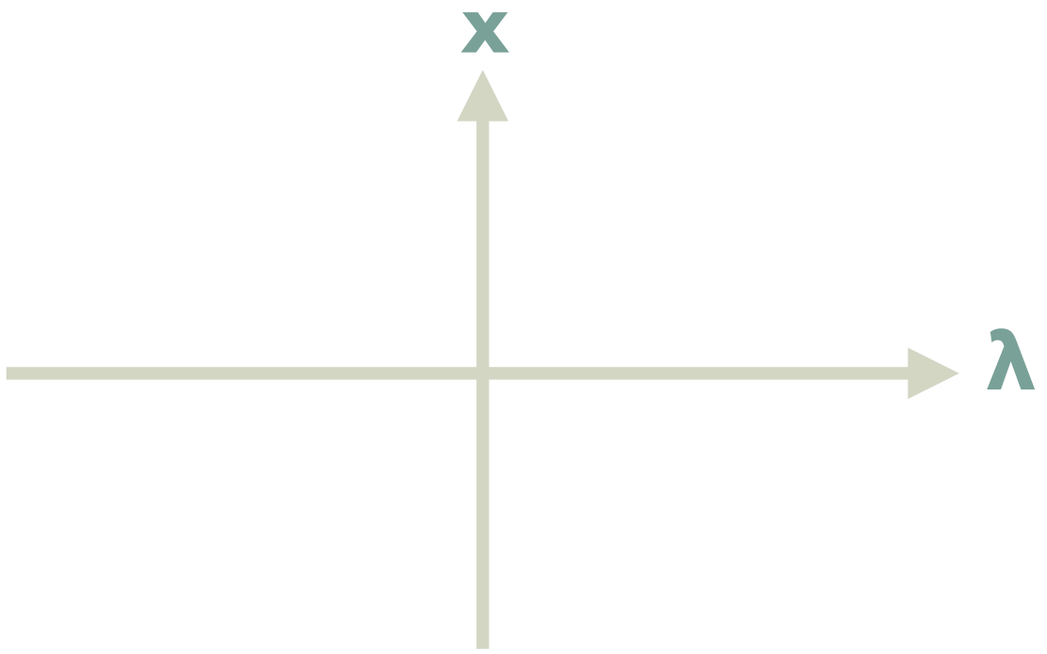
slit

line emission

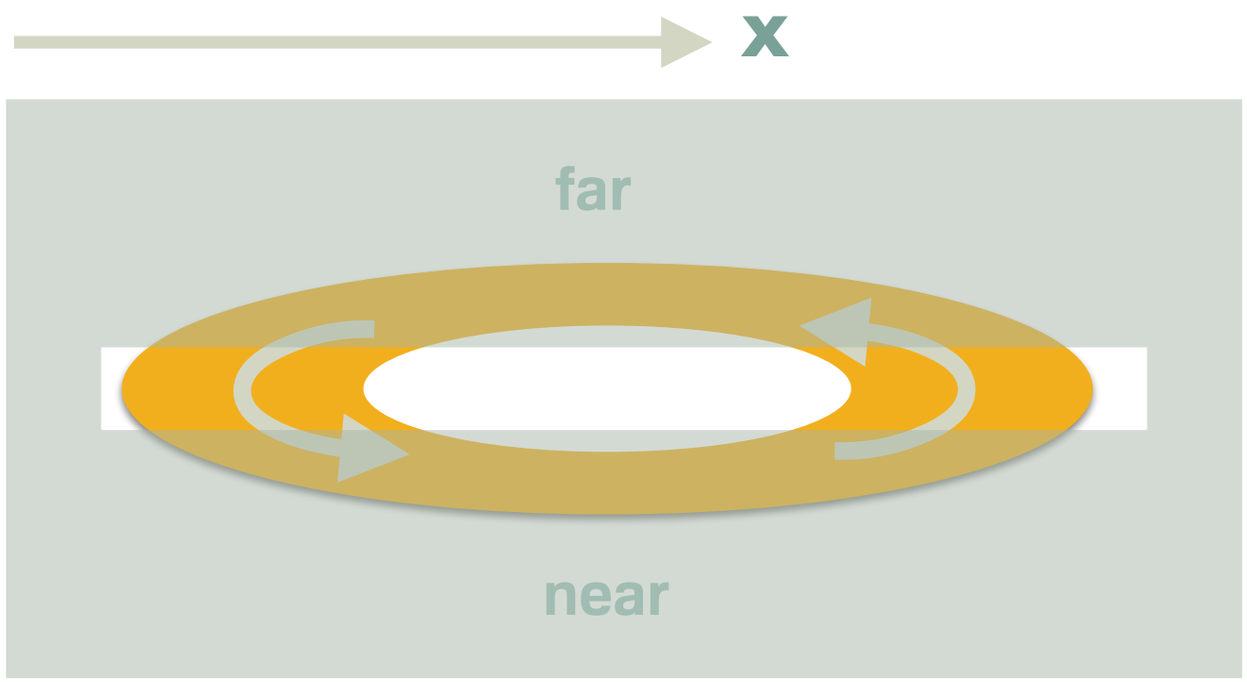
how spectrum looks like?

