Radiative transfer simulations of Lyman escape through anisotropic gas distributions

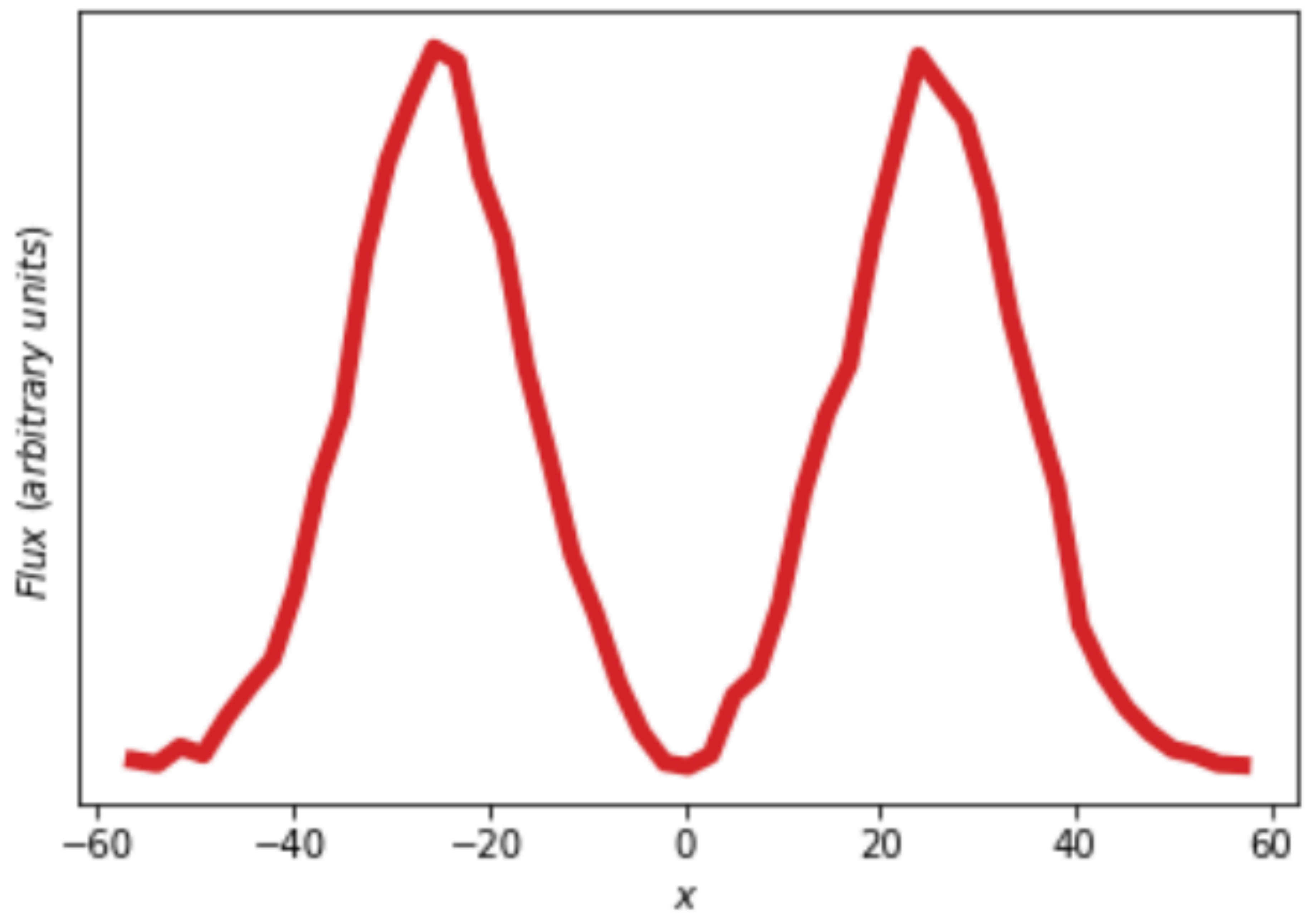
Silvia Almada Monter
Max Planck Institute for Astrophysics

Escape of Lyman radiation from galactic labyrinths
OAC, Kolymbari, Crete
April 18th, 2023

MAX PLANCK INSTITUTE
FOR ASTROPHYSICS

Radiative transfer simulations of Lyman escape through anisotropic gas distributions

✓ Easy: Lyman-alpha line profiles give us information about gas surrounding galaxies



Radiative transfer simulations of Lyman escape through anisotropic gas distributions

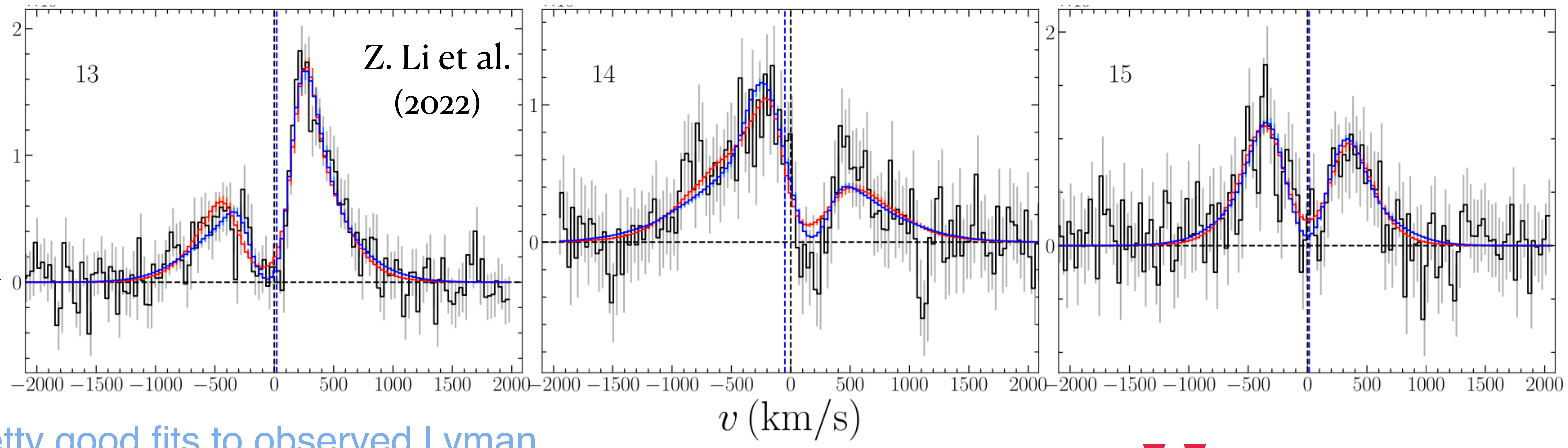
~~Easy~~: Lyman-alpha line profiles give us information about gas surrounding galaxies

So far, most attempts to 'decode' Lyman-alpha have been made through ***isotropic*** models that don't necessarily represent real scenarios

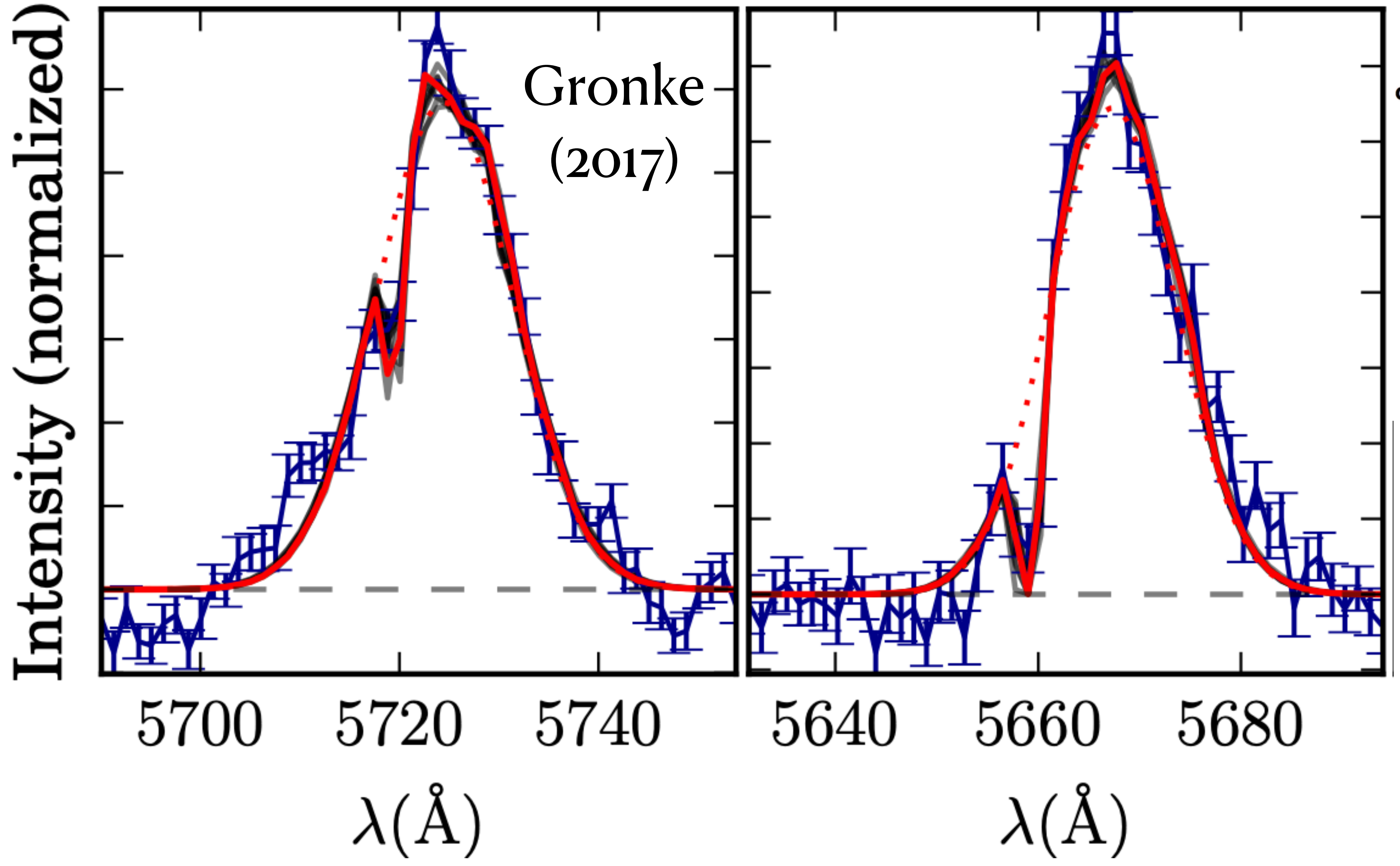
Are these enough?

