Investigating the Accretion Disk and Iron Line Complexity in Mrk 841

Siham Kalli (M'sila University - Algeria) *siham.kalli@univ-msila.dz*

Abdu Zoghbi (CRESST/UMD/GSFC - US) - Elisa Costantini(SRON, Netherlands)

Summary

We present a spectral analysis of the Seyfert 1 galaxy Mrk 841, utilizing the longest and most recent XMM-Newton observations with exposures exceeding 100 ks. This highly variable source features a complex iron line profile and a strong soft excess. By fitting a comprehensive model that integrates disk ionization, relativistic effects, and absorption components, we investigate the structure of the accretion disk alongside the origin and variability of the reflected emission.

Introduction

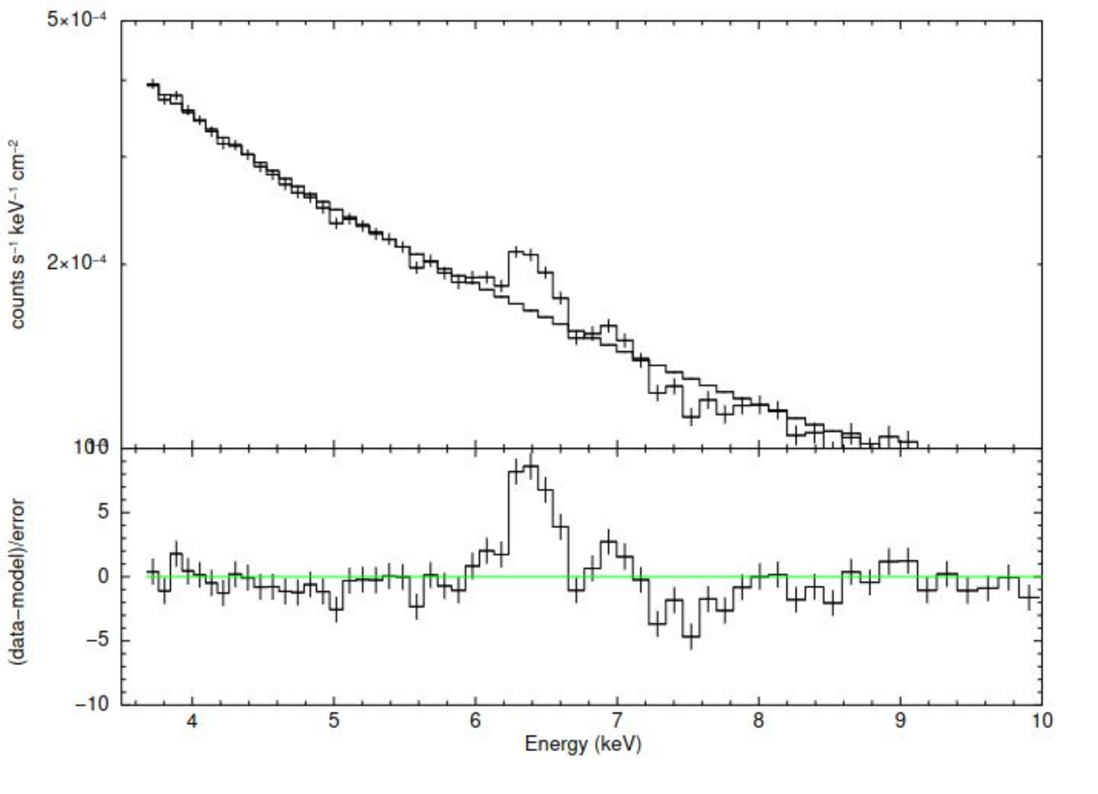
Mrk 841 is an active galaxy that provides a clear view into the region near a supermassive black hole. It exhibits notable spectral complexity, particularly regarding its iron line profiles and soft X-ray properties. Earlier X-ray data (2001–2005) revealed two main components to its iron emission feature: a broad line that changes within a few hours, likely originating from the inner accretion disk, and a stable narrow line from more distant material, such as the outer torus[1]. Additionally, while observations from 2001, 2005, and 2015 showed a strong soft X-ray excess, recent data indicate that this feature is dimming[2]. Using the latest X-ray observations, this project will examine these spectral transitions by modeling both absorption and reflection effects. This analysis will clarify the physical geometry and conditions of the gas near the central black hole.

