EXPLORING THE X-RAY UNIVERSE IN THE MICROCALORIMETER ERA

Priyanka Chakraborty
Center for Astrophysics | Harvard & Smithsonian

Image: https://chandra.harvard.edu/photo/2017/perseus/

Motivation:

- High resolution spectrum in the micro-calorimeter era from Hitomi and upcoming microcalorimeter missions- XRISM and Athena.

- Understanding atomic processes in collisionally-ionized, photoionized, and hybrid astrophysical plasma.

- Developing a general tool that can be applied for other systems with broad range of column densities.

- Making Cloudy compatible with the future microcalorimeter observations.

The Astrophysical Journal, 901:68 (10pp), 2020 September 20 https://doi.org/10.3847/1538-4357/abaaab

X-Ray Spectroscopy in the Microcalorimeter Era. I. Effects of Fe XXIV Resonant Auger Destruction on Fe XXV Kα Spectra

P. Chakraborty, G. J. Ferland, M. Chatzikos, F. Guzmán, and Y. Su
University of Kentucky, Lexington, KY, USA
Received 2020 June 19; revised 2020 July 26; accepted 2020 July 30; published 2020 September 23

The Astrophysical Journal, 901:69 (12pp), 2020 September 20 https://doi.org/10.3847/1538-4357/abaaac

X-Ray Spectroscopy in the Microcalorimeter Era. II. A New Diagnostic on Column Density from the Case A to B Transition in H- and He-like Iron

P. Chakraborty, G. J. Ferland, M. Chatzikos, F. Guzmán, and Y. Su
University of Kentucky, Lexington, KY, USA
Received 2020 June 19; revised 2020 July 6; accepted 2020 July 8; published 2020 September 23

The Astrophysical Journal, 912:26 (12pp), 2021 May 1 https://doi.org/10.3847/1538-4357/abed4a

X-Ray Spectroscopy in the Microcalorimeter Era. III. Line Formation under Case A, Case B, Case C, and Case D in H- and He-like Iron for a Photoionized Cloud

P Chakraborty[1], G. J. Ferland[1], M. Chatzikos[1], F. Guzmán[2], and Y. Su[1]
[1] University of Kentucky, Lexington, KY, USA
[2] University of North Georgia, Dahlonega, GA, USA
Received 2021 February 5; revised 2021 March 6; accepted 2021 March 8; published 2021 April 30

The Astrophysical Journal, 935:70 (11pp), 2022 August 20 https://doi.org/10.3847/1538-4357/ac7eb9

X-Ray Spectroscopy in the Microcalorimeter Era 4: Optical Depth Effects on the Soft X-Rays Studied with CLOUDY

Priyanka Chakraborty[1,2], Gary J. Ferland[2], Marios Chatzikos[2], Andrew C. Fabian[3], Stefano Bianchi[4], Francisco Guzmán[5], and Yuanyuan Su[2]
[1] Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA, USA; priyanka.chakraborty@cfa.harvard.edu
[2] University of Kentucky, Lexington, KY, USA
[3] Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK
[4] Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, via della Vasca Navale 84, I-00146 Roma, Italy
[5] University of North Georgia Dahlonega, GA, USA
Received 2022 March 31; revised 2022 June 22; accepted 2022 July 4; published 2022 August 17

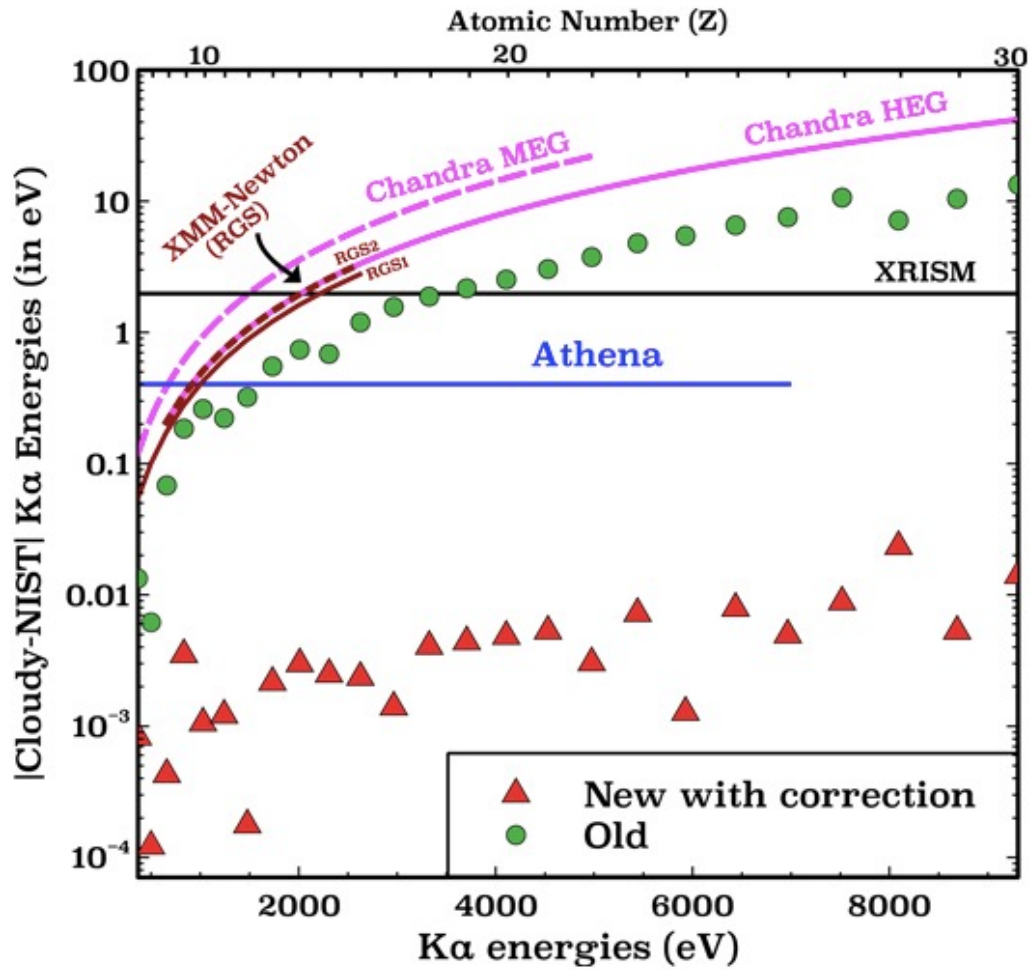
Cloudy in the Microcalorimeter Era: Improved Energies for Kα Transitions

