C25
Stout Database Updates

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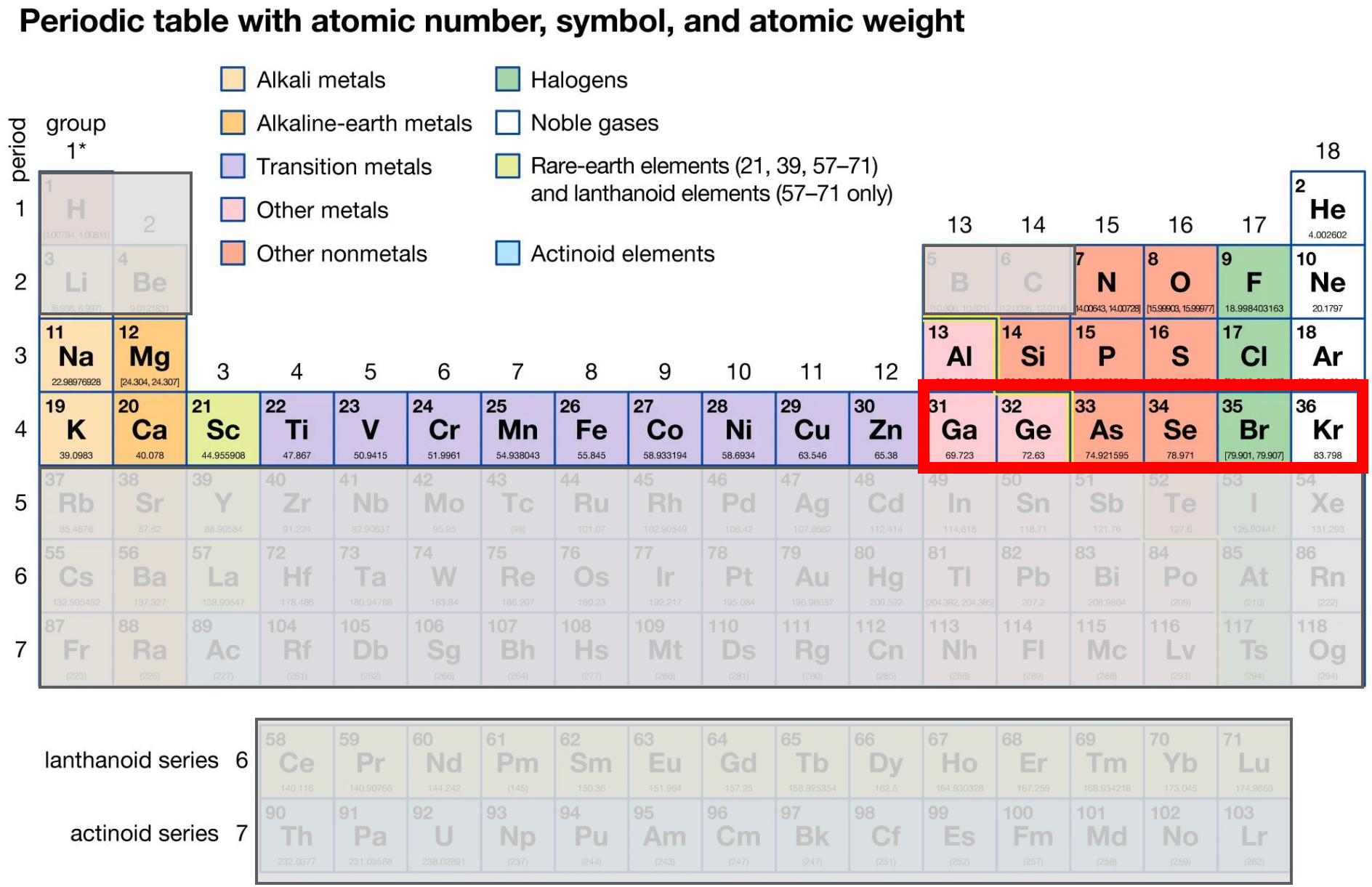
August 2025


Periodic table with atomic number, symbol, and atomic weight
Alkali metals
Alkaline-earth metals
Transition metals
Other metals
Other nonmetals
Halogens
Noble gases
Rare-earth elements (21, 39, 57–71) and lanthanoid elements (57–71 only)
Actinoid elements
group
period
1*
18
13
14
15
16
17
3
4
5
6
7
8
9
10
11
12
lanthanoid series 6
actinoid series 7
*Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC).
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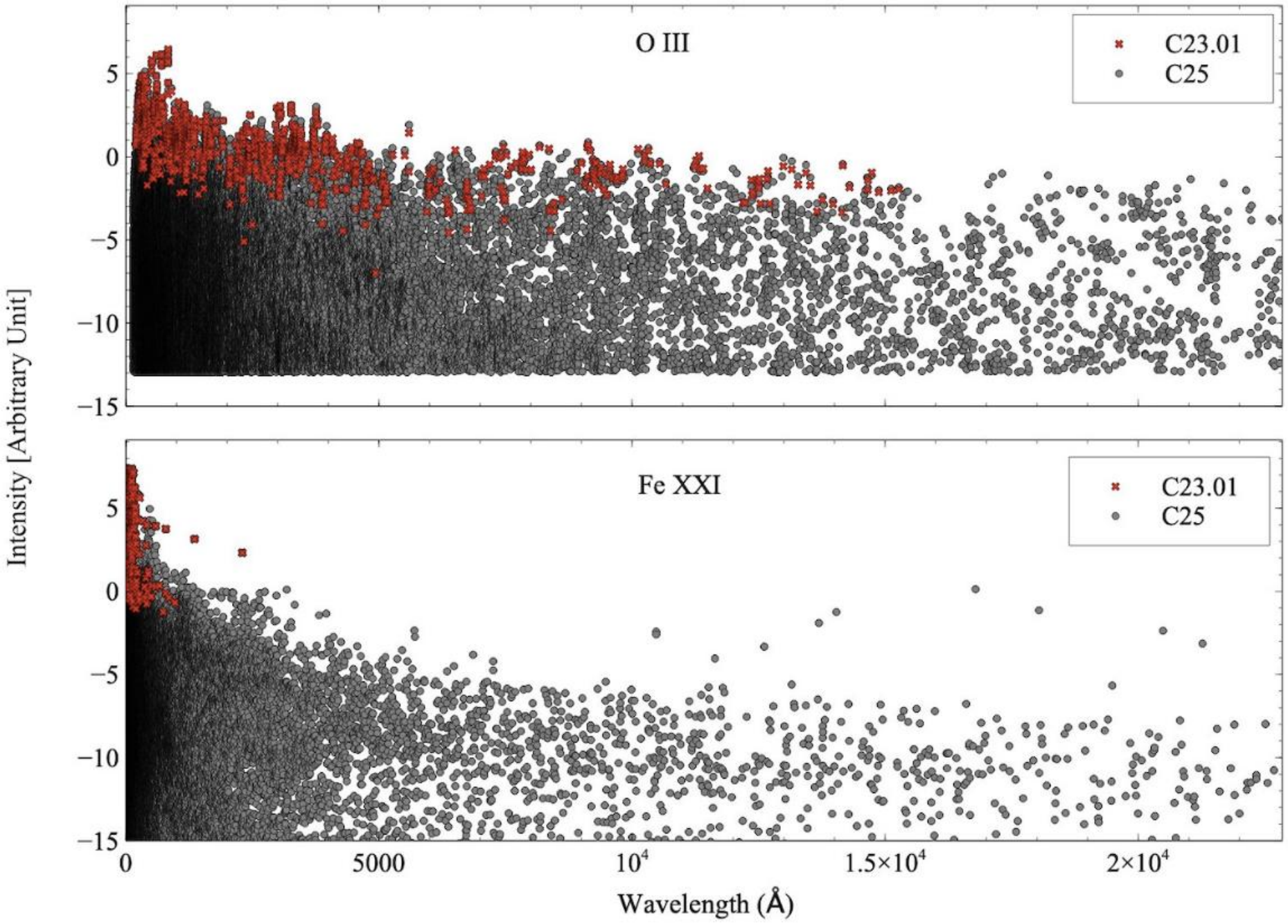
R-matrix electron-impact excitation data sets for C-like ions in the literature merely cover a few ions, and often only for the ground configuration→**Mao et al. 2020 and Del Zanna et al. 2025**

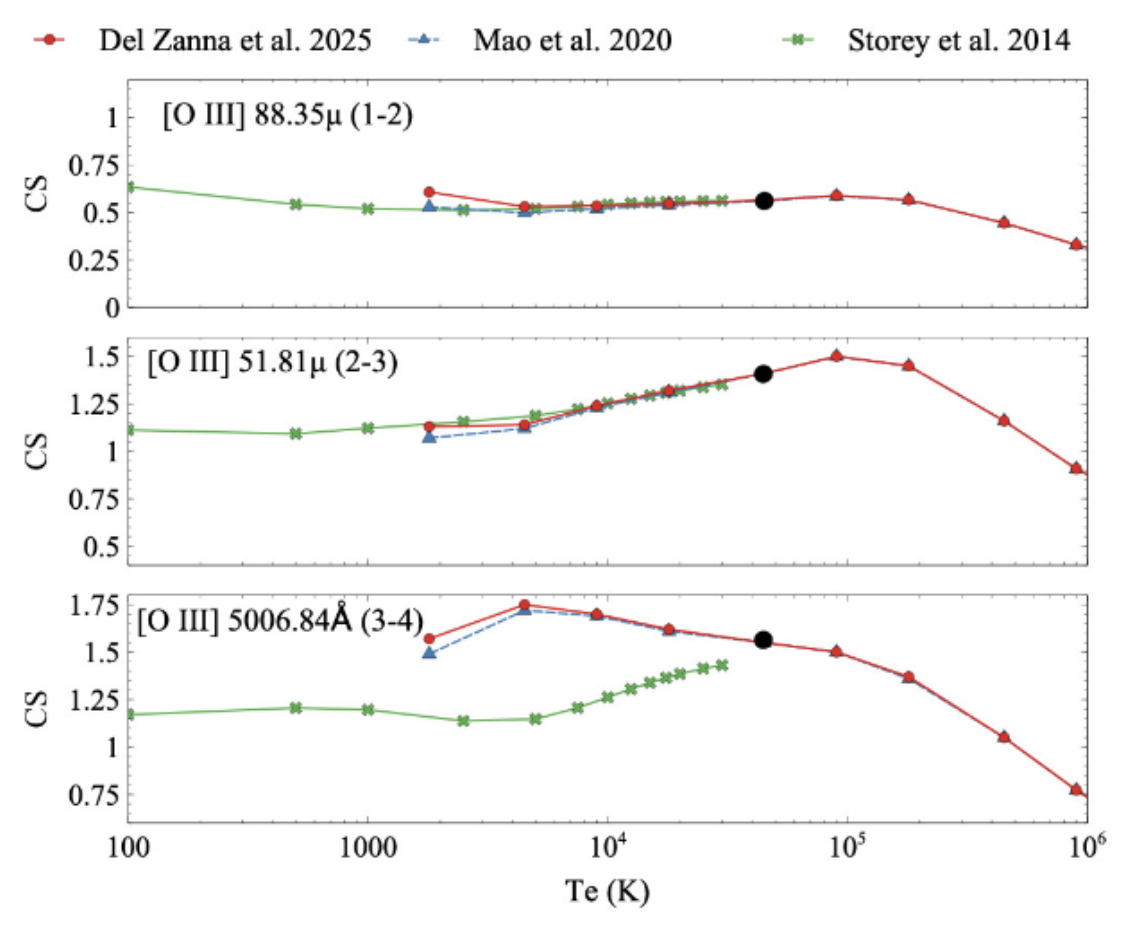
level-resolved effective collision strength over a wide temperature range for C-like ions from **N II to Kr XXXI** (i.e., N^{+} to Kr^{30+}) with a systematic set of R-matrix calculations.

For each ion, we included a total of **590 fine-structure levels** in both the configuration interaction target and close-coupling collision expansion.

Wherever **targeted studies** are available we used them: ex: **Fe XXI, OIII**

All Experimental levels from **NIST** are also included.


O III
C23.01
C25
Fe XXI
C23.01
C25
Intensity [Arbitrary Unit]
5
0
−5
−10
−15
0
5000
10^4
1.5×10^4
2×10^4
Wavelength (Å)




```
...
O   3        5005.93A?    -8.714    17.4419
O   3        5006.19A?    -9.581     2.3652
O   3        5006.33A?    -8.964     9.7965
O   3        5006.84A     -5.809 13994.061
O   3        5006.88A?    -2.166 *********
O   3        5006.89A     -6.589 2323.5645
...
```

Solving Mysteries Using Cloudy

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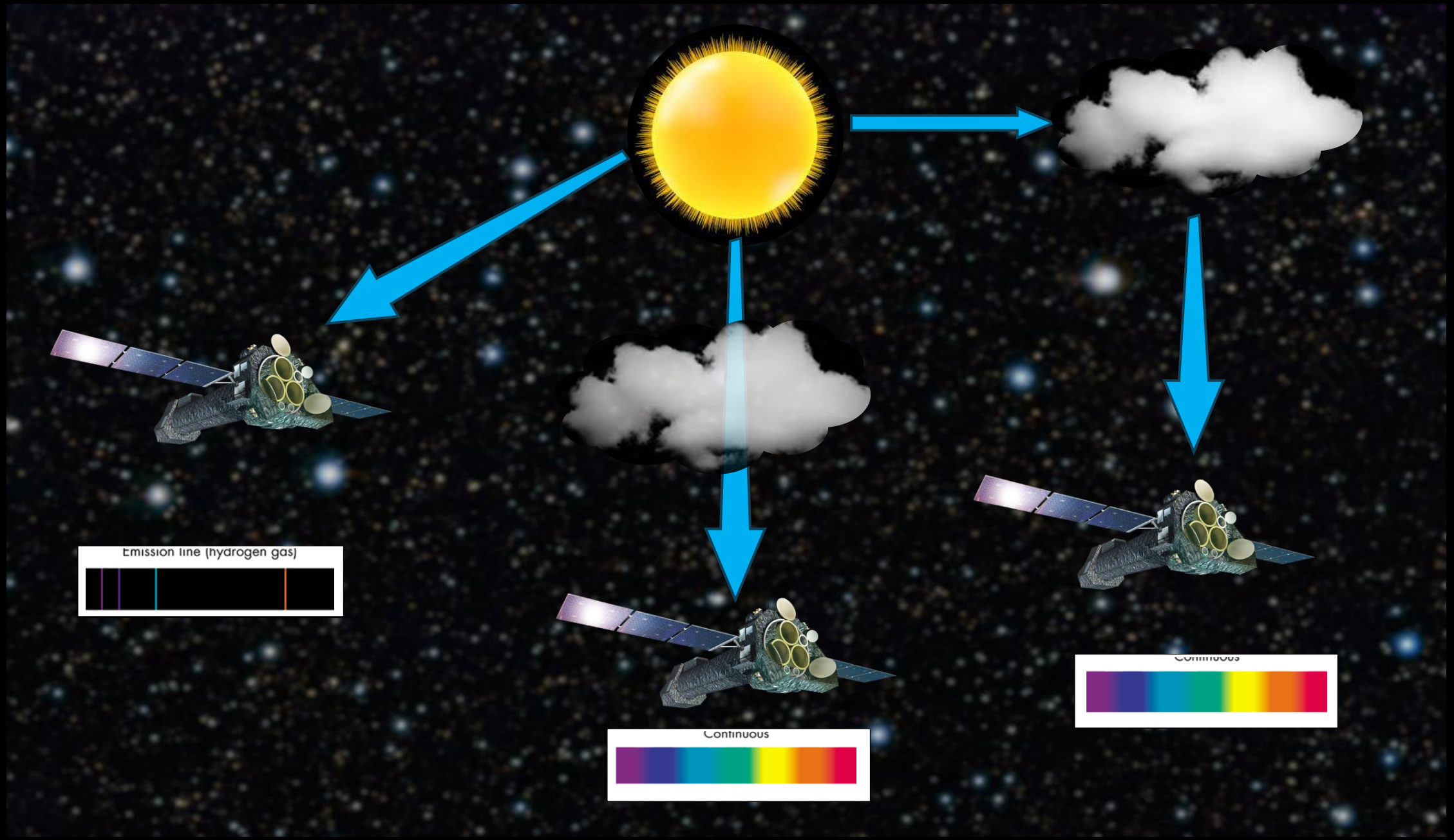
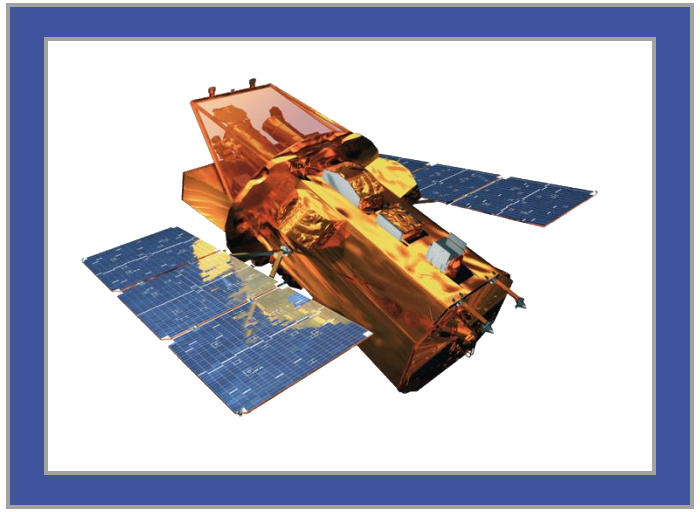
August 2025

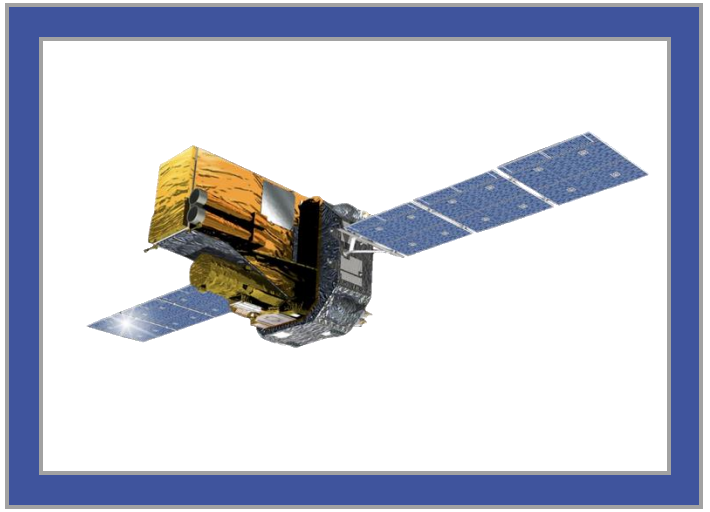
Credit: ESA/Hubble, L. Calçada (ESO)

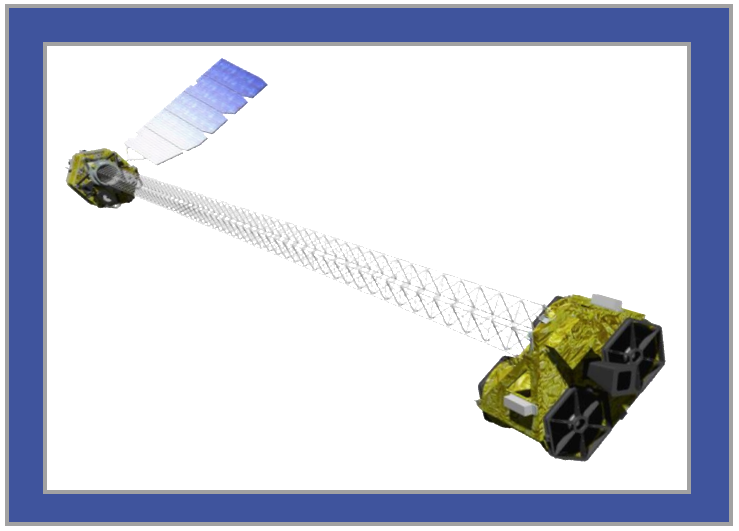
Some Background

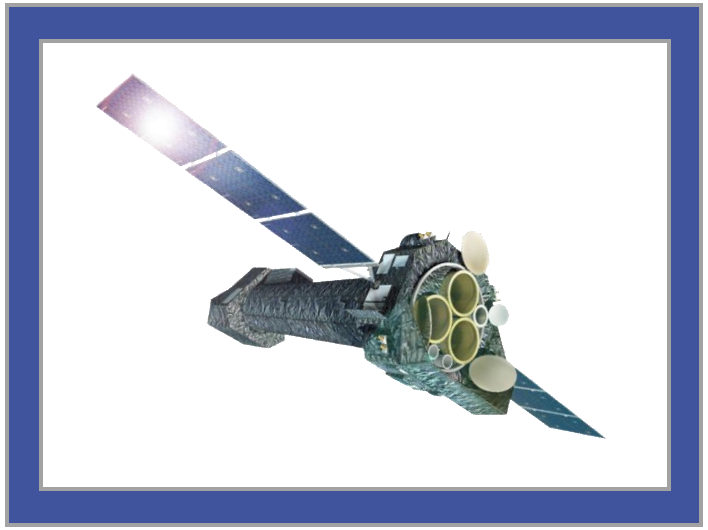

Emission line (hydrogen gas)
Continuous
Continuous

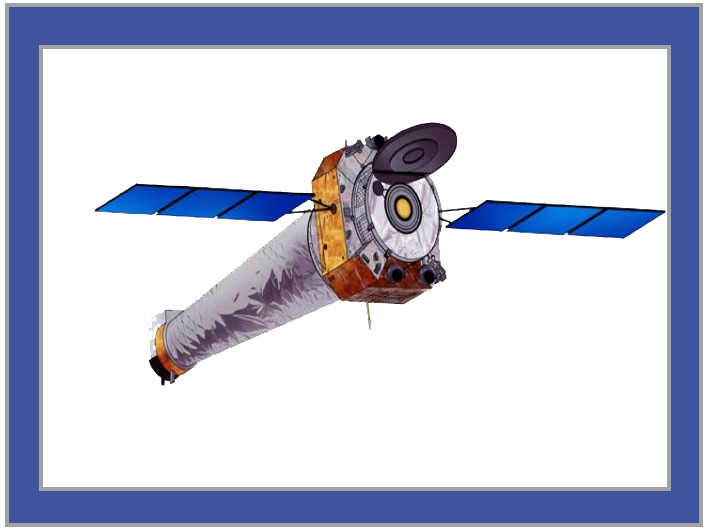
AGN S T O R M Project (2014)



