Computer practicum, final test

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1 Introduction

With a new X-ray mission, named USXS (Ultra Sensitive X-ray Spectrometer) we observe the Seyfert galaxy Markarian 4958 The instrument is a grating spectrometer similar to the Chandra Low Energy Transmission Grating Spectrometer, but with a 100 times larger effective area. Due to budget limitations, the spectral resolution is however 50 % worse than the LETGS, namely 0.08 Å (Full-Width at Half Maximum). You find the response matrix leg.res and the spectrum mrk4958.spo at
www.sron.nl/∼kaastra/leiden2018/finaltest/leg.res and
www.sron.nl/∼kaastra/leiden2018/finaltest/mrk4958.spo

The galaxy Markarian 4958 is a typical Seyfert galaxy, at a redshift of 0.0139 (you may adopt the standard cosmology of SPEX, namely $H_0 = 70$ km/s/Mpc, $\Omega_{\rm m} = 0.3$ and $\Omega_\Lambda = 0.7$). Accurate 21 cm observations showed that the neutral hydrogen column density to this source is 1.0 (in units of 10^{24} m^{-2}). Both the redshift and the column density appear to be a very accurate value.

The galaxy harbours an active nucleus with a strong power law continuum. In addition, there is soft X-ray emission from the accretion disk. For some not well understood reason, this disk appears to emit preferentially blackbody radiation at each radius. In addition, there is a strong, photoionized outflow. As optical spectroscopy of the nucleus shows enhanced ongoing star formation (massive stars) near the nucleus, we may expect enhanced nitrogen abundances in all material in the nuclear region. There is no reason to assume that the other elements have non-solar abundances. Although in general abundances are larger at the cores of galaxies, measurements of the composite stellar spectrum of the host galaxy show, apart form nitrogen, normal abundances in the innermost region. Finally, the disk shows the signatures of a mysterious broadened emission line. It is your task to find and characterise this line and derive its physical properties.

The source has been observed in the past by INTEGRAL, a hard X-ray detector. The INTEGRAL observations show that the power law has an abrupt high energy cut-off at

100 keV, i.e. there are no photons at higher energies.

2 Task

Read the spectrum in SPEX, and analyze it. Write a report about it.

The following questions / items should be adressed at a minimum.

1. Include a plot of the effective area of the instrument
2. Include a plot of the spectrum
3. Describe which operations you perform on the spectrum (binning or omitting of data channels), and why
4. Describe the model you use for SPEX, and explain why and what it means
5. Make a table with the best-fit parameters
6. Include a plot of the spectrum with your best fit through it
7. As above, but for the 18–24 Å range only
8. Derive the inclination angle of the accretion disk
9. Derive the mass M of the central black hole as well as $\dot{M}$
10. What is the maximal relative thickness h/r in the inner part of the accretion disk? Is a thin disk approximation self-consistent?
11. Do you think the black hole rotates?
12. Derive the bolometric luminosities of all components as well as the Eddington luminosity; describe how you obtain these values.
13. Make a small table with wavelength, predicted optical depth at line center and equivalent width of approximately 5 of the strongest absorption lines in the energy band observed by the instrument. Where possible, try to identify these transitions using the SPEX line list of the CIE model that you used before, and try to find the spectroscopic term notation of upper and lower level (you may find additional info about this in Mewe, Gronenschild & van den Oord 1985, A&A Supp 62, 197, in particular their table III (guide to transition numbers) and table IV (a precursor of the SPEX line list)).
14. For the warm absorber, estimate the mass outflow assuming it is a stationary outflow within a solid angle Ω.

15. Adopting the mass loss through the photoionised wind should be less than the accretion rate, estimate an upper limit to the solid angle Ω.
16. Estimate the characteristic Keplerian rotation period for the bulk of the soft X-ray emission from the disk. This gives you an idea of the expected time variability scales.
17. Make a sketch of the radial emissivity profile of the broad line, and compare it to the radial profile of the total soft X-ray flux from the disk
18. include error bars on all free parameters (suggestion: start already writing / discussing your report while you have the error searches running)
19. where possible, draw further physical implications / make conclusions
20. any additional ideas are a bonus and appreciated

Some useful hints:

1. read these instructions and hints **carefully**
2. First read the section about the disk blackbody (dbb) model in the SPEX manual
3. Start with fitting a simple continuum, then try to add other components subsequently. Try to make realistic starting values before you start the fitting procedure
4. it may be wise to freeze temporary some parameters if you think you are close to the final result, and thaw them later (but do not forget to thaw them...)
5. take good care of the order of multiplicative components
6. The lecture notes on accretion disks might be useful
7. The ionisation parameter ξ of the outflow is defined as $\xi = L/nr^2$, where L is the 1–1000 Ryd luminosity.
8. You may assume here that any (broadened) emission line is due to a transition from the hydrogen iso-electronic sequence
9. Use SI units throughout
10. Plotting spectra with y-axis unit ”fang” (counts $\mathrm{m}^{-2}\,\mathrm{s}^{-1}\,\text{Å}^{-1}$) may be useful sometimes
11. idem about log log plots (if you want to find power laws)