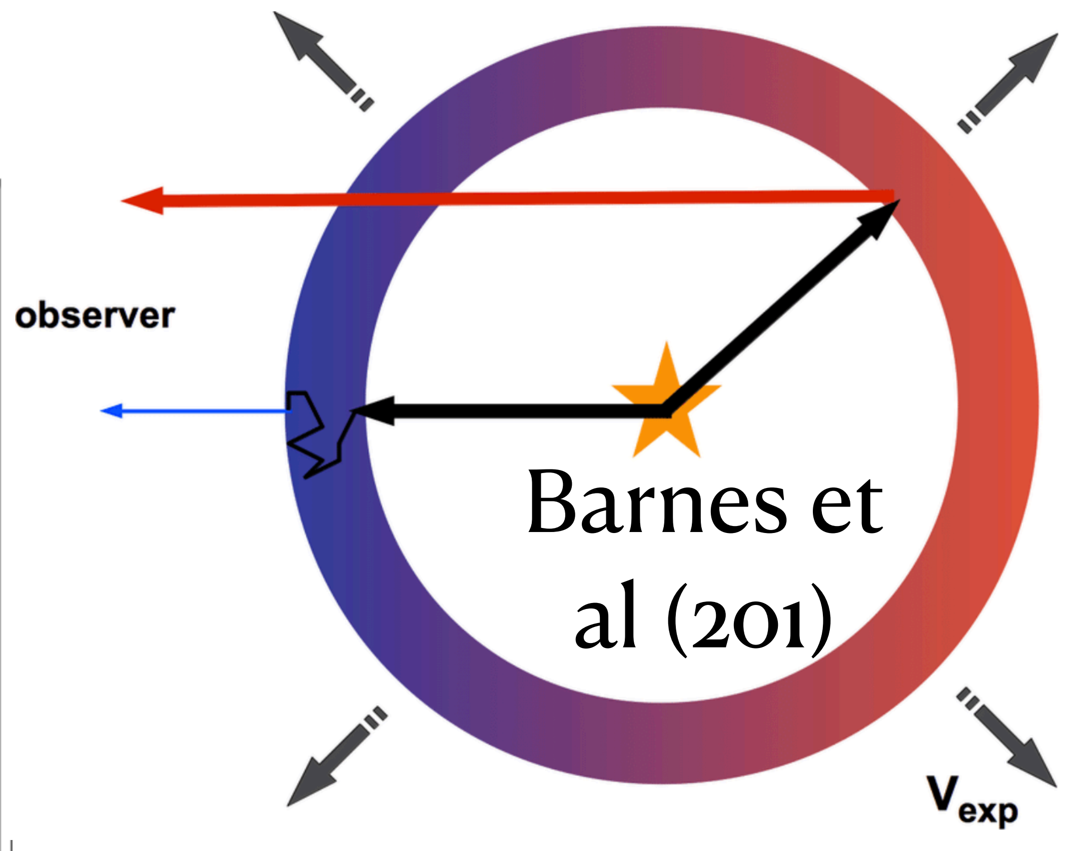
Well...

Shell models



Pretty good fits to observed Lyman alpha line profiles





However...

