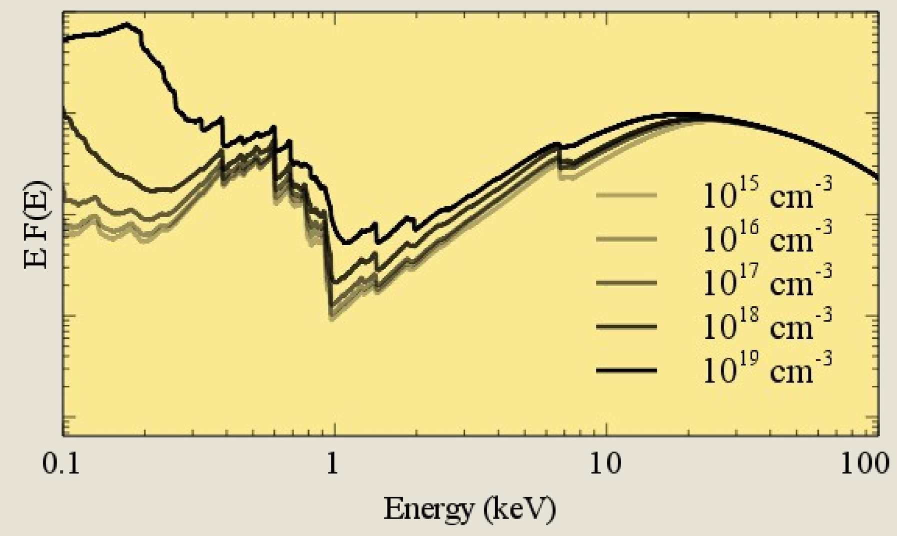
HIGH DENSITY BLACK HOLE DISK REFLECTION

ACCRETION DISK DENSITY vs. ACCRETION RATE & BH MASS

Jiachen Jiang

"A weak low-temperature thermal component is commonly seen in the X-ray spectra of black hole (BH) X-ray binaries (XRBs) in the hard state. Similarly, a blackbody-shaped soft excess emission has been found in the spectra of Syefert galaxies hosting super-massive BHs. The origin of these features remain unclear. Another common result obtained in previous reflection-based spectral analysis is supersolar iron abundance. A disk reflection model with a higher disk density might be the solution to both problems."