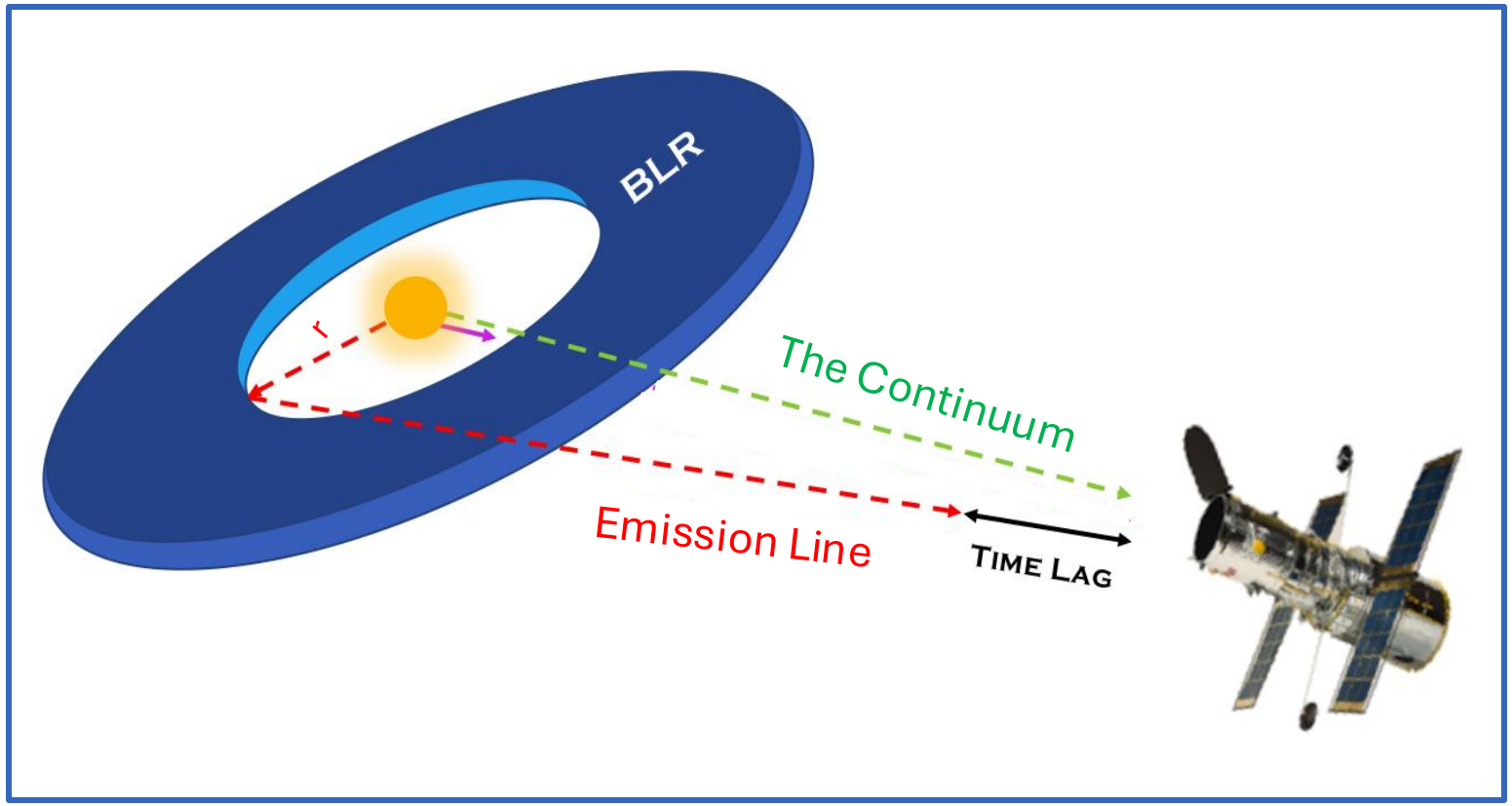








Reverberation Mapping



Estimation of AGN's Mass

$$M = \frac{r v^2}{G}$$

Two parameters needed:

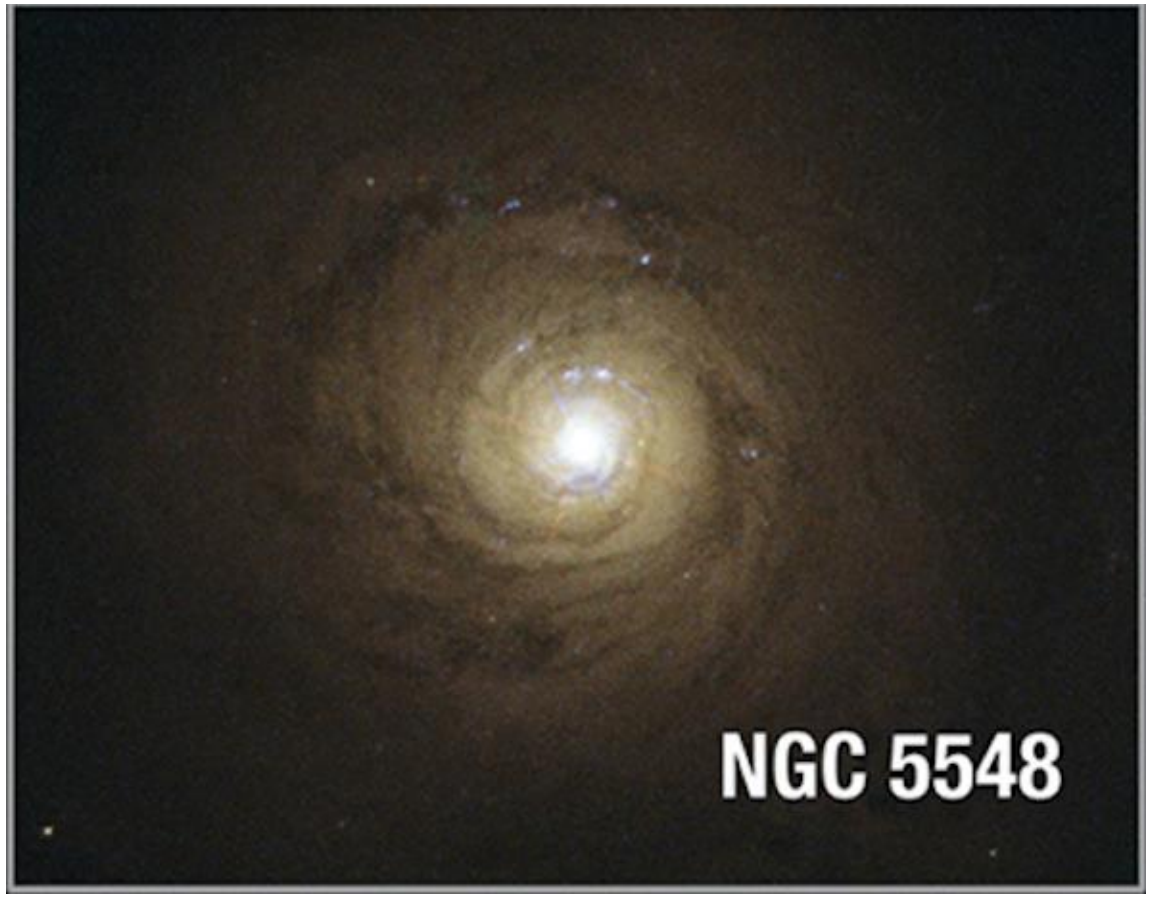
1-**velocity** → from Doppler line broadening!

2-**distance** → through "Reverberation Mapping"

NGC 5548

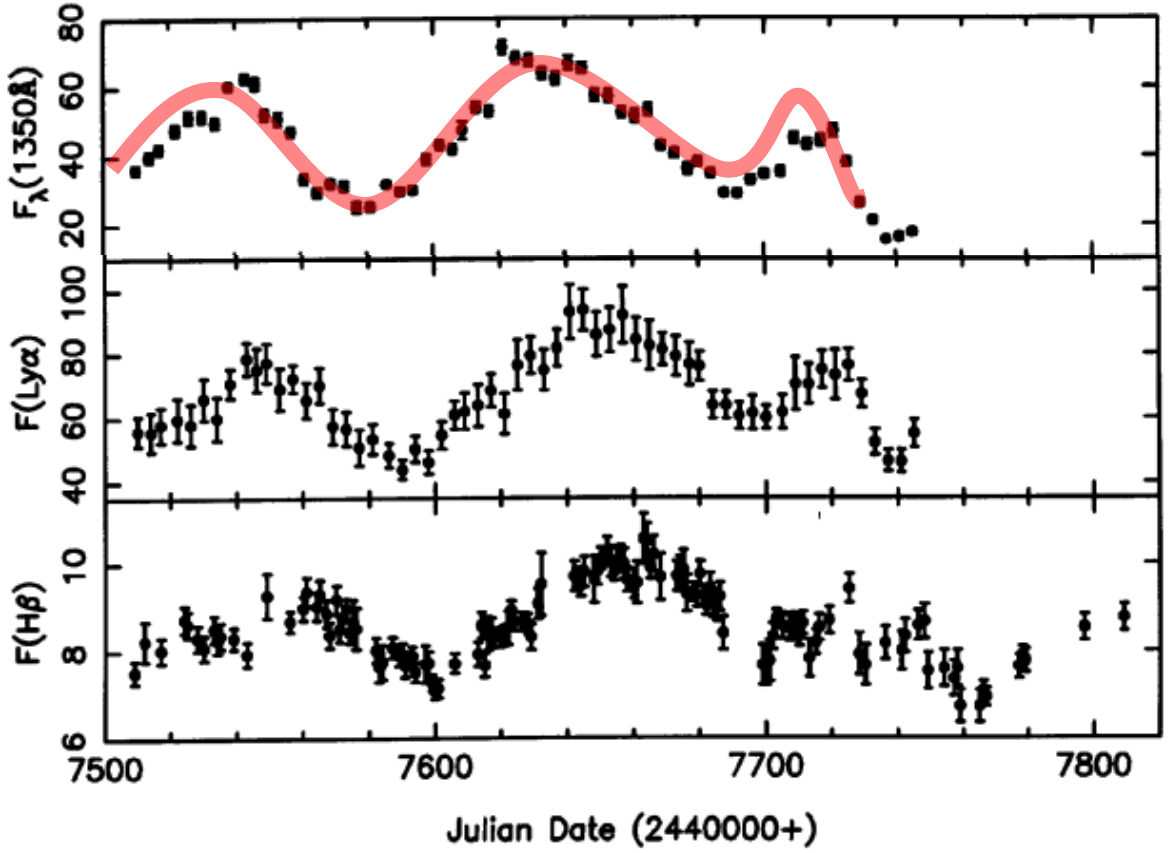
Distance: 245 million LY

Mass of BH: $7 \times 10^7 \, M_\odot$



What they expected to see:

Sample light curves for NGC 5548 from 1988-1989



The Continuum

The emission lines

Peterson(1993)

Also:

- The dimensionful ionization parameter ξ is defined as:

$$\xi = \frac{L}{n_H R^2}\,[\mathrm{erg\,cm\,s^{-1}}]$$

- The dimensionless ionization parameter U is defined as:

$$\mathrm{U} = \frac{Q_H}{4\pi c n_H R^2}$$

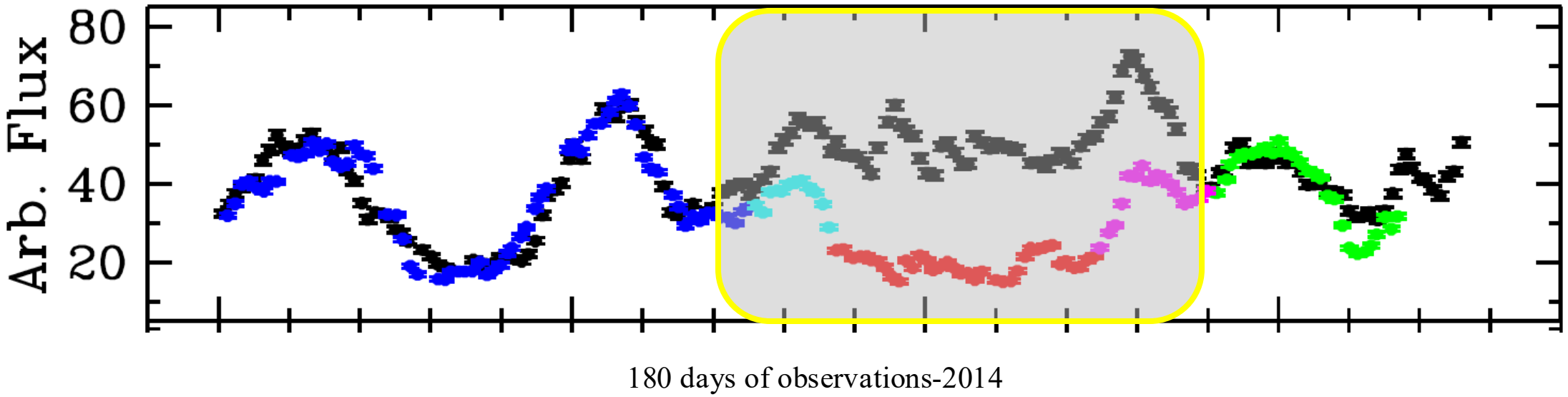
$$\log \xi = \log U + constant.$$

Part I:

The Sad Story 2014-2017

Results from the campaign

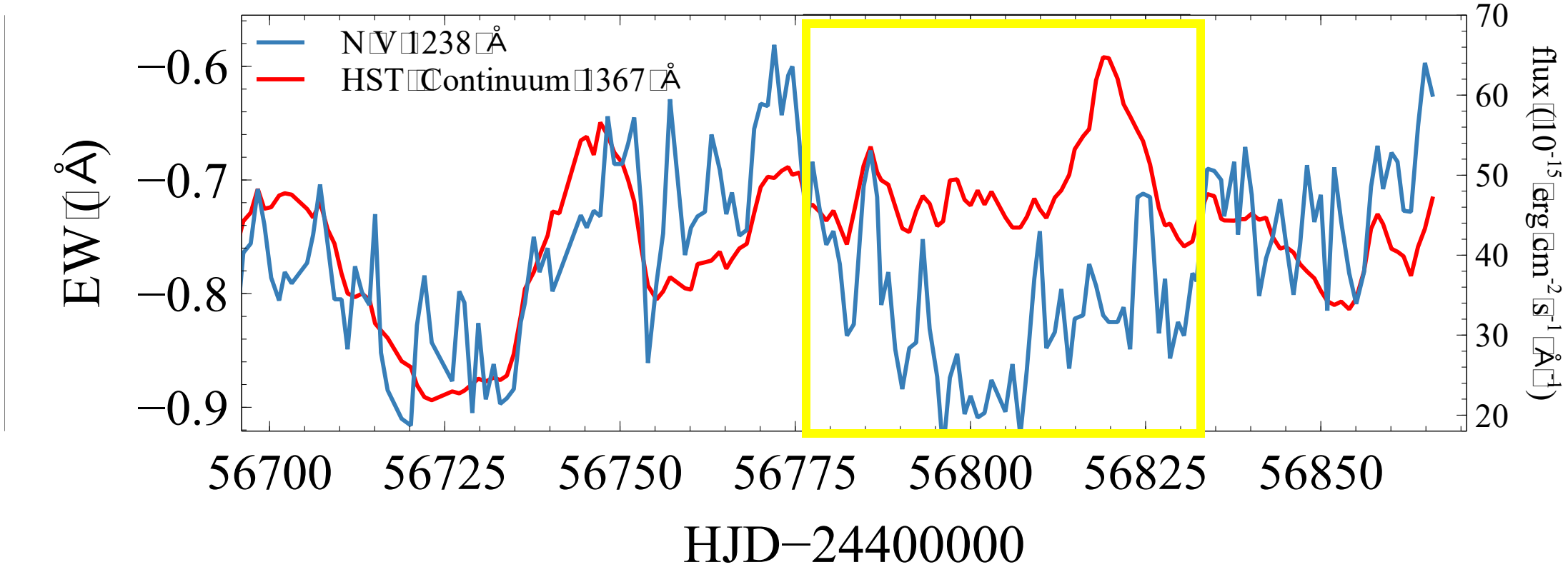
1- Emission Line Holiday (STORM)



The Continuum **CIV Emission Line**

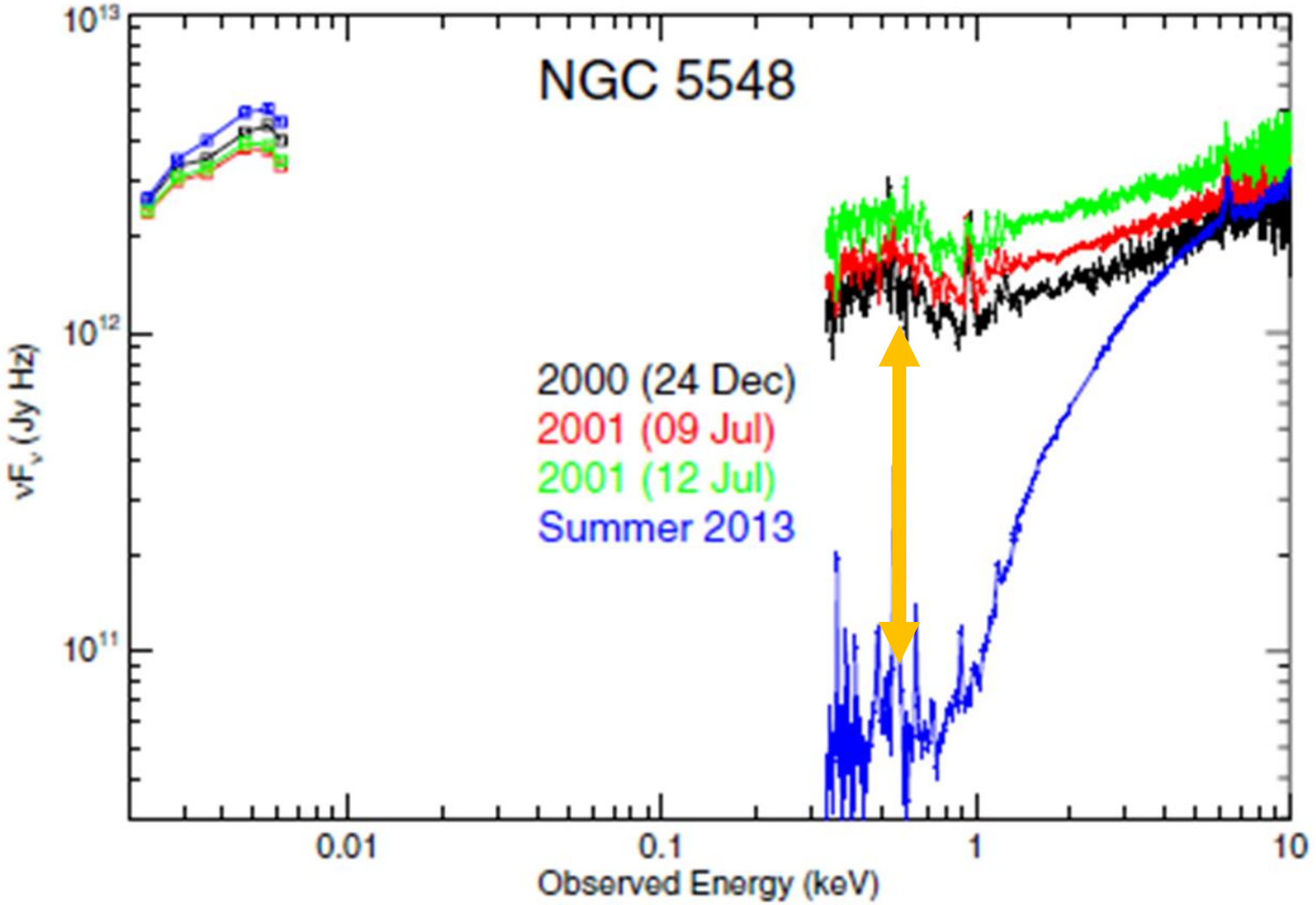
Goad et la. 2016

2- Absorption Line Holiday (STORM)



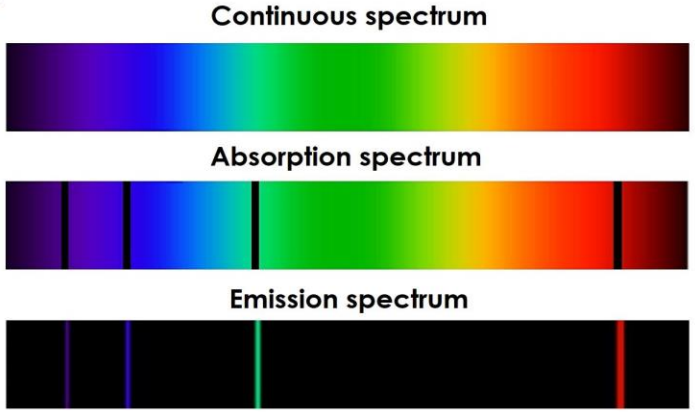
Dehghanian et al. 2019a

3- Heavy Absorption in X-ray (Anatomy)

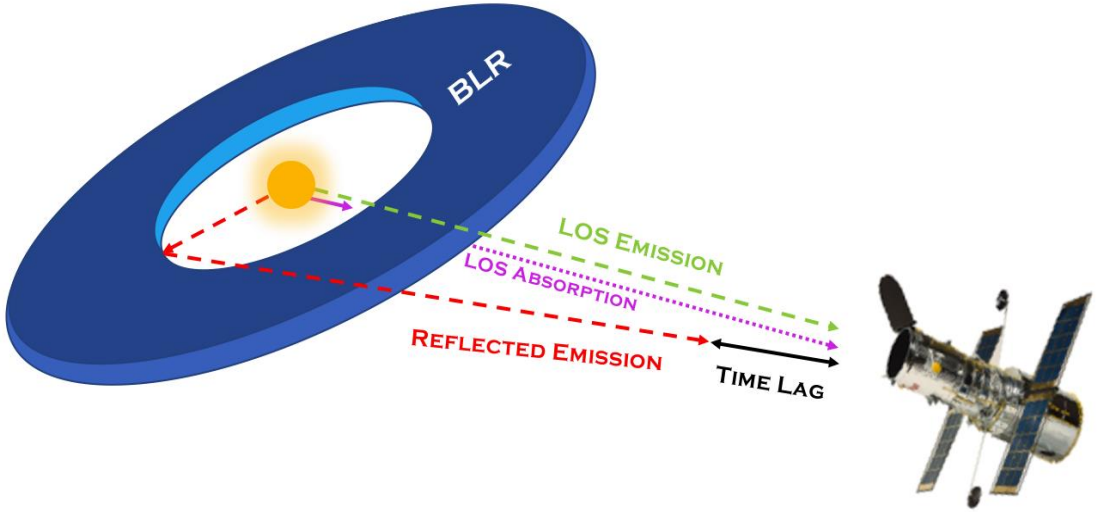


Mehdipur et al. 2015

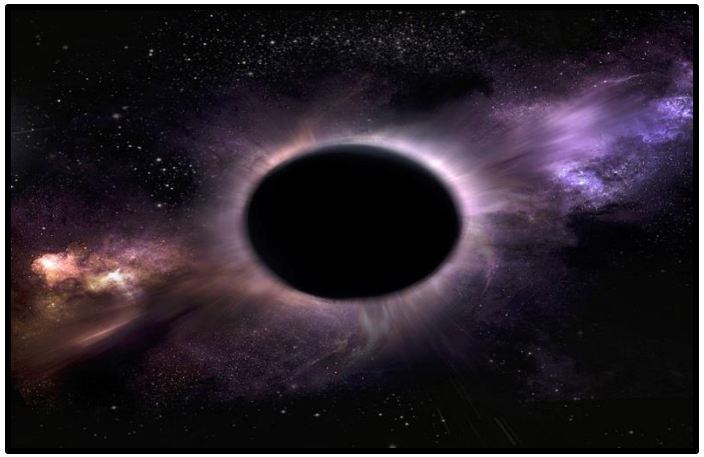
Why are these results so important?