spherically expanding

constant v



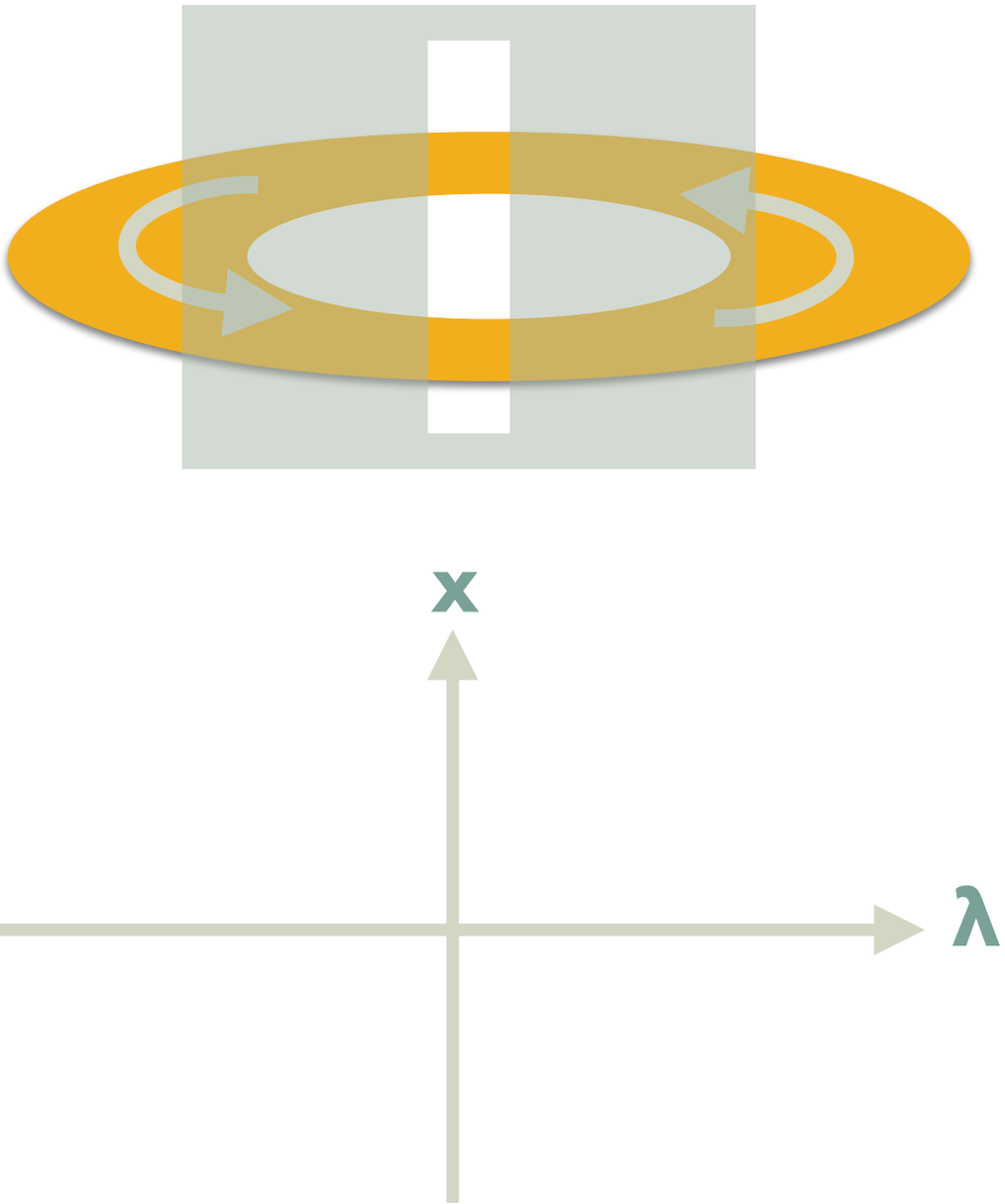
Spatial axis



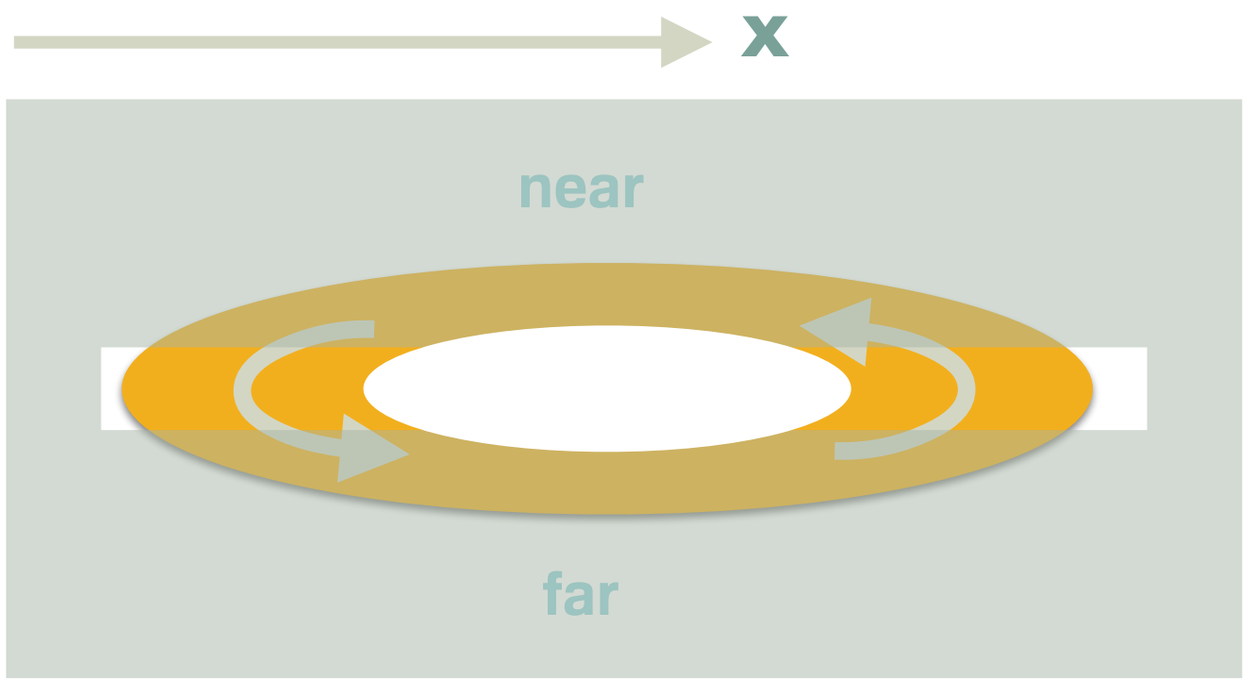
slit

line emission

how spectrum looks like?