P. Chakraborty[1], G. J. Ferland[1], S. Bianchi[2], and M. Chatzikos[1]

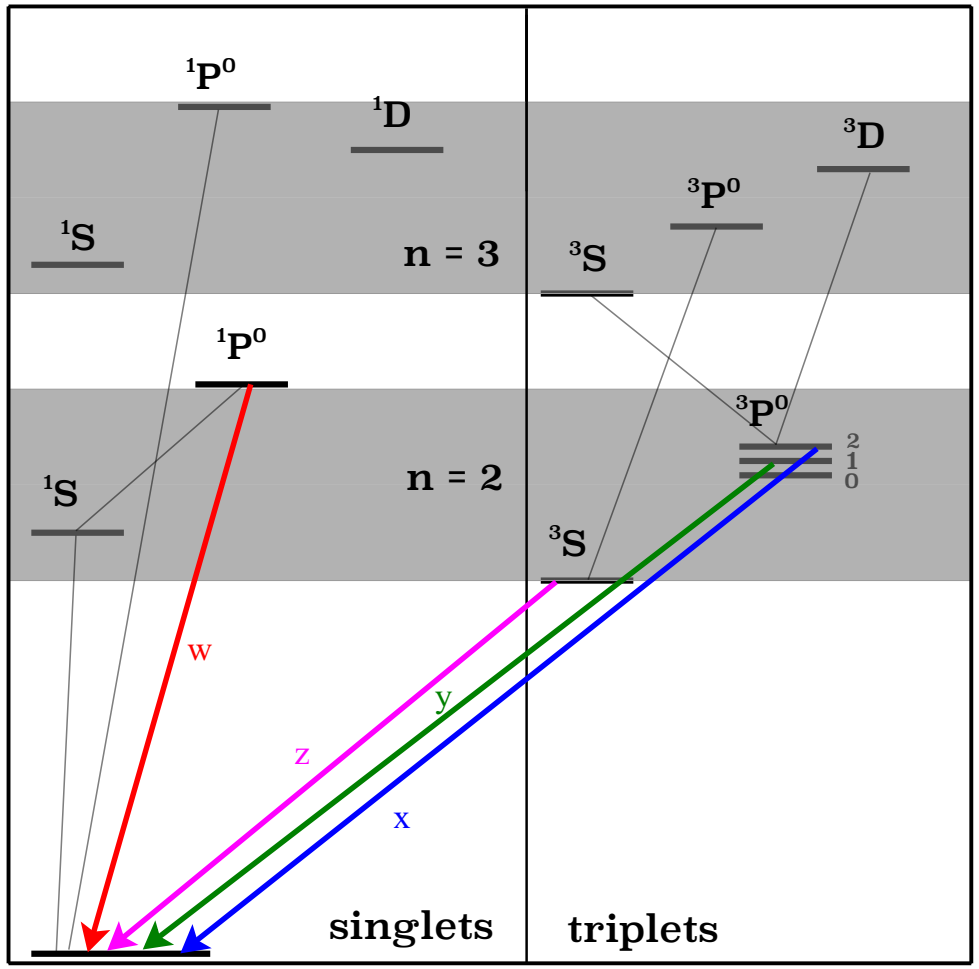
Published 2020 October 19 •

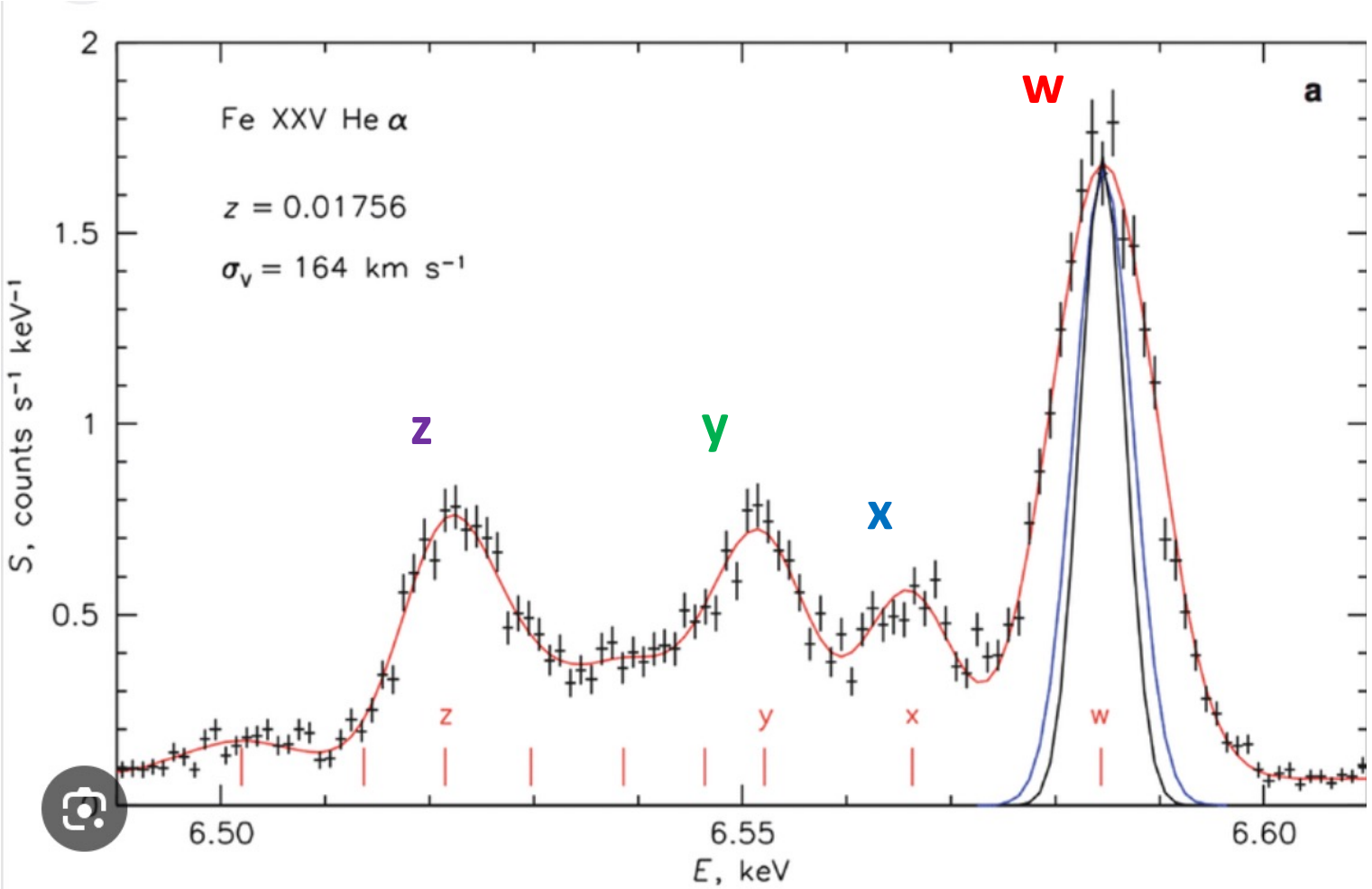
Research Notes of the AAS, Volume 4, Number 10

Citation P. Chakraborty *et al* 2020 *Res. Notes AAS* **4** 184



Atomic transitions in He-like iron





Hitomi collaboration et al.(2016c)

Various atomic processes contributing to change in line intensity:

1) Case A to B transition → Collisionally ionized/ Photoionized cloud

or

Case C to D transition → Photoionized cloud

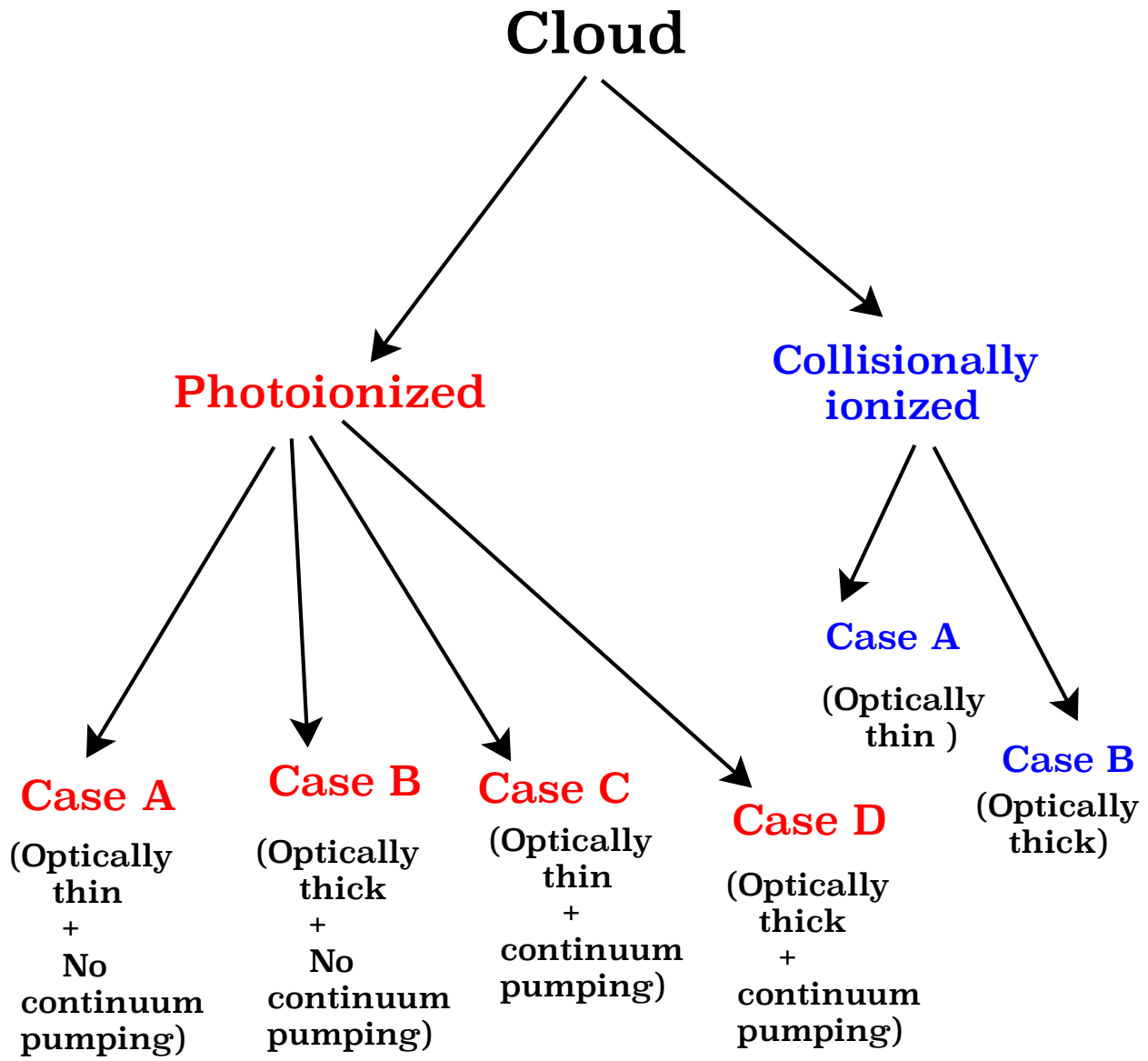
Case A, Case B, Case C, Case D are different line formation conditions

2) Line interlocking and Resonant Auger Destruction (RAD)

3) Electron scattering escape (ESE)

