Ionized winds driven away from black holes
(SPEX/PION exercise)
(Continued 1)

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Explore the PION absorption model

The model is:

$$\texttt{hot} \times \texttt{reds} \times \texttt{pion} \times (mbb + pow) \tag{1}$$

The first case: I do not set:

```
SPEX > com rel 5 1,2
```

The second case: I set this command. This document considers **the first case**.

Plot and compare the model spectra with $\log \xi = 2.0$ (frozen) but different column densities ($N_{\rm H} = 10^{19}, 10^{20}, 10^{21}..., 10^{24}$ cm^{-2}); Summarize the trends of the absorption feature with increasing $N_{\rm H}$.

```
bash > cat 5-5-1.com
data inst_amo1 bhiw_amo1
plot device xs

dist 0.01158 z
comp reds
comp hot
comp pow
com mbb
log exe 5-2-2result

com pion
com rel 3:4 5,1,2

SPEX > log exe 5-5-1
SPEX > par 1 5 nh val xxx
SPEX > cal
SPEX > pl x lin
SPEX > pl y lin
SPEX > pl
SPEX > pl adum xxx
```

From Fig. 1, we can see that:

1. The larger $N_{\rm H}$, the earlier the continuum decreases, which means, in small wavelength, the flux of the spectra which set large $N_{\rm H}$ for `pion` component is smaller than that set small $N_{\rm H}$ for `pion` component.

2. When $N_{\rm H}$ is smaller than 10^{-3} m^{-2}, the continuum is almost the same but absorption lines become more with the increment of $N_{\rm H}$. When $N_{\rm H}$ is larger than 10^{-3} m^{-2}, the absorption is evident for the continuum.

3. The larger $N_{\rm H}$, the more absorption lines.

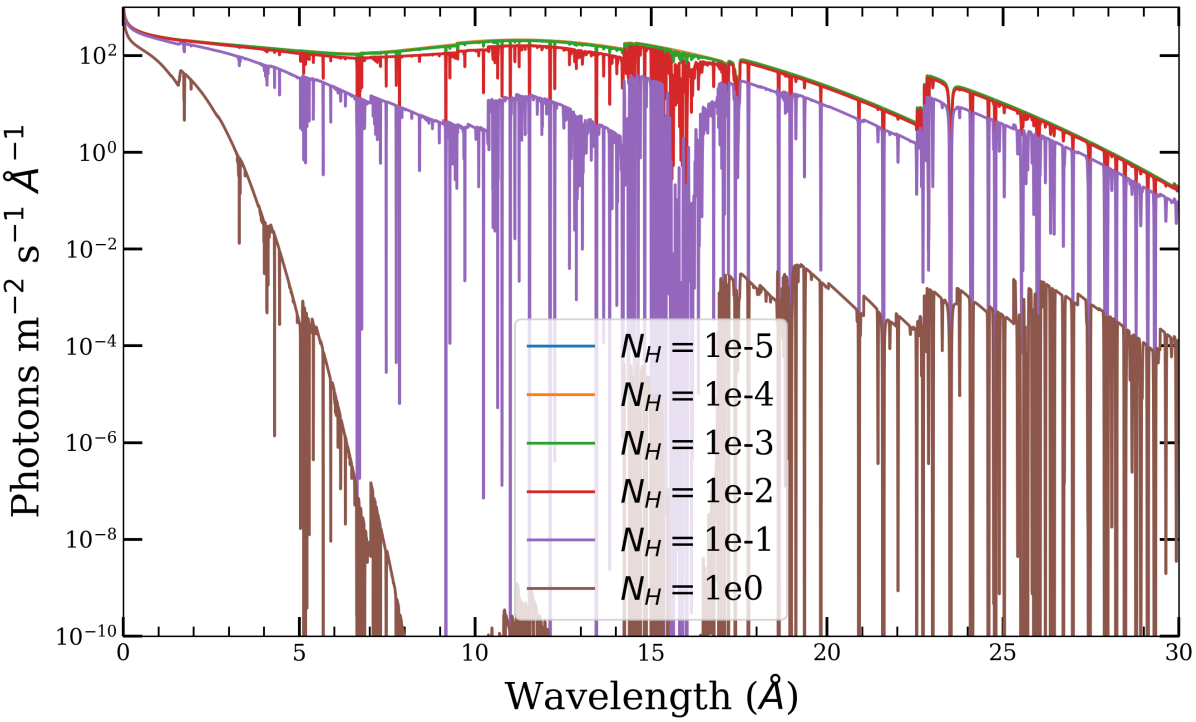


Figure 1: The wavelength-Flux figure.