The correlation between the continuum and the emission lines is the basic requirement for the RM method



RM method is the only direct way to measure the mass of black holes

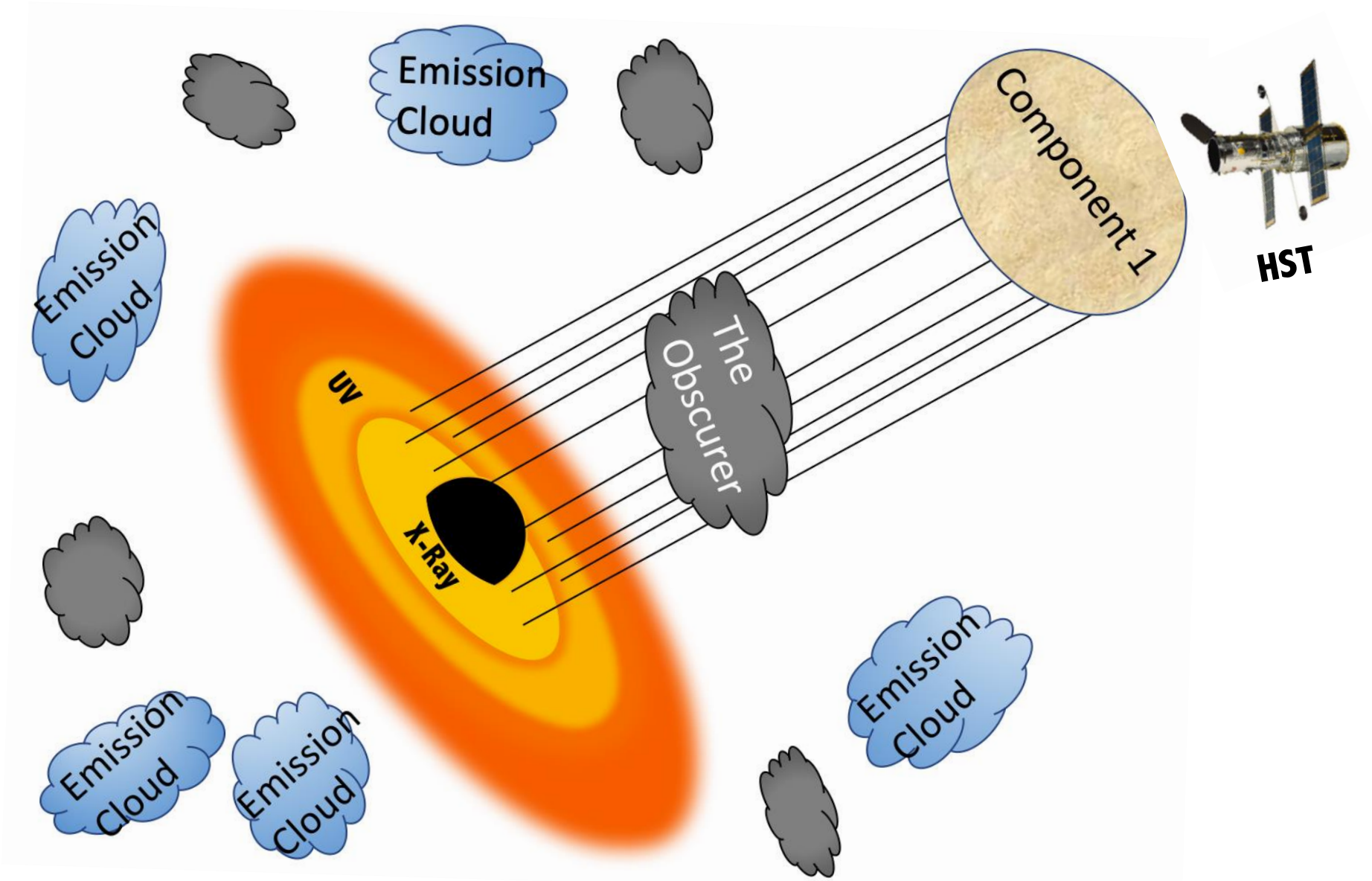


Mass of BH is what everybody wants to know. It controls the galaxy and it teaches us about the evolution of the galaxies.

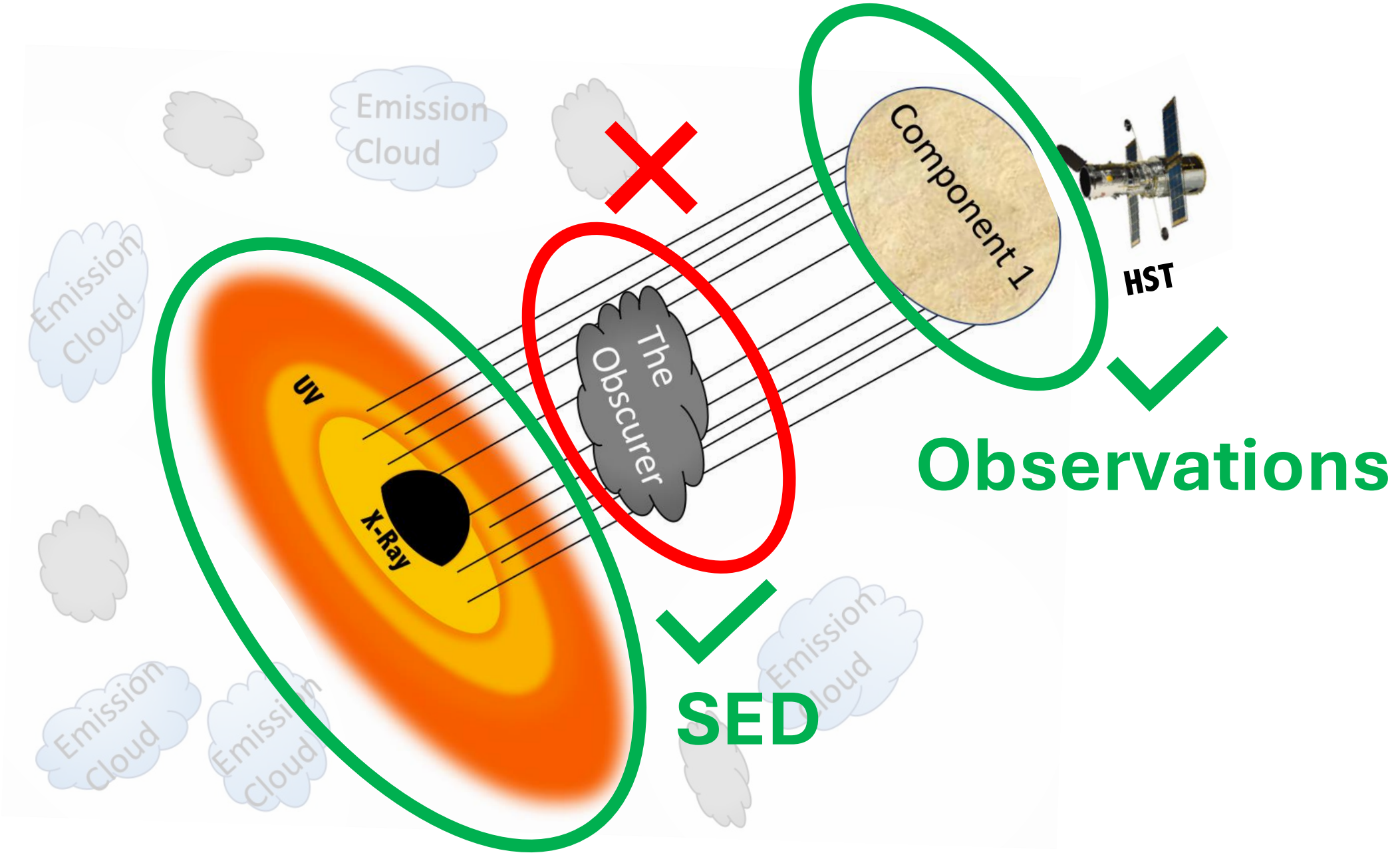
Part II:

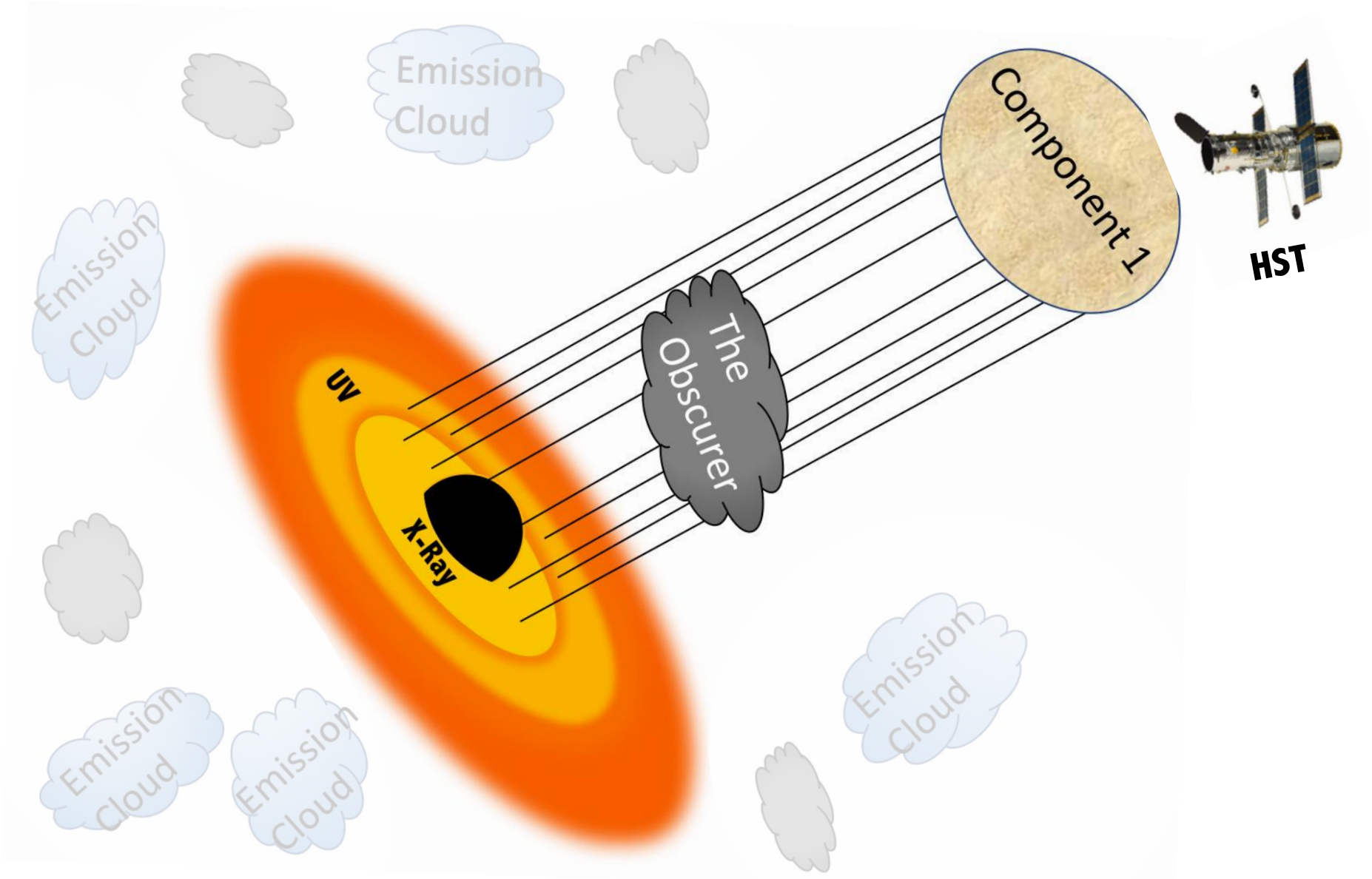
Cloudy Team Into Action

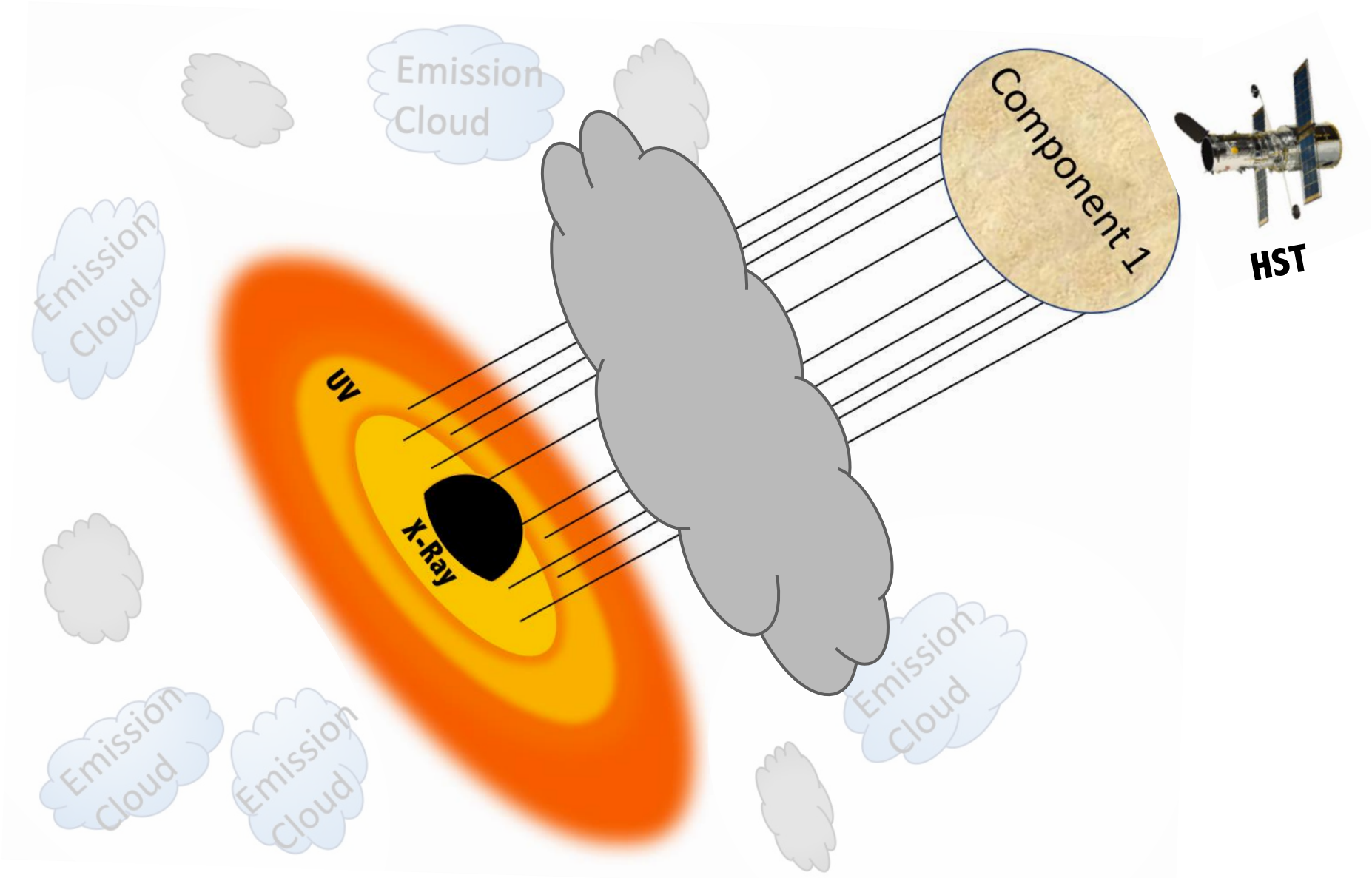
2017-2019

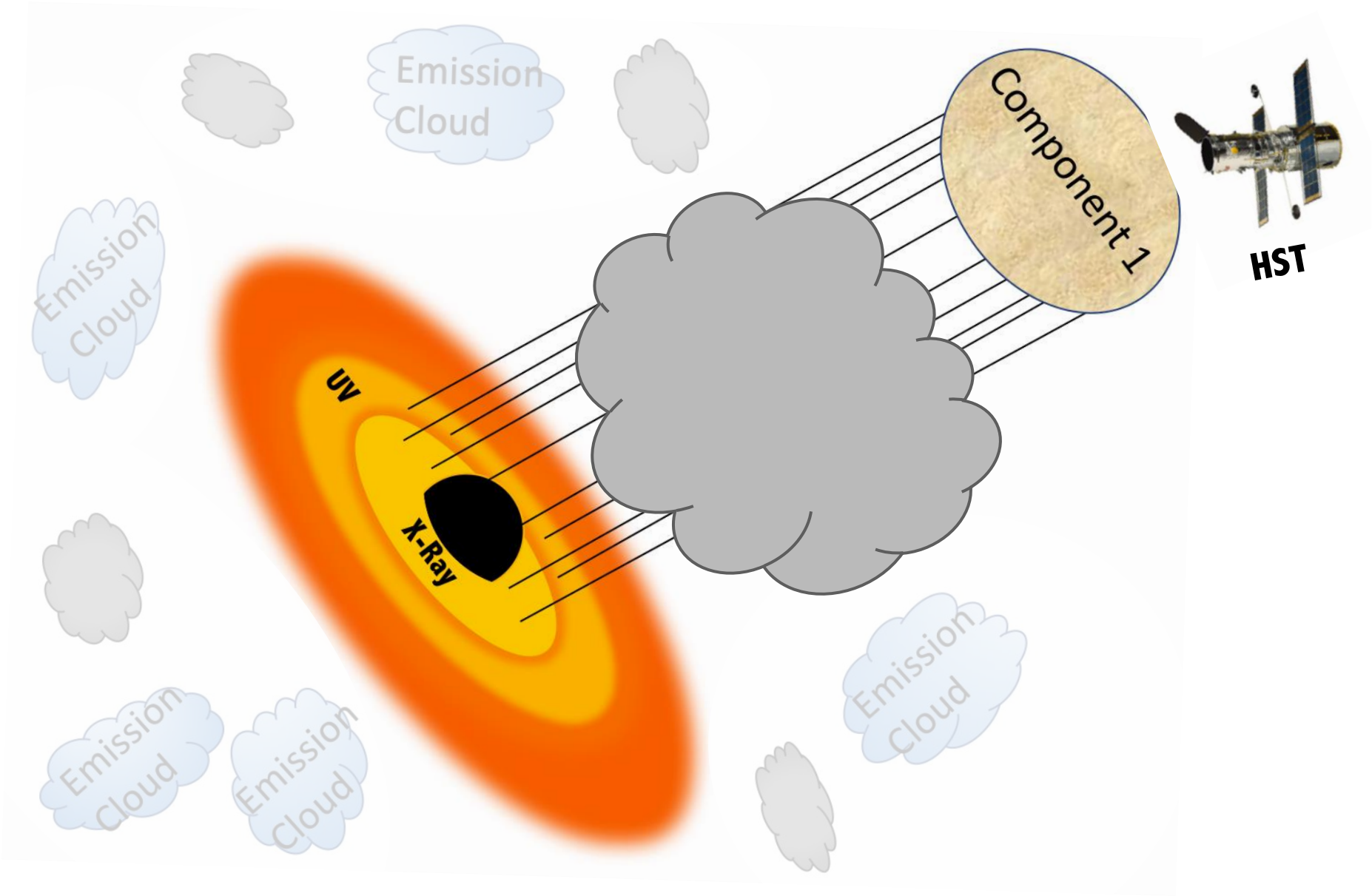


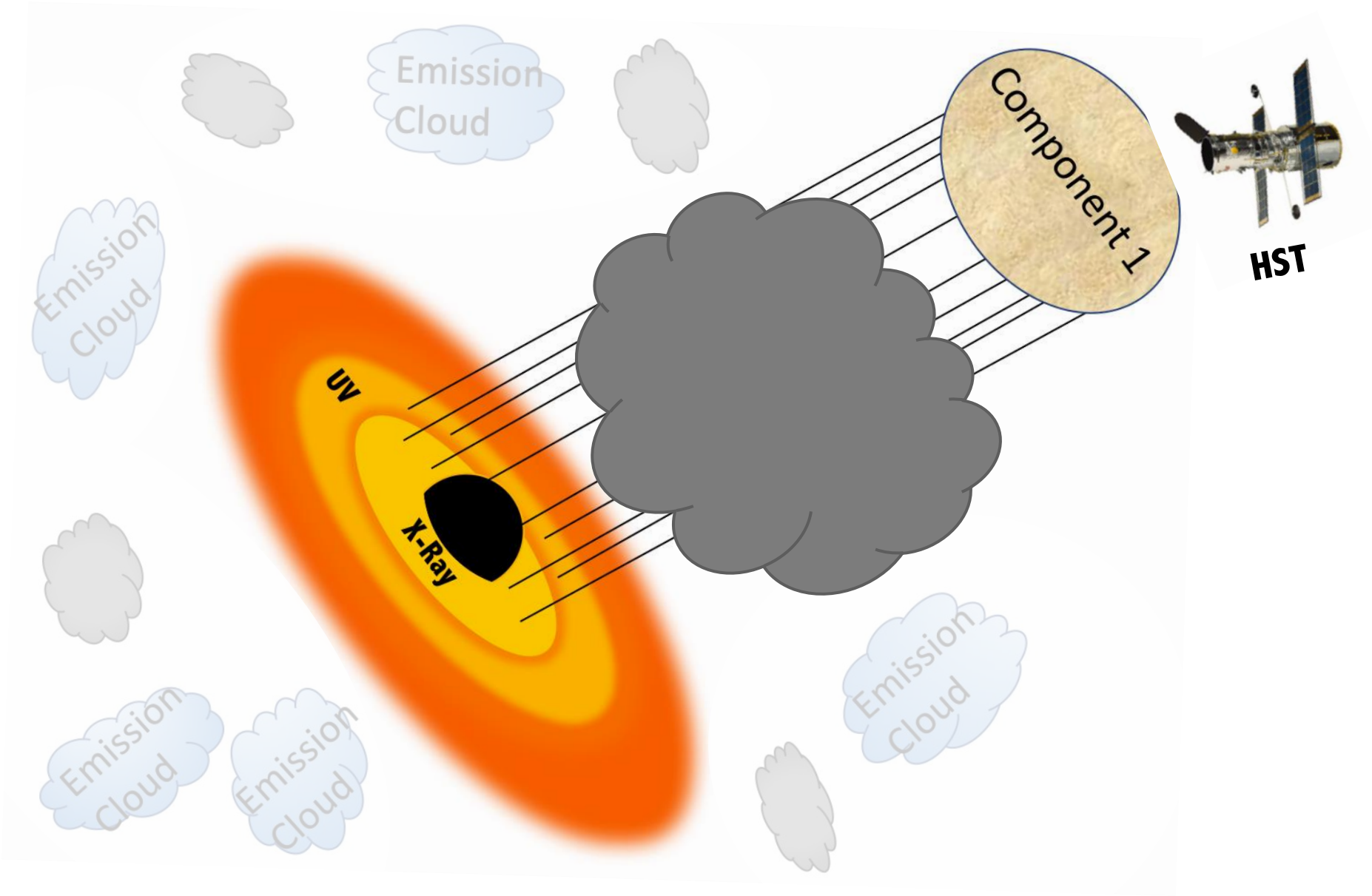
Dehghanian et al. 2019a


Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud
UV
X-Ray
The Obscurer
Component 1
HST
SED
Observations