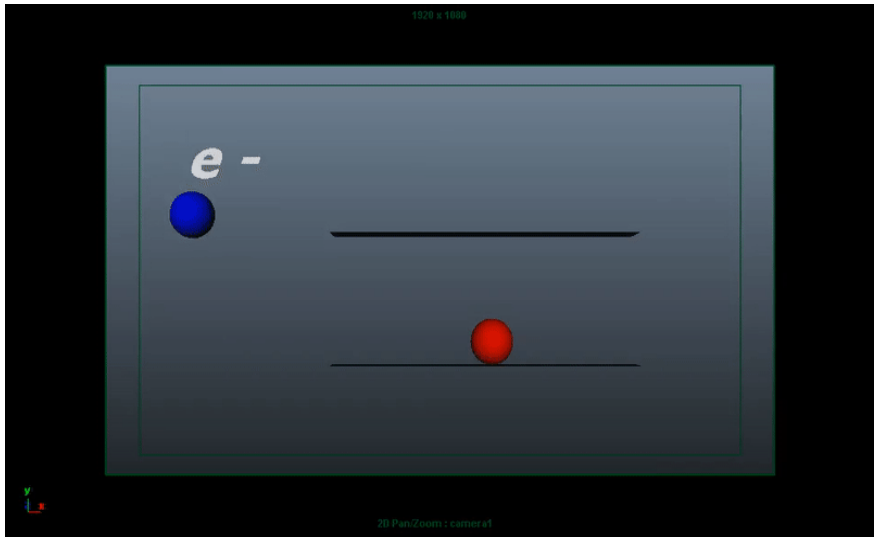
4) Photoelectric absorption

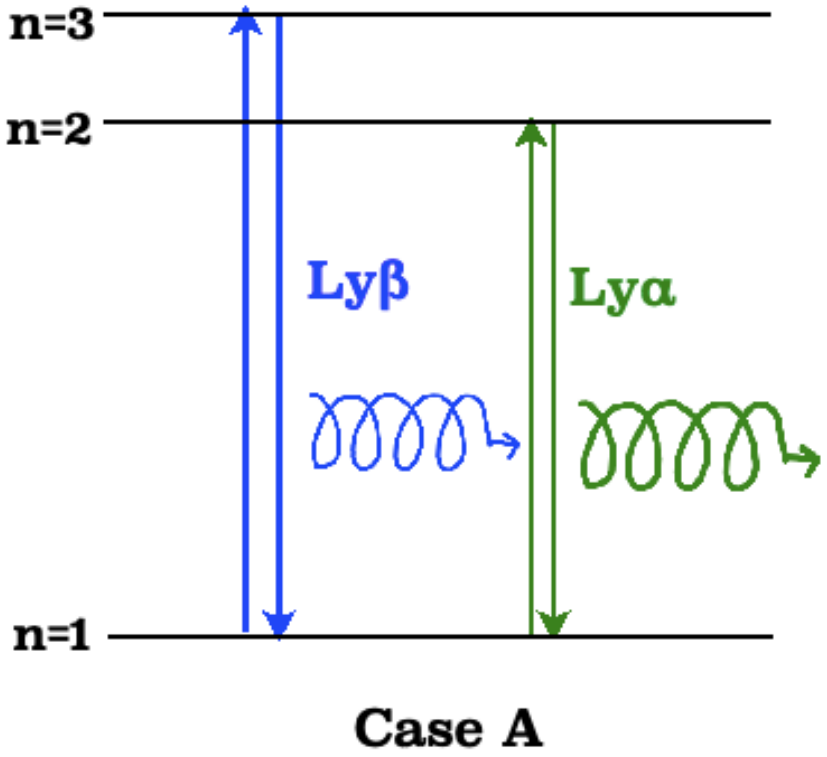
Various line formation conditions in a cloud

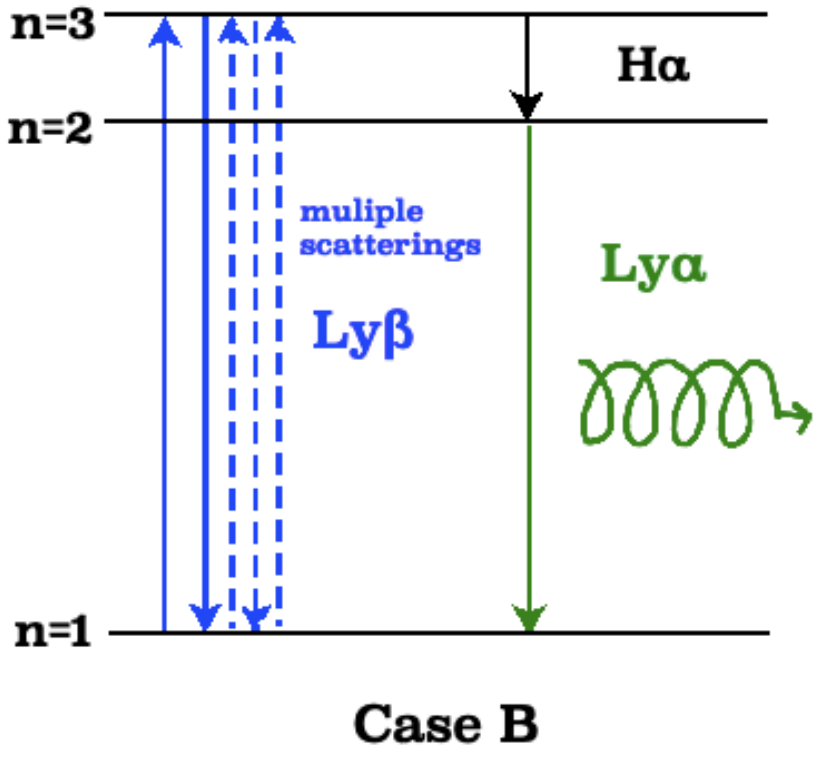


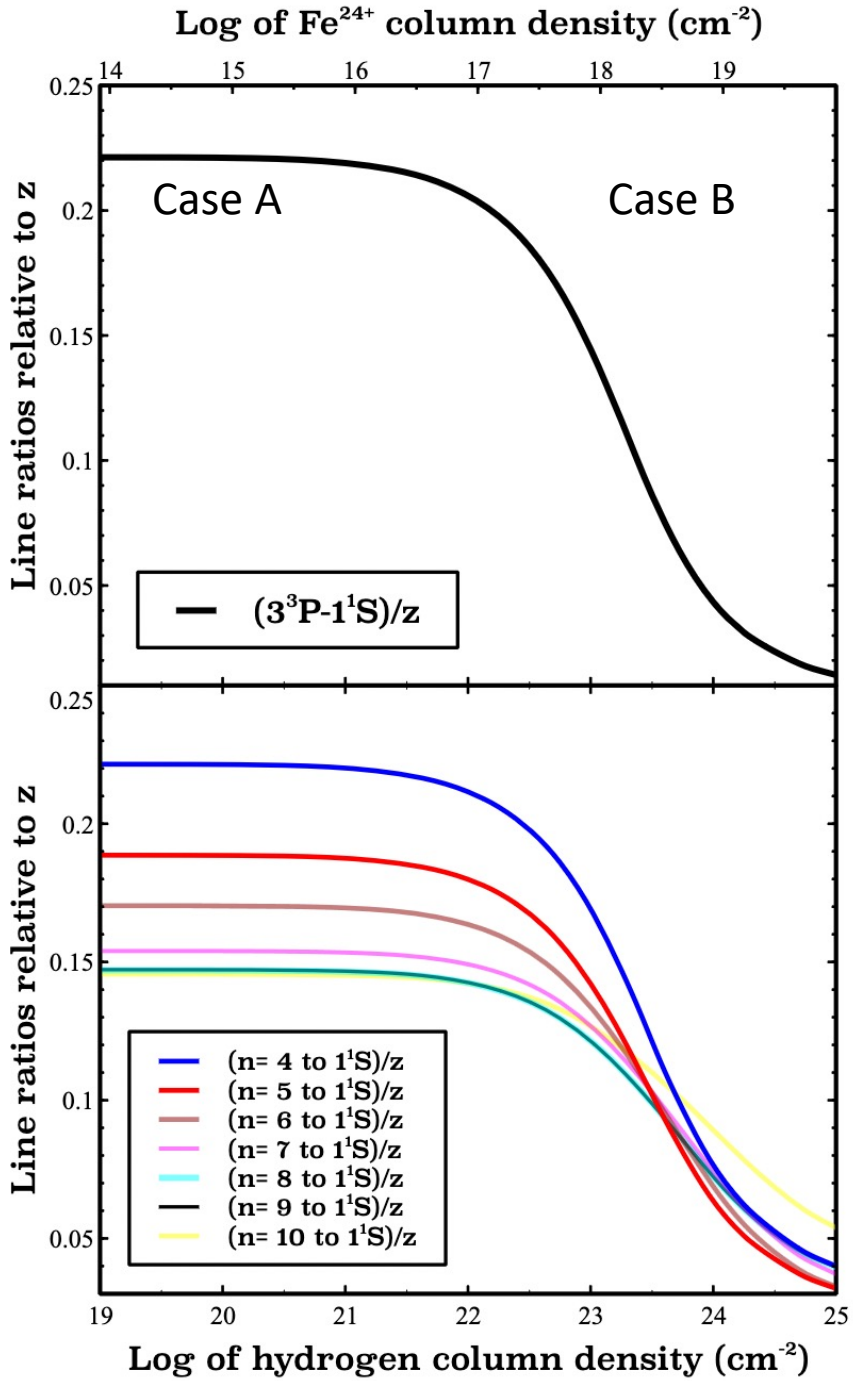
Chakraborty et al. (2021)

