

Rafał Wojaczyński

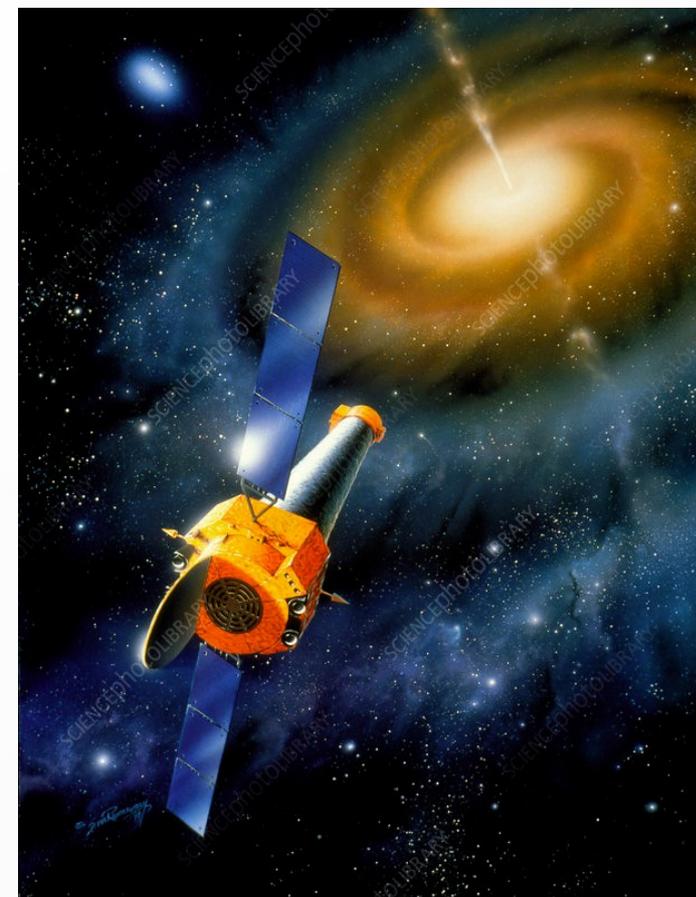
Astrophysics Department II

Progress on developing photoionization codes for modelling X-ray spectra of AGN

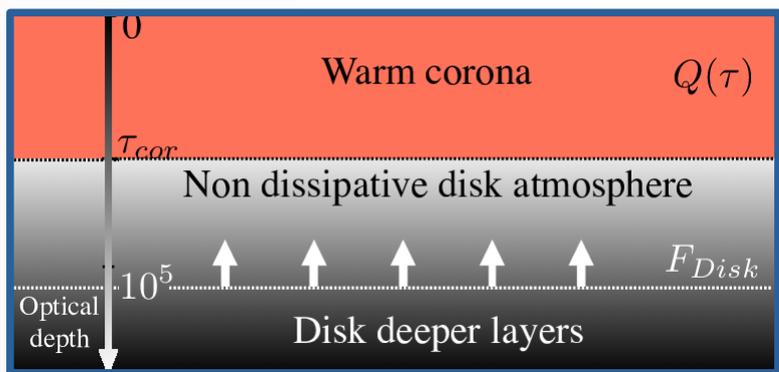
AGENDA:

- > Introduce comptonisation into full radiative code
- > Test iron line visibility in NEWAthena simulated data
- > GEANT4 simulations of particles penetrating AHEPAM