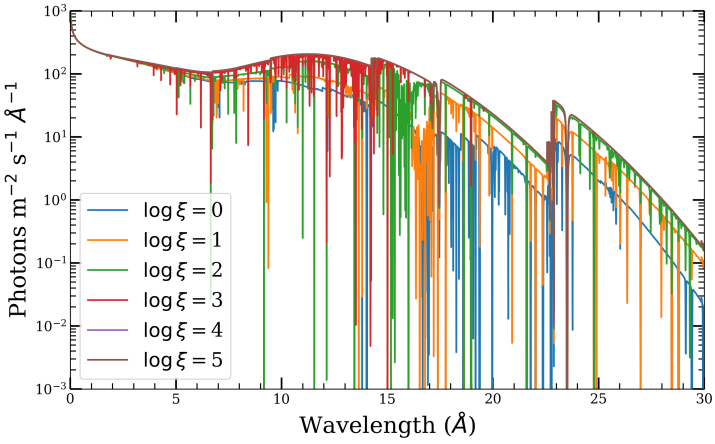
Plot and compare the model spectra with $N_{\rm H} = 10^{22}$ cm^{-2} (frozen) but different $\log\xi = 0, 1, 2, ..., 4, 5$, where ionization parameter ξ is in units of erg s^{-1} cm (i.e., 10^9 W m). Zoom into the wavelength region of $6.6 - 7.3$ Å. What are these lines? Summarize the trends of the absorption feature with increasing $\log\xi$ for global and zoom-in regions.

```
SPEX > log exe 5-5-2
SPEX > par 1 5 xil val xxx
SPEX > cal
SPEX > pl x lin
SPEX > pl y lin
SPEX > pl
SPEX > pl adum xxx
```

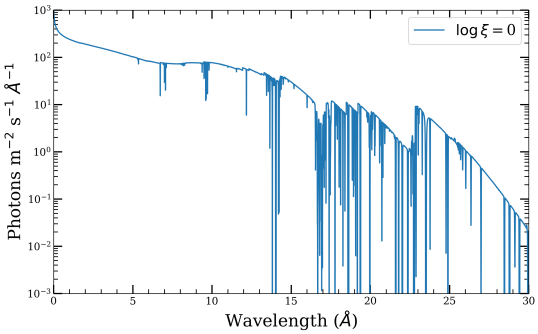
From Fig. 2 and Fig. 4, we can see that:

1. When $\log\xi < 4$, as $\log\xi$ increases, the flux of the continuum increases, which means that the absorption of the continuum decreases. The spectra no longer change when $\log\xi \geq 4$.

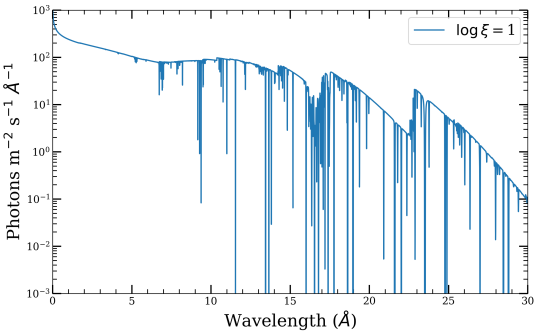
2. Different $\log\xi$ will lead to the absorption of different lines (see Tab. 1). When $\log\xi$ is large enough (> 4), it will hardly lead to absorption (see Fig. 3).