Case A and B in a collisionally ionized cloud



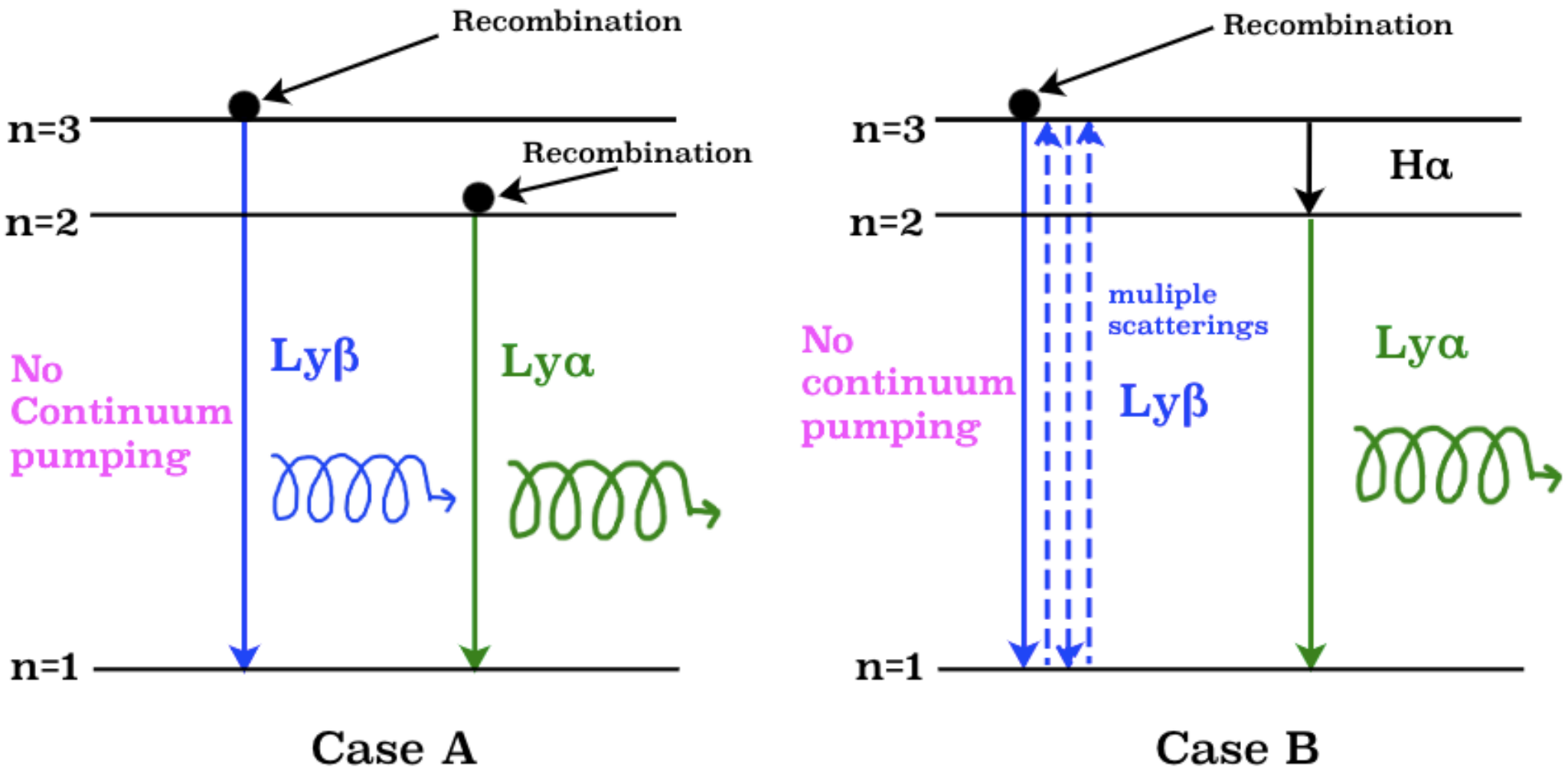






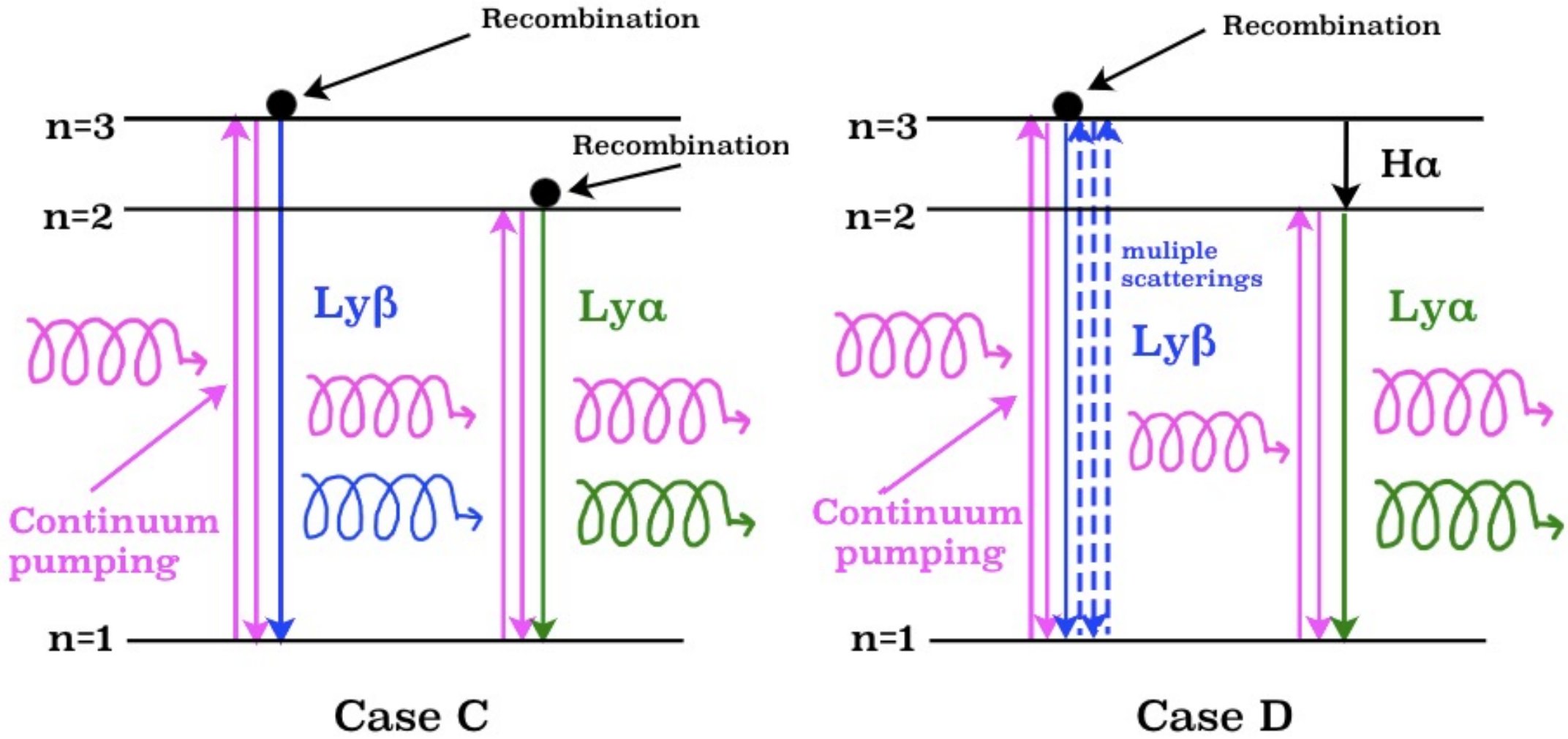
Decrease in the higher-order Lyman line intensity due to Case B