Emission Cloud
Emission Cloud
Component 1
HST
The Obscurer
UV
X-Ray
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud


Emission Cloud
Emission Cloud
Component 1
HST
UV
X-Ray
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud


Emission Cloud
Emission Cloud
Component 1
HST
UV
X-Ray
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud


Emission Cloud
Emission Cloud
Component 1
HST
UV
X-Ray
Emission Cloud
Emission Cloud
Emission Cloud
Emission Cloud

Cloudy:

1- Takes the SED produced by the AGN

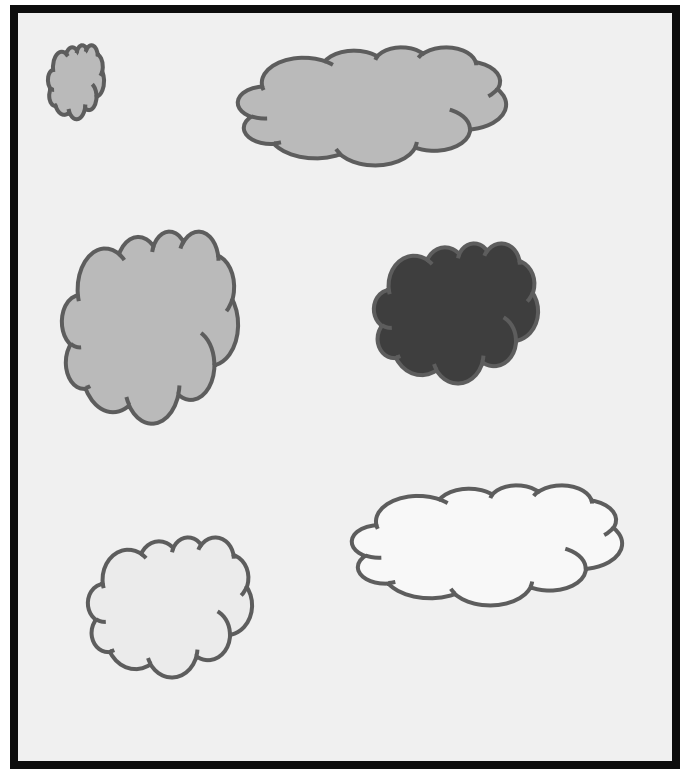
2- Passes this SED through the obscurer and
predicts the transmitted SED

3-Passes the OBSCURED SED through the absorption component1
and predicts the spectrum observed by HST

Cloudy:

1- Takes the SED produced by the AGN

2- Passes this SED through the obscurer and predicts the transmitted SED

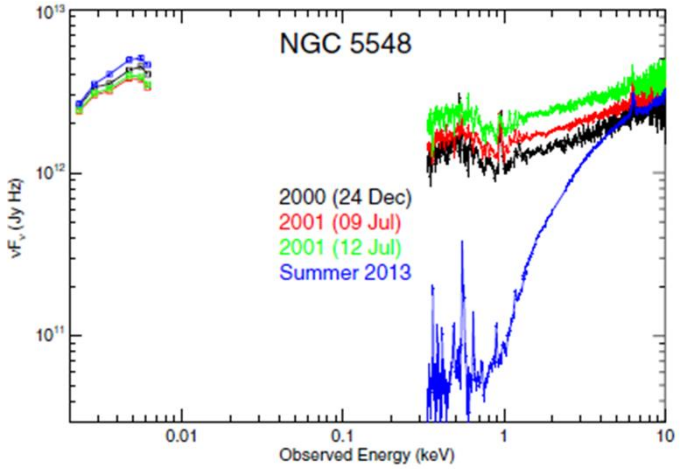


3-Passes the OBSCURED SED through the absorption component1 and predicts the spectrum observed by HST

VIRGINIA TECH

AGN

```
Table SED "NGC5548.sed"
set save prefix "obs1"
hden 10
xi -1.2
stop column density 22.08
save continuum units kev ".con"
save transmitted contnuum ".tran"
```



The Obscurer

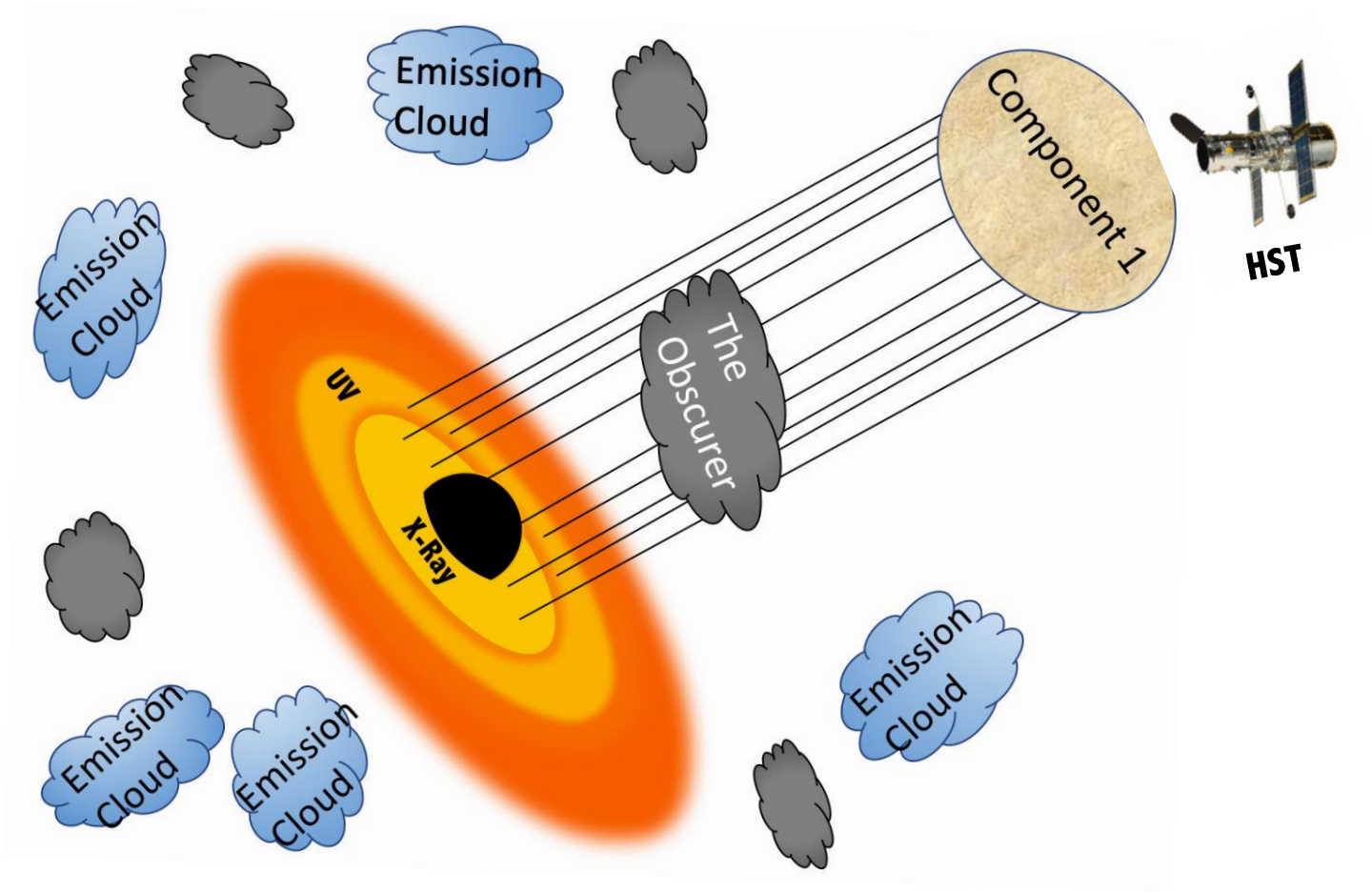
```
Table Read "obs1.tran"
nuF(nu) 3.023 0.2
set save prefix "cf99"
hden 4.72
#stop zone 1
stop column density 21.5
save line list ".lin" "lines.dat" absolute no hash
save continuum units kev ".cone"
save continuum units angstorm ".cona"
save species column densities ".dens" no hash last
"H"
"H+"
"H2+"
"C"
"C+"
"C+2"
"C+3"
"Si"
"Si+"
"Si+2"
"Si+3"
"N"
"N+"
"N+2"
"N+3"
"N+4"
"He"
"He+"
"He+2"
"He[2]"
end
```

Part III:

The Happy Ending

2019-2020

The Absorption-Line Holiday

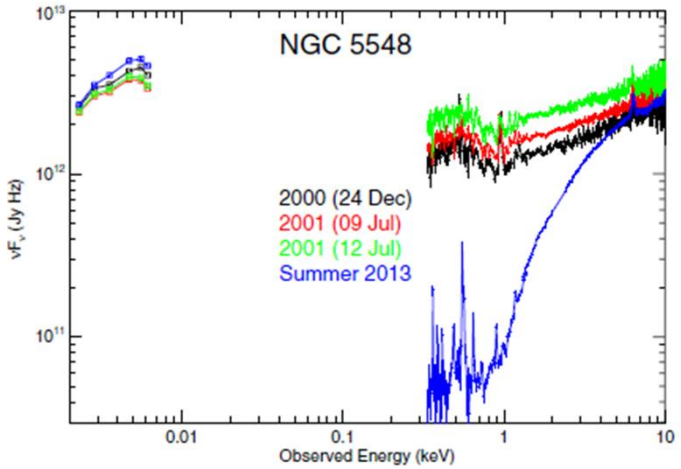


There are two possibilities

1- Holiday is a result of variable luminosity

2- Holiday is a result of variable shape

```
Table SED "NGC5548.sed"
set save prefix "obs1"
hden 10
xi -1.2
stop column density 22.08
save continuum units kev ".con"
save transmitted contnuum ".tran"
```



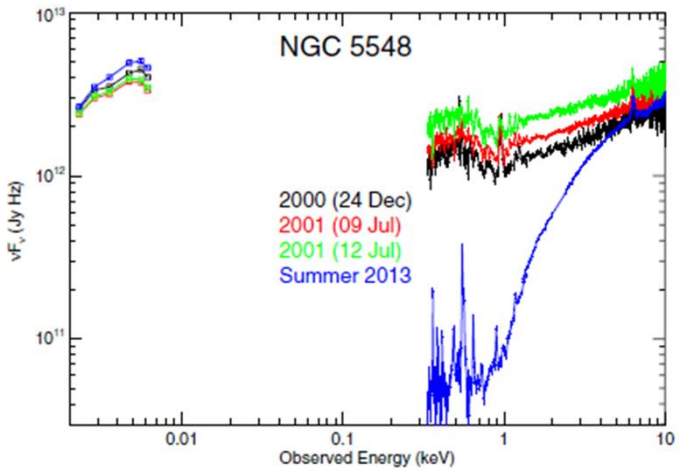

```
Table Read "obs1.tran"
nuF(nu) 3.023 0.2
set save prefix "cf99"
hden 4.72
#stop zone 1
stop column density 21.5
save line list ".lin" "lines.dat" absolute no hash
save continuum units kev ".cone"
save continuum units angstorm ".cona"
save species column densities ".dens" no hash last
"H"
"H+"
"H2+"
"C"
"C+"
"C+2"
"C+3"
"Si"
"Si+"
"Si+2"
"Si+3"
"N"
"N+"
"N+2"
"N+3"
"N+4"
"He"
"He+"
"He+2"
"He[2]"
end
```

There are two possibilities

~~1- Holiday is a result of variable luminosity~~

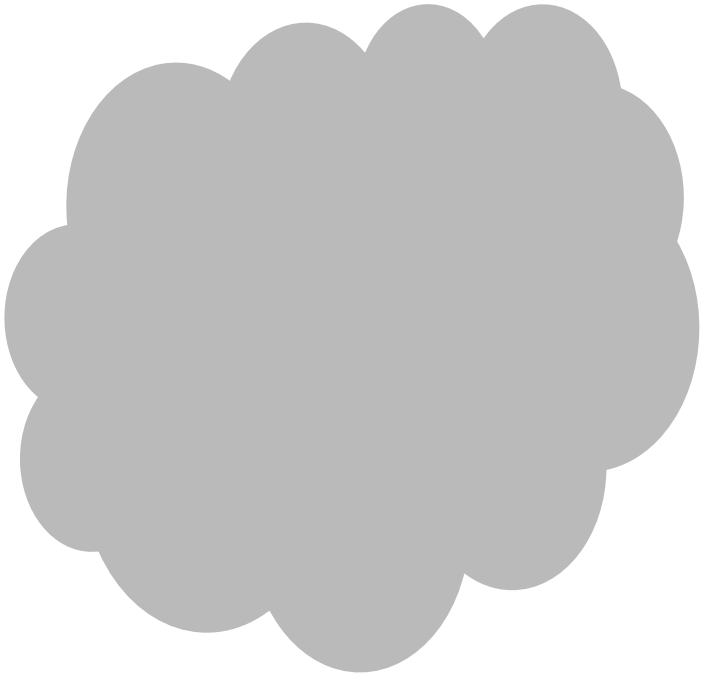
2- Holiday is a result of variable shape

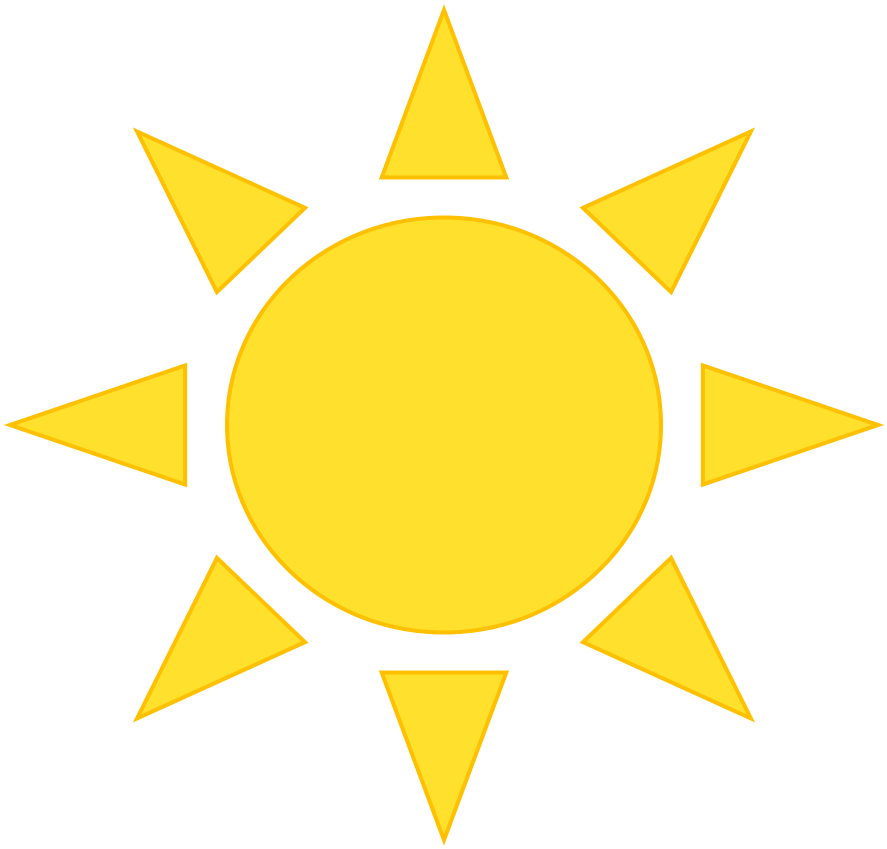
```
Table SED "NGC5548.sed"
set save prefix "obs1"
hden 10
xi -1.2
stop column density 22.08
save continuum units kev ".con"
save transmitted contnuum ".tran"
```




```
Table Read "obs1.tran"
nuF(nu) 3.023 0.2
set save prefix "cf99"
hden 4.72
#stop zone 1
stop column density 21.5
save line list ".lin" "lines.dat" absolute no hash
save continuum units kev ".cone"
save continuum units angstorm ".cona"
save species column densities ".dens" no hash last
"H"
"H+"
"H2+"
"C"
"C+"
"C+2"
"C+3"
"Si"
"Si+"
"Si+2"
"Si+3"
"N"
"N+"
"N+2"
"N+3"
"N+4"
"He"
"He+"
"He+2"
"He[2]"
end
```

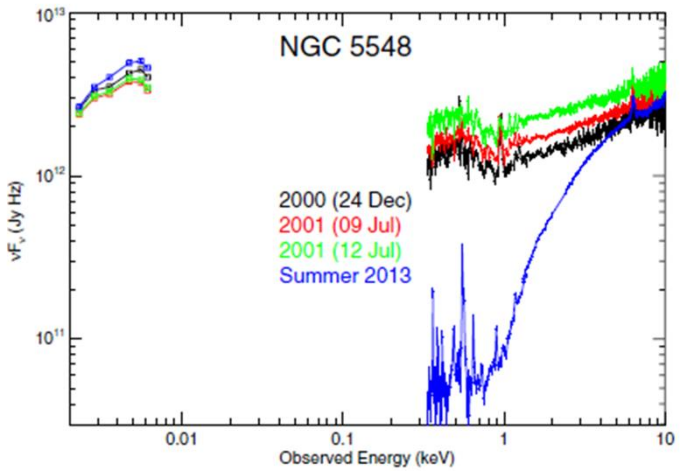
Changes in the obscurer affects the shape of the SED





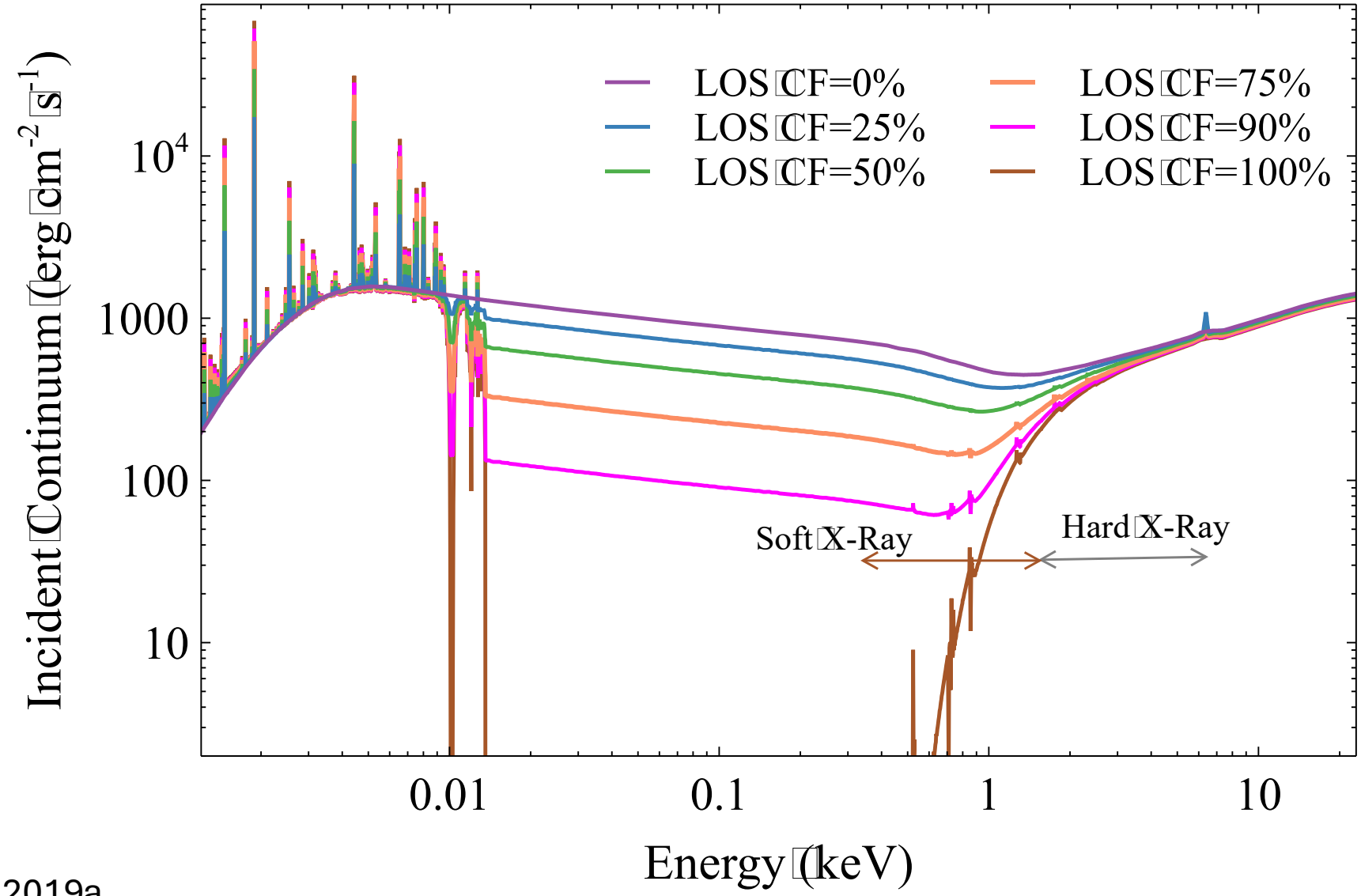
Line of Sight Covering Factor 100 %

```
Table SED "NGC5548.sed"
set save prefix "obs1"
hden 10
xi -1.2
stop column density 22.08
save continuum units kev ".con"
save transmitted contnuum ".tran"
```