Geometry does not always capture complex structure of gas

Not clear what the parameters mean physically

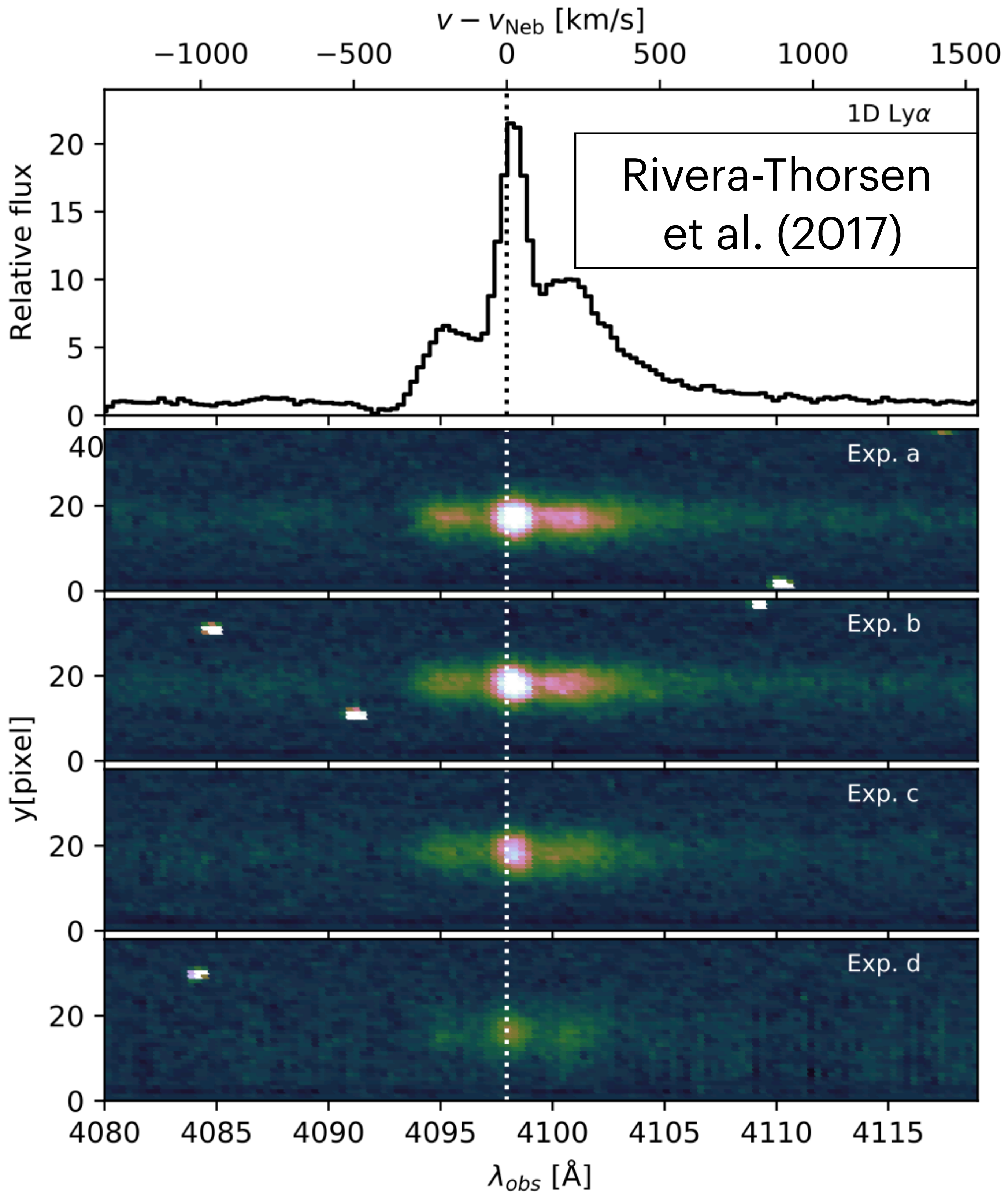
The Sunburst Arc

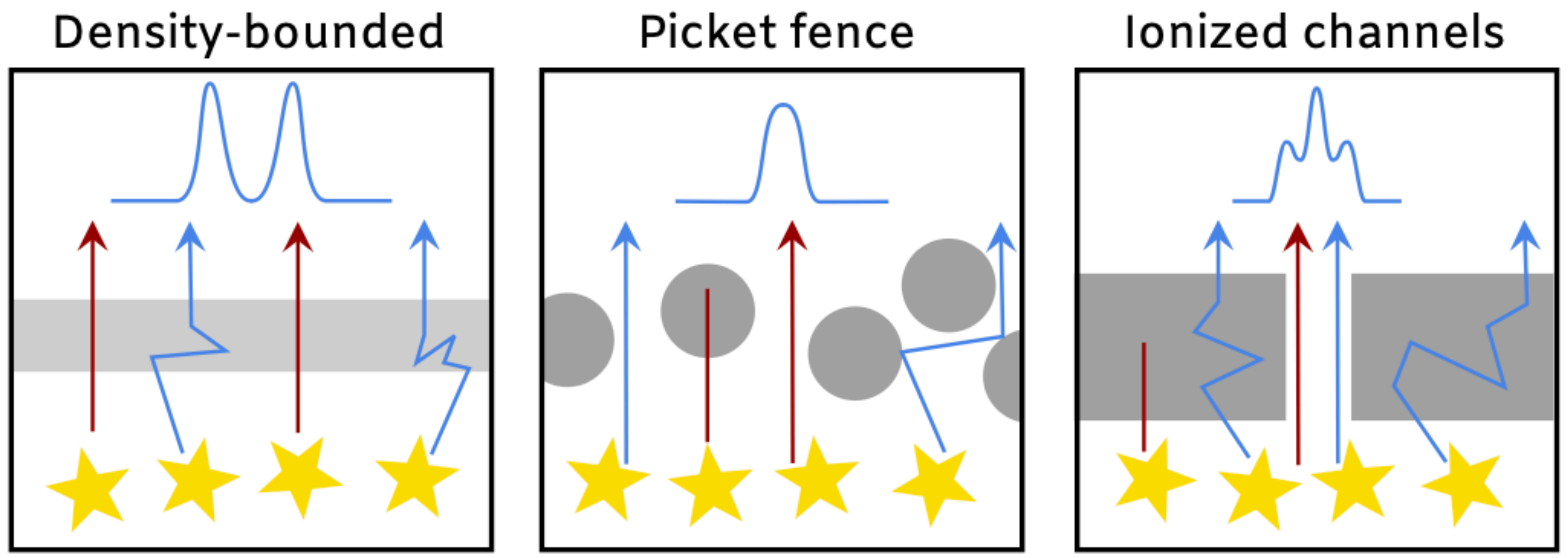
Bright lensed galaxy

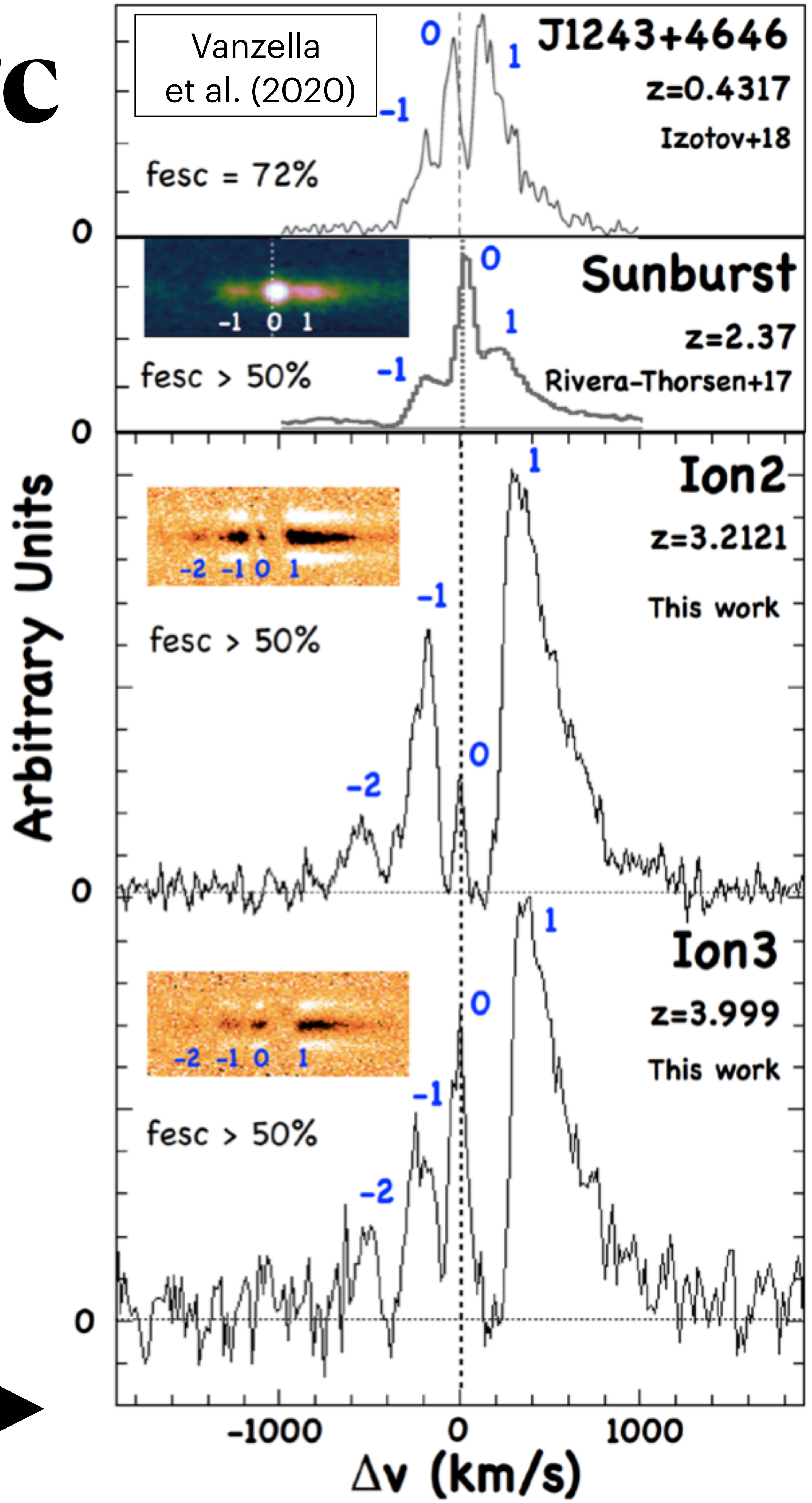
z=2.4

ESA/Hubble, NASA, Rivera-Thorsen et al.

The Sunburst Arc







... is not alone

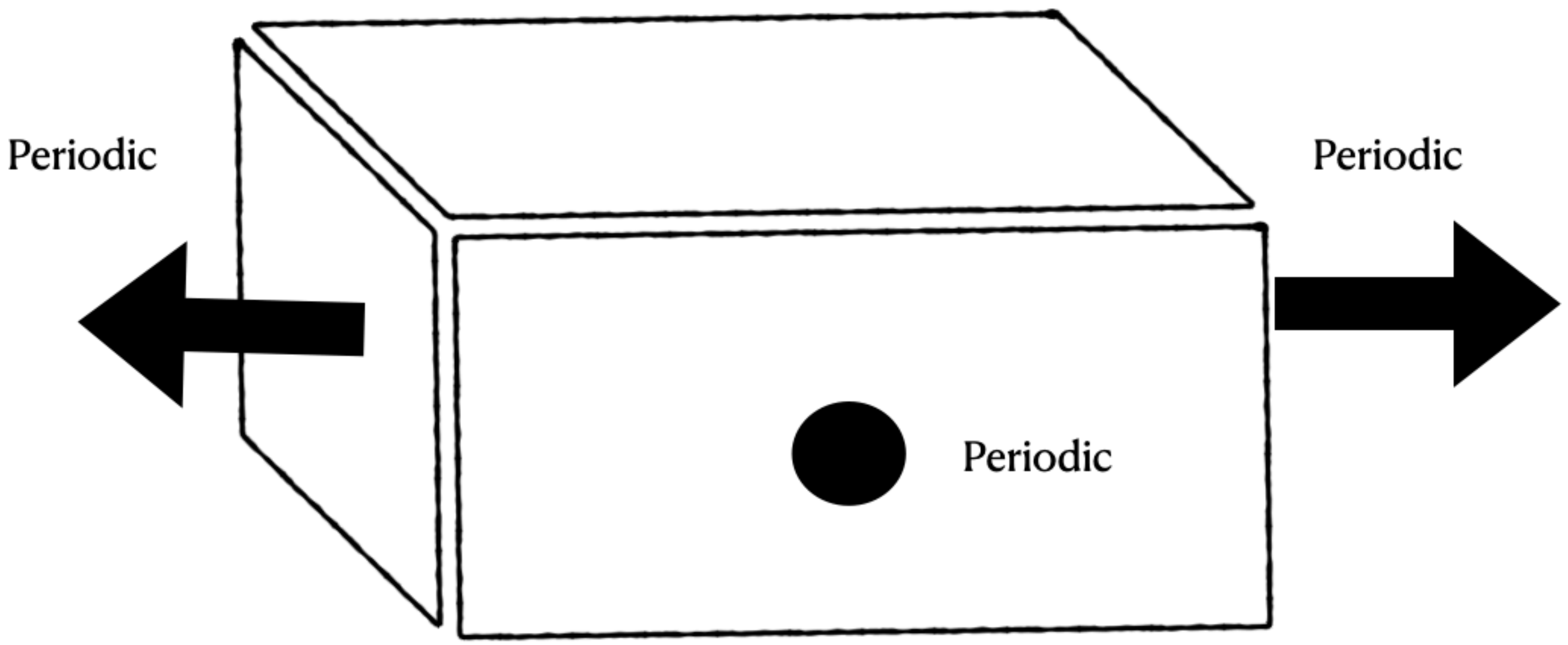
Radiative transfer simulations of Lyman escape through anisotropic gas distributions

(even more) complicated than isotropic

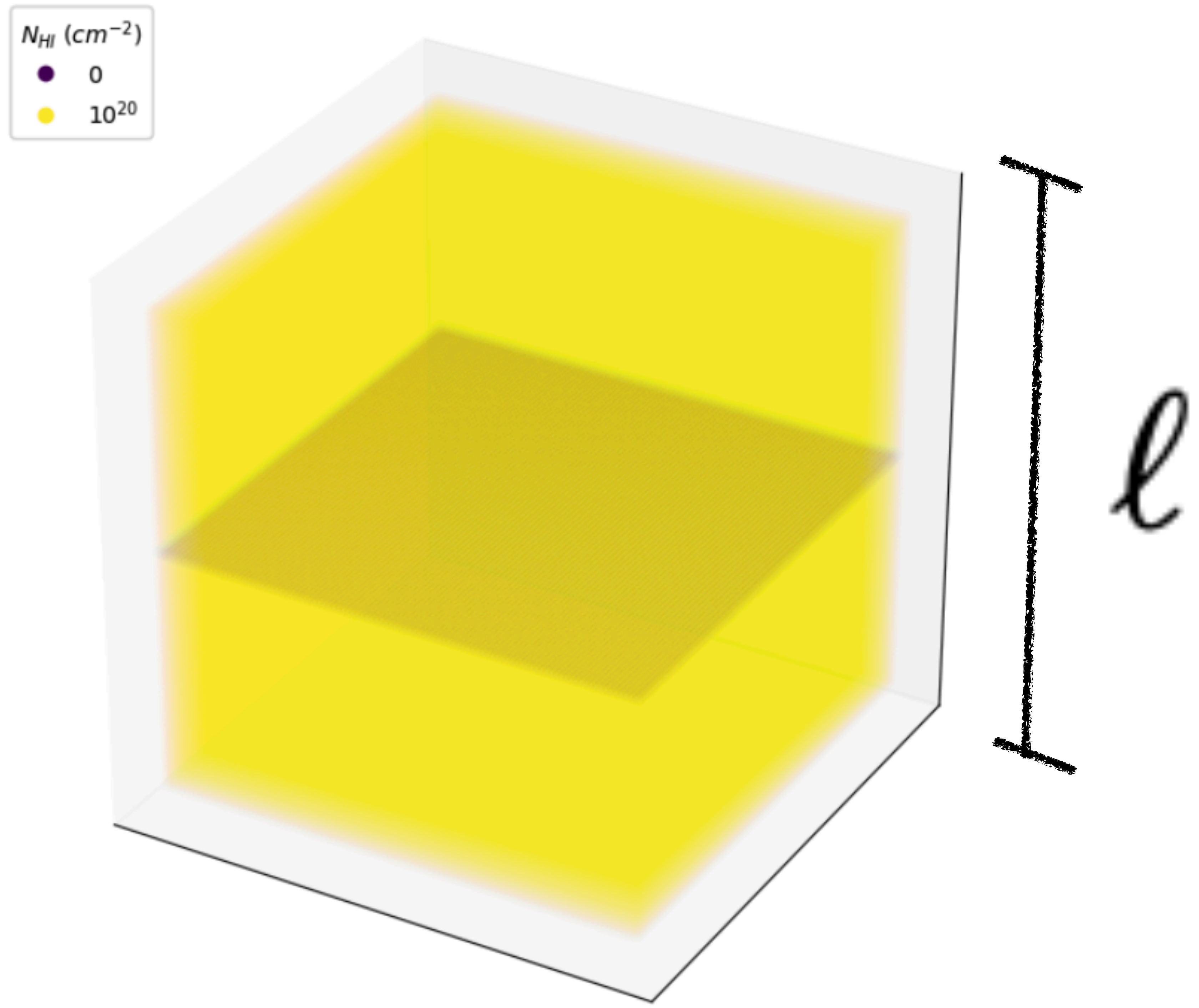
What do we do then?