Case A and B in a photoionized cloud



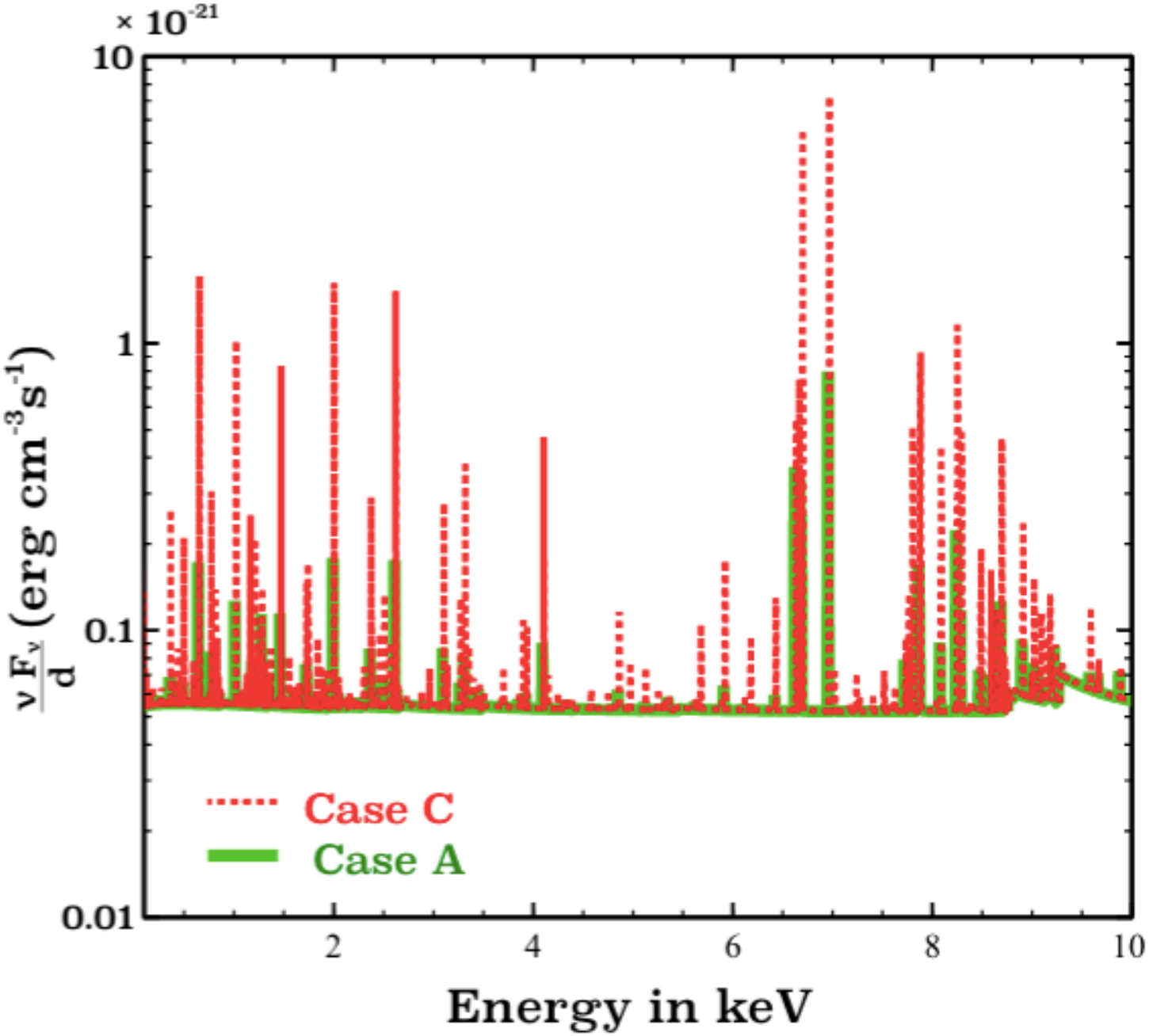
Chakraborty et al. (2021)

Case C and D in a photoionized cloud



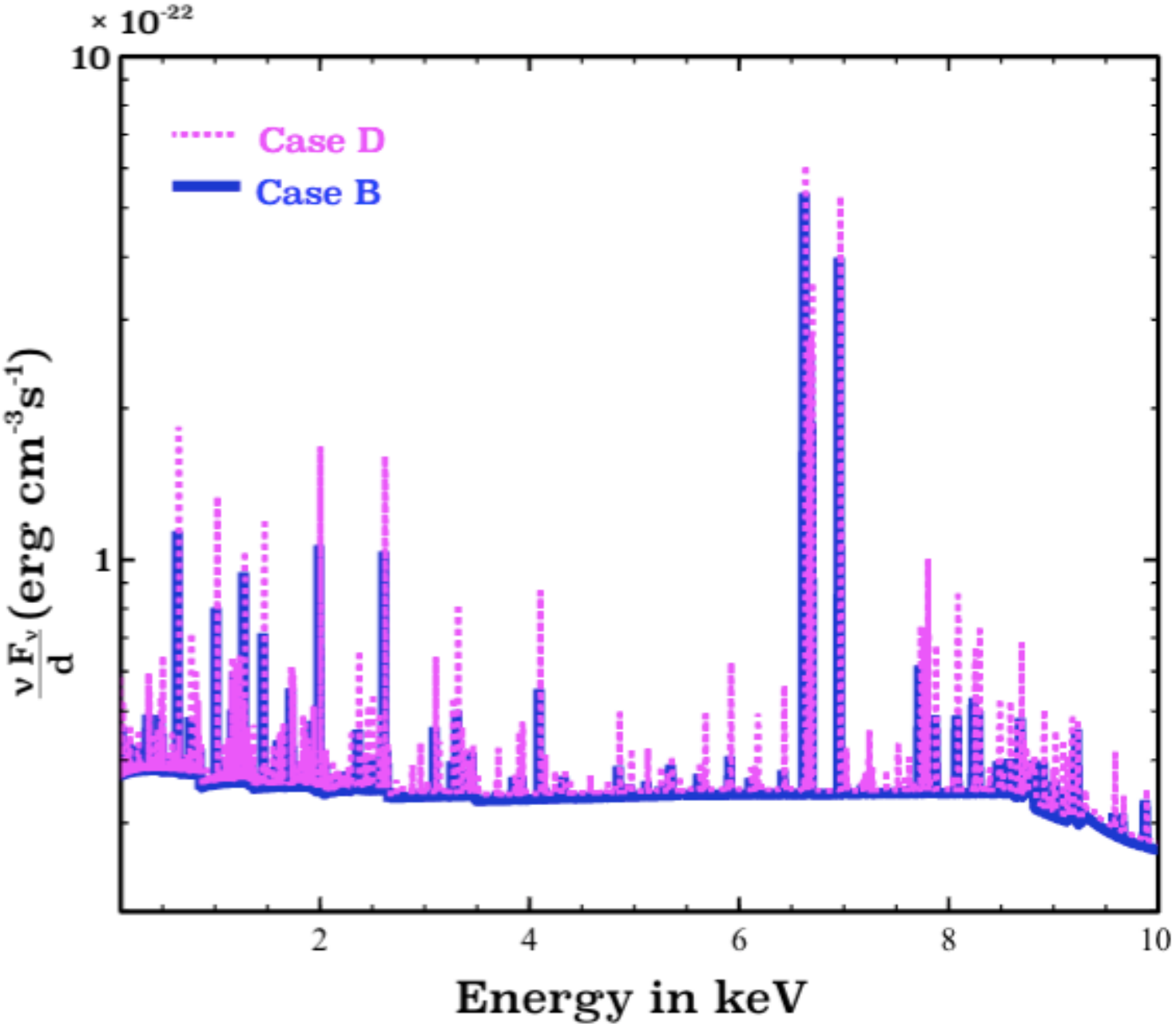
Chakraborty et al. (2021)

Case A and Case C

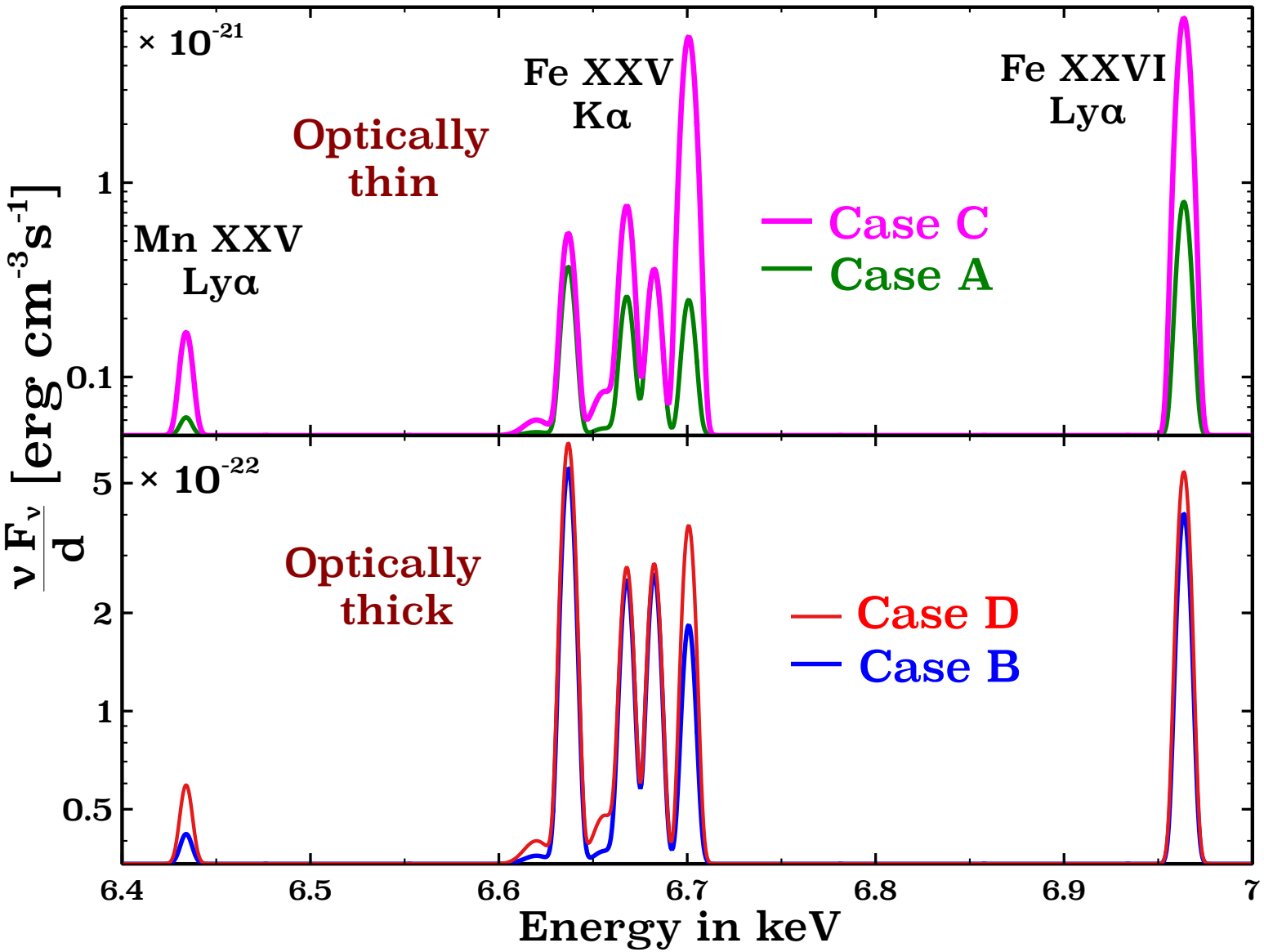


Chakraborty et al. (2021)