Data reduction

- ❏ Reduction of EPIC data using *epproc* in SAS.
- ❏ Extraction of source and background photons from circular regions with a radius of 40"
- ❏ Instrumental corrections using the epiclccorr task.
- ❏ Pileup correction, using epatplot → new region = annulus with different inner radii

Obs ID	Date	Duration [s]	Exposure [s]	pileup correction inner radius
0882130401	12-02-2022	132000	42670	5”
0882130301	10-02-2022	132000	87150	4”
0890640201	09-01-2022	62800	85430	6.5”

Spectral Analysis



- Fitting tool : **xspec** [3] - Fitting the continuum in [3.5-10] keV with absorbed power law
  - ❏ A broad excess between 6–7 keV → relativistic Fe Kα line from the inner disk
  - ❏ A narrow line near 7 keV → likely Fe Kβ (7.06 keV), Fe XXVI (6.97 keV), or model residuals
  - ❏ A dip between 7keV and 8 keV → warm absorber

- **Phenomenological fitting** Models : tbabs*(zga + po), tbabs*(zga + zga + po) , zxipcf *tbabs* (zga + zga + po) → applied to combined spectrum and individual spectra

Results : ***Combined spectrum*** : the best fit model is ***zxipcf *tbabs* (zga + zga + po)***.

zxipcf : N_h 10^{22} = 3.00 ±2.58, log_xi = 4.11±0.26 , Redshift = −0.04±0.01,

zga1 : E = 6.38±0.01, σ = 0.11±0.02, and its flux (15.2±1.1)×10^{-14} erg cm^{-2} s^{-1}.

zga2 : E = 6.99±0.02 and the flux is (8.53±2.02)×10^{-17} erg cm^{-2} s^{-1}.

power law : flux (1.09±0.01)×10^{-11} , Photon Index = 1.61±0.01

Spectrum 2 : both ***tbabs*(po+zga+zga)*** and ***tbabs*zxipcf*(po+zga)*** provide a statistically good fit →The spectrum is explained by either an ionized reflection or warm absorption.

Spectrum 1 and **Spectrum 3** : the best model ***tbabs*(po+zga)*** → nor highly ionized reflection neither warm absorption are detected

- **Physical fitting** The little broad gaussian at 6.4 keV is replace by xillver [4] to fit the distant reflection. The narrow gaussian at 6.97 keV is replaced by apec to model collisionally-ionized diffuse gas. rdblurr and kdblurr are applied to xillver to smooth a spectrum by relativistic effects from an accretion disk

Models : tbabs*(xillver + po), tbabs*(kdblur*xillver + po), tbabs*(rdblur*xillver + po), tbabs*(xillver +apec+ po)

Results : ***Combined spectrum*** : tbabs*(xillver + po) χ^2 /dof = 83 / 57 for logξ = 0 and χ^2 /dof =78 / 56 for logξ variable. **Spectrum 2** shows the same behaviour, however there is no improvement when putting logξ variable for both **spectra 1 and 3**. When applying rdblurr and kdblurr, there is no improvement in the fit for all spectra.

Adding apec to tbabs*(xillver + po) improves the fit only for **spectrum 2.** Adding zxipcf to tbabs*(xillver + po) improves the fit only for **combined spectrum**

Results & Discussion

- ❏ The combined spectrum of the most recent observations of Mrk841 : presence of a little broad neutral iron line, a highly ionized reflection line at 6.97 keV and a warm absorber
- ❏ The neutral iron line Fe K at 6.38 keV is modest in width σ ~ 0.11 keV → it originates far from the black hole. When we applied relativistic convolution models (kdblur and rdblur) to the physical reflection model (xillver), the fit did not improve for any of the spectra → the reflection spectrum is dominated by emission from distant, non-relativistic material—such as the molecular torus or outer broad-line region—rather than gas orbiting near the innermost stable circular orbit (ISCO) of the accretion disk.
- ❏ The narrow emission feature near 7.0 keV corresponds well to hydrogen-like iron (Fe XXVI at 6.97keV). The statistical improvement seen when adding a collisionally ionized plasma model (apec) to Spectrum 2 indicates that this line is likely produced by hot, diffuse thermal gas surrounding the nuclear region.
- ❏ Adding an apec thermal component improves the fit only for Spectrum 2, while incorporating a partial-covering ionized absorber (zxipcf) yields a statistically significant improvement exclusively in the combined spectrum. This indicates that the hot, collisionally ionized gas is a transient feature specific to the epoch of Spectrum 2, whereas the warm absorber is a weaker or time-averaged outflow feature that only becomes statistically detectable when combining the full exposure time of all observations.
- ❏ Spectral variability across observations is driven by the transient nature of both the thermal gas and the absorber. Spectrum 2 uniquely requires an additional apec component alongside warm absorption or ionized reflection, whereas Spectra 1 and 3 are well fitted by a simple powerlaw + Gaussian model. Furthermore, the warm absorber (zxipcf) only becomes statistically detectable when combining all datasets to boost the signal-to-noise ratio. This indicates that the surrounding environment undergoes short-term physical changes, marked by temporary thermal emission and variable or weak obscuration along our line of sight.

Reference [1] P. O. Petrucci et al. 2007 A&A, 470, l3 . [2] Mehdipour, M.,et al. 2023, ApJL, 952, L5,418 [3] Arnaud, K. A., et al. 1985, MNRAS, 217, 105 [4] Dauser et al, 2022, MNRAS , 514, 3965