Spatial axis

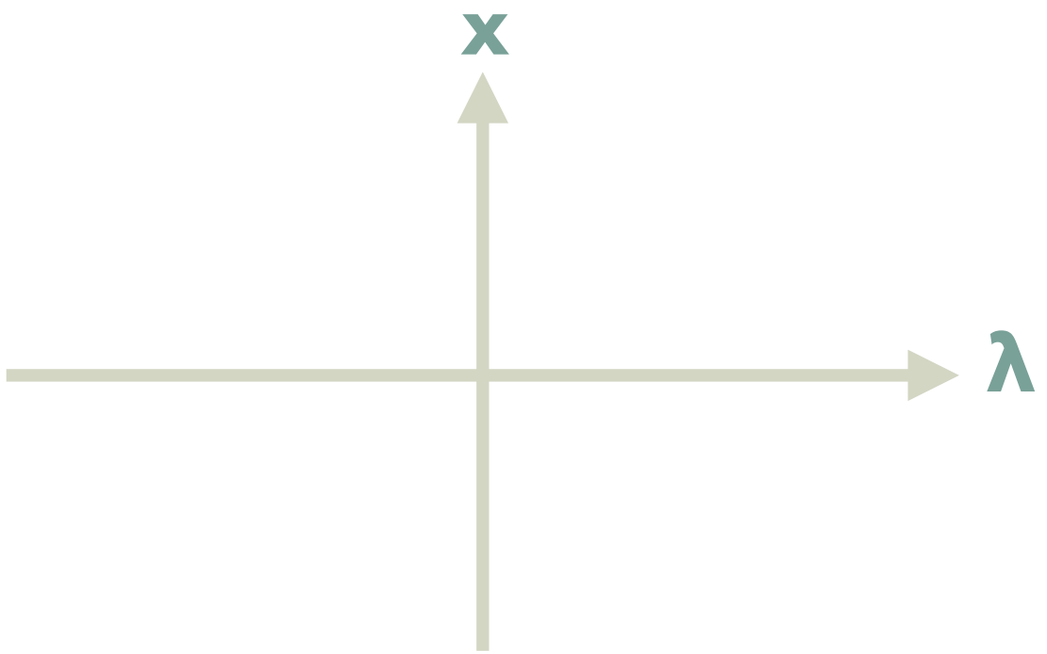


slit

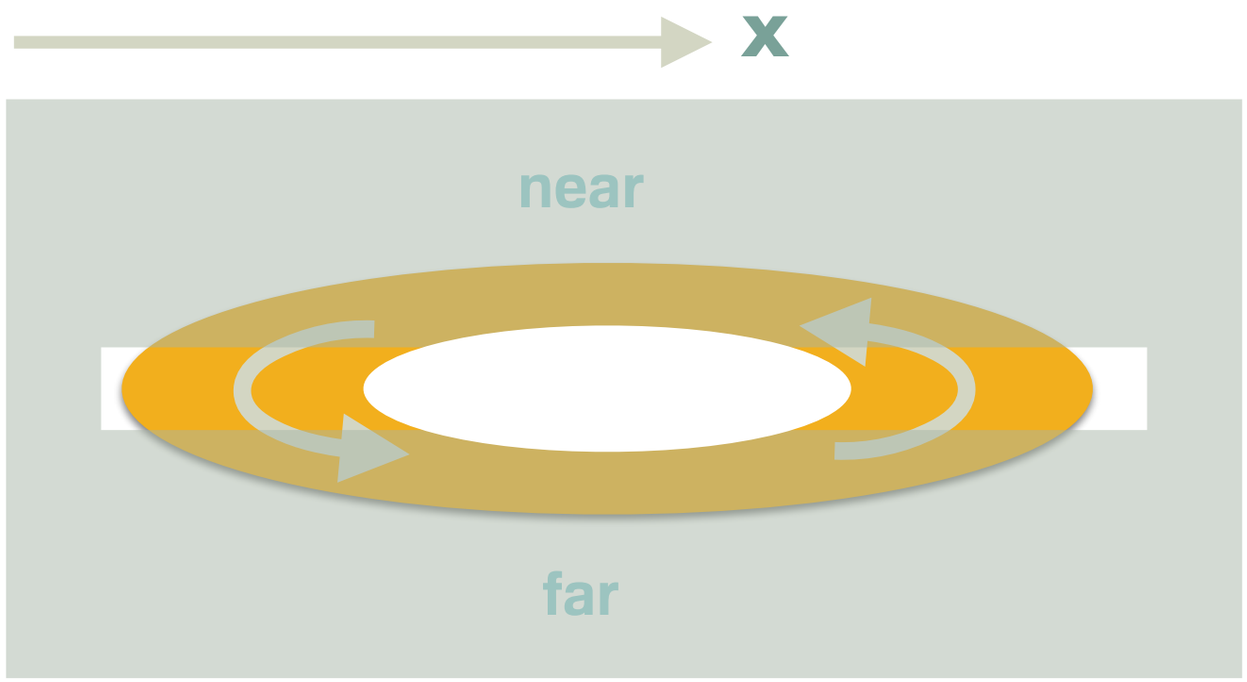
line emission

how spectrum looks like?