Case B and Case D



Chakraborty et al. (2021)


× 10^-21
Fe XXV
Kα
Fe XXVI
Lyα
Optically
thin
Mn XXV
Lyα
Case C
Case A
1
0.1
× 10^-22
5
2
1
0.5
Optically
thick
Case D
Case B
νF_ν / d [erg cm^-3 s^-1]
6.4
6.5
6.6
6.7
6.8
6.9
7
Energy in keV

The Astrophysical Journal, 912:26 (12pp), 2021 May 1 https://doi.org/10.3847/1538-4357/abed4a

X-Ray Spectroscopy in the Microcalorimeter Era. III. Line Formation under Case A, Case B, Case C, and Case D in H- and He-like Iron for a Photoionized Cloud

P Chakraborty[1], G. J. Ferland[1], M. Chatzikos[1], F. Guzmán[2], and Y. Su[1]
[1] University of Kentucky, Lexington, KY, USA
[2] University of North Georgia, Dahlonega, GA, USA
Received 2021 February 5; revised 2021 March 6; accepted 2021 March 8; published 2021 April 30

Case D studied for the first time in X-ray

Various atomic processes contributing to change in line intensity:

1) Case A to B transition → Collisionally ionized/ Photoionized cloud

or

Case C to D transition → Photoionized cloud

Case A, Case B, Case C, Case D are different line formation conditions

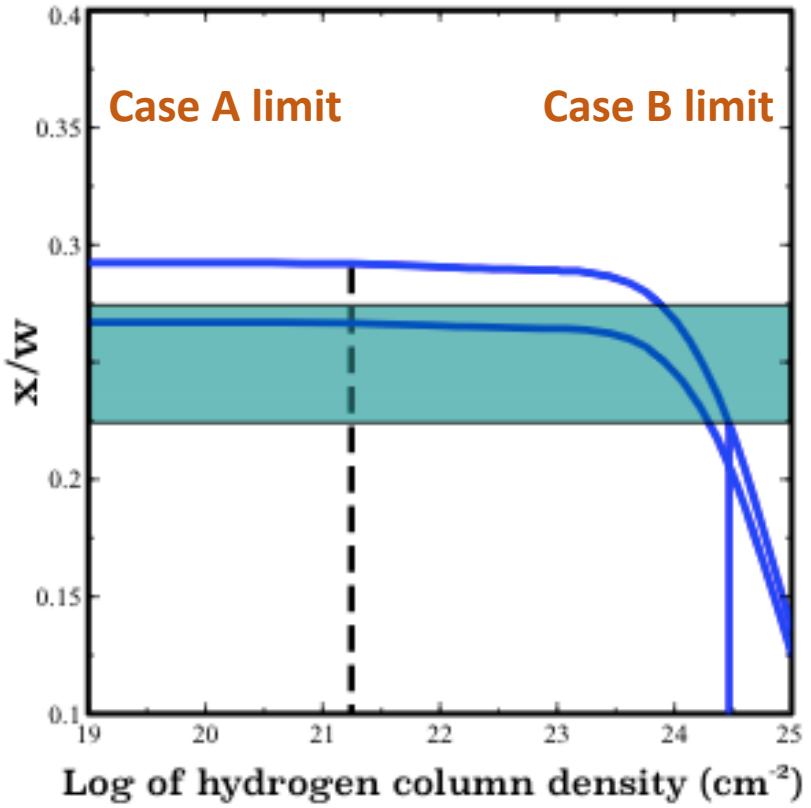
2) Line interlocking and Resonant Auger Destruction (RAD)

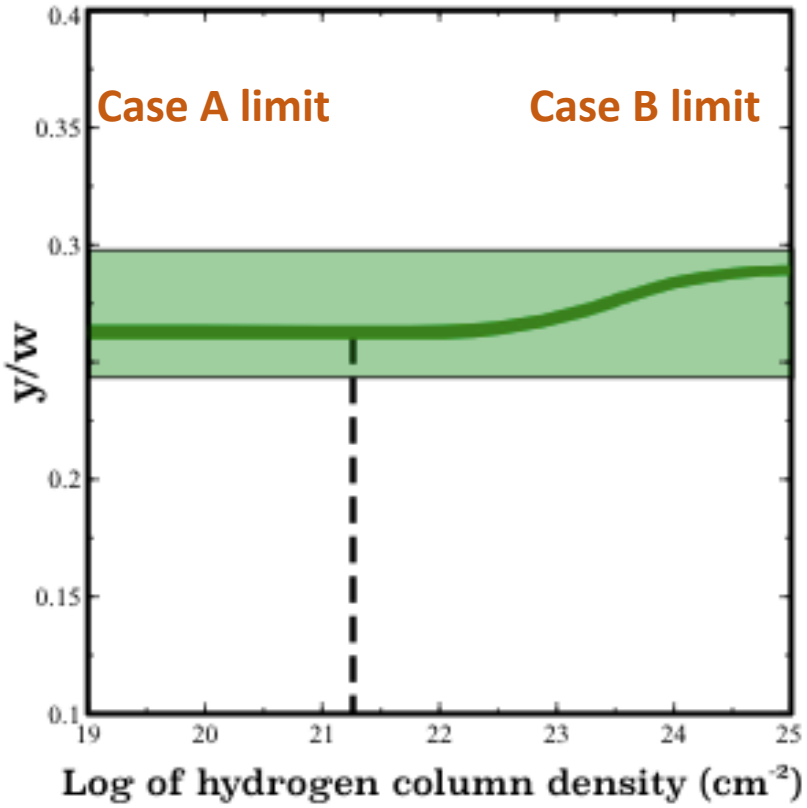
3) Electron scattering escape (ESE)

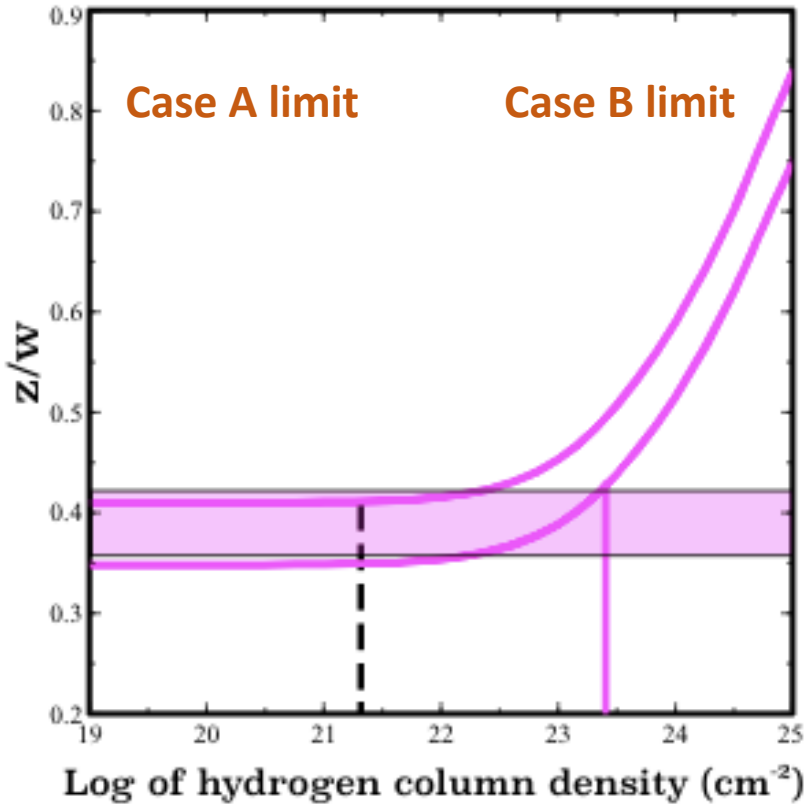
4) Photoelectric absorption

Collisionally ionized case:

Case A to B transition in Perseus
(novel method of measuring column density)