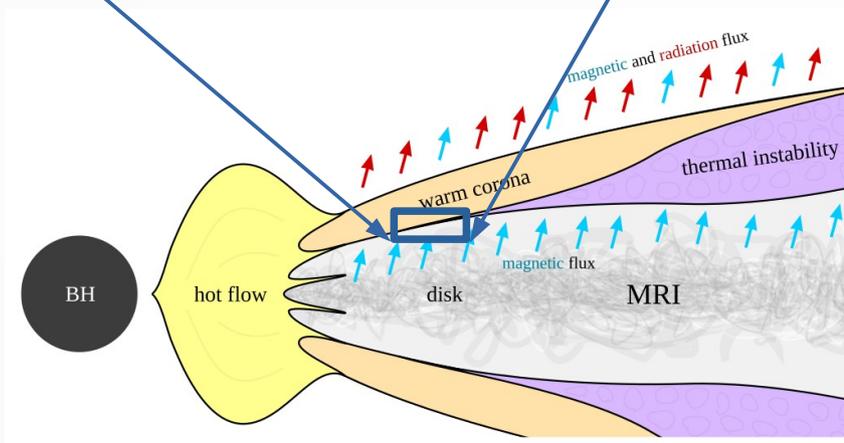
4-6.02.2026



TITAN software and its successor – KRONOS



Róžańska et al. 2015



Gronkiewicz et al. 2020

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 $Q(\tau)$
- ▶ 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

Goals:

Develop a new code in Julia for radiative transfer:

- ▶ include comptonisation of lines by redistribution functions into full radiative transfer code ✓
- ▶ include hydrostatic equilibrium
- ▶ enlarge atomic database
- ▶ towards common model of accretion (AGN vs XRBs)

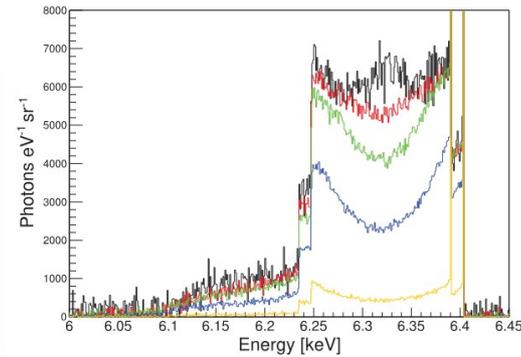
Implementing comptonisation into full radiative transfer code

Steps achieved:

- introduced scattering part to source function
- modified ALI mechanism for rapid convergence
- precompiled redistribution functions used for large frequency grid (continuum + 4141 lines) and wide temperature range (1e4-1e8 K)

TODO:

- more dense grid at Fe 6.4 keV line red wing
- introduce asymmetry of line



Inclination:

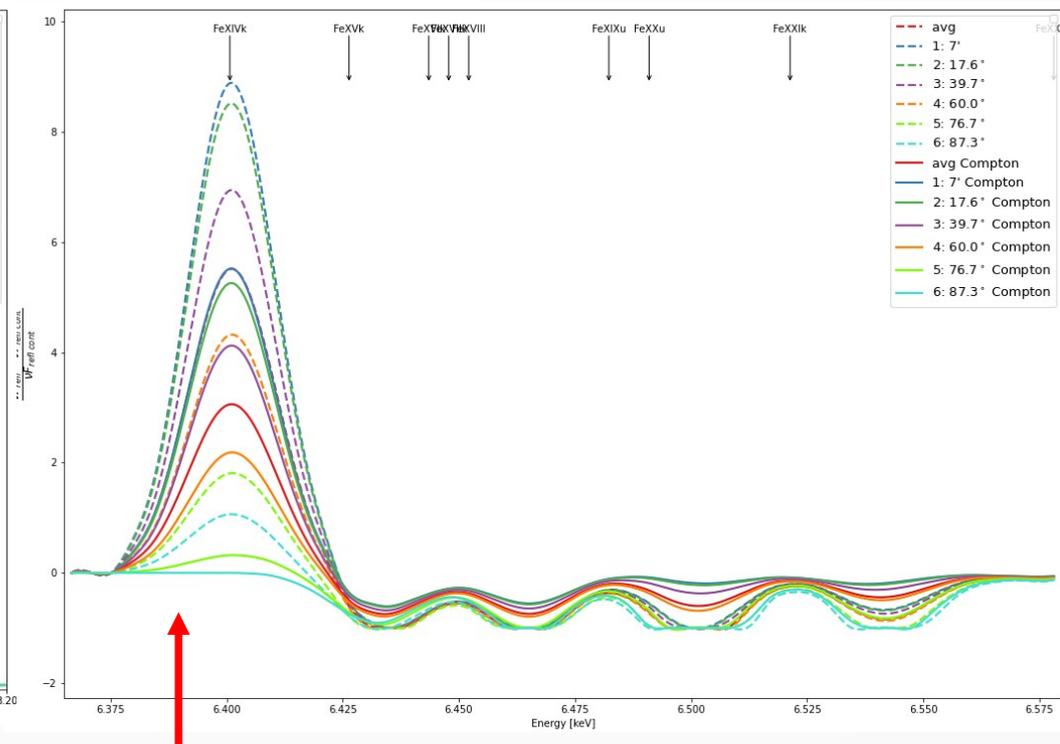
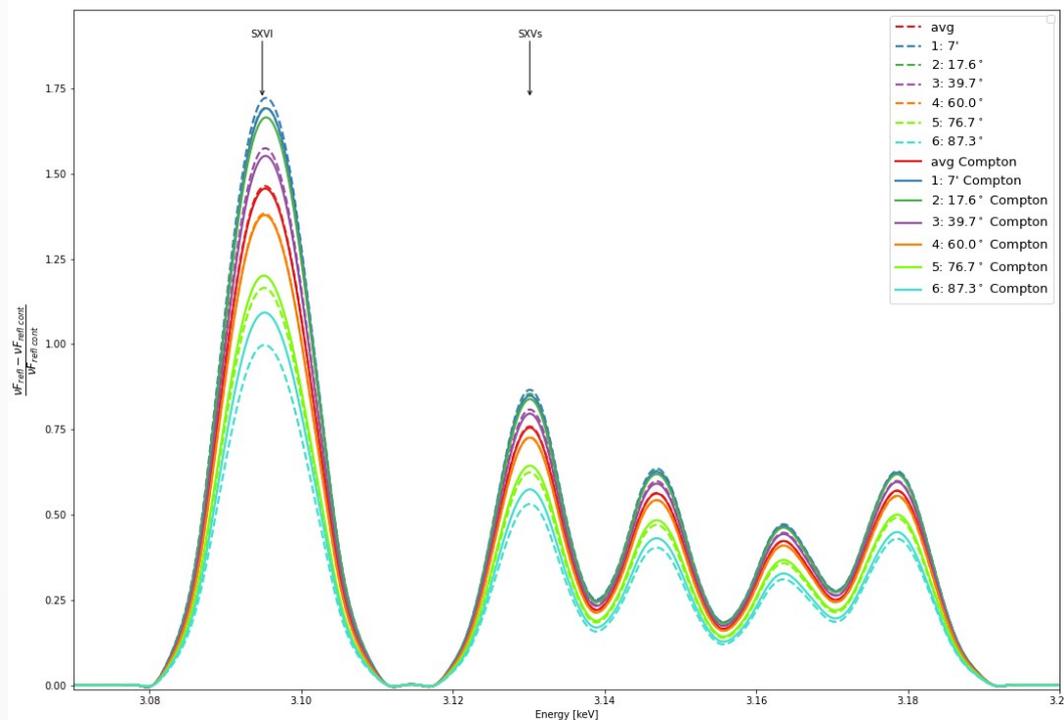
$0^\circ \leq \theta < 10^\circ$ (black)

$20^\circ \leq \theta < 30^\circ$ (red),

...

$80^\circ \leq \theta < 90^\circ$ (yellow)