top view



Spatial axis

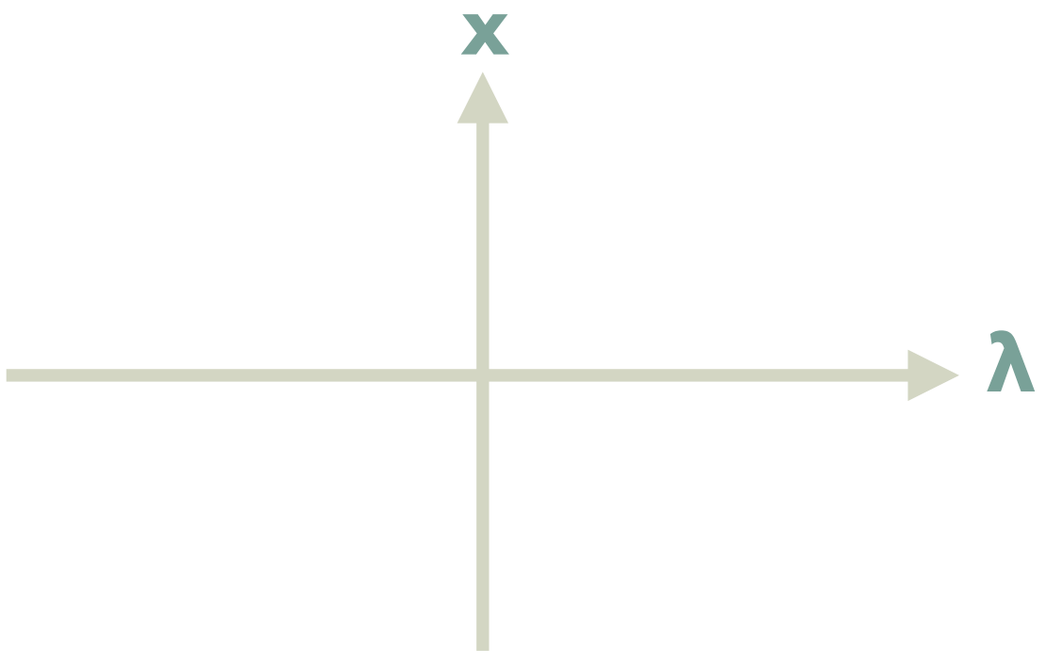


slit

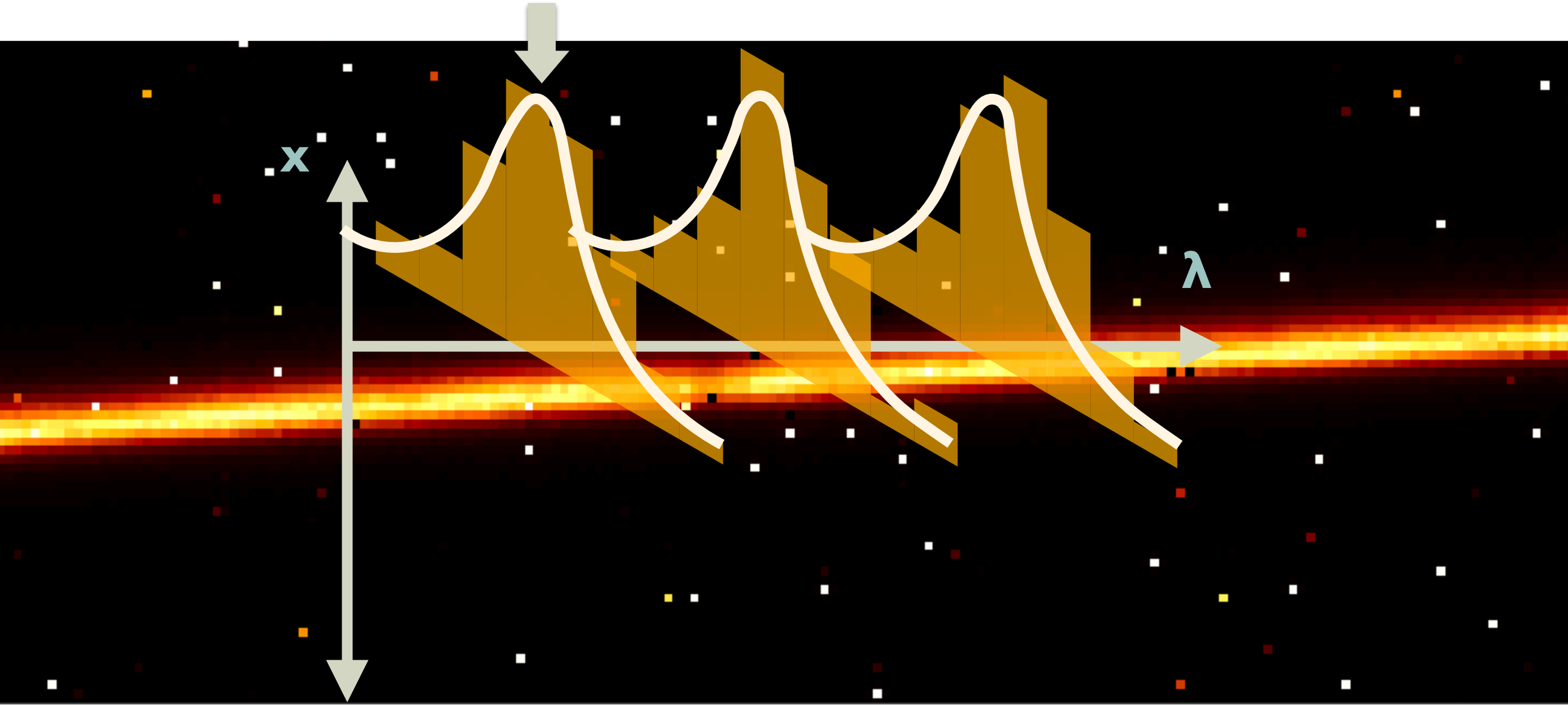
line emission

how spectrum looks like?