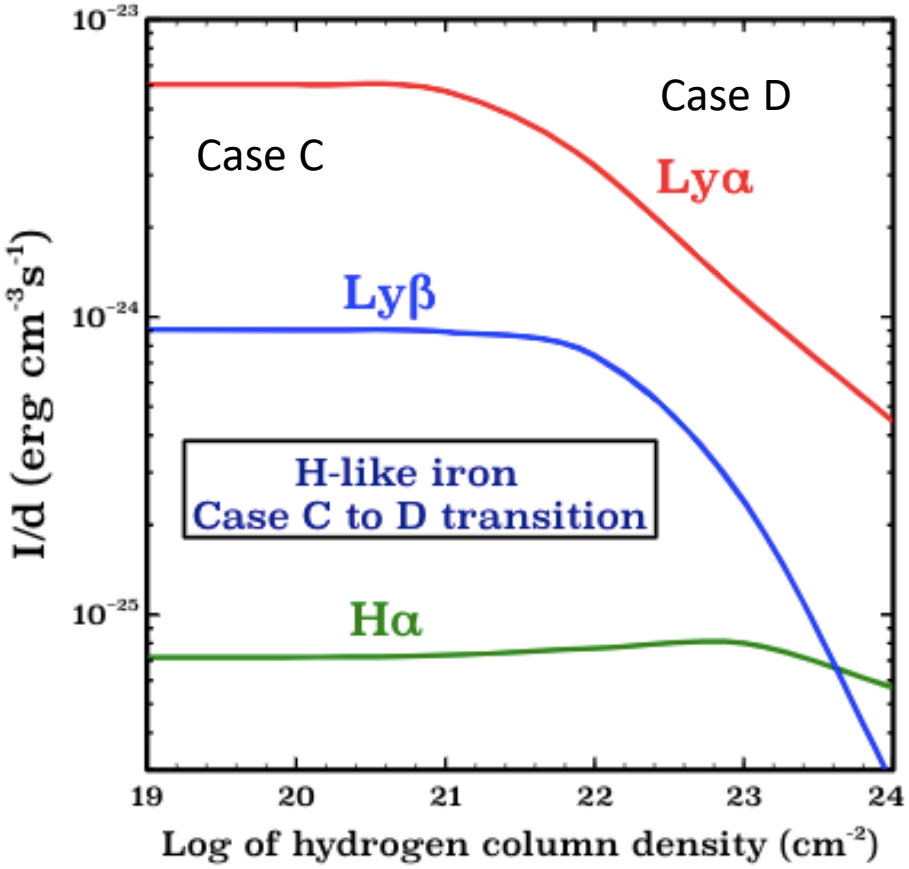


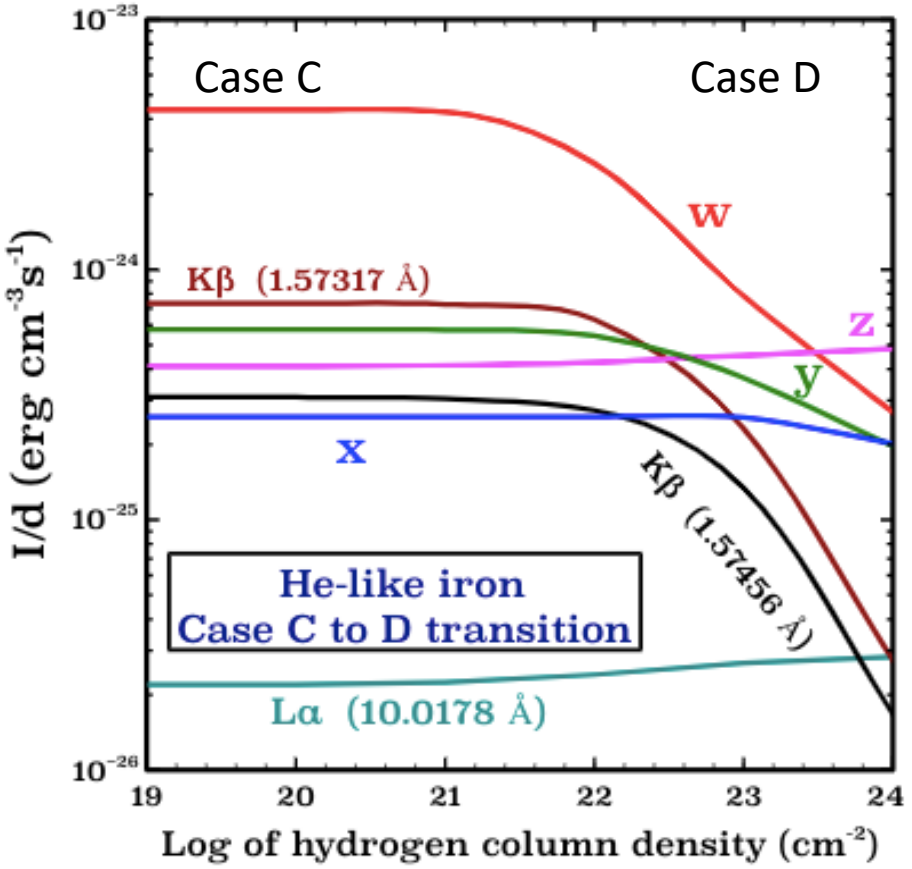


Chakraborty et al. (2020c)

Photoionized case:

Case C to D transition





Chakraborty et al. (2020c)

How can you simulate these line formation conditions in Cloudy?

Set up a small column density like 10^20 cm^{-2}, for Case A and Case C

The command you can use for Case A, this will switch off all the continuum pumping:

no induced processes

By default, the continuum pumping is on, with small column density, cloudy will produce Case C emission

Set up a large column density like 10^23 cm^{-2}, for Case B and Case D

Update in Iron He-like collision strengths

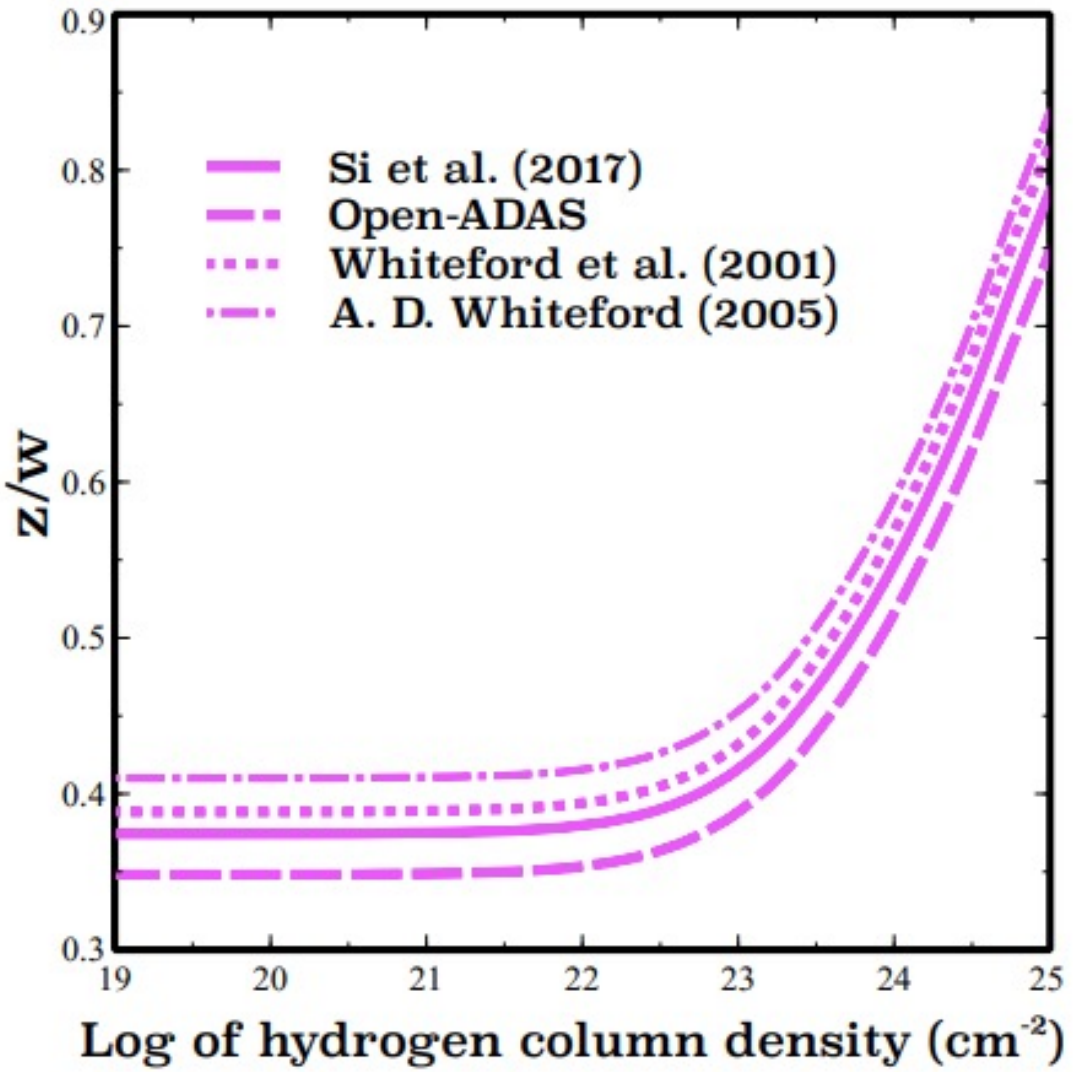
Replace Zhang and Sampson (1987)