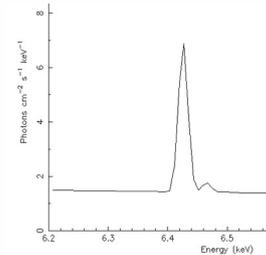
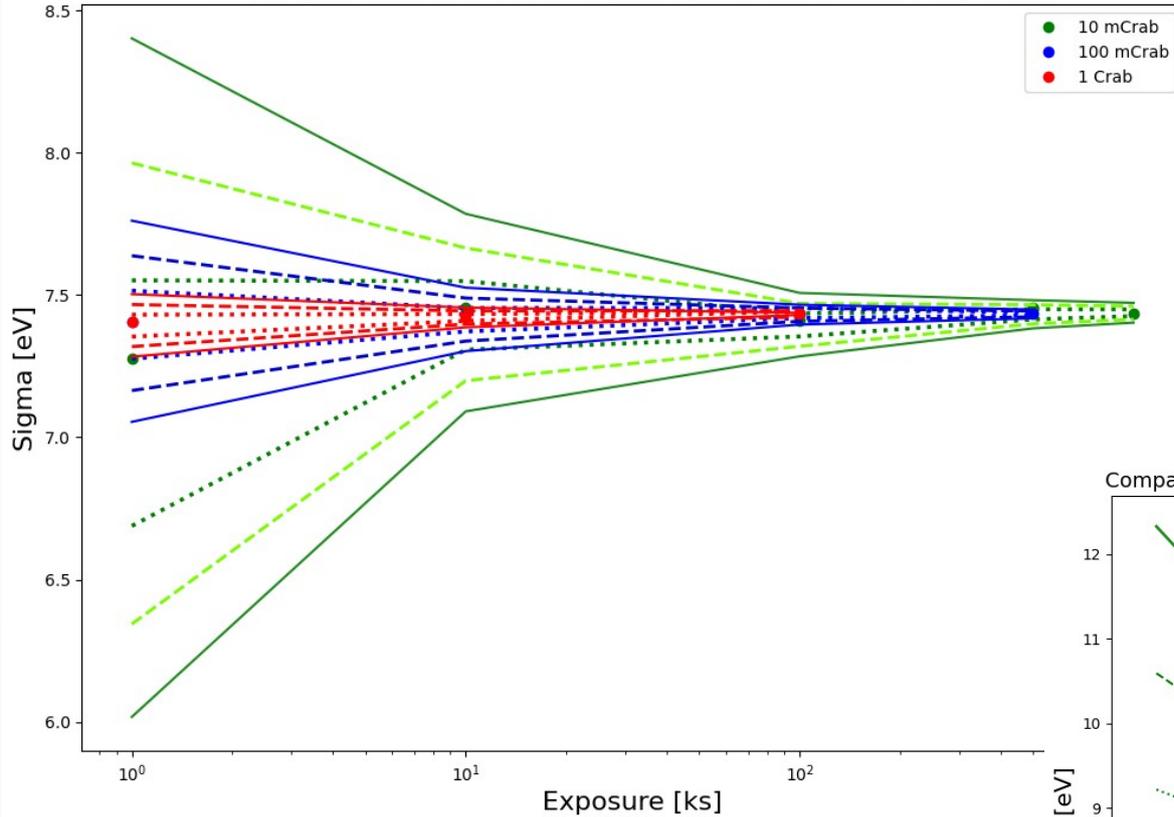
Odaka et al 2016



First look at full transfer comptonisation of Fe neutral line at 6.4 keV

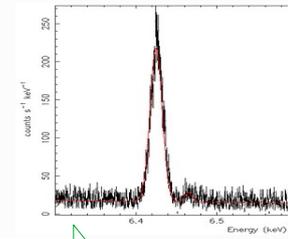
NewATHENA iron line visibility studies based on TITAN models