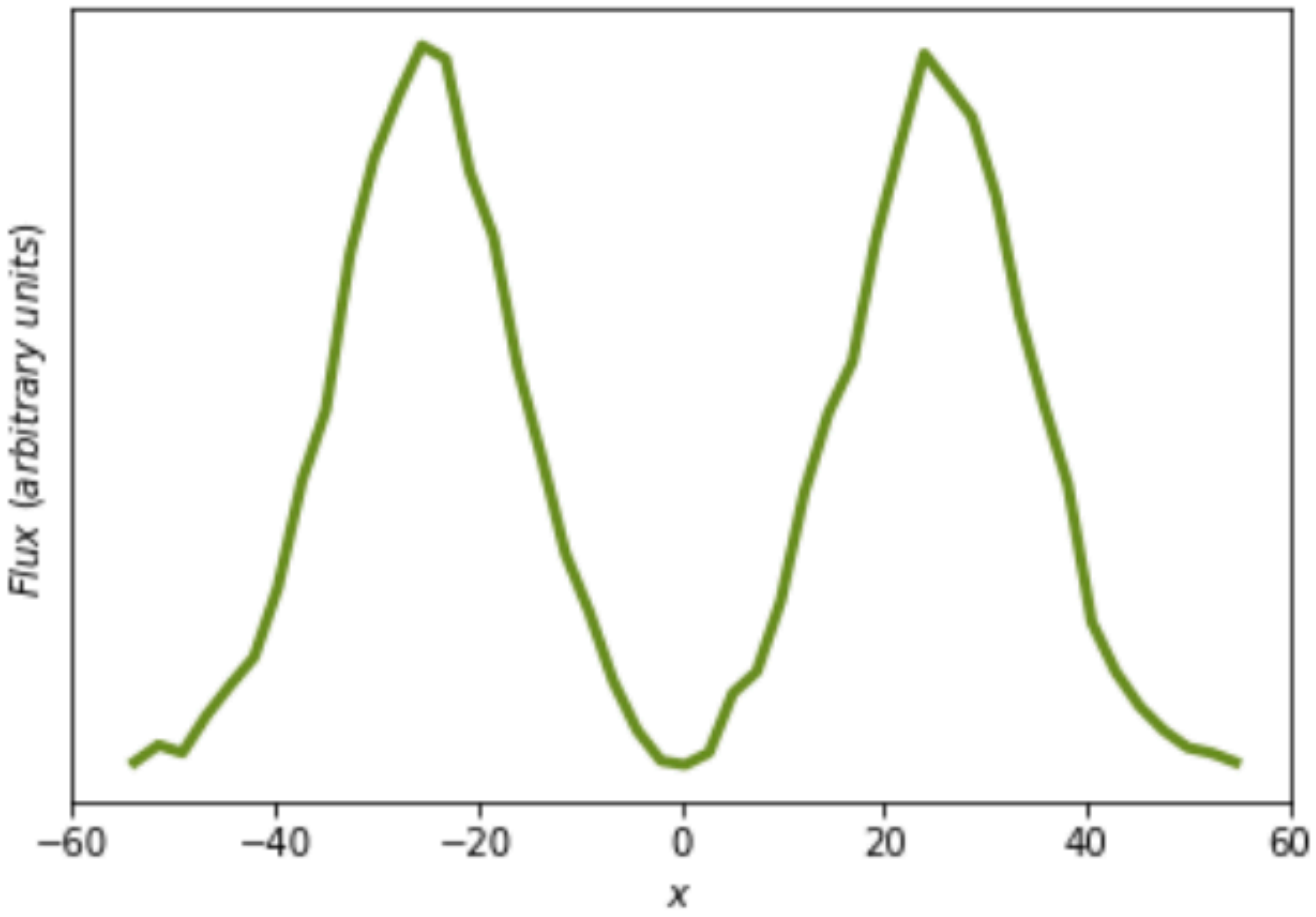
Take a simplified approach:

- Slab filled with gas
- Add anisotropies: 'Poke' holes through which photons can escape.
- Monte Carlo radiative transfer: talc (Gronke et al. , 2014)