top view



Spectroastrometry



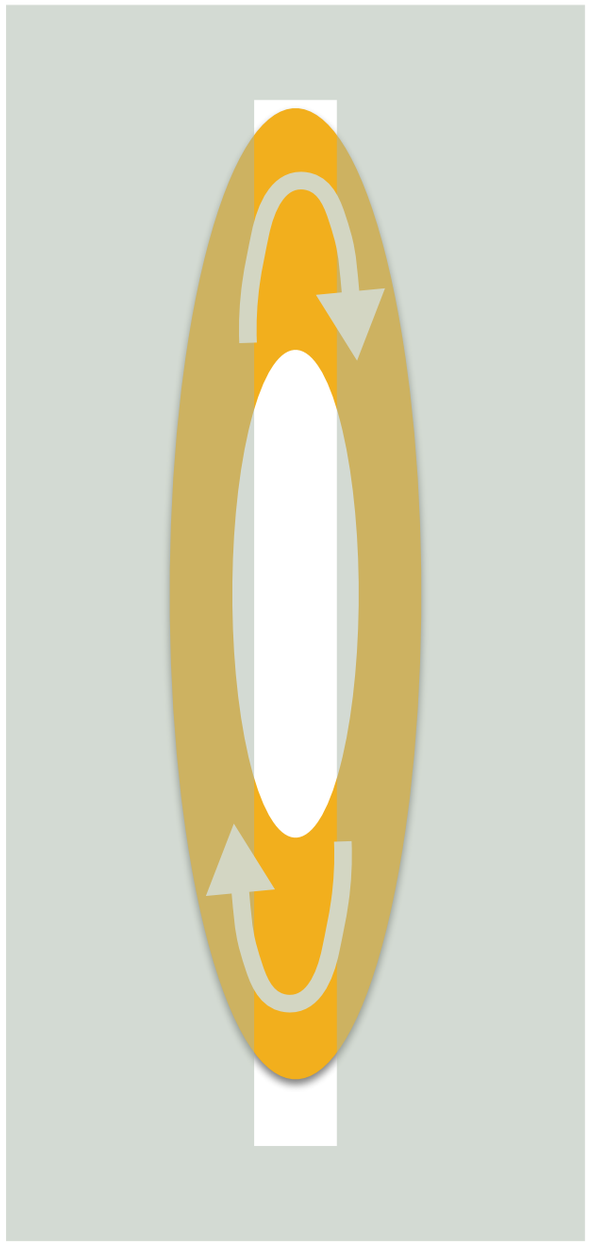
at each wavelength

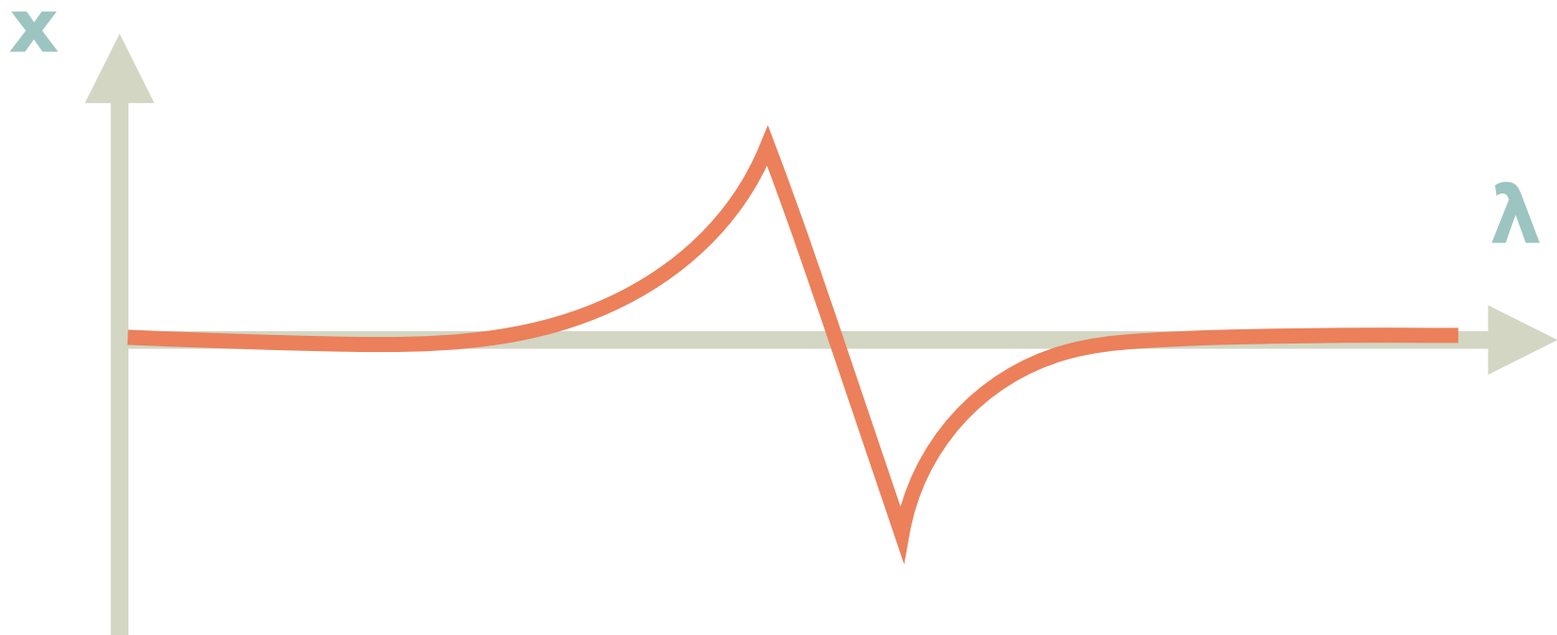
by fitting Gaussian / Box / empirical profile