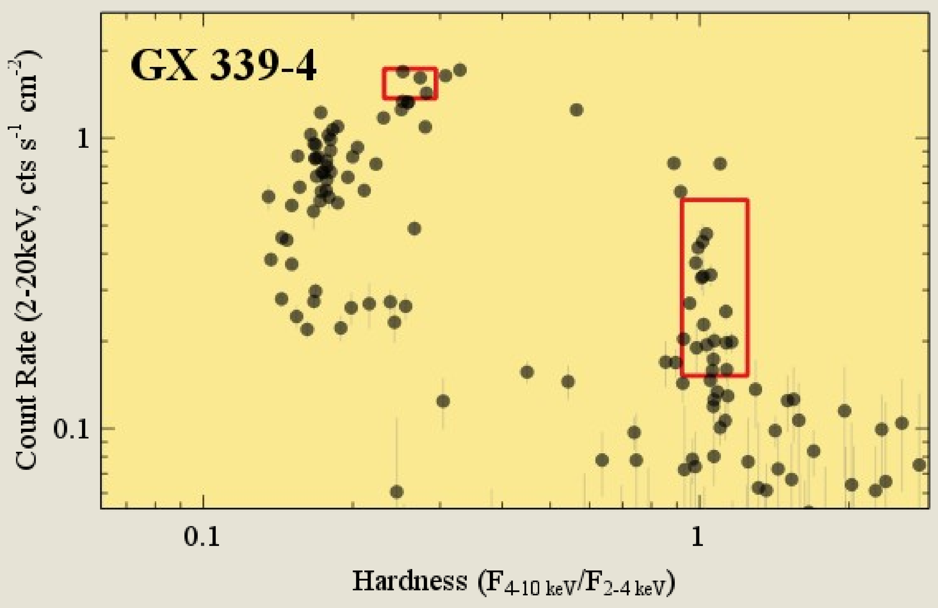
Introduction



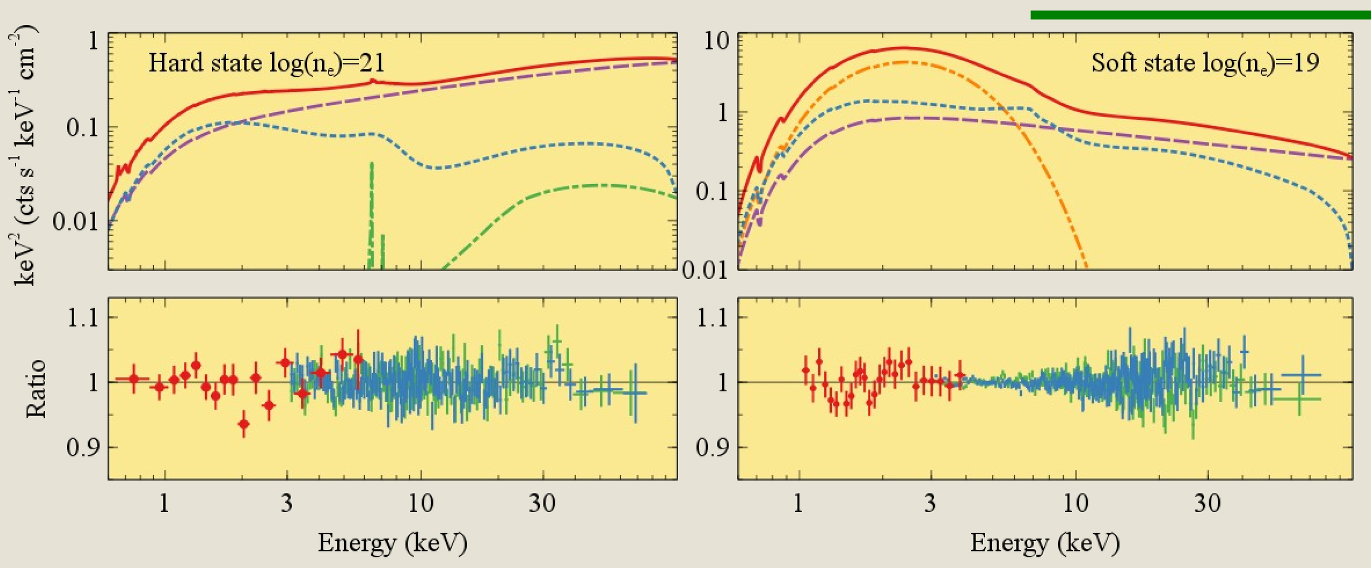
The reprocessing of the coronal radiation in the top layer of the disk produces a hump above 20 keV and a series of atomic lines, most notably the strong Fe K emission line at 6.4 keV. These features are referred to the disk reflection component.

Previous disk reflection models assume a fixed disk electron density of 10^{15} cm^{-3}. Such a density is appropriate for the disk of a massive SMBH that accretes at a near-Eddington accretion rate. At higher disk densities, the temperature of the disk surfaces increases due to stronger free-free absorption. The disk reflection spectrum turns into a blackbody-shaped emission in the soft X-ray band (Ross+07, Garcia+16). This feature may explain the soft excess emission mentioned in the abstract.

Stellar-mass BHs

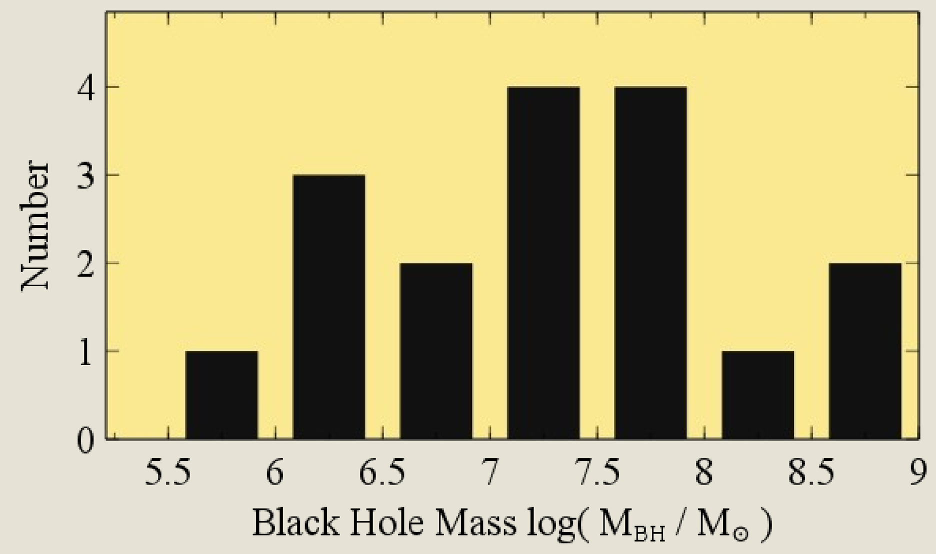


The figure above presents different accretion states of the BH transient GX 339-4, monitored by MAXI. The red boxes show the flux and hardness states when the observations considered in this work were taken, that include all the NuSTAR observations prior to 2016. The high flux-soft state of GX 339-4 is approximately 10 times brighter than the low flux-hard state in the X-ray band.