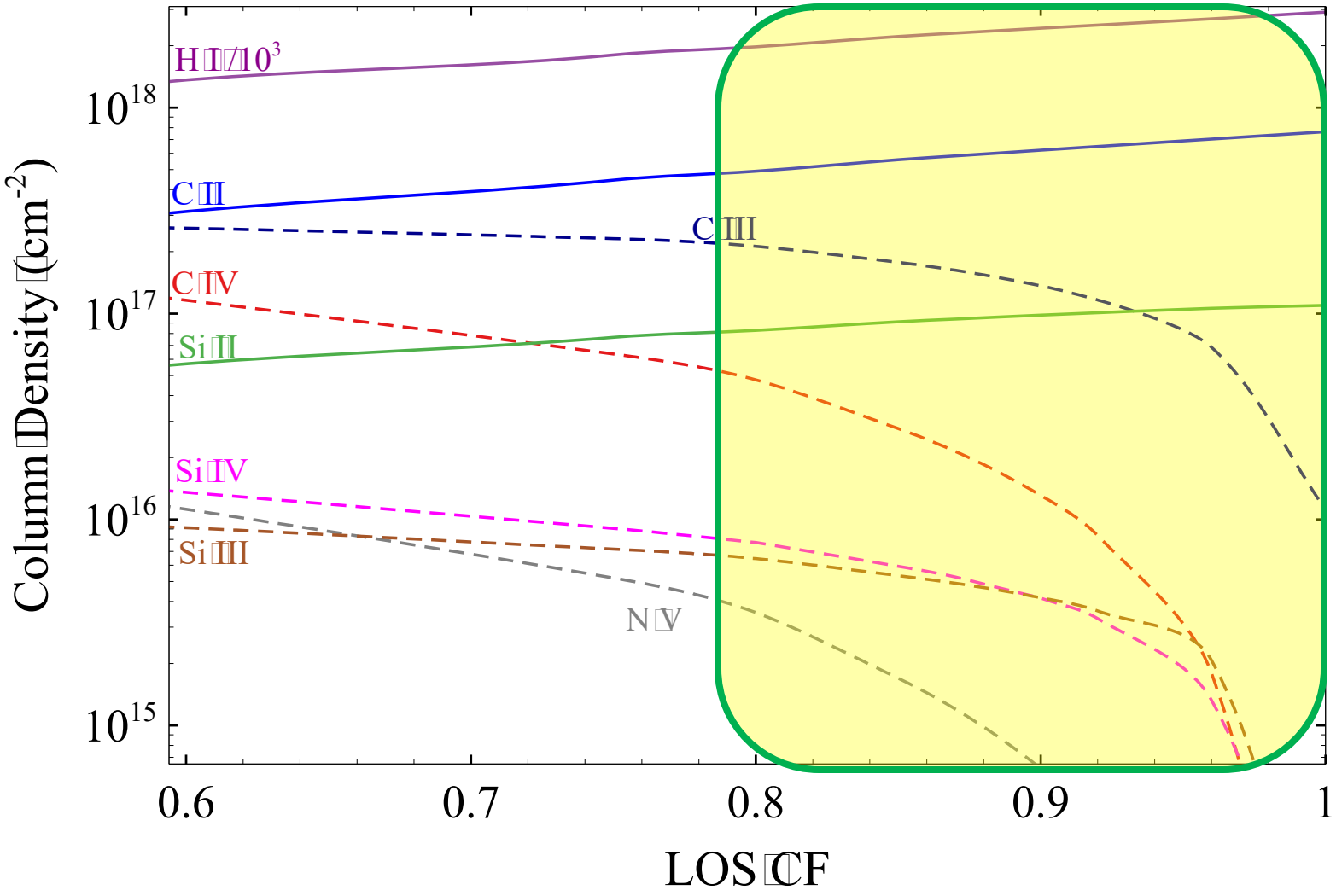

```
Table Read "obs1.tran"
#in next line we make the coverage by obs-comp1 80%
nuF(nu) 2.926 0.2
Table SED "NGC5548.sed"
#in next line we make the not-covered transmitted line 20%
nuF(nu) 2.340 0.2
set save prefix "cf80"
hden 4.72
#stop zone 1
stop column density 21.5
save line list ".lin" "lines.dat" absolute no hash
save continuum units kev ".cone"
save continuum units angstorm ".cona"
save species column densities ".dens" no hash last
"H"
"H+"
"H2+"
"C"
"C+"
"C+2"
"C+3"
"Si"
"Si+"
"Si+2"
"Si+3"
"N"
"N+"
"N+2"
"N+3"
"N+4"
"He"
"He+"
"He+2"
"He[2]"
end
```

The effects of variable covering factor on the shape of the SED

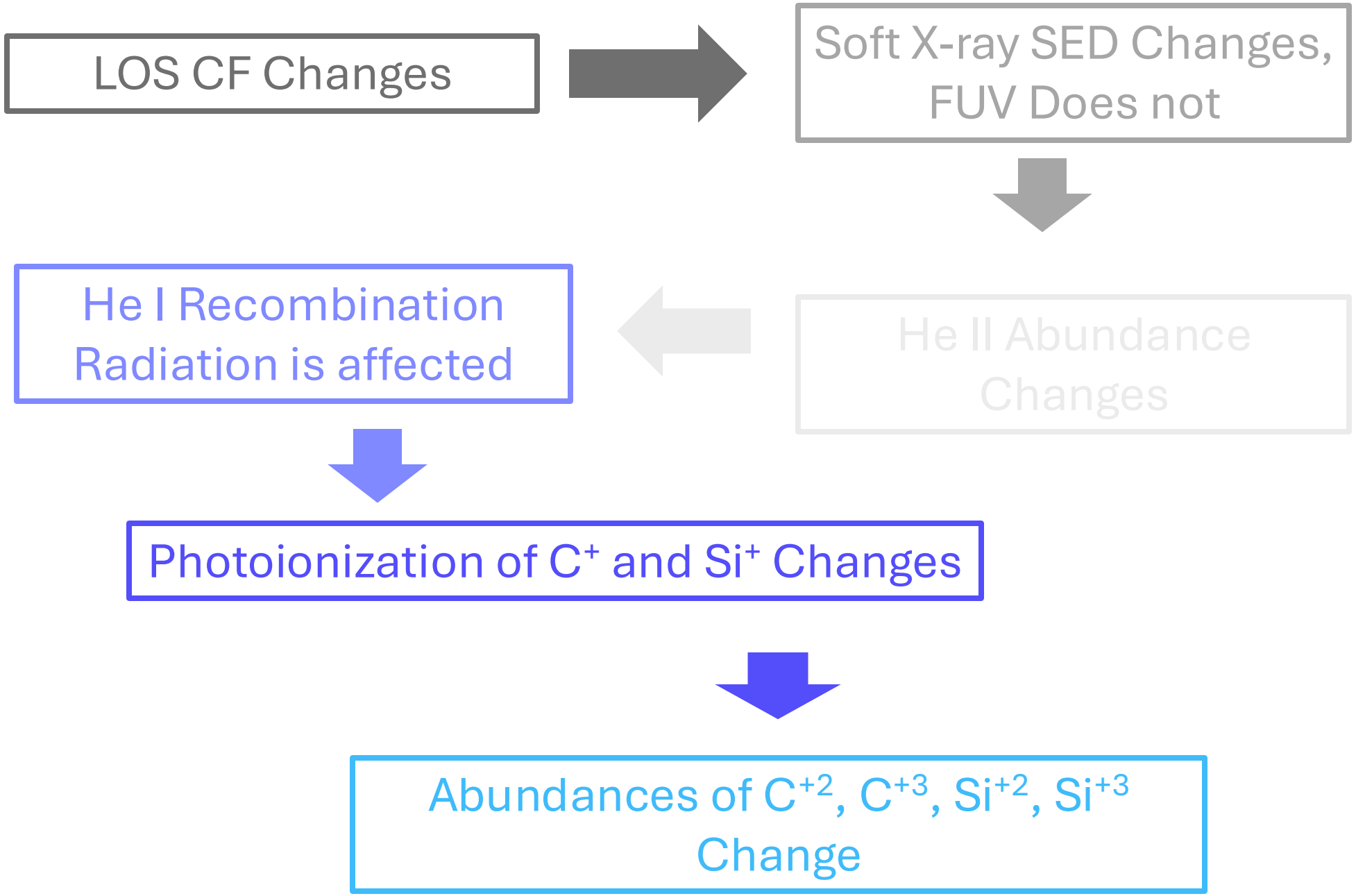


Dehghanian et al. 2019a

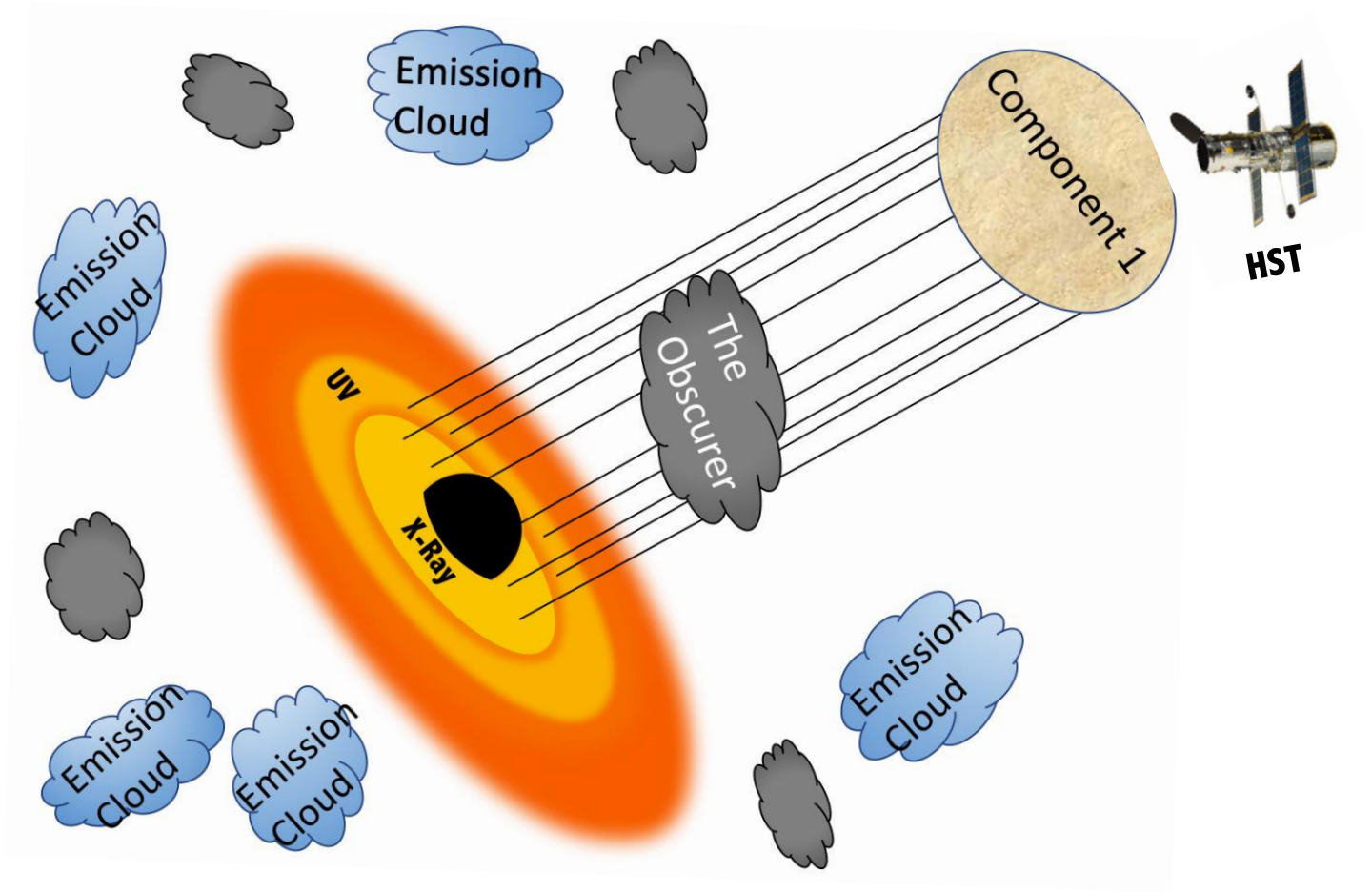
The effects of variable CF on the absorption lines



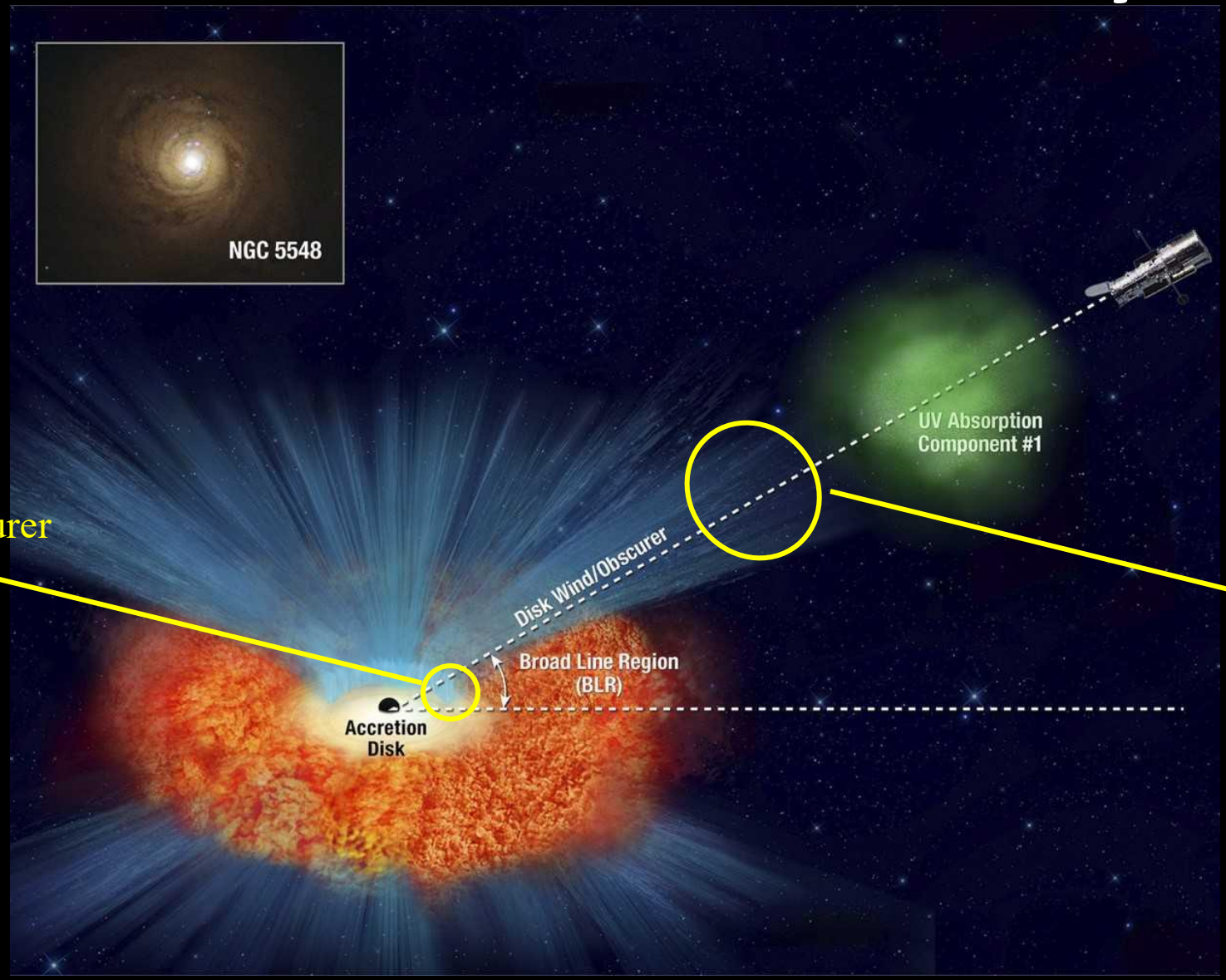
Dehghanian et al. 2019a


LOS CF Changes
Soft X-ray SED Changes, FUV Does not
He II Abundance Changes
He I Recombination Radiation is affected
Photoionization of C^{+} and Si^{+} Changes
Abundances of C^{+2}, C^{+3}, Si^{+2}, Si^{+3} Change

The Emission-Line Holiday



The Emission-Line Holiday



The equatorial obscurer

The LOS obscurer

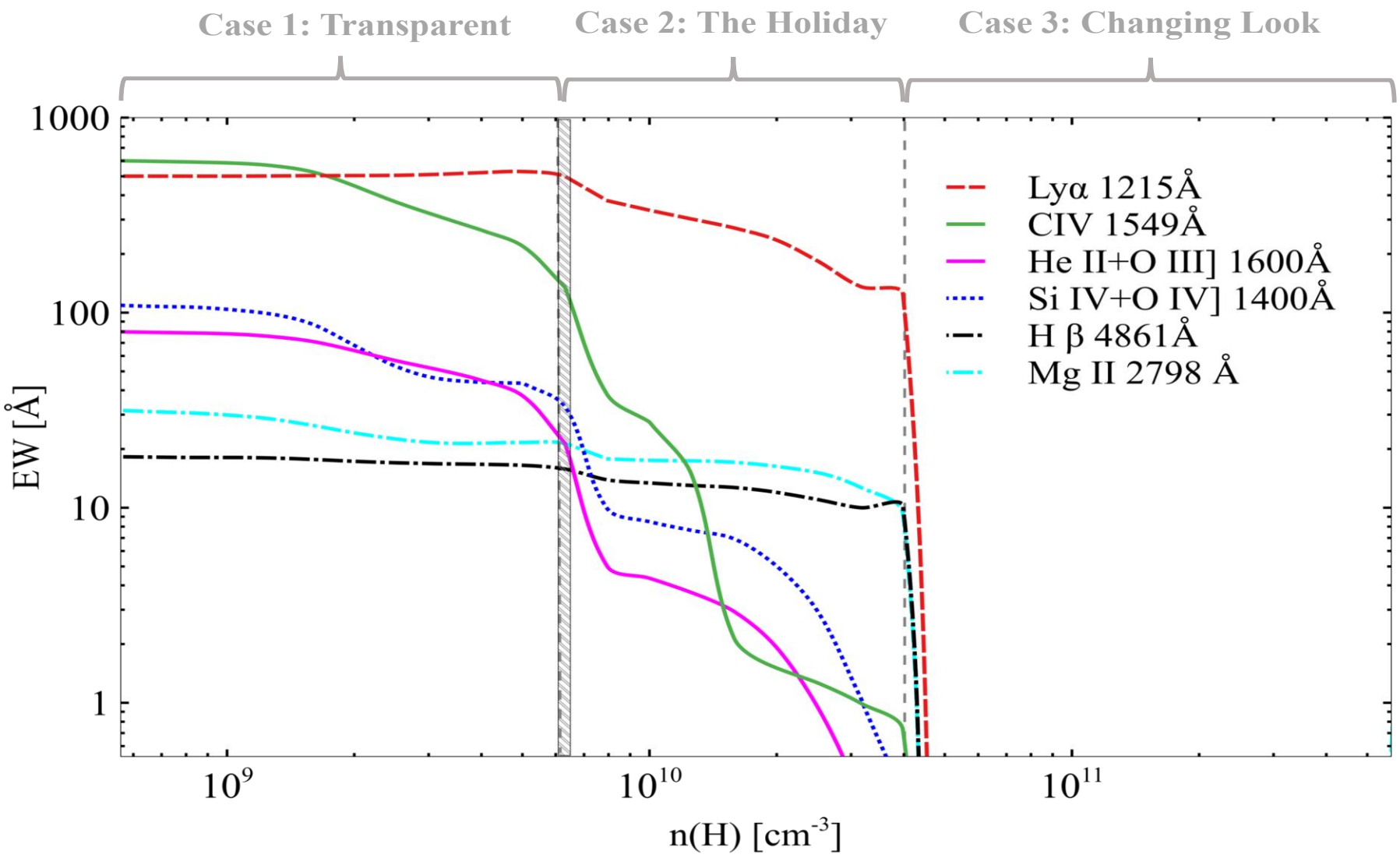
Dehghanian et al. 2019b

There are two possibilities

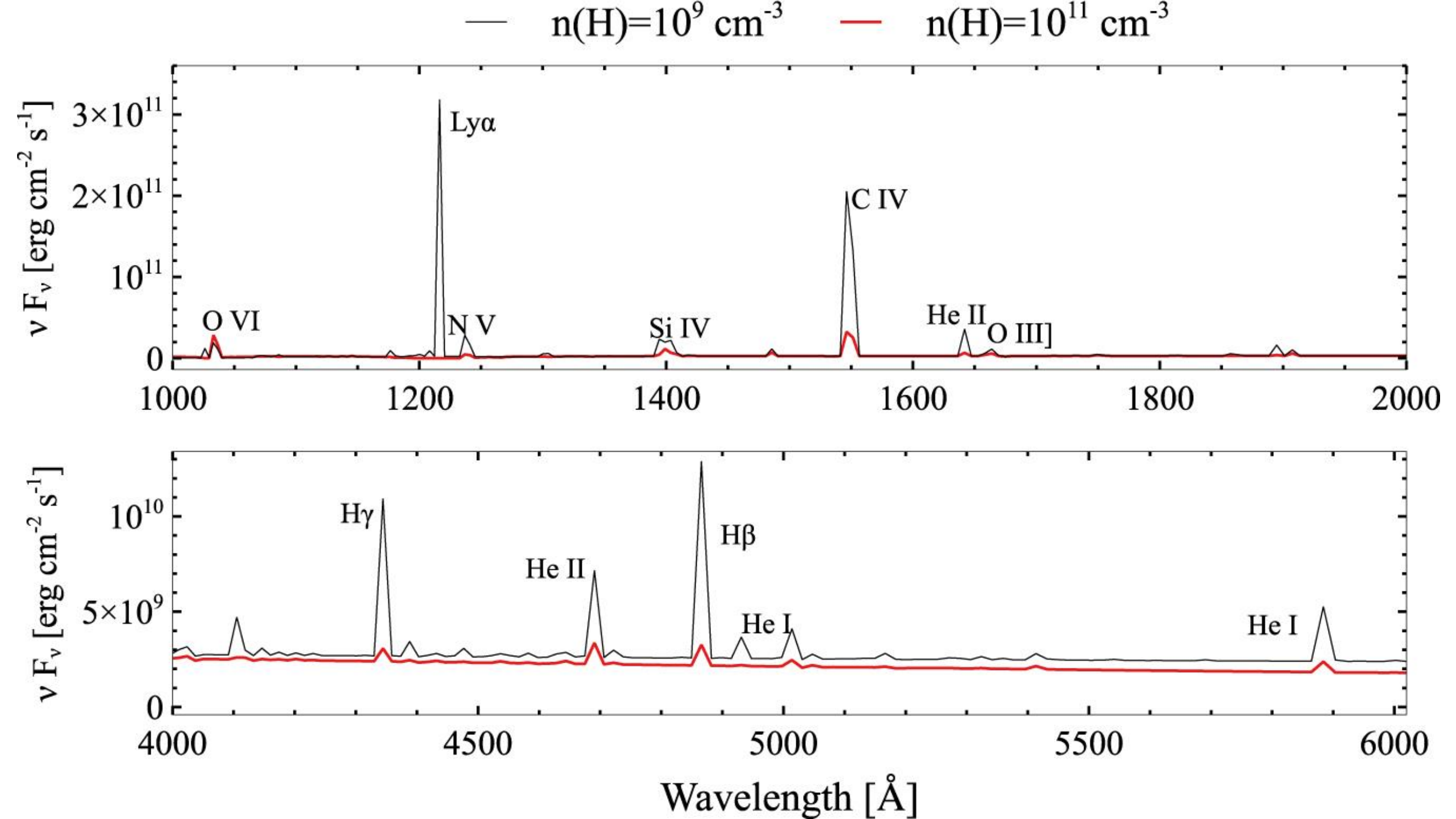
1- Holiday is a result of variable luminosity