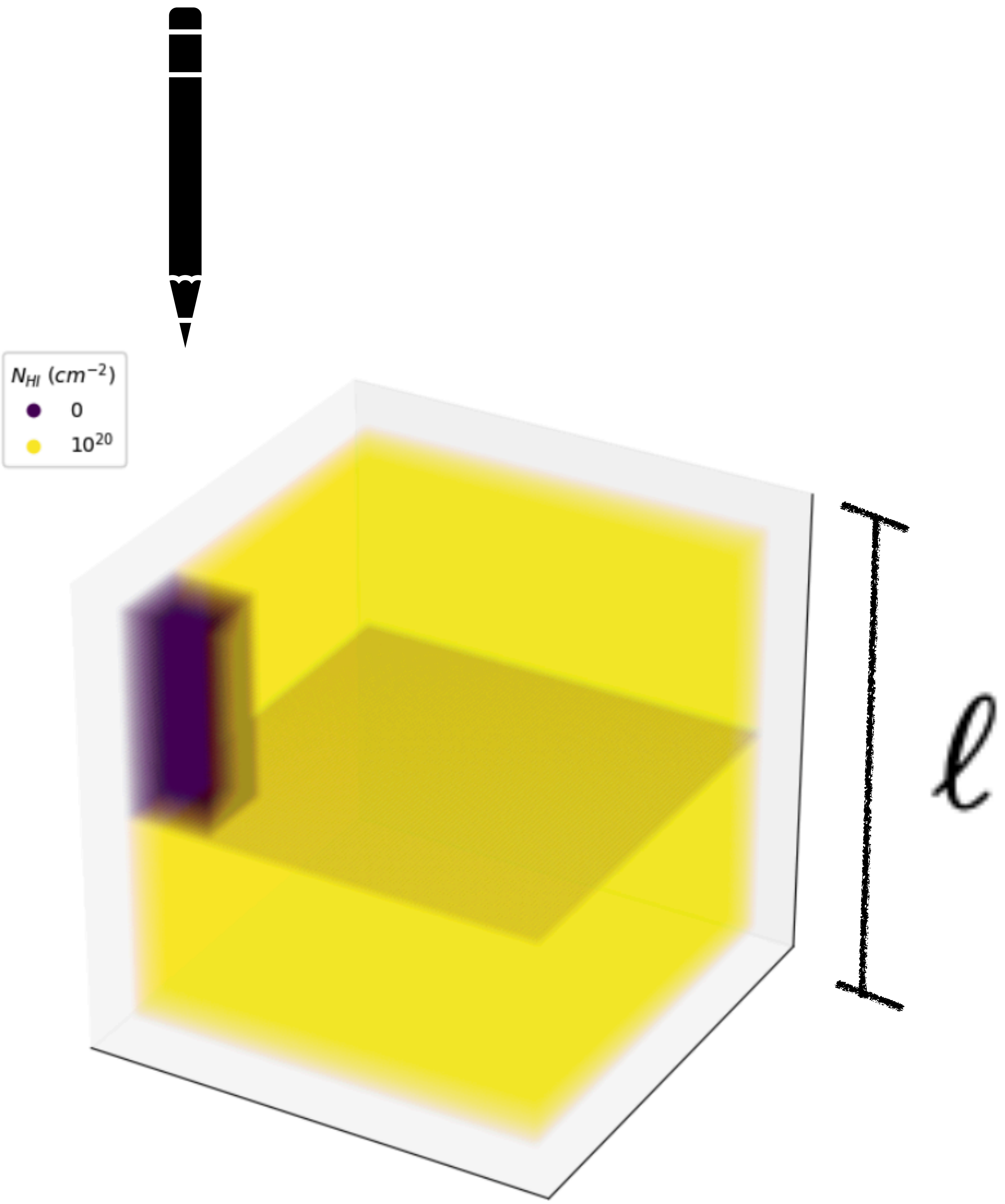
Integrated Spectrum



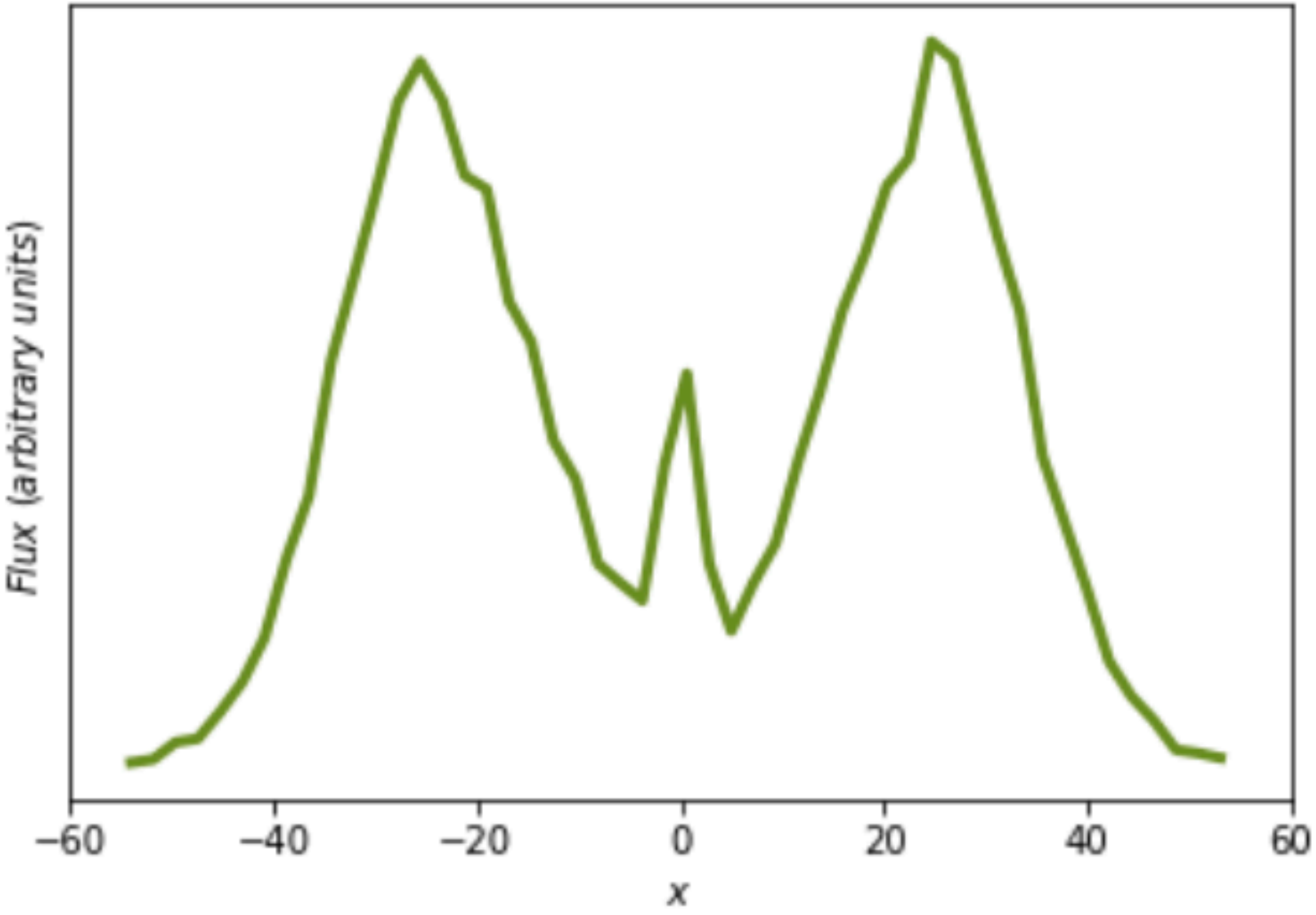


$$x \equiv \frac{\nu - \nu_0}{\Delta\nu_D}.$$

Dimensionless frequency parameter



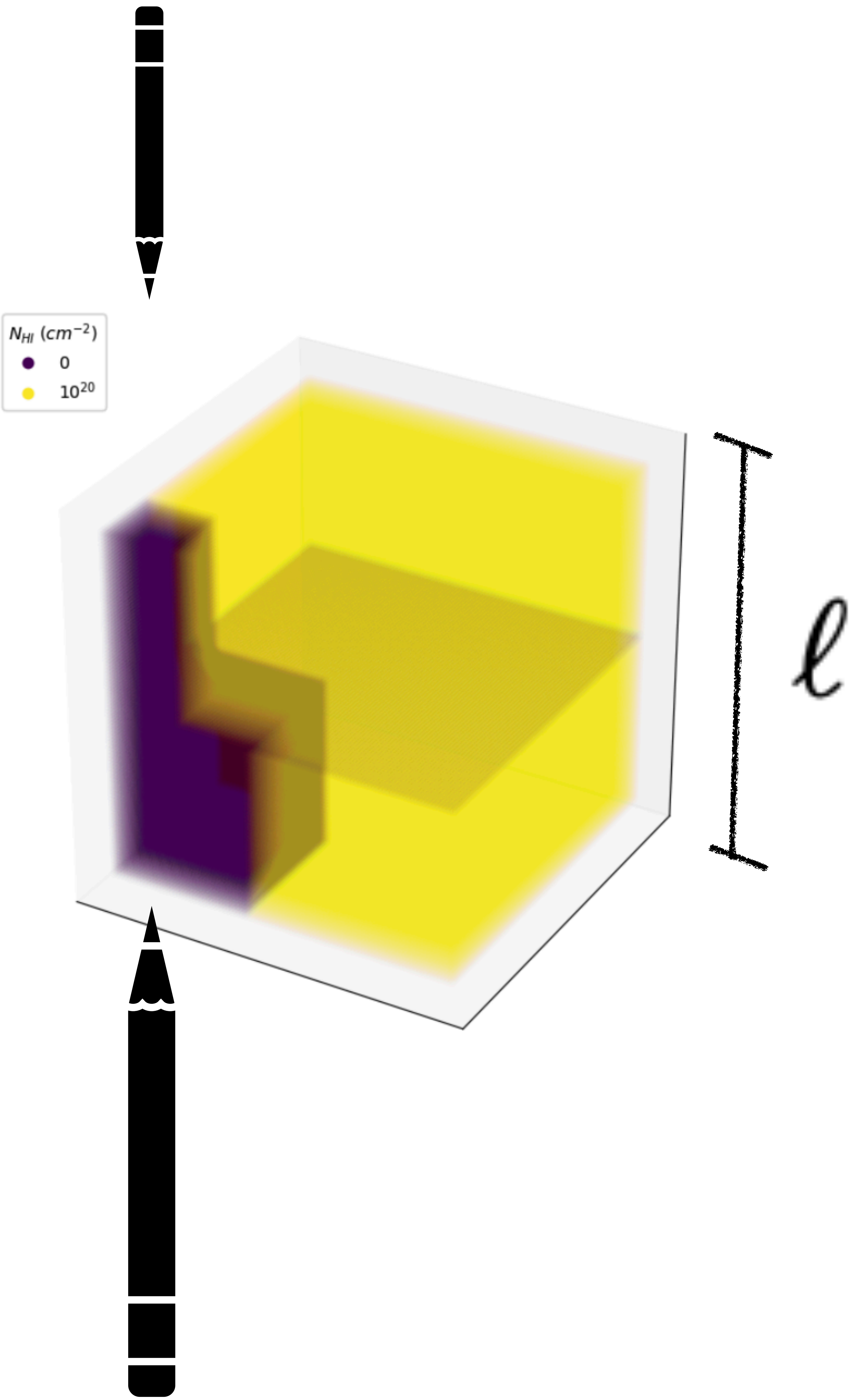
Integrated Spectrum

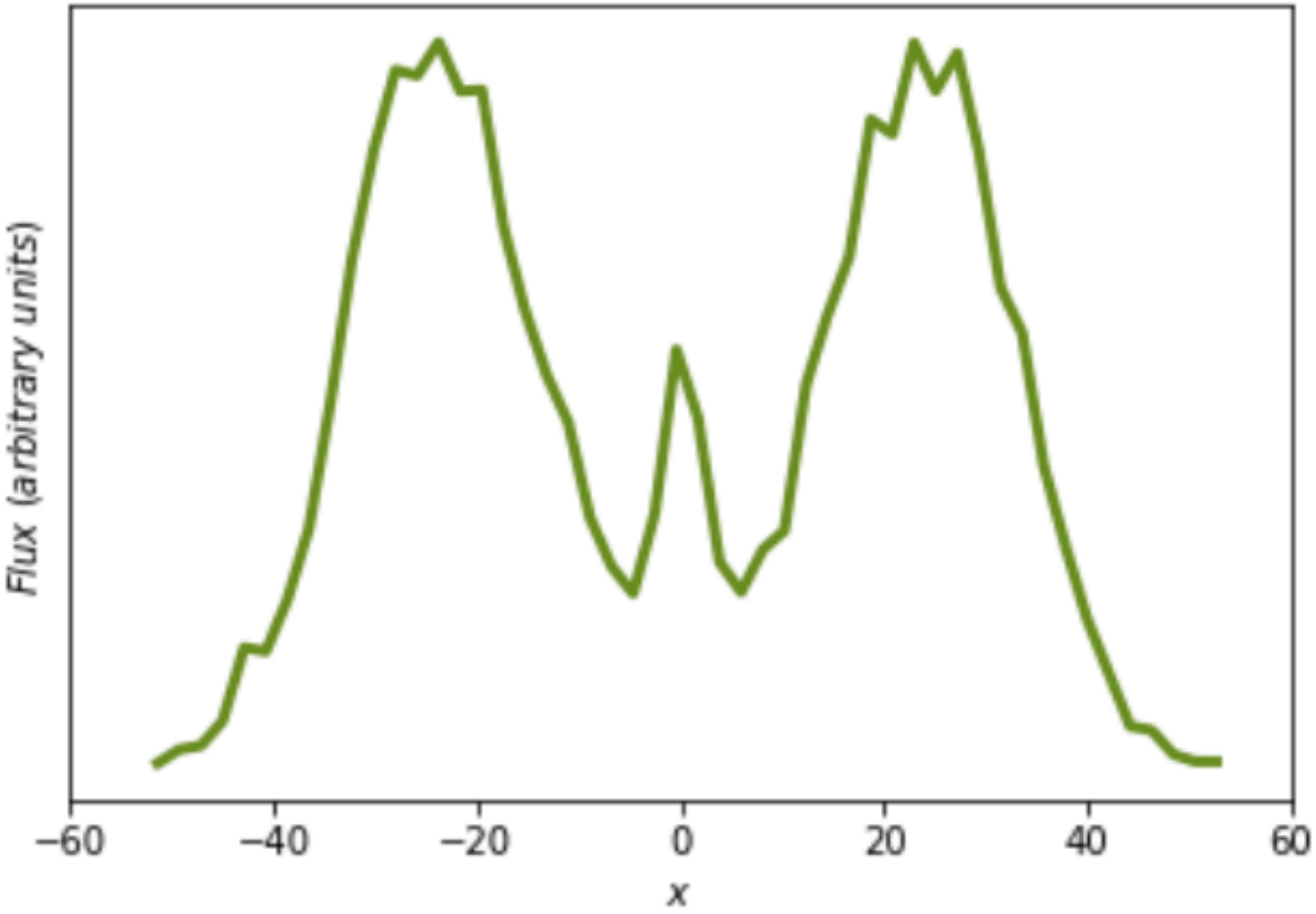


$$x \equiv \frac{\nu - \nu_0}{\Delta \nu_D}.$$

Dimensionless frequency parameter

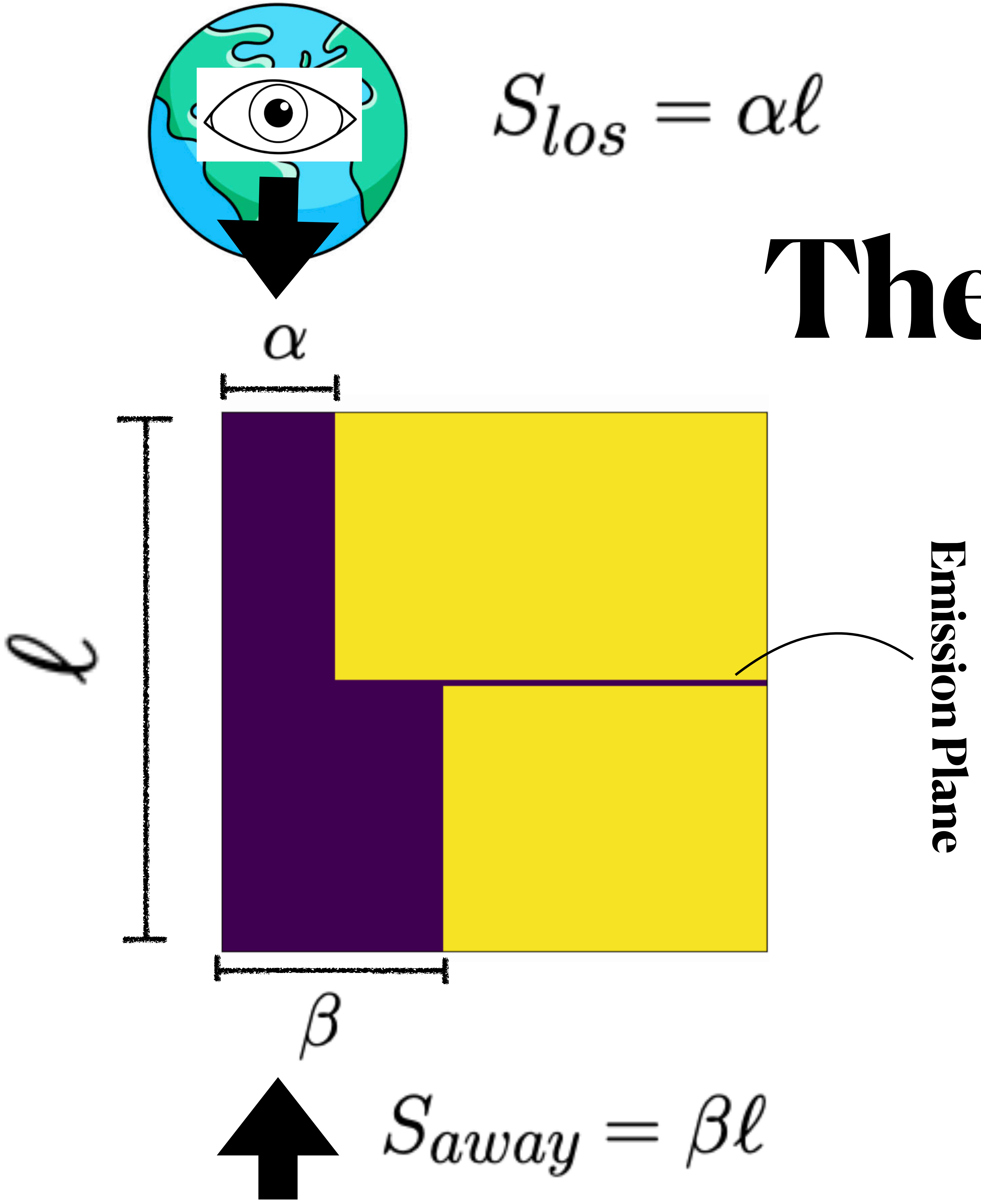
Integrated Spectrum





$$x \equiv \frac{\nu - \nu_0}{\Delta \nu_D}.$$

Dimensionless frequency parameter



The 'labyrinth'

Let's focus for now on observers that are looking directly 'down the hole'.