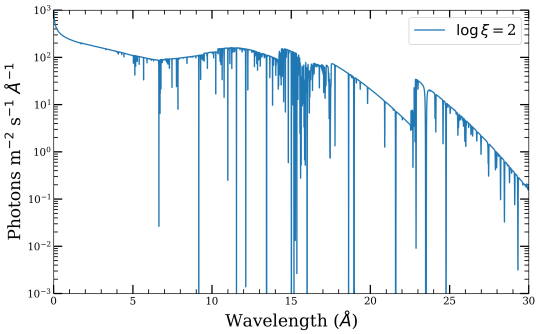
(a)



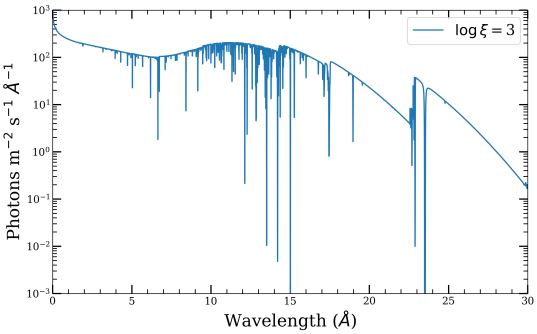
(b)



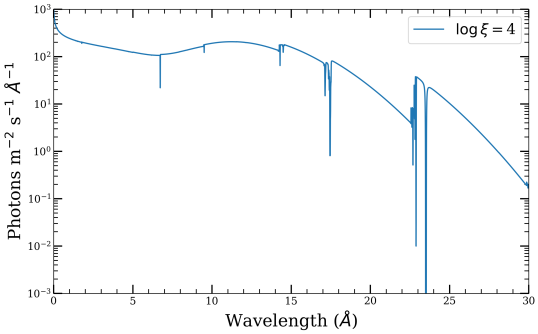
(c)



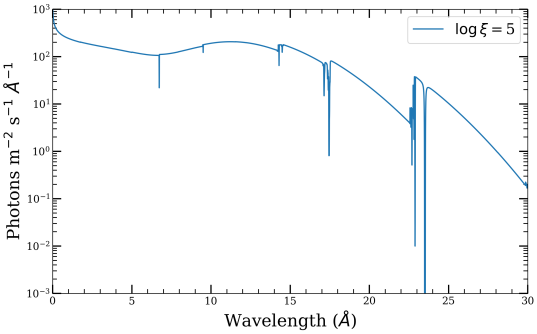
(d)



(e)

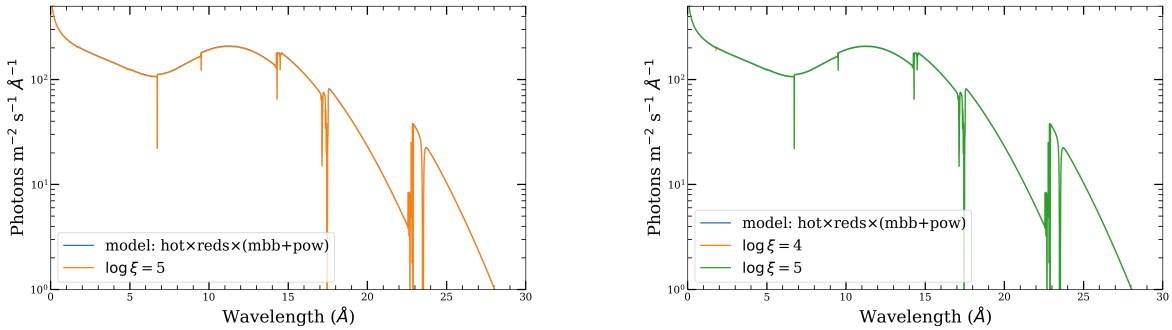


(f)



(g)

Figure 2: The Wavelength-Flux figure. The x-axis range is $0 - 30$ Å.



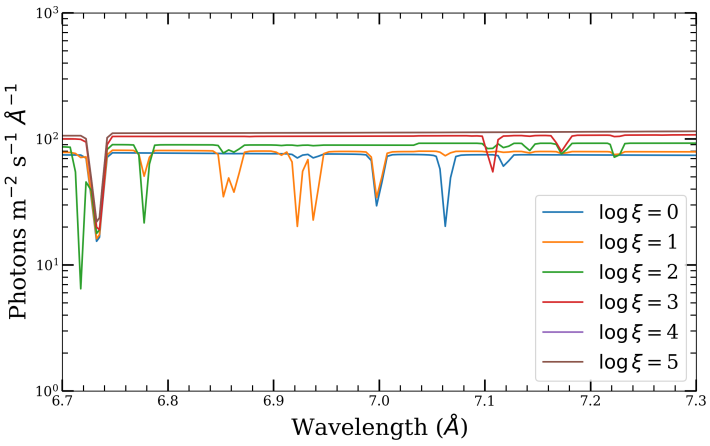
(a) (b)

Figure 3: The wavelength-flux figure with different model components.