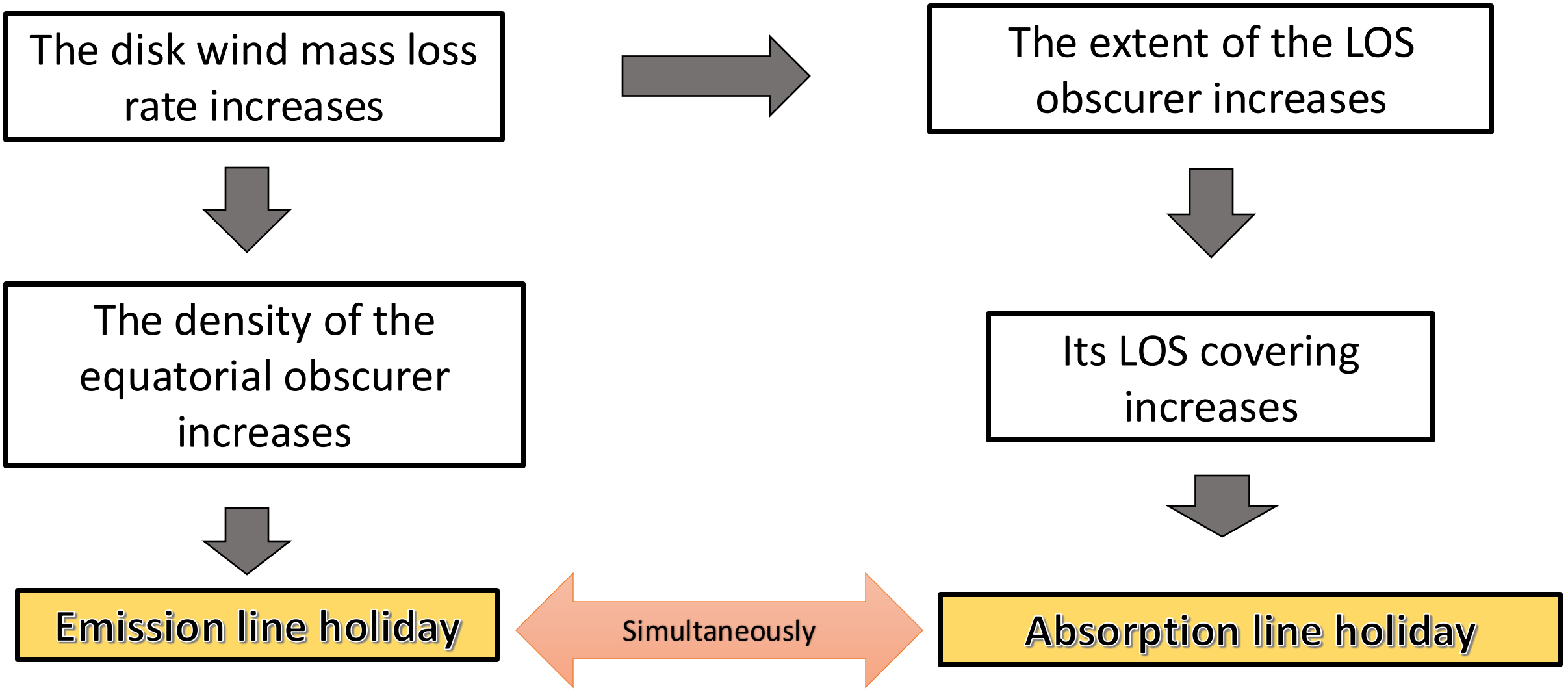
2- Holiday is a result of variable wind

Changes in the BLR- considering the equatorial obscurer

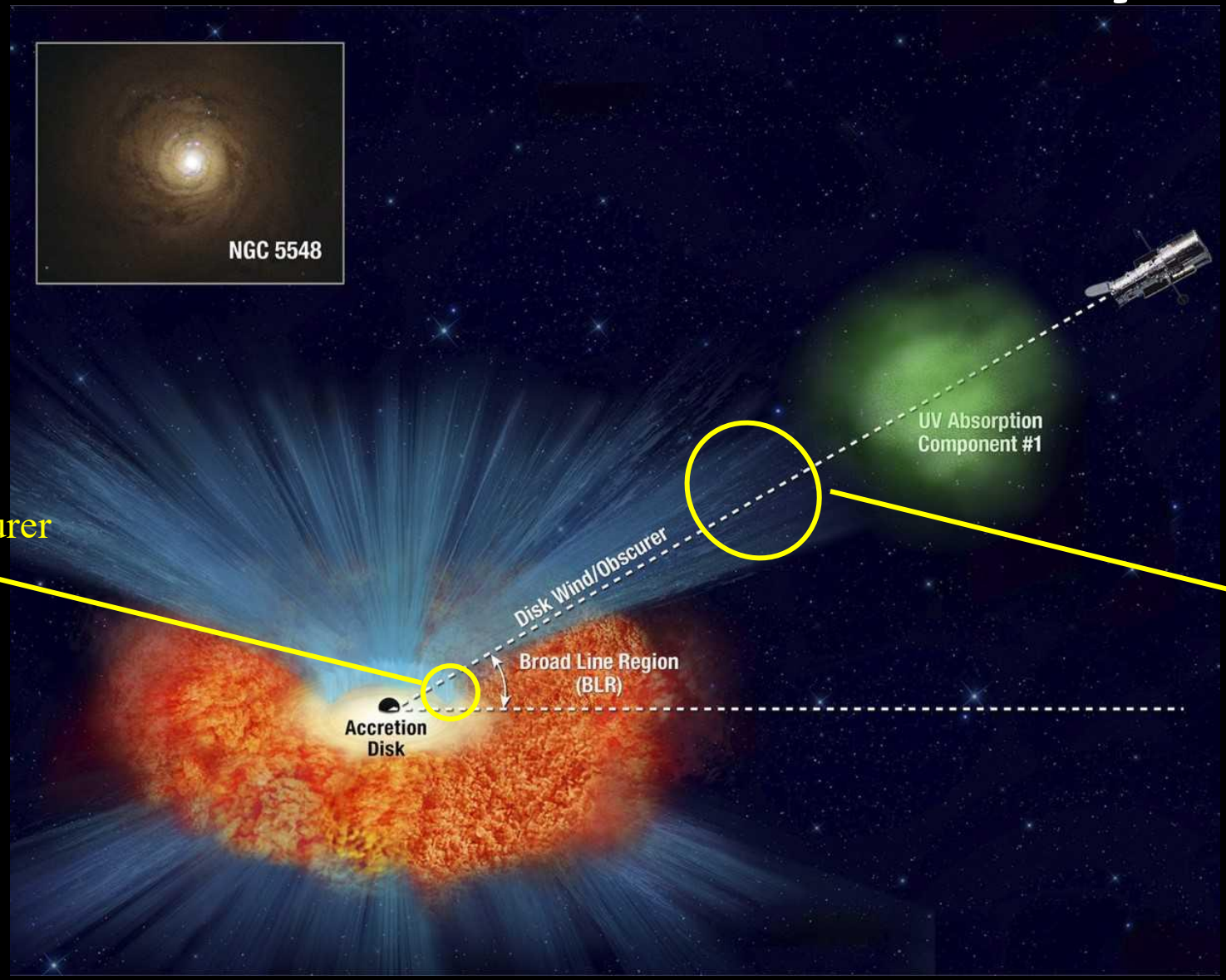


Dehghanian et al. 2019b


n(H)=10^9 cm^-3
n(H)=10^11 cm^-3
ν F_ν [erg cm^-2 s^-1]
3×10^11
2×10^11
10^11
0
Lyα
C IV
O VI
N V
Si IV
He II
O III]
1000
1200
1400
1600
1800
2000
ν F_ν [erg cm^-2 s^-1]
10^10
5×10^9
0
Hγ
He II
Hβ
He I
He I
4000
4500
5000
5500
6000
Wavelength [Å]


The disk wind mass loss rate increases
The extent of the LOS obscurer increases
The density of the equatorial obscurer increases
Its LOS covering increases
Emission line holiday
Simultaneously
Absorption line holiday

The Emission-Line Holiday



The equatorial obscurer

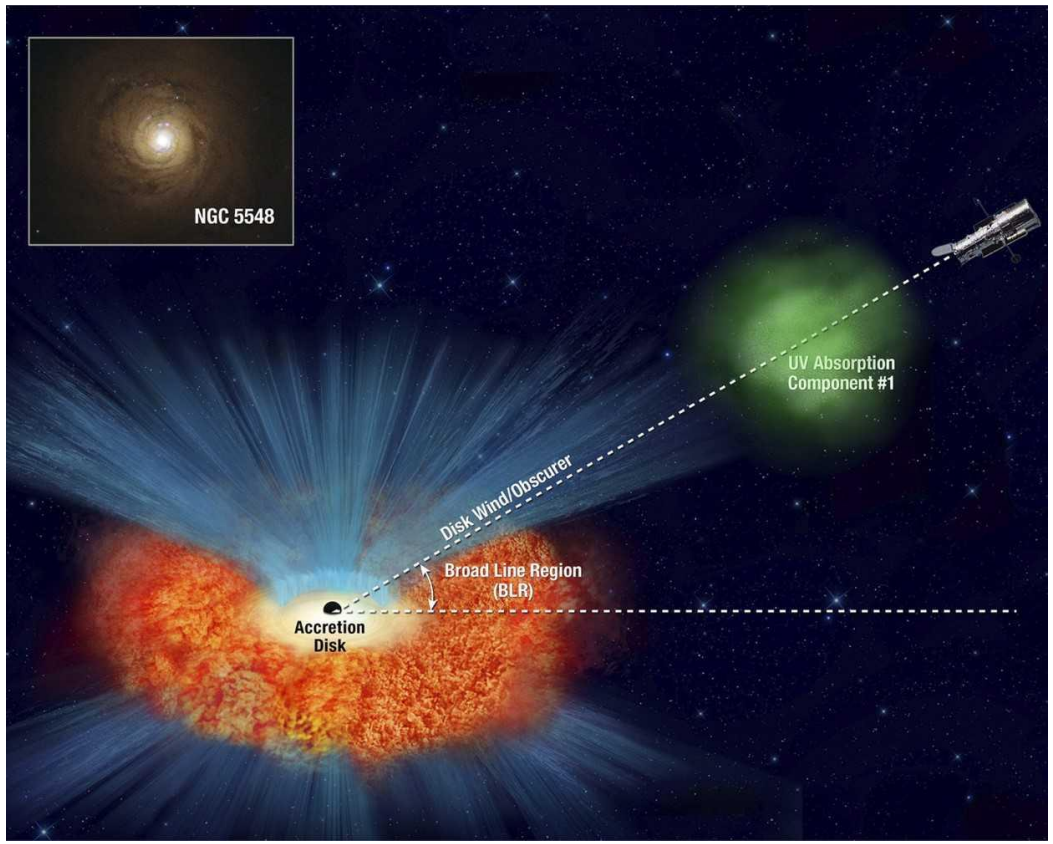
The LOS obscurer

Part IV:

Lets Go Beyond

2021

```
Table SED "NGC5548.sed"
set save prefix "LOC_case1"
hden 13 vary
grid 10 18 0.25
phi(H) 22 vary
grid 20 24 0.25
```



```
Table SED "NGC5548.sed"
set save prefix "LOC_case1"
hden 13 vary
grid 10 18 0.25
phi(H) 22 vary
grid 20 24 0.25
```

Warnings?	Exit code	#rank	#seq	HDEN=%f L	phi(h) %f	grid parameter string
F	ok	22	16	10.000000	20.000000	10.000000, 20.000000
F	ok	5	7	10.000000	20.250000	10.000000, 20.250000
F	ok	21	13	10.000000	20.500000	10.000000, 20.500000
F	ok	26	7	10.000000	20.750000	10.000000, 20.750000
F	ok	24	3	10.000000	21.000000	10.000000, 21.000000
F	ok	28	12	10.000000	21.250000	10.000000, 21.250000
F	ok	6	17	10.000000	21.500000	10.000000, 21.500000
F	ok	21	6	10.000000	21.750000	10.000000, 21.750000
F	ok	6	14	10.000000	22.000000	10.000000, 22.000000
F	ok	8	0	10.000000	22.250000	10.000000, 22.250000
F	ok	25	12	10.000000	22.500000	10.000000, 22.500000
F	ok	3	9	10.000000	22.750000	10.000000, 22.750000
F	ok	20	15	10.000000	23.000000	10.000000, 23.000000
F	ok	10	10	10.000000	23.250000	10.000000, 23.250000
T	warnings	17	6	10.000000	23.500000	10.000000, 23.500000
T	warnings	3	4	10.000000	23.750000	10.000000, 23.750000
T	warnings	9	2	10.000000	24.000000	10.000000, 24.000000
F	ok	23	0	10.250000	20.000000	10.250000, 20.000000
F	ok	19	1	10.250000	20.250000	10.250000, 20.250000
F	ok	14	9	10.250000	20.500000	10.250000, 20.500000
F	ok	4	17	10.250000	20.750000	10.250000, 20.750000
F	ok	19	16	10.250000	21.000000	10.250000, 21.000000
F	ok	9	11	10.250000	21.250000	10.250000, 21.250000
F	ok	15	14	10.250000	21.500000	10.250000, 21.500000
F	ok	7	13	10.250000	21.750000	10.250000, 21.750000
F	ok	11	17	10.250000	22.000000	10.250000, 22.000000
F	ok	1	16	10.250000	22.250000	10.250000, 22.250000
F	ok	29	4	10.250000	22.500000	10.250000, 22.500000
F	ok	14	10	10.250000	22.750000	10.250000, 22.750000
F	ok	7	14	10.250000	23.000000	10.250000, 23.000000
F	ok	14	1	10.250000	23.250000	10.250000, 23.250000
F	ok	1	3	10.250000	23.500000	10.250000, 23.500000
T	warnings	18	2	10.250000	23.750000	10.250000, 23.750000
T	warnings	26	15	10.250000	24.000000	10.250000, 24.000000
F	ok	8	13	10.500000	20.000000	10.500000, 20.000000
F	ok	22	10	10.500000	20.250000	10.500000, 20.250000
F	ok	8	15	10.500000	20.500000	10.500000, 20.500000
F	ok	18	7	10.500000	20.750000	10.500000, 20.750000
F	ok	16	9	10.500000	21.000000	10.500000, 21.000000
F	ok	14	14	10.500000	21.250000	10.500000, 21.250000
F	ok	1	1	10.500000	21.500000	10.500000, 21.500000
F	ok	4	14	10.500000	21.750000	10.500000, 21.750000
F	ok	7	6	10.500000	22.000000	10.500000, 22.000000
F	ok	15	16	10.500000	22.250000	10.500000, 22.250000
F	ok	24	10	10.500000	22.500000	10.500000, 22.500000
F	ok	0	17	10.500000	22.750000	10.500000, 22.750000
F	ok	24	13	10.500000	23.000000	10.500000, 23.000000
F	ok	6	4	10.500000	23.250000	10.500000, 23.250000
F	ok	18	13	10.500000	23.500000	10.500000, 23.500000
F	ok	14	6	10.500000	23.750000	10.500000, 23.750000
T	warnings	28	3	10.500000	24.000000	10.500000, 24.000000
F	ok	18	15	10.750000	20.000000	10.750000, 20.000000
F	ok	12	4	10.750000	20.250000	10.750000, 20.250000
F	ok	5	11	10.750000	20.500000	10.750000, 20.500000
F	ok	24	16	10.750000	20.750000	10.750000, 20.750000

```
Table SED "NGC5548.sed"
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grid 10 18 0.25
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grid 20 24 0.25
```
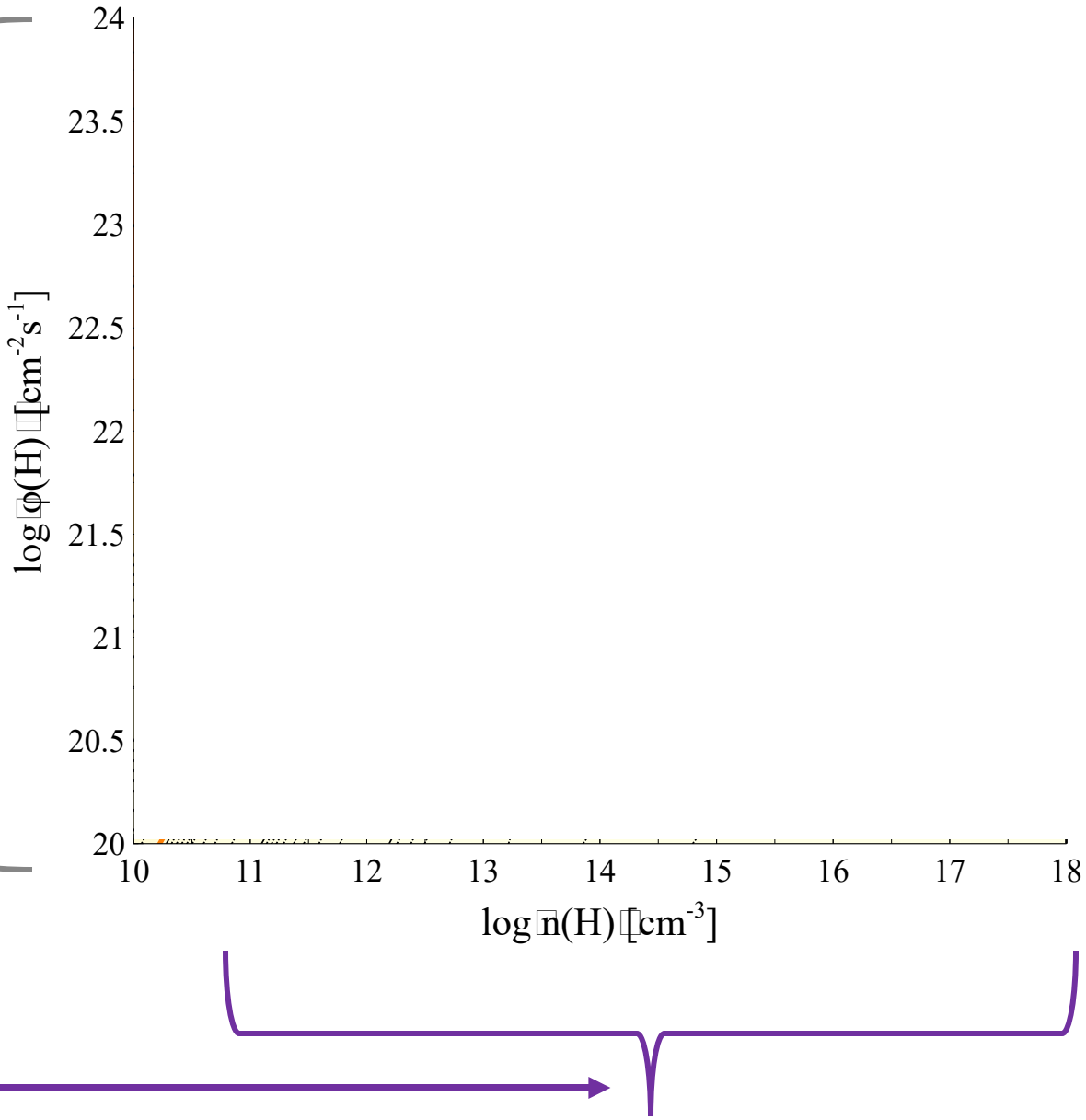
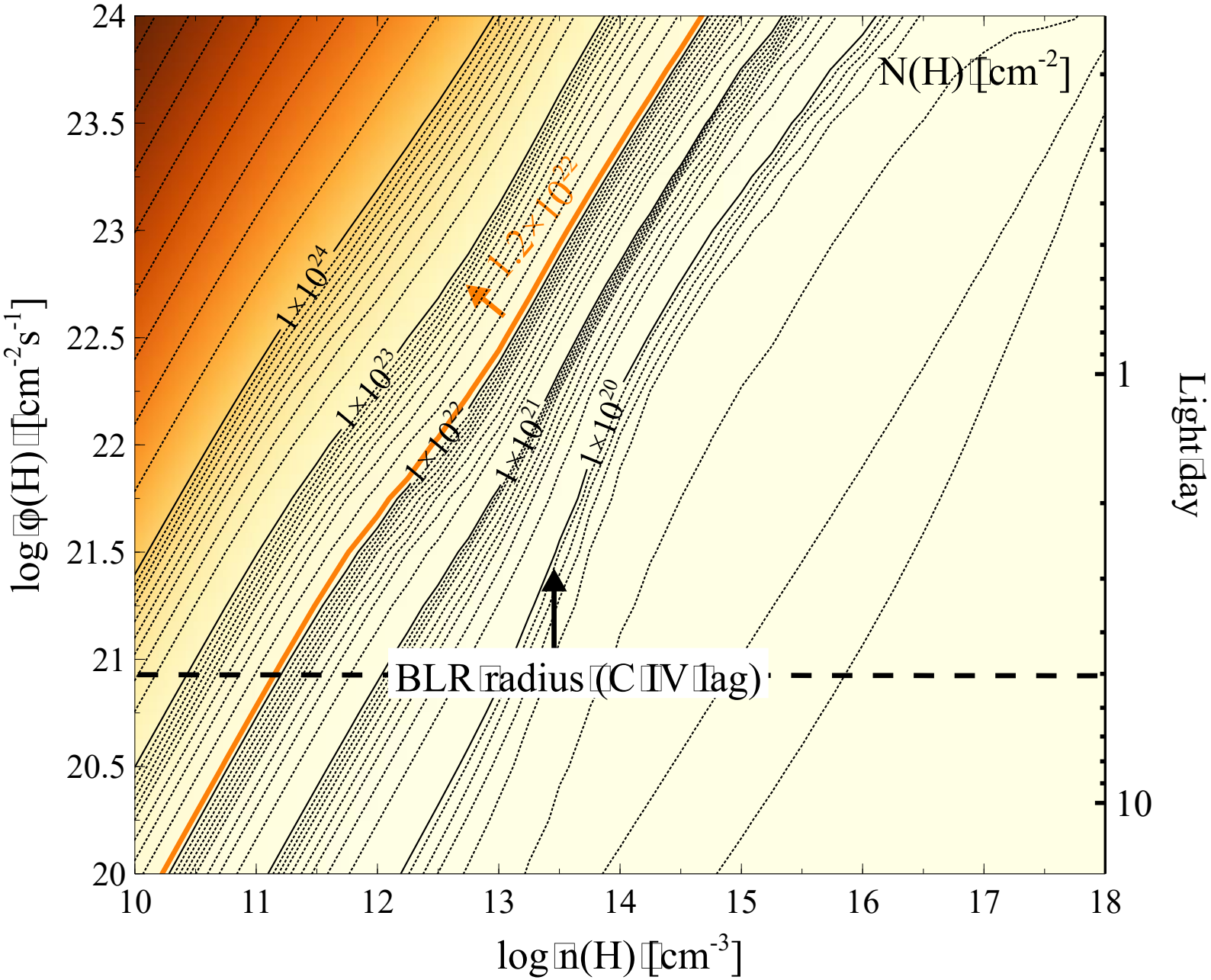
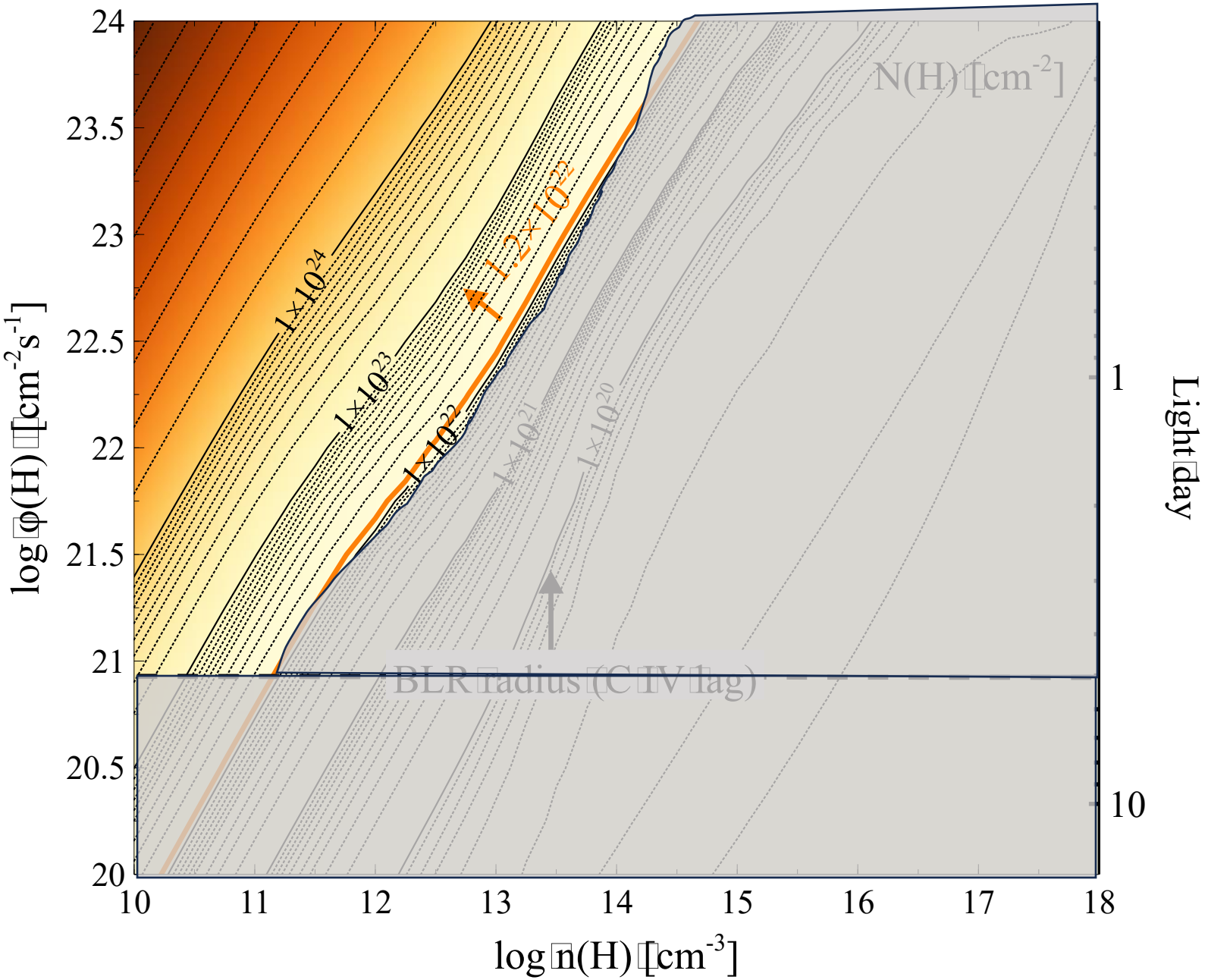