Si et al. (2017)

Open- ADAS (A. Giunta (2012))

A.D. Whiteford (2005)

Whiteford et al. (2001)



The Astrophysical Journal, 901:69 (12pp), 2020 September 20 https://doi.org/10.3847/1538-4357/abaaac

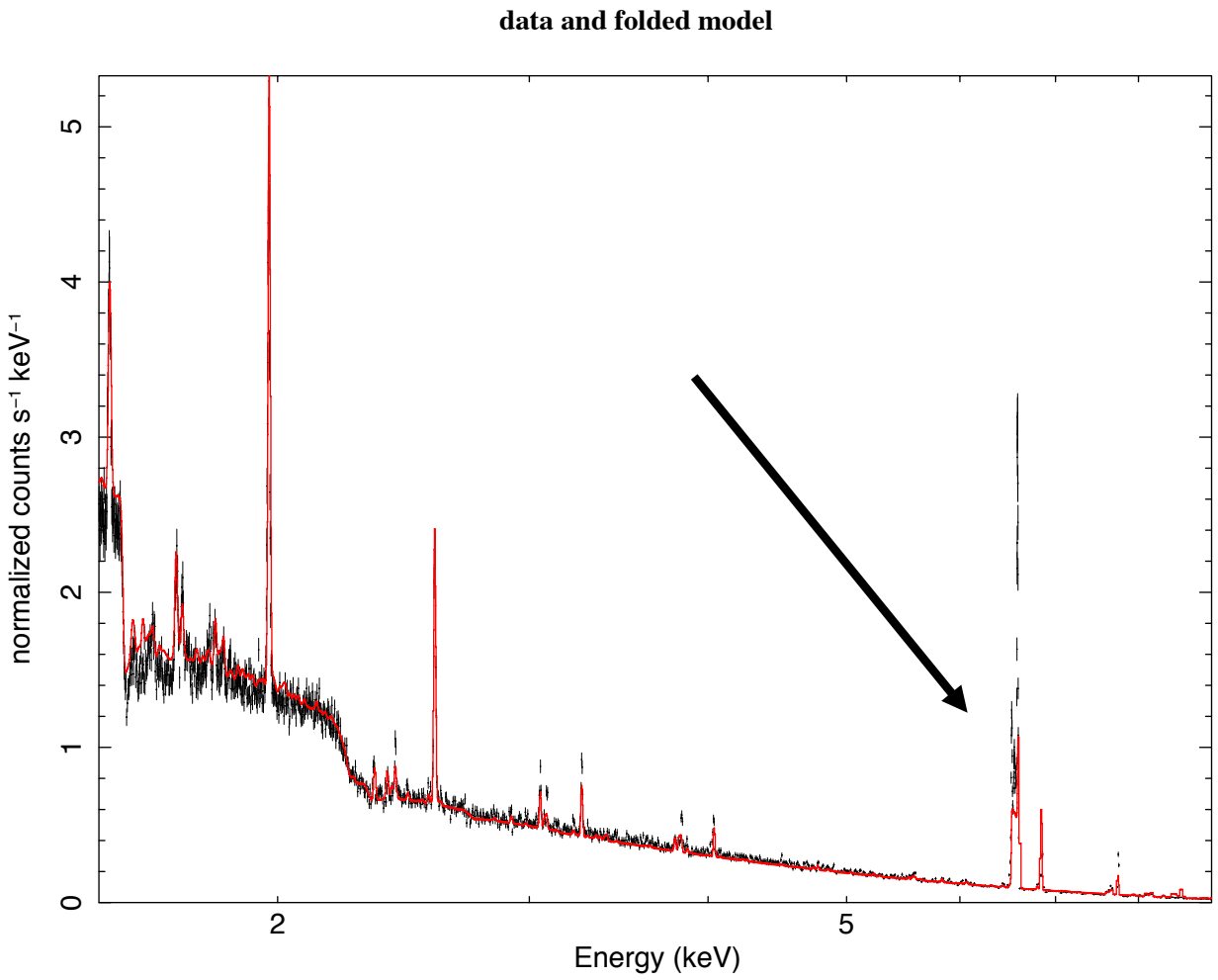
X-Ray Spectroscopy in the Microcalorimeter Era. II. A New Diagnostic on Column Density from the Case A to B Transition in H- and He-like Iron

P. Chakraborty, G. J. Ferland, M. Chatzikos, F. Guzmán, and Y. Su
University of Kentucky, Lexington, KY, USA
Received 2020 June 19; revised 2020 July 6; accepted 2020 July 8; published 2020 September 23

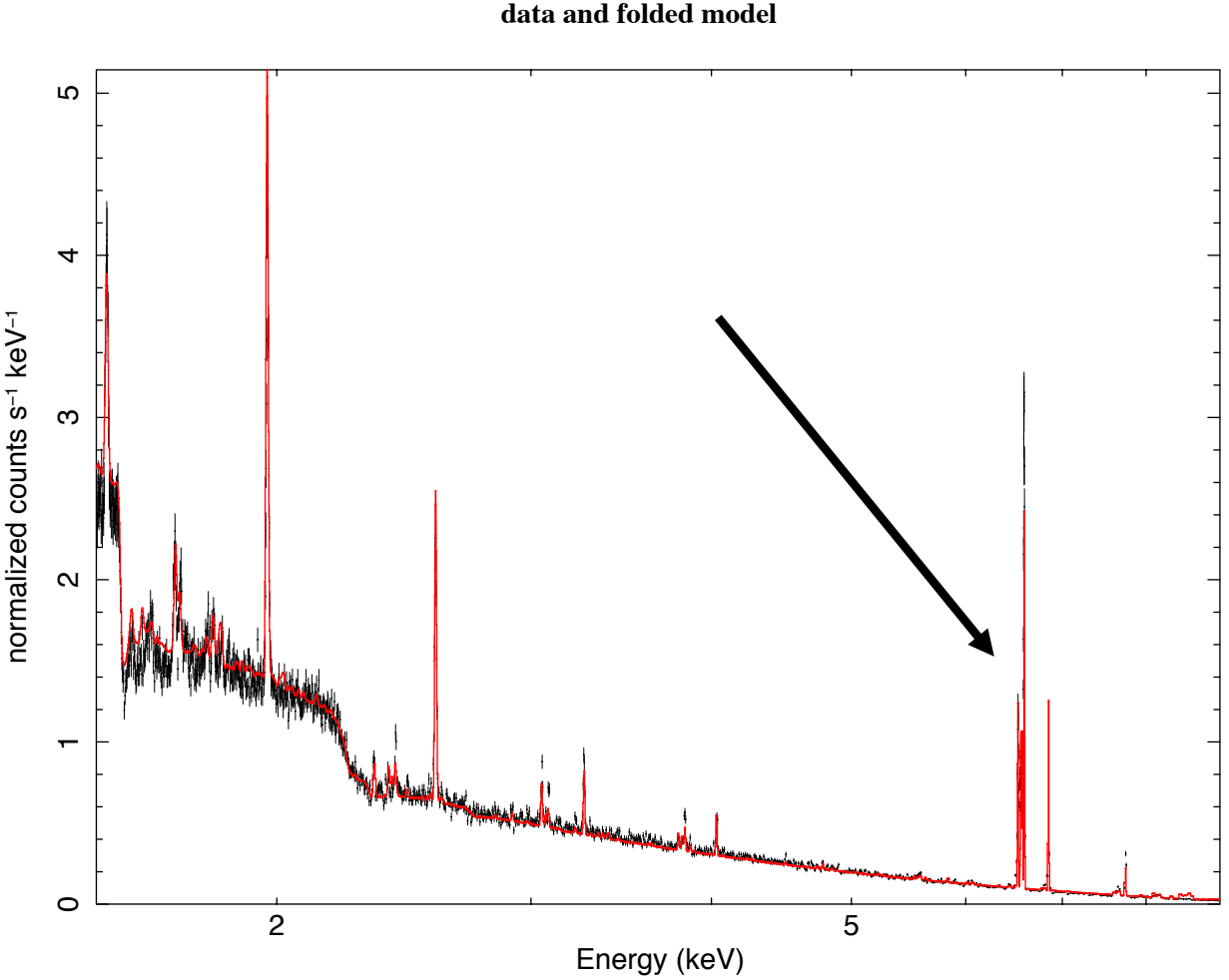
Update to ….data/continuum_mesh.ini

Update in Resolving Power
Cloudy/XSPEC Interface- XRISM Simulation

Previous version



Updated version



Summary

- Understanding atomic processes in collisionally ionized and photoionized cloud is important to interpret spectra from XRISM and Athena.

- This work established four asymptotic limits - Cases A, B, C, and D to describe the line formation processes in H- and He-like systems emitting in the X-rays (Chakraborty et al. 2021).

- A novel method of measuring column density comparing Cloudy simulated spectra with Hitomi observations was introduced from Case A to B transition (Chakraborty et al. 2020c).

- Case D is the least discussed of all four cases in the literature, but in interpreting XRISM spectrum, will in most cases be the most physical scenario for modeling spectrum from X-ray Binaries and AGNs.