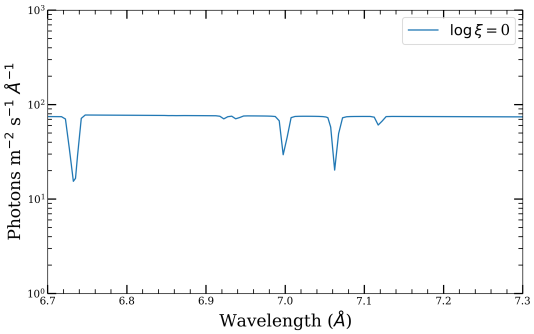
```
SPEX > log exe 5-5-2
SPEX > par 1 5 xil val xxx
SPEX > pl rx 6.6:7.3
SPEX > pl ry 1e0:350
SPEX > cal
SPEX > pl
SPEX > asc file xxx 1 5 tral
```

log ξ	hot	pion1	pion2	pion3
0	Si I	Si		
1	Si I	Si	Mg	Al
2	Si I	Si	Mg	Al
3	Si I	Si	Mg	Al
4	Si I			
4	Si I			

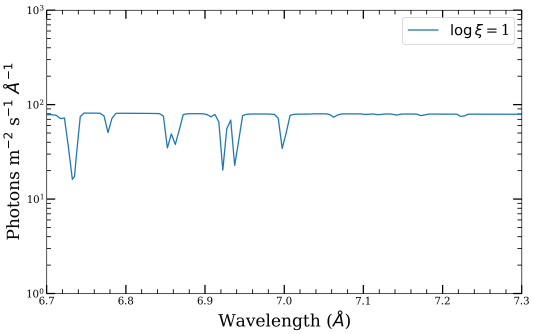
Table 1: The absorption lines in different log ξ.



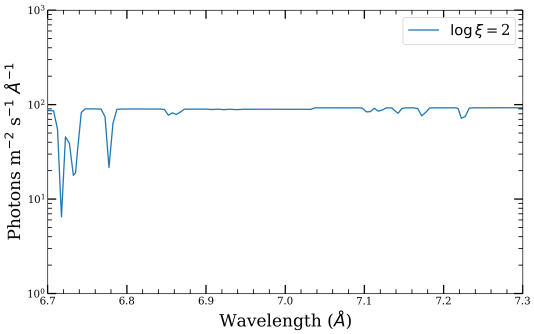
(a)



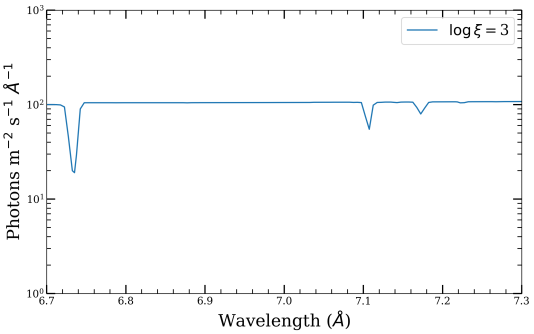
(b)



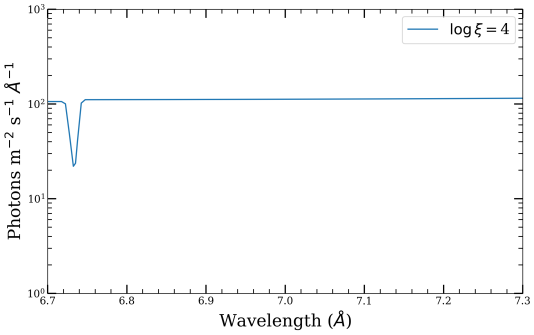
(c)



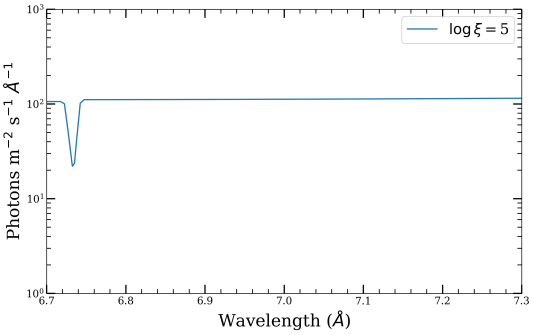
(d)



(e)



(f)



(g)

Figure 4: The Wavelength-Flux figure. The x-axis range is $6.6 - 7.3$ Å.