A Novel Approach to Trace the Disk Wind



Dehghanian et al. 2020

A Novel Approach to Trace the Disk Wind



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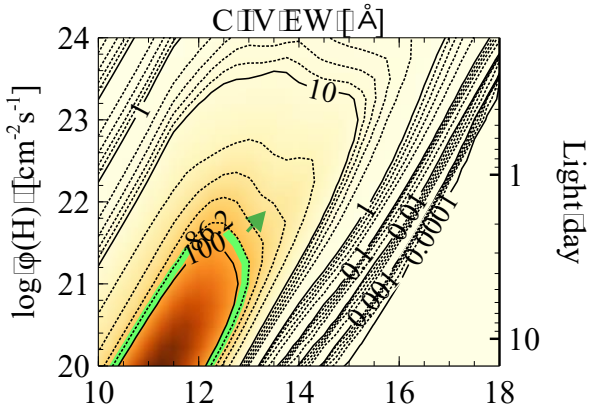
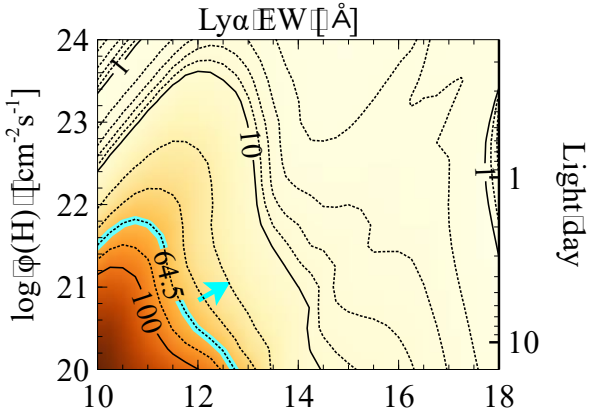
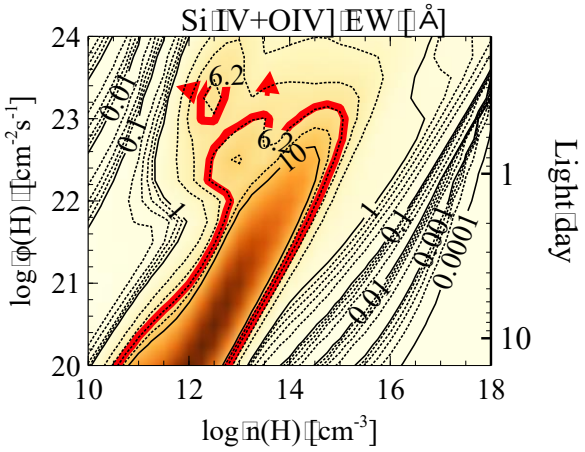
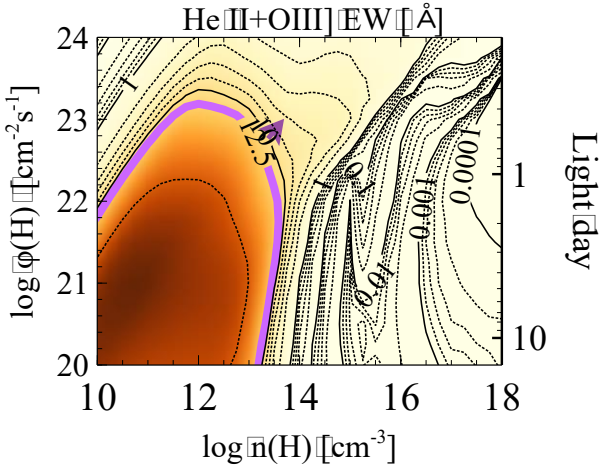
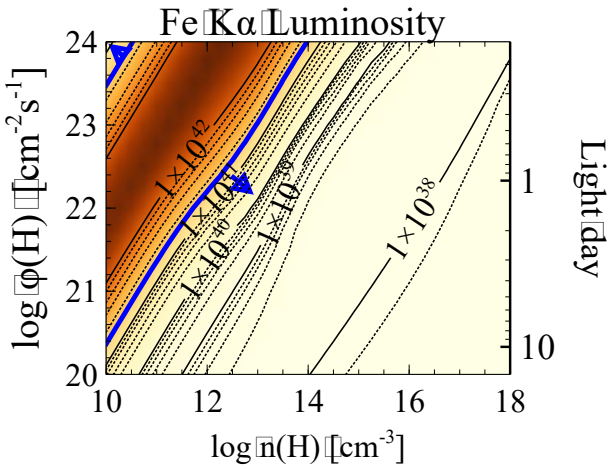
Emission from the disk wind











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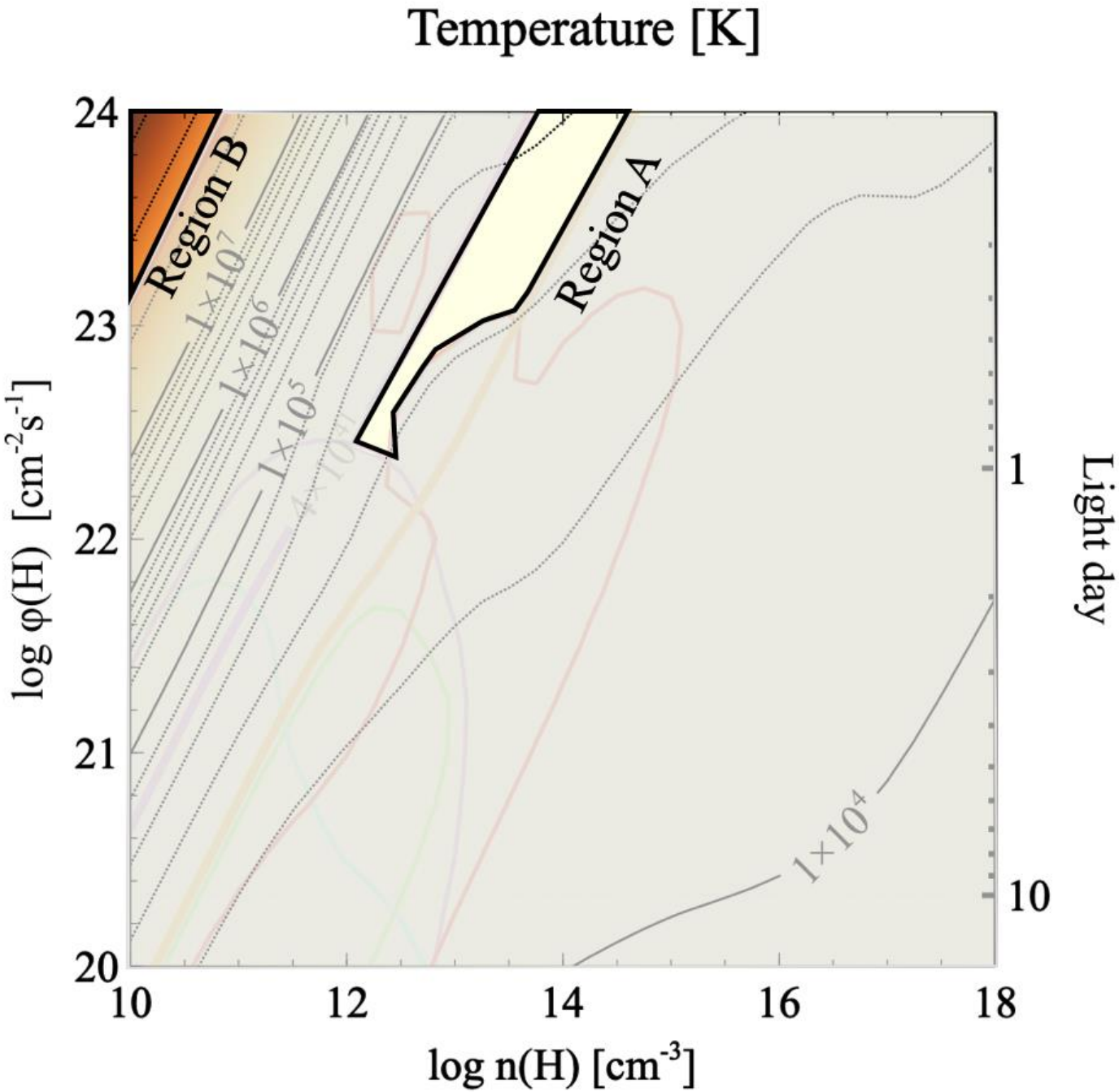
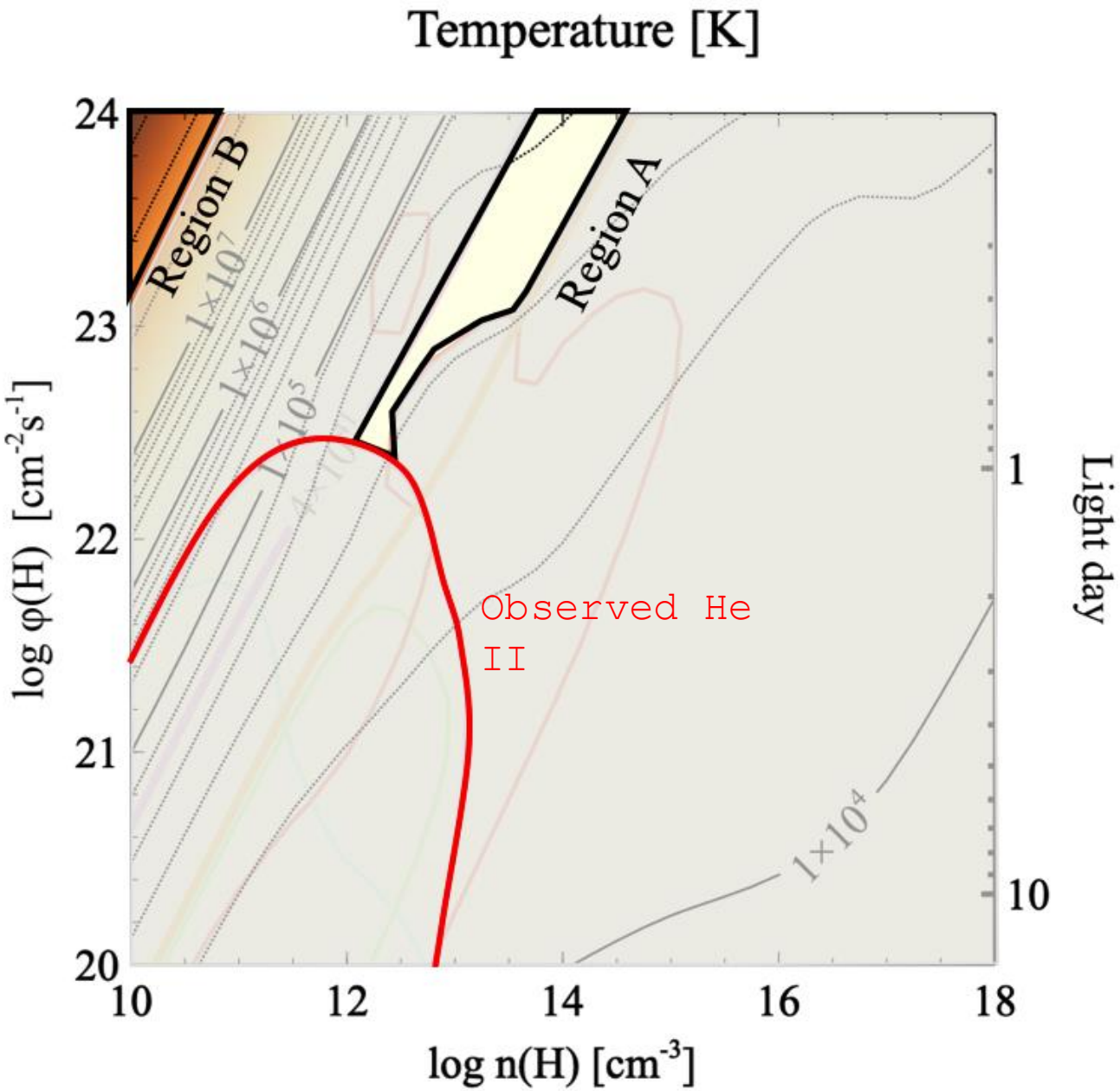
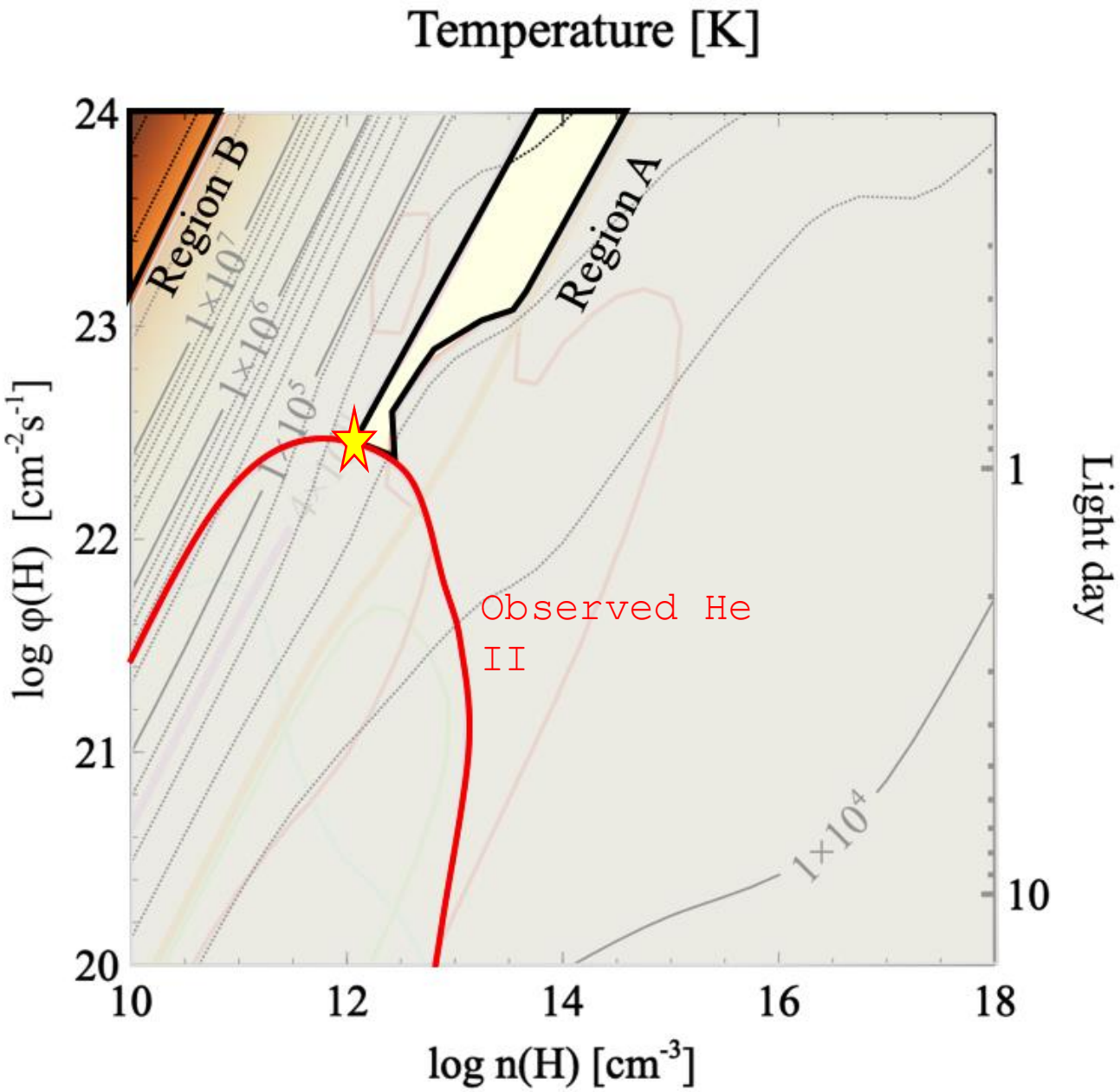

Temperature [K]
Region B
Region A
1×10^7
1×10^6
1×10^5
1×10^4
log φ(H) [cm^-2 s^-1]
log n(H) [cm^-3]
Light day
24
23
22
21
20
10
12
14
16
18
1
10


