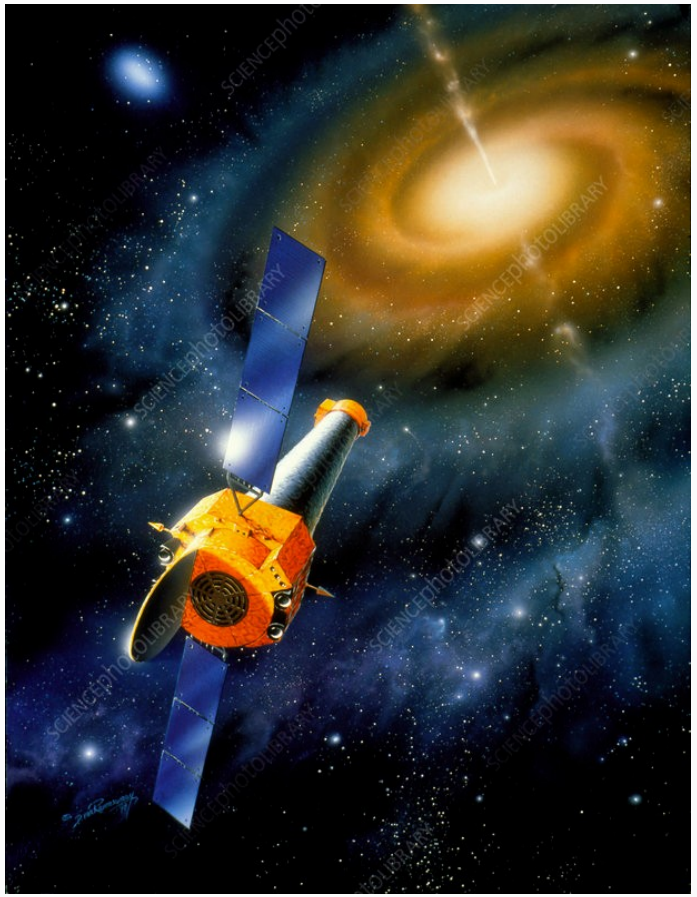
Rafał Wojaczyński

Astrophysics Department II

Radiative transfer simulations of accreting objects atmospheres and beyond

22-24.01.2025

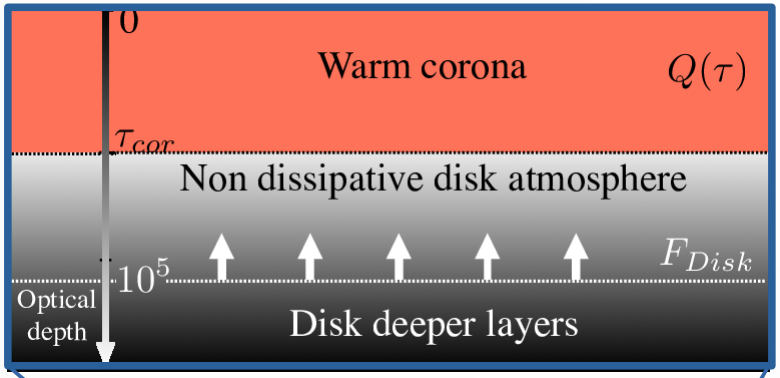


Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences

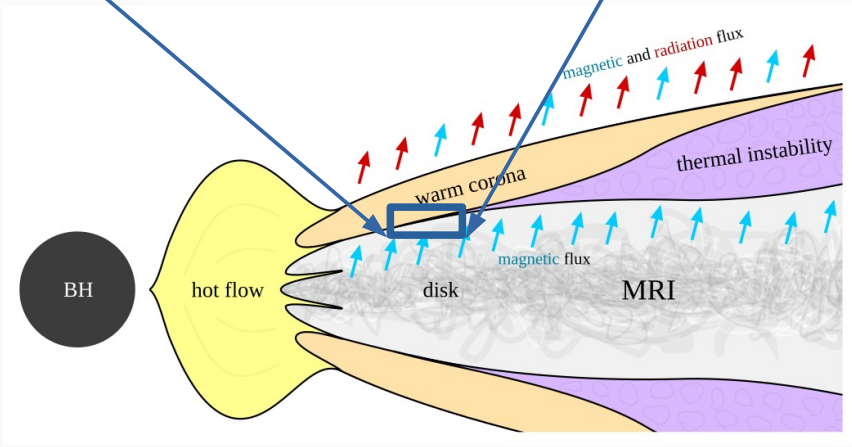
NATIONAL SCIENCE CENTRE POLAND

OPUS: 2021/41/B/ST9/04110

Iron Line Dependence on Plasma Parameters, Illumination, and Internal Heating