accuracy improve with S/N

sub-pixel precision possible

Spectroastrometry





20 mas / pix

0.1 pix accuracy

140 pc away

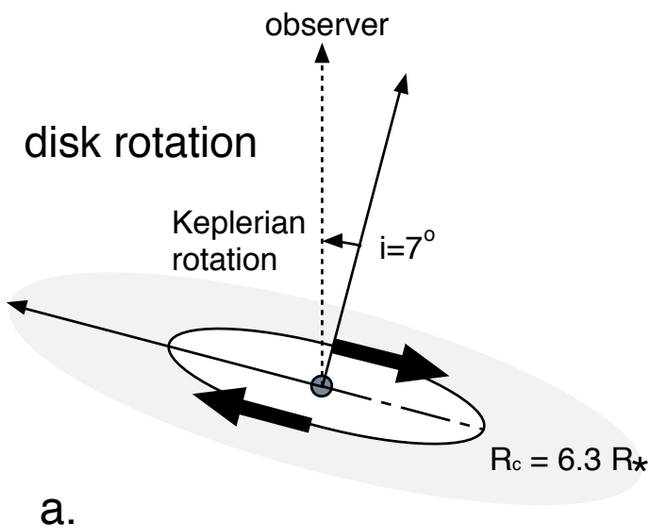
140 pc * 2 mas = 0.3 AU

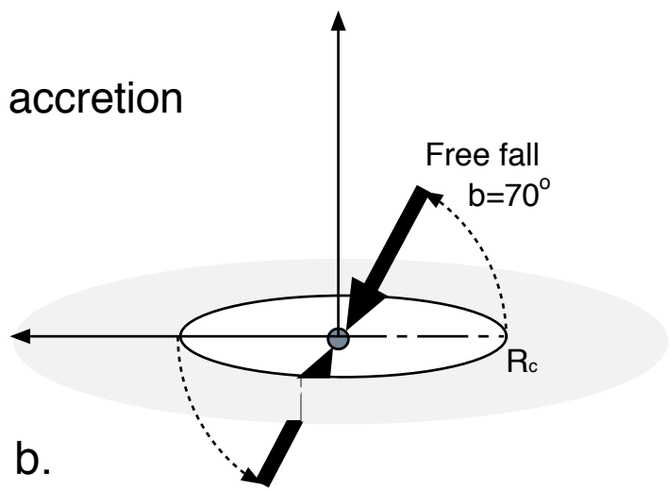
10 L* / 0.3 AU / 900 K

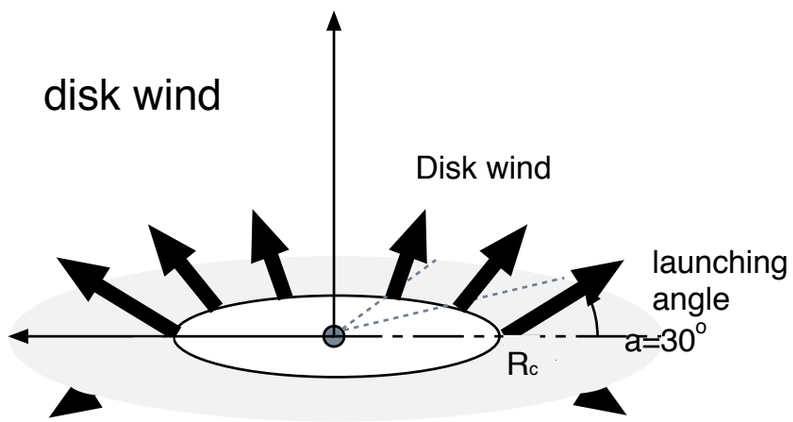
inner truncation of a disk

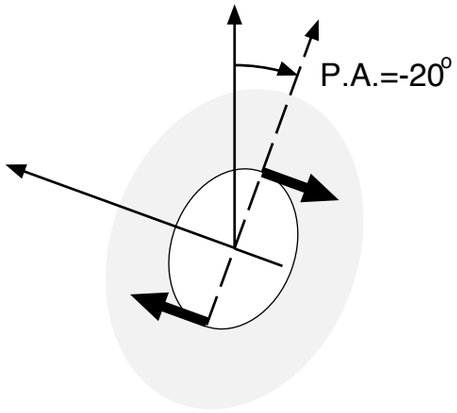
Spectroastrometry

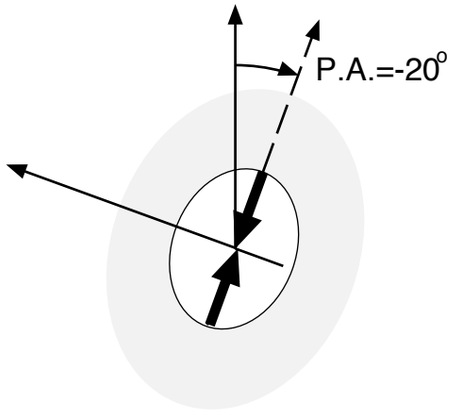
one can combine spectroastrometry with IFU