- The goal: a more realistic column density PDF.
- We start with a delta function (gas + hole)
- Possible scenarios:

$$S_{los} = 0; \; S_{away} = 0$$

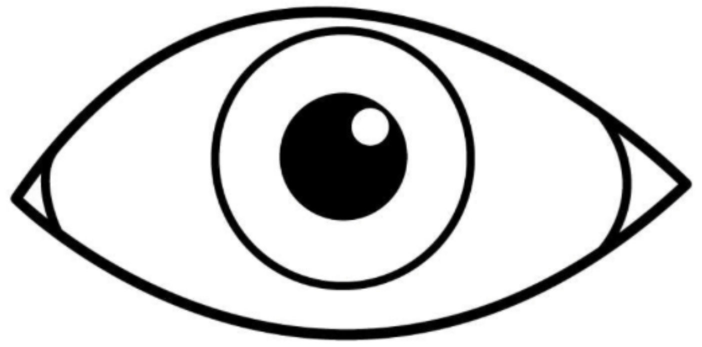
$$S_{away} = 0$$

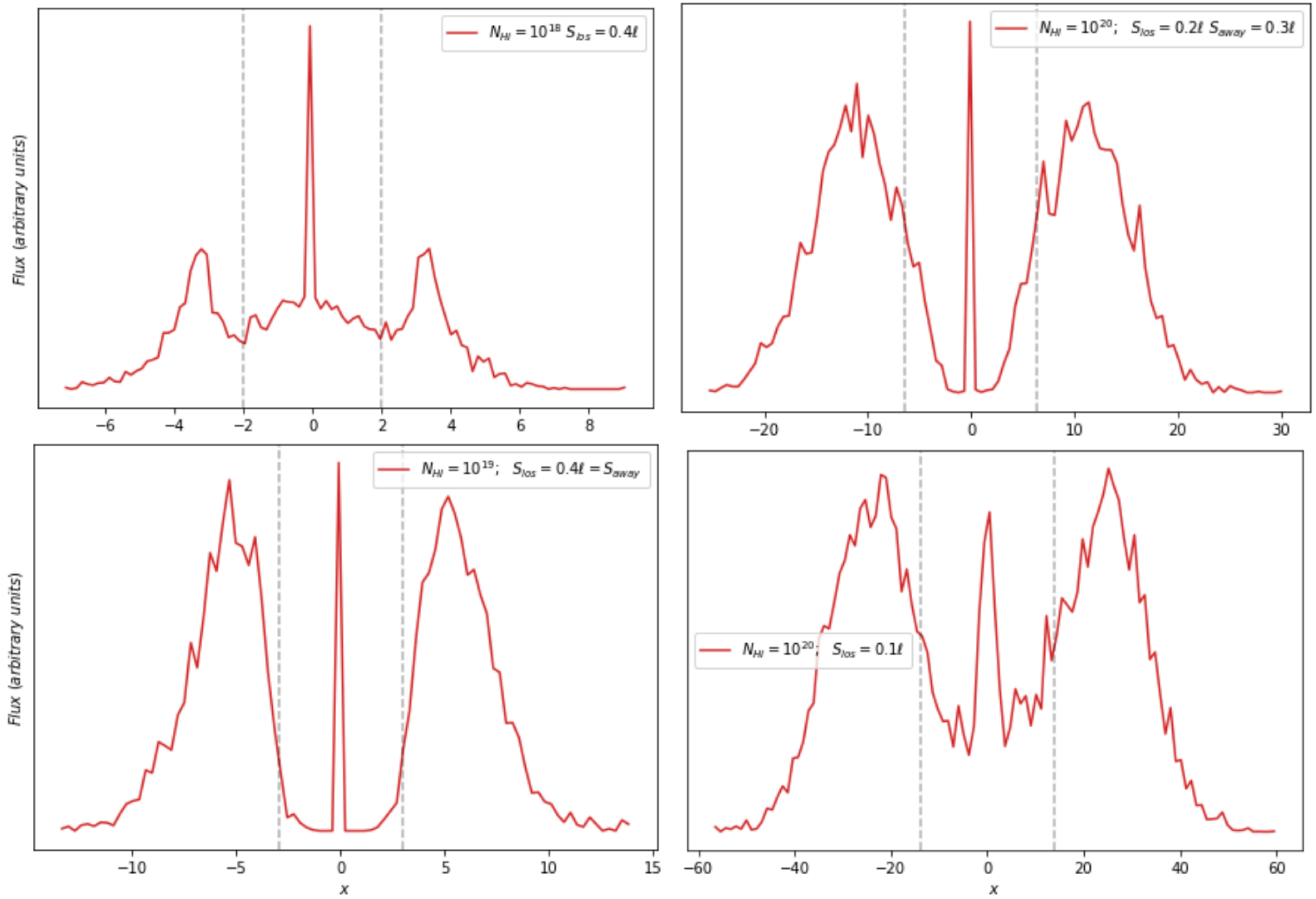
$$S_{los} = S_{away}$$

$$S_{los} \neq S_{away}$$

OAC, Crete
Escape of Lyman radiation from galactic labyrinths
2023

Looking 'down the hole'