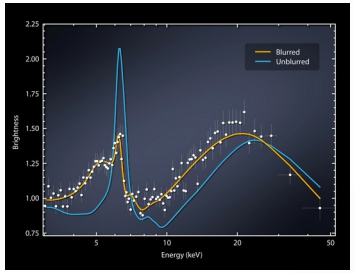


Różańska et al. 2015



Gronkiewicz et al. 2020

Final Fe line



TITAN properties:

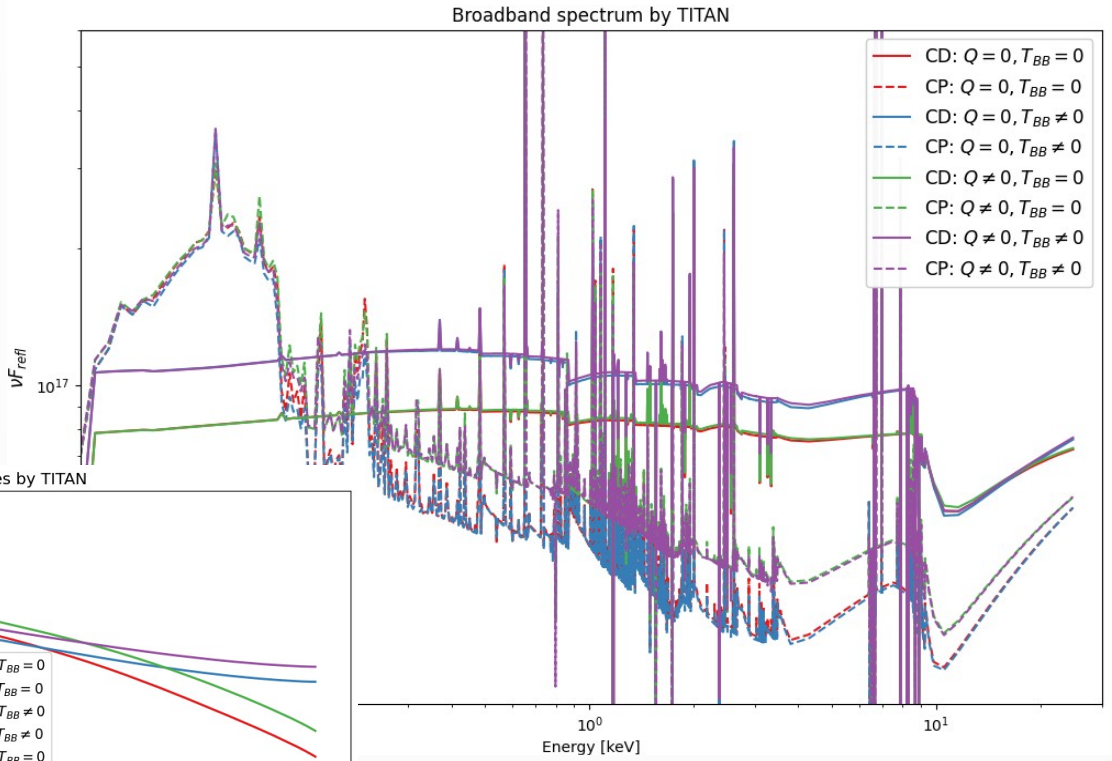
- External illumination by X-ray source
- Photoionization on heavy elements
- Radiation processes included: Free-Free, Compton, photoionization, recombination, fluorescence on iron
- ~ 4100 atomic lines included
- Internal mechanical heating considered Q(τ)
- Back illumination T_{BB} from disk F_{Disk}