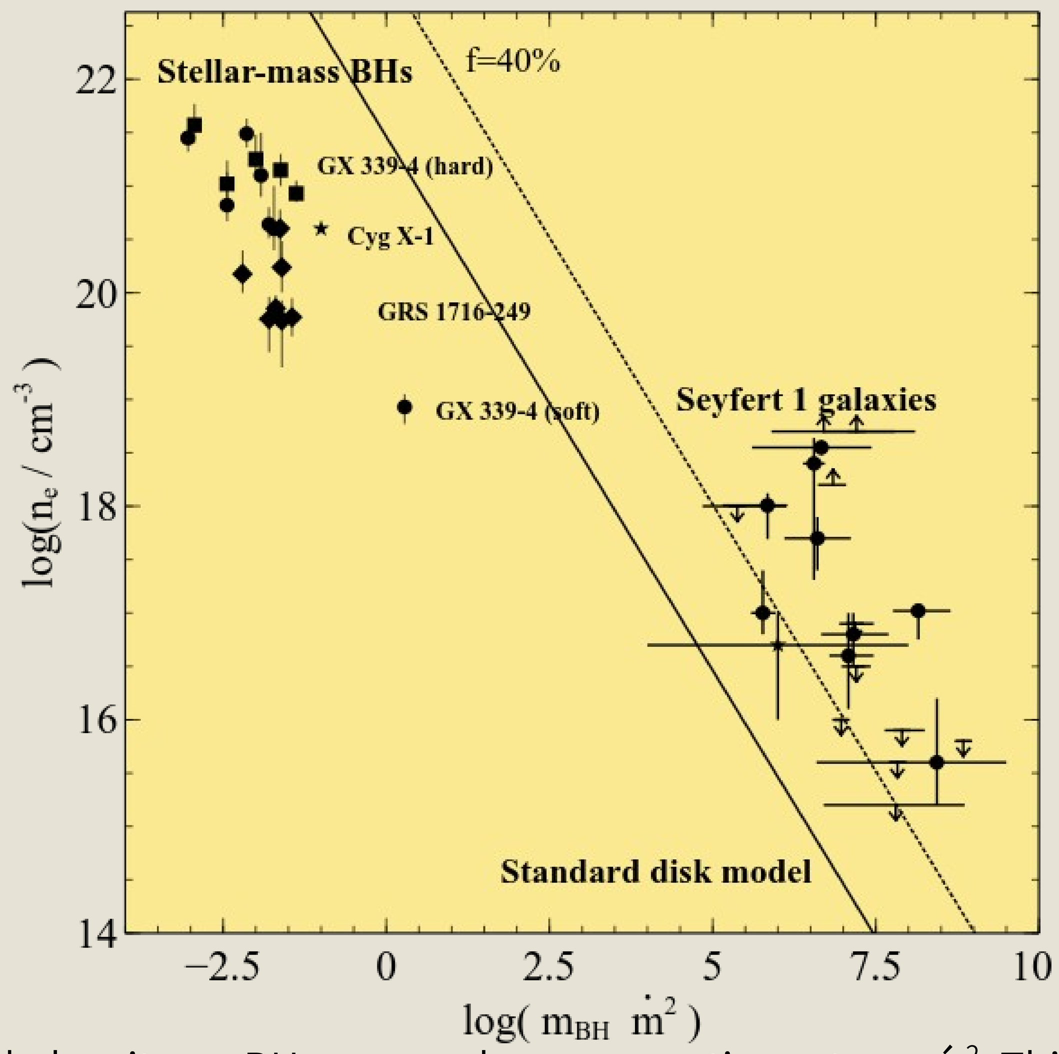
The high density disk reflection model can explain the hard state spectra of GX 339-4 with no requirement for an additional low temperature thermal component, as shown in the left panel above (purple: coronal emission; blue: disk reflection; green: distant reflector; red crosses: Swift XRT; blue crosses: NuSTAR FPMA; green crosses: NuSTAR FPMB). This model enables us to compare the disk density in different states. For example, a 100 times higher disk density is found in the low flux-hard state than in the high flux-soft state.