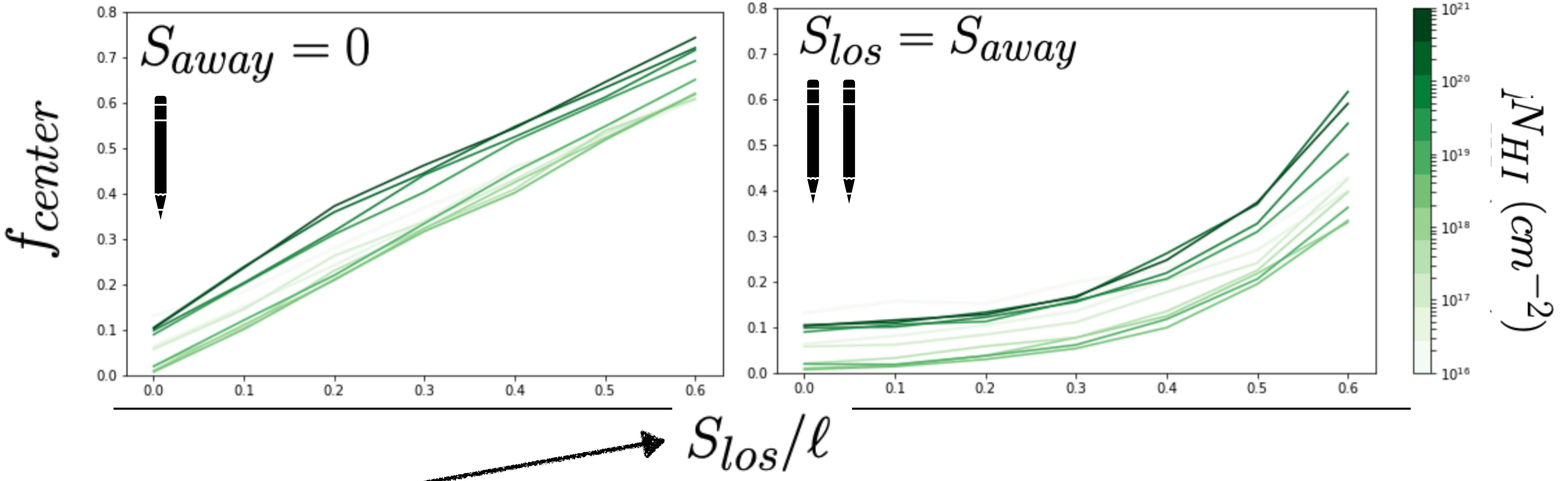




Strong central peaks

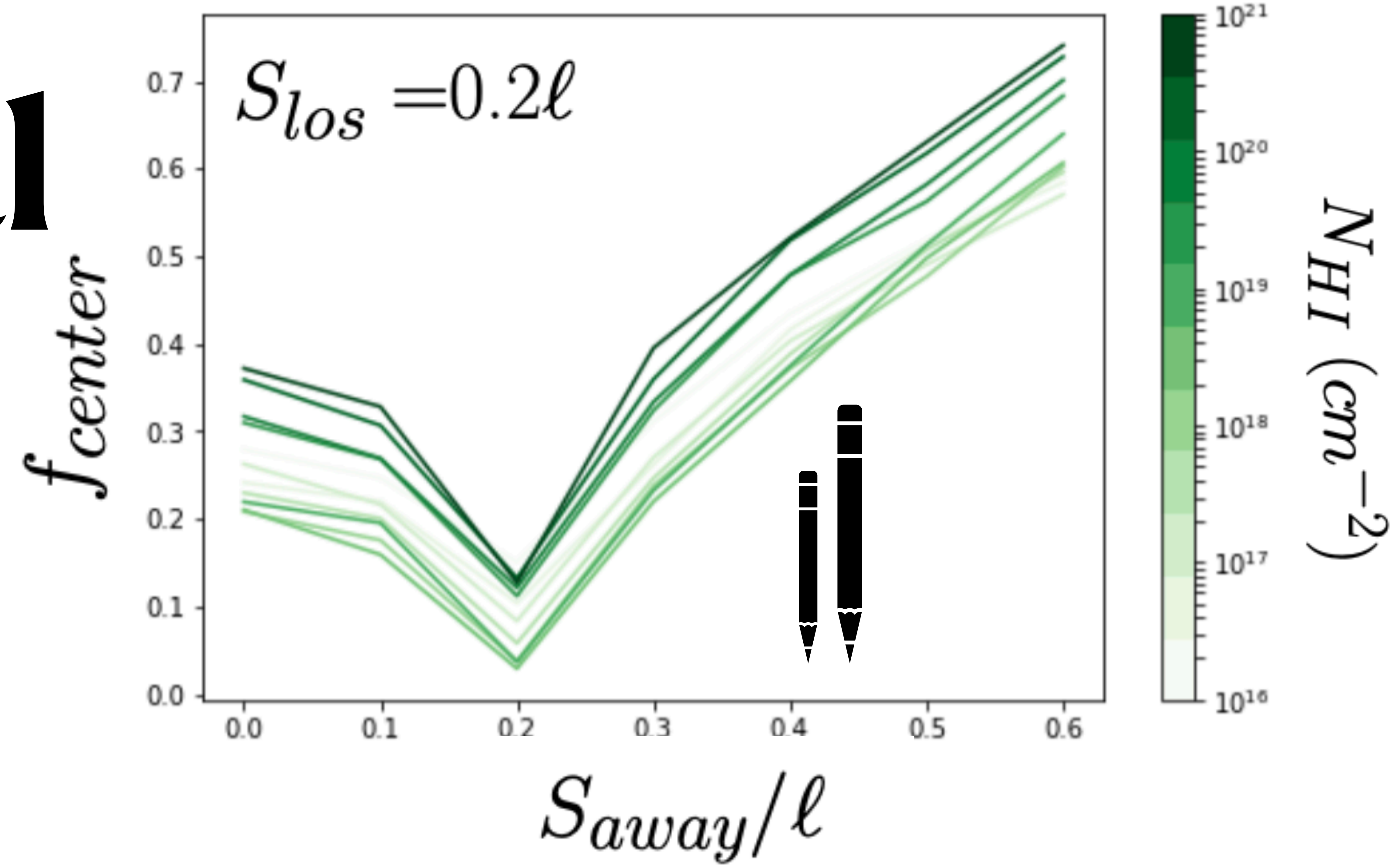
To quantify them we define:

$$f_{center} = \frac{F_{center}}{F_{tot}}$$

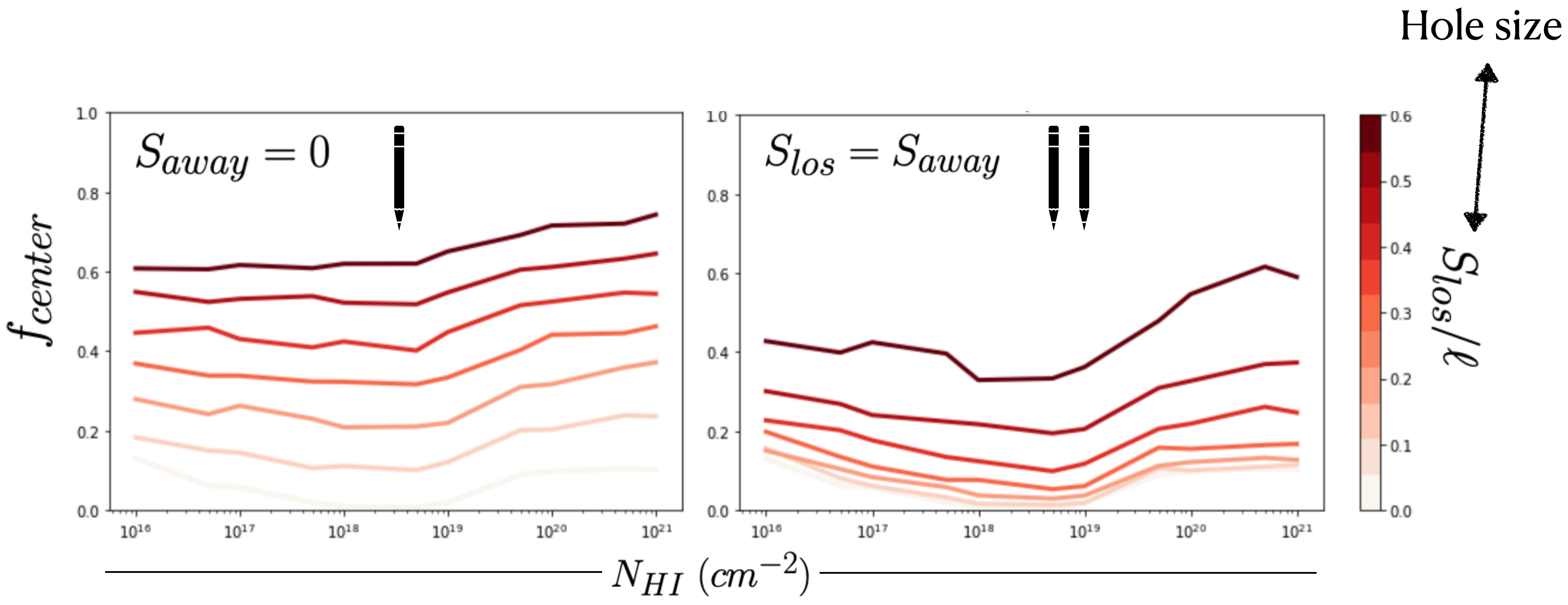


Hole size

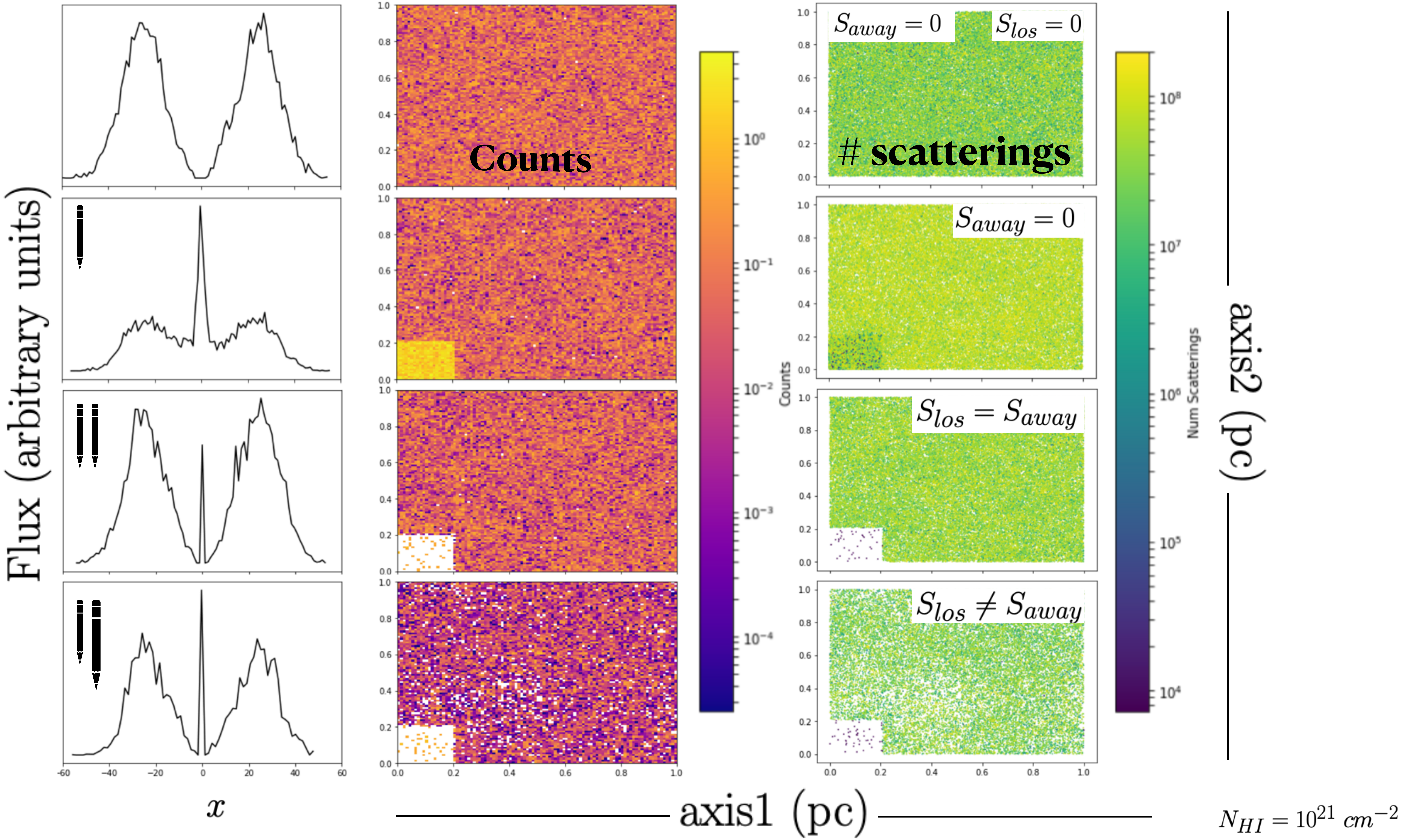
The central fraction



Not only has the line-of-sight hole an effect on the central fraction and central peak, but also the presence or lack of gas behind it.