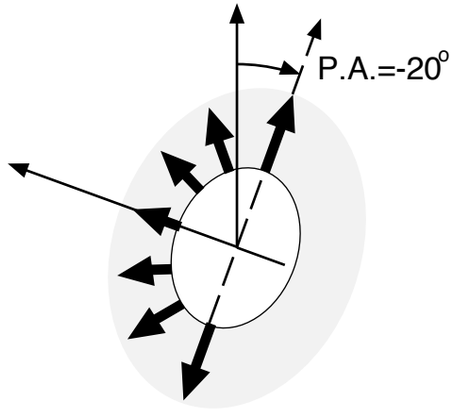






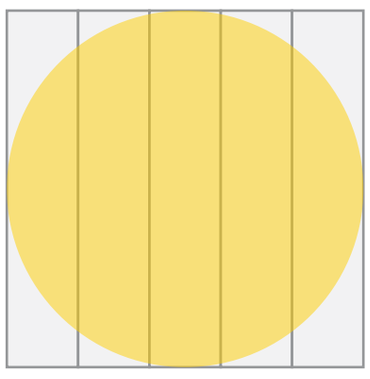






IFU integral field unit

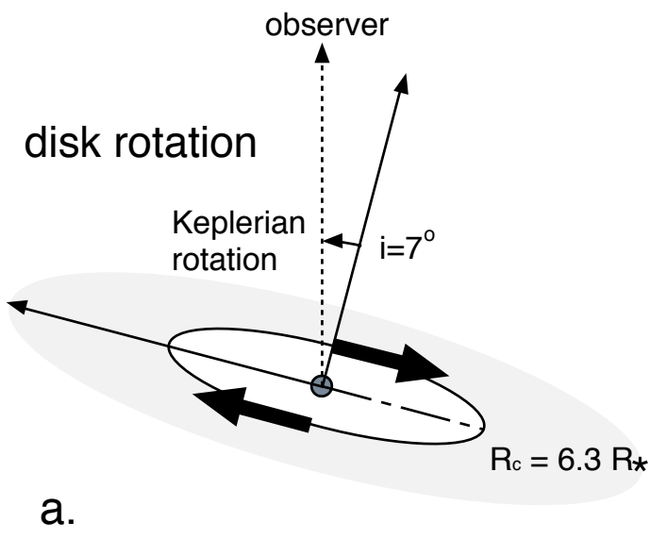
image slicer

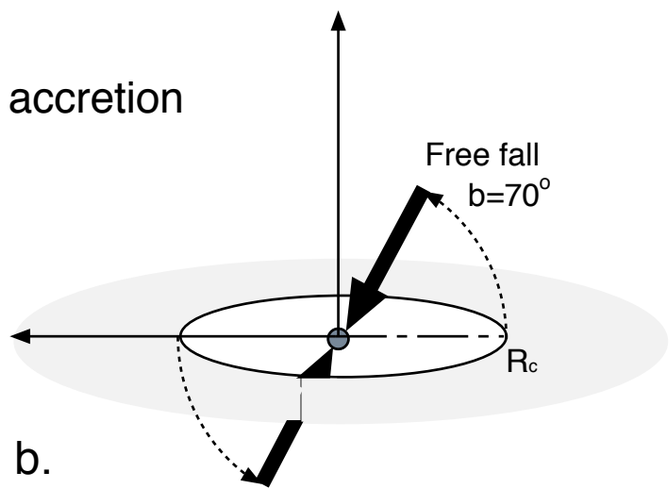


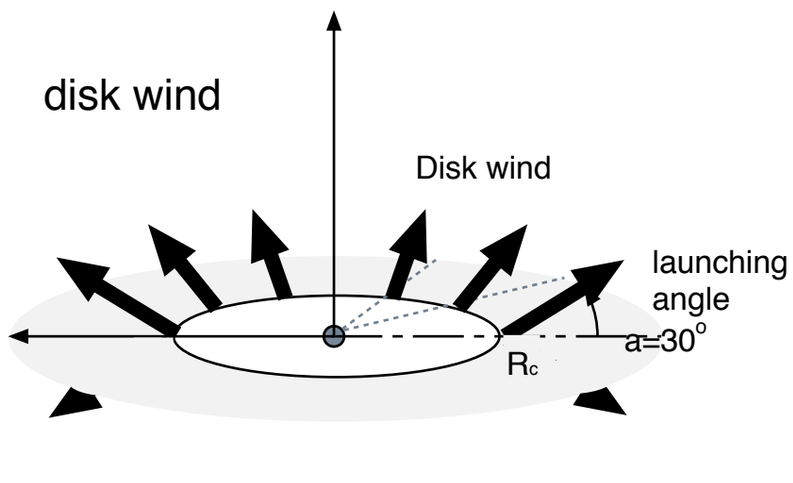
extended source

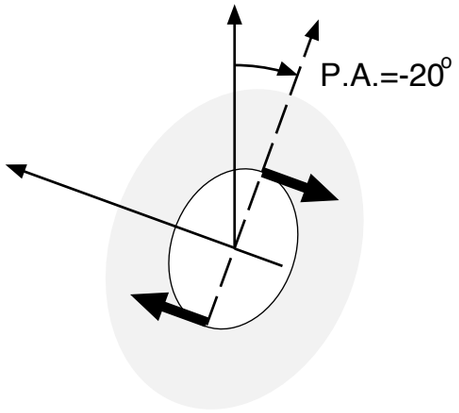
Spectroastrometry

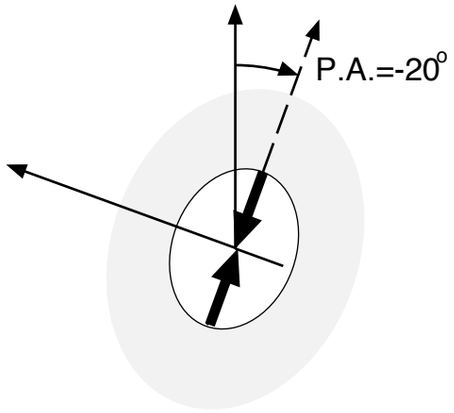
one can combine spectroastrometry with IFU