1-2-3 sigma confidence levels for different NewATHENA/X-IFU exposures



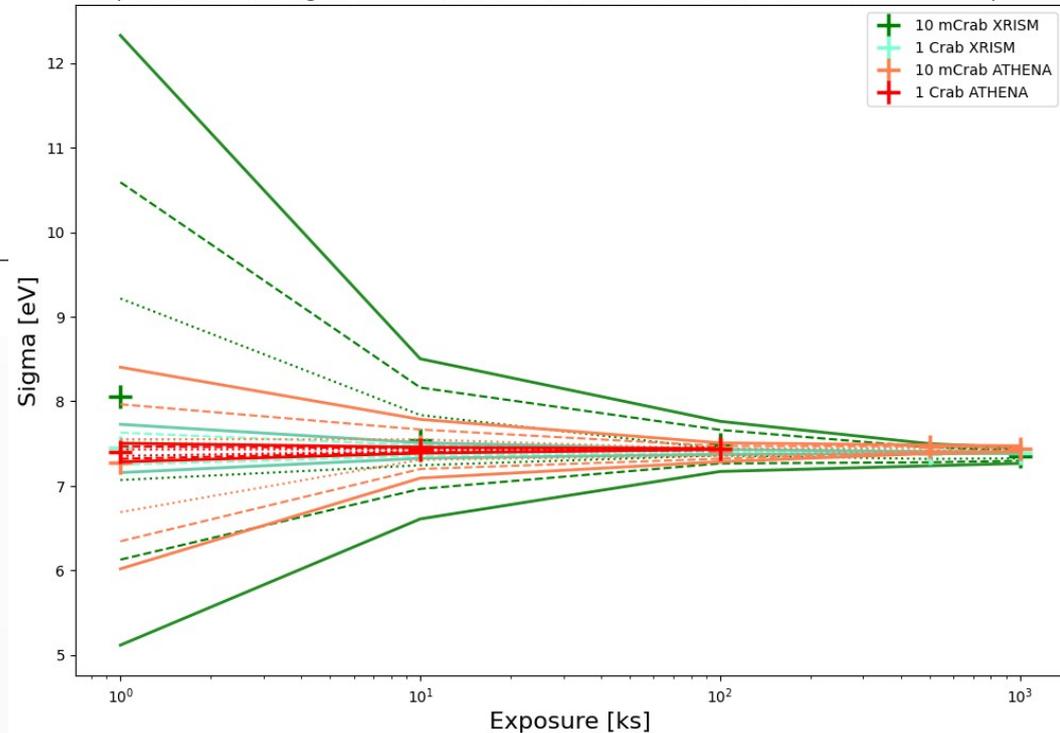
TITAN model:
Reflection component

XSPEC – fakeit
NewATHENA
- response matrix
- auxiliary & background files



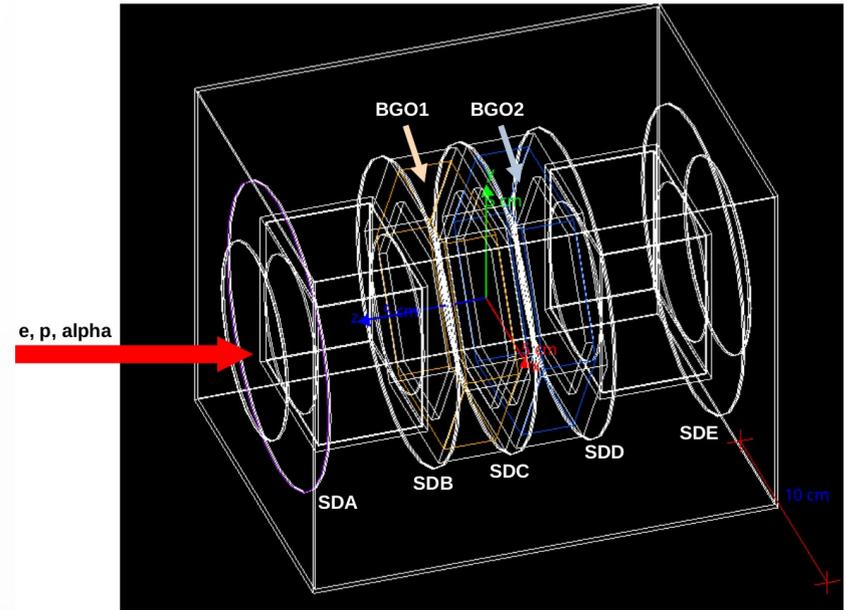
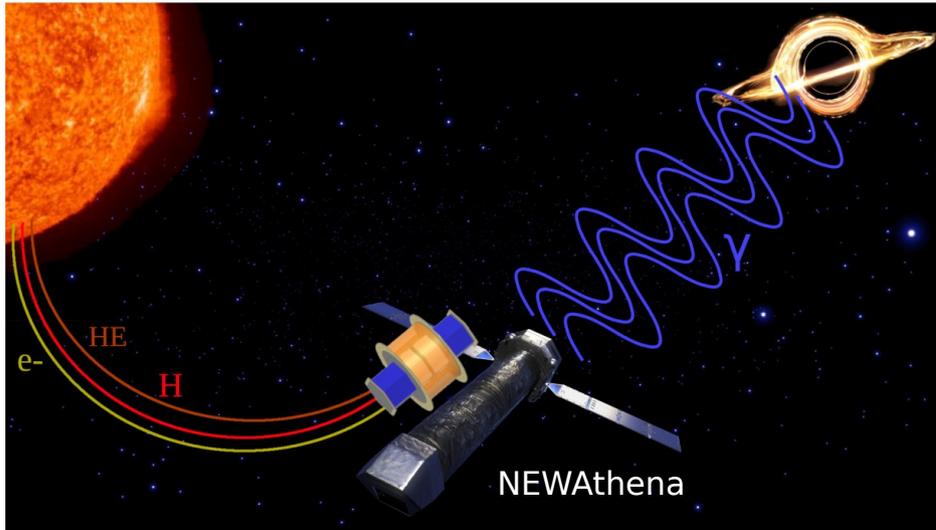
Simulated data of NewAthena