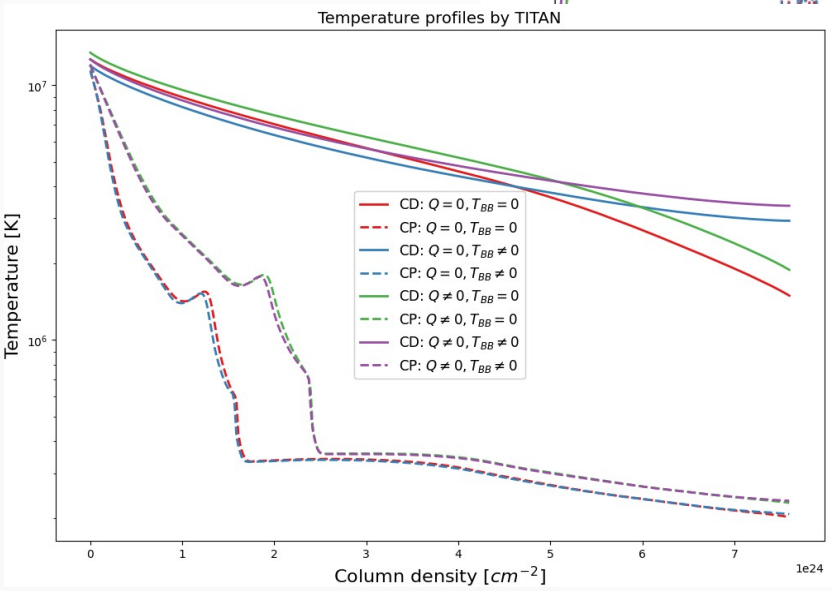
- No magnetic field
- Neglect the modification of line profile due to the: Compton scattering, disk rotation and General Relativity effects

Broadband spectrum and temperature profiles (generated with TITAN)

- 1) Internal heating Q=0, accretion disk illumination T_{BB}=0
- 2) Internal heating Q=0, *accretion disk illumination $T_{BB} \neq 0$*
- 3) *Internal heating $Q \neq 0$*, accretion disk illumination T_{BB}=0
- 4) *Internal heating $Q \neq 0$, accretion disk illumination $T_{BB} \neq 0$*

CD: constant density, CP: constant pressure





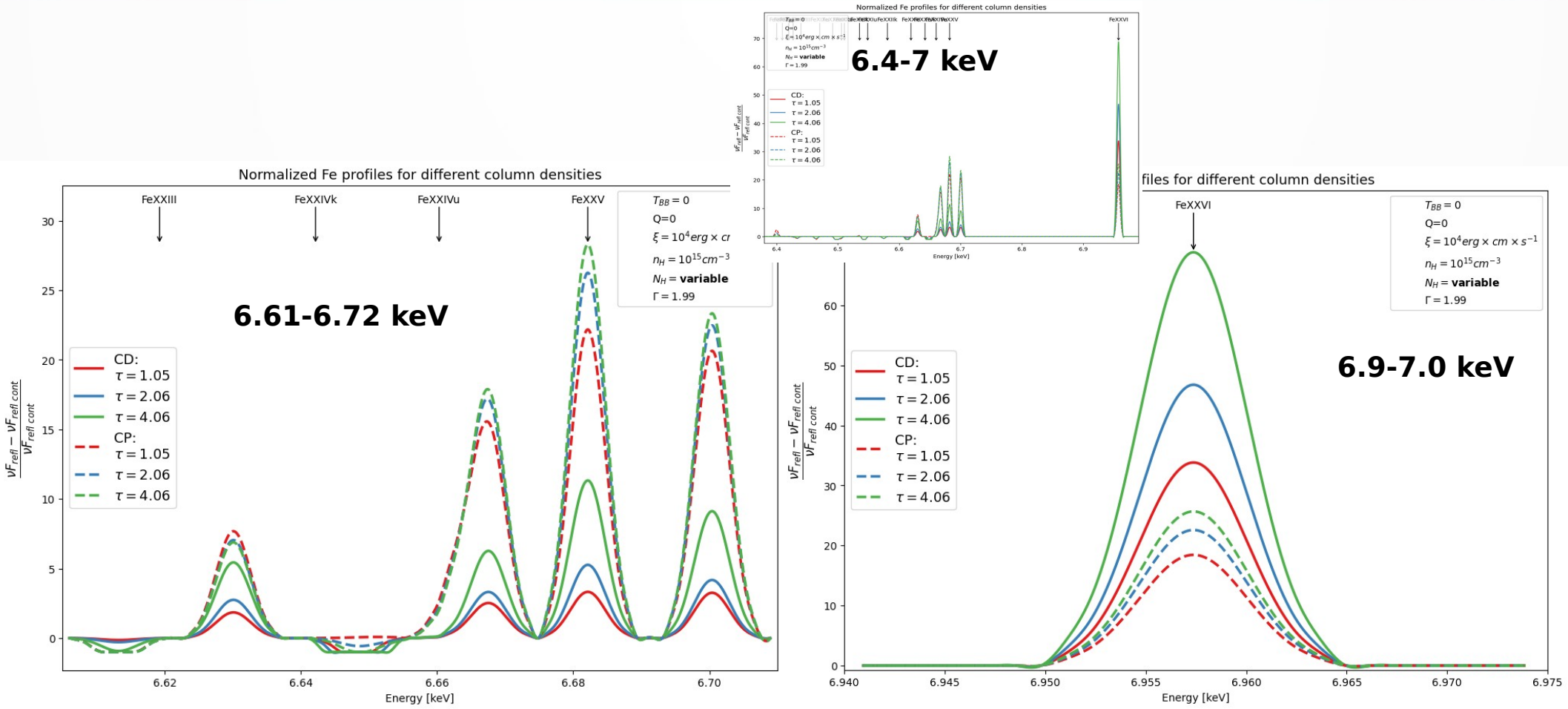
All scenarios assume the same:

- external illumination (PL, Γ=1.99)
- ionization $\xi = 10^4$ *erg* cm/s
- gas density at surface $n_H(0) = 10^{15}$ cm^{-3}
- τ = 6.34

In addition we considered:

- mechanical heating Q = 10^{-24} erg cm^3/s
- back illumination $T_{BB} = 10^5$ K

External illumination by X-rays only



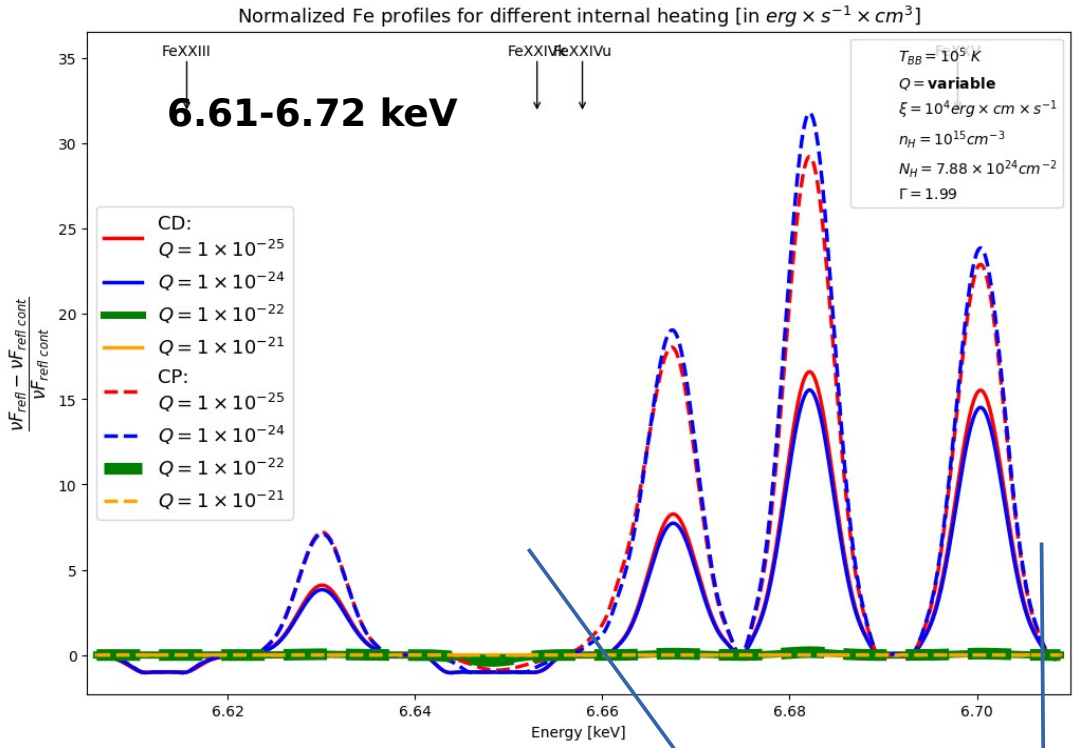
Dependence on column densities