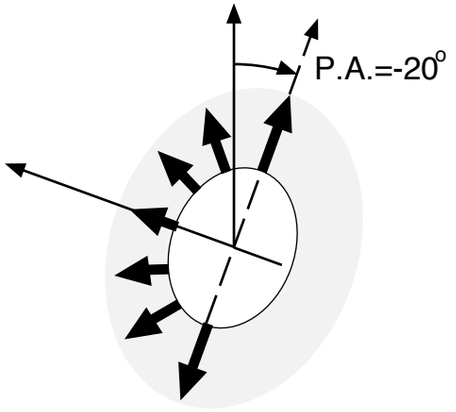


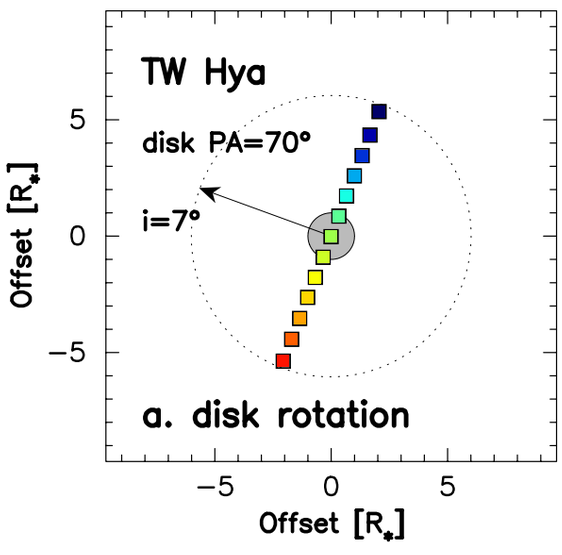


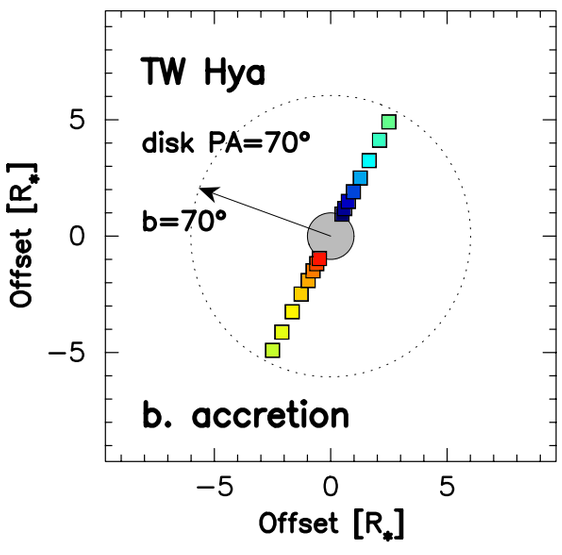


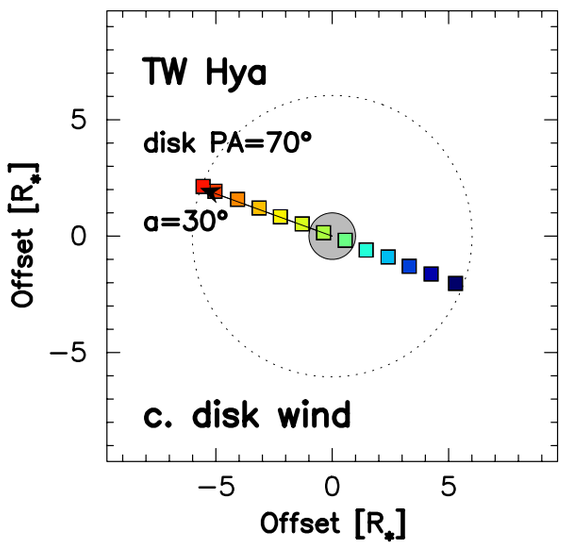




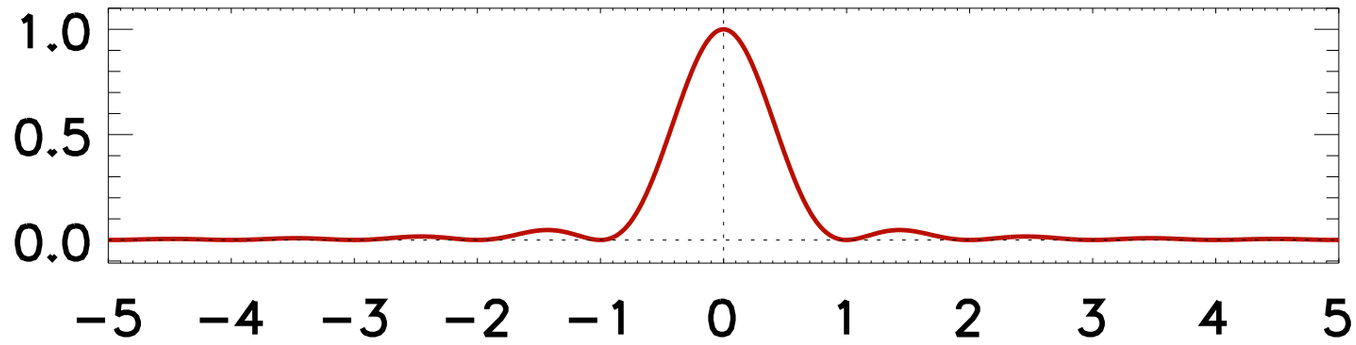








Exercise today



1 Fraunhofer diffraction

I=0 when $\frac{kax}{f} = \pi$

$$k = \frac{2\pi}{\lambda}$$

first minimum

$$\frac{x}{f} = \frac{\lambda}{R}$$

angular resolution — **wavelength / telescope aperture**

$$I = |u(r)|^2 = \frac{4a^2}{r^2}\left(\frac{\sin\frac{kax}{f}}{\frac{kax}{f}}\right)^2$$

calculate diffraction limited angular resolution of VLT (diameter 8.2 m) at *K* band (2.2 μm)

2 Calculate the size of spectrograph

that works at the mid-infrared $\lambda = 10\ \mu m$

with the spectral resolution $R = 100{,}000$

$m = ?$

$d = ?$

$N = ?$

$$\frac{\lambda}{\Delta\lambda} < mN$$

why there is no high resolution infrared spectrograph in space?