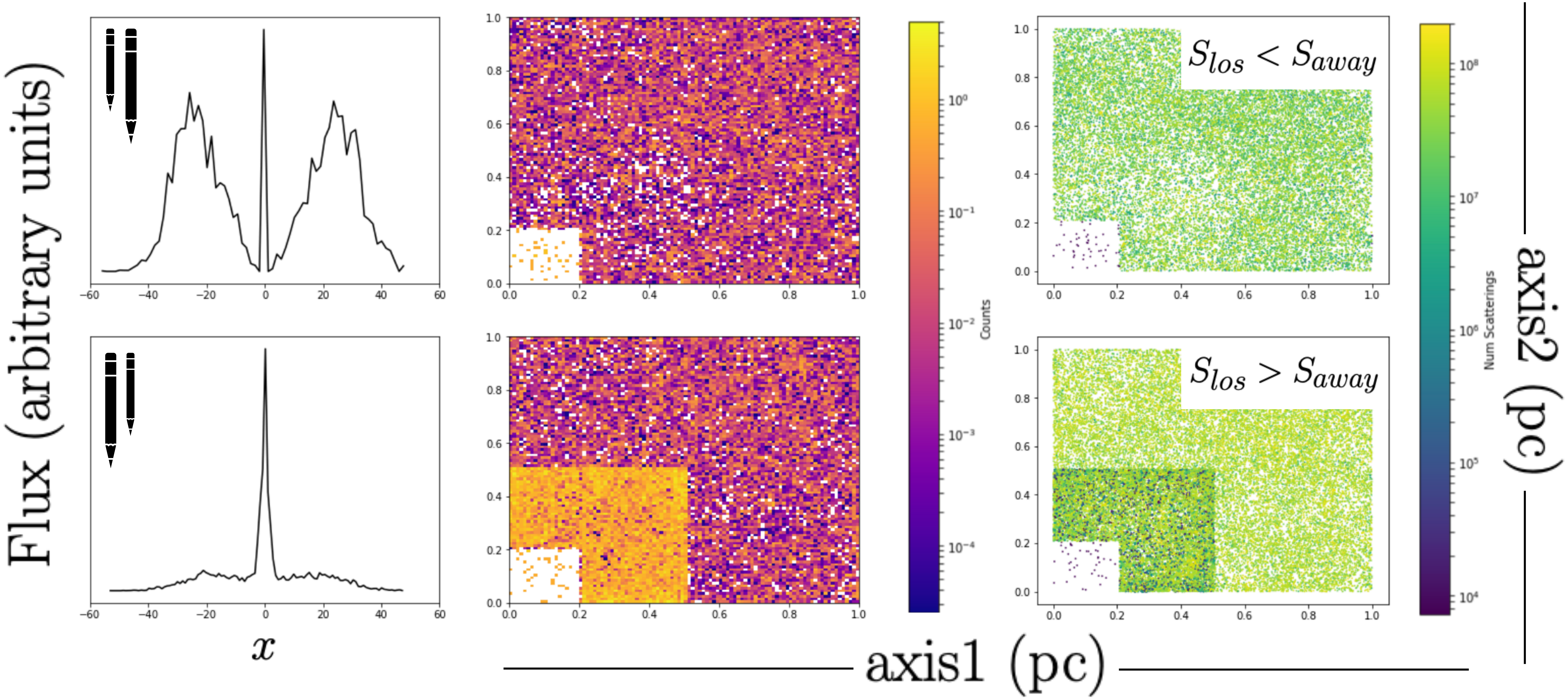


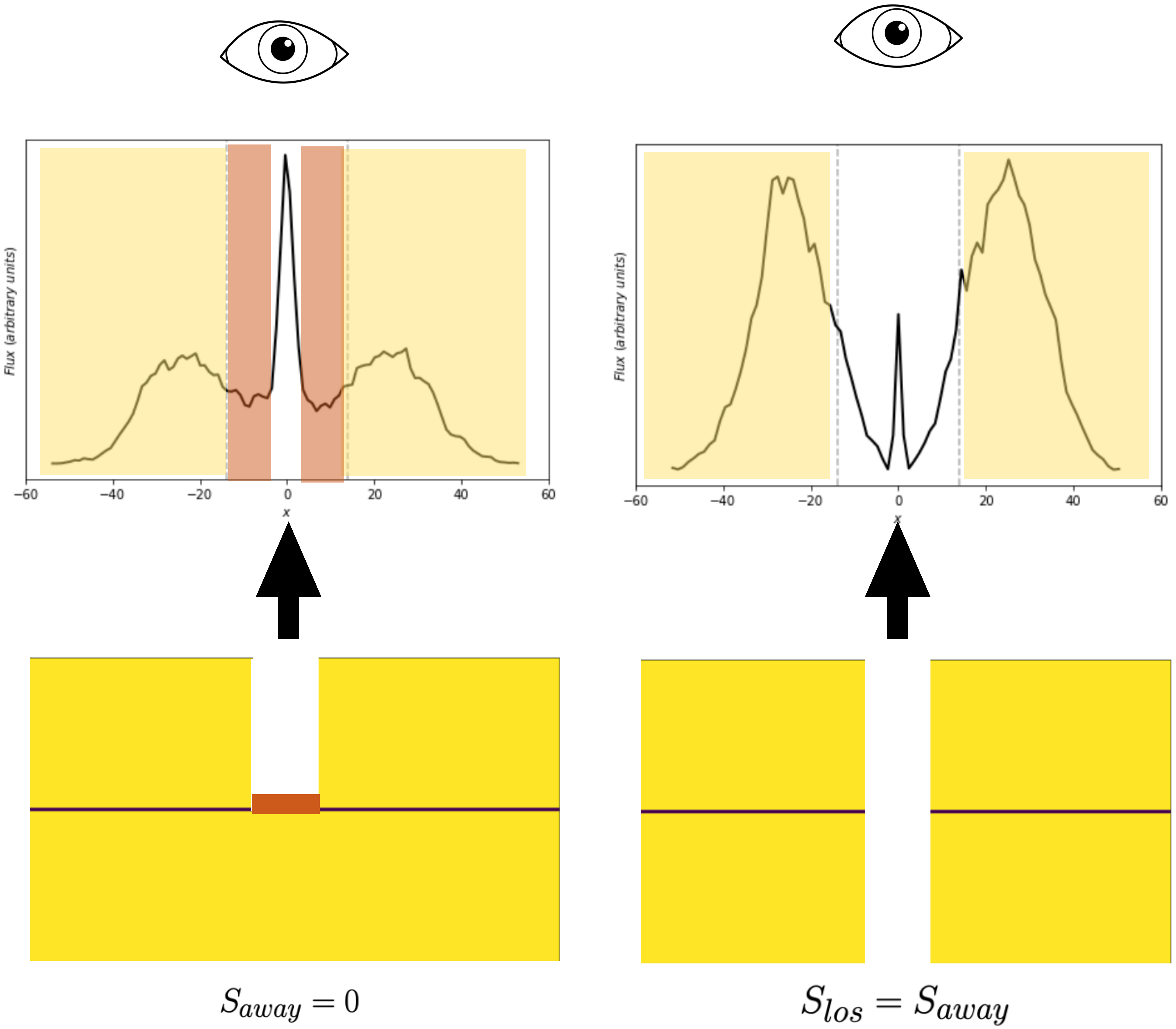
Hole size
$S_{away} = 0$
$S_{los} = S_{away}$
f_{center}
N_{HI} (cm^{-2})
S_{los}/ℓ
1.0
0.8
0.6
0.4
0.2
0.0
0.5
0.3
0.1
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}



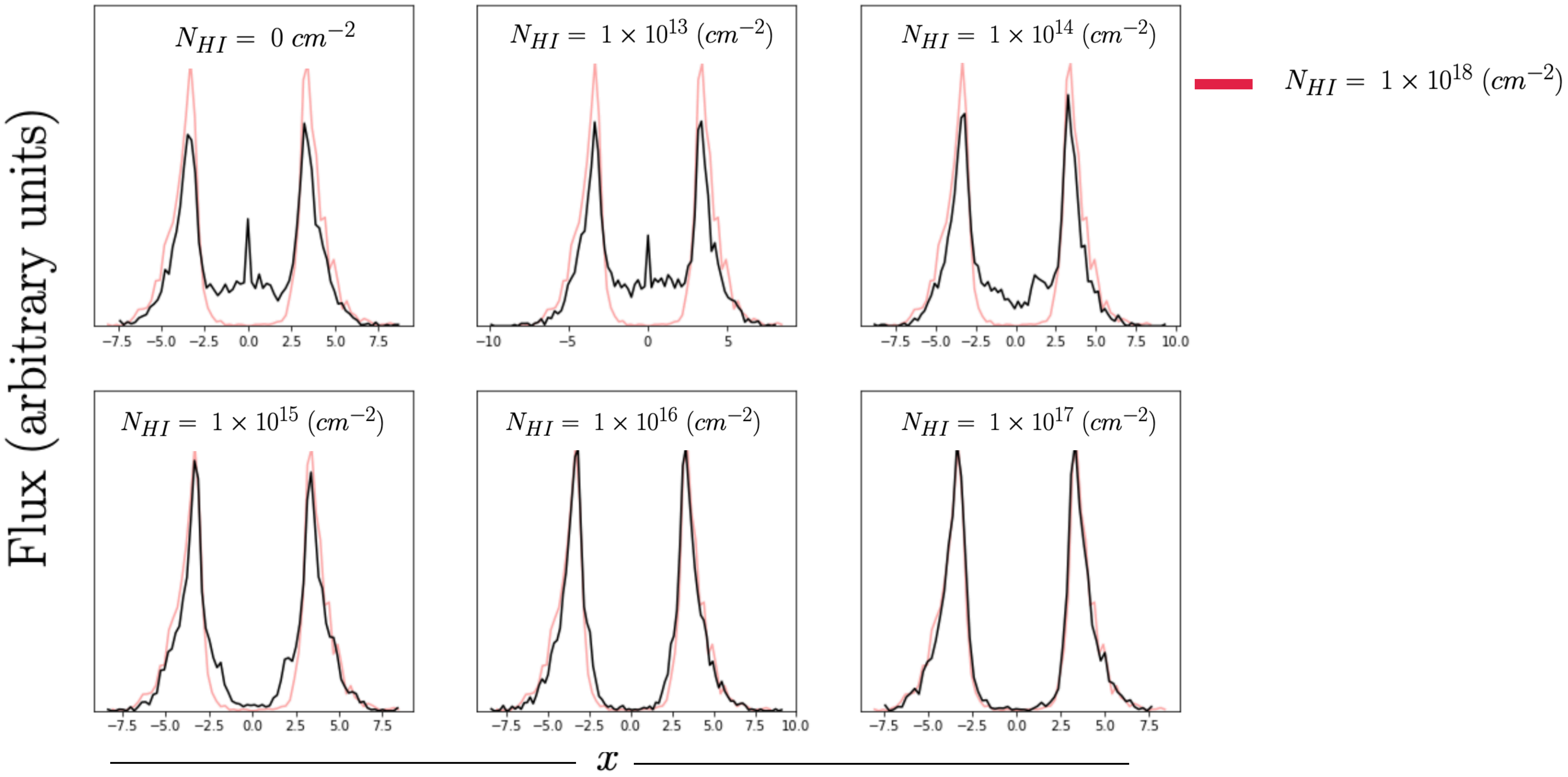
Flux (arbitrary units)
x
Counts
scatterings
$S_{away} = 0$
$S_{los} = 0$
$S_{away} = 0$
$S_{los} = S_{away}$
$S_{los} \neq S_{away}$
Counts
Num Scatterings
axis1 (pc)
axis2 (pc)
$N_{HI} = 10^{21}\ cm^{-2}$

$S_{los} \neq S_{away}$




Flux (arbitrary units)
−60
−40
−20
0
20
40
60
x
Flux (arbitrary units)
−60
−40
−20
0
20
40
60
x
$S_{away} = 0$
$S_{los} = S_{away}$

Future: general gas distributions



Summary

- Radiative transfer simulations with empty channels reproduce triple peaked spectra.
- Very strong peaks are present if the observer line-of-sight is aligned with these channels.
- The line-of-sight channel and the presence/absence of material on the other side (hole away the line-of-sight have a significant effect on the central region.
- The region away the line-of sight plays an important role on the shape of the central peak

If no hole away the line-of-sight is present:

- Central fraction grows linearly with hole size
- Central fraction is relatively flat with respect to column density
- Central peak is also conformed by photons that scattered at the back .

Future: general gas distributions