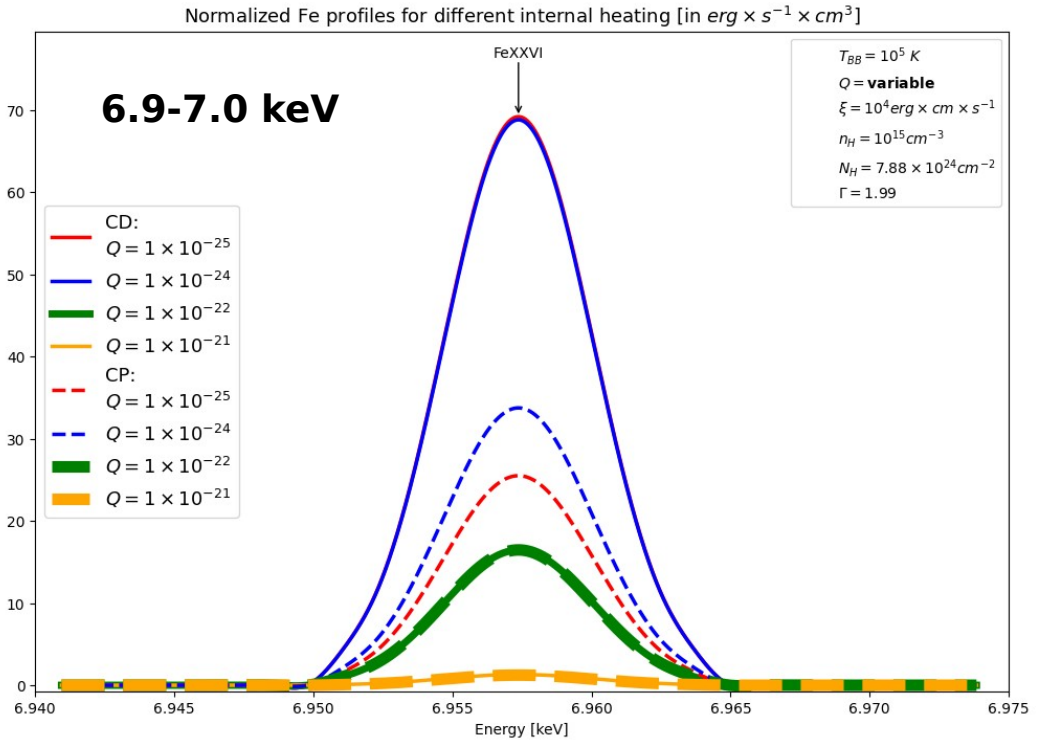
CP vs CD: Constant pressure give stronger lines for the same optical thickness (column density).

CP vs CD: Constant density give stronger lines for the same optical thickness (column density).

Stronger lines created with higher optical thickness.

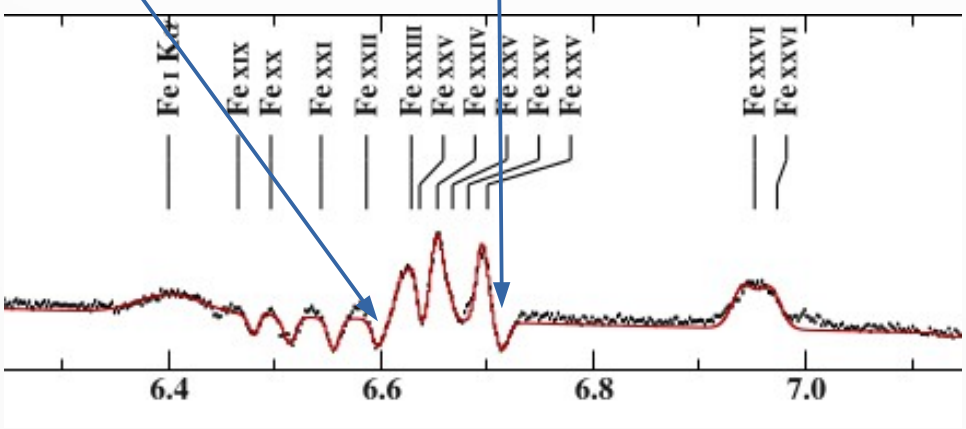
Internal mechanical heating Q≠0, no back illumination