Comparison of 1-2-3 sigma confidence levels for NewATHENA/X-IFU vs XRISM/Resolve exposures



- Fe 6.4 keV line: fluorescence of iron atoms illuminated by the intense X-ray continuum
- model **Mrk 509** using the constant pressure model (**CTP**)
- source intensity varied via normalization (in **Crab** units) 1,10,100 mCrab and 1 Crab.
- simulated data for NewAthena/X-IFU and XRISM/Resolve
- NewAthena will need around 1 order of exposure less to determine line width with the same accuracy as XRISM/Resolve

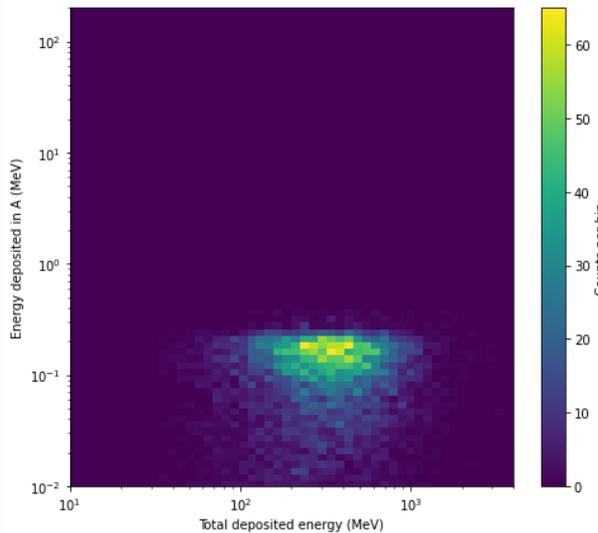
GEANT4 simulations for particle detector AHEPAM



New detector on board on NEWAthena:

AHEPAM (**A**thena **H**igh **E**nergy **P**article **M**onitor):

- to be designed/build by Polish Collaborators: NCBJ AND CAMK.
- additional measurement of x-ray background
- sensitive for electrons, protons, alpha particles



Our role:

- simulations of particles in GEANT4 package
- recreation of Design Justification file figures within the same energy ranges
- energy deposited in SDA vs total deposited energy (left)
- particle spectra simulated with SPENVIS



Publication update & summary

Publications:

- **A constant pressure model for the warm absorber in Mrk 509**
Krzysztof Hryniewicz, Agata Róžańska, Tek Prasad Adhikari, Matteo Guainazzi, Biswaraj Palit, Rafał Wojaczyński
A&A, 705, A119 (2026)
- **NewATHENA iron line visibility studies based on TITAN models**
Wojaczyński, R., Róžańska A.
MNRAS in preparation (2026)

Conferences:

- Poster: **'NewATHENA iron line visibility studies based on TITAN models'**
Wojaczyński, R., Róžańska A.
42nd Meeting of the Polish Astronomical Society (PTA) 8-12.09.2025, Warsaw
- Czech-Polish summer school on Galactic Nuclei 2025,
18-22.08.2025, Gerlosberg, Austria

Other:

- Polish Astronomical Society, member since May 2025
- Assistant technical supervisor for PhD student Parikshit P. Biswas, Modelling X-ray spectrum for accreting compact objects

The End

Thank you !