Super-massive BHs



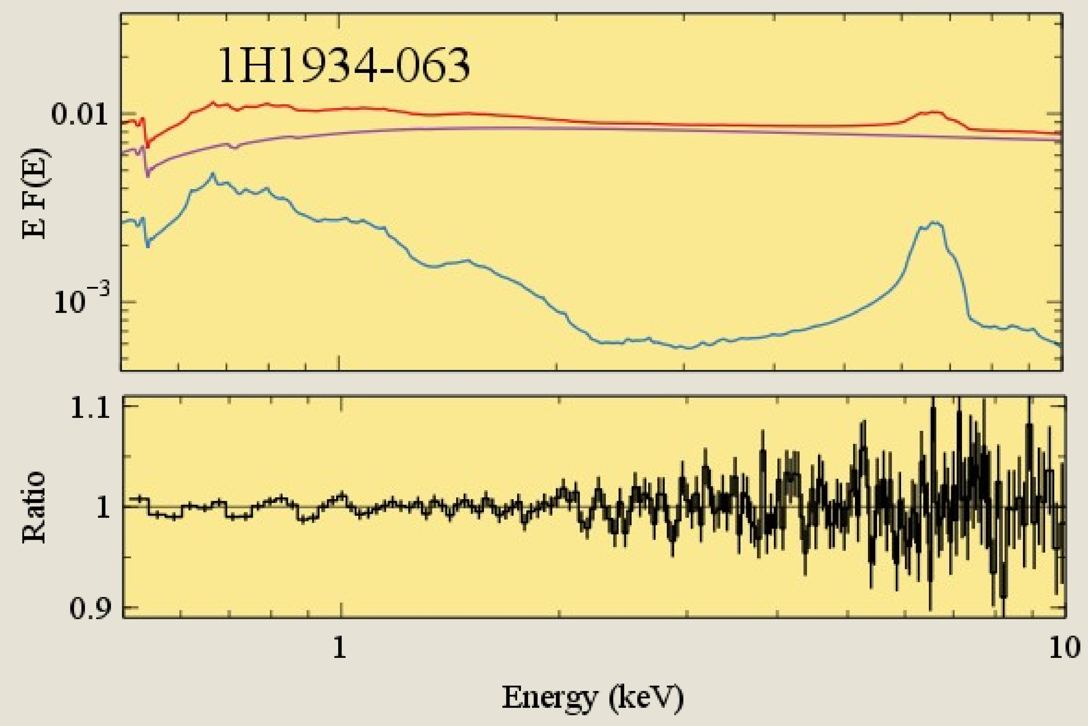
We select 17 unobscured Seyfert 1 galaxies to study their disk reflection. These AGN show no evidence for strong warm absorbers, neutral obscuration, or outflow absorptions. Our sample includes all the XMM-Newton observed Syefert 1 galaxies in the 'AGN BH Mass Database' (Bentz+15).

We consider all the available XMM-Newton observations in the archive and model the averaged spectra with the high density reflection model. A distant neutral reflector is added if a narrow iron line is shown in the iron band. No extra component is used for the soft excess emission during the spectral fitting.



Disk density vs. BH mass and mass accretion rate m $\dot{m}^2$. This diagram includes our work and previous analysis in Tomsick+18. Mallick+18, Garcia+18, Jiang+18, 19a. The solid line shows the prediction of a standard thin disk model (Shakura+73). The dashed line shows the density of a disk with 40% energy transferred to the coronal region calculated by Svensson+97.

The figure below shows an example, where a high density disk reflection model successfully explains the broad iron line in the iron band and the soft excess below 2 keV in the narrow-line Seyfert 1 galaxy 1H 1934-063. A disk density of 10^{17} cm^{-3} is obtained. A disk iron abundance of 6 times solar abundance is obtained, which is significantly lower than the value in a previous analysis (>9, Frederick+18)



Conclusions

1. The high density disk reflection model can successfully explain the broad band spectra of XRBs in the hard state and the soft state of GX 339-4 with a near-solar iron abundance. No additional blackbody component is required for the hard state spectral modelling.

2. The model enables us to compare the disk density in different accretion states of GX 339-4. The low flux-hard state of GX 339-4 shows 10 times lower X-ray luminosity but 100 times higher disk density than the high flux-soft state of the same source.

3. The model enables us to compare the disk density at different BH mass scales. A disk density significantly higher than 10^{15} cm^{-3} is found in all the BH sources with log(m $\dot{m}^2$)<7.5.

4. The offset of the observed disk densities compared to the standard disk model might be due to 1) the vertical structure of the disk; 2) energy transfer from the disk to the coronal region; 3) uncertainties of the BH mass and distance measurements.

References:

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Collaboration:

Andy Fabian, Javier Garcia, John Tomsick, Michael Parker, Dom Walton

Contact Information

jj447 @ cam.ac.uk

UNIVERSITY OF CAMBRIDGE

Institute of Astronomy, University of Cambridge
TAO Fellow, Tsinghua Center for Astrophysics, Tsinghua University