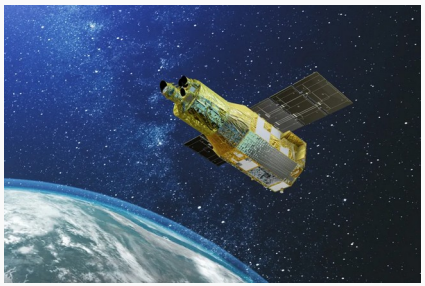




Influence of internal heating

No back illumination





Spectrum of Cyg X-3:
Audard et all (XRISM Collaboration), ApJL 977:L34 2024

CP vs CD:
Constant pressure give stronger lines with the same internal heating at 6.6-6.7 keV

Constant density give stronger lines at 6.9 keV

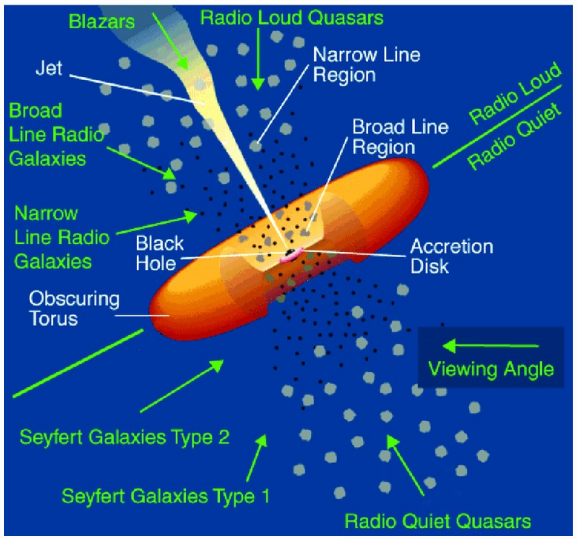
No iron lines for large heating.
Lines are created when Q < 10^{-23}

X-ray fingerprints of accreting objects

Goals:

develop a new code in Julia for radiative transfer

- cover 5 characteristic X-ray fingerprints of accreting objects
- towards common model of accretion (AGN vs XRBs)
  - **the same physical processes in central parts of accretion flows**
  - **strong X-ray radiation**



ALI method of radiative transfer (TITAN)

non-LTE equation of state (TITAN), Dumont 2003

Atomic data:
- TITAN db (4100 transitions)
- atomdb.org atomic data for astrophysicists

NEW CODE

Compton scattering: Compton redistribution functions Madej et. Al 2017

Thermal instability in the warm corona (Gronkiewicz & Różańska 2020)

New code witch changes tracked, stored on git repo, and open to public.

Publication update & summary

Publications:

→ Iron line emission from the accreting gas in AGN
Parikshit P. Biswas, Rafał Wojaczyński, Agata Różańska and Dominik Gronkiewicz
MNRAS, in preparation (2025)

Conferences:

→ Talk: 'Investigating Iron Line Dependence on Plasma Parameters, Illumination, and Internal Heating Using TITAN Photoionization Code'
Wojaczyński, R., Biswas P. , Palit B., Różańska A.
Sexten 2024. From the Dolomites to the event horizon, Italy, 8-12 July 2024

→ Talk: 'Investigating Iron Line Dependence on Plasma Parameters, Illumination, and Internal Heating Using TITAN Photoionization Code'
Wojaczyński, R., Biswas P. , Palit B., Różańska A.
Galactic and Extragalactic X-ray Transients, theory and observational perspectives, Warsaw, 11-13 September 2024

Other:

→ Academic supervision of PhD student Laetitia Gibaud from the University of Białystok during her internship in CAMK in August - September 2024

→ Assistant supervisor for PhD student Parikshit P. Biswas, Modelling X-ray spectrum for accreting compact objects

The End

Thank you !