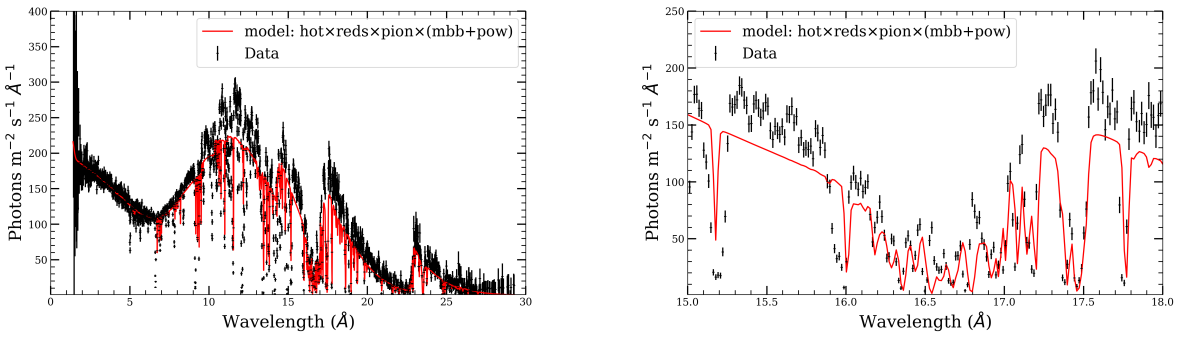
Fit the spectrum with the model set up as Eq. 1

To reproduce the Fe UTA (Unresolved Transition Array) feature, I think `xil` in the `pion` component should be set to 1.

```
bash > cat 5-5-3after.com
data inst_amo1 bhiw_amo1
plot device xs

dist 0.01158 z
comp reds
comp hot
comp pow
com mbb
com pion
com rel 3:4 5,1,2
log exe 5-5-3result
cal
pl ty data
pl ux ang
pl uy fang
pl

SPEX > log exe 5-5-3after
```



(a) (b)

Figure 5: The wavelength-flux figure. (a): the x-axis range is $0 - 30$ Å. (b): the x-axis range zoom in $15 - 18$ Å.

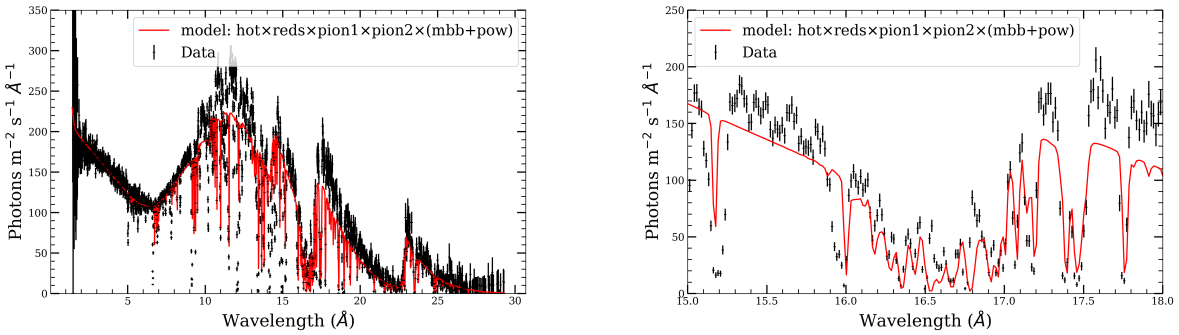
After manual adjustments, we obtained the updated spectrum.

```
bash > cat 5-5-3afetr-final.com
data inst_amo1 bhiw_amo1
plot device xs

dist 0.01158 z
comp reds
comp hot
comp pow
com mbb
com pion
com rel 3:4 5,1,2
```

```
    log exe 5-5-3fit2
    cal
    pl ty data
    pl ux ang
    pl uy fang
    pl

    SPEX > log exe 5-5-3after-final
```



(a) (b)

Figure 6: The wavelength-flux figure. (a): the x-axis range is $0 - 30$ Å. (b): the x-axis range zoom in $15 - 18$ Å.