Temperature [K]
Region B
Region A
1×10^7
1×10^6
1×10^5
1×10^4
Observed He II
log φ(H) [cm^-2 s^-1]
log n(H) [cm^-3]
Light day
24
23
22
21
20
10
12
14
16
18
1
10



n(H)=12 cm^{-3}

N(H)=$10^{23}cm^{-2}$

R= 1 Light Day

T=5 x 10^4 K

ξ= 1 erg cm s^{-1}

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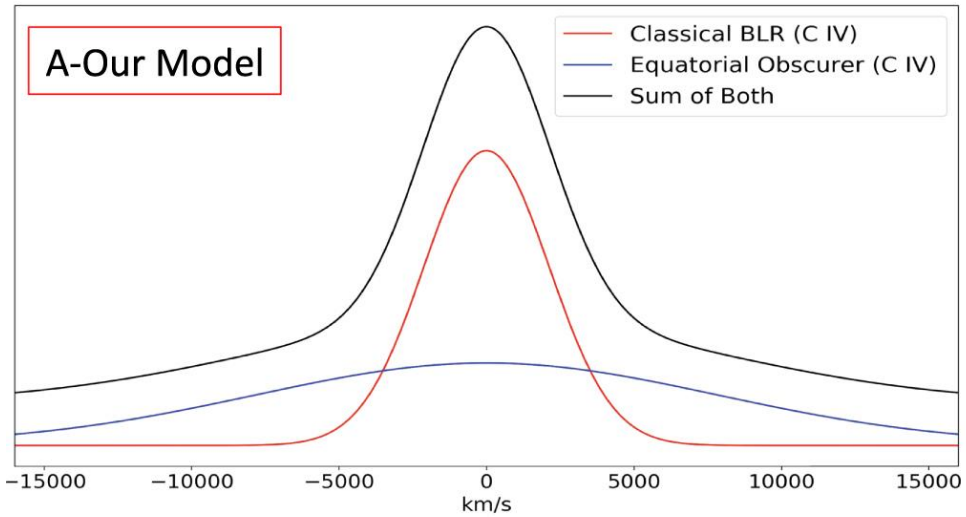
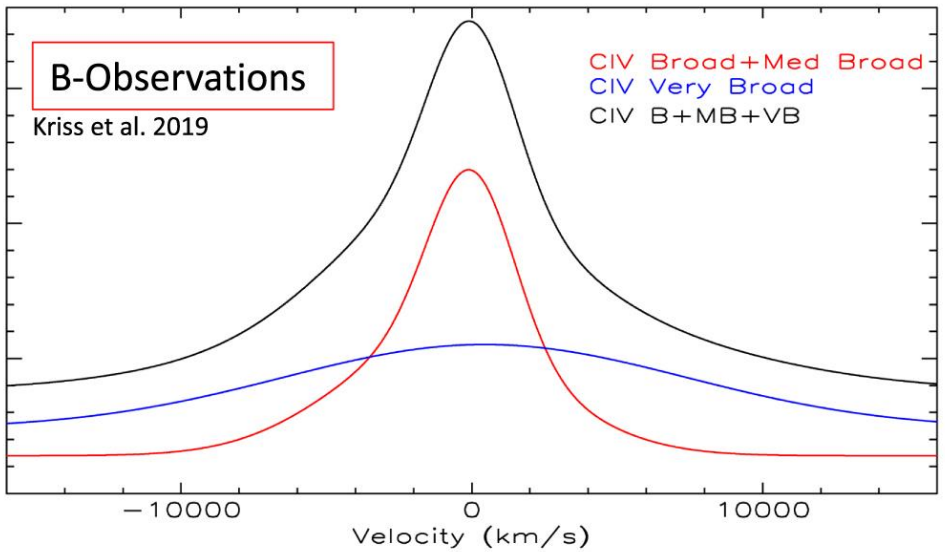
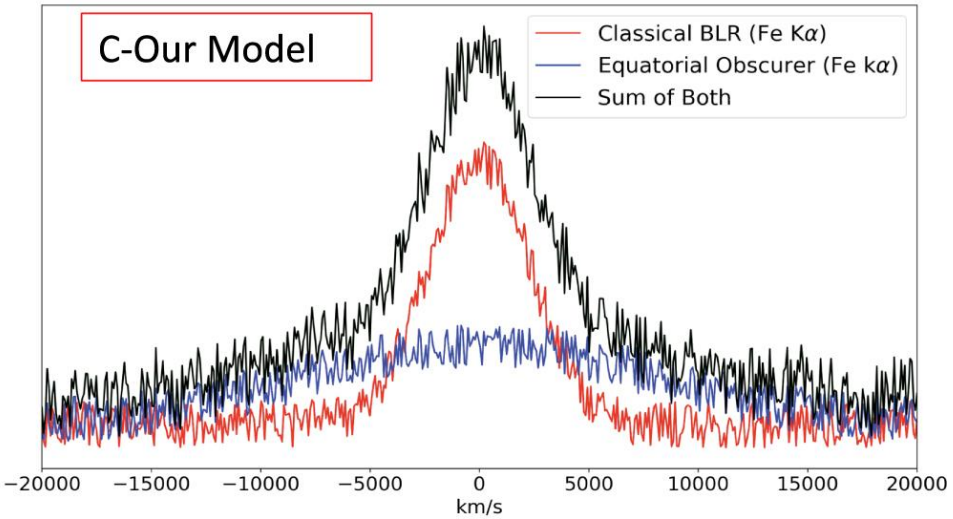
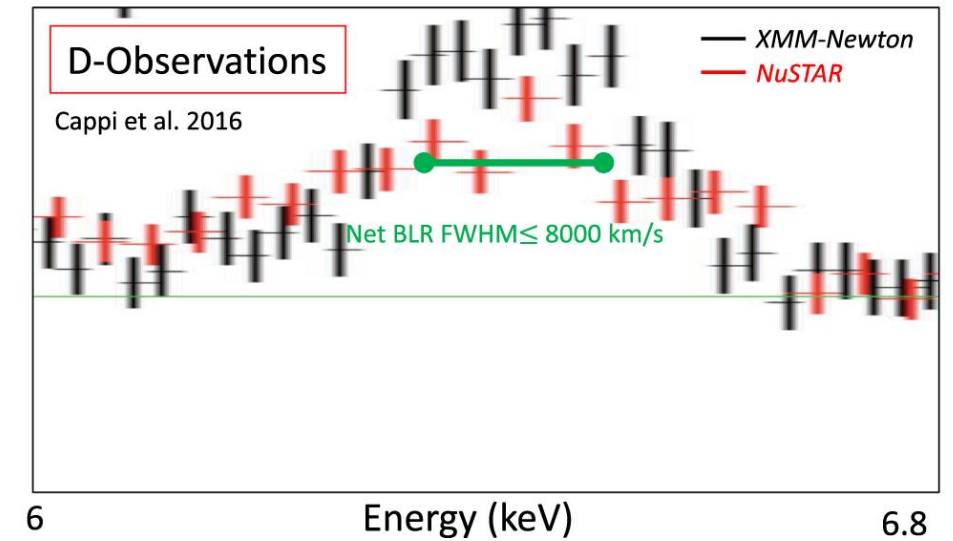
C IV (EW_{wind}=EW_{BLR}= 50% EW_{total})





Fe Kα (EW_{wind}=EW_{BLR}= 50% EW_{total})





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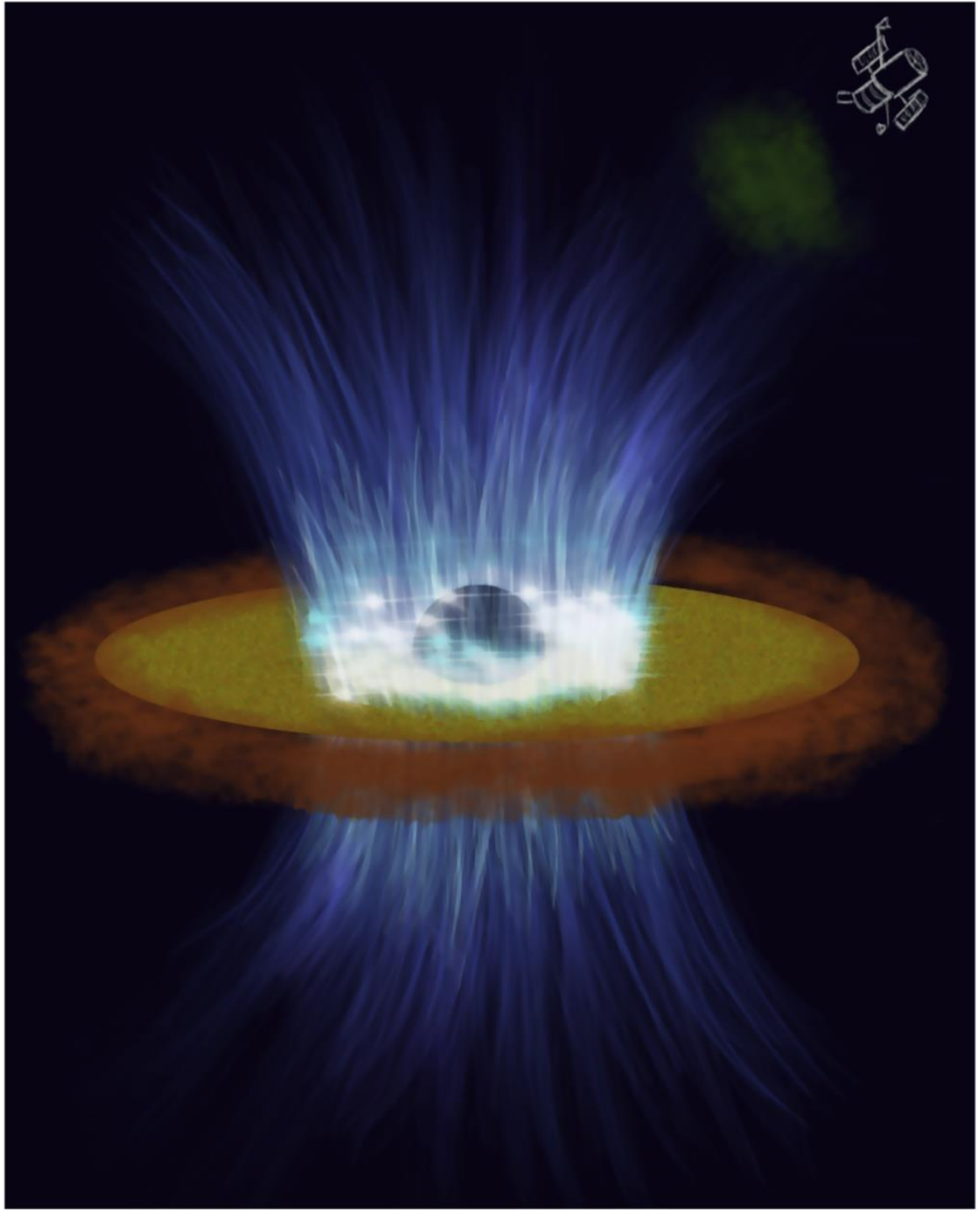
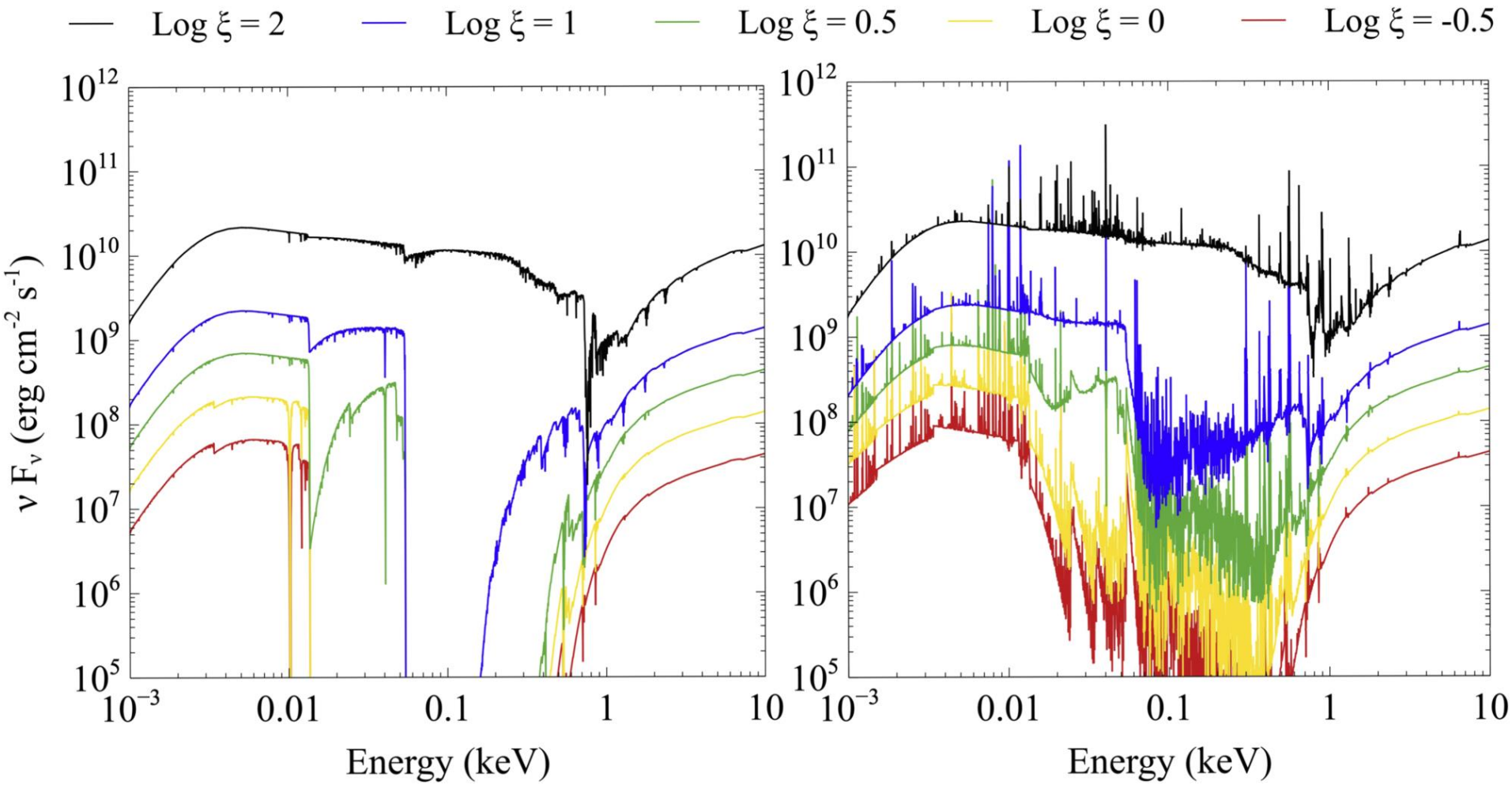


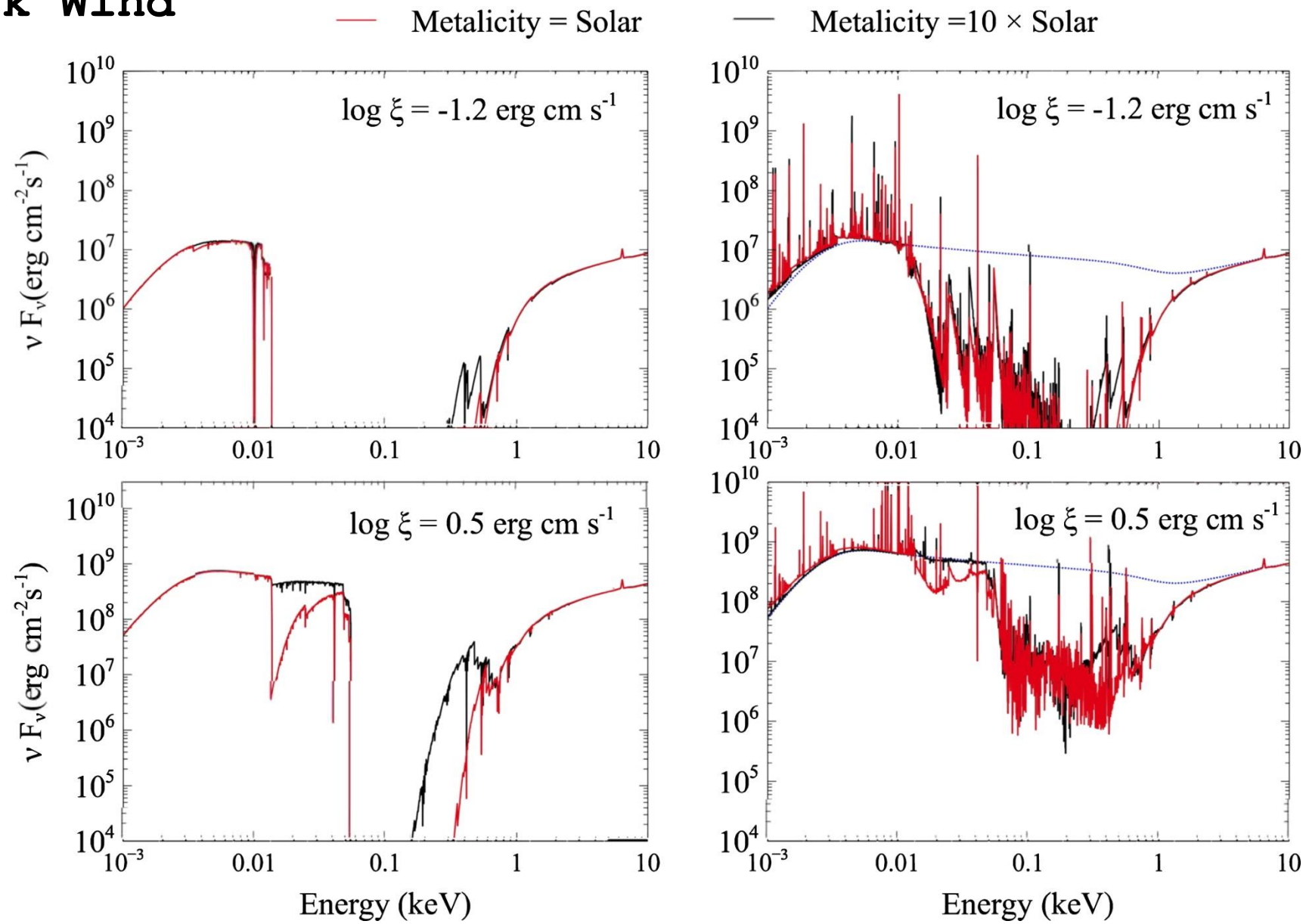
Dehghanian et al. 2020

Atlas of UV and X-Ray Spectroscopic Signatures of the Disk Wind



Dehghanian et al. 2021

Atlas of UV and X-Ray Spectroscopic Signatures of the Disk Wind

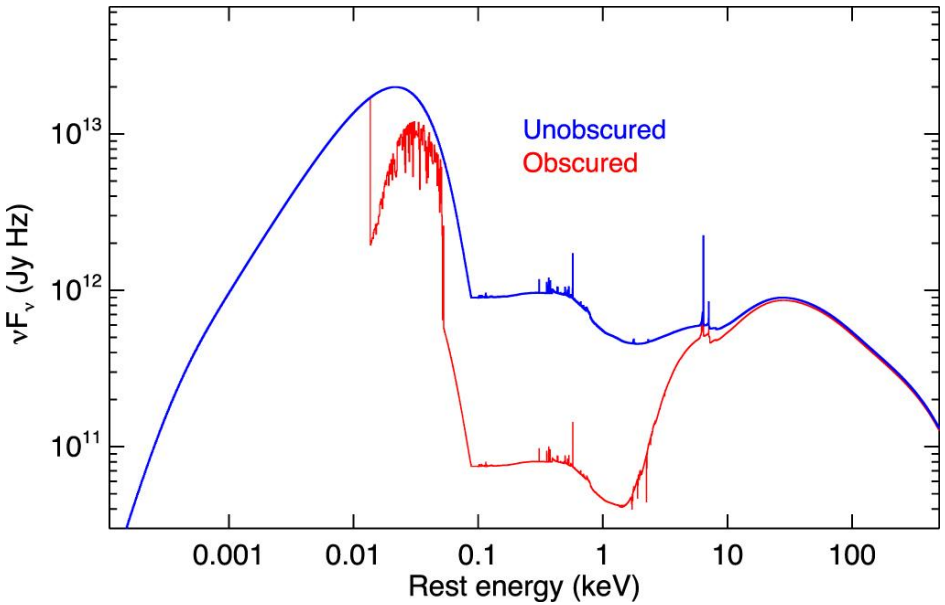


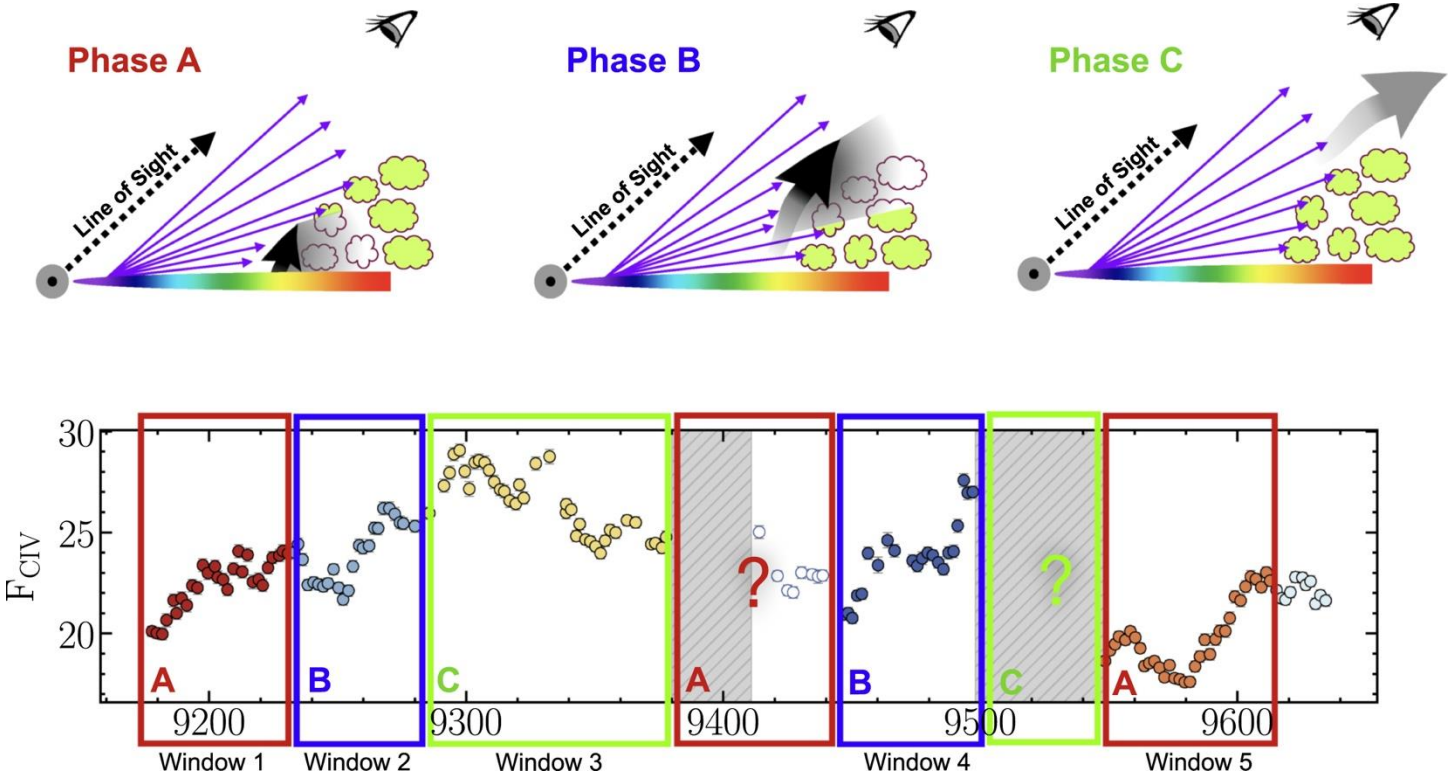
Dehghanian et al. 2021

Future:

Not a unique phenomenon

AGN STORM2: Mrk 817





Thank You for Your Attention!

Any questions? Please ask.